Hard Probes 2018

Probing jet medium interaction via dijet and photon-jet p_T imbalances

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Ecole Polytechnique

L. Chen, G.Y. Qin, S.Y. Wei, B.W. Xiao, H.Z. Zhang (arXiv:1612.04202)
L. Chen, G.Y. Qin, L. Wang, S.Y. Wei, B.W. Xiao, H.Z. Zhang, Y.Q. Zhang (arXiv:1803.10533)

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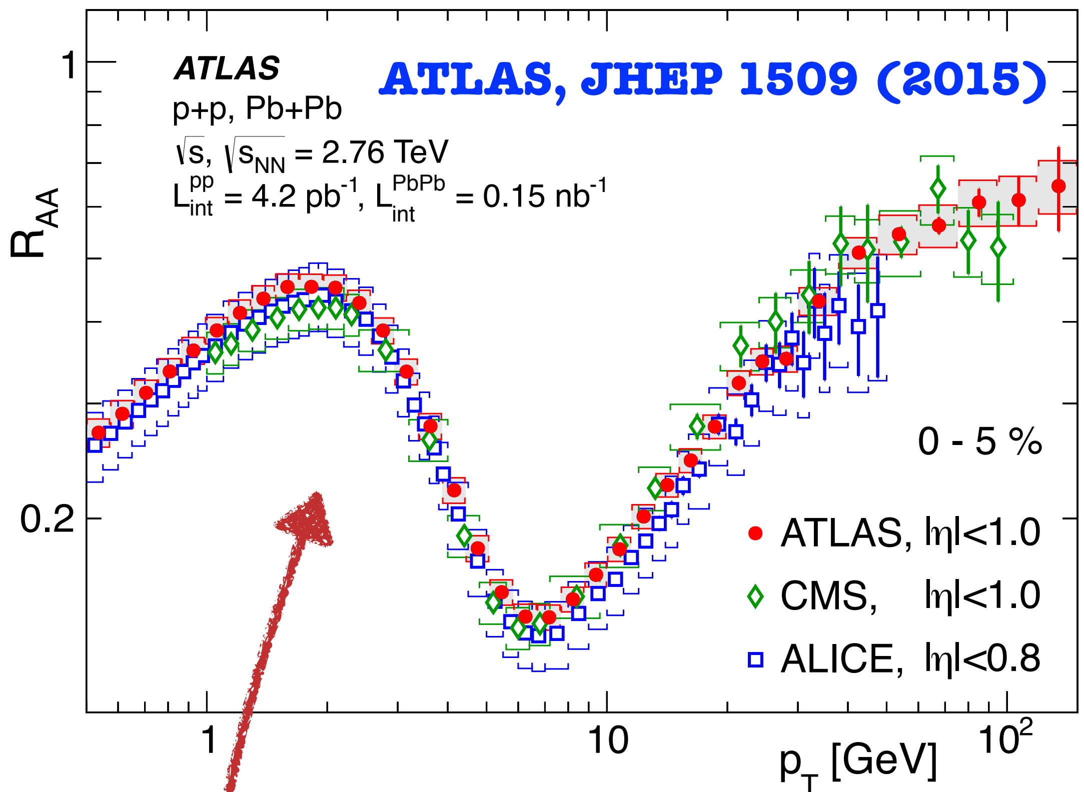
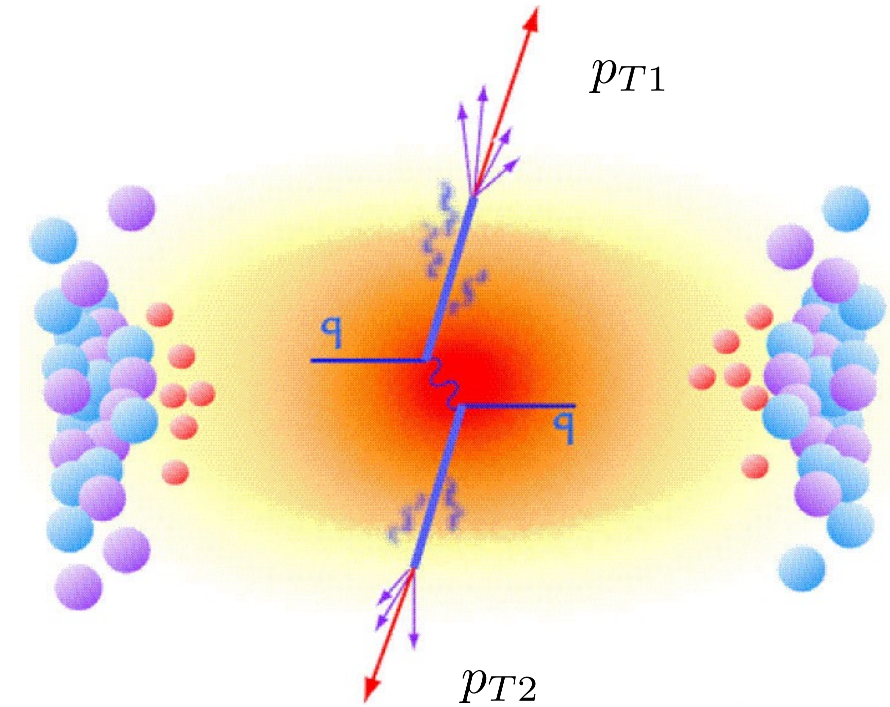
Jet Quenching and Jet Energy Loss



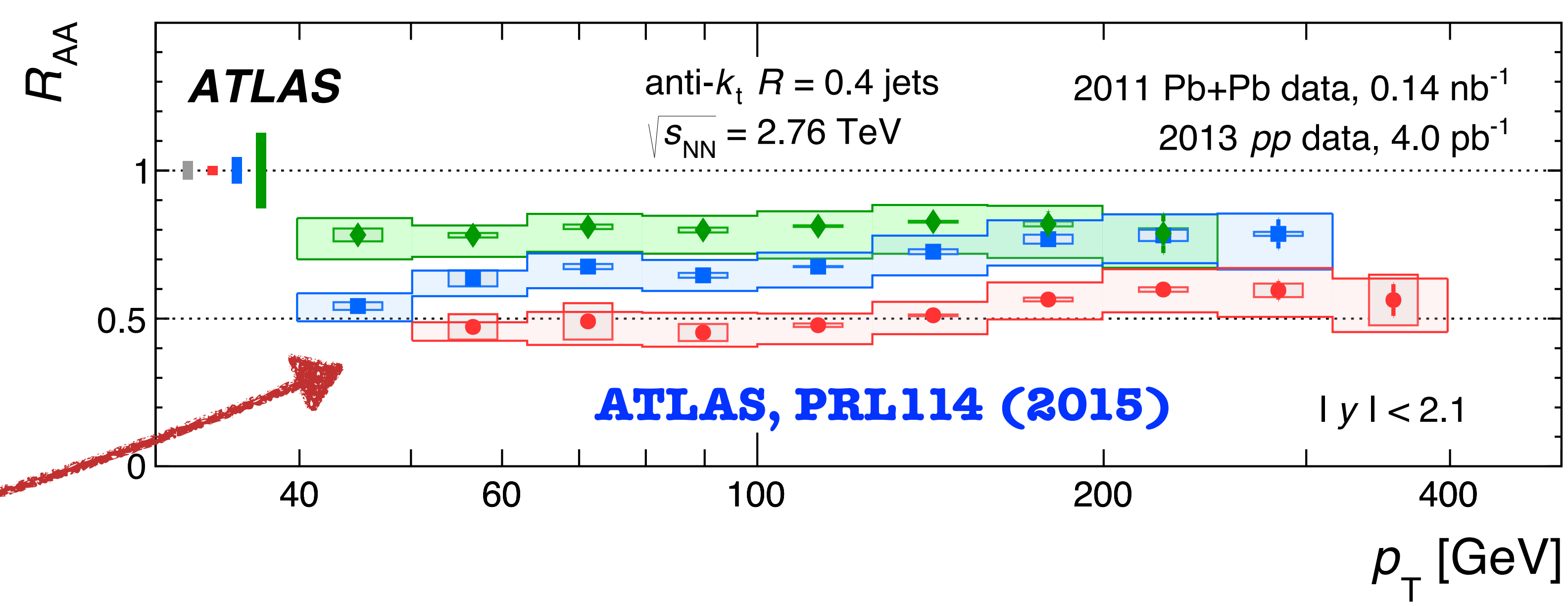


$$R_{AA} = \frac{\text{cross section in AA}}{\text{cross section in pp}}$$

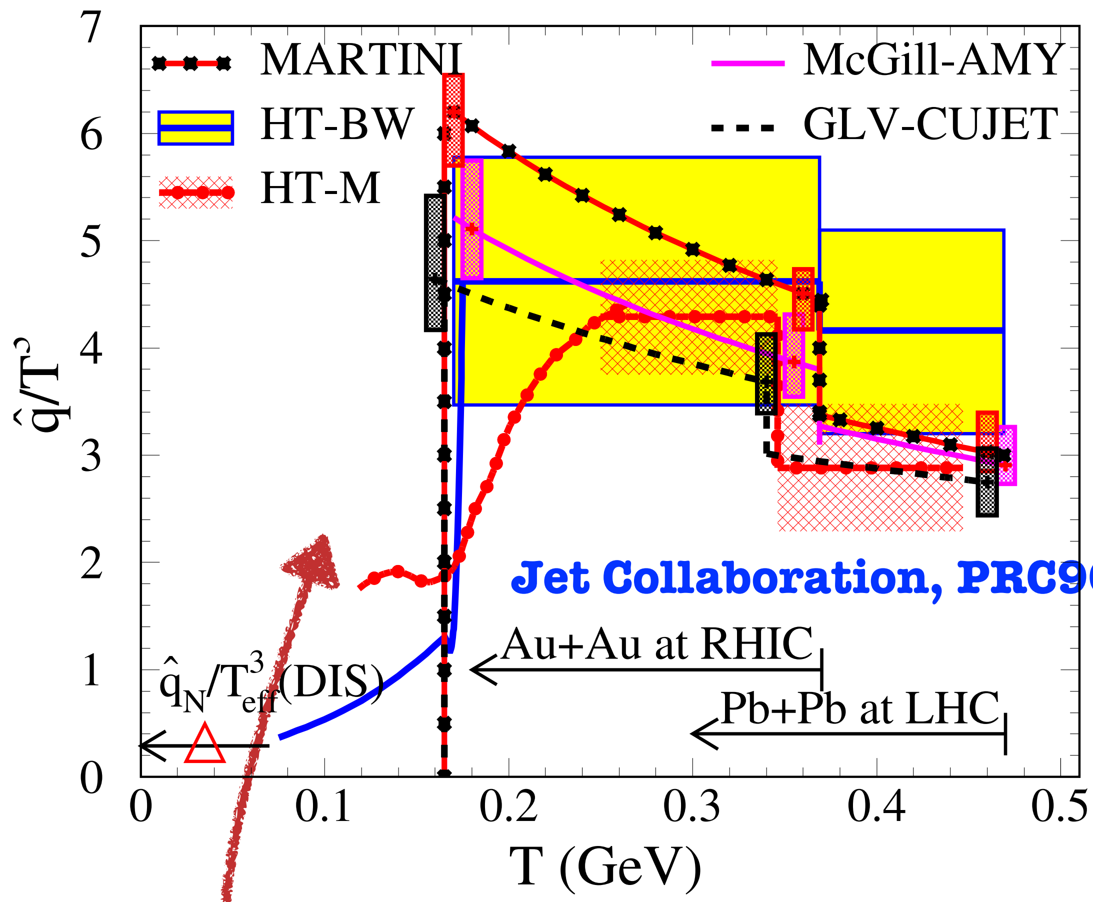
Inclusive Hadron

Parton/Jet Energy Loss

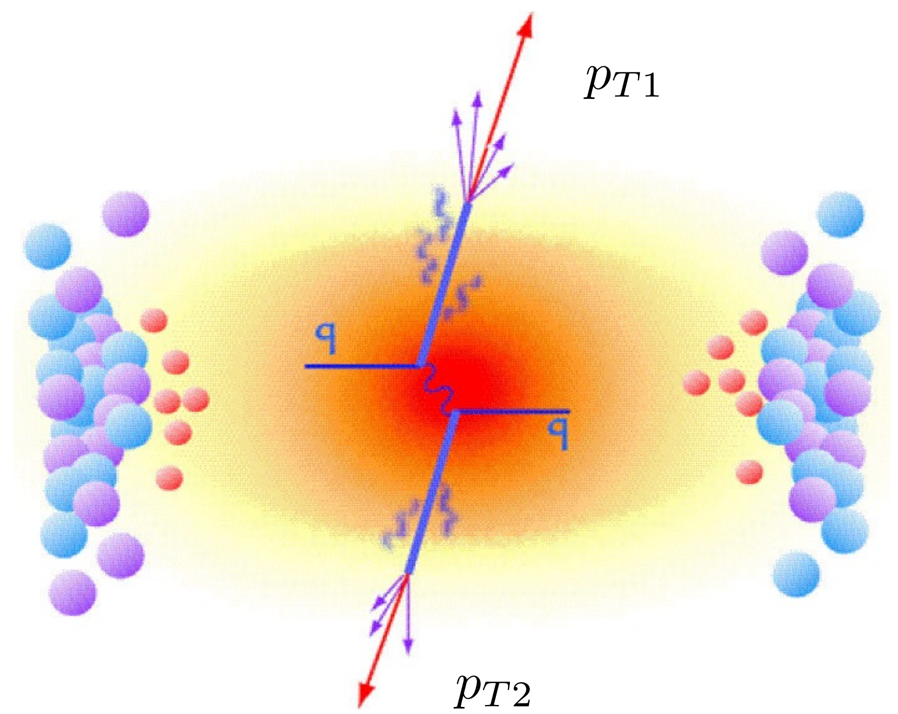
Inclusive Jet



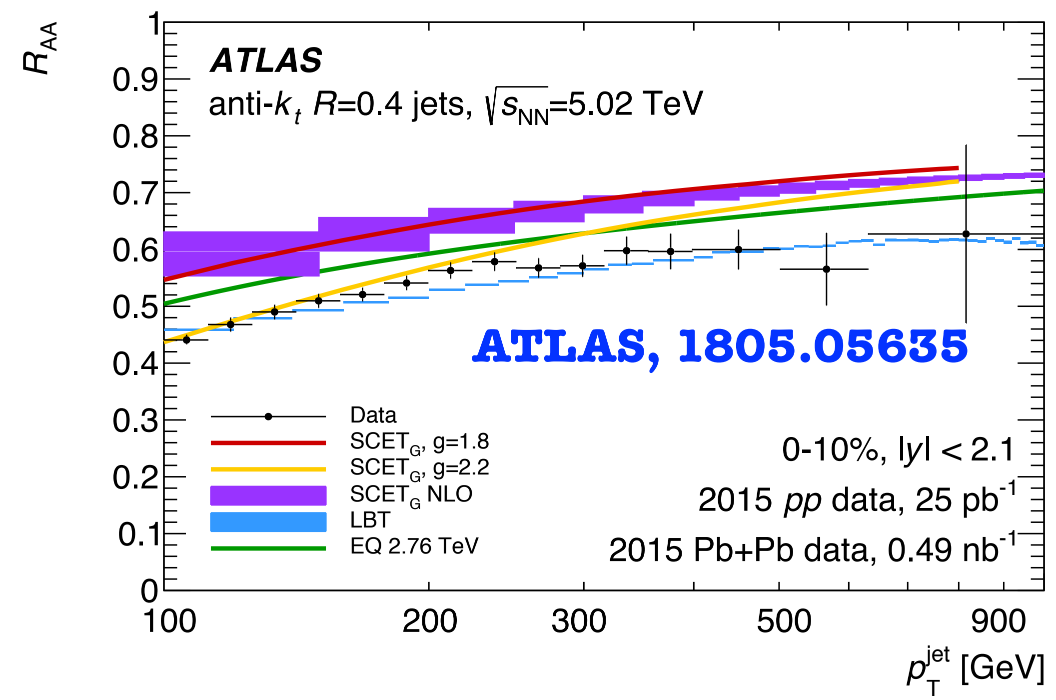
Jet Quenching and Jet Energy Loss



Jet Collaboration, PRC90 (2014)



$$R_{AA} = \frac{\text{cross section in AA}}{\text{cross section in pp}}$$

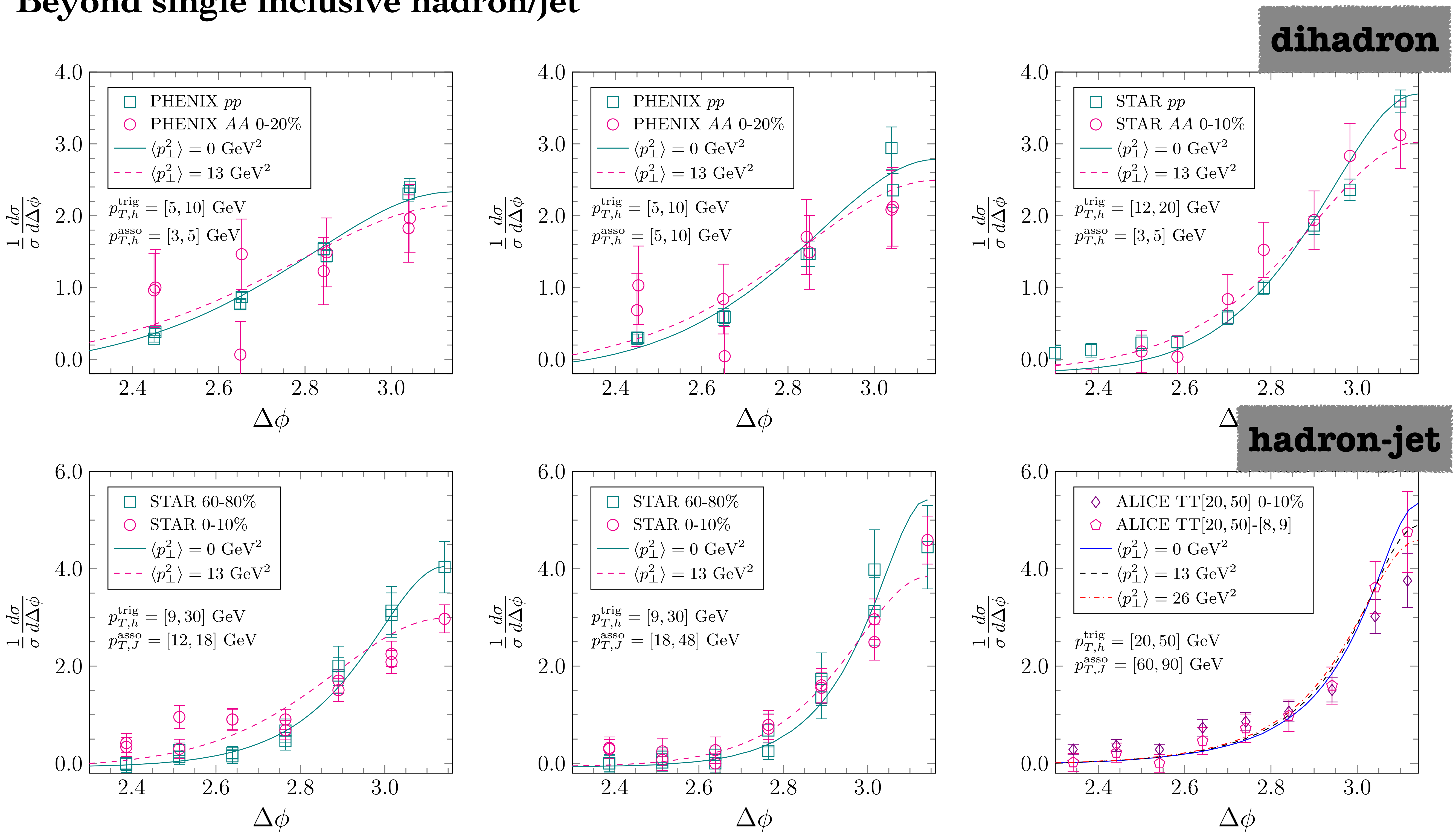


Inclusive Hadron

Parton/Jet Energy Loss

Inclusive Jet

Beyond single inclusive hadron/jet

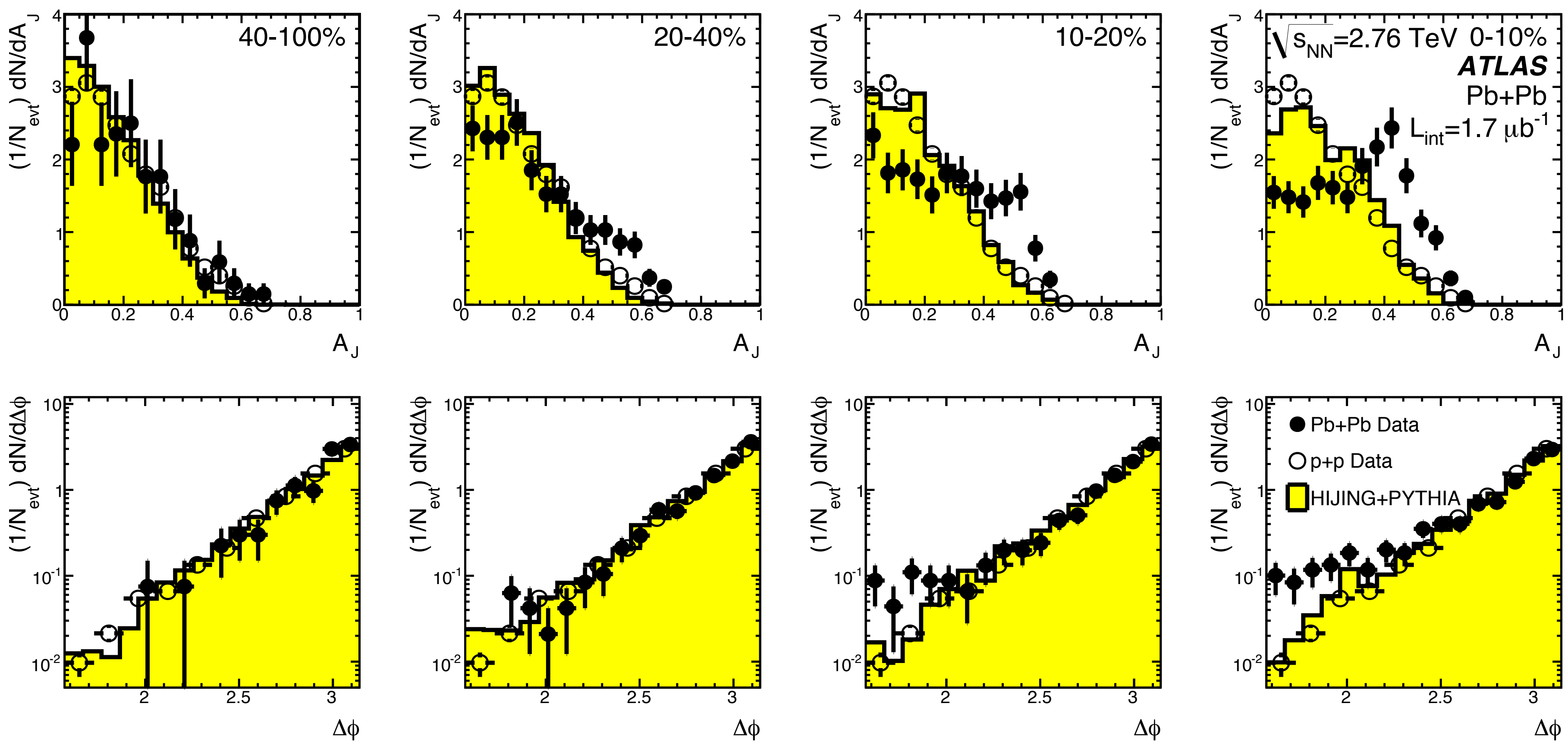


L. Chen, G.Y. Qin, S.Y. Wei, B.W. Xiao, H.Z. Zhang (arXiv:1607.01932)

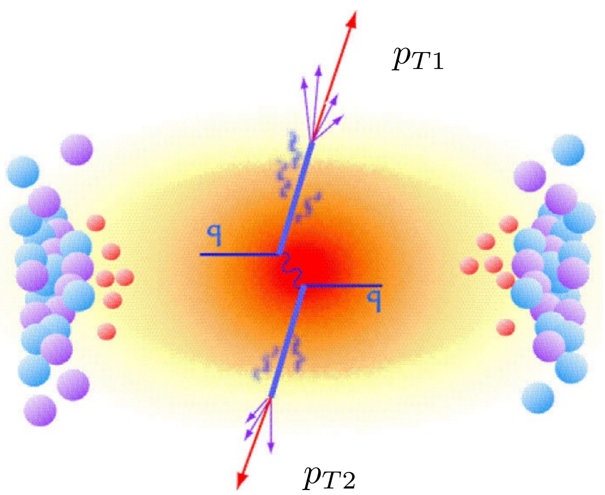
Introduction

Why is it interesting?

ATLAS [PRL 105, (2010)] & CMS [PRC 84, (2011)]



$$A_J \equiv \frac{p_{T1} - p_{T2}}{p_{T1} + p_{T2}}$$



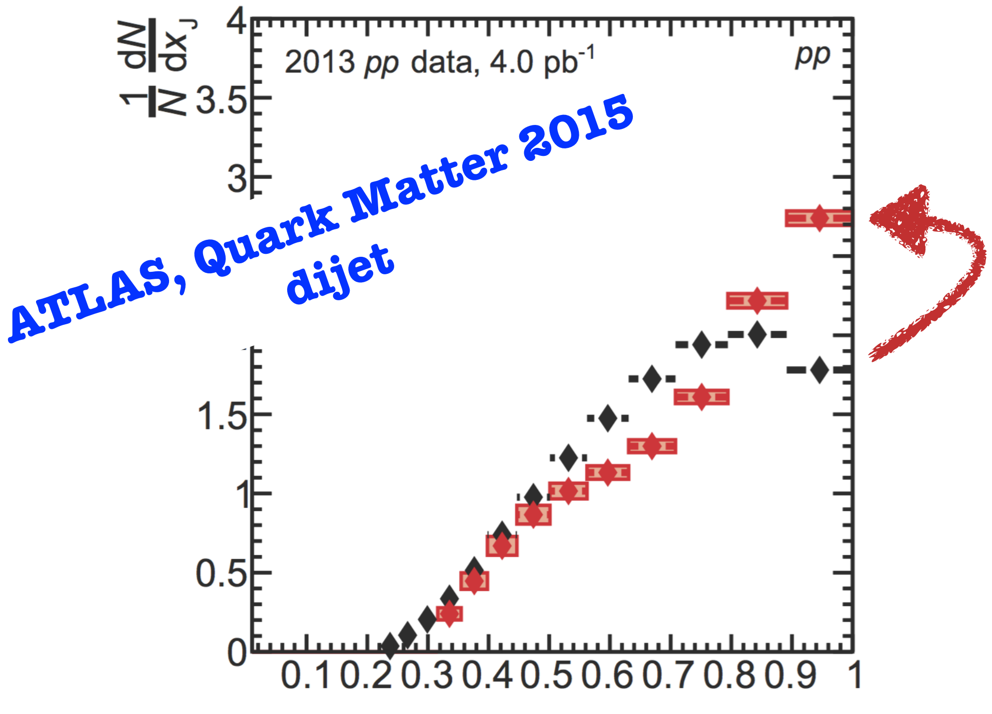
Dijet Asymmetry

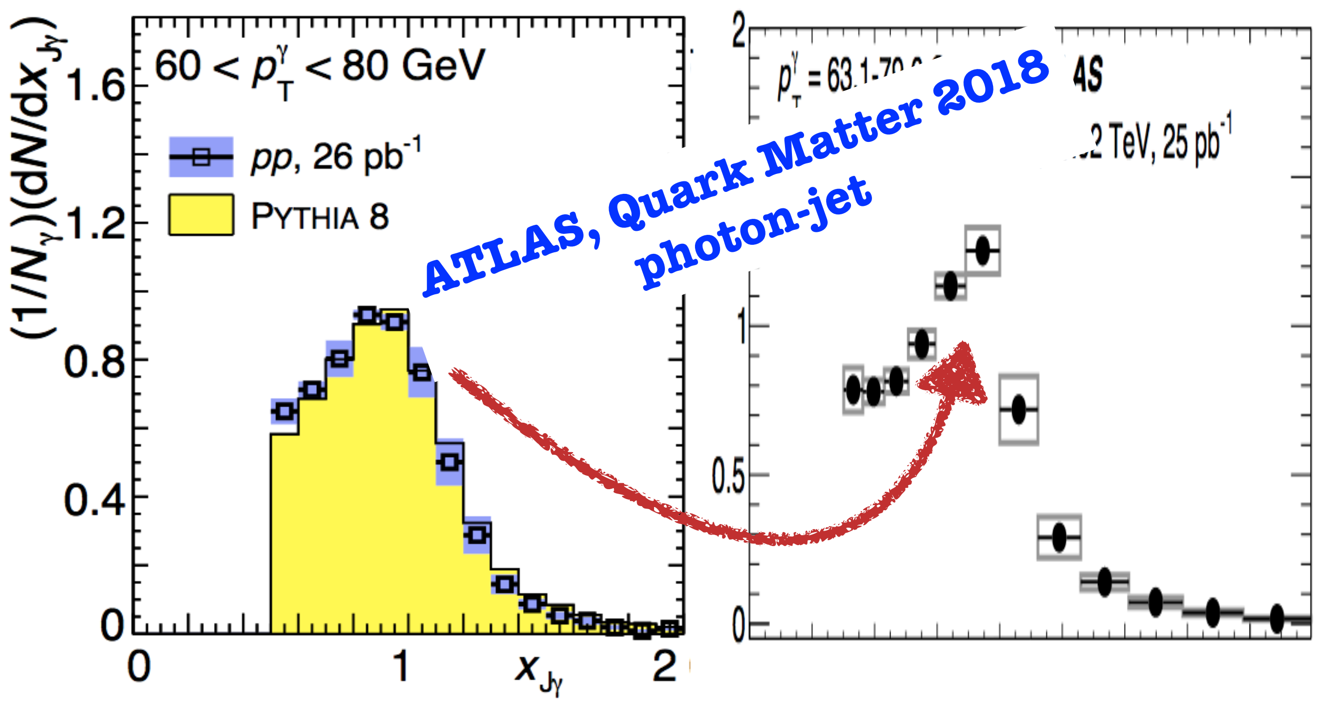
- ☑ Intuitive picture on the jet energy loss.
- ☑ Sensitive to geometry, qhat, energy loss formalism…

First Thing: baseline in *pp* collisions

- ☑ From Event Generators to a solid QCD calculation.
- ☑ Unfolding

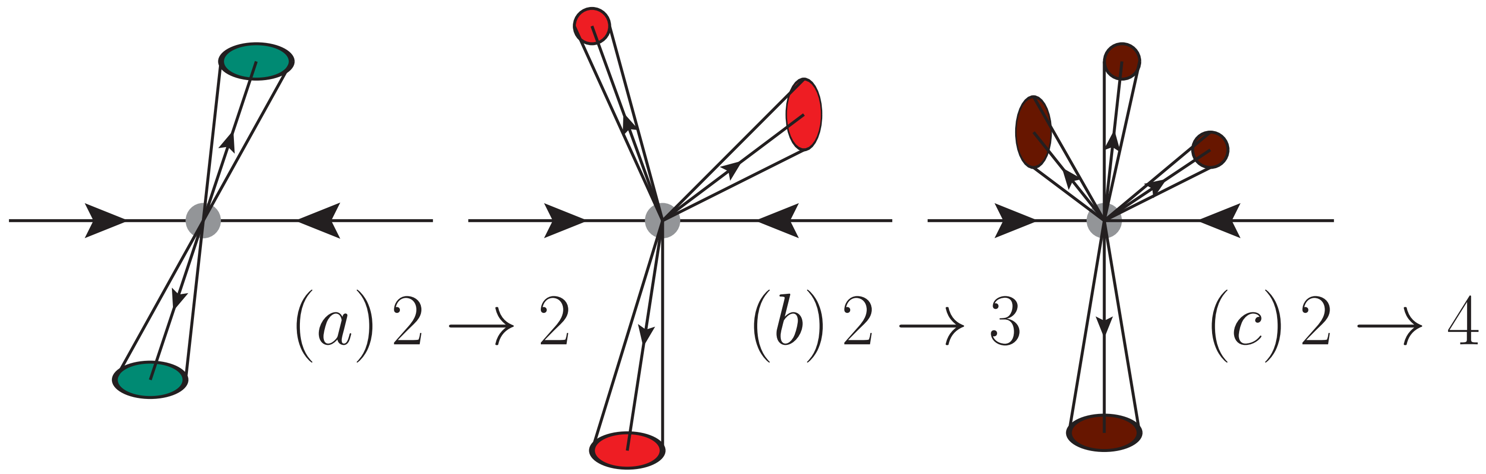
> detector effects. Recent measurements of dijet p_{T} correlations [12] and inclusive jet fragmentation functions at large longitudinal momentum fraction [22] in Pb+Pb collisions used unfolding procedures to correct for bin-migration effects and return the distributions to the particle level, i.e. free from detector effects. In these cases, fully correcting the data revealed non-trivial features in the distributions which would not otherwise be evident.





Establish a baseline that can describe the fully corrected data without any free parameters.

Perturbative Expansion



Correlations:

- $2 \to 2$: 0th order
- $2 \to 3$: leading order
- $2 \to 4$: next-to-leading order

Normalization

$$\frac{1}{N}\frac{dN}{dx_J}\bigg|_{\text{exp.}}$$

$$\frac{1}{\sigma_{\text{LO}}}\frac{d\sigma_{\text{LO}}}{dx_J}$$

$d\sigma_{\text{LO}}$: $2 \to 3$

σ_{LO}: $2 \to 2$

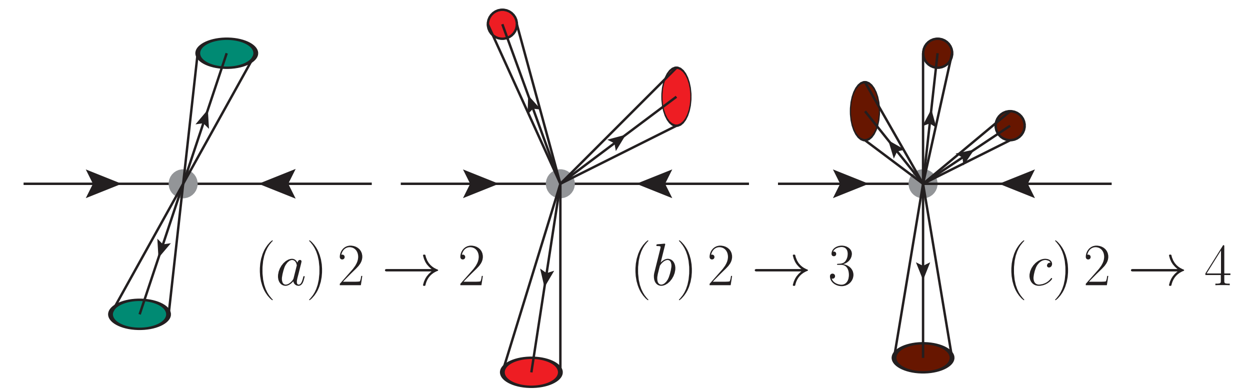
$$\frac{1}{\sigma_{\text{NLO}}}\frac{d\sigma_{\text{NLO}}}{dx_J}$$

$d\sigma_{\text{NLO}}$: $2 \to 3,\ 2 \to 4$

σ_{NLO}: $2 \to 2,\ 2 \to 3$

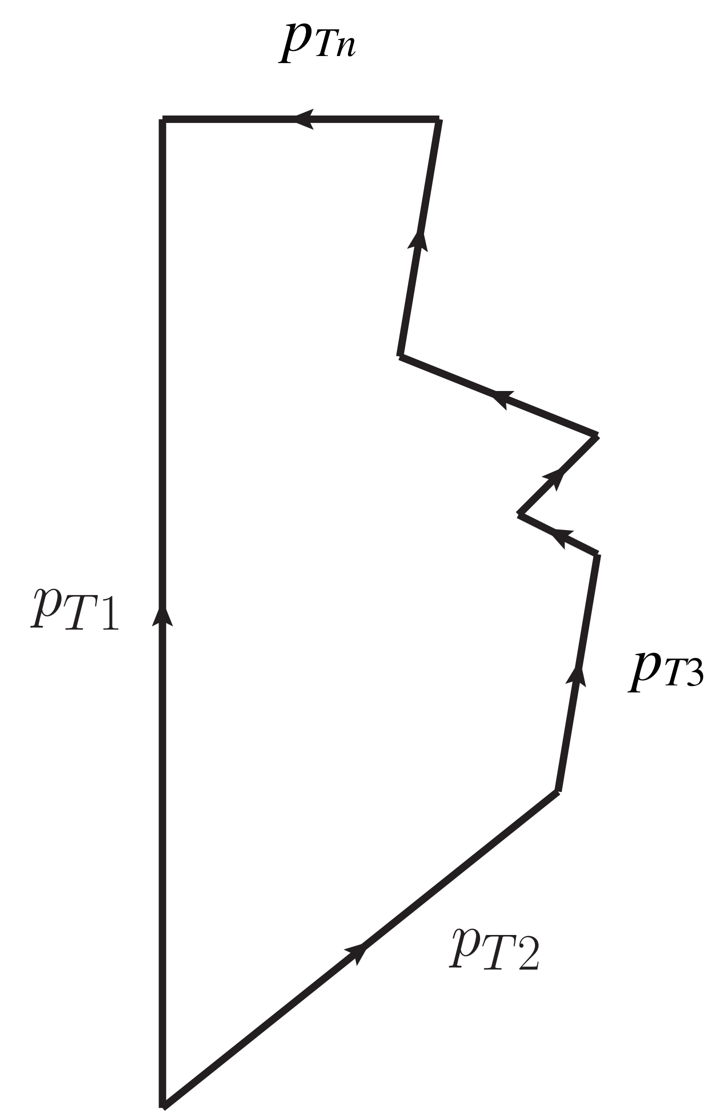
Our approach Establish baselines without free parameters

Perturbative Expansion

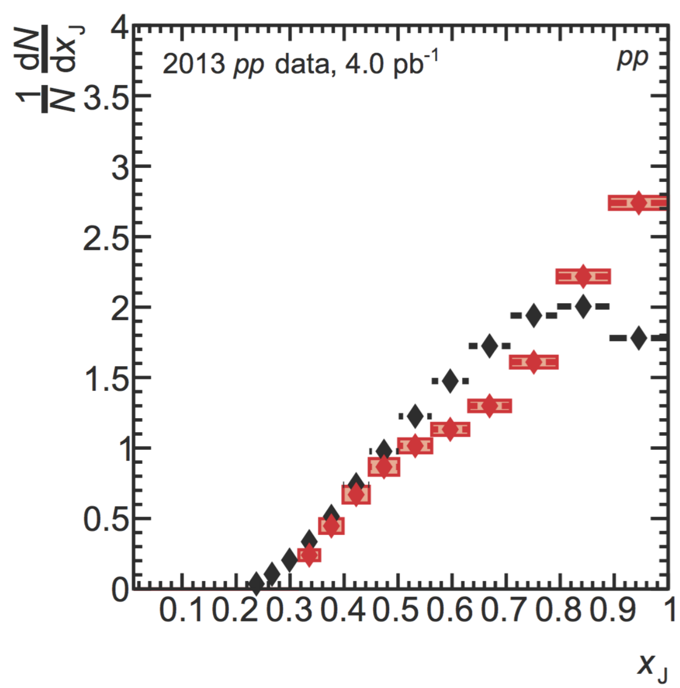


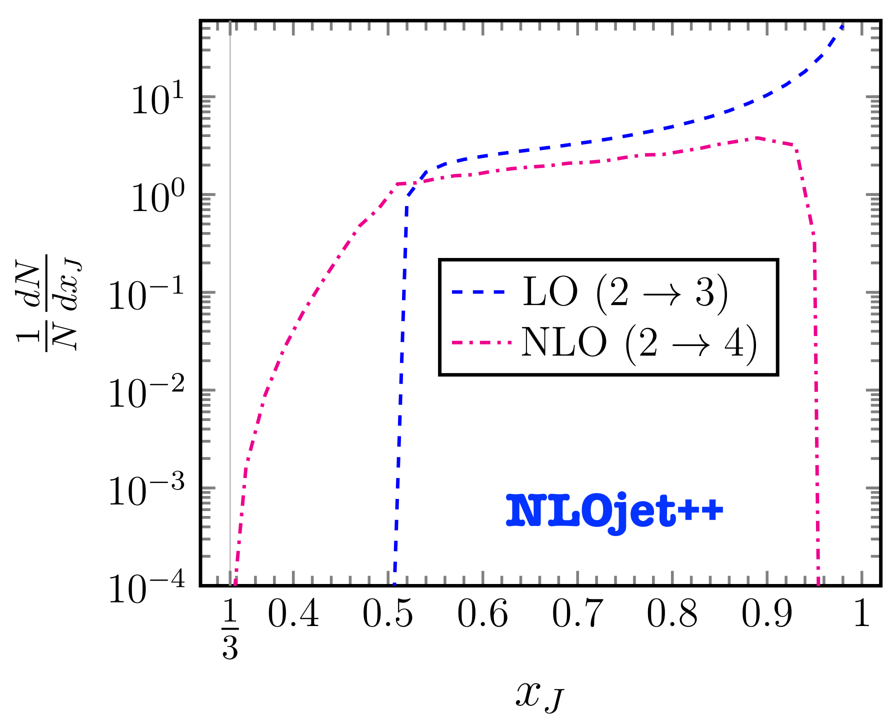
- ☑ energy conservation
- ☑ 4π coverage (no missing jet)
- ☑ leading and sub-leading jets

For *n*-jet final state

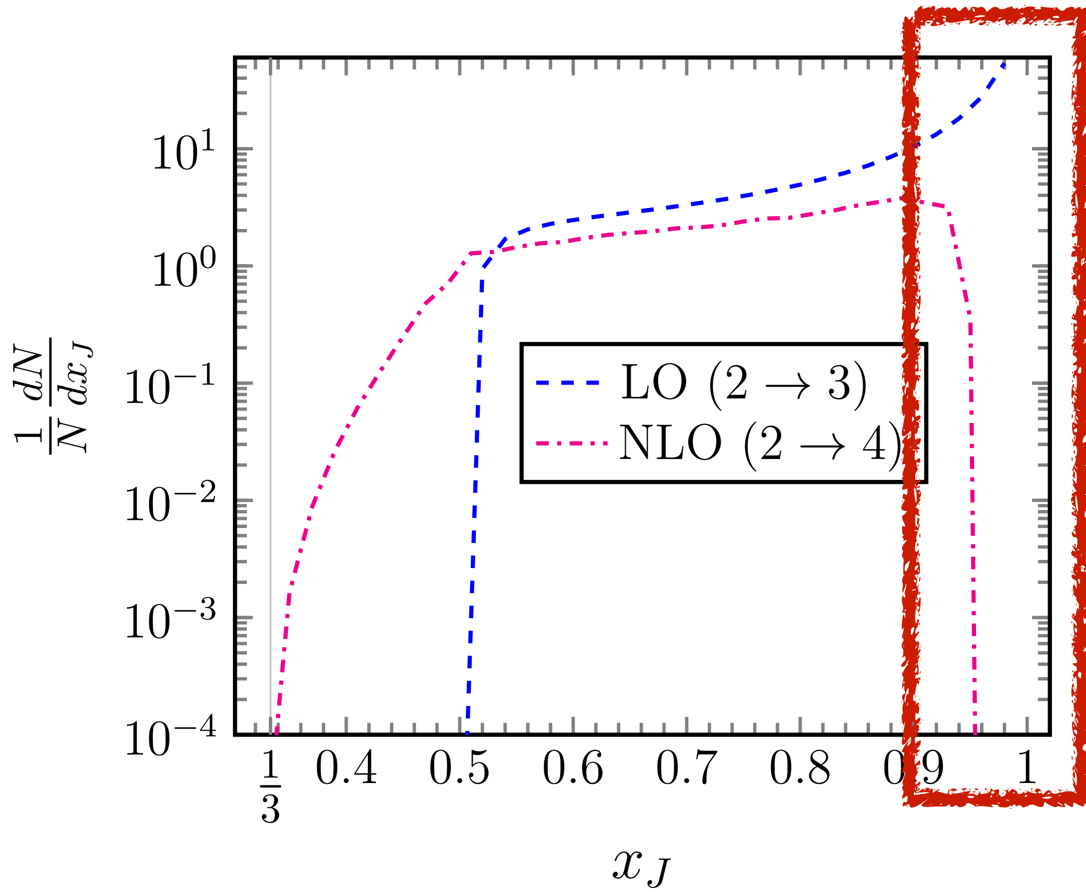


$$(n-1)p_{T2} \geq p_{T1} \qquad x_J^{2\to n} \equiv \frac{p_{T2}}{p_{T1}} \geq \frac{1}{n-1}$$

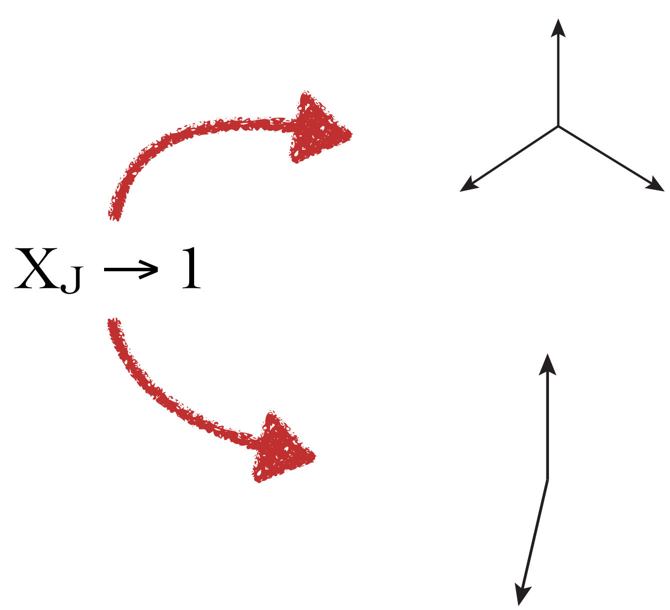




Perturbative Expansion

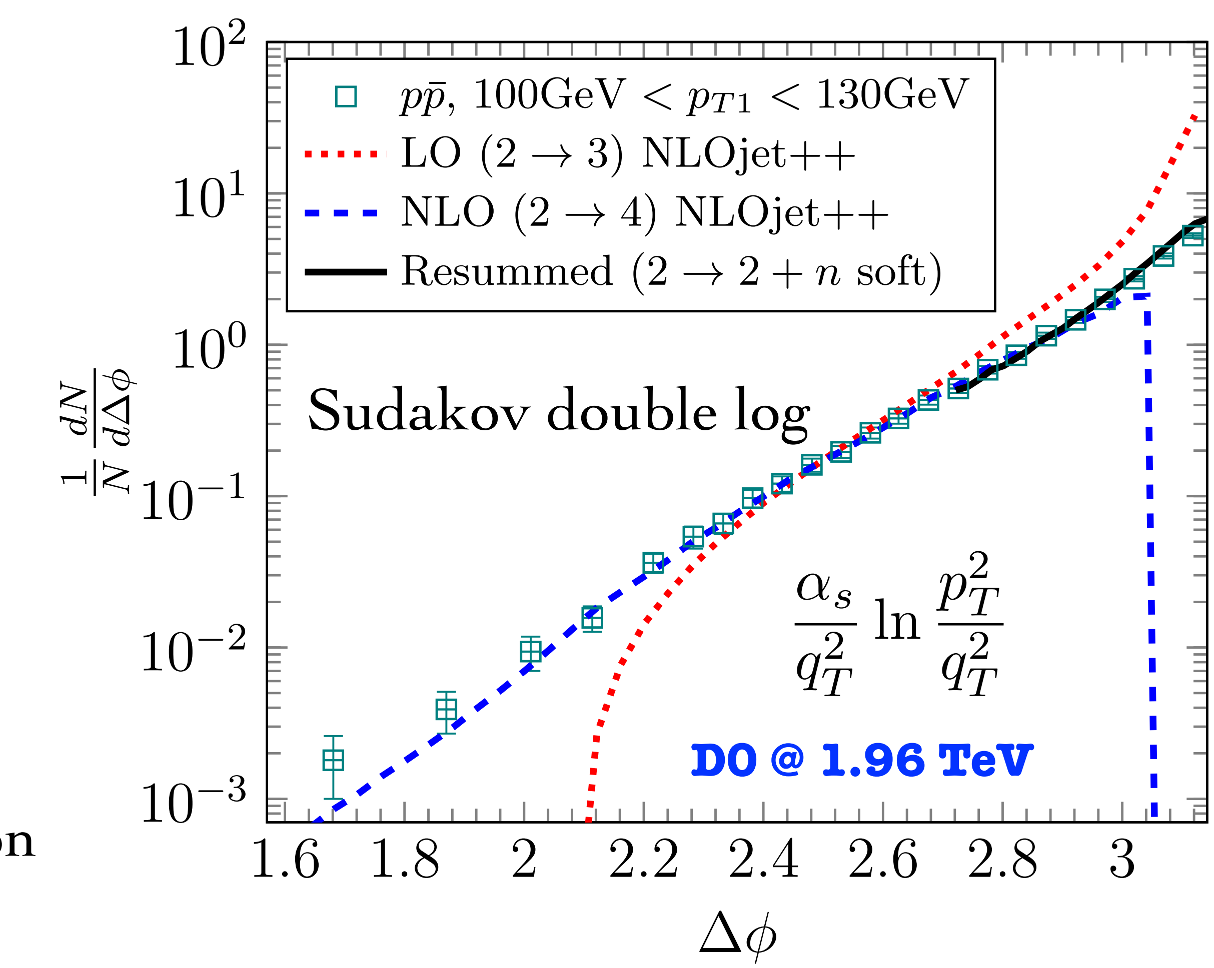


perturbative expansion fails

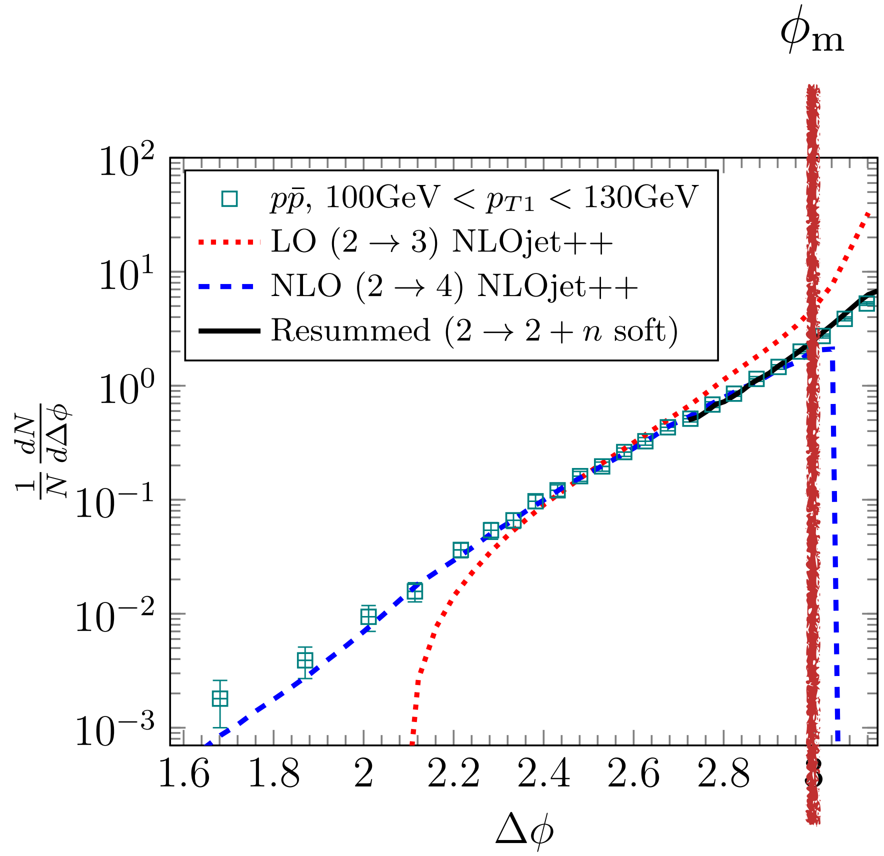


stable

back-to-back configuration



Resummation Improved pQCD approach



$$\sigma_0 \sum_{i=0}^{\infty}\Big((\alpha_s \mathrm{Log})^i + \alpha_s^i C_i\Big)$$

no large logs — ϕ_m — large logs

perturbative expansion	Sudakov resummation
$\sigma_0 \sum_{i=0}^{n}\Big((\alpha_s \mathrm{Log})^i + \alpha_s^i C_i\Big)$	$\sigma_0 \sum_{i=0}^{n}\Big((\alpha_s \mathrm{Log})^i\Big) + \sigma_0 \sum_{n+1}^{\infty}\Big((\alpha_s \mathrm{Log})^i\Big)$

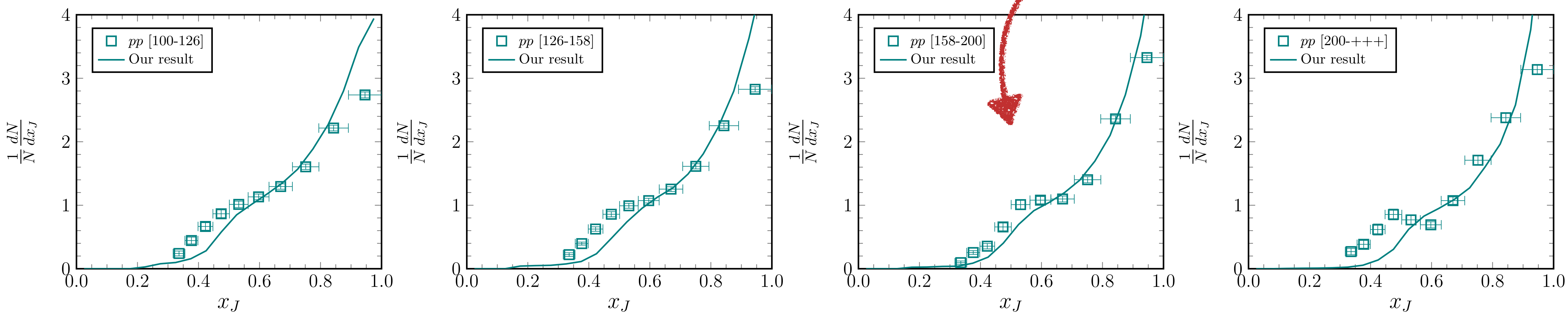
$$\frac{1}{\sigma}\frac{d\sigma}{dx_J}\Big|_{\mathrm{Improved}} = \frac{1}{\sigma_{\mathrm{NLO}}}\frac{d\sigma_{\mathrm{NLO}}}{dx_J}\Big|_{\Delta\phi<\phi_m} + \frac{1}{\sigma_{\mathrm{Sudakov}}}\frac{d\sigma_{\mathrm{Sudakov}}}{dx_J}\Big|_{\pi>\Delta\phi>\phi_m}$$

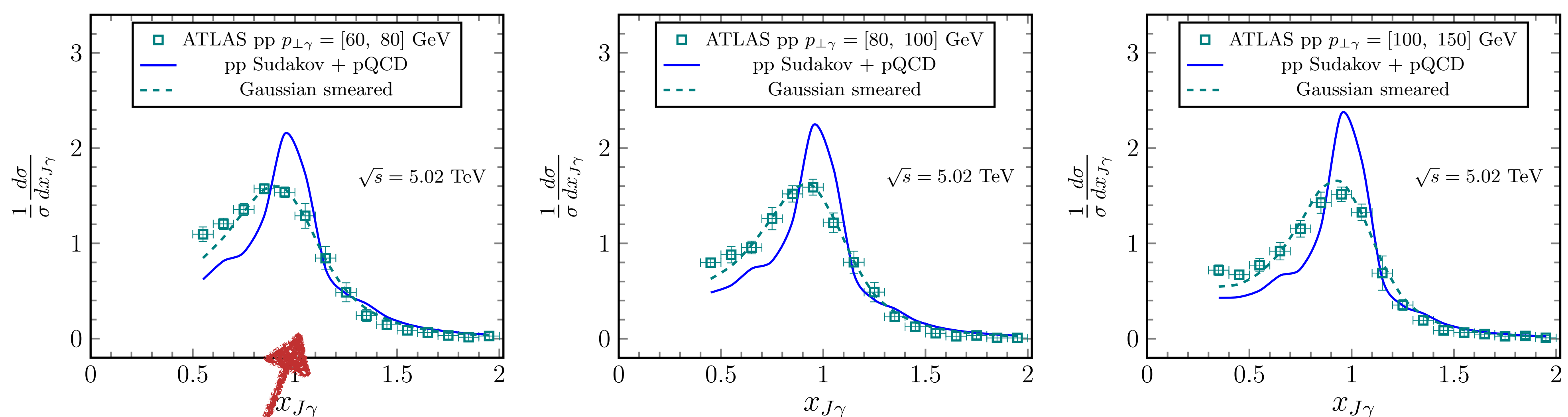
- ☑ NLO pQCD provides very precious result at small X_J region.
- ☑ Sudakov resummation resums the alternating sign series of large logarithms.
- ☑ There is no free parameter in this calculation.

Our approach Establish baselines without free parameters

Resummation Improved pQCD approach

dijet, Sudakov + NLO(2→ 3&2→ 4)





To compare with the uncorrected data.

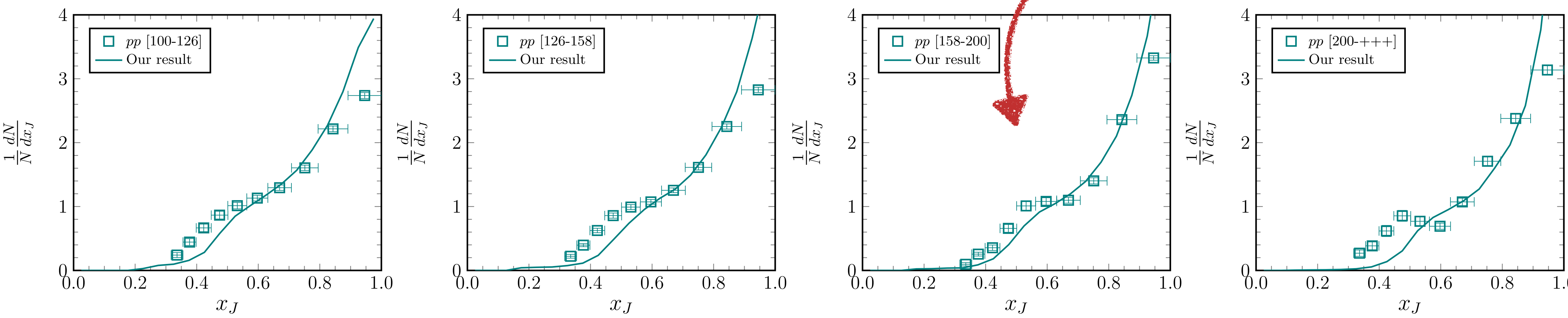
photon-jet, Sudakov + LO(2→ 3)

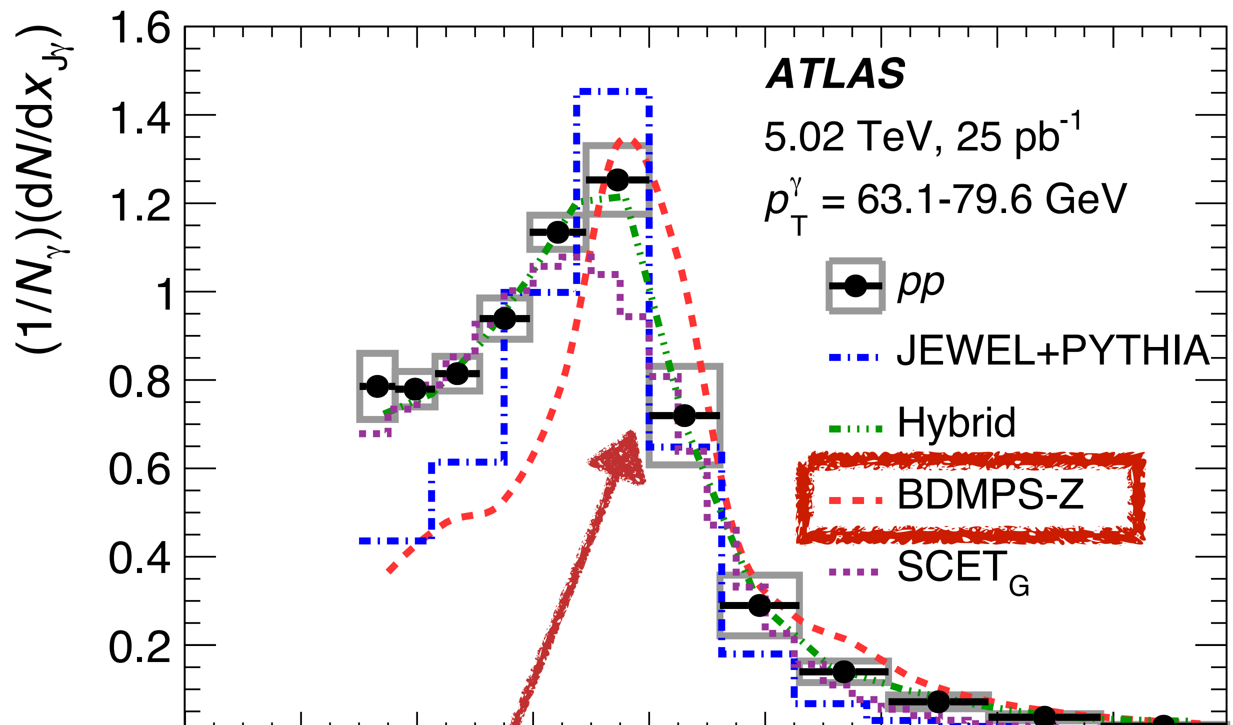
$$\frac{d\sigma_{\rm smeared}}{dp_{\perp J}} = \int \frac{dE}{\sqrt{2\pi}\Delta} e^{-\frac{(E-\bar{E})^2}{2\Delta^2}} \left.\frac{d\sigma}{dp'_{\perp J}}\right|_{p'_{\perp J}=p_{\perp J}+E}$$

Our approach Establish baselines without free parameters

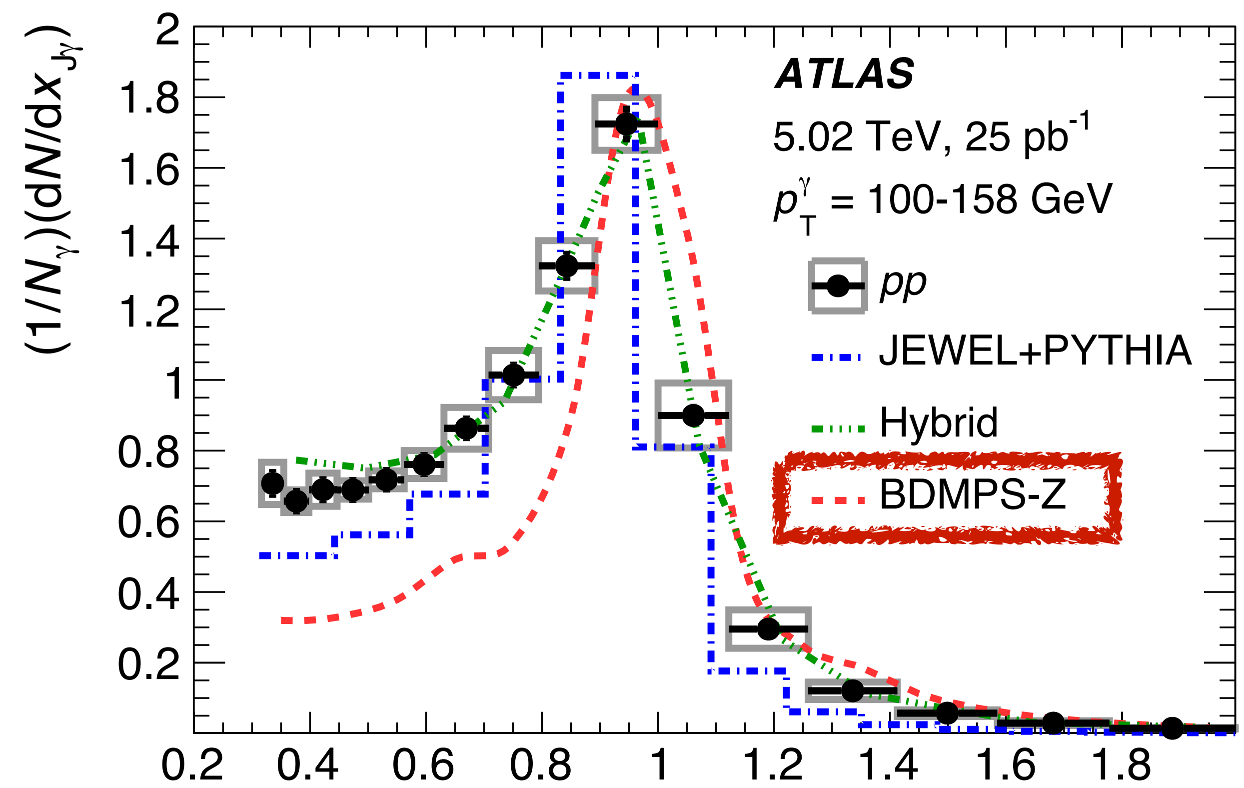
Resummation Improved pQCD approach

dijet, Sudakov + NLO(2→ 3&2→ 4)





photon-jet, Sudakov + LO(2→ 3)



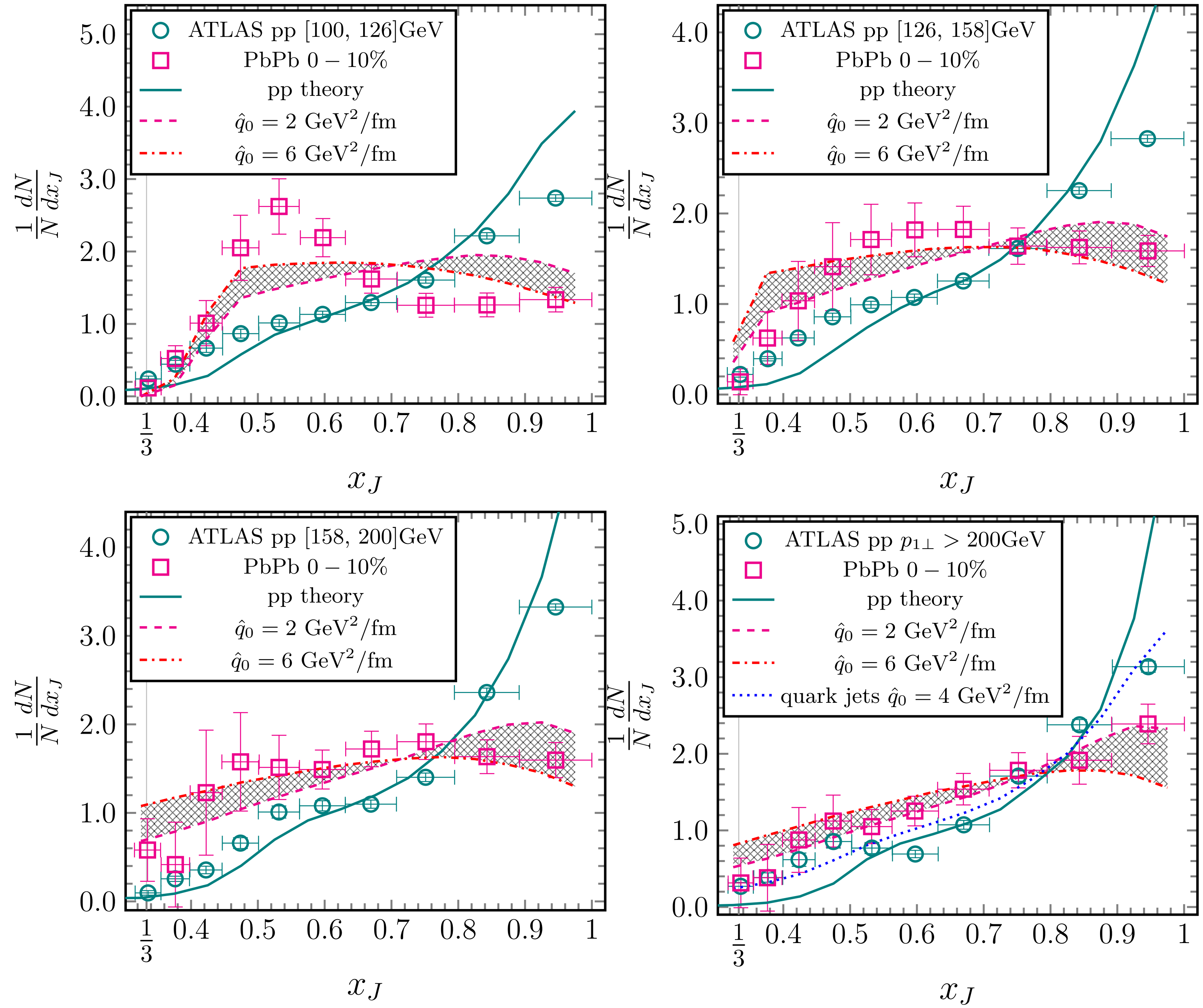
ATLAS, 1809.07280

BDMPS formalism

$$\epsilon D(\epsilon) = \sqrt{\frac{\alpha^2 \omega_c}{2\epsilon}} \exp\left(-\frac{\pi\alpha^2\omega_c}{2\epsilon}\right)$$

$$\omega_c \equiv \int dL\ \hat{q}L \qquad \alpha \equiv \frac{2\alpha_s C_R}{\pi}$$

- ☑ Probability for a jet to lose energy (ε).



Results:

- ☑ Assuming all the jets are gluon jets.
- ☑ Typical energy loss is 20 ~ 30 GeV.
- ☑ $\hat{q}_0$ is 2 ~ 6 GeV²/ fm at T_0 = 481MeV.
- ☑ Agrees with the original BDMPS estimate $\hat{q}$ ~ 0.3-0.8 GeV²/ fm at T = 250 MeV. **hep-ph/9608322**

$$\frac{d\sigma}{dp'_{T1}dp'_{T2}} = \int d\epsilon_1 d\epsilon_2 D(\epsilon_1)D(\epsilon_2)\frac{d\sigma}{dp_{T1}dp_{T2}}\Big|_{p_{T1}=p'_{T1}+\epsilon_1;\ p_{T2}=p'_{T2}+\epsilon_2}$$

p_T imbalance in AA collisions & jet energy loss

BDMPS formalism

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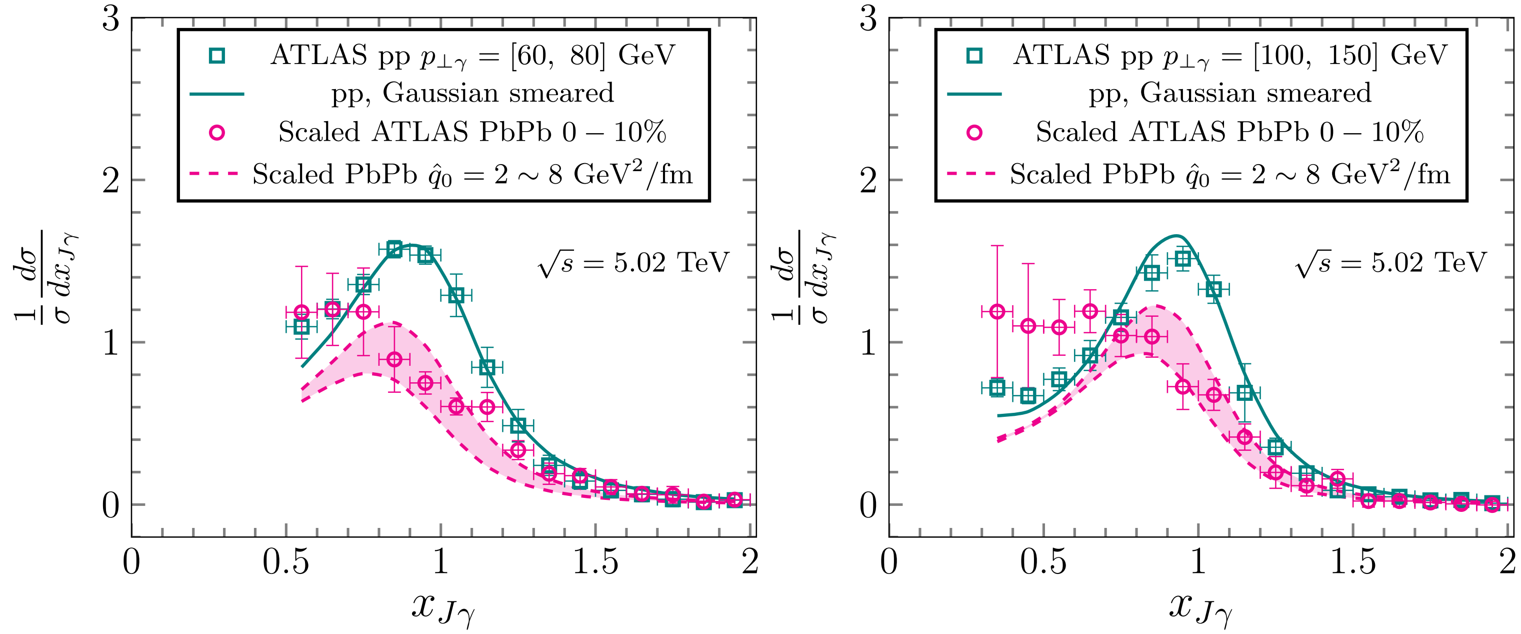
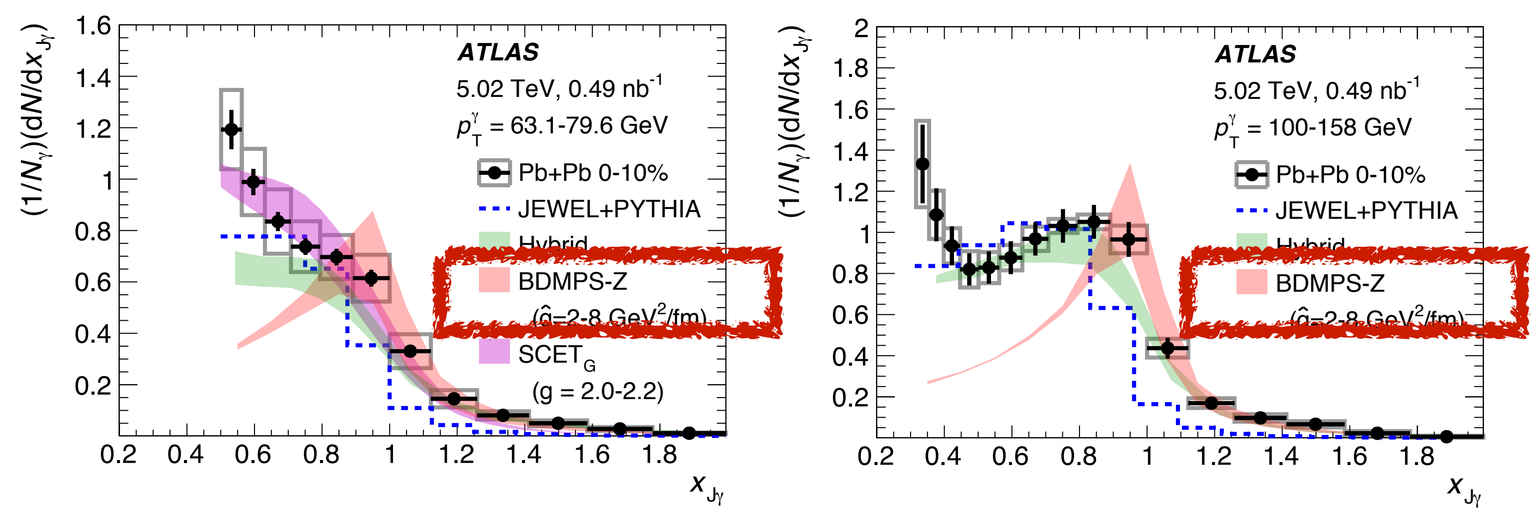


Results:



- ☑ $\hat{q}_0$ is 2 ~ 8 GeV²/ fm at T_0 = 509MeV.

$$\frac{d\sigma}{dp'_{T1} dp'_{T2}} = \int d\epsilon_1 d\epsilon_2 D(\epsilon_1) D(\epsilon_2) \frac{d\sigma}{dp_{T1} dp_{T2}}\Big|_{p_{T1}=p'_{T1}+\epsilon_1;\ p_{T2}=p'_{T2}+\epsilon_2}$$

Summary

- ☑ We established a framework to calculate the p_T imbalances.
  Sudakov resummation + perturbative expansion.

- ☑ We extracted $\hat{q}_0$ using BDMPS energy loss approach.
  $\hat{q}_0$ is 2 ~ 6 GeV^2 / fm at T_0 = 481MeV. (dijet)
  $\hat{q}_0$ is 2 ~ 8 GeV^2 / fm at T_0 = 509MeV. (photon-jet)

Thank you very much for your attention!

The End