LHC predictions with the Parton Quenching Model

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in collaboration with
A.Dainese and G.Paic

PQM: Dainese, Loizides, Paic, EPJC38 (2005), 461.

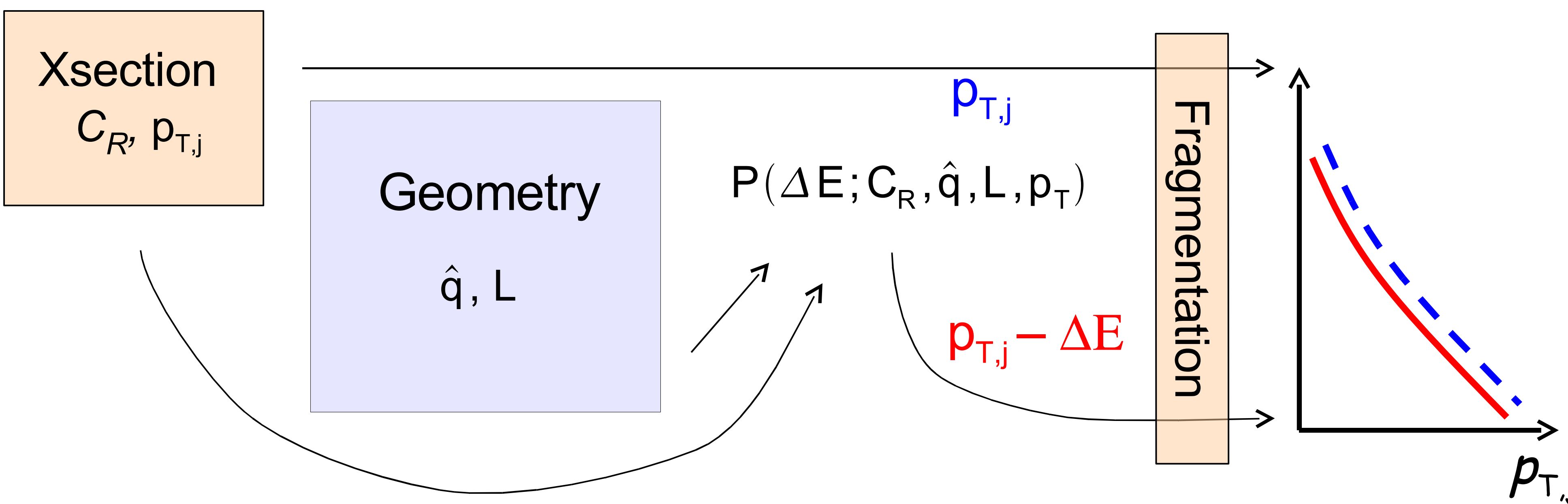
Transverse momentum spectra in PQM

Factorized pQCD + final state quenching + vacuum fragmentation

$$\left.\frac{d^2\sigma^{h}_{quenched}}{dp_T\,dy}\right|_{y\approx 0} = \sum_{a,b,j}\int dF_{ab}\, d\Delta E_j\, dz_j\, dp^{init}_{T,j} \left.\frac{d^2\sigma^{ab\to jX}}{dp^{init}_{T,j}\,dy}\right|_{y\approx 0} \times$$

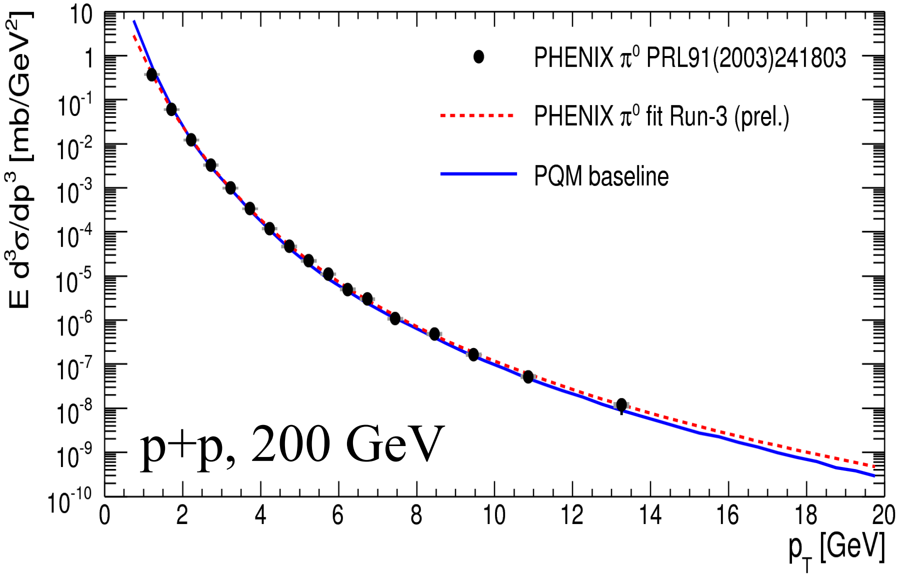
$$\delta(p^{init}_{T,j}-p_{T,j}-\Delta E_j)\, P(\Delta E_j; C_j, \hat{q}_j, L_j, p_{T,j})\, \frac{D_{h/j}(z_j)}{z_j^2}$$

Monte Carlo approach:



PQM ingredients: Vacuum case

- Pythia parton p_T distributions
  - CTEQ4L neglecting intrinsic k_t
  - No nuclear effects for the PDFs
- KKP fragmentation functions
- BDMPS-SW quenching weights
  - Eikonal limit requires treatment for finite parton energies
    - reweighted vs <u>non-reweighted</u>
  - Fixed $\alpha_s = 0.3$



- Optical Glauber with Wood-Saxon density distribution
  - Parton production in transverse plane according to ρ_{coll}
  - Matter density according to $\rho \propto k \times T_A T_B(x_0+\xi\cos\phi_0, y_0+\xi\sin\phi_0; b)$
    - Determine length and transport coefficient using $I_i = \int_0^\infty d\xi\, \xi^i\, \rho(\xi)$
  - Static scenario (no expansion and no transverse flow)

PQM ingredients: Quenching weights

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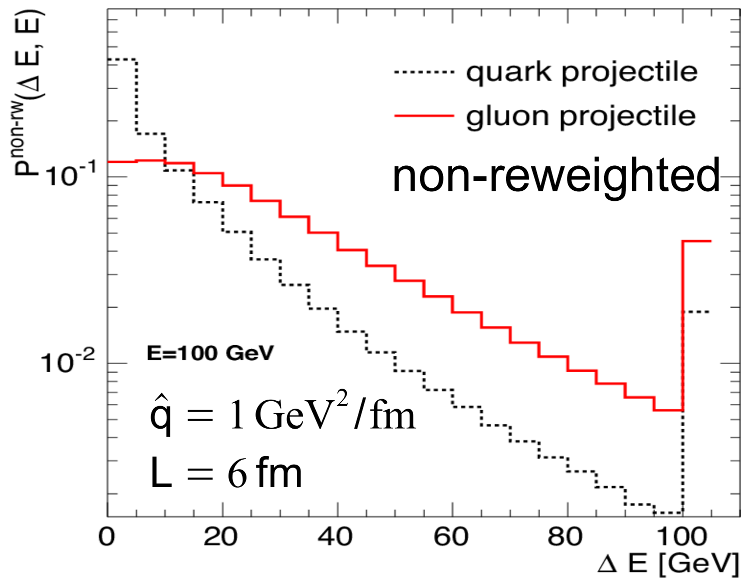

BDMS, JHEP 0109 (2001) 033
Salgado, Wiedemann, PRD 68 (2003) 014008

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PQM ingredients: Geometry

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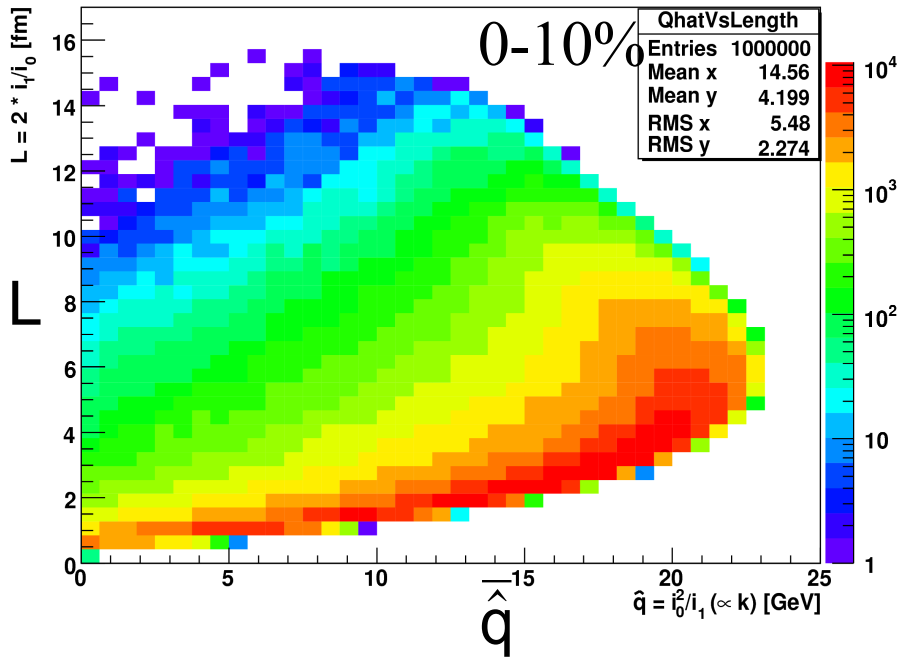

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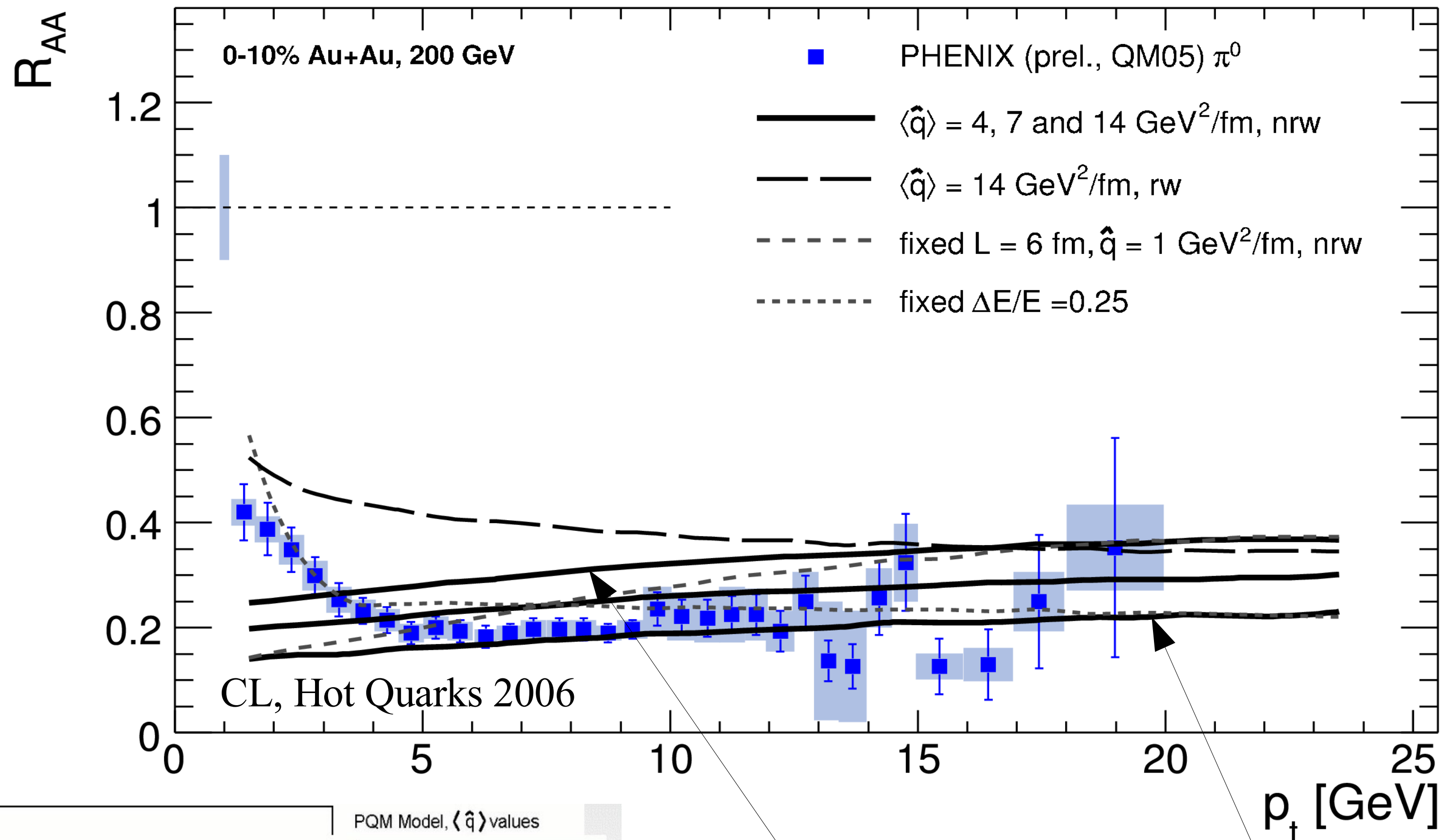
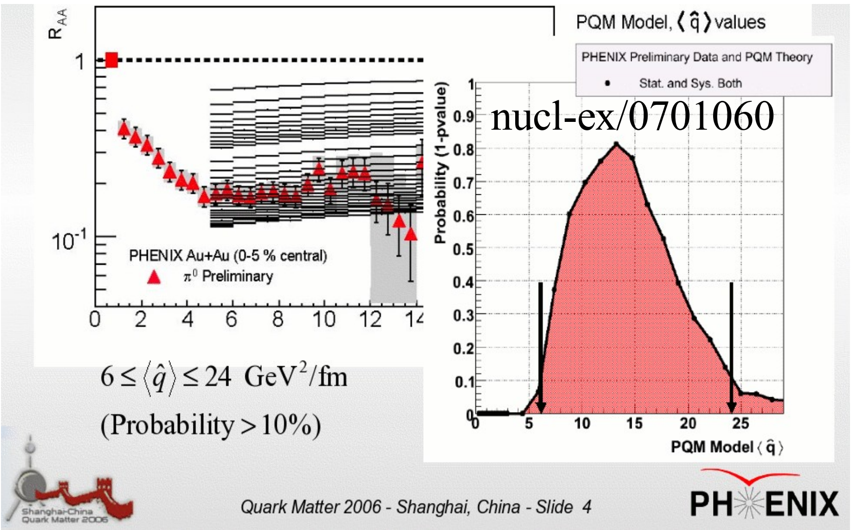
Results at RHIC



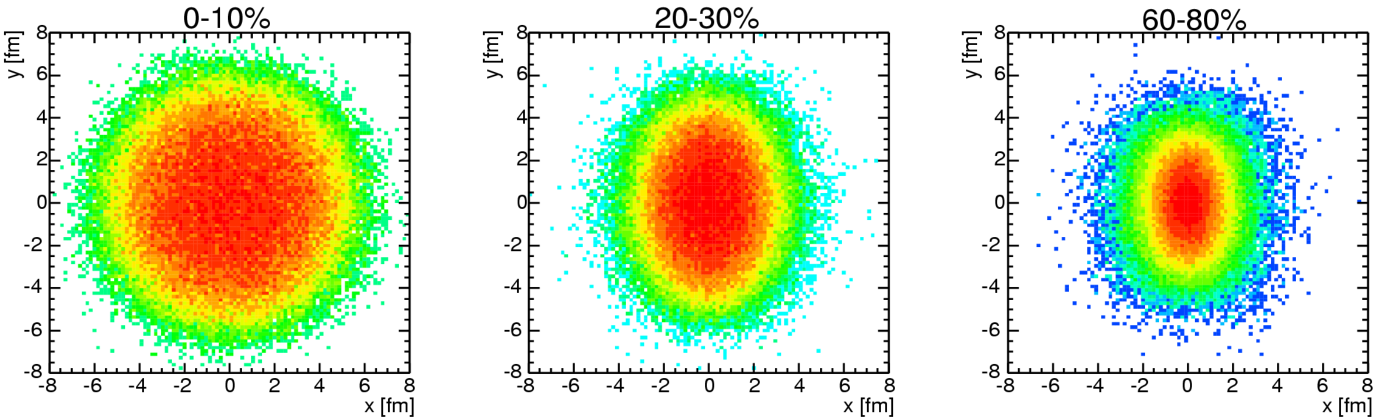


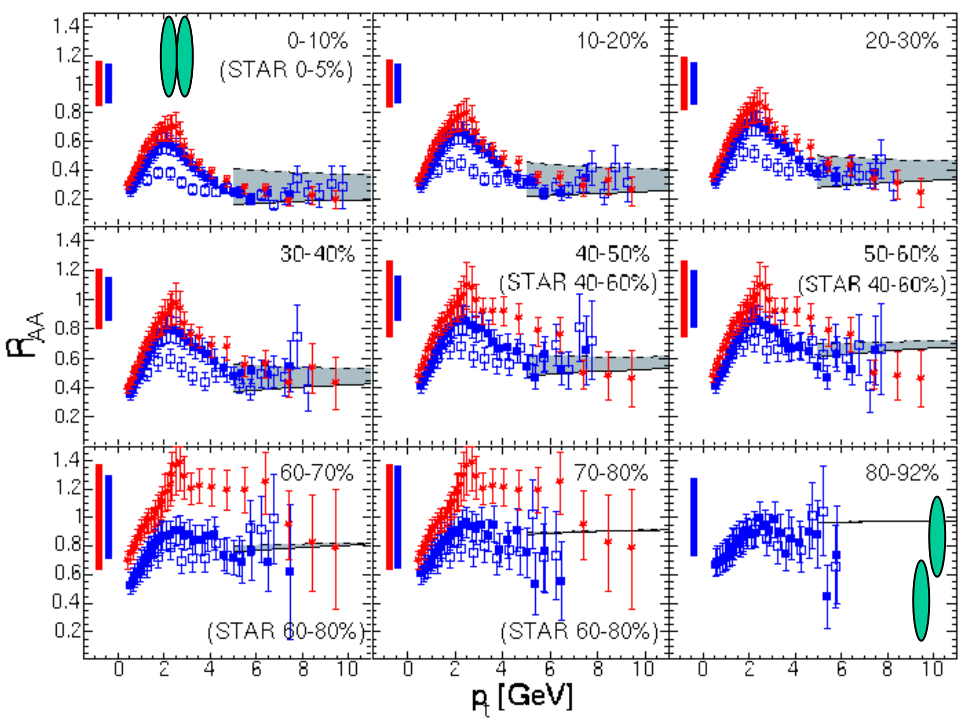
$$4\,\text{GeV}^2/\text{fm} \le \langle\hat{q}\rangle \le 14\,\text{GeV}^2/\text{fm}$$

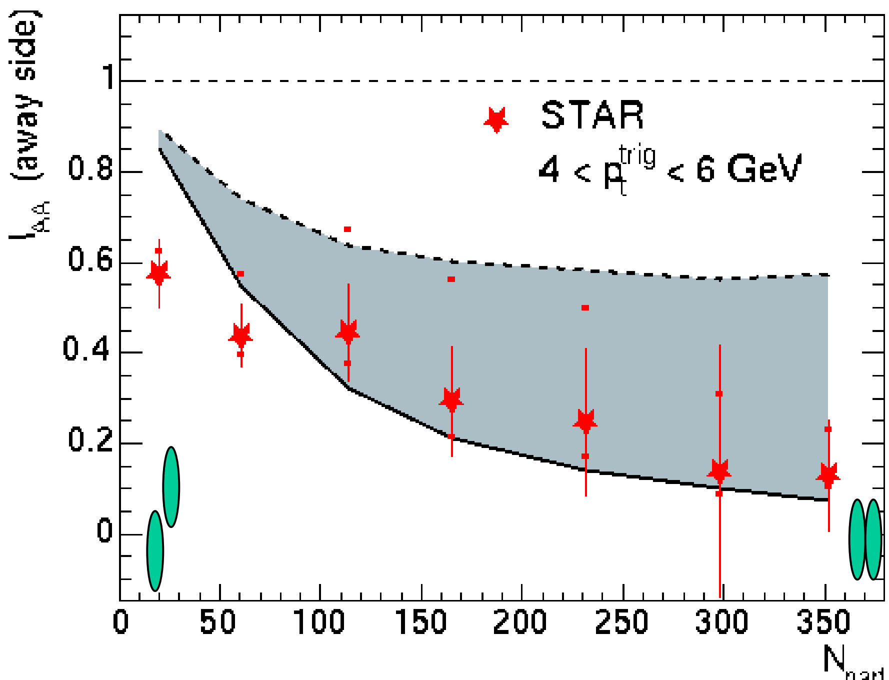
See also
Escola, Honkanen, Salgado, Wiedemann, NPA747 (2005) 511.

Results at RHIC (2)

Centrality evolution: $\hat{q}(b) = k^{AuAu,200\,GeV} \times T_A T_B(b)$

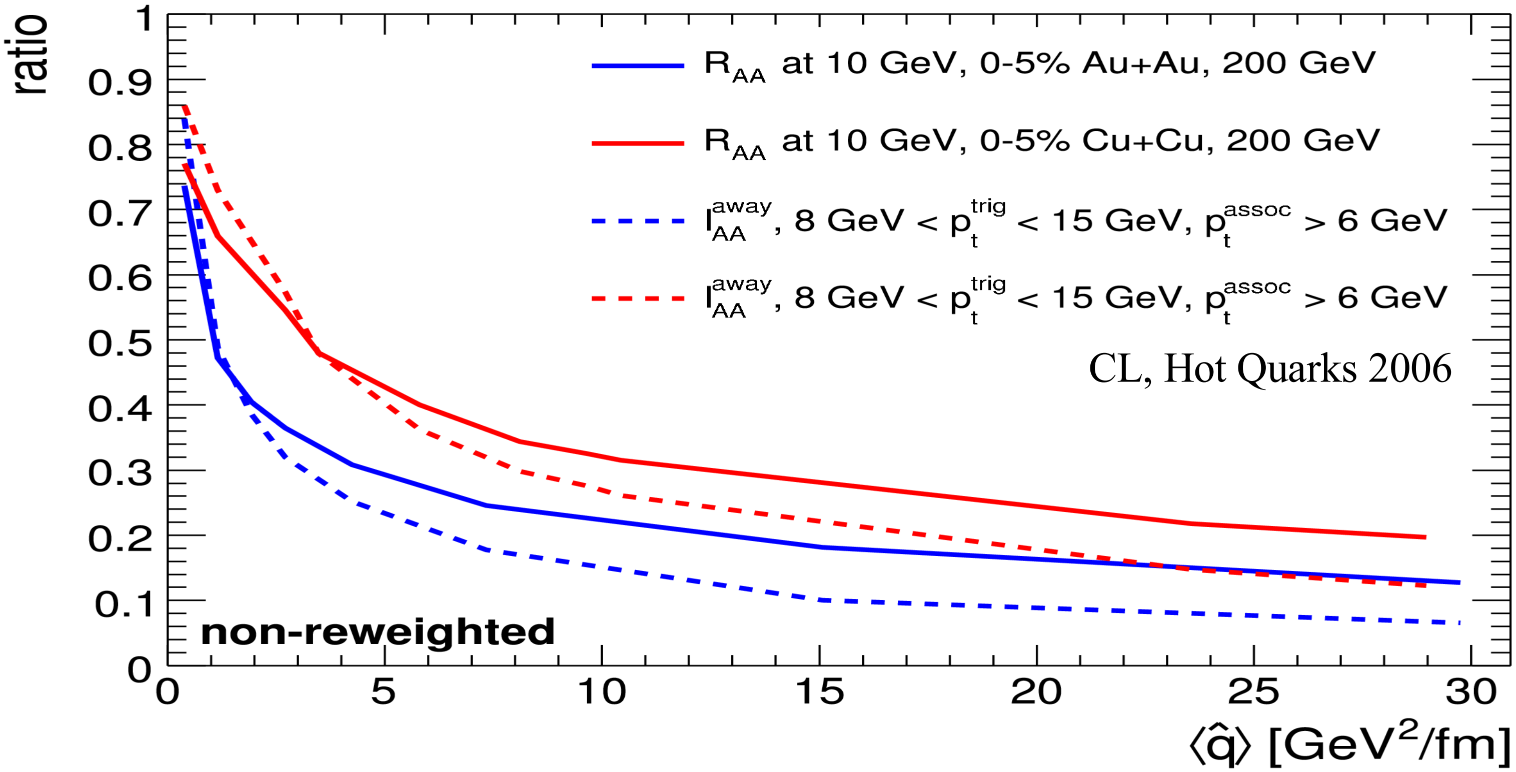


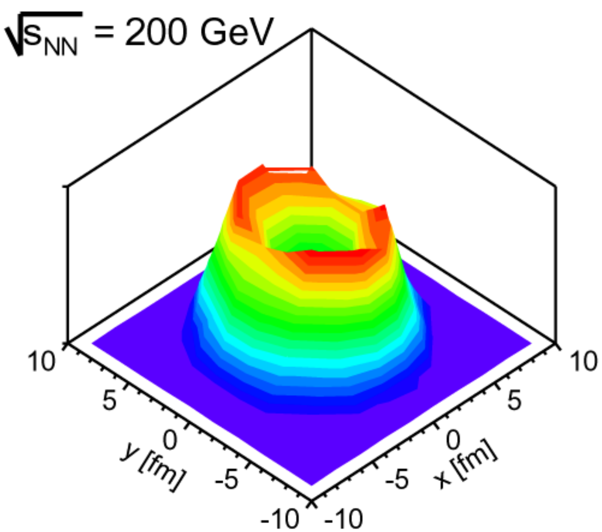




For further observables see,
Dainese, Loizides, Paic, EPJC (2005) 461.

Surface emission and trigger bias



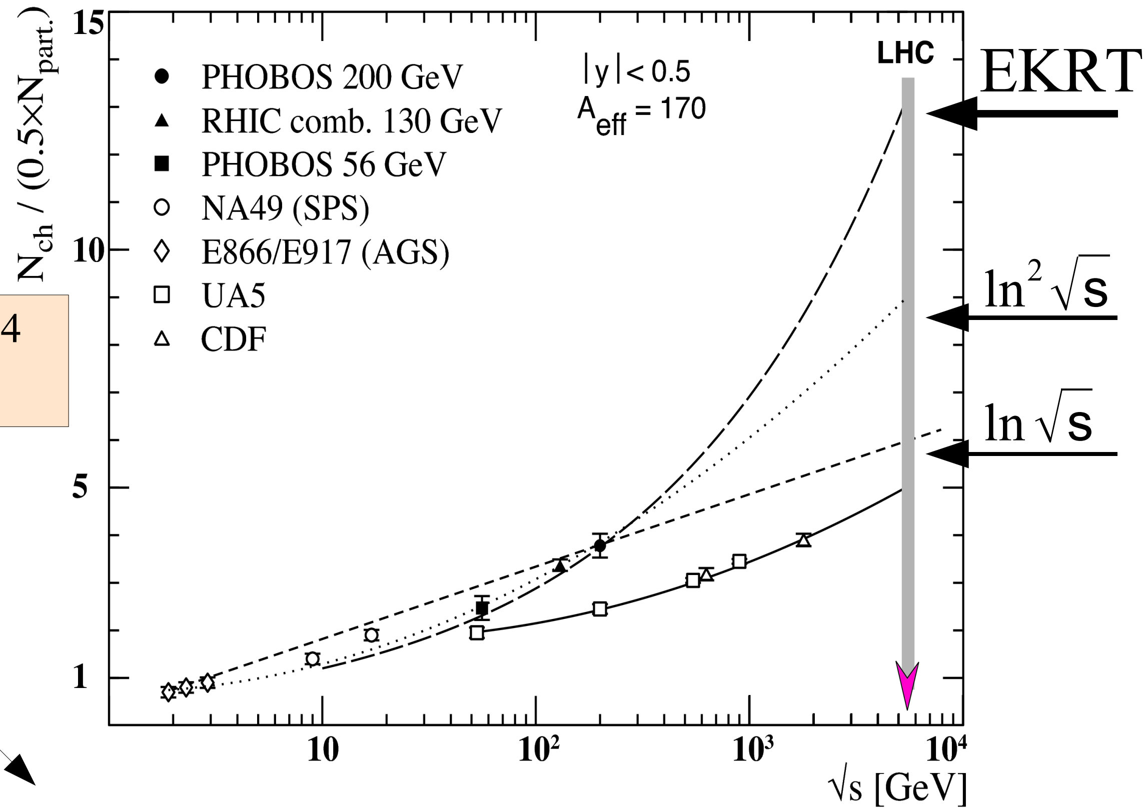


- Strong observed suppression implies large densities
- Opaque medium leeds to strong trigger biases
- R_{AA} and I_{AA} pre-dominantly determined by geometry

Müller, PRC67 (2003) 061901.
Drees, Feng, Jia, PRC 71 (2005).
Escola, Honkanen, Salgado, Wiedemann, NPA747 (2005) 511.

The transport coefficient is proportional to the gluon density, which according to the saturation model (EKRT) scales with

$$\langle \hat{q} \rangle \propto n^{\text{gluons}} \propto A^{0.383} \sqrt{s_{NN}}^{0.574}$$

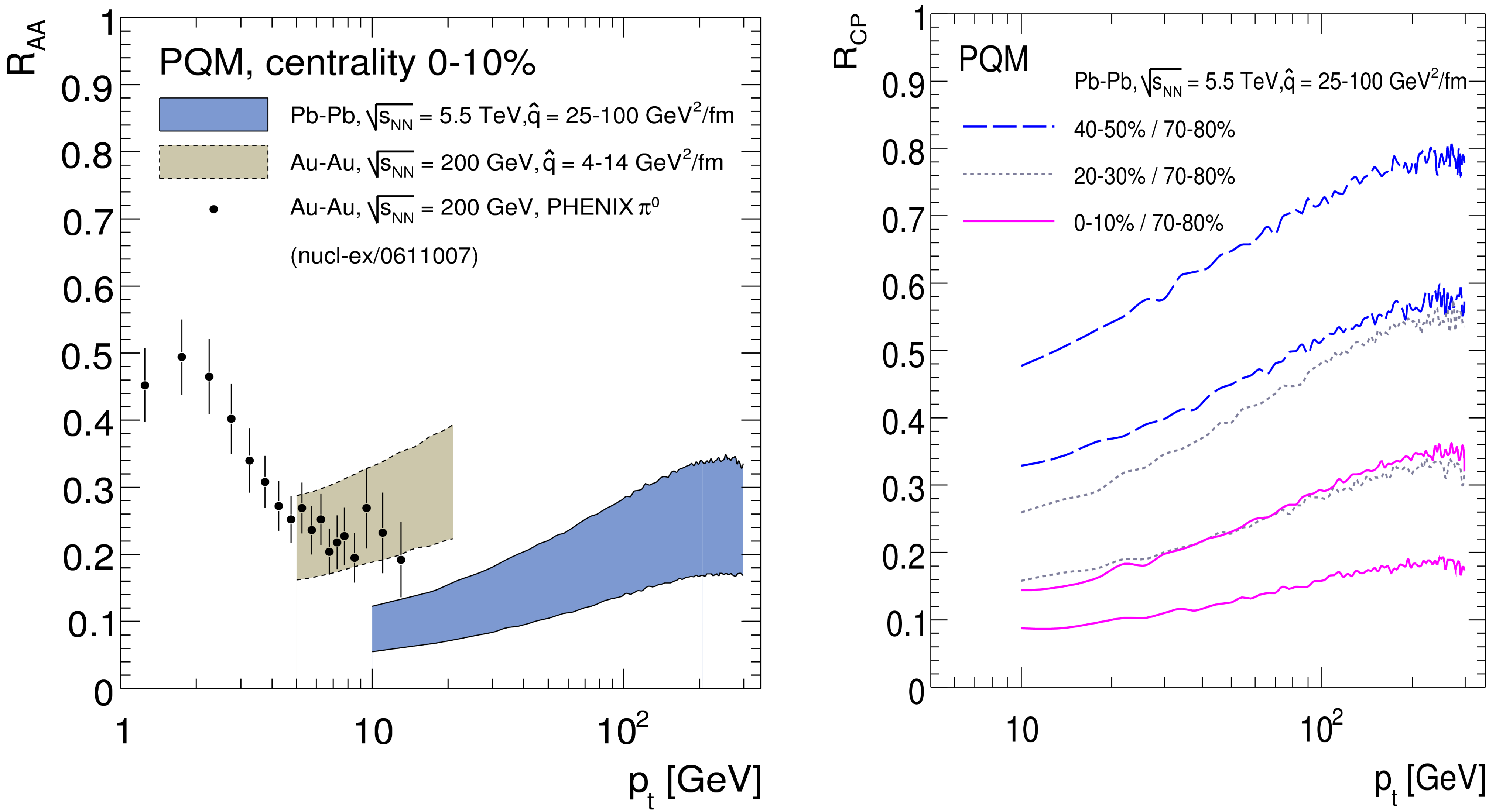


Using the extracted value at Au+Au 200 GeV gives (for 0-10% collisions)

$$\langle \hat{q} \rangle = \left(A/197\right)^{0.383} \left(\sqrt{s_{NN}}/200\right)^{0.574} \times \langle q^{Au+\hat{A}u,200} \rangle \left[\text{GeV}^2/\text{fm}\right]$$

Scale with 6.8 for 5.5 TeV at LHC

Eskola, Kajantie, Ruuskanen, Tuominen, NPB 570 (2000) 379.



$$25\,\mathrm{GeV}^2/\mathrm{fm} \leq \langle \hat{q}^{LHC} \rangle \leq 100\,\mathrm{GeV}^2/\mathrm{fm}$$

Summary

- Parton Quenching Model
  - BDMPS-SW quenching weights married with Glauber geometry
    - Simple model with one single parameter
  - Rather consistently describes most high-p_T RHIC data
  - Exhibits trigger biases in R_{AA} and I_{AA}
    - Transport coefficient can not precisely be determined
- Extrapolation to LHC collision energy requires an assumption of the achieved density (multiplicity) at LHC
  - Considered EKRT model (based on $\langle \hat{q} \rangle^{0-10\,,\,200\mathrm{GeV}} = 4 - 14\,\mathrm{GeV}^2/\mathrm{fm}$)
  - Predictions made for R_{AA} and R_{CP} depend on this (dN/dy~3000)
    - Only moderate increase with hadron p_T

Backup Slides

Systematic variation of PQM ingredients

- Geometry
  - Matter density according to $\rho \propto k \times \rho_{part}$ (rather than $\rho \propto k \times \rho_{coll}$)
  - Include (longitudinal) expansion
- Quenching weights
  - Compare with fixed $\alpha_s = 0.5$
  - Compare with single hard approximation
- Parton p_T distributions
  - Nuclear effects in PDFs
- Vary fragmentation functions
  - AKK fragmentation

Work in progress

Dainese, Loizides, Paic, EPJC38 (2005), 461.

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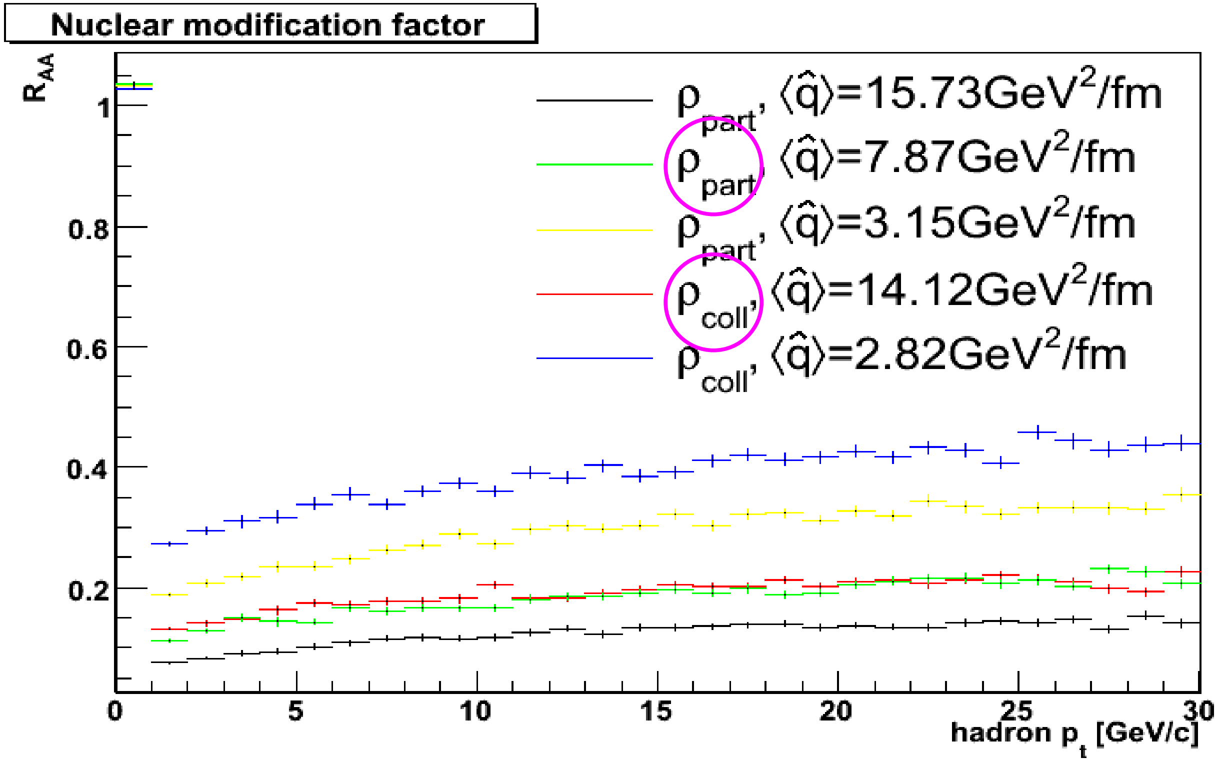
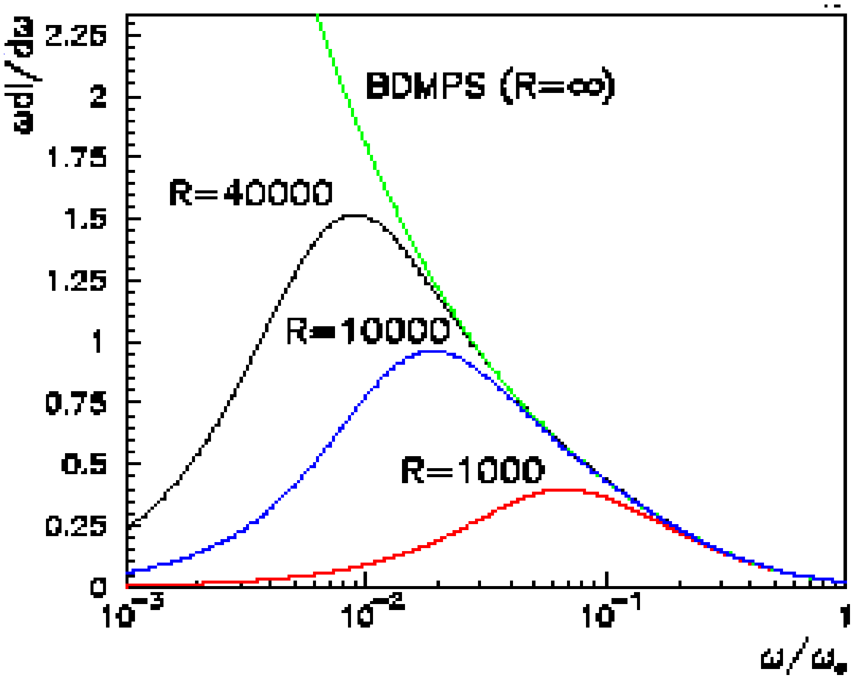


Work in progress

Parton energy loss in BDMPS-Z formalism



BDMPS-Z formalism

$$\hat{q} = \frac{\langle q_T^2 \rangle}{\lambda} \quad \text{transport coefficient}$$

Radiated-gluon energy distrib.:

$$\omega \frac{dI}{d\omega} \propto \alpha_S C_R \begin{cases} \sqrt{\omega_c / \omega} & \text{for } \omega < \omega_c \\ (\omega_c / \omega)^2 & \text{for } \omega \geqslant \omega_c \end{cases}$$

C_R	Casimir coupling factor: 4/3 for q, 3 for g
$\omega_c = \hat{q} L^2 / 2$	determines the scale of the radiated energy
$R = \omega_c L$	related to constraint $k_T < \omega$ and controls shape at $\omega << \omega_c$

Baier, Dokshitzer, Müller, Peigne‘, Schiff, NPB 483 (1997) 291.
Zakharov, JTEPL 63 (1996) 952.
Salgado, Wiedemann, PRD 68(2003) 014008.

Parton energy loss in BDMPS-Z formalism

$$\langle \Delta E \rangle \approx \int_0^{\omega_c} d\omega\, \omega \frac{dI}{d\omega} \propto \alpha_S\, C_R\, \omega_C \propto \alpha_S\, C_R\, \hat{q}\, L^2$$

$$\langle \Delta E \rangle \propto \hat{q} \propto \rho \int dq_T^2 q_T^2\, d\sigma / dq_T^2$$

(gluons volume-density and interaction cross section)

→ **Probe the medium**

Finite parton energy (qualitatively)

- If $E < \omega_c$ (e.g. small p_T with traversing large L) :

$$\langle \Delta E \rangle \approx \int_0^{E} d\omega\, \omega \frac{dI}{d\omega} \propto \alpha_S\, C_R \sqrt{E\, \omega} \propto \alpha_S\, C_R \sqrt{E} \sqrt{\hat{q}}\, L$$

  - Introduces dependence on parton energy
  - Reduces sensitivity to density
  - Leads to linear dependence on path length

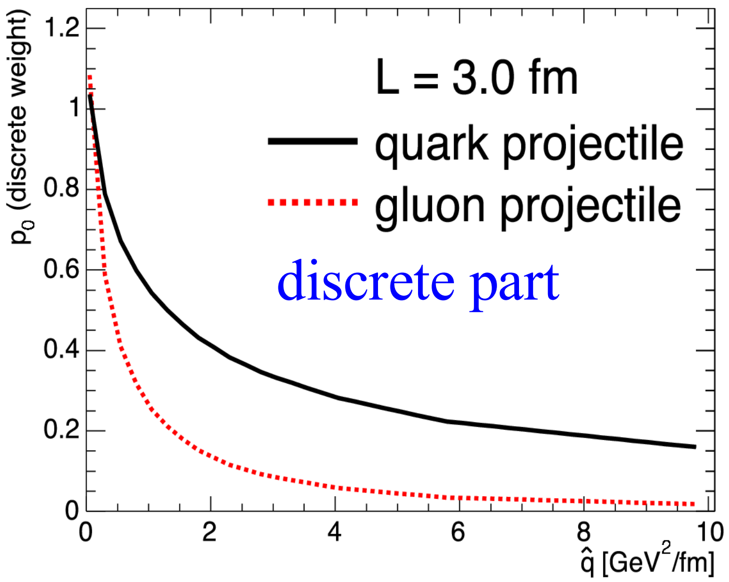
Quenching weights

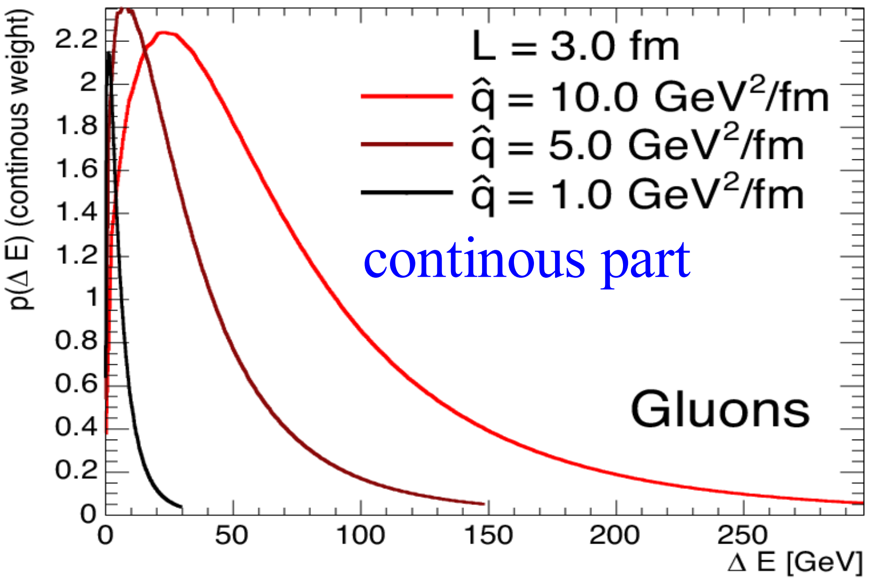
- Compute energy loss probability distributions

$$P(\Delta E) = \sum_{n=0}^{\infty}\left[\prod_{i=1}^{n}\int d\omega_i \frac{dI(\omega_i)}{d\omega}\right]\delta\left(\Delta E - \sum_{i=0}^{n}\omega_i\right)\exp\left[-\int d\omega \frac{dI}{d\omega}\right]$$

- Calculated from $\omega\, dI/d\omega$ in the $E \to \infty$ approximation (no E dep.)

$$P(\Delta E; C_R, \hat{q}, L) = p_0(C_R, \hat{q}, L) + p(\Delta E; C_R, \hat{q}, L) \qquad [\alpha_S = 1/3]$$





BDMS, JHEP 0109 (2001) 033
Salgado, Wiedemann, PRD 68 (2003) 014008

→ **Constrained weights**

Quenching weights

- Compute energy loss probability distributions

$$P(\Delta E; C_R, \hat{q}, L) = \sum_{n=0}^{\infty} \left[\prod_{i=1}^{n} \int d\omega_i \frac{dI(\omega_i)}{d\omega} \right] \delta\left(\Delta E - \sum_{i=0}^{n} \omega_i \right) \exp\left[-\int d\omega \frac{dI}{d\omega} \right]$$

- Calculated from $\omega\, dI/d\omega$ in the $E \to \infty$ approximation (no E dep.)

$$P(\Delta E; C_R, \hat{q}, L) = p_0(C_R, \hat{q}, L) + p(\Delta E; C_R, \hat{q}, L) \qquad \left[\alpha_S = 1/3\right]$$

$$P(\Delta E; C_R, \hat{q}, L, E) \quad \text{with} \quad \Delta E \leq E$$

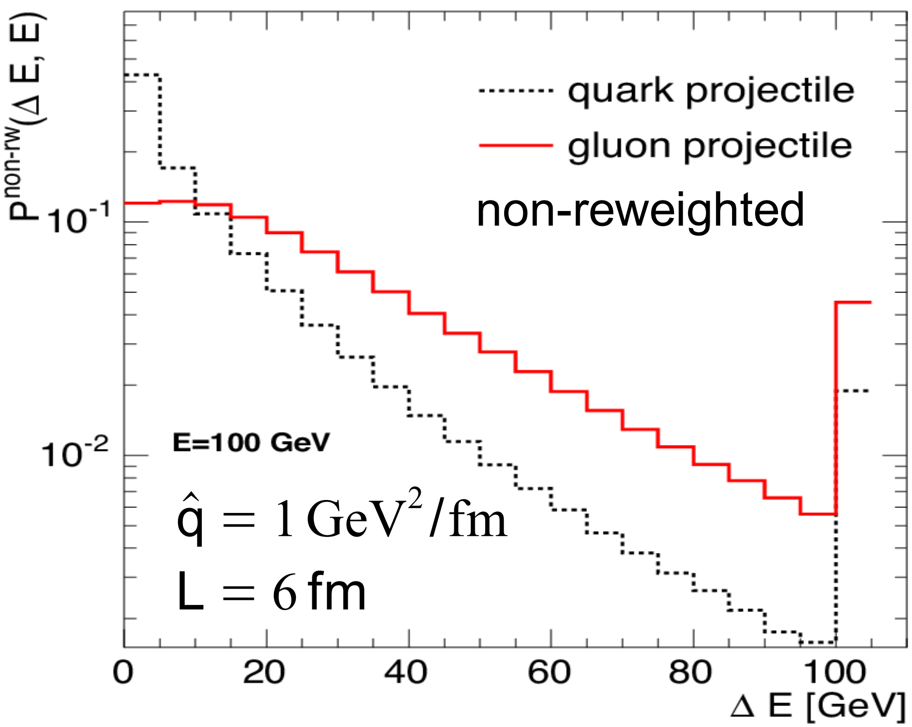
BDMS, JHEP 0109 (2001) 033
Salgado, Wiedemann, PRD 68 (2003) 014008

Constrained quenching weights

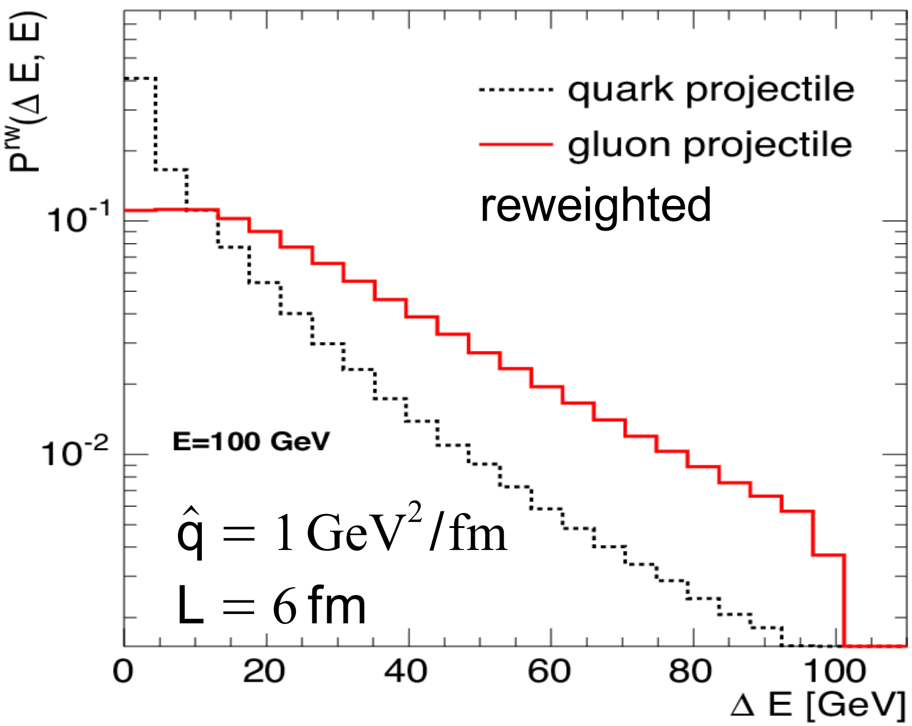
Construct constrained weights from quenching weights

$$P(\Delta E; C_R, \hat{q}, L, E) \text{ with } \Delta E \leq E$$

a) non-reweighted weight
(thermalize for ΔE>E)



b) reweighted weight
(truncate + renormalize at ΔE=E)



Expanding medium

- Time-dep. density of scattering centers

$$\hat{q}(\tau) = \hat{q}_0 \times \left(\frac{\tau_0}{\tau}\right)^\alpha$$

- Dynamical sc... same spectru... an equivalent... transport coe...

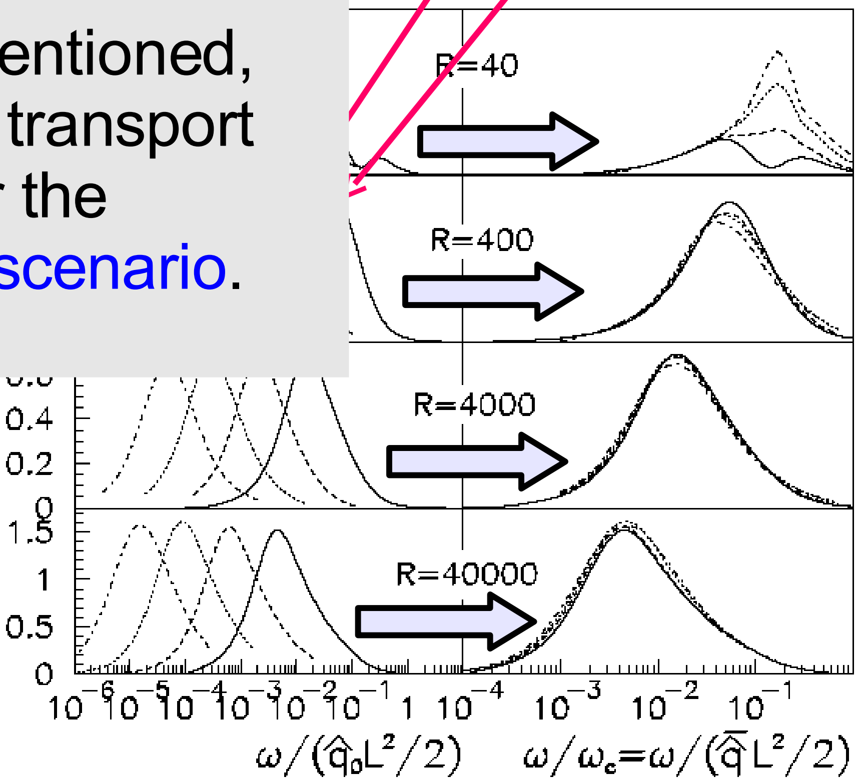
$$\bar{\hat{q}} = \frac{2}{L^2} \int_{\tau_0}^{L+\tau_0} d\tau (\tau - \tau_0)\, \hat{q}(\tau)$$

If not explicitly mentioned, all values for the transport coefficient are for the equivalent static scenario.

Calculations for a static scenario apply for also for expanding systems

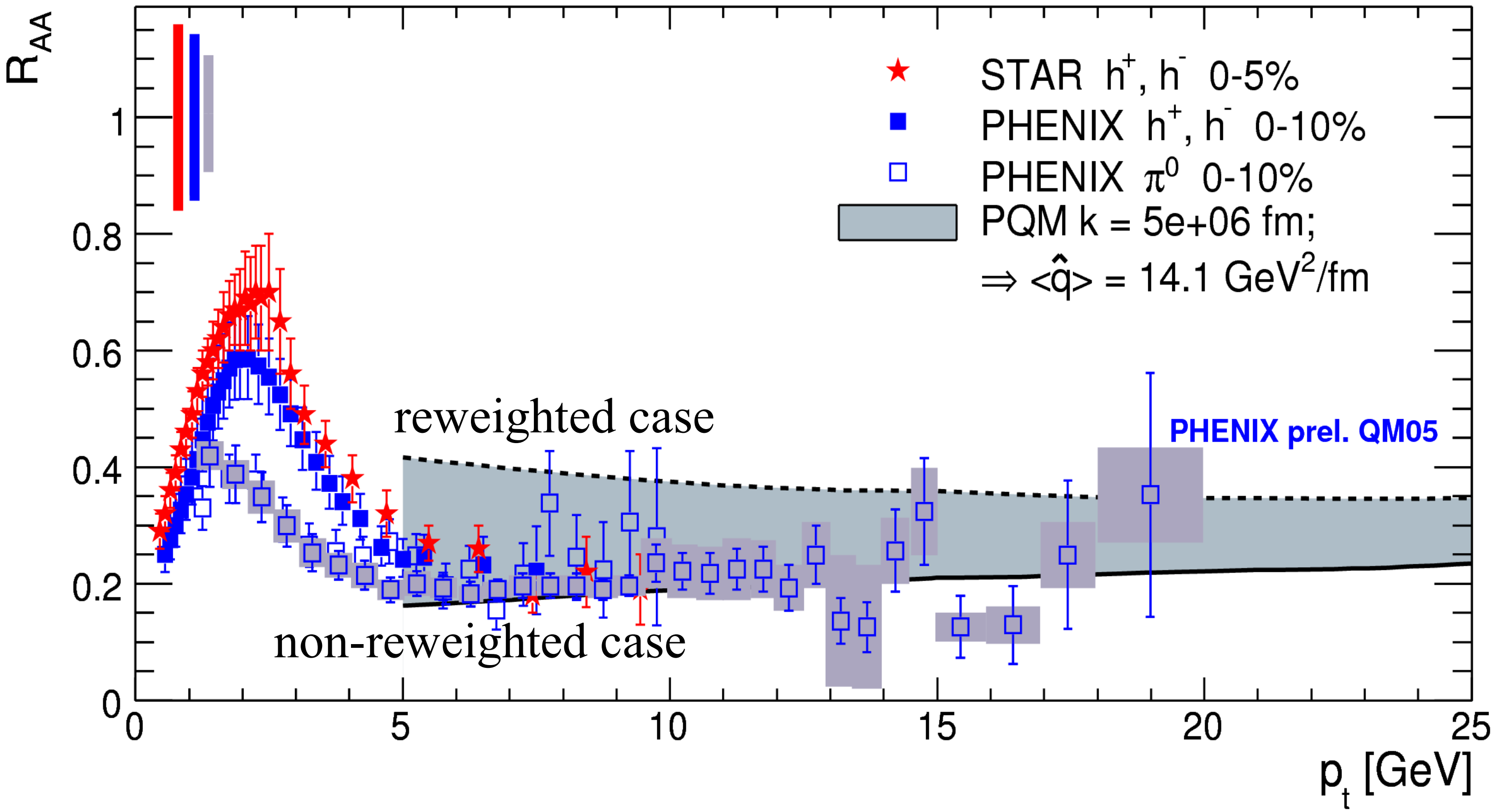
EQUIVALENT STATIC SCENARIO

α = 1.5, 1.0, 0.5, 0



Salgado, Wiedemann, PRL 89 (2002) 092303.

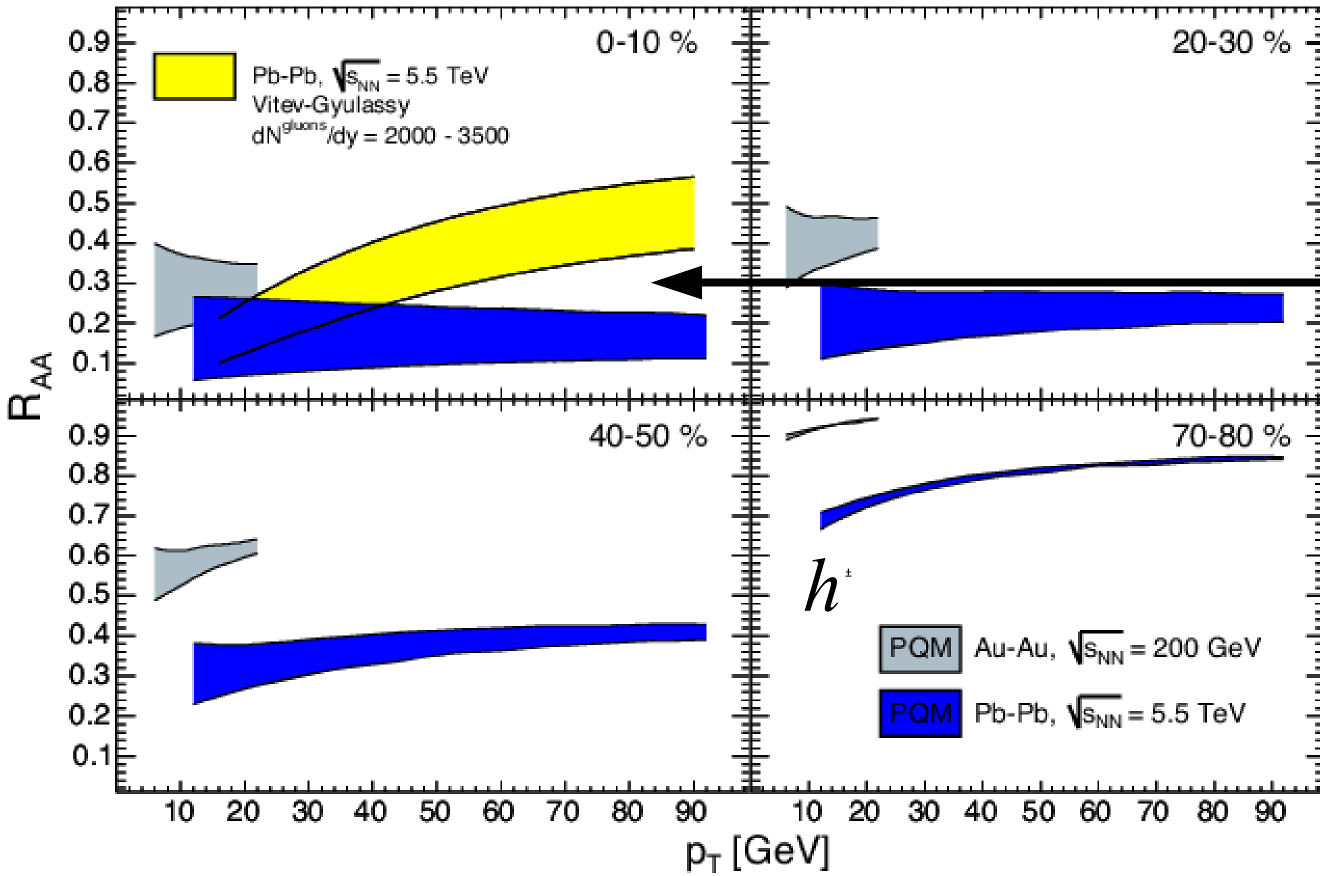
Results at RHIC



The scale of the energy loss is estimated with central Au+Au collisions at 200 GeV, which fixes the single, free parameter of the model.

Original PQM LHC prediction

$$\langle \hat{q}^{5500,\,\mathrm{PbPb}} \rangle \approx 25 - 100\,\mathrm{GeV}^2/\mathrm{fm}$$



Interesting(?) difference in predictions.

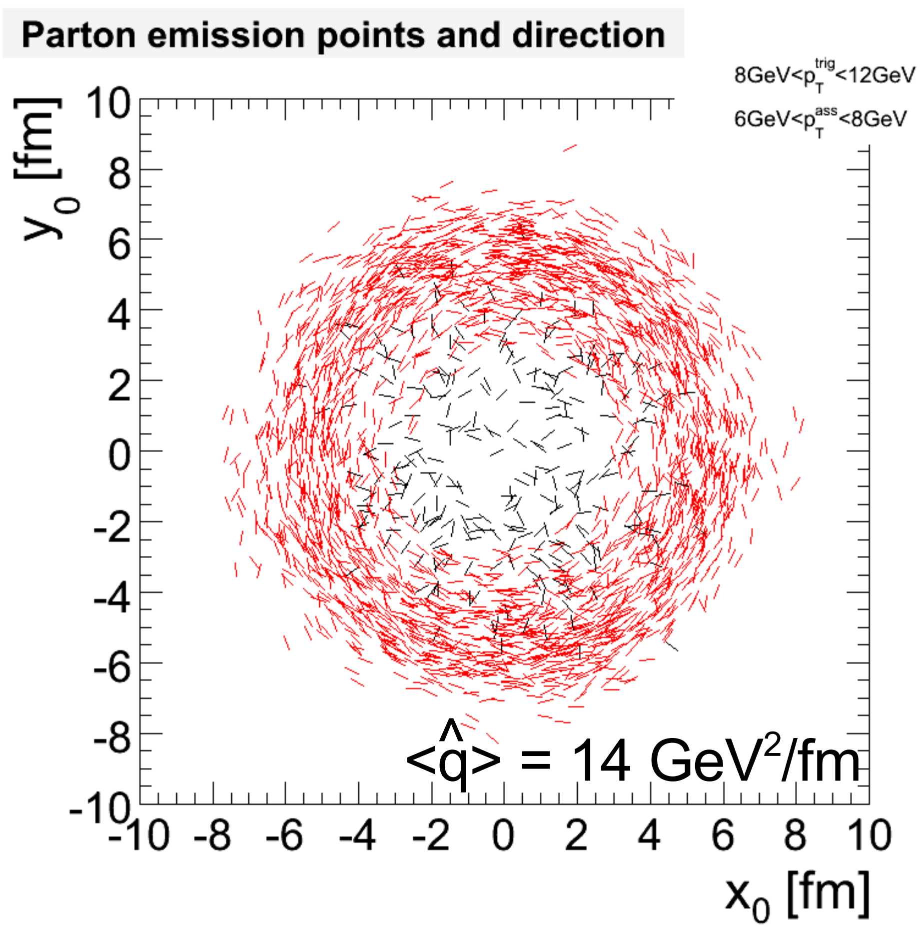
Similar results:
Eskola et.al.
NPA 747 (2005) 511.

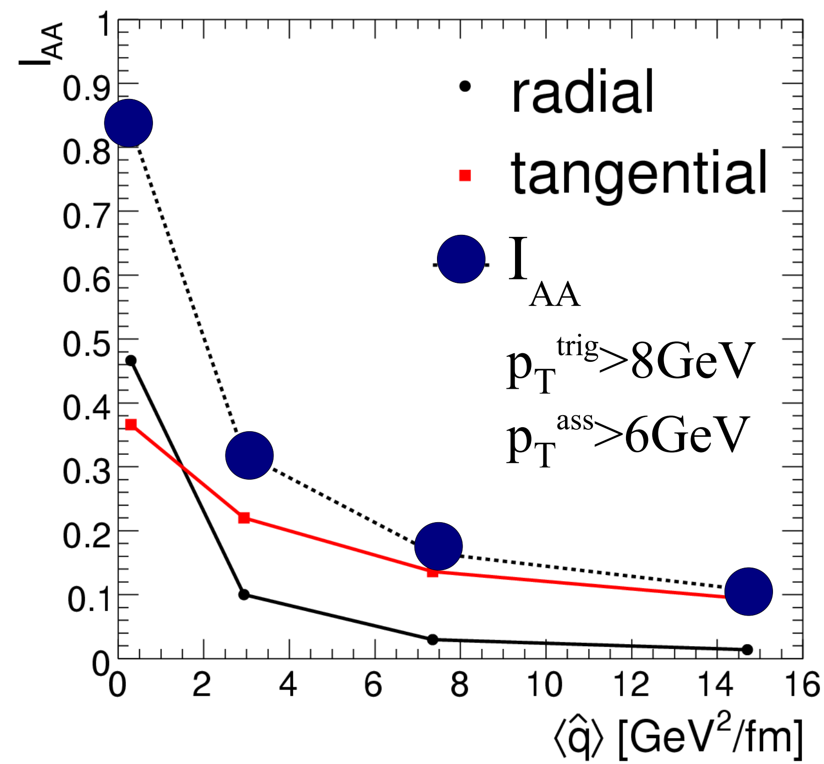
PQM predics also for large p_T a rather p_T-independent R_{AA}
(for central collisions)

Vitev and Gyulassy, PRL 89 (2002) 252301.
Dainese, Loizides, Paic, EPJC38 (2005), 461.

PQM: Tangential di-jet emission?

EQUIVALENT STATIC SCENARIO





Radial (black) lines: one jet of the dijet crosses inner core of R=3 fm.
Tangential (red) lines: none of the jets crosses inner core.

➡ **Large medium density biases dijets towards edges of surface ("tangential emission")**

Müller, PRC67 (2003) 061901.
Dainese, Loizides, Paic, QM 2005 Poster.

Change to larger α_S