Study of the production of strange and multi-strange particles in lead-lead interactions at the CERN SPS: the NA57 experiment

F. Antinori, A. Badala, R. Barbera, I.J. Bllodworth, M. Botje, R. Caliandro, M. Campbell, E. Cantatore, W. Carena, N. Carrer, et al.

ELSEVIER

Nuclear Physics A681 (2001) 165c–173c

NUCLEAR PHYSICS A

www.elsevier.nl/locate/npe

Study of the Production of Strange and Multi-Strange Particles in Lead-Lead Interactions at the CERN SPS: the NA57 Experiment

Presented by T. Virgili for the NA57 Collaboration

F. Antinori[k], A. Badalà[f], R. Barbera[f], I.J. Bloodworth[d], M. Botje[r], R. Caliandro[a], M. Campbell[g], E. Cantatore[g], W. Carena[g], N. Carrer[k], A.P. de Haas[r], D. Di Bari[a], S. Di Liberto[n], R. Divia[g], D. Elia[a], D. Evans[d], K. Fanebust[b], J. Fedorisin[h], G.A. Feofilov[p], R.A. Fini[a], J. Ftáčnik[e], B. Ghidini[a], G. Grella[o], M. Gulino[f], H. Helstrup[c], A.K. Holme[j], A. Jacholkowski[a], G.T. Jones[d], P. Jovanovic[e], A. Jusko[h], R. Kamermans[r], J.B. Kinson[d], W. Klempt[g], K. Knudson[g], B. Kocper[h], A.A. Kolojvari[p], I. Králik[h], P. Kuijer[r], V. Lenti[a], R. Lietava[e], G. Løvhøiden[j], M. Lupták[h], V. Manzari[a], M.A. Mazzoni[n], G. Martinska[h], F. Meddi[n], A. Michalon[q], M.E. Michalon-Mentzer[q], M. Morando[k], D. Muigg[r], E. Nappi[a], F. Navach[a], P.I. Norman[d], A. Palmeri[f], G.S. Pappalardo[f], B. Pastirčák[h], J. Pisut[e], N. Pisutova[e], F. Posa[a], E. Quercigh[g], F. Riggi[f], D. Röhrich[b], G. Romano[o], K. Šafařík[g], L. Šándor[h], E. Schillings[r], M. Senè[l], R. Senè[l], G. Segato[k], W. Snoeys[g], P. Staroba[m], M. Thompson[d], G. Tomasicchio[a], G.D. Torrieri[d], T.A. Tulina[p], T.S. Tveter[j], J. Urbán[h], F. Valiev[p], A. van den Brink[r], P. van de Ven[r], P. Vande Vyvre[g], N. van Eijndhoven[r], L. Vannucci[i], A. Vascotto[g], O. Villalobos Baillie[d], I. Vinogradov[p], T. Virgili[o], M.F. Votruba[d], J. Vrlakova[h] and P. Závada[m]

[a] Dipartimento IA di Fisica dell'Università e del Politecnico di Bari and INFN, Bari, Italy
[b] Fysisk Institutt, Universitetet i Bergen, Bergen, Norway
[c] Høgskolen i Bergen, Bergen, Norway
[d] University of Birmingham, Birmingham, UK
[e] Comenius University, Bratislava, Slovakia
[f] University of Catania and INFN, Catania, Italy
[g] CERN, European Laboratory for Particle Physics, Geneva, Switzerland
[h] Institute of Experimental Physics SAS and Šafárik University, Kosice, Slovakia
[i] INFN, Laboratori Nazionali di Legnaro, Legnaro, Italy
[j] University of Oslo, Oslo, Norway
[k] University of Padua and INFN, Padua, Italy
[l] Collège de France and IN2P3, Paris, France
[m] Institute of Physics, Prague, Czech Republic
[n] University "La Sapienza" and INFN, Rome, Italy
[o] Dipartimento di Scienze Fisiche "E.R. Caianiello" dell'Università and INFN, Salerno, Italy
[p] State University of St. Petersburg, St. Petersburg, Russia
[q] IReS/ULP, Strasbourg, France
[r] Utrecht University and NIKHEF, Utrecht, The Netherlands

PII S0375-9474(00)00499-1

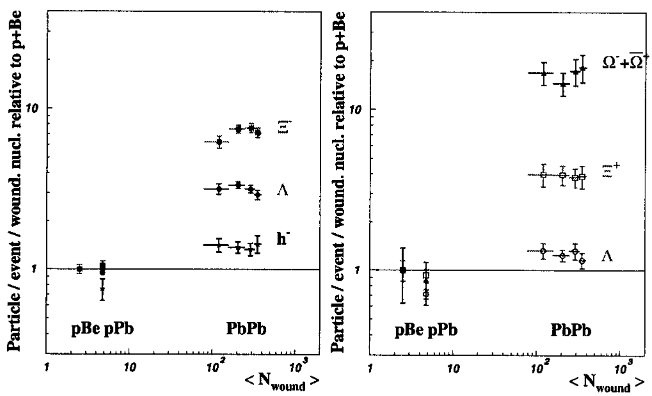

Figure 1. WA97 Particle yields relative to p-Be, divided by the number of wounded nucleon N_{wound} as a function of N_{wound}, assumed as definition of the number of participants.

The NA57 experiment studies the production of strange and multi-strange baryons and antibaryons in ultrarelativistic nucleus-nucleus collisions at the SPS.

The main aim of NA57 is to investigate the behaviour of the enhancement of the production of particles with strangeness $|s|$=1,2,3 in nucleus-nucleus collisions at the variation of the energy and of the centrality of the collision defined e.g. as the number of participant nucleons.

We shall recall the main features of the experimental set-up, and we shall illustrate the collected data samples and the status of their analysis.

1. Introduction

The NA57 experiment [1] studies the production of strange and multi-strange baryons and antibaryons in ultrarelativistic nucleus-nucleus collisions at the SPS. The results from the previous experiment WA97 [2] show that the strange hyperons abundances increase faster than the number of participants in the collision when going from proton-nucleus to nucleus-nucleus interactions. The strangeness enhancement shows a hierarchical pattern, being stronger for the hyperons of higher strangeness content, as shown in fig. 1. This effect was predicted [3] as a signature of a phase transition from hadronic matter to a plasma of deconfined quarks and gluons.

The main aim of NA57 is to investigate the behaviour of the enhancement of the production of particles with strangeness $|s|$=1,2,3 in nucleus-nucleus collisions at the variation of the energy and of the centrality of the collision defined e.g. as the number of participant nucleons.

NA57 has taken data with Pb beams of 158 A GeV/c and 40 A GeV/c momentum. The latter corresponds to a centre-of-mass energy (8.8 GeV/c per nucleon) intermediate between that achieved at the AGS (4.7 GeV/c per nucleon) and the top energy available at the SPS (17.3 GeV/c per nucleon for a Pb beam). A sample of p-Be data at 40 GeV/c has been also collected for reference.

2. The experimental apparatus

The main experimental challenge is to handle the large density of primary tracks produced in central lead-lead interactions. To reconstruct Λ, Ξ, Ω and K decays in such an environment, we employ a high granularity telescope of silicon pixel planes.

The apparatus, shown schematically in fig. 2, is placed inside the GOLIATH magnet which provides a maximum field of 1.4 T. The main features of the apparatus are:

- a telescope made of 13 silicon pixel detector planes, for a total of about $1.1\text{x}10^6$ channels; 7 planes use the Omega2 [4] front end chip with a pixel size of 75x500 μm^2, 6 planes use the Omega3 [5] front end chip, with a cell size of 50x500 μm^2. The silicon pixel technique was succesfully pioneered by WA97 in collaboration with RD19 [6]. The mechanical support of the telescope allows to change its position with respect to the target. The telescope is placed above the beam line and it is inclined in such a way that the lower edges of the detectors lay on a line pointing to the target.

  Hyperons and K mesons are identified via the following decay channels: $\Lambda \rightarrow p + \pi^-$, $\Xi^- \rightarrow \Lambda + \pi^-$, $\Omega^- \rightarrow \Lambda + K^-$, $K^0 \rightarrow \pi^+ + \pi^-$ and $K^\pm \rightarrow \pi^+ + \pi^- + \pi^\pm$. As an example, fig 3 shows an Ω^- decay topology with all the decays tracks in the telescope acceptance. In both the 158 A GeV/c and 40 A GeV/c run, the telescope was set-up so as to have maximum acceptance at mid rapidity.

- an array of 6 scintillator petals, placed 10 cm downstream of the target, covering the pseudorapidity region $1 < \eta < 2$, used to trigger on the centrality of the collision.

- two planes of multiplicity silicon detectors (MSD) sampling the charged multiplicity at mid-rapidity, used in the determination of the centrality of the nucleus-nucleus collision.

3. Multiplicity measurement

The centrality of the collision is measured by sampling the charged multiplicity at central rapidity, with two stations of Multiplicity Strip Detectors (MSD).

The NA57 and WA97 experiments have similar layouts, and in particular they employ the same multiplicity detectors (MSD, see figure 4). In NA57 additional efforts were made to reduce the empty target contamination in the triggered sample, in order to extend the covered centrality range towards more peripheral events. The two MSD planes were placed respectively 19.8 cm and 54.5 cm downstream of the target for the 158 A GeV/c run. In the 40 A GeV/c configuration the planes were positioned 20.4 cm and 38 cm from the target .

With this geometry, the first and the second plane cover approximately the pseudorapidity regions $2 < \eta < 3$ and $3 < \eta < 4$ for the 158 A GeV/c run, and $2 < \eta < 3$ and

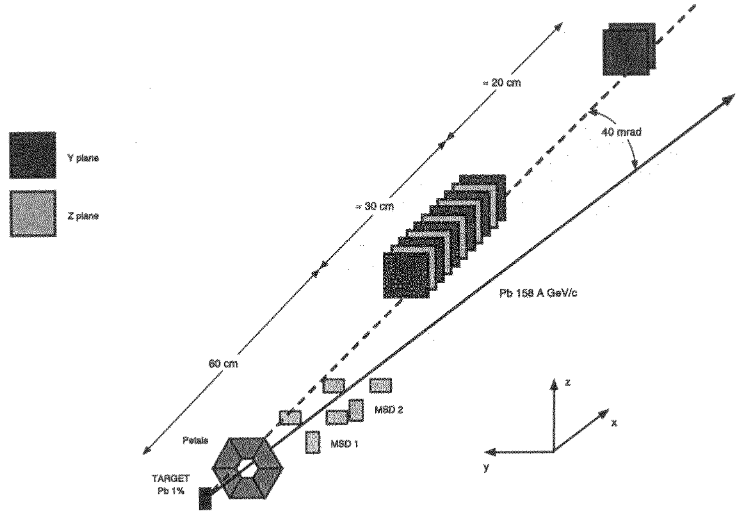

Figure 2. A 3D view of the NA57 apparatus.

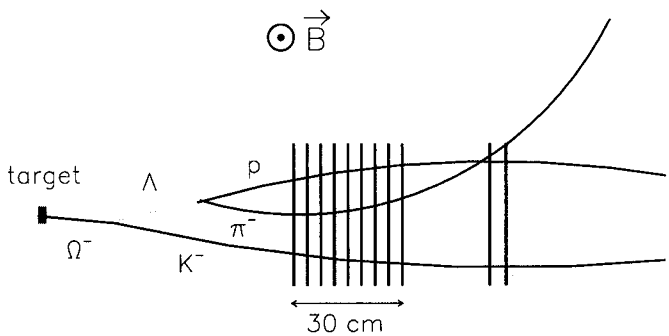

Figure 3. An example of a Ω^- decay topology, with all the decays tracks in the telescope acceptance.

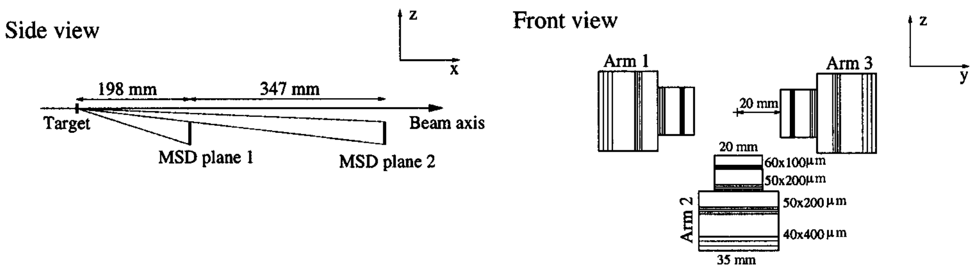

Figure 4. Layout of the micro–strip multiplicity detectors (158 A GeV/c run). Only the lower arm is shown on the side view.

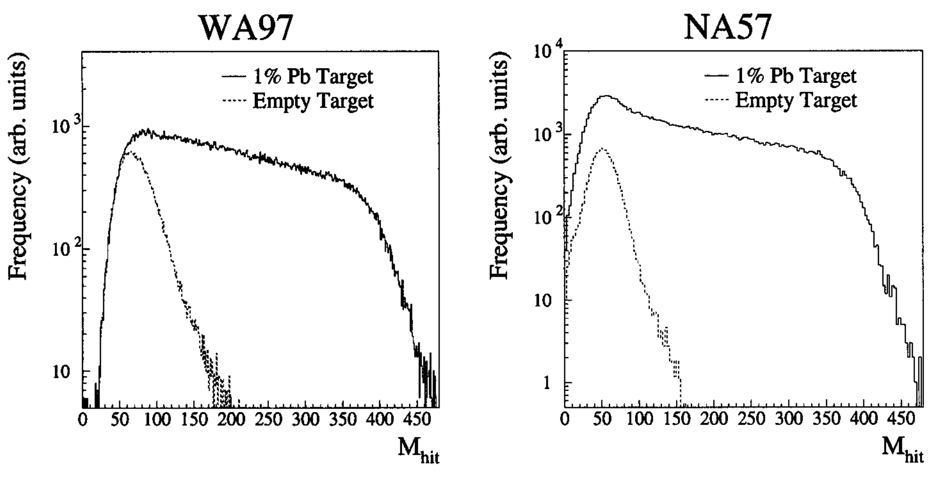

Figure 5. Hit multiplicity distribution of the triggered events with a 1% Pb + Pb interaction length target (solid histogram) and of the empty target sample (dashed histogram).

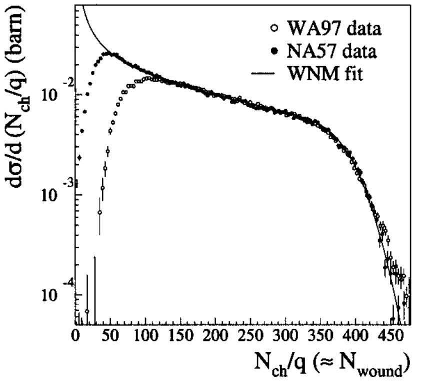

Figure 6. Fit of the multiplicity distributions with the Wounded Nucleon Model for the WA97 and NA57 experiments.

$2.4 < \eta < 3.7$ for the 40 A GeV/c run. The azimuthal acceptance is about 30% for both planes.

The distributions of the total hit multiplicity in the two detector planes for the WA97 and NA57 experiments (158 A GeV/c) are shown in figure 5. The drop at low multiplicities is the effect of the scintillator petals centrality trigger suppressing low multiplicity events.

The contamination of the triggered sample resulting from interactions in air or other materials along the beam line (*empty target* contamination) was evaluated using data collected without the target and then subtracted. It was $\simeq$ 17% of the triggered events for WA97 and $\simeq$ 6% for NA57. Figure 5 shows the multiplicity distributions for the 1% Pb + Pb interaction length target and for the empty target runs. Details on the multiplicity recostruction procedure can be found in [7].

The multiplicity distribution can be described in the framework of the wounded nucleon model (WNM) [8]. In this model, it is assumed that the average charged particle multiplicity is proportional to the number of wounded nucleons, computed from the Glauber model [9]:

$$\langle N_{ch} \rangle = q N_{wound}, \tag{1}$$

where q is a proportionality constant. The only physical inputs to the model are the density distribution of the nucleons inside the nucleus and the nucleon–nucleon cross section.

The corrected WA97 and NA57 charged particle multiplicity distributions in the range $2 < \eta < 4$ are shown in fig. 6, together with the fitted curve. In the abscissa the number of charged particles is divided by the fitted scale factor q; the resulting variable, which -

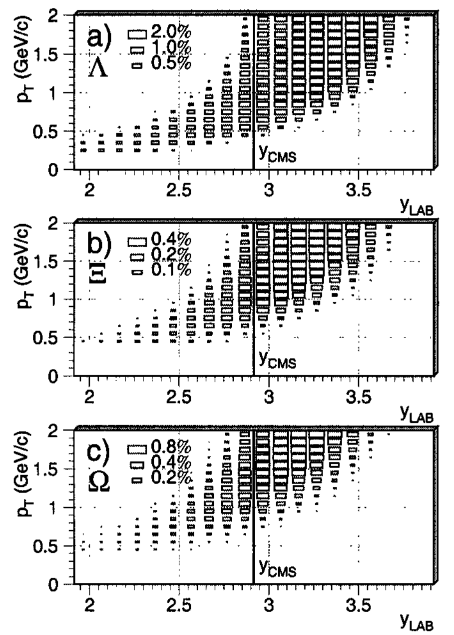

Figure 7. NA57 acceptances table for strange particles (158 A GeV/c).

apart for the experimental and physical smearing - is close to N_{wound}, is used to compare directly the centrality distributions from the two experiments.

As can be seen from fig. 6, NA57 extend the centrality range down to events with $N_{wound} \simeq 50$. The fitted trigger cross section for the WA97 experiment is compatible with the estimated experimental value of about 40% of the total Pb + Pb inelastic cross section. In the NA57 experiment the trigger cross section was measured with a 3% precision and its value, $\sigma_{\mathrm{trig}}^{\mathrm{exp}} = (4.29 \pm 0.12)\,\mathrm{barn}$, corresponding to about 60% of the total nuclear inelastic cross section, is in agreement with the value obtained from the WNM fit.

4. The data sample

4.1. Pb-Pb at 158 A GeV/c

In 1998 we collected about 230 M events, with the set-up shown in fig. 2. The telescope was inclined at 40 mrad and the first plane was placed 60 cm downstream of the target.

The acceptance tables for Λ, Ξ, and Ω, reported in figure 7, are similar to the corresponding ones in WA97. The full data sample has been processed through the track finding and reconstruction program ORHION. A partial statistics Ξ+$\bar{\Xi}$ invariant mass distribution is shown in fig. 8 as an example.

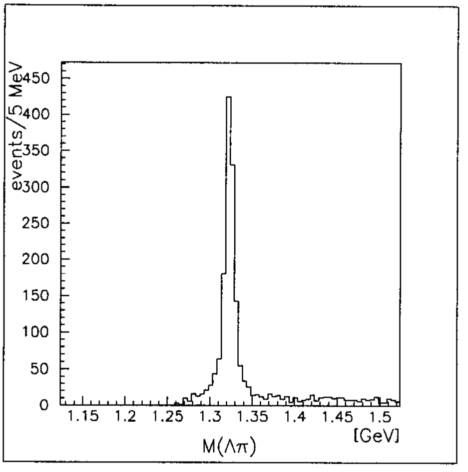

Figure 8. Invariant mass of Λ-π (+c.c.) pairs from a partial sample collected at 158 A GeV/c.

4.2. Pb-Pb and p-Be at 40 A GeV/c

In 1999 we collected a sample of 260 M of Pb-Pb interactions at 40 A GeV/c. In order to have maximum acceptance at mid rapidity the telescope was inclined at 72 mrad. The first plane was positioned 40 cm downstream of the target. The acceptance tables for this configuration are shown in fig. 9. The alignment and the calibration of the detector for this set of data are going on, and the multiplicity analysis is in progress.

In addition, a sample of 60 M p-Be interactions at 40 GeV/c was also collected with the same set-up. The beam was in this case a mixture of pions and protons (about 40% of the total), which were identified by two Čerenkov counters.

5. Conclusions

The NA57 experiment can play a unique role in the investigation of the onset of a phase transition from hadronic matter to Quark Gluon Plasma by addressing the two main questions arising from WA97 results, namely: i) how strange particle yields behave at lower values of the number of nucleons participating to the collision and ii) how this behaviour depends on the centre-of-mass energy of the collision.

The WNM analysis of the multiplicity distribution shows that we collected statistics for a centrality range extended down to $N_{wound} \simeq 50$.

The physical analysis of the data samples at 158 A GeV/c and at 40 A GeV/c is in progress.

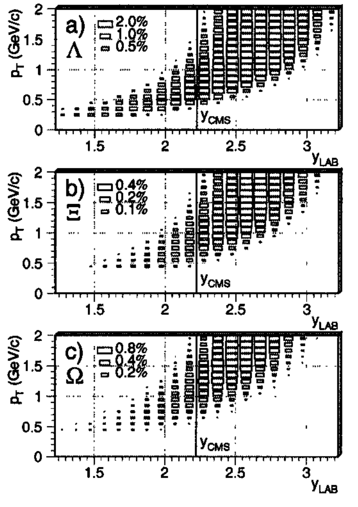

Figure 9. NA57 acceptance table for strange particles (40 A GeV/c).

REFERENCES

1. R. Caliandro *et al.*, NA57 proposal, CERN/SPSLC 96-40 SPSLC/P300.
2. WA97 Collaboration: E. Andersen et al., Phys. Lett. B433 (1998) 209.
   WA97 Collaboration: E. Andersen et al., Phys. Lett. B449 (1999) 401.
3. J. Rafelski and B. Müller, Phys. Rev. Lett. **48**, (1982) 1066.
4. M. Campbell *et al.*, Nucl. Instr. and Meth. **A290** (1990) 149.
5. E.H.M. Heijne *et al.*, Nucl. Instr. and Meth. **A383** (1996) 55.
6. RD19 Collaboration: E.H.M. Heijne et al., Nucl. Instr. Meth. **A349** (1994) 138
7. F. Antinori *et al.*, CERN preprint CERN-EP-2000-002 (to be published in Eur. Phys. J. **C**).
8. A. Białas, M. Bleszyński and W. Czyż, Nucl. Phys. **B111** (1976) 461.
9. C.Y. Wong, Introduction to High-Energy Heavy-Ion Collisions (World Scientific Publishing, Singapore 1994) 251-264.