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FIRST EXPERIMENTS WITH THE PLASTIC BALL

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After two and a half years of development and construction, an electronic 4π detector has been used for the first time in studying relativistic nuclear collisions. This detector complements the visual 4π detectors like emulsions, AgCl detectors, and the streamer chamber, which have been in use for many years. Only the streamer chamber has the same important feature as the Plastic Ball in being triggerable for specific event types. In a series of experiments with beams of ^{20}Ne, ^{40}Ar, and ^{40}Ca up to energies of 1.05 GeV/u, approximately three million events were measured with various trigger conditions. In contrast to the visual detectors, these events are already totally digitized and ready for immediate analysis. All multiparticle correlations of charged particles are measured in each event and do not have to be determined as an average quantity from two particle inclusive data. Besides the particle identification of the hydrogen and helium isotopes, the Plastic Ball identifies the positive pions. This makes it interesting for the study of pion production, which sets in at around 100 MeV/u incident energy, and has promise to shed some light onto the equation of state of nuclear matter. Besides the analysis of the data in the standard way of selections and of single particle inclusive data, a global analysis is in progress that should allow us to determine the reaction plane, and the event shape in phase space.

The general layout of the experiment is shown in fig. 1. The Plastic Wall, placed 6 m downstream from the target, covers the angular range from 0 to 10 degrees and measures time of flight, energy loss, and position of the reaction products. In addition, the inner counters serve together with the beam counter as a trigger.

The Plastic Ball covers the region between 10 and 160 degrees, 96% of the total solid angle. It consists of 815 detectors, where each module is a ΔE-E telescope capable of identifying the hydrogen and helium isotopes and positive pions. The ΔE measurement is performed with a 4-mm thick CaF_2 crystal and the E counter is a 36-cm long plastic scintillator. Both signals are read out by a single photomultiplier tube. Due to the different decay times of the two scintillators, ΔE and E information can be separated by gating two different ADCs at different times. The positive pions are additionally identified by measuring the delayed $\pi^+ \rightarrow \mu^+ \rightarrow e^+$ decay. A schematic drawing of the electronics and of the timing of the different gates is shown in fig. 2.

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A cluster of 13 prototype modules (a central counter and all 12 neighbors) was tested at the LAMPF low-energy pion line with monoenergetic pions and protons. The energy response curve for protons and pions and pion efficiencies could be measured in that experiment. In addition, the effect of the scattering out of particles into neighboring modules could be studied. By taking into account information from adjacent modules, this problem can be solved nearly completely[1].

Before assembling the Plastic Ball, all modules were irradiated at the Berkeley 184" cyclotron with 400 MeV and 800 MeV α beams in order to determine the high voltage for each individual photomultiplier and to measure the characteristic response of each module. A complete set of energy calibration curves for protons and all composite particles could be obtained by fragmenting the 800 MeV α beam in a thick target and by determining the energy of the fragments by a time of flight measurement in front of the module.

Figure 3 shows the acceptance of the Plastic Ball experiment in the plane of rapidity versus transverse momentum. In the different areas charged particles can be identified with different quality.

For the different beam-target combinations data were taken with a reaction (minimum bias) trigger and with a central trigger. The reaction trigger requests that a beam particle was identified in the start detector and that this particle lost at least one charge in a reaction with a target nucleus. The central trigger excludes reactions where particles with beam velocity (or higher velocity) are emitted within a forward cone of two degrees.

The analysis of the first experiments performed in June 1981 is in progress. Calibration factors for all detectors could be extracted from the data and test measurements so that all ΔE-E diagrams coincide. The quality of the particle separation is shown in fig. 4 for the hydrogen and helium isotopes.

Figure 5 shows the multiplicity distribution for the reaction 800 MeV/u Ne on Pb for the reaction trigger and for the central trigger (85% reduction of the trigger rate), where events with low multiplicity are strongly reduced. It is obvious that a large group of events with high multiplicity is rejected by the central trigger because in those reactions fast particles are emitted in the forward direction.

Due to the ability of identifying the particles, the Plastic Ball is well suited for investigating the emission of protons and light clusters in high energy heavy ion reactions. Such studies should yield information about the reaction mechanism and answer the question whether composite particles come from a thermalized source, or whether a coalescence process that only requires closeness in phase space of the constituents, is reponsible for cluster production. Especially the ratio of the production cross sections of deuterons to protons has been related to the entropy in the reaction zone in ref. 2. This proposition to determine the entropy from directly accessible experimental results has stimulated a vivid discussion[3-5].

Figure 6 shows that for the reaction 800 MeV/u Ne on Pb the number of protons bound in clusters increases with the multiplicity of the reaction products and equals the number of free protons in high multiplicity events. Consequently as shown in fig. 7 the deuteron to proton ratio increases with multiplicity indicating that the entropy slightly decreases.

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REFERENCES

1) H.H. Gutbrod, M.R. Maier, H.G. Ritter, A.I. Warwick, F. Weik, H. Wieman, and K.L. Wolf, IEEE Trans. Nucl. Sci. Vol. NS-28 No. 1, 451 (1981)
2) P.J. Siemens and I. Kapusta, Phys. Rev. Lett. 43, 1486 (1979)
3) H. Stöcker, LBL Preprint 12302
4) J. Knoll, L. Münchow, G. Röpke, and H. Schulz, GSI Preprint 82-2
5) G Bertsch and J. Cugnon, Phys. Rev. C24, 2514 (1981)

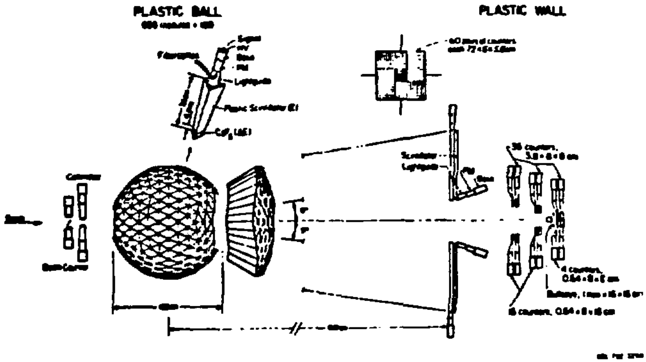

Fig. 1. General layout of the experiment

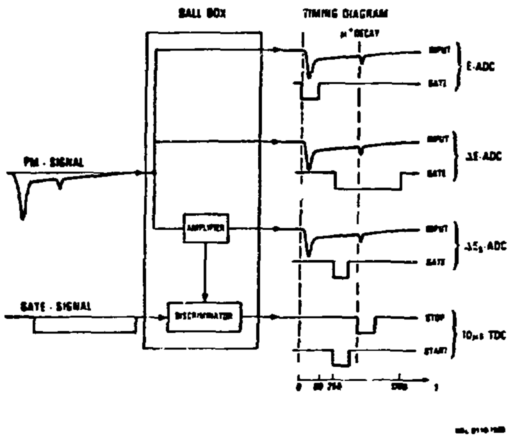

Fig. 2. Electronics scheme for one module

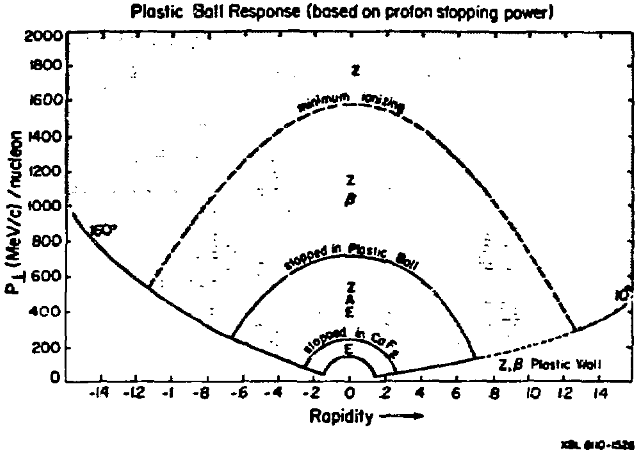

Fig. 3. Plastic Ball acceptance in the plane rapidity versus transverse momentum

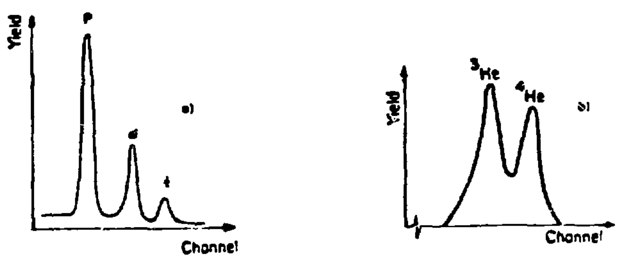

Fig. 4. Quality of the particle separation (655 modules added) a) hydrogen isotopes, b) helium isotopes

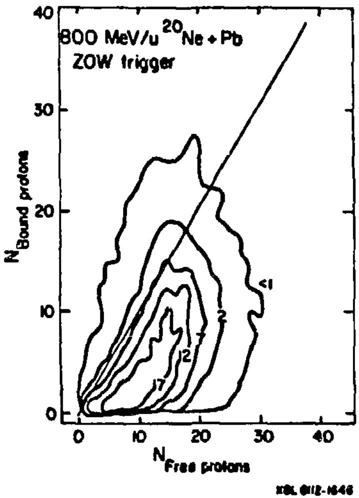

Fig. 6. Event by event contour plot of the number of free protons versus the number of protons bound in clusters

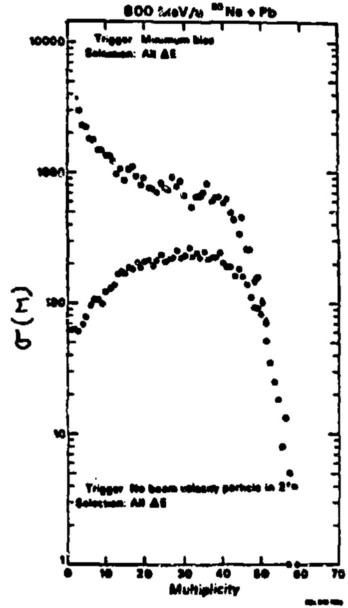

Fig. 5. Multiplicity distributions accumulated with a reaction trigger and a central trigger configuration

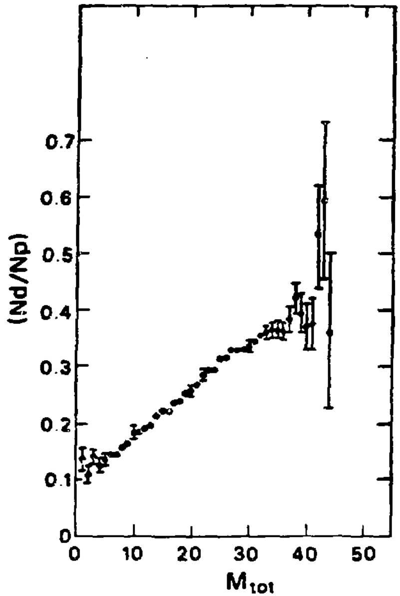

Fig. 7. Deuteron to proton ratio as a function of the total multiplicity for the reaction 800 MeV/u Ne on Pb (central trigger)