Forward rapidity J/ψ azimuthal anisotropy in Au+Au collisions measured by the PHENIX experiment

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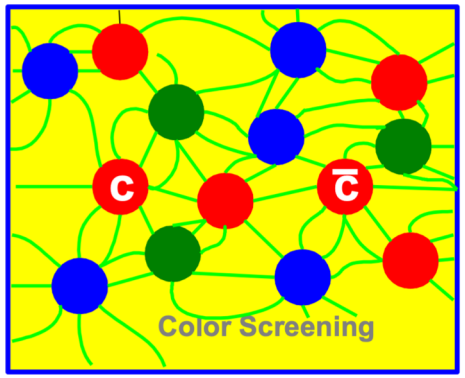
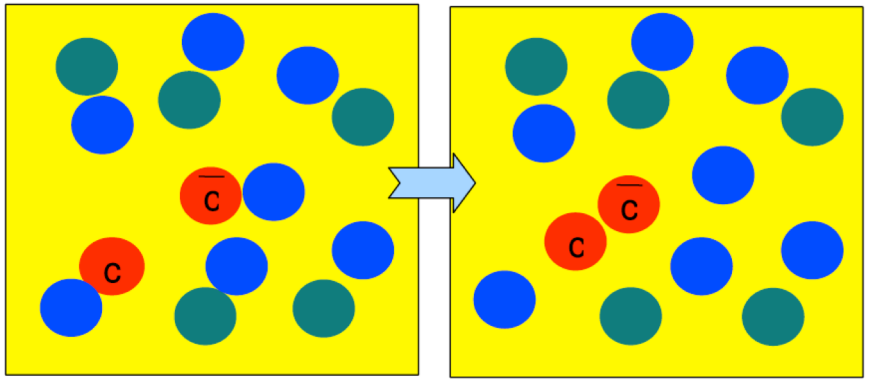
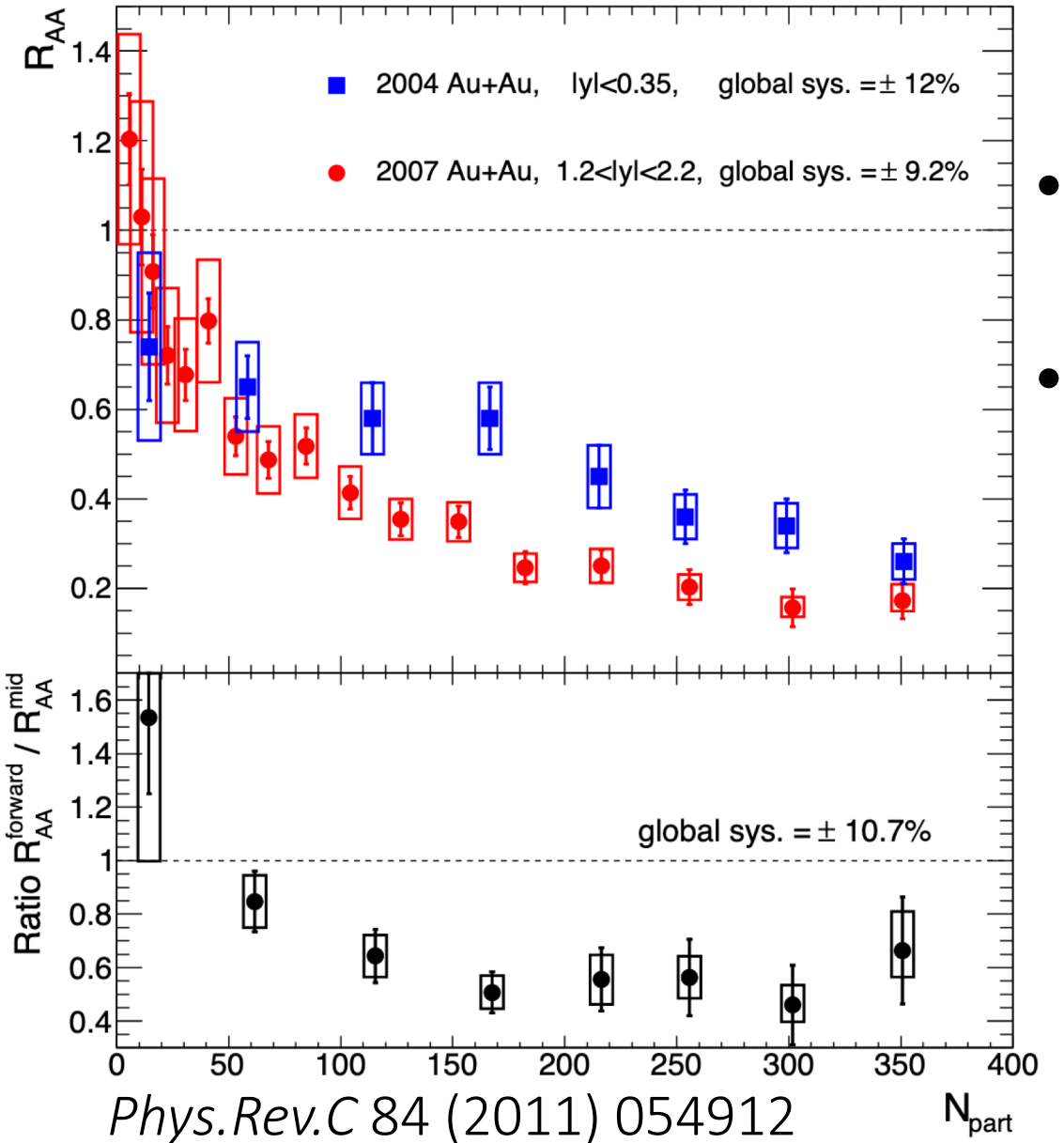
Probing the QGP using the J/ψ

- Quark Gluon Plasma is a nearly perfect fluid
- Interactions of heavy quarks are still under investigation
- Heavy quarks play a special role due to their large mass
- Open heavy flavor particles flow. Does J/ψ flow?
- Mechanisms that may generate azimuthal anisotropy of observed J/ψ:
  - Path-length dependent dissociation
  - Charm equilibration and J/ψ regeneration
  - Primordial J/ψ equilibration





The J/ψ suppression puzzle



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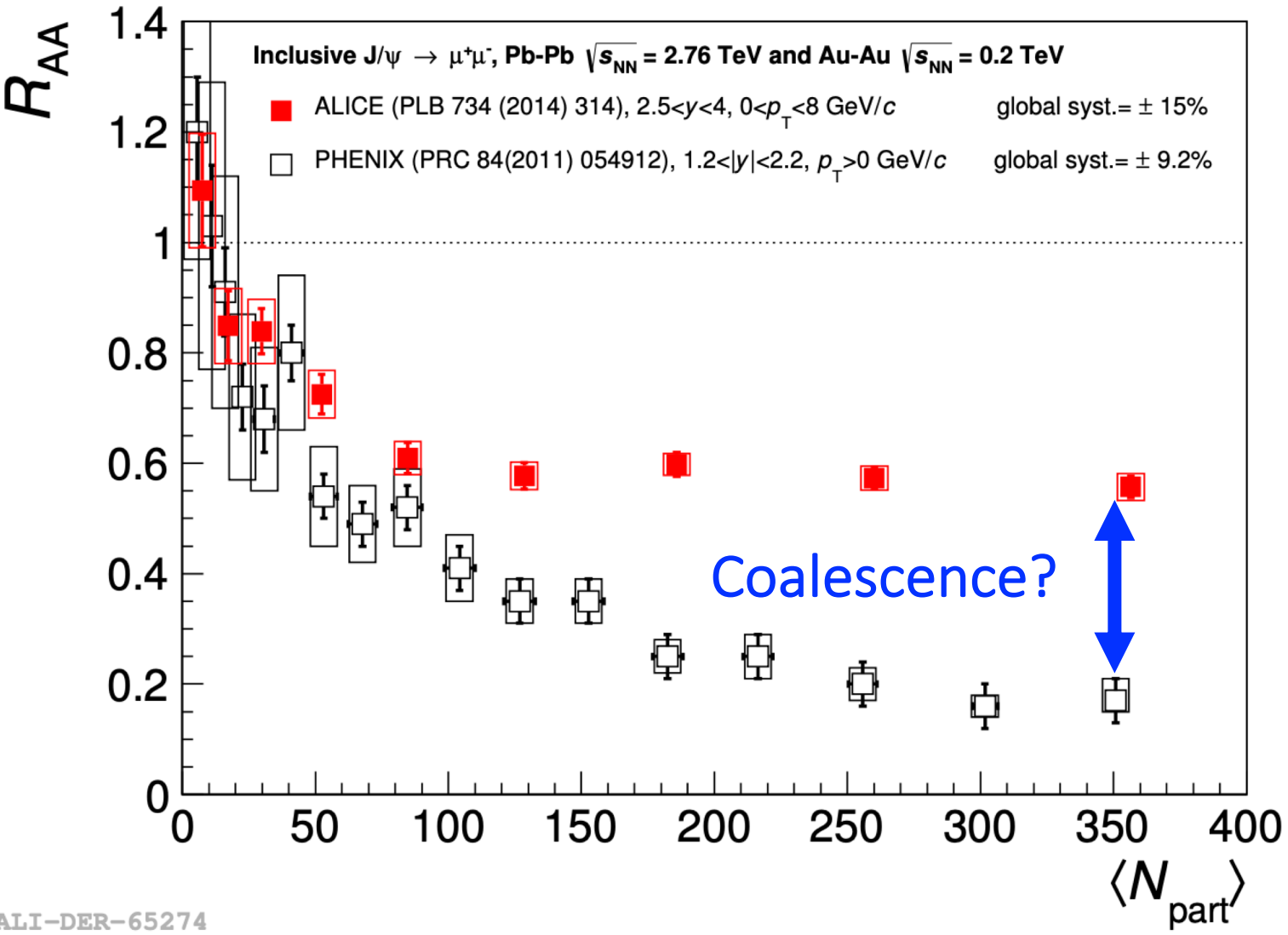
- $R_{AA}^{\mathrm{Fwd}} > R_{AA}^{\mathrm{mid}}$, contrary to expectation
- ~20 $c\bar{c}$ pairs in collisions at RHIC (mostly at mid-rapidity)

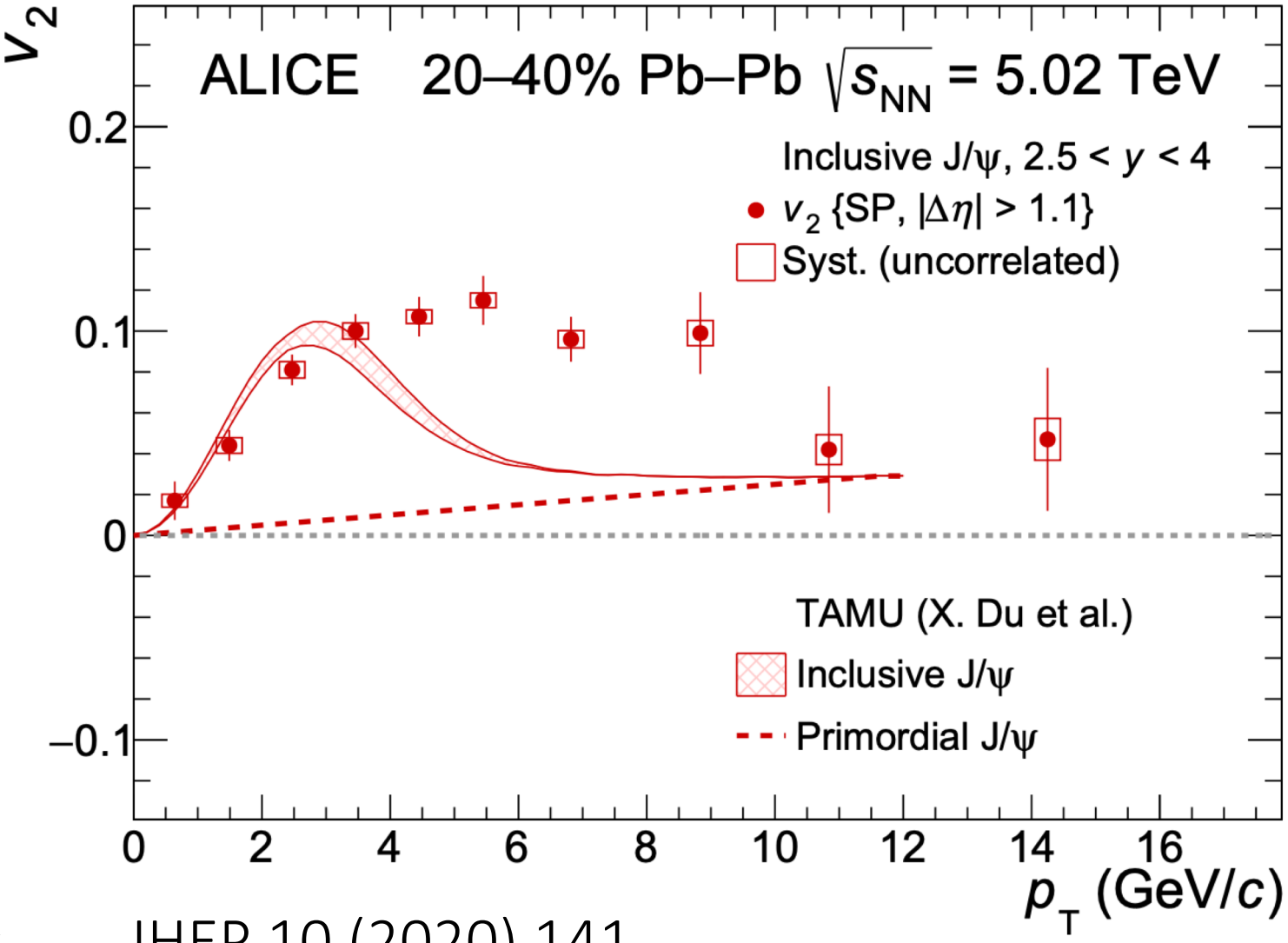
Can we attribute this significant difference in J/ψ R_{AA} to regeneration of J/ψ from $c\bar{c}$ pairs at mid-rapidity?

Coalescence as the solution



- $R_{AA}^{\mathrm{LHC}} > R_{AA}^{\mathrm{RHIC}}$
- Greater J/ψ suppression predicted at higher T
- ~200 $c\bar{c}$ pairs at LHC
- Coalescence increases R_{AA}

J/ψ v_2 at LHC energies and forward rapidity



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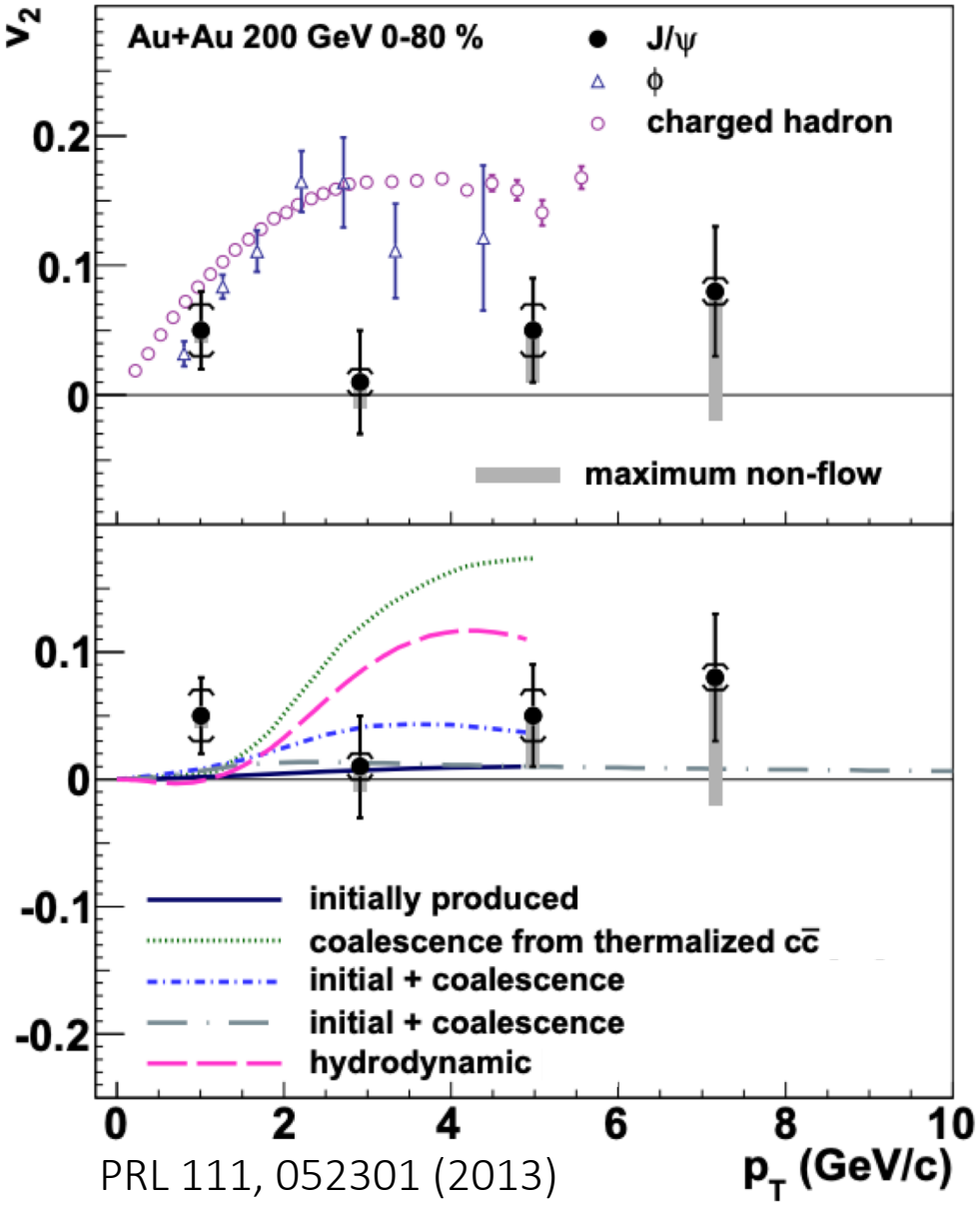
- Large J/ψ v_2 at LHC
- Coalescence model agrees below 4 GeV/c
- Primordial J/ψ model agrees only at high-p_T

J/ψ v_2 at RHIC energies and mid-rapidity



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- ϕ-mesons and charged hadrons flow
- J/ψ v_2 is significantly smaller

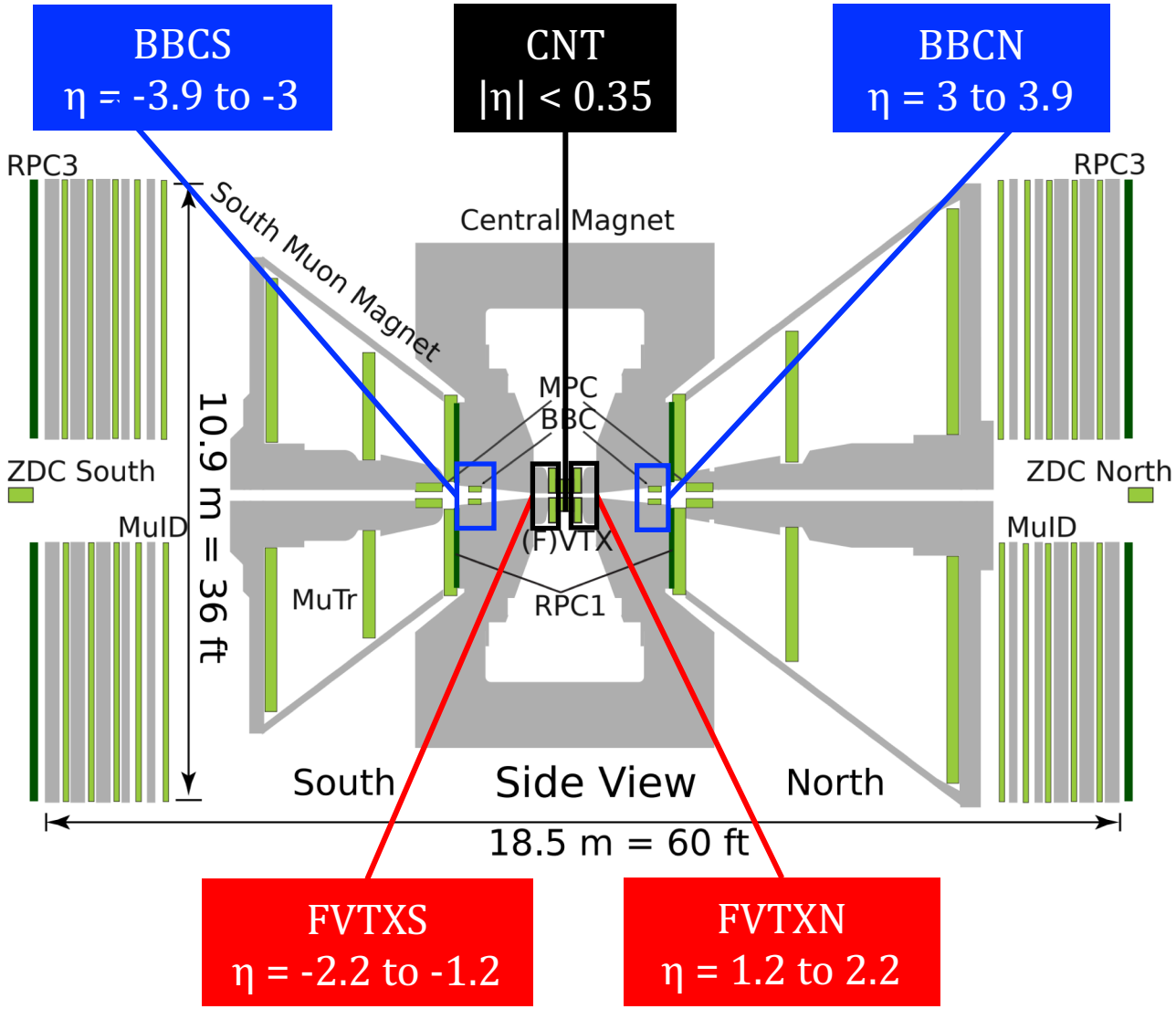
- Hydrodynamic model and coalescence from thermalized $c\bar{c}$ pairs overestimate v_2
- "Initial" models with/without coalescence are favored by the data

J/ψ v_2 is still inconclusive

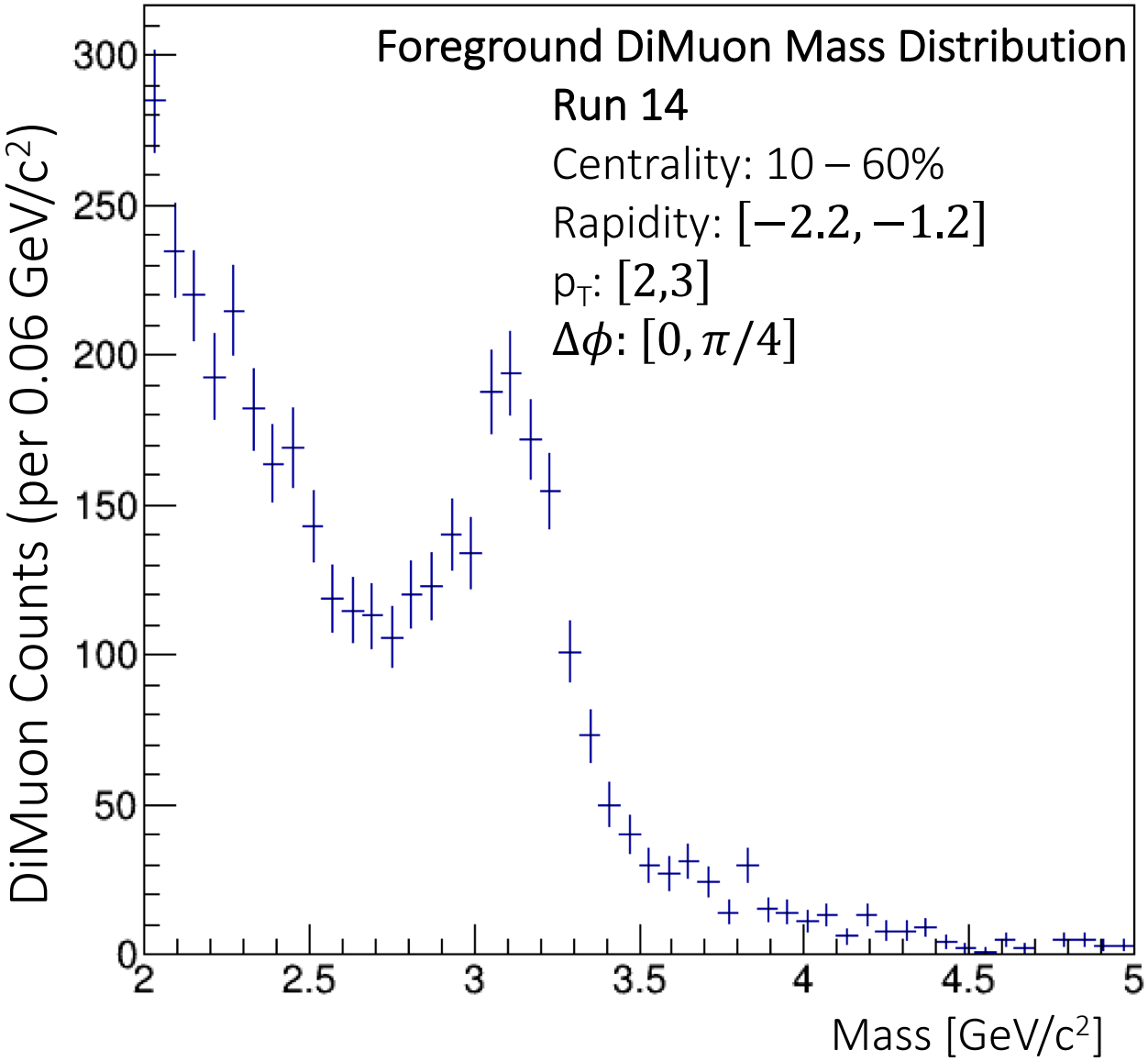
PHENIX muon dataset

- PHENIX Run14 Au+Au 200 GeV (19B events)
- Muon Arms: $J/\psi \rightarrow \mu^+ + \mu^-$
- Run16 (15B events) COMING SOON!

The combined dataset will allow for a statistically improved measurement of J/ψ elliptic flow.



J/ψ reconstruction



Combinatorial background subtraction

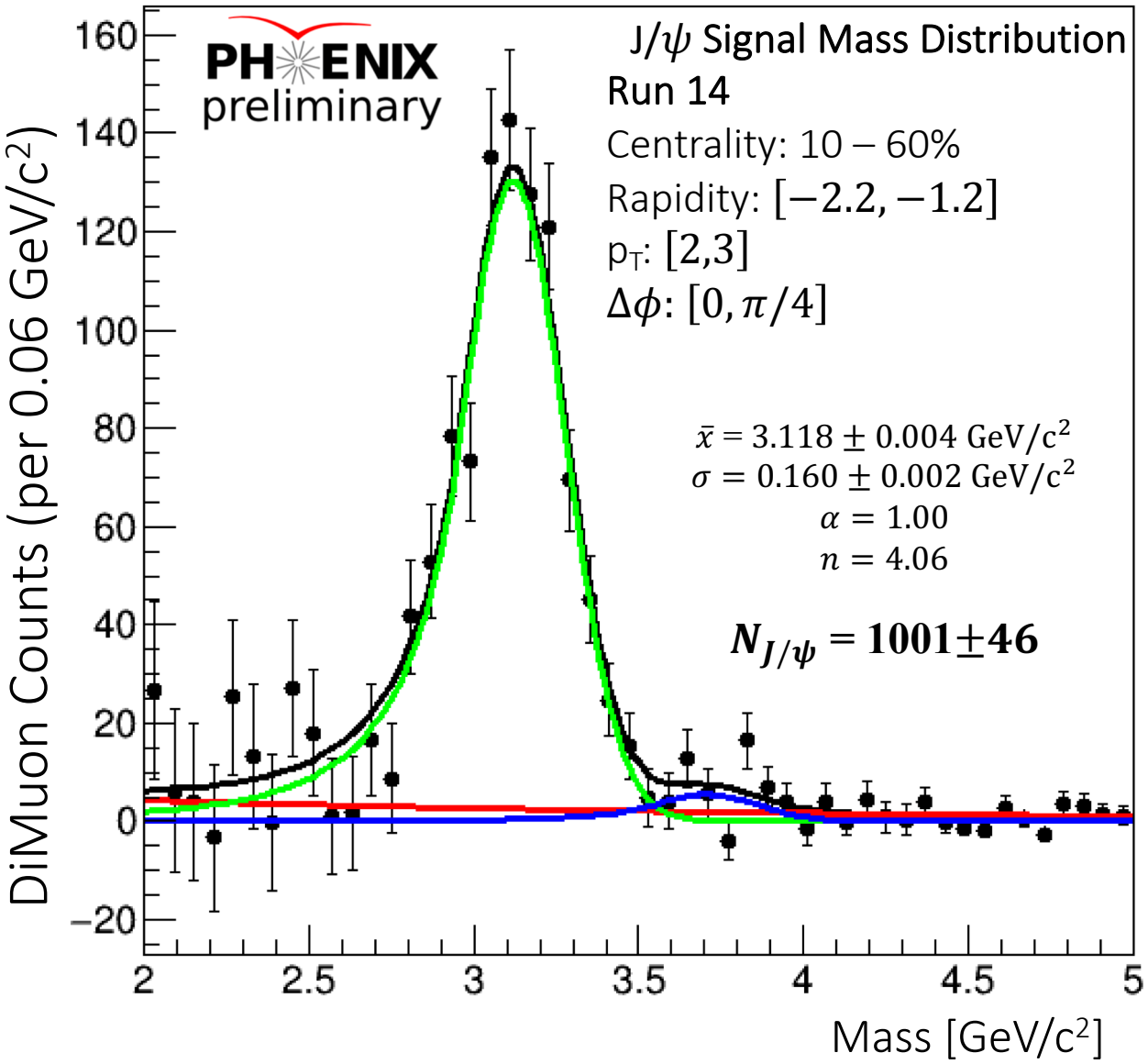
- Mixed-event subtraction:

$$S = N_{SE}^{+-} - R \cdot N_{ME}^{+-}$$

- Like-sign subtraction (Systematic):

$$S = N^{+-} - 2R\sqrt{N^{++}N^{--}}$$

J/ψ reconstruction



J/ψ simulated with PYTHIA embedded in Au+Au data

- Obtain Crystal Ball fit parameters

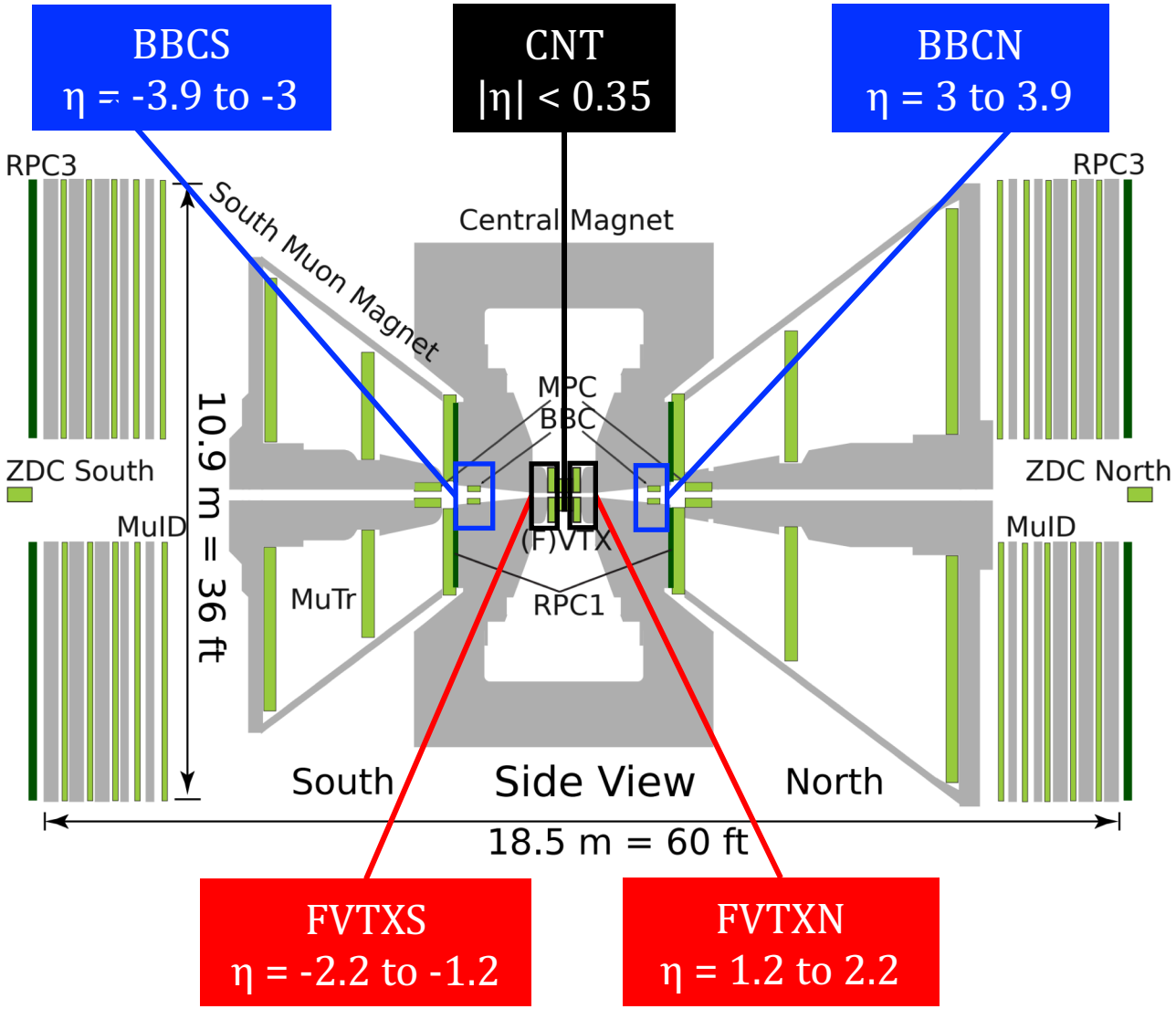
Constructing the signal and fit

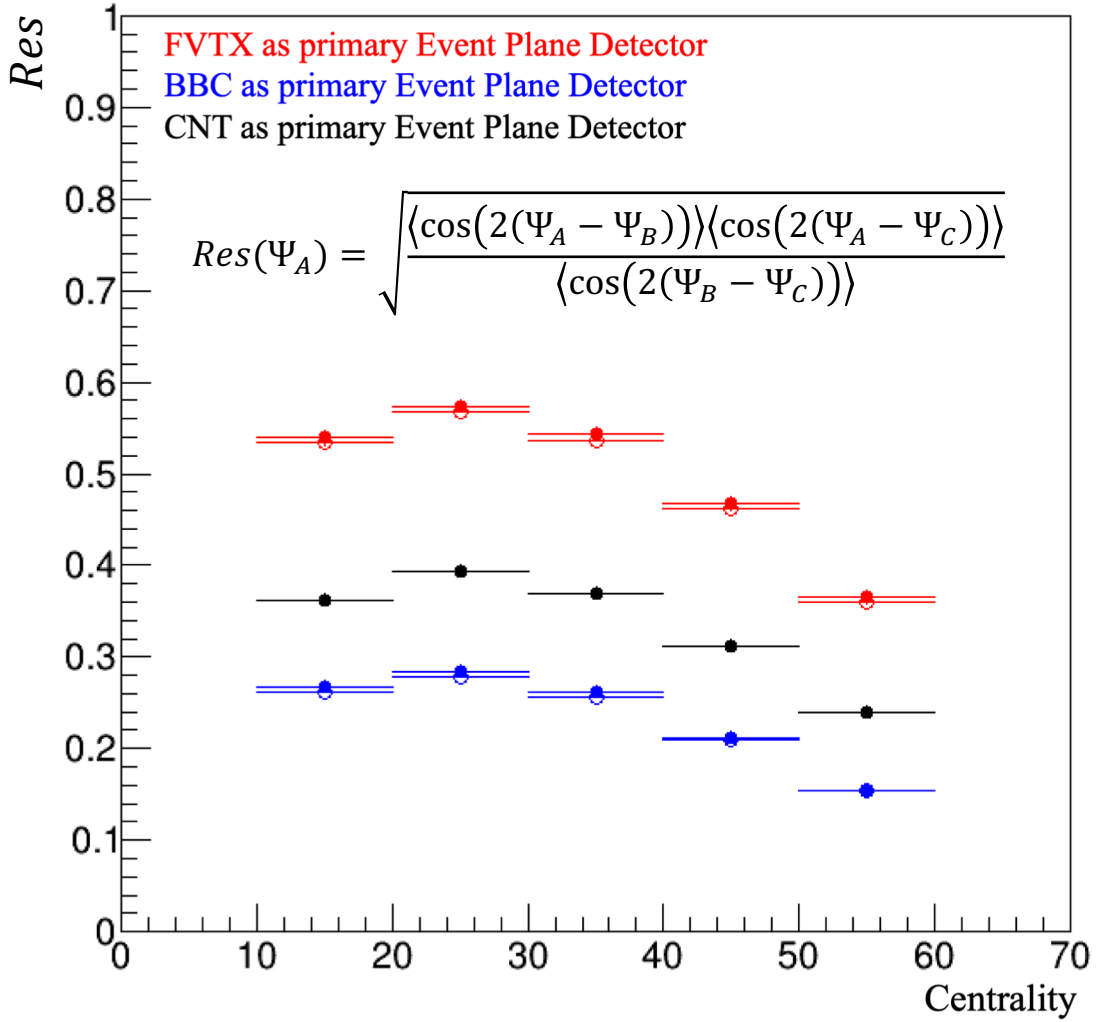
- Crystal Ball function (J/ψ)
- Crystal Ball function (ψ(2S))
- Exponential (residual background)

J/ψ count from signal

- Integral of Crystal Ball function

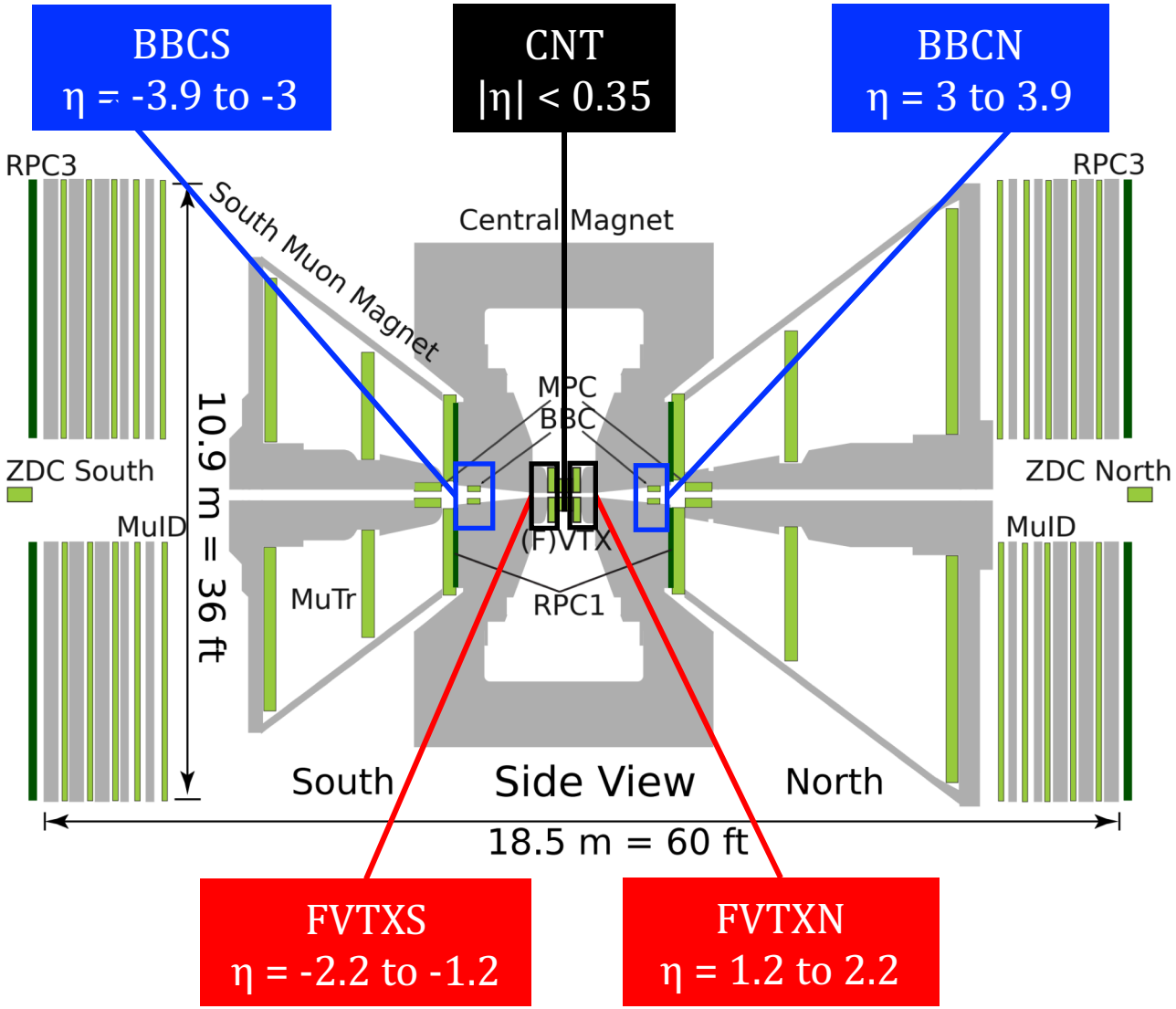
Event plane determination and resolution





Using the FVTX provides us with the best resolution for the event plane.

J/ψ v_2 measurement method



In/out ratio method (for v_2):

$$\Delta\phi = \phi - \Psi_2$$

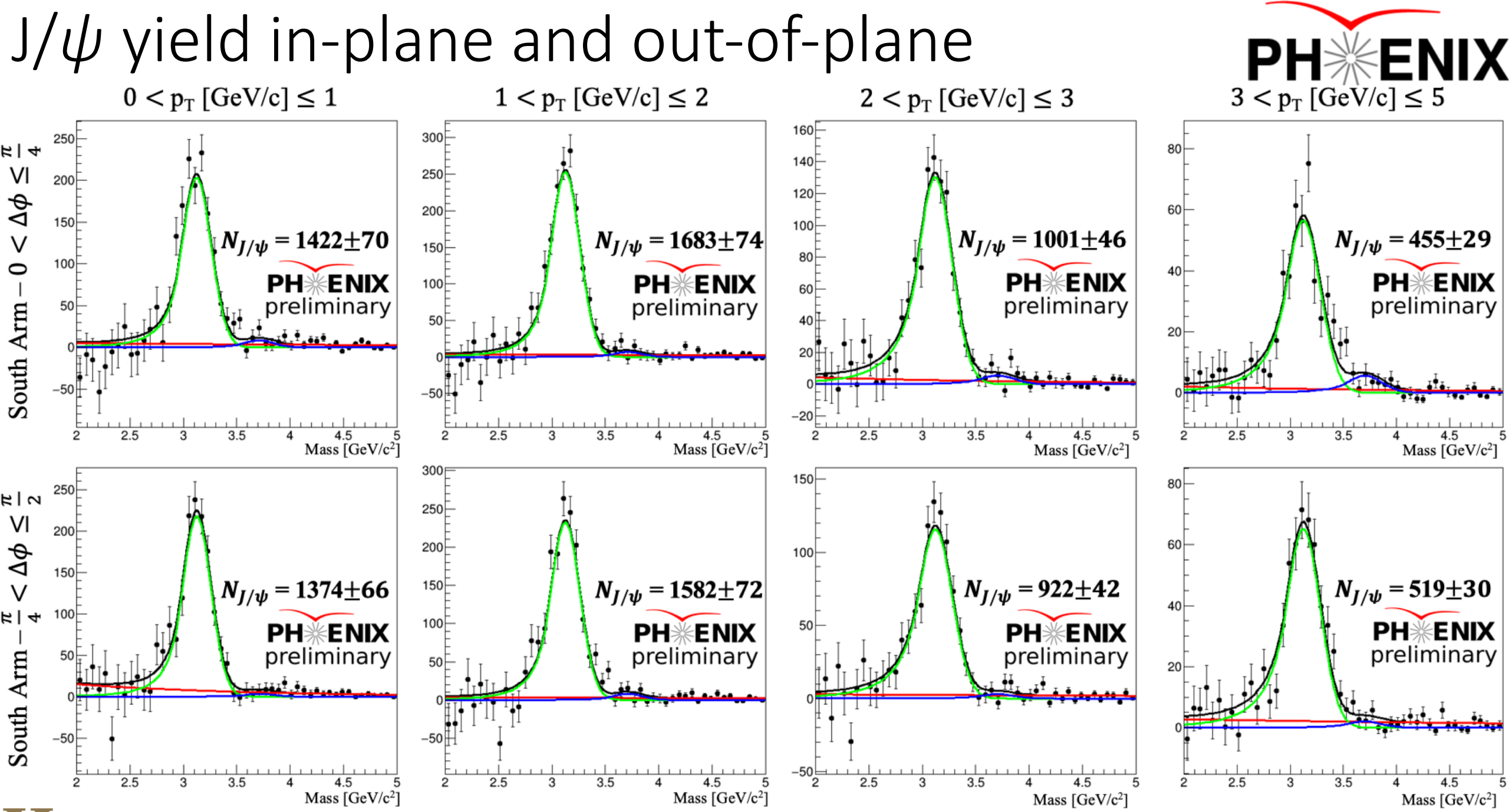
In-plane and out-of-plane counts:

$$N_{in} = \Delta\phi \in [0, \pi/4]$$
$$N_{out} = \Delta\phi \in [\pi/4, \pi/2]$$

$$v_2^{obs} = \frac{\pi}{4} \frac{N_{in} - N_{out}}{N_{in} + N_{out}}$$

$$v_2 = \frac{v_2^{obs}}{Res}$$

J/ψ yield in-plane and out-of-plane



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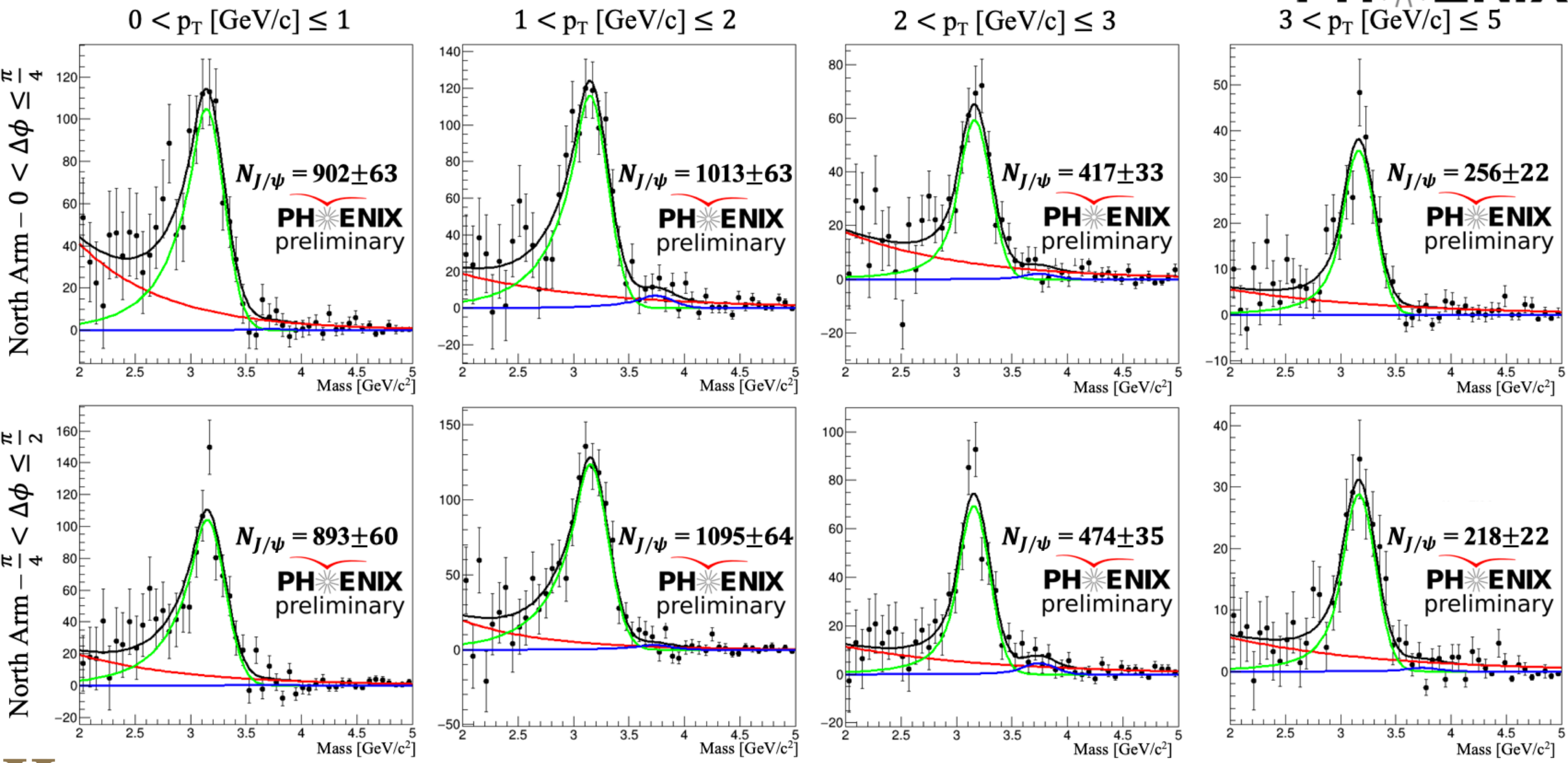
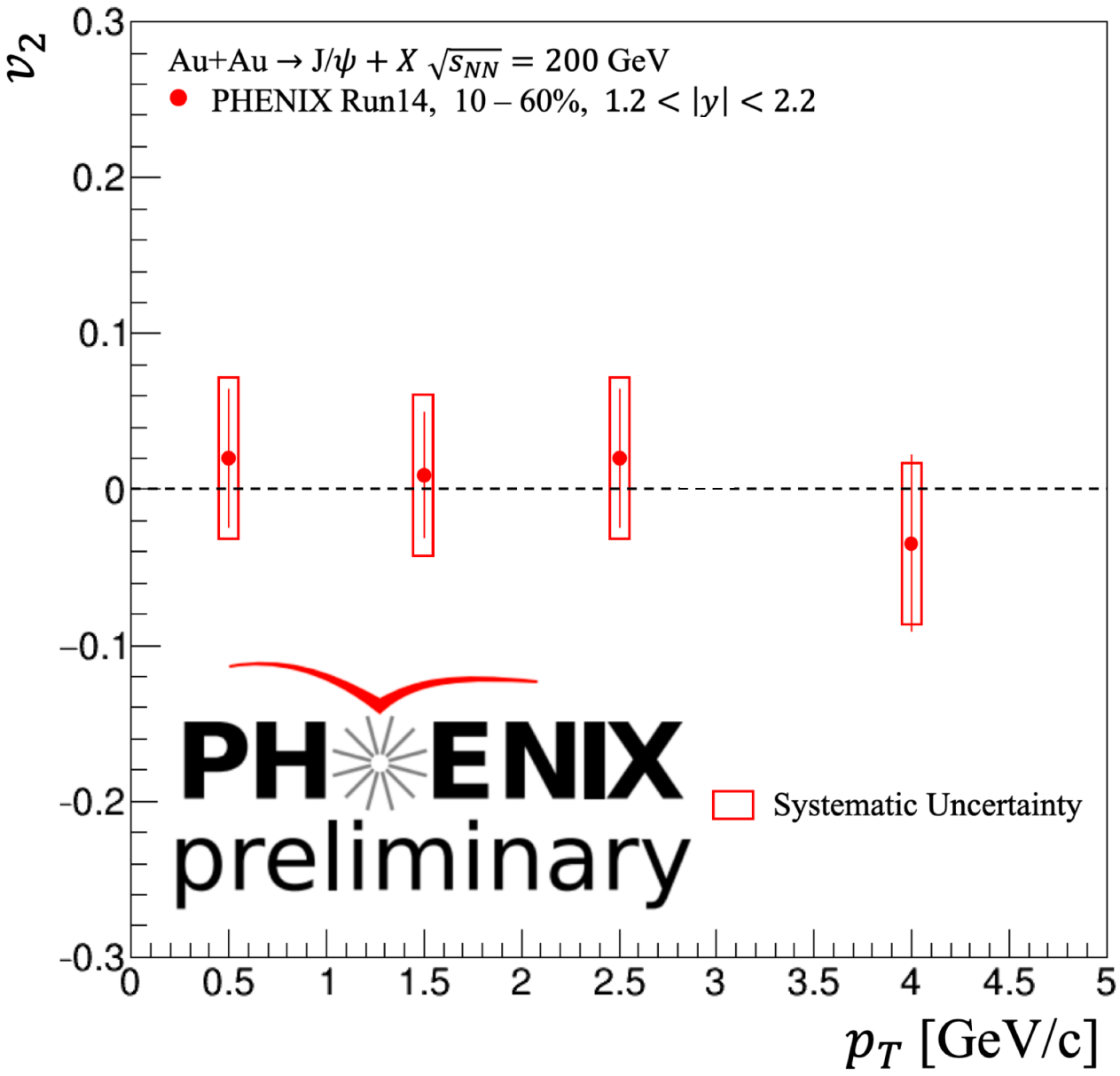
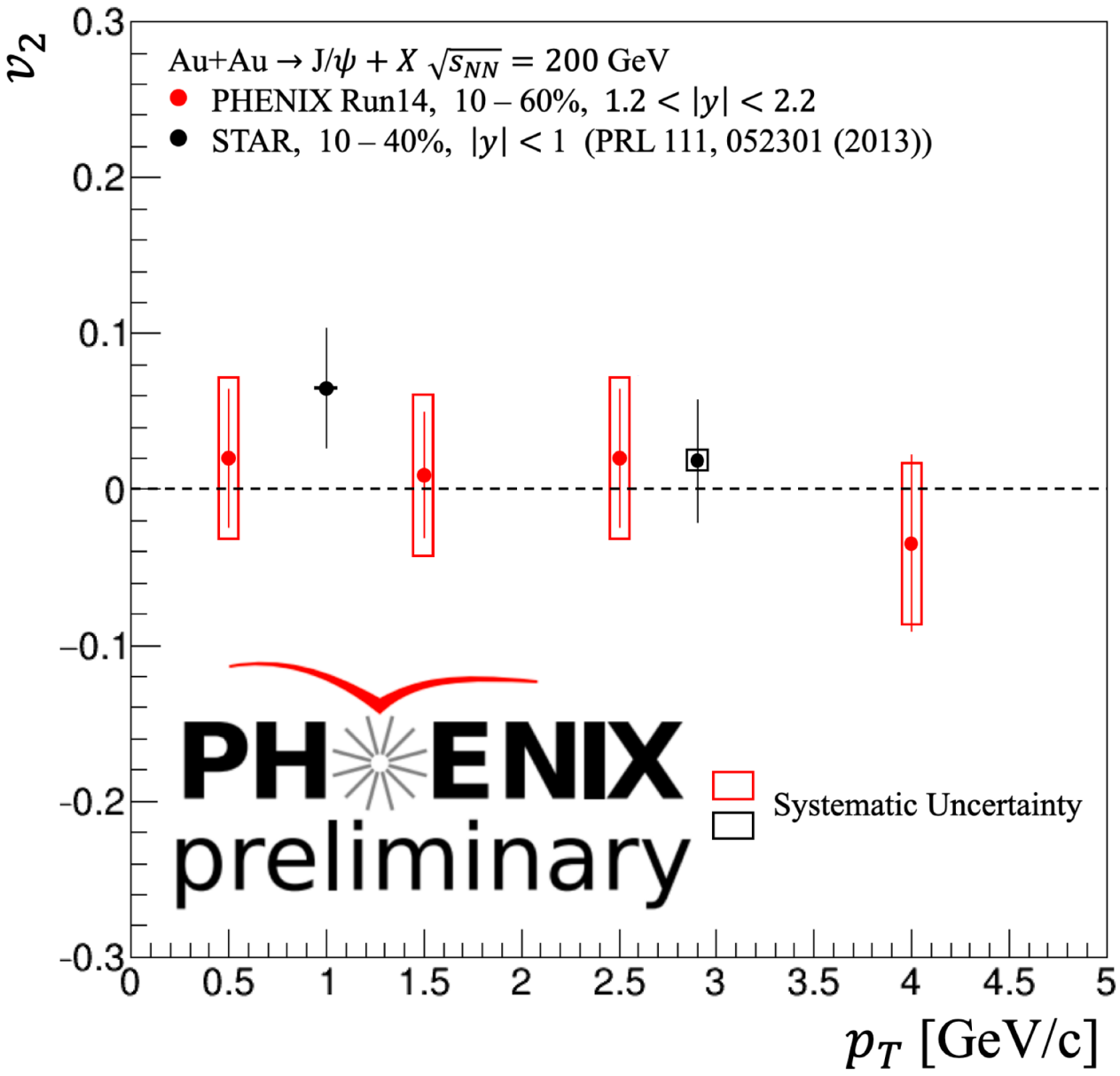


J/ψ v_2 measurement



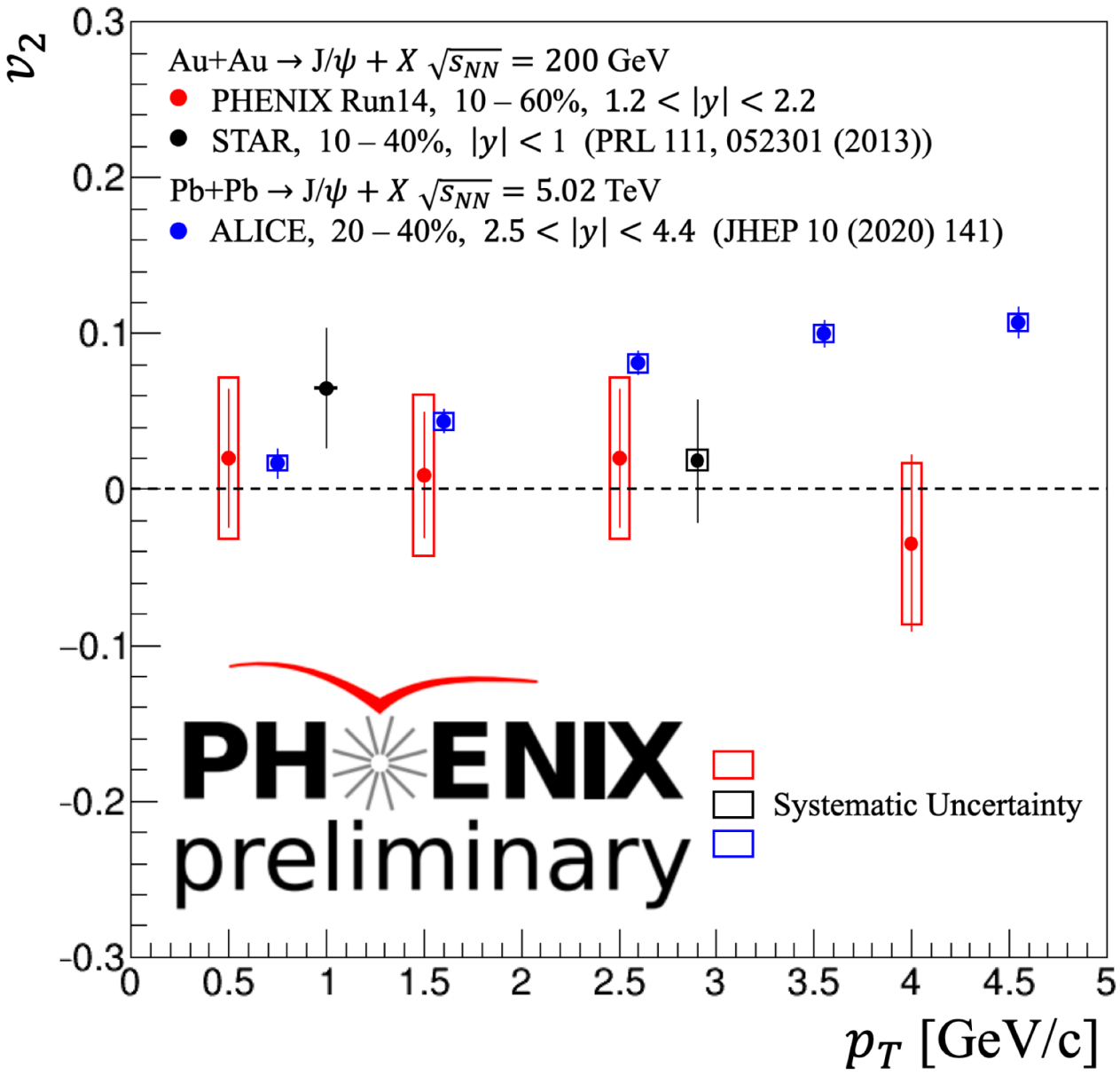
- PHENIX J/ψ v_2 at forward rapidity is consistent with zero

J/ψ v_2 measurement



- PHENIX J/ψ v_2 at forward rapidity is consistent with zero
- Forward and mid-rapidity results at RHIC are consistent, but the uncertainties are large

J/ψ v_2 measurement



- PHENIX J/ψ v_2 at forward rapidity is consistent with zero
- Forward and mid-rapidity results at RHIC are consistent, but the uncertainties are large
- The ALICE nonzero result is different from our measurement

J/ψ summary and outlook

Summary:

- **PHENIX has measured a J/ψ v_2 at 200 GeV at forward rapidity that is consistent with zero**
- The ALICE result is distinctly different than our measurement
- Forward and mid-rapidity results at RHIC are consistent, but the uncertainties are large

Outlook:

- We will improve the PHENIX measurement by reducing systematics and including the Run 16 dataset
- PHENIX will also study open heavy flavor v_2 providing a complete picture of heavy-flavor dynamics at RHIC