

High- p_T phenomena in partonic transport simulations

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Z. Xu, C. Greiner

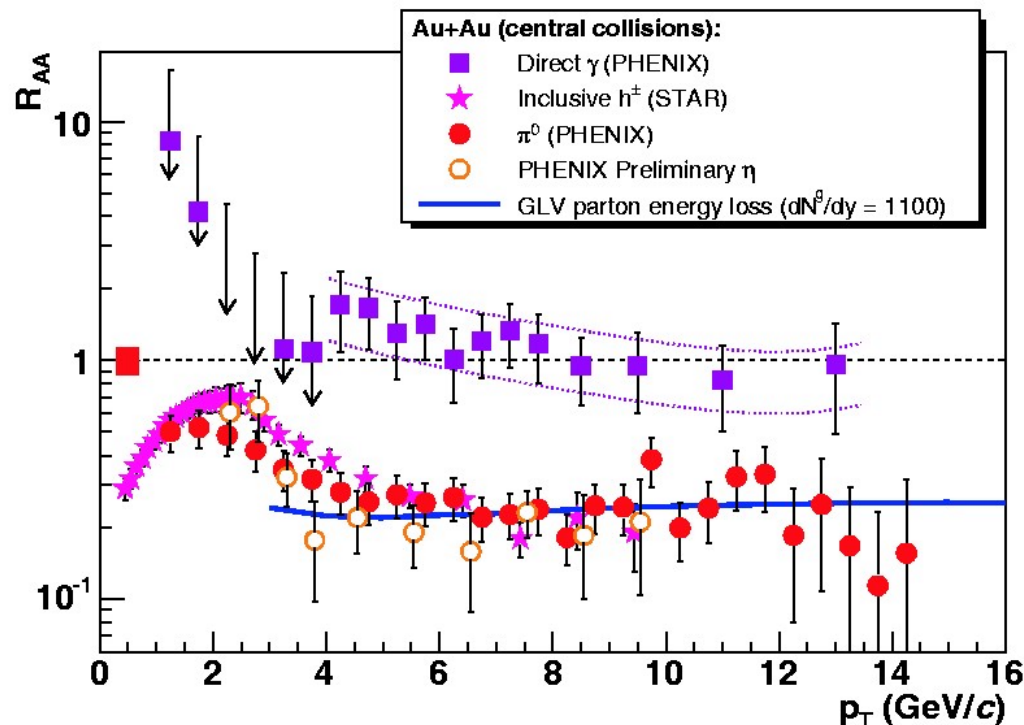
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What is it all about?

- investigating the properties of a new state of matter, the QGP
 - finding and to understanding suitable observables

high energy particles considered to be promising probes of the medium created in AA-collisions



- nuclear modification factor

$$R_{AA} = \frac{d^2 N_{AA}/dp_T dy}{T_{AA} d^2 \sigma_{NN}/dp_T dy}$$

relative to pp (binary collision scaling)

$$T_{AA} = \frac{\langle N_{coll} \rangle}{\sigma_{NN}}$$

- experiments show approx. factor 5 of suppression in hadron yields

What is our approach?

- microscopic transport simulations with **full** dynamics
 - attack various problems within **one** model(thermalization, R_{AA} , **jet tomography**, v_2 , initial conditions,...)

→ investigation of jet quenching within our stochastic parton cascade model (Z. Xu, C. Greiner, Phys. Rev. C71)

today's focus

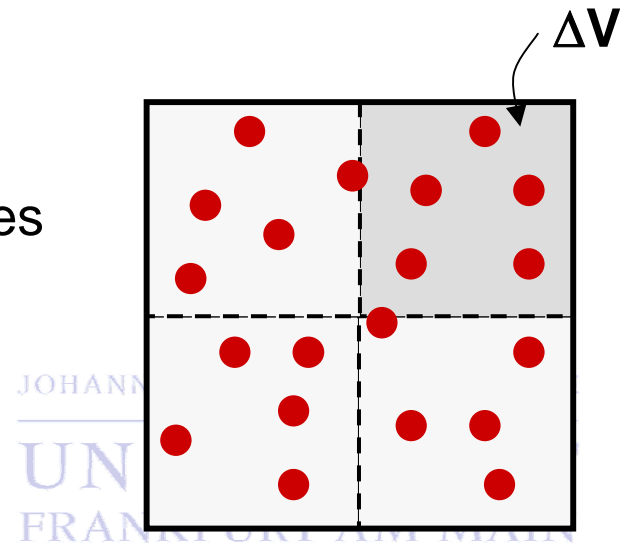
How does it work?

- LO pQCD cross sections
- calculate transition probabilities for (test)particles within spatial cells
 - no geometric interpretation of cross sections
- simulate gluon plasma including the processes

$gg \leftrightarrow gg$

$gg \leftrightarrow ggg$

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Some more details

- transition probabilities

$I_{32} \equiv$ matrix element integrated over momentum space

$$P_{22} = v_{\text{rel}} \frac{\sigma_{22}}{N_{\text{test}}} \frac{\Delta t}{\Delta V} \quad P_{23} = v_{\text{rel}} \frac{\sigma_{23}}{N_{\text{test}}} \frac{\Delta t}{\Delta V} \quad P_{32} = \frac{1}{8E_1 E_2 E_3} \frac{I_{32}}{N_{\text{test}}^2} \frac{\Delta t}{\Delta V}$$

- $gg \rightarrow gg$ cross section (in small- t (small angle) approximation)

$$\frac{d\sigma_{gg \rightarrow gg}}{dt} \approx \frac{9\pi\alpha_s^2}{(q_{\perp}^2 + m_D^2)^2}$$

- $gg \rightarrow ggg$

Gunion-Bertsch

$$|M_{gg \rightarrow ggg}|^2 = \left(72\pi^2 \alpha_s^2 \frac{s^2}{(q_{\perp}^2 + m_D^2)^2} \right) \left(48\pi\alpha_s \frac{q_{\perp}^2}{k_{\perp}^2 [(k_{\perp} - q_{\perp})^2 + m_D^2]} \right)$$

- Debye screening

$$m_D^2 = 16\pi\alpha_s \int \frac{d^3p}{(2\pi)^3} \frac{1}{p} (N_c f_g + N_f f_q)$$

thermal case:

$$m_D^2 = (3 + N_f) \frac{8}{\pi} \alpha_s T^2$$

Why is that difficult?

- obtain total cross section for $gg \rightarrow ggg$ via integration of the matrix element

$$\sigma_{gg \rightarrow ggg} \sim \int_0^{s/4} dq_{\perp}^2 \int_{1/\Lambda_g^2}^{s/4} dk_{\perp}^2 \int_{-y_m}^{y_m} dy \int_0^{\pi} d\phi \dots$$

energy conservation

LPM cutoff

LPM-effect (Landau-Pomeranchuk-Migdal)

- incoherent treatment of $gg \rightarrow ggg$ processes
 - parent gluon must not scatter during formation time of emitted gluon

$$\lambda_g'' > \tau''(k_{\perp}) \quad \text{with} \quad \tau''(k_{\perp}) = \frac{1}{k_{\perp}}$$

λ_g : MFP in lab frame
 $\lambda_g'' = \lambda_g / \gamma$

→ $\Theta(k_{\perp} - \frac{1}{\lambda_g}) \Theta(B - (\cosh y + A \sinh y))$

$$A = \beta' \cos \theta$$

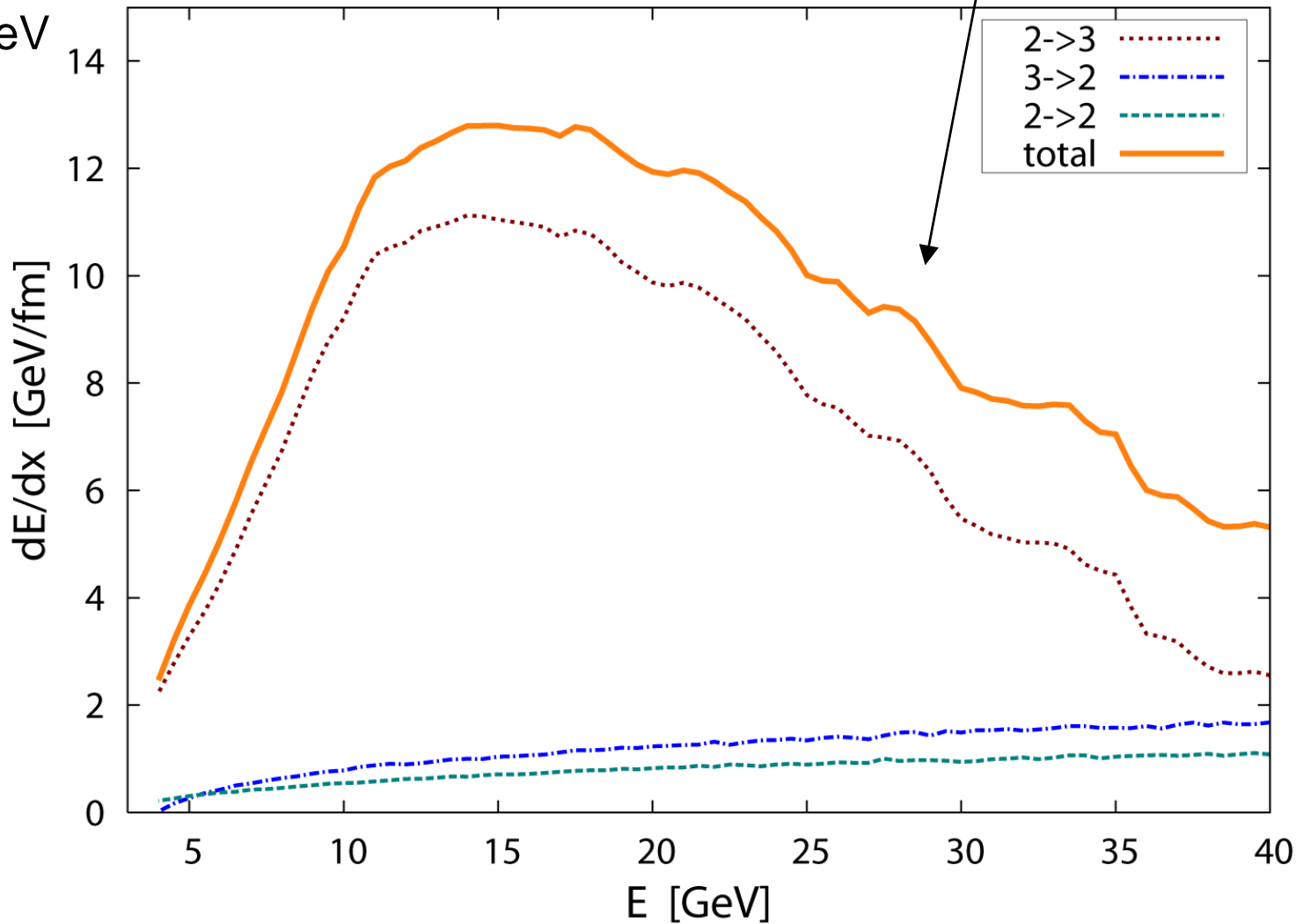
discard all possible interference effects (Bethe-Heitler regime)

$$B = k_{\perp} \lambda_g \sqrt{1 - \beta'^2}$$

Energy loss in a static medium

- gluon jet in a static, thermal medium of gluons
- $T = 400$ MeV

LPM cutoff increases due to boost



dominant process is 2->3

preliminary

Au+Au – Setup

- central ($b=0$ fm) Au-Au collision at 200 AGeV
- sampling of initial **gluon plasma**:
 - initial momentum distribution (mini-jets) according to

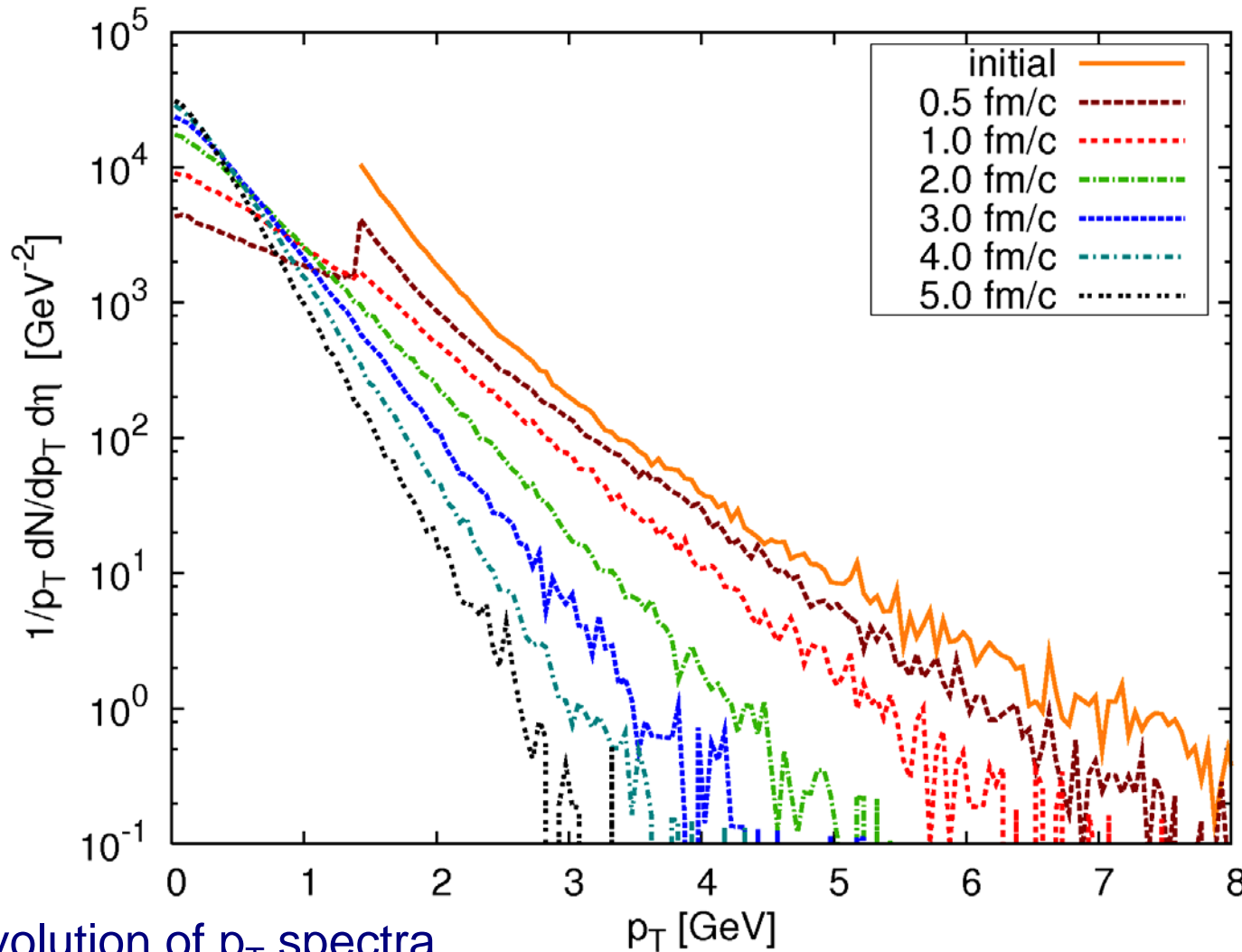
$$\frac{d\sigma_{jet}}{dp_T^2 dy_1 dy_2} = K \sum_{a,b} x_1 f_a(x_1, p_T^2) x_2 f_b(x_2, p_T^2) \frac{d\sigma_{ab}}{d\hat{t}}$$

- Glück-Reya-Vogt parameterization for structure functions; $K = 2$
- lower cut-off: $p_0 = 1.4$ GeV (reproduces dE_T/dy)
- particle production via standard nuclear geometry (Wood-Saxon density profile, Glauber-Model)

$$N = 2T_{ab}\sigma_{jet}$$

- each parton is given a formation time $\Delta t_f = \cosh(y)/p_T$
- 35 testparticles
- simulate evolution of fireball up to ~ 5 fm/c
- when energy density in a cell drops below $\varepsilon = 1$ GeV
 - free streaming (in the respective cell)

Au-Au – Thermalization



time evolution of p_T spectra

(central region, $x_T < 1.5$ fm, $|\eta| < 0.5$)

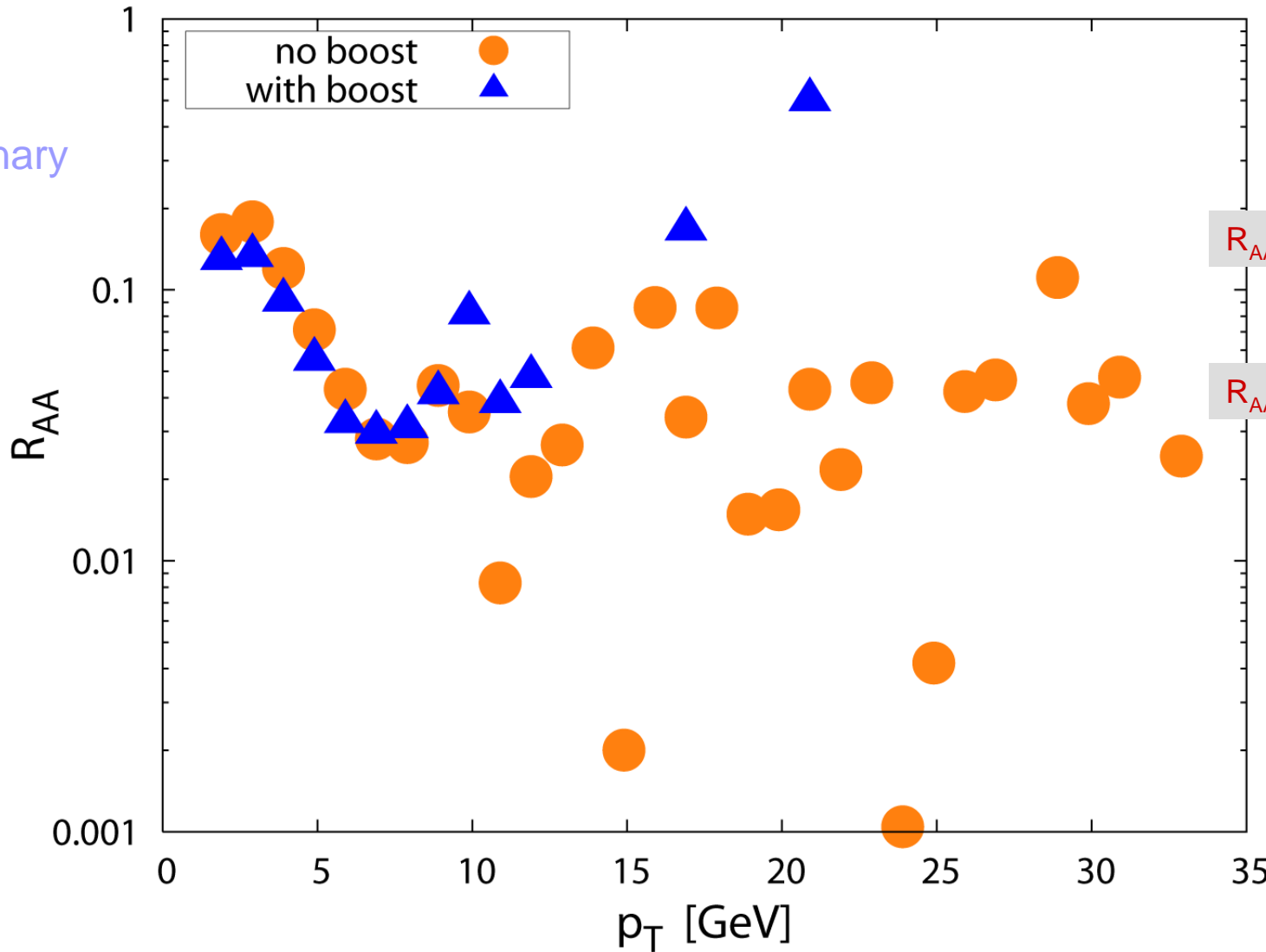
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Au-Au – Nuclear modification factor

preliminary



Summary and to-do list

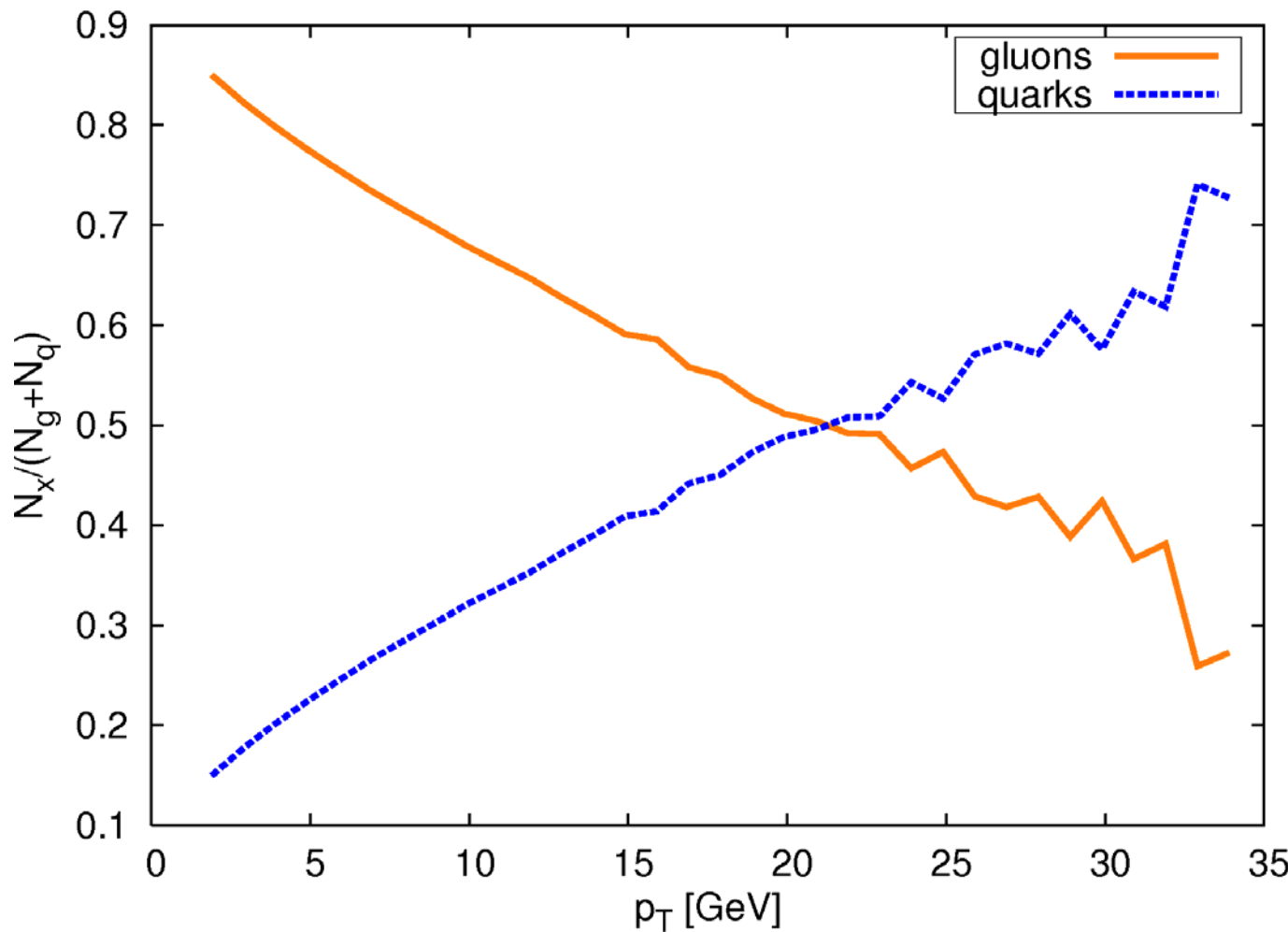
- possibility to examine v_2 and R_{AA} (and various other observables) within one framework, consistently including inelastic processes
- rapid thermalization (on the order of 1-2 fm/c)
- non-perturbative transport simulations of jet events up to $p_T=35$ GeV
- R_{AA} (w/o boost) very low – full results w/ boost yet to come

- energy loss depends crucially on the modeling of the LPM effect
 - Abelian vs. non-Abelian LPM effect? How to incorporate?

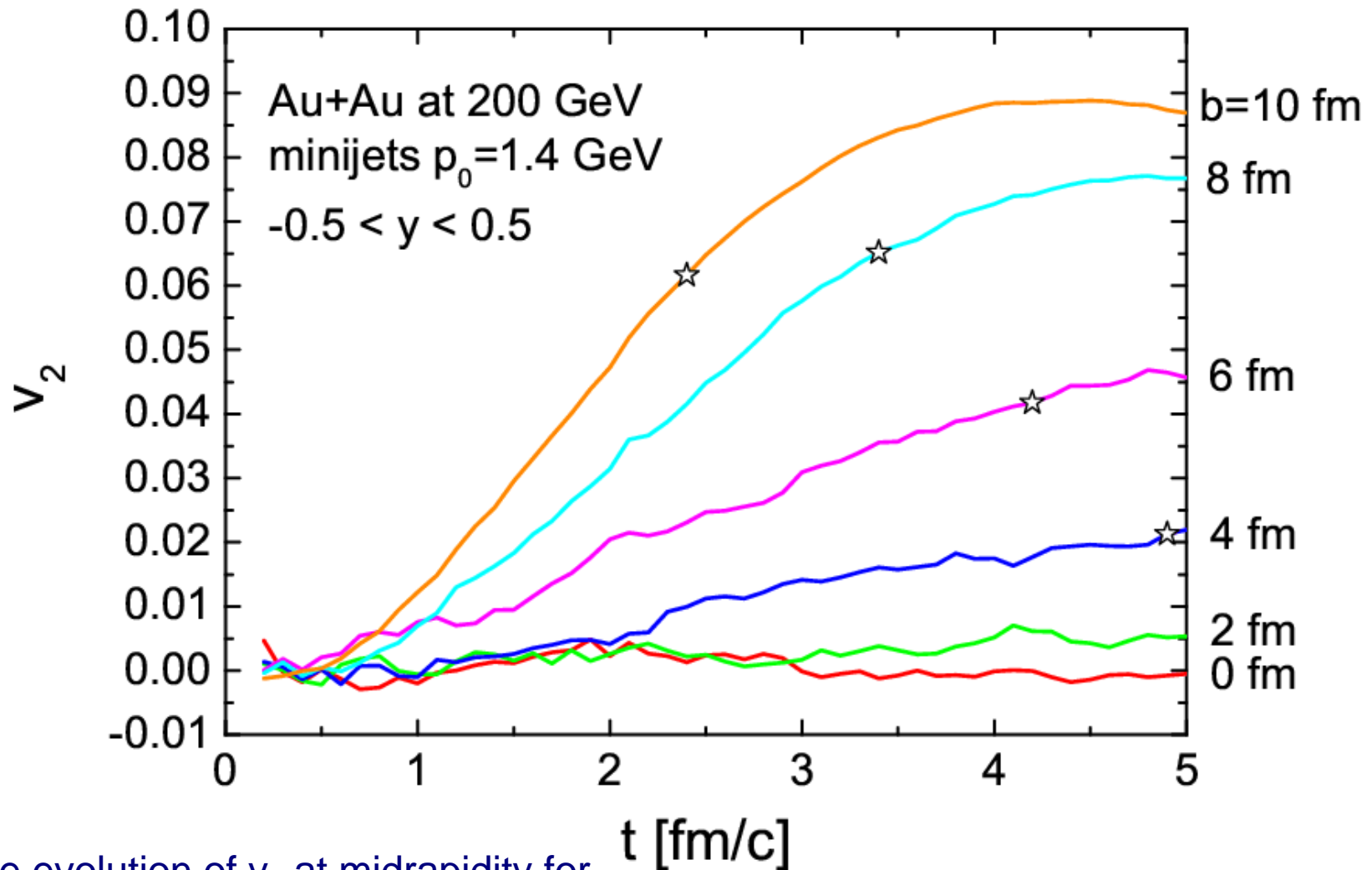
- no quarks included so far (smaller energy loss \rightarrow higher R_{AA} ?)
 - \rightarrow include quark degrees of freedom and examine quark jets
- incorporate hadronization scheme
 - \rightarrow effects on shape of R_{AA} ?
- simulate LHC-energies

Backup slides

Gluon-Quark-Ratio



Elliptic flow



time evolution of v_2 at midrapidity for different impact parameters

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Experimental v_2 vs. centrality

