Characterization of a facility for the measurement of fission fragment transport effects: experimental determination of the fission rates for fissile and fissionable isotopes

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Abstract

The transfer facility of the LENA laboratory allows the direct neutron irradiation of fissionable material in the D channel of the TRIGA reactor. A test measurement carried out with a ionization chamber and a ^{239}Pu sample shows the possibility to use this tool for the study of the transport effects of the fission fragment emerging from thin layers of fissile materials.

1. Introduction

The study of the transport effects of the fission fragment emerging from thin layers of fissile material is object of interest from the INFN which supports to this purpose a dedicated experimental programme (see for example references [1] and [2]). The proposed measurements consist of neutron irradiation of fissionable isotopes and the determination of the fission fragment energy by means of a ionization chamber. The LENA laboratory is an ideal place to carry out these measurements, since recently came out the possibility to use, for the neutron irradiation, the D channel of the TRIGA reactor thanks to a dedicated transfer facility.

In this work we briefly describe the main characteristics of the LENA transfer facility and we presents some preliminary test results obtained with a ionization chamber and a ^{239}Pu sample.

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2. The Lena Transfer facility

The facility, a part of which is diplayed in fig. 1, consists of a transfer device, “train”, which is able to run along a “rail” as far as the opening of the channel D of the TRIGA reactor.

The whole facility finds place inside a radiation shield, which is composed by two parts (see fig. 2):

1. The beam dump. It consists of baryte-concrete and colemanite-concrete blocks set in front of the channel D opening. It covers a volume of about 3×3×3 m^3.
2. The facility tunnel. It consists of baryte-concrete bricks. The tunnel, which extend from the beam dump, is 5000 mm long, 1300 mm high and 850 mm large.

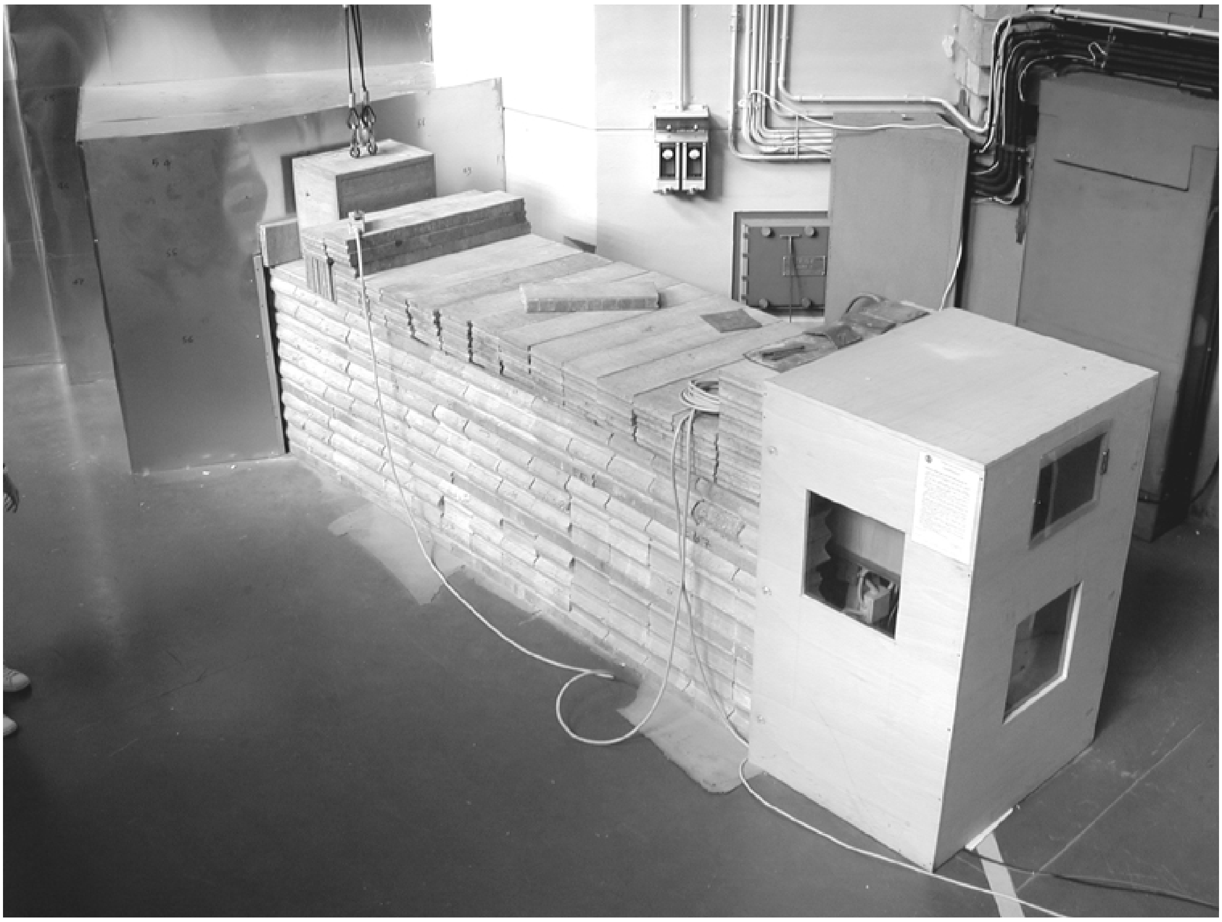

Fig 1: The transfer facility tunnel in the LENA reactor hall.

The rail, physically realized with an aluminium band, is about 7000 mm long. The first rectilinear part, about 5000 mm long, is fully contained in the facility tunnel and is used for the train loading and movement. This part is protected against the dust by an internal structure made of policarbonate and wood layers. Inside the beam dump the rail develops into two bending ways and into a final rectilinear part which ends just in front to the channel D opening where the maximum neutron flux intensity, coming directly from the reactor core, is the order of 10^7 neutron cm^2 s^{-1}.

The train, 4950 mm long, is made up with 23 aluminium trolleys and joints. The first two trolleys support the ionization chamber and a preamplifier. The remaining allows the signal cable laying and running during the train displacement. The last trolley is connected to a drag cable which allows the train movement by means of an electromotor closed inside a wood protecting frame.

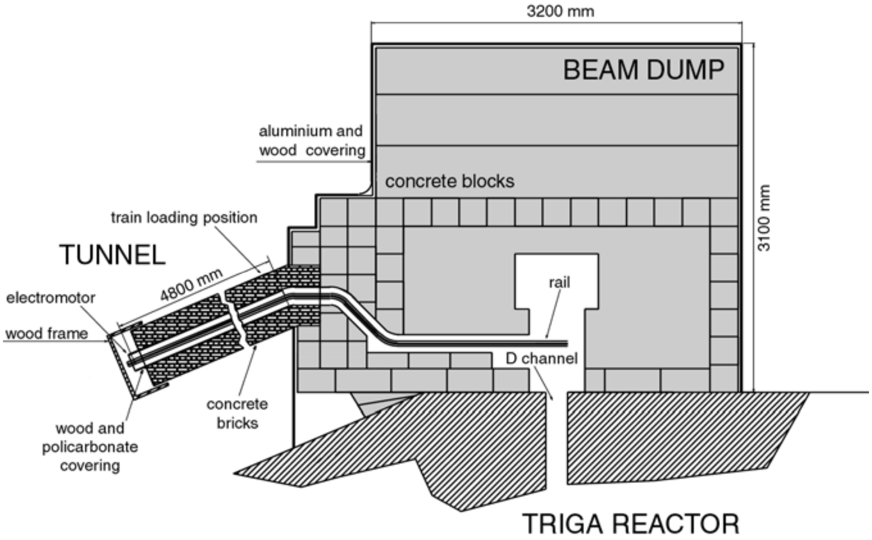

Fig 2: The transfer facility set-up in the LENA reactor hall.

3. The ionization chamber

The ionization chamber used for the measurements was especially realized for the mounting on the LENA transfer facility. The main geometrical characteristics are presented in figure 3. It consists of an aluminium box ($100\times100\times88\ \mathrm{mm}^3$) connected to a KF-flanged aluminium valve. The internal cylindrical-shaped cavity contains two aluminium electrodes and a grid, mounted on a peek sustaining structure. The cathode disk (∅ = 80 mm, 3 mm thickness) has a central hollow (∅ = 25 mm) where is possible to fix the fissionable sample to test. The anode (∅ = 80 mm, 2 mm thickness) is composed by an external ring, used as field shaper, and an internal disk (∅ = 50 mm), used for the charge collection. Between the two electrodes find place the screening grid realized with 150 μm stainless-steel wire mounted on a circular aluminium frame (∅ = 80 mm). The grid position, 30 mm far from the cathode and 15 mm far from the anode, defines the relation between the electric fields in the ionisation (E_D) and in the drift (E_I) region

$$E_D=2E_I$$

which allows the complete transparency of the grid to the ionisation electrons.

The electronics used for the test is typical for this type of detector. The voltage, coming from the counting room using a 15 m RG58 cable, is distributed to the electrodes by means of a MHV connector and an internal resistive voltage divider (20 MΩ + 20 MΩ). The anode, which acts as charge collector, feeds, by means of a BNC connector and a short (300 mm) RG58 cable, an integrating preamplifier (ORTEC 142A) mounted on the second train trolley. The output signal, by means of a 15 m RG58 cable, feeds a shaper amplifier (ORTEC 572) in the counting room. The data acquisition is accomplished by means of a multichannel analyzer card (MCA, ORTEC TRUMP) plugged in a personal computer in the counting room.

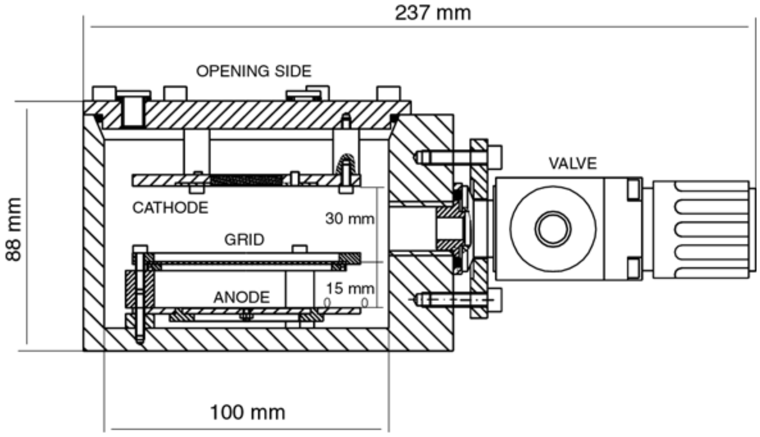

Fig 3: Geometrical characteristics of the ionization chamber.

The sample loading is accomplished by removing the upper side of the device which supports the cathode disk. The sample is placed in the cathode hollow. The chamber is closed back in order to proceed to the vacuum and gas-filling phase. This phase is carried on in the radiochemical hall of the LENA laboratory connecting the chamber valve to a dedicated set-up. This consists of a gas distributor provided with two valves, a pressure gauge, a vacuum pump and an argon-methane bottle.

The ionization chamber is mounted on the first train trolley by removing some of the bricks of the external tunnel. The chamber is positioned on the train with the electrodes parallel to the rail but in crosswise way with respect to the horizontal direction. In this way, once the detector is transferred in the irradiation position, the neutron beam coming from the D channel crosses, as first, the cathode with the maximum cross section.

4. Test run and results

The facility and the ionization chamber above described were used during a test run in June 2002 in order to make experience with the system and to define the best operating conditions for future measurements. We describe the adopted procedure and the obtained results.

Tables 1 summarize the operating condition of the ionisation chamber during the test.

Table 1

Operating condition of the ionization chamber.

Gas mixture	argon (90%) methane (10%)
Gas pressure	≈ 1 bar (absolute)
H.V.	1000 V
Fissionable material	^{239}Pu (4 kBq α) 1.3 μg

The chamber was mounted on the train by removing some of the tunnel bricks during a stop of the TRIGA reactor. The chamber was transferred to the irradiation position and a complete electronics check was carried out. The removed bricks were placed in their original position and the irradiation phase was started.

The frequency spectra for different nuclear reactor powers (0W, 100 W, 10 kW) are shown in figure 4. The data frequency is displayed as a function of the MCA channel which is proportional to the ionizazion charge and codes the kinetic energy of the interacting particles (gamma-rays, alpha-particles, fission fragments). From the figure three different distributions can be identified:

3. The background gamma-ray activity in the channel D;
4. The alpha activity of the ^{239}Pu source;
5. The induced ^{239}Pu fission fragments.

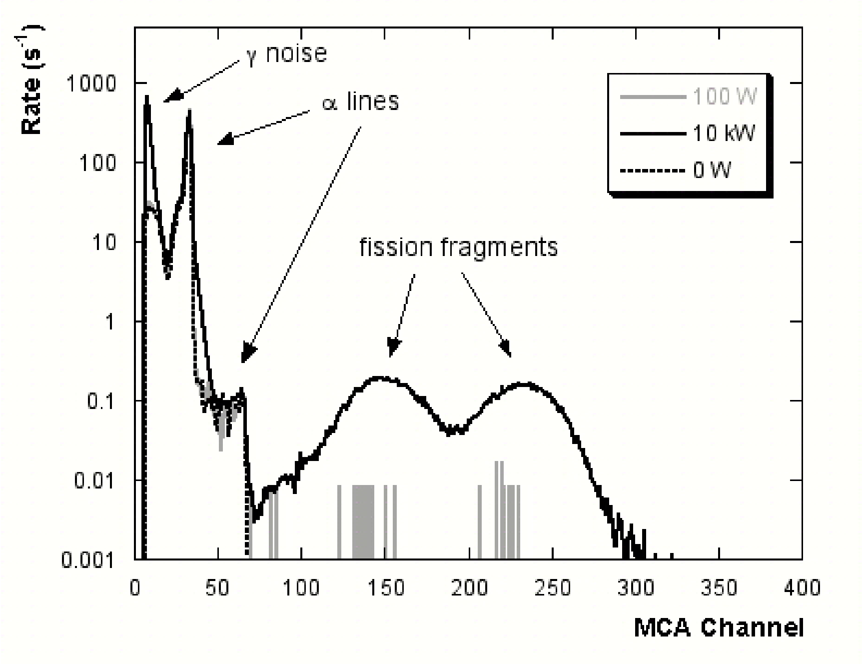

Fig 4: ^{239}Pu FF frequency spectra for different nuclear reactor powers (0W, 100 W, 10 kW).

The background gamma-ray radiation gives rise to low energy events which bypass the electronics threshold of the acquisition system. Its presence could be the cause of electronic pile-up and acquisition dead-time when high reactor powers are used.

The alpha activity of the ^{239}Pu source is shown by the presence of two peaks the rate of which does not depend on the nuclear reactor power. The measured total rate, 1200 CPS, is in good agreement with the source declared data (3 kBq corresponding to 1500 CPS in 2π st solid angle).

The induced fission activity of the ^{239}Pu source is shown by the presence, in the spectra acquired with the reactor on, of the two typical peaks induced by the heavy and by the light fragments. The rate of this events is proportional to the nuclear reactor power (see table 2).

Table 2

Fission fragment (FF) frequency during the ^{239}Pu irradiation.

Reactor power	FF rate (CPS)
0 W	0.0
100 W	0.169
10 kW	16.82

We consider good, for the proposed measurements, irradiation with a maximum reactor power of about 10 kW for which, taking into account the ionization chamber efficiency, the corresponding fission rate of the ^{239}Pu source is 20 fission per second.

5. Conclusions

The obtained results testify a fairly good confidence and reliability in our method of measurement of the fission fragment transport effects making the transfer facility of the LENA laboratory a very good tool for measurements which require the direct irradiation of fissionable material.

Acknowledgments

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References

[1] P. Benetti et al., Measurement of fission fragments energy loss, accepted for publication in Nucl. Instr and Meth. A.

[2] P. Benetti et al., Non-destructive diagnostics of thin fissile layers, 10th Symposium on Radiation Measurements and Applications, Ann Arbor, Michigan USA, 21-23 May 2002, to be published in Nucl. Instr. and Meth. A.