Measurements of jet fragmentation and jet substructure with ALICE

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For the ALICE Collaboration

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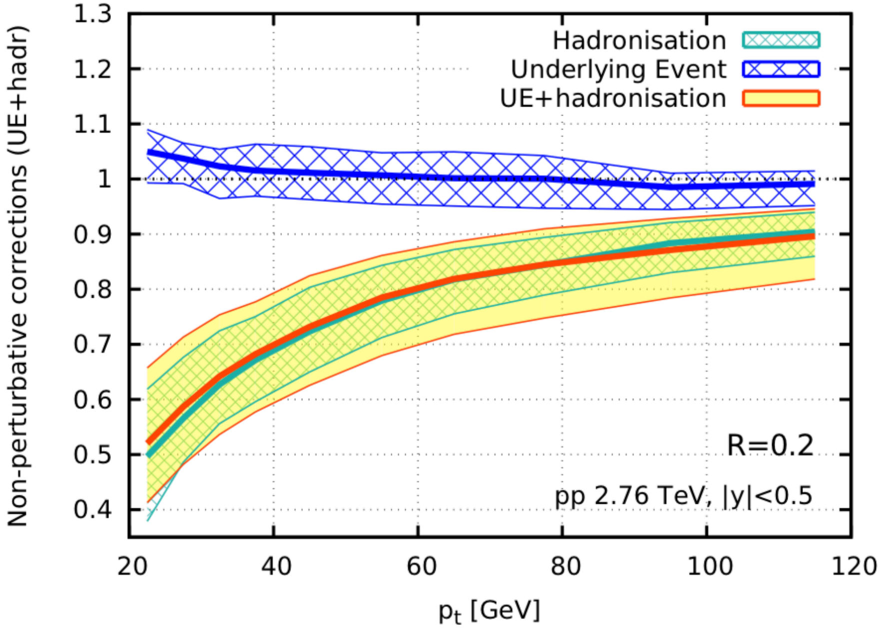
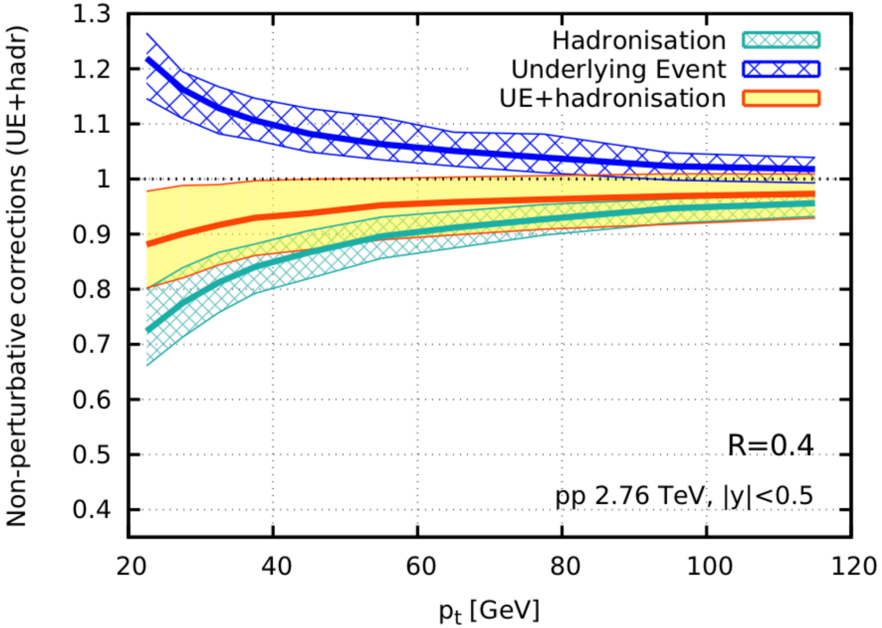
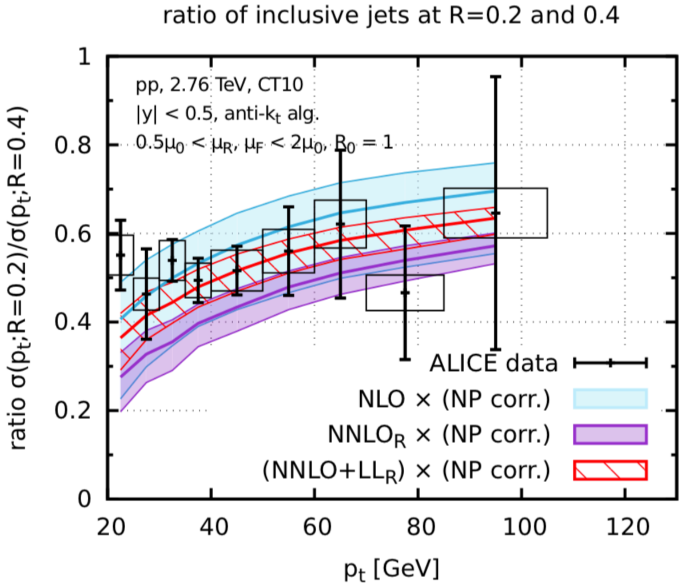
ALICE · Oak Ridge National Laboratory · The University of Tennessee Knoxville

Jet measurements at low p_T in vacuum

M. Dasgupta,F. Dreyer, G. Salam, G. Soyez JHEP 06 (2016) 057







Different sensitivity to various effects for different jet radii

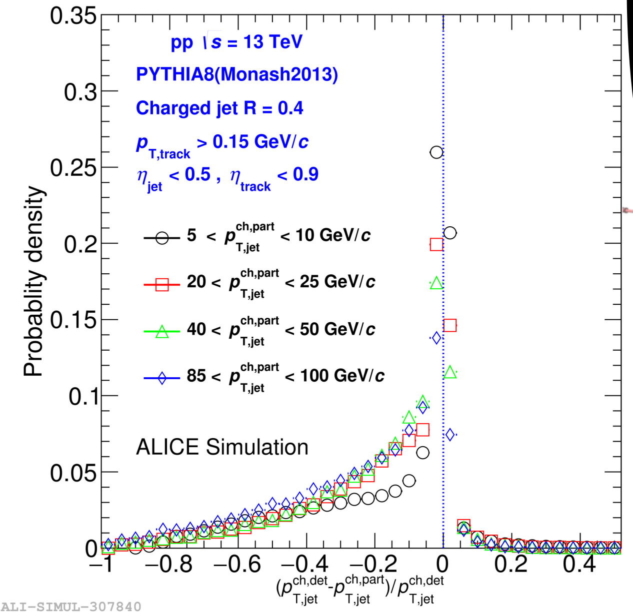
Unique opportunity to constrain perturbative and non-perturbative effects with ALICE

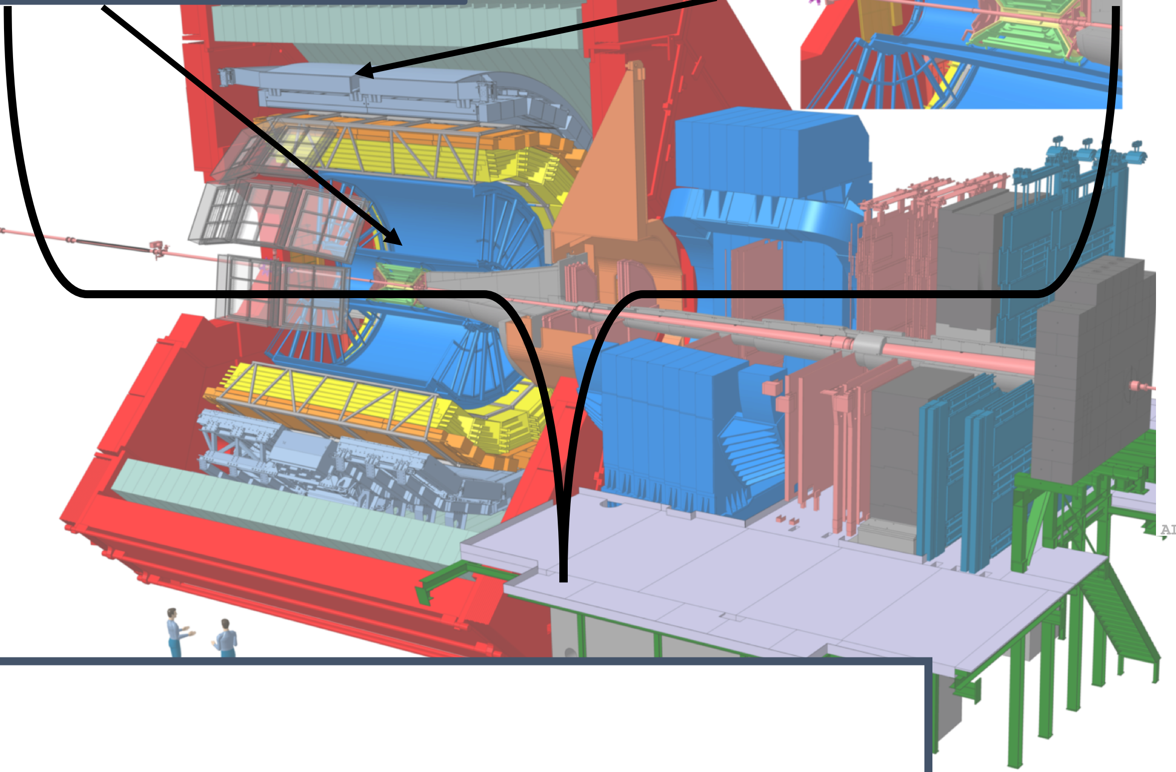
New data allows for more differential studies using jet substructure observables

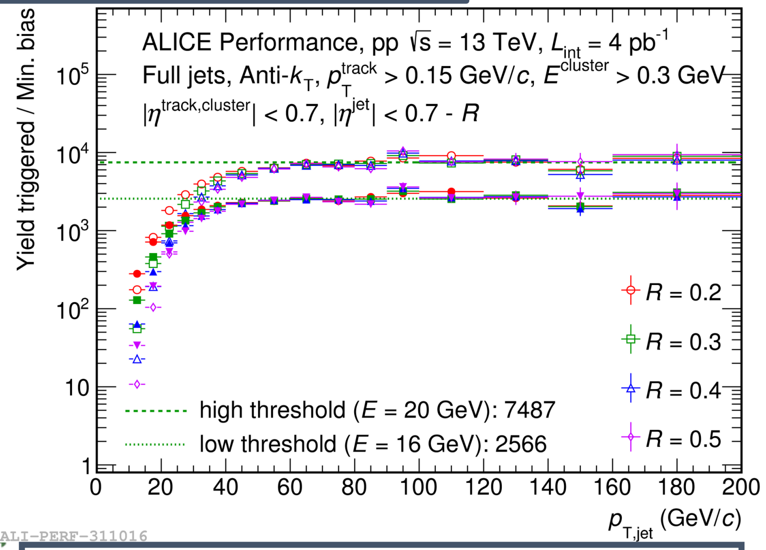
Jet substructure measurements with ALICE

ITS + TPC: Charged constituents
$p_{T,\text{cut-off}}$ = 150 MeV/c, for full jets restricted to EMCal acceptance

EMCal: Neutral constituents
$E_{\text{cut-off}}$ = 300 MeV, $|\eta| < 0.7$ and $1.4 < \varphi < 3.1$ (rad)
Jet trigger







Jets

- Track-based jet: Only reconstructed tracks
- Full jets: Tracks + EMCal clusters

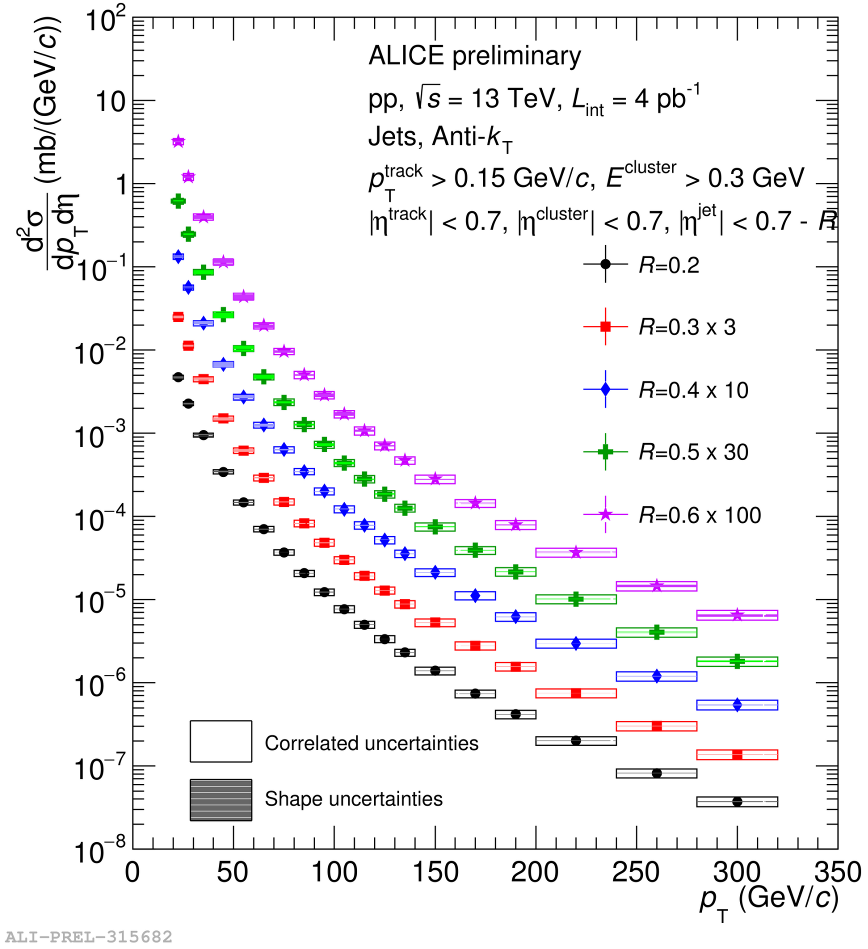
Anti-k_T algorithm
E-/p_T-scheme

Datasets:

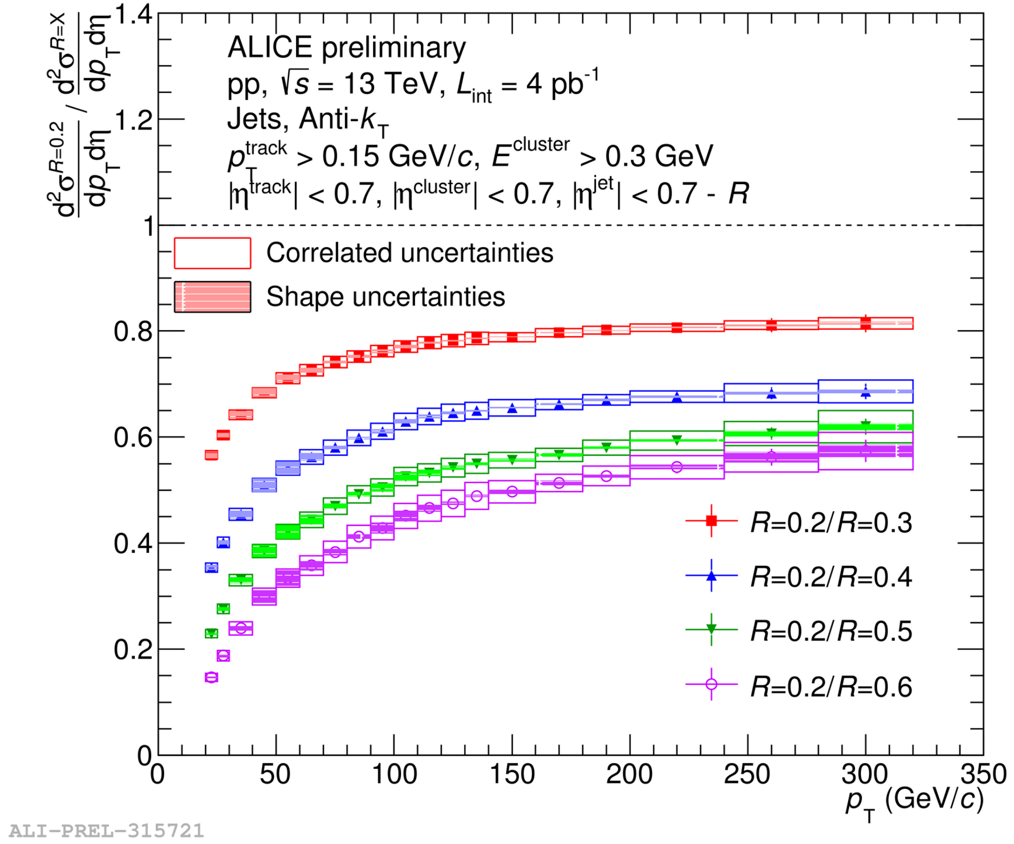
- pp, $\sqrt{s}$ = 5 TeV, min. bias, L_{int} = 15.7 nb^{-1}
- pp, $\sqrt{s}$ = 13 TeV:
  - min. bias: L_{int} = 11.57 nb^{-1}
  - Jet triggered: L_{int} = 4 pb^{-1}
- Pb-Pb, $\sqrt{s_{NN}}$ = 2.76 TeV, 19 M central events

Differential cross section in pp collisions at √s = 13 TeV

NEW



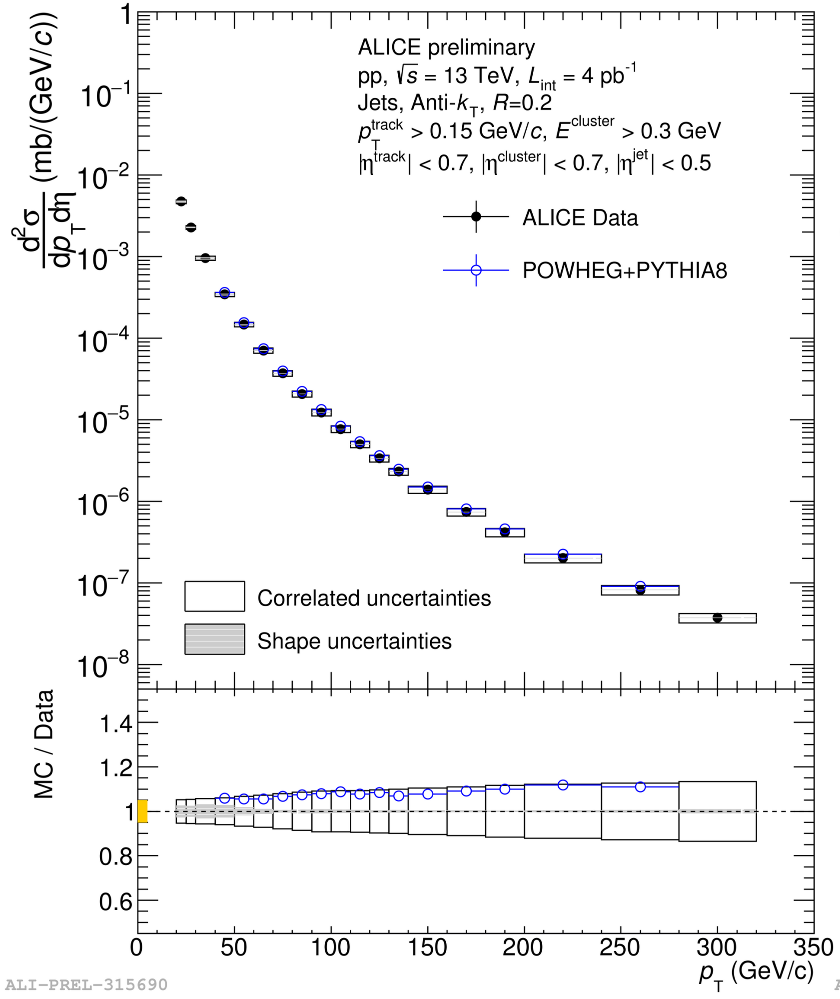
Probing jet production in a wide range from the non-perturbative to the perturbative region and in a wide range of jet radii

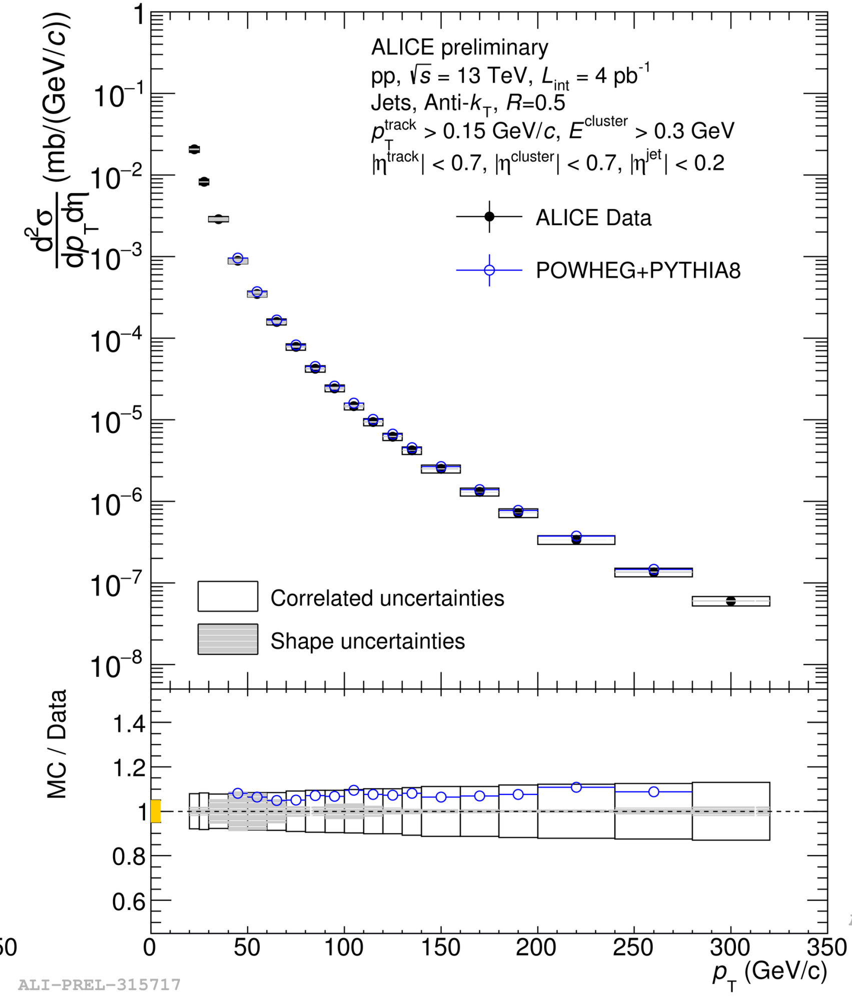


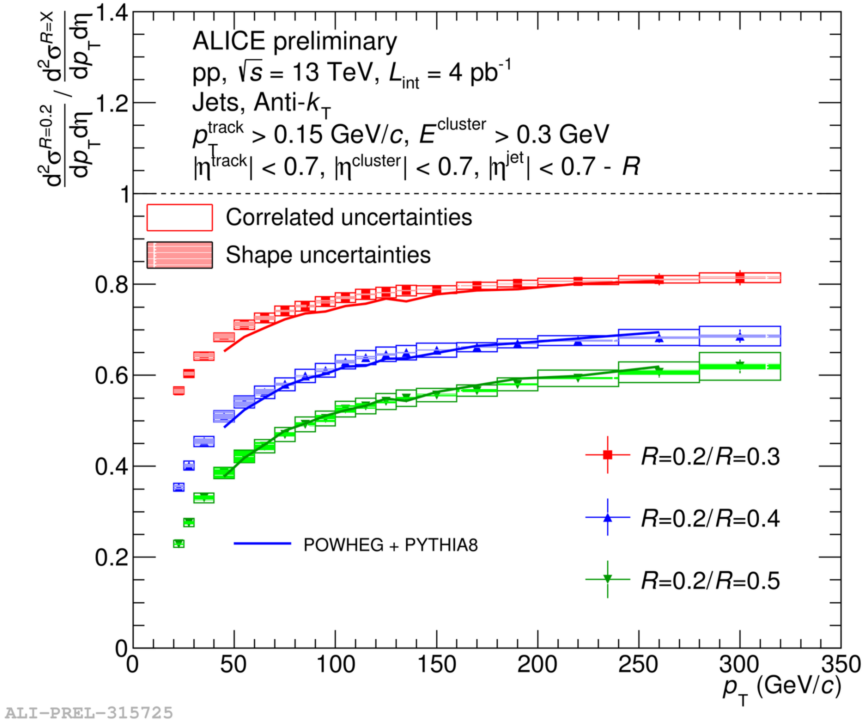
Cross section ratios decreasing with increasing jet radius and almost constant for p_T > 100 GeV/c

Comparison to POWHEG + PYTHIA

NEW

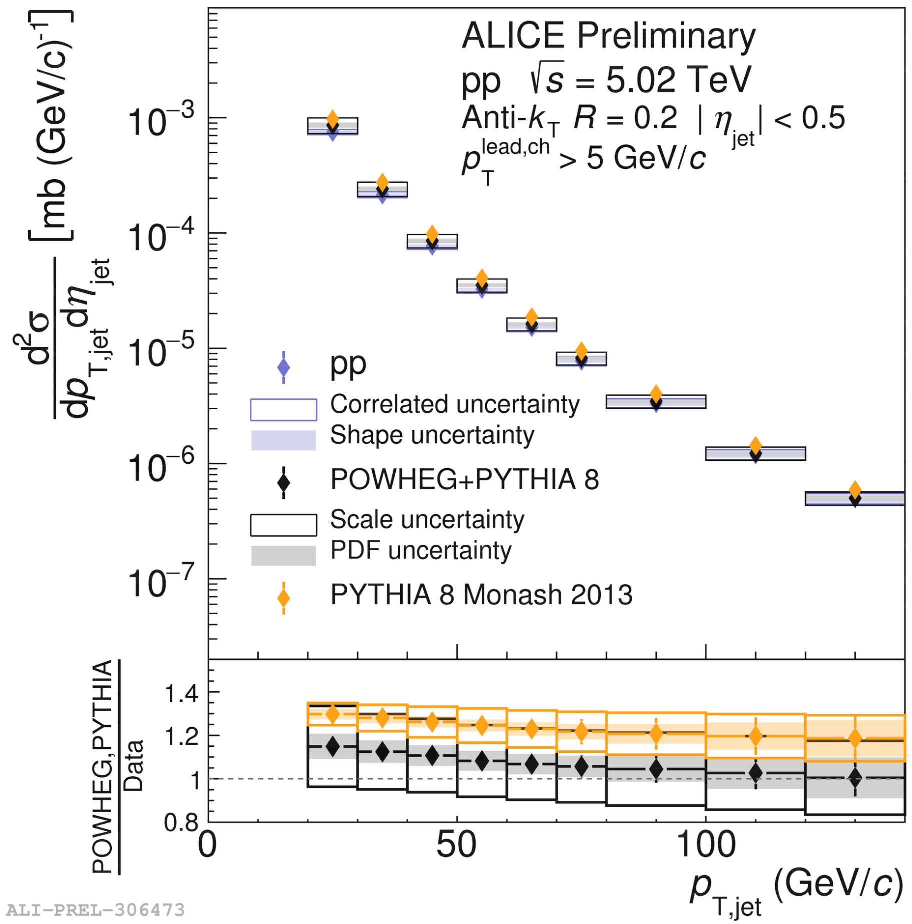


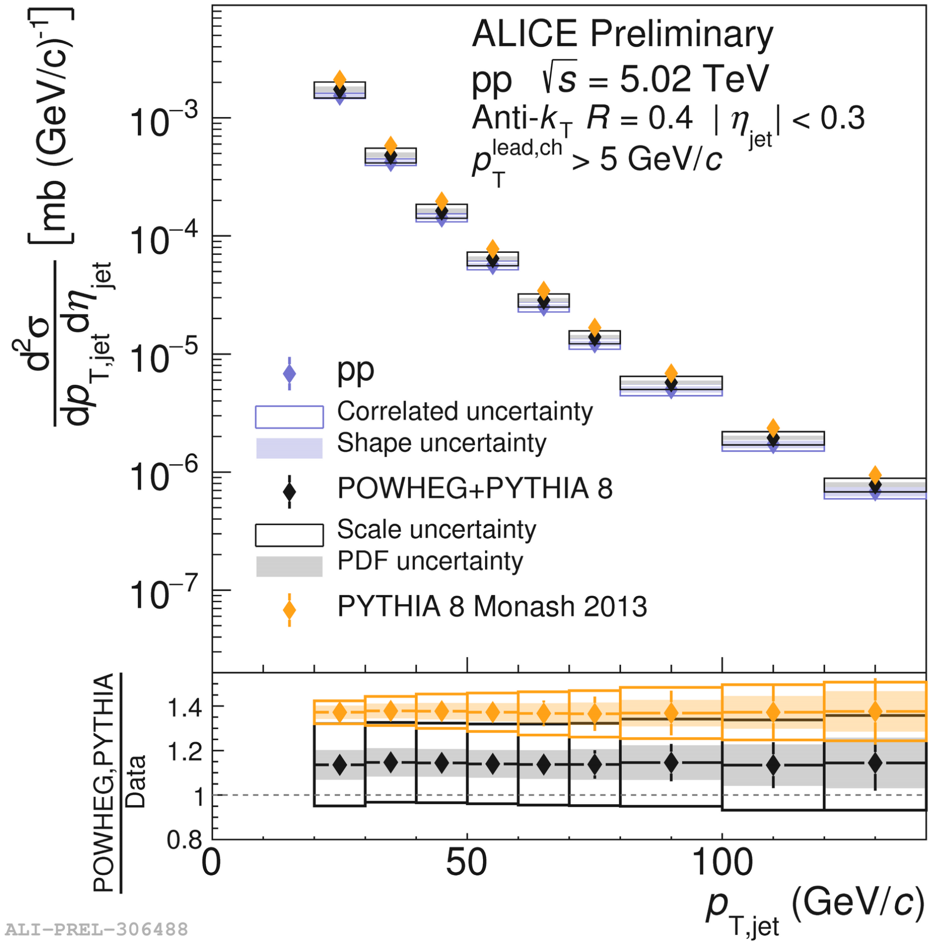




Jet production well described by POWHEG+PYTHIA8 for various jet radii in a wide p_T range

Differential jet cross section in pp collisions at √s = 5.02 TeV





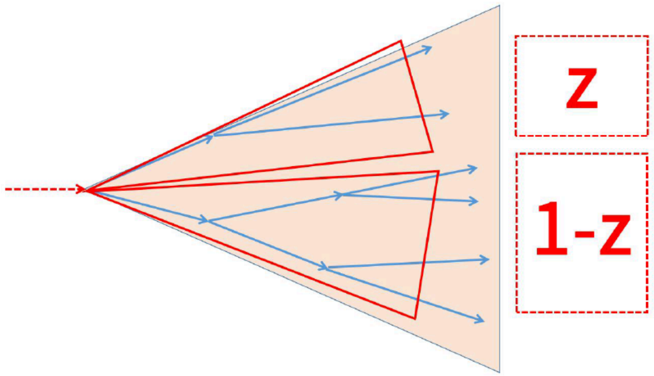
Good description of the jet production by POWHEG+PYTHIA at various center-of-mass energies

lower panel includes POWHEG scale uncertainty

Grooming via the SoftDrop algorithm

Extract the hard components of a jet

- Recursively removing large-angle soft radiation
- Method:
  - Recluster jet (with Cambridge/Aachen algorithm)
  - Decluster tree
  - Remove softer branch until SoftDrop condition is fulfill



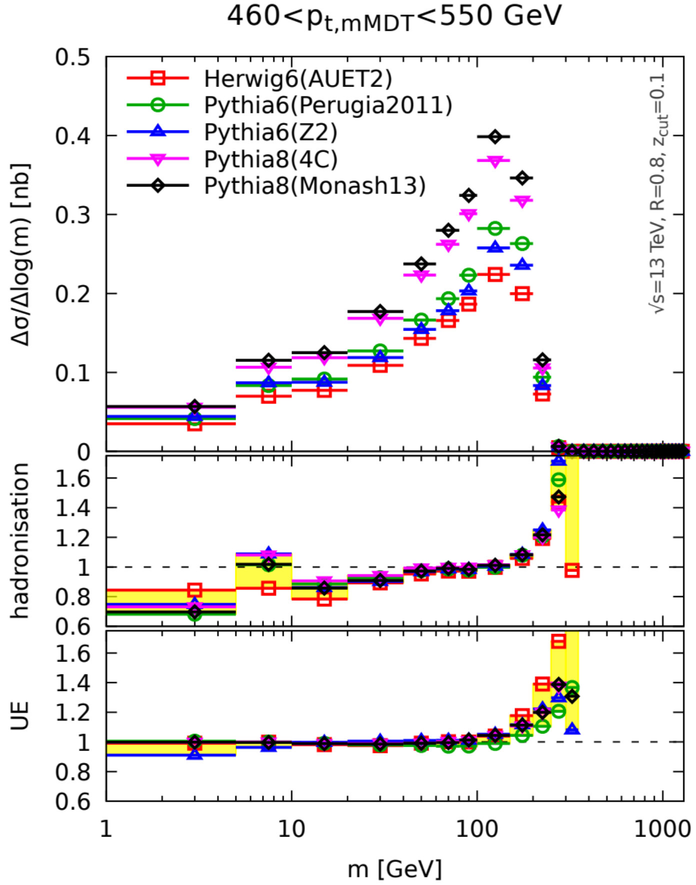
$$z_g = \frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} > z_{cut} \left(\frac{R_g}{R_0}\right)^{\beta}$$

  - Grooming controlled by z_{cut} and β

M.Dasgupta, A. Fregoso, S. Marzani, G. P. Salam JHEP09 (2013) 029,
A. Larkoski, S. Marzani, G. Soyez, J. Thaler JHEP 1405 (2014) 146

Expectations from theory

Related example: groomed mass



S. Marzani, L. Schunk, G. Soyez JHEP 07 (2017) 132

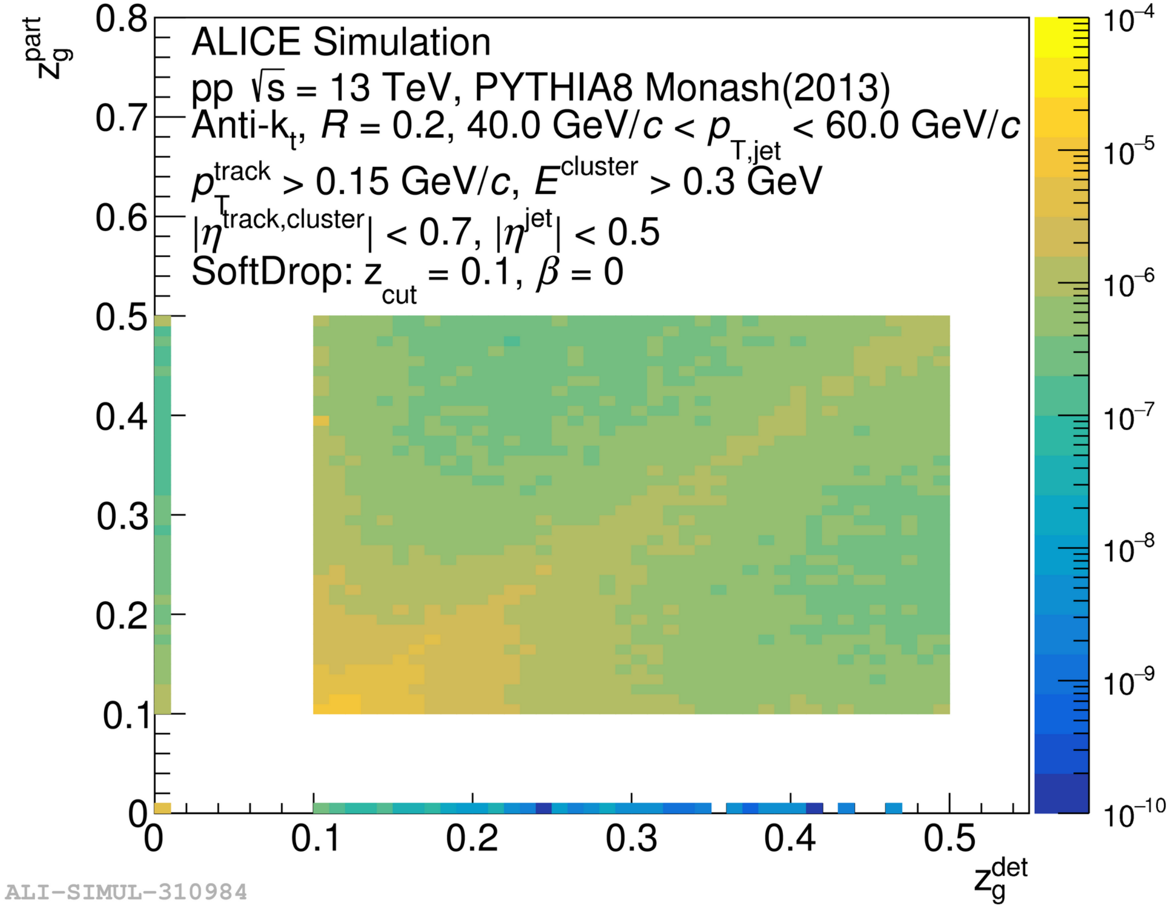
- z_g directly related to the splitting function
- p_T-depence:
  ⇒ Not expected (directly connected to QCD z kernel)
- R-dependence
  ⇒ Different perturbative / non-perturbative effects dominate for different R

Perturbative Radiation	$\delta p_t \sim \ln(R)$
Hadronisation	$\delta p_t \sim -\frac{1}{R}$

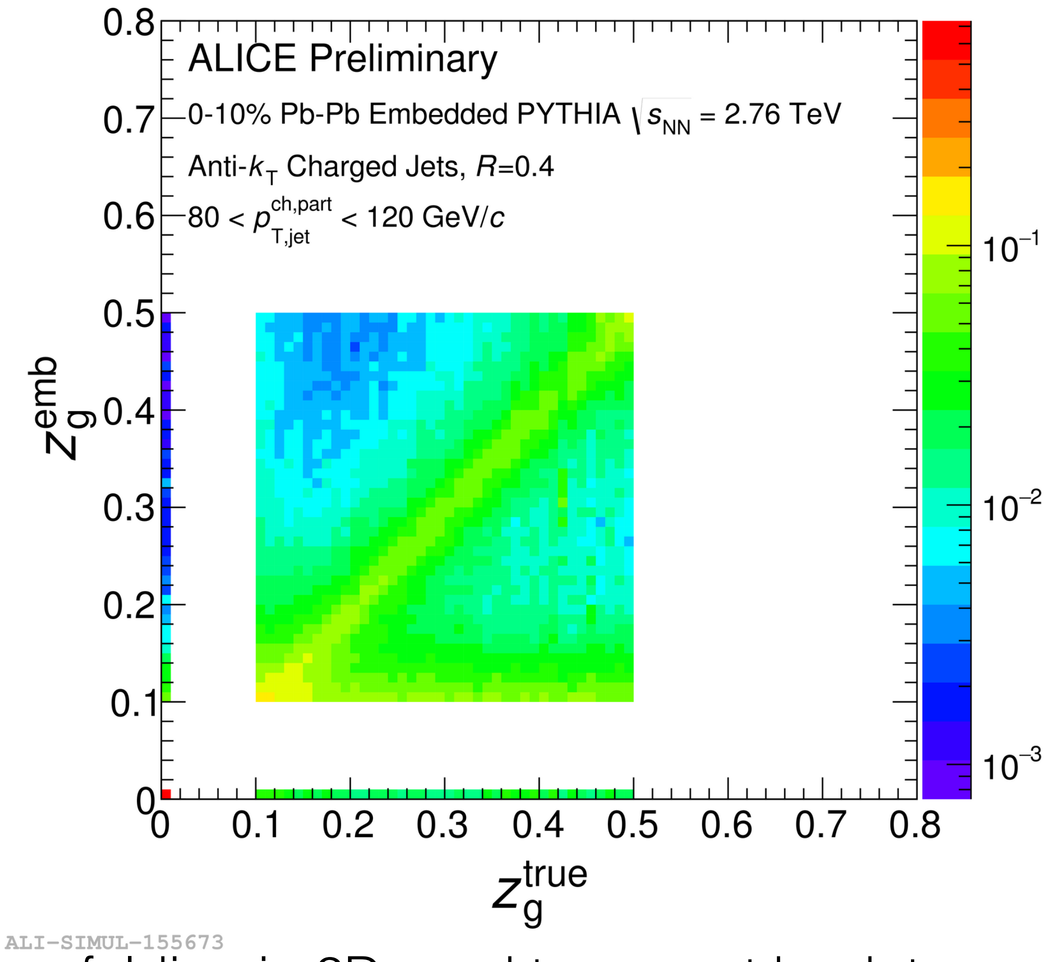
Substructure allows to isolate ingredients of the theoretical description of jet production

Instrumental response of the z_g shape

pp collsions



Pb-Pb collisions

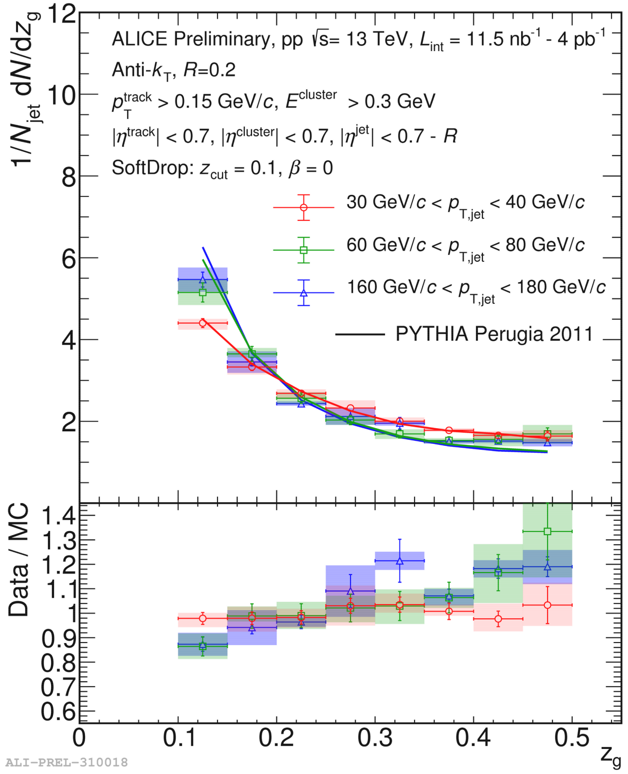


z_g response has wing / off-diagonal entries

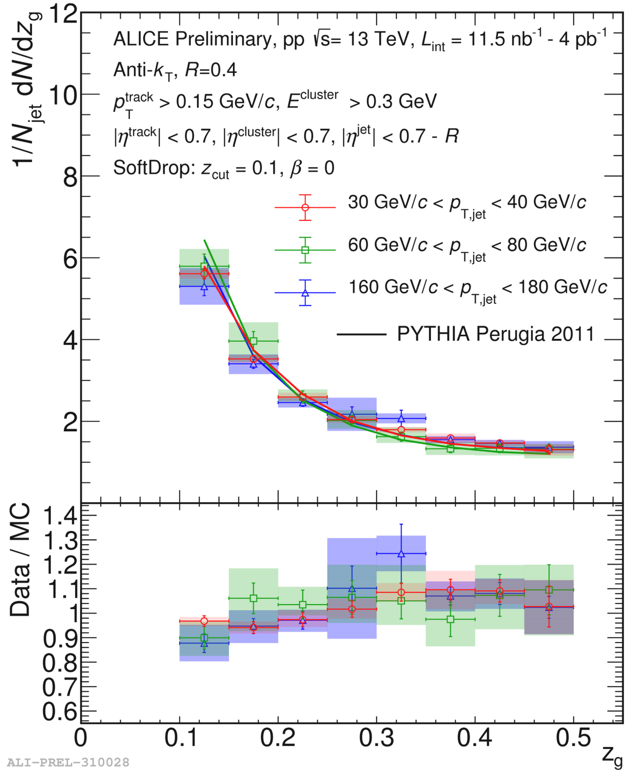
Bayesian unfolding in 2D used to correct back to particle level

Groomed momentum fraction vs p_T

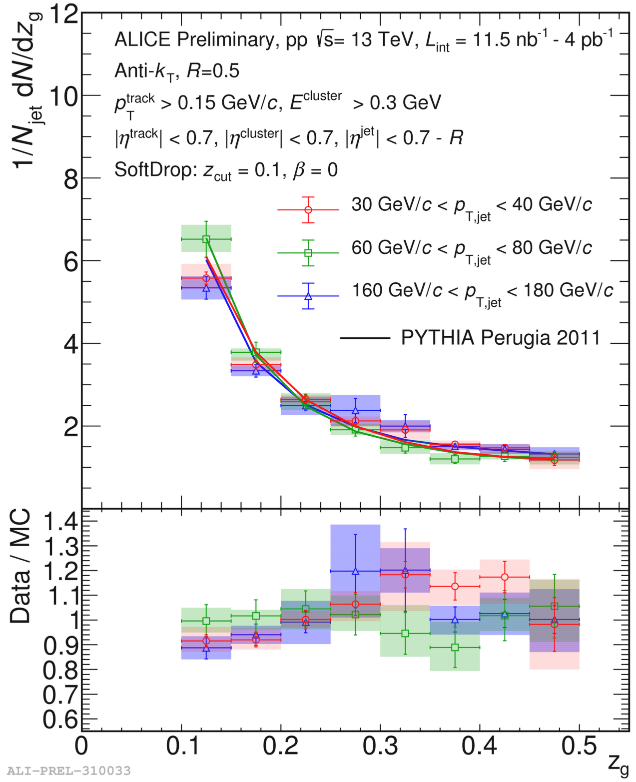
R=0.2



R=0.4



R=0.5



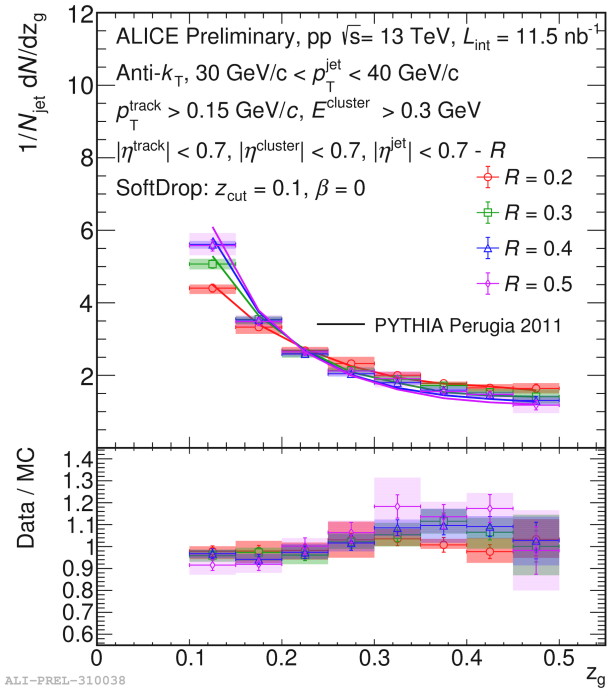
- p_T dependence for small radii
  - Trend to larger z_g at low p_T and towards smaller z_g at high p_T
- No p_T dependence or larger jet radii
- Generators reproduce p_T-dependence well

No underlying event subtraction applied

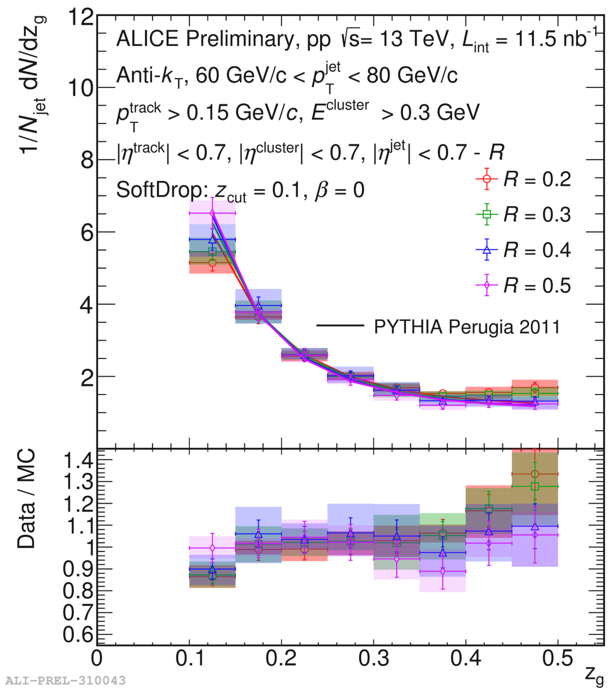
- Grooming already removes the soft component
- No underlying event subtraction in PYTHIA as well

Groomed momentum fraction vs R

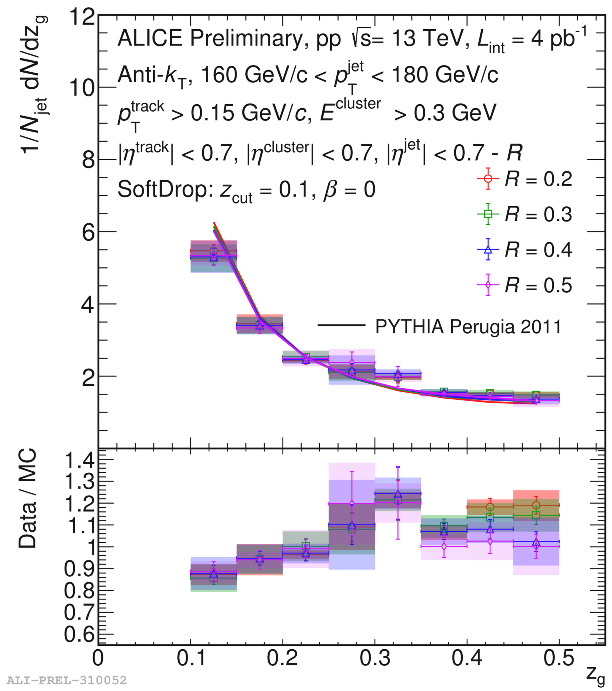
30 GeV/c < p_T < 40 GeV/c



60 GeV/c < p_T < 80 GeV/c



160 GeV/c < p_T < 180 GeV/c



Low p_T: Shape different for small and large jet radii

- Trend towards **more asymmetric splitting for larger R**
- At the same p_T larger jets capture more soft large-angle radiation
- Sensitivity to non-perturbative effects / underlying event

High p_T: z_g independent of R

- Dominant part of the jet energy in core, small influence of large angle radiation

PYTHIA reproduces the trend at low p_T very well

Jet quenching in heavy-ion collisions

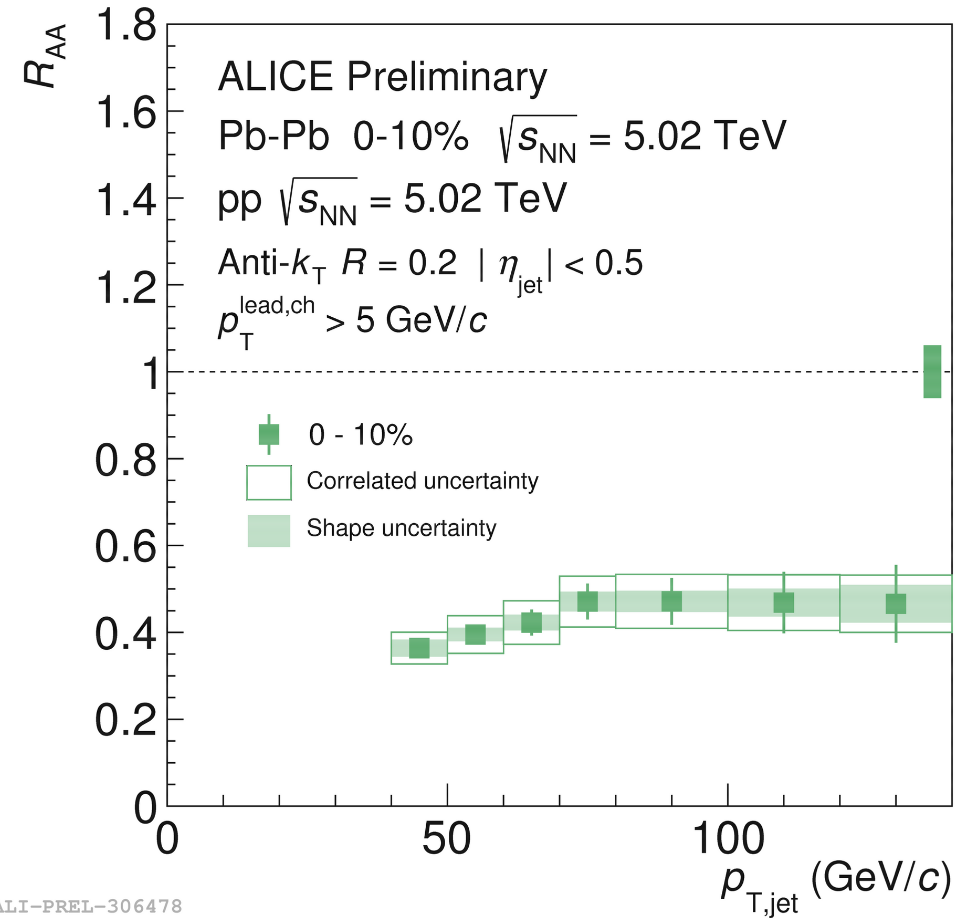
Particles passing through the medium created in ultra-relativistic heavy-ion collisions loose energy

⇒ Jet quenching

Effect quantified by the nuclear modification factor

$$R_{AA} = \frac{1}{\langle T_{AA} \rangle} \frac{dN^{AA}/dp_T}{d\sigma^{pp}/dp_T}$$

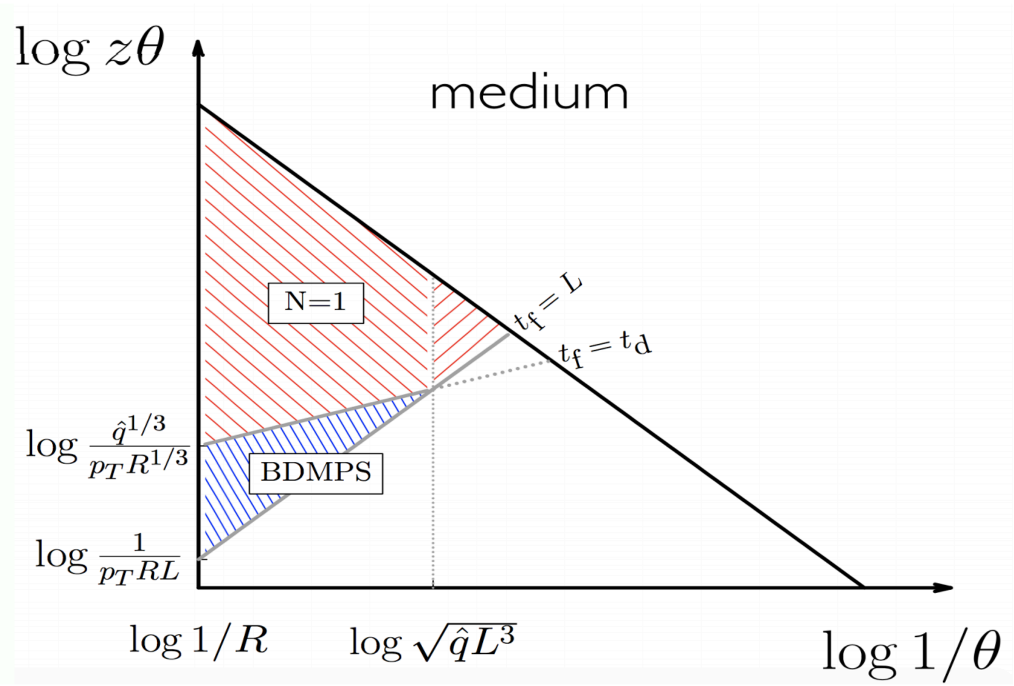
- R_{AA} ~ 1 : No modification by the medium
- R_{AA} < 1 : Energy loss for particles passing the hot and dense medium



Measurements of the jet substructure in heavy-ion collisions

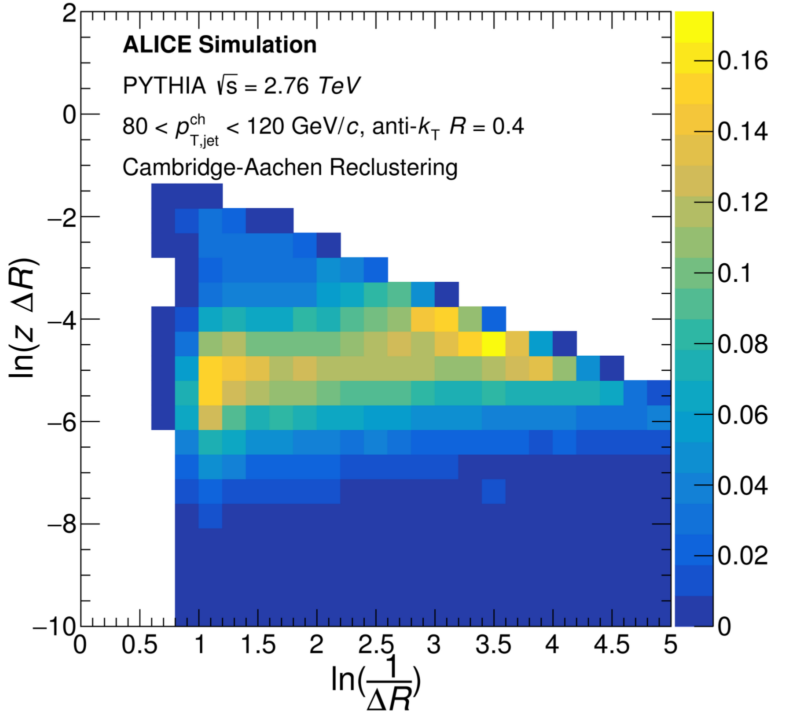
Measurement of jet substructure sensitive to modification in the medium

Quenching effect:
- Coherence
- Medium-induced Radiation



arXiv:1808.03689

Lund maps:
- Derived from the QCD splitting function
- Powerful tool to study splitting

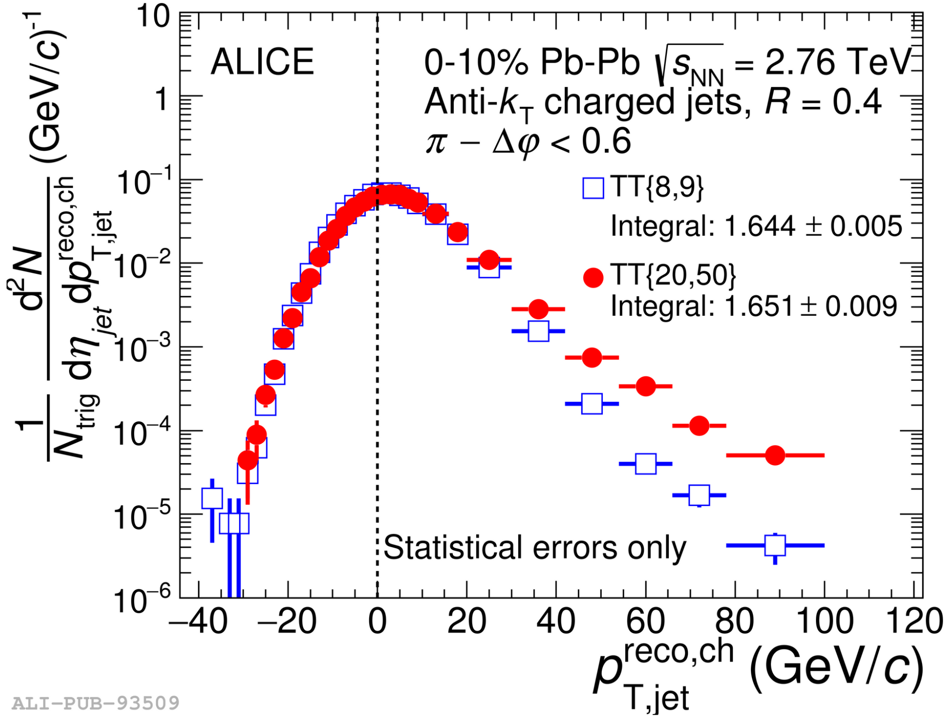


ALI-SIMUL-161454

Jet reconstruction in high-density environment

Large background in heavy-ion collisions affecting limiting jet reconstruction at low p_T

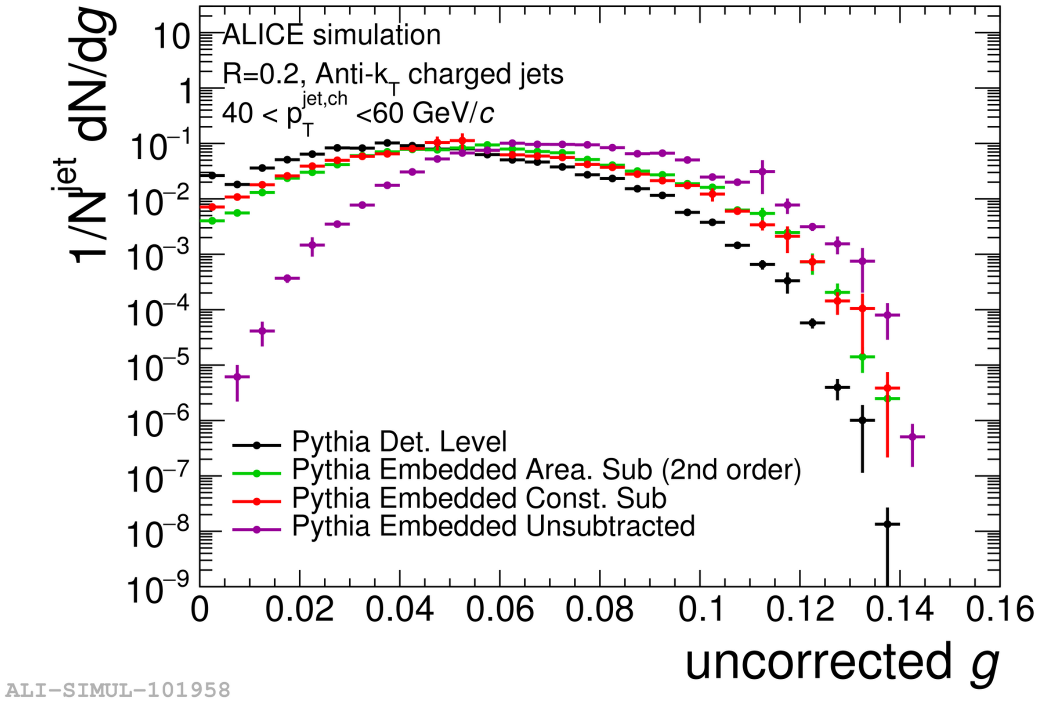
Using observables with low sensitivity to combinatorial background



Hadron-jet correlations: Measuring per-trigger jet recoil yield

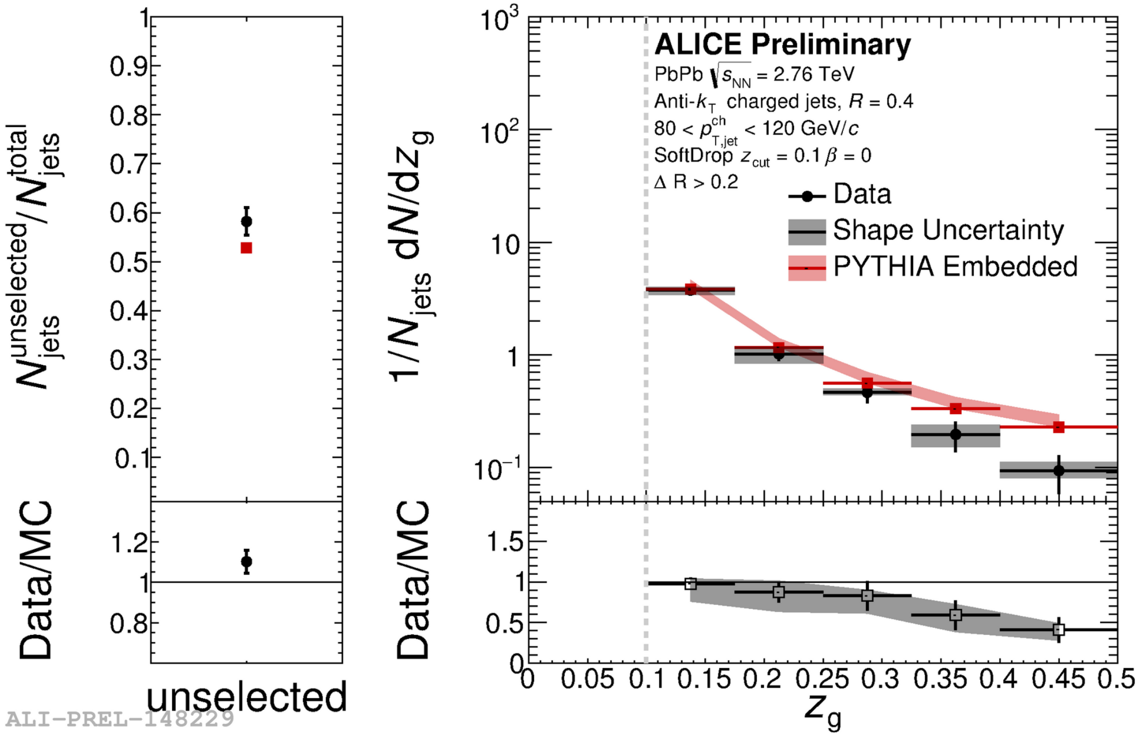
JHEP09(2015)170

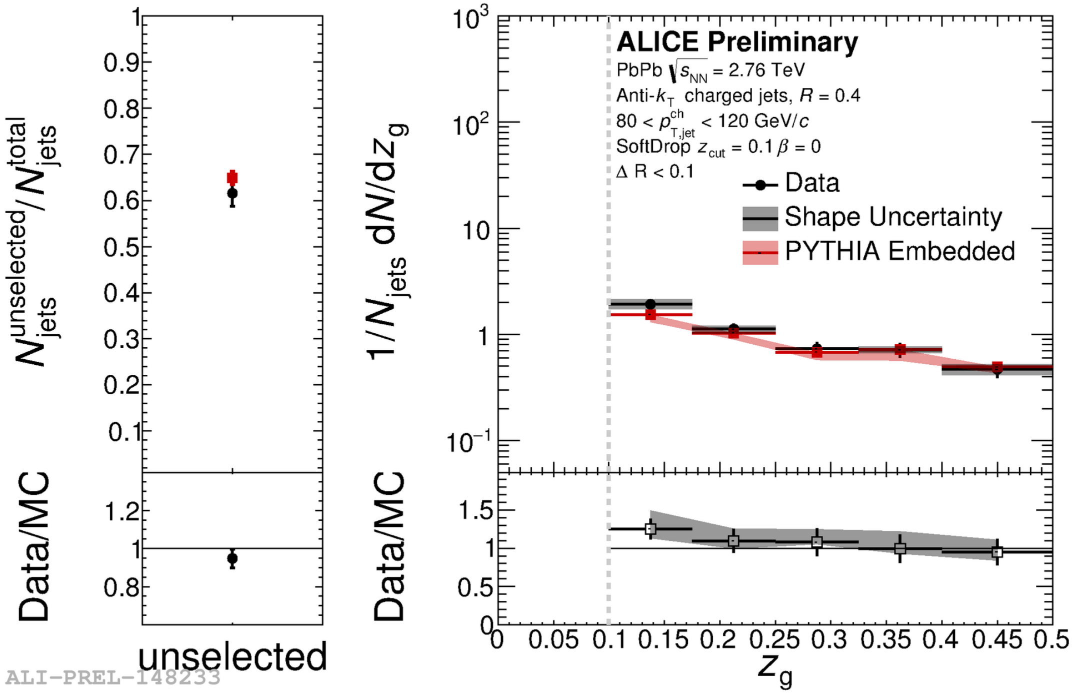
Accounting for uncorrelated background in detector response and comparison to vacuum: Embedding and subtraction



JHEP 1810 (2018) 139
Area Sub. :G. Soyez, G. P. Salam, J. Kim, S. Dutta M. Cacciari, Phys. Rev. Lett. 110 (2013) 162001
Const. Sub.: P. Berta, M. Spousta, D. W. Miller and R. Leitner, JHEP 1406 (2014) 092

Jet grooming measurements in heavy-ion collisions





Modification of the groomed momentum fraction in central Pb-Pb collisions with respect to the vacuum

- Supression of symmetric splittings relative to the vacuum reference
- No modification of for very collimated subjets

arXiv: 1905.02512

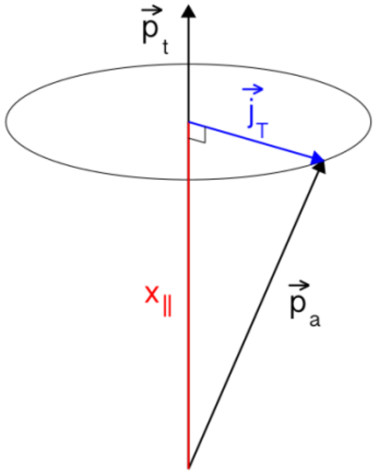
Conclusions and outlook

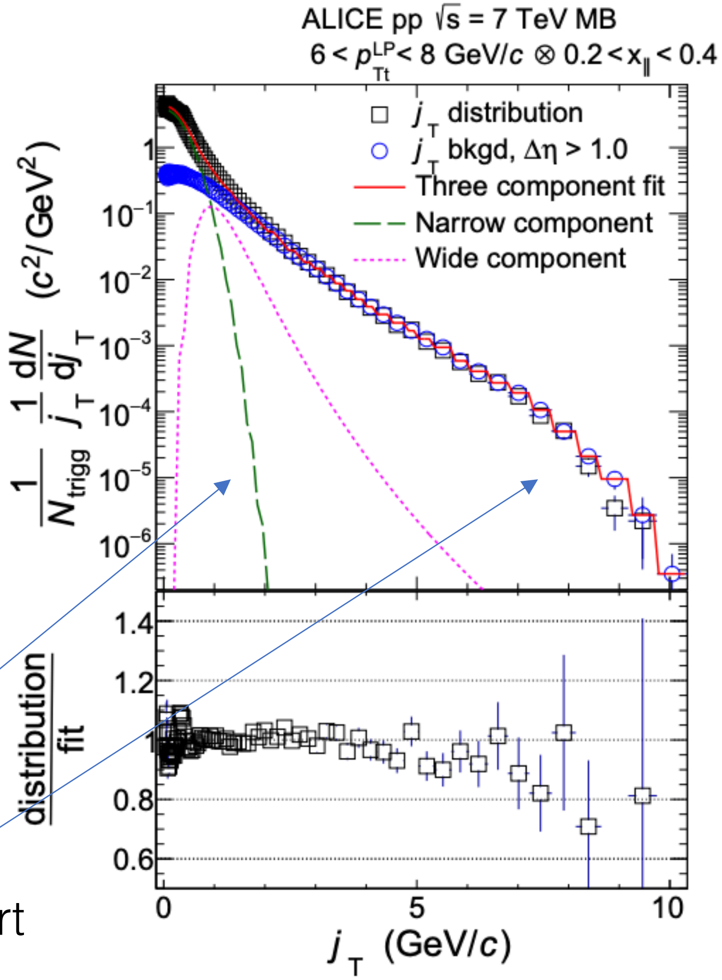
- Measurement of jet substructure in a wide range of jet radii and jet p_T
- No dependence of z_g on the jet p_t except in the lowest p_T-bins
- Production of jets well described by POWHEG+PYTHIA for various jet radii
- Ratios of cross sections of various jet radii in good agreement with PYTHIA+POWHEG
- Jet substructure measurements extended to heavy-ion collisions, searching for medium-induced signal

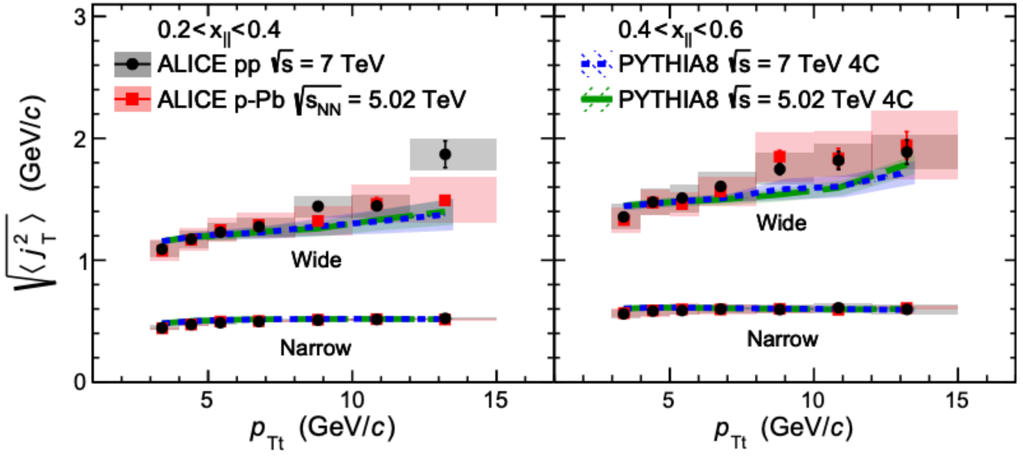
Backup

Jet fragmentation measurements via di-hadron correlations

Correlation of associated particles with a high-p_T trigger particle







3-component fit to j_T distribution

- Narrow component: hadronization part
- Wide component: shower part

RMS of the narrow component: weak dependence on p_T

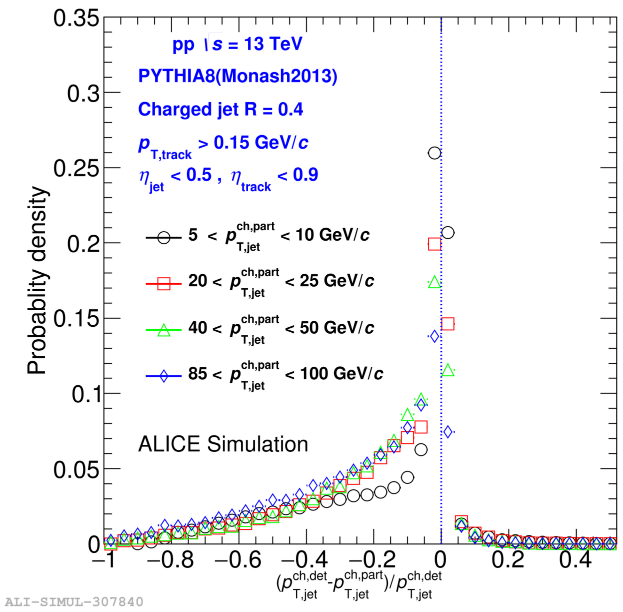
RMS of the wide component: increasing with p_T

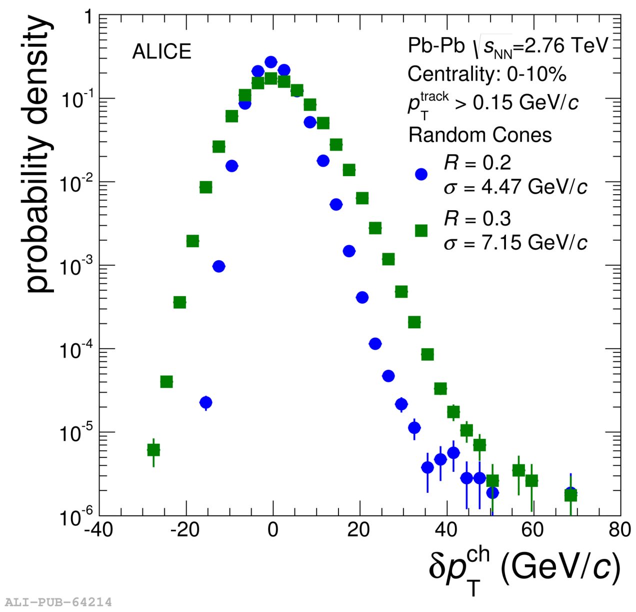
Similar for pp and p-Pb

arXiv:1811.09742

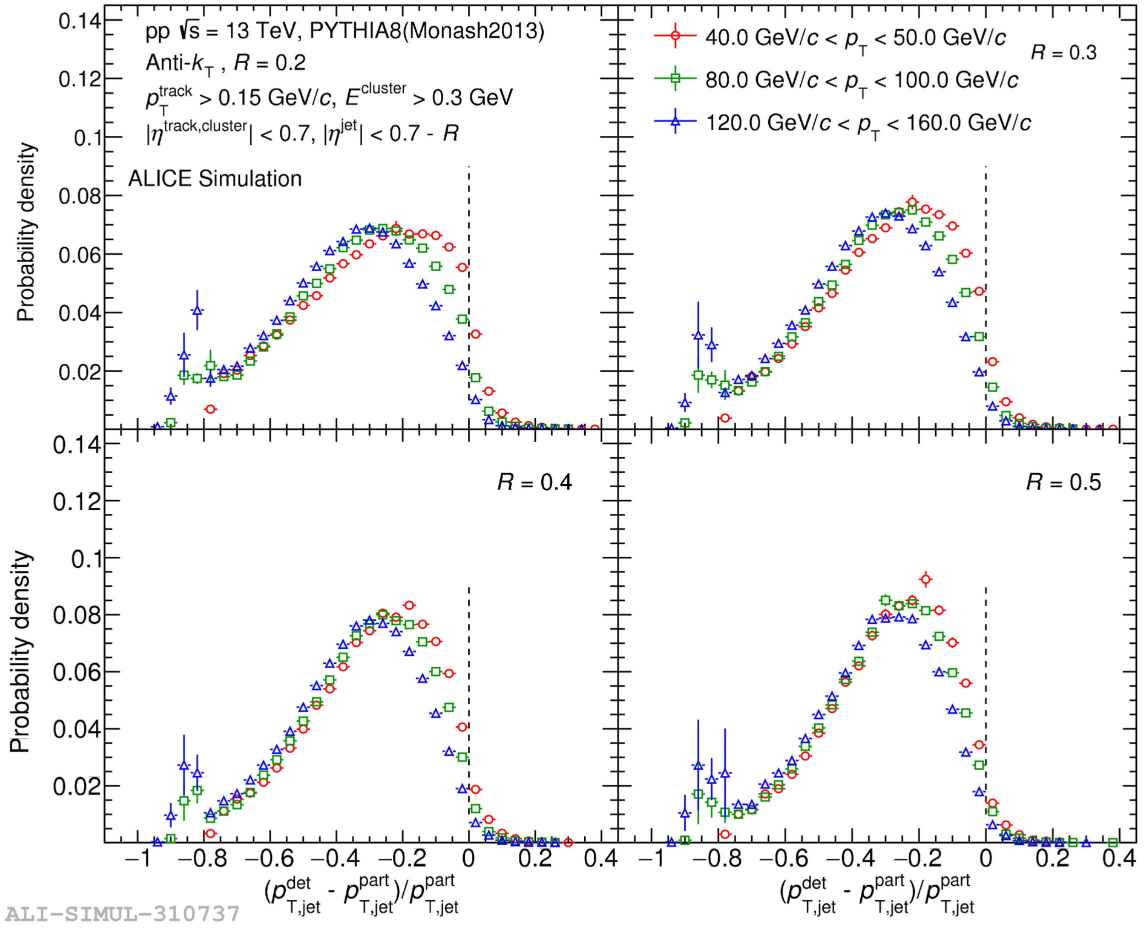
Detector response

Track-based jets





Full jets



Track-based jets: comparing to jets made of charged constituents only at particle level

Full jets: comparing to full jets at detector level

In heavy-ion collisions response needs to include contribution from combinatorial jets