ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна



E15-95-236

A.S.Fomichev, I.David, M.P.Ivanov, I.V.Kuznetzov,
V.F.Kushniruk, S.M.Lukyanov, L.V.Mikhailov, Yu.G.Sobolev

# A NOTE ON THE APPLICATION OF CsI(Tl)-COUNTER TO LIGHT CHARGED PARTICLE DETECTION IN THE SPONTANEOUS FISSION OF $^{252}$Cf

Submitted to «Nuclear Instruments and Methods»

1995

The rare modes of heavy nuclei spontaneous fission accompanied by light charged particles (LCP) emission appear a subject of experimental and theoretical investigations for a long time [1-3]. At the present time numerous data are obtained and it was established that energy spectra of LCP (with excepting of proton data) may be well approximated by gaussian form. Most probable energies and the widths of energy distributions of particles have a weak dependence on $Z^2/A$ parameter in wide range of *Z* and *A* fissioned nuclei. At the same time in the proton energy spectra a low-energy component with $E_p \leq 4$ MeV was observed. This cannot be explained as a contribution of the background from (n,p) or (α,p) reactions [4].

Usually LCP emission has been measured by the different ΔE-E telescopes [1-5] which allow to detect the particles with energy threshold ≈1-2 MeV/A. As it will be shown in this paper the same threshold of measurement can be reached by pulse shape analysis method (PSA) of particles identification using single CsI(Tl) counter [6,7]. Two CsI crystals with the thickness of 0.25 mm and 1.6 mm were tested. The thin detector has a low sensitivity to gamma rays emission and therefore it has the best quality of particles separation. However, the thick crystal is much more suitable for energy measurements of long range charged particles, especially the proton.

Spontaneous fission source $^{252}$Cf with the intensity of $\approx 2*10^4$ ff/s was situated at a distance of 5 mm from the scintillator. The 20 μm Al foil was installed to absorb the natural α-activity and the fission fragments of $^{252}$Cf. The scintillation counter consisted of CsI(Tl) crystal (manufactured by the Harshow Chemical Company) with the size of 10x10x1.6 mm$^3$ or 10x10x0.25 mm$^3$ and photomultiplier FEU-87 with the photocathode diameter of 15 mm. Both crystals had a 5.5 μm aluminized mylar reflector on the front polished surface. The thin crystal was optically connected to the 3 mm plexiglass light quide.

Scheme of data acquisition is shown in fig.1a. It was based on the linear split-box (Fan-In/Fan-Out), two QDC modules (LeCroy, Model 2249W) needed for integration of different paths of the light output signal (front and tail) and one ADC module for total light output collection. Thus one can observe 3 different matrices caused by these parameters. The best particles identification was obtained by $L(T_1)$ versus $L(T_2)$ plot, but for the precision energy measurements of LCP the $L_{tot}$-$L(T_2)$ spectrum was used. The best values of gate duration, delay line between two gates and shaping constant of the spectroscopic amplifier were chosen as: $T_1$=0.4 μs, $T_2$=2 μs, $t_1$=0 μs, $t_2$=1 μs, $\tau_{SA}$ =1.5 μs, respectively. The counting scheme was triggered by CFD signals with the energy threshold about 4 MeV on α-particles scale. Two-dimensional plot $L(T_1)$ versus $L_{tot}$ of α-γ separation from $^{226}$Ra source for the thin CsI(Tl) detector is shown in fig.1b. Here the single calibration spectrum for the total light output collection is presented too. For this CsI counter energy resolutions ($E_\alpha$=7.68 MeV) were equal to 8%, 6% and 5%, respectively, at the $T_2$, $T_1$ gates and with shaping constant 1.5 μs in the spectroscopy channel. The same results were also reached for the thick detector.

The measurement of LCP energy spectra from $^{252}$Cf source was about 60 hours for the both crystals. The results for the 1.6 mm CsI(Tl) crystal are plotted in fig.2 and fig.3(a,b,c). In this case the energy threshold of particles separation was equal to 1.5 MeV/A whereas for the thin crystal it was equal to 1.2 MeV/A. As seen from fig.2 the particles with *Z*=3 and *Z*=4 are well separated. The data were analysed to extract the total yields of p, t, α, Li and Be isotopes accompaning the fission of $^{252}$Cf, see table 1. The tritium and alpha spectra were approximated by gaussians with the most probable energies and widths (FWHM) as follows: $E_\alpha$=15.9 ± 0.6 MeV, $\Gamma_\alpha$=11.1 ± 0.5 MeV and $E_t$=8.7 ± 0.7 MeV, $\Gamma_t$=6.3 ± 0.8 MeV. Good agreement with the results of [3] was found. Proton spectrum manifests a more complicated form, it was fitted by two gaussians with the most probable energies $E_{p1}$=3.5 ± 0.2 MeV and $E_{p2}$= 8.5 ± 1.5 MeV. These values are in coincidence with early results obtained by silicon detectors [4]. The energy calibration for *p* and *t* was achieved taking into account that the total light output of CsI(Tl) detector is a simple function of $\varepsilon=E^{3/2}/(A^{1/2} Z^{2/3})$ at low energy [8]. Moreover the recoil protons from Pu(Be) source with $E_p$=2.2 MeV were used to check this calibration. Because of low statistics most probable energies and the widths of energy distributions of Li and Be isotopes were not extracted in these measurements.



In summary, the possibility to use CsI(Tl) for the identification of LCP in the spontaneous fission start up E≥1.5 MeV/A is demonstrated. A low sensitivity of this counter to neutron and gamma background was shown. There is a current interest in the reaction channel identification in connection with a rare mode of simultaneous α-α, α-p emission [9]. For this purpose a 4π array of thin CsI(Tl) scintillators could be used for energy and angular distribution measurements of LCP accompaning fission of different spontaneous sources.

The authors would like to thank Prof. V.V.Avdeichikov for useful discussion.

The authors acknowledge the support of the RFFI (Project 95-02-05676-a).

Table 1. Parameters of light charged particles spectra emitted in triple fission of $^{252}$Cf.

| LCP | $E_{avr}$ (MeV) | FWHM (MeV) | Yield per $10^4$ α |
|---|---|---|---|
| p | 8.5 ± 1.0 | 7.2 ± 1.5 | 186 ± 35 |
| t | 8.7 ± 0.7 | 6.3 ± 0.8 | 798 ± 77 |
| α | 15.9 ± 0.6 | 11.1 ± 0.5 | 10000 |
| Li | | | 28 ± 13 |
| Be | | | 63 ± 22 |

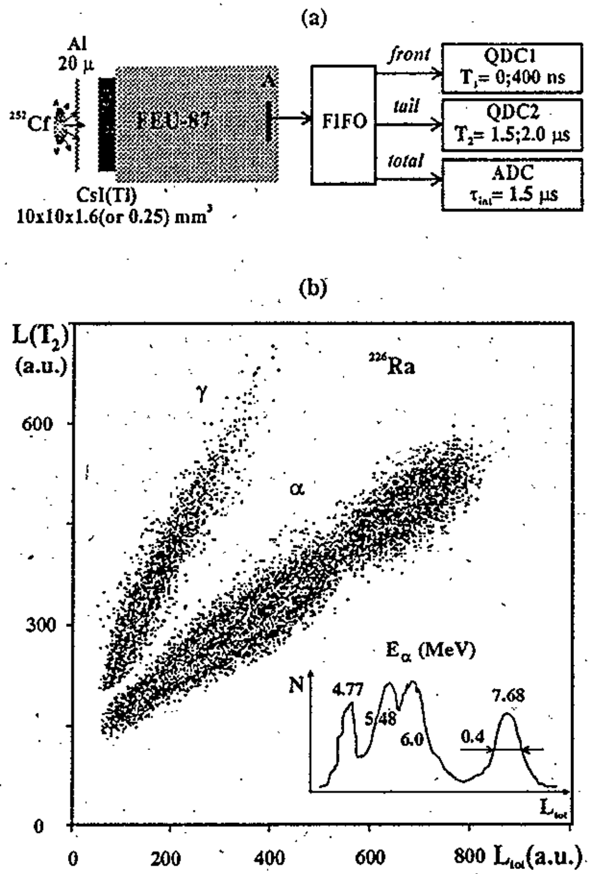


Fig.1. Layout of the electronics (a) and calibration spectrum from a $^{226}$Ra source measured with the 0.25 mm CsI(Tl) detector(b).



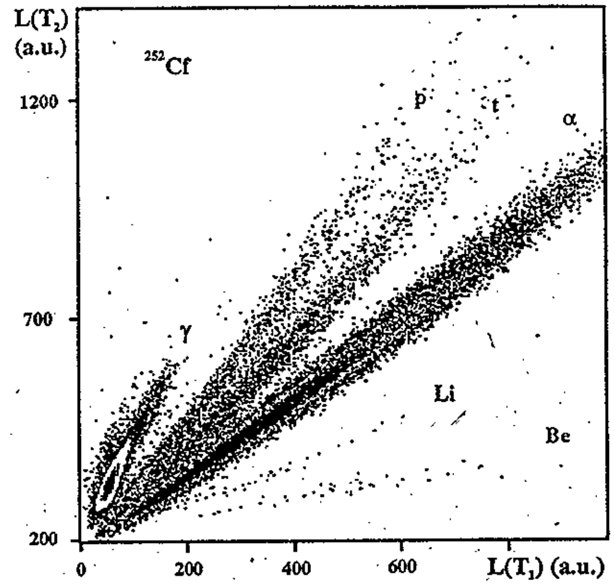


Fig.2. The identification of LCP in the spontaneous fission of $^{252}$Cf by PSA method with the 1.6 mm CsI(Tl) detector.

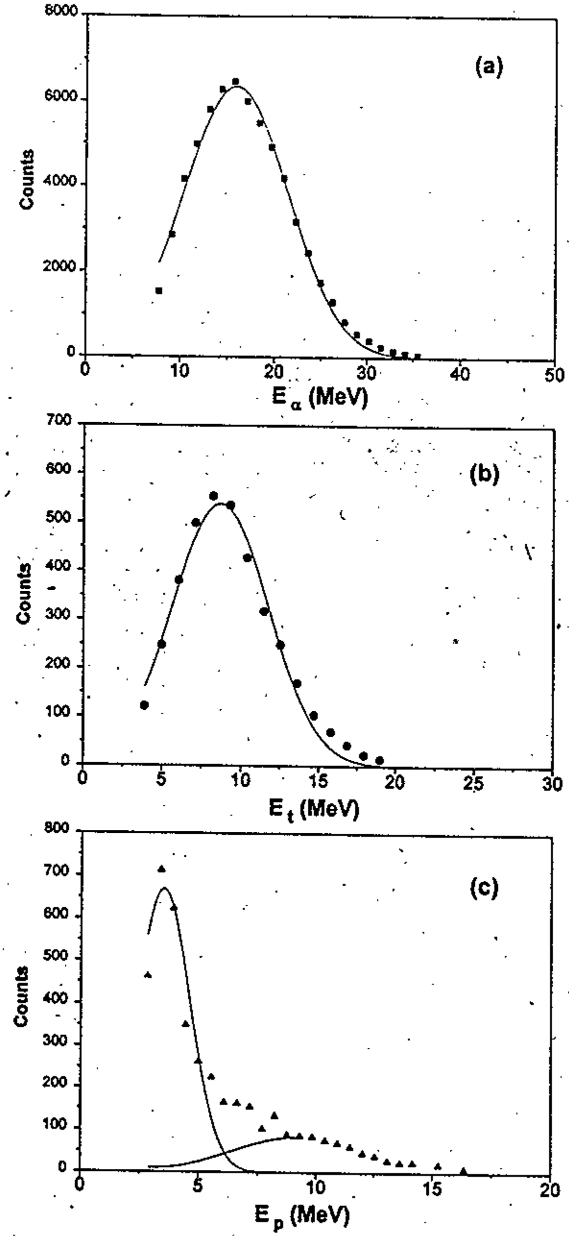


Fig.3. Measured energy distributions of protons, tritons and alpha-particles (symbols) and gaussian approximations (lines).



## References

[1] I. Halpern, Ann.Rev.Nucl.Sci. 21 (1971) 245 and ref. therein.
[2] J. Theobald, Proc.Int.Scholl-Seminar on Heavy Ion Phys., Dubna, Russia, 1993, eds. Yu.Ts. Oganessian, Yu.E. Penionzhkevich, R. Kalpakchieva, E7-93-274, v.1, p.262.
[3] J.F. Wild et al., Phys.Rev. C32 (1985) 488 and ref. therein.
[4] I.V. Kuznetzov et al., JINR Rapid Com. 3[66]-94 Dubna (1994) 30.
[5] M.P. Ivanov et al., JINR Rapid Com. 2[65]-94 Dubna (1994) 55.
[6] A.S. Fomichev et al., Nucl.Instr.and Meth. A344 (1994) 378.
[7] A.S. Fomichev et al., Nucl.Instr.and Meth. A350 (1994) 605.
[8] F. Benrachi et al., Nucl.Instr.and Meth. A281 (1989) 137.
[9] S.K. Kataria, E.Nardi and S.G.Thompson, IAEA-SM-174/63 (1973) p.389

Received by Publishing Department
on June 2, 1995.