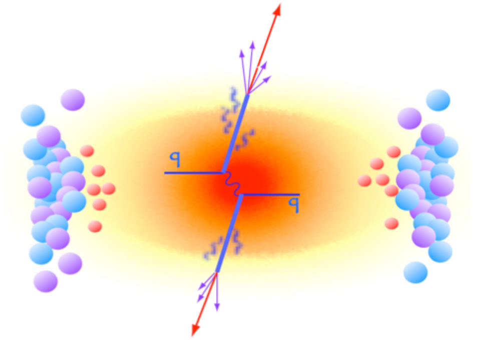


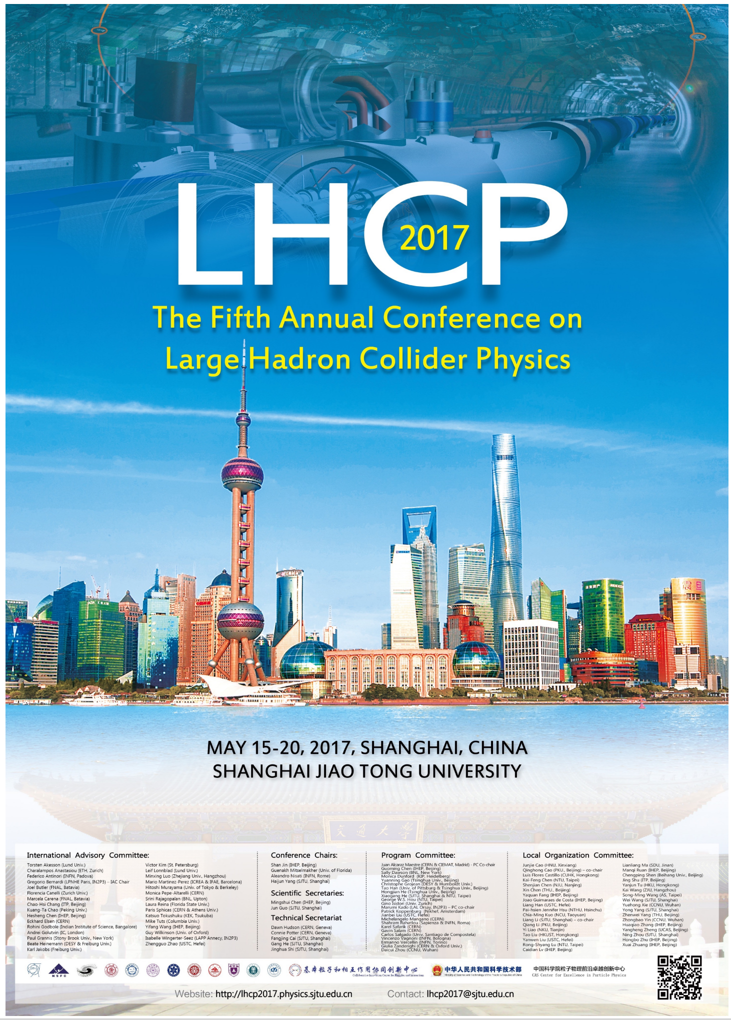
Jet properties in ALICE

Yaxian MAO

for the ALICE Collaboration

Central China Normal University

5th Annual Large Hadron Collider Physics (LHCP2017)
Shanghai, May. 15-20, 2017



LHCP 2017
The Fifth Annual Conference on
Large Hadron Collider Physics

MAY 15-20, 2017, SHANGHAI, CHINA
SHANGHAI JIAO TONG UNIVERSITY

International Advisory Committee:

Conference Chairs:

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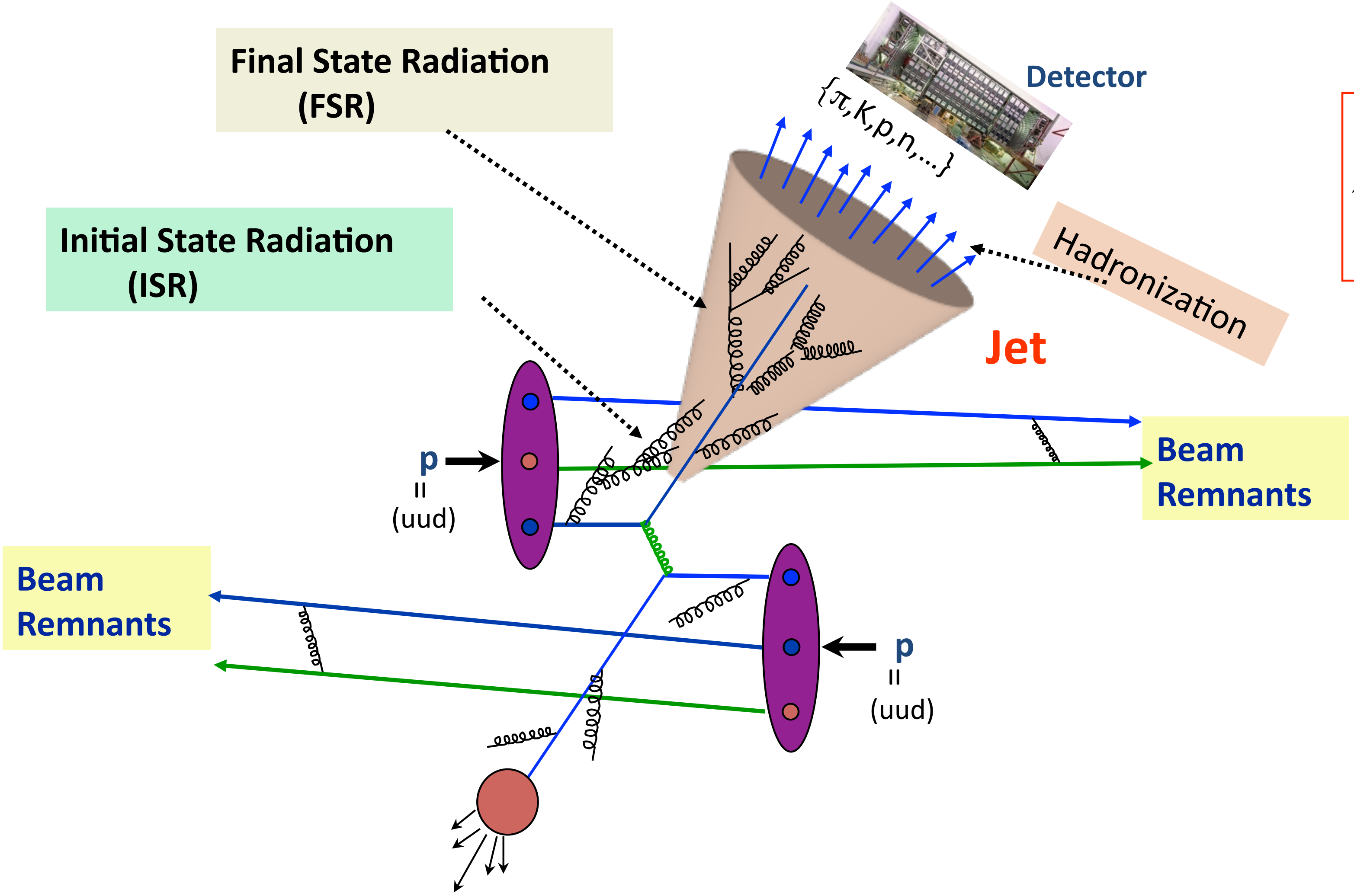
Website: http://lhcp2017.physics.sjtu.edu.cn
Contact: lhcp2017@sjtu.edu.cn

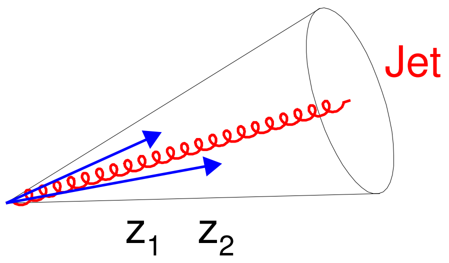
Jets: a tomographic probe of the medium



Final State Radiation (FSR)

Initial State Radiation (ISR)

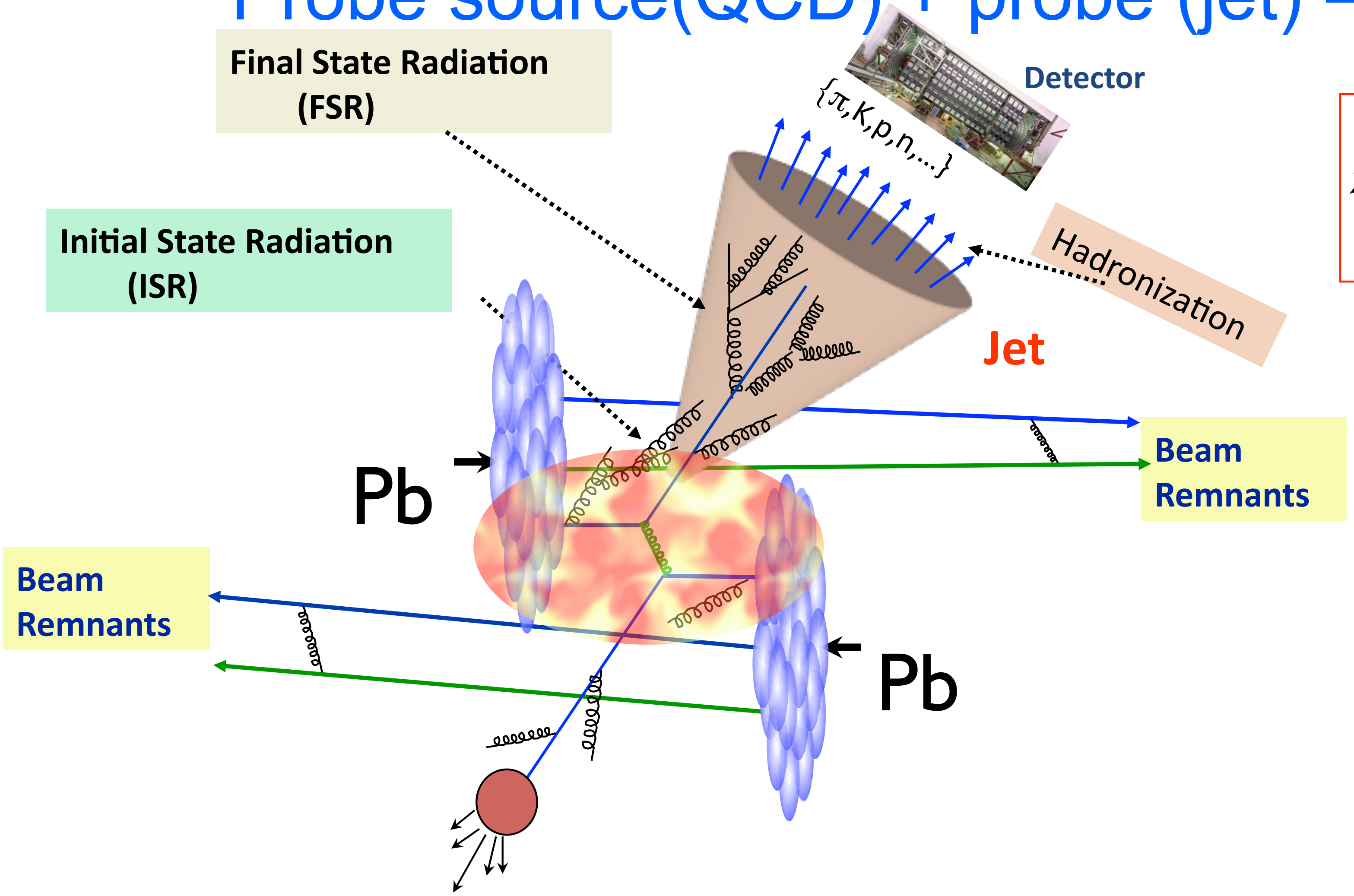
$$z = \frac{p_{\text{hadron}}}{p_{\text{jet}}}$$



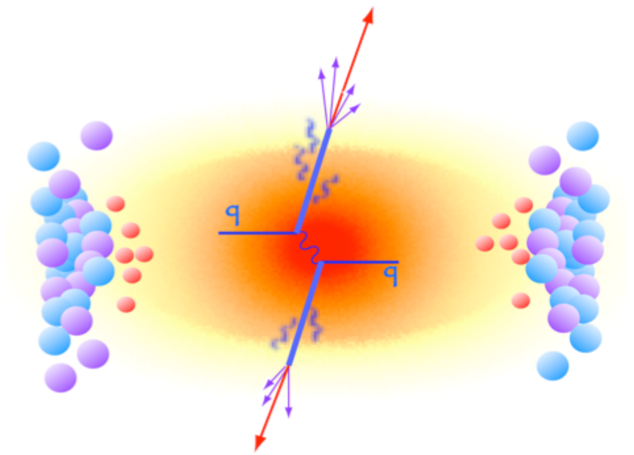
- High momentum transfer scattering in 2→2 process (LO pQCD) develops a partonic shower and hadronizes into final state particles (non pQCD) collimated in a spray of hadrons (jet)

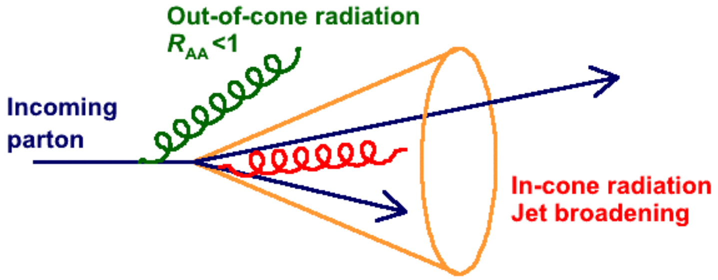
Jets: a tomographic probe of the medium

Probe source(QCD) + probe (jet) → QGP properties



$$z = \frac{p_{\text{hadron}}}{p_{\text{jet}}}$$

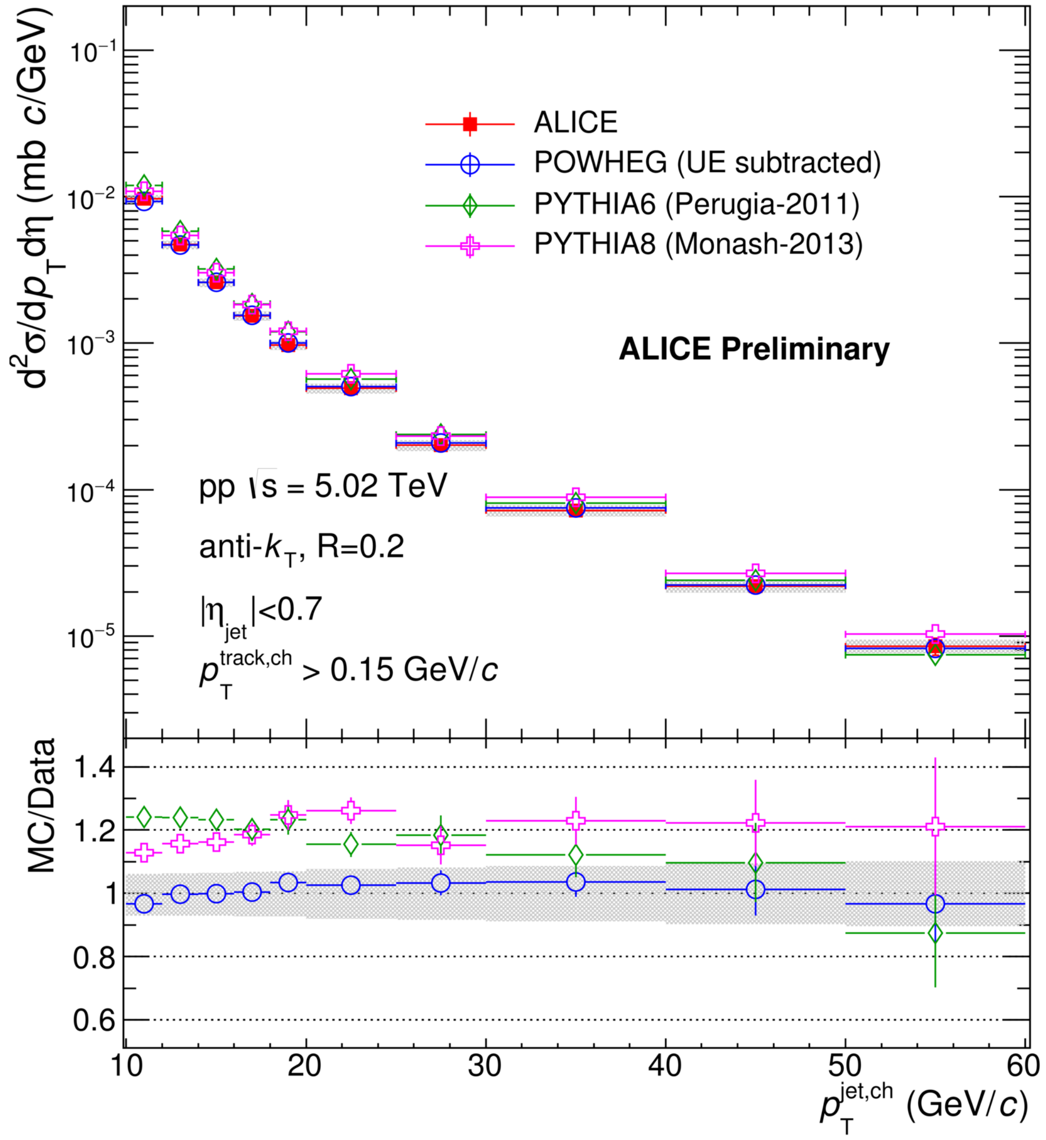




- High momentum transfer scattering in 2→2 process (LO pQCD) develops a partonic shower and hadronizes into final state particles (non pQCD) collimated in a spray of hadrons (jet)
- Partons loose energy ΔE (collision + radiation) when traversing the medium

$$\text{Jet}(E) \rightarrow \text{Jet}\ (E' = E-\Delta E) + \text{soft particles}(\Delta E)$$

Jet cross section measurements



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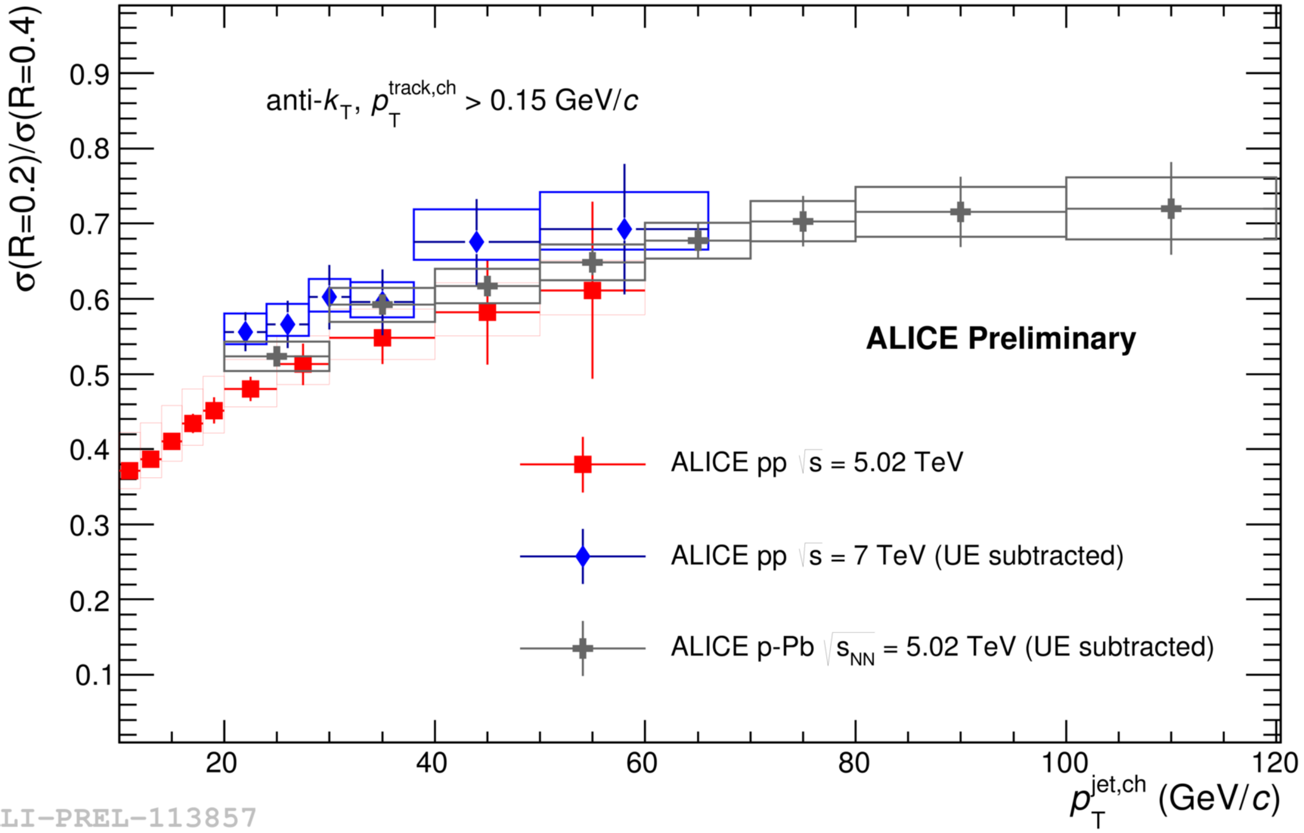
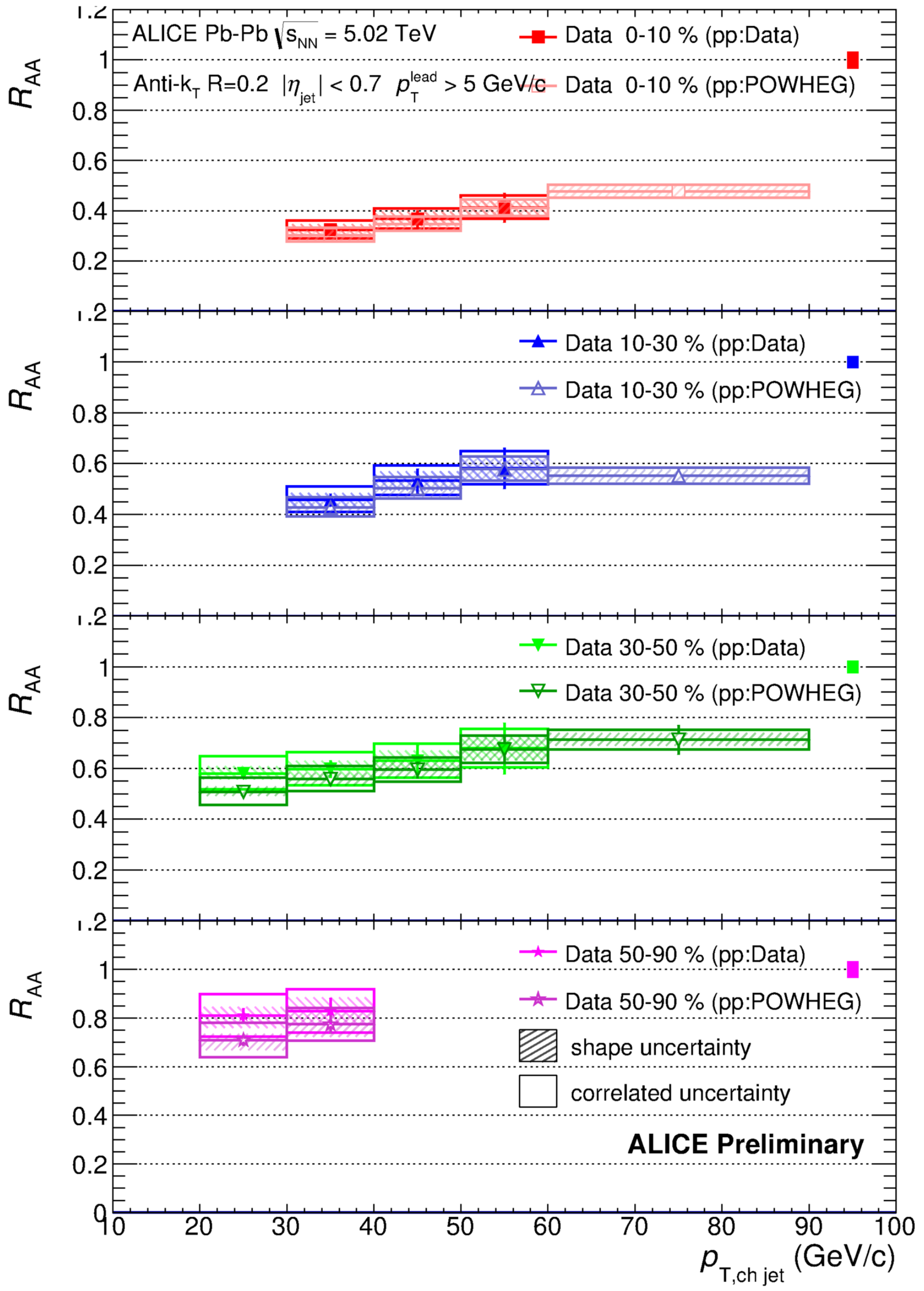


ALI-PREL-113857

- Jet cross section is well described by POWHEG+PYTHIA8 NLO calculations within systematic uncertainties
- Cross section ratio between R = 0.2/R = 0.4 consistent with different √s, slightly increasing with jet p_T → reflect jet collimation info

Jet nuclear modification factor R_{AA}



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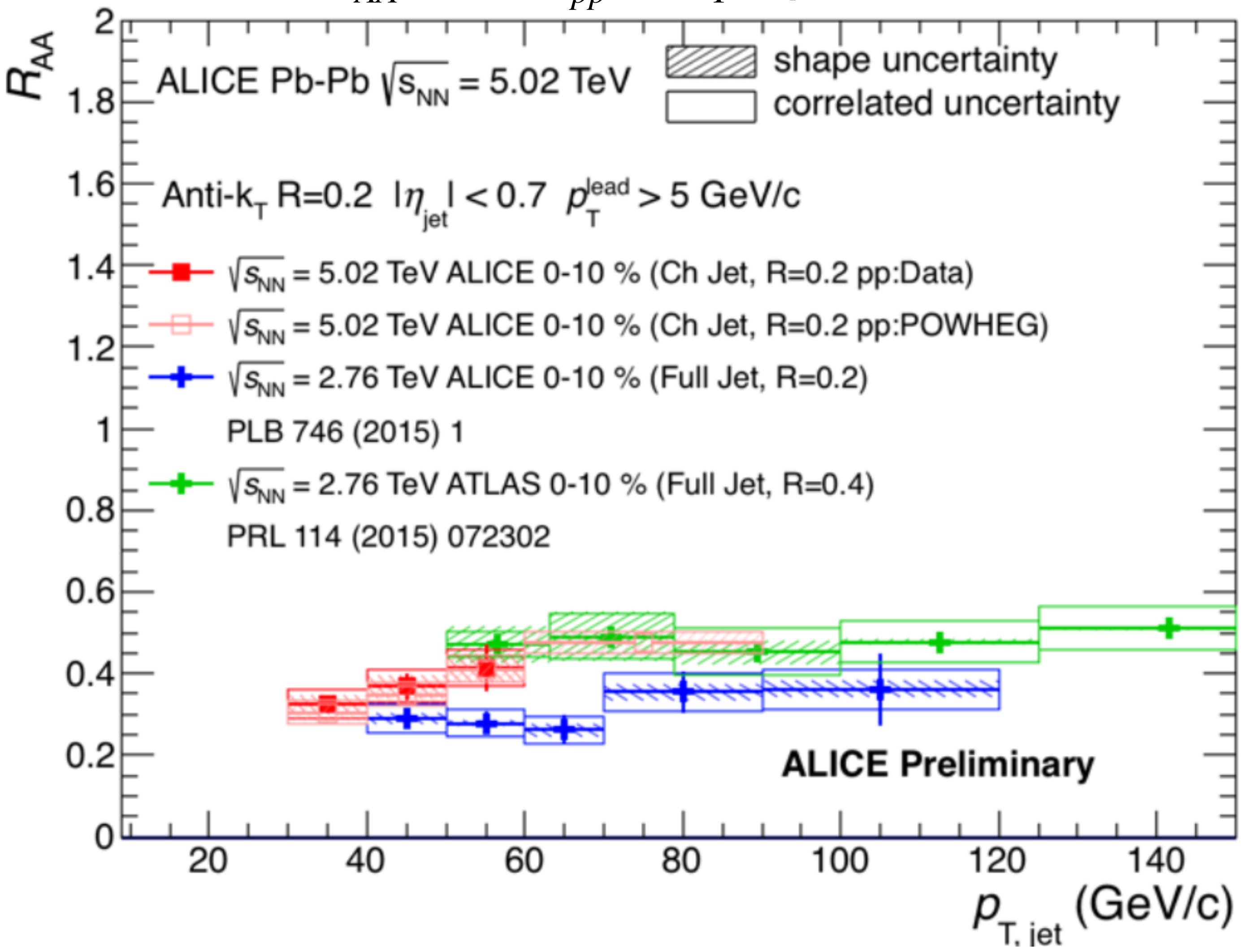
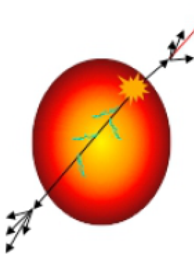
$$R_{AA} = \frac{1}{<T_{AA}>} \frac{d^2N_{AA}/dp_T d\eta}{d^2\sigma_{pp}/dp_T d\eta}$$

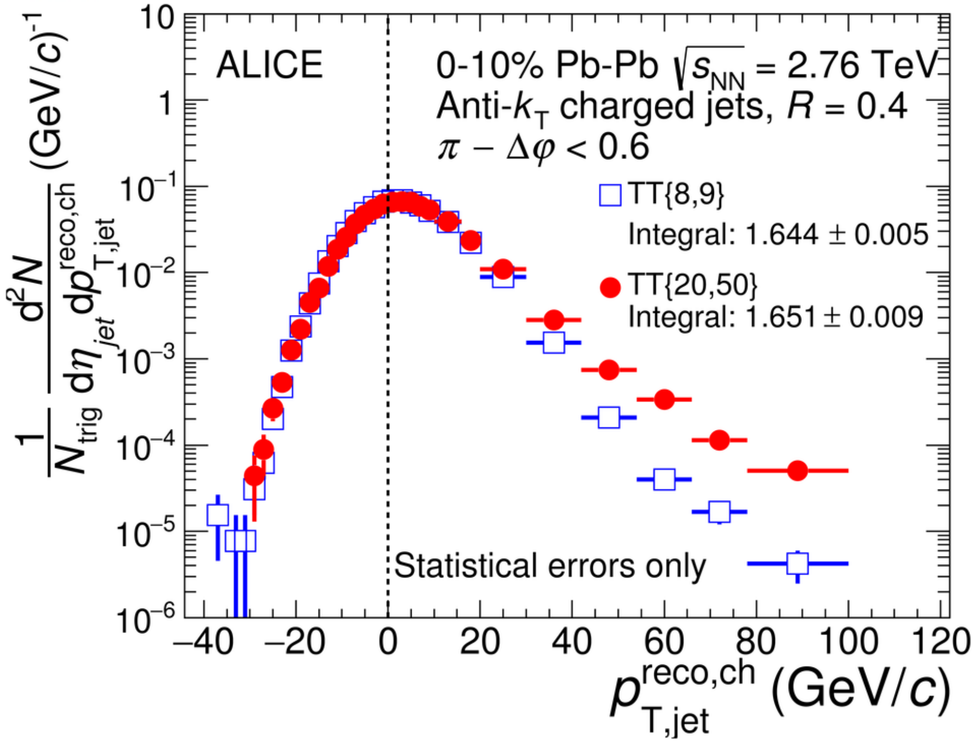


- Strong suppression of jet yield in most central collisions
- R_{AA} at 5.02 TeV similar to 2.76 TeV
  - ➡ "compensation" between increasing suppression and change of the shape of the spectra

Semi-inclusive hadron-jet correlation

- Trigger-normalized yield of jets recoiling from a high p_T trigger





$$\Delta_{recoil} = \frac{1}{N_{trig}} \frac{d^2N_{jet}}{dp^{ch}_{T,jet}\,d\eta}\Bigg|_{p_{T,trig}\in\{20,50\}} - c_{Ref}\cdot\frac{1}{N_{trig}} \frac{d^2N_{jet}}{dp^{ch}_{T,jet}\,d\eta}\Bigg|_{p_{T,trig}\in\{8,9\}}$$

c_{Ref}: accounts for invariance of jet density with TT-class ($c_{Ref} \approx 0.94$)

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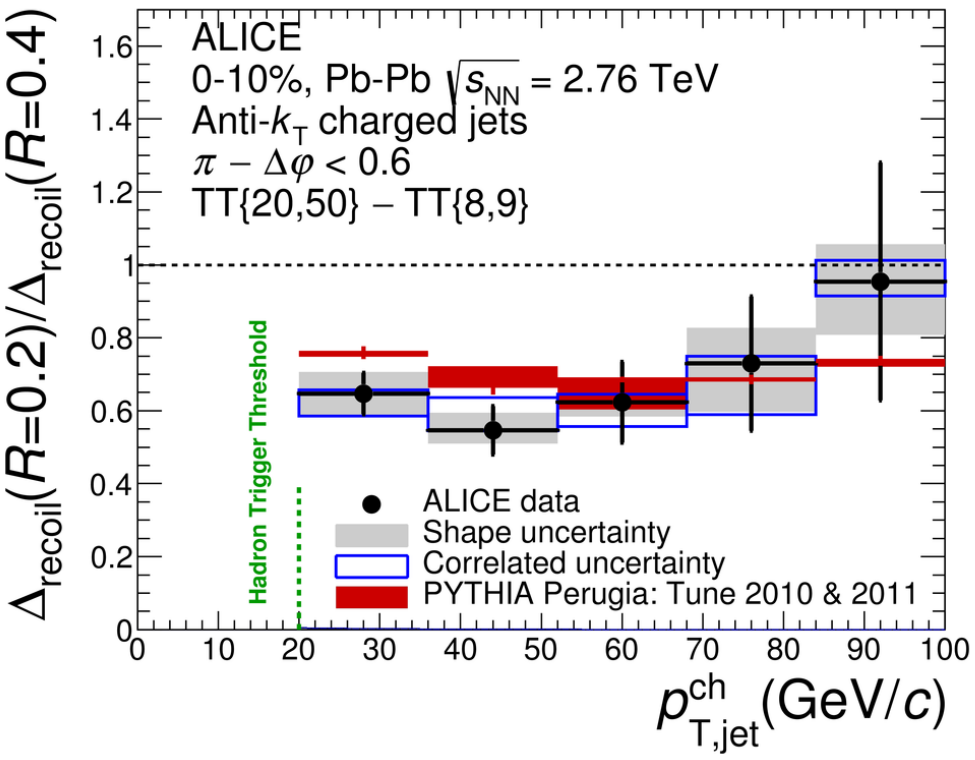
TT = Trigger Track

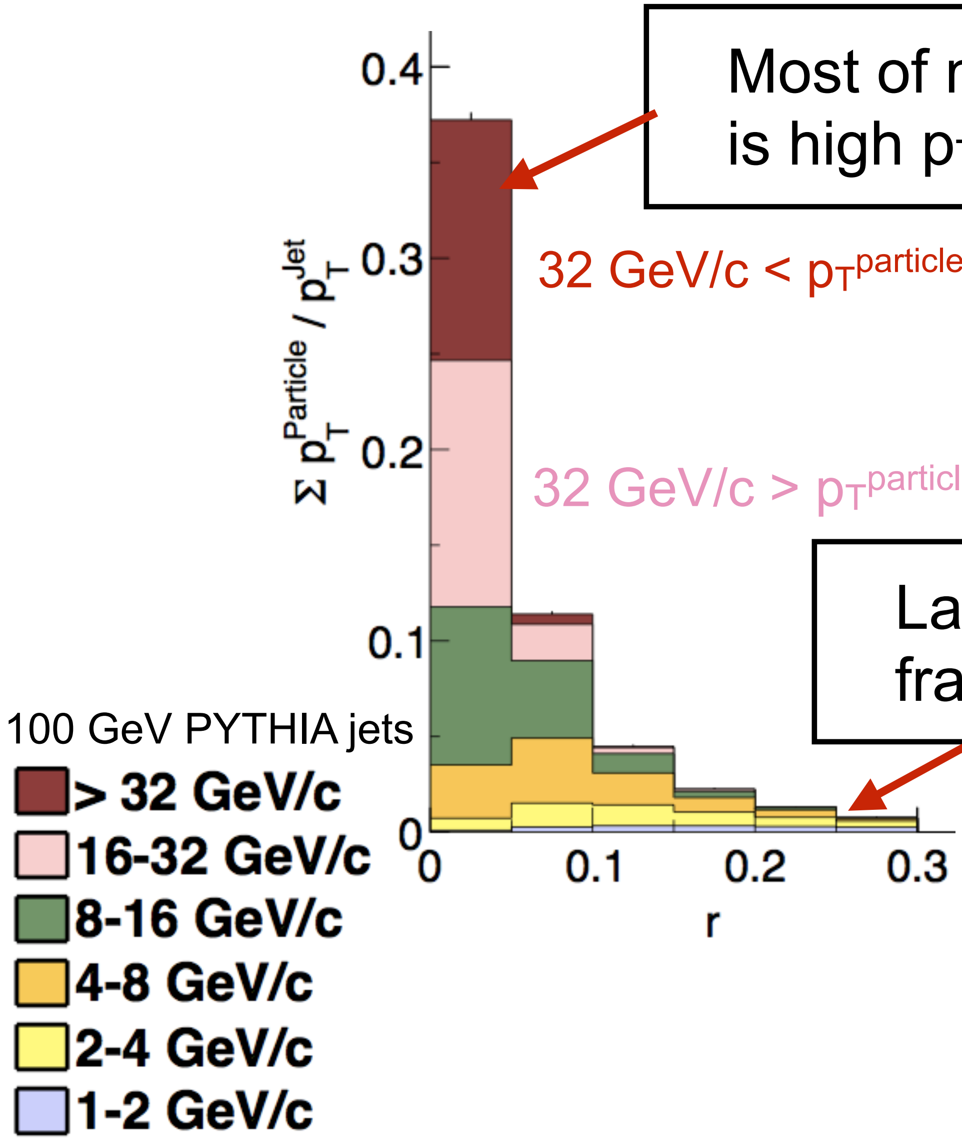
TT{X,Y} means $p_{T,\,trig} \in$ {X,Y} GeV/c



- New observable of jet quenching
  - pp: calculable via pQCD
  - AA: data-driven correction for large uncorrelated background by varying $p_{T,trig}$ →systematically well-controlled at low p_{Tjet}, large R
- No broadening observed

Jet anatomy

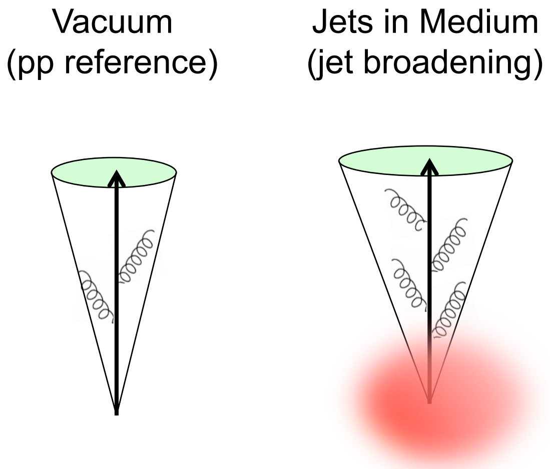
- Jet are extended objects with momentum and angular structure

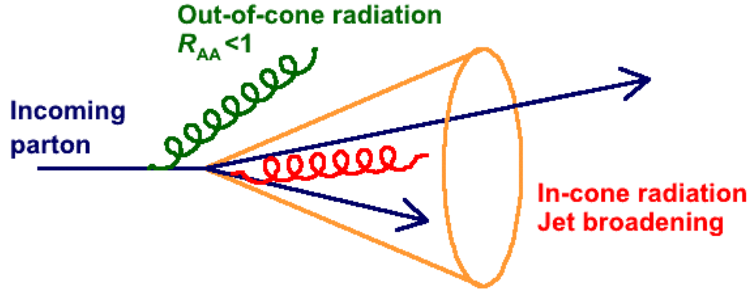


Most of momentum found close to jet axis is high p_T particles (p_T > O(10 GeV))

Large angle component of jet contains small fraction of jet p_T in soft particles (p_T > O(1GeV))

$r = \sqrt{(\eta_{jet}-\eta_{ch})^2+(\varphi_{jet}-\varphi_{ch})^2}$





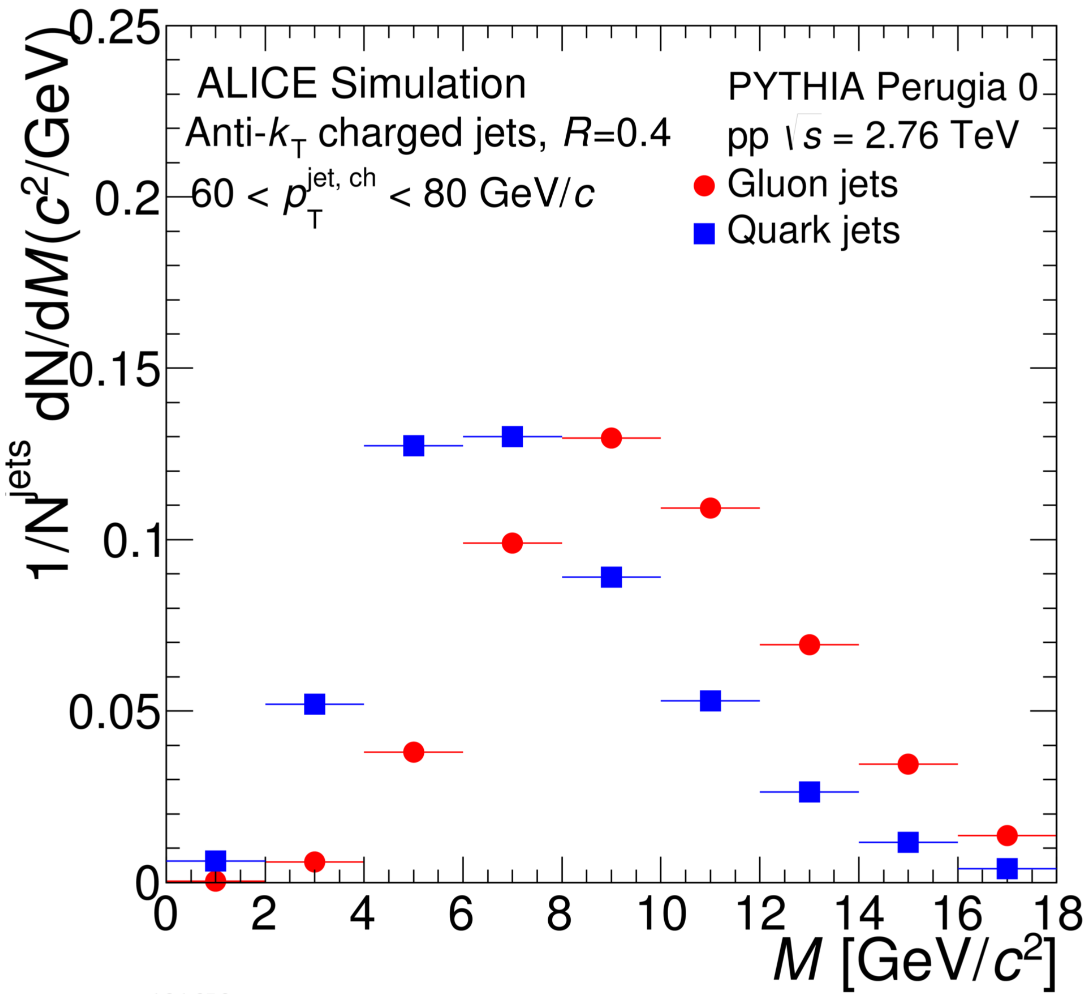
- How the parton shower modified?
- What is the mechanism modifying the shower?
- Can we relate to shower modifications to medium properties?

Jet mass

- Difference of the momentum of the jets and the energy of its constituents weighted by their pseudo-rapidity

$$M = \sqrt{p^2 - p_T^2 - p_z^2} \qquad p = \sum_{i=1}^{n} p_{T_i} \cosh\eta_i. \qquad p_z = \sum_{i=1}^{n} p_{T_i} \sinh\eta_i$$

- Related to the virtuality of the parton traversing the medium
  - small mass: collimated jet, small number of constituents → low virtuality
  - large mass: broad jet, large number of constituents → high virtuality



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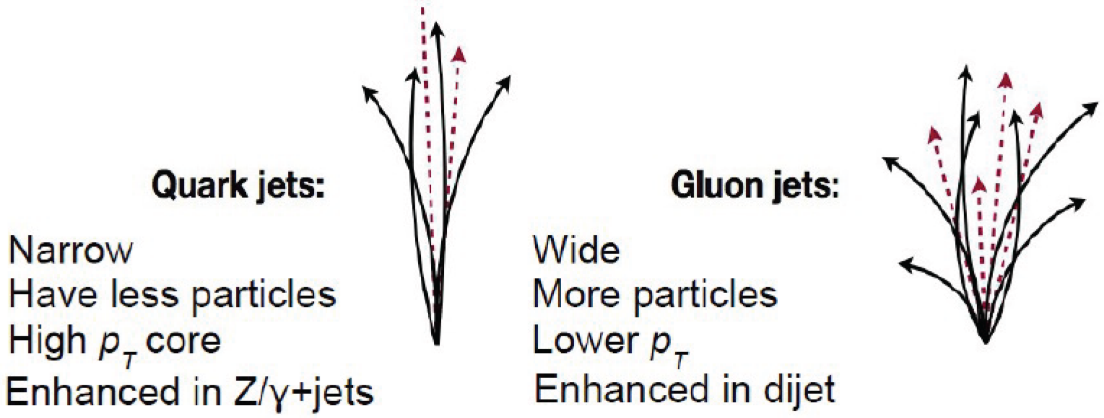


Quark jets:

Narrow
Have less particles
High p_T core
Enhanced in Z/γ+jets

Gluon jets:

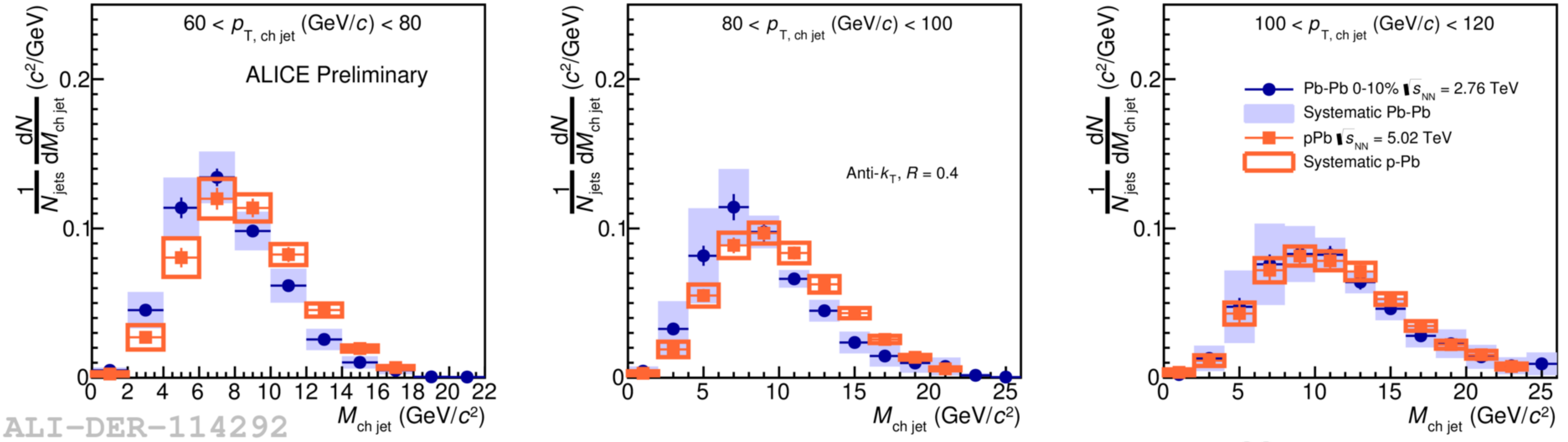
Wide
More particles
Lower p_T
Enhanced in dijet

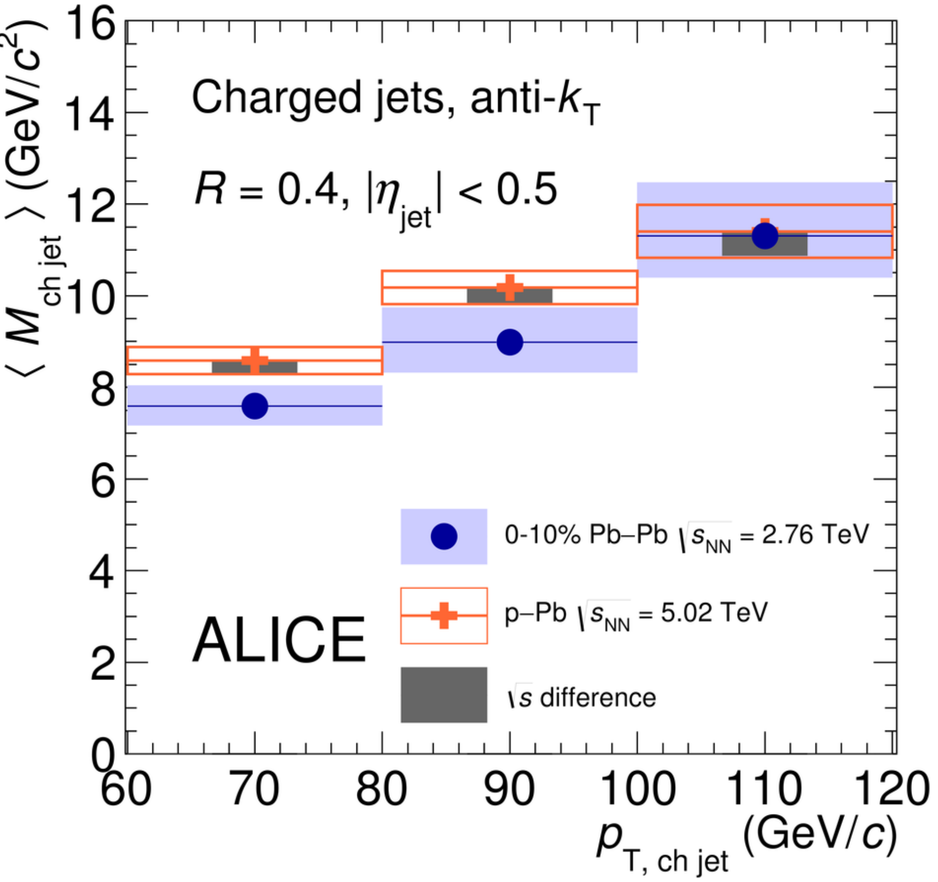
Gluon jets are wider than quark jets

↓

Jet mass of gluon jets are larger than quark jets

Charged jet mass in different collision systems

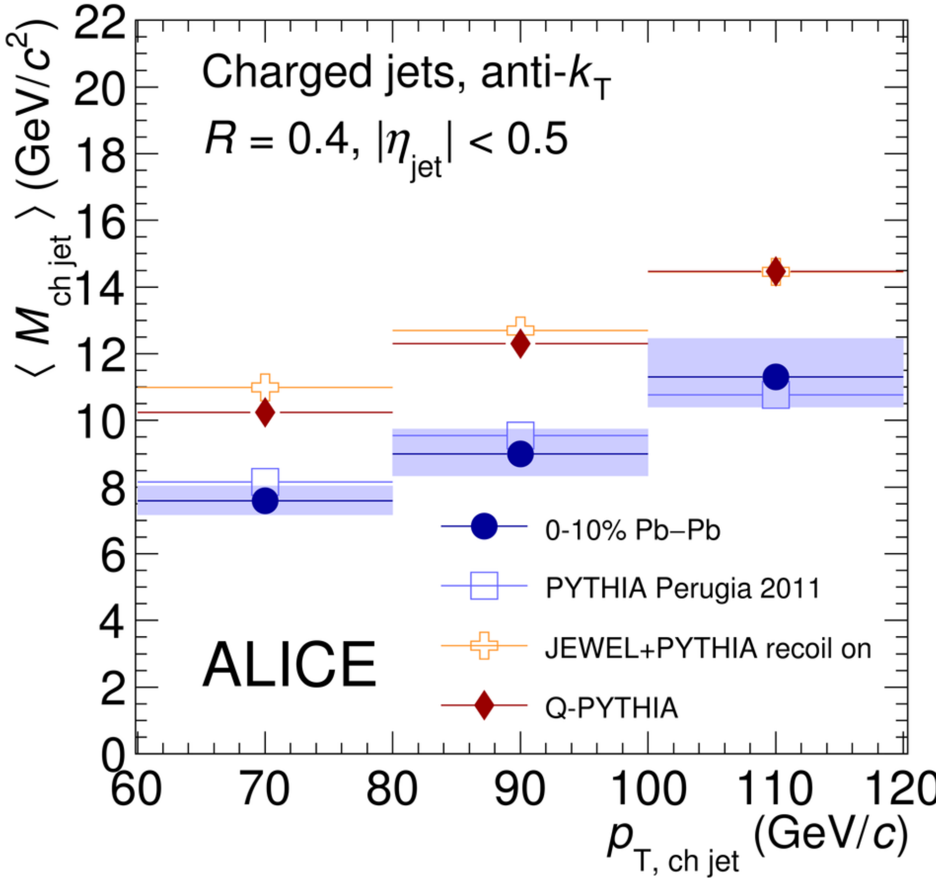




arXiv:1702.00804, submitted to PLB

anti-k_T, charged jets

R = 0.4, $|\eta_{jet}|$ < 0.5



- Different observed between pPb and Pb-Pb jet mass distribution
- Models with quenching unable to reproduce data

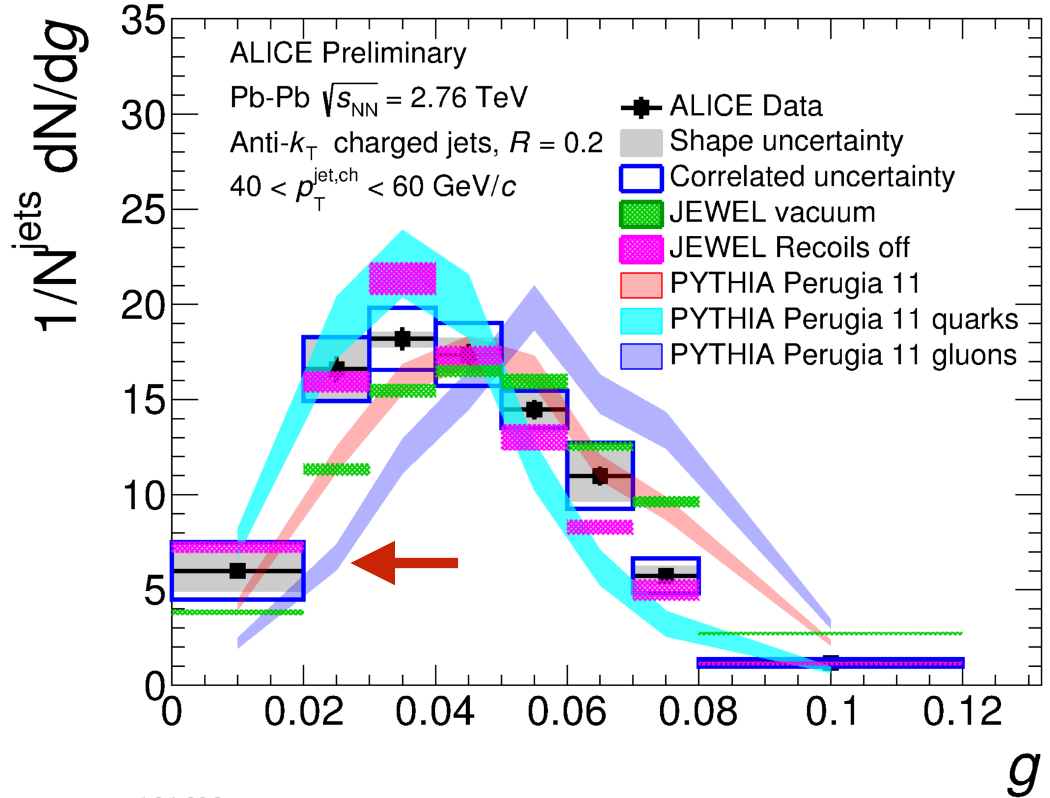
Jet angularity and p_T dispersion

- Probe angular and momentum scale of quenched jets

jet width:
momentum redistribution of jet constituents weighted by distance

anti-k_T, charged jets
R = 0.2

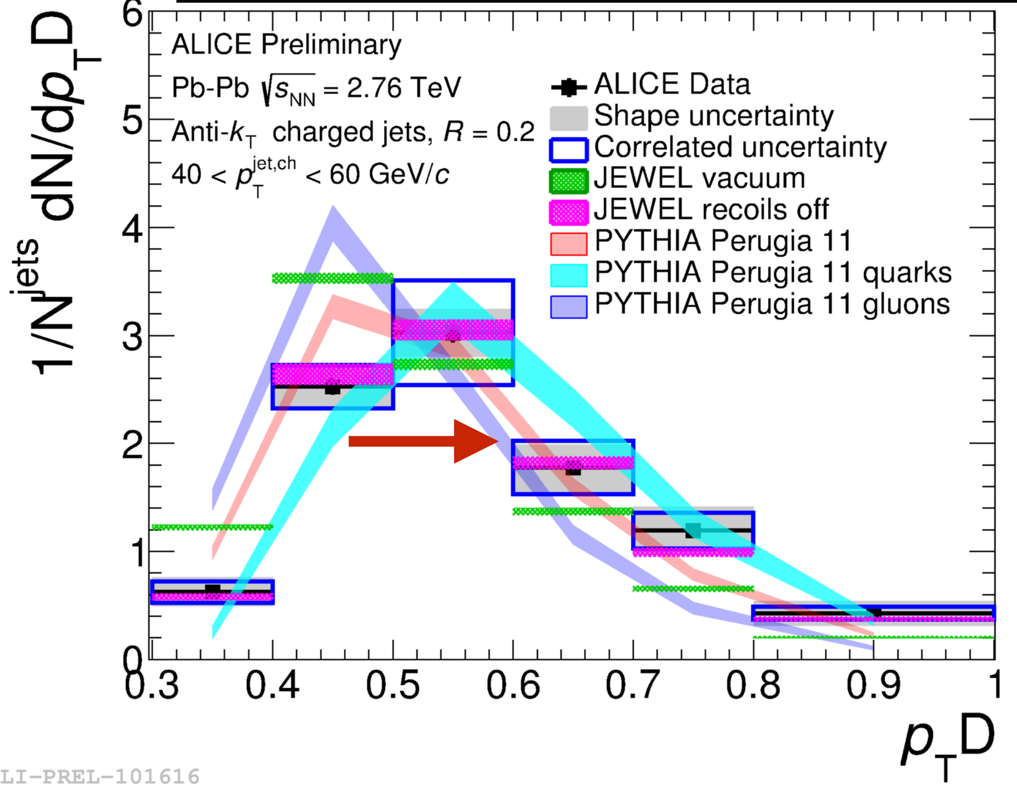
p_T-dispersion $p_T D$:
momentum redistribution of jet constituents



ALI-PREL-101608

$$g = \sum_{i\in\text{jet}} \frac{p_T^i}{p_T^{\text{jet}}} |r_i|$$

$$p_T D = \frac{\sqrt{\sum_i p_{T,i}^2}}{\sum_i p_{T,i}}$$

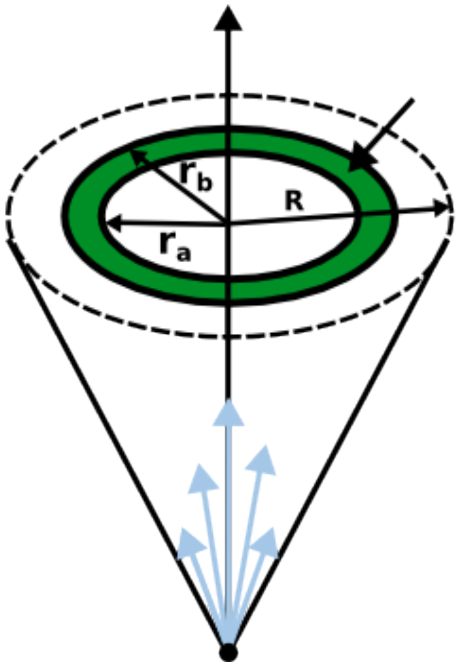


ALI-PREL-101616

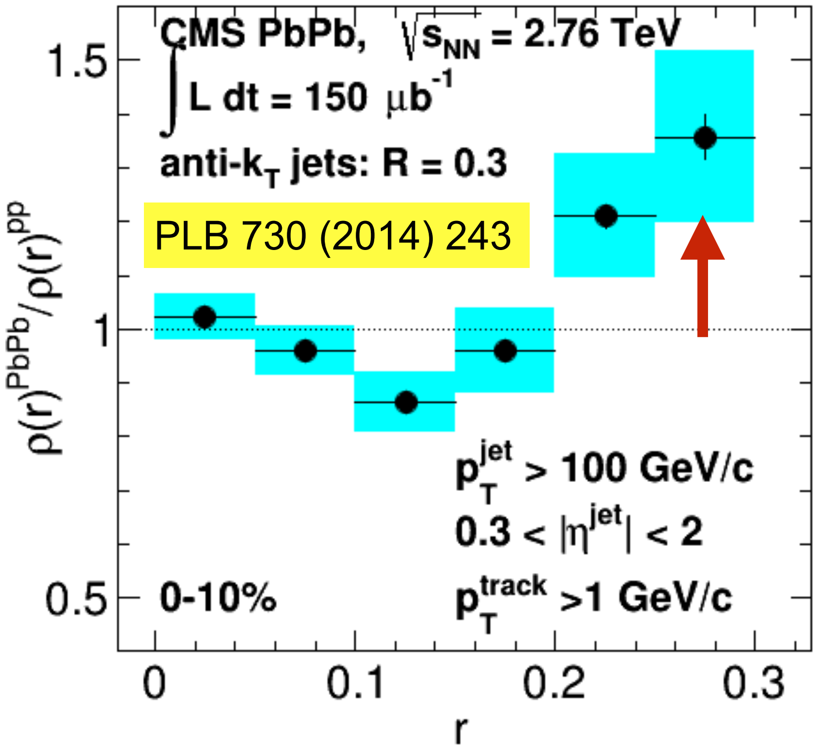
- Accelerated shower leads to higher angularities (broader) and small $p_T D$ (more constituents)
- Qualitatively consistent with collimation of the jet core
- g and $p_T D$ qualitatively described by JEWEL model with recoils off

Jet broadening

- Probe angular scale of quenched jets



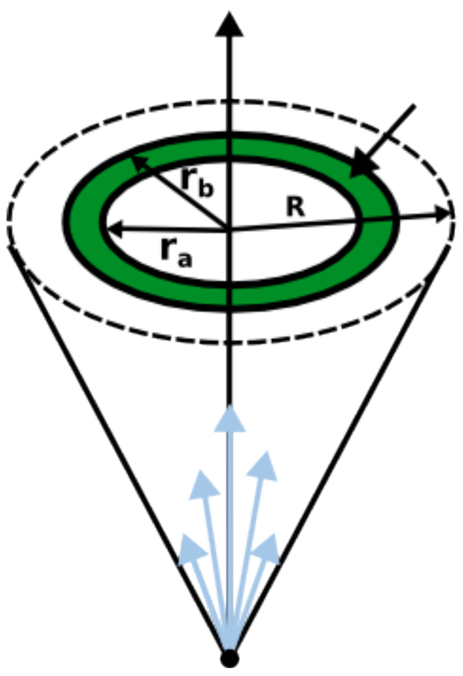
radial profile:
energy flow redistribution



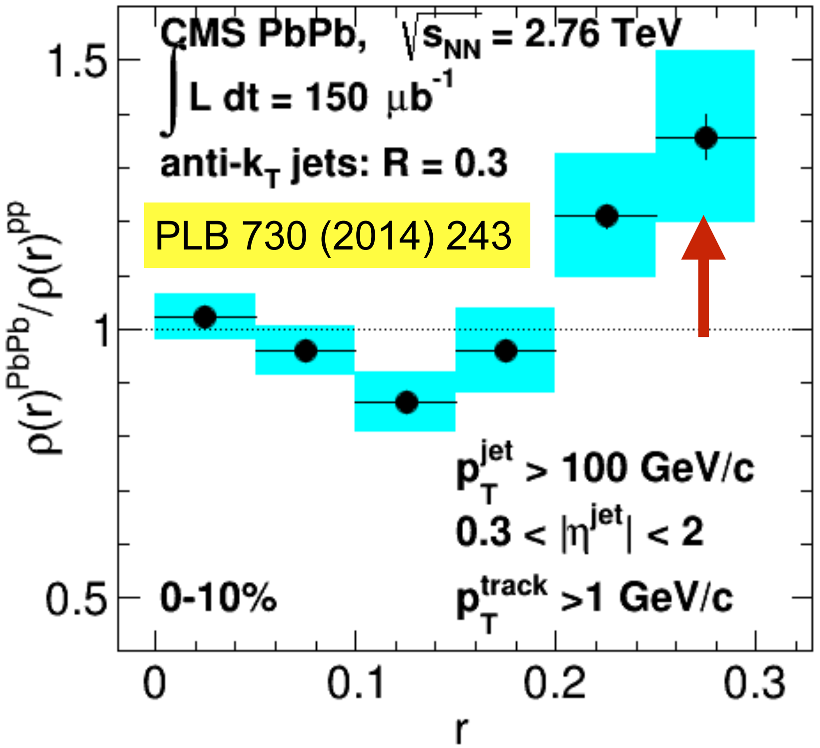
$$\rho(r) = \frac{1}{f_{ch}}\frac{1}{\delta r}\frac{1}{N_{jet}}\sum_{jets}\frac{p_T(r-\delta r/2, r+\delta r/2)}{p_T^{jet}},$$

Jet broadening

- Probe angular scale of quenched jets

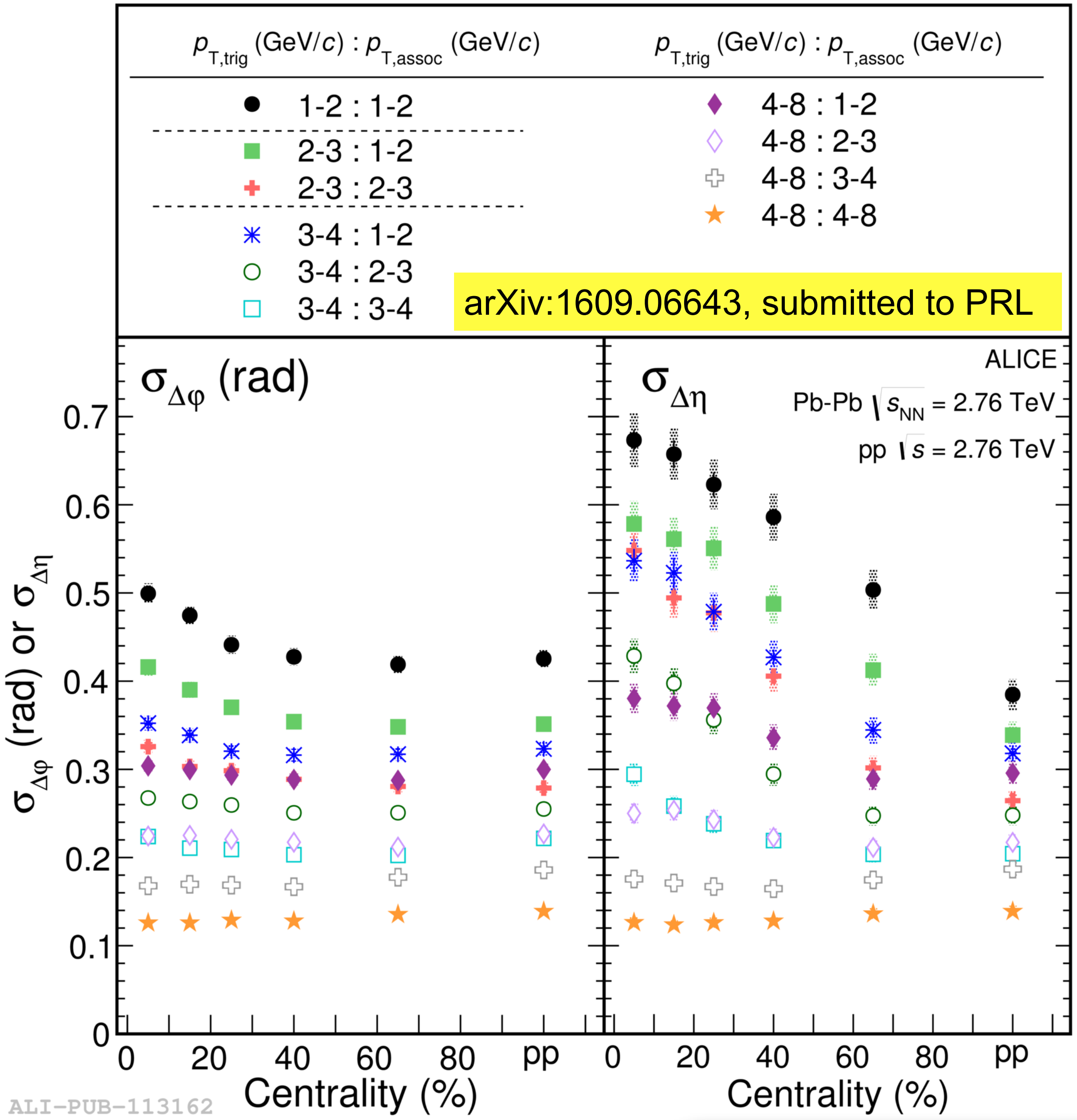


radial profile:
energy flow redistribution



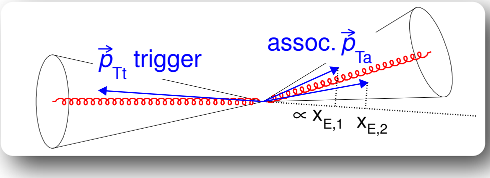
PLB 730 (2014) 243

$$\rho(r) = \frac{1}{f_{ch}}\frac{1}{\delta r}\frac{1}{N_{jet}}\sum_{jets}\frac{p_T(r-\delta r/2, r+\delta r/2)}{p_T^{jet}},$$



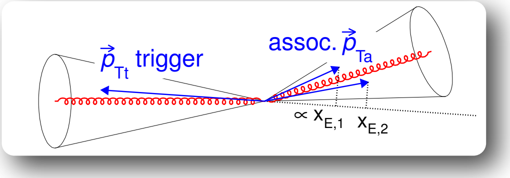
arXiv:1609.06643, submitted to PRL

- Excess at large angular distance → jet broadening



- Jet broadening quantified using two particle correlations:
  - ➡ Small broadening in Δφ, significant broadening in Δη ($p_{T,trig}$ ↑, width ↓)

Low p_T excess from two particle correlations



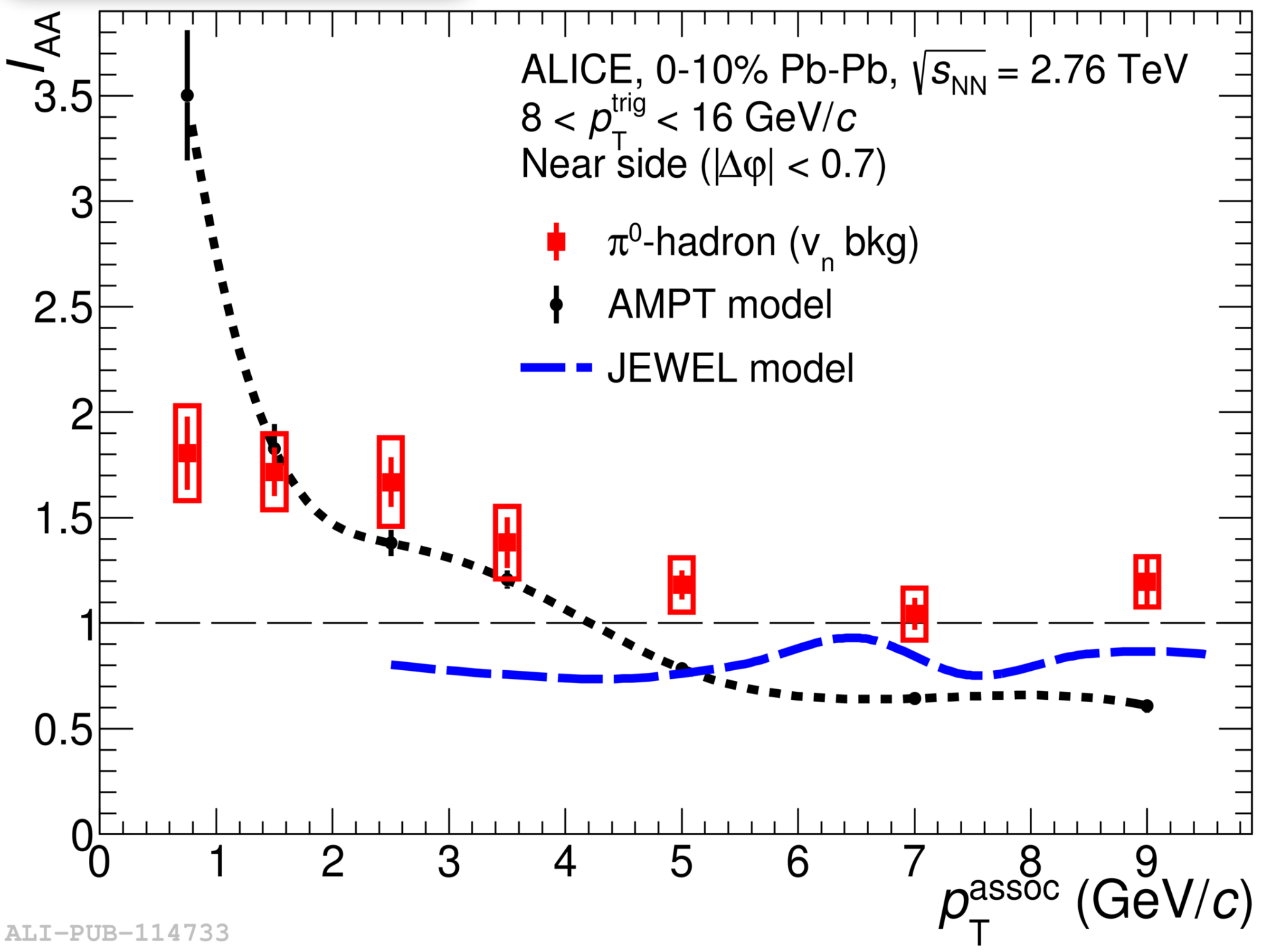
near side

$$I_{AA} = \frac{Y_{\text{Pb-Pb}}}{Y_{\text{pp}}}$$

$$Y = \int \frac{dN_{assoc}}{d\Delta\varphi} d\Delta\varphi$$

away side

PLB 763 (2016) 238



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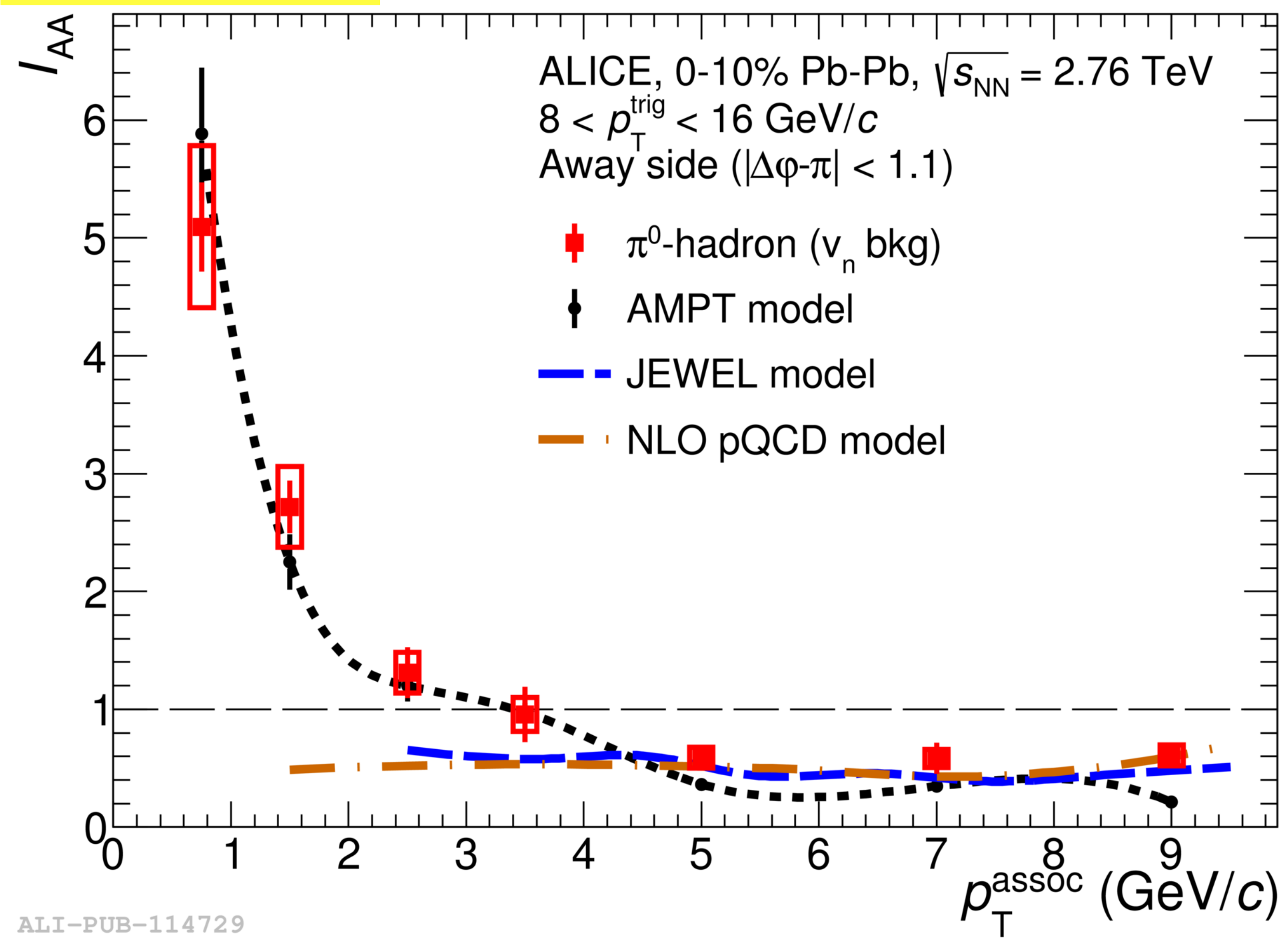
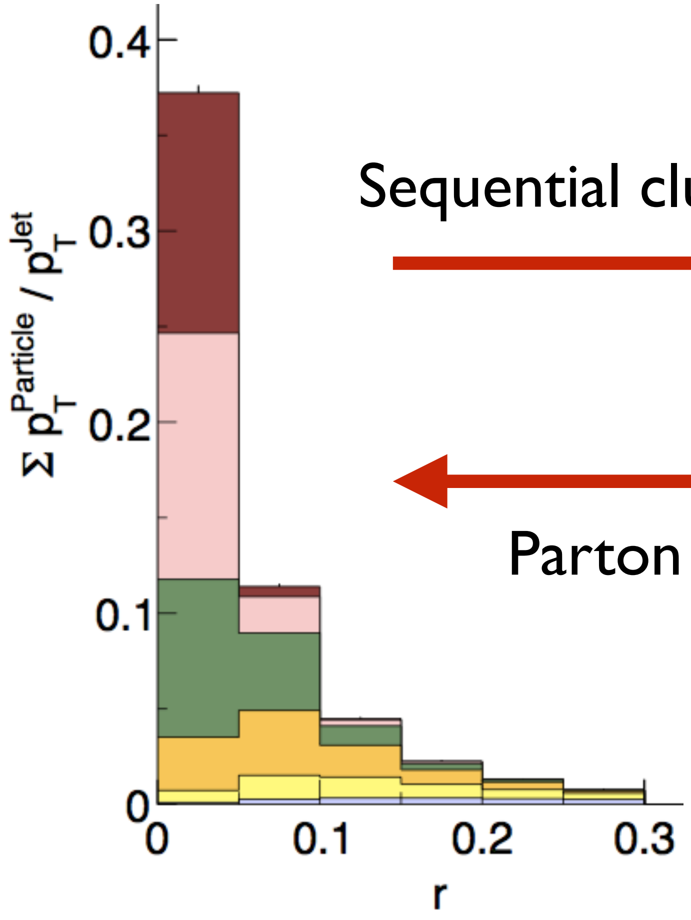


ALI-PUB-114729

- Enhancement at very low p_T, indicating extra particles excess → consistent with low p_T broadening (soften of fragmentation functions? excited by medium?)
- Suppression on the away side for high p_T → consistent with jet quenching

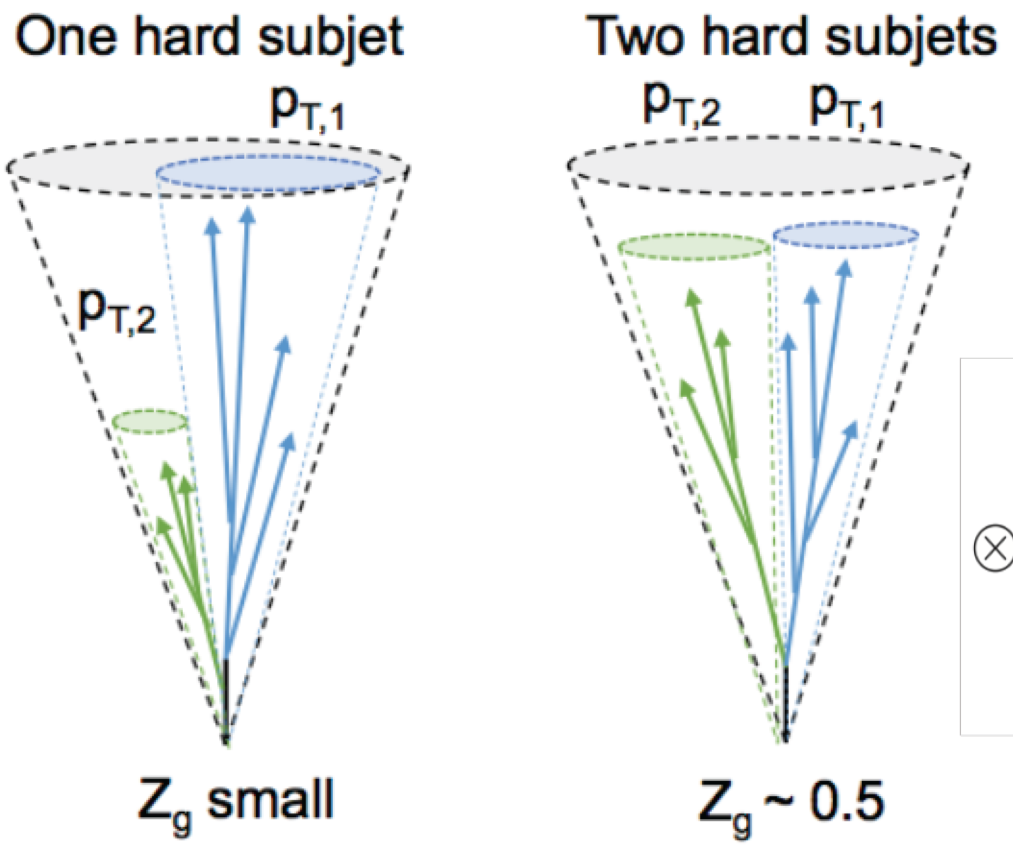
Jet substructure

- Using clustering+jet grooming techniques to map structure of final state jets to evolution of parton shower (e.g. "splitting function")

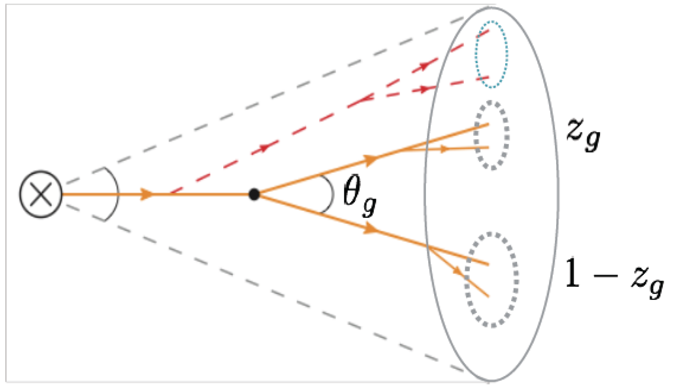


Sequential clustering →

← Parton shower

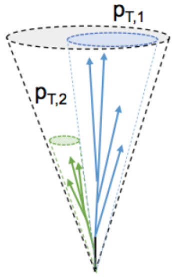


$$z_g = \frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$

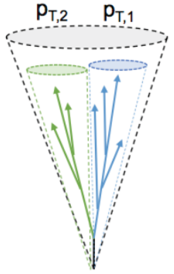


- Splitting function z_g: observable connected to the hardest splitting
- Measure the momentum balance of the two hard sub-jets
- Looking for modifications of the jet hard substructure

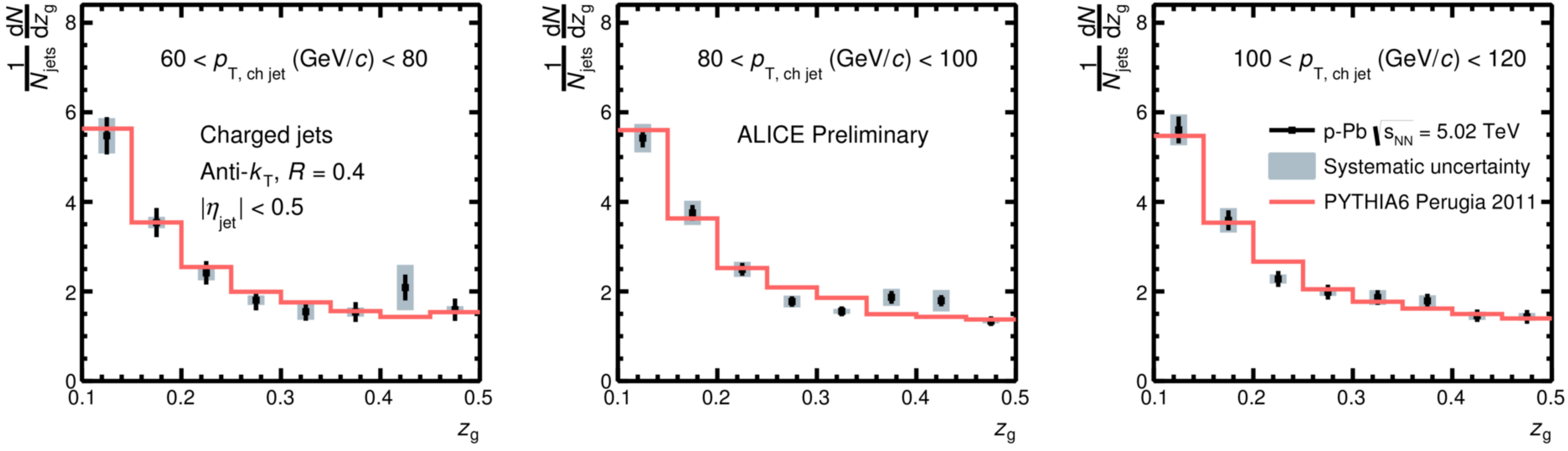
Splitting function in p-Pb collisions



$$z_g = \frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$



anti-k_T, charged jets
$R = 0.4$, $|\eta_{jet}| < 0.5$

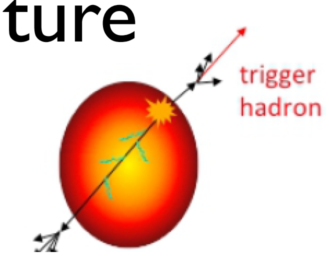


ALI−PREL−120123

- First measurement of z_g in p-Pb collisions at 5.02 TeV
- No modification observed in minimum-bias p-Pb data compared to PYTHIA
- Next: redo the analysis in multiplicity classes, measurements in pp and PbPb collisions

Nsubjettiness measurements

- Nsubjettiness jet shape τ_N: measures how N pronged a jet substructure

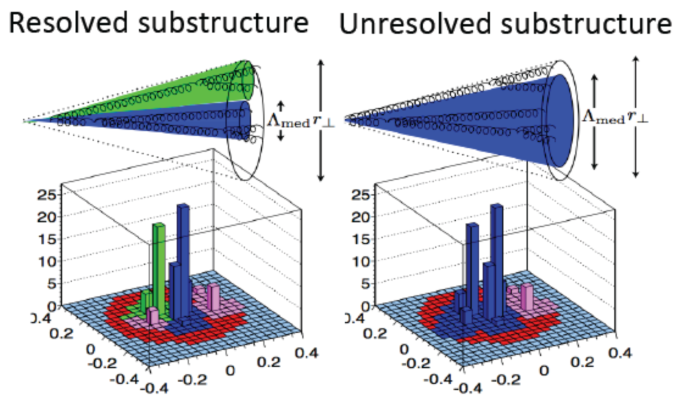


$$\tau_N = \frac{\sum_{i=1} p_{T,i} Min(\Delta R_{i,1}, \Delta R_{i,2}, ..., \Delta R_{i,N})}{R_0 \sum_{i=1} p_{T,i}}$$

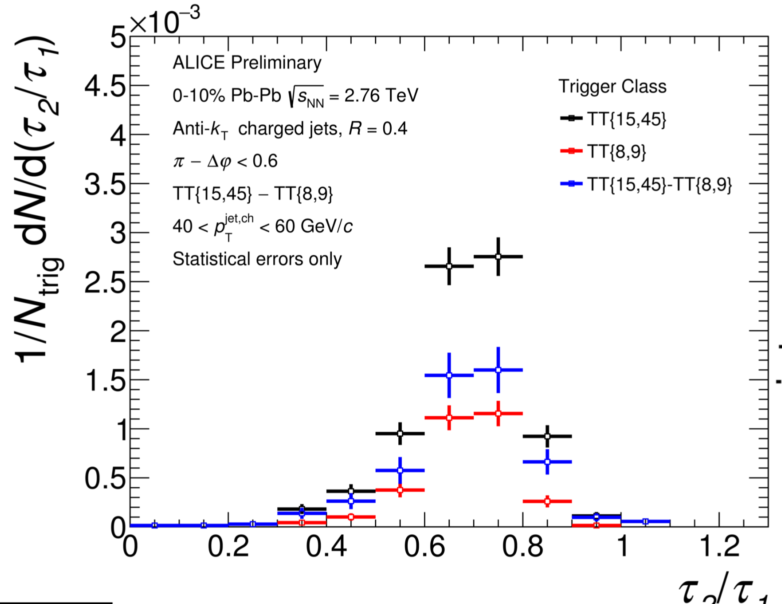
$\Delta R_{i,j}$: η-φ distance between track i and subject j

$p_{T,i}$: p_T of the i^{th} jet constituent

R_0: jet resolution parameter

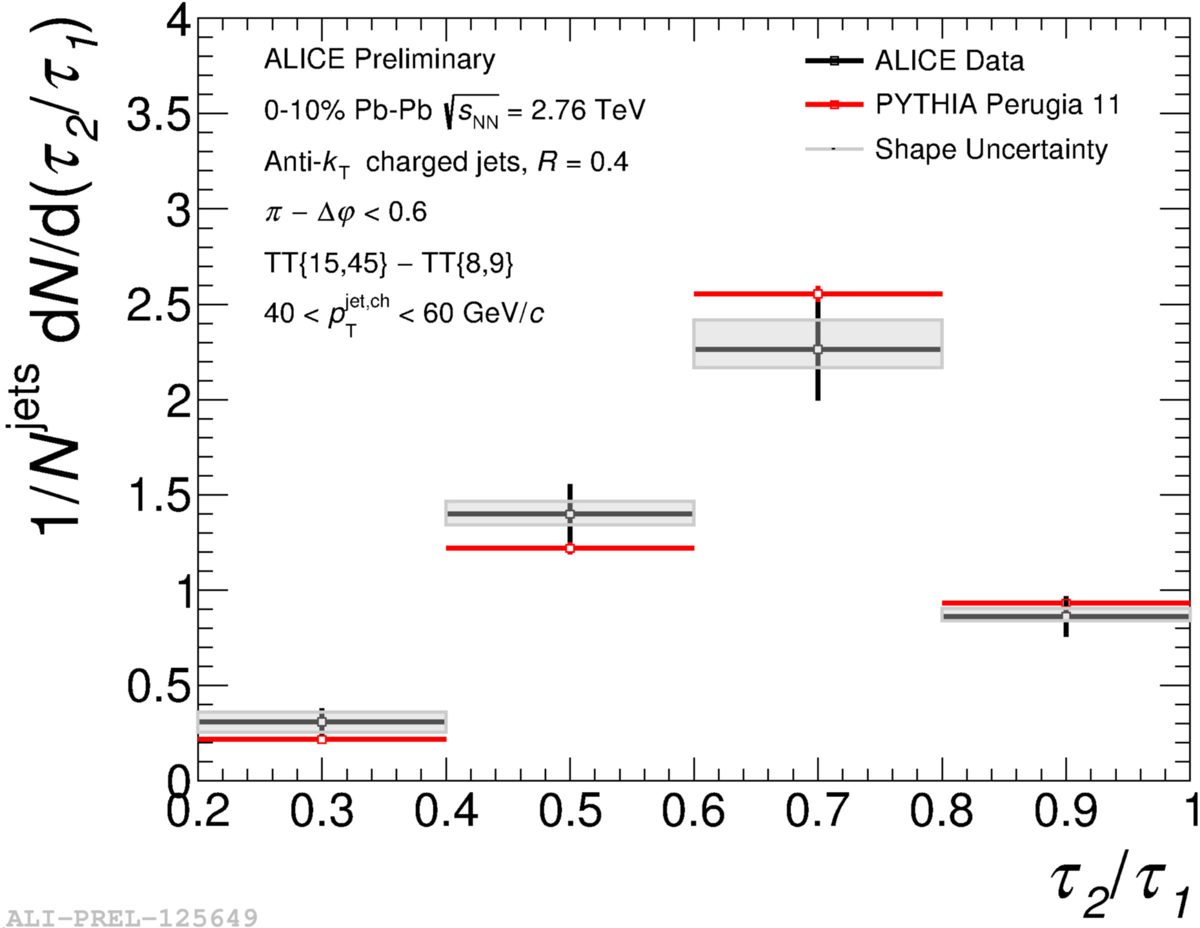


Casalderrey-Solana, Mehtar-Tani, Salgado, Tywoniuk Phys.Lett.B ***725*** *(2013) 357–360*



ALI-PREL-125645

$\tau_N \rightarrow 0$: jet has N or fewer well defined cores
$\tau_N \rightarrow 1$: jet has at least N+1 cores
$\tau_N/\tau_{N-1} \rightarrow 0$: jet has N cores



ALI-PREL-125649

- τ_2/τ_1: measures the two prongness of the jet
  - ➡ Small τ_2/τ_1 related to leading parton splitting into 2 resolvable partons
  - ➡ Medium modifications can shift τ_2/τ_1 to a higher value
- Data comparable with PYTHIA prediction without quenching effect

Summary and outlook

- A consistent picture about jet quenching in PbPb collisions at LHC
  - high p_T jets/particles strongly suppressed
  - Jet fragmentation patterns and structure are modified
- New sets of jet observables probing additional aspects of QCD developed
  - sophisticated measurements (g, $p_T D$, z_g, τ_2/τ_1, ...)
  - improving understanding on jet thermalization and resolving power of jets

➡ More new jet results will come soon with precision measurements from Run2

Thank you!