JUBILEE

NEWSLETTER

INSTITUTE FOR PARTICLE PHYSICS PHENOMENOLOGY

NEWSLETTER SEPTEMBER 2025

25 YEARS OF IPPP!

Twenty-five years on from its founding, the IPPP remains a place where ideas travel quickly from blackboard to experiment—and, just as often, back again. This special jubilee edition of the IPPP newsletter celebrates that arc: landmark meetings organised by IPPP staff members, a thriving outreach programme that reconnects us with the public, a summer school that equips the next generation, and research highlights that push the Standard Model and its frontiers.

As we mark the anniversary with talks, memories, and a look ahead to the next quarter-century, we thank our community of students, staff, visitors, alumni and partners. Here's to the discoveries we'll make together in the next 25 years!

ANNOUNCEMENTS

1. The IPPP is pleased to announce the following workshops
(detailed information can be found on ***ippp.dur.ac.uk/workshops):***
- The 5th Asian-European-Institutes Workshop for BSM
(September 29, 2025 - October 2, 2025, Durham University)
- The UK HEP Forum 2025: "Wandering in the Dark"
(October 20, 2025 - October 22, 2025, The Cosener's House in Abingdon / zoom)
- The FCC-UK Meeting (November 12, 2025, IPPP)
- The Annual Theory Meeting
(December 15, 2025 - December 17, 2025, Durham University)

2. 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 March 2026.

3. We encourage organisers of workshops related to HEP theory to reach out for support. The IPPP can help organise workshops in the UK, administratively and financially.

IPPP 25TH ANNIVERSARY CELEBRATION

https://conference.ippp.dur.ac.uk/event/1454/

Wednesday, September 24

12:30–14:00
Lunch
(Calman Learning Centre)

14:00–14:30
IPPP: Welcome
(Calman Learning Centre)

14:00–14:05
Welcome Address
— Michael Spannowsky

14:05–14:15
Welcome Address
— Clive Roberts

14:15–14:22
Welcome Address
— Paula Chadwick

14:22–14:30
Welcome Address
— Grahame Blair

14:30–15:10
IPPP: the early years
(Calman Learning Centre)

14:30–14:50
Memories
— Jonathan Butterworth

14:50–15:10
Ideas, People and Precision Phenomena
— Tony Doyle

15:10–16:00
Coffee break
(Calman Learning Centre)

16:00–16:40
IPPP: the early years
(Calman Learning Centre)

16:00–16:20
Why the IPPP?
— Ian Halliday

16:20–16:40
Memories
— Adnan Bashir

Evening (Durham Castle)

18:30–19:20
Reception

19:20–19:30
Photo

19:30–21:30
Dinner

Thursday, September 25

09:30–10:15
Science Talks
(Calman Learning Centre)

09:30–09:45
B-Anomalies/Z'
— Ben Allanach

09:45–10:00
Dark Matter
— Christopher McCabe

10:00–10:15
Neutrinos
— Silvia Pascoli

10:15–11:15
Coffee break
(Calman Learning Centre)

11:15–12:30
More talks: Memories and Outlook
(Calman Learning Centre)

11:15–11:30
Memories
— Gudrid Moortgat-Pick

11:30–11:45
Memories
— Joerg Jaeckel

12:00–12:15
IPPP: the next 25 years
— Sinead Farrington

12:30–13:30
Lunch
(Calman Learning Centre)

14:00–15:00
Physics Science Show
— Sam Gregson
(Calman Learning Centre)

PUBLIC ENGAGEMENT AND OUTREACH AT IPPP

Public engagement and outreach are core missions of the IPPP. Over the past few years, we have rebuilt our in-person outreach programme, as well as developing online and digital public engagement content. This has allowed us to reach a broader audience, while also maintaining links to our local community.

One of the flagship outreach events for the IPPP is the International Particle Physics Masterclass, for which we welcome local secondary school students for talks on particle physics and hands-on data analysis activities. Following a pause due to the Covid-19 pandemic, the Masterclass was restarted by Jessica Turner, running in both 2024 and 2025. IPPP physicists also frequently give talks and demonstrations to school groups, giving a wide range of children and young people the opportunity to hear first-hand about particle physics and life as a researcher.

During the academic year 2023/24, IPPP hosted an outreach researcher, Sergio Francesco. Sergio organised a Café Scientifique at a local pub in Durham over six months, including informal talks by researchers from IPPP and elsewhere in the university. Sergio and Jessica Turner also spoke at the Durham Pint of Science event in 2024. These events provide an informal and enjoyable setting for the general public to learn more about particle physics.

Our science communication programme also continued further afield, with Djuna Croon representing the IPPP at CERN's public 70th anniversary programme. Djuna gave a talk on Dark Matter to hundreds of attendees in the CERN auditorium with a viewership of 40,000 on YouTube. Francesca Chadha-Day has also taken science communication to a broader audience by performing stand-up science comedy at a range of venues across the UK, including a solo science comedy show "Are dreams made of atoms?" at Durham Fringe Festival 2022.

The IPPP continues to use a range of digital public engagement to reach a wide audience. IPPP researchers have discussed particle physics on the Naked Scientist podcast and radio show, the Physics for Students podcast and YouTube cast, the Math & Beyond podcast and YouTube cast and the Even Bananas YouTube show, reaching over 85,000 viewers.

Over the coming years, we aim to continue our successful core outreach activities, as well as further developing a flexible and varied public engagement programme. We envisage offering further opportunities for IPPP students and staff to give talks at local schools, as well as teaming up with local pubs and festivals to offer a range of creative science communication.

PASCOS 2025

The IPPP was delighted to host the 30th instalment of PASCOS, the international symposium on Particles Strings and COSmology, from July 21-25, 2025. More than 170 delegates gathered in the Calman Centre for a week of plenaries and discussions. The aim of the conference is to review recent progress in these areas with particular emphasis on their interconnections. The packed programme included a host of luminaries covering topics such as LHC Physics and its theoretical status, dark matter and dark energy, string theory methods and string phenomenology, neutrino physics, precision measurements and non-accelerator probes of new physics, inflation and alternatives and gravitational waves. Between sessions, coffee was served on the top floor with views of the Cathedral, mid-week featured a free afternoon for visits to Durham Cathedral and Crook Hall & Gardens, and the conference dinner took place in the Castle.

DARK MATTER BEYOND THE WEAK SCALE

Dark Matter Beyond the Weak Scale III, held 7–10 April 2025 at Oxford's Denys Wilkinson Building, was the third instalment of a conference series organised by Djuna Croon (IPPP), Edward Hardy, and Juri Smirnov. It gathered theorists and experimentalists to chart discovery paths for non-WIMP dark matter, emphasising how early universe dynamics -- such as early matter domination, inhomogeneities, and phase transitions -- reshape relic-abundance predictions and open routes to primordial black holes and other compact dark objects. Talks also explored particle production from gravitational perturbations, minimal sterile-neutrino and electroweak-multiplet candidates, and fresh directions in direct detection, including machine-learning-guided scintillators.

A recurring theme was diversification of searches across mass scales and messengers. Speakers highlighted prospects with gravitational-wave observatories, atom interferometers (e.g., AION), pulsar timing and astrometry, and even ocean-acoustic arrays for ultra-heavy candidates, complementing underground detectors. The meeting conclusions can be summarised with a few concrete ideas: define common benchmarks for nonstandard cosmologies, refine forecasts for compact-object scenarios, and strengthen coordination between theory and emerging experimental efforts to ensure truly complementary coverage of dark-sector parameter space.

STANDARD MODEL AT THE LHC 2025

Standard Model at the LHC is an important conference series in particle physics and was recently hosted at both Fermilab (2023) and CERN (2022). The first conference in the series was in Durham in 2012, and it was a pleasure to welcome it back in 2025.

The workshop brings together theorists and experimenters to discuss the latest developments and future prospects in Standard Model phenomenology at the LHC, with emphasis on the most interesting and topical aspects at the interface between theory and experiment. The workshop has sessions devoted to Electroweak, QCD, Higgs, Top, Heavy Flavour and EFT, all organised by experts from leading institutions around the globe. They and the invited speakers came together for four days in Durham to discuss topical measurements and predictions. The unique programme put together by both theorists and experimental physicists led to insightful discussions.

The conference dinner was held in the Great Hall of Durham Castle next to Durham Cathedral.

THE 2025 STFC HEP SUMMER SCHOOL

This year, the STFC High Energy Physics (HEP) Summer School was co-organised by the Institute for Particle Physics Phenomenology (IPPP), led by Deputy Director Daniel Maitre, together with Stefania Ricciardi from STFC Rutherford Appleton Laboratory (RAL). The School is aimed at UK-based PhD students in experimental particle physics, specifically those nearing the end of their first year.

In 2025, the School welcomed approximately 100 students from institutions across the UK. Its primary objective was to provide participants with a solid foundation in theoretical aspects of particle physics, which will be essential to their future research careers.

The two-week programme, held from 31st August to 12th September, offered a broad curriculum spanning both formal and phenomenological aspects in particle physics. Students attended lectures on core theoretical topics such as Quantum Field Theory, Quantum Electrodynamics, Quantum Chromodynamics, and the Standard Model. These were complemented by more phenomenology-focused lectures covering areas such as neutrino physics, dark matter, cosmology, and collider phenomenology.

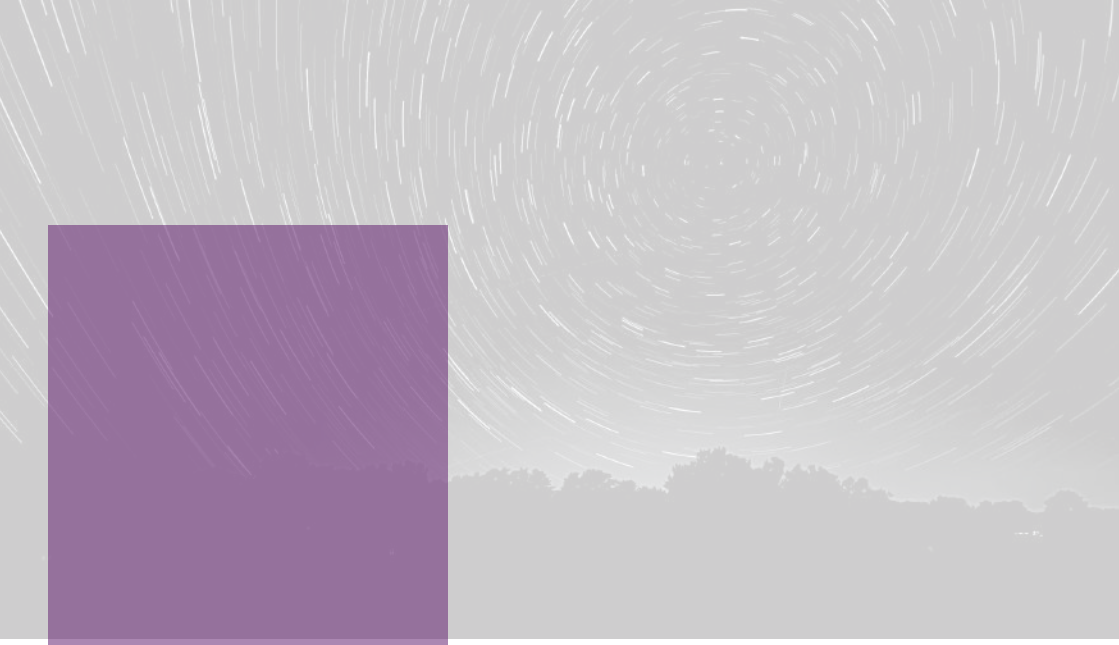
Leading researchers delivered the lectures from institutions across the UK, including Jonas Lindert (University of Sussex), Ken Mimasu and Biapasha Chakraborty (University of Southampton), Martin Bauer and Silvia Nagy (Durham University), among others.

In addition to lectures, students participated in daily tutorial sessions, working in groups of 10 to 12. These sessions were designed to reinforce lecture material through problem-solving and collaborative discussion. The tutorials were led by experts in collider physics, such as Sudan Paramesvaran (University of Bristol), Will Barter (University of Edinburgh), and Gitanjali Poddar (Queen Mary University of London), as well as specialists in neutrino physics, including Phil Litchfield (University of Glasgow) and Clarence Wret (Imperial College London). Theoretical support was provided by researchers such as Jack Holguin and Hesham El Faham (University of Manchester), and Arturo De Giorgi (Durham University).

These small-group sessions fostered a collaborative environment, encouraging students to engage in in-depth discussions and develop a deeper understanding of complex topics.

Throughout the two weeks, students also had the opportunity to present their own research during four dedicated poster sessions, held on separate days at Grey College, Durham University, where they were accommodated during the School. These sessions allowed students to showcase their work, receive feedback from peers and faculty, and further develop their presentation skills.

Overall, the 2025 STFC HEP Summer School was an enriching and intellectually stimulating experience, strengthening the next generation of researchers in the UK particle physics community.



NEW NU PHYSICS: FROM COLLIDERS TO COSMOLOGY

The workshop 'New-nu Physics: From Colliders to Cosmology' took place in Durham University campus from the 9th until the 11th of April, drawing physicists from all over Europe and beyond.

This one-off workshop had a moderately sparse schedule for talks in order to allow for discussion, the discussion itself often a follow-up of the questions during seminars. Some of the most debated topics included neutrinos at colliders, the experimental results of the 'Dark Energy Spectroscopic Instrument'(DESI), and recently proposed physics beyond the Standard Model scenarios to accommodate the DESI data.

The attendance reflected the composition of the organising committee with an almost even mix of theorists and experimentalists. The IPPP members of the committee were Michael Spannowsky and Rodrigo Alonso, while the ATLAS collaboration members, Chris Hays from Oxford University and Chris Pollard from Warwick University, completed the panel. There are currently no plans to repeat this workshop next year, but its impact lives on in the theory-experiment exchange of ideas and the projects that started over the three day duration of the conference in April.

INTERNATIONAL MASTERCLASS IN PARTICLE PHYSICS

On the 28th of March, with spring in full bloom, the IPPP welcomed over 110 sixth form students to Durham University's Teaching and Learning Centre for the International Masterclass in Particle Physics. The event brought together students from six schools - Newcastle High School for Girls, Durham Johnston Comprehensive School, Cramlington Learning Village, Thirsk School, Wellfield School, and Durham Sixth Form Centre - for a day of discovery, curiosity, and hands-on science.

The morning began with a lively particle physics card game, designed to get students thinking like physicists from the start. Armed with colourful cards representing quarks, leptons, and bosons, the students debated and invented their own ways of organising the Standard Model. The game quickly filled the room with laughter, energy, and curiosity, an ideal launchpad for the day ahead.

Next came the inspiring talks. Jessica Turner set the stage with "What is Our Universe Made Of?", introducing the big questions that drive modern physics. Arturo de Giorgi followed with "Why Neutrinos Matter", sparking intrigue around one of the most mysterious particles in nature. Both talks left students buzzing with questions that they carried into the hands-on sessions.

Even during the mid-morning break, students surrounded the volunteers with questions: about physics, university life, and what it really means to be a researcher. The sense of curiosity and energy never dipped throughout the day.

After the break, Dhruv Pasari introduced the highlight of the masterclass: analysing real data from the MINERvA neutrino experiment at Fermilab. With guidance from IPPP PhD students and postdoctoral researchers, the students worked in teams to sift signal events from background noise, tackling the same challenges faced by professional physicists. The computer rooms soon hummed with excitement as groups argued over candidate events, pieced together evidence, and celebrated their “discoveries.”

The day also offered a glimpse into the life of a researcher. Ansh Bhatnagar shared his journey as a PhD student, followed by a lively Q&A session in which students asked everything from “what is life as a PhD like?” to “what inspired you to pursue physics?”, and even “how does one sustain themselves while doing a PhD?”.

In the afternoon, the students connected via video call with neutrino physicists at Fermilab, gaining a direct link to the international collaboration behind the data they had just analysed. The masterclass closed with certificates, warm farewells, and a group photo that captured the energy and enthusiasm of the day.

This year’s masterclass was made possible thanks to the dedication of our volunteers: Ansh Bhatnagar, Pablo Candela, Arturo de Giorgi, Deppy Dimakou, Zara Graham-Jones, Daniel Maitre, Aidin Masouminia, Ivan Martinez-Soler, Ery McPartland, Dhruv Pasari, and Malina Rosca. Their support created an inspiring environment that students will remember long after.

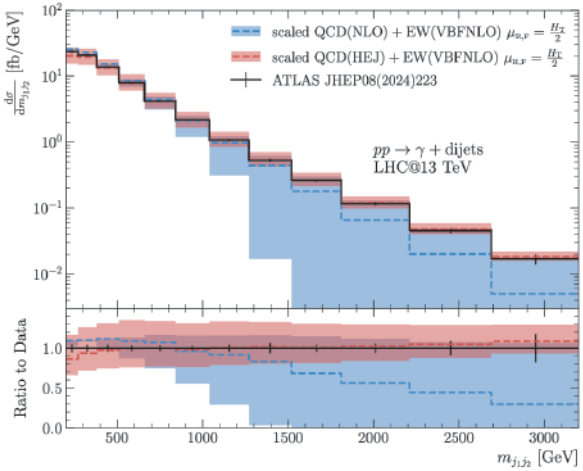
Once again, the International Masterclass showcased the joy of discovery, the power of collaboration, and the excitement of fresh beginnings. Plans are already underway for the 2026 edition.

RESEARCH HIGHLIGHT:

ACCURATE PREDICTIONS FOR LHC PROCESSES AT THE HIGHEST PARTONIC ENERGIES

Two recent papers by ATLAS analysing data collected at the highest collision energies at the LHC have highlighted the necessity of developing methods to systematically tackle the intricate behaviour of large logarithmic corrections in the perturbative series to all orders in the perturbative coupling in order for predictions to be accurate and useful in developing the understanding of the underlying theory describing the collisions. Specifically, the analysis of the processes of the production of at least two jets (pp -> jj [1]) and the production of a hard photon or an electroweak vector boson in association with at least two jets (pp -> γ,Z,W +jj [2]) all indicate systematic deviations from data with increasing partonic collision energy for e.g. fixed order perturbative predictions. Perturbative predictions taking into account the source of the large logarithmic corrections at high energies on the other hand obtain stable predictions in agreement with data [2,3].

Stable predictions at high energies are required in order to utilise data to study directly e.g. the coupling of the Higgs boson to the electroweak gauge bosons. While the high energy logarithmic corrections to the perturbative series have been studied for some time, this is the first conclusive demonstration of the need for their inclusion in standard analyses at the LHC. The accurate predictions from the team at the IPPP allow for investigation of data for effects of physics beyond the Standard Model. The data had hitherto been discarded in such analyses, because the Standard Model prediction was too poor.



[1] https://arxiv.org/abs/2405.20206
[2] https://arxiv.org/abs/2403.02793
[3] https://arxiv.org/abs/2506.17438

RESEARCH HIGHLIGHT:

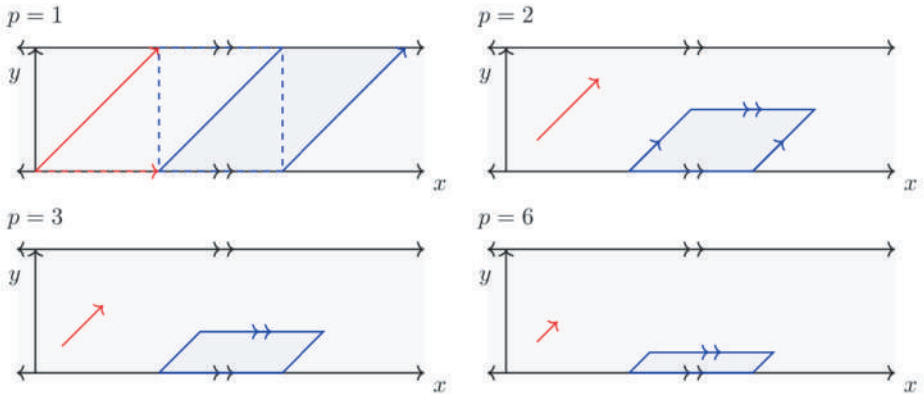
CHARGE QUANTISATION AND THE STANDARD MODEL GROUP

What is the fundamental quantum of charge? Quantum mechanics gave substance and rigour to the millennia-old idea that matter is made of indivisible elemental components and extended it to light. Each particle we distinguish from others by its fundamental properties: mass and charge. Ratios of known masses span a broad range of real numbers but for charge one finds that all values are an integer multiple of a fundamental unit.

These discrete values for charge arise from the fundamental symmetries of nature; with the charge-symmetry connection tracing back to the work of Emmy Noether. The full set of symmetry transformations forms a group and charge quantisation is related to trajectories in group space that circumnavigate it going back to the starting point. Modern science hence ties together charge quantisation, gauge theory and topology while the emerging field of generalised symmetries aims at an overall cohesive picture incorporating works from Dirac and 't Hooft alongside more recent results.

It is in this context that IPPP PhD students Despoina Dimakou and Yunji Ha together with staff members Rodrigo Alonso and Valentin Khoze explored the four possibilities for the gauge group of Nature (does it take n= 6, 3, 2 or 1 units of an elementary group-distance to circumnavigate it?). In their work in [1] they analysed the consequences of each choice for the particle spectrum and the grand or partial unification of each group, while proposing a new model for the unexplored n=6 case.

[1] https://arxiv.org/abs/2507.01777



Depiction of a toroidal subspace of each group as the plane with an equivalence relation set by the vectors in red. One has p=6/n

RESEARCH HIGHLIGHT:

HUNTING MAGNETIC MONOPOLES WITH FUTURE NEUTRINO DETECTORS

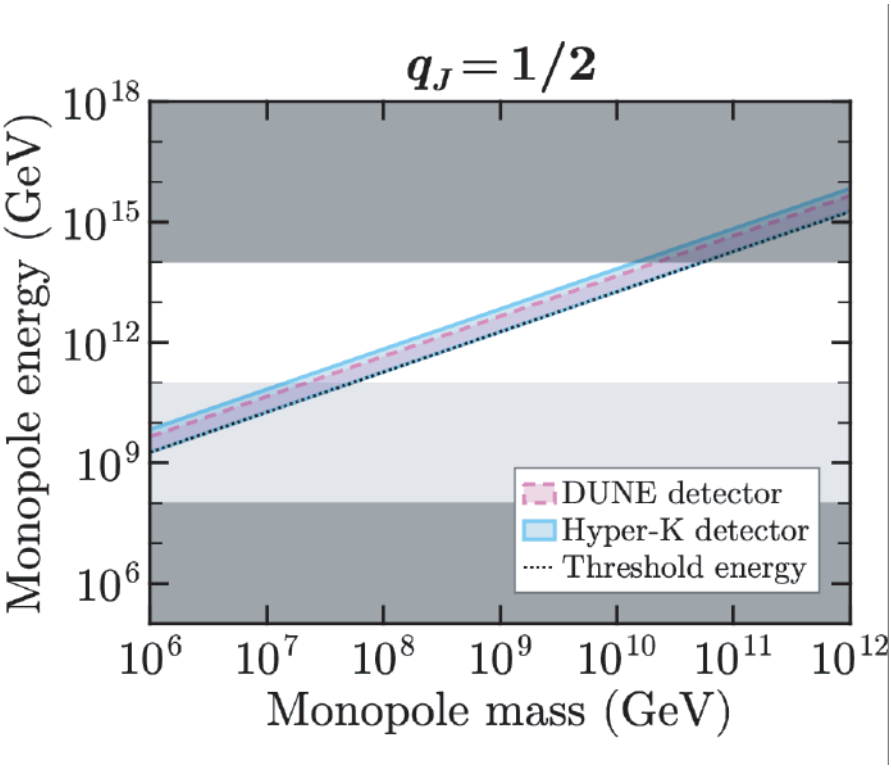
Dirac first introduced magnetic monopoles to explain why electric charge is quantised. They also arise naturally as topological relics in many grand unified theories (GUTs). Their discovery would provide deep insights into fundamental symmetries and the early Universe, but no experimental evidence has been found to date.

In recent work, Pablo Candela (IFIC, Valencia), Valya Khoze and Jessica Turner (IPPP, Durham) examined how the upcoming Deep Underground Neutrino Experiment (DUNE) in the United States and Hyper-Kamiokande in Japan can explore the parameter space of monopoles through Callan–Rubakov (CR) processes. These interactions, predicted since the 1980s, enable monopoles to induce baryon and lepton number violation, resulting in two primary experimental signatures: the production of high-energy antiprotons by relativistic monopoles and proton decay catalysis by non-relativistic monopoles.

The analysis shows that including interactions in the surrounding Earth's crust substantially increases the effective sensitivity of the detectors. For example, high-energy antiprotons produced in rock near the experimental volume can still be detected, enhancing the effective target mass by up to 238% for DUNE and 25% for Hyper-Kamiokande. This improved reach allows both experiments to test monopole fluxes below the astrophysical Parker bound, which is derived from the stability of galactic magnetic fields. For relativistic monopoles, the CR process is predicted to generate antiprotons with energies close to 900 GeV. Such events are well separated from the expected backgrounds of atmospheric neutrinos and cosmic muons, enabling a background-free analysis. The study maps the sensitivity of DUNE and Hyper-Kamiokande in the monopole mass–energy plane, identifying regions where each experiment can set limits an order of magnitude below the Parker bound. Hyper-Kamiokande can also detect the Cherenkov radiation emitted directly by relativistic monopoles traversing the water volume, providing an additional, independent signal.

For non-relativistic monopoles, the authors recast the expected proton decay sensitivities of DUNE and Hyper-Kamiokande. In this case, monopoles can catalyse rapid proton decay through CR interactions. Assuming benchmark values for the cross-section, Hyper-Kamiokande could exclude monopole fluxes down to 2.3×10^{-23} cm^{-2} s^{-1} sr^{-1}, while DUNE could reach 1.1×10^{-22} cm^{-2} s^{-1} sr^{-1}. These constraints extend several orders of magnitude beyond the Parker bound. Importantly, monopole-induced proton decay has distinct kinematics compared to GUT-mediated proton decay, with forward-going final states rather than back-to-back configurations, offering a potential way to distinguish between the two.

Overall, this work highlights how DUNE and Hyper-Kamiokande, while primarily designed for neutrino oscillation physics, will also be sensitive to magnetic monopoles across a wide range of masses and velocities. Their large fiducial volumes and extended running times provide an opportunity to improve existing limits and to explore unexplored regions of monopole parameter space.



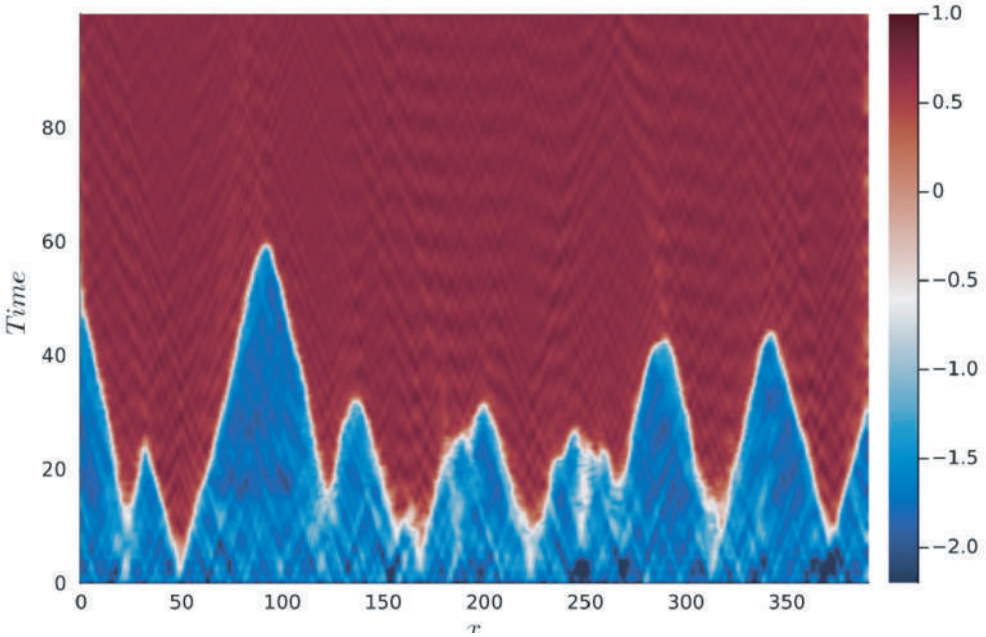
Reference: arXiv:2504.14918

RESEARCH HIGHLIGHT:

QUMODE TENSOR NETWORKS FOR FALSE VACUUM DECAY IN QUANTUM FIELD THEORY

False vacuum decay in quantum field theory (QFT) plays a central role in cosmology and particle physics. Most work in this area has relied on semi-classical approximations such as the famous Callan-Coleman treatment, but it has remained intractable for classical simulation due to its non-perturbative, highly entangled dynamics. In recent work Steve Abel, Michael Spannowsky and Simon Williams discovered a novel method for Hamiltonian simulation of false-vacuum decay in self-interacting scalar field theories, based on a spatial discretisation into a lattice of bosonic local modes called “qumodes”. The framework is ideal for realisation on continuous-variable quantum computers, but it can also be used on present day Tensor networks. This work demonstrated that the real-time dynamics of scalar fields can be captured including the complicated non-perturbative dynamics associated with false vacuum decay. Furthermore the method also works in curved gravitational backgrounds, making it ideal for studies of the false vacuum decay in cosmological settings.

Reference: arXiv:2506.17388



Simulation of vacuum decay in 1+1D scalar QFT.