Recent Results on Hard Probes of the Quark-Gluon Plasma with the ATLAS Experiment at the LHC

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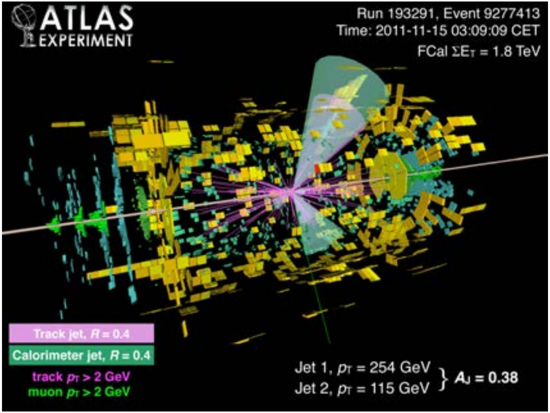
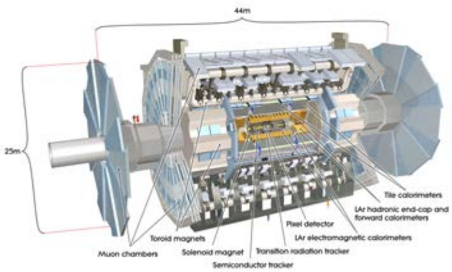
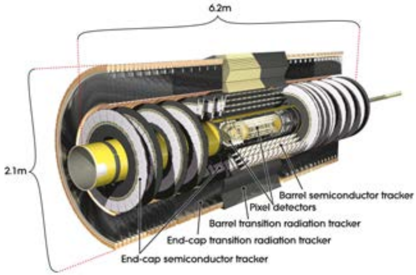
Motivation

- The main goal of the presented measurements is to study properties of the strongly coupled medium created in Heavy-ion (HI) collisions
- Hard probes are ideal tools for these studies
  - created in the early stages of the collision
  - relatively low background from the underlying event



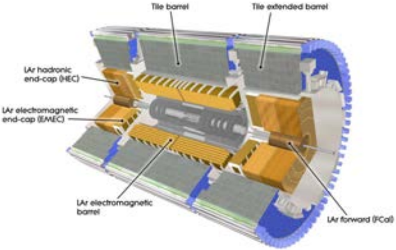
ATLAS experiment

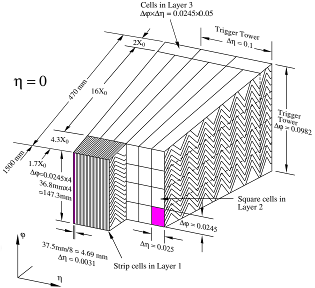




- ATLAS is multi-purpose detector well capable of measuring heavy-ion collisions
- Excellent tracking performance within $|\eta| < 2.5$. Combination of silicon pixel and strip detectors and transition radiation tracker.
- Powerful calorimeter system with fine segmentation with η coverage up to $|\eta| < 4.9$

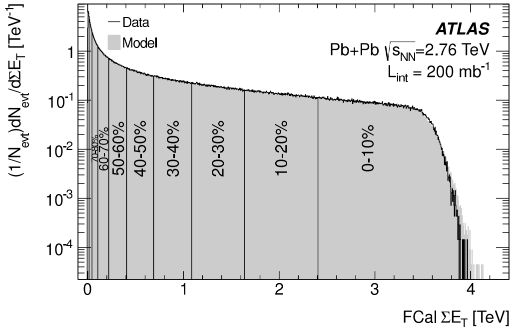
More about calorimetry





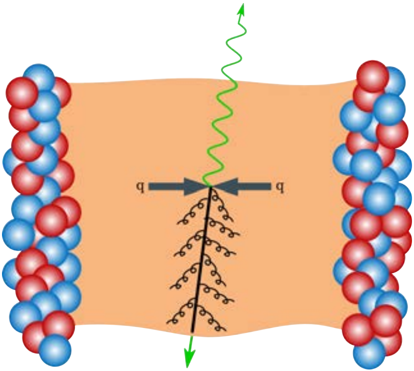
- Calorimetry system is composed of electromagnetic, hadronic and liquid-argon (LAr) forward calorimeters
- High granularity LAr electromagnetic calorimeter covers range of $|\eta| < 3.2$ and is composed of barrel and end-cap modules
- EM calorimeter is backed by hadronic calorimeter
- Allows for precise measurement of photons, electrons and jets
- Forward calorimeters are located in the range $3.1 < |\eta| < 4.9$, used for centrality bin selection

Centrality in Pb+Pb collisions

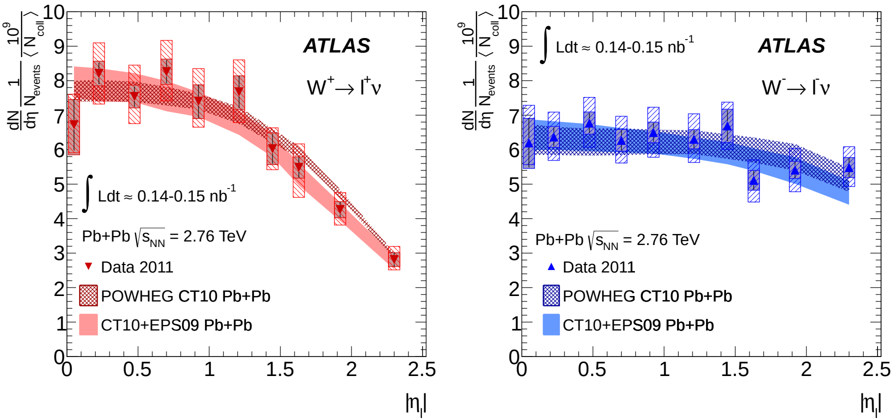


- Centrality expresses measure of overlap of two colliding nuclei
- Is closely related to the average number of participant nucleons and number of binary inelastic collisions
- Centrality determined by the sum of E_{T} deposited in the FCAL calorimeter $(3.1 < |\eta| < 4.9)$
- Events divided into successive percentiles of the $\sum E_{\mathrm{T}}^{\mathrm{FCal}}$

EW probes

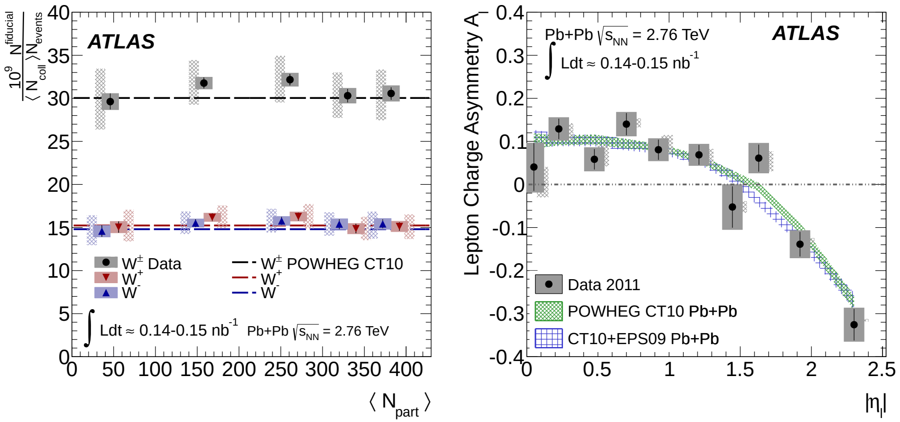


- Since EW bosons don't interact strongly, they aren't influenced by the medium
- We can look at the EW boson+jet events - is p_{T} balanced?
- Or we can test modification of the PDF's caused by the nuclear effects

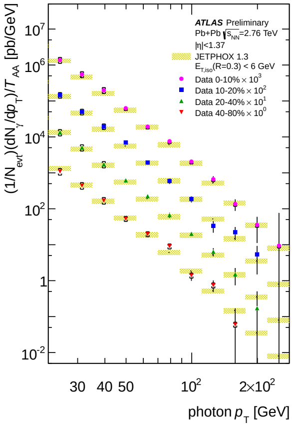


- Differential production yield per binary collision for W^+ and W^- integrated over centralities and compared to theoretical predicitons

W bosons (2)

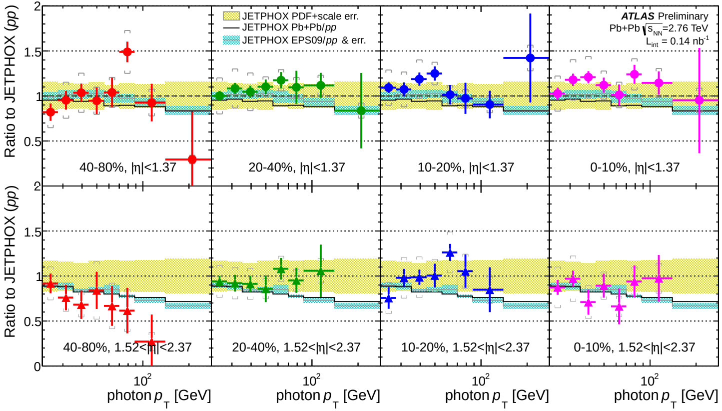


- W production yield per binary collision doesn't show any dependence on $\langle N_{\mathrm{part}} \rangle$ and is consistent with POWHEG prediction
- Lepton charge asymmetry agrees with theoretical predictions



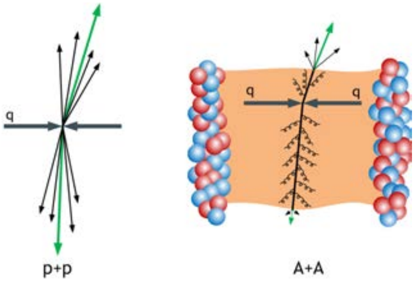
- Fully corrected yields of prompt photons in four centrality intervals as a function of p_{T}
- Compared to JETPHOX calculations

Photons (2)



- The ratio of the data to the JETPHOX *pp* prediction
- Data agree well with JETPHOX predictions in all centrality and η regions

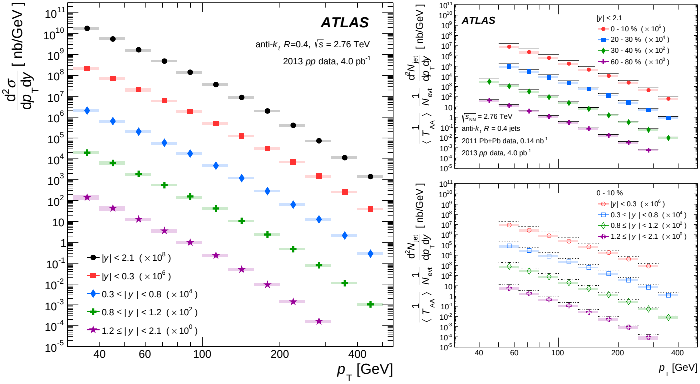
Jets



- Partons from the hard scattering have to traverse through the deconfined medium
- Do we observe suppression of jet yields or modification of fragmentation functions?
- Is production of the associated jets influenced by the medium?
- We can compare to *pp* data at the same energy or look at differences between central and peripheral collisions

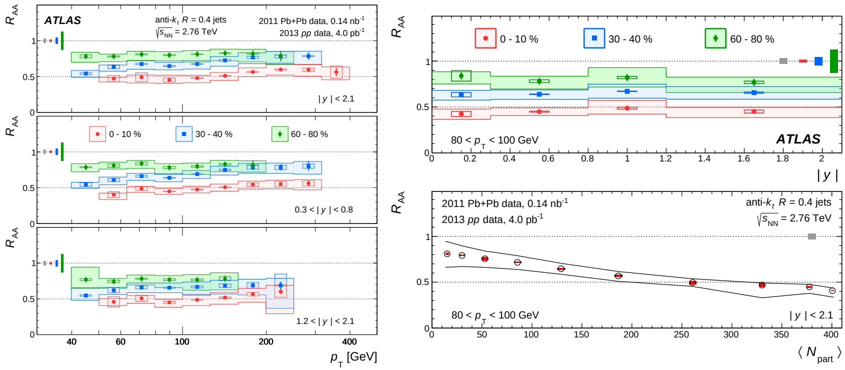
Jet spectra

arXiv:1411.2357



- Differential cross sections for the different rapidity ranges
- Differential per-event jet yield in Pb+Pb collisions divided by $1/\langle T_{\mathrm{AA}} \rangle$ with *pp* jet cross sections
- Normalized Pb+Pb yields in central collisions are below the *pp* yields

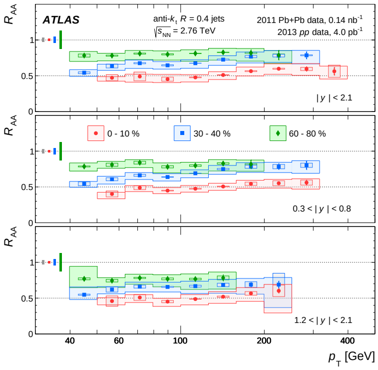
Jet R_{AA}

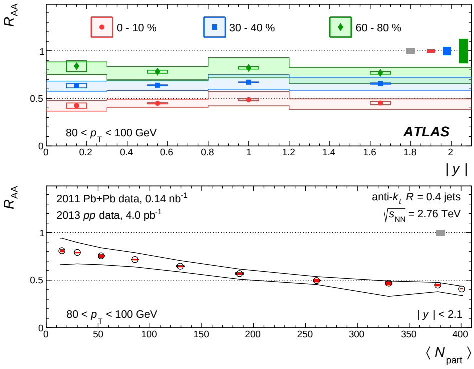


- Variable that expresses the size of the suppression/enhancement is the so called R_{AA} defined as

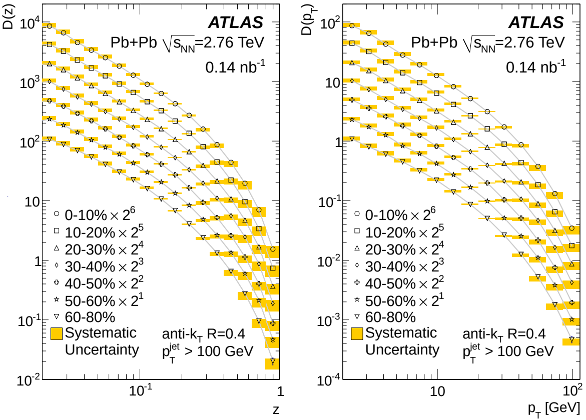
$$R_{\mathrm{AA}} = \frac{\frac{1}{N_{\mathrm{evt}}} \frac{\mathrm{d}^2 N_{\mathrm{jet}}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}\Big|_{\mathrm{central}}}{\langle T_{\mathrm{AA}} \rangle \frac{\mathrm{d}^2 \sigma^{pp}_{\mathrm{jet}}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y}}$$

Jet R_{AA}





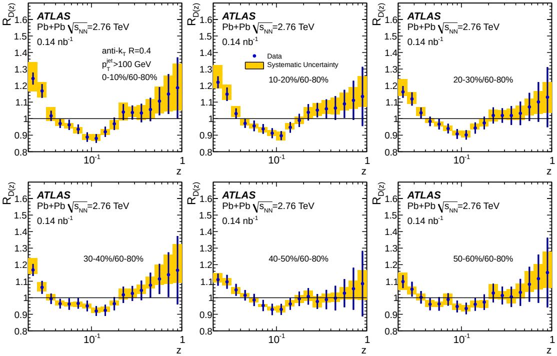
- R_{AA} plots clearly show suppression down to ≈ 0.5 for most central collisions
- Weak dependence of R_{AA} on the p_{T} (slope parameter significantly above zero)
- No significant dependence on the y observed



- Fragmentation functions $D(p_{\mathrm{T}})$ and $D(z)$ are defined as

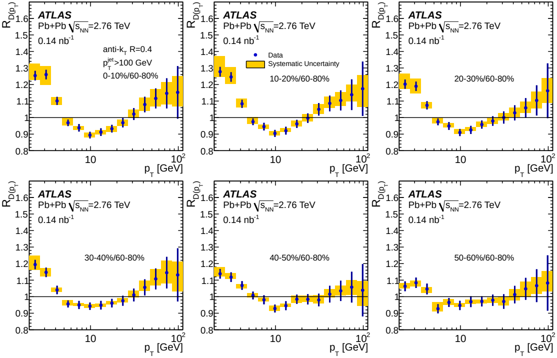
$$D(z) = \frac{1}{N_{\mathrm{jet}}} \frac{\mathrm{d}N_{\mathrm{ch}}}{\mathrm{d}z} \qquad D(p_{\mathrm{T}}) = \frac{1}{N_{\mathrm{jet}}} \frac{\mathrm{d}N_{\mathrm{ch}}}{\mathrm{d}p_{\mathrm{T}}^{\mathrm{ch}}}$$

Fragmentation functions (2)

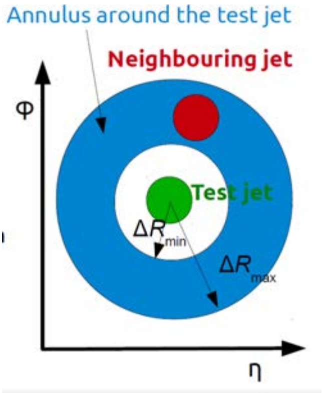


- Centrality dependence evaluated as the ratio of the all centrality bins to the 60-80% bins
- Enhanced yield of small and large z fragments for all centralities, suppression of fragments at intermediate z
- Size of modification gradually decreases from central to peripheral collisions

Fragmentation functions (3)



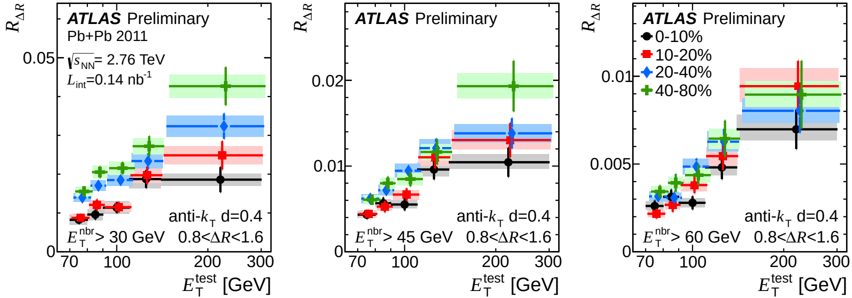
- Centrality dependence evaluated as the ratio of the all centrality bins to the 60-80% bins
- Similar modifications of $D(p_{\mathrm{T}})$ as for $D(z)$



- The rate of the neighbouring jets that accompany a test jet, $R_{\Delta R}$ is defined as

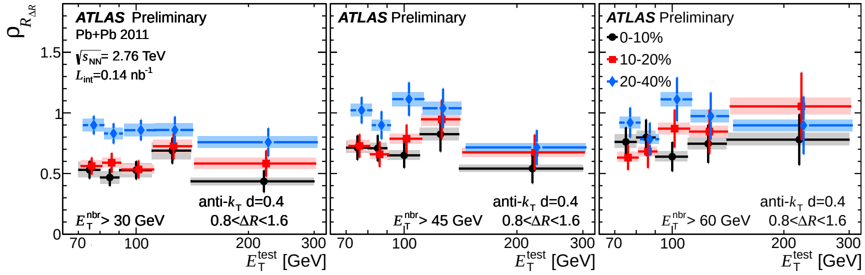
$$R_{\Delta R} = \frac{1}{\mathrm{d}N_{\mathrm{jet}}^{\mathrm{test}}/\mathrm{d}E_{\mathrm{T}}^{\mathrm{test}}} \sum_{i=1}^{N_{\mathrm{jet}}^{\mathrm{test}}} \frac{\mathrm{d}N_{\mathrm{jet},i}^{\mathrm{nbr}}}{\mathrm{d}E_{\mathrm{T}}^{\mathrm{test}}} (E_{\mathrm{T}}^{\mathrm{test}}, E_{\mathrm{T,min}}^{\mathrm{nbr}}, \Delta R)$$

Nearby jets (2)



- $R_{\Delta R}$ for $R = 0.4$ jets evaluated as a function of E_T^{test}
- Production of nearby jets is suppressed in central collisions compared to peripheral collisions

Nearby jets (3)



- The ratio of $R_{\Delta R}$ for three centrality bins to 40-80% centrality bin
- Suppression by a factor ≈ 2 in central collisions, no strong E_{T} dependence observed

Conclusions

- Measurements of EW probes don't imply any modification of production yields
  - W production yield doesn't show any dependence on $\langle N_{\mathrm{part}} \rangle$
  - Photon yields agree well with JETPHOX prediction
- Jet measurements clearly shows the modification of jet properties due to the interaction with the medium created in the collision
  - Jet R_{AA} falls down to 0.5
  - R_{AA} dependence on the $\langle N_{\mathrm{part}} \rangle$
  - Modification of the fragmentation functions