Experiment NA57 at the CERN SPS

Presented by V. Manzari for the NA57 Collaboration:

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

[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] Institute of Physics, Prague, Czech Republic
[m] University "La Sapienza" and INFN, Rome, Italy
[n] Dipartimento di Scienze Fisiche "E.R. Caianiello" dell'Università and INFN, Salerno, Italy
[o] State University of St. Petersburg, St. Petersburg, Russia
[p] IReS/ULP, Strasbourg, France
[q] Utrecht University and NIKHEF, Utrecht, The Netherlands

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

The principal aim of NA57 is to investigate the existence of an onset for the strangeness enhancement effect at the variation of the energy and centrality (i.e. number of participants) of the nucleus-nucleus collisions.

The experiment was successfully installed and commissioned in 1997.

1. Introduction

Experiment NA57 studies the production of strange and multi-strange baryons and antibaryons in ultrarelativistic nucleus-nucleus collisions at the SPS. The previous experiments WA85, WA94 and WA97 [1] have shown that the strange hyperons abundance increases faster than the number of participants in the collision when going from proton-nucleus to nucleus-nucleus interactions. This strangeness enhancement effect is progressively stronger for the hyperons of higher strangeness content, as shown in Figure 1. This effect was predicted [2] as a possible consequence of a phase transition from standard hadronic matter to a plasma of deconfined quarks and gluons.

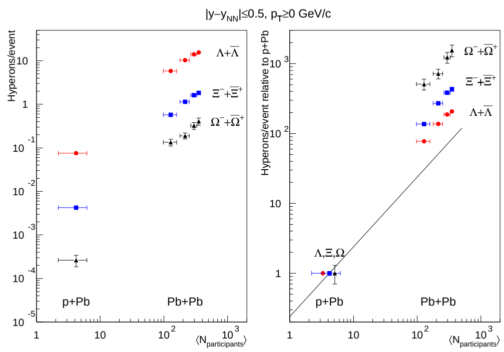

Figure 1. WA97 Particle yields as a function of the number of participants. The solid line drawn through the p-Pb point corresponds the expectation in case the hyperon yields were proportional to the number of participants.

The principal aim of NA57 is to investigate the existence of an onset for the strangeness enhancement effect at the variation of the energy and centrality, i.e. number of participants, of the nucleus-nucleus collisions. The observation of such a threshold effect would indicate a discontinuity in the behaviour of highly compressed matter, as one would expect from a first order phase transition, and help locate the transition point. NA57 will take data with a Pb beam both at 158 A GeV/c and 40 A GeV/c, which is the minimum energy available from the SPS for lead ions. The latter corresponds to a centre-of-mass energy (8.8 GeV per nucleon) intermediate between that achieved at the AGS (4.7 GeV per nucleon) and what is currently used at the SPS (17.3 GeV per nucleon).

2. The experimental apparatus

The principal 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 enviroment, we employ a high granularity telescope of silicon pixel planes. The high rate capability of these detectors allows us to collect a large statistics.

The apparatus, shown schematically in Figure 2, is placed inside the GOLIATH magnet in the configuration with 1.05 m gap and 1.4 T maximum field. The main features of the apparatus are:

- a telescope made of 13 silicon pixel detector planes, for a total of about 1.1x10^6 channels; 7 planes use the Omega2 front end chip with a pixel size of 75x500 μm^2, 6 planes use the new Omega3 front end chip, with a cell size of 50x500 μm^2. The silicon pixel technique was succesfully pioneered by WA97 in collaboration with RD19 [3].
- 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.
- A set of silicon multiplicity detectors sampling the charged multiplicity produced in the region $2 < \eta < 4$, in order to measure the centrality of the nucleus-nucleus collision.

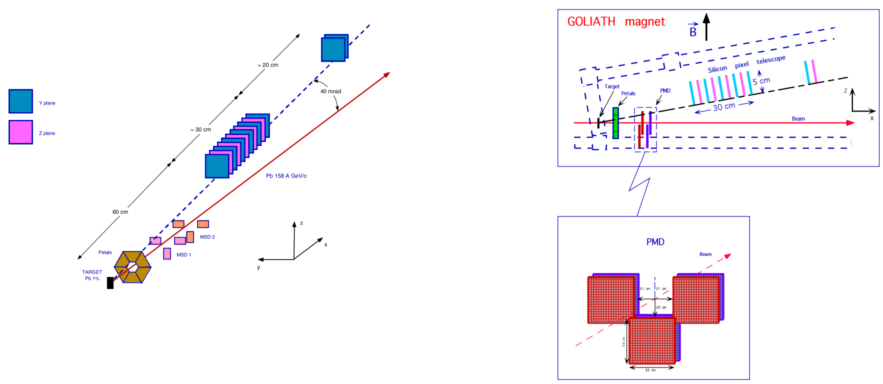

Figure 2. An artistic 3D view of the NA57 apparatus on the left and a side view on the right.

The telescope is placed above the beam line, is inclined and is aligned with the lower edge of the detectors on a line pointing to the target. The inclination angle α and the distance d of the first pixel plane from the target depend on the beam momentum in order to cover in both cases the central rapidity region: at 158 A GeV/c ($y_{LAB} \simeq 2.9$) is $\alpha = 40$ mrad and d $= 60$ cm, at 40 A GeV/c ($y_{LAB} \simeq 2.2$) is $\alpha = 72$ mrad and d $=$ 30cm.

Hyperons and K mesons are identified via decay channels with only charged particles in the final state, namely $\Lambda \rightarrow p + \pi^-$, $\Xi^- \rightarrow \Lambda + \pi^-$, $\Omega^- \rightarrow \Lambda + K^-$, $K^0 \rightarrow \pi^+ + \pi^-$ and $K^\pm \rightarrow \pi^+ + \pi^- + \pi^\pm$. As an example, Figure 3 shows an Ω^- decay reconstructible with our silicon telescope.

NA57 will address the question of how the increase in the production of hyperons evolves with the number of participants when going from proton-nucleus to nucleus-nucleus interactions, by measuring strange hyperons yields as a function of the centrality of the collision. The aim is to enlarge the investigated centrality window from about 40% σ_{inel} (WA97) to 50-60% σ_{inel}.

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

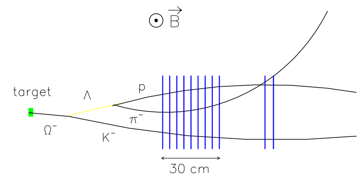

Figure 3. An example of a hyperon decay reconstructable with the NA57 setup

The relation between the sampled multiplicity and the number of participant nucleons is obtained by fitting the multiplicity distribution to a curve obtained by a Glauber model calculation of the distribution of the number of participants, assuming proportionality between the number of participants and the measured multiplicity, and accounting for experimental smearings. An example of such a fit from WA97 is shown in Figure 4.

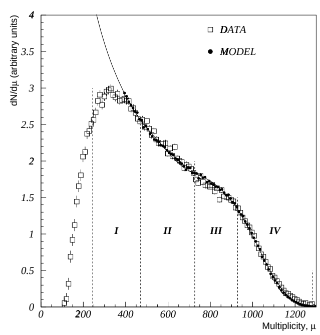

Figure 4. The WA97 charged measured multiplicity (squares) is compared with a Glauber model calculation (points): in each bin of the spectrum the average number of participant nucleons is estimated from the model.

3. Installation and commissioning of the experiment in 1997

The NA57 apparatus was prepared and thoroughly debugged in the course of 1997. In particular:

- the GOLIATH magnet was installed and commissioned in early 1997 and the magnetic field was mapped in May;
- four additional planes of Si pixel detectors were built, bringing the total number of planes in the telescope to 13;
- a sliding optical bench, combining the high alignment accuracy required for Si pixel detectors with ease of maintenance in the restricted volume of the Goliath

magnet, was designed, built and installed;

- the detector service systems (cabling, cooling, etc.) were completely redesigned, installed and commissioned;
- a new Data Acquisition has been installed and debugged. The DAQ is based on parallel subsystem VME processors running Unix, which are connected to an Event Builder through a Fast Ethernet switch. The Event builder, also a VME processor running Unix, sends data to the CERN Computer Center, where they are written on to tapes;
- a new Detector Control System was designed, installed and commissioned. It is based on the CAEN SY527 high/low voltage system, remotly controlled by a workstation running a LabView user interface.

The full apparatus was succesfully commissioned with a proton beam in October 1997. All the detectors performed as expected, and the quality of the data is good. The alignment and calibration of the detectors have been performed, and a preliminary Λ peak, obtained with an online program, is shown in Figure 5. The full reconstruction program ORHION is being tuned on these data.

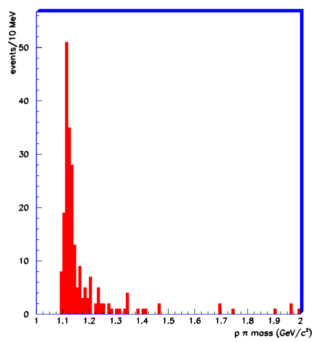

Figure 5. Preliminary Λ peak from the 1997 commissioning run.

4. Future developments

In the future, we plan to equip the multiplicity detectors with silicon pixel planes. This new Pixel Multiplicity Detector (PMD), shown in Figure 2, will allow us to measure the net baryon density at central rapidity, by measuring the sign of the charge of the particles produced in the collision.

The principle of the charge determination algorithm is illustrated in Figure 6. A charged particle trajectory, bent in the magnetic field, leaves one hit in each of the two pixel planes which make up one arm of the PMD detector. A straight line is computed joining the outer pixel hit to the center of the target, and the intercept with the inner pixel plane is calculated. Assuming that the closest hit to the intercept has been produced by the same particle, the charge of the track is determined by looking on which side of the intercept the hit lies in the bend plane projection.

The combined use of the total and net (positive minus negative) multiplicity

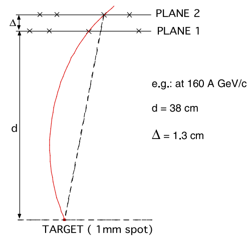

Figure 6. The sign of the charge can be determined using 3 points: target and 2 hits.

measurements will allow us to study whether the observed strangeness enhancement effects are accompanied by an increase in multiplicity (entropy) per baryon.

5. Conclusions

The NA57 experiment can play a unique role to explore 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 nucleon participants to the collision and ii) how this behaviour depends on the centre of mass energy of the collision.

References

[1] I. Kralik et al., WA97 Collaboration, Nucl. Phys. **A638** (1998) 115c
WA97 Collaboration: E. Andersen et al., Phys. Lett. B433 (1998) 209
[2] J. Rafelski and B. Muller, Phys. Rev. Lett. **48**, (1982) 1066.
[3] RD19 Collaboration: E.H.M. Heijne et al., Nucl. Instr. Meth. **A349** (1994) 138