Jet-Energy Loss in Heavy-Ion Collisions
Where Does the Energy Loss Lose Strength?

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Quark Matter 2008
4-10 February 2008 – Jaipur, India
5th February 2008

O U T L I N E

-I. Results

0. Motivation – paradox behaviors in R_{AB}

- R^{π}_{AuAu} seems to increase at high-p_T...
- ...but, R^{h}_{dA} and R^{γ}_{AuAu} decrease at high-p_T?
- Signatures for EMC effect in dAu and $AuAu$ at RHIC

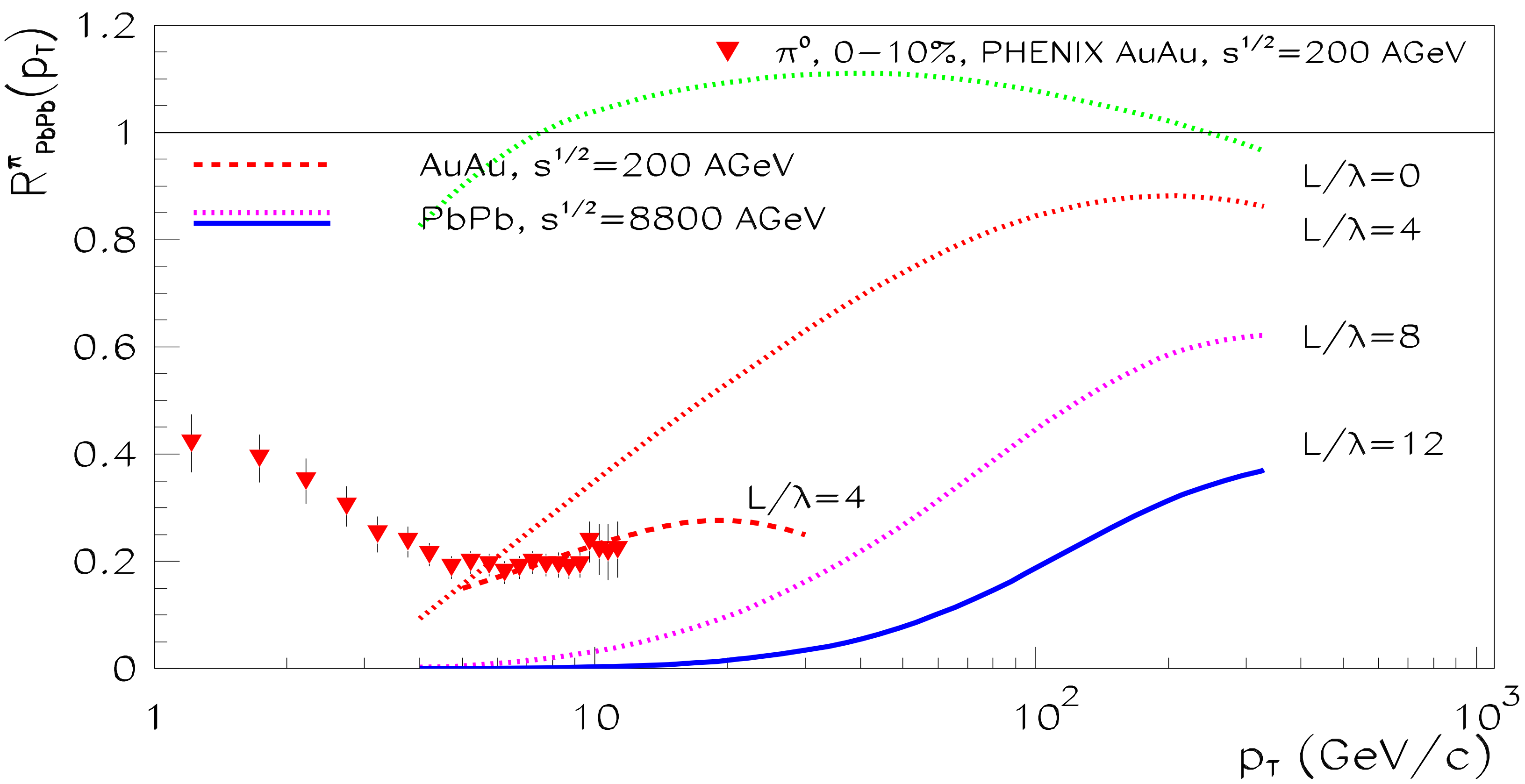
I. The strength of HOT quenching at high-p_T at RHIC

- What are the good parameters: L, λ, μ, $\hat{q}$,... ?
- Conservative test: GLV energy loss at high-p_T

II. Nuclear Modifications at LHC – results again...

- Analysing EMC effect in high-energy AA' collisions
- Predictions for LHC at 5.5 TeV $PbPb$ collisions

Results: What do we expect for the energy loss

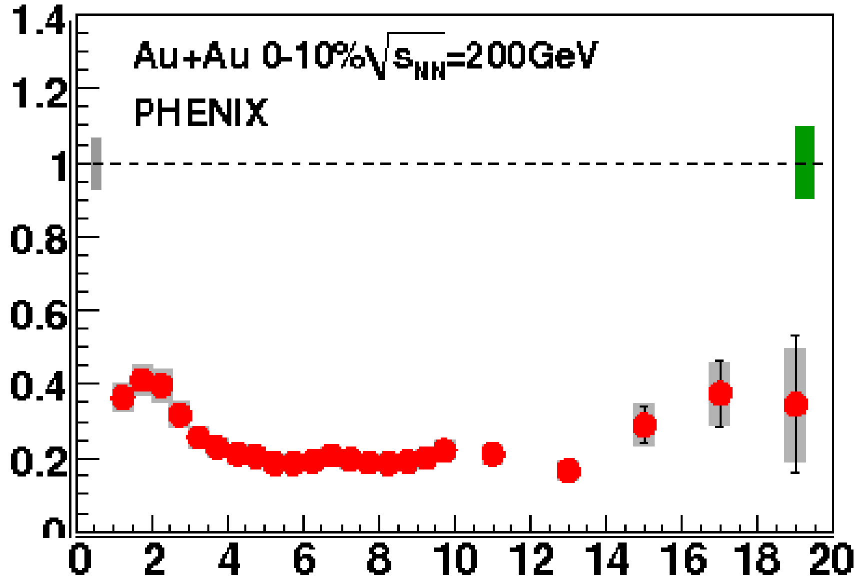


in *PbPb* collisions in LHC experiments?

MOTIVATION – π^0

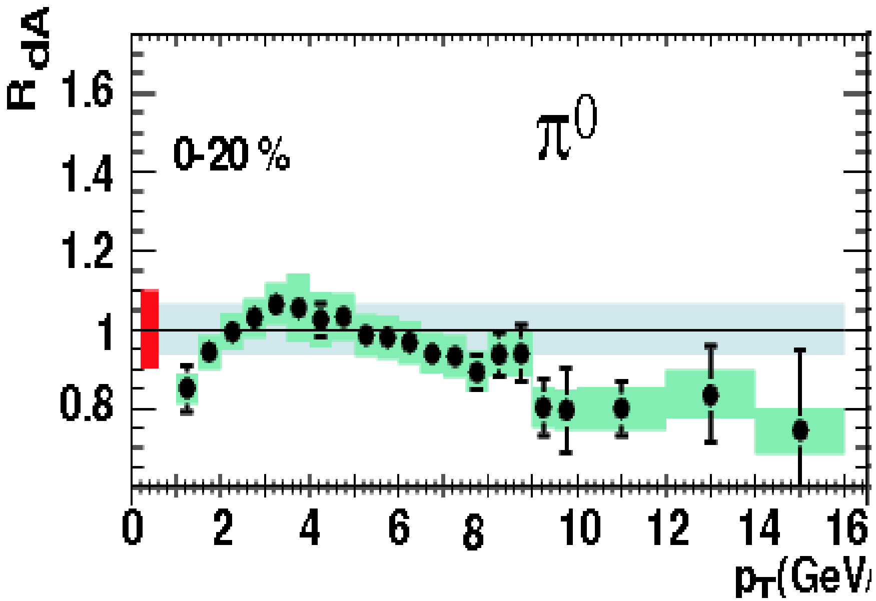
HOT PHENIX π^0 data

- arXiv:0801.4020v1 (2008)
- $R_{AuAu} \approx 0.2$ at low p_Ts
- At high $p_T \sim 15 - 20$ GeV/c
  $R_{AuAu} \approx 0.4$, where this will go?



More precise PHENIX dAu data

- PRL 98 (2007) 172302
- Only huge errors at high p_T?
- 20 – 25% suppression and
  slope structure at high p_T?

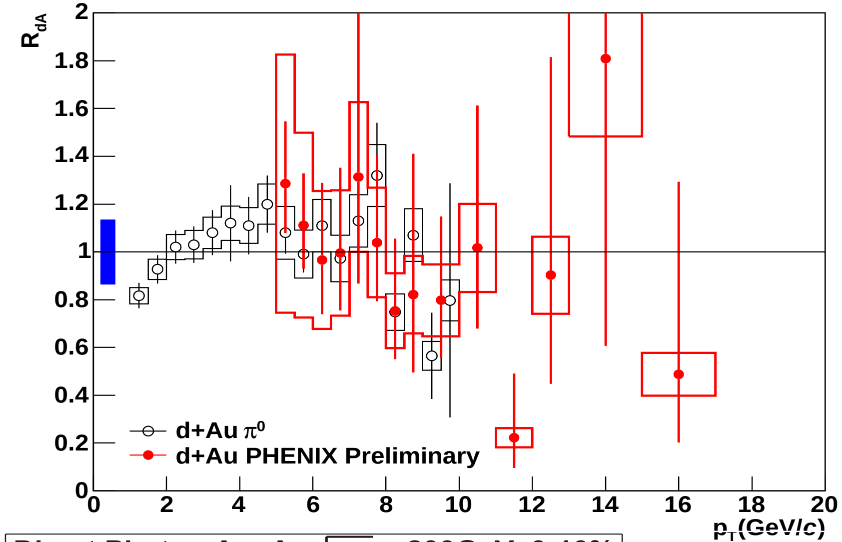


MOTIVATION – γ

PHENIX prelim. γ data in dAu

– D. Peressounko, hep-ex/0609037

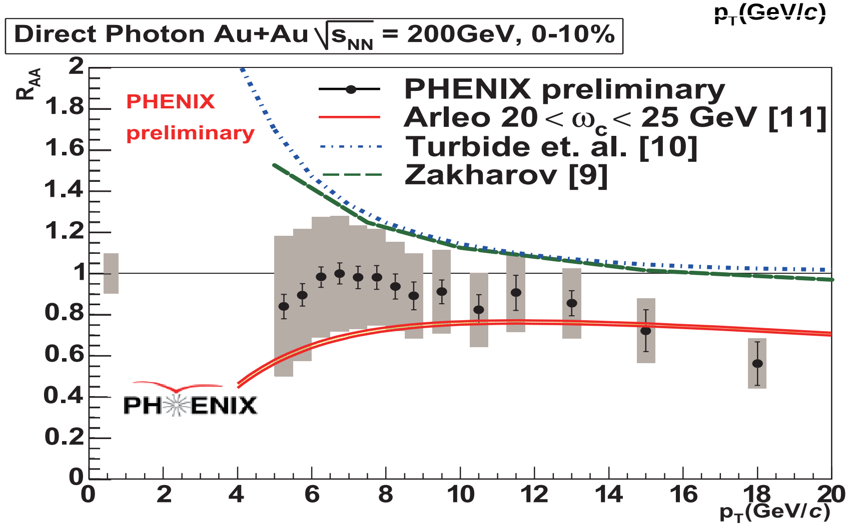
– Weak but, $R^{\gamma}_{dAu} \lesssim 1$, so negative slope at high p_T.



PHENIX prelim. γ data in $AuAu$

– T. Isobe, nucl-ex/0701040

– This is a 20 – 40% effect with negative slope again.



Paradoxon: why do differ the slopes in π^0 and γ production?

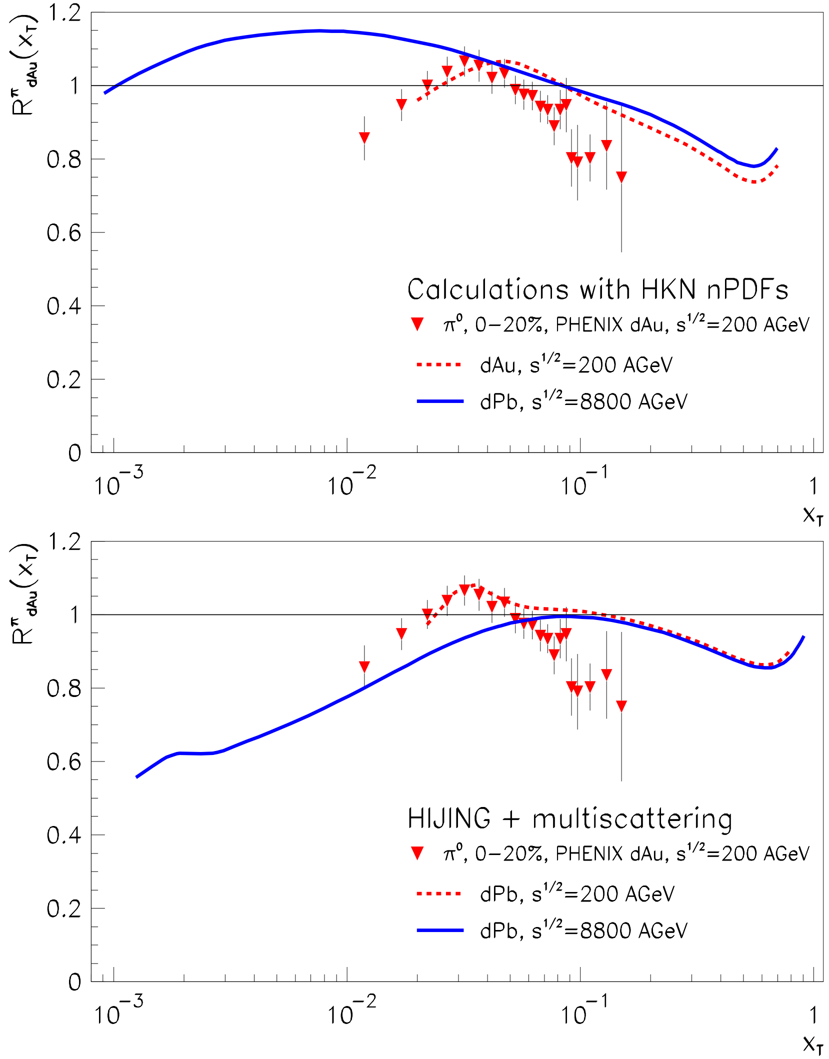
THEORETICAL INPUT

Baseline: dAu analysis for π^0 and γ (see poster #31)

– Shadowing function has x scaling by its nature, but parameterizations differ even $\sim 40\%$ at low-x.

– Common properties at high x all has constant negative log slope.

– Multiple scattering also scales: based on E706 measurement in FNAL we found, this is $\sim \ln(\sqrt{s})$



It's time to see the energy loss...

Models for jet energy loss in heavy-ion collisions

The 'conservative' non-Abelian jet energy loss methods

– Energy loss in THICK plasma BDMS, LCPI

– Energy loss in THIN plasma GLV

New models on jet energy loss

– PQM model Loizides, Daniese, Paić

– AdS CFT for heavy quarks, see the talk of W. Horowitz

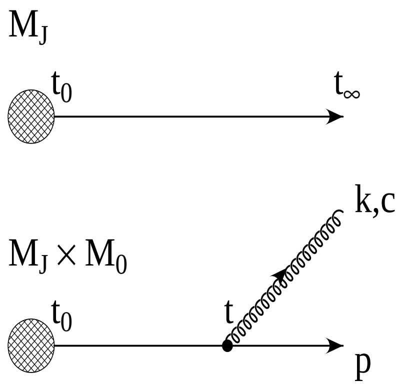
– ...

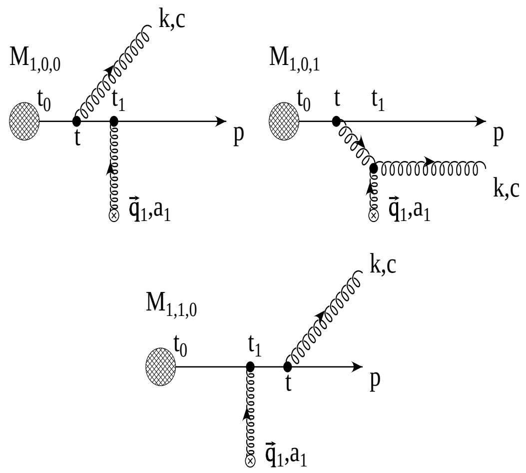
Here, I will use the 'conservative' way with L/λ

Medium induced radiative energy loss – for $L \sim \lambda_g$

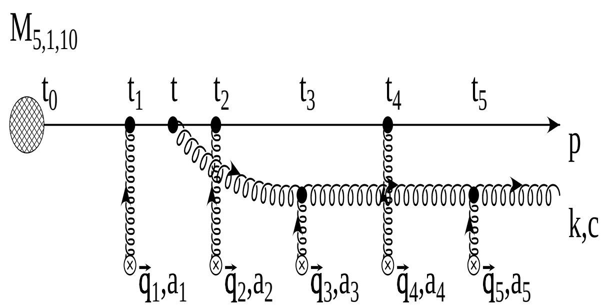
Gyulassy – Lévai – Vitev, Phys. Rev. Lett. **85**, 5535; Nucl. Phy s. **B594**, 371

GLV: time-ordered pQCD (Feynman diagramms)
+ OPACITY expansion $(n = 1, 2, 3, ...)$
+ kinematical cuts





$\mathcal{M}_{n_s,m,l}$ where $l = 2^{n_s - m} - 1$



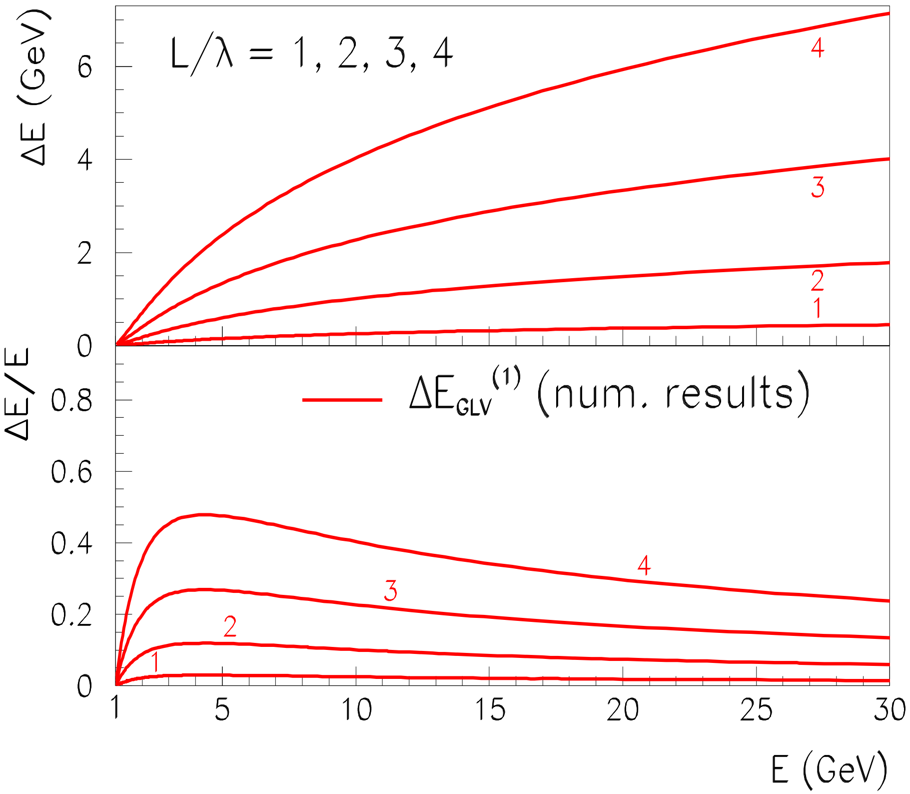
Simplification of this equation:

Relative Energy Loss vs. Jet Energy

Energy dependence of GLV jet energy loss

$$\Longrightarrow \Delta E_{GLV} \approx \Delta E^{(1)}_{GLV} \approx \frac{C_R \alpha_s}{N(E)} \frac{L^2 \mu^2}{\lambda_g} \log \frac{E}{\mu}$$

- **ΔE is E-dependent**
  $N(E)$ is a numerical function,
  $N(E) \longrightarrow 4$ at $E \longrightarrow \infty$.
- **$\approx$ E-independent $\Delta E/E$**
  in $3 <$ GeV $E < 10$ GeV
- **Opacity $n = L/\lambda$**
- **logarithmic tail**

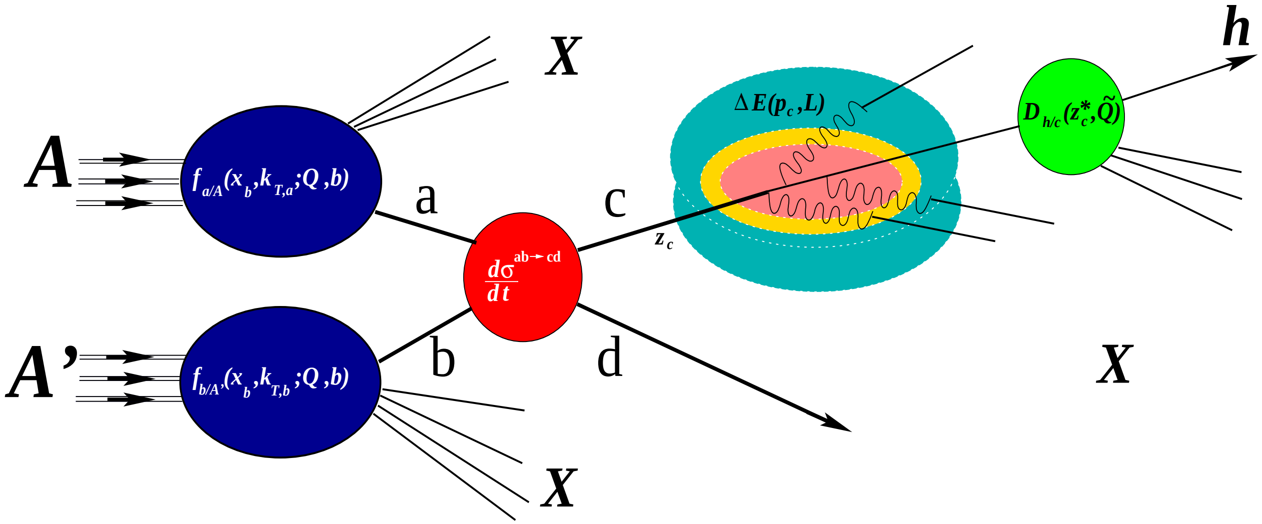


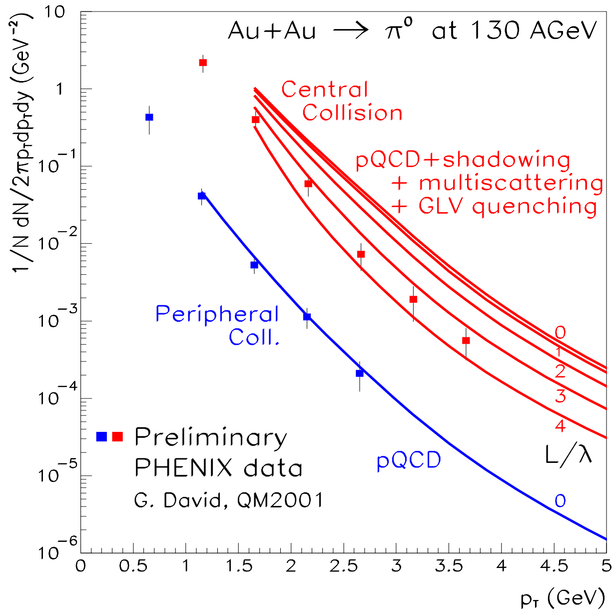
GLV jet-quenching in thin plasma approximation $L \sim \lambda_g$

$$\Delta E_{GLV} \approx \frac{C_R \alpha_s}{N(E)} \frac{L^2 \mu^2}{\lambda_g} \log \frac{E}{\mu} = \frac{C_R \alpha_s}{N(E)} \frac{1}{A_\perp} \frac{dN}{dy} \langle L \rangle \log \frac{E}{\langle \mu \rangle}$$

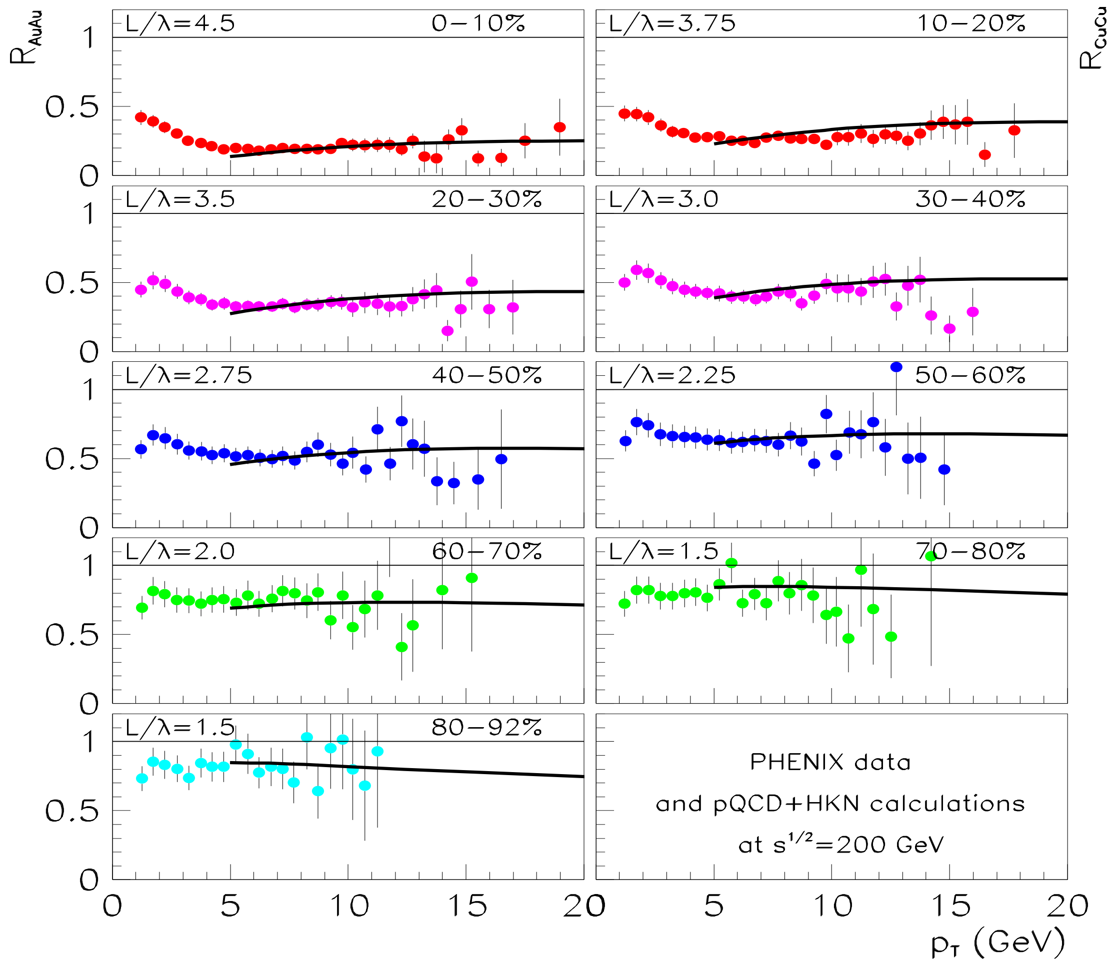
Energy loss of jet decreases the p_c momenta of c before fragmentation:

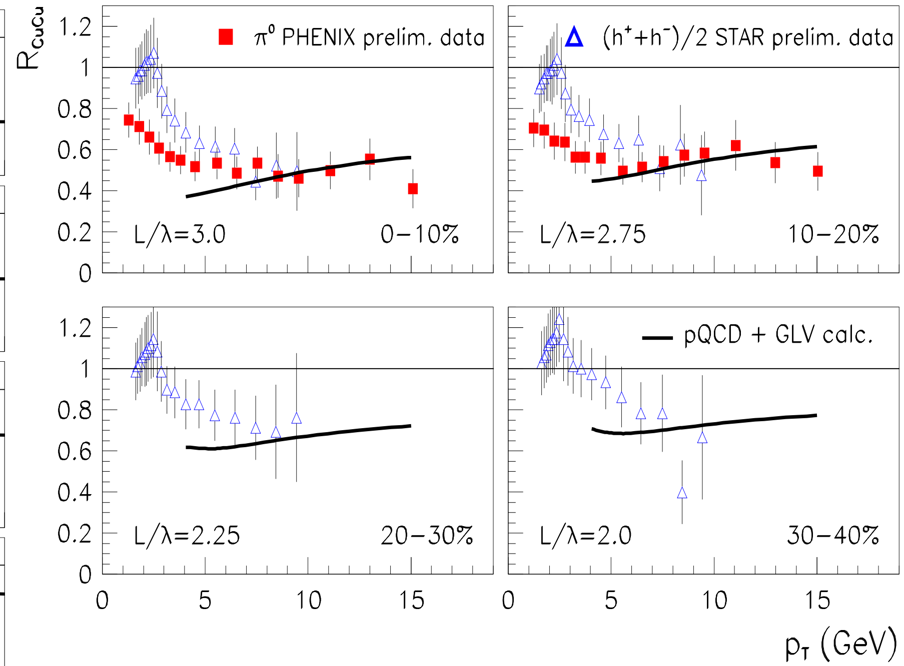
$$\frac{D_{\pi/c}(z_c, Q'^2)}{\pi z_c^2} \rightarrow \frac{z_c^*}{z_c} \frac{D_{\pi/c}(z_c^*, Q'^2)}{\pi z_c^2}, \quad \text{where} \quad z_c^* = \frac{z_c}{1 - \Delta E / p_c},$$





Jet-tomography at midrapidity in *AuAu* and *CuCu*



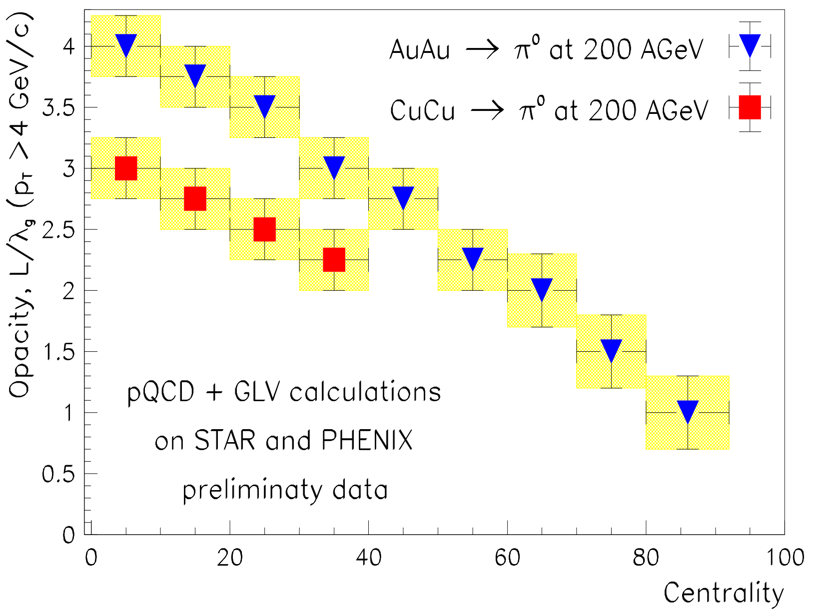


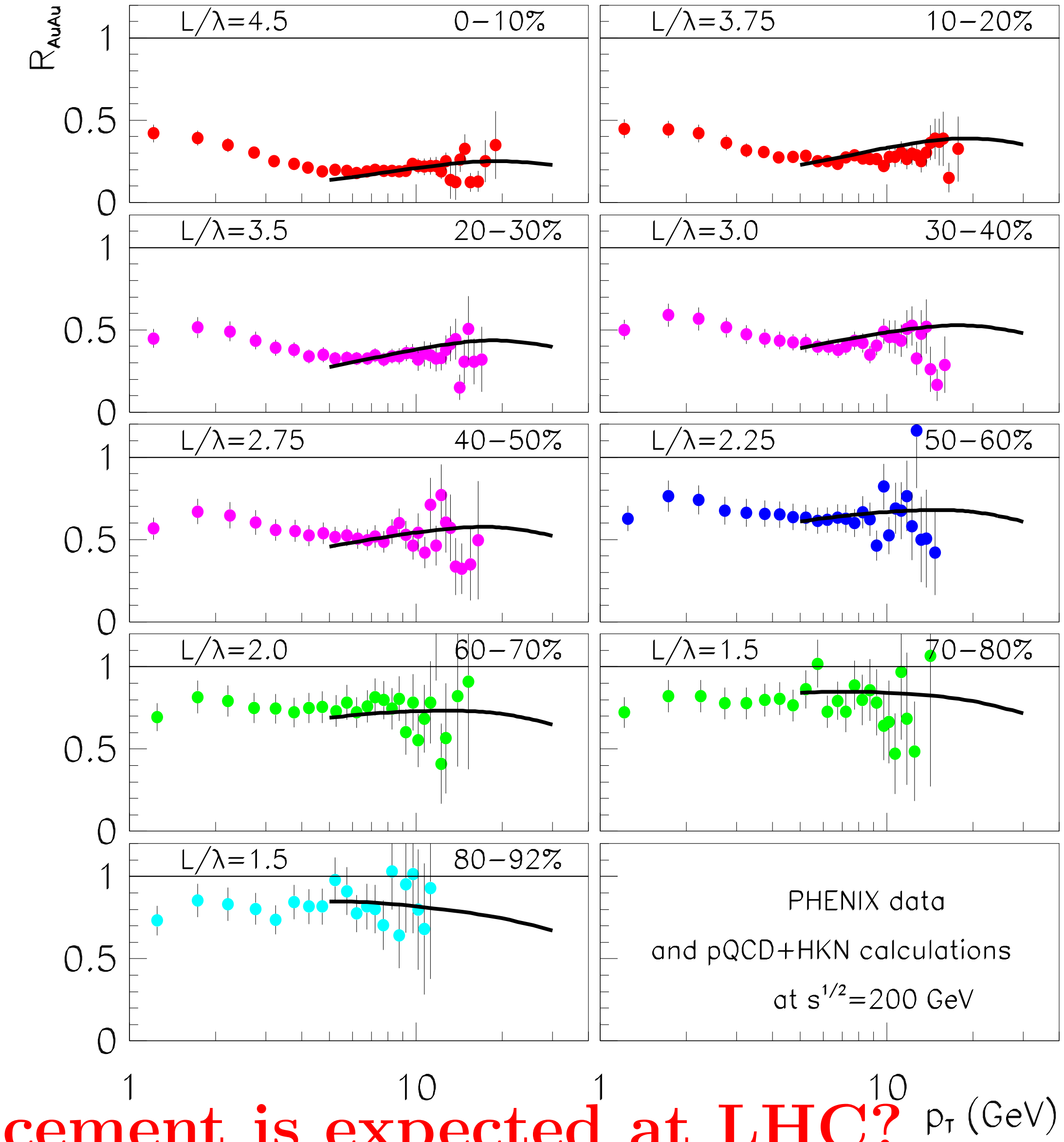
Extracting opacities in all centralities for $p_T > 4$ GeV/c

(See more in P. Lévai's talk)

All of these information are summarized $\Longrightarrow$

Analyzing opacity dependence in midrapidity AA' collisions



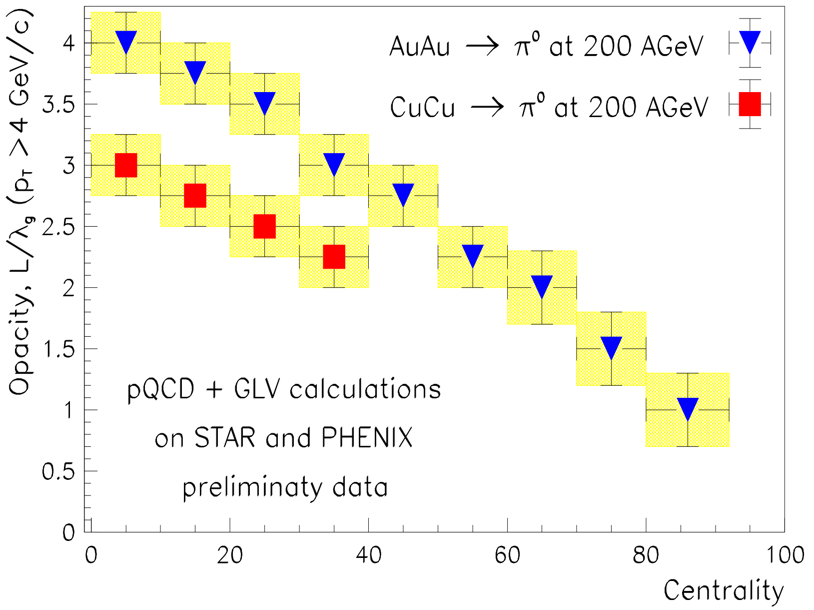


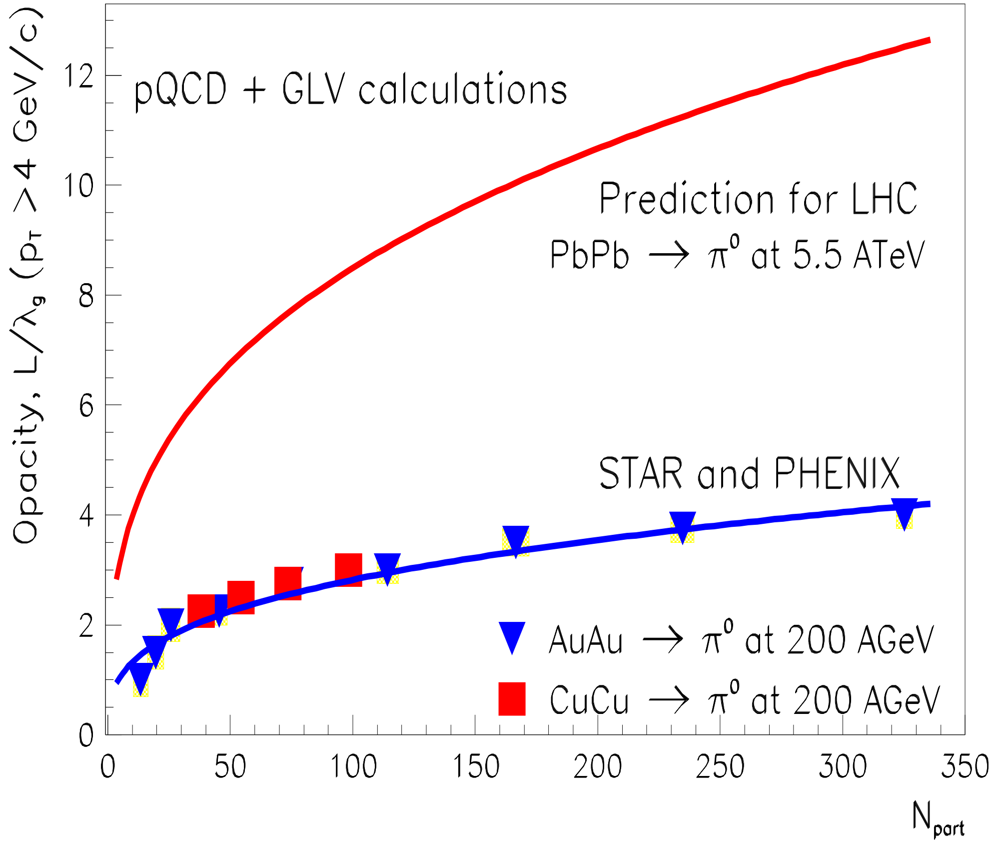
$$L \propto A^{1/3} \propto N_{part}^{1/3}$$

$$\varepsilon = \Delta E/E \propto L^2 \propto N_{part}^{2/3}$$

$\Longrightarrow$ **Suppresssion or enhancement is expected at LHC?**

Opacity Prediction for $PbPb$ collisions at LHC





$$L \propto A^{1/3} \propto N_{part}^{1/3}$$

$$\varepsilon = \Delta E/E \propto L^2 \propto N_{part}^{2/3}$$

$\Longrightarrow$ L/λ will NOT disappear in very peripheral collisions;

$\Longrightarrow$ N_{part} suggests strong suppression for LHC with $L/\lambda \approx 8 - 12$;

$\Longrightarrow$ **... but energy loss looses its strength at high** p_T

How the energy loss will look like at high energies?

Without shadowing

– General rule: $\frac{dN}{dy} \sim \ln\sqrt{s}$

– Central $AuAu$ at RHIC

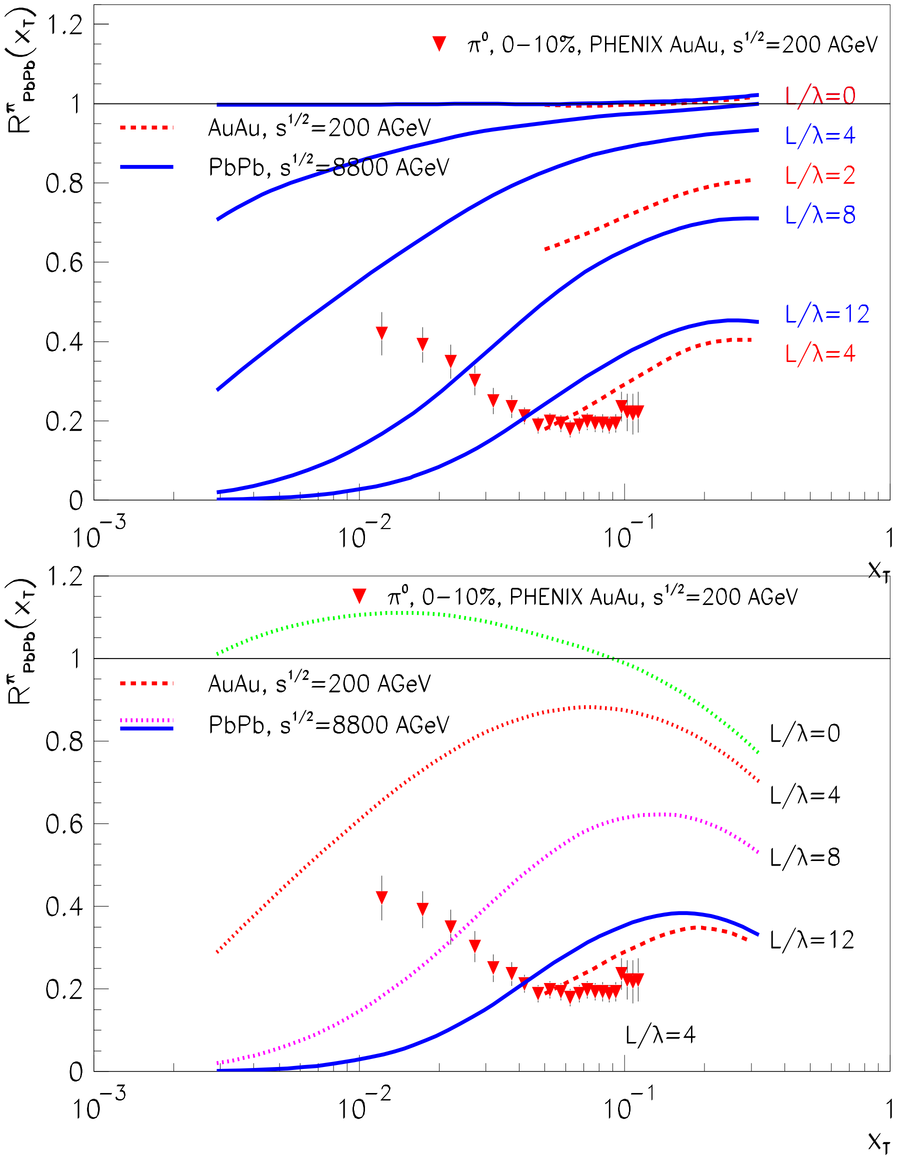
$$\frac{1}{A_\perp}\frac{dN}{dy} \approx \frac{680}{\pi R^2_{AuAu}} = 5.1$$

– LHC: $\frac{dN}{dy} \sim 1500 - 2000$

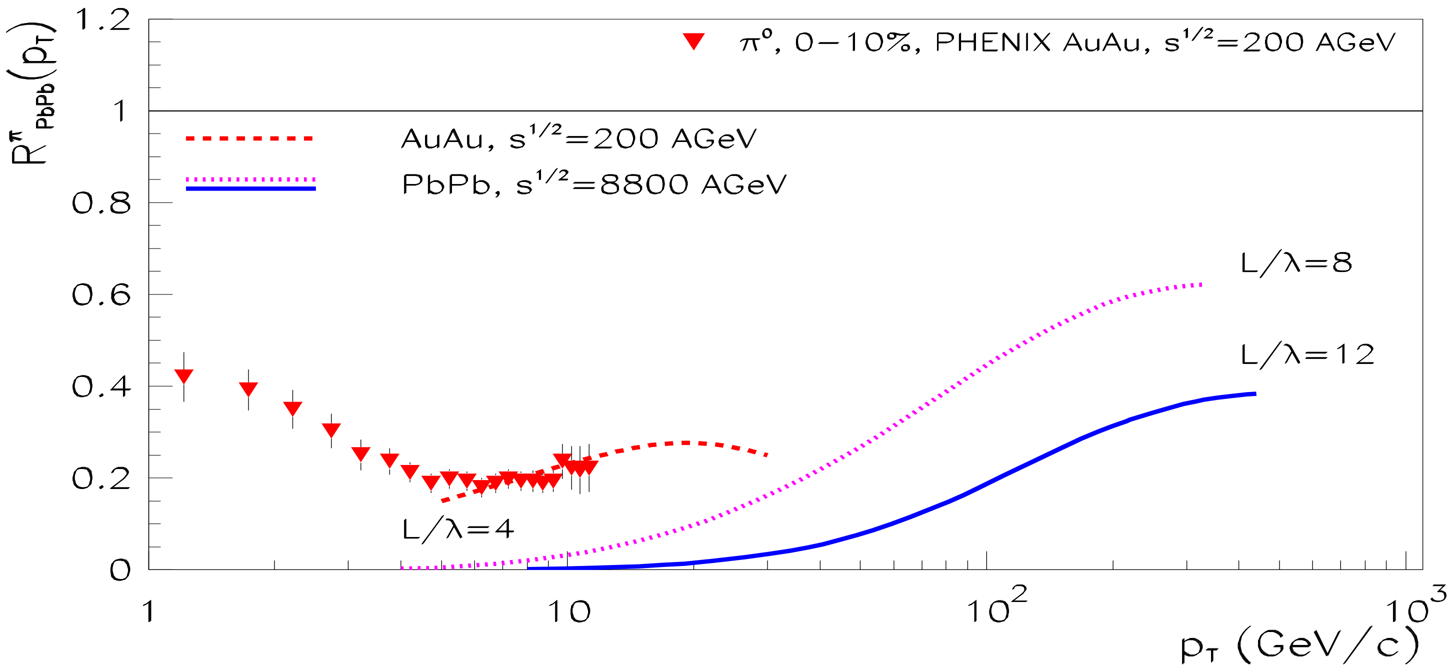
$$\frac{1}{A_\perp}\frac{dN}{dy} \approx 10 - 15$$

With all nuclear effects

– Shadowing (EMC) effect will will suppress again at high-x



R_{PbPd} might enhance at $p_T \sim 15$ at RHIC



but, makes a maximum even at LHC energies.

SUMMARY

Latests PHENIX R_{AB} data have paradox behavior

– R^{π}_{AuAu} seems to increase at high-p_T...
– ...but, R^{h}_{dA} and R^{γ}_{AuAu} decrease at high-p_T?
– possible signature of the EMC effect in dAu and $AuAu$

I. The strength of HOT quenching at high-p_T

– Conservative test: GLV energy loss at high-p_T
– We expect a maximum of $R^{\pi}_{AuAu}(p_T)$ at $p_T \approx 15$ GeV/c

II. Nuclear Modifications at LHC energies – result again...

– Opacity estimated $L/\lambda \approx 8-12$ in $PbPb$ at LHC
– Using this $R^{\pi}_{AuAu}(p_T)$ were shown for LHC at 5.5 TeV $PbPb$

Identified high-p_T particle measurements in ALICE

– HMPID and VHMPID detectors in ALICE posters: 97 & 98