

# POF V.

Finalization of MU-FPF topics and  
writing organization

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HELMHOLTZ



# PoF V Subtopic Structure and Science Drivers

Our science drivers address the big questions of nature: Understanding the quantum universe

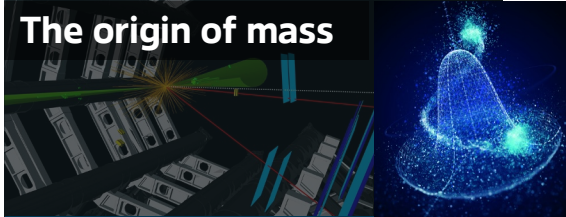
## Fundamental interactions



Pushing the limits of our understanding of fundamental interactions

- QCD (incl. lattice and QC)
- Electroweak (EW) precision and Higgs physics (HH and Higgs potential)
- Strong-field QED
- Searches for extensions of the SM (e.g. SUSY, additional gauge or Higgs bosons,...)
- Search for the unknown (aka anomaly detection)

## The origin of mass



Investigating the mass and the flavour puzzle, and the imbalance between matter and anti-matter

- Dynamics of EW symmetry breaking
- Top and B and Tau physics
- Higgs as portal to new physics
- Charge-parity violation
- Lepton flavor universality

## The early universe



Understanding the evolution of the early universe and the nature of the dark sector

- Cosmology (inflation, baryogenesis,...)
- Searches for dark matter candidates (incl. collider searches, Axions, ALPs,...)
- Gravitational waves
- EW phase transition

# Technicalities for writing the report

- **Total space: 14 pages:**
- **1 page introduction, 2.5 pages per subtopic for “challenges and objectives”**
  - One figure (or two side-by-side) per subtopic
- **1 page for future colliders and detector developments in FPF**
  - FCC, Linear Collider (Positron source), HALHF, MuonCollider (reference LDG acc. roadmap); reference to DRDs in MT
- **4 pages for sections on “competences and expertise” and “implementation”**
  - WPC should be here, together with ML and other tools, axion platform, cryo platform, ELBEX, DAF, management experience, DESY as national lab, excellence clusters (QU,CMF), ZMP (centre for mathematical physics), Terascale, QC (check with Friederike for MT)
  - Timeline and milestones needed
- **All on overleaf, we will work on a specific FPF copy [1]**
- **Currently all is in one file: 02MUT1.tex**
- **All writers should have received an invitation (contact me by email if you didn't get one)**
- **Internal deadline for first version: 15 August**

[1] <https://www.overleaf.com/project/684be62a1d9622a403db707e>

# Technicalities for writing the report

- **All writers should have received an invitation (contact me by email if you didn't get one)**
- **Our suggestion for splitting:**
  - Subtopic 1: Elisabetta (input for LUXE from Federico), Sasha, Georg, Cigdem (?), includes strings, QC (input needed from Stefan Kühn), Lattice (input from Stefan Schäfer)
  - Subtopic 2: Federico, Isabell, Kai/Georg, Sasha (as Belle 2 hat)
  - Subtopic 3: Kai, Axel, Isabell, Cigdem
- **Additional input:**
  - Thomas, Felix: on future colliders (extra section)
  - KIT-theory: a lot of synergies with DESY theory, needs to be incorporated as well (input from Felix K.)
  - 4 pages: Thomas
- **Cross connections:**
  - Friederike/Thomas/Felix: connections to MT/DMA + ML at the end in the last 4 pages
- **Some ideas for stories to tell:**
  - Introduction on vacuum stability and how to connect cosmology to Higgs and fundamental interactions physics
  - Connection from collider physics to cosmology and gravitational waves + precisions in fundamental interactions
  - PoF III was Higgs discovery, PoF IV precision coupling measurements, PoF V will be double Higgs
  - General introduction on lifetime competences and link to FC activities

# Forschungsziele von "Matter and the Universe" (MU)

from 04.12.2023

- Identifizierung der fundamentalen Teilchen und ihrer Wechselwirkungen sowie ein genaues Verständnis der Struktur des Vakuums.
- Verstehen der Struktur und Dynamik von Hadronen, Kernen und Kernmaterie und ihrer Rolle bei der astrophysikalischen Bildung chemischer Elemente.
- Verständnis der Natur der Dunklen Materie und der Dunklen Energie sowie des Universums bei hohen Energien.

## **Spezifische Ziele des Themas: "Grundlegende Teilchen und Kräfte":**

- Genaue Messungen der Eigenschaften des Higgs-Bosons werden am LHC/HL-LHC durchgeführt, ebenso wie hochpräzise Untersuchungen der elektroschwachen und starken Wechselwirkung am LHC/HL-LHC und an Belle II. Suche mit diesen Experimenten nach neuen Teilchen und Phänomenen, entweder durch direkte Beobachtung oder durch Abweichungen zwischen Theorie und Präzisionsmessungen.
- Suche nach Axionen und ähnlichen hypothetischen Teilchen mit dem ALPS II Experiment bei DESY. Darüber hinaus wird die technische und finanzielle Machbarkeit der möglichen Nachfolgeprojekte MADMAX und IAXO erarbeitet, die möglicherweise zu ersten Demonstratoren führen werden.
- Sie fördern das Verständnis der Kosmologie, beleuchten sozusagen die "dunkle Seite" des Universums und ergänzen die Aktivitäten der Astroteilchenphysik zum Thema "Materie und Strahlung aus dem Universum".



# Milestones from PoF IV

Table 1: Overview of milestones for the Topic MU-FPF.

Number	Year	Milestone
FPF-1	2021	First scientific results from the ALPS II experiment
FPF-2	2022	Interpretation of LHC results, electroweak precision measurements, and results from flavor physics in global fits
FPF-3	2022	First observation of four-top process by ATLAS/CMS; use of this channel for searches for new physics
FPF-4	2022	Reduction of the theoretical uncertainty for the mass of the SM-like Higgs in supersymmetric models to below 1 GeV
FPF-5	2022	Determination of cross sections for all accessible Higgs production and decay channels in the simplified template cross section framework
FPF-6	2023	Collection of 300 fb <sup>-1</sup> of high-quality LHC data with both ATLAS and CMS
FPF-7	2023	With approx. 10 ab <sup>-1</sup> of Belle II data, coverage of a new regime in coupling strength for dark photons and ALPs in the mass range of around 100 MeV – 10 GeV; factor 5–10 improvement on branching ratio limits on various LFV and LNV tau decay channels
FPF-8	2024	Extension of the discovery reach on dark matter at the LHC by a factor 3 to 5 (depending on the specific model) compared to present limits based on 2016 data, employing modern analysis methods such as machine learning
FPF-9	2024	Precise phenomenological predictions using perturbation theory (below 1% theory uncertainty) and lattice field theory (reduction of uncertainty by a factor of 2) for the strong coupling
FPF-10	2024	With approx. 15 ab <sup>-1</sup> of Belle II data, establishment of first combined fit results for $ V_{ub} $ and $m_b$ based on inclusive $B$ decays using improved theoretical predictions
FPF-11	2025	Completion of system-tested silicon tracker end-caps for ATLAS and CMS
FPF-12	2026	Increase of the precision of Higgs couplings determined from combined ATLAS/CMS data by a factor of 2 (compared to today) using high-precision theory predictions
FPF-13	2027	Collection of 50 ab <sup>-1</sup> with the Belle II experiment

# FH retreat on 21 July

## **Current information on the agenda:**

- Will need to present FPF strategy in 15-20 mins, with teaser on discussion session
- Main idea for discussion session: future experiment(s) – do we want to join any and if yes which one?

# Backup / further info



# Questions to be answered in the report

- **Brief description of challenges, scientific goals and strategic relevance, also in relation with research policy objectives and in the context of international developments.**
- **Key questions:**
  - How would you rate the objectives of the topic with regard to **scientific relevance and leadership**?
  - Which pressing societal or **scientific challenges** does it address?
  - How would you rate the topic's potential **impact** with regard to the research field, its technologies and its societal context?
  - How would you evaluate its **alignment with the research policy objectives** of the research field (and with the strategy of the program)?
  - Do you envision **further objectives** that the topic should consider addressing?

# Panel members nearly finalized

Norbert	<a href="#">Holtkamp</a>	SLAC, USA (Chair)
Klaus	<a href="#">Blaum</a>	MPG, Germany
Pascale	<a href="#">Ehrenfreund</a>	GWU, USA
Trevor	<a href="#">Forsyth</a>	LINXS, Sweden
Giovanna	<a href="#">Fragneto**</a>	ESS, Sweden
Rolf	Heuer	
Berthold	<a href="#">Schmidt</a>	TRUMF, Germany
Ora	<a href="#">Furman</a>	Hebrew University of Jerusalem, Israel
Patrizia	<a href="#">Rossi</a>	Jefferson Lab, USA
Christian	<a href="#">Rüegg</a>	PSI, Switzerland, Chair
Francesco	<a href="#">Sette</a>	ESRF, France
Daniel	<a href="#">Zajfman</a>	Weizmann, Israel

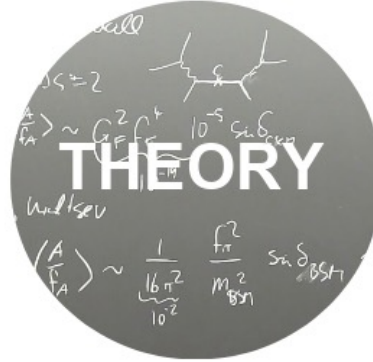
# Timeline for submission of the strategy report

- **21 July**  
Present first summary of the strategy (including inputs from retreat) at the FH retreat  
Collect further input during the retreat
- **Summer 2025 (~July, not yet defined further)**  
Definition of the "Startwerte" by the DESY directorate
- **15 August**  
Writing team to finalize input for first version for FPF and then circulation with FH internal reviewers
- **~September:**  
First version of the report should be ready
- **15 December 2025**  
Handing in of the report; then discussion in the MB, layout and proof-reading
- **17 March 2026**  
Final version to be handed in

Let's get started!

# Towards PoF V

Focus areas in MU-FPF (Fundamental Partices and Forces)



## Off-site experiments:

Key contributions (data analysis, commissioning and operation) to global projects at CERN and KEK:

- ATLAS and CMS
- Belle II

Engage in future collider decision and preparation

New detector project?

## Theory:

Establish the Wolfgang-Pauli Center as world-leading interdisciplinary center for theoretical physics

Idea factory for future science endeavours

## On-site experiments:

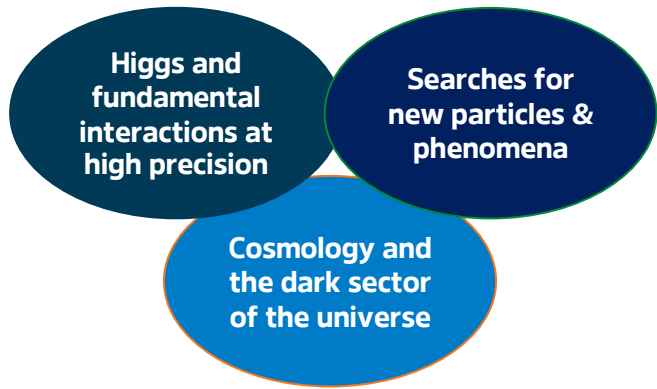
- Planned axion experiments: BabyIAXO, MADMAX
- QED at the extreme: LUXE

## New ideas:

- VMB @ ALPS II
- High-frequency GW experiments

# Changes from PoF IV to PoF V

Foreseen change / adaption of subtopic structure



Pushing the limits of our understanding of fundamental interactions

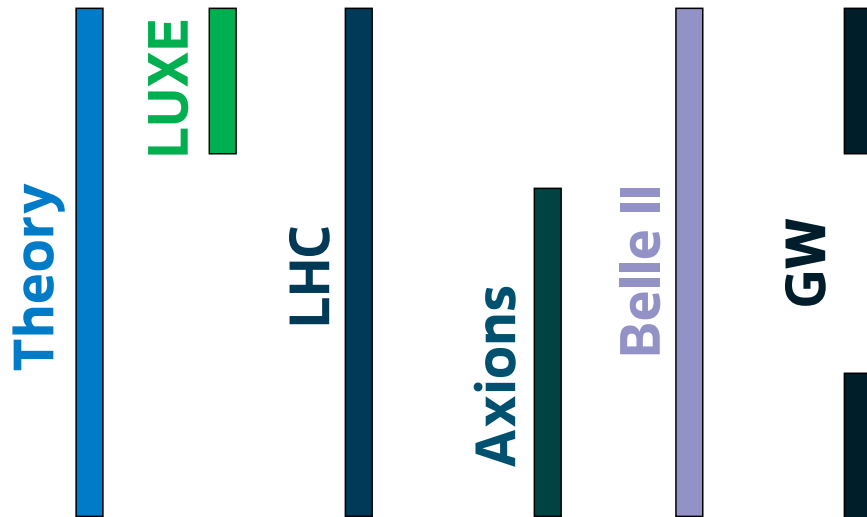
The origin of mass, the flavour puzzle, and the imbalance between matter and anti-matter

The evolution of the early universe and the nature of the dark sector

Motivation for the change: closer to the science drivers, less thematic overlap between subtopics.

# Changes from PoF IV to PoF V

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Pushing the limits of our understanding of fundamental interactions

The origin of mass, the flavour puzzle, and the imbalance between matter and anti-matter

The evolution of the early universe and the nature of the dark sector

Testbeam  
Facility  
(DESY)



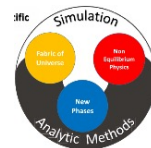
Detector Assembly  
Facility (DAF, DESY)



Computing Centres  
GridKa and IDAF

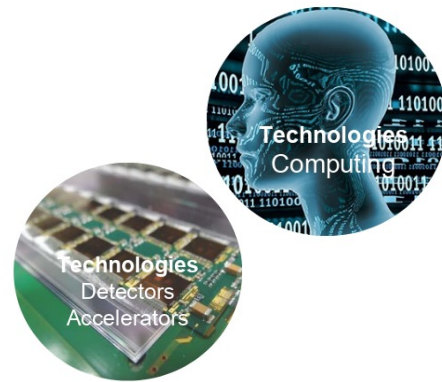
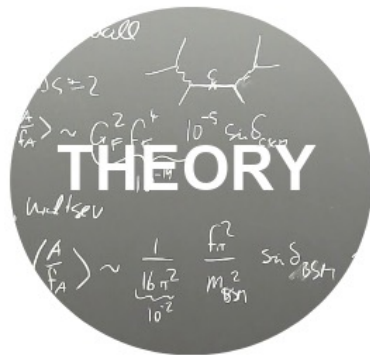


Wolfgang  
Pauli  
Centre



# Particle Physics at DESY: the Next 10-15 Years

## Specific focus areas



Key contributions to global projects at CERN and KEK

- HL-LHC preparation and running in 2029 onwards
- Belle II: expect ~50/ab by 2034

Engage in planning and preparation for future projects (EPPSU decision by 2028)

Maintain broad and world-leading portfolio.

Establish WPC as world-leading interdisciplinary center for theoretical physics

Theory as "Idea factory"

ALPS II: first science run started running in May 2023.

BabyIAXO, LUXE: Solve challenges & find financial resources for PoF V

MADMAX: proof concept in prototyping phase & find financial resources

New ideas, e.g. HF GW local experiments (complementing ET)

~50% of topic resources go into technical work!

Strengthen innovation in detectors and computing

Increase 3<sup>rd</sup> party funding

Strengthen exchange across divisions



# Mid- and Long-Term Strategy

Fundamental Particles and Forces

