Quark Matter 2014 - May 20th 2014

Jet reconstruction and calibration in heavy-ion collisions with the ATLAS detector

Underlying event

- Due to the large HI underlying event (UE) contribution one needs to use specific reconstruction algorithms to account for UE energy deposited in the region of the jet.

- The energy density of the UE in p+Pb collisions is approximately 30 times smaller than in central Pb+Pb collisions.

- Despite that, the subtraction procedure is still necessary in p+Pb collisions

HI subtraction procedure

- In ATLAS the jet reconstruction algorithm is based on the event-by-event estimation of the average UE energy density which is subtracted from all calorimeter cells. It is estimated in bins of η for each layer and is modulated in φ to account for the the measured elliptic flow in each event. The ρ in layer *i* is then

$$\rho_i(\eta) = \frac{1}{N_i}\sum_j^{N_i} \frac{E_{\mathrm{T}\,j}}{\Delta\eta_j\Delta\phi_j}\frac{1}{1+2v_{2\,i}\cos(2(\phi_j-\Psi_2))}$$

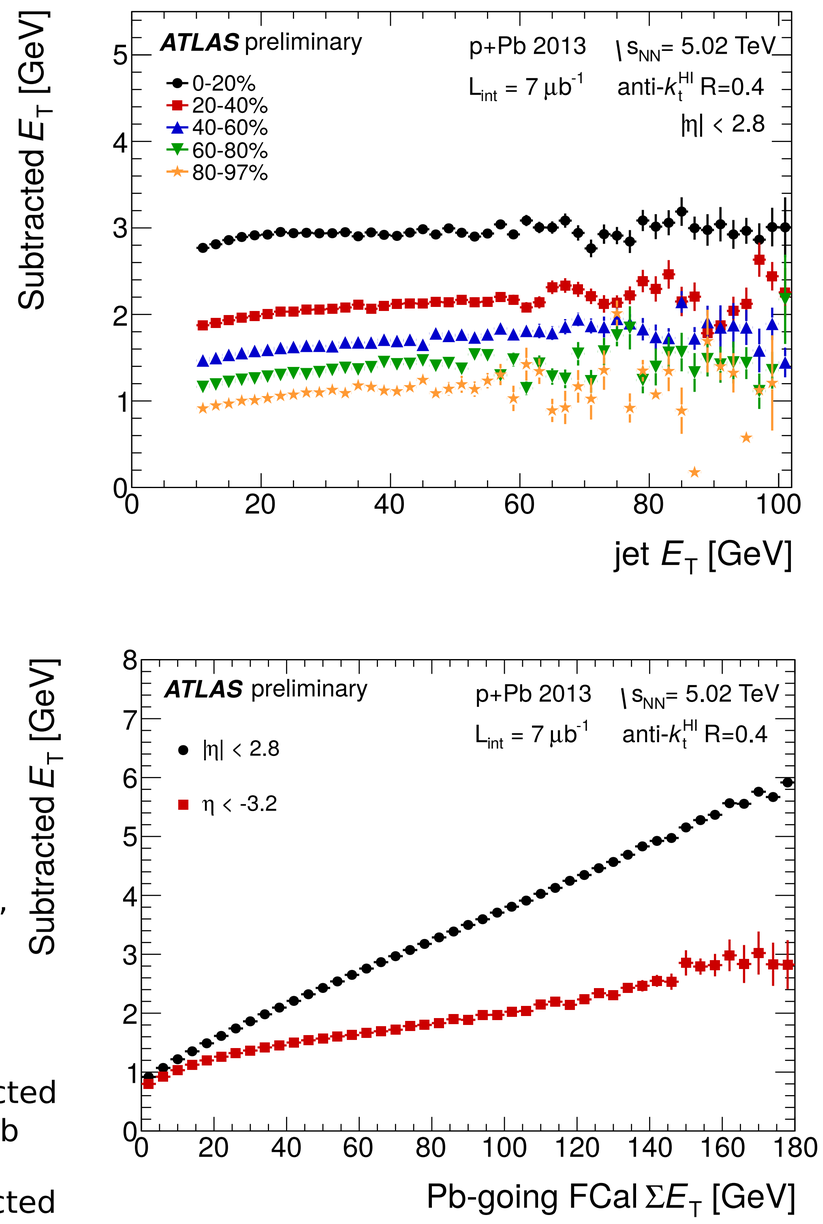
- For a cell at position η, φ in layer *i*, the corrected E_T is determined from the raw E_T as

$$E_\mathrm{T} = E_\mathrm{T}^\mathrm{raw} - \rho_i(\eta)\Delta\eta\Delta\phi[1+2v_{2\,i}\cos(2(\phi-\Psi_2))]$$

- Since jets bias the estimation of ρ they have to be excluded from the ρ estimation.
- When the clustering algorithm is run over raw η-φ distribution the result is that the entire distribution is tessellated by reconstructed jets. Some discriminant has to be used to decide which jets likely correspond to a true jet signal. $D > 4$ is used in ATLAS HI jet reconstruction, where *D* is defined as

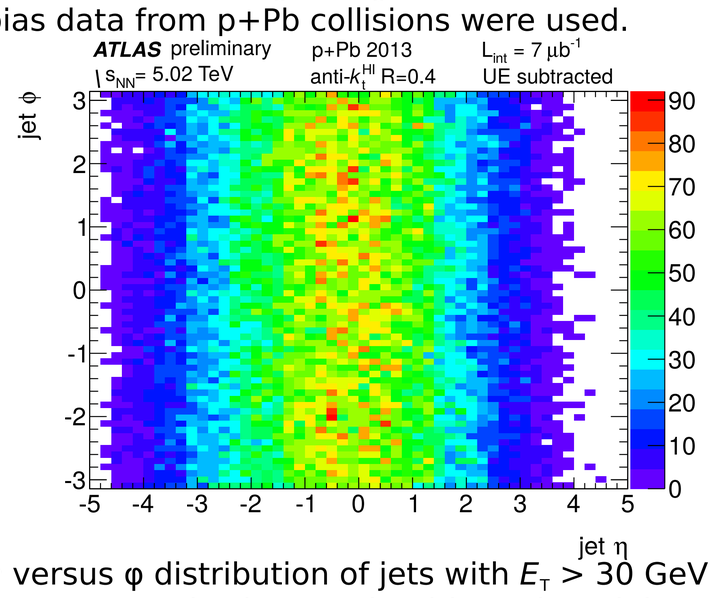
$$D = \frac{\max(E_\mathrm{T}^\mathrm{tower})}{\langle E_\mathrm{T}^\mathrm{tower}\rangle}$$

- The algorithm is iterative: after the ρ estimation, the clustering is run, giving set of jets that are in the next step excluded from a new ρ calculation. This ρ is then used to subtract energy from cells which are clustered
- Upper plot shows the dependence of the subtracted E_T on the jet E_T in different centrality bins in p+Pb collisions.
- Lower plot shows the dependence of the subtracted E_T on the FCal ΣE_T for two η bins in p+Pb collisions.



HI versus pp jet reconstruction

- η versus φ distribution of jets with $E_\mathrm{T} > 30$ GeV reconstructed using HI algorithm. The minimum bias data from p+Pb collisions were used.



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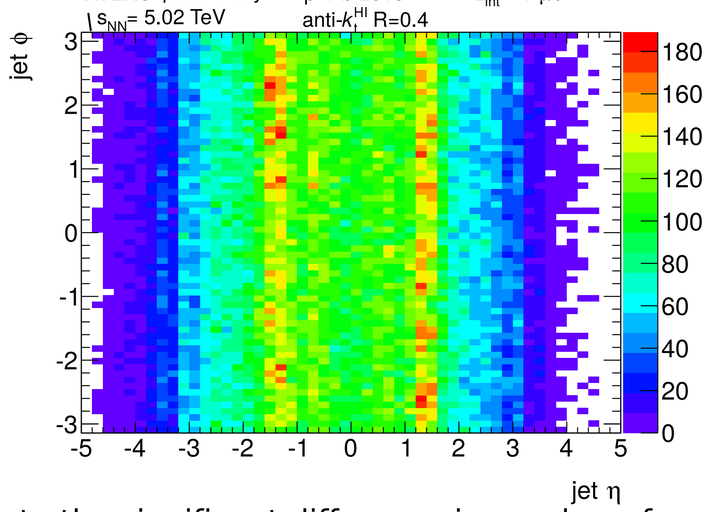


- Note the significant difference in number of reconstructed jets in midrapidity. This is due to the subtraction procedure used in HI reconstruction algorithm that properly reduces contribution from UE that would be reconstructed as a jet.

Numerical inversion

- Pythia jet events embedded into the minimum bias Pb+Pb or p+Pb events were used for calibration determination.

- Several corrections improving imperfections in η-φ response and subtraction procedure are applied to the jets at the EM scale at the analysis level and were used also when deriving calibration.

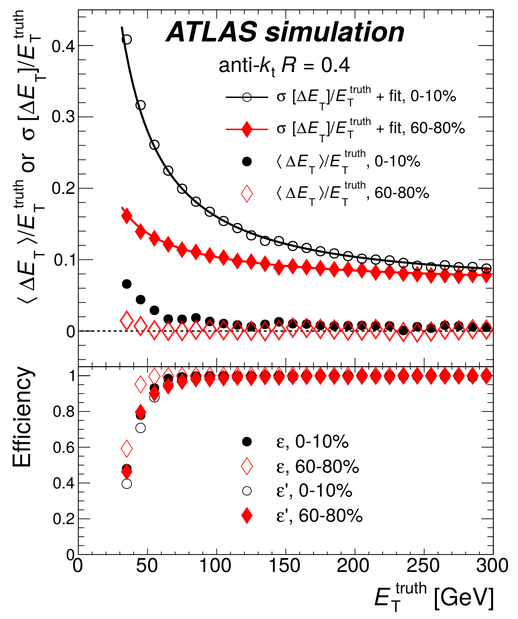
- Response is defined as the ratio of jet transverse energy reconstructed at the EM scale to truth transverse energy

$$R = \frac{E_\mathrm{T,calo}^\mathrm{EM}}{E_\mathrm{T,truth}}$$

- For each bin in η and $E_\mathrm{T,truth}$ mean response is defined as gaussian fit of the response distribution in the given bin.

- Mean reconstructed transverse energy is then

$$\langle E_\mathrm{T,calo}^\mathrm{EM}\rangle = \langle R\rangle E_\mathrm{T,truth}$$



- Response dependence on the $E_\mathrm{T,calo}^\mathrm{EM}$ is fitted for each η bin with function parametrised as

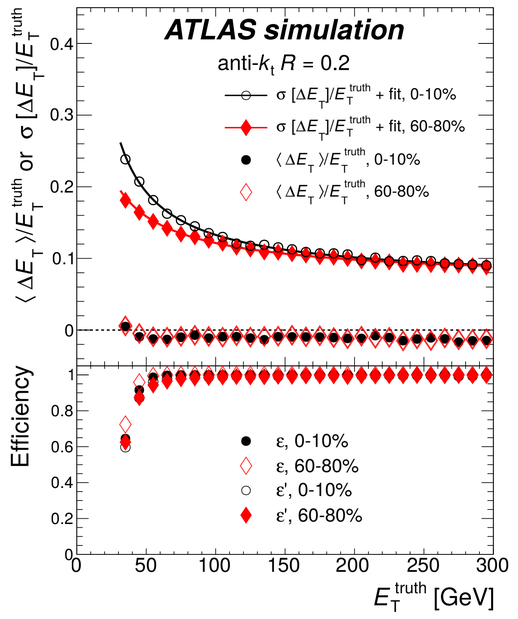
$$F_\mathrm{calib}(E_\mathrm{T,calo}^\mathrm{EM}) = \sum_{i=0}^{N_\mathrm{max}} a_i \left(\ln(E_\mathrm{T,calo}^\mathrm{EM})\right)^i$$

- Having the fit of the response the jets are calibrated via the relation

$$E_\mathrm{T,calo}^\mathrm{EM+JES} = \frac{E_\mathrm{T}^\mathrm{EM}}{F_\mathrm{calib}(E_\mathrm{T,calo}^\mathrm{EM})}$$

- Jet energy scale consistent with zero with minimal differences between central and peripheral events can be seen.

- Difference between central and peripheral events in JER can be explained as a consequence of the difference in the size of UE fluctuations.



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