A 4π CHARGED-PARTICLE DETECTOR ARRAY FOR LIGHT-ION-INDUCED NUCLEAR FRAGMENTATION STUDIES

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1. Introduction

In order to investigate fragmentation processes in intermediate-to-high energy nuclear collisions, a versatile 4π detector array is required. Because of the multiparticle nature of such events, accompanied by a broad dynamic range of ejectile nuclides and energy spectra, such a detector must possess the following characteristics: (1) nuclide (Z and/or A) identification of products with high resolution; (2) low energy thresholds; (3) spatial characterization of the ejectiles, with good granularity; (4) stable operation, and (5) easy, reliable energy calibrations. Several such devices have been completed during the past several years. Early designs were based on phoswich scintillator techniques.[1–6] More recently, passivated silicon devices[7–10] have been introduced as basic telescope elements and have been incorporated in the design of the Indiana Silicon Sphere, which is briefly described in this paper.

2. Mechanical

The Indiana Silicon Sphere detector (Fig. 1) is based on a spherical geometry and is designed primarily for the study of light-ion-induced nuclear reactions. It consists of 162 triple-element detector telescopes–90 in the forward hemisphere and 72 in the backward hemisphere–covering the angular ranges from 14° to 86.5° and 93.5° to 166°. The detector telescopes are arranged in eight rings, each composed of 18 truncated pyramid telescope housings. Each telescope is composed of (1) a gas-ionization chamber (GIC) operated at 15-30 Torr of CF_4 or 12-20 Torr of C_3F_8; (2) a 500 μm ion-implanted passivated silicon detector, Si(IP), and (3) a 28-mm thick CsI(Tl) crystal with light guide and photodiode readout. To increase granularity for the most forward angles, the silicon and CsI components of each telescope in the ring nearest 0° are divided into two segments. Detectors are operated in a common gas volume in each hemisphere. Vacuum isolation is provided by a $\sim 150\ \mu g/cm^2$ polypropylene window covered with a conducting graphite coating ($\sim 50 - 80\ \mu g/cm^2$) and supported by a cage-like structure, matched to the telescope geometry. The telescope dynamic range permits measurement of $Z \approx 1 - 16$ fragments

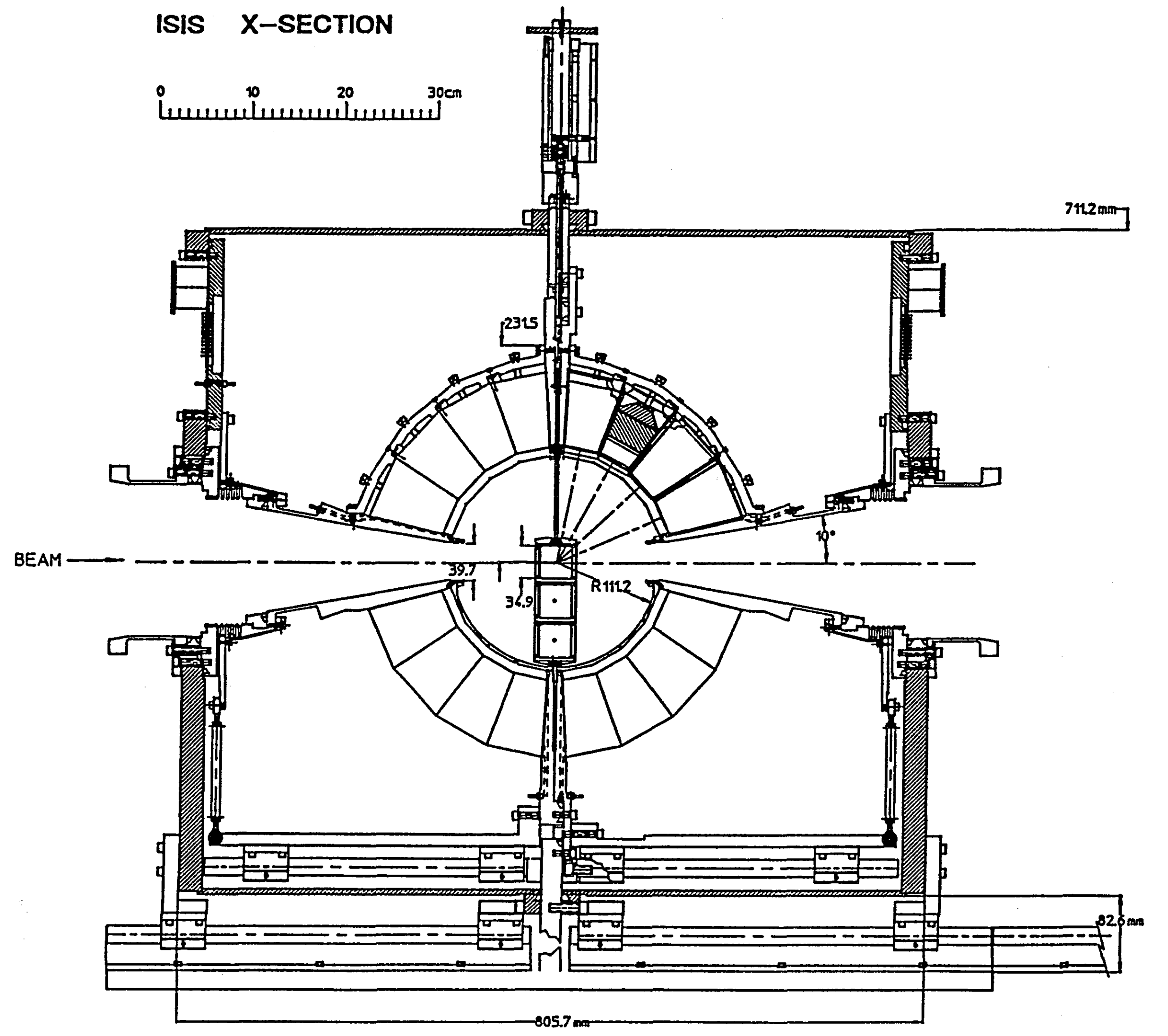

Figure 1. Schematic cross sectioned view of Indiana Silicon Sphere detector array.

with discrete charge resolution over the dynamic range $0.6 \leq E/A \leq 96$ MeV (Fig. 2). The Si(IP)/CsI(Tl) telescopes also provide particle identification (Z and A) for energetic H, He, Li and Be isotopes (E/A $\geq$ 8 MeV), also shown in Fig. 2. The Si(IP) detectors[11] constitute a critical component of the array in that they provide both excellent energy resolution and reliable energy calibration for the GIC and CsI(Tl) elements. The Si(IP) detectors also produce event trigger signals and provide a total solid angle coverage of 74% of 4π.

3. Electronics

Detector signals were shaped and amplified by means of 5-channel charge-sensing preamplifier/linear shaper NIM units, with gains custom-designed for each detector type, constructed in-house (IU Department of Chemistry). Analog signals were digitized via

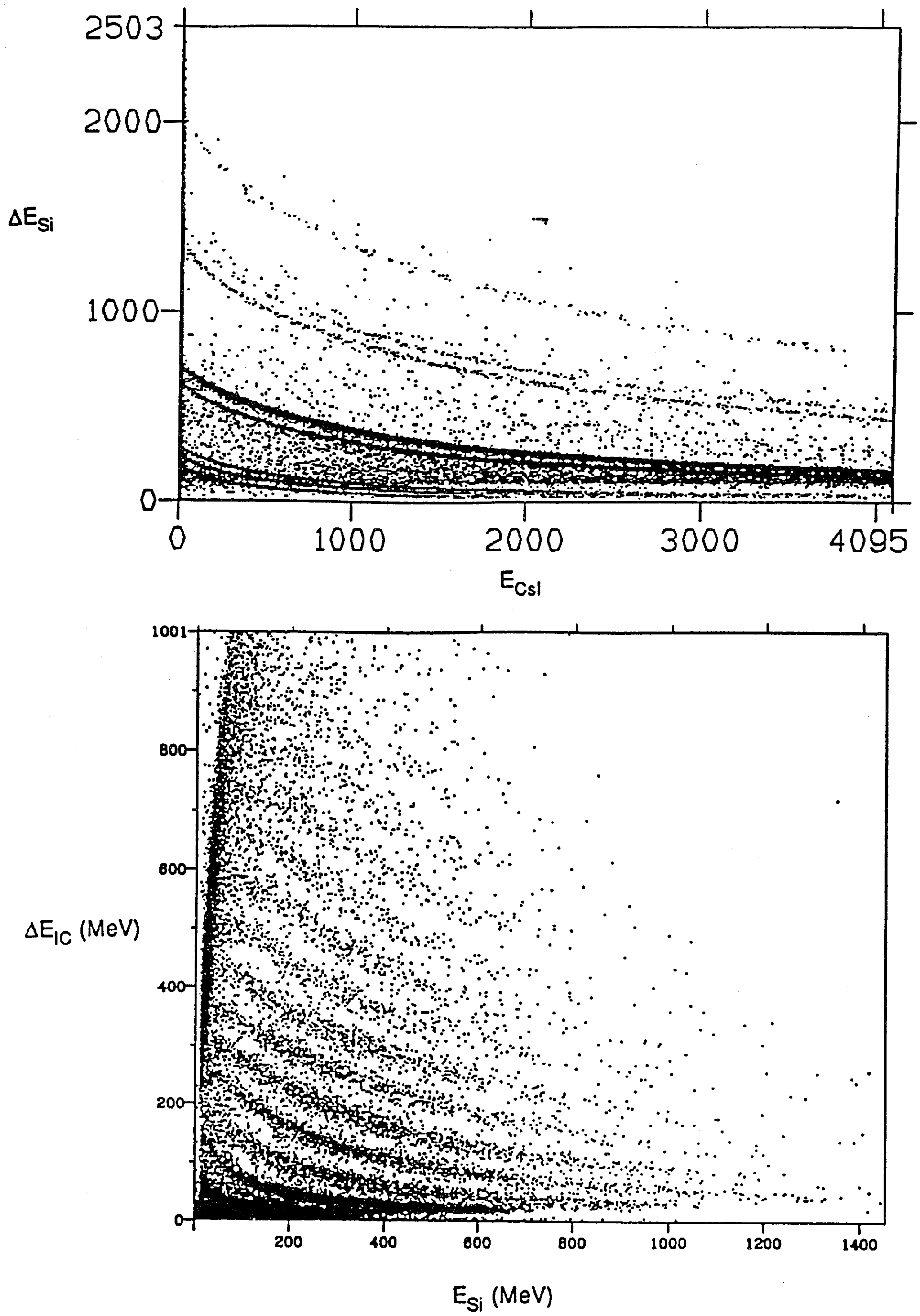

Figure 2. Upper frame: particle identification spectrum for silicon vs. CsI elements. Lower frame: summed particle identification spectrum for eighteen gas-ionization chamber vs. silicon telescopes in 22° - 32° ring.

Phillips 7164H 16-channel peak-sensing ADCs, which provided 12-bit resolution and fast (8 μs) conversion times. Fast signal discrimination and multiplicity sensing was accomplished with constant-fraction-discriminators of the Apex[12] design, constructed by LeCroy (current model no. 3240) and time-to-digital converters from Phillips Scientific (model no. 7186H). Bias for each detector type was supplied by in-house-designed, multi-channel, remote-controlled bias supply units. This permitted application and removal of bias, as well as readout of all parameters, via computer.

4. Summary

During its inaugural run in October-November, 1993 at the Saturne II accelerator, CEN Saclay, the array performed reliably for a five-week running period. Data were taken for bombardments of ^{nat}Ag and ^{197}Au targets with 1.8, 3.6 and 4.8 GeV ^{3}He ions. Excellent separation of He and Li fragments was achieved, an essential performance criterion in these experiments in order to distinguish between the dominant yield of light-charged particles and intermediate-mass fragments ($3 \lesssim Z \lesssim 16$).

In summary, the Indiana Silicon Sphere detector has met design specifications and performed reliably under experimental conditions.

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