PHENIX Measurements of Heavy Flavor Production and Flow in Au+Au Collisions

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ISMD 2022

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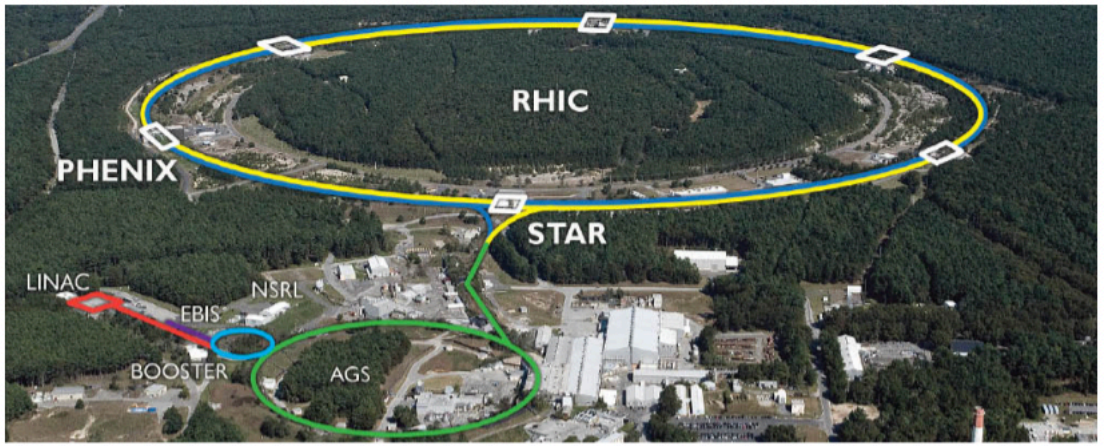
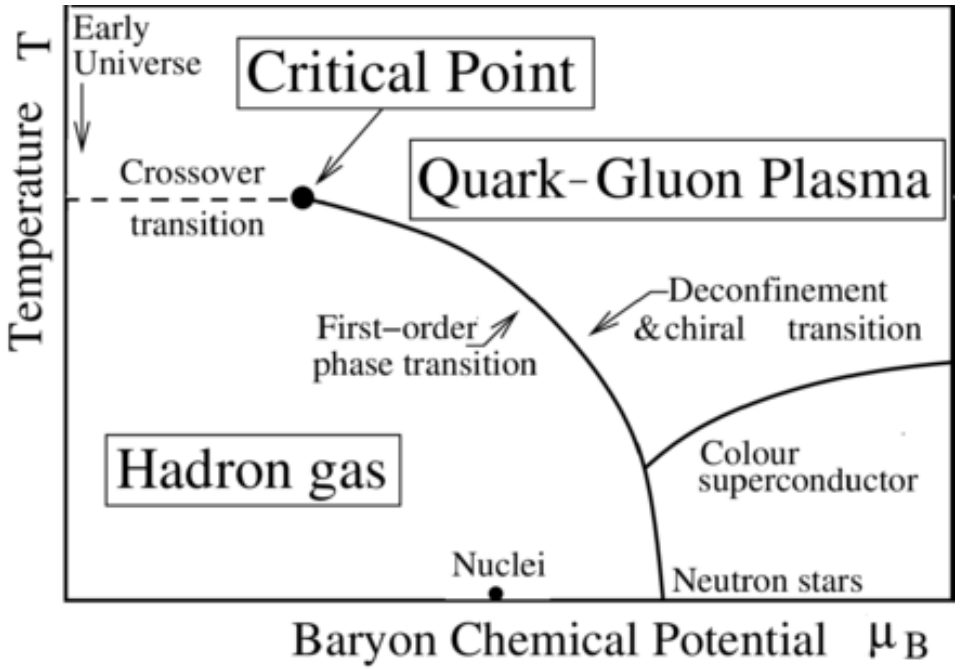
Introduction

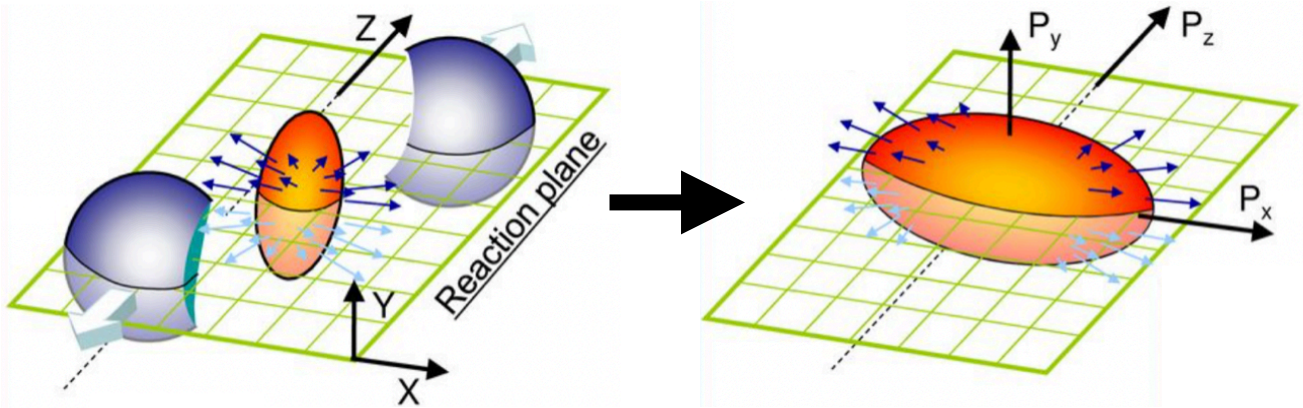
- The quark gluon plasma (QGP) is a hot and dense state of matter created in high energy nuclear collisions where quarks and gluons become deconfined
- Heavy quark (charm and bottom) production is a powerful tool for probing the QGP
  - Large mass (M_c~1.3 GeV/c^2, M_b~4.2 GeV/c^2) means they are only produced in initial hard scatterings
- PHENIX measurements for nuclear modification (R_{AA}) and elliptic flow (v_2) of heavy quarks probe unique QGP properties, which are reflected in modifications to yield and azimuthal distributions
- There is expected to be a mass ordering to these properties which is of specific interest for potential measurements



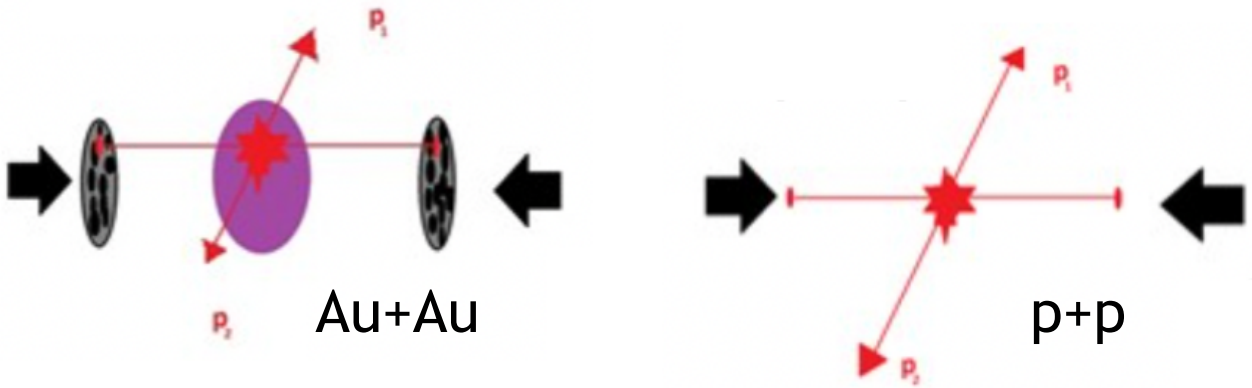


v_2 and R_{AA}

- In heavy ion collisions the initial overlap region is often ellipsoidal
  - This initial state spatial anisotropy creates pressure gradients that drive final state momentum anisotropy
  - Final state momentum anisotropy is described using Fourier series with coefficients v_n
- Relative to proton+proton collisions there is a modification of high momentum particle production in nuclei-nuclei collisions (nuclear modification factor)
  - As particles produced in collisions traverse the QGP medium their energy is reduced through elastic (collisions) and inelastic (gluon emission) energy loss



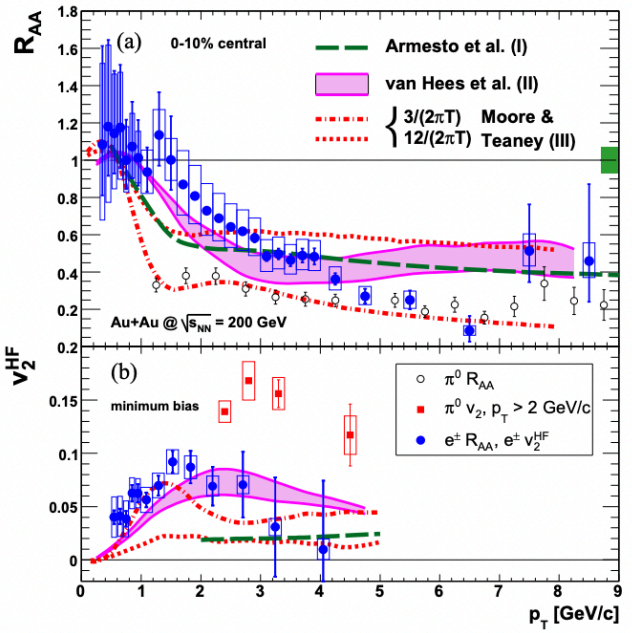
$$\frac{dN}{d\phi} = N(1 + 2v_2 cos(2(\phi - \psi))$$

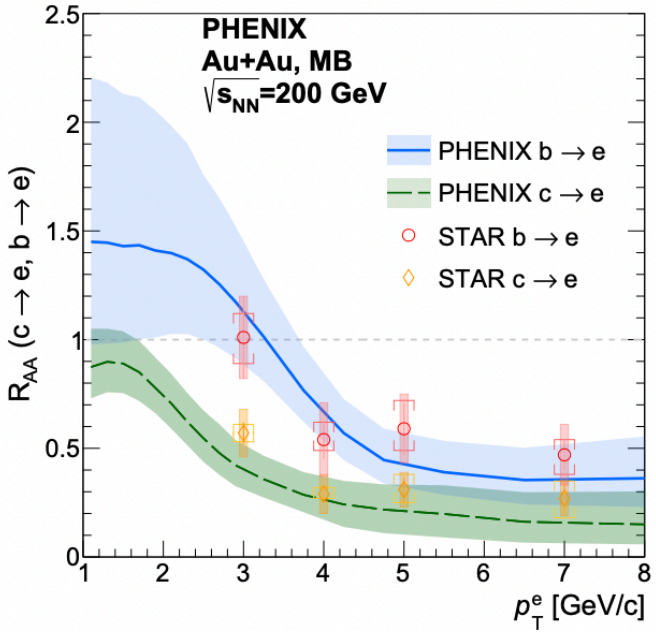


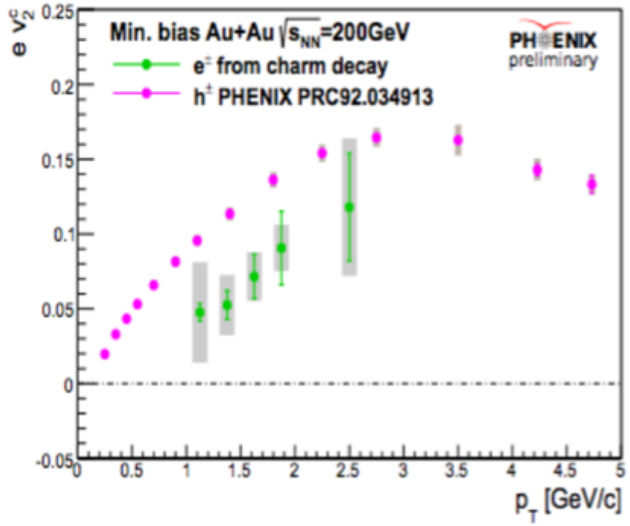
$$R_{AA} = \frac{Yield(Au+Au)}{Ncoll * Yield(p+p)}$$

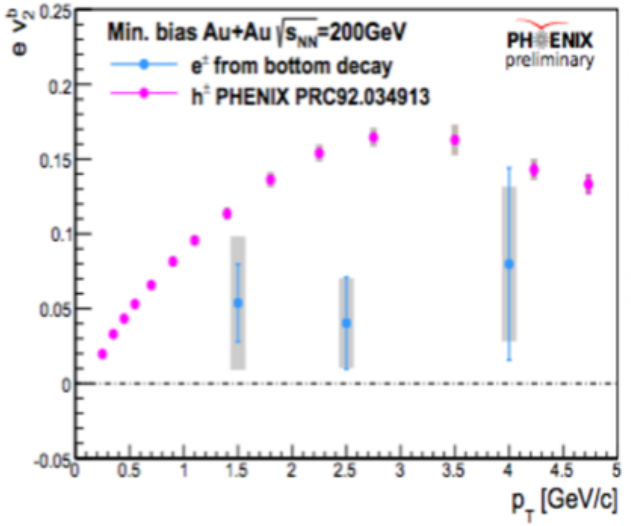
Open heavy flavor measurements

- Electrons from inclusive open heavy flavor v_2 and R_{AA} (top left) show significant differences compared to neutral pions
  - Validates mass ordering theory of particle interaction with QGP
- RHIC measurements of separated *c* and *b* R_{AA} also show mass ordering behavior
- Electrons from charm have positive v_2 and similar p_T dependence as charged hadrons, whereas v_2 of electrons from bottom is less conclusive
  - More measurements necessary to determine if bottom "flows" at RHIC energies









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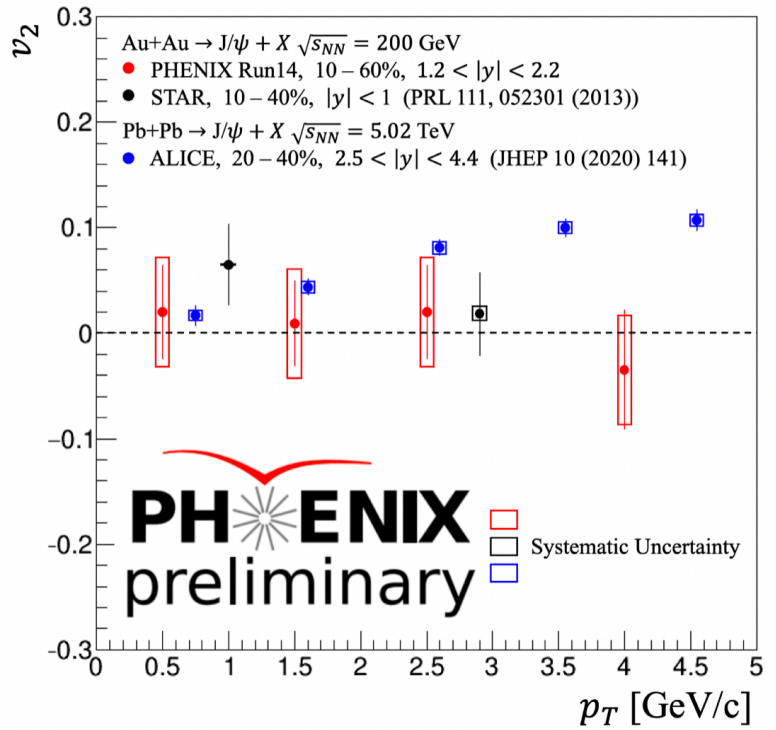
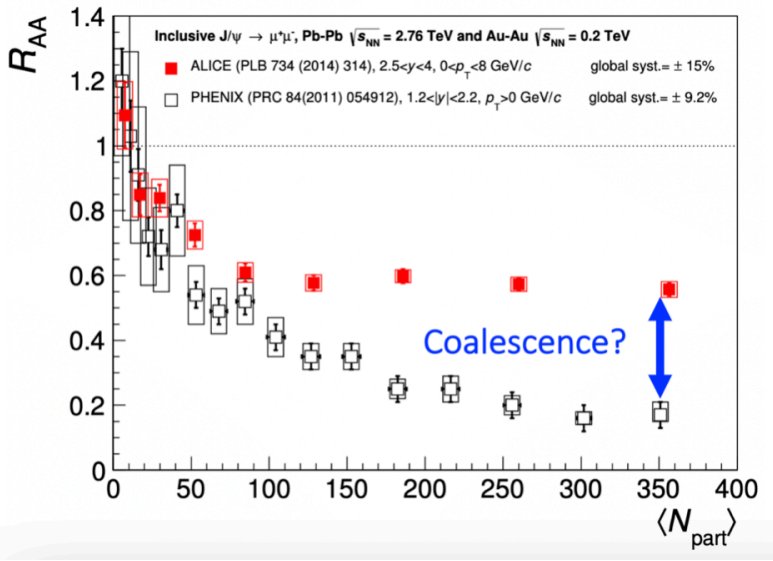
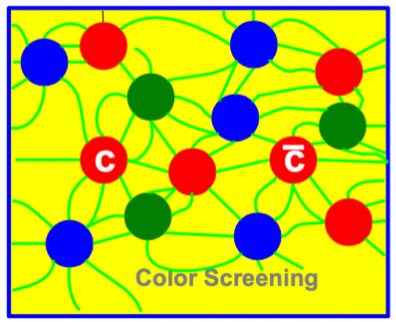
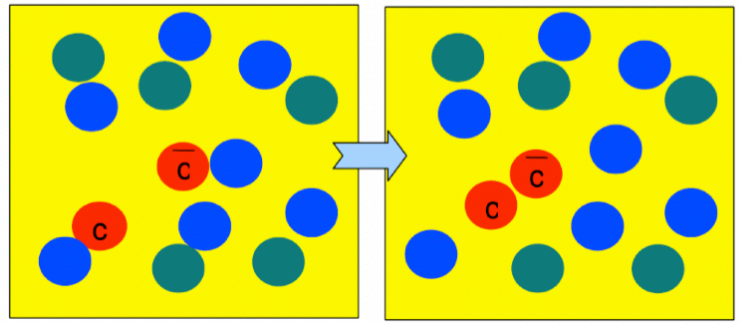
J/Ψ measurements

- J/Ψ yields are suppressed due to color screening in QGP and path length dependence of suppression may create azimuthal anisotropy
- RHIC measurements of J/Ψ v_2 are consistent with zero, whereas higher energy ALICE measurements are not
- ALICE measurements also show significantly less suppression than PHENIX measurements for J/Ψ R_{AA}
- Higher energy collisions create more $c\bar{c}$ pairs which can then flow with the medium more readily, as independently each c quark has lower mass than the J/Ψ









Conclusions

- Heavy quarks are useful probes of the unique properties of the QGP
- Yield modifications and anisotropic azimuthal distributions of particles are medium-induced effects that can be used to study the QGP
- RHIC and LHC measurements of J/Ψ v_2 and R_{AA} are not consistent, but this can be explained by increased quark coalescence at higher energies
- Inclusive and separated open heavy flavor measurements confirm mass ordering of particle interactions with the QGP
- More study is needed to confirm if bottom quarks flow at RHIC energies