Heavy Flavor Summary

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Open Heavy Flavor Physics

Hard probes produced in the initial nucleon-nucleon collisions

Interact strongly so momentum can be modified by collisions during the evolution of the system leading to effects such as:

- Energy loss in dense matter (Djordevic et al, Lin et al, Kharzeev and Dokshitzer).
- Transverse momentum broadening due to hadronization from QGP (Svetitsky) or cold nuclear matter.
- Collective flow (Lin and Molnar, Rapp, Ko et al)
- Charm thermalization ? (Van Hees)

Heavy Flavor Measurements

Heavy flavor studies through reconstruction of final state hadron and decays to leptons.

Experimental approaches to separate leptons from D and B decays require upgrades and RHIC II luminosities.

D measurements in hadronic decay channels are extremely desirable, and very hard. Will require upgrades at least.

We are starting to see some interesting and unexpected experimental results. Still very early days!

Uncertainty Bands for Electrons from Heavy Flavor Decays at 200 GeV

Electrons from B decays begin to dominate at $p_T \sim 5$ GeV

Electron spectra very sensitive to rapidity range – to get $|y| \leq 0.75$ electrons, need $|y| \leq 2$ charm and bottom range

Forward electron spectra thus not possible to obtain using FONLL code due to problems at large y

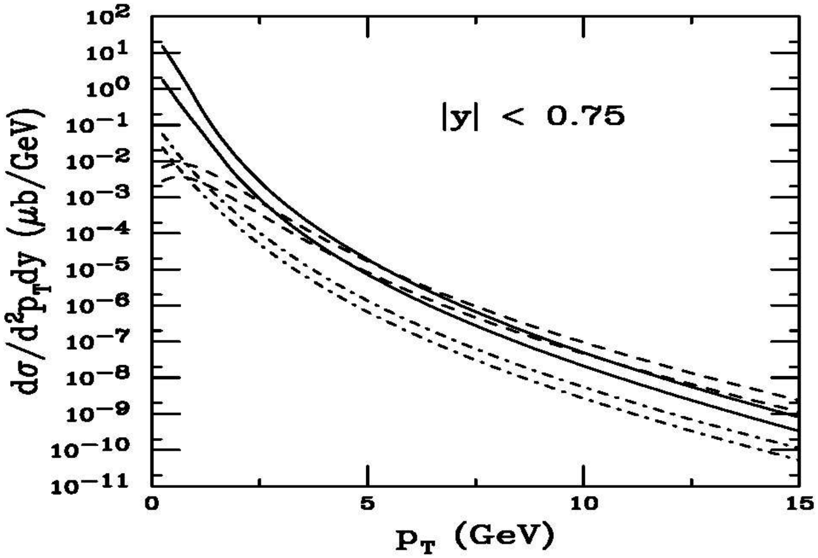
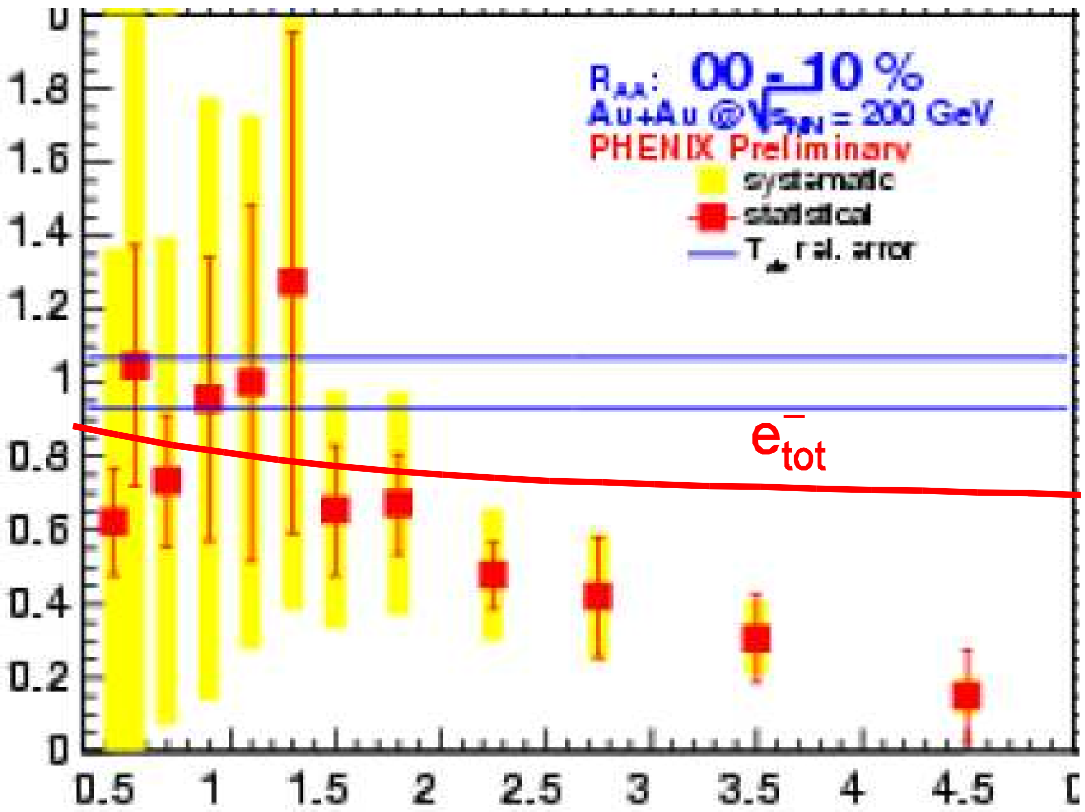


Figure 7: The theoretical FONLL bands for $D \rightarrow eX$ (solid), $B \rightarrow eX$ (dashed) and $B \rightarrow DX \rightarrow eX'$ (dot-dashed) as a function of p_T in $\sqrt{s} = 500$ GeV pp collisions for $|y| < 0.75$.

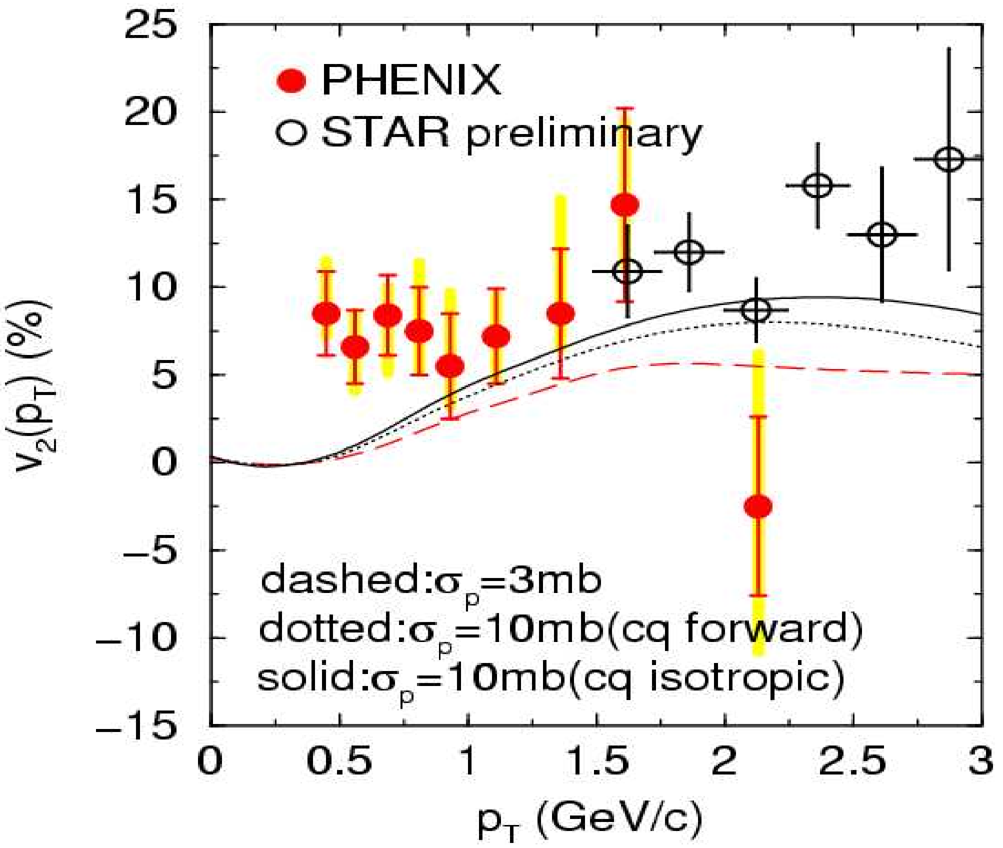
Comparison with experiment



Our predictions do not agree with PHENIX preliminary data

Charmed meson elliptic flow from AMPT

Zhang, Chen & Ko, nucl-th/0502056



Smaller charmed meson elliptic flow is largely due to small current light quark mass used in AMPT

Hidden Heavy Flavor: Quarkonium

Quarkonium melting?

- Finite temperature lattice studies indicate that ψ(1S) and Υ(1S) do not melt at RHIC.
- But χ_c, ψ', Υ(2S), Υ(3S), χ_b do melt at RHIC, and **close to T_c**.
- Significant lattice model uncertainties remain.
- Initial production mechanism has to be addressed first.
  - NRQCD vs Color Evaporation model.
  - Feed down from higher states.
  - Shadowing effects on initial production.
  - Nuclear absorption and initial state energy loss for each state.
- Complicated by possibility of charmonium recombination.

Heavy quark bound states from Schrödinger-Equation

- Schrödinger equation for heavy quarks:

$$\left[2m_a + \frac{1}{m_a}\nabla^2 + V_1(r,T)\right]\Phi_i^a = M_i^a(T)\ \Phi_i^a \quad , \quad a \ = \ \mathrm{charm,\ bottom}$$

  - T-dependent color singlet heavy quark potential mimics in-medium modification of $q\bar{q}$ interaction
  - reduction to 2-particle interaction clearly too simple, in particular close to T_c

- recent analyses:

using F_1: S. Digal, P. Petreczky, H. Satz, Phys. Lett. B514 (2001) 57;

using V_1: C.-Y. Wong, hep-ph/0408020;

state	J/ψ	χ_c	ψ'	Υ	χ_b	Υ'	χ_b'	Υ"
E_s^i [GeV]	0.64	0.20	0.05	1.10	0.67	0.54	0.31	0.20
T_d/T_c	1.1	0.74	0.1 - 0.2	2.31	1.13	1.1	0.83	0.74
T_d/T_c	$\sim$ 2.0	$\sim$ 1.1	$\sim$ 1.1	$\sim$ 4.5	$\sim$ 2.0	$\sim$ 2.0	–	–

V_1 leads to dissociation temperatures consistent with spectral function analysis

Rapidity Dependence of Homogeneous Absorption

Results shown for different charmonium states: inclusive and direct J/ψ, ψ' and χ_c

Constant and growing octet indistinguishable in detector range, singlet absorption only effective for $y < -1$, NRQCD also shows little rapidity dependence

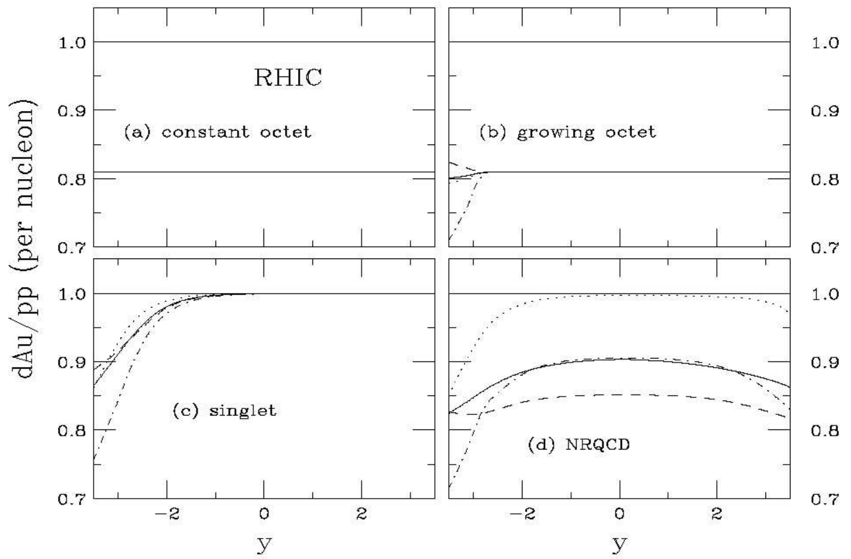
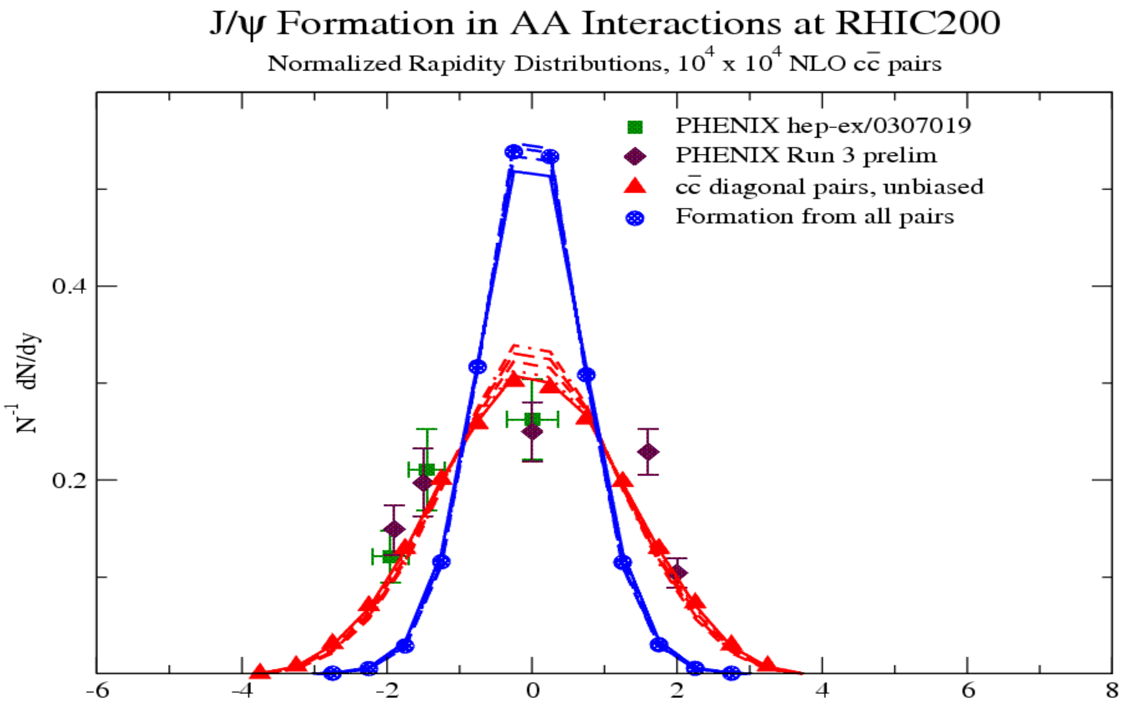
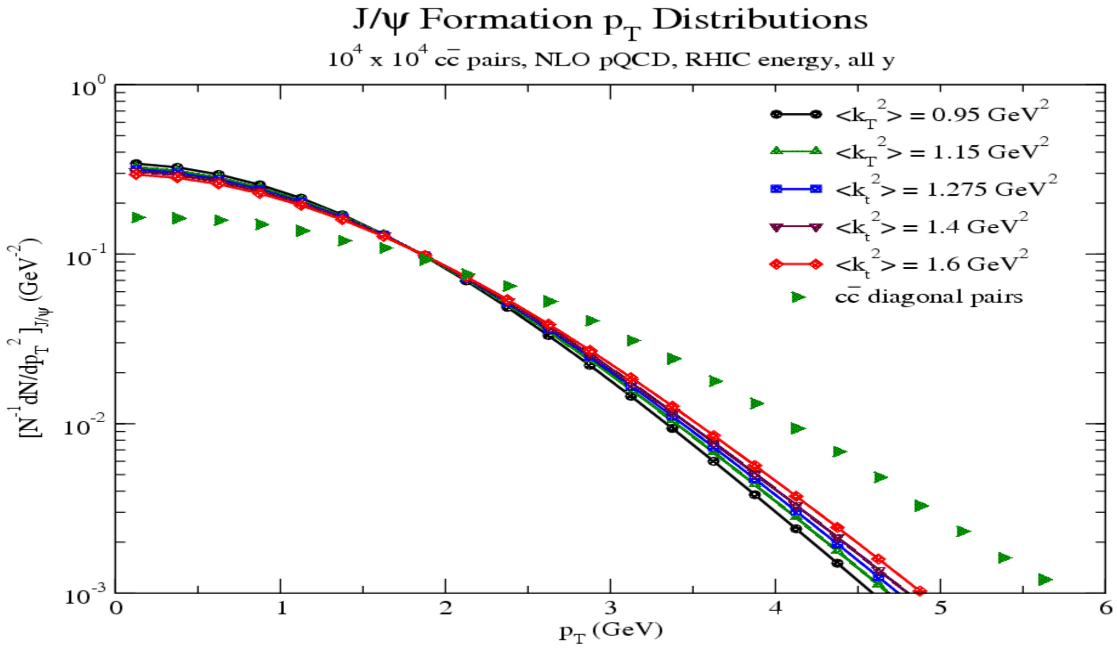


Figure 33: The J/ψ dAu/pp ratio at 200 GeV as a function of rapidity for absorption alone. We show (a) constant octet with 3 mb, (b) growing octet with 3 mb asymptotic cross section for all states, (c) singlet with 2.5 mb J/ψ absorption cross section, all calculated in the CEM and (d) NRQCD with a combination of octet and singlet matrix elements. The curves show total J/ψ (solid), direct J/ψ (dashed), ψ' (dot-dashed) and χ_c (dotted).

Thews and Mangano, recombination narrows rapidity and p_T distributions





Quarkonium measurements

We need to look at all quarkonium states

- Measurement of χ_c, ψ', Υ(1S, 2S, 3S) are all key measurements, and all require upgrades and RHIC II.

Tests of initial production mechanism:

- Polarization measurements at high p_T in pp (at 500 GeV?).
- pp and pAu to establish shadowing and absorption baselines for all states.

Conclusions - RHIC

We must have the RHIC II luminosity upgrade to get usable statistics for:

- χ_c yields vs η - charmonium ratios
- Upsilon yields - bottomonium baseline at RHIC temperature
- B->J/ψ measurements - critical (background for prompt high p_T J/ψ, open b)
- High statistics charmonium (& open charm) correlations - flow, thermal.
- High statistics charmonium (& open charm) at high p_T - recombin. (E loss)
- ψ' yields - charmonium ratios

We must complete detector upgrades at RHIC in addition to the luminosity upgrades so that we can do:

- χ_c yields vs η - charmonium ratios
- Upsilon yields - bottomonium baseline at RHIC temperature
- B->J/ψ measurements - critical (background for prompt high p_T J/ψ, open b)
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- High statistics charmonium (& open charm) at high p_T - recombin. (E loss)