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D. Bollini, F. Fossati, A. M. Paolillo and S. Rovera: ENERGY SPECTRUM OF PROTONS FROM Cs AND I WITH 17.6 MeV INCIDENT γ-RAYS.

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Abstract. -

Energy spectra of protons from the $I^{127}(\gamma, p)Te^{126}$ and $Cs^{133}(\gamma, p)Xe^{132}$ reactions were measured at 17.6 and 14.8 MeV γ-rays energy. Pulse-shape discrimination has been used. The cross-sections for these reactions were estimated to be 2.5 ± 0.8 mbarn. The spectra are consistent with the statistical theory for $E_p < 4.75$ MeV and present in the high region, effects of direct interactions.

This paper presents experimental results on the energy spectrum of protons emitted by Cs^{133} and I^{127} of a CsI(T1)-crystal, irradiated with 17.6 and 14.8 MeV γ-rays. The γ-rays are produced in the $Li^7(p, \gamma)$ reaction at the 440 KeV resonance.

The crystal acts both as target and as detector for p and α particles; moreover, exploiting the property of the crystal to present a fluorescence decay time which depends on the particular particle detected, it is possible to discriminate between p, α and electrons produced by γ-rays.

The use of pulse shape analysis allows one to increase the γ-flux, to use relatively thick crystals, and therefore to reduce corrections not easy to estimate, for protons escaping from the crystal.

Although it is impossible to separate the Cs^{133} and I^{127} contributions to the observed reaction, it is reasonable to assume that both elements will behave similarly. In fact, the two nuclides are close together in Z and A values (I^{127} Z=53; Cs^{133} Z=55) and both contain an odd number of p and an even number of n. The (γ, p) reaction Q-values are pratically equal (-6.25 MeV and -6.37 MeV for I^{127} and Cs^{133}). Besides, the 4π-geometry of the target detector system, does not allow angular distribution measurements.

The work was carried out with a 560 KeV Cockroft-Walton accelerator with the radio-frequency source in a fixed magnetic field. The γ activity was monitored continuously during the irradiation with a Geiger-Müller counter

(x) - This work has been carried out under contract EURATOM-CNEN.

(20^{th} Century Electronics G. 5H) calibrated with the β^+ activity induced in a copper foils by the reaction $Cu^{63}(\gamma, n)Cu^{62}$. With an ion current of 70 μA the γ-rays intensity was 1.2×10^6 $\gamma \times sec^{-1}$ over the whole solid angle.

The experimental arrangement is shown in fig. 1. The CsI(Tl) crystal (a) has a diameter of 40 mm and a thickness of 3 mm. It is mounted, with a 10 mm high perspex light pipe (b), on a Dumont 6292 photomultiplier (c). An aluminium sheet of 0.18 mgr/cm^2 (d) covers the crystal and the light-pipe.

To avoid the counting of protons from (γ, p) reactions in the sorrounding metallic structures, a foil of polythene (e) of 2 mm thickness is placed over the crystal and absorbs protons with an energy up to 15 MeV.

The detector is screened by a 80 mm thick cylinder of Pb (f) with a 20 mm collimation hole (g) coaxial with the crystal (a).

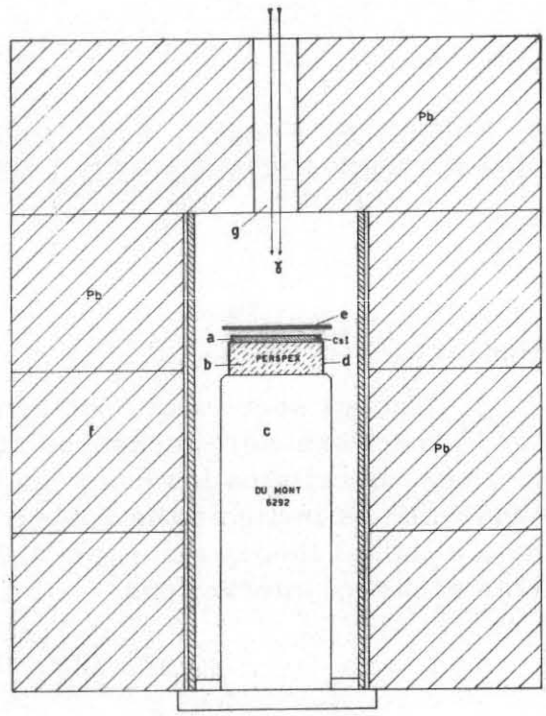

Fig. 1

The signals from the photomultiplier were sent to a discriminator circuit and analysed by a 100 channel pulse hight analyser. The block diagram of the electronic apparatus is outlined in fig. 2; it is similar to that used by Marcazzan and al. [1].

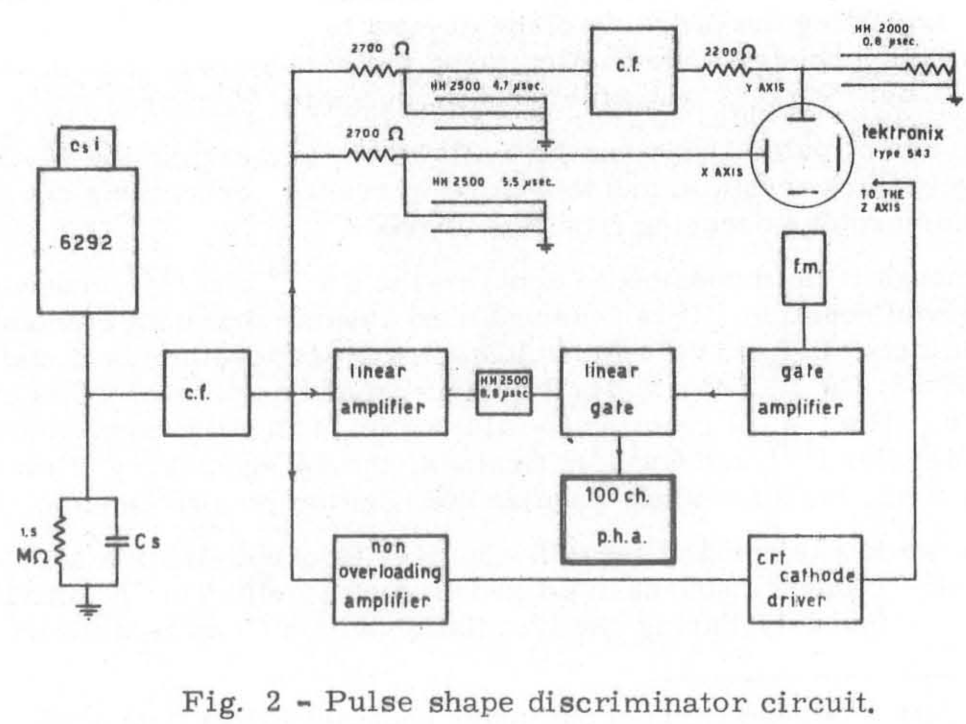

Fig. 2 - Pulse shape discriminator circuit.

The calibration of the proton energy scale was made with 3.9 and 8.77 MeV α-particles from a natural Th source. The energy calibration curves given by Dixon[2] for α and p in a CsI crystal were used.

Experimental results and discussion. -

The experimental spectrum of protons, representing a total of 22700 counts, is shown in fig. 3. This spectrum was obtained in a series of successive runs for a total irradiation time of 260 hours.

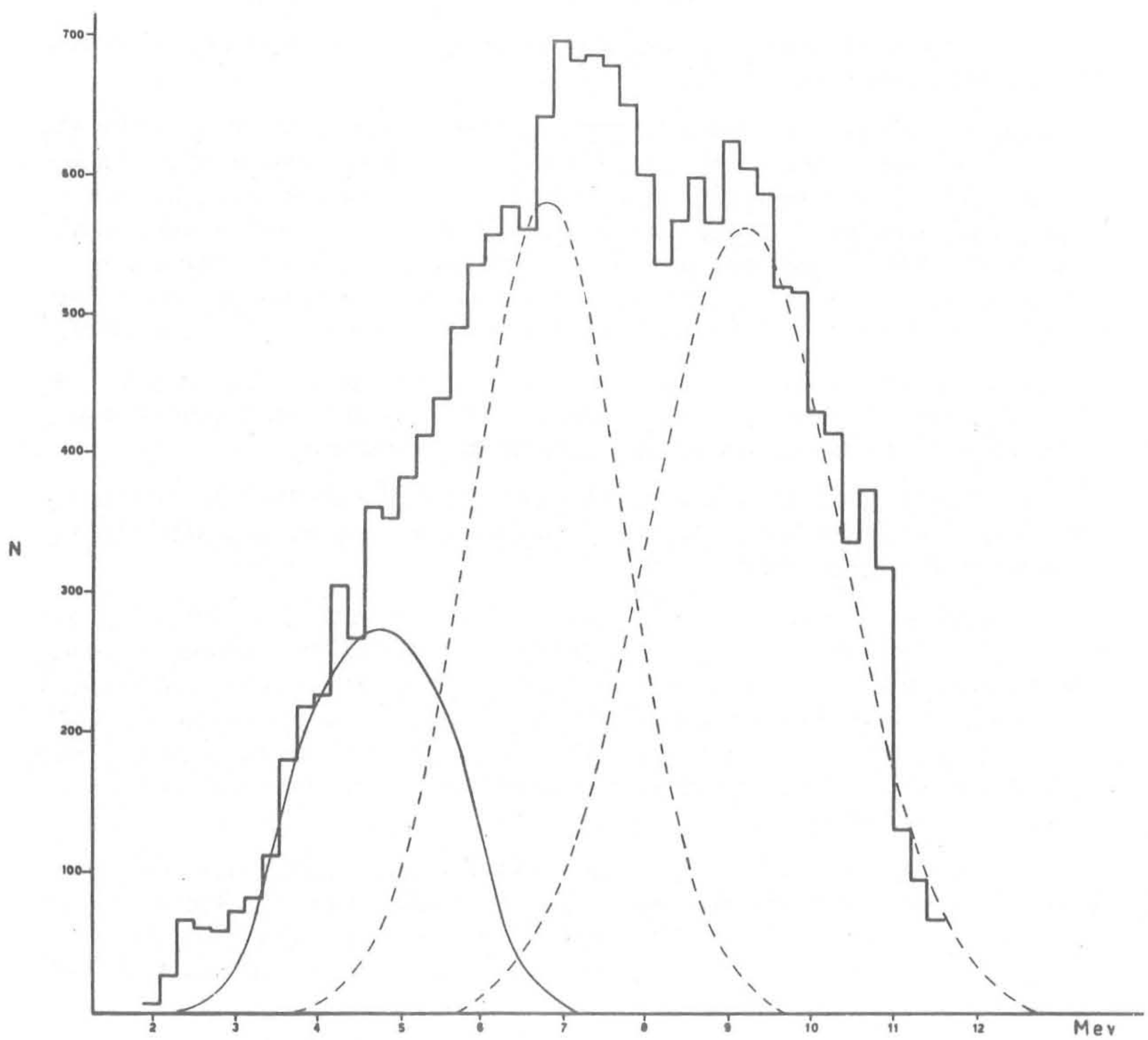

Fig. 3 - Experimental spectrum of protons.

The following corrections were applied to the spectrum:

a) correction for protons escaping from the crystal, due to its particular geometry;
b) correction for the protons due to (n, p) reactions in Cs and I and the recoil protons in polythene. Neutrons are produced by a $Li^7(d,n)$ reaction, with deuterons from our unanalysed proton beam.

The correction (a) was calculated assuming an isotropic angular distribution of protons; and was found to change from 5% for 6 MeV protons to 10% for 10 MeV protons.

For correction (b), the number of protons due to neutrons from $Li^7(d,n)$ was determined from the yield of the reaction and the (n,p) cross-section in CsI. They do not alter substantially the spectrum shape.

The corrected spectrum seems to be in agreement with that of Sébaoun(3) and Bormann-Neuert(4).

Fig. 4 shows an analysis of the spectrum made according to the statistical theory. We plotted $\ln N(\varepsilon)/\varepsilon \times \sigma_c(\varepsilon)$ versus ε, where $N(\varepsilon)$ is the number of protons of energy ε, and $\sigma_c(\varepsilon)$ is the cross-section for the reverse process. Values of $\sigma_c(\varepsilon)$ were taken from Shapiro's(5) work, assuming $r_o = 1.5 \times 10^{-13}$ cm. The plot shows that the spectrum in the lower energy region corresponds to a nuclear evaporation process of the form: $N_p(\varepsilon) = \text{cost}\, \varepsilon \cdot \sigma_c(\varepsilon)\, e^{-\varepsilon/\vartheta}$ with a nuclear temperature $\vartheta = 0.23$ MeV.

The high energy part of the spectrum, can be attributed to direct interactions, possibly two peaks are separable, one at 7 MeV and one at 9 MeV, in spite of the poor resolving power of the apparatus.

The analysis of the experimental spectrum shows that the protons emitted from the statistical process are about 21% of those produced by the resonance direct mechanism.

According to Wilkinson's(6) theory for elements with Z=53-55, the ratio of proton emission to total absorption is 0.85% in the case of a bremsstrahlung beam with 23 MeV maximum energy. The same ratio, calculated by Weinstock(7) with the statistical theory for bremsstrahlung of 22 MeV maximum energy is 0.2%. Therefore the ratio between the evaporative process and the Wilkinson theory should be about 23%. This value is in good agreement with our experimental value of 21%.

To calculate the $\sigma(\gamma, p)$, it was assumed that Cs^{133} and I^{127} were identical in behaviour, and that the cross-sections with 14.8 MeV incident γ-rays was equal to that with 17.6 MeV γ-ray. The last assumption is reasonable because the maximum of the giant resonance is at 15.2 MeV for Iodine and at 16.0 MeV for Cesium.

We estimated that the cross-sections for $Cs^{133}(\gamma, p)$ and $I^{127}(\gamma, p)$ reactions were : 2.5 ± 0.8 mbarn.

This value is to be compared with 1.5 mbarn obtained by Sébaoun(3) and Kestelyi-Erő(8) for the same reactions.

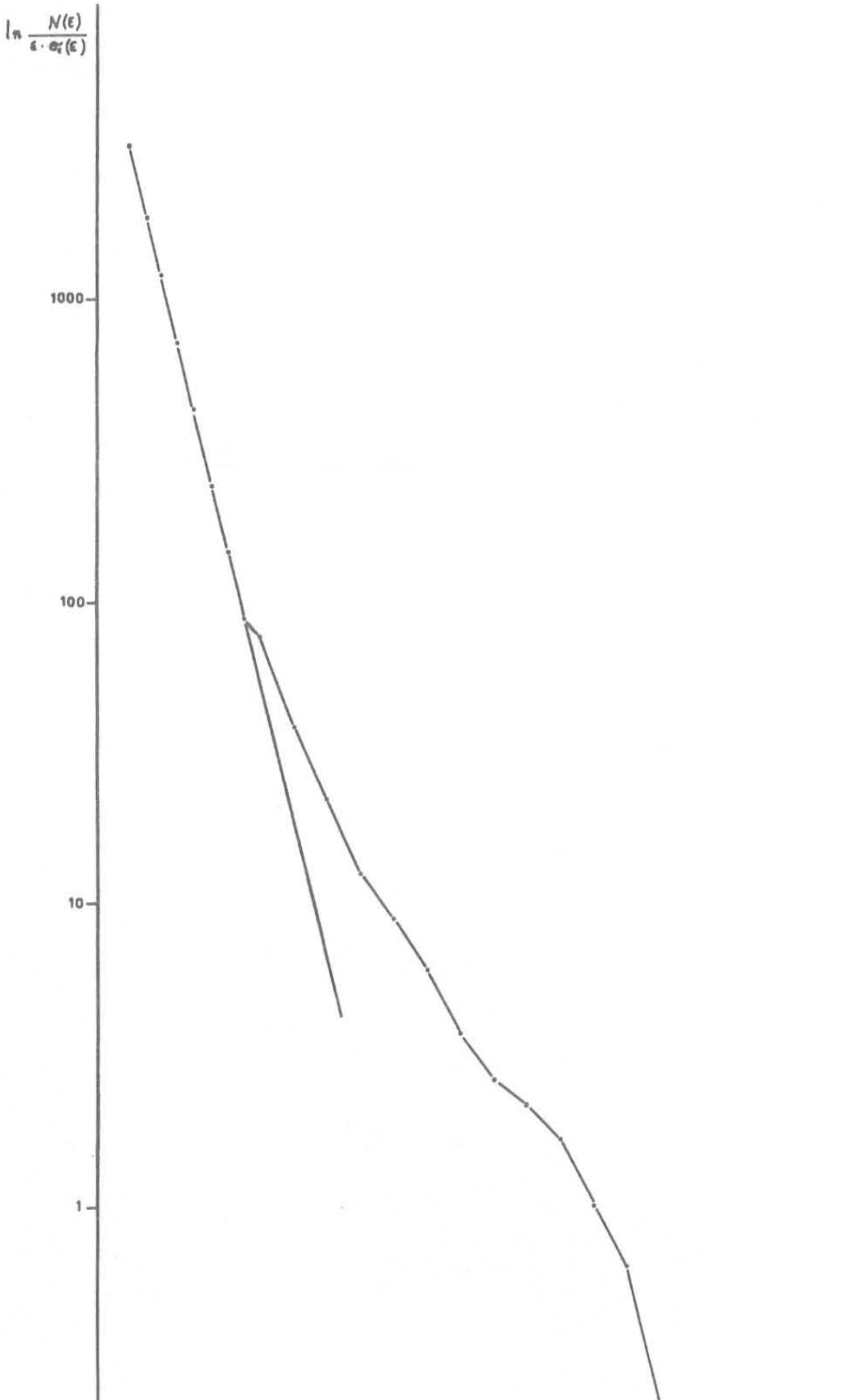
ln $\frac{N(\varepsilon)}{\varepsilon \cdot \sigma_i(\varepsilon)}$
1000
100
10
1
0,1
3
4
5
6
7
8
9
10
11
Mev

FIG. 4

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