Phenomenology of Elementary Particle Physics (Prof. Peter Uwer)

Precision Physics in Quantum Field Theories as Probe of Fundamental Interactions (Dr. Markus Schulze, Heisenberg Fellow)

Motivation
Understanding of Nature at the quantum level.
What are the basic building blocks and interactions?
What are the fundamental principles?

The Standard Model of particle physics is inspired by symmetries.
It describes a vast number of phenomena with high precision.

Colliders are the only controlled environment for elementary particle studies.
Conditions like 10^{-24} sec after the Big Bang.

Open Questions
- Are there new particles hiding (weakly interacting or heavy)?
- What is Dark Matter?
- How do neutrinos acquire their masses? Neutrino CP violation?
- Does the Higgs mechanism “correctly” describe Electroweak Symmetry Breaking (EWSB)?
- Does the Higgs restore unitarity of scattering amplitudes?

Main research directions
- Conceptual developments for perturbation theory
- Precision calculations for collider processes
- Refining the interface theory - experiment

Selected Results
First determination of the running top-quark mass
\[ m(t) = 160.0^{+0.3}_{-0.3} \text{GeV} \]
Recent determination using jet rates from ATLAS:
\[ m_{t}(m_{t}) = 169.9^{+0.9}_{-0.9} \text{GeV} \]

Understanding the Higgs Boson
How does the Higgs boson couple to bosons, fermions and itself?

KIRA — First Laporta type program using finite field techniques

Traditional methods (e.g. low stability of the universal denominator for top-quark amplitudes)

How to measure the mass of a top quark?

Mathematical Physics
Theoretical Particle Physics
Experimental Particle Physics

Embedding at HU

KIRA — First Laporta type program using finite field techniques

Higher order calculations require the evaluation of Feynman integrals:
\[ I(a, b_1, b_2, \ldots) = \int d^{4}x \frac{1}{(\tau - \mathbf{m})^{a_1}(\mathbf{b_1} - \mathbf{2m})^{b_1}} \]
In practical applications thousands or even millions of integrals occur
Using integration-by-parts equations systematic reduction do so-cal master integrals
Algebraic solution increasingly difficult for multi scale problems, \[ N^{3} \text{law} \] for numerical

Solution:
Use arithmetic over finite field to simplify calculation
Special treatment of algebraic simplifications

Significant boost in performance compared to existing tools

Open Questions
- Are there new particles hiding (weakly interacting or heavy)?
- What is Dark Matter?
- How do neutrinos acquire their masses? Neutrino CP violation?
- Does the Higgs mechanism “correctly” describe Electroweak Symmetry Breaking (EWSB)?
- Does the Higgs restore unitarity of scattering amplitudes?

Contact Details and Information
Peter Uwer  Email: Peter.Uwer@Physik.HU-Berlin.de
Markus Schulze  Email: Markus.Schulze@Physik.HU-Berlin.de
www.physik.hu-berlin.de/pep  Supported by

Supported by

Supported by

Supported by

Supported by

Supported by