Ref: CERN/SPSLC 95-43, SPSLC/M557

Date: April 6, 1995

MEMORANDUM

From/De : E.Quercigh (Spokesperson) and F.Antinori (Contactperson) on behalf of the WA97 Collaboration
To/à : K.Koenigsmann
Subject/Sujet : Future Plans of the WA97 Collaboration
Copies : SPSLC

In this memorandum we discuss a plan for a comprehensive study of strangeness production in nucleus-nucleus collisions and for the development of detectors for the Alice experiment at LHC. Strong interest in the program outlined here has been expressed by most of the institutes currently participating in the WA97 collaboration, and by most of the Alice Inner Tracker community.

INTRODUCTION

The study of the production of strange hadrons in nucleus-nucleus collisions at OMEGA started back in 1987, with the first S-W run of WA85. In WA85, the tracks emerging from the weak decays of strange particles were detected by a system of suitably modified multi-wire proportional chambers. Figure 1 shows the complete series of signals detected in WA85 (K^0_s, K^+, K^-; Λ, Ξ^-, Ω^- and their antiparticles). As is shown in figure 2, a clear enhancement of the relative yields of K^0_s, Λ, $\overline{\Lambda}$, Ξ^- and $\overline{\Xi}^+$ with respect to negative particles is observed when going from p-W to S-W collisions. This enhancement increases with the strangeness content of the particles i.e. it is larger for Ξ^- and $\overline{\Xi}^+$ (strangeness $|s|=2$) than for Λ, $\overline{\Lambda}$ and K^0 ($|s|=1$). The first results on Ω^- and $\overline{\Omega}^+$ ($|s|=3$) suggest that they are even more enhanced than Ξ^- and $\overline{\Xi}^+$ [1]. This unexpected effect seems to indicate that the system has come close to chemical equilibrium among particle species even for the rare multi-strange antibaryons. This has been put forward [2,3] as an indication that the system undergoes a phase transition to a state of deconfined quarks and gluons (QGP), since the equilibration of these rare antibaryons by rescattering in a hadronic fireball is a particularly slow process on the collision timescale. Results compatible with those of WA85 have been obtained in WA94, again a wire-chamber experiment, studying S-S collisions.

The first results from the WA97 silicon telescope (see below) indicate that we shall be able to detect all the strange particle signals detected by WA85 and WA94, with a considerable improvement in resolution, statistics and phase space coverage. We shall then be able to follow the evolution of the effects mentioned above going to the much heavier Pb-Pb system.

STATUS OF WA97

The WA97 Collaboration is currently studying the production of strange particles at central rapidity in 160 A GeV/c Pb-Pb collisions at the OMEGA Spectrometer with an apparatus (sketched in figure 3) centred on a telescope of silicon strips, silicon pads and silicon pixel detectors developed in collaboration with the RD19 group. In 1994 we operated, for the first time in an experiment, four 30 cm^2 planes of silicon pixels with a cell size of 75 μm x 500 μm, giving a total of 300K channels. A field-off event with 40 reconstructed tracks going through the four pixel planes is shown in figure 4.

During the first Pb beam run of WA97, about 60 million events of central Pb-Pb collisions were collected. The reconstruction of tracks and vertices has started, and clean signals from Λ, $\overline{\Lambda}$ and K^0 decays are obtained, as shown in Figure 5. The Λ mass resolution (figure 6) is about four times better than in

WA85 and WA94, which used MWPCs with sulphur beams.

The addition of a second telescope, which extends the WA97 acceptance towards higher rapidities, has been approved by the SPSLC. A new generation of pixel detectors has been designed for this purpose. The two-telescope set-up is expected to be completed for the last scheduled run of WA97, at the end of 1996. Its acceptance will cover the two central units of rapidity down to transverse momenta of a few hundred MeV/*c*, i.e. a substantially larger window than in the WA85 and WA94 experiments.

FUTURE PLANS FOR PHYSICS AND DETECTOR DEVELOPMENT

Under the current planning our study of Pb-Pb collisions at 160 A GeV/*c* should be completed within the WA97 runs planned in 1995 and 1996, i.e. before the presently projected shutdown of OMEGA. These runs shall allow us to study the abundances of various species of strange particles in a larger, hotter and denser system than S-W or S-S. The comparison of the WA97 results with those already obtained with the lighter systems shall put additional constraints on the competing models of heavy-ion collisions.

We think that some additional questions, beyond those currently addressed by WA97, will then need to be answered. For example, we would like to know how the pattern of strangeness enhancement we have observed depends on the collision energy and on the projectile mass. To this end, we want first to see whether the effect can be made to disappear by going to lower beam momenta. We think that the use of beams of lower energy should have priority over the use of projectiles of intermediate mass.

Such a study should start with a Pb run at the lowest beam momentum attainable in the SPS (about 40 A GeV/*c*). While the absolute yields of strange baryons and antibaryons will decrease, it will be of interest to study the evolution of their yields relative to one another. For example, the decrease of the ratios between (anti-)baryons of different strangeness (e.g. $\overline{\Xi}^+ / \overline{\Lambda}$) towards the values they have in proton reactions would suggest that the large values measured at 200 A GeV/*c* might be due to new processes setting on at large energy densities, e.g. a phase transition to QGP. One could then proceed to study more closely the energy dependence of the effects, and look for a possible threshold. It has been recently suggested that in a QGP scenario as the collision energy is lowered these ratios should at first increase, due to the increased baryon stopping and hence baryon density, reach a maximum at the transition energy, and then drop [4].

The onset of a phase transition is expected to be accompanied by an increase of the entropy produced per elementary nucleon-nucleon interaction [5]. In order to constrain further the interpretation of the strange particle results, we intend to estimate both the produced entropy and the scattered baryon number, hence the entropy per baryon, in the same phase space region where we study the production of strange particles. For this purpose, we plan to upgrade our setup with a system, based on pixel detectors, to measure the rapidity density separately for positive and negative tracks.

In principle this programme could be completed in one or two years, since each run needs about one month of beam time. However, constraints on the choice of beam energy and projectile type come from the different requirements of the various ion experiments and make it unlikely that the programme could be completed in such a short time. Therefore we think that it is realistic to spread the necessary beam time over a period of four calendar years.

We intend to take advantage of this longer schedule: it gives us the unique opportunity to continue and accelerate the development of detectors for the Alice Inner Tracking System (ITS). Over the years going from 1997 to 2000, a crucial period for the finalization of the Alice components, we would progressively replace the existing detectors in the telescope with new ones, developed taking into account more strictly the Alice specifications in terms of segmentation, material thickness, read-out, mechanics and bussing. We could also profit from the possibility of increasing the spatial precision of our telescope by the use of silicon drift detectors [1]. The lever arm could be extended by employing silicon and gas microstrips. The high granularity, high resolution environment for the study of nucleus-nucleus collisions at high interaction rates provided by our experiment would offer a unique opportunity for real-life studies of all ITS detectors. We therefore plan to extend the detector development activities to all parts of the ITS, in a combined effort between most of the present WA97 collaboration and most of the groups involved in the Alice ITS.

SCHEDULING AND BEAM LINES

The implementation of the new programme would require about four months of ions plus 6 months of protons, spread over a further four years after the end of our approved programme in 1996 i.e. after the date presently foreseen for the closing down of the OMEGA Spectrometer.

Clearly we think it is regrettable to move and re-install in another beam line the apparatus we already succesfully operate at OMEGA. We note that the continuation of beam extraction to the West Area after 1996/1997 is still under discussion and that it seems unlikely that the floor space for the LHC magnet activities will actually be required until after the year 2000. Then the only remaining obstacle to an extension of our activity in OMEGA would be the current plans to dismantle what remains of the traditional OMEGA support group. Such an obstacle could be overcome if we ran the whole system ourselves, except for the operation of the magnet.

This scenario could be cost effective and we suggest it should be evaluated.

If this is not possible, alternative options would require:

- a beam line capable of delivering 10^6 Pb ions per spill with a O(1 mm^2) spot. We are studying the possibility of installing the experiment either in H4, after the completion of NA44, or in H8, behind NA45. As NA45 does not stop the beam in a zero-degree calorimeter, there would be the possibility of making use of the ions which do not interact in their apparatus. This would allow both experiments to run simultaneously, provided that the beam is properly refocussed on our target: this seems to be feasible with the currently installed optics. The H4 option would be preferable, as besides ensuring us full control of the beam line, it would allow us to make full use of the Pb beam time independently of the NA52 schedule.
- a magnetic field of around 1.5 Tesla over appropriate dimensions. It could be provided by one of the existing large spectrometer magnets besides OMEGA i.e. Goliath and NA49. Otherwise we could use one of the smaller magnets available at CERN, and we have identified two or three candidates which could be adequate.

SUMMARY AND CONCLUSIONS

In the experiments WA85 and WA94 we have observed an unexpected behaviour of strangeness production when comparing proton- and sulphur- induced reactions. In WA97 we have successfully operated 300000 channels of Si pixel detectors with associated Si strips and Si pads in Pb-Pb interactions; the first results indicate excellent reconstruction efficiency and mass resolution of this system. We intend to pursue this experiment, as approved by the SPSLC, with an extension of the phase space window by using a second, more evolved telescope. This will end the WA97 programme in 1996.

---

[1] We are presently exploring what additional physics possibilities could be offered by the employment of silicon microdetectors in the the study of nucleus-nucleus collisions at high interaction rates. In particular, we are investigating the extension of the use of such detectors to K^0 interferometry and charm detection.

For a clearer picture of the physics involved in the observed strangeness enhancement, we would need to study this effect under different energy densities and have information about the entropy produced in the collision. We therefore would like to take measurements with lower energy (and eventually intermediate mass) beams and measure positive and negative particle densities individually for each event.

Furthermore, we would like to combine these, possibly crucial, measurements with the development and testing of detectors foreseen for the Alice Inner Tracking System. This combination would be fruitful: the development of new silicon detectors and their implantation and testing in a high particle density environment is motivated by the immediate physics interest and by the interest for Alice.

We think that this program will lead us to the year 2000. We would need an experimental area in a beam. The present position in the West Hall would be preferred by us and we ask for an unbiased evaluation of its cost-effectiveness. If this proposal turned out to be not feasible, we would need an area in the H8 or, preferably, in the H4 beam line; we would also need a magnet of moderate size and field integral.

The (relatively modest) financial and manpower needs for this programme would be met by the collaborations around WA97 and Alice ITS. CERN should assume the coordination of this effort and contribute with the expertise and the specialists for advanced particle detectors.

REFERENCES

[1] S. Abatzis et al., to be published in Phys. Lett. B.

[2] J. Letessier, J. Rafelski and A. Tounsi, Phys. Lett. B321 (1994), 394.

[3] U. Heinz, Proceedings Quark Matter '93 (Borlänge, Sweden). Nucl. Phys. A566 (1994), 205c.

[4] J. Rafelski, Proceedings Strangeness '95 (Tucson, AZ, U.S.A.). To be published.

[5] J. Letessier et al., Phys. Rev. Lett. 70 (1993), 3530.

[6] D. Evans et al., Proceedings Quark Matter '93 (Borlänge, Sweden). Nucl. A566 (1994), 225c.

[7] J.P. Davies et al., Proceedings Strangeness '95 (Tucson, AZ, U.S.A.). To be published.

[8] D. Di Bari et al., Proceedings Quark Matter '95 (Monterey, CA, U.S.A.). To be published.

Figure Captions:

Fig. 1 Strange particle signals detected by WA85.

Fig. 2 Ratios between the S-W and the p-W values of the relative abundances with respect to negative particles of K^0_S, Λ, $\bar{\Lambda}$, Ξ^- and $\bar{\Xi}^+$ (e.g. $(\Lambda/h^-)_{S\text{-}W}/(\Lambda/h^-)_{p\text{-}W}$). Calculated from published WA85 data [6,7,8].

Fig. 3 Sketch of the WA97 apparatus.

Fig. 4 A Pb-Pb event with 40 reconstructed tracks as detected by the Si pixels. The event is viewed looking down the telescope towards the primary interaction vertex. The magnetic field was off.

Fig. 5 Armenteros-Podolanski plot from a small sample of WA97 Pb-Pb data. Accumulations around the K^0_S, Λ and $\bar{\Lambda}$ ellipses are visible.

Fig. 6 The Λ peak in the $p\pi^-$ mass spectrum from the sample of figure 5.

WA85 Strange Signals

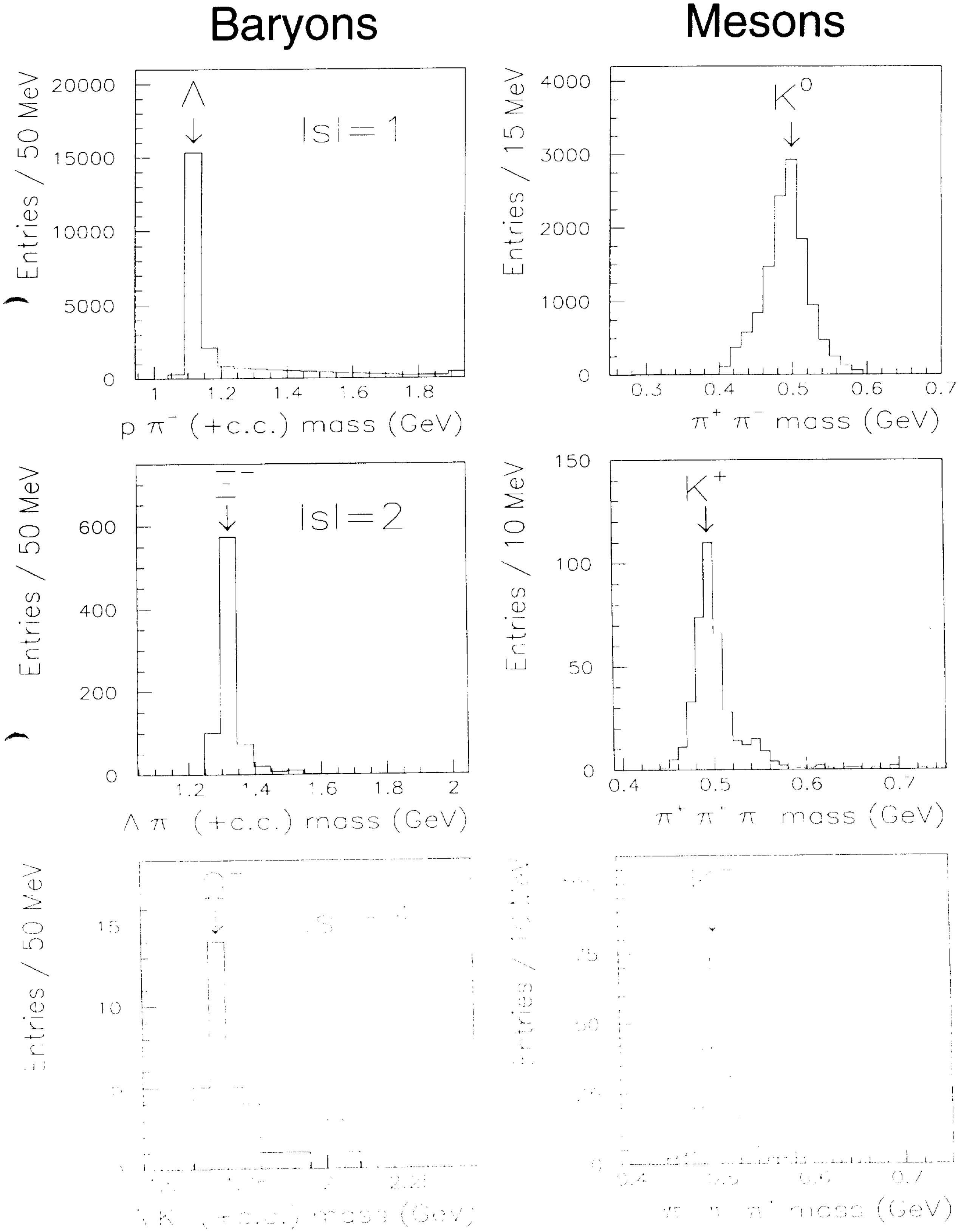


Fig. 1

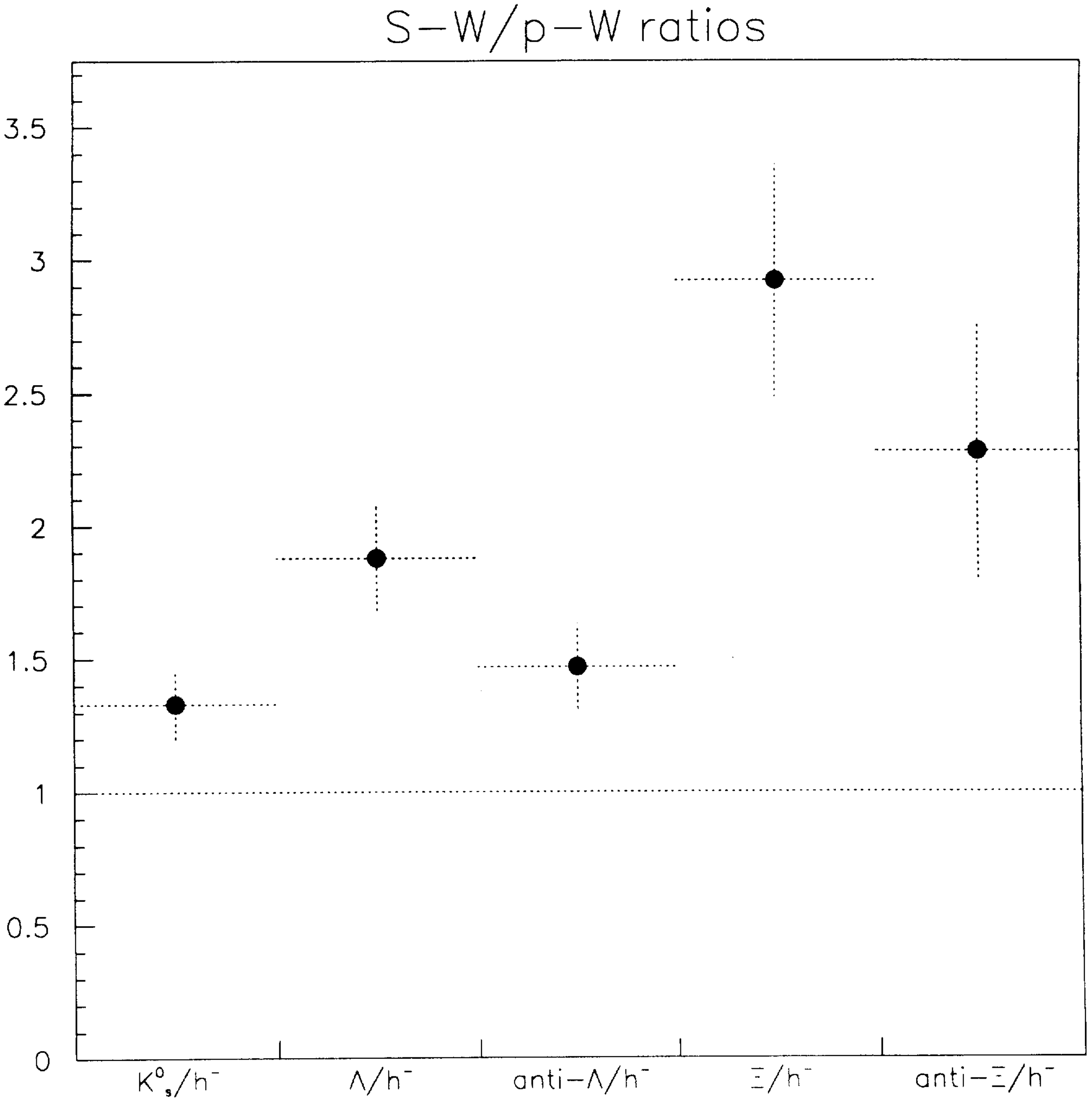


Fig. 2

WA97 set-up
in the Omega magnet

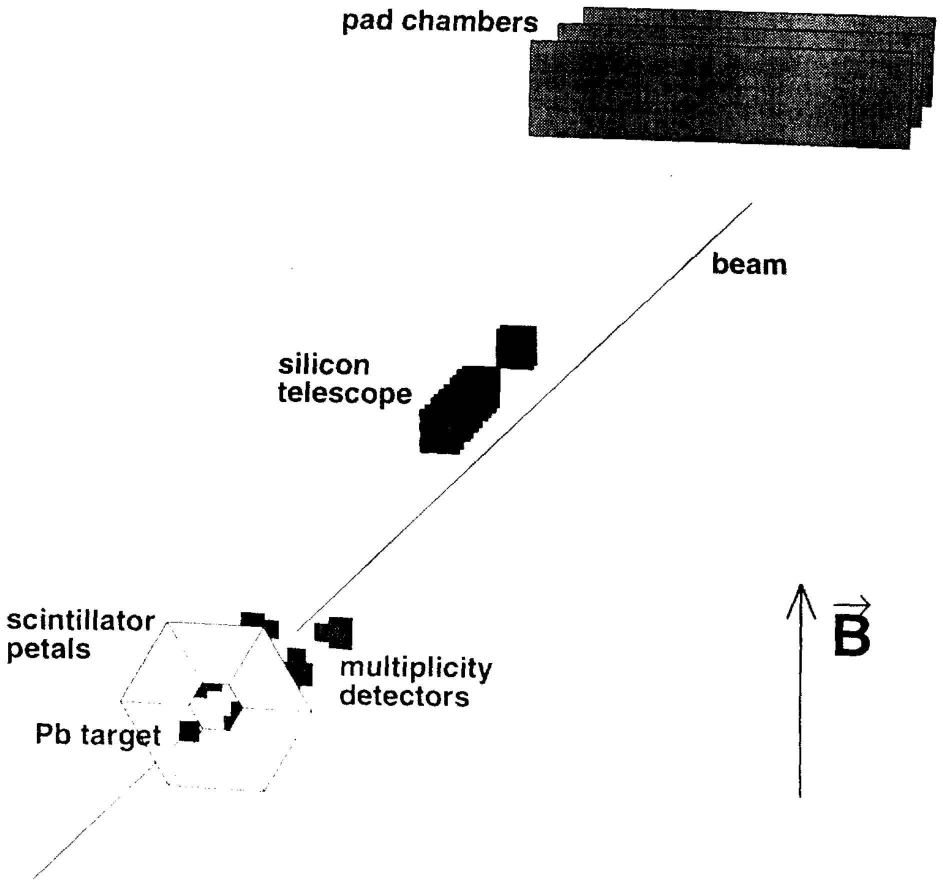
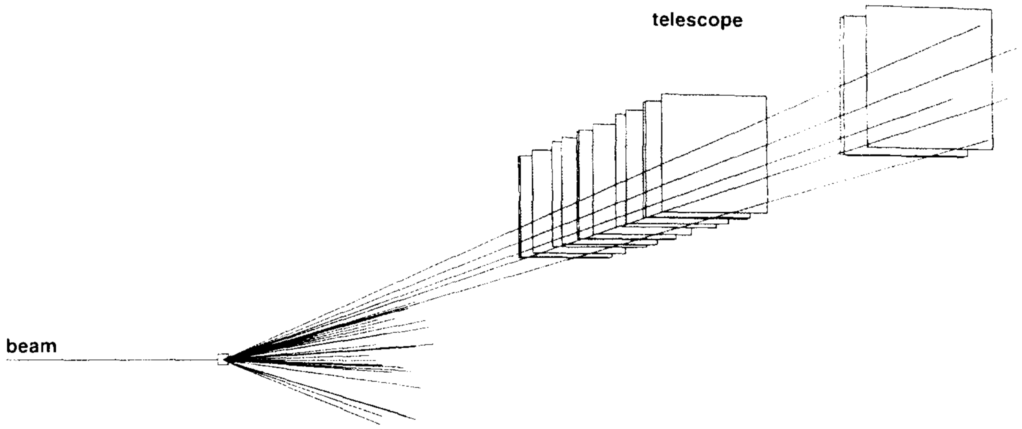


Fig. 3

WA97 33.3 TeV Pb+Pb



40 tracks through the silicon pixel telscope

the detector cross-section is 5cm x 5cm

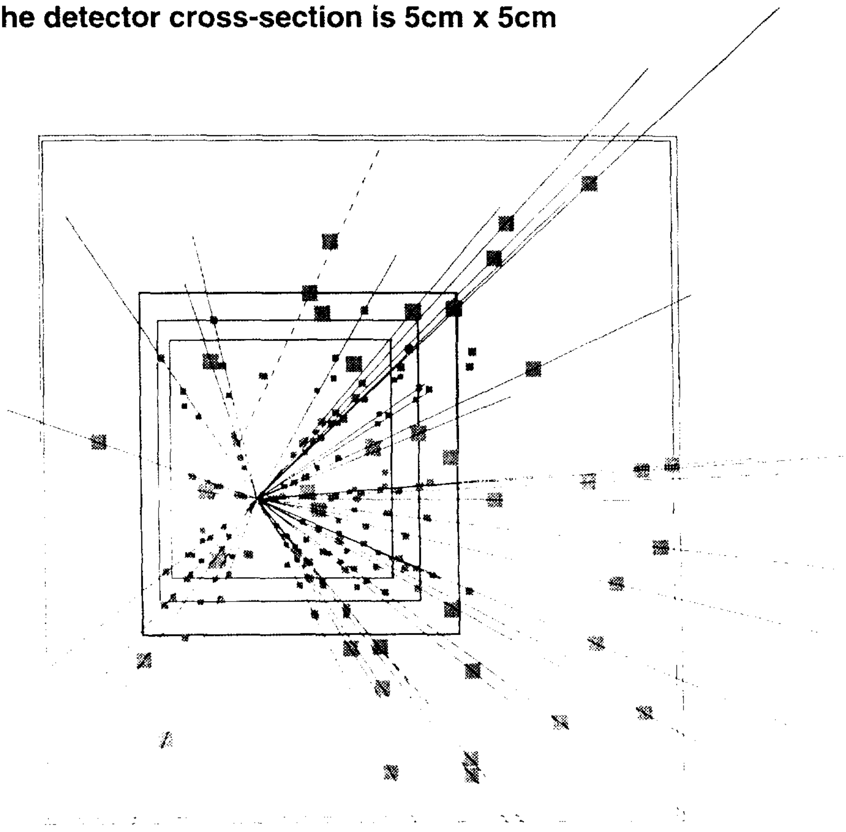


Fig. 4

WA97 Armenteros-Podolanski plot

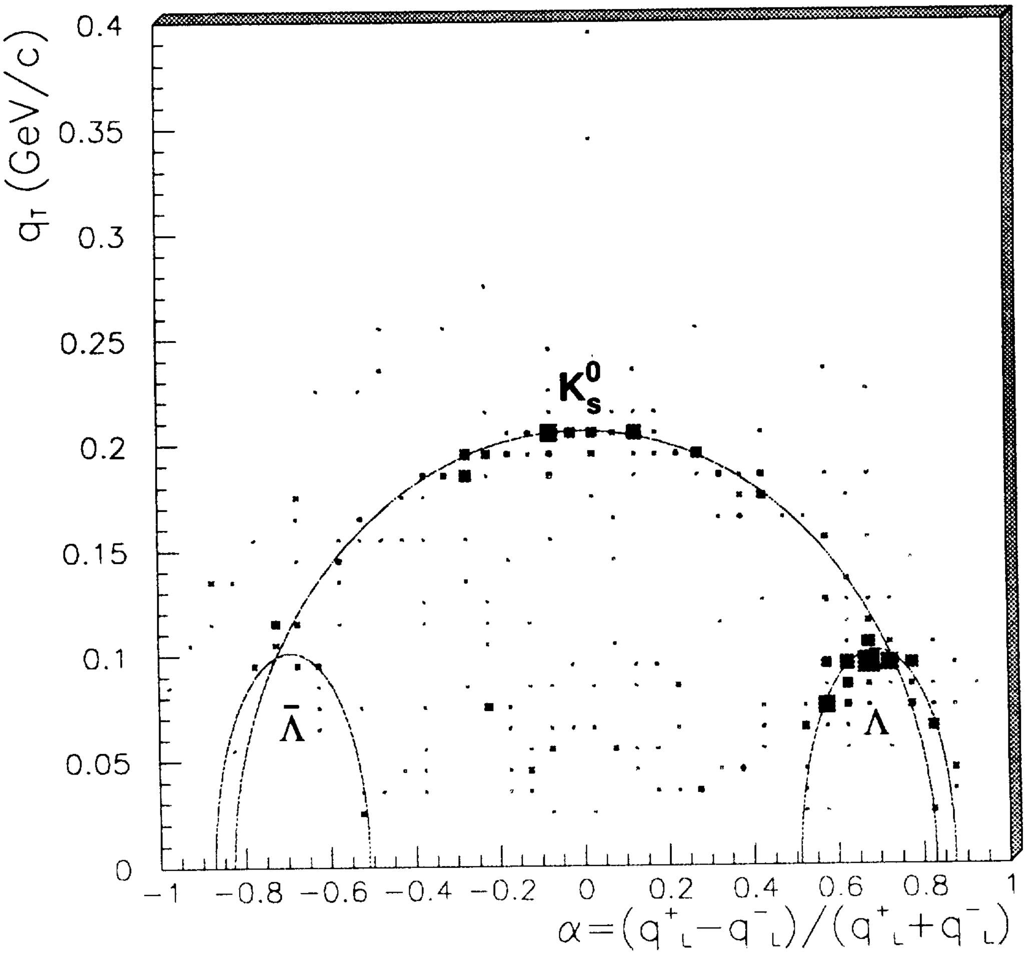
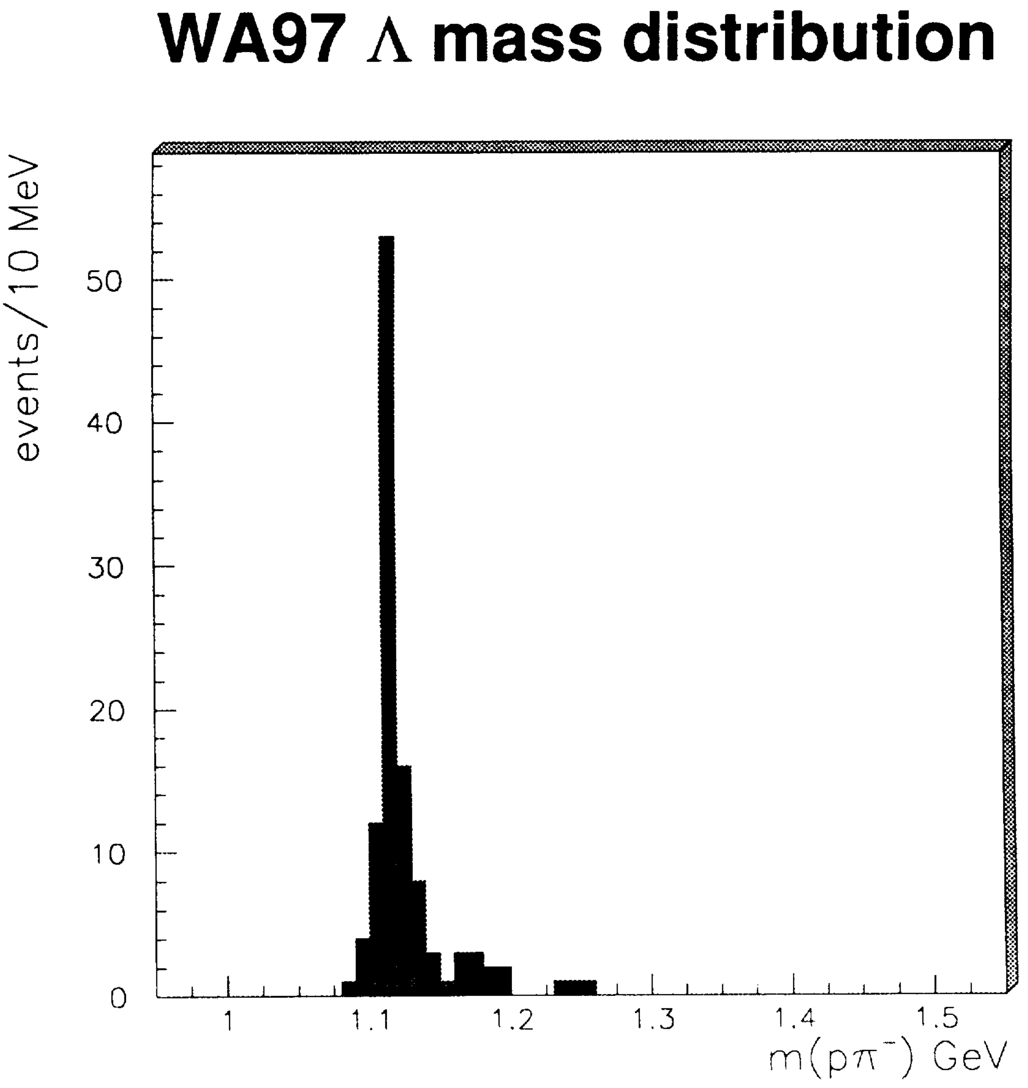


Fig. 5



WA97 Λ mass distribution

Fig. 6