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MEMORANDUM

From/De : Federico Antinori and Emanuele Quercigh

To/à : Bernard D'Almagne, SPSLC Chairman

Subject/Sujet : Plans for an extension of the WA97 program in the North Area

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This document follows memorandum CERN/SPSLC 95-43 submitted by the WA97 Collaboration at the 1995 Cogne meeting of the SPSLC, and the status report of WA97 presented at the January 1996 SPSLC meeting. We write on behalf of a collaboration among the following institutions:

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We wish here to reiterate our intention to pursue after the shutdown of the West Area for hadron physics at the end of 1996 the study of the production of strange and multi-strange particles in nucleus-nucleus collisions which was initiated at the OMEGA Spectrometer. Three ion experiments have been performed at the OMEGA Spectrometer: WA85 (S-W collisions at 200 A GeV/c), WA94 (S-S collisions at 200 A GeV/c) and WA97 (Pb-Pb collisions at 160 A GeV/c). WA97 will complete its data taking in 1996.

The main purpose of the new experiment is to extend the physics scope of WA97 [1]

- by correlating the information on strangeness production not only with centrality, but also with information on the entropy per baryon as obtained from the measurement of positive and negative multiplicities [2], and
- by repeating the Pb-Pb study at a lower beam momentum in order to investigate the energy dependence of the enhancements of multi-strange particle production reported by the previous experiments.

We propose to move the GOLIATH magnet, which will not be used by WA98 after the end of 1996, from the West to the North Area and to install it, together with WA97 detectors, in the H4 beam line when this becomes available. The experiment would re-use most of the apparatus built for WA97 and would therefore require very limited new investment.

PHYSICS MOTIVATION

The aim of WA85, WA94 and WA97 was to measure the yields of several species of strange particles (K^0_S, $K^\pm$; Λ, Ξ^-, Ω^- and their antiparticles) in nucleus-nucleus collisions and to compare them to those in proton initiated reactions. The idea was to use strangeness production as a diagnostic probe [3, 4] for the phase transition from a system of hadrons to a plasma of quarks and gluons (QGP) expected to occur under the extreme conditions of energy density attained in the collision of two heavy nuclei at ultrarelativistic energies. It has been suggested that if such a phase transition were to occur, the yields of strange particles would increase towards their chemical equilibrium values. Due to the high density of $s\bar{s}$ pairs expected in the plasma, the enhancement effect should be more pronounced for multi-strange objects [5].

An enhancement of strange versus non-strange particles when going from hadron-hadron to nucleus-nucleus collisions could also be obtained in a purely hadronic scenario, i.e. without the onset of a QGP phase, due to particle reinteractions in the large hadronic fireball created in the collision. The approach to equilibrium would be significantly slower with this mechanism, and would be limited by the interaction time (a few fm/c). In particular, since the number of reinteractions needed to form a hyperon increases with its strangeness content, one would expect the enhancement to be less pronounced for particles of higher strangeness content [6]. It is therefore interesting to study the production of multi-strange hyperons, comparing the yields of particles carrying one, two and three units of strangeness in the same experiment. More generally, data on multi-strange hyperons and antihyperons are an important benchmark for the models (e.g.[7, 8, 9, 10]) which attempt a comprehensive description of hadron abundances in nucleus-nucleus collisions.

While other ion experiments have studied mainly the production of mesons and baryons carrying one unit of strangeness, the WA85, WA94 and WA97 experiments have also studied the production of the rare Ξ^- and Ω^- baryons. Strange (anti-)baryon enhancements at central rapidity have been reported by WA85 and WA94 in sulphur initiated reactions. These enhancements appear to increase with the strangeness content of the baryon, i.e. Λ ($\overline{\Lambda}$) are enhanced with respect to pions [11] and Ξ^- ($\overline{\Xi}^+$) are in turn enhanced with respect to Λ ($\overline{\Lambda}$) [11, 12, 13]. WA85 also detected an ($\Omega^- + \overline{\Omega}^+$) signal in S-W collisions [14]. The $(\Omega^- + \overline{\Omega}^+)/(\Xi^- + \overline{\Xi}^+)$ ratio at central rapidity and $p_T > 1.6$ GeV/c was measured to be of the order of 1 [15], significantly larger than in pp collisions [16]. WA97 has observed production of Λ, Ξ^- and Ω^- in Pb-Pb and in p-Pb collisions at 160 A GeV/c. The first results [17] indicate a significant enhancement of Ω over Ξ production at central rapidity when going from p-Pb to Pb-Pb.

These results suggest a reaction scenario where $s\bar{s}$ pairs are copiously and freely produced in nucleus-nucleus collisions at SPS energies, as expected in the case of QGP formation. However, additional questions need to be answered in order to get a clear insight into the mechanisms at work. For example, a deconfinement phase transition is expected to be reached only when a sufficiently large energy density is attained. We therefore need to know how the observed pattern of strangeness enhancement depends on the energy density reached in the collision. A variation of the energy density can be obtained by reducing the beam energy; this has the advantage of keeping the same collision geometry for events of given centrality [18].

We envisage a Pb run at a beam momentum of about 40 A GeV/c. This is the minimum momentum attainable in the SPS, and corresponds to a center-of-mass energy per nucleon (8.8 GeV) intermediate between those achieved at the BNL AGS (4.7 GeV) and at the SPS (17.3 GeV). It has also been suggested that in this intermediate energy regime the longest lived system with high density could be obtained [19].

It will be of great interest to study the relative yields of strange and multi-strange hadrons. For example, a drop of the ratios between baryons of different strangeness (like Ξ/Λ, Ω/Ξ) near the values found in proton-initiated reactions would indicate that something very interesting is happening between 40 and 160 A GeV/c.

Since the onset of a deconfinement phase transition is expected to be accompanied by an increase of the entropy produced per elementary nucleon-nucleon interaction, we intend to use a simple arrangement, presently under study, of a few silicon pixel planes close to the target to measure the entropy (roughly proportional to the total multiplicity) and the baryon number (proportional to the net multiplicity, i.e. to the difference between the positive and negative multiplicities) at central rapidity both at 160 and 40 A GeV/c.

SET-UP

We intend to install the WA97 detectors in the North Area H4 beam line inside the GOLIATH magnet in its 1.05 m gap, 1.5 T maximum field configuration. We intend to run both at 160 and 40 A GeV/c with such a new spectrometer; therefore we have studied two possible set-ups, for 160 and 40 A GeV/c. The idea is shown in figure 1. At 160 A GeV/c, the set-up is similar to the WA97 1995 Pb run configuration: the microdetector telescope is placed above the beam line and inclined; it is aligned with the lower edge of the detectors on a line pointing to the target at an angle $\alpha = 40$ mrad. The cross section of the planes is 5×5 cm^2. The distance from the target is $d = 60$ cm. The phase space acceptance for the detection of the $\Lambda \rightarrow p\pi^-$ decay for this configuration is shown in figure 2. We are sensitive to hyperons produced at medium-high p_T, around central rapidity ($y_{LAB} = 2.9$). Multiplicity detectors are placed after the target, providing information on event centrality. The first station is an arrangement of scintillator petals at 10 cm from the target covering the pseudorapidity region $1 < \eta < 2$, which is used in the trigger to select events according to their centrality. The other multiplicity stations could be equipped either with silicon microstrip arms for the measurement of the multiplicity, as in WA97, or with silicon pixel planes for the measurement of the specific entropy. In the 40 A GeV/c set-up the telescope has a larger inclination ($\alpha = 100$ mrad), to cover the new central rapidity region ($y_{LAB} \simeq 2.2$) and is located closer to the target ($d = 30$ cm) to compensate the expected reduction in the yield of hyperons with respect to 160 A GeV/c. The phase space acceptance for the Λ in this configuration is shown in figure 3.

The telescope will be based on silicon pixel detector planes. The use of this technique was succesfully pioneered by WA97 in collaboration with RD19 [20, 21]. To illustrate its power for the analysis of high track densities, we show in figure 4 a Pb-Pb event with 153 reconstructed tracks in the seven WA97 pixel planes. The plan is to employ the seven existing pixel detector planes based on the Omega2 [22] front-end chip, plus new planes currently under construction based on the new Omega3 [23] front-end chip. This would lead to a telescope made entirely of silicon pixel detectors. Several planes of silicon microstrips and silicon pad detectors, built for WA97, will be available for use if needed. Three planes of multiwire proportional chambers with pad cathode readout are currently being employed by WA97 as lever arm detectors, and could also be available.

For data acquisition, we plan to set up a system which incorporates many of the ideas under development for the ALICE data acquisition system. The implementation of such a system will be taken care of by the CERN ALICE-DAQ group.

RATES

Assuming that we shall use a 1% λ_i Pb target, and that we shall trigger on 30% of the inelastic cross section, and assuming:

- a beam intensity of 10^6 ions/burst
- 4300 bursts/day

- 60 % dead time
- 70 % overall running efficiency

we expect a data collection rate of about 6 10^6 events/day; or about 180 10^6 events in a 30 day run.

In the 160 A GeV/c configuration, extrapolating from WA97 data, we expect about 500 000 Λ, 100 000 $\overline{\Lambda}$, 3000 ($\Xi^- + \overline{\Xi}^+$) and 500 ($\Omega^- + \overline{\Omega}^+$) in a 30 day run.

In the 40 A GeV/c configuration, we should collect, in a 30 day run, about 170 000 Λ and 30 000 $\overline{\Lambda}$, where we have assumed the number of Λ produced per unit of rapidity not to vary between 160 and 40 A GeV/c. The numbers of Ξ^-, $\overline{\Xi}^+$, Ω^- and $\overline{\Omega}^+$ detected will depend on the detailed pattern of strangeness enhancement at 40 A GeV/c, which we intend to measure. However, in a 60 day run at 40 A GeV/c, we should be able to collect about 100 ($\Omega^- + \overline{\Omega}^+$) even if the ($\Omega^- + \overline{\Omega}^+$) yield at 40 A GeV/c were to be ten times smaller than at 160 A GeV/c.

REQUEST

The running time needs for completing the program outlined above consist of

- 60 days of Pb run at 40 A GeV/c
- 30 days of Pb run at 160 A GeV/c.
- 80 days - i.e. 2 $\times$ 40 - of proton time for setting up, calibration and Ω^- reference data, prior to the ion runs.

We would like to start with the setting up in 1997.

We would rely on CERN resources for the transport, set-up, powering, operation and maintenance of the GOLIATH magnet in the present NA44 area, and for any minor rearrangements which might be needed in the configuration of the area itself.

The experimental area and part of the equipment (magnet, DAQ, detectors) could be shared with the ALICE collaboration for detector tests with hadron and ion beams [24] for part of the remaining beam time. We do not plan to stop the beam in our set-up, so that the experiment will be essentially transparent, allowing for other activities down the same line.

FUTURE DEVELOPMENTS

There is the possibility of improving the apparatus described above by using ALICE Inner Tracking System (ITS) detector prototypes. We are considering the use of doublets covering about 4 $\times$ 7 cm^2, each consisting of three ALICE pixel single ladders giving a precise measurement (50 μm cell size) in the non-bend direction, and one ALICE double-sided microstrip module with stereo-angle, 95 μm pitch strips giving information essentially on the bend plane (figure 5). The use of ALICE prototype doublets in place of the existing detectors will reduce the material thickness per plane, and therefore multiple scattering and secondary interaction effects. This, combined with the reduced pixel cell size (50 μm $\times$ 300 μm, to be compared with 75 μm $\times$ 500 μm for the Omega2 planes and 50 μm $\times$ 500 μm for the Omega3 planes presently under construction) will ease the track finding in a high multiplicity environment.

We are also studying the possibility of introducing ALICE prototype Micro Channel Plate (MCP) detectors for a fast measurement of charged multiplicity at large rapidity. This information would complement that coming from the scintillator petals which are sensitive at backward rapidity, and could also be used at trigger level.

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Figure Captions

Fig. 1. Schematic view of the proposed set up in the GOLIATH magnet: at 160 A GeV/c $\alpha = 40$ mrad, $d = 60$ cm; at 40 A GeV/c $\alpha = 100$ mrad, $d = 30$ cm.

Fig. 2. Phase space acceptance for the $\Lambda \to p\pi^-$ channel in the 160 A GeV/c configuration.

Fig. 3. Phase space acceptance for the $\Lambda \to p\pi^-$ channel in the 40 A GeV/c configuration.

Fig. 4. A WA97 Pb-Pb event with 153 tracks reconstructed in the seven silicon pixel planes. The event is viewed looking down the telescope towards the primary interaction vertex. The magnetic field was off.

Fig. 5. A sketch of the ALICE prototype silicon pixel, silicon strip doublet which we envisage to use in the new experiment.

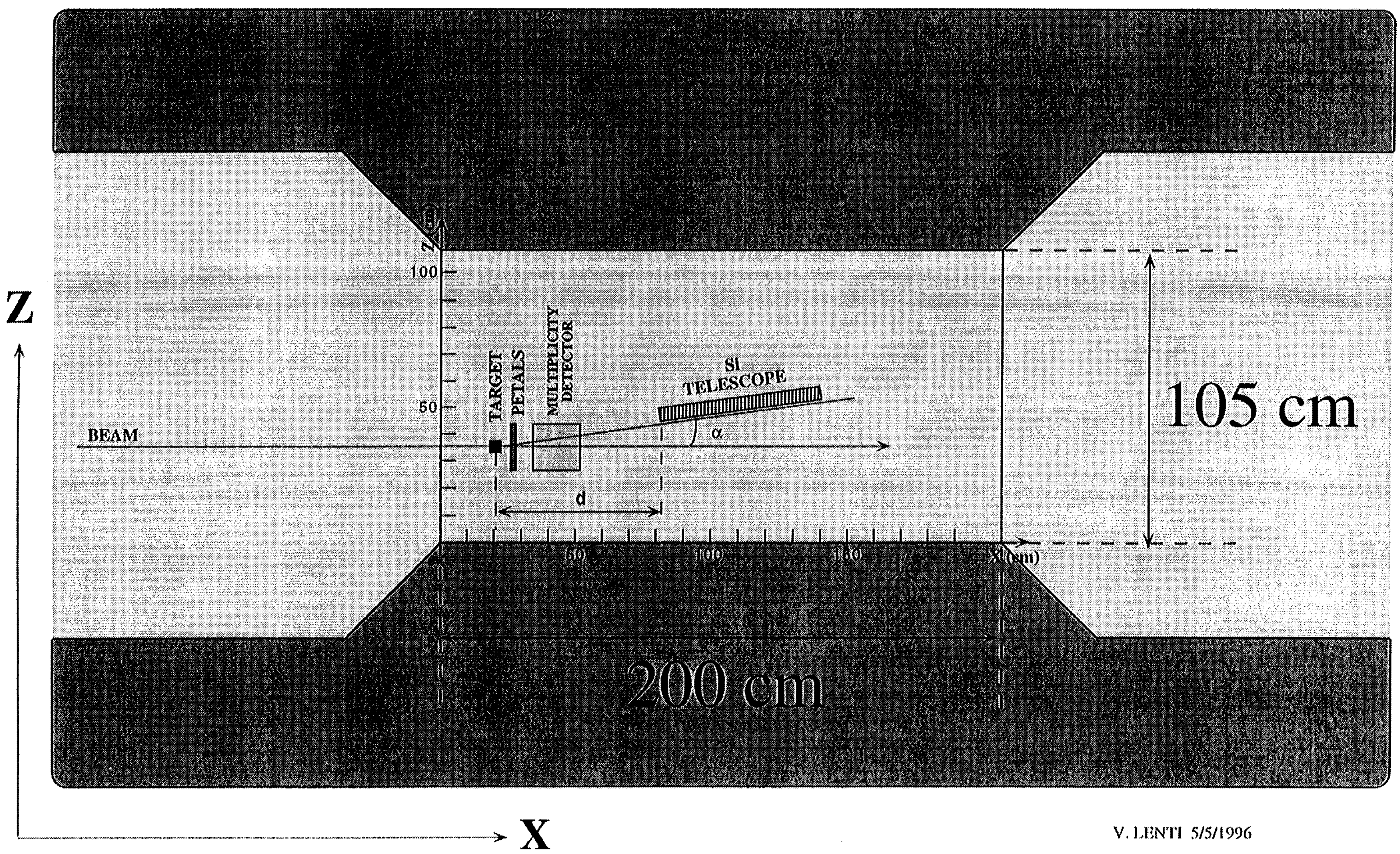
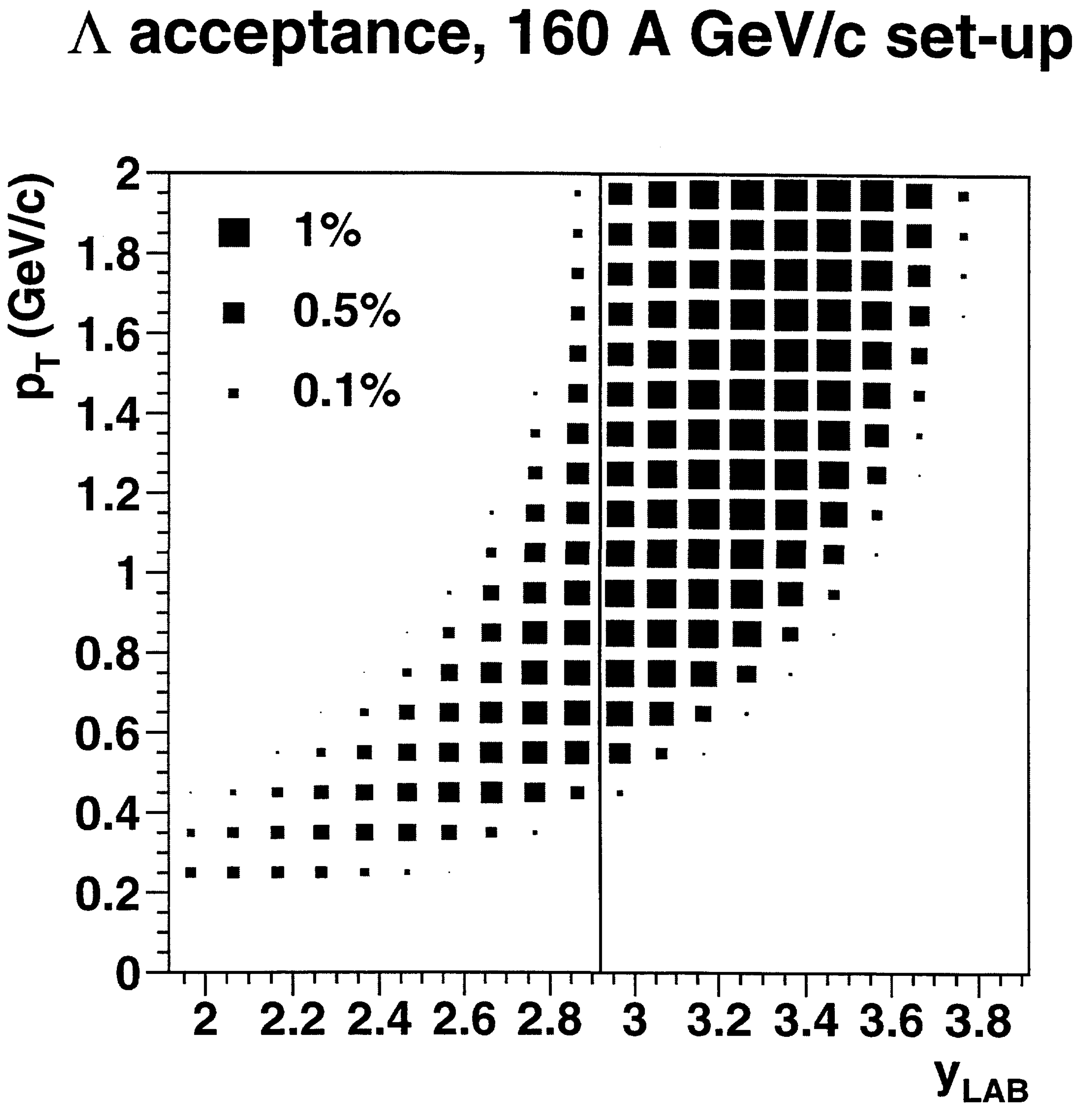

Z
BEAM
100
50
TARGET
PETALS
MULTIPLICITY DETECTOR
Si TELESCOPE
α
d
50
100
150
X (cm)
105 cm
200 cm
X
V. LENTI 5/5/1996

Fig.1



Λ acceptance, 160 A GeV/c set-up
pT (GeV/c)
1%
0.5%
0.1%
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
yLAB

Fig.2

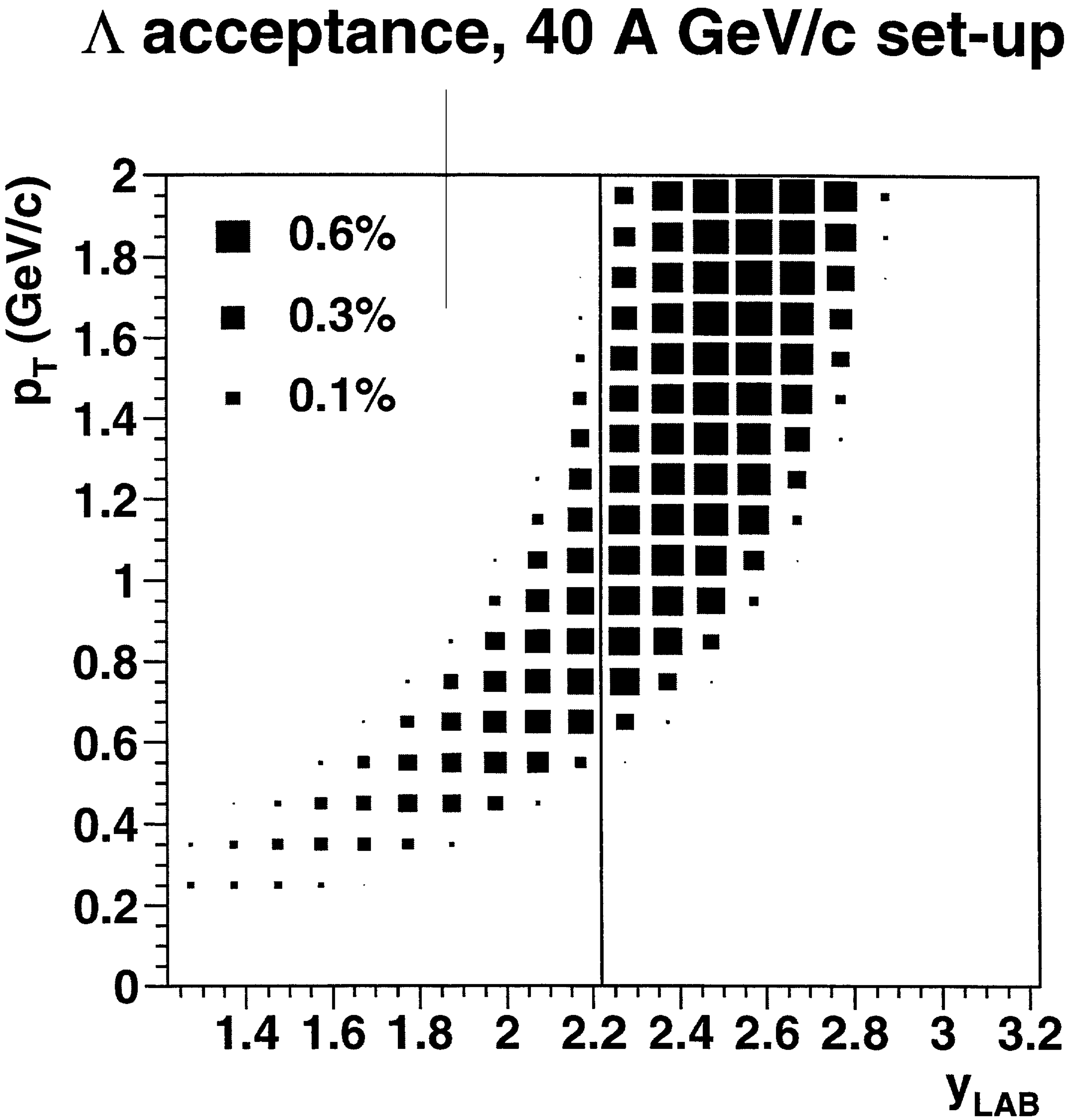

Λ acceptance, 40 A GeV/c set-up
0.6%
0.3%
0.1%
p_T (GeV/c)
y_LAB
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2

Fig.3

WA97 Pb–Pb event 1995

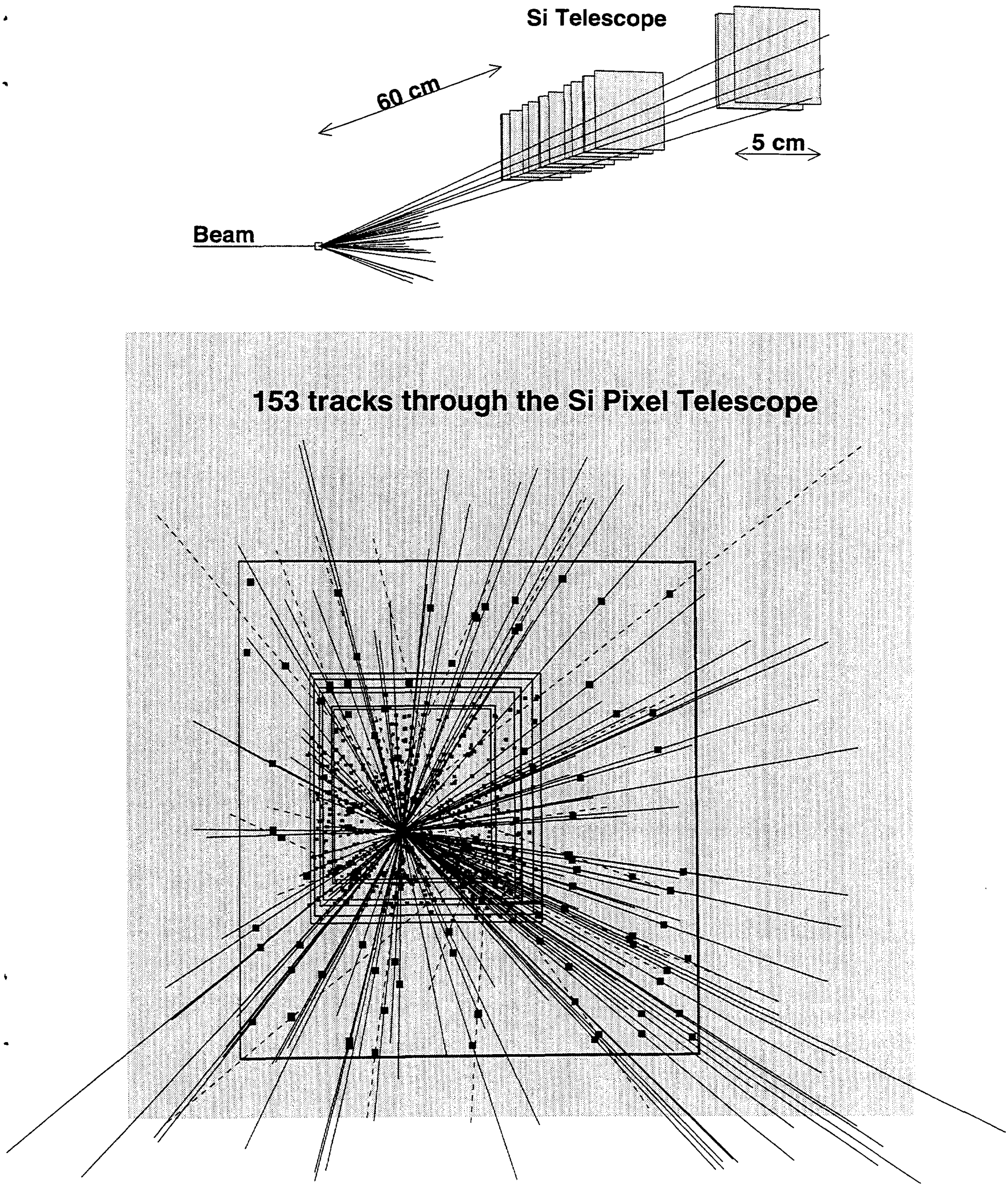
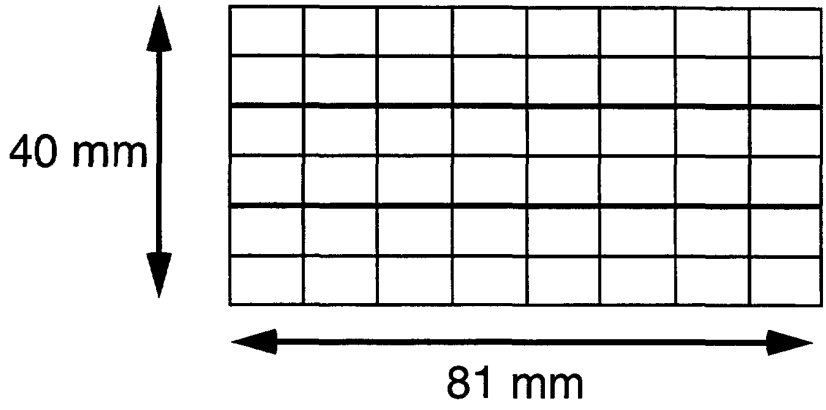
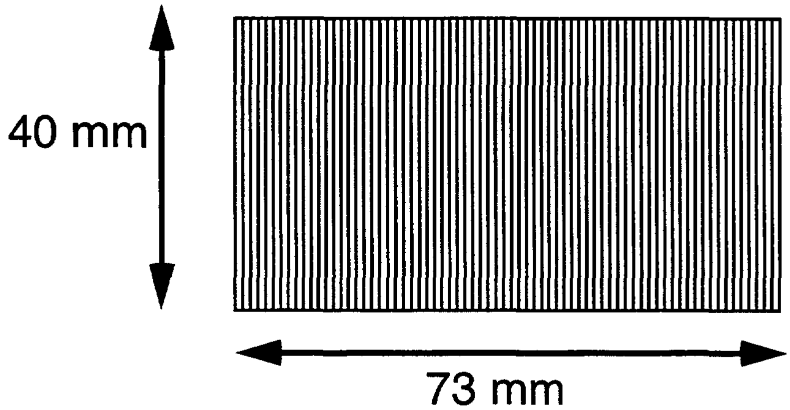


Fig.4

- Pixel plane:
  3 ALICE ladders
  196608 pixels, 50 μm (z) x 300 μm (y)



- μstrip plane:
  1 ALICE module
  2 x 768 strips, 95 μm pitch (~y), analog r/o
  double-sided with 35 mrad stereo angle



- ALICE prototype doublet:

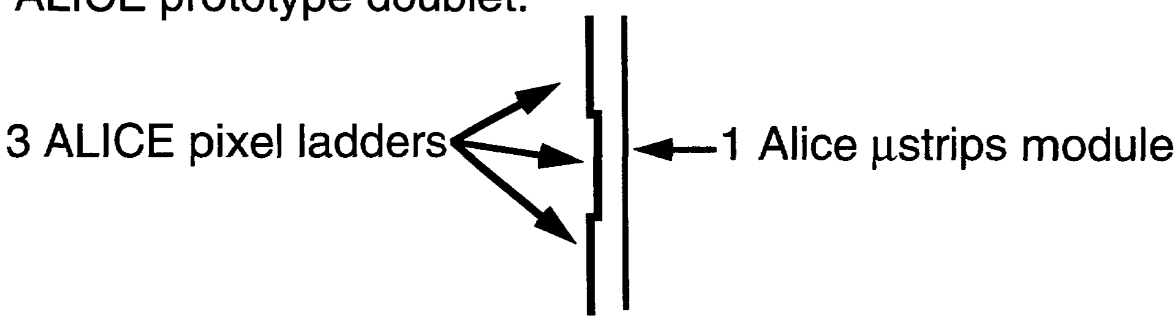


Fig.5