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Open heavy flavour production in nuclear collisions

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Contents:

1. Motivation:
    - Collinear factorization.
    - Characterizing the medium in HIC through hard probes.

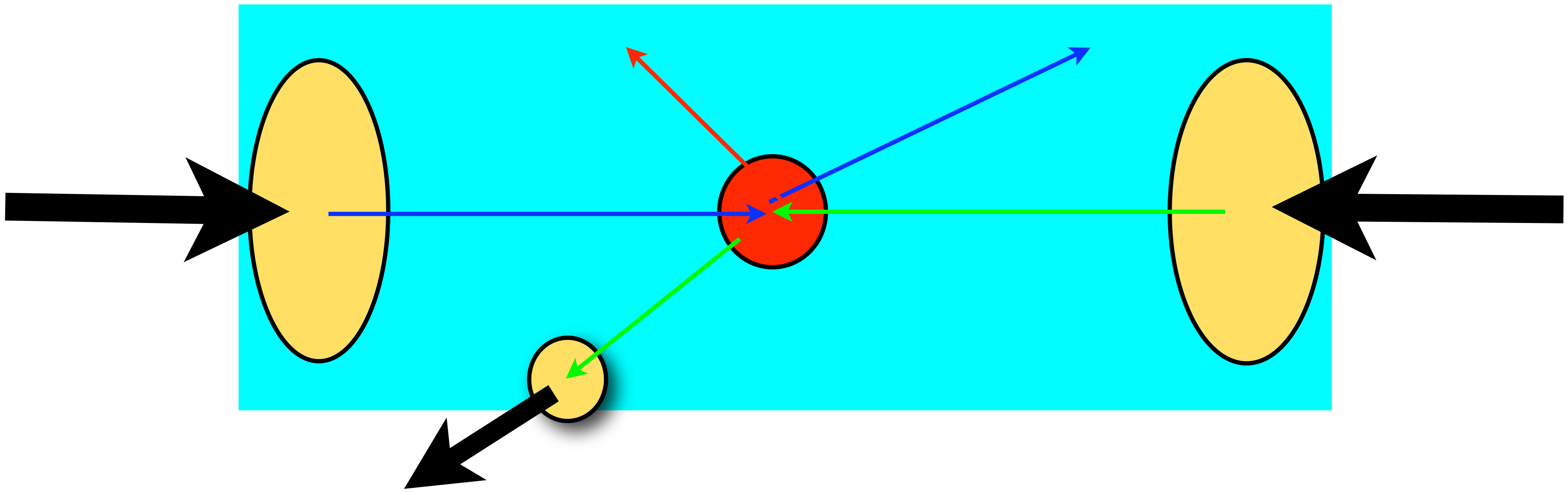
2. Benchmark: pp and pA (dAu).

3. Heavy-ion collisions:
    - Mechanisms for energy loss.
    - Comparison with data.

4. Summary.

See the talks by R. Covarelli, A. Dion, T. Matsushita, G. Odyniec, A. Rakotozafindrabe, A. Rossi, A. Sickles and W. Xie.

Collinear factorization:



$$d\sigma(AB \to hX) \propto \int [dx] f_i^A(x_1, \mu_{F1}) f_j^B(x_2, \mu_{F1}) \otimes d\hat{\sigma}_{ij \to kX}(x_1, x_2, \mu_R) \otimes D_{k \to h}(z, \mu_{F2}) + \mathcal{O}\left(\frac{1}{Q^n}\right)$$

- Collinear factorization (for $Q, M \sim E_{cm} >> \Lambda_{QCD}$): nuclear

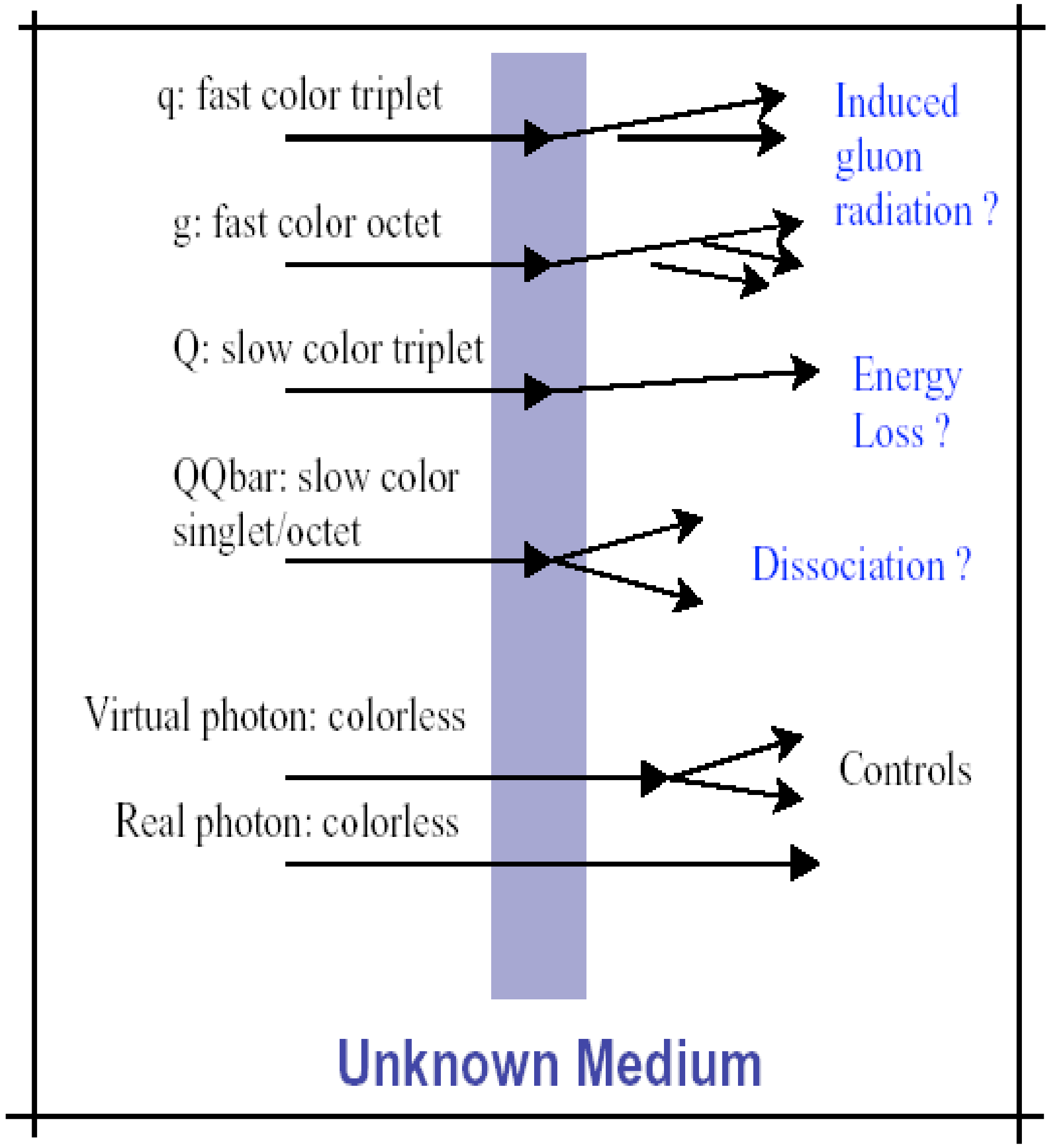
modification of f's and D's, poorly known in the nuclear medium (few data in the kinematical regions relevant for e.g. LHC).

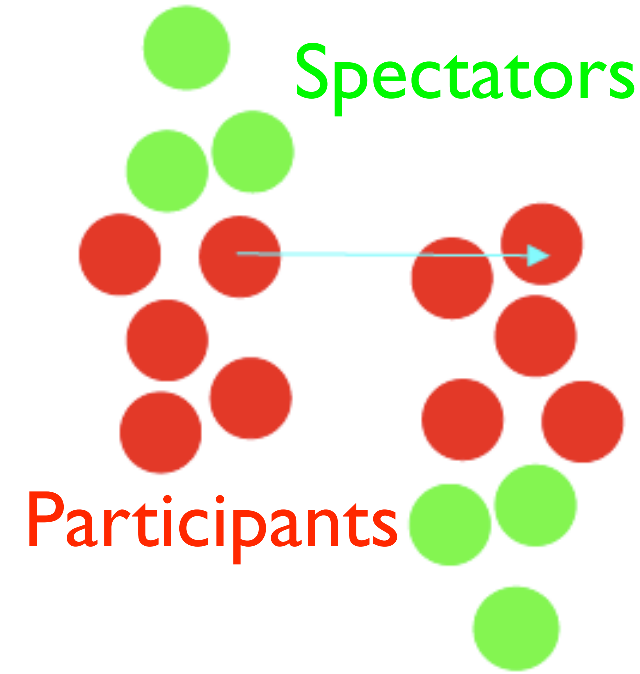
- Open heavy flavour production offers a possibility to check the validity of collinear factorization in nuclear collisions:

  * Higher twist terms expected to increase with nuclear size (Qiu, hep-ph/0305161).

  * Saturation implies a different factorization (if any).

Characterizing the medium:





$$R^k_{AB}(y,p_T) = \frac{\frac{dN^k_{AB}}{dydp_T}}{\langle N_{coll}\rangle \frac{dN^k_{pp}}{dydp_T}}$$

- Hard probes are those whose comparison measured/expected (in perturbative QCD) characterizes the (hot) medium: suppression of quarkonium, energy lost of fast particles.
  - * Control of the denominator: pp.
  - * Control on non-medium (cold) effects on the numerator: pA.

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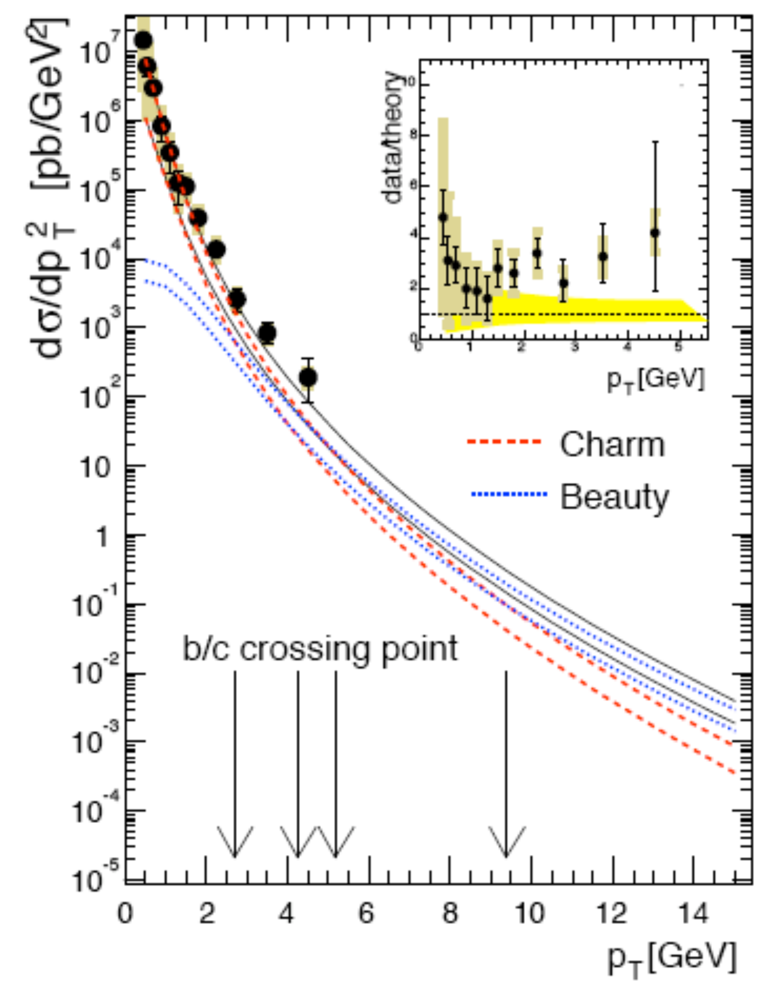
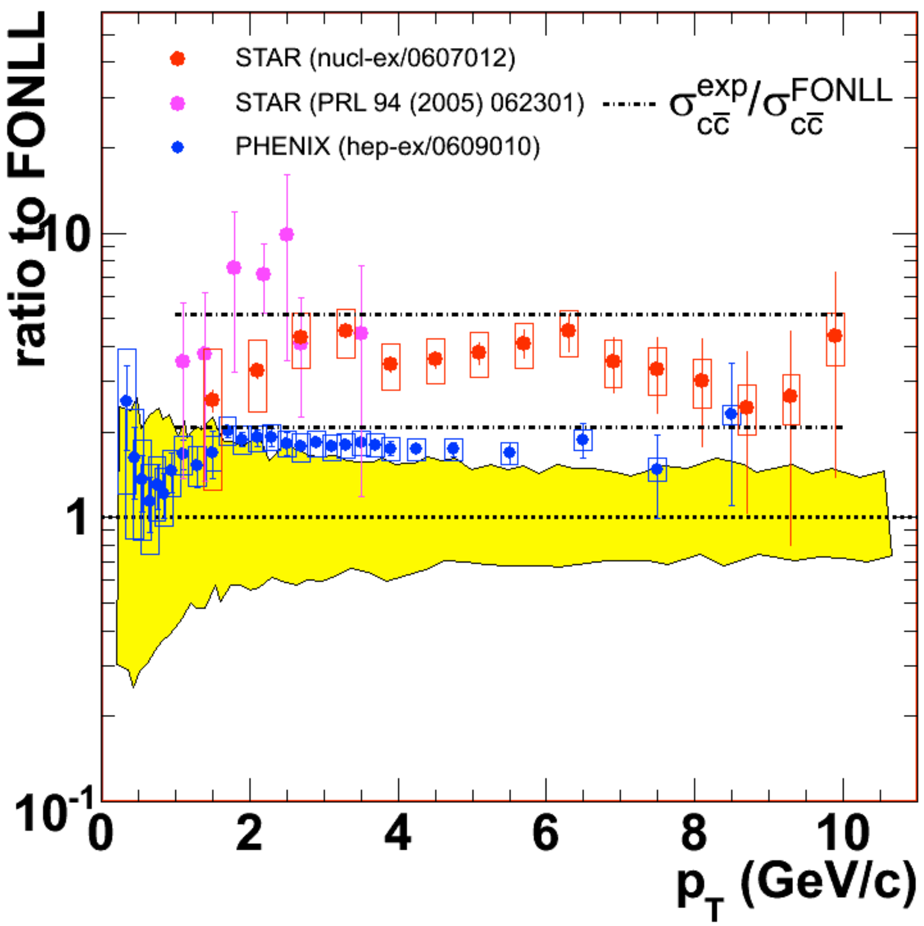
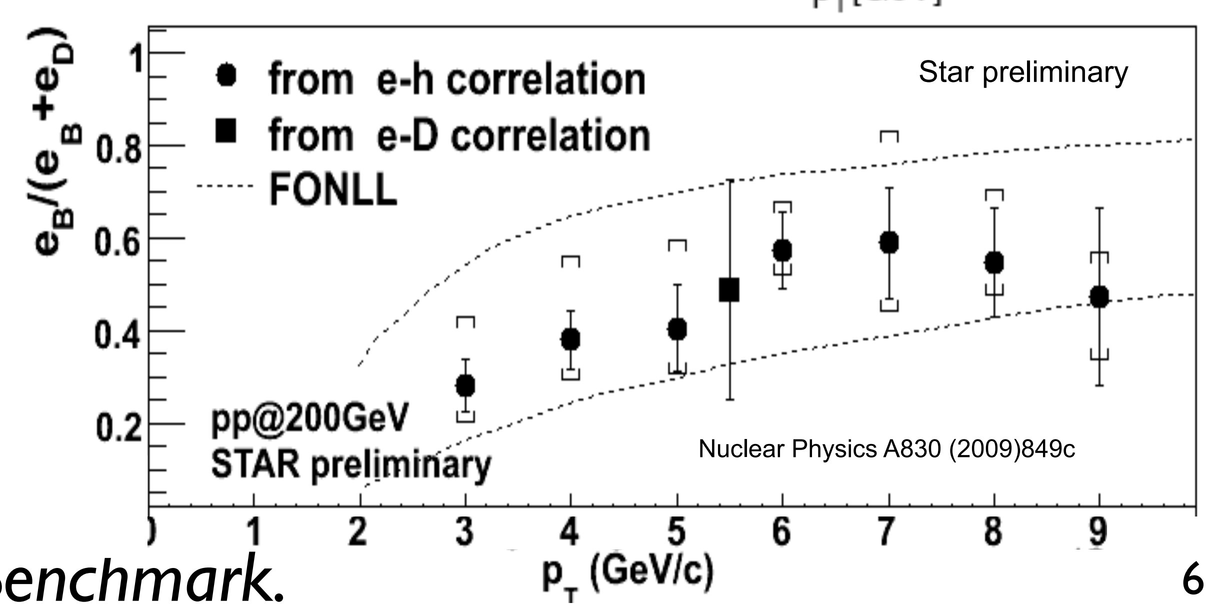
HQ in pp@RHIC:

- State-of-the-art resummed pQCD (FONLL) which is quite successful in b-production at Tevatron, systematically low at RHIC.
- b/c ratio looks reasonable, though: most important for energy loss which depends on the mass.
- PHENIX vs. STAR?
- Non-photonic e's: D, B, Λ_c, DY, QQbar,...

NA et al '06







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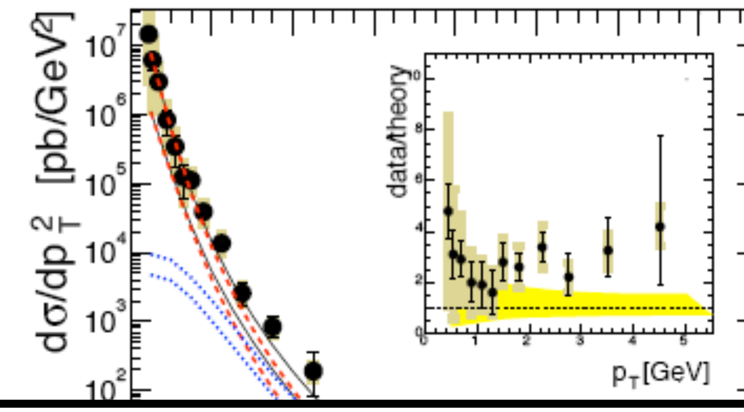
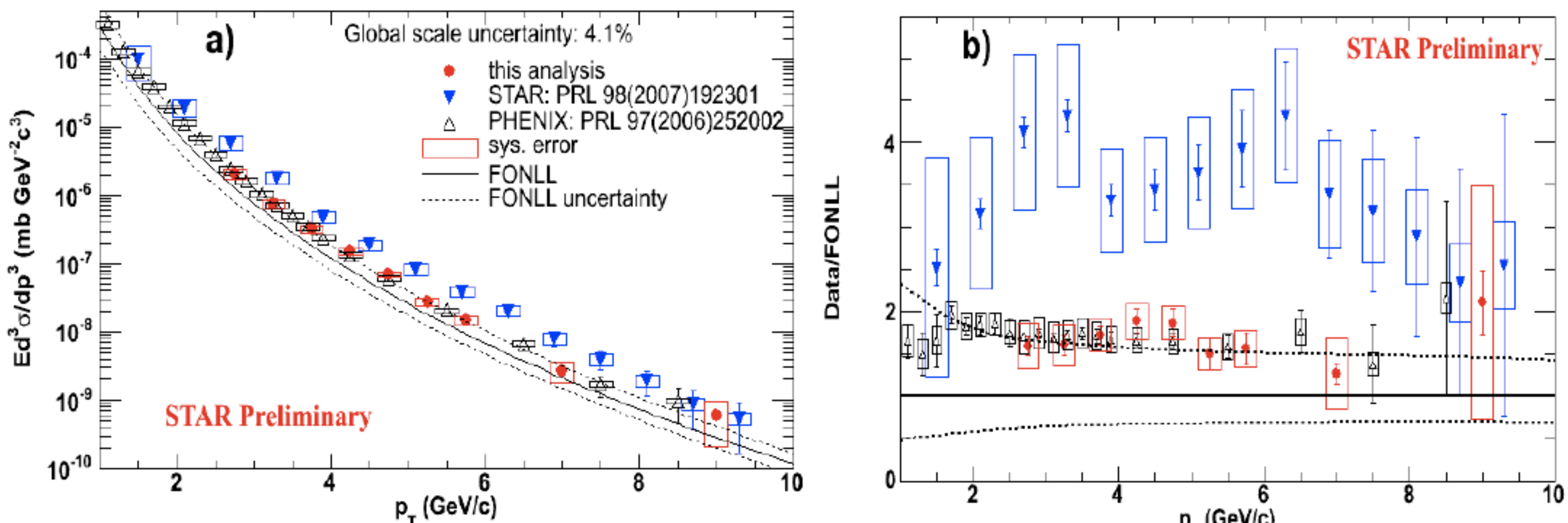
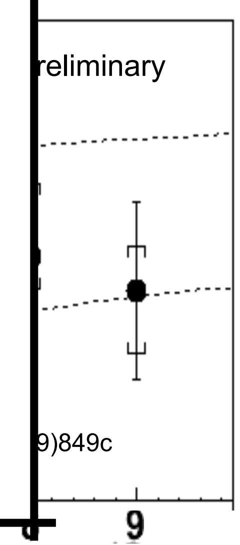




STAR and PHENIX NPE result in 200GeV p+p collisions

✓Are consistent within errors at pt > 2.5 GeV/c

Xie's talk



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- PHENIX vs. STAR? (see Xie's talk).
- Non-photonic e's: D, B, Λ_c, DY, QQbar,...

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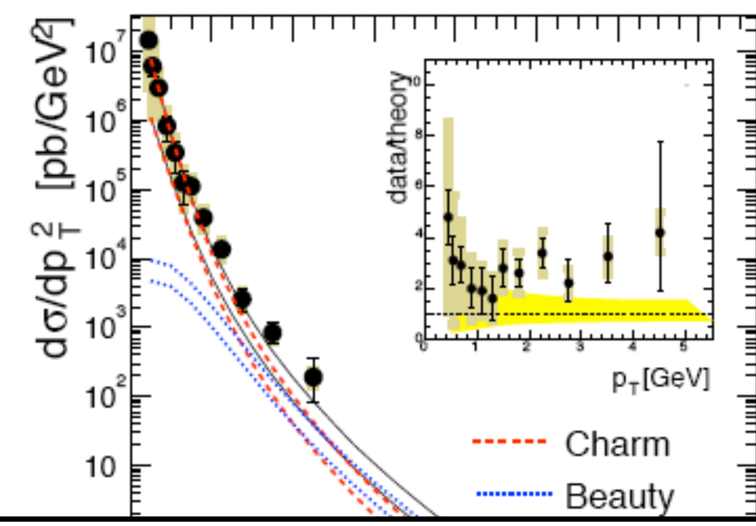
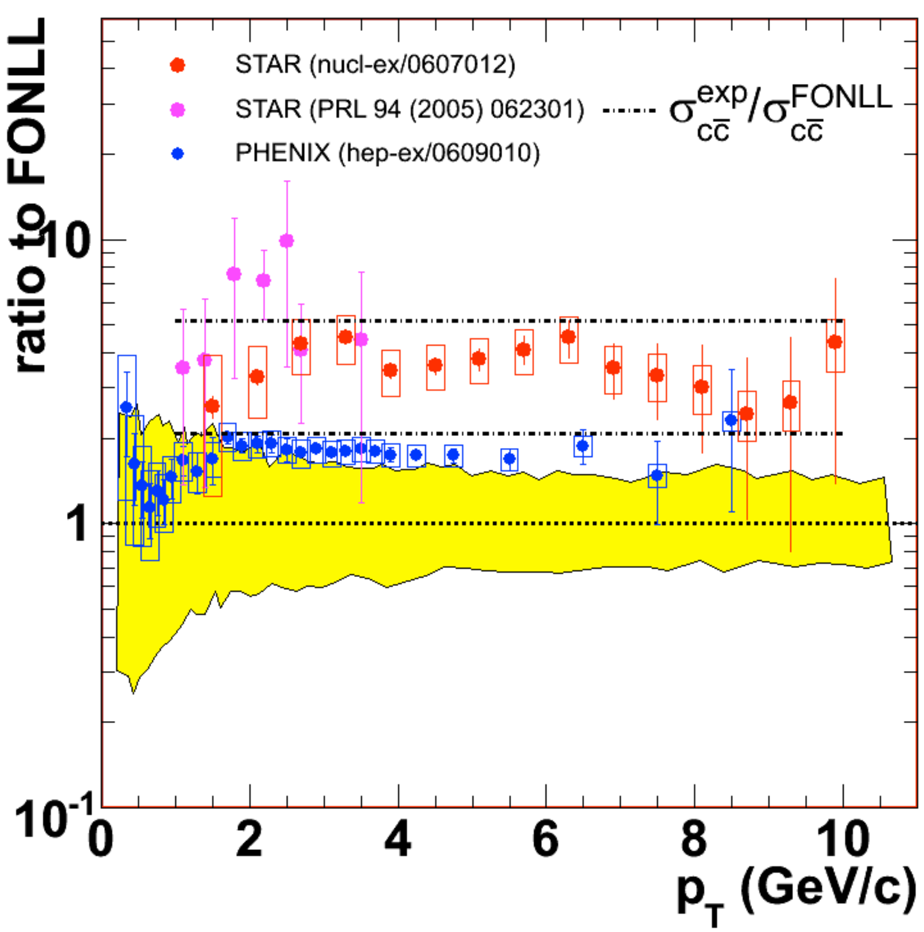
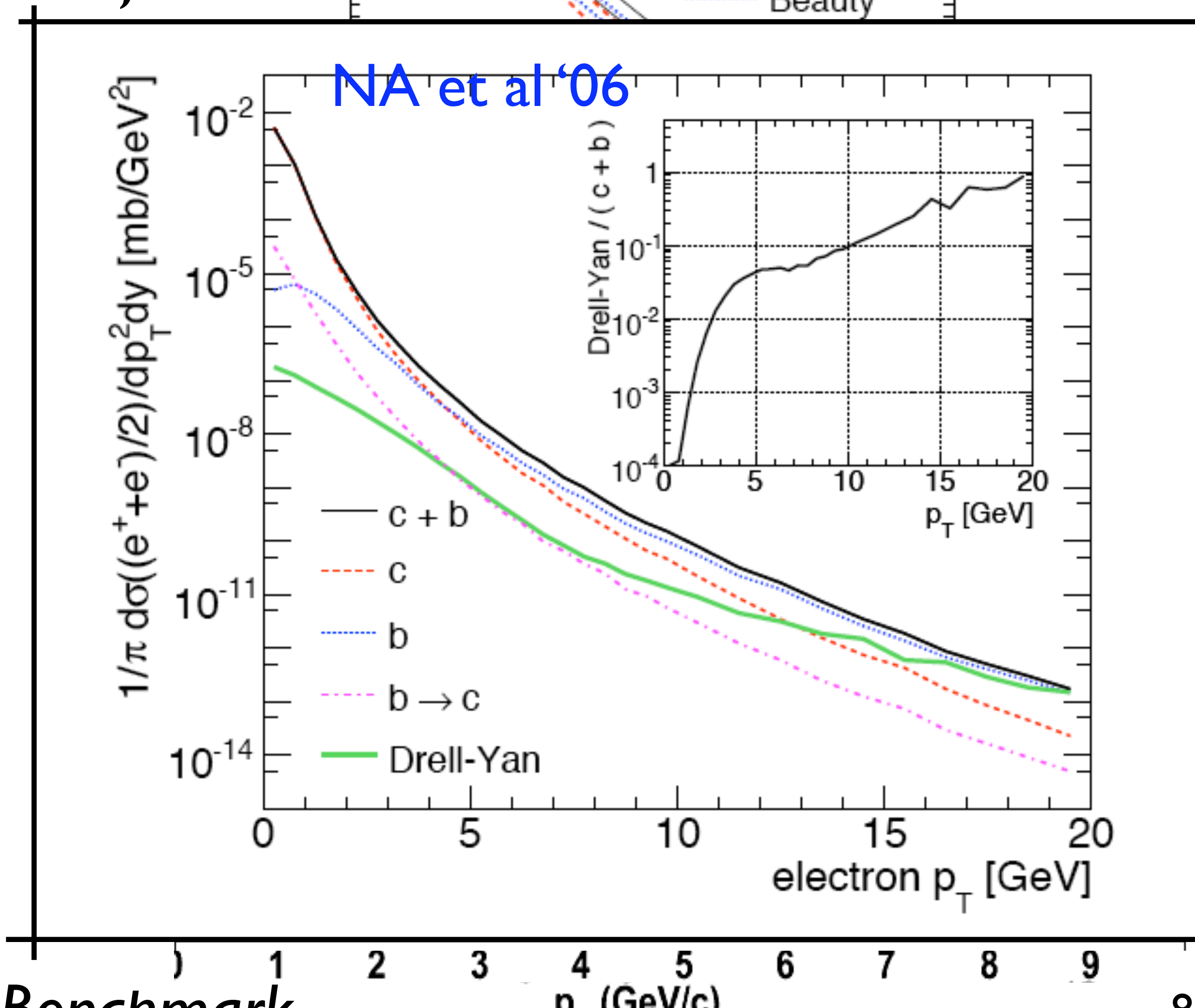


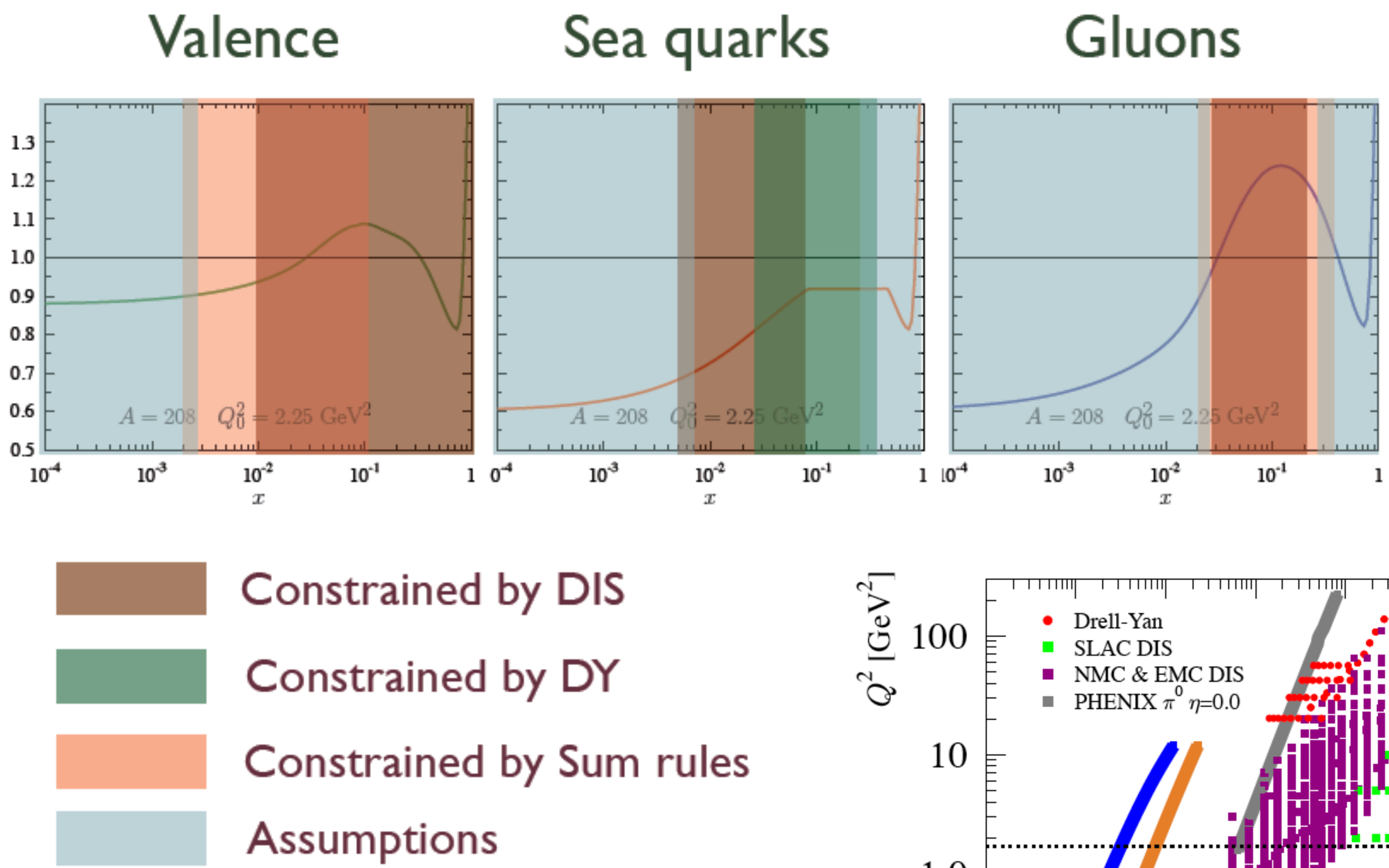




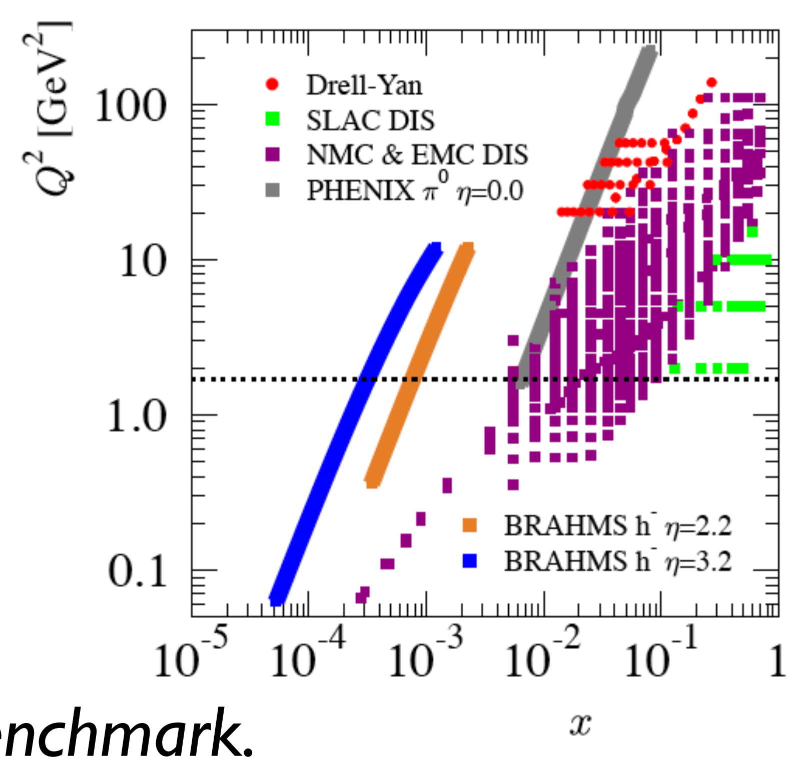
DGLAP analysis of npdf's:

- Data sets: ~100 DY, ~20 from π^0, rest up to ~<u>900</u> from NC DIS;

neutrino data under discussion (see Kovarik's and Paukkunen's talks).



Salgado

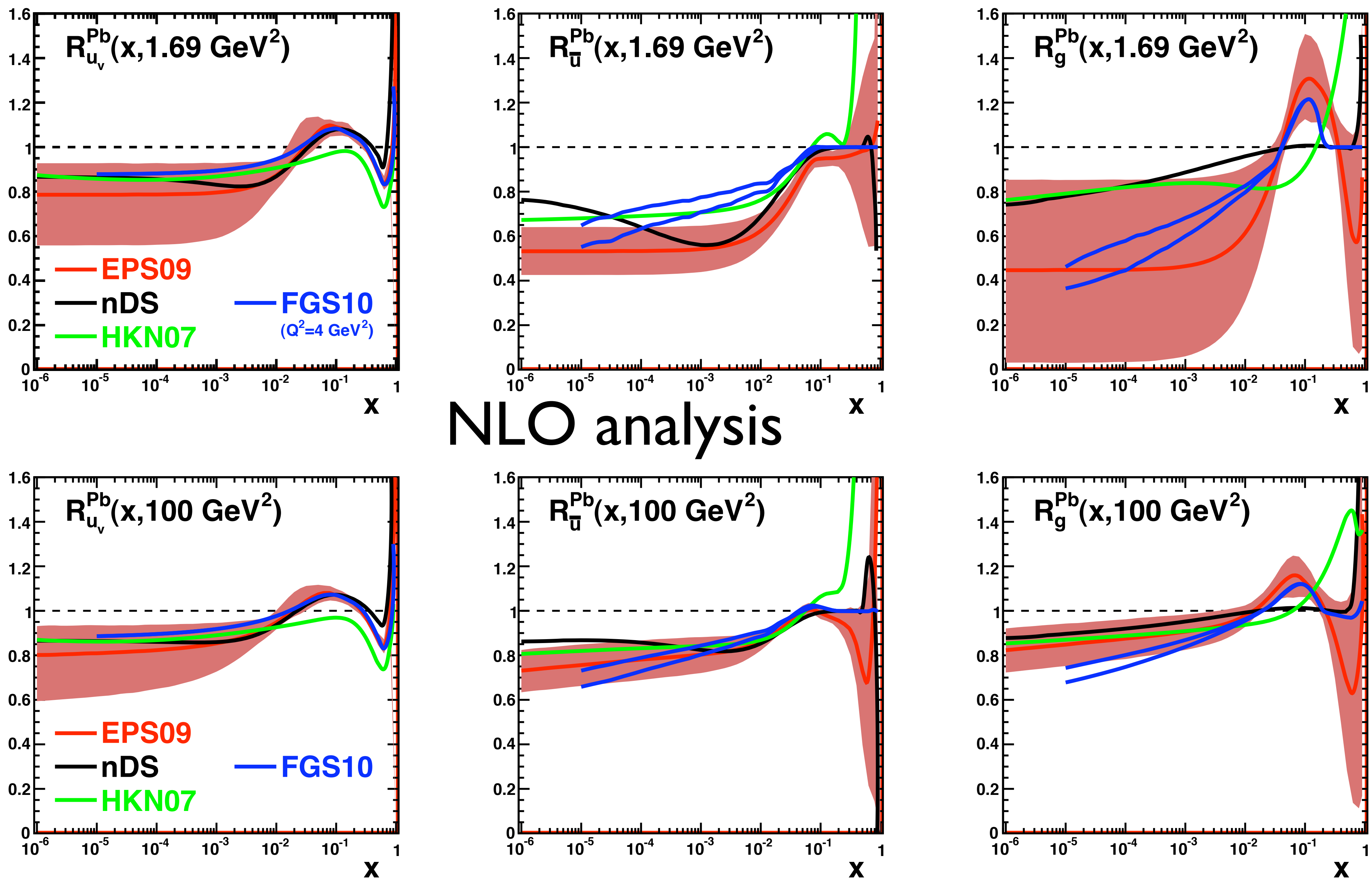


DGLAP analysis of npdf's:

- Data sets: ~100 D[partly hidden] ~900 from NC DIS;

neutrino data under[partly hidden] Paukkunen's talks).

$$R^A_{F_2}(x, Q^2) = \frac{F^A_2(x, Q^2)}{A F^{\rm nucleon}_2(x, Q^2)}$$



x

DGLAP analysis of npdf's:

- Data sets: ~100 D ... ~900 from NC DIS;

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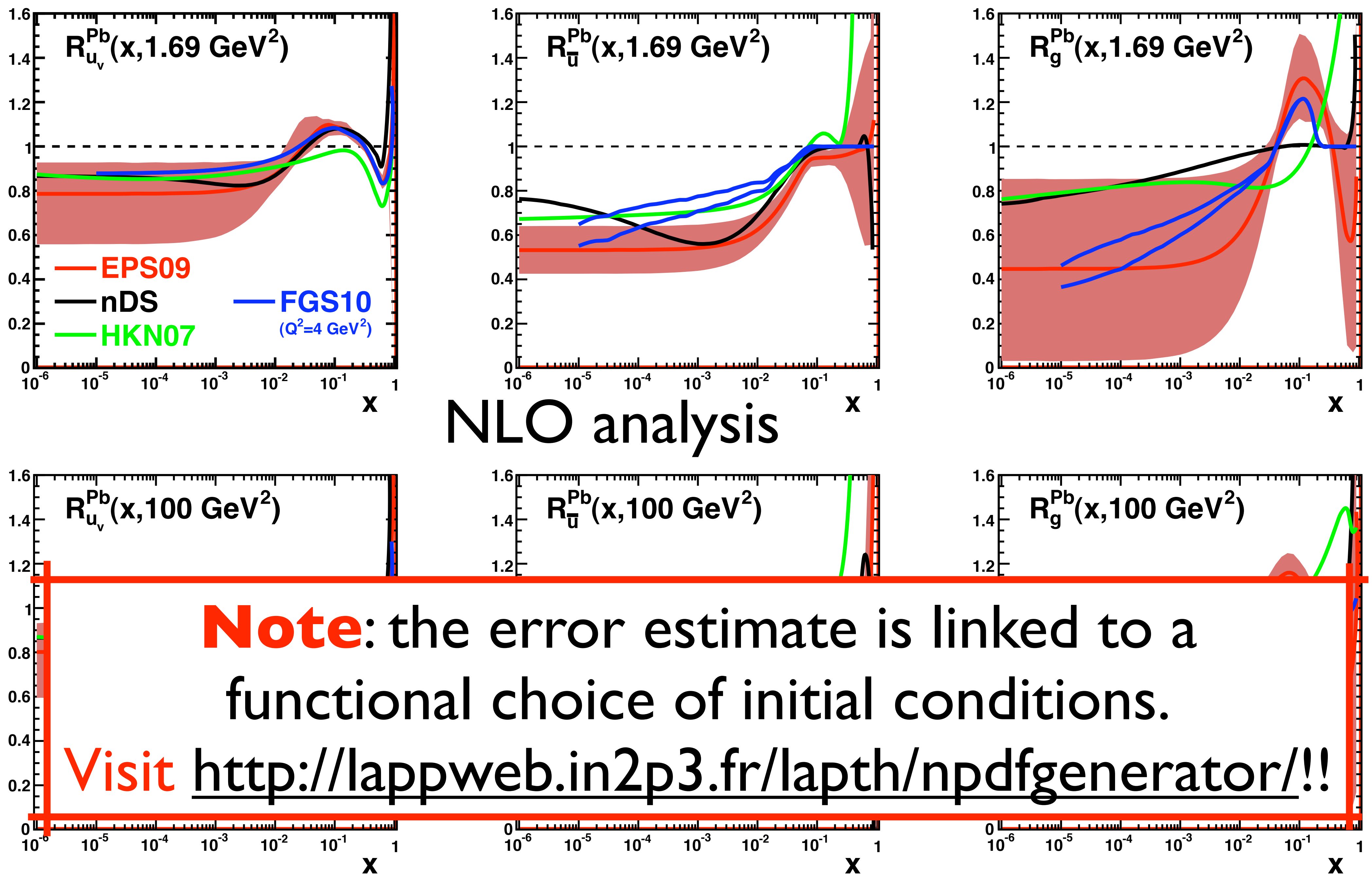


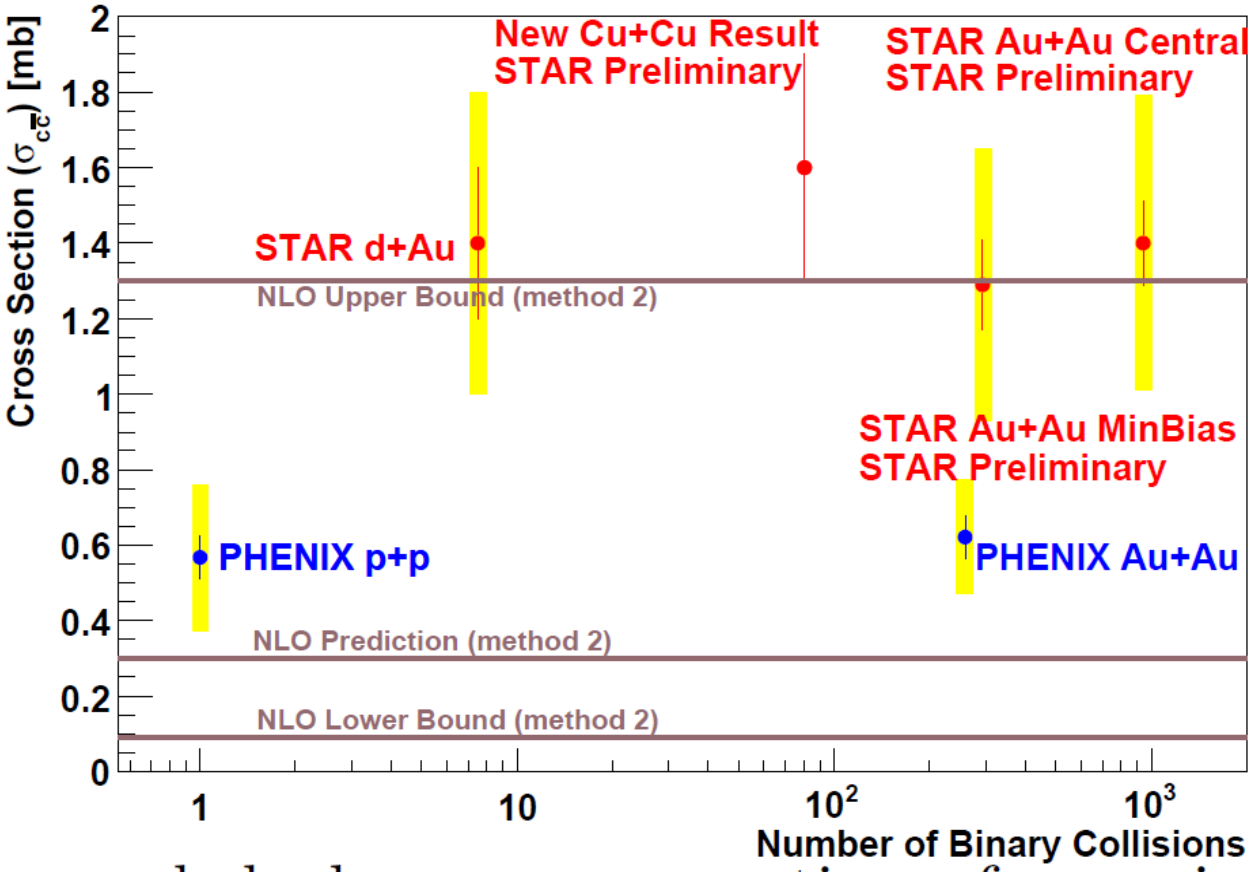
Note: the error estimate is linked to a functional choice of initial conditions.

Visit http://lappweb.in2p3.fr/lapth/npdfgenerator/!!

HQ in dAu@RHIC:

- Rough scaling with the number of binary collisions (R=1) ⇒

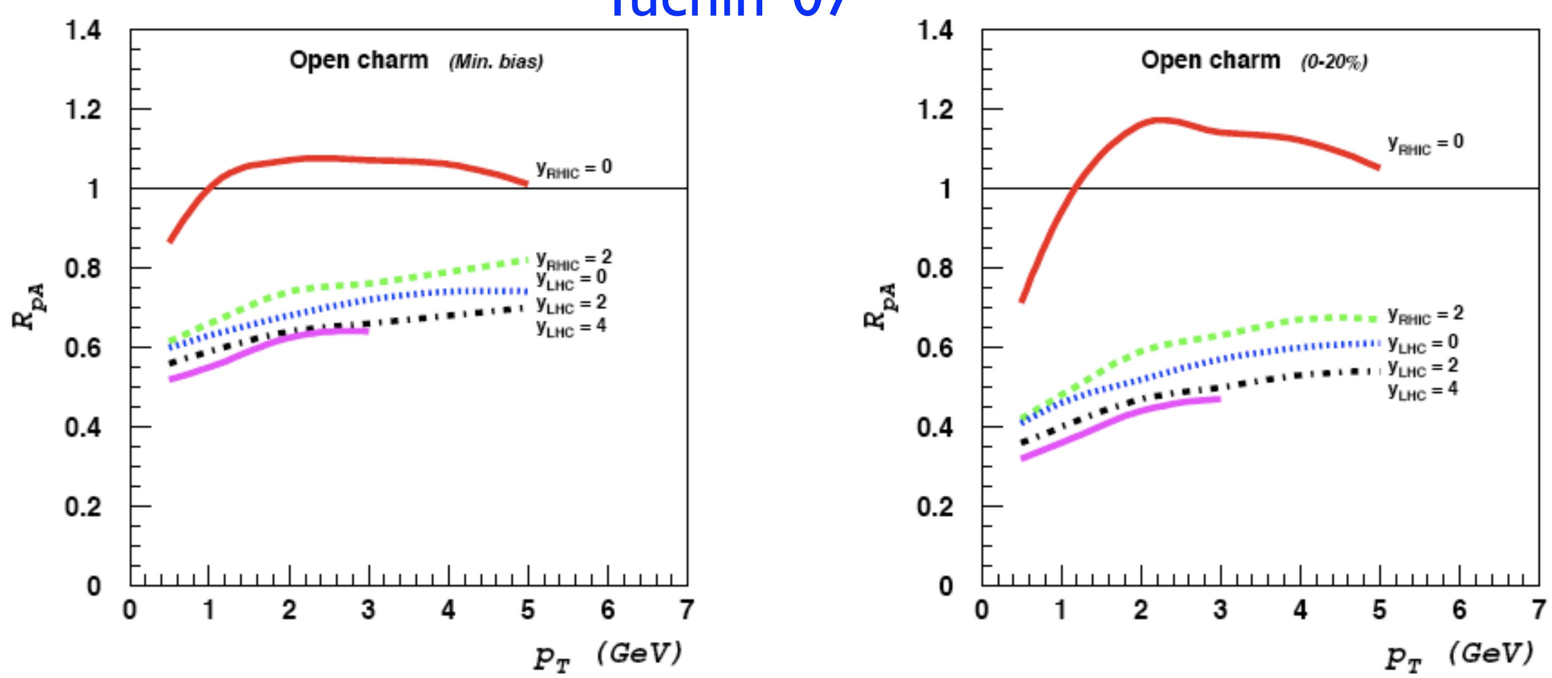
nuclear effects on npdf's for charm at RHIC look < 20 %.



- Place to look for high-density effects: factorization may be not collinear (Gelis et al '06), place to check saturation models ($Q_s \sim m_c$):

enhanced production (wrt collinear).

Tuchin '07



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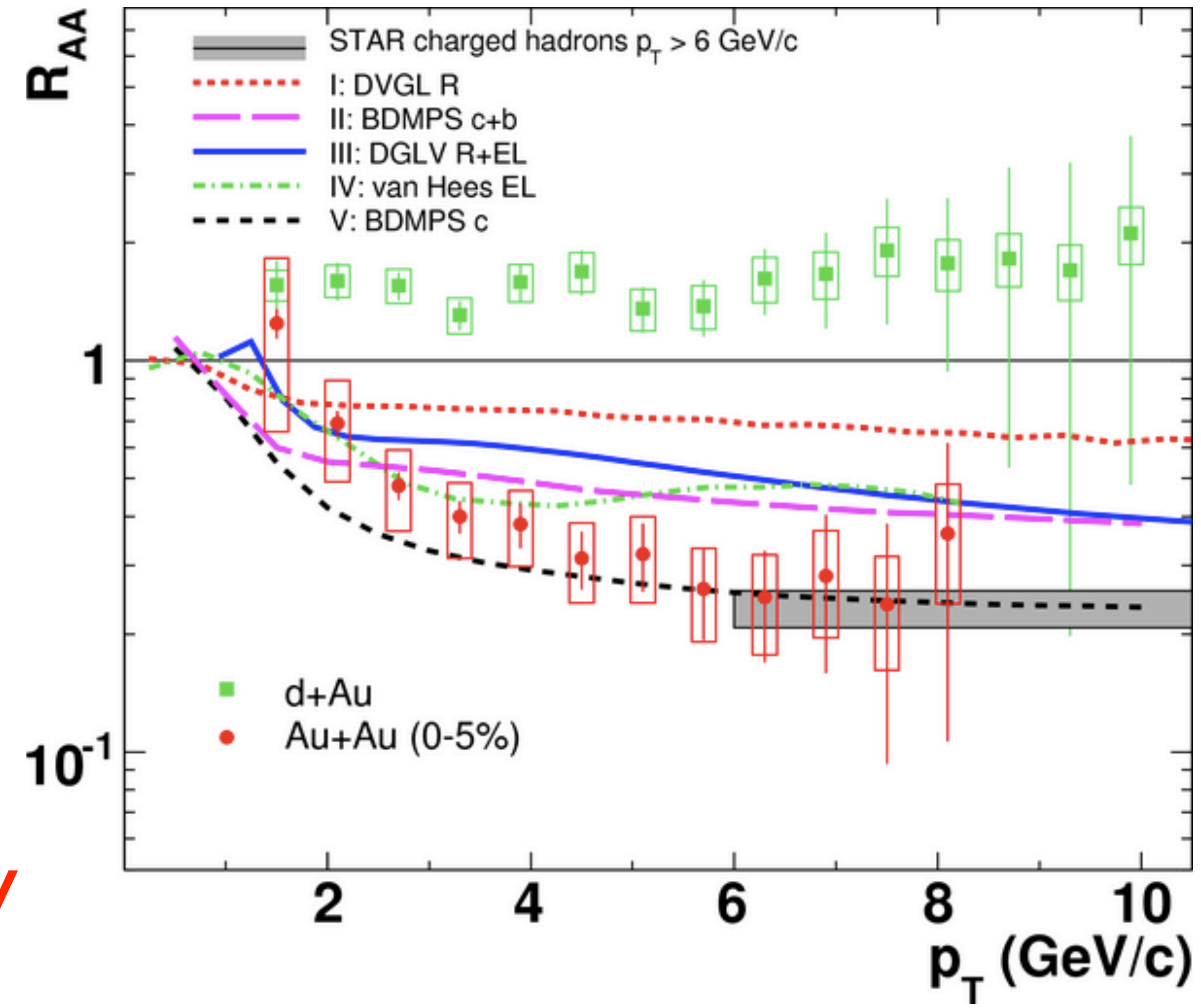
Mechanisms for eloss:



- In AuAu collisions at RHIC, light hadrons are suppressed a factor ~ 5.

- In AuAu collisions at RHIC, non-photonic electrons appear as suppressed as light hadrons.

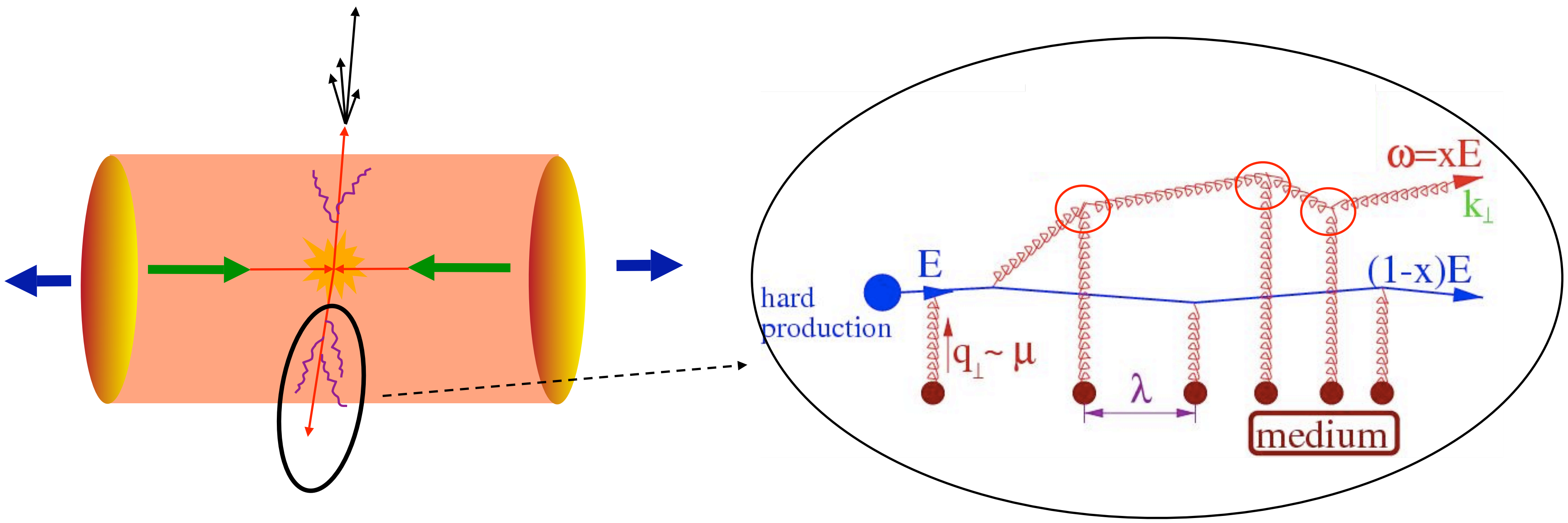
- Three explanations (not mutually exclusive):

  * Radiative energy loss: $E_Q > E_{crit}$: hadronization outside.

  * Collisional energy loss: $E_{crit} > E_Q > m_Q L / t_{hadr}$: hadronization outside.

  * Meson dissociation/eloss: hadronization inside.

Radiative eloss:



- Medium-modified gluon radiation through interference of production and rescattering.

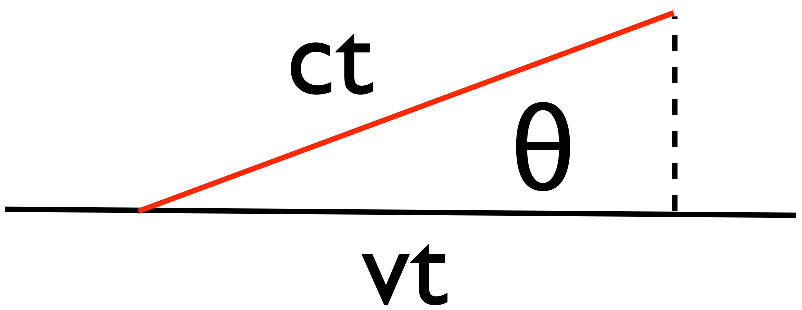
- Two parameters define the medium: density times scattering strength, and length (geometry, dynamical expansion,...).

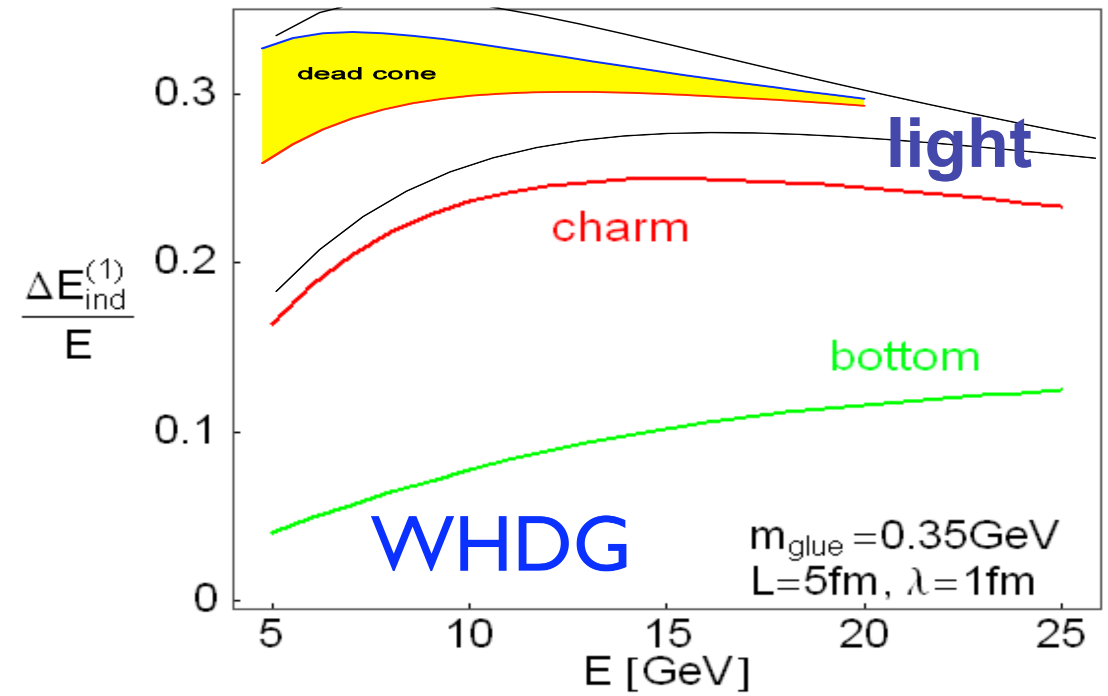
- Different realizations (DGLV, AMS, AMY, GMW) within a high energy approximation: static or thermal medium, treatment of interference, re-summation of diagrams in different ways.

- Extensive comparisons under way (TECHQM), Monte Carlo realizations to go beyond HE approx., correlations,...

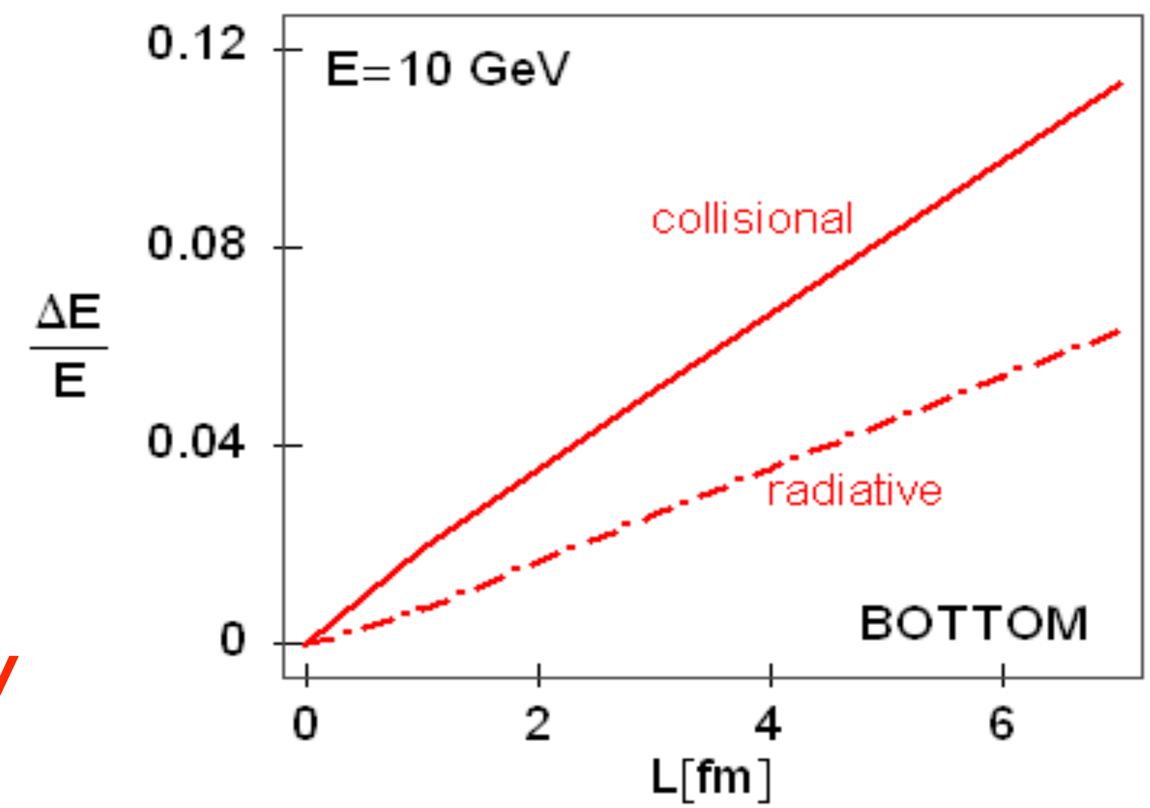
Mass hierarchy:

- Radiative eloss: $\Delta E(g) > \Delta E(q) > \Delta E(Q)$, dead cone effect (Dokshitzer-Kharzeev '01, AMS, DGLV, GMW '03). The mass effect is reduced in a thermal medium (Djordjevic '08).





- Elastic eloss (Gyulassy-Braaten-Thoma '90, Mustafa '05, WHDG '06,...): relatively more important for heavy (depends on the relation $m_Q/m_{scat.\ cent.}$).



- Meson eloss (Adil-Vitev '06): more (only) important for heavy.

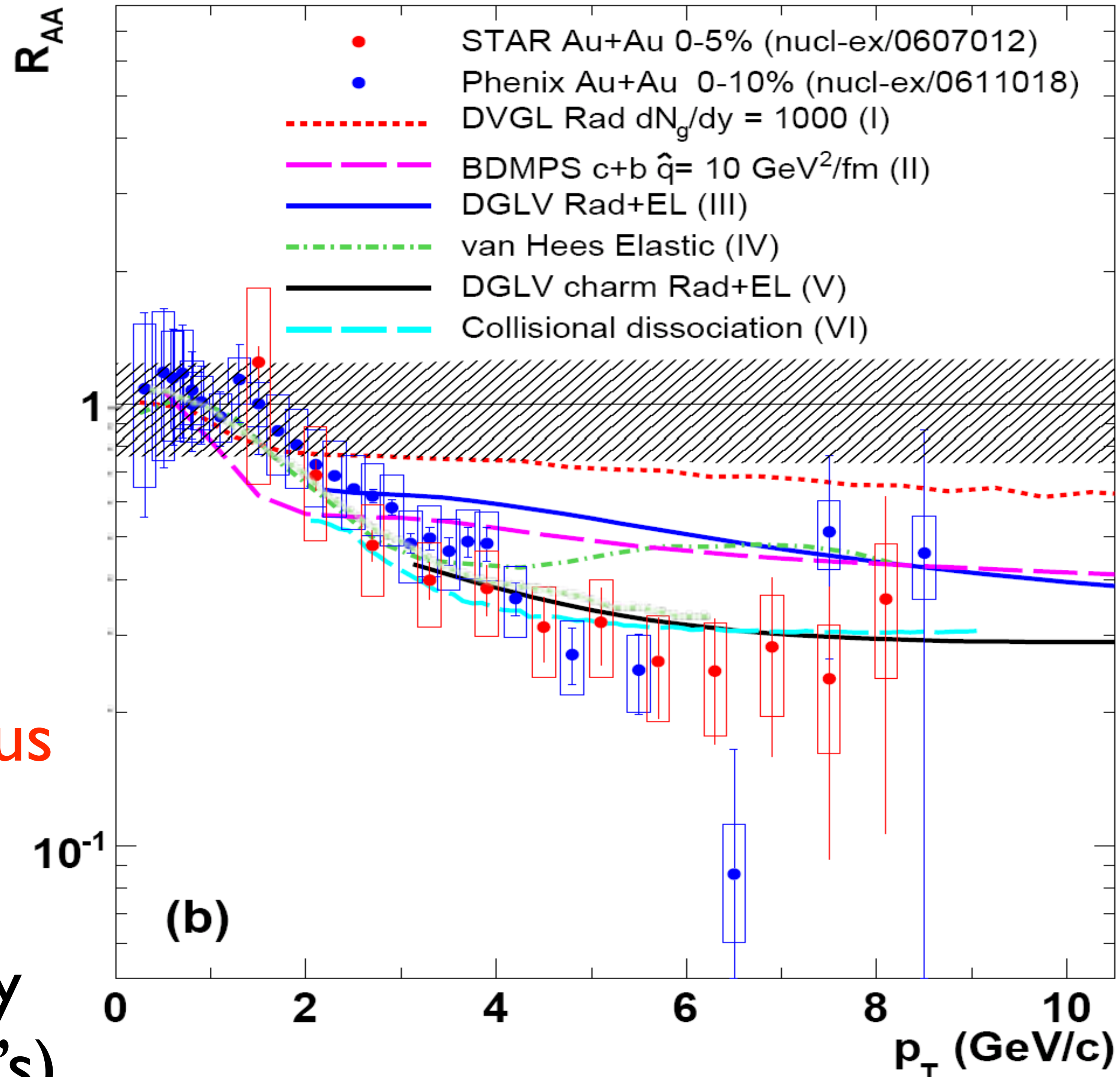
- Key question: is the medium weakly or strongly coupled (AdS/CFT)?

Comparison with data (I):

- Radiative eloss tends to overestimate the dat, except for pure c composition.

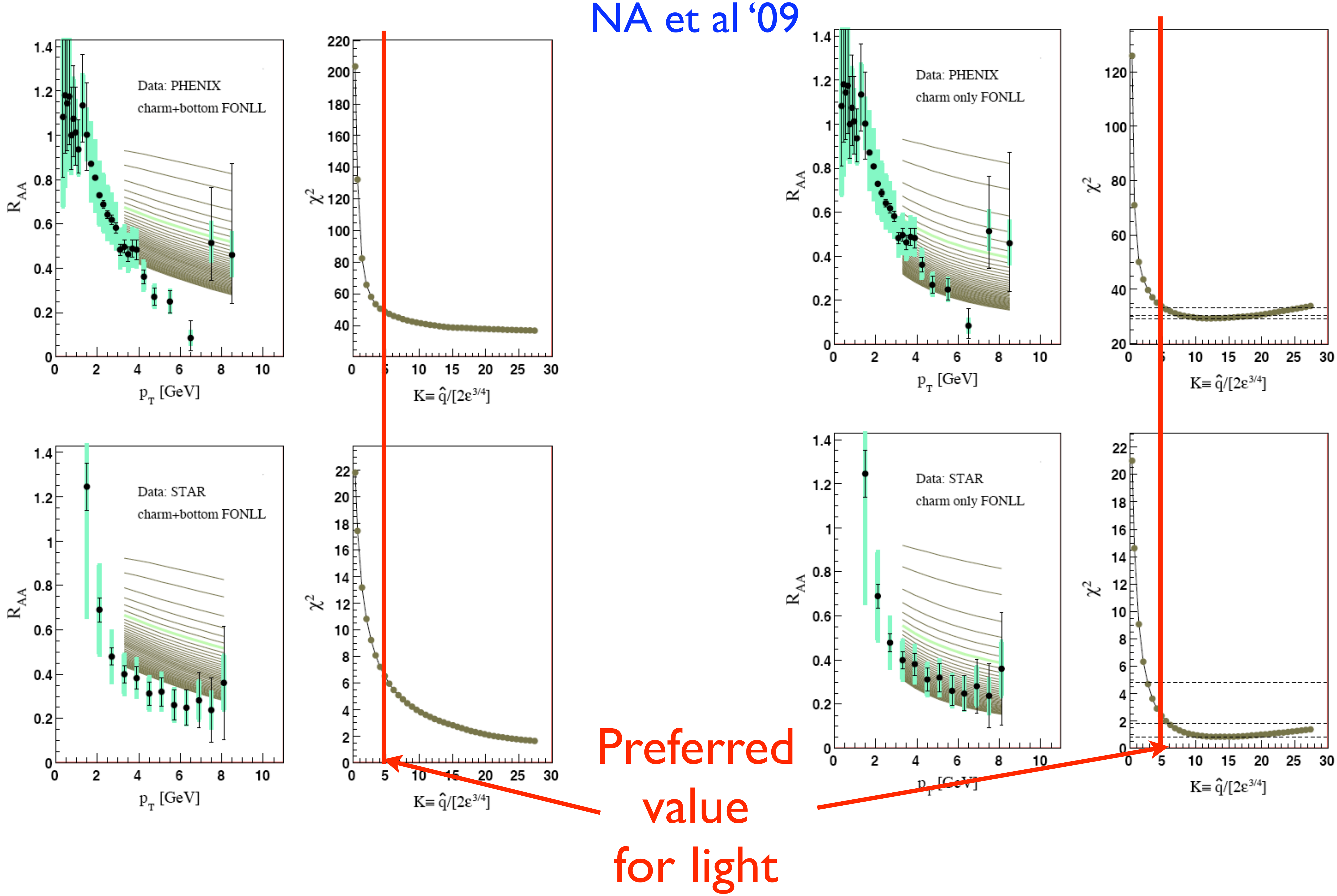
- Elastic plus radiative has problems, too.

- Collisional dissociation (plus radiative) looks OK: D's and B's equally suppressed. But only if hadronization is nearly instantaneous (~0.1 fm for B's).



Comparison with data (II):

NA et al '09



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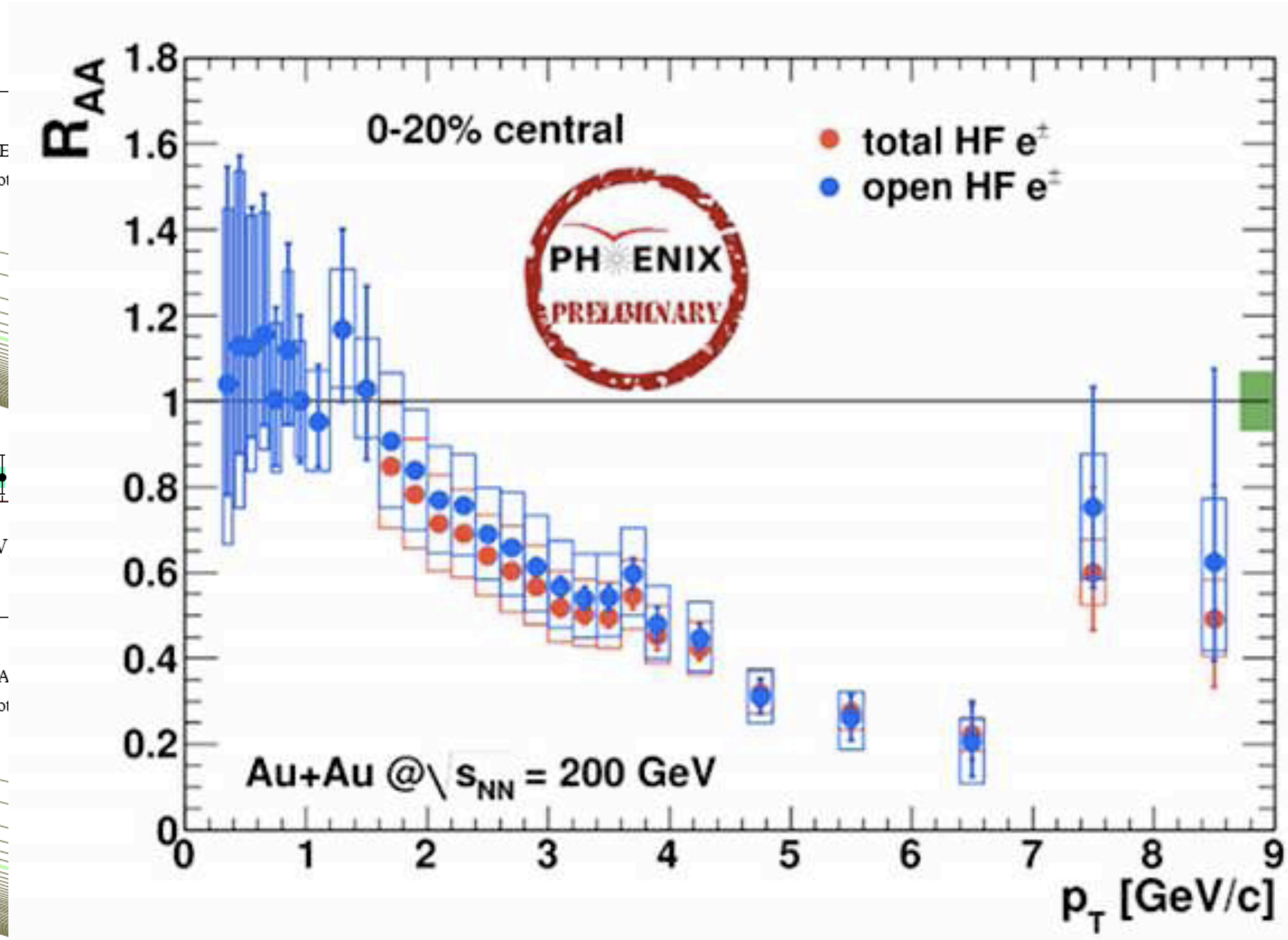
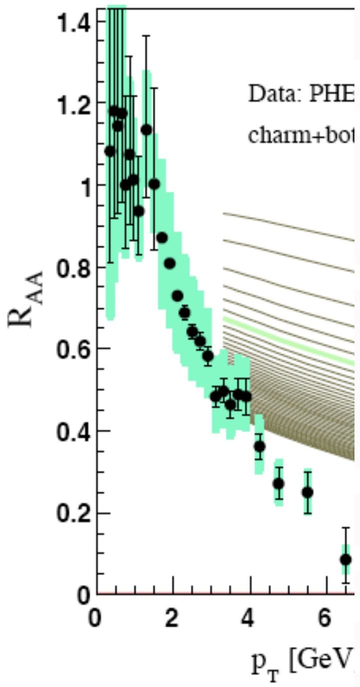
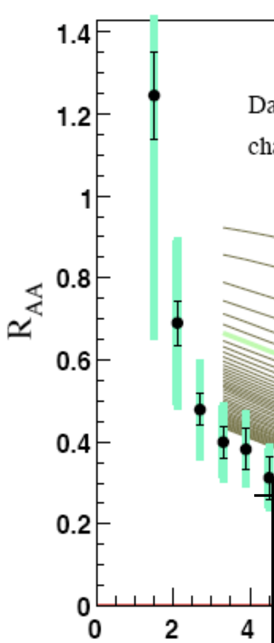


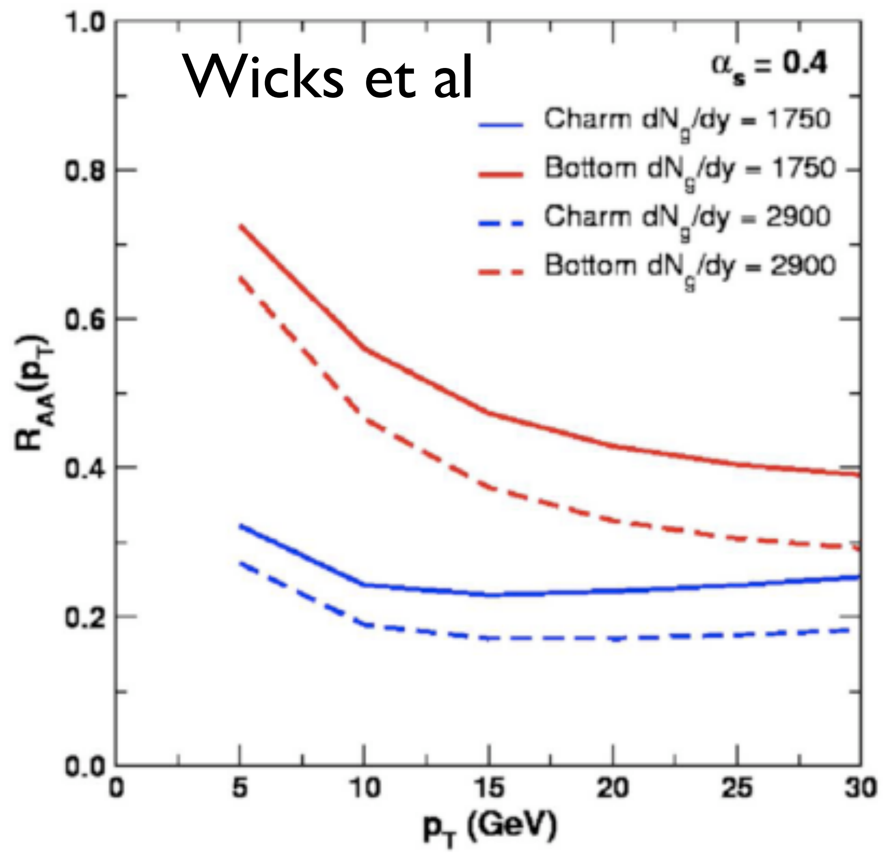


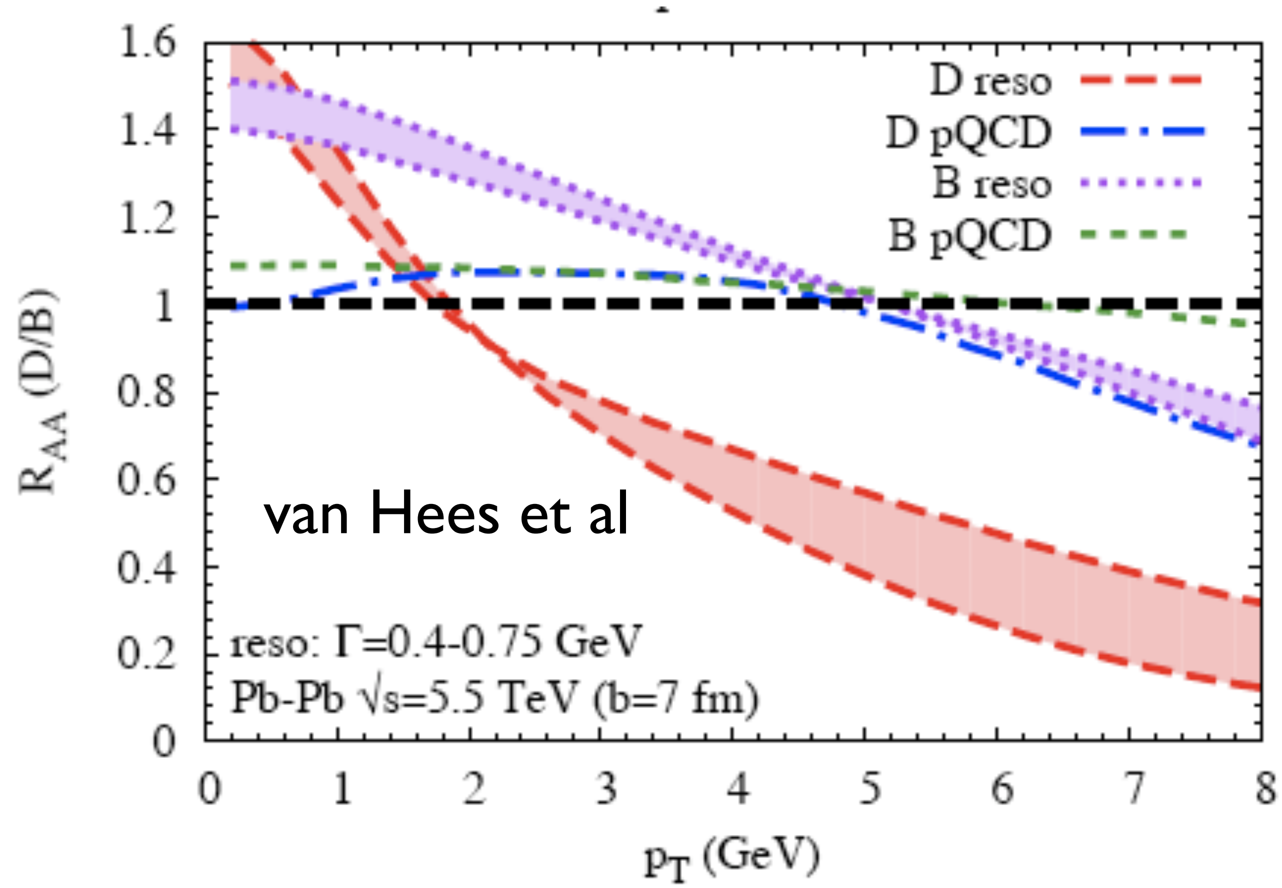


Note: no smooth model can explain this; even a small contamination may affect the ratio sizably.

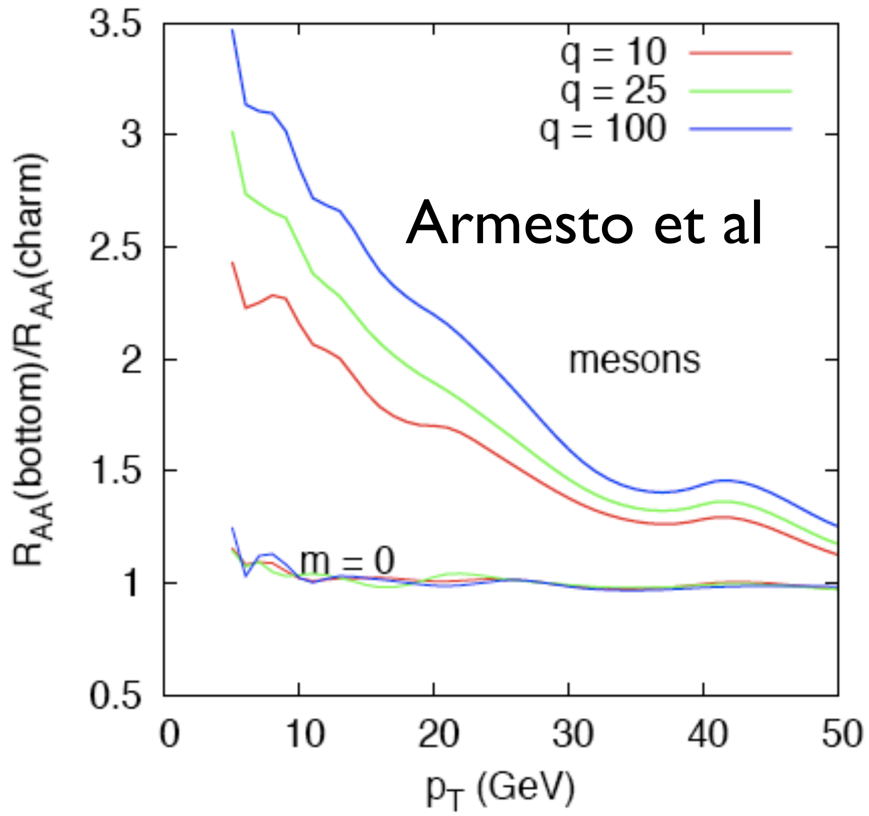
for light

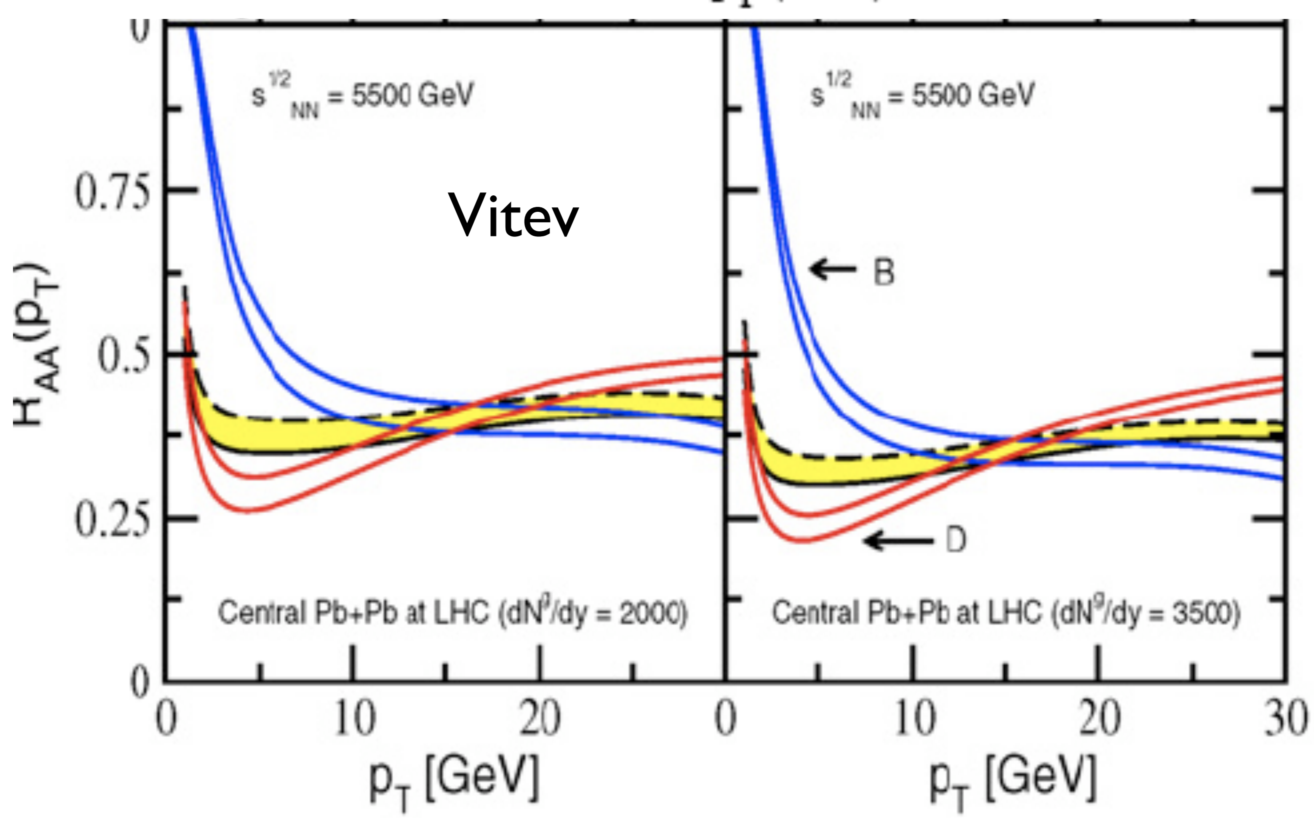
Predictions for the LHC:





JPB35 (2008) 054001





Open heavy flavour production in nuclear collisions: 3. HIC.

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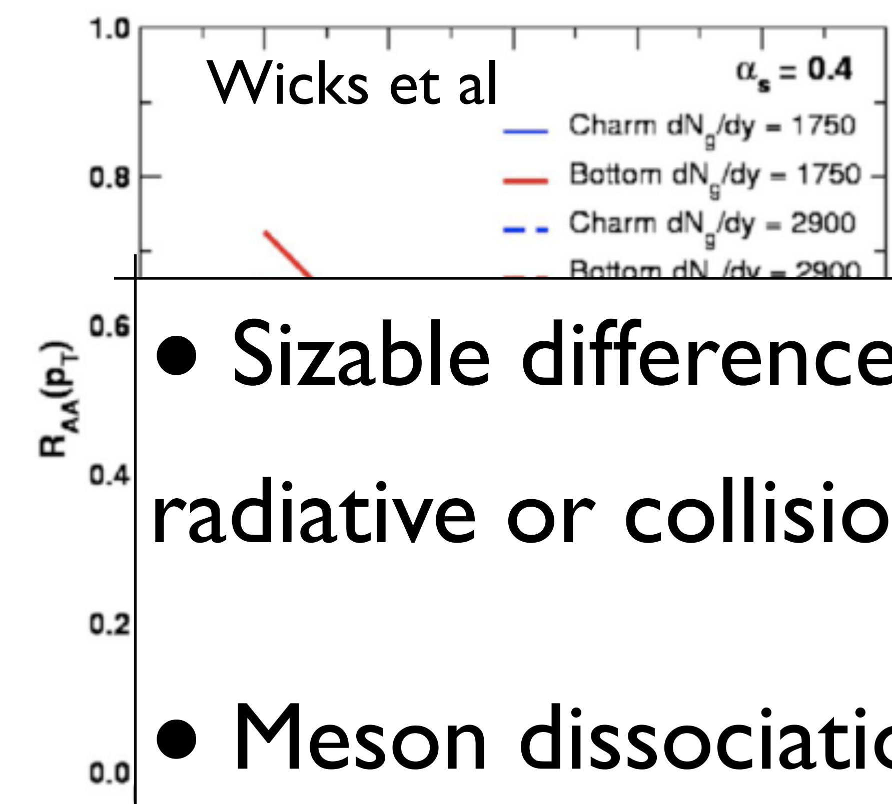
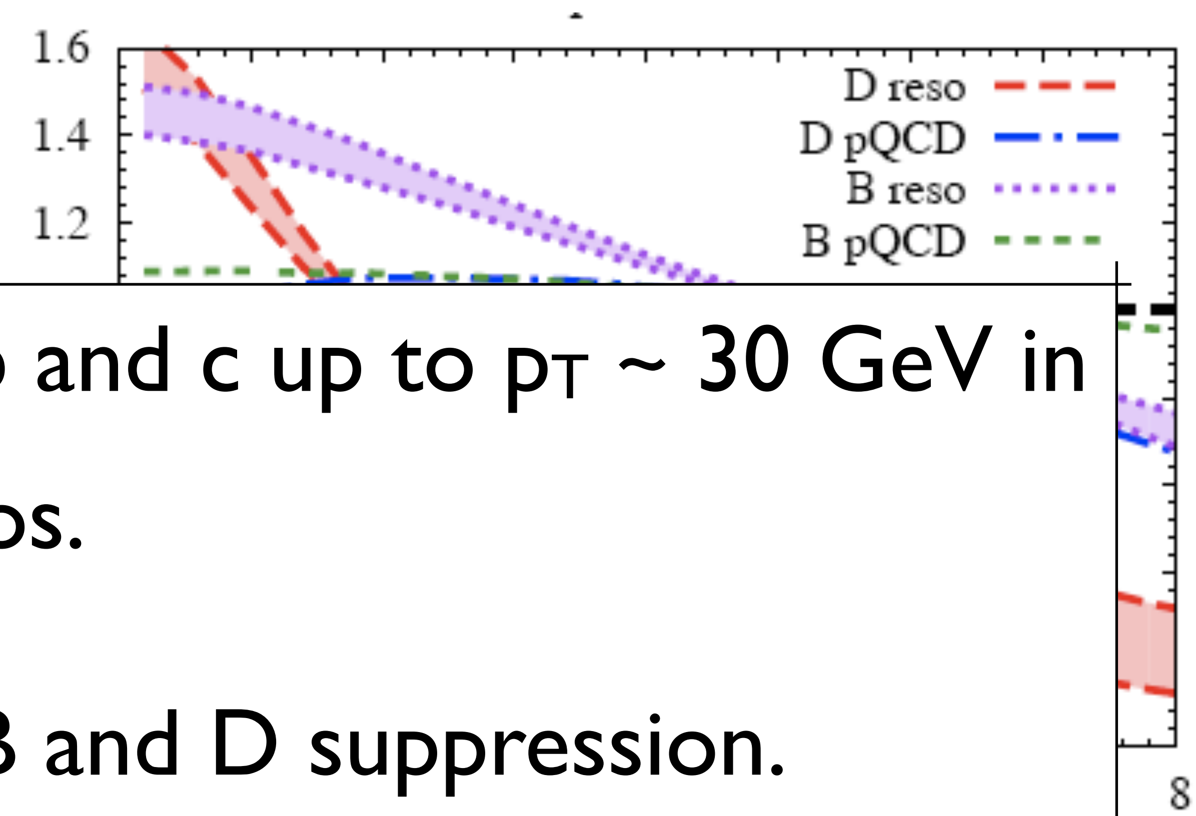


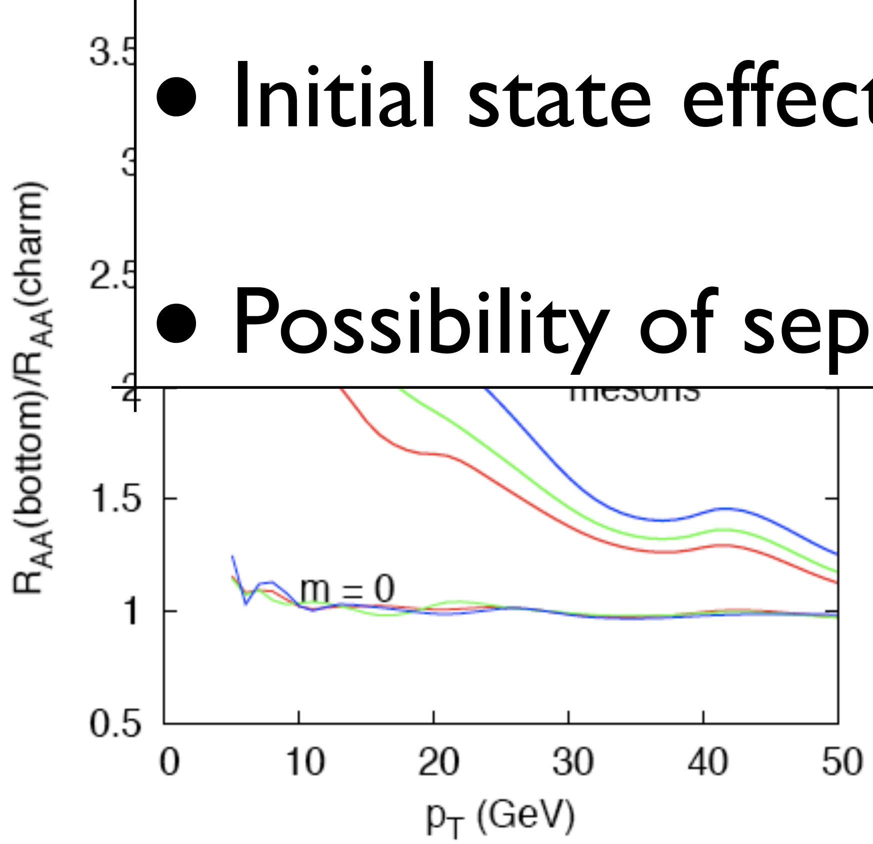


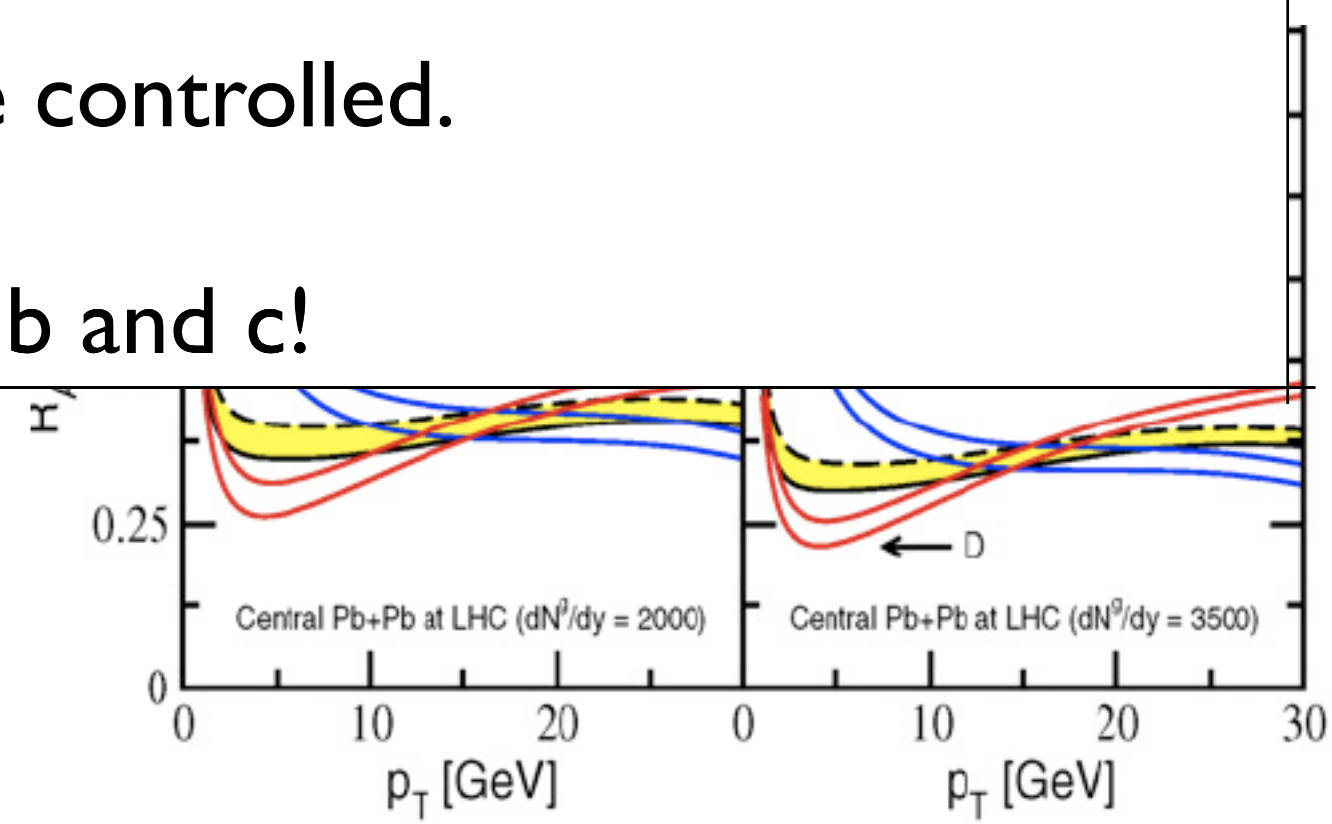
- Sizable difference between b and c up to p_T ~ 30 GeV in radiative or collisional scenarios.

- Meson dissociation: similar B and D suppression.

- Initial state effects to be controlled.

- Possibility of separating b and c!





Summary:

- Heavy flavour production in nuclear collisions provides a stringent test of our factorization ideas.

- For its use as a tool to analyze the medium created in HIC, an accurate control of the benchmark is demanded: npdf's.

- Benchmark at RHIC?

- Unsatisfactory situation in HIC at RHIC: data are hard to be reproduced, models are not really consistent with data for light hadrons,...

- LHC and RHIC-II offer large possibilities to clarify these issues, through D/B identification.