The η dependence of charged particle v_n using the Silicon Vertex Detector at RHIC-PHENIX

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Outline

- Introduction
  - Motivation
  - Silicon Vertex Detector (VTX)
- Analysis Method
- p_T dependence of v_2 , v_3
- η dependence of v_2
- η dependence of event plane correlation
- Summary

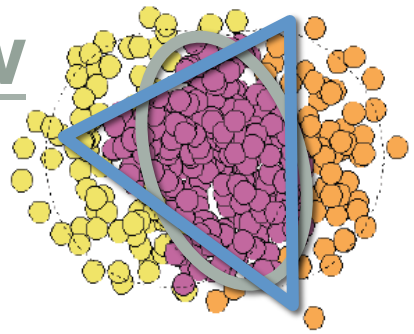
Motivation

Silicon Vertex Detector(VTX) was installed in PHENIX

- ✓ VTX can separate bottom and charm
  - There are two types of tracking
- ✓ VTX covers wide η range

- Can VTX measure charged hadron v_n using these tracks? Is it consistent with previous results?
- How about η dependence of v_2 in PHENIX ?

Flow



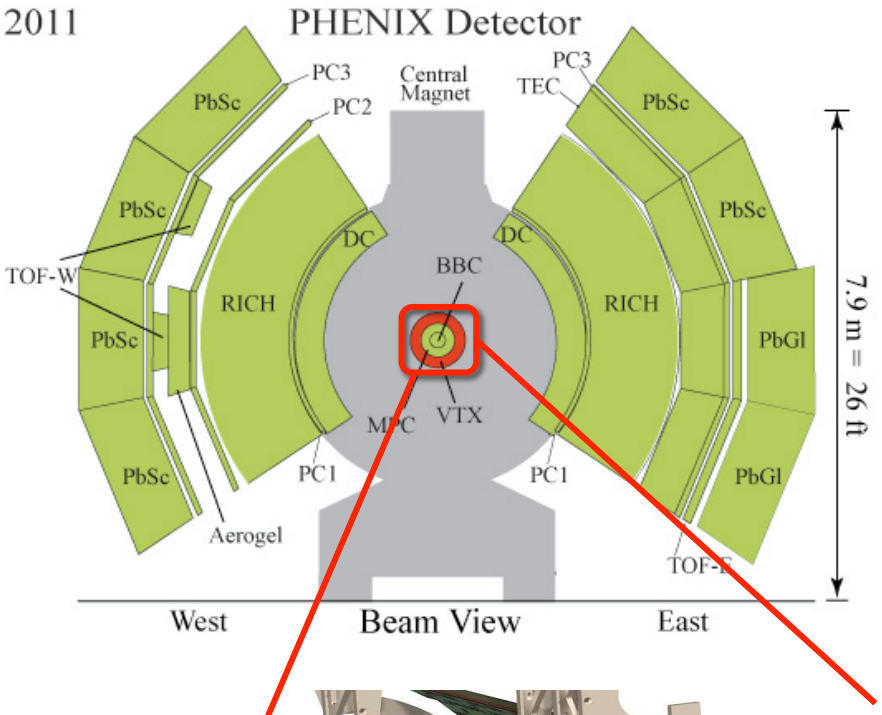
- n-th fourier coefficient of dN/d(**φ**-**Ψ**n)

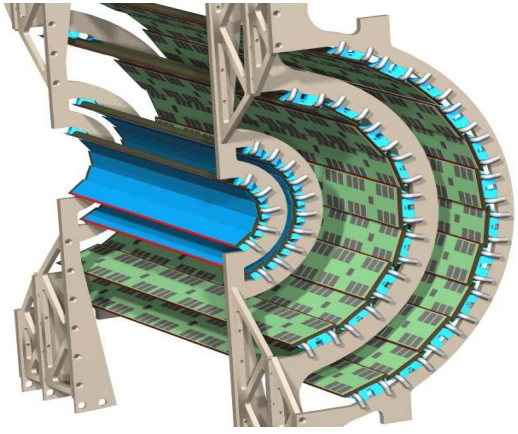
$$v_n = < \cos(n(\phi - \Psi_n)) >$$

✓ Sensitive Prove for early stage of heavy ion collision

Silicon Vertex Detector (VTX)

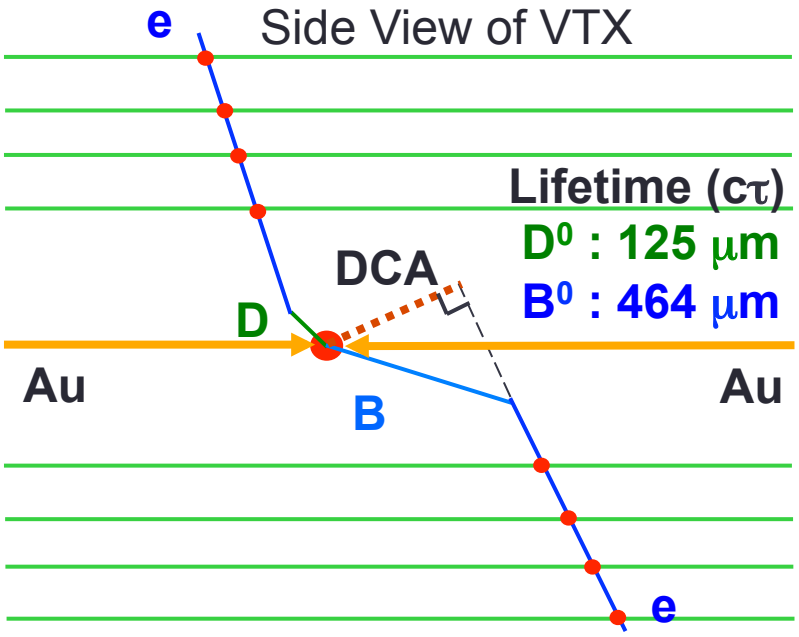
- Silicon Vertex detector was installed from run 2011
  - -Physics Motivation
    - Measurement of heavy flavor
  - -Detector design
    - Barrel Type & 4 layers
      - Inner 2 layers : pixel detector
      - Outer 2 layers : strip detector
    - $\Delta\varphi \sim 2\pi$
    - $|\eta| < 1.2$



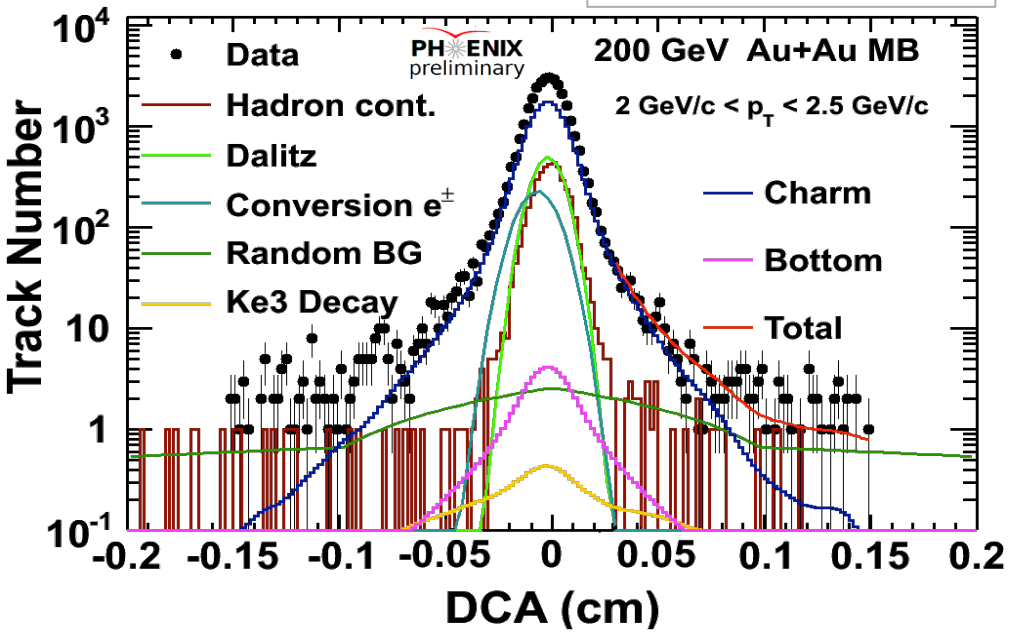


Heavy flavor Measurement

- VTX can measure distance of closest approach(DCA) to separate charm and bottom components of heavy flavor spectra.
  - D and B mesons travel before semi leptonic decay to electron



QM2012, Maki Kurosawa

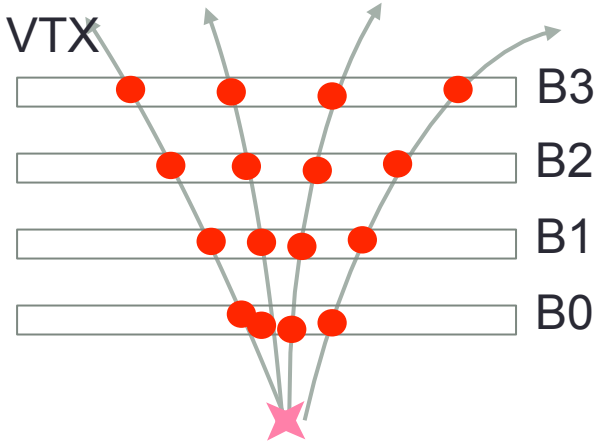


- We know the shape of each component from Monte Carlo simulation
- By simultaneous fitting of DCA distribution, each component can be separated statistically.

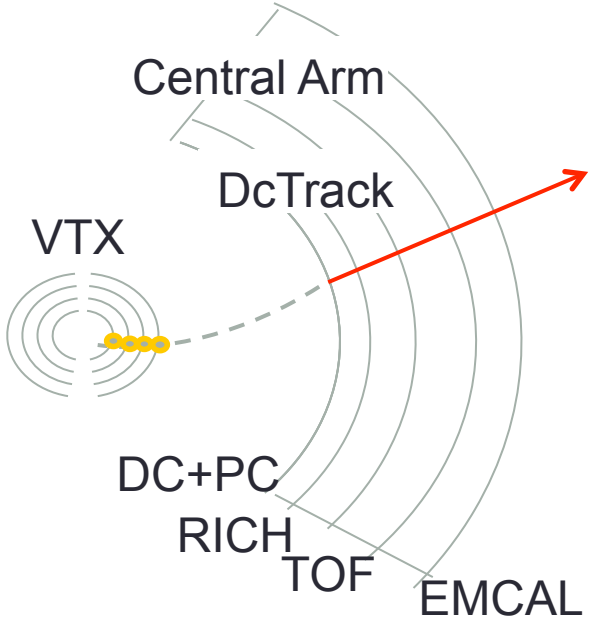
VTX Track Reconstruction

There are two types of tracking

- VTX Standalone Tracking
  - VTX can reconstruct charged particle tracks (require more than 3 hits on VTX)
  - $|\eta|<2.0$
  - Measurement of Primary Vertex



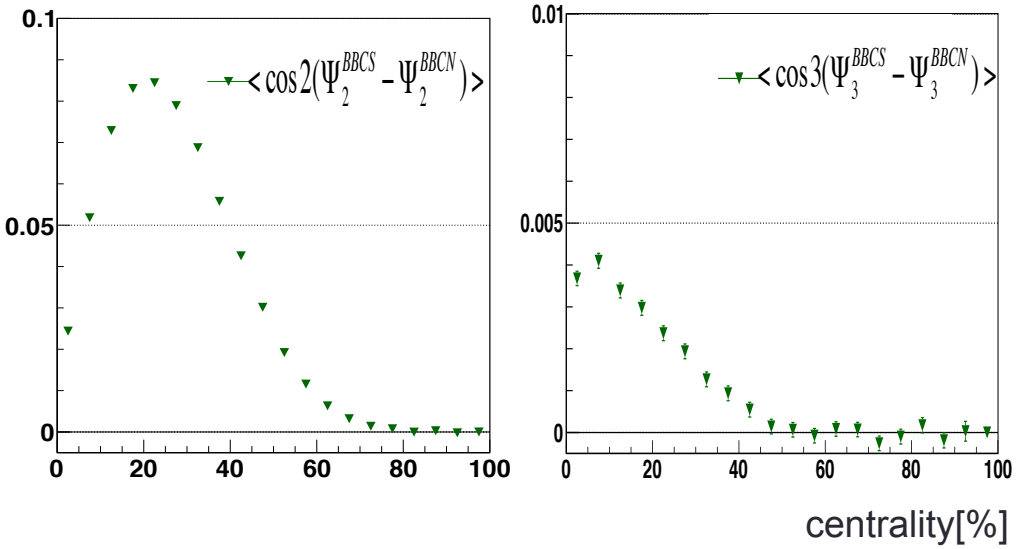
- Central Arms + VTX tracking
  - Central Arms track is associated with the VTX clusters(charged particle hits)
  - High momentum resolution
  - $|\eta|<0.35$
  - Measurement of distance of closest approach (DCA)



Analysis Method : Event Plane Method

$$v_n = \frac{< \cos n(\phi - \Psi_n^{ob}) >}{\sigma}$$

$$\sigma = < \cos n(\Psi_n^{ob} - \Psi_n^{tr}) >$$

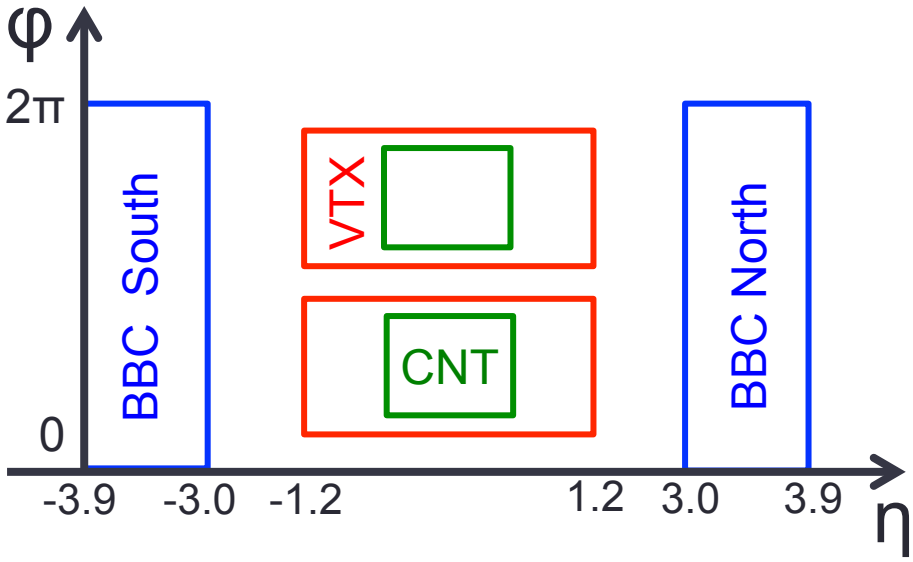


Event Plane measurement

Ψ_2^{ob} :BBC South/North/South + North

Track reconstruction

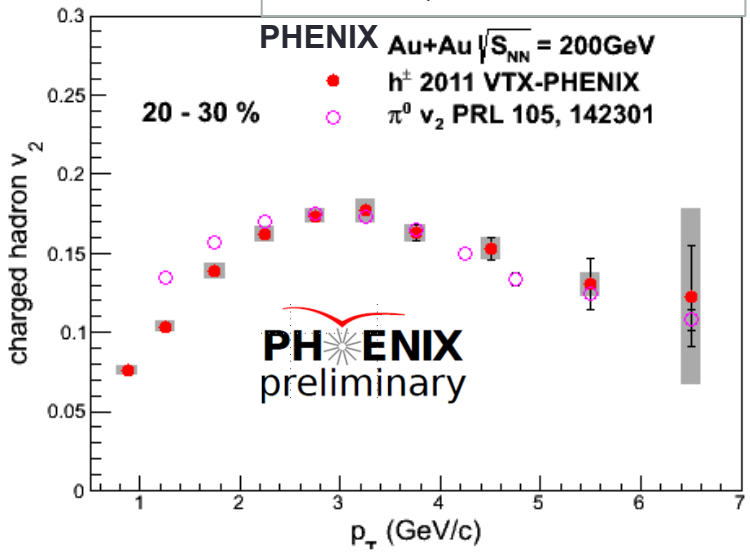
ϕ : CNT+VTX tracks
(CNT tracks was associated with stand-alone track of VTX)
or
VTX standalone tracks

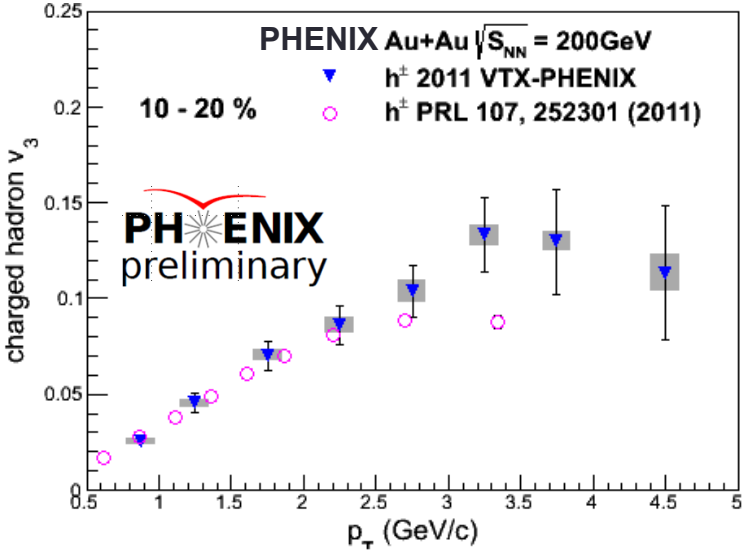


v_2,v_3: p_T dependence (CNT+VTX tracks)

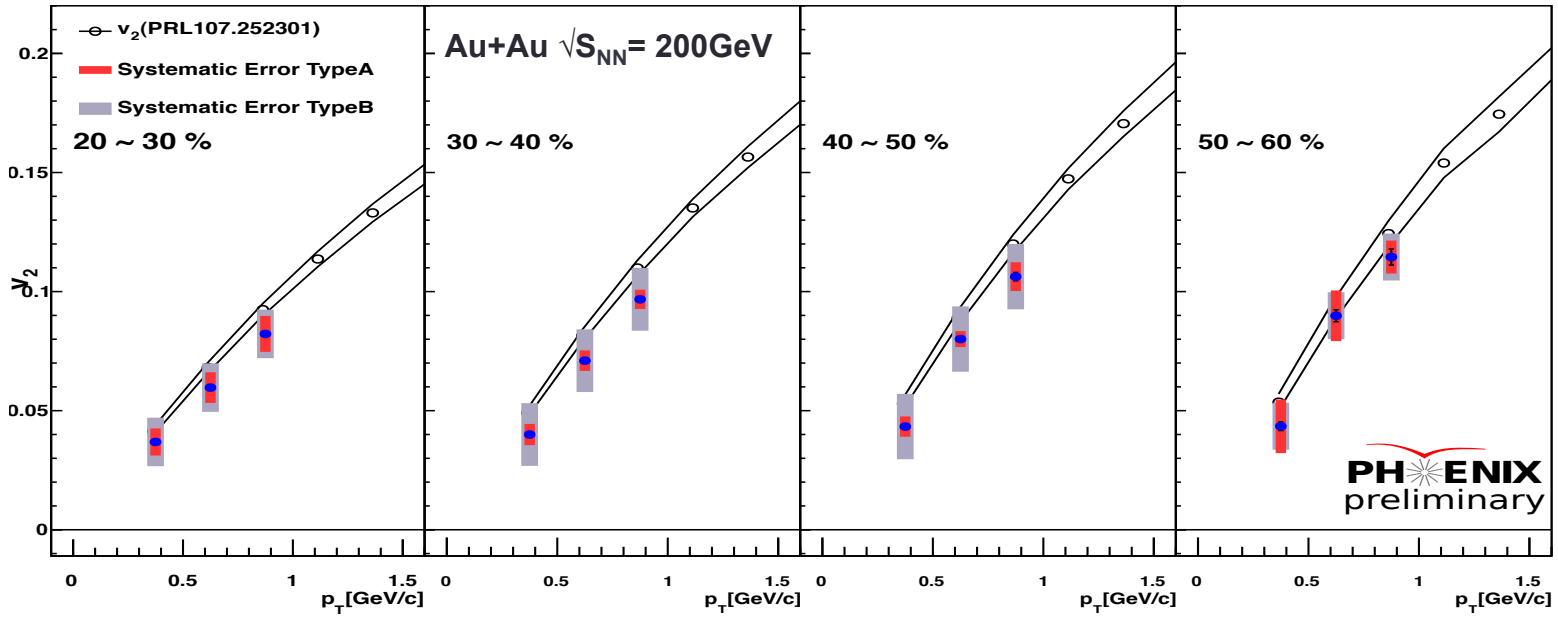
- v_2 and v_3 of charged hadron has reduced background by association of VTX hit with CNT track and application of DCA cut < 200um.
- v_2 are consistent with previous measurements of π^0 v_2 in high p_T region.
- Extend to high p_T region for v_3.
  - Good agreement with previous data in low p_T region.
- A non-zero v_3 is still observed in high p_T region.

QM2012, Maki Kurosawa





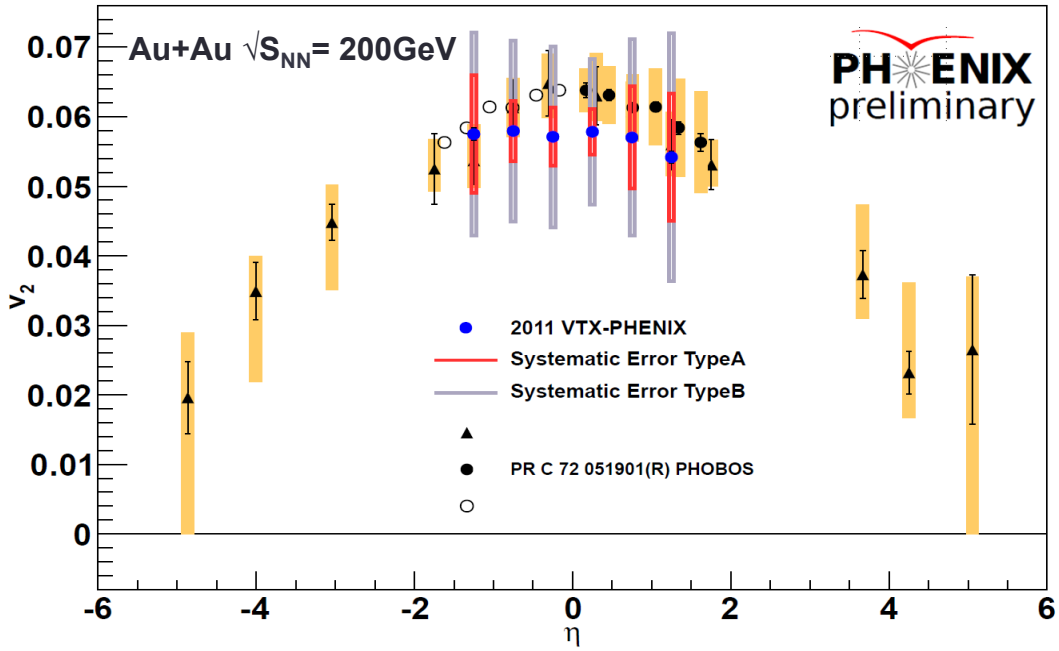
v_2:p_T dependence(VTX standalone tracks)



- Comparison between previous PHENIX result (PRL107.252301) v_2 using CNT tracks and v_2 using VTX standalone tracks
  - Standalone tracks p_T region is 0.25<pt<1[GeV/c]

Consistent with previous PHENIX result p_T<1[GeV/c]

v_2: η dependence(standalone tracks)



- Comparison to PHOBOS v_2
  - PHOBOS : centrality 25-60%, $p_t > 0$[GeV/c]
  - PHENIX : centrality 20-60%, $0.25 < p_t < 1$[GeV/c]

Consistent with PHOBOS result within systematic error bars

v_2 : η dependence(cluster)

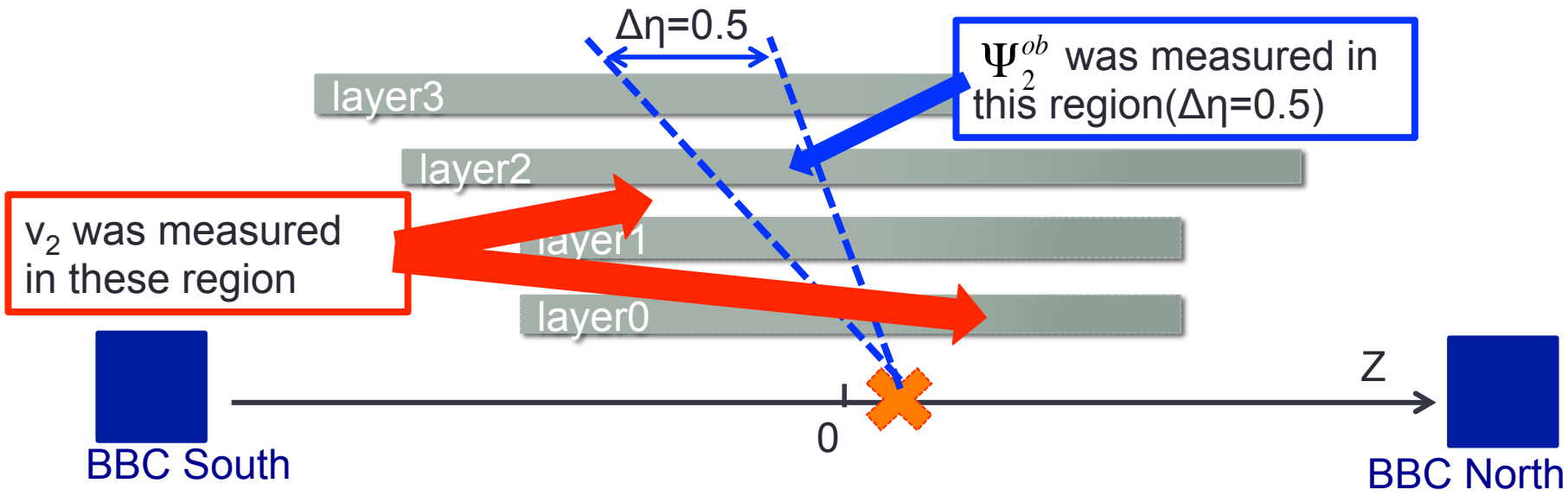
So far, we used,

EP : BBC South/North/South+North
Tack : CNT+VTX track
VTX standalone track

We used VTX plane and VTX charged particle hits

EP : VTX 0.5-η slice

Track : VTX cluster

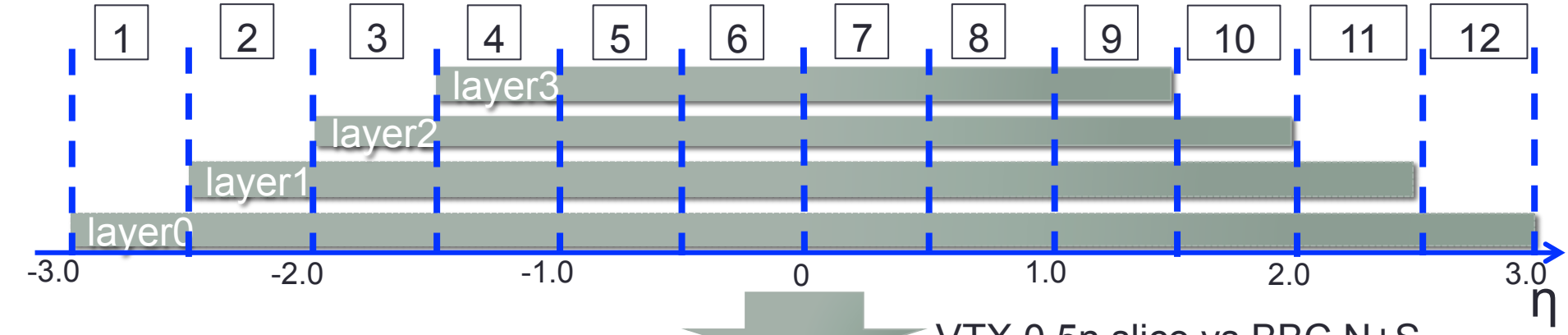


✓ To calculate VTX EP resolution, I used BBC South + North

v_2 : η dependence(cluster)

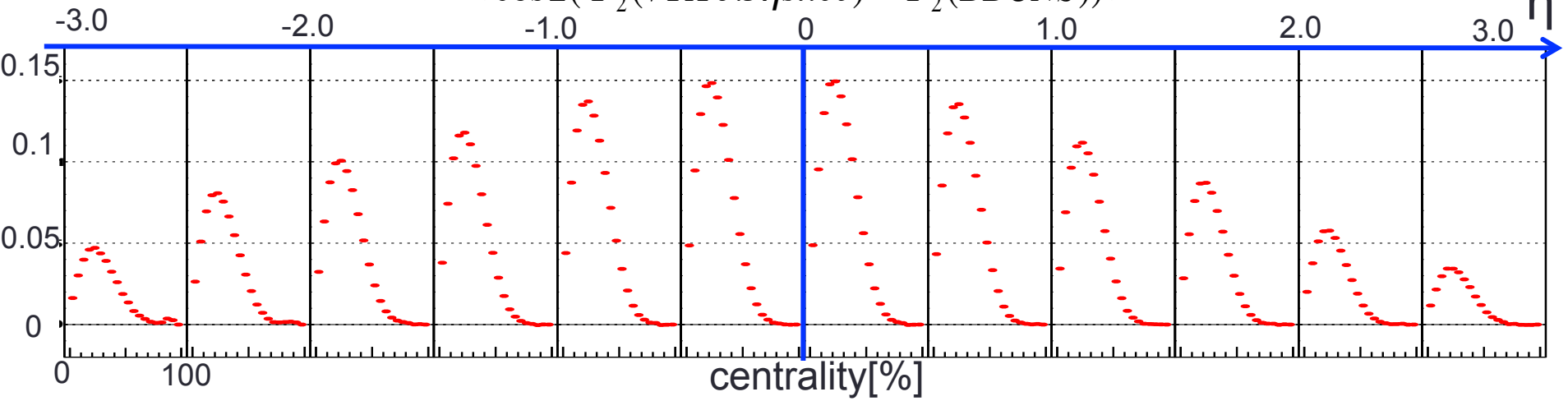
η coordinate : VTX

- I divided VTX into 12 parts by 0.5η slice.



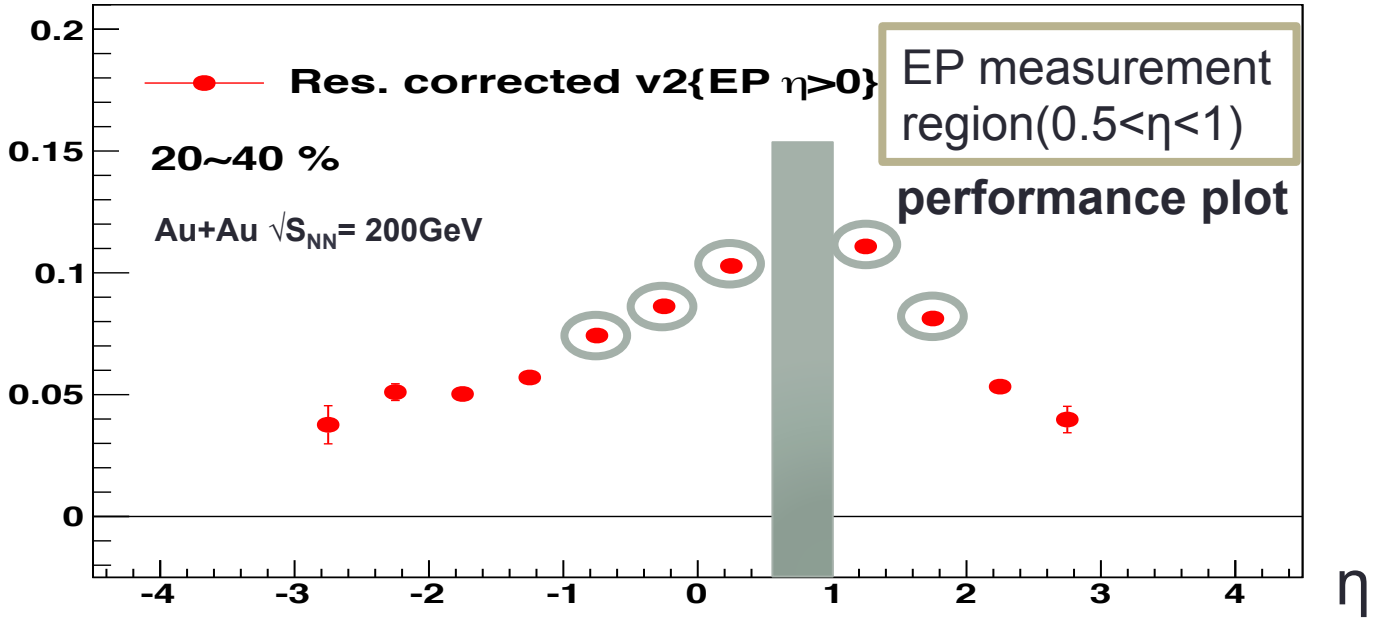
VTX 0.5η slice vs BBC N+S

$$< \cos 2(\Psi_2(VTX0.5\eta slice) - \Psi_2(BBCNS)) >$$



- Correlation is strong at mid rapidity due to high multiplicity.

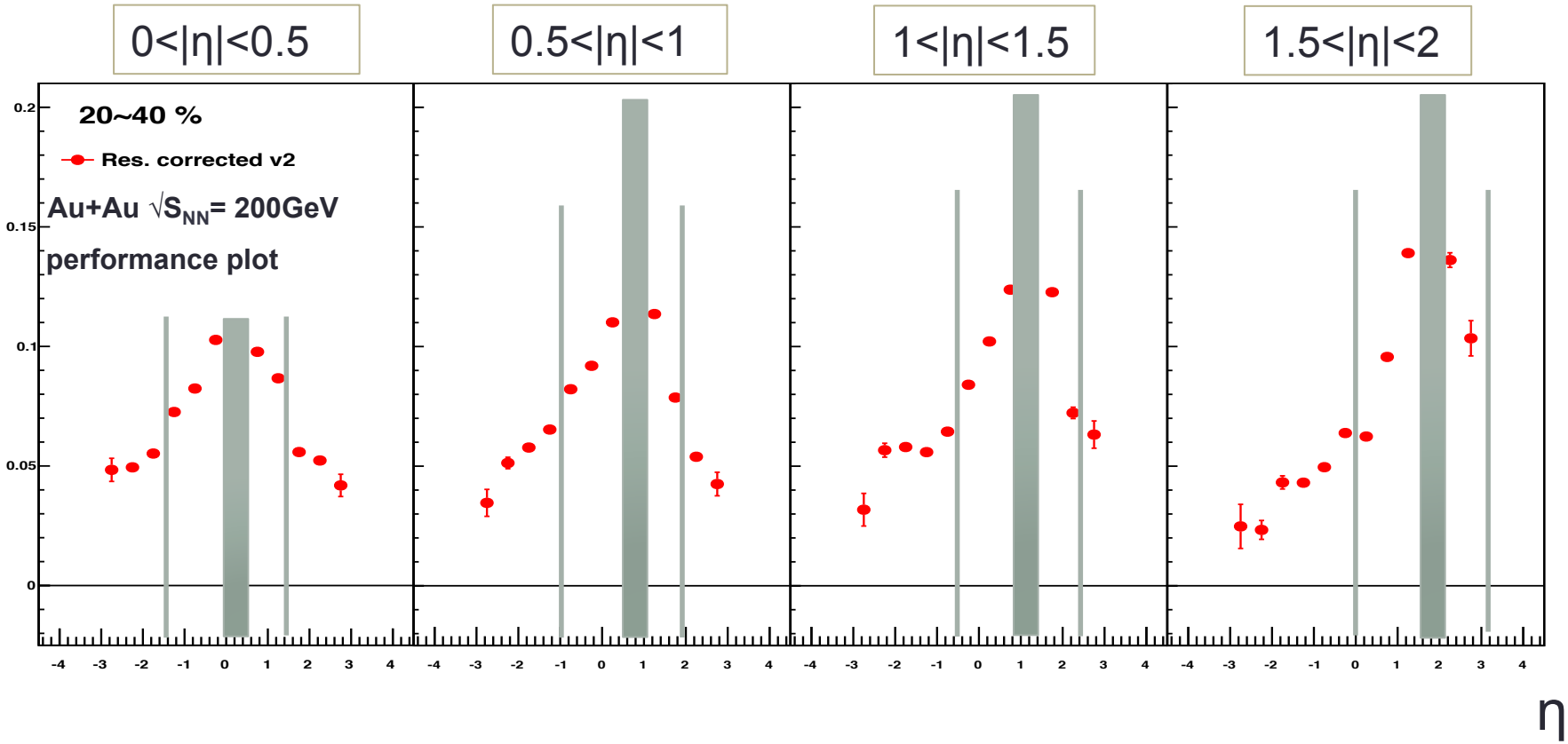
v_2 : η dependence(cluster)



- η dependence of v_2 using cluster(charged particle hit)
  - no BG subtraction and no p_t selection
- v_2 around EP measurement region is higher than v_2 in other region
  - Non flow effect is seen
  - Non flow effect seems to be asymmetry.

We should separate Mid-rapidity side : Δη=1.5 , Forward rapidity side : Δη=1

v_2 : η dependence(cluster)

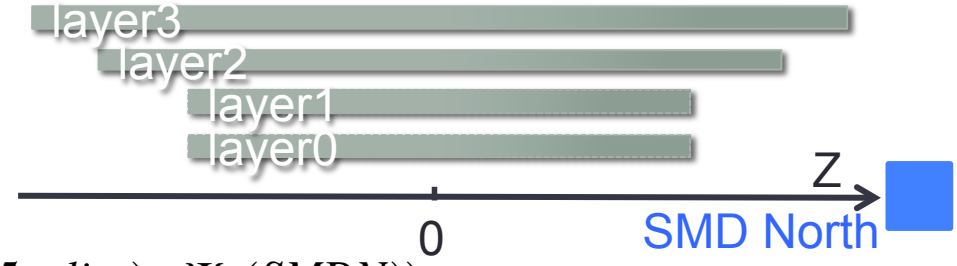


- v_2 using EP measured in other rapidity region.

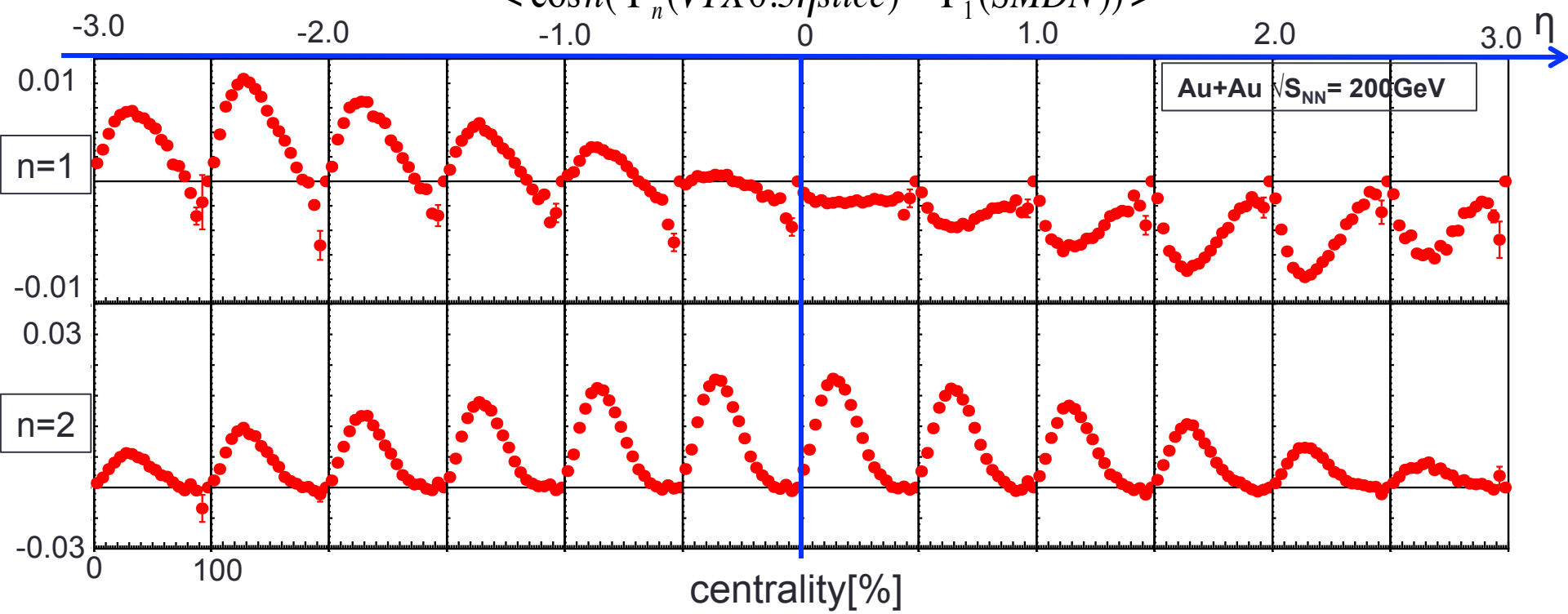
  In other EP measurement regions, v_2 distributions also look asymmetry.

EP correlation : η dependence

- Measured η dependence of Event Plane correlation between Ψ,spectator (SMD N) and Ψ,participant (VTX 0.5 η slices)



$$<\cos n(\Psi_n(VTX0.5\eta slice) - \Psi_1(SMDN))>$$



- In Ψ_1 correlation, this correlation is similar to v_1 structure.
- In Ψ_2 correlation, correlation is strong at mid rapidity → same with BBC vs VTX

Summary

- Azimuthal anisotropy measurements had been done with VTX in AuAu 200 GeV.
  - Extend to high p_T region with low background.
  - Charged hadron v_2 at high p_T region were consistent with previous results of π^0 v_2.
  - Non-zero v_3 was observed at high p_T region.
- η dependence of charged hadron v_2 was measured using stand-alone track of VTX.
  - Although systematic errors are large, standalone tracking can use other physics analysis.

Next Step

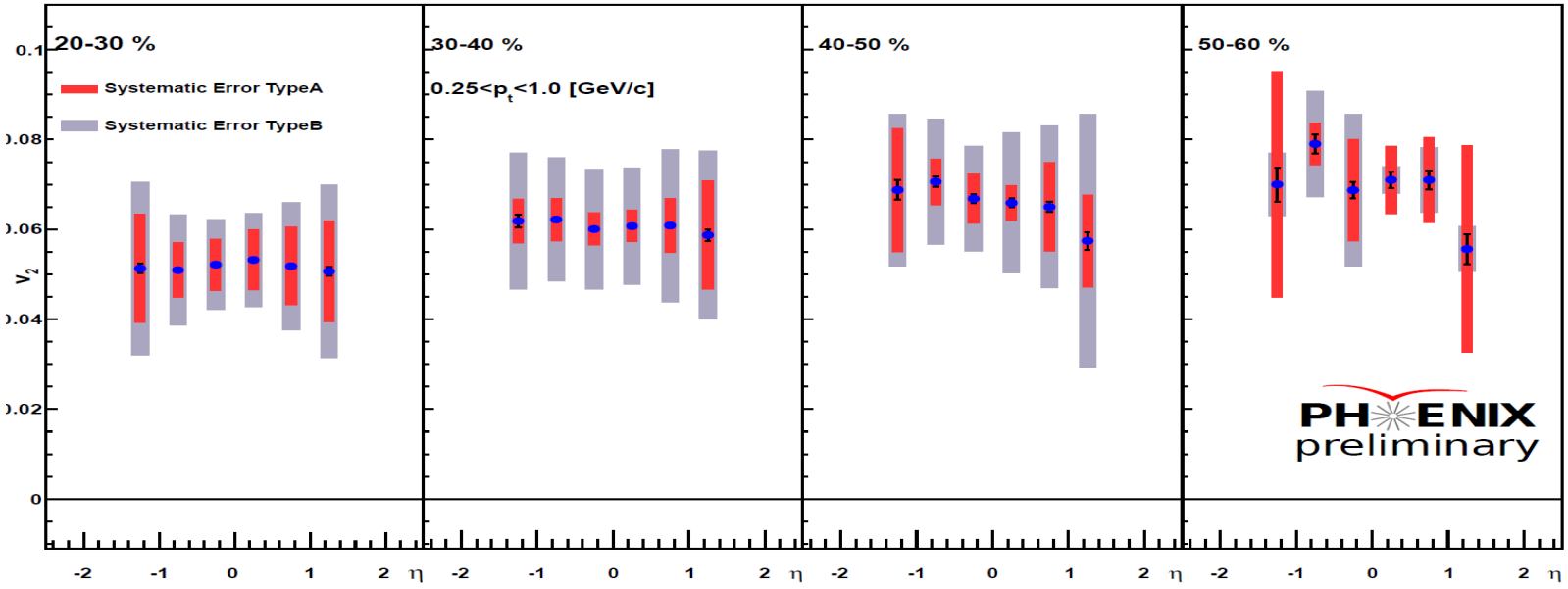
- Reduce systematic errors of $v_2(\eta)$
- Measure v_3 using VTX standalone tracking

Thank you for your attention!

END

Back up

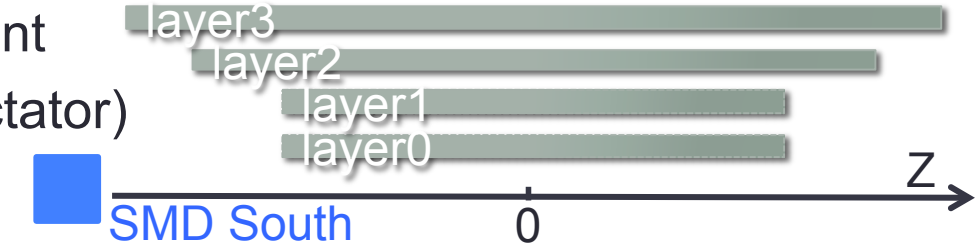
v_2:η dependence(VTX standalone tracks)

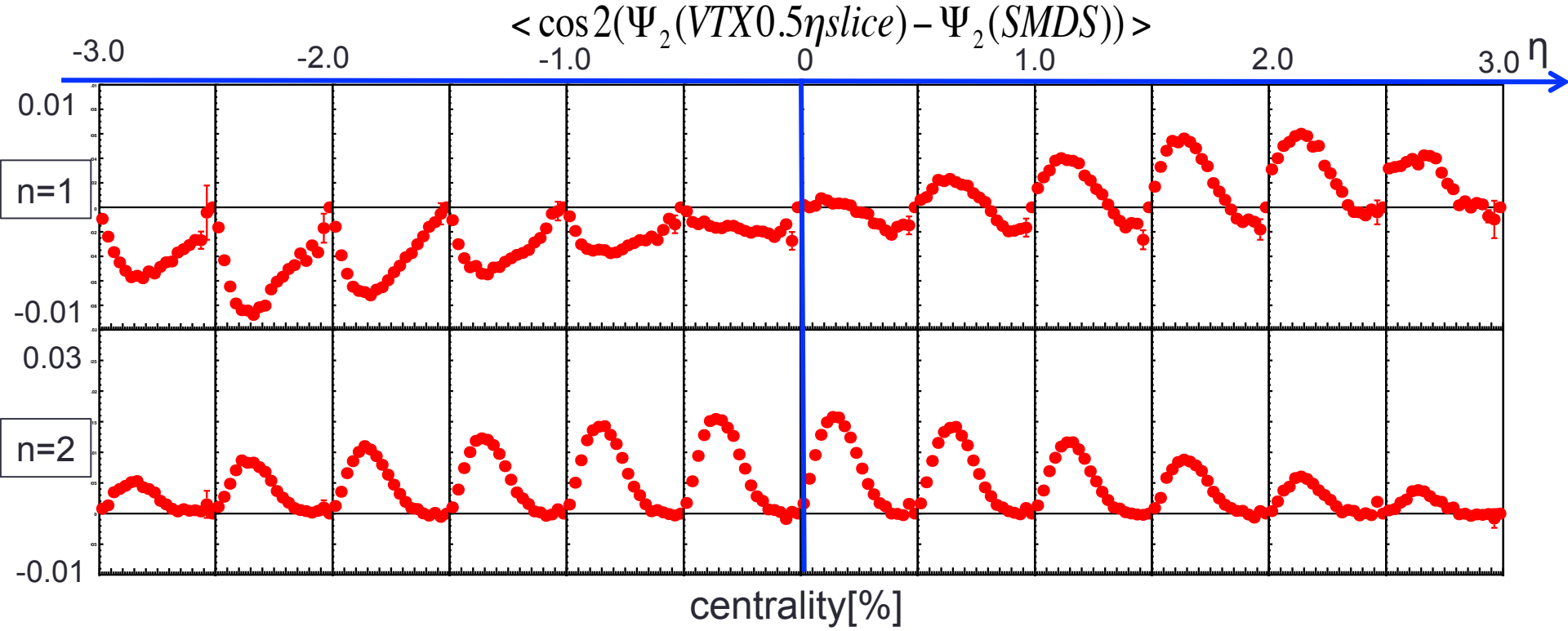


- Measured η dependence of v_2
  - $0.25<p_t<1$[GeV/c]
  - centrality 20-60% with 10% step

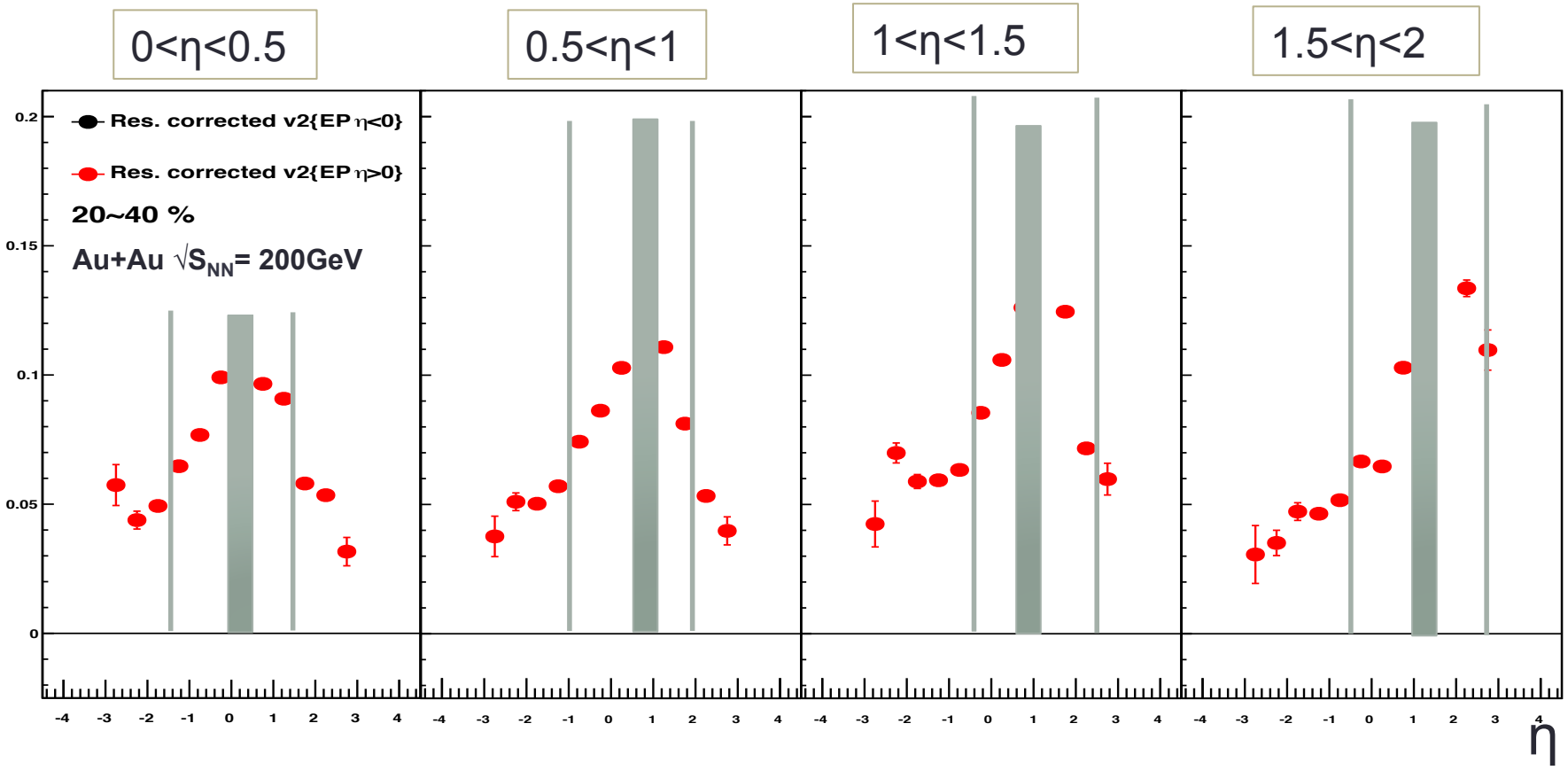
SMD S vs VTX 0.5 η slice(n=1,2)

- Measured η-dependence of Event Plane correlation using SMD (spectator) South and VTX 0.5 η-slices.





Cluster v_2:η-dependence of non-flow

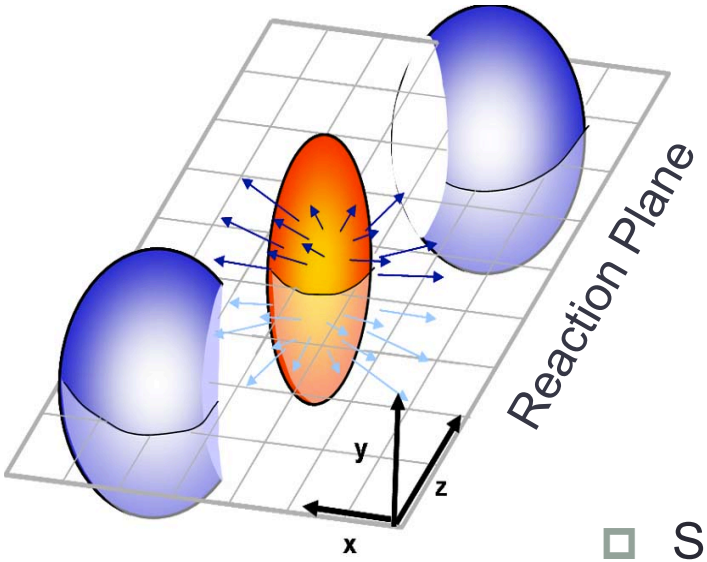


- v_2 using EP measured in other rapidity region(η>0)

  In other EP measurement regions, v_2 distributions also look asymmetry.

Azimuthal anisotropy

In high energy nuclear-nuclear collision, emitted particles from the overlap region have a collective flow.



Fourier expansion

$$\frac{dN}{d\phi} = N_0(1 + \sum 2v_n \cos(n(\phi - \Psi_n)))$$

$$v_n = < \cos(n(\phi - \Psi_n)) >$$

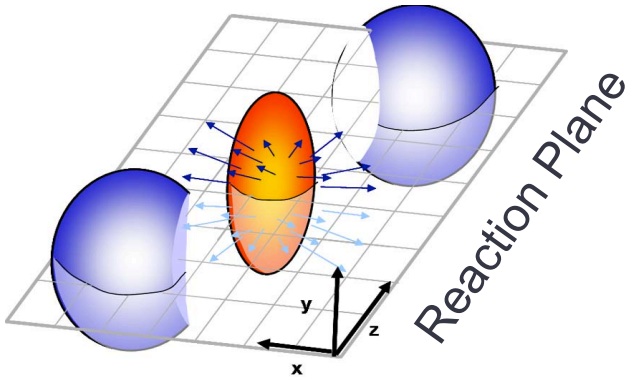
- Sensitive Prove for early stage of heavy ion collision

Azimuthal anisotropy for heavy flavor

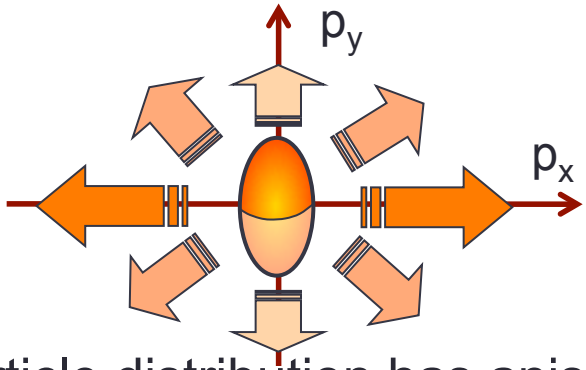
Azimuthal anisotropy

In high energy nuclear-nuclear collision, emitted particles from the overlap region have a collective flow.

Initial spatial anisotropy

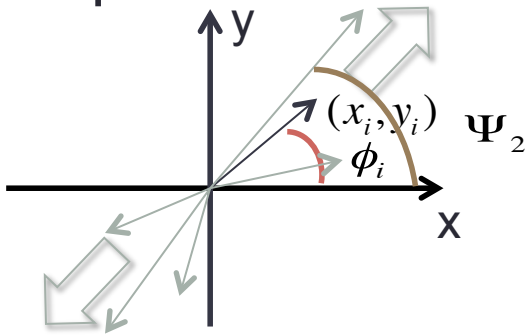


Pressure gradient



Emitted particle distribution has anisotropy in momentum space

The azimuthal distribution of emitted particles is analyzed with respect to the event plane in terms of a Fourier expansion

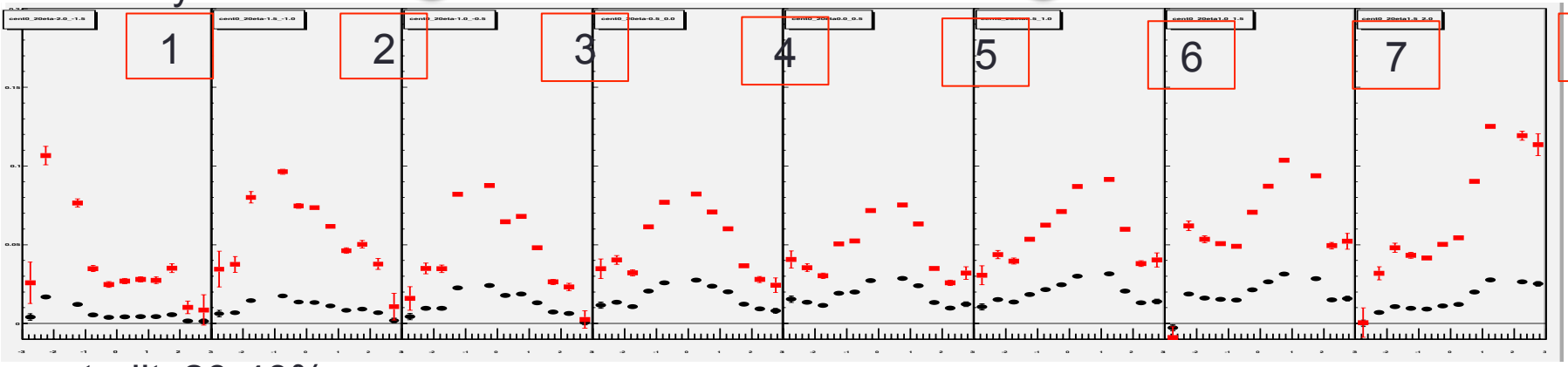


plane with the elliptic moment(n=2)

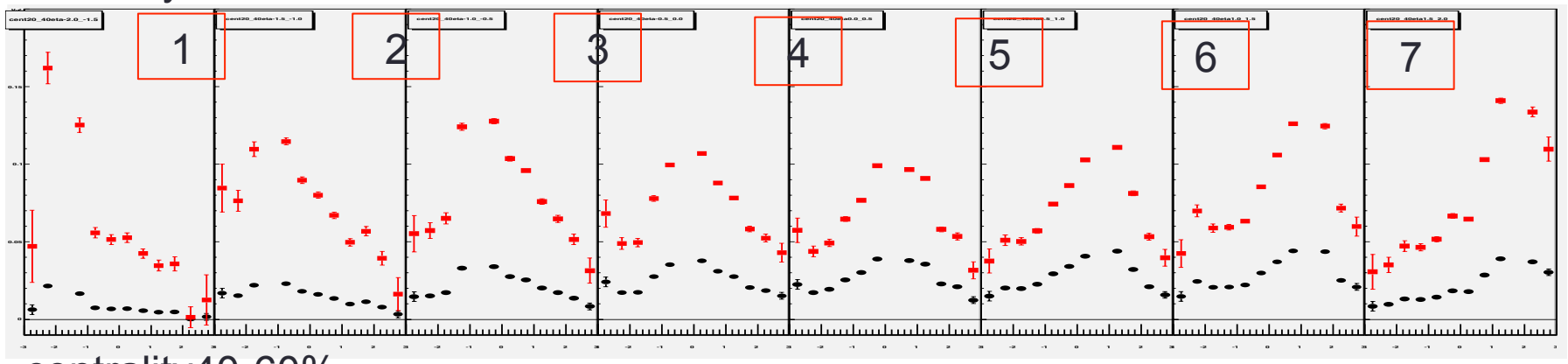
$$\frac{dN}{d\phi} = N_0(1 + \sum 2v_n \cos(n(\phi - \Psi_n)))$$

$$v_n = < \cos(n(\phi - \Psi_n)) >$$

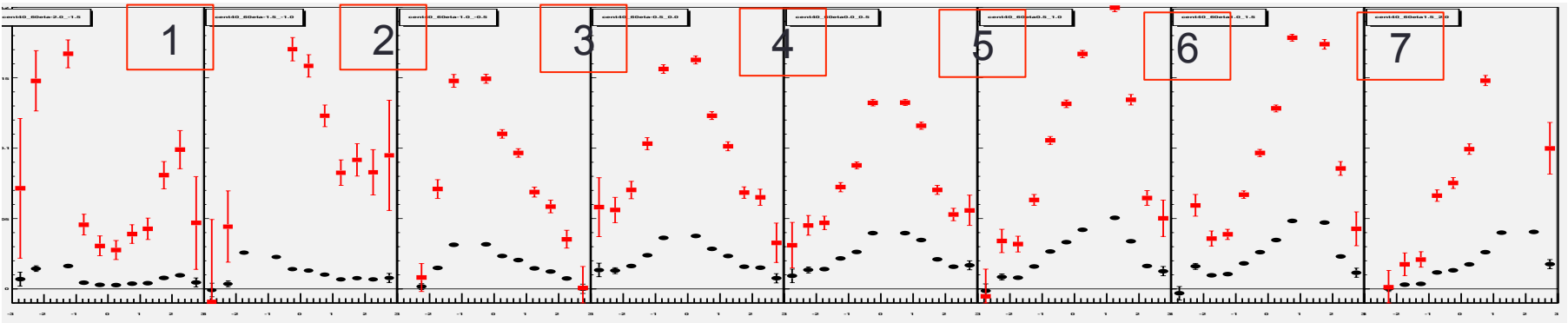
centrality0-20% ;r.p.resolution corrected v_2 ; observed v_2 x-axis-3.0~3.0(η)



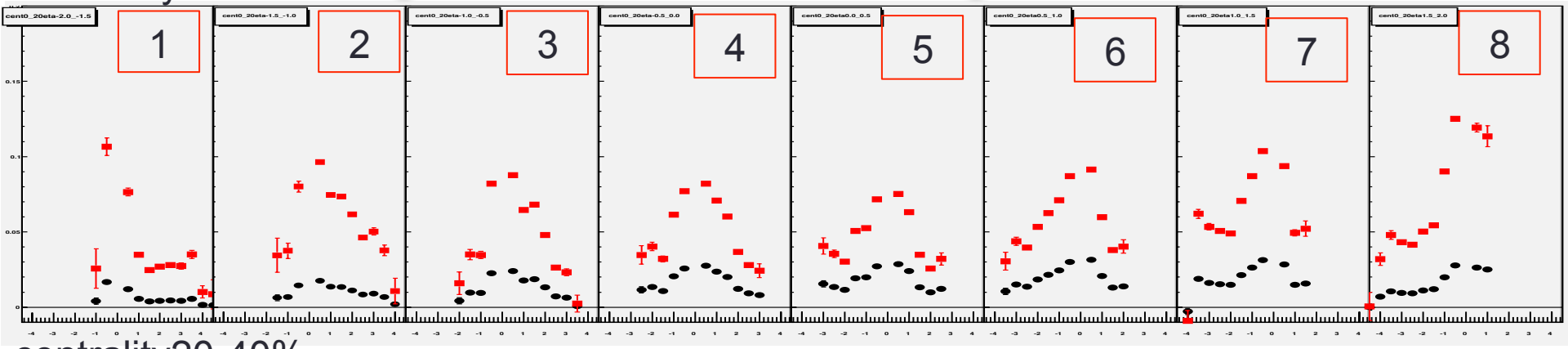
centrality20-40%



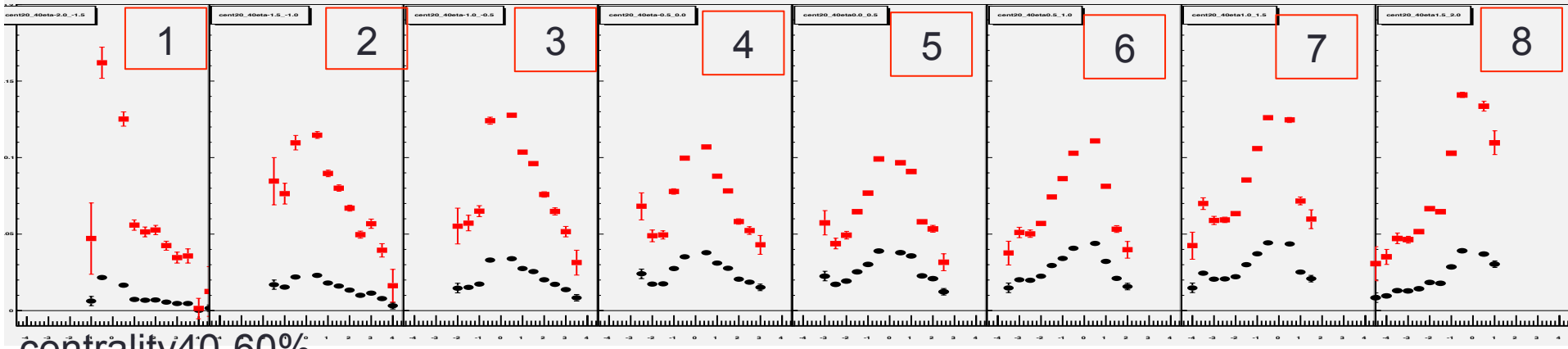
centrality40-60%



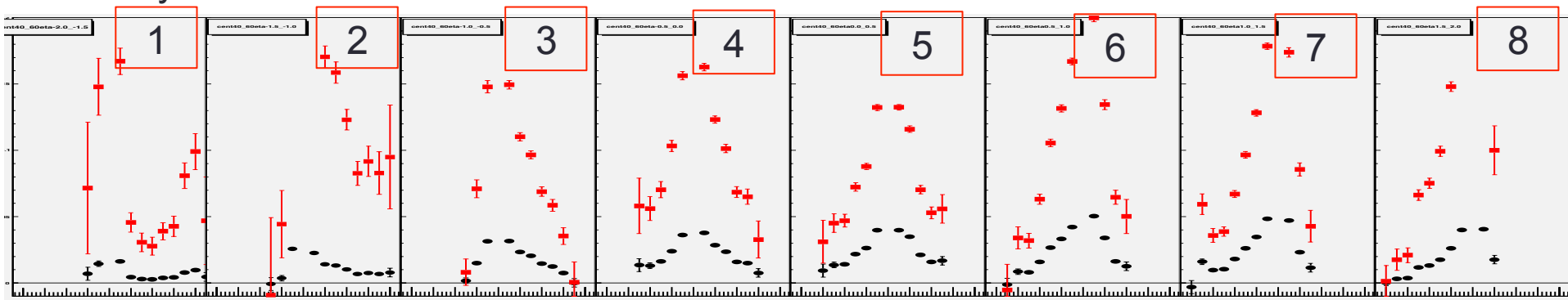
centrality0-20% ;r.p.resolution corrected v_2 ; observed v_2 x-axis-3.0~3.0(η)



centrality20-40%



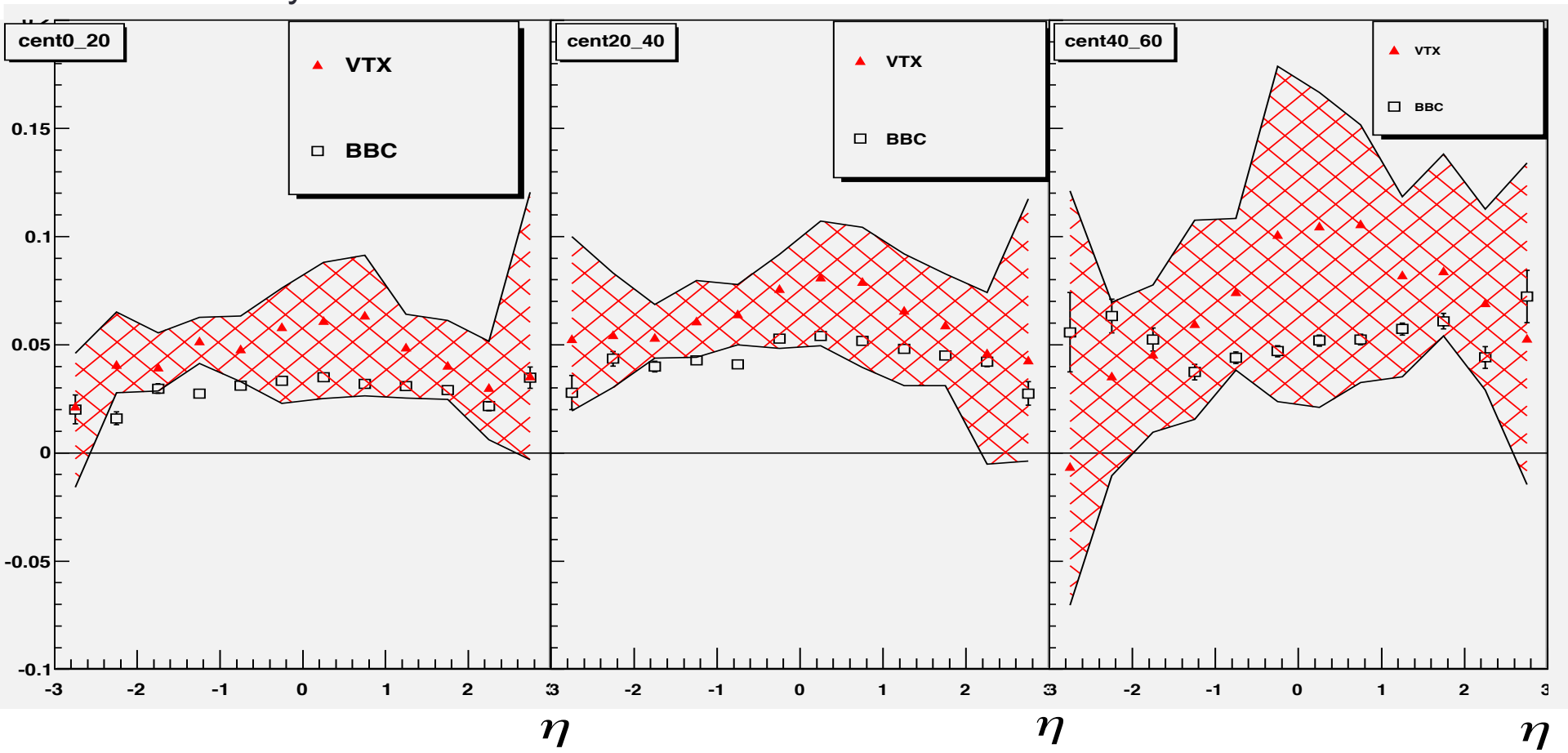
centrality40-60%



centrality0-20%

centrality20-40%

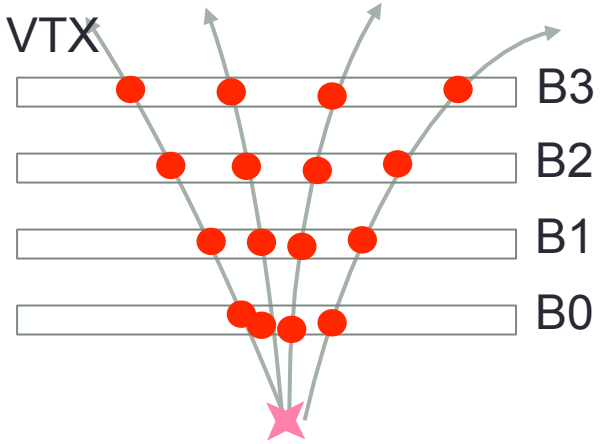
centrality40-60%



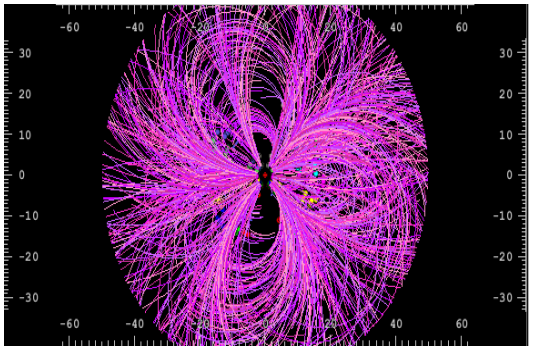
VTX Track Reconstruction

There are two types of tracking

- VTX Standalone Tracking
  - VTX can reconstruct charged particle tracks (require more than 3 hits on VTX)
  - |η|<2.0
  - Measurement Primary Vertex



RUN2011: Au+Au at 200 GeV

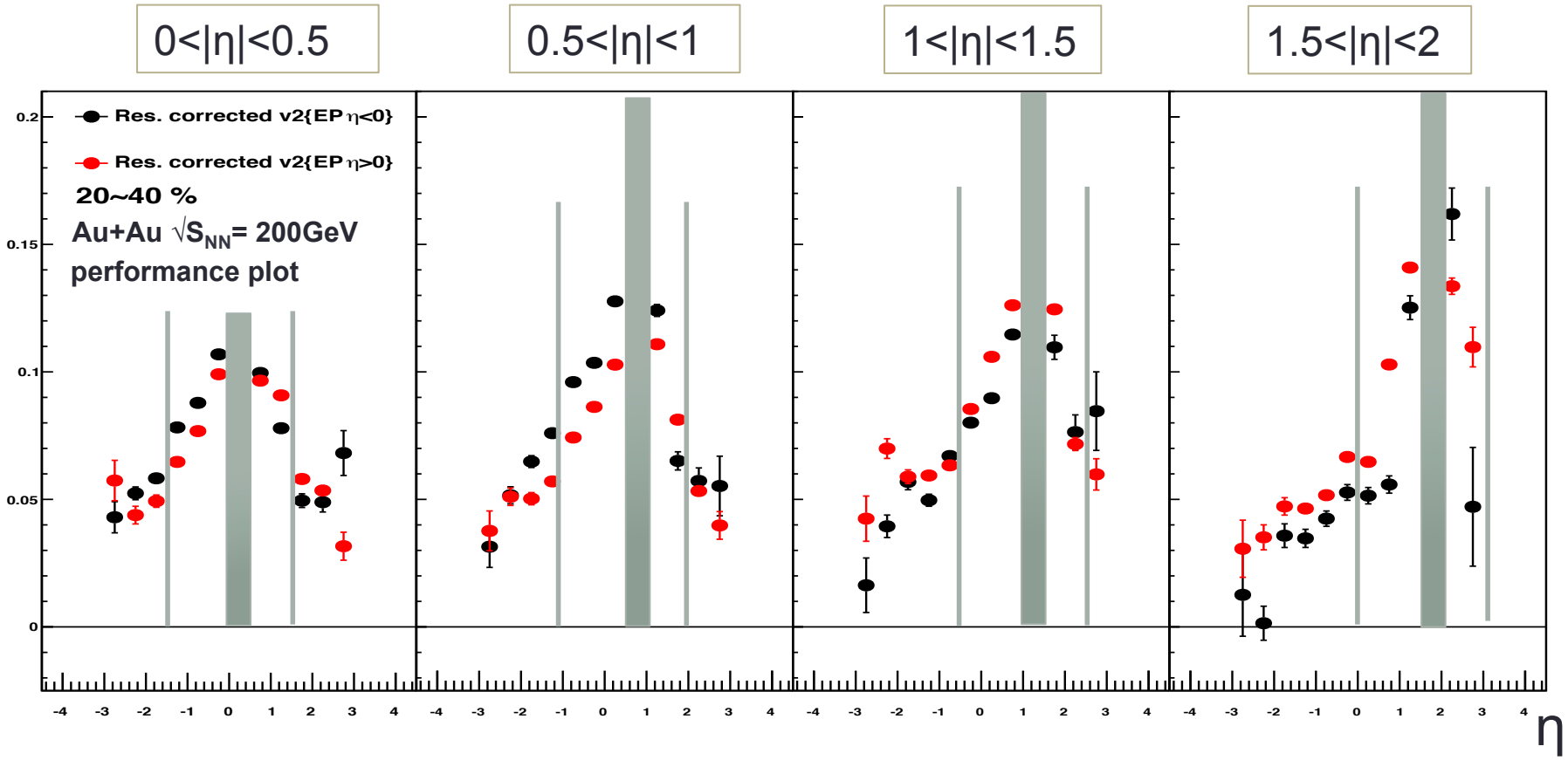


- Central Arms + VTX tracking
  - Central Arms track is associated with the VTX clusters(charged particle hits)
  - High momentum resolution
  - |η|<0.35
  - Measurement distance of closest approach(DCA)

η dependence of v_2 and event plane correlation

- η dependence of v_2
  - standalone tracking |η|<1.5
    reduce background , pt selection
  - cluster(hit information) |η|<3.0 (performance plot)
    include background , non pt selection
- η dependence of event plane correlation (performance plot)
  - Spectator vs Participant Psi1,Psi2 correlation

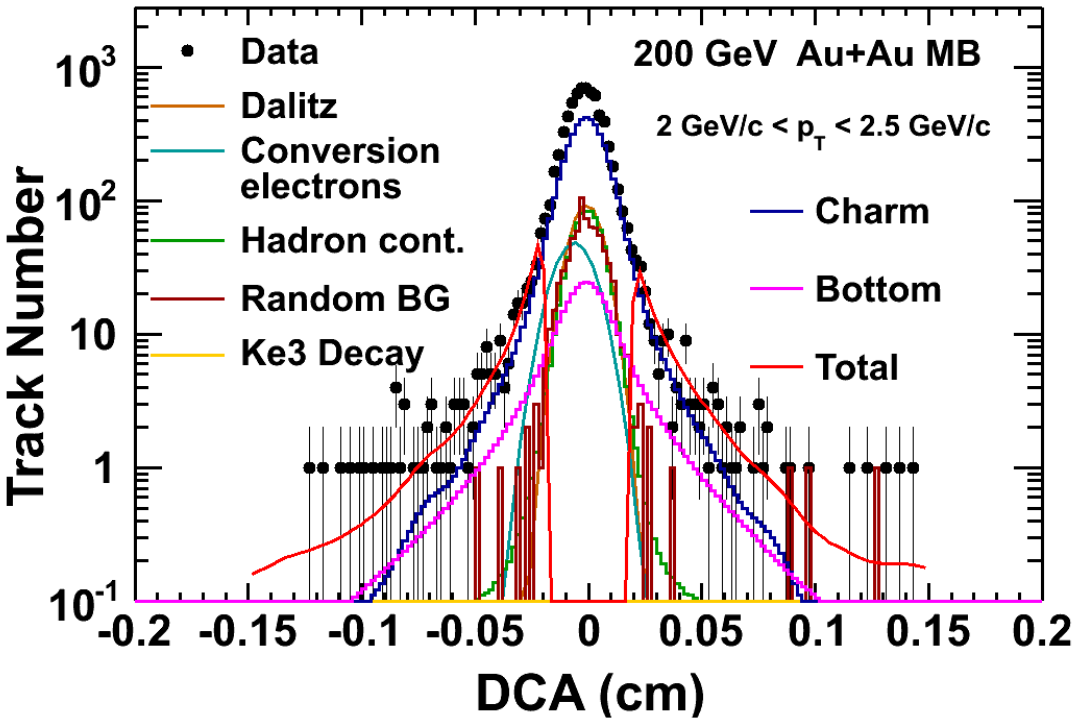
v_2 : η dependence(cluster)



- v_2 using EP measured in other rapidity region(Black:η<0, Red:η>0)

  In other EP measurement regions, v_2 distributions also look asymmetry.

DCA Decomposition



- DCA decomposition uses expected DCA shapes from simulation for all known electron sources to extract bottom/charm ratio

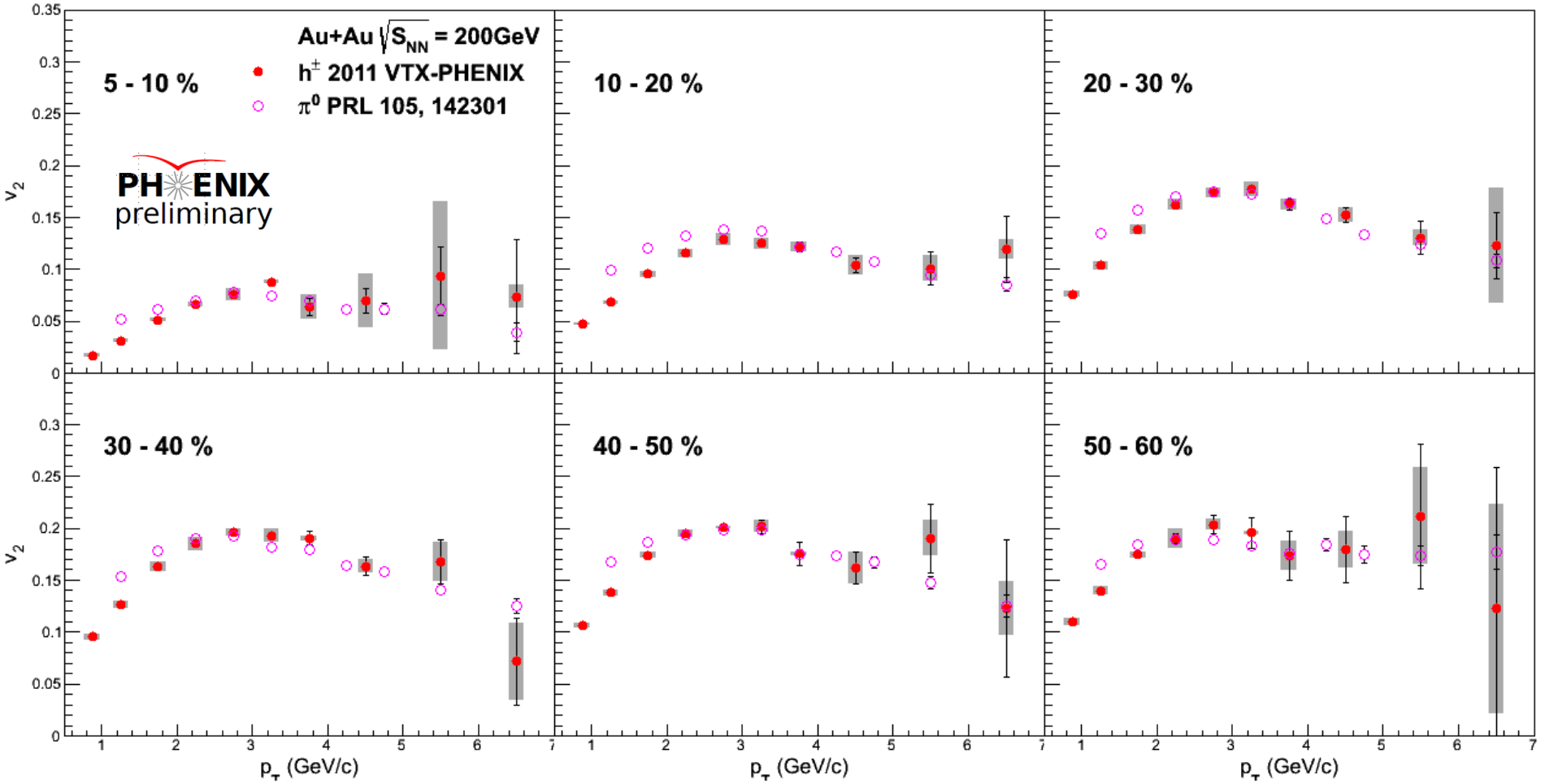
- Input spectral shape
  - Charm/Bottom : PYTHIA
  - Dalitz/Conversion: measured Pi0 spectra
  - Hadron Cont.: measured hadron
  - Random BG : event mixing

2012/10/23 QM2012, Maki Kurosawa

Charged Hadron v_2

- Comparison with v_2 of π^0 from PRL 105, 142301

2011 VTX-PHENIX
PRL. 105, 142301 (2010)

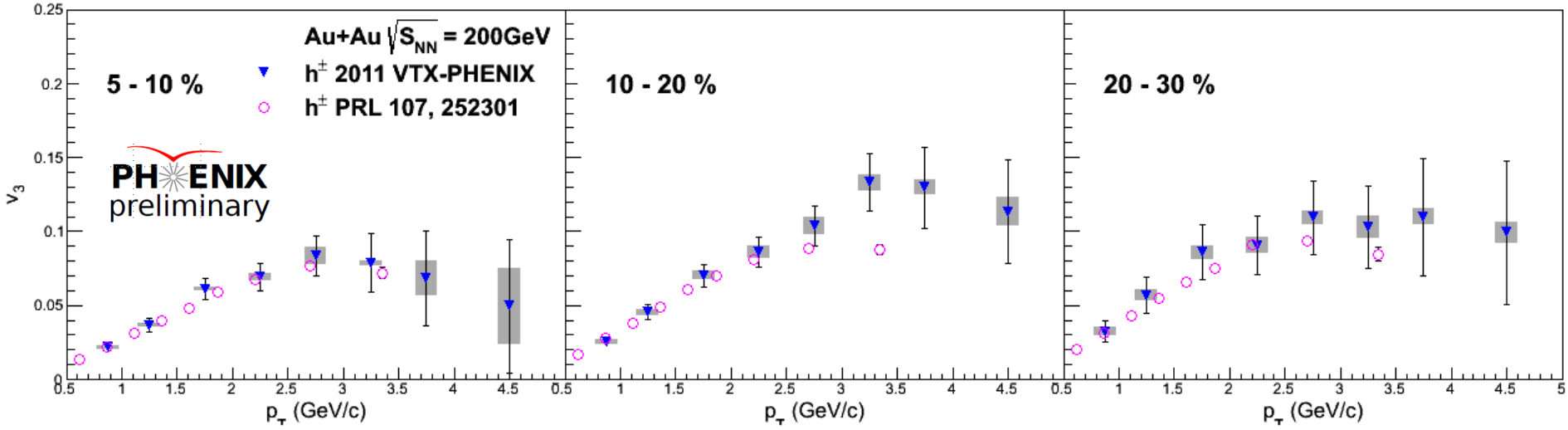


- Results are consistent with previous measurements of π^0 v_2 in high p_T region.

2012/10/23 QM2012, Maki Kurosawa

Charged Hadron v_3

▼ 2011 VTX-PHENIX
○ PRL. 107, 252301

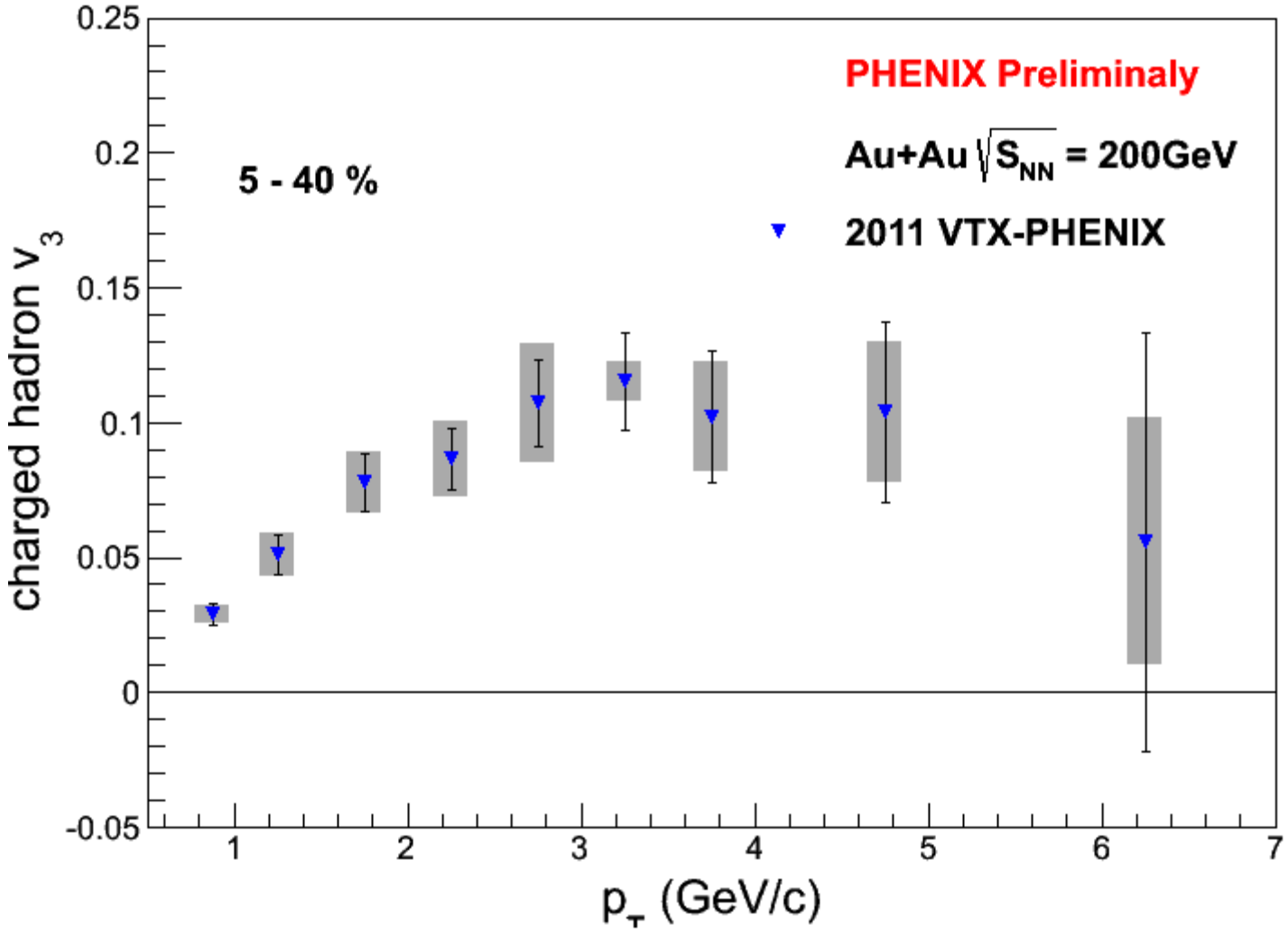


- Comparison with v_3 of charged hadrons from PRL 107, 252301.
  - Good agreement with previous data in low p_T region.
- In high p_T region, a non-zero v_3 is still observed.

2012/10/23 QM2012, Maki Kurosawa

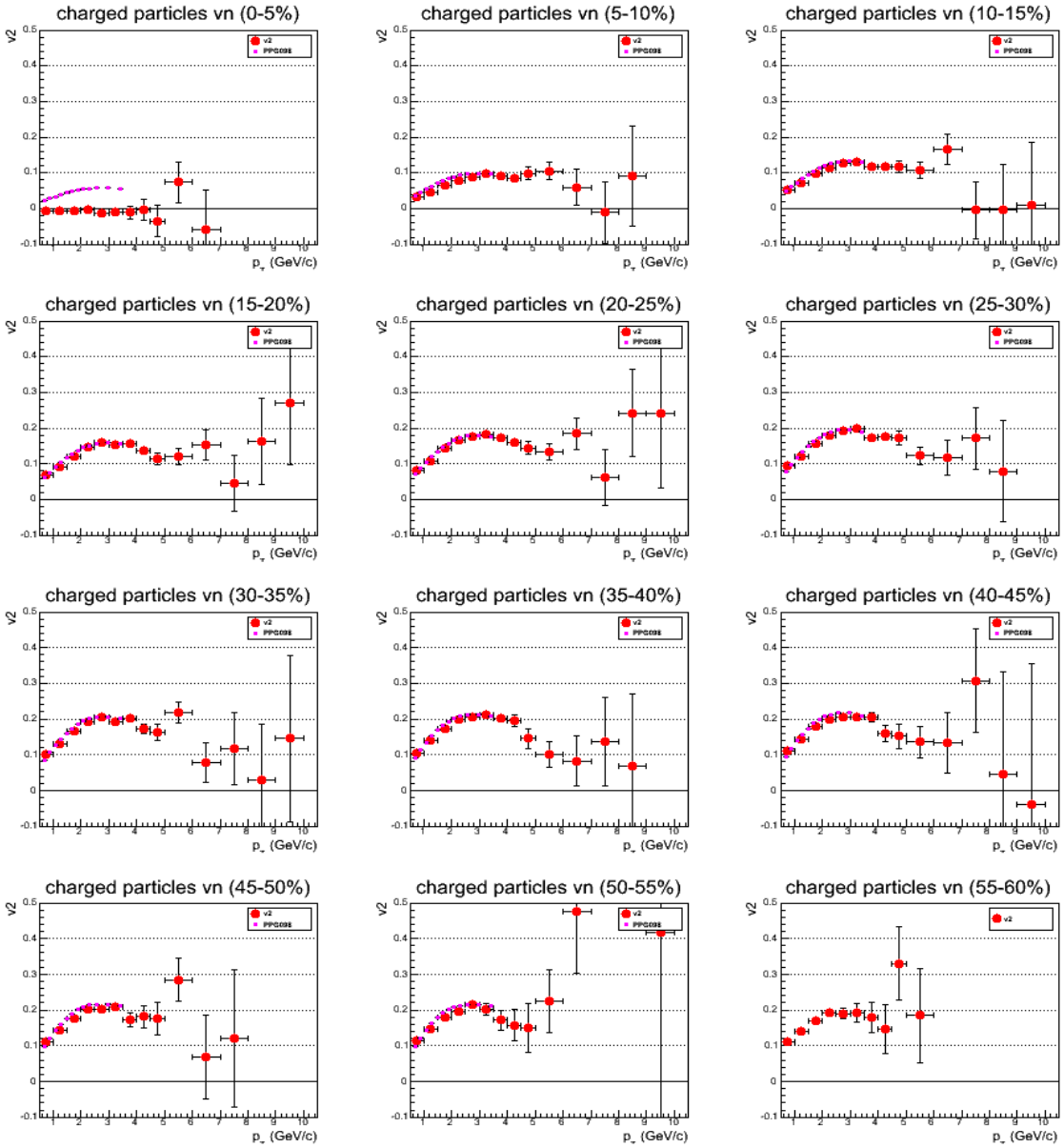
Charged Hadron v_3

Run11 VTX-PHENIX
Phys. Rev. Lett. 105, 142301 (201



Charged Hadron v_2

2012/10/23 QM2012, Maki Kurosawa



- Run11 VTX-PHENIX
- Phys. Rev. Lett. 105, 062301 (201 ppg098

Centrality dependence of v2 as a function of pT. 5% centrality step

CNT track was associated with VTX.

Required isolation cut and |DCA| < 700 μm to reduce miss-association tracks except for 0-5% centrality bin.

Our data is consist with the results from PPG098.