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Abstract
The procedure employed by the WA97 and NA57 experiments to determine the number of wounded nucleons in different Pb + Pb centrality classes is discussed. We will also compare different centrality scales and their influence on the measurement of the centrality dependence of strange particle yields.

1. Introduction

The number of nucleons taking part in a collision is a fundamental parameter in the study of heavy-ion reactions at high energy since, for a given colliding system and beam energy, it determines the volume and the energy of the fireball. We define the number of participants as the number of wounded nucleons ($N_{\rm wound}$) calculated from the Glauber model (see, e.g., [1] and references therein). The WA97 and NA57 experiments estimate the number of wounded nucleons from the charged particle multiplicity ($N_{\rm ch}$) measured over the pseudo-rapidity range $2 < \eta < 4$.

In this paper we will compare the results from different methods used to extract the number of wounded nucleons and we will discuss different centrality scales.

2. Multiplicity measurement

The NA57 and WA97 experiments have similar layouts, and in particular they employ the same multiplicity detectors. In NA57, however, a special effort was made to reduce various background sources in order to extend the covered centrality range towards more peripheral events and to investigate the presence of an onset of the strangeness enhancement effect measured by WA97. The NA57 set-up has been described in [2, 3]; the WA97 set-up has been described in [4]. The multiplicity of charged particles is measured by two planes of silicon micro-strip detectors (MSD), covering the pseudo-rapidity regions $2 < \eta < 3$ and $3 < \eta < 4$, respectively. The layout of the MSD detectors and the details on the analysis applied to extract the number of charged particles in the pseudo-rapidity range $2 < \eta < 4$ are described in [5].

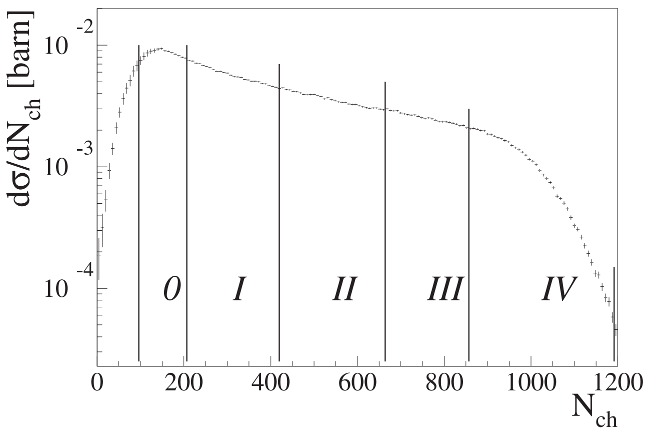

Figure 1. NA57 charged particle multiplicity distribution for Pb + Pb collisions.

Figure 1 shows the charged particle multiplicity distribution measured by the NA57 experiment for Pb + Pb collisions. The data have been binned in five classes. The most central classes (I to IV) correspond to the same centrality classes used in the analysis of WA97 data [5, 6]. The extended centrality range of NA57 allows one to define one more peripheral class (bin 0 in the figure). The drop at very low multiplicities is the effect of the centrality trigger suppressing low multiplicity events.

In the NA57 experiment the trigger cross section was measured with a 3% precision and its value, $\sigma_{\rm trig}^{\rm exp} = (4.15 \pm 0.11)$ barn, corresponds to about 60% of the total nuclear inelastic cross section. The error on the cross section is dominated by the error on the target thickness and on the subtraction of off-target interactions.

3. Determination of the number of wounded nucleons

In the WA97 experiment the number of wounded nucleons was calculated assuming proportionality between the average charged particle multiplicity and the number of wounded nucleons (wounded nucleon model, WNM [7]) [5, 8]. If we relax this hypothesis assuming a power-law dependence (not imposing $\alpha = 1$ as in WA97):

$$\langle N_{\rm ch} \rangle \propto N_{\rm wound}^{\alpha} \tag{1}$$

we find that values of α between 1.02 and 1.09 are compatible with the NA57 measured multiplicity spectrum. We note that the value of α measured by the WA98 experiment [9] ($\alpha = 1.07 \pm 0.02$) falls in this range. Such an uncertainty on the value of α however, has little effect on the determination of the centrality dependence of hyperons reported by WA97, as can be seen in figure 2 where we show the WA97 enhancements (see [10]) for $\bar{\Lambda}$, $\bar{\Xi}^{+}$ and $\Omega^{-} + \bar{\Omega}^{+}$, using $\alpha = 1$ and 1.07. The maximum difference in the number of wounded nucleons is observed for the most peripheral class where it amounts to 7%. No significant change is observed on the centrality dependence of the strange and multi-strange baryons.

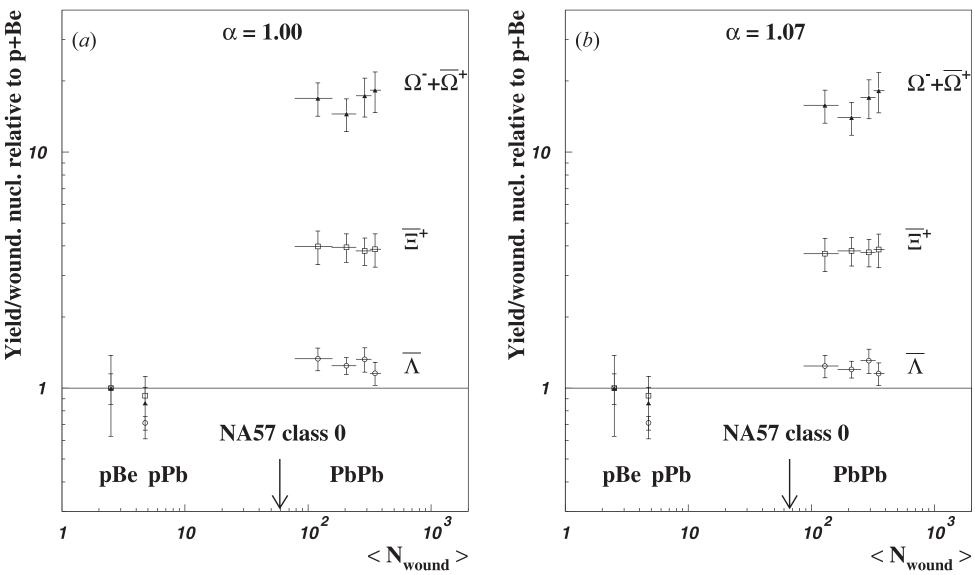

Figure 2. WA97 enhancements using $N_{\rm wound}$ from (*a*) the WNM fit and (*b*) from a power-law fit with $\alpha = 1.07$.

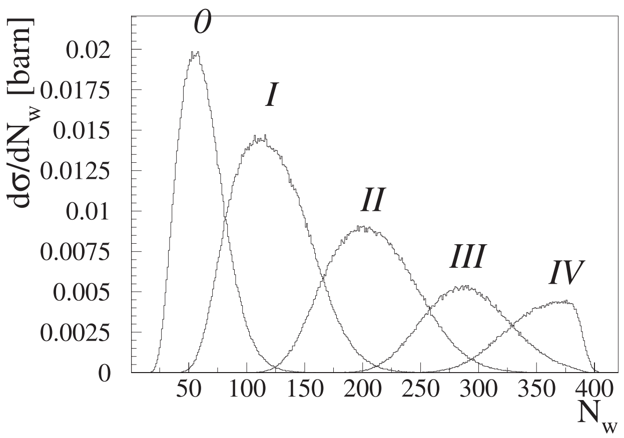

Figure 3. Distribution of $N_{\rm wound}$ for the NA57 centrality classes.

In order to obtain a determination of $N_{\rm wound}$ which is much less dependent on the relation between $N_{\rm ch}$ and $N_{\rm wound}$, we applied an alternative method which relies only on the measured trigger cross section. In this method the centrality classes for the model have been chosen so as to represent the same absolute cross section as in the data. If the smearing due to fluctuations of $N_{\rm ch}$ at fixed $N_{\rm wound}$ could be neglected, choosing the same absolute cross section for the classes would select the same sample of events. Therefore, a particular choice of the relation between $N_{\rm ch}$ and $N_{\rm wound}$ affects the determination of the number of wounded nucleons only through smearing effects. This effect is, however, very small. As an example, we consider the distribution of $N_{\rm wound}$ shown in figure 3, corresponding to the measured cross section for the centrality classes shown in figure 1. The average number of wounded nucleons in each class changes by less than one unit if we change the exponent in the relation between $N_{\rm ch}$ and $N_{\rm wound}$, equation (1), from $\alpha = 1$ to 1.09.

4. Centrality scales

4.1. Wounded nucleons and net baryons

When comparing results from different experiments, the same centrality scale must be used. As an example, in figure 4 we compare the average charged kaons $(K^+ + K^-)/2$ yields as a function of the number of participants from NA49 [11] with the WA97 K^0_S yields. As a measure of the number of participants the WA97 collaboration has used the number of wounded nucleons, while the NA49 collaboration estimated both the number of net baryons (baryons minus antibaryons) [11, 12], figure 4(*a*), and the number of wounded nucleons [13], figure 4(*b*). There is a significant discrepancy in the measured centrality dependence of the kaon yield per participant, depending on the centrality scale used; this discrepancy may arise from the fact that the net baryons also include nucleons knocked out of the spectator matter through cascading of produced particles, while wounded nucleons are only the nucleons which underwent at least one primary inelastic scattering with another nucleon. We see that, when the same centrality scale is used, the data from the two experiments are compatible (figure 4(*b*)).

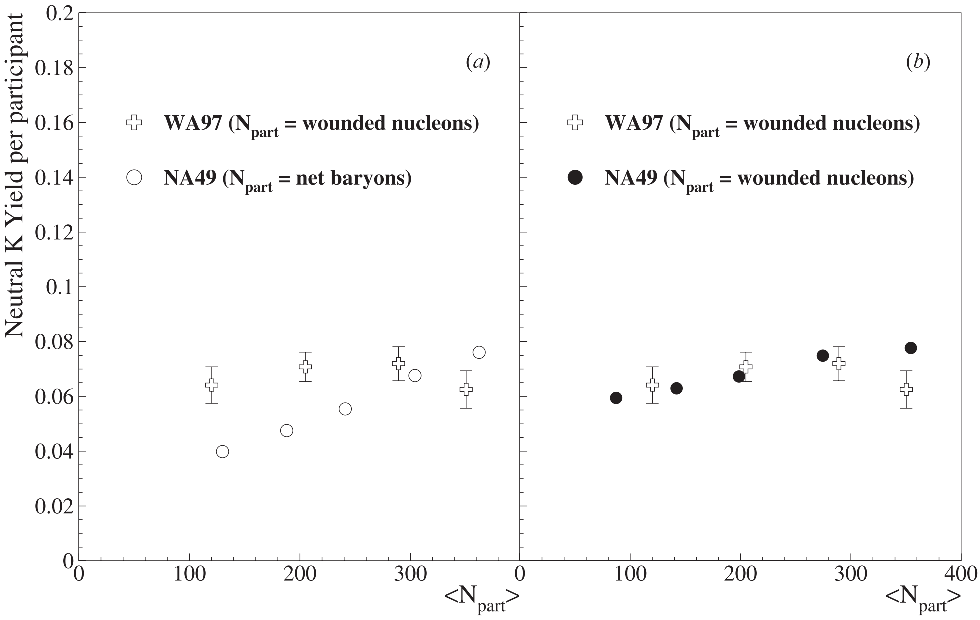

Figure 4. Kaon yields per participant from WA97 and NA49. For WA97 the participants are defined as wounded nucleons; for NA49, the participants are defined as the number of net baryons in (*a*) and as the number of wounded nucleons in (*b*).

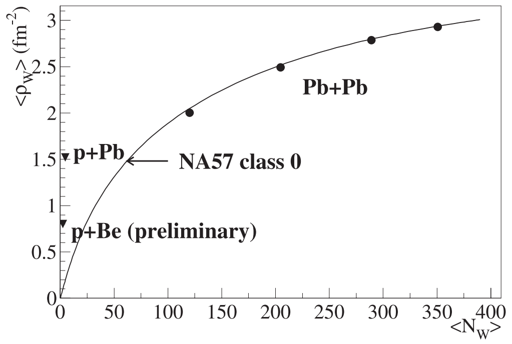

Figure 5. $\langle \rho_{\mathrm{wound}} \rangle$ versus $\langle N_{\mathrm{wound}} \rangle$ for p + Be, p + Pb and Pb + Pb collisions. The value for p + Be is still preliminary since the calculation for small nuclei is complicated by the fact that the width of the nuclear thickness function is comparable to the nucleon–nucleon cross section.

4.2. Wounded nucleons: number versus density

As pointed out by Nardi [14], the density of wounded nucleons in a plane orthogonal to the beam axis (ρ_{wound}) could be an interesting centrality scale since it is more directly related to the baryon and energy density in the initial stage of the collision. Figure 5 shows the relation between the number and density of wounded nucleons. The line corresponds to the Pb + Pb system. The circles represent the four WA97 centrality classes, while the triangles correspond to the p + A systems. It should be noted that the p + A systems are characterized by a small number of wounded nucleons but a relatively high density. We note that the most peripheral NA57 class is of particular interest in comparing the two scales since it corresponds to an average density which is very similar to that of the p + Pb system, for a number of wounded nucleons about ten times smaller.

5. Conclusions

In the NA57 experiment the precise measurement of the trigger cross section allows one to estimate the number of participants without assumptions on the scaling between N_{ch} and N_{wound}. The most peripheral NA57 class, corresponding to $\langle N_{\text{wound}}\rangle \simeq 60$, $\langle b\rangle \simeq 10\,\text{fm}$ and $\langle \rho_{\text{wound}}\rangle \simeq 1.5\,\text{fm}^{-2}$, covers a region where the J/ψ is not yet suppressed.

A difference in the centrality scale employed can produce an apparent discrepancy between results from different experiments. For example, the number of wounded nucleons and the number of net baryons correspond to different centrality scales, possibly because of significant cascading of produced particles into the spectator matter.

The wounded nucleon number and density are related to the volume and to the initial energy density of the fireball. To understand their role in the onset of the phase transition the behaviour of the QGP signatures must be studied as a function of both these variables in p + A and A + B collisions. The most peripheral NA57 Pb + Pb class is of particular interest, since it is characterized by a density similar to that of p + Pb collisions, for a number of wounded nucleons one order of magnitude smaller.

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