Transverse momentum and multiplicity correlations in NICA and SPS energy range

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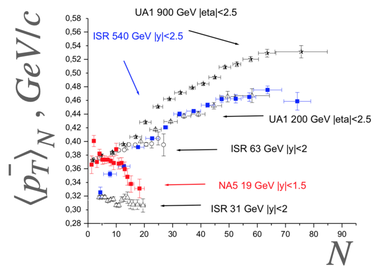
Introduction

Experimentally observed correlations between event-mean transverse momentum and charged particle multiplicity in inelastic pp interactions in large collision energy range put significant restrictions on event generators and led to significant improvements of a number of models (see color reconnection mechanism in PYTHIA [1], modified multi-pomeron exchange approach [2] etc.). Already available results [3] span region from top SPS energies up to TeV-scale of LHC. They are characterized by change of sign of correlations with the increase of collision energies.



Experimental analysis at lower collision energies would help to improve models even further. There is a possibility for this kind of measurements at the NA61/SHINE experiment at SPS (with $\sqrt{s}$ from 6 GeV up to 17 GeV) [4] and at the future MPD experiment at NICA [5] where even lower collision energies would be possible. In this contribution we perform the first step in the direction of experimental analysis and look at the results of Monte Carlo simulations in realistic kinematic acceptances of NA61/SHINE and MPD.

Definitions and observables

In this work we studied correlations between multiplicity N and event-mean transverse momentum $\bar{p_T} = \frac{1}{N}\sum_{i=1}^{N} p_T^i$ by means of the correlation coefficient:

$$b_{corr} = \frac{\langle \bar{p_T} N \rangle - \langle \bar{p_T} \rangle \langle N \rangle}{\langle N^2 \rangle - \langle N \rangle^2}, \quad (1)$$

where $\langle \ldots \rangle$ stands for averaging over all events. It is clear that $\bar{p_T}$ can be defined only in events with $N > 0$ in the considered acceptance. In order to make a correlation coefficient dimensionless it is often considered in the following re-scaled way:

$$b_{corr} \to b_{corr} \cdot \frac{\langle N \rangle}{\langle \bar{p_T} \rangle} \quad (2)$$

NA61/SHINE and MPD

NA61/SHINE (SPS Heavy Ion and Neutrino Experiment) is a multi-purpose facility to study hadron production in hadron-proton, hadron-nucleus and nucleus-nucleus collisions at the CERN Super Proton Synchrotron (SPS). It allows to perform very precise tracking in forward rapidity semisphere [4].

The MPD is designed as a 4π spectrometer capable of detecting of charged hadrons, electrons and photons in heavy-ion collisions in the energy range of the NICA collider. The major goal of the NICA/MPD project is the study of in-medium properties of hadrons and the nuclear matter equation of state, including a search for possible signals of deconfinement and/or chiral symmetry restoration phase transitions and the QCD critical endpoint in the region of the collider energy $\sqrt{s_{NN}}$ = 4 – 11 GeV [5].

Models and kinematic selection

In this study we used EPOS1.99 [6] event generator (string decays) for SPS energy range and SMASH [7] event generator (hadronic transport) for NICA energy range. As we want to analyze correlations in realistic experimental environment we apply certain kinematic selection corresponding to NA61/SHINE (including NA61/SHINE acceptance map [8]) and MPD:

EPOS (for NA61/SHINE))	SMASH (for MPD)
$0<p_T<1.5$ GeV/c	$0.15<p_T<2$ GeV/c
$0<y_\pi<y_{beams}$	$\lvert\eta\rvert<1$
acceptance map cut[8]	

$\bar{p_T}$-N correlations

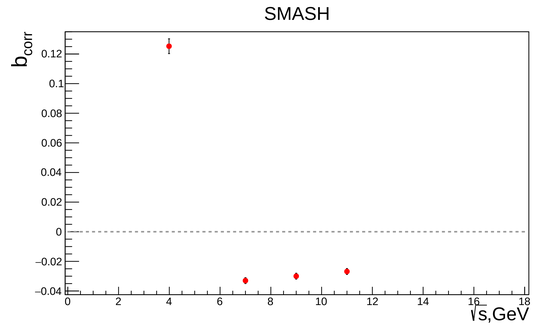


Figure 1:Correlation coefficient as a function of collision energy obtained in SMASH for p+p interactions in the NICA energy range.

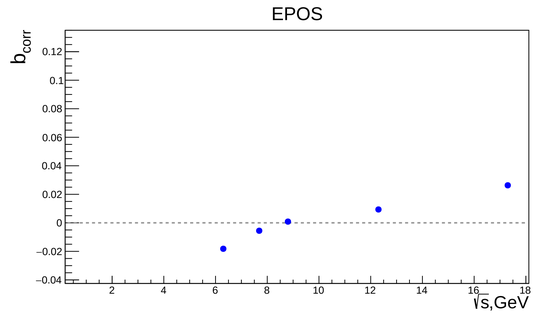


Figure 2:Correlation coefficient as a function of collision energy obtained in EPOS for p+p interactions in the NICA/SHINE energy range.

Peculiar change of the correlation coefficient's sign with the increase of collision energies can be seen in Figure 1. Particle production in the SMASH model is dominated by resonances decays for collision energies below 5 GeV and by decays of quark-gluon strings at higher energies.

In both models the decrease of correlations with a decrease of collision energy is observed, with negative correlations being an outcome of energy-momentum conservation.

Correlation function

Alternative definition of correlation coefficient is coming from the linear regression method [9].

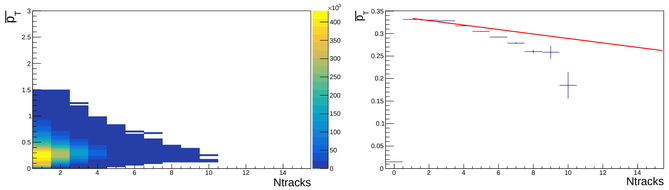


Figure 3:pt-N histogram (left) and its profile (right) in EPOS for p+p interactions for energy $\sqrt{s} = 6.3$ GeV.

Correlation coefficients obtained by two definitions would coincide in case of linear correlation function. In Fig. 3 we see that correlation function deviates from the linear trend at larger multiplicities.

Comparison of two methods is given below:

- Coefficient from formula (1): b_{corr} = -0.0035±0.0001 GeV/c
- Coefficient from linear regression: b_{corr} = -0.00496±0.00004 GeV/c

Summary

In this work, the correlations between transverse momentum and multiplicity were studied in such Monte Carlo simulators as EPOS and SMASH. The graphs of the correlation coefficient versus energy were plotted. Decreasing of correlation coefficient with lowering of the collision energy was observed both in EPOS and SMASH models. Also change of regime in SMASH at $\sqrt{s} = 4$ GeV was found.

We also studied two different methods for obtaining the correlation coefficient: directly from formula (1) and from a linear regression model. Deviation of correlation function from linearity led to some difference in values of correlation coefficient.

In the future it is planned to perform an analysis of experimental data on inelastic p+p interactions recorded by the NA61/SHINE experiment.

Acknowledgment

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