INSTITUTE FOR PARTICLE PHYSICS PHENOMENOLOGY

NEWSLETTER MARCH 2021

WELCOME TO THE IPPP

A new year ushers in new hope, better weather and our second instalment of IPPP newsletter!

While the last year has been a challenging time, we are pleased that many group activities have successfully migrated online. These include our theory seminar, coffee meetings and journal clubs. To keep track of what's happening in the broader UK HEP see:
https://www.ippp.dur.ac.uk/uk-hep-community

Since our last newsletter, we have hosted several large meetings online. These include the "IPPP topical meeting on physics with high-brightness stored muon beams":
https://conference.ippp.dur.ac.uk/event/967/overview
This meeting brought together neutrino, accelerator and collider physicists, and we thank the speaker and participants for their lively engagement. This meeting was made possible through our unique associateship programme, which brings together experimentalist and theorists in the UK HEP community. If you are interested in our associateships, please see:
https://www.ippp.dur.ac.uk/ippp-associateships

Many of our PhD students also joined the Young Theorist Forum (YTF) hosted by the IPPP and the 50th British University Summer School in Theoretical Elementary Particle Physics (BUSSTEPP). The BUSSTEPP guest lecturers were Dr Jess Wade and Prof David Tong. You can read about the student's experience in our newsletter.

Finally, we are happy to welcome six new postdoctoral researchers whom you can read about in this newsletter as well as IPPP research highlights on skyrmions, W production in jets and light dark matter production.

WE HOPE YOU ENJOY READING OUR NEWSLETTER!

ANNOUNCEMENTS

1 We are pleased to announce a three-day workshop organised by Djuna Croon, Fran Chandra-Day and Jessica Turner on the intersectionality between neutrino, dark matter and gravitational wave physics. The workshop will be held in the first week of May.

2. The IPPP is pleased to remotely host the annual PLANCK conference, which is to be held on 21-25 June.

3. A new year, a new website! Our website will soon be live:
https://www.ippp.dur.ac.uk/

5. We are thrilled to announce two postdoctoral researchers will join our group in October: Yuber Perez-Gonzalez (Fermilab & Northwestern) and Daniel Reichelt (Gottingen).

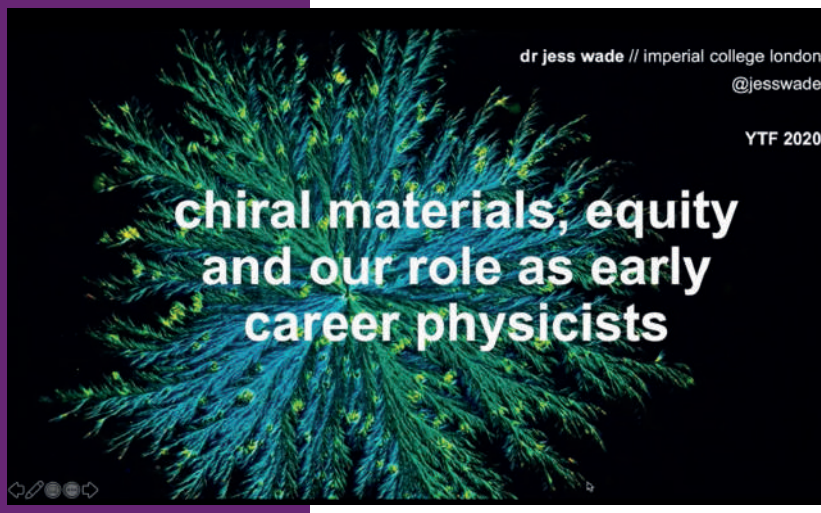
6. The Associateship, Durham IPPP Visiting Award, and Senior Experimental Fellowship programmes are continuing. We encourage applications for all three schemes and invite you to consult the following webpages for application deadlines:

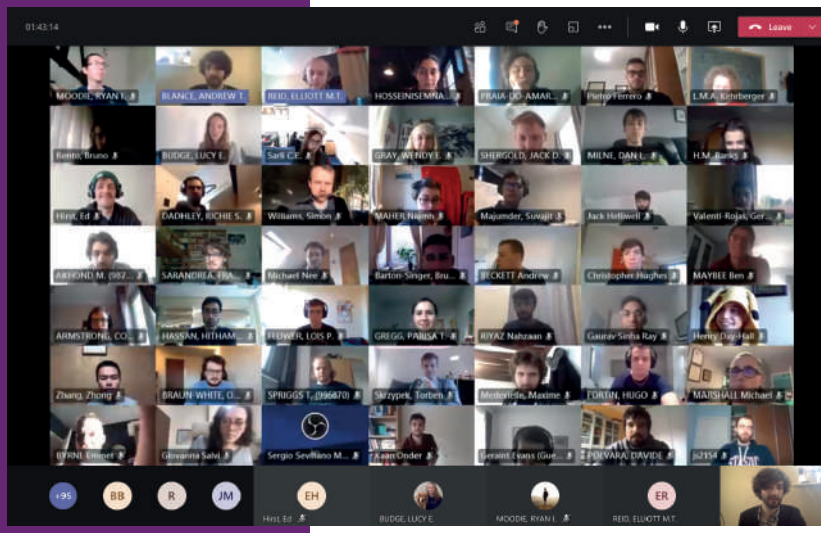
IPPP Associateship:
https://www.ippp.dur.ac.uk/ippp-associateships
DIVA:https://www.ippp.dur.ac.uk/diva

Senior Exp. Fellowship:
https://www.ippp.dur.ac.uk/senior-experimental-fellowships

7. Keep an eye open for the announcement of YETI and the Higgs-Maxwell Meeting in July 2021 (specific dates to be confirmed).

THE YOUNG THEORIST FORUM





Mid-December usually sees postgraduate students descend on Durham for YTF, a chance to meet other HEP theory students and learn about their work. This year, however, the conference was held entirely online. Around 150 people signed up to attend. The most-watched talk was seen by over 100 people. We heard from about 50 people; covering topics from machine learning in dark matter to the fifth force. We listened to all the talks in Teams, and instead of having tea and coffee in the Bransden Room we met up and chatted in **wonder.me** (with participants providing their own refreshments). The difference in location did not reduce the level of enthusiasm, though, in fact, YTF20 turned out to be the largest YTF ever! We had two plenary speakers: Prof. David Tong and Dr Jessica Wade. On Tuesday evening Dr Wade gave a thought-provoking talk about her research and EDI in physics titled "chiral materials, equity and our role as early-career physicists". Then, on Wednesday Prof. Tong gave a highly anticipated and entertaining talk titled "Are we living in the matrix?". It wasn't all physics, though: we held a "pub quiz with a difference". Eight teams battled through rounds making Fermi estimates, playing the Wikipedia game and writing Christmas cracker jokes! We would like to thank Durham University, the IOP, all the speakers and everyone who attended YTF this year. We hope we will see everyone in-person at YTF21!

BUSSTEPP 2021

To start the new year (between 11th Jan. and 5th Feb.), Queen Mary University of London hosted the summer school in a fully online setting, with lectures and tutorials taking place over Zoom and covering a wide variety of material from Holography/Ads-CFT Correspondence to Lattice Field Theory. Students were also allowed to give short presentations on their research with prizes for the best talks each night.

Special talks were also given on physics topics that many were perhaps less familiar with, including Connections to Condensed Matter Physics (by Prof. Steve Simon at Oxford), Gravitational Waves (by Dr Justin Vines at Postdam) and Multi-Agent Machine Learning (by Dr Edward Hughes at Google DeepMind). These were all very interesting and presented a fantastic opportunity to expand students' knowledge of other areas of physics.

Additionally, an invaluable and exciting talk was given by Prof. Cristina Lazzeroni at Birmingham on Communication and Outreach. On the final day, representatives from Karlsruhe, Capula Investment Management, QMUL and Rolls Royce hosted a fantastic and hugely informative careers session wherein the many paths available to postgraduate students were emphasised.

Students didn't miss out on the opportunity to mix and socialise either! There were several social sessions every week and attendees made use of the online gather.town platform to simulate the coffee breaks and chats that would have taken place in person! Additionally, the hosts organised two virtual escape room events which were very well-attended and a lot of fun!

We would like to warmly thank Queen Mary University of London for hosting the event, especially the organising committee. Further, we also thank the fantastic lecturers and tutors from across the world who attended and gave such fantastic talks and assistance. It must not have been easy to organise the School under such difficult circumstances. Still, the combined effort of all of the organisers, tutors and speakers made it an enormous success. Every attendee gained a lot as a result!

NEW POSTDOCTORAL RESEARCHERS

The IPPP is happy to announce the addition of six new postdoctoral researchers.

RACHEL HOUTZ

Rachel works on a variety of topics in particle physics phenomenology. She came to the IPPP from a postdoctoral position at the IFT in Madrid. Before that, she did her PhD at the University of California, Davis. Her research interests include heavy axion model building, axion phenomenology, dark matter, and Higgs naturalness.

JACK ARAZ

Jack is a new postdoc who started last September, fresh from his PhD which he undertook at Concordia University. He is interested in collider phenomenology, beyond the Standard Model physics, and computational tools in HEP phenomenology (specifically machine learning and quantum computing). Thanks to COVID-19, he hasn't seen his new office yet. He is excited to be a part of IPPP and can't wait to discuss physics with his new colleagues on a climbing wall (or over coffee, that's okay too!).

JUAN CARLOS CRIADO

Juan joined the IPPP as a postdoc in October 2020. Before, he did his PhD at the University of Granada, and then a postdoc at the NICPB in Tallinn, Estonia. His research interests include Higgs physics, dark matter, neutrino physics, and topological effects such as solitons and instantons. He is especially interested in studying these subjects from an effective field theory point of view and applying machine learning methods to them.

LUCIEN HEURTIER

Lucien moved to Durham in October 2020 after he completed his PhD in École Polytechnique (France) in 2015 and two research postdocs in ULB (Brussels) and the University of Arizona (USA). He dedicated most of his work to particle physics's phenomenology beyond the standard model and its application to cosmology and astroparticle detection. In particular, he worked extensively on dark-matter model building, inflationary scenarios, supergravity and ultra-high-energy cosmic rays. Moreover, he is a keen pedagogue and enjoys, beyond science, activities involving the

SEBASTIAN JASKIEWICZ

Sebastian joined the IPPP last October for his first postdoctoral position following PhD studies at the Technical University of Munich. He has obtained his Master degree at the University of Edinburgh. His research focuses on collider phenomenology using effective field theories and higher-order calculations. He is particularly interested in improving theoretical predictions by developing factorisation and resummation techniques beyond leading power. He is also keen to promote research in physics among minorities.

YANNICK ULRICH

Yannick works on precision predictions for low-energy experiments and regularisation scheme dependence. He is the maintainer of the McMule project (Monte Carlo for MUons and other LEptons) and a member of the MUonE theory initiative. Yannick passed his PhD at the University of Zurich and the Paul Scherrer Institut under the supervision of Adrian Signer.

MEET THE IPPP ON YOUTUBE

Public engagement with physics is a key aspect of the IPPP's work. As part of this, we have started a project to expand our YouTube channel with interviews with IPPP physicists. We will feature accessible explanations of our research, as well as discussing our journeys into physics. In the first videos, Fran Chadha-Day interviews Lucy Budge and Lucy interviews Elliott Reid. We cover making the most out of the Large Hadron Collider and dark matter detectors, physics-inspired dog names, and ancient Roman lead.

We are in the process of recording and editing more interviews and also hope to feature questions from local schools. We have hugely enjoyed the process of creating these videos so far. We are happy to be able to continue telling people about physics even during the Covid-19 pandemic! We hope this will be the start of a wide variety of new content for our YouTube channel, featuring physicists and research from across the IPPP.

SKYRMIONS

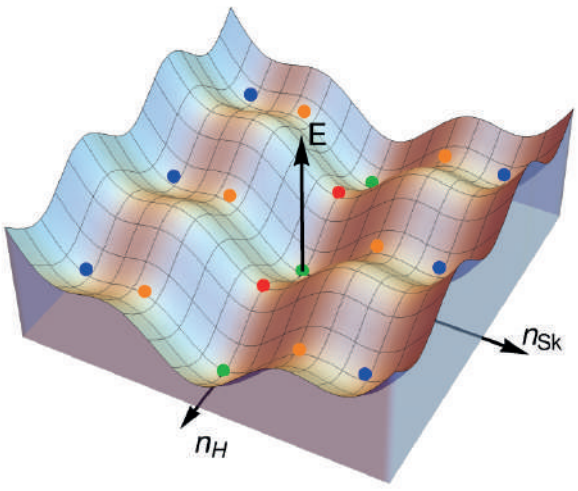
Skyrmions are extended field configurations, initially proposed to describe baryons as solitons in an effective theory of mesons. As the low-energy description of nucleons, this works reasonably well, but there have been no direct evidence for the existence of skyrmions in particle physics.

This contrasts with condensed matter systems where skyrmions were experimentally observed as vortex-like textures of magnetic moments in magnetically ordered materials and have received much attention.

Motivated by the striking parallels between the QFT ideas in particle physics and in condensed matter, Juan Criado, Valya Khoze and Michael Spannowsky in arXiv2012.07694 decided to reexamine skyrmions in particle physics, and in particular, searched for skyrmions in the electroweak sector of the Standard Model.

They found that the interplay of a dynamical Higgs field and the presence of certain dimension-8 operators in the Standard Model EFT leads to a non-trivial vacuum structure with the skyrmion and perturbative vacuum sectors separated by a finite energy barrier. They confirmed the existence of electroweak skyrmions and studied their properties using the neural network method. It was also shown that the dimension-8 Skryme term can be induced by a large class of UV models.

Electroweak skyrmions are non-topological solitons, but are exponentially long-lived, is a viable dark matter candidate. While the skyrmion production cross section at collider experiments is suppressed, measuring the Skyrme EFT operator's size in multi-Higgs-production processes at high-energy colliders is a promising avenue to experimentally probe the very existence of electroweak skyrmions.

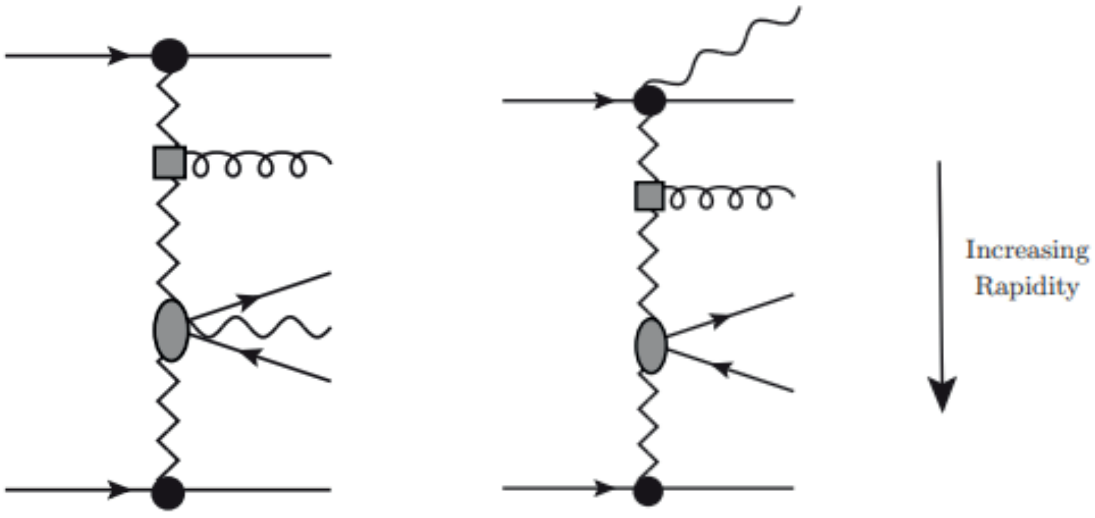


COMBINED SUBLEADING HIGH-ENERGY LOGARITHMS AND NLO ACCURACY FOR W PRODUCTION IN ASSOCIATION WITH MULTIPLE JETS

Combined subleading high-energy logarithms and NLO accuracy for W production in association with multiple jets.

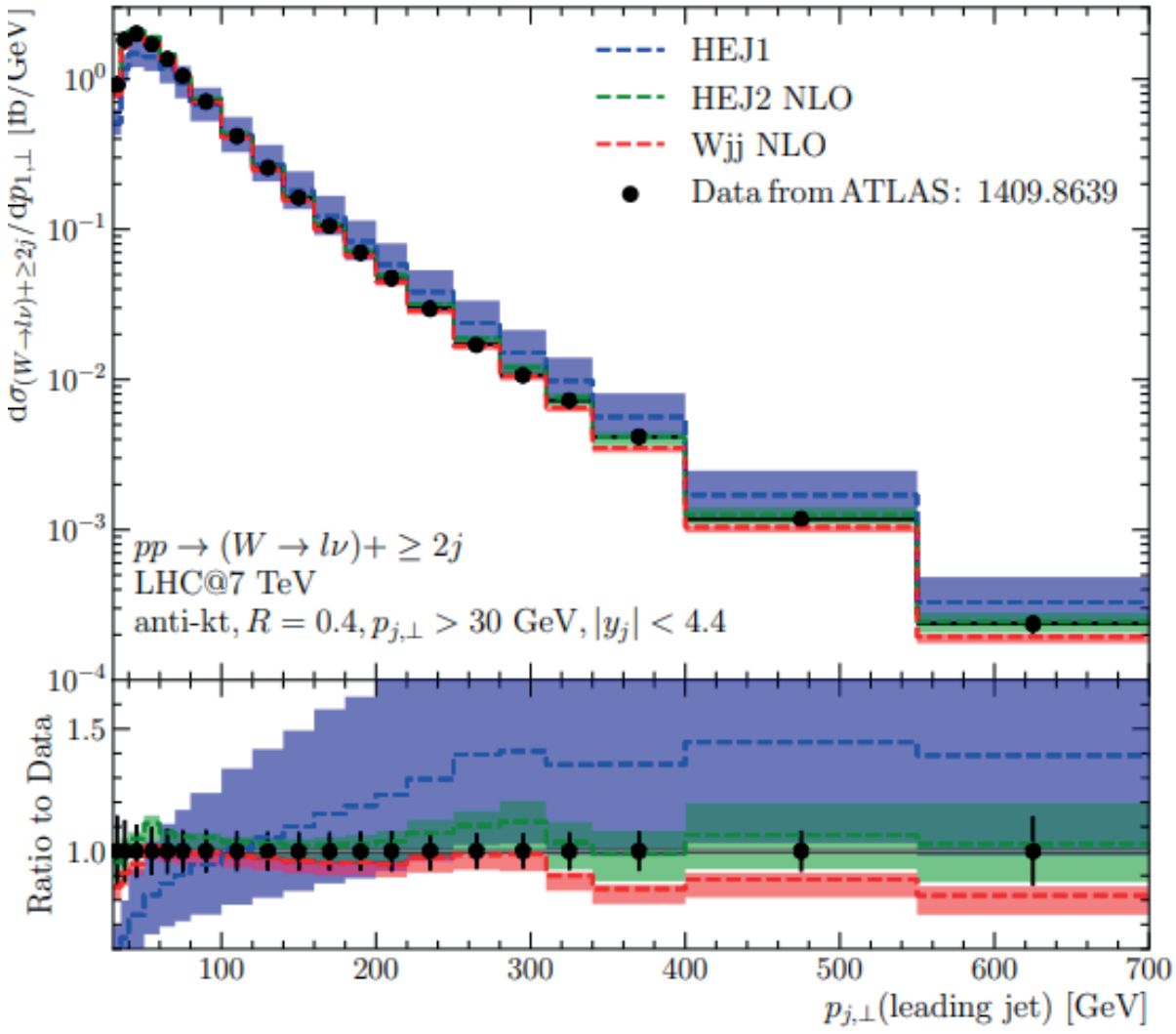
The much-celebrated fixed order perturbative calculations provide predictions of unparalleled accuracy for scattering processes with a single, hard scale. However, some processes are of interest in regions of phase space with several hard, perturbative scales. Such processes include e.g. W,Z and H production in association with two jets, where the two jets have a large invariant mass. Both electroweak and QCD processes contribute, and precise predictions for both are needed to extract fundamental parameters from the measurements.

In recent work by Jeppe R. Andersen, James A. Black, Helen M. Brooks, Emmet P. Byrne, Andreas Maier and Jennifer M. Smillie they showed that in the region of large $s >> p_t^2$, large logarithmic corrections in s/p_t^2 lead to substantial variations in the perturbative predictions for the QCD process. This instability can be cured by summing the logarithmic contributions in s/p_t^2 to all orders in αs.



As expected, though, leading logarithmic accuracy is insufficient to guarantee a suitable description in regions of phase space away from the high energy limit. We present the first calculation of all partonic channels contributing at next-to-leading logarithmic order in W-boson production in association with at least two jets.

We improve the perturbative description further by matching the description of observables to next-to-leading fixed-order accuracy. This new combination of perturbative input systematically improves upon the description of NLO in regions of phase space which are formally subleading with respect to s/p_t^2 and the NLO input significantly reduces the scale variation of the logarithmic corrections, thus stabilising the perturbative predictions.



LIGHT DARK MATTER THROUGH RESONANCE SCANNING

While there is an abundance of observational evidence that dark matter makes up most of the matter in the universe, experiments have yet to directly detect evidence of dark matter particles. Upcoming direct detection experiments will expand the search for dark matter to probe weaker couplings and lighter masses. Light dark matter, with mass below the GeV scale, is becoming a focus of this program.

In arXiv:2012.15284, a group including Djuna Croon and Rachel Houtz propose a mechanism to produce light dark matter: resonance scanning. The mechanism has two important features. First, the dark matter mass changes with temperature. As the universe cools, the dark matter mass decreases until it settles into its final light mass ~MeV mass.

Second, the dark matter production benefits from resonant enhancement. As the dark matter mass decreases, its mass generically scans through the value of half the Higgs mass. The Higgs-mediated interactions between the dark matter and the Standard Model occur on resonance, leading to dark matter production enhancement.

The study traces the evolution of the dark matter population as its mass shifts and as the dark matter mass passes through the resonance. This resonance scanning mechanism is found to accommodate a large range of possible dark matter masses, extending well into the light dark matter region. Dark matter's history informs the search for dark matter, and exciting features of this mechanism's history lead to unexpected combinations of dark matter mass and interaction strength for experiments to target today.