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Letter to the Editor

CHARGED PARTICLES IDENTIFICATION WITH A CsI(Tl) SCINTILLATOR

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A CsI(Tl) scintillator with two light decay components is used to detect and identify p, d, t, ^{3}He and α particles with a low energy threshold. Besides, the addition of a thin plastic scintillator in front of the CsI(Tl) crystal allows charge identification for ions with Z up to 19.

The detection of light particles provides a precious tool to study the different processes involved in heavy ion collisions. Since the physicists are now interested in reactions induced by higher and higher incident energy beams, the increasing multiplicity and energy of the light particles to be detected leads to a greater number of detectors and to larger thicknesses of those detectors. As a consequence standard solid state Si telescopes have been gradually replaced at first by telescopes composed of silicon and scintillator and then by phoswich detectors [1–3]. But the capabilities of the phoswich technique are limited by the working principle itself of the telescope, i.e., the particle to be detected passes through a first scintillator which reduces the possibility of detecting low energetic yields if thick, and high energetic yields if thin. Some properties of scintillators, although well known in the past, are now rediscovered. Namely the shape of the light output may depend on the ionizing power of the detected particle. That leads to different ways of identifying light particles by analysing the pulse output of the photomultiplier coupled to a scintillator. This technique still uses the simple pulse shape analysis of the phoswich detector but simplifies the mechanical design and, above all, avoids the problems of low energy cut off. Here are described the abilities of a CsI(Tl) detector as already proposed by Biggerstaff et al. [4] 25 years ago!

The scintillation pulses decay of CsI(Tl) crystal is a combination of exponentials of different time constants:

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

where $L(t)$ is the light pulse amplitude at time t, L_s and L_f are the total light amplitudes, τ_s and τ_f are the constant time decays for the slow and fast components respectively ($\tau_f \sim 0.4$–0.7 μs, $\tau_s \sim 7$ μs).

Discrimination among particles is then possible because (i) the amplitudes ratio of fast and slow components L_f/L_s varies with the particles type, (ii) there is a change in decay constant with the density of ionization of the particle, mainly for the short decay constant [5]. The emission probability $1/\tau_f$ seems to be an increasing function of the stopping power $\epsilon = \mathrm{d}E/\mathrm{d}x$. As it was shown for low energy protons and alphas [6] the L_f/L_s ratio increases with ϵ. Consequently the ratio R of the pulse heights at two different times t_1 and t_2 depends on M, Z and E. A characteristic sampling of the light output at a time t is supplied by measuring the light output $L(t, T)$ obtained by integrating the charge output between times t and $t+T$.

Fig. 1 displays a bidimensional plot $L_2(t_2, T_2) = f[L_1(t_1, T_1)]$ measured with a CsI(Tl) scintillator * (diameter $\varnothing = 50$ mm, thickness $l = 30$ mm) covered with a ~ 6 μm thick Al–mylar foil. A very good mass identification for $Z = 1$ and $Z = 2$ particles can be appreciated, with an energy threshold lower than 5 MeV for α's. However in these experimental conditions (time gates for integration), no identification can be seen for particles with $Z > 3$.

To improve the identification capabilities for $Z > 3$, the fast over slow light decay ratio can be modified by gluing in front of the CsI crystal a fast plastic scintillator (NE102A) 0.2 mm thick. This whole detector works as a phoswich. Above a 5 MeV/n threshold due to

* Identical results can be obtained with different CsI(Tl) scintillators supplied by several makers as Merck, Horiba, Harshaw, and Quartz et Silice.

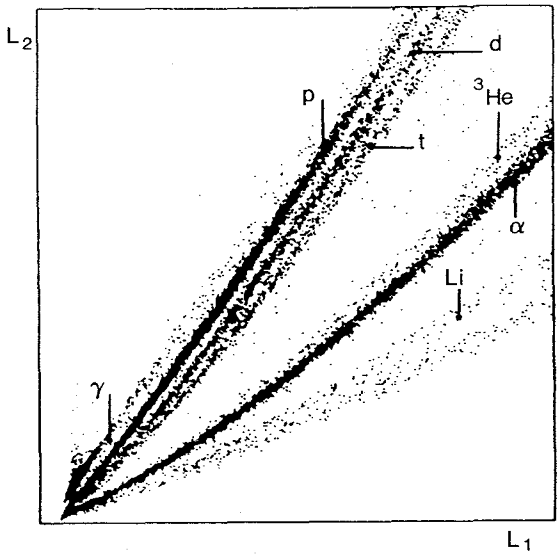

Fig. 1. Identification of light charged particles with a 50 mm wide and 30 mm thick CsI(Tl) crystal. L_1 and L_2 are the light outputs obtained when integrating the signal within time intervals $T_1 = 400$ ns and $T_2 = 1$ μs at times $t_1 = 0$ and $t_1 = 1.6$ μs. The photomultiplier was a RTC 2262. This spectrum has been obtained at $\theta = 7.5°$ with a 30 MeV/n Ar beam impinging on a CD_2 target.

passing through the plastic scintillator, the ions are detected and identified as nicely as above with the same experimental conditions. Fig. 2 displays neatly the trend

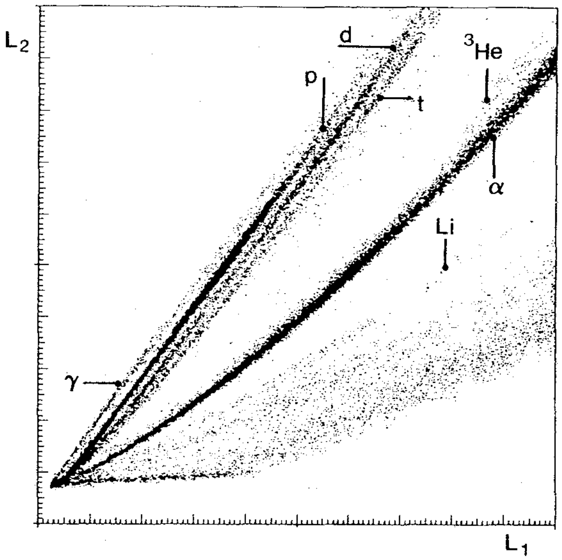

Fig. 2. Identification of light charged particles with a phoswich detector composed of a thick CsI(Tl) scintillator on which had been glued a 0.2 mm NE102A scintillator. L_1 and L_2 and the experimental conditions are identical as the ones defined in fig. 1.

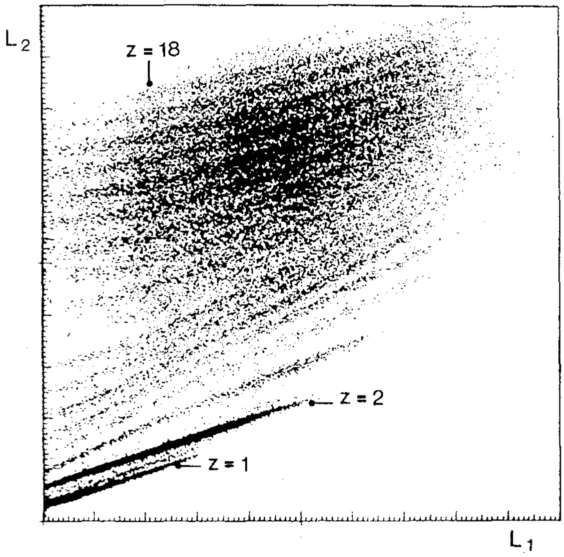

Fig. 3. Two dimensional plot $L_2 = f(L_1)$ obtained with the same phoswich detector as in fig. 2 but with a different set of timing gates: the time intervals corresponding to L_2 and L_1 were 30 and 400 ns wide respectively and taken at times $t_2 = 80$ ns and $t_1 = 0$.

to separate the $Z > 3$ particles, owing to the superposition of the NE102A fast component which increases as the detected ion is heavier. To use in a better way the very fast ($\tau = 2.4$ ns) light component of NE102A, other time conditions were chosen: $T_1 = 400$ ns, $T_2 = 30$ ns. Fig. 3 displays a very nice charge identification up to $Z = 19$. On the other hand the addition of a thin scintillator in front of the CsI(Tl) crystal unfortunately increases the energy threshold up to 15 MeV for alphas.

In conclusion the CsI(Tl) crystal alone allows a good mass identification for light particles $Z = 1$ and $Z = 2$ by integrating the light decay over two different gates. Adding a thin NE102A plastic scintillator in front of the CsI crystal leads to a good charge separation, up to $Z = 19$ for the Ar induced reactions (and perhaps upper Z), by using a third gate, much faster. Among the different types of scintillators (BaF_2, NaI [7]) the CsI(Tl) is an interesting one for detecting light ions in nuclear physics experiments with many detectors of large solid angles, because of its mechanical qualities, low hygroscopy and rather low cost.

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