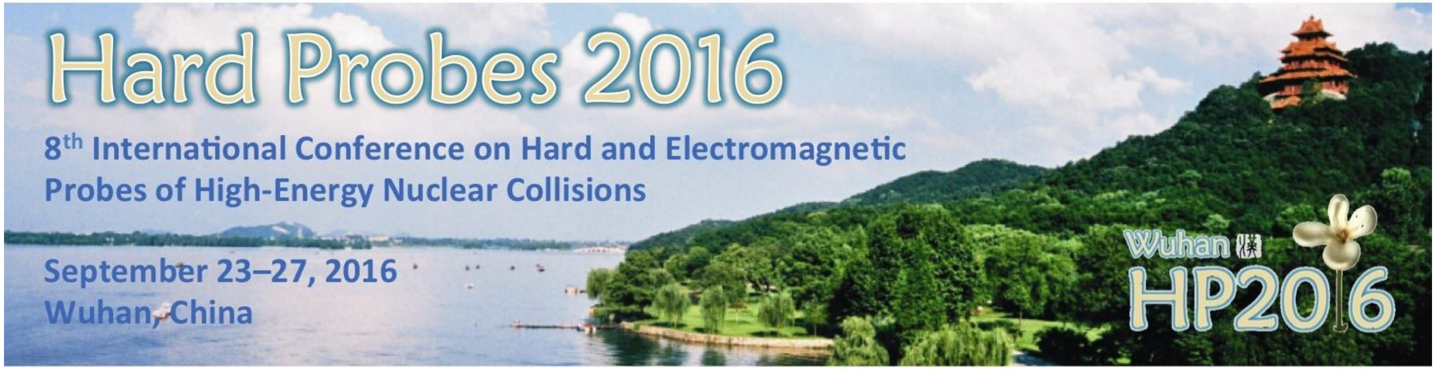


Energy flow in gamma-jets and dijet events in heavy-ion collisions

Tan Luo

Central China Normal University
Institute of Particle Physics

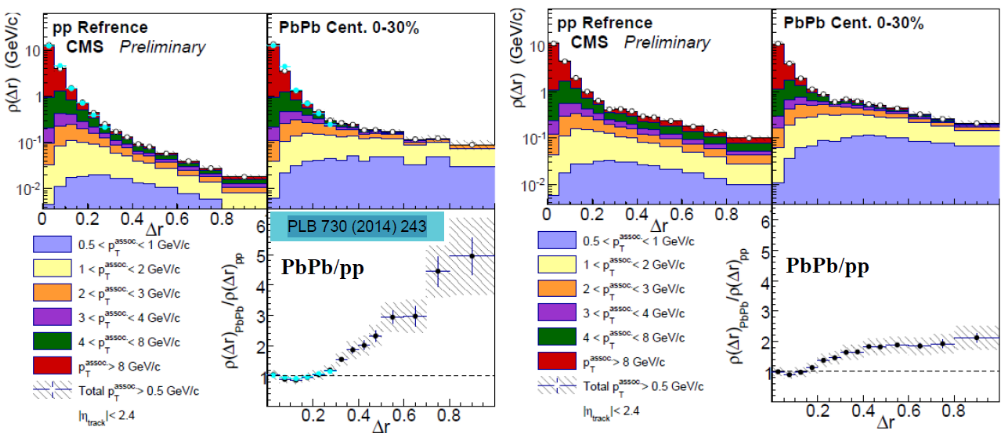
In collaboration with
Shanshan Cao, Wei Chen, Yayun He, Longgang Pang, Enke Wang, Xin-Nian Wang, and Yan Zhu

Outline

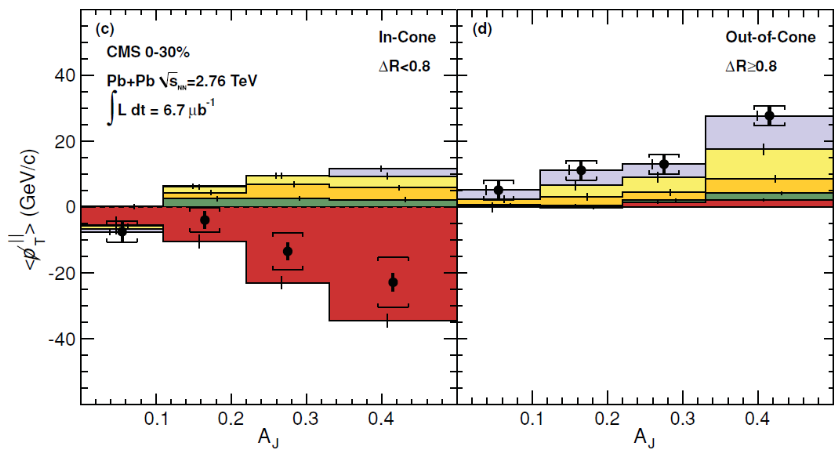
- Introduction
- Jet propagation within a Linearized Boltzmann Transport (LBT) model
- Gamma-jets and Dijet in heavy-ion collisions
- Summary and Outlook

Introduction

The jet shape and transverse momentum imbalance in Dijet events



arXiv:1609.02466 CMS

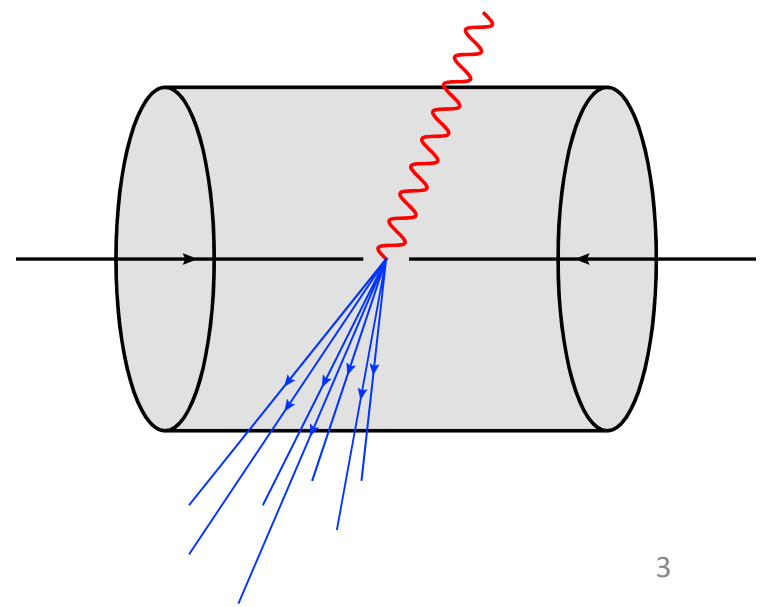


Phys. Rev. C 84, 024906 CMS

Gamma-jet → *The golden channel*

XN Wang, Z Huang Phys. Rev. Lett. 77, 231 (1996)

- High PT photons are unmodified by the medium
- No "surface bias" in triggered events which dijet events suffer



Boltzmann Equation:

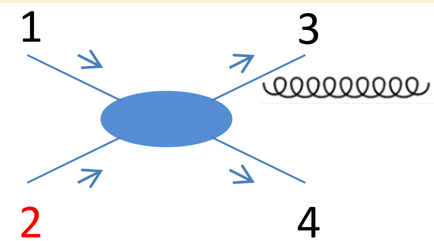
Jet-induced medium partons in LBT Model

$$p_1 \cdot \partial f_1(p_1) = -\int dp_2 dp_3 dp_4 (f_1 f_2 - f_3 f_4)|M_{12\to 34}|^2 \times (2\pi)^4 \delta^4(P_1 + P_2 - P_3 - P_4)$$ + radiation

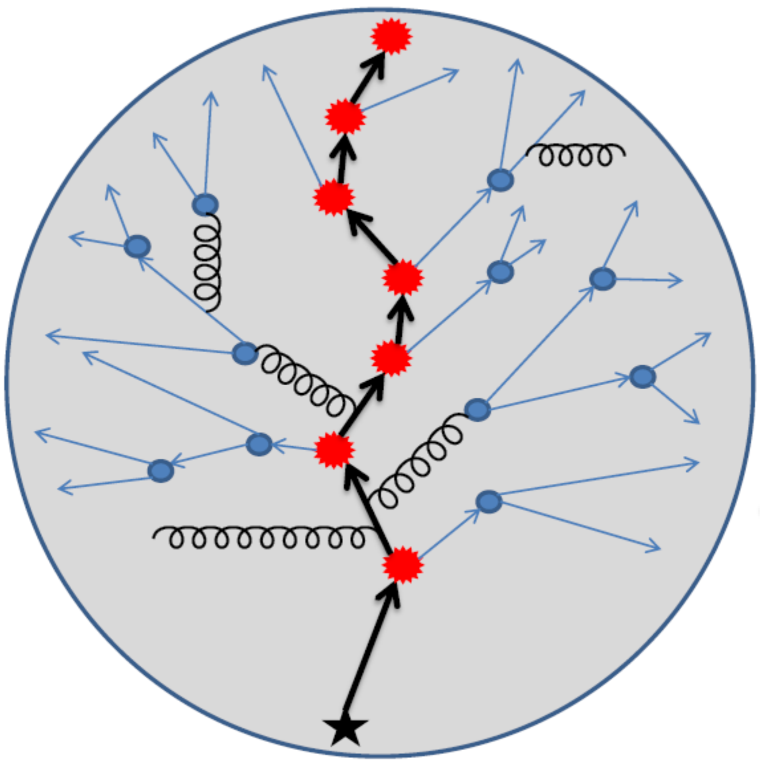
$$dp_i \equiv \frac{d^3 p_i}{2E_i(2\pi)^3},$$

Complete set of 2-2 processes

$$f_i = 1/(e_i^{p.u/T} \pm 1)(i = 2,4), f_i = (2\pi)^3 \delta^3(\vec{p} - \vec{p}_i)\delta^3(\vec{x} - \vec{x}_i)(i = 1,3)$$



Linearized Boltzmann jet transport



Medium Excitation

- Elastic collision + Induced gluon radiation.
- Follow the propagation of recoiled parton
- Include recoiled parton in jet reconstruction

Jet-induced medium partons

Global energy momentum conservation

Xin-Nian Wang, Yan Zhu
Phys.Rev.Lett. 111, 062301

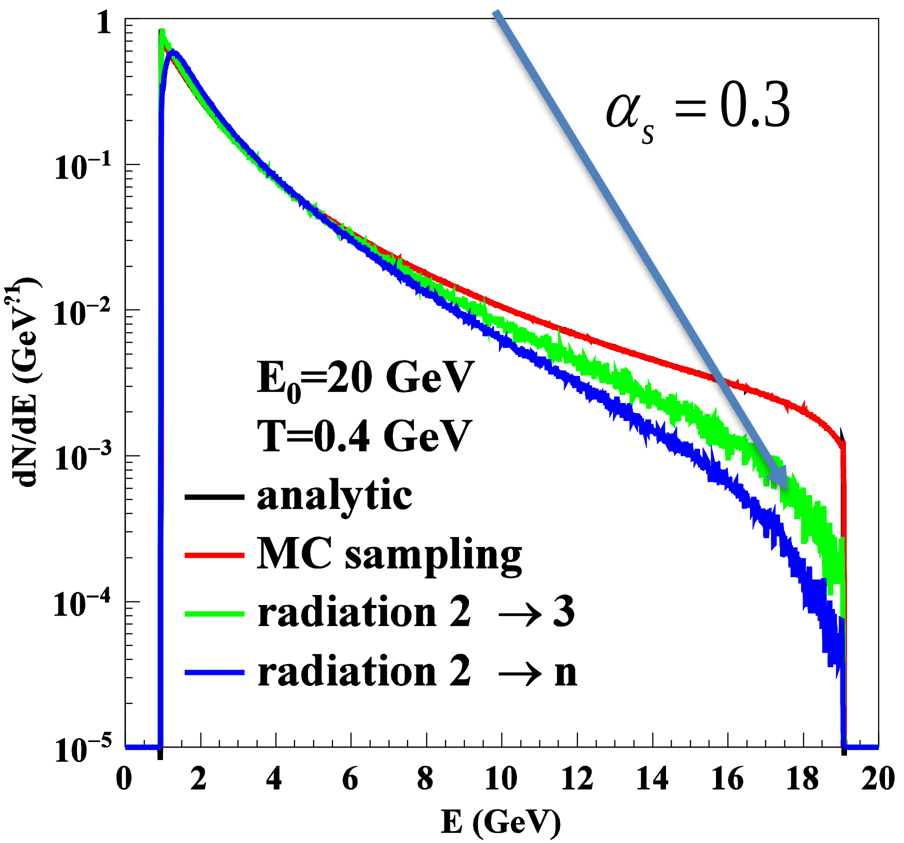
X. Guo, X. Wang
Nucl.Phys. **A696** (2001) 788-832

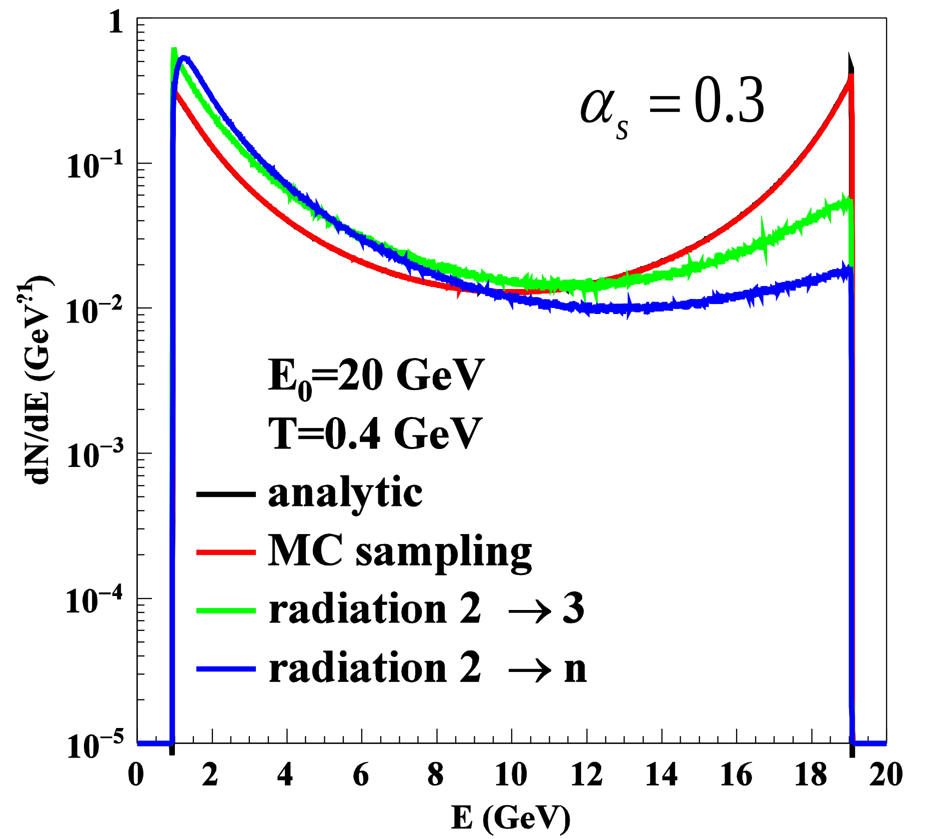
$$\frac{dNg}{dx dk_\perp^2 dt} = \frac{2C_A \alpha_s P(x)\hat{q}}{\pi k_\perp^4} \sin^2 \frac{t-t_i}{2\tau_f}$$

$$\tau_f = 2Ex(1-x)/k_\perp^2 \qquad P(N_g, \langle N_g \rangle) = \frac{\langle N_g \rangle^{N_g} e^{-\langle N_g \rangle}}{N_g!}$$

Energy distribution of the radiated gluon

Total energy momentum Conservation in 2→ n



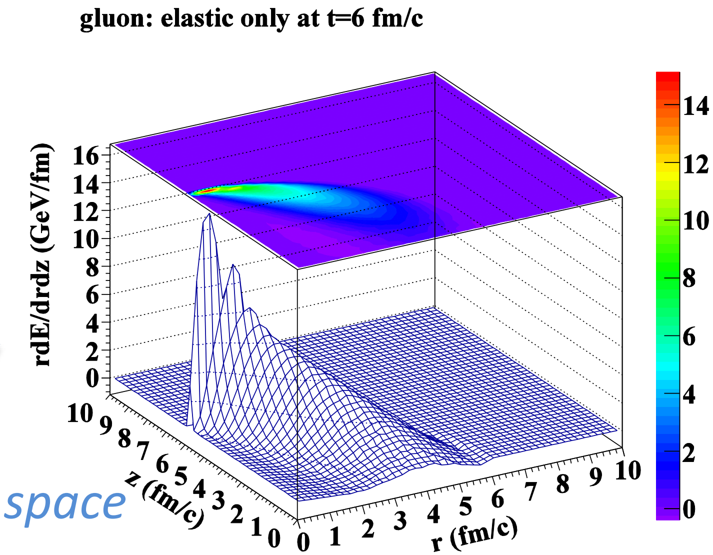


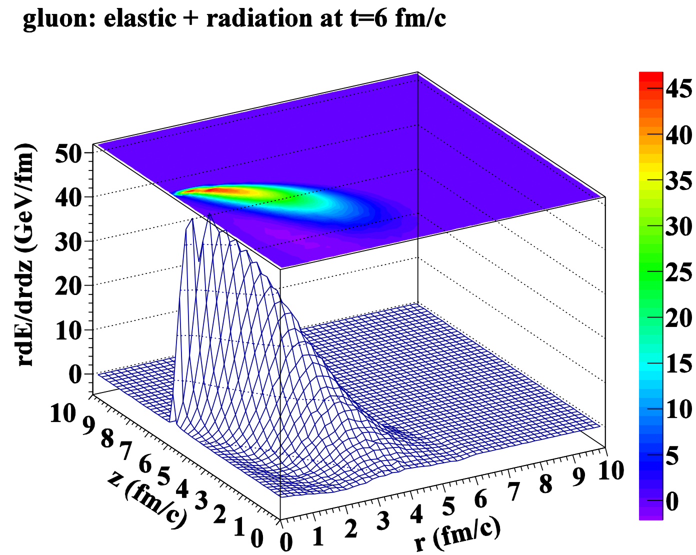
Jet induced medium excitation

Elastic only | Elastic + Radiation

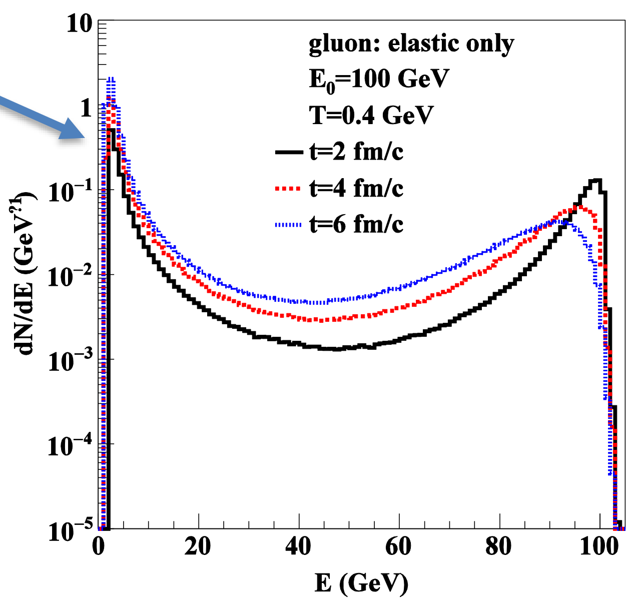
Propagation of a single initial jet parton in a uniform medium

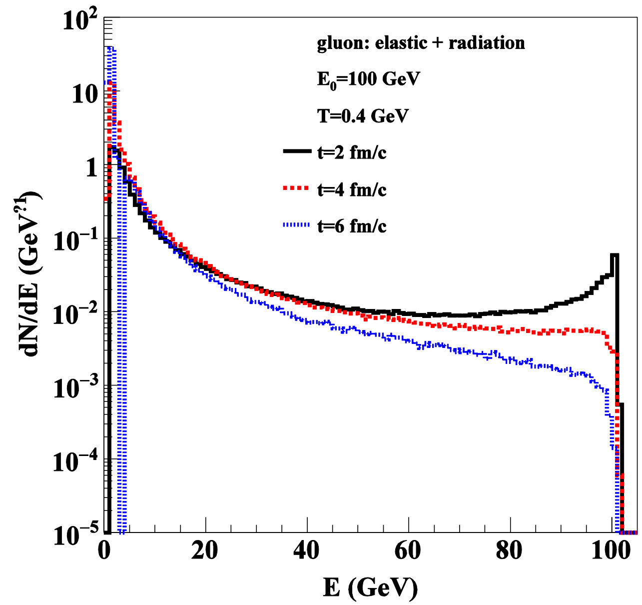
Energy distribution in space





Energy distribution at different Time





Initial jet parton: gluon

E = 100 GeV

T = 0.4 GeV

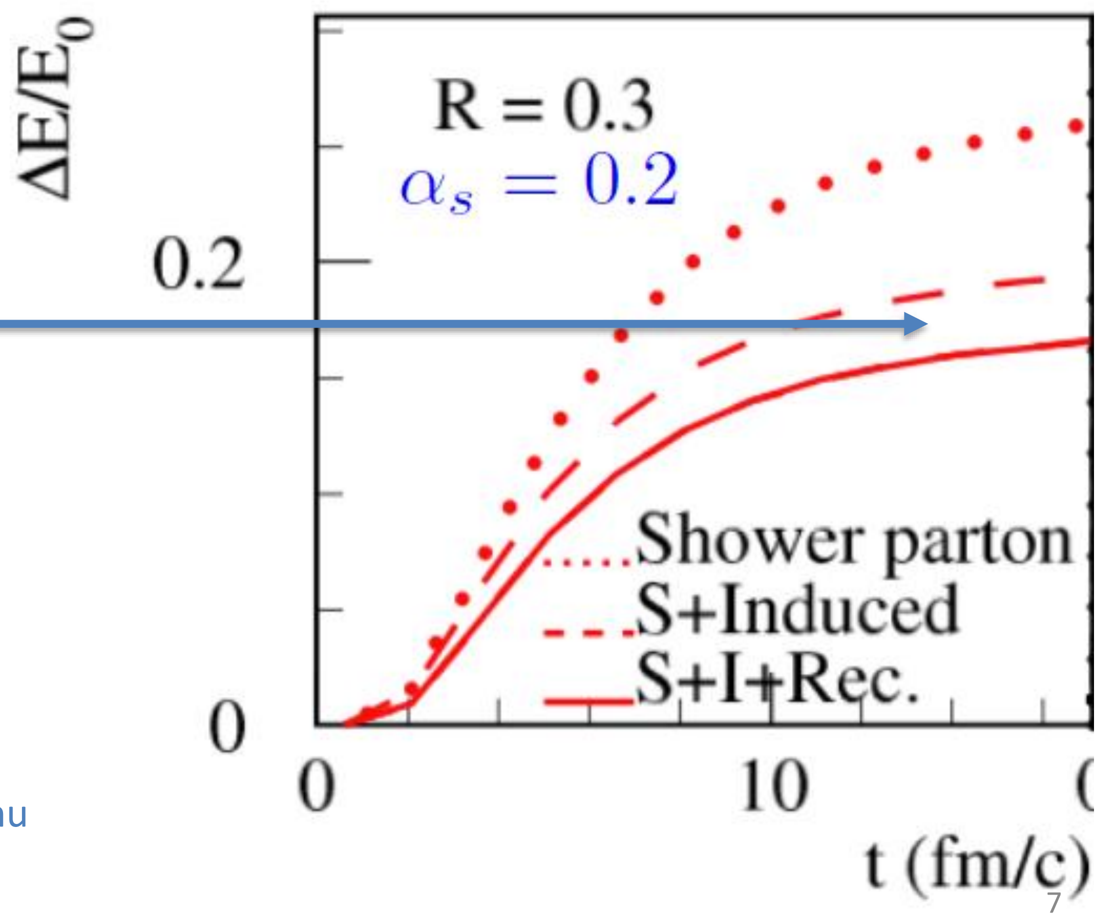
$\alpha_s = 0.3$

Jets in a 3+1D hydro

- 3+1D Ideal hydro Longgang Pang, Qun Wang, Xin-Nian Wang Phys.Rev. C86 (2012) 024911
- Location of gamma-jet is decided according probability of binary collision.

Recoiled effect in the reconstructed jets

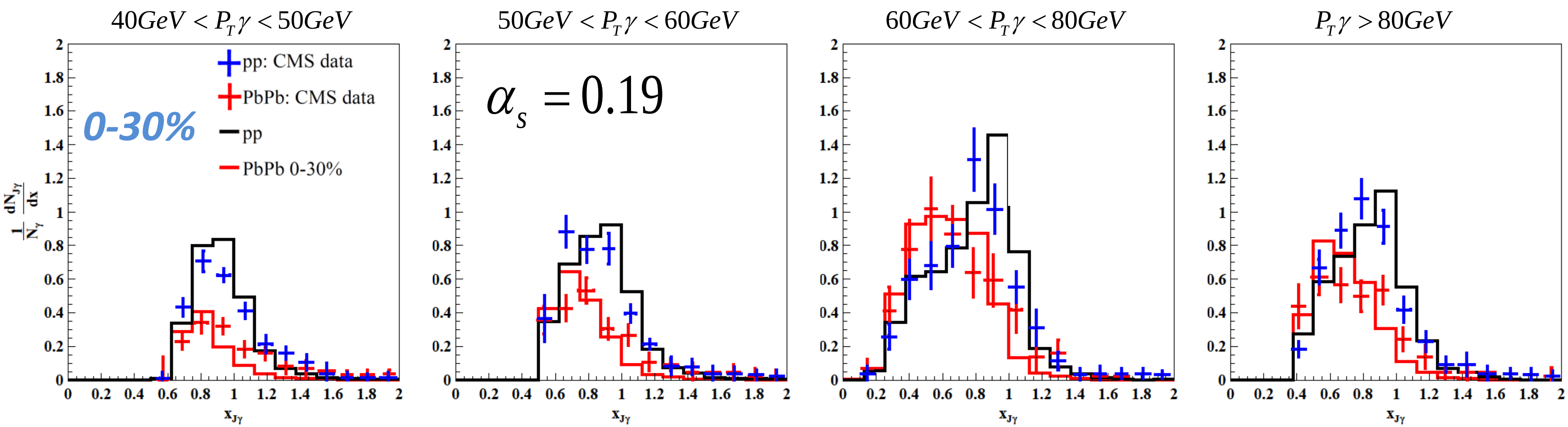
The contribution of the recoiled parton in the reconstructed jets



HL Li, FM Liu, GL Ma, XN Wang, Y Zhu
Phys.Rev.Lett. 106, 012301
Xin-Nian Wang, Yan Zhu
Phys.Rev.Lett. 111, 062301
Yayun He, Tan Luo, Xin-Nian Wang, Yan Zhu
Phys.Rev. C91 (2015) 054908

Asymmetry distribution of gamma-jets in heavy-ion collisions

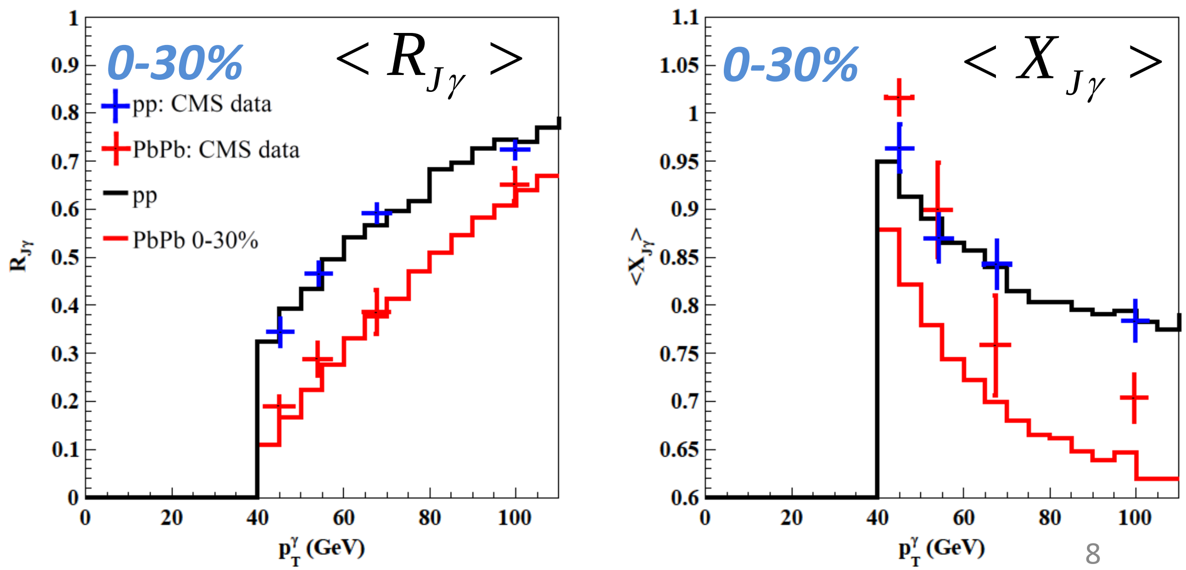
- fix the parameter α_s via the comparison with the γ-jet asymmetry



$|\eta_\gamma| < 1.44$

$P_{Tjet} > 30GeV$

$|\eta_{jet}| < 1.6$

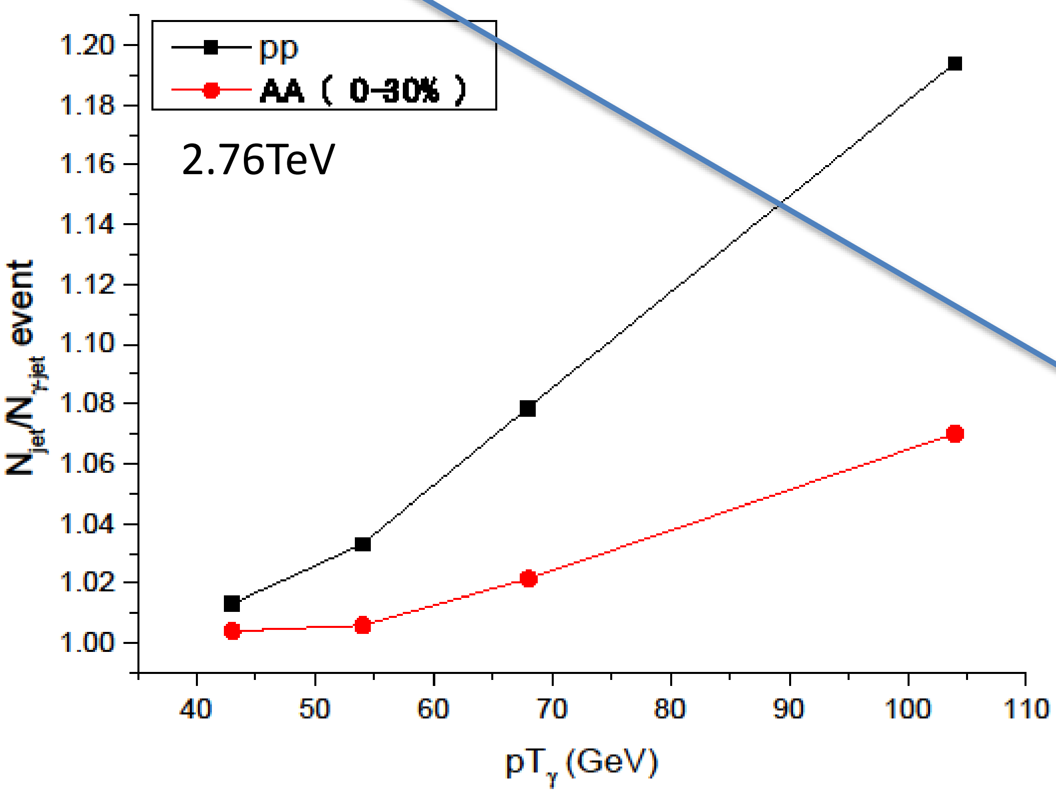


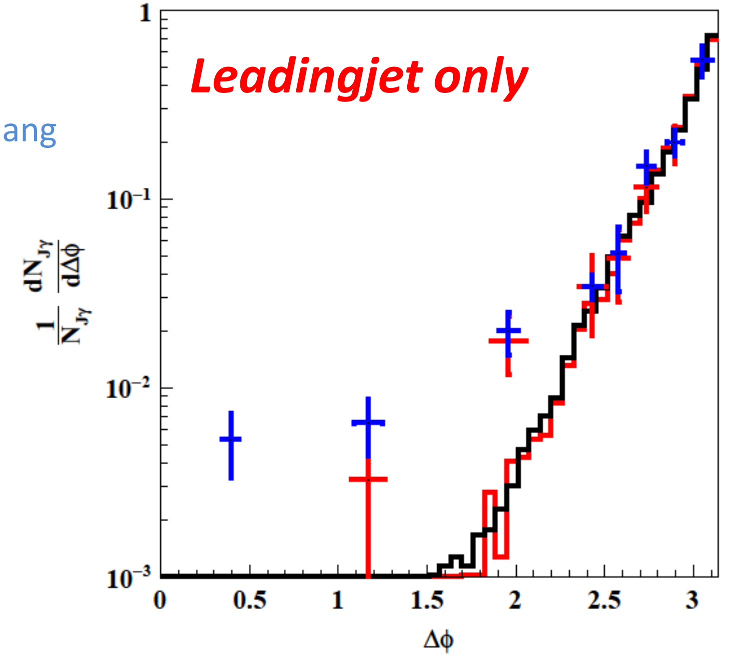
Azimuthal distribution of gamma-jets in heavy-ion collisions

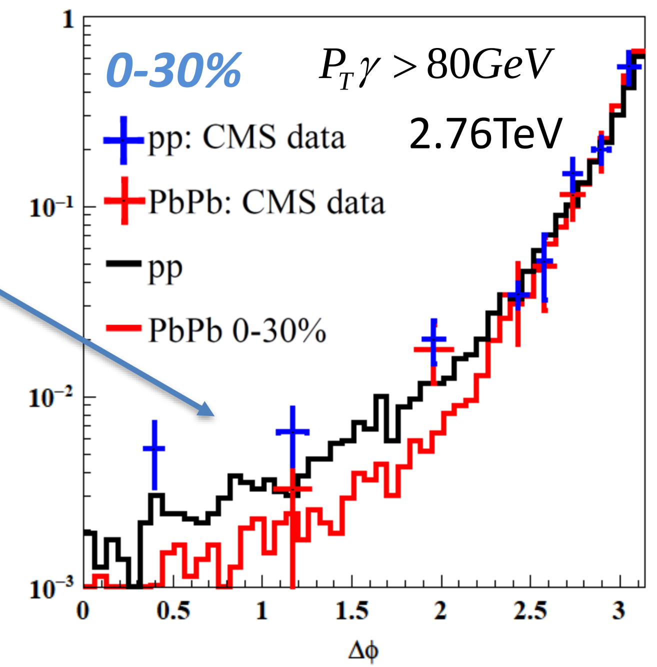
- Dominance of the initial state radiation in angular correlation

L Chen, GY Qin, SY Wei, BW Xiao, HZ Zhang
arXiv:1607.01932
A. H. Mueller, B Wu, BW Xiao, F Yuan
arXiv:1604.04250

- Multiple jets in gamma-jets events



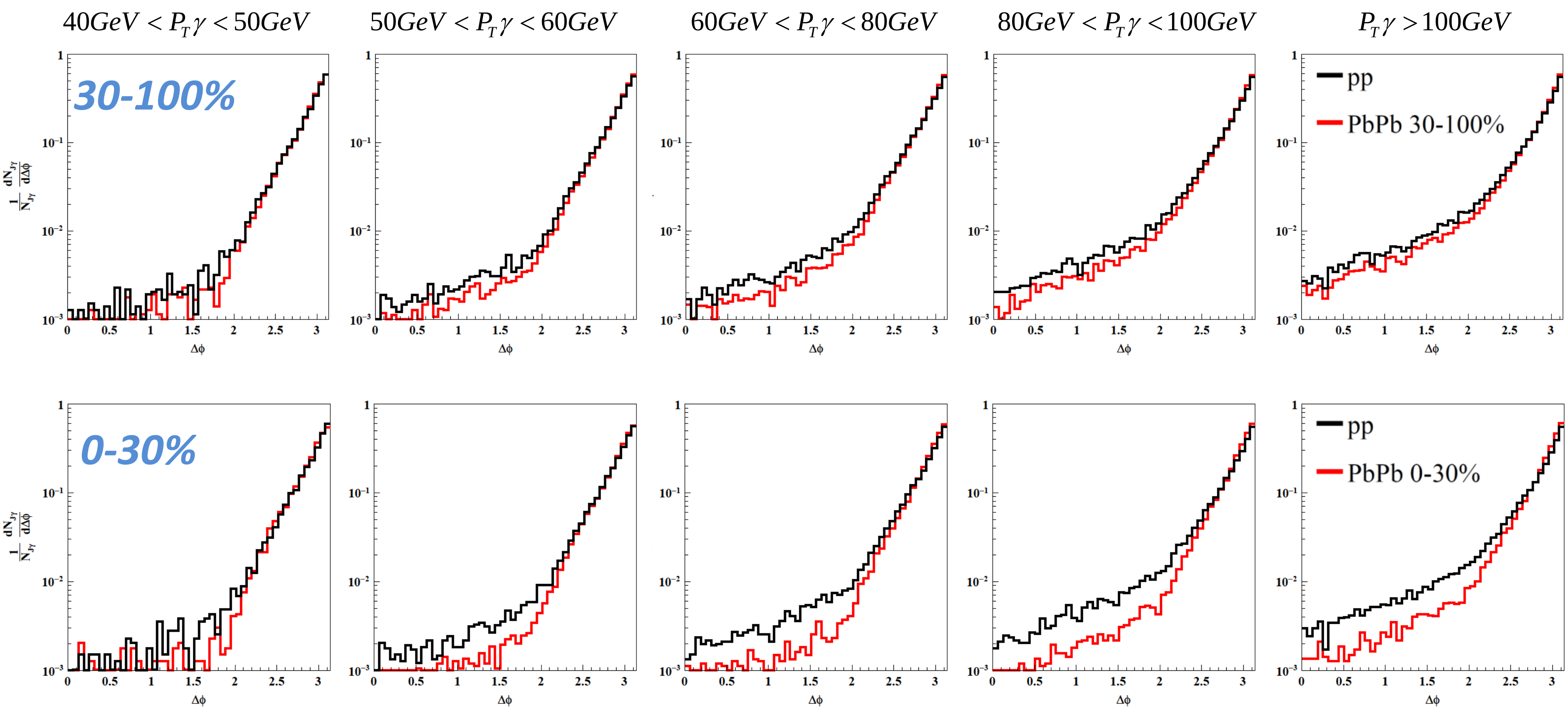




Azimuthal distribution of gamma-jets in heavy-ion collisions

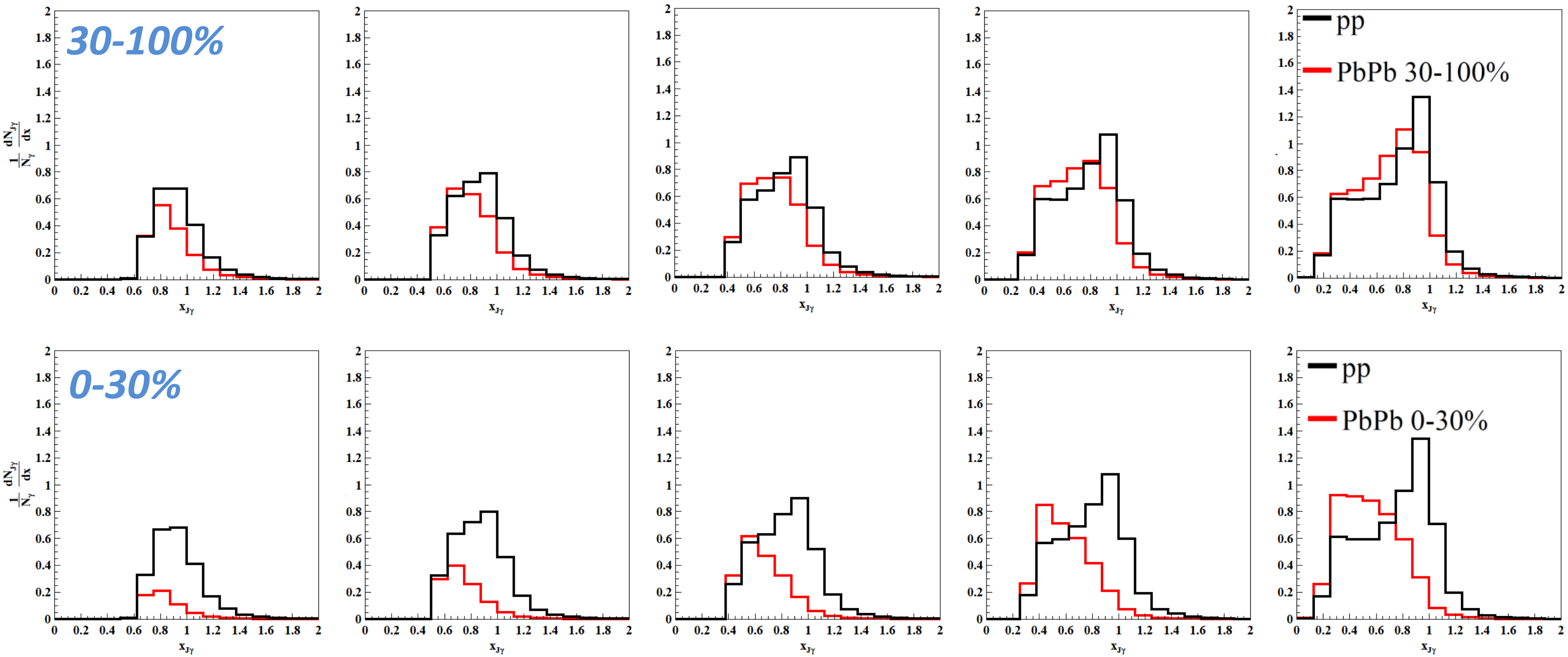
5.02TeV

$|\eta_\gamma| < 1.44, P_{Tjet} > 30GeV, |\eta_{jet}| < 1.6$



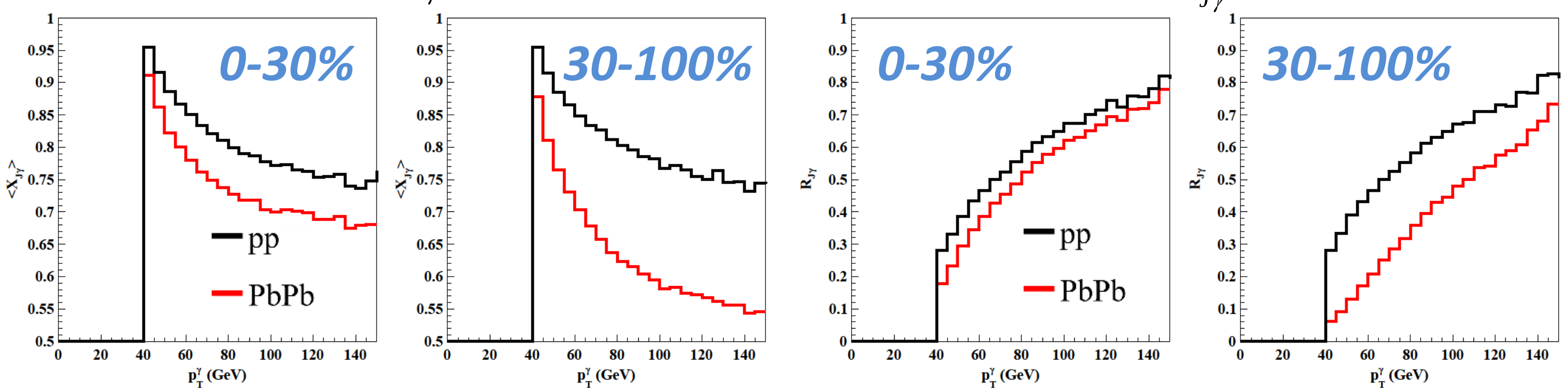
Asymmetry distribution of gamma-jets in heavy-ion collisions

$40GeV < P_T\gamma < 50GeV$ | $50GeV < P_T\gamma < 60GeV$ | $60GeV < P_T\gamma < 80GeV$ | $80GeV < P_T\gamma < 100GeV$ | $P_T\gamma > 100GeV$



5.02TeV

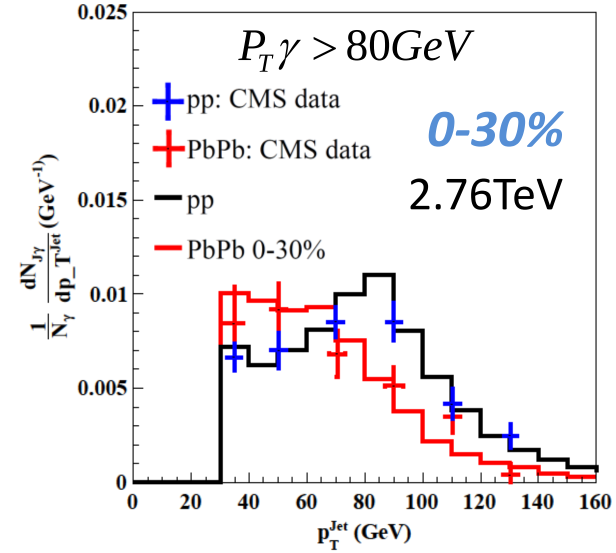
$< X_{J\gamma} >$ $< R_{J\gamma} >$

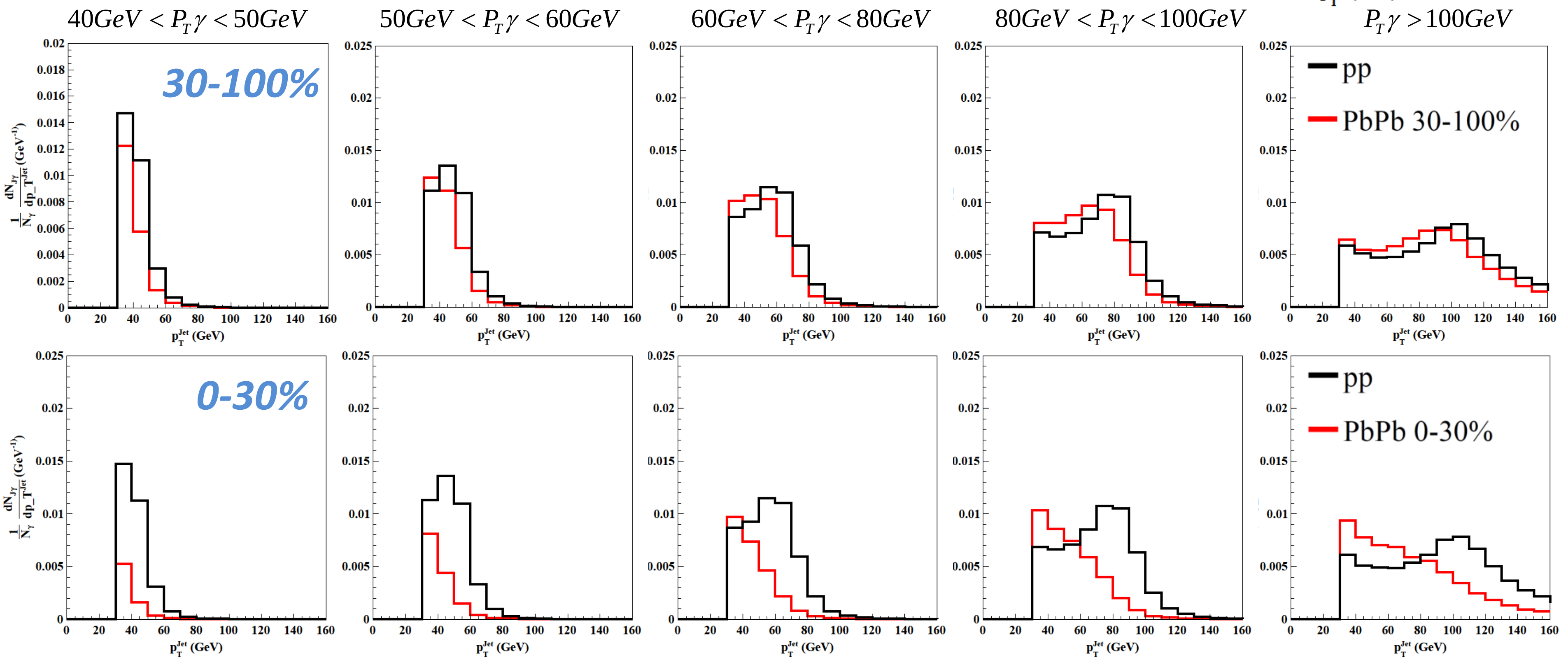


pT distribution of gamma-jets in heavy-ion collisions

- Shift of the peak of the pt distribution
- Path length dependence of the energy loss

5.02TeV $\Delta\phi_{J\gamma} > 7/8\pi$

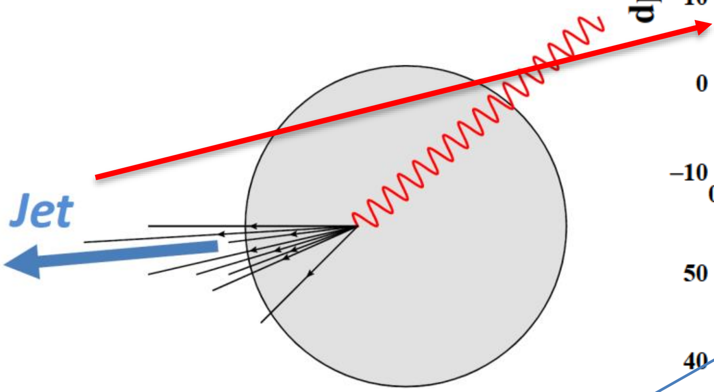


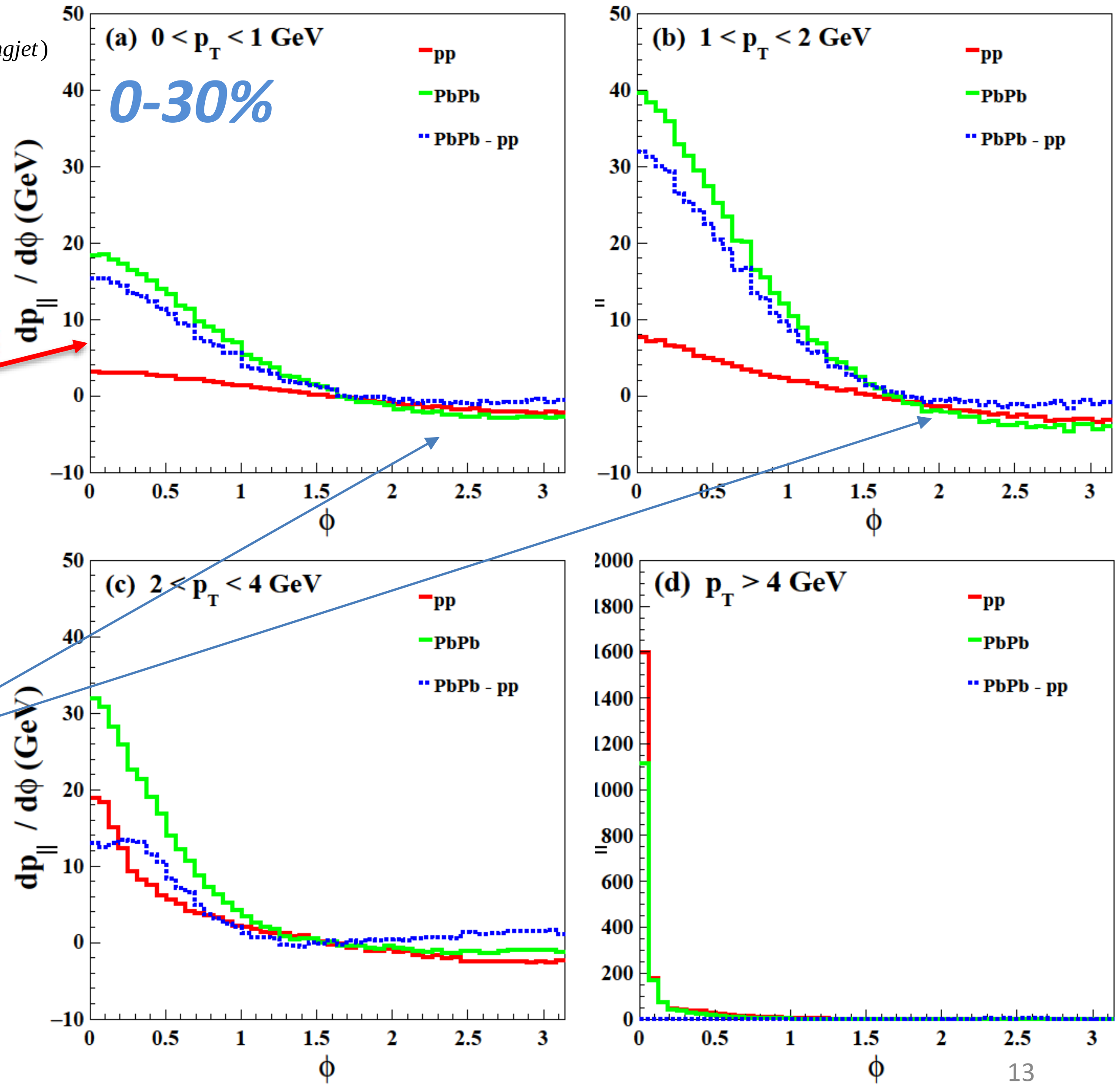


Energy flow in gamma-jets events

$$P_{\parallel} = \sum_i P_{i(parton)} * \cos\theta_{i(parton-leadingjet)}$$

$$\phi = |\phi_{parton} - \phi_{leadingjet}|$$





- Energy flow to the opposite direction of the jet

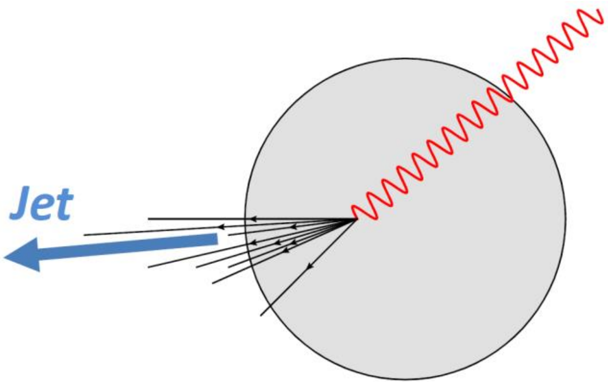
$$P_{T_\gamma} > 100GeV, |\eta_\gamma| < 1.44$$

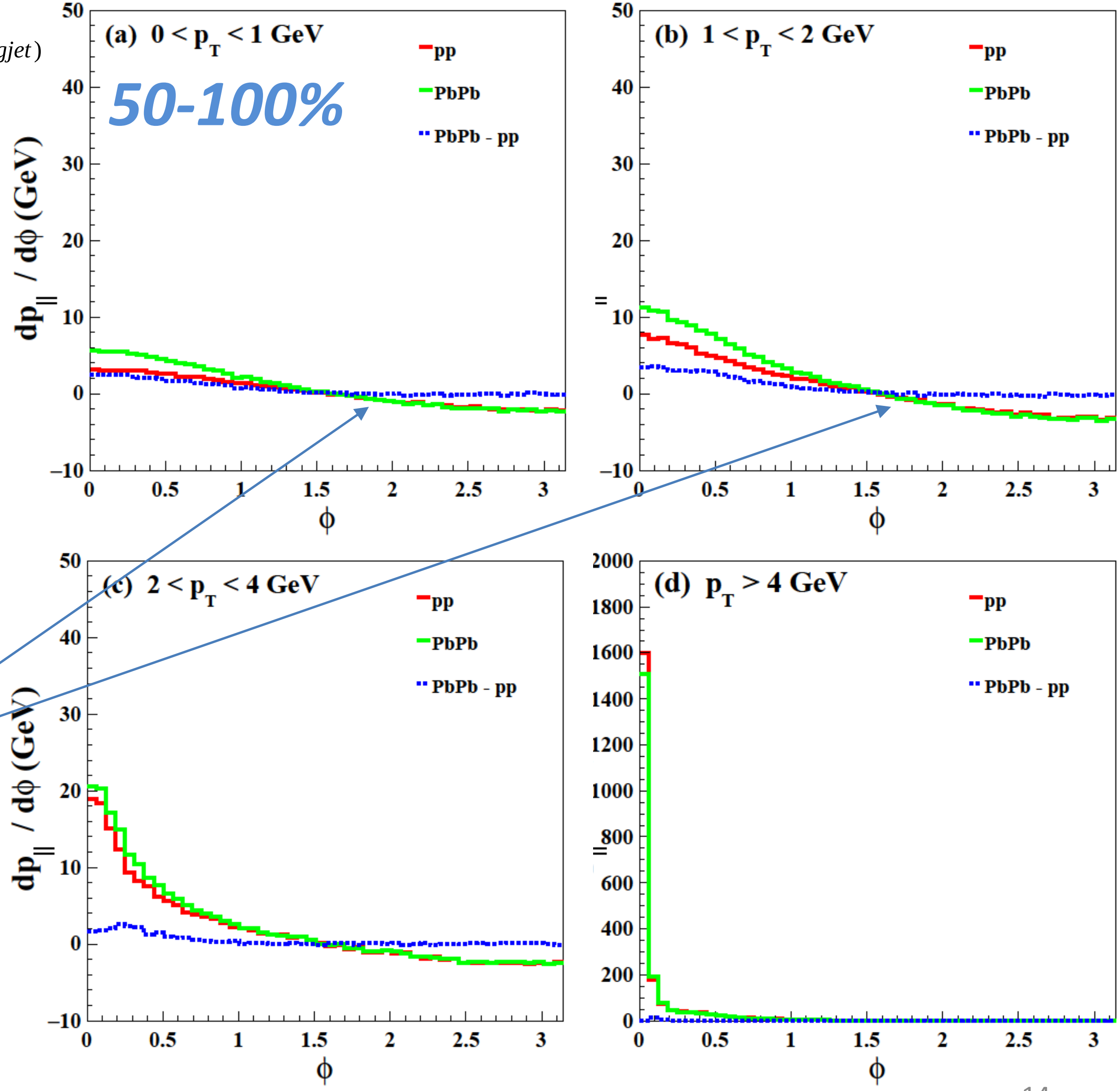
$$P_{Tjet} > 30GeV, |\eta_{jet}| < 1.6$$

Energy flow in gamma-jets events

$$P_{\parallel} = \sum_i P_{i(parton)} * \cos\theta_{i(parton-leadingjet)}$$

$$\phi = | \phi_{parton} - \phi_{leadingjet} |$$





- Energy flow to the opposite direction of the jet

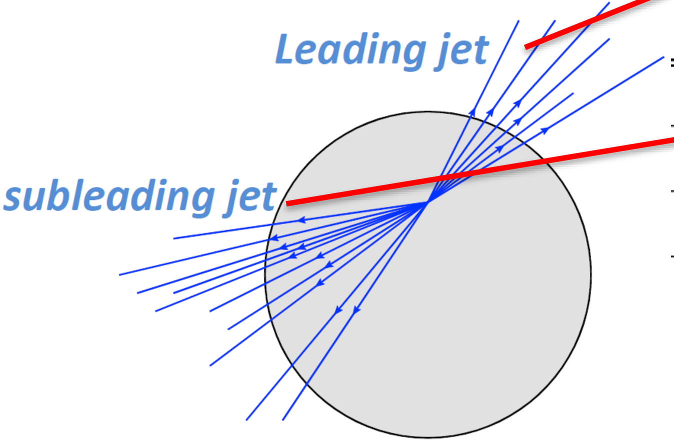
$$P_{T_\gamma} > 100 GeV, |\eta_\gamma| < 1.44$$

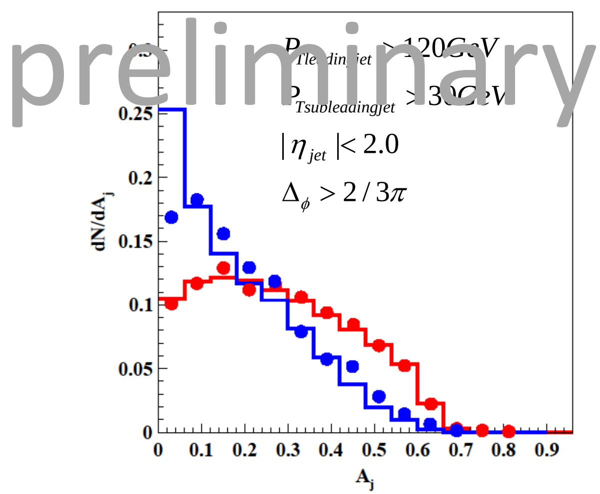
$$P_{Tjet} > 30 GeV, |\eta_{jet}| < 1.6$$

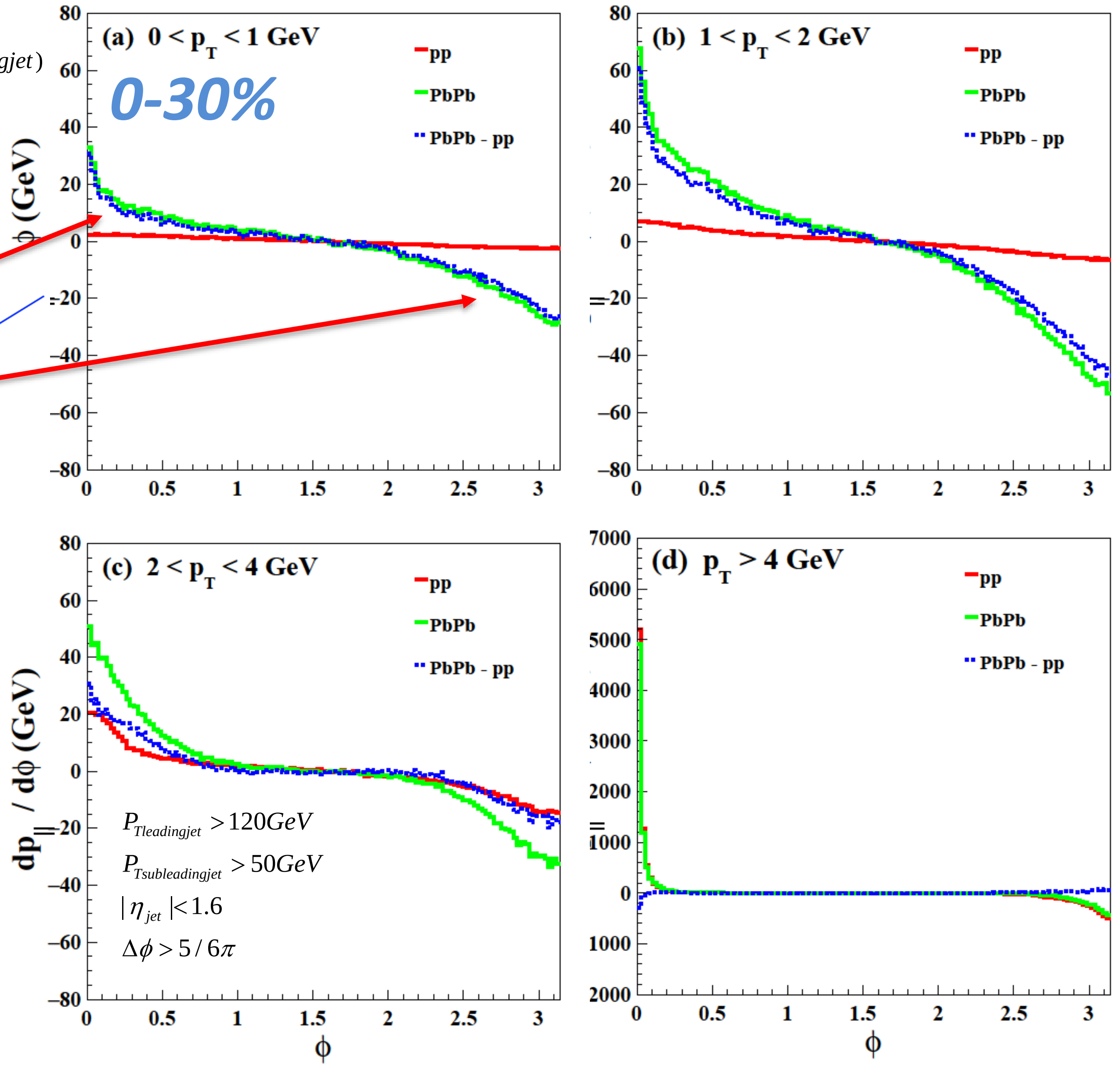
Energy flow in dijet events

$$P_{\|} = \sum_i P_{i(parton)} * \cos\theta_{i(parton-leadingjet)}$$

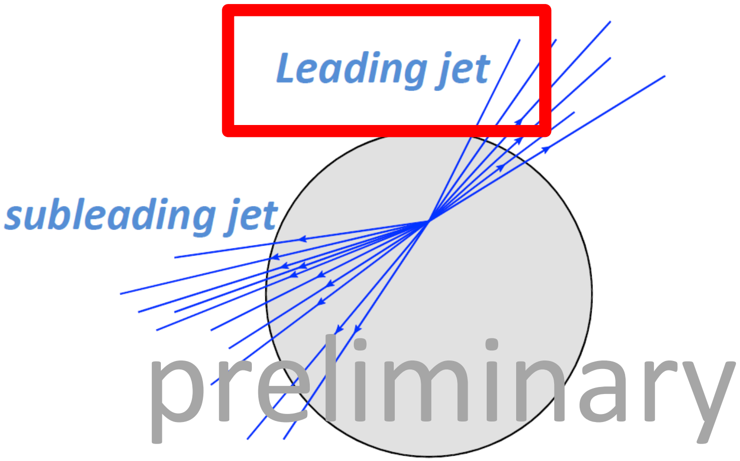
$$\phi = |\phi_{parton} - \phi_{leadingjet}|$$

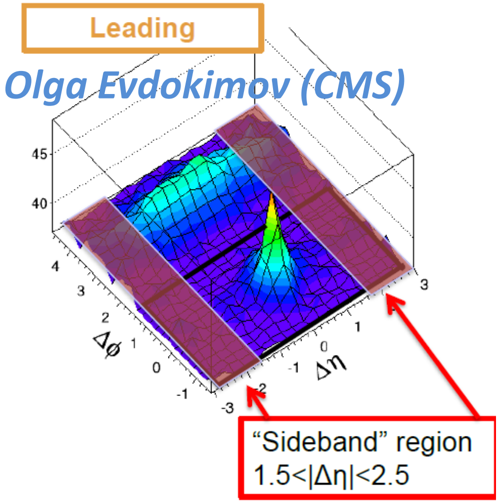


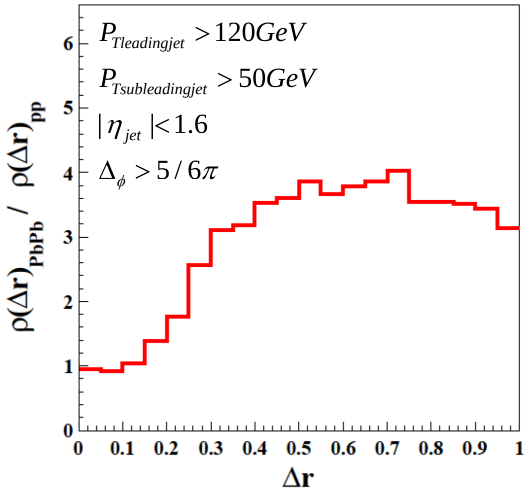


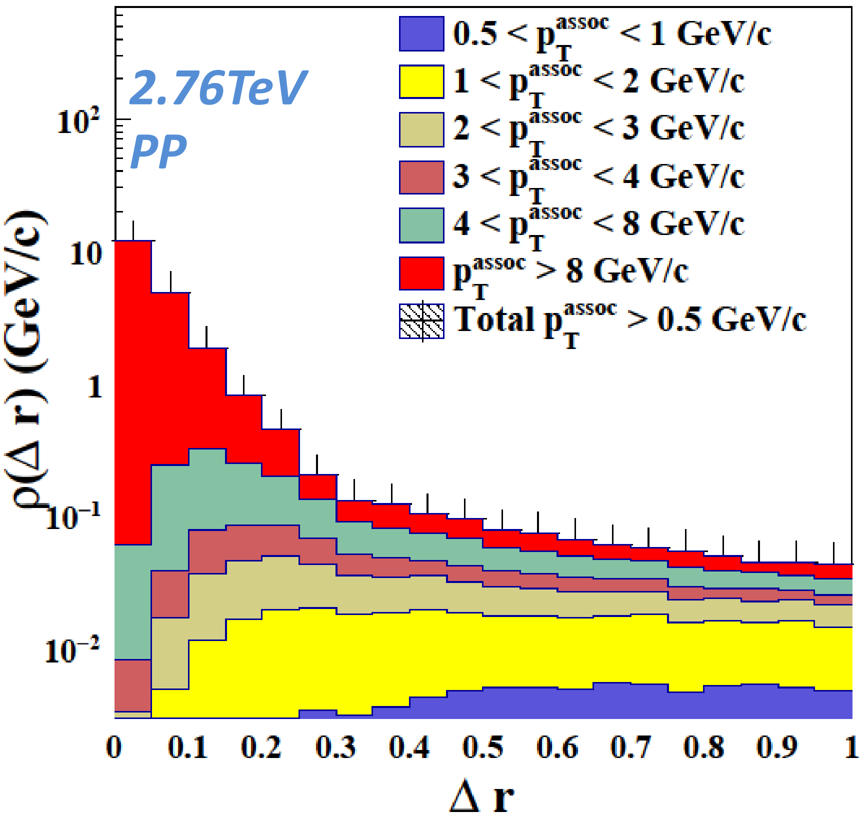


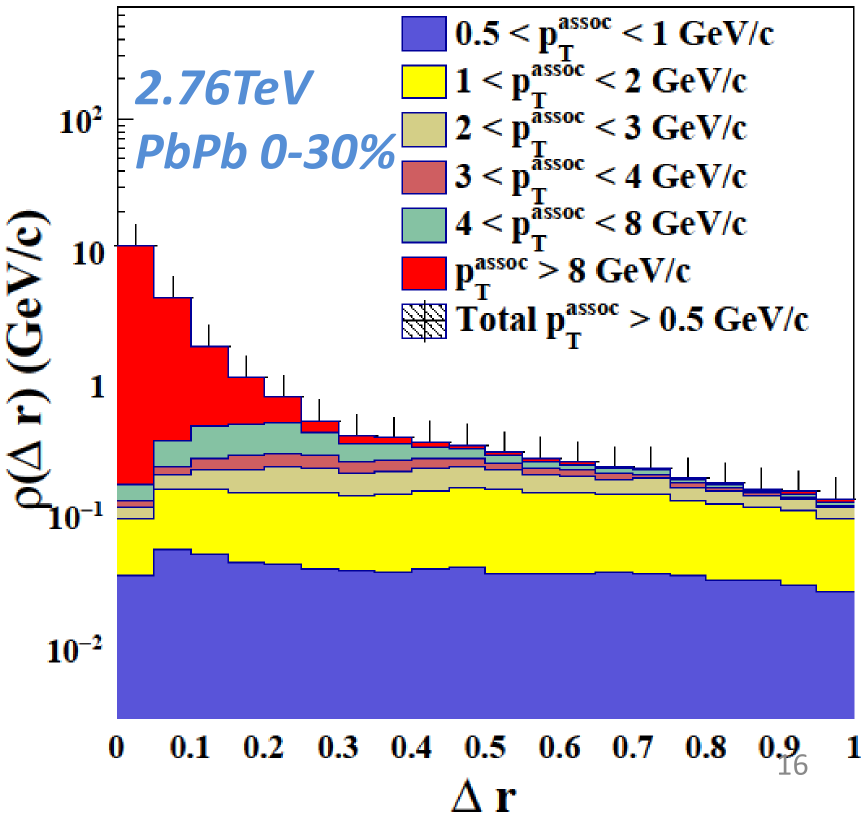
Jet shape of leading jet in heavy-ion collisions











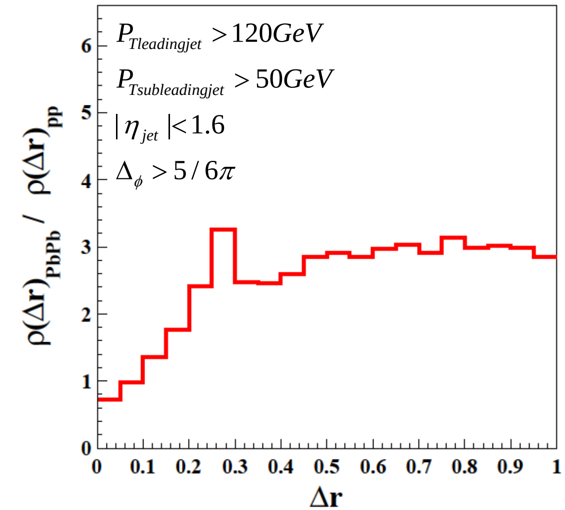
Jet shape of subleading jet in heavy-ion collisions

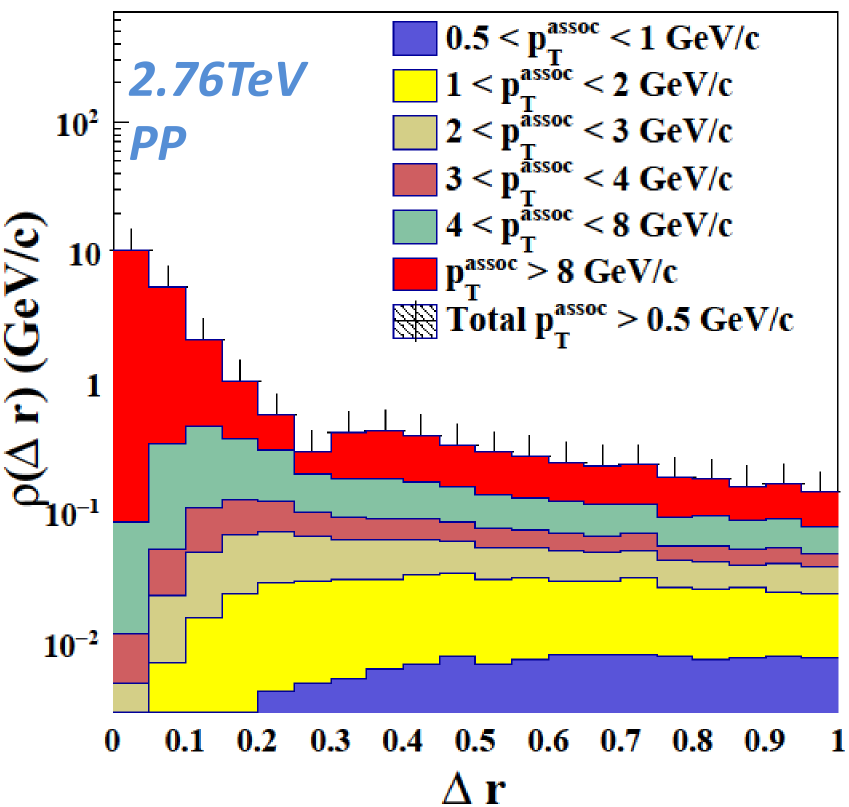
$P_{Tleadingjet} > 120GeV$

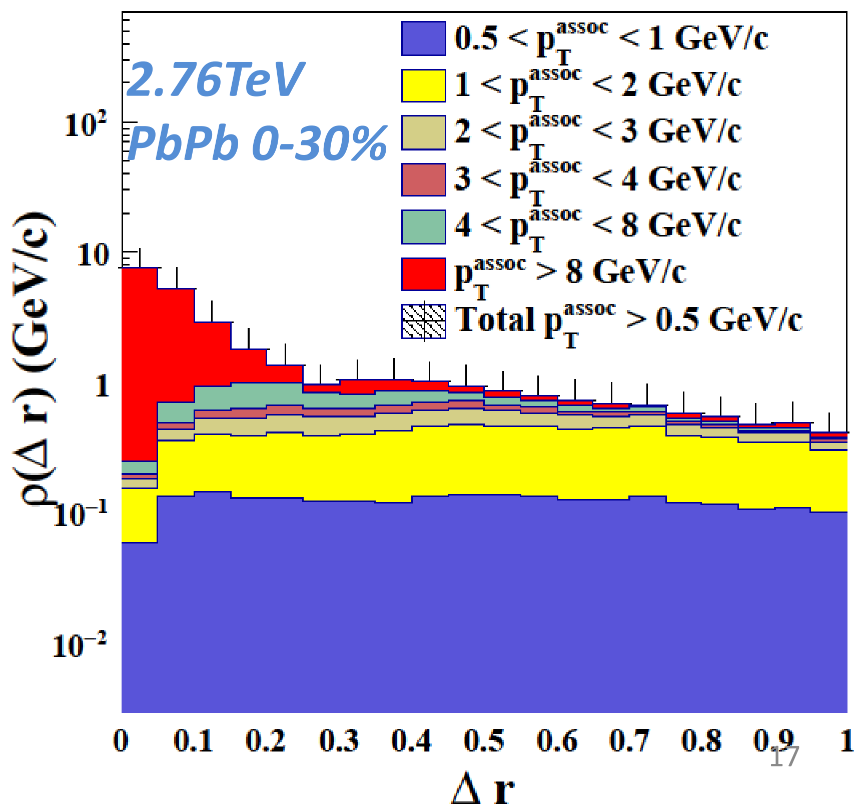
$P_{Tsubleadingjet} > 50GeV$

$|\eta_{jet}| < 1.6$

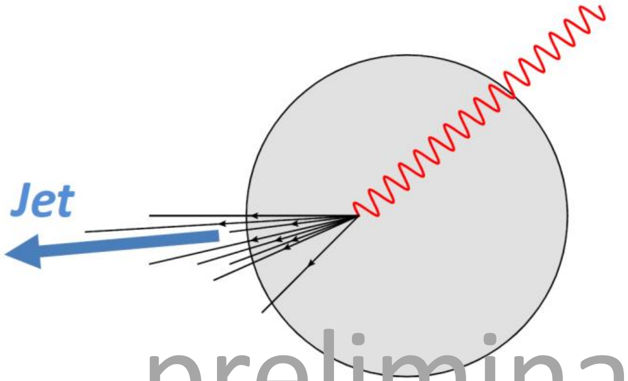
$\Delta_{\phi} > 5/6\pi$







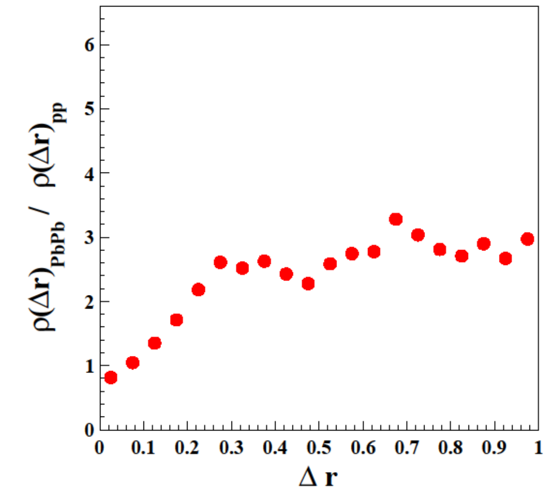
Jet shape of gamma-jets in heavy-ion collisions

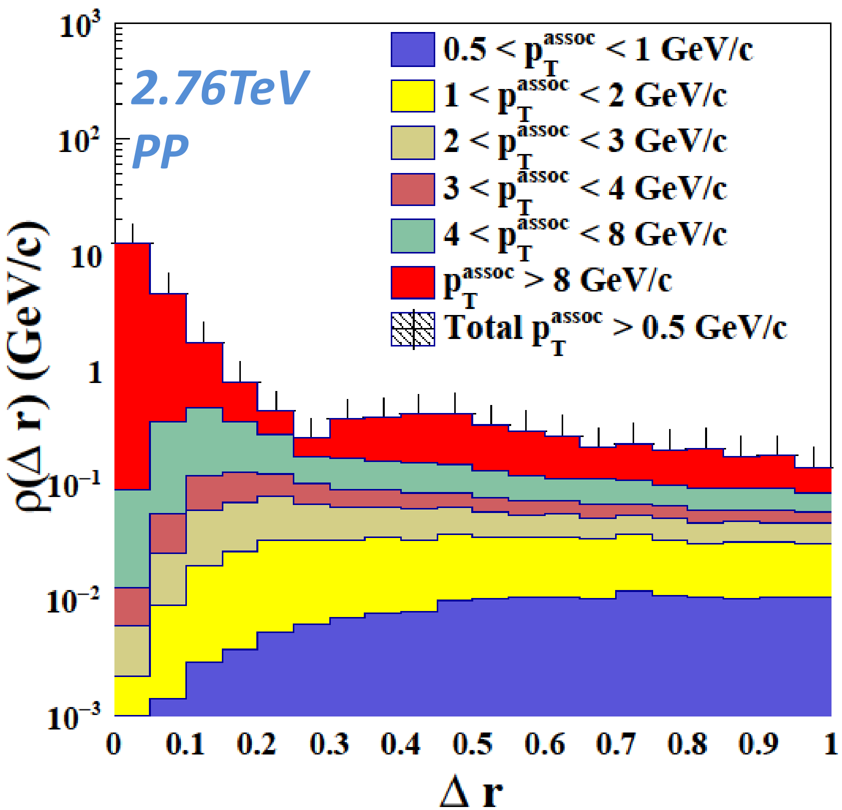


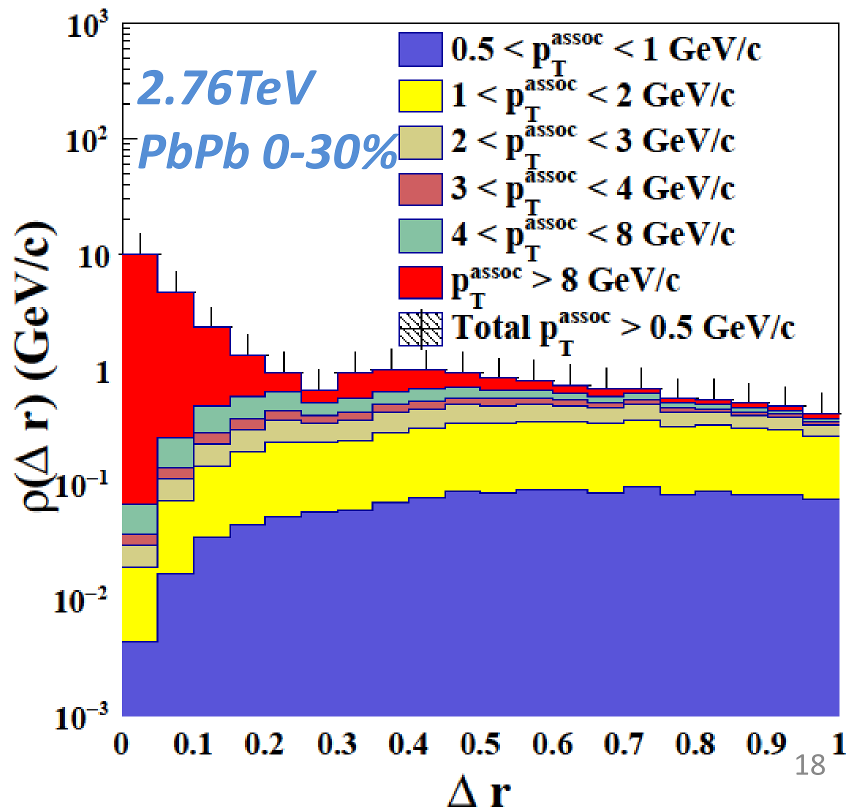
preliminary

$$P_{T_\gamma} > 100GeV, |\eta_\gamma| < 1.44$$

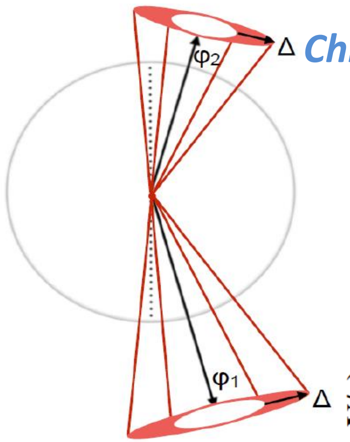
$$P_{Tjet} > 30GeV, |\eta_{jet}| < 1.6$$







pT imbalance of dijet in heavy-ion collisions



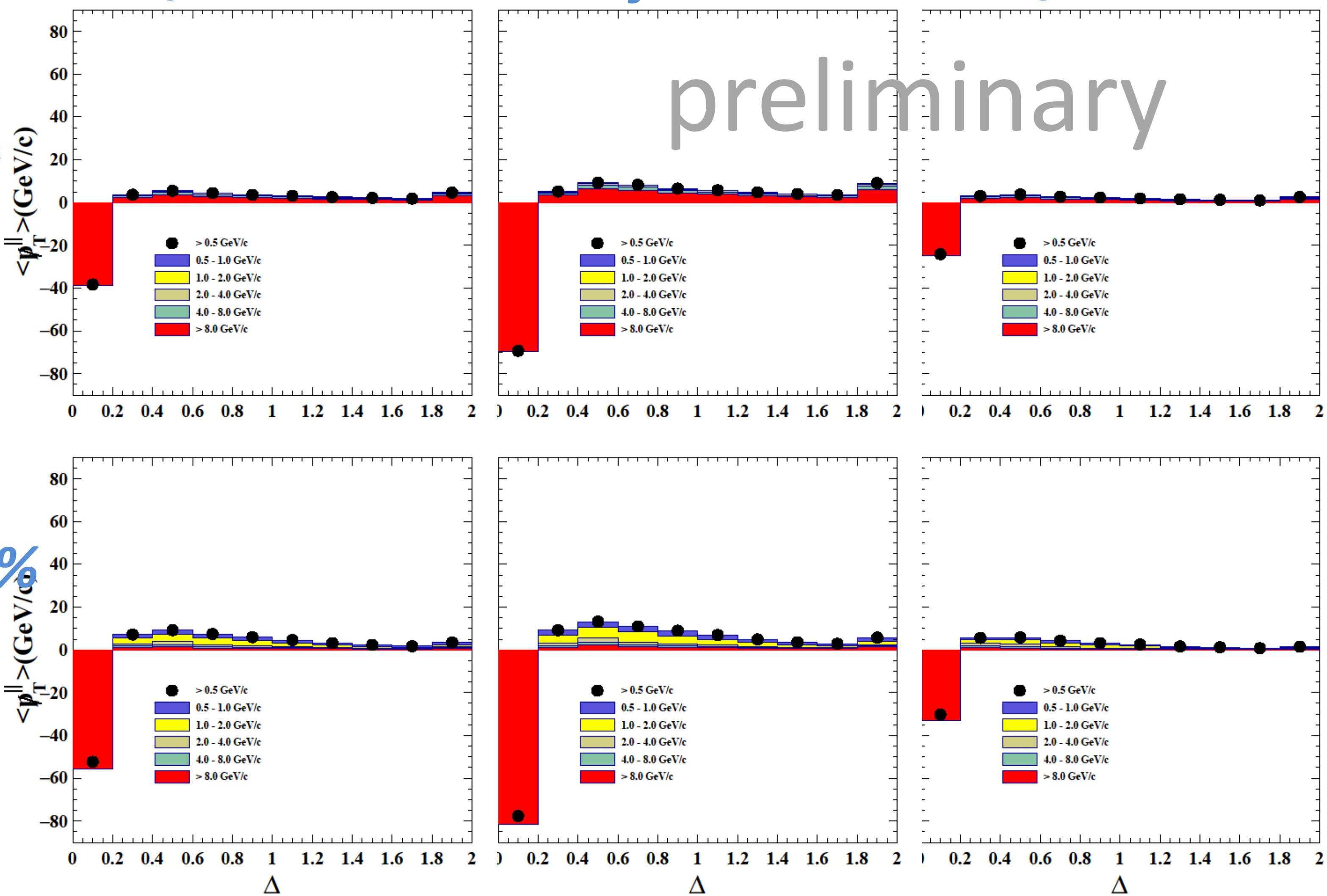
Christopher McGinn (CMS)

$$p_T^{ll} = p_{T_{particle}} \times \cos(\phi_{particle} - \phi_{dijet})$$

Aj inclusive | **Aj > 0.22** | **Aj < 0.22**

2.76TeV PP

2.76TeV PbPb 0-30%



$P_{T leadingjet} > 120 GeV$

$P_{T subleadingjet} > 50 GeV$

$|\eta_{jet}| < 1.6$

$\Delta_{\phi} > 5/6\pi$

Summary

- We present a computation of gamma-jets and Dijet in QGP within the Linear Boltzmann Transport model in which both the elastic and inelastic process are included.

Outlook

- *Hadron jet and Heavy quark jet (with the recombination model developed by Texas A&M group)* Shanshan's talk in the morning

Beyond LBT model (modified medium background)

Yasuki's talk tomorrow

CoLBT-Hydro model

(A coupled LBT Hydro (3+1D) Model)

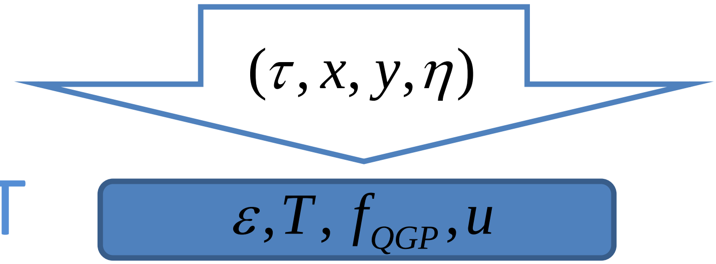
Wei Chen's talk in the last session

Thanks

Gamma-jets in a 3+1D hydro

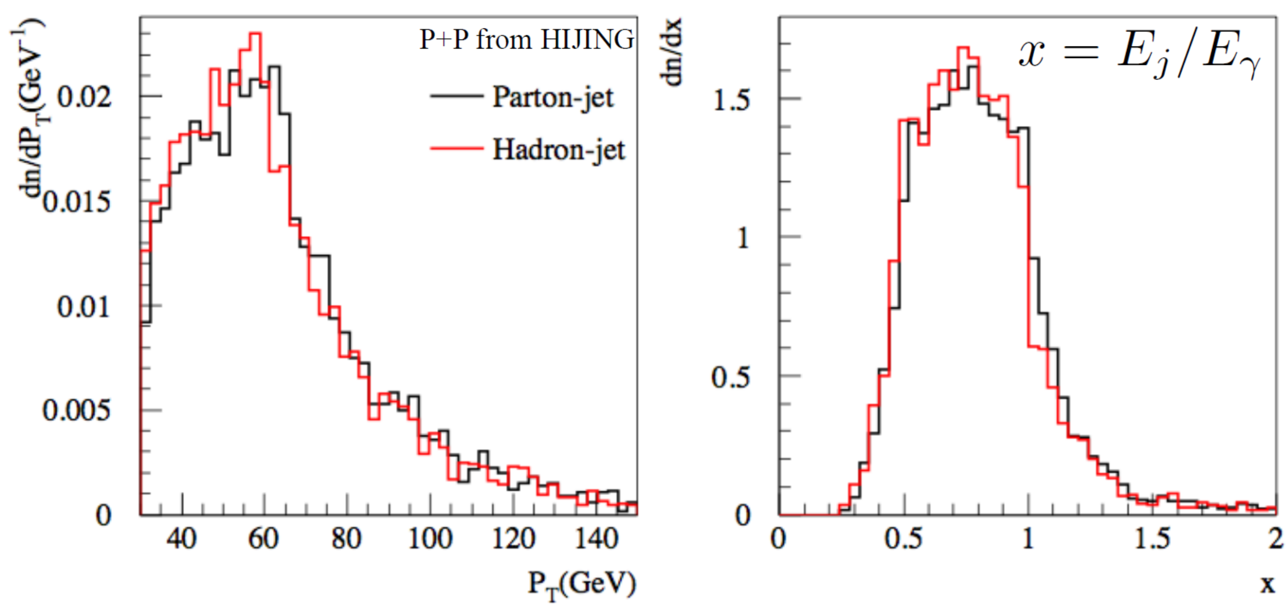
- 3+1D Ideal hydro Longgang Pang, Qun Wang, Xin-Nian Wang   Phys.Rev. C86 (2012) 024911

LBT



- Location of gamma-jet is decided according probability of binary collision.

- Small difference between parton-jet and hadron-jet.



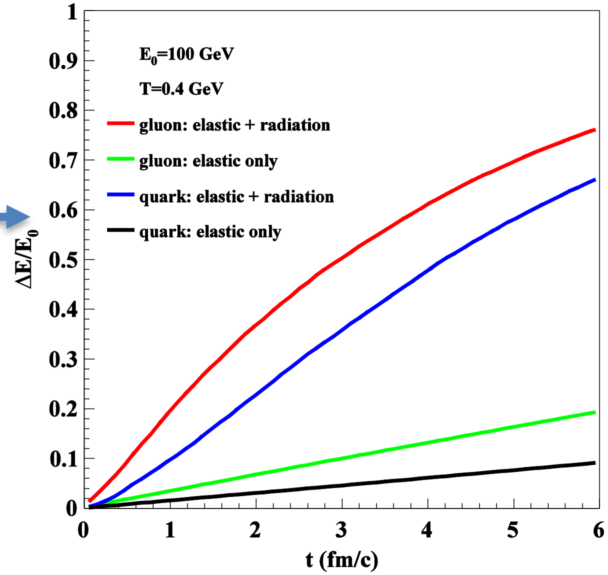
Nontrivial path length dependence on parton energy loss

Propagation of a single initial jet parton in a uniform medium

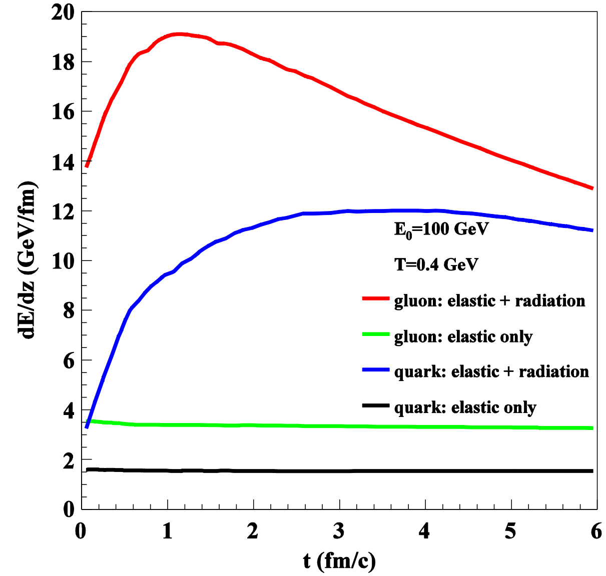
E = 100 GeV
T = 0.4 GeV
$\alpha_s = 0.3$

Leading parton energy loss

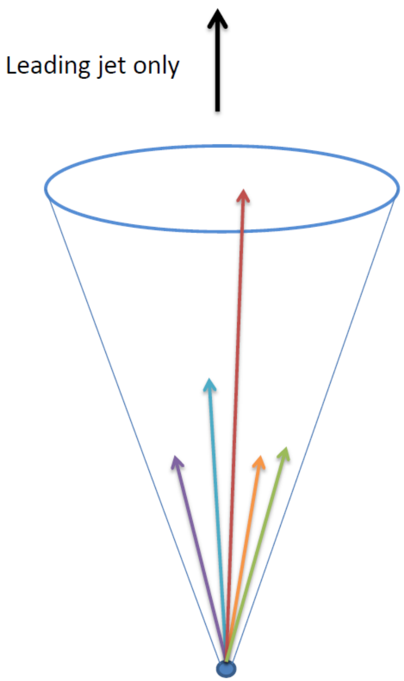
Fractional energy loss



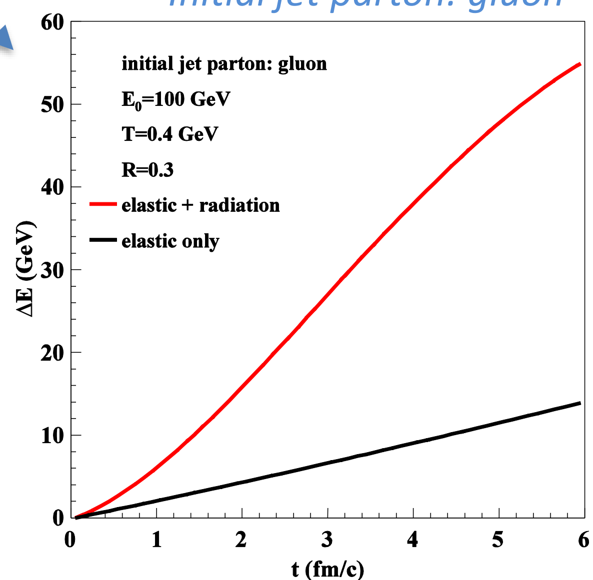
Energy loss per unit length



Leading jet energy loss



Initial jet parton: gluon



Initial jet parton: quark