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Study of integrated and transverse momentum differential production rates for particles emitted in high energy collisions at the LHC

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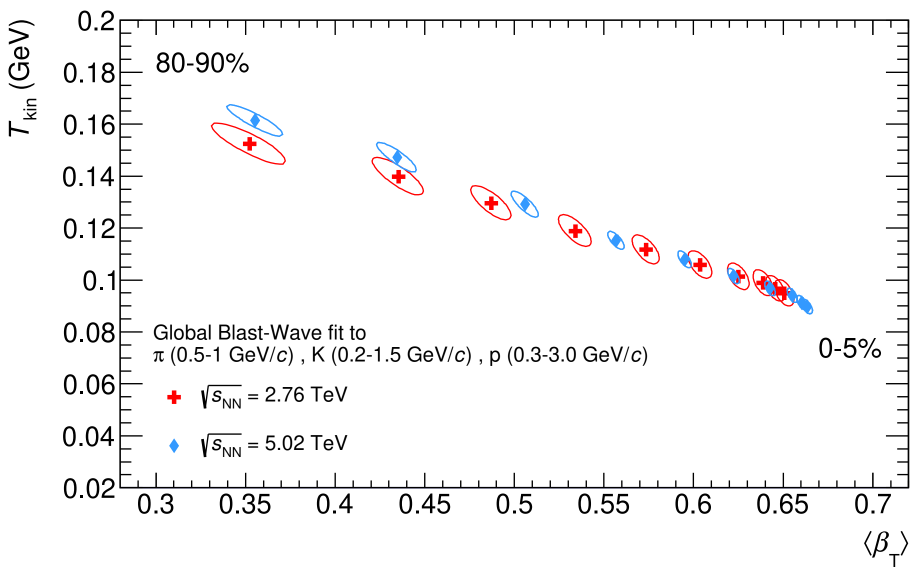

1 Introduction

This project proposes to determine of integrated production rates for hadron species obtained in proton-proton (pp) and lead-lead (Pb–Pb) collisions at 5.02 TeV per nucleon pair using data collected by the ALICE experiment [1, 2] then to compare them to the results of a statistical thermal model THERMUS [3].

2 Measurements of particle momentum in pp et Pb–Pb collisions

At colliders such that the LHC [1] (where the data to be analysed here are extracted), it is important to precisely identify particles in order to understand the mechanisms at the origin of different quark flavour production. One of the difficulties in the case of collisions involving ^{208}Pb nuclei stems from the large number of track combinations leading to fake candidates especially for decaying hadrons.

[1] Large Hadron Collider

The following event display illustrates the large number of reconstructed particles which are produced for such collision system, when seen from a direction slightly tilted from the beam axis.

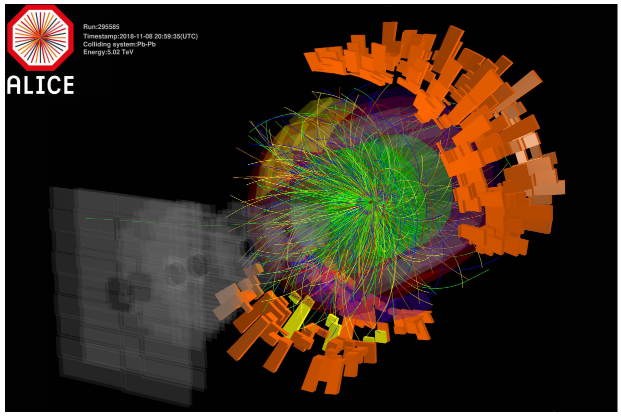

Figure 1: Event display visualisation of a Pb–Pb collision at 5.02 TeV recorded with ALICE.

The reconstructed momentum of any particle created at the primary vertex of the collision can be projected along two directions. These directions are usually the ones of a polar system because most of the detectors have a cylindrical geometry (in order to maximise the acceptance around the primary vertex, see figure 2). The fiducial region is generally located in a longitudinal magnetic field: the curvature of tracks provides crucial information on the momentum and the sign of the electric charge for the produced particles.

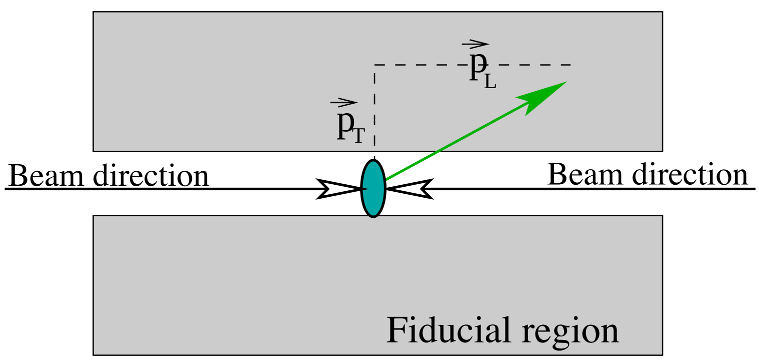

Figure 2: Schematics of the transverse and longitudinal components of the momentum.

The momentum can be written as : $\vec{p} = p_{\mathrm{T}}\ \vec{t} + p_{\mathrm{L}}\ \vec{l}$ where p_{T} and p_{L} are the transverse and longitudinal components of the momentum respectively (see figure 2). Another particularly useful kinematic variable is the transverse mass: $m_{\mathrm{T}} = \sqrt{m^2 + p_{\mathrm{T}}^2}$.

After correcting for detection efficiency, the transverse momentum distributions of the reconstructed particles should be integrated in order to obtain production rates i.e. the number of particles emitted per collision on average. However, the magnetic field needed for determining the momentum leads to an inefficiency at low transverse momenta: it is therefore mandatory to extrapolate the distribution in this region using a function which is fitted on the measured momentum range. For this project, the best fit(s) should be determined for each provided transverse momentum distribution in order to infer general information about production mechanisms.

3 Topics and main steps

The project touches on several topics:

- Organisation of data, data representation and error analysis;
- Fits, goodness of a fit;
- Integration and extrapolation for unmeasured regions ;
- Interpretation of results.

The project can be conducted in several parts. The different steps can be dealt with using ROOT or any other framework that contains minimisation routines and provides the possibilities of performing fits and visualising the results.

The Pb-Pb data for the produced protons and anti-protons ($p + \overline{p}$) will have to be plotted first using the provided tables together with corresponding uncertainties [4]. In parallel, the two following distribution functions will be superimposed: an exponential distribution, and a Boltzmann distribution law in order to visualise their behaviour in the transverse momentum interval where particles are measured (normalisation should be chosen so the distribution can be observed simultaneously e.g. [5]). Two additional distribution functions corresponding respectively to a Lévy-Tsallis [6] and a power law [7] will be also displayed.
During the second part of the project, fits of the protons and anti-protons ($p + \overline{p}$) Pb-Pb data will be performed using the first two distribution functions. The different options used for performing the fits should be properly described and explained. The parameters obtained for these fits will have to be discussed. It will be important to specify and evaluate the ranges used for performing the fits. The fit results will be compared with the ones obtained for ϕ mesons (for the most central bin available in Pb-Pb collisions) which have a mass similar to the proton one. The pp data for the baryons ($p + \overline{p}$) and the mesons (ϕ) will then be fitted using the Lévy-Tsallis parameterisation.
In the third part of the project, the production rates for both particles and both collision systems will have to be estimated: integrating the fitted distributions which are matching the data over the full range will provide the fraction of the yield which is measured and the fraction which is extrapolated at low transverse momentum for the baryons ($p + \overline{p}$) then for the ϕ mesons.
During the fourth part, the Pb-Pb data will be fitted using a blast-wave model which can be justified due to the very fast expansion of the system [8, 9]. The results will then be compared to the ones obtained in the second part. The fifth part corresponds to the interpretation of the obtained results. According to you, what are the best estimations of the production rates with discussing the associated uncertainties ? Which part of the uncertainties dominates for the extracted production rates ? Propose a method in order to reduce the fit function dependence.

It must be noted that the blast-wave parameters can be interpreted as the mean transverse velocity $\langle \beta_T \rangle$ and the kinetic freeze-out temperature T_{fo}. Determine the 1– and 2–σ contours for the blast-wave fit then represent them on a two-dimension diagramme with superimposing the critical temperature for the transition from nuclear matter to deconfined partons obtained with lattice QCD calculations [10]. Depending on the available time, a comparison between the extracted production rate and the ones obtained from a thermal statistical model could be envisaged [3].

References

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[10] S. Borsanyi *et al.*, *"Is there still any* T_c *mystery in lattice QCD? Results with physical masses in the continuum limit III"*, JHEP 09 (2010) 073, `http://arxiv.org/abs/arXiv:1005.3508`.

Links to access the data

The relevant tables can be found using the following url. They contain the values of the transverse momentum distributions for Pb–Pb collisions as well as inelastic pp ones at 5.02 TeV in the centre of mass.

- [a] $p + \overline{p}$
- [b] ϕ