# Reconstruction of K short and $\Lambda$ at CEPC Baseline Detector

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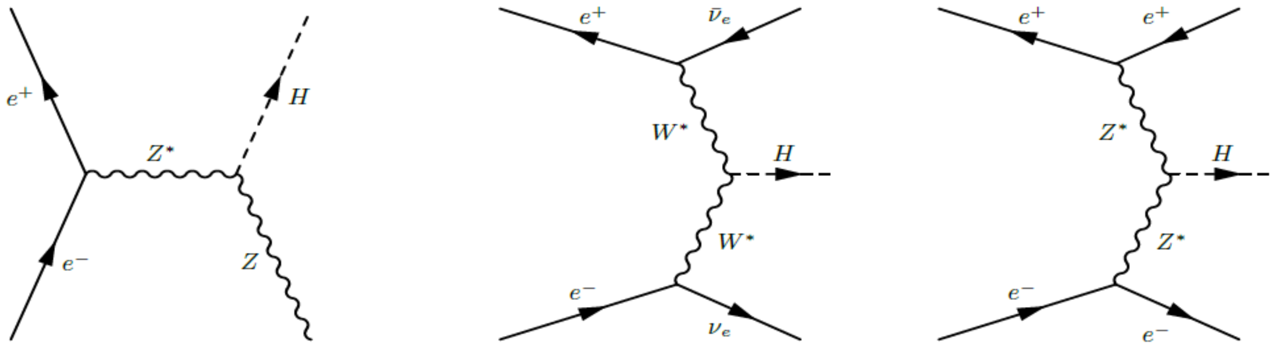
## Introduction

Expected boson yields at CEPC

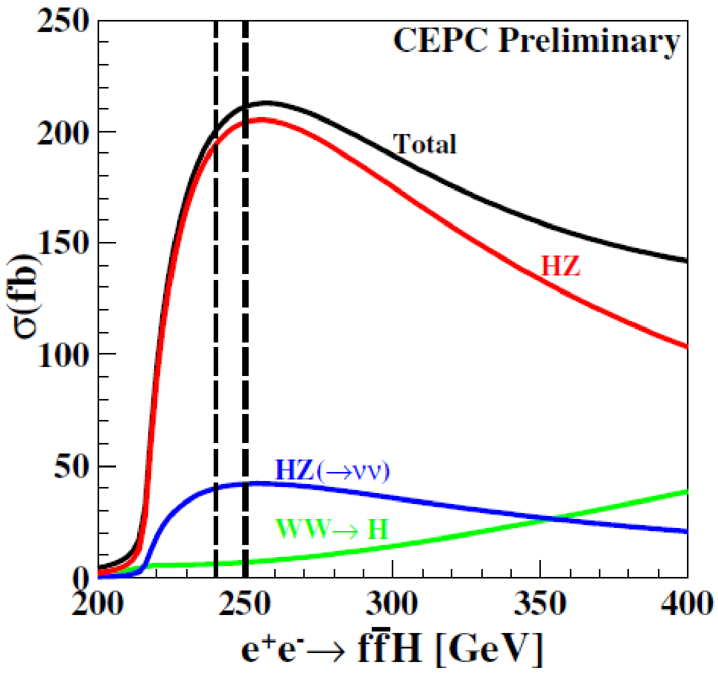
| Operation mode | $Z$ factory | $W$ threshold scan | Higgs factory |
|---|---|---|---|
| $\sqrt{s}$/GeV | 91.2 | 158 - 172 | 240 |
| $\mathrm{L}/10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ | 16-32 | 10 | 3 |
| Running time/year | 2 | 1 | 7 |
| Integrated Luminosity/$\mathrm{ab}^{-1}$ | 8 - 16 | 2.5 | 5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

## Introduction

Main Higgs production channels in CEPC




Feynman diagrams of the $e^+e^- \to ZH$, $e^+e^- \to \nu\bar{\nu}H$ and $e^+e^- \to e^+e^-H$ processes.




Higgs production cross sections

- Z is most numerous & most important for Higgs production
- Z is also important for flavor physics

## 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→qq event.
- Has high probability to decay into a pair of charged pions (leave tracks)
- To study CP violation in $\tau \to \pi + K_s + \nu$
- Can be used to evaluate detector performance

etc …

## Introduction

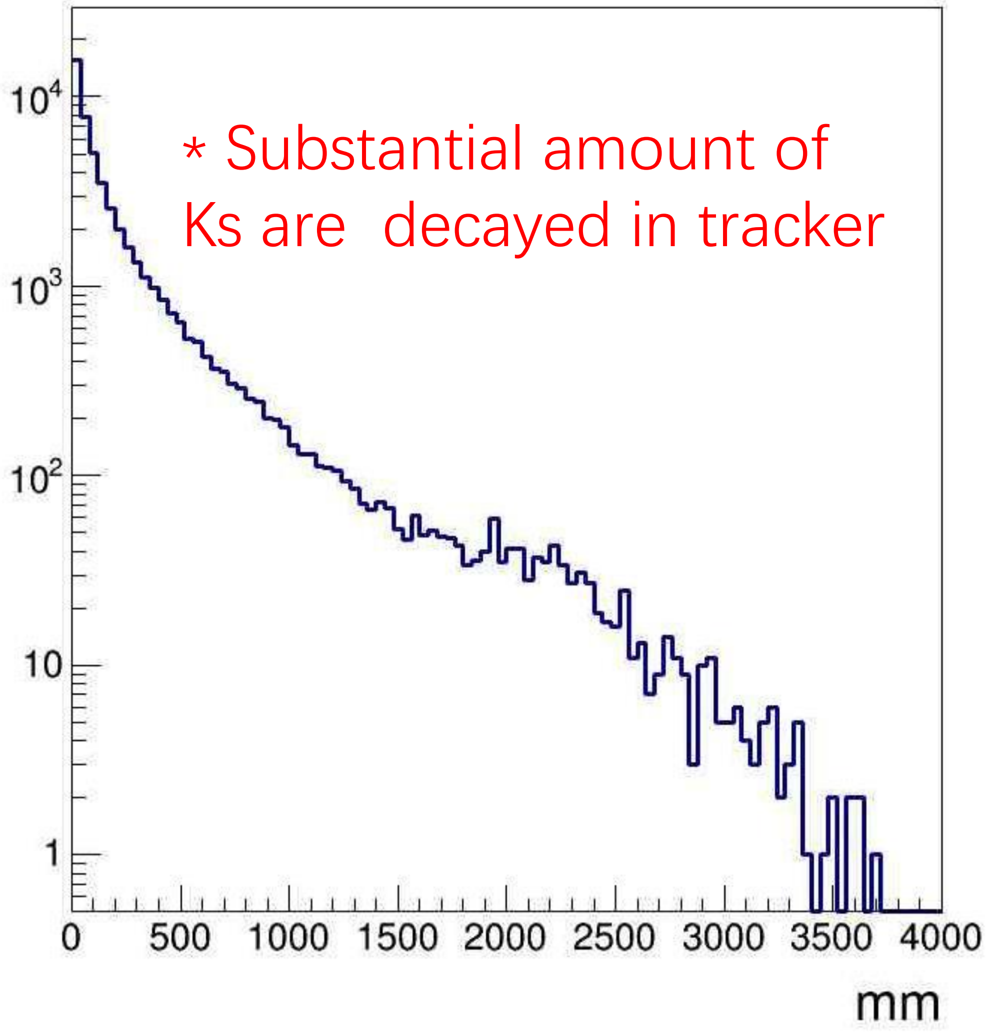
K short info:

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

  $\pi0\pi0$ : 30.7 %

  $\pi+\pi-$: 69.2 %

Arbor, the current particle reconstruction algorithm can only reconstruct final state particles, we need another one on top of that to reconstruct K short decayed in tracker.




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

## Introduction

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  $\boxed{\pi^+\pi^-: 69.2\ \%}$

We will reconstruct Ks through this mode

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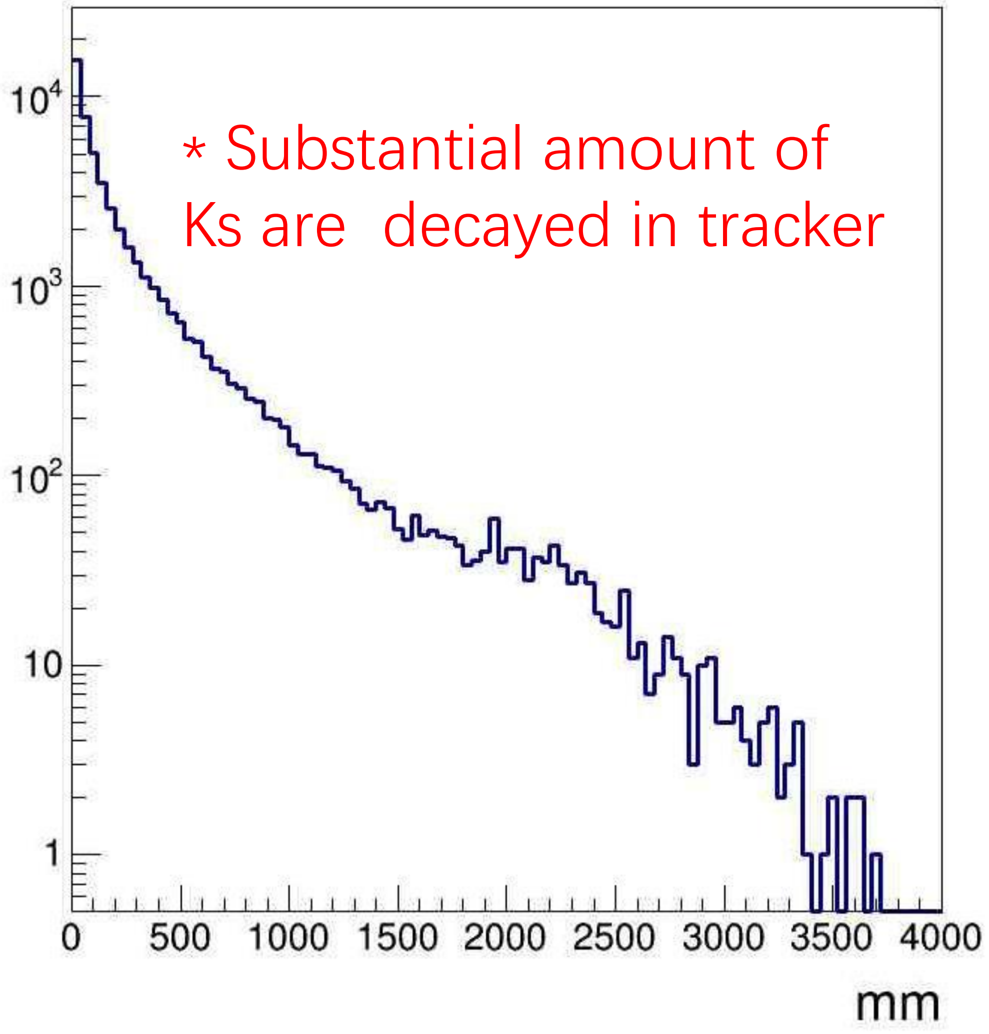



Distance from Ks end point to its origin(IP)

## Simulation Sample

5x10^4 Z→qq events.

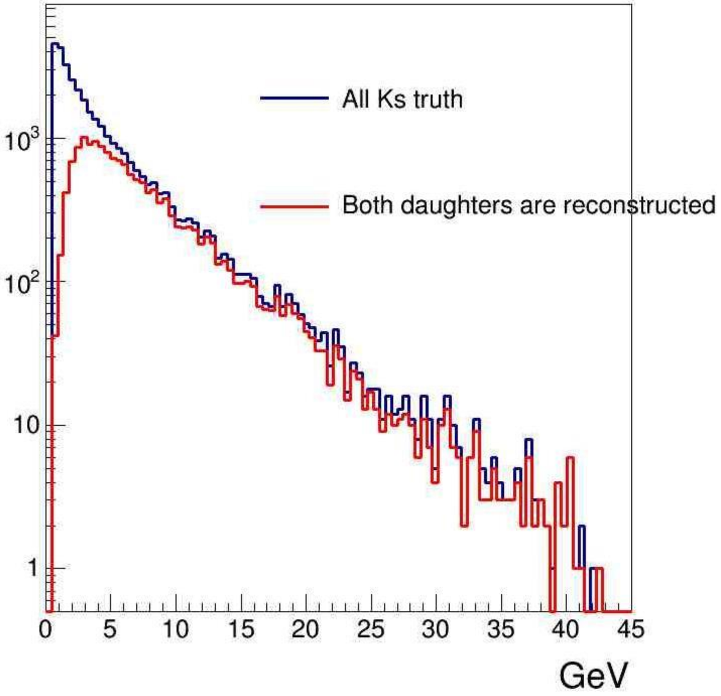
Total Ks truth: 50093

Decayed into π+π- : 33993

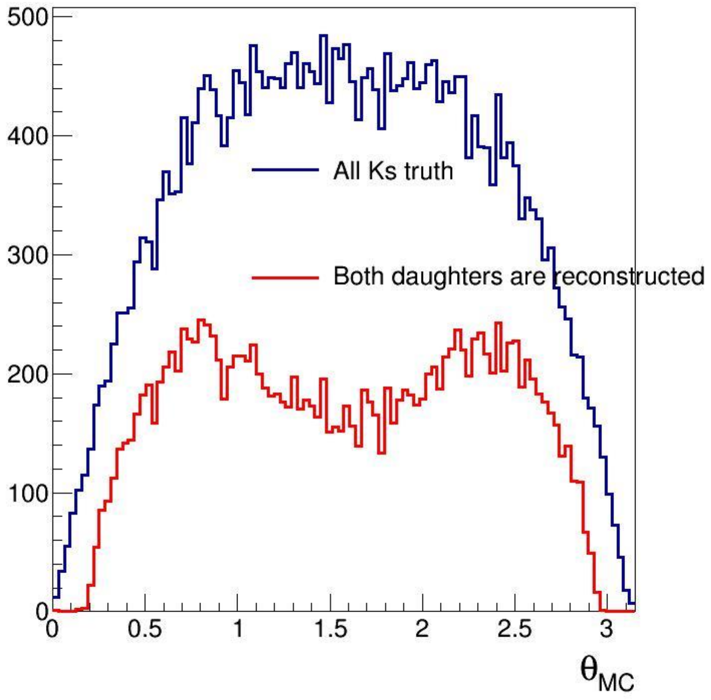
Both daughters are reconstructed: 15561 →Denominator of efficiency

Both PID are correct: 14734

Both of daughters are reconstructed only 46% of the time




Ks energy

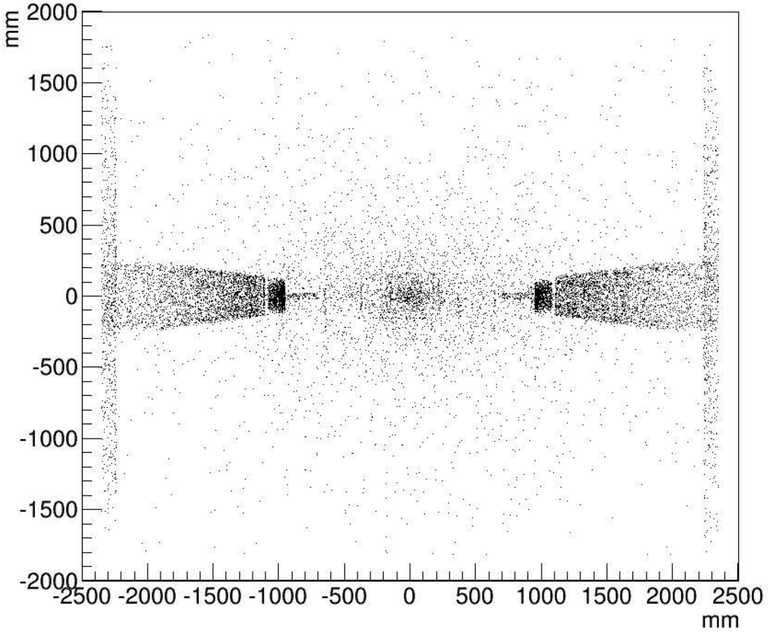



Ks direction

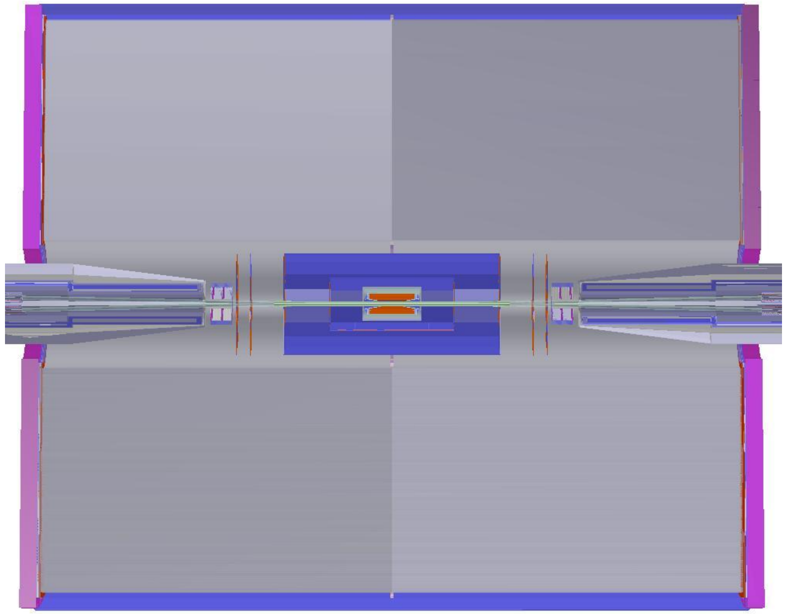
## Where are the lost pions?

Take π+ as an example:
Among 33993 π+ created, 30% interacted with tracker, 7.2% decayed in the tracker, most of these aren't reconstructed.

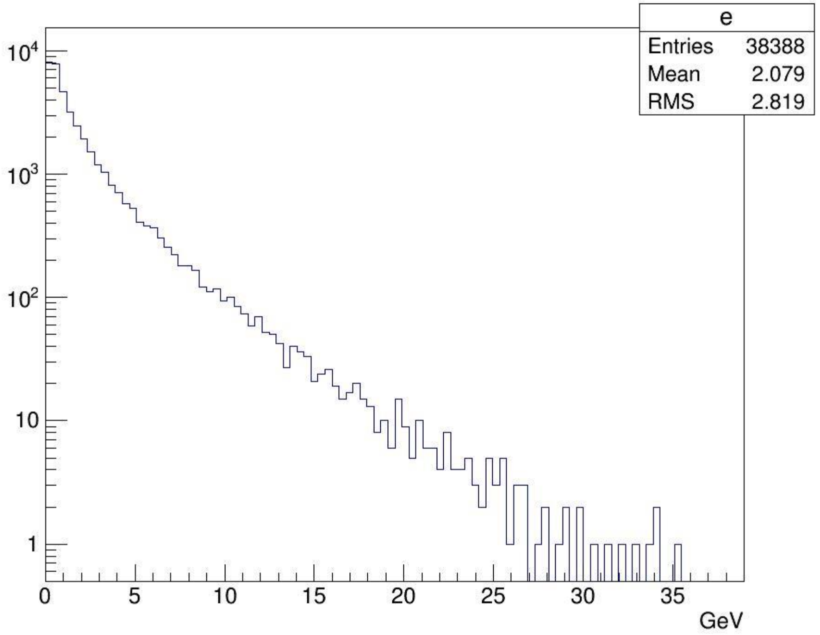
π+ end points in tracker




CEPC tracker layout



π+ energy distribution



## Loss of Efficiency Through PID

5.3 % of efficiency is lost because of PID, their statistics are as follows

```
Pi+ PID is wrong: 415
    Pi+ identified as PDGID = -13: 263          31.8017 %
    Pi+ identified as PDGID = -11: 116          14.0266 %
    Pi+ identified as PDGID = -211: 34          4.11125 %
    Pi+ identified as PDGID = 13: 2          0.241838 %
Pi- PID is wrong: 429
    Pi- identified as PDGID = 13: 274          33.1318 %
    Pi- identified as PDGID = 11: 116          14.0266 %
    Pi- identified as PDGID = 211: 37          4.474 %
    Pi- identified as PDGID = -13: 2          0.241838 %
```

**Reconstruction Method**

1. Find the K short decay point(secondary vertex) using a pair of $\pi+\pi-$ tracks.

2. Reconstruct K short 4-momentum at vertex.

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

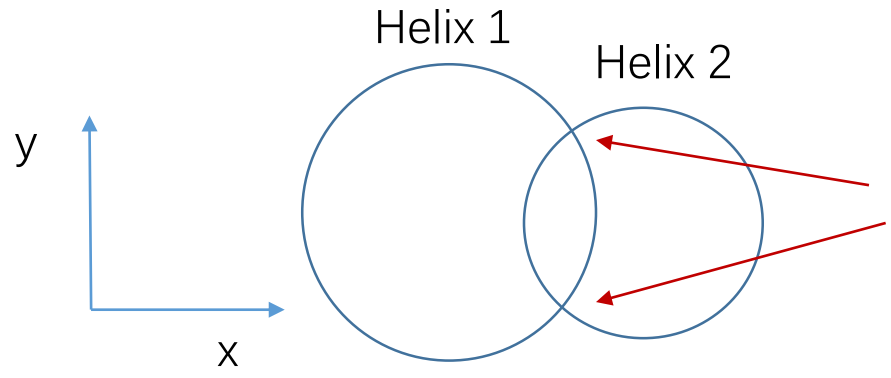
4. Perform appropriate cuts along the way
    1) Closest distance between two tracks
    2) K short mass
    3) K short flight path line to IP distance / length of flight

## Secondary Vertex Finding(Preliminary Method)

1. Find a pair of π+ and π-.

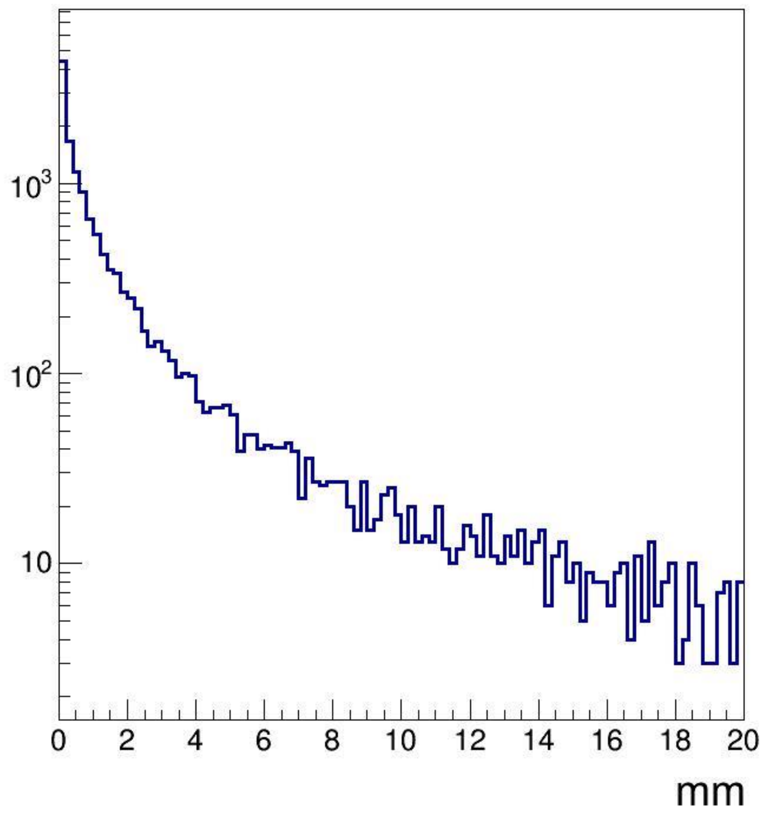
2. Determine track helix using track parameters. Pick one loop of helix near IP.

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

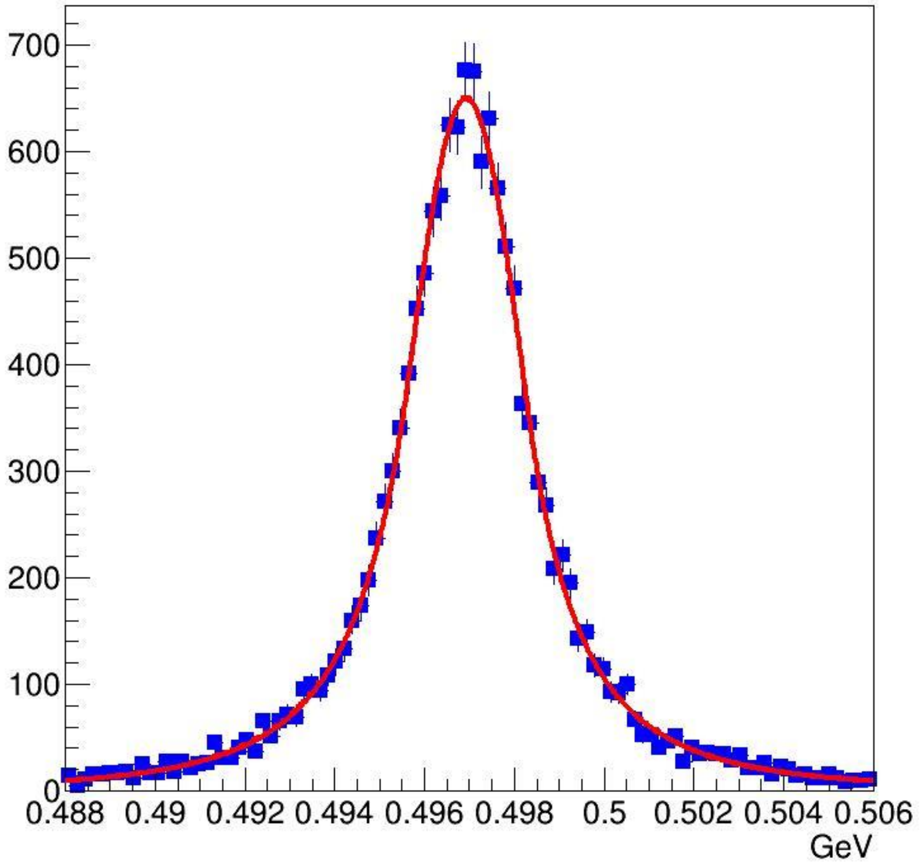



Find vertex near these intersections using binary search

# Test the Algorithm Using Reconstructed K short Daughters




Vertex reconstruction error




K short mass resolution: 0.25%

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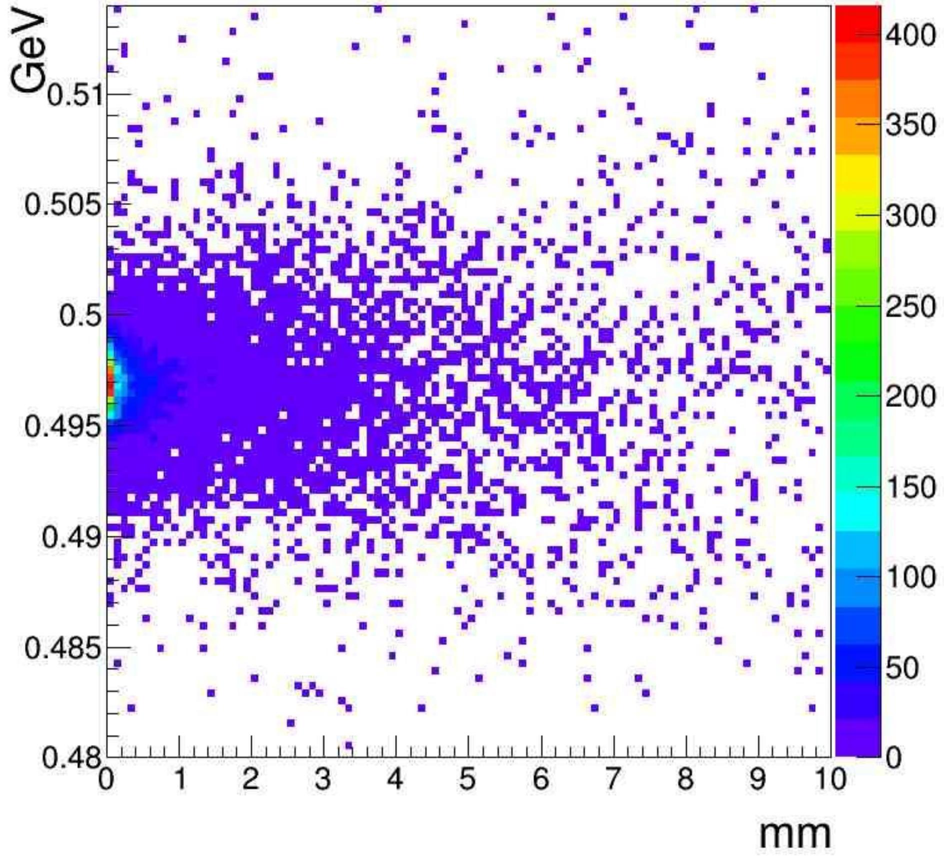
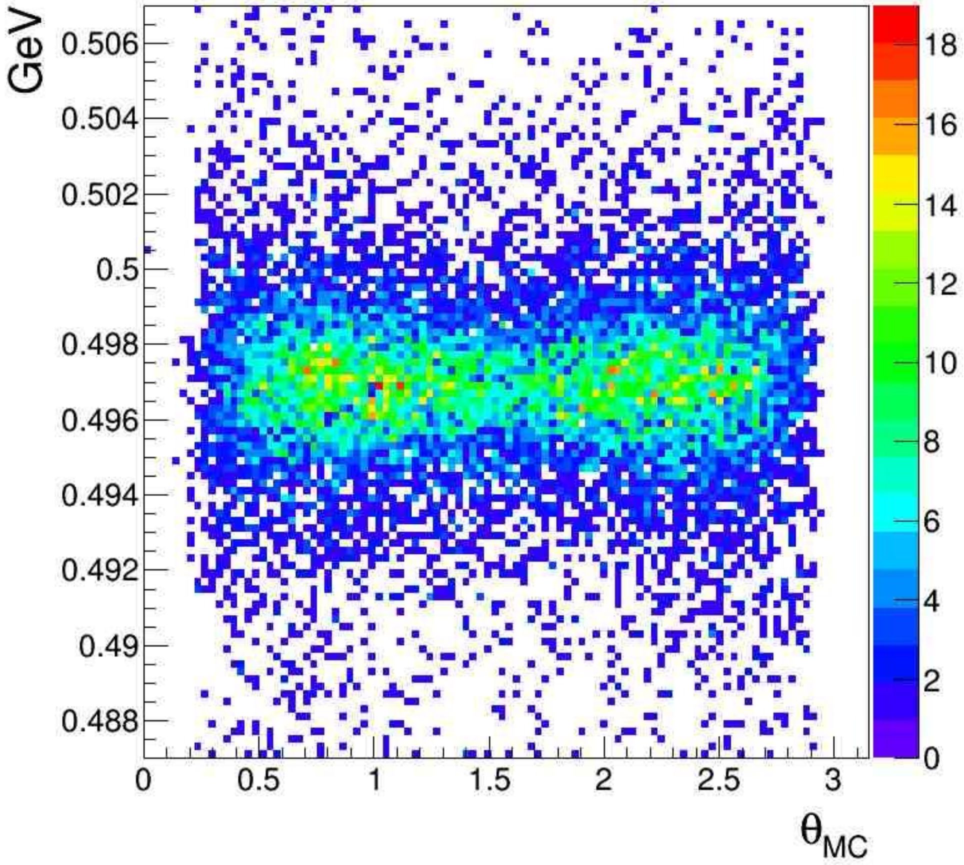
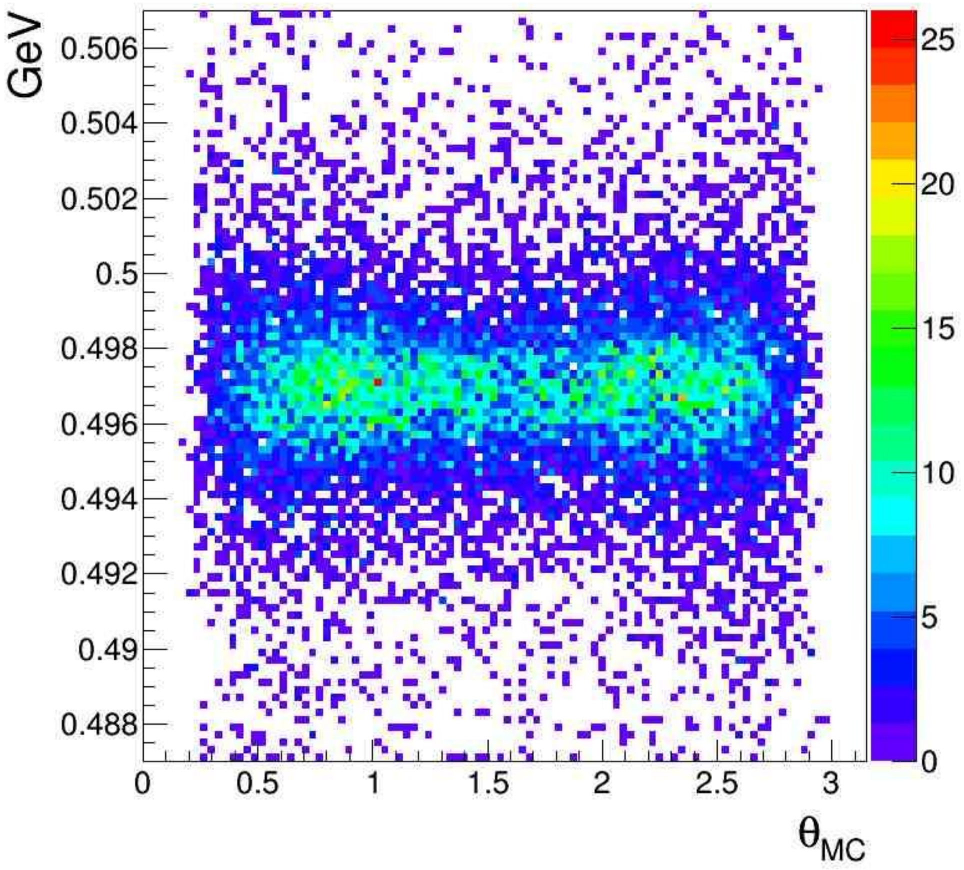



Ks mass vs Vertex error

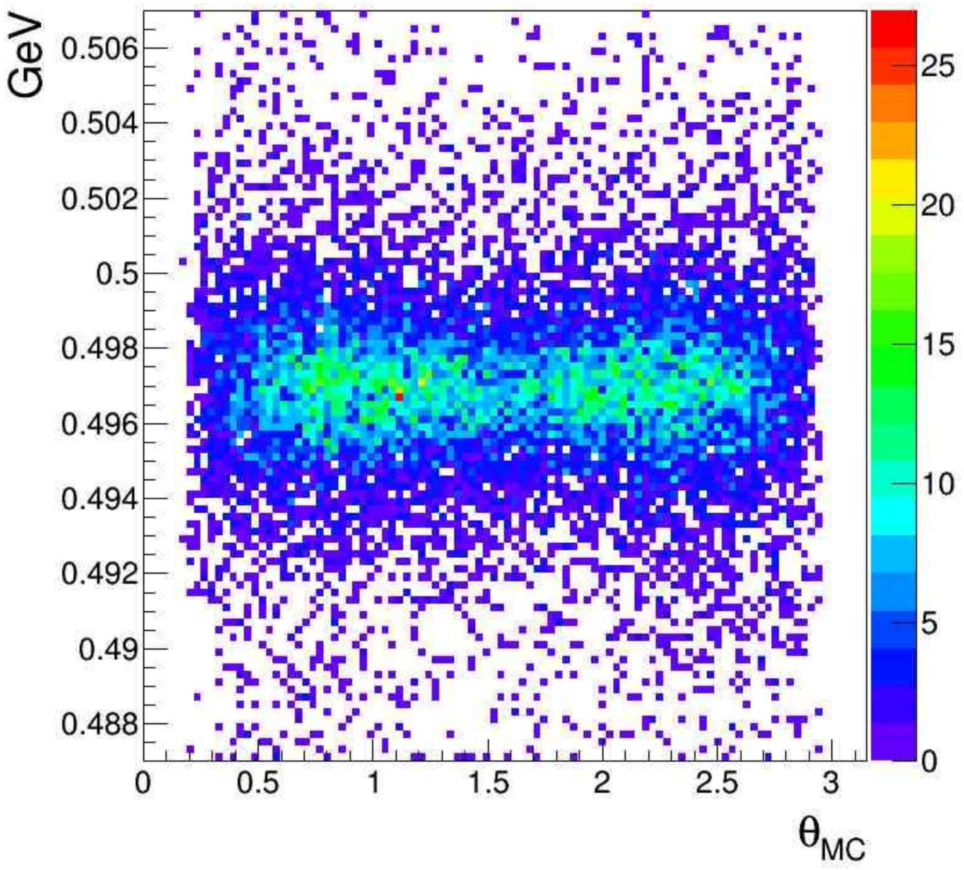



Ks mass vs Ks momentum direction

# Test the Algorithm Using Reconstructed K short Daughters

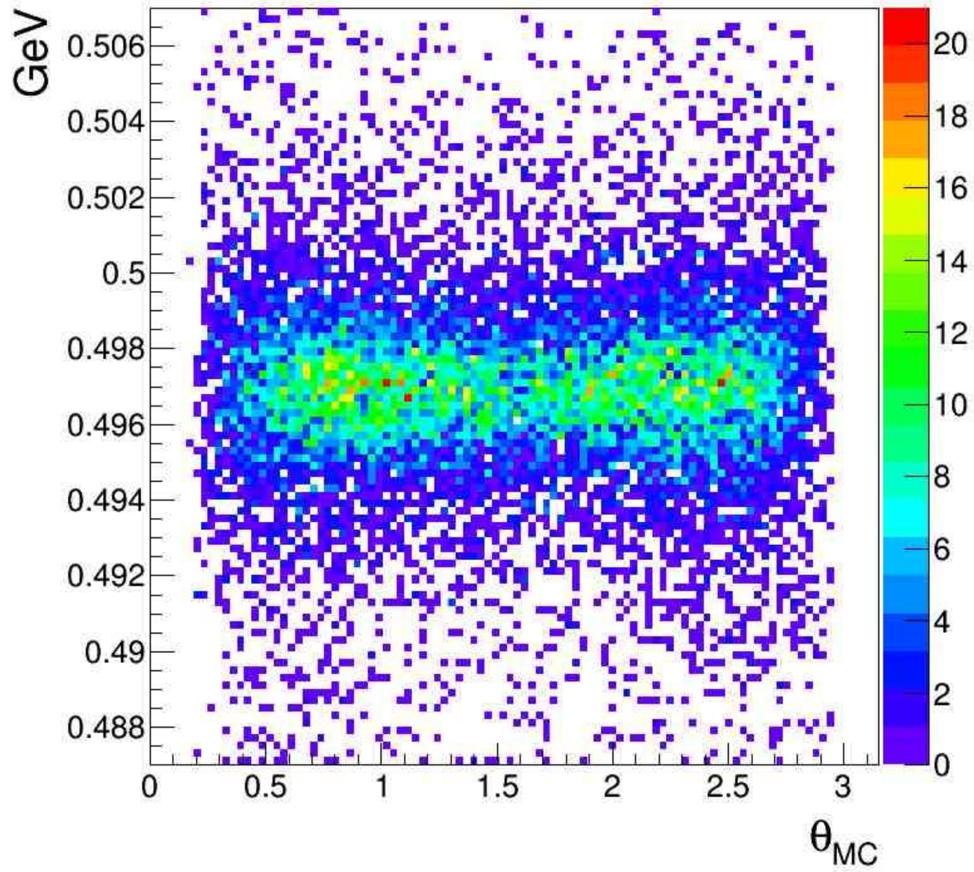



Ks mass vs pion of lesser En's momentumdirection



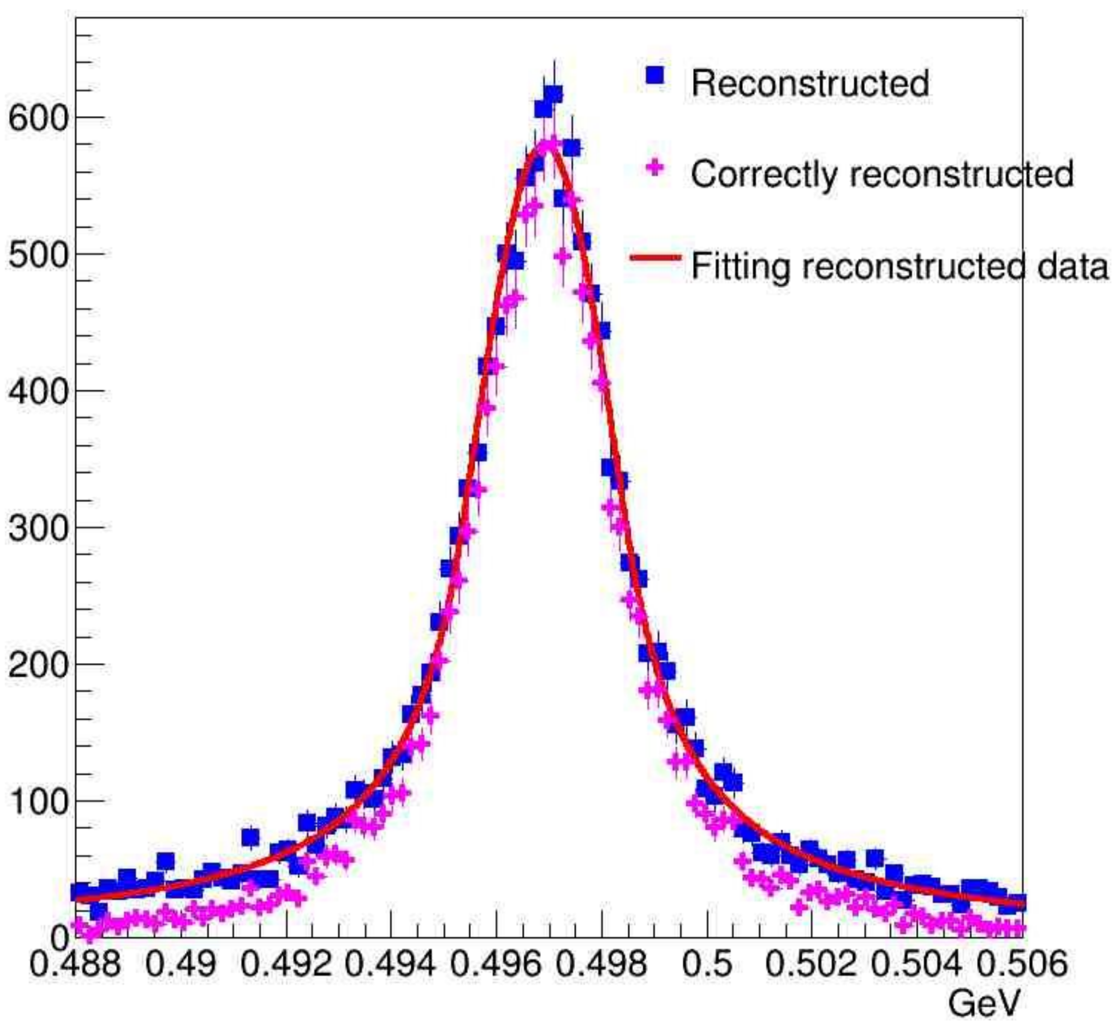

Ks mass vs pion of bigger En's momentum direction

# Test the Algorithm Using Reconstructed K short Daughters




Ks mass vs π+ momentum direction

# Apply the Algorithm in the Simulation Sample




Reconstructed Ks mass:

Mass resolution: 0.27%
Efficiency: 80.1%
Purity: 80.1%

# Background Analysis

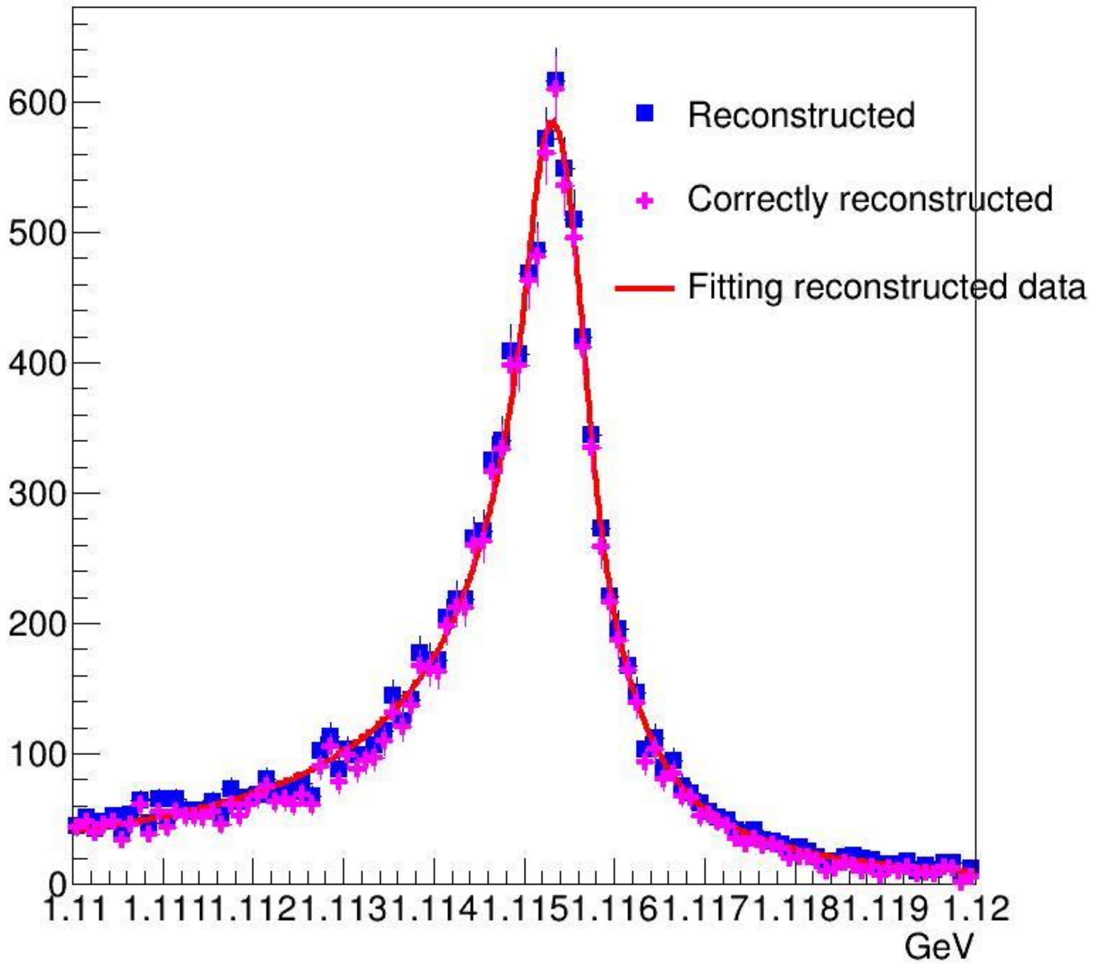
20% from Hadron→ π+ π- + others
10% from Λ→proton + π- (proton identified as π+)
70% from random combination

```
Coral = 15560
CoralSuccess = 12585
Total background = 2975
    ParentType1 == ParentType2: 977        32.8403 %
        Same parent: 881             29.6134 %
            Parent PDGID = 223: 303        10.1849 %
            Parent PDGID = 3122: 152        5.10924 %
            Parent PDGID = -3122: 150        5.04202 %
            Parent PDGID = 310: 73        2.45378 %
            Parent PDGID = 113: 34        1.14286 %
            Others:             169          5.68067 %
        Different parent: 96        3.22689 %
            Parent PDGID = 223: 67        2.2521 %
            Others:             29           0.97479 %
```

ParentType1 means parent type of *supposed* π+
ParentType2 is for π-

```
ParentType1 != ParentType2: 1998        67.1597 %
    ParentType1:
        Parent1 PDGID = 223: 282        9.47899 %
        Parent1 PDGID = 213: 277        9.31092 %
        Parent1 PDGID = 113: 227        7.63025 %
        Parent1 PDGID = 92: 169        5.68067 %
        Parent1 PDGID = 323: 85        2.85714 %
        Parent1 PDGID = 10213: 75        2.52101 %
        Parent1 PDGID = 221: 71        2.38655 %
        Parent1 PDGID = 313: 65        2.18487 %
        Parent1 PDGID = 310: 60        2.01681 %
        Parent1 PDGID = -421: 56        1.88235 %
        Parent1 PDGID = 413: 45        1.51261 %
        Parent1 PDGID = -313: 37        1.2437 %
        Parent1 PDGID = 211: 36        1.21008 %
        Others:         513        17.2437 %
    ParentType2:
        Parent2 PDGID = 223: 293        9.84874 %
        Parent2 PDGID = -213: 254        8.53782 %
        Parent2 PDGID = 113: 187        6.28571 %
        Parent2 PDGID = 92: 177        5.94958 %
        Parent2 PDGID = -323: 83        2.78992 %
        Parent2 PDGID = -10213: 78        2.62185 %
        Parent2 PDGID = 421: 65        2.18487 %
        Parent2 PDGID = 310: 62        2.08403 %
        Parent2 PDGID = 221: 53        1.78151 %
        Parent2 PDGID = -413: 50        1.68067 %
        Parent2 PDGID = -313: 50        1.68067 %
        Parent2 PDGID = 313: 44        1.47899 %
        Parent2 PDGID = -10323: 38        1.27731 %
        Parent2 PDGID = -421: 37        1.2437 %
        Others:         527        17.7143 %
```

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




Since Arbor(CEPC particle reconstruction algorithm) identifies all hadrons as pions, we need to cheat the proton PID.

Reconstructed Λ mass:

Mass resolution: 0.037%
Efficiency: 81.7%
Purity: 94.4%

Most of the backgrounds are from random combinations

## If Arbor PID Had 100% Purity While Maintaining Current Efficiency

K short mass resolution and efficiency are virtually same, purity go from 80.1% to 87.1%

For Λ, all parameters are virtually same since we already cheated the proton PID before.