Jet production in relativistic heavy-ion collisions

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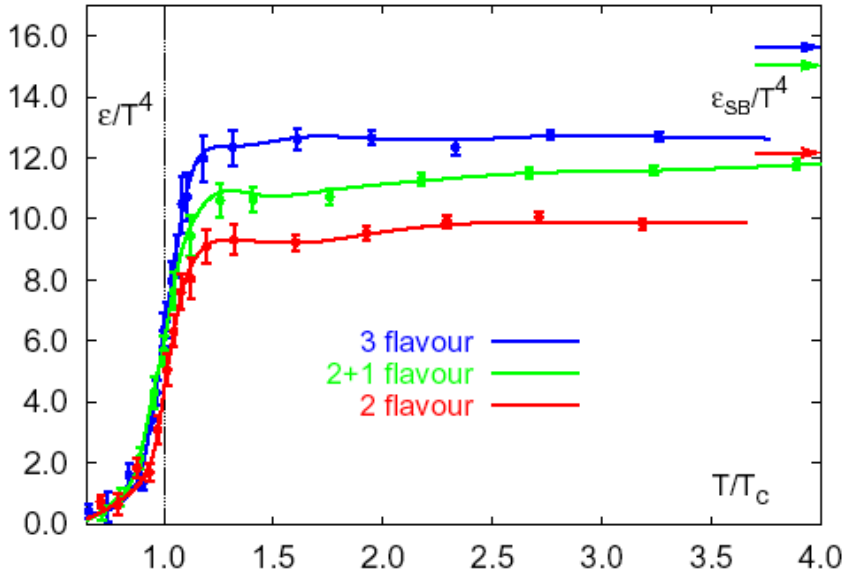
Introduction:
From hadrons to jets

Formation of the QGP

It would be interesting to explore new phenomena by distributing high energy or high nuclear density over a relatively large volume.

T. D. Lee (1978)

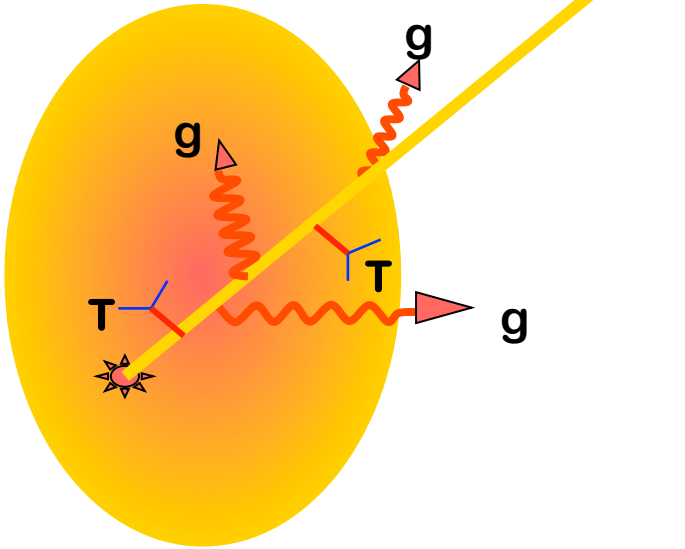
Lattice QCD predicts phase of thermal QCD matter with sharp rise in number of degrees of freedom near T_c=170MeV.

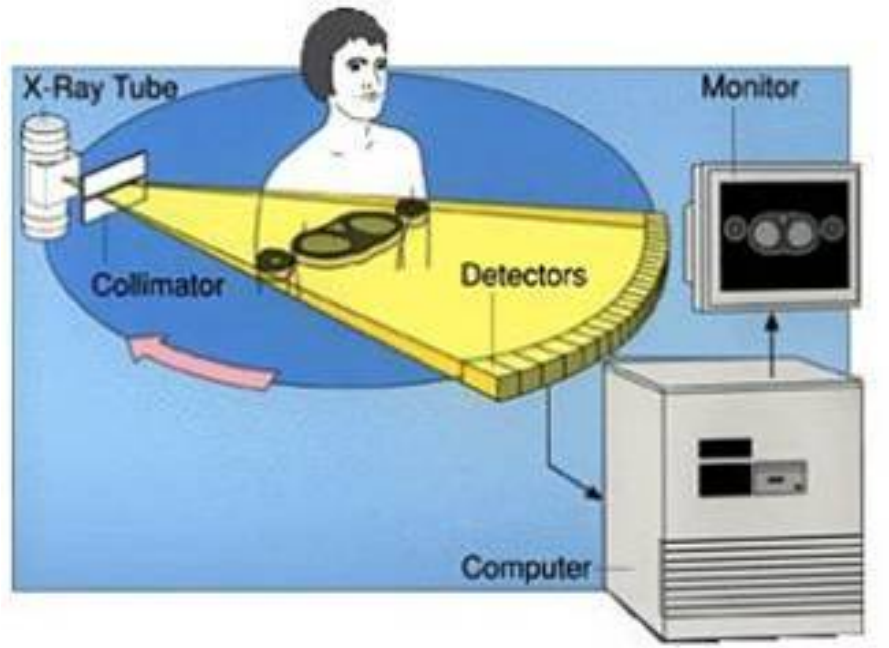


Jet quenching as a hard probe

Jet quenching has been proposed as an excellent probe of the hot/dense matter created at HIC.

Single Hadron Tomography

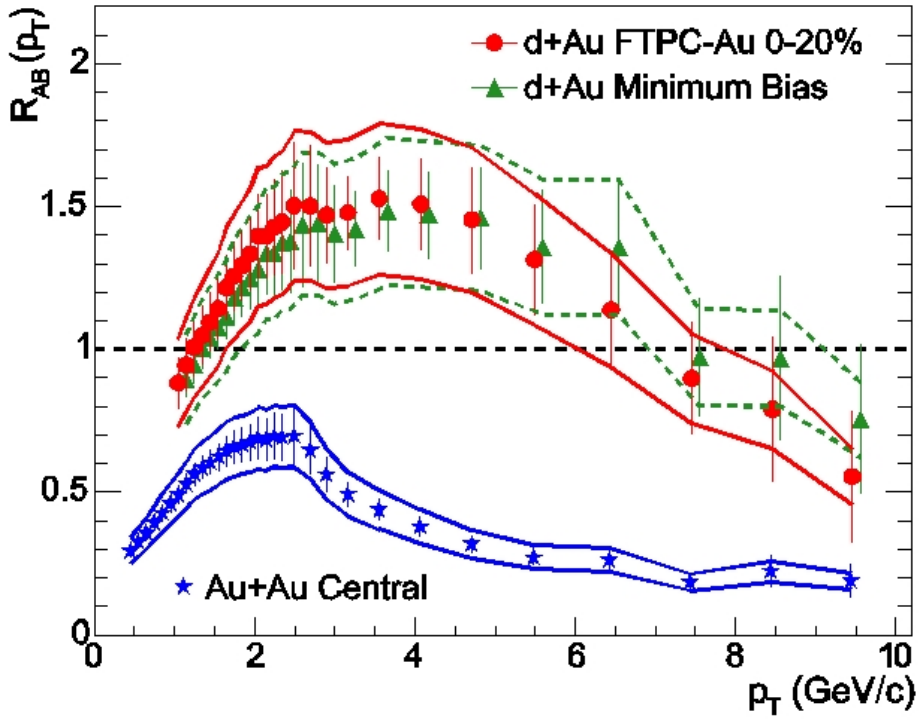


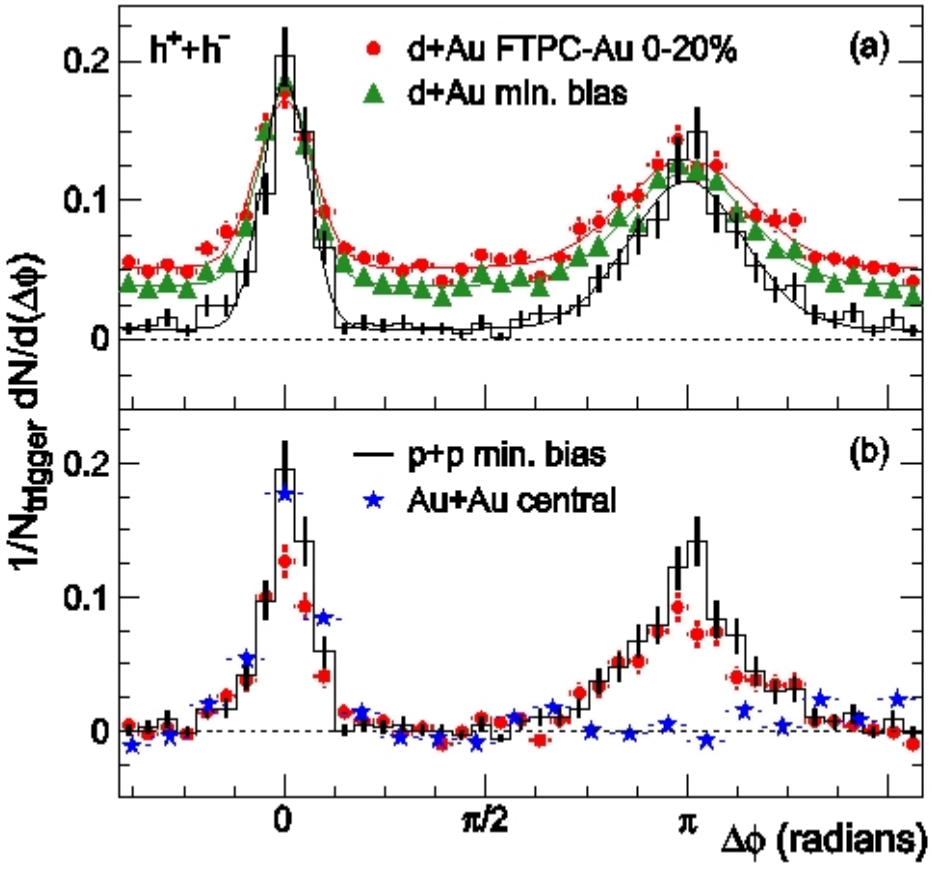


Xin-Nian Wang, M. Gyulassy, PRL68(1992)1480

Jet quenching at RHIC

$$R_{AA} = \frac{\text{Yield}_{AuAu} / \langle N_{binary} \rangle_{AuAu}}{\text{Yield}_{pp}}$$

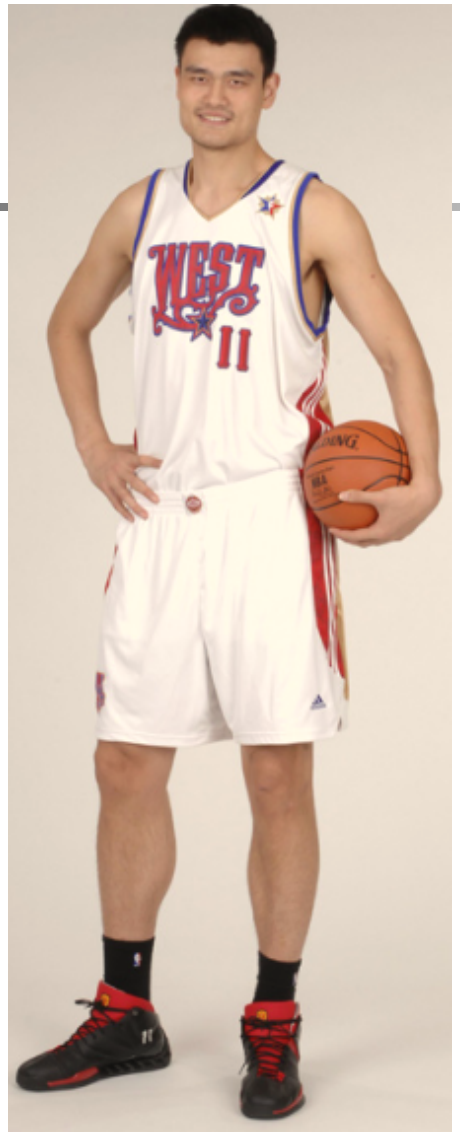




Finding of the jet quenching effect in A+A collisions has been regarded as one of the most important discoveries made at RHIC.

Gyulassy, Vitev, X-N Wang, BWZ, 《QGP3》 p123-191 (2004), nucl-th/0302077.

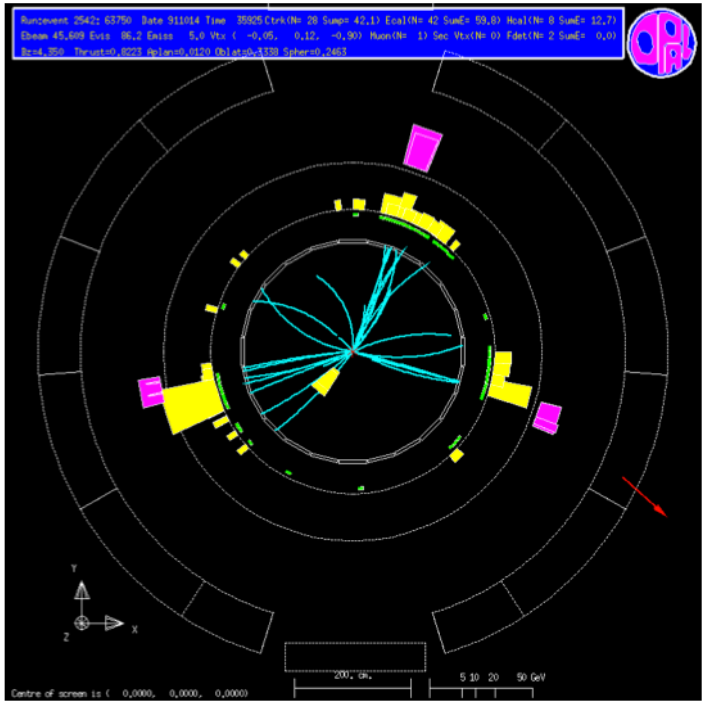
leading hadrons

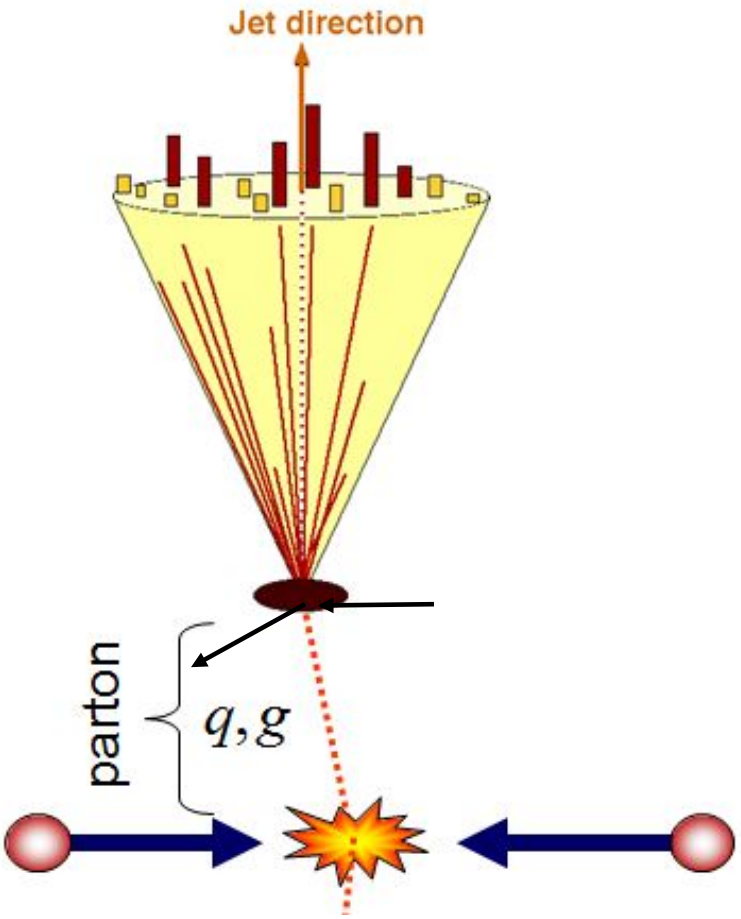


leading hadrons

jets

What is a Jet?





$$E_T = \sum_{i \in jet} E_{T,i}$$

$$y = \sum_{i \in jet} y_i E_{T,i} / E_T$$

$$\phi = \sum_{i \in jet} \phi_i E_{T,i} / E_T$$

$$R_{ij} = \sqrt{(y_i - y_j)^2 + (\phi_i - \phi_j)^2}$$

Full jet in HIC: new opportunities

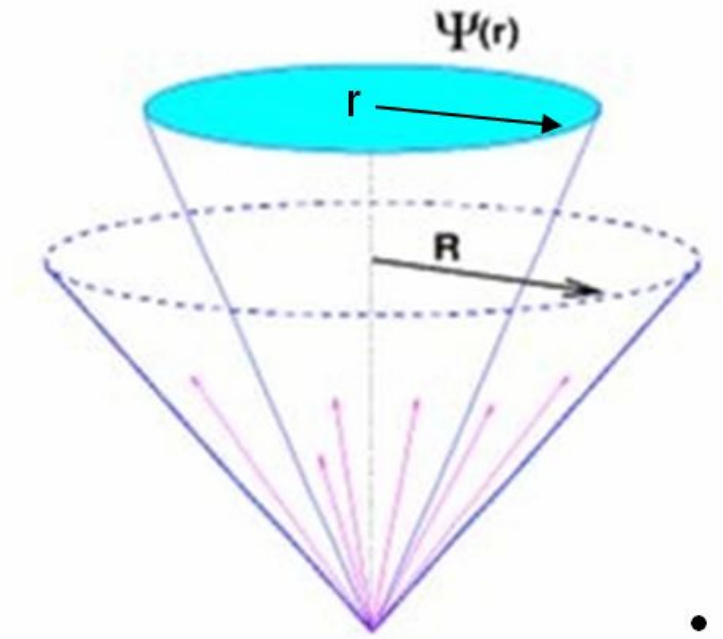
1) jet shape
2) inclusive jet cross section
3) tagged jet production
4) dijet correlation

Jet shape in HIC

$$\Psi_{\rm int}(r;R) = \frac{\sum_i (E_T)_i \Theta(r-(R_{\rm jet})_i)}{\sum_i (E_T)_i \Theta(R-(R_{\rm jet})_i)} ,$$

$$\psi(r;R) = \frac{d\Psi_{\rm int}(r;R)}{dr} .$$

$$\Psi_{\rm int}(r=R,R)=1$$



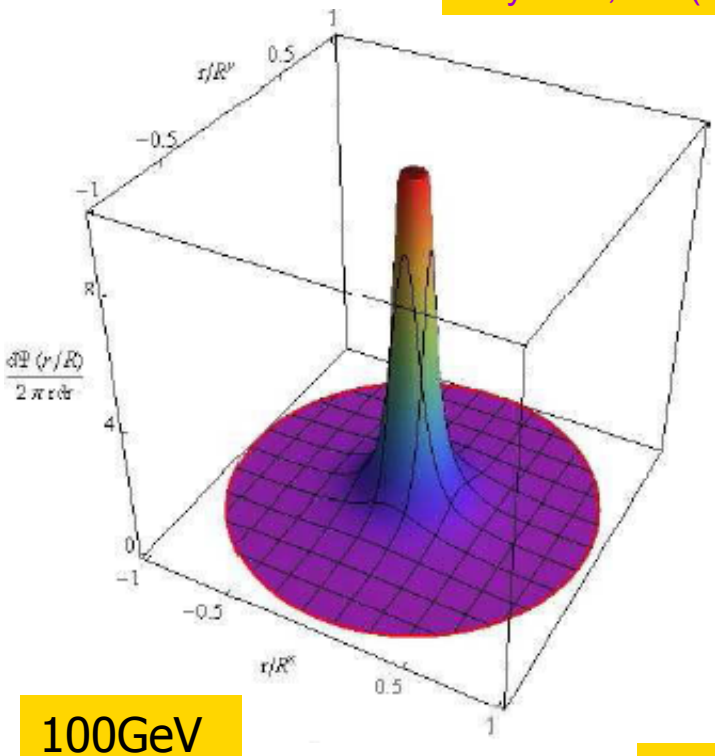
I Vitev, S Wicks, BWZ,

JHEP 0811,093 (2008); EPJC 62, 139 (2009).

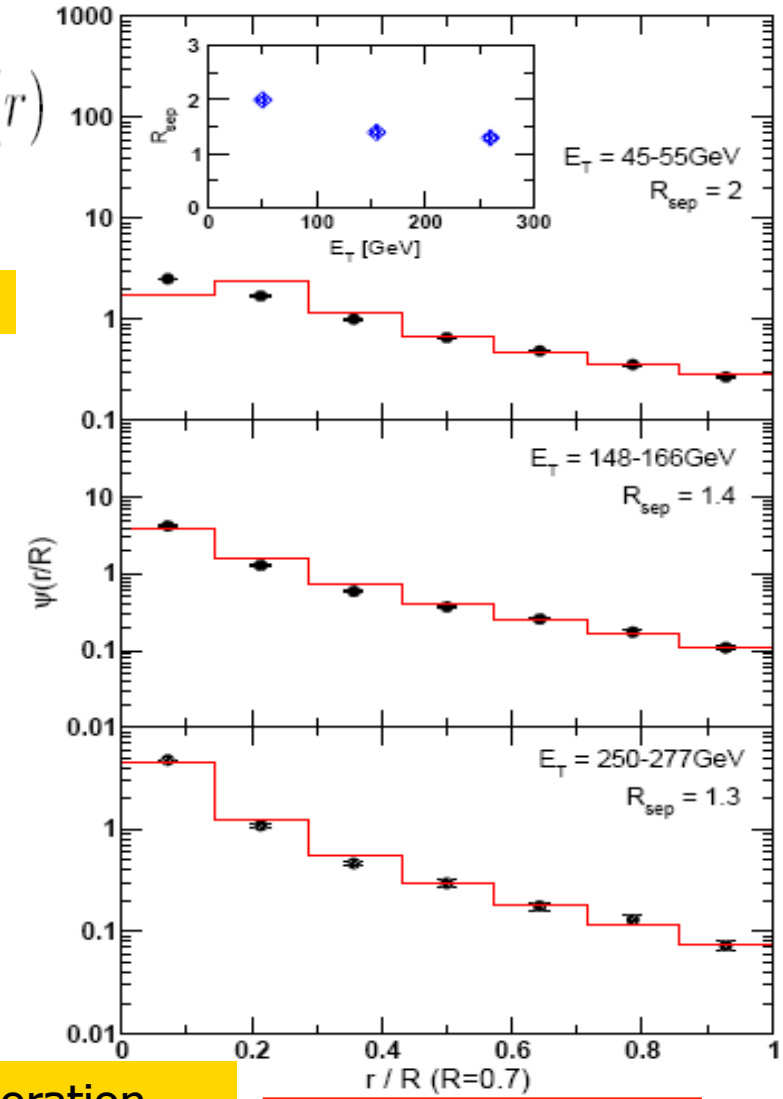
Jet shape p+p: baseline

$$\psi(r) = \psi_{\mathrm{coll}}(r)\,(P(r)-1) + \psi_{\mathrm{LO}}(r) + \psi_{i,\mathrm{LO}}(r) + \psi_{\mathrm{PC}}(r) + \psi_{i,\mathrm{PC}}(r)\,,$$

Seymour, M. (1998)



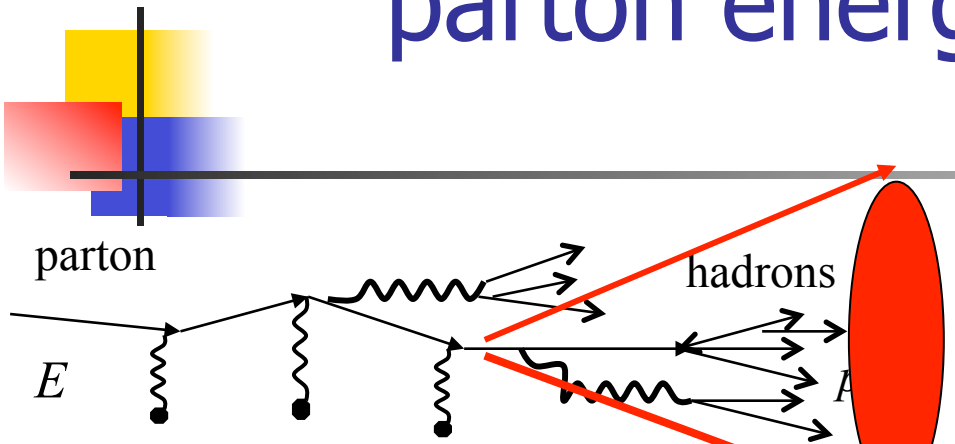
100GeV



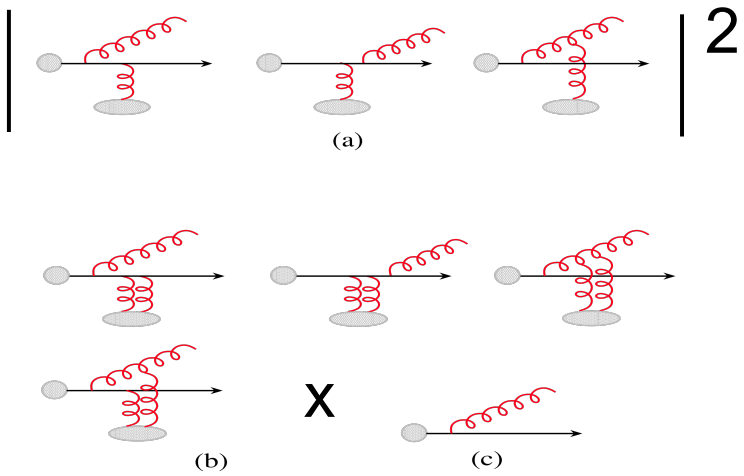
CDF collaboration
Acosta et al (2005)

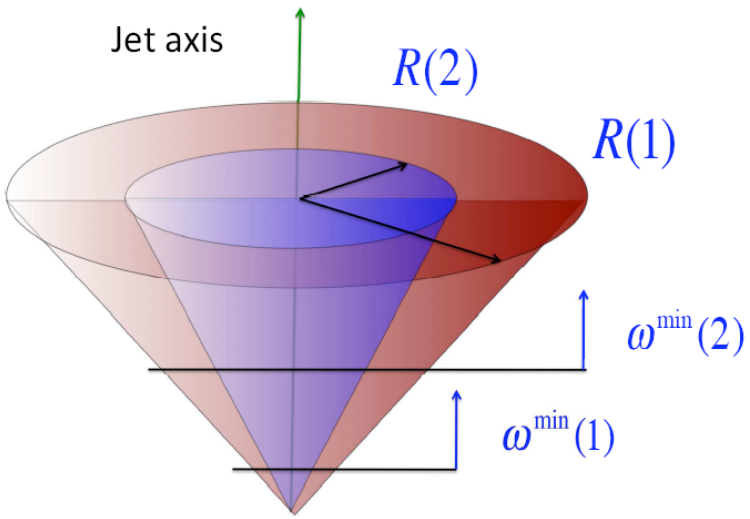
$\sqrt{s} = 1960$ GeV

parton energy loss in QGP



Gyulassy-Levai-Vitev



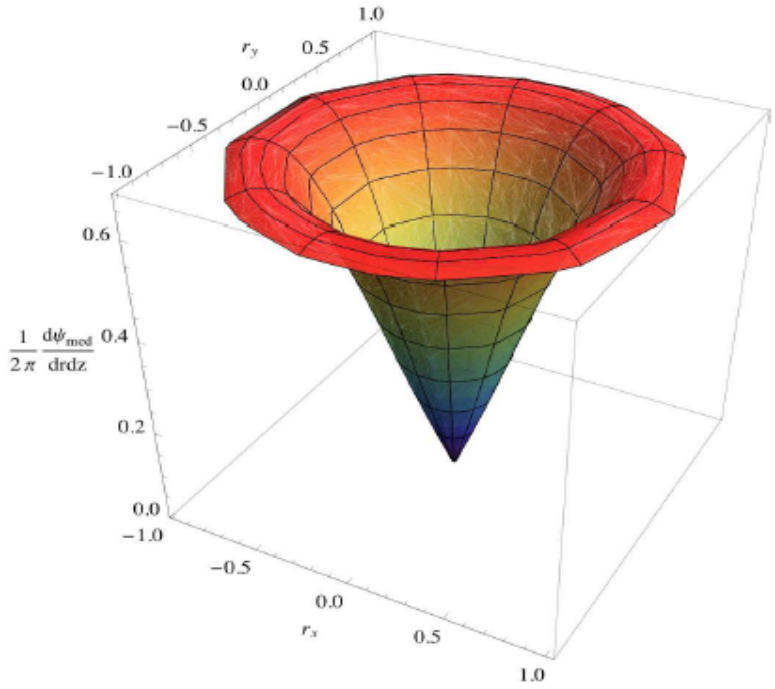


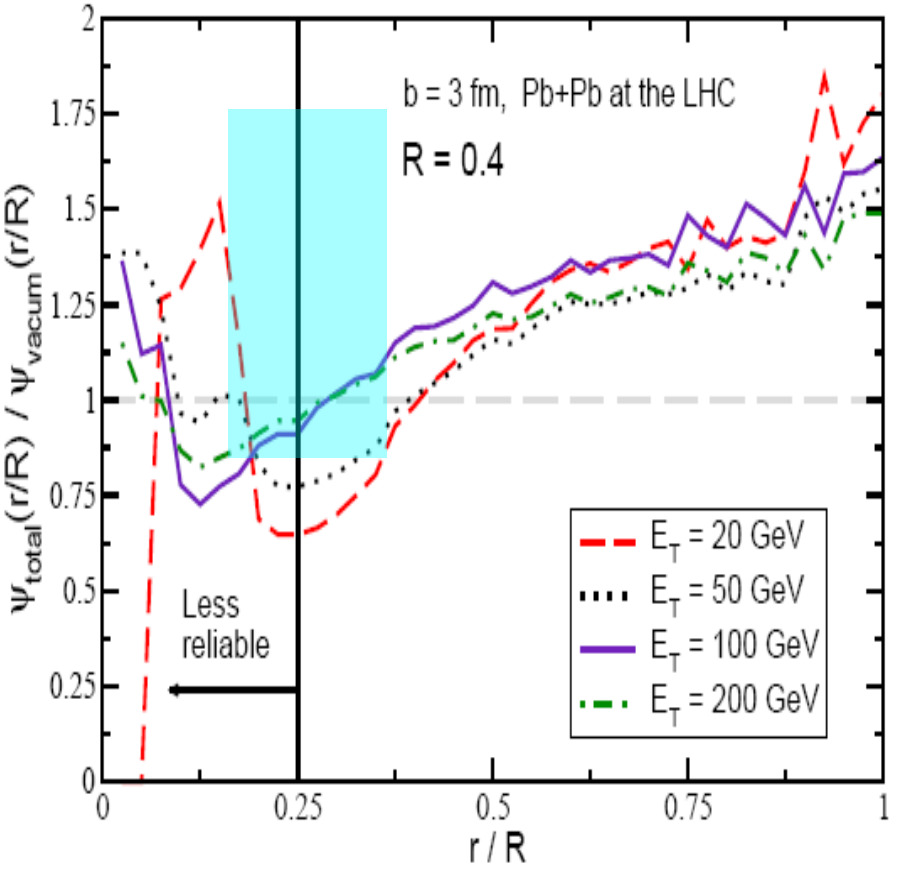
- GLV formalism provides an analytic approach

Total jet shape in HIC

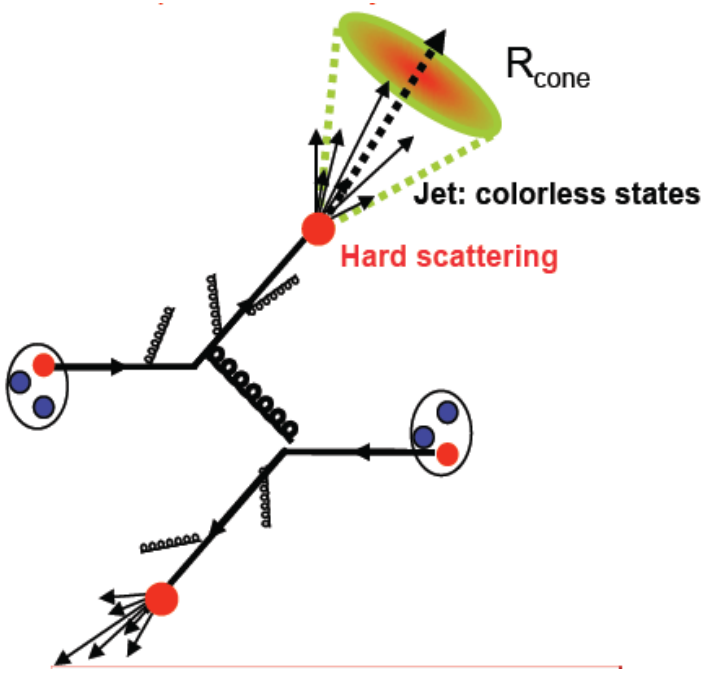
- Medium-induced jet shape is much broader than the jet shape in p+p

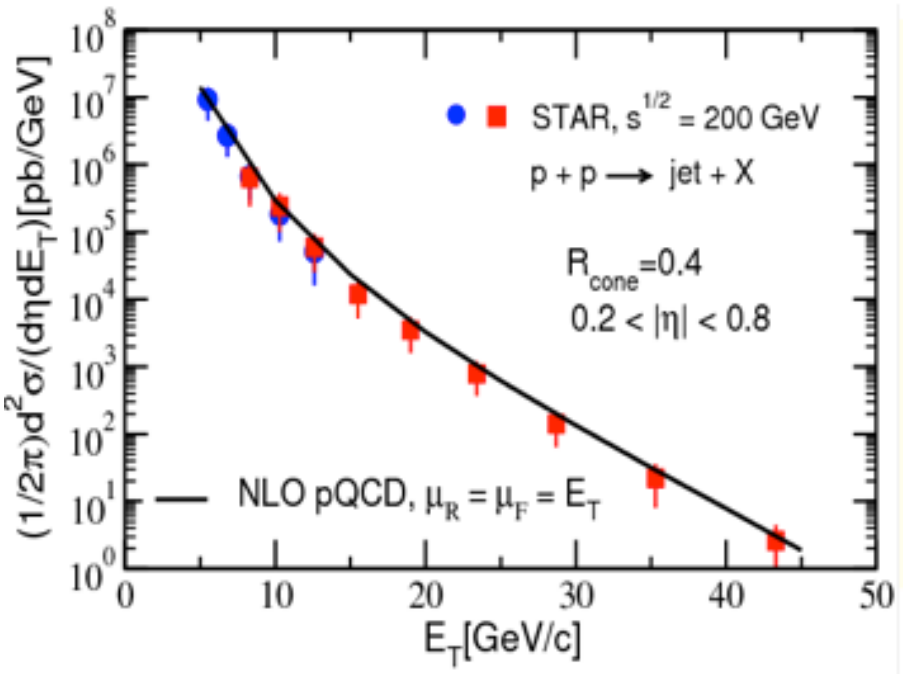
$$\psi_{\mathrm{tot.}}(r/R) = \frac{1}{\mathrm{Norm}} \int_{\epsilon=0}^{1} d\epsilon \sum_{q,g} P_{q,g}(\epsilon) \frac{1}{(1-(1-f_{q,g})\cdot\epsilon)^3} \times \frac{\sigma_{q,g}^{NN}(R,\omega^{\min})}{d^2 E_T' dy} \left[(1-\epsilon)\ \psi_{\mathrm{vac.}}^{q,g}(r/R) + f_{q,g}\cdot\epsilon\ \psi_{\mathrm{med.}}^{q,g}(r/R) \right]$$





Inclusive jet cross section in HIC at NLO

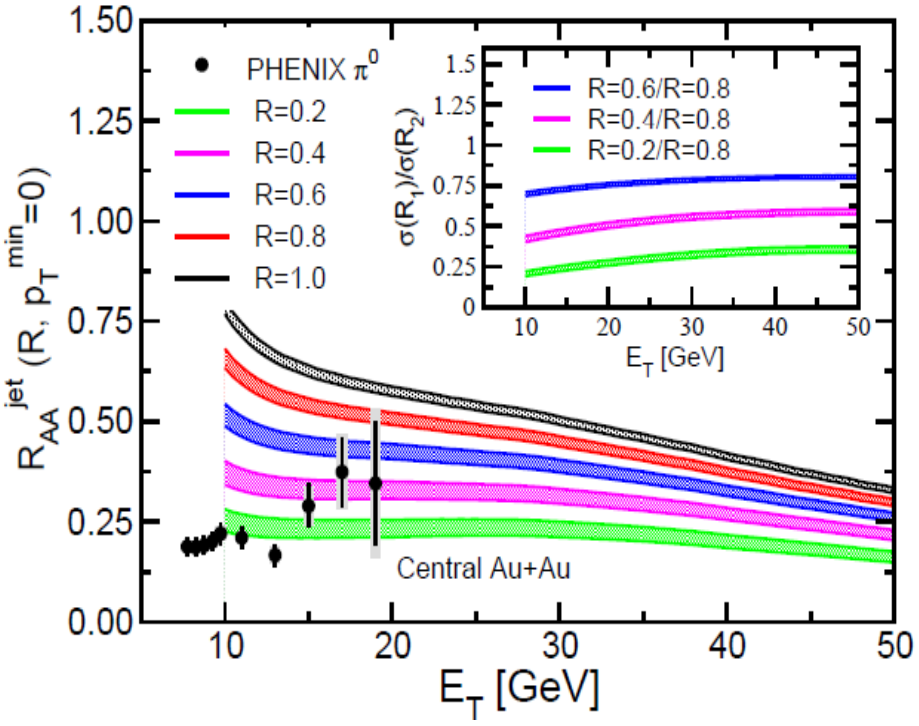


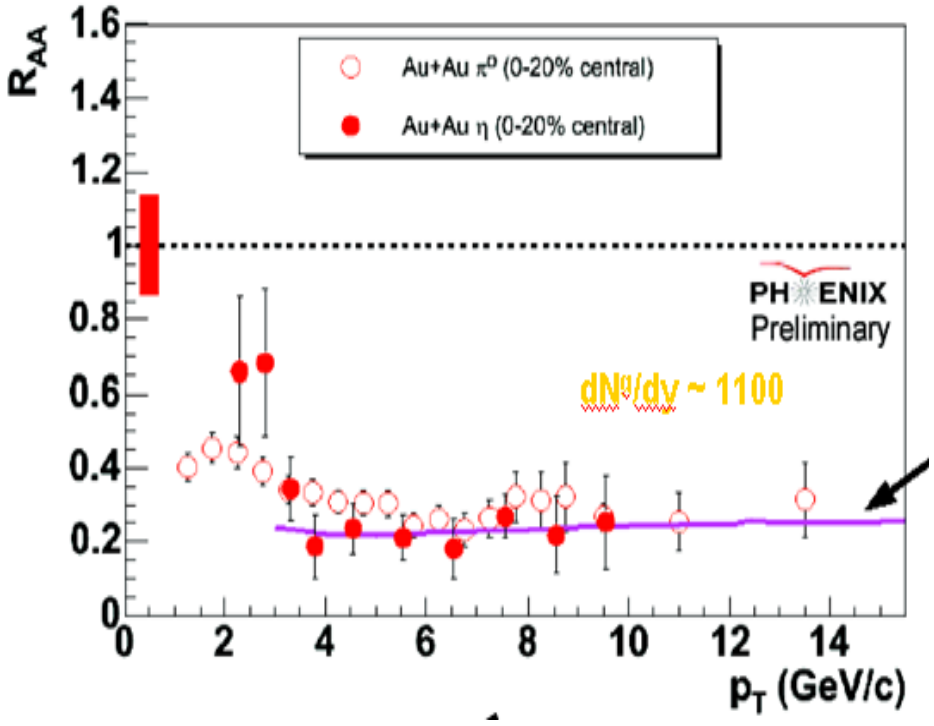


I Vitev, BWZ, PRL 104,132001 (2010), arXiv: 0910.1090.

Inclusive jets in A+A at RHIC

- R_{AA} for inclusive jets evolves continuously with cone size R;
- Ratios of jet cross sections at different R in p+p, Cu+Cu and Au+Au have a similar trend with different magnitudes.





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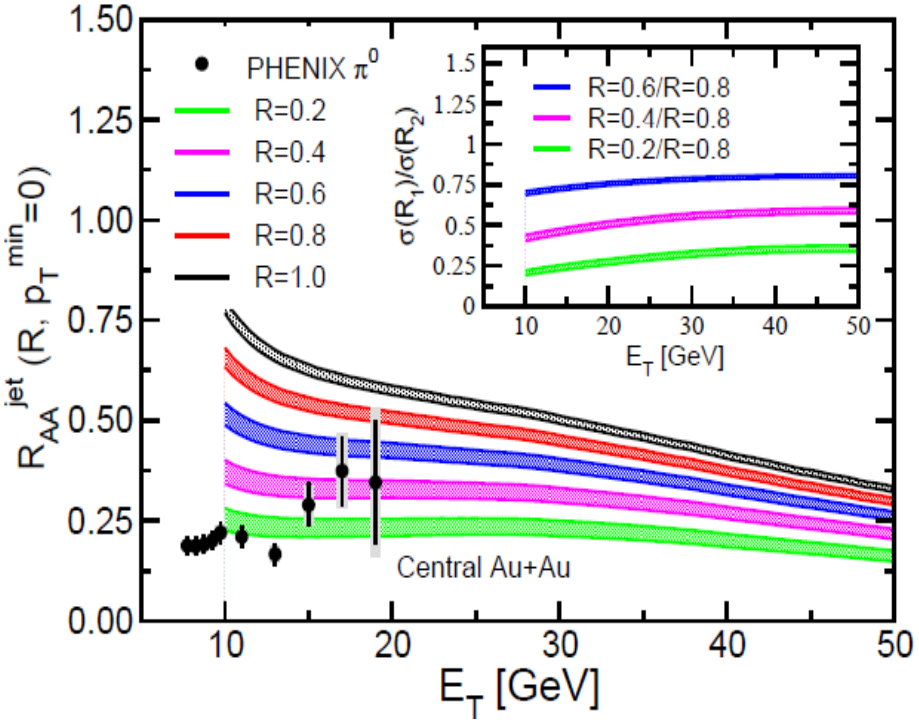
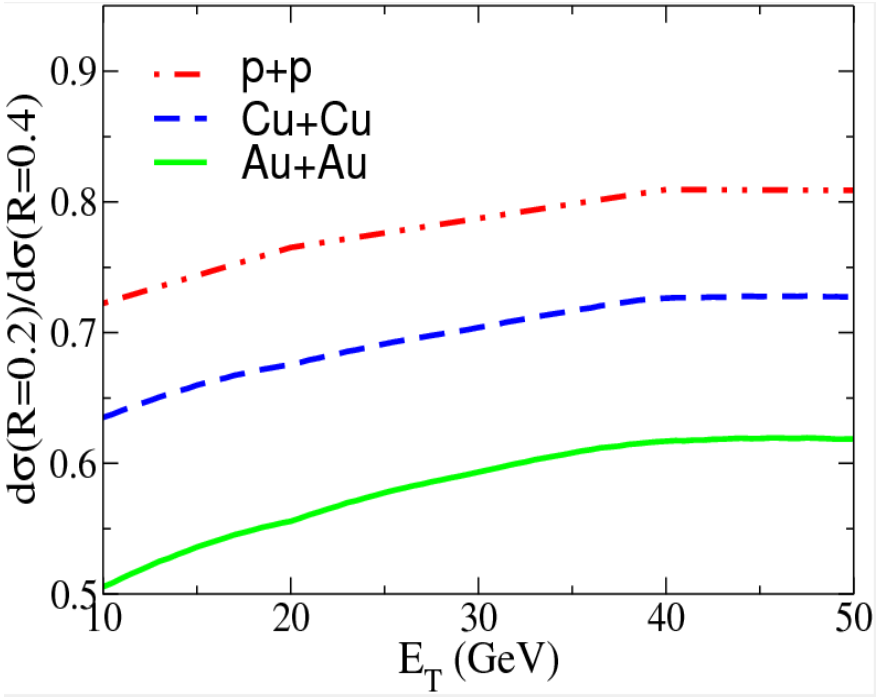
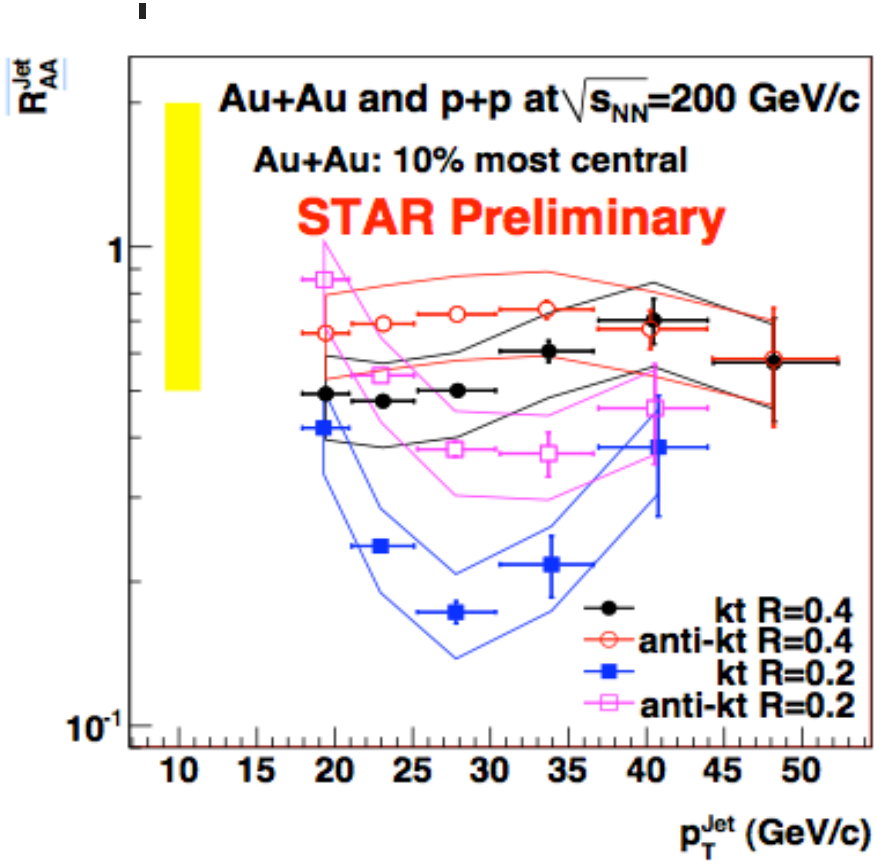
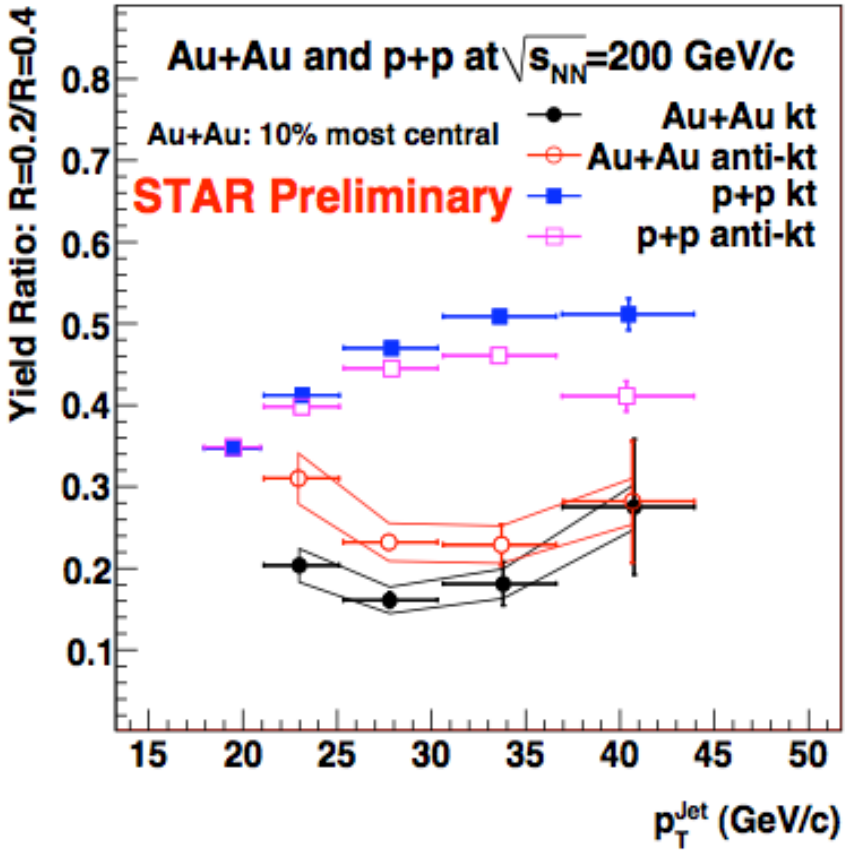




Jet measuring at RHIC



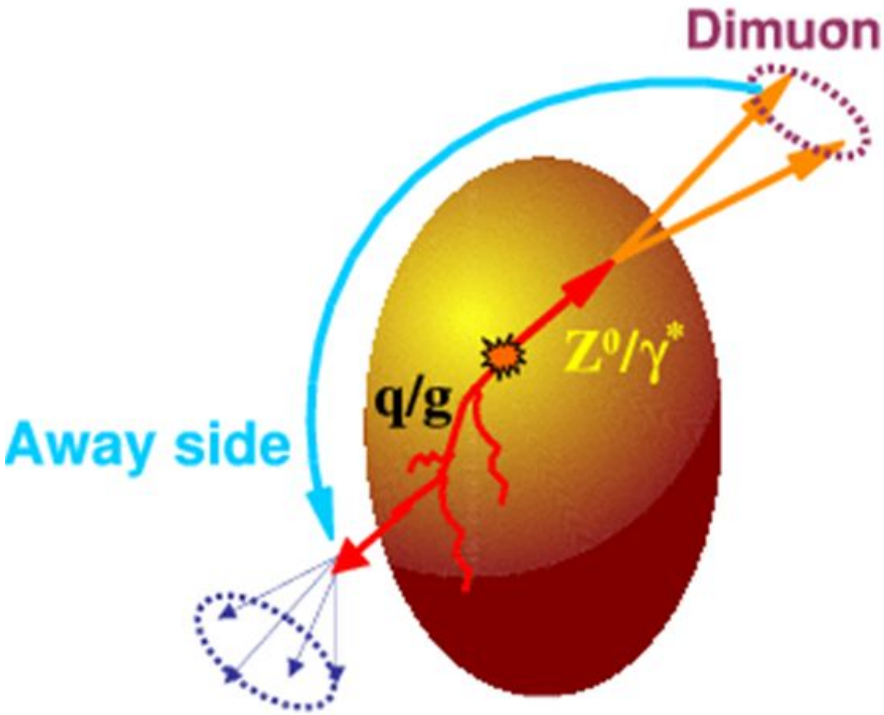


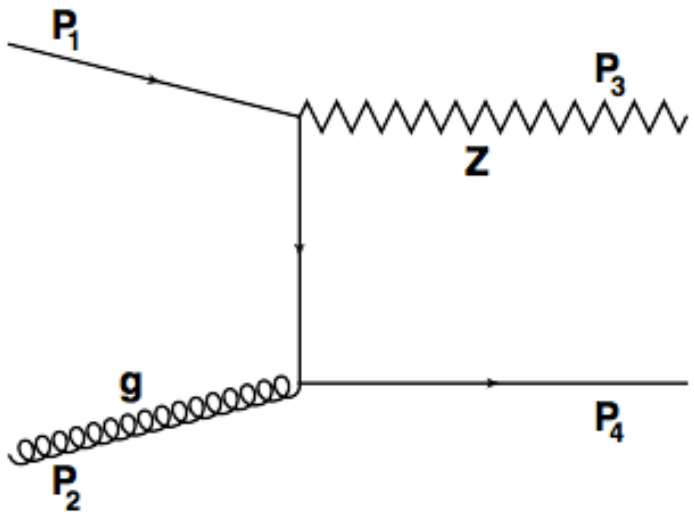
- Jets in Au+Au by STAR

M. Poloszkon et al, (2010)

S. Salur et al, (2010)

Tagged jet production in HIC at NLO

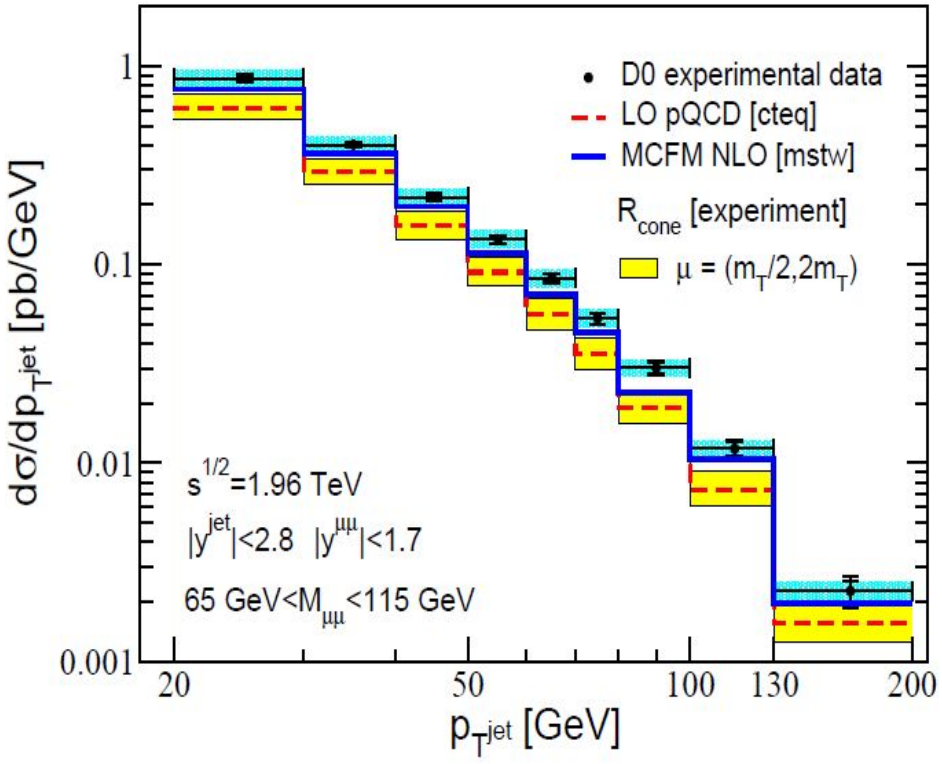


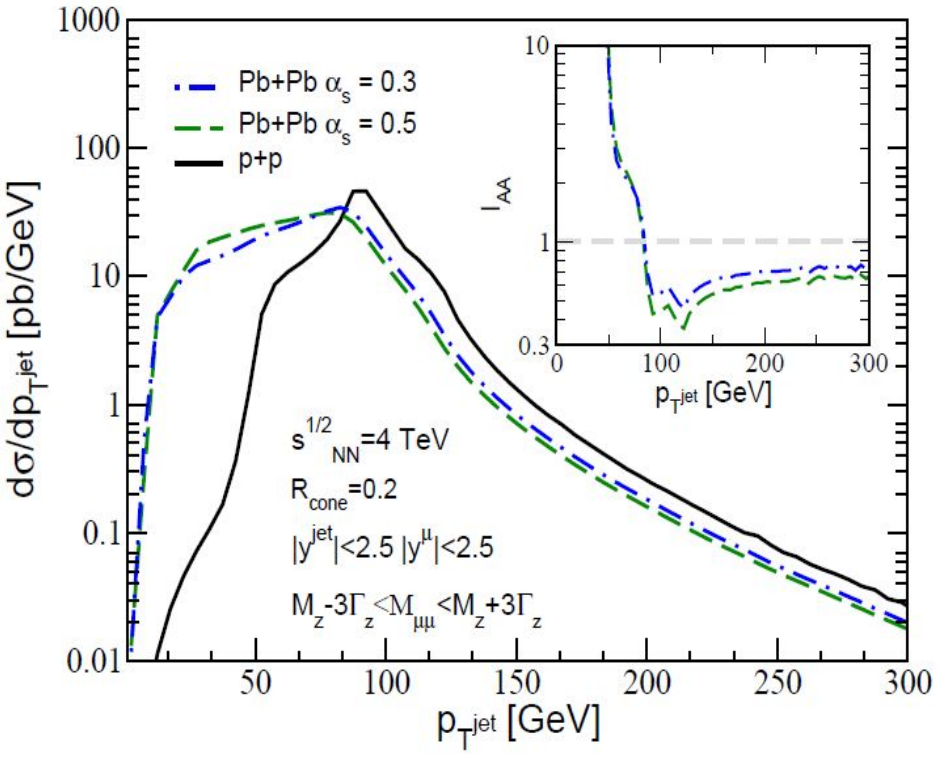


Neufeld, Vitev, BWZ, PRC 83, 034902 (2011).

Z^0 + jet in HIC

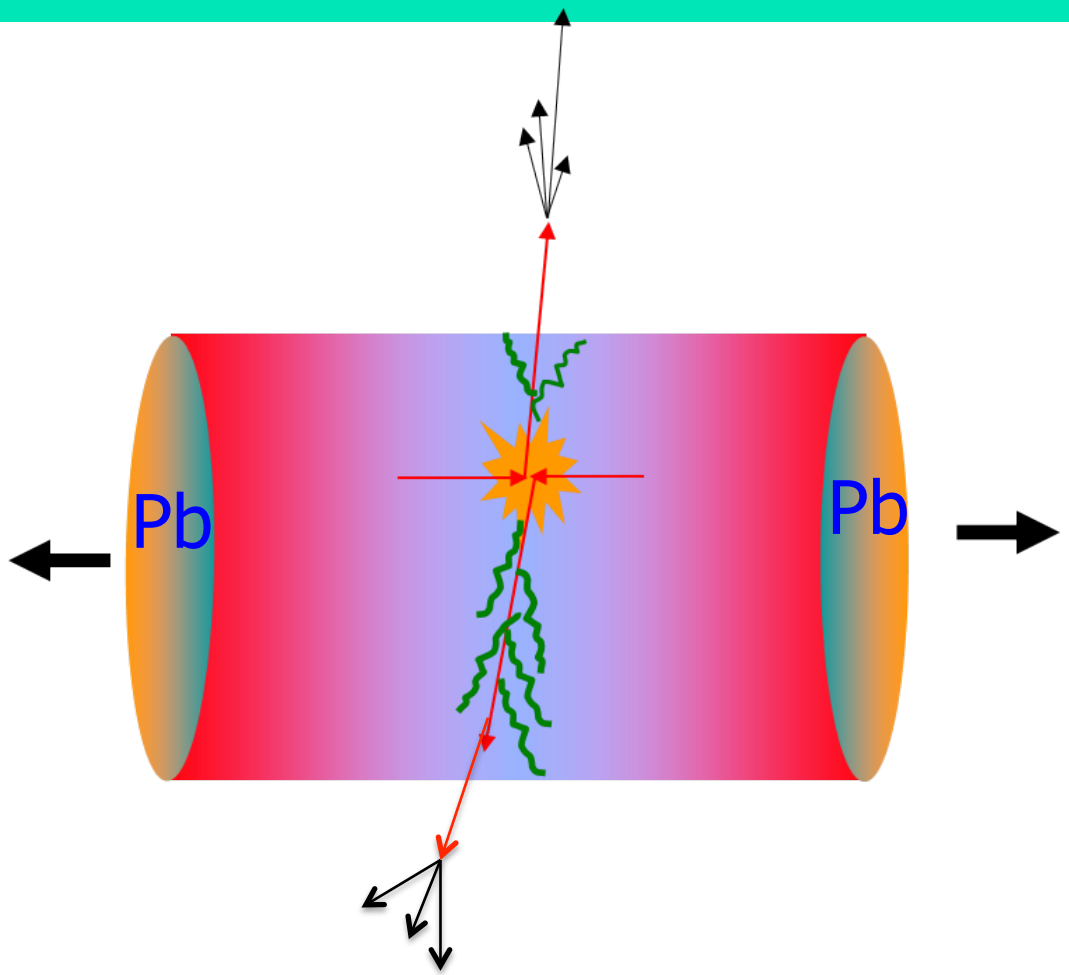
- The momentum balance is broken due to NLO contribution
- A sharp transition from tagged jet suppression above ~pT of Z to tagged jet enhancement below ~pT of Z





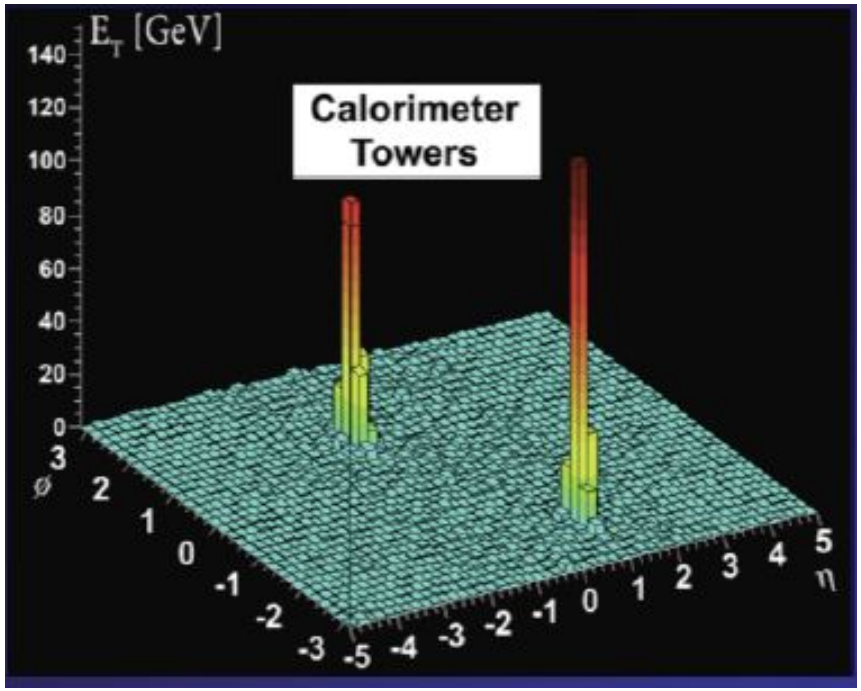
$p_T \in (92.5\text{GeV}, 112.5\text{GeV})$

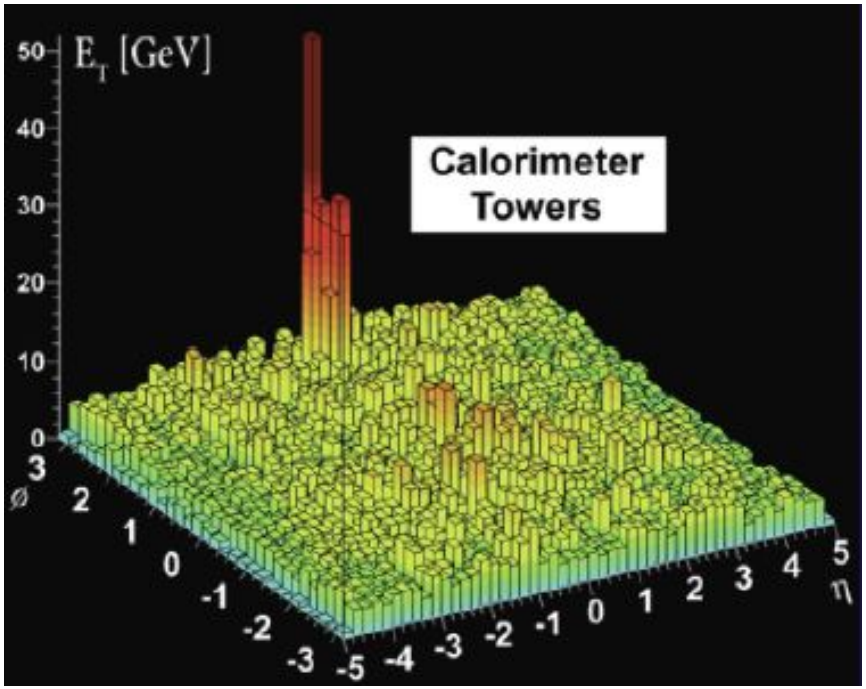
Dijet production in HIC at NLO



Dijet in Pb+Pb at LHC

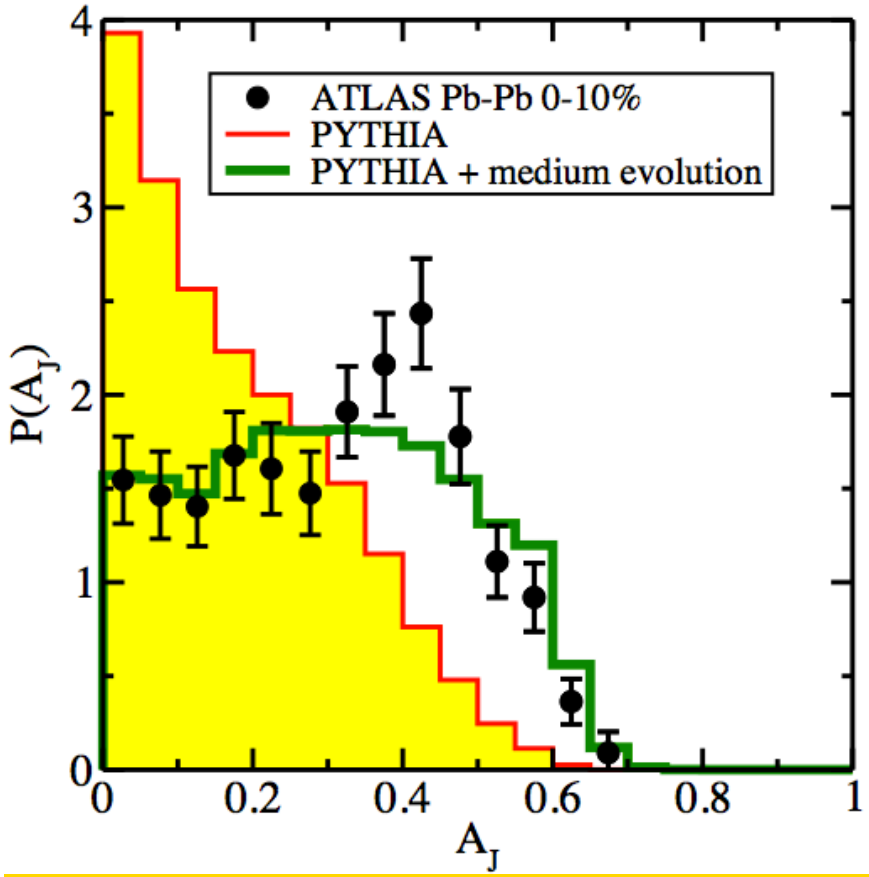
- Jet quenching at LHC has been observed for the first time in dijet productions at Pb+Pb by ATLAS and CMS。



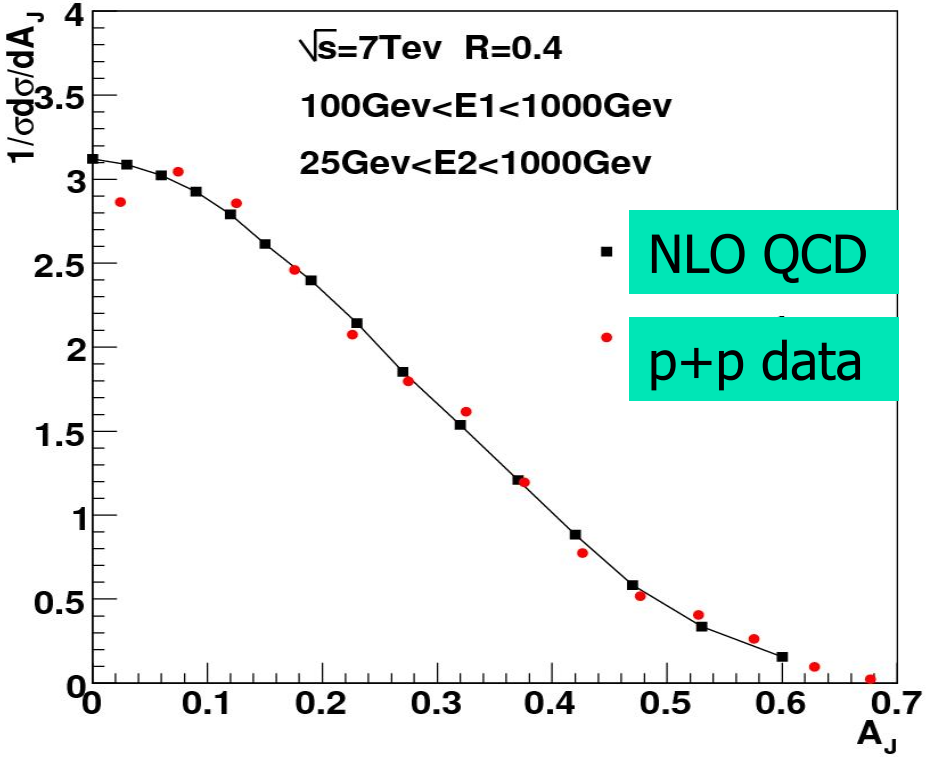


ATLAS, arXiv:1011.6182; CMS, arXiv: 1102.1957.

Dijet in HIC at NLO



$$A_J = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}, \Delta\phi > \frac{\pi}{2}$$



Casalderrey-Solana, et al, arXiv:1012.0745;

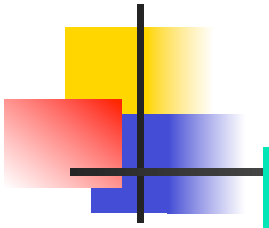
G Qin, B Muller, arXiv:1012.5280;

I Lokhtin, et al, arXiv:1103.1853;

Y He, Vitev, BWZ, E Wang， in progress.

Summary

- An entirely new frontier of HIC —— jet observables: jet shapes, inclusive jets, tagged jets, dijets, ...



非常感谢！

Thank you!