Performance of kinematic fitting for Λ selection.

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Introduction.

I used a Kinematic Refit prepared by Jenny Regina, Jana Rieger and Waleed Esmail, to try to select Λ particle. I was using simluated files prepared for HADES.

Kinematic Refit basis.

Kinematic fitting for HADES minimizes χ^2 by applying Lagrange's multiplayer method with chosen constraint.

I have used only vertex constraint.

Kinematic refit mathematics.

Kinematic refit uses three sets of variables:

- $\vec{x}$-vector of measured quantities.
- $\vec{\xi}$-vector of unmeasured quantities.
- $\vec{y}$-vector of estimated quantities.

However for calculation of χ^2 we need covariance matrix V of variables.

χ^2 is calculated as:

$$\chi^2(\vec{x}) = (\vec{y} - \vec{x})^T V^{-1} (\vec{y} - \vec{x}) \tag{1}$$

Constraint equations uses measured and unmeasured variables.

$$\vec{g}\left(\vec{x}, \vec{\xi}\right) = 0 \tag{2}$$

Kinematic refit mathematics.

After applying Lagrange's multipliers method to equation 1 with constraint 2:

$$\chi^2\left(\vec{x},\vec{\xi},\vec{\lambda}\right) = \left(\vec{y}-\vec{x}\right)^T V^{-1}\left(\vec{y}-\vec{x}\right) + 2\vec{\lambda}^T\vec{g}\left(\vec{x},\vec{\xi}\right) = min \qquad (3)$$

Equation 3 gives equations for iterative change in parameters:

$$\begin{aligned} \xi^{v+1} &= \xi^v - \left(G_\xi^T S^{-1} G_\xi\right)^{-1} G_\xi^T S^{-1} r, \\ \lambda^{v+1} &= S^{-1}\left(r + G_\xi\left(\xi^{v+1}-\xi^v\right)\right), \\ x^{v+1} &= y - V G_x^T \lambda^{v+1}. \end{aligned} \qquad (4)$$

Where r and S are given by:

$$\begin{aligned} r &= g^v + G_x^v(y - x^v), \\ S &= G_x^v V \left(G_x^v\right)^T. \end{aligned} \qquad (5)$$

Vertex constraint

Track Representation.

$$\left(\frac{1}{p}, \theta, \phi, R, Z\right) \quad (6)$$

- p-particle momentum.
- θ-polar angle.
- ϕ-azimuthal angle.
- R-closest distnace to a beam line
- Z-closest point along beamline

Vertex constraint.

Distance d between tracks is calculated as:

$$d = \left(\vec{d_1} \times \vec{d_2}\right) \cdot \left(\vec{b_1} - \vec{b_2}\right) \quad (7)$$

where $\vec{d}$ is a direction vector of particle track and $\vec{b}$ is its base vector.

$$\begin{aligned} d_x = \sin(\theta)\cos(\phi), b_x = R\cos\left(\phi + \frac{\pi}{2}\right), \\ d_y = \sin(\theta)\sin(\phi), b_y = R\sin\left(\phi + \frac{\pi}{2}\right), \\ d_z = \cos(\theta), b_z = Z. \end{aligned} \quad (8)$$

Studied interaction.

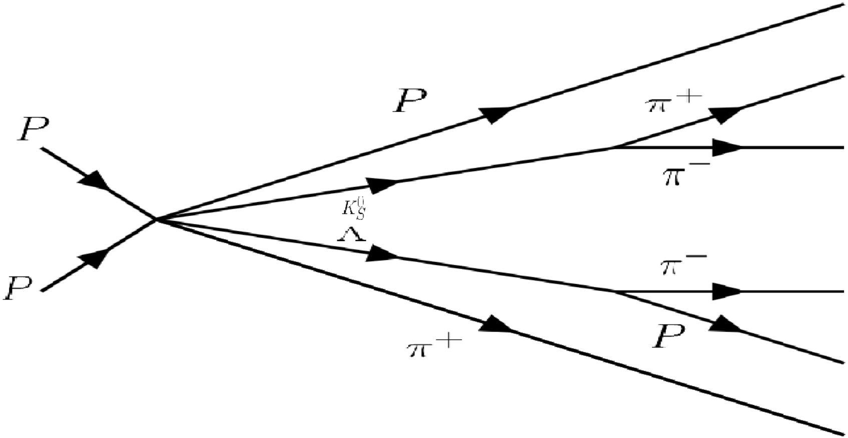


Figure: Studied interaction.

Analysis procedure.

1. Obtain variances of track parameters
   1. Plot differences of reconstructed and simulated parameters.
   2. Fit Gauss function to obtained histograms, or calculate FWHM to obtain varainces of prameters.
2. Particle selection
   1. Discard particles with zero momentum P().
   2. Use getGeantParentPID to find "real" particles that took part in interaction. Store their indices.
   3. Find protons and pions using momentum and charge cuts ($838.27 MeV < p_p < 1038.27 MeV, 39.57 < p_\pi MeV < 239.57 MeV$).
3. Analysis
   1. Check if enough particles have been detected.
   2. Separately reconstruct primary, K_S^0, Λ vertex, using all possible combination of particles.
   3. Find best combination of all three fits.
   4. Check convergence, probability cuts and fill data.

Momentum distributions.

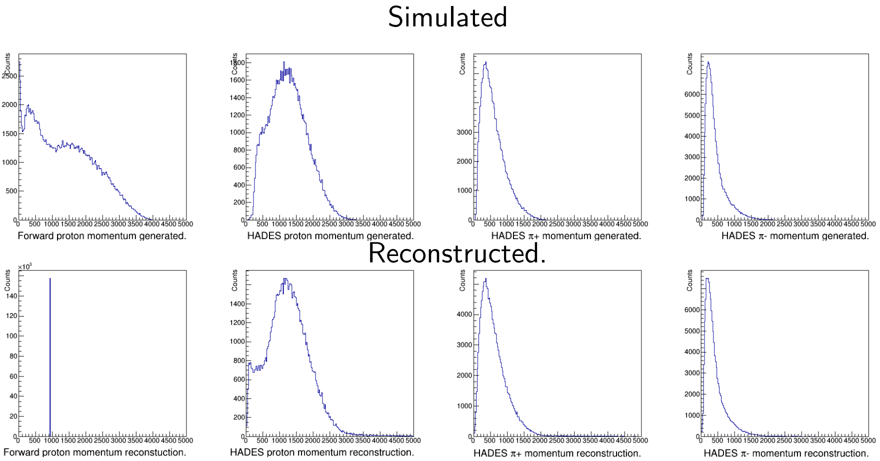
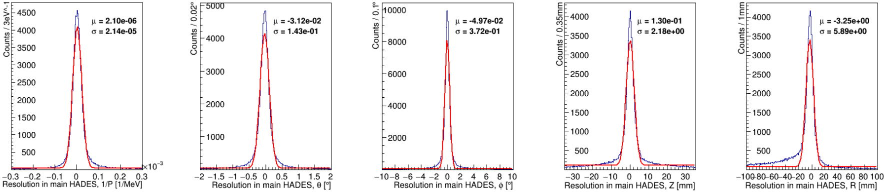


Figure: Momentum distribution.

Proton track parameters resolution.

HADES proton.



Forward proton.

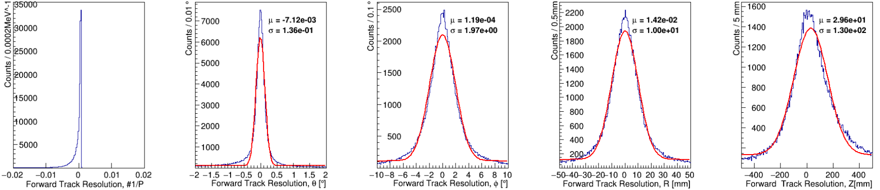


Figure: Proton resolution.

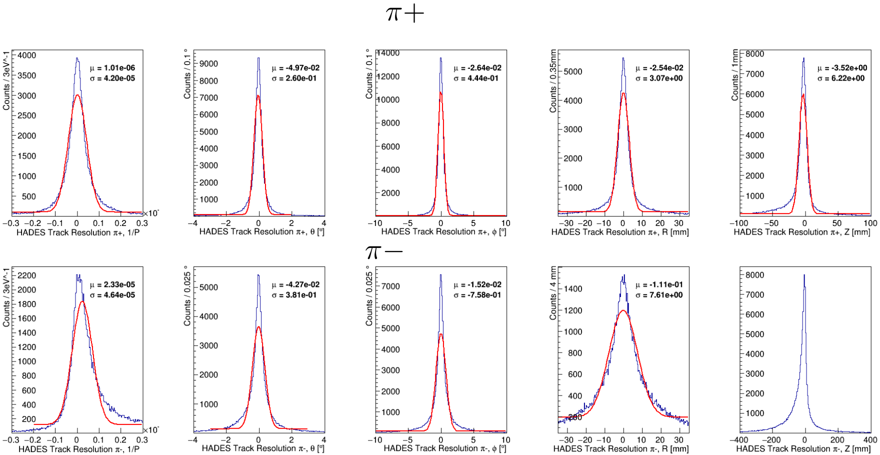
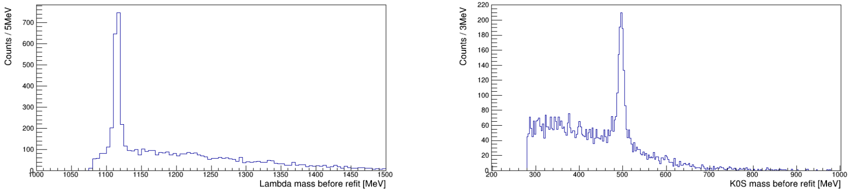


Figure: Pion resolution.

Λ and K_s^0 refit results for simulations.

Before refit.



After refit.

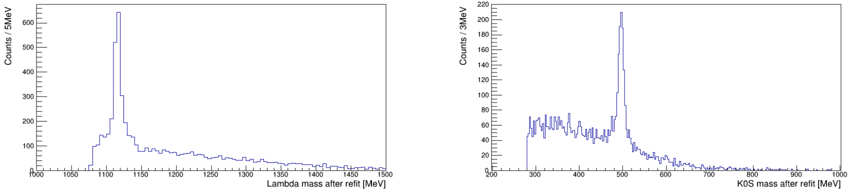
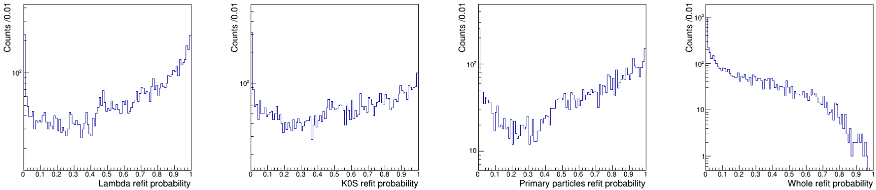


Figure: reconstructed mass.

No probability cut is done so far.

Probability and iterations.

Probability.



Iterations.

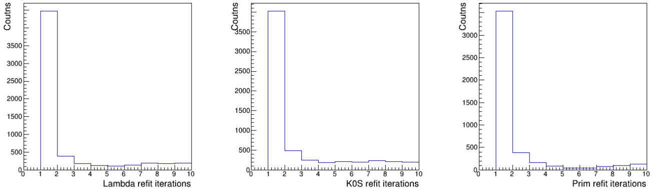
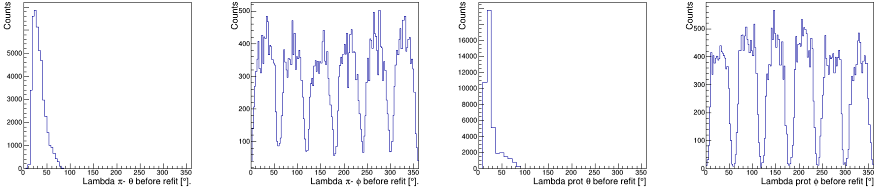


Figure: Probability and iterations distributions.

λ particles angular distributions.

Before refit.



After refit.

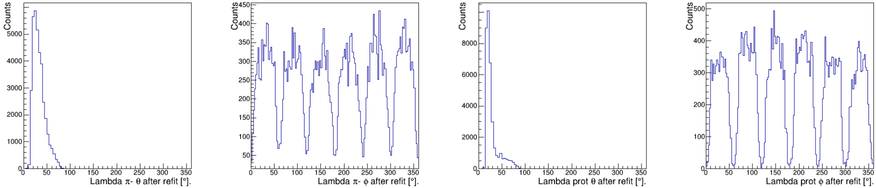
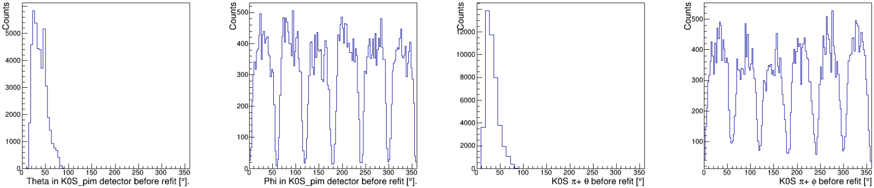


Figure: Lambda particles angular distributions.

K_S^0 particles angular distributions.

Before refit.



After refit.

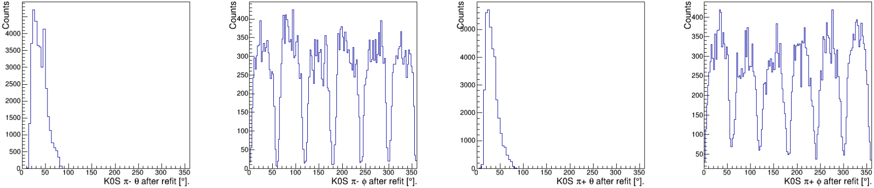


Figure: K_S^0 particles angular distributions.

Λ selection.

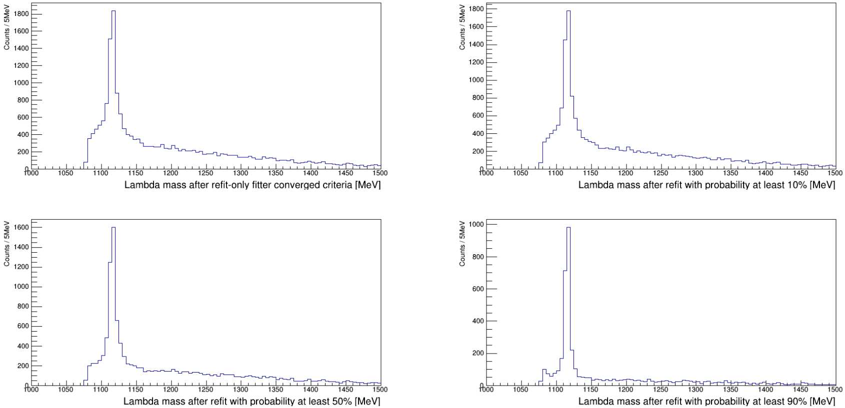


Figure: Reconstructed Λ mass with Λ probability cut.

Λ selection.

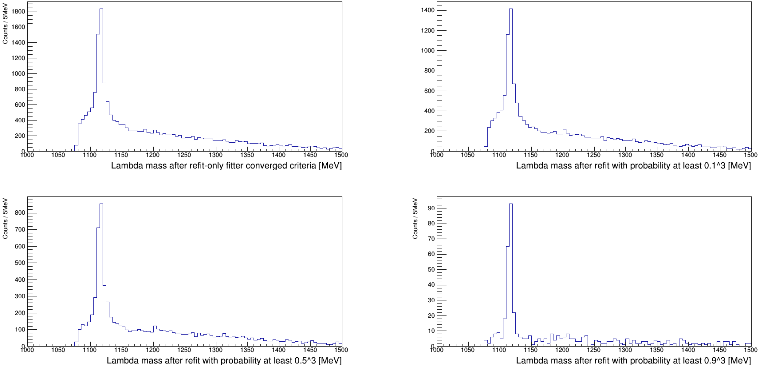


Figure: Reconstructed Λ mass with whole interaction probability cut.

Selection efficiency.

All events	5000100
events with all particles detected	2630
events with all particles matched	99
events with Λ particles detected	11521
events with Λ particles matched	3424
events with k_s^0 particles detected	11149
events with k_s^0 particles matched	3212
events with primary particles detected	10445
events with primary particles matched	3166

Λ particles selection efficiency	29.7%
K_s^0 particles selection efficiency	28.8%
Primary particles selection efficiency	30.3%
Whole interaction selection efficiency	3.76%

Outlook

- Performance of Λ selection with other constraints can be tested.
- Systematically quantify the performance of the fitter by varying the probability and iteration cut.
- Instead of reconstructing all three vertices, one can check performance of Λ selection when looking only at Λ vertex reconstruction (inclusive analysis).
- Selection efficiency need to be tested with presence of forward protons.
- It was suggested that, change of track parametrization in forward detector can enhance Z resolution.