Theory prospects

Needs for running and future collider projects

Thomas Mannel,
Center for Particle Physics Siegen
Universität Siegen

November 21st, 2025

Discussion points

- The role of theory projects
- History of Theory in the BMFTR (former BMBF) collaborative research (“Verbundforschung“)
- Needs for runninng and future colliders
- General Discussion

The Role of Theory

- The link between fundamental parameters to observables is often very indirect and need sopisticated theoretical methods
- Measurement of the oservables requires an enormous technical effort and large apparatus
- Division of work between Theory and Experiment, which is well established

- „Theory projects can have very different nature“:
  - BMBF collaborative research: TH projects are taylored to the needs of experimental collaborations and are often based on a direct cooperation
  - DFG projects: Oftne not specific to an experiment, even if they are phenomenological projects.

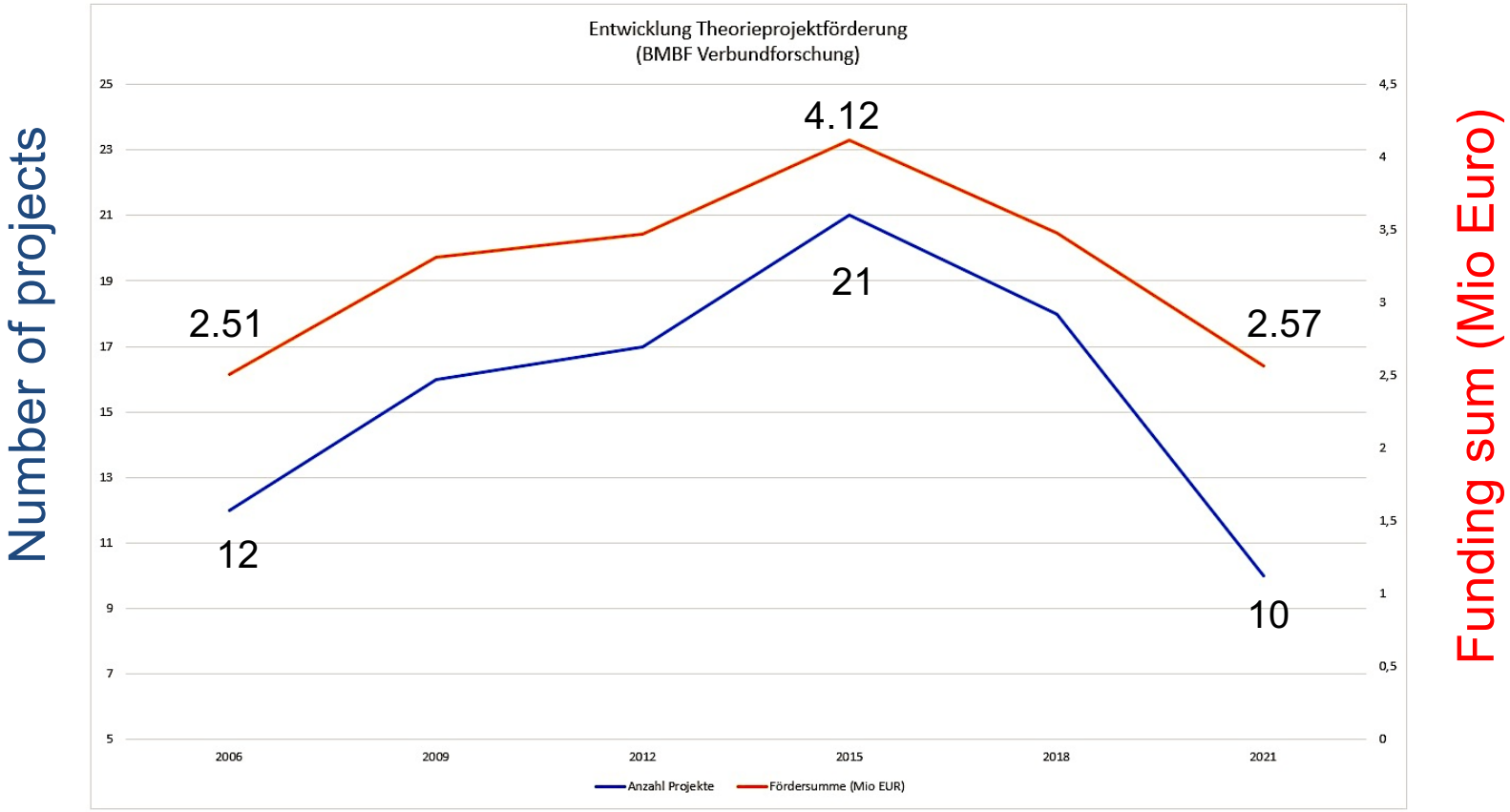
Role of Theory II

- Monte Carlo Simulations
  - Multi purpose programs (Sherpa, Herwig, Pythia ..)
  - Dedicated programs for precision
- Phenomenological Parametrization
  - Parton distributions etc.
- Precision calulations / Quantum corrections
  - Jets, Top and Higgs physics
- Analysis tools including hadronic physics
  - Bottom, Charm
- Tools for new physics searches

History of Theory within the BMBF collaborative research I

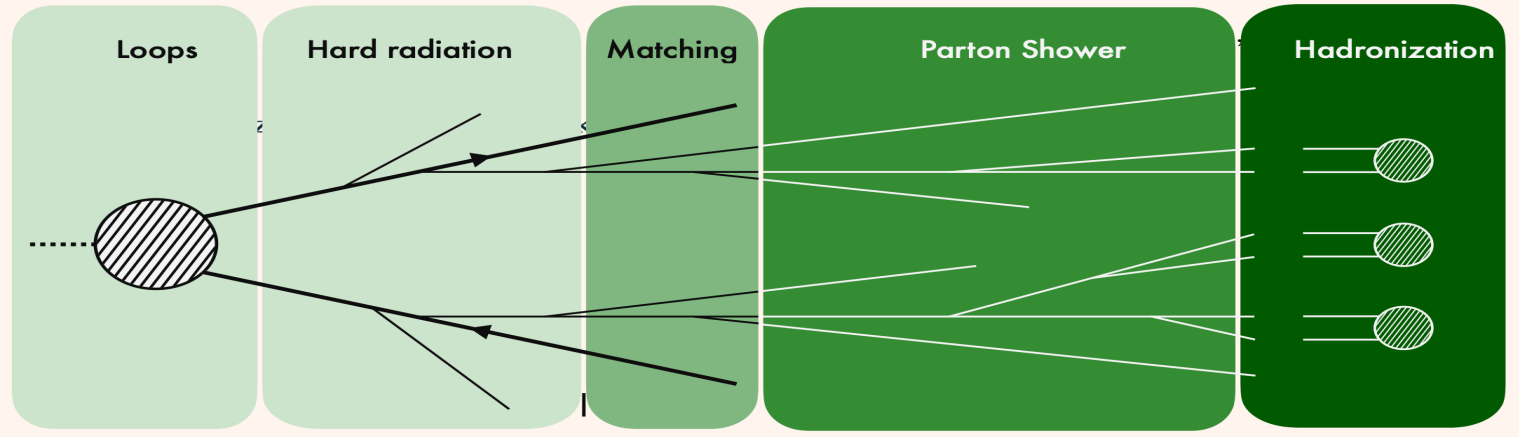
- Since FP2006: Restriction of TH funding to projects with evident connection to BMBF funded experiments
  - Significant increase of theory funding in BMBF collaborative research
  - Strong support from our experimental colleagues
- 2006: BMBF Theory Collaboration was established ("BMBF Theorieverbund")
  - FP2006-2009 und FP2009-2012: Spokesperson ThM
  - FP2012-FP2015: Spokesperson Gudrun Hiller
  - Created international visibility of experiment-related Theory
- Since FP2015-2018: All TH projects had to be a part of experimental projects, termination of the BMBF Theorie Collaboration
- Since this time the BMBF funding for TH projects kept on decreasing, despite the continuous support of our experimental colleagues

History of Theory within the BMBF collaborative research II



(Theory) Needs for LHC-HLK and future colliders

- **K. Melnikov's presentation this morning: Precision**



(From K. Melnikov)

  - Perturbative calculations
  - Electroweak corrections
  - Tools and Methods for BSM searches
- Bottleneck are the non-perturbative effects
- The achievable precision of the TH prediction depends crucially on the chosen observable!

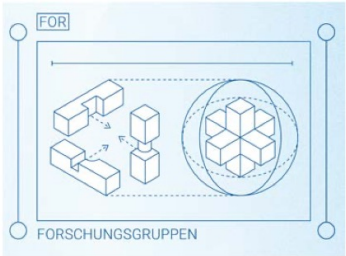
(Theory) Needs for Belle II (and also others)

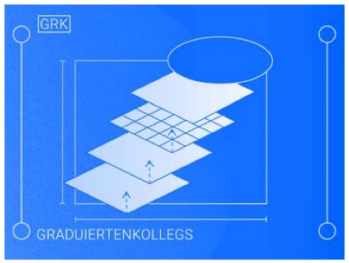
- **KEKb and Belle II**
  - Perturbative Calculations
  - Factorization of perturbative from Non-perturbative contributions

- Lattice QCD simulations become more and more reliable
  - Calculation on large lattices with realistic pion masses
  - Prediction of decay form factors at the percent level in some regions
  - First calculation of hadronic matrix elements of non-local operators

Landscape of Phenomenological Theory in Germany

- 7 **Research Units** (FOR)
  - New since 7/2024: **FOR 5582**
    "Modern Foundations of Scattering Amplitudes" (Duhr, Bonn)
- 5 **Research Training Groups** (GRK)
  - New since 1/2025: **GRK 2994**
    "Particle physics at colliders in the LHC precision era" (Porod, Würzburg)
- 7 **Collaborative Research Centres** (SFB / TRR)
  - New since 4/2024: **SFB 1639**
    "NuMeriQS: Numerical Methods for Dynamics and Structure Formation in Quantum Systems" (Urbach, Bonn)
  - New since 10/2024: **SFB 1660**
    "Hadrons and Nuclei as Discovery Tools" (Sfienti, Mainz)





(from M Kraemer's Presentation this morning)

Landscape of Phenomenological Theory in Germany

- **Second round** of the **Excellence Strategy**
- Decision in May 2025: **70 Clusters of Excellence** (EXC) will be funded from 1st January 2026 – up from 57 clusters

EXCELLENCE STRATEGY
of the German federal & state governments

- **3** existing clusters and **1** new cluster in particle and nuclear physics will be funded
  - **EXC 2118** "Precision Physics, Fundamental Interactions and Structure of Matter" (PRISMA++) JGU Mainz, HI Mainz
  - **EXC 2121** "Quantum Universe II", U Hamburg, DESY
  - **EXC 2094** "ORIGINS: From the Origin of the Universe to the First Building Blocks of Life" Munich: LMU, TUM, several Max Planck Institutes
  - **New: EXC 3107** "Color meets Flavor – Search for new phenomena in strong and weak interactions" U Bonn, TU Dortmund, U Siegen, FZ Jülich

(from M Kraemer's Presentation this morning)

color meets flavor

Germany has a strong tradition in phenomenological theory

Discussion Points

- Funding of Theory projects in BMFTR collaborative research continuously decreased since 2015
- Many Theory colleagues do not apply any more in this funding line
- This will affect (or maybe already has affected) the German contributions to data analysis:
  - Compared to a typical DFG TH Project an embedded TH project in a BMFTR collaborative research project will be quite different
  - TH and EXP collaboration is essential for the interpreation of (not only) the LHC data

- The problem of separating DFG TH research from what is fundable in the BMFTR collaborative research is long standing and still unsolved