Reconstruction of K_S^0 and Λ in $Z \to q\bar{q}$ events at CEPC Baseline Detector

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Introduction

Importance of Z (and W)

- Flavor physics
- Precise measurements are critical to test SM
- Many BSM models predict their couplings to other elementary particles
- CEPC will operate in Z pole for at least two years and will produce up to 10^{12} Z bosons
- Etc…

Introduction

The K_S^0 and Λ:

- abundant in $Z \to qq$ events. (1.0 K_S^0 and 0.17 Λ per event).
- decay into a pair of charged particles. BR($K_S^0 \to \pi^+\pi^-$ or $\Lambda \to p\pi^-$) > 60%.
- relatively long life time ($c\tau > 2$ cm), and require secondary vertex reconstruction.

Introduction

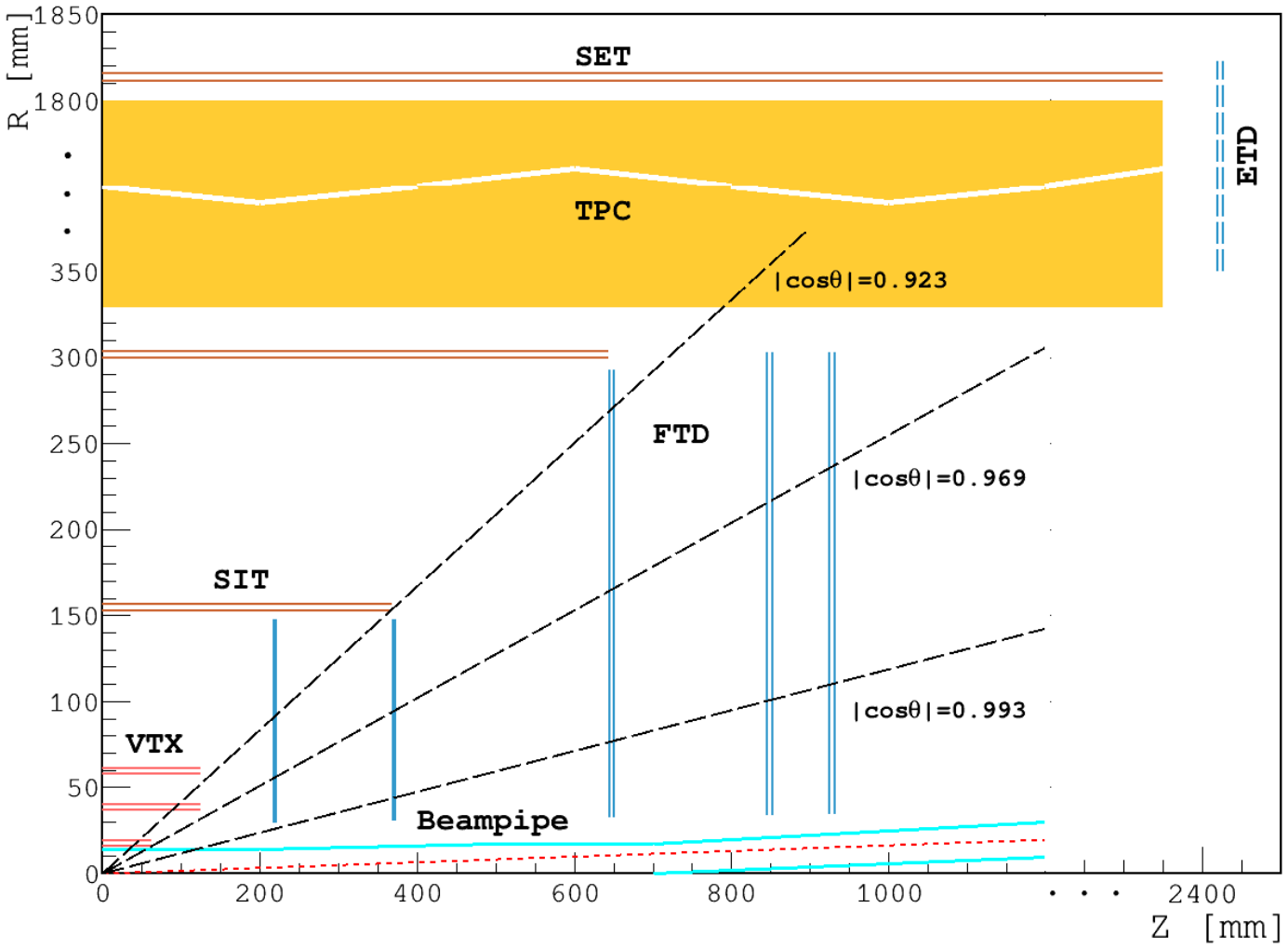
Their reconstruction is useful for:

- Calibrate and monitor the tracking system and the PID performance operation.
- Important for flavor physics measurements, such as CP violation in $\tau \to \pi^- K_S^0 \nu_\tau$,

  the search for $K_S^0 \to \mu^+ \mu^-$.

CEPC Tracker Layout

1. Silicon hits → silicon tracks
2. TPC hits → TPC tracks
3. Silicon track + TPC track + leftover hits → final track

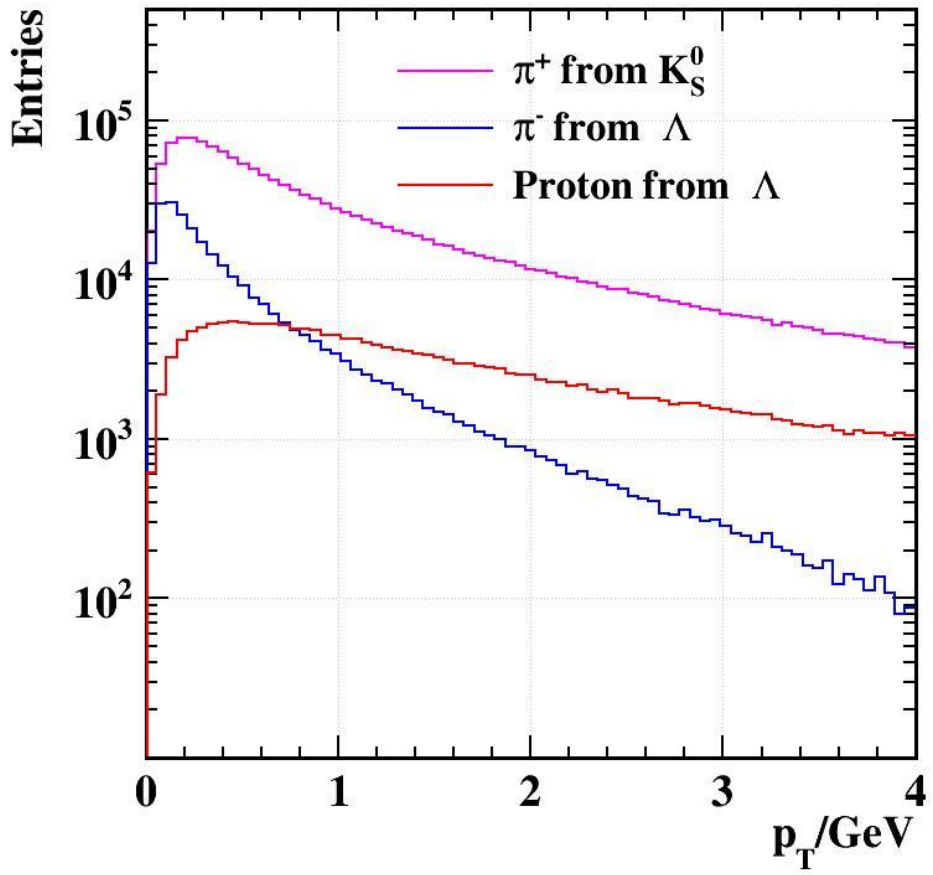


Track Momentum

The tracker is in a 3 T magnetic field.

Therefore:

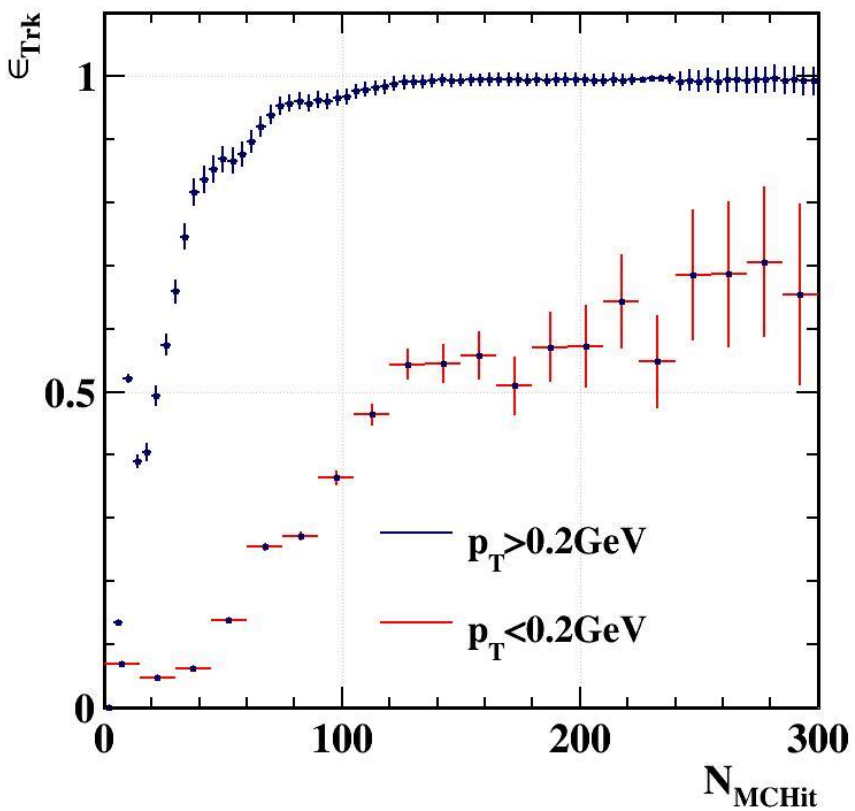
- $p_T > 0.15$ GeV, the particle reaches TPC.
- $p_T > 0.8$ GeV, the particle penetrates the tracker barrel.



Track Reconstruction Efficiency

$$\epsilon_{Trk} = \frac{Number\ of\ reconstructed\ \pi^+\ tracks}{Number\ of\ K_S^0 \rightarrow \pi^+\pi^-\ events}$$

The ϵ_{Trk} for π^+ from K_S^0 is 86.5%. Resulted mainly from low efficiency for π^+s with $p_T < 0.2$ GeV.



73.64% of $K_S^0 \rightarrow \pi^+\pi^-$ & 62.9% of $\Lambda \rightarrow p\pi^-$ have both daughter tracks reconstructed.

Definitions of Efficiency and Purity for $\boldsymbol{K_S^0}$ and Λ

Reconstruction efficiency:

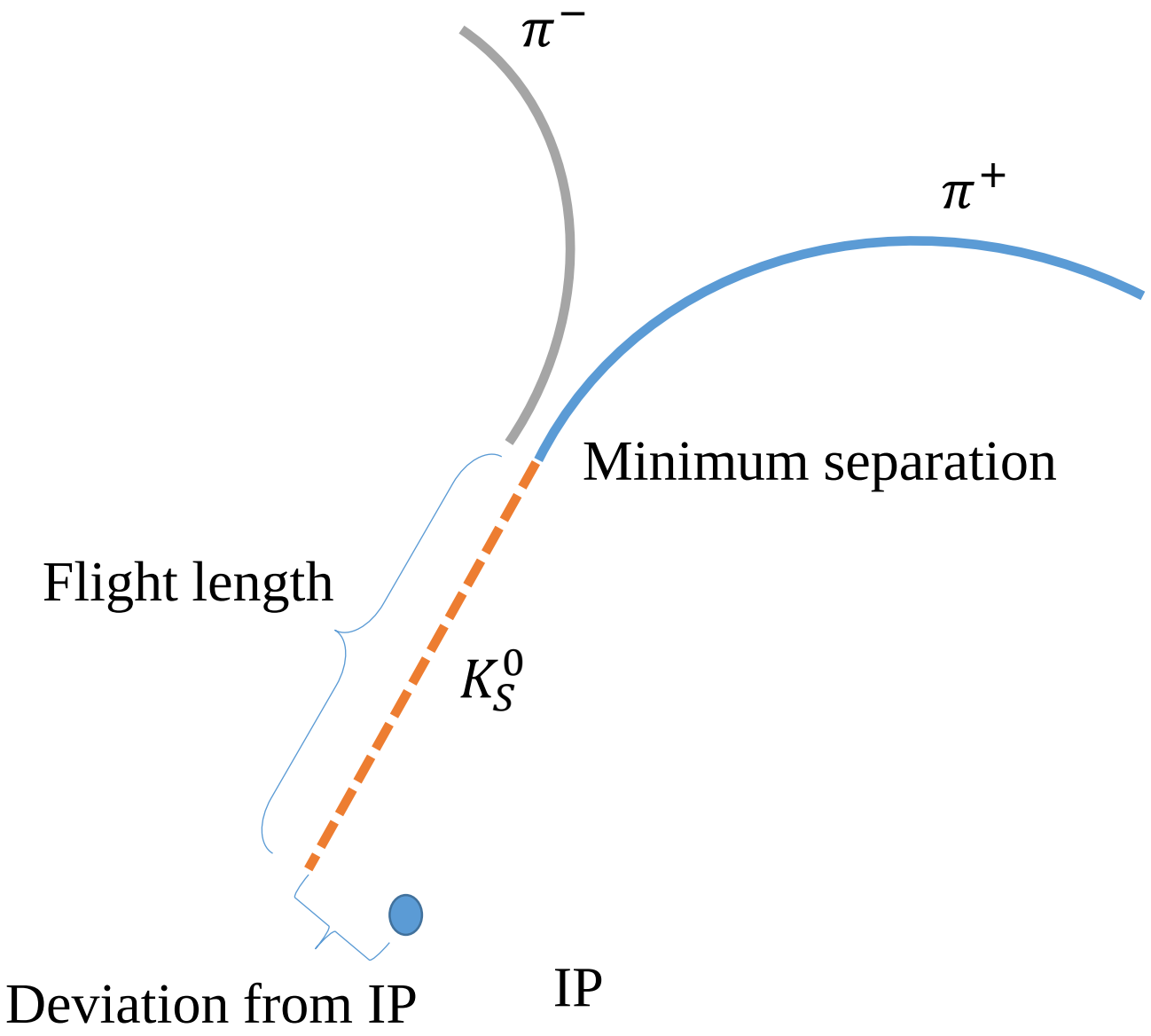
$$\epsilon_R = \frac{Number\ of\ correctly\ tagged\ track\ pairs}{Number\ of\ K_S^0\ /\ \Lambda\ daughter\ track\ pairs}$$

Purity:

$$P = \frac{Number\ of\ correctly\ tagged\ track\ pairs}{Number\ of\ tagged\ track\ pairs}$$

The inclusive efficiency $\epsilon_T = \epsilon_R \times \epsilon(Both\ tracks\ reconstructed) \times BR\left(K_S^0 \rightarrow\right.$

Reconstruction Method



Reconstruction Method

Use the purity distribution on the Armenteros plot to demonstrate the performance:

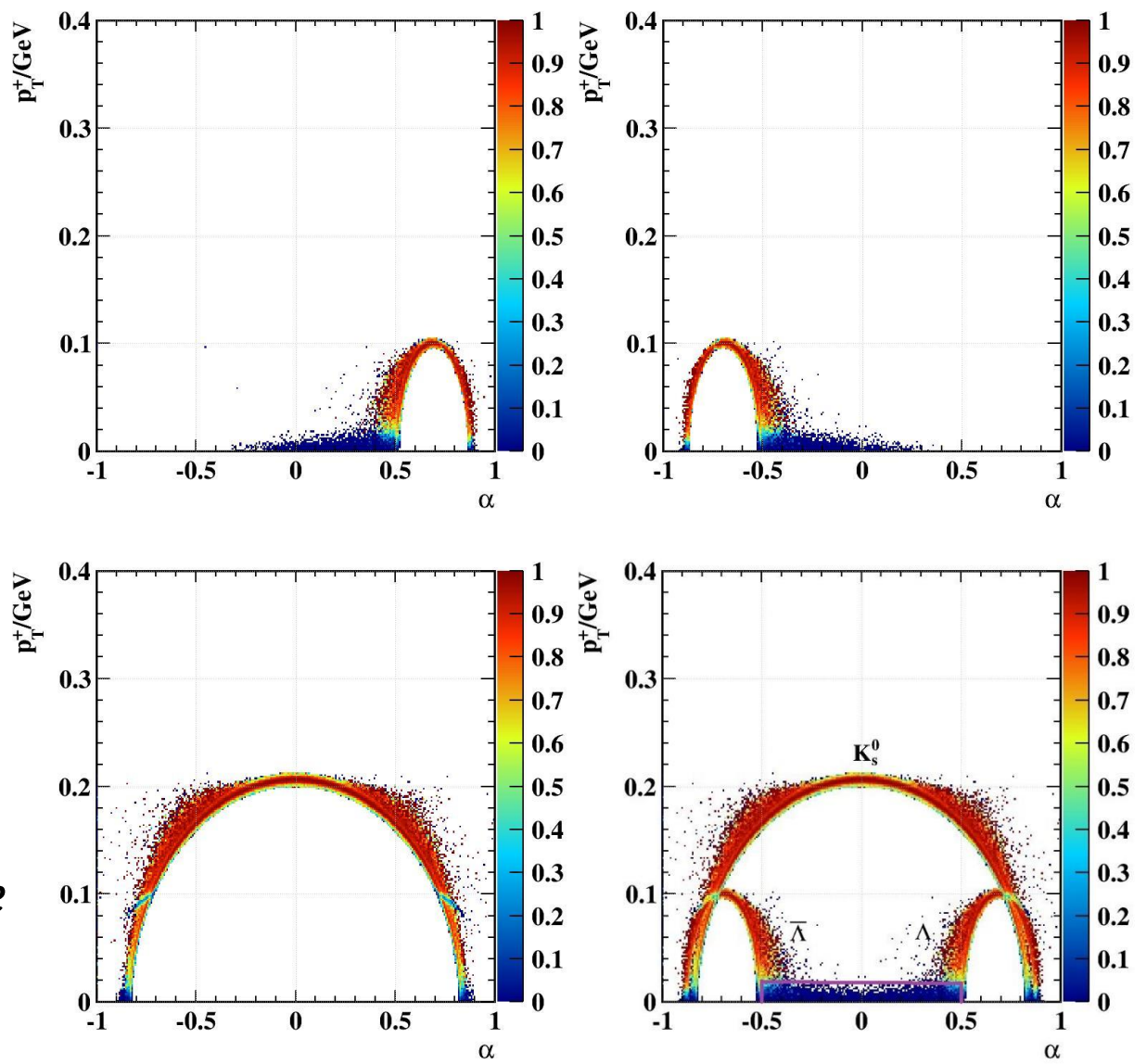
y axis: positive daughter's transverse momentum p_T^+.
x axis: longitudinal momentum asymmetry, defined as:

$$\alpha = \frac{p_L^+ - p_L^-}{p_L^+ + p_L^-}$$

, all in respect to the parent's momentum.

The three arcs represent $K_S^0/\Lambda/\overline{\Lambda}$ respectively.
The low purity tails of $\Lambda/\overline{\Lambda}$ are mostly $\gamma \to ee$

Cut off where $p_T^+ < 0.02$ GeV and $|\alpha| < 0.5$.

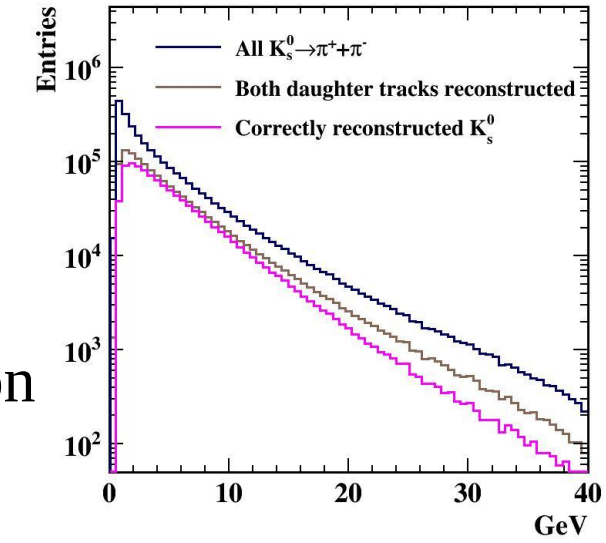


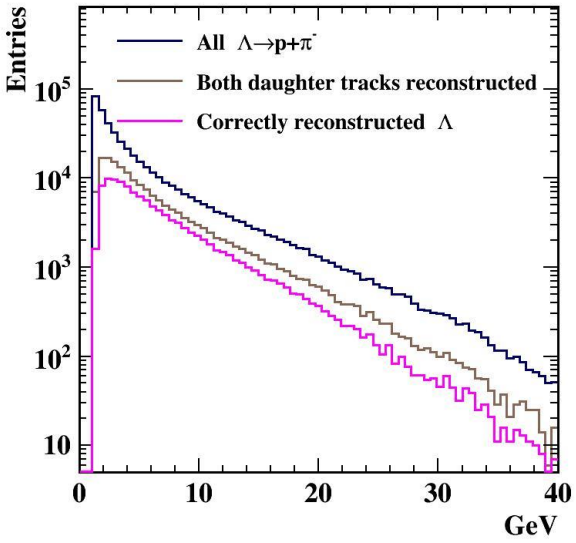
Results

Particle	K_S^0	Λ
ε_R	79.7%	65.1%
ε_T	39.8%	25.5%
P	89.7%	87.9%
$\varepsilon_R \cdot P$	0.715	0.572
$\varepsilon_T \cdot P$	0.357	0.224

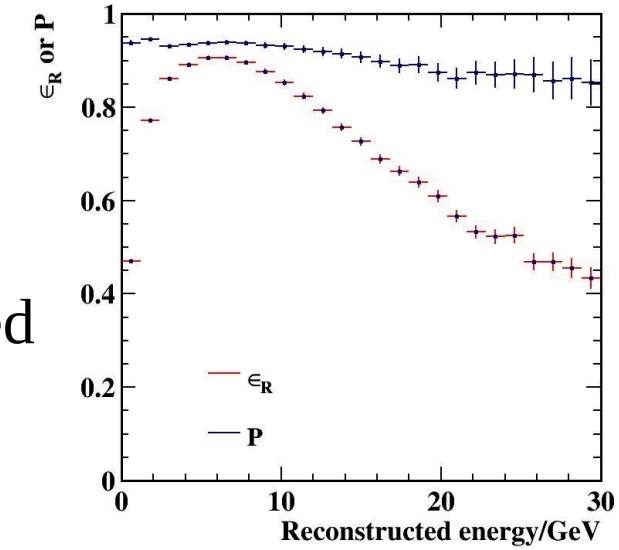
Reconstruction performance

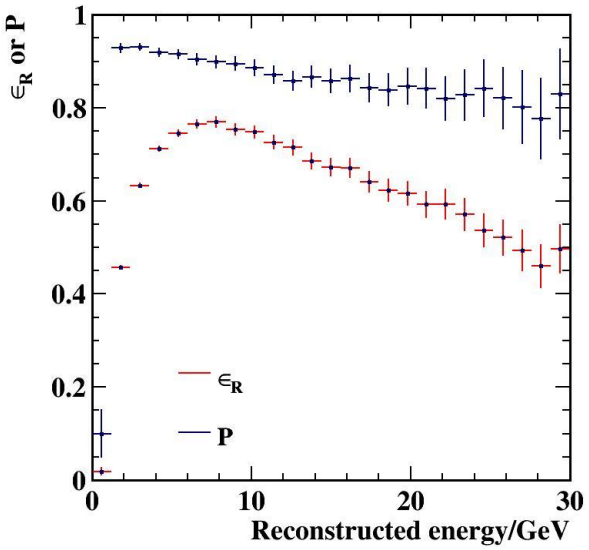
Energy distribution





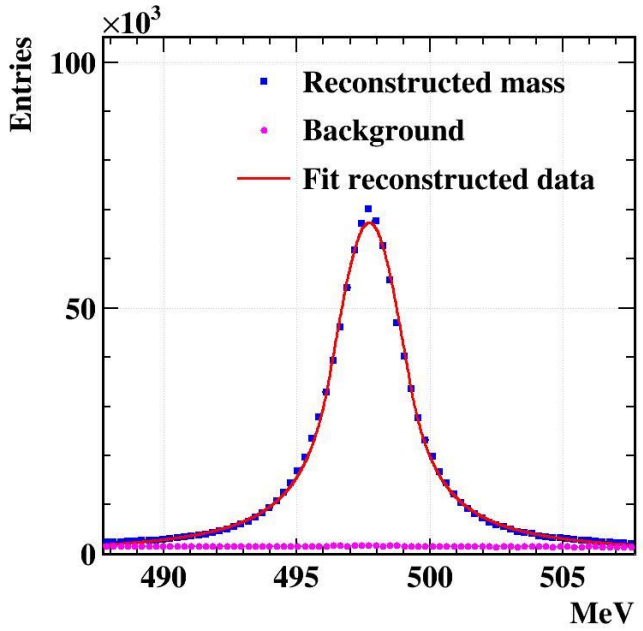
ϵ_R and P versus reconstructed energy



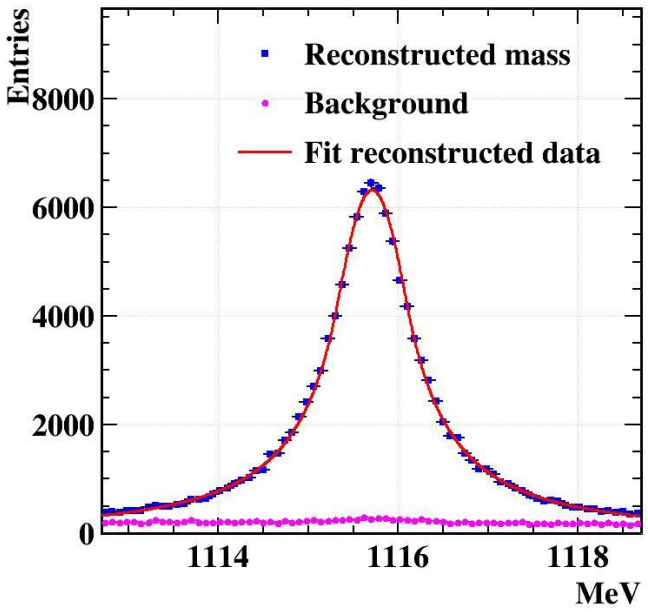


K_S^0 Λ

The Value of Mass



K_S^0



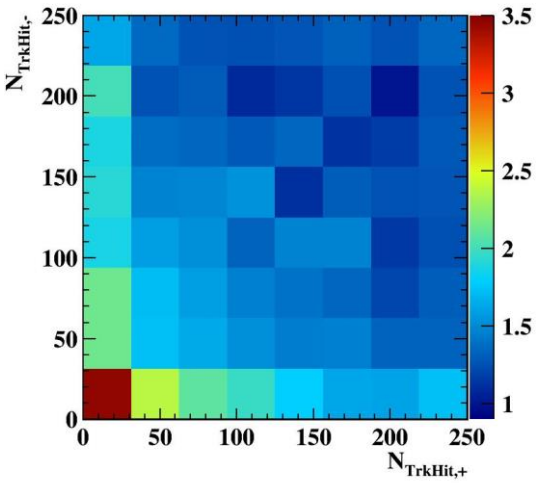
Λ

Particle	K_S^0			Λ	
Experiment	CEPC	KLOE [11]	NA48 [10]	CEPC	AGS [12]
Mass/MeV	497.719	497.583	497.625	1115.708	1115.678
Statistical error/MeV	0.002	0.005	0.001	0.003	0.006
Systematical error/MeV	—	0.020	0.031	—	0.006

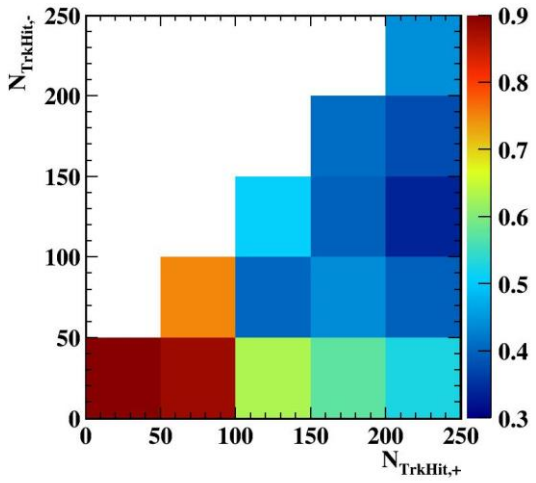
Mass Resolution

Add two more conditions.

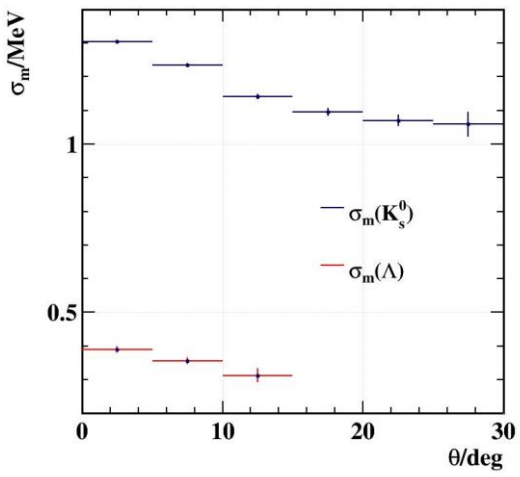
1. $N^{\pm}_{TrkHit} > 200$ for K^0_S, $N^{+}_{TrkHit} > 200$ & $N^{-}_{TrkHit} > 100$ for Λ.
2. The angle between the to momenta at closest approach is grater than $20°$ for K^0_S and $10°$ for Λ.



σ_m versus $N^{\pm}_{TrkHit}$ (K^0_S)



σ_m versus $N^{\pm}_{TrkHit}$ (Λ)

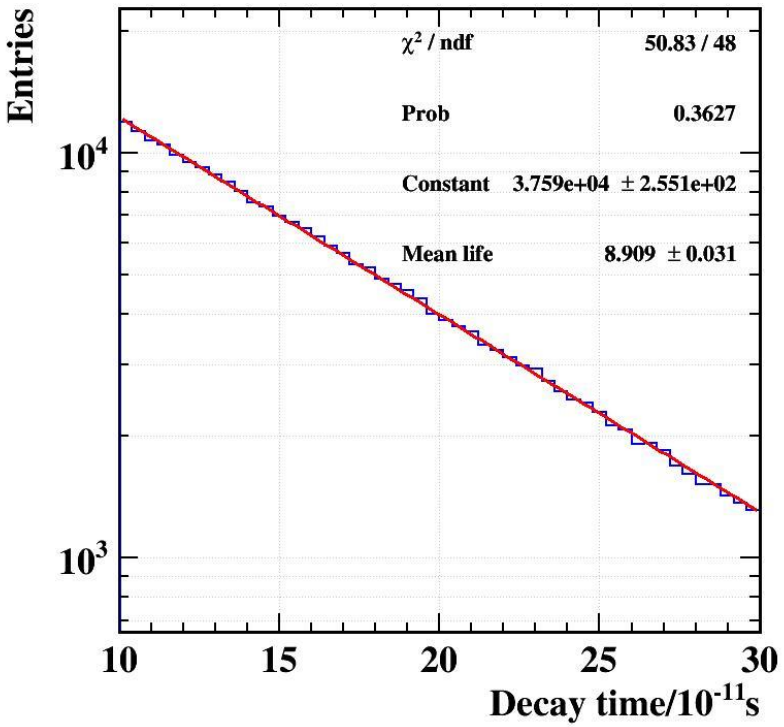


σ_m versus the angle at closest approach

The achieved resolutions are 1.05 ± 0.02 / 0.32 ± 0.02 MeV for K^0_S and Λ.

Life Time

The measured value is $8.909 \pm 0.031_{stat} \times 10^{-11}$s for K_S^0. The input value is 8.954×10^{-11}s.



Estimations for Future Improvements

1. A proper PID algorithm. Especially the proton identification will reduce K_S^0 backgrounds and increase Λ efficiency. Assuming a perfect PID, we have

Particle	K_S^0	Λ
ε_R	82.8%	88.7%
ε_T	41.4%	34.8%
P	93.1%	91.2%
$\varepsilon_R \cdot P$	0.771	0.832
$\varepsilon_T \cdot P$	0.385	0.326

Estimations for Future Improvements

2. Ideal track reconstruction performance for $p_T > 0.2$ GeV, $p_T > 0.1$ GeV, and (to test the limit) all charged particles.

Particle	K_S^0			Λ		
p_T threshold/GeV	0.2	0.1	—	0.2	0.1	—
ε_T	41%	46%	48%	36%	37%	39%
P	89%	89%	88%	87%	87%	86%
$\varepsilon_T \cdot P$	0.37	0.41	0.42	0.28	0.32	0.34

Application on the Detector Material and Alignment Studies

Material studies:

- K_S^0 has high statistics, which could ensure it is populated inside the detector with fine granularity, and the detector material modeling could be done precisely at the small structure, even for the large decay radii and very forward region.
- K_S^0 has a large decay length ($c\tau \approx 2.7$ cm), which allows studying the detector material as a function of the radial position of the decaying vertex.

Application on the Detector Material and Alignment Studies

Alignment:

Some detector global distortions preserve the helicoidal trajectory of the tracks. Hence the track-based alignment algorithms have a low sensitivity to those distortions and it is difficult to correct them. We can tackle the problem using the invariant mass constraint of track pairs. This method limited by the maximum opening angle between decaying product, so the low mass of the K_S^0 makes it particularly suitable.

A Brief Touch on Other Mesons

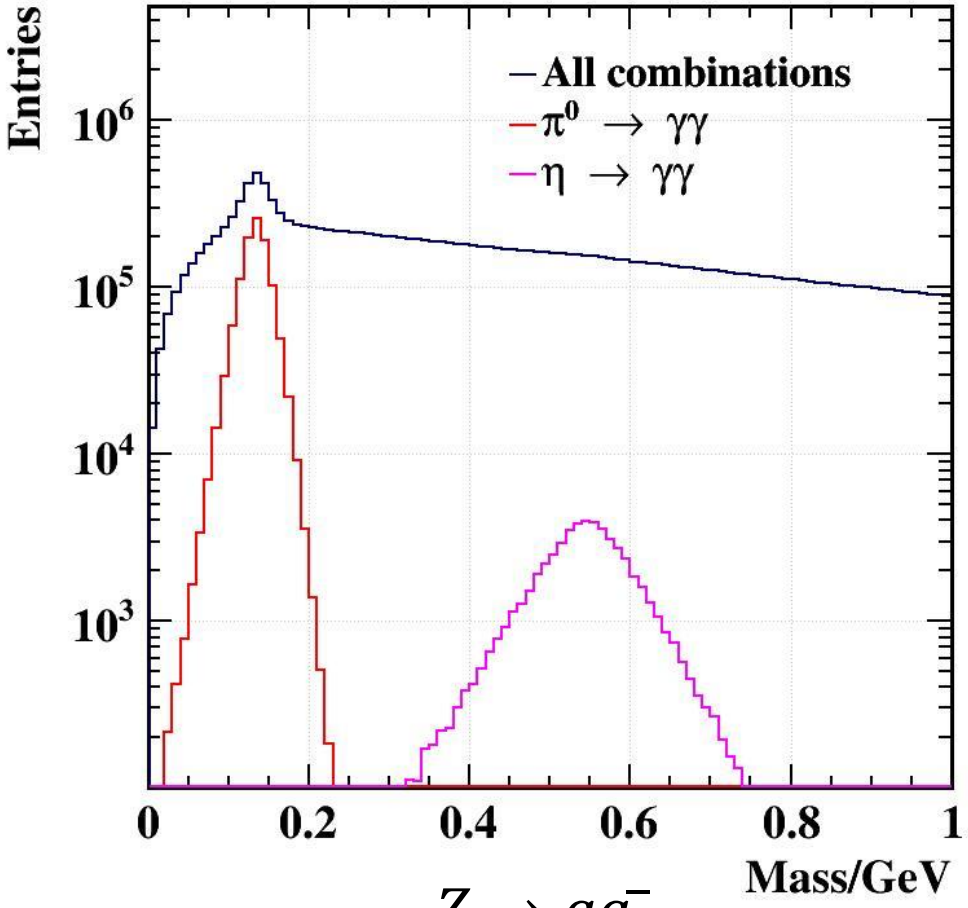
Using similar methods for other mesons:

ϕ: Mass: 1.02 GeV; full width = 4.3 MeV. $BR(\phi \to K^+K^-)$ = 48.9%. $\epsilon_R = 77\%, P = 72\%$.

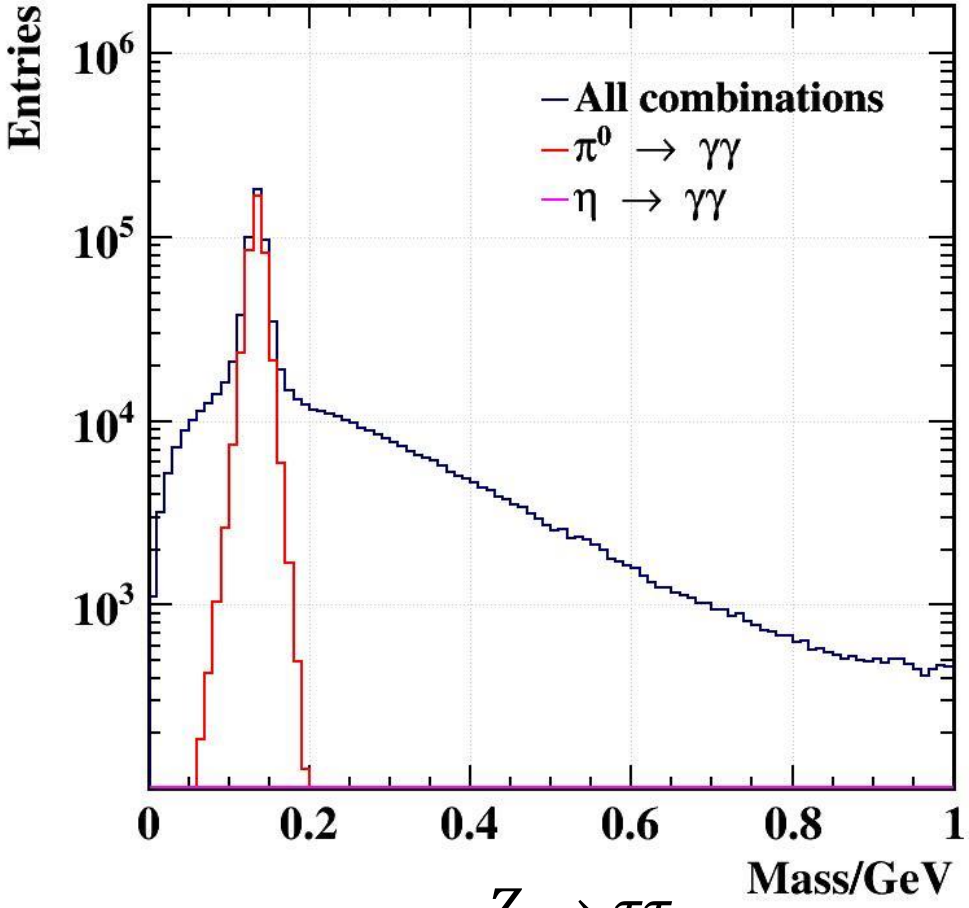
$K^*(892)^0$: Mass: 0.896 GeV; full width = 48.7 MeV. $BR(K^*(892)^0 \to K^+\pi^-) = 66.5\%$, $\epsilon_R = 21\%, P = 42\%$.

A Brief Touch on Other Mesons

Combinatory π^0 and η in fast simulation.



$Z \rightarrow q\bar{q}$



$Z \rightarrow \tau\tau$