Helix Correction for Tracks from Secondary Vertex Fit

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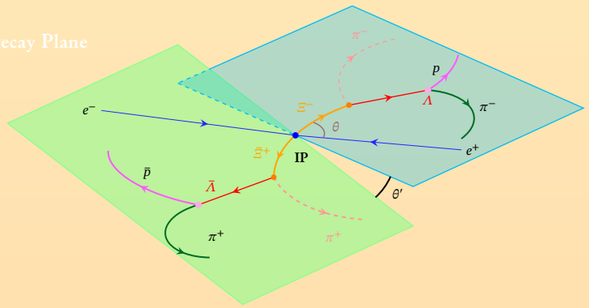
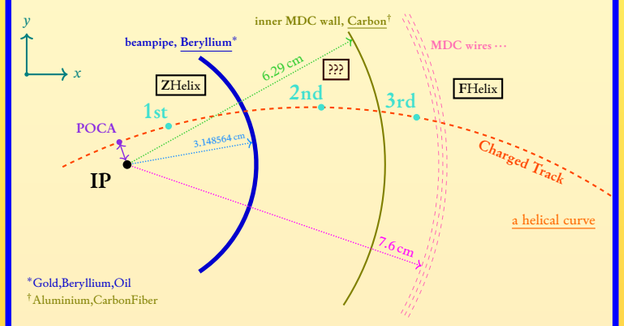
Introduction

Recently, BESIII Collaboration has reported precision measurements on hyperon physics using world's largest J/ψ data sets collected at the e^+e^- collider BEPCII [1]. For the first time, we measure the weak CP phase difference in the baryon sector and provide very high sensitivity test on CP violation.

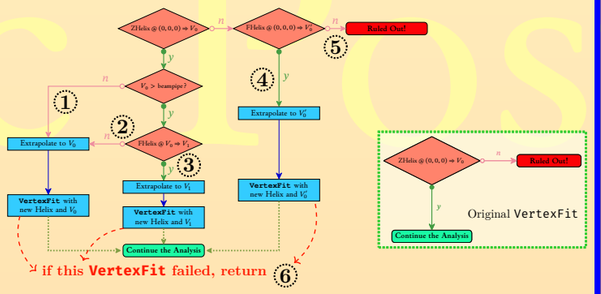
Hyperon is one type of baryons, consisting of at least one strange quark. It is firstly observed at cosmic ray experiments and had been widely studied in the fixed-target experiments in 1960s. Compared with proton which is stable, the lifetime of hyperons is very short. However at BEPCII-BESIII, the decay length of them are typical a few centimeters due to their high momentum. In other words, hyperons fly some non-negligible distance until they decay into other particles. Since hyperon production at J/ψ peak is relatively rare ($\sim 10^{-3}$), the official tracking algorithm for charged tracks does not take the decay length into consideration in the default options i.e. charged tracks are always assummed to be produced at the origin. As we are performing precision research, this effect should be handled with care. Therefore we **developed a new `VertexFitRefine` package** to correct the reconstructed parameters (helix) of charged tracks from secondary vertex (usually, we refer e^+e^- colliding point as the first vertex). For instance, in the process $e^+e^- \to J/\psi \to \Lambda\bar{\Lambda} \to (p\pi^-)(\bar{p}\pi^+)$ [2], the proton, antiproton, and pions are all decayed from secondary vertices, the default helix has not included the factors that their mother particles Λ would fly a few centimeters in the detector. This is also the case for the target decay in Ref. [1] as illustrated below,



Core Algorithm

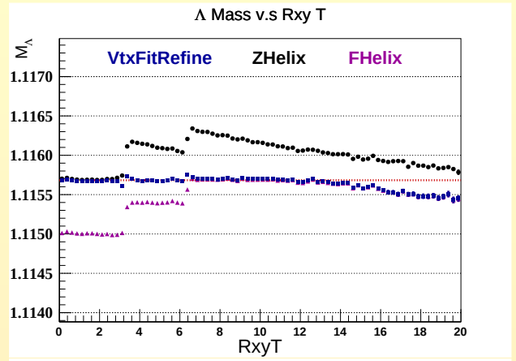


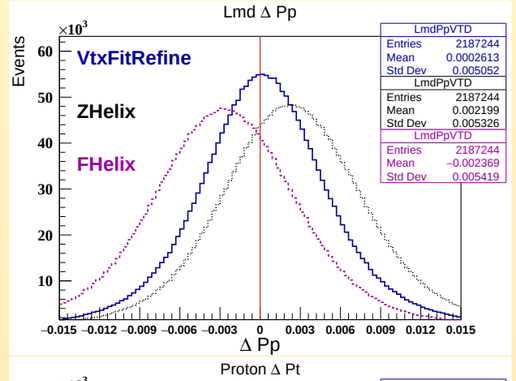
Inside the BESIII detector nearing the interaction point(IP), usually, most charged tracks (1st) are produced at the origin, then fly through multiple materials' layers into the Main Drift Chamber (MDC) [3] and leave footprints there used for reconstruction offline and the flight line is not straight due to the strong magnetic field. However, hyperons would possibly fly to 2nd or even 3rd point then decay into charged particles. If they were reconstructed to the IP as others', unnecessary materials' effect and magnetic field effect would be involved!

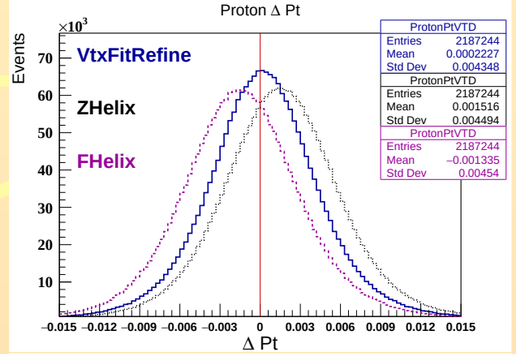


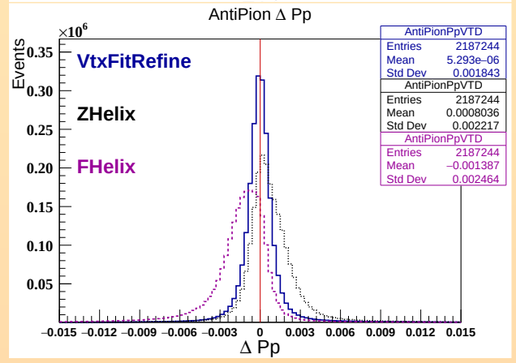
Therefore, we developed a more sophiscated algorithm and take every detail into consideration to correct both the materials' effect and magnetic field effect. We combine the traditional vertex fitting algorithm, Kalman filtering method, and intelligently choosing the default helix together into a well designed flow chart to cover all the cases in the analysis.

Main Results









Targeted Particles

ALL daughter charged particles decayed from K_S, Λ, Ξ^-, Ω^-, etc.

References

[1] BESIII Collaboration, *Nature* **606** *(2022) 64*

[2] BESIII Collaboration, *Nature Phys.* **15** *(2019) 631*

[3] BESIII collaboration, *Nucl. Instrum. Meth. A* **614** *(2010) 345*

Summary

In summary, from the figures in the Main Results section, the `VertexFitRefine` package we developed successfully corrects the shift from nominal values and enhances the invariant mass measurements, also improves the reconstructed magnitude and direction of charged particles' momentum.