

STAR overview

Prithwish Tribedy for the STAR collaboration (Brookhaven National Laboratory)



IS2021

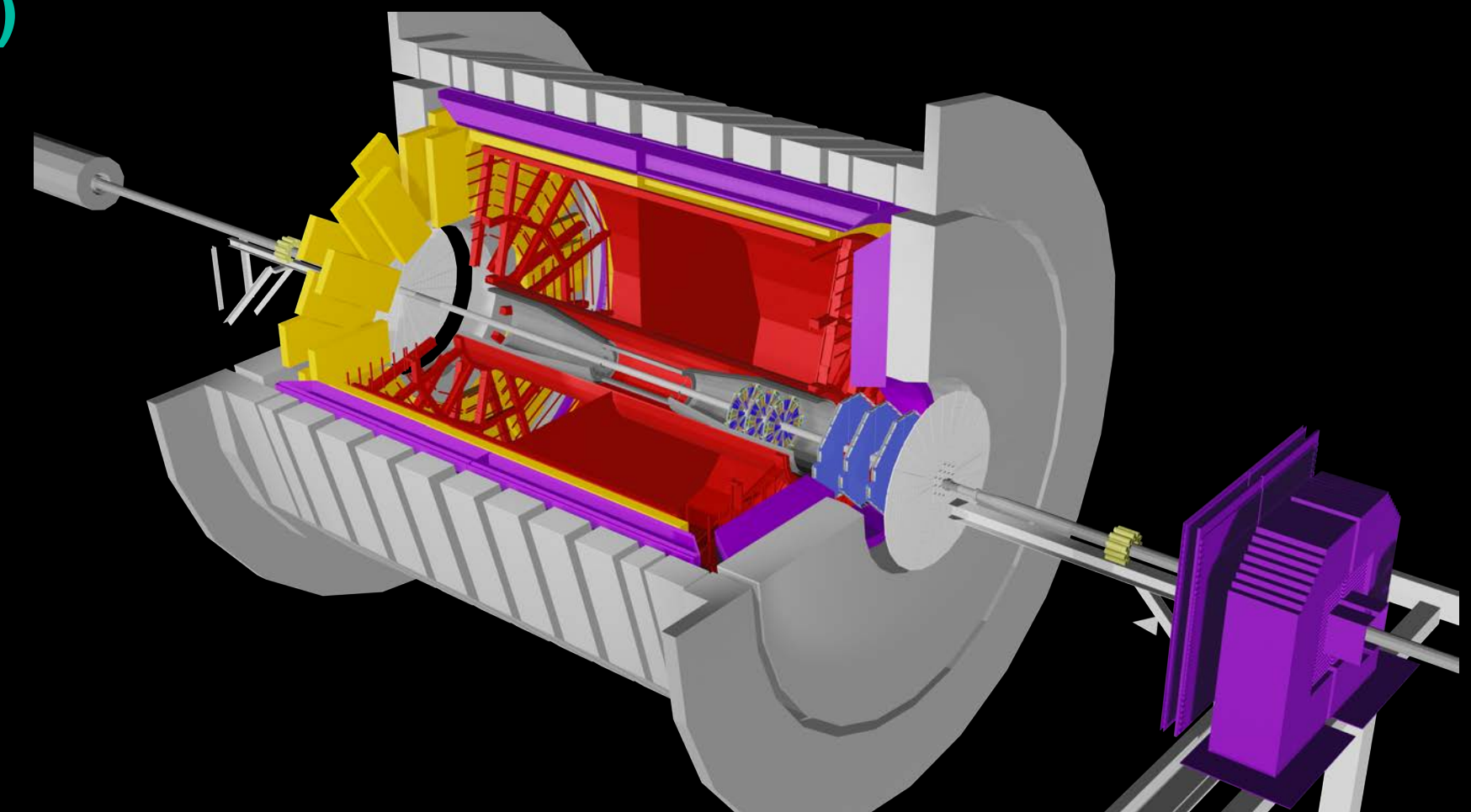
The VIth International Conference on the
INITIAL STAGES
OF HIGH-ENERGY NUCLEAR
COLLISIONS



Outline



- Small systems:
 - Forward di-hadron correlations **Talk by Xiaoxuan Chu (Tue 18:40)**
 - Collectivity in $^3\text{He}+\text{Au}$, $\text{d}+\text{Au}$ and $\text{p}+\text{Au}$ **Talk by Shengli Huang (Tue 18:40)**
- Initial Stages of A+A:
 - Effect of deformation on $v_n - \langle p_T \rangle$ correlations and $\langle p_T \rangle$ fluctuations **Talk by Jiangyong Jia (Thu 16:35)**
 - Longitudinal de-correlations, (anti)-particle v_3 , elliptic flow at high p_T **Talk by Maria Stefaniak (Tue 18:40)**
- Ultra-peripheral collisions and strong field effects:
 - Photoproduction of J/ψ in $\text{d}+\text{Au}$ collisions **Talk by Xiaofeng Wang (Wed 18:45)**
 - Photoproduction of low p_T di-electron in UPC & peripheral A+A **Talk by Xiaofeng Wang (Wed 18:45)**
 - Probing nuclei with linearly polarized photons **Talk by Daniel Brandenburg (Wed 19:25)**
 - Search for the Chiral Magnetic Effect **Talk by Jie Zhao (Thu 15:55)**
- Forward upgrade and STAR beyond 2021+ **Talk by Ting Lin (Thu 16:35)**



Small Systems

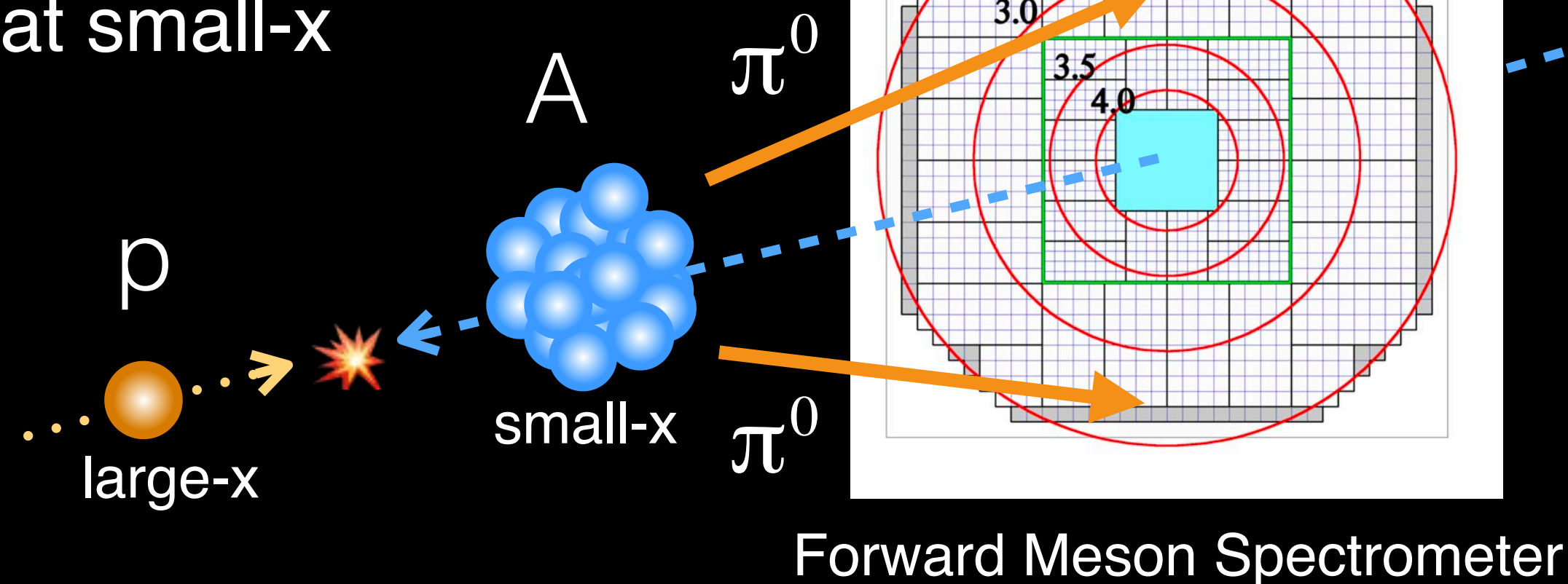
- Forward di-hadron correlations
- Collectivity in $^3\text{He}+\text{Au}$, $\text{d}+\text{Au}$ and $\text{p}+\text{Au}$

Forward di-hadron correlations in p+A collisions

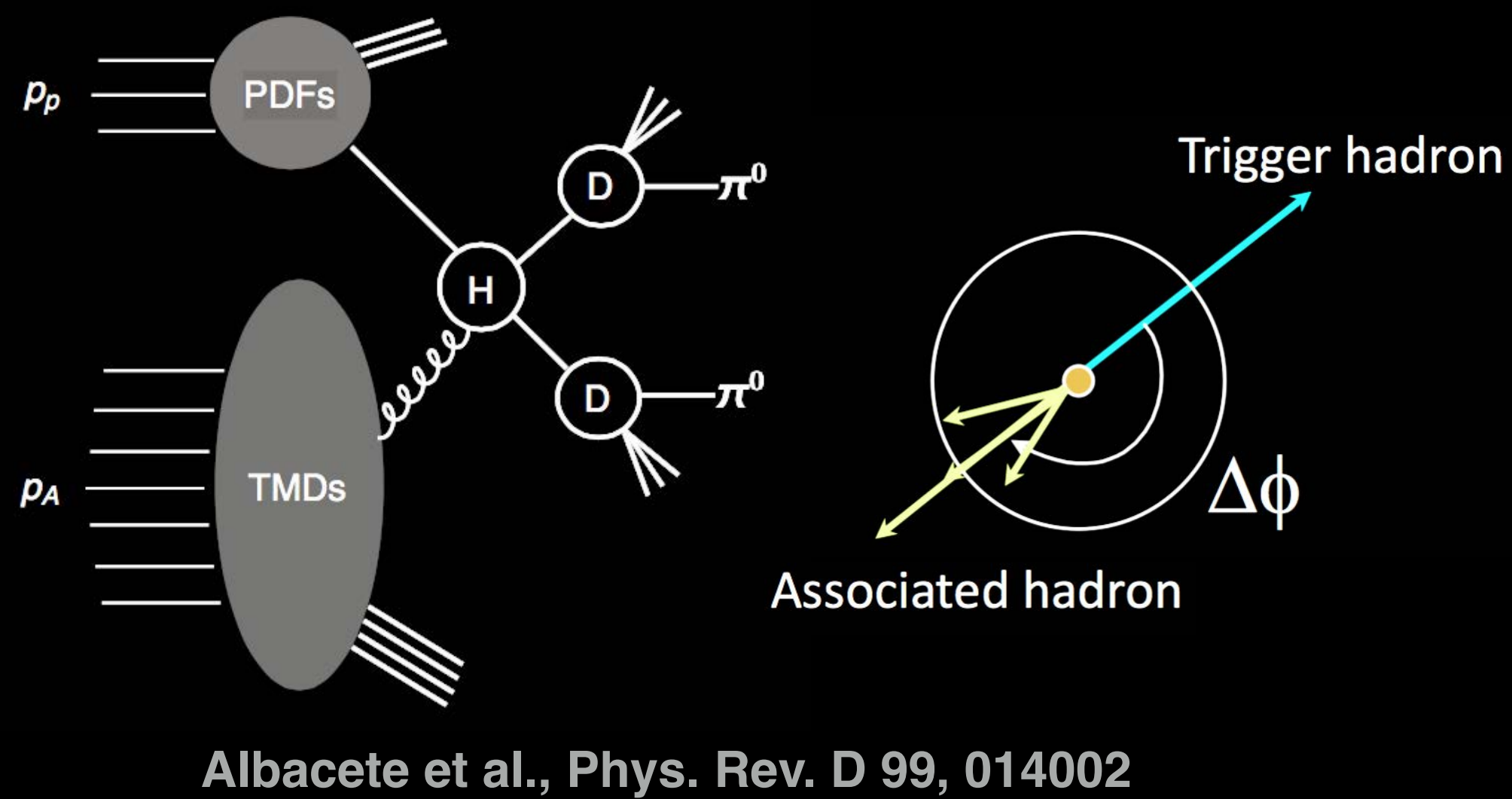
Talk by Xiaoxuan Chu
(Tue 18:40)



Kinematics probe
gluons inside nuclei
at small-x



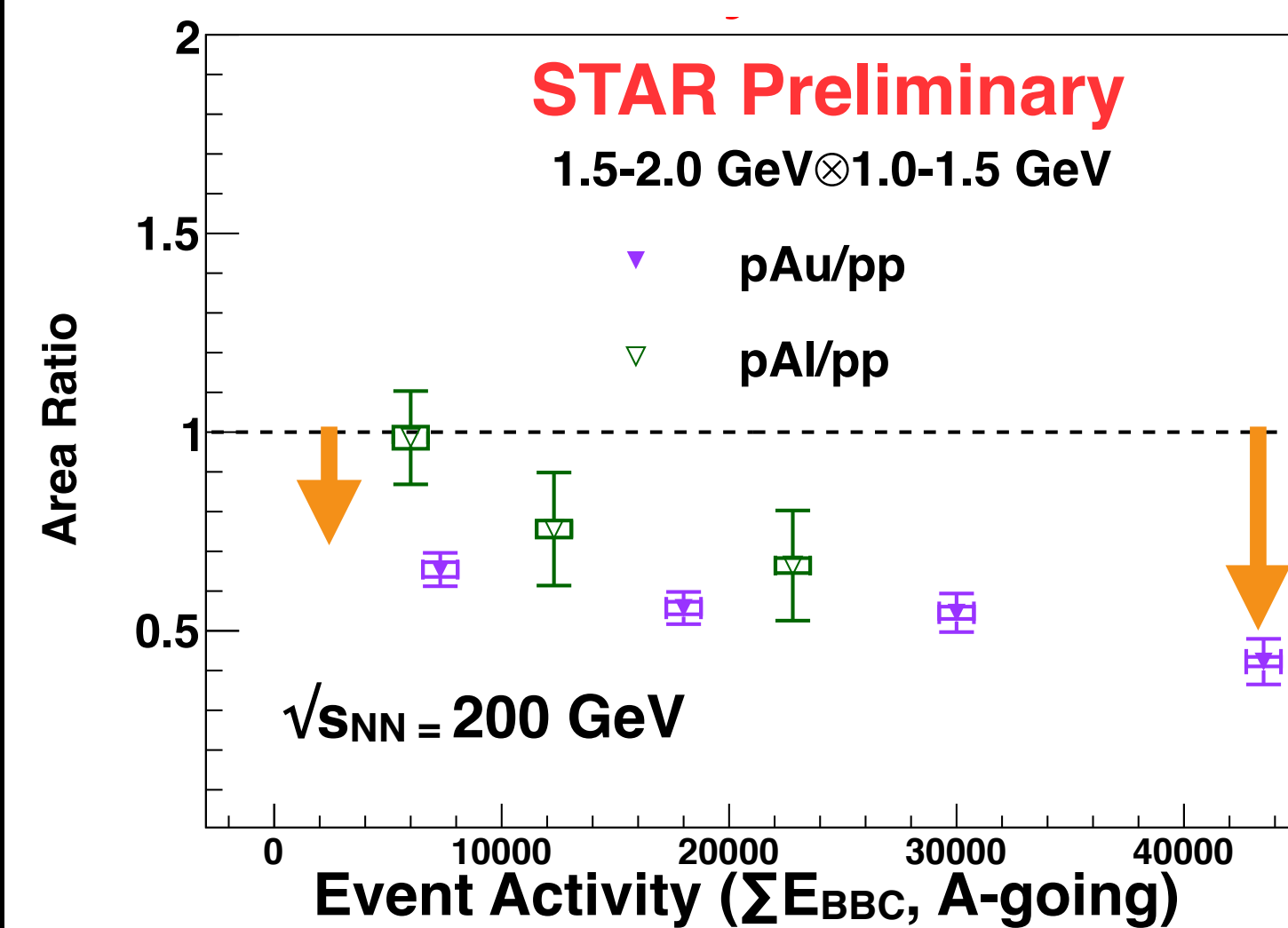
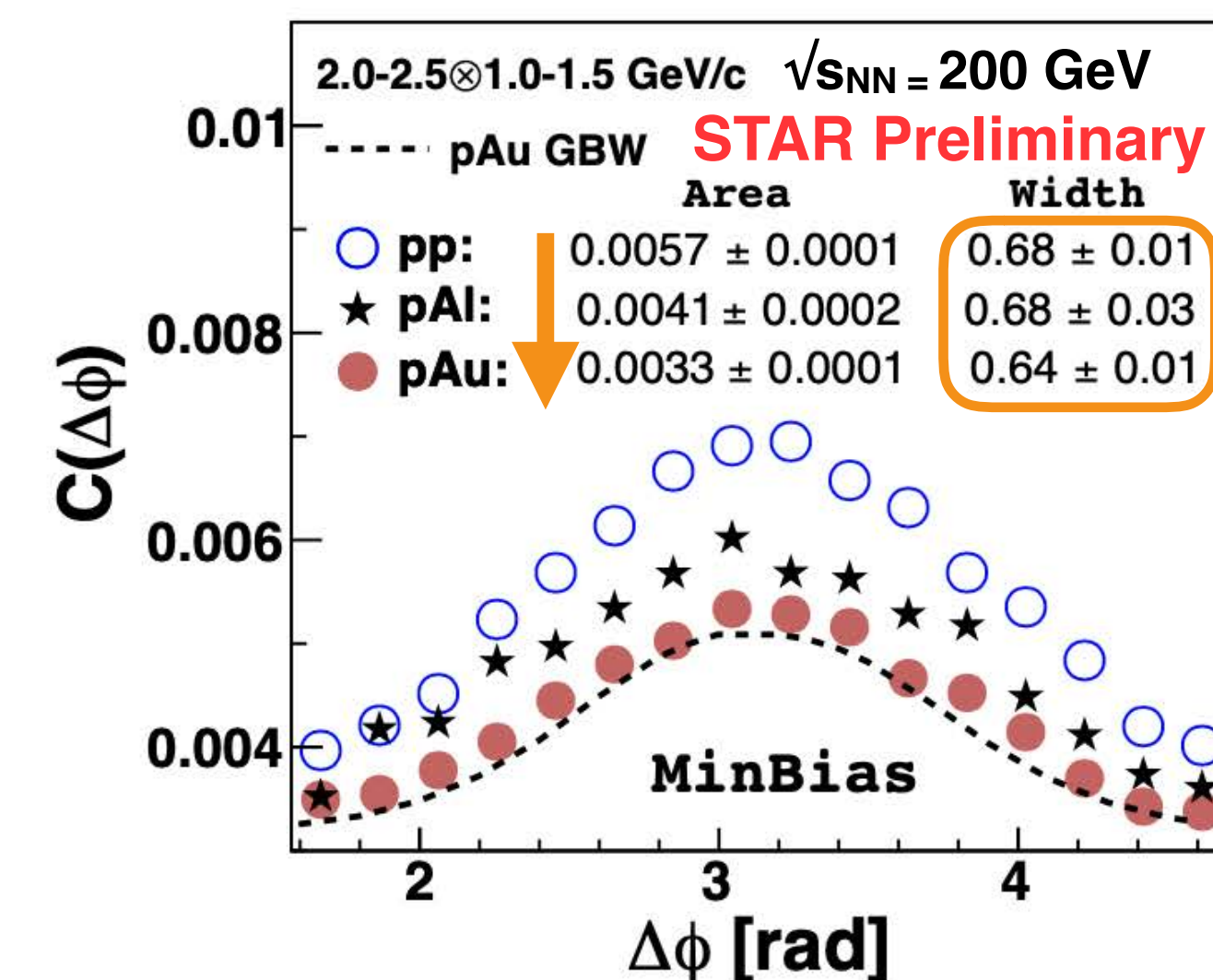
$$C(\Delta\phi) = \frac{N_{pair}(\Delta\phi)}{N_{trig} \times \Delta\phi}$$



Area of $C(\Delta\phi)$:
 $p+p > p+Al > p+Au$

Width of $C(\Delta\phi)$:
 $p+p \sim p+Al \sim p+Au$

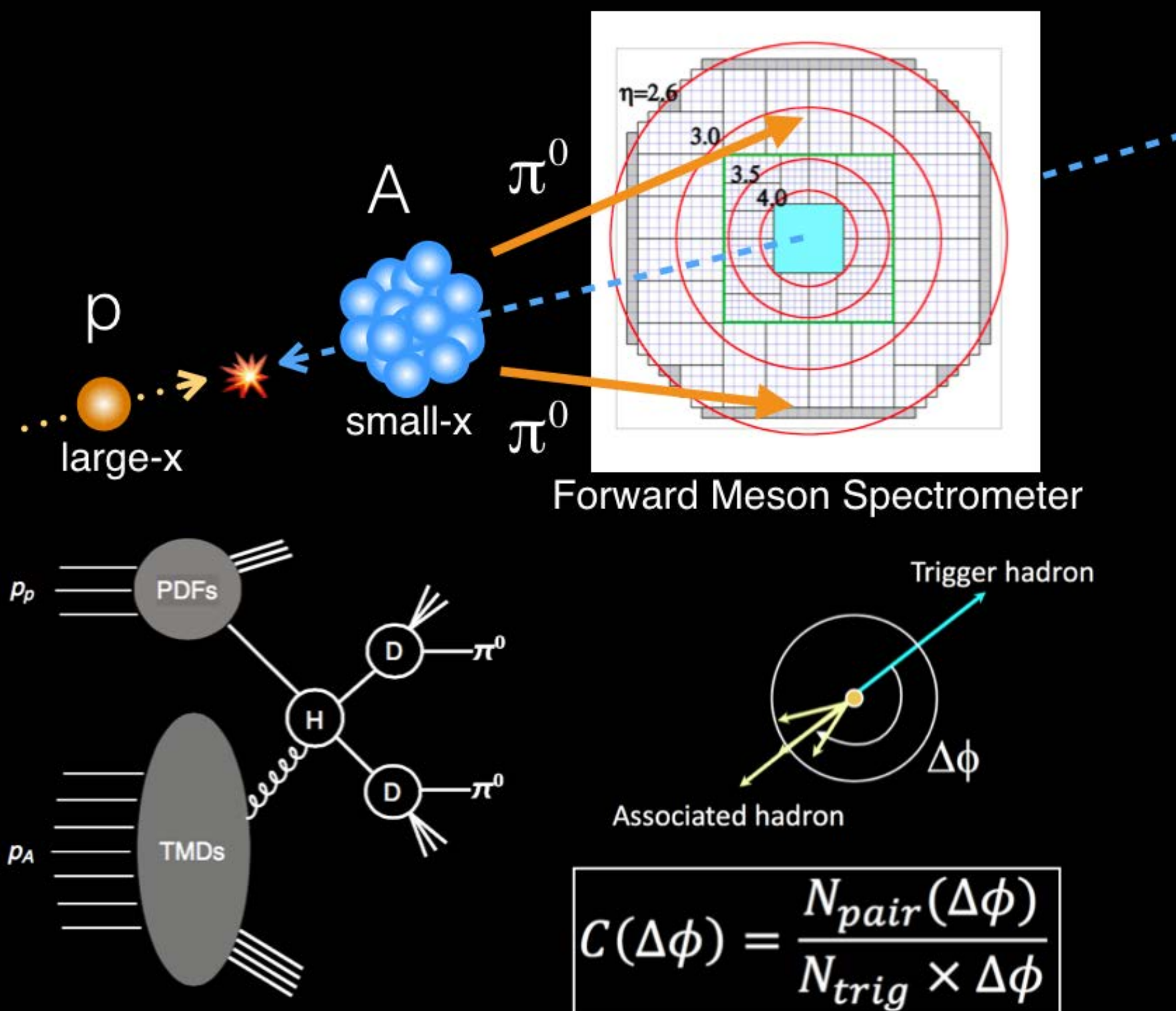
GBW model:
Stasto et al., Phys. Lett. B,
716(2012) 430-434



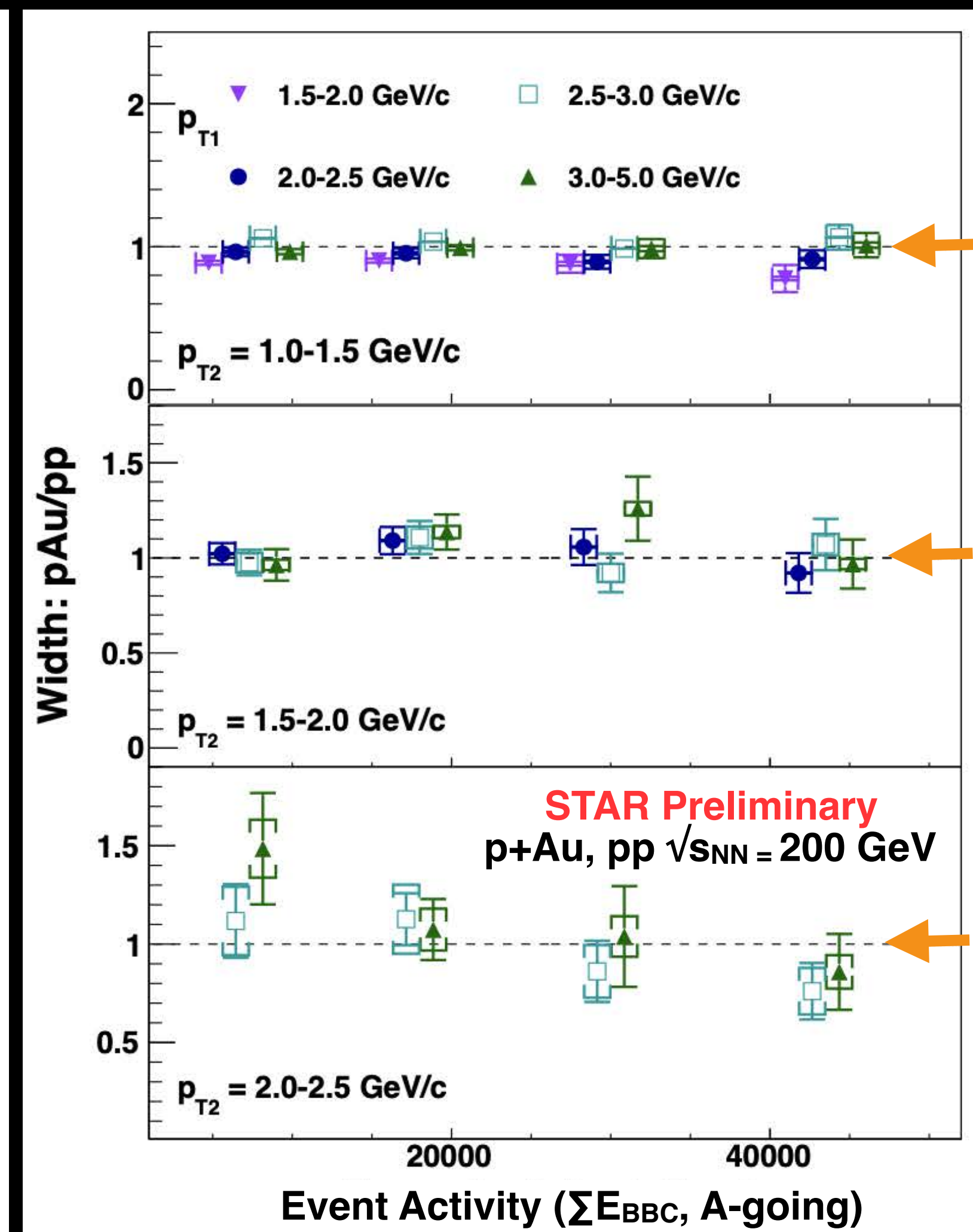
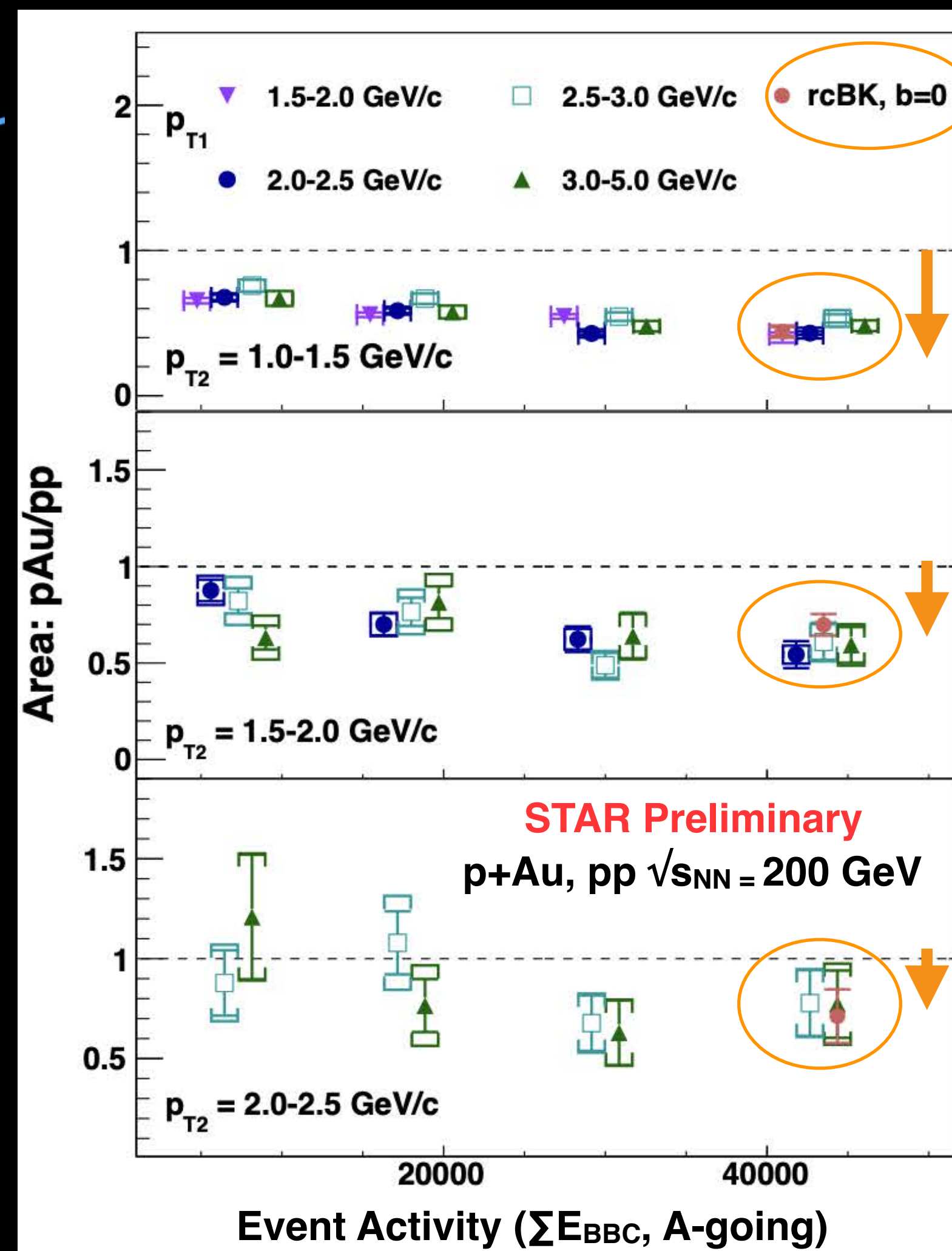
Suppression of back-to-back π^0 pairs in p+A relative to p+p increases with A & event activity

Forward di-hadron correlations in p+A collisions

Talk by Xiaoxuan Chu
(Tue 18:40)



$$C(\Delta\phi) = \frac{N_{pair}(\Delta\phi)}{N_{trig} \times \Delta\phi}$$



More significant suppression of area at lower p_T and no modification of width
Saturation frameworks correctly predict the systematics of area suppression in p+A

Collectivity in small collision systems

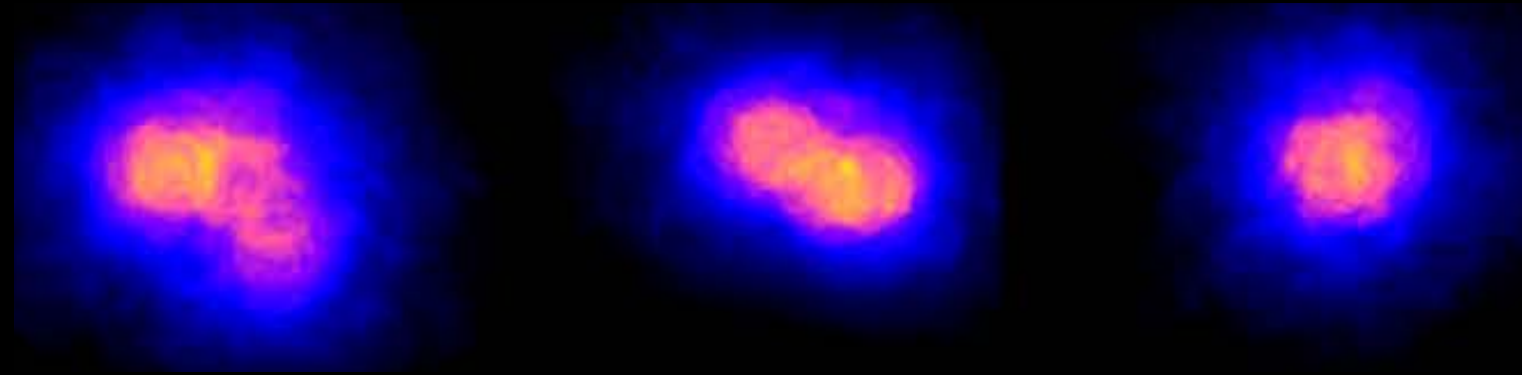
Talk by Shengli Huang
(Tue 18:40)



$^3\text{He}+\text{Au}$

$\text{d}+\text{Au}$

$\text{p}+\text{Au}$

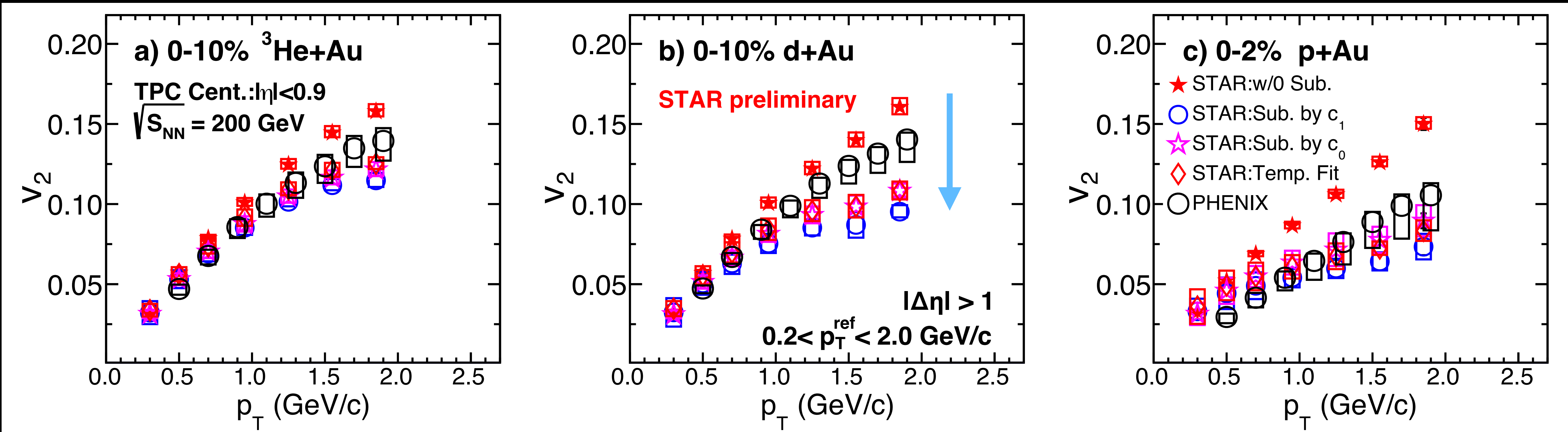


$$Y(\Delta\phi)^{\text{template}}(\text{sys}) = F \times Y(\Delta\phi)(pp) + Y(\Delta\phi)^{\text{ridge}}(\text{sys})$$

$$c_n^{\text{sub}}(\text{sys}) = c_n^{\text{raw}}(\text{sys}) - c_n(pp) \frac{N_{ch}(pp)}{N_{ch}(\text{sys})}$$

$$c_n^{\text{sub}}(\text{sys}) = c_n^{\text{raw}}(\text{sys}) - c_n(pp) \frac{c_1(pp)}{c_1(\text{sys})}$$

Consistent results using different methods
of non-flow subtraction that decreases v_2



$v_2(^3\text{He}+\text{Au}) \sim v_2(\text{d}+\text{Au}) > v_2(\text{p}+\text{Au})$, ordering consistent with PHENIX results, role of final state is established

Collectivity in small collision systems

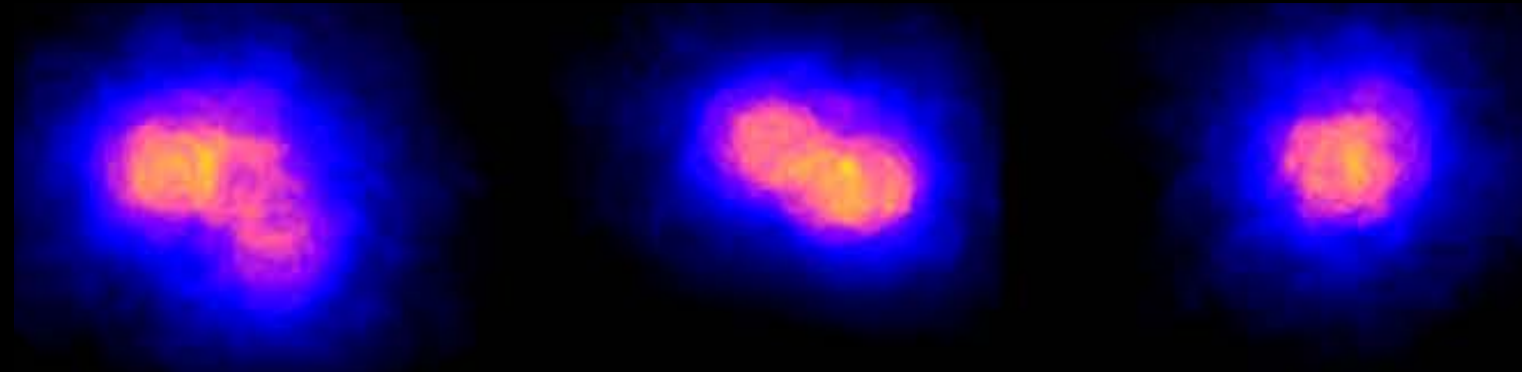
Talk by Shengli Huang
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$^3\text{He}+\text{Au}$

$\text{d}+\text{Au}$

$\text{p}+\text{Au}$

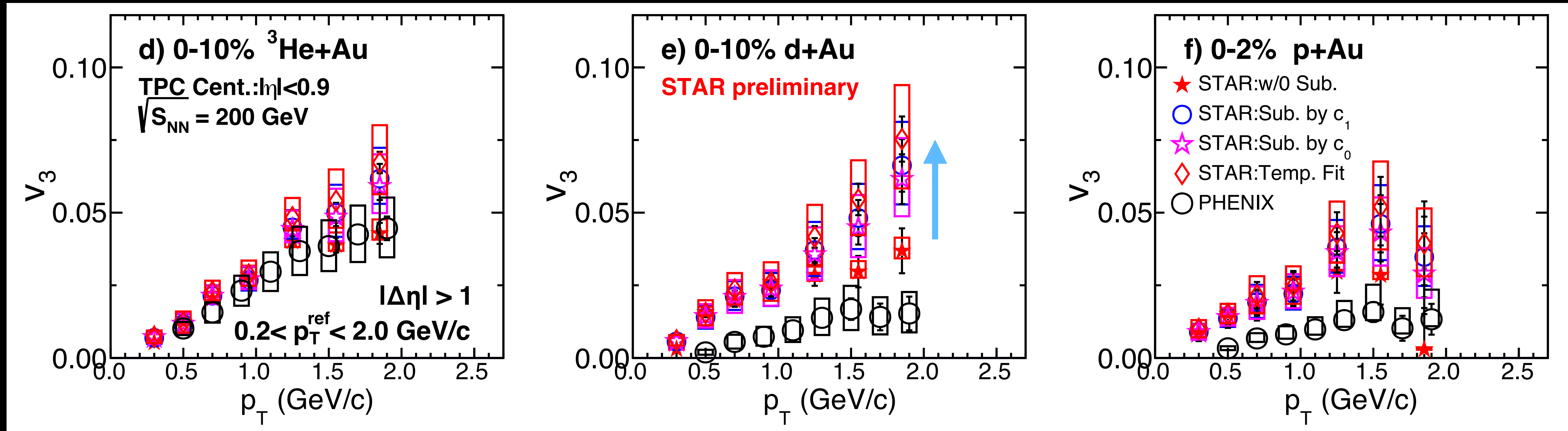


$$Y(\Delta\phi)^{\text{template}}(\text{sys}) = F \times Y(\Delta\phi)(pp) + Y(\Delta\phi)^{\text{ridge}}(\text{sys})$$

$$c_n^{\text{sub}}(\text{sys}) = c_n^{\text{raw}}(\text{sys}) - c_n(pp) \frac{N_{ch}(pp)}{N_{ch}(\text{sys})}$$

$$c_n^{\text{sub}}(\text{sys}) = c_n^{\text{raw}}(\text{sys}) - c_n(pp) \frac{c_1(pp)}{c_1(\text{sys})}$$

Consistent results using different methods
of non-flow subtraction that increases v_3



STAR results: $v_3(^3\text{He}+\text{Au}) \sim v_3(\text{d}+\text{Au}) \sim v_3(\text{p}+\text{Au})$, using different methods & coverage from PHENIX
Cross-experiment task force working to understand the apparent STAR-PHENIX discrepancy

Initial Stages of A+A

- Effect of deformation on $v_n - \langle p_T \rangle$ correlations and $\langle p_T \rangle$ fluctuations
- Longitudinal de-correlations, (anti)-particle v_3 , elliptic flow at high p_T

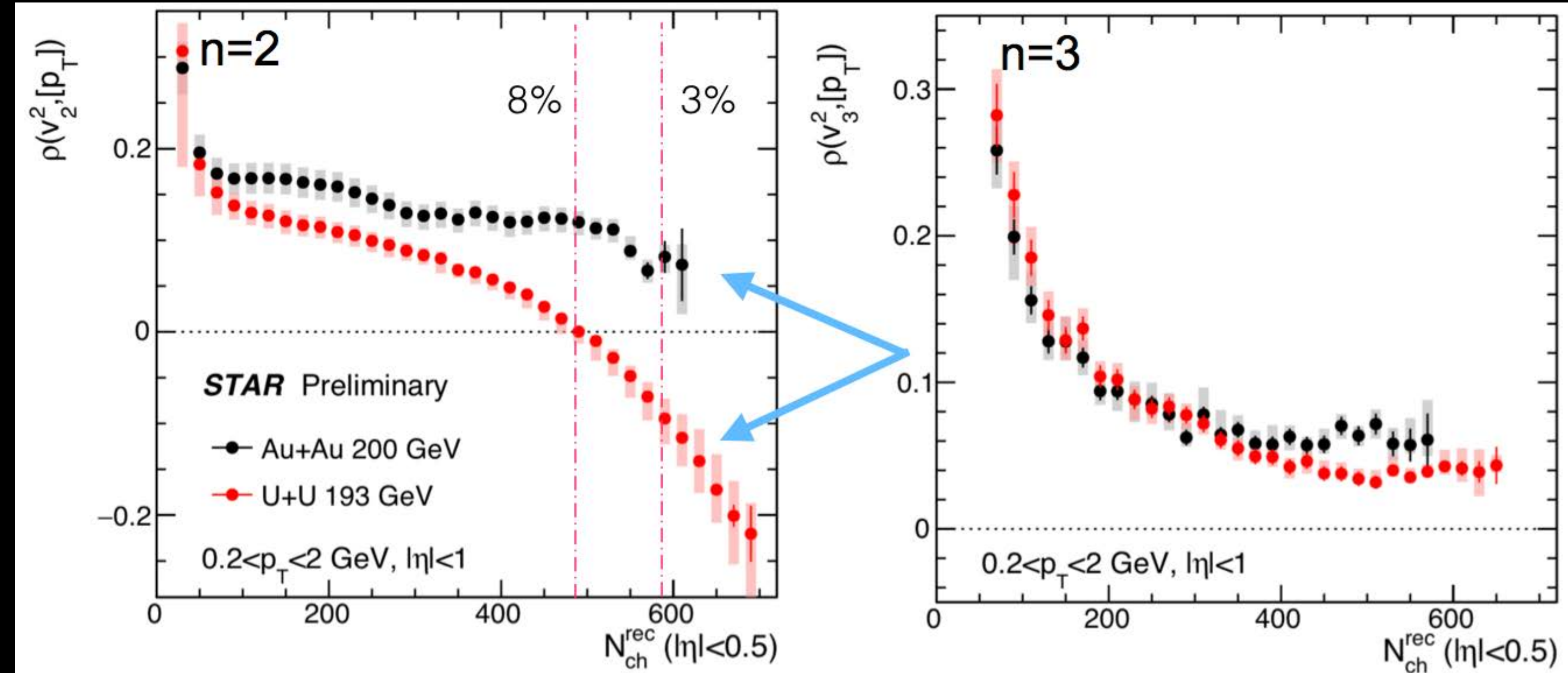
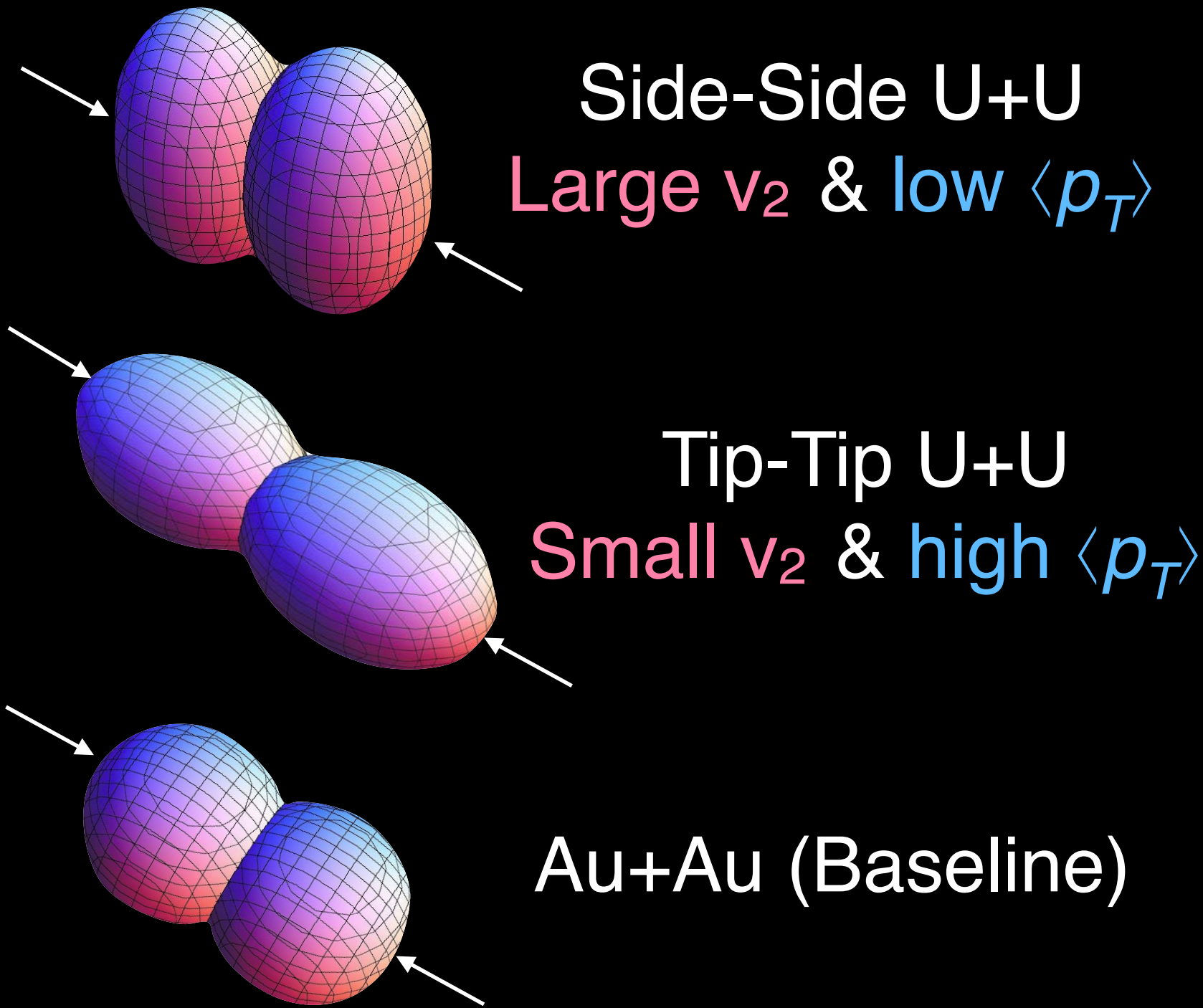
Nuclear deformation & $v_n - \langle p_T \rangle$ fluctuations

Talk by Jianguo Jia
(Thu 16:35)



Poster by Chunjian Zhang (Mon 19:40)

Giacalone, Phys. Rev. Lett. 124, 202301 (2020)



v_2 (sensitive to shape) & $\langle p_T \rangle$ correlations are negative in central U+U

v_3 (less sensitive to shape) & $\langle p_T \rangle$ correlations are positive
Au+Au results \rightarrow good baseline for nearly spherical shape

$$\rho(v_n^2, [p_T]) = \frac{\text{cov}(v_n^2, [p_T])}{\sqrt{\text{Var}(v_n^2)_{\text{dyn}} \langle \delta p_T \delta p_T \rangle}}$$

Anti-correlation of v_2 and $\langle p_T \rangle$ indicates possible sensitivity to deformed shape of Uranium

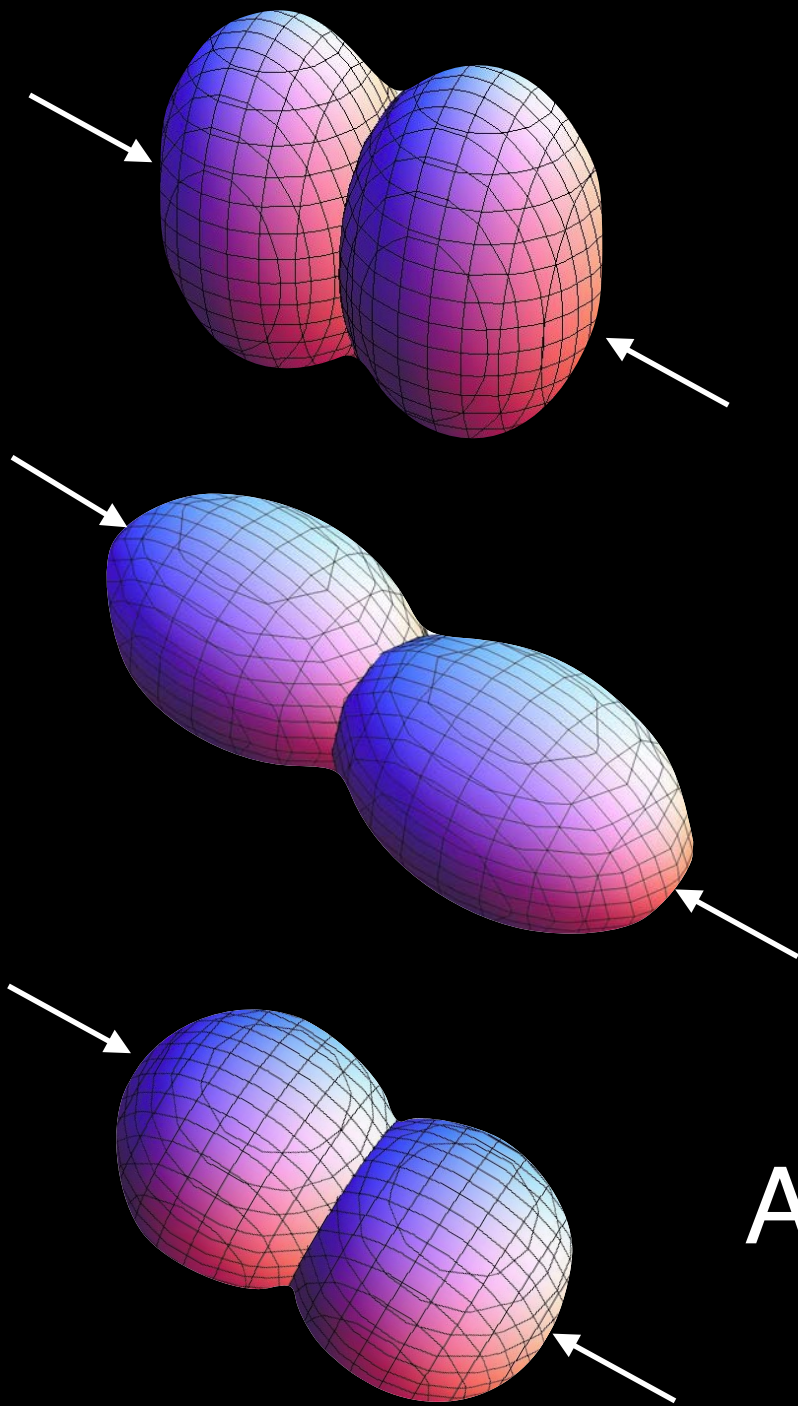
Nuclear deformation & $\langle p_T \rangle$ fluctuations

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Side-Side U+U
low $\langle p_T \rangle$

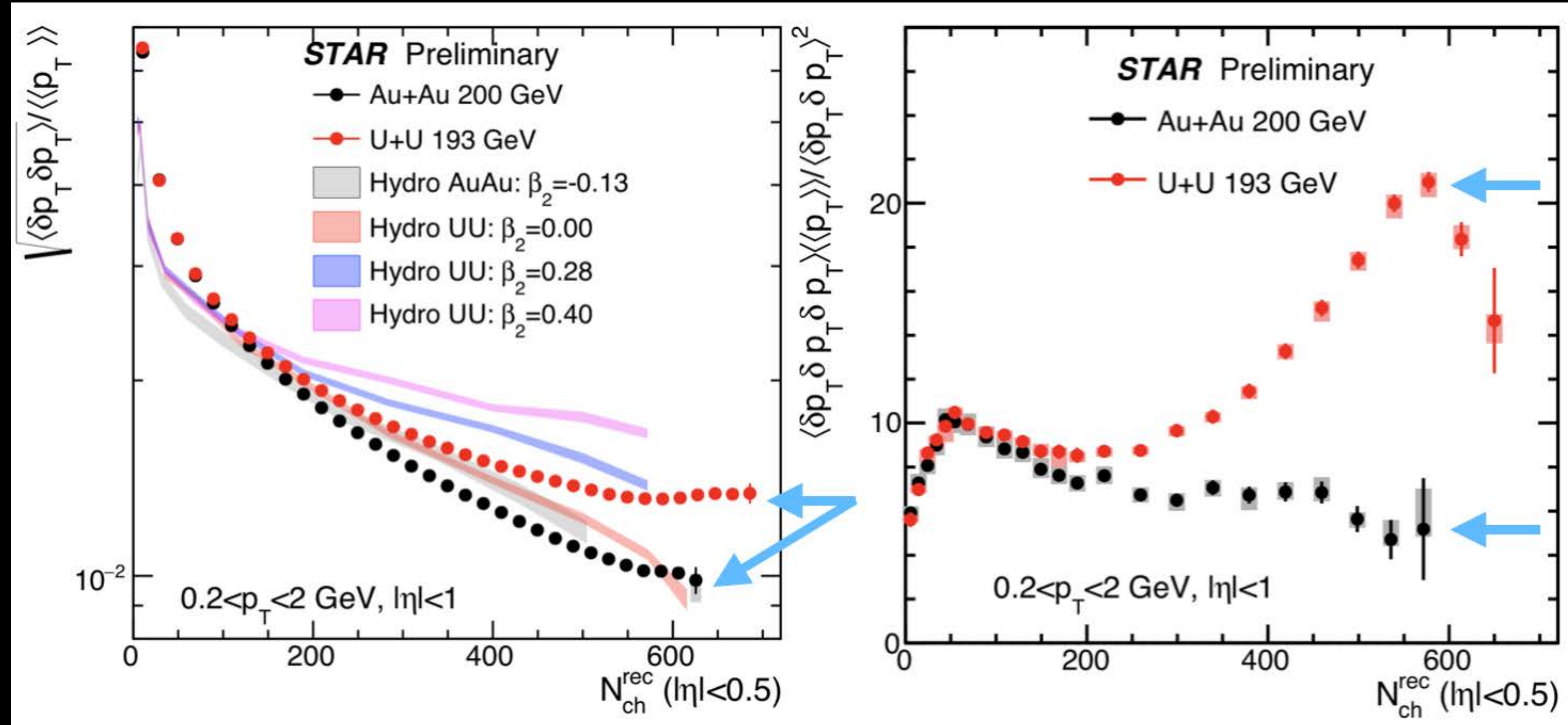
Tip-Tip U+U
high $\langle p_T \rangle$

Au+Au (Baseline)

$$\delta p_T = p_T - [p_T]$$

Standard Variance $\sigma_{p_T} = \frac{\sqrt{\langle \delta p_T \delta p_T \rangle}}{\langle \langle p_T \rangle \rangle}$

Intensive Skewness $\Gamma_{p_T} = \frac{\langle \delta p_T \delta p_T \delta p_T \rangle \langle \langle p_T \rangle \rangle}{\langle \delta p_T \delta p_T \rangle^2}$



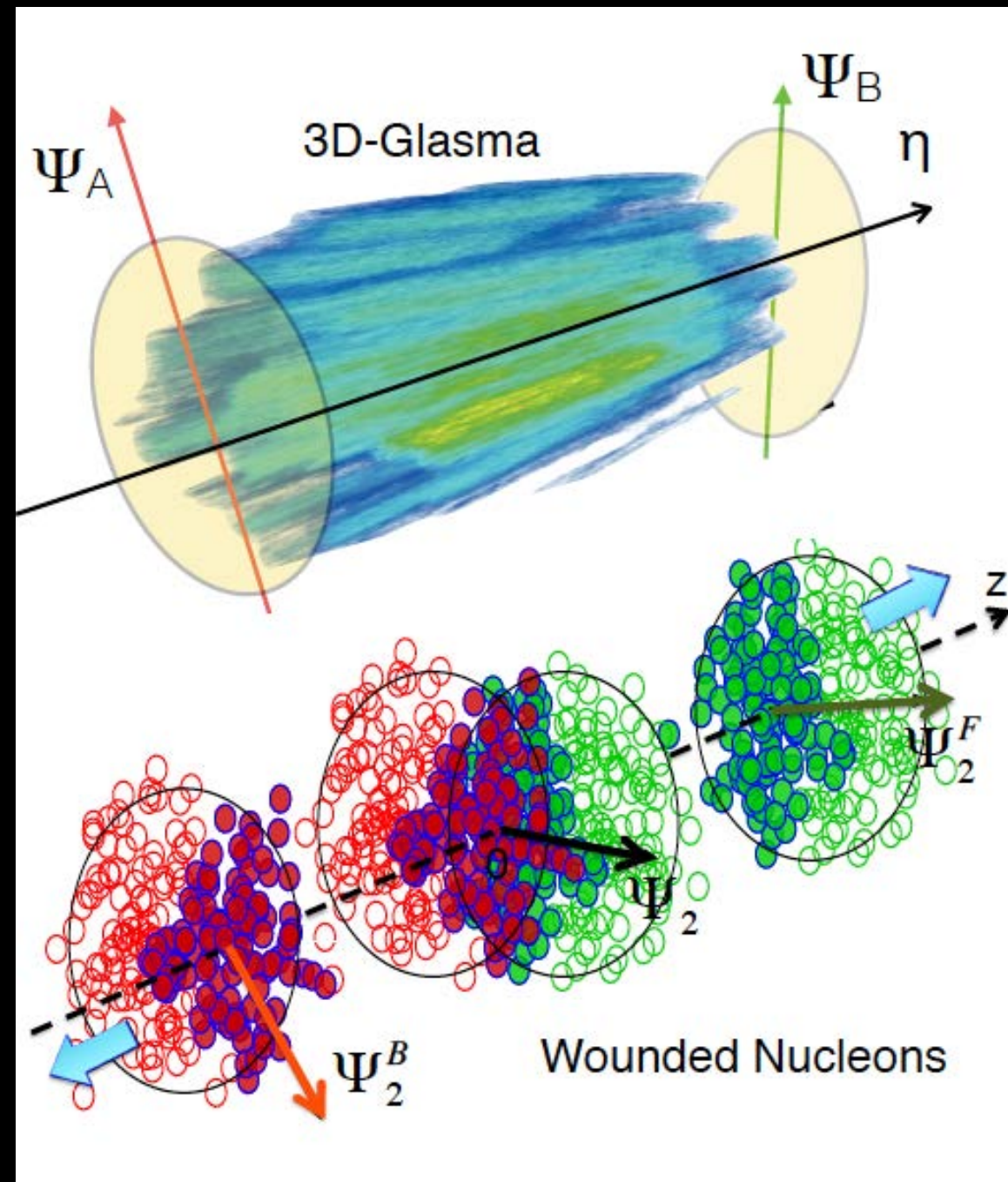
Higher order fluctuations of $\langle p_T \rangle$ show difference in central U+U and Au+Au \rightarrow sensitivity to deformation

More on flow and de-correlation & 3D initial state

Talk by Maria Stefaniak
(Tue 18:40)

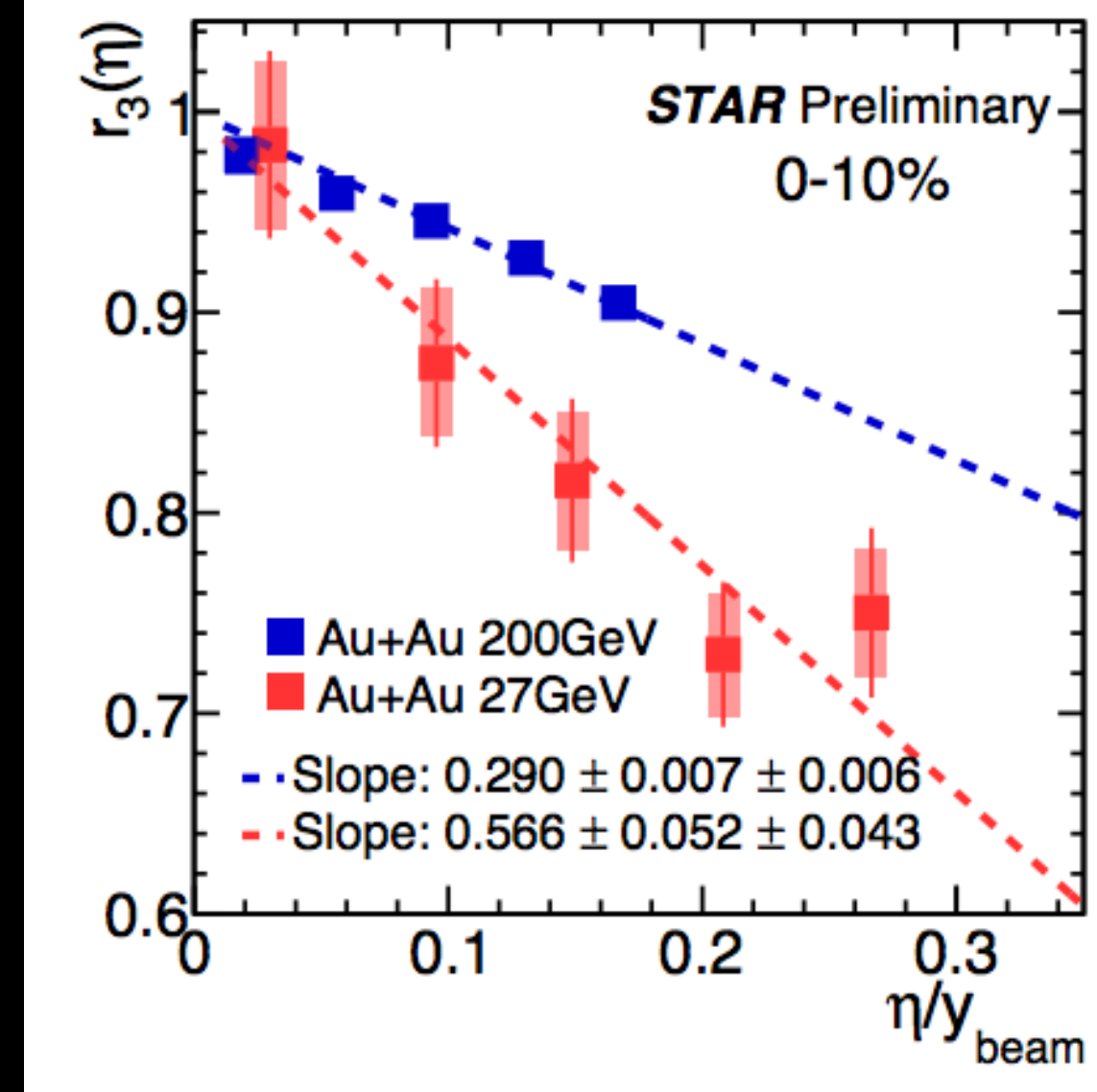
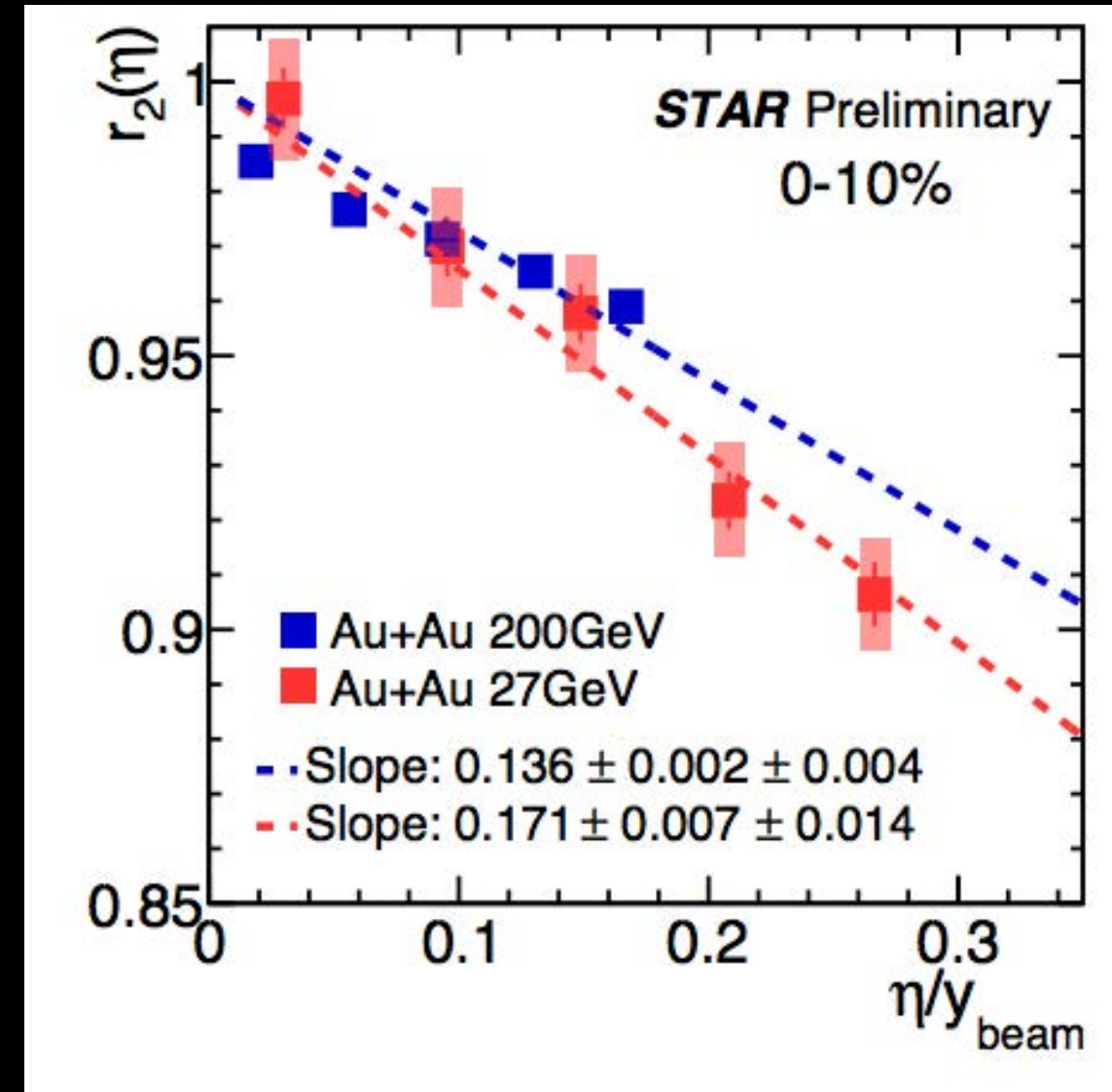


Poster by Maowu Nie (Mon 19:40)



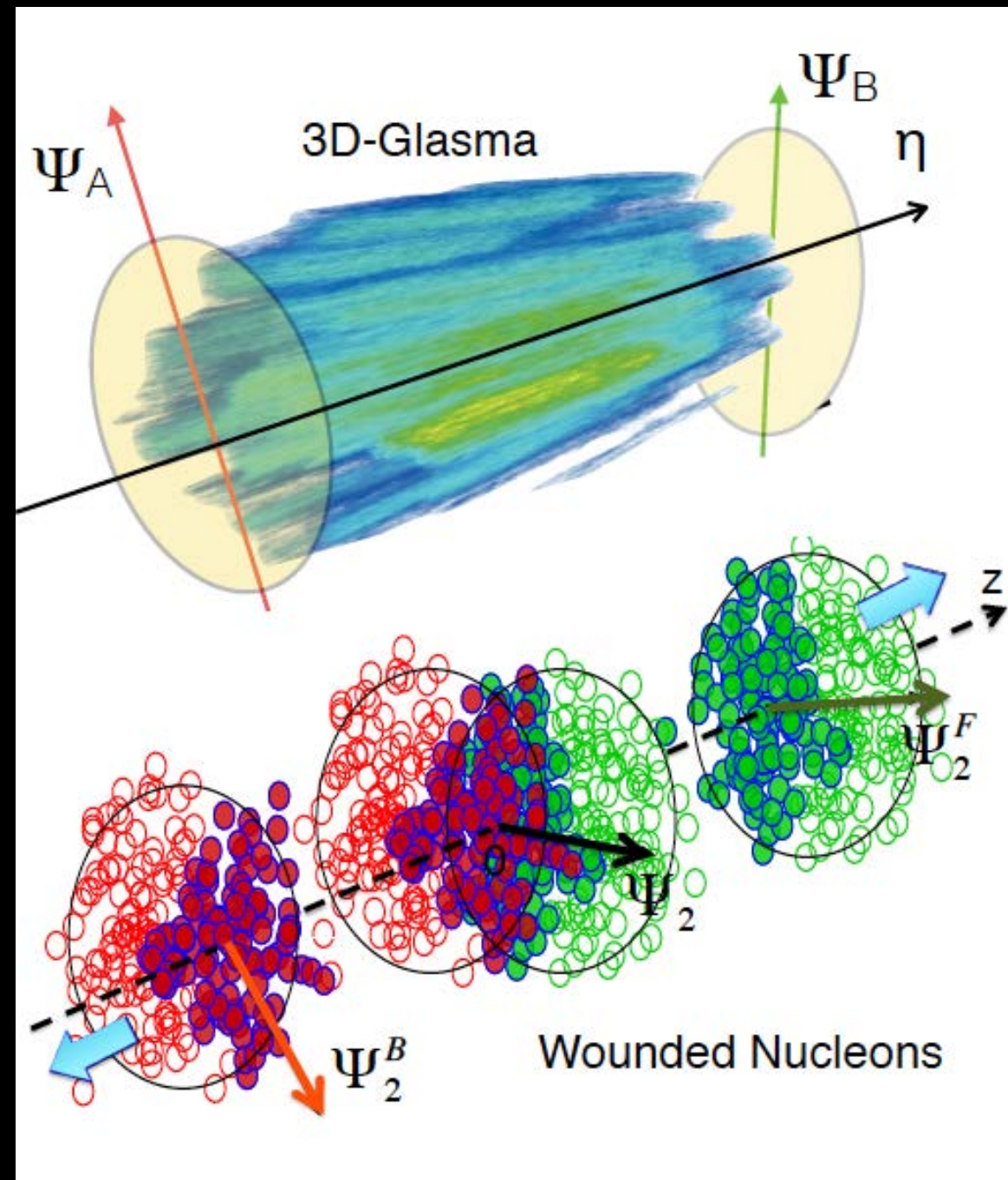
$$r_n(\eta^a, \eta^b) = \frac{V_{n\Delta}(-\eta^a, \eta^b)}{V_{n\Delta}(\eta^a, \eta^b)}$$

RHIC de-correlation
results do not follow
beam rapidity scaling

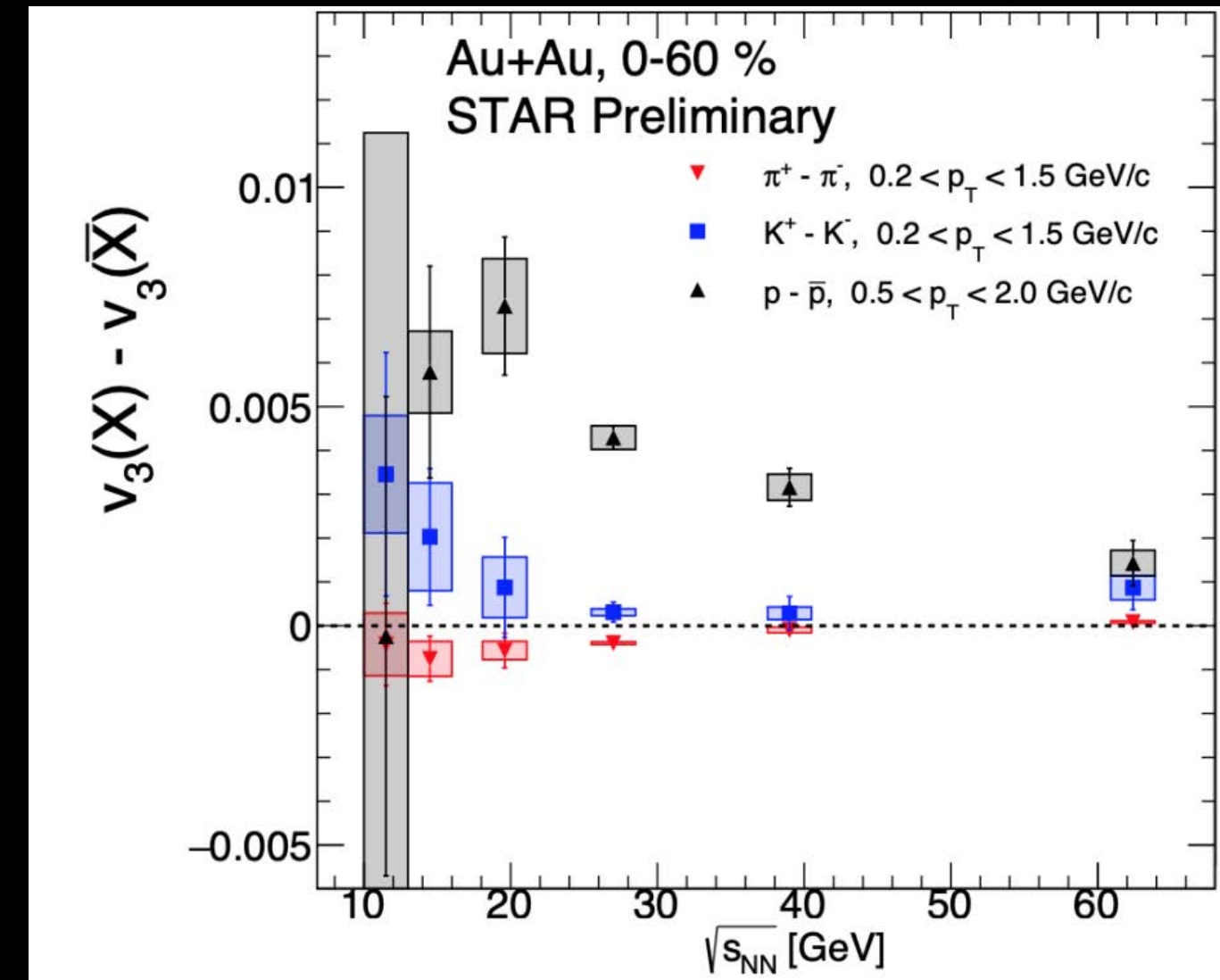
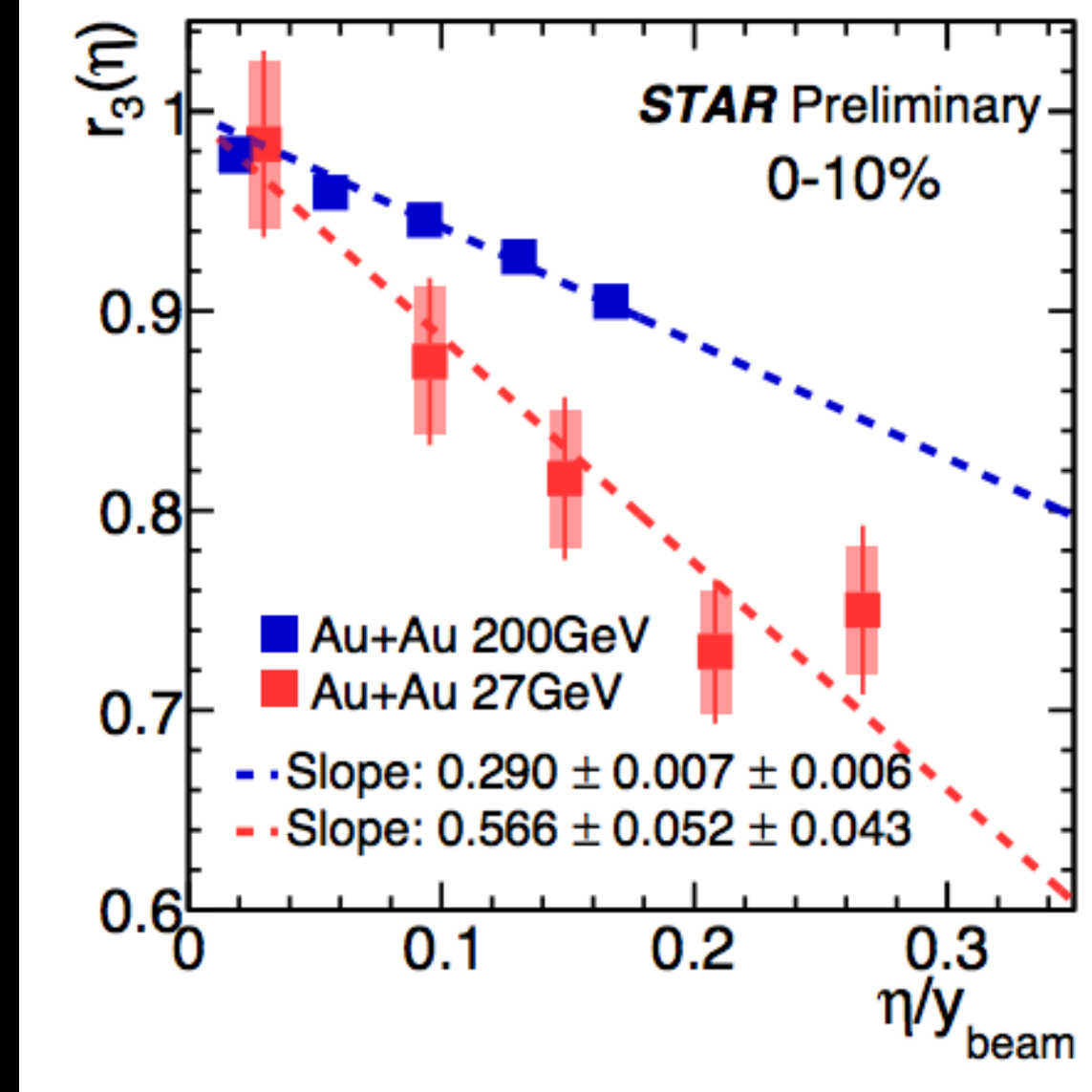
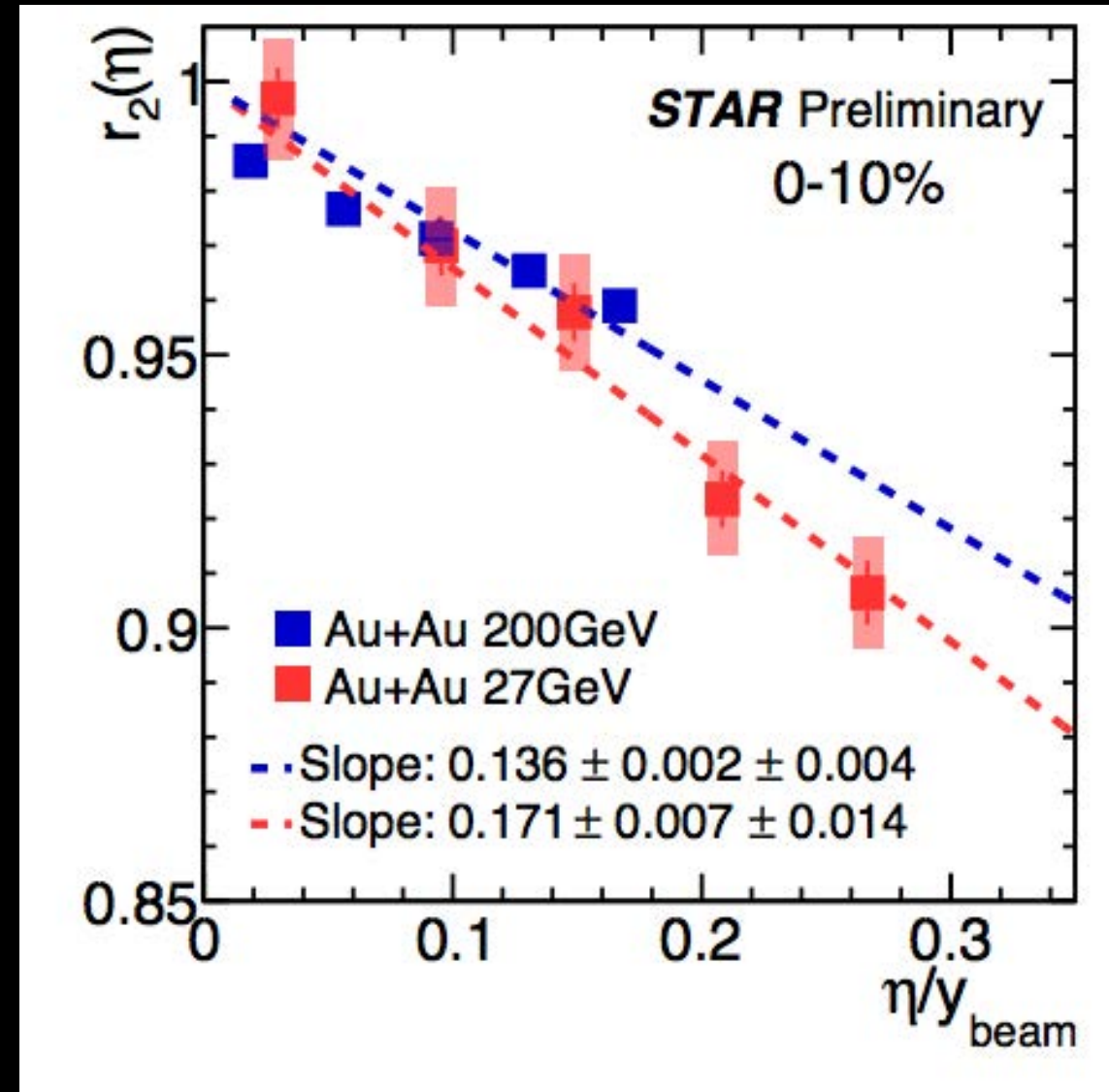


More on flow and de-correlation & 3D initial state

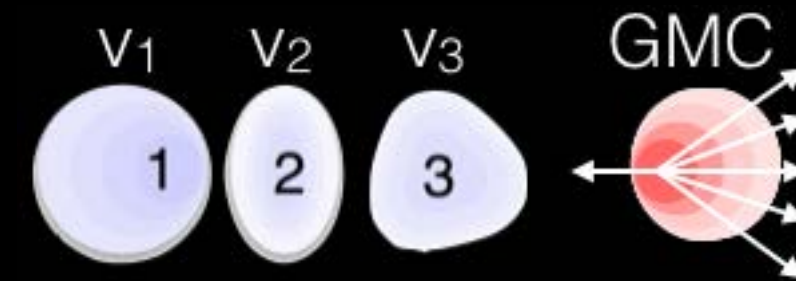
Talk by Maria Stefaniak
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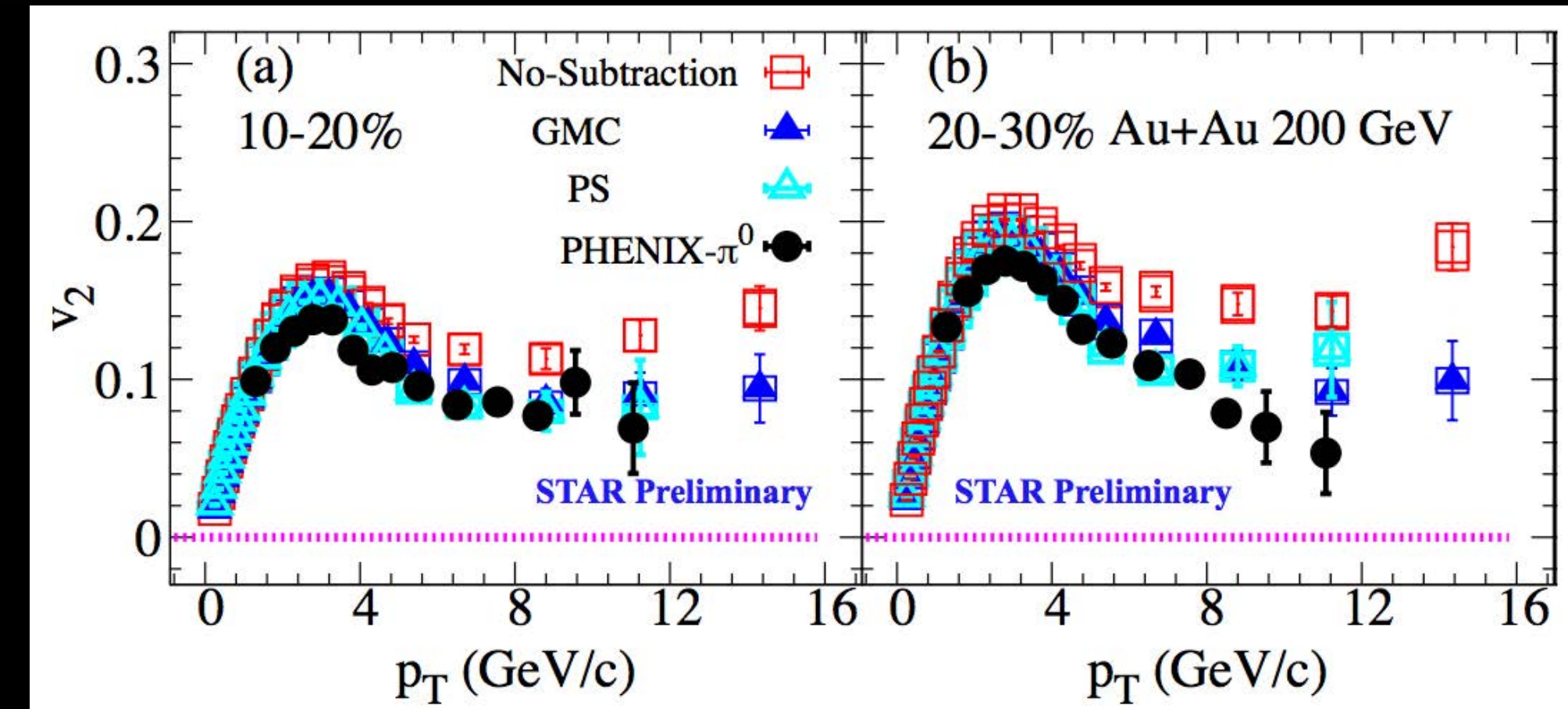
Anti-(particle) v_3 :
constraints on
initial state
models at low \sqrt{s}



Isolating flow & global mom.
conservation at high p_T

$$r_n(\eta^a, \eta^b) = \frac{V_{n\Delta}(-\eta^a, \eta^b)}{V_{n\Delta}(\eta^a, \eta^b)}$$

RHIC de-correlation
results do not follow
beam rapidity scaling



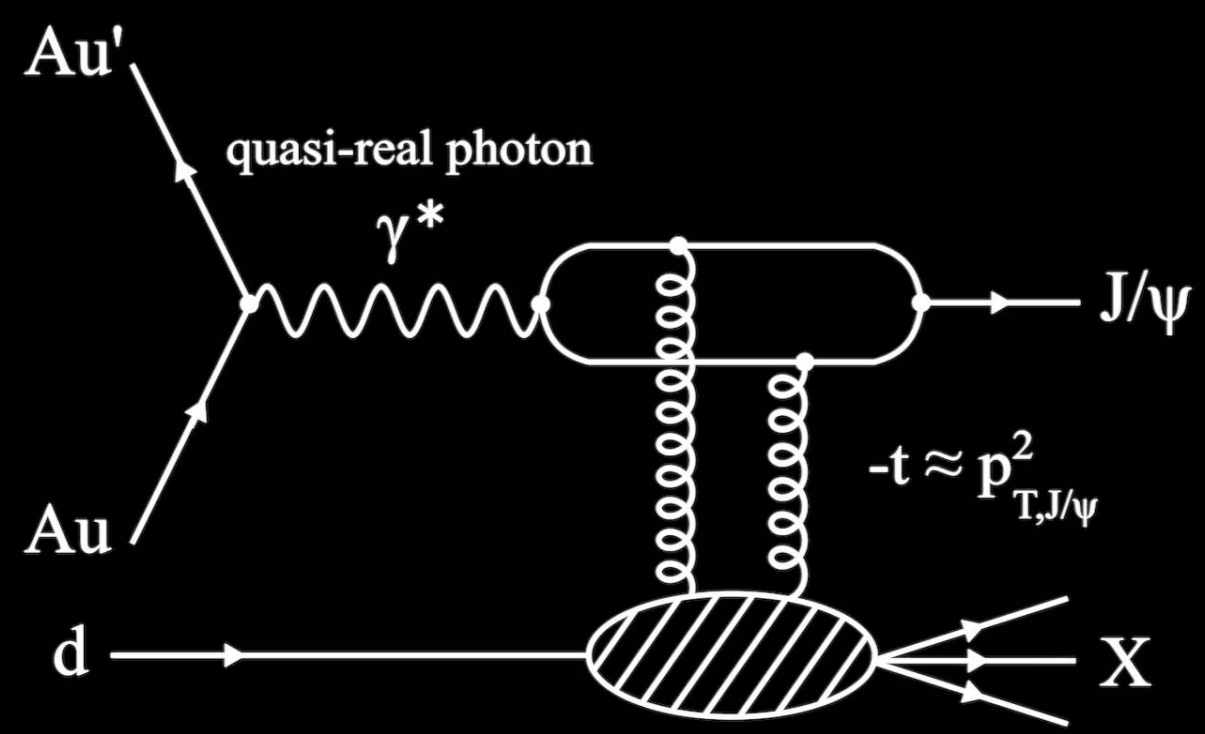
Poster by Niseem Magdy (Sun 19:45)

Ultra-peripheral Collisions & Strong Fields

- Photoproduction of J/ψ in d+Au collisions
- Photoproduction of low p_T di-electron in UPC & peripheral A+A
- Probing nuclei with linearly polarized photons
- Search for the Chiral Magnetic Effect

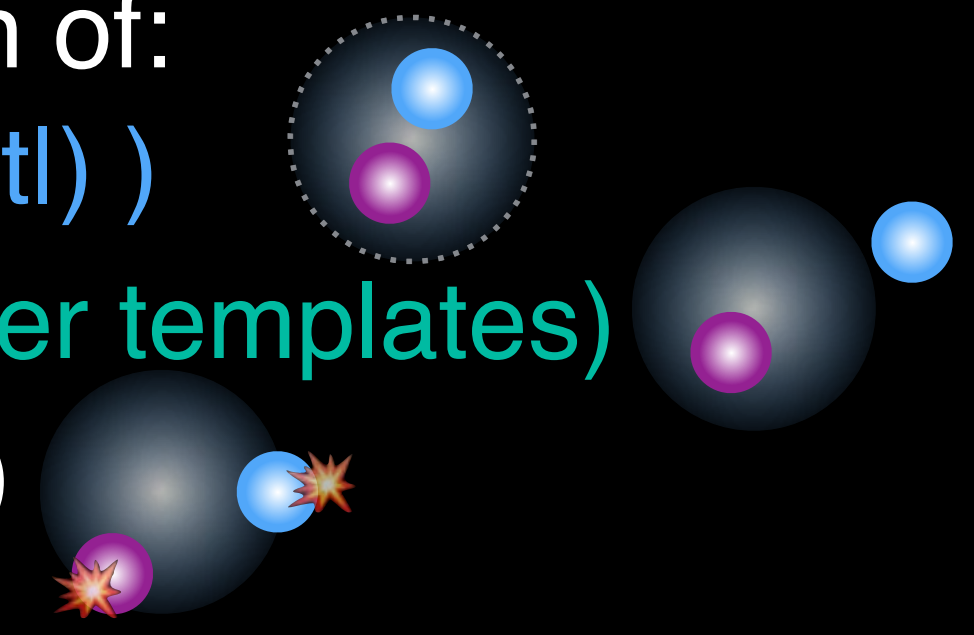
Photoproduction of J/ψ in d+Au UPC

Talk by Xiaofeng Wang
(Wed 18:45)

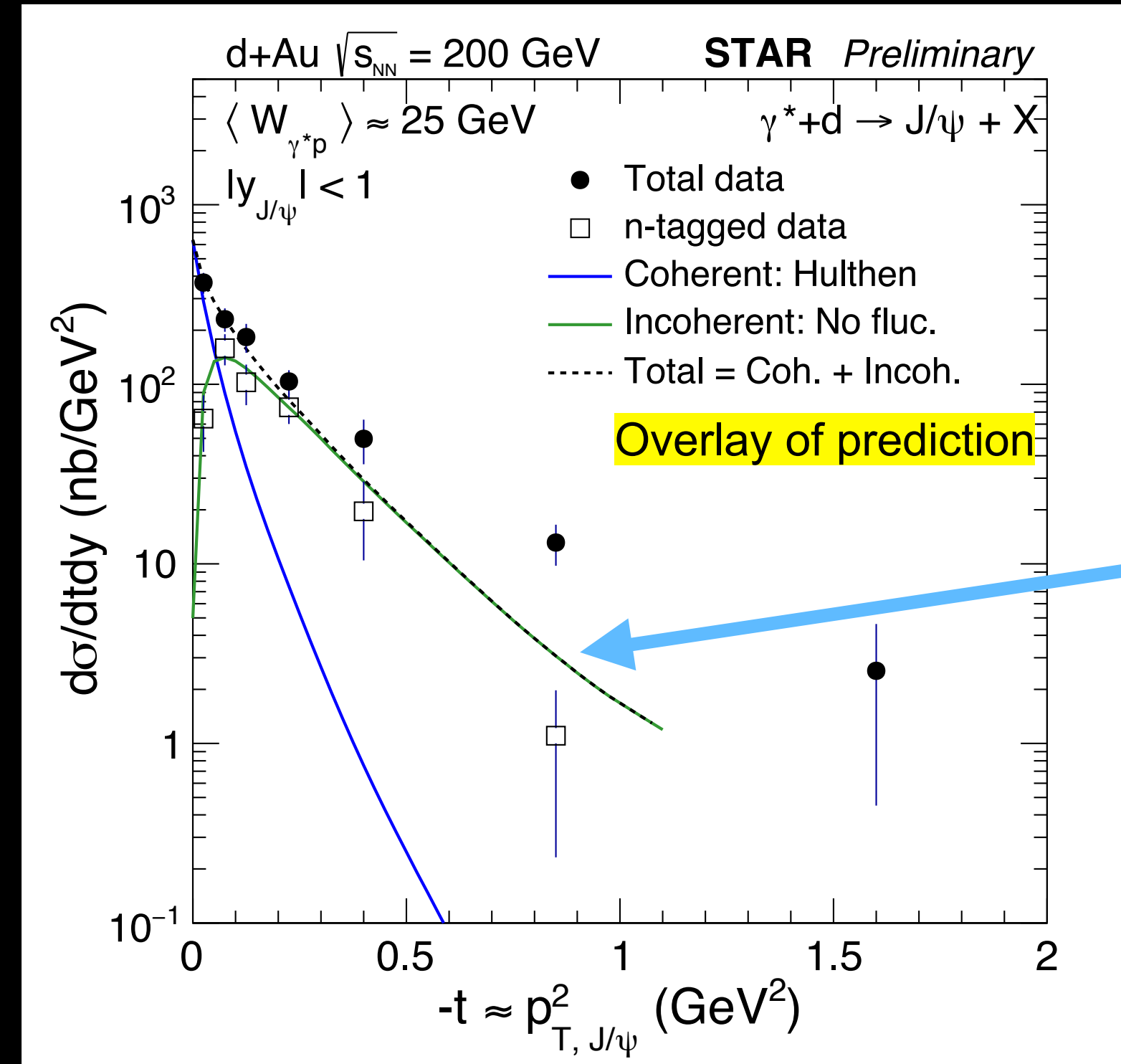
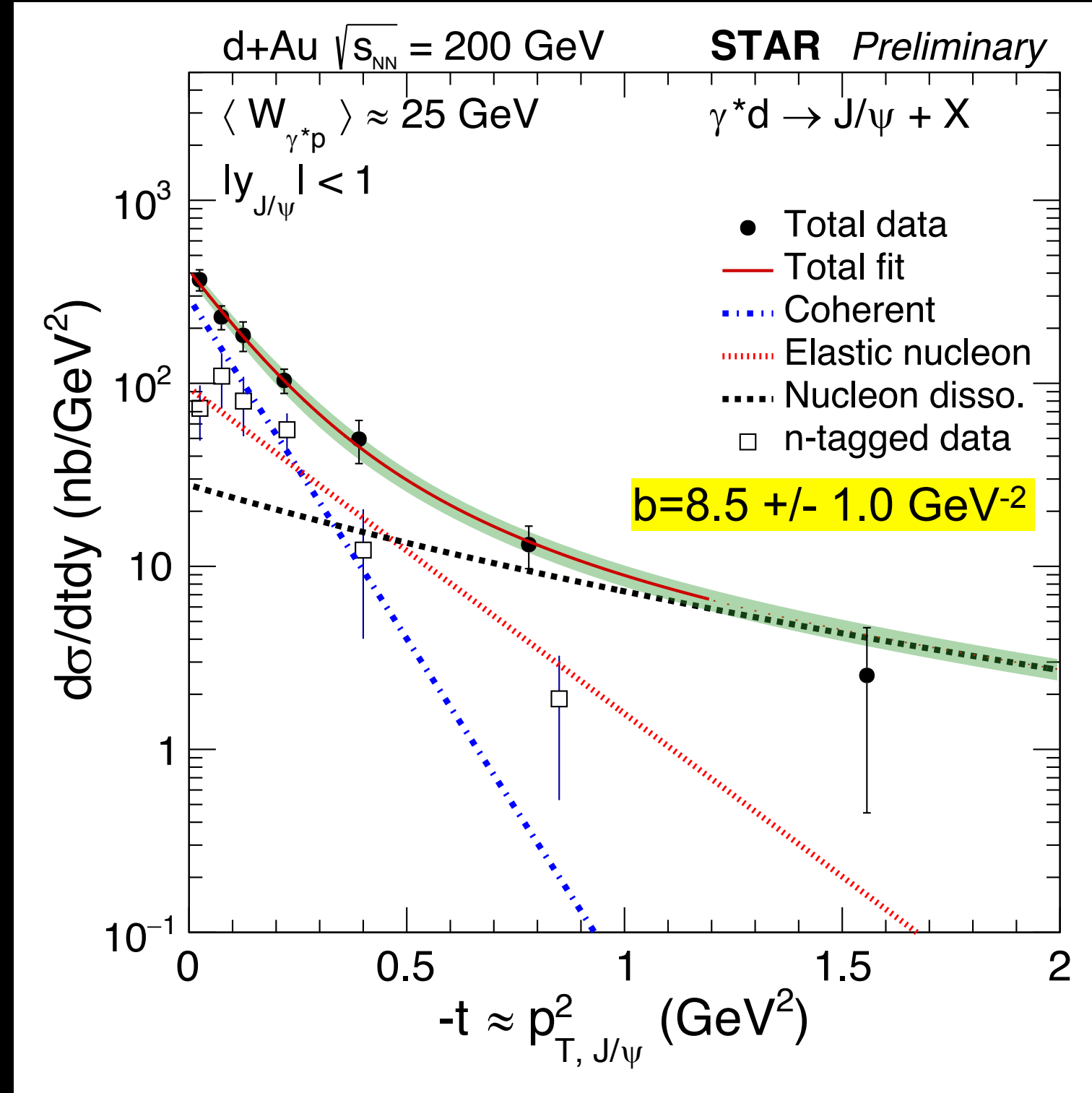


Total cross section is a combination of:

1. Coherent contribution ($\sim \exp(-b|t|)$)
2. Elastic nucleon (ep HERA & other templates)
3. Nucleon dissociative (ep HERA)

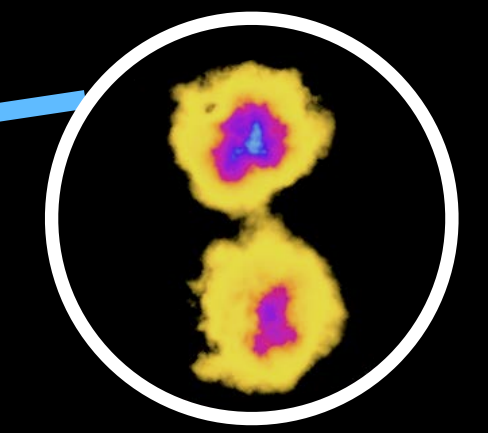


Fit to data:
Coherent +
Elastic nucleon +
Nucleon disso:
ep H1:
Eur.Phys.J.C 73 (2013) 6,
2466



Prediction:
Hulthen+CGC

Mäntysaari, Schenke,
Phys. Rev. C 101,
015203 (2020)

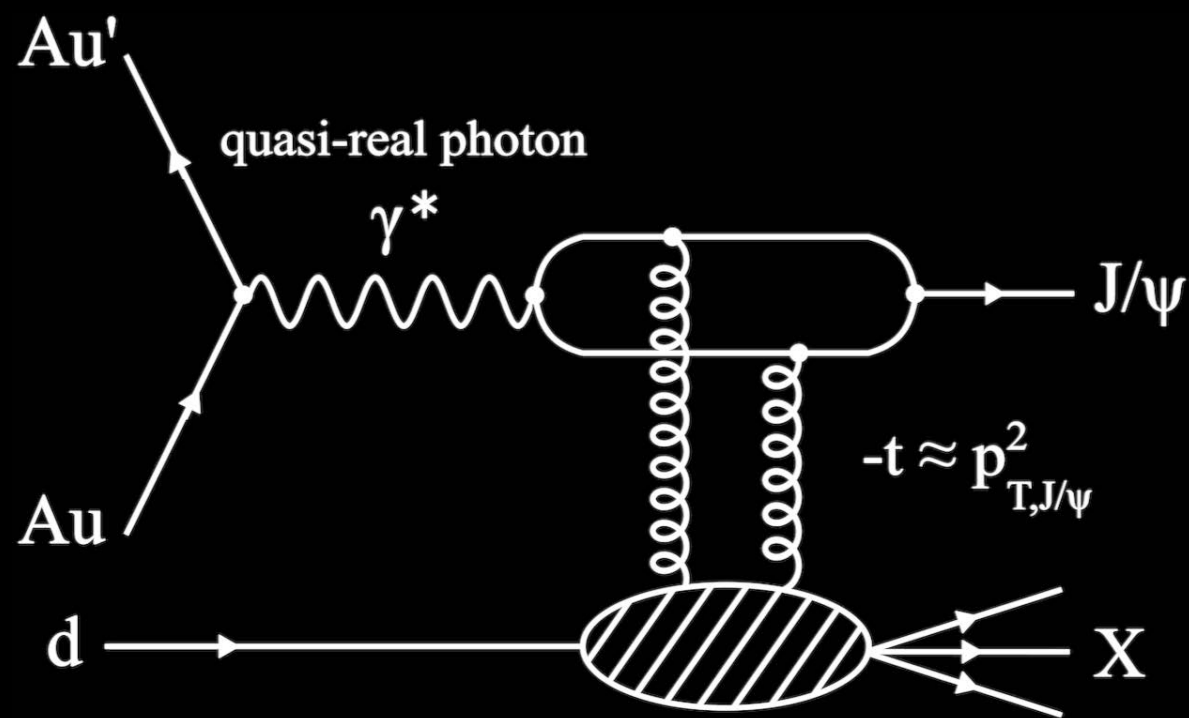


Without sub-nucleonic & Q_s fluctuations

The coherent diffractive component extracted constrains gluon distribution inside deuteron

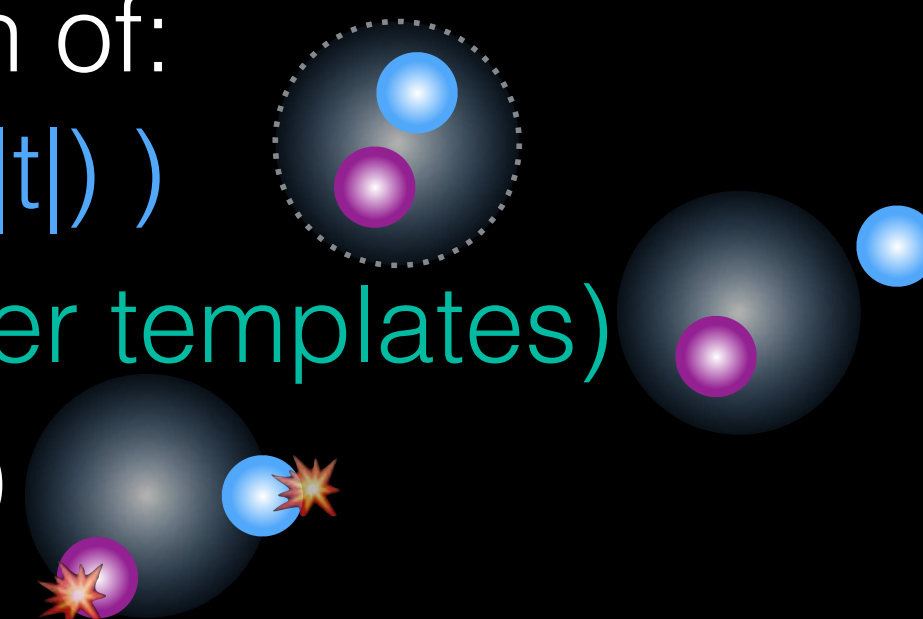
Photoproduction of J/ψ in d+Au UPC

Talk by Xiaofeng Wang
(Wed 18:45)



Total cross section is a combination of:

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Fit to data:

Coherent:

$$\sim \exp(-b |t|)$$

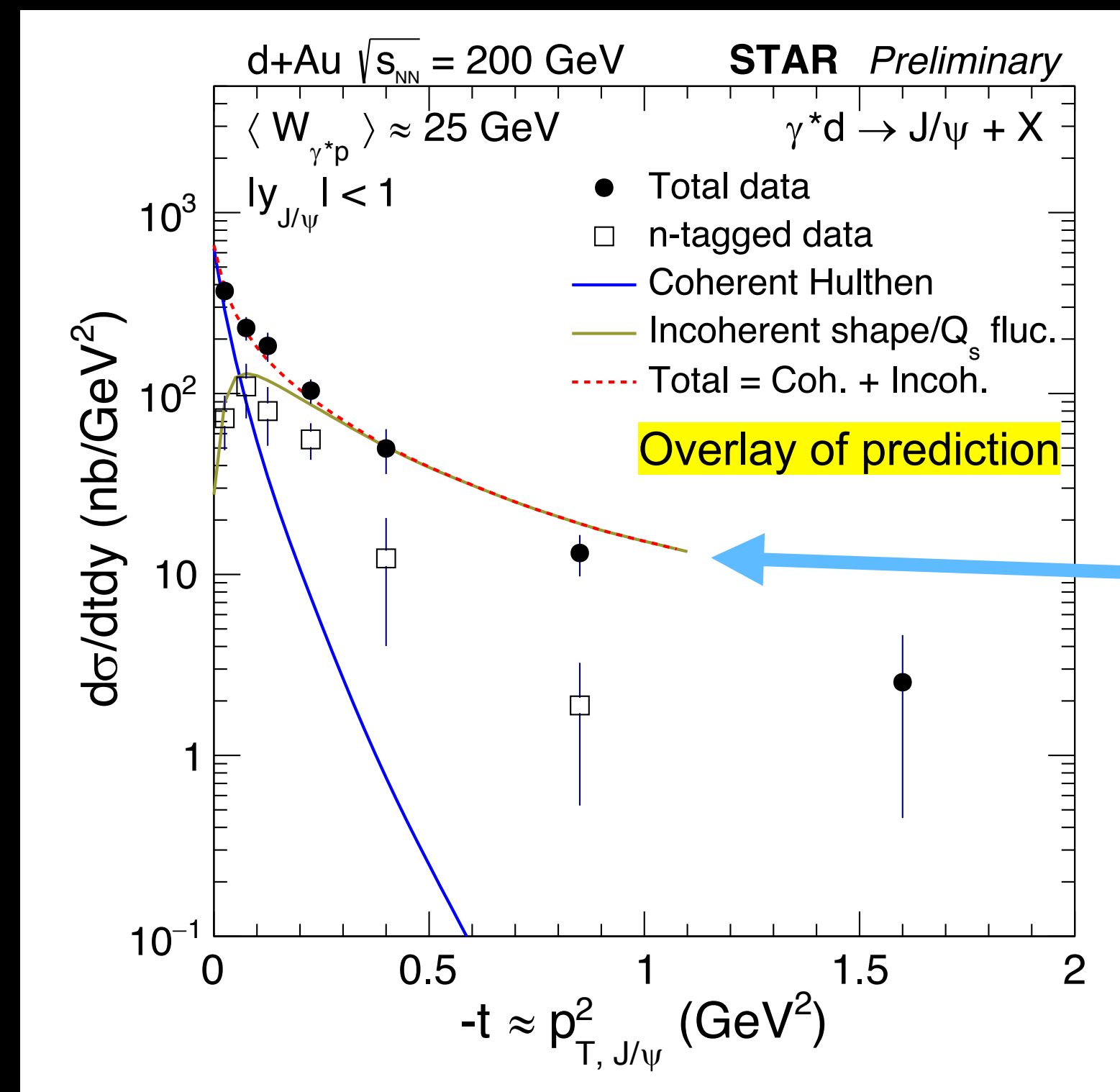
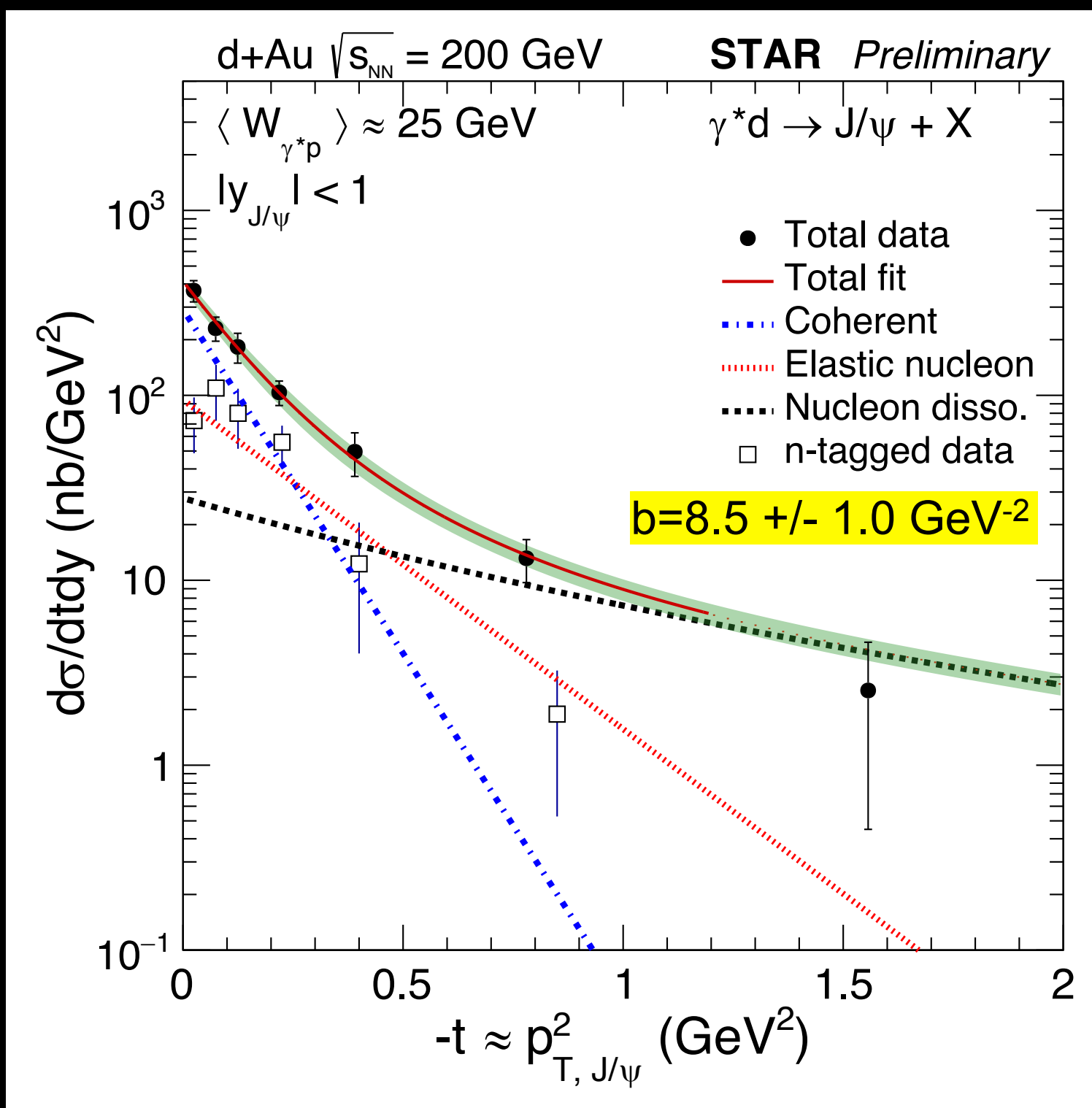
Elastic nucleon:

ep H1

Nucleon disso:

ep H1

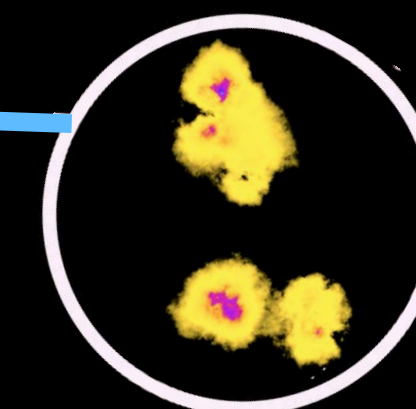
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Prediction:

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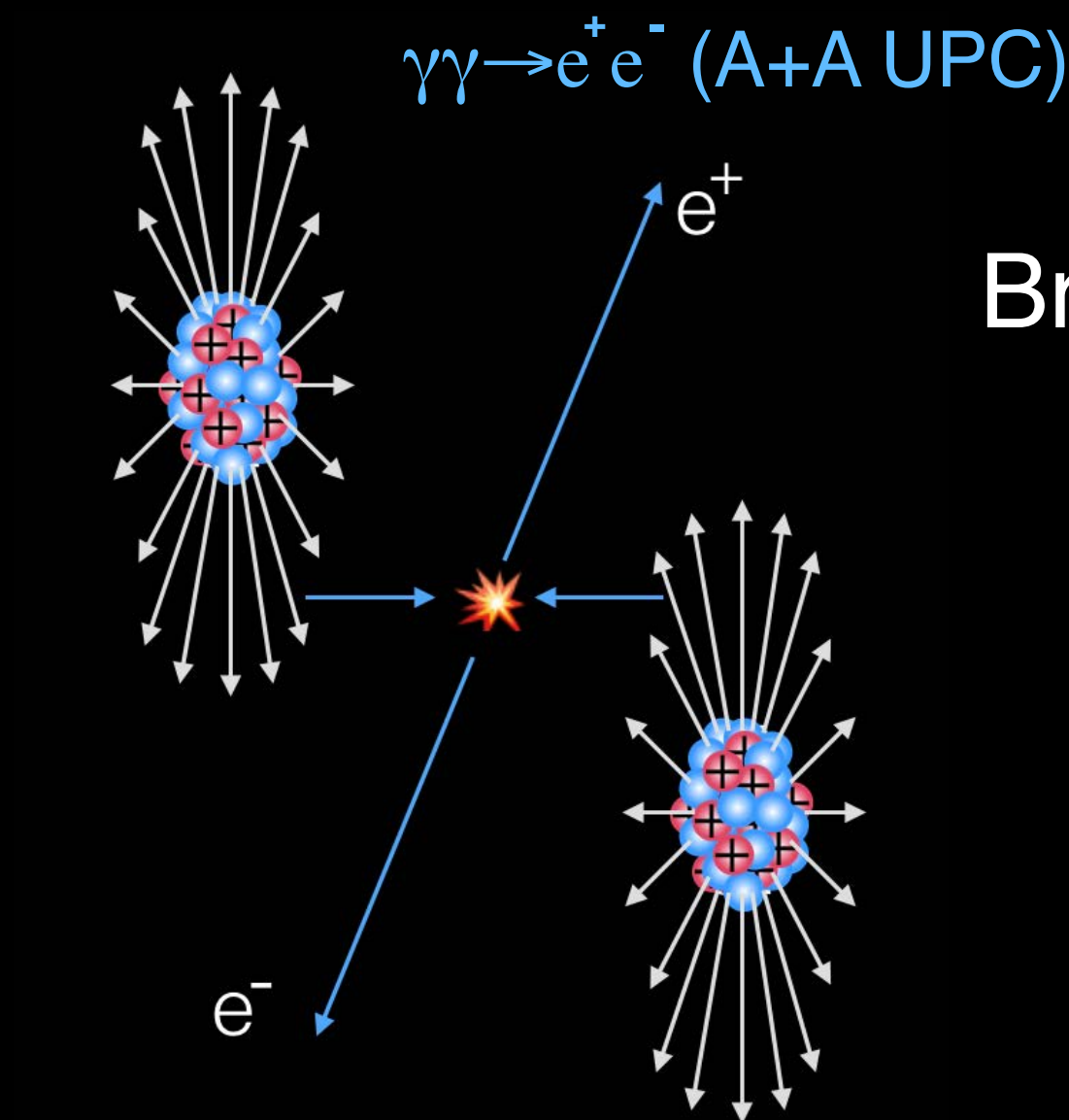
Mäntysaari, Schenke,
Phys. Rev. C 101,
015203 (2020)



With sub-nucleonic & Q_s fluctuations

Data at large t (mostly incoherent) favors CGC predictions with sub-nucleon scale and Q_s fluctuations

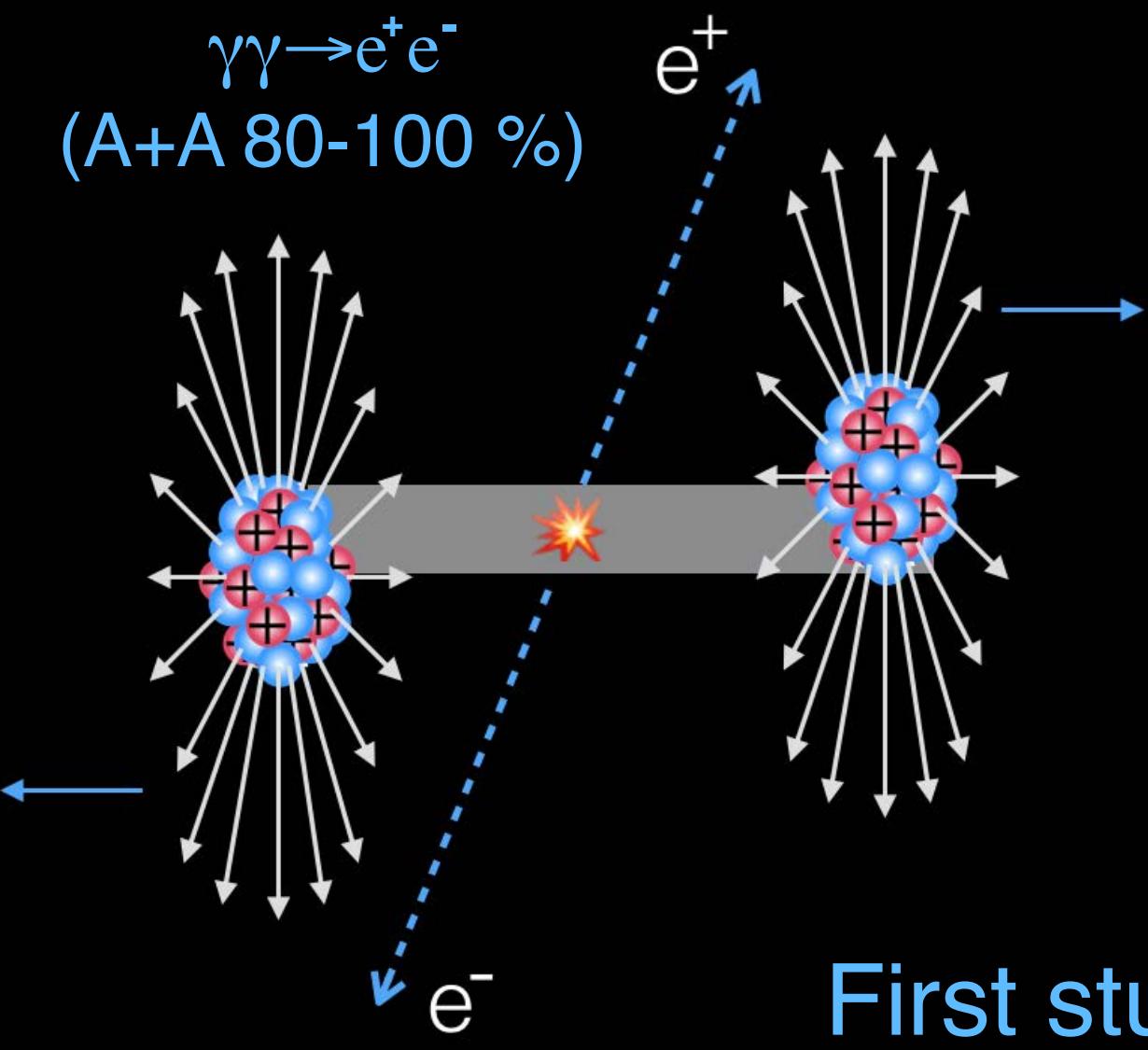
Photoproduction of low p_T electron-positron



Breit-Wheeler Process and vacuum birefringence

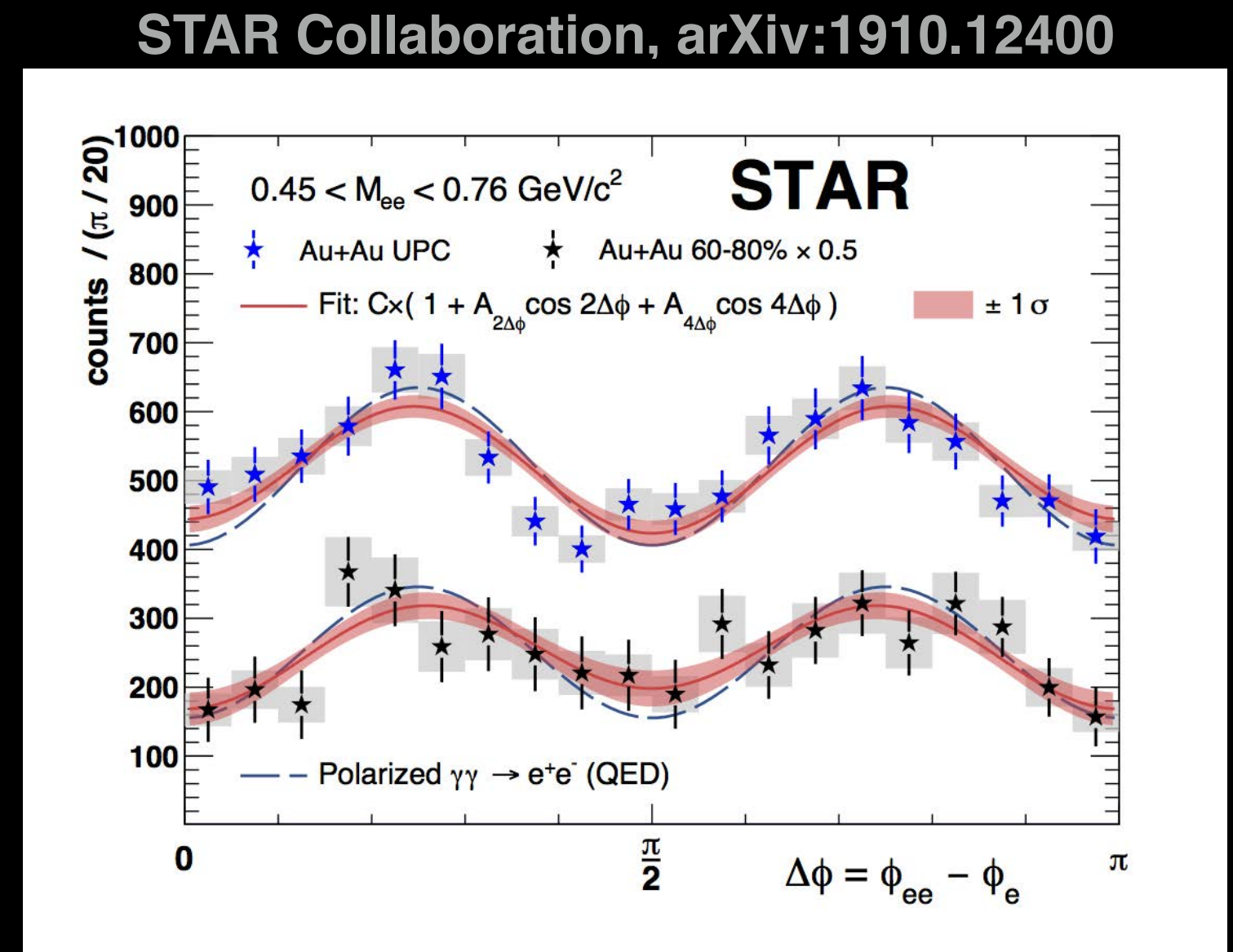
$$eB > eB_C \approx m_e^2 \sim 10^8 T$$

Constraints on B-field strength & linear polarization of photons

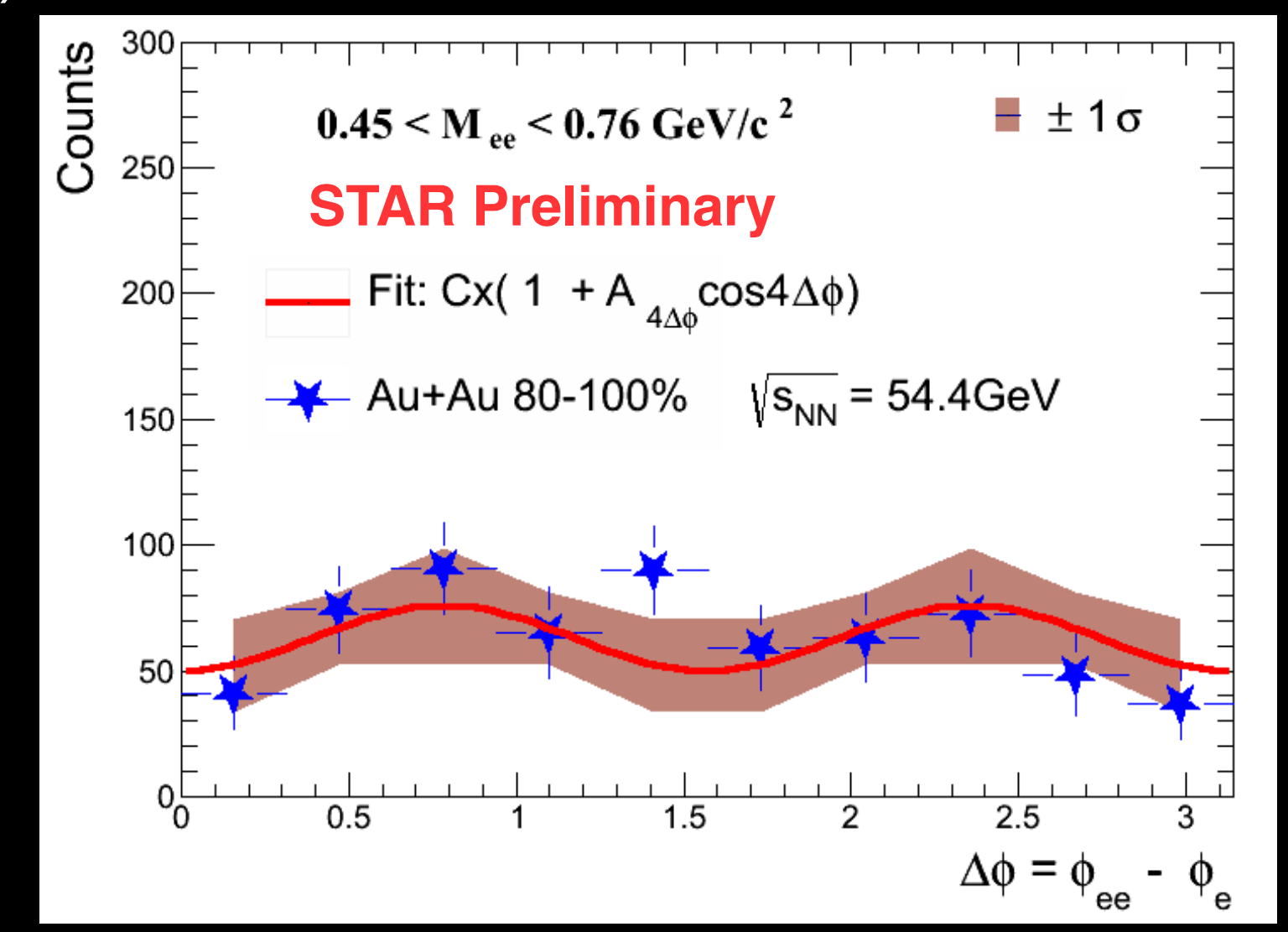
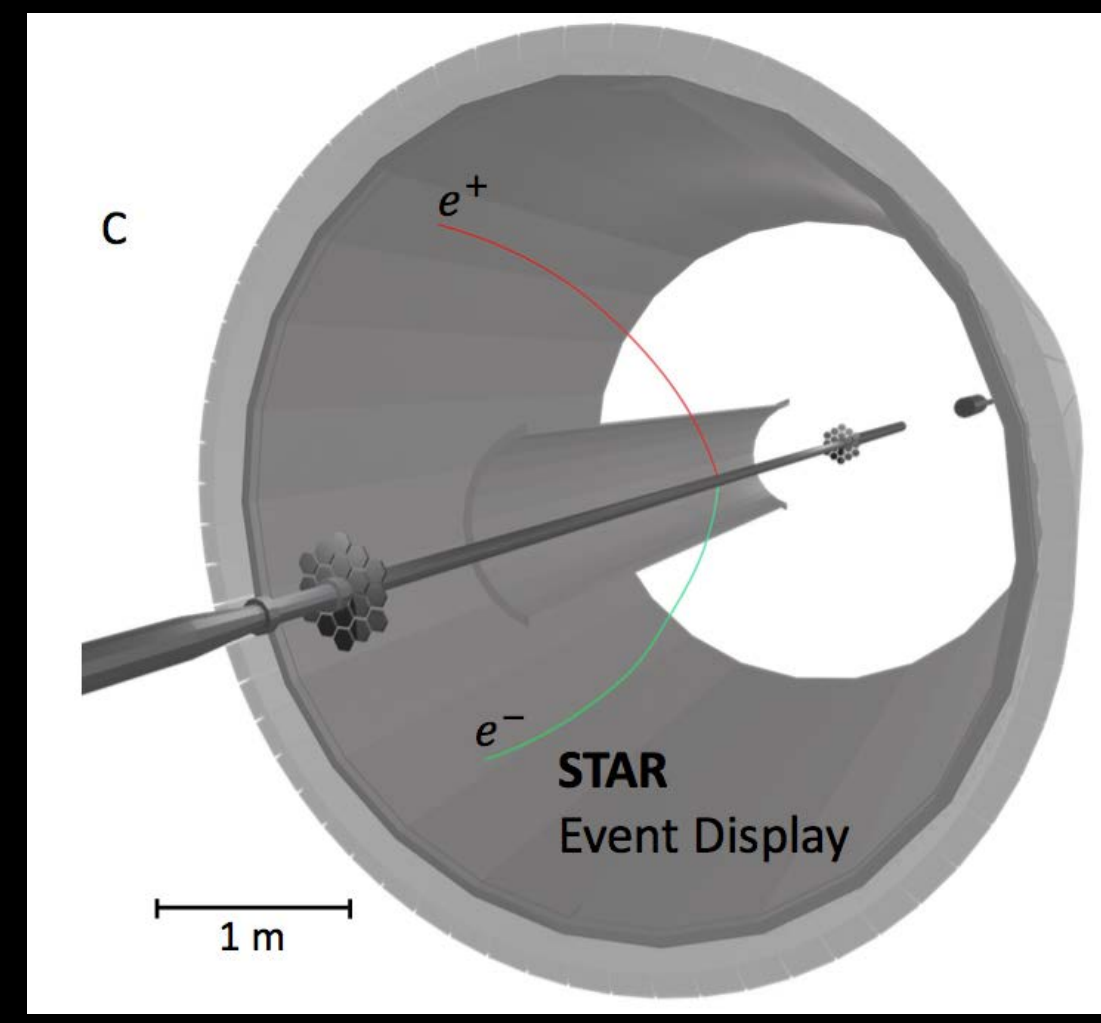


Excess of low p_T electron-positron production studied in 54.4 GeV peripheral Au+Au collisions


First study of azimuthal angular modulations of in peripheral AA and its energy dependence

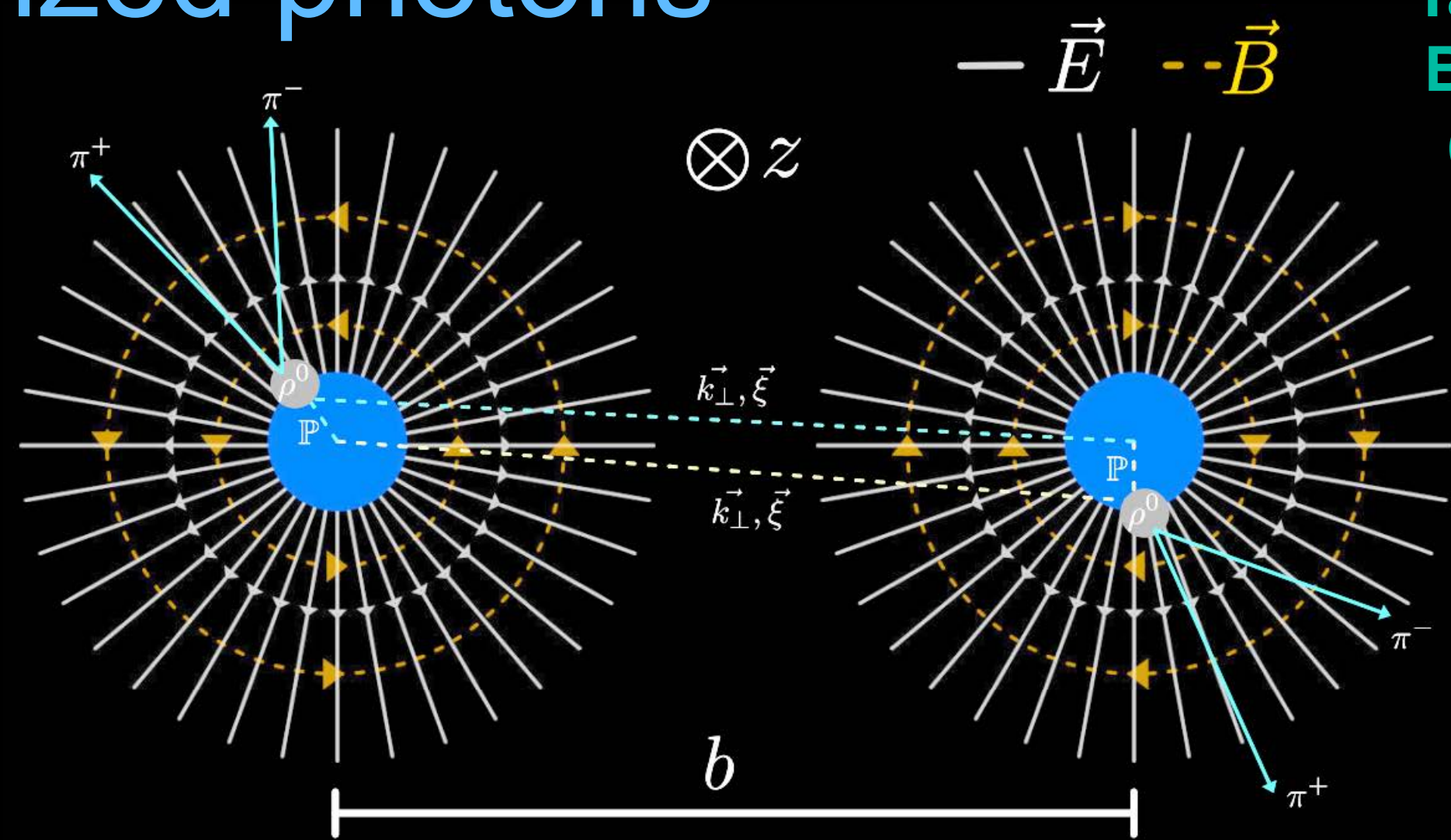
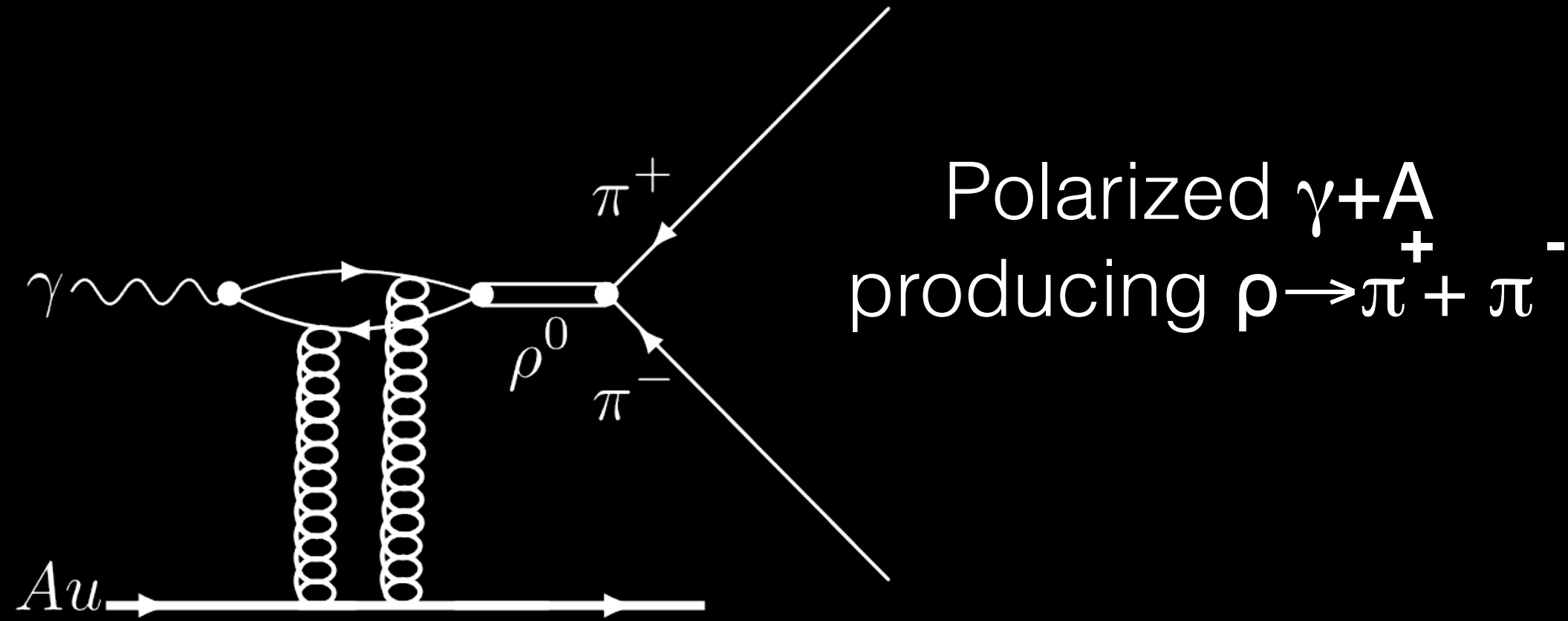


$$\Delta\phi ([e^+ + e^-], [e^+ - e^-])$$



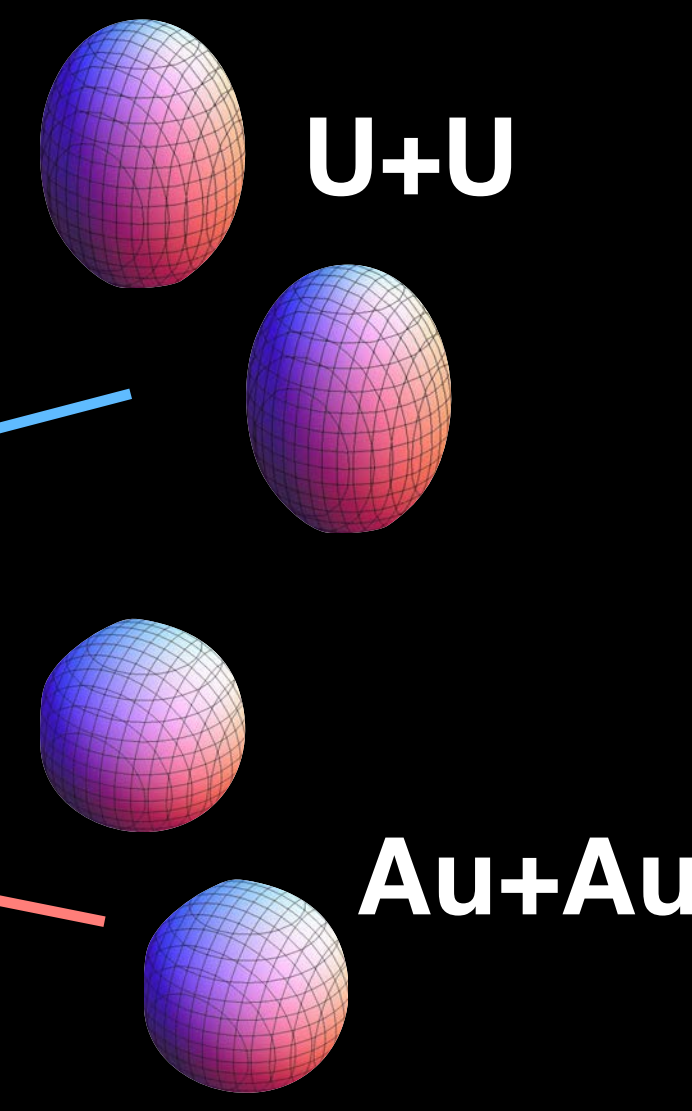
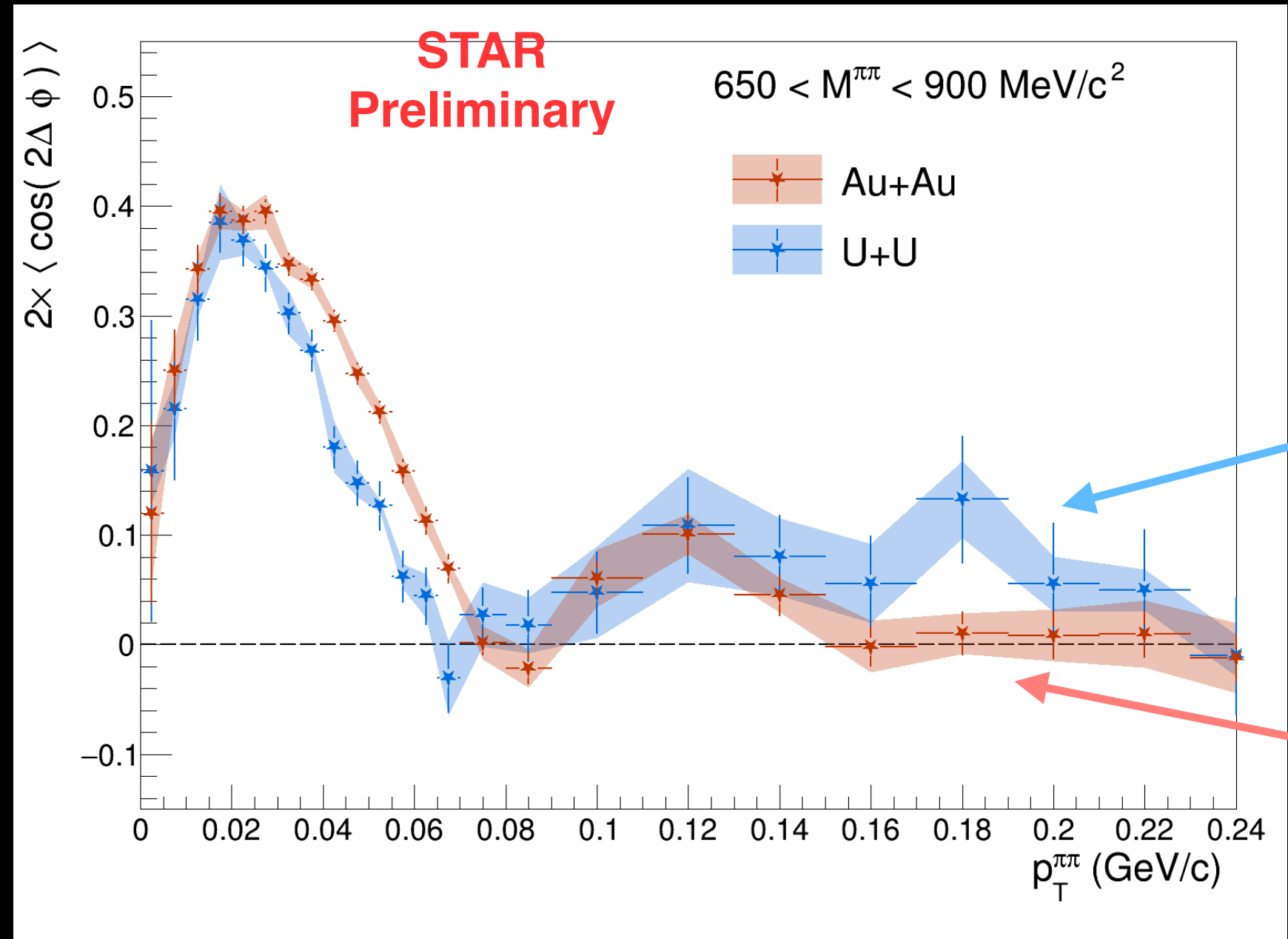
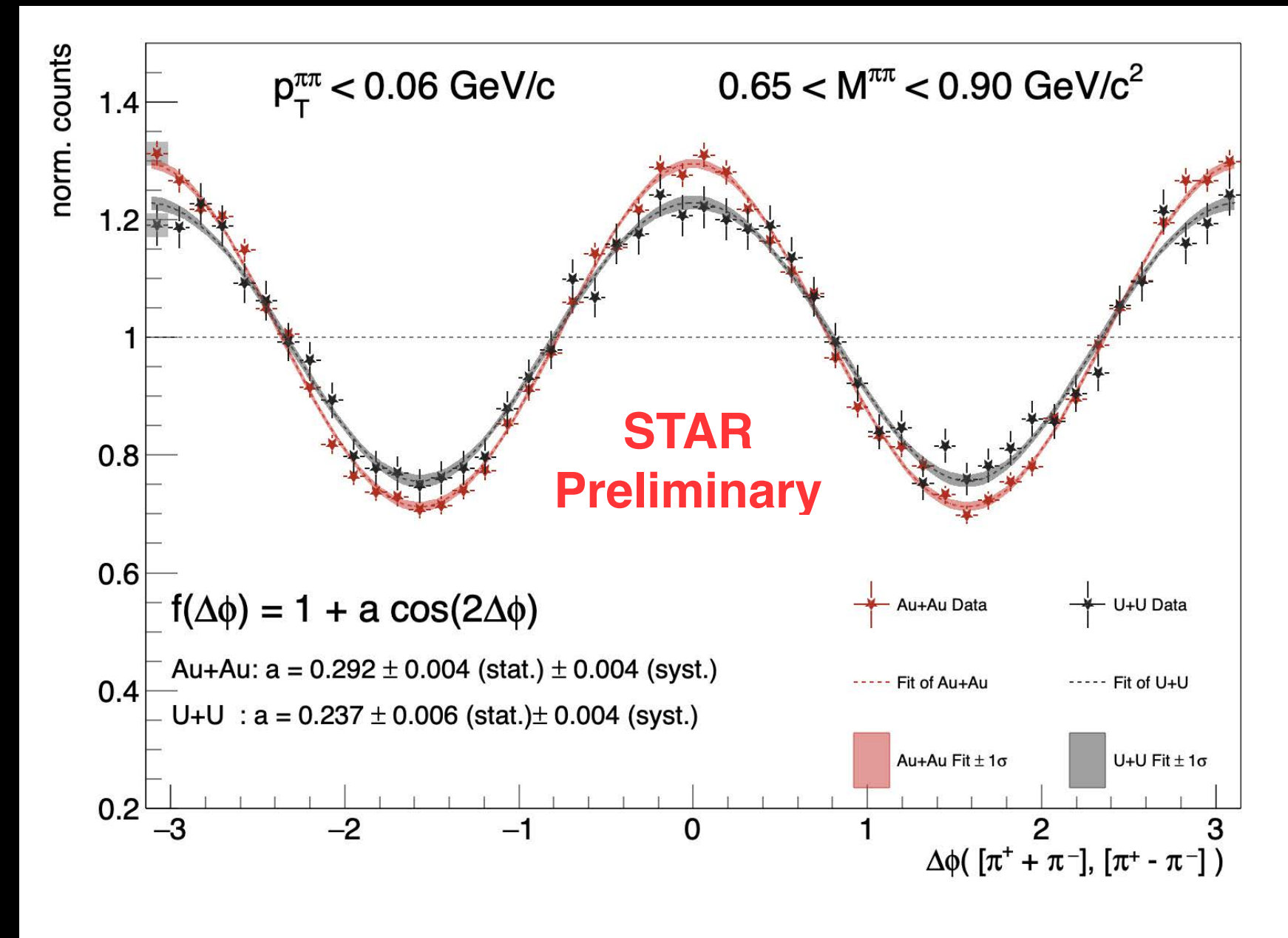
Probing nuclei with linearly polarized photons

Talk by Daniel Brandenburg (Wed 19:25) 



Interference due to two nuclei

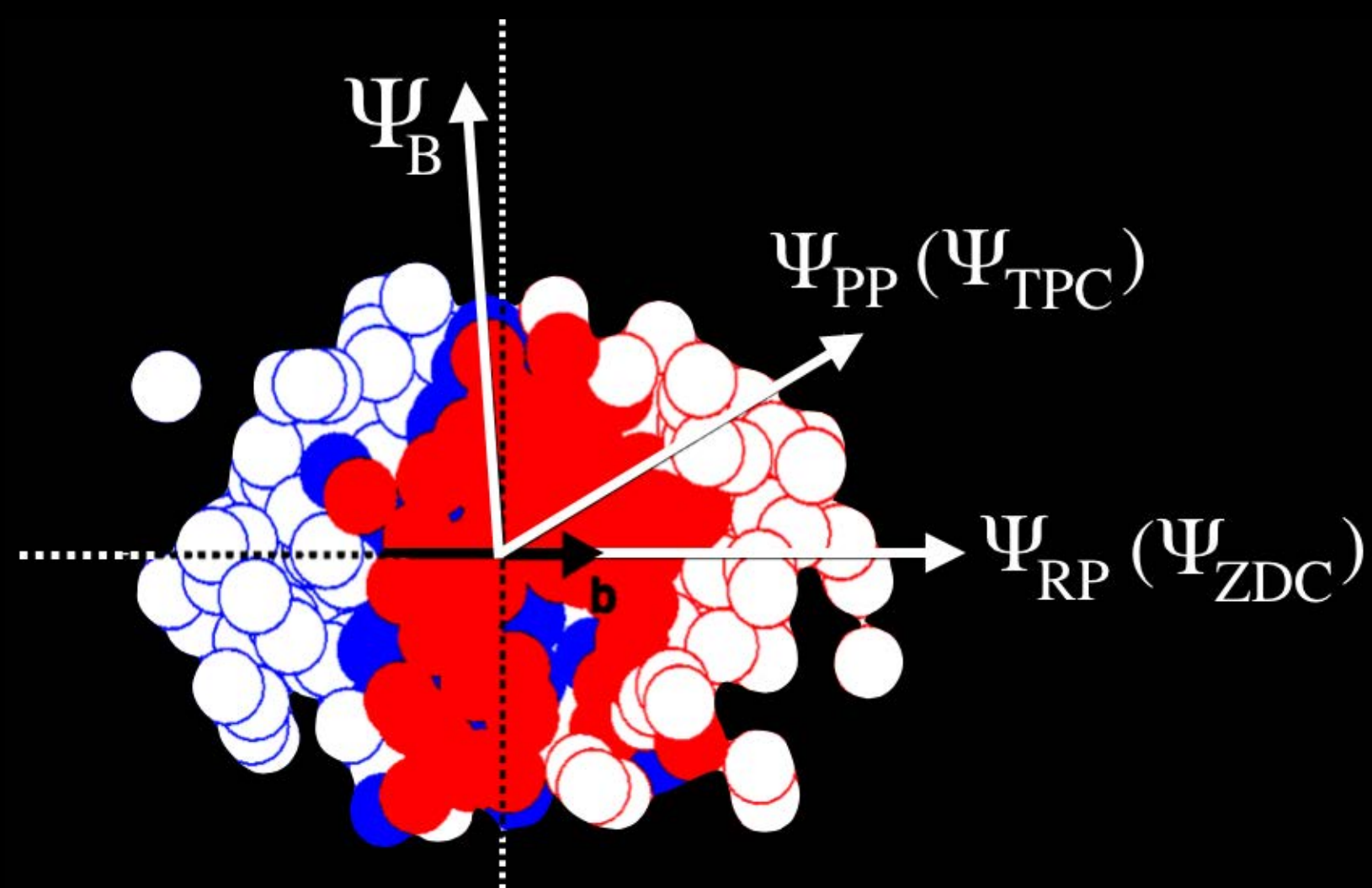
$\langle \cos(2\Delta\phi) \rangle$ modulation, $\Delta\phi$ ($[\pi^+ + \pi^-], [\pi^+ - \pi^-]$)



Observation of two-source interference effects, amplitude shows structure & sensitivity to nucleus shape

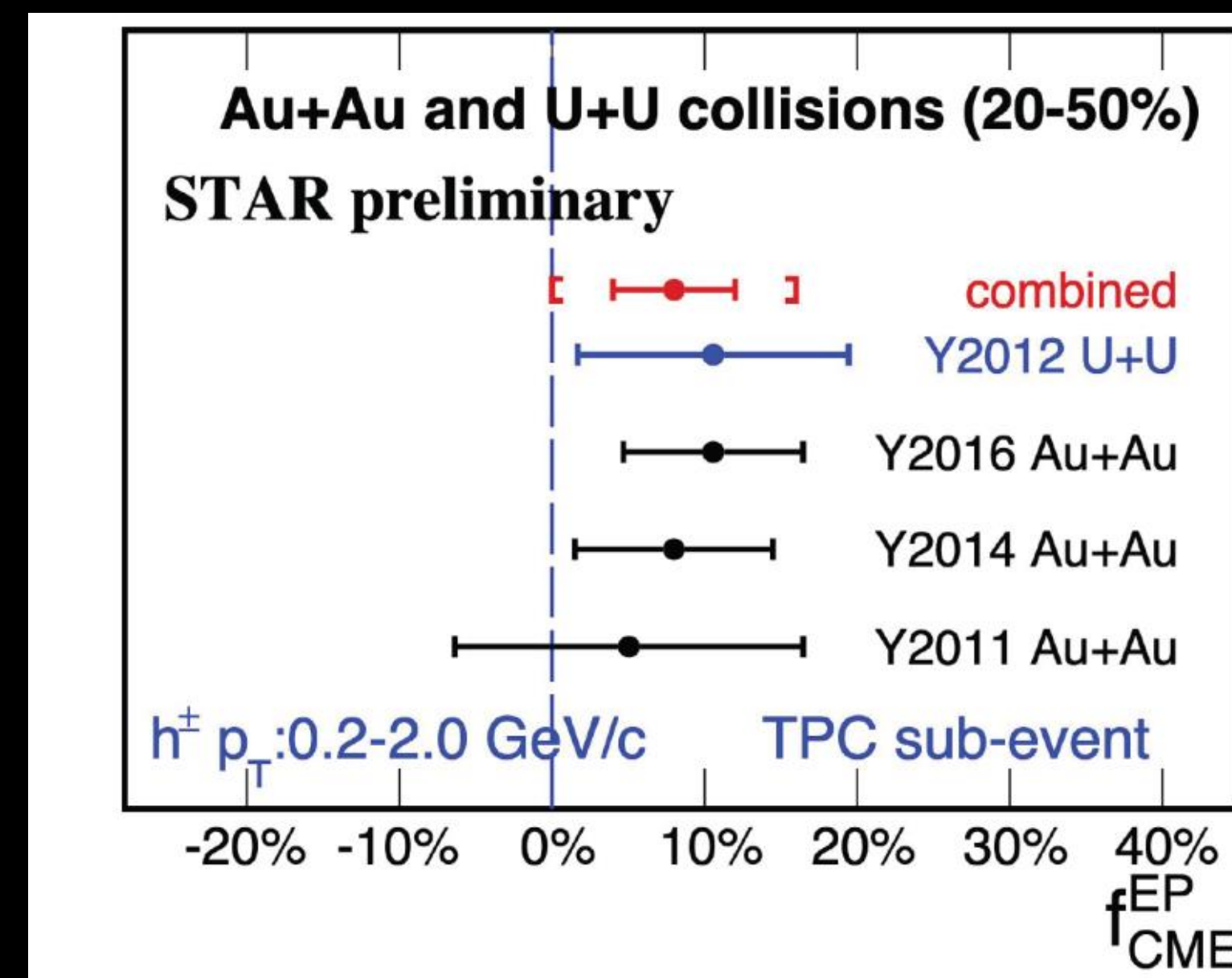
Search for the Chiral Magnetic Effect

Talk by Jie Zhao
(Thu 15:55)



$$\Delta\gamma = \Delta\gamma^{\text{sig}} + \Delta\gamma^{\text{bkg}}$$

$$f_{\text{CME}} = \frac{\Delta\gamma^{\text{sig}}}{\Delta\gamma}$$



Four equations, four unknowns:

$$\Delta\gamma^{\text{sig}}(\Psi_{\text{ZDC}}) + \Delta\gamma^{\text{bkg}}(\Psi_{\text{ZDC}}) = \Delta\gamma(\Psi_{\text{ZDC}})$$

$$\Delta\gamma^{\text{sig}}(\Psi_{\text{TPC}}) + \Delta\gamma^{\text{bkg}}(\Psi_{\text{TPC}}) = \Delta\gamma(\Psi_{\text{TPC}})$$

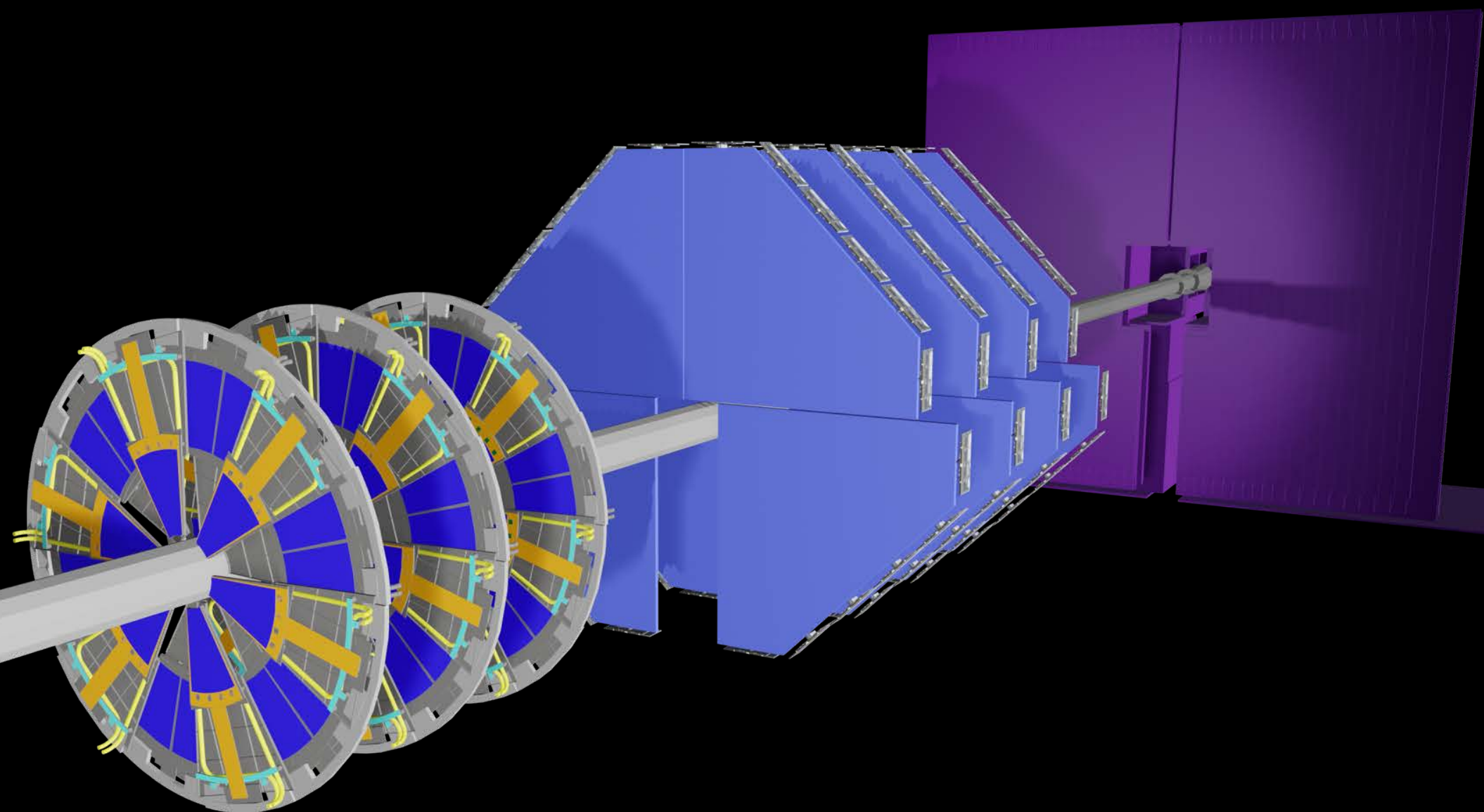
$$\Delta\gamma^{\text{bkg}}(\Psi_{\text{ZDC}})/\Delta\gamma^{\text{bkg}}(\Psi_{\text{TPC}}) = v_2(\Psi_{\text{ZDC}})/v_2(\Psi_{\text{TPC}})$$

$$\Delta\gamma^{\text{sig}}(\Psi_{\text{ZDC}})/\Delta\gamma^{\text{sig}}(\Psi_{\text{TPC}}) = v_2(\Psi_{\text{TPC}})/v_2(\Psi_{\text{ZDC}})$$

Case of CME from this analysis is $f_{\text{CME}}(\text{Ru}) > f_{\text{CME}}(\text{Zr})$

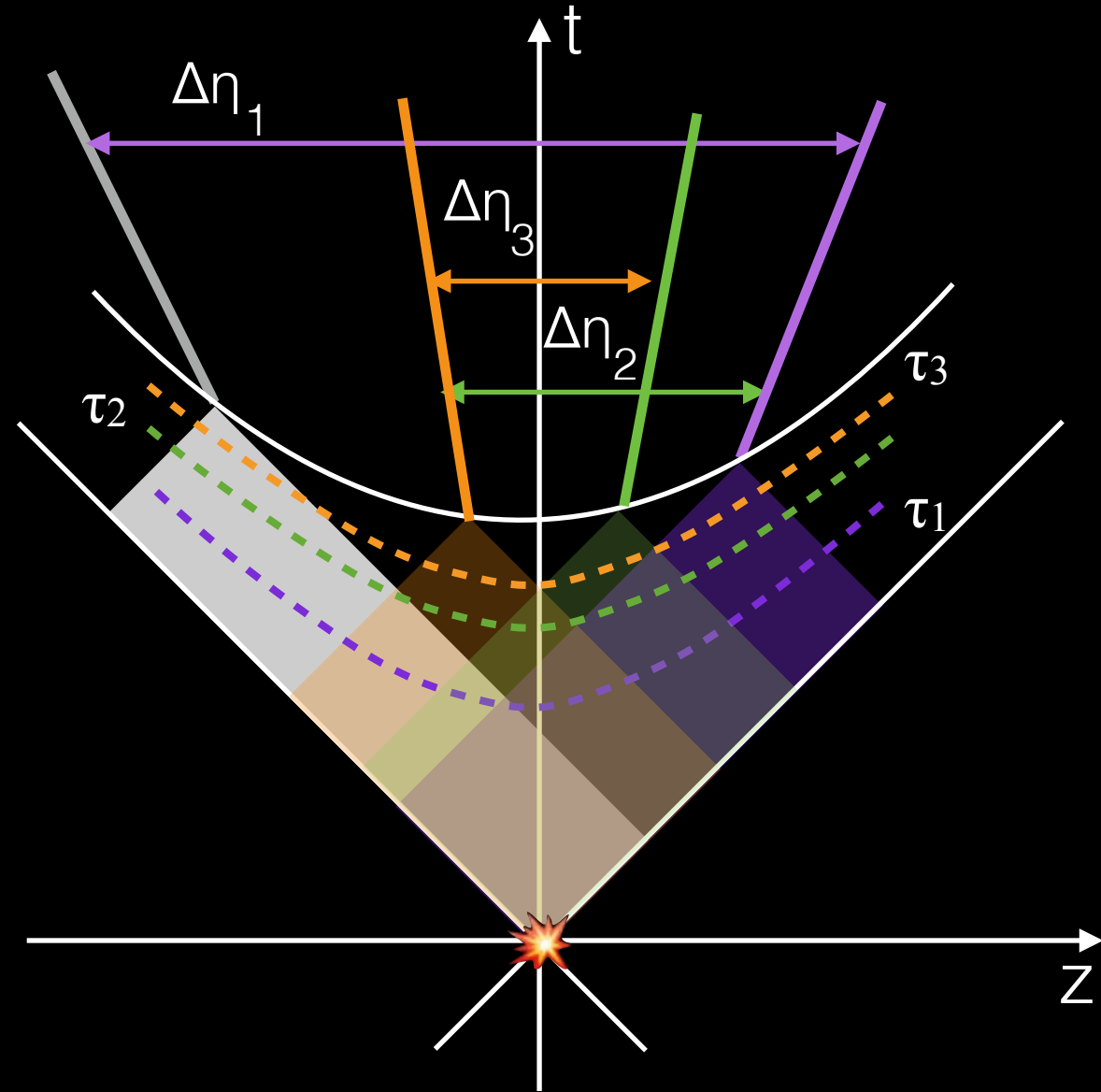


Forward upgrade and STAR beyond 2021+



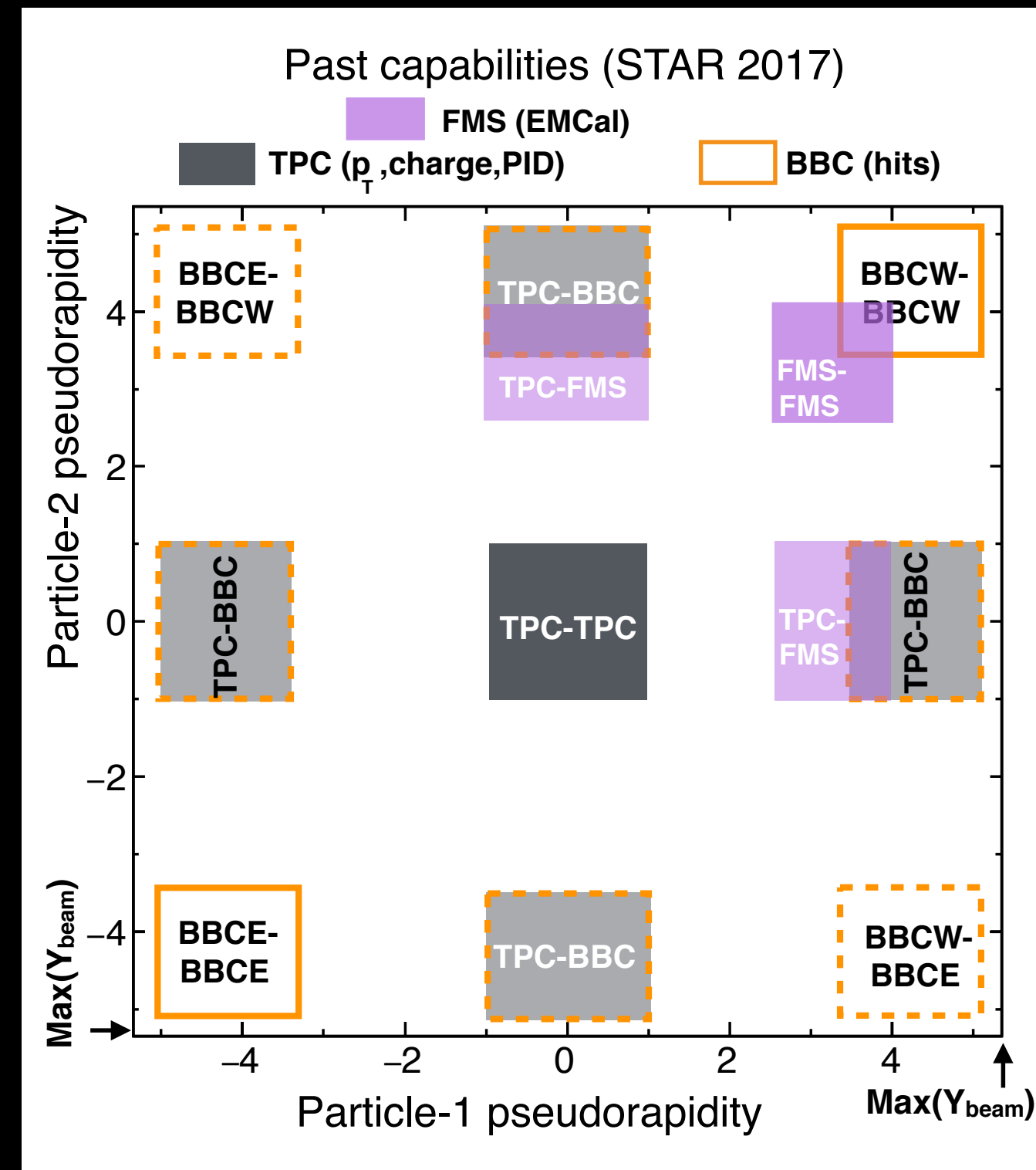
Prospects of initial state physics: why STAR and RHIC ?

Causality precludes late-time correlations to spread over large η (wide acceptance \rightarrow strength)



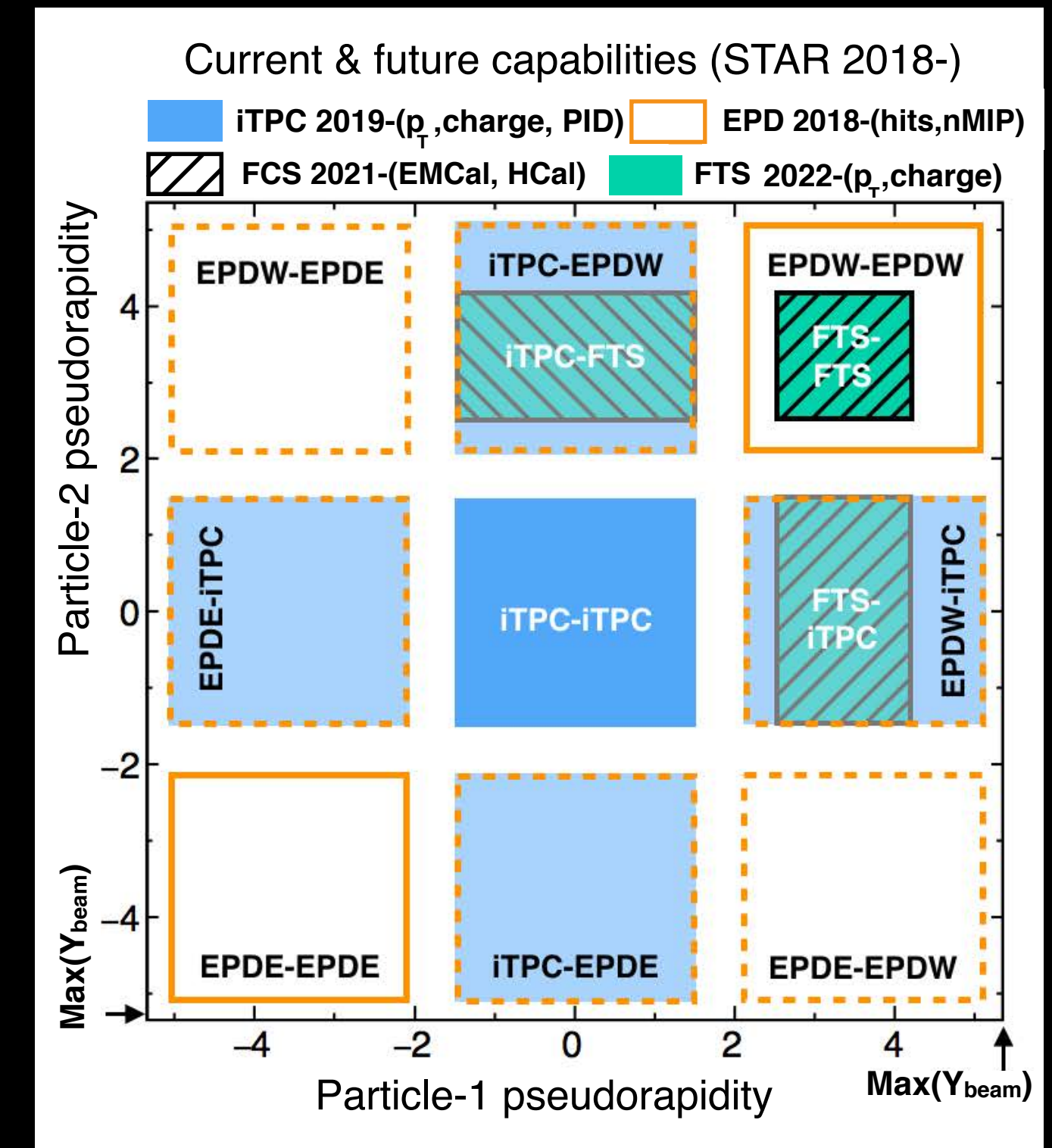
Wide range of species & energy \rightarrow strength

IS2021



BES-II
+
Forward upgrade

IS 202N



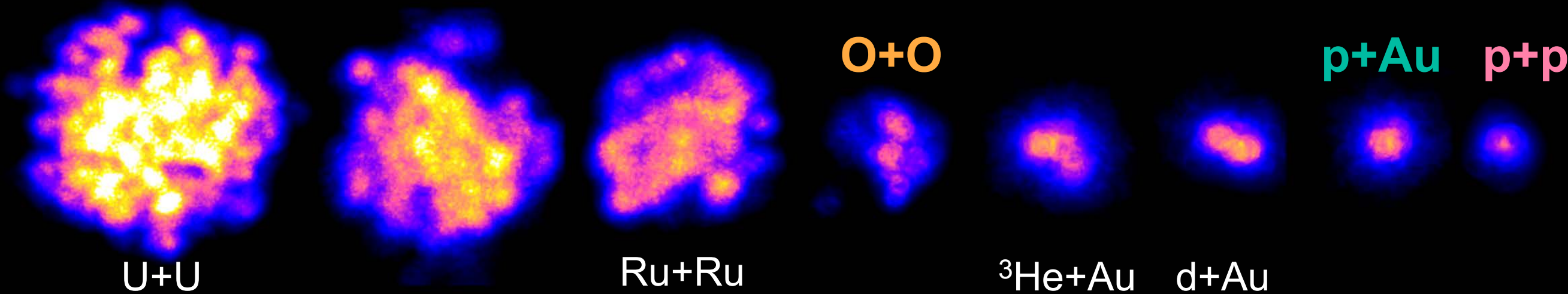
At RHIC it is possible to build detectors that can span from mid-rapidity to beam rapidity

Goal: best utilize the remaining few years of RHIC running to better understand initial stages before the EIC era

Au+Au

O+O

p+Au p+p



IP-Glasma initial energy density, $\tau=0.4$ fm, single central event, fig: Chun Shen QM19

Prospects of future measurements (A+A)

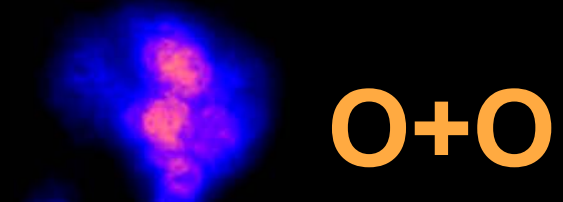
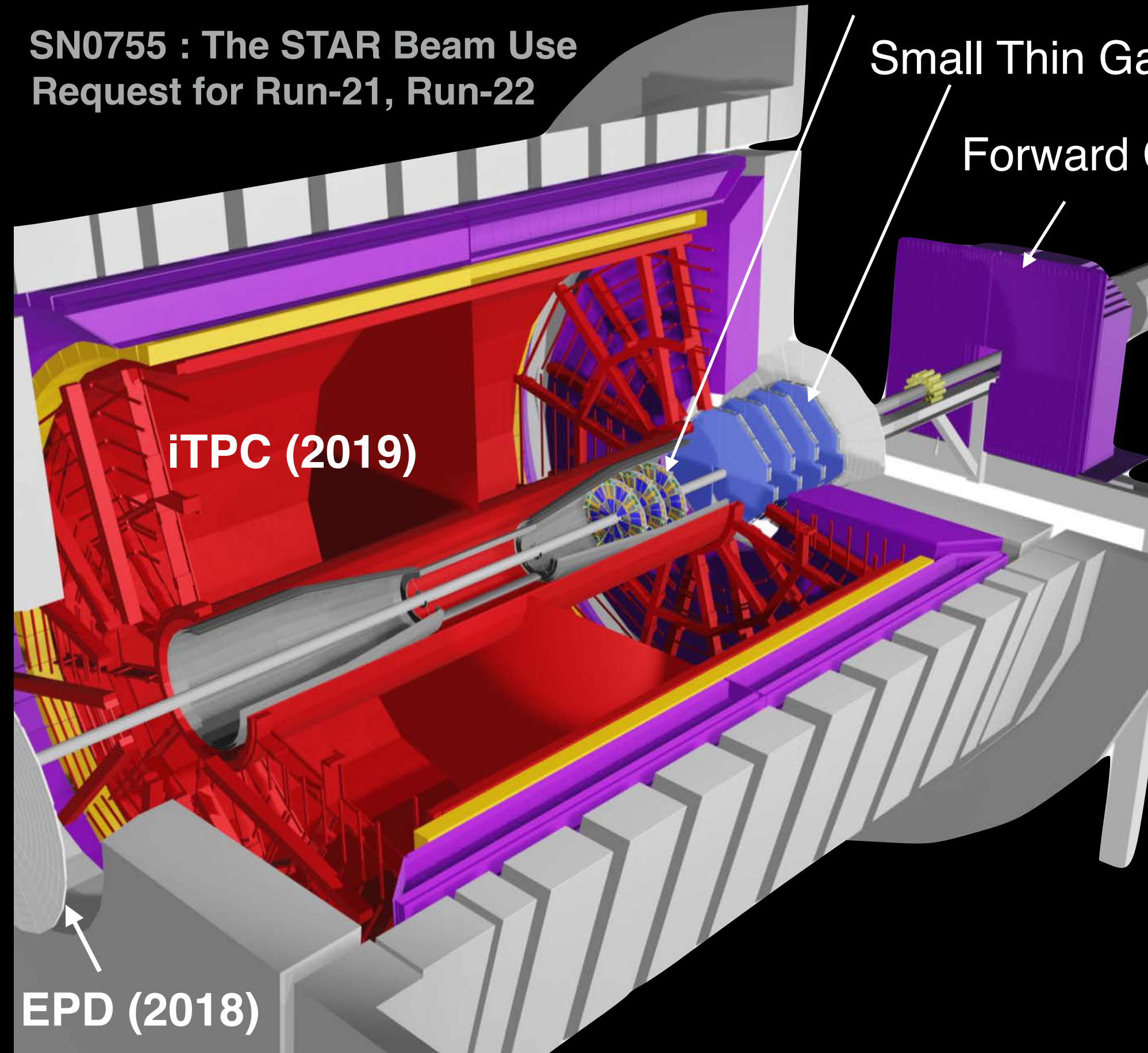
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Poster by David Kapukchyan (Sun 19:45)

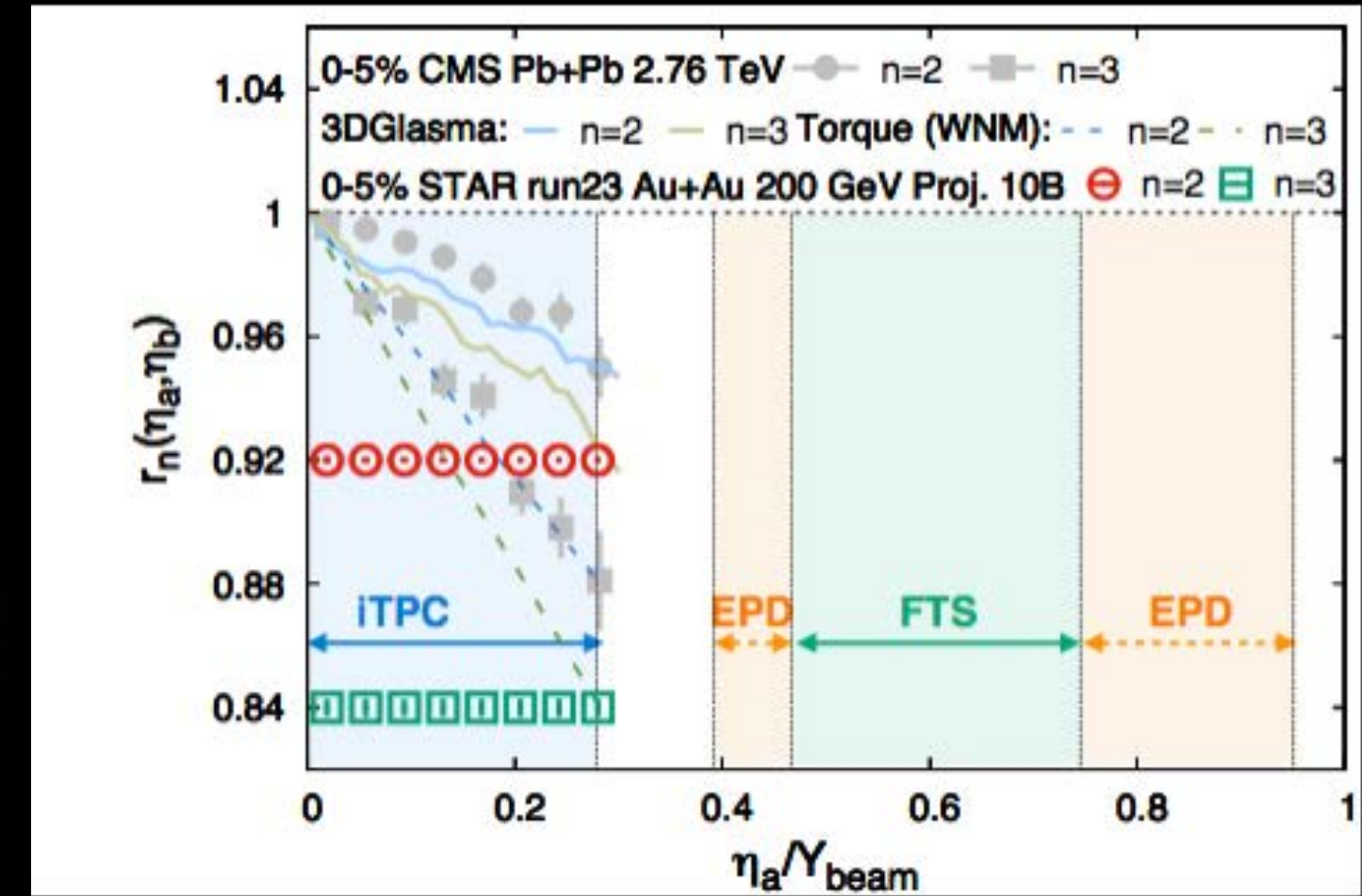
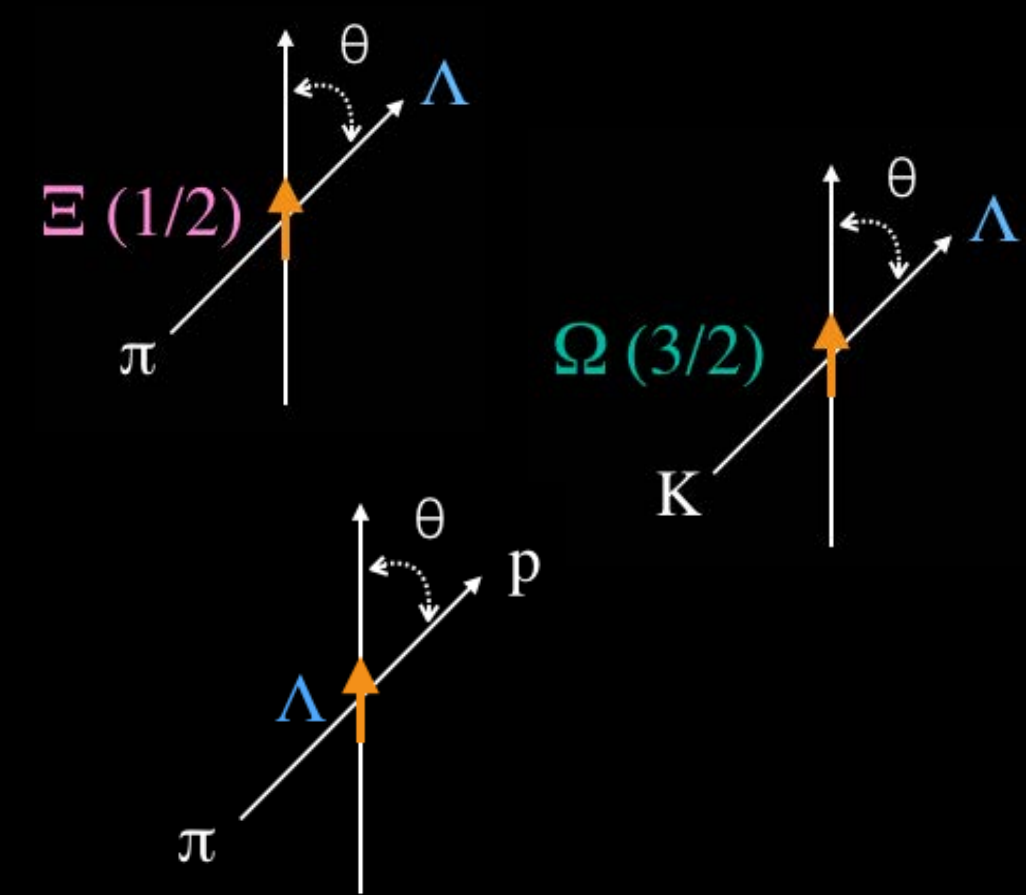
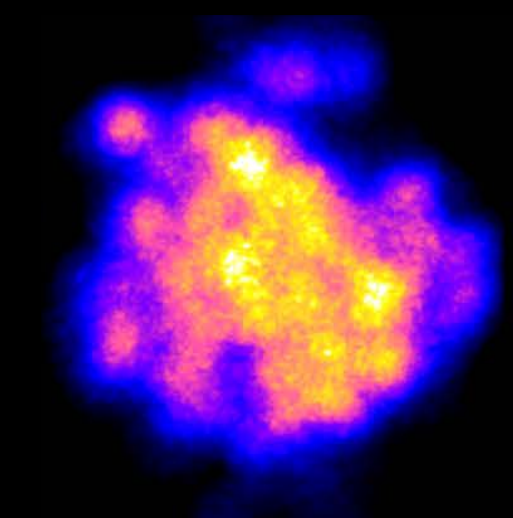


Forward Silicon Tracker (fall 2021)

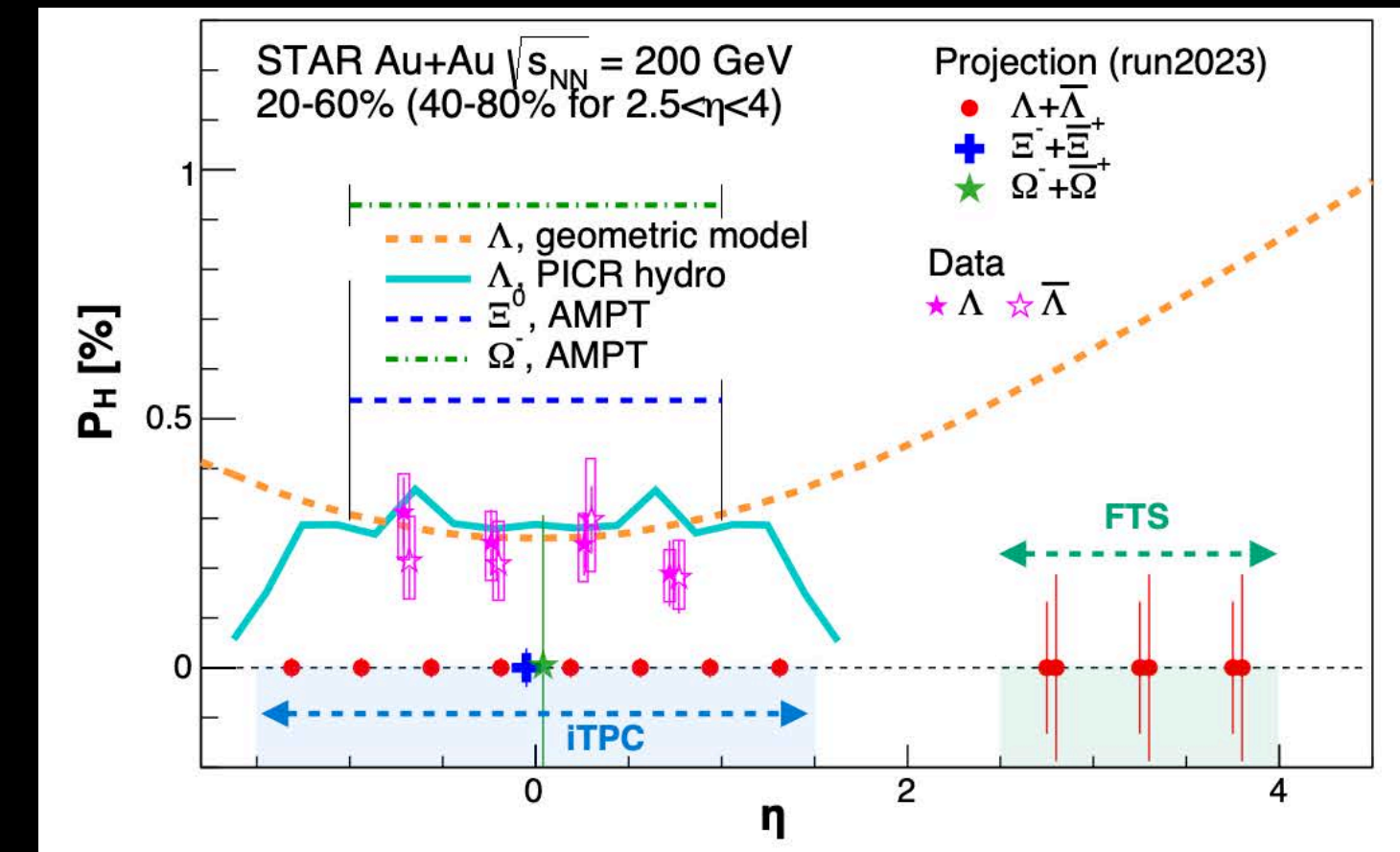
SN0755 : The STAR Beam Use Request for Run-21, Run-22



Au+Au



STAR collab., e-Print: 2012.13601 [nucl-ex]



Anticipated O+O: more insights on collectivity in small collision system
 Au+Au: 3D initial state, space-time structure of vorticity with hyperon $P_H(\eta)$

Prospects of future measurements (p+p/A)

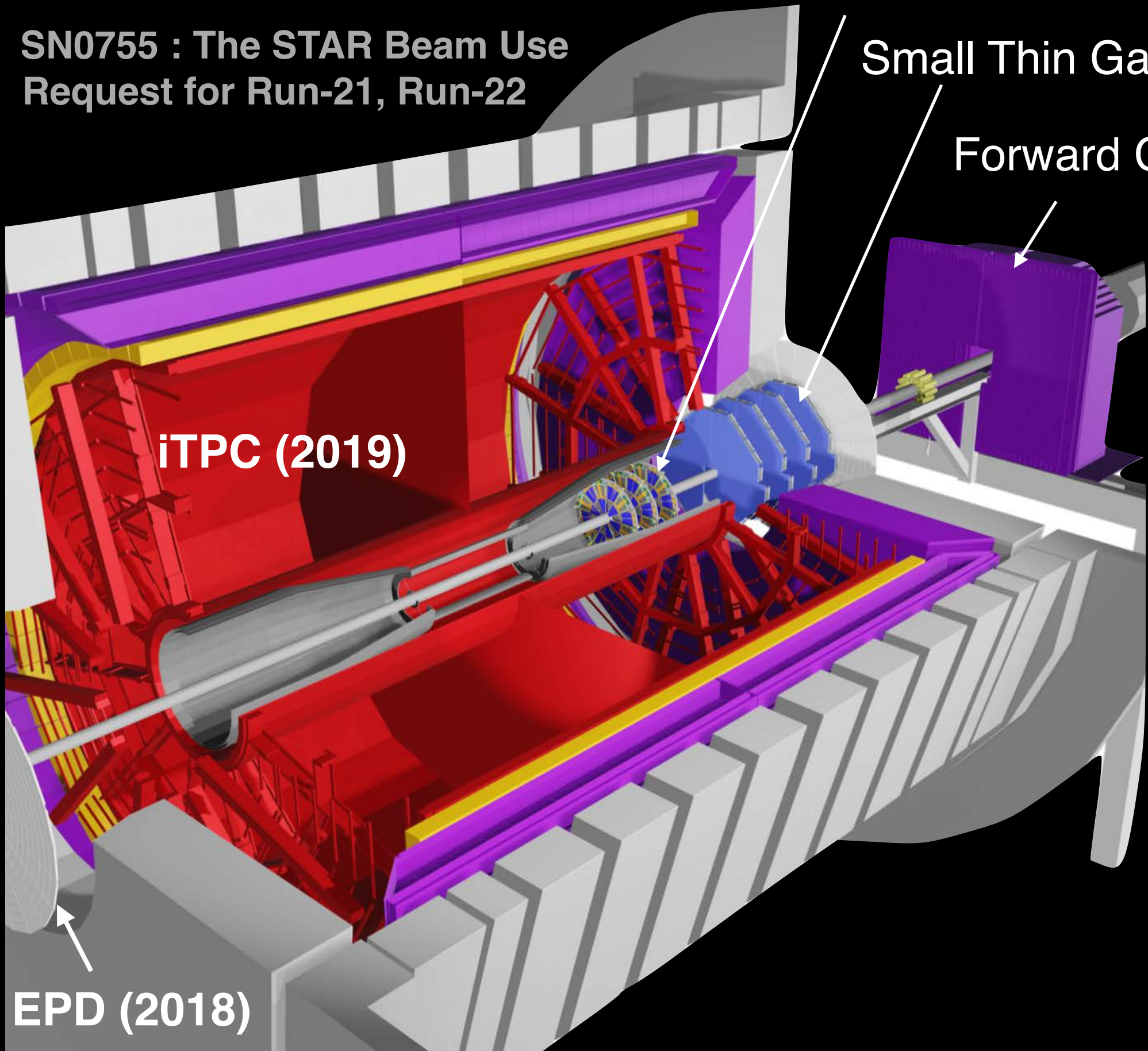
Talk by Ting Lin (Thu 16:35)

Poster by David Kapukchyan (Sun 19:45)



Forward Silicon Tracker (fall 2021)

SN0755 : The STAR Beam Use Request for Run-21, Run-22



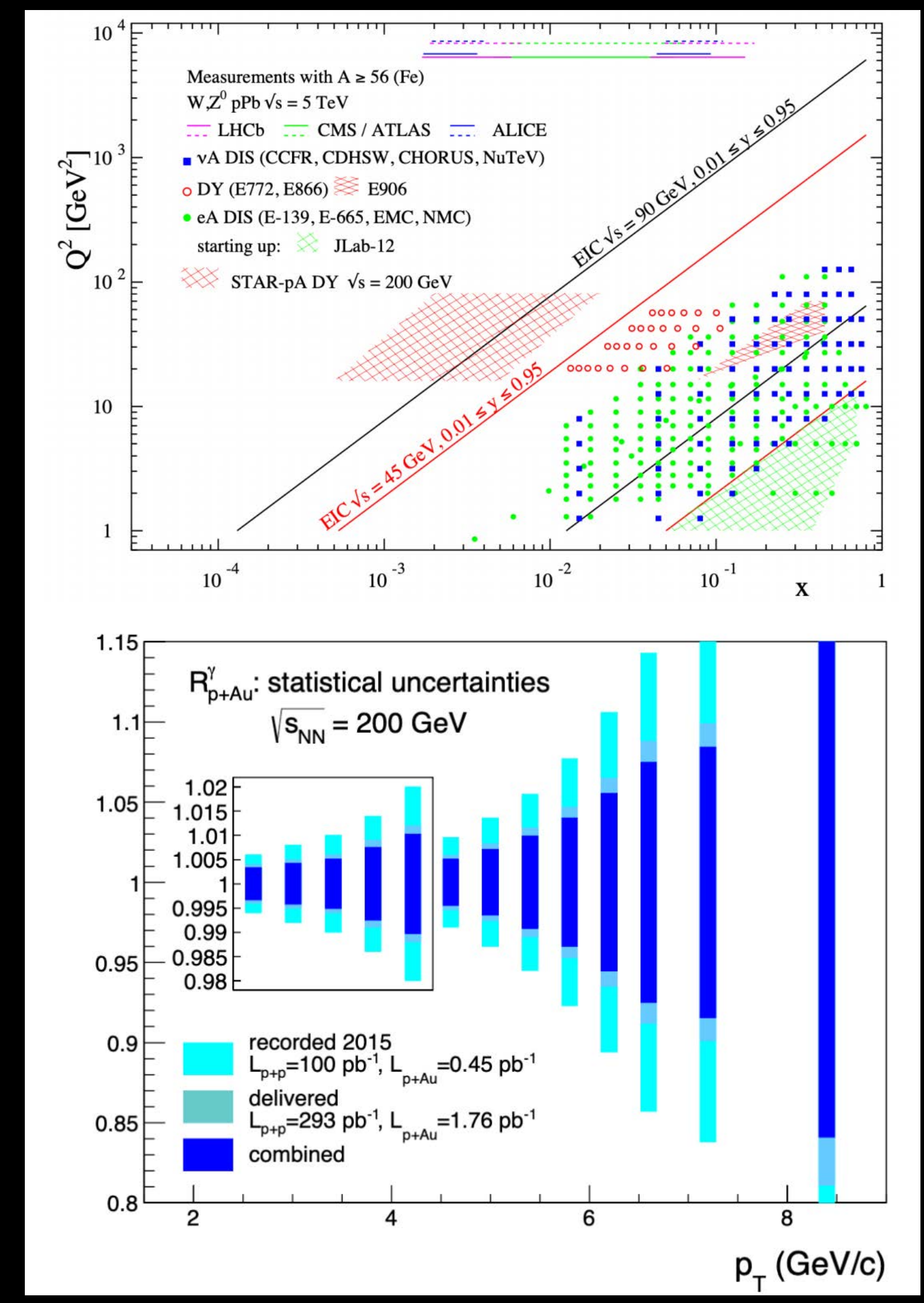
Small Thin Gap Chamber (fall 2021)

Forward Calorimetry (Jan 2021)

p+p
p+Au

Kinematics of RHIC measurements is close to EIC

Direct photon & Drell-Yan measurements with STAR forward upgrade → strong constraints on nPDF, High statistics p+p/A → more insights on small system collectivity



Summary & Take Stay Home



Interesting systematics of suppression of back-to-back forward di-hadron pairs in p+A relative to p+p

[More from Xiaoxuan Chu](#)

STAR observes consistent system independent v_3 in p/d/He+Au with three non-flow subtraction methods

[More from Shengli Huang](#)

$v_2 - \langle p_T \rangle$ correlation and higher order fluctuations of $\langle p_T \rangle$ hint sensitivity to deformed nuclear geometry

[More from Jiangyong Jia, Chunjiang Zhang \(poster\)](#)

Longitudinal de-correlation, (anti-)particle v_3 and high $p_T v_2$ revisited, many new insights

[More from Maria Stefaniak, Niseem Magdy \(poster\), Maowu Nie \(poster\)](#)

Photoproduction of J/ ψ in d+Au UPC studied with different template to extract the coherent component

[More from Xiaofeng Wang](#)

Observation of two-source interference effects in polarized γ +A collisions, sensitive to colliding nuclei

[More from Daniel Brandenburg](#)

First observation of azimuthal angular modulations of di-electron in peripheral Au+Au at 54.4 GeV

[More from Xiaofeng Wang](#)

Isobar results to make decisive test of CME is coming soon, new techniques, prospects beyond isobar

[More from Jie Zhao](#)

The STAR Forward Upgrade is progressing very well, initial state physics will be of paramount interest

[More from Ting Lin, David Kapukchyan \(poster\)](#)