Reconstruction of K short and Λ at CEPC Baseline Detector

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Introduction

Expected boson yields at CEPC

Operation mode	Z factory	W threshold scan	Higgs factory
$\sqrt{s}$/GeV	91.2	158 - 172	240
L/$10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	16-32	10	3
Running time/year	2	1	7
Integrated Luminosity/ab^{-1}	8 - 16	2.5	5
Higgs yield	-	-	10^6
W yield	-	10^7	10^8
Z yield	10^{11-12}	10^9	10^9

Introduction

Importance of Z(and W)

- 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 about 10^{12} Z bosons
- Etc…

Introduction

Z decay modes:

- Leptonic: 10%
- Invisible: 20%
- Hadronic: 70%

We will try to reconstruct its neutral hadronic decay products.
Starting from K short, because:

- On average, 1 Ks per $Z \rightarrow qq$ event.
- Has a high probability to decay into a pair of charged pions (leave tracks)
- To study CP violation in $\tau \rightarrow \pi$+Ks+ν
- Can be used to evaluate detector performance

etc …

Introduction

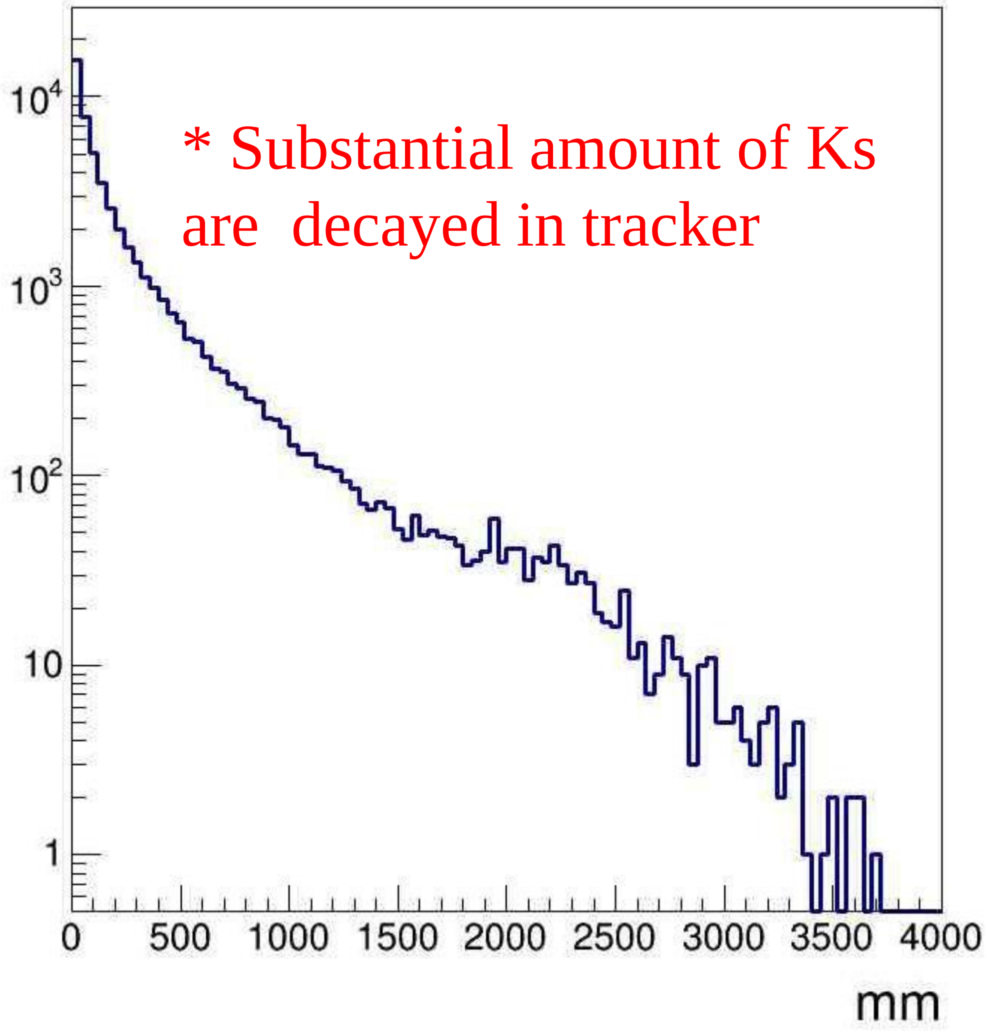
K short info:

- Mass: 497.6 MeV
- $c\tau$ = 2.68 cm
- Decay modes:

  $\pi^0\pi^0$: 30.7 %

  $\pi^+\pi^-$: 69.2 %

Arbor can only reconstruct final state particles, an algorithm on top of this is needed to reconstruct decayed particles.



Distance Ks traveled in Z→qq events (Ks end point to IP distance)

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We will reconstruct Ks through this mode

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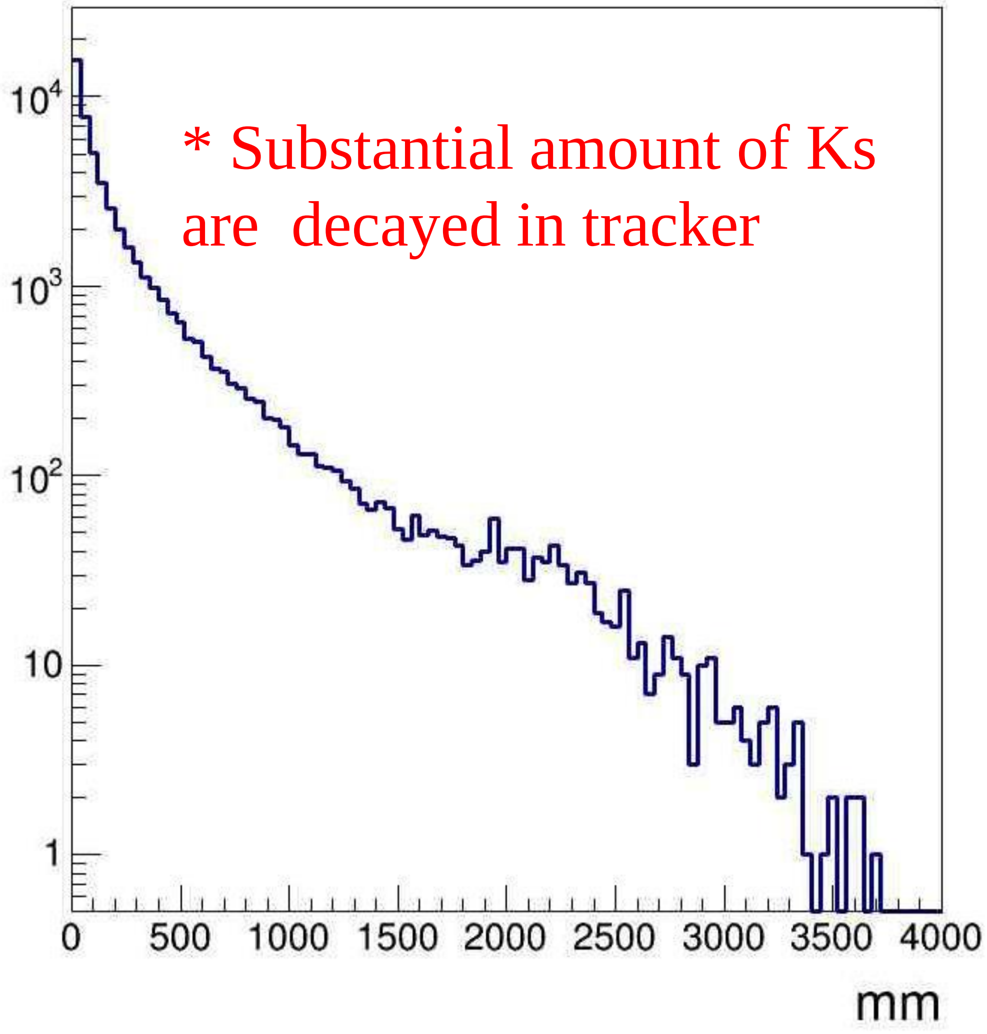
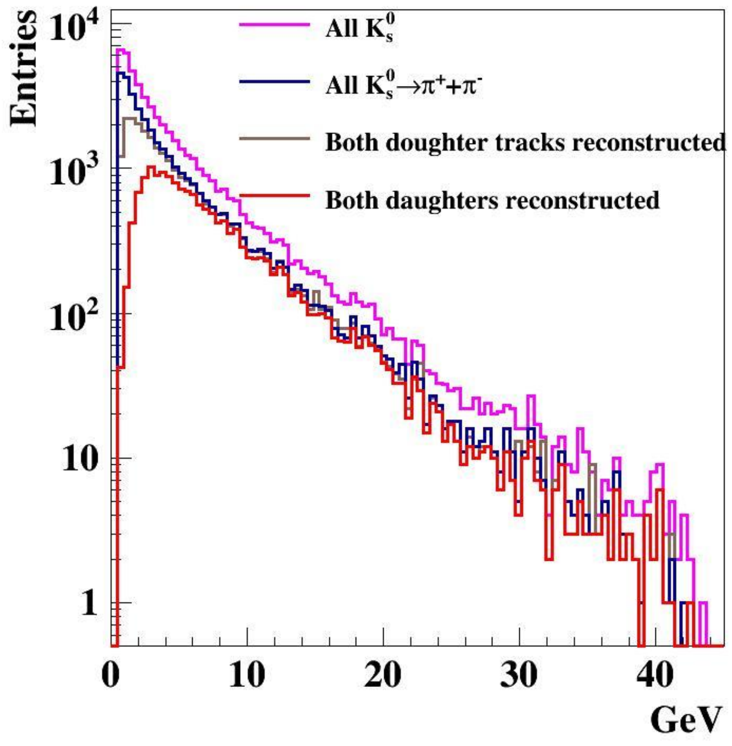


Distance Ks traveled in Z→qq events (Ks end point to IP distance)

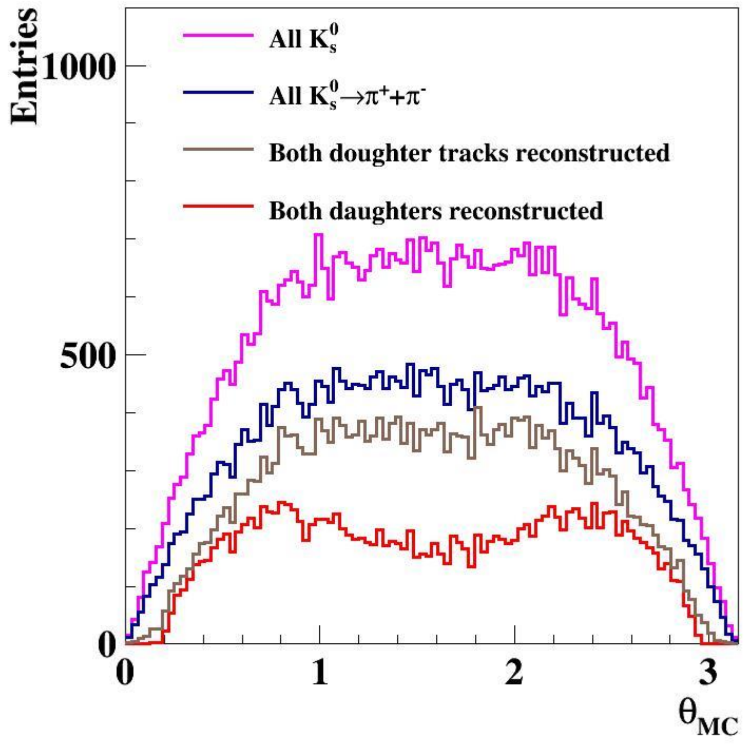
Simulation Sample

$5*10^4$ Z→qq events:

Total Ks truth: 50093	100%
Decayed into $\pi^+\pi^-$:	67.9%
Both $\pi^+\pi^-$ tracks are reconstructed:	51.7%
Both $\pi^+\pi^-$ are reconstructed:	31.1%
Both PID are correct:	29.4%



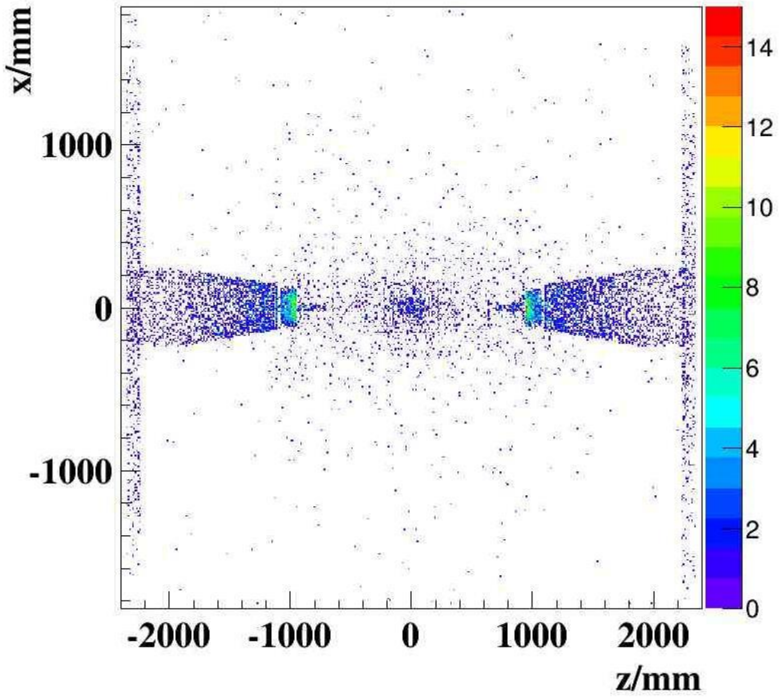
E_{Ks}



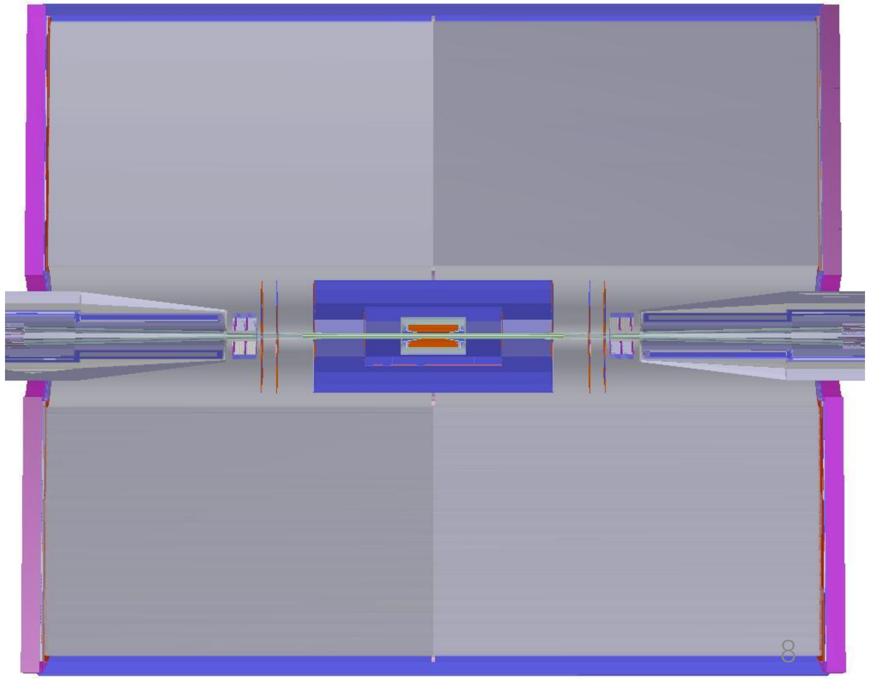
θ_{Ks}

What Happened to Lost Pions?

Let's look at π^+.		
Total π^+ decayed from Ks: 33993	100%	
Interacted with tracker material or decayed:	37.0%	
But still have tracks:		66.9%(of 37.0%)
And π^+ is reconstructed:		13.6%(of 37.0%)
Neither interacted nor decayed:	63.0%	
And have tracks:		96.4%(of 63.0%)
And $\pi+$ is reconstructed:		91.0%(of 63.0%)

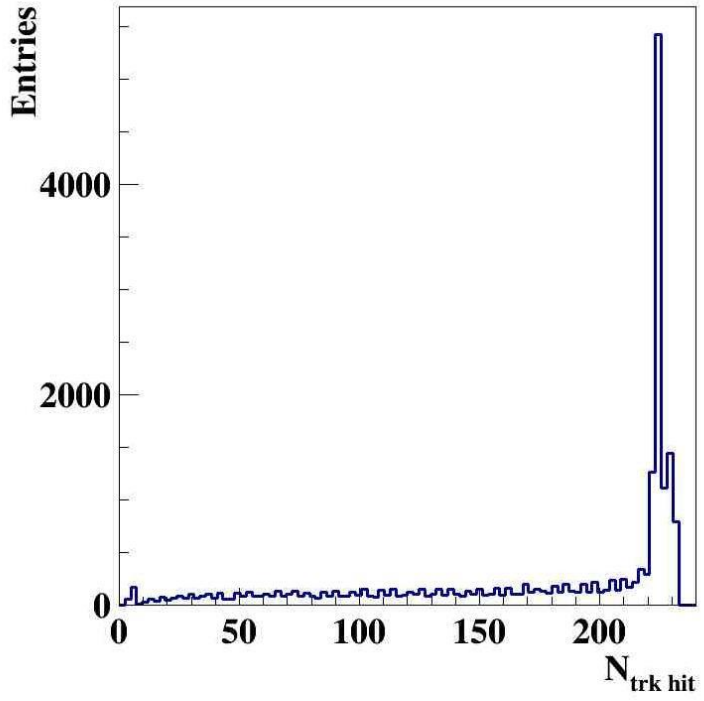


π^+ end points in tracker
&
CEPC tracker layout

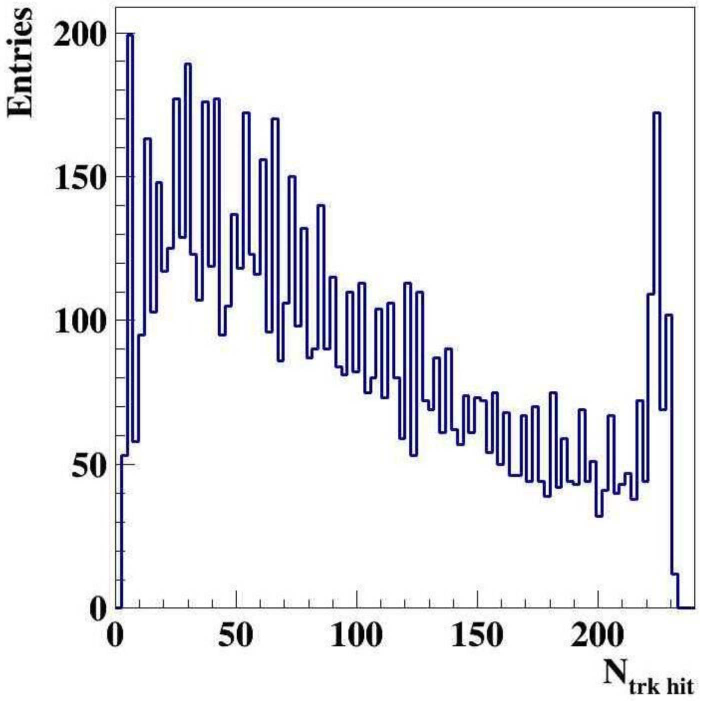


What Happened to Lost Pions?

π^+ N(tracker hits) distribution



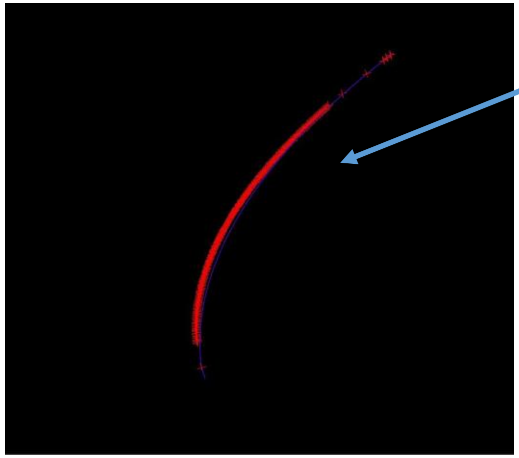
Neither interacted nor decayed



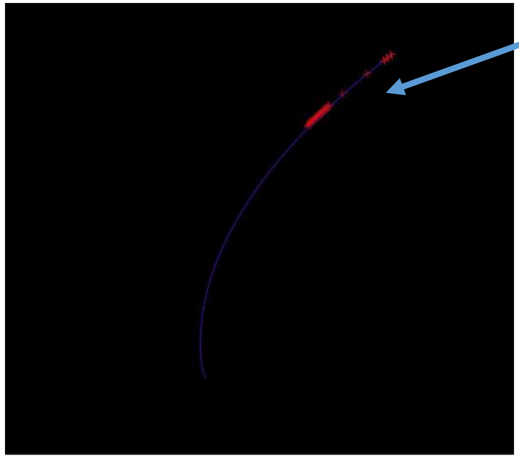
Interacted or decayed

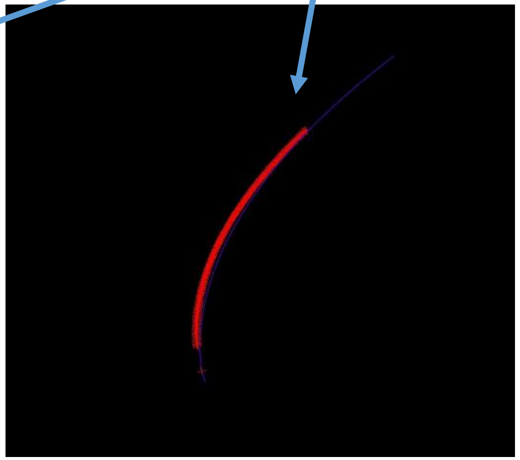
Broken Tracks

Tracker hits left by the particle

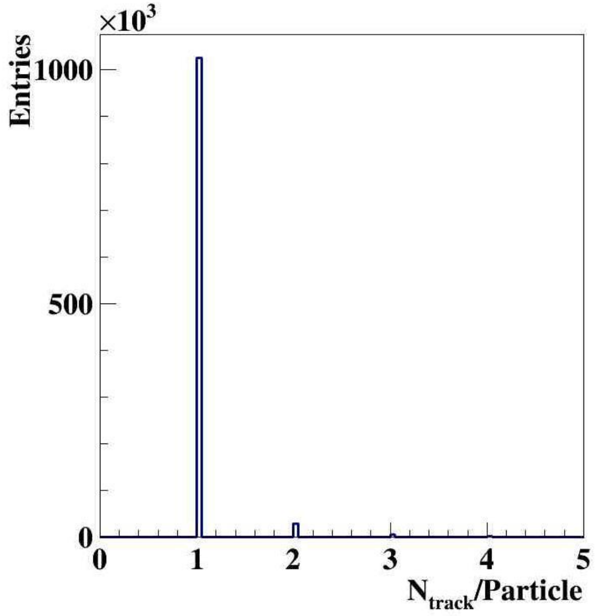


The track reconstruction algorithm broke them into two tracks





A singled out 1.6GeV e$^-$ in the sample



N(track) per particle

Reconstruction Method

1. Assume all tracks belong to charged pions.

2. Find the K short decay point(secondary vertex) using a pair of opposite curvature tracks.

3. Reconstruct K short 4-momentum at vertex.

4. Reconstruct K short flight path, check its vicinity with IP.

5. Perform appropriate cuts along the way

    1) Closest distance between two tracks

    2) K short mass

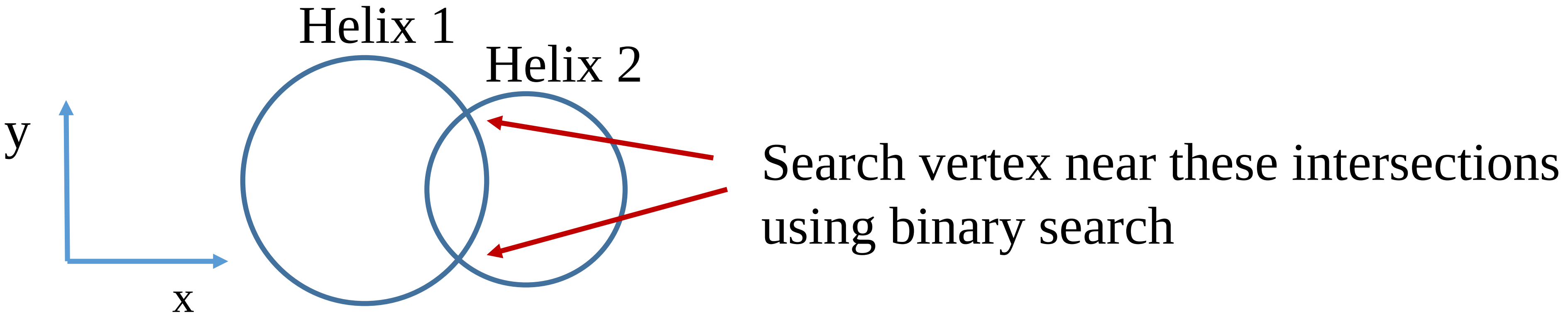
    3) K short flight path line to IP distance / length of flight

Secondary Vertex Finding(Preliminary Method)

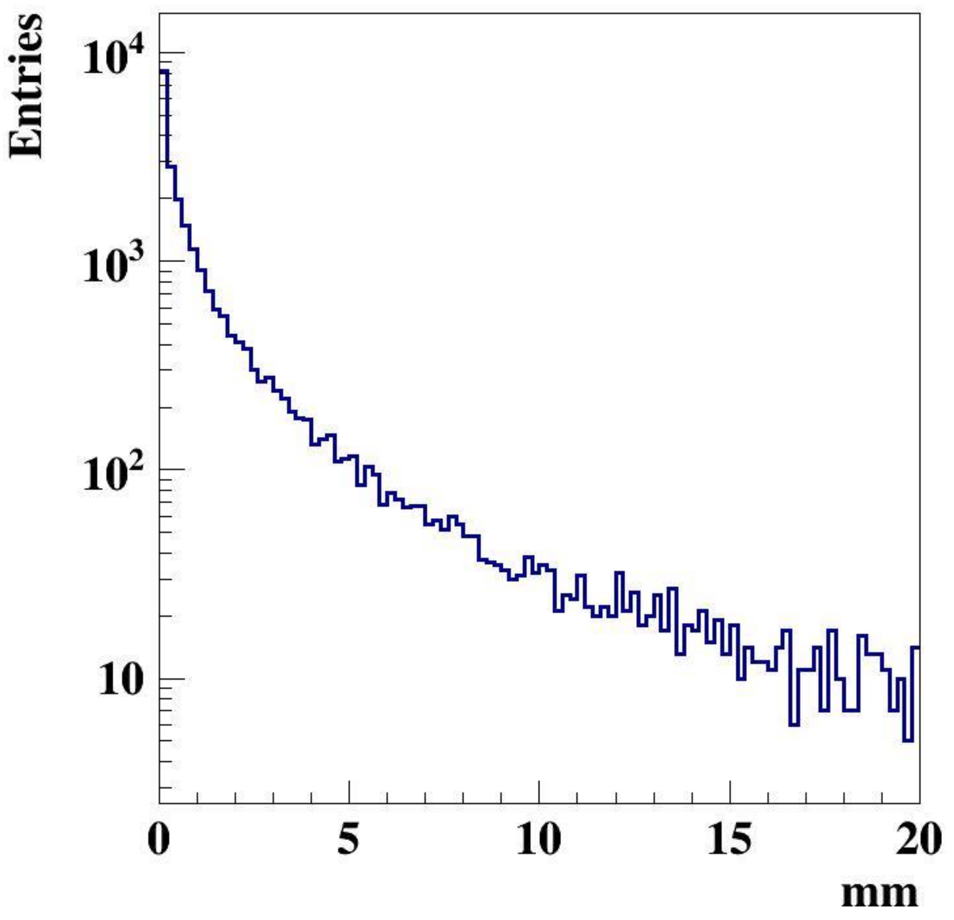
1. Find a pair of opposite curvature tracks.

2. Determine track helix using track parameters. Pick one loop of helix near IP.

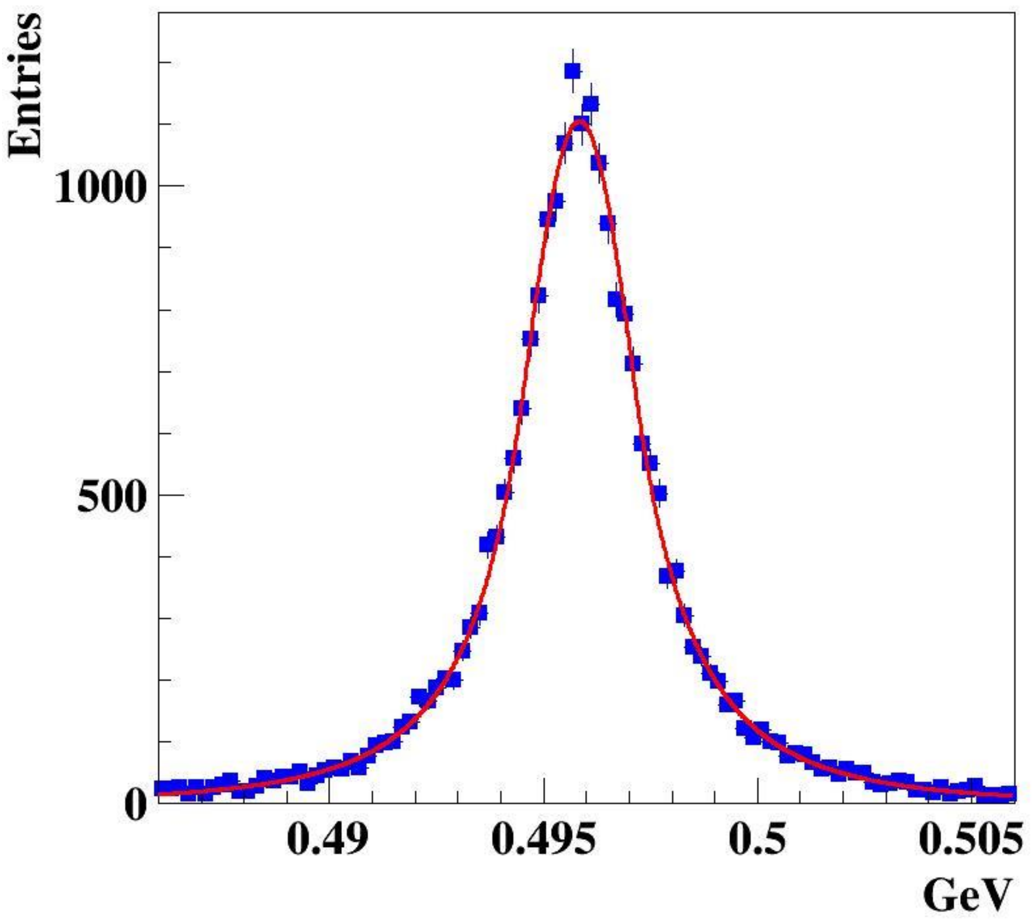
3. Apply geometric method to find possible vertex, i.e. the point where the distance between two tracks are very close.



Test the Algorithm Using Known K short Daughter Tracks

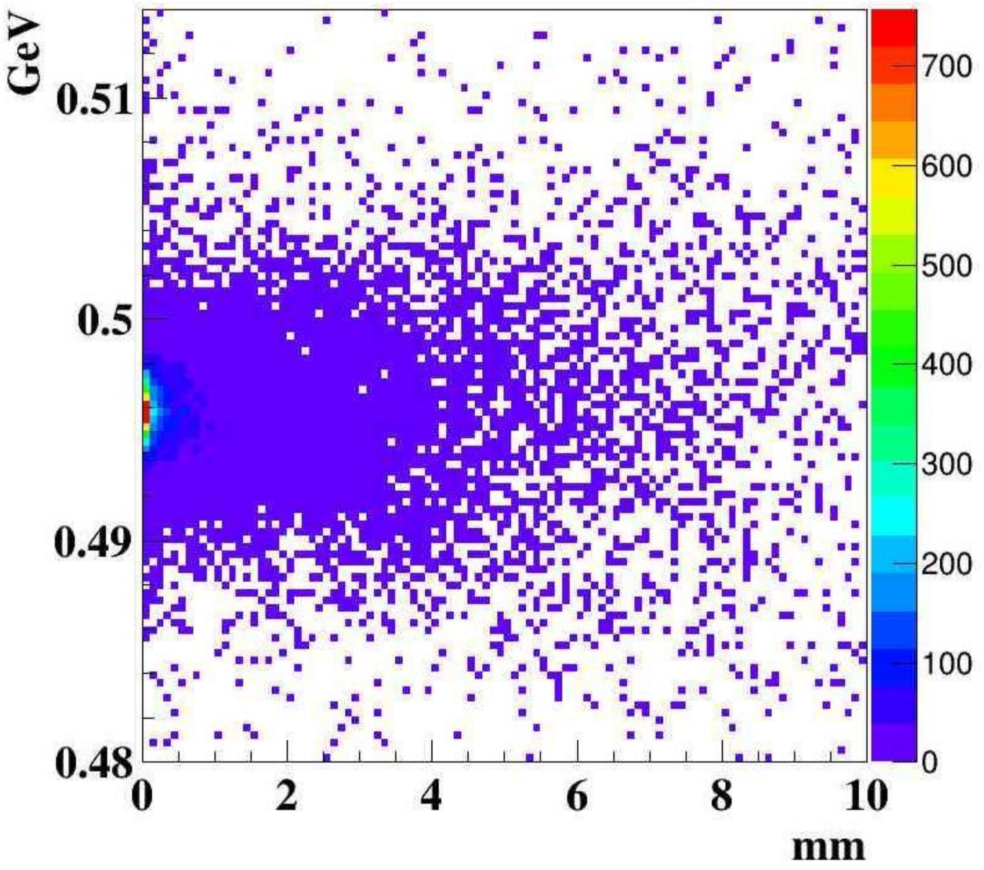


Vertex reconstruction error

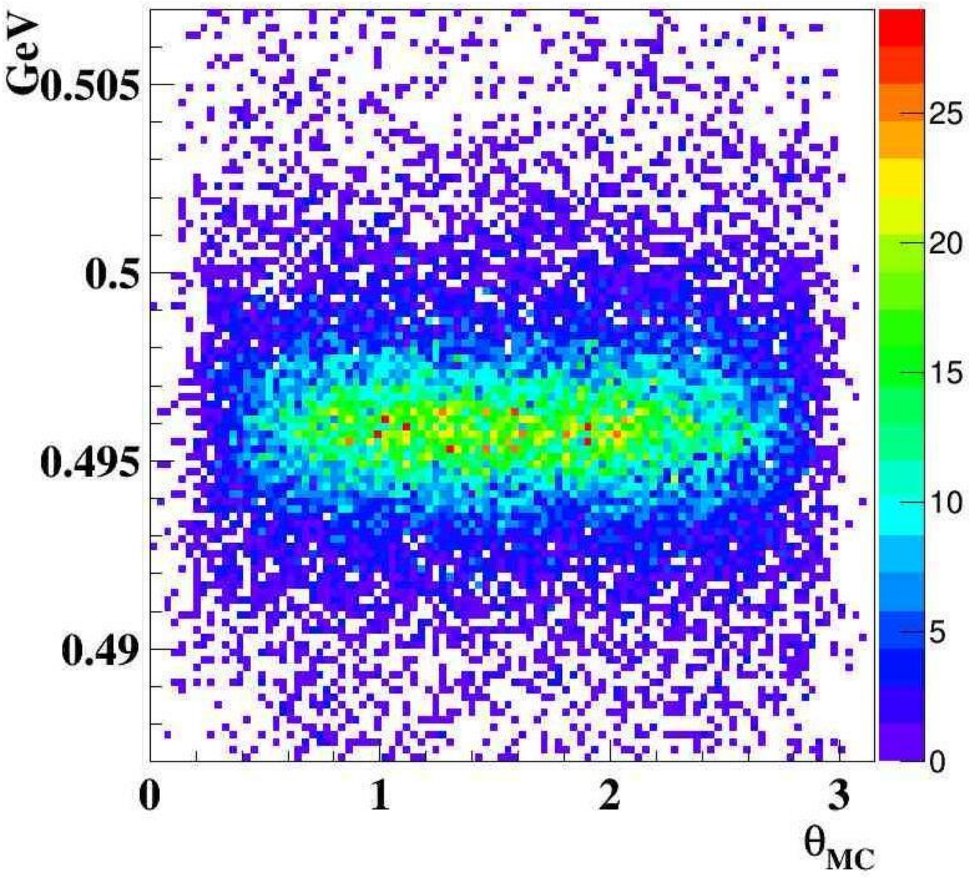


K short mass resolution: 0.26%

Test the Algorithm Using Reconstructed K short Daughters

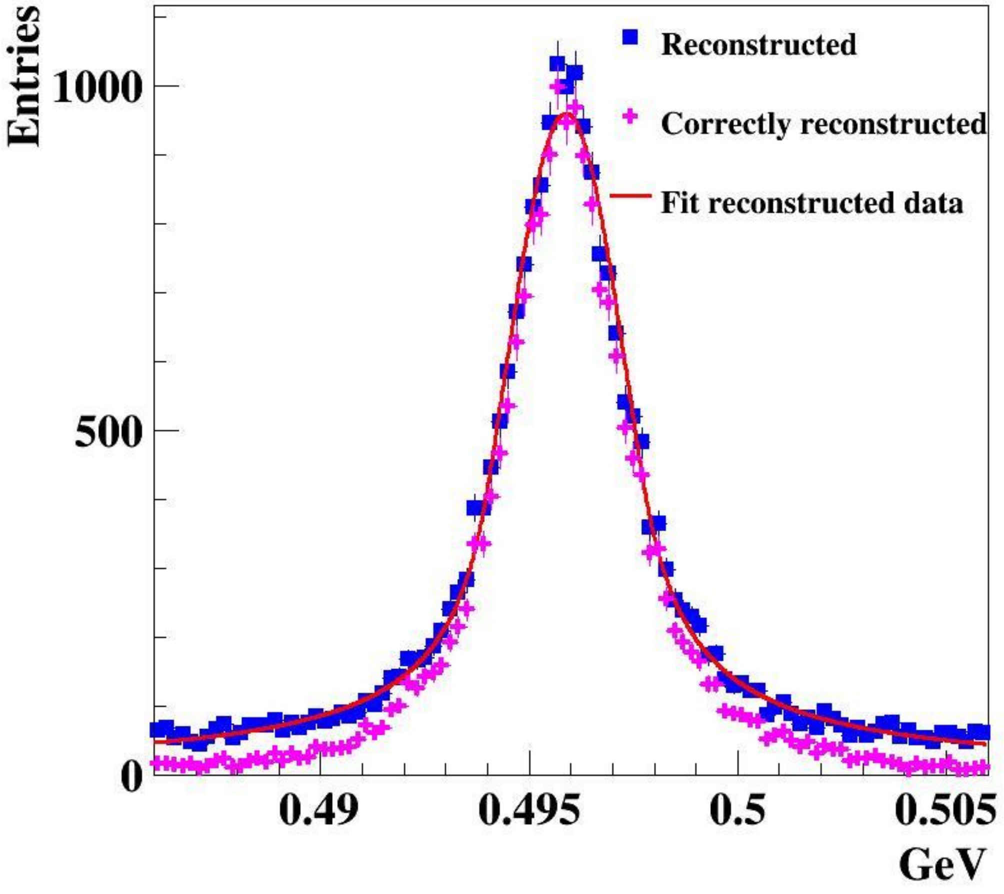


Ks mass vs Vertex error



Ks mass vs θ_{Ks}

Apply the Algorithm in the Simulation Sample



Reconstructed Ks mass
Mass resolution: 0.29%
Efficiency: 74.9%
Purity: 81.6%

$$\text{Efficiency} = \frac{N(\text{Correctly reconstructed Ks})}{N(\text{Ks with both daughter tracks reconstructed})}$$

$$\text{Purity} = \frac{N(\text{Correctly reconstructed Ks})}{N(\text{All reconstructed Ks})}$$

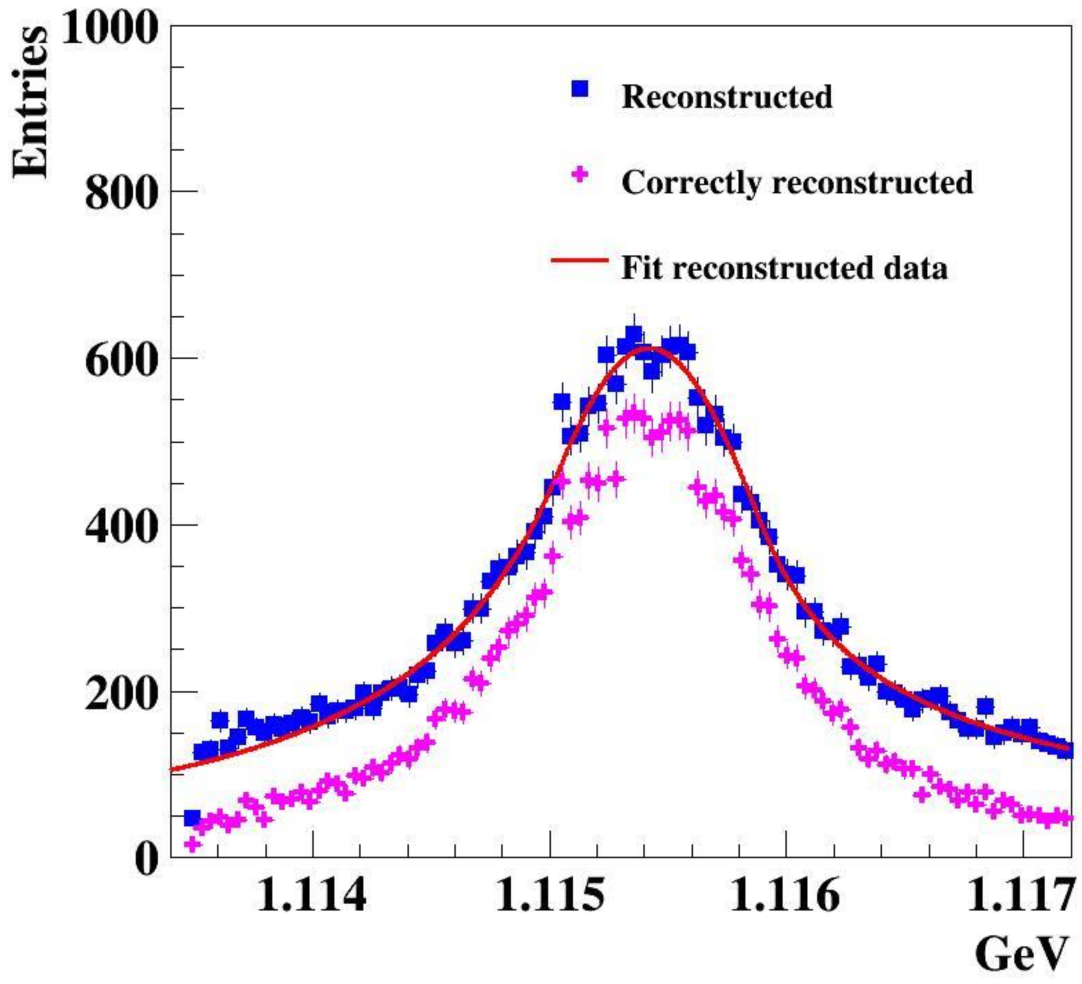
Background Analysis

72% from random combinations
12% from $\Lambda \rightarrow$ proton + π^- (proton identified as π^+)
6% from $\omega(782) \rightarrow \pi^+ + \pi^- + \pi^0$
10% from others

```
Same parent: 1232             28.083 %
            Parent PDGID = 223: 386       8.79872 %
            Parent PDGID = 3122: 279       6.3597 %
            Parent PDGID = -3122: 253       5.76704 %
            Parent PDGID = 22: 50       1.13973 %
            Others:             264         6.01778 %
Different parent: 3155        71.917 %
       Pi+  Parent PDGID = 223: 471       10.7363 %
       Pi+  Parent PDGID = 213: 403       9.18623 %
       Pi+  Parent PDGID = 113: 374       8.52519 %
       Pi+  Parent PDGID = 92: 237       5.40233 %
       Pi+  Parent PDGID = 310: 144       3.28243 %
       Pi+  Parent PDGID = 323: 128       2.91771 %
       Pi+  Parent PDGID = 10213: 114       2.59859 %
       Pi+  Parent PDGID = 221: 112       2.553 %
       Pi+  Parent PDGID = 313: 92       2.09711 %
       Pi+  Parent PDGID = -421: 73       1.66401 %
       Pi+  Parent PDGID = -313: 66       1.50444 %
       Pi+  Parent PDGID = 211: 62       1.41327 %
       Pi+  Parent PDGID = 413: 56       1.2765 %
       Pi+  Parent PDGID = 421: 44       1.00296 %
            Others:             779         17.757 %
```

If Arbor implements proper PID, some backgrounds could be eliminated through track-particle matching.

Reconstructing Λ through Λ →proton + π^- in the Simulation Sample



Reconstructed Λ mass:
Mass resolution: 0.046%
Efficiency: 67.6%
Purity: 68.9%

Background Analysis

65% from random combinations
14% from Ks→ $\pi^+\pi^-$(π^+ identified as proton)
10% from photon daughters
11% from others

```
Same parent: 3152            34.5993 %
            Parent PDGID = 310: 1256        13.787 %
            Parent PDGID = 22: 944         10.3622 %
            Parent PDGID = 223: 447         4.9067 %
            Parent PDGID = 221: 104         1.1416 %
            Others:            401           4.40176 %
Different parent: 5958       65.4007 %
     proton Parent PDGID = 213: 809         8.88035 %
     proton Parent PDGID = 113: 782         8.58397 %
     proton Parent PDGID = 92: 743         8.15587 %
     proton Parent PDGID = 223: 729         8.0022 %
     proton Parent PDGID = -421: 283         3.10648 %
     proton Parent PDGID = 323: 277         3.04061 %
     proton Parent PDGID = 10213: 249         2.73326 %
     proton Parent PDGID = 313: 202         2.21734 %
     proton Parent PDGID = -313: 113         1.2404 %
     proton Parent PDGID = 421: 102         1.11965 %
            Others:             1669          18.3205 %
        Pi- Parent PDGID = 223: 1336         14.6652 %
        Pi- Parent PDGID = -213: 502         5.51043 %
        Pi- Parent PDGID = 113: 468         5.13721 %
        Pi- Parent PDGID = -413: 405         4.44566 %
        Pi- Parent PDGID = 22: 399         4.3798 %
        Pi- Parent PDGID = 310: 294         3.22722 %
        Pi- Parent PDGID = 221: 289         3.17234 %
        Pi- Parent PDGID = -323: 187         2.05269 %
        Pi- Parent PDGID = -10213: 170         1.86608 %
        Pi- Parent PDGID = 111: 164         1.80022 %
        Pi- Parent PDGID = 92: 164         1.80022 %
        Pi- Parent PDGID = 313: 121         1.32821 %
        Pi- Parent PDGID = -211: 117         1.2843 %
            Others:             1342          14.7311 %
```

If Reconstructed with Reconstructed Particles that Have Tracks

Almost similar to the previous method, but (in theory) we know which particle does a track belongs to.

For Ks:

- Mass Resolution: 0.29%→0.27%
- Efficiency: 74.9%→48.2%
- Purity: virtually same(~80%)

For Λ(need to cheat proton PID):

- Mass Resolution: 0.046%→0.037%
- Efficiency: 67.6%→39.8%
- Purity: 68.8%→94.4%

Thank You!