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EFFECT OF PULSE TIME GATE ON CsI(Tl) LIGHT OUTPUT

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The mass and charge identification of secondary particles with $Z < 4$ by a large CsI(Tl) scintillation detector is performed using the pulse shape analysis and the time-of-flight methods. The dependence of light output on E, A and Z is studied in an energy range of 1—20 MeV/A and special attention is paid to the integration time of the photo multiplier anode signal. It is found that the behaviour of the calibration curves strongly depends on the choice of the integration time interval.

The investigation has been performed at the Flerov Laboratory of Nuclear Reactions, JINR.

Влияние сигнального временного окна на световой выход CsI(Tl)

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Представлена массовая и зарядовая идентификация вторичных частиц с $Z < 4$ большим сцинтилляционным детектором на основе CsI(Tl) с помощью анализа формы импульса и времяпролетного метода. Исследовалась зависимость светового импульса от E, A и Z в диапазоне энергий 1— 20 МэВ на нуклон, специальное внимание при этом уделялось времени интегрирования анодного сигнала фотоумножителя. Было установлено, что поведение калибровочных кривых сильно зависит от выбора временного интервала интегрирования.

Работа выполнена в Лаборатории ядерных реакций им.Г.Н.Флерова ОИЯИ.

1. Introduction

The light output of the same inorganic crystals BaF_2, NaI(Tl), CsI(Tl) as an explicit function of E, A, Z has a strong dependence on integration time interval. It is explained by a different pulse form of front and tail, essentially for the light charged particles with $Z < 4$ [1].

Storey et al. [2] showed that the light output of the scintillator could be described by a sum of two exponential functions with the fast and slow components:

$$L(t) = h_f/\tau_f \exp(-t/\tau_f) + h_s/\tau_s \exp(-t/\tau_s). \quad (1)$$

On the basis of properties of the crystal luminescence: i) with decreasing ionisation density, the ratio $R = h_s/(h_f + h_s)$ strongly increases and ii) the fast component τ_f is an increasing value as the ionisation density of the particle decreases, a good identification of *E, A, Z* for $Z < 4$ is obtained using the pulse shape analysis (*PSA*), i.e. measurement of the amounts of charge in two regions of the anode pulse [3—5]. Sophisticated understanding of the behaviour of rise and decay times of light pulse versus particle type provides a substantial help for optimisation of the *PSA* conditions. However, accurate measurements of the light output as a function *F(E, A, Z, t)* in case of low energies are very poor because there is difficult particle identification and large energy error. Really, these measurements are possible if the energy of particle is fixed using a magnetic spectrometer. In this work the dependence of light output on time interval, over which the anode current signal of the photo multiplier was integrated is studied for light secondary particles with $Z = 1—3$ in the energy range of 1—20 MeV/A.

2. Experimental Procedure

The main characteristics of CsI(Tl) counter with a crystal diameter of 200 mm and a thickness of 15 mm coupled by a hollow light guide to the photomultiplier have been determined in ref. [5,6]. The present investigation is based on the possibility to detect secondary beams produced in reaction ^{11}B(20 MeV/A) + ^{181}Ta using the U-400 (FLNR, JINR) cyclotron when the energy of particles is fixed and known exactly on a magnetic spectrometer. The identification of the products in this case, by the pulse shape analysis is shown in Fig.1 (a) at a magnetic rigidity $B_\rho = 1.32$ Tm. It is noticed that the proton peak is out of $Z = 1$ systematics because the 15 mm thickness of CsI(Tl) crustal can't keep them from stopping. Changing a magnetic rigidity B_ρ from 0.81 Tm up to 1.35 Tm secondary particles are measured at energies of $E = 1—20$ MeV/A. In this energy range the CsI pulse height is investigated for ^{1-3}H, ^{3-6}He and ^{6-9}Li isotopes versus time intervals $T_1(0.0; 0.4\ \mu s)$, $T_2(0.0; 2.0\ \mu s)$, $T_3(1.5; 2.0\ \mu s)$ of the anode signal. Both T_1 and T_2 gates are started well before the pulse rise and have a duration of 0.4 μs, 2.0 μs respectively, while T_3 window has a delay line equal to 1.5 μs. Particle identification is carried out using the *PSA* and *TOF* methods as shown in ref. [6] and Fig.1 (a,b) with the standard *LeCroy* electronics ADC 2249W and TDC 2228A.

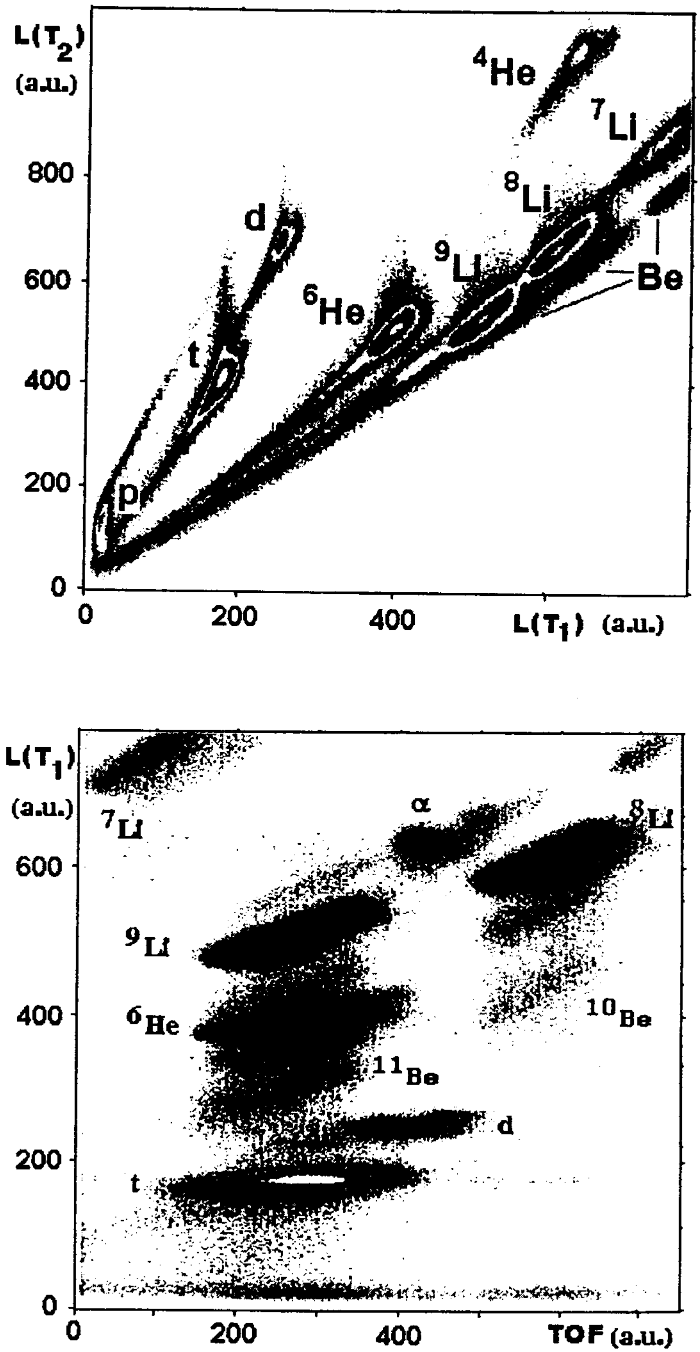

Fig.1. The identification of secondary particles emitted in the ^{11}B(20 MeV/A) + ^{181}Ta reaction by a) PSA and b) time-of-flight methods

3. Results

The light output measurements for three integration intervals reflecting the front (T_1) and the tail (T_3) of light pulse and also their mixing (T_2) are presented in Fig.2.

First, we are concerned with the charge dependence of the light output for different integration time windows. It is known that with the increase of Z of the detected particle the total light output expressed as $L = h_f + h_s$ decreases because the ratio $h_s/(h_f + h_s)$ increases with decreasing ionisation density. This behaviour can be clearly seen in Fig.2c where the light output integrated in the time window T_3 is shown. With its window the slow light component dominates and, as a rule, it is weaker for higher Z. This fact also is confirmed by the plot resulting from the integration over interval T_1 (see Fig.2a). Within this time interval, where the fast light component plays the dominant role, the behaviour of calibration curves is quite reversed. The results point out that for higher Z the contribution of the fast light component dominates that is in a full agreement with the statement made above.

The same interplay of the slow and fast light components is observed for the mass dependence of light output for the given Z. As an example, the absolute values of light output for ^{3}He, ^{4}He, ^{6}He ions are increasing for the first interval and decreasing for the third one. As the T_2 window (Fig.2b) includes both the fast and slow components, this interval is not very suitable for identification and the calibration curves can hardly be separated.

In the same way the mass dependence of the light output is studied. The relative mass dependence ΔL of light output of a triton and proton gives 21 % and 16% for T_1 and T_2, respectively, at E_t = 30 MeV. However, there is almost no difference ($\Delta L \sim 2\%$) for the time interval T_3 like in ref. [7], where a spectroscopy amplifier operates with a 3 μs shaping time. On the other hand, for particles with $Z = 2$, the difference of the ^{6}He, ^{4}He light outputs results in a variation of 6% and 8% in ΔL for T_1 and T_3, respectively, at energy $E = 55$ MeV of ^{6}He. For T_2, the difference amounts to less than 4%. The front edge of the pulse (the integration in T_1) does not allow to separate different Li isotopes. Nevertheless, if slow component participates in integration, as it is in (T_2) or (T_3), our procedure starts to separate ^{9}Li and ^{7}Li at energy of about 40 MeV. At higher energies ΔL further increases and reaches a value of about 8 % at $E = 80$ MeV.

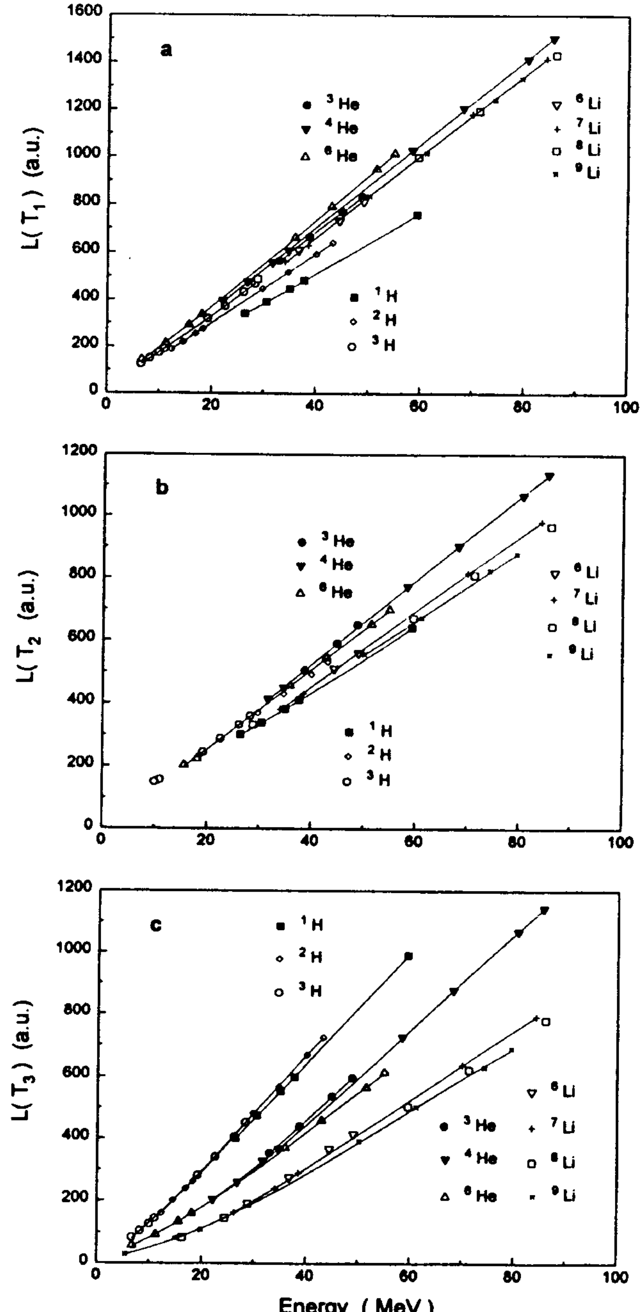

Fig.2. The energy dependence of the CsI(Tl) light output for particles with Z = 1—3 produced in ^{11}B(20 MeV/A) + ^{181}Ta reaction at low energies: a) the time integration interval T_1(0.0; 0.4 μs); b) — T_2(0.0; 2.0 μs); c) — T_3(1.5; 2.0 μs).

The fact that the behaviour of the calibration curves differs, if integration is done within two separate time intervals, enables one to use the CsI(Tl) detector for the good particle identification. The pulse shape analysis is applied and for different time interval combinations the matrices (T_1, T_3) and (T_1, T_2) have been compared earlier [6]. Since in T_2 both the fast and slow components are present, the combination with T_2 gives a slightly worse identification, which agrees well with the data presented in ref. [4].

Moreover, one should note (Fig.2) that non-linear effects of calibrated curves are essentially different in T_1 and T_3 intervals. $L(T_1)$ can be practically described by a linear function of energy as $L(T_1) \sim \gamma E + \beta$, where γ and β denote the slope and the intercept, respectively, while the light output in T_3 $L(T_3) = \gamma E + \beta \{\exp(-\alpha E) - 1\}$ has the outstanding non-linear dependence of energy especially in the region of $E < 5$ MeV/A. These results are in fairly agreement with measurements of Benrachi et al. [4] where it is shown that the relative intensity of the slow component increases as a function of energy and that the fast pulse decay is slower as the energy increases.

4. Conclusion

The response of CsI(Tl) scintillator to light ions (Z = 1—3) separated by a magnetic spectrometer is studied in this work at the energies of 1—20 MeV/A. To optimise the *PSA* condition special attention is paid to the choice of integration time intervals. It is found that the relative light output and nonlinear effects of the calibration curves strongly depend on the delay line and gate duration. One can conclude that the edge part of the pulse (T_3) is very suitable for the energy calibration of hydrogen isotopes because there is scarcely any difference between p, d, t signals. On the contrary, the particles with $Z = 3$ fall on a single straight line in T_1 window. Finally, the light output for helium isotopes is essentially distinctive in all studied intervals.

Reference

1. Birks J.B. — The Theory and Practice of Scintillation Counting. Pergamon, Oxford, 1964.

2. Storey R.S., Sack W., Ward A. — Proc.Phys.Soc.London, 1958, 72, p.1.
3. Alarja J. et al. — Nucl.Instr. and Meth., 1986, A242, p.352.
4. Benrachi F. et al. — Nucl.Instr. and Meth., 1989, A281, p.137.
5. Wagner W. et al. — JINR Rapid Com. 4[61]-93 Dubna, 1993, p.49.
6. Fomichev A.S. et al. — Preprint GANIL P-93-23, 1993; to be published in Nucl.Instr. and Meth.A.
7. Horn D. et al. — Nucl.Instr. and Meth., 1992, A320, p.273.

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