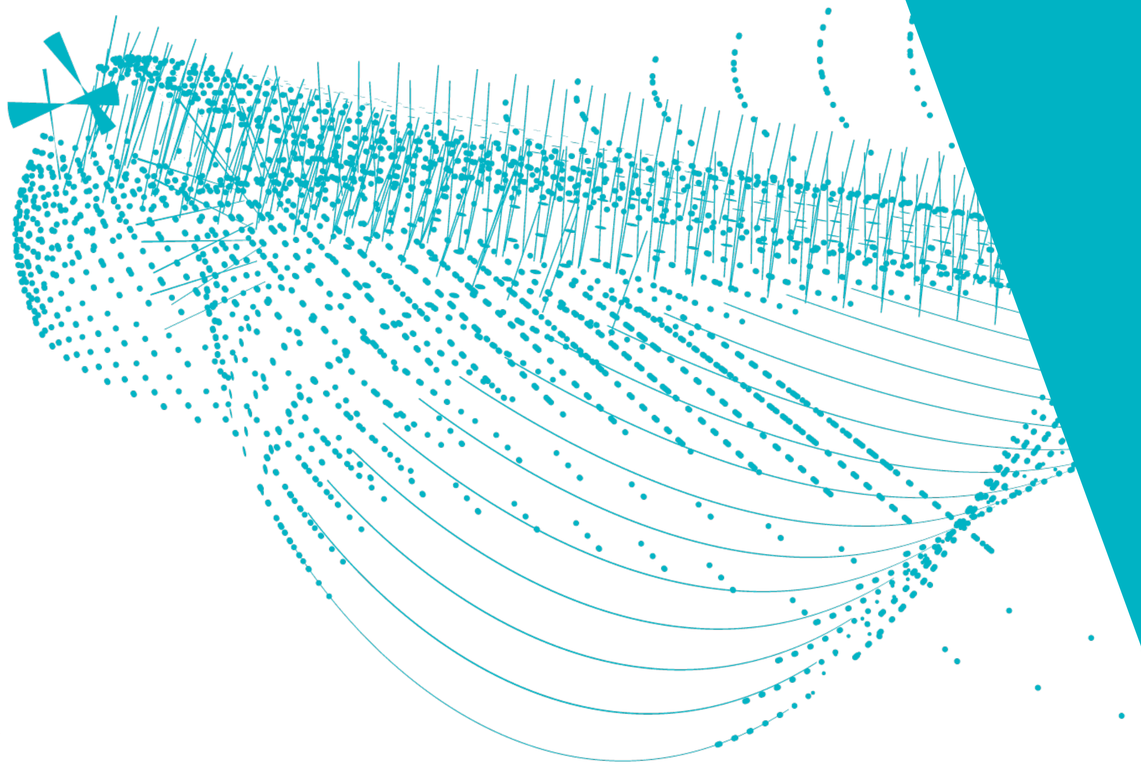
Nikhef



SAC MEETING, AMSTERDAM, 5 JUNE 2025

NIKHEF THEORY

Robert Fleischer

DUTCH THEORETICAL PARTICLE PHYSICS

- Amsterdam: Nikhef, VU, UvA
- Nijmegen: Radboud Universiteit
- Groningen: Rijksuniversiteit
- Utrecht: Universiteit Utrecht
- Leiden: Universiteit Leiden
- Maastricht: Maastricht University

Nikhef Theory Groups

- Large and diverse community:

Mathematical physics,
string theory, cosmology, …

[No theoretical particle physics at Technical Universities]

NIKHEF THEORY GROUP

- Serves as a national centre for particle physics theory and phenomenology.
- Broad spectrum of research topics:
  - QCD and collider physics, proton structure
  - Flavour physics, New Physics, effective field theories
  - Dark matter, cosmology, gravitational waves, …
- Close interactions with the experimental programs and University partners of Nikhef.
- A'dam: 7 staff (3 NWO-I), 9 PD, 9 PhD, 13 MSc

NIKHEF THEORY GROUP WEBSITE:

Nikhef Theory

PEOPLE RESEARCH ACTIVITIES OUTREACH SOFTWARE COMPUTING FOR STUDENTS VACANCIES CONTACT

ZOEKEN

Theoretical physics at Nikhef

Welcome to the website of the Theory Group of Nikhef! Here you will find information about who we are, what are our research interests, how to contact us, as well as related information which would be useful for bachelor and

Instagram

NWO SEP EVALUATION

Evaluation 2017 - 2022

NWO Institute and partnership Nikhef

Excerpt from the committee report:

Supports our excellent international reputation.

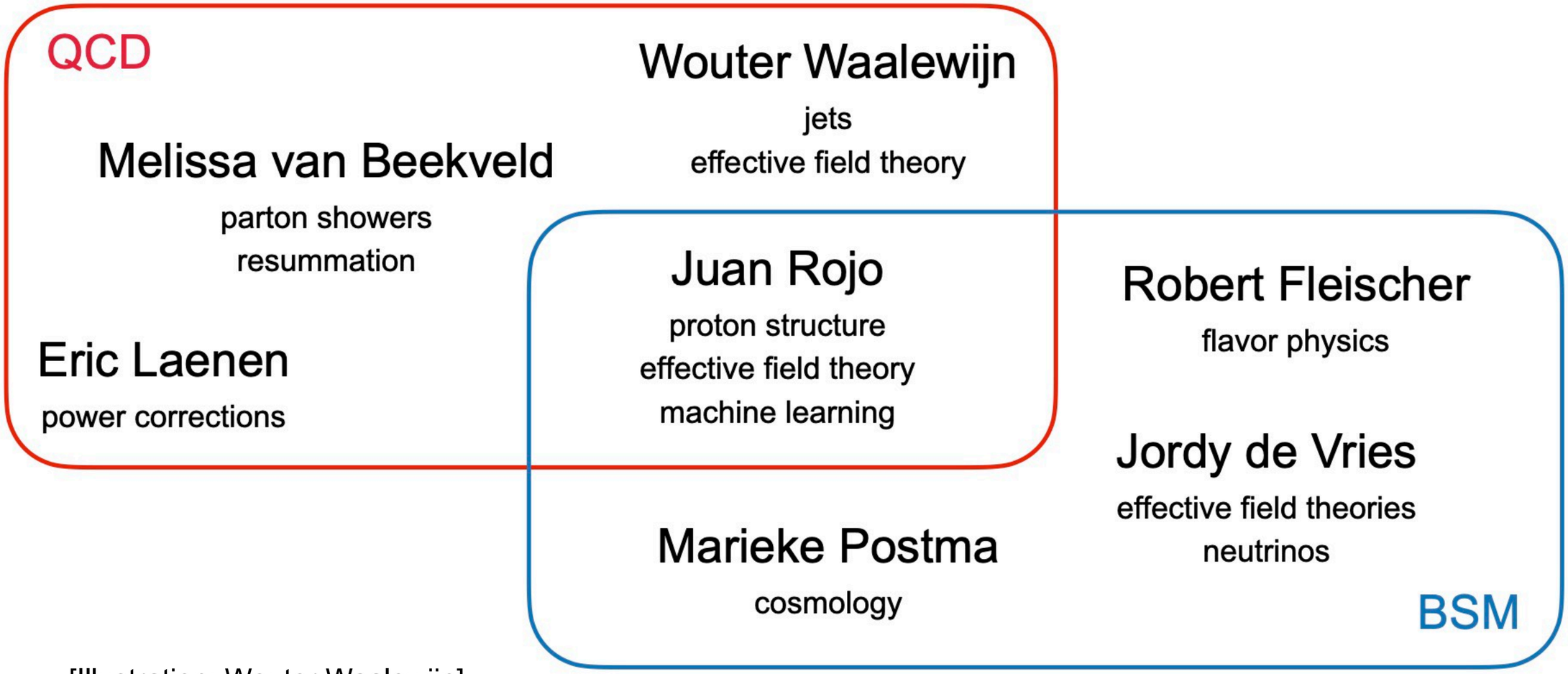
5.7. Theory

The activity of the theory group at Nikhef has covered a very broad canvas and involved all the frontline areas in the theoretical investigations in particle and astroparticle physics. Important contributions have been made towards all the goals listed for the period 2017-2022. In particular, Nikhef has been the world leader in the subject of development of theoretical techniques and tools in the subject of precision calculation required for the precision measurements at the LHC(HL-LHC) as well as at the high intensity facilities. These are essential for the exploitation of the full LHC(HL-LHC) data to its complete potential and at the current/future high intensity facilities. The QCD studies have also involved explorations of the parton structure of the proton, again an essential ingredient to a reliable analysis of the wealth of the data from hadronic colliders: current and future LHC as well as the upcoming Electron Ion Collider.

The group members have made very significant contributions not just to the formalism of computing higher order QCD and QCD/EW corrections but also to the understanding of conceptual issues in the study of jets at colliders. All this, in the end, also allows more accurate and effective methods for using the data to study beyond standard model (BSM) physics at the LHC as well as at the future particle physics facilities such as the EIC in planning and those under consideration such as the FCC.

The contribution to studying the BSM physics is not just restricted to this aspect. Group members have developed methods for a global analysis of BSM physics using the entire gamut of low and high energy data. Phenomenology of sterile neutrinos, axion like particles as well lepton number violating processes, electroweak baryogenesis and DM physics are examples of BSM fields studied by the members. Very important contributions have been made to pursuing BSM in flavour physics (mainly in B physics) and some have been implemented in actual experimental searches by the experimental groups, most often in collaboration with the Nikhef theorists.

AMSTERDAM STAFF RESEARCH PROFILES



[Illustration: Wouter Waalewijn]

STAFF PORTFOLIO

R.F. [NWO-I (VU)]
Melissa van Beekveld [NWO-I]
Marieke Postma [NWO-I (RU)]

Eric Laenen [UvA, UU, Nikhef]
Juan Rojo [VU]
Jordy de Vries [UvA]
Wouter Waalewijn [UvA]

3 NWO-I positions

Affiliated Staff: [being sharpened…]

Wim Beenakker [RU]
Daniël Boer [RUG]
Béatrice Bonga [RU]
Gideon Koekoek [MU]
Wilke van der Schee [UU, CERN]
Keri Vos [MU]
Susanne Westhoff [RU]

(Most recent hires ~ 2023)

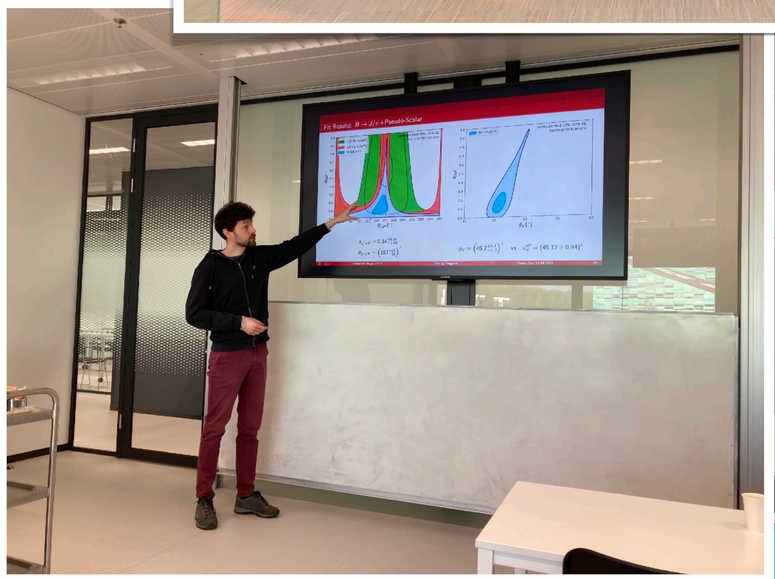
Additional NWO-I position cannot be filled in the foreseeable future (budget) …

Colleagues from Universities have many other non-Nikhef obligations.

“THEORY DAY” MEETINGS

- Mini Workshops to connect the Dutch phenomenology community.
- Include a student session without staff members being present.
- Recent meeting in Groningen, upcoming ones in Nijmegen and Maastricht (+ Nikhef).

Further strengthen our community networking…



BIGGEST INVESTMENT & KEY RESOURCE

Person power & talent: diverse group

- Flat hierarchy in the theory group, aim to develop people and their careers.
- We attract people from top institutes: CERN, MIT, Oxford, Zurich, …
- We are an attractive group for MSc students: typically 10-15 per year.
- Our PhDs & PDs succeed in pursuing careers in and outside academia.

RECENT PHD THESES / DEFENCES

Ruben Jaarsma [R.F, Mulders]

Eleftheria Malami [R.F, Merk]

Anders Rehult [R.F, Vos]

Jaco ter Hoeve [Rojo, Verkerke]

Giacomo Magni [Rojo, Senghi Soares]

Coenraad Marinissen [Laenen, Vonk]

VISITORS

- Visitors are a key element of our scientific culture and operations.
- Broad spectrum of visitors from junior to senior: seminars, discussions, projects,…
- Examples of recent longer-term visits:

  Herbert Dreiner (University of Bonn): colloquium on “entanglement” and “Physics Show” performance.

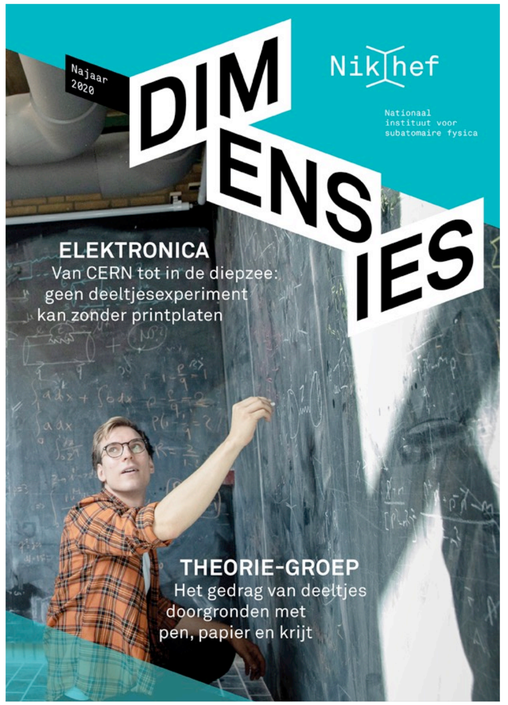
  Iain Stewart + postdocs (MIT): How strong is the strong force? [IoP colloquium @ Nikhef], …

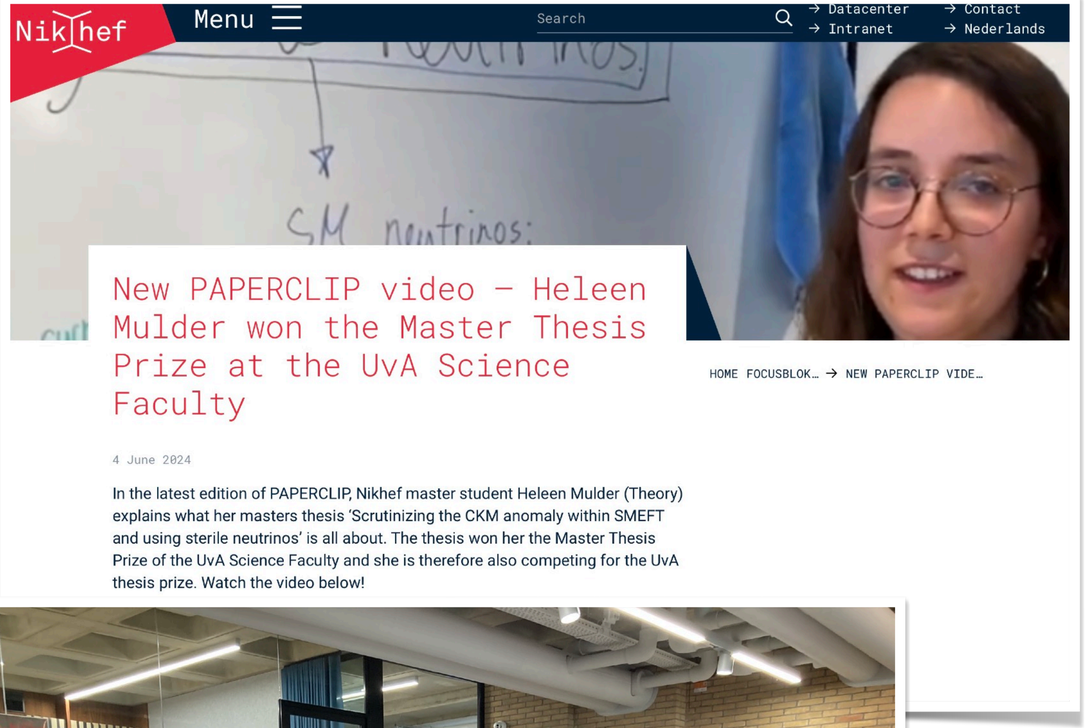
Utilise further to profile the Nikhef theory group…

OUTREACH

- Blogs
- Podcasts
- Paperclip videos
- Dimensies
- Nikhef tours
- (Open) Science Days

Links with the Nikhef Communications Group.





THEORY INVOLVEMENT IN THE ESPP UPDATE 2026

- Maria Laura Piscopo:
  Scientific Secretary of the Flavour Physics Working Group

- Eric Laenen:
  European Strategy Group

- Wouter Waalewijn:
  Activities @ Nikhef

FORM: DEVELOPMENT & PRESERVATION

[Jos Vermaseren]

Computer Algebra for Precision Calculations in Particle Physics: the FORM project

Contact persons: Jos Vermaseren, Eric Laenen, Joshua Davies, Thomas Gehrmann, Nigel Glover, Franz Herzog, Gudrun Heinrich, Andreas von Manteuffel, Sven Moch, Matthias Steinhauser, Lorenzo Tancredi, Takahiro Ueda

March 2025

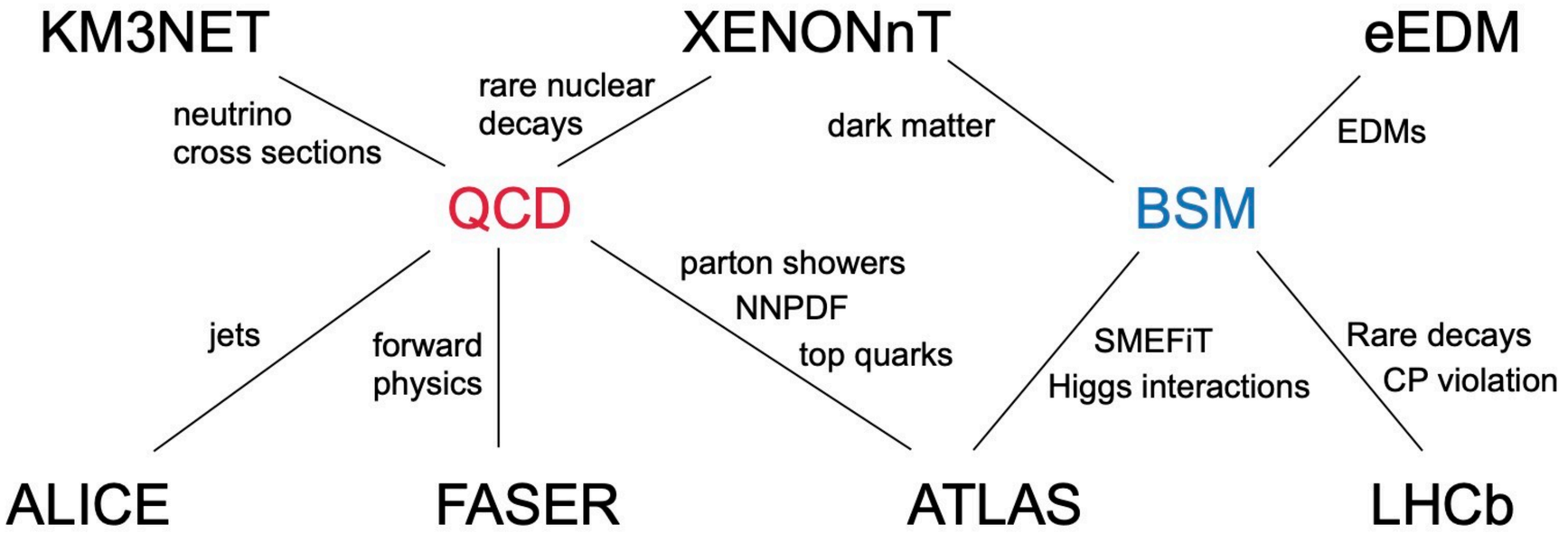
Abstract

Precision calculations in particle physics rely on computer algebra tools to manipulate and process the large-scale algebraic expressions that result from applying perturbation theory in the Standard Model. Commercial computer algebra packages are often insufficient to handle state-of-the-art problems. The FORM computer algebra system is a community-based effort overcoming these restrictions, which has been developed continuously and has enabled the vast majority of precision calculations up to now. This document discusses the current status and future objectives of computer algebra for particle physics, and outlines the needs required to accomplish them.

[Input document ESPP 2026 Update]

Get the community more involved: new postdoc (Coenraad Marinissen)

INTERACTION THEORY-EXPERIMENT



[Illustration: Wouter Waalewijn]

Aim to strengthen links with the gravitational waves programme.

“Theory Meets Experiment” Mini Workshop Series (W mass, KM3NeT, …)

Joint theory-experiment projects, shared students, joint papers, …

FUNDING:

Two main pillars:

- Base funding:
  - NWO-I: Nikhef mission budget
  - University consortium partners
- Grant applications:
  - NWO
  - ERC
  - NWA call “New types of symmetry”, +…
  - Encourace postdocs to apply with us as host:
    - Success: Veni (L. Graf), SNF (P. Klose)

RECENT GRANT SUCCESS

Melissa van Beekveld: Veni

Juan Rojo: SNF grant (with Anna Sfyrla, University of Geneva)

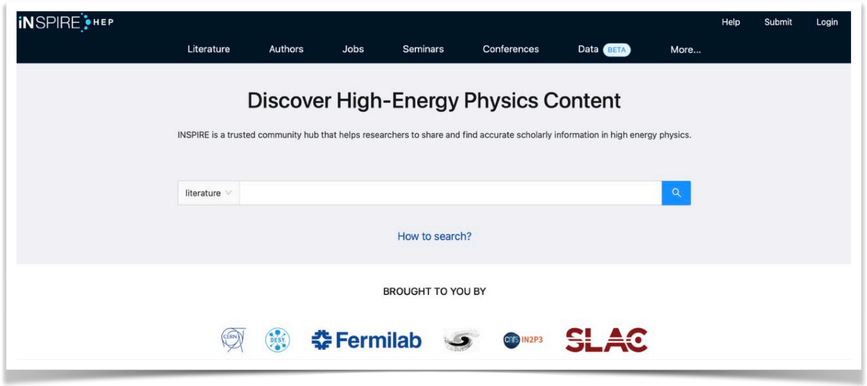
Jordy de Vries: ENW-M1

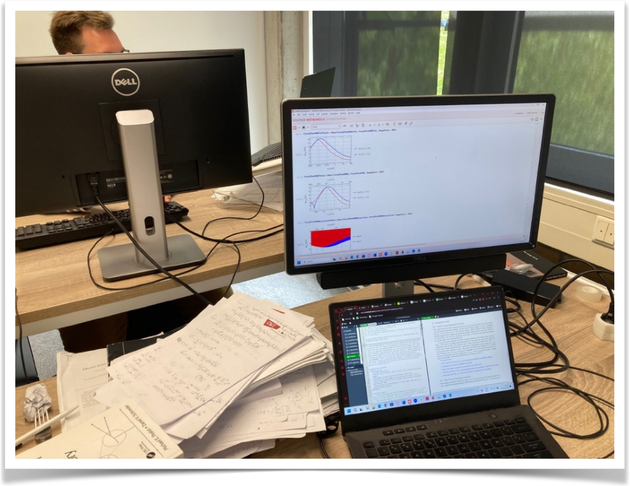
Marieke Postma: ENW-M1

Maria Laura Piscopo: Marie Curie (with CERN Theory)

RESULTS AND OUTPUT

- Scientific results:
  - Key output through publications, covering a wide spectrum of results at the forefront of our research lines (see backup slides for “snapshots”).
- Software and codes:
  - FORM (highest-order loop calculations)
  - NNPDF (parton distribution functions)
  - PanScales (parton showers for colliders)
  - SMEFiT (toolbox for SMEFT analyses) + …
- Societal impact: knowledge + training of talent.





FUTURE PLANS AND AMBITIONS

- Moving forward with world class research.
- Strengthen our role as national centre for particle physics theory.
- Strengthen visitor program.
- Community support of FORM.
- Grant applications (NWO ENW-XL, …).
- Explore new opportunities: AI/ML initiative + …
- R.F. program leader since 2018: succession.

A rich theoretical particle physics program will be crucial.

BACKUP SLIDES

“SNAPSHOTS” OF RESEARCH (I)

[hep-ph] 13 Mar 2025

Next-to-leading power jet functions in the small-mass limit in QED

Robin van Bijleveld,[a] **Eric Laenen,**[a,b,c] **Coenraad Marinissen,**[a,b] **Leonardo Vernazza**[d] **and Guoxing Wang**[e]

[a] *Nikhef, Theory Group, Science Park 105, 1098 XG, Amsterdam, The Netherlands*
[b] *IoP/ITFA, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands*
[c] *ITF, Utrecht University, Leuvenlaan 4, 3584 CE Utrecht, The Netherlands*
[d] *INFN, Sezione di Torino, Via P. Giuria 1, I-10125 Torino, Italy*
[e] *Laboratoire de Physique Théorique et Hautes Energies (LPTHE), UMR 7589, Sorbonne Université et CNRS, 4 place Jussieu, 75252 Paris Cedex 05, France*

21 Oct 2024

New Angles on Energy Correlators

Samuel Alipour-fard,[1,*] Ankita Budhraja,[2,†] Jesse Thaler,[1,‡] and Wouter J. Waalewijn[2,3,§]

[1] *Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[2] *Nikhef, Theory Group, Science Park 105, 1098 XG, Amsterdam, The Netherlands*
[3] *Institute for Theoretical Physics Amsterdam and Delta Institute for Theoretical Physics, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands*

Energy correlators have recently come to the forefront of jet substructure studies at colliders due to their remarkable properties: they naturally separate physics at different scales, are robust to contamination from soft radiation, and offer a direct connection with quantum field theory. The current parametrization used for energy correlators, however, is based on redundant pairwise angles with complex phase space restrictions. In this Letter, we introduce a new parametrization of energy correlators that features a simpler phase space structure and preserves information about the orientation of jet constituents. Further, our parametrization drastically reduces the computational cost to compute energy correlators on experimental data; whereas the time to compute a traditional projected N-point energy correlator scales as $M^N/N!$ on a jet with M particles, our new parametrization achieves a scaling of $M^2 \ln M$ independently of N. Theoretical calculations for our new energy correlators differ from those of traditional parametrizations only at next-to-next-to-leading logarithmic accuracy and beyond, and we expect that our simpler phase space structure will simplify those calculations. We also discuss how to extend our parametrization to resolved N-point energy correlators that encode angular distances between greater numbers of particles, and we propose two possible generalizations for probing multi-prong jets and testing jet scaling behaviour.

2025

MIT-CTP 5818, Nikhef 2024-020, DESY-25-034

Towards a Quantum Information Theory of Hadronization: Dihadron Fragmentation and Neutral Polarization in Heavy Baryons

Rebecca von Kuk,[1,*] Kyle Lee,[2,†] Johannes K. L. Michel,[3,4,‡] and Zhiquan Sun[2,§]

[1] *Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg, Germany*
[2] *Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[3] *Institute for Theoretical Physics Amsterdam and Delta Institute for Theoretical Physics, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands*
[4] *Nikhef, Theory Group, Science Park 105, 1098 XG, Amsterdam, The Netherlands*

(Dated: March 28, 2025)

We pioneer the application of quantum information theory to experimentally distinguish between classes of hadronization models. We adapt the CHSH inequality to the fragmentation of a single parton to hadron pairs, a violation of which would rule out classical dynamics of hadronization altogether. Furthermore, we apply and extend the theory of quantum contextuality and local quantum systems to the neutral polarization of a single spin-1 hadronic system, namely the light constituents of excited Sigma baryons $\Sigma^*_{c,b}$ formed in the fragmentation of heavy quarks.

2024

A collinear shower algorithm for NSL non-singlet fragmentation

Melissa van Beekveld,[a] **Mrinal Dasgupta,**[b] **Basem Kamal El-Menoufi,**[c] **Jack Helliwell,**[d] **Pier Francesco Monni,**[e] **Gavin P. Salam**[d,f]

[a] *Nikhef, Theory Group, Science Park 105, 1098 XG, Amsterdam, The Netherlands*

“SNAPSHOTS” OF RESEARCH (II)

The Higgs trilinear coupling in the SMEFT at the HL-LHC and the FCC-ee

Jaco ter Hoeve,[1] Luca Mantani,[2] Juan Rojo,[3,4] Alejo N. Rossia,[5] and Eleni Vryonidou[6]

[1] *The Higgs Centre for Theoretical Physics, University of Edinburgh, Mayfield Road, Edinburgh EH9 3JZ, United Kingdom*
[2] *Instituto de Fisica Corpuscular (IFIC), Universidad de Valencia-CSIC, E-46980 Valencia, Spain*
[3] *Department of Physics and Astronomy, VU Amsterdam, De Boelelaan 1081, NL-1081, HV Amsterdam, The Netherlands*
[4] *Nikhef, Science Park 105, NL-1098 XG Amsterdam, The Netherlands*
[5] *Dipartimento di Fisica e Astronomia "G. Galilei",*

Nikhef 2024-012
CERN-TH-2024-111

A Phenomenological Analysis of LHC Neutrino Scattering at NLO Accuracy Matched to Parton Showers

Melissa van Beekveld[1], Silvia Ferrario Ravasio[2], Eva Groenendijk[1], Peter Krack[1,3], Juan Rojo[1,3], and Valentina Schütze Sánchez[1]

[1] *Nikhef Theory Group, Science Park 105, 1098 XG Amsterdam, The Netherlands*
[2] *Theoretical Physics Department, CERN, Esplanade des Particules 1, Meyrin, Switzerland*
[3] *Department of Physics and Astronomy, Vrije Universiteit, NL-1081 HV Amsterdam*

hj 8 Apr 2025

Nikhef 2025-002
Edinburgh 2024/10
CERN-TH-2024-16

Parton distributions confront LHC Run II data: a quantitative appraisal

Amedeo Chiefa[1], Mark N. Costantini[2], Juan Cruz-Martinez[3], Emanuele R. Nocera[4], Tanjona R. Rabemananjara[5,6], Juan Rojo[5,6], Tanishq Sharma[4,5,6], Roy Stegeman[1], and Maria Ubiali[2]

24

Probing the QCD $\bar{\theta}$ term with paramagnetic molecules

Heleen Mulder[a,b], Rob Timmermans[a,b], and Jordy de Vries[a,c]

[a] Nikhef, National Institute for Subatomic Physics, The Netherlands
[b] Van Swinderen Institute for Particle Physics and Gravity, University of Groningen, The Netherlands
[c] Institute of Physics and Delta Institute for Theoretical Physics, University of Amsterdam, The Netherlands

eb 2025

TUM-HEP-1545/24, P3H-24-101, SI-HEP-2024-31, TTP24-046, Nikhef 2024-019, ZU-TH 67/24

Total decay rates of B mesons at NNLO-QCD

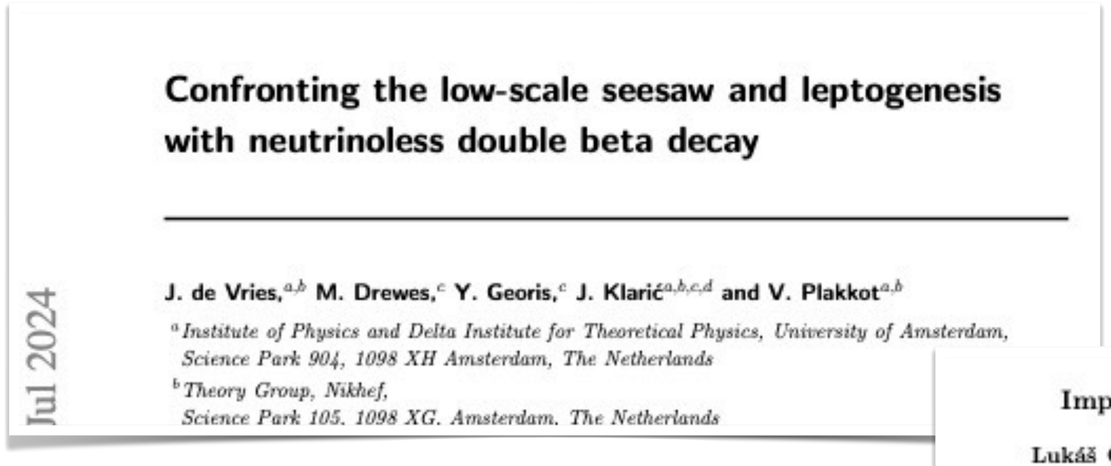
Manuel Egner,[a] Matteo Fael,[b,c] Alexander Lenz,[d] Maria Laura Piscopo,[d,e,f] Aleksey V. Rusov,[d,g] Kay Schönwald,[h] Matthias Steinhauser[a]

Probing light sterile neutrinos in left-right symmetric models with displaced vertices and neutrinoless double beta decay

2025

Jordy de Vries,[a,b] Herbi K. Dreiner,[c] Jelle Groot,[a,b] Julian Y. Günther,[c] Zeren Simon Wang[d]

“SNAPSHOTS” OF RESEARCH (III)



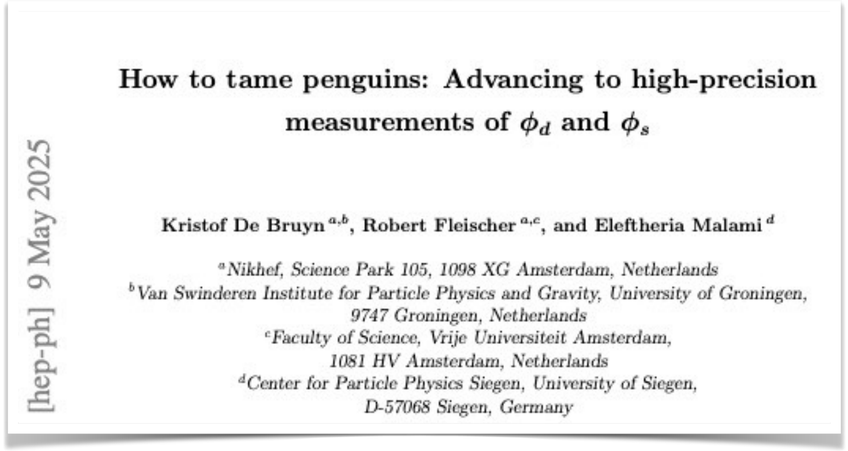
Jul 2024

Confronting the low-scale seesaw and leptogenesis with neutrinoless double beta decay

J. de Vries,[a,b] M. Drewes,[c] Y. Georis,[c] J. Klarić[a,b,c,d] and V. Plakkot[a,b]

[a] *Institute of Physics and Delta Institute for Theoretical Physics, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands*

[b] *Theory Group, Nikhef, Science Park 105, 1098 XG, Amsterdam, The Netherlands*

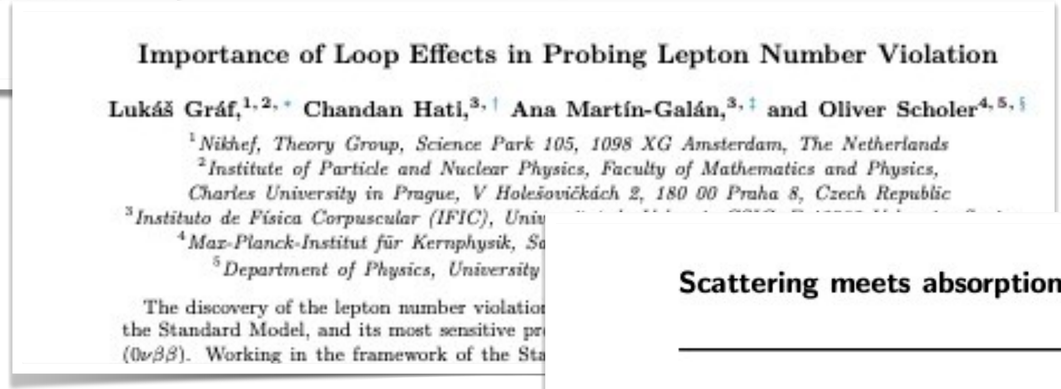


[hep-ph] 9 May 2025

How to tame penguins: Advancing to high-precision measurements of ϕ_d and ϕ_s

Kristof De Bruyn [a,b], Robert Fleischer [a,c], and Eleftheria Malami [d]

[a] *Nikhef, Science Park 105, 1098 XG Amsterdam, Netherlands*
[b] *Van Swinderen Institute for Particle Physics and Gravity, University of Groningen, 9747 Groningen, Netherlands*
[c] *Faculty of Science, Vrije Universiteit Amsterdam, 1081 HV Amsterdam, Netherlands*
[d] *Center for Particle Physics Siegen, University of Siegen, D-57068 Siegen, Germany*

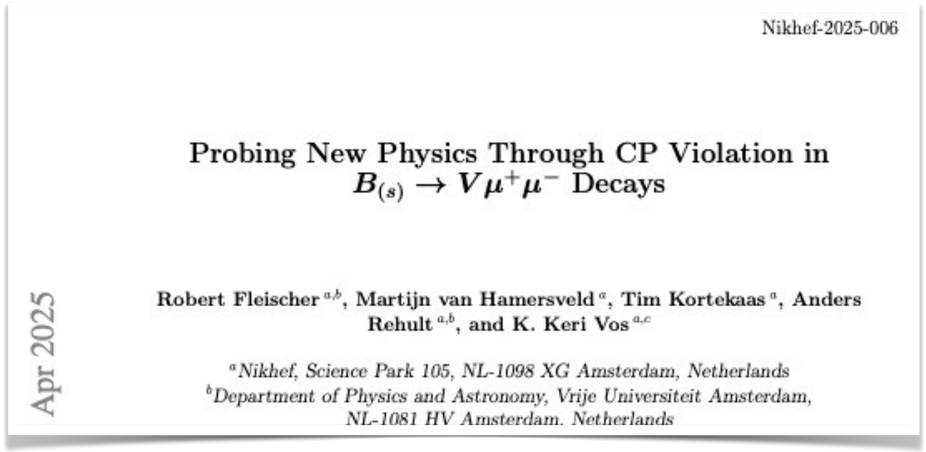


Importance of Loop Effects in Probing Lepton Number Violation

Lukáš Gráf,[1,2,*] Chandan Hati,[3,†] Ana Martín-Galán,[3,‡] and Oliver Scholer[4,5,§]

[1] *Nikhef, Theory Group, Science Park 105, 1098 XG Amsterdam, The Netherlands*
[2] *Institute of Particle and Nuclear Physics, Faculty of Mathematics and Physics, Charles University in Prague, V Holešovičkách 2, 180 00 Praha 8, Czech Republic*
[3] *Instituto de Física Corpuscular (IFIC), Univ*
[4] *Max-Planck-Institut für Kernphysik, Sa*
[5] *Department of Physics, University*

The discovery of the lepton number violatio
the Standard Model, and its most sensitive pr
($0\nu\beta\beta$). Working in the framework of the Sta



Nikhef-2025-006

Apr 2025

Probing New Physics Through CP Violation in $B_{(s)} \to V\mu^+\mu^-$ Decays

Robert Fleischer [a,b], Martijn van Hamersveld [a], Tim Kortekaas [a], Anders Rehult [a,b], and K. Keri Vos [a,c]

[a] *Nikhef, Science Park 105, NL-1098 XG Amsterdam, Netherlands*
[b] *Department of Physics and Astronomy, Vrije Universiteit Amsterdam, NL-1081 HV Amsterdam, Netherlands*

6 Jan 2025

Scattering meets absorption in dark matter detection

Pieter Braat,[1,2] Anh Vu Phan,[1,3] Marieke Postma,[1,3] and Susanne Westhoff [1,3]

[1] *Nikhef, Science Park 105, 1098 XG Amsterdam, The Netherlands*
[2] *Institute of Physics, University of Amsterdam, Science Park 904, 1098 XH Amsterdam, The Netherlands*
[3] *Institute for Mathematics, Astrophysics and Particle Physics, Radboud University, 6500 GL Nijmegen, The Netherlands*

+ many more papers and results …