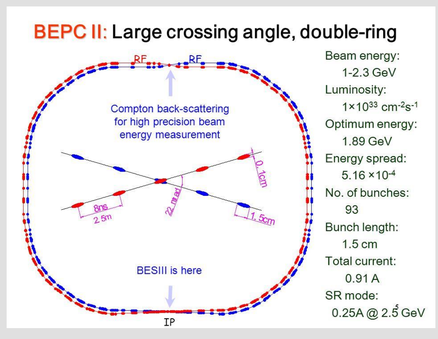
dE/dx Software in the BESIII Experiment

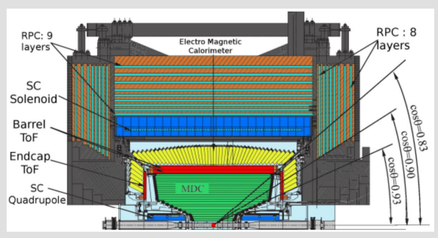
Wenxing Fang, Weidong Li, Shengsen Sun

Institute of High Energy Physics, CAS / fangwx@ihep.ac.cn

Introduction of the BESIII experiment

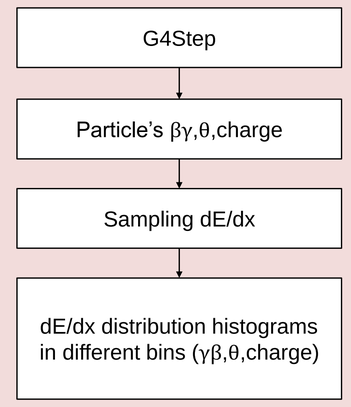
- The Beijing Electron Collider Ⅱ (BEPCⅡ) is a high luminosity e^+e^-collider with center mass-energy from 2 to 4.6 GeV [1]
- The BESIII experiment at BEPCⅡ focuses on tau-charm physics. Such as non-perturbative QCD, exotic hadrons, and BSM [2]
- The BESIII has accumulated an unprecedented amount of data. For example, 10 billion J/psi data





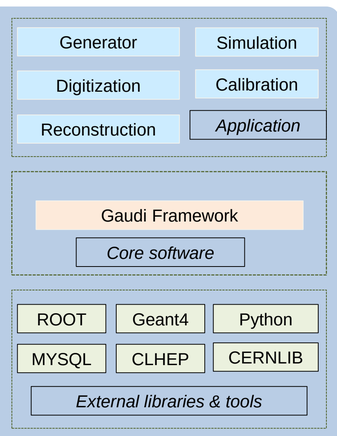
dE/dx simulation

- The Geant4 can not precisely simulate the deposited energy of charged particles in the thin gas
- A data-driven dE/dx simulation method is adopted
  1. Producing dE/dx distribution histograms for different βγ, θ, and charge of the track regions using real experiment data
  2. Performing dE/dx sampling together with the Geant4 simulation



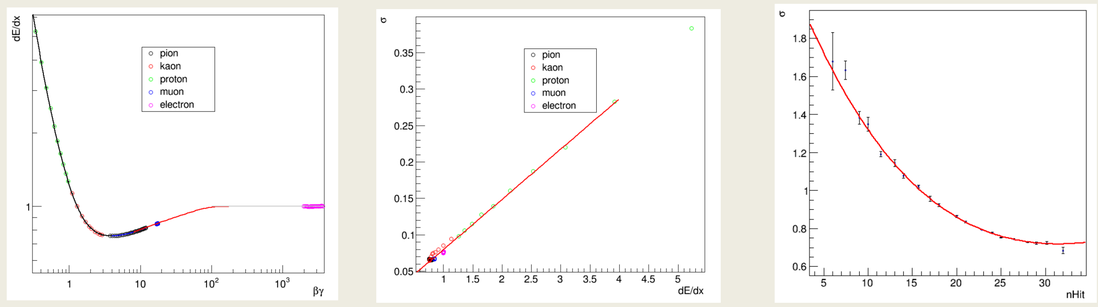
dE/dx software

- The offline software system of the BESIII is called "BOSS". It consists of external libraries, core software, and the BESIII specific applications
- The particle identification (PID) is essential for the BESIII experiment. The PID for π, K, proton relies on the dE/dx and the time of flight measurements
- For some analyses, the statistic uncertainty is small enough, so it is important to reduce the systematic uncertainties, such as the systematic uncertainties from PID
- The dE/dx software in the BOSS including dE/dx correction, reconstruction, simulation, and calibration [3]



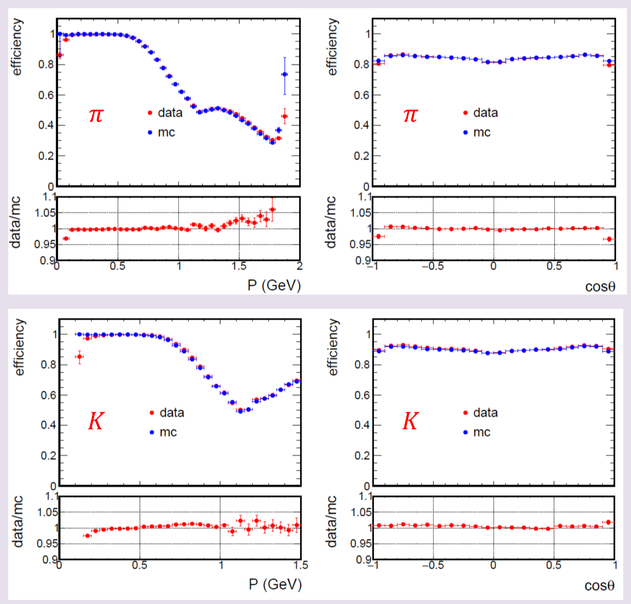
dE/dx calibration

- Using the reconstructed dE/dx of different particles
- Calibrating the expected dE/dx vs βγ. Calibrating the σ of dE/dx vs dE/dx, cosθ, and number of hits in the track (nhit)



- The $\chi_{dE/dx}$ is used for PID: $\chi_{dE/dx} = \frac{|(\frac{dE}{dx})_{obs} - (\frac{dE}{dx})_{exp}|}{\sigma_{dE/dx}}$

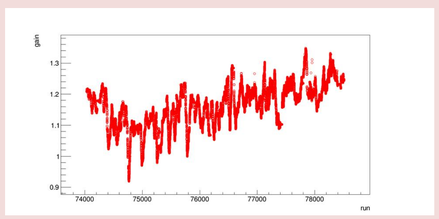
dE/dx PID Performance

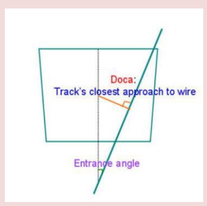


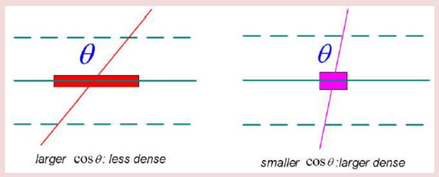
- The psi(3770) data taken in 2023 is used for the PID efficiency plots
- Three hypotheses—pion, kaon, and (anti)proton—are being considered
- Good agreement between data and MC simulation

dE/dx correction

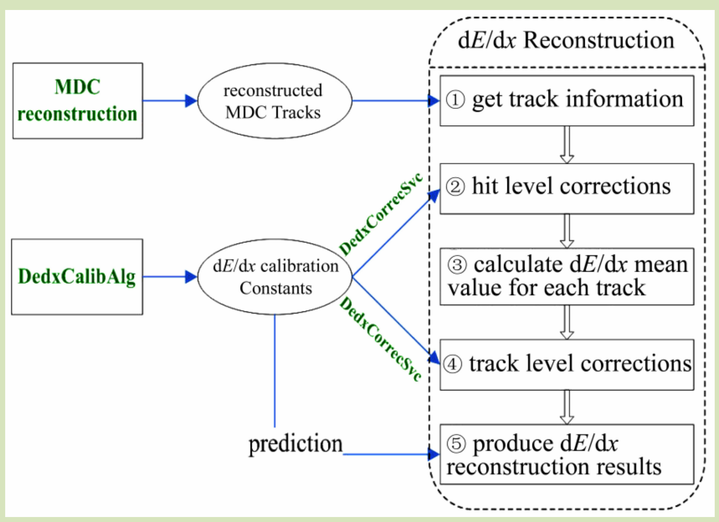
- To get unbiased dE/dx measurements
- Hit level corrections:
  - Run by run: due to the changes in gas pressure and temperature
  - Wire by wire: different drift chamber cell size, geometry, high voltage of signal wire, the radius of the signal wire
  - Doca and entrance angle: different drift distance of ionized electron to signal wire, non-uniform electromagnetic field
- Track level corrections:
  - Space charge effect depends on cosθ and dE/dx itself. Smaller cosθ or larger dE/dx will have a larger space charge effect
  - Different samples are used: e, mu, π, K, proton

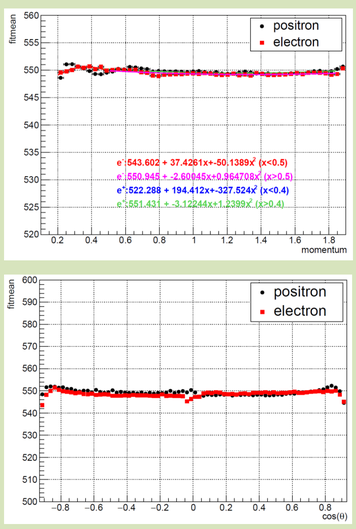






dE/dx reconstruction





Conclusion and outlook

- The dE/dx software in the BESIII experiment is presented
- The dE/dx software consists of dE/dx correction, reconstruction, simulation, and calibration
- The dE/dx software has been smoothly working for many years and the PID performance looks good
- Machine learning (ML) is increasingly being applied in the field of high-energy physics
- Integrating ML technology into the dE/dx software is worth exploring. Such as the ML-based dE/dx simulation [4]

Reference

[1]: BESIII Collaboration, Design and Construction of the BESIII Detector. Nucl.Instrum.Meth.A614:345-399,2010

[2]: For BEPC II Team, BEPC II: construction and commissioning, Chinese Phys. C 33 60, 2009

[3]: Cao Xue-Xiang, et al. Studies of dE/dx measurements with the BESIII. Chinese Phys. C 34 1852,2010

[4]: Wenxing Fang, et al. A data-driven dE/dx simulation with normalizing flow. Nucl.Instrum.Meth.A1065, 2024