Transverse momentum distributions of charged particles

Bachelorarbeit
am Institut für Kernphysik Frankfurt

vorgelegt von

Youssef El Mard Bouziani

Fachbereich Physik
der Goethe-Universität
Frankfurt am Main

Februar 2019

Erstgutachter: Prof. Dr. Henner Büsching
Zweitgutachter: Prof. Dr. Harald Appelshäuser

Contents

0 Abstract

1 Introduction

1.1 The Structure of Matter

1.2 Quantum Chromodynamics

1.3 Phase diagramm and Quark-Gluon-Plasma

1.4 Physics of particle collisions (pp, A-A col.)

- Creation of QGP in heavy ion collisions
- Mechanisms of the particle production (event types, elementary cross section)

1.5 (charged particle) p_{T} spectra and nuclear modification factor

- Problem statement (analysis of primary charged-particle)
- Definition of a p_{T} spectrum/differential cross section (without normalization, see Eq. 1.19 in mknichel) .
- Definition of the nuclear modification factor and of related variables (N_{coll}, T_{AA})
- Present previous results of nuclear modification factors published by the charged-particle group

1.6 Monte Carlo simulations

Definition and comparison of spectra with HIJING models

2 The ALICE Experiment at CERN

2.1 The LHC

2.2 ALICE

2.2.1 ITS

2.2.2 TPC

2.2.3 Track reconstruction

Track reconstruction (introduce the observables associated with track cuts, for example number of clusters, CHi2 per cluster, etc.), existence of a p_{T} resolution, introdue DCA, definition of primary particles (and secondaries)

2.2.4 V0 detectors

Centrality determination

specific for ALICE, Gabriels thesis

3 Analysis

Short introduction.

3.1 Data sample

- Compare data sets used for the published results with data sets (data and MC, pp and Pb-Pb) selected for this thesis. More statistics in pp allow an improved precision of p_{T} spectra at high p_{T}
- Introduce FAST and CENT (wSDD and woSDD) reconstructions for the case of pp. Problem statement: Are FAST and woSDD similar enough to combine them? The question will be answered later on by analysing the ratio between the corrected p_{T} spectra that result from CENT woSDD and CENT wSDD.

3.2 Event selection

- Trigger overview (working principle of the ALICE trigger), Minimum Bias
- Selection of events in stages (selection of col. candidates, background and pile-up discrimination)
- Introduce $|V_Z| < 10$ cm cut motivated by acceptance coverage of tracking system

3.3 Track selection

- Kinematik propierties. p_{T} and η range. Present track cuts.

3.4 Corrections

- Uncorrected p_{T} spectra
- Several detector effects must be corrected.

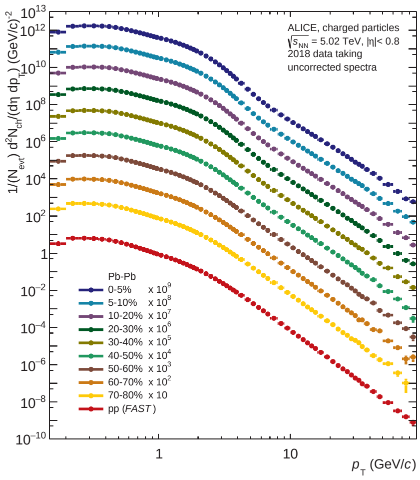

Figure 3.1: Uncorrected p_{T} spectra

- Fully corrected spectrum

$$\frac{\mathrm{d}^2 N^{\mathrm{INEL}}}{\mathrm{d}\eta \mathrm{d}p_{\mathrm{T}}} = \frac{1}{N_{\mathrm{ev}}^{\mathrm{rec}}} \cdot \epsilon_{\mathrm{Trig}} \cdot \epsilon_{Vz} \cdot \frac{\mathrm{d}^2 N_{\mathrm{corr}}}{\mathrm{d}\eta \mathrm{d}p_{\mathrm{T}}}$$

- Correct number of reconstructed events due to 2 effects at event-level:
  - → Trigger efficiency ϵ_{Trig}
  - → Vertex reconstruction efficiency ϵ_{Vz}

Figure 3.2: Normalisation of the pt spectrum

- Track and event level corrections

3.4.1 Normalisation of the pt spectrum

- Follow line of argument presented in status update from 6.10.2020
- Normalize with number of reconstruced events.
- In case of pp, this number does not correspond number of inelastic events and must be therefore corrected (trigger and vertex efficiencies).
- Trigger efficiency: ratio between visible and inelastic cross section. van-der-Meer scans were used for the determination of σ_{vis}, while sophisticated fit approximation for σ_{inel}. ϵ_{trig}. Equal 1 in the case of Pb-Pb.
- Vertex efficiency: ratio of the number of events with vertex to the number of triggered events. Equal 1 in the case of Pb-Pb.
- Verex efficiency must be combined with a correction at track level in order to regain the signal loss.

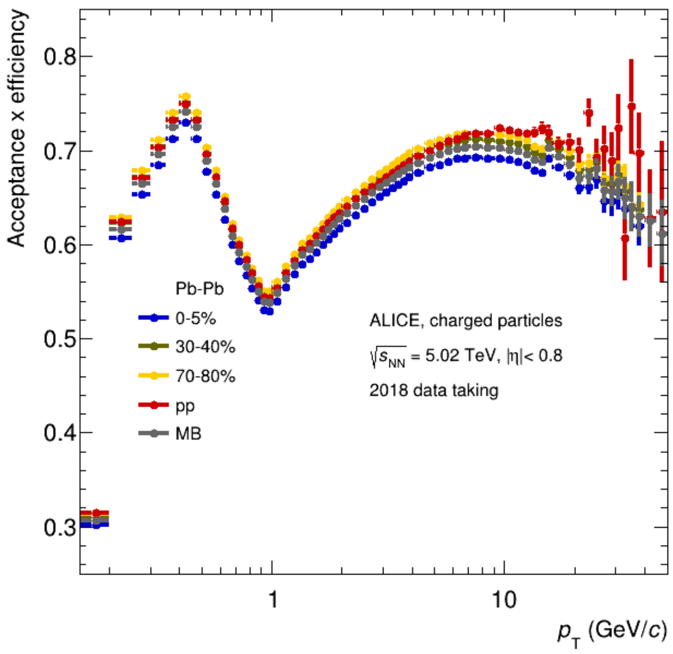

Figure 3.3: Tracking efficiency

3.4.2 Tracking efficiency

- Definition: reconstructed primary tracks/ generated primary tracks.
- Describe shape: at low p_T efficiency increases due to the more sharper bending of the tracks in this p_T range. Then, efficiency decreases at $p_T = 1$ GeV because of track length cut.
- In Pb-Pb: statistics are not sufficient large to divide tracking eff. in centrality classes (show plot). Instead scale the MB efficiency with a factor extracted from fitting the ratio cent. dependent eff to MB eff. (show plot).
- Particle compositon by Patrick. Yield of some strange particles is underestimated by MC generators. Therefore an additional correction is needed. Correction not implemented by presented analysis, but used.

3.4.3 Secondary contamination

- Even using track selection, a small amount of secondaries (decay products and particles esulting intereaction with detector material) remain. Use MC to correct this amount (show plot).
- More secondaries at low p_T , since secondaries take a fraction of the energy of the mother particle

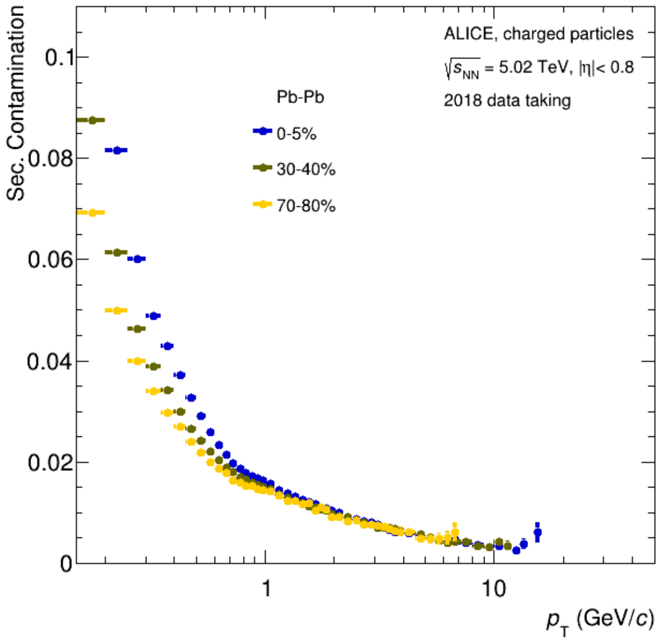

Figure 3.4: Secondary Contamination

- Again, the underestimation by the MC generators of strange particles (do research about this underestimation and describe it) must be corrected -> Secondary scaling.

Secondary scaling

- Secondary scaling: make use of DCA disitributions, since those of primaries are different to those of secondaries. Use template fits (define template fit) using the MC predictions of the distributions to determine the fractions of secondaries in data (show DCA plot). Compare obtained fractions to MC fraction to calculate a p_T dependent correction factor.
- To get best possible results, p_T , multiplicity and DCA intervals were optimized.
- To evaluate the quality of the fit, chi2-test and pulls were used (define chi2-test and pulls, show pull distributions).
- Make plot with resulting correction factors.

3.4.4 p_T resolution correction

Follor arguemnt line presentend on the status update from 7.4.2020

- Momentum determinaton explained in detector chapter. $1/p_T$ is a parameter of the covariance matrix, so we know its resolution.

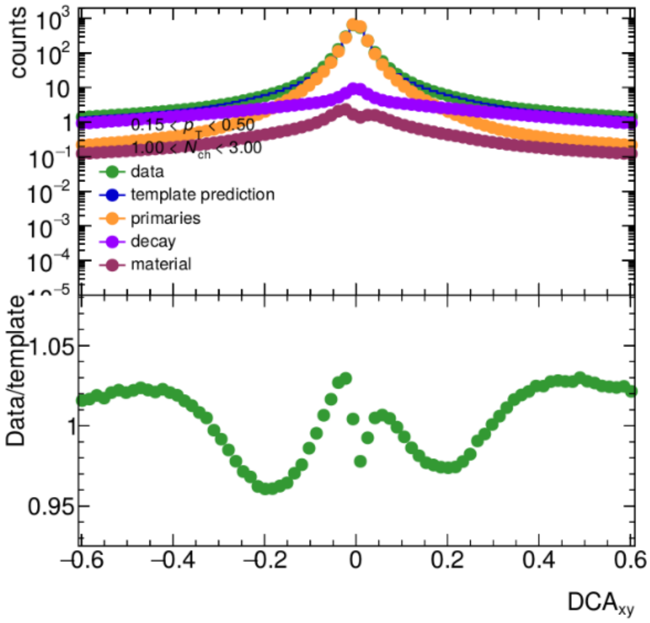

Figure 3.5: DCA distributions

- Gluckstern paper states $\sigma(p_{\mathrm{T}})/p_{\mathrm{T}} \approx p_{\mathrm{T}}\sigma(1/p_{\mathrm{T}})$
- Present $\sigma(p_{\mathrm{T}})/p_{\mathrm{T}}$ distribution. At low p_{T} , it is dominated by multiple scattering. Minimum at 1 GeV$/c$. At high p_{T} , resolution increases because tracks get less curved
- Due to the p_{T} resolution, the measured spectrum deviates from the true spectrum. This is expressed by means of a convolution between measured spectrum and function R that characterize the detector response.
- Correction factor needed. This is defined as ration of measured spectrum to convoluted measured spectrum.
- Explain toy MC used to calculate the correction factor: Fit $< \sigma(1/p_{\mathrm{T}}) >$. Eliminate statistical fluctuations in $\sigma(1/p_{\mathrm{T}})$ by extracting the fit from it. Project resulting $\sigma(1/p_{\mathrm{T}})$ along y axis. As result, one obtains the statsitical distribution of $\sigma(1/p_{\mathrm{T}})$. Fit now the measured spectrum with a Hagedorn (this allows, of course, to get centrality dependent correction factors in the case of Pb-Pb col.). Use fit to produce a p_{T} distribution. Calculate $1/p_{\mathrm{T}}$ and shift the distribution of $\sigma(1/p_{\mathrm{T}})$ so that the peak coincides with the corresponding $< \sigma(1/p_{\mathrm{T}}) >$ value. Genearate a $\sigma(1/p_{\mathrm{T}})$ value randomly. Smear $1/p_{\mathrm{T}}$ with this value assuming a gaussian form. Calculate p_{T} from smeared $1/p_{\mathrm{T}}$. Proudce a p_{T} distribution. Correction factor: ratio of measured spectrum to smeared measured spectrum.

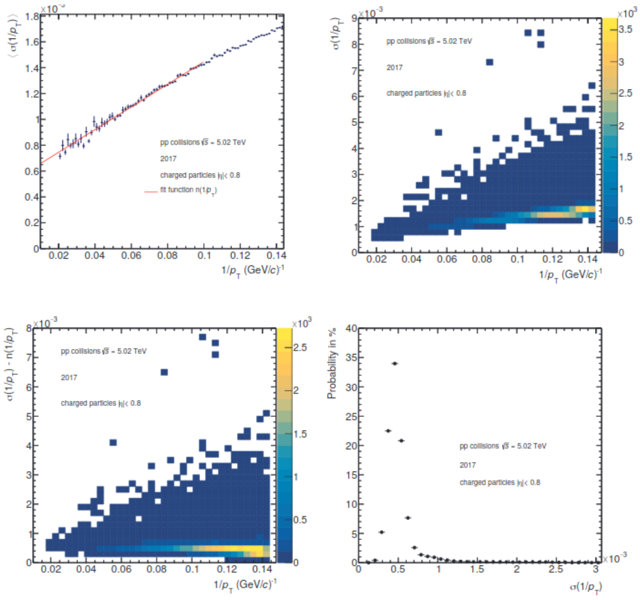

Figure 3.6: Method used to obtain the statistical distribution of $\sigma(1/p_{\mathrm{T}})$

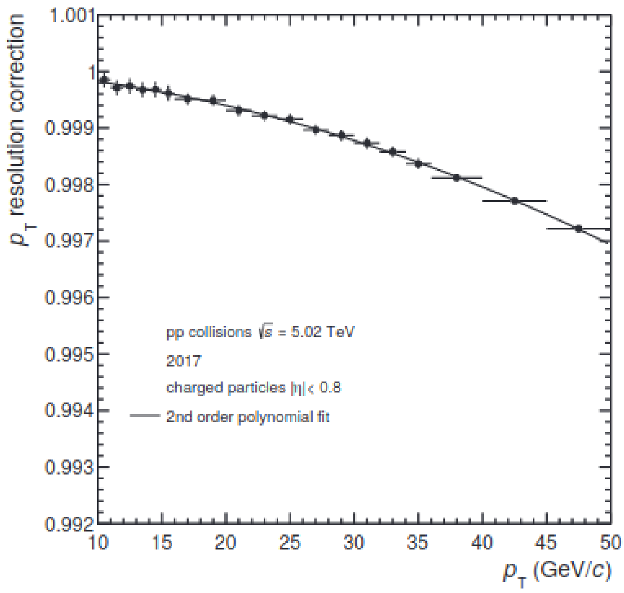

Figure 3.7: pt resolution correction factor

3.5 Corrected p_{T} spectra

- In pp: Compare p_{T} spectra from CENT wSDD and CENT woSDD. If they match, combine FAST and CENT woSDD data sets.
- In pp: Compare Edgar's fully corrected spectrum with mine. Emphazise the achivement of a more precise binning and a larger range.
- In Pb-Pb: Compare Julius's fully corrected spectra with mine.

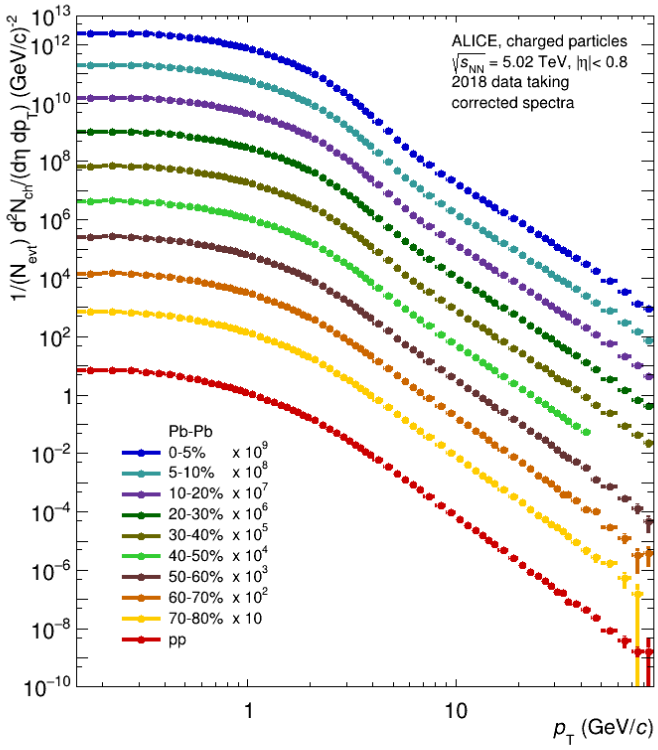

Figure 3.8: Corrected p_{T} spectra

3.6 Systematic uncertanties

- Present systematic uncertanties of the spectra calculated performing cut variations.

Calculate sys. uncertanties with method suggested by Joshua (calculate R_{AA} for the different track cuts)

3.7 Results

Discuss R_{AA} distributions including comparison with previous results.

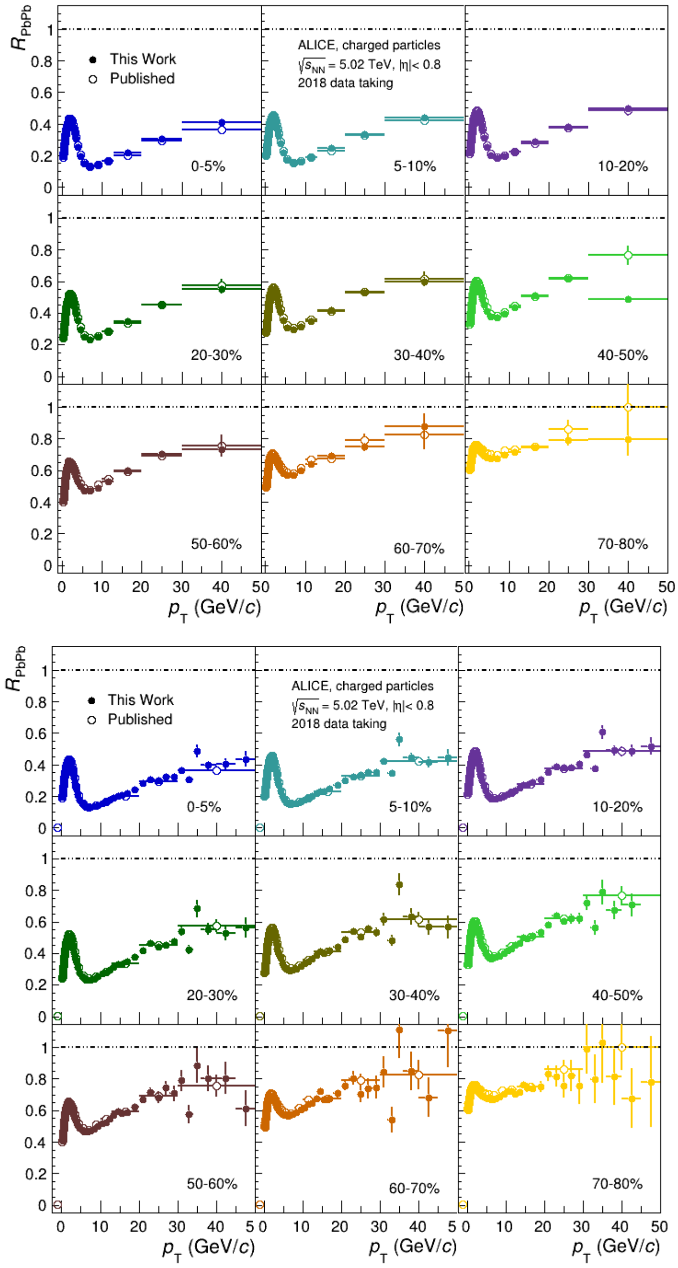

Figure 3.9: R_{AA} (with and without rebin)

4 Summary