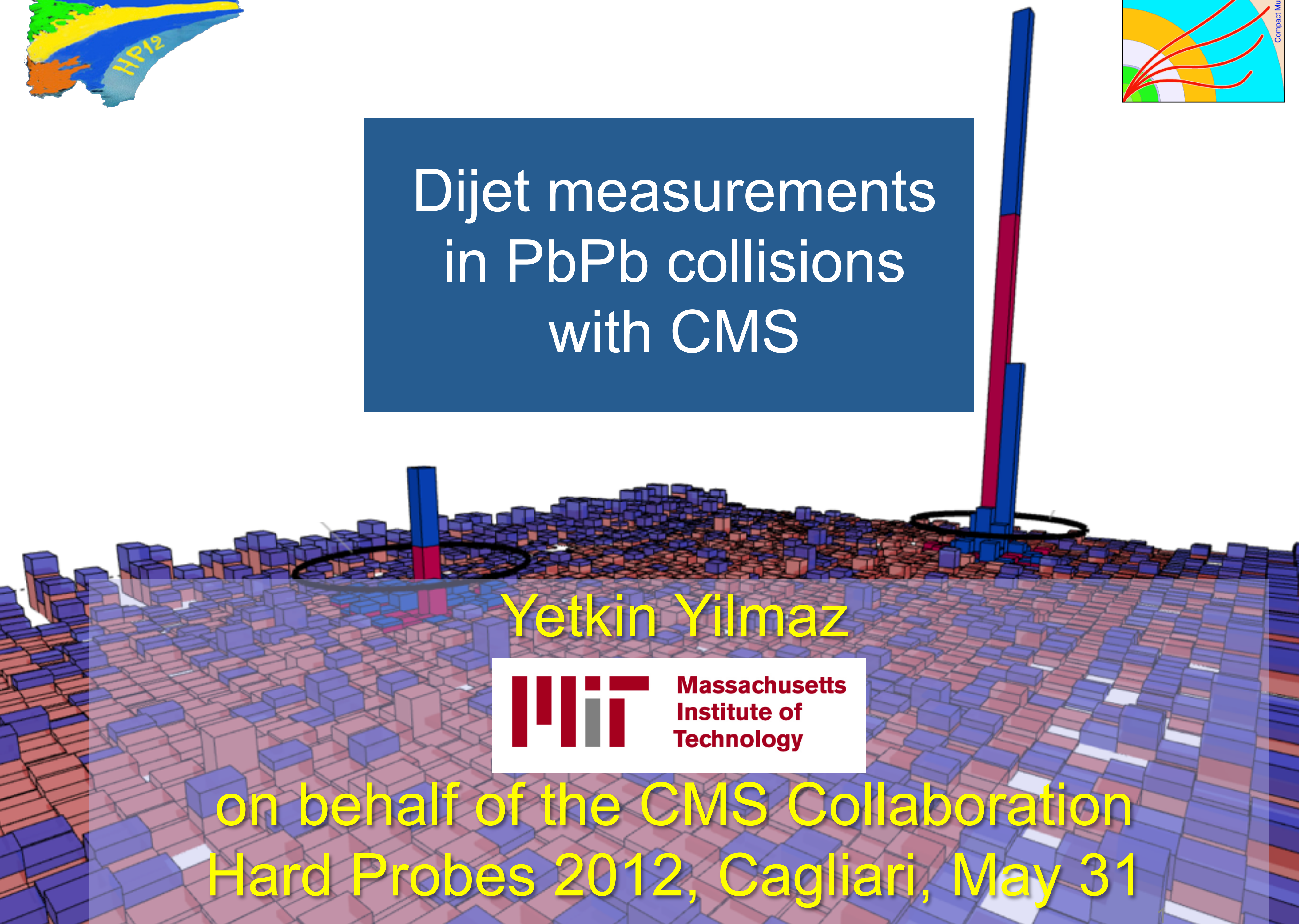
Dijet measurements in PbPb collisions with CMS



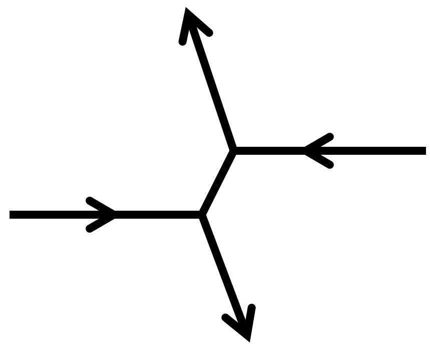
Yetkin Yilmaz

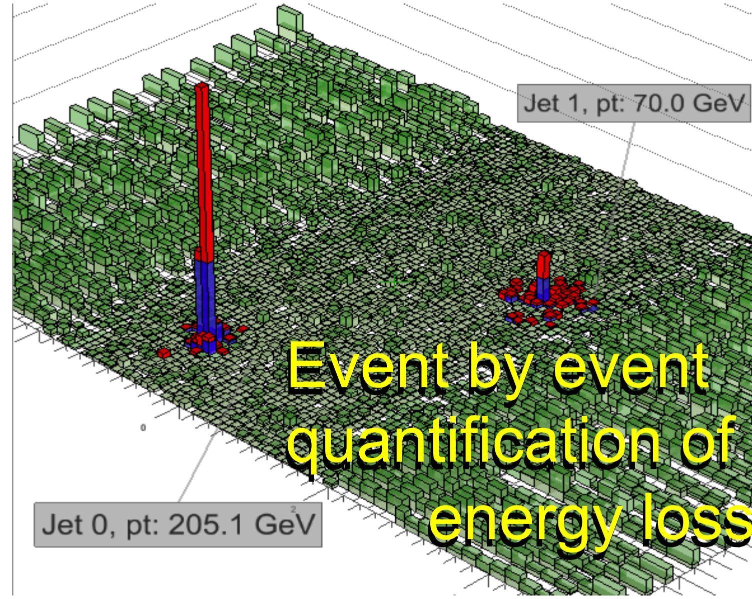
Massachusetts Institute of Technology

on behalf of the CMS Collaboration

Hard Probes 2012, Cagliari, May 31

Why jets?



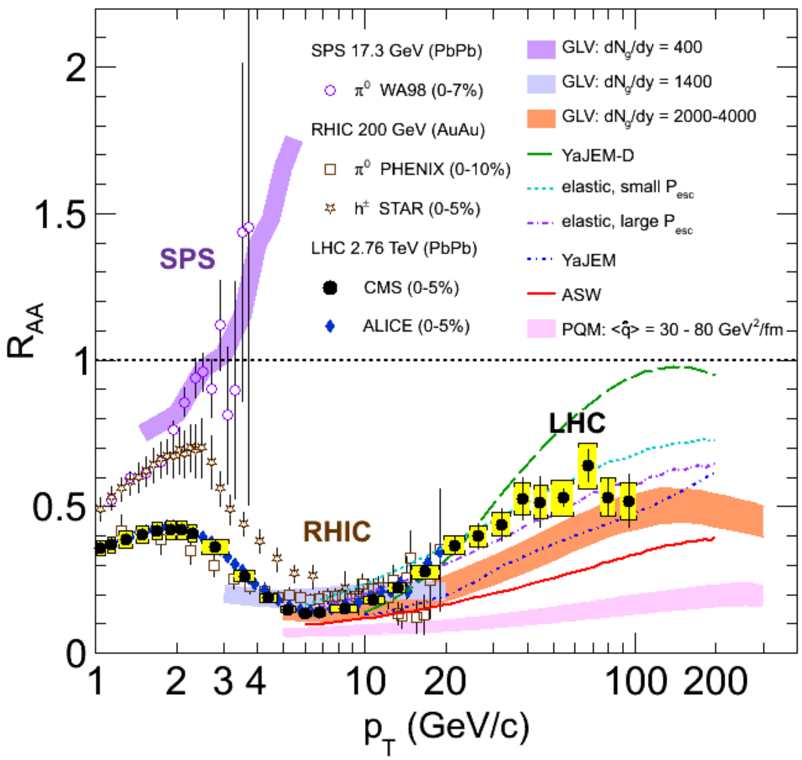


Higher order terms
&
Energy loss

Fragmentation

Hadrons

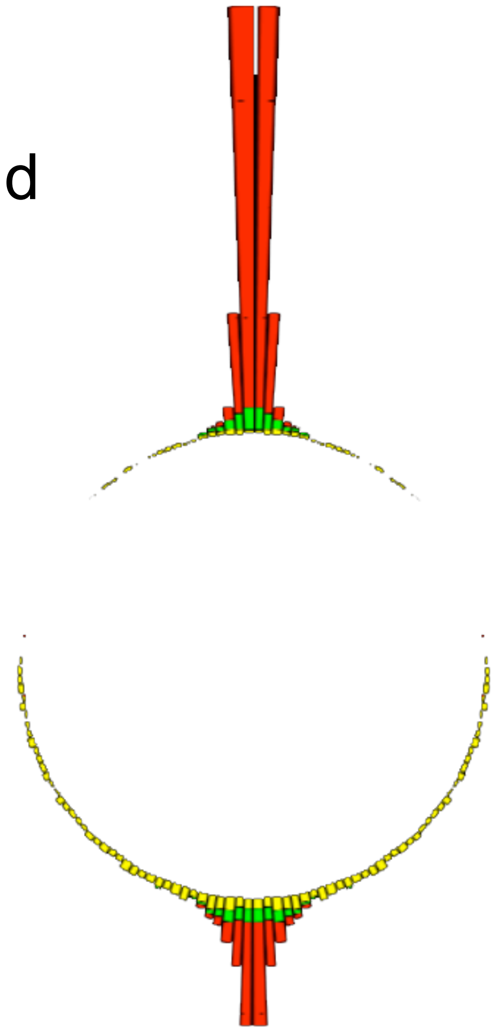
Probe deeper into the the underlying mechanism



Eur. Phys. J. **C72** (2012) 1945

Summary of analyses of 2010 PbPb dataset

Data sample of 6.8 μb^{-1}



First observations with calorimeter (cone, 0.5) jets and jet-track correlations:

- Enhanced dijet imbalance in central collisions
- Similar dijet angular correlations
- Lost energy is redistributed over a large range

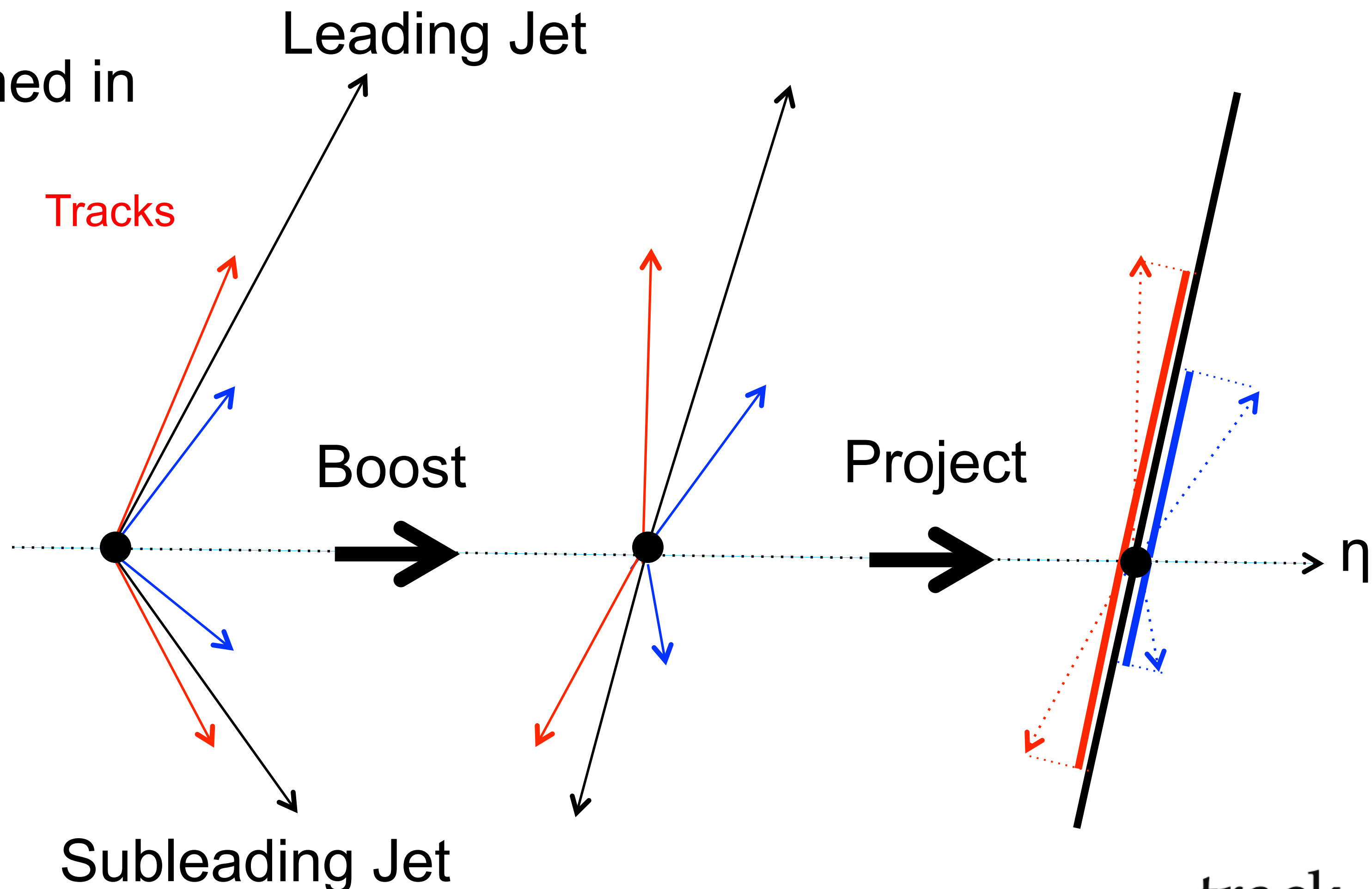
(Phys.Rev.C84:024906,2011)

Further studies for details of jet production mechanism:

- Using *ParticleFlow* jets
  - More efficient for low p_T jets
  - Better jet p_T resolution
- Using anti-k_T, $R = 0.3$
  - Minimize underlying event fluctuations
- Using pp data ($\sqrt{s} = 2.76$ TeV) as reference

Fragmentation Functions

As previously defined in
Phys. Rev. Lett.
65 (1990) 968

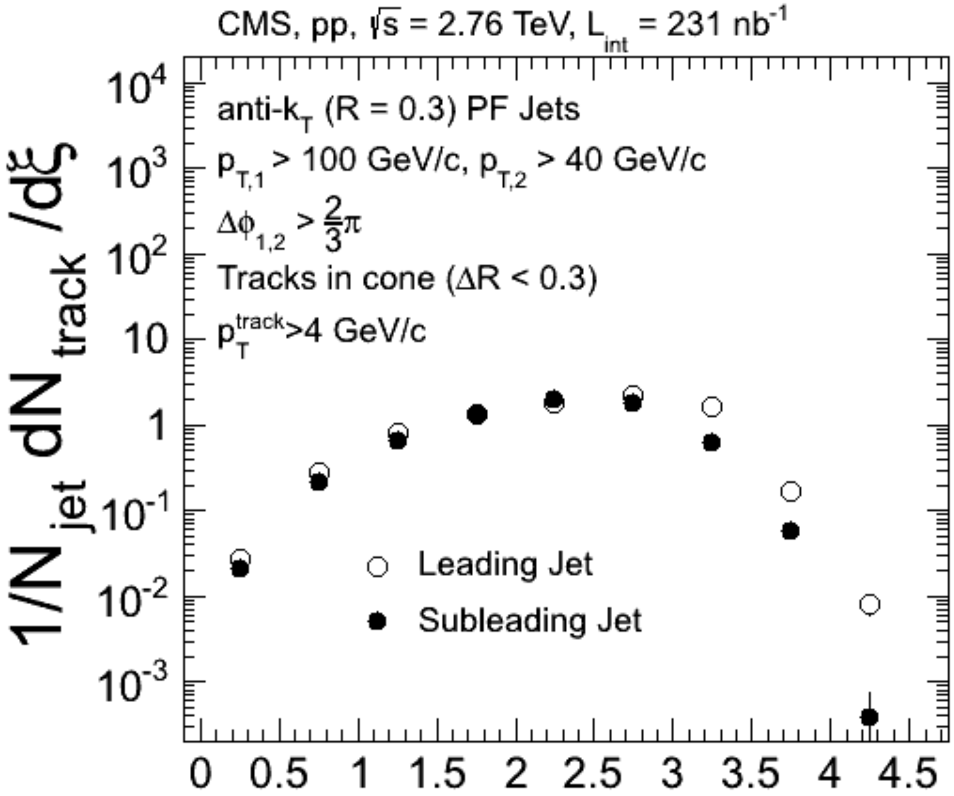


$$z = \frac{p_{\parallel}^{\text{track}}}{p^{\text{jet}}}$$

Using reconstructed jet momentum,
corrected to **hadron level**,
not tracing back to the parton before energy loss

Details in the recent publication: arXiv:1205.5872

pp results and reference for PbPb

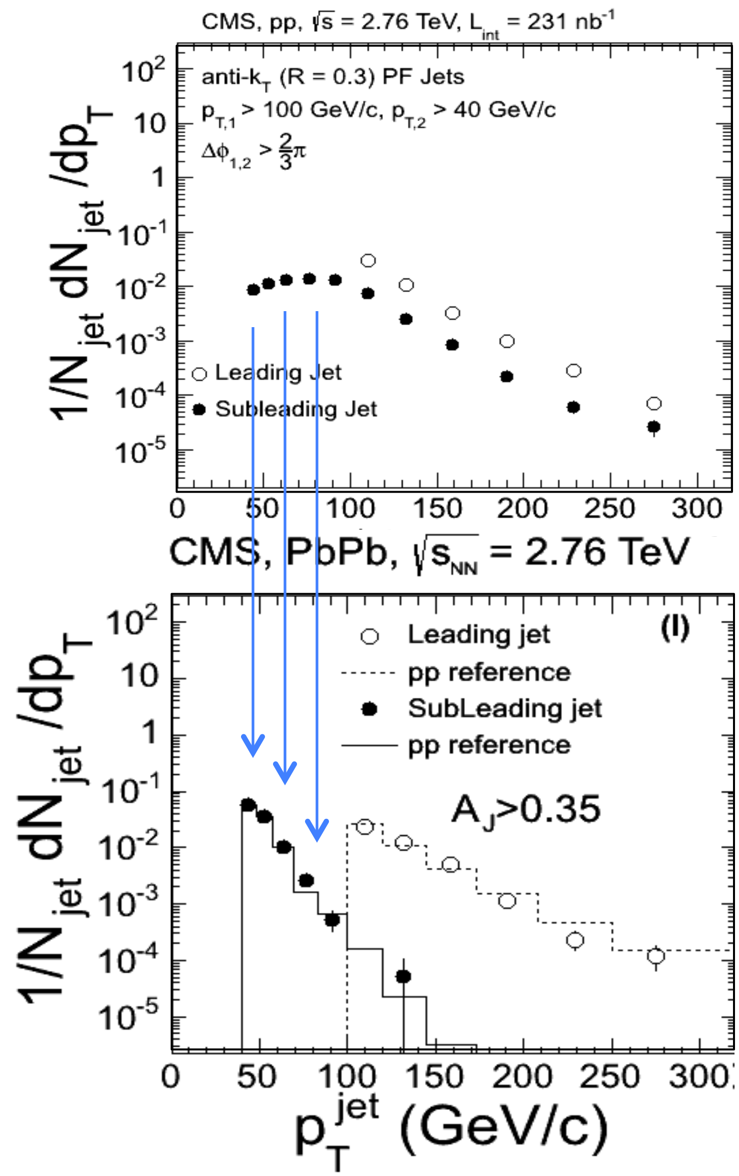


Hard fragments

$\xi = \ln(1/z)$

Soft fragments

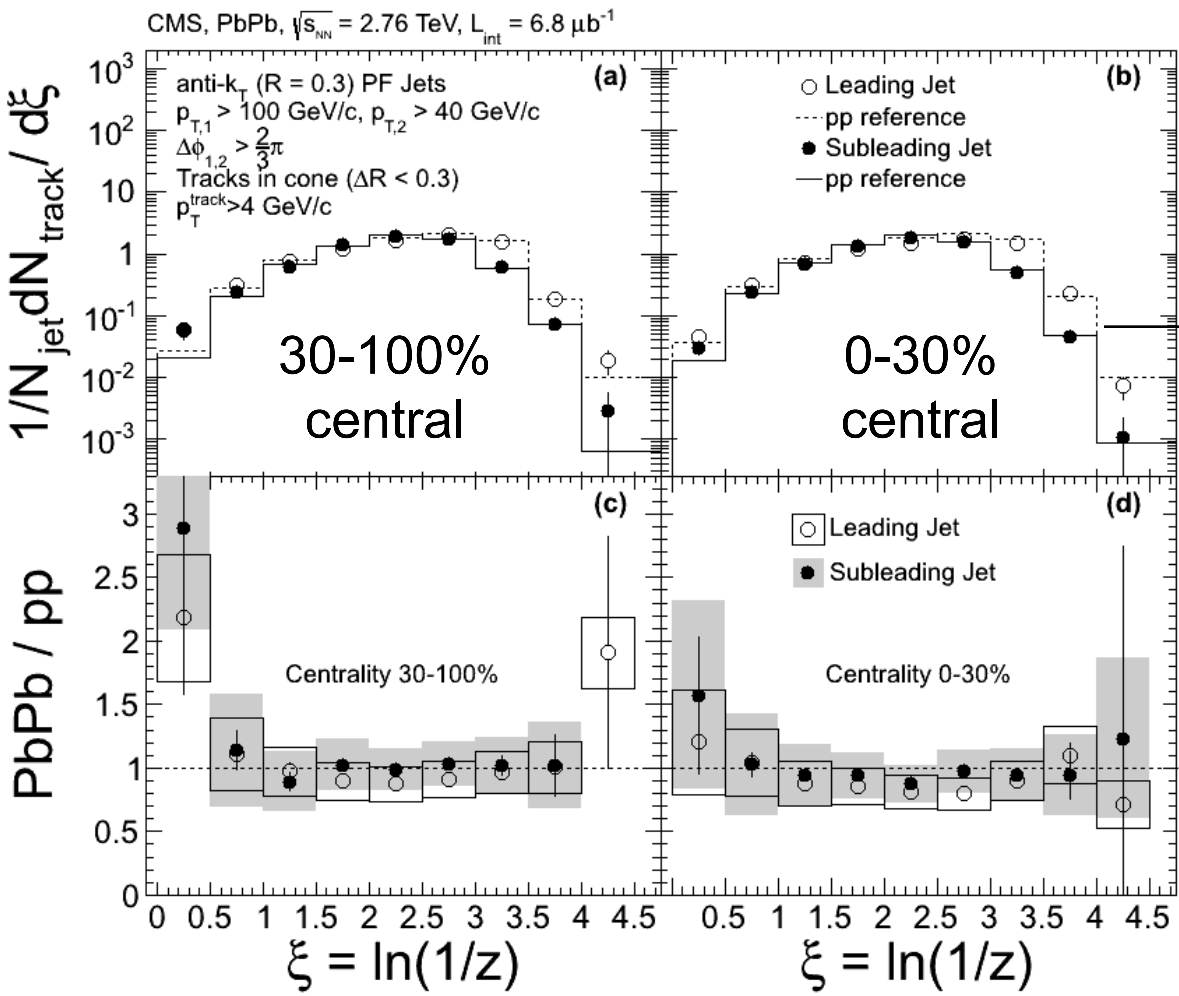
$$z = \frac{p_{\parallel}^{\text{track}}}{p^{\text{jet}}}$$



arXiv:1205.5872

Reference for PbPb data by reweighting pp data

PbPb results



pp reference smeared for background fluctuations and reweighted

Comparison in reconstructed level

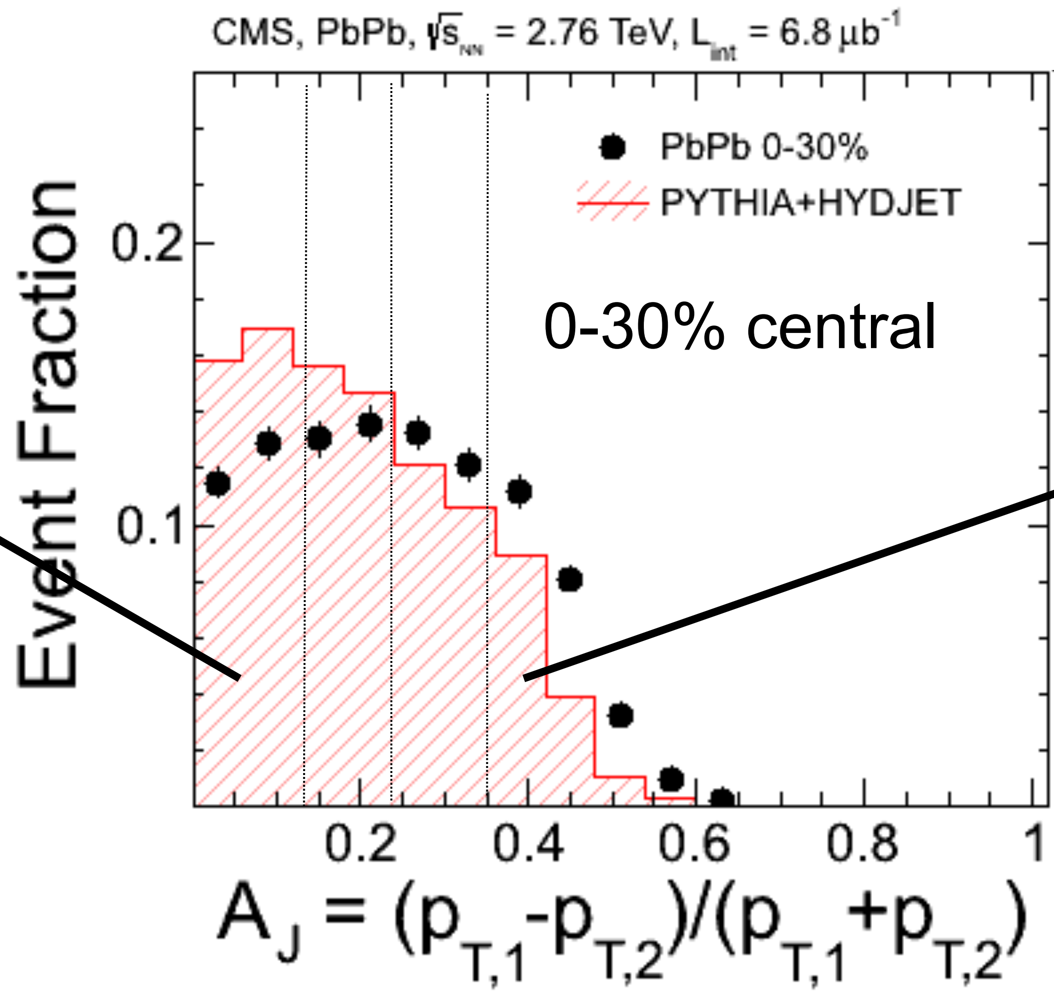
$$z = \frac{p_{\parallel}^{\text{track}}}{p^{\text{jet}}}$$

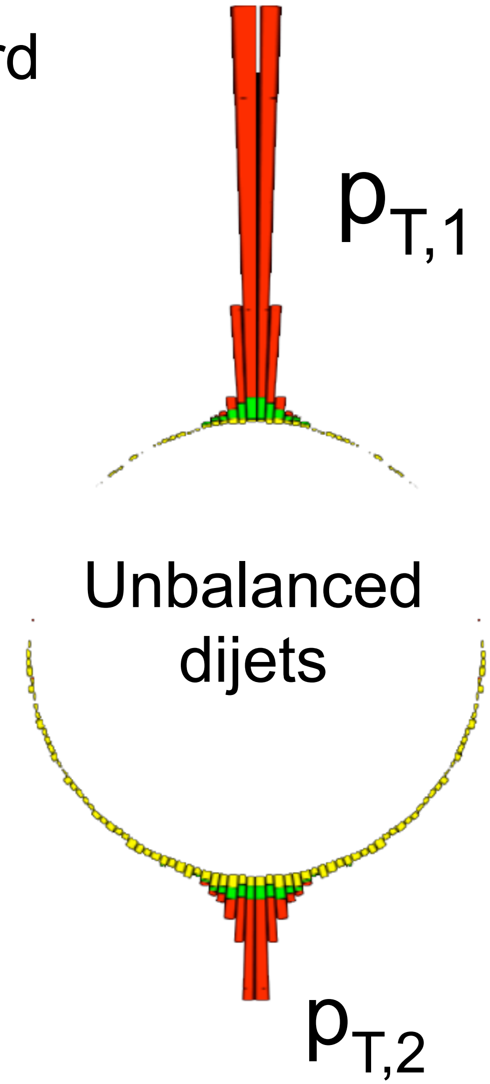
Structure of reconstructed jets resembles those that were produced in vacuum

arXiv:1205.5872

Differentiating in A_J

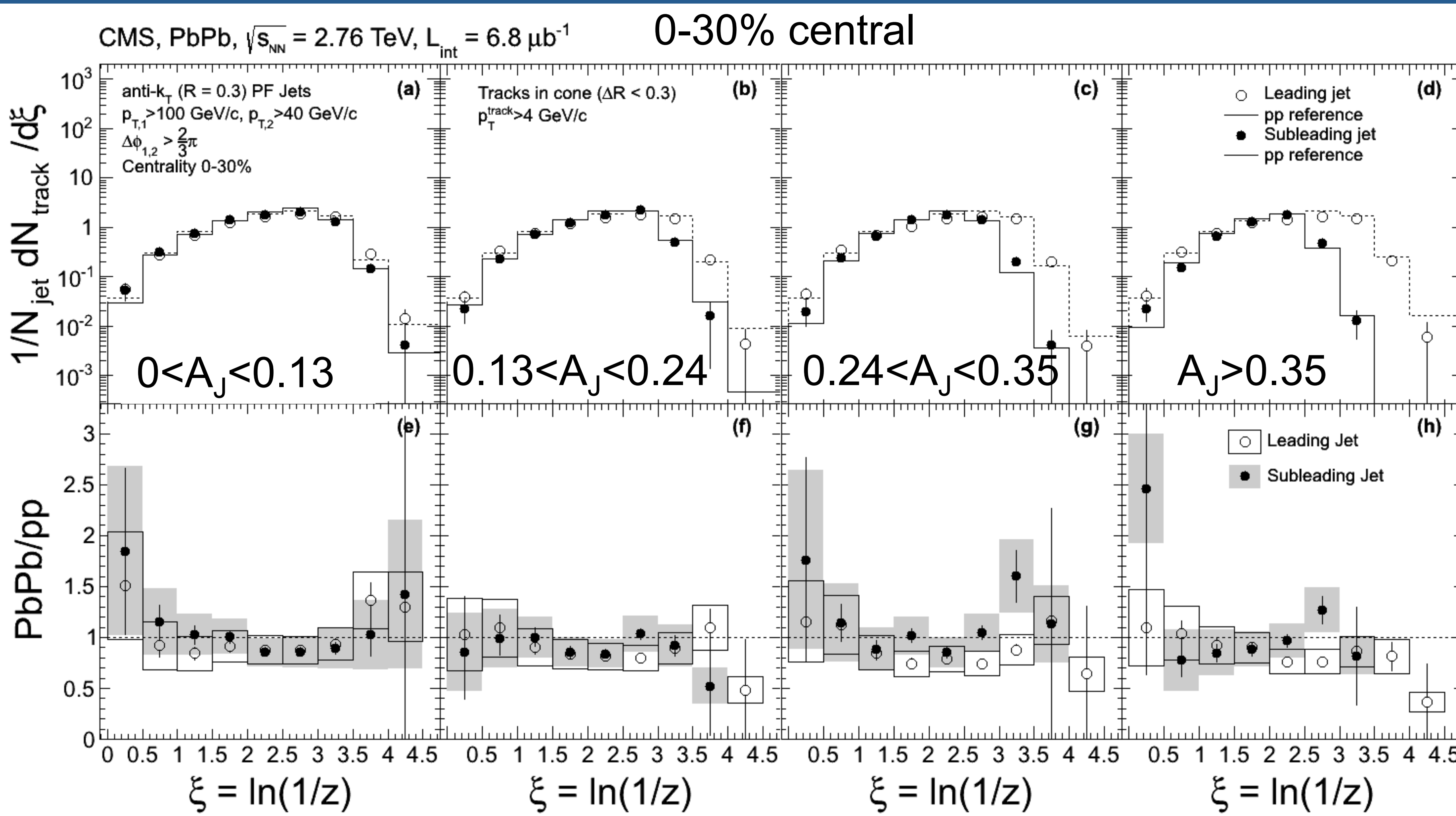
Probing any effects of quenching on the hard fragmentation...





More quenched subleading jet

PbPb results in A_J bins



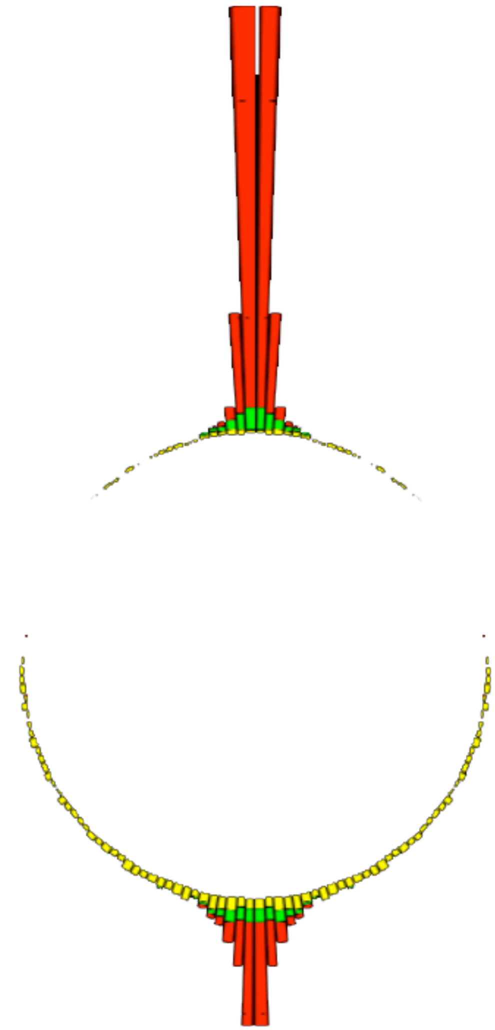
$$z = \frac{p_{\parallel}^{\text{track}}}{p^{\text{jet}}}$$

Structure of reconstructed jets resemble those that were produced in vacuum, despite the energy loss

arXiv:1205.5872

Analysis of 2011 PbPb dataset

150 μb^{-1} ~ 20 times more data than in 2010!!!
Able to perform same measurements more differentially



Analysis improved:

- Higher leading jet threshold
- Lower subleading jet threshold
- Background subtraction based on $\Delta\phi$ correlations

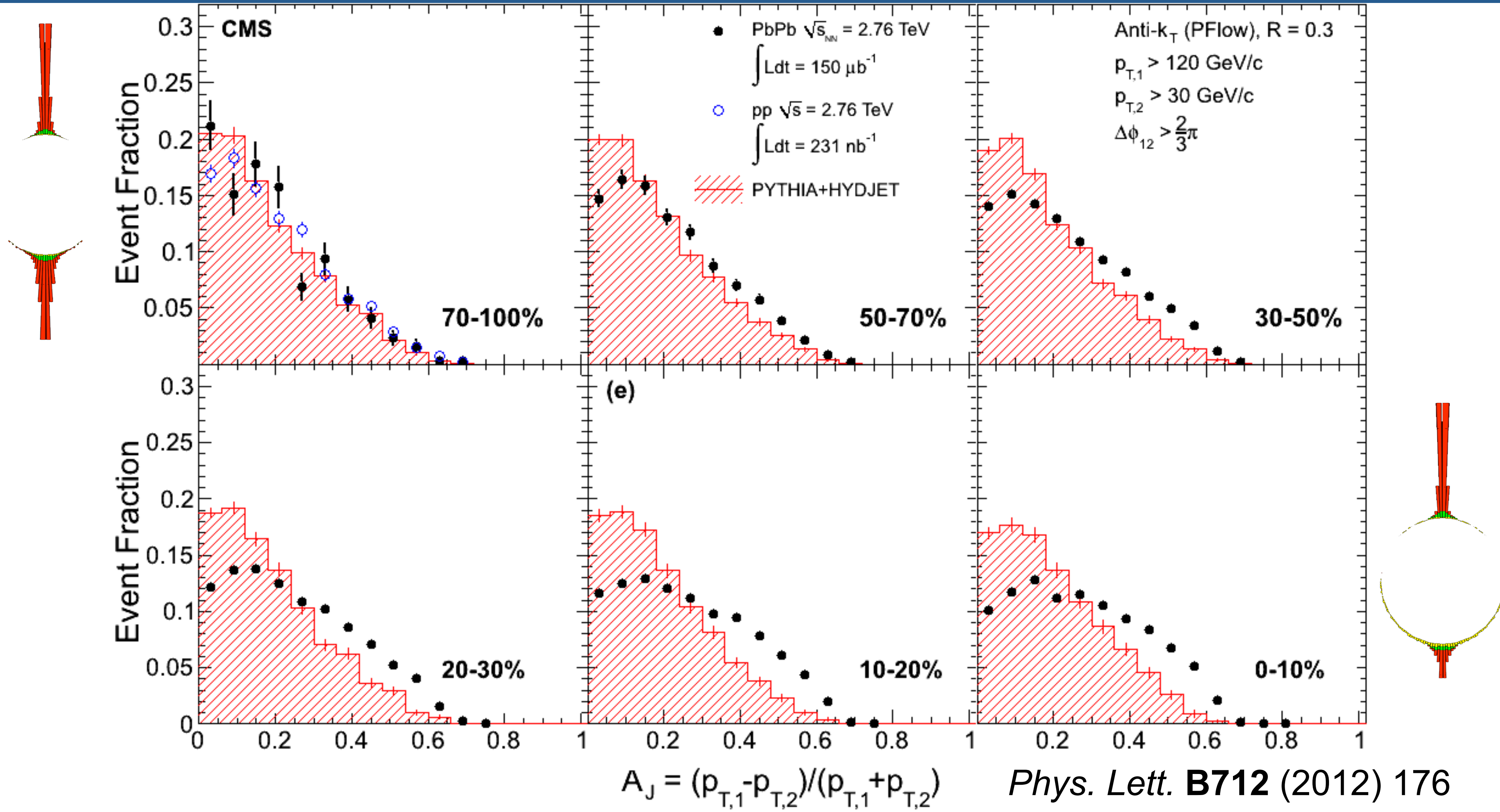
Motivation:

- Investigate the p_T dependence of the energy loss

Same jet algorithm:

- anti-k_T , R = 0.3

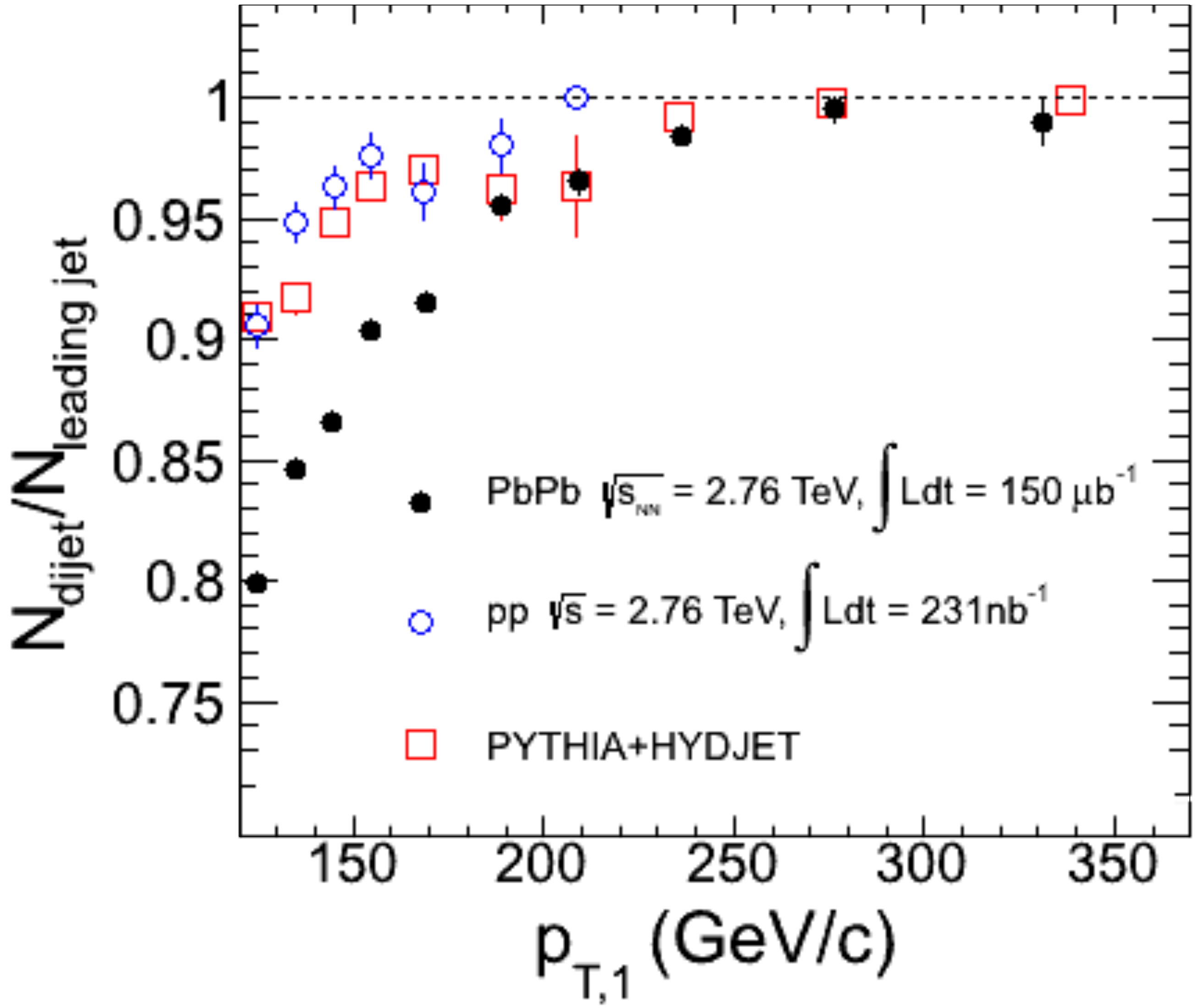
Results from 2011 data



Phys. Lett. **B712** (2012) 176

Earlier results confirmed
Statistical uncertainties significantly reduced

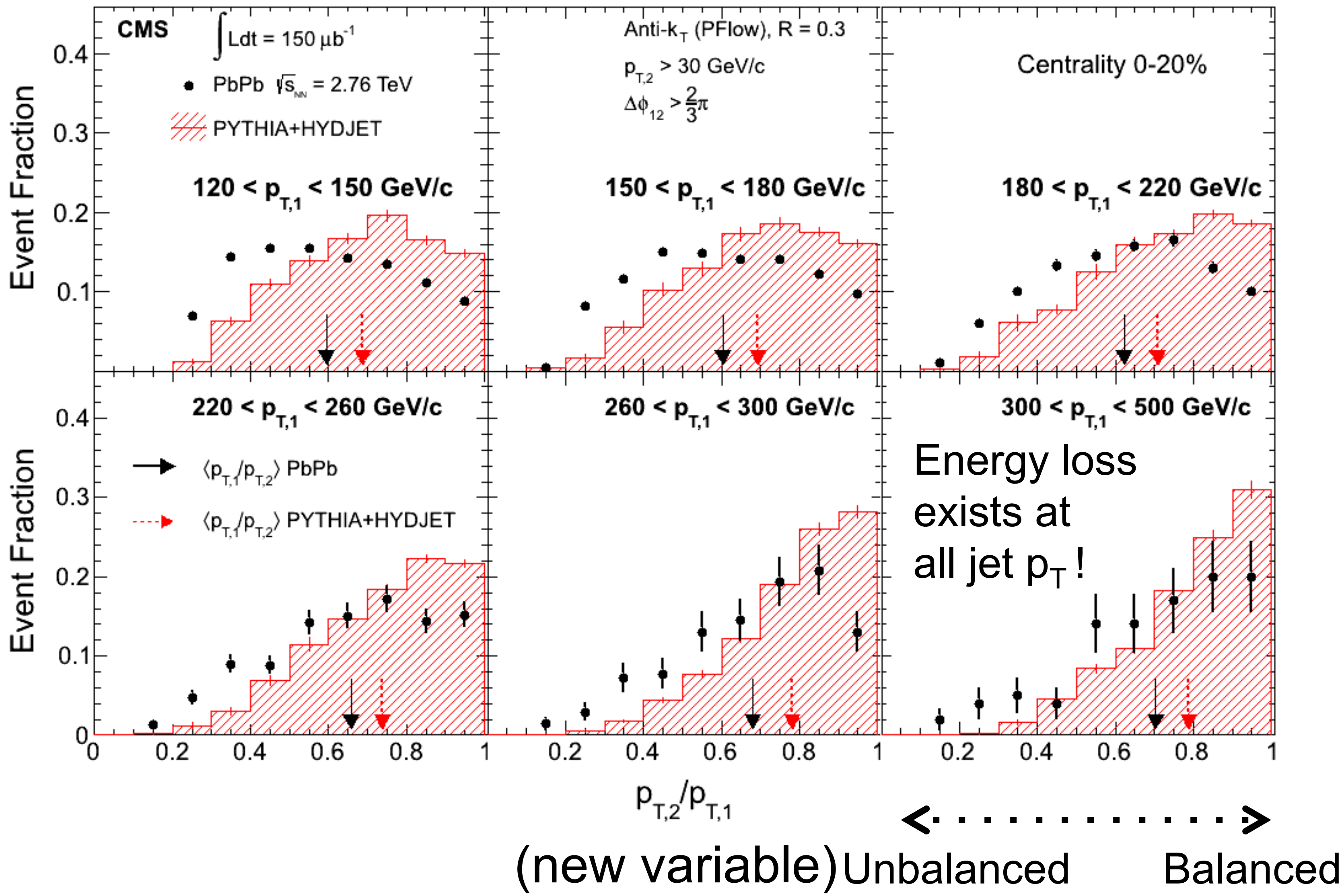
Dijet correlation and background



At high p_T, only very few jets get completely lost on the away side:
A less biased quantification of energy loss

Phys. Lett. **B712** (2012) 176

p_T-dependence of the dijet imbalance



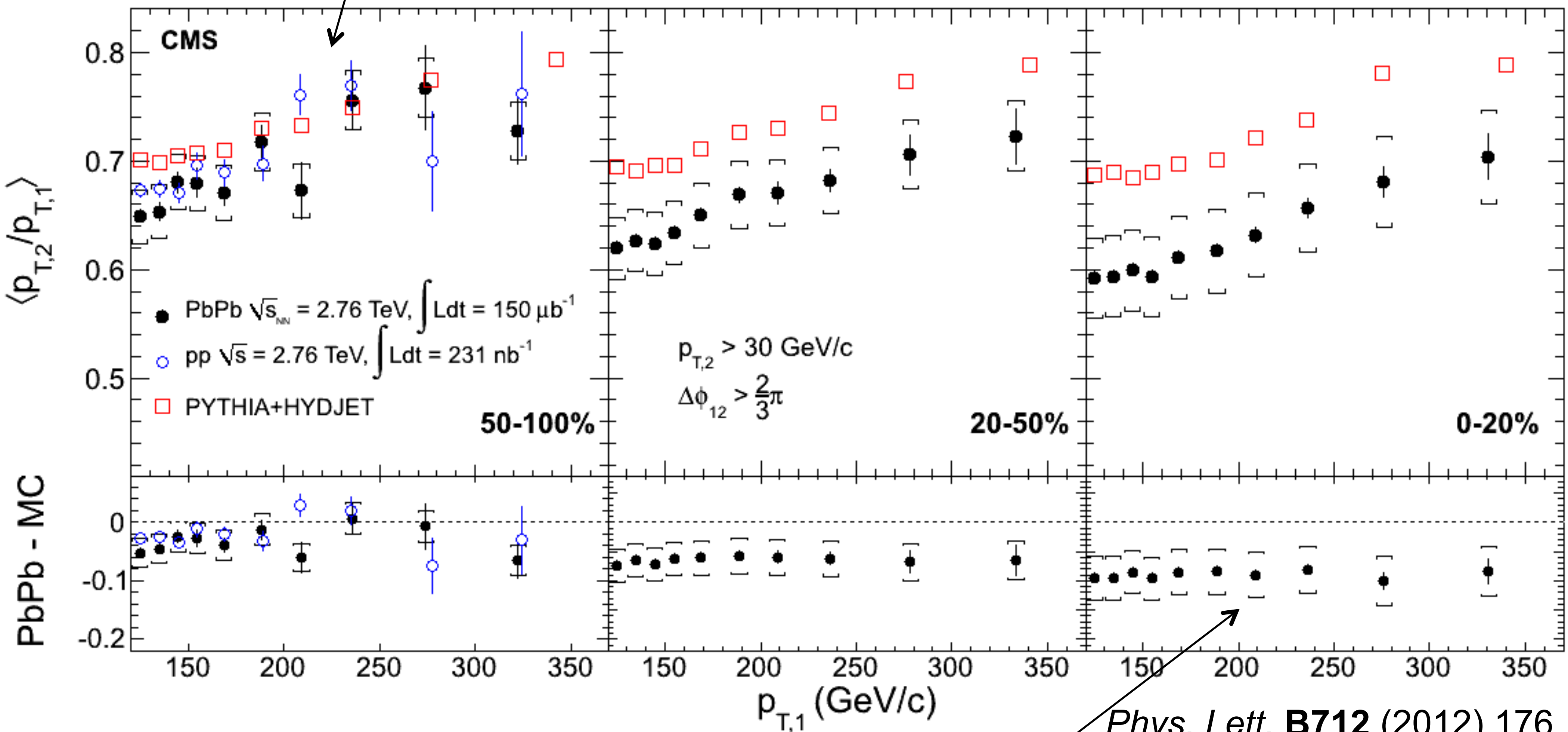
(new variable)

Dijets in PbPb are more imbalanced than Pythia at **all bins of leading jet p_T**

Phys. Lett. **B712** (2012) 176

p_T-dependence of the dijet imbalance

Reference and pp already have an increasing trend
Differences in initial state, different jet resolution



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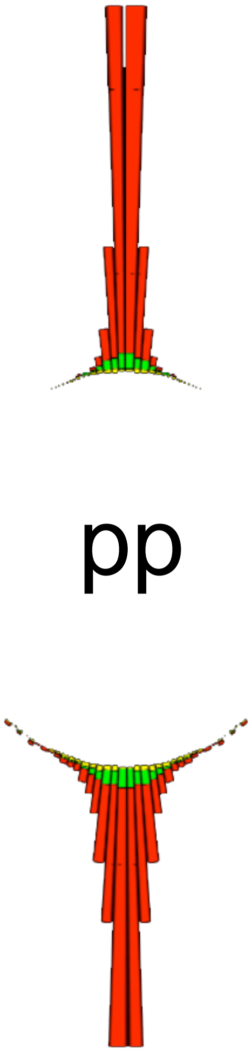
No significant dependence on jet p_T

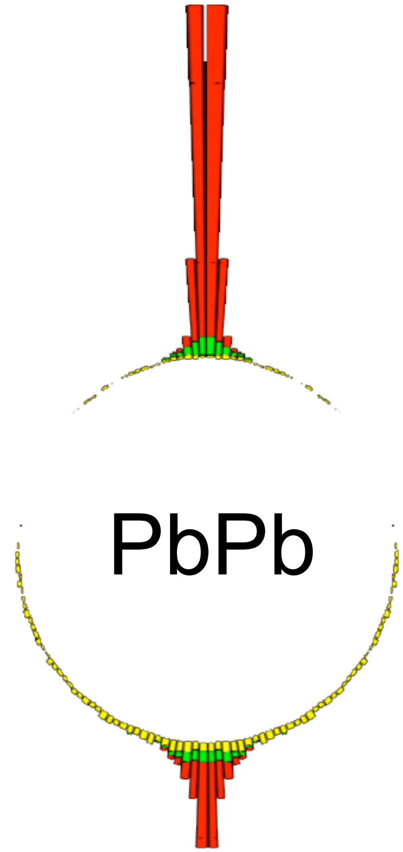
Conclusions



pp

Enhanced imbalance
at all jet p_T
increasing with centrality

Jet fragmentation pattern
similar to
pp collisions

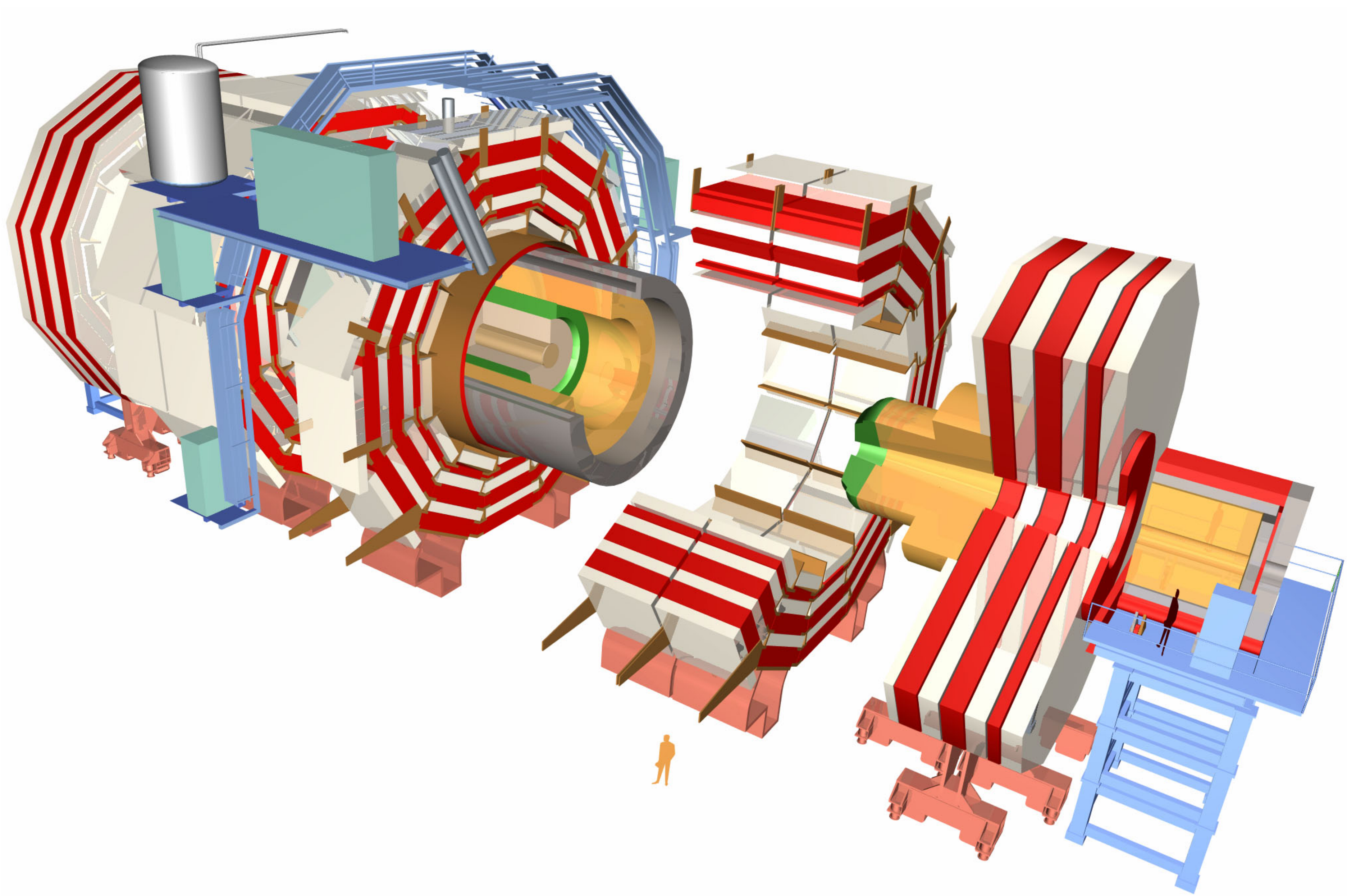


PbPb

The fraction of the energy that a jet loses
does not dramatically change with jet p_T

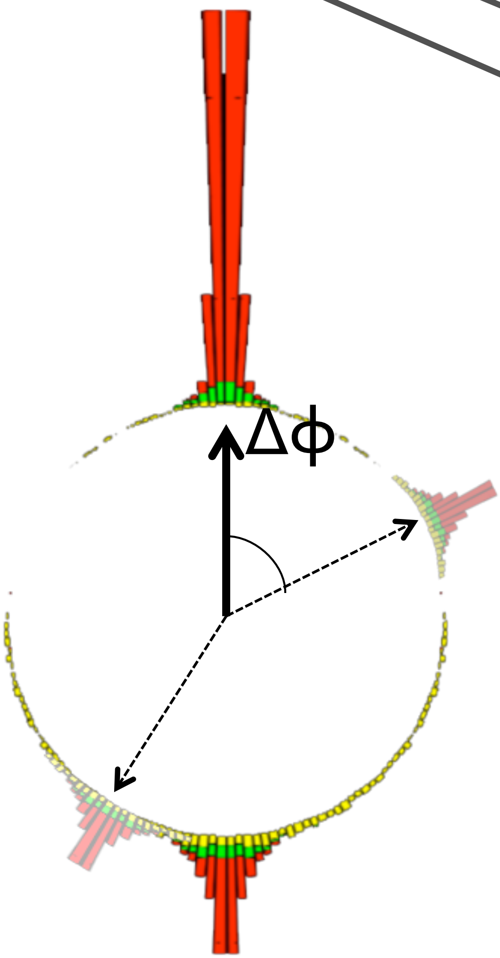
Back up

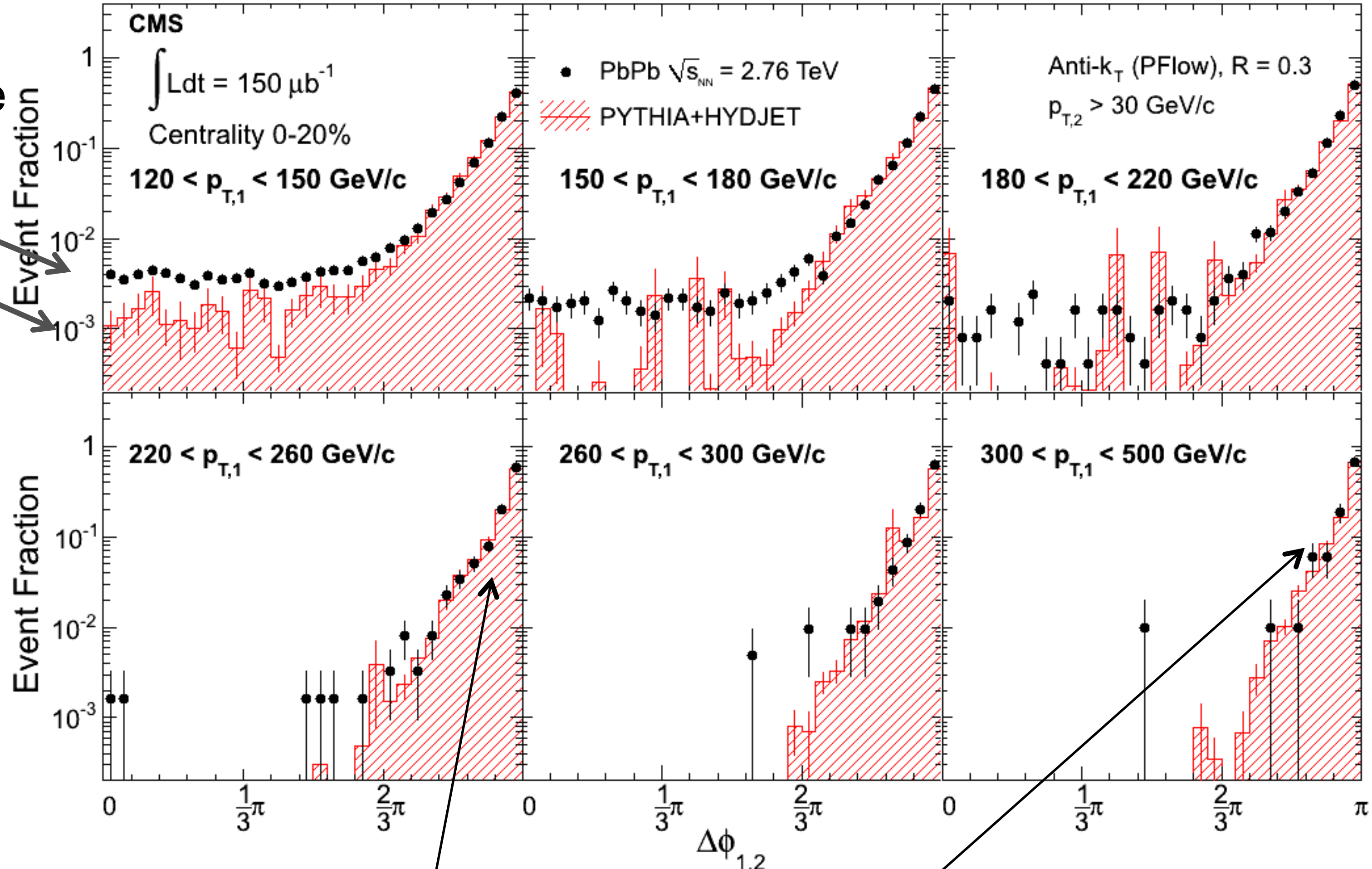
The CMS detector



Dijet angular correlations

Background fluctuations supersede the recoil jet more often in data



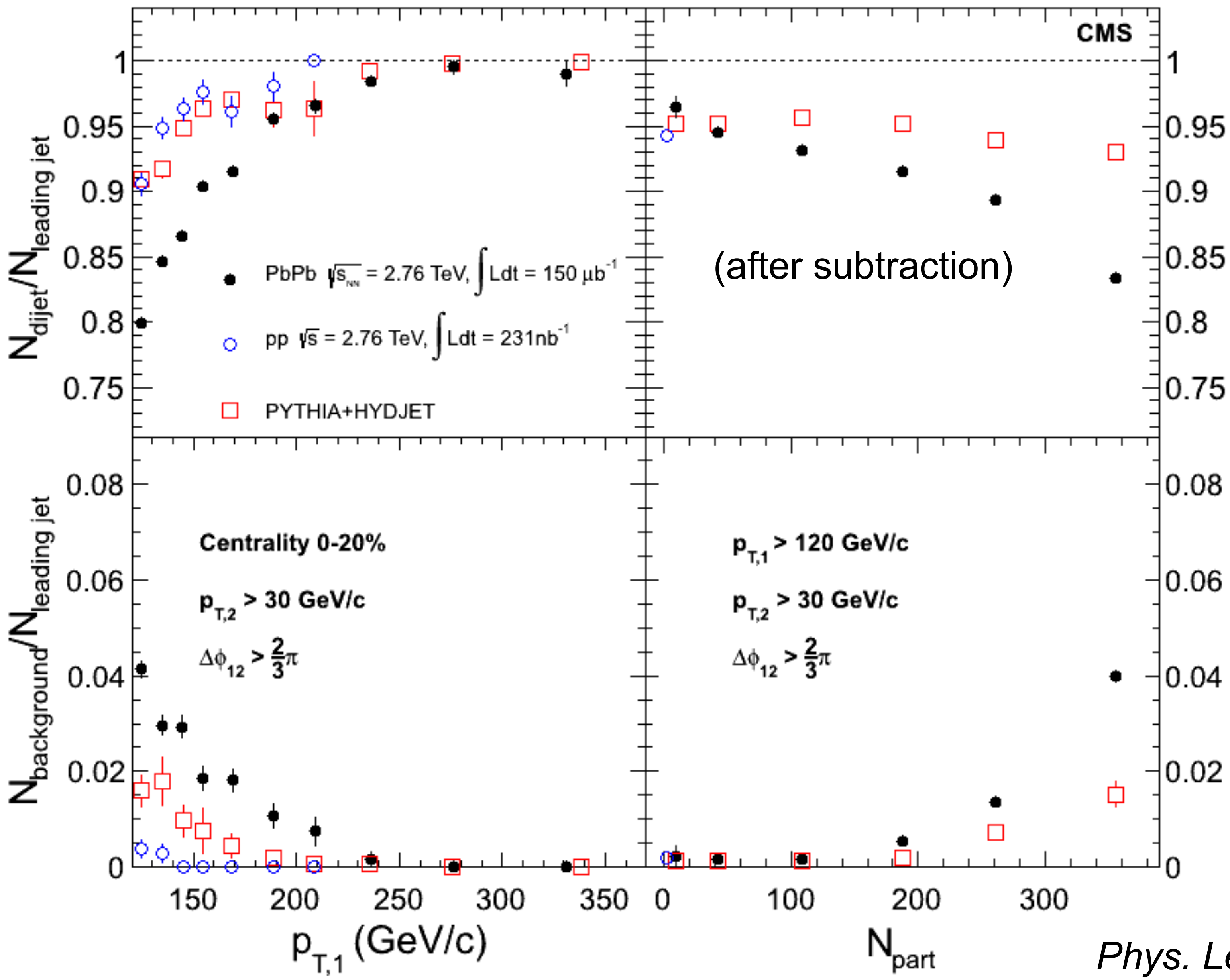


Correlation peak is the same in data and Pythia across all values of p_T

Phys. Lett. **B712** (2012) 176

No significant angular decorrelation of dijets.

Dijet correlation and background



Background increases with centrality:
- Larger UE
- More quenching

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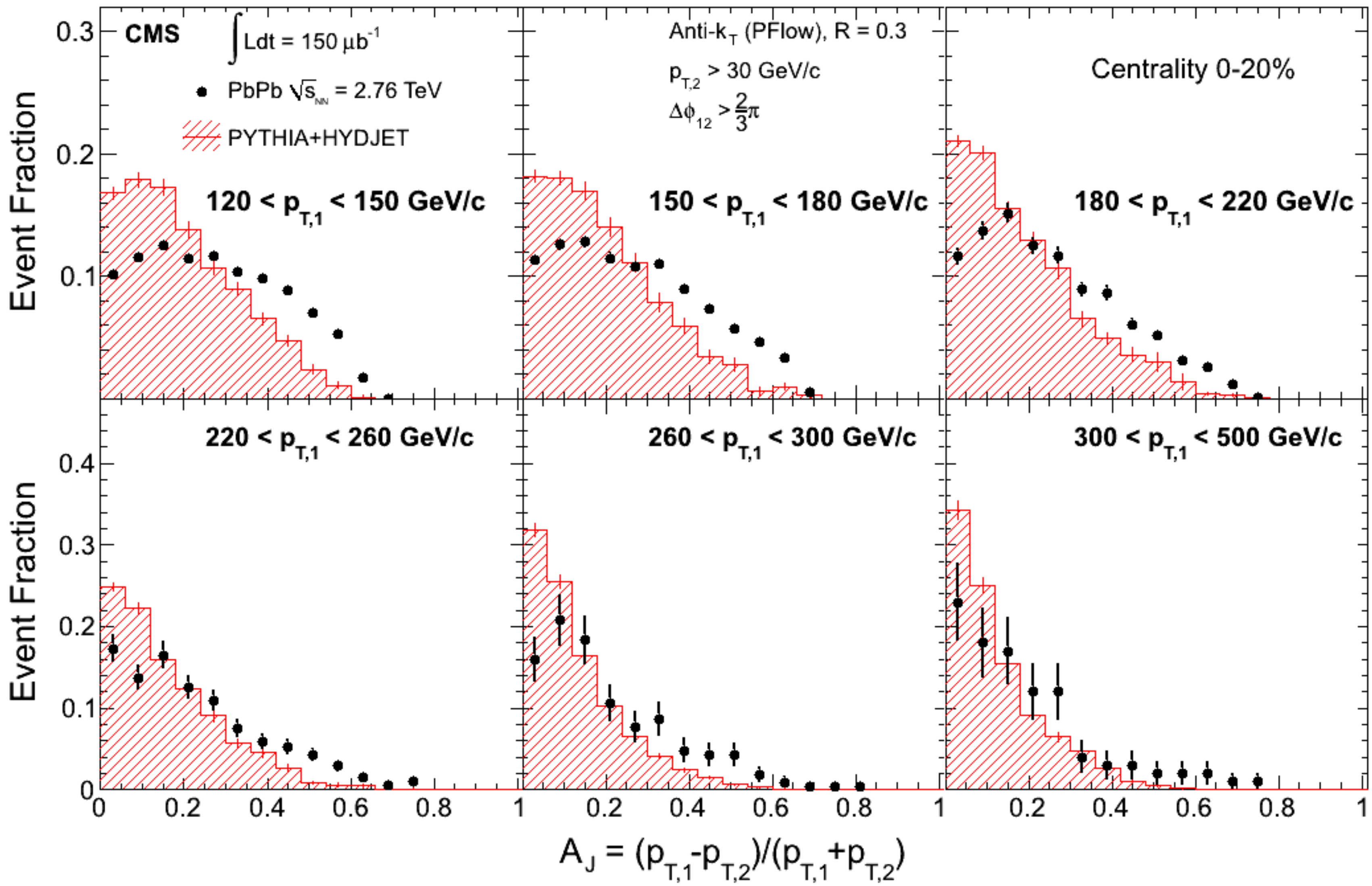
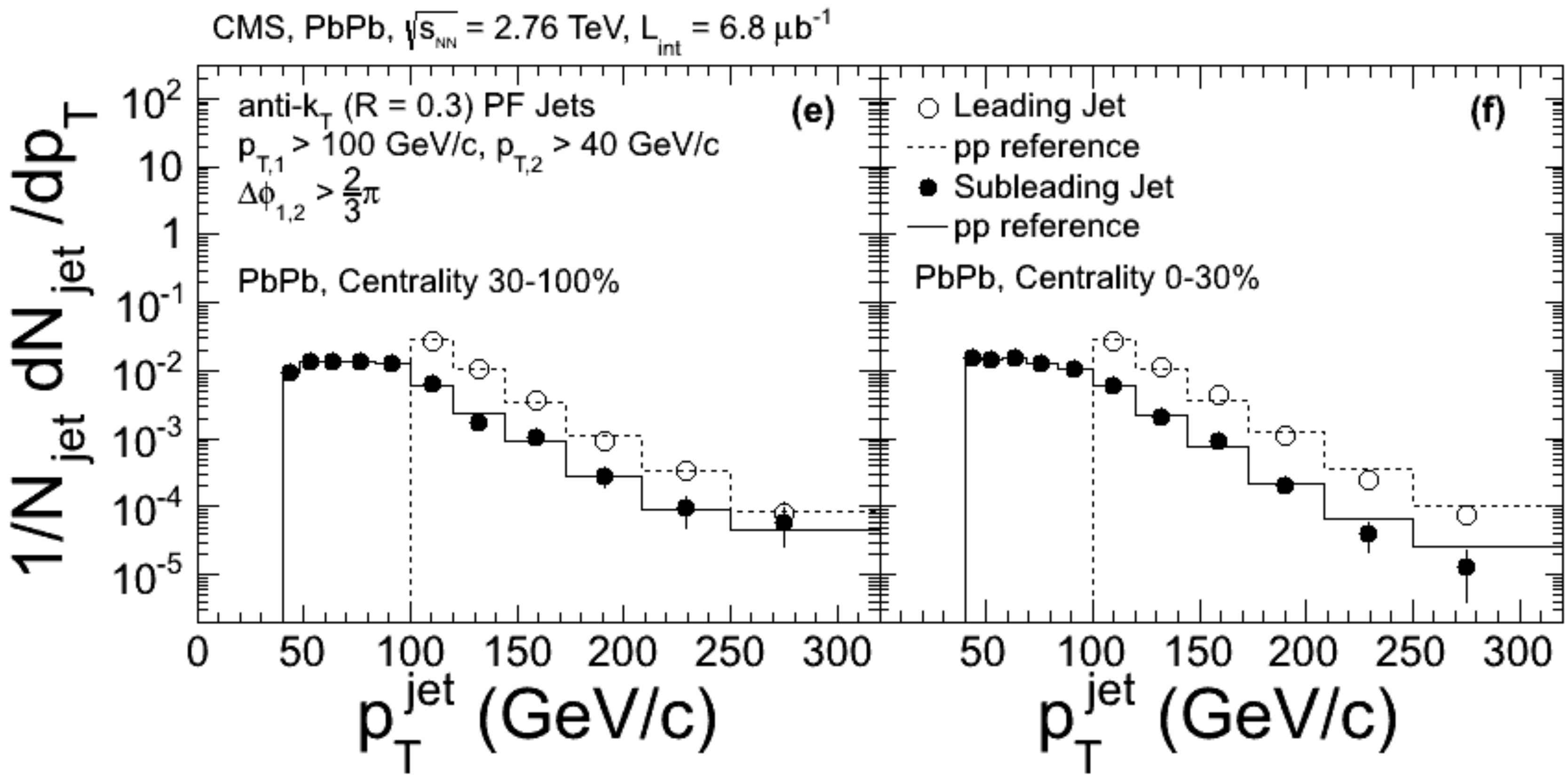
A_J in p_T bins



Dijets in PbPb are more imbalanced than Pythia at all bins of leading jet p_T

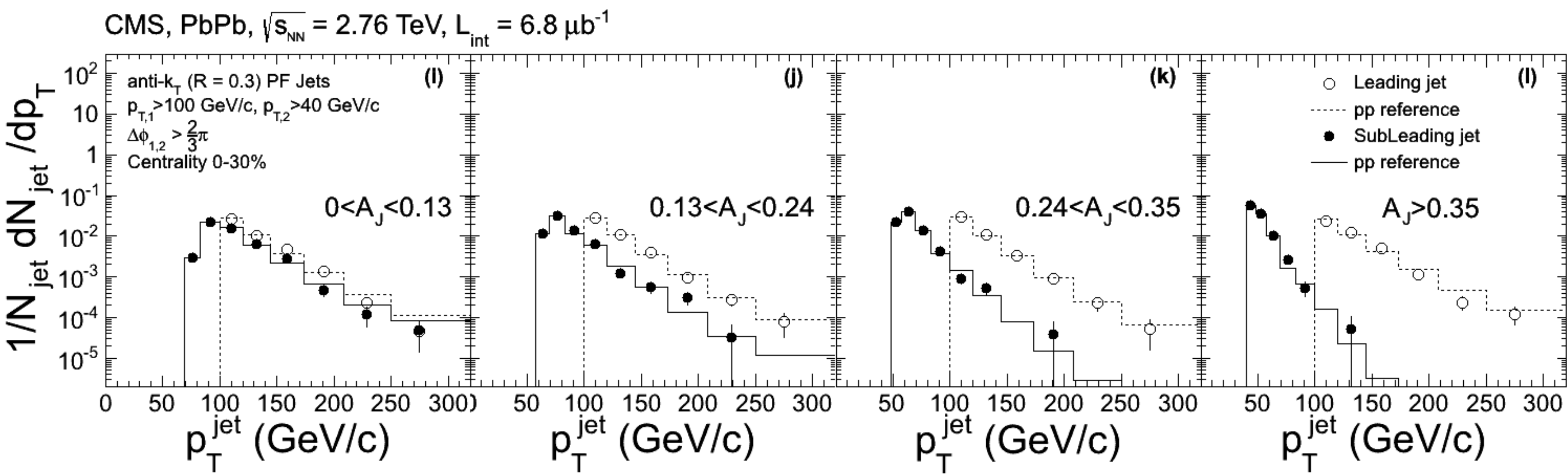
Phys. Lett. **B712** (2012) 176

Jet p_T vs pp-based reference



arXiv:1205.5872

Jet p_T vs pp-based reference



arXiv:1205.5872

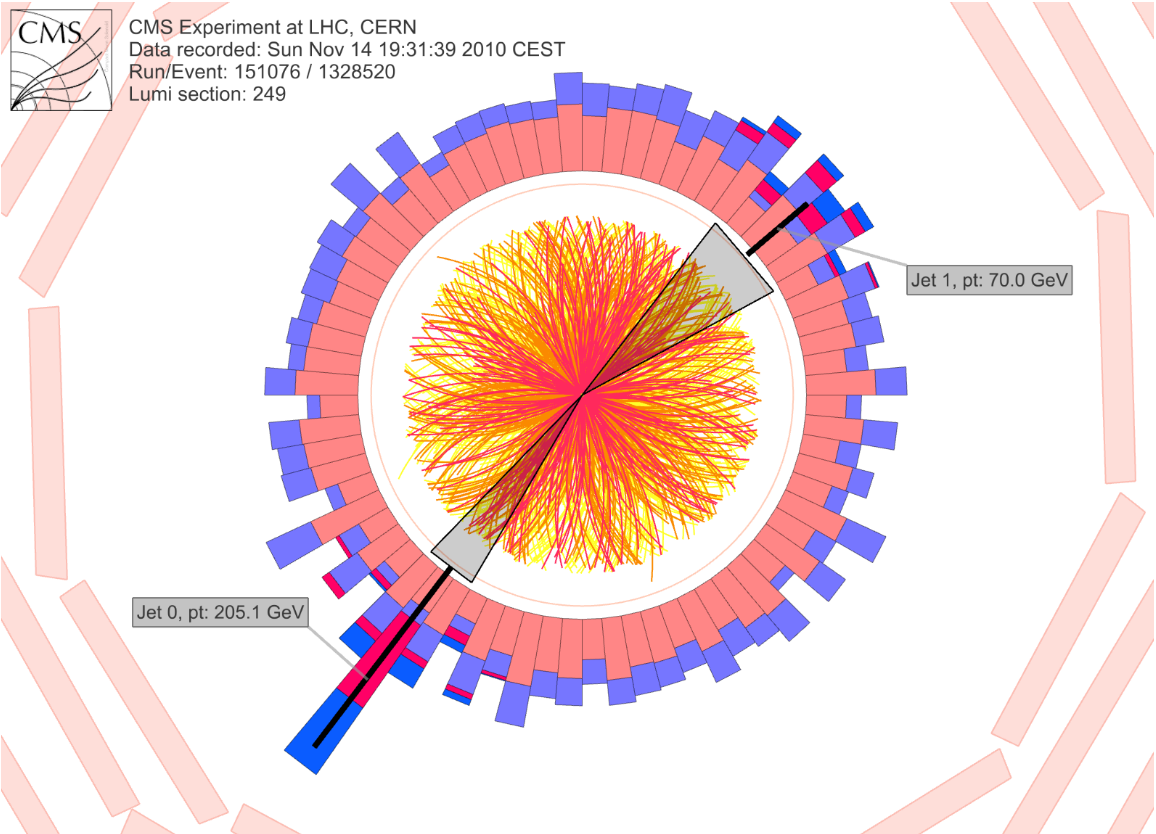
Jet reconstruction

Lots of underlying event activity:

dN/dη(η=0) ~ 2000

Local fluctuations from semi-hard interactions

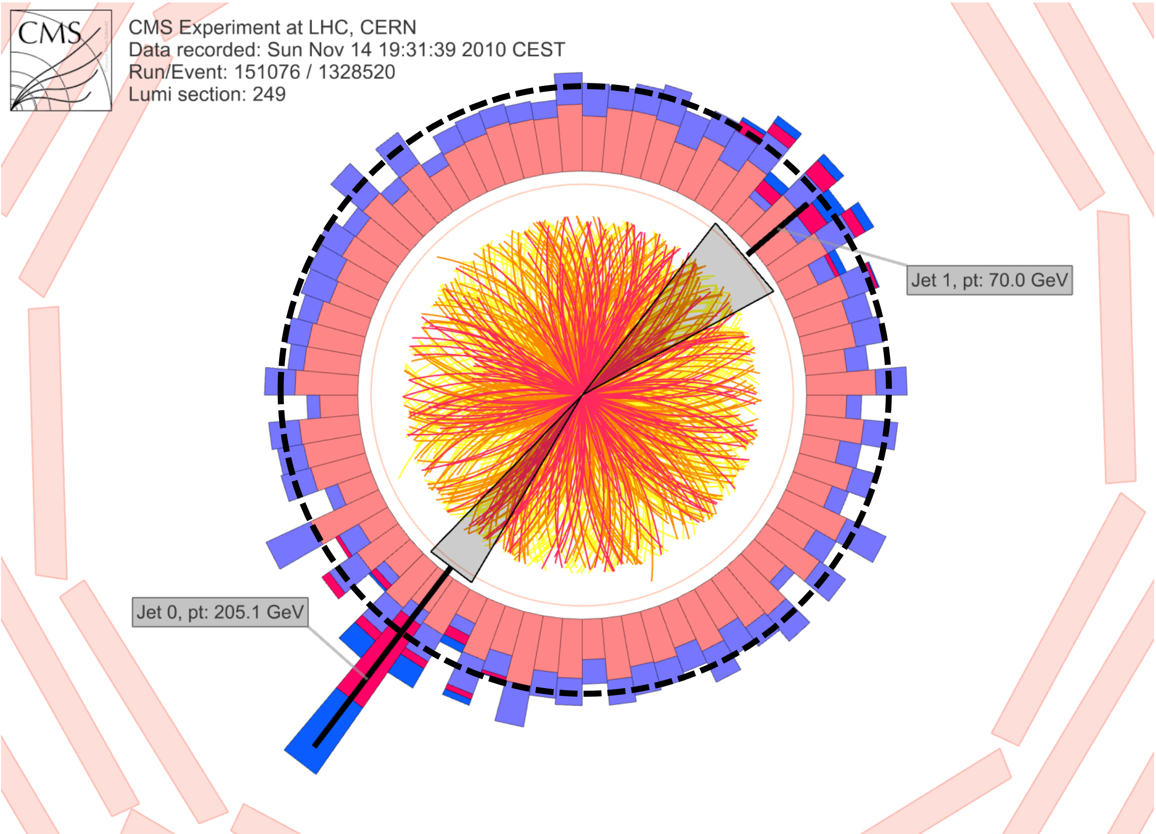
Depends on collision centrality



Jet reconstruction

Background estimated for each calorimeter ring of constant η

The background estimation is re-iterated after excluding the jets found in the first iteration

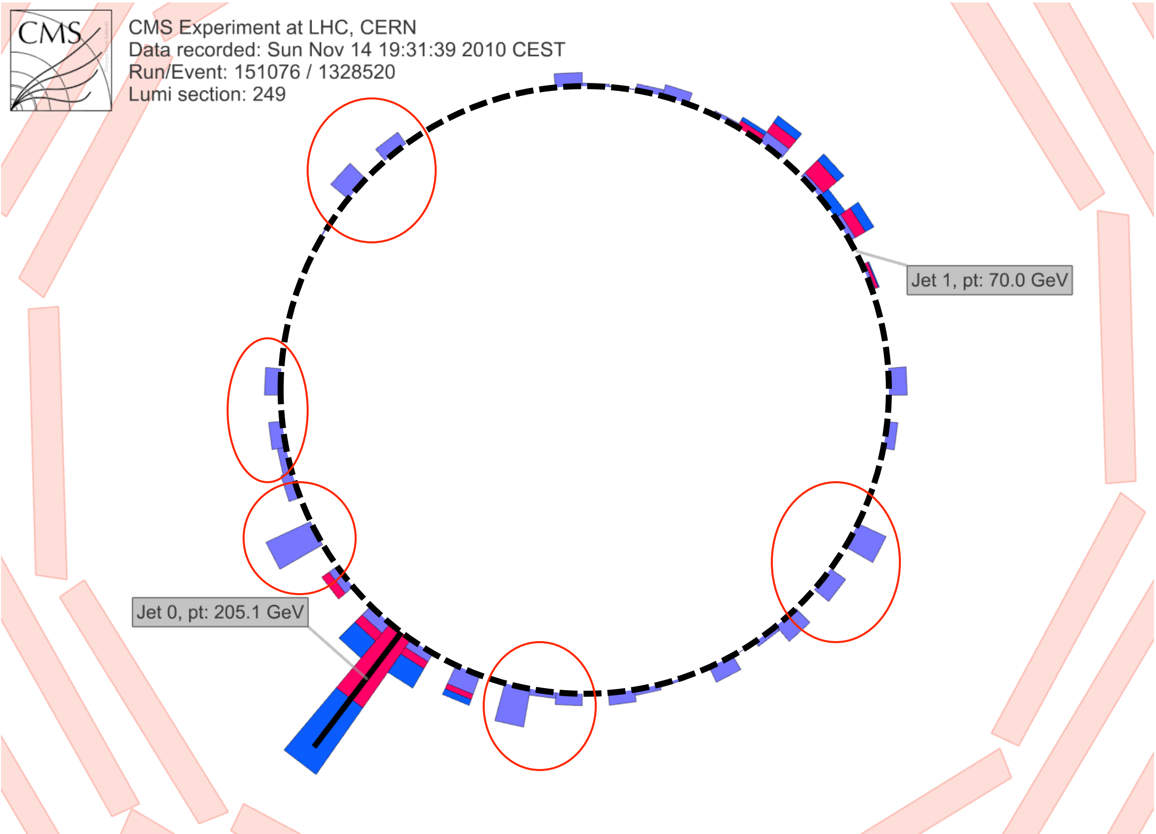


Jet reconstruction

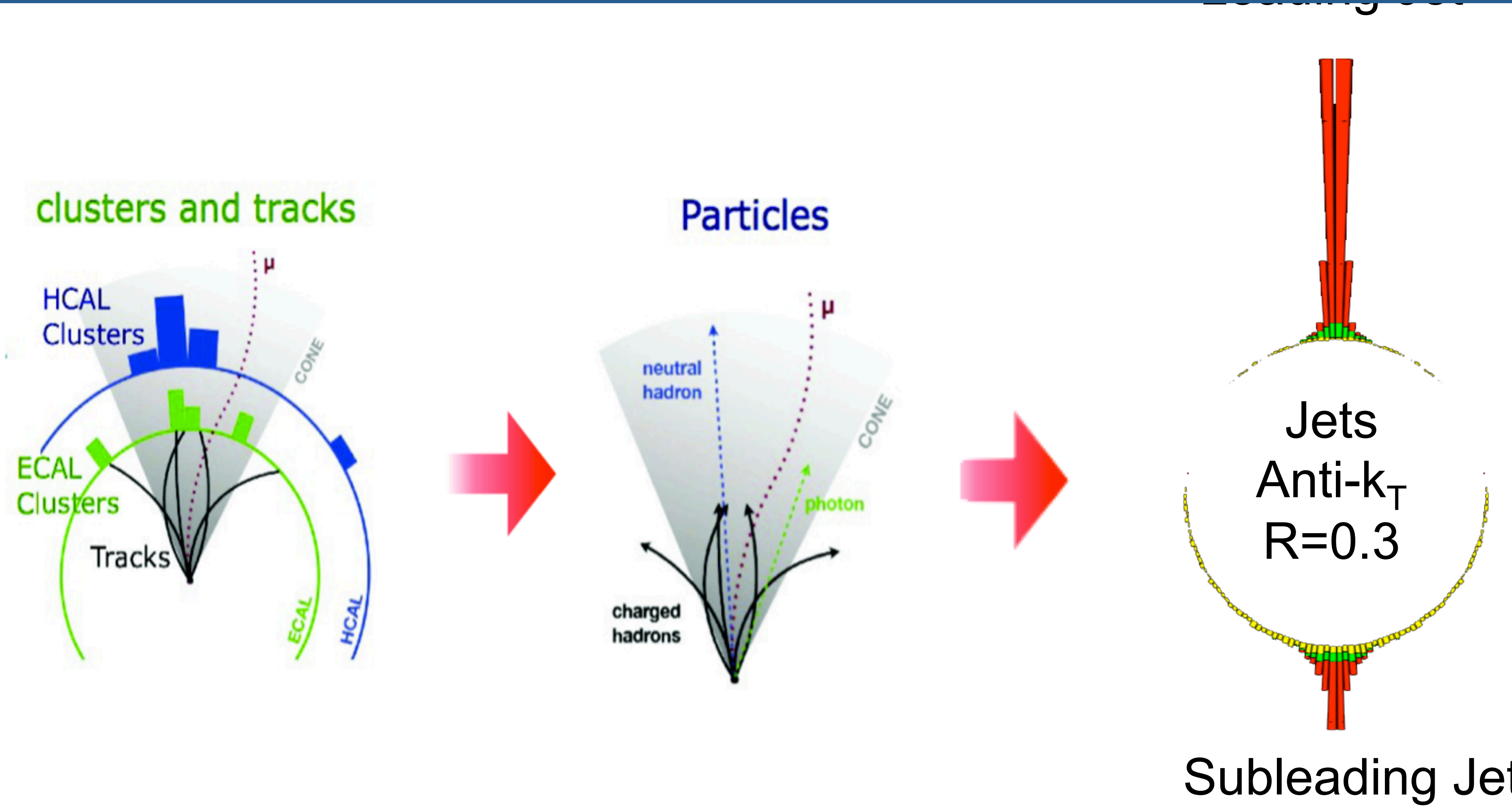
After the background subtraction, some higher local fluctuations remain (fake jets)

The fluctuations also deteriorate the jet resolution in central events

→ Important to represent these fluctuations well in simulated reference

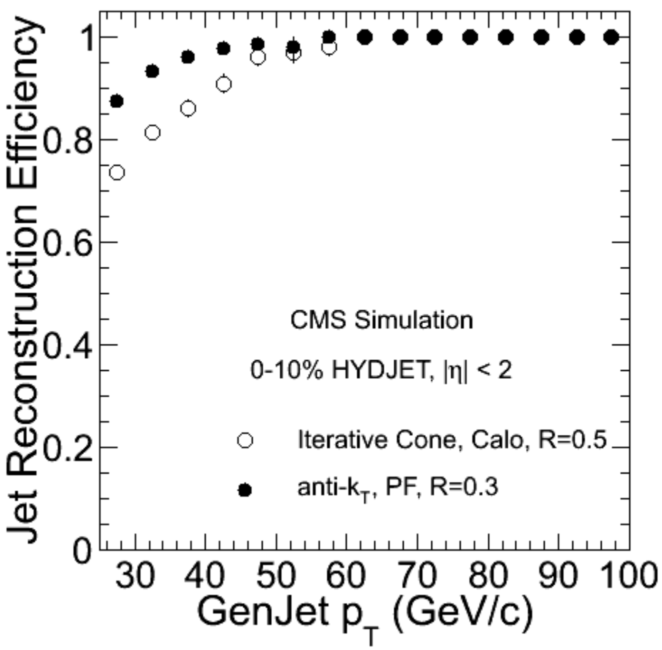


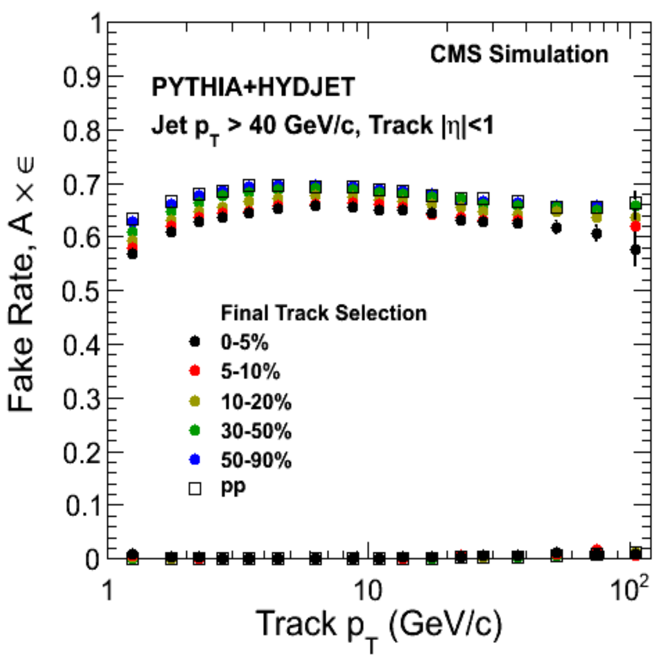
Improved jet reconstruction

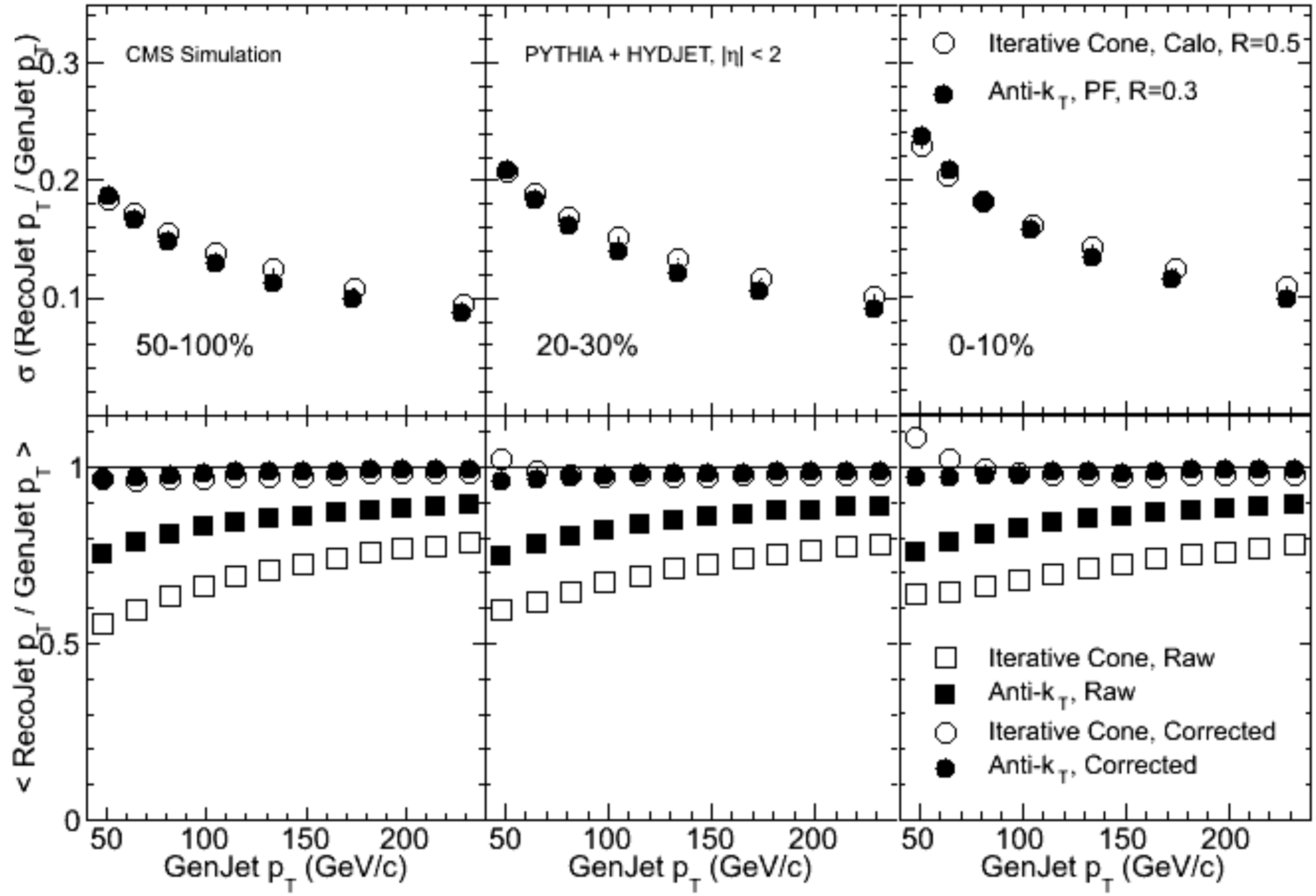


Calorimeter clusters and tracks are matched and combined to obtain most detailed information of particles in the event
(Details: CMS-PAS-HIN-11-004)

Jet reconstruction performance





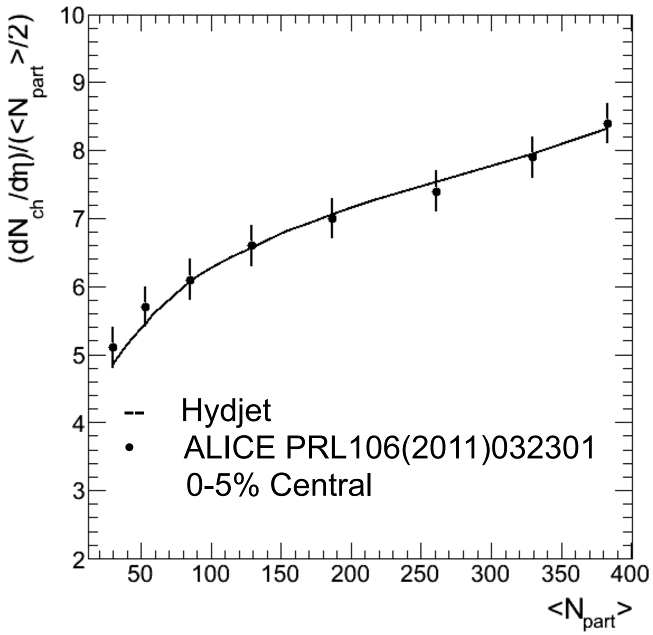


Combining various subdetectors provides strong tools for analysis of jets

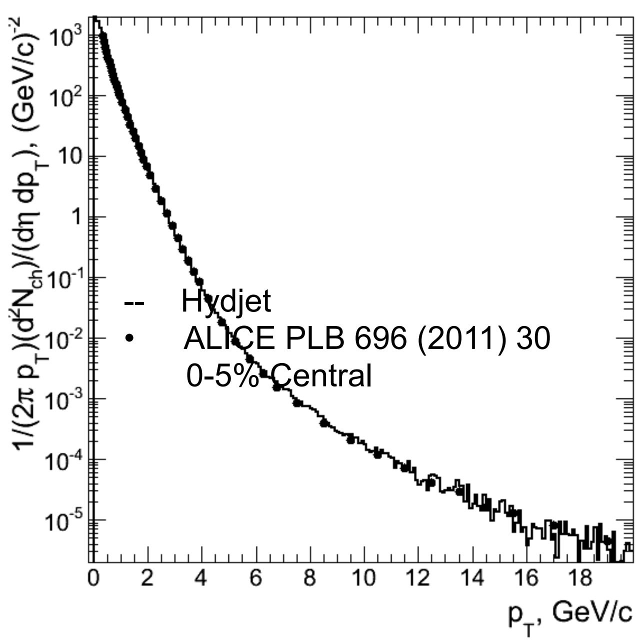
Low p_T efficiency is important for unbiased measurement

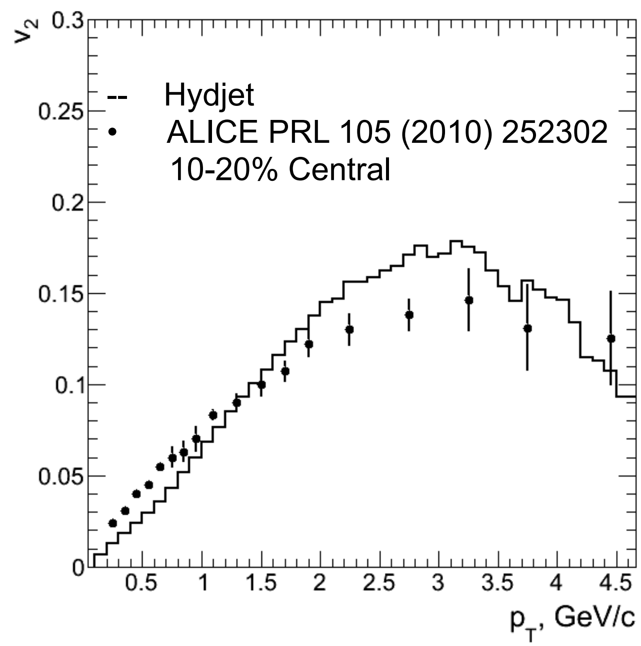
CMS-PAS-HIN-11-004

PbPb event simulations with Hydjet 1.8



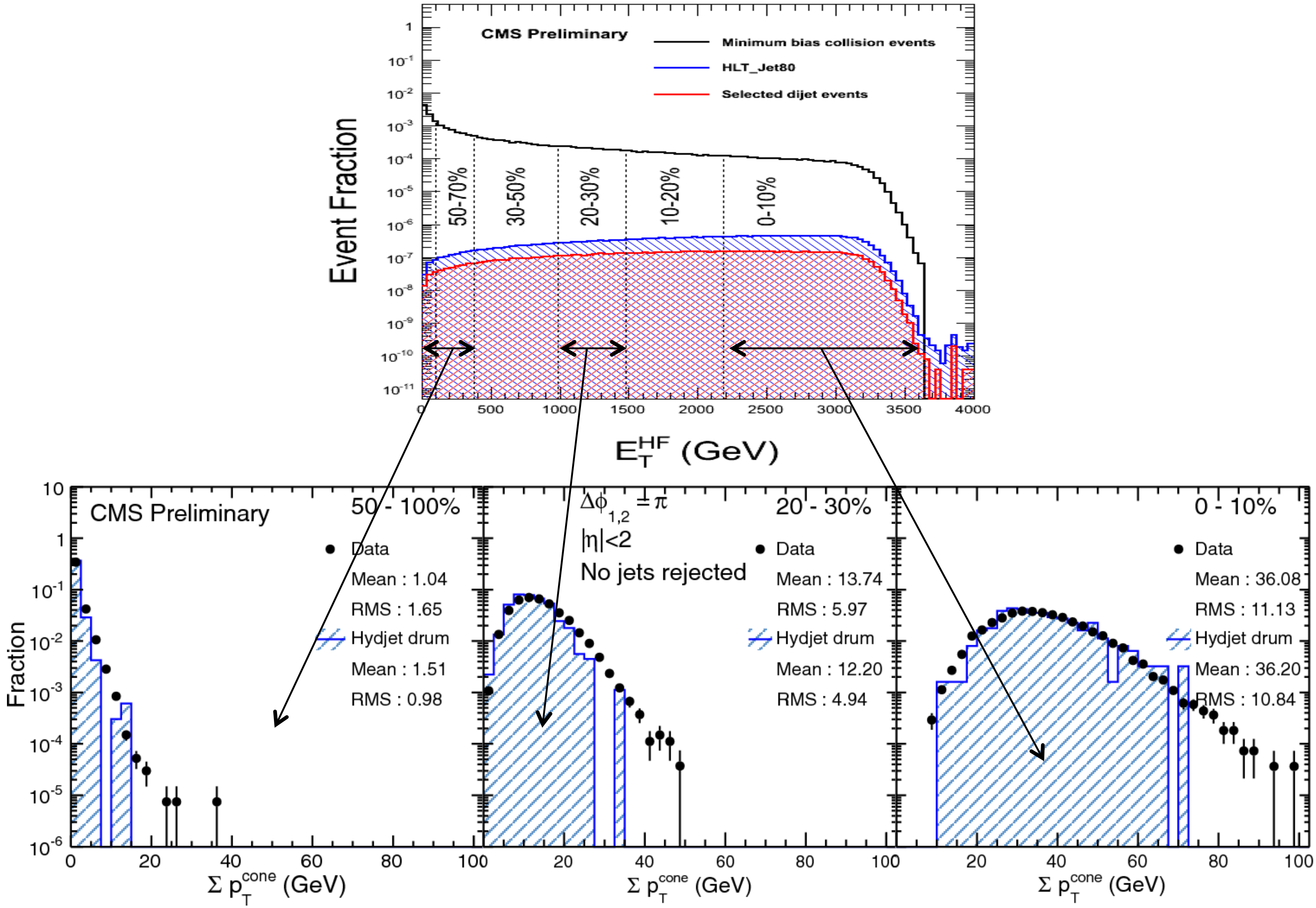
- Hydjet 1.8 default tune successfully reproduces:
  - Charged hadron multiplicity
  - Charged hadron p_T spectrum
  - Azimuthal asymmetry of low-p_T particles (Elliptic Flow)
- Pythia dijet events are mixed with the Hydjet sample at the same vertex



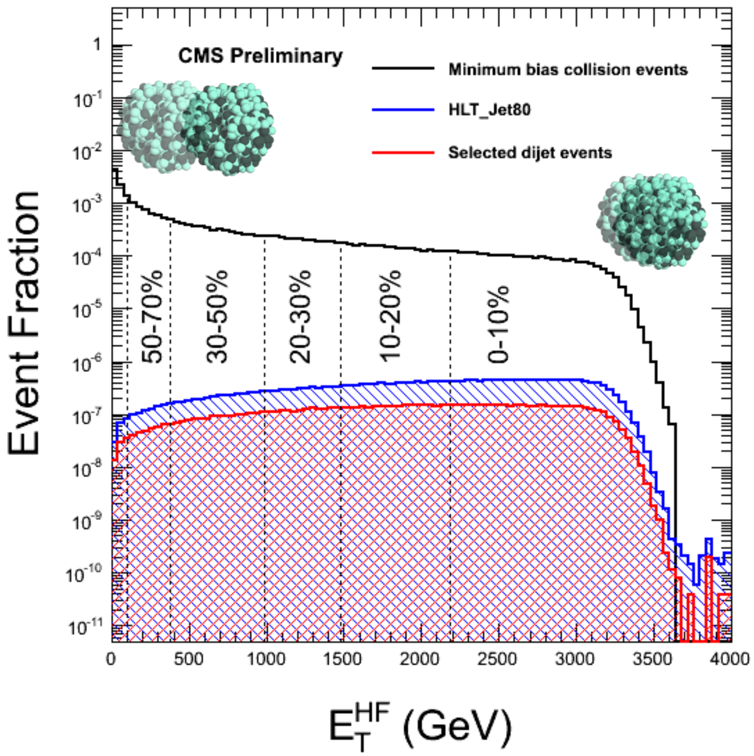


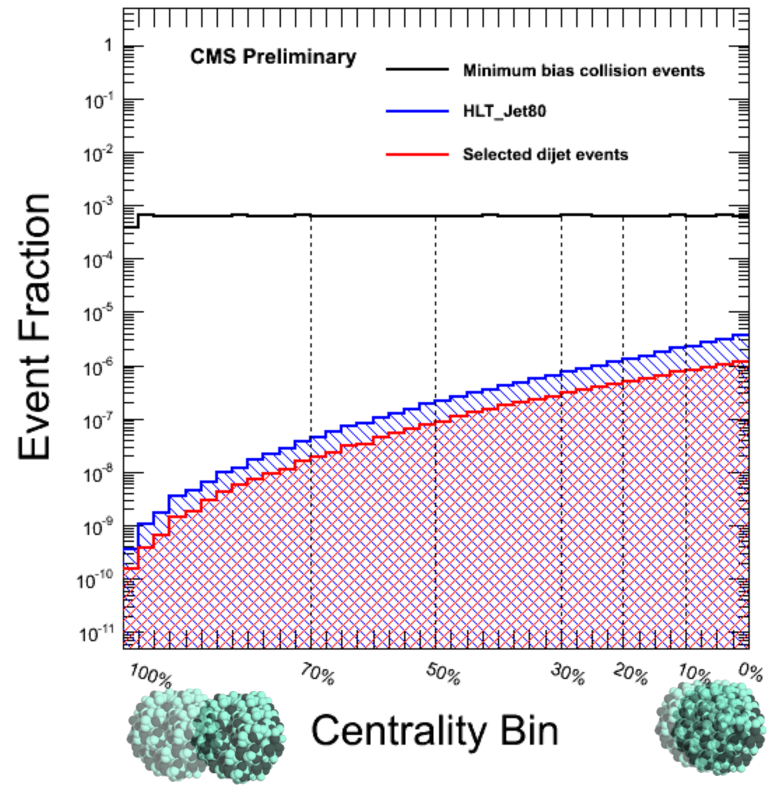
http://lokhtin.web.cern.ch/lokhtin/hydro/plots

Background fluctuations in Hydjet 1.8



Centrality determination in CMS

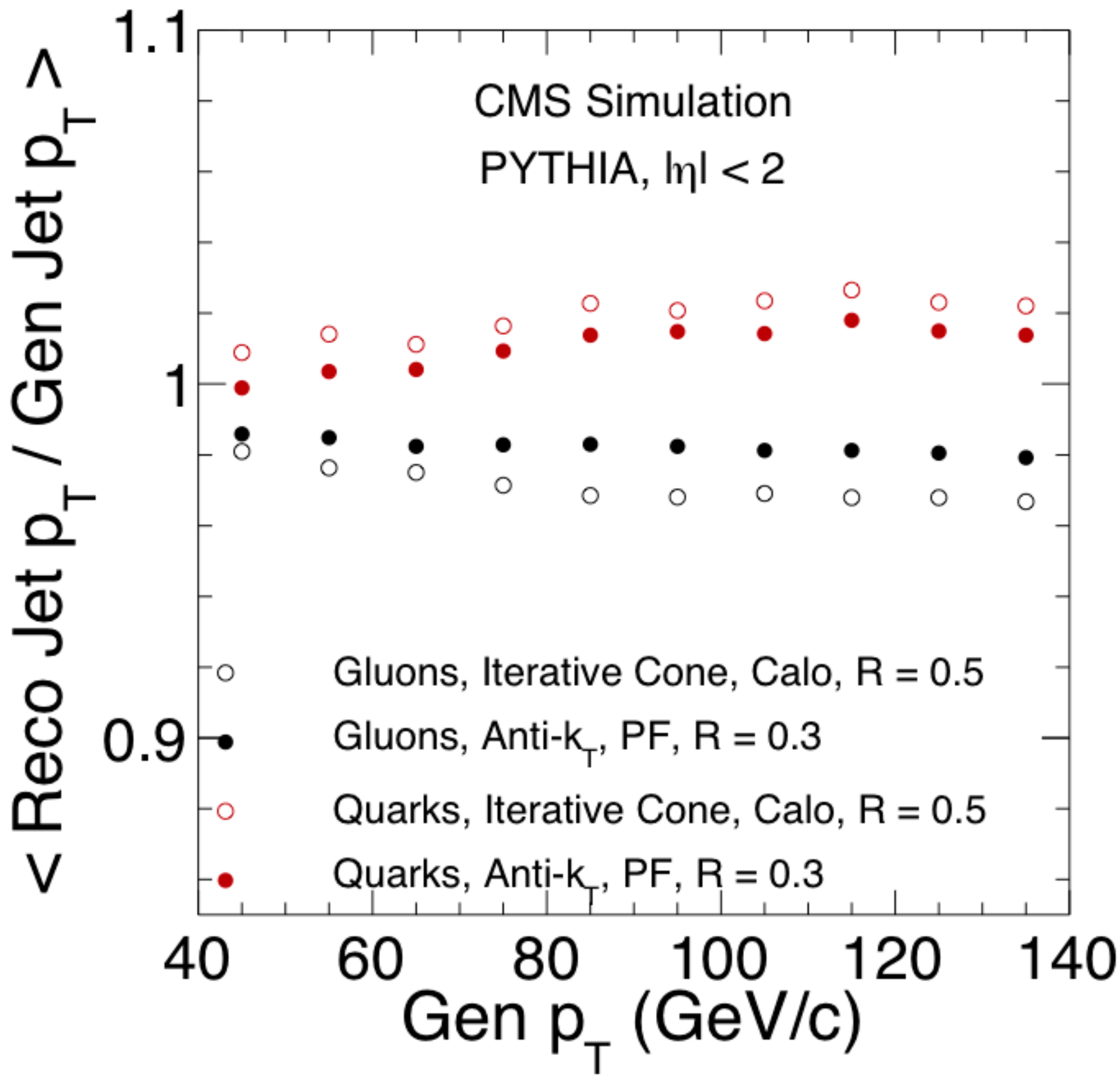




More peripheral ← 70-100%, 50-70%, 30-50%, 20-30%, 10-20%, 0-10% → More central

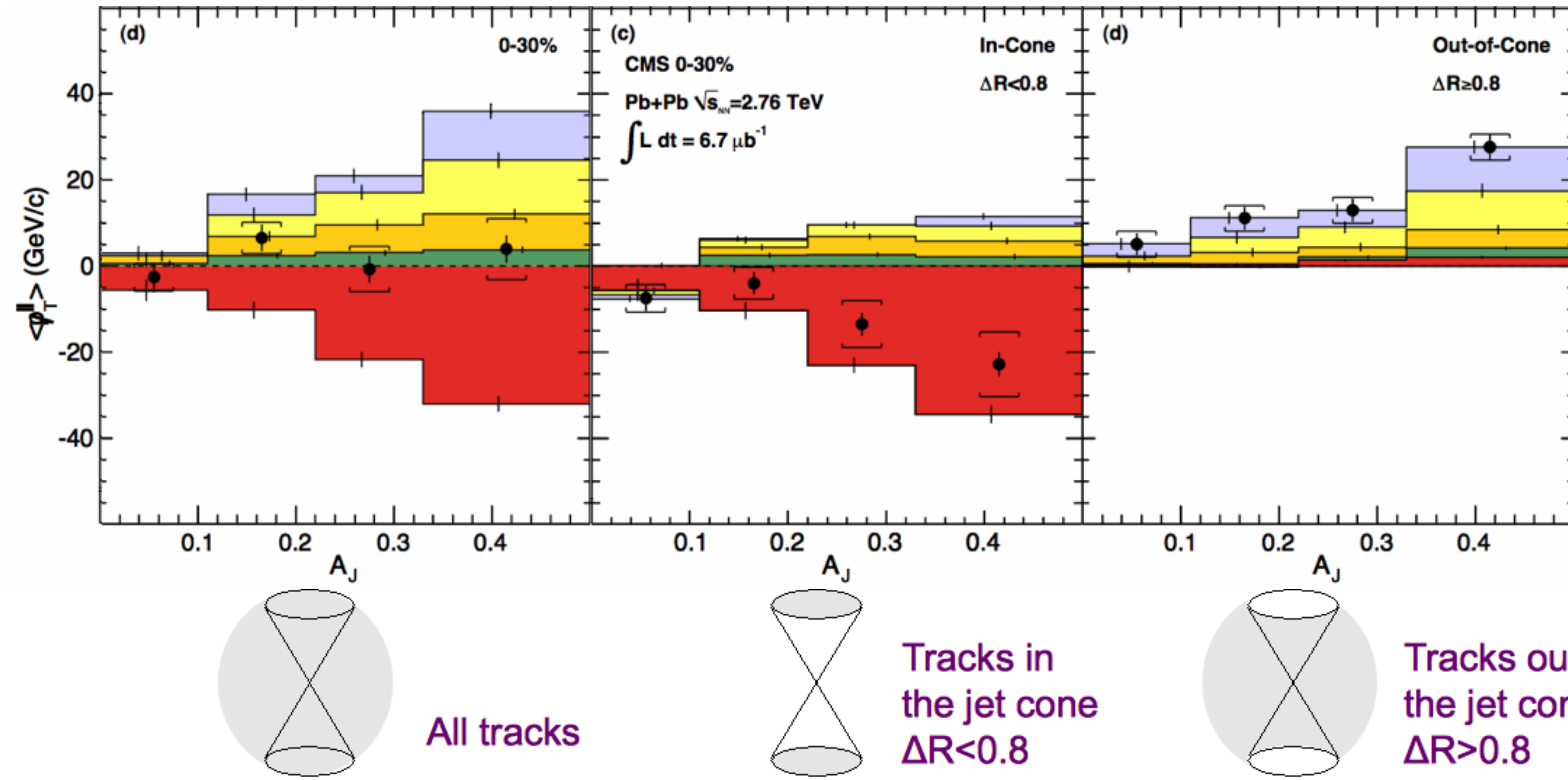
N_{part} : Number of participating (overlapping) nucleons in event
N_{coll} : Number of binary interactions in event
Transverse energy in the forward calorimeter is correlated to N_{part}
Rare probes exhibit a bias towards central events (N_{coll} scaling)

Jet response to parton types



CMS-PAS-HIN-11-004

Missing $p_T^{\parallel}$: $$\not{p}_T^{\parallel} = \sum_{\text{Tracks}} -p_T^{\text{Track}} \cos\left(\phi_{\text{Track}} - \phi_{\text{Leading Jet}}\right)$$



The global event properties are modified with the existence of quenching
The missing energy is found at large angles from the jet axis

Phys.Rev.C84:024906,2011