Charged pion spectra at high p_T measured via dE/dx with the ALICE TPC

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The ALICE TPC detector allows measurements of charged pion p_T spectra out to very large p_T via the ionization energy loss (dE/dx) on the relativistic rise. In this poster, the first ALICE measurement of high p_T charged pion spectra and R_{AA} are reported in $\sqrt{s_{NN}} = 2.76$ TeV Pb-Pb and $\sqrt{s} = 2.76$ TeV p-p collisions for $3 < p_T < 20$ GeV/c.

1. Introduction

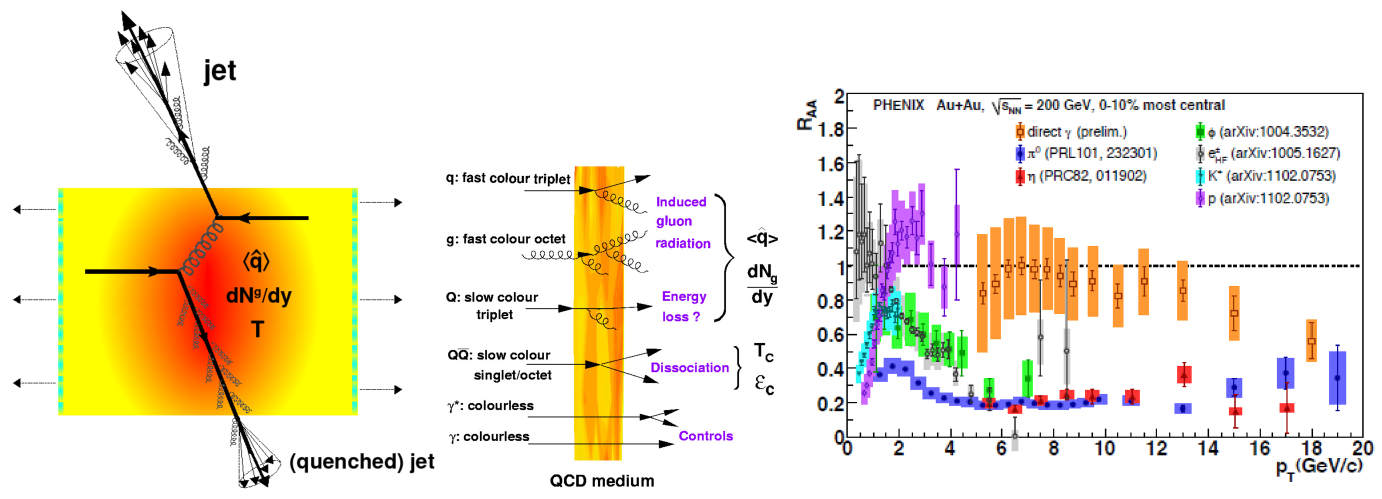

Figure 1: *Left: Cartoon illustrating how one expects jets to be quenched by the medium. Center: Examples of how different particles can interact with the medium. Right: The nuclear modification factor, R_{AA}, for different identified particles measured by PHENIX.*

The four RHIC experiments have demonstrated that high p_T particles are suppressed with respect to binary scaled p-p production, see [1] for a review. It was also shown that the nuclear modification factor, R_{AA}, for different identified particles follows distinct suppression patterns, see Figure 1. ALICE has published first measurements of R_{AA} for unidentified particles which shows an even stronger modification (lower R_{AA} at LHC) [2]. In this analysis we extend these results to charged pions.

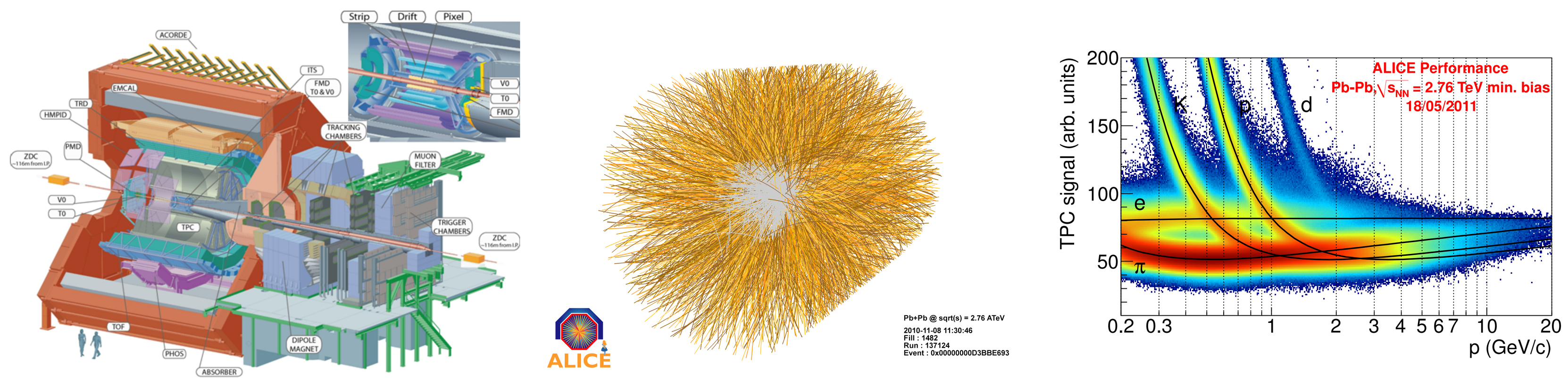

Figure 2: *Left: Schematic view of the ALICE experiment. Center: TPC event display of a central Pb-Pb event from the High Level Trigger. Right: TPC dE/dx vs momentum p measured for Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. The solid curves are similar to the extracted $\langle dE/dx\rangle$ curves, see text.*

Figure 2 (center) shows the tracks identified by the ALICE TPC for a central Pb-Pb collisions. In addition to tracking the TPC provides particle identification through the measurement of dE/dx, which depends only on $\beta\gamma = p/m$. Figure 2 (right) shows an example of the measured dE/dx vs p for Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. In principle statistical PID of π, K, and p can be done up to 50 GeV/c or more, because the energy loss rises logarithmically from $\beta\gamma \sim 3.6$ (MIP) to $\beta\gamma \sim 1000$ (the plateau). As $\beta\gamma = p/m$, one will have an almost constant separation between particles with different mass proportional to $\log(p/m_1) - \log(p/m_2) = \log(m_2/m_1)$ so that the separation between π and K is much larger than the separation between K and p. The STAR experiment at RHIC has demonstrated that with a dE/dx resolution of 8 % statistical PID is feasible on the relativistic rise ($\beta\gamma > 4$, $p_T > 3$ GeV/c) [3].

2. Method

The strategy adapted to extract π spectra is to combine the measured charged spectra with the additional information from the dE/dx. Using the following schematic relation:

$$\frac{d^2N_{ch}}{dp_T d\eta}(|\eta| < 0.8) = C \times 1/\epsilon_{ch} \times N_{ch} \quad (1)$$

$$\frac{d^2N_{\pi}}{dp_T d\eta}(|\eta| < 0.8) = C \times 1/\epsilon_{\pi} \times N_{\pi}, \quad (2)$$

where ϵ are the reconstruction efficiencies, N is the number of particles, and C is the normalization constant taking into account all other corrections, we see that:

$$\frac{d^2N_{\pi}}{dp_T d\eta} = \frac{d^2N_{ch}}{dp_T d\eta} \times \frac{\epsilon_{ch}}{\epsilon_{\pi}} \times \frac{N_{\pi}}{N_{ch}}. \quad (3)$$

So by extracting the fraction of charged pions in the data, using Monte Carlo estimates for the efficiency ratio, and combining with the measured charged spectra [2], the pion spectra can be extracted. The correction needed to transform from $dN/d\eta$ to dN/dy is negligible for pions at $p_T > 3$ GeV/c and $|\eta| < 0.8$ ($\ll 1$ %).

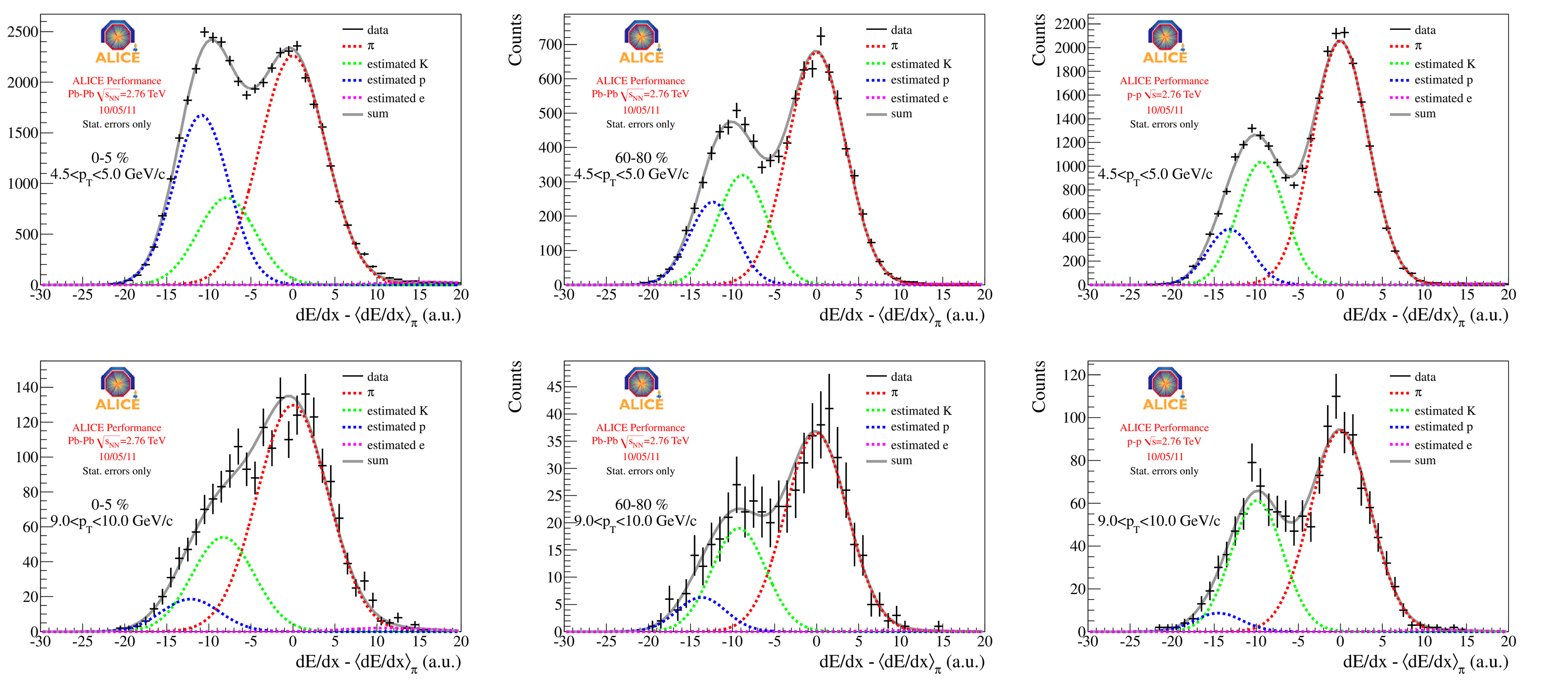

Figure 3: *Δ_π distribution fitted with a sum of 4 Gaussians for two p_T intervals, $4.5 < p_T < 5.0$ GeV/c (upper) and $9.0 < p_T < 10.0$ GeV/c (lower), in central and peripheral Pb-Pb and p-p collisions.*

For particle identification the quantity used is Δ_π defined as:

$$\Delta_\pi = dE/dx - \langle dE/dx\rangle_\pi(p), \quad (4)$$

where dE/dx is the specific energy loss of a track calculated as the truncated mean of the 60 % lowest cluster charges, and $\langle dE/dx\rangle_\pi(p)$ is the average specific energy loss of a pion with momentum p. $\langle dE/dx\rangle_\pi(p)$ is extracted from the dE/dx vs p distribution (Figure 2) using a global fit. In the same fit the resolution is determined. This choice of method is based on studies done in [4].
Figure 3 shows the sum of 4 Gaussian fits to the Δ_π distributions. All the shapes (means and widths) have been constrained using the global fit to dE/dx vs p, so that only the 4 yields are free parameters.

3. Results

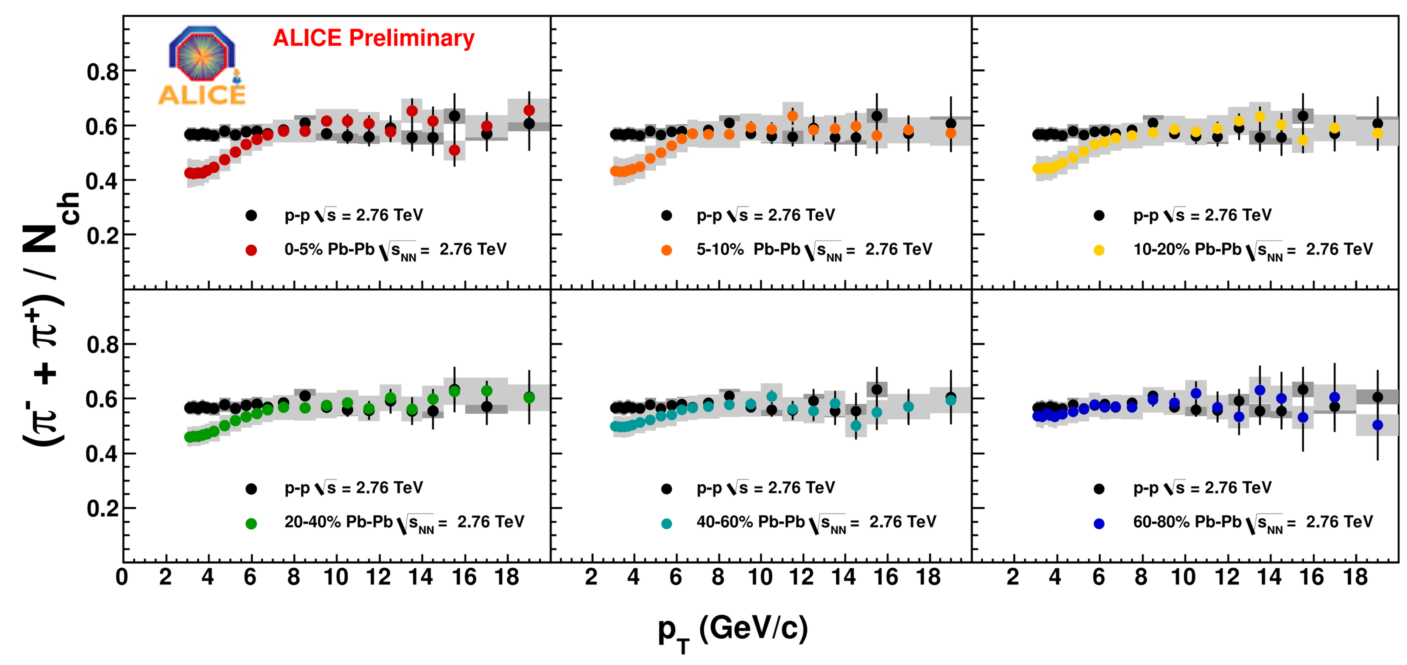

Figure 4: *The fraction of primary pions, $(\pi^- + \pi^+)/N_{ch}$, as a function of p_T for different Pb-Pb centrality classes and p-p. The light gray boxes show the systematic error on the Pb-Pb data, while the dark gray boxes shows the systematic error on the p-p data.*

Figure 4 shows the results for the pion fraction. The results have been corrected for the efficiency ratio ($\epsilon_{ch}/\epsilon_\pi \sim 0.94$) which is independent of p_T in the measured interval and dominated by weakly decaying particles (where the decay products are not observed as primaries). Systematic errors have been evaluated using Monte Carlo and by relaxing the constraints on the means and widths for the Δ_π fits.

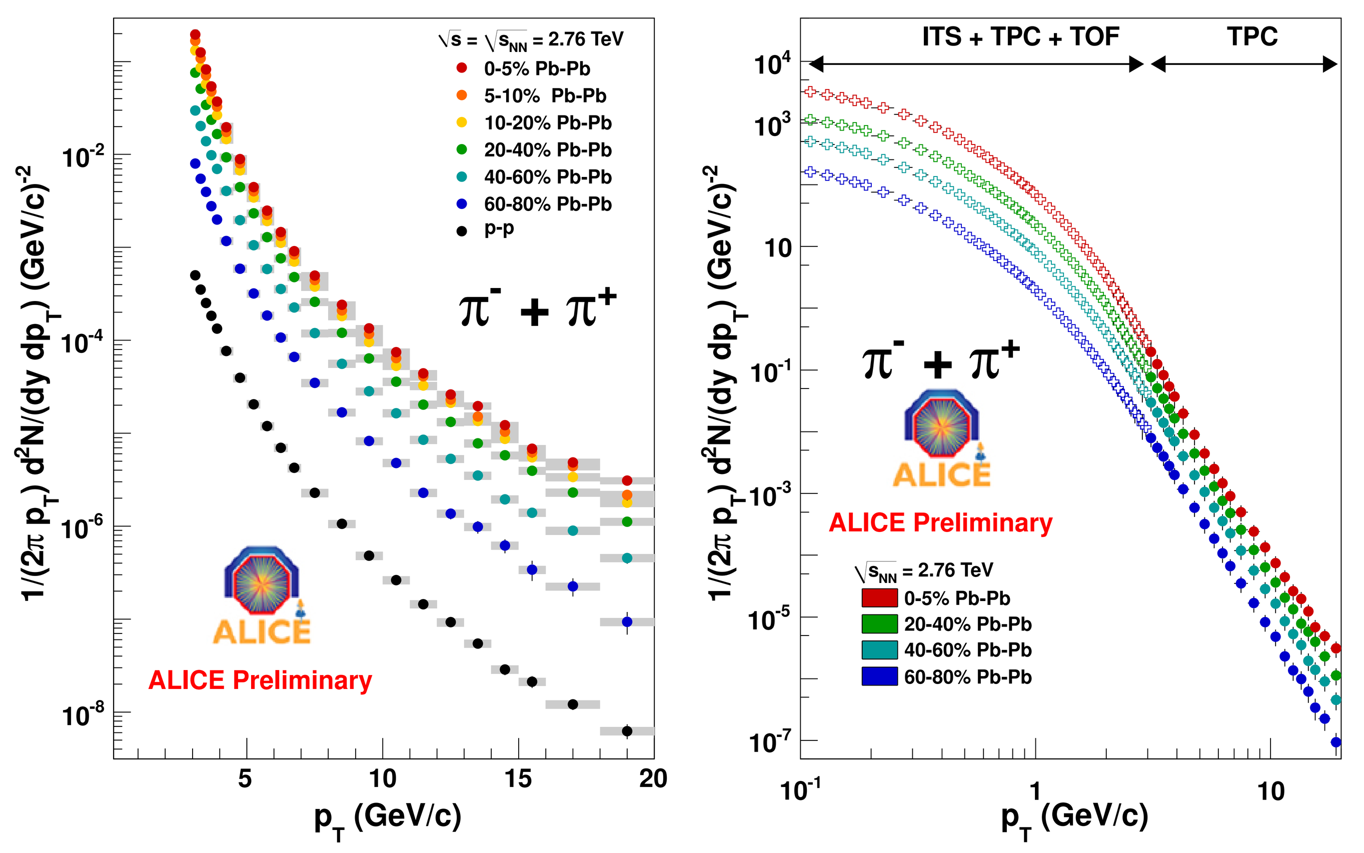

Figure 5: *Left: the invariant yield for charged pions, $\pi^- + \pi^+$, as a function of p_T for different Pb-Pb centrality classes and p-p. Statistical errors are shown by the vertical error bars. Systematic errors are shown by the gray boxes. Right: the invariant yield from this analysis, compared to low p_T spectra from other ALICE analyses for selected centrality classes.*

Figure 5 shows the charged pion invariant yields obtained for this analysis by combining the charged pion fractions with the unidentified charged spectra using Eq. 3.

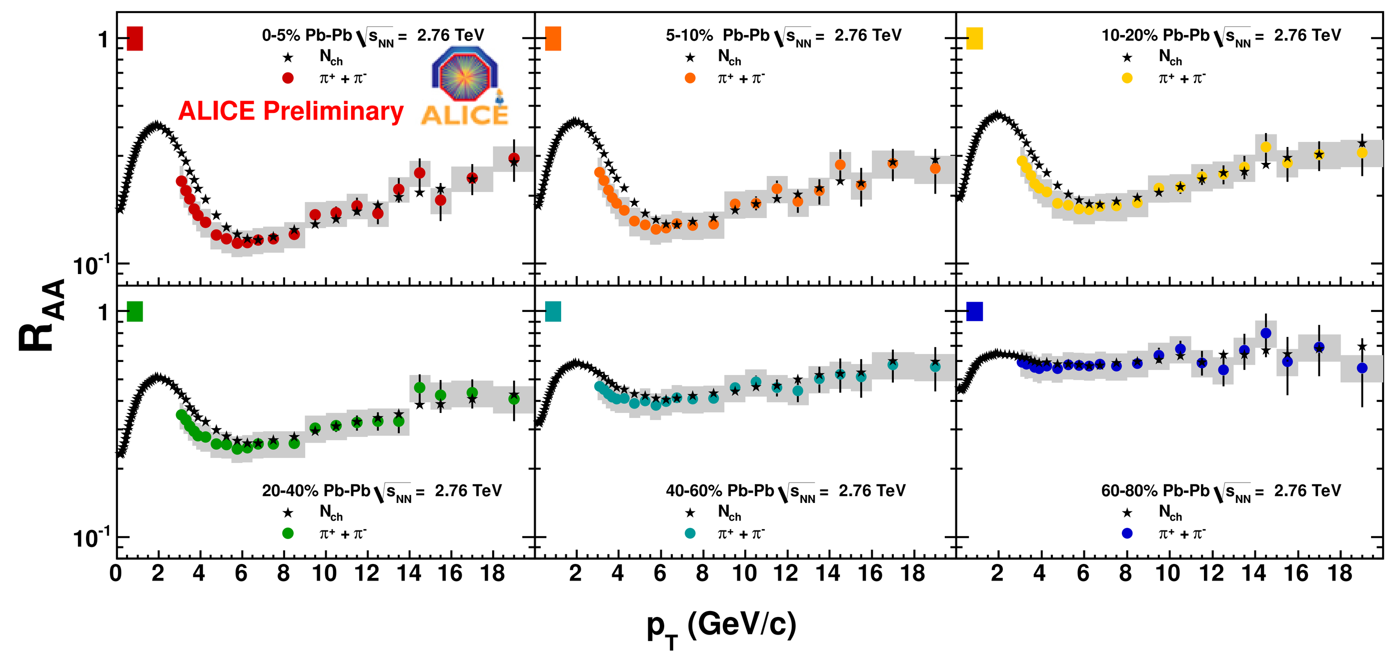

Figure 6: *The figure shows the charged pion R_{AA} compared to the R_{AA} for unidentified particles as a function of p_T for different centrality classes. Statistical (vertical error bars) and systematic (gray and colored boxes) are shown for the charged pion R_{AA}. The colored boxes contains the common systematic error related to p-p normalization to INEL and on the number of collisions. Only statistical errors are shown for the unidentified charged R_{AA}.*

Figure 6 shows the results for R_{AA}, which has been obtained from the spectra using:

$$R_{AA} = \frac{d^2N_{AA}}{dp_T dy} / (\langle N_{coll}\rangle \frac{d^2N_{pp}}{dp_T dy}), \quad (5)$$

where the number of binary collisions, N_{coll}, is obtained from a Glauber Monte Carlo simulation.

4. Conclusion and Outlook

For $p_T > 6 - 8$ GeV/c the nuclear modification factors for charged pions are similar to those of unidentified charged particles for all centralities. Below this p_T the charged pions are stronger suppressed as was also observed at RHIC results.
Due to the lower separation betwen kaons and protons, more work is needed to understand the systematics of the obtained yield with this method. Already, parts of the dE/dx spectrum, where the kaon contamination is small, have been used to measure $v_2(p_T)$ for protons out to $p_T = 20$ GeV/c. Eventually, when all systematics are under control, this method can be used to measure identified fragmentation functions of jets for p-p and Pb-Pb collisions.

References

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[4] A. Dobrin Ph. D. thesis, Lund University 2010.