A transparent XY MicroMegas neutron beam detector:

Intermediate Report

E. Berthoumieux, E. Ferrer-Ribas, F. Gunsing,
M. Kebbiri, Th. Papaevangelou, M. Diakaki, E. Dupont,
E. Monmarthe, D. Desforge, D. Jourde, S. Anvar, P. Sizun
CEA Saclay, Irfu, F-91191 Gif-sur-Yvette

L. Tassan-Got, L. Audouin
CNRS-IN2P3-IPN, F-91406 Orsay

October 25, 2014

Theme:

- Capteurs de nouvelle génération et leurs retombées

Subvention received:

- 43 kEUR (2013-2015)

1 Project Goals

This project aims to develop a Micromegas detector based on microbulk technology with an embedded XY strip structure, obtained by segmenting both the mesh and the anode. The mesh strips provide the Y information, while the anode strips provide the X information. This will result in a very low-mass device with good energy resolution capabilities. Such a detector will be practically “transparent” to neutrons, being ideal for in-beam neutron measurements like flux and profile monitoring with minimal beam perturbation and very suitable for neutron time-of-flight facilities. The proposed development simplifies and accelerates enormously the 2D microbulk production procedure, making economically possible the construction of large-area microbulk detectors, appropriate for rare event experiments such as dark matter searches. The segmentation of the mesh requires the development of an on-board data acquisition system with capability of triggering on each channel. This acquisition system is based on the GET (Generic Electronics for TPC) system.
The goal of this project is to develop and test a working prototype neutron detector with the development of the low-mass XY segmented mesh-anode microbulk detector together with the on-board data acquisition system. It will be used in real neutron beams of time-of-flight

facilities (CERN n_TOF EAR1 and EAR2, JRC-IRMM GELINA) to measure the neutron flux without disturbing it (a ''transparent'' detector).

2 Description of work achieved

2.1 Development of the microbulk XY detector

The characterization of a neutron beam is essential for most applications. One of the challenges in the study of neutron-induced reactions is to determine both the number of incident neutrons and their spatial distribution. Neutron beams are typically used with a diameter of a few centimeters and are often not spatially uniform in intensity. The total number of neutrons is usually measured with a beam flux monitor, counting the number of incident neutrons with a low-mass reaction chamber. In this case experiments can be performed downstream of the detector.

For the project a first development of the segmented mesh and anode has been performed at the Microbulk Laboratory at CERN with the mesh and anode each divided into a number of 20 strips. Although the technique is within reach, investigation and testing was a necessary preliminary step. Three different prototypes were built and tested in order to find the optimum design in term of mesh hole diameter and their corresponding spacing, as well as in the interstrip spacing at the mesh level. The goal of this optimisation was to ensure the feasibility construction with an acceptable loss in energy resolution (12.% on the optimum prototype with a ^{55}Fe source instead of 11% achievable using the microbulk technology).The production gave satisfactory results with respect to feasibility and performance. Subsequently, a final Microbulk was designed and produced, consisting of 60x60 strips on a 6x6 cm^2 area, where each strip was spaced by 40 µm and with a repeat distance of 1 mm. The mesh was created using an etching of 60 µm diameter holes with a pitch of 100 µm. This final Microbulk was fixed on a PCB ring for mounting inside the detector chamber. On fig. 1 this configuration is shown.

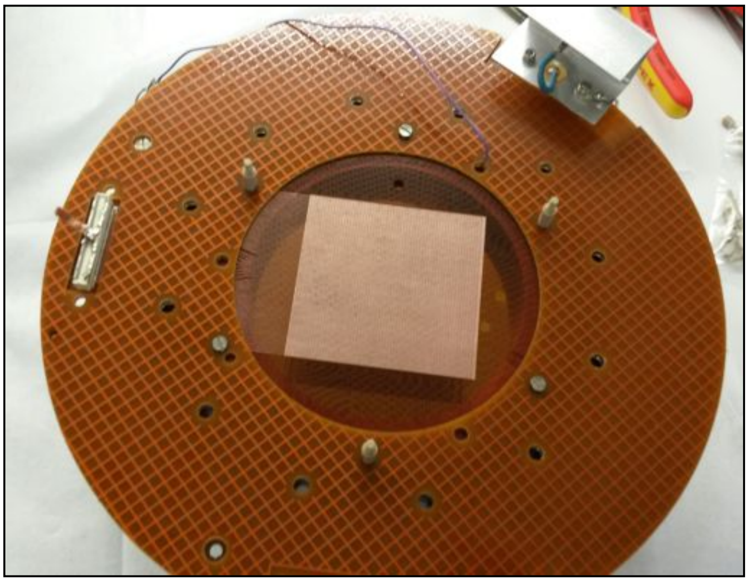

fig. 1 The 6x6 cm^2 microbulk mounted on the PCB ring. The 60 strips on the facing side are clearly visible.

This setup was then tested by shortcutting all strips such that a convention acquisition system could be used, and using a ^{55}Fe 5.9 keV X-ray source. The resolution obtained for the 5.9 keV line was 13.5%, which is only slightly higher than single pad microbulks of this size.

2.2 Development of the AGET acquisition

The AGET acquisition system was implemented in its reduced setup mode, capable of acquiring 256 channels, which is sufficient for one XY detector. A number of 4 AGET on a AsAd board was used as the principal acquisition card. A separate protection circuit was designed to shield the card from the direct output of the microbulk detector and to distribute the high-voltage on each mesh strip. The card and its associated electronics have been tested in stand-alone mode and found working fine. However, the coupling of the card with the detector was not trivial, mainly due to noise problems. These issues are presently under investigation.

2.3 Design of the detector chamber

A detector chamber has been designed which receives the XY microbulk detector together with two independent 4-pad microbulk detectors. Two chambers are shown in figure 2 in a lab configuration.

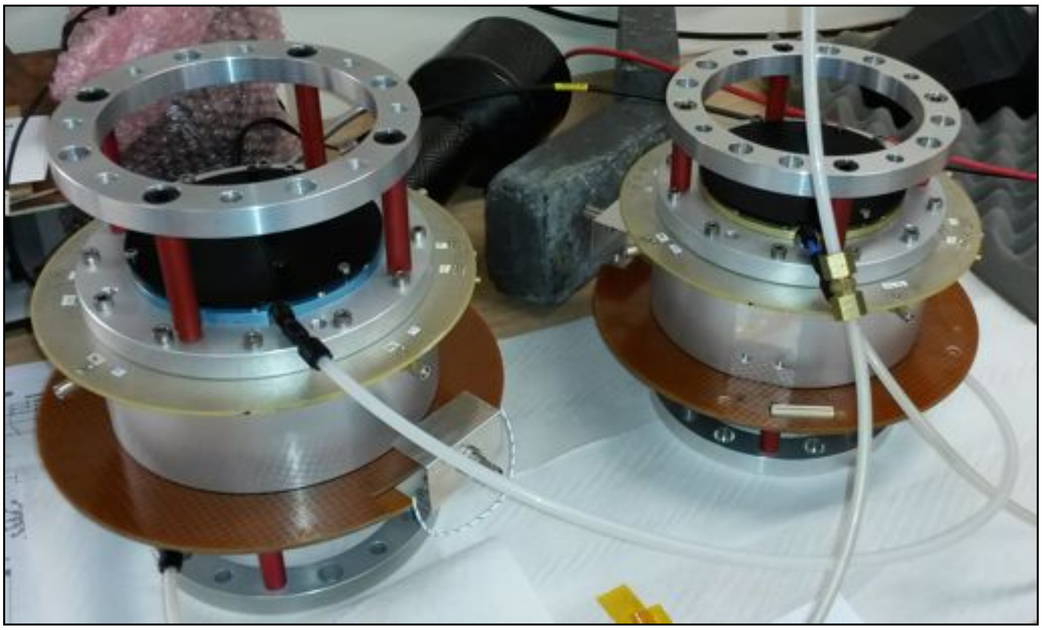

fig. 2. Two detector chambers containing each an XY microbulk in addition to two 4-pad microbulk detectors.

2.4 Neutron converter sample preparation

In this detector a thin deposit of ^{235}U, ^{10}B or ^{6}Li serves as a cathode by converting neutrons into charged particles through reactions with a cross section considered standard like ^{235}U(n,f), ^{10}B(n,α) and ^{6}Li(n,α). Using standard cross sections in combination with neutron time-of-flight allows reconstructing the relative energy distribution of the neutron flux. This is an essential ingredient for the absolute normalization of cross section measurements at a given energy. For the present detector samples of ^{235}U, ^{10}B or ^{6}Li have been produced as thin layers on an aluminized mylar backing (^{10}B or ^{6}Li) and on a thin aluminum backing (^{235}U) by the EC's Joint Research Centre IRMM in Geel.

3 Publications

[1] A. Del Rosso, CERN Bulletin 2014-07-29, http://cds.cern.ch/record/1746358?ln=en
[2] E. Berthoumieux, GET General Meeting VI, Saint Avit de Vialard, 22-25 sept 2014

Since the detector is still in the R&D phase, publications concerning the final instrumentation or with in-beam data are not available yet.

4 Relevance of the project within P2IO and specific added value for P2IO

Microbulk technology is the newest Micromegas manufacturing technique, based on kapton etching: a thin foil of kapton (12.5/25/50 µm thickness) with a thin layer of copper on both sides is processed in order to create the Micromegas structure. Holes are produced in one copper layer by chemical etching and, then, the underlying kapton is removed. This results in a typical mesh-anode structure filled with gas and with the two parallel layers separated by the remaining kapton pillars. Microbulk is the key material for very flexible detector setups and configurations due to its use as a thin foil. The mesh segmentation will also reduce a lot the detector capacitance allowing very low energy threshold. The low mass structures, the good performance and energy resolution and the use of radiopure materials in the segmented mesh and anode microbulk may find its way in applications in other fields of particle detection, not only for neutron transparent detectors for in-beam measurements, but it will also boost the production of microbulk detectors with imaging capabilities and will offer new possibilities for several experiments, like MIMAC or future axion searches with helioscopes (IAXO), where large area detectors of high radiopurity and high performance are needed. Also large area detectors can be used in other applications like neutron imaging/ tomography, or event UV imaging with the help of solid convertors like ^{10}B or CsI deposited on the mesh surface. The R&D project fits well in the P2IO technology programme "Capteurs de nouvelle génération et leurs retombées" with the development of a segmented microbulk detector and its potential use in many other applications.

5 Possible valorization of the project

Since the project is still in the R&D phase, its development coincides with the commissioning of the second experimental area (EAR2) of the n_TOF facility at CERN. During the first beam of this new facility in July 2014, the detector chamber was installed in the beam and reported as such [1]. Even if the XY microbulk was not taking data by then, the other two microbulk detectors inside the chamber were operating. First results with the neutron imager are expected at n_TOF by the end of 2014. In addition, the device will be tested for in-beam measurements at the JRC-IRMM's neutron time-of-flight facility GELINA.

6 Expenses

The list of expenses as of October 2014 is given in the next table.

item	EUR
Amptek MCA	4310
CAEN Low Voltage module	3900
Bronkhorst gas mixer	5993
DAQ computer	2295
Mécanique chambre	7350
SAMTEC cabling	2924
PCB, Composants elecroniques	3999
Composants elecroniques	2130
Microbulk production (10650 CHF)	8735
total	41636