Abstract Book

Joint APP and HEPP Annual Conference

8–10 April 2019
Imperial College London, London, UK

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Organised by the IOP Astroparticle Physics and High Energy Particle Physics Groups

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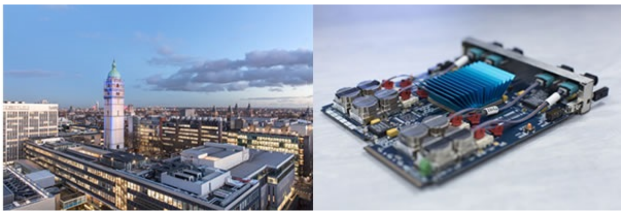

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Programme Overview

	Monday 8 April			
10:00	Registration and Coffee (*Reception Foyer and Huxley 341*)			
11:00	Welcome			
	Plenary Session 1 (*Clore Lecture Theatre, Huxley 213*)			
11:10–12:30	(Invited) Jim Virdee (Invited) Dave Wark (Invited) Eleonora Di Valentino			
13:00	Lunch (*Huxley 341*)			
	Parallel Session 1			
	Stream 1 (*Clore Lecture Theatre, Huxley 213*)	**Stream 2** (*Huxley 340*)	**Stream 3** (*Huxley 308*)	**Stream 4** (*Huxley 311*)
14:00–15.45	Albert Kenneth Dow Nicolas Scharmberg Matthew Heath Yixuan Zhang Tom Brooks Dominic Barker Tom Coates Herschel Chawdhry	Alice Morris Miha Zgubic Russell Turner Teppei Katori Elena Massera Brais Lopez Paredes Umit Utku	Robert Vallance James Kendrick James Mead Mikkel Bjorn Laurent Kelleter Tereza Kroupova Martti Nirkko	Joseph Taylor Baptiste Ravina Matthew Anthony William Parker Edward Millard Toby Nonnenmacher Alexandra Rollings Samuel Maddrell-Mander
16:30	Tea and coffee (*Huxley 341*)			
	Plenary Session 2 (*Clore Lecture Theatre, Huxley 213*)			
17:00–18:00	(Invited) Martin Bauer (Invited) Gavin Hesketh (Invited) Steve Leach			
19:00	Poster Session with buffet (*Queens Tower Rooms*)			

	Tuesday 9 April			
	Plenary Session 3 (*Clore Lecture Theatre, Huxley 213*)			
09:00–10:00	(Invited) Yvonne Peters (Invited) Christos Leonidopoulos (Invited) Katherine Dooley			
10:30	Tea and coffee (*Huxley 341*)			
	Parallel Session 2			
	Stream 1 (*Clore Lecture Theatre, Huxley 213*)	**Stream 2** (*Huxley 340*)	**Stream 3** (*Huxley 308*)	**Stream 4** (*Huxley 311*)
11:00–12:15	Nellie Marangou Peter Rossiter Fabio Tresoldi Holly Pacey Mark Stringer Matthew Malek	Joseph Walding Giacomo Zecchinelli Edward Thorpe Amy Tee Wai Yuen Chan Ashlea Kemp	Thomas Hancock Emmy Gabriel Fabrizio Trovato Alexander Titterton Tommaso Boschi	Susana Molina Sedgwick Celeste Pidcott Felix Kress Malte Hecker Beojan Stanislaus Santiago Paredes Saenz
13:00	Lunch (*Huxley 341*)		HEPP AGM (*Huxley 311*)	
	Plenary Session 4 (*Clore Lecture Theatre, Huxley 213*)			
14:00–15:00	(Invited) Andy Blake (Invited) Jon Coleman (Invited) Andrew Rose			
15:30	Tea and coffee (*Huxley 341*)			
16:00	STFC Town Meeting (*Clore Lecture Theatre, Huxley 213*)			

	Wednesday 10 April			
	Plenary Session 5 (*Clore Lecture Theatre, Huxley 213*)			
09:00–10:00	(Invited) Trevor Vickey (Invited) Asher Kaboth (Invited) Christopher McCabe			
10:30	Tea and coffee (*Huxley 341*)			
	Parallel Session 3			
	Stream 1 (*Clore Lecture Theatre, Huxley 213*)	**Stream 2** (*Huxley 340*)	**Stream 3** (*Huxley 308*)	**Stream 4** (*Huxley 311*)
11:00–12:15	Hannah Pullen Jennifer Zonneveld Jared Vann Ioannis Katsioulas Marco Montella Luca Ambroz	Matthew Sullivan Artur Sztuc Wouter Van De Pontseele Lewis Millward Lydia Beresford Deshan Abhayasinghe	Lauren Douglas Gediminas Sarpis Athoy Nilima Rob Taylor Thomas Powell Elliot Reynolds	Vasilis Konstantinides Paolo Agnes Daria Santone Scott Melville Eshwen Bhal Vukasin Milosevic
13:00	Lunch (*Huxley 341*)		APP AGM (*Huxley 311*)	
	Plenary Session 6 (*Clore Lecture Theatre, Huxley 213*)			
14:00–16:00	(Invited) Linda Cremonesi (Invited) Cheryl Patrick (Invited) Sneha Malde (Invited) Lars Eklund			

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Poster Programme

P1. On the Use of Photomultiplier Waveform Information with Machine Learning Techniques for the Cherenkov Telescope Array
S Spencer, University of Oxford, UK

P2. Constraints on the Higgs boson self coupling from ttH + tH, H->gammagamma differential measurements with CMS at the HL-LHC
J Langford, Imperial College London, UK

P3. Improving the performance of the CMS ECAL Level-1 trigger for LHC Run 3
W Smith, University of Southampton, UK

P4. 21cm Cosmology and radiative neutrino decays
K Farrag, Queen Mary University of London, UK

P5. Quest for new physics using astrophysical neutrino flavour in IceCube
K Farrag, Queen Mary University of London, UK

P6. A case for studying Flat Spectrum Radio Quasars (FSRQs) and prospects for gamma-ray observations with the CTA
A Acharyya, Durham University, UK

P7. Sensitivity study for the μ+ → e+ e+ e- search with the mu3e experiment and work to prepare for Mupix pixel tracker module in Liverpool module
A Wasili, University of Liverpool, UK

P8. How to monitor your Gd-loaded water Cherenkov detector
T Boschi, Queen Mary University of London, UK

P9. Quality Control for ATLAS Inner Tracker Strip Sensor Production
C Klein, University of Cambridge, UK

P10. New L1 seeds for HLT jet trigger
E Villhauer, CERN, Switzerland

P11. Measuring the space charge effect in the ProtoDUNE-SP detector
J Thompson, University of Sheffield, UK

P12. The role of photon isolation in the measurement of Zγ production with the ATLAS detector
D Lewis, University of Birmingham, UK

P13. Imaging nuclear waste in a V/52 CASTOR drum using muon scattering tomography
A Alrheli, University of Sheffield, UK

P14. Quarkonia in jets at LHCb
N Cooke, University of Birmingham, UK

P15. Prospects for the observation of true muonium at LHCb
J Plews, University of Birmingham, UK

P16. A Novel Light Source for Hyper-Kamiokande Calibration Tests
K McElwee, University of Sheffield, UK

P17. Background rejection measurements for electron identification with the ATLAS detector
K Saoucha, University of Sheffield, UK

P18. Ultra-pure Copper Electroplating for Background Reduction in the NEWS-G Experiment
P Knights, University of Birmingham, UK

P19. Studying the Effect of Polarisation in Compton Scattering in the Undergraduate Laboratory
P Knights, of Birmingham, UK

P20. ATLAS Upgrade: Production of the cooling circuits for the ITk Strip Stave and Forward Pixel End-Caps at The University of Sheffield
W Yeadon, University of Sheffield, UK

P21. Fast Simulation of Muon Backgrounds at SHiP using Machine Learning
A Marshall, University of Bristol, UK

P22. Investigation of Gas Properties and the Effect of Electronegative Contaminants in the NEWS-G Experiment
R Ward, University of Birmingham, UK

P23. Reducing top quark background in measurements of W+W- cross sections at √s = 13TeV with the ATLAS detector
J MacDonald, University of Sheffield, UK

P24. Search for CP violation in D0 →π- π+ π0 at LHCb with the energy test method
J Cobbledick, The University of Manchester, UK

P25. Applications of muon scattering tomography to image and characterise materials in nuclear waste drums
M Weekes, University of Sheffield, UK

P26. Experimental Determination of Proton Hardness Factors at Various Irradiation Facilities
C Simpson-Allsop, University of Birmingham, UK

P27. Study of ttH production with H→bb at the HL-LHC
A M Mendes Jacques da Costa, University of Birmingham, UK

P28. Progress Towards a First Measurement of the Pion – Argon Cross Section in ProtoDUNE-SINGLE PHASE
S Vergani, University of Cambridge, UK

P29. Track vs Shower Hit-Based Classification Using Deep Learning in LArTPC Experiments
S Vergani, University of Cambridge, UK

P30. B-Tagging Calibration using the Combinatorial Likelihood Method with Particle Flow Jets
J Hall, University of Sheffield, UK

P31. Construction of the ATLAS Phase-II upgrade Inner Tracker semiconductor barrel micro-strip detector
T Zorbas, University of Sheffield

P32. Towards a gas filtration setup for ultra-sensitive SF6 gas based rare-event physics experiments
R R Marcelo Gregorio, University of Sheffield, UK

P33. Searching for electroweak supersymmetry in events with two leptons and missing transverse momentum in the final state at 13TeV with the ATLAS detector
H Pacey, University of Cambridge, UK

P34. Advantages and limitations of neural networks for jet tagging
H Day-Hall, University of Southampton, UK

P35. SBND Recombination Study for Shower Calorimetry
E Tyley, University of Sheffield, UK

P36. ATLAS ITk Pixel Sensor Measurements
M Mironova, University of Oxford, UK

P37. Measurement of D0 mixing parameters using D0 → KSPiPi Decay at LHCb
M Hilton, The University of Manchester, UK

P38. Data-driven corrections to ATLAS trigger simulation
D Köck, University of Sussex, UK

P39. A High Pressure gaseous Time Projection Chamber for future long-baseline neutrino experiments
E Atkin, Imperial College London, UK

P40. Integration-by-parts identities and multi-loop QCD amplitudes
H Chawdhry, University of Cambridge, UK

P41. Observation of H->bb decays in the VH production mode and first differential measurement with the ATLAS detector
L Ambroz, University of Oxford, UK

P42. Measuring the mass of the Higgs Boson at the ATLAS detector in the H→ZZ*Đ4l channel using an analytic model
T Powell, University of Sheffield, UK

P43. Beam test studies of a prototype TORCH detector
T Hancock, University of Oxford, UK

P44. Searches for electroweak supersymmetry in final states containing one lepton, two b-tagged jets and missing transverse energy at the ATLAS experiment
M Sullivan, University of Liverpool, UK

P45. Prospects for ttZ measurements at ATLAS with the full 140 fb-1 Run 2 dataset
B Ravina, University of Sheffield, UK

P46. The search for invisibly decaying Higgs bosons at the LHC
V Milosevic, Imperial College London, UK, The CMS Collaboration, Switzerland

P47. Top quark charge asymmetry at LHCb
J Mead, University of Liverpool, UK

P48. The High Pressure gas Time Projection Chamber: a Future Neutrino Detector
T Nonnenmacher, Imperial College London, UK

P49. Measurement of the CP nature of the Htt Yukawa coupling using gluon fusion production in association with two jets with a Higgs boson decay to a tau lepton pair
A Dow, Imperial College London, UK

P50. Background Modelling in the ttH(H→γγ) Channel
M Heath, University of Edinburgh, UK

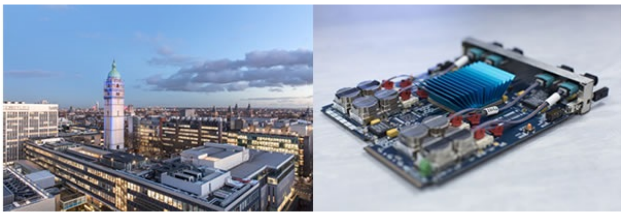
P51. Electron neutrino selection in the MicroBooNE LArTPC using the Pandora pattern recognition reconstruction
W Van De Pontseele, University of Oxford, UK

P52. Determination of hadronic resonance contributions to the B0 → K*0μμ decay
M Hecker, Imperial College London, UK

P53. Non-parametric Bayesian event reconstruction in Super-Kamiokande detector
A Sztuc, Imperial College London, UK

P54. Matter density profile effects on neutrino oscillations at T2HK and T2HKK
S Molina Sedgwick, Queen Mary University of London, UK, University of Southampton, UK

P55. Applications of Machine Learning to the Monopole and Exotics Detector At The Large Hadron Collider (MoEDAL)
L Millward, Queen Mary, University of London, UK, The MoEDAL Collaboration, Switzerland



Monday 8 April

Measurement of the CP nature of the Htt Yukawa coupling using gluon fusion production in association with two jets with a Higgs boson decay to a tau lepton pair

A Dow

Imperial College London, UK

Since the discovery of the Higgs boson with a mass near 125 GeV, much effort has been dedicated to studying its properties. This talk presents one such study, which investigates the CP structure of the Higgs boson by exploiting the gluon fusion production process in association with two jets. Analysis of the azimuthal angle correlations of the jets provides an insight into the CP nature of the Htt Yukawa coupling. Higgs bosons decaying into a pair of tau leptons are considered, and the full 2016 and 2017 datasets collected at the CMS experiment are used.

Measuring the top higgs couplings CP-nature in ttH(->bb) dilepton events

N Scharmberg[1], Y Peters[1], J Howarth[1], Yang Qin[1], Ian Connelly[2]

[1]University of Manchester, UK, [2]University of Glasgow, UK

The coupling strength of the higgs boson to fermions is predicted to be proportional to the fermions mass, making the higgs top coupling the strongest in the SM.

This coupling strength can be directly measured in the production of a higgs boson in combination with two top quarks, which was observed in 2018. In the SM, the higgs top coupling is predicted to be a CP-even coupling but measuring a CP-odd component would suggest physics beyond the SM.

I will present how the current data collected with the ATLAS experiment can be used for a measurement on the top higgs coupling.

I will concentrate on the case where both two top quarks decay leptonically and the higgs decays into a bbbar pair. In this decay channel, there are many challenges such as the two neutrinos and high multiplicity of jets in the final state. This talk will demonstrate the full event reconstruction including reconstruction of the top quarks using neutrino weighting. I will also present how kinematic variables in the event may be combined in MVA techniques to optimise the sensitivity of this measurement and allow us to set limits on the coupling parameters with existing and upcoming LHC data.

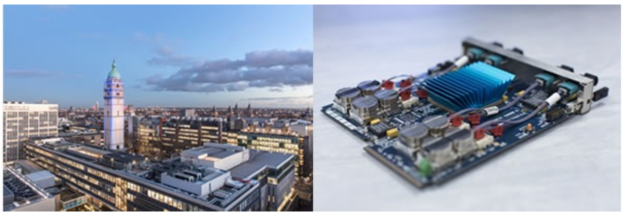
Background Modelling in the ttH(H→γγ) Channel

M Heath

University of Edinburgh, UK

The discovery of the Higgs boson in 2012 by the ALTAS and CMS experiments at CERN was only the beginning, the properties of this particle still need to be measured and compared with theoretical predictions. The ttH production channel allows a direct measurement of the Higgs coupling to top quarks, the heaviest particle in the Standard Model, while the H→γγ decay channel gives a narrow peak in the $m_{\gamma\gamma}$ spectrum that is easily distinguished from background.

The shape of this background model needs to be as accurate as possible in order to minimise uncertainty on measurements. With the models being created from analytical functions fitted to simulated Monte Carlo



background samples, a method for estimating how much the resulting model differs from the true distribution is required. For $H \rightarrow \gamma\gamma$ analyses this is carried out using the spurious signal method which quantifies how much background could falsely be interpreted as signal and assigns it as the systematic error on the model.

However, the spurious signal method is highly dependent on the statistical fluctuations of the Monte Carlo sample, making it difficult for the production of simulated events to keep up with the rising luminosity of data-sets. This has resulted in the background systematics becoming dominant in several measurement channels. A study to quantify the effects of Monte Carlo sample statistics on the systematic error on the background model has been undertaken to provide estimates to help decide which channels are not feasible for producing enough Monte Carlo events for the spurious signal test or for which channels need an increase in production. This talk will address the spurious signal problem and present the results of this study.

Prospects for top-Yukawa coupling and Higgs boson CP at the CLIC e+e- collider

Y Zhang[1], V Martin[1], P Roloff[2]

[1]University of Edinburgh, UK, [2]CERN, Switzerland

The compact linear collider - or CLIC - is a proposed electron-positron collider and is currently the only mature option for a multi-TeV linear collider. The CLIC accelerator is based on a novel two-beam acceleration technique at an acceleration gradient of 100 MV/m. It would be built in stages, with three centre-of-mass energies of 380 GeV, 1.5 GeV and 3 TeV. CLIC will make precise measurements of Standard Model processes, including the Higgs boson, and study any new physics processes. In this talk, I will present my studies of ttH production at 1.5 GeV, using polarised beams and an integrated luminosity of 2.5/ab. This can be used to measure the precision of the top-Yukawa coupling in the Standard Model to be 2.7% and to investigate the CP properties of the top-Higgs coupling.

A preliminary charged-current muon neutrino inclusive selection in SBND

T Brooks

University of Sheffield, UK

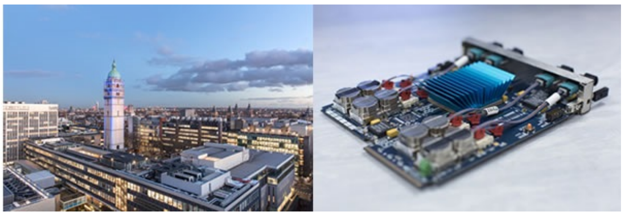
SBND, a 112 ton liquid argon time projection chamber, is the near detector of the short-baseline neutrino program at Fermilab. Once data taking begins in 2020, it will provide flux constraints for sterile neutrino searches and produce world leading neutrino-argon cross-sections with seven million neutrino events in 3 years. This talk will demonstrate the capability of SBND's time projection chamber and cosmic ray tagger system to select charged-current muon neutrino interactions above the largest source of background, cosmic ray muons.

An electron neutrino event selection procedure in the Short-Baseline Near Detector

D Barker

University of Sheffield, UK

The Short Baseline Neutrino (SBN) programme at Fermilab consists of three Liquid Argon Time Projection Chambers (LArTPCs) on the Booster Neutrino Beam. The key goal of the SBN programme is to perform the most sensitive search to date for sterile neutrinos in the eV-mass scale through appearance and disappearance oscillation channels. In order to achieve the sensitivities capable to the SBN programme, sophisticated reconstruction algorithms are being developed to identify the flavour and energy of neutrino events. An electron neutrino event selection procedure is being developed to evaluate the proposed sensitivities for electron neutrino appearance and cross-section measurement in the closest detector, at 110



m from the neutrino source, the Short Baseline Near Detector (SBND). The current effectiveness of the selection process will be presented.

DQM4HEP – a generic online monitor for particle physics experiments

T Coates[1], R Ete[2], A Pingault[3]

[1]University of Sussex, UK, [2]DESY, Germany, [3]Ghent University, Belgium

Currently there is a lot of activity in R&D for future colliders. Multiple detector prototypes are being tested, each with different requirements for data acquisition and monitoring, which has generated different *ad hoc* software solutions. We present DQM4hep, a generic C++11 framework for online monitoring for particle physics experiments, and results obtained at several testbeams with detector prototypes using the framework as it was developed. The work on DQM4hep forms part of AIDA-2020, a collaboration for establishing common tools and infrastructures for particle physics experiments.

Integration-by-parts identities and multi-loop QCD amplitudes

H Chawdhry[1], A Mitov[1], M Lim[2]

[1]University of Cambridge, UK, [2]University of Milano-Bicocca, Italy

As the LHC gathers ever more data and makes measurements with increasingly high precision, it is essential for theorists to match this precision when making predictions for cross-sections. In QCD and other gauge theories, this high precision is achieved by including multi-loop Feynman diagrams when calculating scattering amplitudes. Integration-by-parts identities (IBPs) are widely used when computing the associated multi-loop integrals. The solution of large systems of IBPs is a major bottleneck in the computation of high-precision QCD amplitudes for processes observed at the LHC, such as 3-jet production.

In this talk, I will discuss my work on IBPs, first presented in arXiv:1805.09182, where we introduce a new strategy for solving systems of IBPs, which we believe to be especially applicable to problems with many kinematic scales and/or many master integrals. Using this strategy, we have solved the IBPs needed for the computation of any planar 2-loop 5-point massless amplitude in QCD. We have also derived some new results for the associated non-planar integrals. Ultimately, we expect that the remaining non-planar contributions will be computable in analytic form, which would allow cross-sections for processes such as 3-jet production to be predicted at Next-to-next-to-leading order in QCD, reducing theoretical uncertainties down to a few percent.

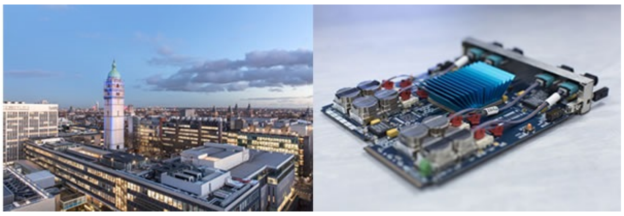
Search for long-lived neutral particles that decay into displaced jets in the ATLAS detector

A Morris, L Corpe

University College London, UK

Long-lived particles feature in many extensions to the Standard Model that have been proposed to address some of its open questions. Decays of long-lived particles created in collider experiments would produce unique signatures that may have been overlooked by previous searches for promptly decaying particles.

A search for pairs of neutral long-lived particles (LLPs) decaying in the volume of the ATLAS detector (mainly in the hadronic calorimeter) is presented, which probes LLP decay lengths ranging between a few centimetres and a few tens of metres. The analysis uses a simplified Hidden Sector model as a benchmark, where scalar LLPs are pair-produced from decays of heavy bosons, and eventually decay to SM fermions (mainly b-quarks). If this decay occurs in the calorimeters, the two resulting fermions are reconstructed as a single displaced jet with unusual features compared to jets from SM processes. A series of machine learning



techniques were employed to identify the displaced jets and reduce the contamination from background in the search region. A data-driven estimate of the remaining background was performed and limits were set on the production cross section times branching ratio, extrapolated as a function of the decay length of the LLPs. These are presented combined with limits from a search which looks for displaced jets in the ATLAS muon spectrometer.

Search for the Higgs boson decay to a pair of muons with the ATLAS detector at the LHC

M Zgubic

University of Oxford, UK

Higgs decay to a muon pair is the most promising way to probe Yukawa couplings to the second generation fermions at the LHC. Experimentally the analysis is challenging due to a small branching ratio (2.2*10^-4) and proceeds as a search for an excess at the Higgs mass in the dimuon invariant mass spectrum dominated by the irreducible Drell-Yan background. This talk presents the search with 79.8 fb-1 of data collected with the ATLAS detector at sqrt(s)=13 TeV, and prospects for the High Luminosity LHC.

Search for H->ee using 140/fb of 13 TeV pp collision data with ATLAS experiment

R Turner[1], P Thompson[1], A Mehta[2], T Neep[1], H Borecka-Bielska[2], J Kretzschmar[2], K Nikolopoulos[2]

[1]University of Birmingham, UK, [2]University of Liverpool, UK

Since the discovery of the Higgs boson in 2012, the observed production and decay modes have all been related to its coupling to gauge bosons and to third generation fermions. The focus is now shifting towards the Higgs boson couplings to the second generation fermions, in particular to muons, but the first generation is much less explored. This talk will present the ongoing efforts within the ATLAS collaboration to search for the rare Higgs boson decay to an electron and a positron using complete Run 2 integrated luminsoity. The search itself uses a similar method to previous searches at ATLAS for the di-muon decay of the Higgs, as the two decay channels have similar backgrounds and signal efficiencies. This talk will cover, in more detail, the motivations for and methods used in the search, as well as the expected results.

IceCube astrophysical neutrino 7.5-year data

T Katori

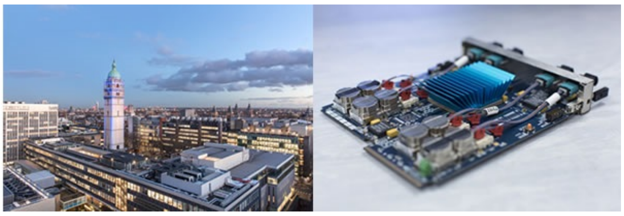
Queen Mary University of London, UK

The IceCube Neutrino Observatory detects astrophysical neutrinos with energies above TeV scales which provides the first solid evidence for astrophysical neutrinos from cosmological accelerators. Here we describe The High Energy Starting Event (HESE) selection and why it is useful for probing the high energy astrophysical landscape. With higher statistics taken over 7.5 years, we have been able to test the diffuse astrophysical flux whilst amplifying our rejection of atmospheric backgrounds using our neutrino veto region method. By doing so, the chance of understanding the characteristics of cosmic sources is also improved. With improved systematics and calibration, we aim to analyze rare topologies in the IceCube detector such as tau candidates, as well as Glashow neutrinos.

Noise Rejection Method Using Spherical Harmonic Decomposition

E Massera, M Fays, E Daw

University of Sheffield, UK



The rapid analysis of gravitational-wave data for burst-like signals is not trivial for many reasons, such as the non-Gaussian non-stationary nature of the background noise in the detectors and the lack of information about potential sources such as exhaustive waveform models or sky position. One active research area is based on the use of X-SphRad (X-Pipeline Spherical Radiometer), a software package designed for performing autonomous searches for un-modeled gravitational-wave bursts. X-SphRad has an approach based on spherical radiometry, that transforms time series data streams into the spherical harmonic domain. We will describe the harmonic coefficients potential in discriminating gravitational wave candidates from background noise, and overview a noise rejection method. We are testing this method on the data given by the LIGO-VIRGO collaboration.

Status of the LUX-ZEPLIN (LZ) dark matter experiment

B Lopez Paredes

Imperial College London, UK

LUX-ZEPLIN (LZ) is a dark matter direct detection experiment under construction at the Sanford Underground Research Facility in Lead, South Dakota. The dual-phase TPC at its core will contain seven tonnes of active liquid xenon to search for Weakly Interacting Massive Particles (WIMPs). Fabrication and assembly operations are on track to start a 1000-day science run in 2020 with a fiducial volume of 5.6 tonnes. In this talk I will present an overview of the current status of the experiment and its timeline.

Radon Backgrounds in LZ

U Utku

University College London, UK

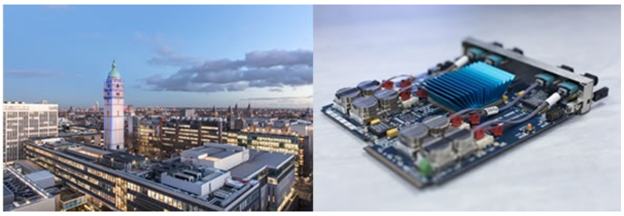
LUX-ZEPLIN (LZ) is a next-generation two-phase xenon TPC detector operating at 4850 feet below ground with an active mass of 7 tonnes. The primary goal of LZ is to search for low-energy interactions from the dark matter halo in our galaxy — hypothesised to be in the form of Weakly Interacting Massive Particles (WIMPs). Operating for 1000 days and using a 5.6-tonne fiducial mass, LZ is projected to exclude at a 90% confidence level, spin-independent WIMP-nucleon cross-sections above 1.6x10-48 cm2 for a 40 GeV/c2 mass WIMP. Radon presents the largest contribution to the background model in achieving this sensitivity. In this talk, I will present the comprehensive radon screening programme in LZ that informs material selection and construction; contributions from various radon-related backgrounds, including emanation, plate-out and mis-reconstruction effects; and finally, the implications of radon levels in LZ for both the experiment's

Top-Antitop Charge Asymmetry with Fully Bayesian Unfolding

R Vallance[1], M Watson[1], J Kempster[1], K Kawade[2], S Kido[2], O Majersky[3], M Melo[3], B Eckerova[3], P Bartos[3], C Helsens[4]

[1]University of Birmingham, UK, [2]Kobe University, Japan, [3]Comenius University, Slovakia, [4]CERN, Switzerland

A measurement of the top-antitop charge asymmetry is underway at the ATLAS experiment at the LHC. This is being being performed at 13 TeV with 80 fb^{-1} of proton-proton collision data, with the eventual aim to use the full 140 fb^{-1} Run 2 dataset. The method of Fully Bayesian Unfolding (FBU) is employed to determine the parton-level charge asymmetry. This technique generates a posterior probability distribution for the asymmetry which we compare with the expectation from Monte-Carlo simulation. The method also helps to reduce the systematic uncertainties and will allow the combination of three ttbar decay channels: dilepton, lepton+jets with resolved jets and lepton+jets with boosted (collimated) jets. The asymmetry is expected to be small, though effects beyond the Standard Model can change this. It is being determined inclusively and



also in bins of top-antitop transverse momentum, mass and velocity. In addition to the asymmetry for the top-antitop pair, a measurement is made in the dilepton channel of the asymmetry between the two leptons. This has reduced uncertainties but the predicted asymmetry is smaller.

Single dissociative diffraction at √s=13 TeV with the ATLAS detector

J Kendrick, P Newman

University of Birmingham, UK

I will be presenting an overview of the ATLAS analysis of the single dissociative diffraction cross-section in p-p collisions at 13 TeV. I am the main analyser for this measurement and it will be the topic of my PhD thesis.

Single dissociative diffraction (pp->pX) occurs when there is a t-channel exchange with the quantum numbers of the vacuum with one proton remaining intact and the other dissociating into a diffractive system 'X'. It's cross-section is approximately 10-20% of the total p-p cross-section at √s=13 TeV but this is not well constrained.

The aim of the analysis is to measure the differential cross-section as a function of the squared four-momentum exchanged in the t-channel and the fractional energy loss of the intact proton. This will enable tests of models based on different approaches to soft strong interactions and the calculation of parameters that are important in the tuning of MC models.

The analysis has several novel components. The data are from a low pile-up, high β^* optics run of the LHC. The ALFA roman pot detectors, situated ~240m away from the interaction point, are used to provide tagging and kinematic reconstruction of intact protons. At the time of writing there are no public LHC diffractive results that use proton tagging.

Top quark charge asymmetry at LHCb

J Mead

University of Liverpool, UK

The LHCb experiment provides unique detector coverage, $2 < \eta < 5$, of high energy proton-proton interactions produced at the Large Hadron Collider. Designed to study b- & c-hadron physics, LHCb is fully instrumented in the forward region with excellent tracking and vertex resolution.

The top quark is the heaviest fundamental particle and is expected to play a special role in new physics scenarios. Higher order interference mechanisms, sensitive to physics beyond the reach of current colliders, result in a charge asymmetry, Att , in the angular distributions of top pairs. LHCb's acceptance offers greater sensitivity to Att due to reduced dilution from gluon-gluon fusion.

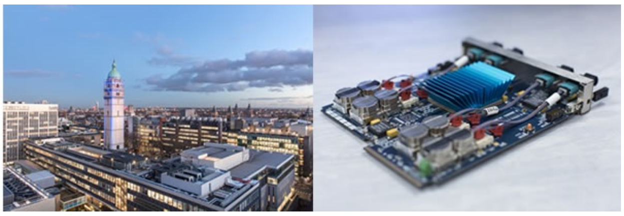
Top quarks are identified through the presence of a high pT muon and b-jet in the final state. Forward production was first observed with Run I data at LHCb in this channel. The increase in available statistics with Run II, as well as improved signal to background ratio, will allow the first measurement of the top charge asymmetry in the forward region.

CP violation measurements in B decays with final state neutral kaons: how precise can we get?

M Bjørn, S Malde, LHCb Collaboration

University of Oxford, UK

Measurements of CP violation in B decays are entering a high precision era, and with the increasing precision comes a need for an equally precise understanding of limiting uncertainties. I will present a recent,



world-leading precision measurement of the CP-violating CKM phase gamma, using data from the LHCb experiment. The measurement used B -> DK decays, where the D meson decays to a neutral kaon and two pions. Sensitivity to the CP violating phase gamma is obtained via interplay between gamma and the phase of the D decay over the decay phase space.

The expected precision within the next five years requires the study of second-order physics effects. I will focus on phenomenological work on a potentially limiting systematic uncertainty due to the inherent CP violation in the neutral kaon system, as well as material dependent kaon regeneration effects that can mimic CP violation signatures. Earlier estimates have put the relative bias due to these effects as high as 4 %, which would soon limit the obtainable precision. Therefore, a detailed understanding of the effects is crucial. I will present arguments for why the effect on measurements in the LHCb Upgrade and Belle 2 is expected to be at the sub-percent level.

A scintillator-based range telescope for quality assurance in proton therapy

L Kelleter, R Radogna, R Saakyan, S Jolly

University College London, UK

In particle therapy, range measurements are an integral part of the daily quality assurance (QA) process. Most treatment centres use water phantoms or Multi-Layer Ionisation Chambers for the range QA. A system is under development at University College London to provide fast, robust and cost-effective range QA measurements based on a plastic scintillator range telescope. This detector would be easy to set up and allow the verification of all range steps of a typical particle therapy centre within the time of delivery.

The results of proof-of-principle experiments with clinical particle beams are presented. A prototype was built at UCL and tested in multiple treatment centres across Europe with protons, Helium and Carbon ions. The range reconstruction of protons has an uncertainty of 0.15 mm, complying with clinical standards for quality assurance detectors. During a radiation damage assessment, a dose of 6,000 Gray was delivered to the range telescope, corresponding to approximately a year's worth of integrated dose. Although a reduction in the scintillator light output of a few percent was observed, there was no quantifiable impact on the range measurement itself.

Neutrinoless Double Beta Decay in the SNO+ Experiment

T Kroupova

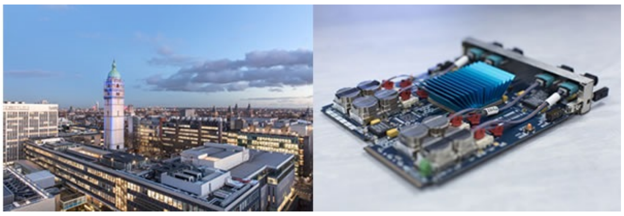
University of Oxford, UK

SNO+ is a multipurpose neutrino detector located in 2km underground in Sudbury, Canada. The main physics goal of the project is to search for neutrinoless double beta decay in Tellurium-130. For phase I, SNO+ will deploy 4t of natural Tellurium inside the detector volume in the form of Tellurium-loaded liquid scintillator. The detector is currently filled water and taking data. The Tellurium loading is expected to start later this year. I will discuss the requirements for the SNO+ scintillator along with the loading technique. The nature of the signal extraction and the projected sensitivity to neutrinoless double beta decay in SNO+ will also be presented.

First physics results from the SNO+ experiment

M Nirkko

University of Sussex, UK



Various theories beyond the Standard Model propose baryon number violating processes in order to explain the matter-antimatter asymmetry in the universe, many of which result in some form of nucleon decay. Some modes of nucleon decay are invisible, in the sense that the final state particles remain undetected. Following the disappearance of one or two nucleons in such a nucleus, the subsequent de-excitation of the remaining daughter nucleus may yet be observed via gamma-ray emission. Understanding the corresponding branching ratios for the population of various energy states in the daughter nuclei is crucial for setting lifetime limits on these decays.

The SNO+ experiment has been taking data for the past two years, during which the detector was filled with ultrapure water for commissioning and calibration purposes. Due to the 2 km rock overburden (6000 m.w.e.) and the high target purity, it was possible to conduct low background measurements as well as new physics searches in the 5-10 MeV energy range. In particular, a search for invisible nucleon and dinucleon decay modes in ^{16}O was conducted. Additionally, the ^{8}B solar neutrino flux was measured with an exceptionally low background rate. Results from these analyses are discussed here.

A search for light Higgs bosons in supersymmetric decay cascades at CMS

J Taylor[1], C Shepherd-Themistocleous[2], J Brooke[1]

[1]University of Bristol, UK, [2]STFC Rutherford Appleton Laboratory, UK

This talk presents a search for pairs of light Higgs bosons produced in NMSSM decay cascades using the CMS detector. The analysis uses data sets corresponding to the 2016 and 2017 proton-proton collisions at a centre-of-mass energy of 13 TeV. The final state targeted is that where both Higgs bosons decay into bbbar pairs.

The signal model is of interest because, under certain mass configurations, the missing transverse energy in the events can be highly suppressed. This produces an all jet final state that typical supersymmetry searches would not be sensitive to. In suppressing the missing transverse energy, the Higgs bosons become highly boosted objects, leading to a small angular separation between the b-quarks. Consequently, each bbbar pair is reconstructed in a single AK8 jet. Substructure techniques are applied to the AK8 jets to measure the mass of the reconstructed object, and to determine how likely it is that the AK8 jet originates from two b-quarks.

Prospects for ttZ measurements at ATLAS with the full 140 fb^{-1} Run 2 dataset

B Ravina

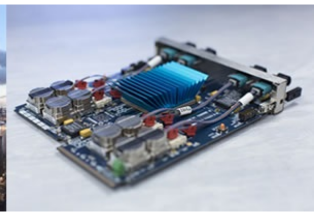
University of Sheffield, UK

We review the recent measurement of the inclusive ttZ cross-section with 36 fb^{-1} of data at 13 TeV at the ATLAS experiment, using EFT considerations and background modelling for generic SUSY/DM searches as motivation for continuing to improve the precision of this result. We then present plans for a differential ttZ measurement in the 3 and 4 lepton channels with the full 140 fb^{-1} Run 2 dataset, and highlight a number of promising research directions, such as a re-interpretation in terms of ttZ spin correlation observables, or the possibility to unfold SUSY/DM validation regions (or even null-result signal regions) to constrain the ttZ(νν) process. Particular attention is also given to the topic of semi-leptonic top reconstruction, necessary to match the performance of the dileptonic decay channels.

Search for the supersymmetric partner to the top quark in the all-hadronic channel with the ATLAS Detector

M Anthony

University of Sheffield, UK



The author/presenter will outline the status of the search for Supersymmetry (SUSY) in the 3rd generation sector, particularly the SUSY partner of the top quark, using the 140.5 ifb dataset collected from the ATLAS detector from LHC Run 2 (2015-2018).

This analysis is searching in the all-hadronic channel for a reconstructed final state of top-antitop pairs and Missing Energy, looking to observe R-Parity Conserving (RPC) SUSY. LHC Run 2 has profited from both increased statistics and improved understanding of the underlying objects of each collision event, and we will present the benefits this has offered for our search.

We will cover the search strategy, namely the definition of signal, control and validation regions for our background processes, the ATLAS detector configuration, key backgrounds and (if possible) new search results. The author will outline their work in particular into the study of constraining the all hadronic ttbar+ Z(-> 2 neutrinos) background in an all hadronic channel using the semi-leptonic ttbar+Z (->2 leptons) in a trilepton channel, a significant new component to the search strategy.

Search for the supersymmetric partner to the top quark in the all-hadronic channel with the Constraining Systematics at T2K with Near-Detector Fits

W Parker

Royal Holloway University of London, UK

T2K is a long baseline neutrino oscillation experiment designed to make precise measurements of the parameters governing neutrino oscillations. A muon (anti-)neutrino beam is produced at the Japan Proton Accelerator Research Complex (J-PARC) on the east coast of Japan, and is aimed towards the Super-Kamiokande (SK) detector 295km away near the west coast. In this analysis, Markov Chain Monte Carlo is used to fit the Monte Carlo prediction to data from the near detectors, ND280 and INGRID, which measure the neutrino flux and interaction cross-sections before oscillation. The flux and interaction models are parameterised using external data and T2K beam line monitoring measurements to set the prior values and uncertainties. The fit to ND280 data incorporates the prior knowledge, further constraining the uncertainties and adjusting the parameters. Several updates have been made to the data samples and cross-section model used for the 2019 oscillation analysis to maximise the constraint on these systematics, and reduce the impact they have on oscillation results. After the near detector fit, the central values and uncertainties of the parameters are used in the prediction of SK data for the full oscillation fit. Typically the near detector fitting process reduces systematic uncertainties from 12-14% to 2-4%, allowing world-leading oscillation parameter measurements to be made at T2K.

The High Pressure gas Time Projection Chamber: a Future Neutrino Detector

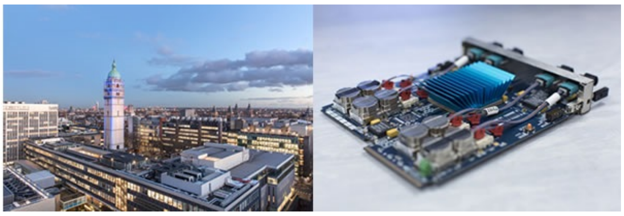
T Nonnenmacher

Imperial College London, UK

Understanding neutrino-nucleus interaction cross-sections at the 1-2 percent level will be crucial for the next generation of long baseline neutrino experiments. Due to its low hadron momentum detection threshold, a High Pressure gas Time Projection Chamber (HPTPC) is a strong candidate for achieving a significant reduction in uncertainties on these cross-sections . An HPTPC is part of the baseline design of DUNE and a candidate for use in Hyper-Kamiokande.

An optically read out prototype HPTPC, rated to 5 bar of pressure, was built at Royal Holloway, University of London. The detector was used to make proton scattering measurements on at the CERN East Area T10 beamline from August to September 2018.

In order to improve experimental uncertainties on neutrino-nucleus cross-sections, it is important to improve the models that we use to describe them. HPTPC data will be used to tune the final state interaction



parameters in NEUT, the primary neutrino Monte Carlo generator used by the T2K experiment. This tuning will enable a reduction in the systematic uncertainty of neutrino oscillation measurements made by T2K and future experiments.

Update on the measurement of the Unitarity Triangle angle γ using B->D(*)K(*) decays at LHCb

A Rollings

University of Oxford, UK

The measurement of the Unitarity Triangle angle γ is a cornerstone of our understanding of the CKM mechanism of quark interactions.
Due to the tiny theoretical uncertainty in self-tagging B decays to D^(*)K^(*) final states, these modes will provide a standard candle in CP-violation physics as we drive towards the ultimate precision in flavour physics.
Results in the simplest final states B->DK are well established and will be reviewed. This presentation/poster will expand on the new developments to exploit DK* a d D*K final states at LHCb.

Angular analysis of $B^+ \to K^+ee$ at the LHCb experiment

S Maddrell-Mander, K Petridis

University of Bristol, UK

Numerous recent anomalies in the b→sll flavour sector give indication of potential lepton flavour universality (LFU) violation in (axial-)vector couplings.

To probe these anomalies and further assumptions about LFU in other couplings, now more than ever, precise measurements of the SM properties are needed.

This talk presents one arm of these investigations using $B^+ \to K^+ee$ decays, with proton-proton collision data at LHCb collected in run 1 and run 2, to conduct the first angular analysis of this mode.

An angular analysis provides a way to measure non-trivial parameters using kinematic information from the decay, and in this mode has access to the coefficients for scalar, pseudo-scalar and tensor couplings.

This angular analysis will provide the most stringent constraint on the NP contributions through scalar, pseudo-scalar and tensor, couplings as the decay is independent of (axial-)vector couplings, and additionally provide vital understanding on the electron reconstruction efficiency in b→sll transitions.

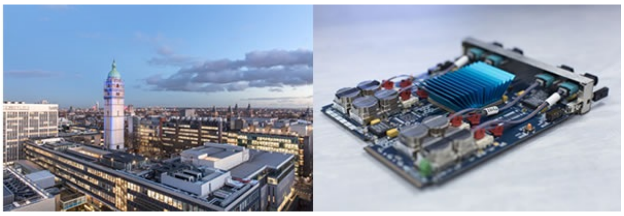
Branching fraction measurement of $B^0 \to \pi^+\pi^-\mu^+\mu^-$ using Run 1 and Run 2 LHCb data

E Millard

University of Warwick, UK

Flavour Changing Neutral Current processes are heavily suppressed in the Standard Model of particle physics and are potentially sensitive to contributions from as yet undiscovered particles. Recent measurements of b→s transitions by the LHCb collaboration show interesting tensions with Standard Model predictions.

The large LHC data set enables measurements of decays involving b→d transitions to be made for the first time. In combination with the b→s processes, these measurements will provide insights into the flavour structure of potential extensions to the Standard Model. The decay $B^0 \to \rho^0\mu^+\mu^-$ is a particularly interesting b→d process, which was first probed using LHCb's Run 1 dataset. Progress towards an updated



branching fraction measurement, using both Run 1 and Run 2 data, will be presented. In addition, the prospects for an angular analysis of the decay are discussed.

Tuesday 9 April

(Invited) SM (including top) at LHC

Y Peters

University of Manchester, UK

Since the discovery of the Higgs boson in 2012, the standard model of particle physics is technically complete. However, despite its success, it is clear that new physics beyond the standard model must exist. Using the ever-increasing data sample at the LHC, one avenue to hunt for new physics is by performing precision studies of the standard model and thus challenging its predictions. In this talk, a selection of recent results from LHC experiments that probe the Standard Model are presented, including precision measurements of the strong and electroweak forces and properties of the top quark.

(Invited) LHC Searches

C Leonidopoulos

University of Edinburgh, UK

Experiments at the Large Hadron Collider have collected the largest datasets of proton-proton collisions at the highest collision energies ever achieved. A very broad physics programme on direct and indirect searches is currently being carried out at the LHC. What have we learned from the first two Runs? New theoretical developments and experimental techniques are currently being put to test. We will review the latest experimental results, and discuss prospects for future searches.

Extending dark matter searches in liquid xenon to single scintillation photons

N Marangou

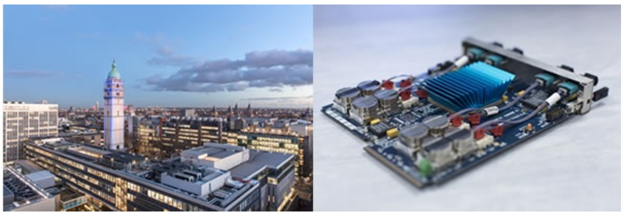
Imperial College London, UK

Dark matter experiments searching for weakly interacting massive particles (WIMPs) probe a variety of rare processes leading to O(keV) energy transfers to ordinary matter. Two-phase xenon detectors record two different signals per interaction: a prompt scintillation response (S1) and a delayed signal from ionisation (S2), with the energy threshold of standard analyses (S1+S2) largely determined by the S1 signal. We present a novel WIMP search analysis of LUX data from 2013, using a class of events with an S1 consisting of a single detected scintillation photon. This exploits a feature in the response of photomultiplier tubes to vacuum ultraviolet light which brings additional sensitivity for light WIMP interactions. We present also a projected WIMP sensitivity for the forthcoming LUX-ZEPLIN (LZ) experiment, with a lower S1 threshold achieved through the same analysis technique.

Background model for the LUX experiment

P Rossiter

University of Sheffield, UK



The Large Underground Xenon (LUX) experiment is a retired dual phase Liquid Xenon Time Projection Chamber (LXe TPC), designed for the direct detection of dark matter. In 2016, LUX published its final limit on the spin independent nuclear cross-section for the scattering of WIMPs with nucleons. Subsequently the collaboration's focus has shifted to exploring new physics beyond this energy range. Due to the possible complexity of such signals, additional attention has been given to the radiogenic backgrounds seen in dual phase TPCs. This presentation will focus on beta, gamma, and neutron backgrounds intrinsic to LUX, with a particular emphasis on electron recoil background events which can mimic nuclear recoil signals.

Latest $B \to \mu^+ \mu^-$ results with the ATLAS detector

F Tresoldi

University of Sussex, UK

The decay of B mesons into a pair of oppositely charged muons is extremely rare in the Standard Model, due to the suppression of Flavour-Changing-Neutral-Current (FCNC). Their Standard Model prediction is accurate and the experimental signature is very clean, therefore these decays are considered one of the golden channels to test the Standard Model and to look for deviations from its predictions due to New Physics phenomena. The latest analysis performed by the ATLAS collaboration on the dataset collected at center-of-mass energies of 13 TeV in 2015 and 2016 is presented, together with the extrapolation of the sensitivity of the analysis to the full 2015-2018 period as well as the future High Luminosity upgrade of the Large Hadron Collider.

Searching for new physics with emu asymmetry at the ATLAS detector

H Pacey, W Fawcett, C Lester, B Brunt

University of Cambridge, UK

The ATLAS experiment has never before measured the ratio of e+mu- to e-mu+ events in its data. Such a ratio is not expected to exceed one in the Standard Model in the LHC's proton-proton collisions. However, it could exceed one for some Beyond the Standard Model (BSM) scenarios like R-Parity violating supersymmetry or scalar leptoquarks. This talk presents a general search for new physics through the measurement of this ratio, that will also provide world-leading limits on these two BSM models which have not been probed with ATLAS before. This ratio measurement is highly unusual for an ATLAS BSM search, requiring little use of Monte Carlo simulation as well as allowing many systematic uncertainties to cancel out. The result will use the full 140.3fb^-1 of luminosity from the full run-2 dataset, taken in 2015-2018, and is aiming for publication in summer 2019.

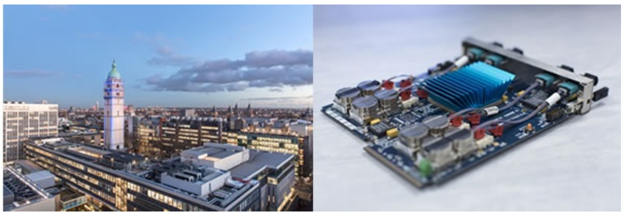
Measuring Muon Induced Neutrons in the Water Phase of the SNO+ Experiment

M Stringer, B Liggins

Queen Mary University of London

When a muon passes through a matter it can liberate neutrons and produce radioactively unstable isotopes. These neutrons and cosmogenic radioisotopes form a background to deep underground low-background experiments.

With a 2 km overburden, SNO+ sees approximately 3 muons per hour passing through the detector. The water phase of the experiment has just completed, and the detector is currently being loaded with scintillator. The low energy threshold and low backgrounds of SNO+ during the water phase allow the detection of neutrons via the capture of the neutron on a free proton releasing a signature 2.2 MeV gamma ray. The deployment of an AmBe source in the centre of the detector produced a tagging efficiency of



46.5±0.4%. This is the highest tagging efficiency achieved of any undoped water Cherenkov detector to date.

By searching for neutron captures following a muon passing through the detector the number of neutrons produced can be estimated. An analysis procedure is presented to determine the distribution of the number of neutrons generated per meter of muon track length within the detector. A measurement of the muon induced neutrons will allow an improved estimate of the backgrounds to the various dark matter experiments which are also hosted by the SNOLAB facility.

The Water Cherenkov Monitor for Anti-Neutrinos (WATCHMAN) at the Advanced Instrumentation Testbed

M Malek

University of Sheffield, UK

The WATer CHerenkov Monitor for Anti-Neutrinos (WATCHMAN) is the flagship project of the Advanced Instrumentation Testbed (AIT), a new US-UK collaboration in fundamental and applied science.

WATCHMAN will contain gadolinium-loaded water to allow it to detect the unique signature produced by an antineutrino interaction. With a total target mass of about 6000 tonnes, it will attempt to demonstrate that this new and scalable technology can be used for the remote monitoring of nuclear reactors. From its location in the STFC Boulby Underground Laboratory in North Yorkshire, WATCHMAN aims to observe the cycles of the Hartlepool dual-core nuclear power plant at a standoff distance of 25 kilometers.

The AIT will also enable testing of new technologies, including fast photosensors (such as Large Area Picosecond Photo-Detectors, or LAPPDs) and novel detection materials (such as water-based liquid scintillator, or WbLS).

In addition to its primary mission of applied antineutrino physics, the initial phase of WATCHMAN will be sensitive to antineutrinos from a galactic supernova burst. Using the new technologies described above, future phases may be able to probe other areas of fundamental science, such as geoneutrinos and CNO solar neutrinos.

This talk will present an overview of AIT-WATCHMAN, including the current status and prospects for future physics.

Modelling Backgrounds and Searching for WIMPs in DEAP-3600

J Walding

Royal Holloway University of London, UK

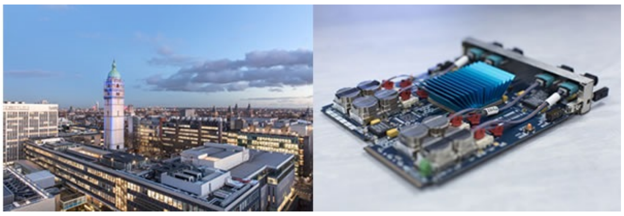
DEAP-3600 is single-phase liquid argon (LAr) direct-detection dark matter experiment, operating 2 km underground at SNOLAB, Sudbury, Canada. The detector consists of 3279 kg of LAr contained in a spherical acrylic vessel.

In this talk, a summary of the second dark matter search analysis of a 758 tonne-day exposure will be presented with emphasis given to modelling the detector backgrounds.

Differential measurement of the Z/γ ratio with the CMS experiment in pp collisions at 13 TeV

A G Zecchinelli

Imperial College London, UK



The large amount of data collected at the Large Hadron Collider in its second phase of running, colliding protons at an unprecedented center of mass energy of 13 TeV, gives us the tremendous opportunity to conduct measurements of vector boson plus jets (V+jets) processes in regions of phase space that were previously limited.

This kind of processes play a key role in precision tests of the Standard Model and also the search for a wide variety of phenomena beyond the Standard Model. They are valuable probes of perturbative QCD and validate fundamental aspects of theoretical calculations, also providing crucial inputs in the determination of Parton Distribution Functions. Moreover, thanks to the high center of mass energy, V+jets processes are sensitive to effects from higher order electroweak (EWK) corrections.

In parallel, developments in theoretical calculations have led to improved predictions and state of the art event generators becoming available, with the near term prospect of having automated Next-to-Leading-Order QCD and EWK corrections.The availability of such predictions, together with the large amount of data, add interest in studying particular phase space corners where EWK corrections are enhanced, such as collinear vector boson emission from a jet, and ratio of V+jets production cross sections, characterized by small systematic uncertainty on the measurement.

In my talk, I will present a precision measurement of the differential cross-sections of Z+jets and photon+jets production as a function of the boson transverse momentum and their ratio. The data was taken during 2016 by the CMS experiment and corresponds to an integrated luminosity of 35.9 fb^{-1}, and are compared with several theoretical predictions.

Search for dark matter produced in association with bottom or top quarks with the ATLAS detector

E Thorpe

Queen Mary University of London, UK

If dark matter interacts weakly with standard model particles it could be produced at the LHC and therefore could be observed with the ATLAS detector. WIMP dark matter would not interact with the detector and therefore would leave a signature involving large amounts of missing transverse momentum. There are a number of models assume a mediator which couples to both dark matter and the standard model. We will present a summary of searches for fermionic dark matter, produced through the exchange of a spin-0 mediator, in association with heavy flavour (bottom and top) quarks.

Associated production of a J/psi + photon at ATLAS

A Tee

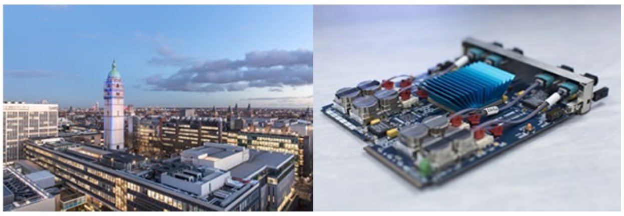
Lancaster University, UK

The aim of this analysis is to study the process pp-> J/psi + photon + X, in order to understand the production mechanisms of this final state, and possibly to assess some information on the spin structure of the gluon distribution inside the proton. Analysing the subprocess g+g->J/psi + photon there is the prospect of seeing azimuthal modulations in the Collins-Soper frame, induced by the polarization of the gluons. The analysis is using the data collected during Run2 by the ATLAS experiment at CERN.

Search for a heavy Higgs boson decaying into a Z boson and another heavy Higgs boson in the llbb final state in 13 TeV pp collision with ATLAS detector

W Y Chan

University of Liverpool, UK



In this talk a search for a Higgs boson cascade in the context of the two-Higgs-Doublet Model is presented. In this cascade, a heavy Higgs boson A decays to ZH, where H is another heavy Higgs boson with mass > 125 GeV. Subsequently, the Z boson decay leptonically and the H boson into a bb pair. The search is motivated by the mechanism which generates the matter-antimatter asymmetry in the context of extended Higgs sectors, known as electroweak baryogenesis. In the context of 2HDM, this mechanism requires large mass splitting between the two heavier Higgs bosons. The search uses a data sample corresponding to an integrated luminosity 36.5 fb-1 from proton-proton collision data at a center-of-mass of 13 TeV recorded in 2015 and 2016 by the ATLAS detector at the LHC.

The A boson is assumed to be produced via gluon-fusion and b-associated production in the mass range 230-800 GeV and to decay to the H boson in the mass range 130-700 GeV, which is prefered by electroweak baryogenesis models. The dominant backgrounds of this analysis are expected to be Standard Model Z + heavy flavour jets and top-pair production. Monte Carlo samples are data driven method are used to develop methods to estimate the backgrounds and improve the sensitivity of the analysis.

The result of the search has been published in 2018 [Phys. Lett. B 783(2018)392]. No evidence for the production of an A boson is found. Considering each production process separately, 95% confidence-level upper limits on the pp->A->ZH production cross-section times the branching ratio H->bb are reported to be in the range 14-830 fb-1 for the gluon-gluon fusion process and 26-570 fb-1 for the b-associated production process for the corresponding mass ranges of A and H bosons. The results are also interpreted in the context of two-Higgs-doublet models.

Searching for dark matter in DEAP-3600 in a 758 tonne-day data set

A Kemp

Royal Holloway University of London, UK

The DEAP-3600 detector, based 2km underground at SNOLAB (Sudbury, Canada) is a dark matter direct detection experiment. The detector is a single phase liquid argon (LAr) target, of 3279 kg mass. In this talk, the results of a dark matter search analysis of 758 tonne-days will be presented. No candidate signal events were observed in the WIMP region of interest, resulting in the leading limit on the WIMP-nucleon spin-independent cross section measured on a LAr target. The world-leading pulse shape discrimination result will be discussed, together with the plans to move towards a profile-likelihood statistical approach to perform the dark matter search analysis.

Beam test studies of a prototype TORCH detector

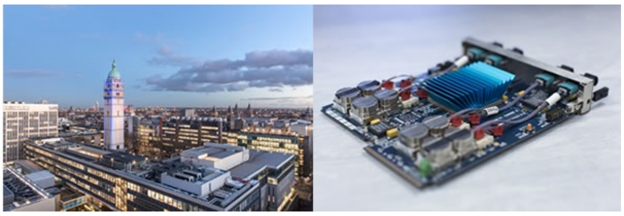
T Hancock

University of Oxford, UK

TORCH is a time-of-flight detector designed to provide particle identification over the 2-10 GeV/c momentum range. Consisting of 18 large quartz plates, TORCH measures the time of arrival of charged particles through prompt Cherenkov light which is trapped by total-internal reflection. At the top of the plate the light is focused onto a row of micro-channel plate (MCP) detectors which measure the photon arrival time and position.

Designed for the LHCb detector, TORCH aims for a 15 ps track time resolution over a 10 m flight path. This translates into a 3 standard deviation separation between pions and kaons with momenta of 10 GeV/c. To achieve such a track resolution requires a time resolution of 70 ps per photon for 30 detected photons per track.

In the latter half of 2018 both a small-scale (120 x 350 x 10 mm^3) and a half-scale (660 x 1250 x 10 mm^3) prototype were tested in a 5 GeV/c mixed proton-pion beam at the CERN PS. Employing data-driven



calibrations, the single photon timing performance has been measured, providing proof of principle for the TORCH concept. The projected performance of a full-scale TORCH detector instrumented in the LHCb experiment, determined through simulation studies, will also be presented. This talk would complement the abstract proposed by Emmy Gabriel, also on TORCH.

Photon yield and MCP-PMTs in a prototype TORCH detector

E Gabriel

University of Edinburgh, UK

TORCH (Time Of Internally Reflected CHerenkov light) is a novel concept of a Ring Imaging Cherenkov time-of-flight detector, which is being developed with a possible application in an upgrade of the LHCb experiment in 2030. Currently it is still in the Research and Development (R&D) phase. It utilises Cherenkov radiation to identify particles at low momenta. It would be located at 10m from the proton-proton interaction point, and consist of a 30 m^2 by 10 mm quartz plate which propagates emitted photons to Micro-Channel Plate Photomultiplier tubes (MCP-PMTs) where they can be captured. Total internal reflection in the detector propagates the photons onto the MCP-PMTs. To achieve a 3-sigma separation between kaons and pions up to 10 GeV/c, a timing resolution of 15 ps per photon is required. This provides the greatest challenge in this project and requires careful testing, performed during the so-called beam tests.

In my talk, I would focus on the MCP-PMTs, going into detail on lab testing of these tubes performed at CERN. In addition, I would give an update on the photon yield, comparing beam test data analysis with simulation. My talk would complement the talk proposed by Thomas H. Hancock on TORCH.

Search for chargino and neutralino production in final state with three leptons and missing transverse momentum, via WH intermediate decays

F Trovato

University of Sussex

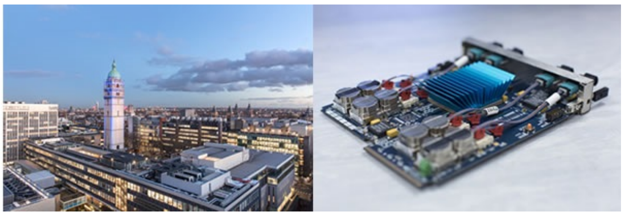
The direct production of chargino-neutralino, $pp \rightarrow \tilde{\chi}^{\pm}_1 \tilde{\chi}^0_2$, followed by their decays via intermediate WH states ($\tilde{\chi}^{\pm}_1 \tilde{\chi}^0_2 \rightarrow W^{\pm} H \tilde{\chi}^0_1 \tilde{\chi}^0_1$), where H is the 125-GeV Standard Model Higgs boson, is a very important channel for the search for electroweak supersymmetry at the Large Hadron Collider. Amongst others, the search can be performed in the channel where both the W and the H decay fully leptonically ($\tilde{\chi}^{\pm}_1 \rightarrow \tilde{\chi}^0_1 (W^{\pm} \rightarrow \ell^{\pm} \nu)$ and $\tilde{\chi}^0_2 \rightarrow \tilde{\chi}^0_1 (H \rightarrow \ell\ell)$), yielding three leptons in final state. Results are presented from this search using 36.1 fb^{-1} of $\sqrt{s}$=13 TeV proton-proton collision data recorded with the ATLAS detector, together with an outlook for the full Run-2 analysis.

Searches for NMSSM Signatures with low Missing Transverse Energy at the CMS detector at the LHC

A Titterton[1], H Flaecher[1], C Shepherd-Themisocleous[2], S Moretti[3], U Ellwanger[4]

[1]University of Bristol, UK, [2]STFC Rutherford Appleton Laboratory, UK, [3]University of Southampton, UK, [4]Université Paris-Sud, France

We examine scenarios in the Next-to-Minimal Supersymmetric Standard Model (NMSSM) whereby two Standard Model-like Higgs bosons are produced via squark and gluino decay cascades along with two light, low-momentum neutrino Lightest Supersymmetric Particles (LSPs), resulting in very little Missing Transverse Energy (MET). Firstly, by recasting a general-purpose Jets+MET α_T-based analysis we demonstrate how the sensitivity of current SUSY search efforts decreases in certain regions of parameter space within these scenarios. Finally we develop a novel search technique utilising machine learning-driven double-b-tagging variables for the case where each Higgs boson decays to a boosted bb pair.



Approaching the neutrino mass problem with a beam dump experiment

T Boschi[1], S Pascoli[2], P Ballett[2]

[1]Queen Mary University of London, UK, [2]Durham University, UK

The origin of the neutrino mass is still an open problem in physics and many efforts are being made to solve it.

Among the possible solutions, the simplest ones involve an extension of the Standard Model, where new singlet fermions are added. The most famous of this mechanism is the Type I seesaw, but the new particles introduced are usually at a scale not accessible by current and future experiments and therefore this model is not appealing for phenomenology studies.

However, symmetry-protected variants of the seesaw mechanism, like the Inverse Seesaw, could explain the existence of light-neutrino masses while also providing observable signatures of Heavy Neutral Leptons (HNLs) in a range of upcoming neutrino beam experiments.

In this talk, I will discuss the phenomenology of sterile neutrinos arising from low-scale neutrino mass models and the implications of a realistic mass model on the search for HNL. I will focus in particular on the impact on the signal of the strong polarisation effects in the beam for Majorana and (pseudo-)Dirac states, providing formulae to incorporate these in both production and decay. I will then talk about signatures for discovery of HNL and signatures of lepton number violation that could be searched for in beam dump experiment, taking the DUNE experiment as a case study.

Matter density profile effects on neutrino oscillations at T2HK and T2HKK

S Molina Sedgwick[1,2], S F King[2], S J Parke[3], N W Prouse[4]

[1]Queen Mary University of London, UK, [2]University of Southampton, UK, [3]Fermi National Accelerator Laboratory, USA, [4]TRIUMF Particle Accelerator Centre, Canada

This project aims to explore the effects that changes in a matter density profile could have on neutrino oscillations, and whether these could potentially be seen by the future Hyper-Kamiokande experiment (T2HK). The analysis is extended to include the possibility of having a second detector in Korea (T2HKK).

Optical calibration design for the Hyper-Kamiokande Outer Detector

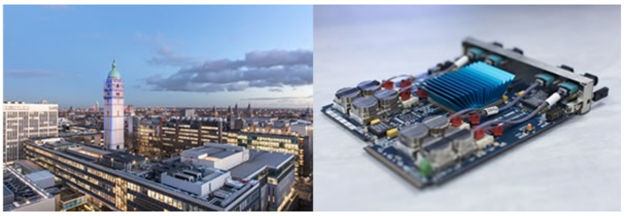
C Pidcott

University of Sheffield, UK

Hyper-Kamiokande will be the next generation water Cherenkov detector, an order of magnitude larger than Super-Kamiokande, capable of studying proton decay, atmospheric neutrinos, and detecting neutrinos from astronomical sources with far greater precision than its predecessor. It will also serve as the far detector for long baseline neutrino beams produced at J-PARC.

The detector will consist of both inner (ID) and outer (OD) detectors filled with ultrapure water. The ID will be instrumented with photomultiplier tubes (PMTs) facing inwards to detect Cherenkov light produced in neutrino interactions and potential nucleon decays, with 40% photocoverage. The OD will have PMTs on the OD inner wall facing outwards, with a photocoverage of 1%, and has the primary purpose of vetoing background events originating outside of the detector, as well as determining whether or not events occurring in the ID are fully contained.

An LED optical calibration system has been designed for the Hyper-Kamiokande ID and deployed for testing in Super-Kamiokande, incorporating narrow and diffuse beams of light. A similar system is intended for use in the OD, with light being delivered by optical fibres around the outside wall of the detector. A specific



challenge of this design arises due to the geometry of the OD and sensor support structures within it, necessitating many light injection points to illuminate all PMTs to the required intensity, as well as allowing sufficient redundancy should any sources become non-functional, all while minimising the final number of injection points to mitigate costs. The initial results of simulated studies of this system using the WCSim software suite will be presented in this talk.

A New Jet Pairing Method for Reconstructing HH -> $b\bar{b}b\bar{b}$ Events

B Stanislaus

University of Oxford, UK

In the ATLAS HH -> $b\bar{b}b\bar{b}$ analysis, jets are paired to form Higgs boson candidates by minimizing the perpendicular distance between the pair and the line joining the point (120 GeV, 110 GeV) to the origin in the plane of leading Higgs boson candidate mass -- subleading Higgs boson candidate mass. This strategy is shown to reconstruct background events such that they peak around the point (120 GeV, 110 GeV) where a signal would be expected. Here an evaluation of an alternative strategy is presented.

Advances and challenges in the full run 2 search of boosted di-higgs decaying to $b\bar{b}b\bar{b}$ with the ATLAS detector

S R Paredes Saenz

University of Oxford, UK

After the discovery of a Standard Model like Higgs boson, new searches can now change focus towards using it as a tool to probe the Standard Model and new physics. With the largest branching fraction, the $b\bar{b}b\bar{b}$ final state is one of the leading candidates to observe this process, but the overwhelming backgrounds and the highly boosted topology reached by this process, present a challenge. This talk will outline a few of these issues and explore novel techniques to mitigate their effect.

Angular Analysis of the B -> K* mu mu decay at the LHCb Experiment

F J Kress

Imperial College London, UK

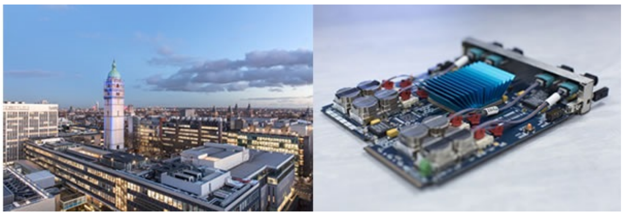
Recent observations of B decays hint at discrepancies with predictions of the otherwise overwhelmingly successful Standard Model of Particle Physics. These observations are extremely intriguing, as they can be interpreted in a coherent way in a number of new physics models by introducing a new vector particle such as a Z' or a leptoquark.

This talk will concentrate on one of these measurements, the angular analysis of the rare decay B->K*mumu, performed on data from the LHCb experiment. An introduction to the measurement will be given and the Run 1 results, which have a 3.4 sigma tension with the Standard Model prediction, are presented. An overview of the current status of the update of this analysis with Run 2 data collected at the LHCb detector will be given.

Determination of hadronic resonance contributions to the B0 -> K*0μμ decay

M Hecker

Imperial College London, UK



The angular observables of the B0 -> K*0μμ decay are showing intriguing discrepancies with Standard Model (SM) predictions [1]. The discrepancies indicate a shift of the vector coupling (C9) with a significance of about 3.4 standard deviations. This could be explained by the existence of new heavy vector particles not described by the SM. However, the discrepancies may also be explained by interference between hadronic resonance amplitudes (long distance) (e.g. B0 -> J/ΨK*0) and the SM flavour changing neutral current (short distance) amplitudes.

To solve this ambiguity, we intend to perform an unbinned fit to the decay angles and the dimuon mass of the B0 -> K*0μμ decay across the full dimuon spectrum. In the empirical model used for this fit hadronic resonances are modelled as relativistic Breit-Wigner amplitudes and the magnitudes and phases of all hadronic resonance amplitudes are defined relative to the short distance amplitudes [2]. This approach allows the simultaneous determination of the Wilson Coefficients C9 and C10 as well as the level of hadronic interference directly from data.

In the talk I will explain the model, relevant experimental effects (such as acceptance, resolution, and backgrounds), as well as the fitting procedure. Furthermore, I will discuss the expected sensitivity to the key signal parameters.

[1] LHCb collaboration, JHEP 1602 (2016) 104

[2] T. Blake et al., Eur.Phys.J. C78 (2018) no.6 453

(Invited) Electronics

A W. Rose

Imperial College London, UK

Since the inception of particle-physics, electronics have been vital in the making of measurements and the taking of data, and the ability to do so consistently and reliably. Since it's conceptual stage, the LHC has posed significant challenges to the physicists and engineers responsible for ensuring the efficient taking of high-quality data, and with every breakthrough in the performance of the accelerator, the challenges faced by both the on- and off-detector electronics has increased, and whilst the HL-LHC may, to the physicist, represent an order-of-magnitude in statistics, it can only live up to that dream if the detector- and trigger-electronics can achieve a similar leap in performance. I will provide an introduction to triggering suitable for beginners, highlight some of the lessons learned at CMS and conclude with the challenges posed by the HL-LHC and how we are preparing for them.

Wednesday 10 April

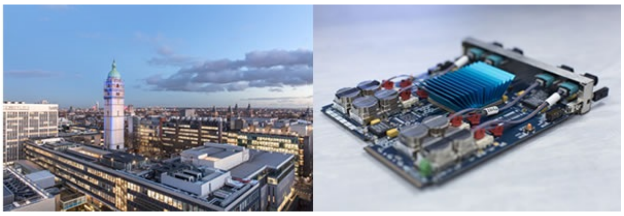
Measurement of CP violation parameters in $B^0 \rightarrow DK^{*0}$ decays

H Pullen

University of Oxford, UK

The CP-violating angle γ is the only angle of the unitarity triangle which can be measured via tree-level processes. γ can also be measured indirectly using loop-level processes, which are susceptible to the effects of new physics. An observed discrepancy between the direct and indirect measurements of γ would be evidence for new physics. Reducing the experimental uncertainty on the direct γ measurement is therefore of great interest.

To measure γ, we exploit interference between decays with $b \rightarrow u$ and $b \rightarrow c$ quark transitions. One such decay is $B^0 \rightarrow DK^{*0}$, where D is a superposition of D^0 and anti-D^0 mesons. An analysis of this mode is presented with D reconstructed in the two-body final states $K^-\pi^+$, $K^+\pi^-$, K^+K^- and $\pi^+\pi^-$, and the four-body final



states $K^-\pi^+\pi^-\pi^+$, $K^+\pi^-\pi^+\pi^-$ and $\pi^+\pi^-\pi^+\pi^-$. The data sample used corresponds to 5 fb^{-1} of proton-proton collisions collected by the LHCb experiment. Several observables are measured, including CP asymmetries. These provide constraints on γ as well the amplitude ratio r_B and strong phase difference δ_B between the interfering decays.

Measurement of the CP violating phase φ_s originating in $B^0_s \rightarrow J/\psi\varphi$ decays using LHCb Run 2 data

J Zonneveld

University of Edinburgh, UK

The LHCb experiment focuses on CP violation, a process that explains the abundance of matter in the Universe. The Standard Model theory prediction of CP violation is much smaller than the observed asymmetry. The 'golden decay mode' $B^0_s \rightarrow J/\psi\varphi$ could easily be influenced by New Physics particles, and shift the experimentally observed amount of CP violation from the theory prediction. I will present the analysis of 2015 + 2016 3fb^{-1} $B^0_s \rightarrow J/\psi\varphi$ data collected by the LHCb experiment at a centre-of-mass energy of 13 TeV. The talk will also cover the combination with Run 1 data, yielding the World's most precise determinations of the CP violating phase φ_s and of the decay width difference between the light and the heavy mass eigenstates in the B^0_s system.

ARIADNE: A 1-ton dual-phase LArTPC with optical readout

J Vann, K Mavrokoridis, K Majumdar, A Roberts, B Philippou

University of Liverpool, UK

ARIADNE is a 1-ton two-phase liquid argon (LAr) time projection chamber (TPC) featuring a novel optical readout method. The detector uses a Thick Gas Electron Multiplier (THGEM) in the extraction region to generate secondary scintillation light which is imaged using 4 Electron-Multiplying (EM)CCD cameras to produce high resolution images of particle interactions within the detector.

This approach has many potential improvements over current readout techniques. A combination of the high level of gain achievable in the THGEM and the single-photon sensitivity of the EMCCDs give's sensitivity at low energies.

ARIADNE underwent testing and commissioning runs in Liverpool at the end of 2017, followed by a beam line test at the CERN East Area in 2018. This was the first beam line test of an optical dual phase TPC for a detector of this scale. Initial results from these tests will be presented.

Further work has been carried out into integrating an optical Timepix3 based camera into the detector providing very fast readouts and true 3D reconstruction. These technologies have the potential to be used at future large-scale LArTPC experiments.

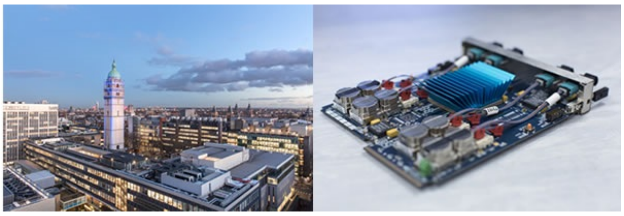
http://hep.ph.liv.ac.uk/ariadne

Recent advancements on the NEWS-G spherical proportional counter sensors

I Katsioulas

University of Birmingham, UK

NEWS-G is an innovative experiment aiming to shine a light on the dark matter conundrum with a novel gaseous detector, the spherical proportional counter. It uses light gases, such as hydrogen, helium, and neon, as targets, to expand dark matter searches to the sub-GeV/c^2 mass region. NEWS-G produced its first results with a detector -60 cm in diameter- installed at LSM (France), excluding cross-sections above $4.4 \cdot 10^{37}$ cm^2 for 0.5 GeV/c^2 dark matter using neon gas. Currently, a larger -140 cm in diameter- more



advanced detector is being built at LSM and a first run is under way there, before its installation at SNOLAB (Canada) at the end of the year. The detector operation will be challenging in terms of gain, electric field intensity and stability of operation, along with the demand for high radiopurity levels. In this talk, I will present new advancements in instrumentation for the spherical proportional counter relying on resistive materials, greatly limiting spark rate and intensity, permitting high gain operation in high pressure. Furthermore, I will present the recent developments on the multi-anode sensor (ACHINOS) that permits high gain operation combined with an increased electric field.

Search for single-production of vector-like B quark decaying into a bottom quark and a Higgs in the H->bb decay mode with the ATLAS experiment

M Montella

University College London, UK

A search is conducted for single-production of a vector-like B quark decaying into a Higgs boson and a *b* quark. Vector-like quarks are theorised to be highly massive colour triplet spin-1/2 fermions arising in models, such as the Little Higgs and Composite Higgs models, which tackle the hierarchy problem resulting from the measured value of the Standard Model Higgs boson mass. Vector-like quarks are predicted to mix prevalently with third generation Standard Model quarks through couplings with the weak Gauge Bosons or the Higgs Boson.

This search targets the $B \to bH$ decay mode in the fully hadronic channel defined by the $H \to bb$ secondary decay. The Standard Model background to the search, consisting mainly of continuum multi-jet production, is estimated through a fully data driven procedure. The search is carried out on the entire Run II collision data with centre-mass energy of 13 TeV, collected between 2015 and 2018, amounting to a total of 140 fb^{-1}. Preliminary results are shown as mass-dependent 95% CL exclusion values for the production cross section of a vector-like b quark according to the benchmark model employed.

Observation of H->bb decays in the VH production mode and first differential measurement with the ATLAS detector

L Ambroz

University of Oxford, UK

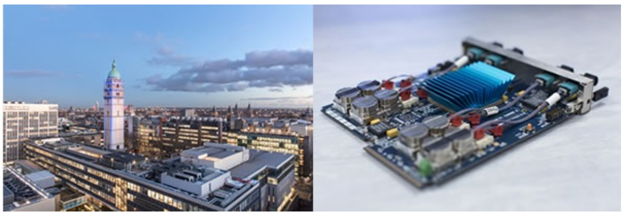
H ->bb decays allow to probe the Yukawa coupling of the Higgs boson to down type quarks. Observing these processes at the LHC is extremely challenging due to the large multi-jet background; however, this can be greatly suppressed by triggering on Missing Energy Transfer and leptons coming from the decay of a weak vector boson produced together with the Higgs.

In this talk, the latest search for H->bb decays associated with a W or Z boson with the ATLAS detector will be presented. Furthermore, the first VH->bb differential measurement in bins of transverse momentum of the vector bosons will be discussed; this type of differential measurement is particularly sensitive to Beyond Standard Model Physics in the form of Effective Field Theory models.

Searches for electroweak supersymmetry in final states containing one lepton, two b-tagged jets and missing transverse energy at the ATLAS experiment

M Sullivan

University of Liverpool, UK



Supersymmetry (SUSY) is one of numerous, and one of the most famous, theoretical extensions to the Standard Model aiming to answer open questions in particle physics, such as the nature of dark matter and the origin of the electroweak symmetry breaking. SUSY extends the particle spectrum of the SM such that each SM particle has at least one supersymmetric partner. Mixtures of the SUSY partners to the gauge bosons and Higgs can form to produce the electroweakinos; charginos and neutralinos. The lightest neutralino, often referred to as the lightest supersymmetric particle (LSP), is one of the most commonly considered WIMP dark matter candidates.

Using data collected in 2015-2016 by the ATLAS collaboration, a search for chargino-neutralino pair-production is presented. The chargino decays via a W boson and an LSP, while the neutralino decays via a Higgs boson and an LSP. The final state contains a lepton from the W decay, two b-jets from the Higgs decay, and missing transverse energy. No significant excess is observed, but exclusion limits on this process are set upto 550 GeV. A projected limit for this search channel for the HL-LHC results in an expected exclusion limit of 1280 GeV and discovery potential up to 1080 GeV. Finally, future prospects for this channel are presented, including the use of machine learning techniques to improve signal-background discrimination.

Non-parametric Bayesian event reconstruction in Super-Kamiokande detector

A Sztuc

Imperial College London, UK

We present a method for non-parametric, Bayesian neutrino event reconstruction for the Super-Kamiokande detector. Particle properties are determined in a way where the number of Cherenkov rings to be reconstructed, and therefore the number of parameters, is one of the unknowns. We discuss Bayesian model selection with Markov Chain Monte Carlo, future scalability and the issues surrounding non-parametric Bayesian reconstruction in Water Cherenkov detectors. We also briefly discuss the application of Bayesian methods in other contexts within T2K and Super-Kamiokande.

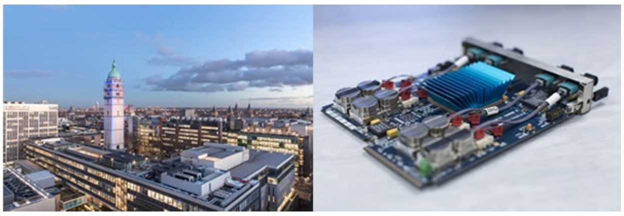
Electron neutrino selection in the MicroBooNE LArTPC using the Pandora pattern recognition reconstruction

W Van De Pontseele[1], R Soleti[2], R Guenette[2]

[1]University of Oxford, UK, [2]Harvard University, USA

MicroBooNE (the Micro Booster Neutrino Experiment) is a liquid argon time-projection chamber (TPC) experiment designed for short-baseline neutrino physics, currently running at Fermilab. It aims to address the anomalous excess of low-energy events observed by the MiniBooNE experiment. In this talk the ability of the experiment to reconstruct electron neutrino-like events in the detector, using the Pandora multi-algorithm pattern recognition, will be demonstrated. In particular, we present a fully automated event selection algorithm to identify charged-current electron neutrino event candidates with no pions and at least one proton in the final state (nu_e CC0pi-Np). We discuss the combination of optical information and TPC information to reduce cosmogenic backgrounds. Additionally, we show some cuts on kinematic and geometric variables to reject background events. These cuts have been validated by analyzing two event samples orthogonal to our signal. Future improvements have been identified which will improve the reconstruction efficiency, especially at low energy. The data shown is an unblinded subsample collected by the detector between February and April 2016. It corresponds to an exposure of 4.3 × 10^19 protons on target.

Applications of Machine Learning to the Monopole and Exotics Detector At The Large Hadron Collider (MoEDAL)



L Millward[1, 2], T Charman[1], J Hays[1], A Bevan[1]

[1]Queen Mary University of London, UK, [2]The MoEDAL Collaboration, Switzerland

The MoEDAL Experiment uses Passive Nuclear Track Detectors (NTDs) to look for magnetic monopoles, and other heavily ionising exotic particles at the LHC. Through a process of chemical etching, the latent ionisation tracks of particles can be converted into microscopically visible structures known as etch-pits.

Heavy particle radiation backgrounds at the Large hadron Collider represent a domain transition for image recognition techniques in the context of nuclear track detectors. This study looks at multidimensional CNN image recognition for identifying particle etch pits in an NTD foil that has been exposed to both a calibration signal (Heavy Ion Beam), and LHC background exposure.

2D Image data was collected with Directed-Bright/Dark-Field illumination, parametrised at multiple off-axis illumination angles. Angular light intensity distribution control was achieved via a paired Fresnel lens and LED array. The 3-d structure of the etch pits may be inferred in the higher dimensional parametrised space. The focal imaging plane and optical motion plane are aligned within the sub-millimetre thickness of the nuclear track detector foil. The weakened alignment constraints of 3D-structure inference allows thousands of etch-pits to be imaged simultaneously in each millimetre scale field of view, while allowing automated scanning to be applied to the macro-scale scanning of large area MoEDAL foils containing trillions of etch-pits.

Inference methods, are used in this 3d-feature space to select anomalies of interest. A variation on standard techniques for dataset normalisation and whitening was used to obtain a local intensity normalisation that eliminates the impact of multiple systematic bias sources, and reduces non-particle noise. Multiple image classifiers are combined in an ensemble representing a Naive Bayesian Classifier, This may be applied to obtain predicted inference classifications on new areas of Nuclear Track detector foil.

Boosting the Search for New Physics in bb Events

L Beresford

University of Oxford, UK

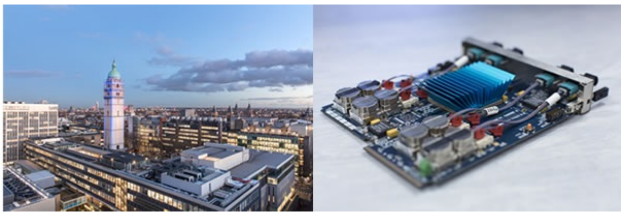
The observation of a new resonance would be powerful evidence for new physics beyond the Standard Model. Searching for such new resonances at the LHC via their decay to pairs of quarks is a natural and broad search for new physics. In order to reduce QCD background and enhance our sensitivity to particles which preferentially couple to mass we search for particles which decay to pairs of b-quarks. This talk will present the search for light resonances in low mass phase space which was previously unexplored by the ATLAS detector at the LHC. As well as the potential to observe new resonances this search also targets the Standard Model Higgs boson. The motivation for this analysis and the methods needed in order to access this interesting low mass region will be presented, as well as the final results which utilise 80 inverse femtobarn of 13 TeV data.

Search for Contact Interactions using 140fb-1 of pp collision data collected at sqrt{s}=13TeV with the ATLAS detector

D Abhayasinghe

Royal Holloway University of London, UK

A search is conducted for non-resonant high-mass phenomena in dielectron and dimuon final states. The search uses the full Run-2 proton-proton collision data collected between 2015 and 2018 at sqrt{s} = 13 TeV by the ATLAS experiment at the LHC corresponding to an integrated luminosity of 140 fb-1. A novel approach involving a functional form is fitted to the dilepton invariant mass distribution of the data in a fit



region and extrapolated to high mass to model the contribution from background processes. Lower limits on the Contact Interaction energy scale are set for various models.

Measurement of the *CP* violation parameter A_Γ at LHCb with $D^0 \rightarrow \pi^-\pi^+\pi^-\pi^+$ decays

L Douglas

University of Glasgow, UK

CP violation in the charm sector is predicted to be very small by the Standard Model and so precise measurements represent a low background environment for new physics searches. A sensitive probe is the parameter A_Γ which measures time-dependent *CP* violation and has previously been measured with the LHCb detector in two-body D^0 meson decays. D^0 neutral mesons are the only ones where oscillations of an up-type quark can occur, and are sensitive to possible contributions to *CP* violation through mixing loops. At LHCb the cross section for charm production is very high allowing unprecedented numbers of D^0 decays to be recorded.

I will present prospects of *CP* violation measurements in the charm sector and, using data collected by the LHCb detector at run I and run II of the LHC, a blinded preliminary result extending A_Γ to four-body modes will be presented utilising the $D^0 \rightarrow K^-\pi^+\pi^-\pi^+$ decay as a control channel.

Search for CP violation in Lb->p3pi decays

G Sarpis[1], W J Barter[2], G Dujany[3], J Fu[4, 5], P Gandini[4, 5], G D Lafferty[1], M Martinelli[6], A Merli[4, 5], N Neri[4, 5], C J Parkes[1]

[1]University of Manchester, UK, [2]Imperial College London, UK, [3]Sorbonne Université, France, [4]INFN, Italy, [5]University of Milan, Italy, [6]CERN, Switzerland

CP violation has been established in kaon and B-meson systems, but has yet to be observed in baryonic decays. However, sizeable CP asymmetries of up to 20% are expected in certain beauty baryon decays in the Standard Model. A family of 4-body charmless baryonic decays offer a good theoretical motivation for the observation of CP violation. In this analysis a single decay channel of Lb->p3pi is used. This decay channel is of particular interest, because it propagates through tree and penguin diagrams, proportional to the same order of the Wolfenstein parameter lambda, of the CKM matrix, which suggest strong interference between these diagrams. Also this decay has a rich resonance structure that might enhance the CP violation.

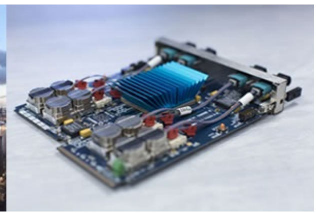
Previous analysis of this channel, using a binned Triple Product Asymmetries approach, yielded the first evidence of CP violation in baryon sector with 3.3 sigma significance. An updated analysis is performed on both Run 1 and Run 2 data, collected by the LHCb detector, which corresponds to approximately 7 fb^-1. This constitutes an approximately sixfold increase in the yield of signal events.

A novel, model independent technique, called the Energy Test is going to be applied alongside the previously used method of Triple Product Asymmetries. This approach allows to test for both, P-even and P-odd contributions to the CP violation and is highly insensitive to detector effects. Together with an optimized binning scheme of the Triple Product Asymmetries method and the increased data sample this analysis has the potential to yield the first observation of CP violation in baryons.

Hunt for Hidden Photons in the LZ Experiment

A Nilima

University of Edinburgh, UK



Motivated by possible theoretical extensions to the standard model, hidden photons (HP) are a suitable candidate for cold dark matter. Their possible masses cover a broad region, from 10^{-12} to 10^{6} eV [1]. Large scale direct detection experiments such as LUX-ZEPLIN (LZ), built primarily to detect WIMPs, could also be sensitive to HP dark matter via the so called hidden photoelectric effect in the keV-MeV mass scale . This work presents the study of the HP sensitivity reach of the LZ experiment in the 10-40 keV mass range.

[1] P.Arias, et al., JCAP06 (2012) 013, "WISPy cold dark matter"

Neutrinoless Double Beta Decay in LZ

R Taylor

Imperial College London, UK

Neutrinoless double beta decay (NDBD) is a hypothesised nuclear decay process that, if observed, shows that neutrinos are Majorana particles, signals the existence of lepton number violation and places constraints on the neutrino mass hierarchy. However, with T1/2 > 10^25 years, searching for NDBD requires low backgrounds from intrinsic radiation and excellent energy resolution. In this talk, I will demonstrate that both of these requirements can be met by the LUX-ZEPLIN (LZ) experiment and present the estimated sensitivity of LZ to 136Xe NDBD.

Measuring the mass of the Higgs Boson at the ATLAS detector in the H→ZZ*→4l channel using an analytic model

T Powell

University of Sheffield, UK

Progress on the development of an analytic signal model for measuring the mass of the Higgs Boson employing the H→ZZ*→4l (l=e,mu) channel is presented. The model consists of a double-sided Crystal ball function, which is a function with a Gaussian core and power-law tails. The model is fitted to the four-lepton invariant mass distribution of H→ZZ*→4l signal Monte Carlo samples. Results from closure tests and performance of the model at expected statistics are also shown.

Search for Decays of the Higgs Boson into a Z Boson and a Light Hadronically Decaying Resonance

E Reynolds

University of Birmingham, UK

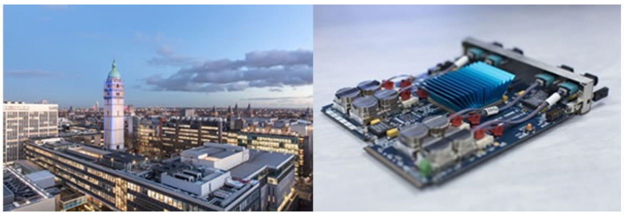
A search is presented for decays of the Higgs boson to a Z boson and a hadronically decaying light resonance, h->ZX->ll+hadrons, using the Run 2 dataset of the ATLAS detector at the LHC. Due to its low mass and high boost, the resonance is reconstructed as a single jet of hadrons. A boosted decision tree is used to suppress the large multijet background. Beyond its potential for new physics, this final state is a potential probe of the charm quark Yukawa coupling and the low Q^2 behaviour of H->ZZ* decays.

Searching for the Invisible using cross-section ratios

V Konstantinides, C Gütschow, E Nurse

University College London, UK

With an abundance of cosmological evidence motivating the existence of dark matter, one of the topmost priorities of the High Energy Physics community is understanding its nature and integrating it into our



extremely successful (yet incomplete) theory of the Standard Model. Presented here is a collider search for invisible new-physics phenomena using cross-section ratios for pp collisions at a centre of mass energy of 13 TeV at the ATLAS detector.

The production of particles invisible to the experimental apparatus can be inferred via a momentum imbalance in the detector, if produced in association with visible objects (e.g. hadronic jets). Ratios of fiducial cross-sections are then measured between the production of jets in association with missing transverse energy and the production of jets in association with either a single lepton or an opposite-sign same-flavour lepton pair, which are very similar to each other in the Standard Model, effectively leading to the cancellation of most theoretical and experimental uncertainties in the ratio.

The particle-level ratios are measured differentially with respect to a number of kinematic properties of the jet system and are readily available to be used in constraining beyond the Standard Model theories without the need of any simulation for the detector apparatus or background processes.

Search for low-mass WIMPs with the DarkSide-50 experiment

P Agnes

Royal Holloway University of London, UK, University of Houston, USA

The DarkSide-50 experiment at the LNGS underground laboratory is using a dual-phase liquid argon TPC to search for particle dark matter. A recent analysis, based on the use of only the ionization signal from very low energy events, shows the potential of liquid argon to detect low-mass WIMPs (<10 GeV/c^2). The null result of this search is currently the world-leading exclusion limit on WIMP-nucleon cross sections for WIMPs with mass between 2 and 6 GeV/c^2. In this region, noble liquids experiments were expected to have only limited sensitivity due to the vanishing scintillation signal. I will discuss the details of this analysis and briefly address the requirements for a future improvement.

The Darkside-20k experiment

D Santone

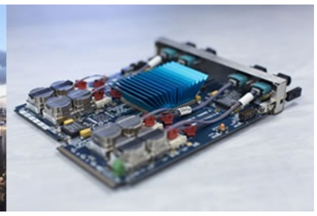
Royal Holloway University of London, UK

The DarkSide program for direct dark matter detection is a global collaboration of all the current argon-based dark matter experiments. The Darkside-20k detector will be located in the Laboratori Nazionali del Gran Sasso. It is designed to be experimental-background free and is optimized for sensitivity to high-mass WIMPs. Darkside-20k consists of an inner dual phase liquid argon (LAr) TPC detector and a surrounding argon veto detector, hosted inside a Proto-DUNE-like cryostat. The inner detector employs argon from underground sources in order to reduce the background produced by the beta-decay of the ^{39}Ar isotope. The total mass of LAr in the inner detector is 50t. The veto detector consists of a Gadolinium-loaded plastic shell, sandwiched between two active natural LAr buffers, with total mass of 750 tonnes. The inner and veto detectors are both read out with novel, large-area silicon photo-sensors developed in a 5 year R&D programme together with Fundazione Bruno Kessler. I will present the current status of the Darkside-20k development, in particular I will focus on the performance studies of the veto system.

Low Energy? Think Positive!

S Melville[1], C de Rham[2], A Tolley[2], S Zhou[3]

[1]University of Cambridge, UK, [2]Imperial College London, UK, [3]University of Science and Technology of China, China



At low energies, the world around us can be accurately described using the Standard Model. However, this is at best only an ``effective'' description: valid at low energies but destined to break down as experiments probe increasingly higher energies, ultimately requiring a new (UV complete) theory to take over.

In this talk, I will demonstrate that certain constraints must be placed on such low-energy Effective Field Theories if they are to have a smooth UV completion at high energies (which is unitary, causal and local). These constraints are known as ``positivity bounds'', and apply to a wide variety of Effective Field Theories in particle physics and cosmology.

As an illustrative example, I'll show how these bounds can be used to constrain Beyond the Standard Model physics (parametrized by higher derivative operators in the Standard Model Effective Field Theory), improving future fits to data by identifying a small region of parameter space for which there is a strong theoretical prior.

Combined Search for an Invisibly Decaying Higgs Boson in Hadronic Channels at $\sqrt{s}$ = 13 TeV with CMS

E Bhal

University of Bristol, UK

The leading upper limit on the Higgs boson to invisible state branching ratio (BR) is 24%, while the Standard Model prediction sits far below at 0.1%. The observed value was measured using pp collision data collected by the CMS experiment between 2011 and 2015. Our analysis targets a better limit by using 13 TeV data from 2016-2018 -- an integrated luminosity of over 130 fb^{-1} -- in addition to performing the combination over all Higgs production modes from the outset rather than in a posthoc fashion. The hadronic channels we include are gluon-gluon fusion, ttH, vector boson fusion (VBF) and Higgs production in association with a vector boson (VH). Analysing each production mode in an orthogonal search region gives a high degree of sensitivity compared to previous attempts. In this talk, the finalised event selection, signal categorisation, data-driven background estimation and systematic uncertainties for the non-VBF modes will be presented. A sufficiently accurate limit on the BR that is still above the Standard Model prediction may be interpreted in a beyond-Standard Model context. Constraints can be placed on theories that posit exotic particles or dark matter that couple to the Higgs, enhancing the invisible state BR.

The search for invisibly decaying Higgs bosons at the LHC

V Milosevic, The CMS Collaboration

Imperial College London, UK

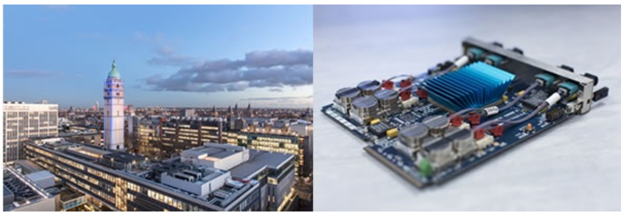
Progress on the search for invisibly decaying Higgs bosons at the LHC will be presented. The analysis is being performed using the CMS Run 2 data, taken in 2016-2018. Several key aspects of the analysis will be reviewed including a description of the novel analysis framework, background estimates including NLO QCD and electroweak corrections, and trigger studies. The search results will be interpreted in terms of several new Dark Matter models. Finally, future prospects for this search in the High-Luminosity LHC phase, with the upgraded CMS detector, will be discussed and simulated results presented.

(Invited) Neutrinoless double beta decay and other neutrino mass stories

C Patrick

University College London, UK

If matter and antimatter are created together, how do we live in a universe made of matter? Neutrinoless double beta decay could provide some possible clues. This process would violate lepton number, creating matter without antimatter - but it is only possible if neutrinos are Majorana particles. Observing it could not



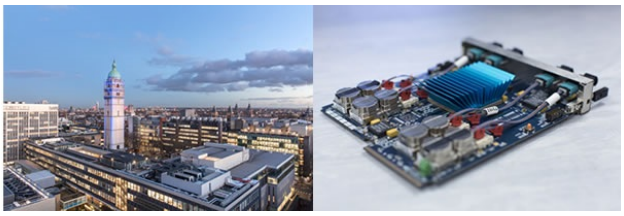
just help us to understand the nature of the neutrino, but also to measure its absolute mass, which is hidden from oscillation experiments. This talk will look at double beta decay experiments, focussing on SuperNEMO and SNO+, which have significant UK involvement, and at the prospects for future tonne-scale detectors. It will also touch on other techniques for measuring the absolute neutrino mass.

(Invited) Flavour physics at the LHC

S Malde

University of Oxford, UK

The study of heavy flavour physics gives insight into QCD, the weak interaction, and can provide sensitivity to beyond the Standard Model physics. Experiments at the LHC continue to investigate heavy flavour phenomena. Analysis of these rich datasets yields a large variety of world leading results and some of the most intriguing anomalies currently present in particle physics. I will give an overview of some of the exciting recent results from flavour physics measurements performed at the LHC.



Posters

P1. On the Use of Photomultiplier Waveform Information with Machine Learning Techniques for the Cherenkov Telescope Array

S Spencer, T Armstrong, J Watson, G Cotter

University of Oxford, UK

Recent developments in machine learning techniques present a promising new analysis method for imaging atmospheric Cherenkov telescopes (IACTs) such as the upcoming Cherenkov Telescope Array. In particular, the use of convolutional and recurrent neural networks could provide a direct event classification and energy reconstruction technique that uses the entire information contained within the Cherenkov shower image, bypassing the need to parameterise the image in terms of its Hillas moments. Existing work in this field has utilised images of the integrated charge from IACT camera photomultipliers, but the majority of current and upcoming generation IACT cameras have the capacity to read out the entire photosensor waveform following a trigger. As the arrival times of Cherenkov photons from extensive air showers (EAS) at the camera plane are dependent upon the altitude of their emission, these waveforms contain information potentially useful for IACT event classification. In this work, we investigate the potential for using these waveforms with machine learning techniques, and find that the most effective means of utilising their information is to create a set of seven additional two dimensional histograms of waveform parameters to be fed into the machine learning algorithm along with the integrated charge image. This appears to be a superior method to using only the waveform integrated charge with these new techniques.

P2. Constraints on the Higgs boson self coupling from ttH + tH, H->gammagamma differential measurements with CMS at the HL-LHC

J Langford

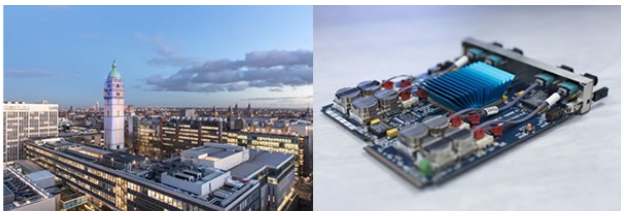
Imperial College London, UK

One of the major goals of the High-Luminosity LHC (HL-LHC) physics program is to shed light on the way in which the Higgs boson interacts with itself, via a measurement of the Higgs boson self coupling. The conventional, direct approach to this measurment is via di-Higgs production, which depends on the Higgs boson trilinear coupling at leading order. However, even with the 3000 fb^-1 of proton-proton collision data predicted to be recorded by the CMS Phase-2 detector at the HL-LHC, constraints using direct measurements remain limited due to the extremely small di-Higgs production cross-section in the Standard Model. The analysis presented here investigates a complementary probe of the Higgs trilinear coupling via ttH+tH, H->gammagamma differential measurements at the HL-LHC. At next-to-leading order, electroweak corrections to single Higgs boson production provide access to the Higgs trilinear coupling, and may lead to sizeable modifications to the external Higgs boson kinematics. A measurement of the differential cross section in bins of pT(H) is studied in the top-associated production modes, where such modifications are expected to be largest. The study uses the Delphes framework to simulate the response of the CMS Phase-2 detector under HL-LHC conditions.

P3. Improving the performance of the CMS ECAL Level-1 trigger for LHC Run 3

W Smith[1, 2], D Petyt[2], A Tishelman-Charny[3], D Valsecchi[4, 5]

[1]University of Southampton, UK, [2]STFC Rutherford Appleton Laboratory, UK, [3]Northeastern University, USA, [4]INFN, Italy, [5]The University of Milano-Bicocca, Italy



The CMS electromagnetic calorimeter (ECAL) is a high-resolution crystal calorimeter that provides precise measurements of the energies of electrons and photons at the CERN LHC. A fast energy reconstruction algorithm is implemented in the on-detector electronics, which is based on a digital filtering method and weighted signal average. This provides energy sums to the trigger system of CMS, which determines whether an event is interesting enough to be written to disk. Despite the challenges of an ageing detector and higher luminosities, it is vital that the best trigger performance is maintained for LHC Run 3 (2021-23).

I will report on new studies that aim to improve the trigger performance for Run 3. Firstly, the current performance of the ECAL trigger algorithm was evaluated using CMS event data from LHC Run 2 (2015-18). An updated set of signal weights, that better suit Run 2 detector conditions was produced and yielded improved energy reconstruction. More granular weights were investigated and were found to further improve the reconstruction performance. The dependence of the algorithm on the LHC bunch structure was studied and optimised. Finally, additional weights, optimised for higher levels of pileup were calculated and evaluated.

P4. 21cm Cosmology and radiative neutrino decays

K Farrag[1], P Di Bari[2], M Chianese[3], R Samanta[2]

[1]Queen Mary University of London, UK, [2]University of Southampton, UK, [3]University of Amsterdam, The Netherlands

We show how 21 cm cosmology can test relic neutrino radiative decays into sterile neutrinos. Using recent EDGES results, we derive constraints on the lifetime of the decaying neutrinos. If the EDGES anomaly will be confirmed, then there are two solutions, one for much longer and one for much shorter lifetimes than the age of the universe, showing how relic neutrino radiative decays can explain the anomaly in a simple way. We also show how to combine EDGES results with those from radio background observations, showing that potentially the ARCADE 2 excess can be also reproduced together with the EDGES anomaly within the proposed non-standard cosmological scenario. Our calculation of the specific intensity at the redshifts probed by EDGES can be also applied to the case of decaying dark matter and it also corrects a flawed expression used in previous literature.

P5. Quest for new physics using astrophysical neutrino flavour in IceCube

K Farrag

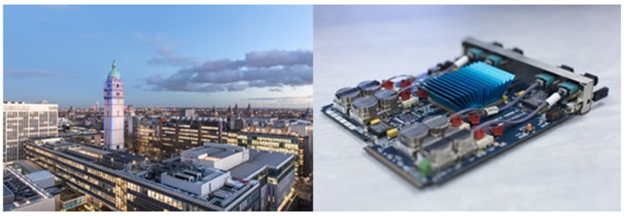
Queen Mary University of London, UK

We have detected astrophysical neutrinos in IceCube that can be used to probe astrophysical sources at ultra high scales. Here we report the first search for anomalous space time effects using astrophysical neutrino flavour data in IceCube. Introducing new effective operators can drive non-standard neutrino flavour mixing, modifying the flavour ratios compared to standard cases. Using the high-energy starting events sample (HESE) 7.5-year data for this analysis, we found no evidence of such flavour anomalies. However, we demonstrate the sensitivity of this new approach goes far beyond any known techniques. Importantly, we achieve the necessary precision to probe new physics using neutrino flavour expected by Planck scale theories. Our quest continues.

P6. A case for studying Flat Spectrum Radio Quasars (FSRQs) and prospects for gamma-ray observations with the CTA

A Acharyya, P Chadwick, A Brown

Durham University, UK



Ten years of gamma-ray observations with the Fermi Large Area Telescope (LAT) have revealed extreme flares from Flat Spectrum Radio Quasars (FSRQs). Yet the location and mechanisms of the emission remain unknown. We first analyse the complete eight year dataset for these objects. We then discuss a method for finding flares. We then discuss ways of using these flares to study the variability, the emission mechanisms involved and constrain size of the emission region. We conclude with a discussion on the Cherenkov Telescope Array (CTA) and make predictions as to whether it will be able to detect these sources as well as obtain simulated spectra.

P7. Sensitivity study for the $\mu^+ \rightarrow e^+ e^+ e^-$ search with the mu3e experiment and work to prepare for Mupix pixel tracker module in Liverpool module

A Wasili

University of Liverpool, UK

The Mu3e experiment will search for the neutrinoless (lepton flavour violating) decay of an anti-muon to two positrons and an electron $\mu^+ \rightarrow e^+e^+e^-$, with a sensitivity to a branching ratio smaller than 10^{-15} (phase I) and 10^{-15} (phase II). To achieve the proposed sensitivity, the mu3e experiment requires excellent vertex resolution, accurate timing, and momentum measurements. These are needed to reduce the main background processes: Michel decays with an internal conversion and combinatorial backgrounds. The proposed poster will present an overview of the mu3e experiment. A study of the projected sensitivity of the experiment is presented as well as work preparing for quality assurance measurement that will take place as part of the assembly work on the Mupix-HV-MAPS pixel tracker in Liverpool.

P8. How to monitor your Gd-loaded water Cherenkov detector

T Boschi, F Di Lodovico, B Richards

Queen Mary University of London, UK

Last year, the Super-Kamiokande detector underwent a complete refurbishment for its new experimental phase, in which gadolinium (Gd) will be dissolved in the water. Gd has a very high cross section for neutron captures, and its presence in water will make neutron tagging more efficient. Neutrons are produced especially in anti-neutrino interactions, which is an important component of the neutrino spectrum of supernovae type II. Super-Kamiokande will become indeed sensitive to supernova relic neutrinos. Other experiments are currently using or planning to use Gd to increase their detection efficiency to neutrons.

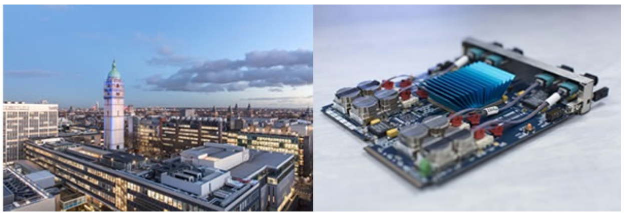
The correct detection of these chargeless hadrons relies on capture efficiency and capture timing, which are parameters that strongly depend on the Gd concentration. In this poster, I will show a technique we have been developing in Queen Mary University of London to monitor the concentration of Gd *in situ*, with a precision that meets the experiment requirements. I will also discuss the experimental challenges of translating this technique in a device.

P9. Quality Control for ATLAS Inner Tracker Strip Sensor Production

C Klein

University of Cambridge, UK

With the upgrade of the LHC to the High-Luminosity LHC (HL-LHC), scheduled to be installed in 2024, the Inner Detector will be replaced with the new all-silicon ATLAS Inner Tracker (ITk) to maintain tracking performance in this high-occupancy environment and to cope with the increase of approximately a factor of ten in the integrated radiation dose. The outer four layers in the barrel and six disks in the endcap region will



host strip modules, built with single-sided strip sensors and glued-on hybrids carrying the front-end electronics necessary for readout.

The strip sensors are manufactured as n-in-p strip sensors from high-resistivity silicon, which allow operation even after fluences expected towards the end of the proposed lifetime of the HL-LHC. Prototypes of different sensor designs have been extensively tested electrically as well as in testbeam setups, yielding generally good results. Since pre-production is scheduled to start at the end of 2019, it is necessary to have a quality control (QC) procedure for strip sensors to confirm that manufactured sensors comply with specifications necessary for operation in the HL-LHC, ranging from generic electric properties to reliability of long-term operation. An overview over the QC procedure and its results will be given as well as details about the ongoing challenges.

P10. New L1 seeds for HLT jet trigger

E Villhauer

CERN, Switzerland

The incorporation of jFEX and gFEX in ATLAS in Run 3 will cause L1 jet triggers to change significantly. To maintain the efficiency of the L1 and HLT jet chains, it is crucial that L1 jet triggers perform as well as possible. The goals are to study the performance of the new L1 jet triggers, derive potential calibrations for L1 jet trigger, and determine the resulting L1 jet triggers that should seed each HLT chain.

P11. Measuring the space charge effect in the ProtoDUNE-SP detector

J Thompson

University of Sheffield, UK

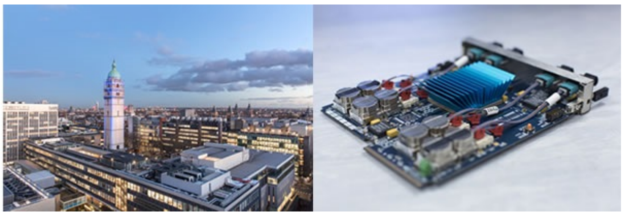
The ProtoDUNE-SP detector is a 1/20 scale prototype, located at the CERN neutrino platform, for the planned first module of the DUNE far detector. Utilising a single phase liquid argon TPC detection mechanism and a charged particle test beam, ProtoDUNE-SP successfully validated the proposed far detector design and collected data which will be used to calibrate neutrino interactions in the future far detector. The space charge effect is the cumulative effect on the electric field inside a TPC caused by slow moving positive ions generated when charged particles pass through the detector. Due to the surface location of ProtoDUNE-SP, space charge has a large effect on the position and number of ionisation electrons reaching the anode plane and mitigation is required in order to allow accurate reconstruction of events. I have studied anode-piercing tracks in order to determine the magnitude of the space charge effect in the ProtoDUNE-SP detector.

P12. The role of photon isolation in the measurement of Zγ production with the ATLAS detector

D Lewis

University of Birmingham, UK

The production of a Z boson in association with a photon provides a test of the electroweak sector of the standard model. True electroweak production of photon is accompanied by a low amount of nearby activity in the tracking and calorimeter systems. Therefore, the isolation of the photon can be used as a discriminant to reject against background processes. The photon isolation is also important in defining the fiducial phase space, in which the analysis measurements are made after correcting for detector effects, to match the detector level phase space in order to reduce the dependence on the choice of physics model. The isolation of the photon is also crucial in the generation of Monte Carlo events to protect against cases where the photon is produced by non-perturbative fragmentation of a parton. The implementation of photon isolation



at the detector, fiducial and generator level is presented and the impact each has on various aspects of the $Z\gamma$ analysis are discussed.

P13. Imaging nuclear waste in a V/52 CASTOR drum using muon scattering tomography

A Alrheli

University of Sheffield, UK

On a nuclear waste management level, characterisation of radioactive waste before disposal leads to safe monitoring and controlled storage inside special casks. However, cases such as conditioned waste are more complex due to that fact that they come from different sources and possess a complex radiological spectrum. Imaging the conditioned nuclear waste ideally requires non-invasive methods to identify the materials which create this complex spectrum. Studying such well-shielded objects needs a method that can penetrate through the cask shielding material which is enough to stop X-ray and g-rays.

Muon tomography (MT) is a non-destructive technique that exploits cosmic muons in imaging to produce a three dimensional image of structures using information that is extracted from Multi Columb Scattering (MCS) of the muons that passed through the probe volume. The muons' scattering angles are larger in materials with a high-Z number than in medium- and low-Z materials, hence the contents of the investigated object could, in principle, be classified according to their atomic number.

This study is a part of the EU H2020-funded CHANCE project that aims to investigate the interior of nuclear waste drums by several methods including the MT technique. In partnership with University of Bristol and Warsaw University of Technology, the University of Sheffield is developing a MT system to investigate conditioned nuclear waste drums. A new detector system has been built to discriminate the contents of the drums by reconstructing the muon trajectory as it enters and leaves the probe drum. In this poster we will report on an investigation into the feasibility of using MT to image large drums by simulating a large CASTOR drum type V/52, filled with fuel assemblies containing mainly Uranium and Tungsten pellets.

P14. Quarkonia in jets at LHCb

N Cooke, P Ilten

University of Birmingham, UK

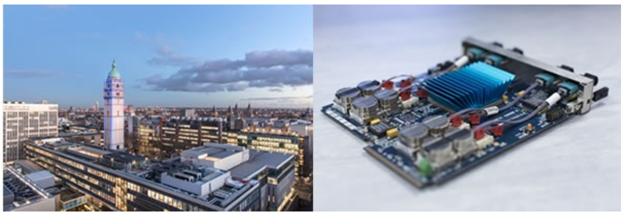
At LHCb, measurements of J/Ψ meson production in jets have been performed at a centre of mass energy of 13 TeV and a pseudorapidity range of $2.5 < \eta(\text{jet}) < 4.0$. The prevailing picture of J/Ψ meson production directly in parton-parton scattering, predicts a large degree of transverse polarisation, whereas minimal polarisation is observed in data. Alternatively, quarkonium production in parton showers can explain the lack of observed polarization. This theory also predicts that J/Ψ mesons are rarely produced in isolation. Measurements of the J/Ψ isolation, given by $z \equiv pT(J/\Psi)/pT(\text{jet})$ taken have been found not agree with the current prompt production model. This measurement will be repeated for various quarkonia states.

P15. Prospects for the observation of true muonium at LHCb

J Plews

University of Birmingham, UK

True muonium is the currently unobserved bound state of a muon and anti-muon, which may decay to an electron and a positron. Measurements of this purely muonic system could provide insight into discrepancies with the Standard Model such as the Proton Radius Puzzle and the muon anomalous magnetic moment. The predicted lifetime is 1.8 ps, which is similar to that of the B mesons that LHCb was designed to measure. The



feasibility of an observation and lifetime measurement at LHCb is examined through a phenomenology study of the signal and expected background processes.

P16. A Novel Light Source for Hyper-Kamiokande Calibration Tests

J McElwee, M Thiesse, L Thompson

University of Sheffield, UK

Hyper-Kamiokande, the proposed successor to Super-Kamiokande, has a rich programme of accelerator and non-accelerator neutrino physics. Improvement in detector systematics is essential to exploit the greater number of statistics provided by Hyper-K and achieve the experimental goals. This poster describes a uniform-cone generating light source (UniCone), a new calibration light source. This is intended to probe detector response and reconstruction of muon-like events in Hyper-K, reducing Cherenkov ring-related systematics that are unexplored using other calibration sources. In order to use UniCone to calibrate the Hyper-K detector, we must first understand the source's own systematics, thus requiring a water tank for pre-calibration. The source will be mounted inside the tank and using a small photodetector, the angular light emission profile for every point on the surface of the cylindrical light source will be measured. A description of the tank, water system and measurement control system is also presented.

P17. Background rejection measurements for electron identification with the ATLAS detector

K Saoucha

University of Sheffield, UK

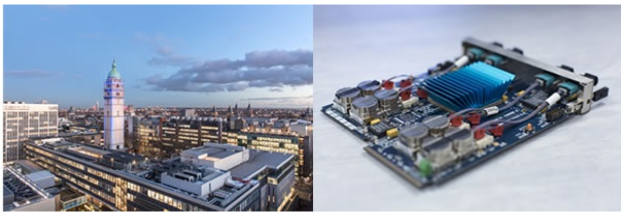
Electron identification in the ATLAS experiment at the Large Hadron Collider (CERN) is based on tracks reconstructed in the inner detector and the shower development in the electromagnetic calorimeter (ECAL). Energy deposits in the ECAL from hadronic jets, converted photons or electrons from the decay of heavy flavour hadrons can mimic the signature of a prompt electron. In order to reject these various background sources, three identification operating points (Loose, Medium and Tight) are optimized to reach specific benchmark efficiencies to select prompt, genuine electrons. In practice, these benchmark efficiencies are difficult to reach due to the mis-modelling of the calorimeter shower shapes. In this study, the rejection of background processes is further investigated in function of the transverse momentum (p_T) and pseudo-rapidity (η). The rejection of the various background sources is presented using Monte Carlo simulation samples containing multi-jet events, based on the 2016 data of proton-proton collisions (produced at the LHC) at 13 TeV center-of-mass energy. The event selection is performed using only electron candidates having $|\eta| < 2.47$ and $p_T > 4.5$ GeV.

P18. Ultra-pure Copper Electroplating for Background Reduction in the NEWS-G Experiment

P Knights

University of Birmingham, UK

The NEWS-G collaboration employs spherical proportional counters to search for light dark matter candidates in the 0.1 - 10 GeV range, with the next generation of detector currently under construction - NEWS-G@SNO. Minimising the background rate is of paramount importance for these searches and requires careful consideration of construction materials. Commercially available copper, a popular choice due to the absence of long-lived radioisotopes, was recently shown to have higher than expected levels of Pb-210 with a potentially detrimental effect on the experimental sensitivity. To suppress this background contribution a 500 μm ultra-pure copper cladding has been electroplated directly onto the detector surface to provide an internal shield. An overview of the NEWS-G@SNO experiment will be given, along with details of the copper



electroplating procedure. Proposed future generations of detector with even higher radiopurity will also be discussed.

P19. Studying the Effect of Polarisation in Compton Scattering in the Undergraduate Laboratory

P Knights[1], K Nikolopoulos[1], F Ryburn[2], G Tungate[1]

[1]University of Birmingham, UK, [2]University of Oxford, UK

The study of Compton scattering has been an integral part of the physics students' training since the 1960s. However, experiments investigating polarisation effects at energies relevant to particle and nuclear physics are rare. Two experiments for the undergraduate laboratory are presented that allow direct observation of the effect of photon polarisation on Compton scattering. In the first, an initially unpolarised beam of photons is first polarised and then analysed through Compton scattering. In the second experiment entangled photons are produced through electron-positron annihilations, and their angular correlations following Compton scattering are measured. Both experiments employ equipment typically available in the advanced undergraduate laboratory. Potential geometry effects are studied with Geant4 simulations.

P20. ATLAS Upgrade: Production of the cooling circuits for the ITk Strip Stave and Forward Pixel End-Caps at The University of Sheffield

W Yeadon, R French

University of Sheffield, UK

The ATLAS detector at CERN is nearing the end of its service life, accumulated radiation damage and component wear necessitates elements undergo replacement. Technological advancements have allowed for the replacement to serve as an upgrade - facilitating investigations into higher centre of mass energy levels probing for new physics. Working at the core of the proposed upgraded ATLAS detector is the ITk, the replacement for the Semi-Conductor Tracking Detector (SCT). The ITk will have an all-silicon semiconductor tracking system consisting of an inner 5-layer pixel detector surrounded by a 4-layer strip detector.

To remove the heat load from the detector electronics, the ITk Strip Detector Stave design has an embedded titanium cooling circuit within its carbon fibre structure. The cooling circuit, constructed from 2.275mm OD ultra-thin walled titanium tubes, uses the CO_2 cooling system from the main ATLAS plant. Titanium was chosen due to the requirements of low mass, high strength, low radiation length and high reliability in a service life of 20+ years with limited maintenance access. Using this specification of Titanium presented challenges for the welding required in the production of the cooling circuits for the ITk Strip Stave and Forward Pixel End-Caps at The University of Sheffield.

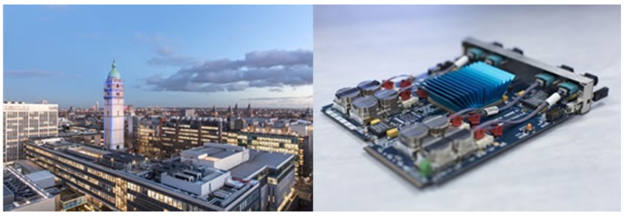
To address these challenges, a novel low heat input Tungsten Inert Gas (TIG) welding technology was developed in an Industry-Academia Collaboration between The University of Sheffield and VBC Instruments Engineering; InterPulse. In order to qualify the ITk cooling system production technique, a custom built Data Acquisition System (DAQ) was designed and constructed to monitor the electrical data from the welding in real time.

This presentation details the latest updates in the production of the ITk cooling circuits featuring DAQ system performance data and metallurgical analysis. In addition, the industrial applications of the novel welding technology, InterPulse, are explored.

P21. Fast Simulation of Muon Backgrounds at SHiP using Machine Learning

A Marshall

University of Bristol, UK



We present a novel and fast approach to simulating muon backgrounds for the SHiP experiment. Using generative adversarial networks (GANs) we show it possible to accurately avoid a large bottleneck in the simulation of 400 GeV proton interactions with the SHiP target. For the simulation requirements at SHiP we show generative networks are capable of accurately approximating the full simulation (Pythia8 and GEANT4) of the dense fixed target with a speed up factor of O(10^6). We present a comparison of hits and track reconstruction in downstream SHiP detectors and spectrometers between generated and fully simulated data.

P22. Investigation of Gas Properties and the Effect of Electronegative Contaminants in the NEWS-G Experiment

R Ward[1], K Nikolopolous[1], I Katsioulas[1], P Knights[1], I Giomataris[2]

[1]University of Birmingham, UK, [2]CEA Saclay, France

NEWS-G is a direct dark matter detection experiment searching for low-mass 0.1 to 10 GeV candidates using a spherical proportional counter. The gas properties are a central aspect for the detector performance, as well as potential contamination by electronegative molecules. The electron transport properties of the gas mixture distort the electronic output signal of the detector and electron attachment can prevent a signal entirely. A study on the properties of the gas mixtures used in the SEDINE detector at LSM, a 60 cm diameter spherical proportional counter, and the effect of possible O_2 and H_2O contamination is discussed.

P23. Reducing top quark background in measurements of W^+W^- cross sections at $\sqrt{s}$ = 13TeV with the ATLAS detector

J MacDonald

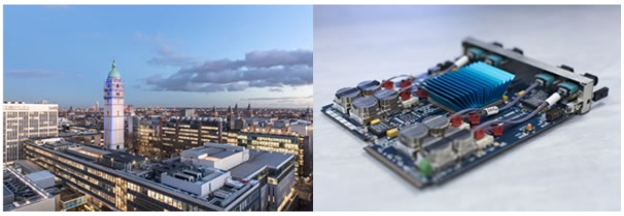
University of Sheffield, UK

An attempt has been made to estimate the top quark background for measurements of W^+W^- production cross sections using data taken by the ATLAS experiment at the Large Hadron Collider at $\sqrt{s}$=13 TeV using an integrated luminosity of 36.1fb^{-1}. Events are considered for which the diboson system decays to two final state leptons with different flavour, corresponding to the process $W^+W^- \rightarrow e^{\pm}\nu\mu^{\mp}\nu$. The largest background for this process is the production of single or pairs of top quarks, which decay to a W boson accompanied by a b-quark, thus producing a very similar signature to the W^+W^- signal. Events can be rejected based on the p_T of the leading jet according to strict or dynamical (including both linear and non-linear) jet vetoes. The resulting distributions have been investigated under such vetoes. The resulting top background is however still quite substantial and needs to be determined precisely. To do so, an approach is studied which uses the azimuthal angle between the 4-vector of the dilepton system and that of the missing transverse energy. The distribution of the azimuthal angle is used to extract templates of the signal and background from MC simulation in a signal and control region. The signal region is defined to contain no event with a jet p_T larger than 35GeV or with a b-jet p_T exceeding 20GeV. The control region contains events with only one b-jet. A maximum likelihood fit of the templates to the data is performed in both signal and control regions simultaneously and used to extract the normalisations of signal and background. Correlating the uncertainties between signal and control regions helps to reduce the uncertainties of the extracted cross sections.

P24. Search for CP violation in $D^0 \rightarrow \pi^- \pi^+ \pi^0$ at LHCb with the energy test method

J Cobbledick

University of Manchester, UK



CP violation has not yet been observed in the charm sector, despite being well-established in strange and beauty mesons. The neutral charm meson system is unique, with mixing and decay being driven by up-type quark transitions, and so is a powerful probe to complement measurements in the beauty sector. We report a search for time-integrated CP violation in the process of neutral charm meson to three pions $D^0 \rightarrow \pi^+ \pi^- \pi^0$ using the energy test method. The energy test is an unbinned, model-independent technique for testing the hypothesis that two samples originate from the same distribution. The data sampled corresponds to an integrated luminosity of 2.0fb-1 of proton-proton collisions obtained from Run 2 of the LHCb collaboration in 2015-16. The control channel $D^0 \rightarrow K^+ \pi^- \pi^0$ is used to evaluate systematic uncertainties such as those arising from pion detection asymmetries. Applying the energy test to subsets of the control sample, each with differing ranges of transverse momentum, confirms that the method is insensitive to instrumental effects or background asymmetries with the current signal yields. This poster intends to motivate the measurement, explain the analysis methods, and present the latest results obtained from LHCb data.

P25. Applications of muon scattering tomography to image and characterise materials in nuclear waste drums

M Weekes

University of Sheffield, UK

Hazardous waste material from nuclear power plants is often stored in steel drums filled with concrete or bitumen. Although it is now compulsory for records to be kept of the material stored in waste drums, such records can be inaccurate or lost. Additionally, legacy waste drums may have no extant records of their contents. It is therefore important to develop methods to determine the contents of drums without opening them and risking highly dangerous material being released into the environment. Such techniques are known as non-destructive analysis (NDA) and comprise both active (artificially introducing particles into the system e.g. x-ray imaging) and passive methods, with passive methods being in general cheaper and less hazardous.

Muon scattering tomography (MST) is a passive NDA technique that makes use of muons originating from atmospheric cosmic ray collisions to investigate waste drum contents. Within matter, muons undergo a random walk from multiple elastic Coulomb scatterings, with scattering angles highly correlated to the atomic number (Z) of the material. An MST experiment generally has two sets of detectors above and below the volume of interest to measure the muon position and momentum before and after encountering the waste drum. Some of the algorithms developed to estimate the drum contents from such detectors are elucidated.

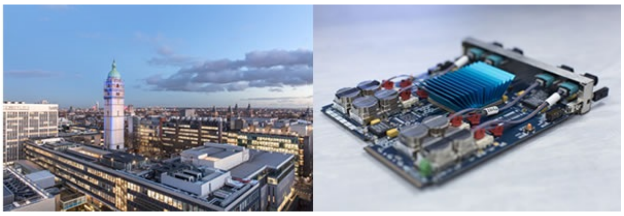
Intuitive ‘ISO’ plots showing the outputs of MST algorithms are presented. High Z materials can be easily distinguished from the concrete matrix on such plots. Low Z materials such as hydrogen cannot be clearly identified with reasonable exposure times. Hydrogen bubbles can form in waste drums containing radioactive material and rupture the steel container, releasing dangerous materials; it is important to identify the presence of hydrogen before this occurs. A method to adapt an MST algorithm to estimate gas volume is presented.

P26. Experimental Determination of Proton Hardness Factors at Various Irradiation Facilities

C Simpson-Allsop[1], P Allport[1], F Boegelspacher[2], A Dierlamm[2], L Gonnella[1], L Ram[1], I Mateu[3], M Moll[3], K Nikolopoulos[1], T Price[1], F Ravotti[3]

[1]University of Birmingham, UK, [2]Karlsruhe Institute of Technology, Germany, [3]CERN, Switzerland

The scheduled High Luminosity LHC presents new challenges in radiation damage studies. Campaigns to measure radiation hardness of detector sensors and components are being undertaken worldwide. The effects of irradiation with beams of different particle species and energy are compared using their respective



hardness factors. The hardness factors for proton beams at three different energies have been measured by analysing the I-V and C-V characteristics of BPW34F photodiodes. This was done by performing irradiations at the University of Birmingham's MC40 Cyclotron, the cyclotron at the Karlsruhe Institute of Technology, and the IRRAD proton facility. The obtained hardness factors are presented, and the methodology behind their determination is discussed.

P27. Study of ttH production with H→bb at the HL-LHC

A M Mendes Jacques da Costa[1], A L Carvalho[2], J R Morais Silva Gonçalo[2, 4], P Conde Muíño[2], A Joaquim Onofre Abreu Ribeiro Gonçalves[3]

[1]University of Birmingham, UK, [2]LIP-Lisbon, Portugal, [3]LIP-Minho, Portugal, [4]University of Lisbon, Portugal

A new approach is proposed to search for ttH(H→bb) production at the LHC and its High Luminosity phase. In contrast to current search strategies, the proposed analysis exploits jet substructure techniques and focuses on the reconstruction of boosted Higgs bosons to obtain sensitivity to the signal in a simple cut-based analysis. An expected signal significance of 5.41±0.12 was estimated using the proposed strategy for L=300 fb^{-1} of LHC data at $\sqrt{s}$=14 TeV, allowing the measurement of the top Yukawa coupling with a 35% statistical uncertainty in this channel alone. A statistical uncertainty of 17% on the coupling and of 5% on the signal strength would be the ultimate precision of the HL-LHC in this channel.

P28. Progress Towards a First Measurement of the Pion – Argon Cross Section in ProtoDUNE-SINGLE PHASE

S Vergani

University of Cambridge, UK

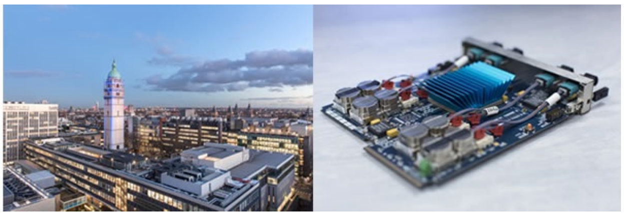
ProtoDUNE Single Phase (SP) is a prototype detector constructed and currently running at CERN. It is a vital step in the R&D path for the DUNE Far Detector (FD) modules. Among the physics measurements that are possible with ProtoDUNE-SP, one of particular interest is the π-Ar cross section. There are almost no existing measurements of this interaction, only old extrapolations from other nuclei and recent measurements in the range $0.2 < p\pi < 1.2$ GeV made by Liquid Argon In A Testbeam (LarIAT). Precise measurements of this cross section will be crucial for accurate modelling of neutrino interactions in LArTPCs and ultimately for physics studies at DUNE. The status of this analysis will be presented, including a multiplicity study of particles produced at the pion interaction vertex.

P29. Track vs Shower Hit-Based Classification Using Deep Learning in LArTPC Experiments

S Vergani

University of Cambridge, UK

Pandora is a novel multi-algorithm approach to pattern recognition that is used for the reconstruction of neutrino interactions, test beam particle interactions and cosmic-ray muons in liquid argon time-projection chamber (LArTPC) experiments such as MicroBooNE, ProtoDUNE and DUNE Far Detector (FD). In order to fully harness the imaging capabilities of LArTPC experiments Pandora needs algorithms able to resolve individual ionisation tracks passing into dense electromagnetic shower-like regions. This poster presents a hit-based approach to this problem, which analyses small patches of simulated events from DUNE-FD. Using those patches, variables of interest are calculated and subsequently fed into machine learning approach in order to classify each hit as track-like or shower-like. Results are presented that show separation between track-like and shower-like hits in complicated topological regions is possible with high background rejection and signal efficiency.



P30. B-Tagging Calibration using the Combinatorial Likelihood Method with Particle Flow Jets

J Hall

University of Sheffield, UK

The Particle Flow reconstruction algorithm uses the tracking system and hits in the ATLAS detector to reconstruction jets, taus and missing transverse energy. It has shown to increase performance at low transverse momentum relative to the previous method of jet reconstruction, named "emtopojets", which are reconstructed using the topological clustering algorithm from hits in the detector. One of the main reasons for this improvement arises from the improved granularity of the tracking detector relative to the calorimeter.

The area of the work that will be presented is within the Flavour Tagging calibration group for the ATLAS experiment. The purpose of flavour tagging is to calibrate the high-level (MV) taggers that are used by analyses. This work specifically focuses on that of b-jets. The method by which they are calibrated is by using the di-leptonic decays of two tops to ensure high purity of b-jets and then using an extended log-likelihood function to calculate the b-tagging efficiencies for several values of the MVA discriminant outputs. These efficiencies, and then corresponding scale factors, are used by analyses to correctly calibrate the taggers.

P31. Construction of the ATLAS Phase-II upgrade Inner Tracker semiconductor barrel micro-strip detector

T Zorbas

University of Sheffield

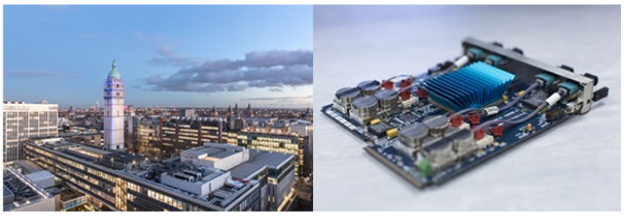
In preparation for CERN's High Luminosity Large Hadron Collider (HL-LHC) upgrade planned for operation from the mid-2020s, the ATLAS experiment will replace its current Inner Detector with a new all-silicon Inner Tracker (ITk), expected to record ~4000 fb^-1 of data in over a decade of operation. This poster will demonstrate the (near-)final design, methods and procedures used in the construction and testing of the semiconductor micro-strip modules which will form part of the ITk barrel region. A worldwide effort with strong UK contribution, The University of Sheffield will assemble ~10% of the required 10976 modules over the next few years, in dedicated cleanroom facilities under strict quality control.

P32. Towards a gas filtration setup for ultra-sensitive SF_6 gas based rare-event physics experiments

R R Marcelo Gregorio, N Spooner, M Norfolk

University of Sheffield, UK

The gas SF_6 has become of interest as a negative ion drift gas for use in directional dark matter searches. However, as for other targets in such searches, it is important that contamination can be removed, because problems with signal detection can arise from contaminants such as radon and impurities. Radon contamination can produce unwanted background events, and impurities such as water and nitrogen can capture interaction-produced electrons, preventing detection of these electrons. In this work, we demonstrated the filtration of radon (up to 87%), water (up to 79%) and nitrogen (up to 89%) from SF_6 using Sigma-Aldrich 5Å molecular sieves. The filtration of contaminants was investigated in separate experiments using a DURRIDGE RAD7 for radon detection and a Hiden Analytical residual gas analyser to monitor impurities. A molecular sieve filtration system for an SF_6 gas-based experiment has been designed. This system is planned to be tested with a low pressure Time Projection Chamber (TPC), using a thick GEM as the avalanche and readout device, to quantify the efficiency of the molecular sieve in reducing gain deterioration due to contaminants over time. In addition to benefits in signal detection, the molecular sieve filtration system can also be applied to reduce the amount of SF_6 used by purifying and recycling it. This is a step towards reducing the amount of SF_6, the most potent greenhouse gas, for use in future large scale directional dark matter experiments.



P33. Searching for electroweak supersymmetry in events with two leptons and missing transverse momentum in the final state at 13TeV with the ATLAS detector

H Pacey

University of Cambridge, UK

This poster shows the results of a search for electroweak supersymmetry through the direct pair production of charginos decaying via W-bosons. This search uses the full integrated luminosity (140.3fb^-1) at 13 TeV collected by the ATLAS detector in the 2015-2018 data taking campaigns. Charginos are searched for in final states with two isolated leptons (electron or muon), missing transverse momentum and at most one light jet in the final state. This result follows on from a conference paper using 80.0fb^-1 of luminosity from the 2015-2017 datasets which placed world-leading limits on this process and was presented at SUSY18. Two additional electroweak supersymmetry processes are also probed through a reinterpretation of our signal regions: direct slepton production and gauge mediated slepton production.

P34. Advantages and limitations of neural networks for jet tagging

H Day-Hall

University of Southampton, UK

Neural networks are popular in many areas of HEP. Jet classification, (jet tagging) has greatly benefited from the application of deep neural networks. They have many exciting properties, they are universal approximates and they interpolate well.

They are not universally well regarded, however. Training a neural net to classify is a black box process and this is rightly seen as a liability. So a proper understanding of what is known is key to using this tool appropriately.

Firstly I will talk about the function space that can be reached by neural nets typical to HEP. Visualising this greatly demystifies this tool. It will also be seen why this function space makes them such good classifiers.

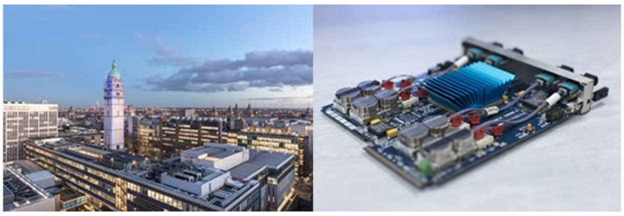
Neural networks are limited by various factors, some of which apply generally to ML approaches to classification others are specific weaknesses. I will talk about the challenges that I have encountered and the various avenues that are available to tackle them.

P35. SBND Recombination Study for Shower Calorimetry

E Tyley

University of Sheffield, UK

The Short Baseline Near Detector, SBND, is a liquid argon detector currently being built at Fermilab as part of the Short Baseline Neutrino, SBN, program which aims to study sterile neutrinos and make cross section measurements in the Booster Neutrino Beam, BNB. Recombination of electrons with argon ions is an important calibration effect that is studied using Monte Carlo simulations. Both electrons and muons were simulated over a range of energies from 100-1500 MeV in order to study any energy dependencies in both showers and the tracks used to calibrate the detector. Both Monte Carlo truth information and hit finding efficiencies were studied to understand both the underlying and subsequent effects on reconstruction. Overall the study shows good agreement with the expected results that broadly agree with the study performed in other SBN experiments. A slight discrepancy between the recombination factors in muons and electrons is seen as well as a small energy dependence that requires further study to be fully understood.



P36. ATLAS ITk Pixel Sensor Measurements

M Mironova

University of Oxford, UK

The ATLAS experiment at the LHC will upgrade its entire tracking system around 2025 in preparation for the High Luminosity LHC (HL-LHC). This includes a new system of five layers of silicon pixel detectors, which will have to face the challenges of an increase in pile-up and luminosity by an order of magnitude. The new inner tracker (ITk) will consist of hybrid pixel detectors with a smaller pixel size (50 x 50 µm2 or 25 x 100 µm2), in order to provide higher granularity and better resolution. It will also include a novel readout chip, RD53A, with an increased bandwidth and improved radiation hardness.

The collaboration is now moving towards the construction of ITk, where the UK intends to provide one of the pixel endcaps. Because of the use of novel technologies and a total of more than 1400 modules required, acquiring an in-depth understanding of the performance of the silicon material, readout and assembled modules is an integral part of the construction process.

This talk reviews the current status of ITk in the UK collaboration and the process of going from bare silicon to the electrical prototype of a ring for the endcap. In particular the characterisation of sensors, automated module assembly and subsequent testing of the produced modules are discussed.

P37. Measurement of D0 mixing parameters using D0 -> KSPiPi Decay at LHCb

M Hilton, M Williams

University of Manchester, UK

Mixing in the charm sector is highly suppressed and experimentally challenging. The decay of a D0 meson to a K-short and two pions offers direct access to the mixing parameters of the neutral D meson through a time-dependent amplitude fit to the Dalitz plane of this decay. While indirect CP violation is possible in mixing (or in the interference between mixing and decay), the Standard Model expectation is small. Thus, enhancement of CP violation in this decay channel could be a hint of new physics.

This analysis uses data from the LHCb detector taken in the Run 2 data taking period. The data used is from semi-leptonic B meson decays and the initial flavour of the D0 is tagged by the muon charge from the B decay, with a sub-sample of decays having additional information from the pion charge in an intermediate D*+ -> D0pi+ decay. The data is split into sub-samples by data taking year, single and double-tagged D0 and K-short track type.

Initial event selection for this analysis includes trigger, offline kinematic pre-selection requirements, as well as some multivariate analysis. Several machine learning techniques including boosted decision trees and neural networks, were investigated for this analysis to further reduce the combinatorial background.

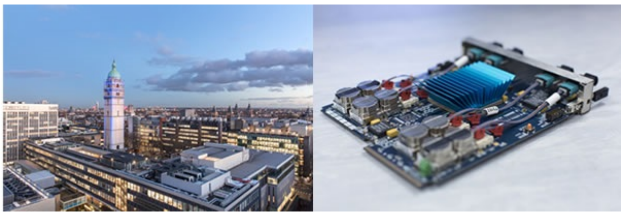
The signal amplitude model is built from the sum of two body decays, decaying through an intermediate resonance and the background model is extracted from data. The full model, including detector efficiency and acceptance effects, is fit to data using the GooFit framework. The mixing parameters can then be extracted from the time-dependent amplitude fit of this amplitude model to data.

The background and future prospects of this decay channel will be presented, as well as the data selection and fit model.

P38. Data-driven corrections to ATLAS trigger simulation

D Köck

University of Sussex, UK



The High Level Trigger (HLT) system used in the ATLAS detector at the Large Hadron Collider provides high efficiency selection of a wide range of signals. Very important targeted signatures are those where we identify single or multiple electron candidate events in the data. This is because they have a very wide application in many types of physics searches, like Higgs searches, searches of physics Beyond the Standard Model (BSM), as well as Standard Model physics.

Understanding the differences in the efficiencies for the selection of such triggers in ATLAS data compared to Monte Carlo simulation is a key preliminary to any measurement (Standard Model as well as BSM).

This talk presents electron trigger efficiency measurements obtained analysing the full Run II ATLAS data collected between 2015 and 2018. The differences in efficiency between data and Monte Carlo are studied using pure electron samples obtained from Z --> ee Monte Carlo and data. From these differences, correction factors have been calculated and will be applied in ATLAS by a large number of analyses.

P39. A High Pressure gaseous Time Projection Chamber for future long-baseline neutrino experiments

E Atkin

Imperial College London, UK

Future long-baseline neutrino experiments, such as Hyper-Kamiokande (Hyper-K) and the Deep Underground Neutrino Experiment (DUNE), will measure neutrino oscillation parameters to the 5 sigma level. To reach this level of precision, systematic uncertainties have to be reduced significantly from their current level, typically from 5-10% to 1-2%. In particular, understanding neutrino-nucleus interaction cross-sections is key to reducing systematic errors.

A High Pressure gas Time Projection Chamber (HPTPC) is a good candidate for a future near detector to reach this level of uncertainty on neutrino-nucleus cross-sections. An HPTPC has a low momentum threshold making it ideal for reconstructing low momentum particles exiting the nucleus. This combined with optical readout means that low-momentum tracks can be reconstructed and cross-section measurements in regions with little to no data can be measured.

An HPTPC proto-type has been built and commissioned at Royal Holloway, University of London. The proto-type underwent a beam test at the CERN East Area T10 beamline from August to September 2018 with the goals being to test the technology as well as to measure low-momentum proton-scattering in gaseous Argon.

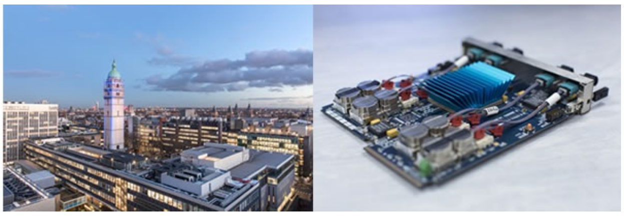
P40. Integration-by-parts identities and multi-loop QCD amplitudes

H Chawdhry[1], A Mitov[1], M Lim[2]

[1]University of Cambridge, UK, [2]University of Milano-Bicocca, Italy

As the LHC gathers ever more data and makes measurements with increasingly high precision, it is essential for theorists to match this precision when making predictions for cross-sections. In QCD and other gauge theories, this high precision is achieved by including multi-loop Feynman diagrams when calculating scattering amplitudes. Integration-by-parts identities (IBPs) are widely used when computing the associated multi-loop integrals. The solution of large systems of IBPs is a major bottleneck in the computation of high-precision QCD amplitudes for processes observed at the LHC, such as 3-jet production.

In this talk, I will discuss my work on IBPs, first presented in arXiv:1805.09182, where we introduce a new strategy for solving systems of IBPs, which we believe to be especially applicable to problems with many kinematic scales and/or many master integrals. Using this strategy, we have solved the IBPs needed for the computation of any planar 2-loop 5-point massless amplitude in QCD. We have also derived some new results for the associated non-planar integrals. Ultimately, we expect that the remaining non-planar contributions will be computable in analytic form, which would allow cross-sections for processes such as 3-



jet production to be predicted at Next-to-next-to-leading order in QCD, reducing theoretical uncertainties down to a few percent.

P41. Observation of H->bb decays in the VH production mode and first differential measurement with the ATLAS detector

L Ambroz

University of Oxford, UK

H ->bb decays allow to probe the Yukawa coupling of the Higgs boson to down type quarks. Observing these processes at the LHC is extremely challenging due to the large multi-jet background; however, this can be greatly suppressed by triggering on Missing Energy Transfer and leptons coming from the decay of a weak vector boson produced together with the Higgs.

In this talk, the latest search for H->bb decays associated with a W or Z boson with the ATLAS detector will be presented. Furthermore, the first VH->bb differential measurement in bins of transverse momentum of the vector bosons will be discussed; this type of differential measurement is particularly sensitive to Beyond Standard Model Physics in the form of Effective Field Theory models.

P42. Measuring the mass of the Higgs Boson at the ATLAS detector in the $H \rightarrow ZZ^* \rightarrow 4l$ channel using an analytic model

T Powell

University of Sheffield, UK

Progress on the development of an analytic signal model for measuring the mass of the Higgs Boson employing the $H \rightarrow ZZ^* \rightarrow 4l$ (l=e,mu) channel is presented. The model consists of a double-sided Crystal ball function, which is a function with a Gaussian core and power-law tails. The model is fitted to the four-lepton invariant mass distribution of $H \rightarrow ZZ^* \rightarrow 4l$ signal Monte Carlo samples. Results from closure tests and performance of the model at expected statistics are also shown.

P43. Beam test studies of a prototype TORCH detector

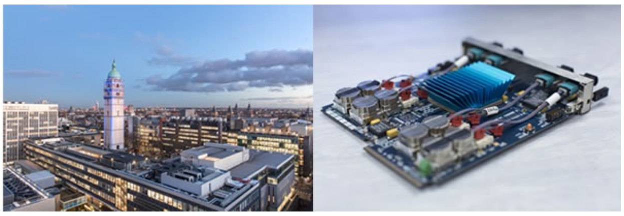
T Hancock

University of Oxford, UK

TORCH is a time-of-flight detector designed to provide particle identification over the 2-10 GeV/c momentum range. Consisting of 18 large quartz plates, TORCH measures the time of arrival of charged particles through prompt Cherenkov light which is trapped by total-internal reflection. At the top of the plate the light is focused onto a row of micro-channel plate (MCP) detectors which measure the photon arrival time and position.

Designed for the LHCb detector, TORCH aims for a 15 ps track time resolution over a 10 m flight path. This translates into a 3 standard deviation separation between pions and kaons with momenta of 10 GeV/c. To achieve such a track resolution requires a time resolution of 70 ps per photon for 30 detected photons per track.

In the latter half of 2018 both a small-scale (120 x 350 x 10 mm^3) and a half-scale (660 x 1250 x 10 mm^3) prototype were tested in a 5 GeV/c mixed proton-pion beam at the CERN PS. Employing data-driven calibrations, the single photon timing performance has been measured, providing proof of principle for the TORCH concept. The projected performance of a full-scale TORCH detector instrumented in the LHCb



experiment, determined through simulation studies, will also be presented. This talk would complement the abstract proposed by Emmy Gabriel, also on TORCH.

P44. Searches for electroweak supersymmetry in final states containing one lepton, two b-tagged jets and missing transverse energy at the ATLAS experiment

M Sullivan

University of Liverpool, UK

Supersymmetry (SUSY) is one of numerous, and one of the most famous, theoretical extensions to the Standard Model aiming to answer open questions in particle physics, such as the nature of dark matter and the origin of the electroweak symmetry breaking. SUSY extends the particle spectrum of the SM such that each SM particle has at least one supersymmetric partner. Mixtures of the SUSY partners to the gauge bosons and Higgs can form to produce the electroweakinos; charginos and neutralinos. The lightest neutralino, often referred to as the lightest supersymmetric particle (LSP), is one of the most commonly considered WIMP dark matter candidates.

Using data collected in 2015-2016 by the ATLAS collaboration, a search for chargino-neutralino pair-production is presented. The chargino decays via a W boson and an LSP, while the neutralino decays via a Higgs boson and an LSP. The final state contains a lepton from the W decay, two b-jets from the Higgs decay, and missing transverse energy. No significant excess is observed, but exclusion limits on this process are set upto 550 GeV. A projected limit for this search channel for the HL-LHC results in an expected exclusion limit of 1280 GeV and discovery potential up to 1080 GeV. Finally, future prospects for this channel are presented, including the use of machine learning techniques to improve signal-background discrimination.

P45. Prospects for ttZ measurements at ATLAS with the full 140 fb^{-1} Run 2 dataset

B Ravina

University of Sheffield, UK

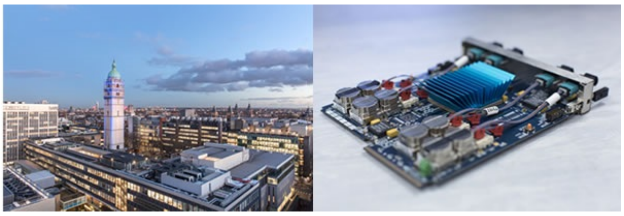
We review the recent measurement of the inclusive ttZ cross-section with 36 fb^{-1} of data at 13 TeV at the ATLAS experiment, using EFT considerations and background modelling for generic SUSY/DM searches as motivation for continuing to improve the precision of this result. We then present plans for a differential ttZ measurement in the 3 and 4 lepton channels with the full 140 fb^{-1} Run 2 dataset, and highlight a number of promising research directions, such as a re-interpretation in terms of ttZ spin correlation observables, or the possibility to unfold SUSY/DM validation regions (or even null-result signal regions) to constrain the ttZ(νν) process. Particular attention is also given to the topic of semi-leptonic top reconstruction, necessary to match the performance of the dileptonic decay channels.

P46. The search for invisibly decaying Higgs bosons at the LHC

V Milosevic, The CMS Collaboration

Imperial College London, UK

Progress on the search for invisibly decaying Higgs bosons at the LHC will be presented. The analysis is being performed using the CMS Run 2 data, taken in 2016-2018. Several key aspects of the analysis will be reviewed including a description of the novel analysis framework, background estimates including NLO QCD and electroweak corrections, and trigger studies. The search results will be interpreted in terms of several new Dark Matter models. Finally, future prospects for this search in the High-Luminosity LHC phase, with the upgraded CMS detector, will be discussed and simulated results presented.



P47. Top quark charge asymmetry at LHCb

J Mead

University of Liverpool, UK

The LHCb experiment provides unique detector coverage, 2 < η < 5, of high energy proton-proton interactions produced at the Large Hadron Collider. Designed to study b- & c-hadron physics, LHCb is fully instrumented in the forward region with excellent tracking and vertex resolution.

The top quark is the heaviest fundamental particle and is expected to play a special role in new physics scenarios. Higher order interference mechanisms, sensitive to physics beyond the reach of current colliders, result in a charge asymmetry, Att , in the angular distributions of top pairs. LHCb's acceptance offers greater sensitivity to Att due to reduced dilution from gluon-gluon fusion.

Top quarks are identified through the presence of a high pT muon and b-jet in the final state. Forward production was first observed with Run I data at LHCb in this channel. The increase in available statistics with Run II, as well as improved signal to background ratio, will allow the first measurement of the top charge asymmetry in the forward region.

P48. The High Pressure gas Time Projection Chamber: a Future Neutrino Detector

T Nonnenmacher

Imperial College London, UK

Understanding neutrino-nucleus interaction cross-sections at the 1-2 percent level will be crucial for the next generation of long baseline neutrino experiments. Due to its low hadron momentum detection threshold, a High Pressure gas Time Projection Chamber (HPTPC) is a strong candidate for achieving a significant reduction in uncertainties on these cross-sections . An HPTPC is part of the baseline design of DUNE and a candidate for use in Hyper-Kamiokande.

An optically read out prototype HPTPC, rated to 5 bar of pressure, was built at Royal Holloway, University of London. The detector was used to make proton scattering measurements on at the CERN East Area T10 beamline from August to September 2018.

In order to improve experimental uncertainties on neutrino-nucleus cross-sections, it is important to improve the models that we use to describe them. HPTPC data will be used to tune the final state interaction parameters in NEUT, the primary neutrino Monte Carlo generator used by the T2K experiment. This tuning will enable a reduction in the systematic uncertainty of neutrino oscillation measurements made by T2K and future experiments.

P49. Measurement of the CP nature of the Htt Yukawa coupling using gluon fusion production in association with two jets with a Higgs boson decay to a tau lepton pair

A Dow

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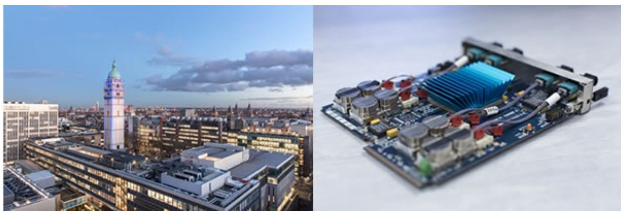
Since the discovery of the Higgs boson with a mass near 125 GeV, much effort has been dedicated to studying its properties. This talk presents one such study, which investigates the CP structure of the Higgs boson by exploiting the gluon fusion production process in association with two jets. Analysis of the azimuthal angle correlations of the jets provides an insight into the CP nature of the Htt Yukawa coupling. Higgs bosons decaying into a pair of tau leptons are considered, and the full 2016 and 2017 datasets collected at the CMS experiment are used.



P50. Background Modelling in the ttH($H\to\gamma\gamma$) Channel

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The discovery of the Higgs boson in 2012 by the ALTAS and CMS experiments at CERN was only the beginning, the properties of this particle still need to be measured and compared with theoretical predictions. The ttH production channel allows a direct measurement of the Higgs coupling to top quarks, the heaviest particle in the Standard Model, while the $H\to\gamma\gamma$ decay channel gives a narrow peak in the $m_{\gamma\gamma}$ spectrum that is easily distinguished from background.

The shape of this background model needs to be as accurate as possible in order to minimise uncertainty on measurements. With the models being created from analytical functions fitted to simulated Monte Carlo background samples, a method for estimating how much the resulting model differs from the true distribution is required. For $H\to\gamma\gamma$ analyses this is carried out using the spurious signal method which quantifies how much background could falsely be interpreted as signal and assigns it as the systematic error on the model.

However, the spurious signal method is highly dependent on the statistical fluctuations of the Monte Carlo sample, making it difficult for the production of simulated events to keep up with the rising luminosity of data-sets. This has resulted in the background systematics becoming dominant in several measurement channels. A study to quantify the effects of Monte Carlo sample statistics on the systematic error on the background model has been undertaken to provide estimates to help decide which channels are not feasible for producing enough Monte Carlo events for the spurious signal test or for which channels need an increase in production. This talk will address the spurious signal problem and present the results of this study.

P51. Electron neutrino selection in the MicroBooNE LArTPC using the Pandora pattern recognition reconstruction

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MicroBooNE (the Micro Booster Neutrino Experiment) is a liquid argon time-projection chamber (TPC) experiment designed for short-baseline neutrino physics, currently running at Fermilab. It aims to address the anomalous excess of low-energy events observed by the MiniBooNE experiment. In this talk the ability of the experiment to reconstruct electron neutrino-like events in the detector, using the Pandora multi-algorithm pattern recognition, will be demonstrated. In particular, we present a fully automated event selection algorithm to identify charged-current electron neutrino event candidates with no pions and at least one proton in the final state (nu_e CC0pi-Np). We discuss the combination of optical information and TPC information to reduce cosmogenic backgrounds. Additionally, we show some cuts on kinematic and geometric variables to reject background events. These cuts have been validated by analyzing two event samples orthogonal to our signal. Future improvements have been identified which will improve the reconstruction efficiency, especially at low energy. The data shown is an unblinded subsample collected by the detector between February and April 2016. It corresponds to an exposure of 4.3 × 10^19 protons on target.

P52. Determination of hadronic resonance contributions to the B0 -> K*0μμ decay

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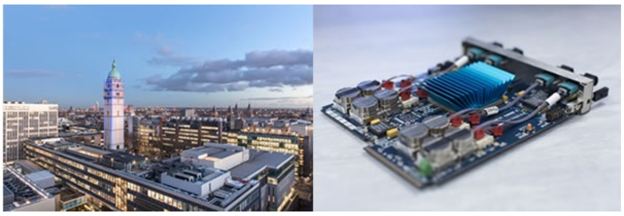

The angular observables of the B0 -> K*0μμ decay are showing intriguing discrepancies with Standard Model (SM) predictions [1]. The discrepancies indicate a shift of the vector coupling (C9) with a significance of about 3.4 standard deviations. This could be explained by the existence of new heavy vector particles not described by the SM. However, the discrepancies may also be explained by interference between hadronic resonance amplitudes (long distance) (e.g. B0 -> J/ΨK*0) and the SM flavour changing neutral current (short distance) amplitudes.

To solve this ambiguity, we intend to perform an unbinned fit to the decay angles and the dimuon mass of the B0 -> K*0μμ decay across the full dimuon spectrum. In the empirical model used for this fit hadronic resonances are modelled as relativistic Breit-Wigner amplitudes and the magnitudes and phases of all hadronic resonance amplitudes are defined relative to the short distance amplitudes [2]. This approach allows the simultaneous determination of the Wilson Coefficients C9 and C10 as well as the level of hadronic interference directly from data.

In the talk I will explain the model, relevant experimental effects (such as acceptance, resolution, and backgrounds), as well as the fitting procedure. Furthermore, I will discuss the expected sensitivity to the key signal parameters.

[1] LHCb collaboration, JHEP 1602 (2016) 104

[2] T. Blake et al., Eur.Phys.J. C78 (2018) no.6 453

P53. Non-parametric Bayesian event reconstruction in Super-Kamiokande detector

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We present a method for non-parametric, Bayesian neutrino event reconstruction for the Super-Kamiokande detector. Particle properties are determined in a way where the number of Cherenkov rings to be reconstructed, and therefore the number of parameters, is one of the unknowns. We discuss Bayesian model selection with Markov Chain Monte Carlo, future scalability and the issues surrounding non-parametric Bayesian reconstruction in Water Cherenkov detectors. We also briefly discuss the application of Bayesian methods in other contexts within T2K and Super-Kamiokande.

P54. Matter density profile effects on neutrino oscillations at T2HK and T2HKK

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This project aims to explore the effects that changes in a matter density profile could have on neutrino oscillations, and whether these could potentially be seen by the future Hyper-Kamiokande experiment (T2HK). The analysis is extended to include the possibility of having a second detector in Korea (T2HKK).

P55. Applications of Machine Learning to the Monopole and Exotics Detector At The Large Hadron Collider (MoEDAL)

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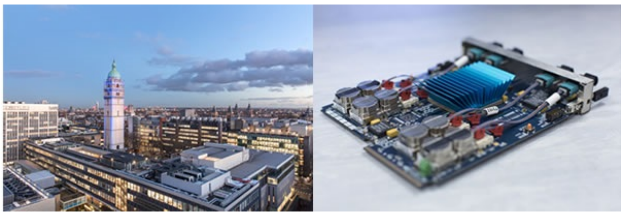

The MoEDAL Experiment uses Passive Nuclear Track Detectors (NTDs) to look for magnetic monopoles, and other heavily ionising exotic particles at the LHC. Through a process of chemical etching, the latent ionisation tracks of particles can be converted into microscopically visible structures known as etch-pits.

Heavy particle radiation backgrounds at the Large hadron Collider represent a domain transition for image recognition techniques in the context of nuclear track detectors. This study looks at multidimensional CNN image recognition for identifying particle etch pits in an NTD foil that has been exposed to both a calibration signal (Heavy Ion Beam), and LHC background exposure.

2D Image data was collected with Directed-Bright/Dark-Field illumination, parametrised at multiple off-axis illumination angles. Angular light intensity distribution control was achieved via a paired Fresnel lens and LED array. The 3-d structure of the etch pits may be inferred in the higher dimensional parametrised space. The focal imaging plane and optical motion plane are aligned within the sub-millimetre thickness of the nuclear track detector foil. The weakened alignment constraints of 3D-structure inference allows thousands of etch-pits to be imaged simultaneously in each millimetre scale field of view, while allowing automated scanning to be applied to the macro-scale scanning of large area MoEDAL foils containing trillions of etch-pits.

Inference methods, are used in this 3d-feature space to select anomalies of interest. A variation on standard techniques for dataset normalisation and whitening was used to obtain a local intensity normalisation that eliminates the impact of multiple systematic bias sources, and reduces non-particle noise. Multiple image classifiers are combined in an ensemble representing a Naive Bayesian Classifier, This may be applied to obtain predicted inference classifications on new areas of Nuclear Track detector foil.

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