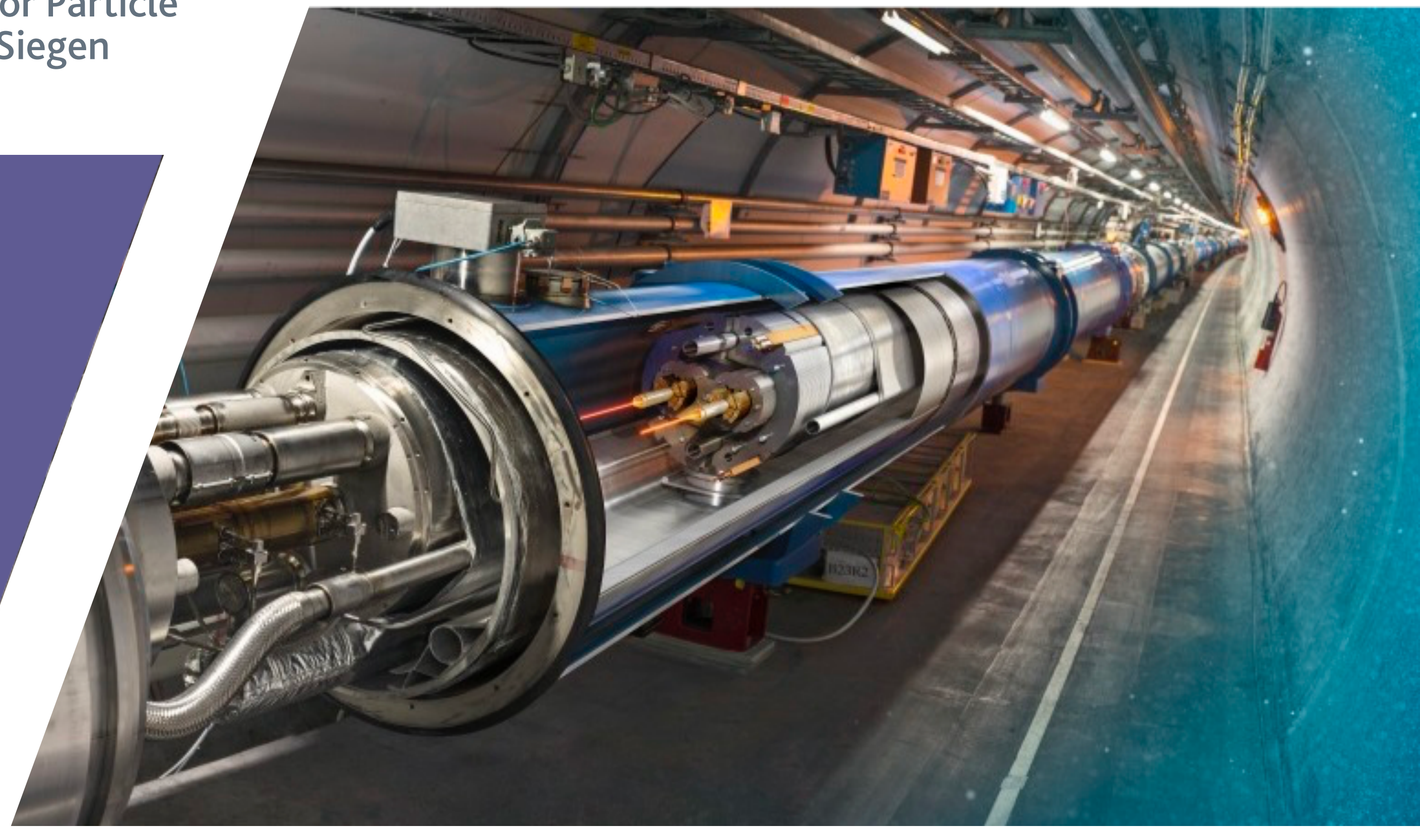
Universität Siegen

HEP Experimental High Energy Physics

CPPS Center for Particle Physics Siegen

Vertex reconstruction using particle tracks in a dense environment

TrackOpt



Diptaparna Biswas, Oliver Lantwin, Vadim Kostyukhin, Markus Cristinziani

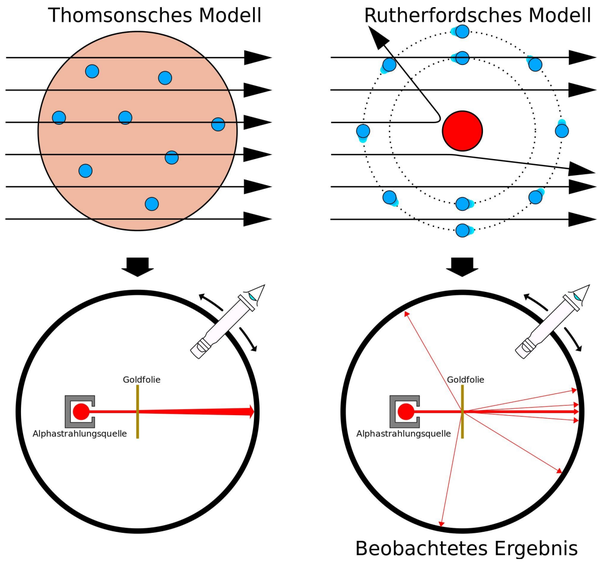
Center for Particle Physics Siegen, Department Physik

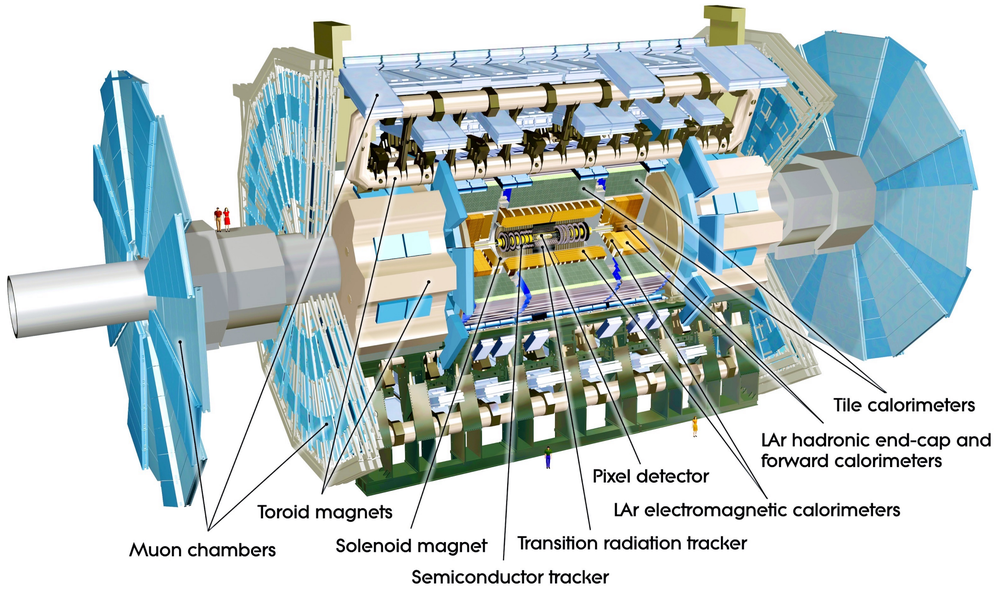
16. January 2026

Particle physics environment

Universität Siegen | HEP Experimental High Energy Physics | CPPS Center for Particle Physics Siegen

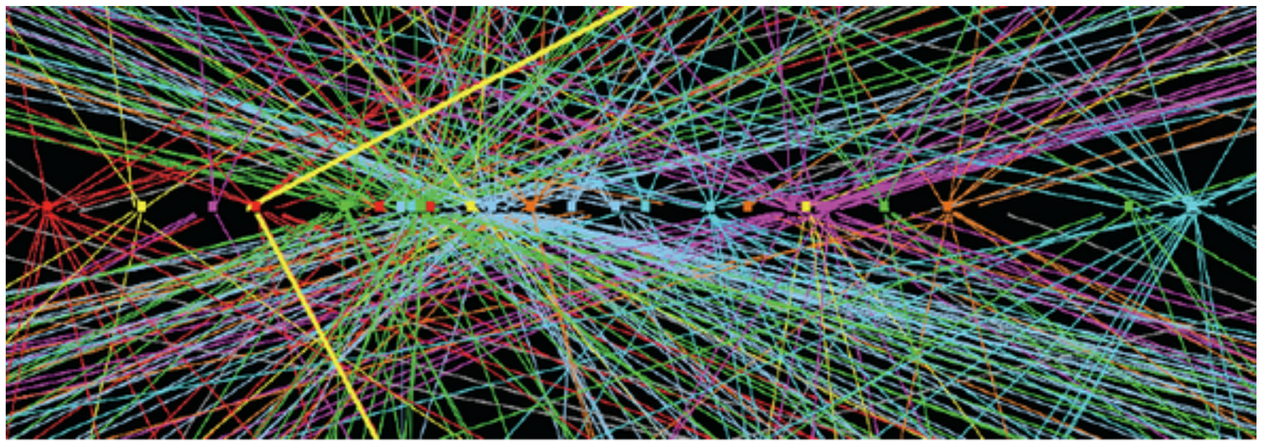
- Goal: understand fundamental structure of matter
- Tool: highest energy collisions (13.600.000.000.000 V) of protons at LHC
- Microscope: ATLAS detector



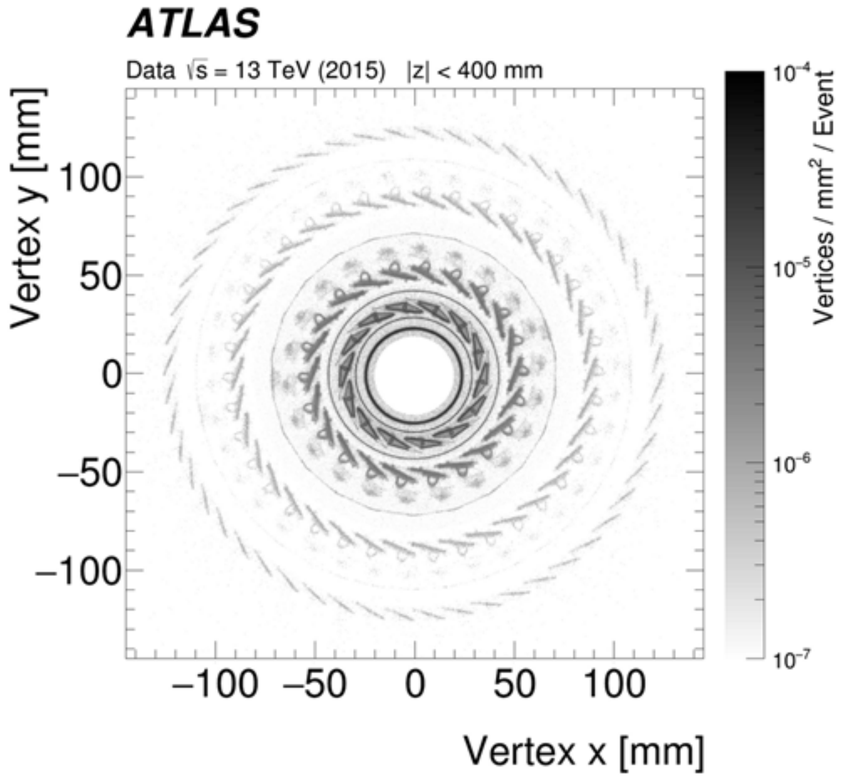


Definitions

- **Track**
  - discrete hits (energy deposits) in detector
    → trajectory of charged particle
- **Vertex (reconstruction)**
  - given a set of tracks, estimate where interaction or decay happens



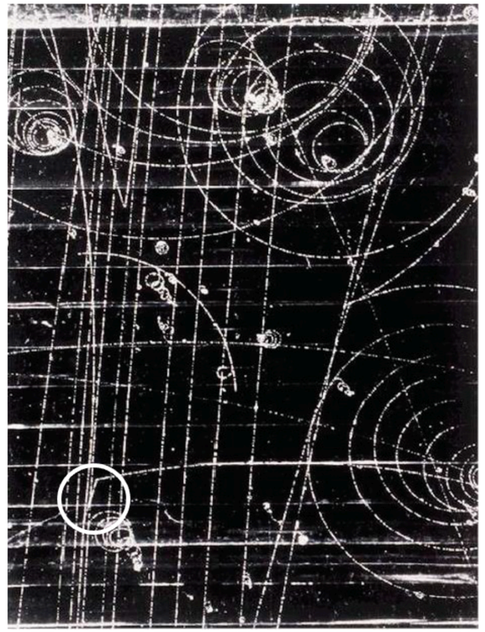
Pileup: Multiple proton-proton collisions at the Large Hadron Collider (up to 200) along the beam line → Primary Vertex

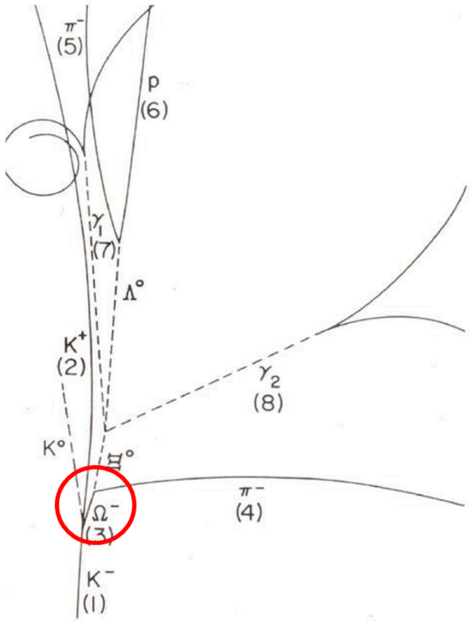


Inner detector “radiography” by reconstructing interaction vertices in detector material

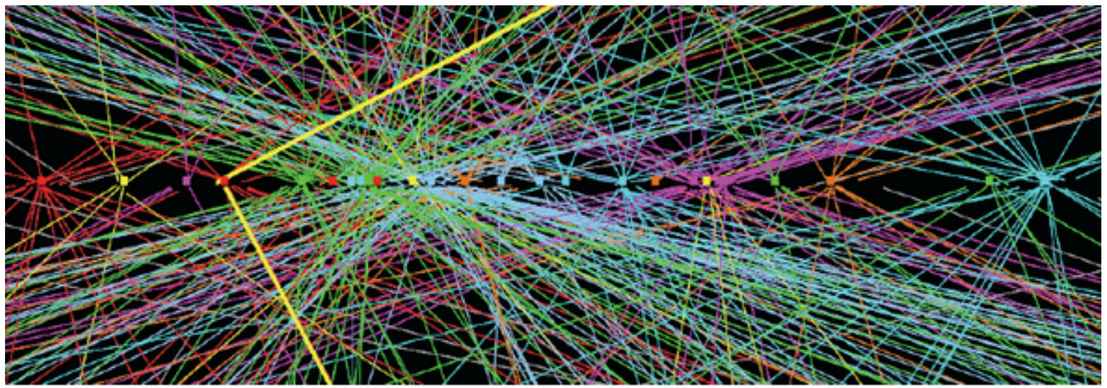
Typical problems

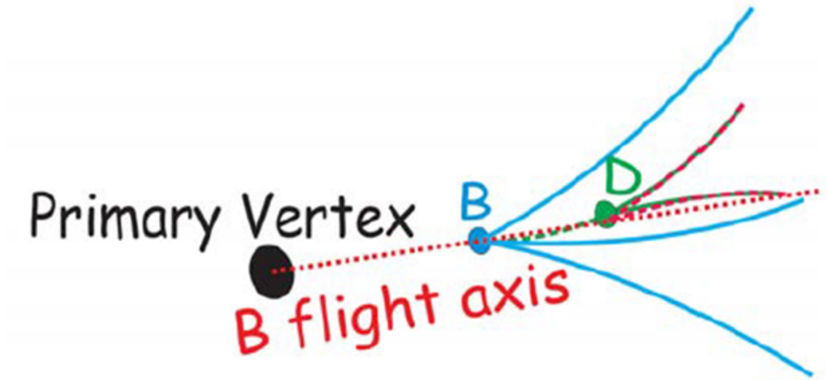
- Vertex reconstruction well known problem
  - e.g. discovery of “strange” Ω^- Hyperon 1964





- Typical problems
  - Primary vertex reconstruction (collisions)
  - Secondary vertex reconstruction (decay)

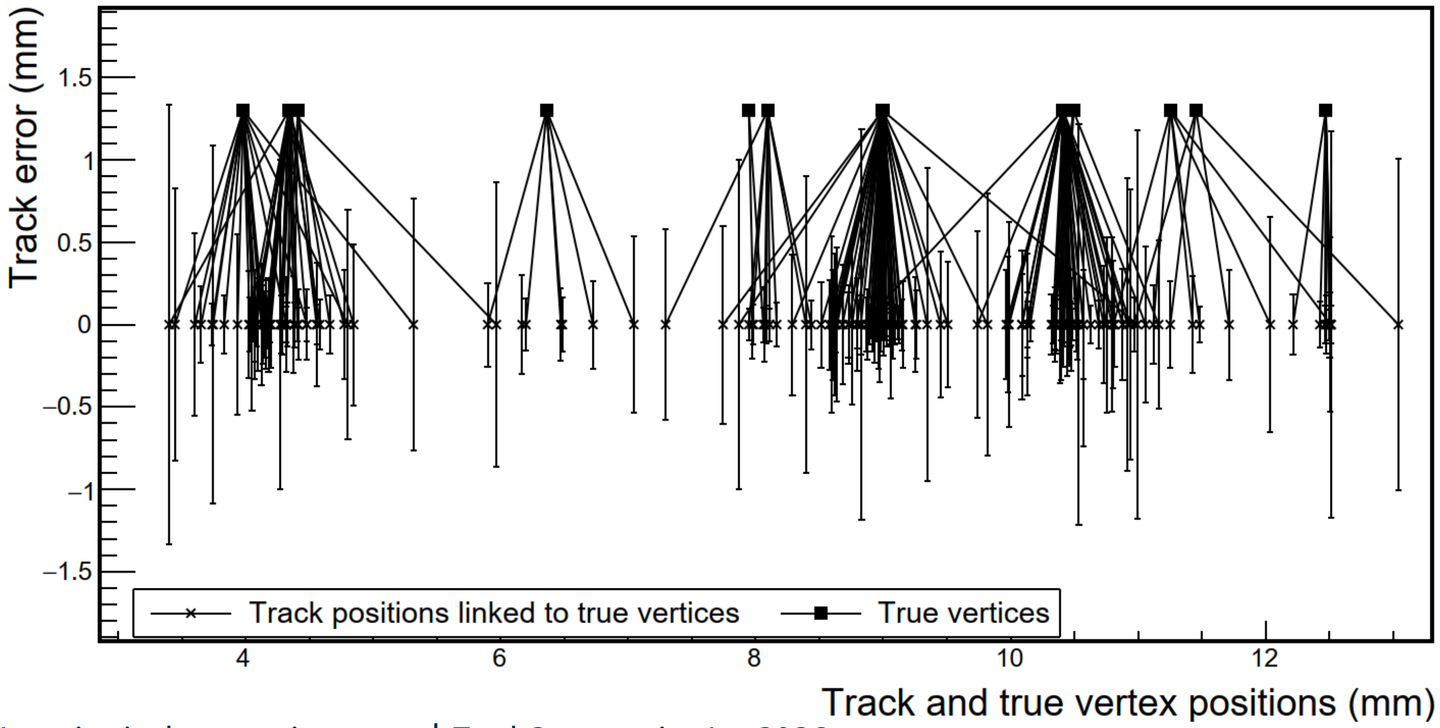




Challenges in vertex fitting

Universität Siegen | HEP Experimental High Energy Physics | CPPS Center for Particle Physics Siegen

- Detector resolution and large track density
  - often vertex-to-vertex distance smaller than track resolution
  - few-track vertex difficult to detect near a many-track vertex
  - limited resolution → fake vertex candidates



Track from different vertices can overlap

WP3: particle physics

Universität Siegen | HEP Experimental High Energy Physics | CPPS Center for Particle Physics Siegen

- WP 3.1 **Data preparation**: Preparing data for 1D and 3D examples (12 months)
- Plan
  - preparation of datasets for 1D and 3D vertex reconstruction studies
  - start from pre-reconstructed particle trajectories
  - simulated datasets validated and extended during the initial project phase
  - address reconstruction inefficiencies and noise (fake tracks)
  - extension of existing 1D results to full 3D as a key preparatory step
- Actual work
  - generated large sample on OMNI cluster: 500k events (ODD dataset), more are possible
  - can be used for publications and stored long-term
  - processing of data turns out to be more difficult than expected

WP3: particle physics

Universität Siegen | HEP Experimental High Energy Physics | CPPS Center for Particle Physics Siegen

- WP3.2 **Modeling and Evaluation** (24 months) Plan
  - Physics constraints in close collaboration with HHU, accounting for measurement uncertainties in track reconstruction
  - Key observables (e.g. inv. masses) must remain compatible with theoretical expectations within errors
  - Evaluation for HL-LHC and FCC-hh, addressing much higher track multiplicities
    - Increase robustness to noise and measurement errors
    - Improve vertex identification efficiency and reduced fake rate
  - Explore approach: direct vertex identification from detector hits without prior track reconstruction
    - Reformulate as 3D pattern recognition (stroboscopic detector images)
    - Potentially bypass track reconstruction and significantly improve vertex finding in sparse, noisy environments