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Transverse momentum fluctuations and $\Delta\eta\Delta\phi$ correlations in p+p interactions at the CERN SPS energies

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The NA61/SHINE experiment aims to discover the critical point of strongly interacting matter and study the properties of the onset of deconfinement. These goals are to be achieved by performing a two dimensional phase diagram ($T - \mu_B$) scan by measurements of hadron production properties in proton-proton, proton-nucleus and nucleus-nucleus interactions as a function of collision energy and system size. Close to the critical point an increase of fluctuations is predicted.
In this contribution preliminary results on transverse momentum fluctuations and two-particle pseudorapidity/azimuthal angle correlations from the NA61/SHINE energy scan of p+p collisions will be presented. These new results will be compared with NA49 data on central Pb+Pb collisions and model predictions.

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1. Introduction

The NA61/SHINE experiment aims to discover the critical point of strongly interacting matter and study the properties of the onset of deconfinement. Close to the phase transition and close to the critical point large fluctuations are predicted.

This poster presents results from the analysis of transverse momentum event-by-event fluctuation analysis and two-particle correlations.

2. The Φ measure

Φ [1] is a strongly intensive measure of fluctuations. In the Wounded Nucleon Model it does not depend on the number of wounded nucleons nor on its fluctuations. In thermodynamical models Φ does not depend on the volume and its fluctuations.
Φ was used extensively by NA49 to study transverse momentum fluctuations (Φ_{p_T}) in Pb+Pb collisions [2].

The Φ_{p_T} formula used for the analysis can be expressed by event quantities:

$$\Phi_{p_T} \equiv \sqrt{\frac{\langle X^2\rangle}{\langle N\rangle} - \frac{2\langle X\rangle\,\langle NX\rangle}{\langle N\rangle^2} + \frac{\langle X\rangle^2\,\langle N^2\rangle}{\langle N\rangle^3}} - \sqrt{\frac{\langle X_2\rangle}{\langle N\rangle} - \frac{\langle X\rangle^2}{\langle N\rangle^2}}$$

where:

$$X = \textstyle\sum_{i=1}^{N} p_{T\,i} \qquad X_2 = \sum_{i=1}^{N} \left(p_{T\,i}^{\,2}\right)$$

N is the number of charged particles in a given event and $\langle N\rangle$ is the mean multiplicity of the event sample.

In order to obtain all these event quantities, two histograms are prepared: the one-dimensional distribution of X_2 and the two-dimensional distribution of N vs. X.

3. Corrections

Contamination by non-target interactions is subtracted as follows (Fig. 1). NA61/SHINE records data with both target inserted and with no target. Then the correction is done by subtracting normalized histograms for data without the target (left) from the corresponding histograms for the target-inserted data (middle). The result is shown by the right plot.

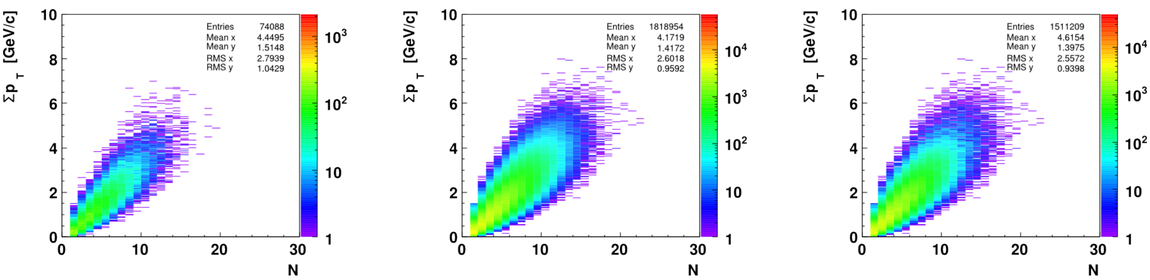

Figure 1: *N vs X for 158 GeV/c target-removed (left), target-inserted (middle) and target-inserted corrected for non-target interactions (right)*

Eventually, Φ_{p_T} will be also corrected for detector effects. The inverse correction factor (Fig. 2 right)will be obtained by dividing corresponding histograms of the reconstructed VENUS data (middle) by pure generated VENUS (left).

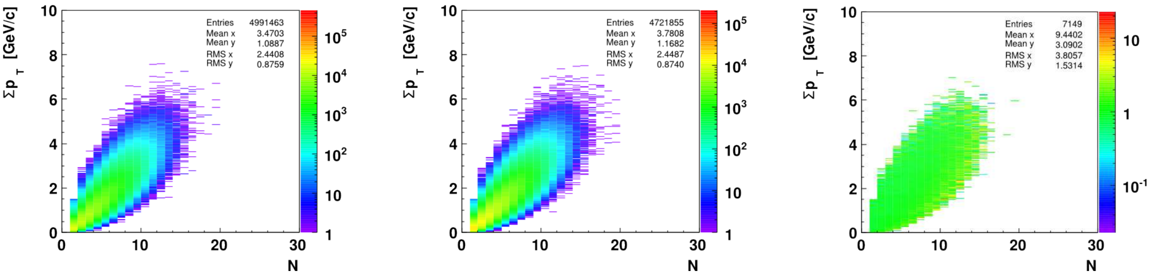

Figure 2: *N vs X for 158 GeV/c VENUS reconstructed (left), VENUS generated (middle) and inverse correction factor (right).*

Then the data, after subtraction of the non-target interaction contamination, will be corrected by dividing the histograms by the inverse correction factor.

4. Φ_{p_T} results

Results, Fig. 3, are only corrected for non-target interactions. Study of corrections for detector effects and feed-down is still ongoing. Results from inelastic p+p interactions were collected at beam momenta: 20, 31, 40, 80, 158 GeV/c.

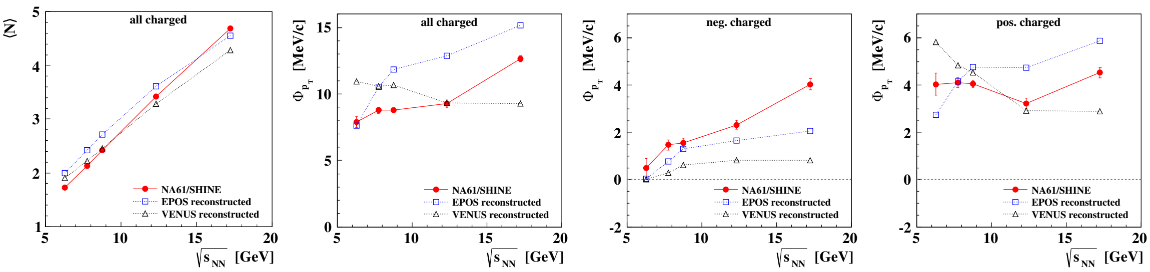

Figure 3: *Mean multiplicity (left) and Φ_{p_T} for the p+p NA61/SHINE energy scan.*

In order to compare Φ_{p_T} from NA61/SHINE for p+p collisions and published NA49 data on central Pb+Pb interactions, additional NA49 acceptance cuts had to be applied:

- because of high density of tracks, analysis in NA49 was limited to the forward rapidity region ($1.1 < y < 2.6$),
- the smallest ϕ acceptance (20 GeV/c) was used for all energies.

Due to the additional cuts (mainly restricted rapidity) Φ_{p_T} for p+p collisions decreased.

The collision energy dependence of Φ_{p_T} for p+p and central Pb+Pb collisions (Fig. 4 left) does not show any anomalies which might be expected for the critical point. A hint of a signal is, however, observed for medium size systems (right). NA61/SHINE will record Ar+Ca and Xe+La data in 2014/15 which will allow a systematic study.

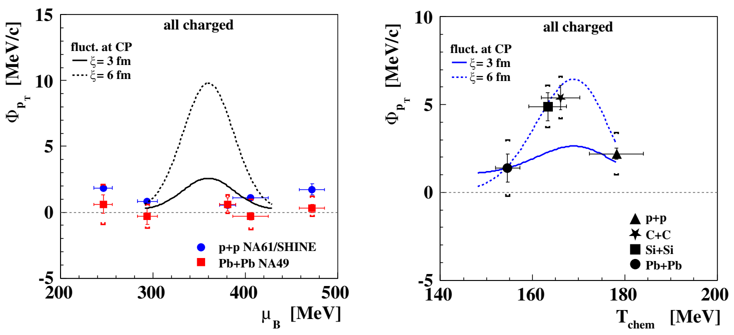

Figure 4: *Comparison of NA61 p+p and NA49 central Pb+Pb results in common acceptance with predictions for the critical point (left). System-size scan published by NA49 with predictions for the critical point (right).*

5. Two-particle correlations

Two-particle correlations were studied for inelastic p+p interactions at 158 GeV/c beam momentum as a function of the difference in pseudo-rapidity η and azimuthal angle ϕ between two particles in the same event:

$$\Delta\eta = |\eta_1 - \eta_2| \qquad \Delta\phi = |\phi_1 - \phi_2|$$

The correlation function is defined as:

$$C(\Delta\eta,\Delta\phi) = \frac{N^{pairs}_{mixed}}{N^{pairs}_{data}} \frac{S(\Delta\eta,\Delta\phi)}{M(\Delta\eta,\Delta\phi)}$$
$$S(\Delta\eta,\Delta\phi) = \frac{d^2N^{signal}}{d\Delta\eta d\Delta\phi}; \quad M(\Delta\eta,\Delta\phi) = \frac{d^2N^{mixed}}{d\Delta\eta d\Delta\phi}$$

The correlation function was folded around $\Delta\phi = 0$, i.e. if $\Delta\phi > \pi$ then $\Delta\phi = 2\pi - \Delta\phi$. η was transformed from LAB to CMS assuming the π mass. Correlations for all events are shown in Fig. 5 (left).

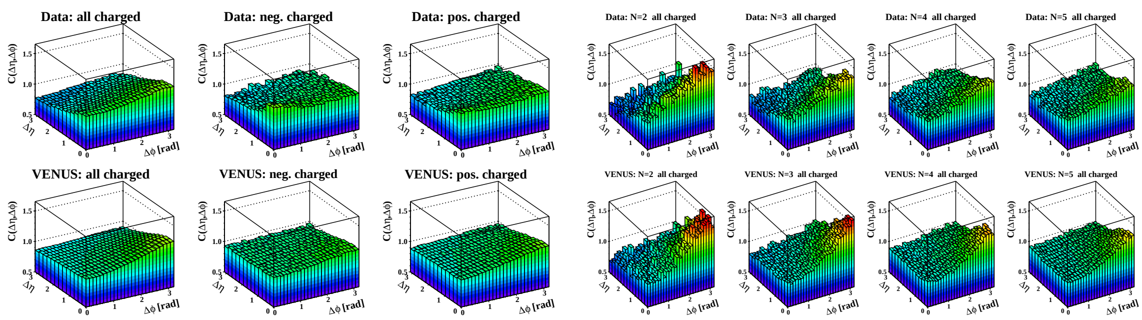

Figure 5: $\Delta\eta\Delta\phi$ *correlations for all events (left) and for multiplicities of 2, 3, 4 and 5 (right) for all charged particles*

Correlations were also calculated for events with multiplicities of 2, 3, 4 and 5 for all charged (Fig. 5 right), positively charged (below, left) and negatively charged particles (below, right).

Results from NA61 data (upper distributions) show several structures:

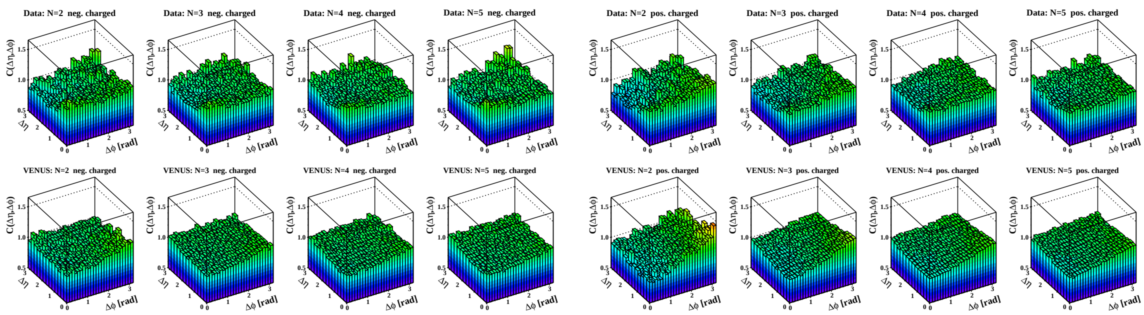

Figure 6: *$\Delta\eta\Delta\phi$ correlations for events with multiplicities 2, 3, 4 and 5 for negatively (left) and positively (right) charged particles*

- A significant maximum for all and positively charged particles at $(\Delta\eta, \Delta\phi) = (0, \pi)$ probably coming from resonance decays and momentum conservation. This maximum is better visible for selected multiplicities (see Fig. 6).
- A lower but also visible enhancement at $(0, 0)$ coming from Coulomb interactions and Bose-Einstein correlation (quantum) effects.

Results from the VENUS model (bottom distributions) show similar structures except the hill at $(0, 0)$, because VENUS does not simulate Coulomb and quantum effects.

Two-particle correlations in $\Delta\eta\Delta\phi$ were also studied at RHIC [3] and LHC [4].

6. Summary

A new method of correcting results of fluctuations for experimental and physics biases was introduced. Φ_{p_T} results corrected for non-target interactions for inelastic p+p interactions at beam momenta: 20, 31, 40, 80 and 158 GeV/c were presented. Fully corrected results will be shown soon.

Two-particle correlations were obtained for inelastic p+p interactions at 158 GeV/c both for NA61 data and the VENUS model. The analysis showed several structures. They depend on the multiplicity selection and may be related to Coulomb interactions, quantum effects, resonance decays and conservation laws.

Acknowledgements

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References

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