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Particle Identification at high transverse momenta with the ALICE TPC

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The ALICE TPC particle identification capabilities have been studied with test beam data and found to be in agreement with theoretical predictions from a photo absorption ionization model calculation of the charged particle energy loss in the gas when detector effects – exponential gas gain variations and diffusion – are taken into account.

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1. Motivation

The measurements at RHIC of elliptic flow and spectra out to high transverse momenta (p_T) have given many interesting results, such as kinetic energy and valence quark scaling of the elliptic flow and the anomalous proton to pion ratio [1, 2]. These results have given rise to speculations that hadronization at intermediate p_T might be due recombination of lower momentum "constituent quark like" degrees of freedom rather than fragmentation of high momentum jet partons. At LHC recombination might result in even larger ratios of up to $p/\pi \sim 20$ in the momentum interval $p_T = 10 - 20$ GeV/c [3] because of the larger jet cross section. The ALICE TPC [4] is the only detector in the ALICE experiment that has direct particle identification (PID) capabilities for pions, kaons, and protons at these high momenta.

2. The ALICE TPC Performance

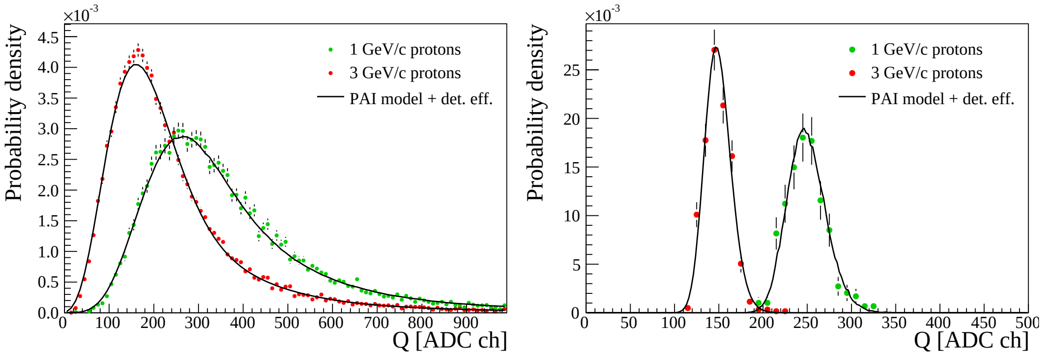

Figure 1: The straggling data (left) and the truncated mean distribution (right) for protons with momentum 1 and 3 GeV/c compared to model calculations with detector effects included.

The TPC performance has been studied with data from a test TPC, consisting of the ALICE TPC field cage prototype in combination with an inner readout chamber (IROC) instrumented with the final electronics, see [5]. The IROC has 63 rows with a total of 5504 pads, so that a track consists of up to 63 clusters. The PID performance in term of the mean truncated charge was studied for $1 \leq \beta\gamma \leq 50$ and found to be in agreement with expectation, see [5] Fig. 8. This, together with the extrapolated truncated mean resolution for the full ALICE TPC ensures that different particle species can be separated statistically on the relativistic rise ($4 \leq \beta\gamma \leq 1000$).

For a small part of the collected data it was possible to identify 1 GeV/c and 3 GeV/c protons track by track with a Time-Of-Flight setup used in the tests. For these tracks, both the charge straggling function (the "Landau-distribution") and the truncated mean distribution could be measured and compared to model calculations of the energy loss in the gas. The model calculations were obtained from Bichsel [6], where the calculation of the energy loss is based on the Fermi Virtual Photon concept, implemented as the Photo Absorption Ionization (PAI) model by Allison and Cobb and elaborated by Bichsel.

The main result of this analysis was that good agreement, see Figure 1, can be achieved when two detector effects – exponential gas gain variations and diffusion – are taken into account. Unfortunately both these effects deteriorate the resolution of the truncated mean - the distribution broadens by ~ 15 % in total. Further more, the diffusion introduces correlations between charge measurements in neighboring rows, so that the truncated mean distribution can no longer be determined from the straggling function alone (as is the case in the model calculations). For a detailed discussion of the model comparison, see [7].

At the end of my presentation a question was raised by the audience on whether the model simulation had the same correlations as the data and this led me to do a comparison between the charge measured in one row and the mean charge in a neighboring row. As can be seen in Figure 2 the model calculations in general describe the correlations well for intermediate cluster charges, $130 \leq Q \leq 500$ ADC ch, where most of the statistics for the truncated mean is, but underestimate somewhat the correlations for low cluster charges, $Q \leq 130$ ADC ch (where one has to remember that for $Q \leq 100$ ADC ch there is very little statistics).

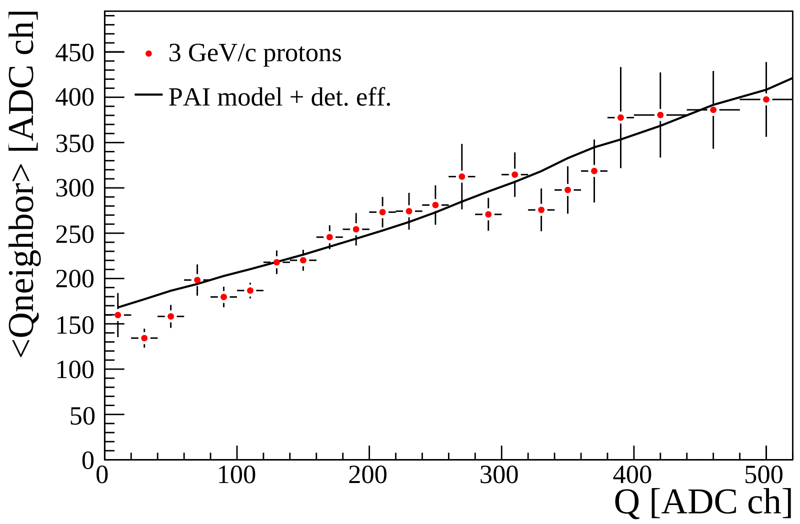

Figure 2: Comparison between the charge in a given row and the mean charge in a neighboring row. If there were no correlations the distribution should be flat. As can be seen, the correlations are well reproduced by the model calculations, where they are the result of diffusion.

3. Conclusions

TPC PID on the relativistic rise requires separation and resolution where the ALICE TPC performance has been shown in [5].

To understand this performance, a small subset of the data where the tracks were fully identified was compared to model calculations based on the PAI model. These calculations could reproduce the performance - straggling functions, truncated mean distributions, and correlations - when a few detector effects were taken into account.

This shows that model calculations are now of a quality where they are important tools for understanding TPC performance. It is the hope of this author, that at high p_T, where the truncated mean separation between pions, kaons, and protons is small and the statistics is low, models can be used to predict/fix the expected PID signal and resolution that would otherwise have to be extracted from the data.

Acknowledgments

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References

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