Update on Hard Probes with CMS

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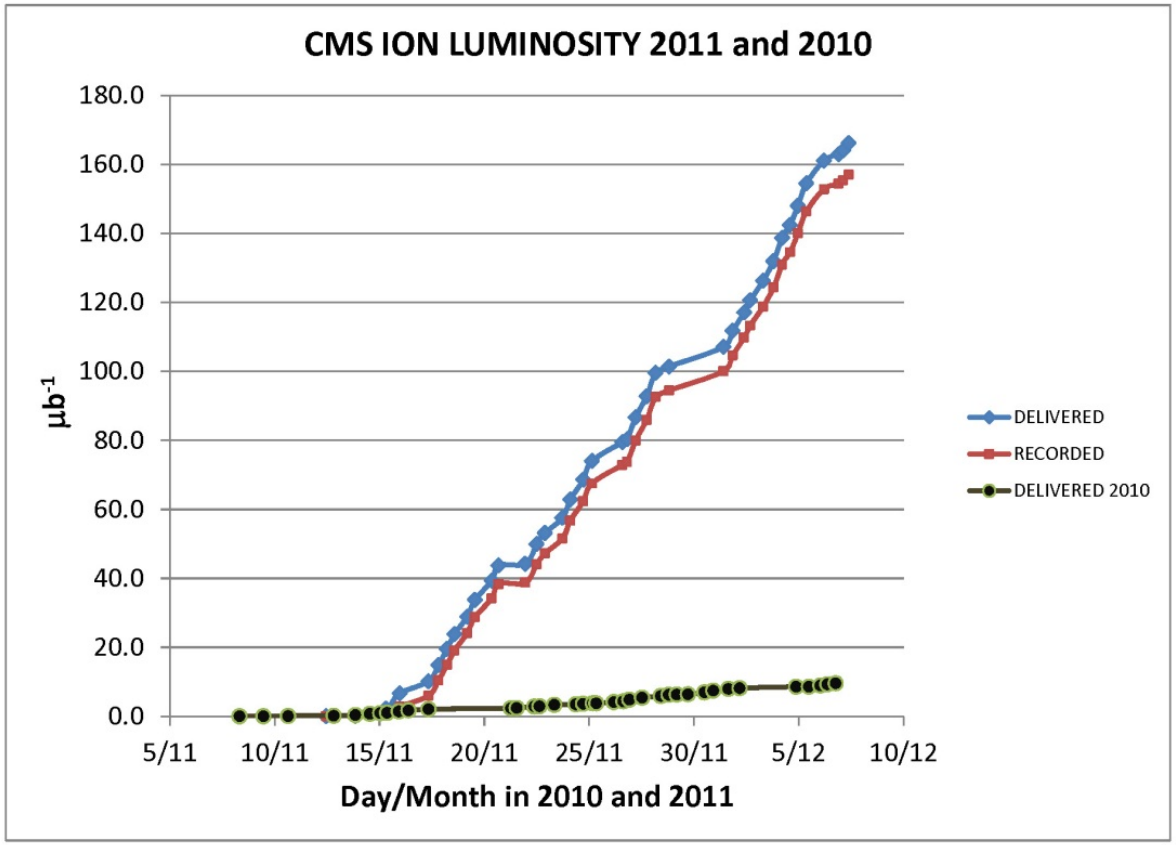
CMS Public Results: https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN11012

Since Last Time …

- Centrality dependence of dihadron correlations and azimuthal anisotropy harmonics in PbPb collisions arXiv:1201.3158v1
- Measurement of isolated photon production in pp and PbPb collisions arXiv:1201.3093v1
- Suppression of non-prompt J/ψ, prompt J/ψ, and Υ(1S) in PbPb collisions arXiv:1201.5069v1
- Study of high-p_T charged particle suppression in PbPb compared to pp collisions arXiv:1202.2554v1
- Jet momentum dependence of jet quenching in PbPb collisions arXiv:1202.5022v1
- Azimuthal anisotropy of charged particles at high p_T in PbPb collisions (In preparation)

2011 Data!

Performance in 2011

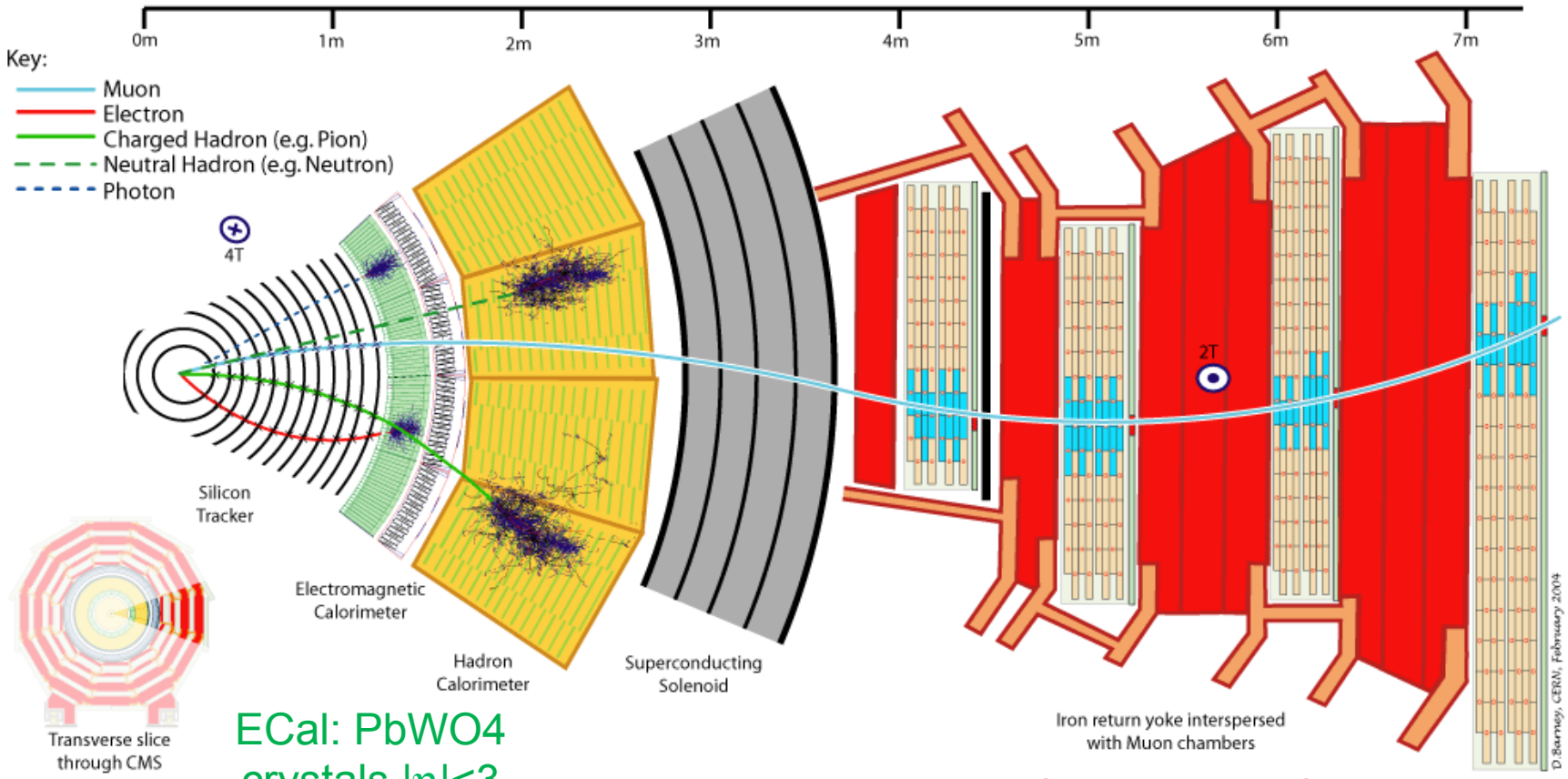


- 150 μb^{-1}
  → 20x 2010 data
- O(10^5) jets,
  p_T > 100 GeV/c

- Data rate and volume pushed CMS nearly to current limits
- Planning to upgrade develop triggers, firmware, etc. for future higher lumi.

The CMS Detector

Particle Identification in |η| < 2.4



ECal: PbWO4 crystals |η|<3

Muon: drift tubes + RPC |η| < 2.4

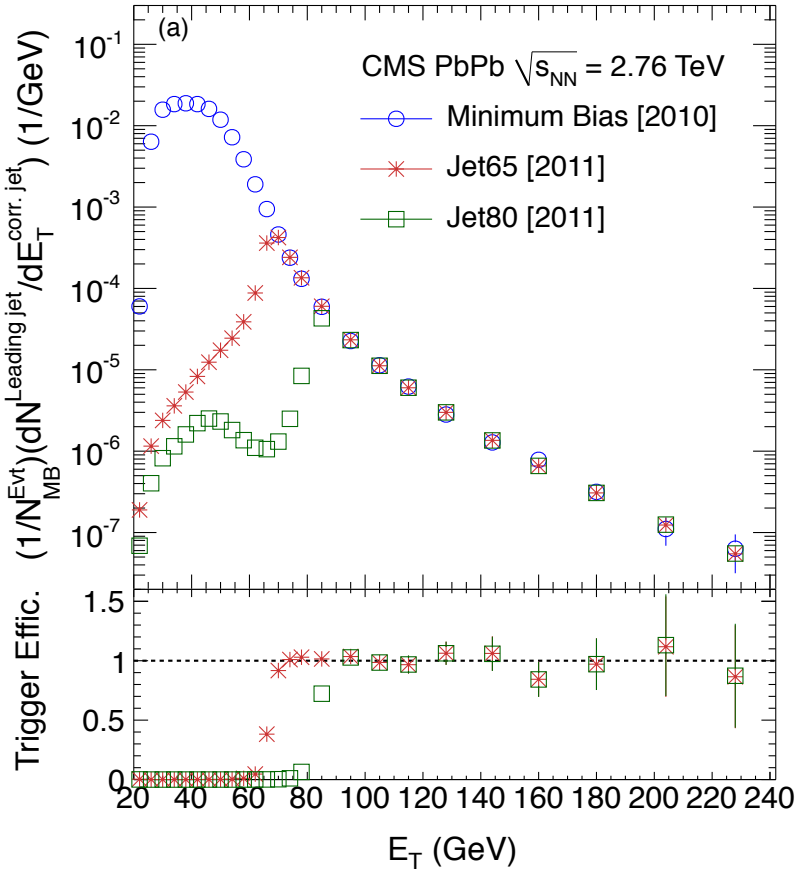
Silicon tracker: pixels (3) and strips (10) |η|<2.4

HCal: Brass-Scintillator |η|<5

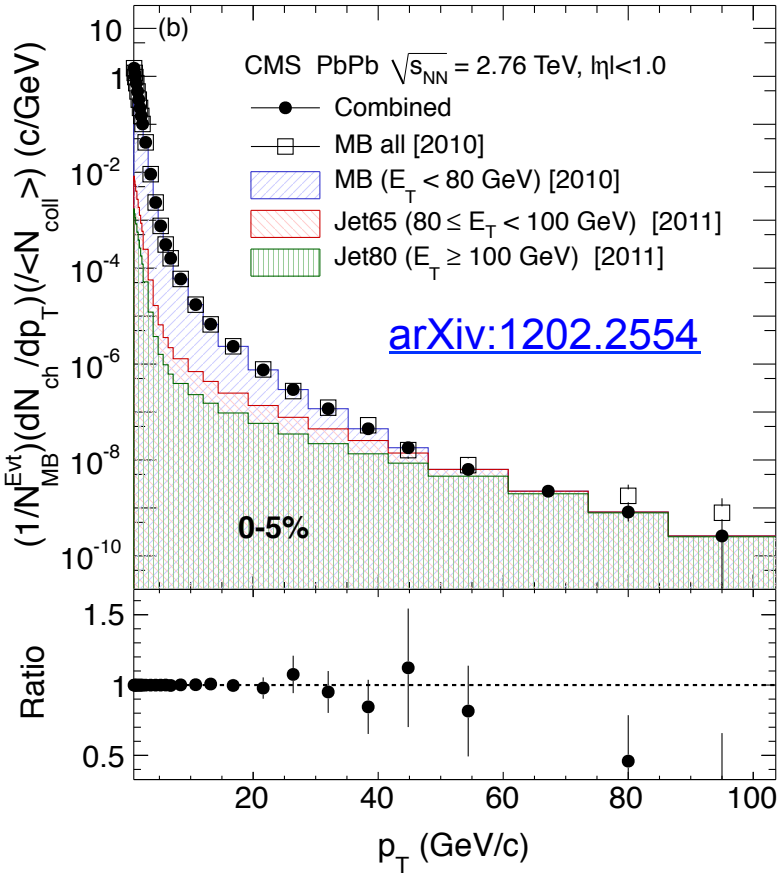
+ Forward calorimetry (HF) at 3 < |η| < 5

Jet-Triggered Spectra

Trigger turn on curves

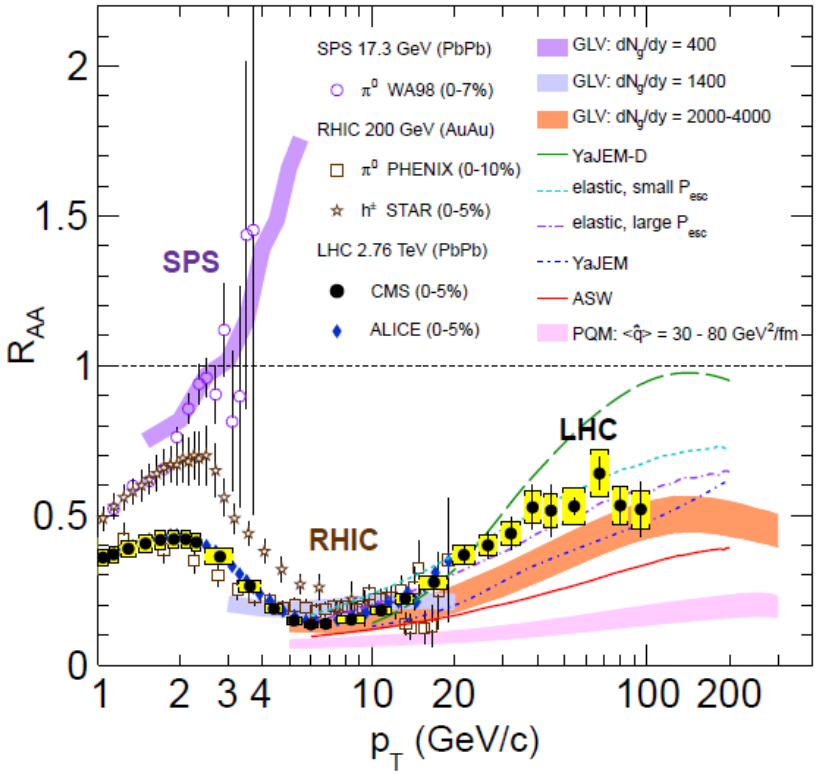


Trigger composition



Jet triggered data extend the p_T reach of charged hadrons

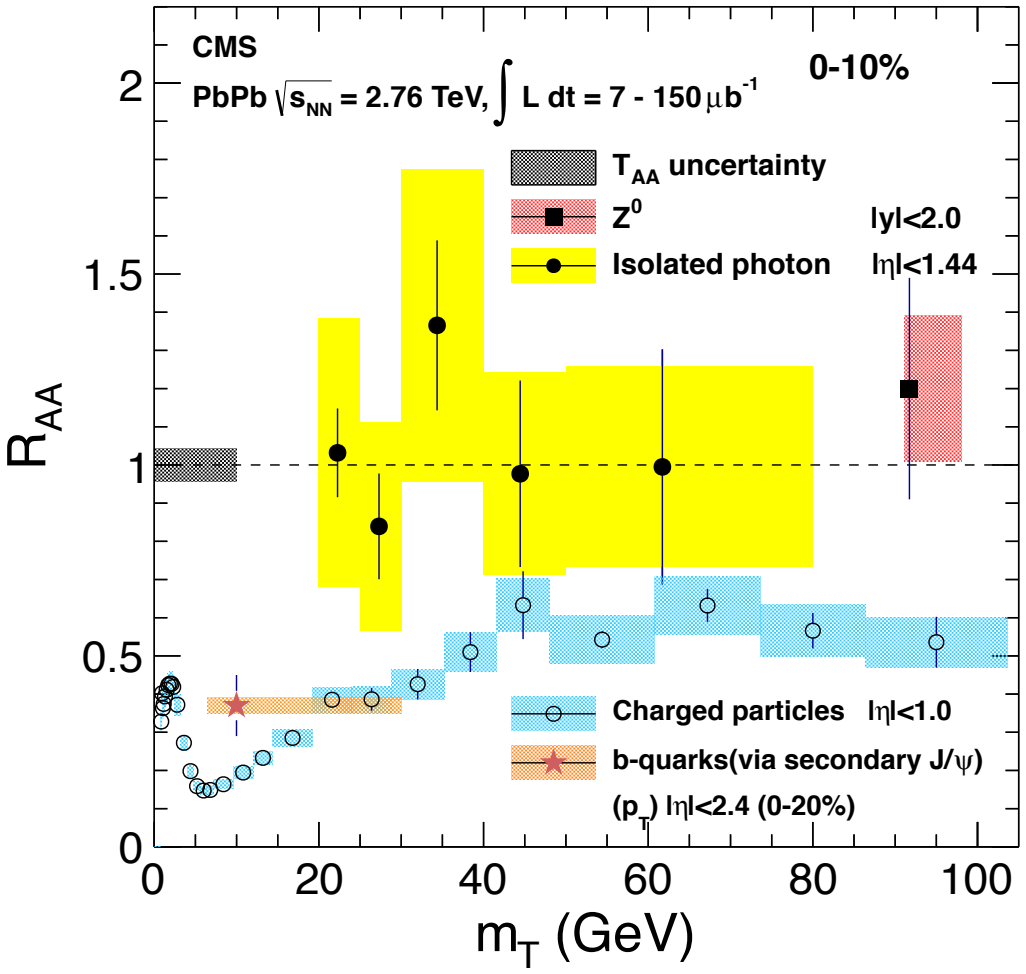
Charged Hadron R_{AA}



arXiv:1202.2554

- Improved statistical precision compared to results shown at Quark Matter 2011
- Now pp comparison data is the limitation

The Emerging CMS R_{AA} Picture



Jet Results From 2010 Data

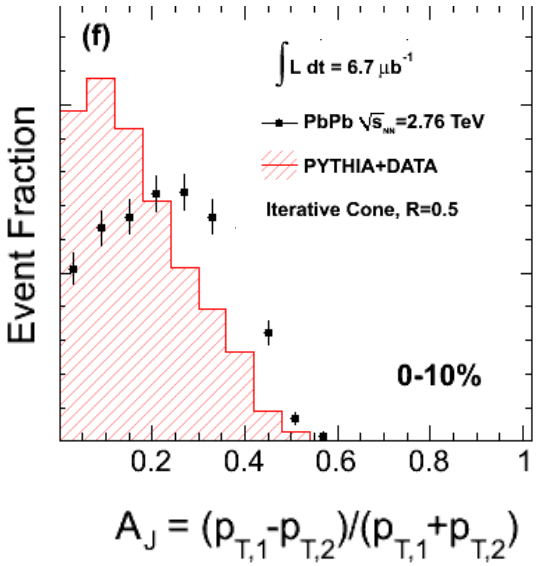
Observation of dijet asymmetry (1st shown by ATLAS)

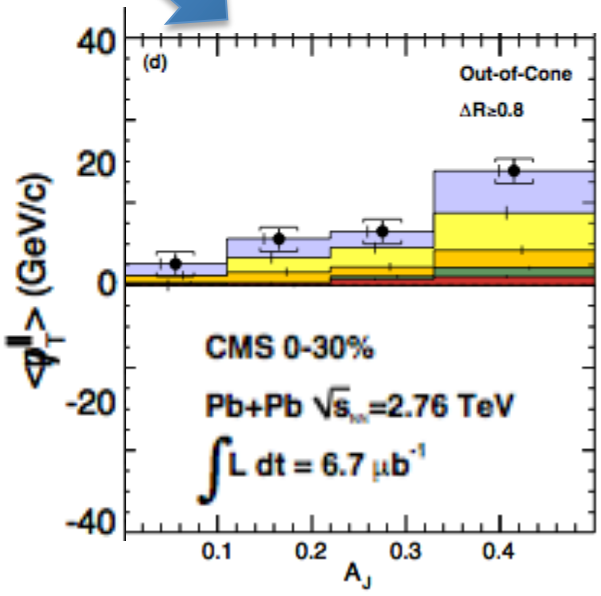
Phys Rev C 84, 024906 (2011)

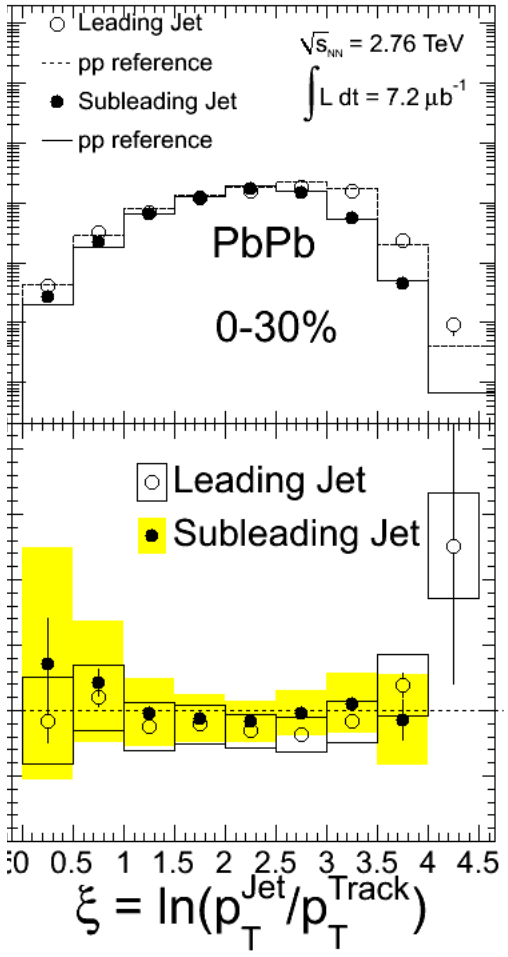
Following the fate of lost energy with jet-track corrections

Vacuum-like behavior of high p_T component of jet fragmentation function

CMS PAS HIN-11-004





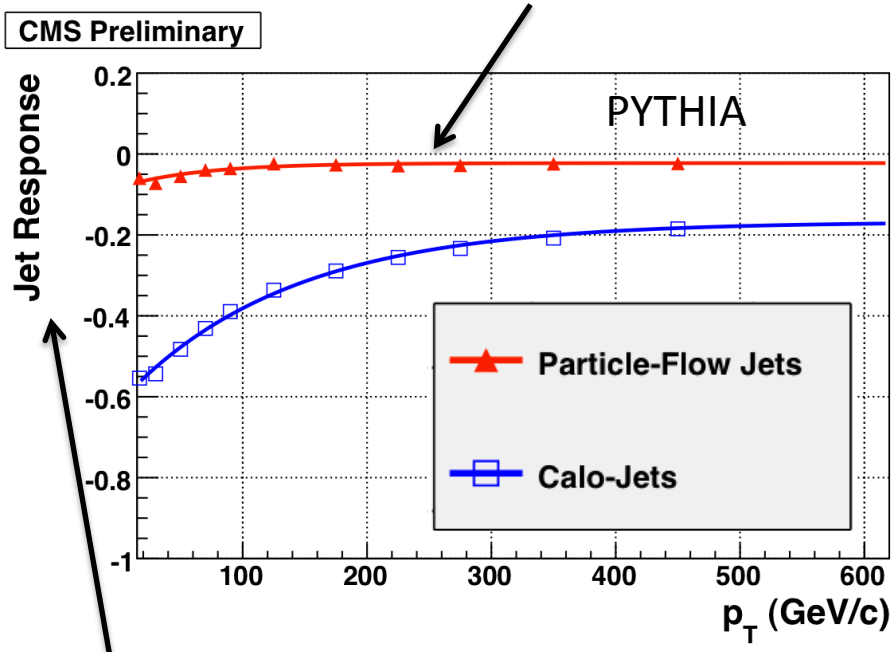


Jet Reconstruction in CMS

- CMS has excellent tracking, but a relatively poor resolution hadronic calorimeter (w.r.t. to ATLAS)
- Makes sense to try to combine tracking and calorimeter information (without double counting!)
- *Particle Flow* Algorithm combines information from all sub-detectors
- Jets are reconstructed from *particle candidates* rather than calorimeter towers

PF in pp [CMS-PAS-PFT-09-001]

PF reconstructs > 95% of the jet p_T (pp)



Mean of Gaussian fit to $\frac{Reco\ p_T - Gen\ p_T}{Gen\ p_T}$

Particle Flow in HI: M.N. for CMS [J.Phys.G38 (2011) 124151]

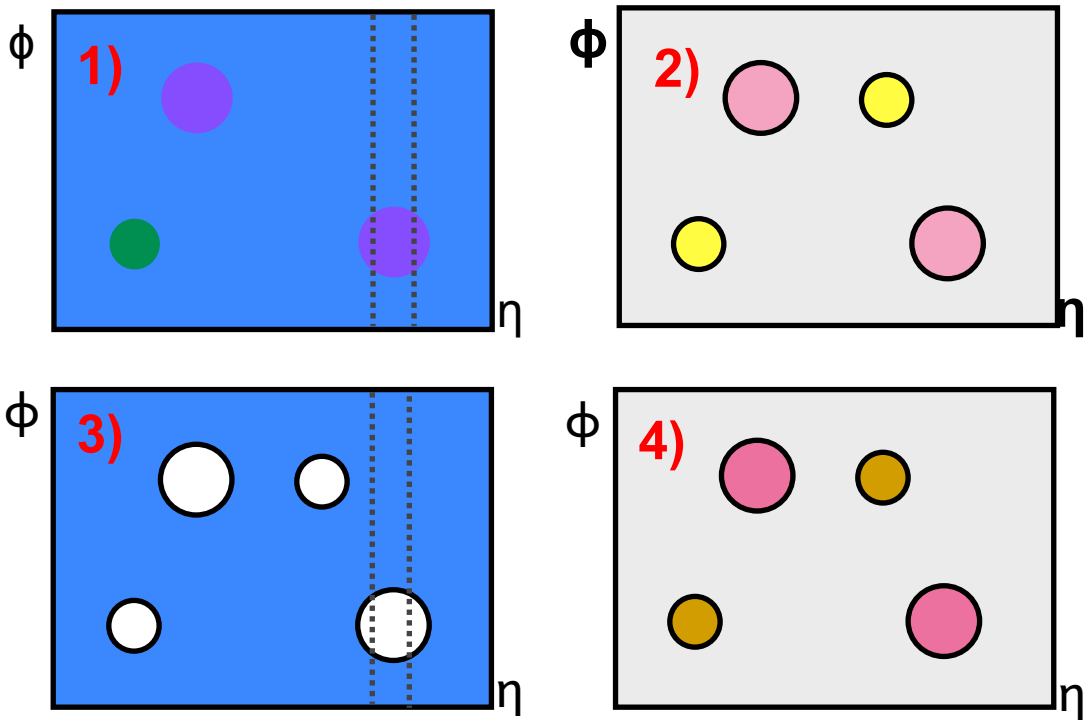
Underlying Event Subtraction

To estimate background E_T density PF candidates are clustered into "pseudo-towers" according to the granularity of the HCAL

O. Kodolova et al., EPJC 50 (2007) 117

Then apply same iterative subtraction as for calo jets:

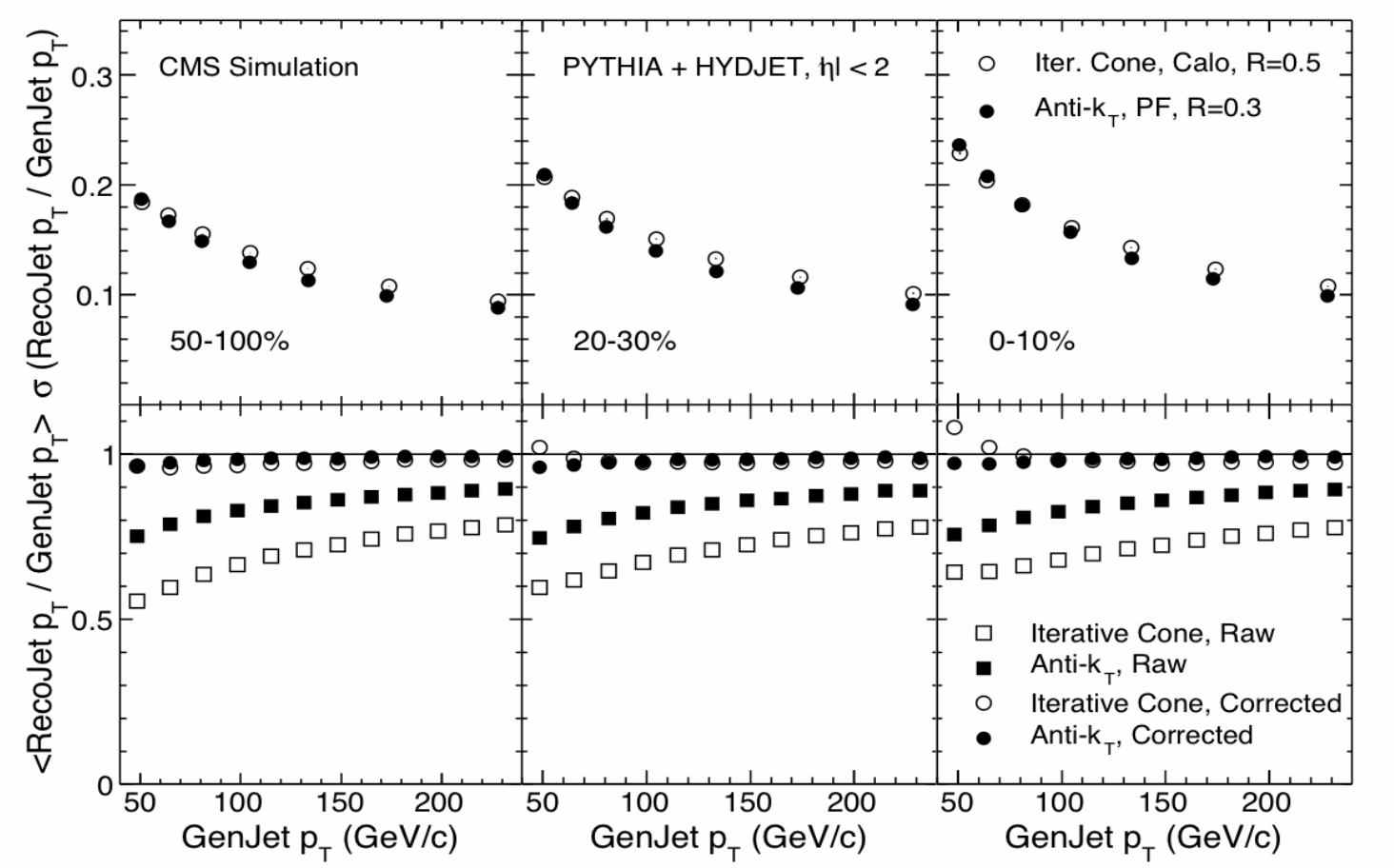
1. Subtract $\langle E_T \rangle + \sigma$ from each η strip
2. Run jet finder on towers with $E_T > 0$
3. Recalculate background excluding jets of $p_T > 15$ GeV/c and subtract it
4. Re-run jet finder on towers with $E_T > 0$



Background subtraction algorithm improves resolution at the cost removing some soft fragments from jet reconstruction

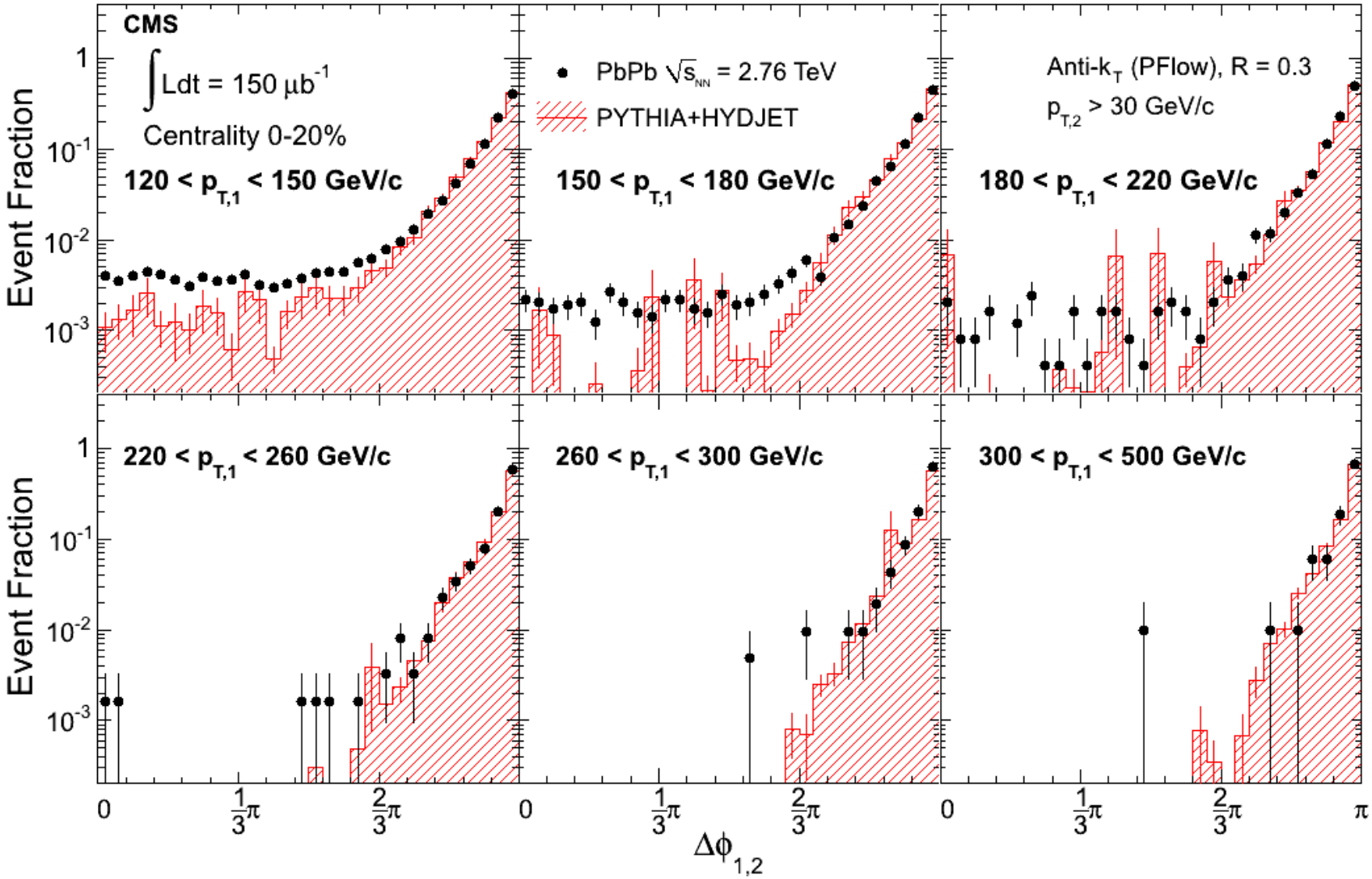
Jet Response and Resolution

Jet Energy Corrections are evaluated from PYTHIA



The corrected energy scale closes to unity validating subtraction procedure

Dijet Azimuthal Correlations



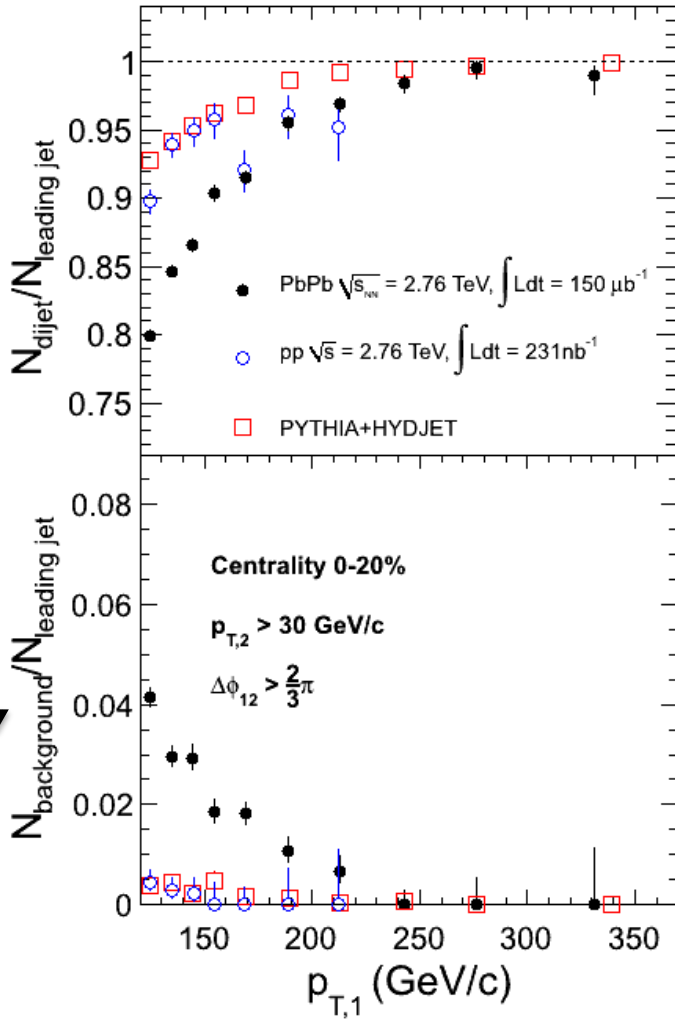
No azimuthal decorrelation out to the largest values of p_T

What Changes at High p_T?

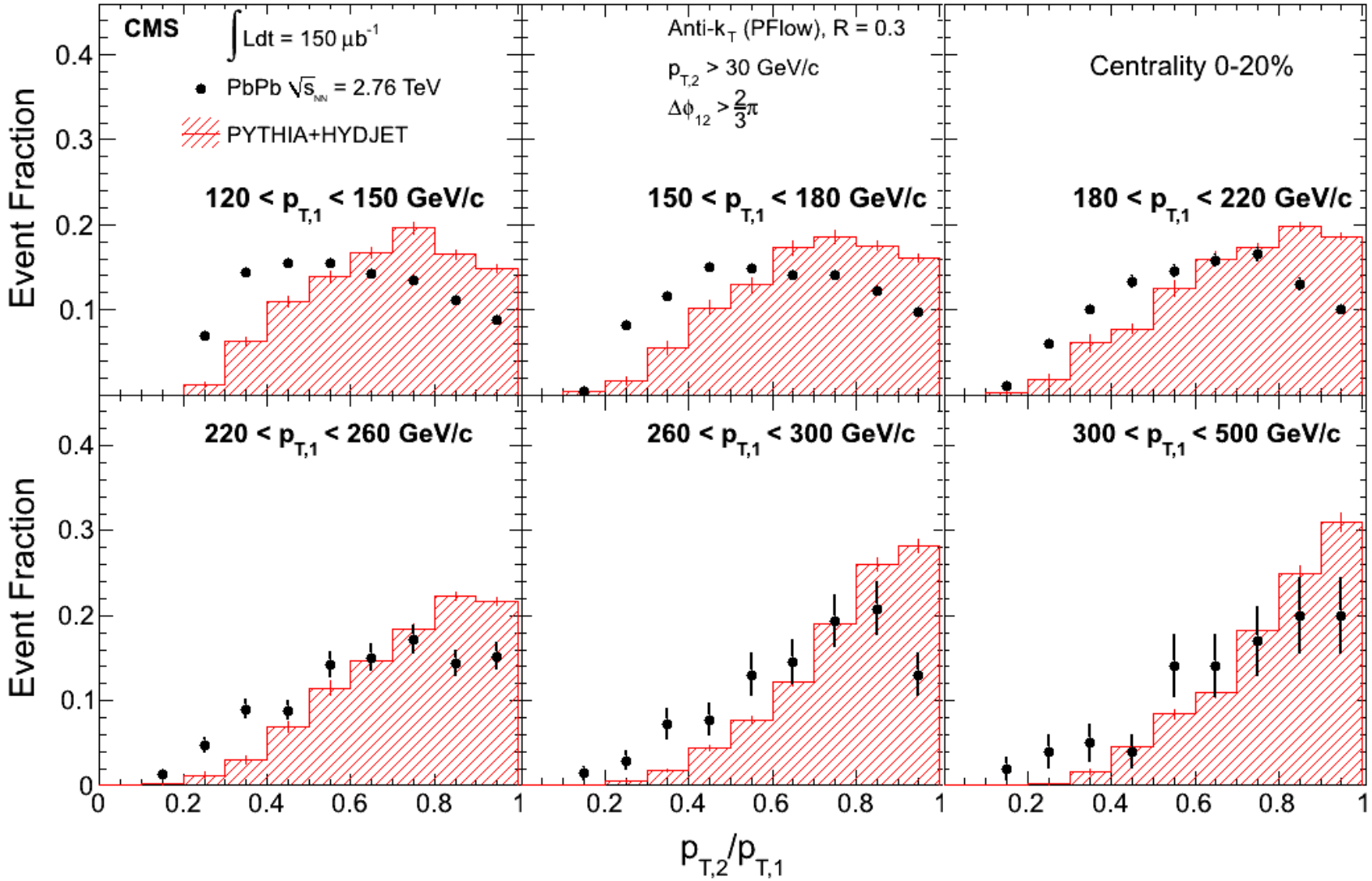
- We always find a sub-leading

- That sub-leading jet is always well correlated in $\Delta\phi$

  # of dijets with $\Delta\phi < \pi/3$ / total



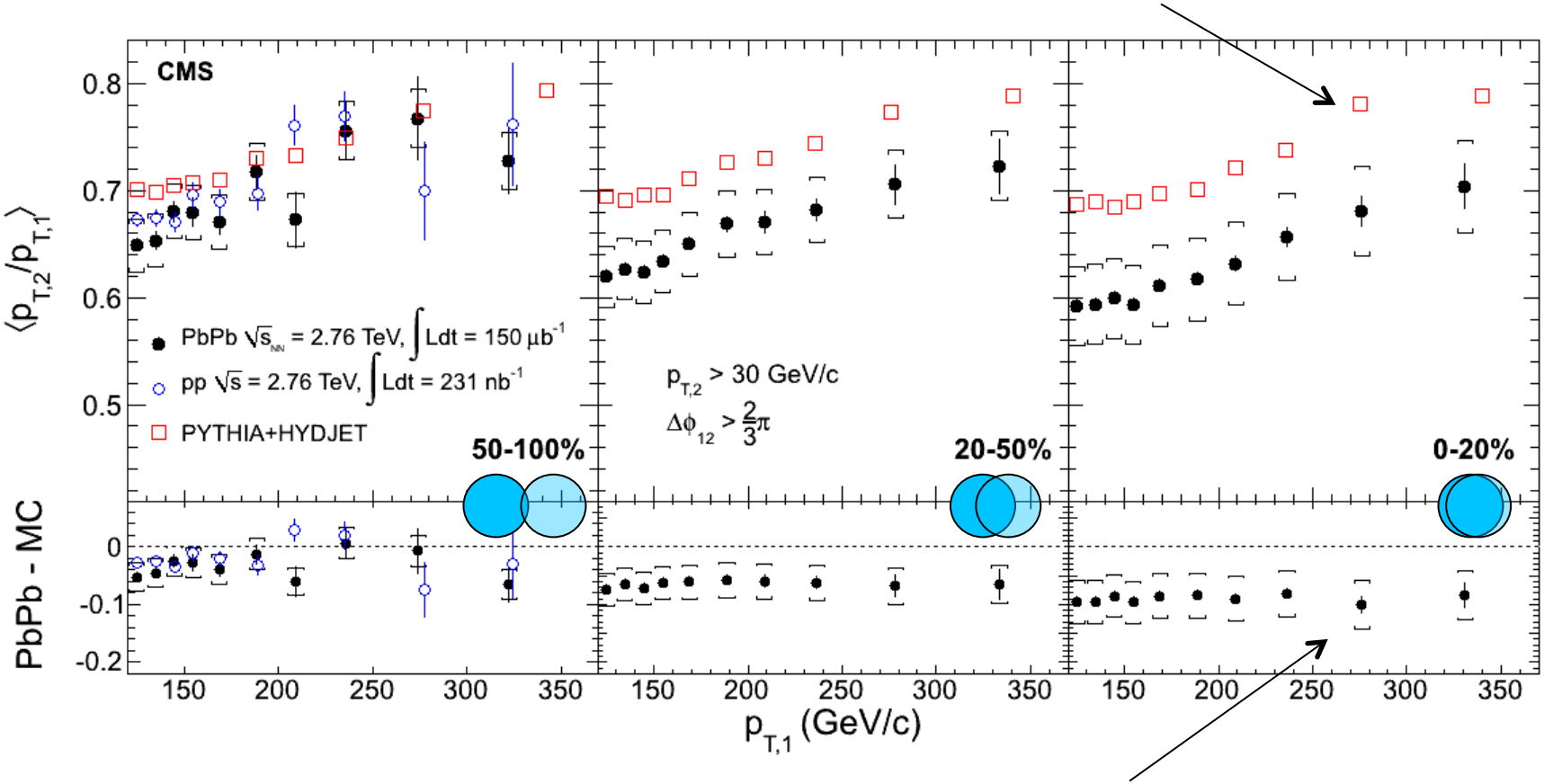
p_T Dependence of Dijet Balance



Anomalous asymmetry persists to largest values of p_T

p_T Dependence of Dijet Balance

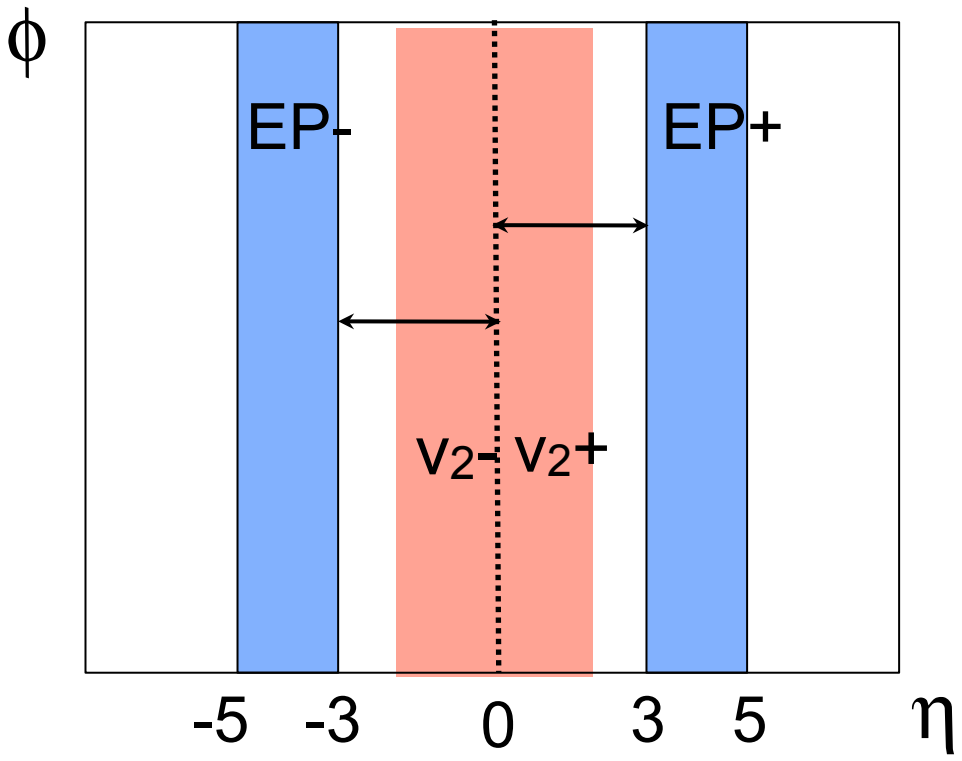
p_T balance increases with leading p_T with no quenching



No clear fractional E-loss dependence of leading jet p_T*

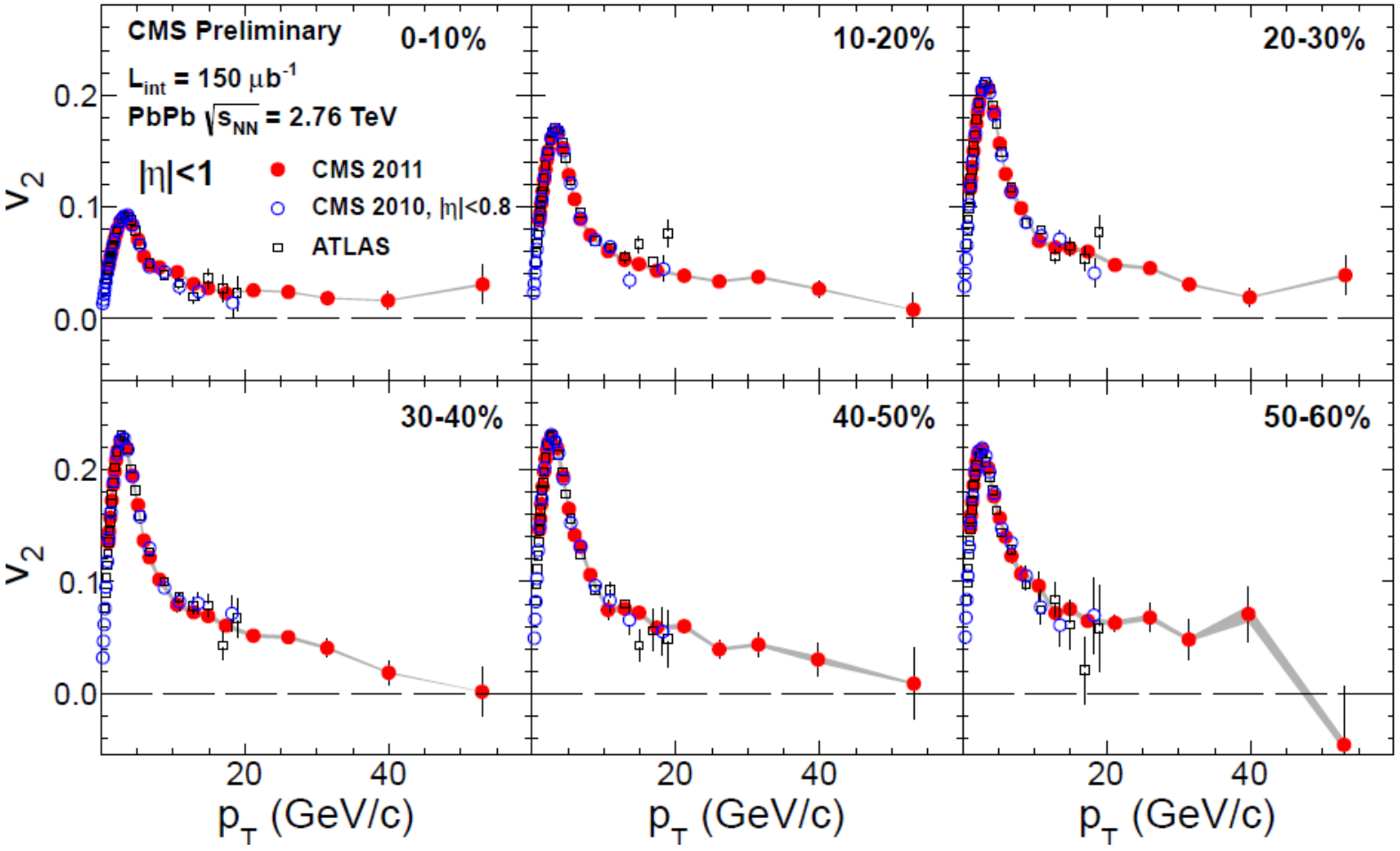
* Results not corrected for p_T-dependent resolution

Reaction Plane for High p_T v_2



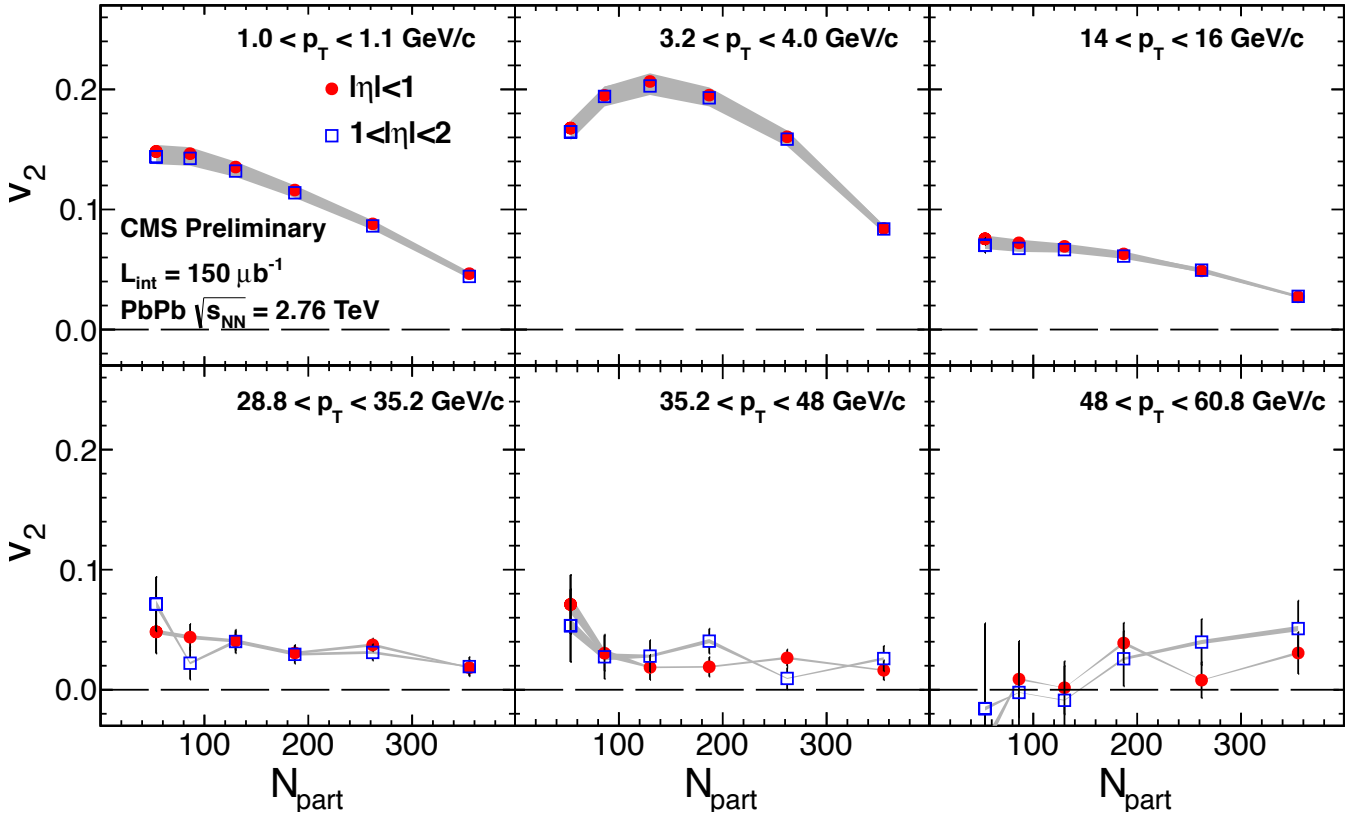
- v_2 is measured in $|\eta| < 2$ from charged tracks
- Reaction plane measured in the forward calorimeters (HF) in $3 < |\eta| < 5$
- To avoid auto-correlations from jets only the opposite side HF is used
- Gives a minimum gap of 3 units

v_2 at High p_T



Not probing flow → path-length dependence of jet quenching

v_2 at High p_T



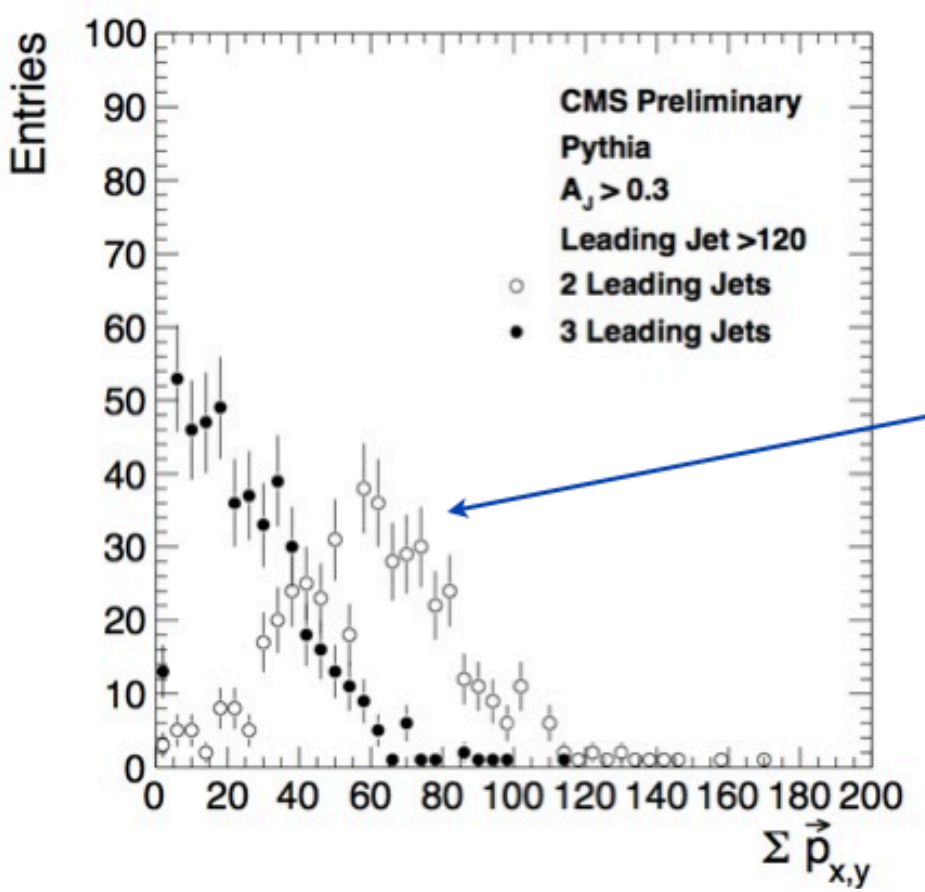
- At high p_T hydronamic flow dies out as expected
- Small, but non-zero v_2 out to ~ 40 GeV/c, only weak centrality dependence

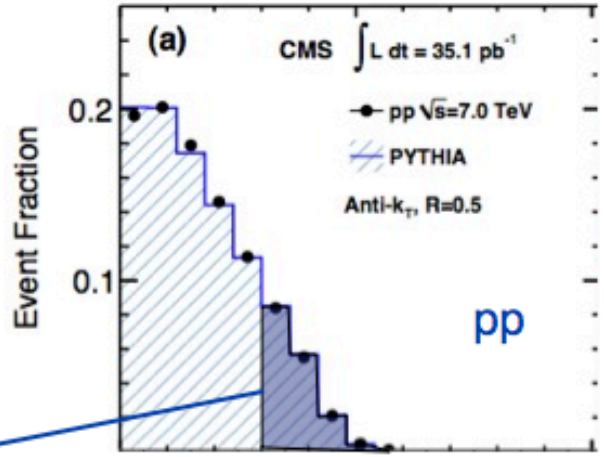
Summary

- CMS has some new results using 2011 data!
  - Charged hadron R_{AA} to $p_T > 100$ GeV/c
  - Dijet imbalance to leading jet $p_T > 300$ GeV/c
  - Charged hadron v_2 to $p_T > 40$ GeV/c
- We're working on more results for the summer conferences!

Backup

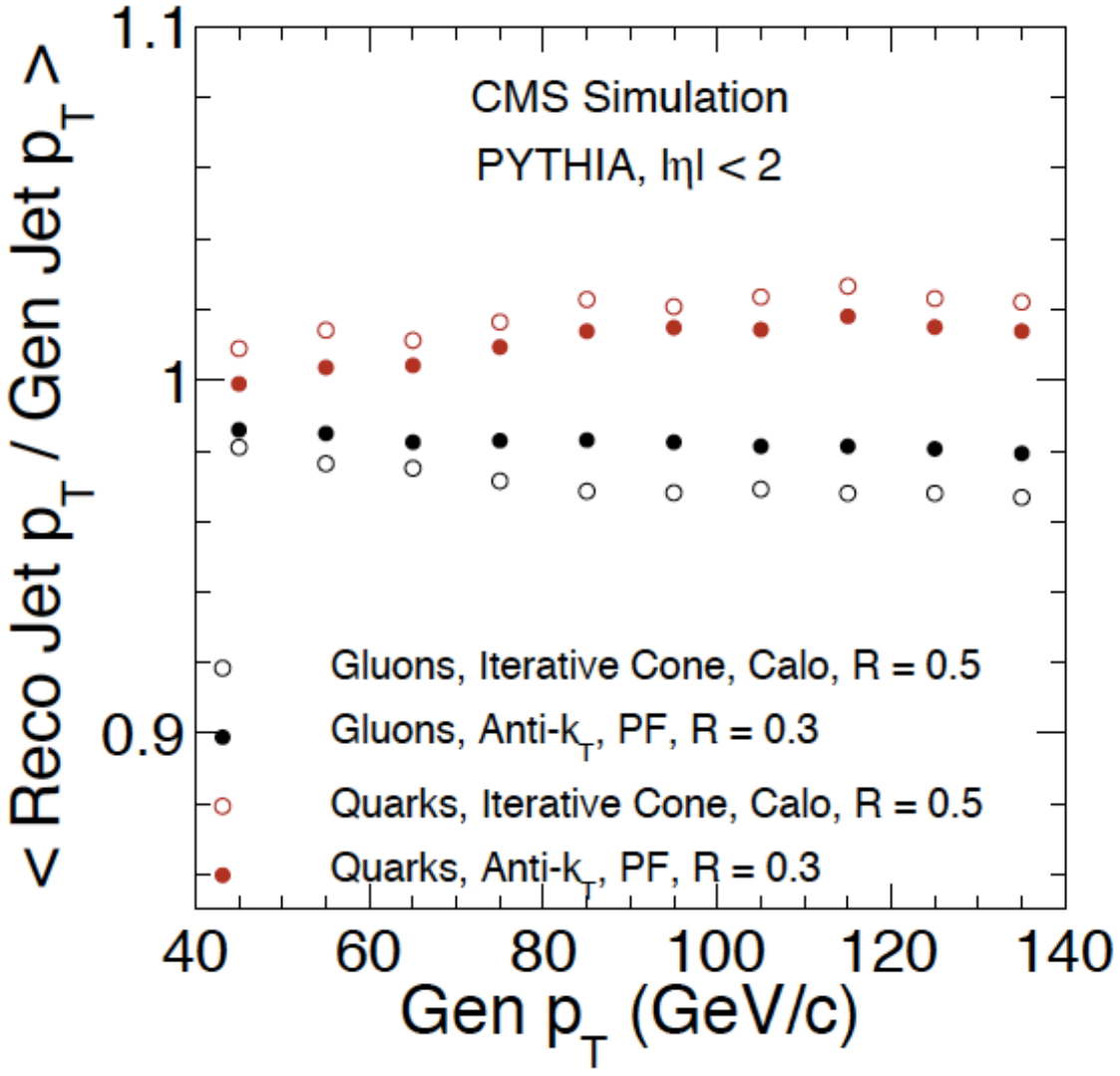
Multi-Jet Events





For the ~10% of unbalanced PYTHIA dijets ($A_j > 0.3$), a 3rd jet provides most of momentum balance

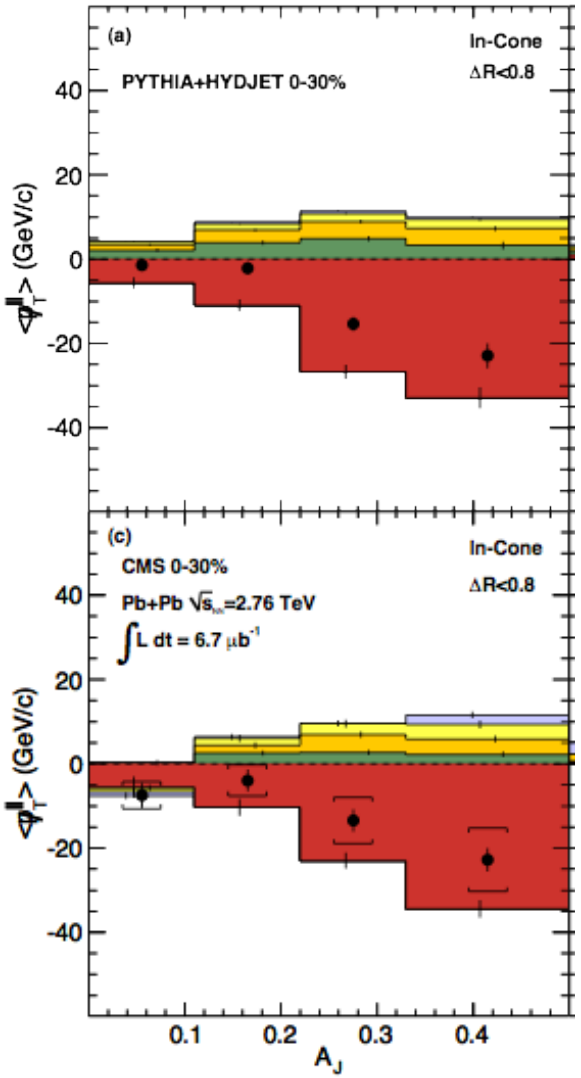
Quark Vs Gluon Jets



Quenching Effects

- A valid criticism:
  If fragmentation was very modified by quenching, subtraction could cause a bias
- Systematics were evaluated by using jet-track correlations to study the soft modes of the jet
- Bottom line: Modification of soft component of quenched jets
  < few GeV <u>inside</u> jet cone

Jet-Track Correlations

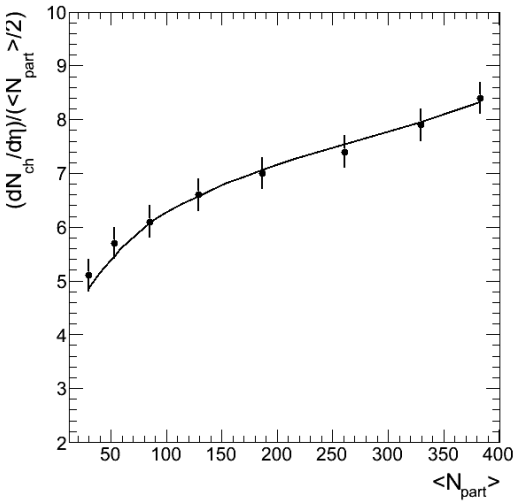


Hydjet Version 1.8

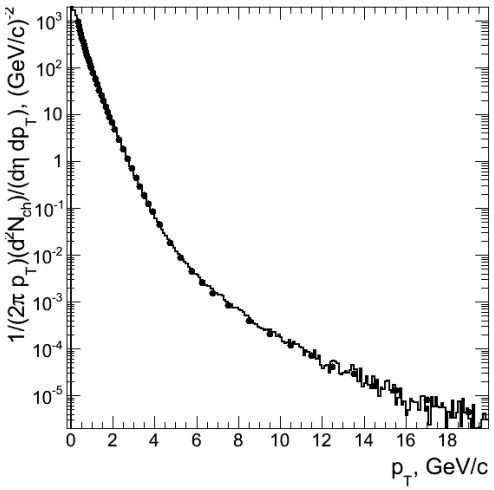
Hydjet 1.8, default tune reproduces:

- Charged hadron multiplicity
- Charged hadron p_T spectrum
- Elliptic Flow

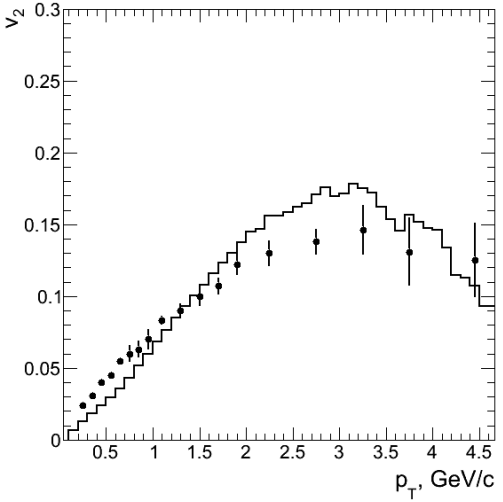
-- Hydjet
• ALICE PLB 696 (2011) 30
0-5% Central



-- Hydjet
• ALICE PRL106(2011)032301
0-5% Central



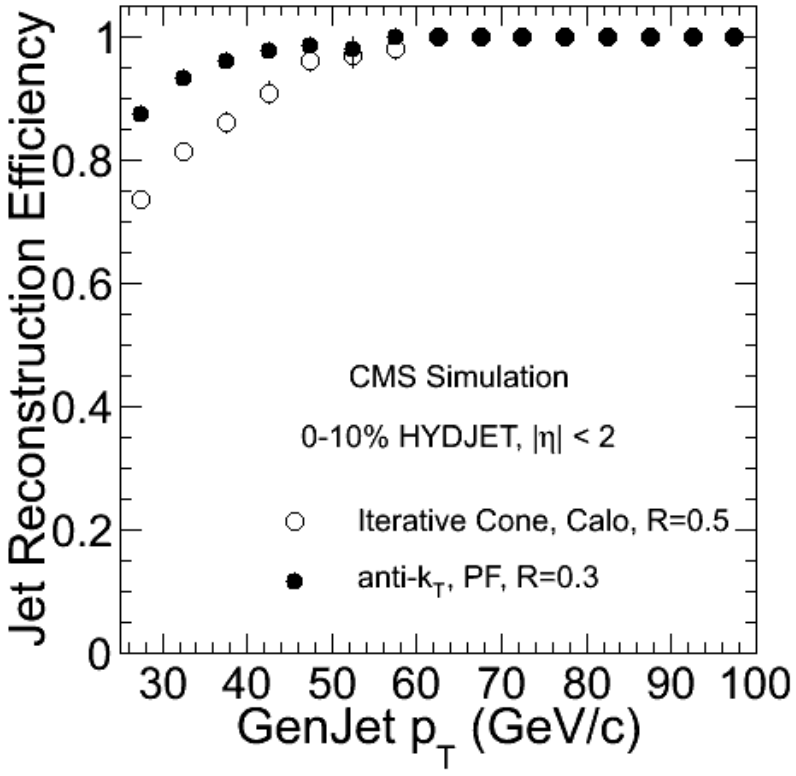
-- Hydjet
• ALICE PRL 105 (2010) 252302
10-20% Central

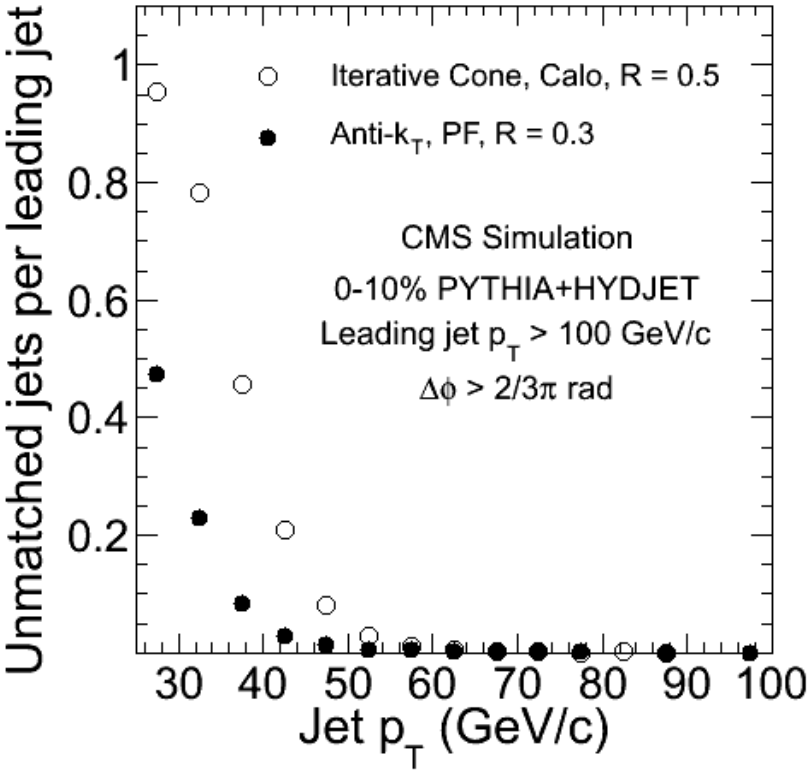


http://lokhtin.web.cern.ch/lokhtin/hydro/plots

Efficiency, Fake/Mismatch Rate

CMS-PAS-HIN-11-004





At low p_T jets may not exceed threshold to be excluded from background calculation

Rate of away-side jets from background fluctuations and secondary hard scatterings

Charged Hadron R_{AA}