Jet shapes in pp and Pb-Pb

Leticia Cunqueiro (CERN) for the ALICE Collaboration

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Jet shapes in pp and Pb-Pb

Fully corrected (to particle level) **well-defined** jet shapes that probe different aspects of the jet fragmentation both in pp and Pb-Pb

A set of three shapes: **Radial Moment (*g*)**, p_T**D** and ***LeSub***

In this talk: focus on small *R*=0.2 (charged) jet shapes:

Characterize the "core" of jets and probe quenching in an IRC safe way at low jet p_T

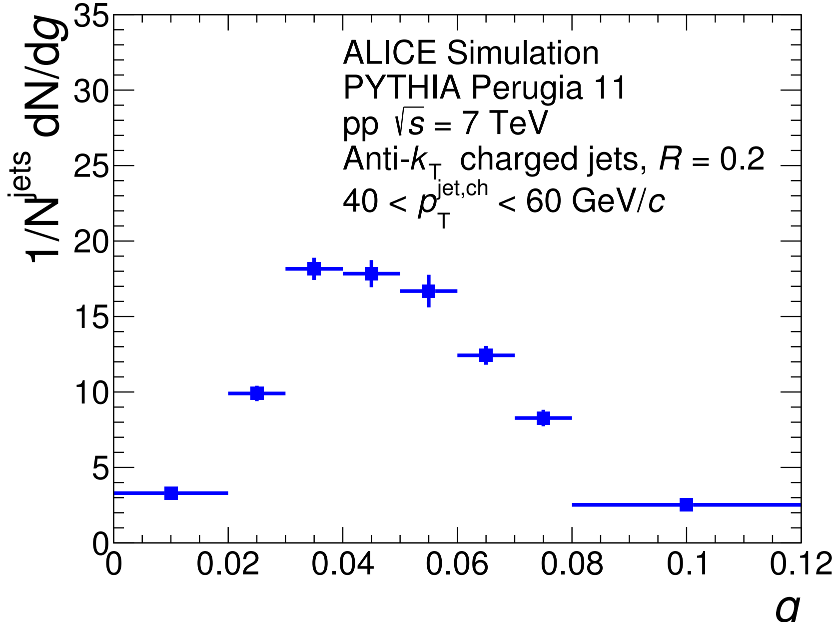
pp measurement at small R, besides a reference to Pb-Pb, provides constraints to pQCD

Jet shapes in pp and Pb-Pb

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

r_i is distance beween Consituent i and jet axis

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



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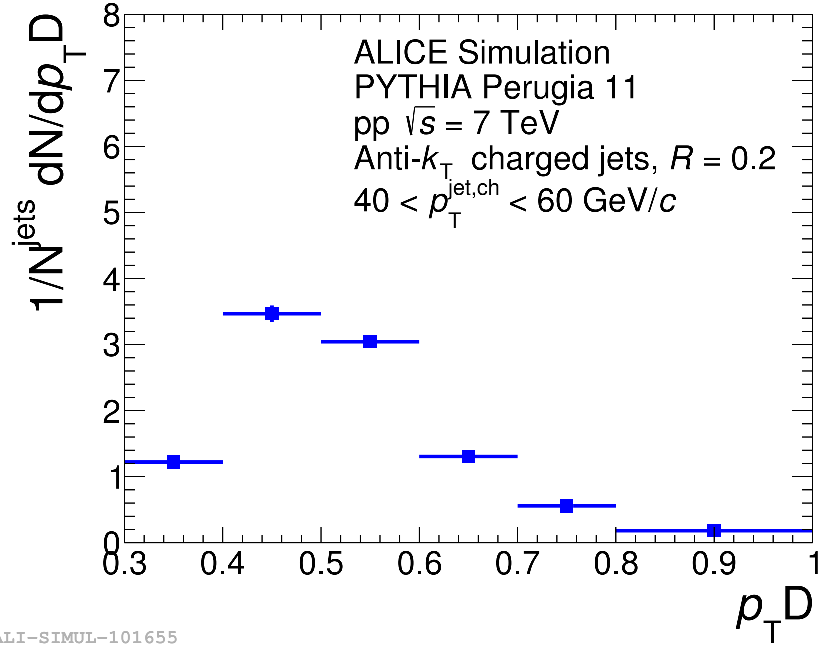

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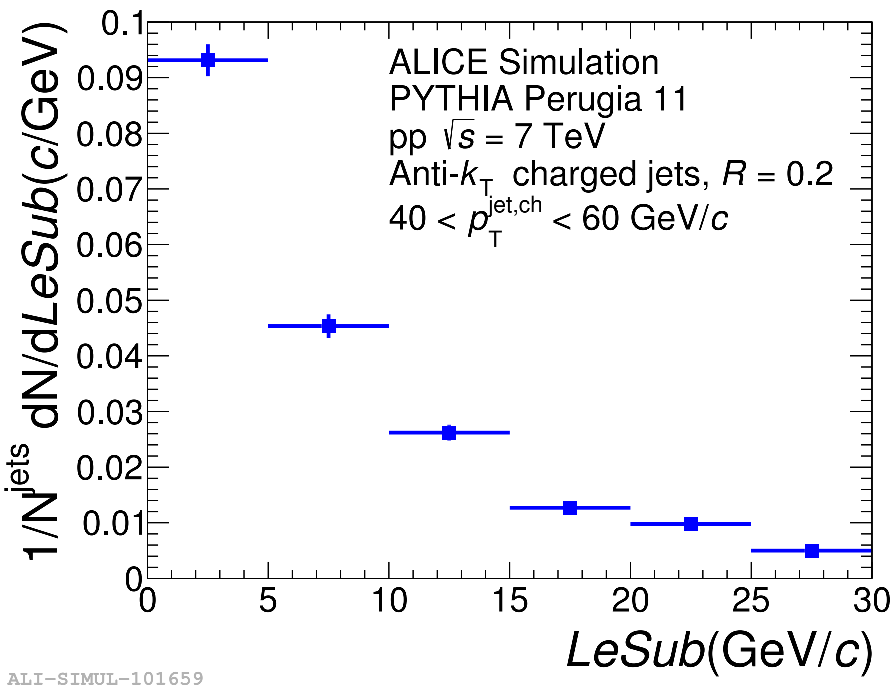
Radial moment (*g*) is a p_T-weighted width of the jet: collimated jets have lower *g*

p_TD measures the dispersion of the constituents in the jet: jets with fewer constituents give higher p_TD

Jet shapes in pp and Pb-Pb

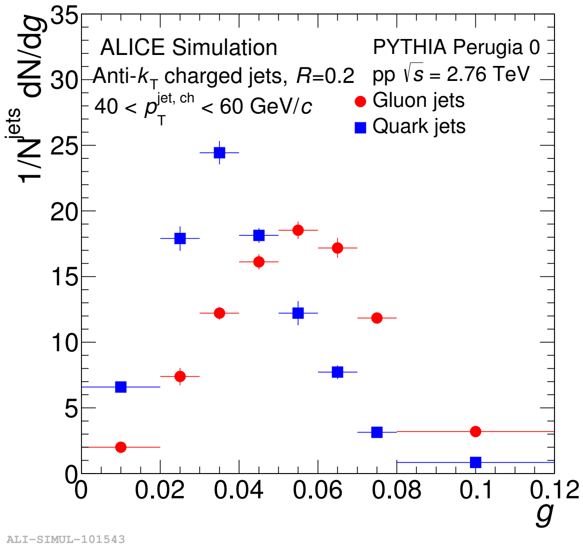
$$LeSub = p_T^{lead,\text{track}} - p_T^{\text{sublead,track}}$$

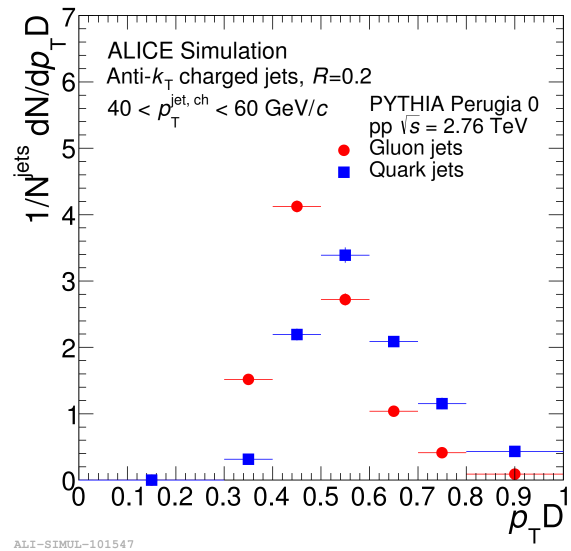


LeSub **is** **not IRC-safe** **but is approximately** **background invariant,** **convenient for Pb-Pb**

Note: there is a degree of (anti)correlation between the three chosen shapes

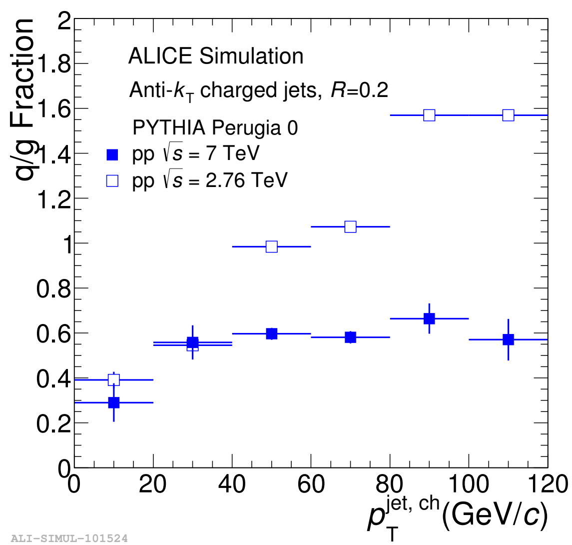
Jet shapes in pp and Pb-Pb

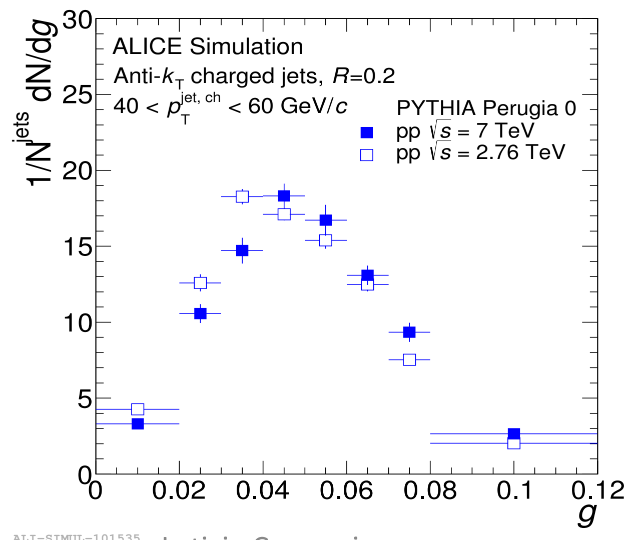




g and p_TD are sensitive to differences in fragmentation of quarks and gluons

q/g fractions change with collider energy -> a √s dependence is expected for the shapes





A direct comparison of pp and Pb-Pb results respectively at 7 and 2.76 TeV not meaningful

We will compare both pp and Pb-Pb data to a PYTHIA reference

Analysis details and correction procedure

Raw distributions:

Two Systems: pp MB at $\sqrt{s}$=7 TeV and Pb-Pb (0-10% central) at $\sqrt{s_{NN}}$=2.76 TeV
Charged particle tracks as input (TPC+ITS detectors), $p_{T,cutoff}^{const}$ = 0.15 GeV/c
anti-k_T algorithm, R=0.2, E-scheme

Background subtraction:

Uncorrelated average background removal from shape observables using new techniques:

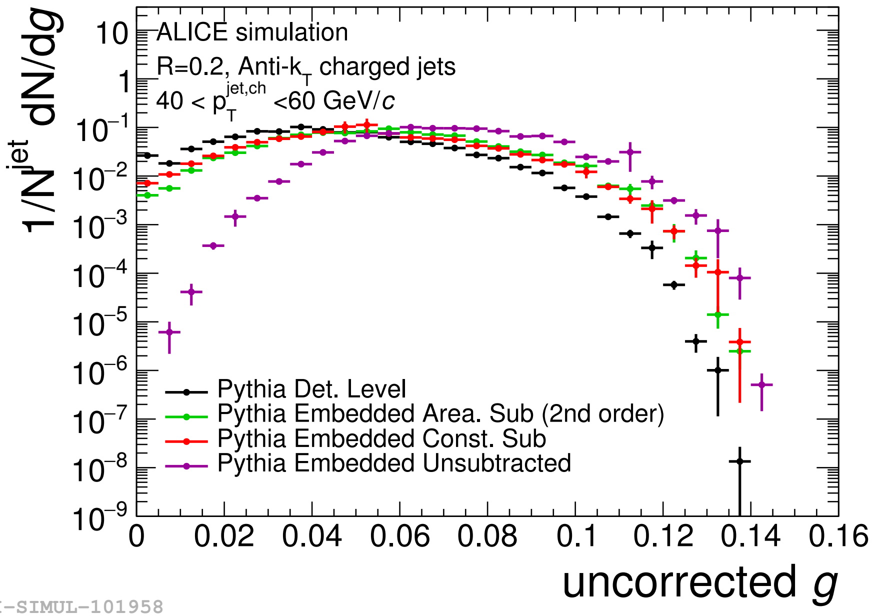
Area Subtraction *[G.Soyez et al, Phys.Rev.Lett 110 (2013) 16]* (default method)
Constituents Subtraction *[P.Berta et al, JHEP 1406 (2014) 092]*

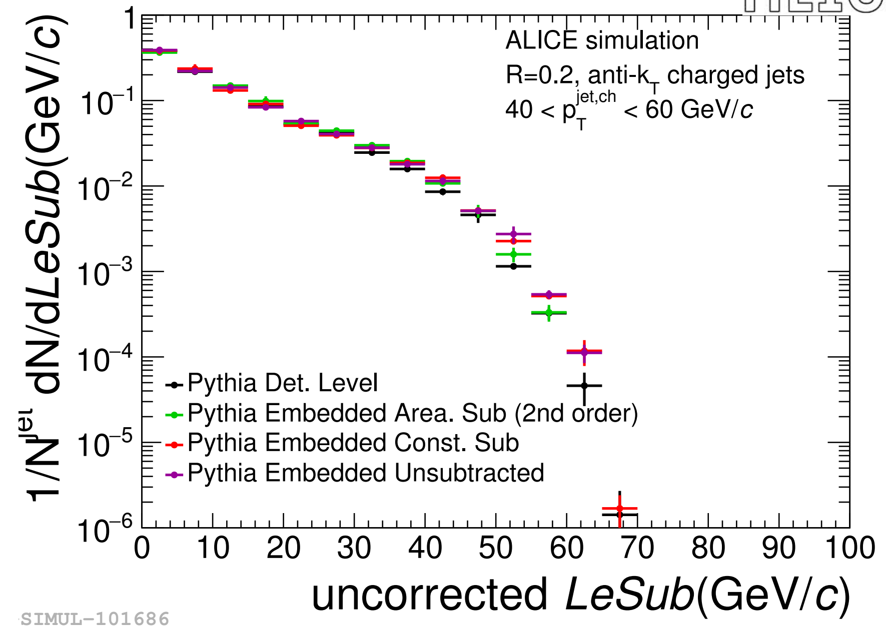
Unfolding of residual background fluctuations and detector effects:

2D Bayesian techniques (*T.Adye, CERN-2011-006)2011) 13*)
are applied to unsmear the jet p_T and the shape simultaneously

Reported corrected p_T range: 40-60 GeV/c in both systems

Background subtraction performance in Pb-Pb





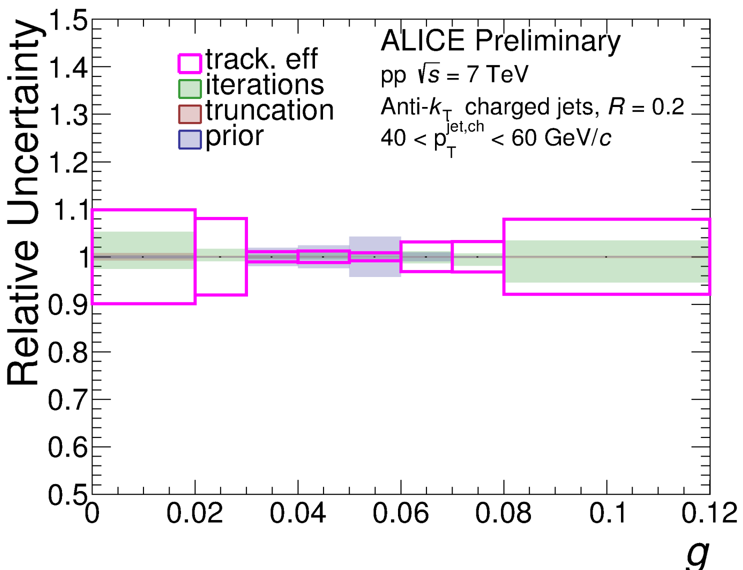
Pythia detector level jet embedded into Pb-Pb events and background subtracted

Subtracted jet shape approaches that of the original probe (compare black and red or green)
Residual differences between the shape in PYTHIA and that of the PYTHIA embedded subtracted come from background fluctuations that **need to be unfolded**

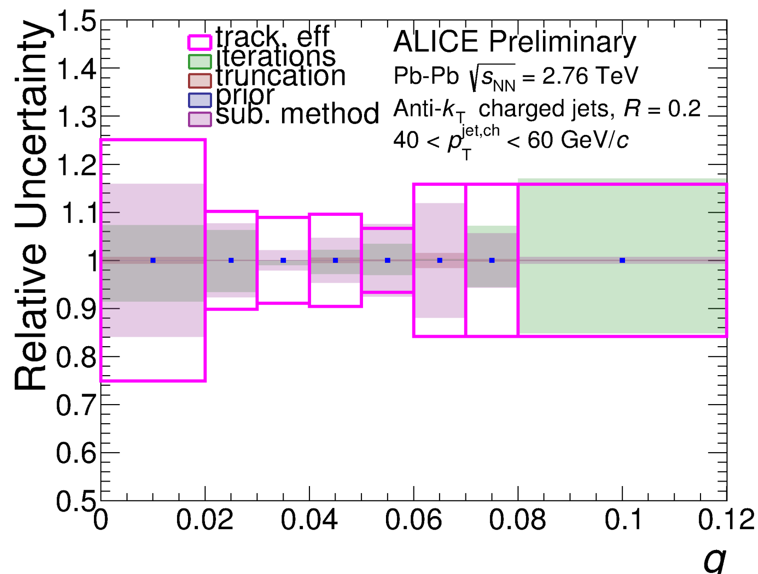
Note: *LeSub* is largely background invariant: very unlikely that an uncorrelated high p_T track replaces the leading or subleading jet tracks.

Uncertainties in the measurement

pp



Pb-Pb



Uncertainties:

-**Tracking efficiency** uncertainty of ±4% dominates the Jet Energy Scale uncertainty

-**Unfolding:**

Regularization variations of ±3 iterations

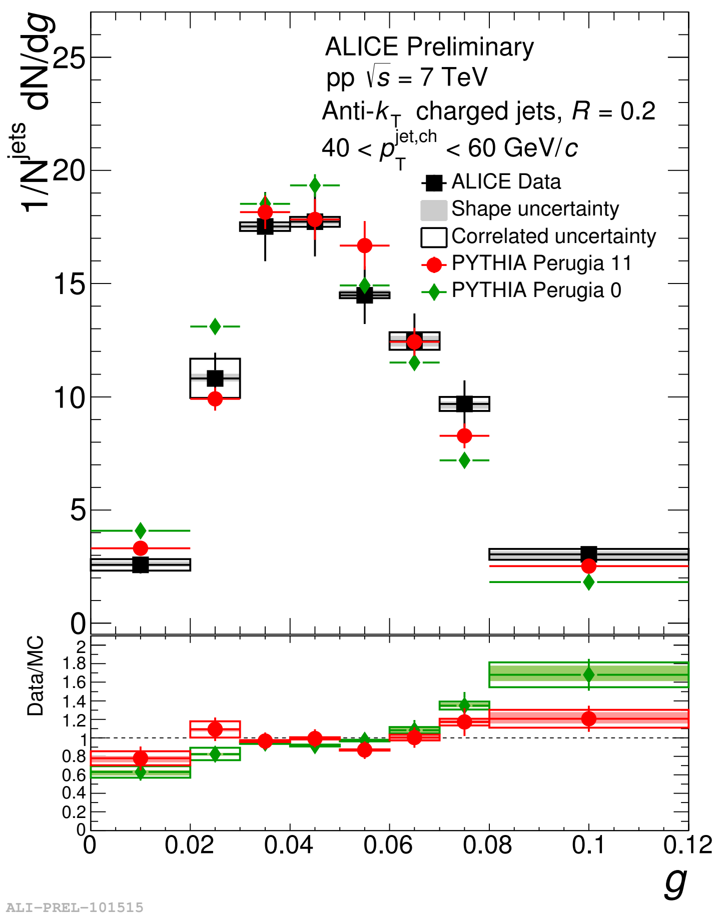
Truncation of the measured yield at a 10 GeV lower value (10 and 20 GeV/*c* in pp and Pb-Pb resp.)

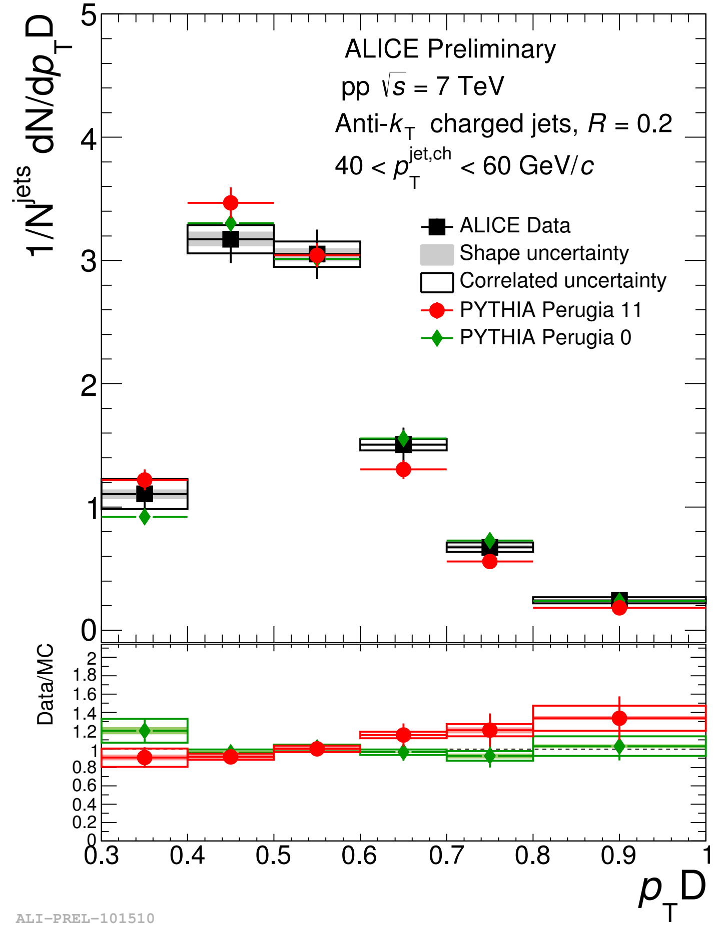
Prior: intrinsic correlation between $p_T^{jet,part}$ and shape^{part} with which response is built.

Default is PYTHIA Perugia 0, variation is a smearing of such correlation by 20%

-**Additional ingredient in Pb-Pb**: background subtraction method variation

Fully corrected jet shapes in pp

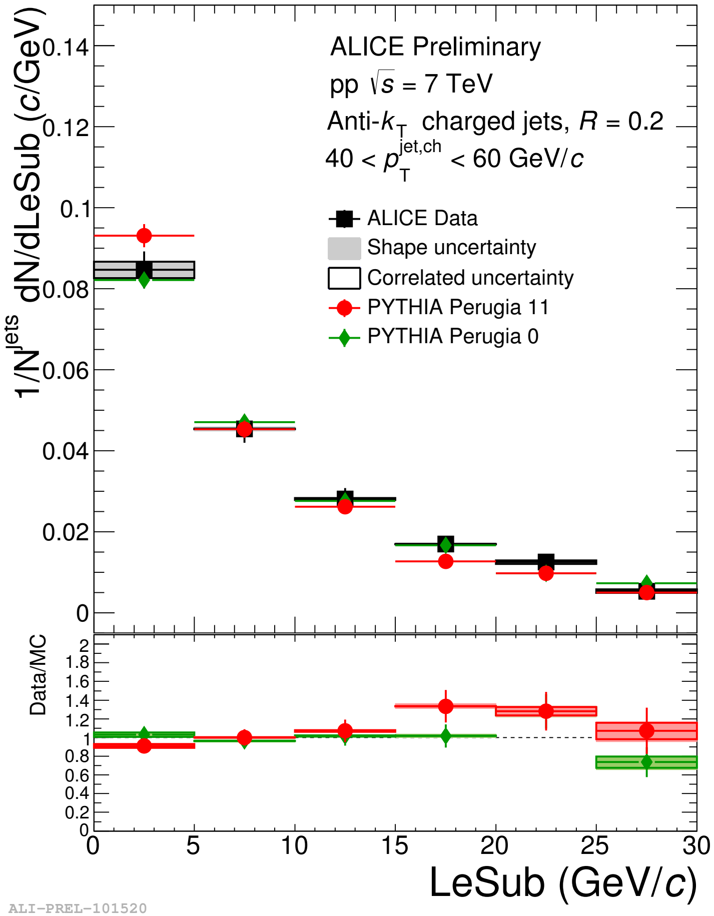




Good agreement with models

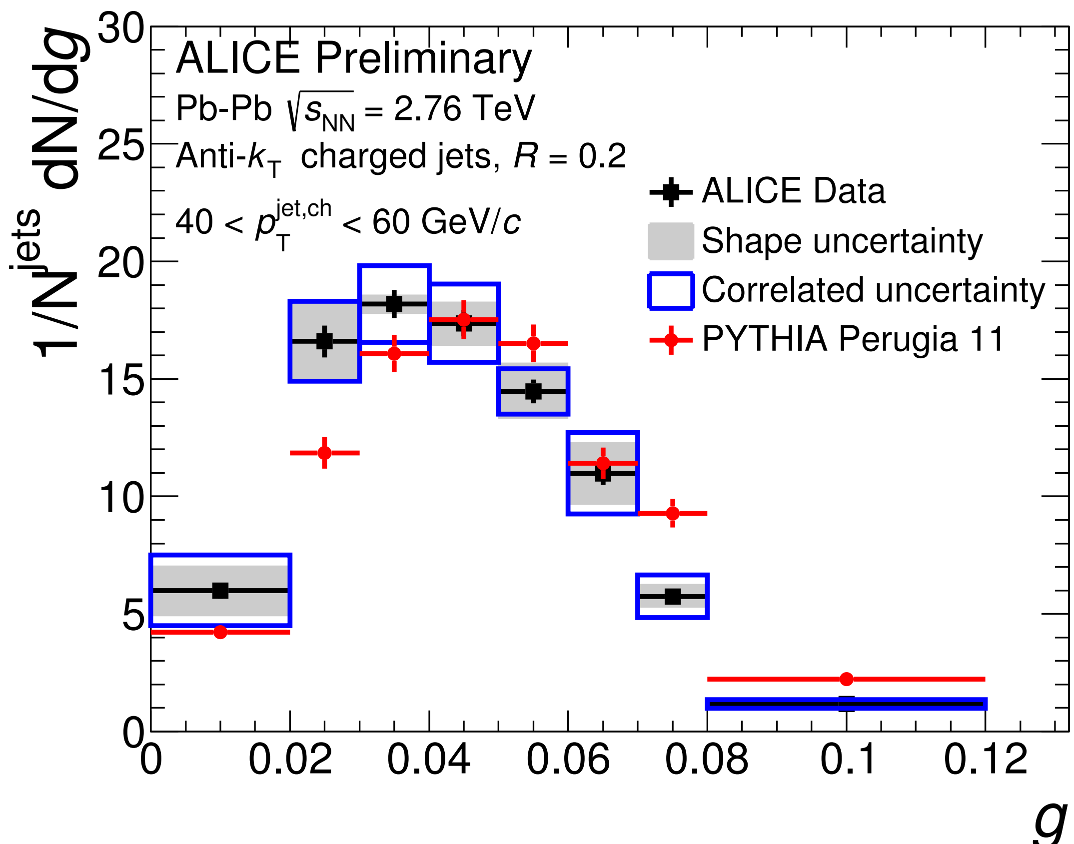
Remarkable at low *R*, where non-perturbative hadronization effects are large

Fully corrected jet shapes in pp



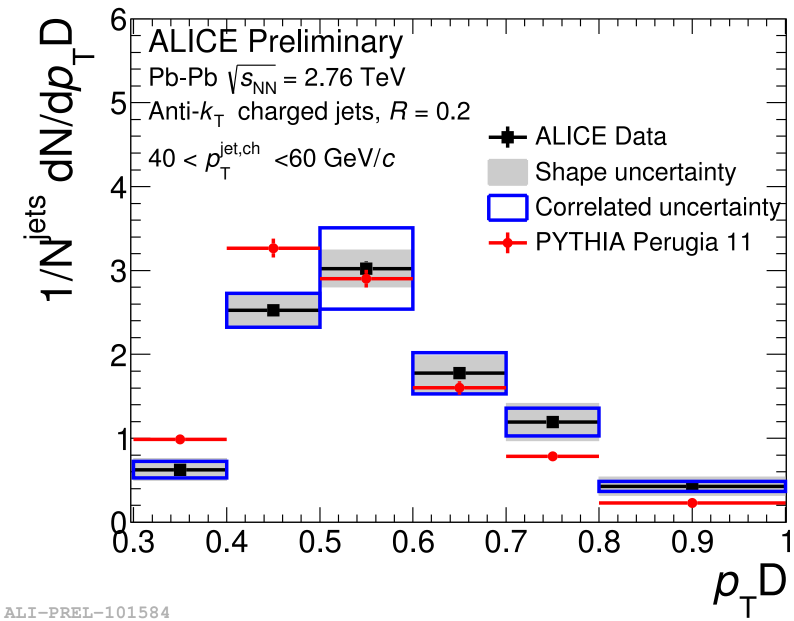
Good agreement with models

Fully corrected jet shapes in Pb-Pb



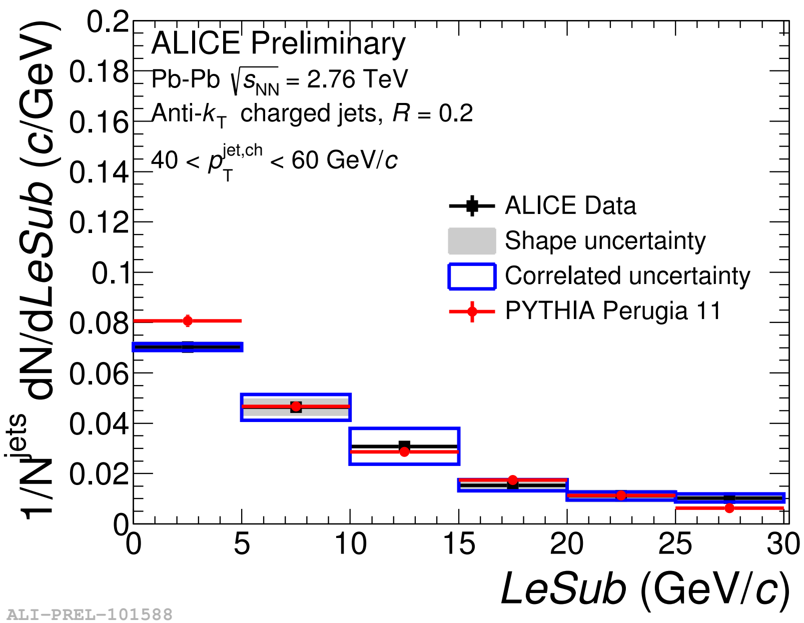
Radial moment shifted to lower values in Pb-Pb relative to PYTHIA Perugia11
→ indication of more collimated jet cores in Pb-Pb

Fully corrected jet shapes in Pb-Pb



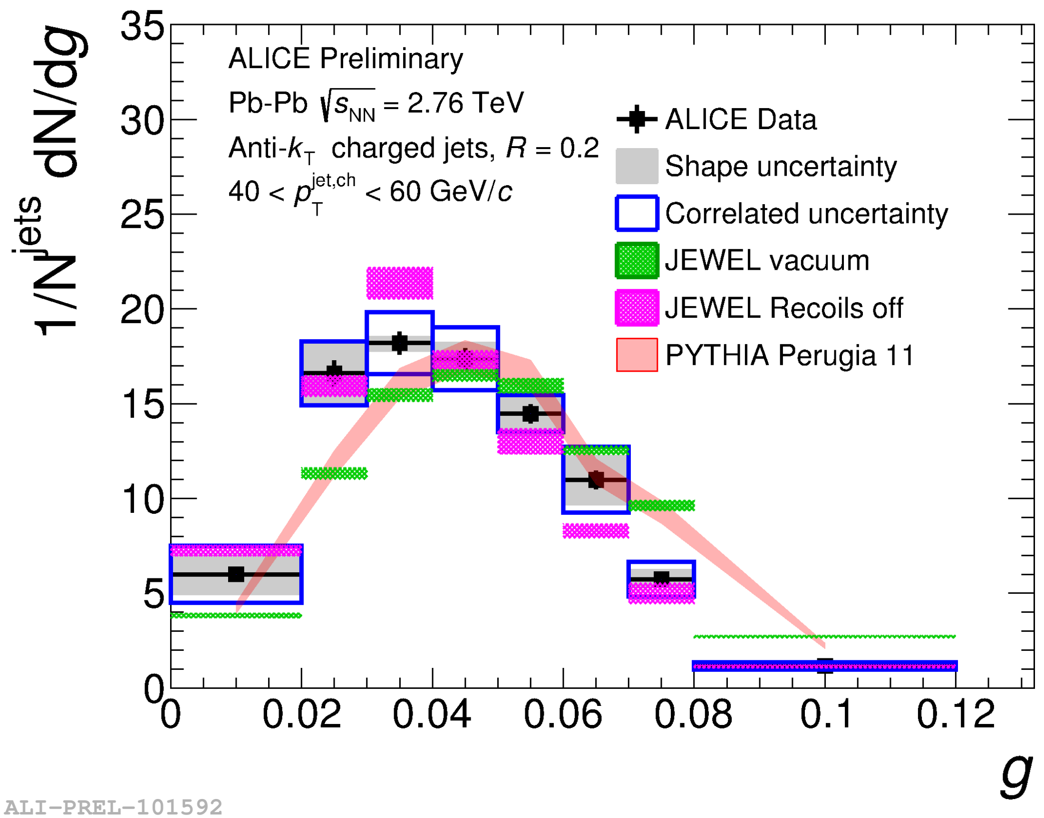
p_TD shifted to higher values in Pb-Pb relative to PYTHIA Perugia11

→ indication of fewer jet constituents and larger p_T dispersion in Pb-Pb



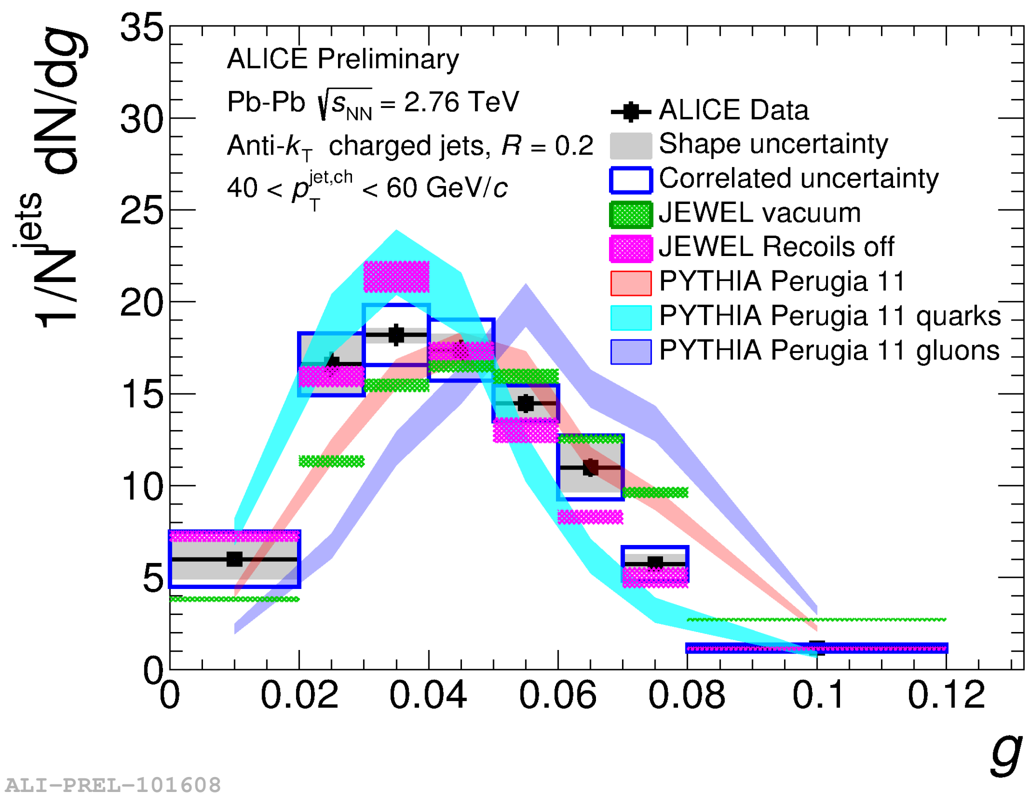
***LeSub* is in fair agreement with PYTHIA Perugia 11 vacuum reference**

Pb-Pb results compared to models



Radial moment in data shifted to lower values relative to PYTHIA Perugia 11
Compatible with a more collimated fragmentation in Pb-Pb
JEWEL is in qualitative agreement with data

Pb-Pb results compared to models



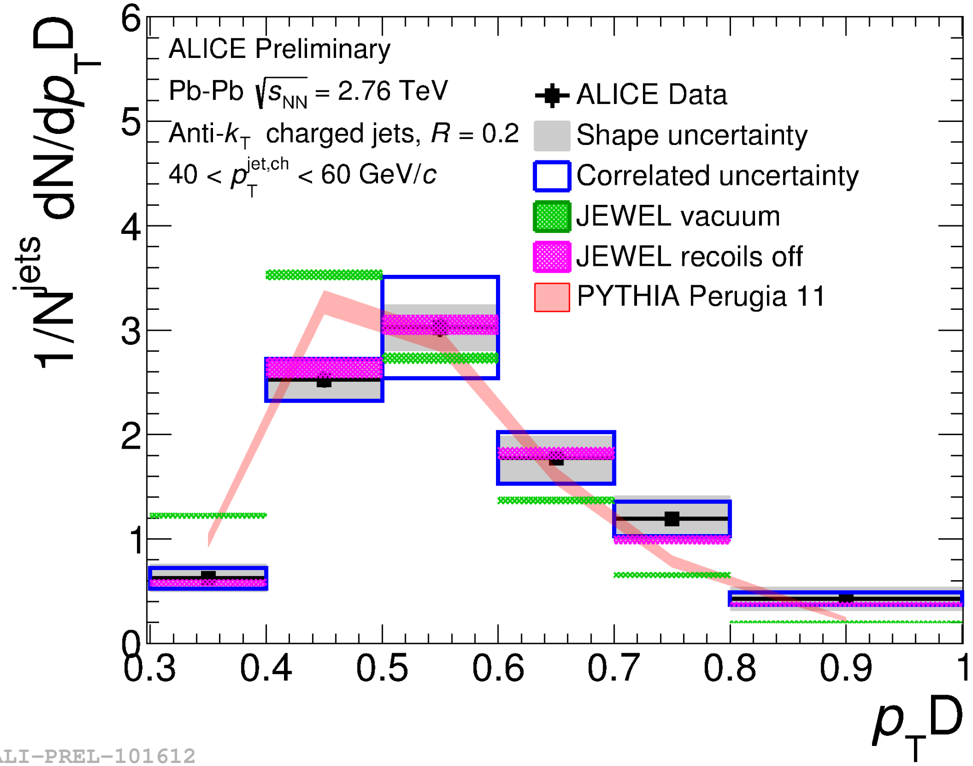
Interesting analogy:

If we compare quark and gluon jets at the same energy:

gluon jets can be seen as jets quenched jets with intrajet broadening (as implemented for example in qPythia with an accelerated shower)

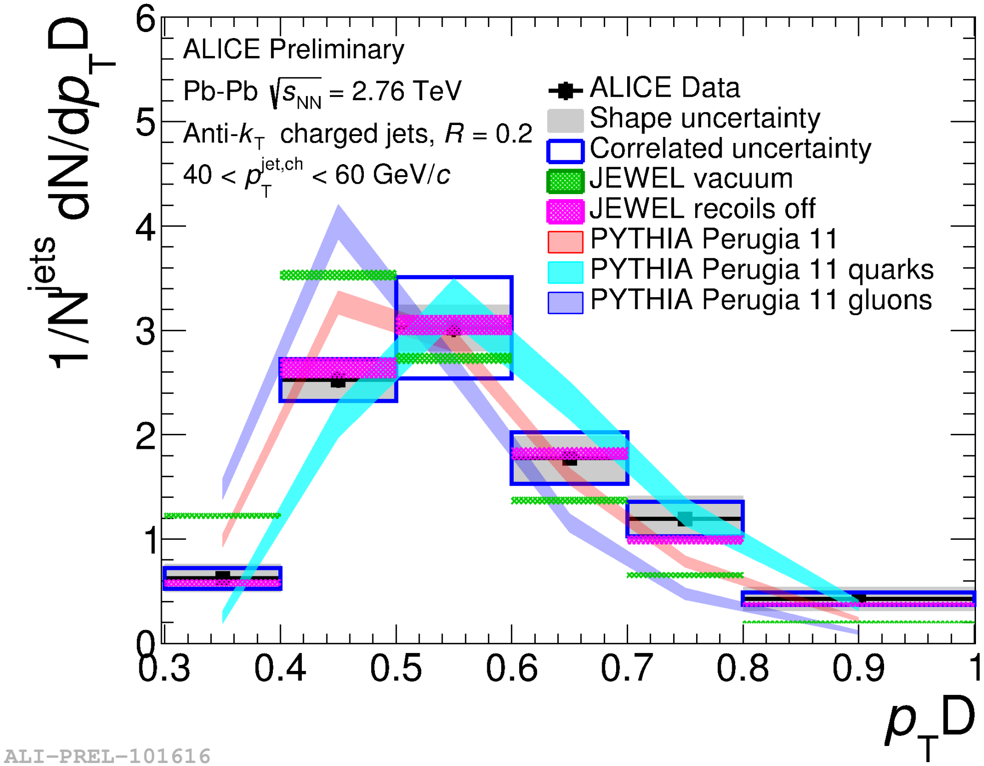
quark jets can be seen as quenched jets without intrajet broadening, as it is the case of JEWEL at small *R*

Pb-Pb results compared to models



p_TD in data shifted to higher values relative to PYTHIA Perugia 11
Compatible with a harder/fewer constituents fragmentation in Pb-Pb
JEWEL is in qualitative agreement with data

Pb-Pb results compared to models



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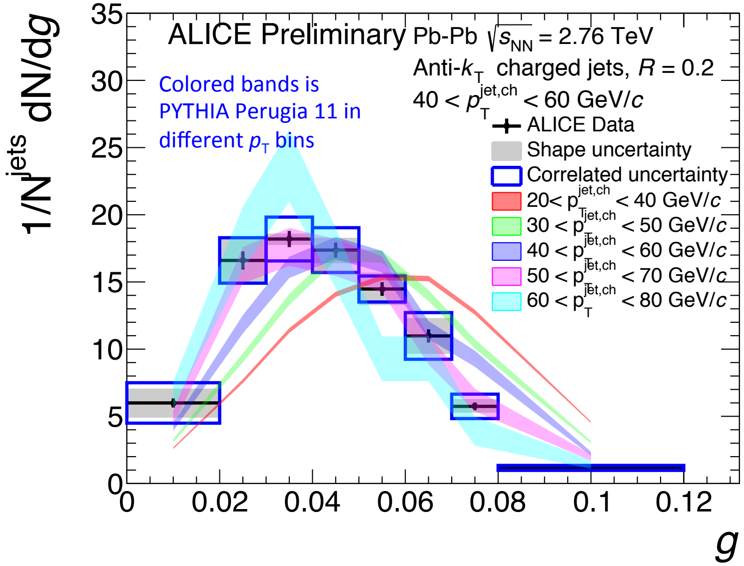
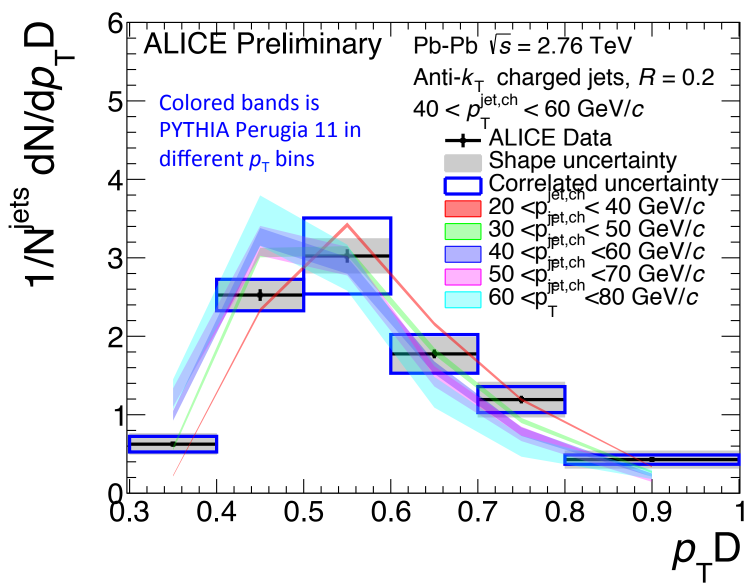
Additional qualitative remarks



If the jet would **lose energy as a whole** (as a single emitter) then we expect Pb-Pb shapes to be in agreement with vacuum shapes at higher p_T



The radial moment g is in qualitative agreement with this expectation but that is not the case for p_TD, for which changes go in the opposite direction

Conclusions and prospects

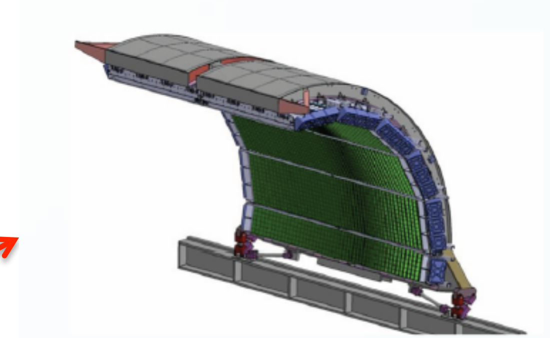
Probed different aspects of fragmentation with a set of well-defined independent shapes

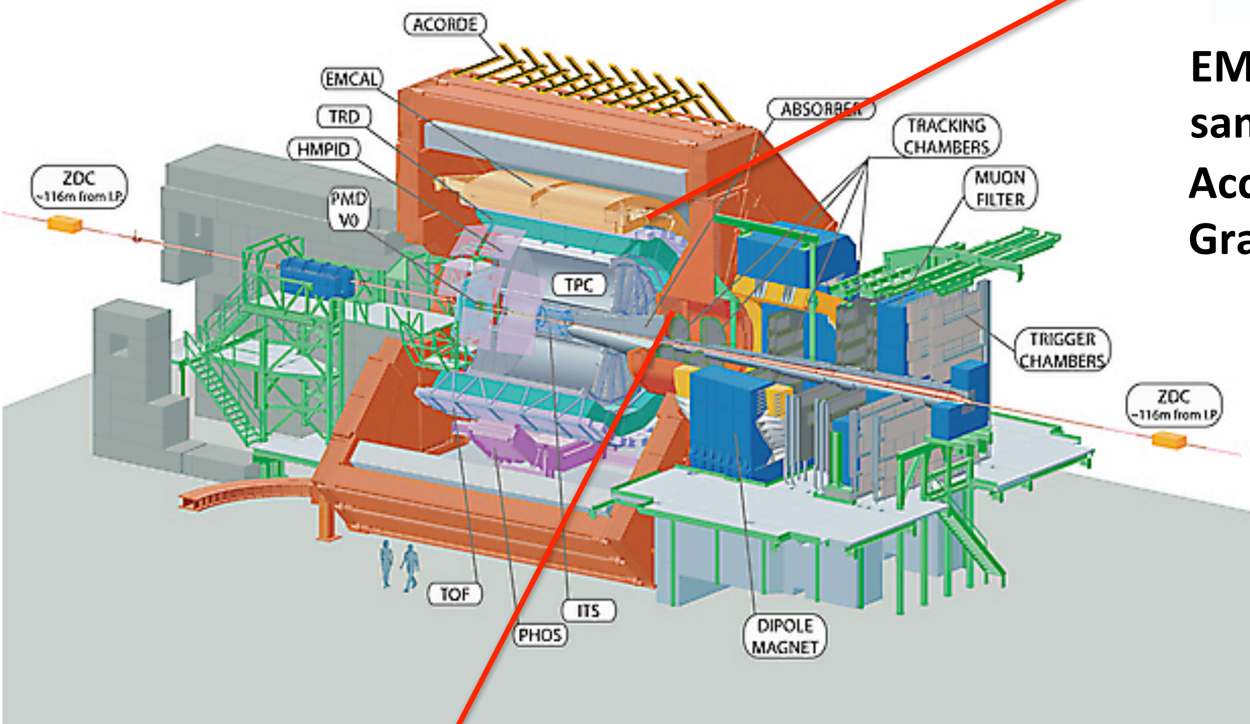
Results in qualitative agreement with quenching models like JEWEL

Results indicate that Pb-Pb jet cores are narrower and are harder/have fewer constituents than vacuum PYTHIA jets

EXTRAS

Jets in ALICE





EMCal is a Pb-scintillator sampling calorimeter

Acceptance: $|\eta|<0.7$, $1.4 <\phi< \pi$

Granularity: $\Delta\eta=\Delta\phi$~0.014

Neutral constituents

$|\eta|<0.9$, $0 <\phi< 2\pi$

TPC: gas drift detector

ITS: silicon detector

Charged constituents

JET