INSTITUTE FOR PARTICLE PHYSICS PHENOMENOLOGY

NEWSLETTER MARCH 2022

WELCOME TO THE IPPP

Spring has sprung, and with it, another exciting issue of the IPPP biannual newsletter. Since the last issue, there have been plenty of IPPP hosted activities, including the Annual Theory Meeting in 14-16 December 2021 (hosted in hybrid mode). Talks featured reviews on g-2, flavour and neutrino physics, and we thank the speakers for their participation. At the same time, the Young Theorist Forum was ongoing, and we are grateful to the participants and Ruth Gregory for giving the guest lecture.

We are pleased to announce several new DIVAs, including Manimala Mitra. She will visit IPPP from the Institute of Physics (Bhubaneswar) to further develop and extend her UK based collaborations in neutrino and dark matter physics. In addition, Adam Falkowski (Laboratoire de Physique Théorique d'Orsay), who specialises in effective field theories, will also visit the IPPP as a DIVA and extend his UK based collaborations. Last but not least, the IPPP is happy to host Rick Gupta (Tata Institute of Fundamental Research, Mumbai) to continue to develop his work on LHC phenomenology with the IPPP and other UK based institutions.

Furthermore, we are happy to host Linda Cremonesi and Kristin Lohwasser as IPPP associates. Linda plans to host a workshop on neutrino nucleon interactions at the IPPP and strengthen ties between the neutrino theory and experimental community. Likewise, Kristin aims to utilise the expertise the IPPP provides to infuse her measurements of light and heavy vector-boson scattering processes at the LHC through a series of mini-workshops and research visits.

There will be several upcoming IPPP affiliated workshops to watch out for. These include the "Bayesian Inference in High-Energy Physics" (25-27 May 2022) hosted by Stephen Jones and Michael Spannowsky and the "15th International Workshop on Top Quark Physics" (4 - 9 September 2022) organised by Ben Pecjak.

The IPPP congratulates Dr Asli Abdullahi, Dr Parisa Gregg, Dr Kevin Kwok and Dr Oscar Ochoa on the successful defence of their PhDs. Finally, this issue's highlights include an article on YTF and research highlights from Djuna Croon and Stephen Jones.

ANNOUNCEMENTS

1. The IPPP is pleased to announce an upcoming workshops on the "Bayesian Inference in High-Energy Physics" (25-27 May 2022) hosted by Stephen Jones and Michael Spannowsky and the "15th International Workshop on Top Quark Physics" (4 - 9 September 2022) organised by Ben Pecjak.

2. Our website has been revamped; check it out at **https://www.ippp.dur.ac.uk/**
We will also maintain the HEP Forum: **https://www.ippp.dur.ac.uk/uk-hep/**
where one can find announcements about seminars, conferences and jobs in the UK.

3. If you are interested in doing a PhD or if you are teaching students who would like to do a PhD in theoretical particle physics at the IPPP, please have a look at this link:
https://www.durham.ac.uk/departments/academic/physics/postgraduate-study/
If you have further questions, email Ben Pecjak at **ben.pecjak@durham.ac.uk**

4. 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 web pages 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**
Our next intake will be in September 2022.

YOUNG THEORIST FORUM 2021

The usual yearly YTF conference took place virtually in December 2021. YTF is a long-running conference organised by a collaboration of PhD researchers from the University's Departments of Physics and Mathematical Sciences. Given the COVID-19 situation at the time, we made the difficult decision to move the conference online for the second year in a row. Regardless of the unfortunate shift to an online setting, the conference was very well attended. We had 128 registered attendees, of which a number gave a variety of talks covering topics from cosmology to string theory and even a little machine learning. As in any other year, the conference was given a novelty theme; this year, the chosen theme was "Lord of the Rings". The theme was woven into many student talks and even the talk from our plenary speaker Ruth Gregory entitled "Return of the String". She took us on a journey through her career work in her talk. She then concluded with an informative discussion in which she offered advice for early career progression in a PhD and further into academia.
Many of the attendees took part in a County Durham-themed Escape Room on the first evening. Players formed small groups on Zoom to solve puzzles online, including the use of Google maps and local websites. Players enjoyed learning about various County Durham landmarks, and hopefully, next year at YTF22, they will get to explore in person!

Thank you to everyone who attended Durham University, our sponsors, and all our fantastic speakers for allowing us to hold another marvellous event.

ANNUAL THEORY MEETING 2021

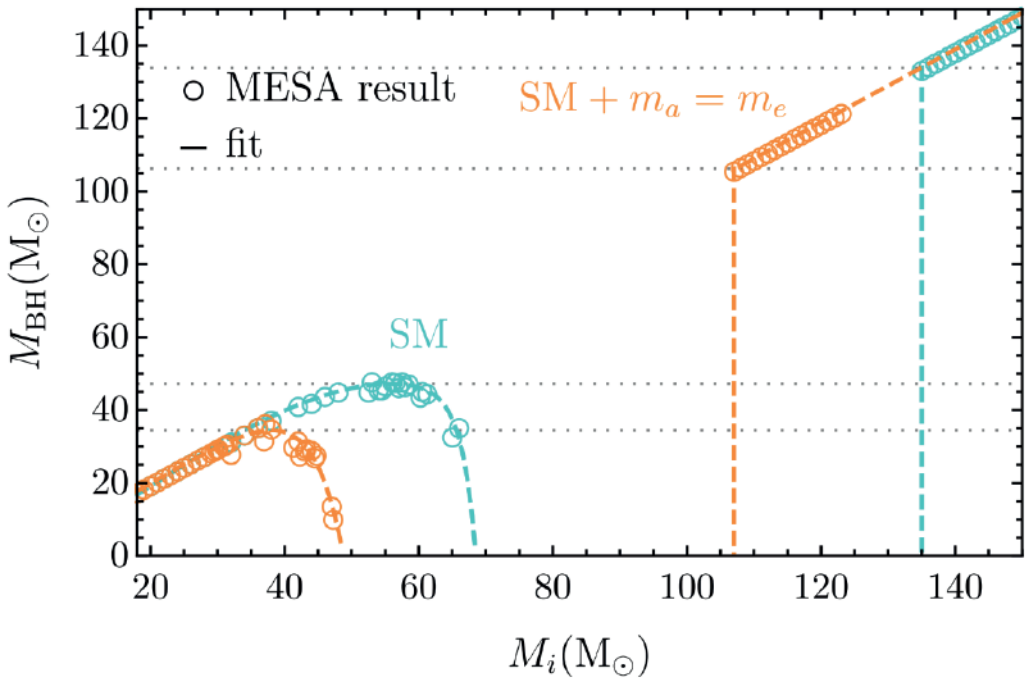
The Annual Theory Meeting 2021, hosted by the IPPP, was one of the first hybrid meetings since the start of the COVID pandemic. More than 100 people connected remotely over the three days, and over 50 people joined in person. The meeting ran from 14-16 December 2021.

It began with talks by Sean Hartnoll (Cambridge), Andrea Puhm (Ecole Polytechnique) and Sakura Schafer-Nameki (University of Oxford) on topics ranging from quantum entanglement, amplitudes to generalised QFTs. The second day began with talks on cosmology by Blake Sherwin (University of Cambridge) and Eugene Lim (King's College London), who joined us from sunny Malaysia! This was followed by a lively talk by Ben Allanach (University of Cambridge) on the interplay between flavour anomalies and collider phenomenology. Next, an entire session was devoted to the recent and exciting result from Fermilab's g-2 experiment, and Aida El-Khadra (University of Illinois at Urbana-Champaign) and Balint Toth (University of Wuppertal) reviewed the theoretical aspects of the measurement. Finally, the last session was neutrinos, and Jessica Turner (IPPP) and Kirsty Duff (University of Oxford) reviewed the theoretical and recent experimental anomalies of neutrino physics. It was a jovial occasion to see our colleagues from across the UK come to Durham, catch up, talk physics and enjoy the hospitality of Collingwood College. Of course, any ATM would not be complete without a customary visit to some local pubs. We thank the speakers and participants, in-person and remote, who took part and made ATM 2021 a great way to end the year.

WE LOOK FORWARD TO THIS COMING ATM 2022

AXION INSTABILITY SUPERNOVAE

Djuna Croon and collaborators have long thought about the late stages of blue supergiant evolution and the effect that new particles can have on it. Earlier work included studies of what happens when these new particles are produced and escape. In a new paper, a novel question is explored: what if they don't? For example, if the particles are a bit heavier and have a decent coupling to the rest of the material in the star, they may equilibrate (on timescales that are shorter than the evolution). When that happens, they start to affect the star's evolution. As it turns out, this may even lead to a new instability in the stellar cores, in addition to the already dramatic pair-instability caused by electron-positron production. What happens is that the star trades radiation for non-radiation, reducing the pressure. Like pair-instability, this new instability can set a chain reaction in motion, leading to the star's ultimate demise (leaving no remnant). This implies the existence of a black hole mass gap: an unpopulated region in the stellar graveyard. Due to new particles, this can now happen for much lighter stars (and black holes). The plot shows the final BH formed from an initial star mass. As you can see, the mass gap (the range of masses in which no black hole is produced) predicted by the instability is quite a lot lower for the case with the extra particle (the orange line) than in the standard model (cyan line). It also ends at lower masses. These effects would have real implications for gravitational wave observations, as these are exactly the types of black holes the LIGO/Virgo/KAGRA collaboration can observe. If this effect is present in stars, we should be able to distinguish that sometime soon!

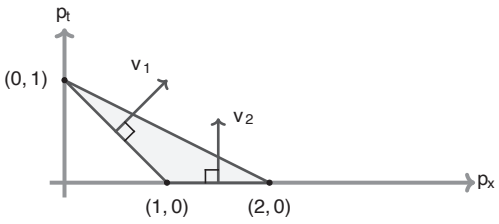


THE GEOMETRY OF FEYNMAN INTEGRALS AND THEIR NUMERICAL COMPUTATION

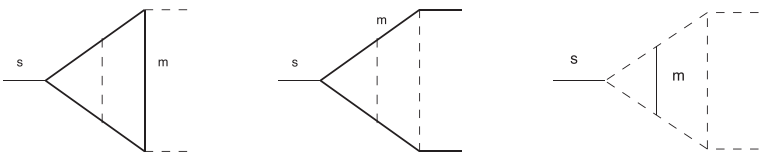
With Run 3 of the LHC and its high-luminosity upgrade (HL-LHC) promising to deliver new and significantly more precise experimental measurements, there is an ever-increasing demand for more accurate theoretical predictions. Fixed-order perturbative calculations of hard scattering matrix elements are a key ingredient of these improved predictions. Feynman integrals naturally arise in the loop diagrams appearing in these calculations and have therefore been the subject of intense study for at least the last 60 years.

However, Feynman Integrals have a rich and interesting mathematical structure that can still reveal itself to us in surprising and novel ways. In arXiv:2108.10807 by G. Heinrich, S. Jahn, S. Jones, M. Kerner, F. Langer, V. Magerya, A. Poldaru, J. Schlenk, and E. Villa, a procedure for expanding Feynman integrands, known as expansion by regions, was explored from a geometric perspective and implemented in the publicly available code, pySecDec. This work and the associated computer package provide methods for analytically exploring the structure of Feynman integrals containing a large hierarchy of scales and for numerically evaluating such integrals.

The geometric perspective on Feynman integrals, considered in this work, is obtained by studying a Newton polytope produced from the polynomials used to define a Feynman integral in the Feynman/Schwinger/alpha parametrisation. The polytope encodes a surprising amount of information about integrals, including their IR and UV divergences, any overlapping divergences, and the leading regions when assuming a scale hierarchy. Moreover, this picture seems to have a lot more to offer, for example, by providing an intuitive procedure for anticipating the IR structure of arbitrary loop integrals as explored in recent work by N. Arkani-Hamed et al.



Newton polytope for P(x,t) = t + x + x^2, together with the directions of the region vectors (drawn as normal vectors to the facets in the positive t-direction).



A selection of Feynman integrals profiled in arXiv:2108.10807.