Charged particle detector array: 45^0-175^0

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Introduction

The K500 superconducting cyclotron (SCC) at the Variable Energy Cyclotron Centre, Kolkata, is expected to deliver a large variety of ion beams over a wide range of energies (~50 - 70 MeV protons, ~10 - 50 MeV/A medium heavy ions with A < 60 and ~5 - 20 MeV/A heavier ions). At this energy, a hot and compressed nuclear system will be formed which will deexcite through multifragmentation process. The study of these mutifragments will help to understand the properties of hot nuclear matter *e.g.*, equation of state, phase transition (liquid - gas), dynamics of nuclear collisions, isoscaling etc. A complete experimental investigation of these properties requires to detect and identify all most all the reaction products, their energy, multifragment correlation etc. For this purpose a 4π Charged Particle Detector Array (CPDA) is being developed at VECC under super conducting cyclotron utilization project (SUCCUP). According to the types of detection system, the array can be divided into three parts; (A) extreme forward part ($\theta = 3^0$-7^0) consists of plastic phoswitch detectors, (B) forward part ($\theta = 7^0$-45^0) consists of three layer highly granular charged particle telescope Si strip-Si strip-4 CsI(Tl) with 256 pixel and (C) backward part ($\theta = 45^0$-175^0) with all parts have φ coverage 0^0-360^0 as shown in schematic diagram shown in Fig 1. Here in this report, the details of backward part will be discussed.

Design of backward part of CPDA

A simulation has been done using the code HIPSE (Heavy Ion Phase Space Exploration) [1], for the reaction 50 MeV/A $^{16}O + ^{119}Sn$, to see how the fragments are distributed at different angles. It has been found that most of the heavier fragments will be emitted in the forward angles, and light charged particles (LCP) emission will be dominated in the backward angle. Hence, it has been decided to detect only LCP up to Z = 2 in the angular range $\theta = 45^0$-175^0 and $\varphi = 0^0$-360^0 using backward part of CPDA. The backward array will be made up of 114 CsI(Tl)

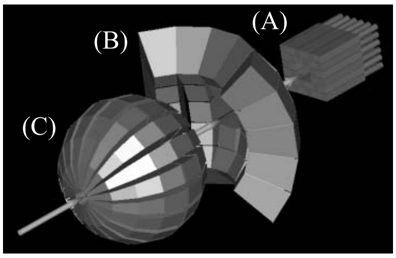

Fig. 1. Schematic 3D diagram of 4π-CPDA.

detectors of different shapes and sizes as shown in Table I. Advantage of using CsI(Tl) detector, is that LCP can be identified using single crystal by pulse shape discrimination (PSD) technique [2]. The geometry of this part of array is such that front face of the detectors form a part of sphere of radius ~150 mm and it should not clash with the other part of the array. There are 6 azimuthally symmetric rings in the backward part of CPDA and number of detectors in each ring has been given in Table I and shown in Fig. 2. Depending upon the size of crystals, all the detectors are coupled with photodiodes of different sizes. For the detectors in ring number 1 to 4, active area of photo diodes will be 18×18 mm^2, for the detectors in ring 5 and in ring 6 it will be 20×10 mm^2 and 10×10mm^2 respectively. Each crystal will be wrapped with special reflective material with aluminized mylar foil of thickness 50μm to ensure no cross talk of light in between adjacent crystals. Entrance window will be covered by ~1.5 μm thick aluminized mylar foil. Non-uniformity of the light output is less than 1%. Energy resolution of each detector is less than 5%. Each of the photodiode will be coupled with vacuum compatible preamplifier with some noise reduction circuit.

Table I: Details of the CsI(Tl) detectors at different rings. Rn→Ring Number, N→Number of detectors in each ring, Th→ thickness (mm), Ty→Name of the detector according to shape in each ring, Q→ Quantity of each type of detectors, θ1→ θ_{min}, θ2→ θ_{max}, Δφ→ 20^0 for all detectors. Angles include detector with its housings.

Rn	N	Th	Ty	Q	θ1	θ2
1	6	40	CsI-1	6	54.3	67.5
2	18×2	40	CsI-2	12×2	67.5 79	79 90.0
			CsI-2A	2×2	67.5 73.5	73.5 79.6
			CsI-2B	4×2	75.1 82.6	82.6 90.0
3	18	30	CsI-2	16	90	112.5
			CsI-2A	2	100.4	112.5
4	18	20	CsI-4	18	112.5	135.0
5	18	20	CsI-5	18	135.0	157.5
6	18	20	CsI-6	18	157.5	170.4

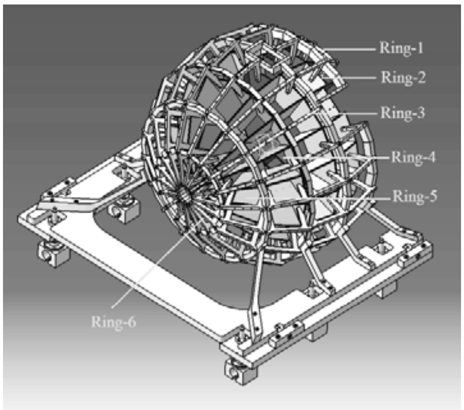

Fig.2. 3D CAD model of support structure and housings of backward part of CPDA.

In beam test of a prototype detector

In beam test of a prototype detector has been done using 50 MeV α beam from VEC, to see its pulse shape discrimination property. The light output of CsI(Tl) detectors have two components which can be approximately written as

$$L(t) = L_s exp(-t/\tau_s) + L_f exp(-t/\tau_f)$$

where L(t) is the light output at time t, L_s and L_f are the total light amplitudes, τ_s and τ_f are the fast and slow component of the decay constants. These constants depend on the type of the incident particle. τ_f depends on the stopping power (dE/dx) of the particle, $\tau_f \propto dE/dx$. This property is used to identify the particle in PSD technique. Here, we have integrated the amplified pulse over fast gate (G_f) and slow gate (G_s) as shown schematically in Fig 3. The spectrum obtained is shown in Fig. 4. It is seen that p, d, t and α are clearly separated.

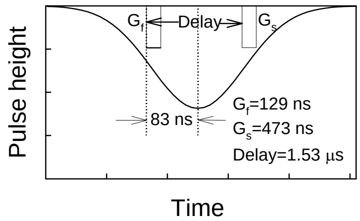

Fig. 3. Schematic diagram of fast gate and slow gate.

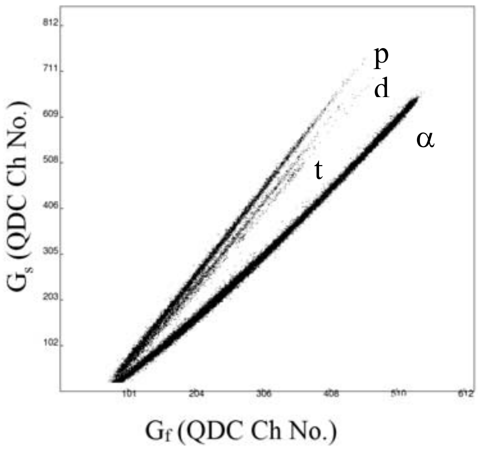

Fig. 4. Fast gate – slow gate spectrum for gates and delay widths as in Fig. 3.

References

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[2] D. Guinet et al., Nuclear Instruments and Methods in Physics Research A **278** (1989) 614-616