Charged, Identified, Strange Hadron Spectra and Flow

Supported in part by:

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for the STAR collaboration

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Outlines

- Physics Motivations
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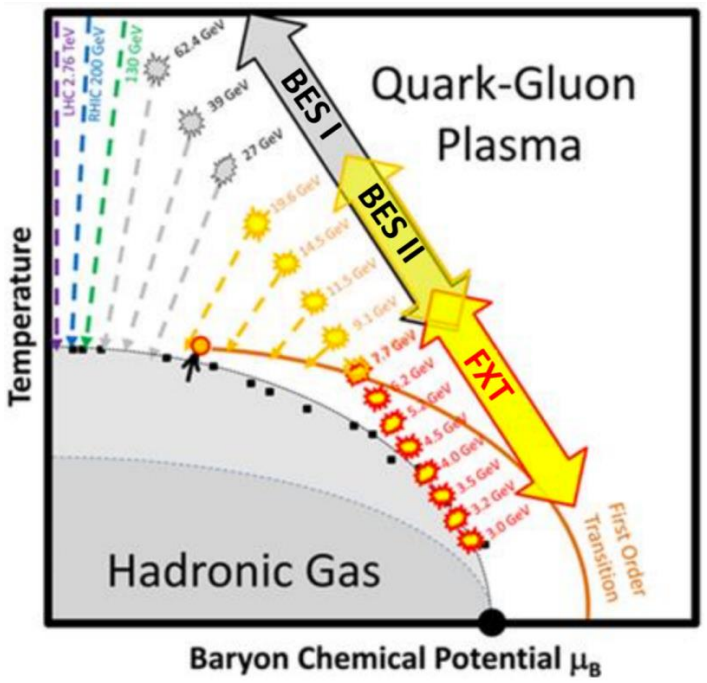
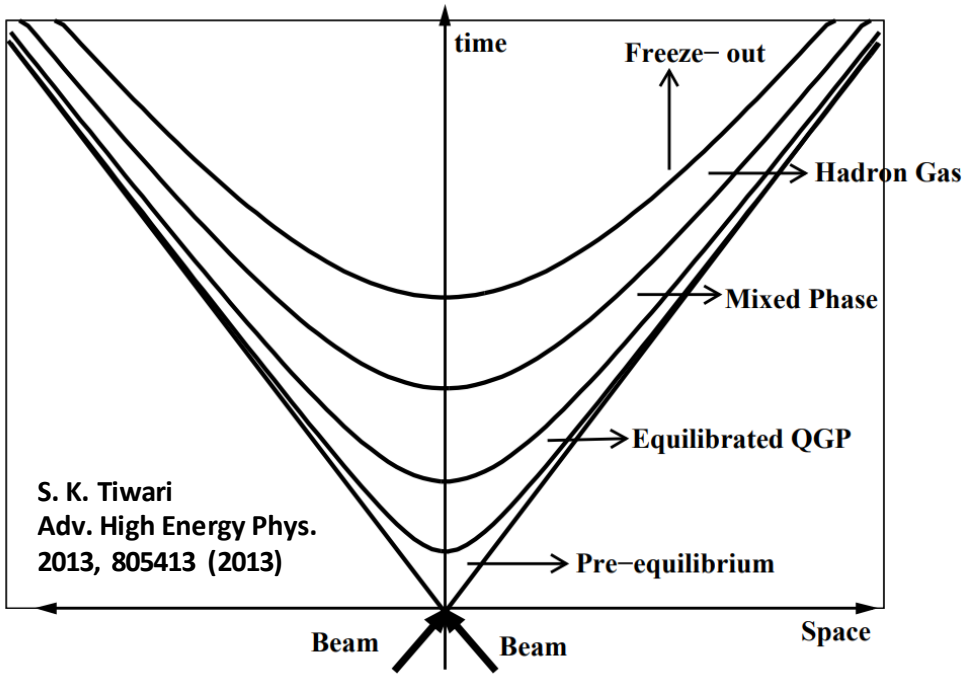
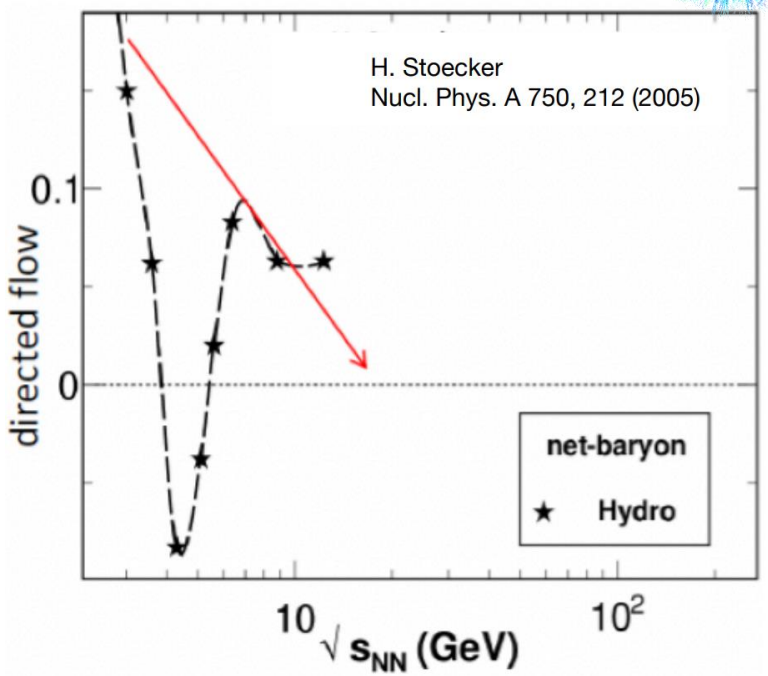
- Recent Results from Charged, Identified, and Strange Hadron Flow
- New Results from Anisotropic Flow and mean P_T correlation
- Outlook from STAR BES-II & FXT for Run-20 and Run-21
- Summary

Physics Motivations







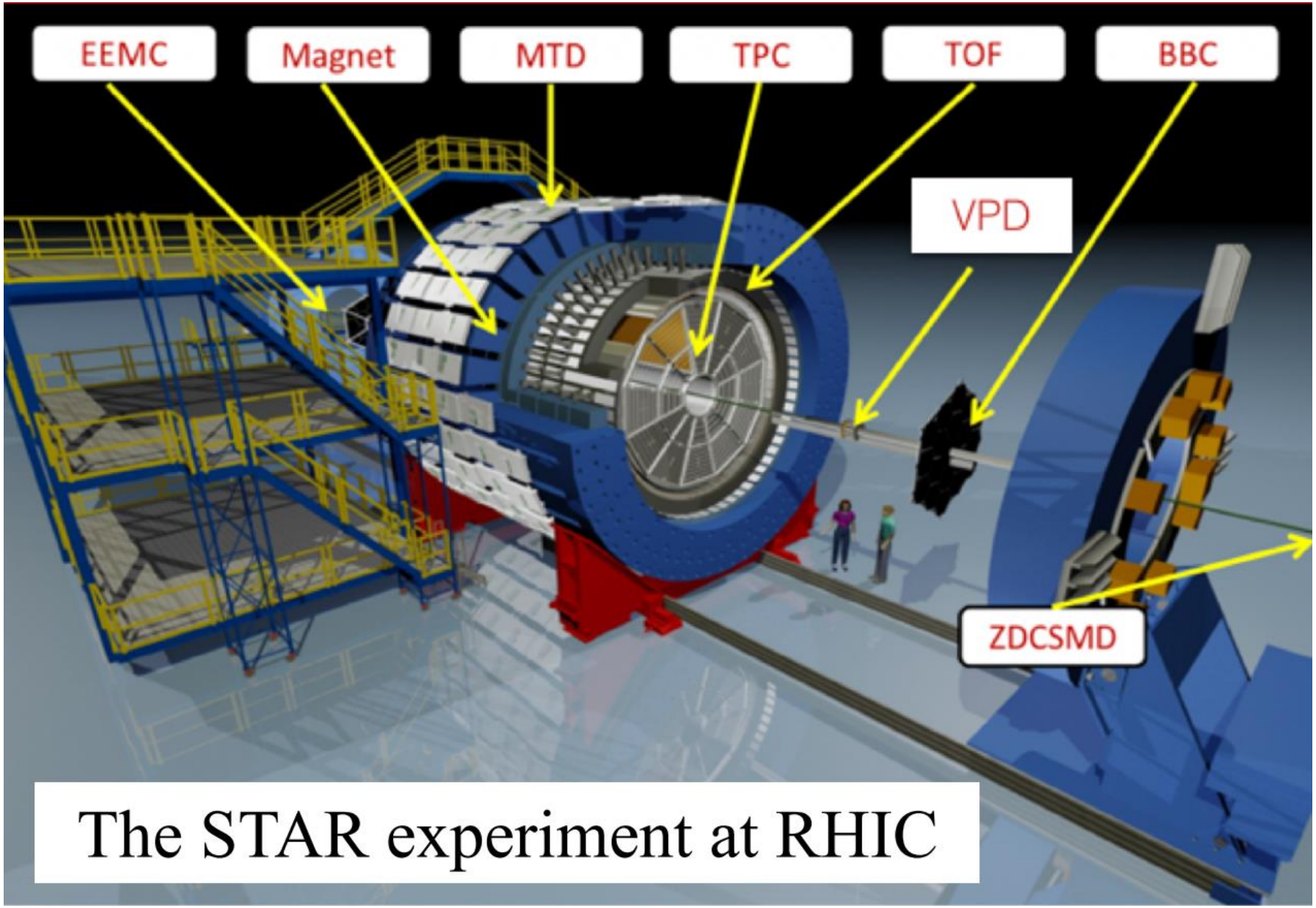
BES & BES-II Goals:

1. Search for the 1st order phase transition
2. Search for the critical point
3. Find turn-off QGP signatures

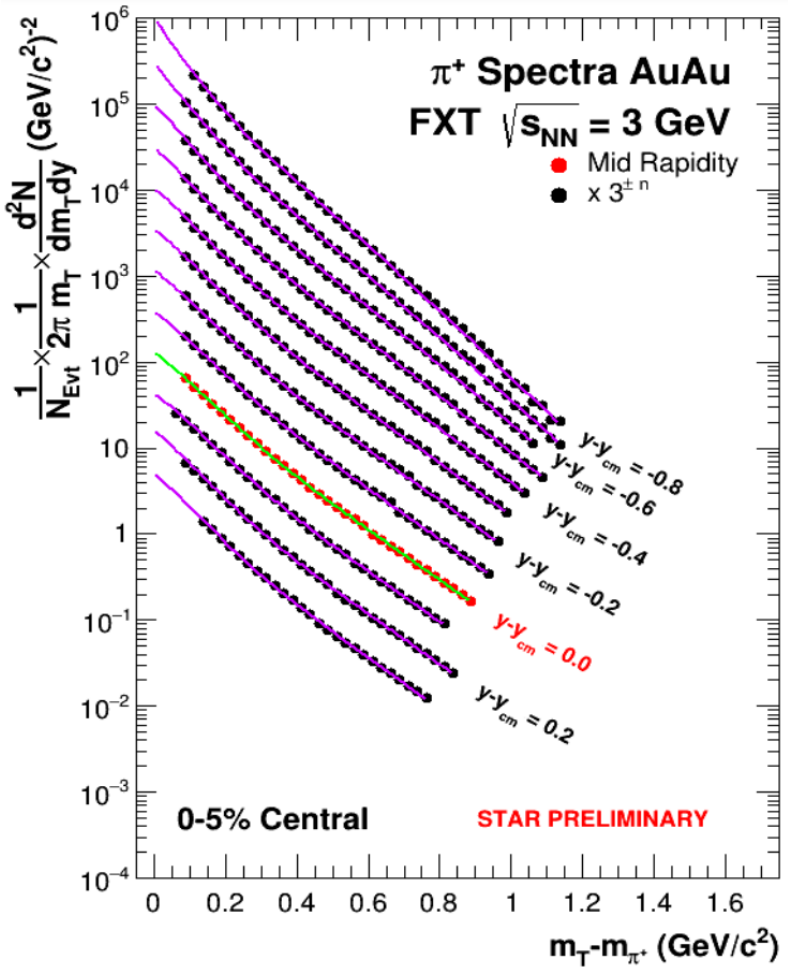
Measurement on multiplicity variations of produced particles wrt collision energy, the momentum spectra of particles, and ratios of various particles, together with model, study the level of equilibration of particles.

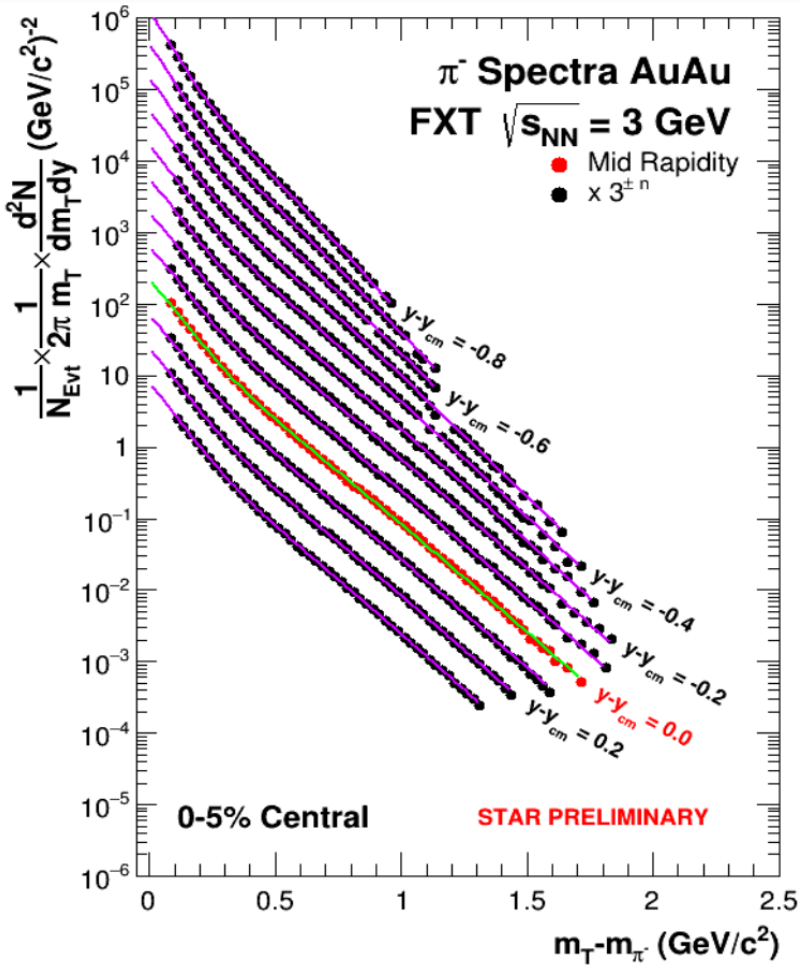
Anisotropic flow probes early collision stage dynamics.
BES net-proton, net-lambda directed flow measurements qualitatively like hydro "softest point" behavior.
ϕ vector meson flow: change of EoS.

The STAR Detector



Recent Results From Hadron Spectra at 3 GeV

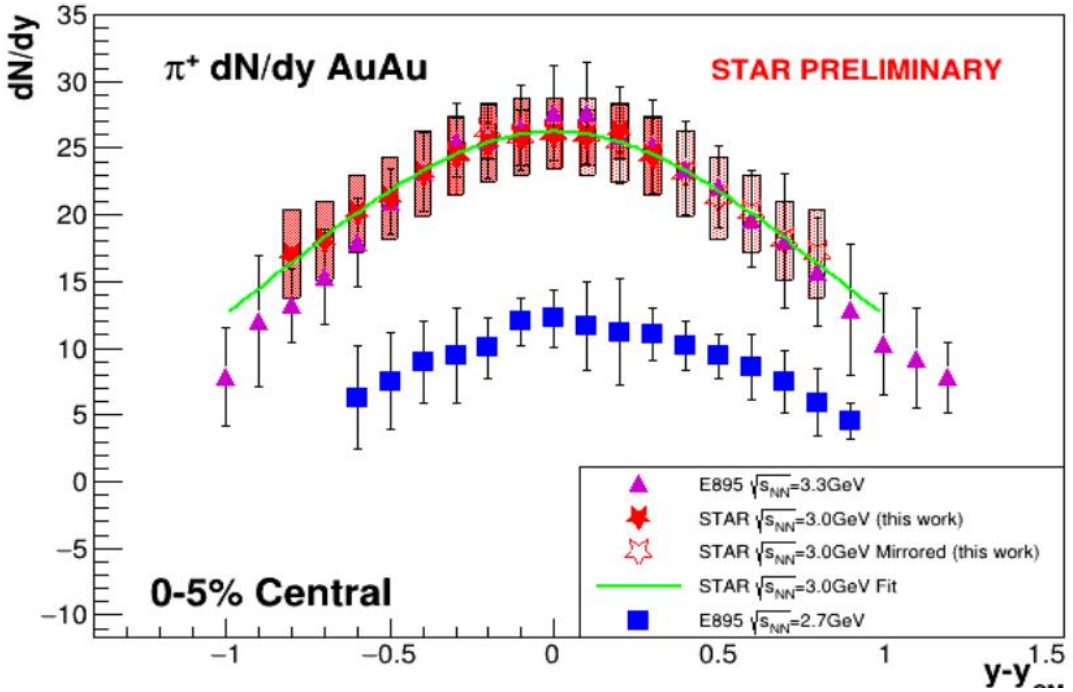


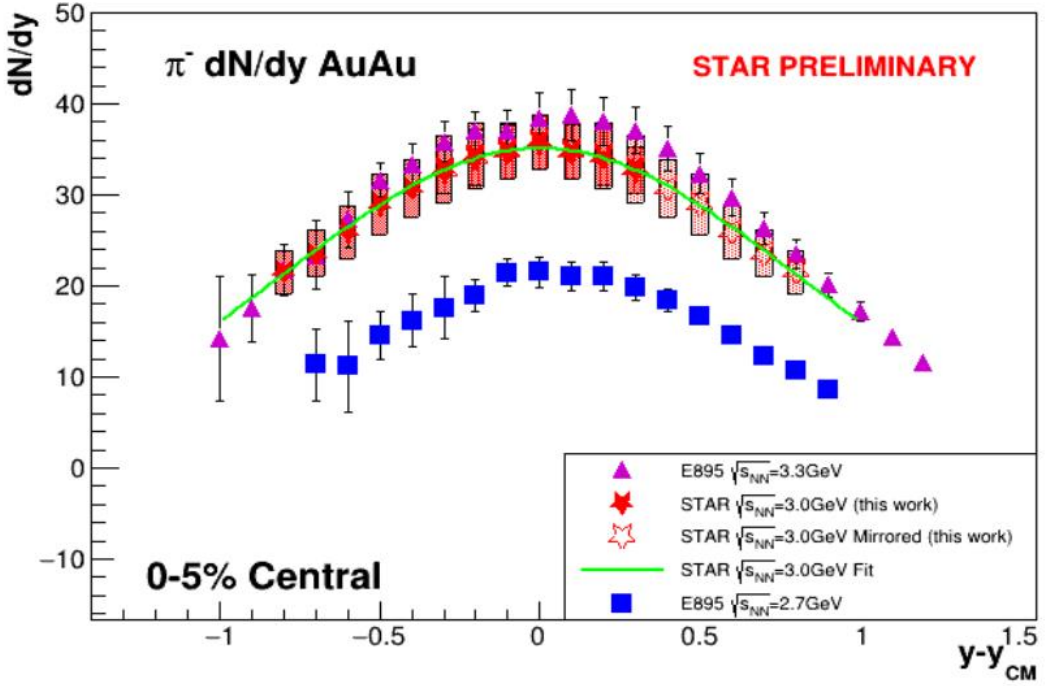


Please see poster by Benjamin Kimelman

Pion transverse mass spectra were fitted with double thermal function.
Pion production from Δ resonance at low temperature and thermal production at high temperature shown by E895 using fit with same function.

Rapidity dependence of particle production at 3 GeV





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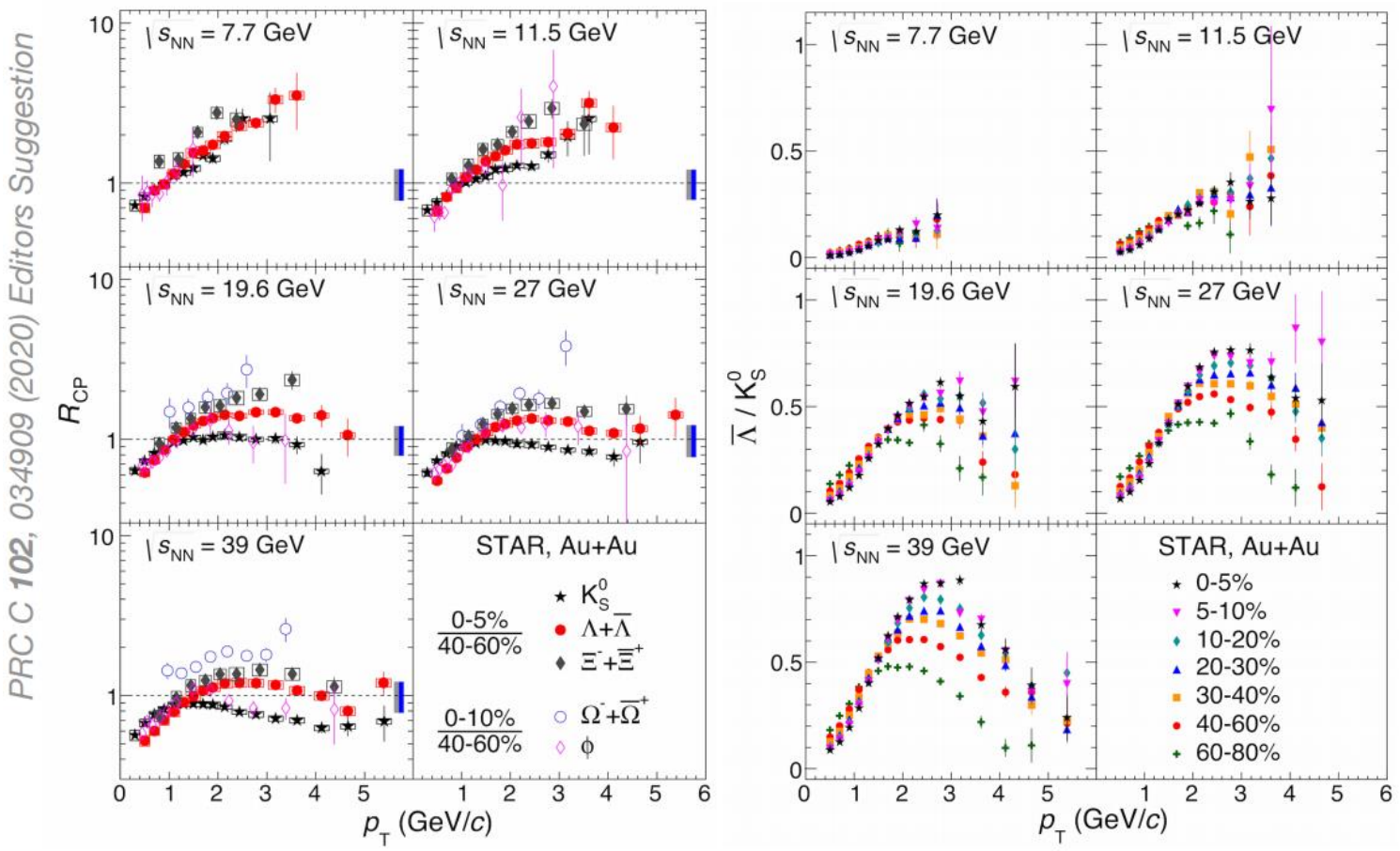
Pion rapidity density measurement is fitted with Gaussian function. STAR FXT measurements agree well with E895 experiment results at the AGS.

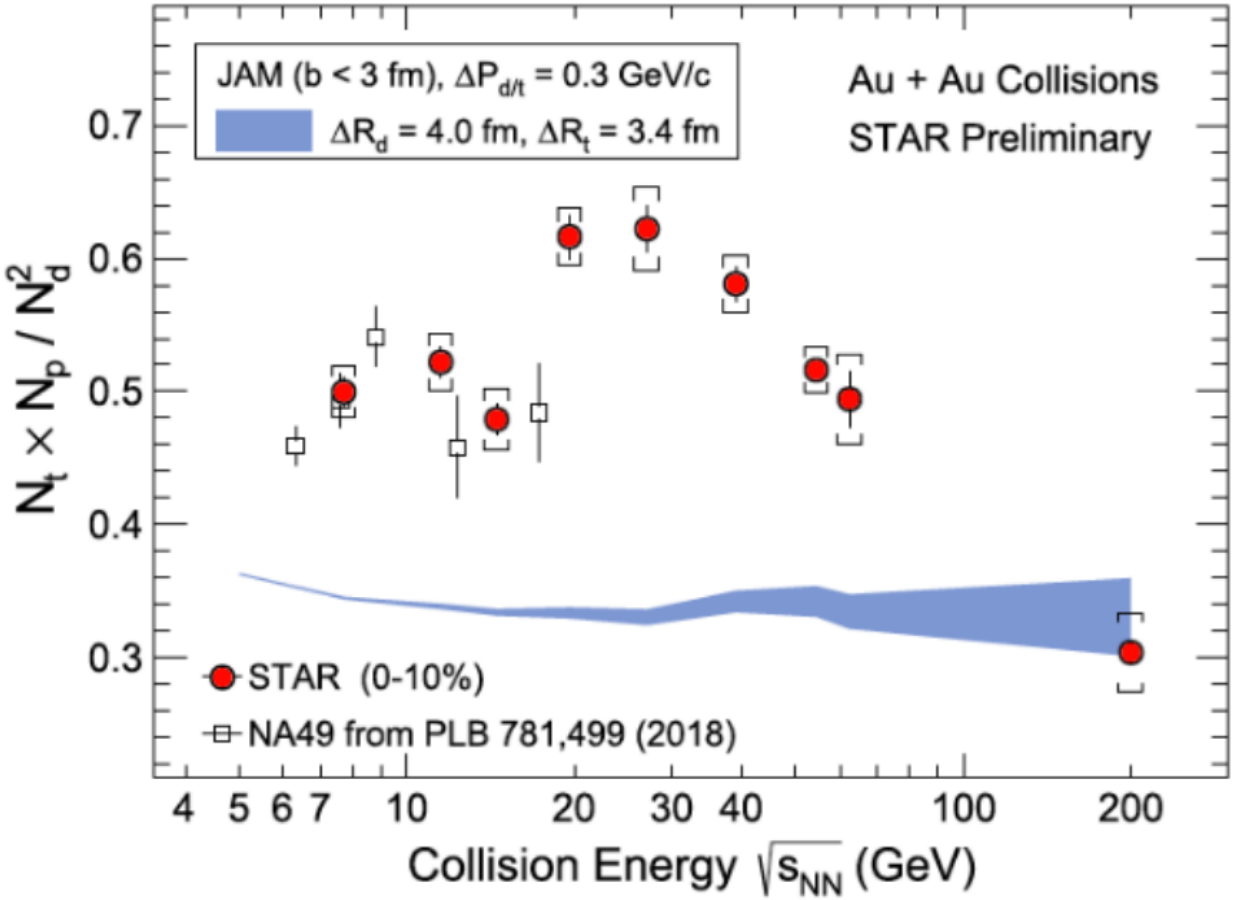
$\sqrt{s_{NN}}$ dependence of nuclear modification factor



In STAR Highlights talk by Raghav Kunnawalkam Elayavalli, https://indico.bnl.gov/event/9385/#6-star-highlights

- Rcp starts to turn over around 20 GeV.
- Baryon-to-meson enhancement at intermediate P_T (≈ 2.5 GeV/c) in central collisions at energies above 19.6 GeV.
- Both suggest a likely change of the underlying strange quark dynamics at energies below 19.6 GeV

Recent Results from Hadron Spectra



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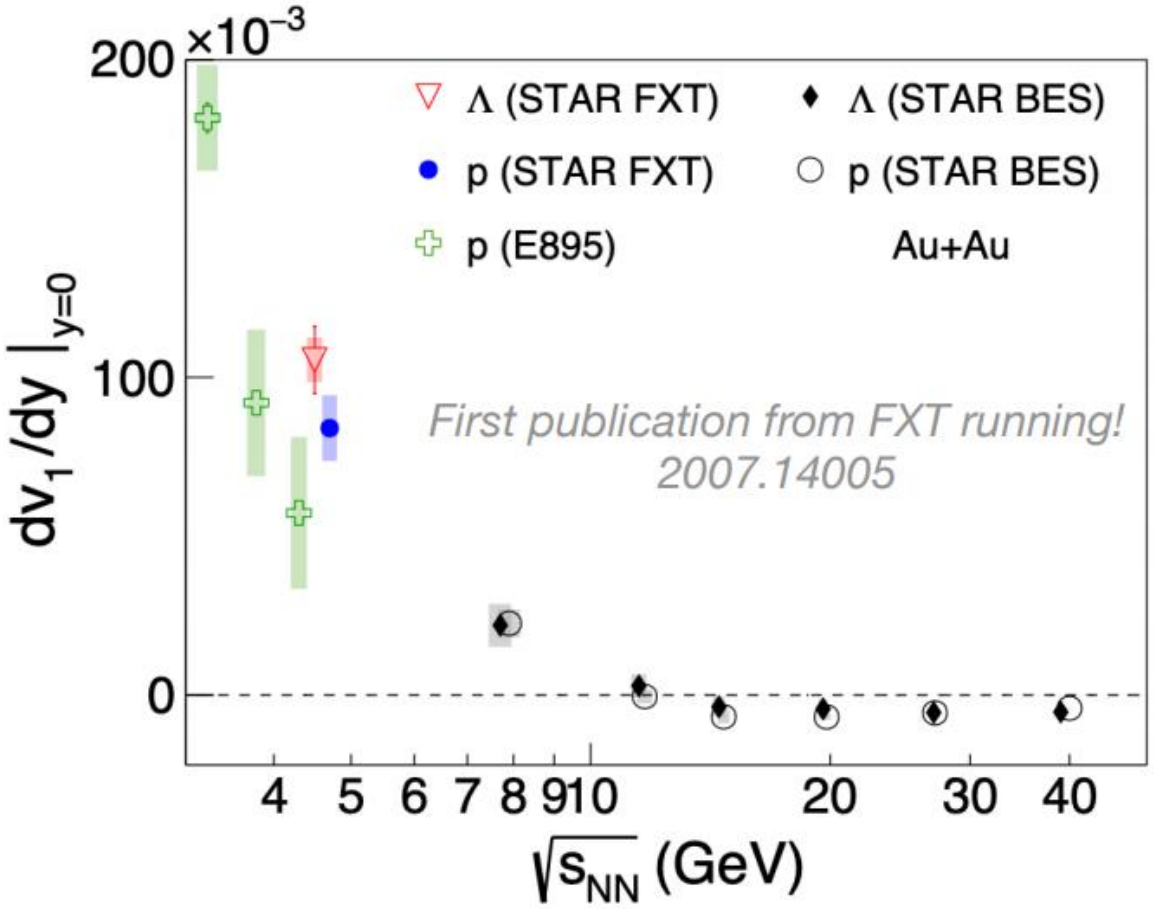
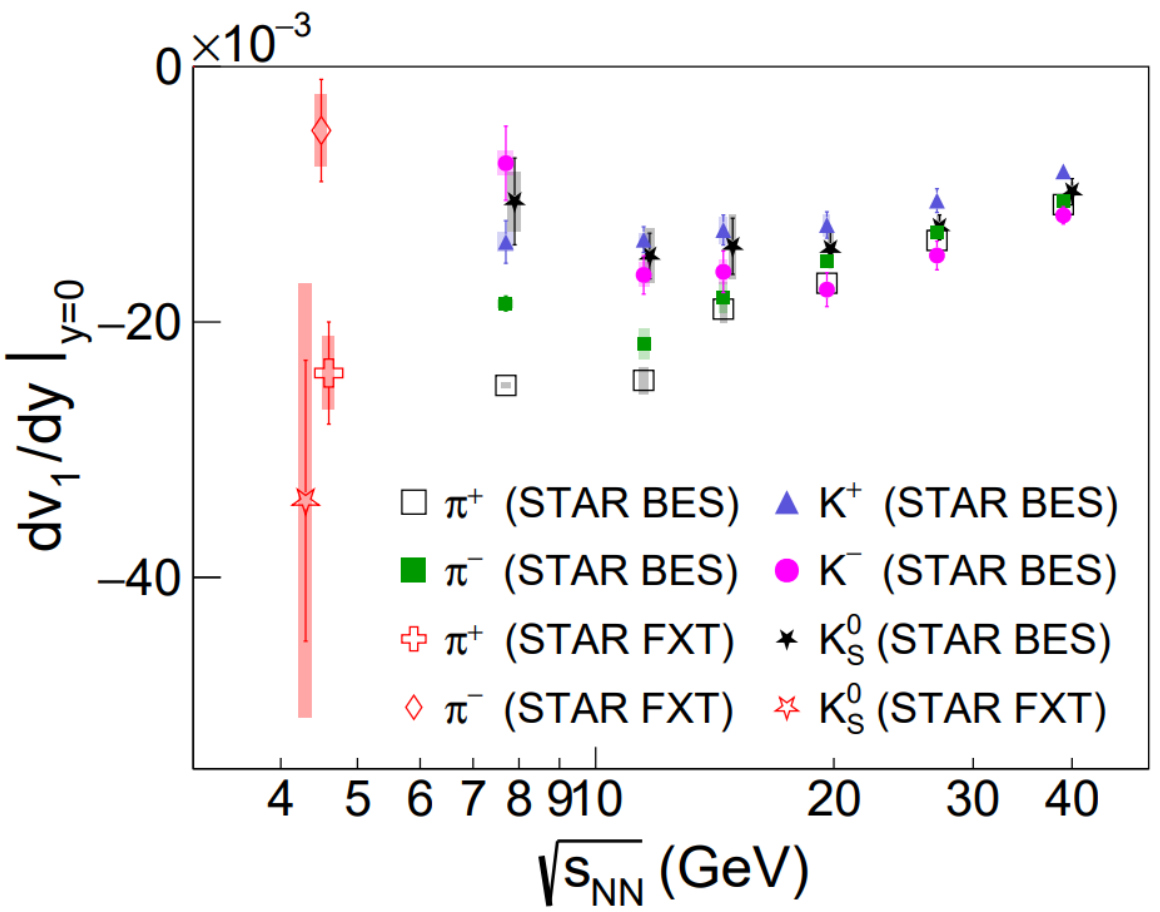
- Measurements from STAR and NA49 are consistent.
- Yield ratio shows non-monotonic dependence on collision energies in 0-10% Au+Au collisions.
- The yield ratio is related to neutron density fluctuations.

Recent Results from Charged, Identified & Strange Hadron Flow

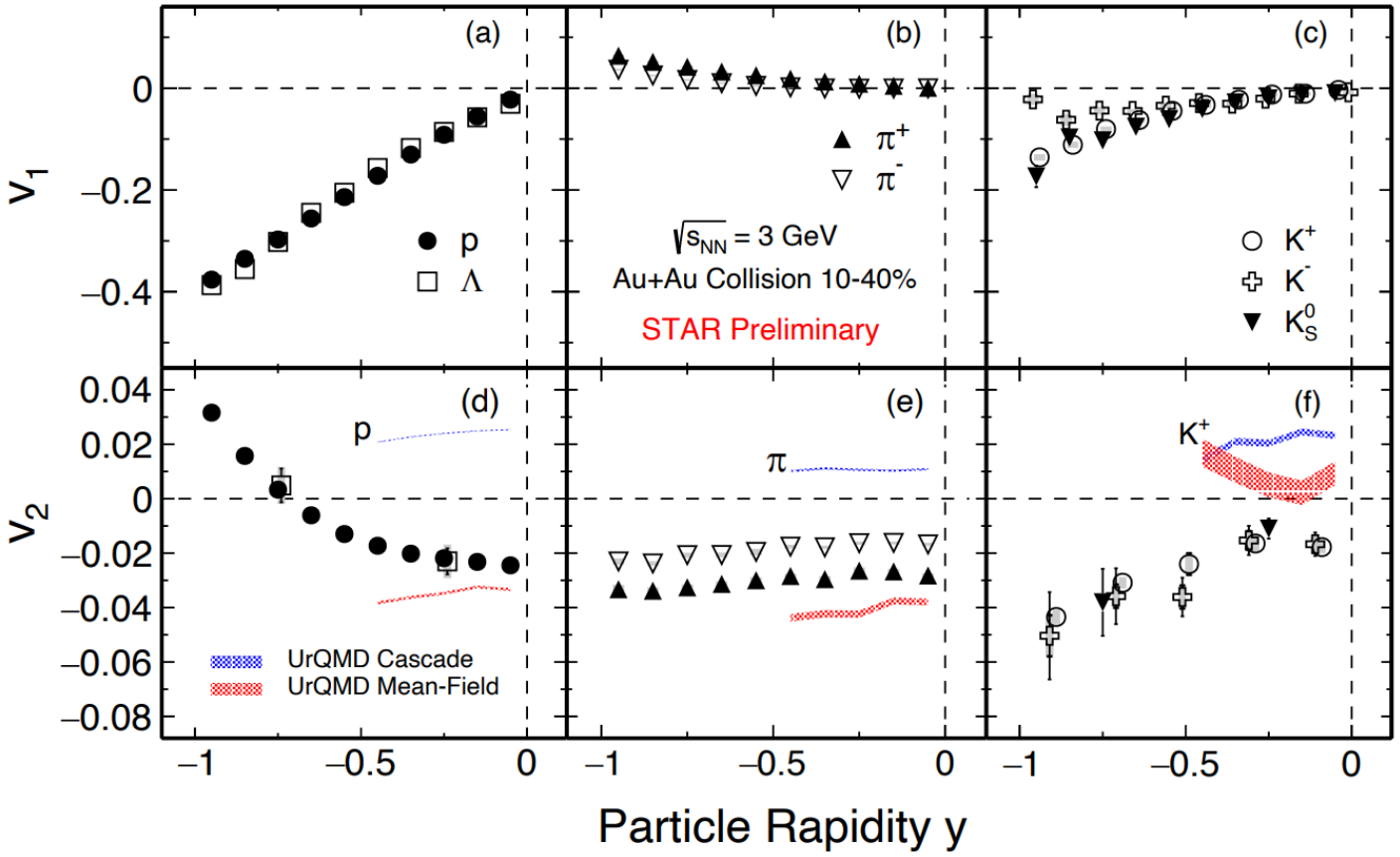


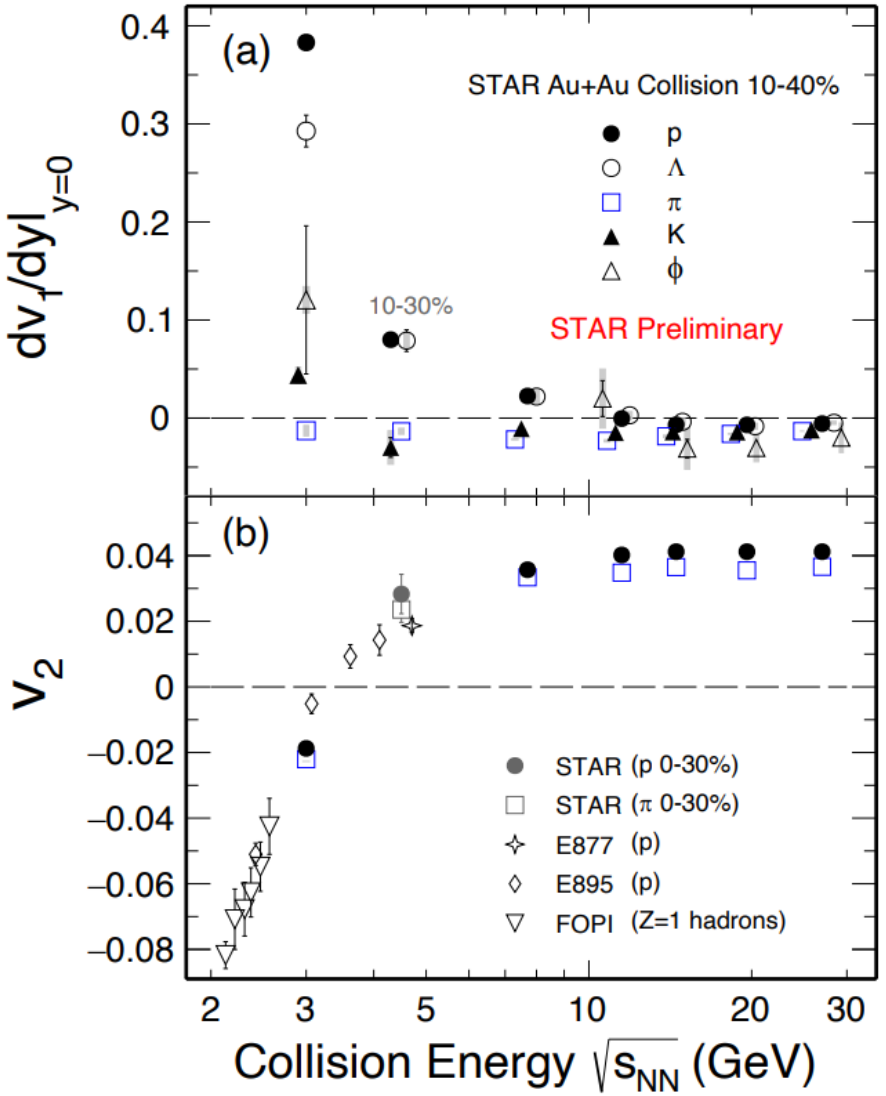


- Positive proton and Λ v_1 in 4.5 GeV Au+Au collisions in line with E895 experiment results at the AGS.
- negative pion and kaon v_1 continues the trend at higher collision energies within systematic uncertainties.

In STAR Highlights talk by Raghav Kunnawalkam Elayavalli, https://indico.bnl.gov/event/9385/#6-star-highlights

Recent Results from Charged, Identified & Strange Hadron Flow

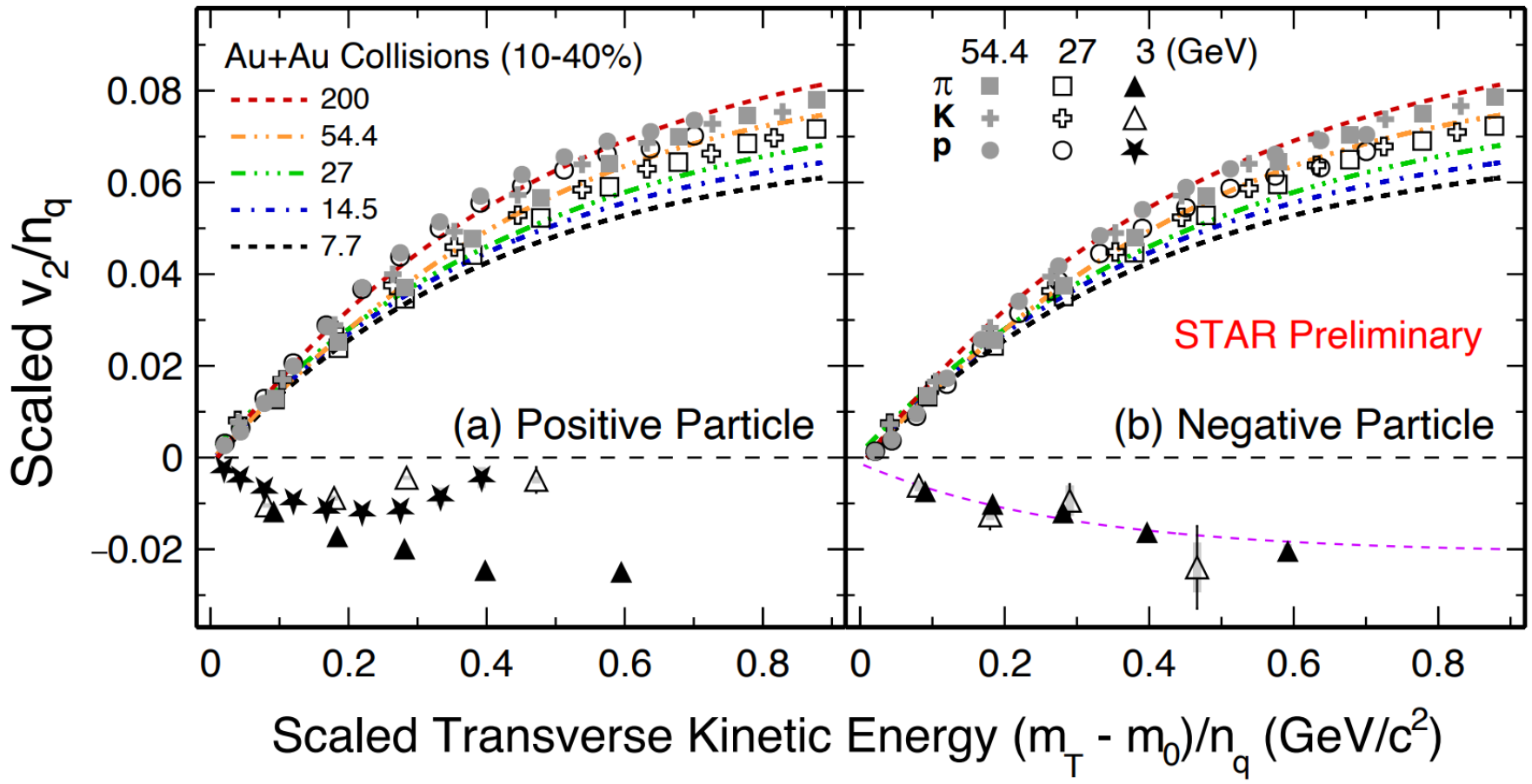




For intermediate centrality:

- Proton, Kaon v_1 show positive slope at midrapidity.
- Pion v_1 slope stay negative at 3 GeV.
- pi/K/p v_2 are negative at midrapidity.

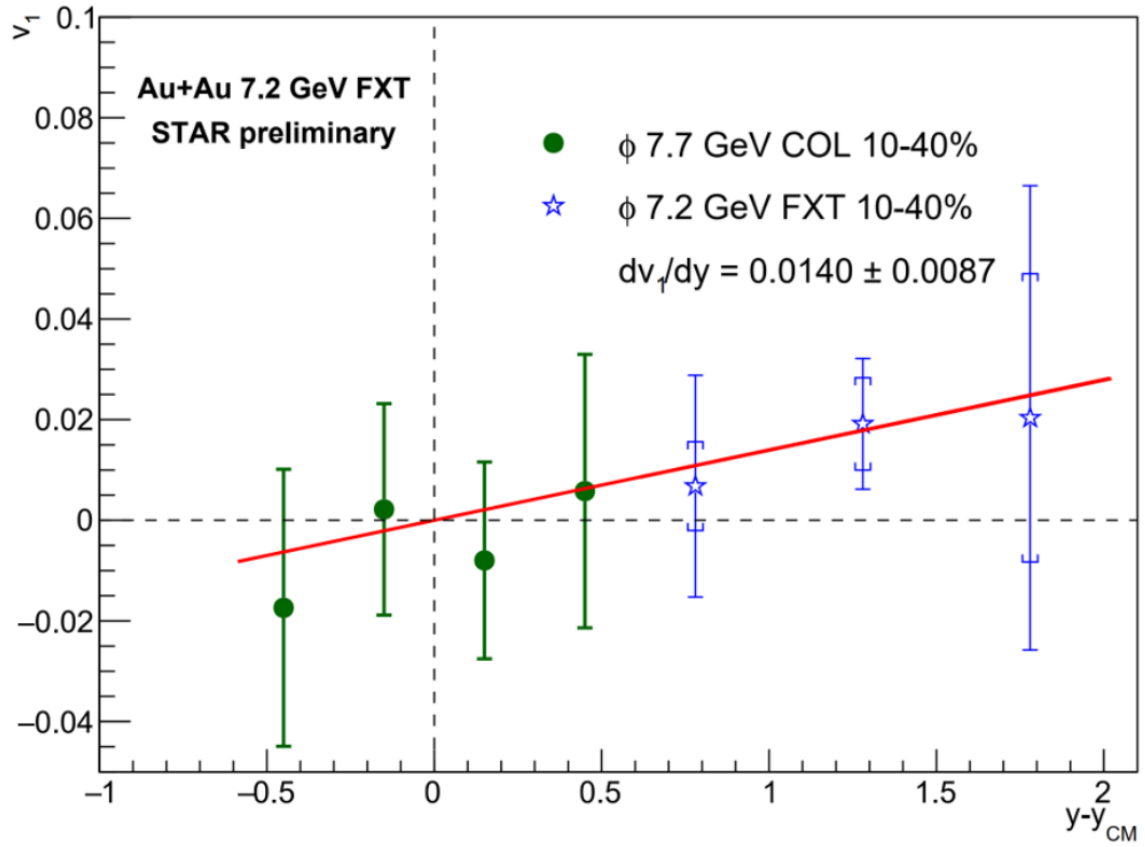
Recent Results from Charged, Identified & Strange Hadron Flow



For intermediate centrality:

- pi/K/p v_2 are negative and the NCQ scaling is absent at 3 GeV.
- Results imply a very different medium behavior at 3 GeV.
- Dashed line indicates the strength of scaled v_2.

Recent Results from Charged, Identified & Strange Hadron Flow

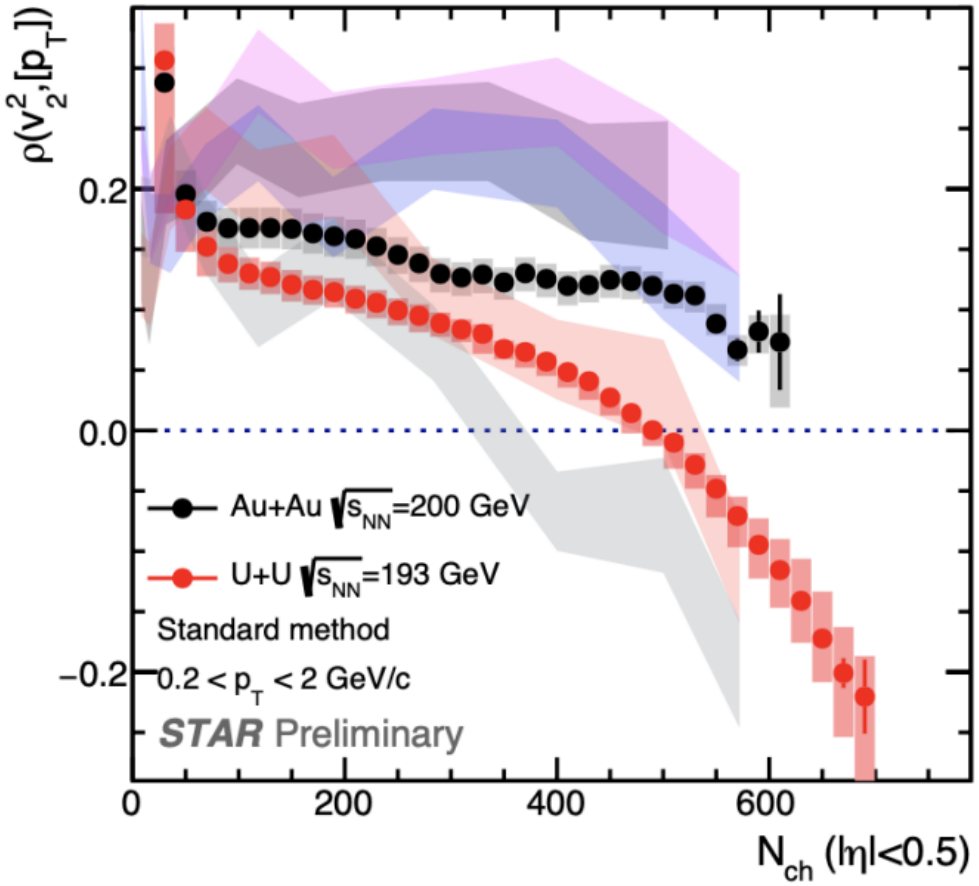


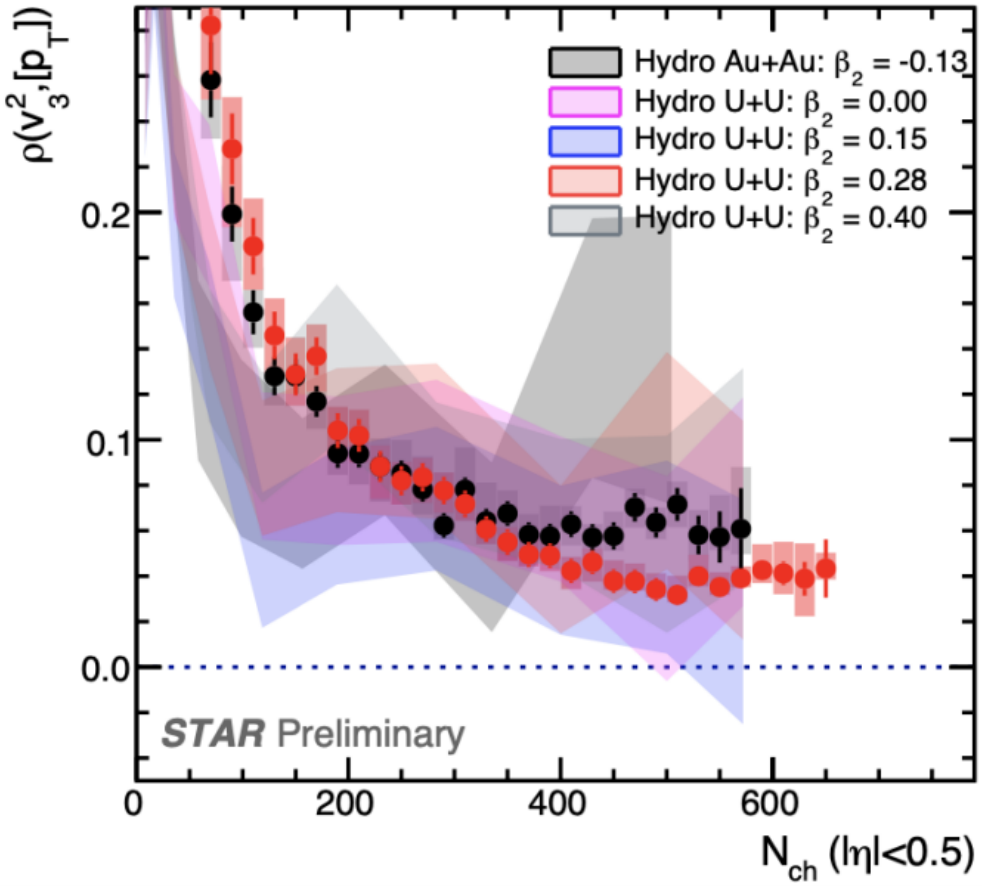
[1]L. Adamczyk et al. (STAR). *Phys. Rev. Lett. 120 062301.*

For intermediate centrality:

- Positive ϕ vector meson v_1 is measured at 7.2 GeV.
- 7.2 GeV result (blue stars) follows a similar trend as BES 7.7 GeV measurement (green dots).

New Results from Anisotropic Flow and mean p_T correlation

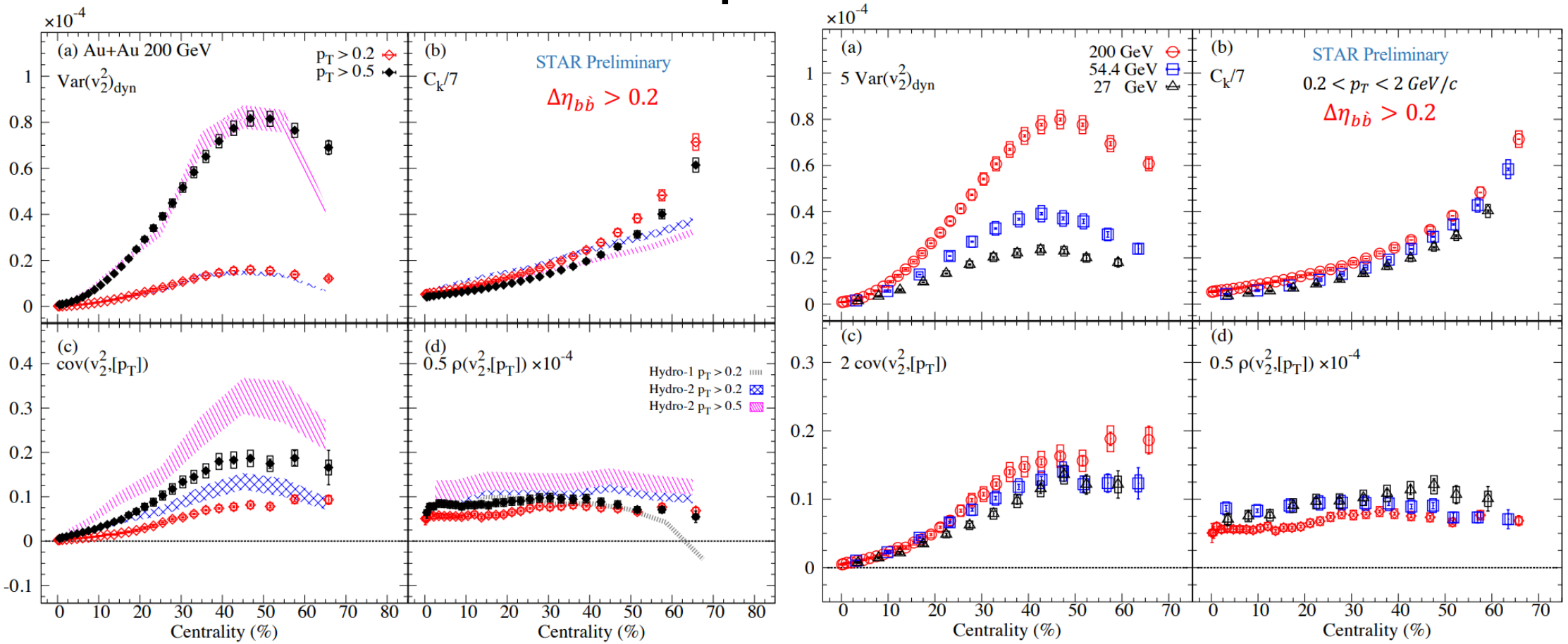




Please see poster by Chunjian Zhang

- The modified Pearson Correlation Coefficient (PCC) $\rho(v_2^2, p_T)$ has a sign-change in U+U central collisions.
- $\rho(v_3^2, p_T)$ is positive in both U+U and Au+Au collisions.
- IP-Glasma + Hydro shows the hierarchical β_2 dependence in $\rho(v_2^2, p_T)$.
- Measurements provide novel ways to constrain quadrupole deformation β_2 in heavy-ion collisions.

New Results from Anisotropic Flow and mean PT correlation



- The modified PCC $\rho(v_2^2, p_{\mathrm{T}})$ scales as a fraction of the flow signal.
- $\rho(v_2^2, p_{\mathrm{T}})$ increases with beam energy.
- Hydro models can qualitatively describe the data.
- Measurements compared to viscous hydrodynamic model calculation will provide constraints on the initial conditions and $\frac{\eta}{s}(T)$.

Outlook from STAR BES-II & FXT for Run-20 and Run-21

Table 1: Summary of all BES-II and FXT Au+Au beam energies, equivalent chemical potential, event statistics, run times, and date collected.

Beam Energy (GeV/nucleon)	$\sqrt{s_{NN}}$ (GeV)	μ_B (MeV)	Run Time	Number Events Requested (Recorded)	Date Collected
13.5	27	156	24 days	(560 M)	Run-18
9.8	19.6	206	36 days	400 M (582 M)	Run-19
7.3	14.6	262	60 days	300 M (324 M)	Run-19
5.75	11.5	316	54 days	230 M (235 M)	Run-20
4.59	9.2	373	102 days	160 M (162 M)[1]	Run-20+20b
31.2	7.7 (FXT)	420	0.5+1.1 days	100 M (50 M+112 M)	Run-19+20
19.5	6.2 (FXT)	487	1.4 days	100 M (118 M)	Run-20
13.5	5.2 (FXT)	541	1.0 day	100 M (103 M)	Run-20
9.8	4.5 (FXT)	589	0.9 days	100 M (108 M)	Run-20
7.3	3.9 (FXT)	633	1.1 days	100 M (117 M)	Run-20
5.75	3.5 (FXT)	666	0.9 days	100 M (116 M)	Run-20
4.59	3.2 (FXT)	699	2.0 days	100 M (200 M)	Run-19
3.85	3.0 (FXT)	721	4.6 days	100 M (259 M)	Run-18
3.85	7.7	420	11-20 weeks	100 M	Run-21[2]

[1] Run-20b data taking completed 7:30am Sept 1.
[2] Data not yet collected, Run-21 forms part of this year's BUR.

Table 2: Proposed Run-21 assuming 24-28 cryo-weeks, including an initial one week of cool-down, one week for CeC, a one week set-up time for each collider energy and 0.5 days for each FXT energy.

Single-Beam Energy (GeV/nucleon)	$\sqrt{s_{NN}}$ (GeV)	Run Time	Species	Events (MinBias)	Priority
3.85	7.7	11-20 weeks	Au+Au	100 M	1
3.85	3 (FXT)	3 days	Au+Au	300 M	2
44.5	9.2 (FXT)	0.5 days	Au+Au	50 M	2
70	11.5 (FXT)	0.5 days	Au+Au	50 M	2
100	13.7 (FXT)	0.5 days	Au+Au	50 M	2
100	200	1 week	O+O	400 M 200 M (central)	3
8.35	17.1	2.5 weeks	Au+Au	250 M	3
3.85	3 (FXT)	3 weeks	Au+Au	2 B	3

- More statistics for COL & FXT energies, enables more precise measurements, such as ϕ meson v_1 v_2, baryon-to-meson enhancement measurement at both COL & FXT energies.
- More collision energies, enables more complete collision energy dependent studies.

Y. Wu, RHIC & AGS Annual Users Meeting, 10/22/2020

STAR note: https://drupal.star.bnl.gov/STAR/system/files/BUR2020_final.pdf

Summary

- Recent hadron spectra & flow measurements from STAR show results coming from FXT energies close to the AGS experiments.
- Agreements with the AGS experiments results at lower energies and with the BES results at higher energies have been observed for hadron spectra and flow measurements.
- New results of nuclear modification factor and baryon-to-meson enhancement show underlying strange quark dynamics at collision energies lower than 19.6 GeV.
- New results of identified and strange hadron directed flow at 3 GeV show first positive mid-rapidity slope for kaon and ϕ meson.
- Negative v_2 of charged hadrons at 3 GeV agree with world data, and v_2 of pi, K, p shows all negative values and doesn't follow NCQ scaling, implying a very different medium behavior at 3 GeV.
- Modified Pearson Correlation Coefficient between $[p_T]$ and v_2 was measured at U+U and Au+Au collisions systems at STAR, showing novel ways to constrain nuclear deformation parameter as well as the initial conditions in heavy-ion collisions.

Thank you for your attention!

Supported in part by:

Office of Science

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