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Nuclear modification factor of inclusive charged particles in Au+Au collisions with the STAR experiment.

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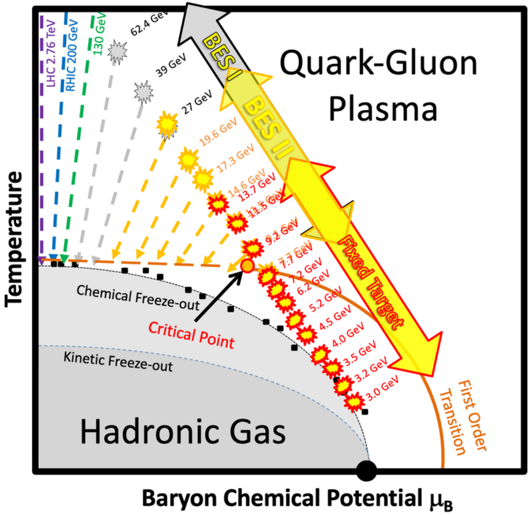
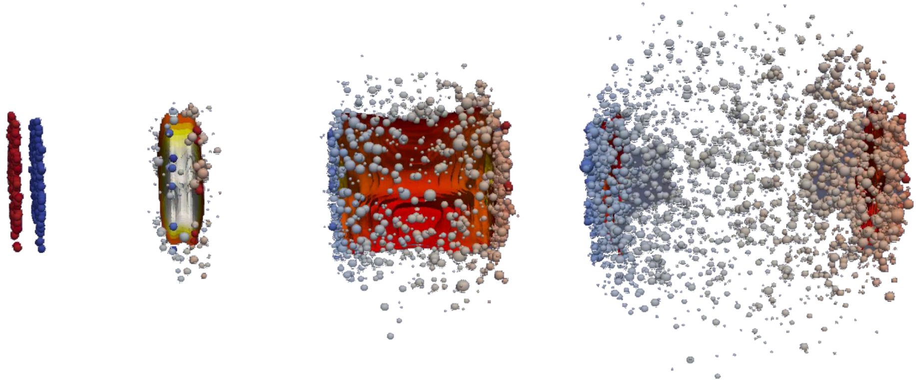
July 3, 2025

Phases of QCD Matter



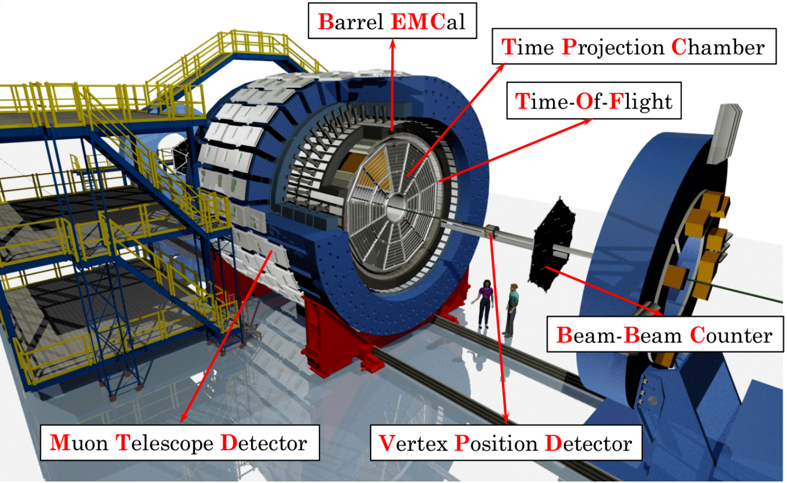
- **QCD Phase Diagram**
  - Cross-over transition expected at low baryon chemical potential (μ_β)
  - First-order transition expected at high μ_B
  - Critical point is the end point of the first order phase transition
- **Beam Energy Scan (BES)**
  - Explore the QCD matter by colliding gold ions at different energies - and search for the potential QCD critical point
  - Seeking to map onset of deconfinement, and the predicted QCD critical point

Heavy Ion Collisions



Different stages of relativistic heavy ion collision. From left to right: (1) two Lorentz contracted nuclei right before the collision, (2) formation of dense, hydro dynamically expanding matter at around 1-2 fm/c after the collision, (3) hydrodynamic expansion of the dense core, surrounded by hadronic corona (the particles on the plot represent individual hadrons), (4) final state hadronic interactions and decoupling of the fireball. (Image from an animation by MADAI)

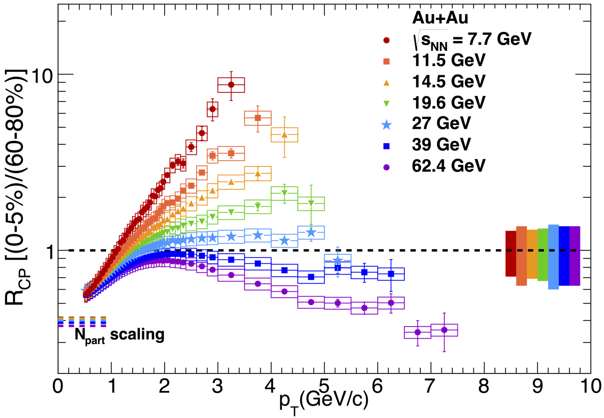
Solenoidal Tracker at RHIC (STAR)



STAR detector and its various detector subsystems

- **Time Projection Chamber (TPC)**
  Measures charged particle momentum with track curvature under B-field.
  Identifies particle with energy loss per unit length (dE/dx).
  TPC: $|\eta| < 1$
- **Time of Flight (TOF)**
  Extends momentum range for particle identification.
  Pile-up rejection.
  TOF: $|\eta| < 1$
- **Detector Modernization (2018+)**
  EPD: $2.1 < |\eta| < 5.1$
  iTPC: $|\eta| < 1.5$
  eTOF (2019+): $-1.6 < \eta < -1$

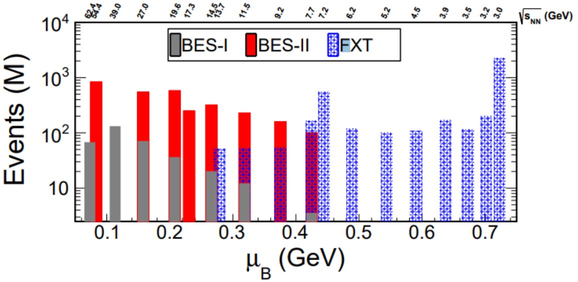
Motivation



Dependence of the nuclear modification factor on the transverse momentum of produced particles (BES-I)

J.Adams (STAR Collaboration), Phys. Rev. Lett., 121 (2018) n.3, 032301

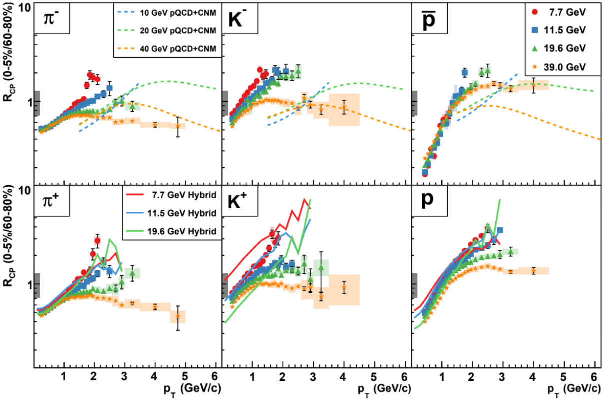
Comparison of statistics between *BES-I* (2010-2017) and *BES-II* (2019-2021)



- Nuclear modification factor:

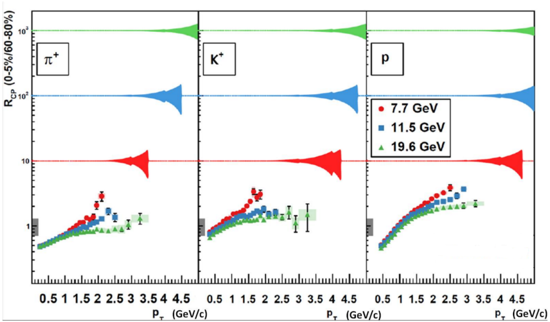
$$R_{CP} = \frac{\langle N_{coll}\rangle_{Peripheral}}{\langle N_{coll}\rangle_{Central}} \frac{\left(\frac{d^2N}{dp_T\,d\eta}\right)_{Central}}{\left(\frac{d^2N}{dp_T\,d\eta}\right)_{Peripheral}}$$

R_{CP} of identified hadrons up to $p_T = 5 GeV/c$



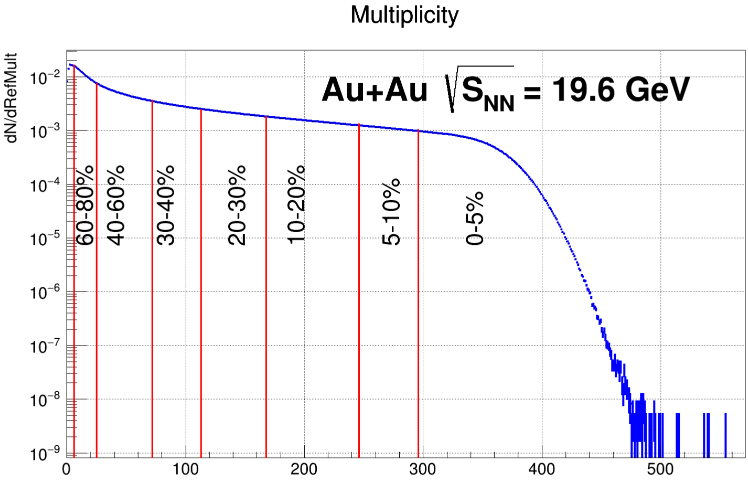
J.Adams (STAR Collaboration), Phys. Rev. Lett., 121 (2018) n.3, 032301

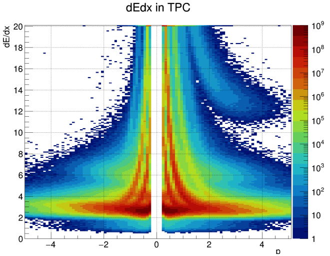
The top three lines represent statistical error bands. For better visibility, the error ranges have been scaled by 10 (for 7.7 GeV), 100 (for 11.5 GeV), 1000 (for 19.6 GeV)

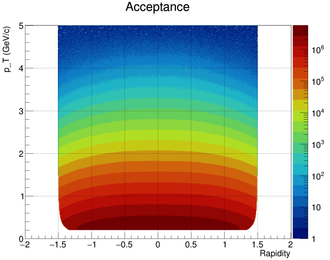


Although the BES-I RCP results hint at the disappearance of the QGP signature, their certainty remains limited due to the constraints of 3-4 GeV/c for inclusive hadrons and 2-3 GeV/c for identified hadrons. The anticipated extension of pT capabilities in BES-II holds paramount importance in establishing unequivocal determinations regarding QGP formation at distinct collision energies.

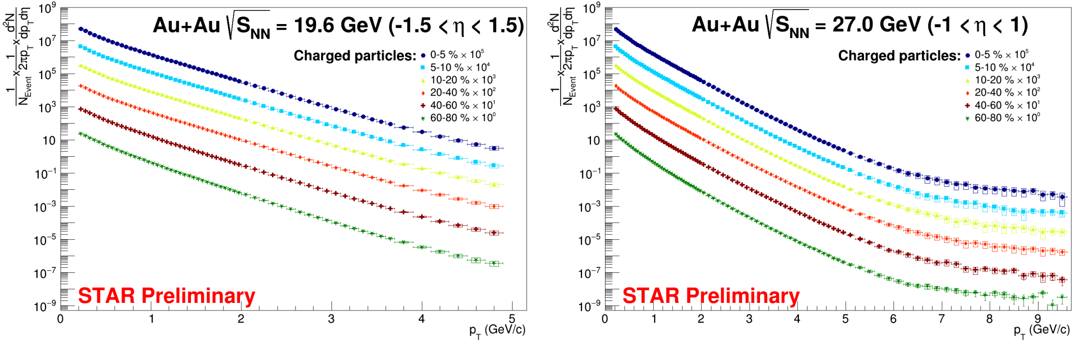
Centrality definition





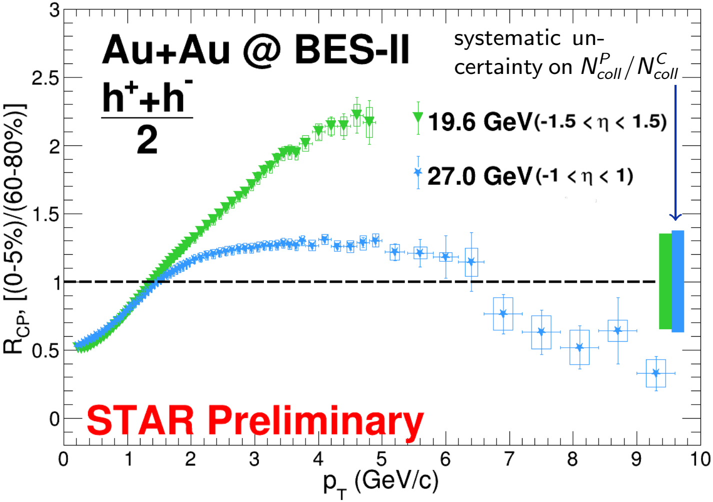


Spectra for centrality classes



Transverse momentum distribution of inclusive charged particles for collision energy of 19.6 GeV (left) and 27 GeV (right). Each spectrum corresponds to a certain centrality class and is multiplied by coefficient from $1 - 10^5$ for visibility. The vertical error bars correspond to statistical uncertainties and the colored boxes to the systematic uncertainties.

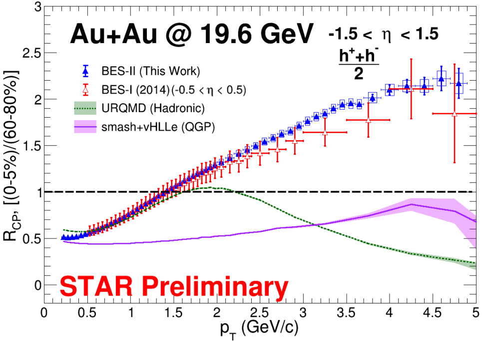
Nuclear modification factor

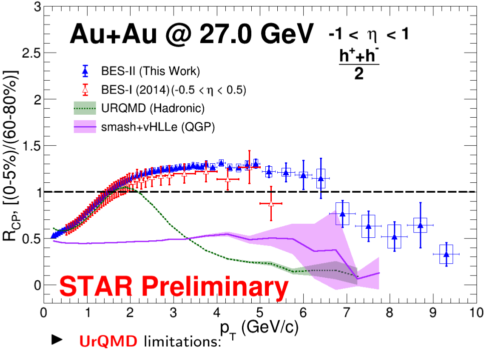


$$R_{CP} = \frac{\langle N_{coll} \rangle_{Peripheral}}{\langle N_{coll} \rangle_{Central}} \frac{Spectra_{0-5\%}}{Spectra_{60-80\%}}$$

- **Low** p_T ($<$ 2 **GeV**/c): Strong R_{CP} growth at both energies
- **27 GeV**:
  - Clear plateau (2-6.5 GeV/c) $\rightarrow$ QGP formation
  - Strong suppression ($>$ 6.5 GeV/c) $\rightarrow$ parton energy loss
- **19.6 GeV**:
  - Extended R_{CP} growth (up to 5 GeV/c)
  - Weaker suppression $\rightarrow$ hadronic dominance

R_{CP} with compare UrQMD and smash+vHLLe





- ✓BES-I/BES-II consistency validates:
  - Statistical significance across p_T ranges
  - Reproducibility of BES program results

- UrQMD limitations:
  - Only describes low-pT (<2 GeV/c) hadronic regime
  - Fails to reproduce:
    Intermediate plateau (27.0 GeV)
    Gradual suppression pattern

- SMASH+vHLLe constraints:
  - Even QGP-enabled model underpredicts data

Conclusion

Key Achievements:

- Measured transverse momentum spectra of inclusive charged particles at $\sqrt{s_{NN}} = 19.6$ and 27 GeV
- Calculated nuclear modification factors (R_{CP}) for both energies
- Performed systematic comparison with UrQMD and SMASH+vHLLE models

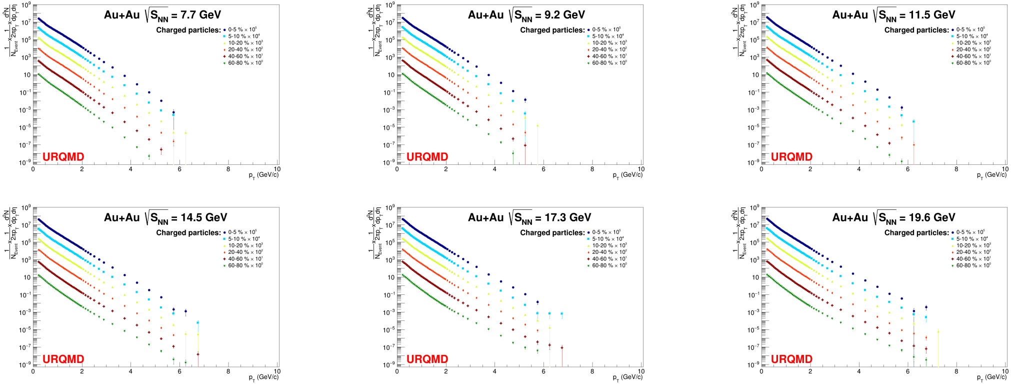
Main Findings:

- Excellent consistency between BES-I and BES-II data at 19.6 GeV
- Extended p_T reach for 27 GeV analysis
- UrQMD describes soft sector ($p_T < 2$ GeV/c) but fails in hard region
- Hydrodynamic model (SMASH+vHLLE) underestimates data by order of magnitude

Thank You!

Back up

Spectra in URQMD model



Nuclear modification factor in URQMD model