

# The study of $v_2$ as a function of multiplicity at different rapidities with PHENIX in Au+Au at $\sqrt{s_{NN}} = 200$ GeV

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National University Corporation  
Nara Women's  
University



# Background & Motivation

- ★ The collective-like effect has been discovered in small systems at high multiplicity. (*Nat. Phys.* **15**, 214–220 (2019))
- attract the attention to **Multi Parton Interaction (MPI)**

**Note:**  
More interacting partons will make larger multiplicity.

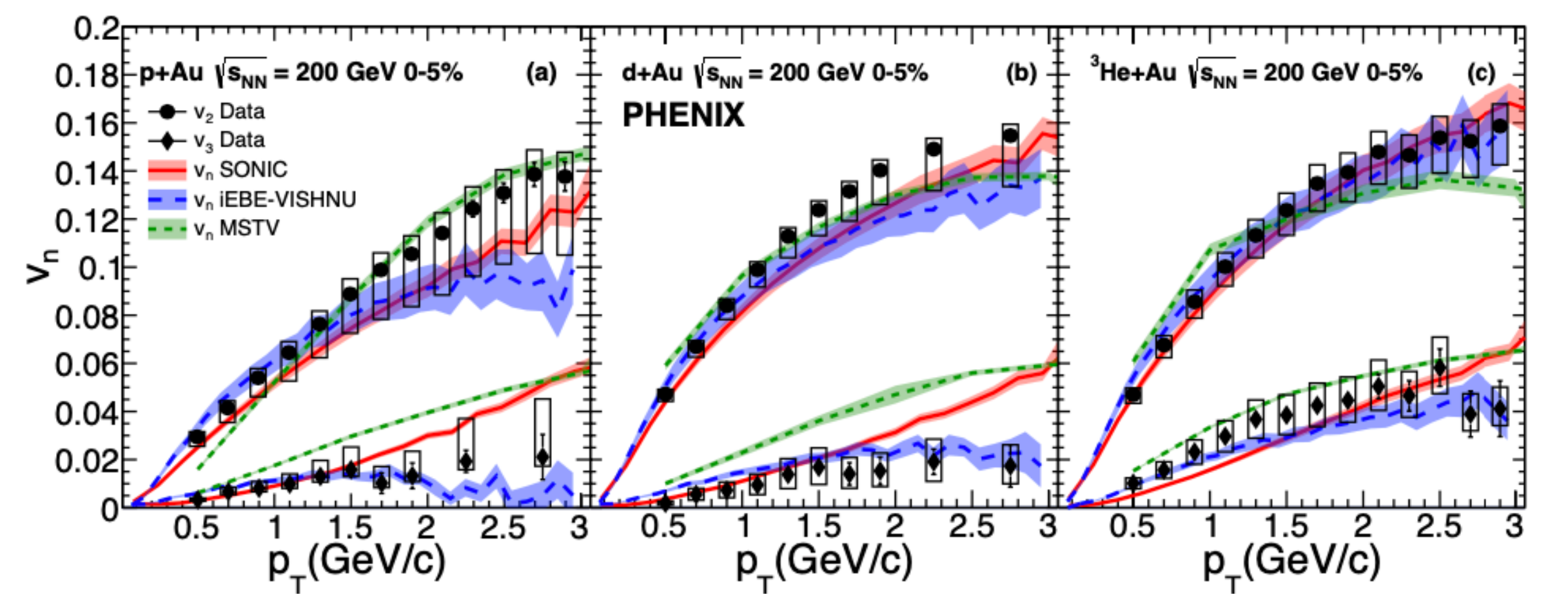
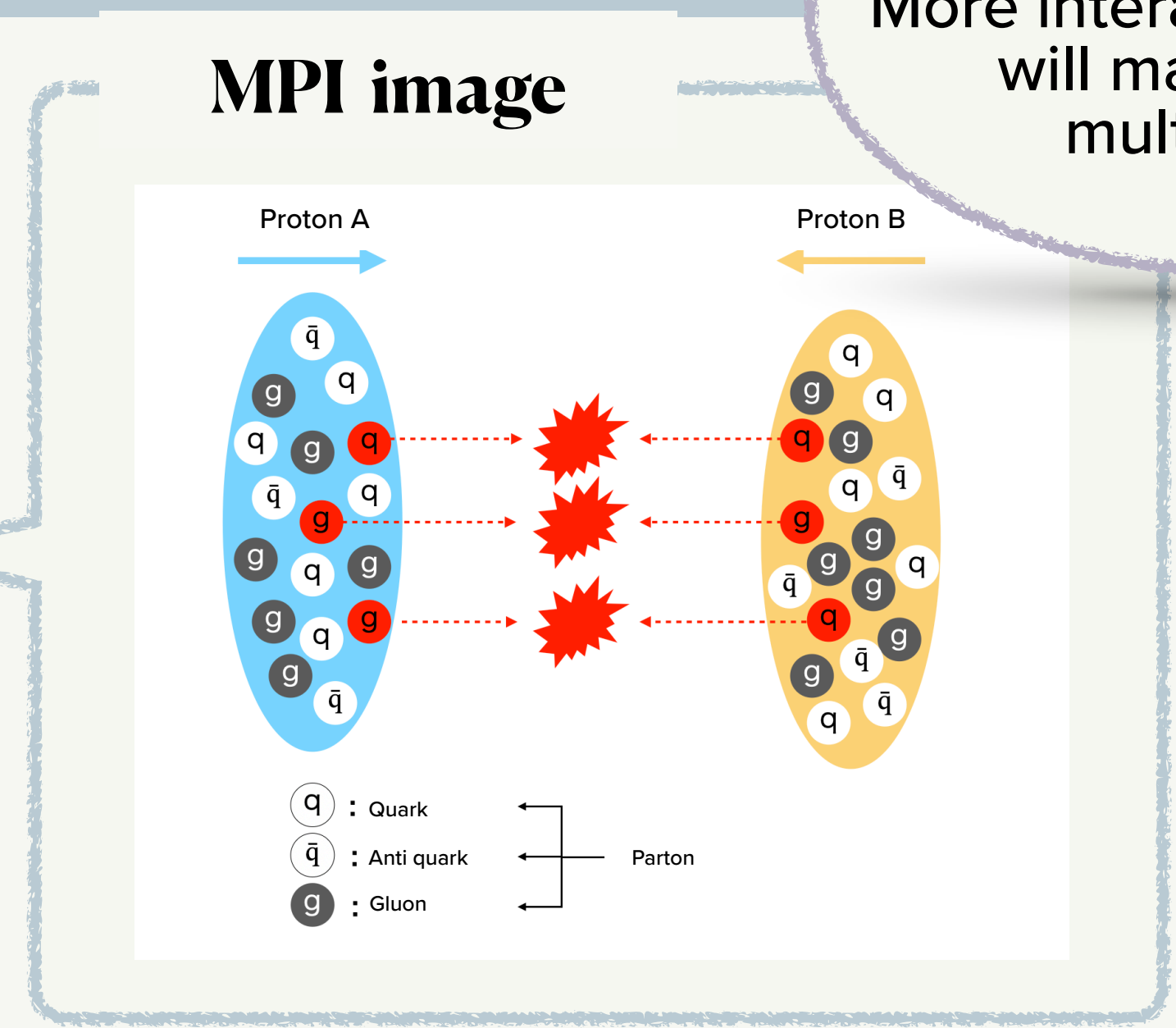


FIG. 3. | Measured  $v_n(p_T)$  in three collision systems compared to models.

**Motivation**

Trying to observe the effect of multiple parton collisions by studying  $v_2$  as a function of multiplicity in nucleon in AuAu at  $\sqrt{s_{NN}} = 200$  GeV.

# Based Idea

- $N_{\text{part}}$  : the number of participating nuclei
- $N_{\text{spec}}$  : the number of spectator of nuclei
- $N_{\text{part}} + N_{\text{spec}} = A$  ( const )

## In A+A collisions ...

✓ When more partons are participated in collisions at same  $N_{\text{part}}$  ( or  $N_{\text{spec}}$  )

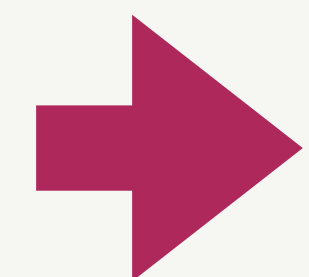
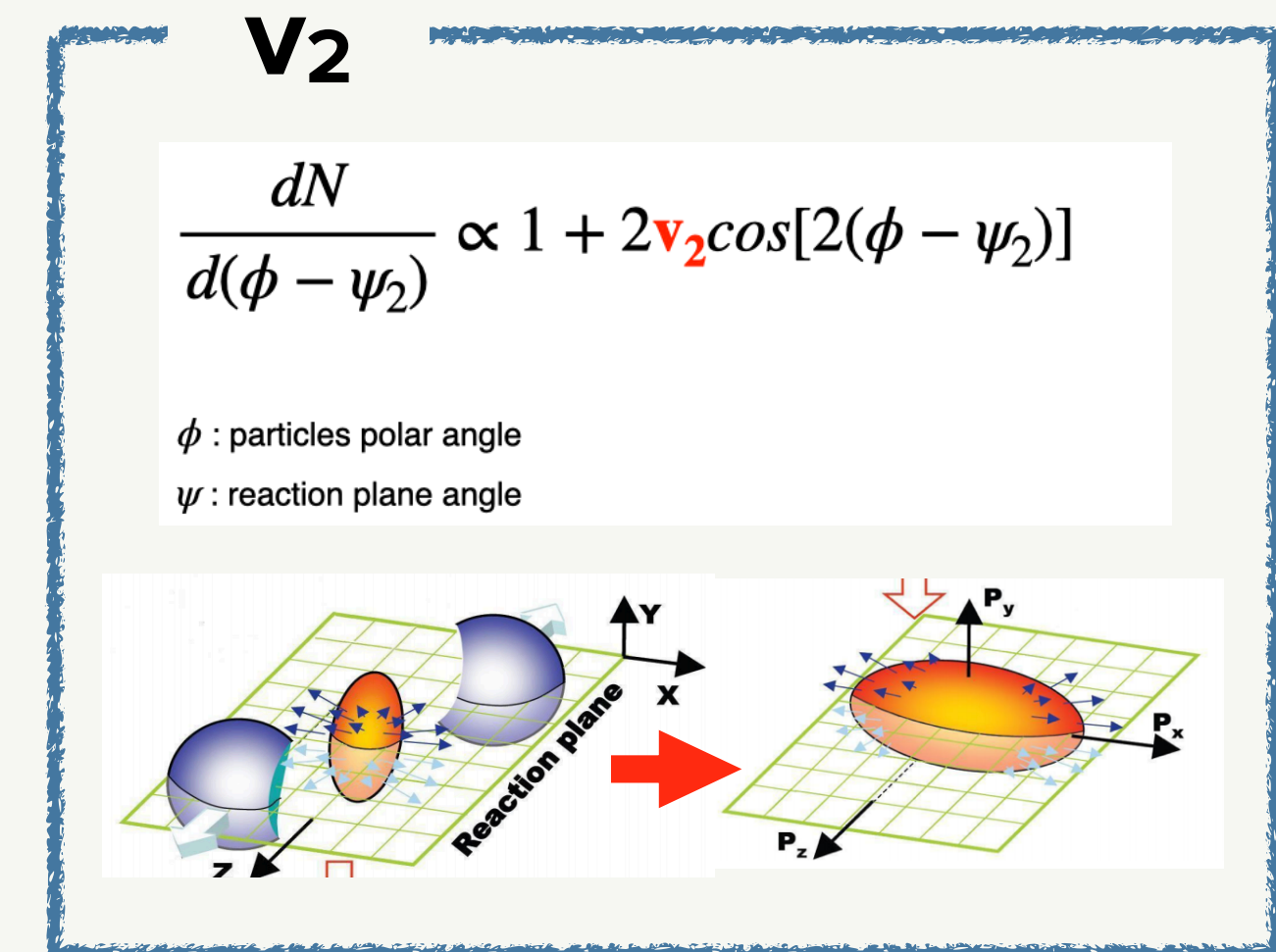
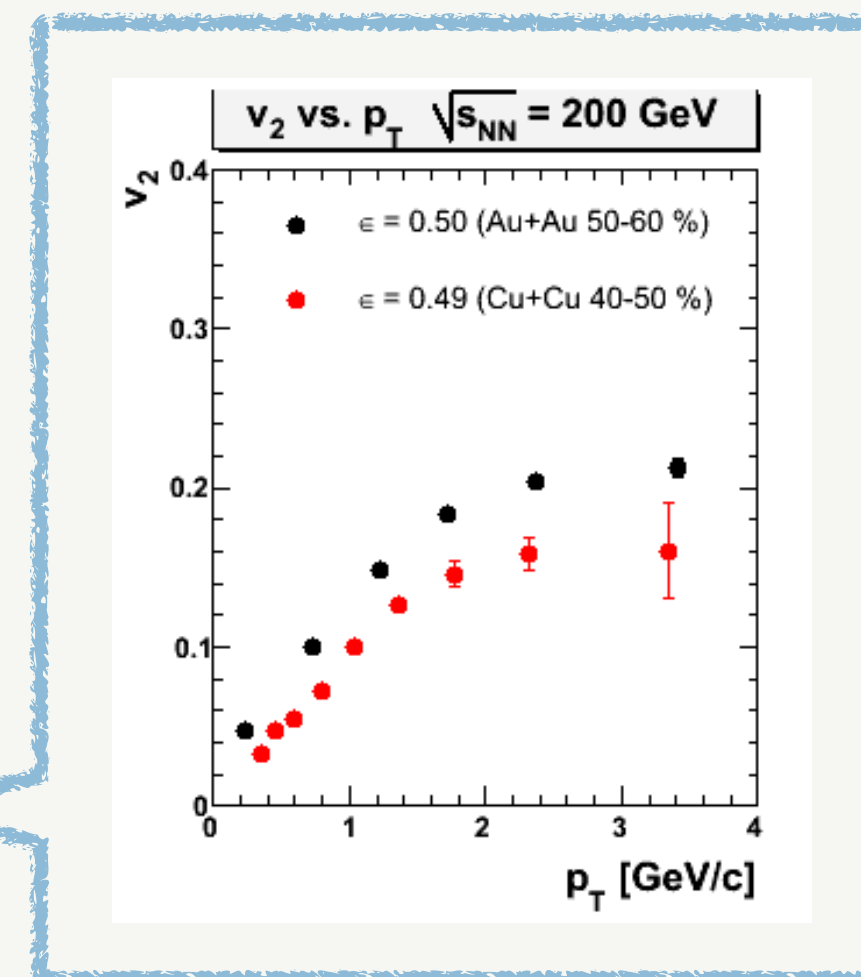
### 1. Multiplicity will be larger.

- sQGP were detected in high multiplicity

### 2. $v_2$ ( or eccentricity ) may be larger.

- more  $N_{\text{part}}$ , larger  $v_2$  at same eccentricity

$v_2^{\text{Cu}} < v_2^{\text{Au}}$  at  $\epsilon^{\text{Cu}} = \epsilon^{\text{Au}}$  (  $N_{\text{part}}^{\text{Cu}} < N_{\text{part}}^{\text{Au}}$  )



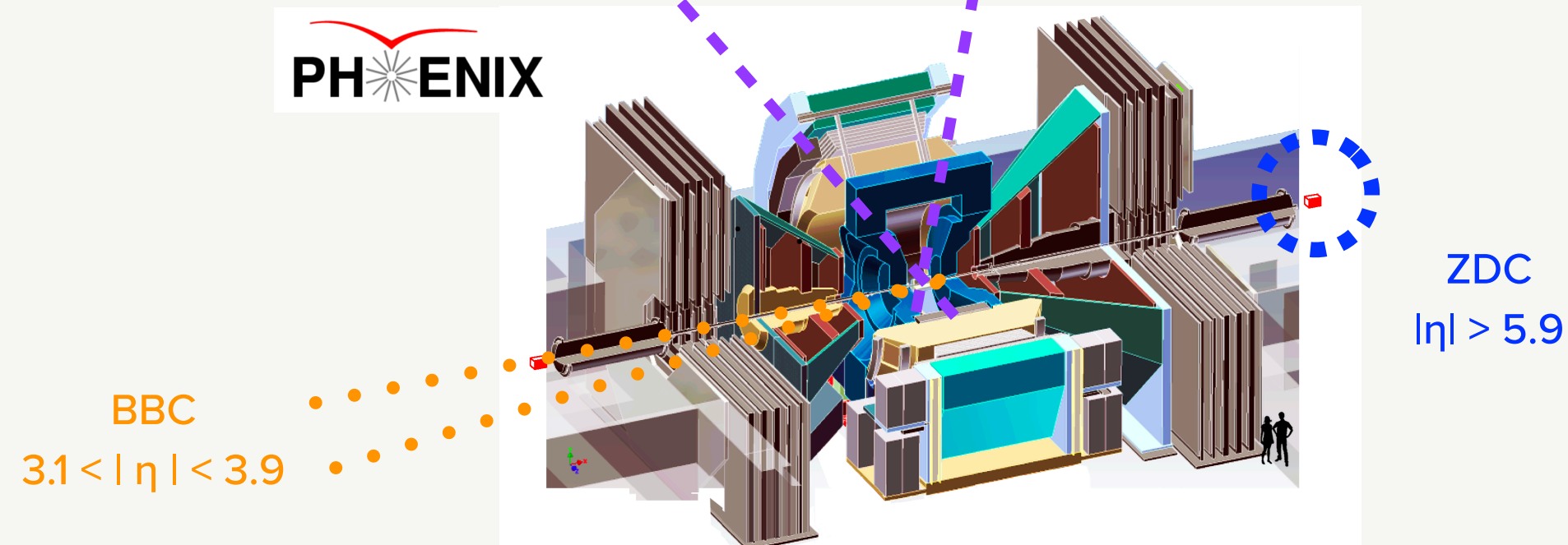
At same  $N_{\text{part}}$ , multiplicity and  $v_2$  are positively correlated with the number of participated partons.



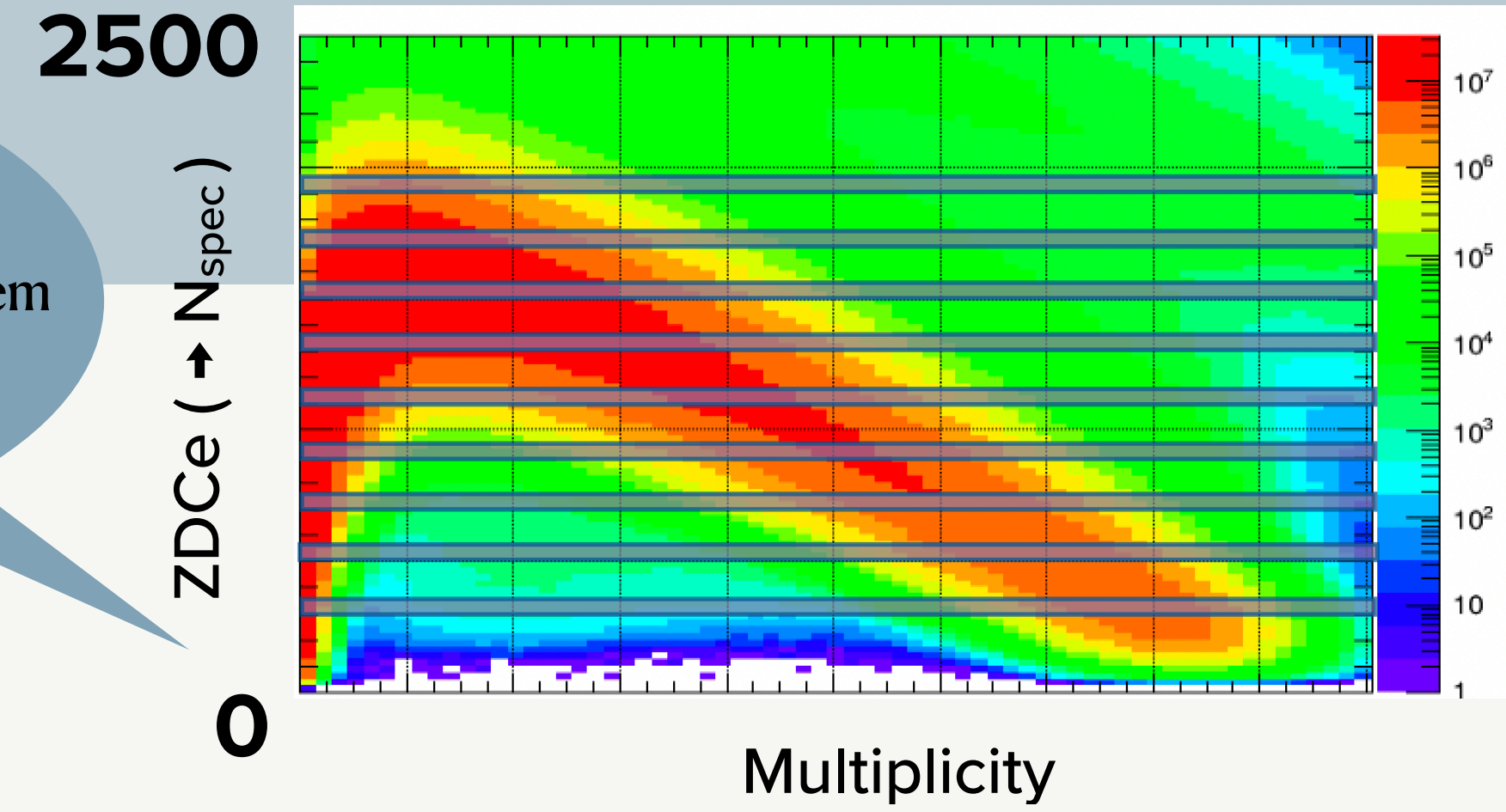
# Analysis Procedure

## We studied “ $v_2$ as a function of multiplicity”

- $v_2$  is measured by Central Arm.
- Used reaction plane method to calculate  $v_2$ .
- Reaction plane is measured by BBC.
- Studied multiplicity dependence at different rapidity measured by
  - Beam Beam Counter ( BBC ) :  $3.1 < |\eta| < 3.9$
  - Central Arm ( CNT ) :  $|\eta| < 0.35$



Did analysis for each blue categorized events and compared them and without ZDCe selection.



### • Event selection

- MB data of Run14 ( year 2014 ) at  $\sqrt{s_{\text{NN}}} = 200$  GeV in Au+Au collisions.
- $|z_{\text{vtx}}| < 10$  cm
- **9 pattern-ZDCe selection ( $300 < \text{ZDCe} < 310$ ,  $500 < \text{ZDCe} < 510$ , ... ,  $1900 < \text{ZDCe} < 1910$ ).**  
ZDC measures the energy of spectator neutrons.

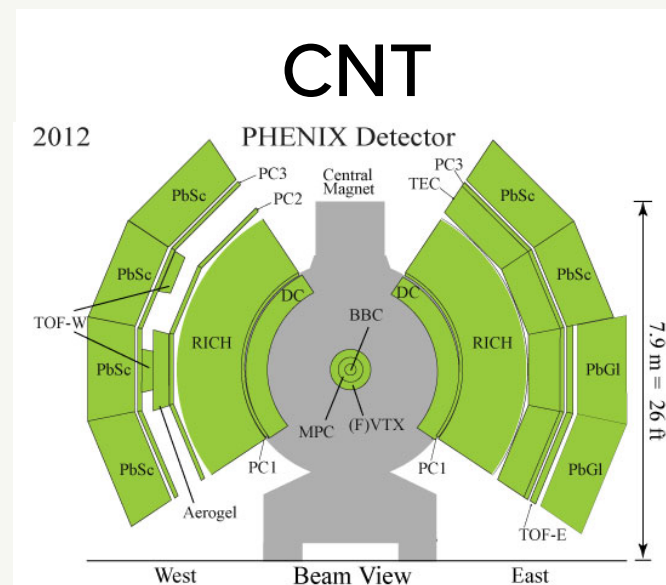
### • Track selection

- $p_{\text{T}} > 0.10$  GeV/c
- Energy / momentum  $> 0.2$

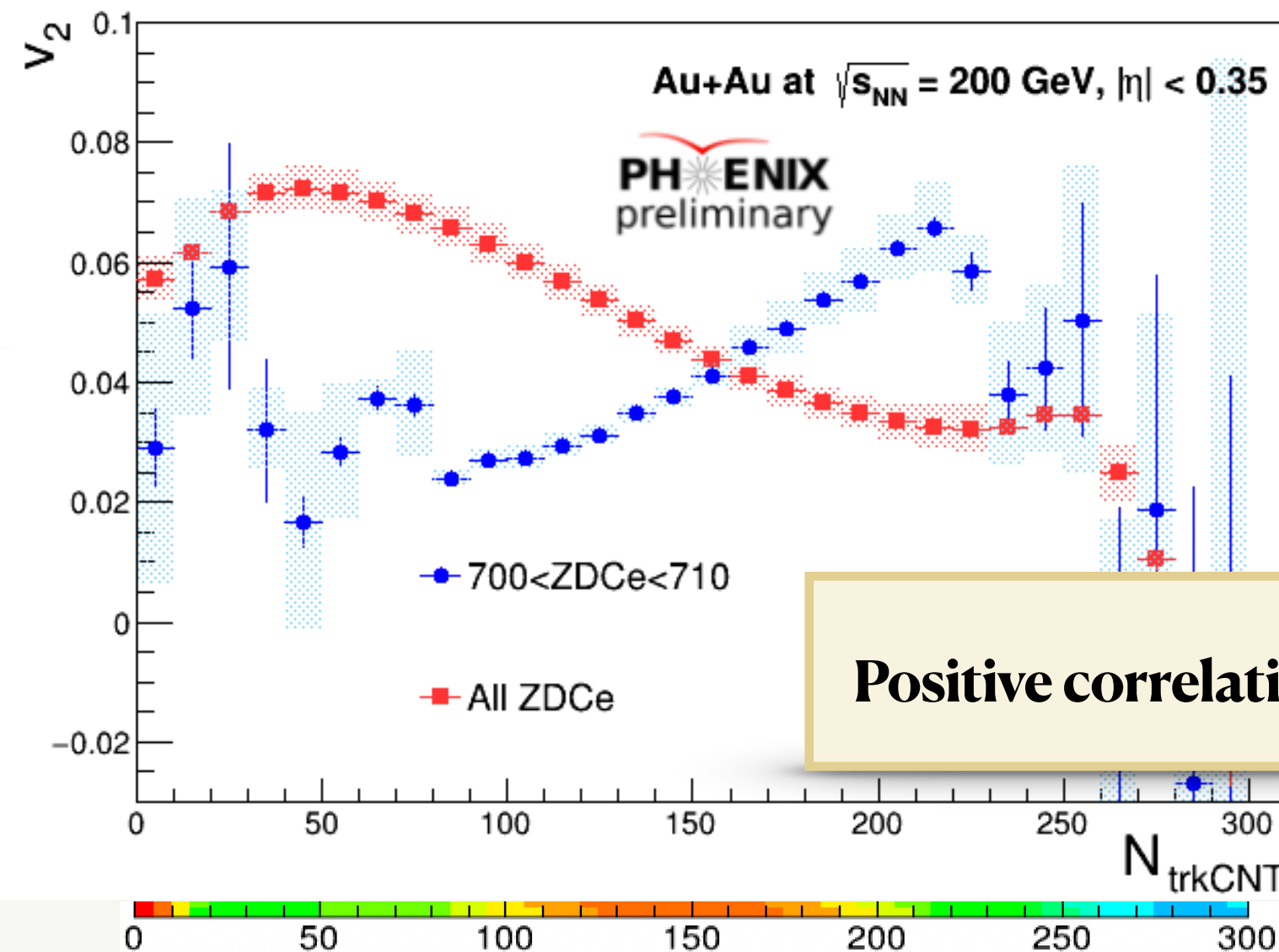
# Result

When ZDCe selection is required ( **blue symbols •** ), the differences of the correlation between  $v_2$  and multiplicity at different rapidities is shown up!

Red symbols ( **■** ) shows data when ZDCe is integrated.

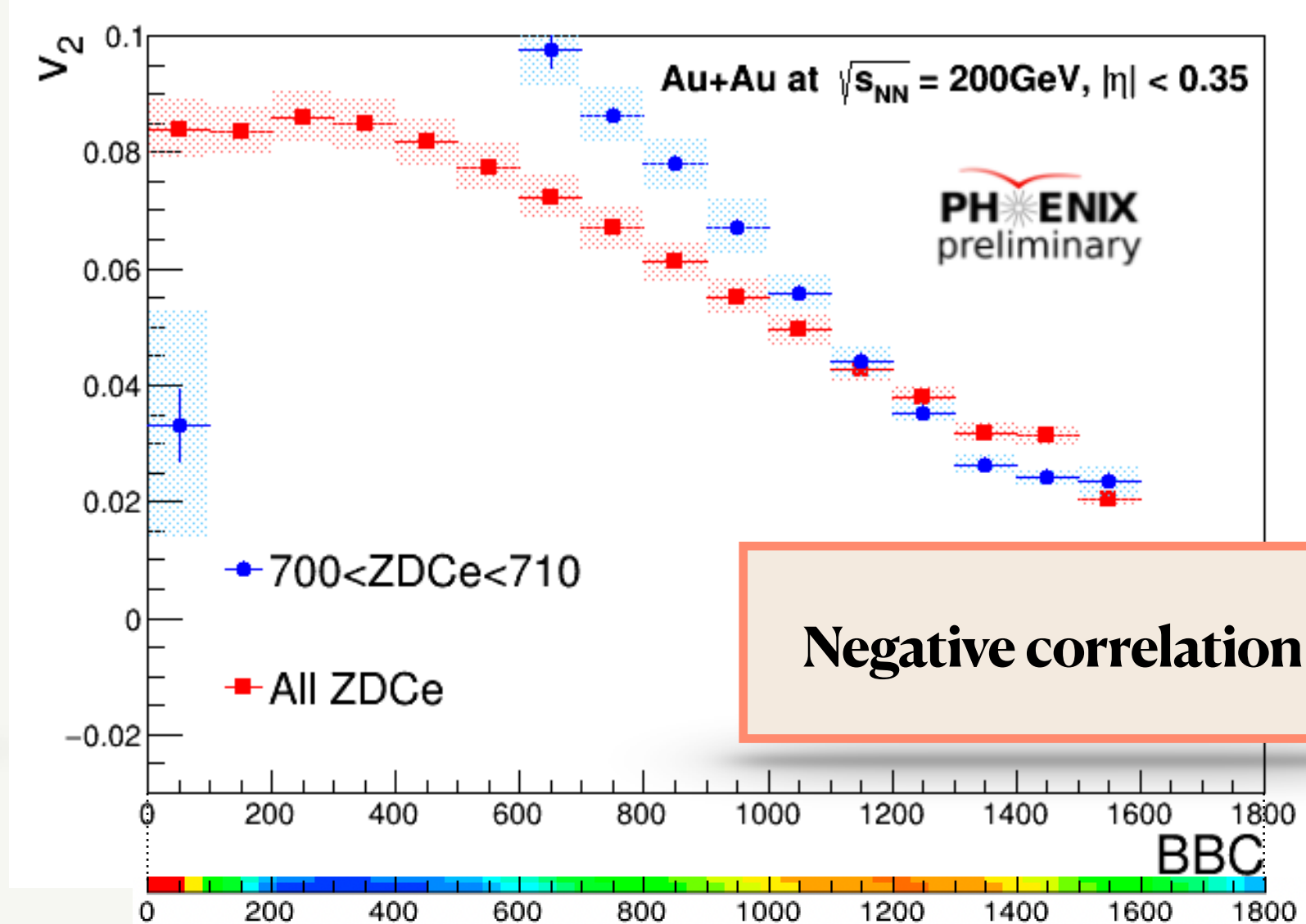


$v_2$  vs. CNT ( $|\eta| < 0.35$ )



Acceptance :  $\pi$

$v_2$  vs. BBC ( $3.1 < |\eta| < 3.9$ )



BBC



Acceptance :  $2\pi$

Since we measured  $v_2$  by CNT, we have to be carefully to some auto correlation in this analysis.

Now we are studying more details about it.



# Summery & over view

✓ To explore the effect of the multiple parton collisions in Au+Au collision,

We studied

- $v_2$  vs. CNT ( $|\eta| < 0.35$ )
- $v_2$  vs. BBC ( $3.1 < |\eta| < 3.9$ )

With ZDCe categorization.

→ We found a **positive correlation** between  $v_2$  and **CNT** when ZDCe selection is required.

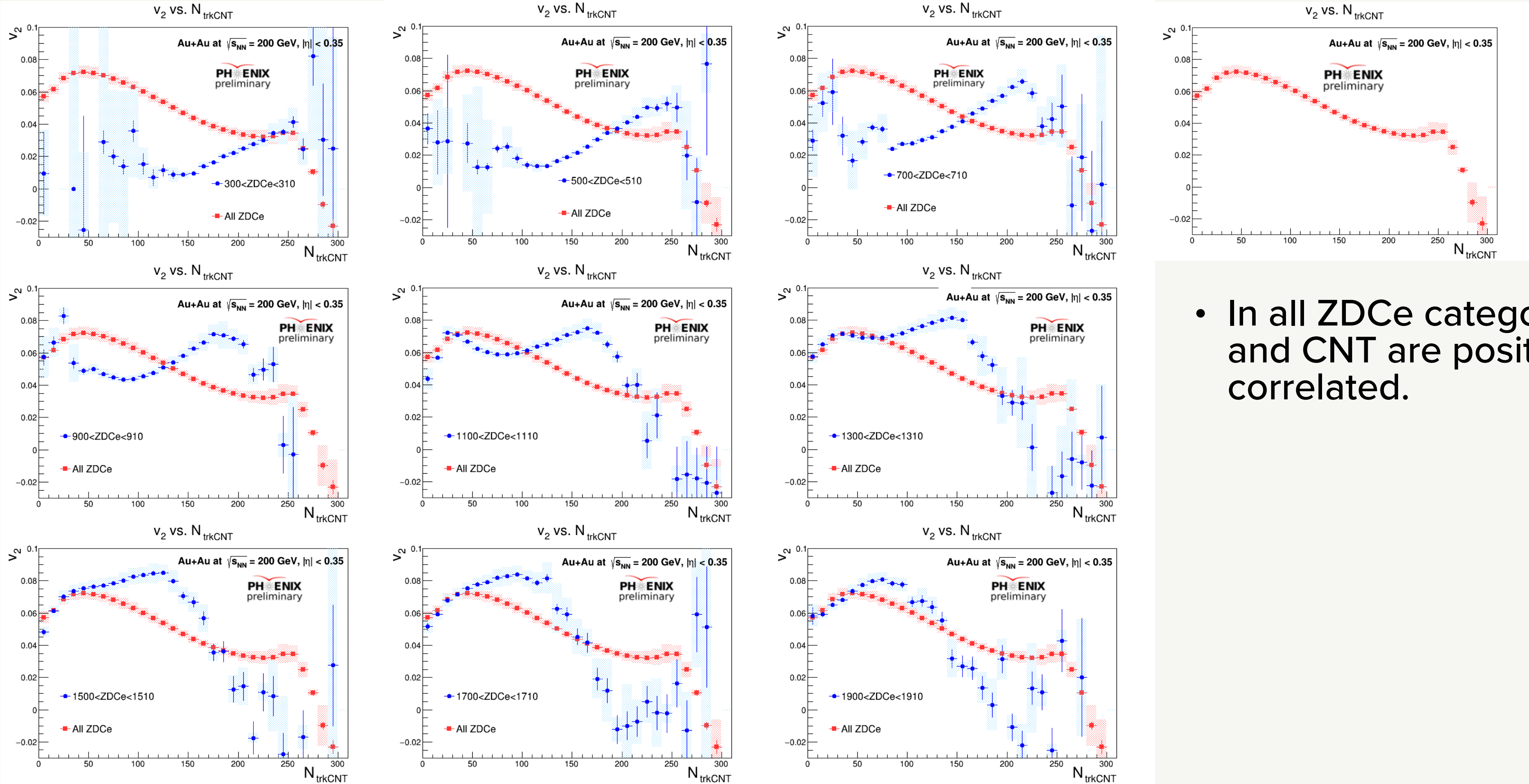
On the other hand, the correlation between  $v_2$  and **BBC** is **negative**.

✓ We are now studying more details about possible auto correlation between  $v_2$  and CNT.

**Thank you For Your Attention.**

**Back up**

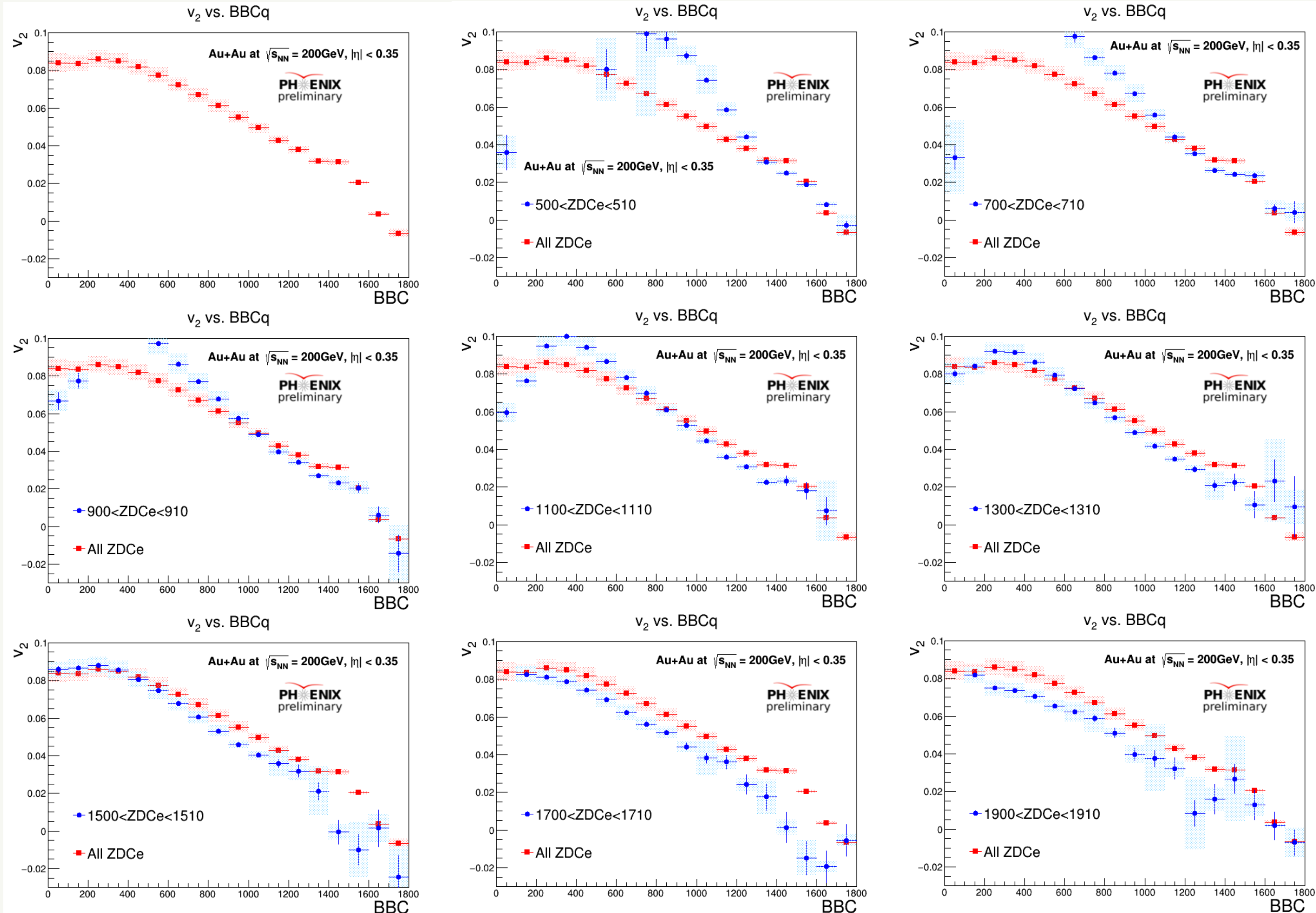
# $v_2$ vs. CNT



- In all ZDCe categorization,  $v_2$  and CNT are positively correlated.



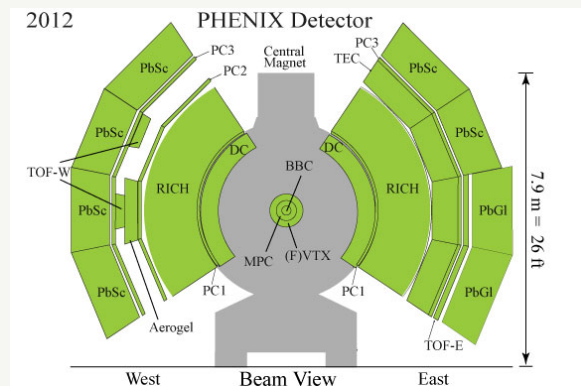
# $v_2$ vs. BBC



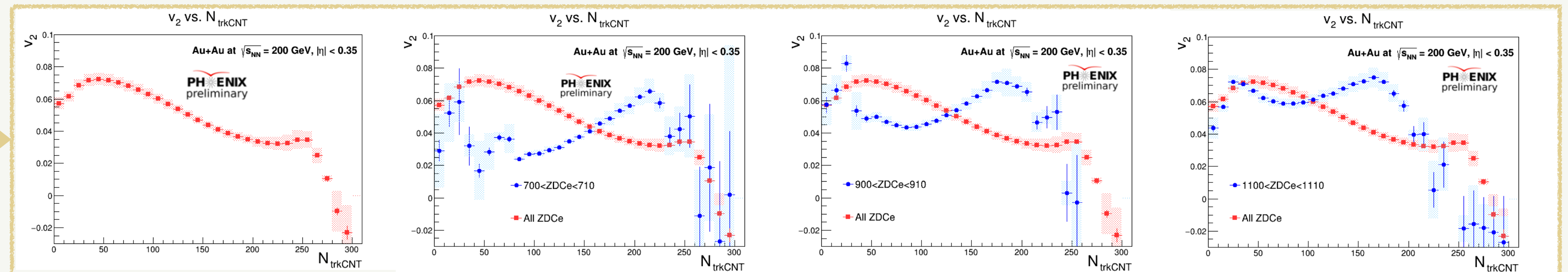
- There is no clear positive correlations in any ZDCe categorizations.

# Comparing

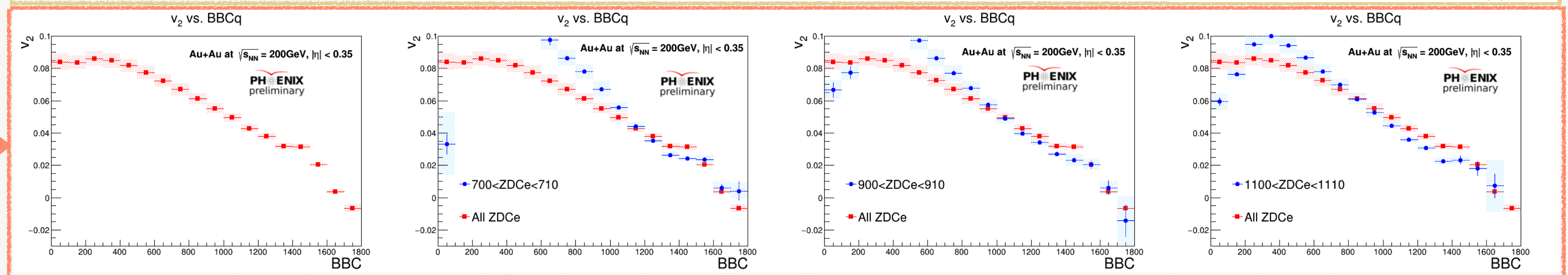
- There is a clear difference between CNT and BBC dependence.
- We are thinking that the effect of detector-coverage rapidity or detector shape is there.



CNT dependence  
positive  
correlation



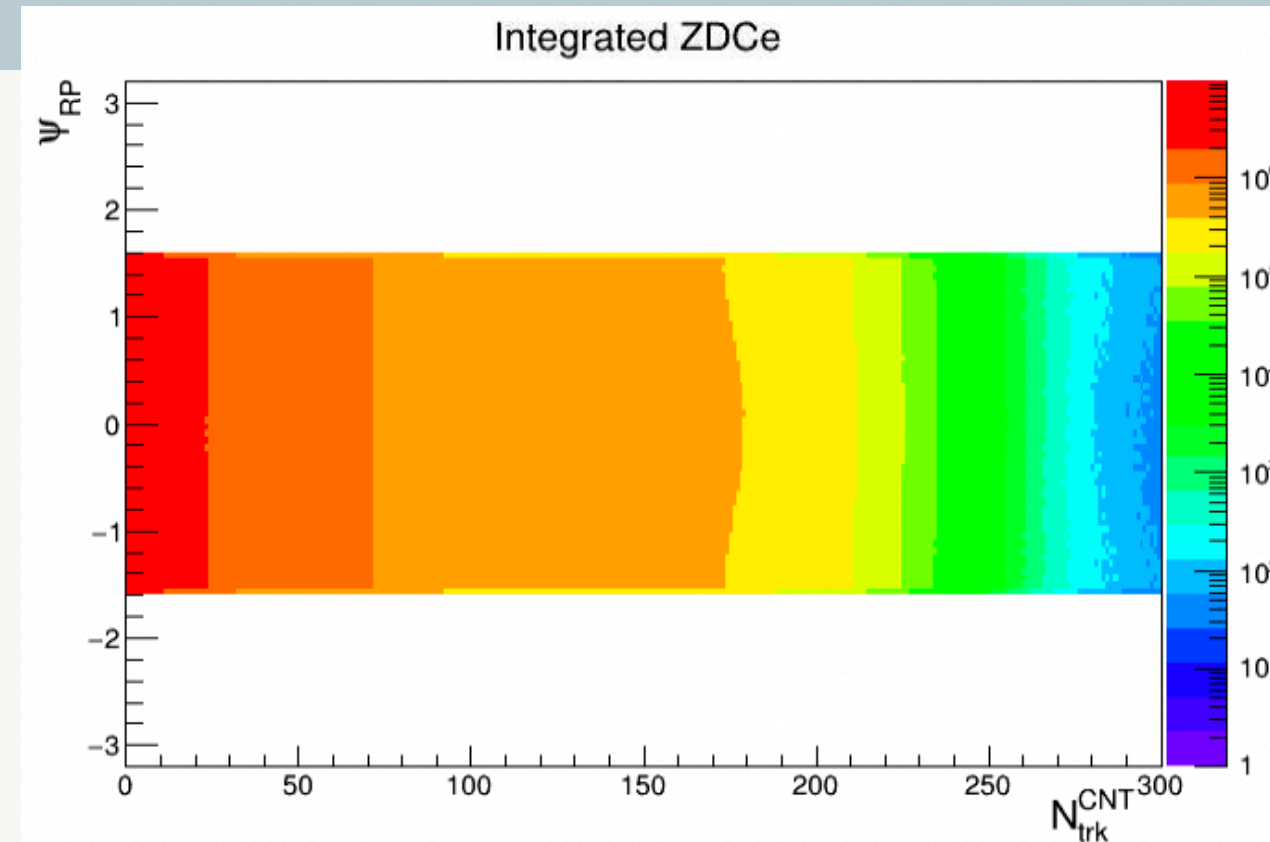
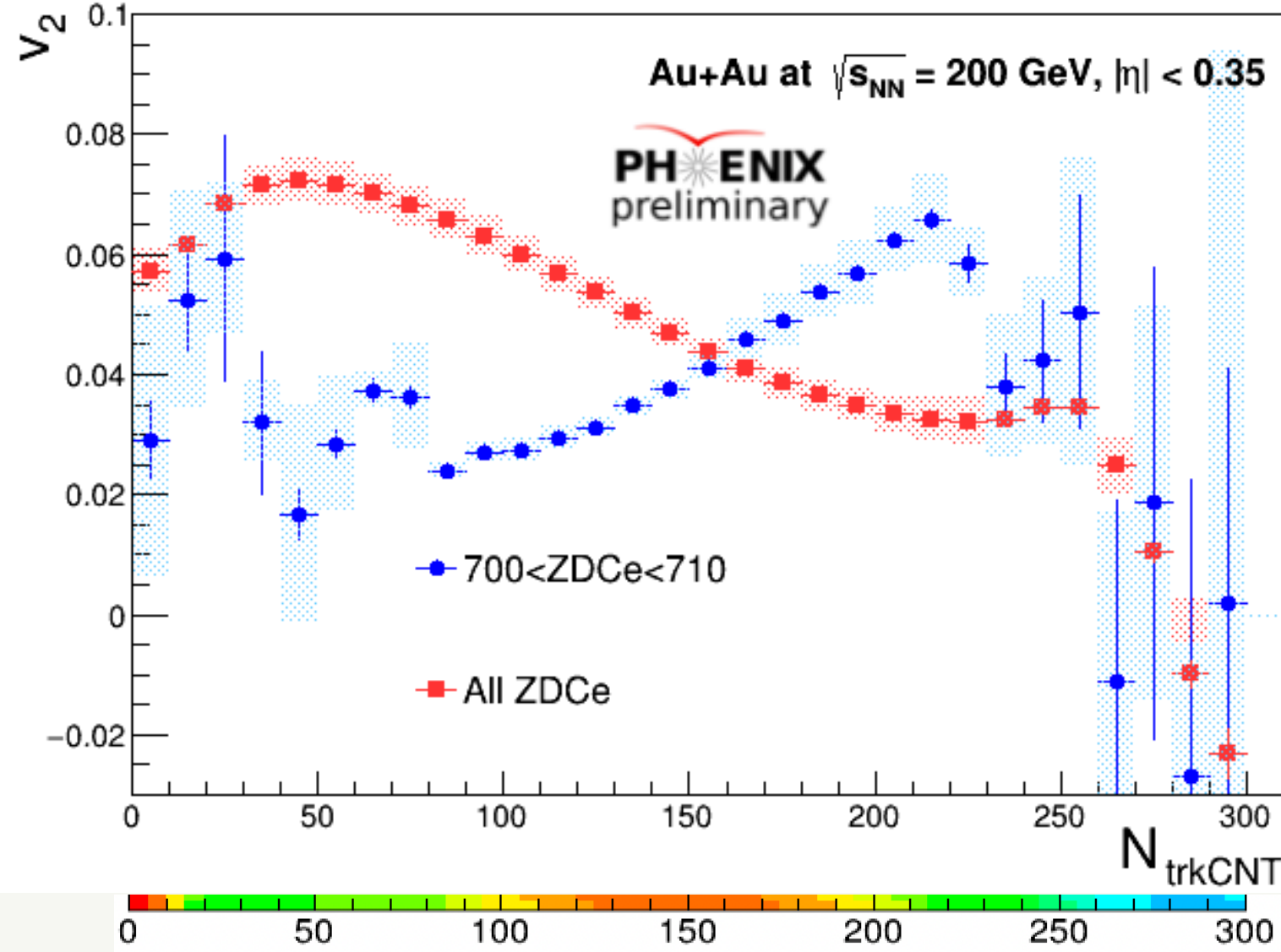
BBC dependence  
Negative  
correlation





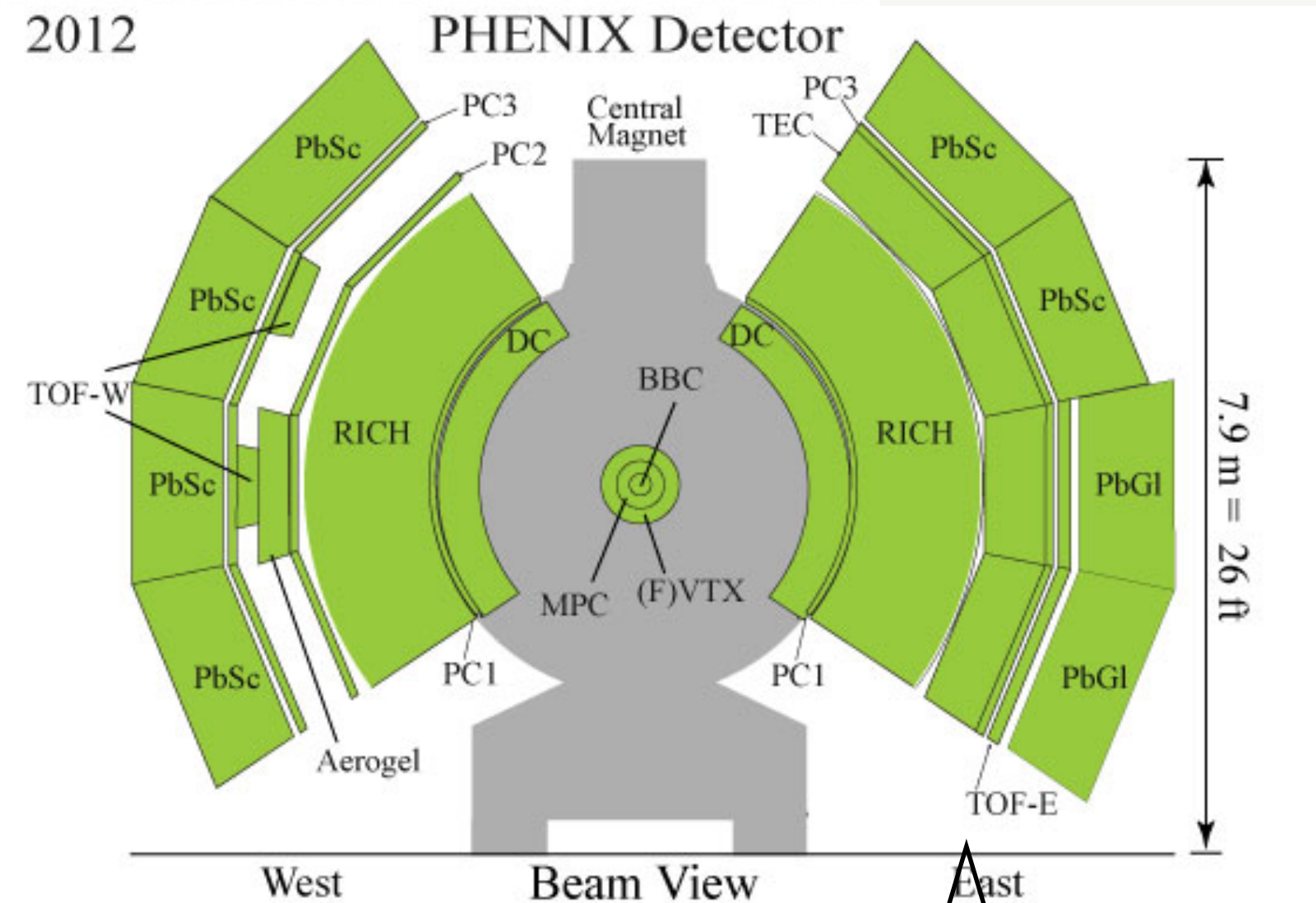
# Possible auto correlation for $v_2$ vs. CNT

$v_2$  vs. CNT ( $|\eta| < 0.35$ )



measured  $v_2$  and multiplicity by  
 are thinking that there are some  
 relations.

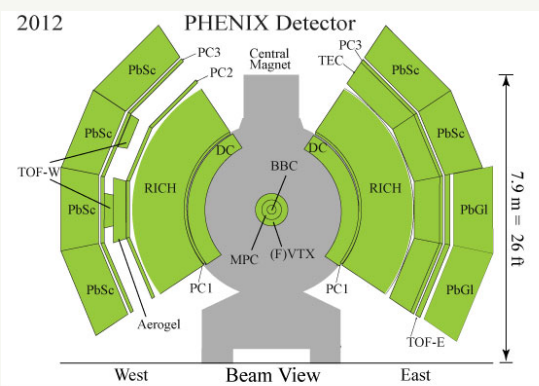
the possible auto correlations is



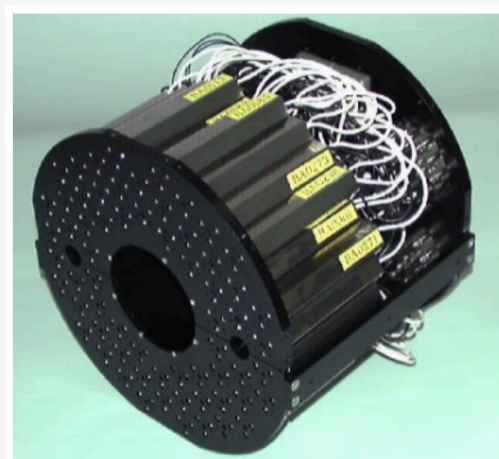
Acceptance :  $\pi$



# When the ZDCe categorization is required, clearly different tendency of the correction is shown up!

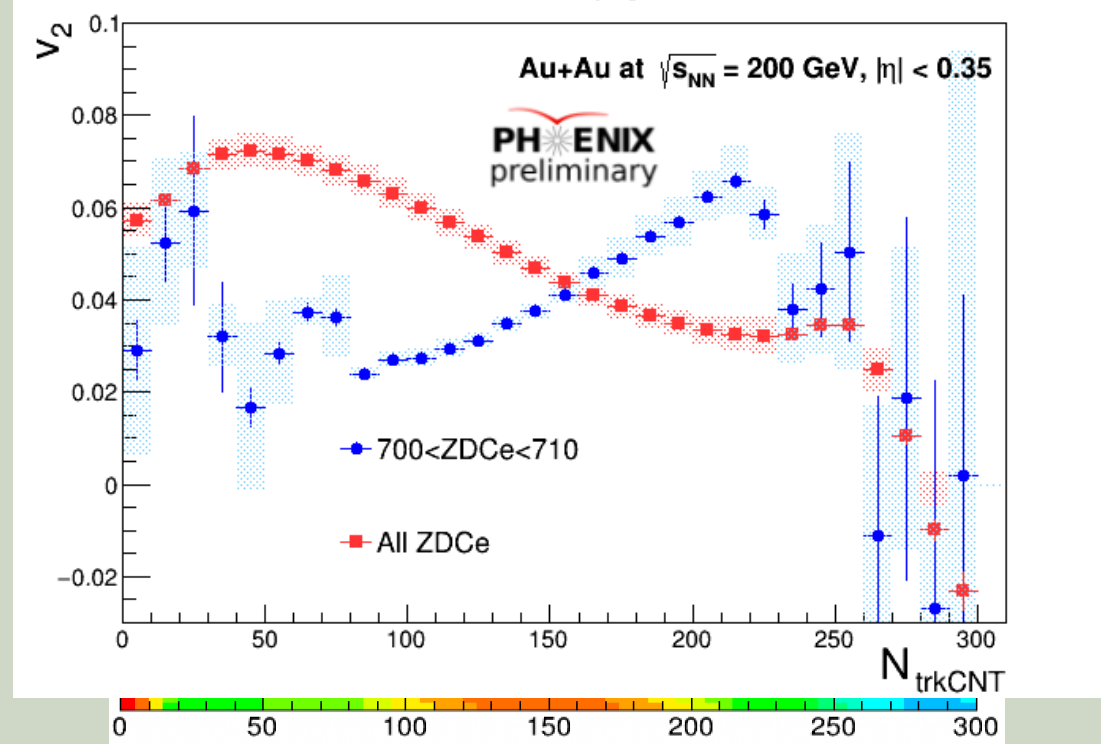


**CNT**  
dependence  
 $|\eta| < 0.35$

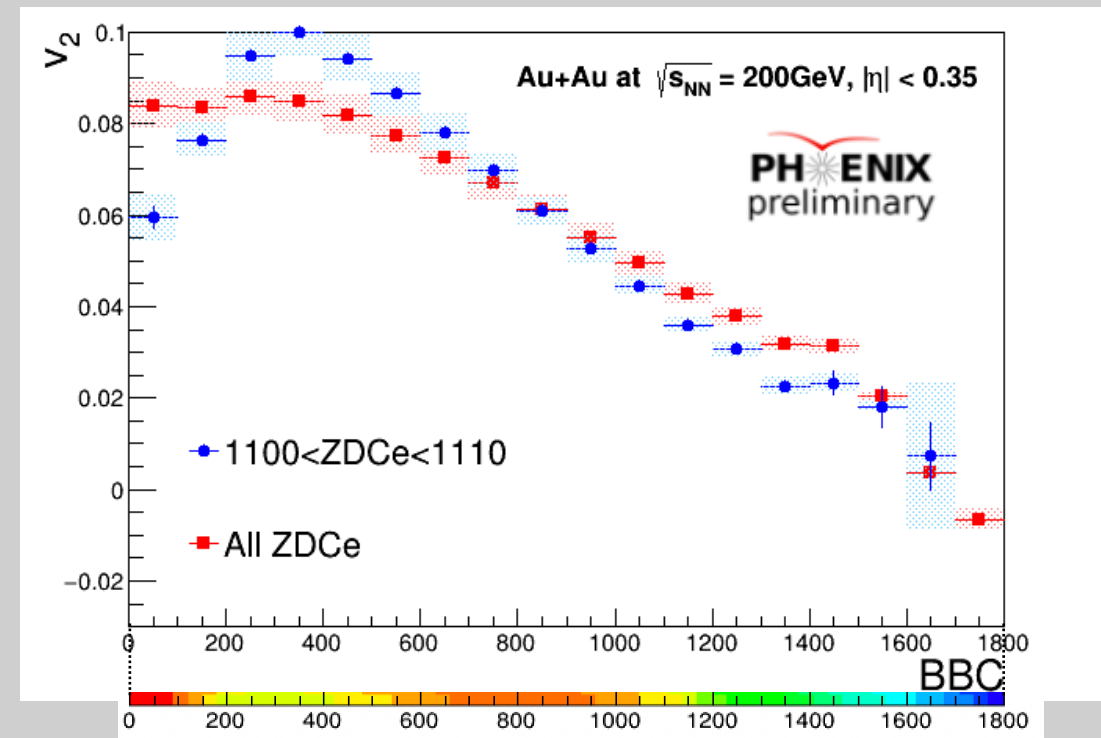
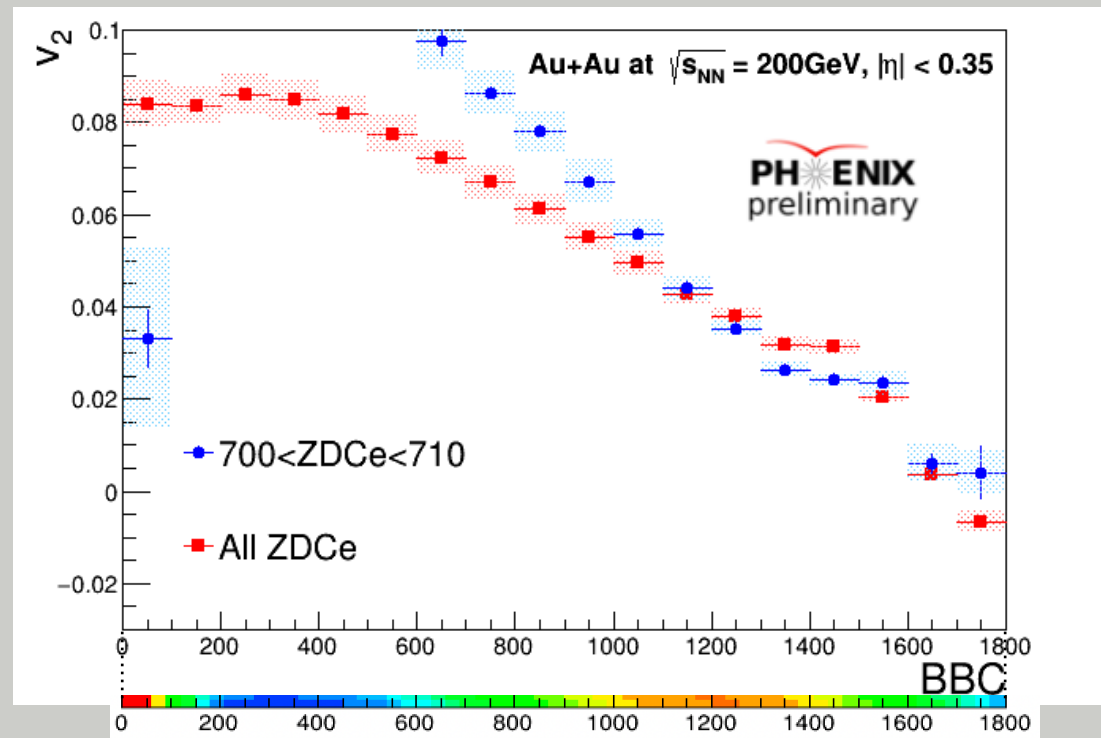
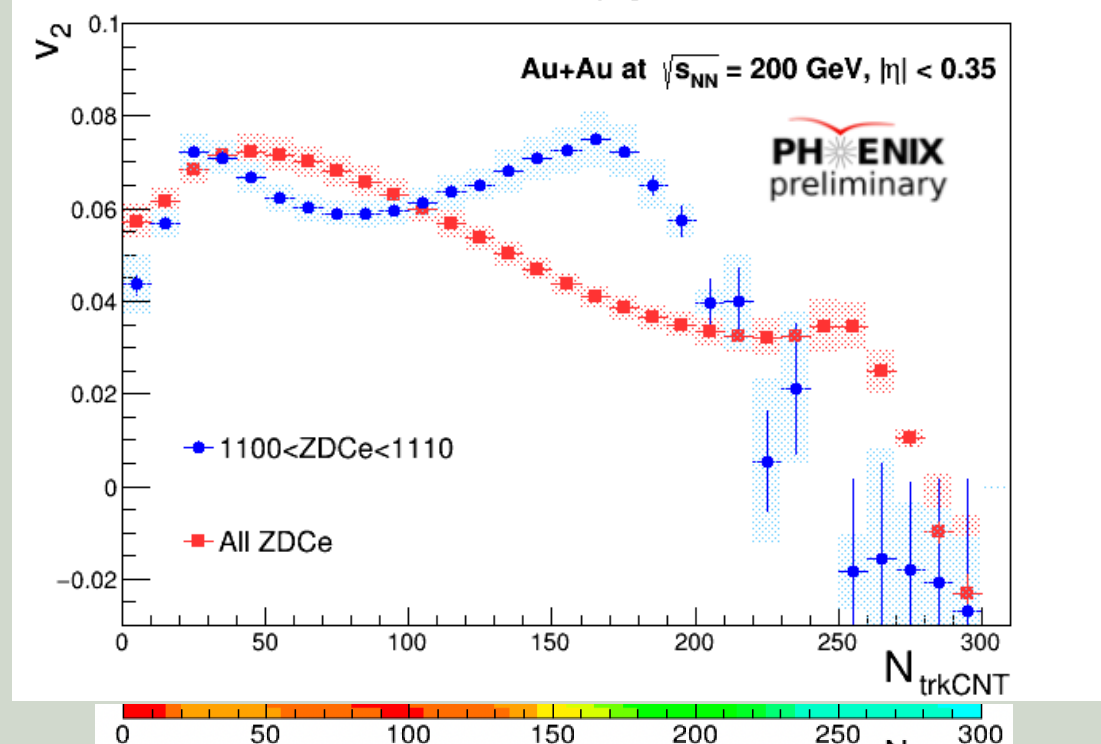


**BBC**  
dependence  
 $3.1 < |\eta| < 3.9$

**700 < ZDCe < 710**



**1100 < ZDCe < 1110**



**Positive correlation**

**Negative correlation**

# Analysis Procedure

## • Event selection

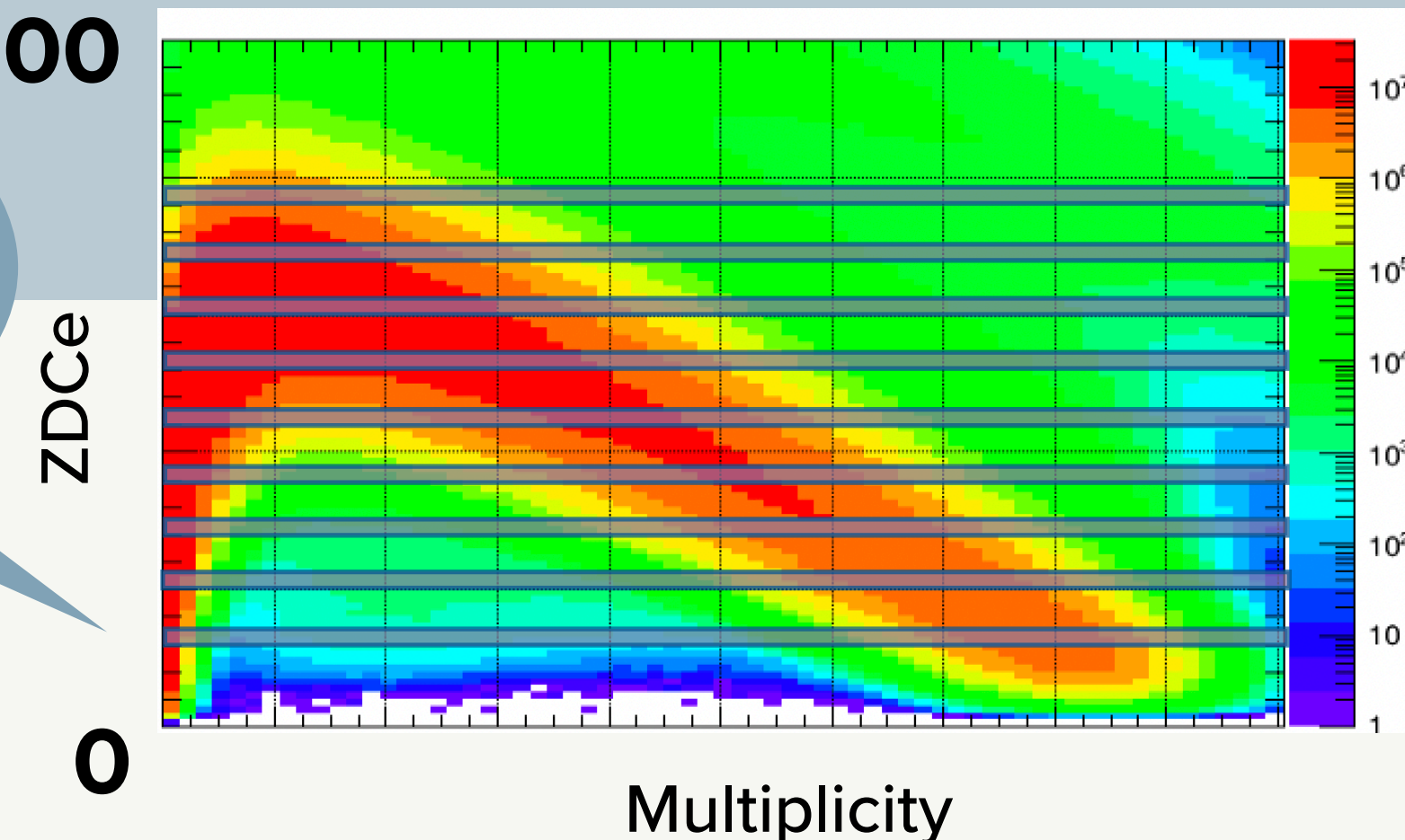
- MB data of Run14 ( year 2014) at  $\sqrt{s_{NN}} = 200$  GeV in Au+Au collisions.
- $|z_{vtx}| < 10$  cm
- **9 pattern-ZDCe selection ( $300 < ZDCe < 310$ ,  $500 < ZDCe < 510$ , ... ,  $1900 < ZDCe < 1910$ )**

## • Track selection

- Quality = 31 or 63
- $p_T > 0.10$  GeV/c
- $|z_{ed}| < 75$  cm
- $E/p > 0.2$

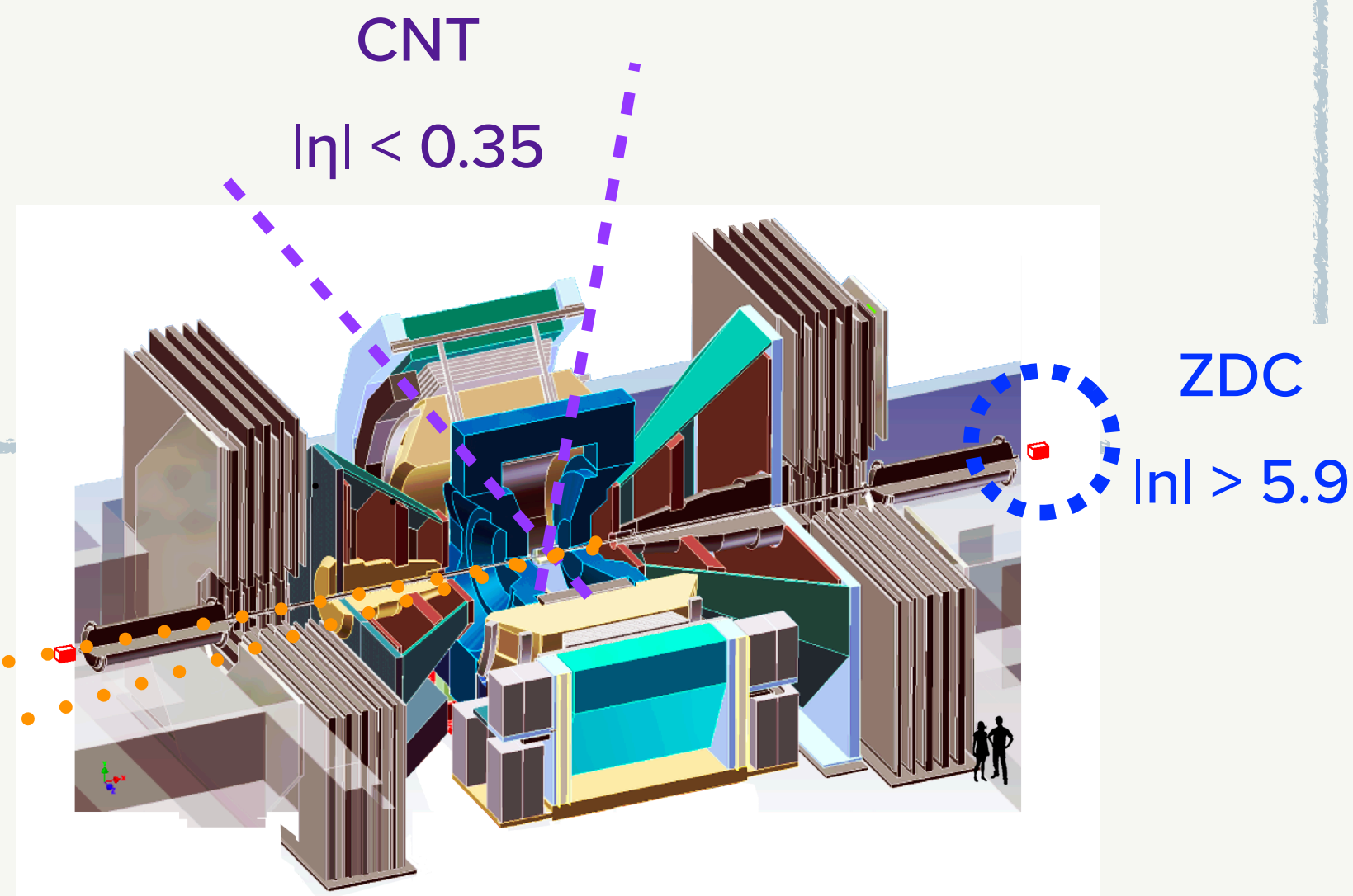
Did analysis for each blue categorized events and compared them and without ZDCe selection.

2500



**We studied**  
**“ $v_2$  as a function of multiplicity”**

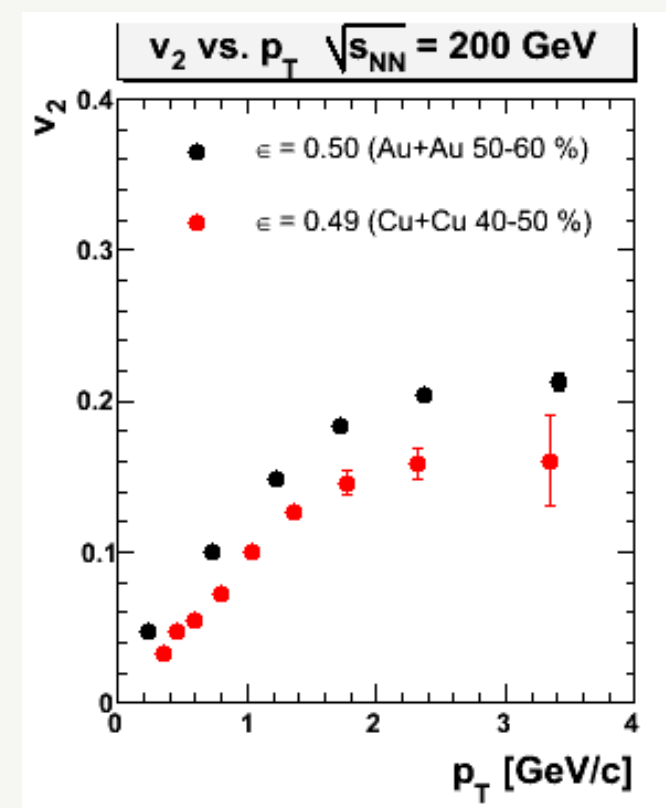
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# Based Idea

- $N_{part}$  : the number of participating nuclei
- $N_{spec}$  : the number of spectator of nuclei

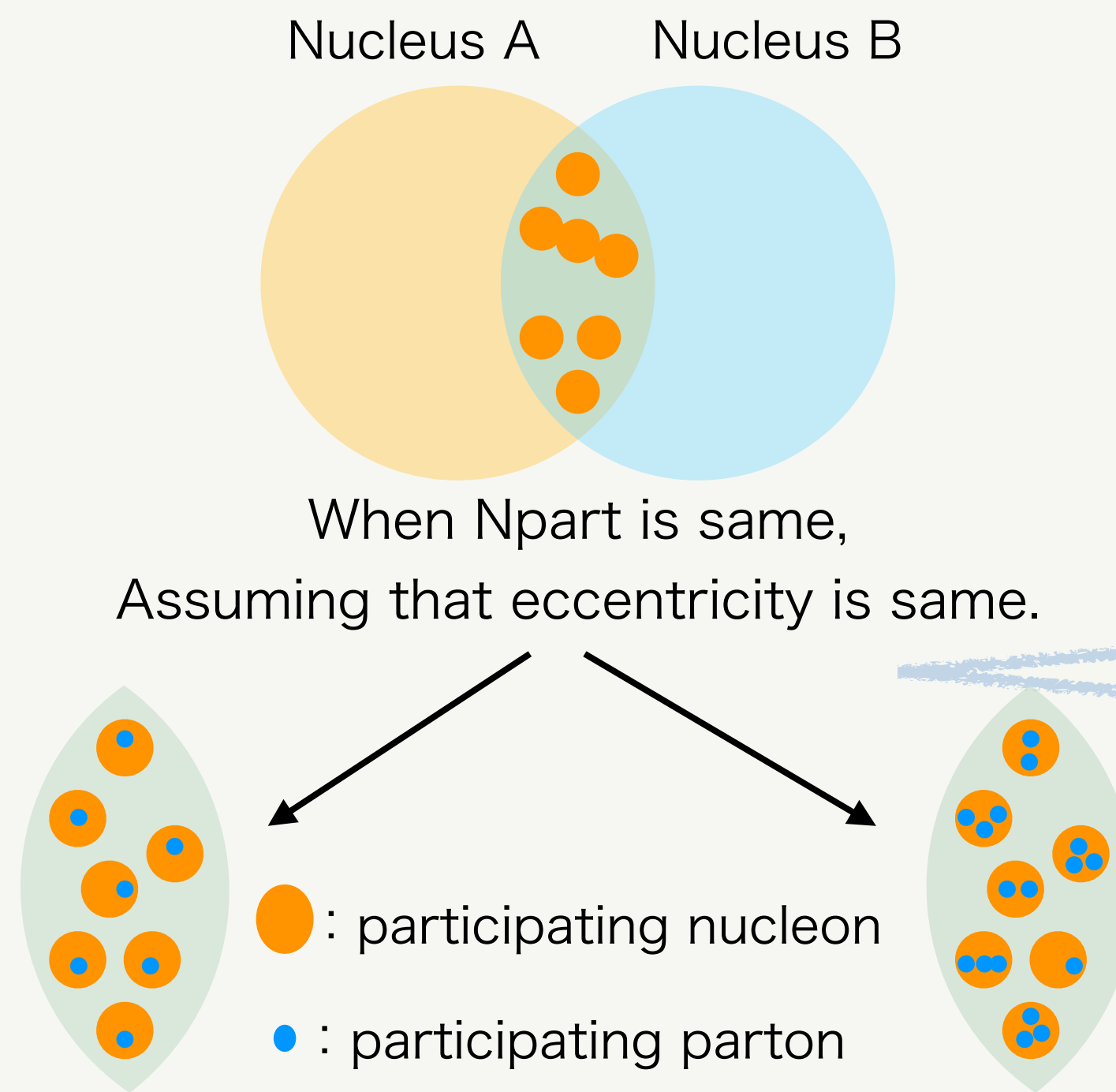


## In A+A collisions ...

✓ More interacting partons will make  $v_2$  larger at same  $N_{part}$ .

✓ Same  $N_{part}$  means same  $N_{spec}$ .

✓ At same  $N_{spec}$ , more participating partons will cause larger  $v_2$ .



$N_{part}$  is calculated by multiplicity, but  $N_{spec}$  is measured directly by ZDC.

→ to select the same  $N_{part}$  events,





# Based Idea

## In A+A collisions ...

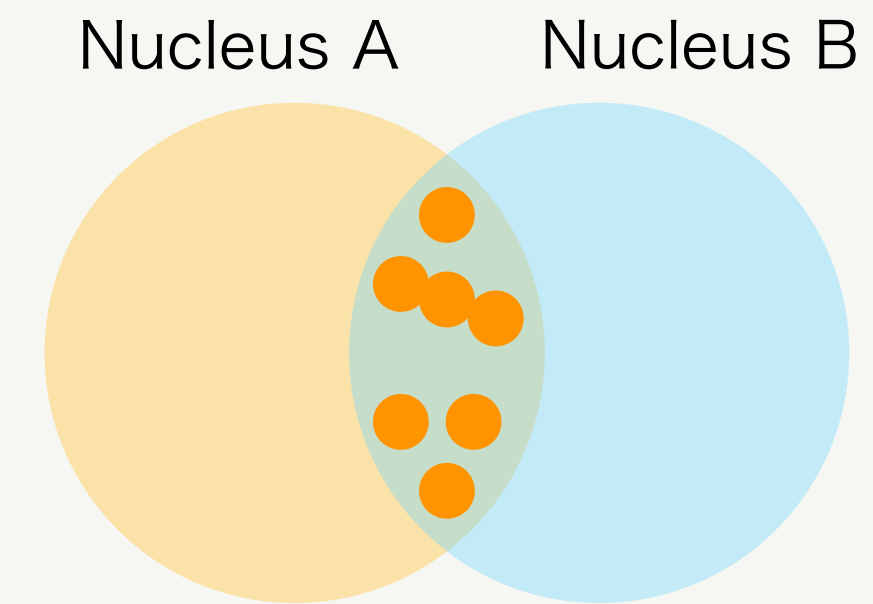
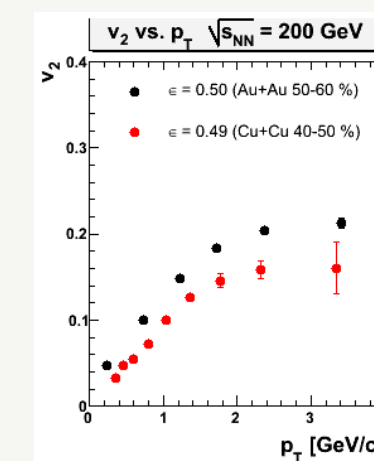
- ✓ More interacting partons will make larger multiplicity at same  $N_{part}$ .
- ✓ Same  $N_{part}$  means same  $N_{spec}$ .
- ✓ At same  $N_{spec}$ , more participating partons will cause larger  $v_2$ .

- Reason 1:

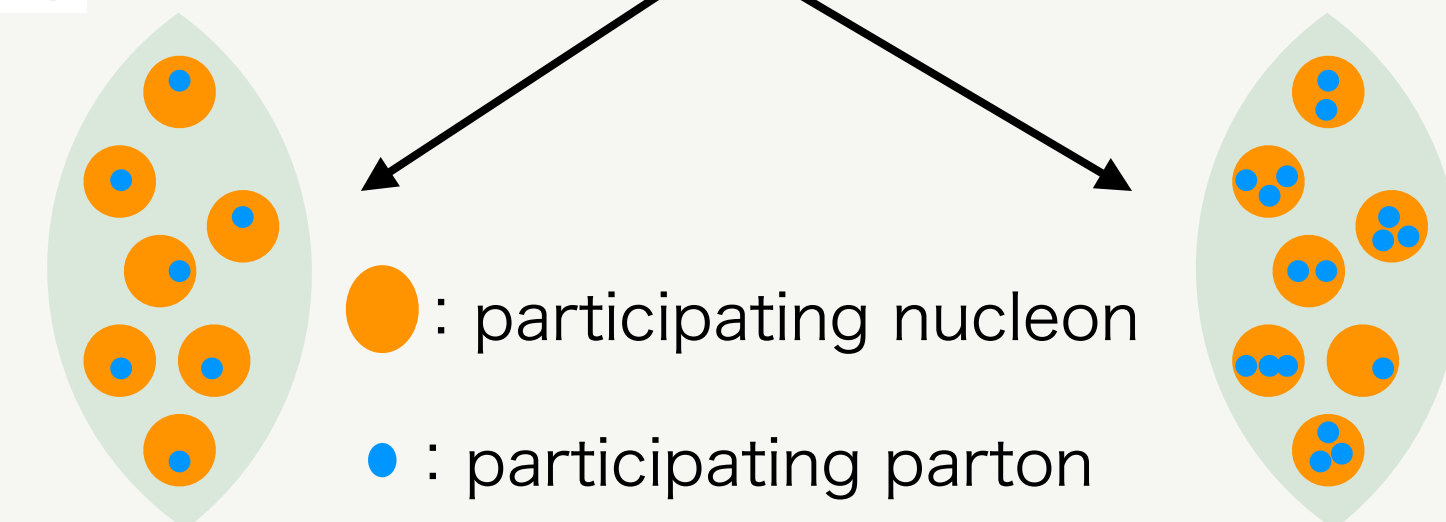
More  $N_{part}$ , larger  $v_2$  at same eccentricity

$$v_2^{Cu} < v_2^{Au} \text{ at } \epsilon_{Cu} = \epsilon_{Au} \text{ ( } N_{partCu} < 88888 \text{ )}$$

- $N_{part}$  : the number of participating nuclei
- $N_{spec}$  : the number of spectator of nuclei



When  $N_{part}$  is same,  
Assuming that eccentricity is same.



- : participating nucleon
- : participating parton

Smaller

$v_2$   
Multiplicity

Larger