Transverse mass spectra of strange and multiply–strange particles in Pb–Pb collisions at 158 A GeV/c

Presented by L. Šándor for the WA97 collaboration:

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The WA97 experiment has measured the transverse mass (m_{T}) spectra for negative hadrons (h^-) and strange particles produced at mid–rapidity in Pb–Pb collisions. The increased statistics of analysed data samples allowed us to perform a study of the spectra of $\mathrm{K}^0_{\mathrm{S}}$, Λ, Ξ, Ω and h^- as a function of the centrality of the collisions. The data, which correspond to the most central 40% of the total inelastic cross section, have been divided into four centrality classes according to the estimated number of nucleons taking part in the collision. The m_{T} spectra, analysed separately for each centrality bin, exhibit only weak ($\leq 15\%$) centrality dependence. The deviation of the Ω inverse slope from the linear dependence on the particle mass is confirmed even for the most central Pb–Pb collisions.

1. INTRODUCTION

Transverse momentum spectra of particles produced in ultrarelativistic nuclear collisions are sensitive to the collisions dynamics, because all transverse motion is generated during the interaction. The presence of strong radial flow in Pb–Pb collisions at the SPS energy was deduced from the systematics of experimental data on non-strange and singly-strange hadrons, suggesting a linear increase of the inverse slope T with the particle mass ([1], [2]). Such a behaviour can be expected in a scenario where a random thermal motion is superimposed onto a transverse collective expansion of the system. The combined analysis of two-pion correlation function and transverse mass spectra [3] made it possible to separate contributions to the 'apparent temperature' T from a common freeze-out temperature ($\simeq$ 120 MeV) and from a transverse flow (with average velocity $\beta_{\perp} \simeq 0.55$).

The WA97 data on inverse slopes for multi–strange hyperons Ξ and Ω, presented for the first time in [4] and confirmed later on with higher statistics [5], seem to fall out of this picture. The compilation of data on the m_{T} inverse slopes as a function of the particle mass is shown in fig. 1 (see, e.g., [6] and references therein). The measured slope of Ω (and possibly also Ξ) is significantly smaller than expected from the general trend, shown in the figure by the dotted line. As was pointed out in [7], this observation favours a scenario in which, in Pb–Pb reactions, multi–strange hadrons freeze out rather early, before most of the transverse flow has developed.

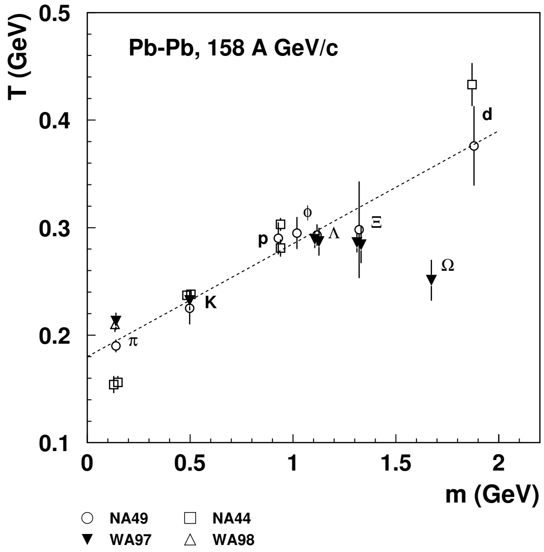

Figure 1. Dependence of the m_{T} spectra inverse slopes T on the particle mass m.

The published NA44 and NA49 inverse slopes correspond to the most central events ($\simeq 5\%$), while the centrality range of WA97 data was much wider: $\simeq 40\%$ of the most central interactions. Therefore, for a detailed study of the Ω inverse slope anomaly, the analysis of the centrality dependence of the WA97 transverse spectra is essential. This is the main goal of the present work.

In general, knowledge on the centrality dependence of m_{T} spectra is rather scarce. For Pb–Pb collisions only data from the WA98 experiment on π^0 production [8] and from NA45 on h^-, pions and 'net proton-like' spectra [9] were published. Both experiments reported at most a weak centrality dependence.

2. EXPERIMENTAL PROCEDURE

The WA97 experiment is designed to study the strange and multi–strange hadron production at central rapidity in Pb–Pb collisions at the CERN SPS. It utilizes silicon pixel and microstrip detectors for precise tracking and two multiplicity microstrip detectors to provide data for the off-line centrality analysis. The interaction trigger selected the most central $\simeq$40% of Pb–Pb collisions. The experimental set-up and the methods of the strange particle signal extraction and analysis are described in [5] (see, also, [10]).

The acceptance region of the experiment is limited (for details see [5],[11]) and for all particles under study covers approximately one rapidity unit at mid–rapidity. The experimental data were corrected for the geometrical acceptance and reconstruction efficiency. For the Ξ and Ω data samples we have applied an individual weight calculation for each particle. This turned out to be a precise but very CPU-intensive procedure, not suitable for high statistics samples. Therefore for h^-, $\mathrm{K}^0_{\mathrm{S}}$, Λ and $\overline{\Lambda}$ only a small fraction ($\leq 1\%$) of data was corrected by individual weighting. For the present study we have analysed high statistics samples of these particles applying the unfolding of measured two-dimensional spectra (see, e.g. [12]). Careful consistency tests demonstrated the full compatibility of $(y, m_{\rm T})$ spectra from individually weighted and deconvoluted data samples.

As a measure of centrality we use the average number of participants, i.e. nucleons participating in the collision $\langle {\rm N}_{part} \rangle$, calculated from the measured charged multiplicity in the framework of the wounded nucleon model. The details of this approach are described in [13]. The data were divided into four centrality classes, the same as we have recently used in the strangeness enhancement study [5],[11]. Note that events in our most central bin are close in centrality to the NA44 and NA49 data shown in fig. 1.

The double-differential $(y, m_{\rm T})$ distributions for each particle and centrality class were fitted using the expression

$$\frac{{\rm d}^2 N}{{\rm d}m_{\rm T}{\rm d}y} = f(y)\, m_{\rm T} \exp(-\frac{m_{\rm T}}{T})$$

assuming the rapidity distribution to be flat in our acceptance region ($f(y) = const.$) and leaving the inverse slope T as free parameter of fit.

In fig. 2 the deconvoluted $m_{\rm T}$ spectra of ${\rm h}^-$, Λ and $\overline{\Lambda}$ in different centrality bins are presented. The superimposed lines represent exponential functions with fitted T values.

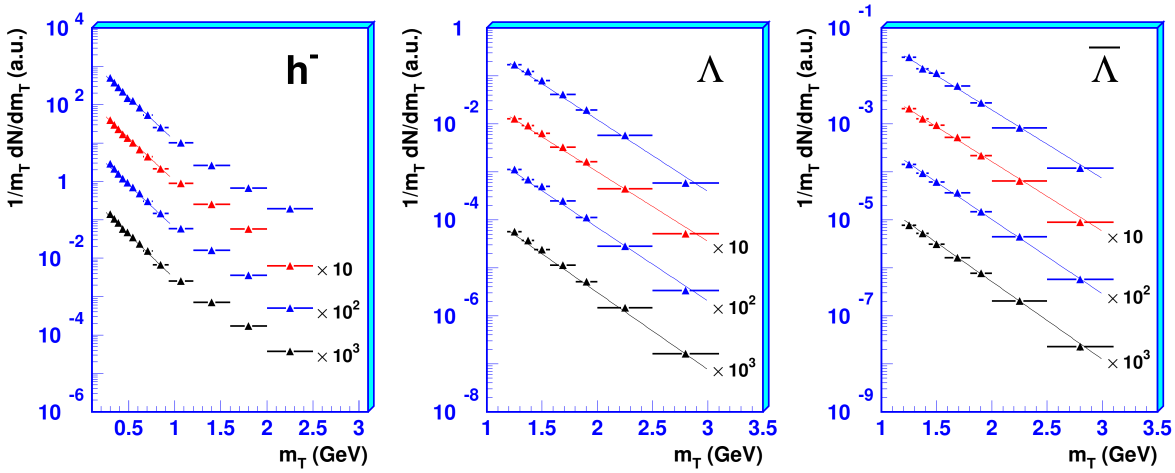

Figure 2. Transverse mass spectra of ${\rm h}^-$, Λ and $\overline{\Lambda}$ shown separately for the four centrality classes. Data for the most central events are shown on the top, data for the most peripheral events (divided by 10^3) in the bottom of each picture.

3. RESULTS

The transverse mass spectra for ${\rm K}^0_{\rm S}$, Λ , $\overline{\Lambda}$, Ξ^- , $\overline{\Xi}^+$ and Ω are described satisfactorily by an exponential function in all the accessible $m_{\rm T}$ regions (up to $\simeq$ 3 GeV). As can be seen in fig. 2, the ${\rm h}^-$ spectrum (dominated by pions) exhibit a more complicated behaviour. It was argued (see, e.g. [8]), that, for pions, the low $p_{\rm T}$ region reflects the behaviour of the hadron system at the freeze-out stage, while the intermediate region might reflect the initial temperature of the system. We restricted our analysis to the low transverse mass region ($m_{\rm T} < 0.9$ GeV), where a fit by the single exponential is adequate.

The dependence of the inverse slopes T on the number of participants ${\rm N}_{part}$, resulting from the fits of $m_{\rm T}$ spectra for different centrality bins, is shown in fig. 3. The ${\rm h}^-$ and ${\rm K}^0_{\rm S}$ slopes

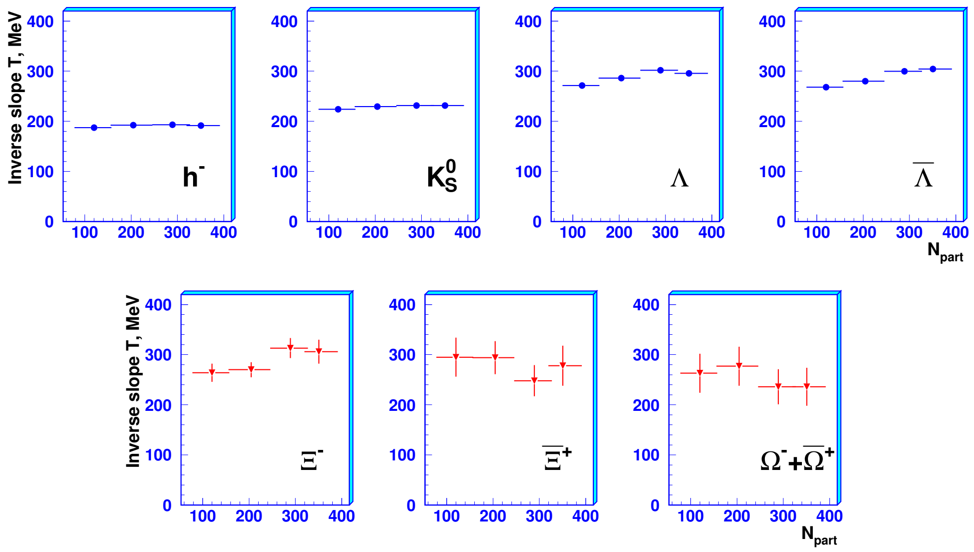

Figure 3. Dependence of $m_{\rm T}$ spectra inverse slopes T on the centrality of collision.

appear to be constant in the $\mathrm{N}_{part} > 100$ range. Values of T for Λ and $\overline{\Lambda}$ exhibit a slow but steady rise, not exceeding 15% in the centrality range under study. The limited statistics do not allow us to draw a precise conclusion on the behaviour of Ξ and Ω inverse slopes yet. Within the error limits the data do not exhibit significant centrality dependence.

The mass dependence of inverse slopes, measured for the most central bin ($\langle \mathrm{N}_{part} \rangle \simeq 350$) is shown in fig. 4. The dotted line indicating the general trend is the same as in fig. 1. The deviation of the Ω slope from the linear mass dependence is present also for the most central Pb–Pb events.

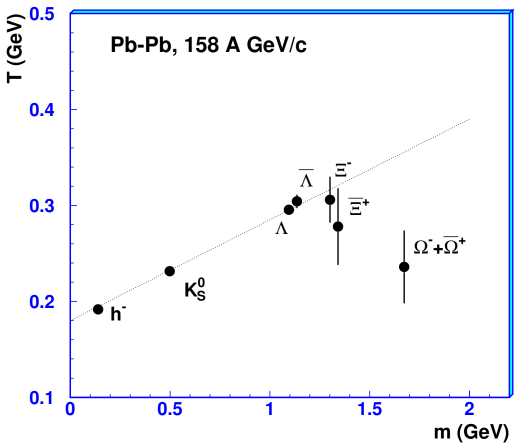

Figure 4. Mass dependence of inverse slopes for the most central WA97 events.

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