THE TP-MUSIC UPGRADE AT THE ALADIN SPECTROMETER

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Abstract

An upgrade of the TP-MUSIC detector at the ALADiN forward spectrometer facility has been performed. In particular, the construction of a new set of proportional counters has been undertaken together with the design of a new read-out system based on high-resolution signal recorders (sampling ADC's) and high-performance digital signal processor (DSP's). The final setup was tested with ^{12}C, ^{65}Zn and ^{84}Kr beams at 600 AMeV.

1. Introduction

A systematic study of isospin effect in the breakup of projectile spectators at relativistic energies with the ALADiN spectrometer facility at the GSI laboratory (Darmstadt) has been proposed [1].

Previous work has resulted in many indications that equilibrium is reached at breakup in these reactions [2]. A signature of the liquid-gas phase transition was obtained in the form of the caloric curve of nuclei [3] which, in particular, suggests that the coexistence region is explored. By using secondary beams the range of isotopic composition of the excited spectator systems can be considerably extended beyond that accessible in reactions with stable beams and targets. This and the clean separation of the spectator sources in rapidity make this type of reaction unique for studying the isospin dependence of nuclear multifragmentation, in particular the study of the isotopic composition of the fragments produced at breakup.

Four different projectiles, with an incident energy of 600AMeV, will be investigated allowing a study of various combinations of masses and N/Z ratios in the entrance channel: ^{124}Sn, ^{197}Au, ^{124}La and ^{106}Sn. The latter beams will be delivered by the FRagment Separator (FRS) of the GSI as products of the fragmentation of ^{142}Nd at 1.1AGeV on a ^{9}Be target. The

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atomic numbers of the incoming projectiles will be measured with diagnostic detectors placed in front of the target. The necessity of low beam intensities for the best operational condition of the ALADiN setup (≈ 1000 particle/sec) and the possibility of using a thick target in order to achieve high interaction rates are indeed conditions compatible with radioactive ion beam experiments.

Moreover, the inverse kinematics offers the possibility of a threshold-free detection of all heavy fragments and residues and thus gives a unique access to the breakup dynamics.

2. The ALADiN setup

The ALADiN (A Large Acceptance Dipole magNet) spectrometer was designed to study projectile fragments produced in heavy ion collisions at relativistic energies. In a series of experiments, the properties of multi-fragment decay of hot nuclei over a wide range of projectile and target combinations and over the relativistic regime of bombarding energies have been explored.

The beam (entering from the left in figure 1) is monitored by diagnostic devices before reaching the target. Therefore, for each beam particle, its arrival time and its position in the plane perpendicular to the beam direction are measured. Projectile fragments entering into the acceptance of the magnet are tracked and identified in the TP-MUSIC III (Time Projecting-Multiple Sampling Ionisation Chamber) detector and in the ToF (Time of Flight) wall.

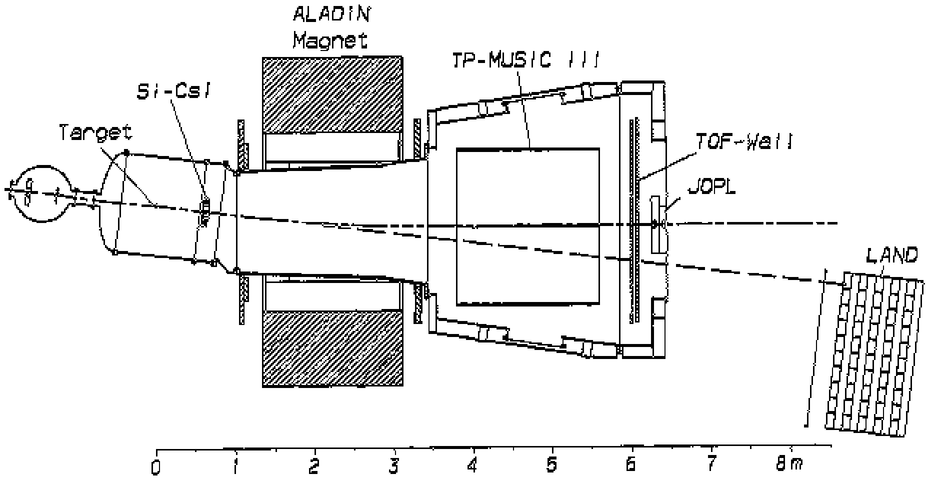

Figure 1. Cross sectional view of the ALADIN setup.

Charges Z≥2 are resolved by the TP-MUSIC III. The track information for all fragments with Z≥2 allows, together with the Z information, a determination of the momentum from the deflection in the known magnetic field.

From the velocities of the particles measured in the TOF-Wall and the momenta measured in the TP-MUSIC a mass resolution A/ΔA = 20 is expected. In addition the TOF-Wall yields additional charge information for the lightest fragments.

3. The TP-MUSIC

The TP-MUSIC detector is a tracking ionisation chamber [4]. The field cage is filled with gas (90% Argon, 10% Methane), a cathode plane in the middle separates the volume of the detector in two distinct drift regions with anode strips on either side (see figure 2).

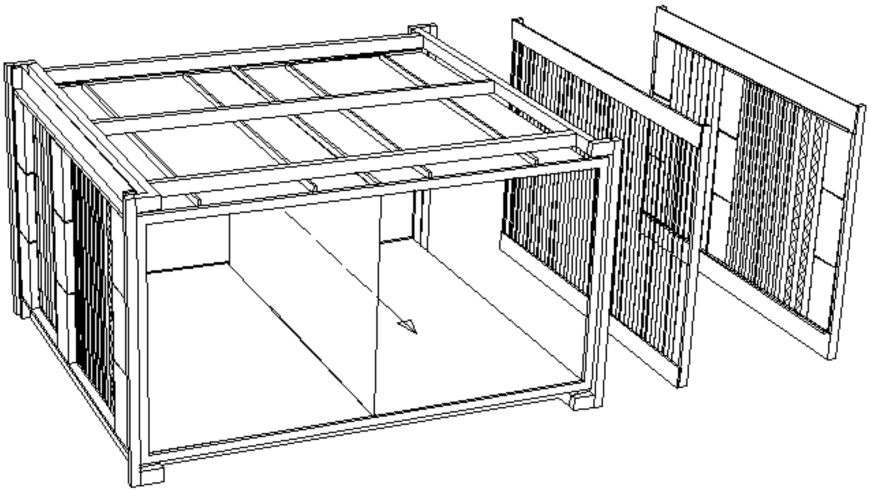

Figure 2.: Schematic layout of the TP-MUSIC detector.

In the electric field, the electrons drift towards the anode strips, whereas the positive charges drift to the cathode. It is possible to reconstruct the position in the bending plane from the drift time of the electrons.

The detector can detect nuclei from He up to Au. Because the energy loss of a charged particle is proportional to the square of its charge, the detector should, with the associated readout electronics, be able to collect signals extending over a wide dynamic range. In order to achieve for light and also heavy fragments the best possible resolution the TP-MUSIC III detector has two different types of readout:

- the smaller signals from light nuclei are measured using proportional counters. This type of detector gives a quite noise-free amplification of the weak signals from light nuclei and moreover, using charge-division and pad techniques, the coordinate in the non bending plane can be determined.

- For heavy nuclei the charge resolution of the proportional counters deteriorates due to quenching effects, therefore these large signals are recorded with the anode strips.

The readout electronics of the anode strips is placed on the back of the strips and these are separated just by few centimeters from the proportional counters, which are operated at a gain of 1000 to 1500. Therefore a very good shielding between the two types of detectors is required (see fig. 3).

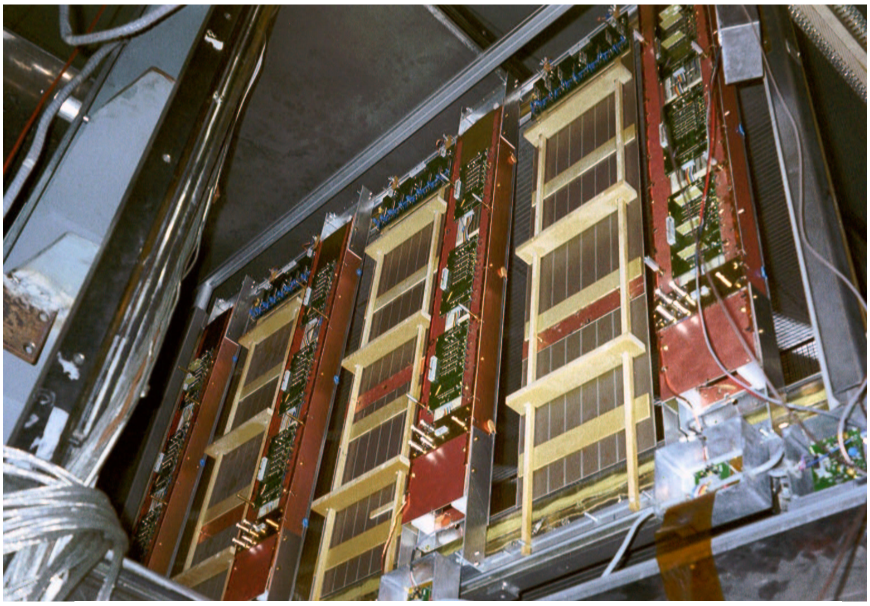

Figure 3.: Side view of the upgraded TP-MUSIC detector.

4. The Upgrade

In order to improve the performances of the TP-MUSIC, an upgrade has been recently undertaken. In particular it has involved the construction of a new set of proportional counters and the associated readout electronics. On each side of the chamber three ionisation chamber sections, each with 8 anodes and four proportional counters are used (see fig. 3)

4.1 The Proportional Counters

The detectors, using charge-division and pads technique, allow the reconstruction of the position of the tracks of nuclei. The dimension of the active area is 96×8 cm^2, and it is subdivided in three different sections: the upper and lower sections are 36 cm whereas the middle one is only 24 cm because it must support a higher event rate. It has two cathode layers, one made of wires (74 μm of diameter) each separated from the other by 2 mm and the other made of pads (30 in the outer sections and 20 in the central one) and used for position reconstruction. The width of all pads is 12 mm.

The anode plane consists of wires (60 in the central section, 90 in the outer ones) with a diameter of 20 μm (4 mm spacing) connected by 30Ω resistors and having 5 mm spacing from the cathode layers.

A serious problem in the operation of all TPC-like detectors is the build up of a space charge due to the drift of positive ions produced in the gas amplification process back into the active gas volume. The proportional counters were therefore also equipped with a gating grid whose potentials prevent the drift of electrons or ions in or out of the proportional volume if the gate is closed. The gate is opened only after an accepted trigger and closed again after the maximal drift time of the electrons has elapsed. This not only prevents the detection of uninteresting tracks and reduces detector loading but also suppresses the drift of positive ions back into the field cage.

To shield the anode plane from the gating grid noise a shielding grid is used.

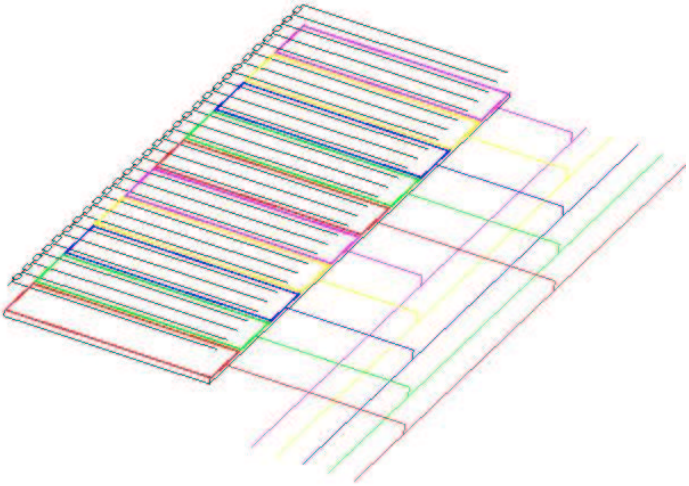

Figure 4.: Cross Sectional view of one proportional counter.

To extract the signal from each sector of the detector seven charge-sensing preamplifiers have been used: two for the anode signals and five for the pad ones. The choice to use only five preamplifiers for the readout of the pads, instead of having one preamplifier for each pad, was taken to reduce the number of the preamplifiers needed without affecting the position measurement.

For this purpose the cathode pads are connected modulo-five to the five preamplifiers (fig. 4): the resulting ambiguity from which group of pad the signal originated (a position uncertainty of 6 cm!) is resolved by using the position derived from the anode wires by the charge division technique.

The combined use of charge division and pad readout in this configuration therefore, allows a better position determination without increasing too much the number of needed electronic channels.

The setup has been tested with beam of ^{12}C, ^{65}Zn and ^{84}Kr beams at 600 AMeV. In figure 5 the pad response function, correlating the signal from the pads and the position reconstructed from the anode, is shown. The appearance of several maxima is carried by the fact that several pads are read out with the same electronic channel (figure 4). In particular, the signal seen from a certain pad preamplifier as a function of the position along the detector exhibits maxima corresponding to the pad's group it is connected with and minima corresponding to the farthest pad group.

A high resolution and a very good position linearity has been achieved both with the anode readout as well as from the pad measurement.

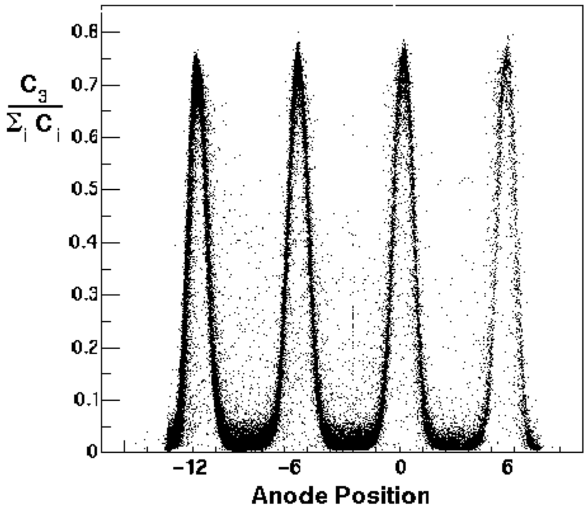

Figure 5.: Pad Response Function for ^{12}C particles swept across the detector.

4.2 Readout Electronics

In order to improve the performance of the device in working out the already mentioned huge dynamic range, also the electronic readout has been modified. In particular, as stated, the signal coming from both the anode plane, the pad and the anode strips are readout by charge sensitive preamplifiers whose gains have been chosen to be 33, 10 and 1 pF, respectively, in order to match the corresponding charge range.

14-bit Flash ADC's digitise the signals coming directly from the preamplifiers. The output, generated at a rate of up to 40 MHz, is stored and processed by a system containing FPGA (Field Programmable Gate

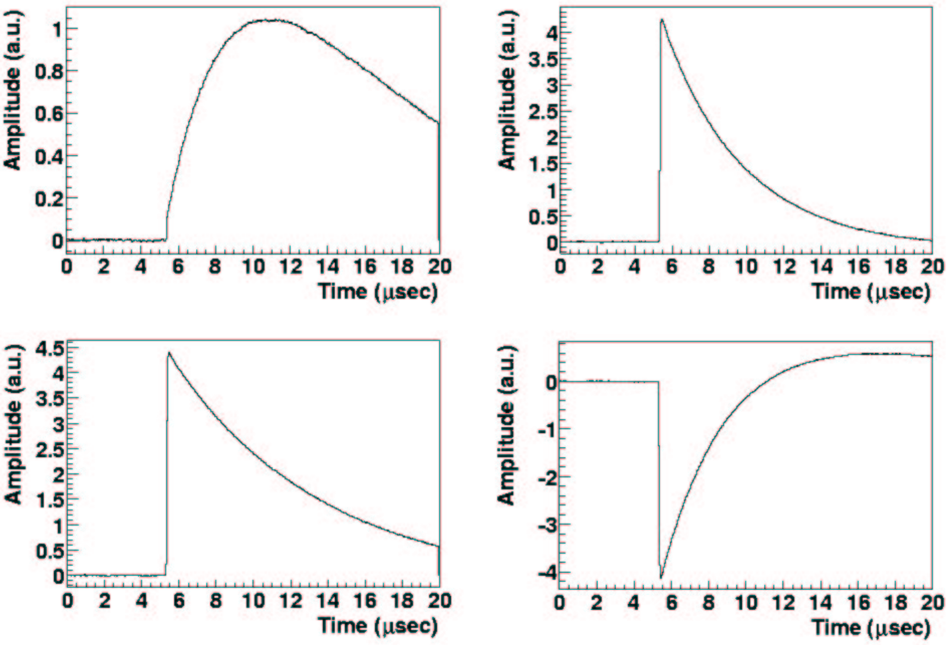

Figure 6. Pulse shape analysis technique. In the upper left and right panels the signals from the left and right anode, respectively, are plotted. In the lower left and right plots the sum and the difference of the two signals are shown.

Array) and DSP (Digital Signal Processor) chips which will perform the necessary signal shaping as well as the determination of the collected charge and arrival time. On the same board fast digital and high-resolution analog circuits are operating without deterioration of the resolution. The upgraded detector, with its dedicated electronics system, is providing at the same time high resolution, a large dynamic range and multi-hit capability.

The capability of the pulse shape analysis technique can be seen in fig. 6 where from the two different signals coming from the two anodes of a proportional counter it is possible to avoid exchange-current position dependent shapes in the signals by analysing their sum and their difference. In the sum these contributions cancel out whereas in the latter it is present but independent on the position.

It should be pointed out that corrections of such effects due to an exchange current mechanism as well as other ones, could have been impossible with standard analog shaping devices.

A good charge resolution (up to Z=30 with a ^{65}Zn beam) with the new proportional counters, as shown in fig. 7 has been obtained. This result indicates that there may be as well good charge resolution for Z>30. On the other side it assures that a large sweep of the Z-range, where the Z is well determined both with the proportional counter and the anode readout is achieved.

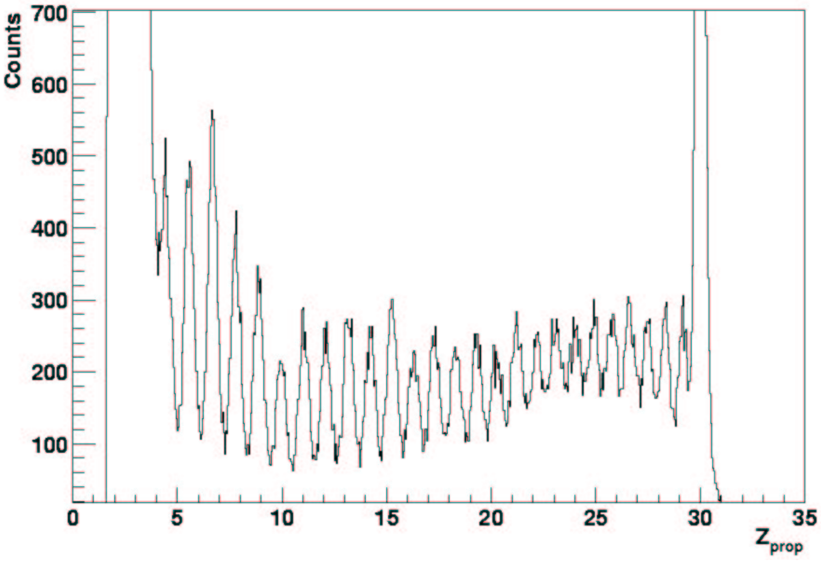

Figure 7.: Charge spectrum in the proportional counters.

4. Conclusions

Performance tests of the upgraded TP-MUSIC III detector have been performed. The construction of new proportional counters and the characterization of the new read-out system based on high-resolution sampling ADC's and high-performance digital signal processor have been undertaken.

The final setup was tested with beams of ^{12}C, ^{65}Zn and ^{84}Kr at 600 AMeV: the obtained results for charge and position resolution indicate that the required system performances will be achieved.

The upgraded TP-MUSIC III detector with this dedicated electronics system, providing high dynamic range and multi-hit capability, will represent a versatile instrument attractive also for other experiments.

4. References

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