Jet suppression and the flavor dependence of partonic energy loss with ATLAS

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- **ATLAS** presented several measurements showing strong modification of jet/track properties in HI collisions since the beginning of LHC run 1
- Studies of asymmetric dijet events, suppressed production of jets and charged tracks in Pb+Pb collisions, measurement of jet fragmentation modification published
- All of these measurements provided fruitful information on the partonic energy loss and its path length dependence

Flavor dependence

- The next step is to understand the flavor dependence of the energy loss
- The difference in quenching between quarks and gluons is not accessible in a straightforward way
- Relative number of quarks and gluons changes with pseudorapidity $\rightarrow$ it's worth to study η dependence of the energy loss

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

- In ATLAS, 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 $\sum E_T^{\text{FCAL}}$

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

$$R_{AA} = \frac{\frac{1}{N_{\text{evt}}} \frac{d^2 N_{\text{Pb+Pb}}}{dp_T dy} \Big|_{\text{centr}}}{\langle T_{AA} \rangle \frac{d^2 \sigma_{pp}}{dp_T dy}}$$

- Data samples: 2010 and 2011 Pb+Pb, 2011 and 2013 pp runs used
- Spectra were corrected for fake tracks, track reconstruction efficiency and momentum resolution (1D Bayesian unfolding)
- Spectra measured up to $p_T=150$ GeV

- Charged particle spectra from pp and HI (scaled by $1/\langle T_{AA} \rangle$) binned in centrality (left) and pseudorapidity (right)

- Very strong suppression at intermediate p_T , saturation at $p_T \approx 60 \text{ GeV}$
- No signs of η dependence

- Complementary measurement for charged track R_{AA}
- We measured R_{AA} for anti- k_t jets using 2011 Pb+Pb and 2013 pp run, MB and jet triggered samples were combined to get continuous jet spectra $32 < p_T < 500$ GeV
- Unfolding based on SVD method was used to account for detector effects

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

- R_{AA} plots clearly show suppression down to ≈ 0.5 for most central collisions
- Weak dependence of R_{AA} on the p_T
- No significant dependence on the y observed

- Jet Fragmentation Functions (FF) $D(p_T)$ and $D(z)$ are defined as

$$D(p_T) = \frac{1}{N_{\text{jet}}} \frac{dN_{\text{ch}}}{dp_T^{\text{ch}}} \quad D(z) = \frac{1}{N_{\text{jet}}} \frac{dN_{\text{ch}}}{dz} \quad z = \frac{p_T}{p_T^{\text{jet}}} \cos \Delta R$$

- New FF measurement of $R = 0.4$ jets measured differentially in 4 η and 4 p_T^{jet} bins
- Jet substructure measured using charged tracks starting at $p_T = 1$ GeV
- Using pp as a reference
- FF are background subtracted, efficiency corrected and fully unfolded with 2-D Bayesian unfolding

- FF for pp and 6 centrality bins in 4 η regions
- Inclusive in p_T^{jet}

- $R_{D(p_T)}$ for 4 centralities in 4 η bins
- Hint of η dependence at large p_T^{ch} observed

- $R_{D(p_T)}$ for 4 centralities in 4 p_T^{jet} bins
- No clear dependence on p_T^{jet} except change of trends at highest p_T

- To quantify the size of enhancement/suppression, we calculated

$$N^{\text{ch}} \equiv \int_{p_{\text{T,min}}}^{p_{\text{T,max}}} \left(D(p_{\text{T}})|_{\text{cent}} - D(p_{\text{T}})|_{\text{pp}} \right) dp_{\text{T}} \quad (1)$$

- N_{part} dependence shown for three characteristic p_{T} regions
- Tells how many extra/missing particles is in p_{T} range

- To quantify the p_T flow, we calculated

$$P_T^{\text{ch}} \equiv \int_{p_{T,\text{min}}}^{p_{T,\text{max}}} \left(D(p_T)|_{\text{cent}} - D(p_T)|_{\text{pp}} \right) p_T \, dp_T. \quad (2)$$

- Tells how much p_T is carried by extra/missing particles in given p_T range

Conclusions

- Charged particle R_{AA} measurement shows modification
 - ▶ strong dependence on centrality
 - ▶ strong dependence on the track p_T
 - ▶ no sign of η dependence observed
- Jet R_{AA} exhibits similar features but weaker dependence on jet p_T
- Fragmentation functions show
 - ▶ Enhancement at low and high p_T^{trk} , suppression at intermediate track p_T
 - ▶ no significant dependence on jet p_T
 - ▶ no significant evolution with η except the largest track p_T

Backup

FF $D(z)$ ratios (1)

FF $D(z)$ ratios (2)