

RTG3186

New SM

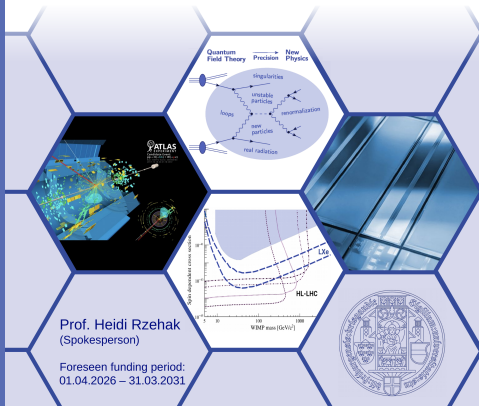
Looking for signposts towards the New Standard Model of particle physics

Heidi Rzehak

New SM

Looking for signposts towards the
New Standard Model of particle physics

Proposal for a DFG Research Training Group

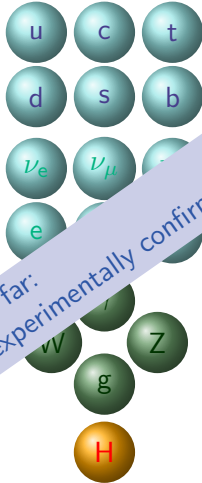


Prof. Heidi Rzehak
(Spokesperson)

Foreseen funding period:
01.04.2026 – 31.03.2031

Status of particle physics

Standard Model (SM):



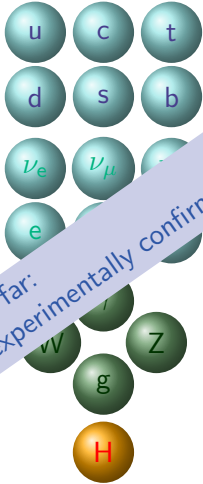
Open questions:

Examples:

- Dark Matter?
- Matter–antimatter asymmetry in the Universe?
- Nature of neutrinos?
- Flavour structure?

Status of particle physics

Standard Model (SM)



So far:
experimentally confirmed

How
do both sides
fit together?

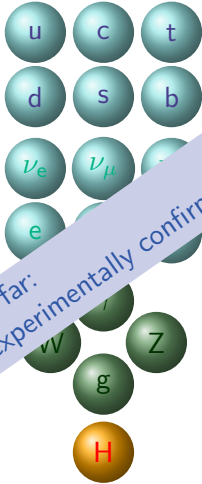
⇒ Extensions of the
Standard Model?

⇒ Search broadly
for signposts
towards new physics

matter asymmetry
reverse?
neutrinos?
structure?

Status of particle physics

Standard Model (SM)



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fit together?

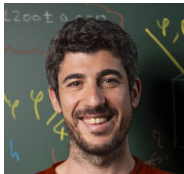
⇒ Extensions of the
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⇒ RTG 3186

Principal investigators

JProf. Dr.
Simone Biondini



Theo. astro-
particle physics

Prof. Dr.
Stefan Dittmaier



Theo. particle
physics (SM)

Prof. Dr.
Heidi Rzehak



Theo. particle
physics (BSM)

Prof. Dr.
Marco Gersabeck



Exp. particle
physics (LHCb)

Prof. Dr.
Karl Jakobs



Exp. particle
physics (ATLAS)

JProf. Dr.
Brian Moser



ATLAS & future
 e^+e^- colliders

Dr.
Ulrich Parzefall



Detector
development

Dr.
Eva Gersabeck



Exp. particle
physics (LHCb)

Prof. Dr.
Markus Schumacher



ATLAS & e^+e^-
colliders, computing

Prof. Dr.
Marc Schumann



Exp. astro-
particle physics

Research project:

Open questions:

Electroweak symmetry breaking?

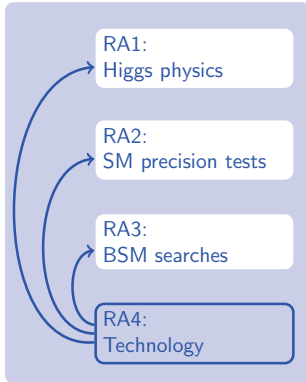
Matter–antimatter asymmetry in the Universe?

Order in particle spectrum?

Nature of neutrinos?

Dark Matter?

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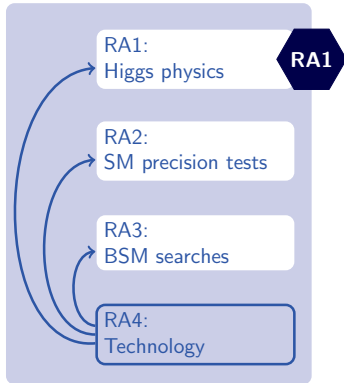
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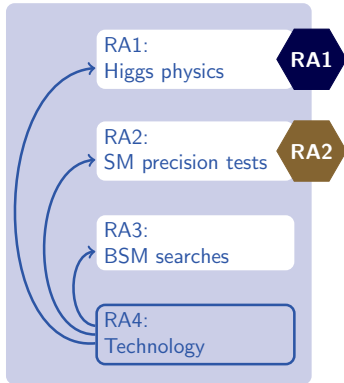
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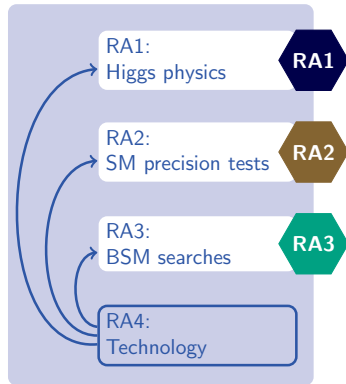
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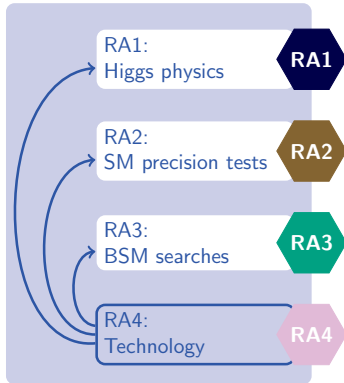
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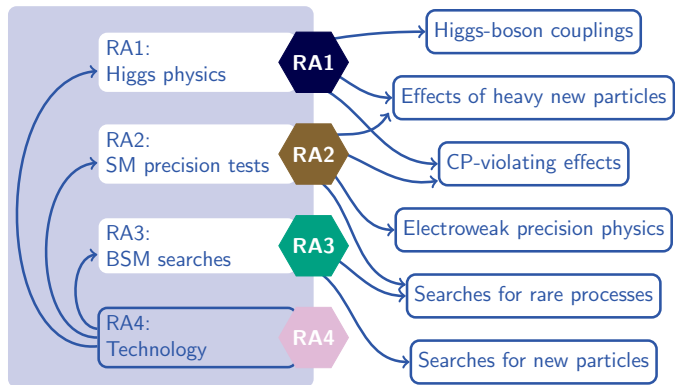
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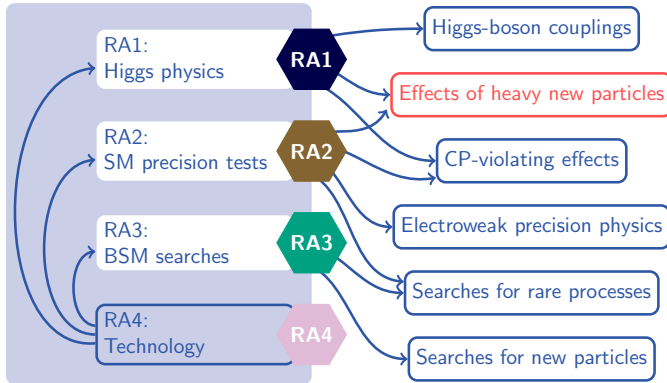
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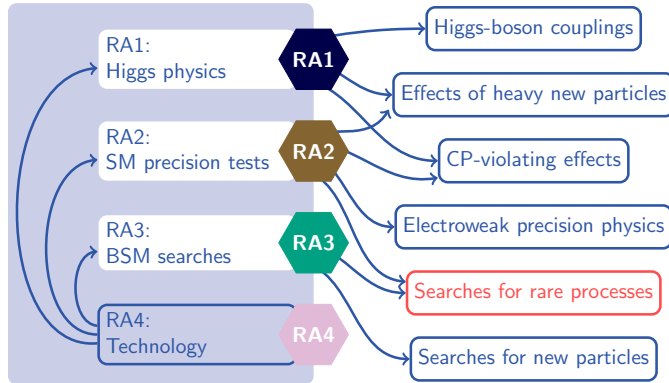
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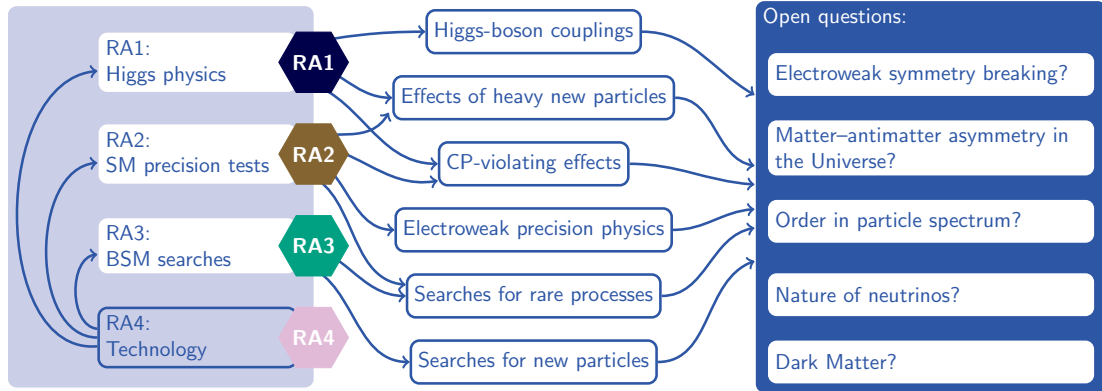
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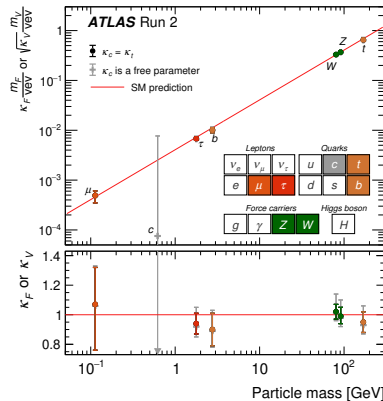


Research project:



Higgs boson couplings to SM particles

- Focus on $H \rightarrow WW^*$, $H \rightarrow \tau\tau$ and measure differential observables at ATLAS for comparison with theory
- New-physics effects captured in matching coefficients of Effective Field Theories
→ also relevant for FCCee
- Benchmark specific SM extensions
→ also relevant for FCCee



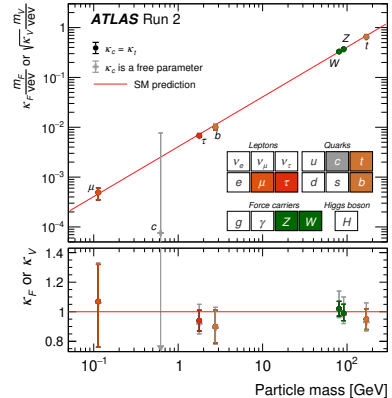
Nature 607 52 (2022)

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CP structure

- e.g. $(c_{H\tilde{W}} v/\Lambda) H W^{\mu\nu} \tilde{W}_{\mu\nu}$, $g_{H\tau\tau}(\cos\phi_{CP} + i\gamma_5 \sin\phi_{CP})H\bar{f}f$
- Develop data analyses based on machine learning
- Benchmark models with additional source of CP-violation
→ also relevant for FCCee

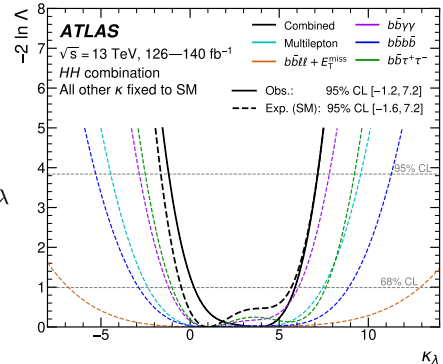


Nature 607 52 (2022)

Higgs self coupling

- $\lambda = m_H^2/(2v^2)$ shapes the Higgs potential
- $HH \rightarrow b\bar{b}\tau\tau$
evidence at LHC followed by measurement at HL-LHC
- Identify new-physics models that introduce modifications to λ
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Phys. Rev. Lett. 133 (2024)



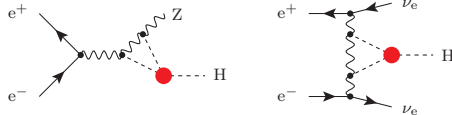
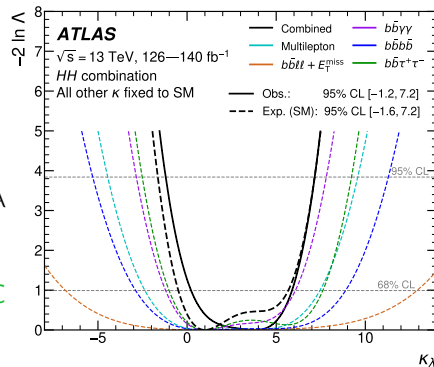
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Higgs Physics at future colliders → relevant for FCC

- $H \rightarrow c\bar{c}, H \rightarrow s\bar{s}$
- Improve on λ and CP-odd admixtures
- e^+e^- colliders require precision
→ pushing radiative corrections to the next level

Phys. Rev. Lett. 133 (2024)



Precision electroweak physics → relevant for FCCee

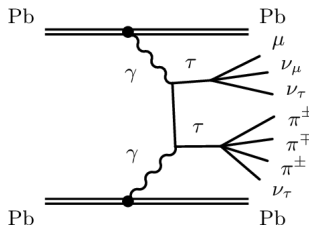
- HL-LHC and future colliders → significantly higher precision in theoretical predictions
- Include electroweak corrections to SM observables relevant to the HL-LHC :
W boson mass (also in BSM scenarios), electroweak interactions at high energies
- Extend capabilities of calculating electroweak boson production
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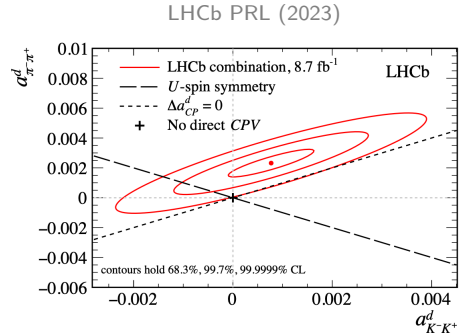
Electric and magnetic dipole moments

- Perform τ measurements at colliders to complement established μ measurements
- Exploit LHC potential
- Theory advances to increase precision and to address conceptual interpretation questions



Charm physics

- Discovery of CP violation in charm decays 2019
- Explore CP-violation in charm observables with precision
 - Measurements of multibody-charm decays at LHCb
 - Time-dependent analysis of D meson decays

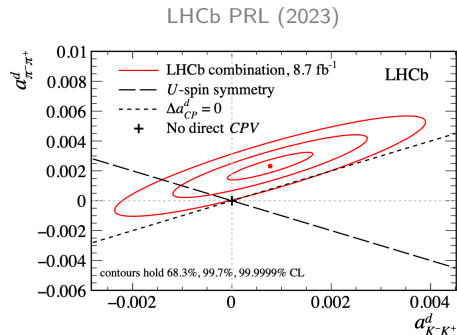


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B physics

- Largest CP asymmetries in the SM
- Work on “standard candles” as well as BSM sensitive measurements
- New approaches to elucidate patterns in existing tensions

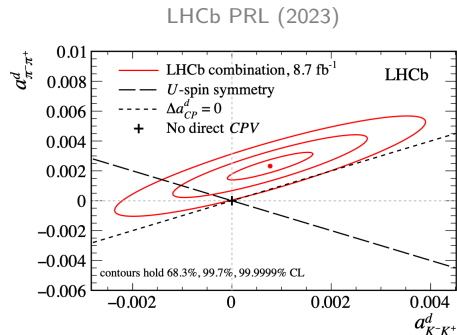


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 - New approaches to elucidate patterns in existing tensions
- Limited direct overlap but dedicated FCCee flavour studies are being considered.



Direct DM searches

- DM scattering off target atoms

$$\begin{cases} m_{\text{DM}} \gtrsim 3 \text{ GeV} \rightarrow \text{XENONnT, XLZD} \\ m_{\text{DM}} \lesssim 3 \text{ GeV} \rightarrow \text{DeLight} \end{cases}$$

- XLZD competitive for $0\nu\beta\beta$
→ **origin of neutrino masses**

Direct DM searches

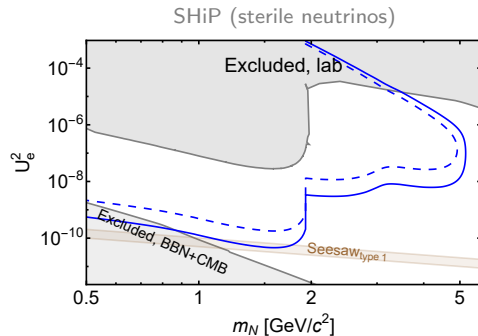
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Feebly Interacting Particles

- Light or heavy particles with $g_{\text{portal}} \ll 1$
- Beamdump experiments → SHiP
- Searches for axions, dark photon/scalar, sterile neutrinos



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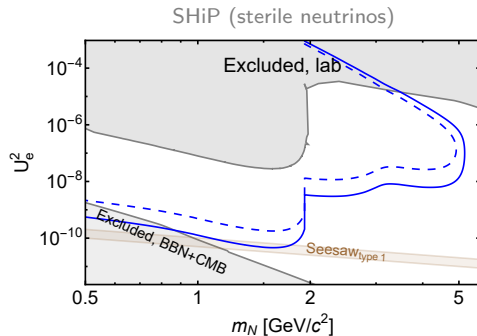
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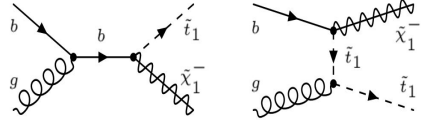
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→ **no direct overlap but implications?**



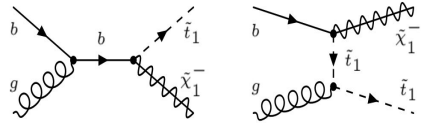
DM and new particles at the LHC

- Simplified DM models with and without SUSY
- DM + partner $\equiv$ dark sector
- Single- $\tilde{t}$ production and compressed spectrum, $m_{\text{DM}} \simeq m_{\tilde{t}}$



DM and new particles at the LHC

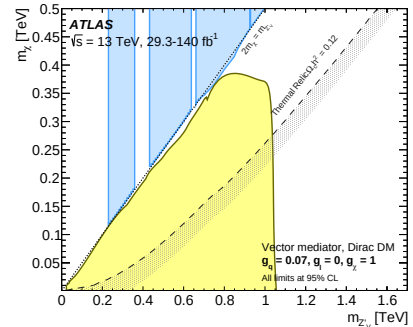
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DM and new particles in the early universe

- Robust predictions with QFT at finite temperature
 - freeze-out, freeze-in
 - leptogenesis, electroweak baryogenesis
- Interplay of cosmologically viable parameter space with experiments
 - **interplay might be relevant for FCCee**

Eur. Phys. J. C 84 (2024)



Development of

- silicon detectors
- low-background detectors
- Surround Background Tagger for the SHiP beamdump experiment
- the use of GPUs for triggering, detector alignment, and event simulation for LHCb
- federated computing infrastructures

→ Limited direct overlap with FCCee



Conclusion

- RTG3186: Broad search for signposts towards new physics:

Combining different experimental as well as theory activities

→ In large parts: Complementary to an FCCee theory initiative

- Some overlap between research topics of RTG3186 and FCCee theory initiative

→ Link between research efforts