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First Results from Experiment NA49 at the CERN SPS with 158 GeV/nucleon Pb on Pb collisions

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ABSTRACT

CERN experiment NA49 had its first beam time in November/December 1994 with a ^{208}Pb beam of 158 GeV/nucleon. The experimental setup to study Pb+Pb collisions is described and first results on two particle correlations and transverse energy production are discussed.

1. Introduction

Experiments using heavy ion collisions to study the properties of highly compressed matter have gone to higher energies and heavier projectiles in recent years. Energies of 200 GeV per nucleon for oxygen and sulfur projectiles could be reached when the CERN SPS accelerator was modified to allow for heavy ion acceleration beginning in 1986.

Several experiments investigated the collisions of those projectiles in fixed target reactions. Tracking of the charged particles emerging from the collision in a magnetic field allows for example to reconstruct pseudorapidity and transverse momentum distributions of those particles and thus learn about the dynamics of the reaction. Quantities such as stopping and the energy density in the collision can then be deduced. At the same time reconstruction of longer-lived strange particles such as Kaons and Lambdas is possible from the tracks, giving important information about possible strangeness enhancement in heavy ion collisions which could be a signature for new phenomena in these reactions.

After a series of experiments at the SPS it became clear that the phase transition of nuclear matter into a so-called quark gluon plasma (QGP) could probably not be produced or at least observed with sulfur and oxygen projectiles at SPS energies. Still heavier systems or higher energies are needed to produce the neccesary energy densities or system size to generate and observe the phase transition. This has led to new projects for heavy ion collisions: acceleration of Au beams at the AGS (BNL), Pb beams at the CERN-SPS, the RHIC accelerator at the Brookhaven National Laboratory and the heavy ion program at the LHC. NA49 is one of the experiments studying collisions of Pb beam particles with a fixed target at the SPS.

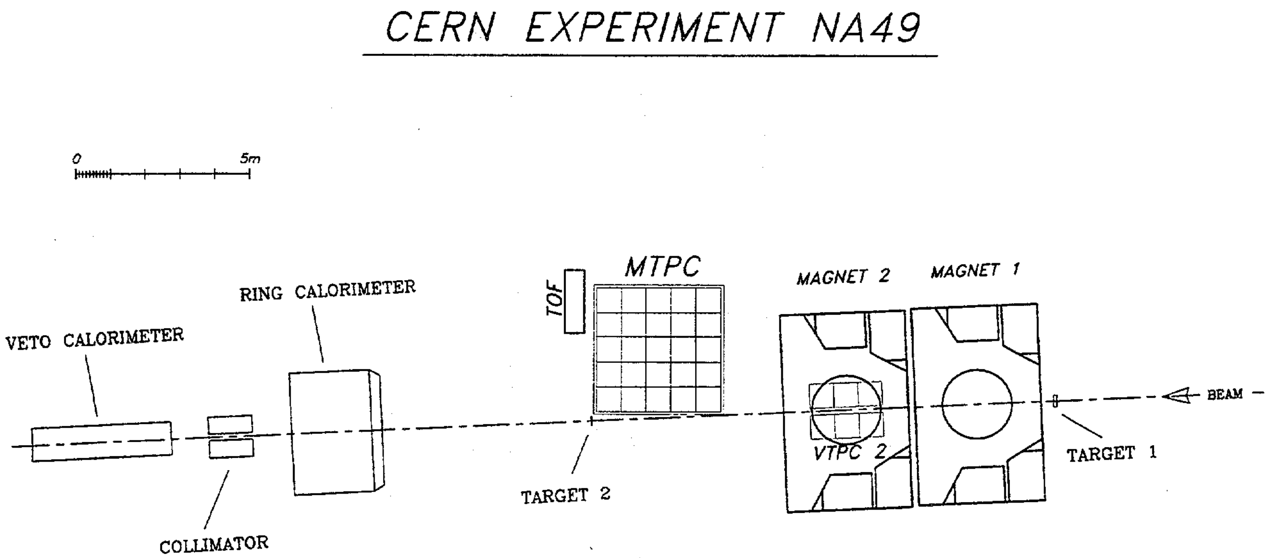

Fig. 1: Setup of experiment NA49 in 1994. The beam enters from the right. The detectors from right to left are: the vertex tpc, the main tpc and the hadronic calorimeters. Target 2 was used for the calorimeter configuration and target 1 for the normal configuration. The 1995 setup will have an additional TPC in magnet 1 and a second MTPC.

2. The experimental setup

The 1994 configuration of experiment NA49 can be seen in Fig. 1. The lead beam enters the experimental area from the right hand side coming from the SPS accelerator. It is defined by a 0.2 mm quartz Cherenkov counter in combination with a veto scintillation counter. Its position is recorded by a silicon strip detector with 200 μm resolution . The magnets 1 and 2 have a field strength of 1.5 T and 1.1 T adding up to a total bending power of 7.8 Tm.

The main detectors are two large time protection chambers, one placed in the second vertex magnet (VTPC 2) the other downstream of the the magnet on the right hand side of the beam (MTPC). These TPCs enable tracking of charged particles in three dimensions over the entire detector volume which is $200 \cdot 72 \cdot 260$ cm^3 for VTPC2 and $384 \cdot 129 \cdot 384$ cm^3 for the MTPC.

TPCs operate in a similar way to drift detectors. The charged particle traverses a large drift volume depositing charge in the chamber gas, which is then drifted under the influence of a uniform electric field towards the readout plane. There the charge is amplified in the vicinity of very thin field wires and a signal is capacitively induced on pads which are positioned close to the wire plane. The coordinates of the initial charge in three dimensions can then be deduced from the charge distribution over several pads and the measurement of the drift time. The signal amplitude on the pads is a measure of the amount of charge deposited by a charged particle. In the MTPC particle identification can be performed using the particle's momentum, mean energy deposition and the relativistic rise of the energy deposition in a gas with increasing momentum.

The pad size for the Vertex TPC is $3.13 \cdot 39$ mm^2. For the Main TPC the pad size

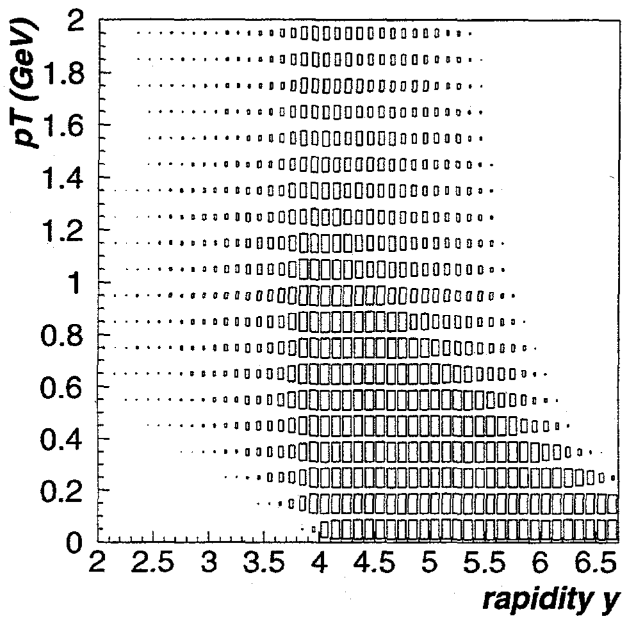

Fig. 2: Transverse momentum p_T and rapidity y distribution in the MTPC for reconstructed pions of a simulated flat phase space pion distribution.

is $3.13 \cdot 39$ mm^2 for the pads close to the beam and $4.95 \cdot 39$ mm^2 for those farther away from the beam. The total number of pads read in the 1994 run is 91008.

The "Ring" Calorimeter[1] downstream of the MTPC consists of an electromagnetic Lead/Scintillator calorimeter 16 radiation lengths (X_0) or 1 interaction length (λ_{int}) thick, followed by a hadronic Iron/Scintillator calorimeter of 6 λ_{int}. It is tube-shaped with an inner/outer radius of 0.28/1.50 meters, and it is divided into 240 cells, 24 in azimuth and 10 radially, with the radial size chosen to cover equal units in pseudorapidity.

Downstream of the Ring Calorimeter, an iron collimator defines the acceptance of the forward ("Veto") calorimeter[1]. It has a hole of $10 \cdot 10$ cm^2 at 11 meters from target 2 that allowed only particles with an emission angle of less than about 0.3^0 ($\approx 5^0$ in the c.m. frame) to reach the Veto calorimeter. This small solid angle covers the projectile spectator region.

A time of flight (TOF) detector positioned at the far right hand side behind the MTPC is used for particle identification in the momentum range where this cannot be achieved by ionisation measurement in the MTPC.

3. NA49 run in 1994

Experiment NA49 took its first data in November/December 1994. The run was subdivided into several periods in order to take data under different apparatus conditions. For the "calorimeter runs" the target was positioned behind the Main TPC (Target 2 in Fig. 1) to have a hadron acceptance of the calorimeter of $2.1 < \eta < 3.4$. For the TPC runs the target was positioned in front of the first vertex magnet (Tar-

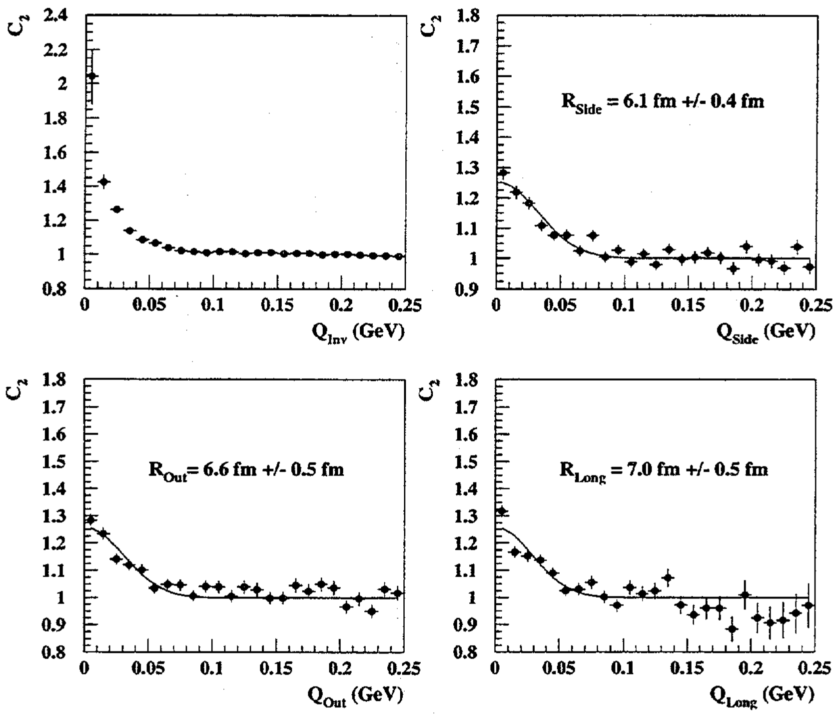

Fig. 3: The correlation function in momentum difference Q_{Inv} and its projections on the components Q_{Long}, Q_{Out} and Q_{Side} with the correlation length values obtained from a fit of function (1) to the data. (Preliminary).

get 1). Several magnet settings were used in this configuration. In the normal mode the magnets were set to B(VT1) = 1.5 T and B(VT2) = 1.1 T to accept positive hadrons into the MTPC and with opposite polarity for measuring negative hadrons. In the "HBT" mode the fields were set to the lower values of B(VT1) = 0.3 T and B(VT2) = 1.5 T in order to obtain better acceptance for low momentum pions in the TPCs.

4. TPC analysis

The coordinates as obtained from the measured charge signals on the pad plane and the drift time can be used to reconstruct the tracks of charged particles traversing the TPCs. Adjacent charge signals first are combined in a plane perpendicular to the beam to form clusters and then tracks are built from these clusters.

The measurement of the bending of a track in the field of the two vertex magnets can be used to calculate the particle momentum. Fig. 2 shows a p_T/y distribution obtained from simulated pions traversing the Main TPC. It shows the very wide p_T and y acceptance of this detector.

5. Two particle correlations

Using tracks reconstructed in the TPC and their measured momenta, a two particle Bose-Einstein correlation analysis can be performed on the data taken with the

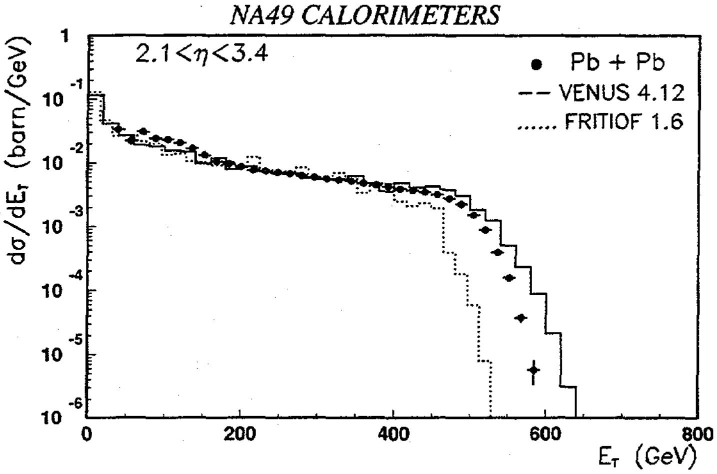

Fig. 4: Transverse energy distribution produced in Pb+Pb collisions as measured by the Ring calorimeter[3]. The experimental results are here compared with two nuclear collision models. (Preliminary).

HBT configuration of the magnets. This type of analysis can provide information about the space-time geometry of the particle emitting source. In the case of an expanding source, as expected in heavy ion reactions, it can be used to study the source dynamics, based upon some model dependent assumptions.

In this analysis[2] a parametrisation of the correlation length is used which was proposed by S. Pratt[7]. The correlation function is defined as:

$$C_2 = 1 + \lambda e^{-(Q_{Side}^2 R_{Side}^2 + Q_{Out}^2 R_{Out}^2 + Q_{Long}^2 R_{Long}^2)/2} \tag{1}$$

where Q_{Long} is the 4-momentum difference of the two particles in the beam direction, Q_{Out} in particle direction and Q_{Side} perpendicular to the other two. The measured correlation function is corrected for losses due to limited two track resolution of the detector, the missing particle identification, the Coulomb repulsion (Gamov factor) and limited momentum resolution. The correlation functions[2] for 550 central NA49 events are shown in Fig. 3 with the resulting values for the correlation lengths.

The values for R_{Long},R_{Side} and R_{Out} are about 40% higher than those obtained from an analysis on S+Au data, in agreement with the expectation of a bigger particle emitting source. The difference $R_{Out} - R_{Side}$ is consistent with zero, hinting at a very short lifetime of the emitting source. Further analysis of this data, in particlar the rapidity and transverse momentum dependance of the correlation length, is in progress. This will give more insight into the reaction dynamics, as explained for example within a model by Sinyukov[8].

6. Calorimeter analysis

The calorimeters (Veto and Ring) used in NA49 had previously been used in other experiments (NA5, NA35). Details about the hardware and their calibration for the

1994 run can be found elsewhere[4,5]. The veto calorimeter is used in all NA49 runs to define the centrality of the reaction by measuring the deposited energy of projectile-like particles. The ring calorimeter is used to measure the transverse energy produced in a reaction.

The transverse energy differential cross section measured[3] in NA49 is given in Fig. 4. In the same figure the predictions of FRITIOF and VENUS are shown in the same acceptance. The data favors the VENUS model predictions. The mean E_T for near head-on collisions can be calculated according to ref. 5 and is found to be $E_T^{b\approx 0} = 520\,\text{GeV}$. The number of participants in central Pb+Pb collisions is 390±5 and therefore the mean E_T per participant is 1.33 GeV which is very similar to 1.31 GeV, the corresponding number for central S+Au collisions at the slightly higher projectile energy of 200 GeV/nucleon. We observe that the average produced E_T per participant is the same in all systems. Since the mean number of collisions each participant undergoes is higher by 45(85)% in Pb+Pb as compared to S+Au (S+S)[3], it appears that the production of E_T is roughly independent of the number of collisions a participant nucleon undergoes. This is in agreement with previous NA35 results where a similar observation was made concerning negative hadron production.

7. Conclusions

Experiment NA49 had a successful first run in 1994. All detector components including the newly built TPCs worked well. A first look at the data shows that physics analysis is possible in the high multiplicity environment of Pb-Pb collisions. Calorimetry and tracking in the TPC give first insights into observables such as transverse energy and source size.

8. Acknowledgements

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9. References

[1] C. de Marzo et al.; Nucl. Instr. and Meth. 217 (1983) 405
[2] T. Alber et al.; Proceedings of the Quark Matter 1995 Conference, to be published in Nucl.Phys. B
[3] S. Margetis et al.; Proceedings of the Quark Matter 1995 Conference, to be published in Nucl.Phys. B
[4] I. Huang et al.; 'Reduction of Calorimeter data in NA49', LBL-36877, LBL, Berkeley, 1995
[5] J. Bächler et al.; Z. Phys. C52(1991)239
[6] J.D. Bjorken; Phys. Rev. D27(1983)140
[7] S. Pratt; Phys. Rev. D33(1986)1314
[8] Yu.M. Sinyukov; Nucl.Phys. A498 (1989) 151c