Studies of jet quenching and b-jet identification in PbPb collisions at 2.76 TeV with CMS

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CMS HI Jet Results

- Dijet imbalance and missing p_T
  PRC 84 (2011) 024906
- Fragmentation Functions
  arXiv:1205.5872

Results with 2010 Data

Results with 2011 Data

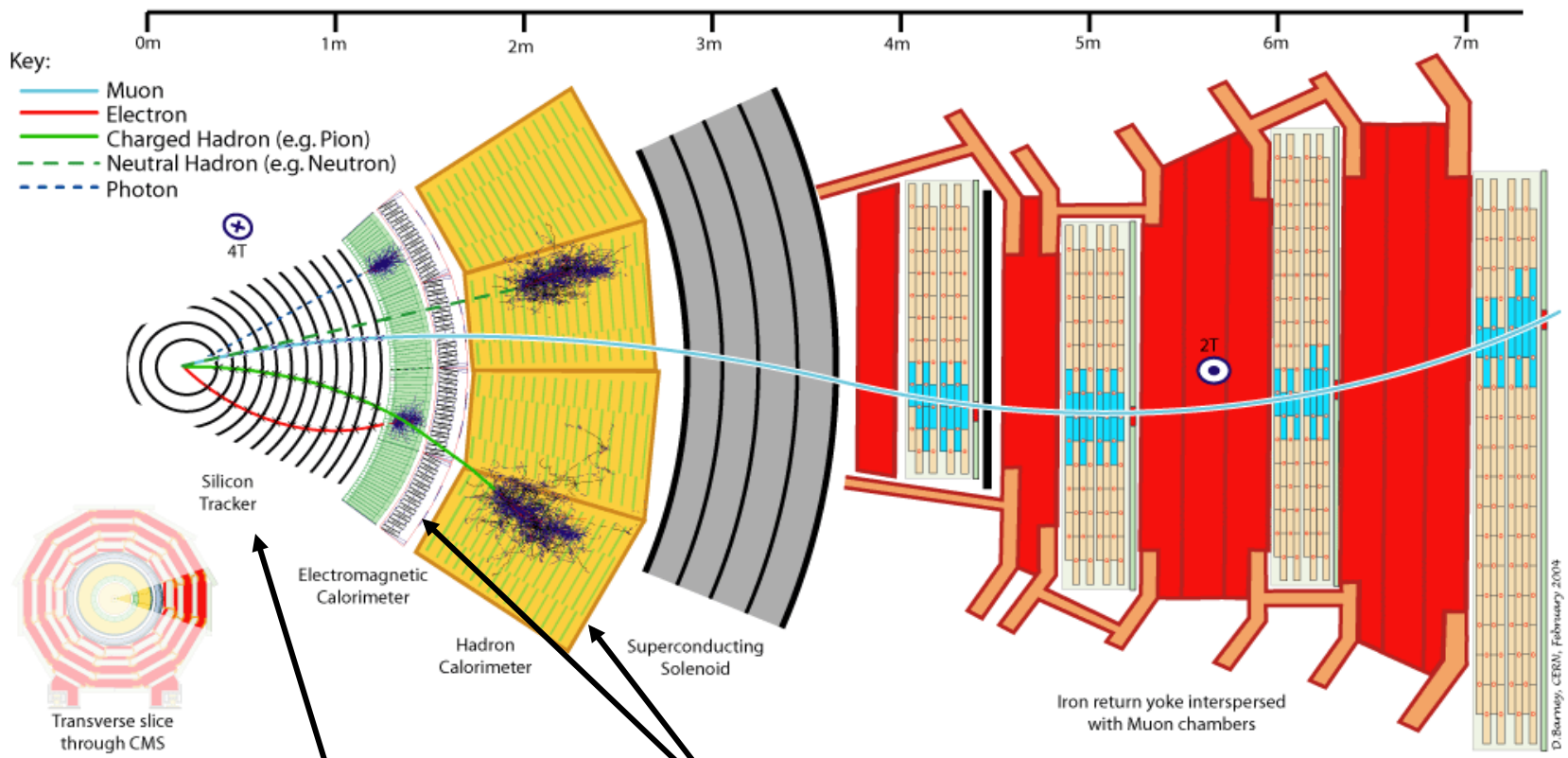
- Updated dijet imbalance with 2011 data
  PLB 712 (2012) 176
- b-tagged jets

This talk

- γ+jet — Parallel 1B, Yue-Shi Lai
  arXiv:1205.0206
- Jet R_{AA} — Parallel 2B, Marguerite Belt Tonjes
- Jet Shapes — Parallel 3B, Pelin Kurt
- Updated FFs — Parallel 3B, Frank Ma

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN

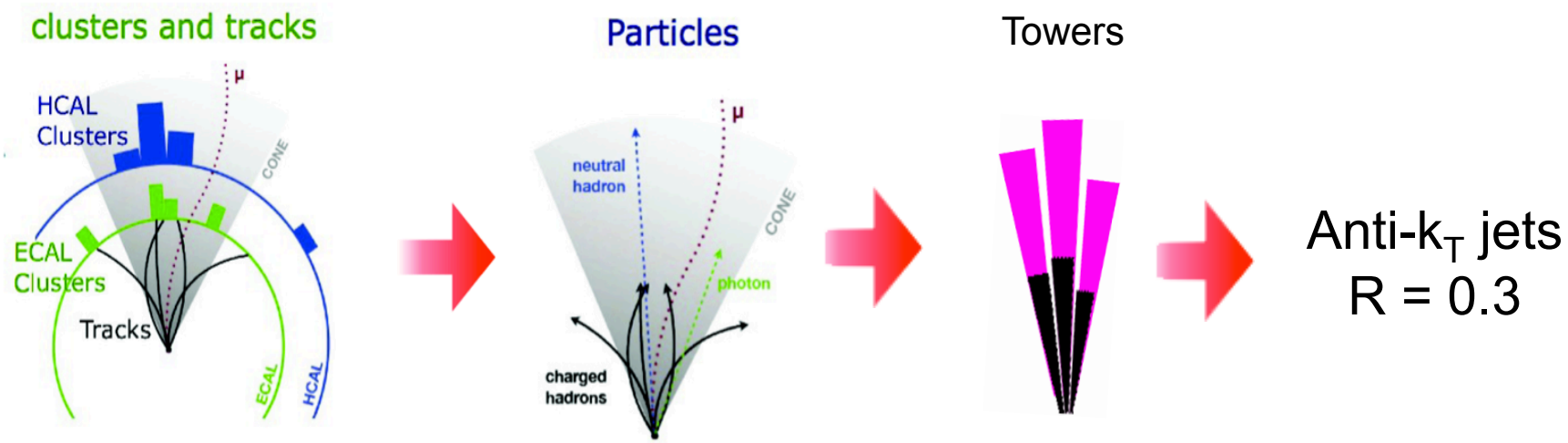
The CMS Detector



Silicon tracker used in jet reconstruction and for secondary vertices

EM and hadronic calorimeters used for jet reconstruction

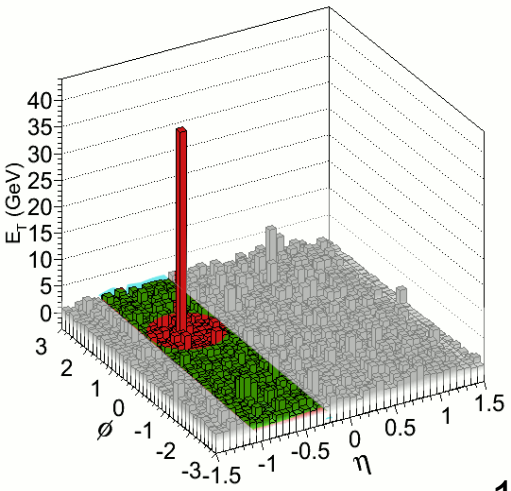
Jet Measurements in PbPb

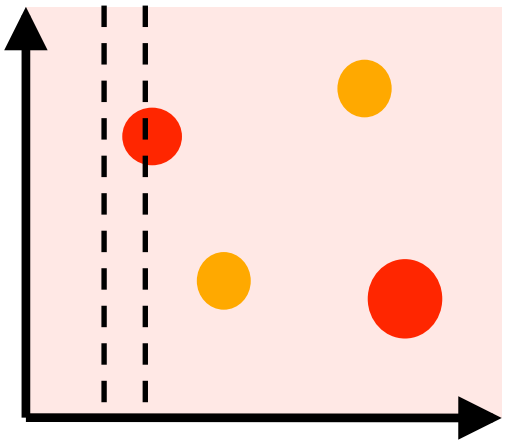


- Information from all sub-detectors are combined into particle candidates → "Particle flow" event reconstruction [1-2]
- Allows to exploit the excellent resolution of the tracker for the charged hadron component of the jet
- Also includes a fully consistent treatment of electron and muons inside jets
- Particle candidates combined into towers in order to subtract the heavy-ion background

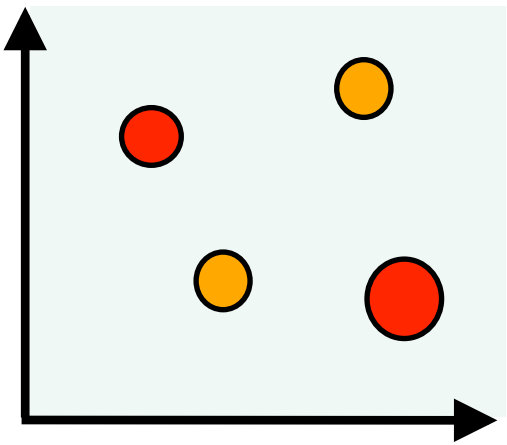
[1] arXiv:1107.0179
[2] CMS-PAS-PFT-09-001

Underlying Event Subtraction

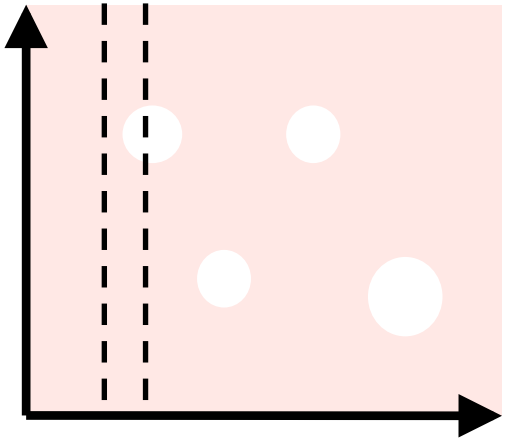




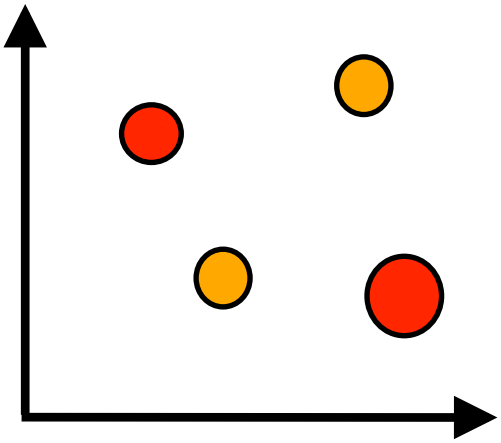
1. $\langle E_T \rangle$ calculated in strips of η. Subtract $\langle E_T \rangle + \sigma$



2. Run anti-k_T algorithm on background-subtracted towers



3. Exclude reconstructed jets and re-estimate background



4. Re-run anti-k_T algorithm to get final jets

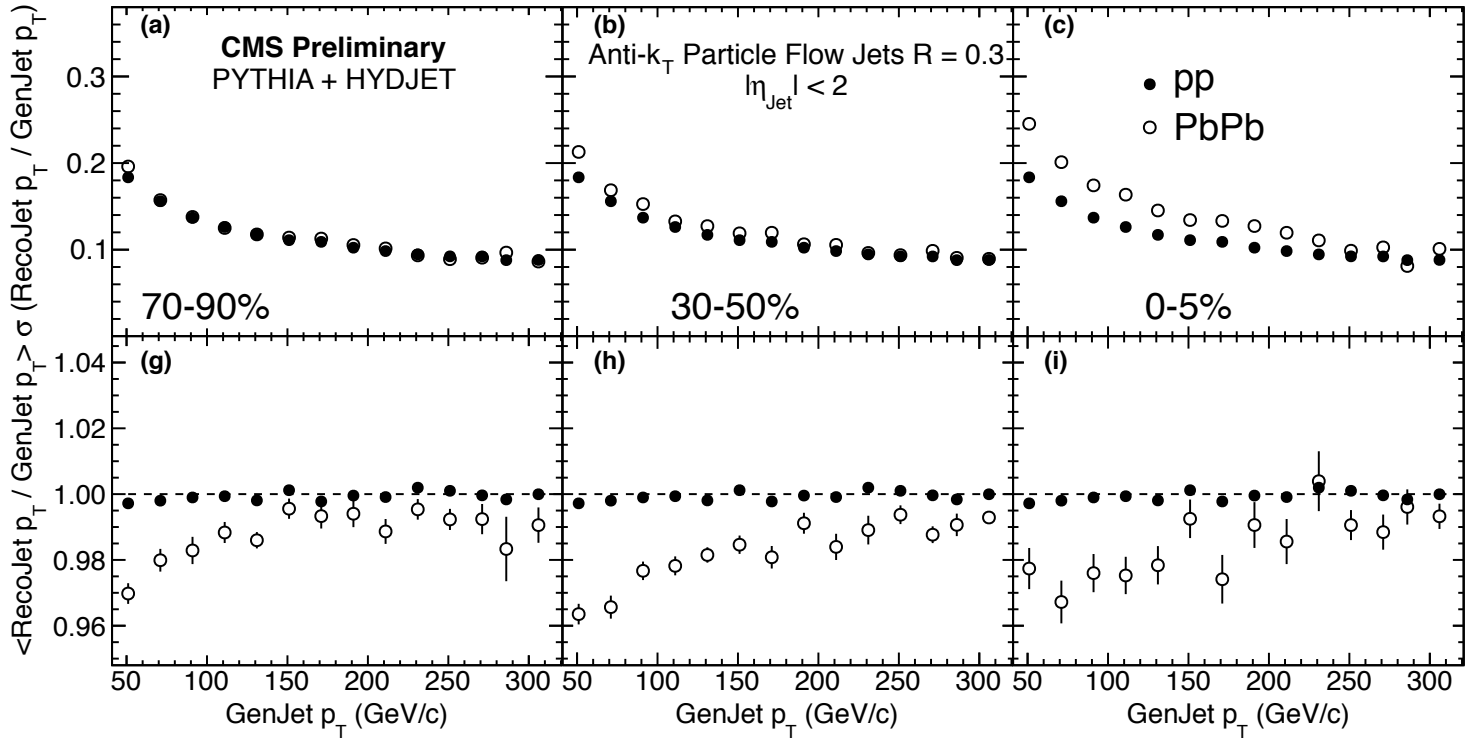
For details see:

- CMS, arXiv:1102.1957
- Kodolova et al., EPJC 50 (2007) 117

Jet Reconstruction Performance

Resolution

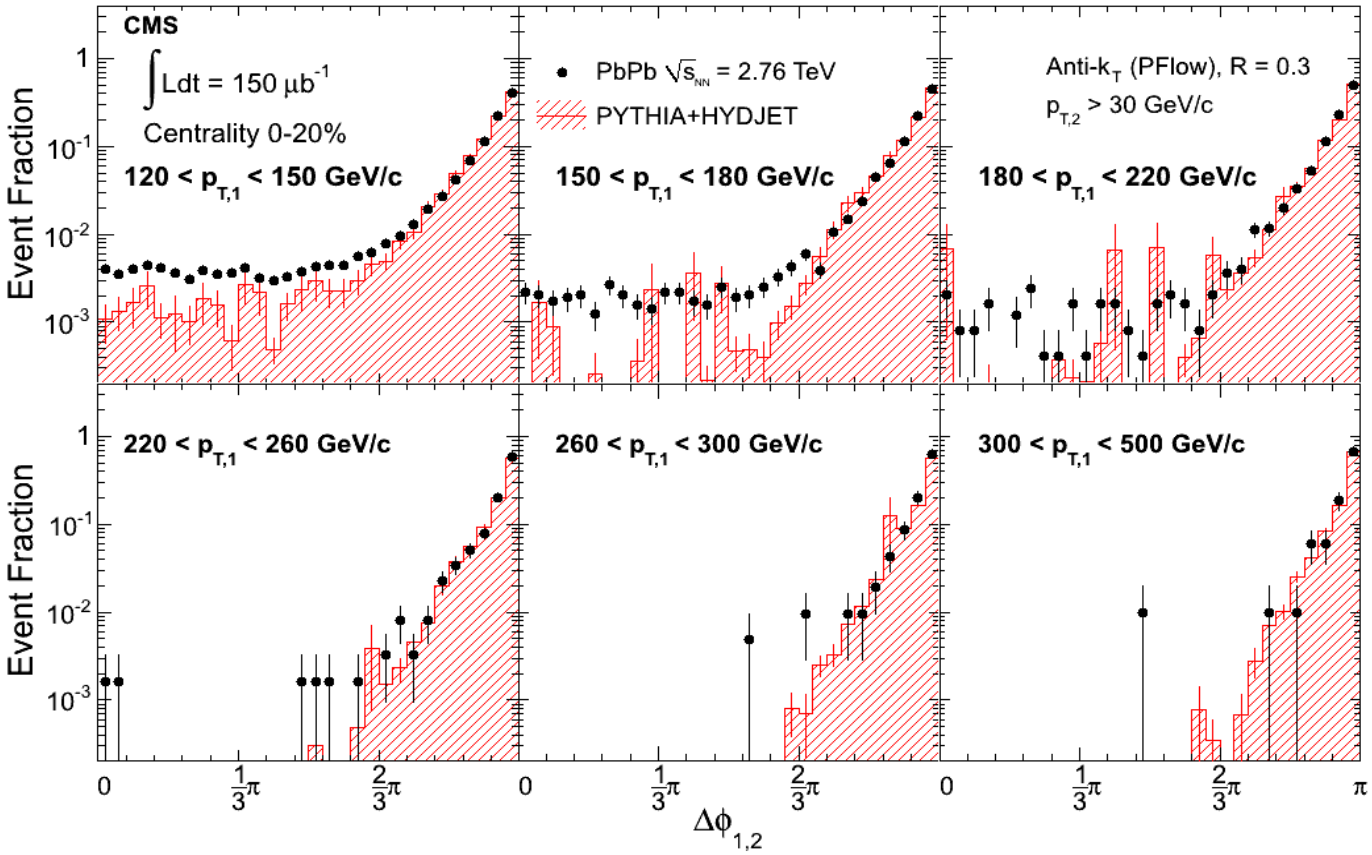
Response

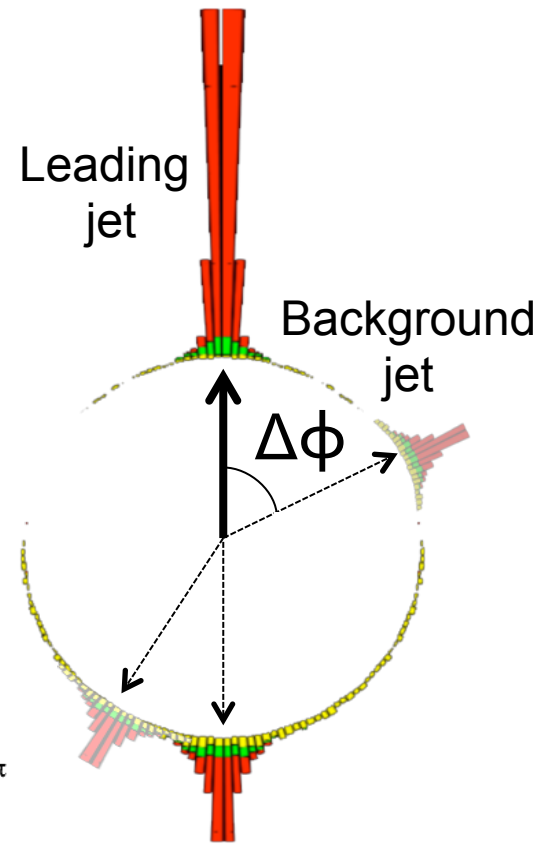


- Jet energy corrections based on PYTHIA simulations
- Corrected jet response close to unity even in central events
  → demonstrates reliability of HI background subtraction

CMS-PAS-HIN-12-004

Dijet Azimuthal Correlations



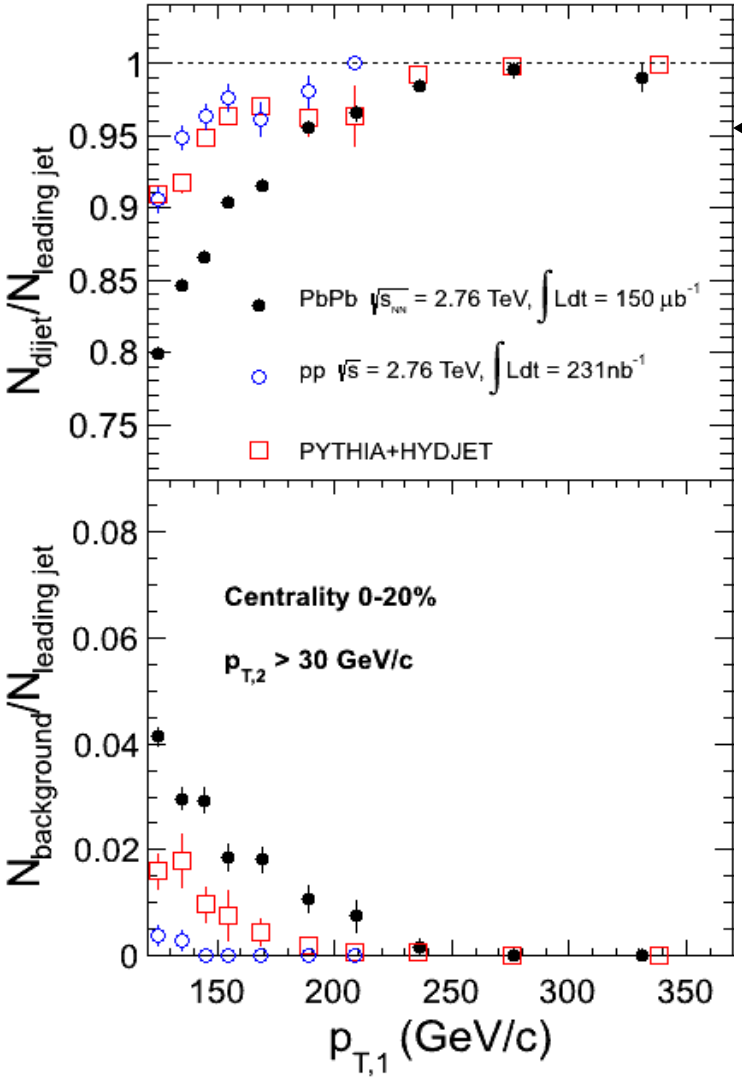


No significant angular decorrelation of dijets

True subleading jet

The pedestal of uncorrelated jets is subtracted using small Δφ events

Uncorrelated Jets



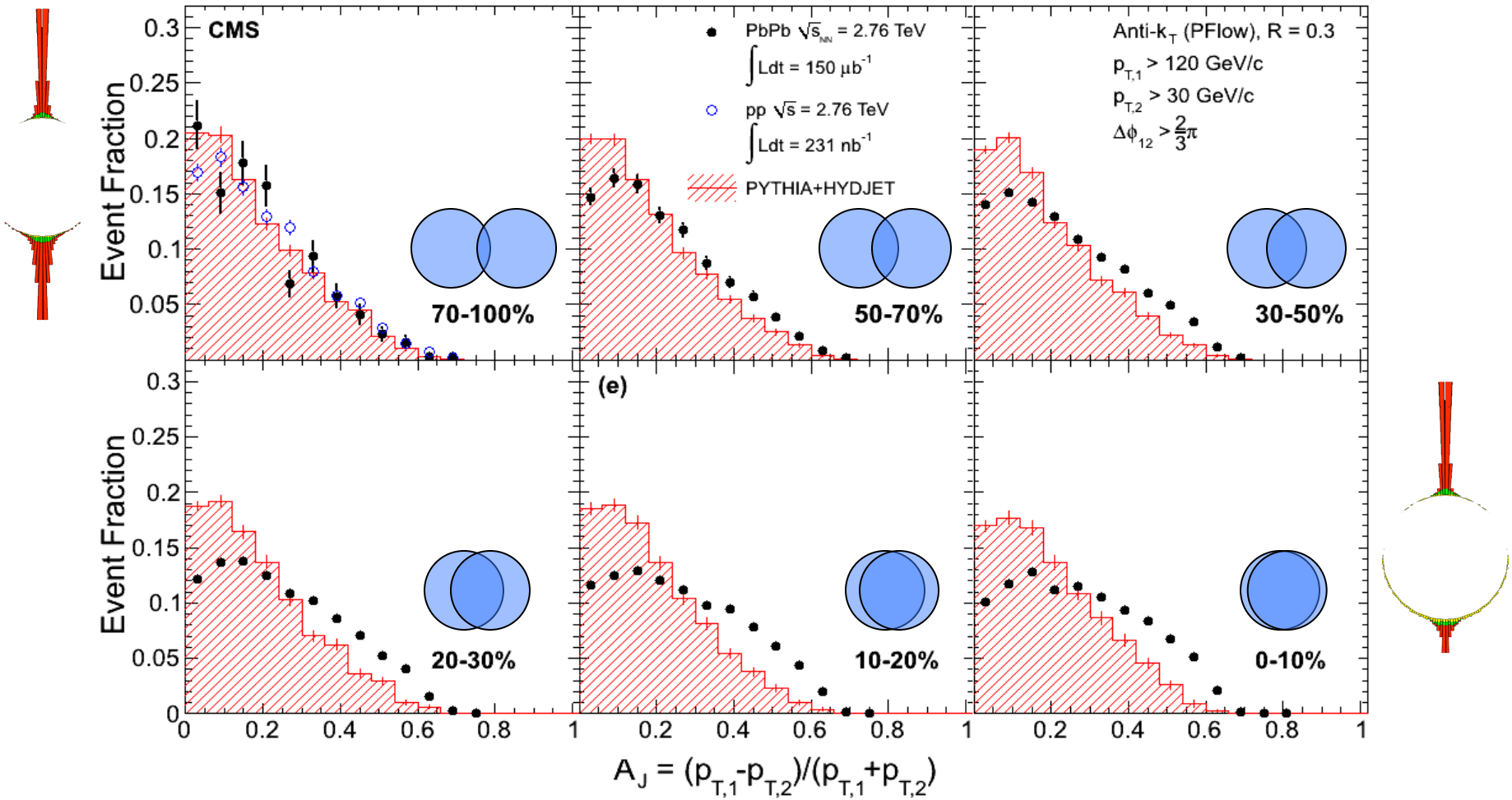
Fraction of leading jets with sub-leading jet passing selection

- $p_{T,2}$ > 30 GeV/c
- $\Delta\phi_{12}$ > 2/3 π

Fraction of jet pairs with $\Delta\phi_{12}$ < 1/3 π

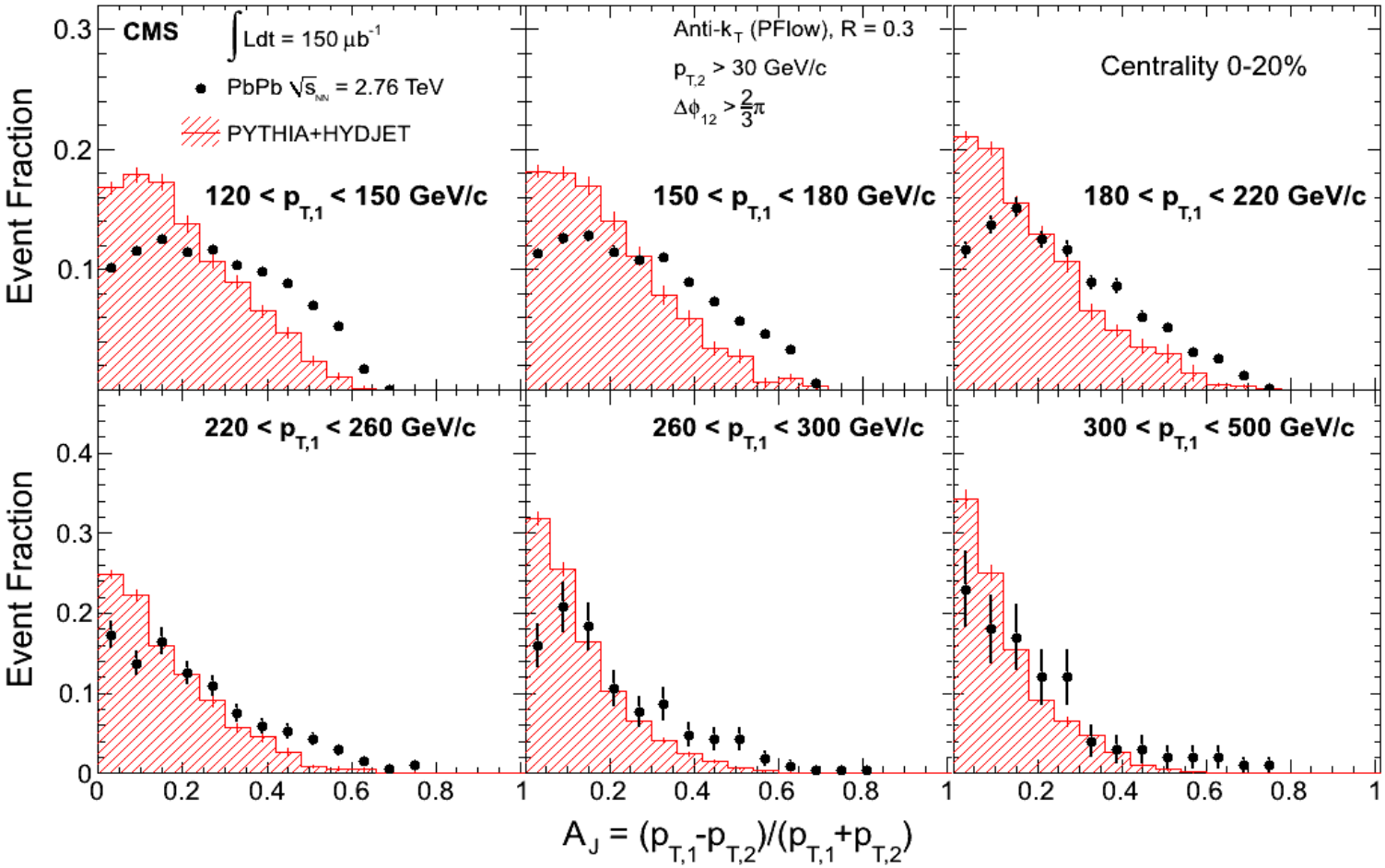
- Small fraction of small $\Delta\phi_{12}$ jets are subtracted in what follows
- Becomes negligible at large leading jet p_T

Dijet Imbalance vs. Centrality



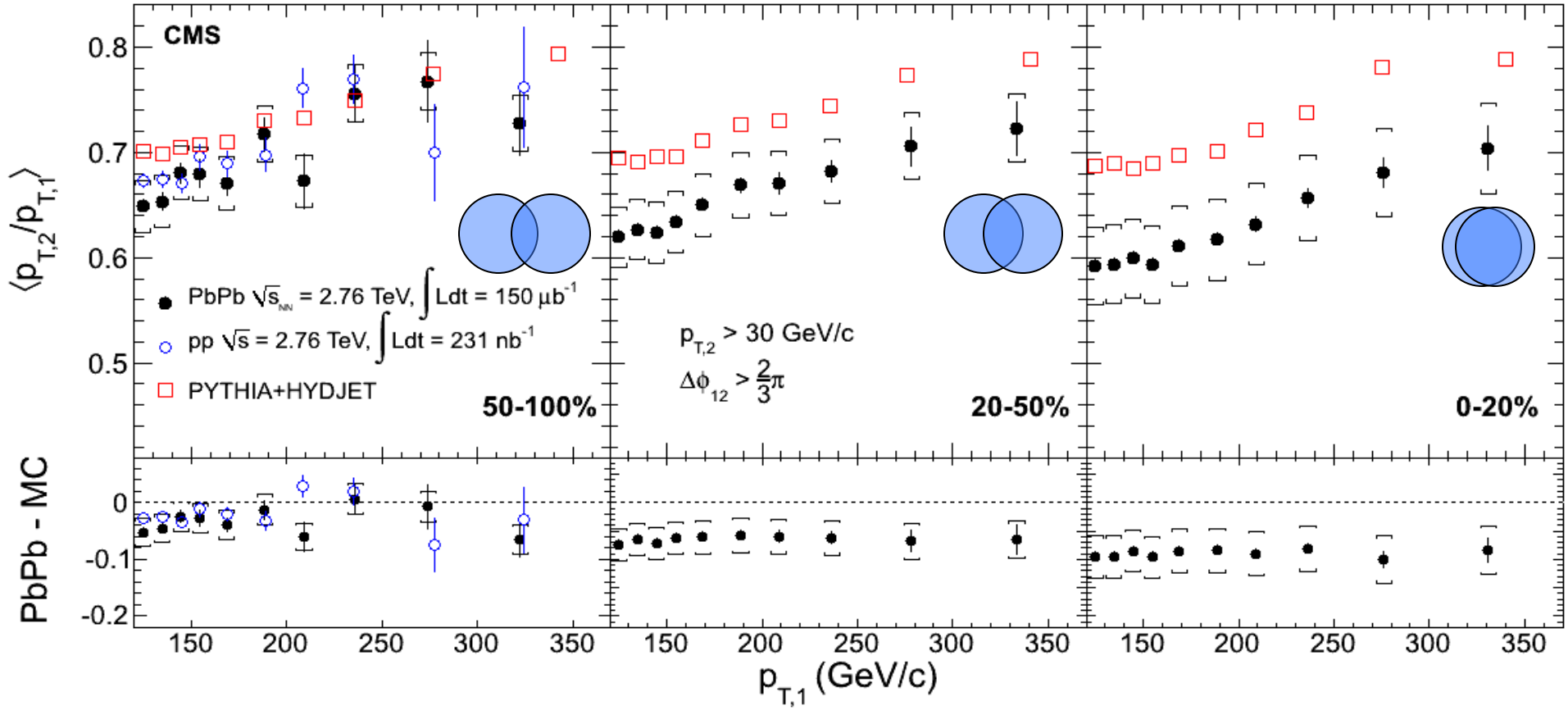
2011 data set shows the centrality evolution of the dijet imbalance more clearly than seen from first 2010 PbPb data

p_T Dependence of Dijet Imbalance



Dijets in central PbPb are more unbalanced than PYTHIA even at large values of leading jet p_T

p_T Dependence Quantified



- Dijets in reference (pp, PYTHIA) become more balanced with increasing p_T
- $\langle p_{T,2}/p_{T,1} \rangle$ in PbPb consistent with a constant offset from the reference MC

b-jet Identification

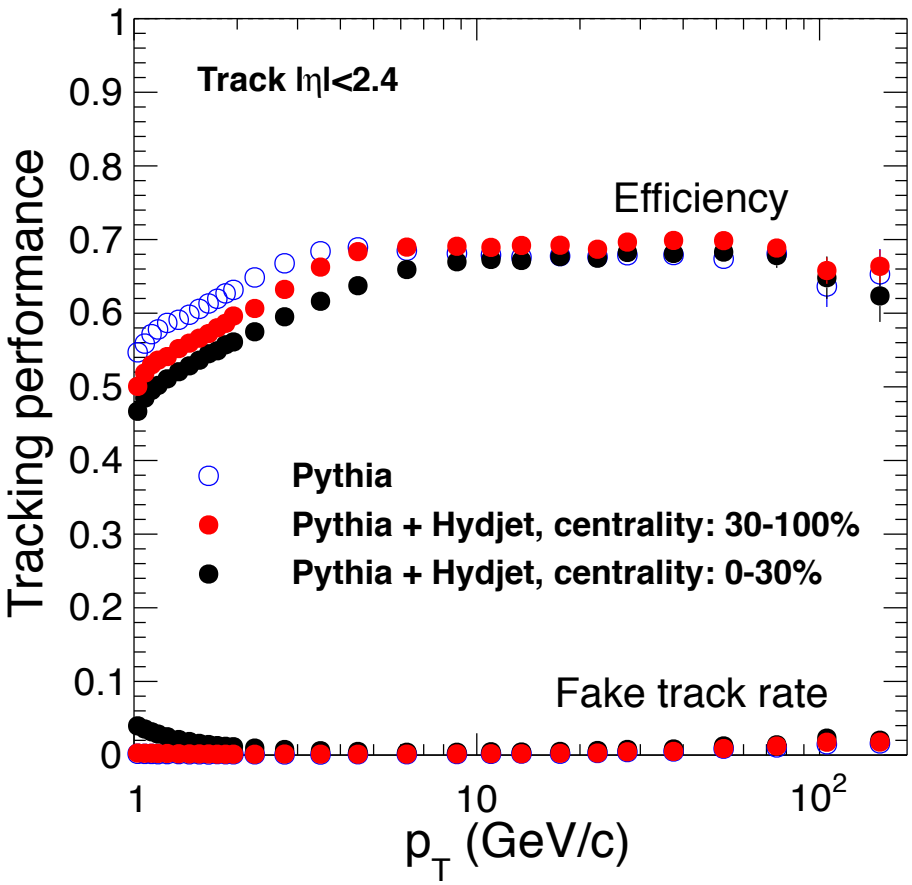
- Long lifetime of b (~1.5 ps) leads to measurable (mm or cm) displaced secondary vertices (SV)

- Subsequent charm decay may lead to a tertiary vertex
- B-jets are tagged using reconstructed SV's, using the flight distance of the SV as a discriminating variable
- We then extract the b-jet fraction by a fit to the SV mass
- An alternative tagger based only the impact parameter of the tracks in the jet is used to corroborate the SV performance

Tracking in Heavy Ions

- Standard track reconstruction and selection in heavy ions gives a reasonable efficiency and low fake rate for primary tracks
- Reconstruction of displaced tracks is computationally intensive in the PbPb environment
- Additional tracking is run locally inside reconstructed jets to recover secondary tracks

"Standard" HI Tracking (2011)



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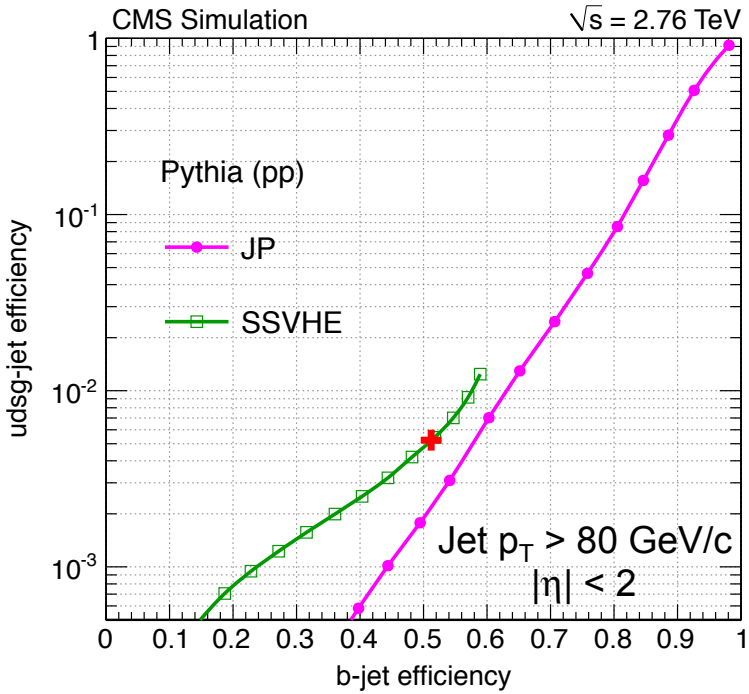
b-tagging Performance

Jets are tagged by cutting on discriminating variables

- *Simple Secondary Vertex High Efficiency* (SSVHE)
- *Jet Probability* (JP)



- Performance is benchmarked by comparing b-tagging efficiency to efficiency to mis-tag light jets
- *SSVHE* uses the SV flight distance
- JP uses large impact parameter tracks to estimate a likelihood that tracks come from the primary vertex

b-jet Identification in CMS: CMS-PAS-BTV-11-004

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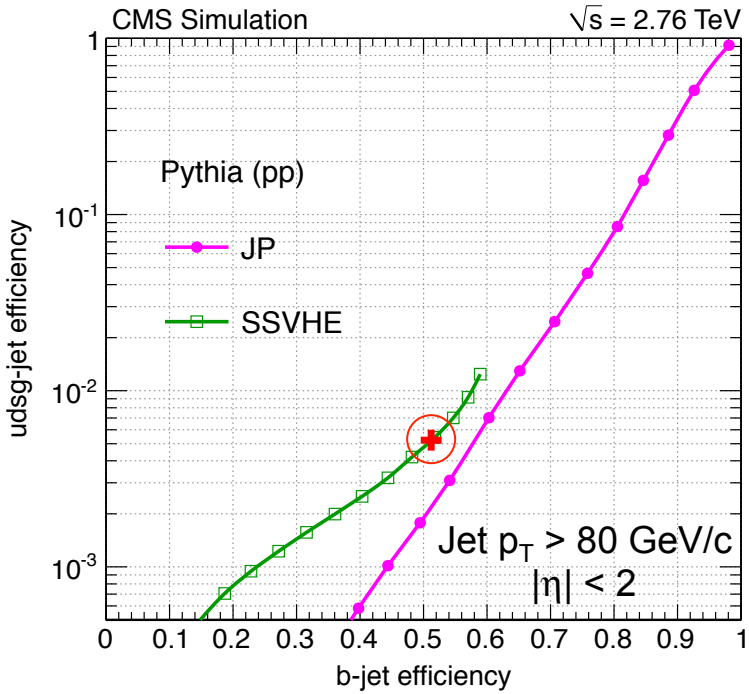

- Performance is benchmarked by comparing b-tagging efficiency to efficiency to mis-tag light jets
- *SSVHE* uses the SV flight distance
- JP uses large impact parameter tracks to estimate a likelihood that tracks come from the primary vertex

- We use an SSVHE working point which gives a factor of several hundred in light jet rejection for a b-jet efficiency of about 50%
- JP is used for data-driven studies of the SSVHE performance

b-jet Identification in CMS: CMS-PAS-BTV-11-004

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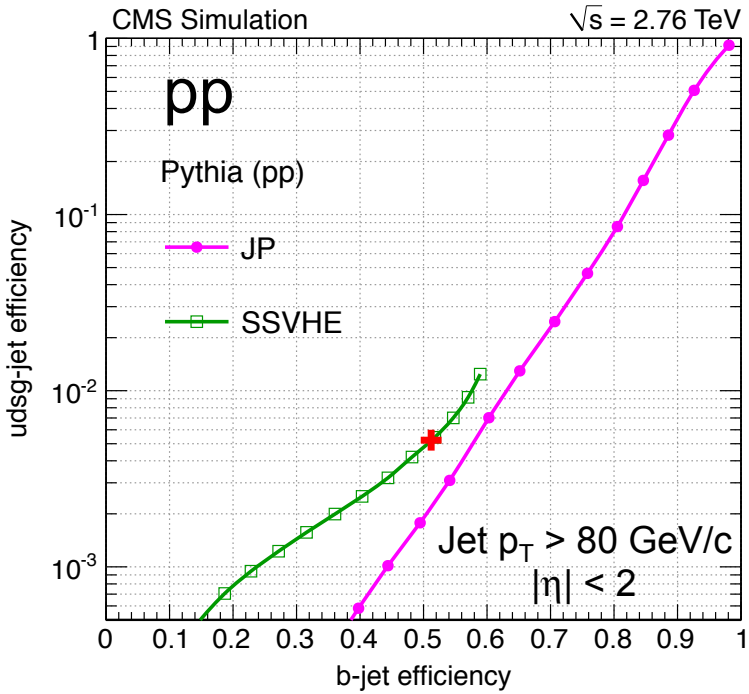
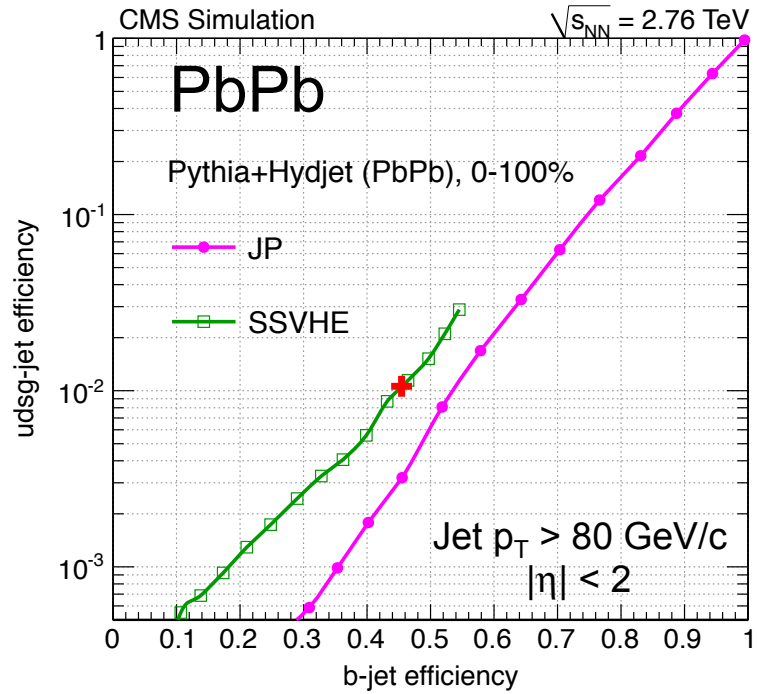


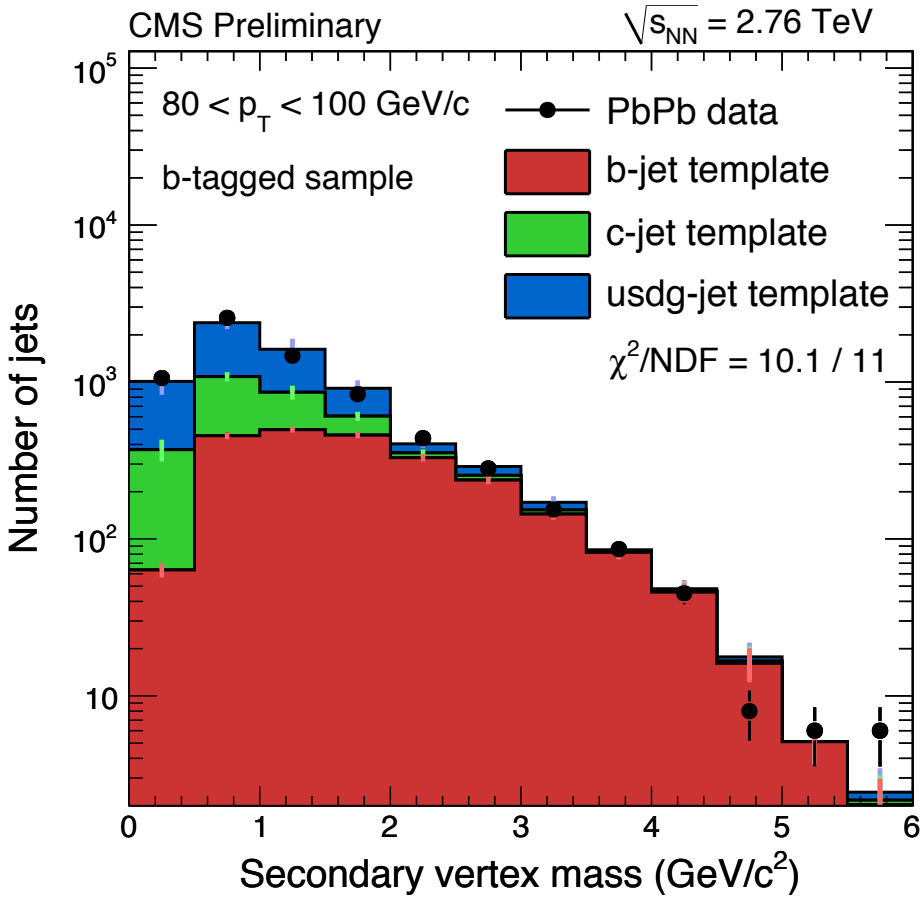


Some degradation of performance in PbPb compared to pp,
but still a factor of ~100 light jet rejection for ~45% b-jet efficiency

b-jet Identification in CMS: CMS-PAS-BTV-11-004

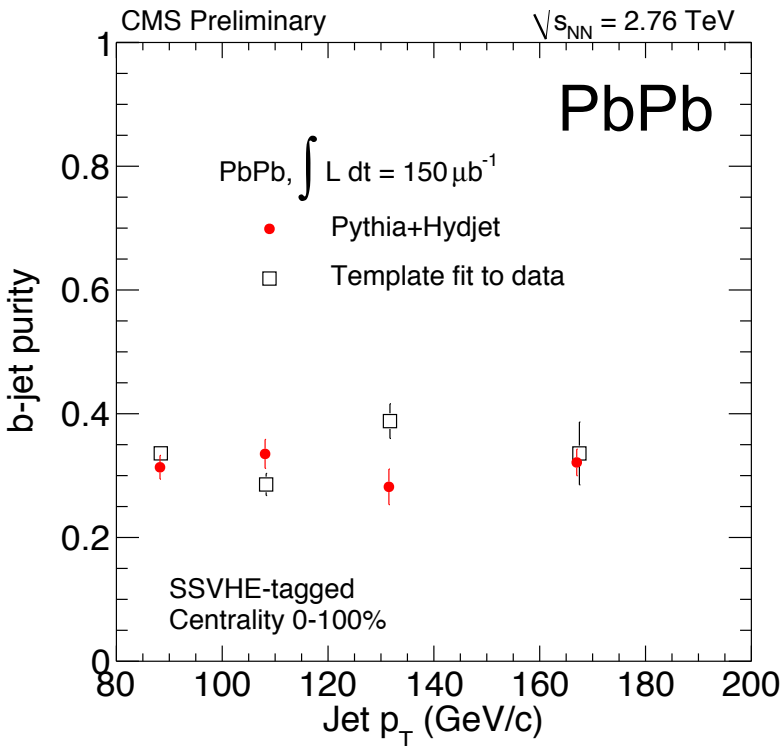
Secondary Vertex Mass Fits

- After enriching sample in b-jets with the SSVHE tagger, we fit the SV mass distribution
- Shapes of b and non-b templates taken from MC, normalizations allowed to float
- The shapes of the non-b templates are cross-checked with a data-driven method
- The stability of the fits and the shapes of the templates are the dominant sources of systematics uncertainty

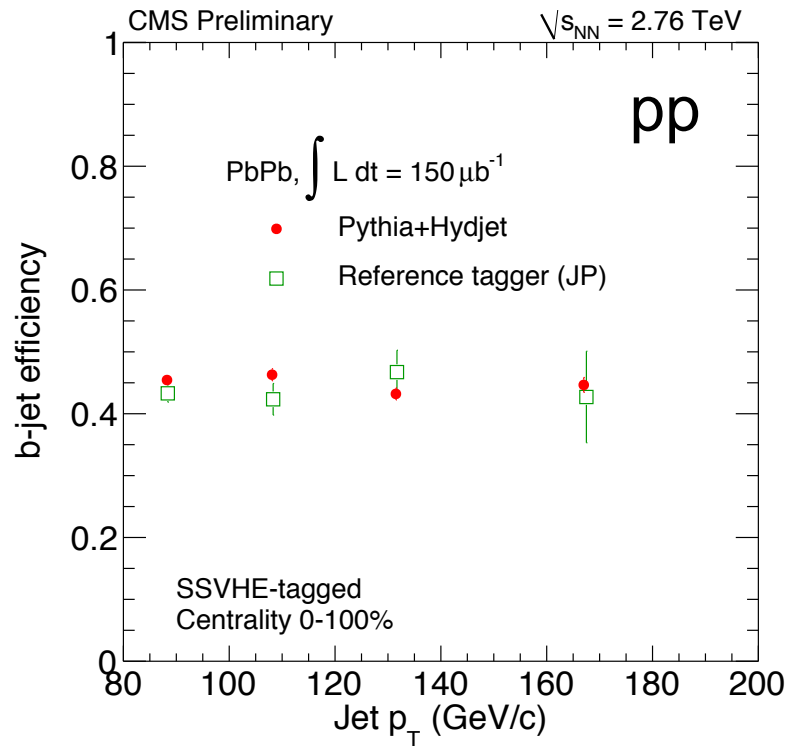


b-Tagging Purity and Efficiency

Purity: b-jet fraction in SV tagged sample extracted from SV mass fit



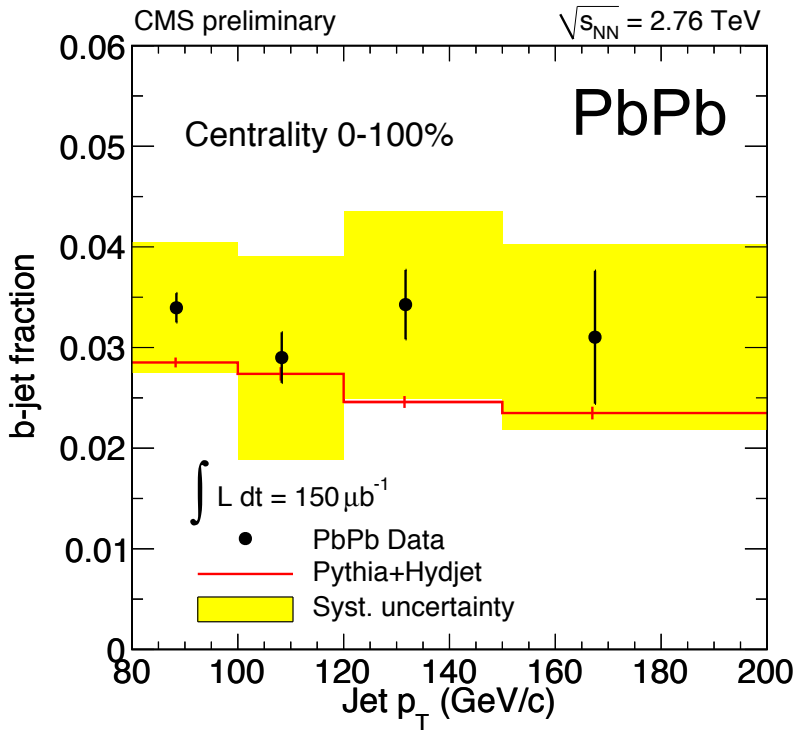
Efficiency: Fraction of b-jets which are tagged by their SV

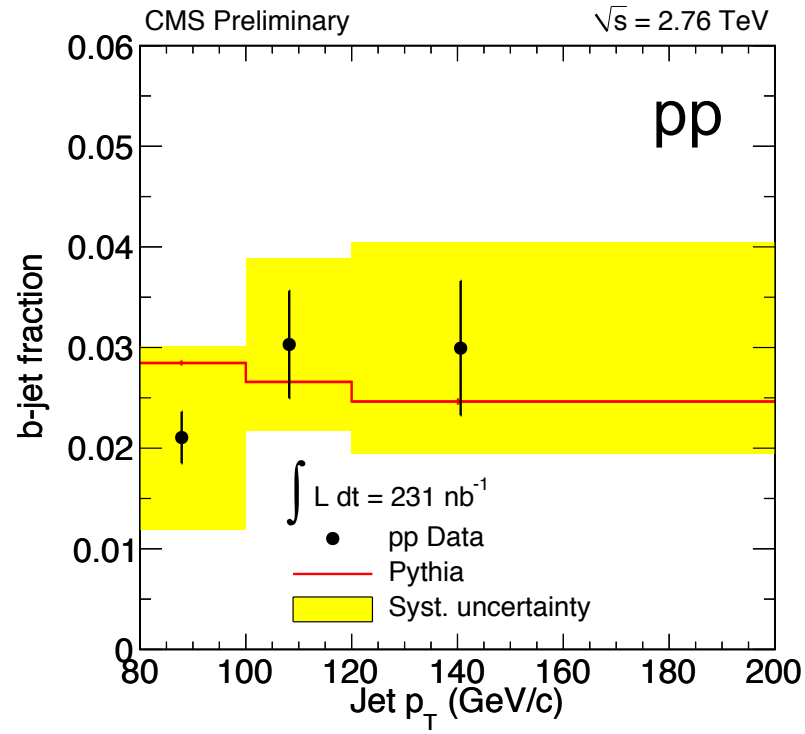


- Efficiency is extracted from simulation and with a data-driven method using the JP tagger, i.e., w/o requiring a SV
- For both efficiency and purity, MC is fairly close to data “out of the box”

b-jet to Inclusive Jet Ratio

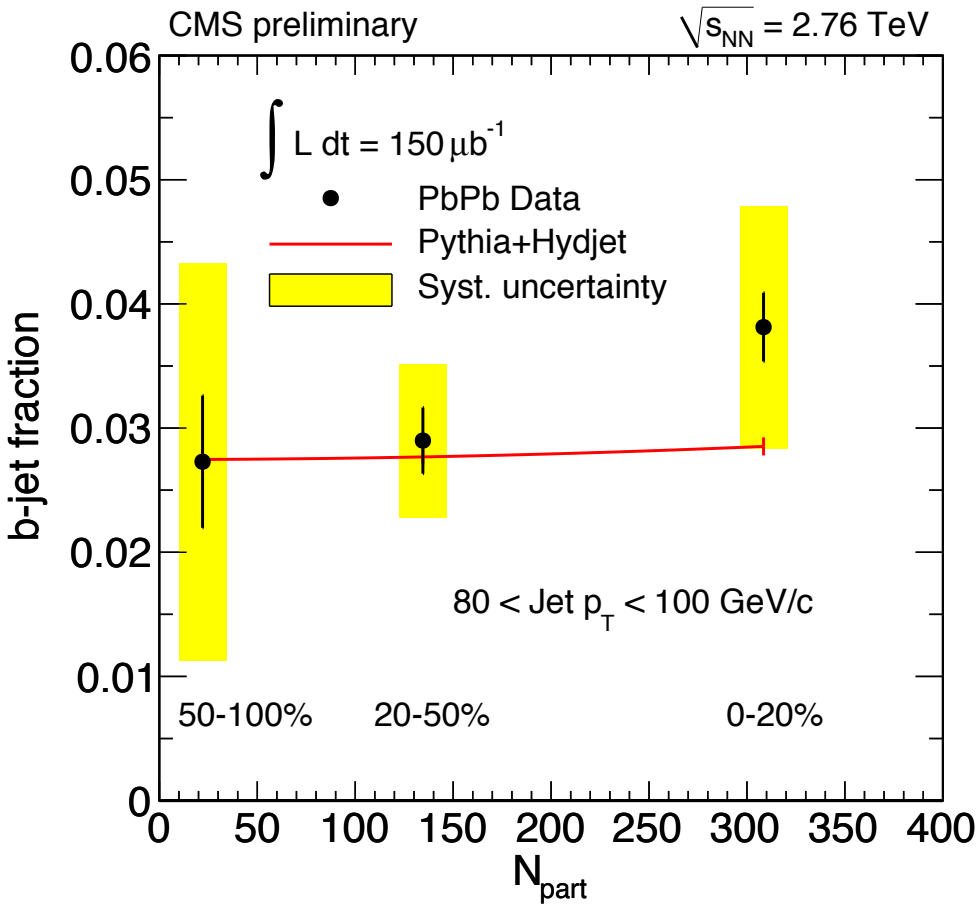
b-jet fraction = # of tagged jets * purity / efficiency





- b-jet fraction in PbPb larger than MC, but consistent within uncertainties
- pp data are also consistent with MC prediction

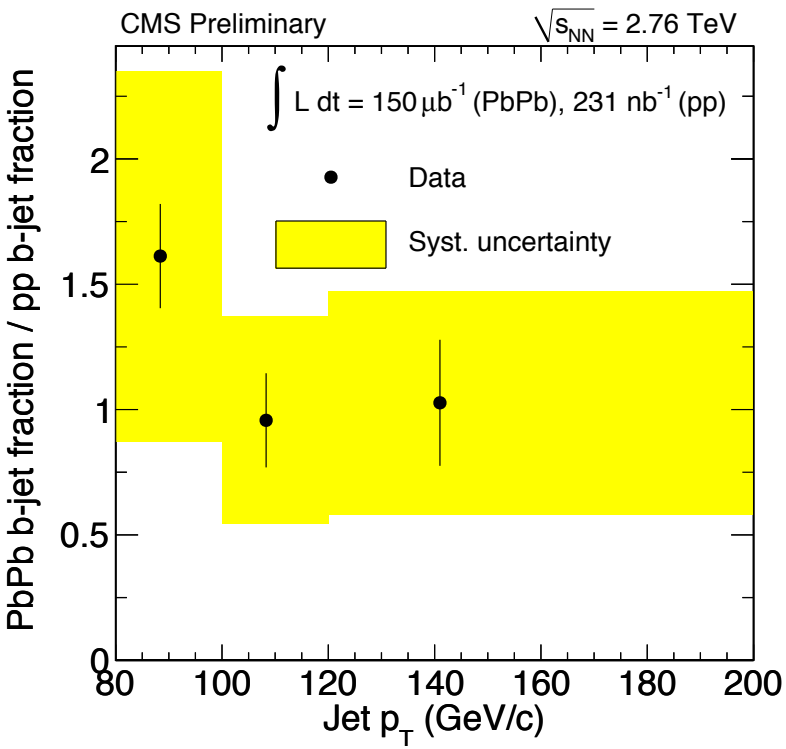
b-jet Fraction vs. Centrality



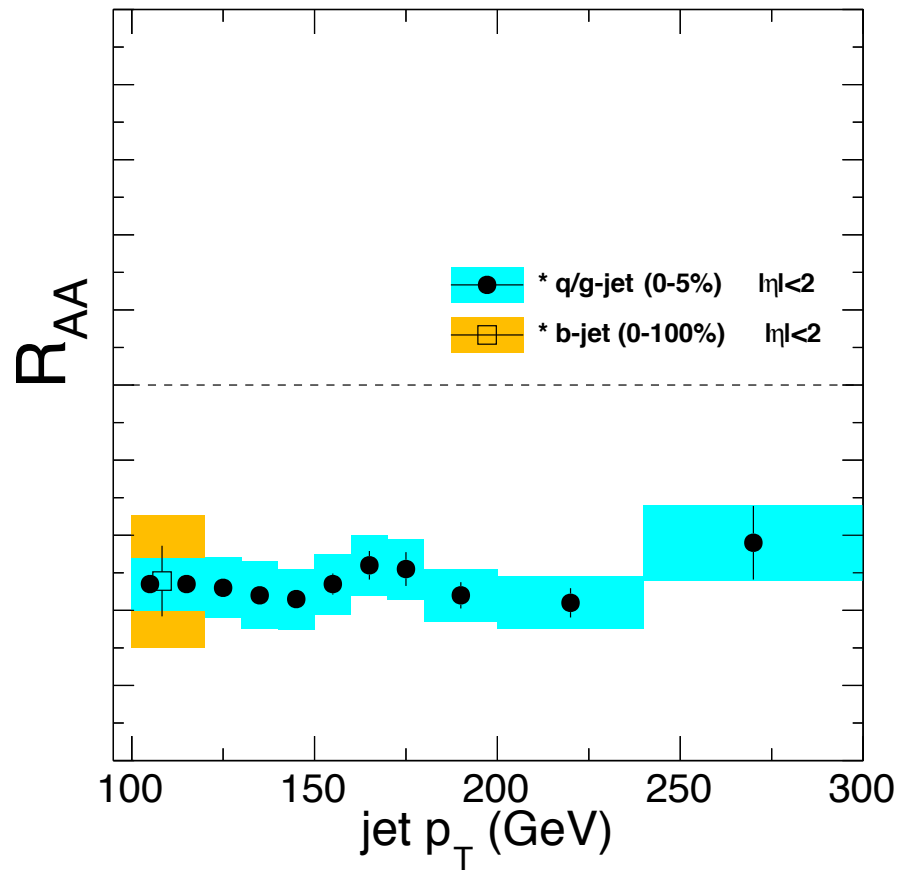
b-jet fraction does not show a strong centrality dependence

b-jet R_{AA}

b-jet fraction double ratio



b-jet R_{AA}
= inclusive jet R_{AA} * double ratio



Conclusions

- Dijets
  - Imbalance persists to large values of leading jet p_T
  - No significant dependence observed in ratio of subleading jet p_T to leading jet p_T → no strong dependence of fractional energy loss on p_T

- b-jets
  - Fully reconstructed b-jets have been identified in heavy-ion collisions for the first time
  - b-jet fraction in PbPb collisions is consistent with PYTHIA and pp data within fairly sizeable uncertainties