FAUST upgrade for experimental proton-proton correlation functions

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The proton-proton correlation function has been predicted to be sensitive to the asymmetry energy of nuclear matter [1]. We plan to measure proton-proton correlation functions for reactions of 45 MeV/A ^{40}Ca, ^{40}Ar+^{58}Ni, ^{58}Fe at the Texas A&M Cyclotron Institute. The data will then be compared to Constrained Molecular Dynamics (CoMD) [2] results, for the purpose of investigating the impact of the asymmetry energy term of the equation-of-state on the shape and size of the correlation function. The FAUST (Forward Array Using Silicon Technology) array [3] of sixty-eight 2x2cm 300 μm thick Si backed by CsI(Tl)-photodiode detectors, arranged to geometrically accept the particles originating from the quasiprojectile (QP), or excited source resulting from the nuclear reaction, will be used for this experiment. The upgrade to enhance data collection for this purpose is described here.

A precise knowledge of the point of detection of the particles is essential when measuring a correlation function for a reaction, so improved angular resolution is of paramount importance [4]. In order to increase the angular resolution of charged-particle detection, the FAUST array is being upgraded using Dual-Axis Dual-Lateral (DADL) Si detectors [5]. The DADLs have uniform resistance across the front and back of the detectors and employ charge-splitting to determine the position of the detected light charged particles to within 200 μm.

Fig. 1 schematically shows the equipotential lines on the surface of a DADL detector. The uniform potential created by the reverse bias allows the holes or electrons to be collected on the opposite sides of the detector. Due to the resistive surface across each face of the detector, the holes on the back of the detector split proportionally to the two back signals, while the electrons are charge split proportionally

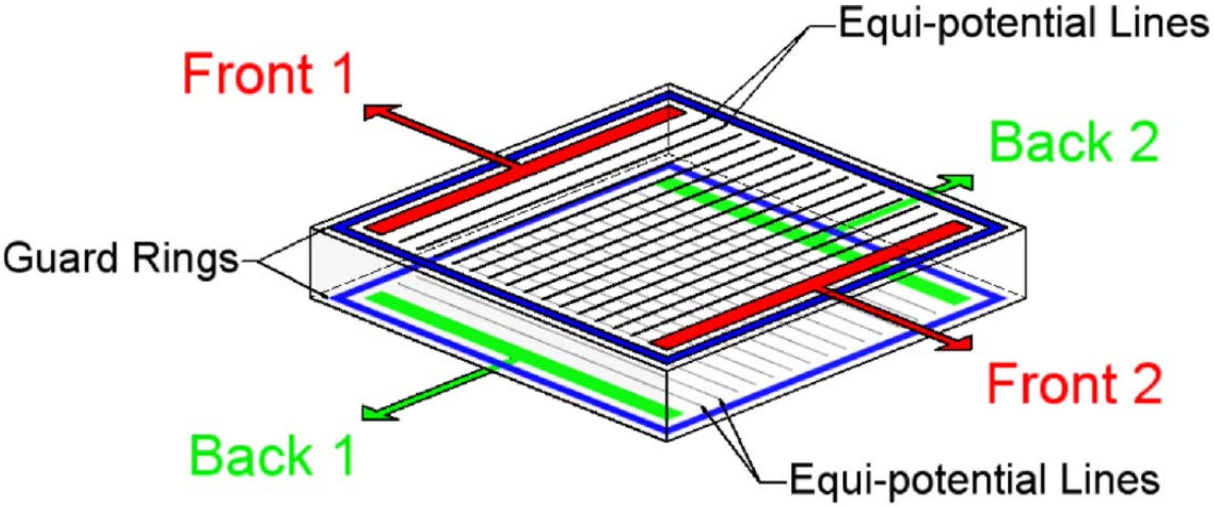

FIG. 1. Schematic of DADL, showing the equipotential lines on the uniformly resistive surface, which allows position to be determined by charge splitting [5].

to the two front signals. These four signals allow the relative x and y position of the detected fragment to be determined. Guard rings ensure a uniform potential across the entire surface of the detector [5].

In the first stage of the upgrade, the original silicon detectors of two of the five rings of FAUST have been replaced with position-sensitive DADLs. Particle identification and position information have been obtained using these 24 Si-CsI(Tl) telescopes, with newly developed software and electronics. Reactions of 15 MeV/A ^{4}He+^{64}Ni, ^{197}Au and ^{40}Ar+^{64}Ni, ^{197}Au were run, to see the results of elastically scattered α particles and light charged particle production, respectively, in the detectors. Protons and light charged particles produced in the reactions were measured in FAUST, with the help of the high-gain CSAs (charge sensitive amplifier), developed by RIS Corporation. The charge-splitting across the surface of the detector can result in a very small signal, which demands high-gain preamps. The total energy deposited in the Si wafer is determined by adding the two sides (Front 1 + Front 2 or Back 1 + Back 2). The separation of the LCPs is shown in a E-dE plot, derived from Si and CsI(Tl) signals, Fig. 2.

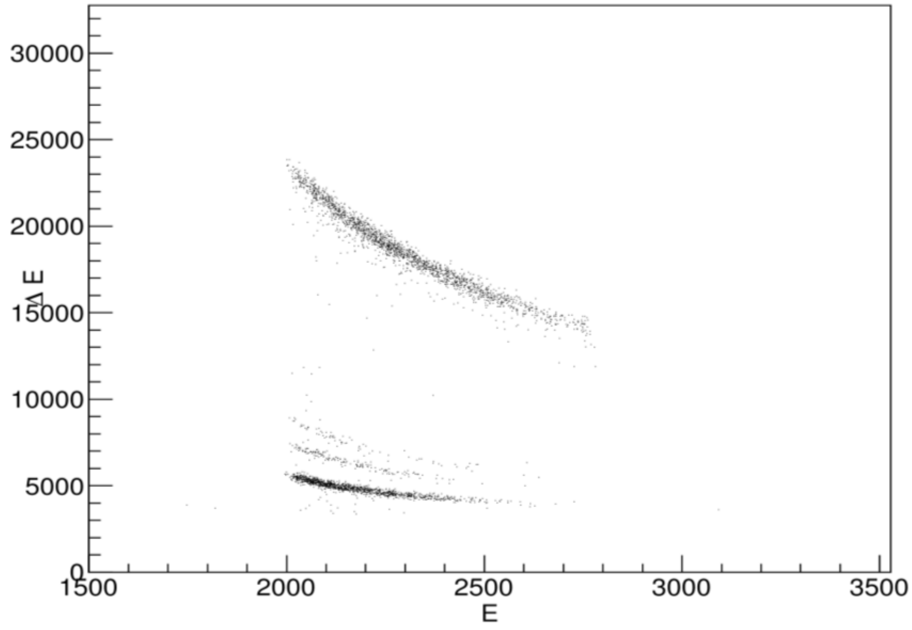

FIG. 2. Rough E-dE plot, shown here in ADC channel numbers from one of the detectors in Ring C for the reaction of 15 MeV/A α+ ^{197}Au, demonstrating the excellent p-d-t delineation using the new silicons and electronics from the FAUST upgrade.

The additional signals on each Si-CsI(Tl) telescope will result in an 150% increase in the number of channels processed, so Application-Specific Integrated Circuit (ASIC) Heavy Ion Nuclear Physics (HINP) chip electronics are used to deal with the increased number of signals. The necessary software and chipboards to accommodate this increase in signals have also been tested on-line during the recent test experiment. The biasing scheme has been scaled-up to accommodate 35% of the total array, and the rest of the cabling and electronics will be designed in an analogous manner. The resultant position spectra for the DADLs installed can be seen in Fig. 3.

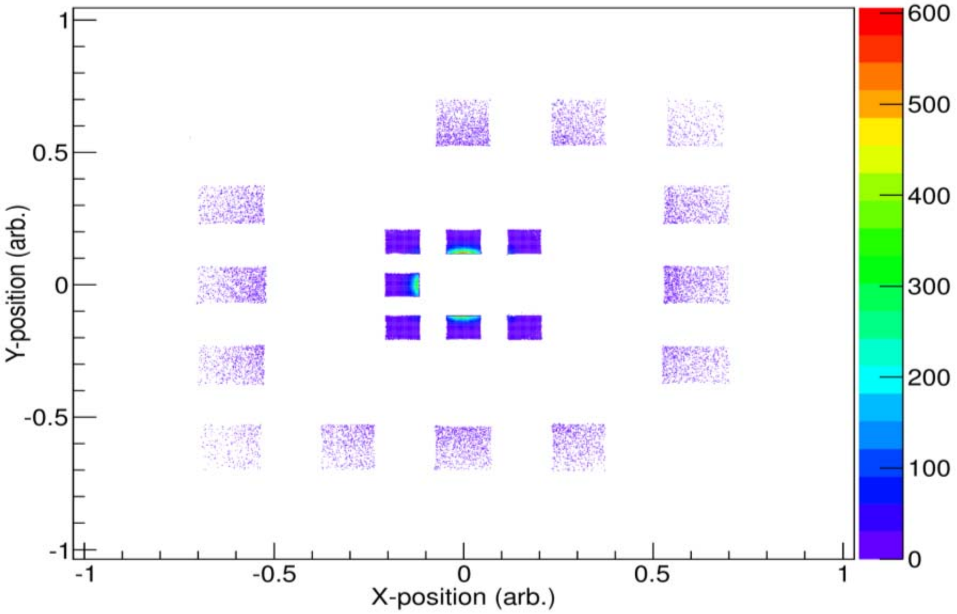

FIG. 3. Position spectra of detectors in rings A and C. The beam profile can be seen as the "hot spots" in Ring A (Innermost squares).

In addition to high positional accuracy of a detected particle, the relative alignment from one detector to another must be known. In order to calibrate relative detector position, a mask of 0.040" tungsten was designed and produced (design shown in Fig. 4). Slits of 0.010" were angled through the

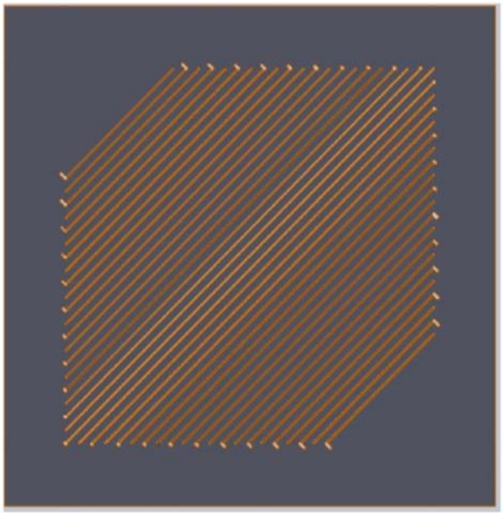

FIG. 4. SolidWorks drawing of mask, designed to position-calibrate all of the detectors in the FAUST array.

mask, in order to allow α particles from a well-collimated source or elastically scattered off of a gold target to reach each ring of FAUST. To prevent the large beam spot from scattering elastic alpha particles effectively around the slits in the mask, an aluminum collimator was used to reduce the beam spot to 1 mm. The square cut through the center (see Fig. 5) allows the beam to pass through, reducing beam particle reactions with the tungsten mask. By gating on the collimated alpha particles elastically scattered from a gold target, the resultant pattern is shown in Fig. 6. The stripes from the mask can also be seen on the face of the detectors using a 228Th source, as shown in Fig. 7.

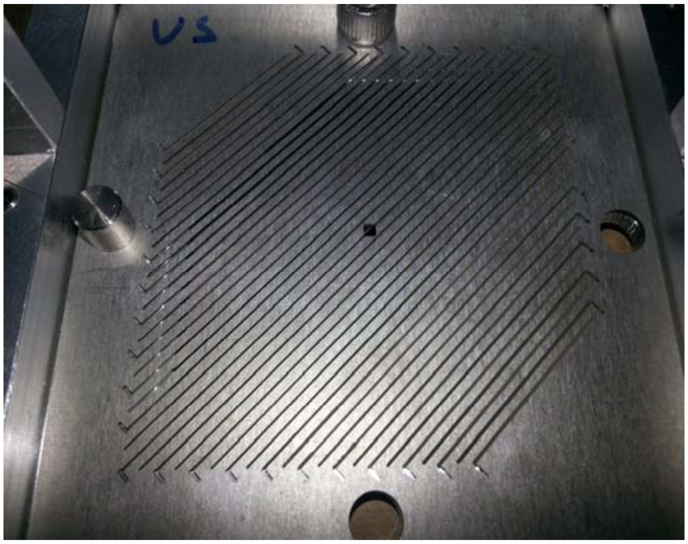

FIG. 5. Mask as machined by sinker and wire EDM at Reliable EDM. Square hole in the center allows the beam to pass through the mask, and deposit into a Faraday Cup after the FAUST array**.**

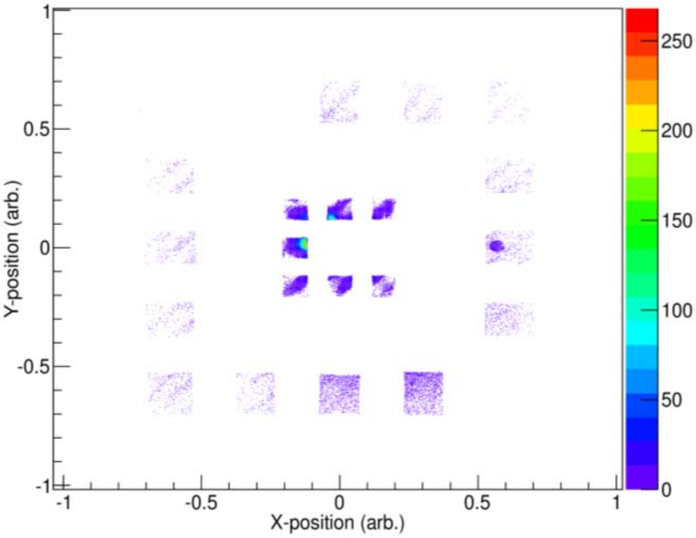

FIG. 6. Position spectra of elastically-scattered collimated 15 MeV/A α beam on the detectors in rings A and C, on ^{nat}Au target, through the W mask.

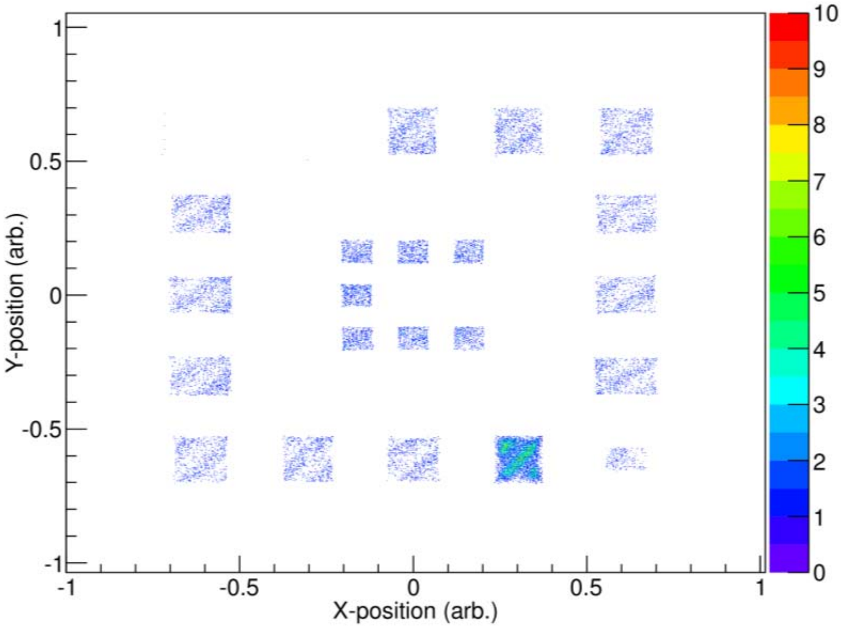

FIG. 7. Position spectra of highest-energy α from ^{228}Th on detectors in rings A and C, through the W mask.

Based on the successful test runs with the upgraded Si detectors, excellent PID and position resolution are expected to be achieved. The actual experiment with the completely upgraded array will allow the correlation function to be extracted from the 45 MeV/A ^{40}Ca, ^{40}Ar+^{58}Ni, ^{58}Fe reactions with different density-dependencies of the asymmetry energy in CoMD and iBUU simulations of the same reactions. For comparison between experimental data and results from simulations (CoMD and iBUU), a software filter of the geometric and energy acceptance of the FAUST array will be used event-by-event. The same data analysis performed upon the experimental results can then be compared to the simulations.

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