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A LARGE AREA CsI(Tl) DETECTOR FOR THE SCINTILLATOR SHELL OF FOBOS*

W.Wagner[1], A.S.Fomichev, H.-G.Ortlepp[1],
C.-M.Herbach[1], A.Matthies[1], G.Pausch[2],
O.V.Strekalowskij, M.A.Milovidov[3], V.A.Vitenko[3]

A large area CsI(Tl) detector for the 4π-array FOBOS has been investigated. The response nonuniformity was reduced to 5% by use of a hollow light guide. The energy resolution amounts to 6—7% for 5 MeV alpha particles.

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

Большой CsI(Tl) детектор для сцинтилляционной части установки ФОБОС

В.Вагнер и др.

Исследовался CsI(Tl) детектор большой площади для 4π-установки ФОБОС. Неравномерность отклика была уменьшена до 5% с использованием пустотельного световода. Полученное энергетическое разрешение для альфа-частиц энергии 5 МэВ составляет 6—7 %.

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

The 4π-multidetector-array FOBOS [1] coming into operation this year in the Flerov Laboratory of Nuclear Reactions at JINR Dubna consists of an inner gas detector array and an outer scintillator shell to register intermediate and heavy fragments produced in heavy ion induced nuclear reactions as well as more penetrating light charged particles (LCP).

The large area CsI(Tl) detector presented here (fig.1) is one element of the scintillator shell of altogether 210 hexagonal crystals (enveloping circles with Ø = 200 mm and Ø = 150 mm) arranged in mosaiclike modules of at

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[1] at present JINR Dubna; on leave from Research Center Rossendorf Inc., Dresden, Germany

[2] Freie Universität Berlin, Germany

[3] V.G.Khlopin Radium Institute, St.Petersburg, Russia

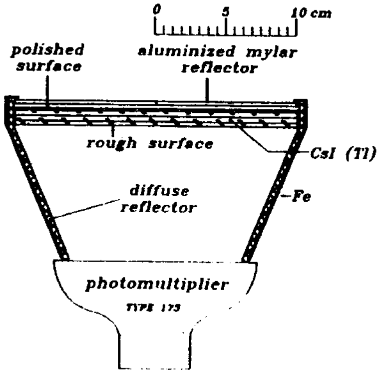


Fig.1. Schematic view of the large area CsI(Tl) detector

that time 7 hexagons which are situated behind the 30 Bragg ionization chambers covering them with 73.4% geometrical efficiency. Crystal thicknesses of 10 mm and 15 mm were chosen for angles of $\vartheta = 53°—164°$ and $\vartheta = 16°—52°$ to stop LCP with energies of up to 50 and 65 AMeV, respectively. Applying pulse-shape discrimination (PSD) [2] LCP can be well separated in relation to mass and charge for $Z \leq 4$ [3,4].

This is demonstarted in fig.2, where we used the reaction ^{20}Ne (9.1 AMeV) + ^{58}Ni and the large CsI(Tl) detector was situated at $\vartheta = 45°$ relative to the beam axis at a distance of 70 cm from the target [5]. The main problem of using large scintillators is the reduction of the position dependent detector responce induced by

(i) the nonuniform light output of the crystal,

(ii) the nonuniform photocathode sensitivity and photoelectron collection efficiency of the photomultiplier (PM),

(iii) the position dependent light collection effiiciency.

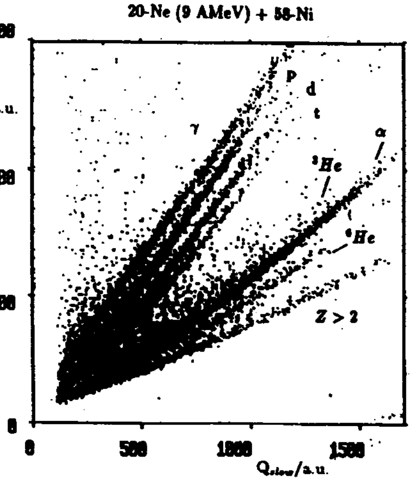
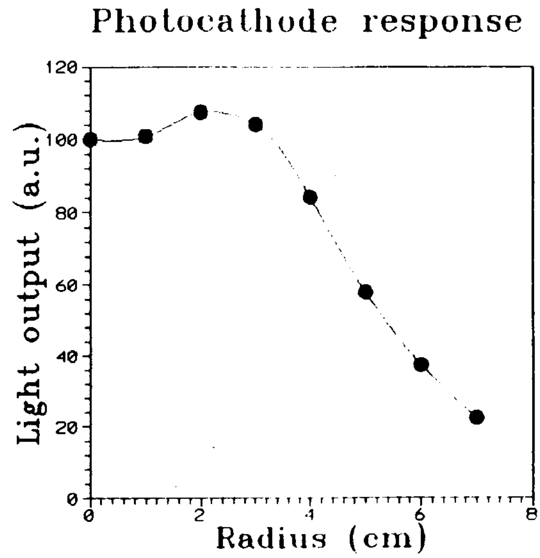


Fig.2. Pulse-shape discrimination of LCP with the large area CsI(Tl) detector integrating the current pulses of the PM within time gates of Δt_1 = 0—400 ns (Q_{slow}) and Δt_2 = 1600—3600 ns (Q_{tail})

The crystals delivered by MONOCRYSTALREACTIV, Kharkov, Ukrain, were grown under vacuum applying Kyropoulos' method. The content of Tl activator amounts to 0.07—0.08% which is an empirical optimum for high light output as well as good PSD properties for LCP. The samples were cut from the central part of the Ø = 500 mm ingots and polished using organic solvents to avoid a dead layer at the surface.

Scanning the crystals with the help of an alpha source and a small diameter phototube, the radial nonuniformity of light output ΔL induced by an inhomogeneous

Fig.3. The radial photocathode responce of PM FEU 173 measured with a small (Ø = 10 mm) CsI(Tl) crystal directly coupled to the PM and a ^{137}Cs source



dopant concentration was checked to be less than 2%.

The scintillation light has to be matched to the PM in such a manner that the nonuniform photocathode response (see fig.3) is averaged, a maximum light collection and a minimum dependence on the position of the light source within the crystal volume is achieved. We coupled the crystal to a spectroscopic PM of type FEU 173 (EKRAN, Novosibirsk, Russia) which has a large (Ø = 150 mm) trialcali photocathode with high

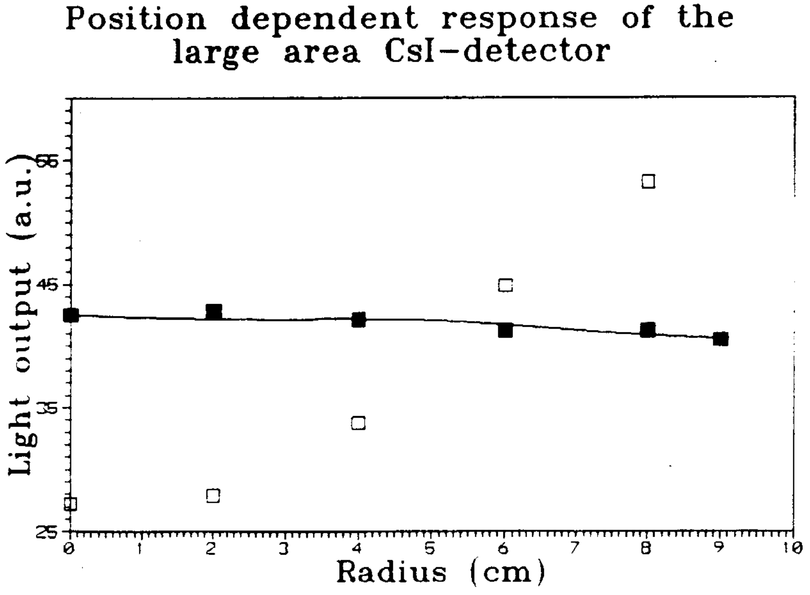


Fig.4. The light output measured for a Ø = 200 mm, 15 mm thick CsI(Tl) crystal coupled by a plexiglas light guide to PM FEU 173 (open squares) and coupled by a hollow diffuse reflecting light guide to PM FEU 173 (full squares) in dependence on the radial position of the alpha source. The line represents a simulation of the light collection for a hollow light guide (*K* = 0.9) normalized to the data at the centre of the crystal

photochatode sensitivity of typical (1.5— —2.5)·10^{-4} A/lm and due to its spectral sensitivity range of λ = 300—850 nm is ideally adapted to the emission spectrum of CsI(Tl) (λ_{max} ≈ 550 nm).

Monte-Carlo-simulations of light transport from the crystal to the PM were carried out for several types of light guides considering light absorption and reflection from different surfaces. As it is shown in fig.4 the coupling by e.g. a conventional plexiglas light quide leads to a very large radial variation of light collection up to a factor of two.

In our conditions a conical shaped hollow light guide with a diffuse reflecting inner surface (h = 110 mm, ⌀ = 150 mm at the PM) was found to be the best solution. It is made from zinc plated sheet metal painted with white TiO_2 enamel and parallelly serves as crystal support allowing a trivial design of the CsI(Tl) mosaics of the scintillator shell.

In the case of a hollow light guide it was found that the read-out of scintillation light from the crystal is enhanced if its back side is optically rough to avoid total inner reflection at the read-out surface and subsequently absorption losses of light. The light output was measured to be nearly 30% higher compared with polished crystals.

Results of simulations as well as experimental data obtained with an alpha source are given in the table and fig.4. The remaining radial variation of the light output amounts to 5%. The measurement well agrees with the simulation for an assumed reflectivity of the light guide surface of $K \approx 0.9$ what seems to us to be a realistic value for the enamel used. Indeed the value of the reflectivity K is the critical parameter determining the remaining ΔL (see tab.).

Due to the rough read-out surface of the crystal and the diffuse reflecting surface of the hollow ligh quide the radial nonuniformity of the photocathode response of the PM FEU 173 (fig.3) will be well averaged due to the nearly homogeneous illumination and, therefore, its influence on energy resolution is minimized.

Table

K	R (cm)					ΔL (%)
	0.00	2.47	4.95	7.42	9.90	
0.99	52.7	52.7	52.7	52.5	52.4	0.6
0.90	42.5	42.1	42.0	41.0	40.5	4.8
0.80	34.1	33.6	33.0	32.2	31.7	7.3
060	24.2	23.5	23.0	22.1	21.0	14.1

In summary we obtained an energy resolution of 6—7% for collimated alpha particles and typically 9% if the ^{238}Pu alpha source was positioned at a distance of 50 cm from the front side simultaneously illuminating the whole crystal.

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