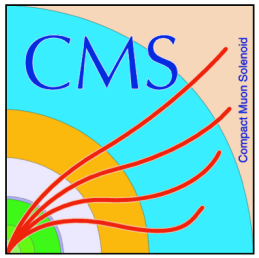
Centrality & rapidity dependence of transverse energy flow in pPb



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Quark Matter 2015, Kobe Japan
28th September, 2015

Motivation

- **Is there sufficient energy density in pPb to create a QGP?**
- **Energy density for a given overlap area *A* at a given time τ given by**

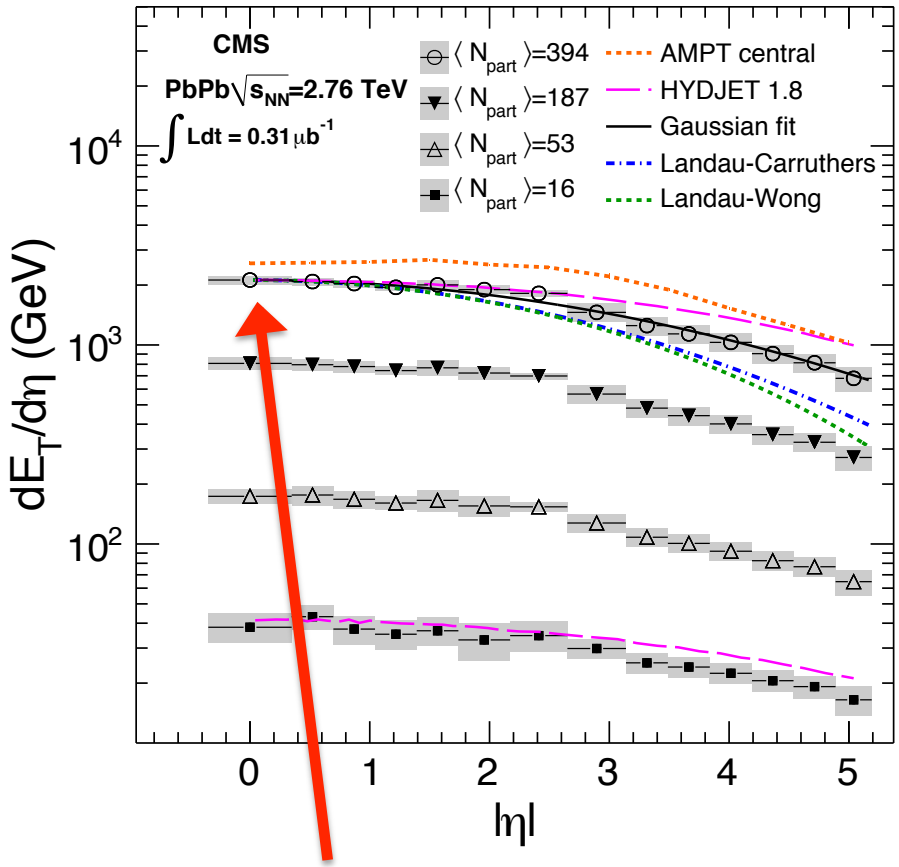
$$\varepsilon = \left(\frac{1}{\tau}\right)\left(\frac{1}{A}\right)\frac{dE_T}{dy}$$

- **Are there long-range η-correlations in E_T production?**
- **What are the auto-correlations induced by using a certain η region to define centrality?**

$$S_{PC} = E_T\left(\text{peripheral}\right)/E_T\left(\text{central}\right)$$

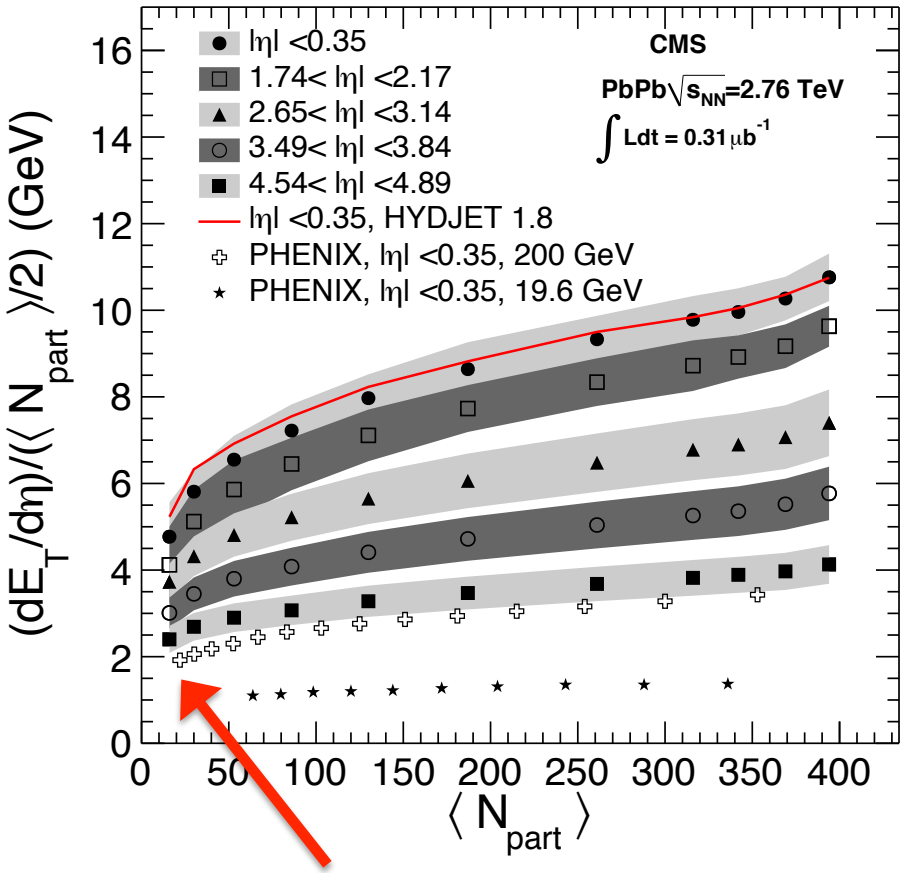
Review of PbPb $dE_T/d\eta$ results

*CMS Collaboration PRL **109**, 152303



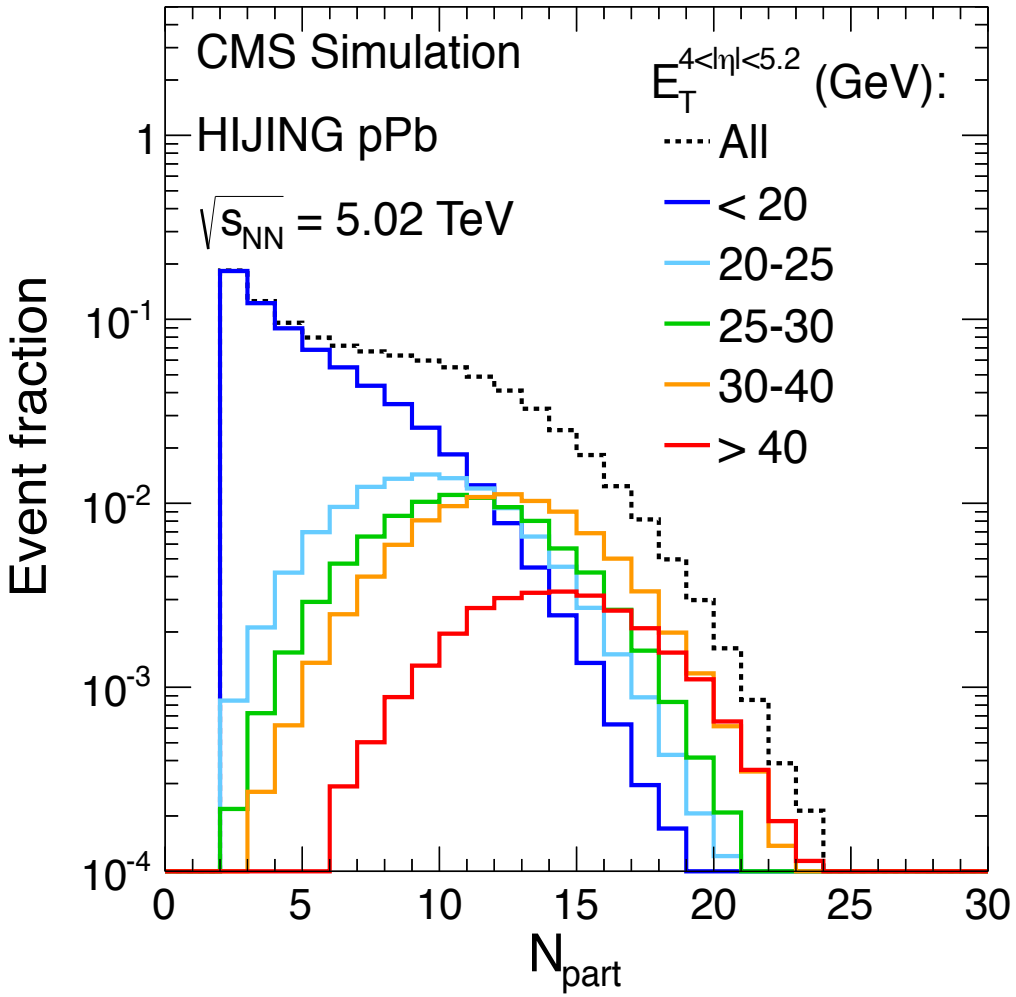
$dE_T/d\eta$ reaches 2 TeV
implying $\varepsilon\tau$ = 14 GeV/fm^3

E_T rises strongly with centrality. Centrality dependence is not a strong function of η.



pPb collisions have N_{part} <16

For pPb fluctuations in N_{part} are large



For this simulation centrality determined from E_T for $4 < |\eta| < 5$, CMS Eur. Phys. J. C 74 (2014) 2951

Since fluctuations are large, study 3 different centrality ranges

Pseudorapidity & Centrality Definition

By CMS convention the proton moves toward positive pseudorapidity. This implies that the center of mass of the pPb collision is at η = +0.45

Centrality Name	Definition
HF Double	E_T within $4 < \lvert\eta\rvert < 5$
HF Single	E_T within $-4 > \eta > -5$
N_{Track}	Tracks within $\lvert\eta\rvert < 2.4$

Trigger & Event Selection

- Level 1 Zero-bias trigger, required two beams
- The high level trigger required one track in the pixel detector with $|\eta| < 2.5$ and $p_T > 0.4$ GeV/c
- For noise studies take empty events with no beam

Calculation of E_T

$$\frac{1}{N}\frac{dE_T}{d\eta}(\eta) = \frac{1}{N}\frac{1}{\Delta\eta}\sum_i E_T^i \cdot C(\eta)$$

- N is the number of events corrected for trigger efficiency
- $\Delta\eta$ is the width of the η bin used
- E_T^j is the E_T of a given particle flow object above noise
- The Monte Carlo correction factor is defined by

$$C(\eta) = \frac{\sum_k E_T^k(\text{generated})}{\sum_j E_T^j(\text{reconstructed})}$$

Monte Carlo is weighted to have the same E_T/particle as the data and after reconstruction is subject to exactly the same cuts as data

Definition of S_{PC} ratio

$$S_{PC}(\eta) = \frac{\frac{dE_T}{d\eta}(\text{peripheral},\eta)}{\frac{dE_T}{d\eta}(\text{central},\eta)}$$

$$S_{PC}(\eta) = \frac{\sum_i E_T^i(\text{peripheral})}{\sum_j E_T^j(\text{central})} \cdot \frac{C(\text{peripheral},\eta)}{C(\text{central},\eta)}$$

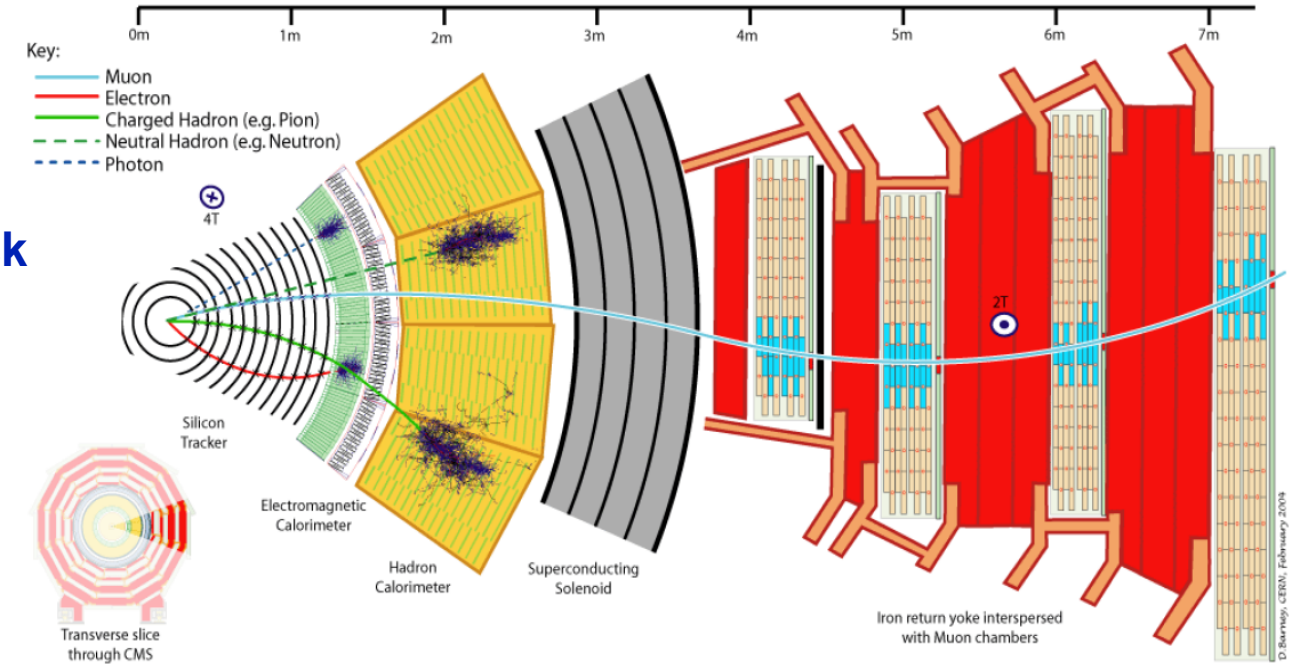
- S_{PC} captures the centrality dependence of E_T production (but with smaller systematic errors)
- Effects such as calibration or radiation cancel in the ratio
- By construction $0 < S_{PC} < 1$
- Since E_T grows faster on the Pb side than the proton side, S_{PC} rises with η as one moves from the lead to the proton side
- Definition of S_{pc} does not contain N_{part}.

Particle Flow Algorithm

- The algorithm combines tracker, calorimeter and muon information to assign all signals to one of 5 particles types
- All tracks and calorimeter signals are assigned to one of 5 particle types

1. Muons
2. Electrons
3. Charged Hadrons
4. Neutral Hadrons
5. Photons

- **Calorimeters signals associated with a track are removed and the energy is estimated from the track momentum**
- **Calorimeter energy is only used for the neutral hadrons and photons**



Systematic Uncertainties

- Data/MC discrepancies for spectra and particle mix **2.7%**
- Different ways of handling the noise **1.7%**
- Energy scale of the calorimeters **1.0%**
- Forward-Backward Asymmetry **2.4%**
- Residual pileup in the sample **<0.4%**

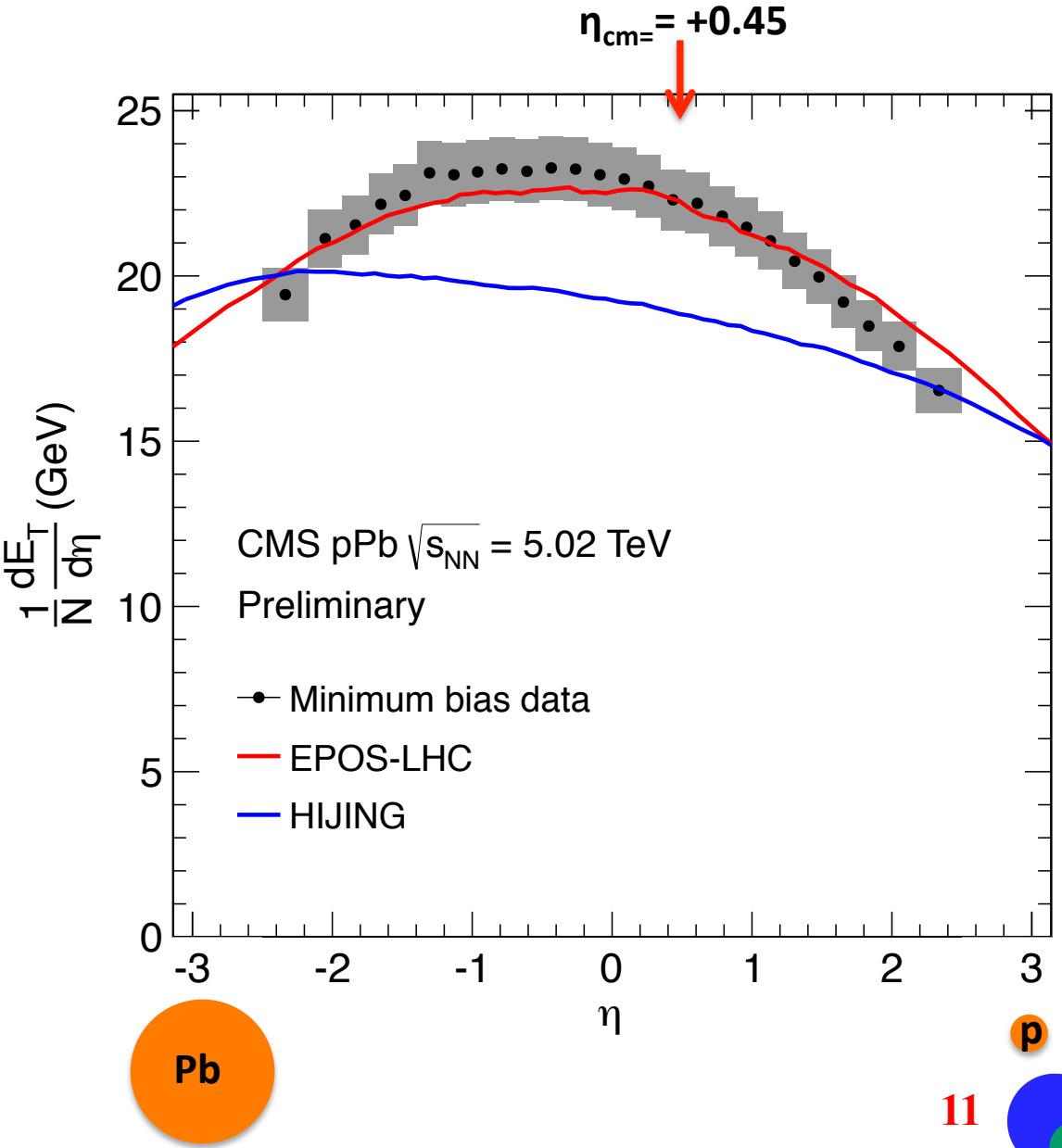
Most of these are highly correlated between different centralities and so largely cancel in S_{PC} the ratio of peripheral to central.

Results: Minimum bias $dE_T/d\eta$

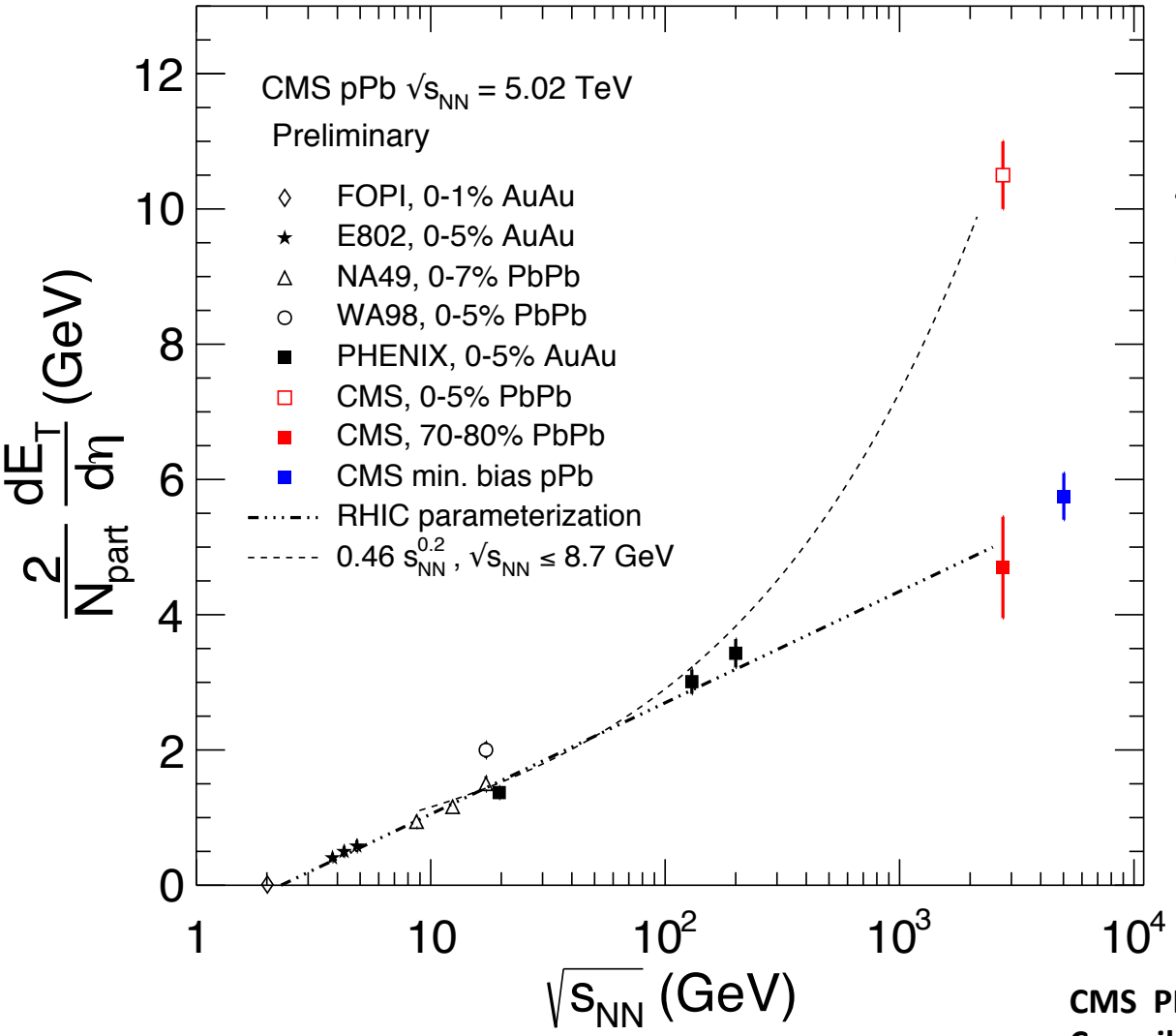
Peak $dE_T/d\eta$ = 23 GeV implies an energy density about 5/9 that of central PbPb.

Peak is shifted about one unit back from the nucleon-nucleon center of mass.

EPOS-LHC is close to data but HIJING is peaked further back



Comparison to lower energy data



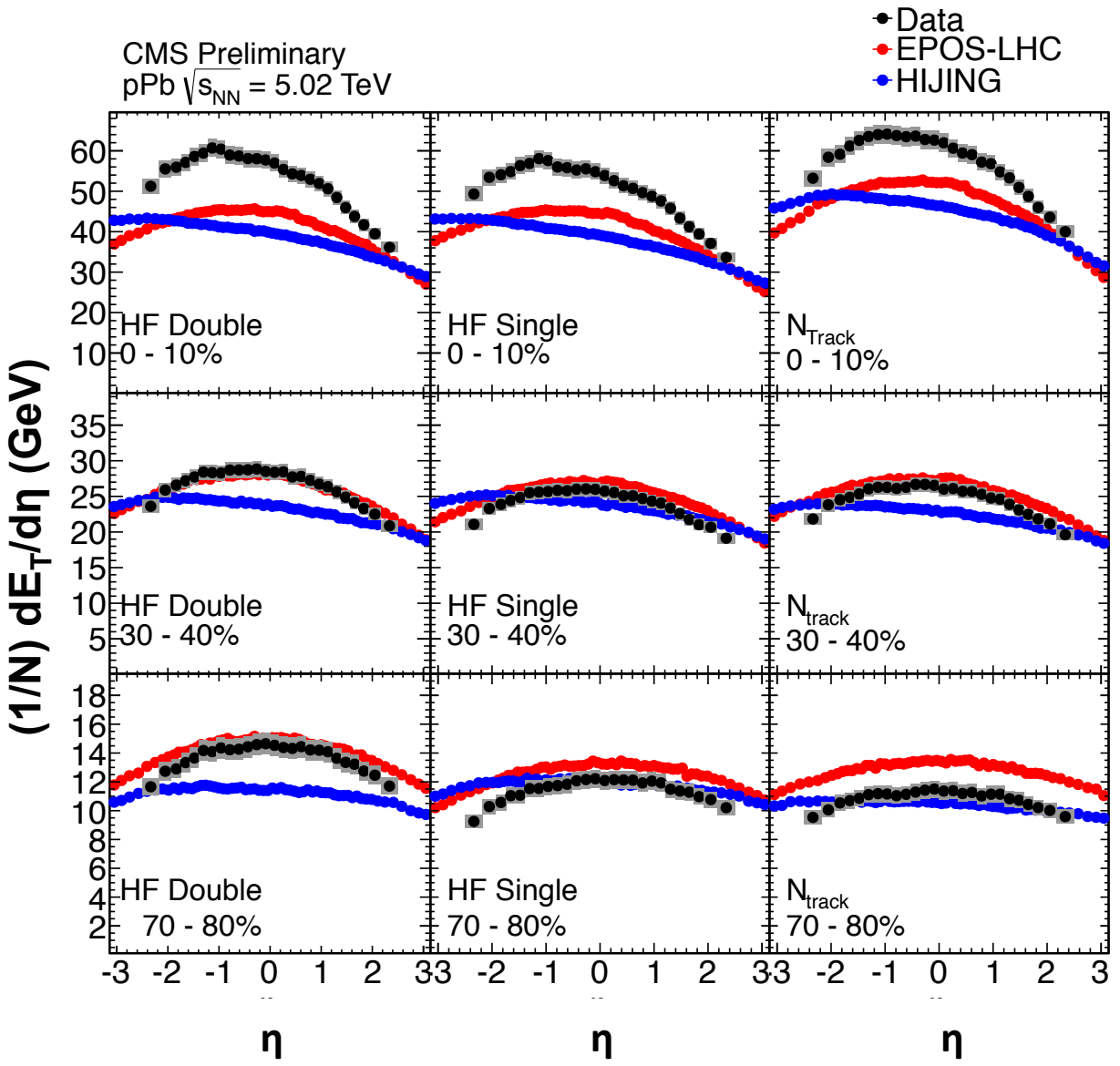
E_T per participant pair for min bias pPb is comparable to peripheral PbPb

CMS PRL 109, 152303
Compilation by PHENIX PRC 71, 034908

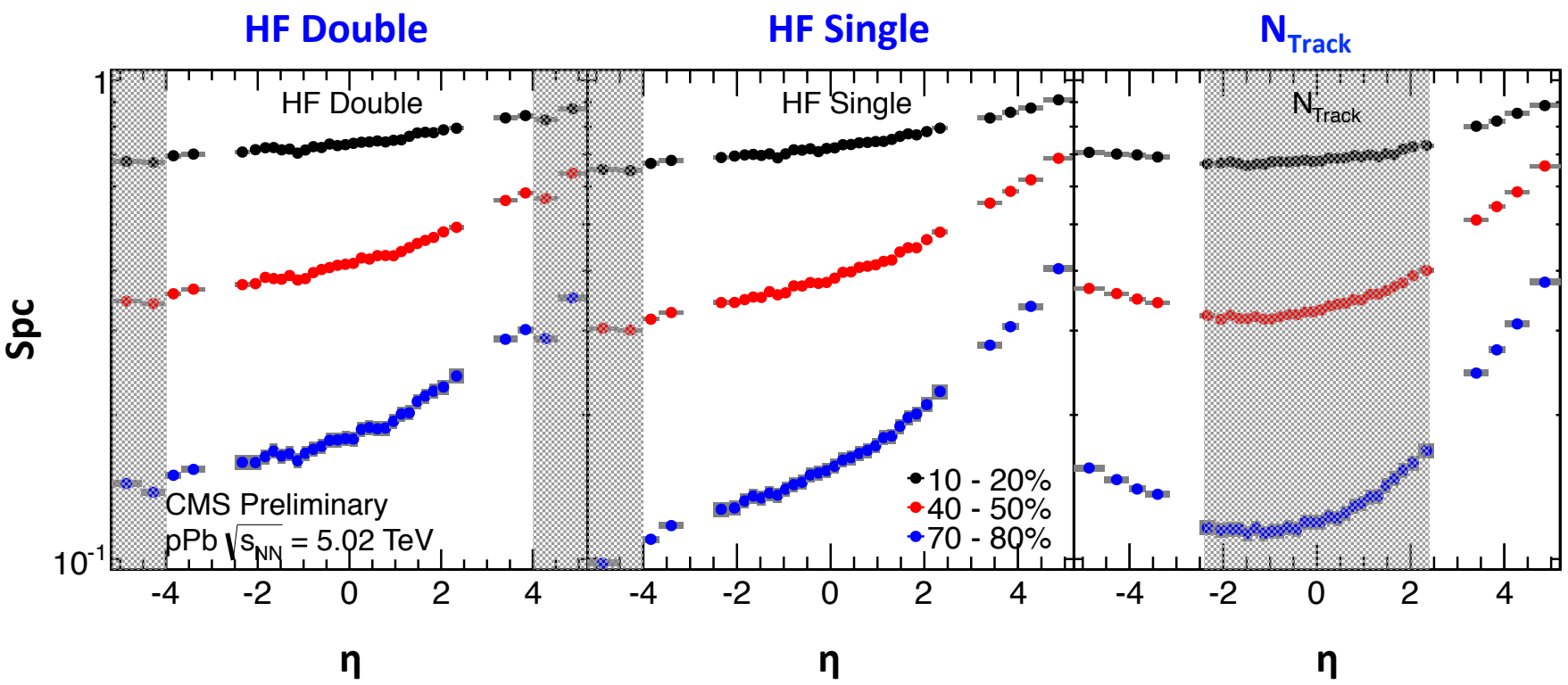
$dE_T/d\eta$ vs. η

E_T builds up faster on Pb side and peak moves backward.

For the N_{Track} definition of centrality $dE_T/d\eta$ for central events is higher at $\eta = 0$ due to the auto-correlation.



S_{PC} for three centrality definitions

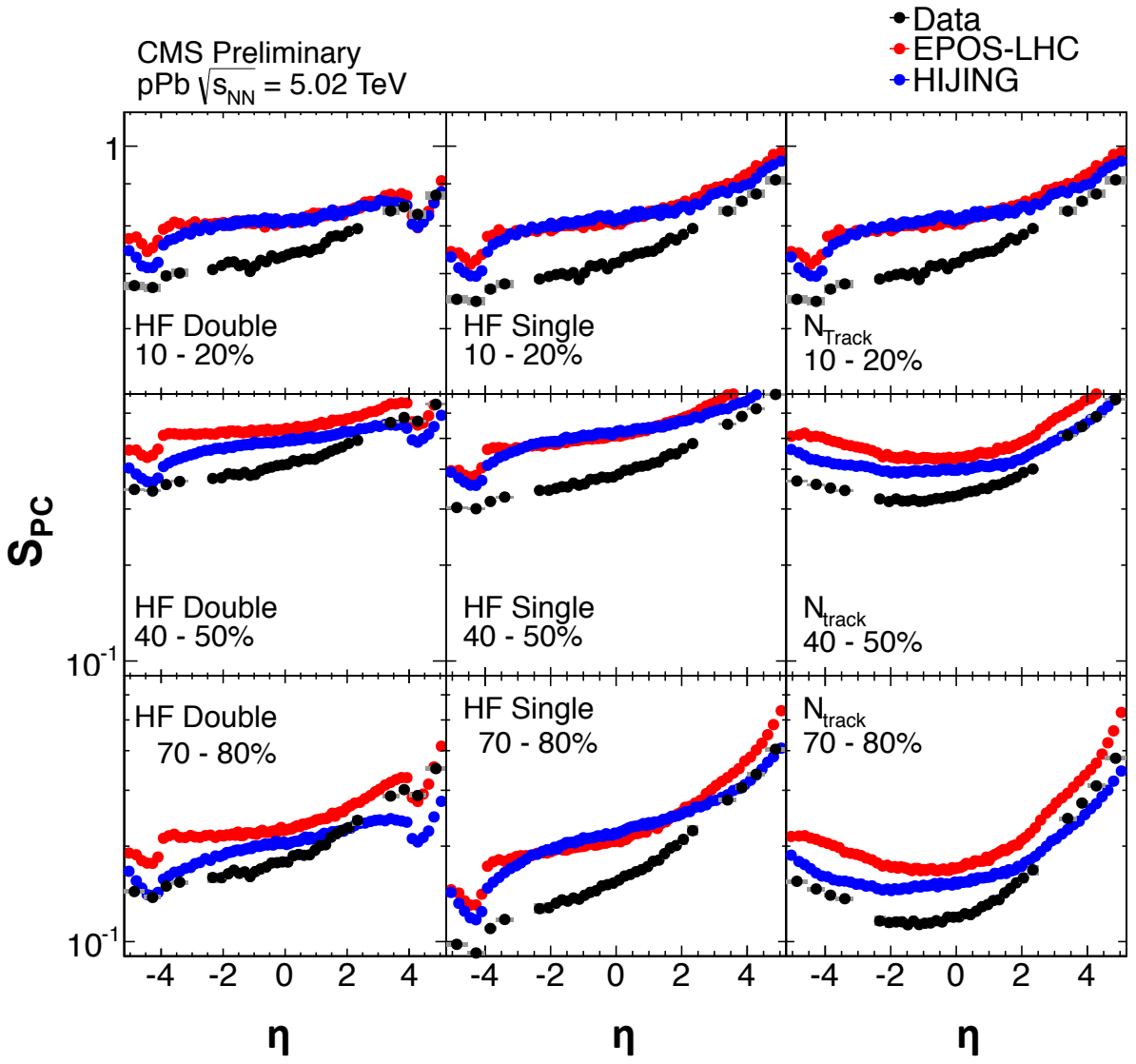


S_{PC} rises with η since centrality dependence is stronger on the lead side

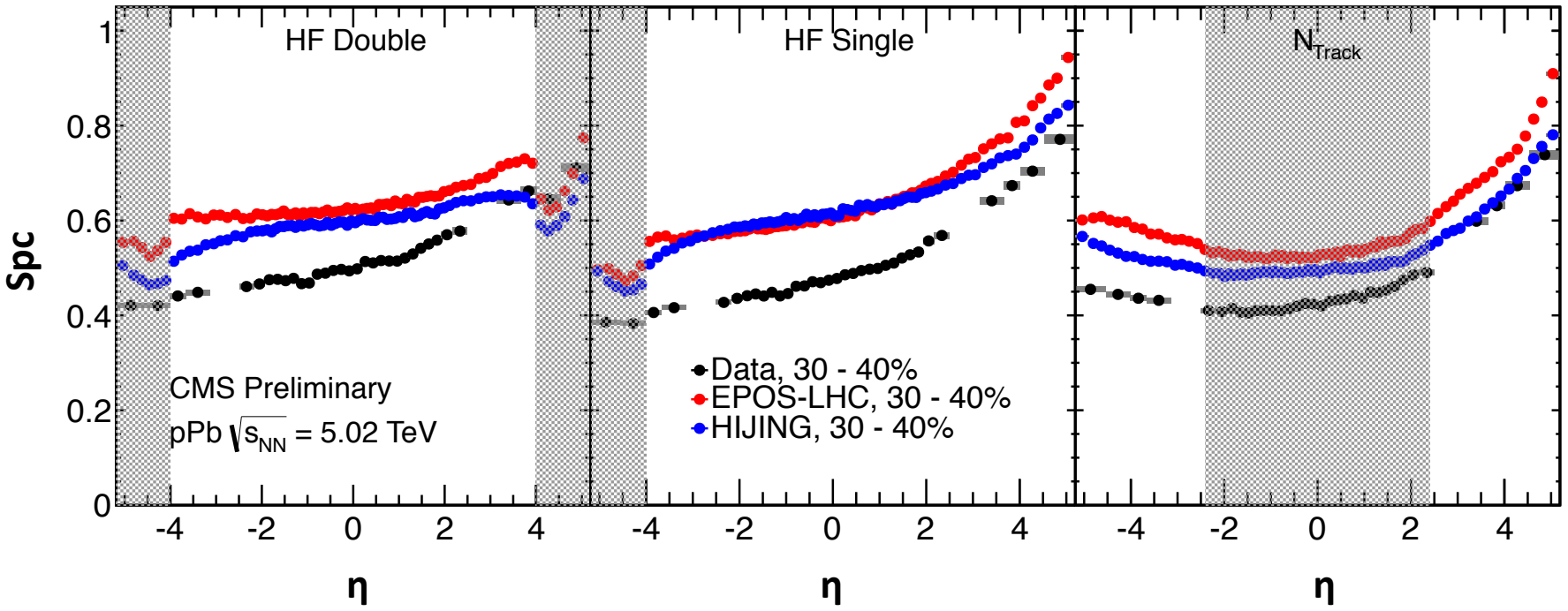
Centrality definition effects the shape of S_{PC} over a wide η range

Results: S_{PC} for data & MC

Centrality definition effects the shape of S_{pc} over a wide η range

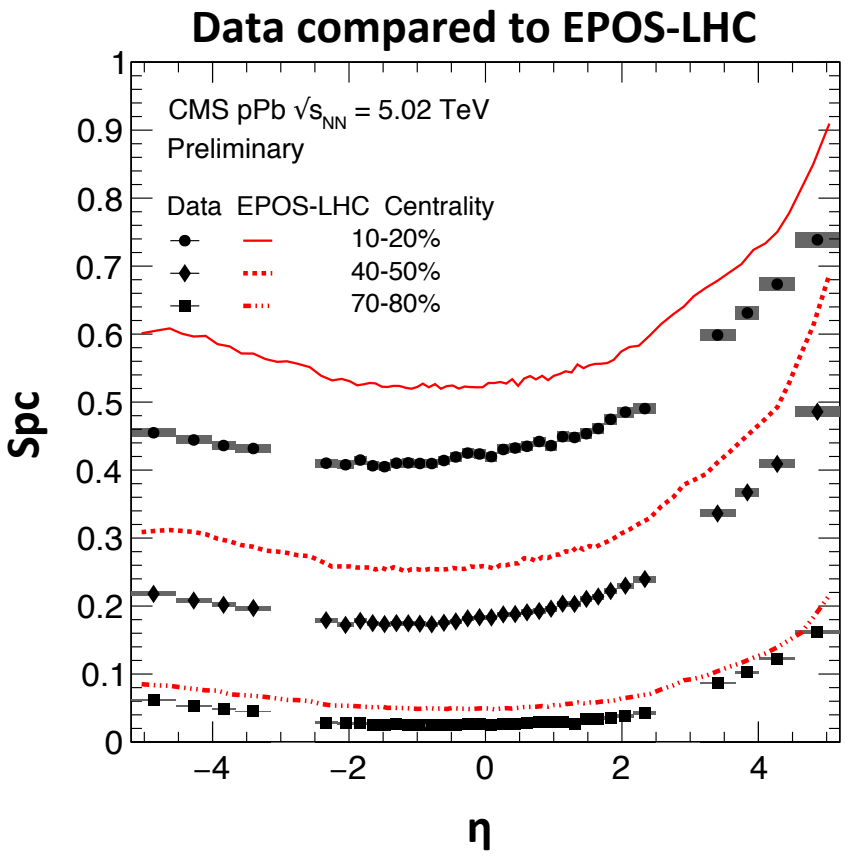


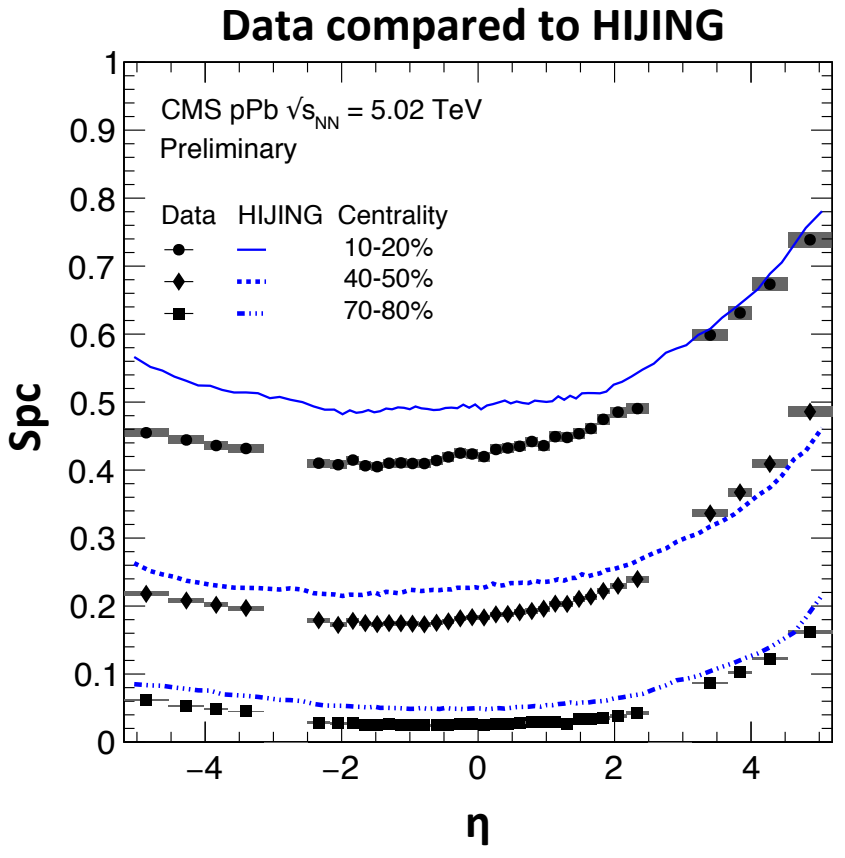
S_{PC}(30-40%) compared to EPOS and HIJING



EPOS-LHC and HIJING don't predict the strength of centrality dependence

S_{PC} compared to MC for different N_{Track} centralities



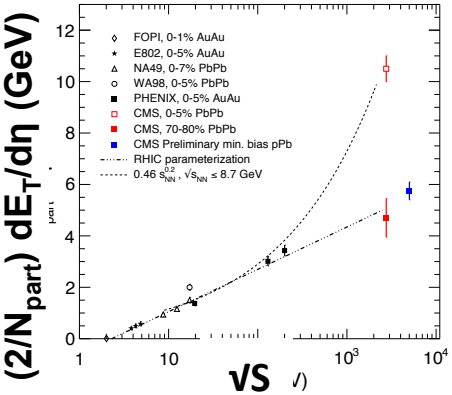


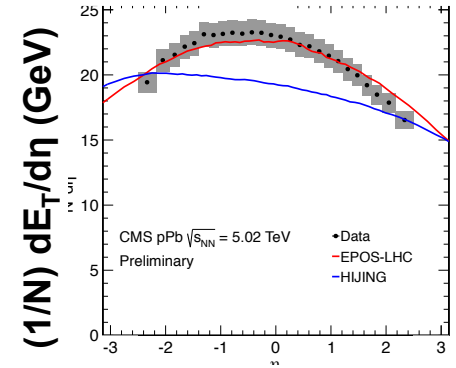
Conclusions

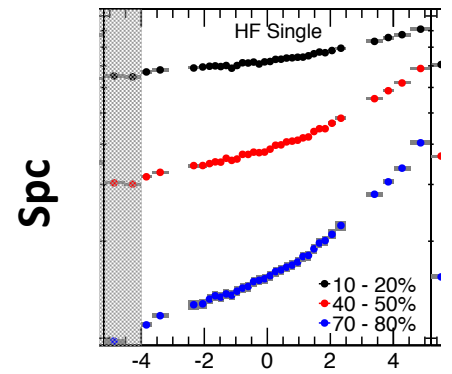
1) In min bias pPb, $dE_T/d\eta$ reachs 23 GeV $(2/N_{part})\, dE_T/d\eta = 5.8$ GeV.

2) For central pPb $(1/N)\, dE_T/d\eta \sim 60$ GeV, which implies an energy density of at least 6 GeV/fm^3.

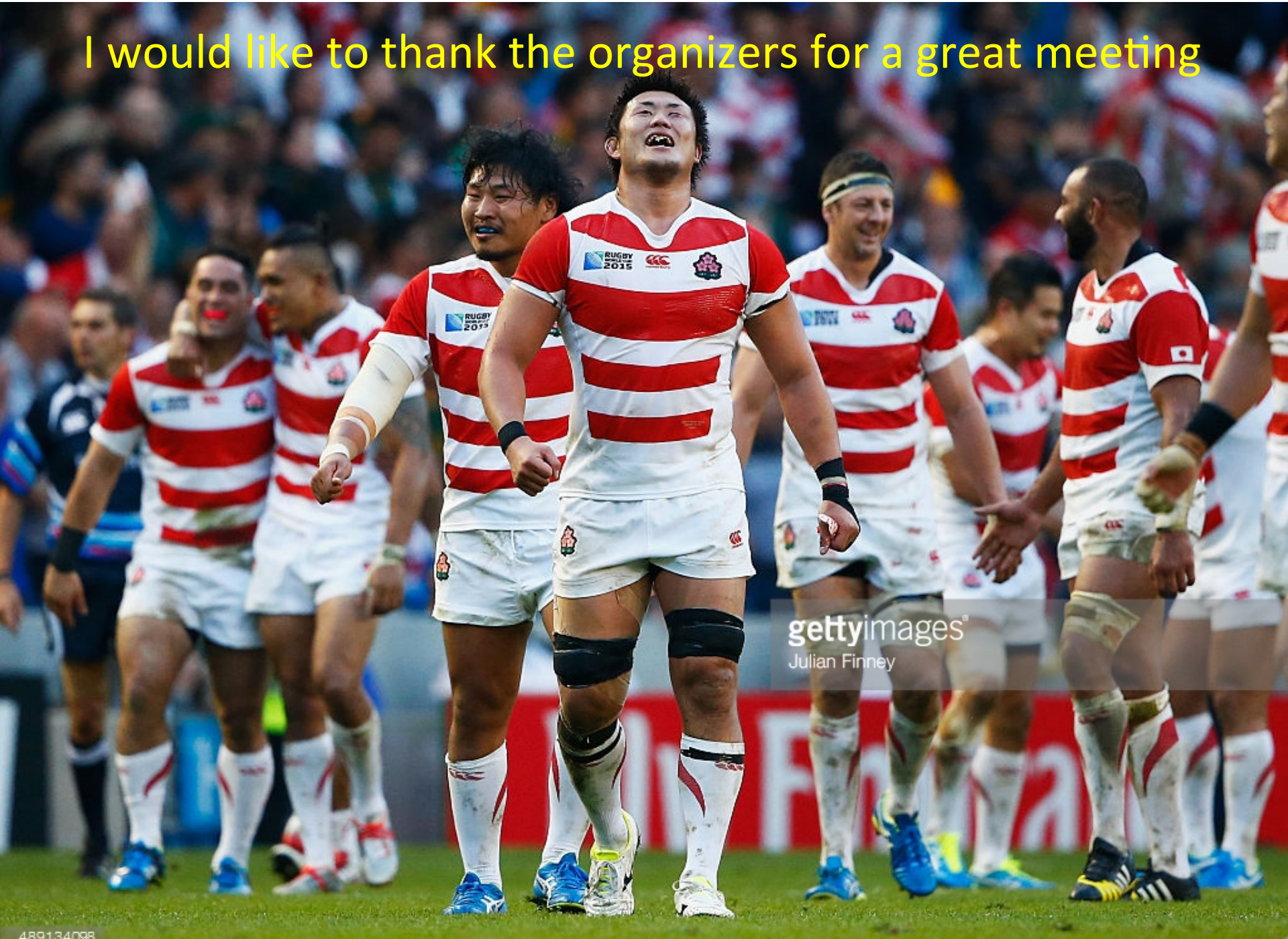
3) η dependence of E_T production depends upon centrality. Defining centrality within a given η region produces long range auto-correlations.





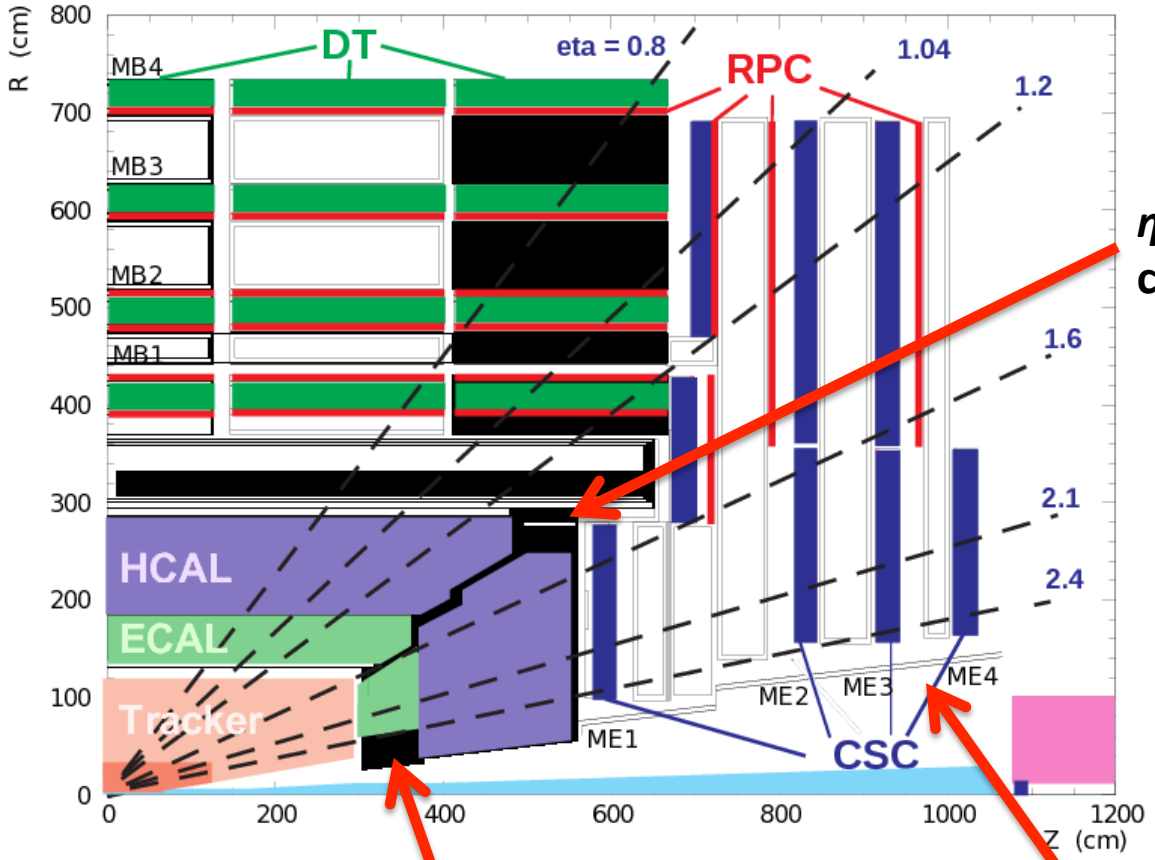


I would like to thank the organizers for a great meeting



Backup

Longitudinal slice through CMS



η = 1.3 Barrel/ end-cap boundary

η = 2.5 to 3.0 no tracker or ECAL

η = 3.0 end-cap/ HF boundary