First Heavy Ions Results with Pb-Pb Collisions in CMS

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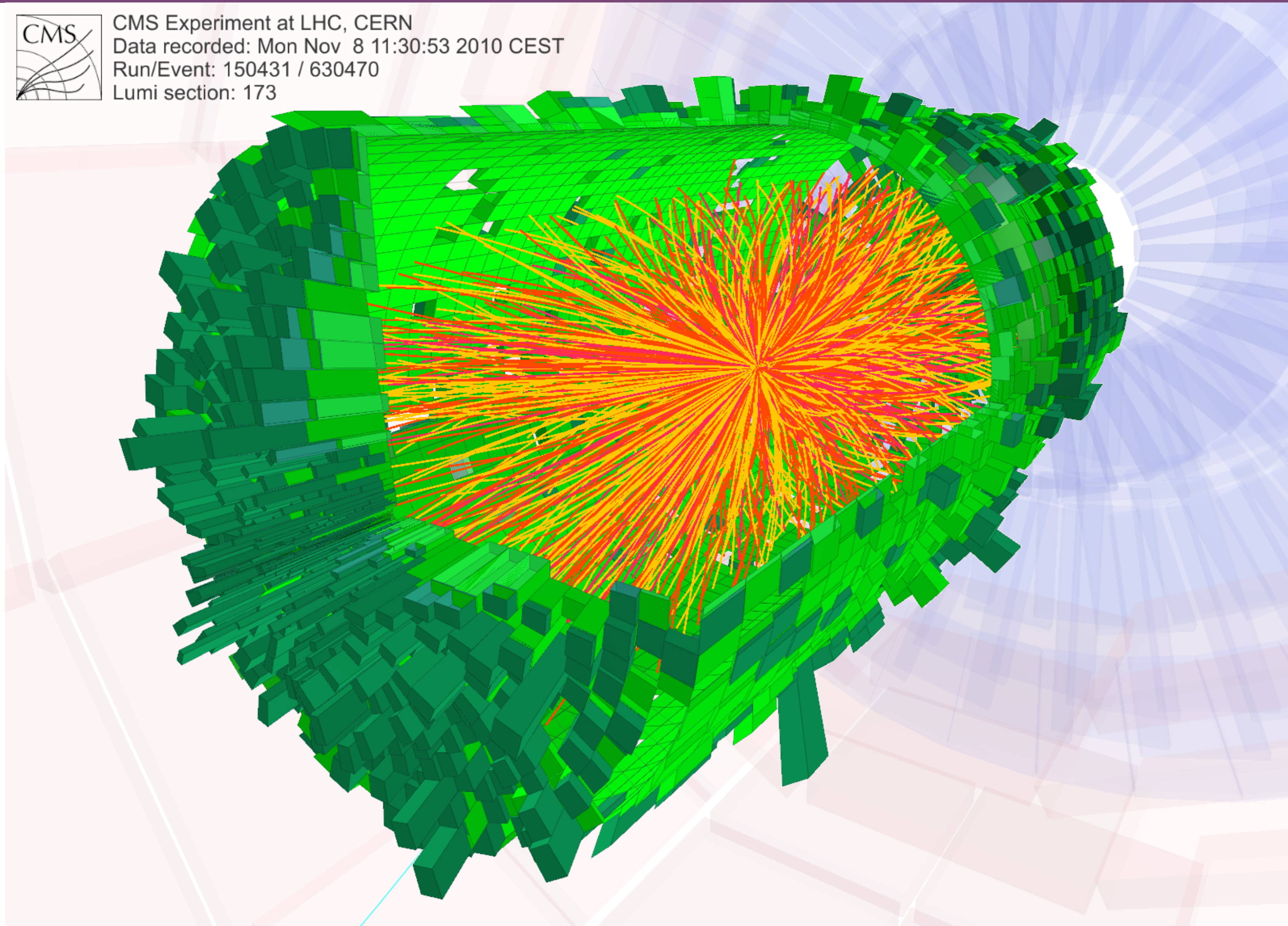
+ Outlouk

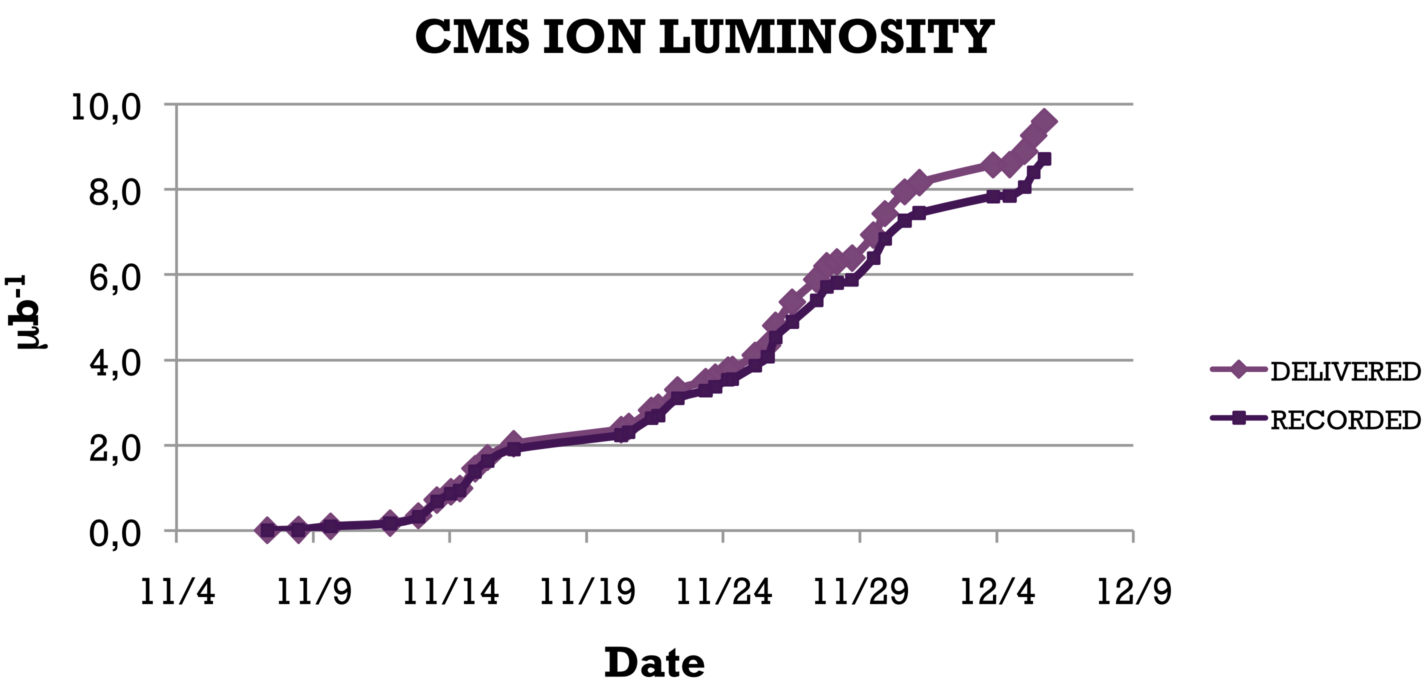
- Data taking, CMS detector and Trigger
- Di-leptons in HI
- Unbalanced jets in HI

Data taking, CMS detector and Trigger

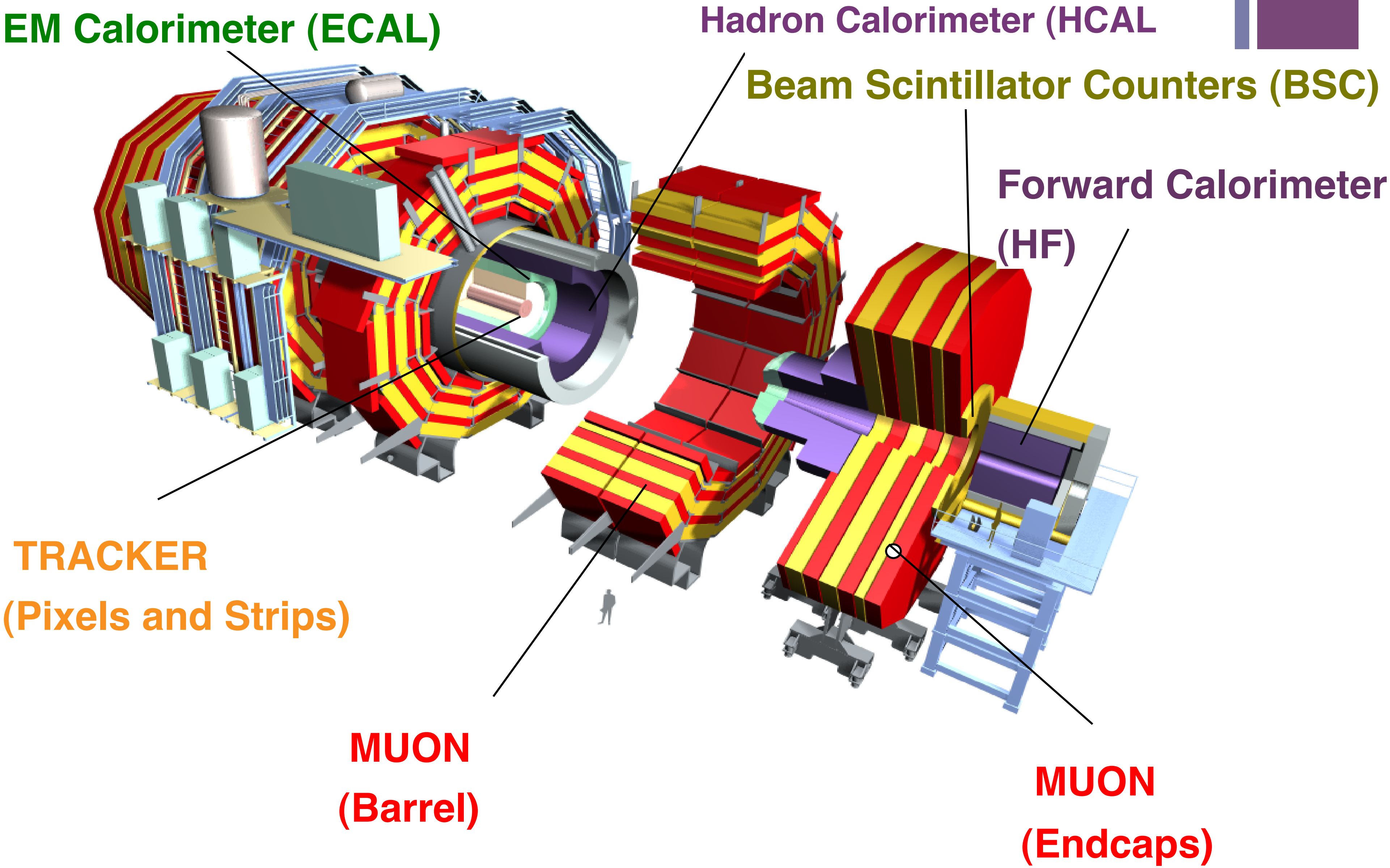


Data Taking

- 8 November, first Pb-Pb collisions **at 2.76 TeV**
- A factor 14 comparing to RHIC energies
- Recorded luminosity : 8.72 μ b^{-1}

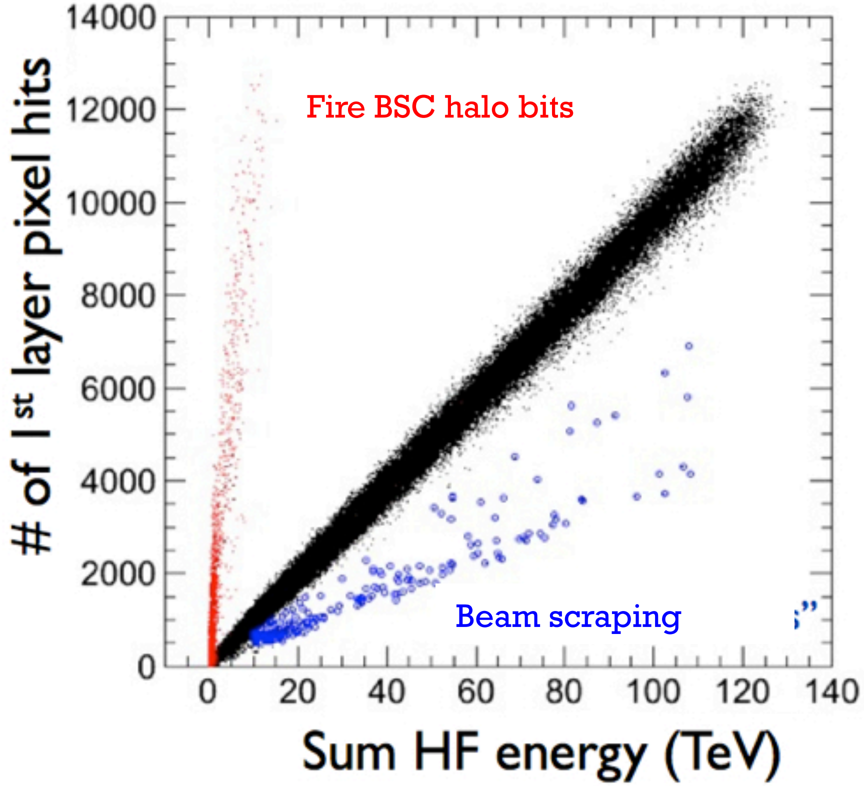


CMS Detector

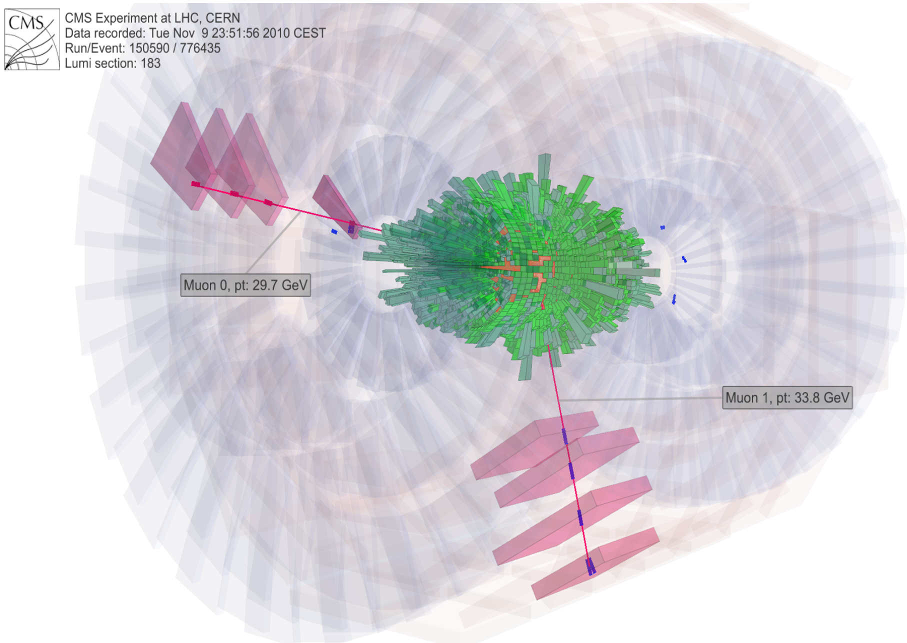


Trigger and Event selection

- Level 1 trigger
  - Coincidence of two scintillator counters or coincidence of two HF towers
  - Muons
- High Level Trigger : Jets, Muons, Photons
- Offline
  - Veto on scintillator beam halo
  - At least 3 HF towers on each side above a threshold (E > 3 GeV)
  - Reconstructed pixel vertex with two or more tracks
  - Beam-scraping removal with pixel cluster vertex compatibility

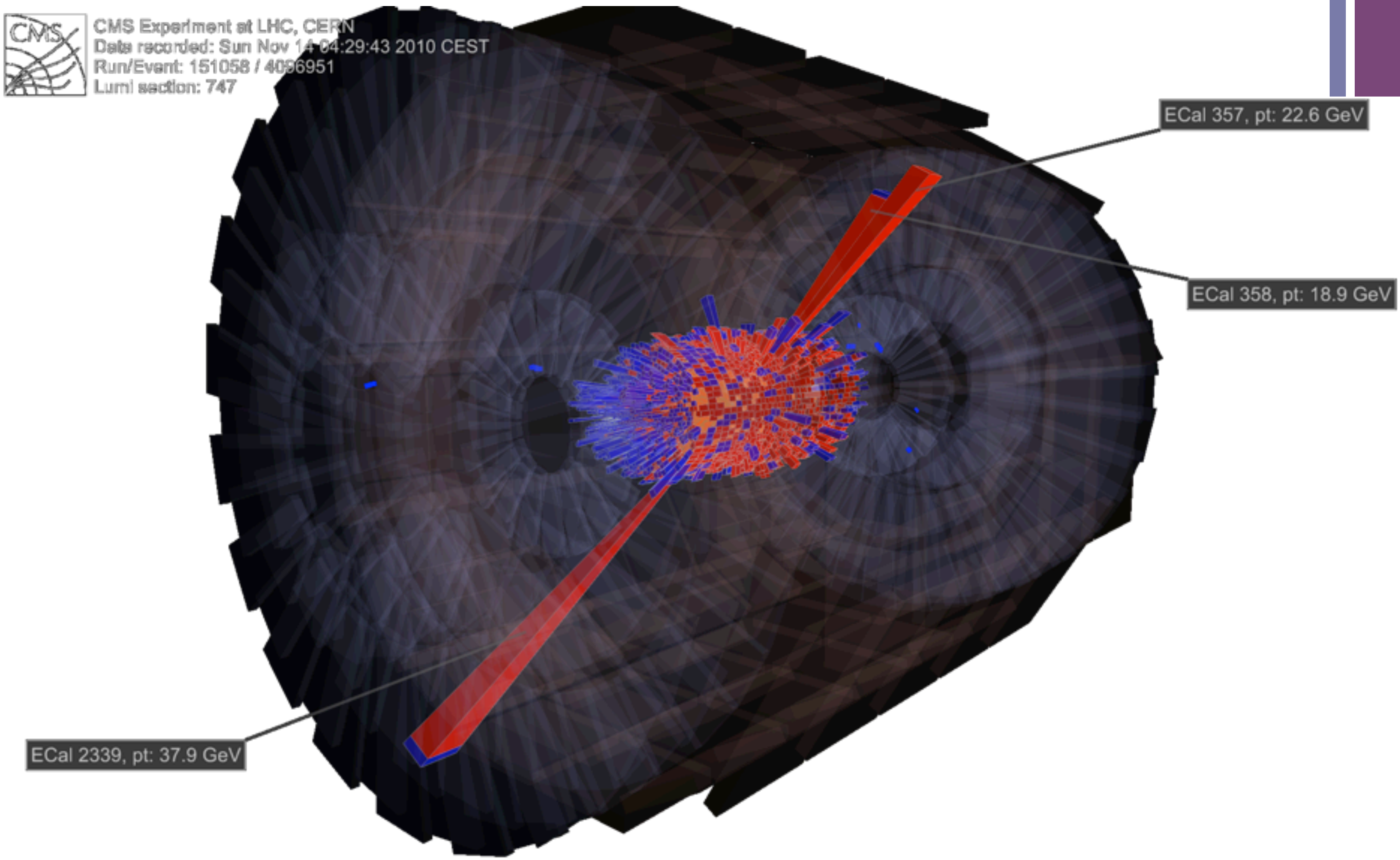


Di-leptons in HI

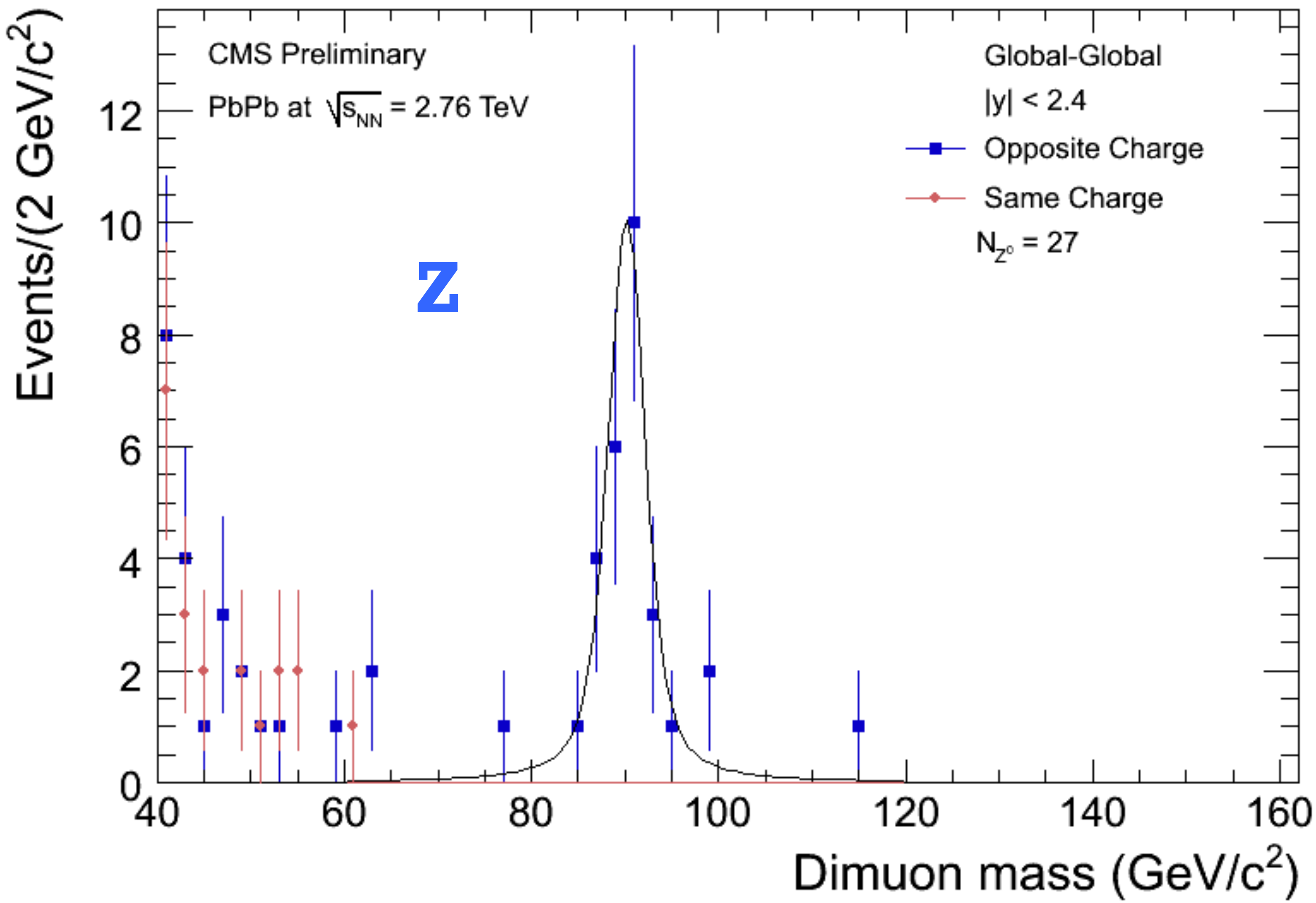


- Motivation
- $J/\psi, \Upsilon \rightarrow \ell^+ \ell^-$ measurement is a good probe for QGP
- At RHIC J/ψ suppression is not well understood and only about 100 Υ observed
- $Z \rightarrow \mu^+ \mu^-, e^+e^-$ first heavy ion measurement!
  - electroweak production not affected by the medium
  - nuclear PDFs modification

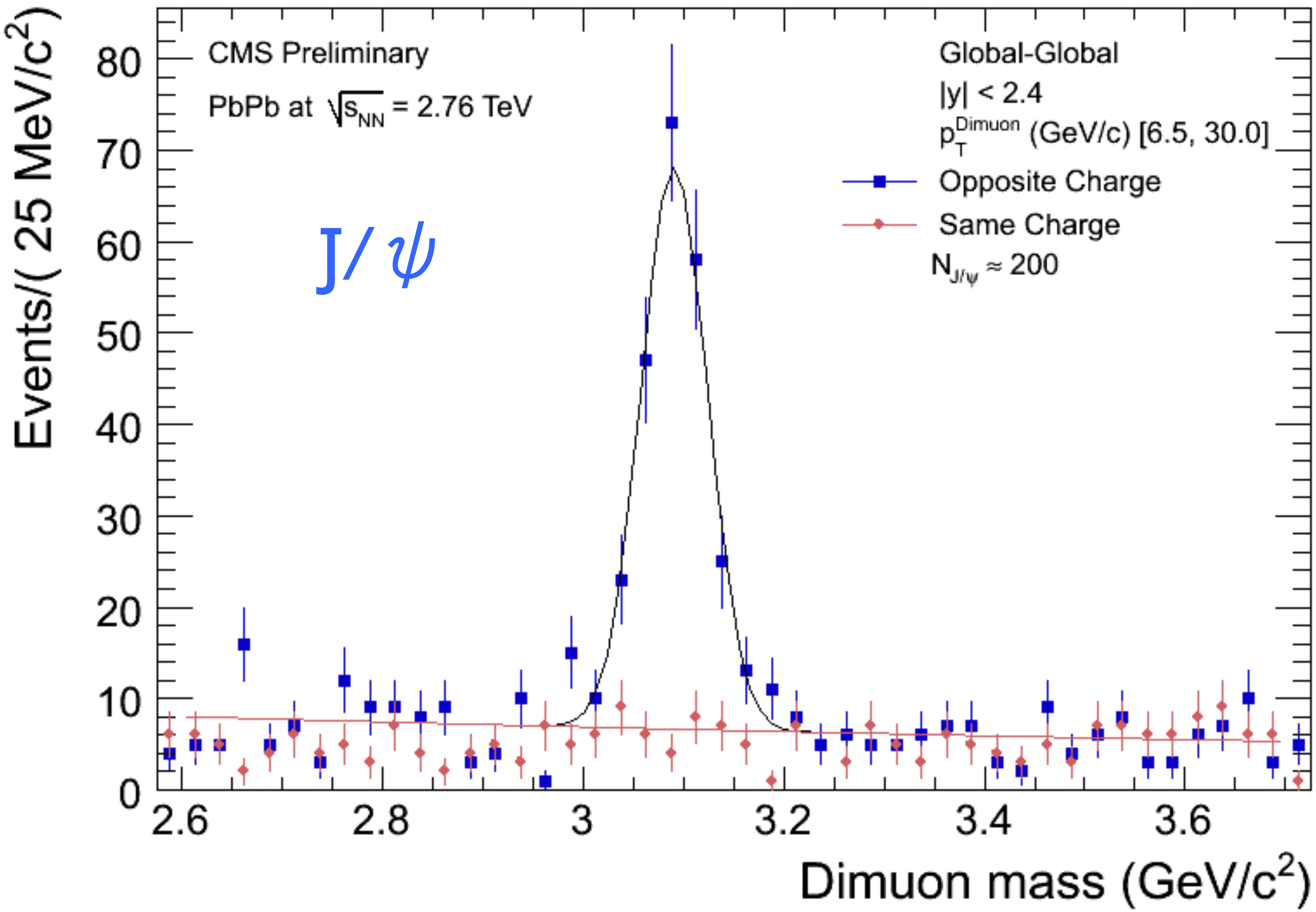
First Z ⟶ e^+e^- in HI



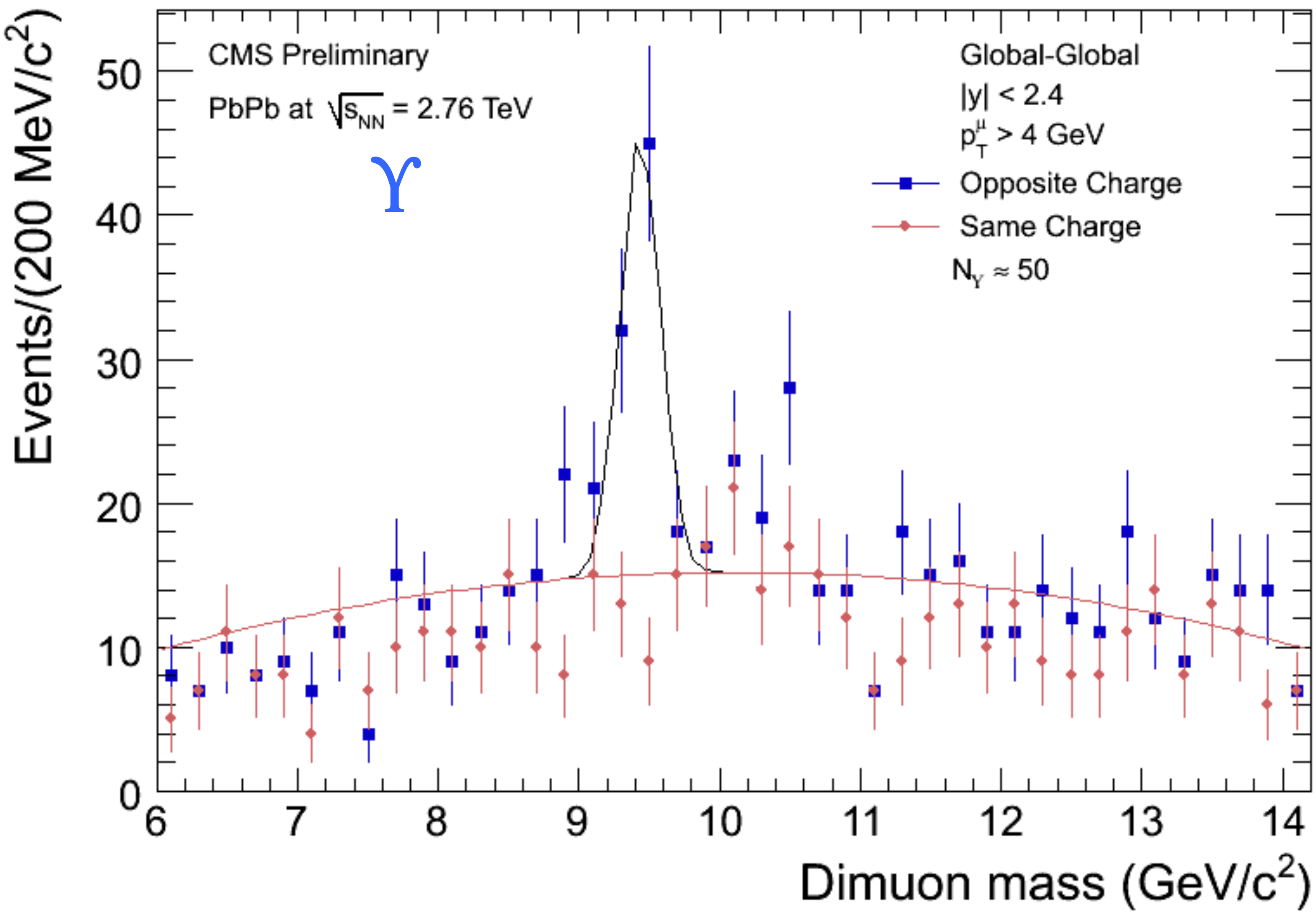
Z |y|<2.4


CMS Preliminary
PbPb at $\sqrt{s_{NN}}$ = 2.76 TeV
Global-Global
|y| < 2.4
Opposite Charge
Same Charge
N_{Z^0} = 27
Z
Events/(2 GeV/c^2)
Dimuon mass (GeV/c^2)
0
2
4
6
8
10
12
40
60
80
100
120
140
160

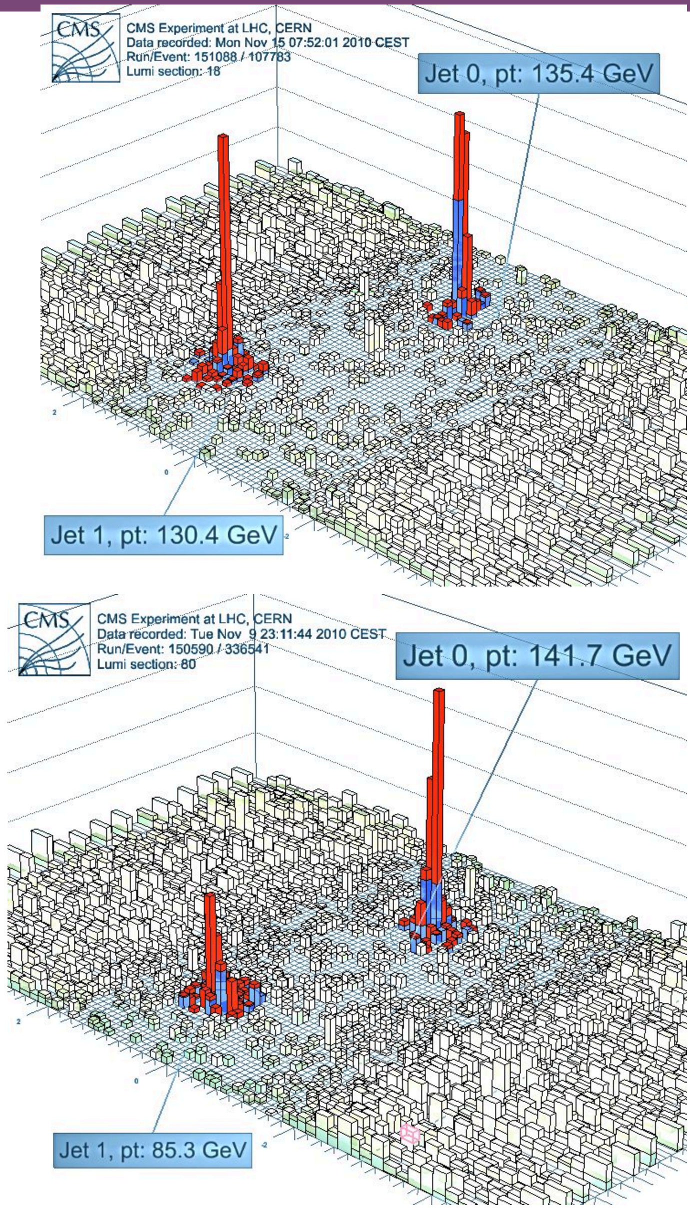
J/ψ : |y| < 2.4 $p_T^{\mu\mu}$ [6.5,30] GeV/c



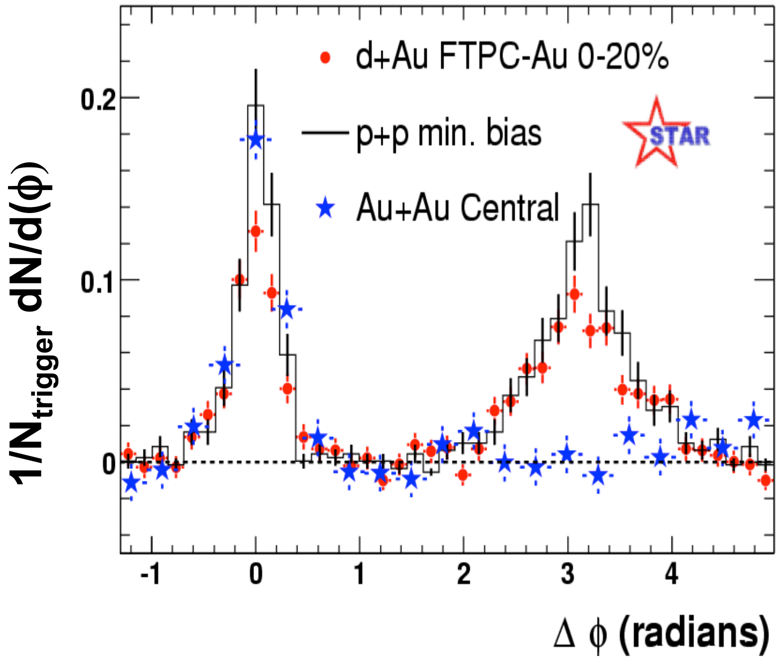
+ Υ : $|y|<2.4$ $p_T^{\mu} > 4$GeV/c



Dijet event candidates in CMS



- Motivation
  - Clear effect of jet quenching seen at RHIC



Reconstruction of Jets in HI collisions

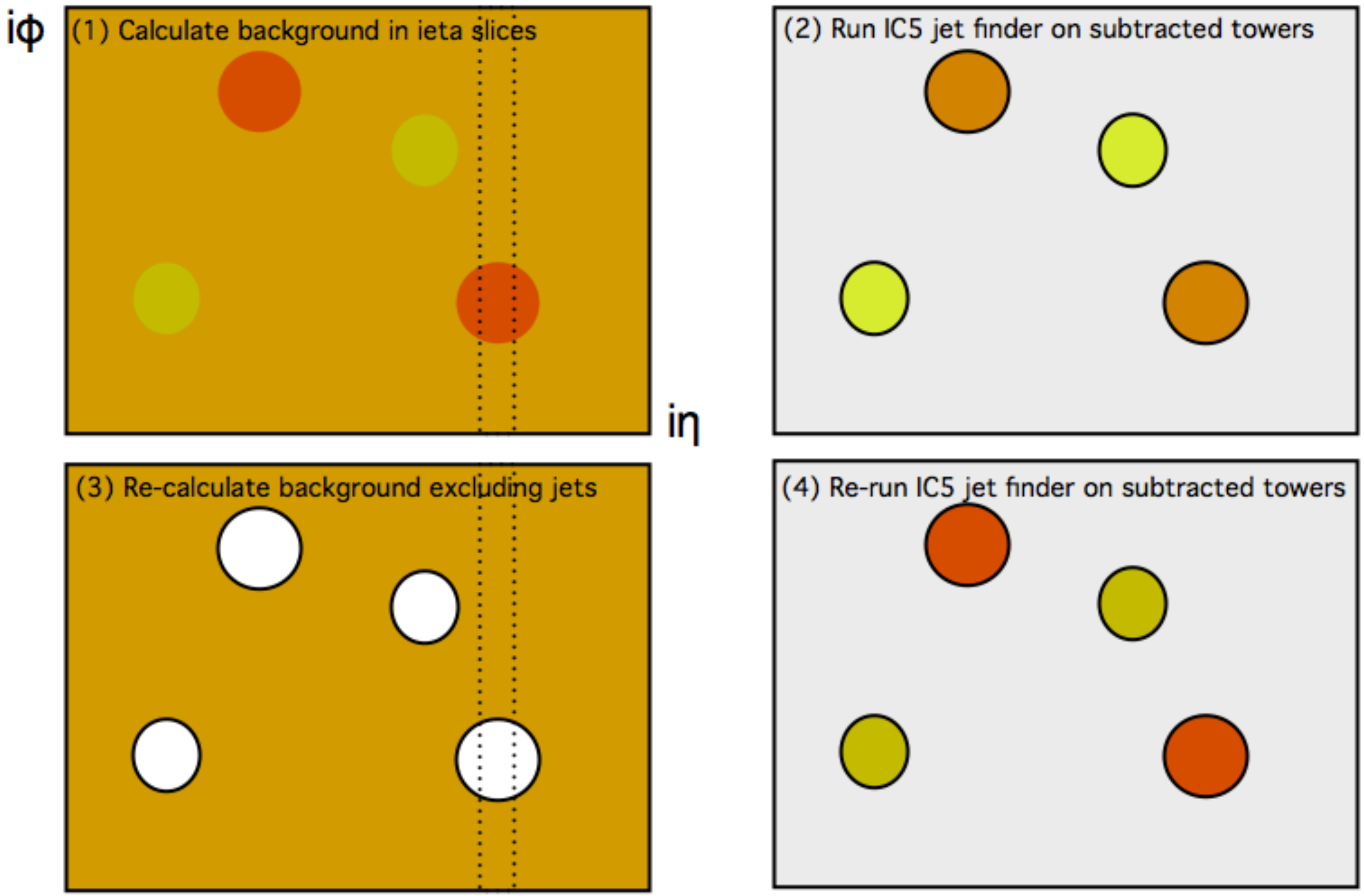
- Background subtraction

- Centrality

- Different sets of detectors to reconstruct jets
  - Calorimetric Jets: use ECAL and HCAL
  - Particle Flow Jets: use Tracker and Calorimeters

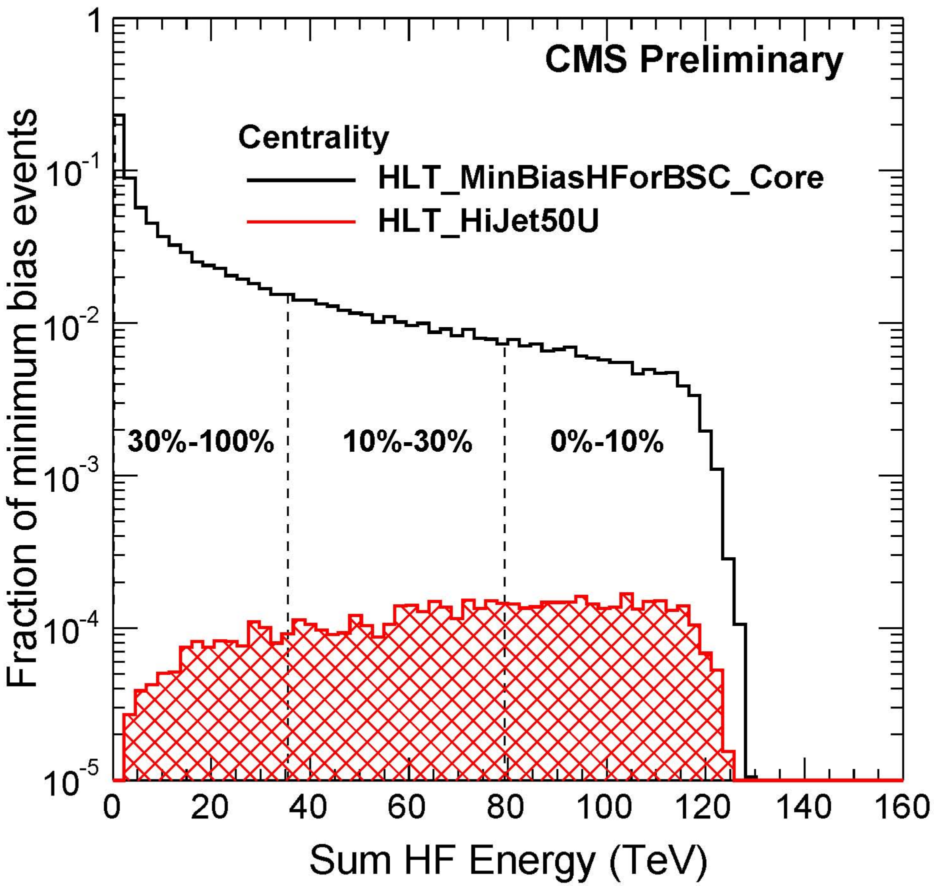
- Jet finding algorithms
  - Iterative Cone (R=0.5)
  - Anti-k_T (M. Cacciari, G. P. Salam, G. Soyez, JHEP 0804:063,2008.)
  - In HI: IC5 CaloJets with iterative background subtraction (O. Kodolova et al., EPJC (2007))

Background subtraction



+ Centrality

- The centrality is determined by the energy deposit in the Forward Calorimeter HF
- 3 centrality bins for this study



Dijet selection

- Leading jet : $E_T^{j1} > 120$ GeV

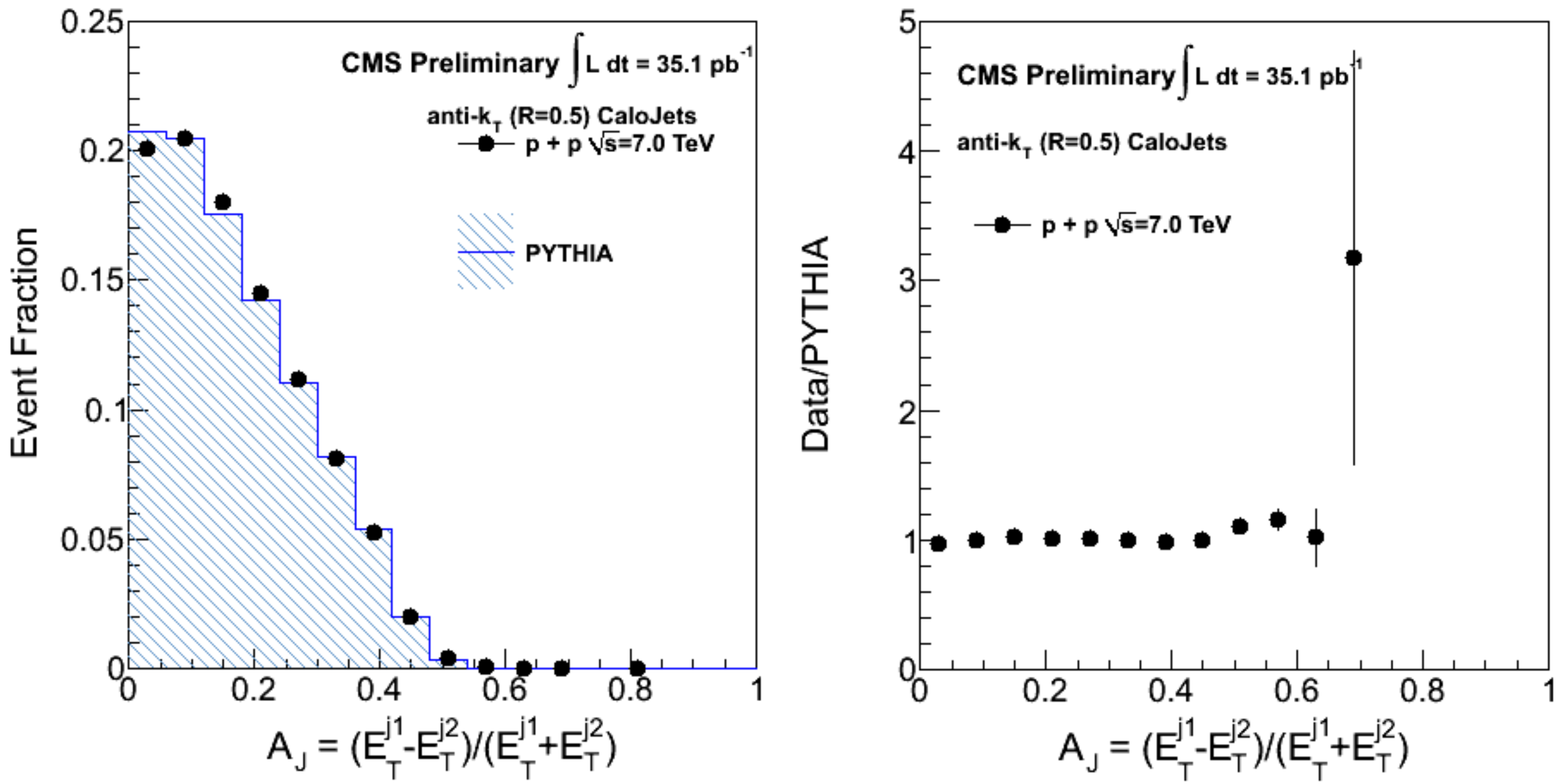
- Sub-leading : $E_T^{j2} > 50$ GeV (above background fluctuations)

- Leading and sub-leading jets with $|\eta| < 2$

- Select back-to-back jets $\Delta\phi > 2.5$

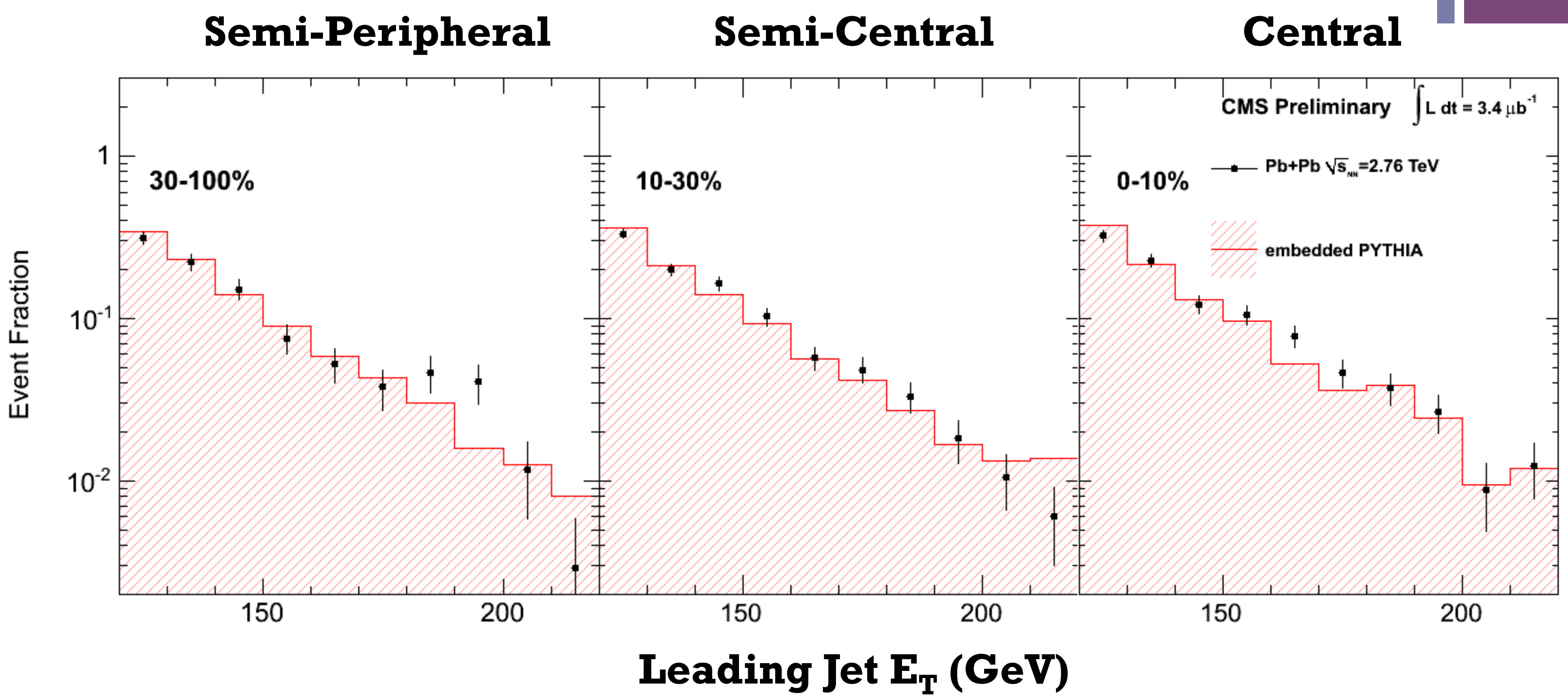
- $A_J = \dfrac{E_T^{j1} - E_T^{j2}}{E_T^{j1} + E_T^{j2}}$ is used to visualize the jet quenching

A_j in p-p collisions at 7 TeV



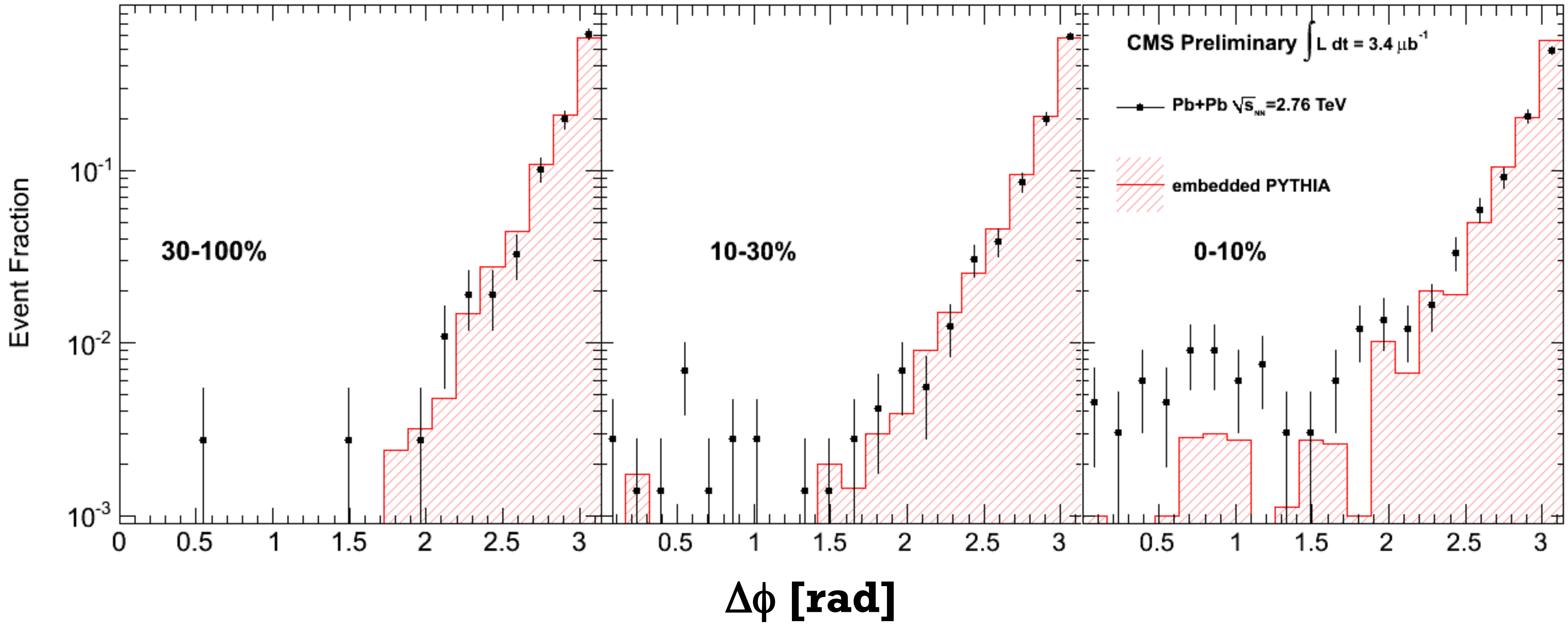
- Excellent agreement between PYTHIA and MC, we will use PYTHIA as a reference at 2.76 TeV

+ Leading Jet E_T Distributions



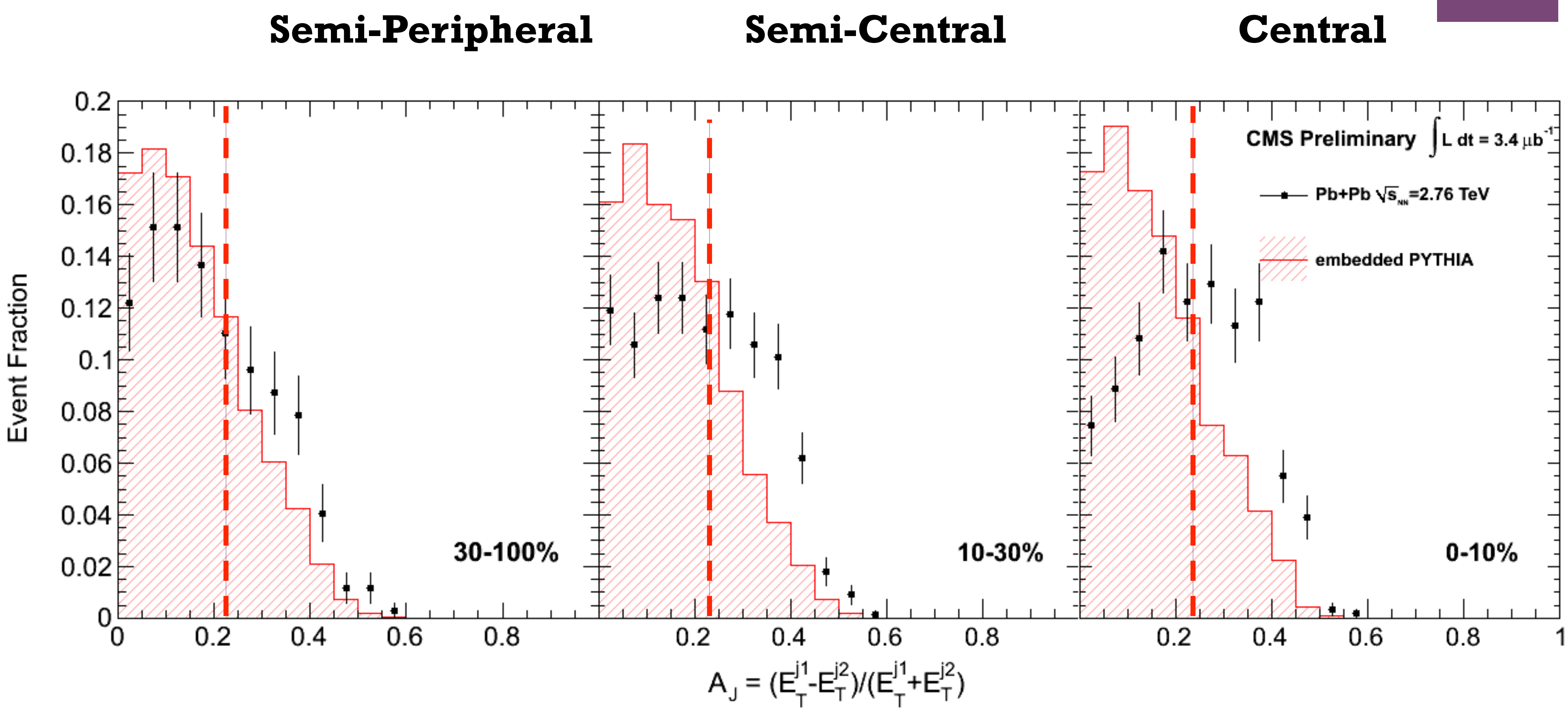
- Leading jet E_T distribution shape well reproduced by simulations

Azimuthal dijet correlation



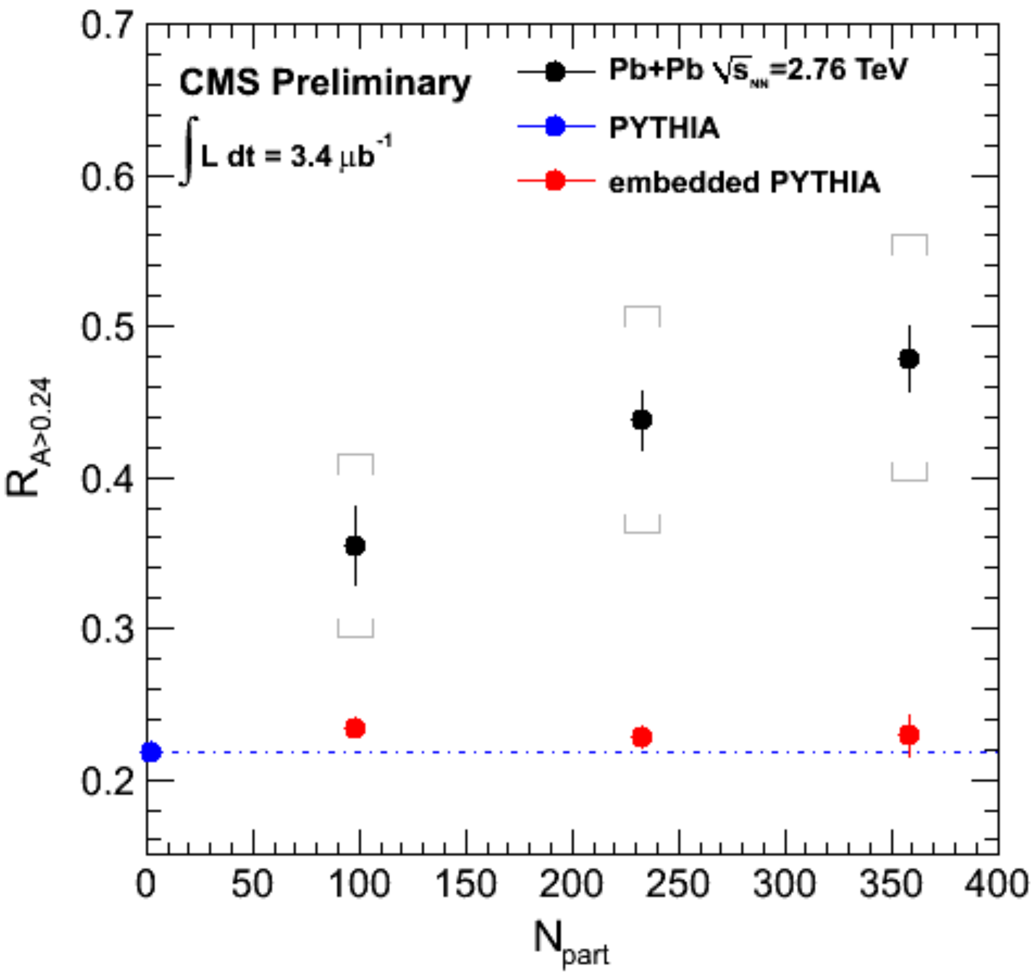
- For further studies we will focus on $\Delta\phi > 2.5$

Dijet energy imbalance



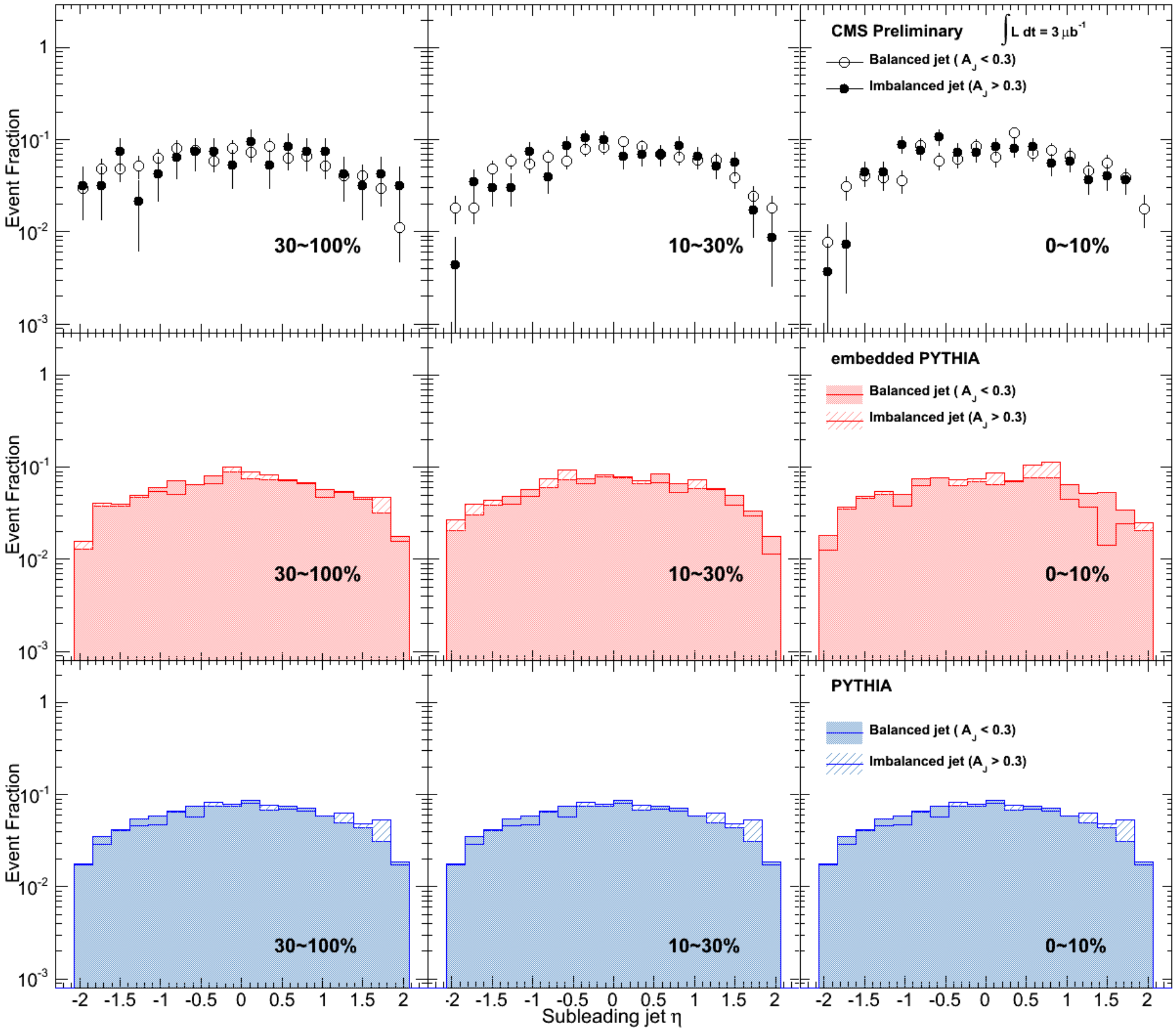
- A significant dijet imbalance, well beyond that expected from unquenched MC, appears with increasing collision centrality

Fraction of unbalanced dijets

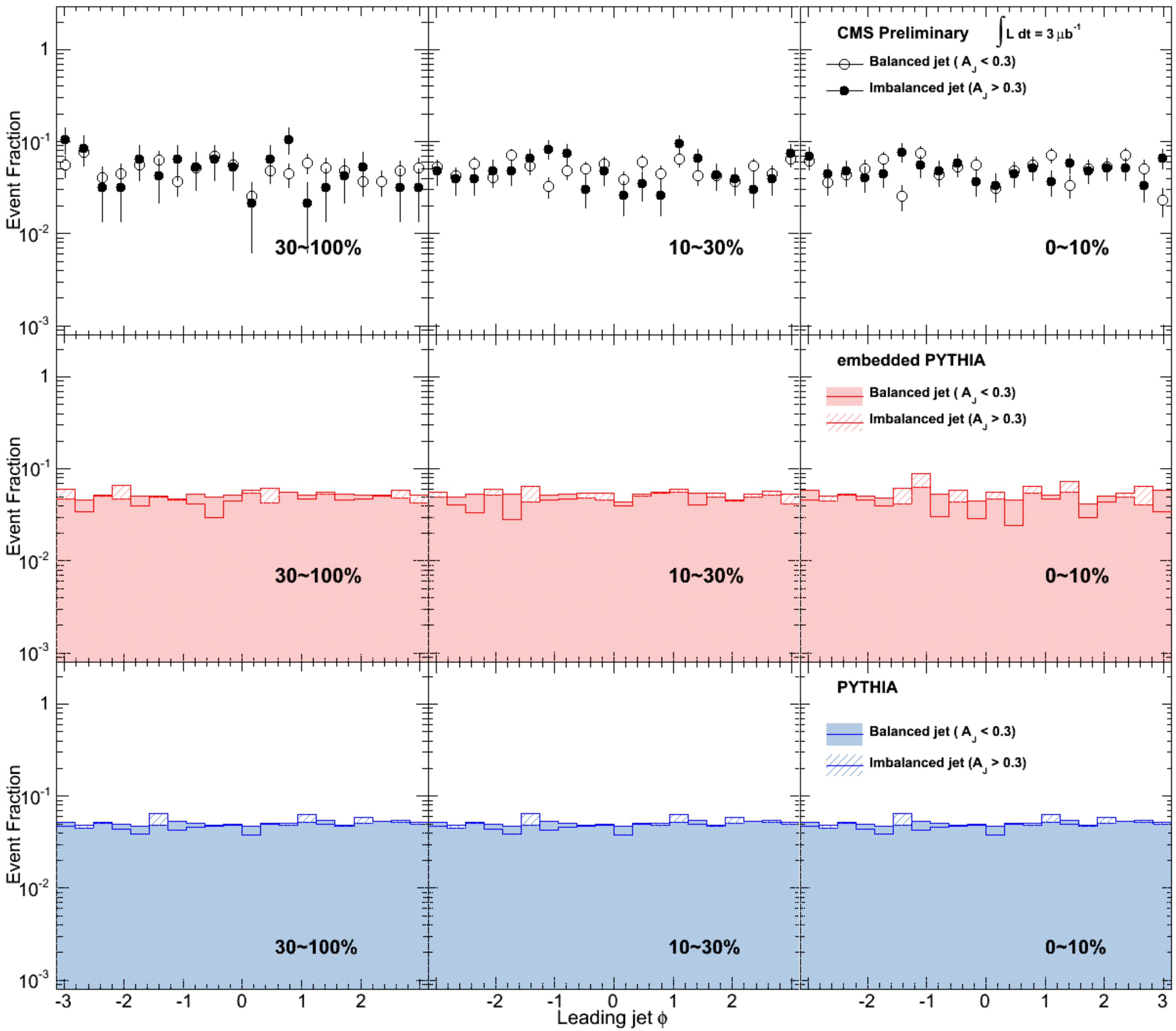


- Fraction of jets with imbalance larger than 0.24
- Plot as a function of number of participating nucleons (volume) averaged over centrality bin

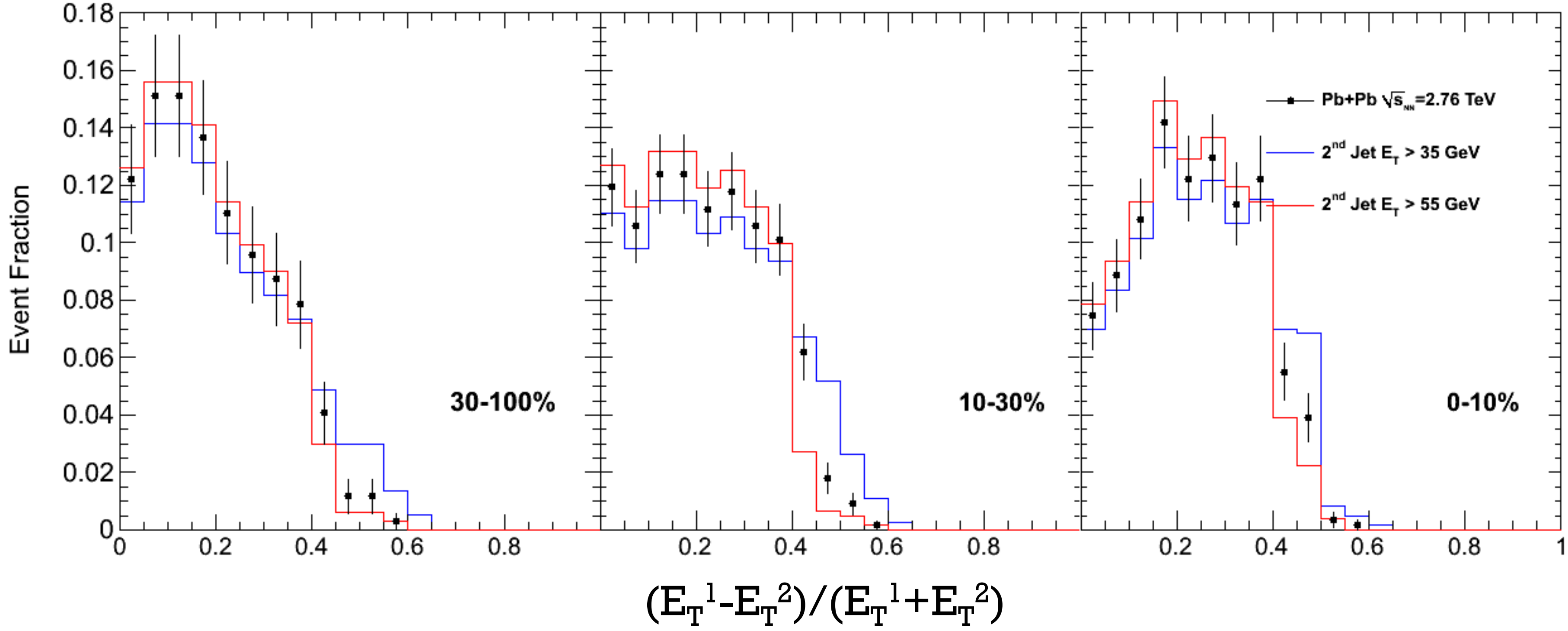
+ Imbalance uniformity: pseudorapidity



+ Imbalance uniformity: azimuth



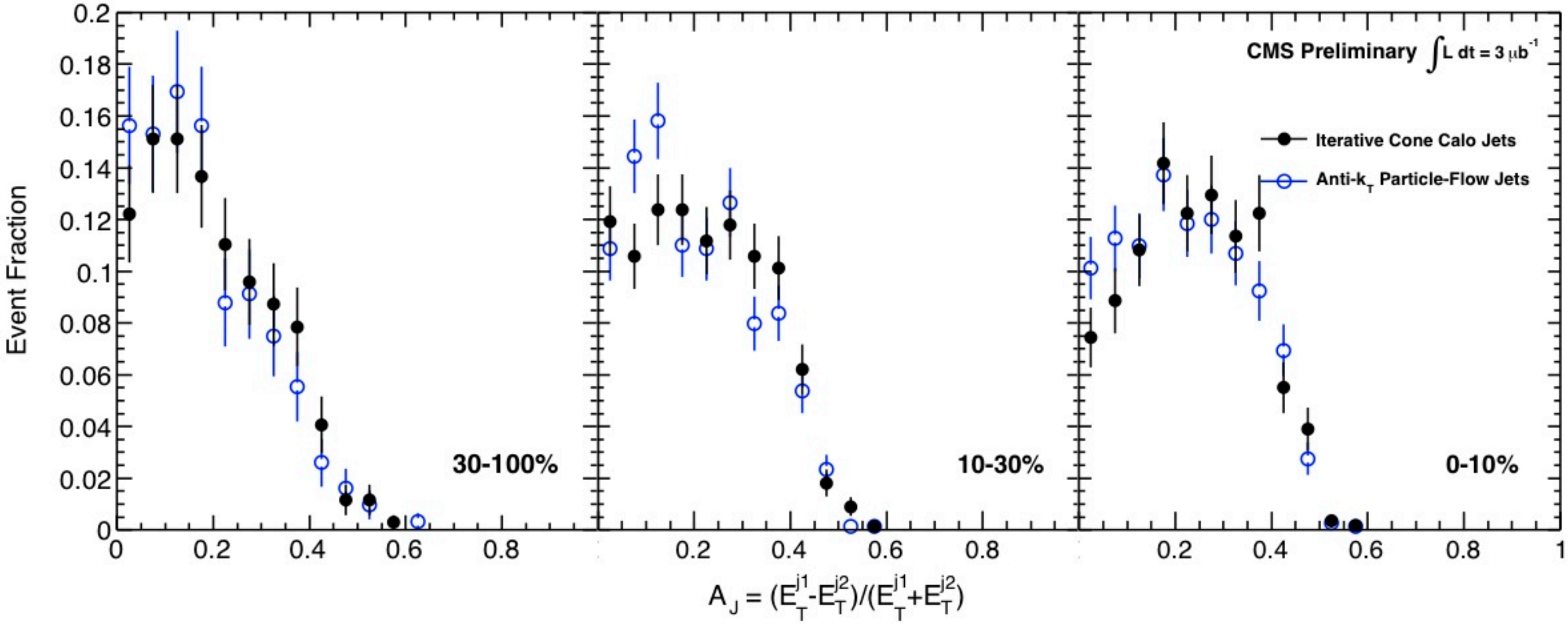
+ Varying jet cuts



- The sub-leading jet cut E_T = **35**, 50, **55** GeV

Dijet imbalance with Calo- and Particle Flow- Jets

Semi-Peripheral **Semi-Central** **Central**



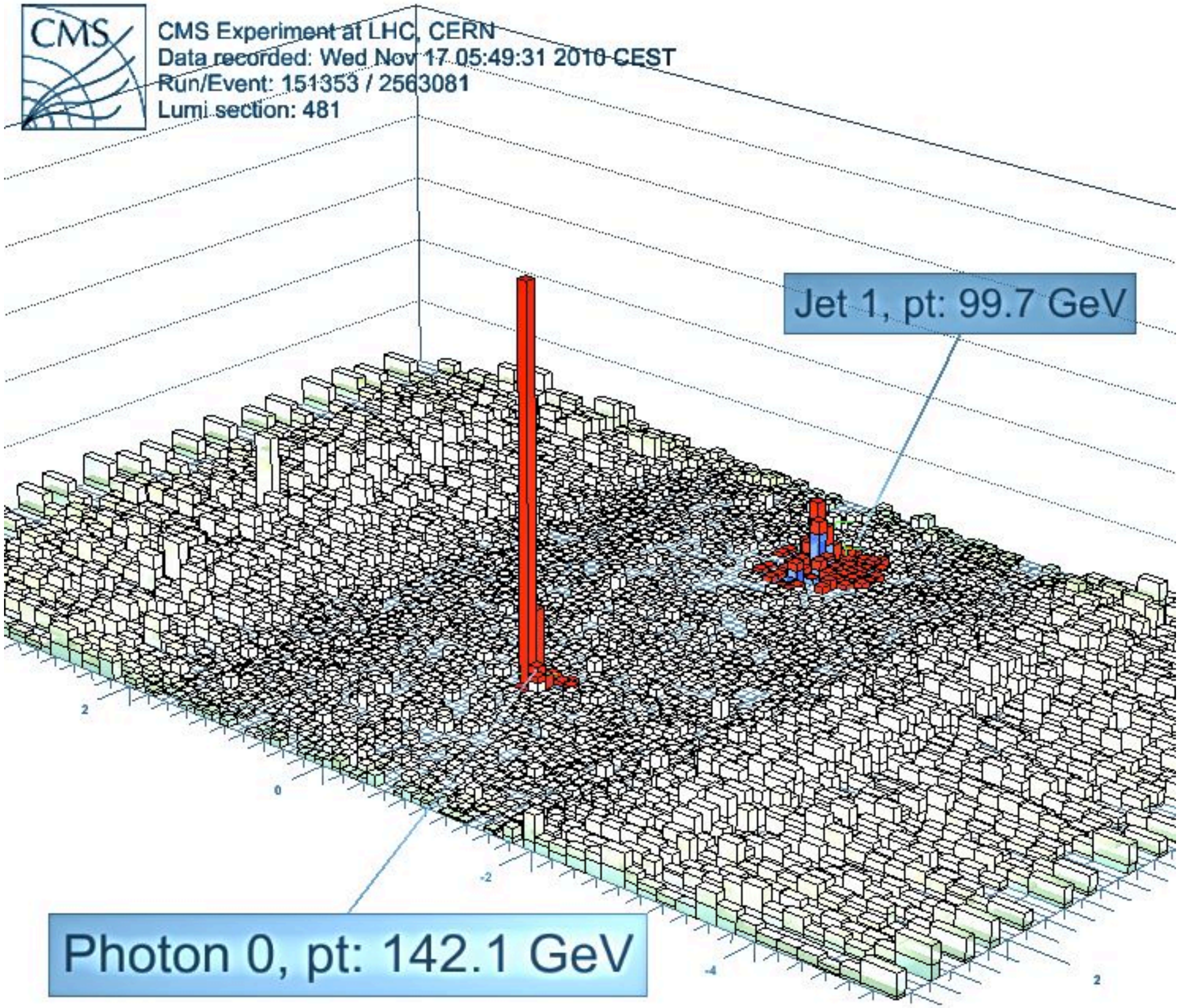
- Particle Flow: Extensive use of tracker information, different background subtraction, different jet finder algorithm
- Jet energy corrections are smaller than for CaloJets
- Excellent agreement between two very different methods

+ Conlusion

- First observation of new phenomena in heavy ion collisions
  - Z^0 production
  - Large number of dijets with unbalanced energies indicative of jet quenching

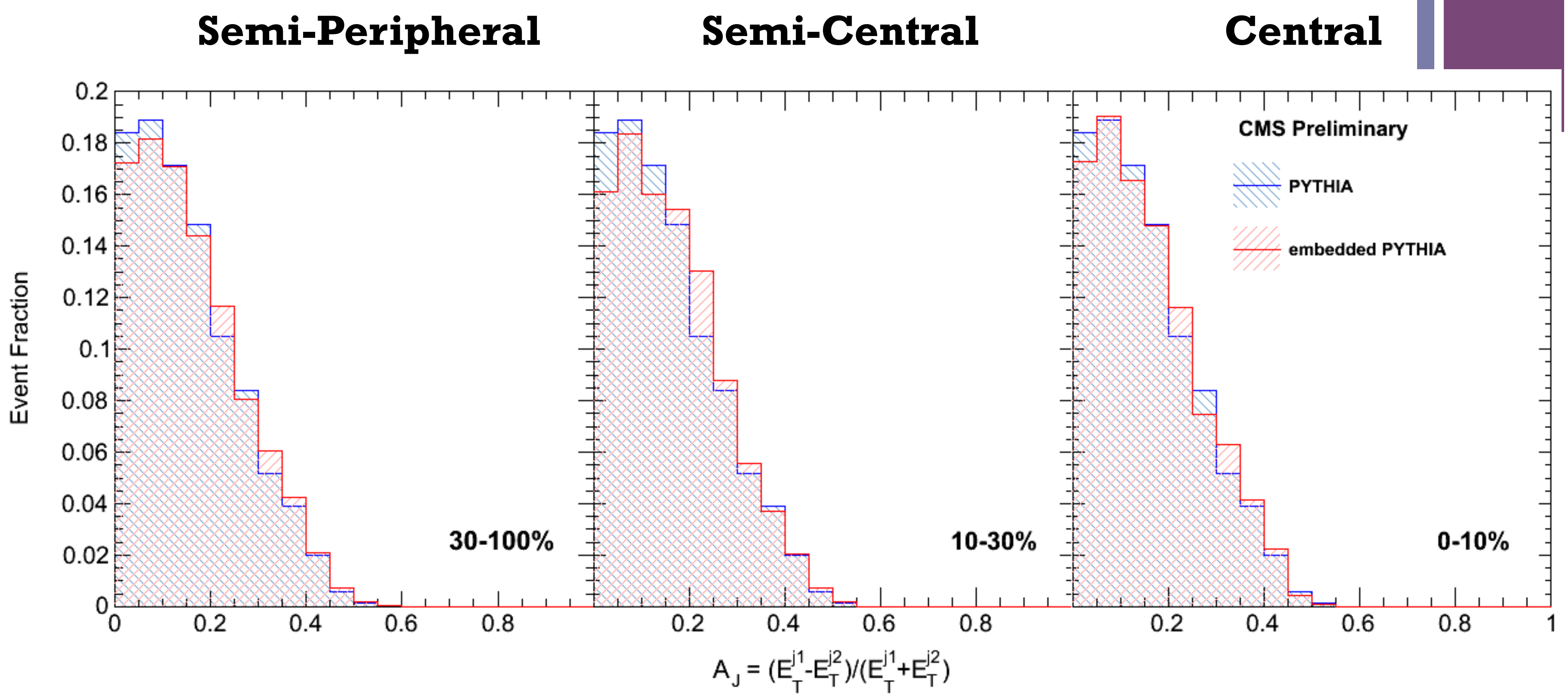
- Papers coming soon!

+ Future studies



Back-up

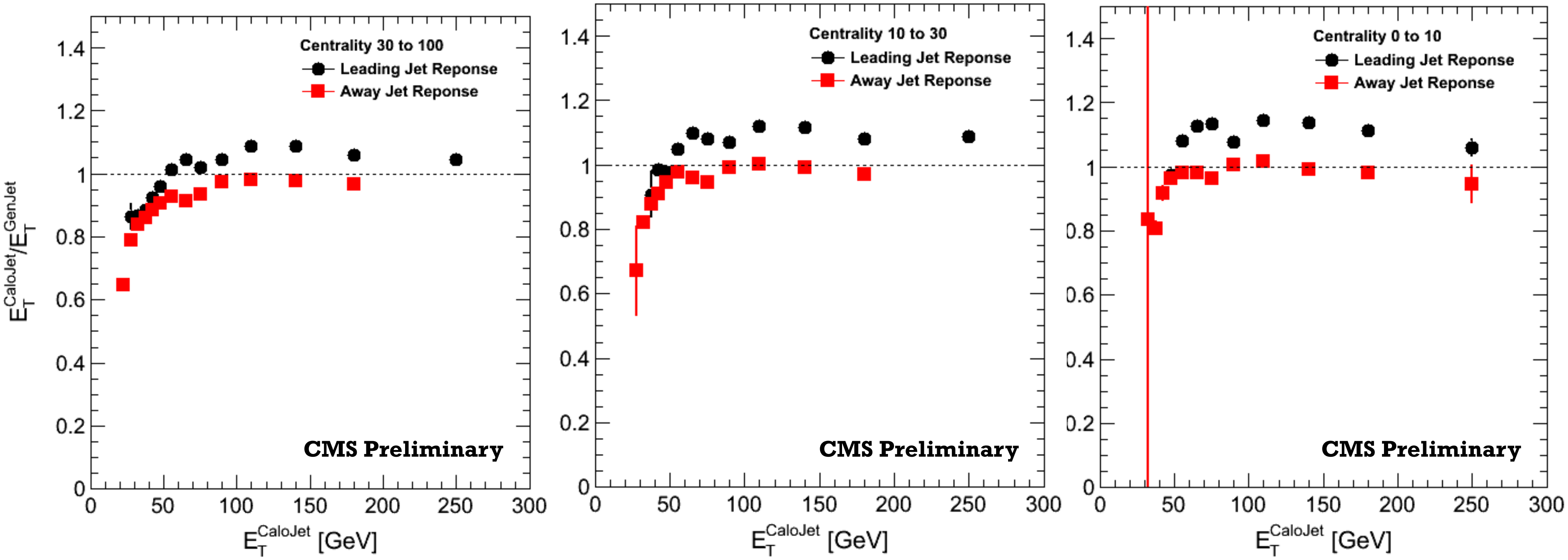
+ Influence of HI underlying event



Comparison of energy imbalance in simulation with and without embedding in data for central events

Background subtraction works really well!

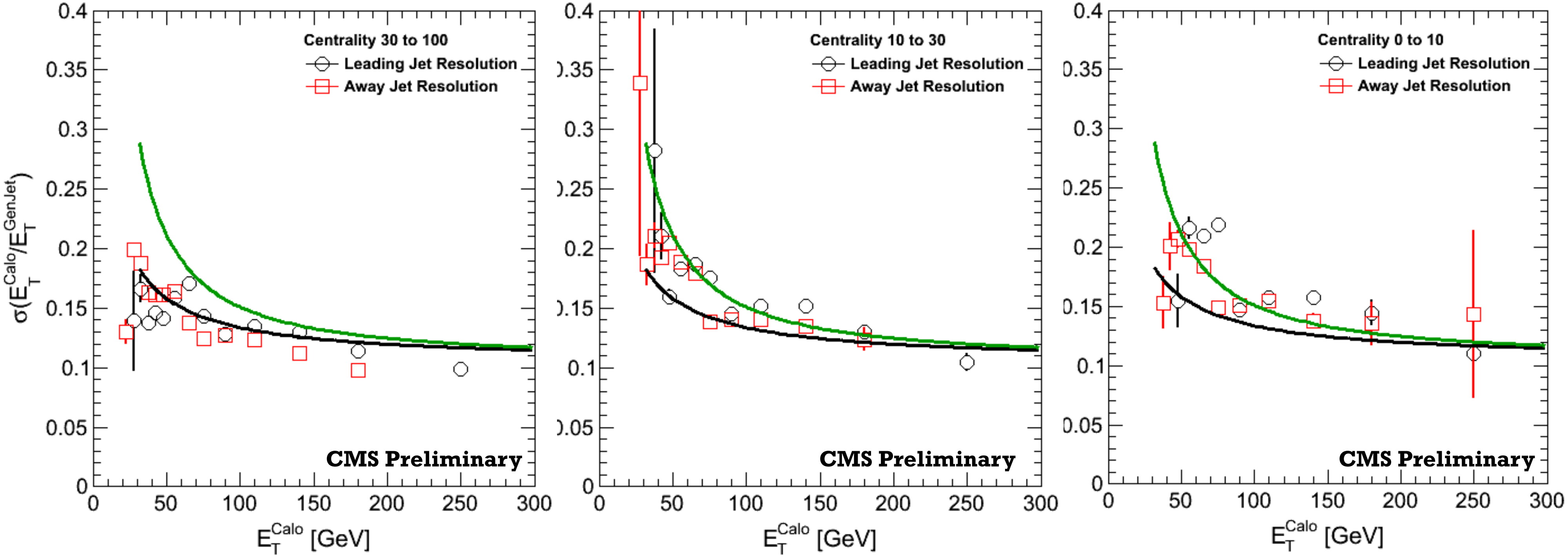
+ Jet response



- **Response of jets is influenced by the dijet selection**
- **Poorer resolution, due to the heavy-ion background, as compared to pp**

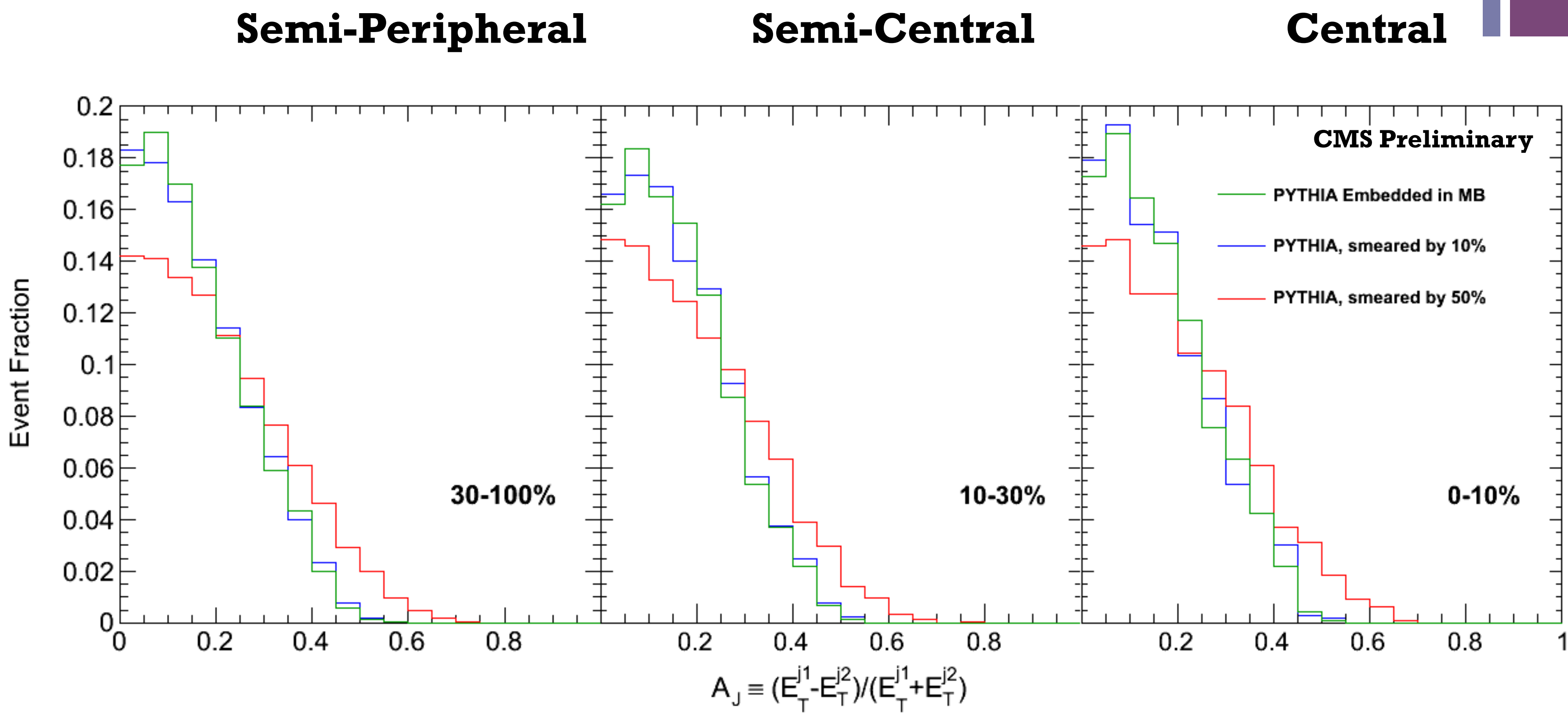
Jet Resolution

Semi-Peripheral **Semi-Central** **Central**



The resolution of jets changes due to the heavy-ion underlying event

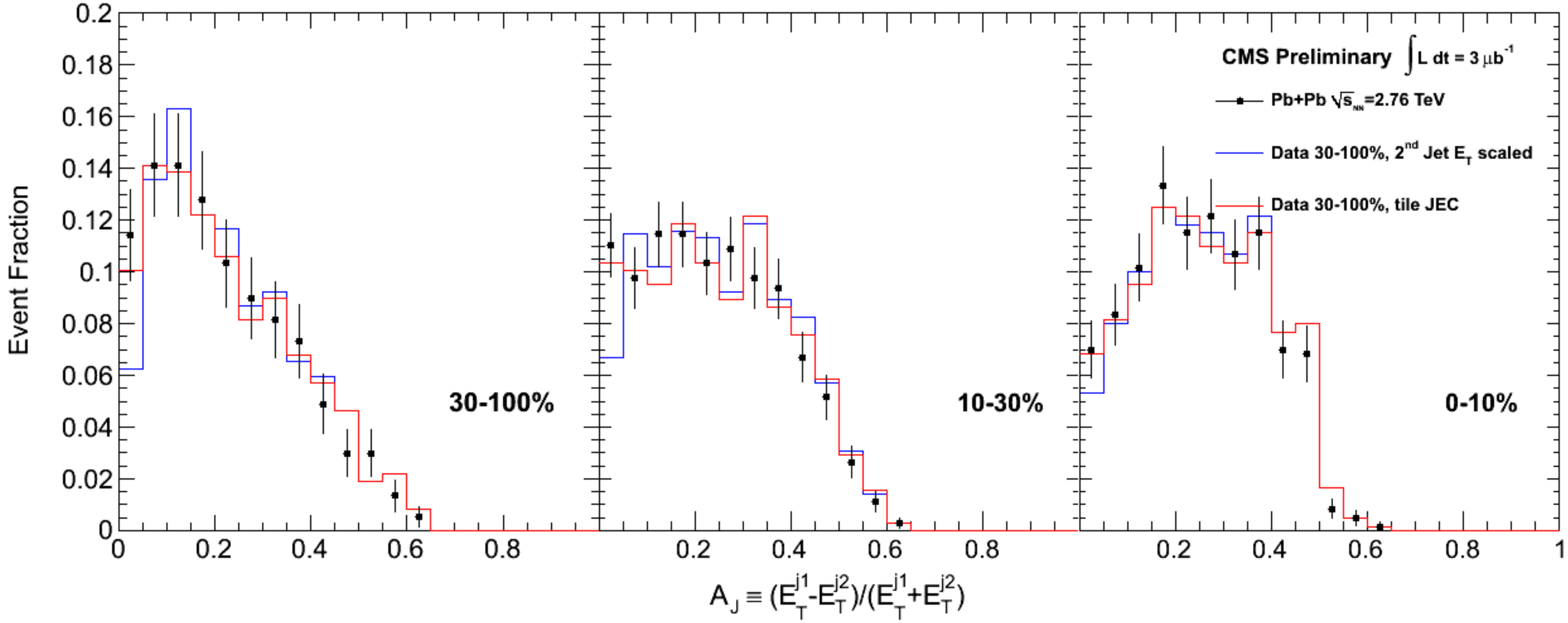
Dijet imbalance and jet energy resolution



- The jet resolution was smeared by 10 and 50% in simulation

+ Dijet imbalance and Jet Energy Scale

Semi-Peripheral **Semi-Central** **Central**



The energies of sub-leading jets were shifted up by 1 σ of the uncertainty in the correction.
The slope of the jet correction as a function of p_T was shifted by 1 σ of its uncertainty

Event statistics in this analysis

Table 2: Various selections on the data set. % values are always with respect to to the line above (the cuts are applied in sequence).

Centrality	0-10%		10-30%		30-100%		0-100%	
Cut	evts	%	evts	%	evts	%	evts	%
tree entries	20023	100.00	19156	100.00	8654	100.00	47833	100.00
L1a36 OR L1a44 (minbias)	20023	100.00	19156	100.00	8654	100.00	47833	100.00
leading jet E_T >120 GeV	976	4.87	991	5.17	419	4.84	2386	5.45
leading jet $\|\eta\|$ <2	748	76.64	841	84.86	404	96.42	1993	83.53
subleading jet $\|\eta\|$ <2	722	96.52	799	95.00	389	96.29	1910	95.84
subleading jet E_T > 50 GeV	649	89.89	721	90.24	363	93.32	1733	90.73
dphi of 2 jets E_T > 2.5	557	85.82	661	91.68	344	94.77	1562	90.13