Hyperon reconstruction methods with high purity and efficiency in Pb+Pb collisions at ALICE

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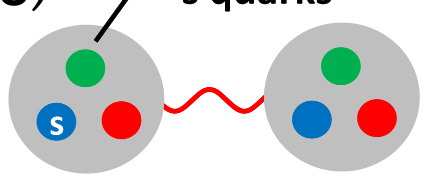
Purpose

Challenge of establishment hyperons reconstruction methods for further understanding of the baryon-baryon interaction in flavor SU(3) in Pb-Pb

Introduction

■ Baryon-Baryon (B-B) interaction in flavor SU(3)

- ✓ Further understanding of QCD
- ✓ Determination of Equation of state in dense nuclear matter
  - ➢ Neutron star's core

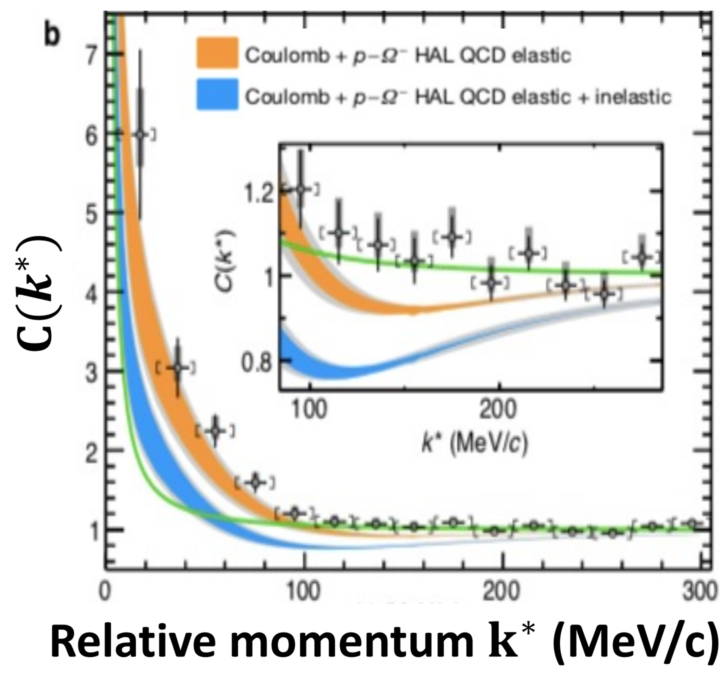


ex : $\Lambda-\Lambda, p-\Xi^-, p-\Omega^-$

■ Experimental understanding

- ✓ Two particle correlation function ($C(k^*)$)
  - Agree with Lattice QCD calculation, but not sufficient to conclude an existence of new bound state
- ➢ Strong attractive force beyond Coulomb's force
- ➢ What is needed for further understanding
  - ・More statistics in low k*
  - ・Data with larger emission source (Pb-Pb)

[1] pp, 13 TeV, $p-\Omega^-$

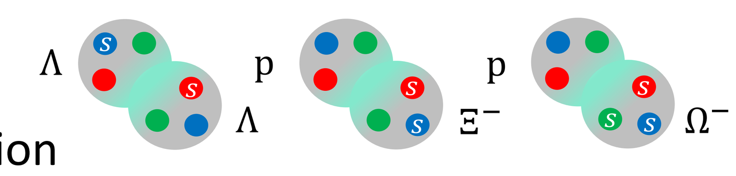


[1] ALICE collaboration, Nature 588 (2020) 232-238

■ Target B-B interactions

- ✓ $\Lambda\Lambda$, $p\Xi^-$, $\Lambda\Xi^-$ & $p\Omega^-$ interactions in Pb+Pb
  - ① Correlation function
    - ➢ Scattering length, effective length
  - ② Dibaryon searches
    - Assumed a resonance/quasi-bound state
      - Direct searches using mass reconstruction
    - ➢ Binding energy (molecular state)

Dibaryon as molecule state

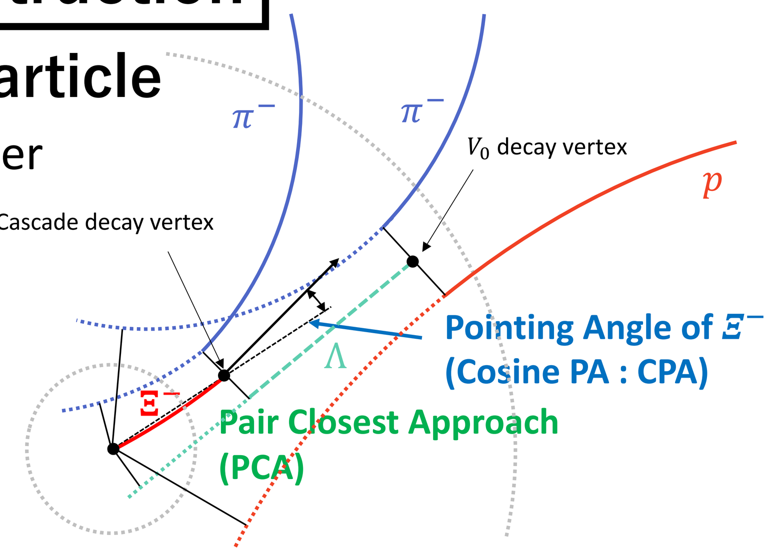


➢ **Single hyperon reconstruction in Pb-Pb is very important**

Current status of hyperon reconstruction

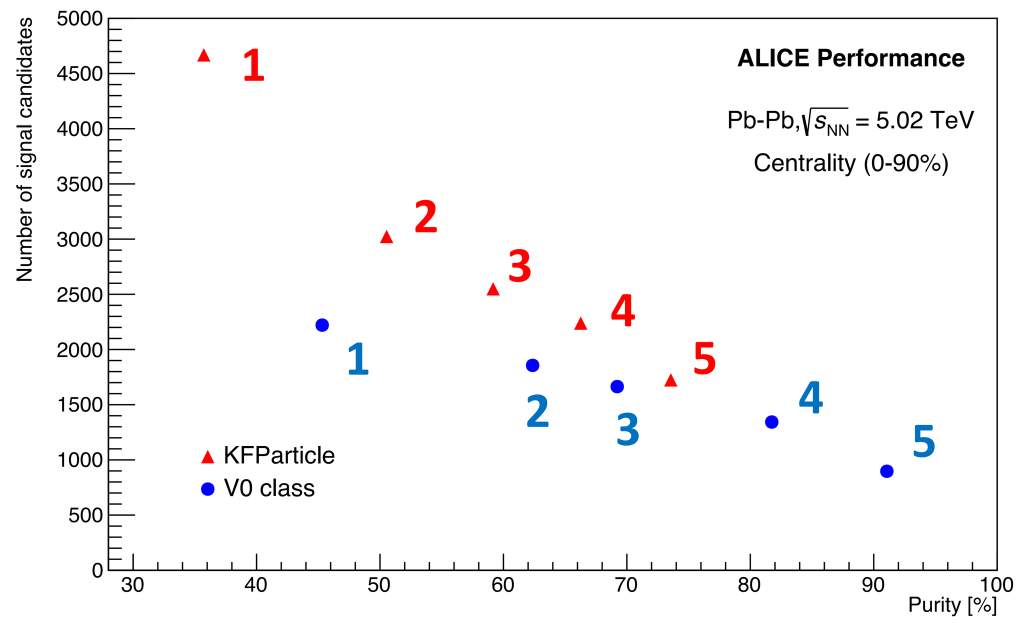
■ Hyperon reconstruction using KFParticle

- ✓ Secondary vertex reconstruction by Kalman Filter
- ✓ All topological cuts are applied manually
  - $\Lambda \to p\pi^-$ (B.R. = 63.9 %, $c\tau$ = 7.89 cm)
  - $\Xi^- \to \Lambda\pi^-$ (B.R. = 99.9 %, $c\tau$ = 4.91 cm)
  - $\Omega^- \to \Lambda K^-$ (B.R. = 67.8 %, $c\tau$ = 2.46 cm)



■ Cut optimization study

- ✓ Check the trend of purity and efficiency
  - Change the most effective cut parameters (CPA, PCA)
    2. +CPA (0.99->0.998), 3. +CPA (0.99->0.999), 4. +PCA (1.5->0.4 cm), 5. +PCA (0.4->0.1 cm)
  - ➢ Purity eventually goes up to over 70%. (Fine tuning is available)
  - ➢ Statistics is about doubled compared to ALICE conventional methods
- ➢ Worse purity and efficiency for Xi & Omega
  -> Boosted Decision Tree (BDT) for further improvement



Background study in Λ

■ Procedure for BDT

① Training with background and true information
- Background and MC samples should be prepared first.

② BDT is applied to data set based on training

Training data

Background samples + Signal information → Apply → Data set: Pb-Pb, 5.02 TeV

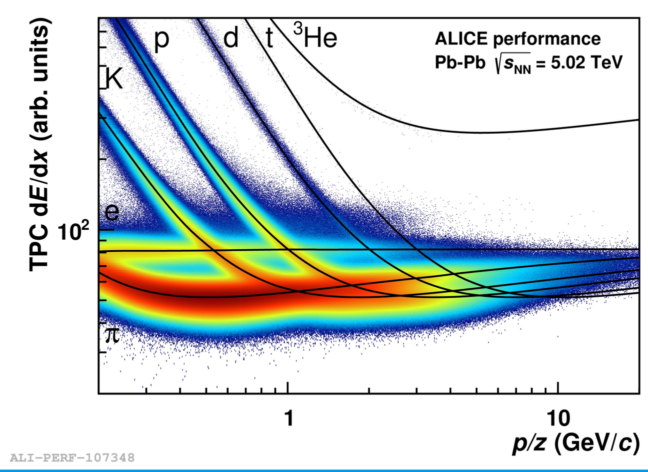
■ Background samples for BDT input

- ✓ Using Event mixing and Like-sign method
  - BG pairs are normalized by # of FG excluding signal region

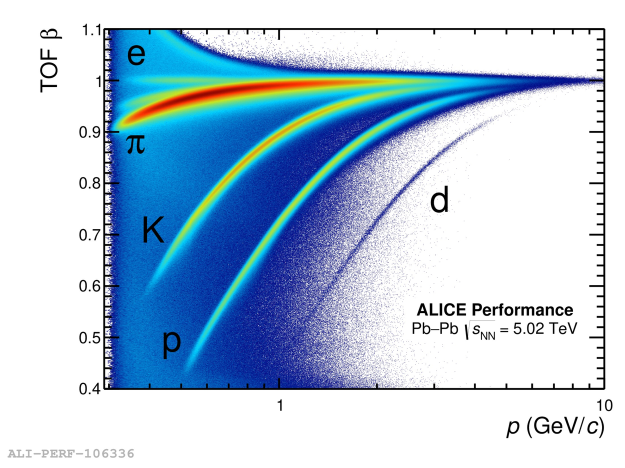
Cut selection for BDT

- Track quality
  - TPC refit
  - TPC cluster > 70
  - TPC chi2 per cluster < 2.5
  - Crossed rows TPC > 70
  - Crossed rows/Findable > 0.8
  - |eta|< 0,8
- Track cut
  - 0.05 < DCA, DCA < 3 cm
  - Nσ (TPC,TOF(if available)) < 5σ
  - m^2 & pT (for proton & pion)
    - Pion : 0.014 – 0.026 GeV²/c⁴, pT < 0.8
    - Proton: 0.84 – 1.08 GeV²/c⁴, pT < 2.0
- Vertex cut
  - CPA > 0.8
  - PCA < 2 cm

TPC PID

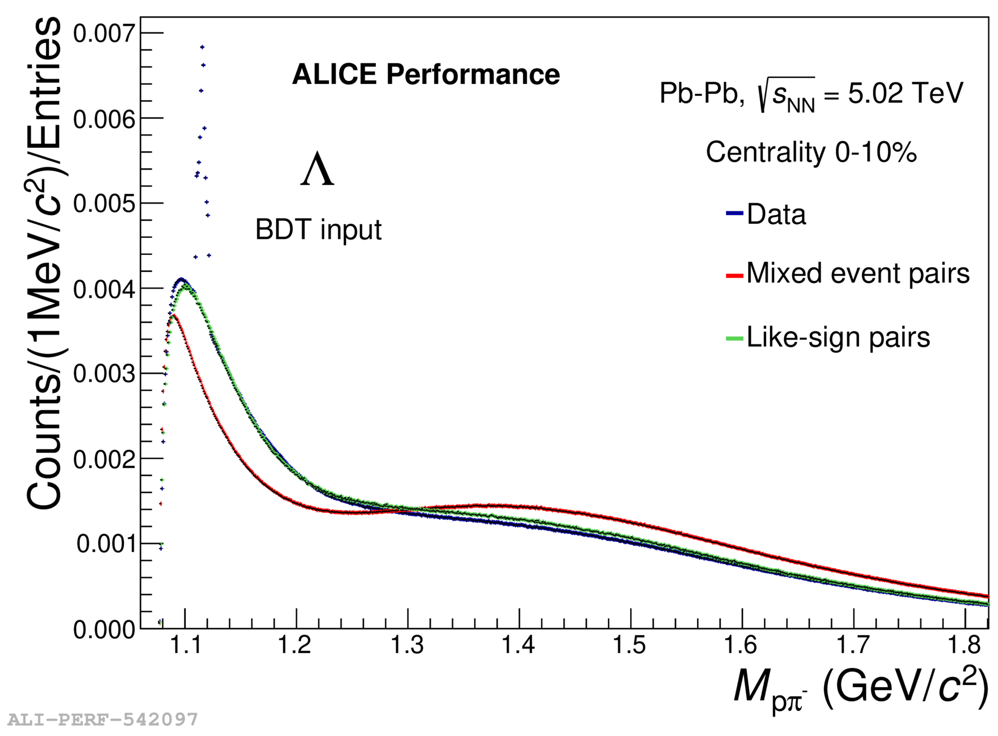


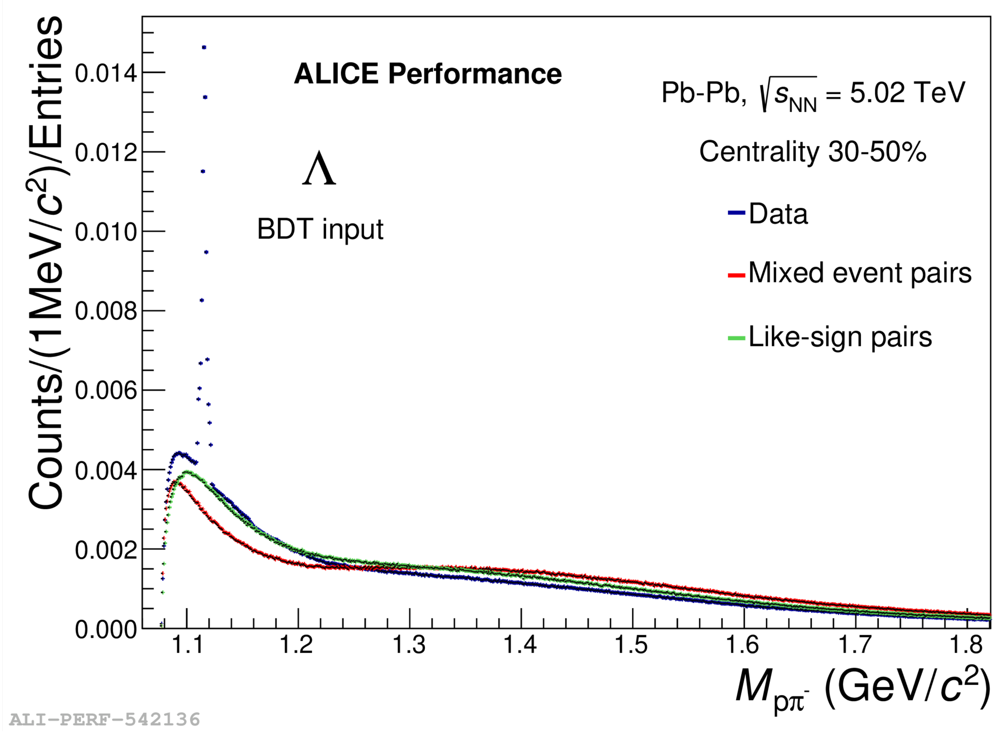
TOF PID

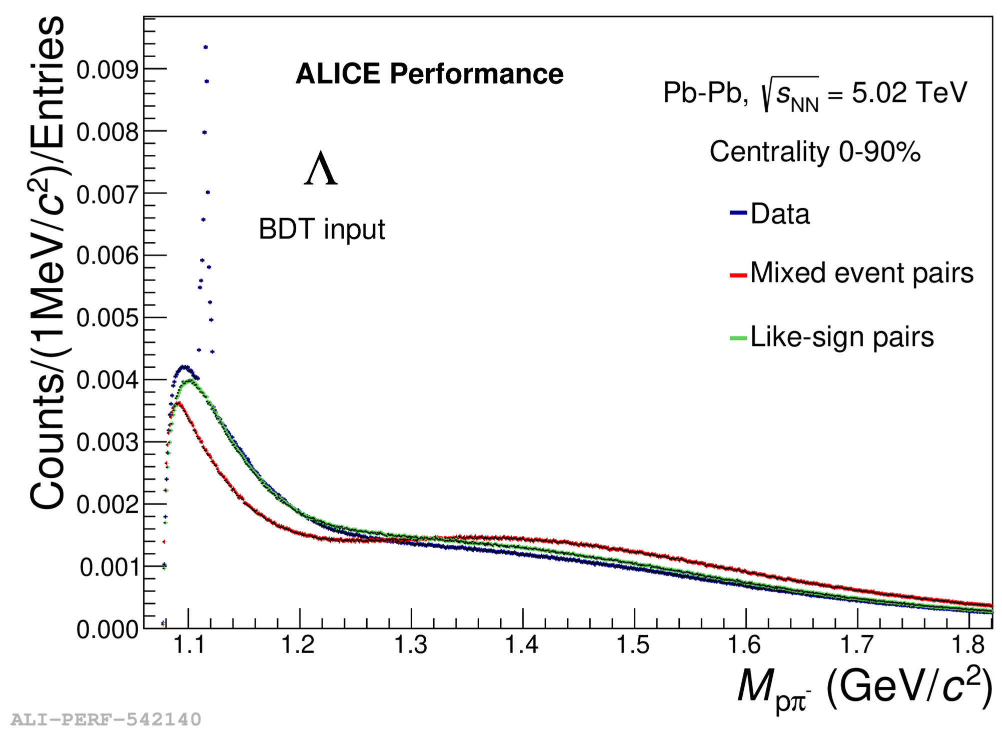


● **Event Mixing method**
- ✓ Event classification with z-vertex and centrality
  - z- vertex every 5 cm in (-10,10), centrality every 5% in (0, 90)
- ➢ Not agree with FG using Central trigger

● **Like-sign method**
- ➢ Agree to BG pairs near the signal region better than Event mixing







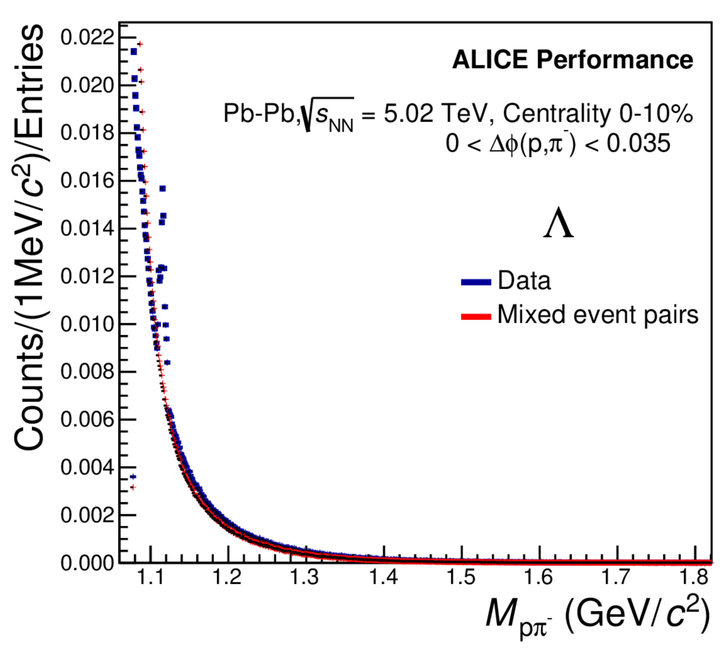
■ Study for the difference of mixed event pairs and FG using central trigger

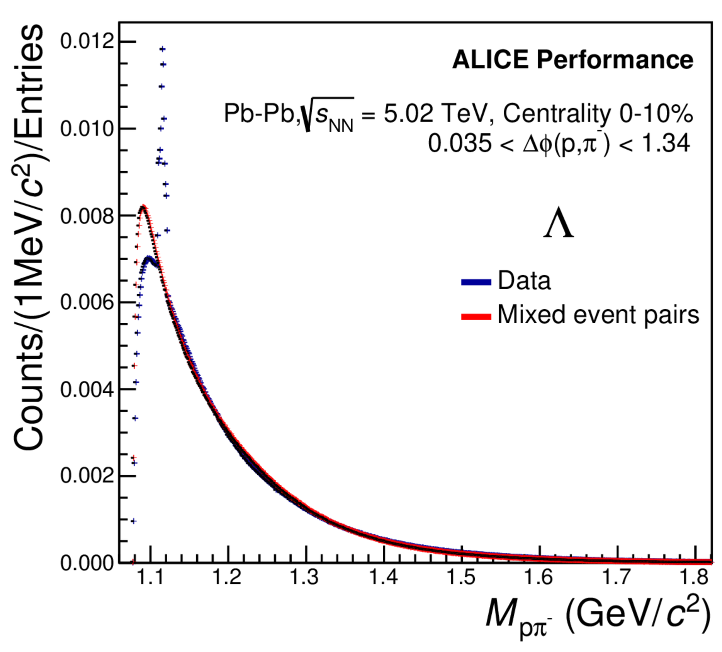
- ✓ Check mass distributions sliced by $\Delta\phi$ between p and π based on $\Delta\phi$ distributions of FG
  - 4 region used for slice : (0, 0,035), (0.035, 1.34), (1.34, 2.45), (2.45, π)
- ➢ Big difference of mixed event pairs and BG in FG in small $\Delta\phi$ region
  - Jet effect can be seen?

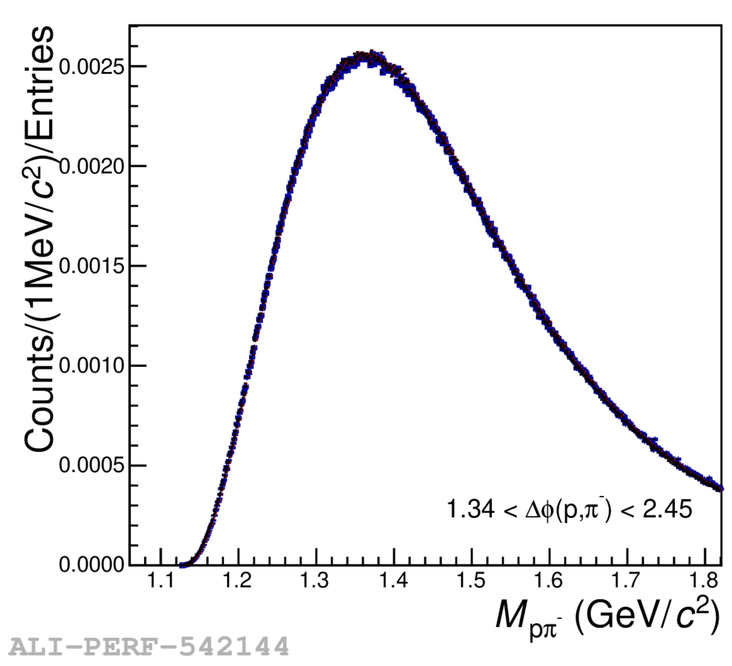
Conclusion

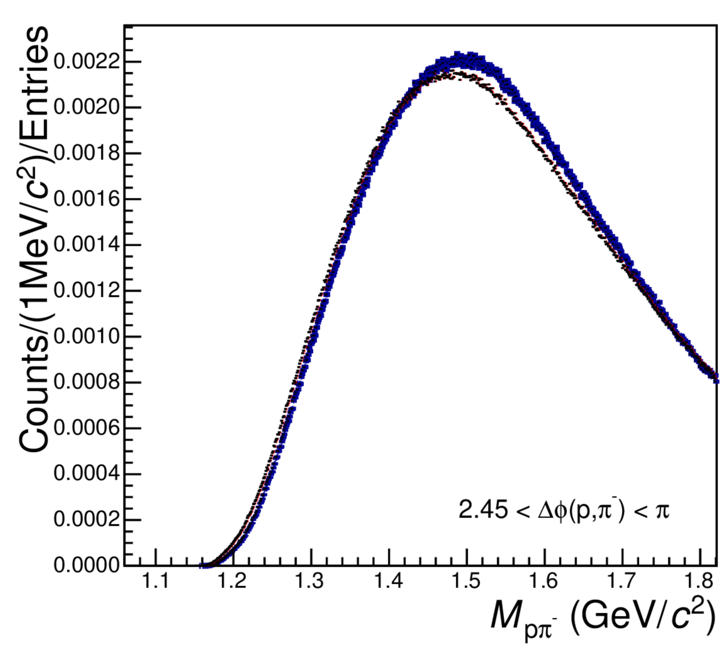
- ● **Like-sign pairs can be used as BG samples for BDT input**
- ● **Need further study of hyperon background using MC**
  - Flow effect, decay particles

Small $\Delta\phi$ → Large $\Delta\phi$









Summary

- ● **Need to improve hyperon purity and efficiency in Pb-Pb for further understanding baryon-baryon interaction**
- ● **Check hyperon purity based on secondary vertex reconstruction by Kalman filter**
  - So far, purity Λ : ~70%, Ξ : ~50%
- ● **Like-sign pairs can describe BG in FG, suitable for BDT input data**

Future plans

- ● **Establishment of hyperon reconstruction method in Pb-Pb**
  - **V0/Cascade class (On the fly, offline), KFParticle, or BDT**
- ➢ **Multi strangeness dibaryon searches**
  - H dibaryon : $^1S_0$, NΩ dibaryon : $^5S_2$
- ➢ **$p\Omega^-$ Correlation function measurement**