Search For Pentaquark And Study on p-K Correlation in Au+Au Collisions

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Pentaquark

Motivation:

- Exotic particles
- Study of subatomic structure

  (e.g. Quark Model, QCD…)

Background:

- Fourquark Zc(3900), Zc(4020)
  - BESIII, 2013 (1303.5949, 1309.1896)
- Pentaquark $P_c^+(4380)$, $P_c^+(4450)$
  - LHCb, 2015… (arXiv: 1507.03414)

Pentaquark

- Particle to search: $\Theta^{++}(uuud\bar{s})$

Decay mode: $\Theta^{++} \rightarrow K^{+} + p$

Method: Rotational BG & Mixed Event

- p/K Selection:

Proton:

- **DCA <= 1 cm**
- **0.2 <= Pt <= 2.8 GeV/c**
- **|Eta| <= 0.5**
- **0 < Flag <= 1000**
- **TOFflag >= 1 && |TofYLocal| <= 1.8 && 0.8 <= $TofM^2$ <= 1**
- **ndEdx >= 10**
- **$|n\sigma_P| <= 2$**

Kaon:

- **TOFflag >= 1**
- **|Eta| <= 0.5**
- **DCA <= 1 cm**
- **0 < Flag <= 1000**
- **P <= 1.6 GeV/c && |TofYLocal| <= 1.8 && 0.2 <= $TofM^2$ <= 0.35**

Pentaquark—Mass Distribution

MB1(~50% data) cen=60~70%

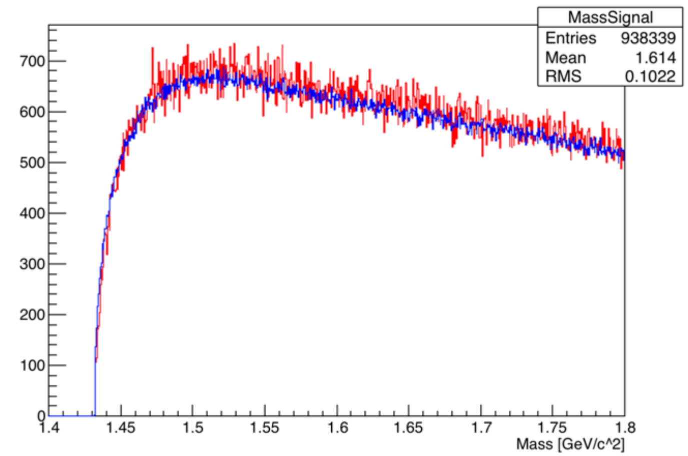
Red: FG Blue: BG

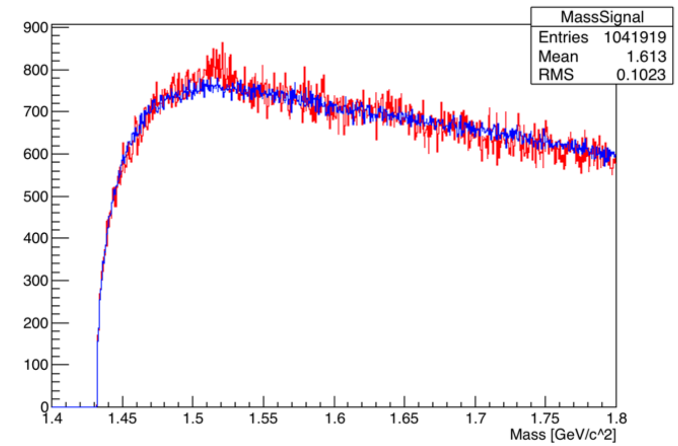
Mixed Event

Rotational BG

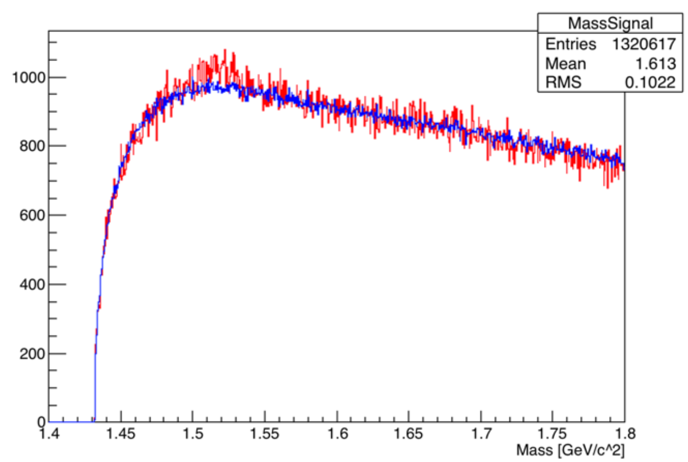
K^- K^+

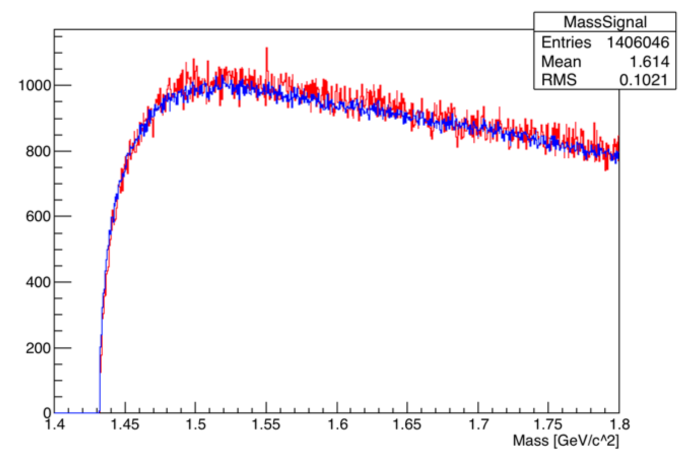
$\bar{P}$





P

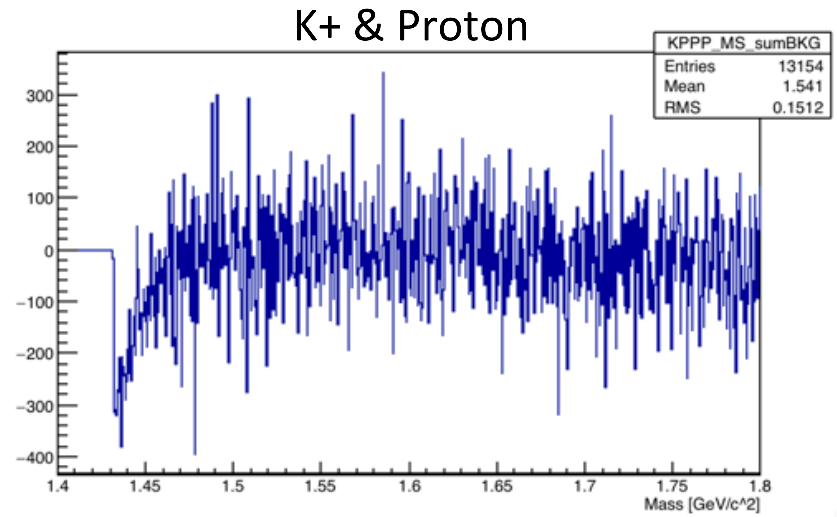


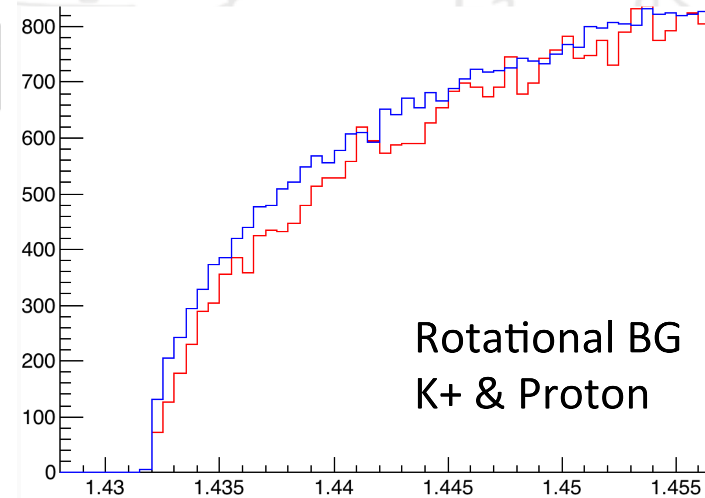


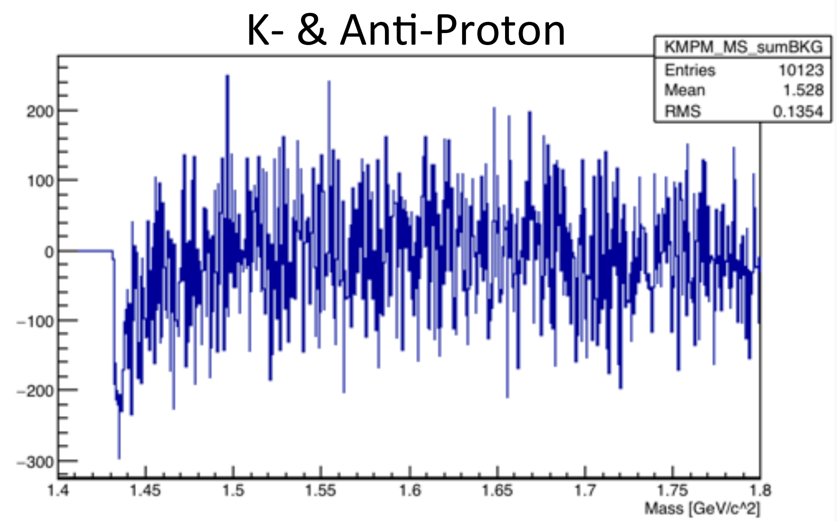
Pentaquark—Mass Distribution

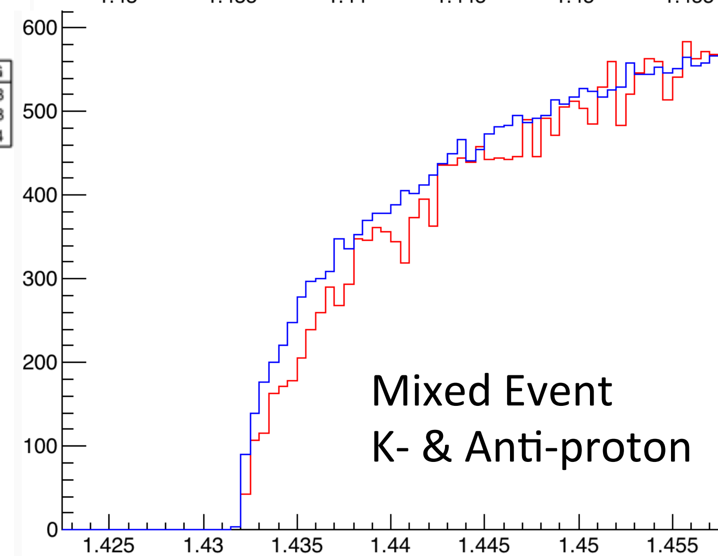
MB1/5/6 cen60~70% Both Rotational and Mixed Event BG

Same Sign :









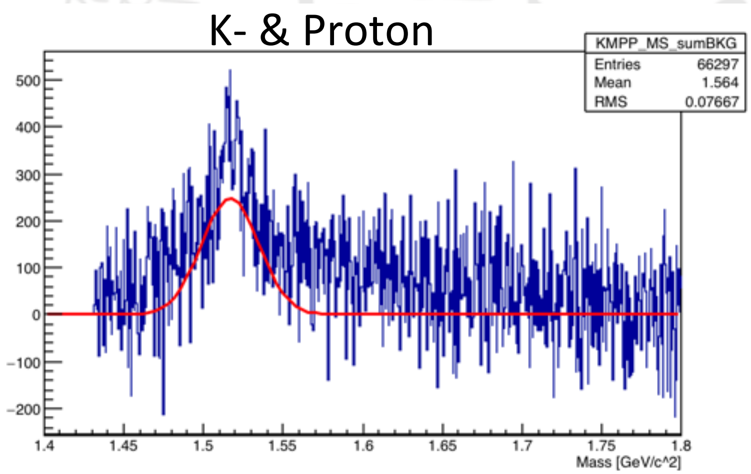
Pentaquark—Mass Distribution

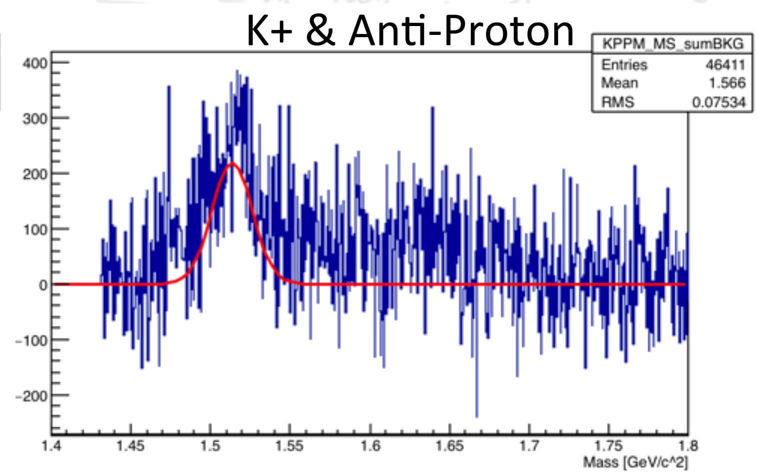
MB1/5/6 cen60~70% Both Rotational and Mixed Event BG

Opposite Sign: $\Lambda(1520) \rightarrow K^{-} + P$

K— & Proton

NO.	NAME	VALUE	ERROR	SIZE	DERIVATIVE
1	Constant	2.46475e+02	3.60199e+00	2.08732e-01	2.27622e-06
2	Mean	1.51690e+00	1.61252e-04	1.60560e-05	-9.54244e-02
3	Sigma	1.79697e-02	2.60803e-04	1.22167e-04	1.08990e-03





K^{+} & Anti-proton

NO.	NAME	VALUE	ERROR	SIZE	DERIVATIVE
1	Constant	2.19258e+02	2.92751e+00	2.17101e-01	-1.24284e-04
2	Mean	1.51370e+00	1.32916e-04	1.34788e-05	6.95243e-01
3	Sigma	1.25410e-02	1.50243e-04	1.08384e-04	1.33239e-01

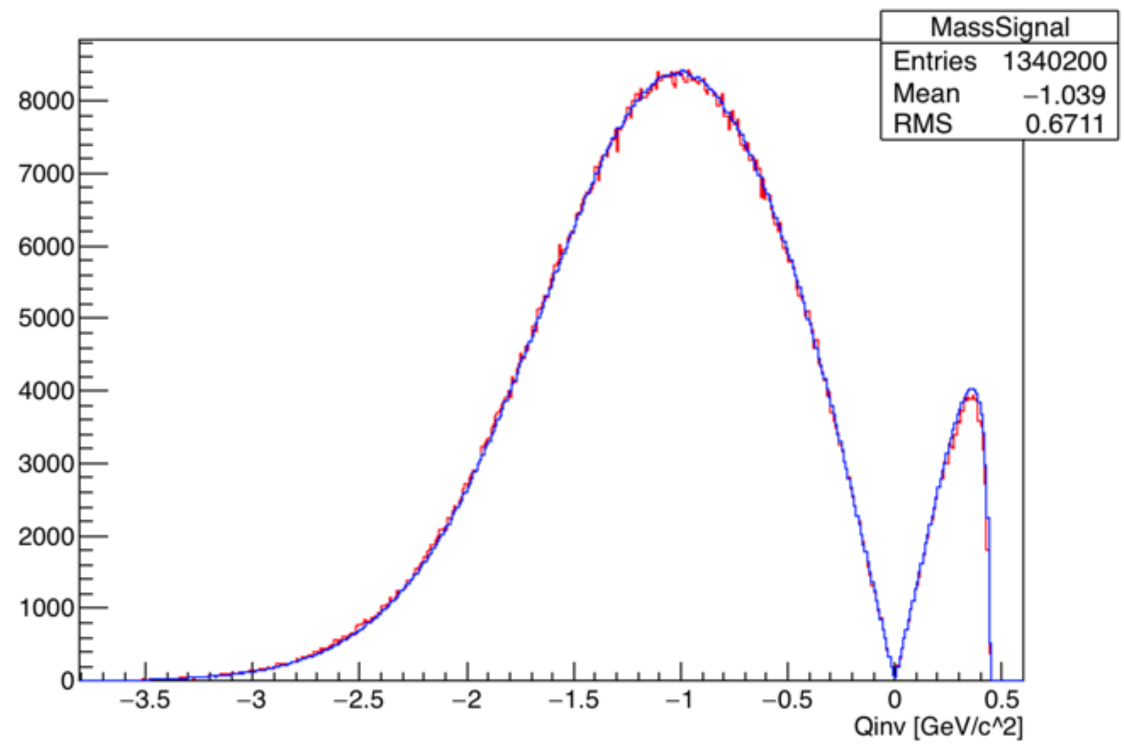
Correlation Function—Kaon & Proton

- Q_{inv}
  - Equation: $Q^2_{inv} = \Delta E^2 - \Delta P^2$
  - Function in code: m() from StLorentzVectorD.h
  - Mixed Event BG & Same KP Selection

    MB5 (~25% data) cen60~70% K— Anti-Proton

Red: FG

Blue: BG



Correlation Function—Kaon & Proton

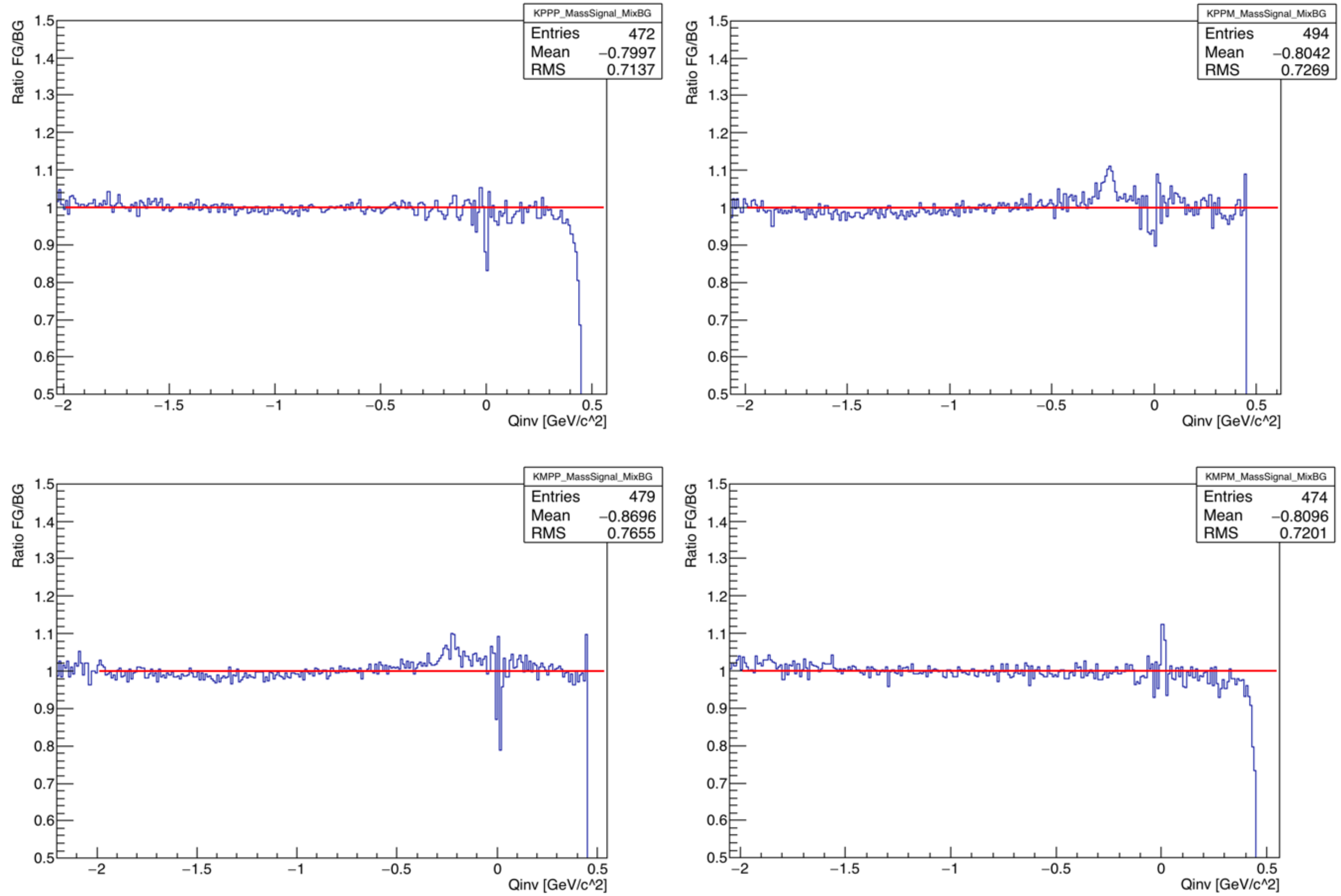
MB5 (~25% data) cen60~70%

$$Ratio = \frac{Foreground}{Background}$$

P $\overline{P}$

K^+

K^-



Correlation Function—Kaon & Proton

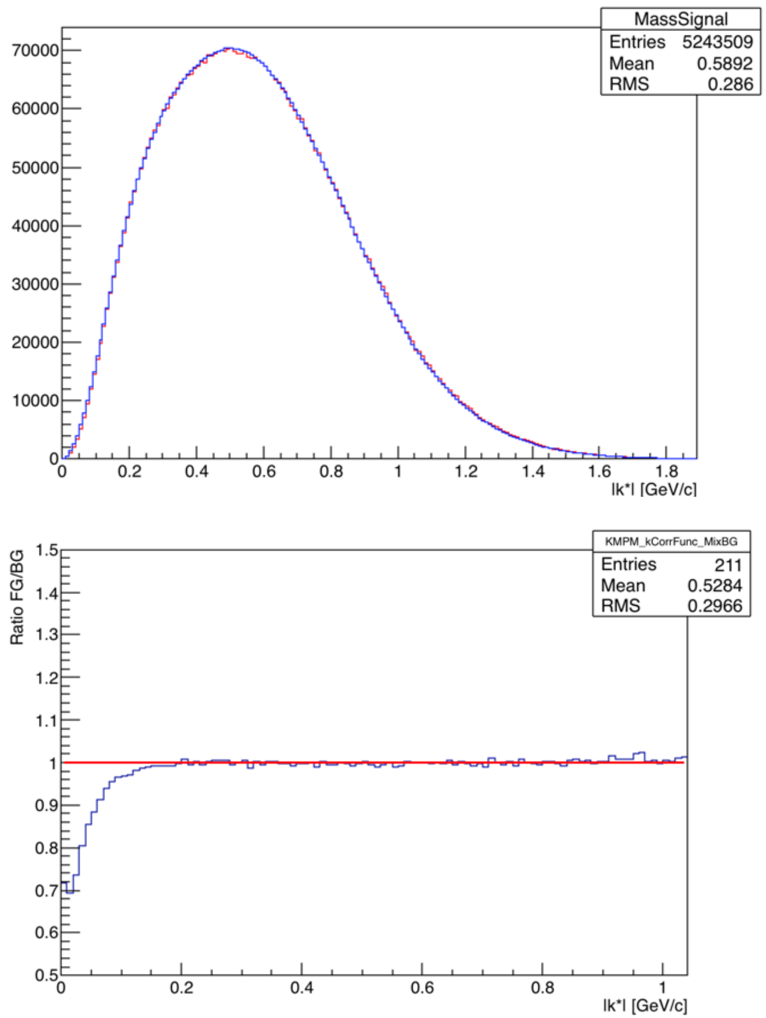
- Momentum in Center of Mass Frame $|k^*|$
  - Mixed Event BG & Same KP Selection
  - Code:

```
double P_CoM(const StLorentzVectorD P1, const StLorentzVectorD P2)
{
StLorentzVectorD Dau1 = P1, Dau2 = P2;
StLorentzVectorD Par = Dau1 + Dau2;
StLorentzVectorD Boo = -Par;
Dau1 = Dau1.boost(Boo); Dau2 = Dau2.boost(Boo); Par = Par.boost(Boo);
double px1 = Dau1.px(), py1 = Dau1.py(), pz1 = Dau1.pz();
double px2 = Dau2.px(), py2 = Dau2.py(), pz2 = Dau2.pz();
double px0 = Par.px(), py0 = Par.py(), pz0 = Par.pz();
double p02 = px0*px0 + py0*py0 + pz0*pz0;
double px = px1 + px2, py = py1 + py2, pz = pz1 + pz2;
double p12 = px1*px1 + py1*py1 + pz1*pz1, p22 = px2*px2 + py2*py2 +
        pz2*pz2;
return sqrt(p12);
}
```

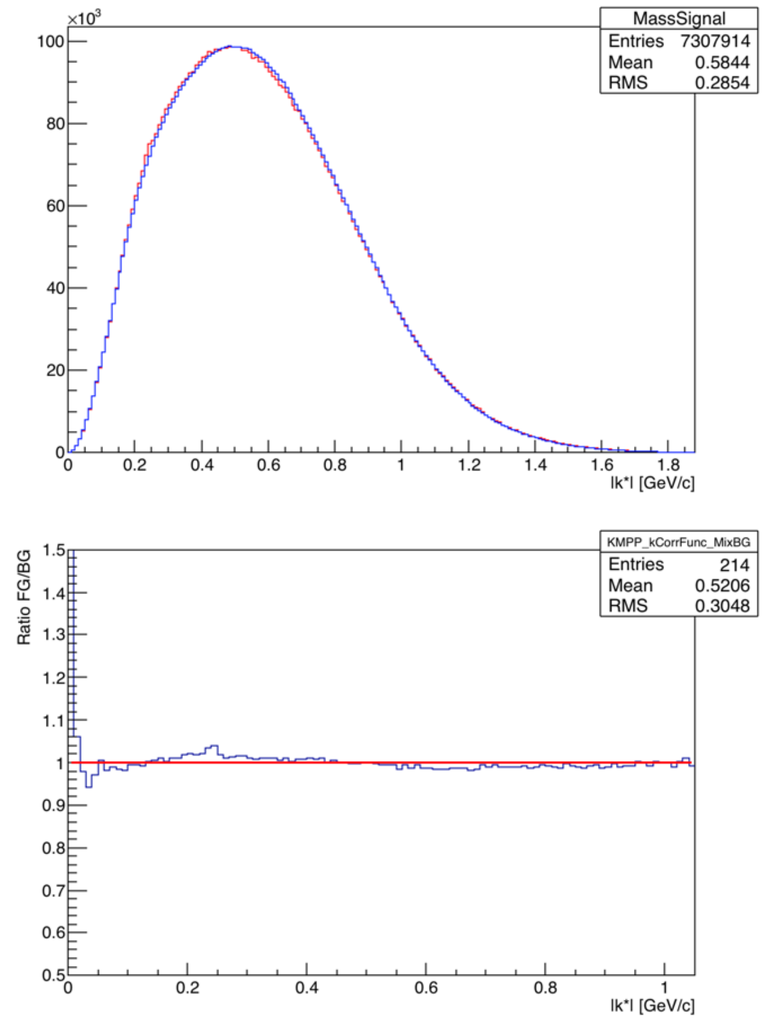
Correlation Function—Kaon & Proton

MB5 (~25% data) cen50~60%

K- & Anti-Proton



K- & Proton

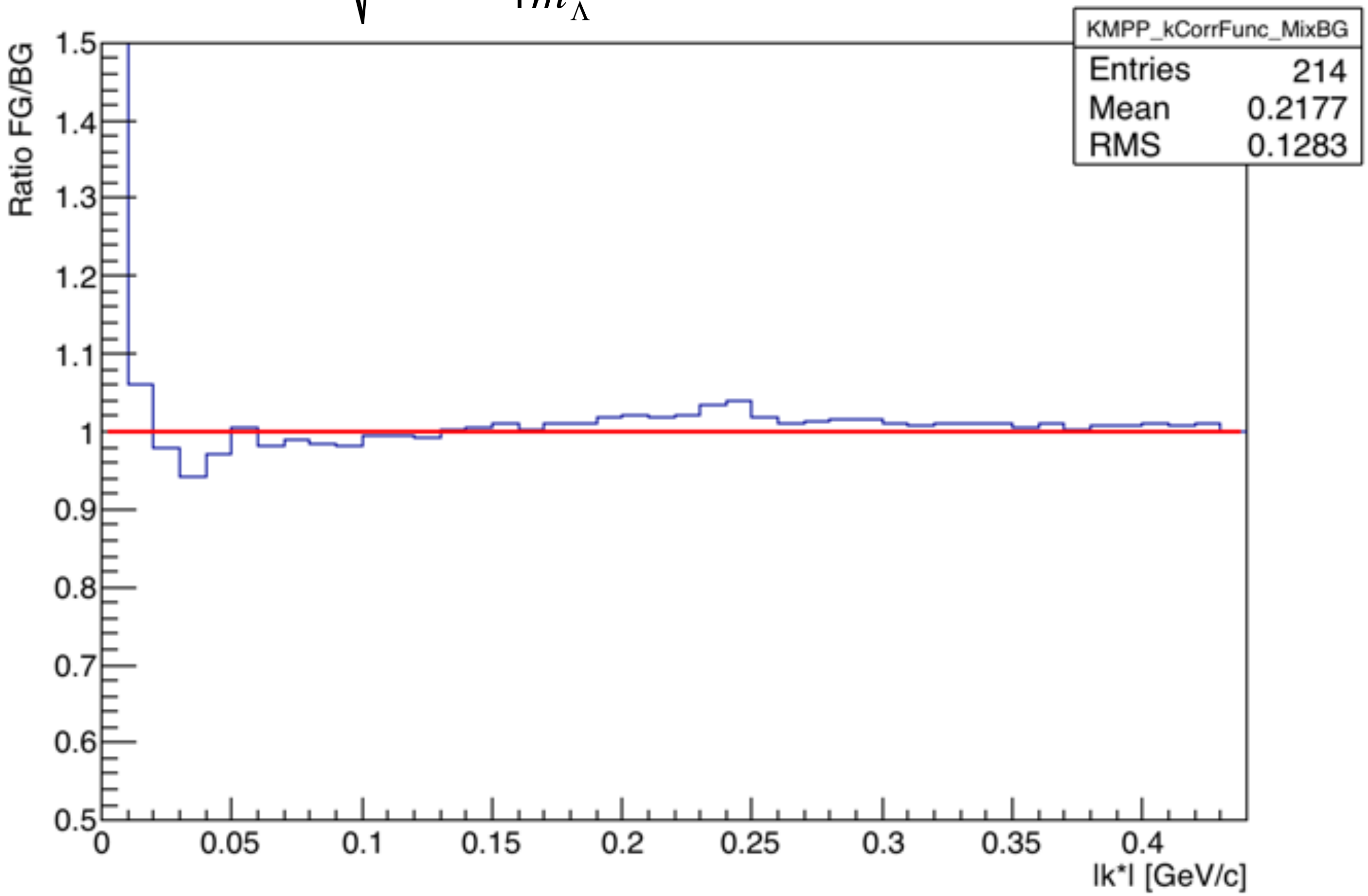


Correlation Function—Kaon & Proton

MB5 (~25% data) cen50~60%

$\Lambda(1520) \rightarrow K^{-}(0.493667) + P(0.938272)$

$$|k^*| = \sqrt{\frac{(m_\Lambda^2 + m_K^2 - m_P^2)^2}{4m_\Lambda^2} - m_K^2} \approx 0.243$$



Summary

- No signal of pentaquark particle
- Further study on P-K Correlation Functions
- Send an abstract to undergraduate conference (CEU):

Study of proton-kaon correlations in heavy-ion collisions

The proton-kaon (pK^+, pK^- and their anti-particles) correlations can be sensitive to several physics topics in heavy-ion collisions. The pK+ correlation could be sensitive to a possible formation of penta-quark candidates with quark contents (uudu-sbar). The pK- correlation measurement could be sensitive to the formation of Lambda (1520) and Lambda(1405). In particular, the Lambda (1405) is below the pK- threshold and a bound state of Lambda (1405), as a molecular state of proton-kaon suggested by recent Lattice QCD calculation[1], could deplete the pK- correlation at small Qinv due to coalescence formation of Lambda(1405) from pK-. We will present the status and further physics implications of our pK correlations from Au+Au collisions at 200 GeV at the STAR experiment.

[1]: PhysRevLett.114.132002

Thanks