Influence of the target on multiparticle production in the forward domain in p+Pb collisions at 158 GeV

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In this talk we show the influence of the target on multiparticle production in the forward hemisphere in p+Pb collisions at top SPS energy. The multiplicity distributions appear to be almost target independent in the projectile fragmentation domain and the effect of fluctuations of the number of target participants is not seen in the projectile fragmentation region. We compare the obtained results with those for p+p interactions and predictions of models.

1. Introduction

The NA49 Collaboration reported [1] large multiplicity fluctuations in the forward rapidity domain of non-central Pb+Pb collisions at beam momentum of 158 GeV/c per nucleon at a fixed number of participating nucleons from the projectile. There is no commonly accepted explanation of the phenomenon but it was observed [2] that even at fixed number of projectile participants, the number of target participants fluctuates and it was suggested that the observed large multiplicity fluctuations in the forward rapidity domain of Pb+Pb collisions are due to the fluctuating number of participants from the target. Such a mechanism, however, assumes that the target (projectile) participants contribute to the projectile (target) fragmentation region, i.e. that the domains of projectile and target fragmentation overlap. A model assuming such a mechanism is called by the authors of Ref. [2] the *mixing* model to be distinguished from the *transparency* model where the projectile participants only contribute to the projectile fragmentation domain and the target participants only to the target fragmentation domain. The transparency model is compatible with the limiting fragmentation hypothesis [3][1] while the mixing model contradicts it. Both models

[1] Hypothesis of limiting fragmentation states that for a sufficiently high collision energy particle production becomes target and energy independent in the projectile (target) fragmentation domain corresponding to the rapidities close to that of the projectile (target).

should obviously be treated as idealizations. The analysis of d+Au collisions at RHIC [4] shows that in reality we have both mixing and transparency. Our objective here is to study the importance of the mechanism of mixing in p+Pb collisions where the number of participants from the target fluctuates but the number of projectile participants is always one.

As a measure of multiplicity fluctuations we use here, as in the study described in ref.[1], the scaled variance $\omega = \mathrm{Var}(N)/\langle N\rangle$ of the multiplicity distribution where $\mathrm{Var}(N)$ is the variance and $\langle N\rangle$ the mean value of the distribution. We analyze minimum bias p+Pb collisions and confront the results with those from p+p interactions at the same collision energy.

2. The NA49 Experiment

The NA49 experiment is a large acceptance hadron spectrometer situated in the H2 beam line at the CERN SPS accelerator complex which was used to study the hadronic final states produced in collisions of protons with a variety of fixed targets. [5]. The main tracking devices are four large volume Time Projection Chambers (TPCs). Two of them, the Vertex TPCs (VTPC-1 and VTPC-2), are located inside the magnetic field of two super-conducting dipole magnets (1.5 and 1.1 T, respectively) and two others (MTPC-L and MTPC-R) are positioned downstream of the magnets symmetrically to the beam line.

Interactions of protons in the target are selected by anti-coincidence of the incoming beam particle with a signal in a small scintillation counter S4 placed on the beam trajectory between the two vertex magnets. For p+p interactions at 158 GeV/c this counter selects a (trigger) cross section of 28.23 mb out of 31.78 mb of the total inelastic cross section [6].

Details of the NA49 detector set-up and performance of the tracking software are described in [5]. The parts of the NA49 experiment specific to the study of p+Pb interactions are described in [7].

2.1. Data sets, detector acceptance, and event and particle selection

In this contribution we show the results of the analysis of 125,000 minimum bias p+Pb collisions and 320,000 p+p interactions both at beam momentum of 158 GeV/c. Although the NA49 detector was designed for a large acceptance in the forward hemisphere [5], the geometrical acceptance is not complete in this region. The acceptance limits in transverse momentum p_T at given azimuthal angle ϕ are parametrized by the function

$$p_T(\phi) = \frac{1}{A + \frac{\phi^2}{C}} + B, \tag{1}$$

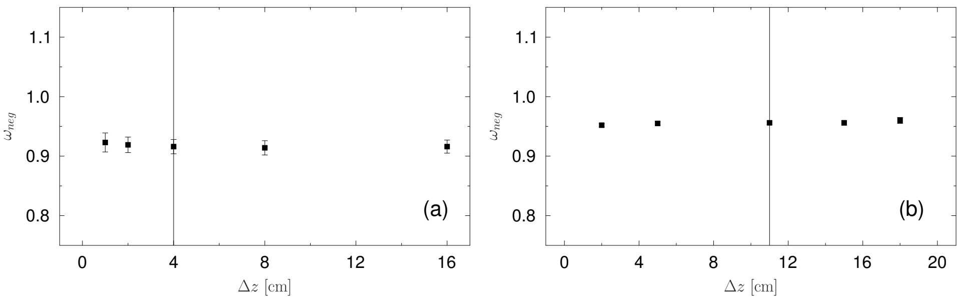

Fig. 1. The scaled variance of the uncorrected multiplicity distribution of negatively charged particles produced in minimum bias p+Pb collisions (panel (a)) and p+p interactions (panel (b)) as a function of the maximally allowed difference Δz between the reconstructed main vertex and the actual target position. The vertical line indicates the value used in the analysis.

where the values of A, B and C depend on the rapidity (see ref.[8]). Only particles within the curves given by Eq. 1 are used in this analysis. Additionally, the particle's transverse momentum is required to obey $0.005 < p_T < 1.5$ GeV/c. This well defined acceptance is essential for later comparison of the results with models and other experiments.

Several event selection criteria are applied to reduce contamination from non-target collisions. The primary vertex was reconstructed by fitting the intersection point of the measured particle trajectories. Only events with a proper quality and position of the reconstructed vertex are accepted for further analysis. The vertex coordinate z along the beam has to satisfy $|z - z_0| < \Delta z$, where the nominal vertex position z_0 and cut parameter Δz values are: -579.5 and 5.5 cm, -581 and 2 cm for p+p and minimum bias p+Pb collisions, respectively. In Fig. 1 we show the stability of the scaled variance of the uncorrected multiplicity distribution of negatively charged particles produced in minimum bias p+Pb and p+p interactions with respect to the maximally allowed difference Δz between the reconstructed main vertex and the actual target position. As seen, the results are stable.

In order to reduce the contamination by poorly reconstructed tracks and particles from secondary interactions and other sources of non-vertex tracks, several track cuts were applied. The accepted particles are required to have measured points in at least one of the Vertex TPCs and the potential number of points (calculated on the basis of the geometry of the track) in the detector has to exceed 30. Moreover, the ratio of the number of points on a track to the potential number of points has to be higher than 0.5 to

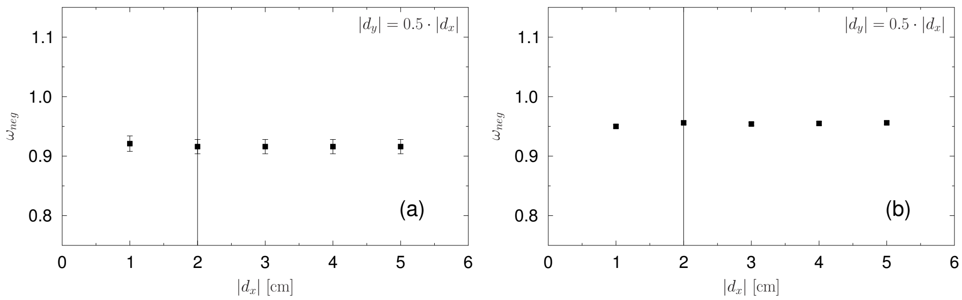

Fig. 2. The scaled variance of the uncorrected multiplicity distribution of negatively charged particles produced in minimum bias p+Pb collisions (panel (a)) and p+p interactions (panel (b)) as a function of the maximally allowed distance between the reconstructed primary vertex and the back-extrapolated track in the target plane $|d_x|$. Simultaneously the deviation in $|d_y|$ is required to be below $0.5|d_x|$. The vertical line indicates the value used in the analysis.

avoid split tracks (double counting). A cut on the extrapolated distance of closest approach (dca) to the fitted vertex of the particle at the vertex plane is applied ($|d_x| < 2$ cm and $|d_y| < 1$ cm) in order to reduce the contribution from weak decay daughters (feeddown). To estimate the effect on the multiplicity fluctuations, the maximally accepted dca was varied. Fig. 2 shows the result for ω and demonstrates that the scaled variance is stable with respect to the cut.

2.2. Corrections for multiplicity distributions based on the VENUS event gereator and detector simulation

In this subsection we describe the VENUS 4.12 [9] simulation of p+Pb minimum bias collisions and p+p interactions used to derive corrections applied later to measured multiplicity distributions. The NA49 apparatus was simulated by using GEANT 3 [10]. The multiplicity distributions were calculated for *pure* VENUS and *accepted* VENUS events, both with acceptance filter of Eq. 1 turned on. *Pure* VENUS results correspond to all charged particles produced in the primary interaction. *Accepted* VENUS results were obtained from GEANT/detector simulated and reconstructed VENUS events applying event and track cuts as for real data. Thus these results correspond to all reconstructed particles which are consistent with originating from the reconstruced event vertex, i.e. particles produced in the primary interaction as some contribution from secondary interactions

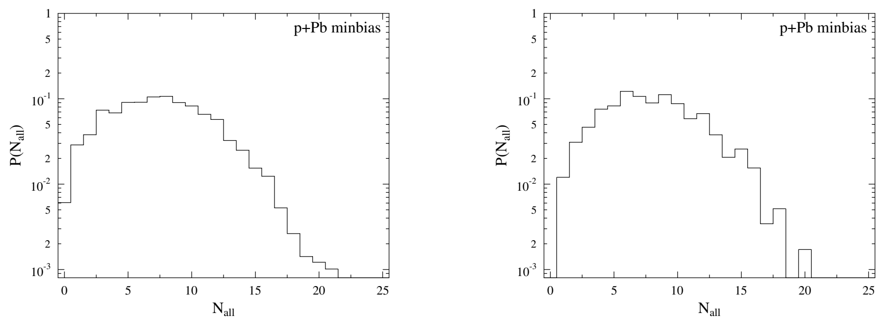

Fig. 3. Multiplicity distributions of all charged particles obtained from *pure* VENUS events of p+Pb minimum bias collisions. Left panel: *good* events for which all measured particles miss the S4 counter. Right panel: *lost* events for which at least one measured particle hits the S4 counter.

and feeddown from decays. The pion mass was assumed for the calculation of the rapidity y in both *pure* and *accepted* VENUS events. Based on the simulation results the unfolding method [11, 12, 13] provided by the ROOT [14] TUnfold class [15] was used to obtain the corrected results.

2.3. Correction for the S4 trigger bias

In this subsection we estimate the effect of a trigger bias caused by the fact that some of the particles produced in an interaction can hit the S4 counter and cause a false veto. All charged particles simulated in full phase-space from each *pure* VENUS p+p and p+Pb minimum bias event were tracked down to the position of the S4 counter: $S4_x = -1.5$ cm, $S4_y = 0.0$ cm and $S4_z = -201$ cm in the NA49 detector coordinate system. If all charged particles from a given event miss the S4 counter then the event is treated as *good*. In the left panel of Fig. 3 we show the corresponding multiplicity distribution of *good* events of p+Pb minimum bias collisions. If a charged particle from an event hits S4 then the event is treated as *lost*. In the right panel of Fig. 3 we show the corresponding multiplicity distribution of *lost* events. The fraction of *lost* events amounts to 10.5%. This number is in good agreement with previous calculations [6, 7]. The *lost* events were excluded from the sample of *accepted* VENUS events used to obtain corrections to the multiplicity distributions.

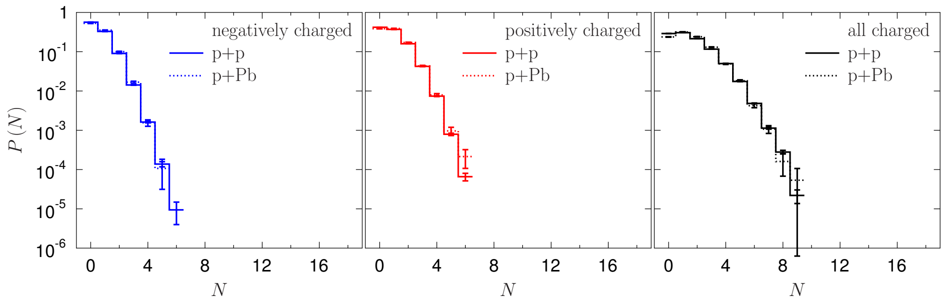

Fig. 4. Uncorrected multiplicity distributions of negatively (left panel), positively (middle panel) and all (right panel) charged particles produced in minimum bias p+Pb collisions (dotted) as well as in p+p interactions (continuous lines).

Table 1. Scaled variance of the corrected multiplicity distributions of particles produced in minimum bias p+Pb collisions and p+p interactions. The errors are statistical only.

Data Set	ω_{neg}	ω_{pos}	ω_{all}
p+p	0.989 ± 0.003	1.002 ± 0.003	1.31 ± 0.004
p+Pb	0.929 ± 0.012	0.924 ± 0.011	1.13 ± 0.013

3. Results

We now proceed to the central subject of our study, the multiplicity fluctuations in the projectile fragmentation region. Results refer to all production (inelastic) reactions in minimum bias p+Pb and inelastic p+p interactions both at beam momentum of 158 GeV/c and to charged hadrons produced in the primary interactions. Figure 4 shows the uncorrected multiplicity distributions of negatively, positively and all charged particles produced in the rapidity interval $4 < y < 5.5$. The distributions in p+Pb and p+p interactions are seen to be very similar again suggesting the validity of the limiting fragmentation hypothesis. In Table 1 we collect the numerical values of the scaled variances ω of the corrected multiplicity distributions. As seen, the second moments of the multiplicity distributions in both classes of collisions are very close to each other. The multiplicity distributions are approximately Poissonian as the scaled variances are close to unity. It is also worth noting that the multiplicity distributions in p+p interactions tend to be broader than those in the p+Pb collisions.

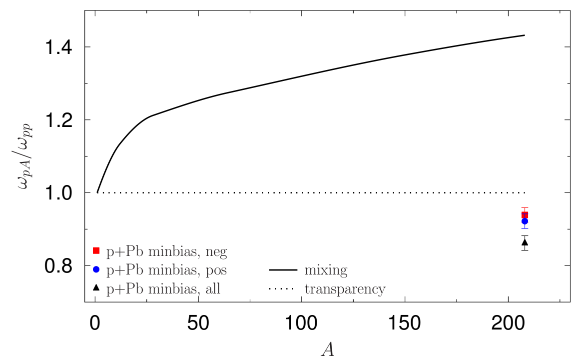

Fig. 5. Scaled variance of the corrected multiplicity distributions of negatively (squares), positively (circles) and all (triangles) charged particles produced in minimum bias p+Pb collisions divided by the respective number from the p+p interactions. The data are plotted as function of atomic mass of target nucleus to show the difference of the mixing (solid line) and transparency (dotted line) models [2].

4. Summary and discussion

We studied particle production in the projectile fragmentation region of minimum bias p+Pb collisions at beam momentum of 158 GeV/c. The results were compared to those from p+p interactions at the same collision energy. The multiplicity distributions appear to be almost target independent in the projectile fragmentation domain. As mentioned in the Introduction, our specific motivation was to test the mixing model proposed in ref.[2]. In Fig. 5 we confront the results on the scaled variance from minimum bias p+Pb collisions with the model predictions. As seen, the transparency model describes the data quite well but the mixing model seems to be excluded. The effect of fluctuating number of target participants is not seen in the projectile fragmentation region. Obviously, the mechanism of Pb+Pb collisions might be rather different from that of p+Pb collisions and thus the mixing model is not ruled out. Nevertheless our results show that there is no strong mixing of the projectile and target fragmentation regions at least in the proton-nucleus collisions.

Acknowledgments

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