Jet conversions in QGP

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- Introduction
- Jet conversion widths in QGP
- Jet drag coefficients in QGP
- Nuclear modification factors for jets
- p/π^+ and $\bar{p}/\pi^-$ ratios
- Conclusions

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PRC 75, 051901 (07); nucl-th/0607047

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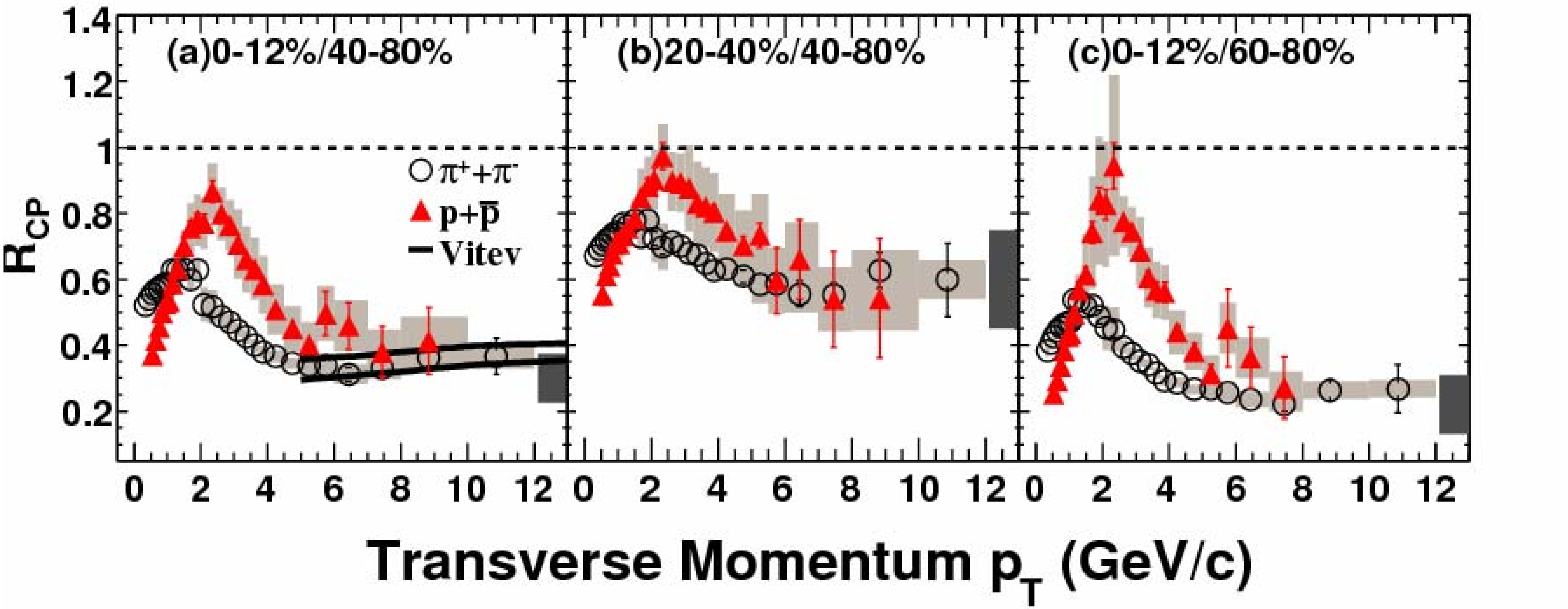
Identified baryon and meson distributions @ RHIC

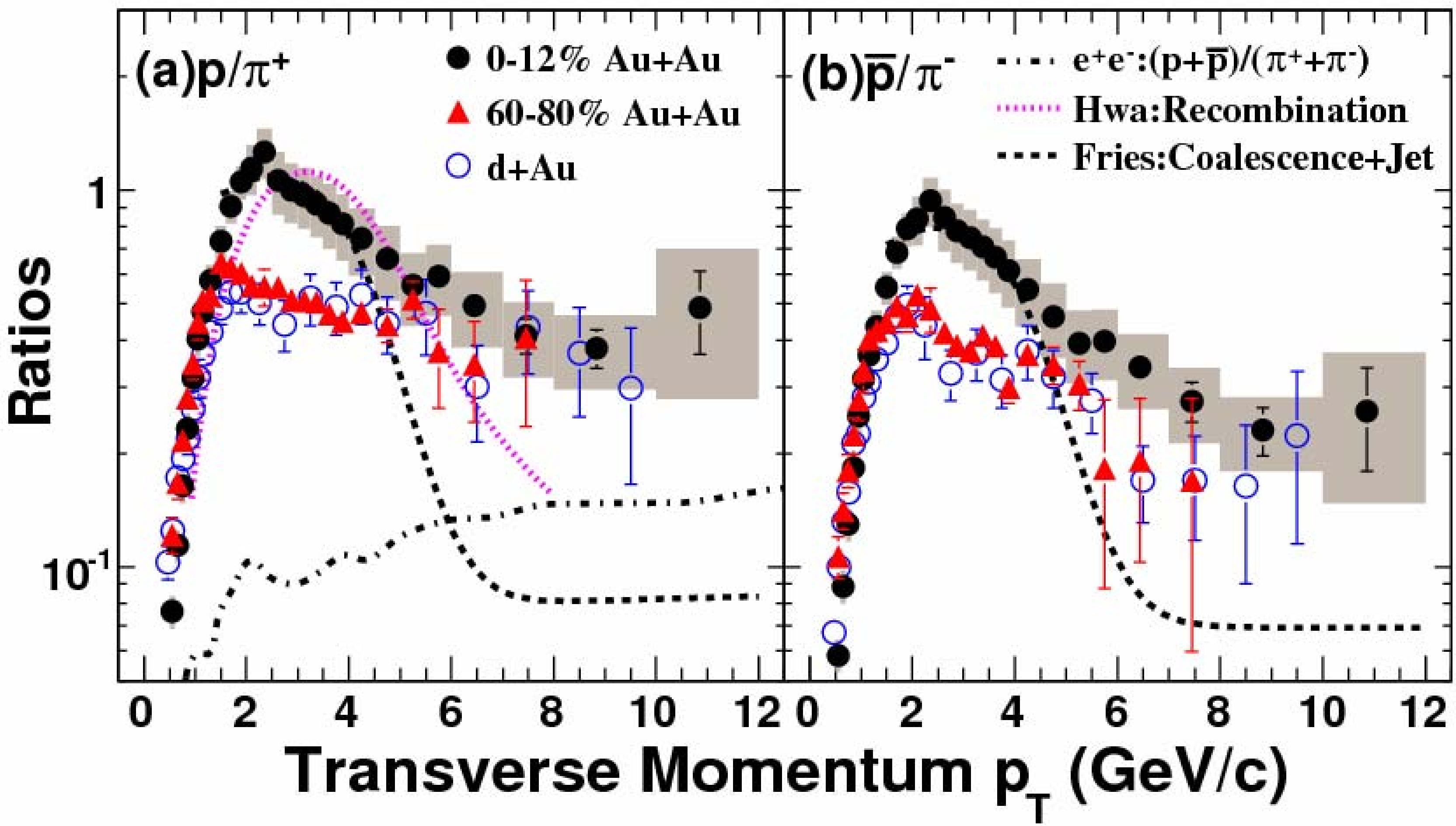
STAR Collaboration, PRL 97, 152301 (06) Au+Au @ 200 AGeV



Suppressions of protons/antiprotons and pions at high transverse momenta are similar.

p/π+ and pbar/π- ratios at high transverse momentum

STAR Collaboration, PRL 97, 152301 (07)

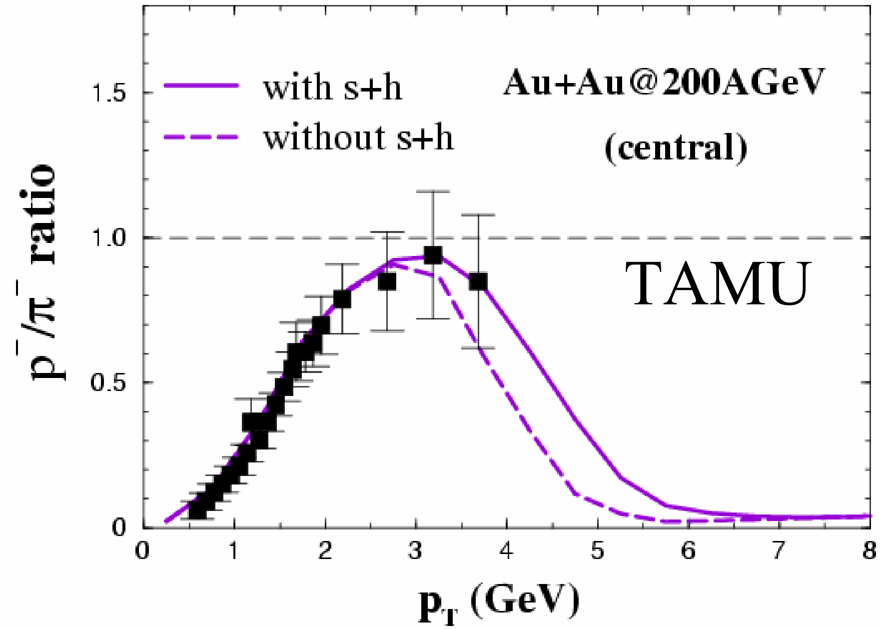


Same p/π^+ and $\overline{p}/\pi^-$ ratios in central and peripheral collisions → Same R_{AA} for gluon and quark jets, which is not expected from radiative energy loss as gluon jets lose more energy than quark jets.

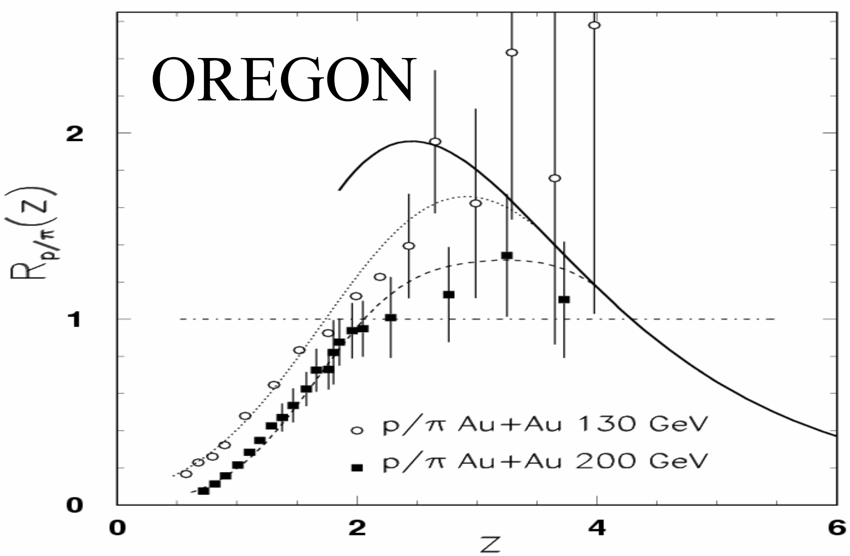
Quark coalescence model

Quark coalescence or recombination can explain observed large p/pi ratio at intermediate transverse momenta in central Au+Au collisions.

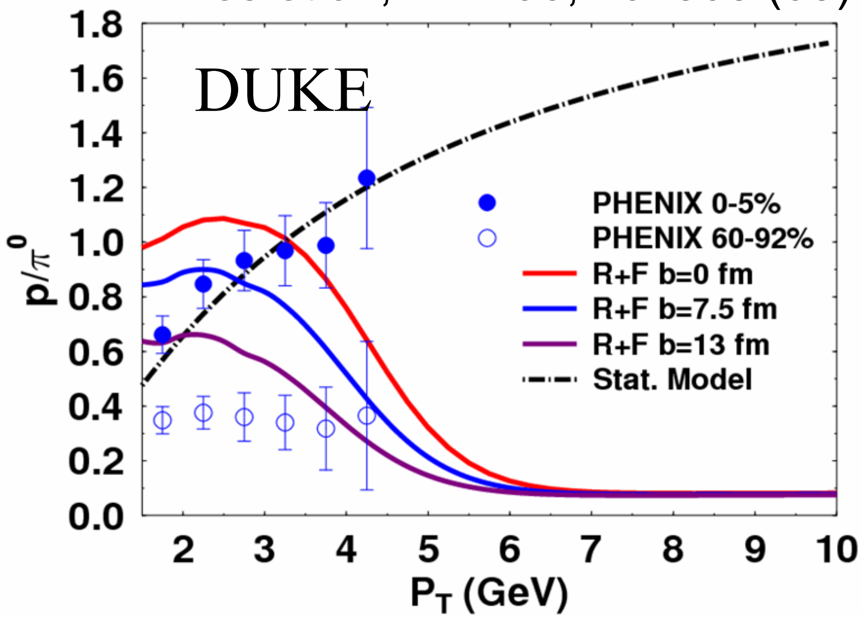
Greco, Levai & Ko, PRL 90, 202302 (03)



Hwa & Yang, PRC 67, 034902 (03)



Fries et al., PRL 90, 202303 (03)

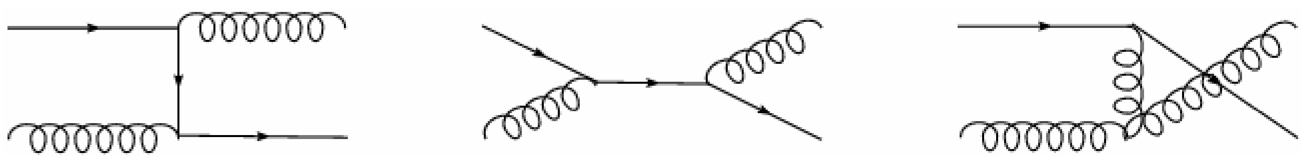


Jet conversions in QGP: 2→2

W Liu, B.W Zhang & C.M. Ko,
PRC 75, 051901 (07); nucl-th/0607047

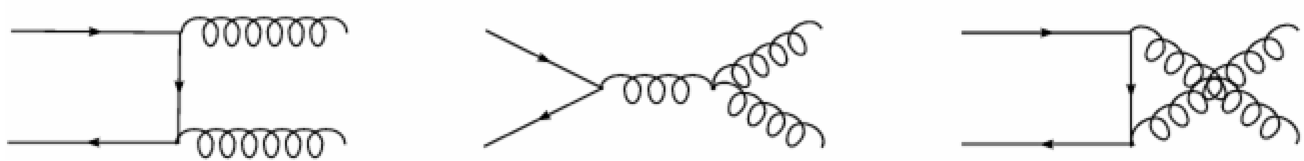
- Quark jet conversion

Elastic process: qg→gq



Gluon is taken to have a larger momentum in the final state

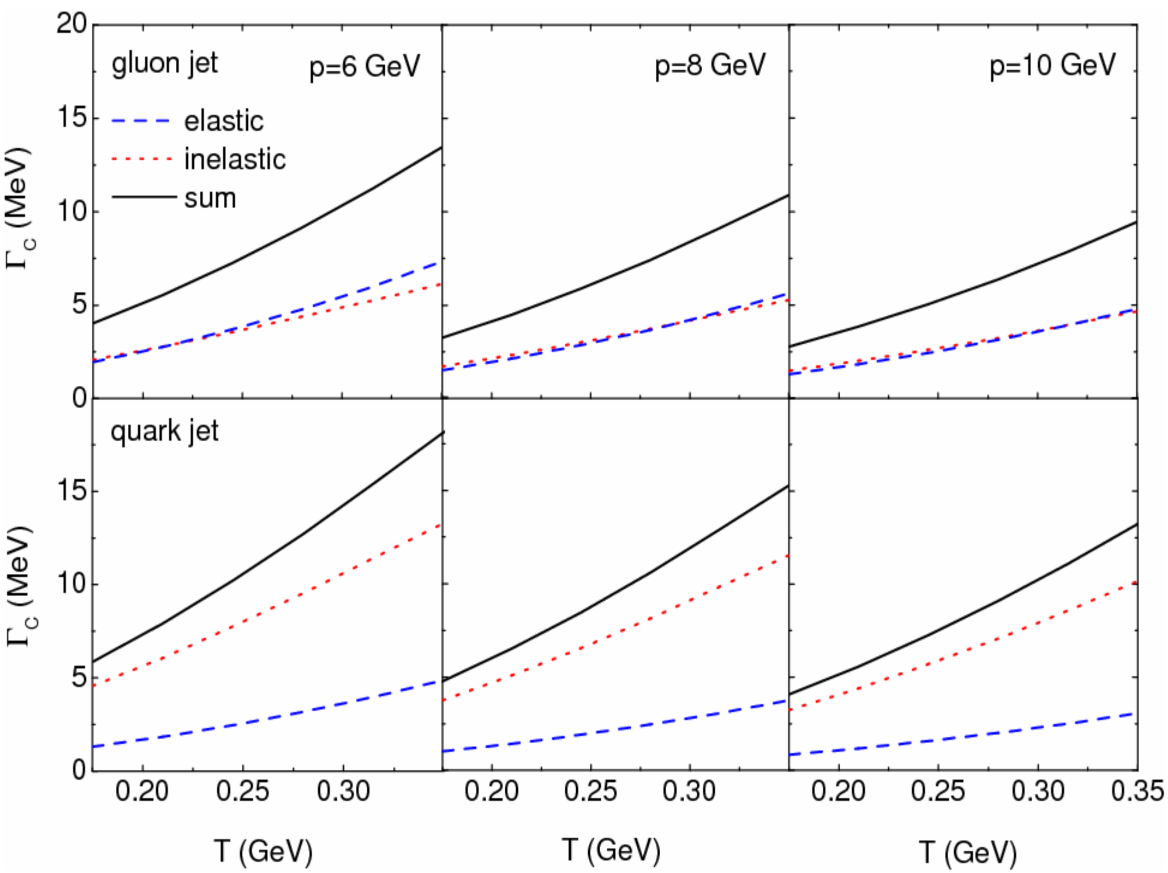
Inelastic process: $q\bar{q} \rightarrow gg$



- Gluon jet conversion: similar to above via inverse reactions

Jet conversion width in QGP: 2→2

$$\Gamma_c = \hbar\left\langle \overline{\left|M_{12\to34}\right|^2} \right\rangle = \frac{\hbar}{2E_1}\int\frac{g_2 d^3\vec{p}_2}{(2\pi)^3 2E_2}\int\frac{d^3\vec{p}_3}{(2\pi)^3 2E_3}\int\frac{d^3\vec{p}_4}{(2\pi)^3 2E_4}$$
$$\times f(\vec{p}_2)(1\pm f(\vec{p}_3))(1\pm f(\vec{p}_4))\overline{\left|M_{12\to34}\right|^2}(2\pi)^4\delta^{(4)}(p_1+p_2-p_3-p_4)$$



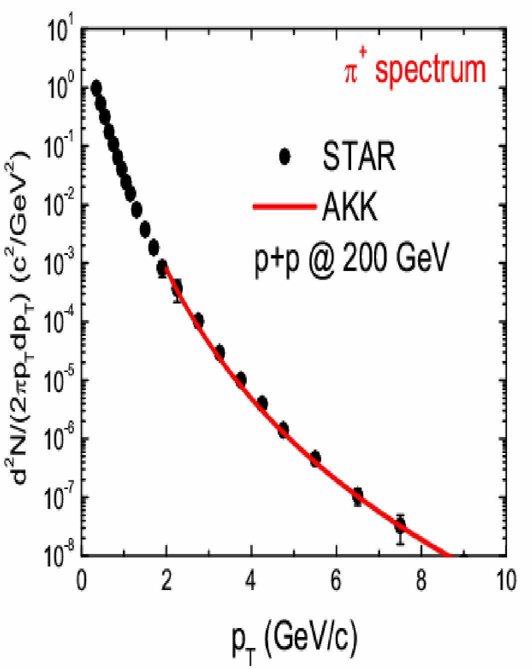
- $\alpha_s = g^2/4\pi = 0.3$
- Screening mass $m_D = gT$
- Thermal masses $m_g = 3^{1/2} m_q = m_D/2^{1/2}$

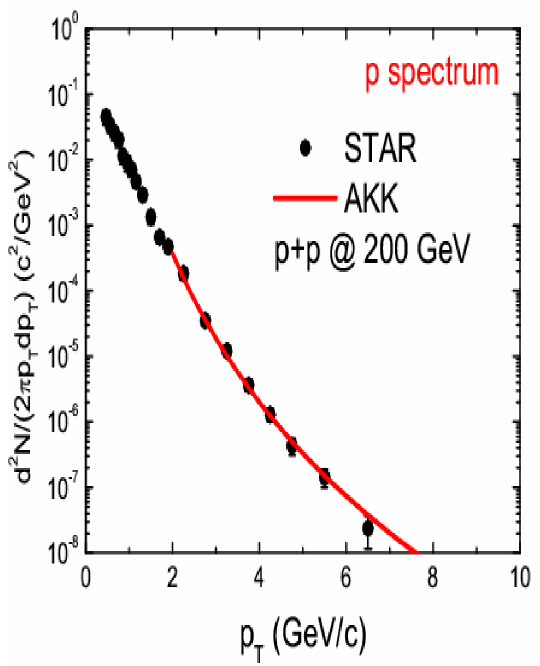
- $\Gamma_c(q\to g) > \Gamma_c(g\to q)$
- $\Gamma_c(q\to g)$: inelastic conversion is more important than elastic conversion
- $\Gamma_c(g\to q)$: elastic and inelastic conversions are comparable

Initial gluon and quark jet spectra

- Taking from PYTHIA for p+p collisions @ $s^{1/2}$=200 GeV and multiplying by the number of binary collisions (~ 960) in central Au+Au collisions
- Using AKK fragmentation function (NPB 725, 181 (2005)) gives a good description of proton and pion spectra in p+p collisions.

$$\frac{dN}{d^2\vec{p}_{had}} = \sum_{jet}\int dz \frac{dN}{d^2\vec{p}_{jet}} \frac{D_{had/jet}(z,Q^2)}{z^2}, \quad z = \frac{p_{had}}{p_{jet}}$$





$$\frac{dN}{dp_T} \approx A\left(1+\frac{p_T}{B}\right)^{\alpha}$$

	$A[\mathrm{GeV}^{-2}]$	$B[\mathrm{GeV}]$	α
q	6720	1.4	-8.8
$\bar{q}$	960	1.6	-9.0
g	19200	1.3	-9.0

QGP fireball dynamics and jet energy loss and conversion

- Volume: $$V(\tau)=\pi\tau[R_0+\tfrac{a}{2}(\tau-\tau_0)^2]$$

$$R_0=7\ \text{fm},\ \tau_0=0.6\ \text{fm},\ a=0.1\ c^2/\text{fm}$$

$$T_i=350\ \text{MeV},\ T_c=175\ \text{MeV}\ @\ \tau_c=5\ \text{fm}$$

- Temperature: T(τ) from entropy conservation → final total transverse momentum similar to observed one

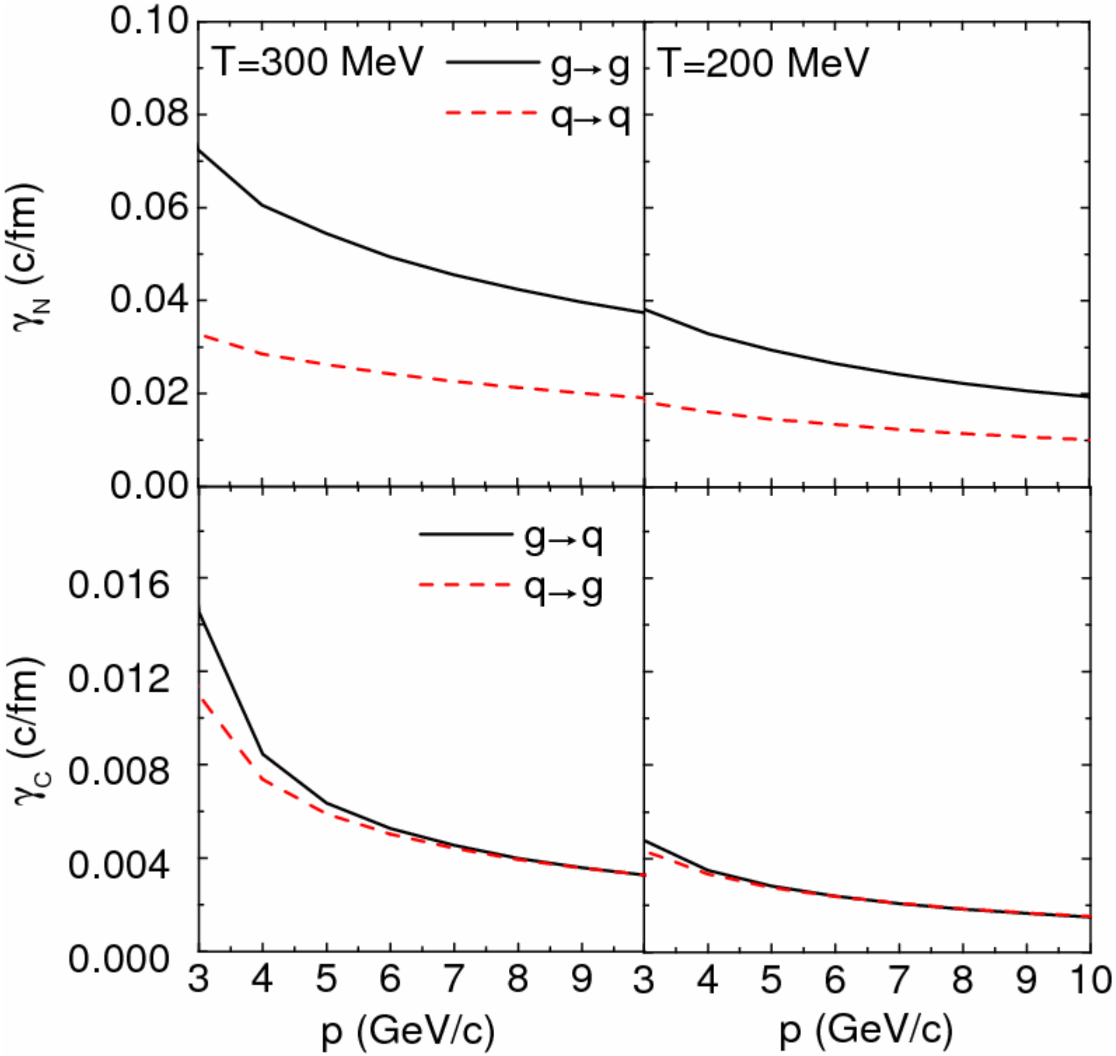
- Jet energy loss in QGP is described via the drag coefficient

$$\frac{d\langle p_T\rangle}{dt}=-\langle\gamma(p_T,T)p_T\rangle$$

$$\gamma(|p|)=\langle|M|^2\rangle-\frac{\langle|M|^2 p\cdot p'\rangle}{|p|^2}$$

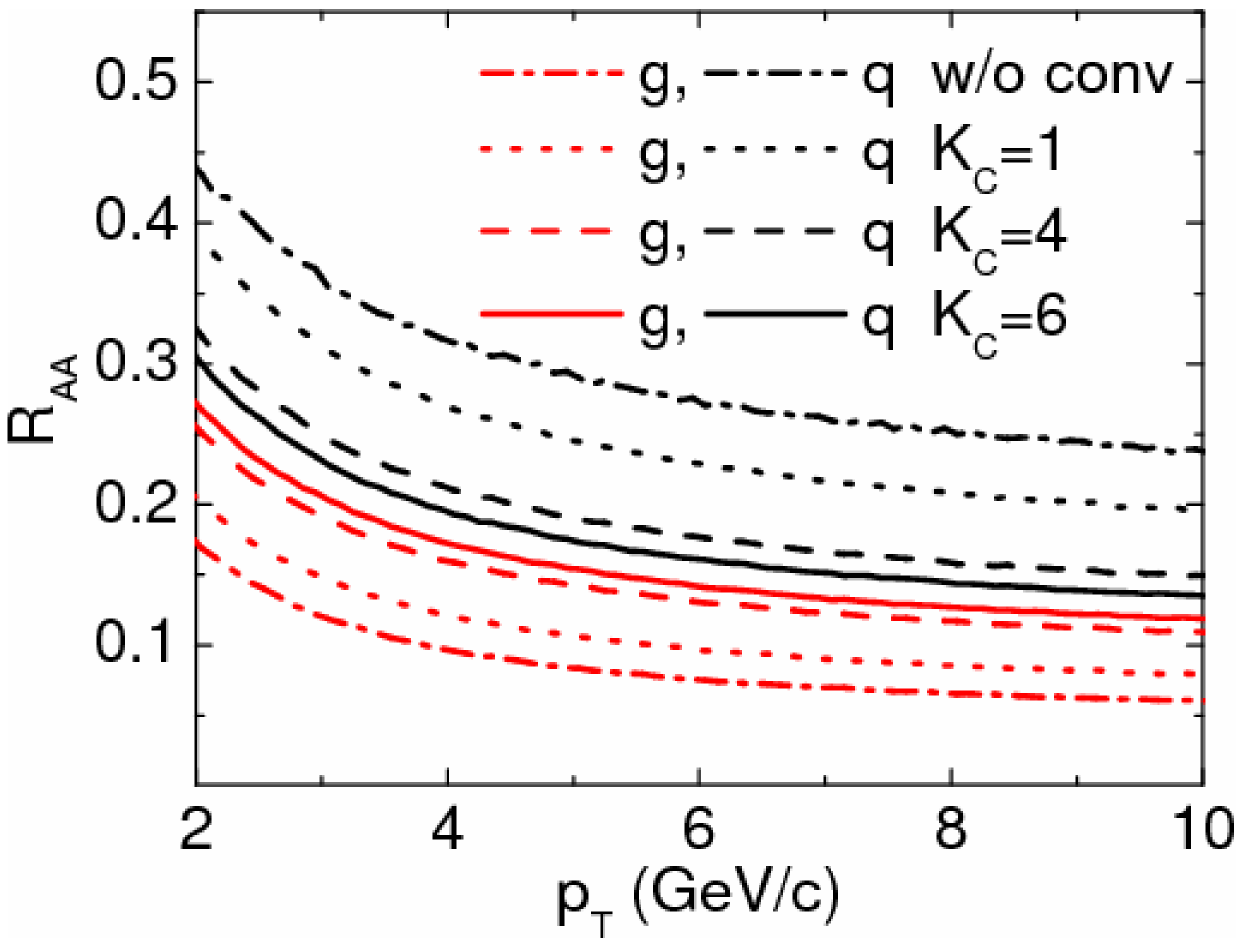
- Jet conversion in QGP with rates given by $\Gamma_c/\hbar$

Gluon and quark jet drag coefficients due to non-conversion and conversion 2→2 collisions



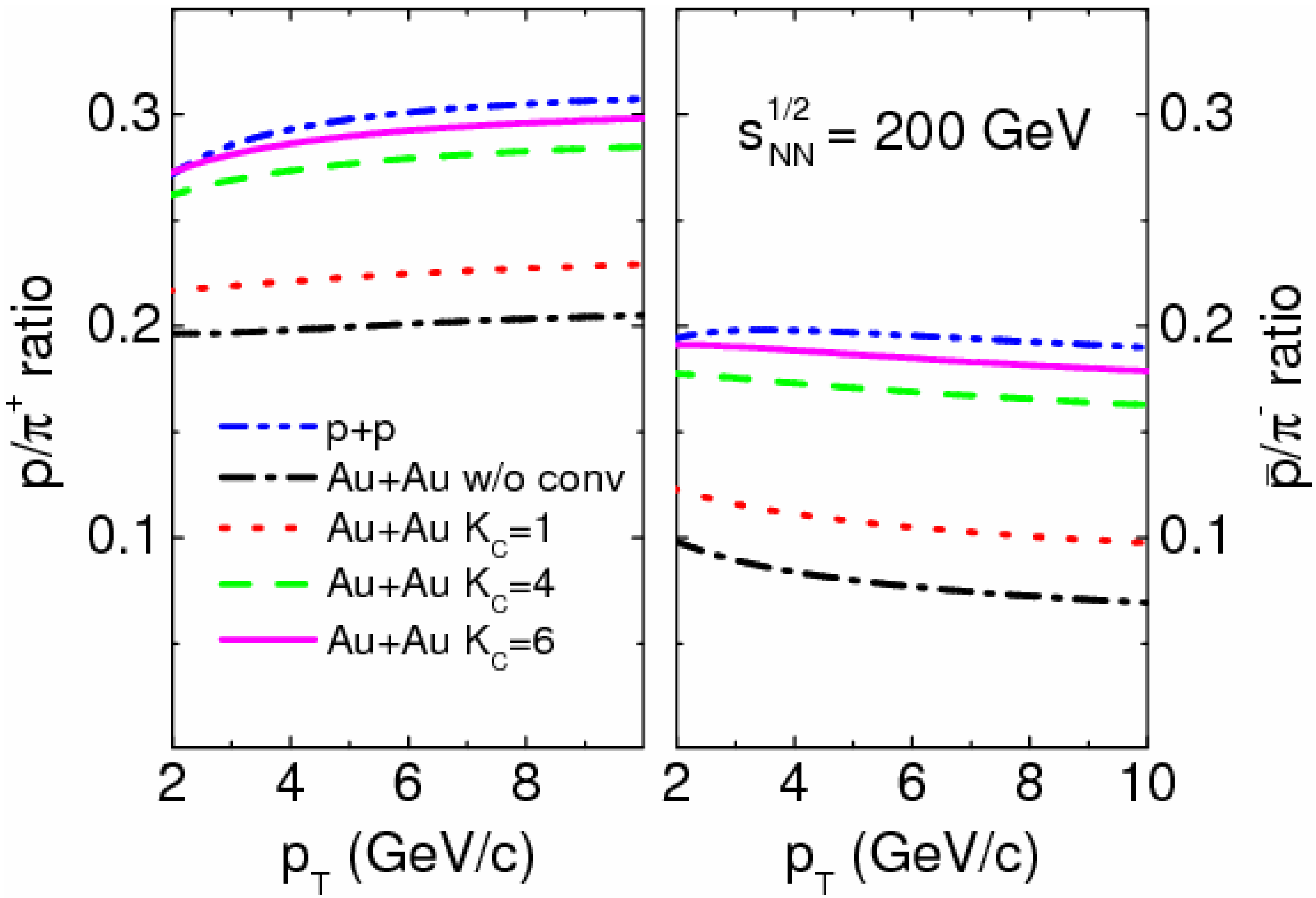
- Non-conversion drag coefficients γ_N are order of magnitude larger than conversion ones γ_c
- For non-conversion scatterings, gluon jet has a larger drag coefficient than a quark jet
- For conversion collisions, gluon and quark jets have similar drag coefficients
- Multiply γ_N by K_E=4 leads to jet energy loss comparable to observed one

Quark and gluon jet nuclear modification factors



Quark and gluon R_{AA} in central Au+Au collisions become similar if their conversion widths are multiplied by K_C~ 4-6.

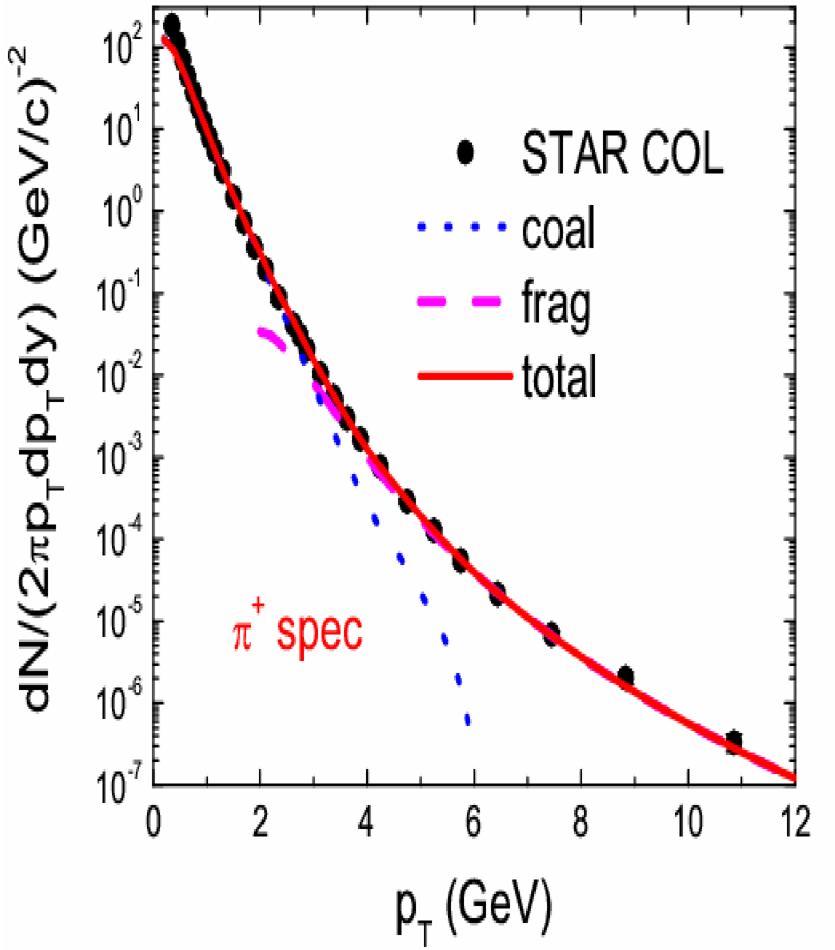
Proton to π^+ and antiproton to π^- ratios

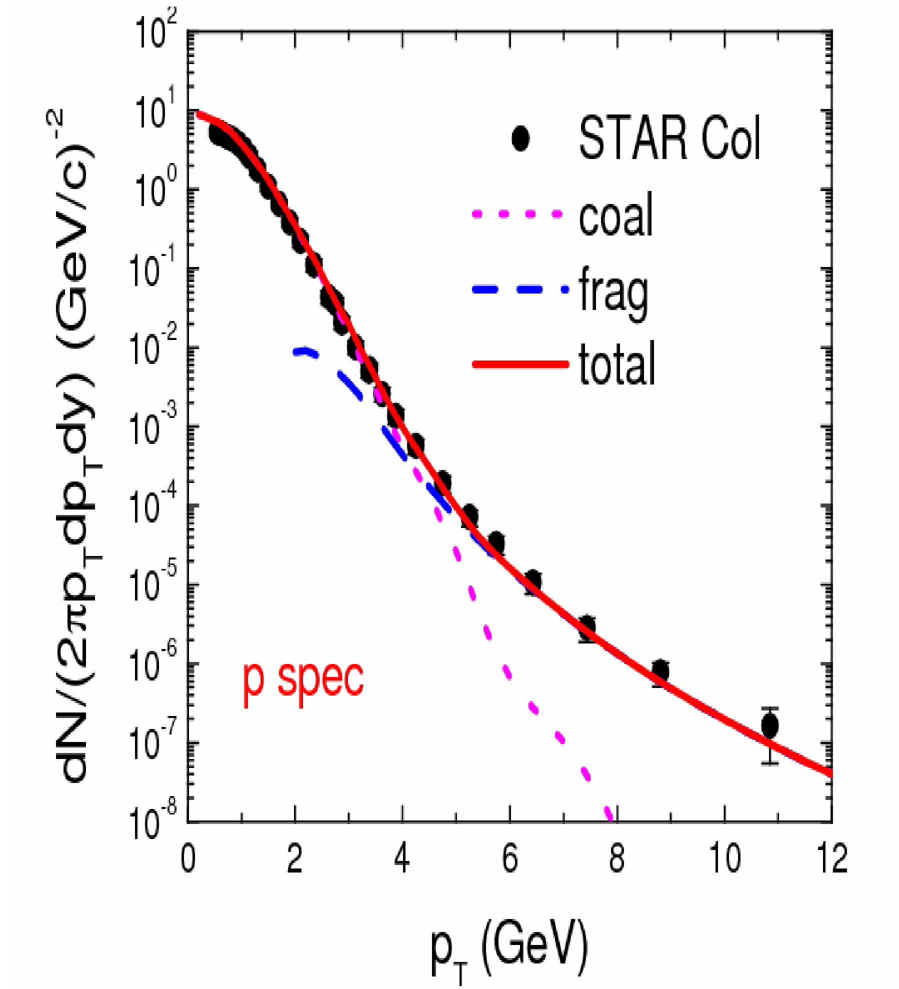


Ratios in central Au+Au collisions become similar to those in p+p collisions when quark and gluon conversion widths are multiplied by K_C~ 4-6.

Proton and pion transverse momentum specta

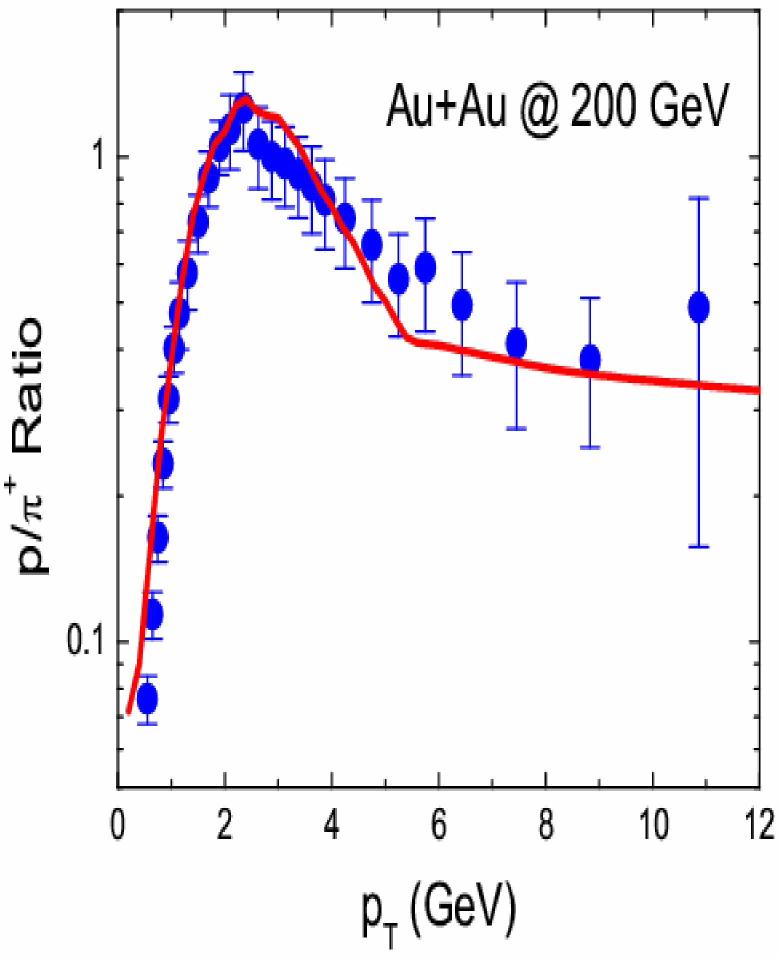
Central Au+Au collisions at $s^{1/2}$=200 GeV

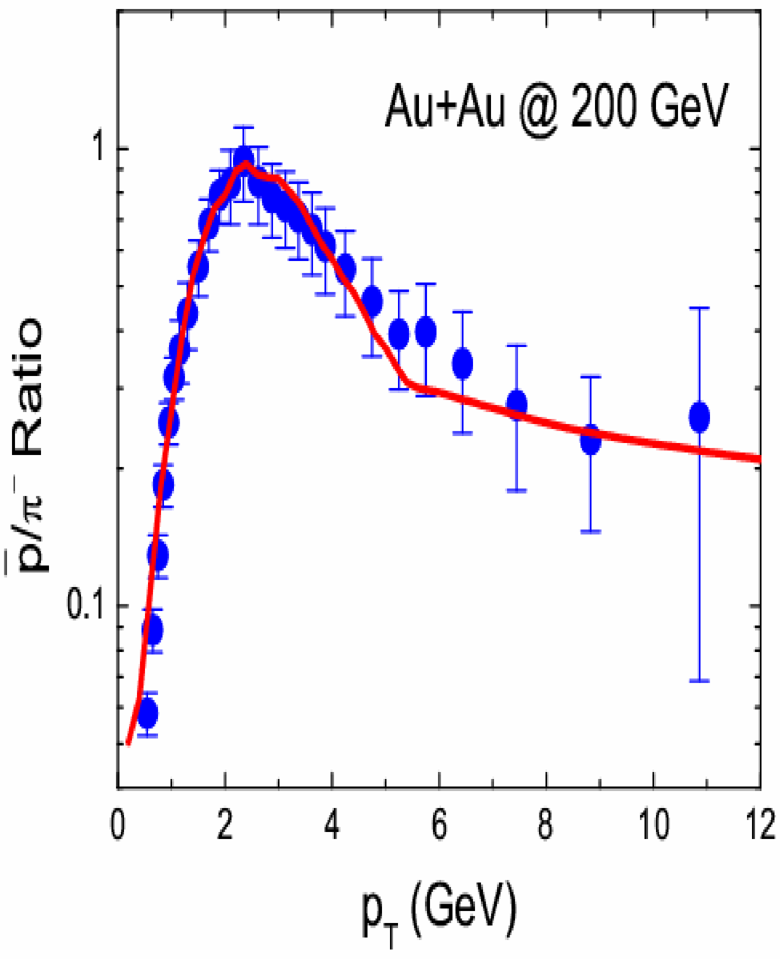




Calculations are based on leading-order multiplied with K_E=K_C=4

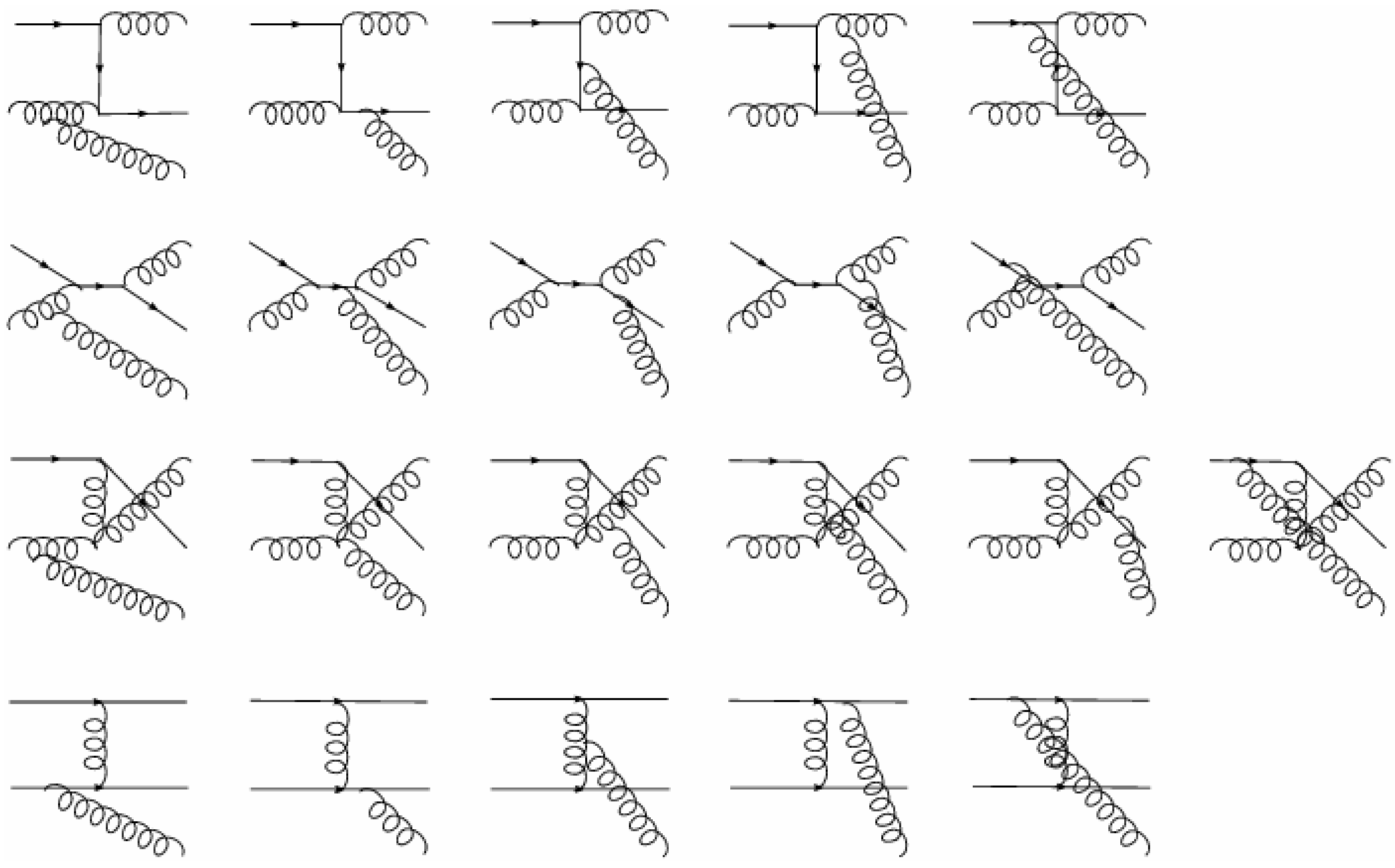
Proton to π^+ and antiproton to π^- ratios





Origin of K_C factor for jet conversion width

- Radiative conversion: 2→3



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QCD coupling and screening mass at finite temperature from lattice gauge calculations

O. Kazmarek et al., Phys. Rev. D 70, 074505 (2004); 71, 114510 (2005)

- QCD Coupling

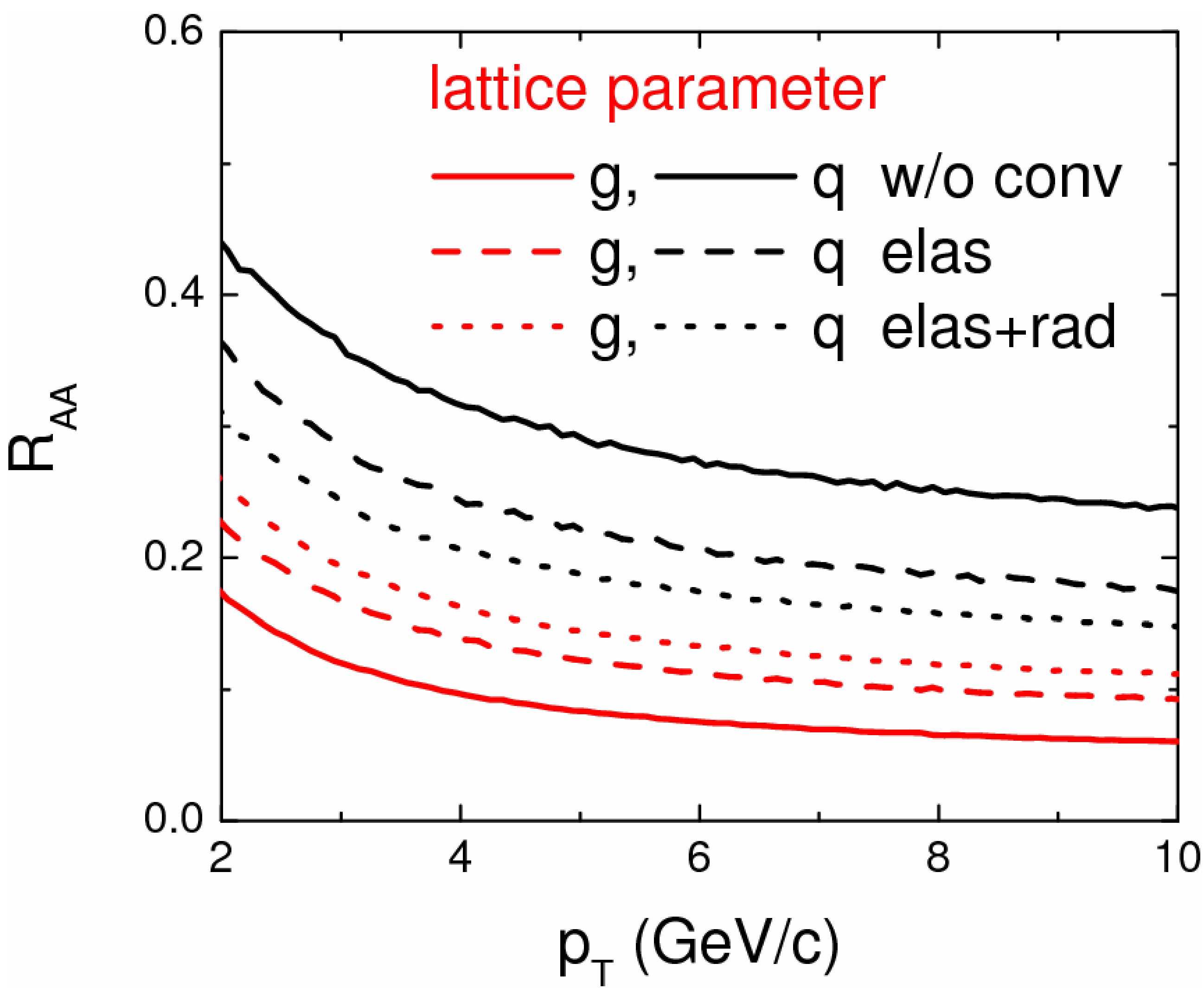
$$\alpha_S = \frac{g^2(T)}{4\pi} = 2.1\alpha_{per}$$

$$g^{-2}_{pert} = \frac{11}{8\pi^2}\ln\left(\frac{2\pi T}{\Lambda_{\overline{MS}}}\right) + \frac{51}{88\pi^2}\ln\left(2\ln\left(\frac{2\pi T}{\Lambda_{\overline{MS}}}\right)\right); \quad \frac{T_c}{\Lambda_{\overline{MS}}} = 1.14$$

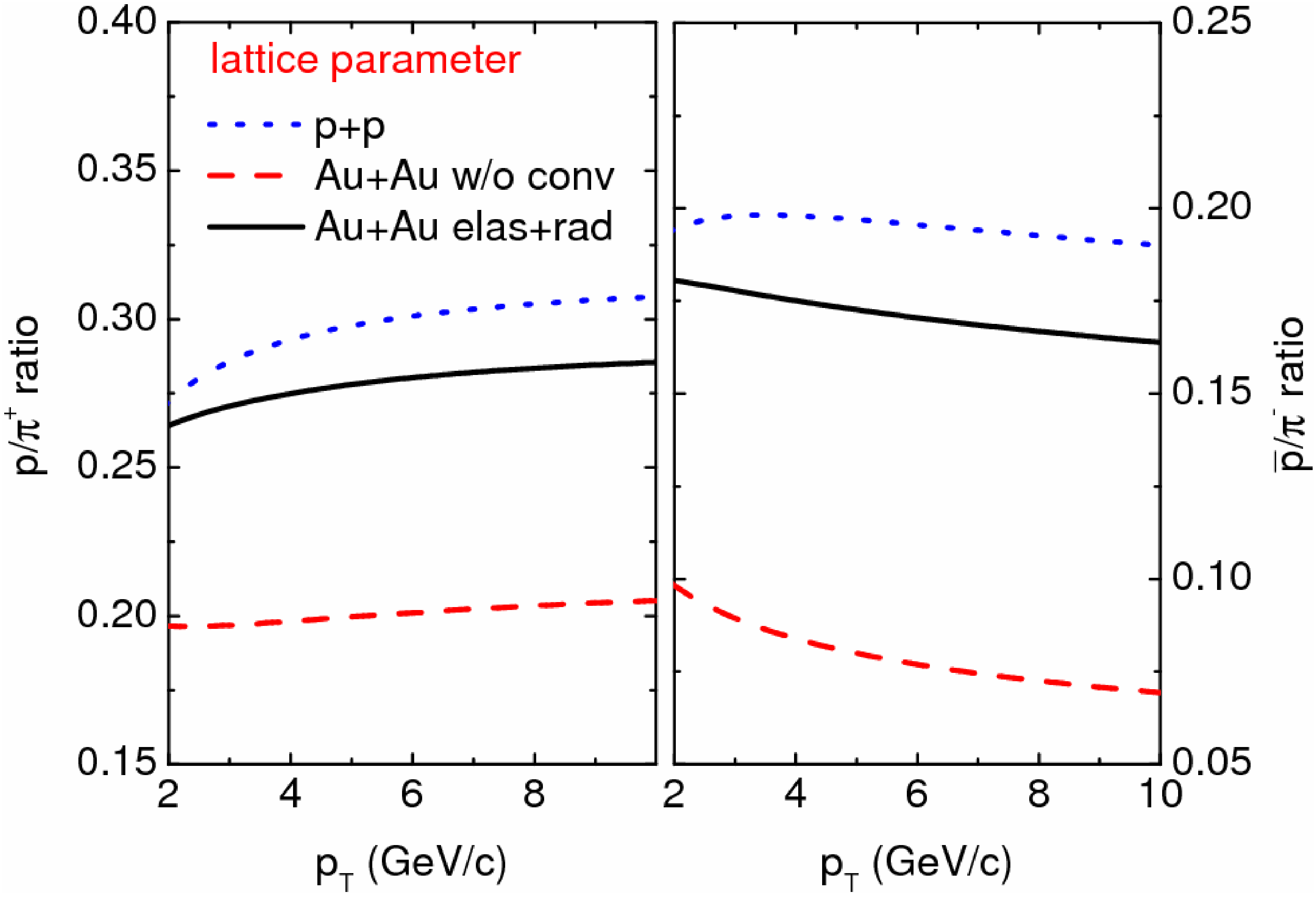
- Screening mass

$$\frac{m_D(T)}{T} = A\left(1 + \frac{N_f}{6}\right)^{1/2} g_{pert}(T); \quad A = 1.417$$

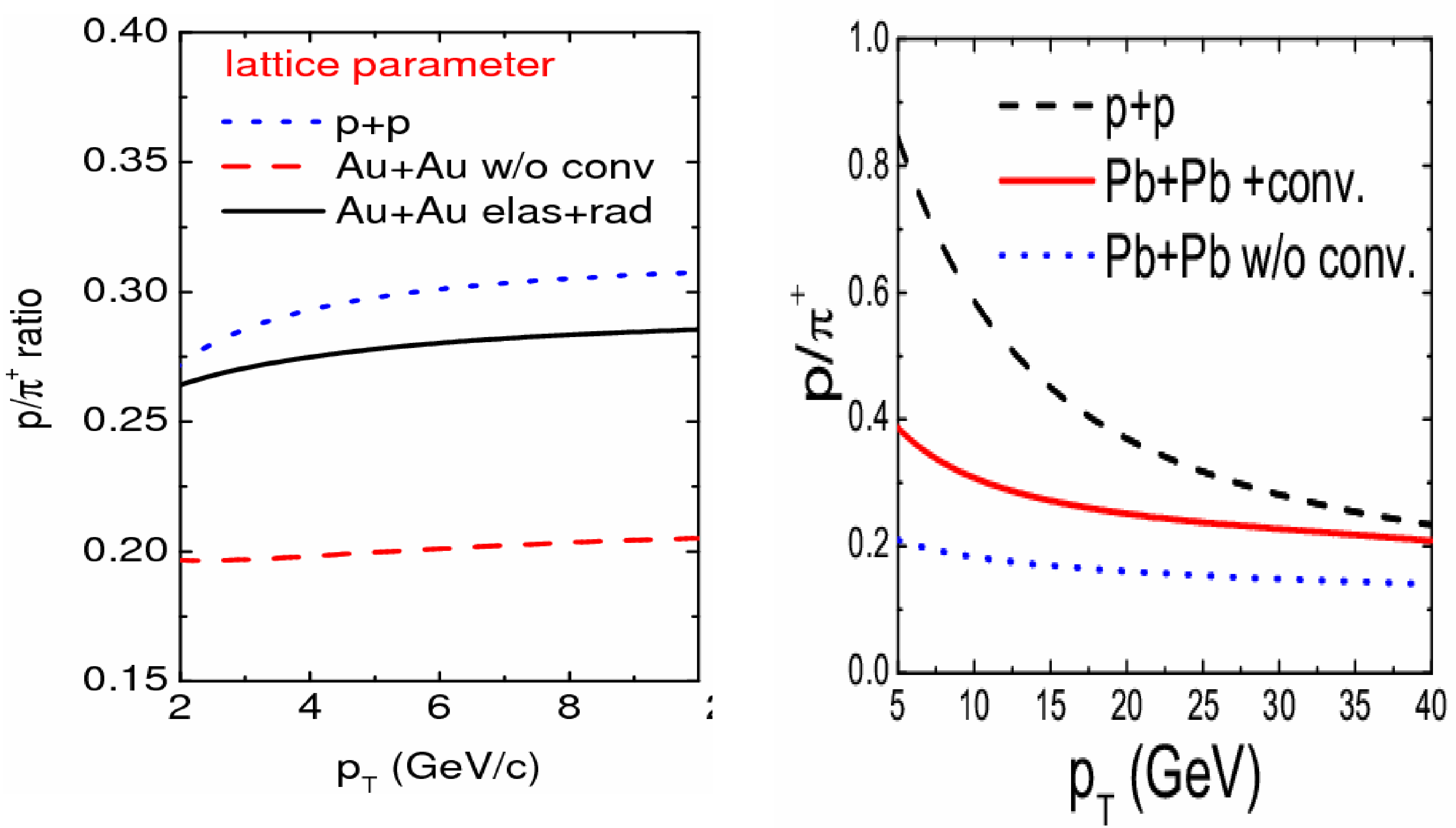
Quark and gluon jets nuclear modification factor using in-medium QCD coupling from lattice gauge calculations



Proton and antiproton to pion ratios using in-medium QCD coupling from lattice gauge calculations



Proton to π⁺ ratio at high transverse momenta at LHC



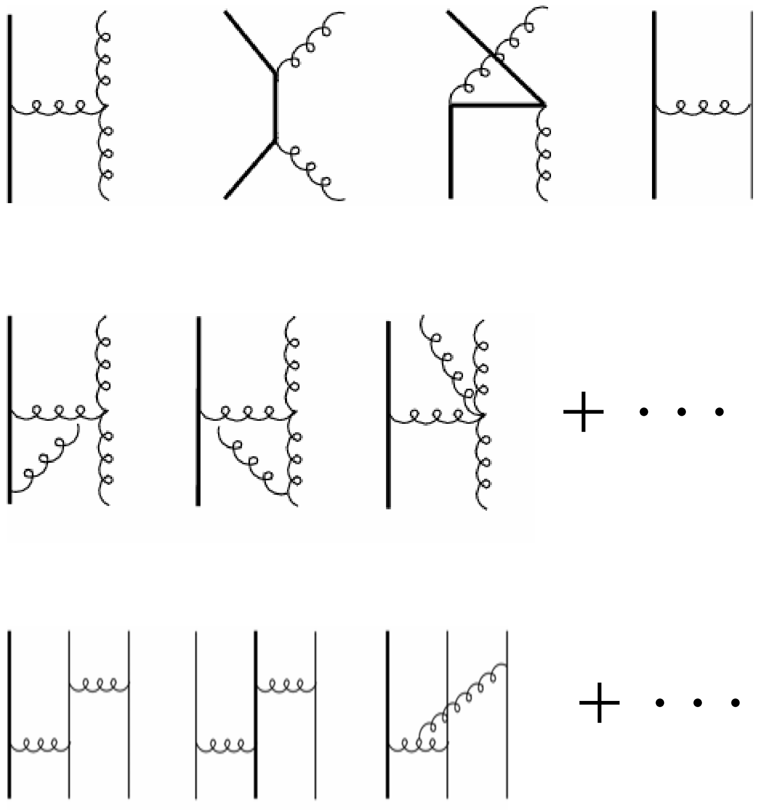
Although p/π ratio similar to that in p+p collisions at RHIC when quark and gluon conversion widths are multiplied by K_C~4-6, it is lower than p+p at LHC.

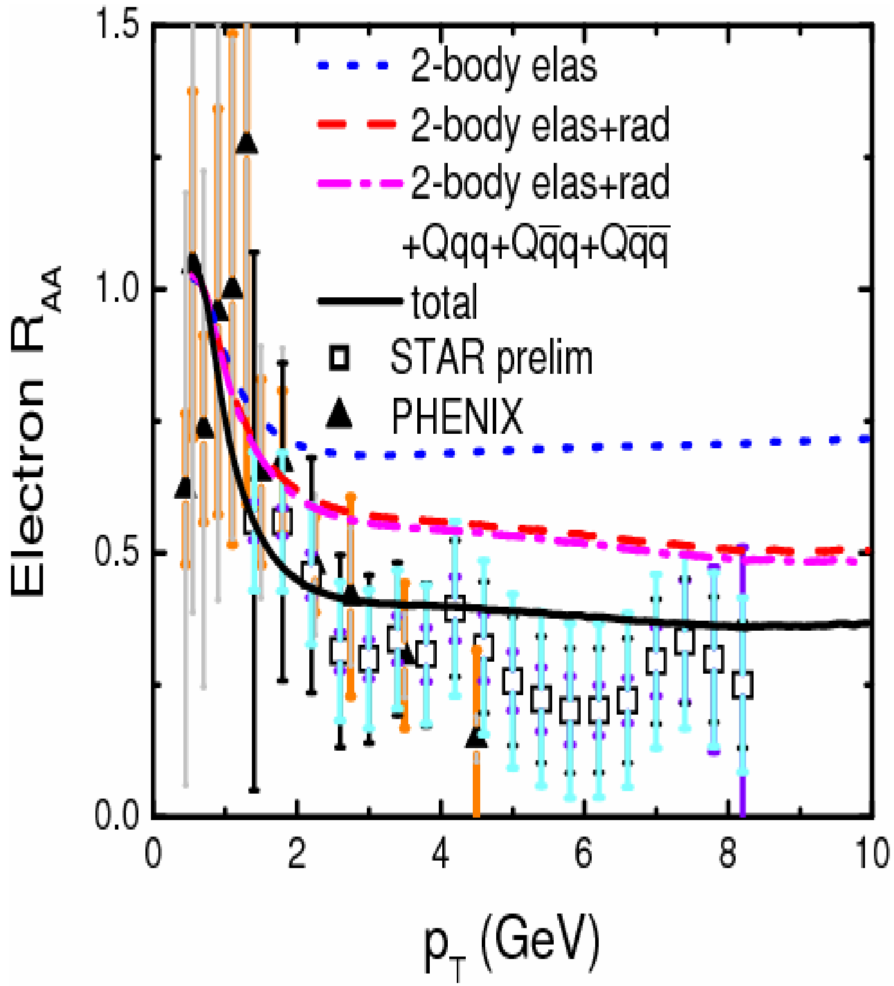
Conclusions

- Same proton and antiproton to pion ratios at high p_T in central Au+Au and p+p collisions → net quark to gluon jet conversions in QGP.
- Including conversions due to elastic and inelastic scattering requires an enhancement factor K_C~ 4-6 to obtain same R_{AA} for gluon and quark jets.
- Including also conversions due to radiative scattering reduces the enhancement factor to K_C~ 3.
- Using in-medium strong QCD coupling from lattice gauge calculations further reduces K_C to ~ 1.5.
- K_C~ 1 may be obtained by improved treatment and by including multi-body scattering, which been shown to give compatible contribution as two-body elastic scattering to heavy quark energy losses.
- Proton to pion ratio at hight p_T in central Pb+Pb at LHC is less than in p+p collisions.

Nuclear modification factor for electrons from heavy meson decays

W. Liu & CMK, NPA 783, 233 (07); nucl-th/0603004





Reasonable agreement with data from Au+Au @ 200A GeV after including heavy quark three-body scattering.