The 27th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions

14–19 May | Palazzo del Cinema

Lido di Venezia, Italy

Highlights from STAR

Zhenyu Ye for the STAR Collaboration

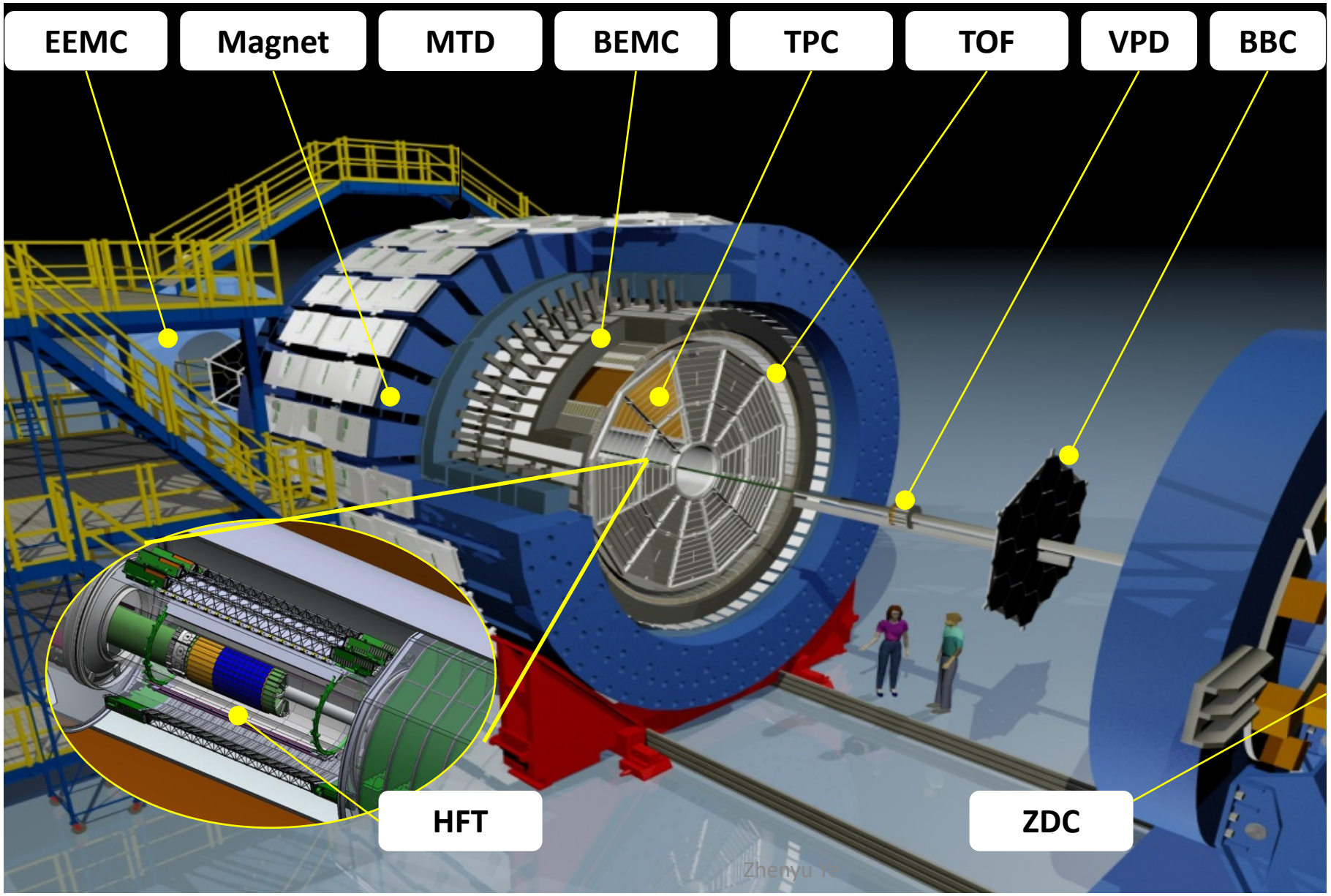
University of Illinois at Chicago

UIC The University of Illinois at Chicago

U.S. DEPARTMENT OF ENERGY | Office of Science

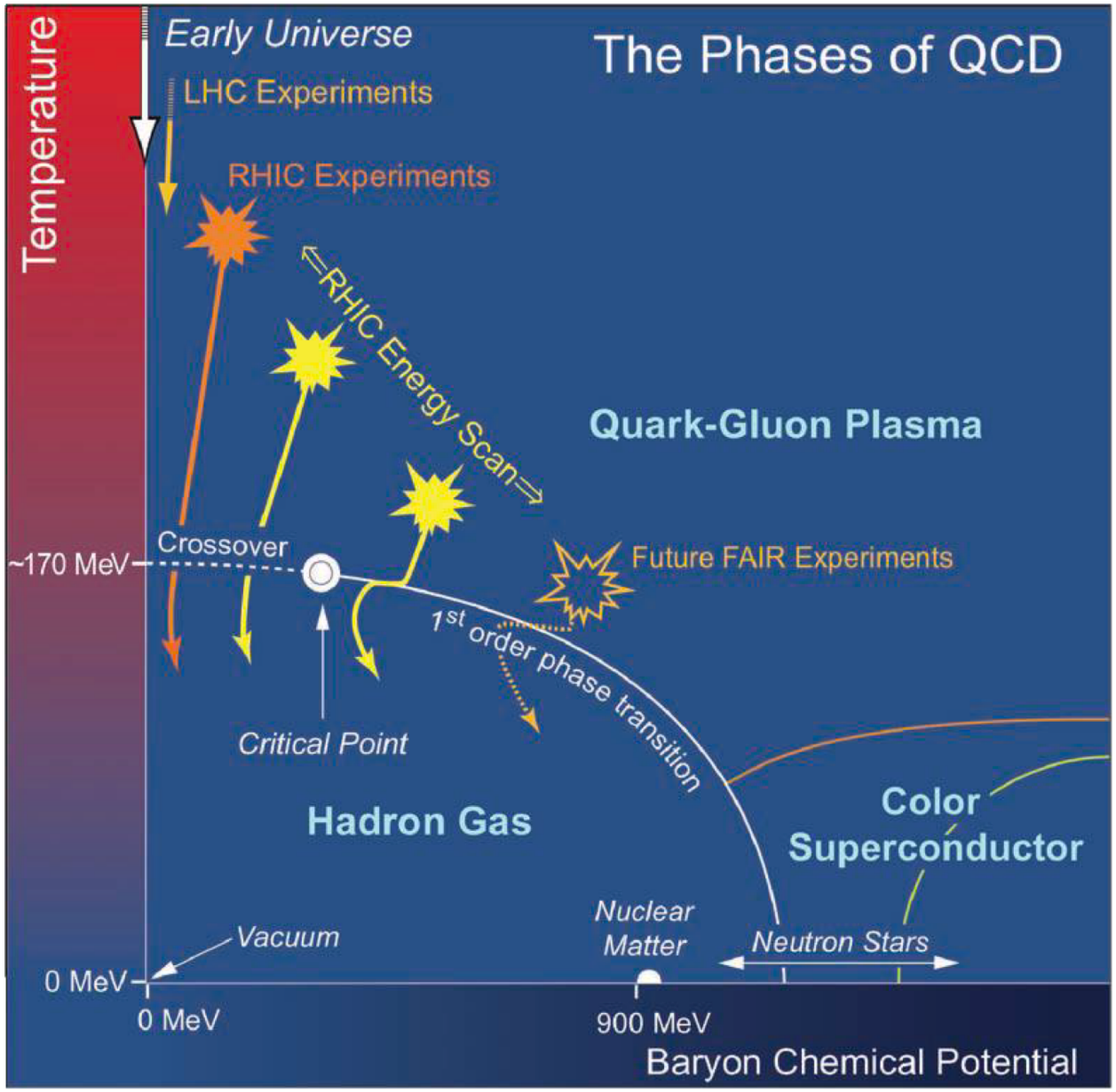
華中師範大學 HuaZhong Normal University

STAR Detector



- **Tracking and PID (full 2π)**
  TPC: $|\eta| < 1$
  TOF: $|\eta| < 1$
  BEMC: $|\eta| < 1$
  EEMC: $1 < \eta < 2$
  HFT (2014-2016): $|\eta| < 1$
  MTD (2014+): $|\eta| < 0.5$
- **MB trigger and event plane reconstruction**
  BBC: $3.3 < |\eta| < 5$
  EPD (2018+): $2.1 < |\eta| < 5.1$
  FMS: $2.5 < \eta < 4$
  VPD: $4.2 < |\eta| < 5$
  ZDC: $6.5 < |\eta| < 7.5$
- **On-going/future upgrades**
  iTPC (2019+): $|\eta| < 1.5$
  eTOF (2019+):$-1.6 < \eta < -1$
  FCS (2021+): $2.5 < \eta < 4$
  FTS (2021+): $2.5 < \eta < 4$

Introduction



RHIC Top Energy

p+p, p+Al, p+Au, d+Au, ^{3}He+Au, Cu+Cu, Cu+Au, Ru+Ru, Zr+Zr, Au+Au, U+U

- QCD at high energy density/temperature
- Properties of QGP, EoS

Beam Energy Scan

Au+Au $\sqrt{s_{NN}}$ =7.7-62 GeV

- QCD phase transition
- Search for critical point
- Turn-off of QGP signatures

Fixed-Target Program

Au+Au $\sqrt{s_{NN}}$=3.0-7.7 GeV

- High baryon density regime with μ_B~420-720 MeV

Outline

1. Open heavy flavor - D^0 v_1, D^0 R_{AA} and R_{CP}, Λ_c
2. Quarkonium - Υ R_{AA}
3. Jet modification and high-p_T hadrons - di-jet imbalance, di-hadron correlation

4. Chirality, vorticity and polarization effects - Λ polarization, ϕ polarization, CME, CMW

5. Initial state physics and approach to equilibrium - v_2 and v_3 fluctuations
6. Collectivity in small systems - v_2 in p+Au and d+Au
7. Collective dynamics - longitudinal decorrelation, identified particle v_1
8. High baryon density and astrophysics - v_1 from fixed target

9. Correlations and fluctuations - femtoscopy
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11. Thermodynamics and hadron chemistry - triton, hypertriton mass

12. Upgrades - BES-II and forward upgrades

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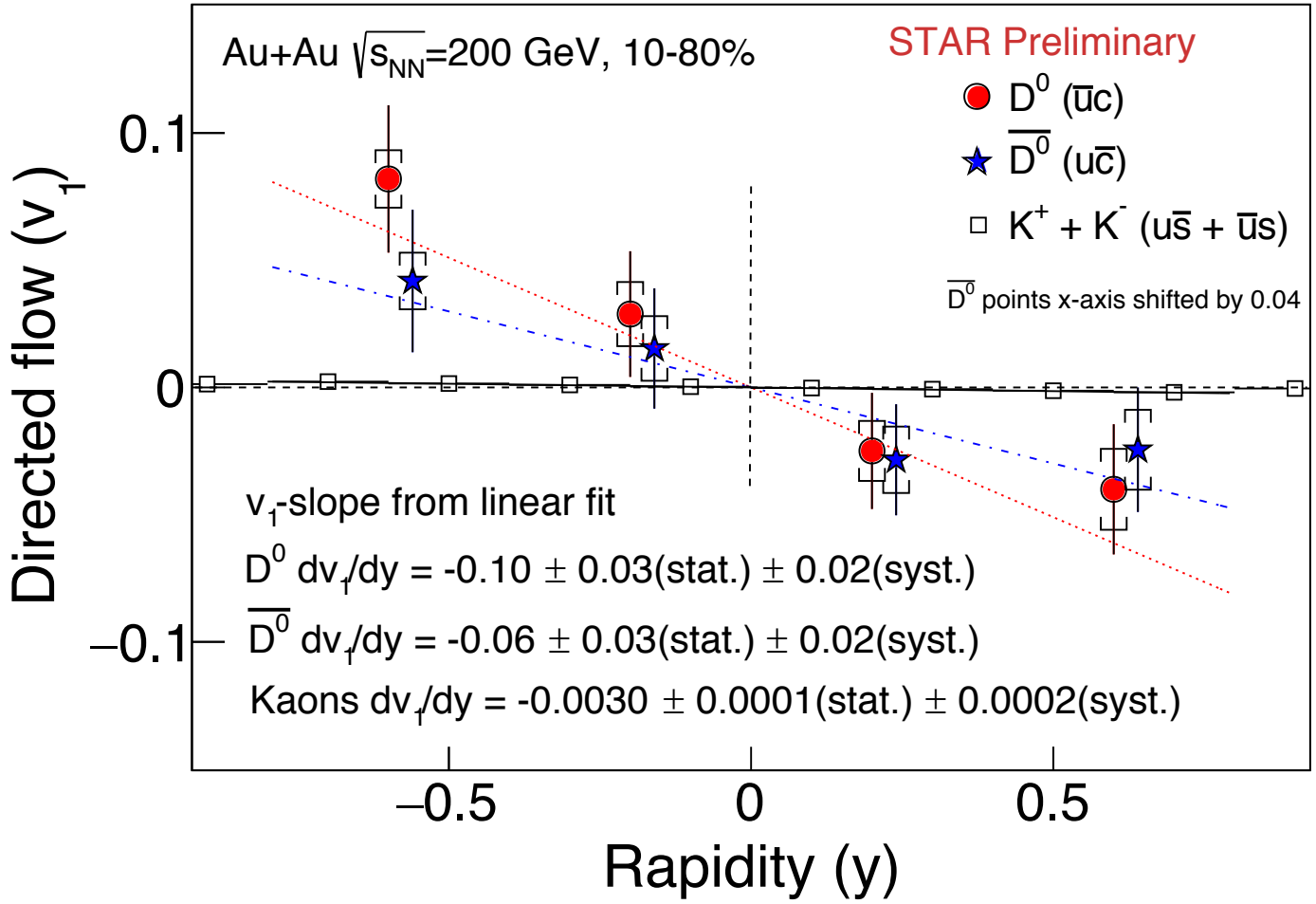
D^0 Directed Flow in 200 GeV Au+Au Collisions



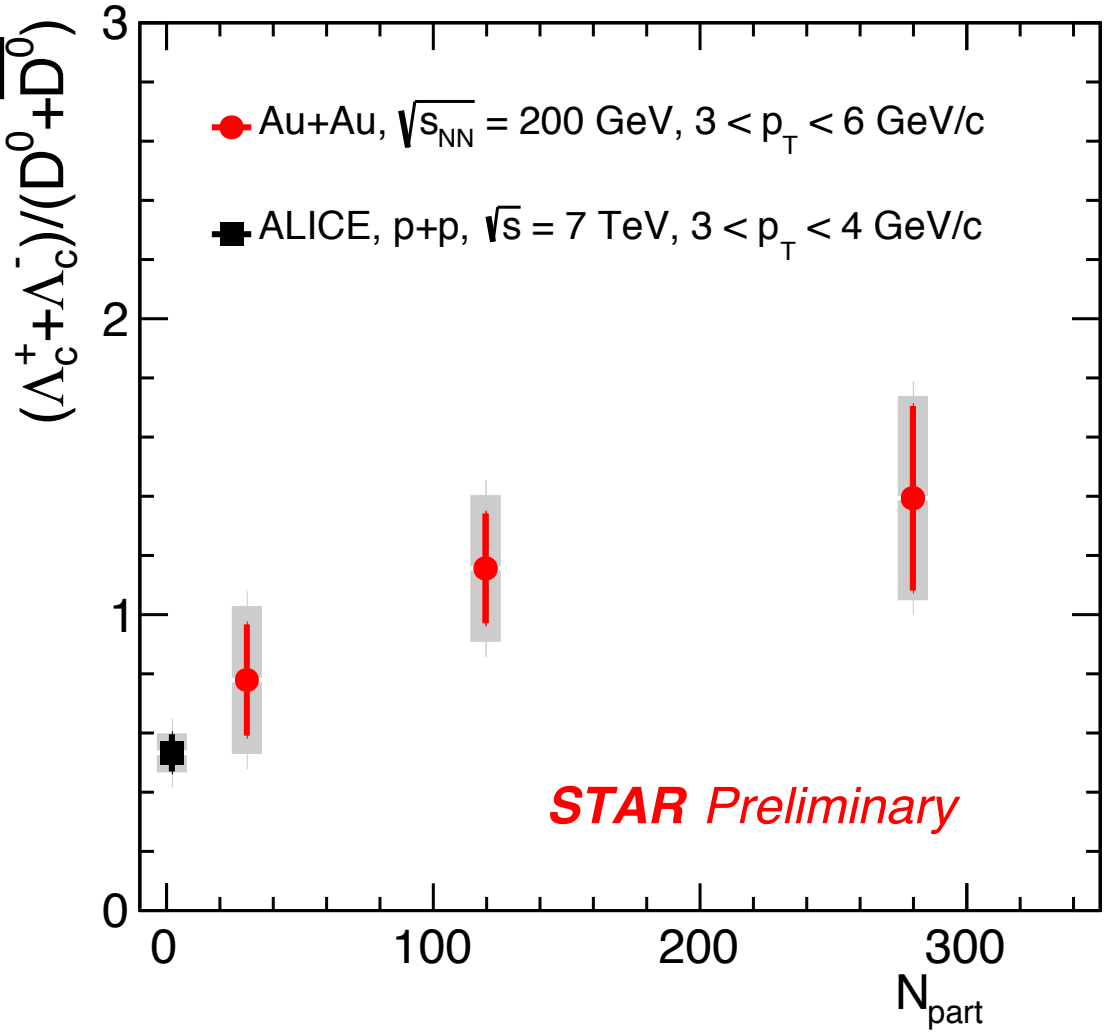
- First evidence for non-zero $D^0 v_1$ from 2014+2016 Heavy Flavor Tracker (HFT) data:

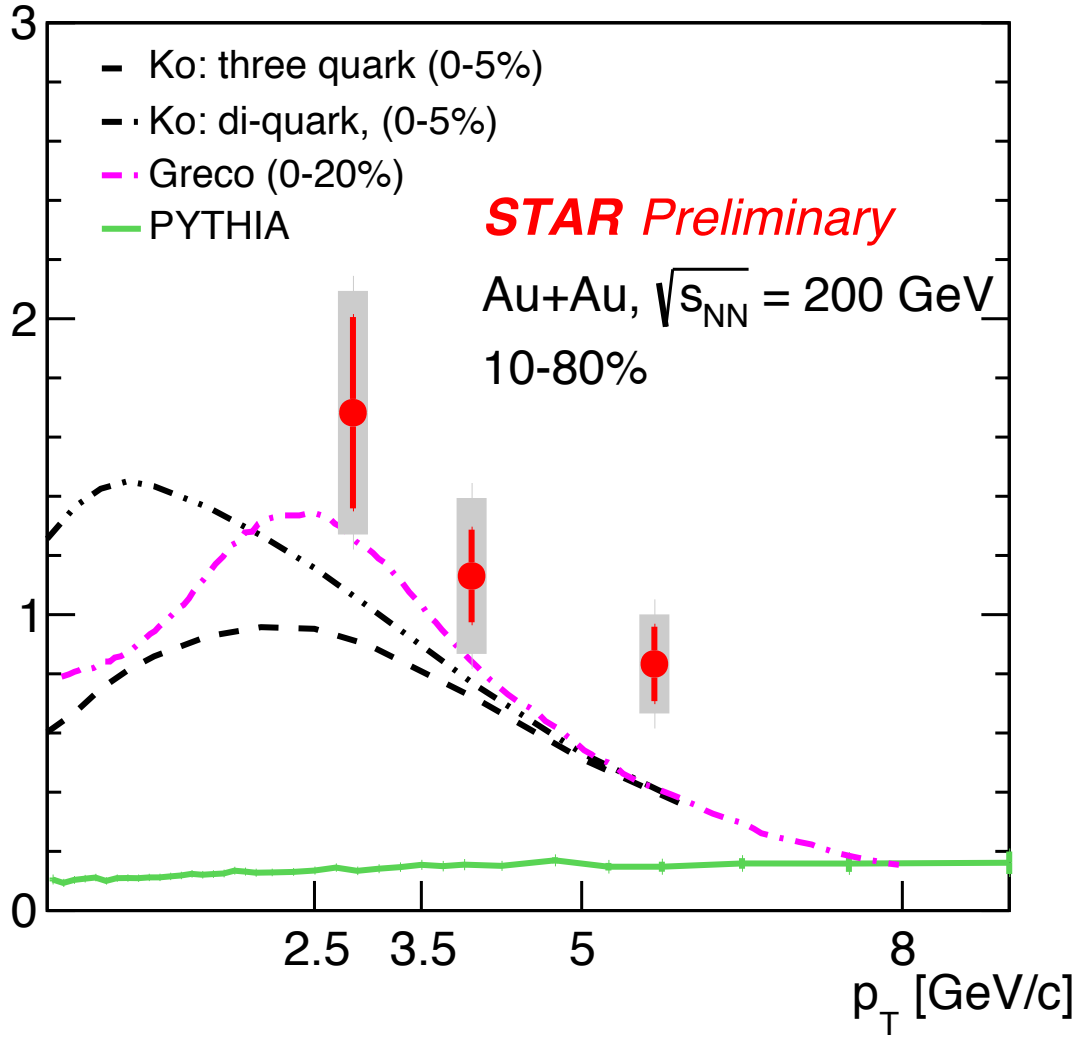
$$\boldsymbol{D^0 + \overline{D^0}\ dv_1/dy = -0.081 \pm 0.021(stat.) \pm 0.017(syst.)}$$

probe the initial tilt of the source and the initial EM field

Subhash Singha
#540 May 16, 9:40

Λ_c Enhancement in 200 GeV Au+Au Collisions

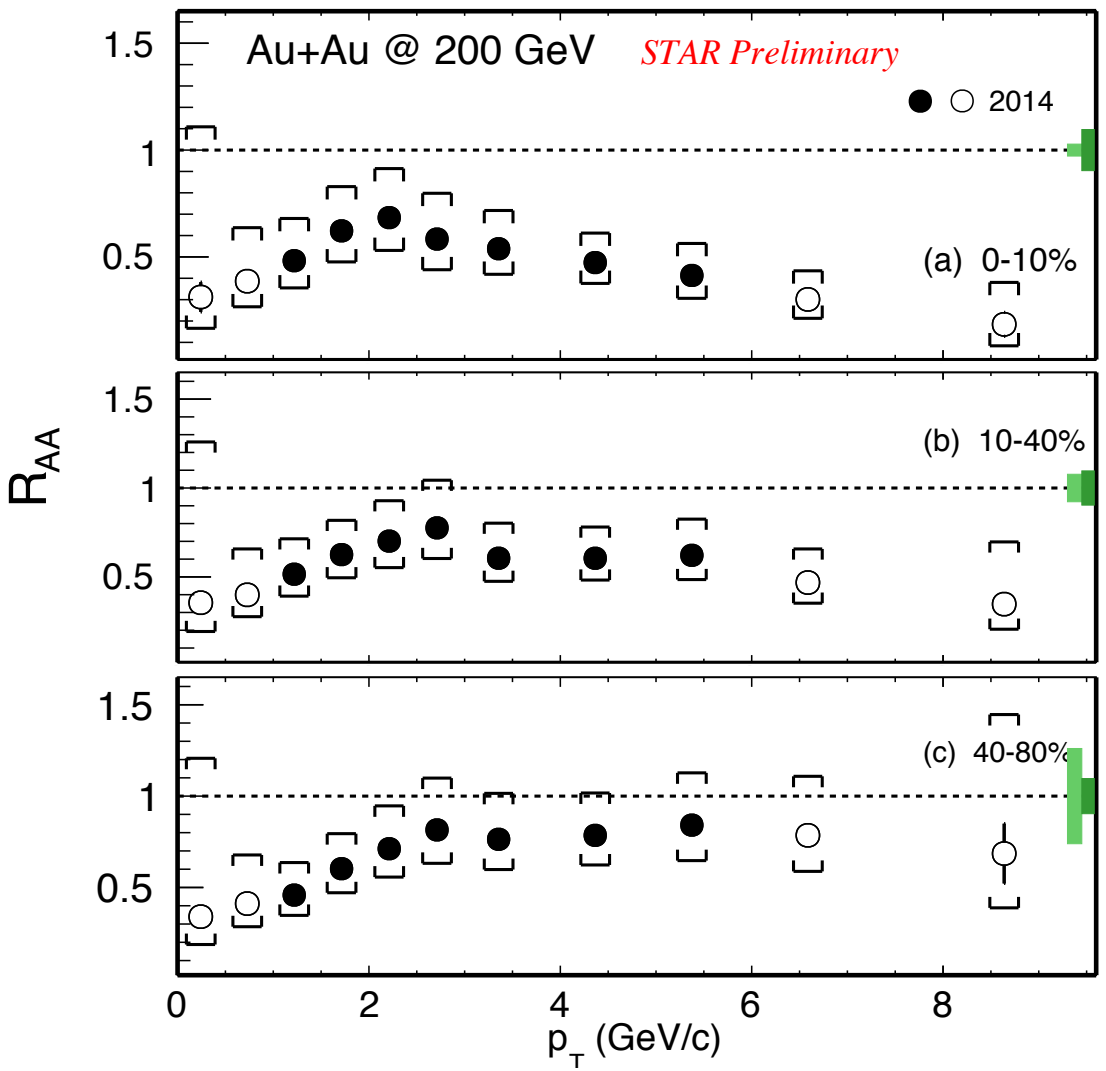


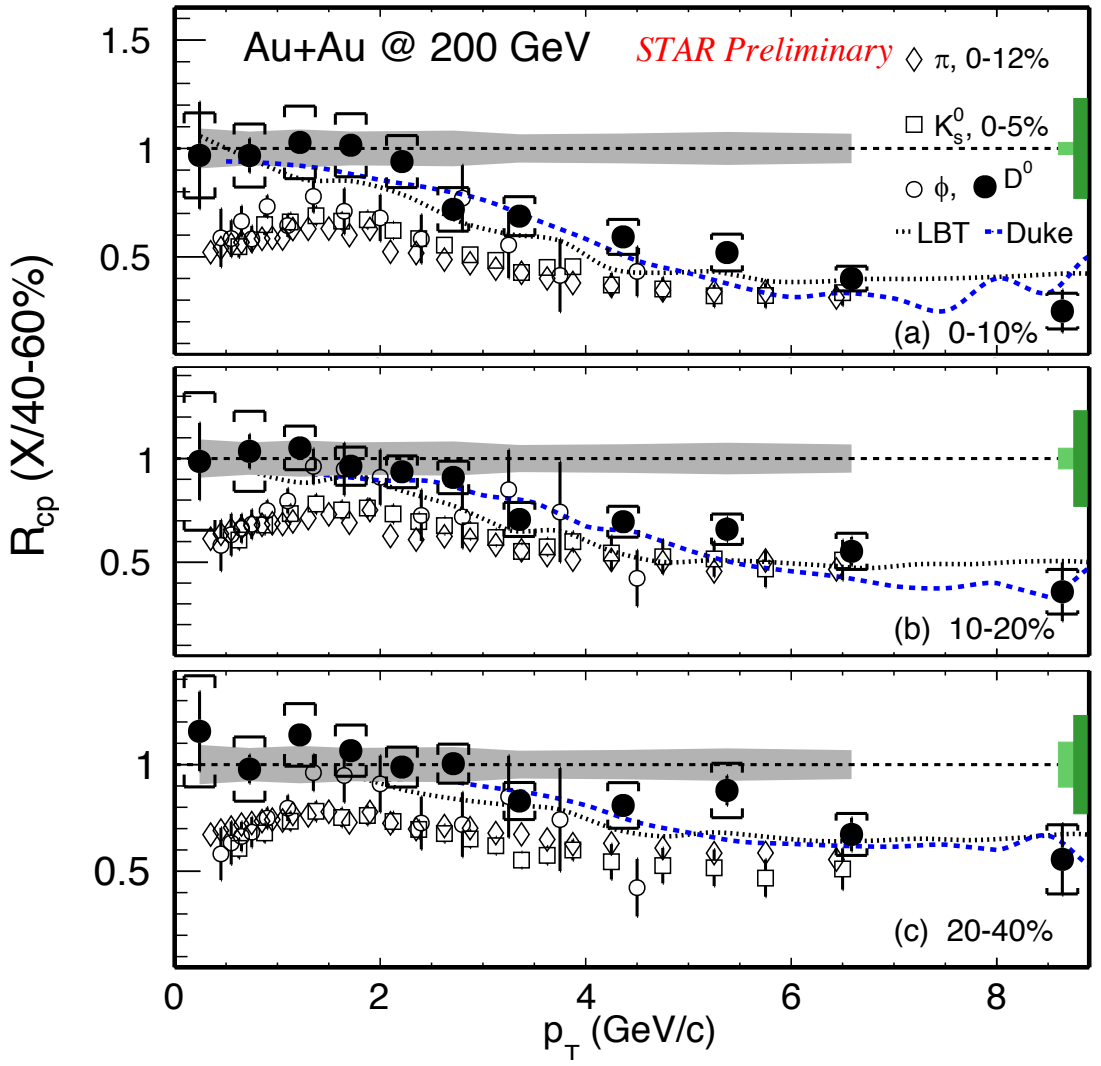


- Λ_c enhancement increases towards more central Au+Au collisions
- Large Λ_c contribution to the total charm cross-section in HI collisions

Sooraj Radhakrishnan
#546 May 15, 15:40

D^0 Nuclear Modification Factors in 200 GeV Au+Au Collisions

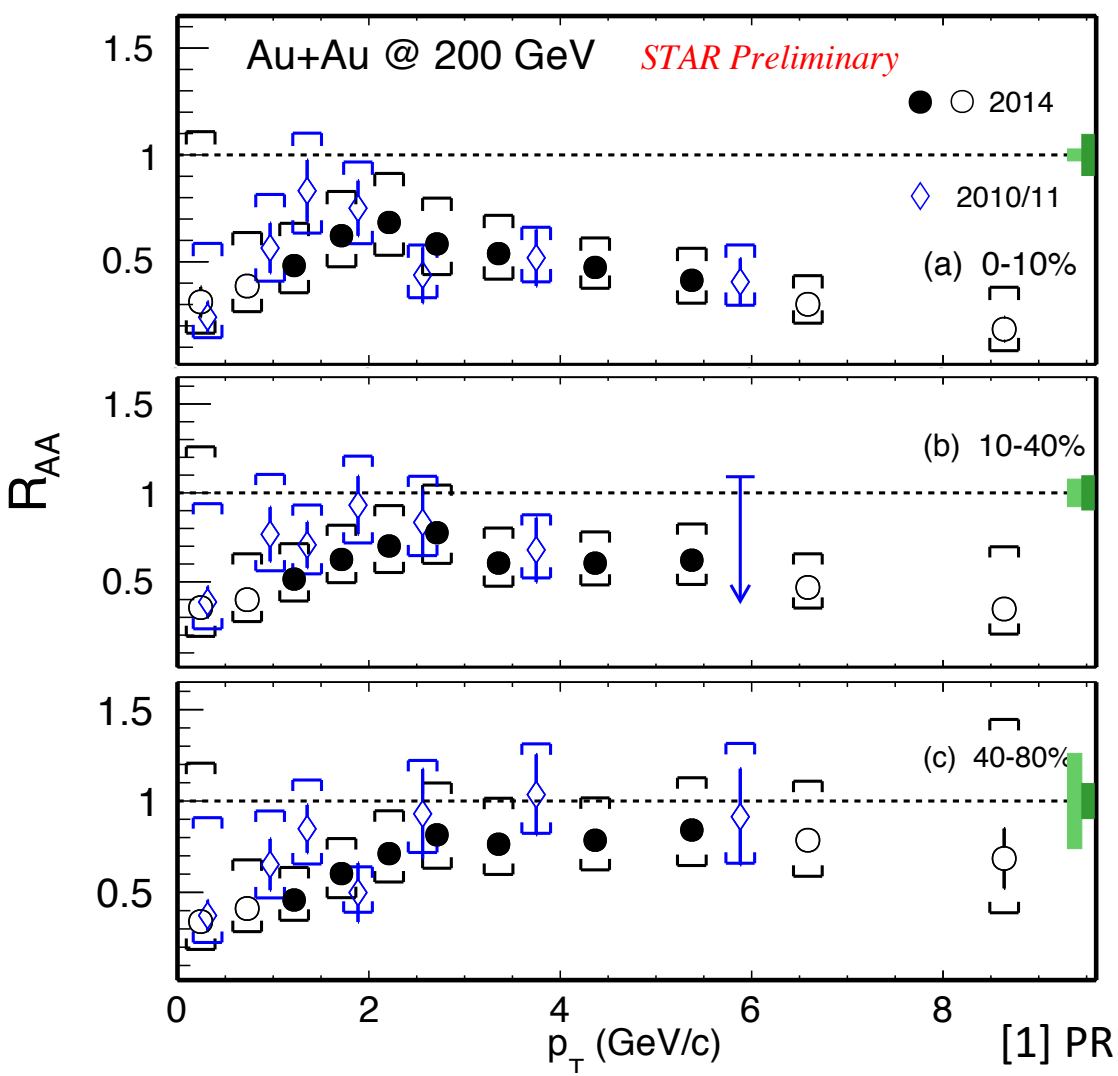


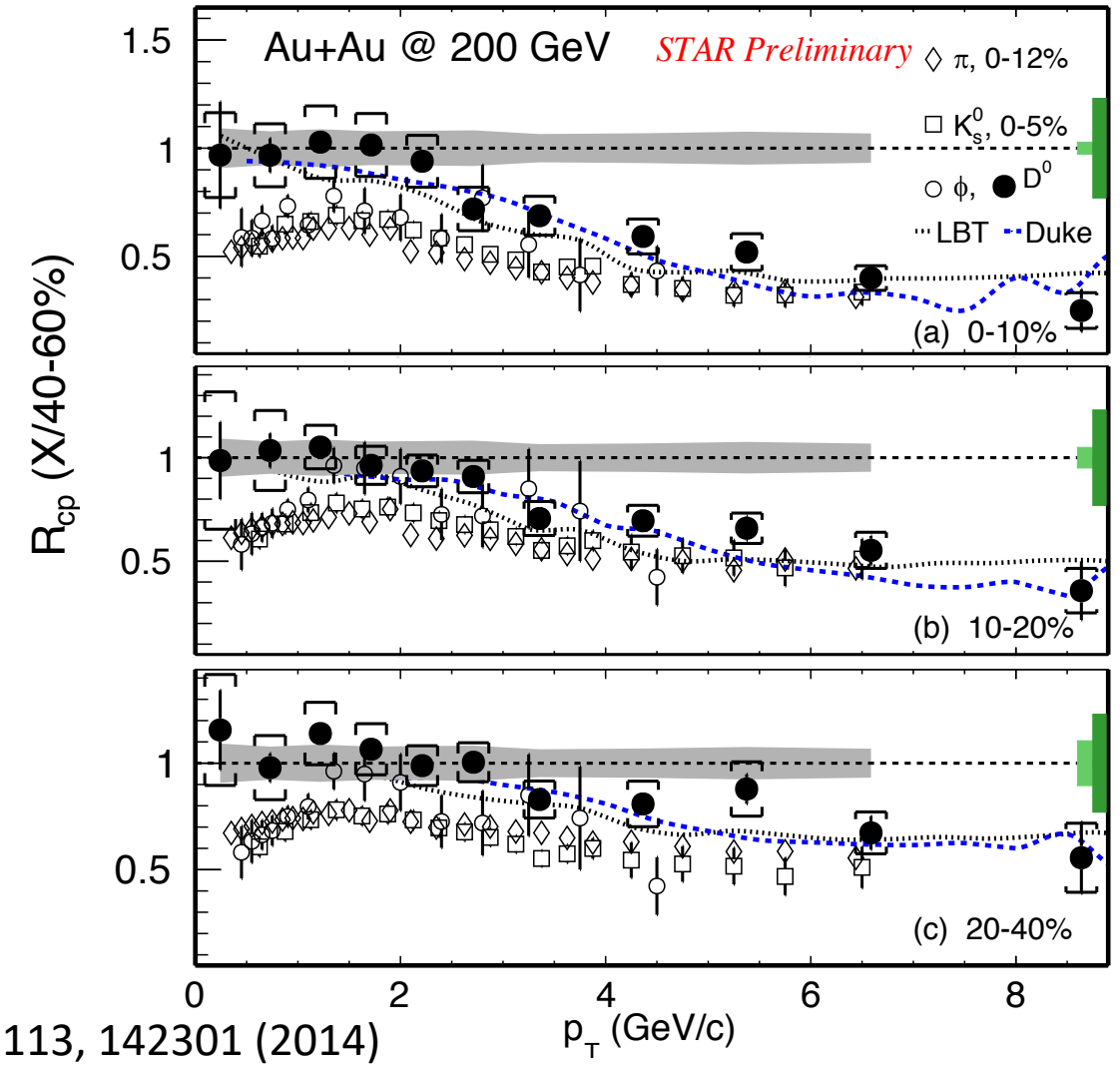


- Significant suppression at low p_T with no strong centrality dependence
- Suppression at high p_T descreases towards more peripheral collisions

Sooraj Radhakrishnan
#546 May 15, 15:40

D^0 Nuclear Modification Factors in 200 GeV Au+Au Collisions

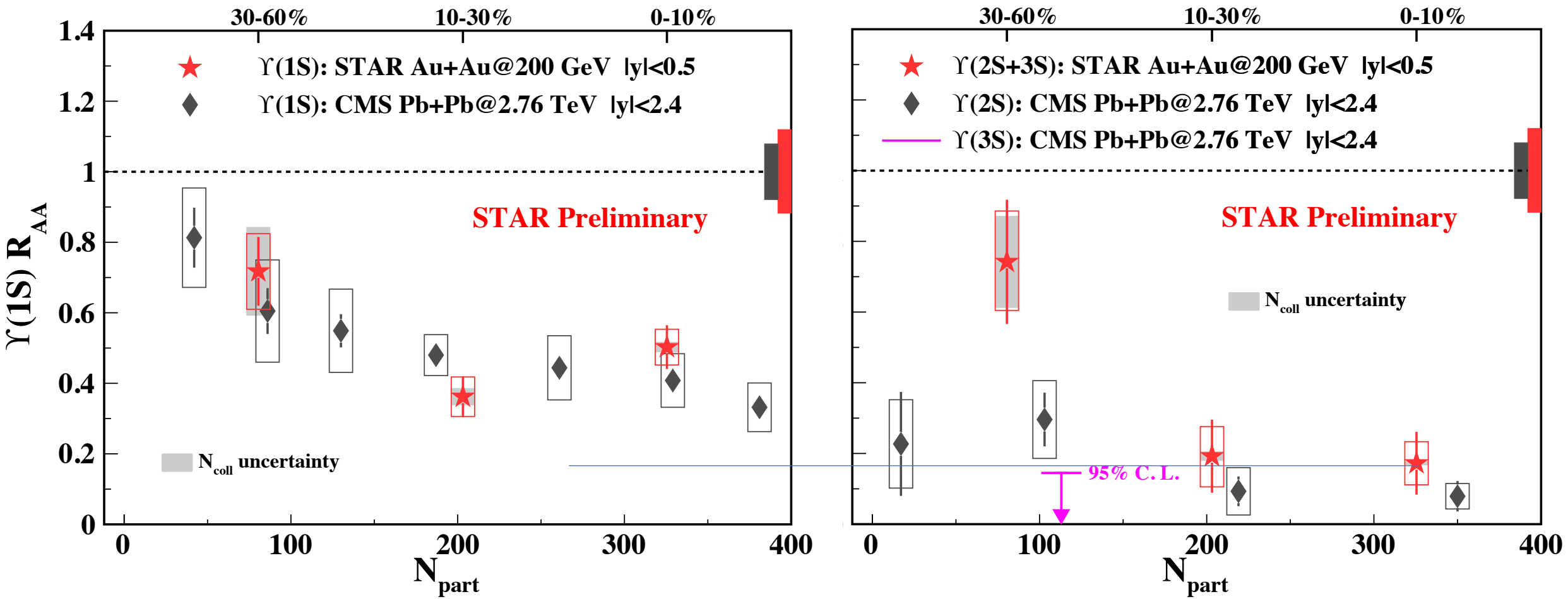




[1] PRL 113, 142301 (2014)

- Error found in previous 2010/11 analysis[1]. Corrected results consistent with 2014 (HFT) data
- Erratum for 2010/11 and a separate paper for 2014 data to be submitted soon

Upsilon Suppression in 200 GeV Au+Au Collisions

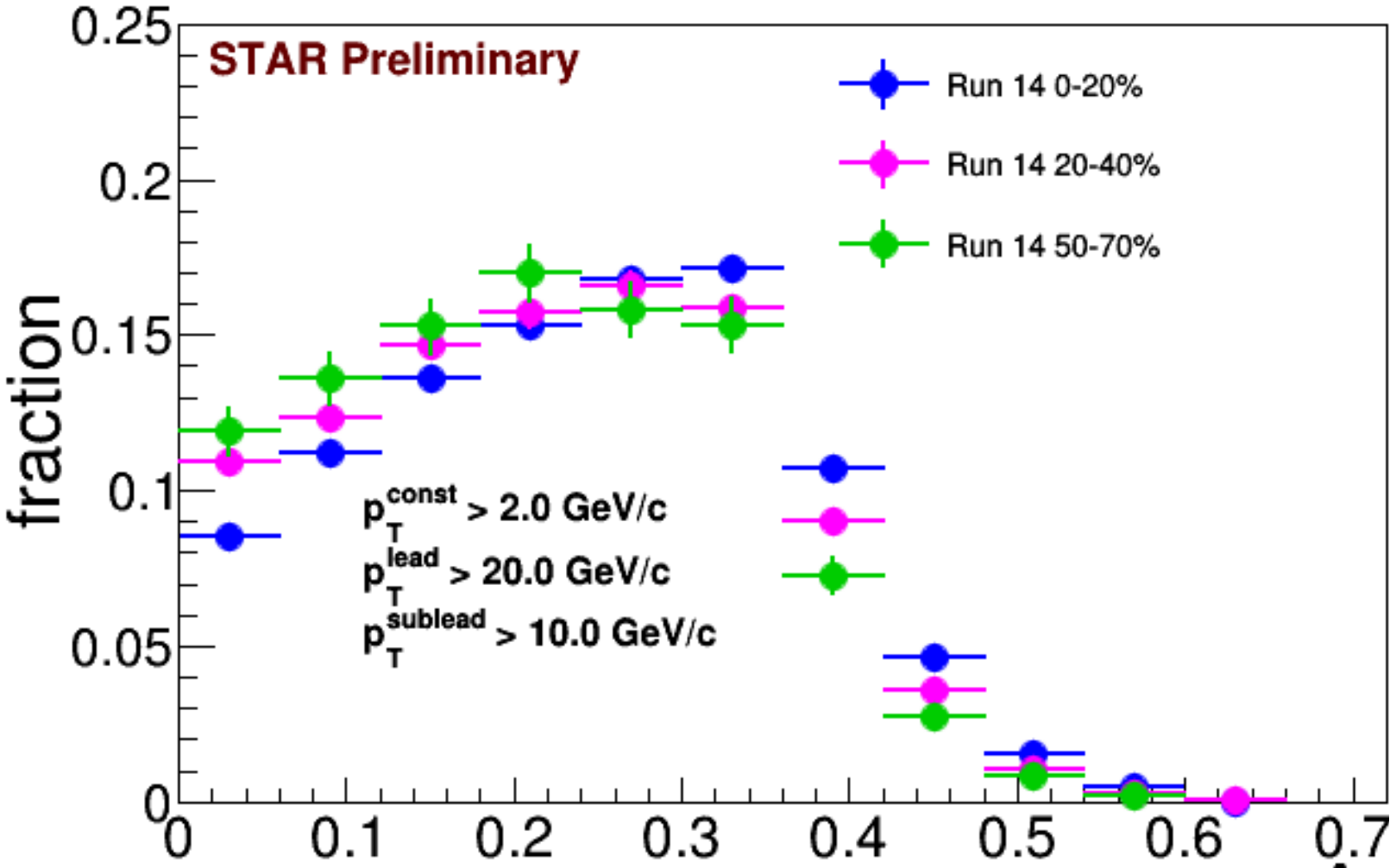


CMS PLB 04, 031 (2017)

- Improved precision by combining 2011 di-electron, 2014+**2016 di-muon**
- $\Upsilon(2S+3S)$ R_{AA} smaller than $\Upsilon(1S)$ in 0-10%, "**sequential melting**" at RHIC

Pengfei Wang
#544 May 15 11:10

Di-Jet Imbalance in 200 GeV Au+Au Collisions



$$A_J = \frac{p_T^{leading} - p_T^{sub\ leading}}{p_T^{leading} + p_T^{sub\ leading}}$$

Run7 0-20%: STAR PRL 119, 062301 (2017)

- First measurement of centrality dependence of A_J at RHIC
- Smaller di-jet imbalance in more peripheral collisions

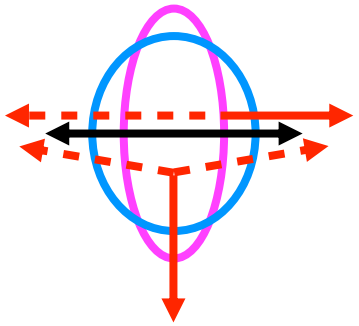
Kun Jiang
#552 May 16, 10:20

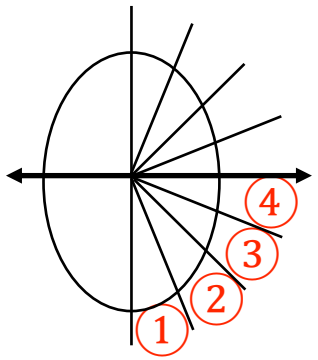
Di-hadron Correlations in 200 GeV Au+Au Collisions

p_T^t=4-10 GeV/c, p_T^a = 1-2 GeV/c

Event Shape Engineering

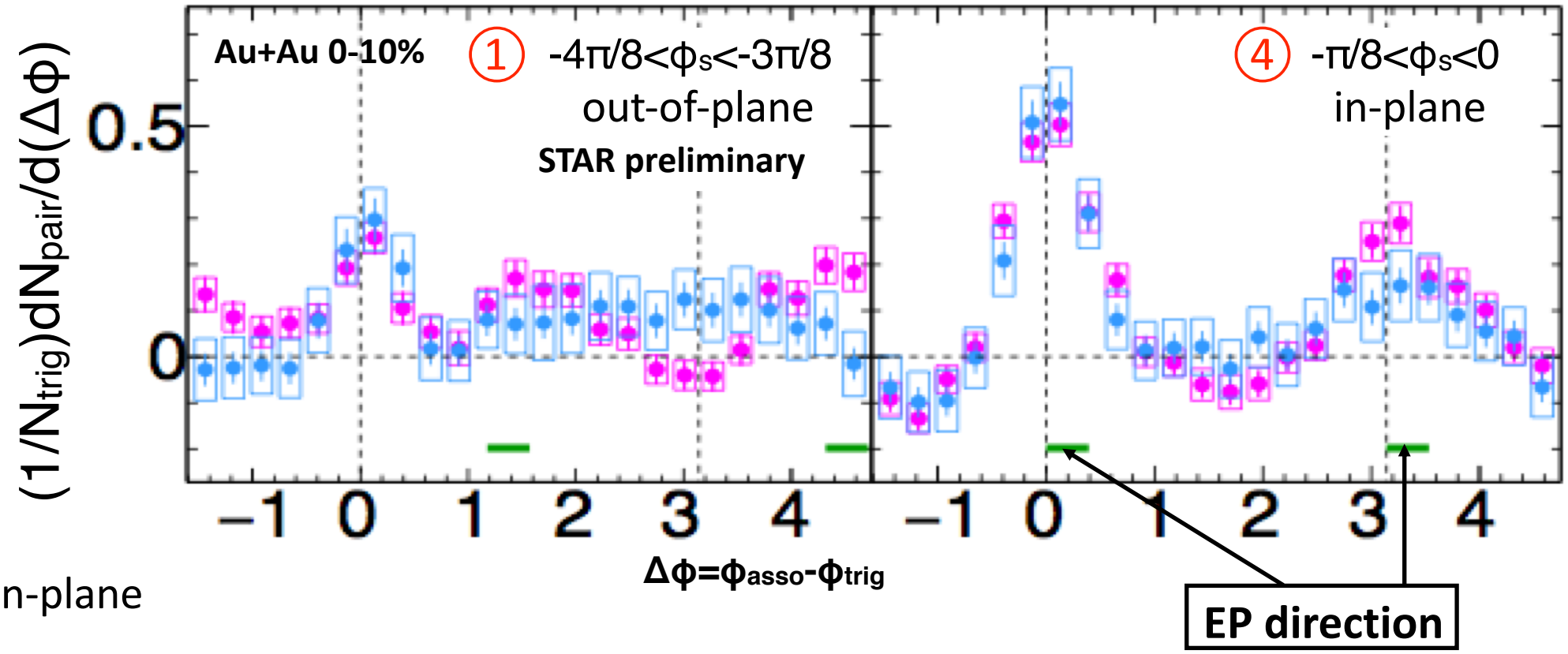
- q_2 top 20%
- q_2 bottom 20%





in-plane

out-of-plane



- Di-hadron correlations depend on the angle of trigger particle w.r.t. event plane, and on q_2 : path-length dependence of jet-medium interaction

Ryo Aoyama #551
May 15 16:40

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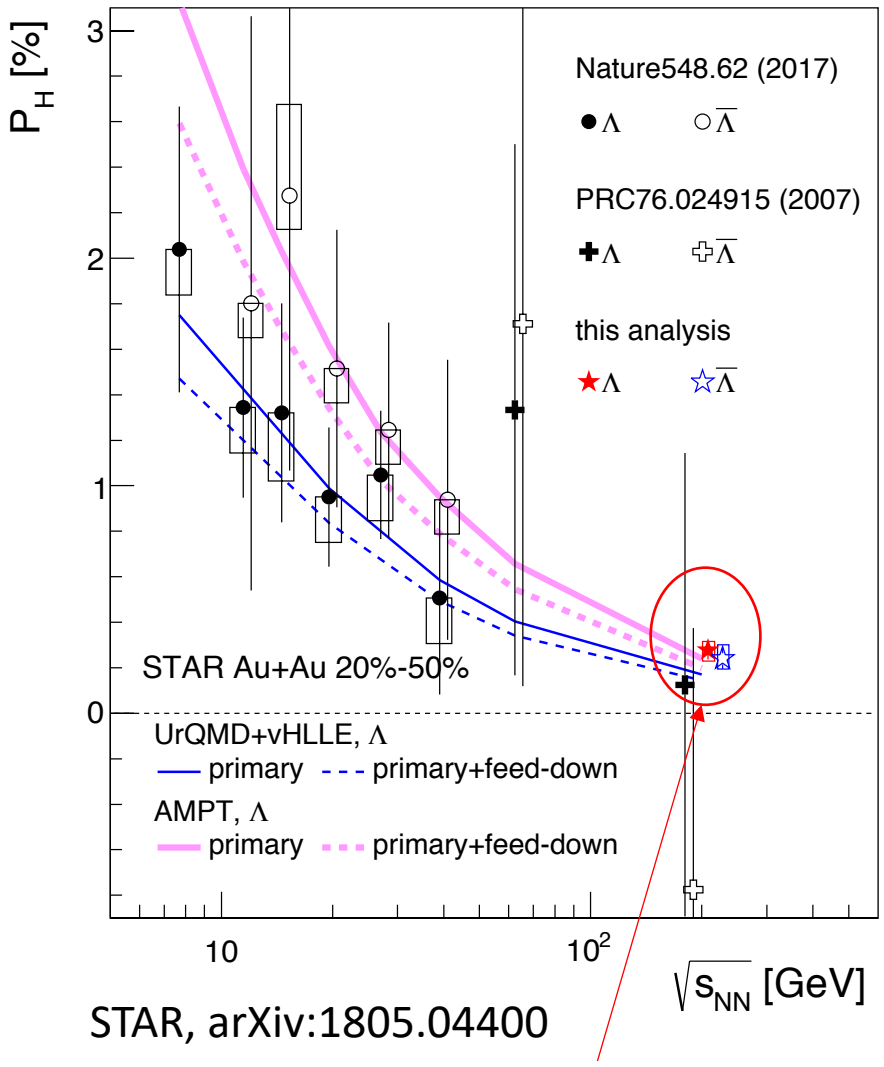
Λ Global and Local Polarization in 200 GeV Au+Au Collisions

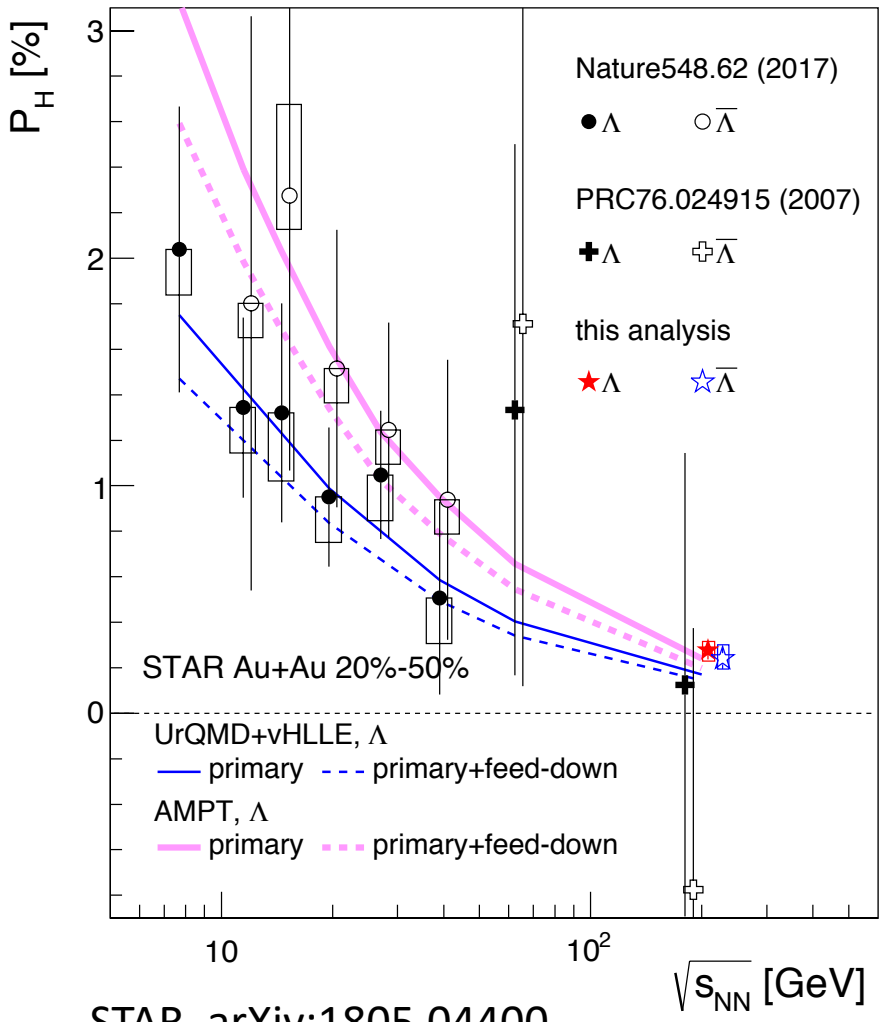


STAR, arXiv:1805.04400

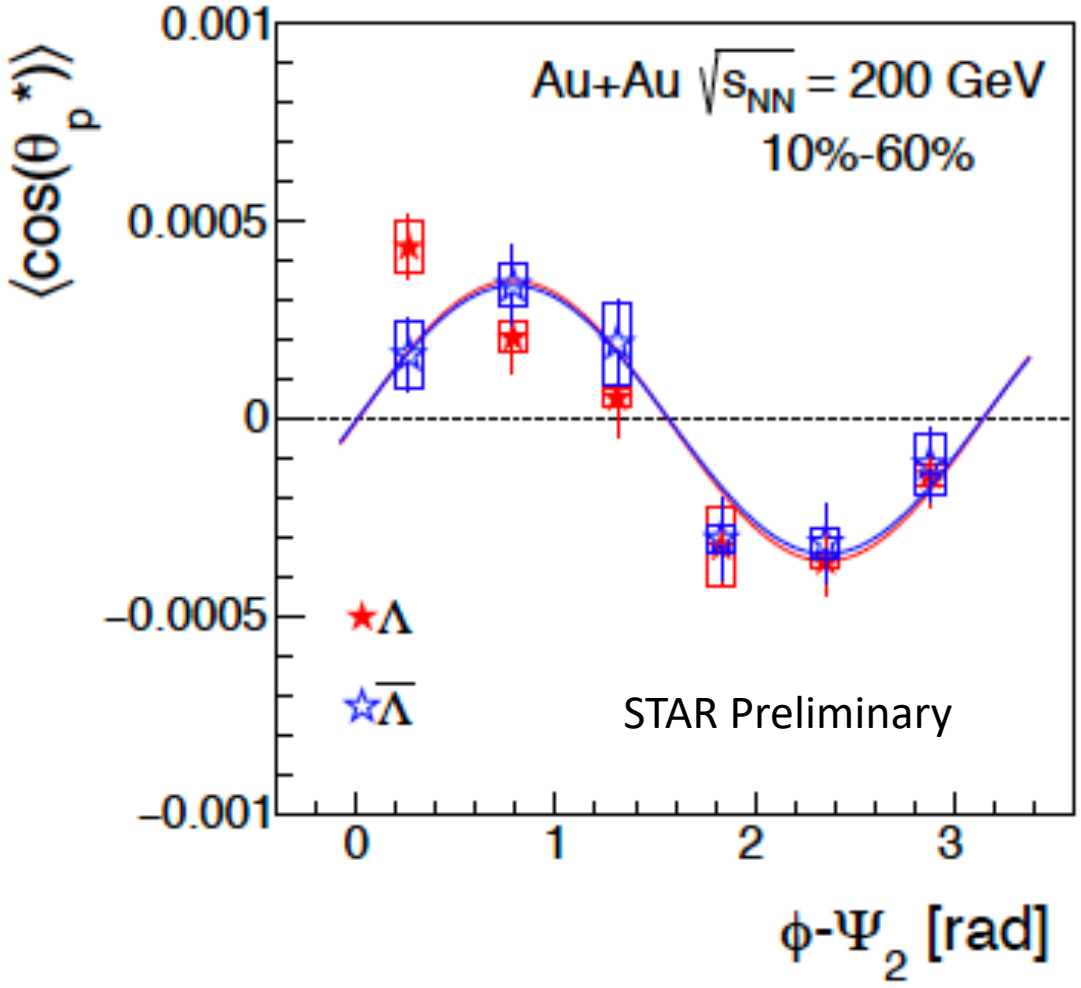
- First observation of Λ **global** polarization at 200 GeV

Takafumi Niida
#584, May 15, 9:00

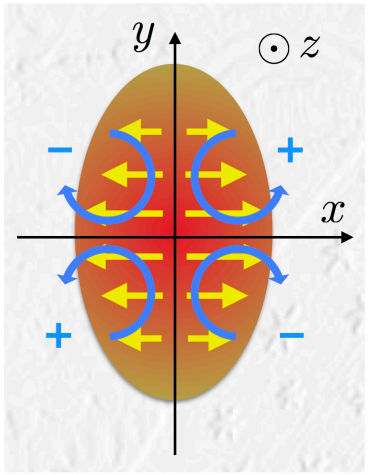
Λ Global and Local Polarization in 200 GeV Au+Au Collisions

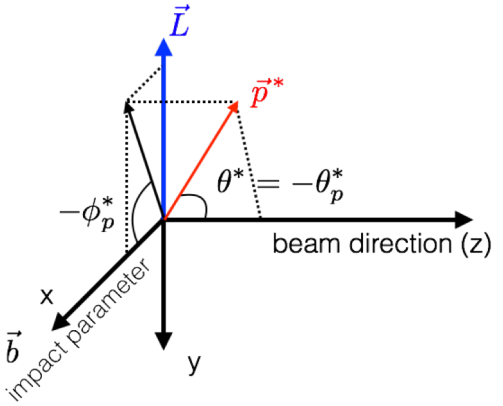


STAR, arXiv:1805.04400



S. Voloshin, sQM2017
F. Becattini and I. Karpenko, PRL120, 012302 (2018)

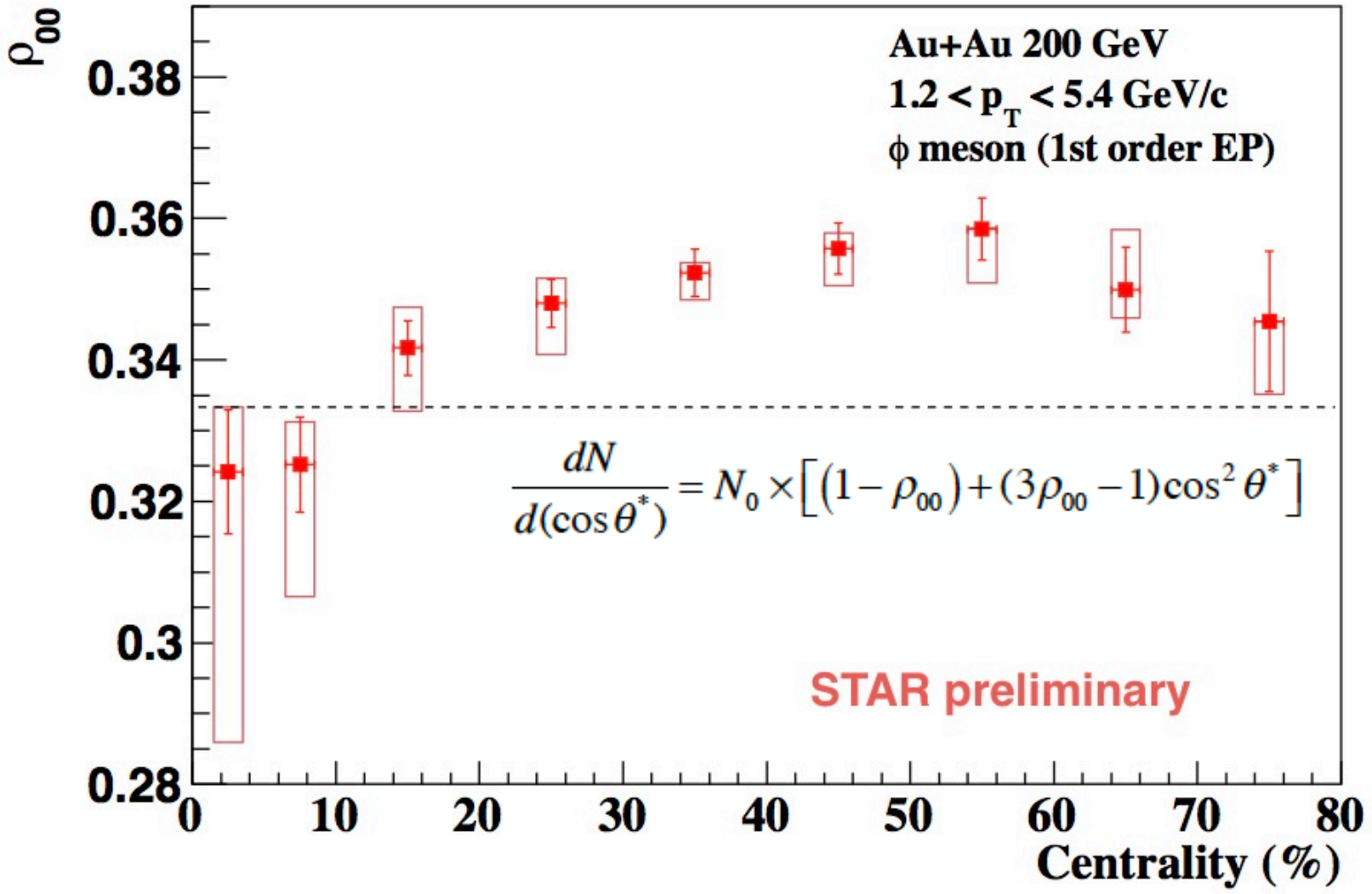




- First observation of Λ **global** polarization at 200 GeV
- First observation of quadrupole structure of Λ **local** polarization along beam direction

Takafumi Niida
#584, May 15, 9:00

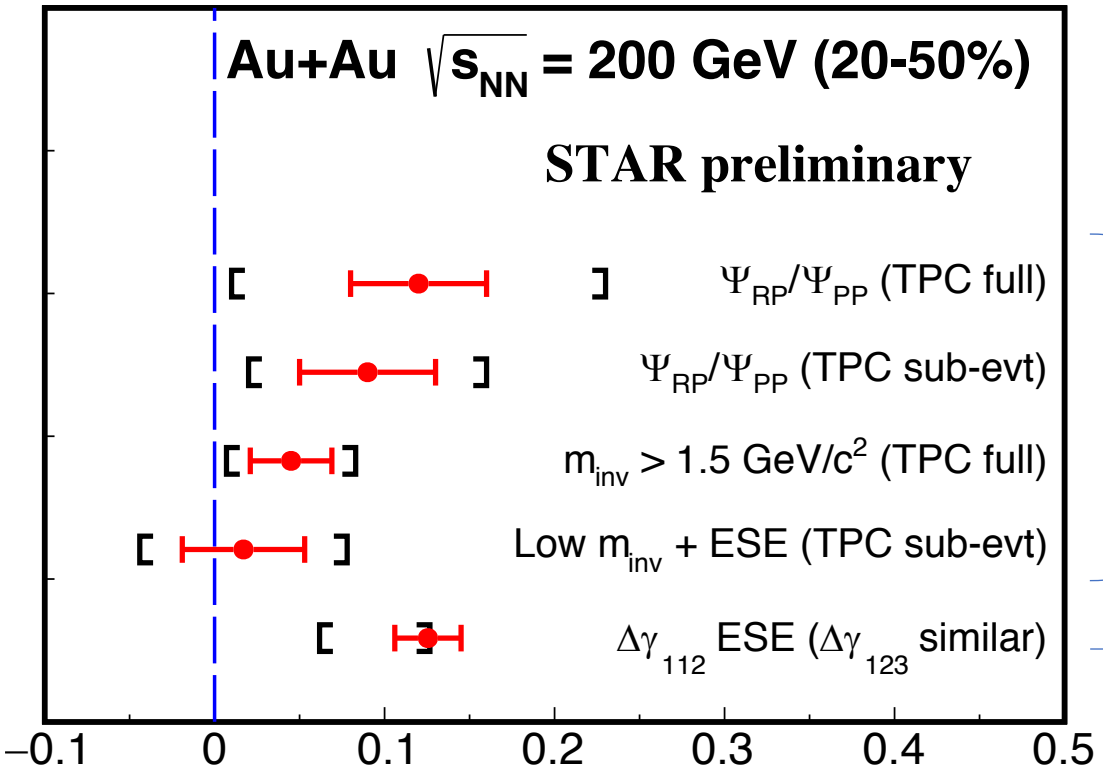
Spin Alignment of ϕ Mesons in 200 GeV Au+Au Collisions



- ϕ-meson ρ_{00} deviates from 1/3 in non-central collisions, probe vorticity induced by initial angular momentum and particle production

Chensheng Zhou
#731, May 16, 18:10

Chiral Magnetic Effect at RHIC Top Energy



Jie Zhao, #848, May 16, 9:40

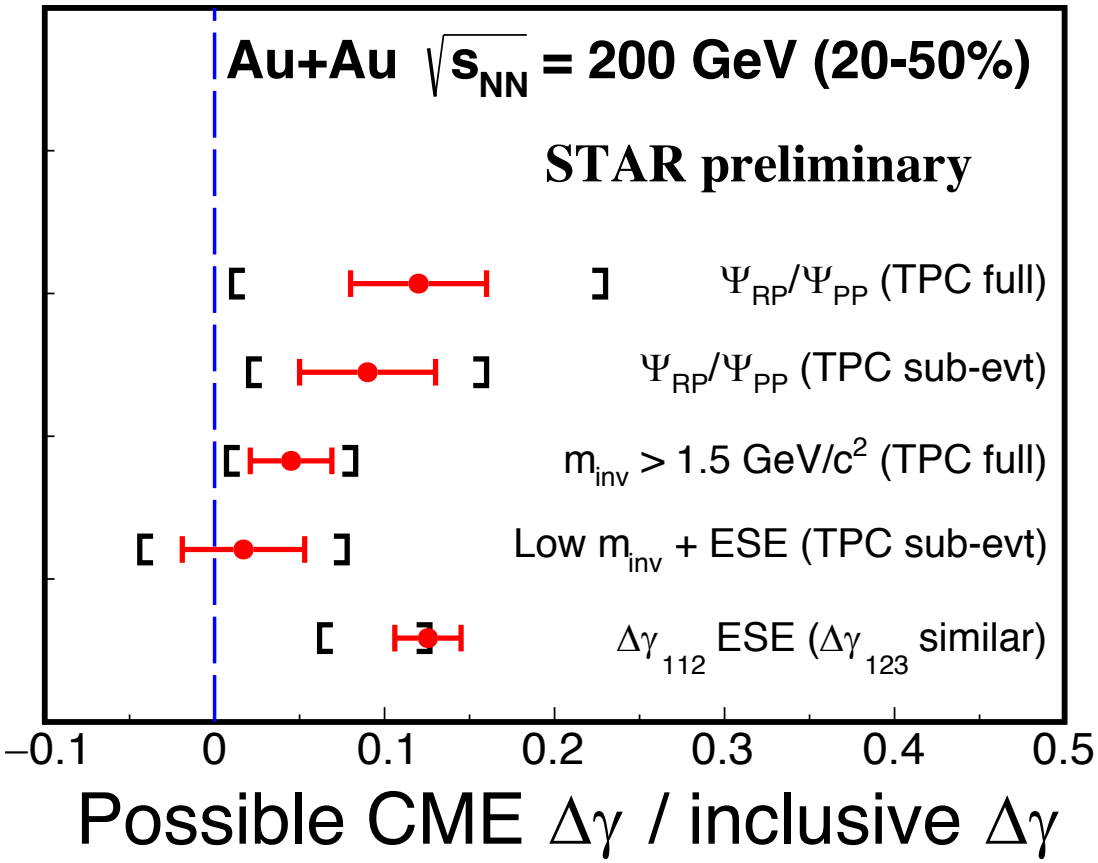
Gang Wang, 2018 Workshop on Chirality, Vorticity and Magnetic Field in Heavy Ion Collisions

H.-J. Xu et al. arXiv:1710.07265

J. Zhao et al. arXiv:1705.05410

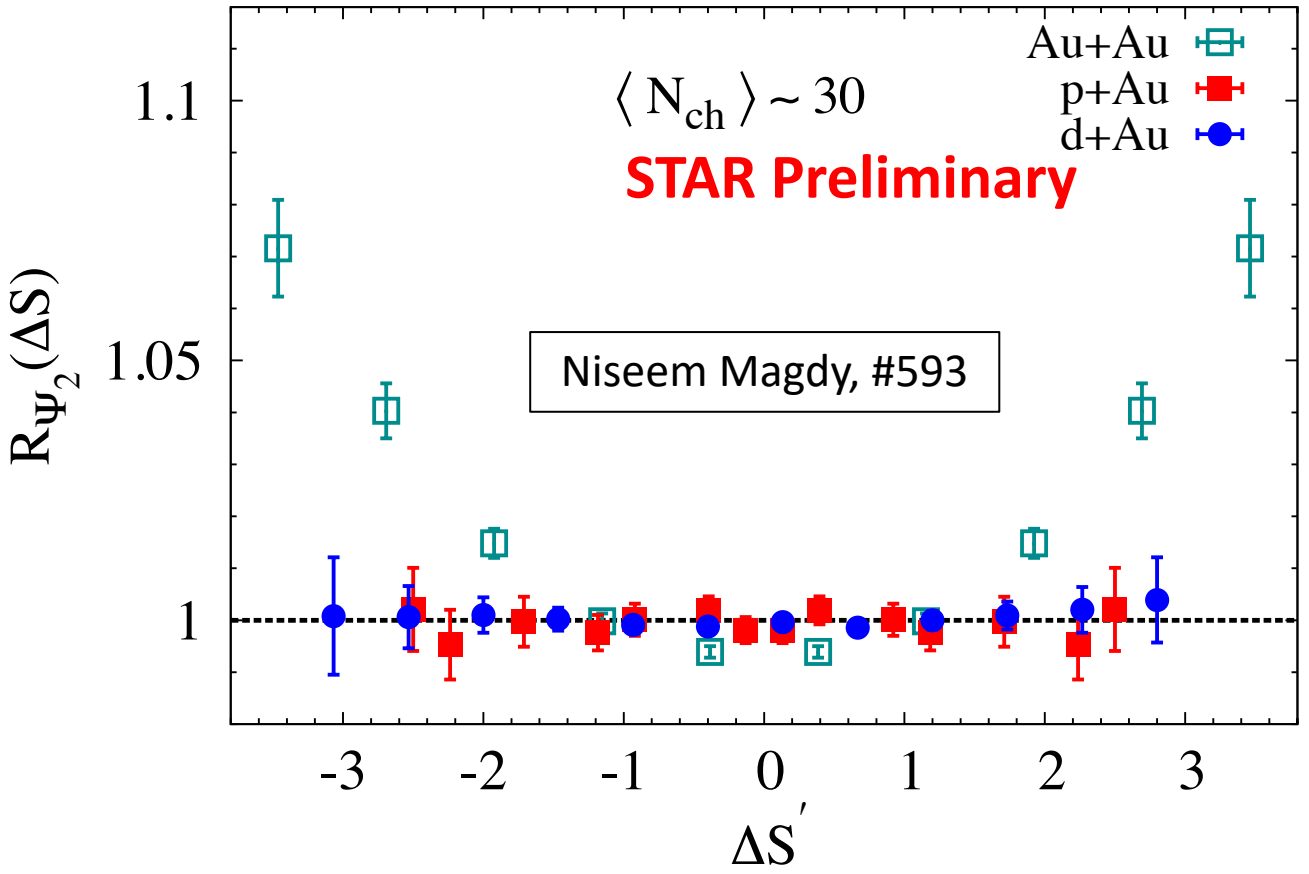
- Isolate possible CME signal in inclusive $\Delta\gamma$ by different methods

Chiral Magnetic Effect at RHIC Top Energy



H.-J. Xu et al. arXiv:1710.07265

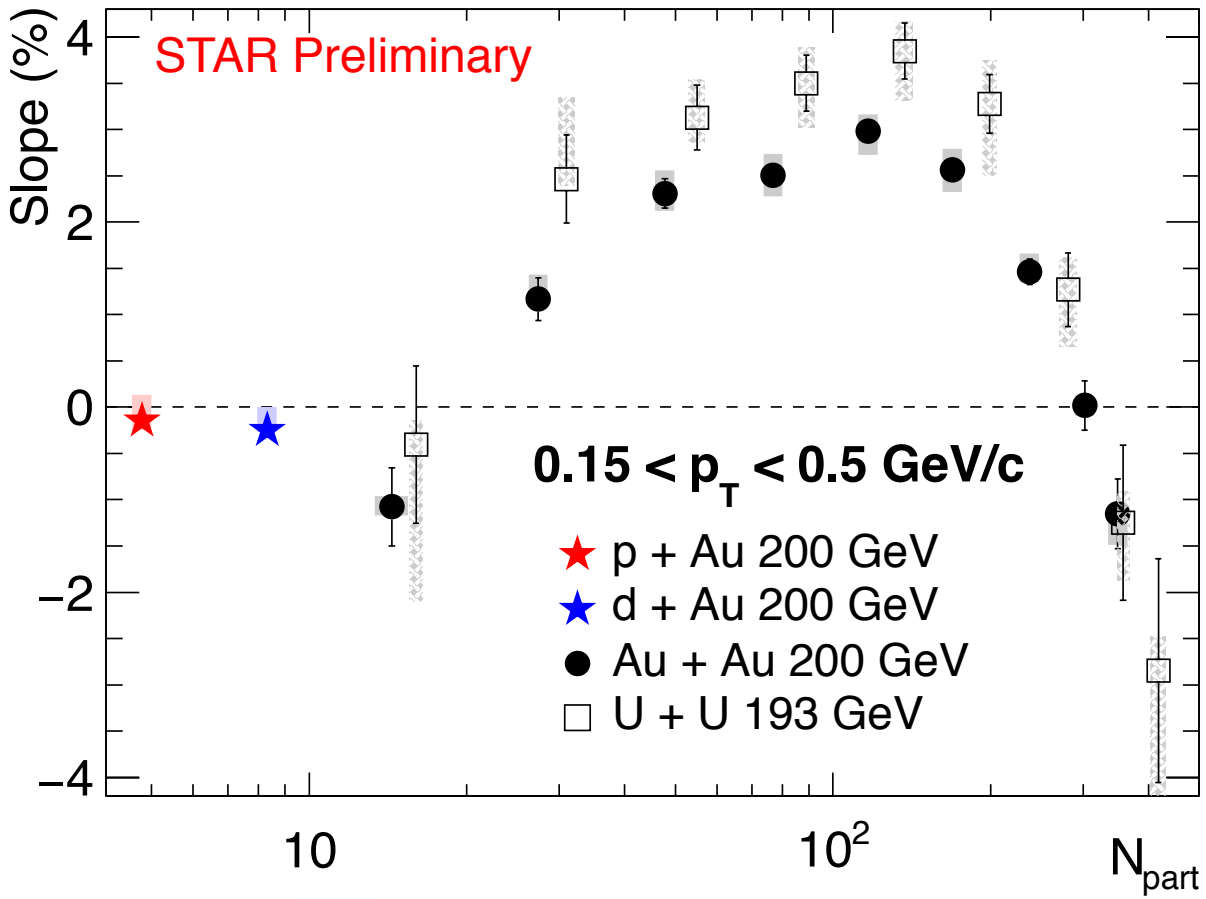
J. Zhao et al. arXiv:1705.05410



N. Magdy, et al., arXiv:1710.01717

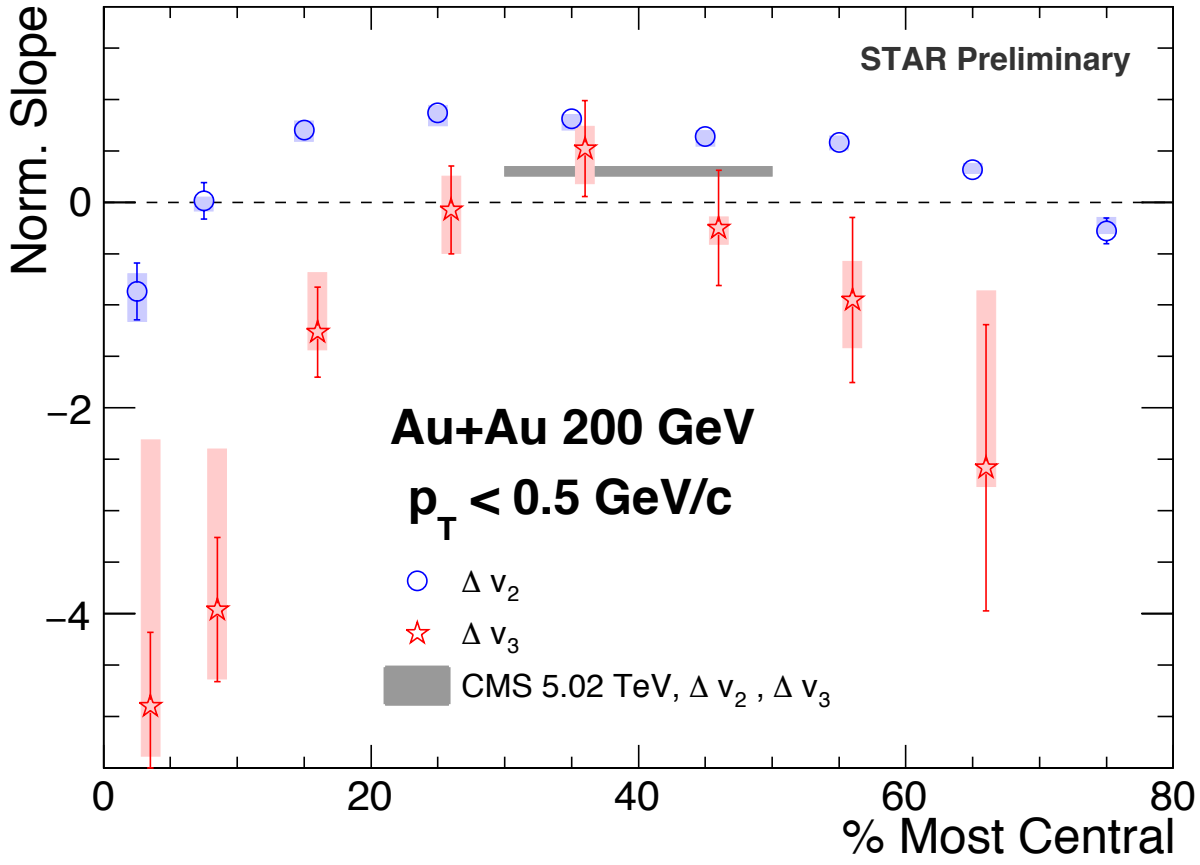
- Isolate possible CME signal in inclusive $\Delta\gamma$ by different methods
- New observable $R_{\Psi_2}(\Delta S)$ shows difference between p(d)+Au and peripheral Au+Au collisions
- Dedicated isobar run this year completed, blind analyses for CME studies being conducted

Chiral Magnetic Wave at RHIC Top Energy



$$A_{ch} \equiv (\bar{N}_+ - \bar{N}_-)/(\bar{N}_+ + \bar{N}_-)$$

$$\Delta v_2 = v_2^- - v_2^+ \approx r\, A_{ch}$$



$$\mathrm{Norm.}\Delta v_n = 2\frac{v_n^- - v_n^+}{v_n^- + v_n^+}$$

- Differences in slope (r) among p/d+Au, Au+Au and U+U consistent with CMW expectation
- Difference between normalized Δv_2 and Δv_3 in most central and peripheral collisions

Qiye Shou
#592, May 16, 17:30

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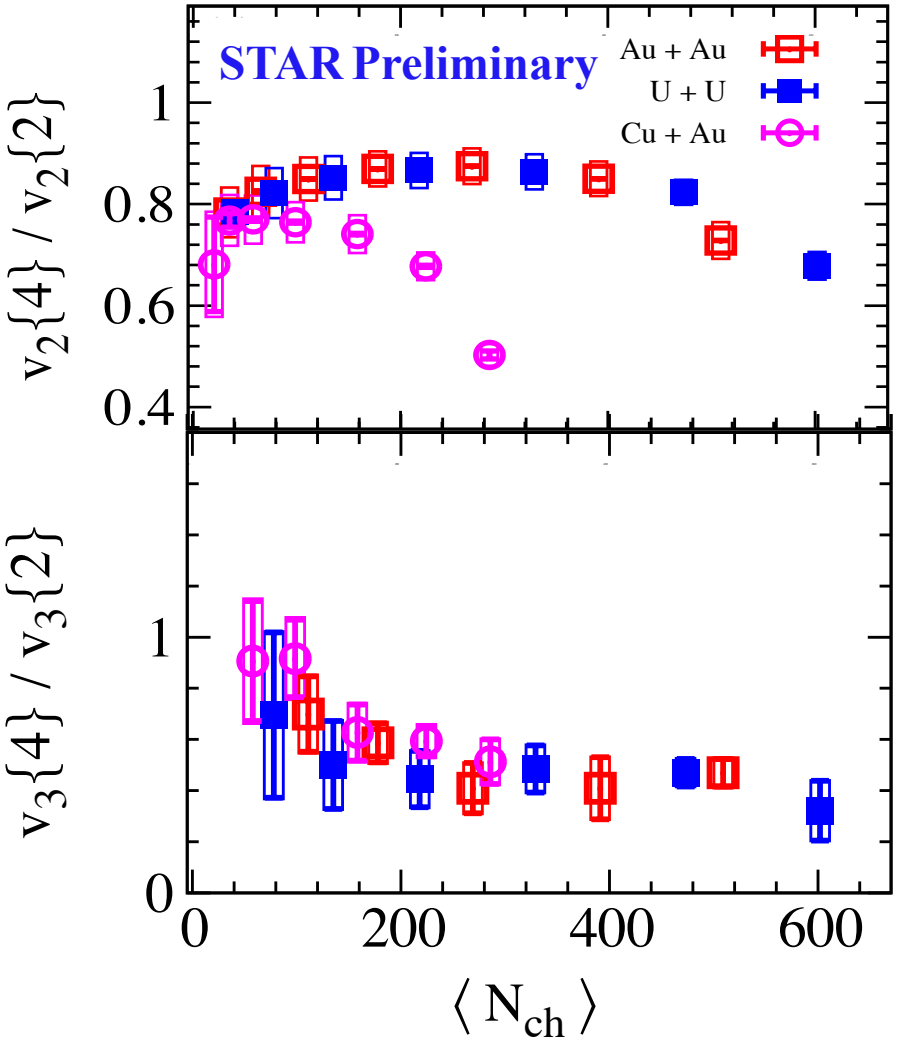
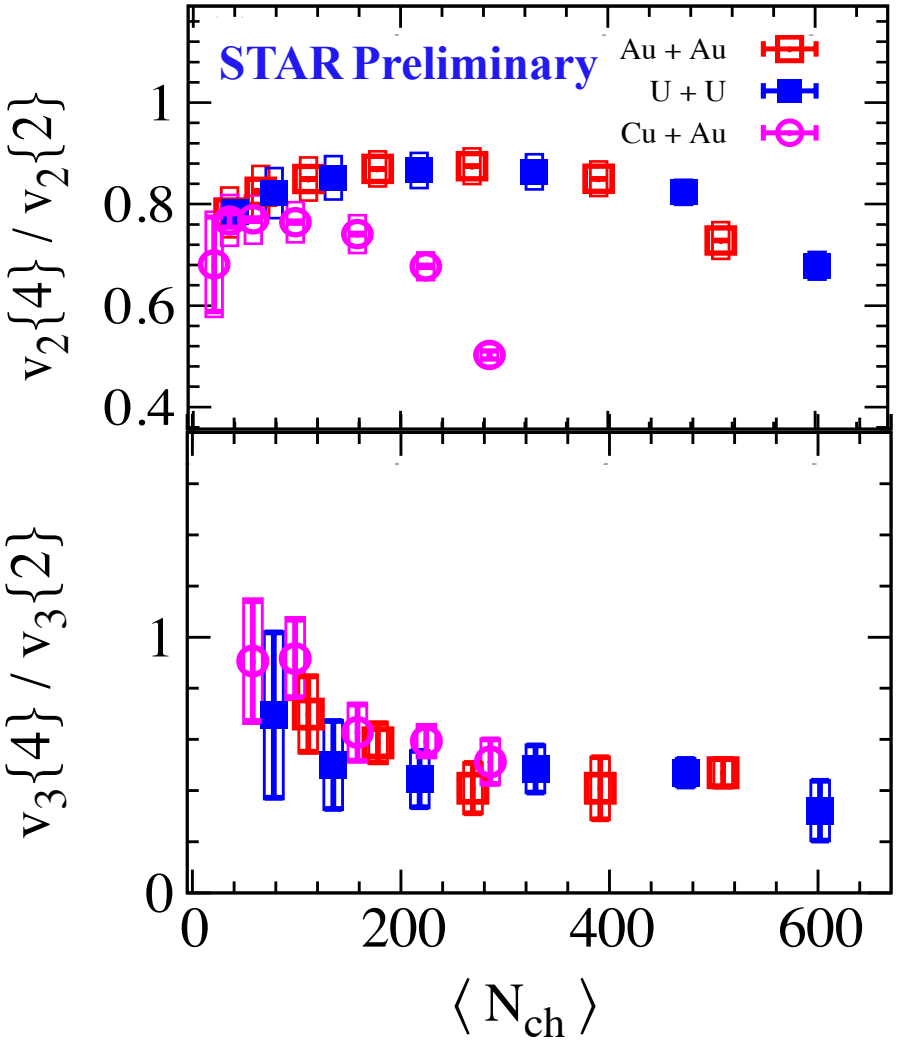
Flow and Fluctuations in Multiple Systems

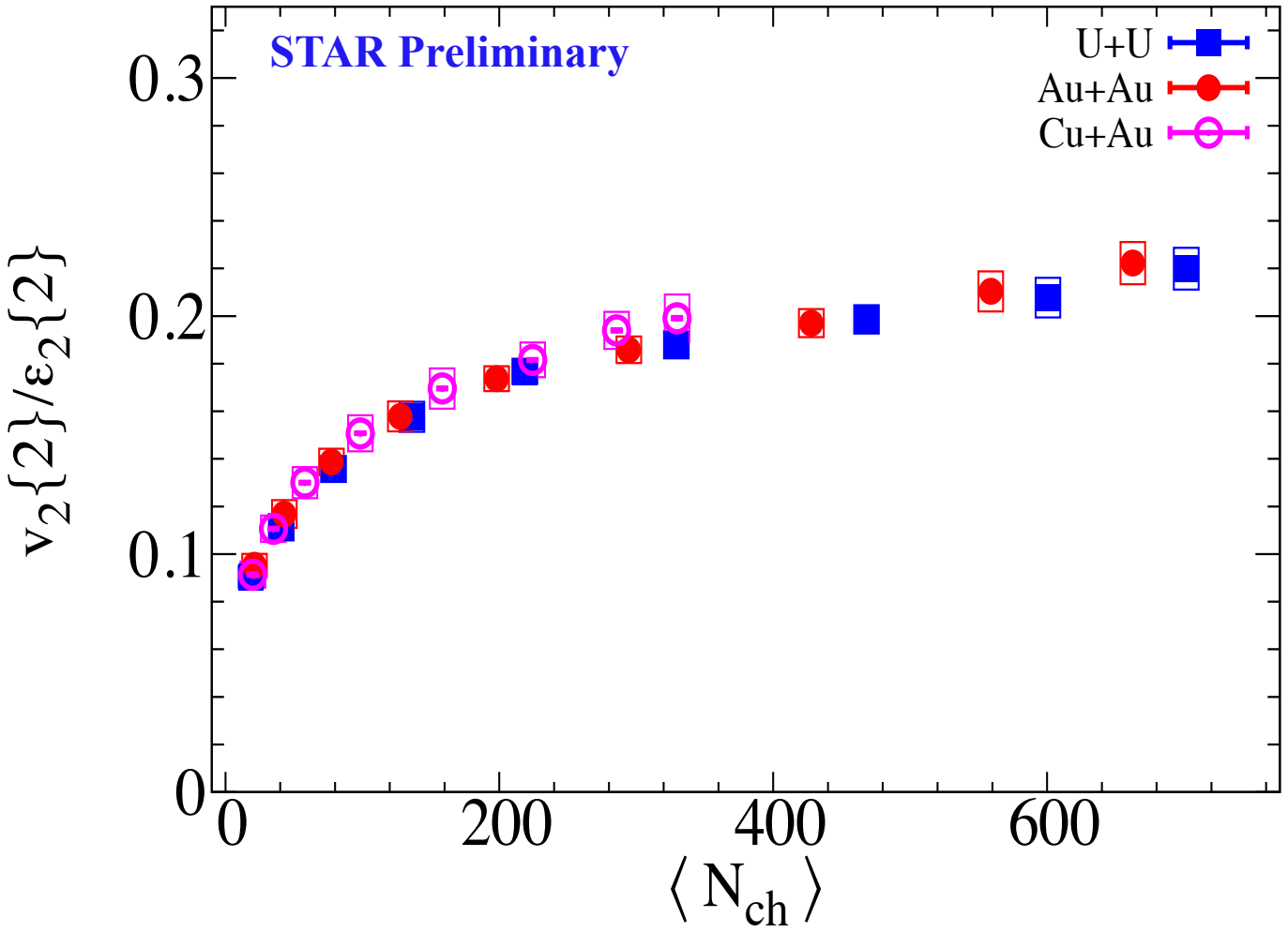


- Ratio of $v_n\{4\}/v_n\{2\}$ is sensitive to flow fluctuations. The ratio for elliptic flow depends on collision system while that for triangular flow is independent

Niseem Magdy
#588, May 15, 11:30

Flow and Fluctuations in Multiple Systems

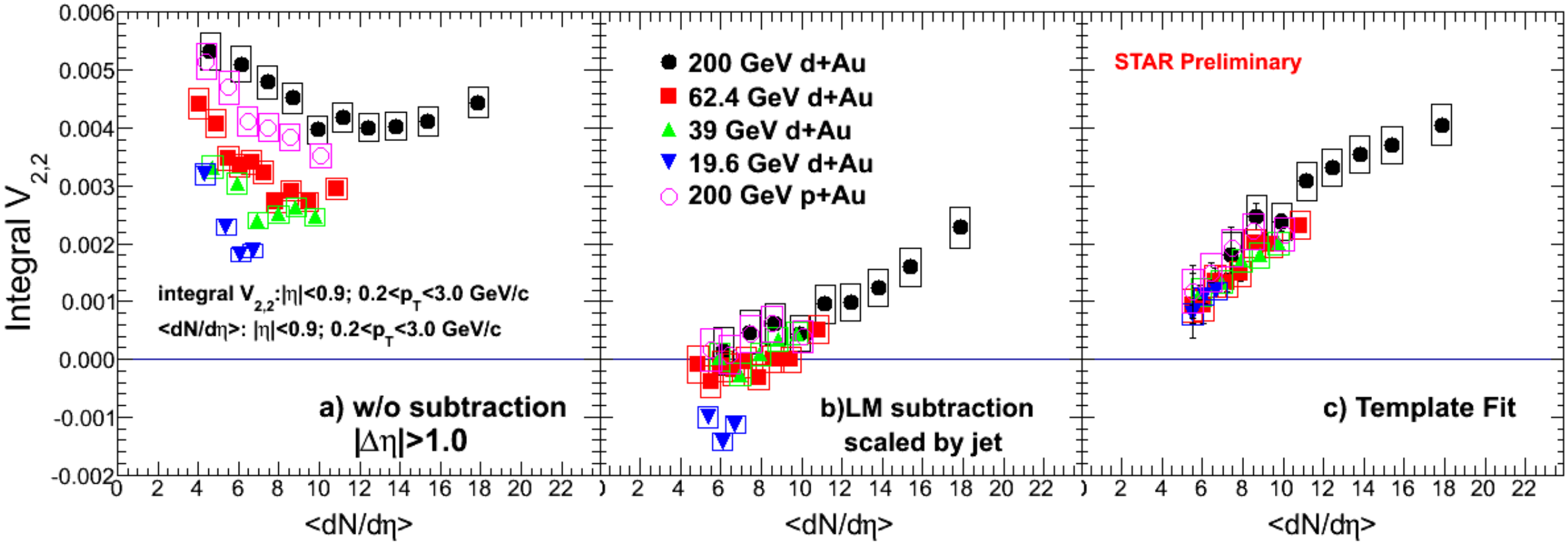




- Ratio of $v_n\{4\}/v_n\{2\}$ is sensitive to flow fluctuations. The ratio for elliptic flow depends on collision system while that for triangular flow is independent
- $v_2\{2\}$ scales with $\varepsilon_2\{2\}$ - similar viscous effect in these collisions

Niseem Magdy
#588, May 15, 11:30

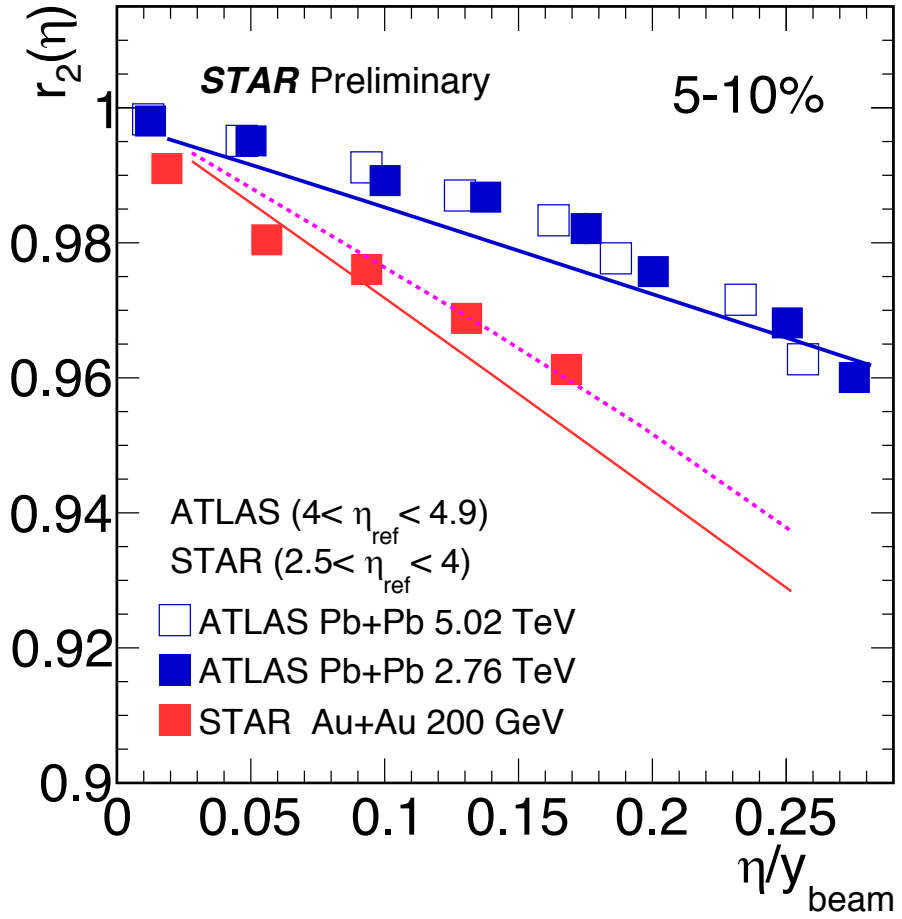
Collectivity in Small Systems

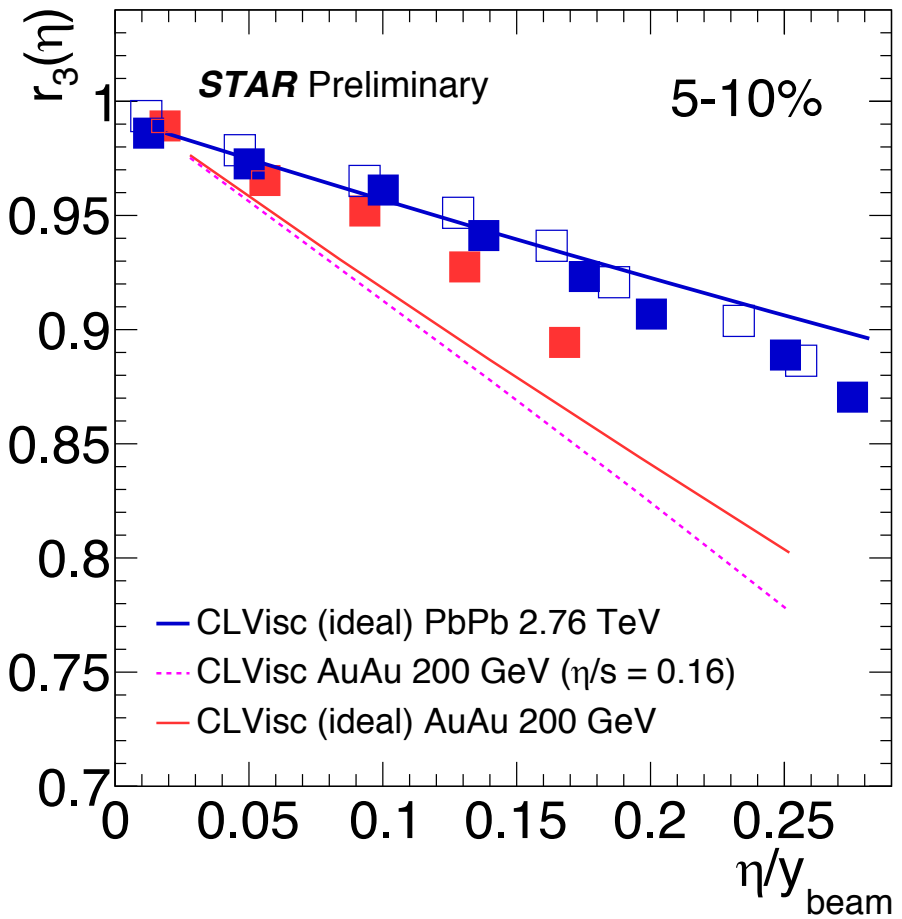


- Different $V_{2,2}$ from different methods to correct for non-flow background in p/d+Au collisions. Be careful about the assumptions of the methods.

Shengli Huang
#734, May 15, 11:30

Longitudinal Flow Decorrelation in 200 GeV Au+Au Collisions



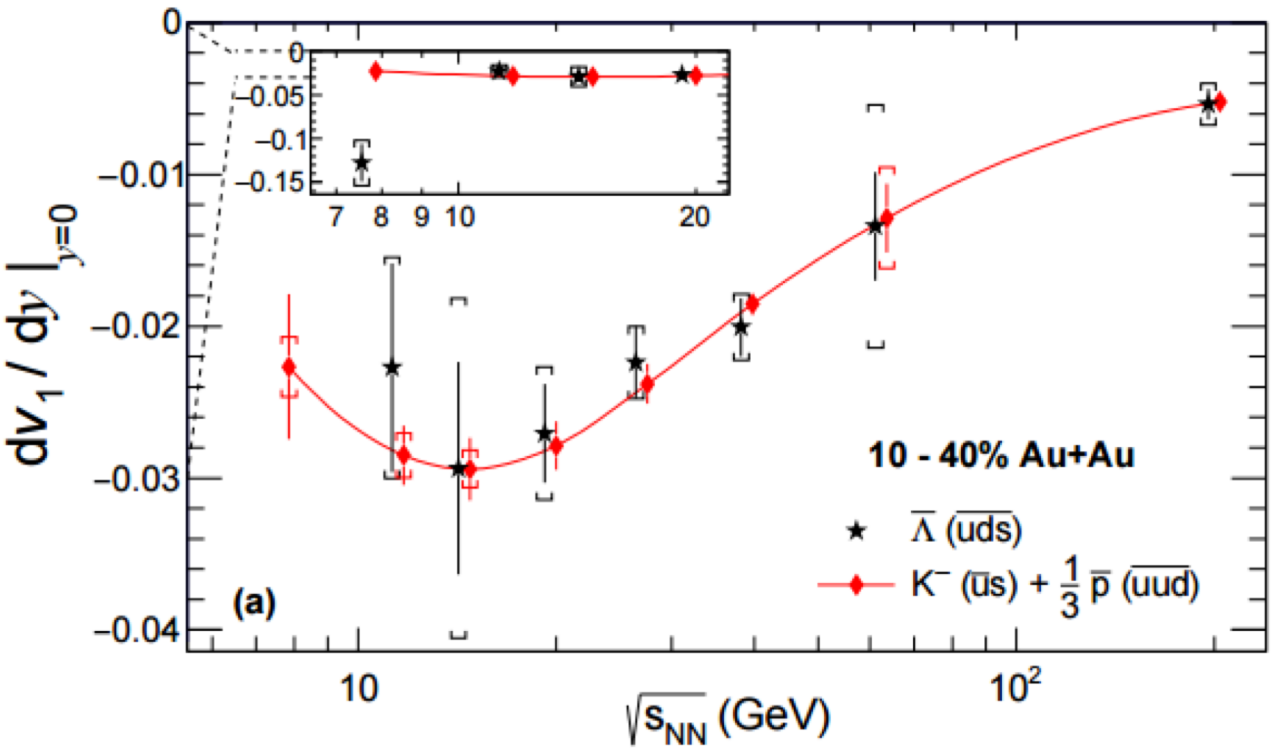


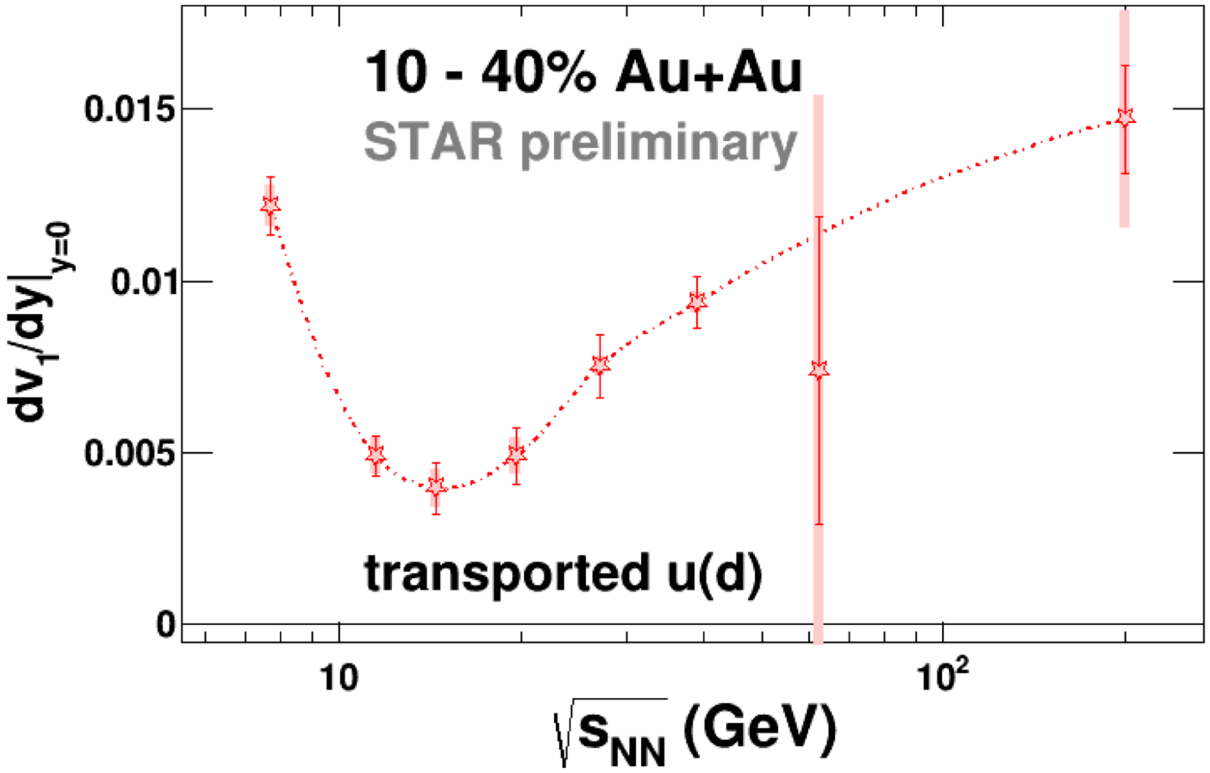
$$r_n(\eta) = \frac{\langle v_n(-\eta) v_n(\eta_{\rm ref}) \cos n(\Psi_n(-\eta) - \Psi_n(\eta_{\rm ref}))\rangle}{\langle v_n(\ \eta) v_n(\eta_{\rm ref}) \cos n(\Psi_n(\ \eta) - \Psi_n(\eta_{\rm ref}))\rangle}$$

- Stronger longitudinal flow decorrelation at RHIC than at LHC
- Hydro calculations can not simultaneously describe LHC and RHIC data

Maowu Nie
#332, May 15 19:10

Directed Flow of Identified Particles in Beam Energy Scan





STAR, Phys. Rev. Lett. **120** (2018) 62301

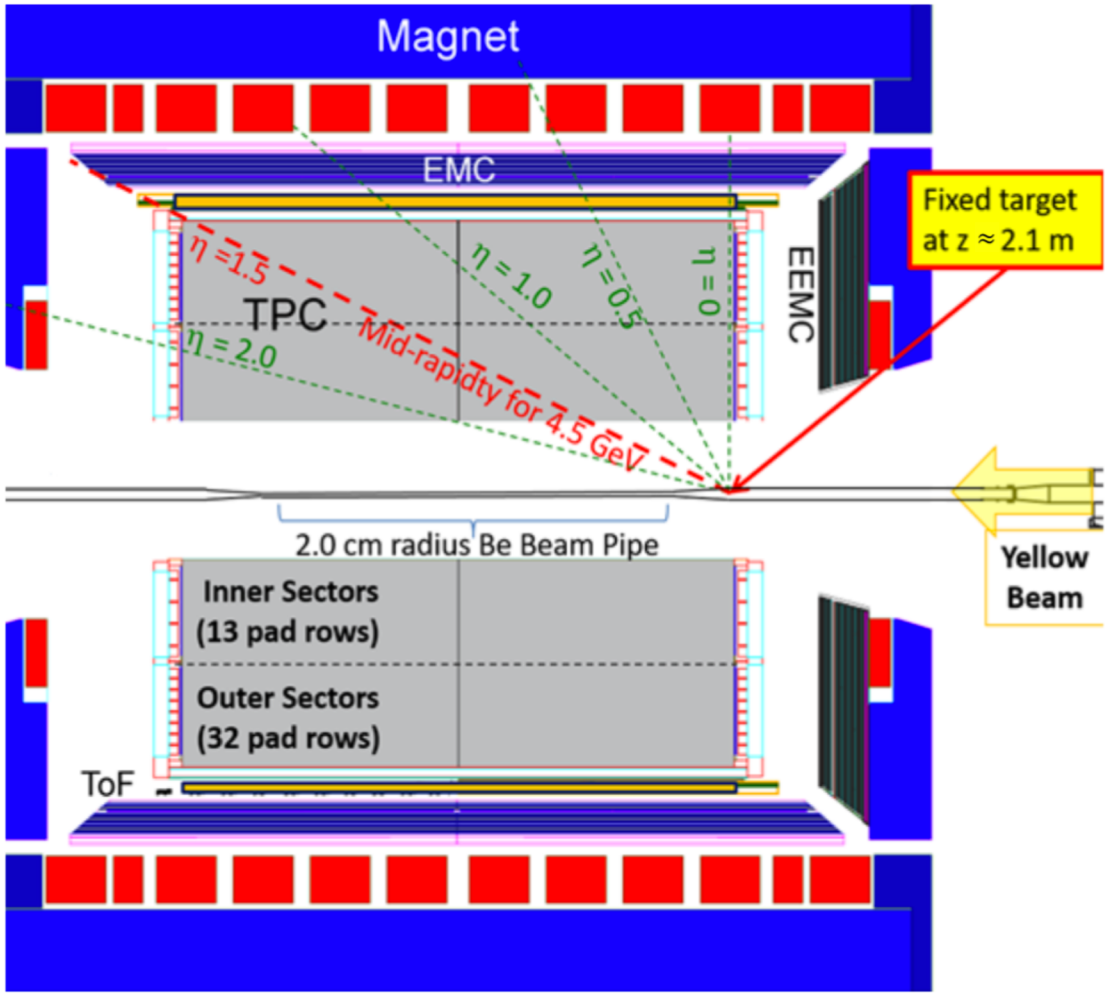
$$(v_1)_{trans.u(d)} = \left[(v_1)_{net\,p} - \left(3 - N_{trans.u(d)}\right)(v_1)_{\bar{u}(\bar{d})}\right]/N_{trans.u(d)}$$

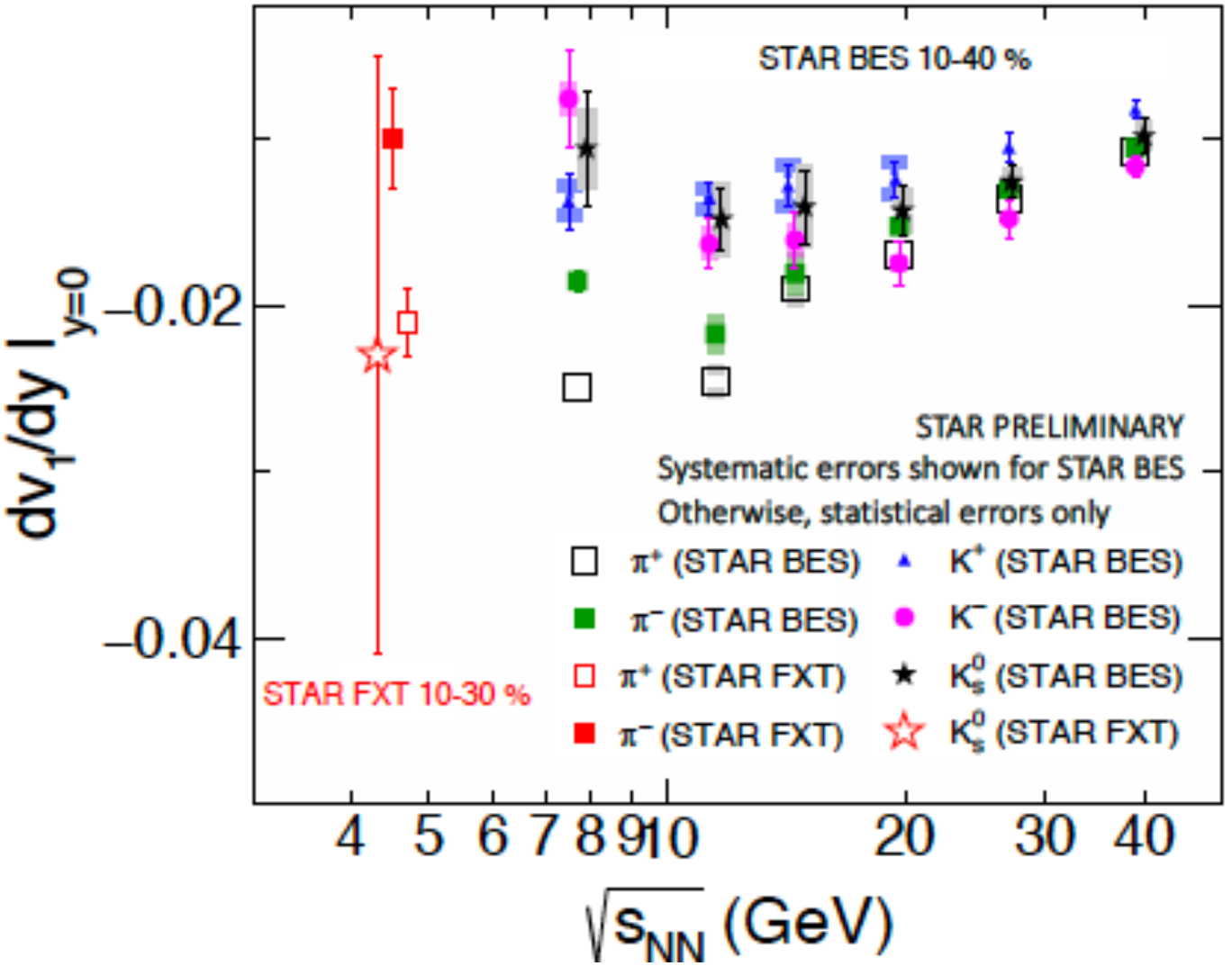
$$N_{trans.u(d)} = 3\left[1 - exp\left(-2\mu_{u(d)}/T_{ch}\right)\right]/(1 - r_{\bar{p}/p})$$

- 10 species & 8 energies allow a detailed study of constituent-quark v_1. In most cases, the coalescence picture works for both "**produced**" particles and "**net**" particles
- "**Transported quark**" v_1 has a local minimum at ~14.5 GeV

Gang Wang
#587, May 16, 11:50

Fixed-Target Test Run for Au+Au at $\sqrt{s_{NN}}$=4.5 GeV





- First π v_1 measurement in this energy range, v_1 slope turning up towards lower energies
- Dedicated FXT runs (3.0-7.7 GeV) in 2019+ to explore high baryon density regime.

Yang Wu
#558, May 15, 16:00

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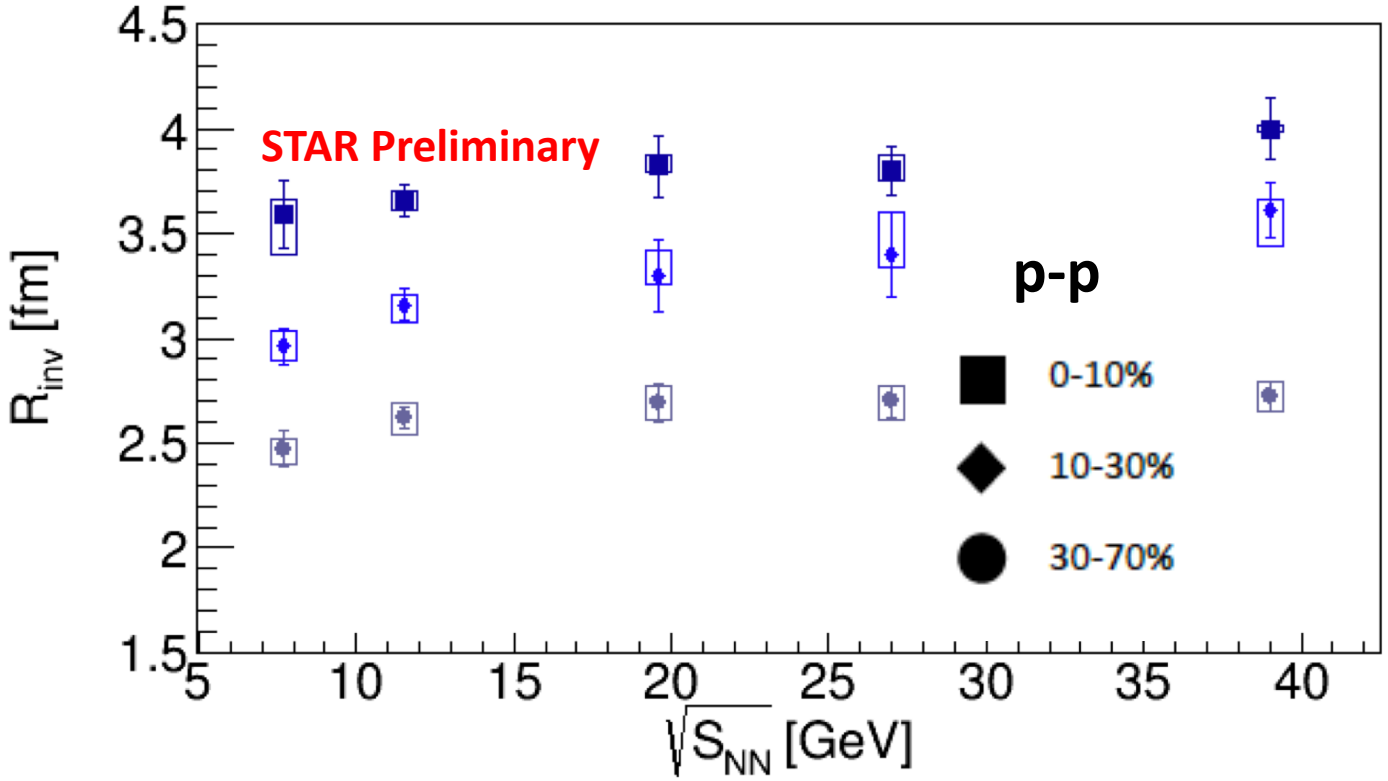
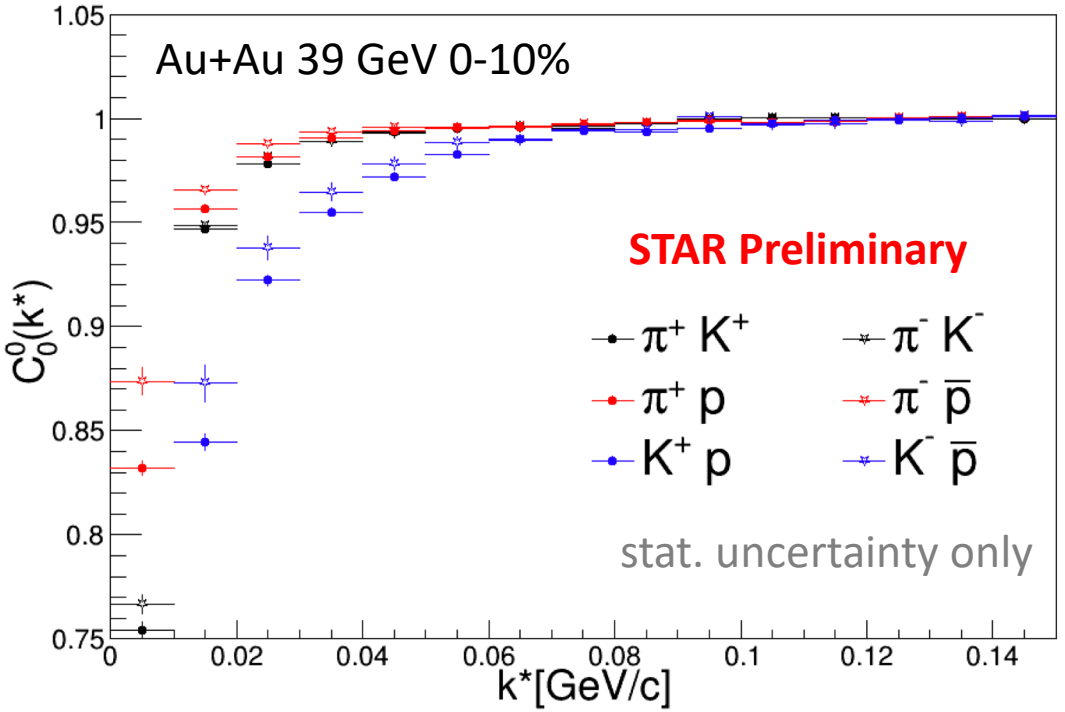
Femtoscopy with Identified Particles in Beam Energy Scan

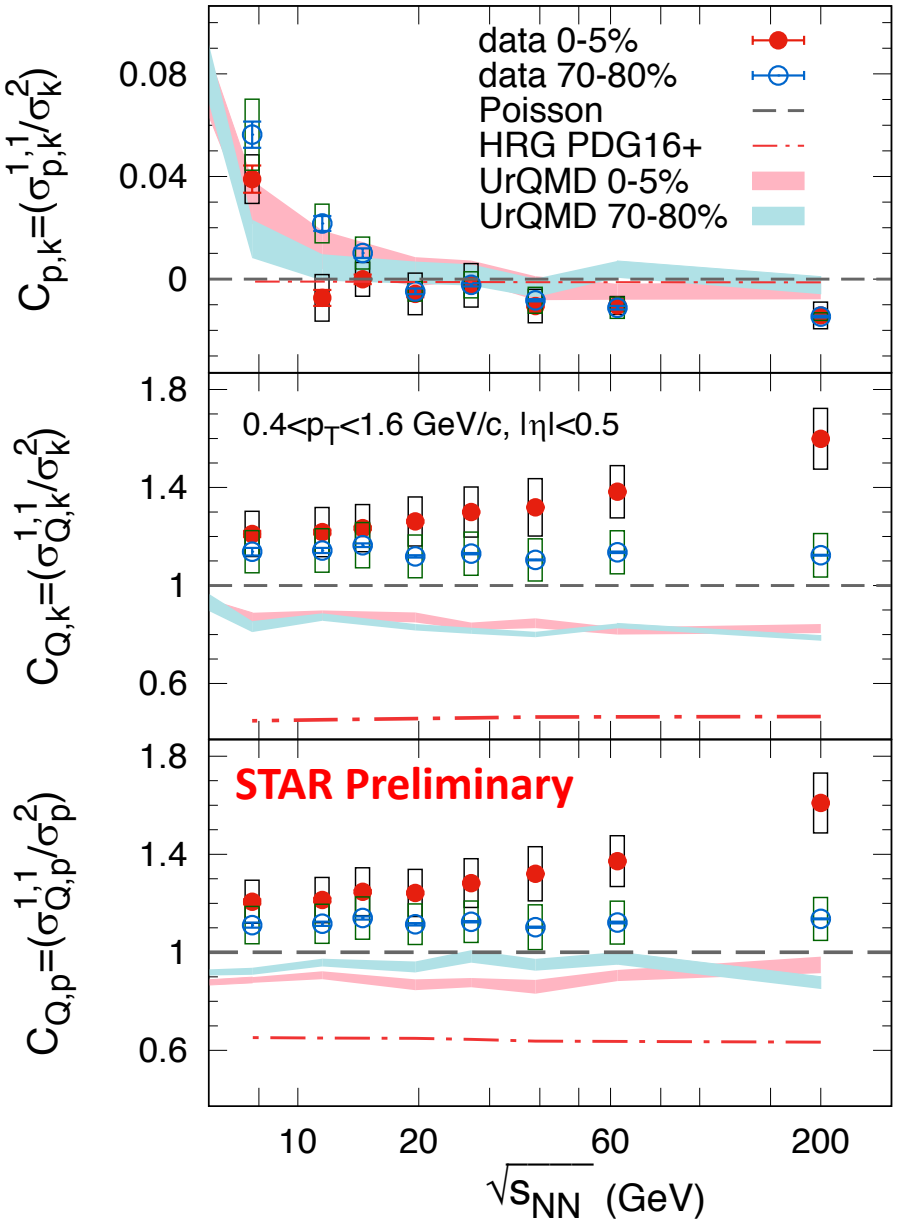




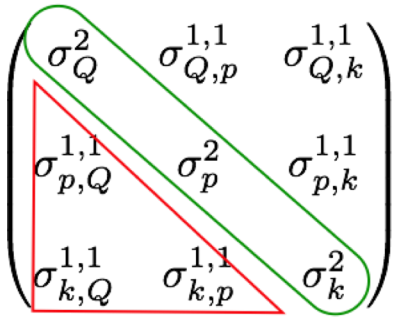
- Energy and centrality dependence of HBT radius studied with BES data
- Lighter particles emitted closer to the center of the source than heavy particles

Sebastian Siejka
#590, May 16, 15:40

Cumulants of Net-Particle Distributions in Beam Energy Scan

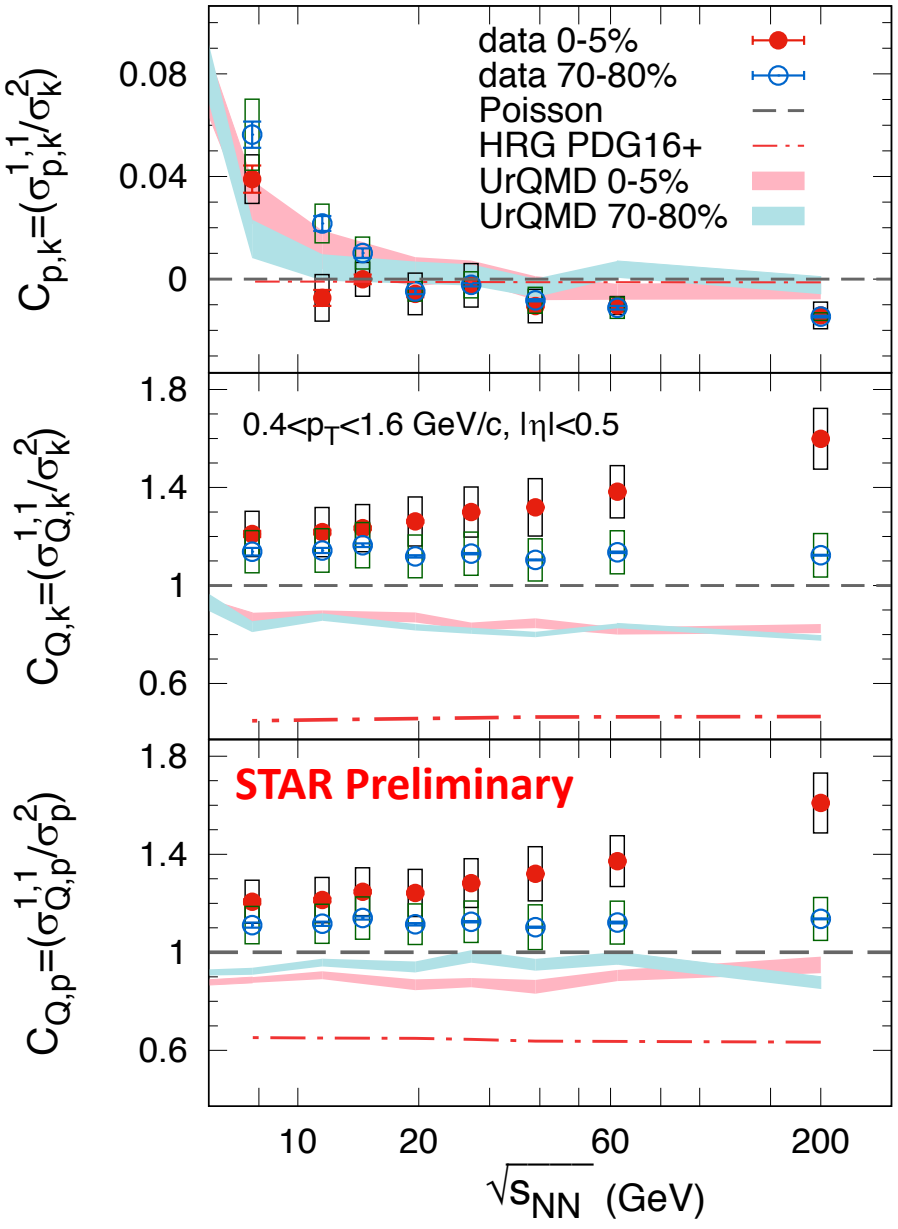


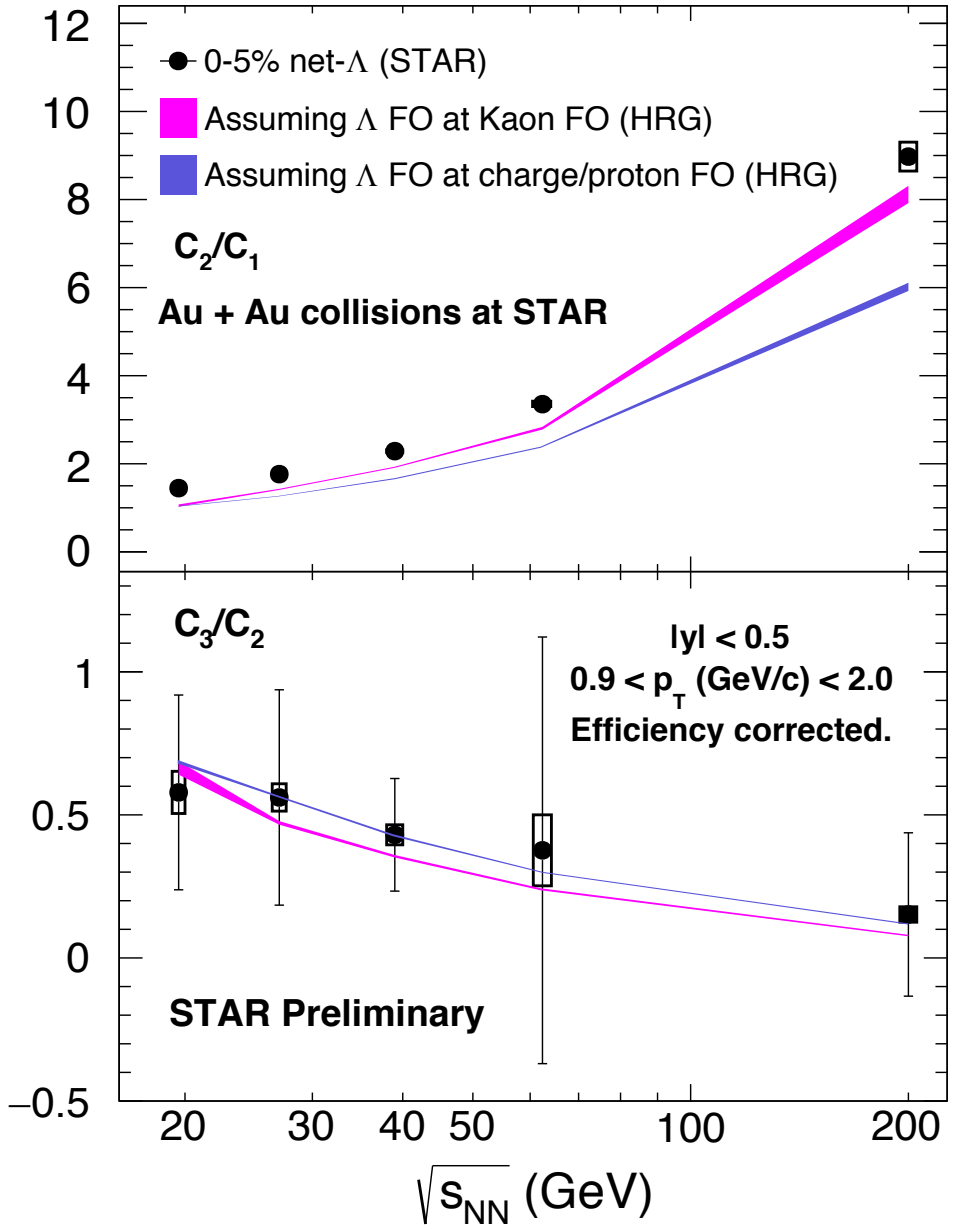
- Significant correlation in Q-k and Q-p is observed that can not be explained by thermal (HRG) or non-thermal (UrQMD) model calculations.



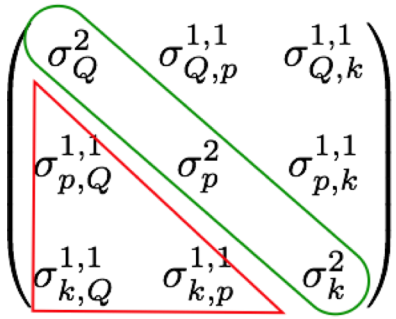
Toshihiro Nonaka
#585, May 16, 12:50

Cumulants of Net-Particle Distributions in Beam Energy Scan





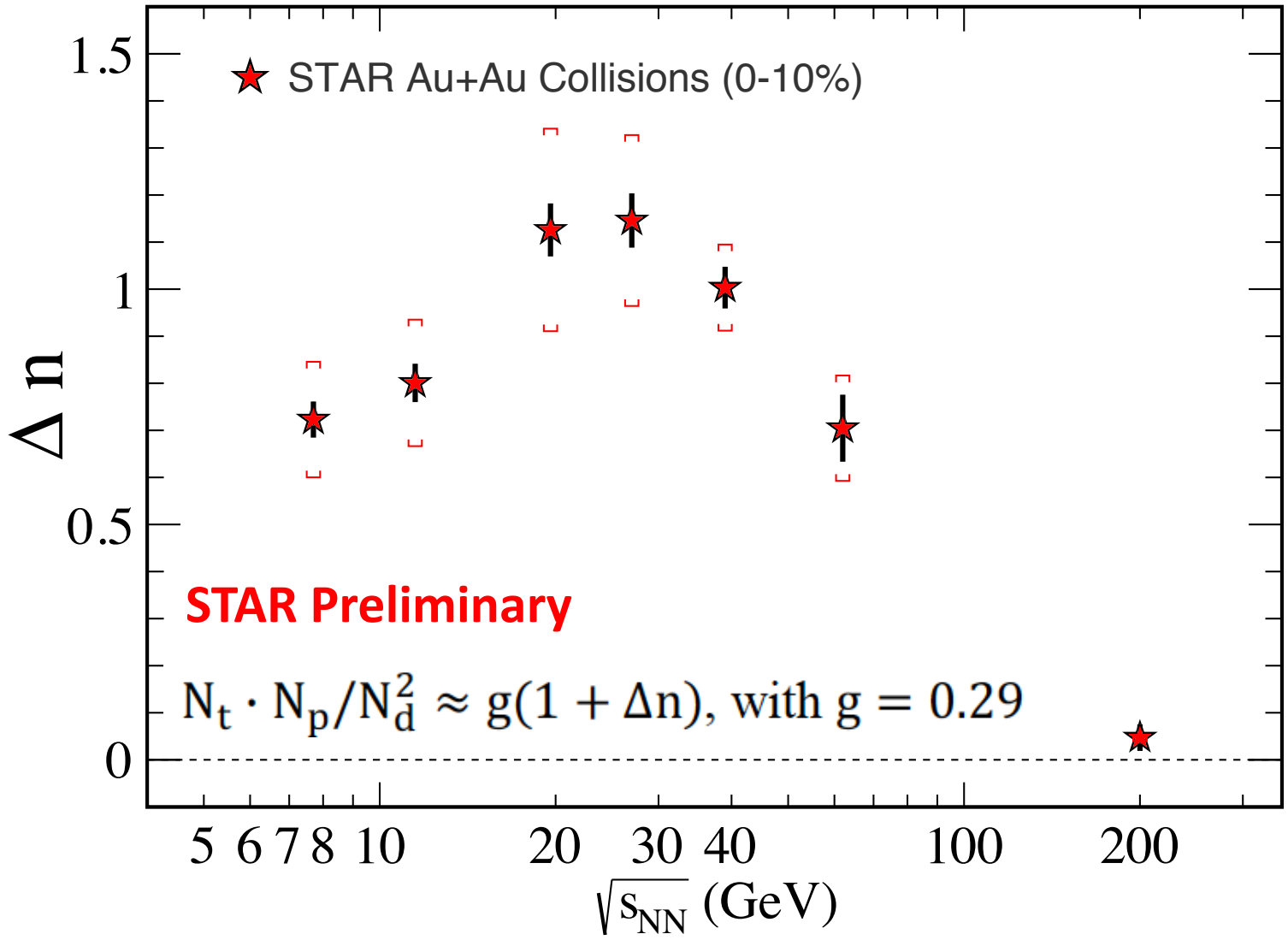
- Significant correlation in Q-k and Q-p is observed that can not be explained by thermal (HRG) or non-thermal (UrQMD) model calculations.



- Net-Lambda cumulant ratio C_2/C_1 closer to HRG calculations with freeze-out condition of kaon than charge/proton.

Toshihiro Nonaka
#585, May 16, 12:50

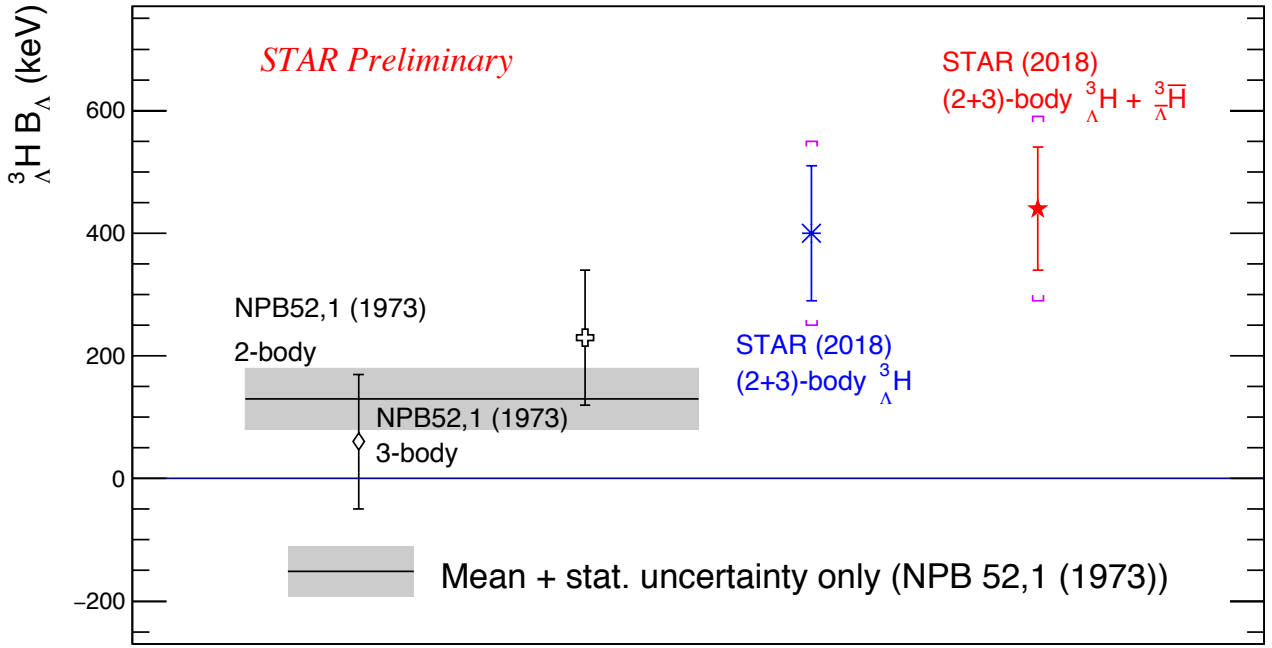
Triton Production in Beam Energy Scan

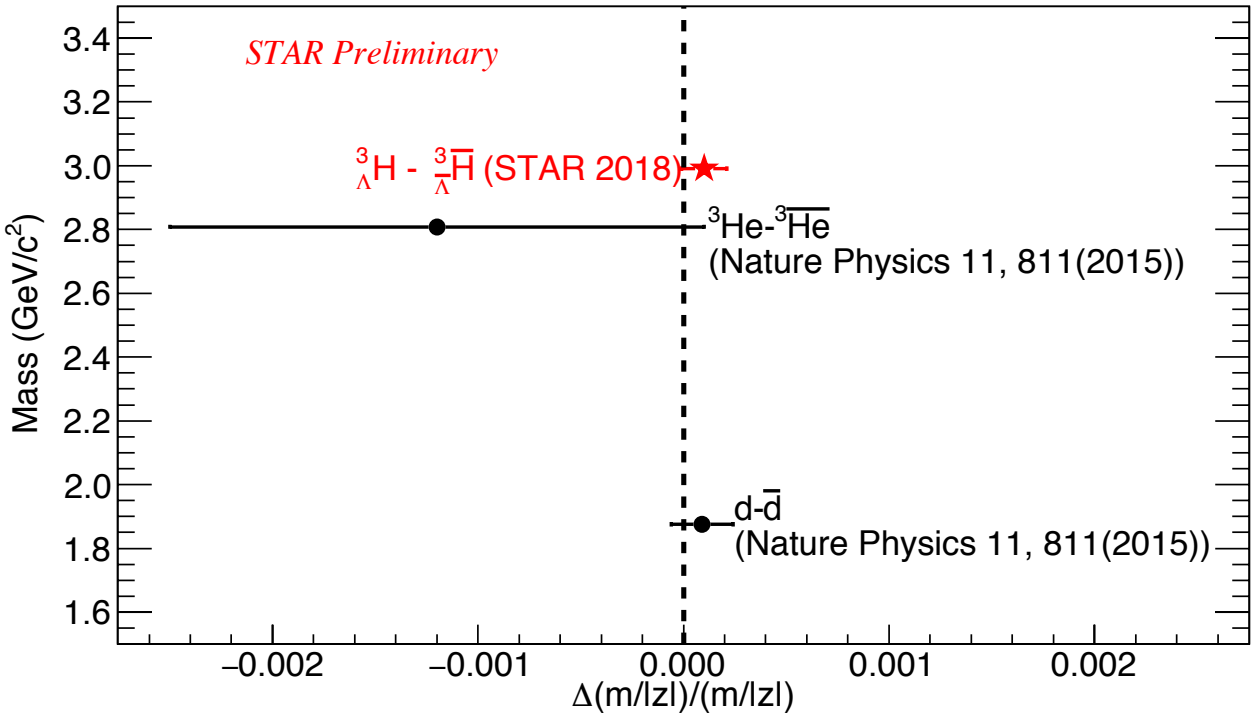


- Non-monotonic energy dependence of neutron density fluctuation $\Delta n = \langle \delta_n^2 \rangle / \langle n \rangle^2$

Peng Liu
#556, May 15, 15:40

Measurement of (Anti-)Hypertriton Masses





- Excellent S/B ratio from the HFT data, allowing for precise determination of the hypertriton binding energy:

$$m_d + m_\Lambda - m_{^{3}_{\Lambda}\mathrm{H}} = 0.44 \pm 0.10\,(\mathrm{stat.}) \pm 0.15\,(\mathrm{syst.})\ \mathrm{MeV}$$

providing insight on Hyperon-Nucleon interaction and thus neutron star structure,

and the mass difference between $^{3}_{\Lambda}\mathrm{H}$ and $^{3}_{\bar{\Lambda}}\bar{\mathrm{H}}$

$$(\Delta m/m)_{^{3}_{\Lambda}\mathrm{H}} = (1.0 \pm 0.9\,(\mathrm{stat.}) \pm 0.7\,(\mathrm{syst.}))\times 10^{-4}$$

is the first test of the CPT symmetry in the light hyper-nuclei sector.

Peng Liu
#556, May 15, 15:40

Outline

1. Open heavy flavor - D^0 v_1, D^0 R_{AA} and R_{CP}, Λ_c
2. Quarkonium - Υ R_{AA}
3. Jet modification and high-p_T hadrons - di-jet imbalance, di-hadron correlation

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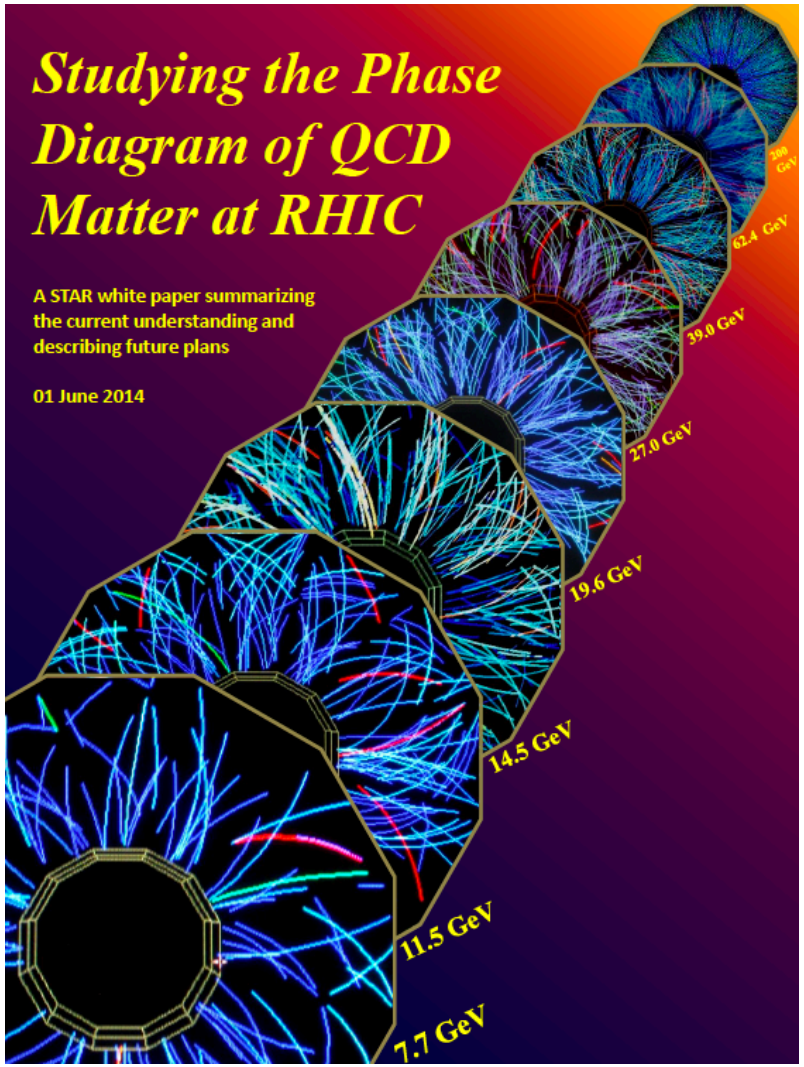
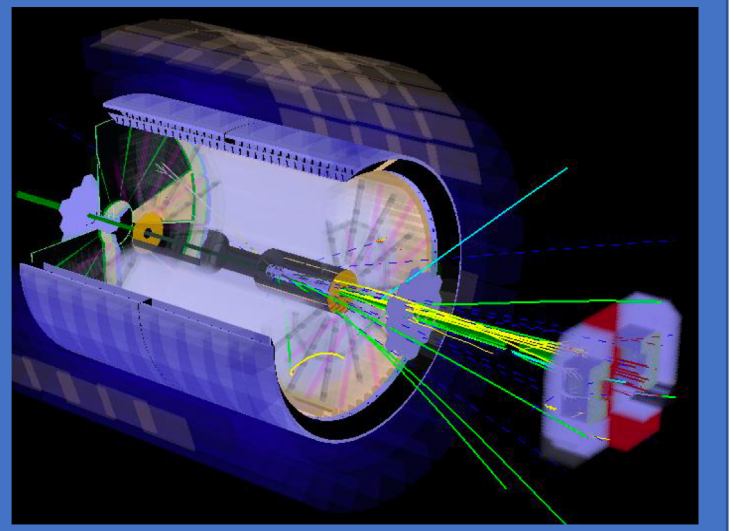
Beam Energy Scan Phase II and Forward Upgrades



The STAR Forward Calorimeter and Forward Tracking System



A Tale of Initial State: Nucleon to Nuclei

Beam Energy Scan Phase II (2019+)
Collider + FXT at 3.5-19.6 GeV
with iTPC, EPD, eTOF

Look for 1st order phase transition
Look for QCD critical point
Turn-off of QGP signatures

Forward Upgrade (2021+)
p+p, p+A, A+A at top energies

(3+1)D correlations
Initial state & hadronization in nucl. collisions
Subprocess driving large A_N at high x_F and η
Signature and A-dependence of saturation
TMDs at low and high x, $\Delta g(x)$ at low x

Qian Yang
#23, May 15, 10:00

Summary

1. Open heavy flavor - D^0 v_1, D^0 R_{AA} and R_{CP}, Λ_c
2. Quarkonium - Υ R_{AA}
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19 oral and 32 poster presentations from STAR (listed in the following slides)

Parallel Talks from STAR

Thermodynamics and hadron chemistry

#556 Precise measurement on hypertriton and anti-hypertriton masses and lifetimes with the Heavy Flavor Tracker and the production of triton in Au+Au collisions at STAR, by **Peng Liu, May 15 15:40**

Initial state physics and approach to equilibrium

#588 Collision System Dependence of Anisotropic Flow, Flow Fluctuations and Mixed Harmonic Correlations at STAR Energies, **by Niseem Magdy, May 15 11:30**

Correlations and fluctuations

#551 Event Plane Dependence of Di-hadron Correlations with Event Shape Engineering at the STAR Experiment**, by Ryo Aoyama, May 15 16:40**

#590 Geometry and Dynamics in Heavy-ion Collisions Seen by the Femtoscopy in the STAR Experiment, **by Sebastian Siejka, May 16 15:40**

Collective dynamics

#591 Measurement of Longitudinal Decorrelation of Anisotropic Flow v2 and v3 in 54 and 200 GeV Au+Au Collisions at STAR, **by Maowu Nie, May 15 12:50**

#587 Directed Flow of Quarks from the RHIC Beam Energy Scan Measured by STAR, **by Gang Wang, May 16 11:50**

Chirality, vorticity and polarisation effects

#584 Global Polarization of Lambda Hyperons in Au+Au Collisions at 200 GeV from STAR, **by Takafumi Niida, May 15 9:00**

#848 Measurements of the Chiral Magnetic Effect with Background Isolation in 200 GeV Au+Au Collisions at STAR, **by Jie Zhao, May 16 9:40**

#592 Search for the Chiral Magnetic Wave with Anisotropic Flow of Identified Particles at RHIC-STAR, **by Qiye Shou, May 16 17:30**

#731 Phi Meson and K* Spin Alignment in High Energy Nuclear Collisions at STAR, **by Chensheng Zhou, May 16 18:10**

Jet modifications and high-pT hadrons

#552 Systematic Studies of Jet-medium Interactions in STAR, **by Kun Jiang, May 16 10:20**

Open heavy flavor

#546 Measurements of Open Charm and Bottom Production in Au+Au Collisions at 200 GeV with the STAR Experiment at RHIC**, by Sooraj Radhakrishnan, May 15 15:40**

#540 Measurements of D0 Meson Directed, Elliptic and Triangular Flow Using the STAR Detector at RHIC, **by Subhash Singha, May 16 9:40**

Quarkonia

#544 Upsilon Measurements in Au+Au Collisions at √sNN= 200 GeV with the STAR Experiment, **by Pengfei Wang, May 15 11:10**

Phase diagram and search for the critical point

#585 Recent Results and Methods on Higher Order and Off-diagonal Cumulants of Identified Net-particle Multiplicity Distributions in Au+Au Collisions at STAR, **by Toshihiro Nonaka, May 16 12:50**

High baryon density and astrophysics

#558 Recent Results from the STAR Fixed-Target Program, **by Yang Wu, May 15 16:00**

Collectivity in small systems

#734 Long-range Collectivity in Small Collision Systems with Two- and Four-particle Correlations at STAR, **by Shengli Huang, May 15 11:30**

Future facilities, upgrades and instrumentation

#23 The STAR BES II and Forward Rapidity Physics and Upgrades, **by Qian Yang, May 15 10:00**

Posters from STAR

Thermodynamics and hadron chemistry

#450 Collision Energy and Centrality Dependence of Light Nuclei (Triton) Production at RHIC with the STAR Experiment, by Dingwei Zhang

#559 Strangeness Production in U+U Collisions at STAR, by Srikanta Kumar Tripathy

Initial state physics and approach to equilibrium

#98 Cold Nuclear Matter Effects on Non-Photonic Electron Production Measured in p+Au Collisions at √sNN = 200 GeV at STAR, by Peipei Zheng

#543 Measurements of D0 Production in p+Au and d+Au Collisions at √sNN = 200 GeV by the STAR Experiment, by Lukas Kramarik

#733 Directed Flow Due to the Initial Source Tilt and Density Asymmetry in Cu+Au and Au+Au Collisions at STAR, by Takafumi Niida

Correlations and fluctuations

#453 Effect of Volume Fluctuation and Non-binomial Efficiency on the Cumulants of Net-proton Multiplicity Distributions at the STAR Experiment, by Toshihiro Nonaka

#467 Angular Correlations Study of Identified Hadrons in the STAR Beam Energy Scan Program, by Andrzej Lipiec

#528 Energy Dependence of the Fluctuations of Net-Lambda Distributions at STAR, by Nalinda Kulathunga

#532 Measurement of the Sixth-order Cumulant of Net-charge Distributions in Au+Au Collisions at √sNN = 200 GeV by the STAR Experiment, by Tetsuro Sugiura

#579 Femtoscopic Measurements for Shape-engineered Events in Au+Au Collisions at STAR, by Benjamin Schweid

Collective dynamics

#124 D0-meson Elliptic Flow Measurement in Au+Au Collisions at √sNN = 200 GeV from STAR, by Yue Liang

#527 Charged Particle Yields and Anisotropic Flow at Forward Rapidities from Au+Au Collisions at 54GeV Using the STAR Event Plane Detector, by Isaac Upsal

Chirality, vorticity and polarisation effects

#452 The Azimuthal Angle Dependence of Lambda (anti-Lambda) Polarization in Au+Au Collisions from STAR, by Biao Tu

#593 Beam Energy and Collisions System Dependence of Charge Separation Relative to the Second-, Third- and Fourth-order Event Planes and the Implications for the Search for Chiral Magnetic Effects in STAR, by Niseem Magdy

Jet modifications and high-pT hadrons

#375 Performance of Heavy-flavor Tagged Jet Identification in STAR, by Saehanseul Oh

Open heavy flavor

#81 Centrality and Transverse Momentum Dependences of D0-meson and D±-meson Production at Mid-rapidity in Au+Au Collisions at √sNN = 200 GeV at STAR, by Guannan Xie

#83 Topological Cut Optimization for Lambda_c Reconstruction Using the Supervised Learning Algorithm in TMVA at STAR, by Chuan Fu

#84 Production of D± Mesons in Au+Au Collisions at √sNN = 200 GeV Measured by the STAR Experiment, by Jan Vanek

#85 Extraction of Bottom Production via the Semi-leptonic Decay Channel in Au+Au Collisions at √sNN = 200 GeV by the STAR Experiment, by Yifei Zhang

#87 D*± Production in Au+Au Collisions at √sNN = 200 GeV Measured by the STAR Experiment, by Yuanjing Ji

#100 Measurement of Lambda_cbar-/Lambda_c+ Ratio in Au+Au Collisions at √sNN = 200 GeV with the STAR Experiment, by Miroslav Simko

#541 Measurements of Open Bottom Hadron Production via Displaced J/psi, D0 and Electrons in Au+Au Collisions at √sNN = 200 GeV at STAR, by Xiaolong Chen

Quarkonia

#80 Measurement of J/psi Polarization in p+p Collisions at √s = 200 GeV through the Di-muon Channel at STAR, by Zhen Liu

#110 Measurements of the Upsilon Meson Production in Au+Au Collisions at √sNN = 200 GeV by the STAR Experiment, by Oliver Matonoha

Electromagnetic and weak probes

Dimuon Invariant Mass Spectra with the Muon Telescope Detector at STAR in p+p collisions at 200 GeV, by James Brandenburg

Phase diagram and search for the critical point

#534 Off-diagonal Cumulants of Net-charge, Net-proton, and Net-kaon Multiplicity Distributions in Au+Au collisions at STAR, by Arghya Chatterjee

#535 Cumulants of Net-Proton Multiplicity Distributions in Cu+Cu Collisions at √sNN = 22.4, 62.4 and 200 GeV from STAR, by Zhenzhen Yang

Collectivity in small systems

#851 STAR Measurements of Elliptic Flow in Small Collision Systems, by Maria Sergeeva 15

Future facilities, upgrades and instrumentation

#14 Performance of the STAR Event Plane Detector, by Justin Ewigleben

#20 Construction of the STAR Event Plane Detector, by Joseph Adams

#25 The STAR Mid-Rapidity Physics Program after the BES-II, by Qian Yang

#26 The STAR Forward-Rapidity Physics Program after the BES-II, by Li Yi