Performance test of a triple GEM detector at CERN n_TOF facility

G. Claps, G. Croci, F. Murtas, A. Pietropaolo, S. Puddu, C.T. Severino, M. Silari

Abstract– **The application of a triple GEM (Gas Electron Multiplier) for neutron detection was tested at the n_TOF facility at CERN. n_TOF allows the neutron energy distribution to be measured via a ~185 m time of flight path. A 20 GeV/c proton beam hits a lead target generating a neutron spectrum ranging from thermal energies to the GeV region. Due to their long flight path and short proton pulse, the neutron arrival times at the experimental area define their energy [1]. A triple GEM detector with a 60 µm Polyethylene (PE) neutron converter and 40 µm of Aluminium, filled with an Ar-CO_2 70-30% mixture, was installed a few meters downstream of the experimental area, just in front of the beam dump. The measurements were purely "parasitic"; they were conducted in parallel and without interfering with the official n_TOF scientific program. Using the n_TOF trigger it is possible to synchronize the GEM data acquisition in order to select a given neutron energy window and measure the detector efficiency as a function of neutron energy. Changing the detector gain, it is possible to perform these measurements with a low γ-background level. Thanks to the pixelated read-out the neutron beam spot and the efficiency of the detector have been measured.**

I. INTRODUCTION

For the first time the performance of a triple GEM detector, coupled with a 60 µm PE neutron converter and 40 µm of Aluminium, was tested at the n_TOF facility at CERN, to examine possible future applications in neutron dosimetry and neutron beam monitoring.

The n_TOF [1] facility allows the neutron energy distribution to be measured via a ~185 m time of flight path. A proton beam with momentum of 20 GeV/c from the Proton Synchrotron (PS) hits a lead target. The produced neutrons are moderated with borated water, in order to introduce a cut in the thermal region [2].

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S. Puddu (tel: +41227673535, e-mail: silvia.puddu@cern.ch) and C. T. Severino are with CERN, 1211 Geneva 23, Switzerland and Universtity of Bern, LHEP, Sidlerstrasse 5, 3012 Bern, Switzerland

F. Murtas is with CERN and LNF-INFN via Fermi 40, 00044 Frascati (Roma) Italy

M. Silari is with CERN

A. Pietropaolo and G. Croci are with CNR-IFP, via R. Cozzi 53, 20125 Milano, Italy

G. Claps is with LNF-INFN

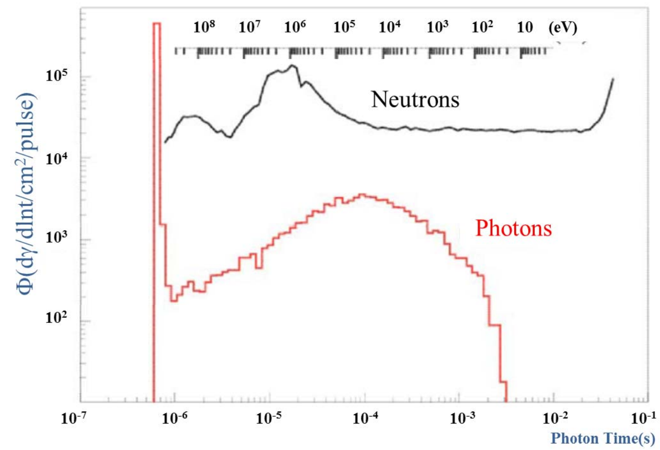

Fig. 1. n_TOF neutron spectrum and γ-background from FLUKA simulations [1]

A neutron energy spectrum is obtained from thermal energies to the GeV region, Fig. 1.

II. EXPERIMENTAL SET-UP

The detector is a prototype optimized for neutron measurements. A triple GEM [3], [4] chamber with a specific fast neutron cathode converter has been used.

As shown in Fig. 2 neutrons are converted into proton in PE thanks to the (n, p) reaction. To ensure direction capability protons that come from neutrons with too wide an angle with respect to the normal of the converter are stopped in the Al layer [5].

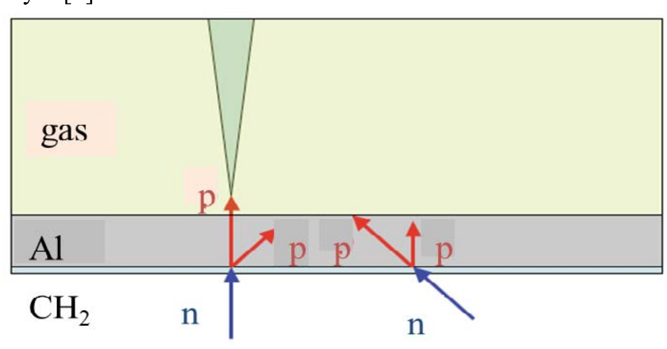

Fig. 2. Coverter and drift zone of triple GEM detector for fast neutrons

The triple GEM is filled with an Ar-CO_2 70-30% gas mixture; the anode has 128 6x12 mm^2 pads organized in an 8x16 matrix, for a total of 10x10 cm^2 sensitive surface. The data acquisition (Fig. 3) is made via a FPGA-based motherboard [6], that can be externally triggered and can also measure the hit rate for each channel.

Several measurements were made in order to evaluate the γ background, the mean efficiency and the efficiency in function of the incoming neutron energy.

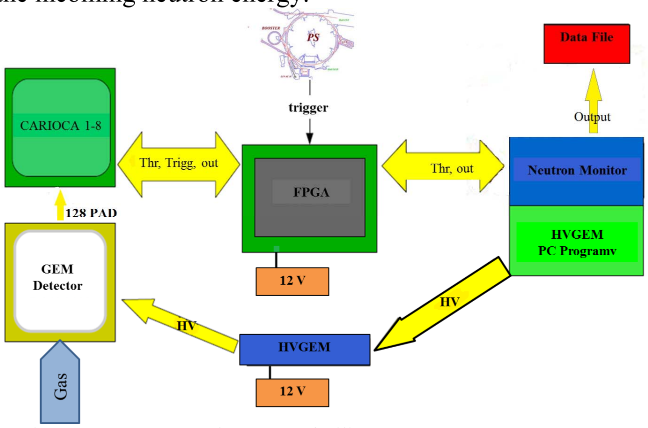

Fig. 3: GEM set up at the n_TOF facility

All measurements were carried out in "parasitic" mode over a period of 3 weeks. The detector was installed between the end of the beam pipe and the beam dump (Fig. 4); 200 m from the spallation target.

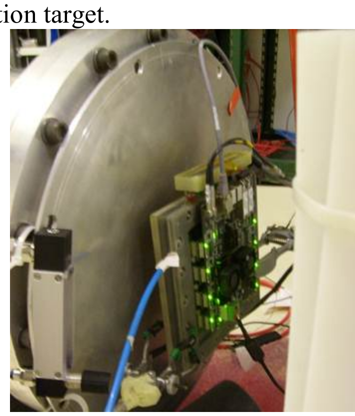

Fig. 4: the GEM installed between the beam pipe and the n_TOF dump

III. Rejection of Gamma Background

The dominant contributions to the γ-background (Fig. 1), come from reactions at the spallation target and are composed of the "γ-flash" from prompt γ-rays and a "slow" component from other reactions such as neutron capture [1]. Due to the proximity to the beam dump there is a secondary contribution from γ-rays due to neutron capture. However, thanks to the possibility to operate the GEM with low gain, it was possible to perform the measurements with the γ-background heavily reduced. In Fig. 5 a GEM gain scan during an n_TOF run and a similar scan with a ^{137}Cs source are compared, the γ-energy emission of which is similar to the n_TOF γ-flash [1].

For this proposal the GEM was randomly triggered with a 1 s gate. The insensitivity to the γ-background was assessed with a measurement triggering the acquisition in the neutron thermal region (where (n, p) reactions do not occur in the PE converter and the signal in the GEM would only be due to the γ-background). To have a high rejection factor a working point of 870 V has been chosen.

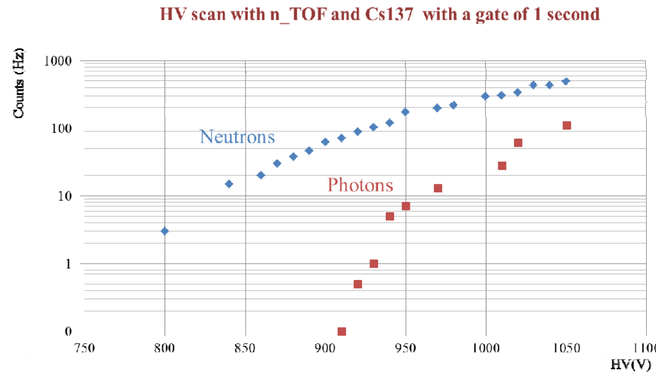

Fig. 5: Gain scan for n_TOF and a Cs-137 source

IV. Mean Efficiency and Beam Profile

Two kind of PS beams arrive at the spallation target, that are different essentially for the proton intensity. Thanks to this peculiarity, correlation and then the mean efficiency were measured (Fig. 6).

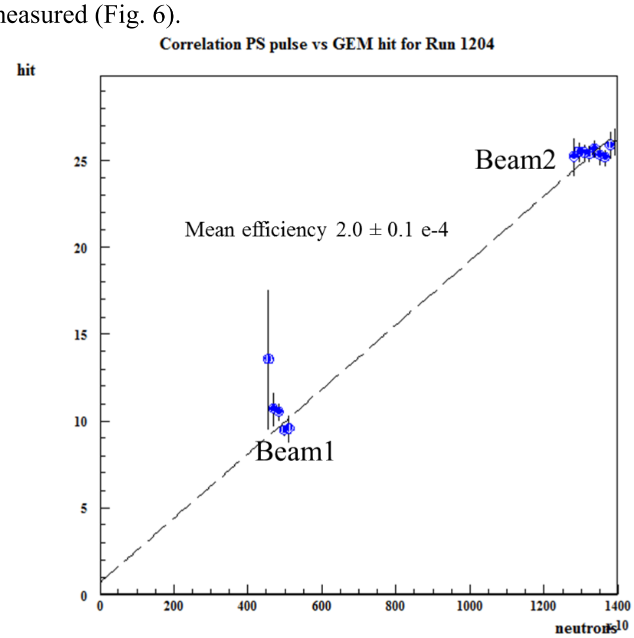

Fig. 6: correlation and efficiency

With a trigger delay of 2 µs, to avoid γ-flash and a gate of 10 ms the 2D beam spot was measured as shown in fig. 7.

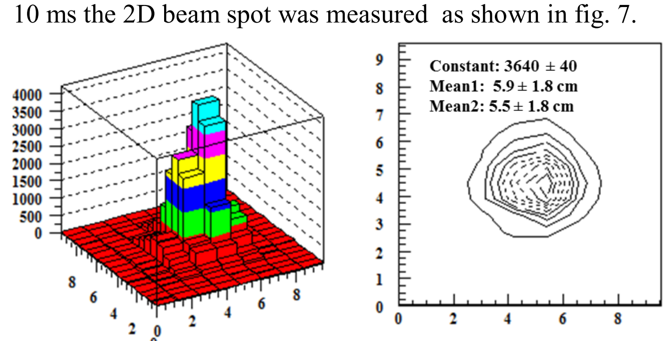

Fig. 7: beam profile

V. NEUTRON ENERGY SCAN

Thanks to the FPGA software, delays from the PS trigger can be set ranging from 4.7 µs up to 63.7 µs in order to select the TOF (i.e. the energy) of the detected neutrons. The acquisition gate was changed from 100 ns up to 5 µs. Thanks to this procedure the efficiency in function of incoming neutron energy can be measured. In fig. 8 the comparison between neutrons that arrive at the detector and GEM counts is shown.

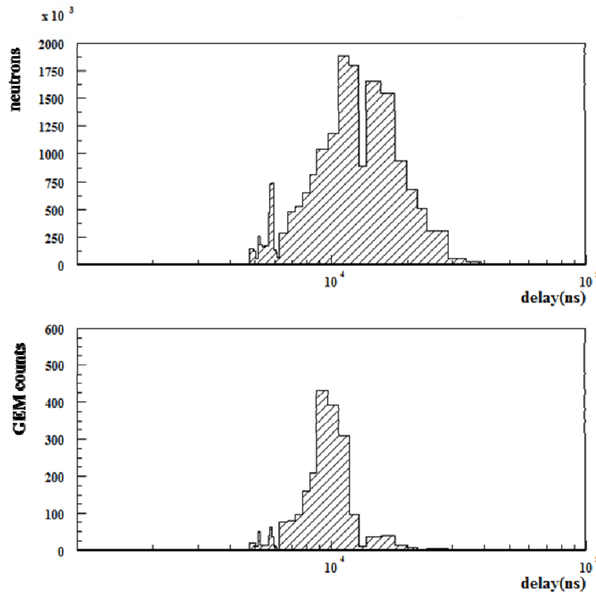

Fig. 8: Comparison between estimated neutron at the detector and GEM counts

The efficiency in function of neutron energy is shown in Fig. 9. Errors was calculated to be between 0.1% and 1%, large oscillations in the first part of the spectrum need to be investigated because of the poor statistics in this region.

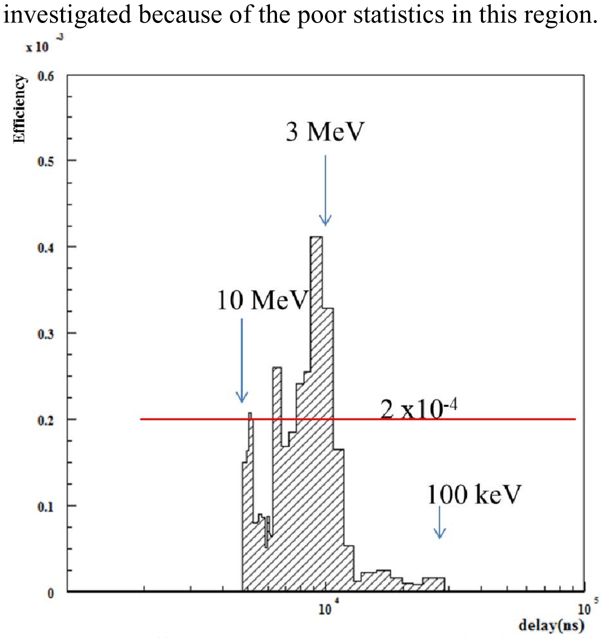

Fig. 9: GEM efficiency VS neutron TOF compared with mean efficiency

VI. CONCLUSION

A triple GEM detector coupled with a fast neutron converter was tested at n_TOF facility at CERN, showing a high γ rejection. The response of the detector is linear and the mean efficiency was measured as $2x10^{-4}$. The 2D beam spot is well recognized. Thanks to the FPGA-based acquisition, the behavior of the detector as a function of incoming neutron energy was measured.

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