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# **Lambda-Kaon and Cascade-Kaon Femtoscopy in Pb-Pb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV from the LHC ALICE Experiment**

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## **Abstract**

My abstract will be contained here. The abstract will introduce my study and inform the reader about the content of this paper. I will state the problem I tackle, and summarize (in one sentence) why no one else has yet to adequately answered the research question. Next, I will explain (again, in one sentence) how I tackled the research question, and (in one sentence) how I went about doing the research which followed from this big idea (i.e. elaborate on previous sentence). Finally, as a single sentence, I will state the key impact of my research.

We present results from a femtoscopic analysis of Lambda-Kaon correlations in Pb-Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV by the ALICE experiment at the LHC. All pair combinations of  $\Lambda$  and  $\bar{\Lambda}$  with  $K^+$ ,  $K^-$  and  $K_S^0$  are analyzed. The femtoscopic correlations are the result of strong final-state interactions, and are fit with a parametrization based on a model by R. Lednicky and V. L. Lyuboshitz[1]. This allows us to both characterize the emission source and measure the scattering parameters for the particle pairs. We observe a large difference in the  $\Lambda$ - $K^+$  ( $\bar{\Lambda}$ - $K^-$ ) and  $\Lambda$ - $K^-$  ( $\bar{\Lambda}$ - $K^+$ ) correlations in pairs with low relative momenta ( $k^* \lesssim 100$  MeV). Additionally, the average of the  $\Lambda$ - $K^+$  ( $\bar{\Lambda}$ - $K^-$ ) and  $\Lambda$ - $K^-$  ( $\bar{\Lambda}$ - $K^+$ ) correlation functions is consistent with our  $\Lambda$ - $K_S^0$  ( $\bar{\Lambda}$ - $K_S^0$ ) measurement. The results suggest an effect arising from different quark-antiquark interactions in the pairs, i.e.  $s\bar{s}$  in  $\Lambda$ - $K^+$  ( $\bar{\Lambda}$ - $K^-$ ) and  $u\bar{u}$  in  $\Lambda$ - $K^-$  ( $\bar{\Lambda}$ - $K^+$ ). To gain further insight into this hypothesis, we currently are conducting a Cascade-Kaon femtoscopic analysis.



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## 1 Introduction

This will be my introduction. Remember, Jai suggested to make each sentence a separate line to make changes easier to track in git. Otherwise, git will treat an entire paragraph as a single line!

And a new paragraph begins with an empty line.

## 2 Data Sample and Software

### 2.1 Data Sample

Talk about the data sample

Run list: 170593, 170572, 170388, 170387, 170315, 170313, 170312, 170311, 170309, 170308, 170306, 170270, 170269, 170268, 170230, 170228, 170207, 170204, 170203, 170193, 170163, 170159, 170155, 170091, 170089, 170088, 170085, 170084, 170083, 170081, 170040, 170027, 169965, 169923, 169859, 169858, 169855, 169846, 169838, 169837, 169835, 169591, 169590, 169588, 169587, 169586, 169557, 169555, 169554, 169553, 169550, 169515, 169512, 169506, 169504, 169498, 169475, 169420, 169419, 169418, 169417, 169415, 169411, 169238, 169167, 169160, 169156, 169148, 169145, 169144, 169138, 169099, 169094, 169091, 169045, 169044, 169040, 169035, 168992, 168988, 168826, 168777, 168514, 168512, 168511, 168467, 168464, 168460, 168458, 168362, 168361, 168342, 168341, 168325, 168322, 168311, 168310, 168115, 168108, 168107, 168105, 168076, 168069, 167988, 167987, 167985, 167920, 167915

### 2.2 Software

Talk about the software

## 3 Data Selection

### 3.1 Event Selection and Mixing

The events used in this study were selected with the following criteria:

- Triggers
  - minimum bias (kMB)
  - central (kCentral)
  - semi-central (kSemiCentral)
- z-position of reconstructed event vertex must be within 10 cm of the center of the ALICE detector
- the event must contain at least one particle of each type from the pair of interest

The event mixing was handled by the AliFemtoVertexMultAnalysis class, which only mixes events with like vertex position and centrality. The following criteria were used for event mixing:

- Number of events to mix = 5
- Vertex position bin width = 2 cm
- Centrality bin width = 5

The AliFemtoEventReaderAODChain class is used to read the events. Event flattening is not currently used. FilterBit(7). The centrality is determined by the "V0M" method of AliCentrality, set by calling AliFemtoEventReaderAOD::SetUseMultiplicity(kCentrality). I utilize the SetPrimaryVertexCorrectionTPCPoints switch, which causes the reader to shift all TPC points to be relative to the event vertex.

### 3.2 $K^\pm$ Track Selection

Talk about how charged kaons are identified

### 3.3 V0 Selection

$\Lambda$  ( $\bar{\Lambda}$ ) and  $K_S^0$  are neutral particles which cannot be directly detected, but must instead be reconstructed through detection of their decay products, or daughters. In general, particles which are topologically reconstructed in this fashion are called V0 particles. The class AliFemtoV0TrackCutNSigmaFilter (which is an extension of AliFemtoV0TrackCut) is used to reconstruct the V0s.

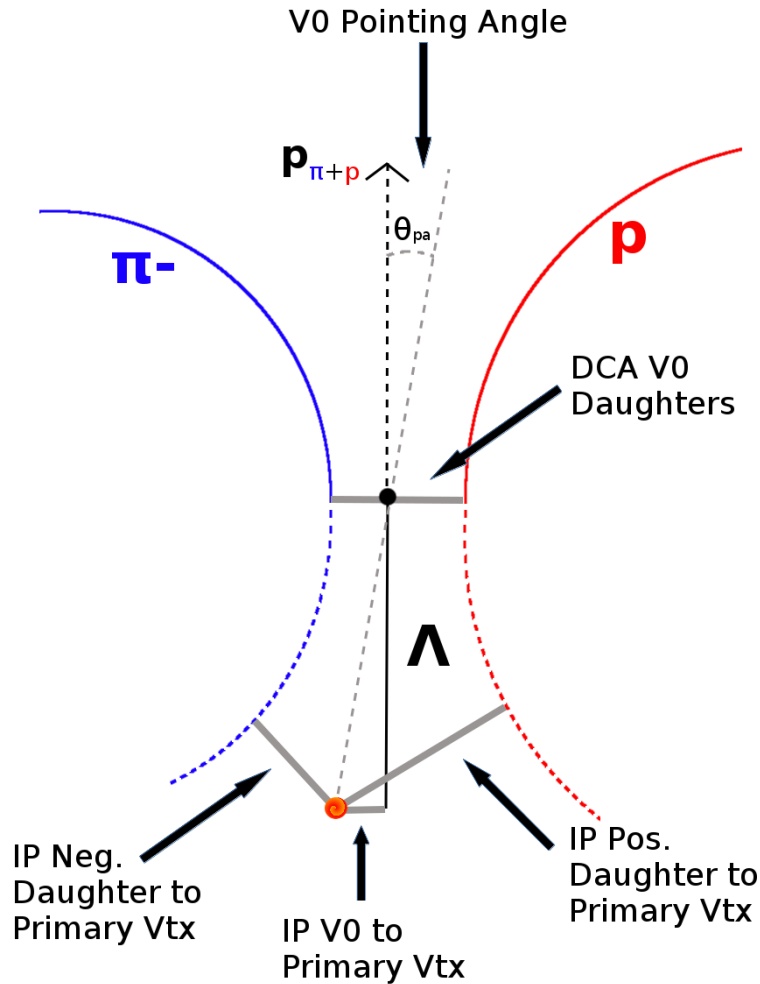


Fig. 1:  $\Lambda$  Reconstruction

#### 3.3.1 $\Lambda$ Reconstruction

The following cuts were used to select good  $\Lambda$  ( $\bar{\Lambda}$ ) candidates:

1. Cuts Common to Both Daughters

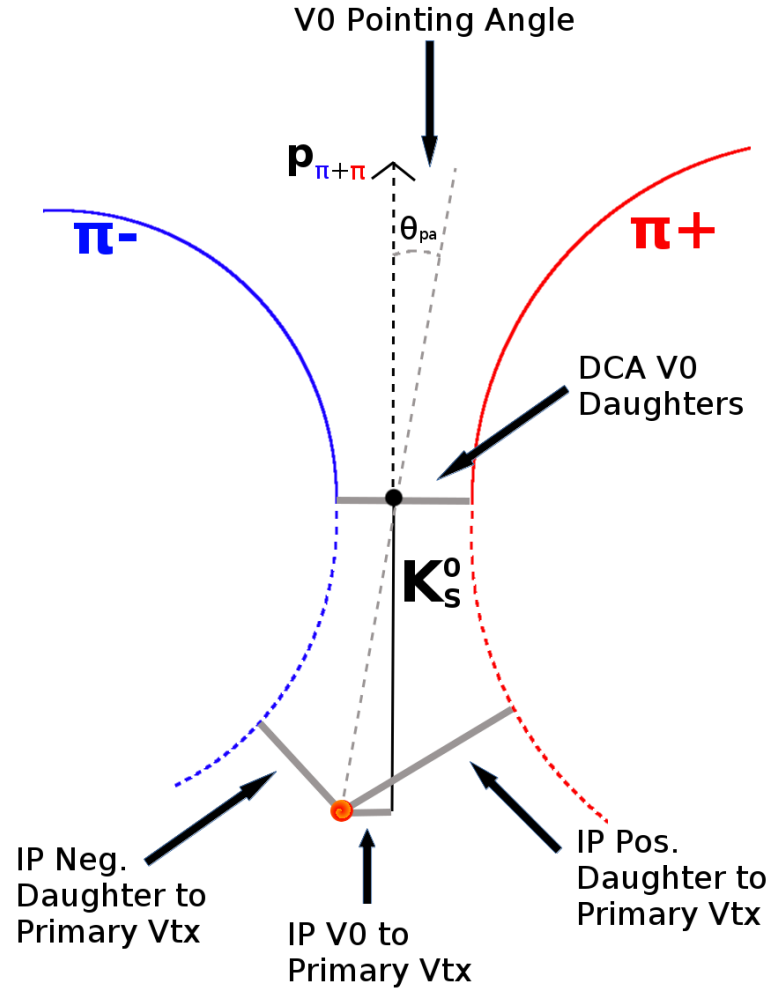


Fig. 2:  $K_S^0$  Reconstruction

- (a)  $|\eta| < 0.8$
- (b) `SetTPCnclsDaughters(80)`
- (c) `SetStatusDaughters(AliESDtrack::kTPCrefic)`
- (d) `SetMaxDcaV0Daughters(0.4)`

## 2. Pion Specific Daughter Cuts

- (a)  $p_T > 0.16$
- (b) DCA to prim vertex  $> 0.3$

## 3. Proton Specific Daughter Cuts

- (a)  $p_T >$ 
  - 0.5 ( $p$ )
  - 0.3 ( $\bar{p}$ )
- (b) DCA to prim vertex  $> 0.1$

## 4. Lambda Cuts

- (a)  $|\eta| < 0.8$

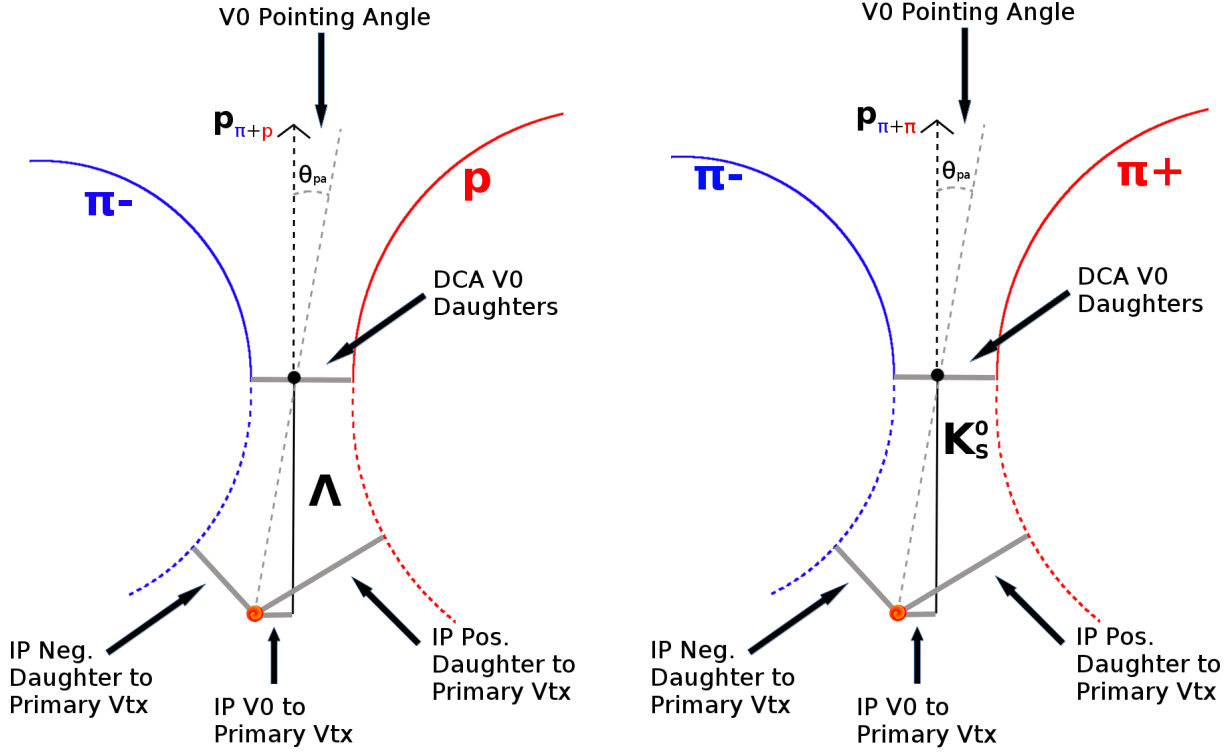


Fig. 3: Long caption

- (b)  $p_T > 0.4$
- (c)  $|m_{inv} - m_{PDG}| < 3.8 \text{ MeV}$
- (d) Cosine of pointing angle  $> 0.9993$
- (e) OnFlyStatus = false
- (f) Decay Length  $< 60 \text{ cm}$

### 3.3.2 $K_S^0$ Reconstruction

The following cuts were used to select good  $K_S^0$  candidates:

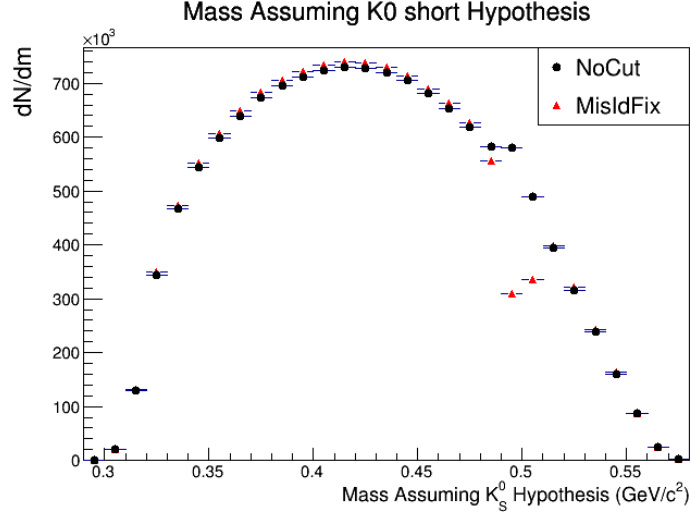
#### 1. Pion Daughter Cuts

- (a)  $|\eta| < 0.8$
- (b) SetTPCnclsDaughters(80)
- (c) SetStatusDaughters(AliESDtrack::kTPCrefic)
- (d) SetMaxDcaV0Daughters(0.3)
- (e)  $p_T > 0.15$
- (f) DCA to prim vertex  $> 0.3$

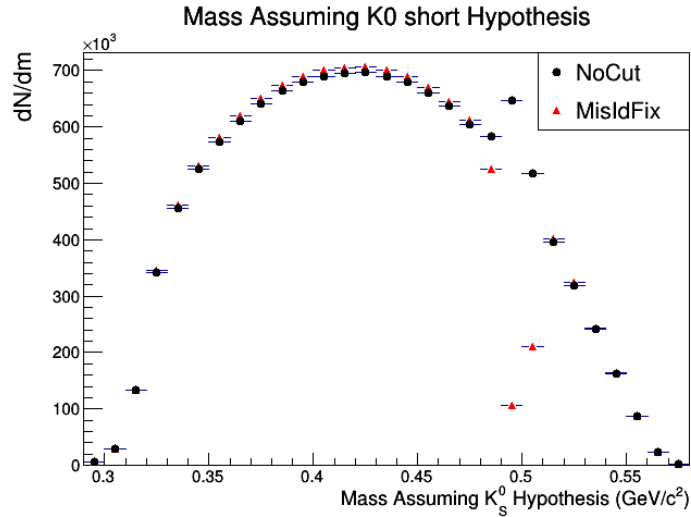
#### 2. $K_S^0$ Cuts

- (a)  $|\eta| < 0.8$
- (b)  $p_T > 0.2$
- (c)  $m_{PDG} - 13.677 \text{ MeV} < m_{inv} < m_{PDG} + 2.0323 \text{ MeV}$
- (d) Cosine of pointing angle  $> 0.9993$





**Fig. 4:** Mass assuming  $K_S^0$ -hypothesis for V0 candidates passing all  $\Lambda$  cuts, i.e. assume the daughters are  $\pi^+\pi^-$  instead of  $p^+\pi^-$ . The slight peak around  $m_{inv} = 0.5 \text{ GeV}/c^2$  likely contains misidentified  $K_S^0$  particles in our  $\Lambda$  collection. If one simply cuts out the entire peak, good  $\Lambda$  particles will be lost. Ideally, the  $\Lambda$  selection and  $K_S^0$  misidentification cuts are selected such that the peak is removed from this plot while leaving the distribution continuous.

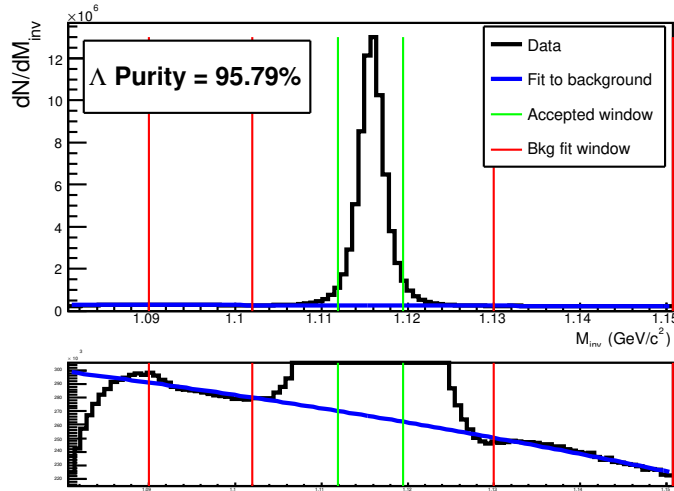
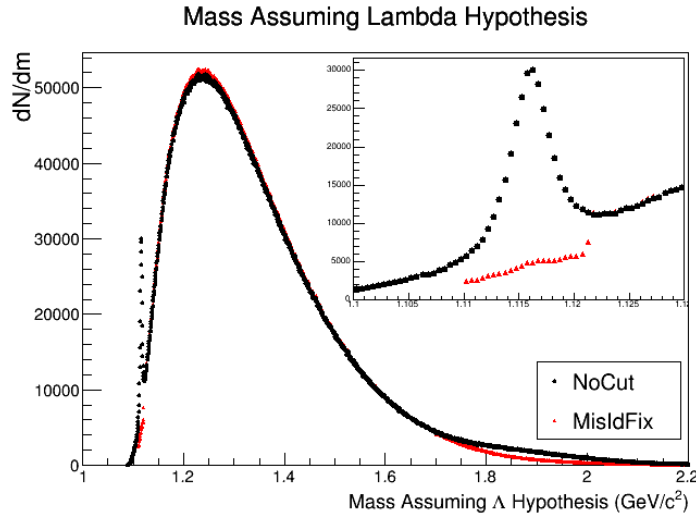


**Fig. 5:** Mass assuming  $K_S^0$ -hypothesis for V0 candidates passing all  $\bar{\Lambda}$  cuts, i.e. assume the daughters are  $\pi^+\pi^-$  instead of  $\pi^+\bar{p}^-$ . Similar to Figure 4

- (e) OnFlyStatus = false
- (f) Decay Length < 30 cm

As can be seen in Figures 7 and 8, some misidentified  $\Lambda$  and  $\bar{\Lambda}$  particles contaminate our  $K_S^0$  sample. To attempt to remove these contaminations without throwing away good  $K_S^0$  particles, the following misidentification cuts are imposed; a  $K_S^0$  candidate is rejected if all of the following criteria are satisfied:

- $|m_{inv, \Lambda(\bar{\Lambda}) \text{ Hypothesis}} - m_{PDG, \Lambda(\bar{\Lambda})}| < 9.0 \text{ MeV}/c^2$
- Positive daughter passes  $p^+(\pi^+)$  daughter cut implemented for  $\Lambda(\bar{\Lambda})$  reconstruction
- Negative daughter passes  $\pi^-(\bar{p}^-)$  daughter cut implemented by  $\Lambda(\bar{\Lambda})$  reconstruction

Fig. 6:  $\Lambda$  Purity

**Fig. 7:** Mass assuming  $\Lambda$ -hypothesis for V0 candidates passing all  $K_S^0$  cuts, i.e. assume the daughters are  $p^+\pi^-$  instead of  $\pi^+\pi^-$ . The peak around  $m_{inv} = 1.115 \text{ GeV}/c^2$  likely contains misidentified  $\Lambda$  particles in our  $K_S^0$  collection. If one simply cuts out the entire peak, some good  $K_S^0$  particles will be lost. Ideally, the  $K_S^0$  selection and  $\Lambda(\bar{\Lambda})$  misidentification cuts can be selected such that the peak is removed from this plot while leaving the distribution continuous.

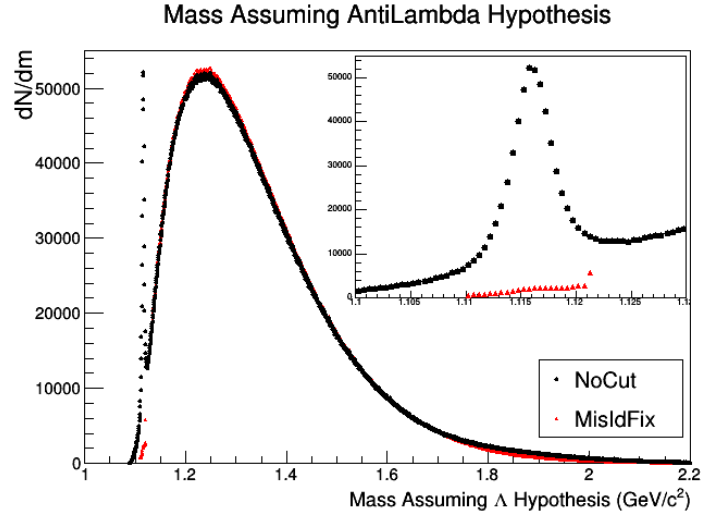
### 3.4 Cascade Reconstruction

Talk about reconstruction cascades

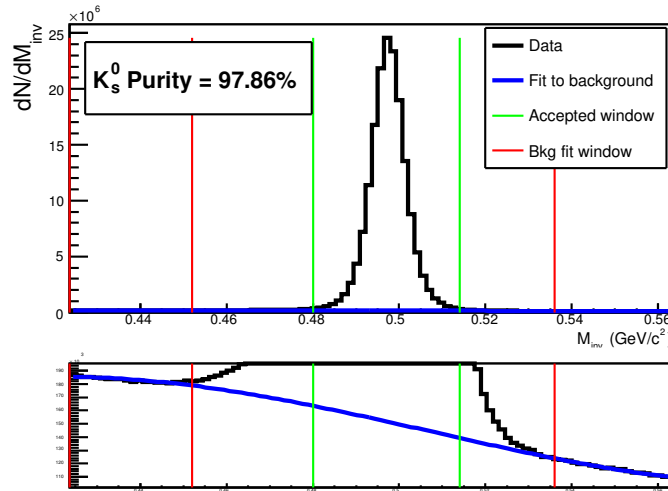
### 3.5 Pair Selection

Some general remarks on forming pairs

It is important to obtain true particle pairs in the analysis. In particular, contamination from pairs constructed with split or merged tracks can introduce an artificial signal into the correlation function, obscuring the actual physics.



**Fig. 8:** Mass assuming  $\bar{\Lambda}$ -hypothesis for V0 candidates passing all  $K_S^0$  cuts, i.e. assume the daughters are  $\pi^+ \bar{p}^-$  instead of  $\pi^+ \pi^-$ . Similar to Figure 7



**Fig. 9:**  $K_S^0$  Purity

## 4 Correlation Functions

General remarks about formaton of correlation functions and what information they provide.

## 5 Fitting

This section will include the Lednický model and the method used to fit the Cascade study. It will also include momentum resolution, residual correlations, and any other aspects to obtain a good fit

### 5.1 Model: Lambda-Kaon

Talk about Lednický model

### 5.2 Model: Cascade-Kaon

Talk about model

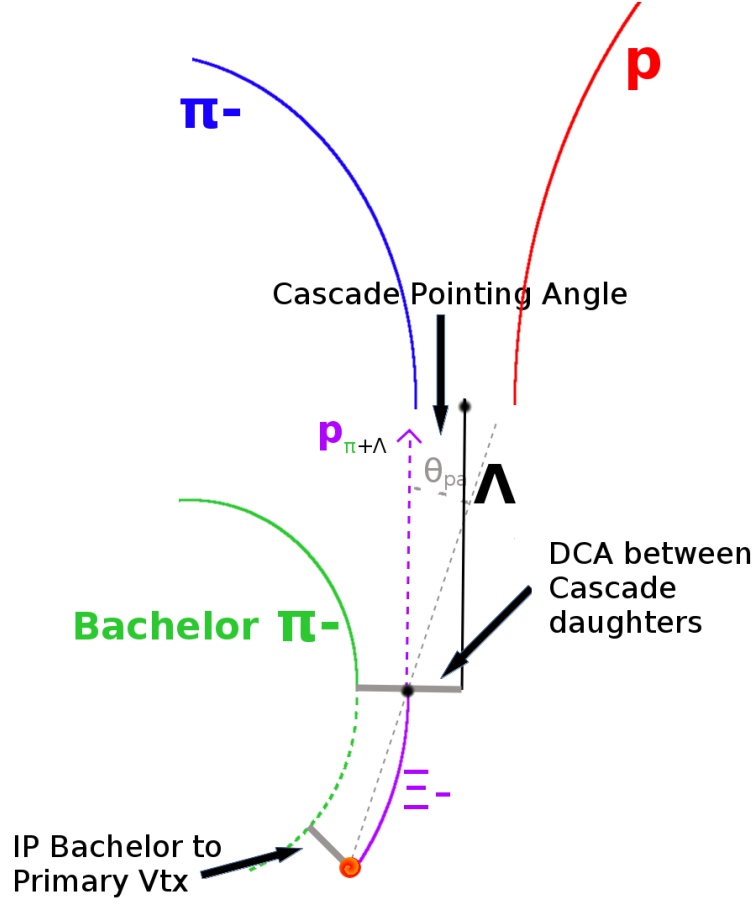


Fig. 10:  $\Xi$  Reconstruction

### 5.3 Momentum Resolution Corrections

Talk about Momentum resolution corrections

$$C_{fit}(k_{Rec}^*) = \frac{\sum_{k_{True}^*} M_{k_{Rec}^*, k_{True}^*} C_{fit}(k_{True}^*)}{\sum_{k_{True}^*} M_{k_{Rec}^*, k_{True}^*}} \quad (1)$$

### 5.4 Residual Correlations

Talk about Lednický model

## 6 Systematic Errors

This study is currently ongoing. See Table 1.

## 7 Results and Discussion

## 8 To Do

DCA  $\Lambda(\bar{\Lambda})$ 

Pair Type	Centrality	p-value	
		0.4 vs 0.5 mm	0.5 vs 0.6 mm
$\Lambda K_S^0$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00
$\bar{\Lambda} K_S^0$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00

**Table 1:** DCA V0 LamK0 captionDCA  $K_S^0$ 

Pair Type	Centrality	p-value	
		0.2 vs 0.3 mm	0.3 vs 0.4 mm
$\Lambda K_S^0$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00
$\bar{\Lambda} K_S^0$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00

**Table 2:** DCA V0 LamK0 captionDCA  $\Lambda(\bar{\Lambda})$ 

Pair Type	Centrality	p-value	
		0.4 vs 0.5 mm	0.5 vs 0.6 mm
$\Lambda K^+$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00
$\bar{\Lambda} K^-$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00
$\Lambda K^-$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00
$\bar{\Lambda} K^+$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00

**Table 3:** DCA V0 LamKch captionDCA  $\Lambda(\bar{\Lambda})$  Daughters

Pair Type	Centrality	p-value	
		0.3 vs 0.4 mm	0.4 vs 0.5 mm
$\Lambda K_S^0$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00
$\bar{\Lambda} K_S^0$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00

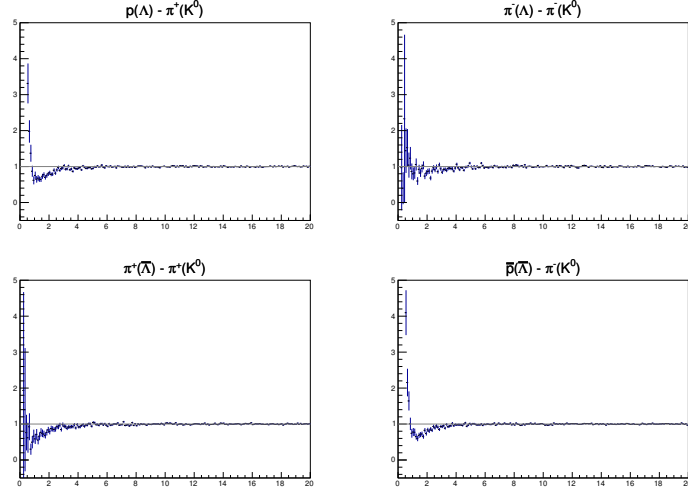
**Table 4:** DCA  $\Lambda(\bar{\Lambda})$  Daughters LamK0 caption

DCA $K_S^0$ Daughters			
Pair Type	Centrality	p-value	
		0.2 vs 0.3 mm	0.3 vs 0.4 mm
$\Lambda K_S^0$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00
$\bar{\Lambda} K_S^0$	0-10%	0.00	0.00
	10-30%	0.00	0.00
	30-50%	0.00	0.00

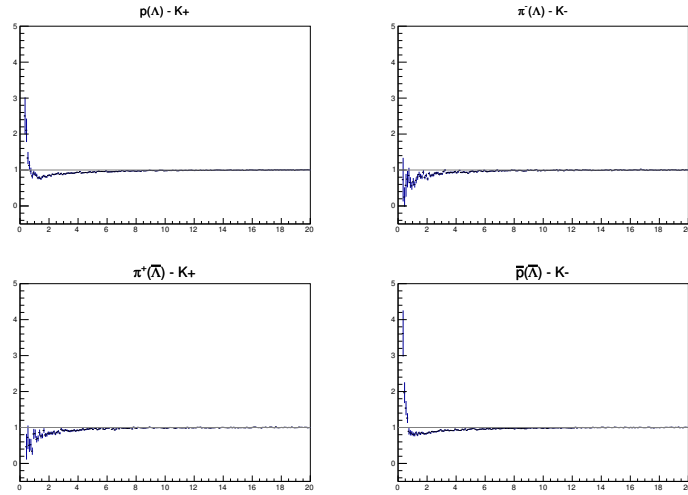
**Table 5:** DCA  $K_S^0$  Daughters LamK0 caption

DCA $\Lambda(\bar{\Lambda})$ Daughters			
Pair Type	Centrality	p-value	
		0.3 vs 0.4 mm	0.4 vs 0.5 mm
$\Lambda K^+$	0-10%	0.79	0.06
	10-30%	0.10	0.60
	30-50%	8.4e-3	0.25
$\bar{\Lambda} K^-$	0-10%	2.4e-4	0.63
	10-30%	0.06	3.3e-4
	30-50%	0.03	0.04
$\Lambda K^-$	0-10%	0.70	0.40
	10-30%	0.94	0.04
	30-50%	0.05	9.5e-5
$\bar{\Lambda} K^+$	0-10%	0.09	0.04
	10-30%	0.10	0.17
	30-50%	0.10	0.43

**Table 6:** DCA  $\Lambda(\bar{\Lambda})$  Daughters LamKch caption



**Fig. 11:** Average Separation  $\Lambda(\bar{\Lambda})K_S^0$



**Fig. 12:** Average Separation  $\Lambda(\bar{\Lambda})K^\pm$