Developmental activities in charge particle detector array at IUAC

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Introduction

Developmental activities in charge particle detector array for discrete gamma ray spectrometry is presented. The multi-detector array is being designed for the detection of light charge particles such as protons and alphas generated in a heavy ion induced reaction. The array will consist of CsI(TI) detectors coupled to photo-diode and is being developed to serve as an ancillary detector system for Indian National Gamma Array (INGA)[1]. The array will be used in future INGA campaigns at IUAC

Description of the proposed detector system

The proposed detector array will be fabricated using CsI(TI) detectors coupled to photo-diodes. The array is likely to have 72 detectors which will have a solid angle coverage of nearly 80% of 4π. Each crystal will have a thickness of 3 mm with an active area 20 mm x 20 mm coupled to a 10 mm x 10 mm photo-diode. This design of the detector was preferred to make it compatible with the proposed TIFR charge particle array. The entire detector system will be housed inside a hollow spherical aluminum scattering chamber. A schematic of the scattering chamber is shown in fig.1.

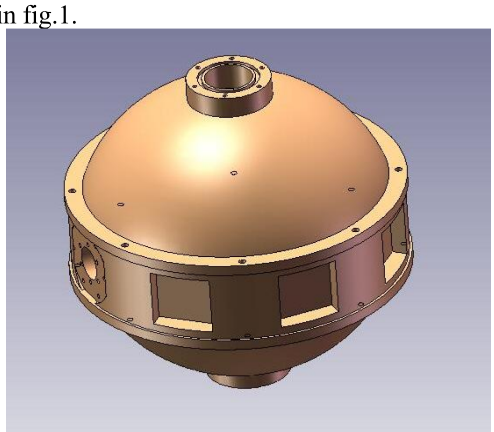

Fig.1: Schematic of scattering chamber

The chamber has been machined from a solid aluminum cylinder at the IUAC mechanical workshop with an outer diameter ~ 10", so as to fit inside the INGA beam-line. The wall thickness of the chamber is kept 3 mm to reduce attenuation of low energy gamma rays. The chamber has four ports, one each for beam exit and entrance. The other two ports (orthogonal to beam axis) will be used for inserting target ladder and routing the signal cables from detector. The chamber has been leak tested. We plan to place the detectors in a cubical manner around the target. This arrangement is inspired by the DIAMANT light charged particle detector array at GANIL.

Detector Instrumentation

One of the main characteristics of CsI(TI) detectors is its intrinsic ability to discriminate between different light charged particles such as protons, alphas, electrons (gamma photons) etc. according to their stopping power. This gives rise to different decay time constants in the light output (fast component) for different particles. Thus instrumentation for this array needs to be competent to exploit these features. The photo-diodes coupled to CsI(TI) detectors are read by conventional charge sensitive pre-amplifiers (CSP). Since the charge generated in photo-diodes is extremely low, it is desirable for the CSP to have a high gain, good timing features (ability to distinguish between different decay times from CsI), and low power consumption so that it can be placed next to photo-diode in vacuum to avoid degradation of signal. For large number of detectors in small volume, power dissipation needs to be small for each preamp. A preamp has been developed in-house with the above requirements in mind. It has a low power consumption < 50 mW, a gain of 2 V/pC (Si equivalent) and exhibits good timing characteristics for particle identification. The preamp has been realized in the form of a 8 pin SIL hybrid with a dimension of 1" x 1" The preamp has been tested thoroughly with Silicon and CsI detector in vacuum.

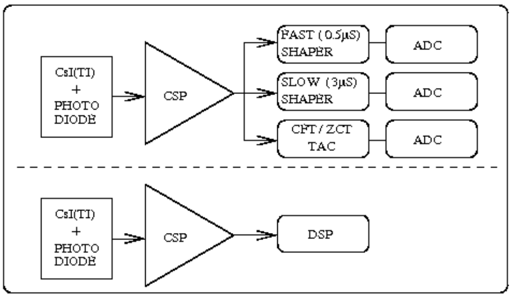

Fig.2: Block diagram for signal processing

Fig.2 shows the signal processing requirements to generate energy information, logic signal to gate with gammas, and identity of the particle (p, α, γ etc.) striking the detector. Ballistic deficit (BD) and zero-cross (ZC) timing are the two widely used techniques for particle identification in CsI. Sometimes both are used simultaneously as the combination of two improves discrimination. The first one uses two shaping amplifiers : one with shorter shaping time (0.5 µs) and other with larger shaping time (3 µs – gives total energy)). The second one uses the ZC time of a doubly differentiated bipolar pulse with respect to a constant fraction trigger generated on the rising edge of the signal. The CSP output from a CsI detector has large rise times varying from 100 ns to 2 us. For such large rise times, it is impractical to use a large cable delay or delay chip (as done in a conventional CFD) for generating CF trigger. Thus a non-delay CF trigger needs to be generated which was realized by mixing two bipolar pulses of 0.5 µs and 1 µs time constant. The resulting tri-polar pulse (two ZC times) was fed to two ZC discriminator. The first ZC time provides CF trigger and the second ZC time gives the identity of the particle. For our preliminary tests we used ORTEC amplifiers and TAC, and CANBERRA discriminators. Alternatively, as shown in fig.2, these can be replaced by a single digital signal processor (DSP) unit. High density electronics (analog as well as digital) is currently under development.

Performance test

Off-line test of CsI detector was carried out using radioactive sources Cs^{134}, Cs^{137}, Co^{60}, Am^{241} and Cf^{252}. Detectors of various sizes (crystal & photo-diode combination) were used to optimize electronics. Fig.3 & 4 are the 2-D plots of ZC PSD and ballistic deficit PSD taken with a 50 mm x 50 mm crystal (Scionix, Holland) coupled to 18 mm x 18 mm photo-diode exposed to Cf^{252} source. A pulser signal was also fed simultaneously. For such a large crystal also, three well separated bands, corresponding one each to alphas, γ from CsI, γ from photo-diode (along with pulser), are observed in both plots. Figure of merit (FOM) observed were 3 and 4 for BD and ZC respectively at alpha energy of 4 MeV. Combination of the two yields a FOM of 5. For BD , as observed from fig.4, the FOM improves with increase in energy whereas for ZC it remains constant. Energy resolution of 150 keV (for 5.48 MeV alpha) and 50 keV (662 keV gamma) were observed.

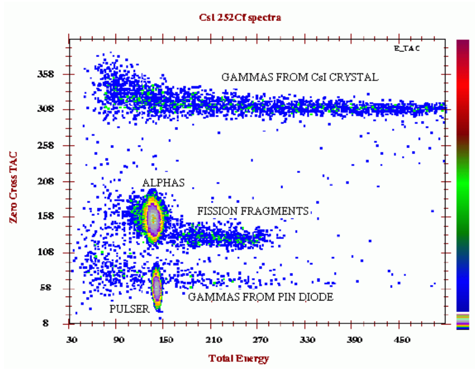

Fig.3: Zero cross PSD spectrum

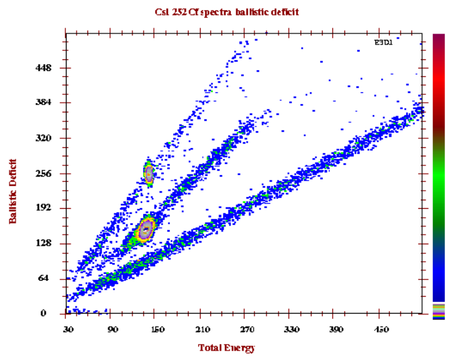

Fig.4: Ballistic deficit PSD spectrum

Detailed test results and activities on instrumentation development and design will be presented.

References :

[1] INGA at IUAC : Proceedings of DAE symposium on Nuclear Physics Vol.53(2008)689