

# **FLOW AND INTERFEROMETRY RESULTS FROM AU+AU COLLISIONS AT $\sqrt{s_{NN}}=4.5$ GEV**

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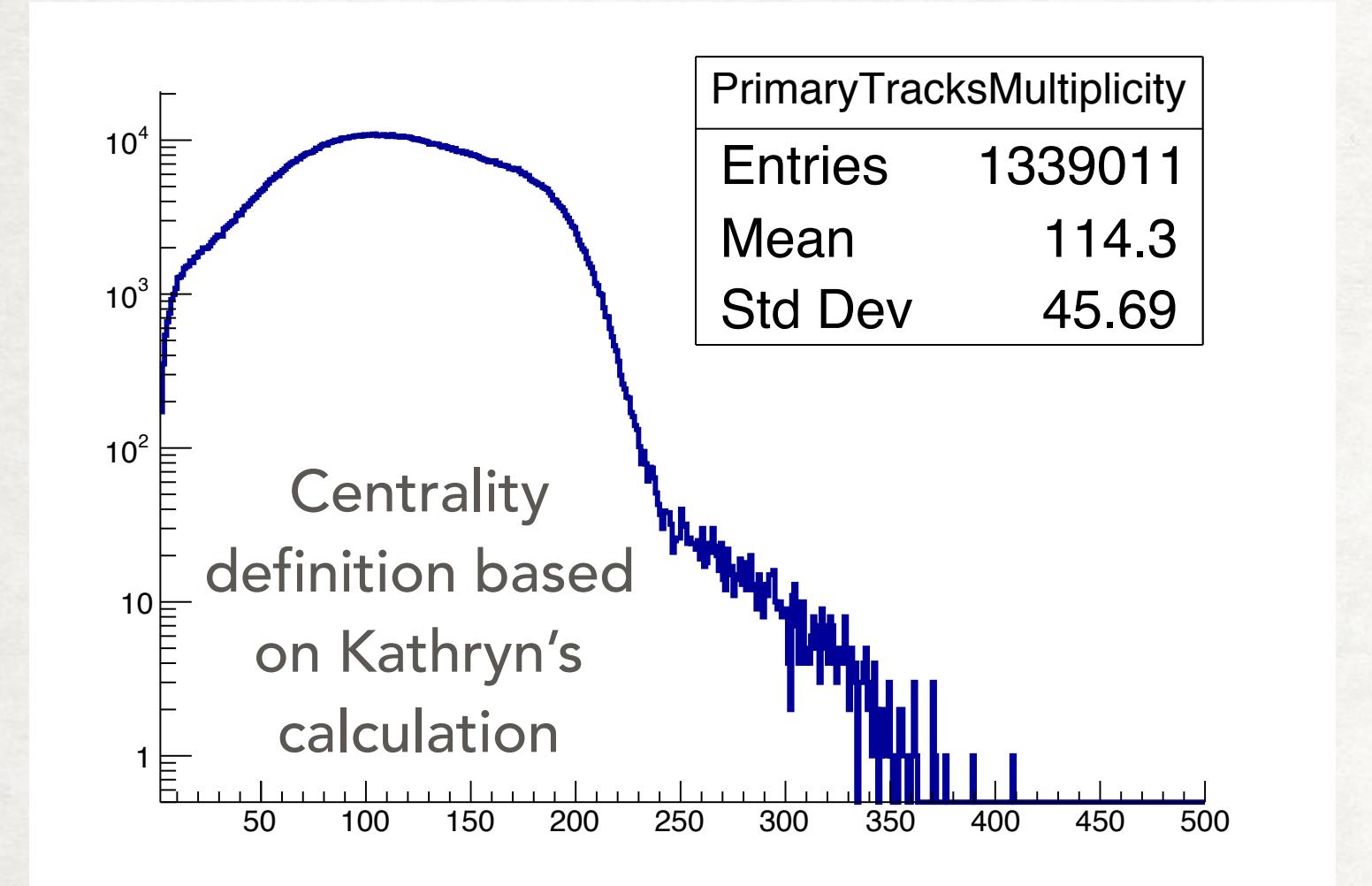
**JAMES DANIEL BRANDENBURG (BNL, SHANDONG, RICE)**

- Trigger Id == 1
- $210 \text{ cm} < V_z < 212 \text{ cm}$
- Vertex Index == 0
- Multiplicity < 240

Instead of RefMult, gRefMult, and other variables standardised for mid rapidity, we have to count **good primary tracks** in order to get correct centrality in Fixed-target data.

**good primary tracks:**

- $\#TpcHits/\#TpcHitsPossible > 0.52$
- $\#TpcHits > 10$
- $\#HitsdEdx > 0$
- Primary Momentum > 0

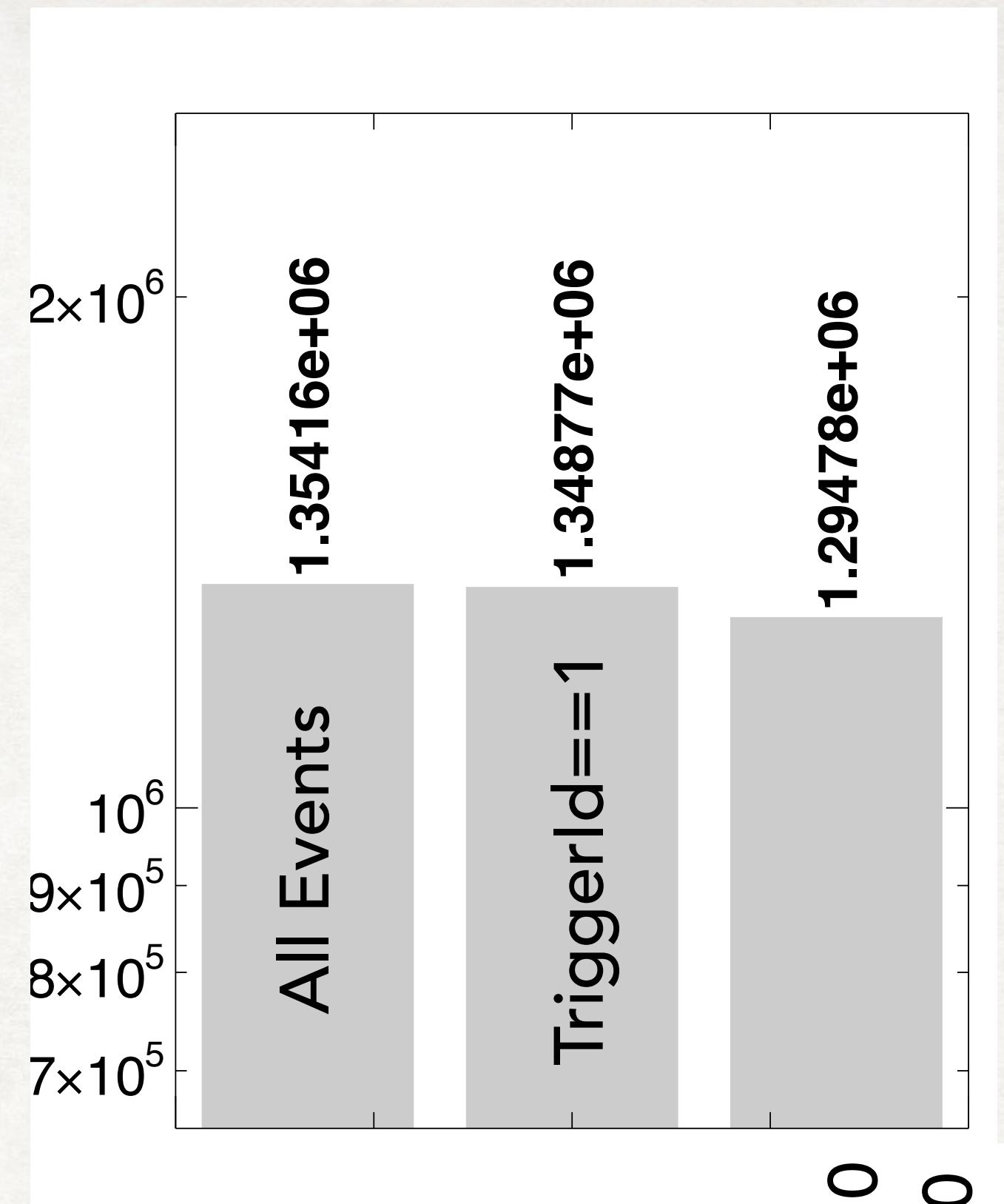
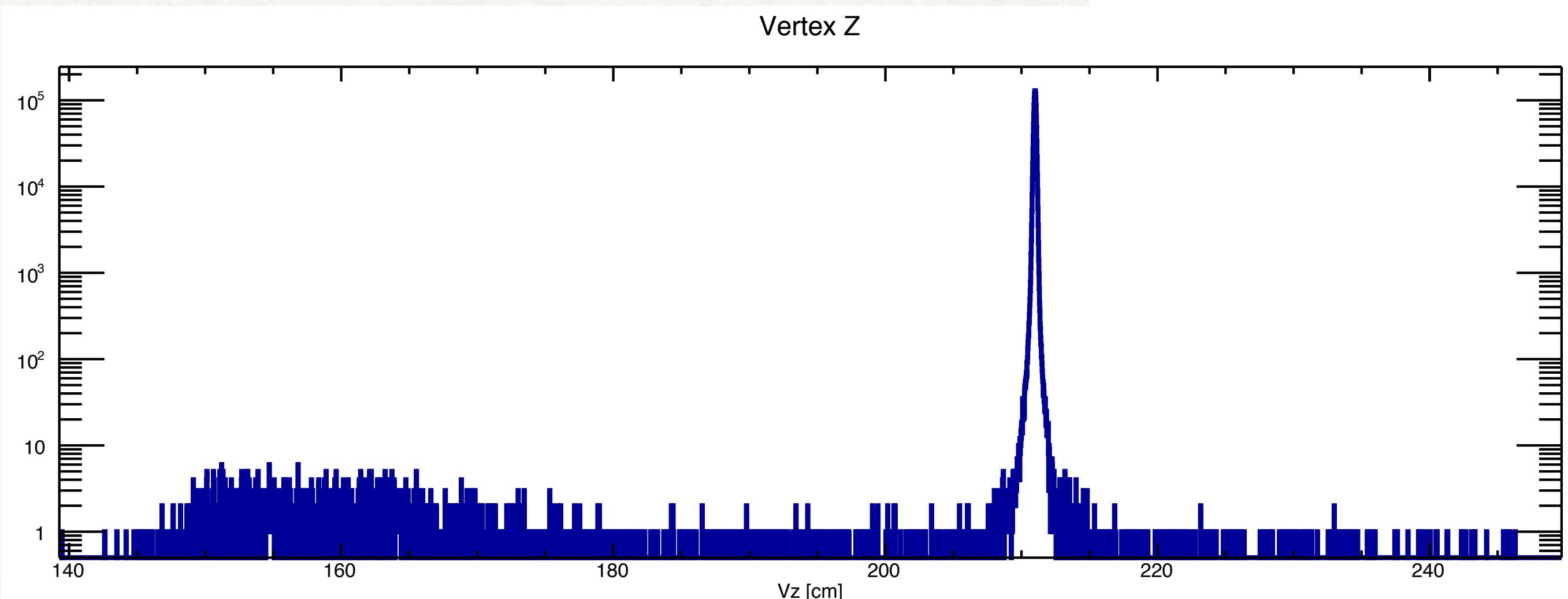


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if (nPrimTracks>152) mCentrality = 0; // 0-5%
else if (nPrimTracks>121) mCentrality = 1; // 5-10%
else if (nPrimTracks>97) mCentrality = 2; // 10-15%
else if (nPrimTracks>77) mCentrality = 3; // 15-20%
else if (nPrimTracks>61) mCentrality = 4; // 20-25%
else if (nPrimTracks>48) mCentrality = 5; // 25-30%
else mCentrality = 6; // >30%

```

# EVENT SELECTION



# DIRECTED FLOW ANALYSIS METHODS

## PROTONS AND PIONS

- TOF information involved in PID
- Q cumulant 4th order and east BBC event plane reconstruction
  - BBC event plane resolution estimated by the method of 3 subevents (two random track TPC subevents reconstructed for this purpose)
  - all tracks included in TPC subevents
  - self correlations safe
- main sources of systematic uncertainty
  - Global DCA and nHitsDedx track cuts

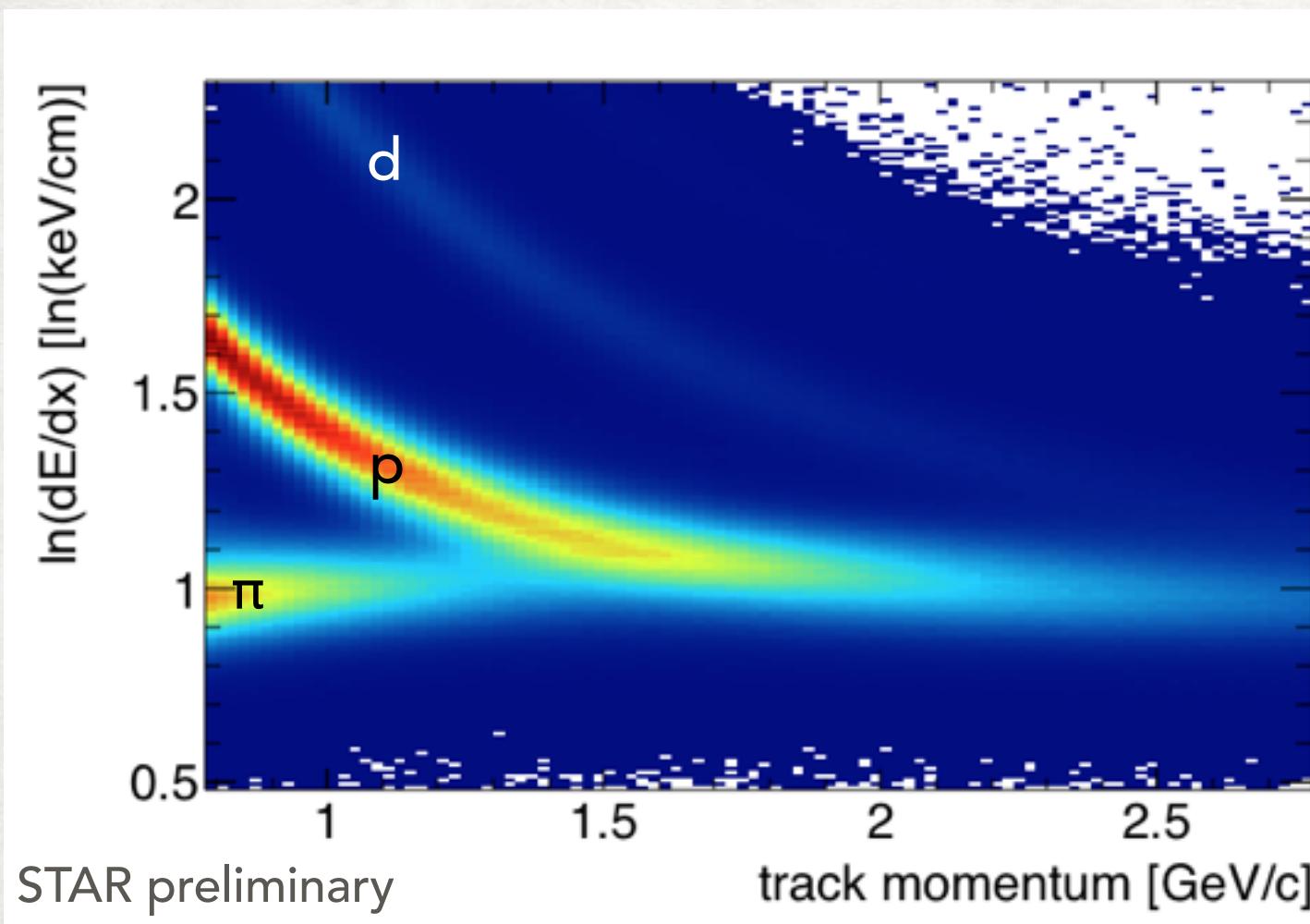
## NEUTRAL KAONS AND LAMBDAS

- PID based on  $dE/dx$  and V0 reconstruction
- TPC and east BBC event plane reconstruction
  - BBC and TPC event plane resolutions estimated by the method of 3 subevents (2 eta-separated TPC subevents and east BBC subevent reconstructed for this purpose)
  - TPC subevents created from protons and deuterons only
  - self correlations safe
- main source of systematic uncertainty
  - Background flow estimation and V0 cuts

# TPC EVENT PLANE RECONSTRUCTION

## IN THE FIRST HARMONIC

- Using TPC identified protons and deuterons coming from the primary vertex
- protons dominate the yield at higher  $p_T$
- $p > 0.3$  (0.4 for deuterons)



Event Flow Vectors:

$$Q_x = \frac{\sum_i \underbrace{(y_{\text{lab}}^{(i)} - y_{\text{c.m.}}) p_T^{(i)}}_{w^{(i)}} \cos \phi^{(i)}}{\sum_i w^{(i)}}$$

$$Q_y = \frac{\sum_i \underbrace{(y_{\text{lab}}^{(i)} - y_{\text{c.m.}}) p_T^{(i)}}_{w^{(i)}} \sin \phi^{(i)}}{\sum_i w^{(i)}}$$

$$y_{\text{c.m.}} = -1.52$$

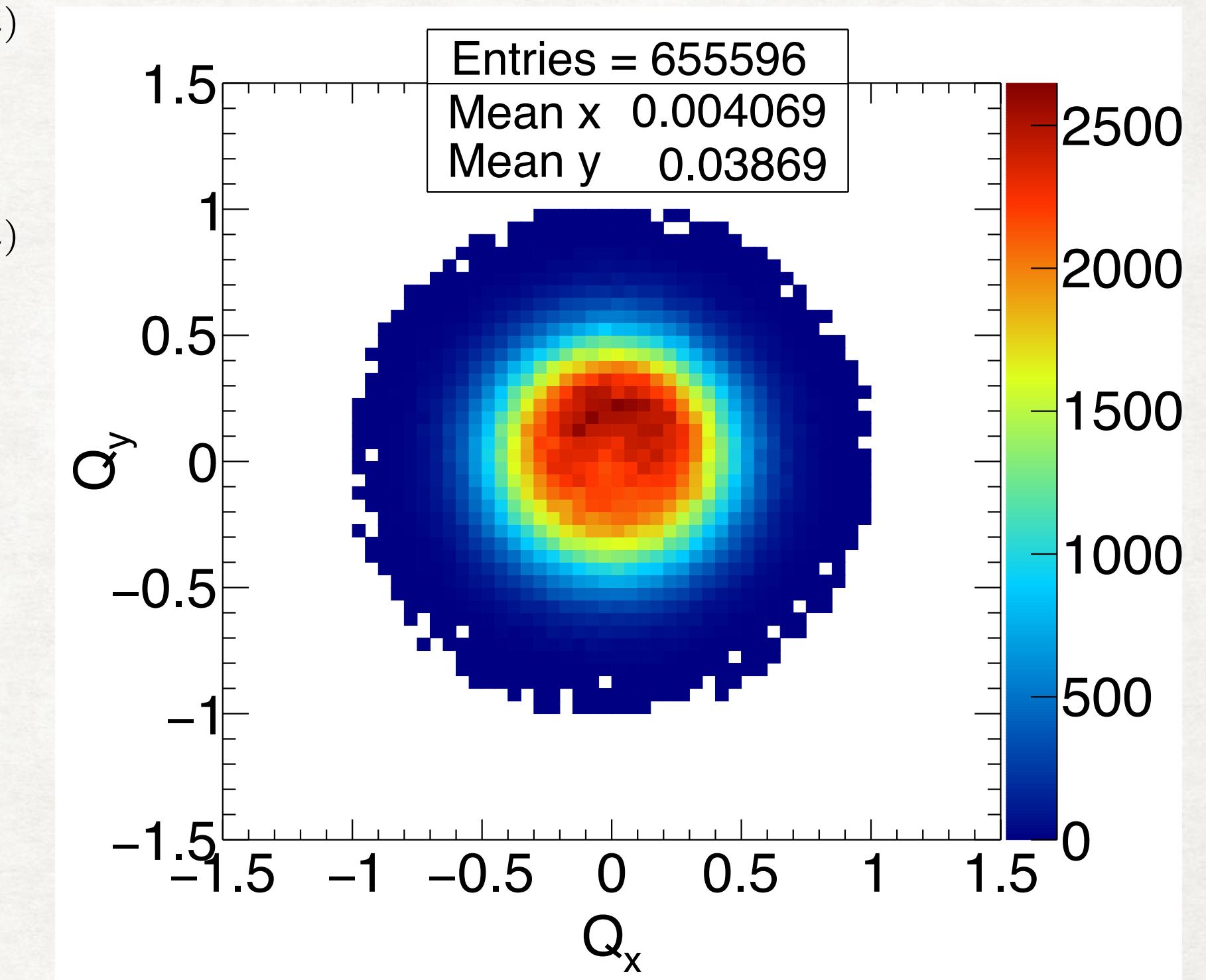
Centering of Event Flow Vectors:

$$Q_x^{\text{centered}} = Q_x - \langle Q_x \rangle$$

$$Q_y^{\text{centered}} = Q_y - \langle Q_y \rangle$$

Event Plane Angle Calculation:

$$\Psi = \tan^{-1} \left( \frac{Q_y^{\text{centered}}}{Q_x^{\text{centered}}} \right)$$



# DEFINITION OF SUBEVENTS (IN LAMBDA AND KAON ANALYSIS)

- Because of BBC as subevent 3 - subevent 1 range can be widened
- Subevent 1 ( $\Psi_1$ ):**  $-0.9 < \eta < -0.1$  : used to estimate  $\Psi_{RP}$
- Subevent 2 ( $\Psi_2$ ):**  $-1.5 < \eta < -0.9$  : used to estimate  $\Psi_1$  resolution
- Subevent 3 ( $\Psi_3$ ):** using BBC event plane instead

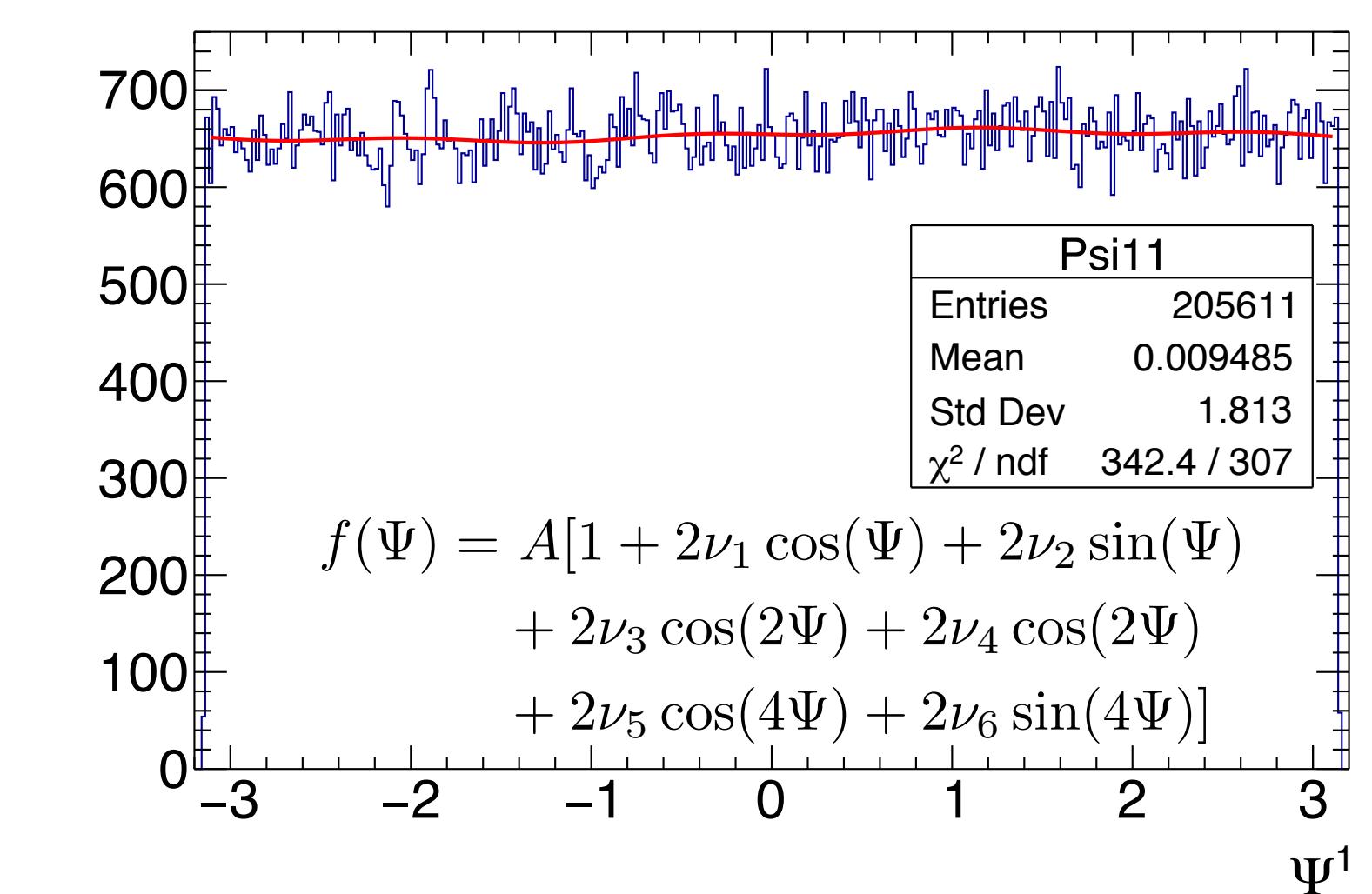
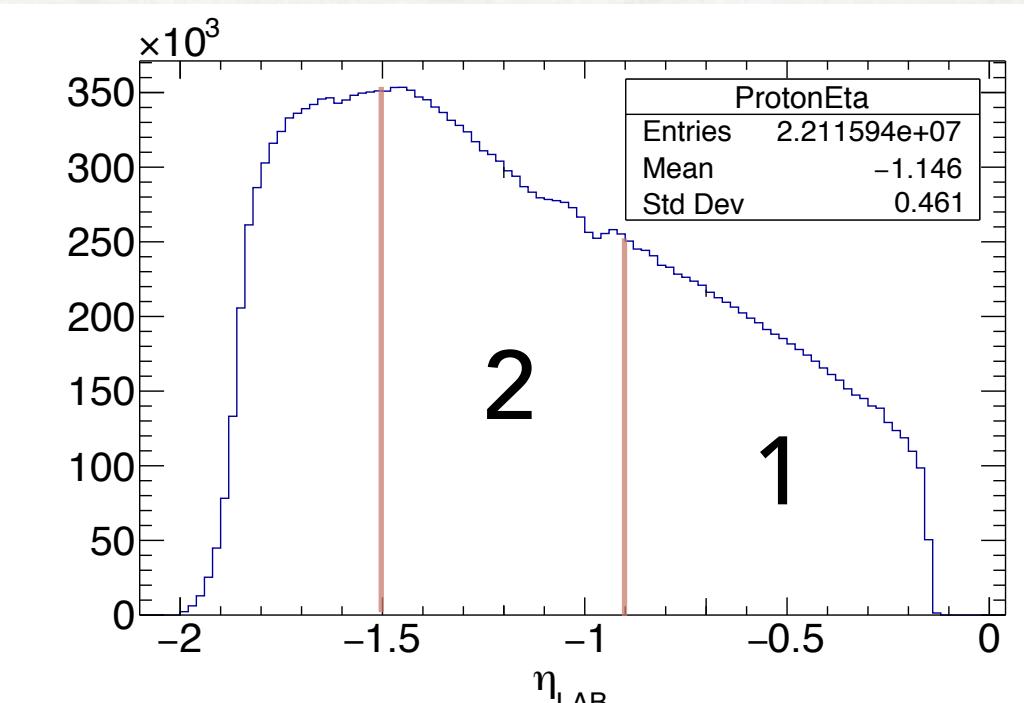
mean rapidity of protons : 1.185

mean rapidity of deuterons : 1.303

Average V1 in the evt. plane: 0.27 (deuterons V1 = 2 x protons V1, protons V1 taken from Yang Wu's results)

Multiplicity in the evt. plane : 13.2

Resolution : 70.2%

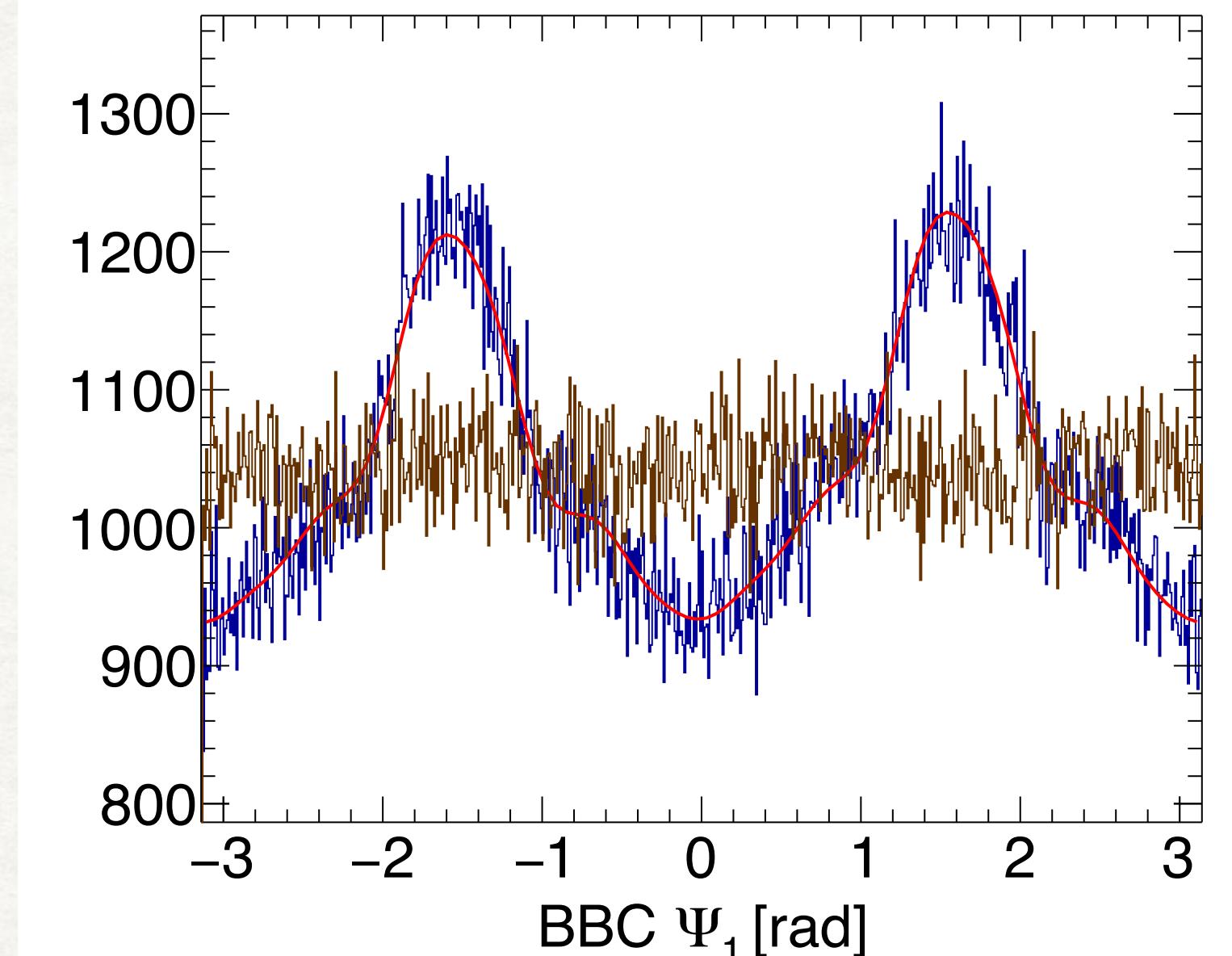


$$\langle \cos(\Psi^{BBC} - \Psi^R) \rangle = \sqrt{\frac{\langle \cos(\Psi^{BBC} - \Psi^A) \rangle \langle \cos(\Psi^{BBC} - \Psi^A) \rangle}{\langle \cos(\Psi^A - \Psi^B) \rangle}} = \sqrt{\frac{0.232 \times 0.252}{0.128}} = (67.5 \pm 0.5)\%$$

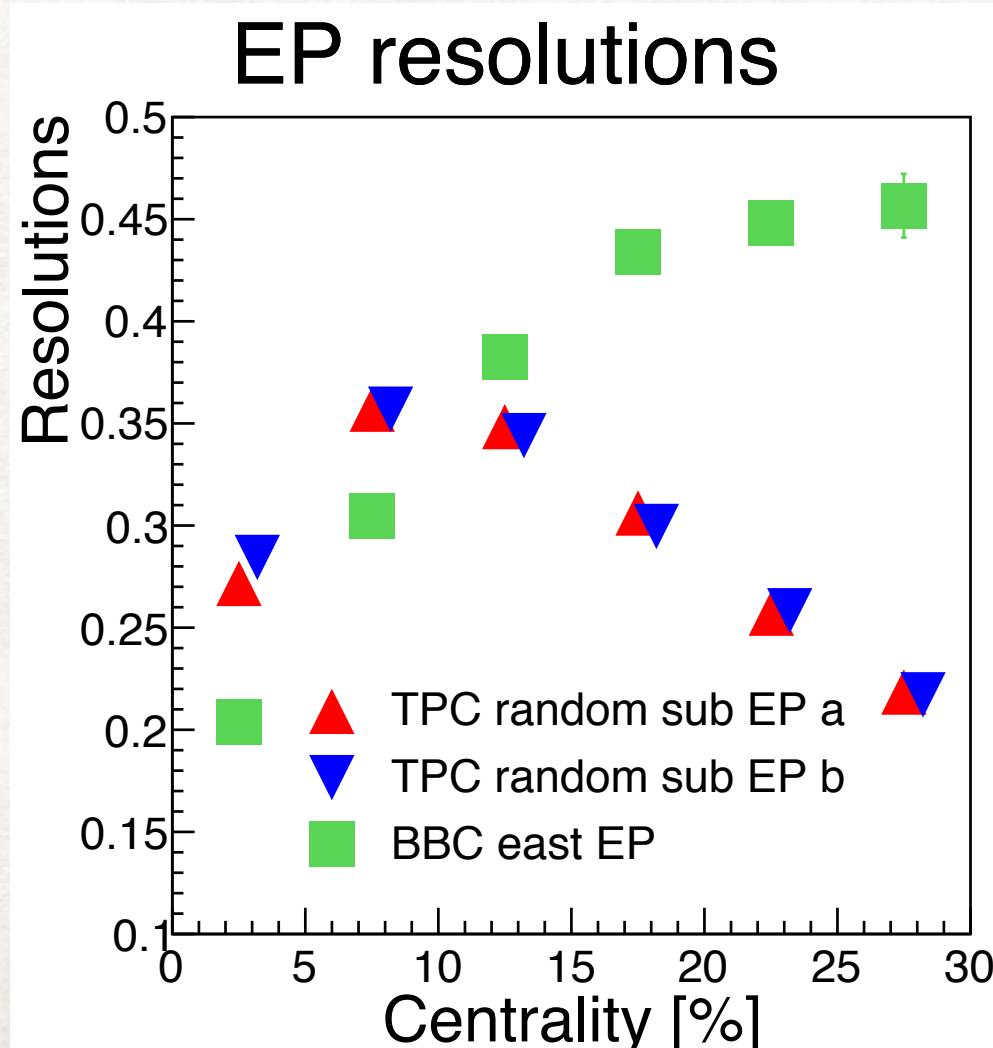
# BBC EVENT PLANE RESOLUTION

- **Sub-event BBC ( $\Psi_{BBC}$ )** : used to estimate  $\Psi_{RP}$
- **Sub-event A ( $\Psi_A$ ):  $-1 < \eta < 0$**  : used to estimate  $\Psi_1$  resolution
- **Sub-event B ( $\Psi_B$ ):  $-2 < \eta < -1$**

$$\langle \cos(\Psi^{BBC} - \Psi^R) \rangle = \sqrt{\frac{\langle \cos(\Psi^{BBC} - \Psi^A) \rangle \langle \cos(\Psi^{BBC} - \Psi^A) \rangle}{\langle \cos(\Psi^A - \Psi^B) \rangle}} = \sqrt{\frac{0.257 \times 0.108}{0.174}} = (40.0 \pm 0.5)\% \quad \text{For 10-30% centrality}$$



## Proton and Pion V1 analysis



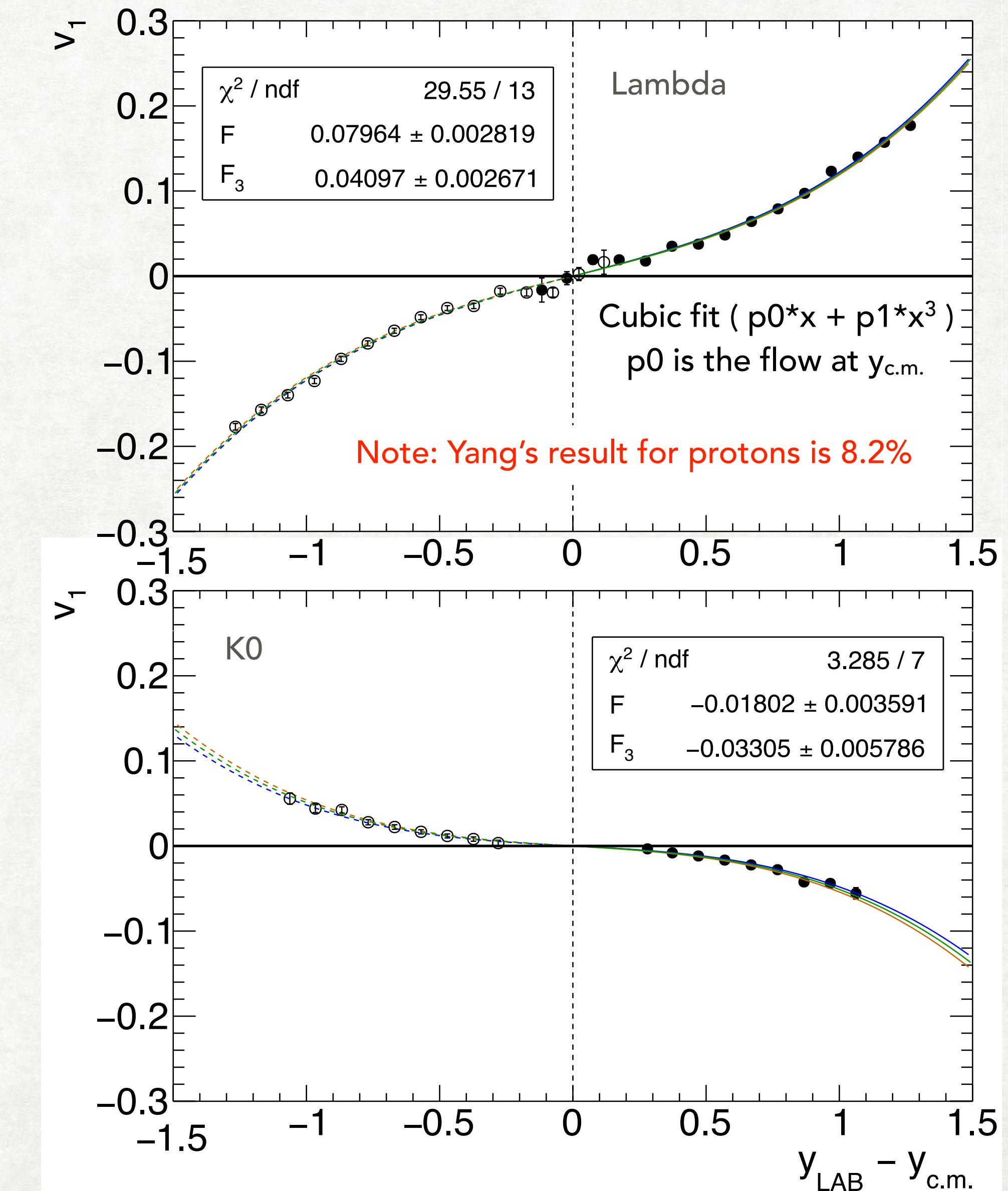
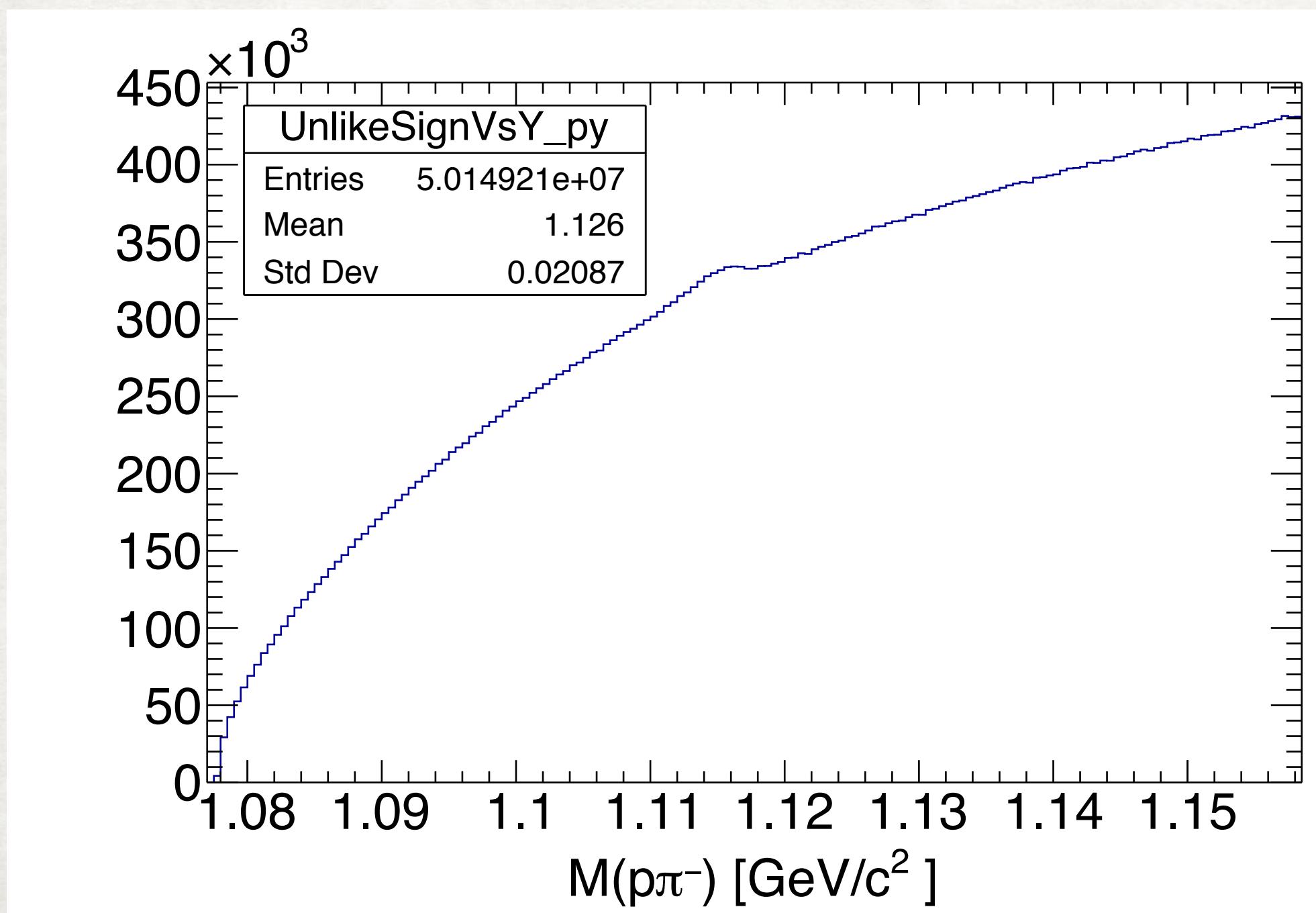
BBC event plane resolution consistent (the same event plane, different sub-events in the resolution estimation)

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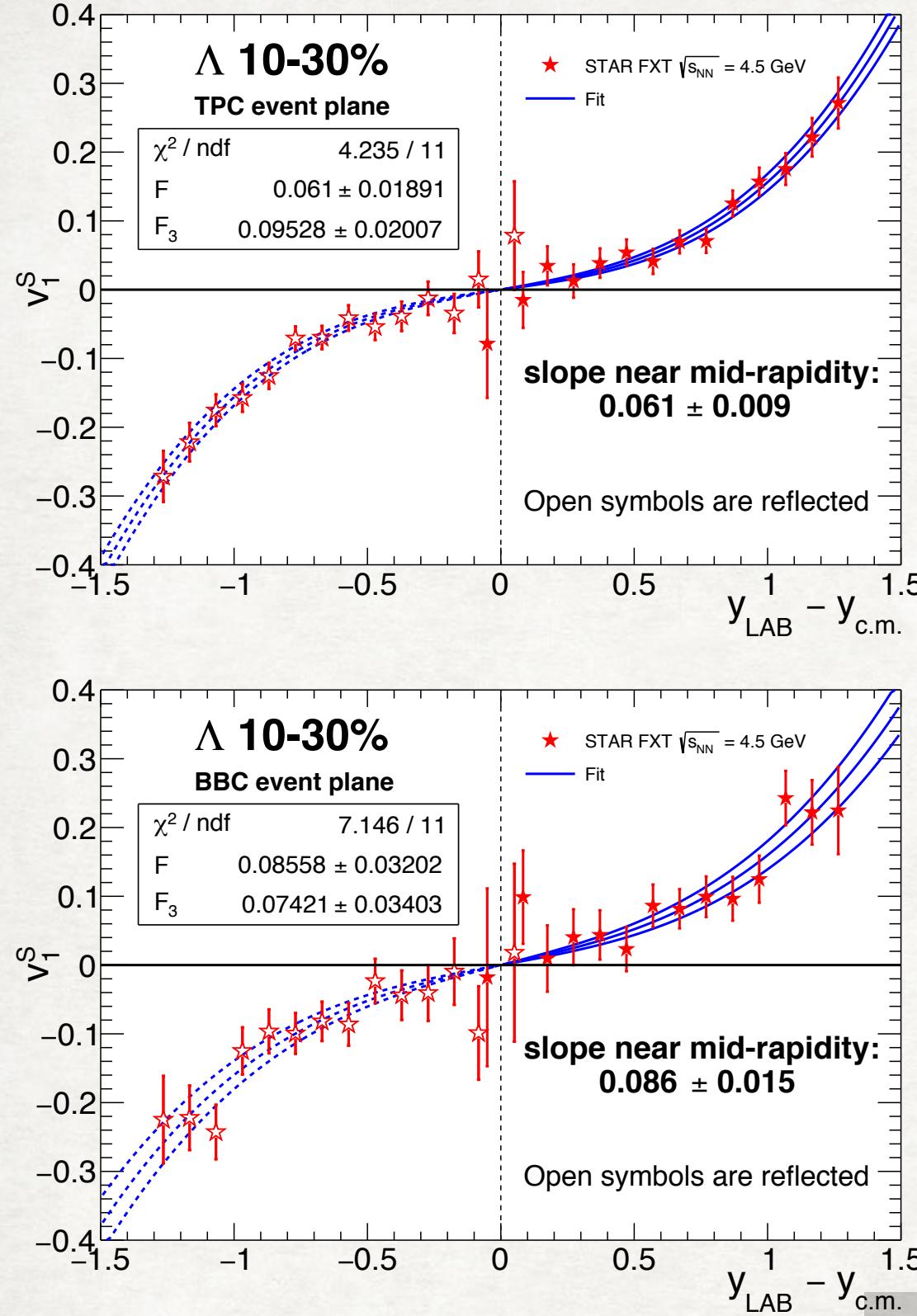
TPC event plane resolution different (different event plane - different eta range, different particles)

# THE FLOW OF COMBINATORIAL BACKGROUND

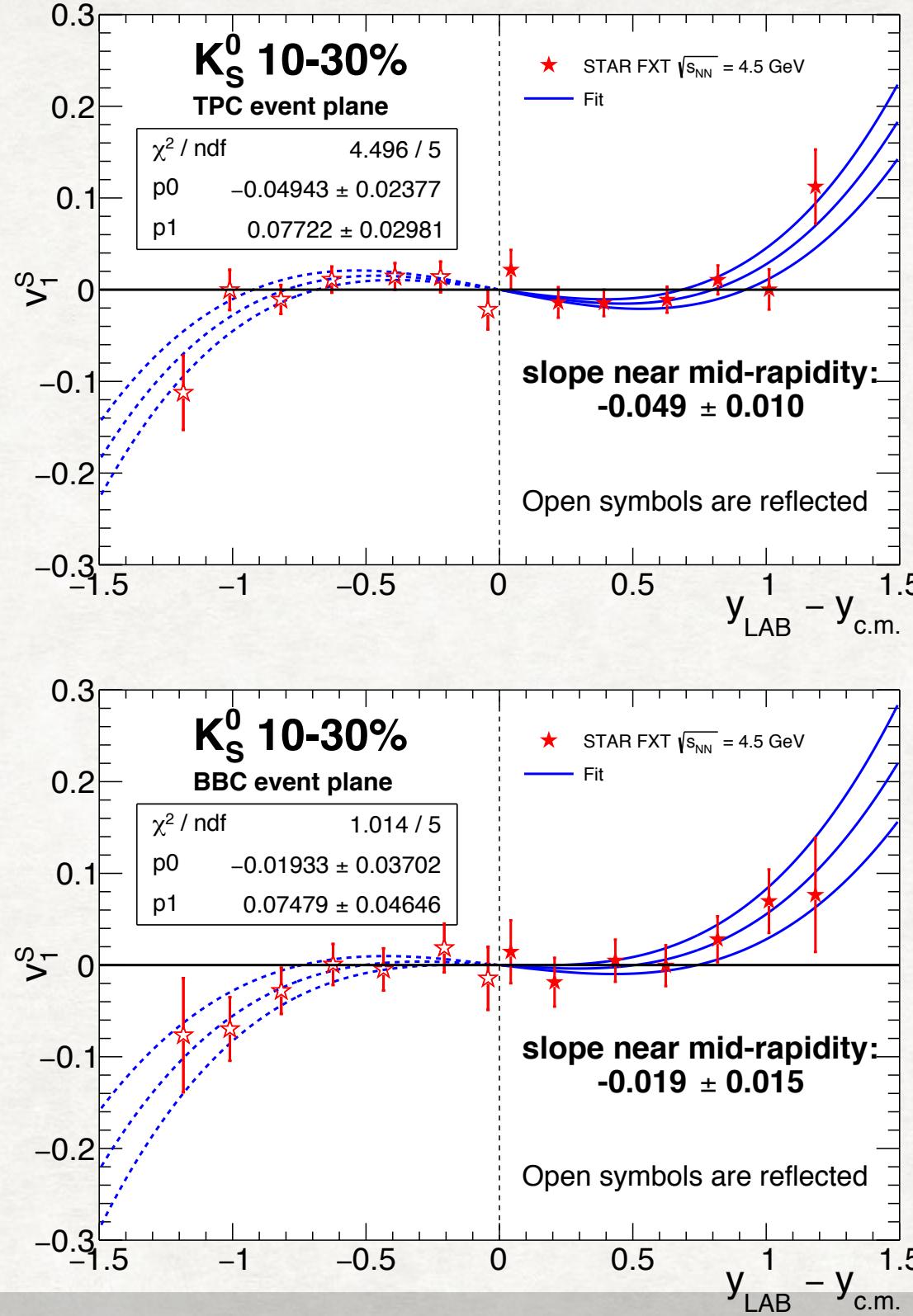
- Directed flow is slightly dependent on the invariant mass
  - ▶ using the side band leads to distortion
- Not enough statistics for fit to  $v_1(M)$  distribution
- No V0 cuts produces distribution where signal/background ratio is close to 0



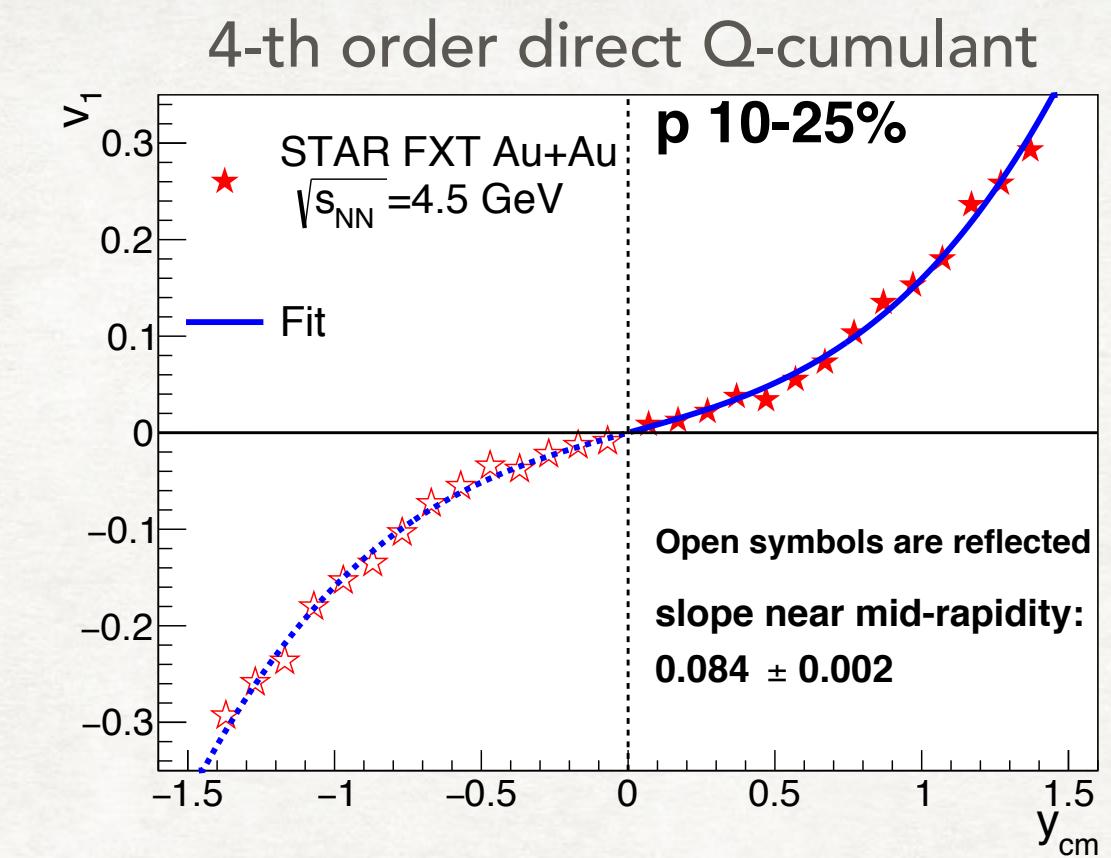
# LAMBDA



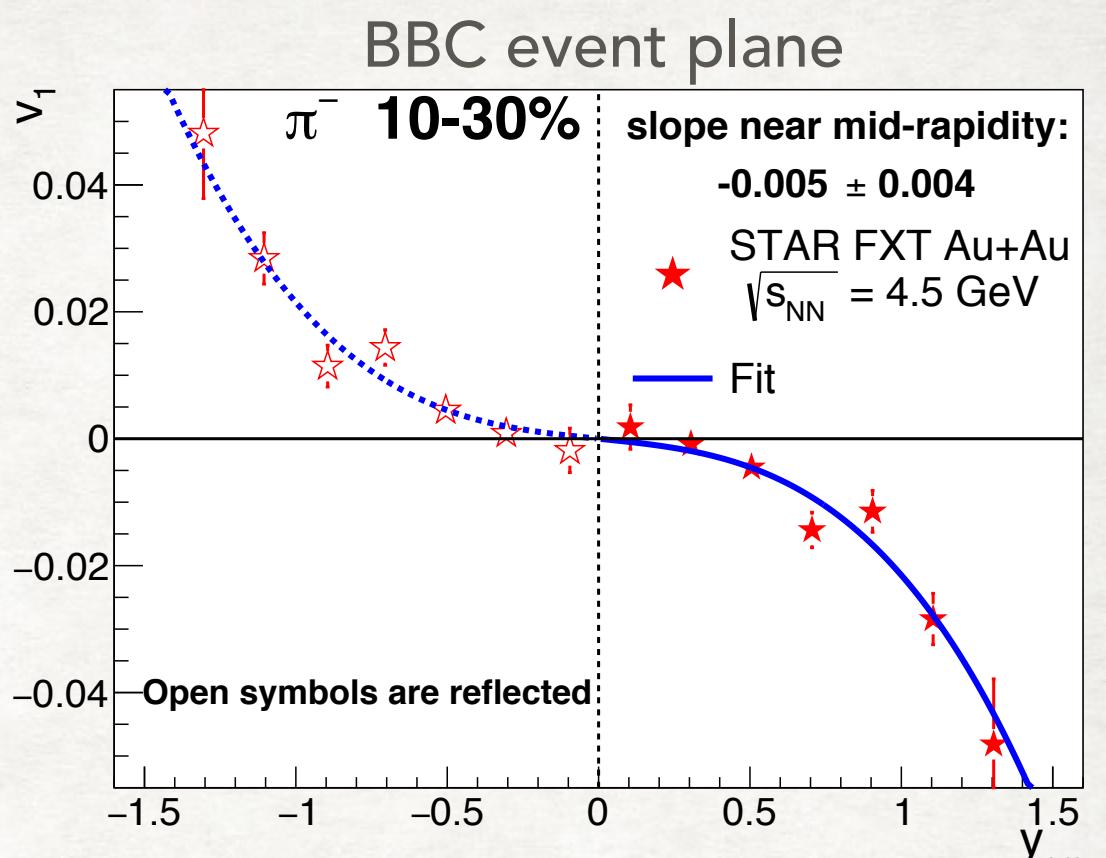
# K0



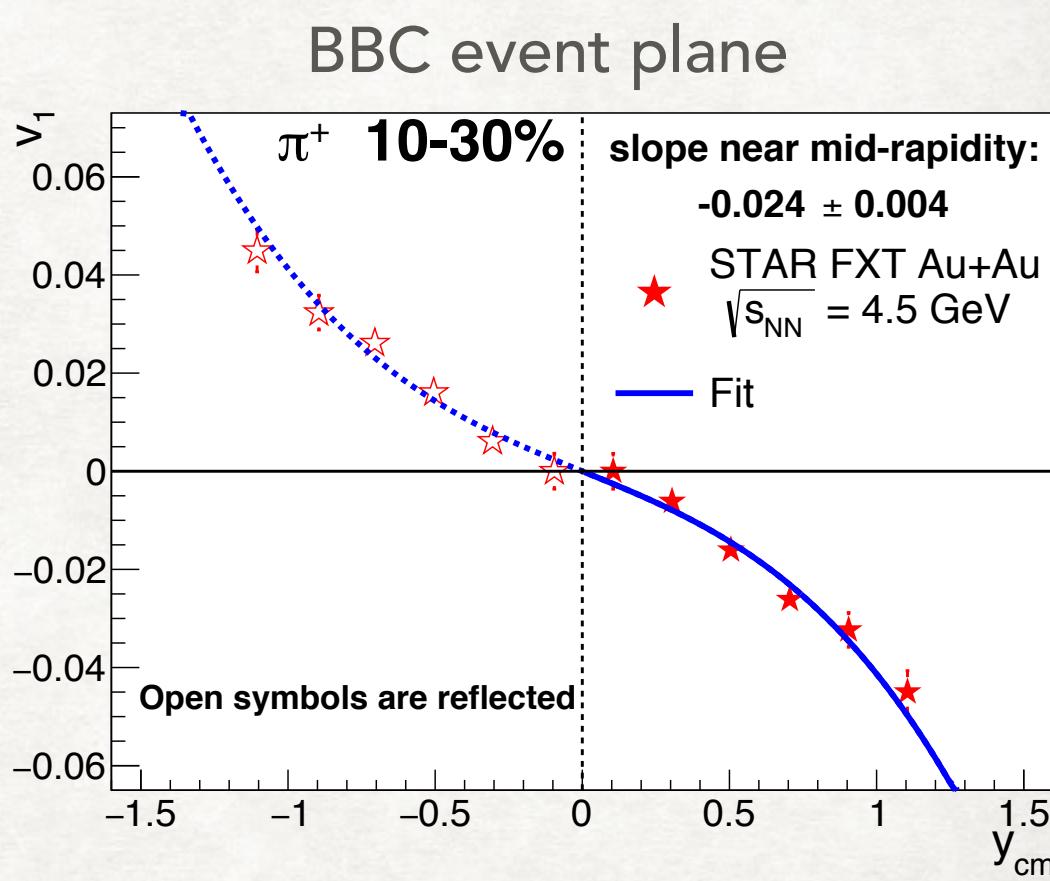
# PROTONS



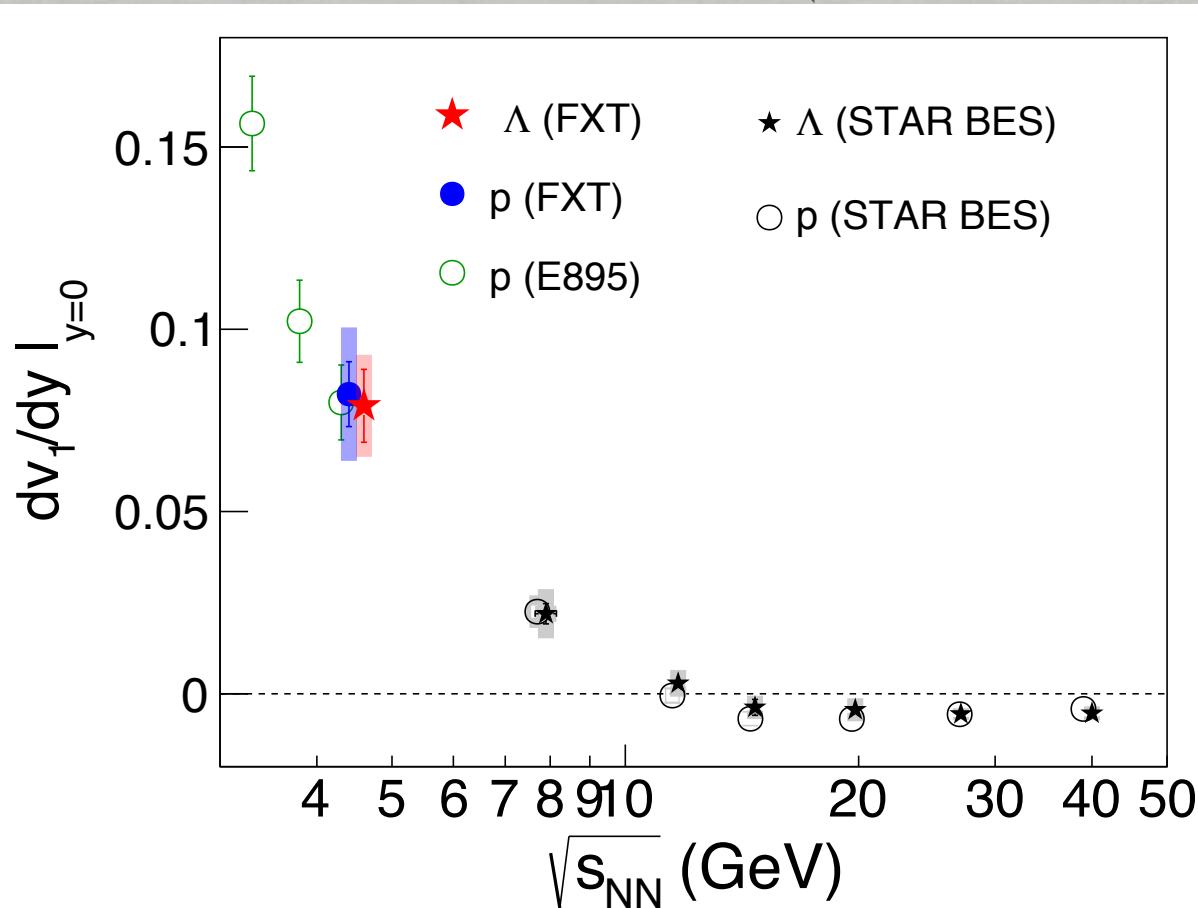
# NEGATIVE PIONS



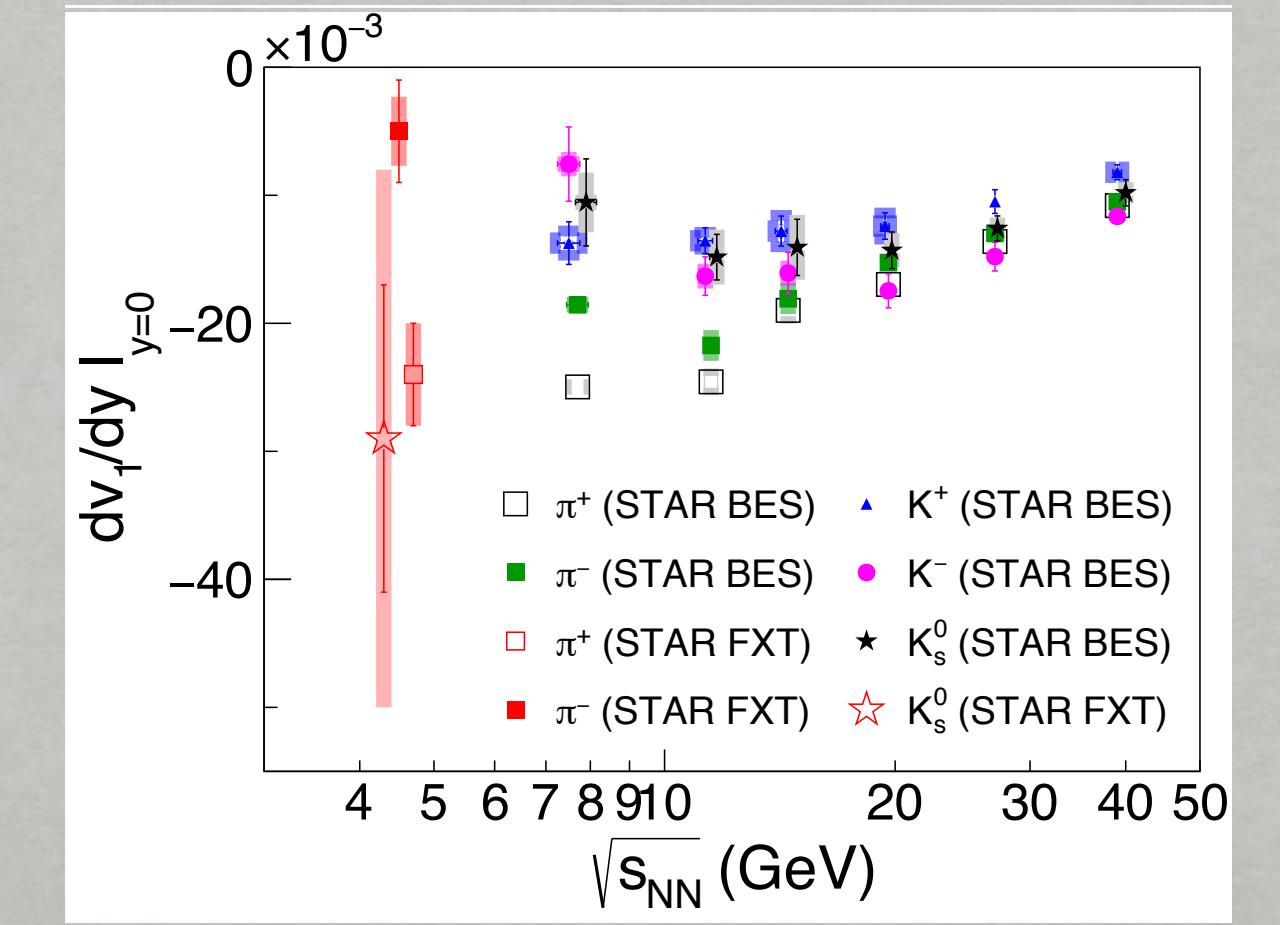
# POSITIVE PIONS



# BARYONS

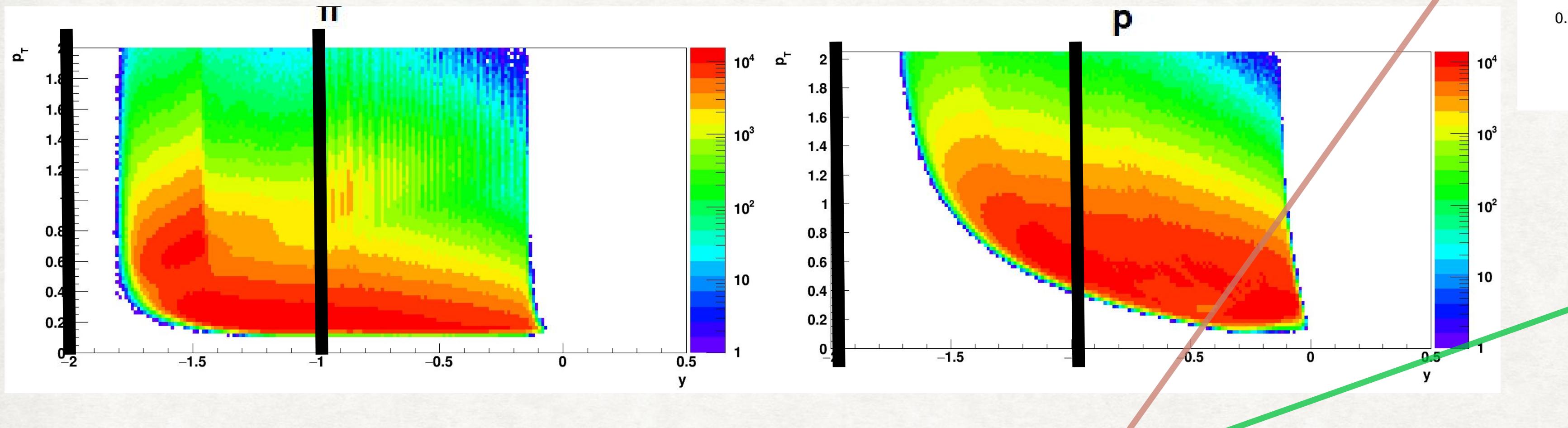


# MESONS

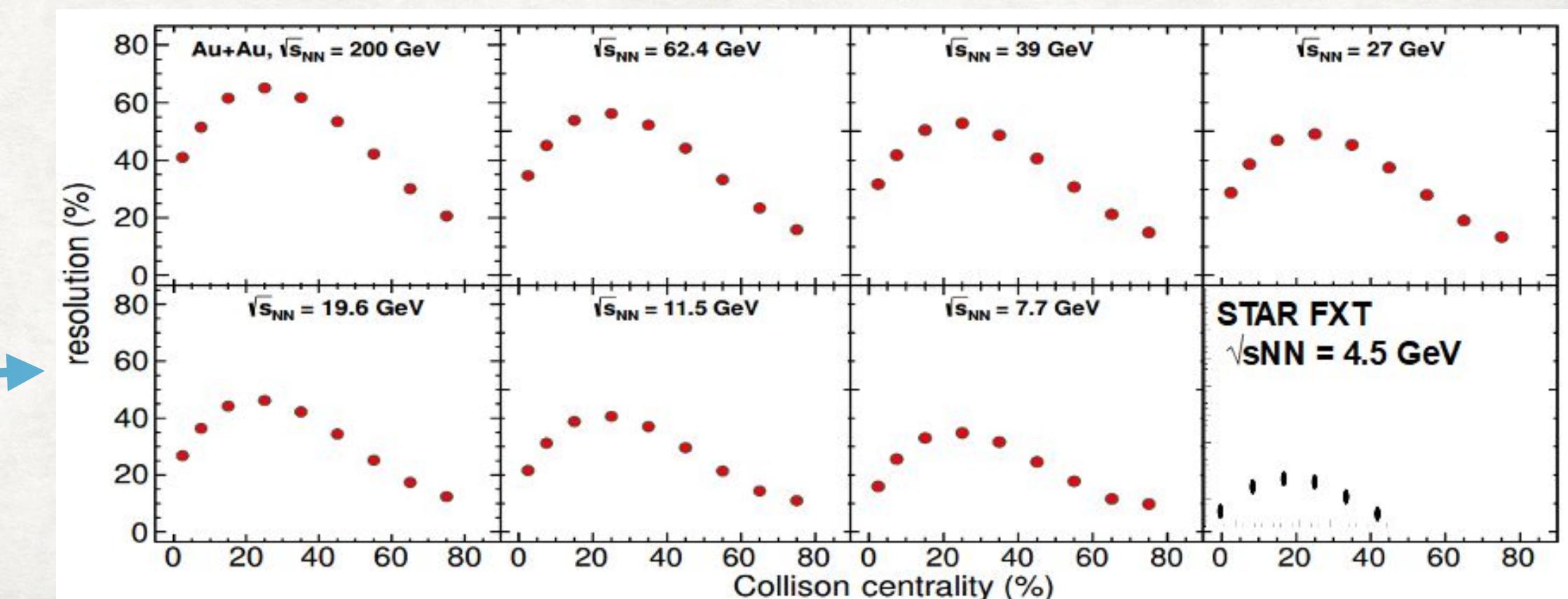
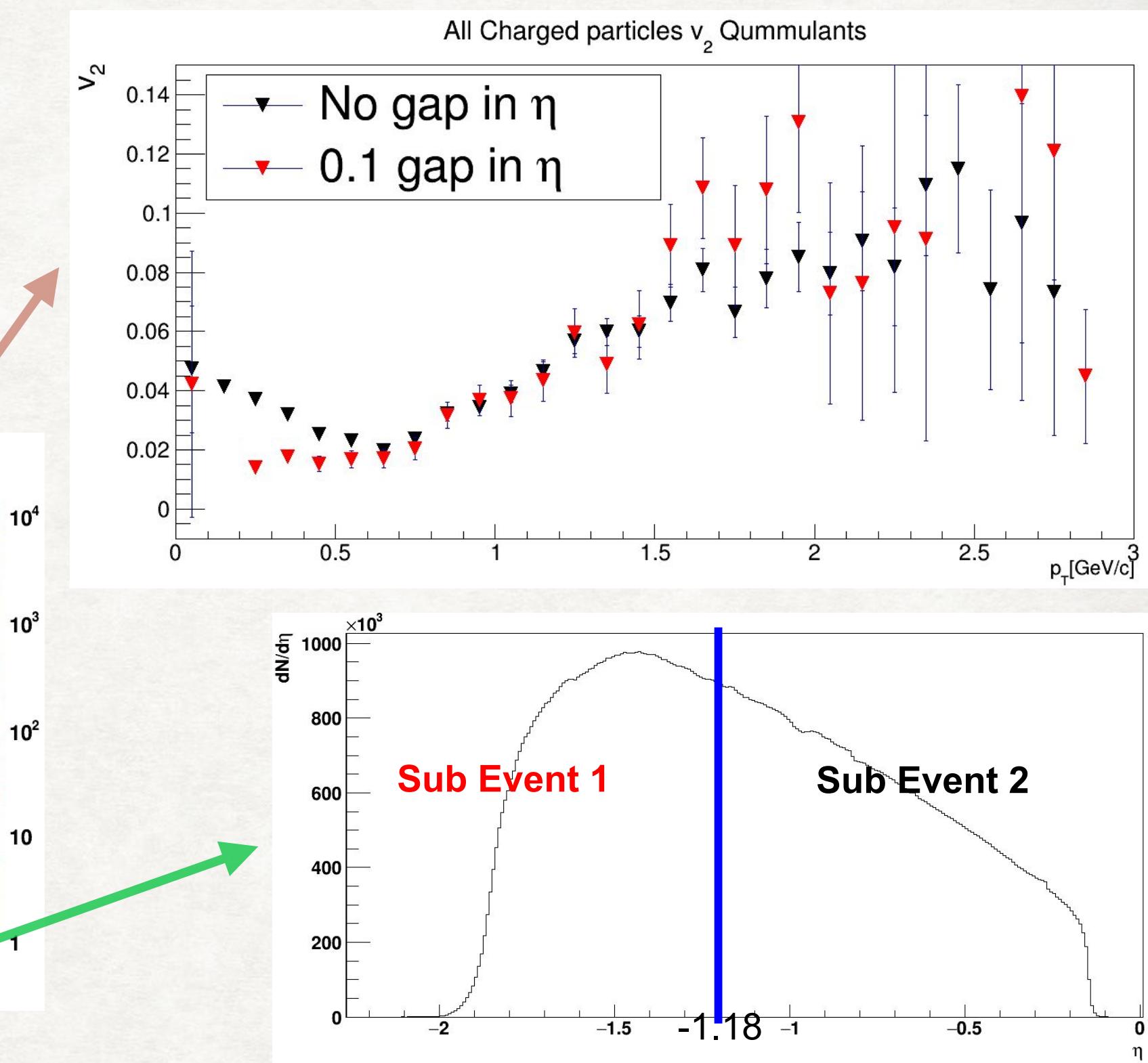


# ELLIPTIC FLOW OF PROTONS AND PIONS

- PID based on  $dE/dx$  and TOF (when available)
- rapidity cut corresponding to  $|y_{\text{cms}}| < 0.5$



- Analysis methods
  - ▶ Two particle correlation using cumulants - correction on non-flow contribution
  - ▶ TPC sub-events in eta - resolution follows the decrease from the BES-I results



# SYSTEMATIC UNCERTAINTIES IN ELLIPTIC FLOW ANALYSIS

I repeated my analysis 6 times implementing additional quality cuts:

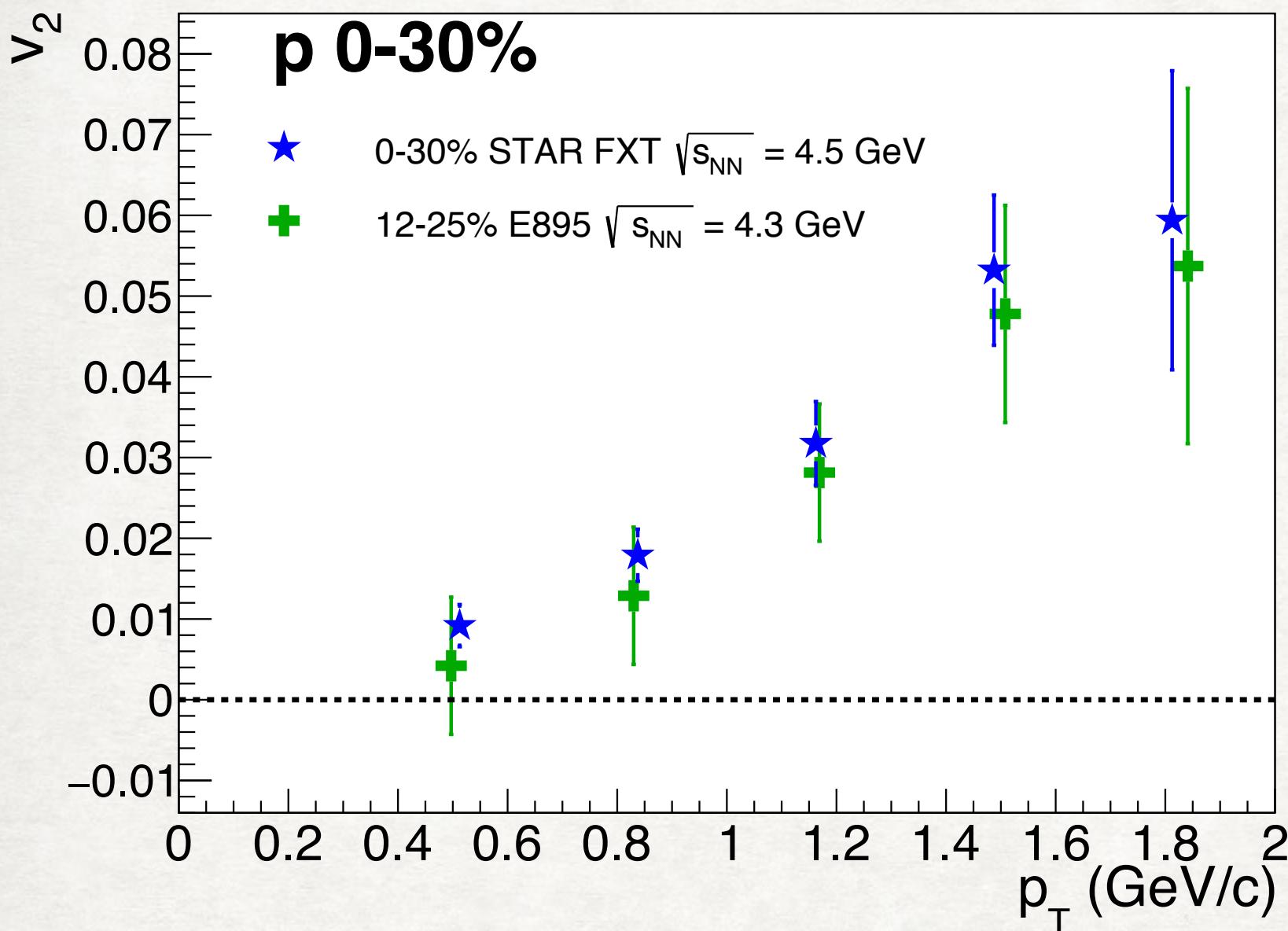
1. NHits > 15
2. NHits > 20
3. NHits > 25
4. NdEdx > 10
5. NdEdx > 15
6. NdEdx > 20

As final measurement I picked the middle between maximal and minimal value obtained from those 6 measurements.

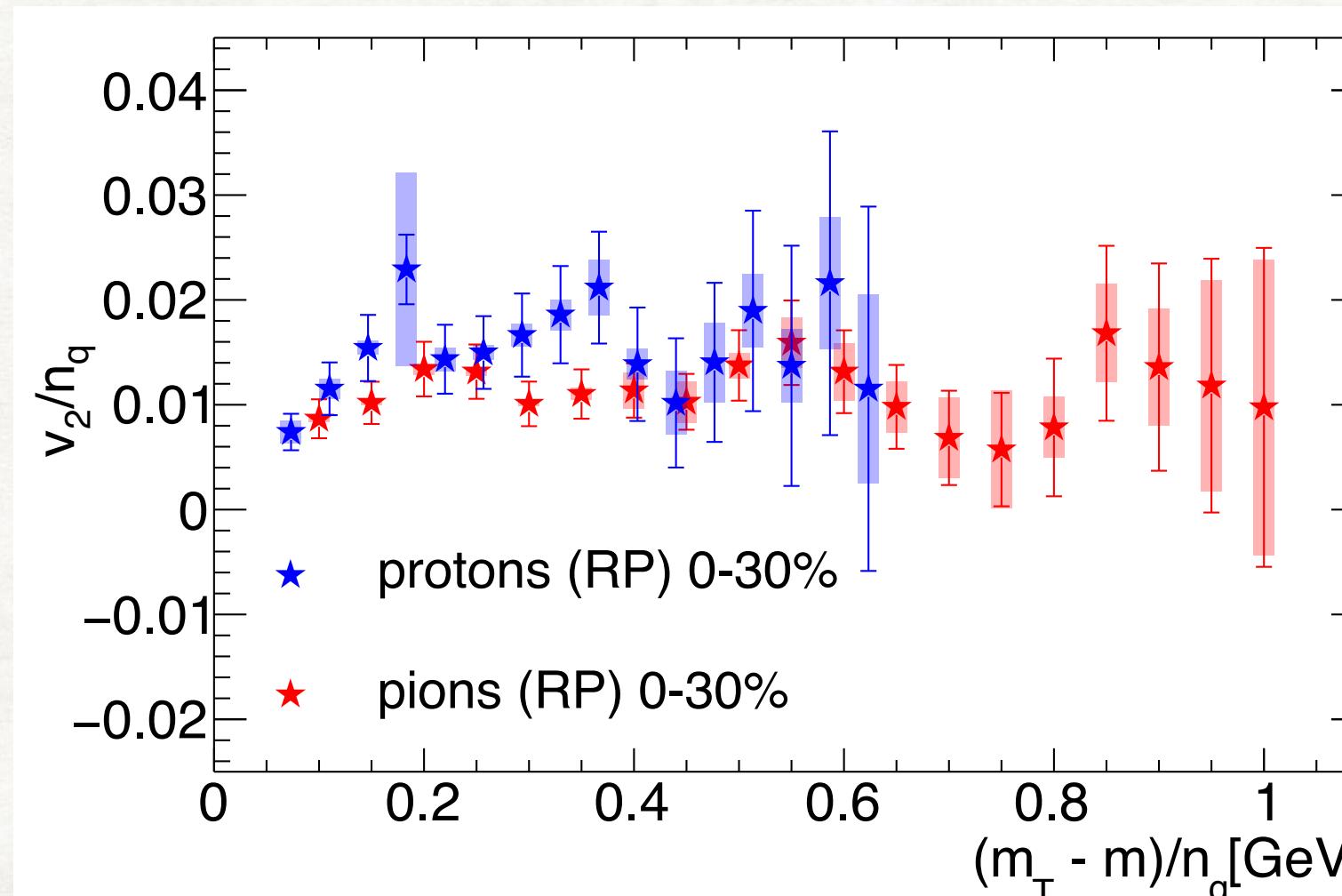
I define **systematic uncertainties** as a half of this range divided by  $\sqrt{3}$  (correction for uniform distribution assumption).

# ELLIPTIC FLOW RESULTS (EVENT PLANE METHOD)

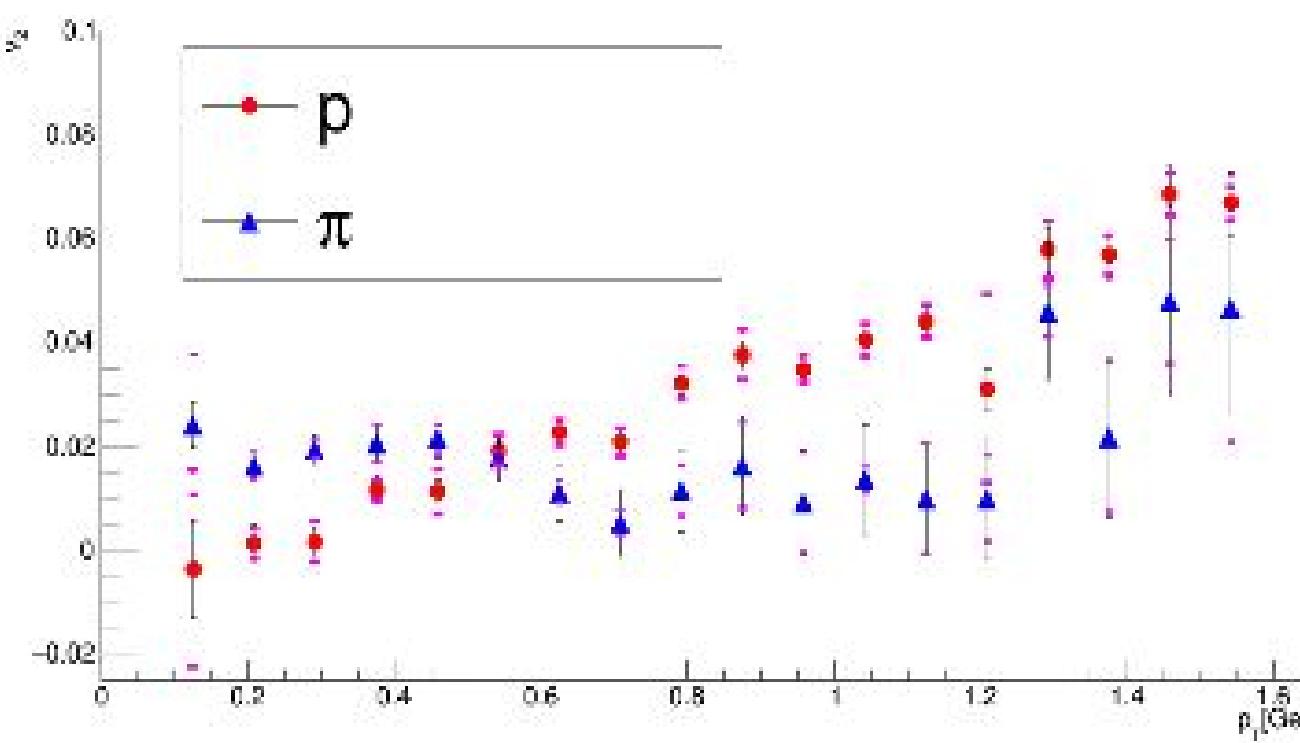
Protons: Comparison with E895



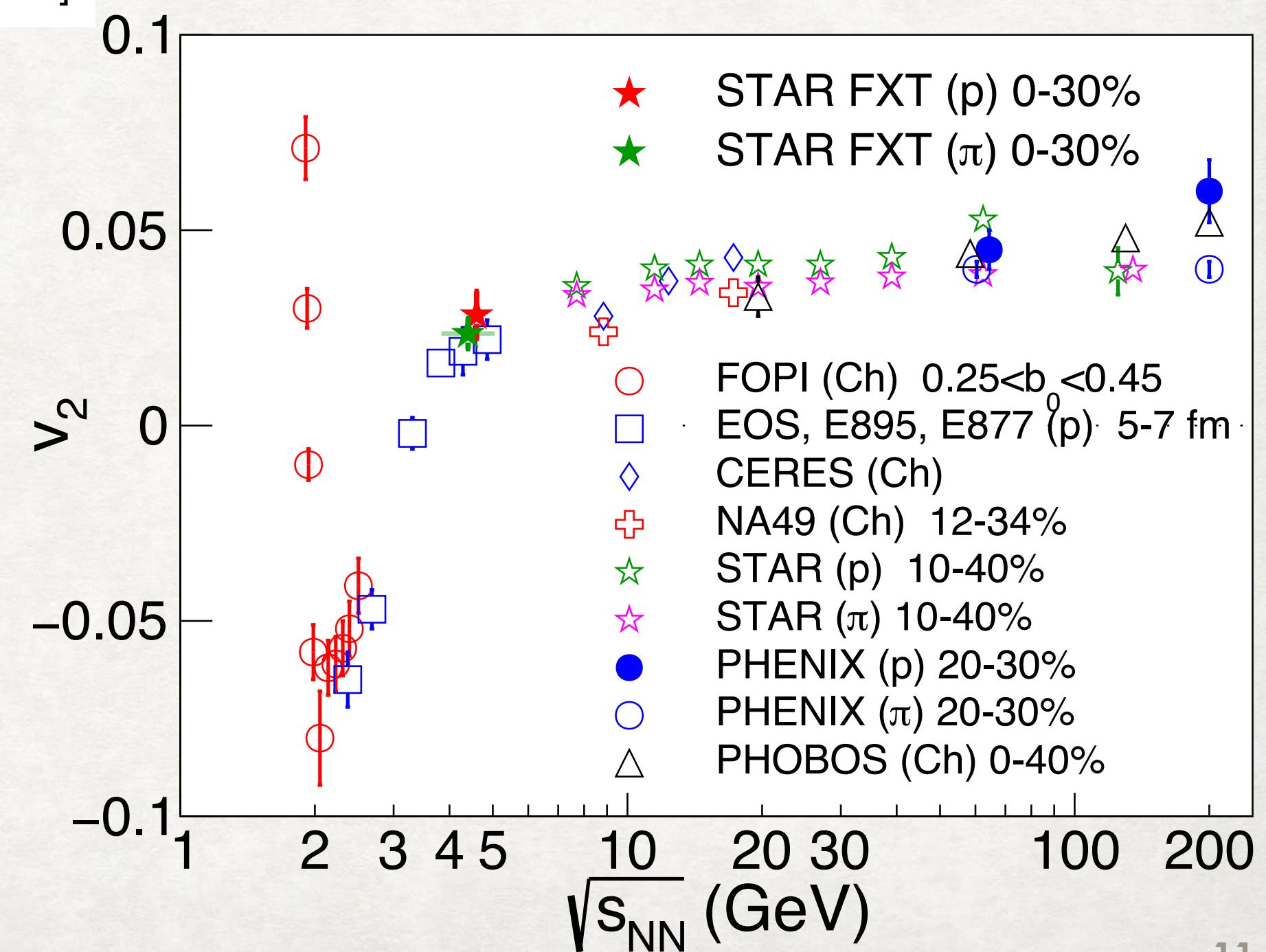
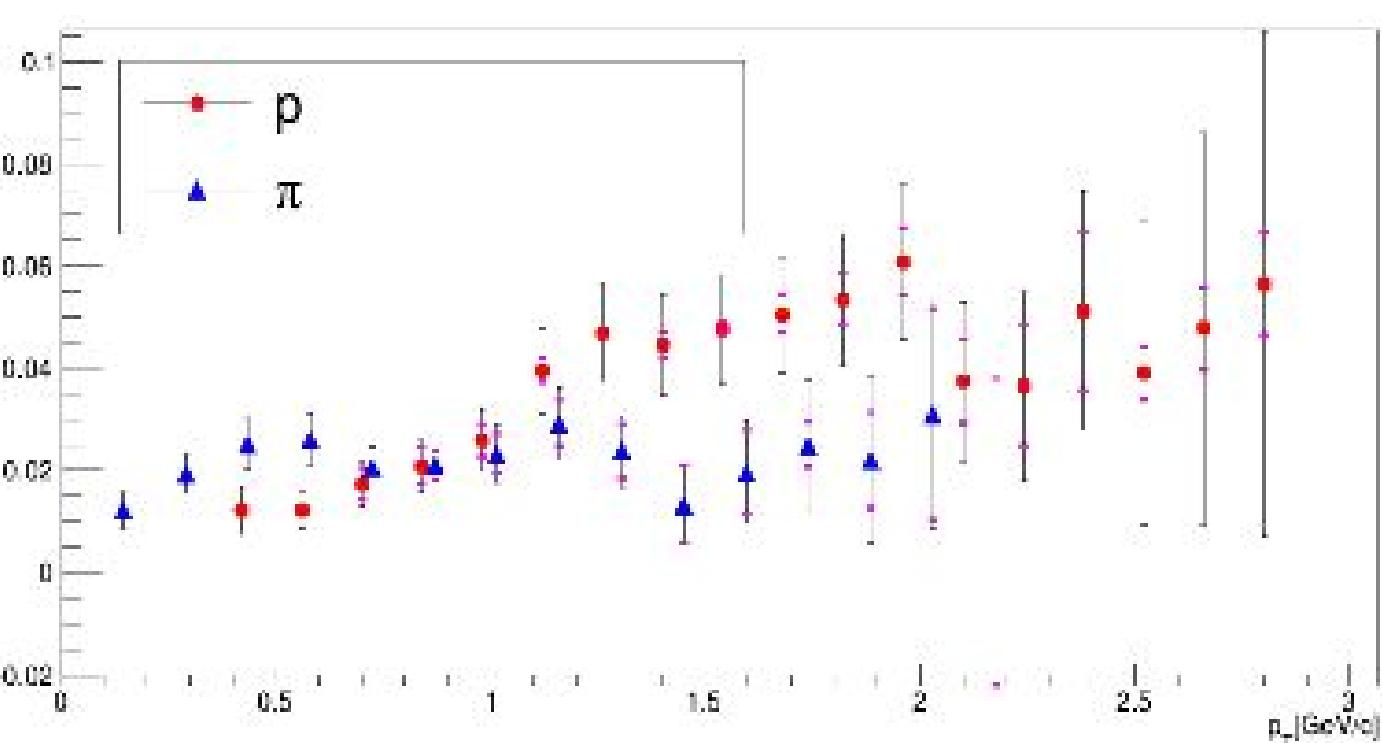
Protons and Pions Scaled by # of Constituent Quarks



2-particle Correaltion



Event Plane



# THANK YOU