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NA36 Set-up and first results from the ^{32}S ion beams.

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ABSTRACT

Preliminary results of the experiment NA36 from the ^{32}S ion beams at the CERN SPS are presented. Total cross sections for the targets Pb, Ag, Cu, Fe and Al, energy flow at zero degrees and neutral transverse energy are given.

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1. INTRODUCTION

NA36 is looking for evidence of the Quark Gluon Plasma (QGP) in relativistic heavy ion collisions (RHIC). The aim of the experiment is to measure central rapidity strange baryon production in RHIC and correlate it with general event parameters such as energy at zero degrees, tranverse energy, rapidity distributions, etc. Strangeness production in RHIC is expected to be a sensitive signature of QGP. In this paper we present a brief description of the experiment and first results from ^{32}S ion beams.

2. THE NA36 SET-UP.

The experimental arrangement of NA36 is shown in Figure 1. The main detectors of the spectrometer are described in the following lines

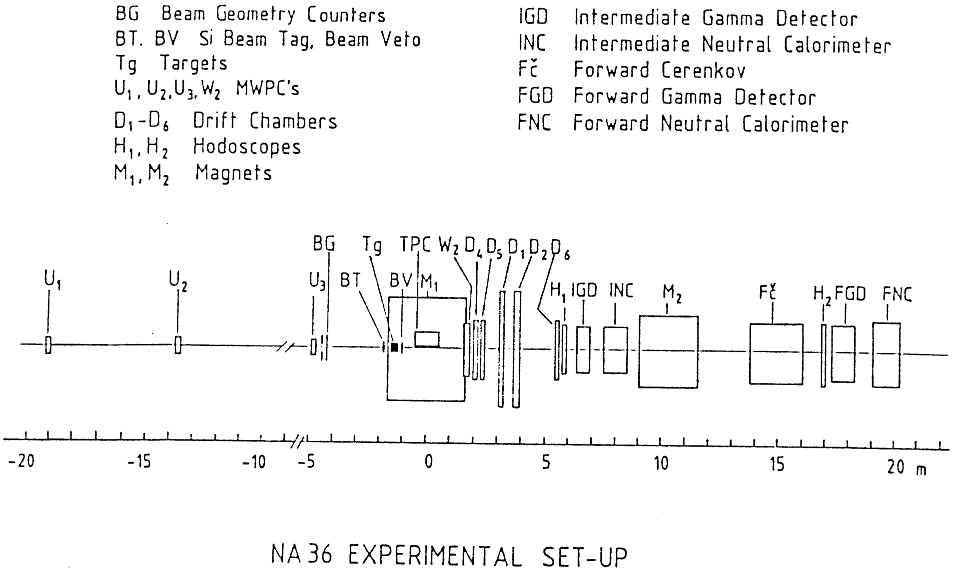

Figure 1: NA36 set-up

Time Projection Chamber (TPC): A strange baryon is identifed by its decay topology in this detector. The TPC is inside the superconducting magnet M1 that generates a magnetic field of 2.7 Tesla. The TPC provides three-dimensional track points. A detailed description can be found in reference 4.

U Chambers: They are three identical wire chambers (U1-U3), placed upstream from the target and used to reconstruct the beam trajectory. Their active surface is 26x36 cm^2 and they are made of 5 coordinate planes. The 20 μm sense wires are spaced by 2 mm [1].

W2: It is a large multiwire chamber, with an acceptance of 1.2x2.15 m^2. W2 has seven planes of sense wires with an spacing of 2 mm [1].

Drift Chambers: The spectrometer contains five planar drift chambers with sensitive areas of 4.25x2.10 m^2 (D1-D2) and 1.3x2 m^2 (D4-D6). Each of them consists of four coordinate planes. The wire angles have been chosen to meet the condition of the butterfly configuration [1].

The Forward Cerenkov: It consists of 14 cells arranged in a 2 x 7 matrix, each cell contains 28.6x52.0 cm^2 concave mirror with radius of curvature of 2 m. It is placed in front of the forward calorimeters (FGD, FNC). The central cells allow the study of the projectile fragmentation.

Intermediate Gamma Detector (IGD): This detector has been designed to measure both the position and the energy of a shower using a two-dimensional matrix of lead-glass counters. A counter size of 5x5x42 cm^3 have been chosen as a compromise between the precision of position measurement and the complexity of the detector. This corresponds to a depth of 15 X_0. It has 1136 counters covering a surface of 195x160 cm^2 with a central aperture of 35x80 cm^2. The energy measured resolution is given by the formula $\sigma(E)/E = (15/sqrt(E) + 2)\%$ [2].

Intermediate Neutral Calorimeter (INC): The detector is placed behing IGD. It is composed of 48 cells arranged to leave a 40x100 cm^2 hole allowing the fast particles to go through. The transverse size of the cells are 41x61 cm^2 on the sides and 16x33 cm^2 on top and botton. Each cell is made of 12 massive, 5 cm thick iron plates, interleaved with 2 cm plastic scintillators. The iron corresponds to 3.6 interaction lengths, and the lead in IGD adds another 2 interaction lengths. Normally 60% of the hadronic showers are initiated in IGD. The total energy is written :

$$E = (E_{NC} + E_{GD})\, x\, f(E,r) \tag{1}$$

where $r = E_{GD}/(E_{GD} + E_{NC})$ is the energy partition. f(E,r) is a polynomial of second degree in both E and r whose coefficients are fitted from calibration data. A fit to the three energy points gives a measured energy resolution of $\sigma(E) = 1.5\sqrt{(E)}$ with E in GeV [1].

Forward Gamma Detector (FGD): It consists of a 14x8 matrix of lead-glass blocks measuring 15x15x60 cm^3 in the central 8x8 portion and 15x15x40 cm^3 in the 3x8 upper and lower portions. The energy resolution is given by the expression $\sigma(E)/E = (0.1/\sqrt{E} + 0.02)$. The block length along the beam axis corresponds to 24 X_0 for the central piece and 16 for the other ones [2].

Forward Neutral Calorimeter (FNC): It is placed behind de FGD and is designed to detect and absorb 95% of the shower hadrons with energies from a few GeV up to 400 GeV. This is achieved with 80 cm iron and the lead in the FGD, corresponding to 4.8 and 1 interaction lengths respectively. The detector has 10x20 cells covering a total area of 150x300 cm^2. 16 iron plates 15x15x5 cm^3 separated by 2 cm thick scintillator form a cell of 114 cm length. The energy resolution is given by $\sigma(E) = 1.21\sqrt{E}$, where E is in GeV [1].

Beam and Trigger: Ions in the incident beam are tracked with the U chambers. They were identified by two detectors : T0, a scintillation counter positioned just after the last magnet of the beam line, and BT, a silicon detector, a few centimeters upstream of the target. The distance between those two detectors is around 17m. The beam traverses most of this distance in a vacuum beam pipe. Downstream of the target(s) the ions are again identified by the BV, another silicon detector, placed at few centimeters beyond the target (Figure 1). A minimum bias interaction trigger is defined by requiring the signal from the BV not to be in coincidence with an identified ^{32}S incoming ion at the BT. In addition, the lack of energy in the central blocks of FNC is used to define a central collision trigger. Those blocks measure the energy flow at zero degrees which is related to the number of nucleons of the projectile that have interacted with the target.

3. CROSS SECTIONS

The charge changing and the particle production cross sections have been measured for ^{32}S projectiles on 5 different materials.

3.1 Experimental Procedure

Cross sections for a given target nucleus are extracted from the ratios $P_i = N_i^{out}/N_i^{in}$, where N_i^{in} are the incoming ^{32}S identified by the counters T0 or BT, and N_i^{out} is the number of non-interacting beam particles and is defined below depending on which of the cross sections are measured. The index i stands for the target thickness. The numbers N_i^{in} of identified incoming ^{32}S ions correspond to the number of particles with T0 or BT pulse heigth within ± 1.5 r.m.s standard deviations about the peak position.

The criteria to select the number of non-interaction events are defined as follows:

- Charge changing cross section

  The outgoing ions are identified by the central cells of the Forward Cerenkov (FC). The number of N_i^{out} of identified outgoing ions is given by the number of incident ions (identified by T0 or BT) with pulse heights exceeding a certain threshold in the FC. The corrections for removed low pulse height ions were made using a Gaussian fit.

- Particle production cross section

  In this case the detectors used to identified interaction are the calorimeters except FNC where the beam particles always hit. Here N_i^{out} is the number of incident ions identified by the upstream devices (T0 or BT) with no hits in any of the three calorimeters: IGD, INC, FGD. The results in this case are underestimated due to the acceptance of these devices.

Of course, the ratios P_i contain a background factor due to the contributions from the Sulphur interactions outside the target. For this reason it is necessary to use targets of different thicknesses in order to extract the cross sections. The non-interaction probability for a target of thickness i is given by :

$$P_i = Ce^{-L_i/\lambda} \tag{2}$$

where C is the background contribution, L_i is the target thickness and λ is the interaction length of the target material. If two target thicknesses are used, the cross section may be expressed as:

$$\sigma = \frac{-A_t}{N_A \rho} \frac{\ln Q}{\Delta L} \tag{3}$$

where A_t is the atomic number of the target material, N_A is the Avogadro's number, ρ is the material density, $Q = P_1/P_2$ the ratio of the non-interaction probability for both targets and ΔL is the difference of the thicknesses of targets 1 and 2.

When more than two thicknesses are used the data are fitted by the equation :

$$Y = \sigma_t L_i + B \tag{4}$$

where

$$Y = -\frac{A_t}{N_a \rho} \log(P_i)$$

and

$$B = -\frac{A_t}{N_a \rho} \log C$$

This is the equation of a straight line and its slope gives the cross section.

In this way the cross sections have been calculated for Al, Fe, Cu, Ag and Pb. It is to be noted that quite thick targets have been used. (Around one interaction length). This is because there is a relation between the statistical cross section error and the target thickness used. For the two targets case the statistical error may be expressed :

$$\frac{\Delta\sigma}{\sigma} \propto \frac{\Delta P}{P} \frac{1}{\log P} \tag{5}$$

If $P \approx 1$, a thin target is used, then the relative error of the cross section is much bigger than the one of the probability. So even if high statistics are available the final error will be large. But if $P \approx 0$, the thick target case, both relative errors are equivalent.

3.2 Results

The square root of the particle production cross section are displayed in Figure 2 as a function of $A_t^{1/3}+A_p^{1/3}$, where A_t and A_p are the target and projectile atomic number respectivily.

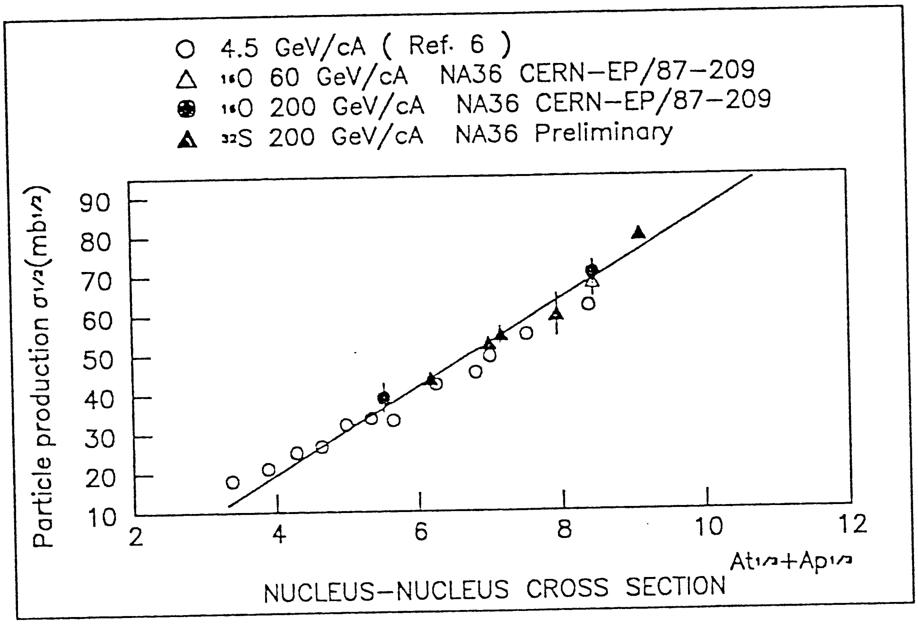

Figure 2: Particle production cross section

Data with ^{16}O as a projectile is also shown [3]. Sulfur and Oxygen data exhibit the same dependence on the atomic number and both sets of data are in good agreement. The comparison with the low energy data (P_{beam} < 4.5 GeV/c/A) [6] shows an enhancement of the cross section at high energies for heavy targets. This result, already seen for ^{16}O, seems to be reenforced with the present Sulphur data.

The particle production cross section determined here are rather close to, but exceeding the ones predicted by the Glauber Theory [5]. The data with 200 GeV/A/c projectiles have been fitted by the equation:

$$\sigma = B(A_t^{1/3} + A_p^{1/3} - C)^{1/2} \qquad (6)$$

The best fit is obtained for B = 123. and C = 2.23 (Figure 2).

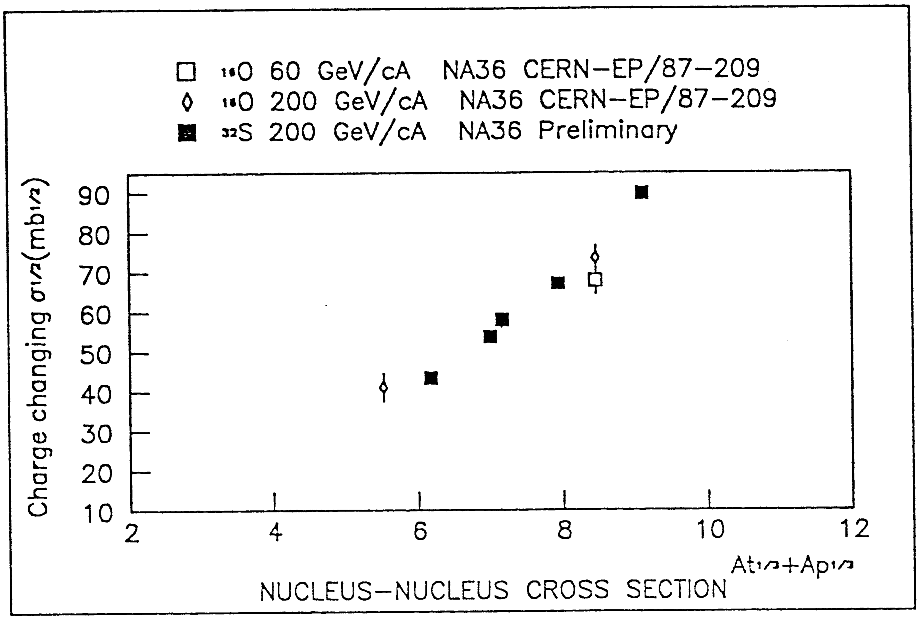

Figure 3: Charge changing cross section

The charge changing cross section is shown in Figure 3 with data for oxygen projectile. A strong enhacement is observed for the heavy target (Pb) compared with the particle production cross section. This is attributed to the electromagnetic dissociation component which for a given projectile has been found to be proportional to $Z_t^{1.8}$, where Z_t is the target charge [7].

In conclusion, preliminary cross sections for ^{32}S collisions on five different materials have been obtained at 200 GeV/c/A. Although they exhibit the well-known dependence on atomic number, the ^{32}S results seem to confirmed the trend already found with ^{16}O projectiles: the cross section at the SPS energies tend to be larger than those measured at much lower energies and the predictions from Glauber Theory.

4. CALORIMETER RESULTS

The IGD has been used to get first data of the transverse energy in the rapidity window $0.5 < Y_{cm} < 1.5$. The Figure 4 shows the results for Sulphur on Copper and Lead at 200 GeV/c/A.

The contribution from interactions not coming from the target has not been subtracted. As it can be observed a larger tranverse energy is obtained for heavier targets.

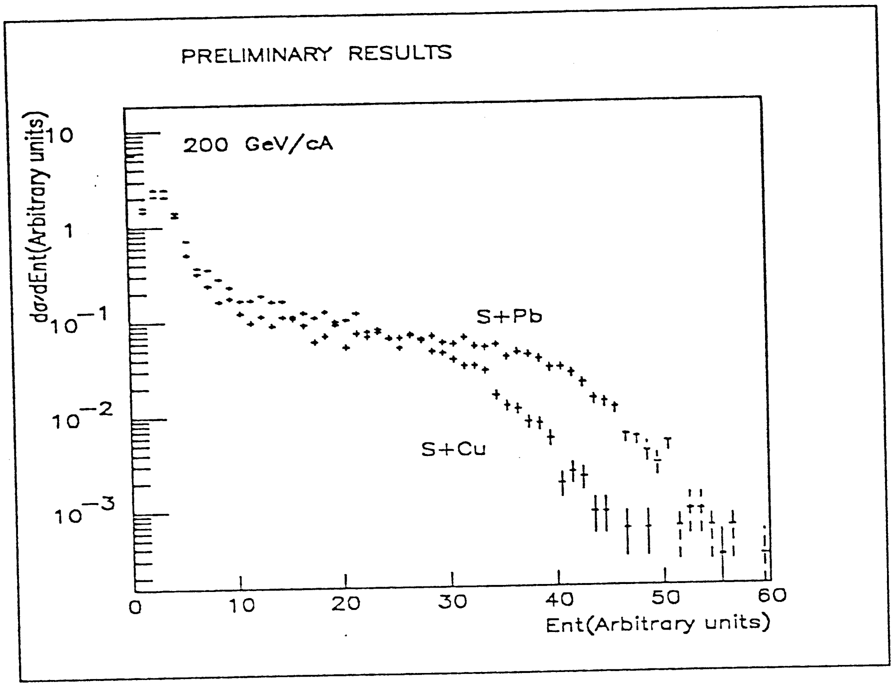

Figure 4: Transverse energy released in IGD

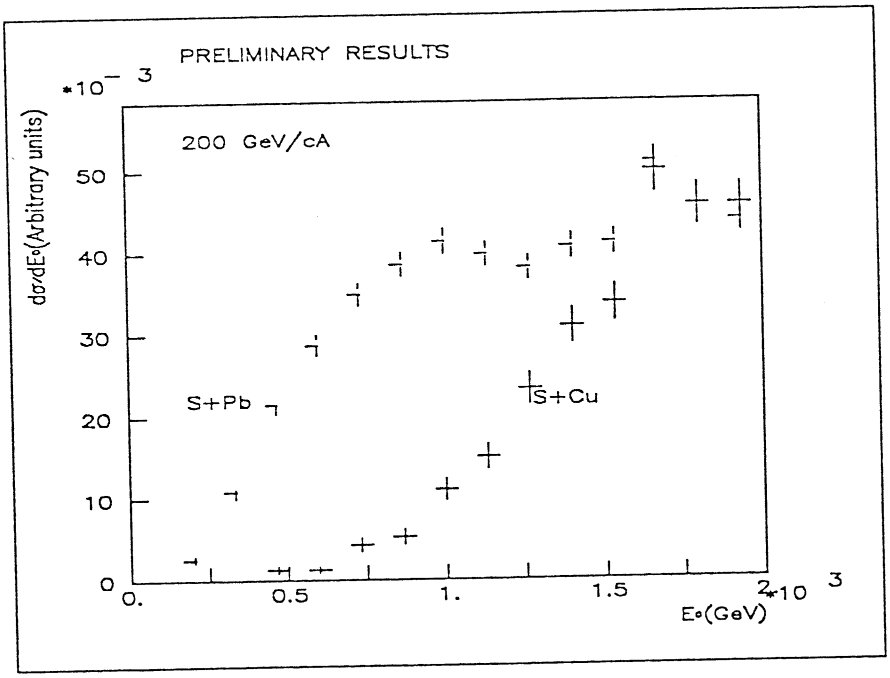

Figure 5: Energy flow at zero degrees

The energy flow at zero degrees has been measured with the central blocks of FNC for the same targets as for the transverse energy. As it can be observed in the lower part of the spectrum shown in the Figure 5, the lead has enough stopping power to dump almost completely the projectile. The minimum energy for the Copper case is around 600 GeV; this corresponds to three nucleons that do not interact.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

1. M. Aguilar – Benitez et al. *NIM A258 (1987) 26*
2. B.Powell et al. *NIM 198 (1982) 217*
3. NA36: P.D.Barnes et al. *CERN-EP/87-209*
4. C.Garabatos *NA36-TPC/87-04*
5. José Casado, Faculty of Physics, University of Santiago. Private communication
6. E.O. Asbdrahmanov et al. *Z. Phys. C5 (1980) 1*
7. D.L. Olson et al. *Phys. Rev. C24 (1981) 1529*
8. P. Koch et al. *Phys. Rep. 142 (1986) 167*