A new detector for neutron beam monitoring

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in collaboration with

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and The n_TOF Collaboration

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Motivation

- For the high precision in neutron cross-section measurements, the knowledge of the energy distribution of the neutron flux during the measurements is crucial

- Need a dedicated detector to measure the neutron flux impinging on the sample placed in the beam; it should be placed upstream of the sample position and of the different detectors in the measurement area.

- Main characteristics of this detector are:

1) have an in-beam mass as small as possible in order to minimize the perturbation on the neutron beam and to minimize the production of background by the device itself.

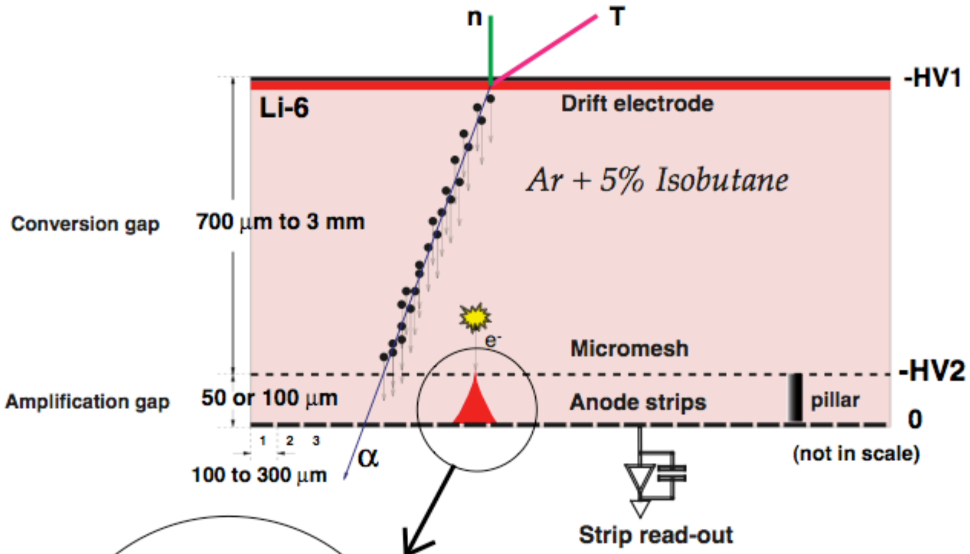
2) capable to cover a large range of the neutron energy (from thermal to several MeV)

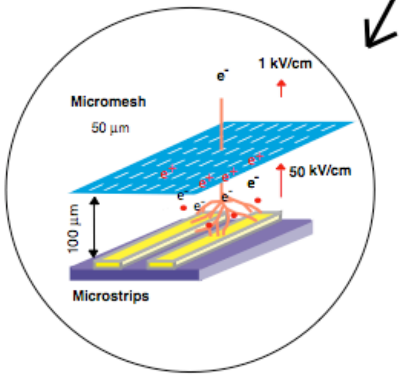
- According to these considerations we have developed a new neutron detector equipped with a small-mass device based on Micromegas micro-bulk technology

Outline

- Micromegas for neutron detection
- The new Micro-Bulk concept
- Description of the new detector for neutron beam monitoring
- First results obtained at GELINA and n_TOF
- Conclusion

Micromegas for neutrons detection (1)





Micromegas (MICRO Mesh Gaseous Structure) is *a* **gaseous detector** developed initially for tracking in high rate high-energy experiments (*Y. Giomataris, Ph. Rebourgeard, J.P. Robert, G. Charpak, Nucl. Instr. and Meth. A 376 (1996) 29*).

The gas volume is separated *in two regions by a thin micromesh;*

1) *Conversion and drift of the ionization electrons*
2) *Amplification and avalanche process*
3) *Charge collection in anode pad or strips*

➲ detection of charged particle by ionisation of the gas

Main advantages of the Micromegas detector: robust and high resistance to radiation.

These qualities have been exploited to develop a new neutron detector (*S. Andriamonje, et al., Nucl. Instr. and Meth. A 535 (2004) 309*). that can also be used in a **nuclear reactor environment**, operating under extreme conditions of intense neutron flux, high gamma ray background and high temperature (*J. Pancin, et al., Nucl. Instr. and Meth. A 592 (2008) 104*)

Micromegas for neutron detection (2)

Need ionizing particules

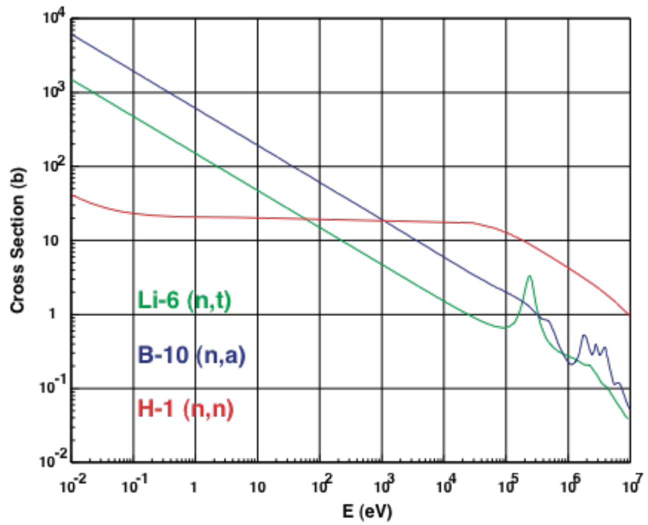
Use of two different kinds
of neutron reactions

Solid Converter

$$ {}^{6}_{3}Li + n \rightarrow {}^{4}_{2}He(2.05\,MeV) + {}^{3}_{1}H(2.73\,MeV)\,Q = 4.78\,MeV $$

$$ {}^{10}_{5}B + n \rightarrow {}^{4}_{2}He(1.47\,MeV) + {}^{7}_{3}Li(0.83\,MeV)\,Q = 2.7\,MeV $$

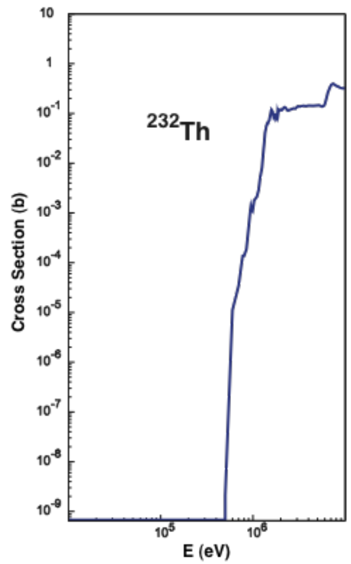
for lower energy

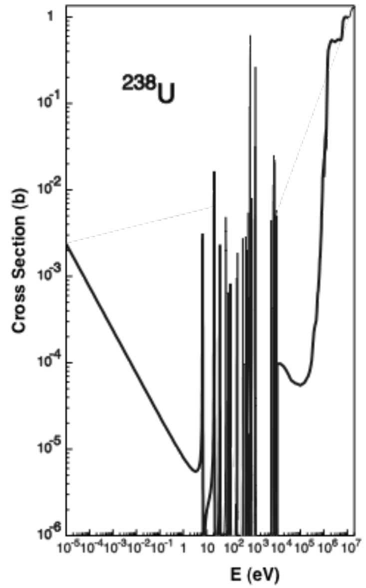


- n + Fissile elements (with fission threshold for higher energy (< 1 MeV for ^{232}Th)

Gas Converter:

Elastic scattering on gas nuclei
^{1}H(n,n')^{1}H and ^{4}He(n.n')^{4}He
for higher energy





Neutron flux for $E_n \geq$ fission threshold

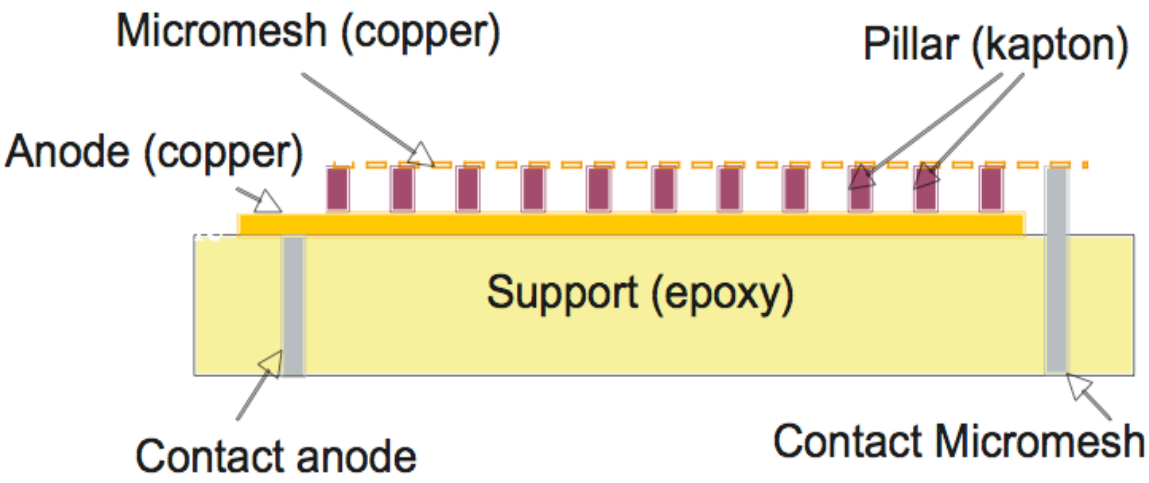
*The Micro-bulk concept**

The micro-bulk principle consists of a manufactured grid starting from a coppered kapton film deposited on an anode of coppered epoxy.

Copper and the Kapton are attacked by a chemical proces in order to form :
-a grid coppers

- insulating kapton pillars
  with a thickness of the used fi
  (50 or 25 microns)

- anode copper



Use of this procedure makes it possible to obtain a perfect alignment of the MicroMesh, the kapton pillars and the reading srtips.

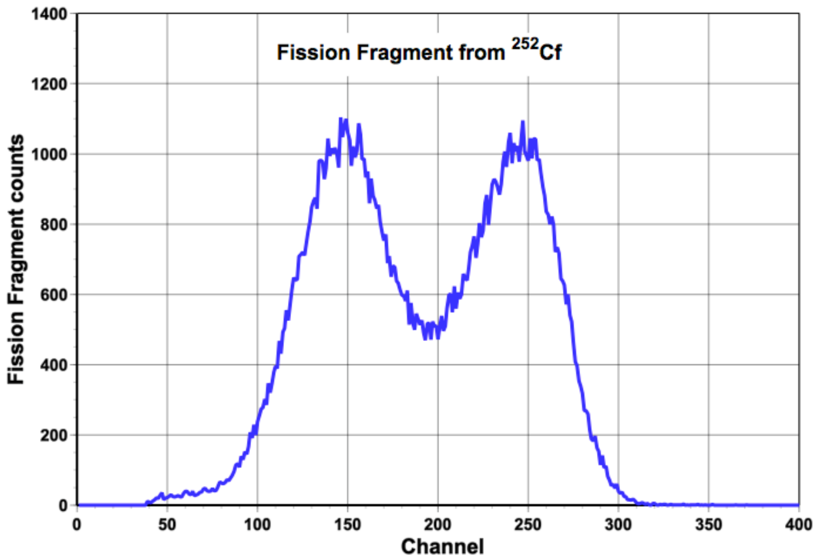
*Invented by **I. Giomataris and R. De Oliveira**

Performances of the Micro-Bulk

Good overall **energy resolution** has been obtained:

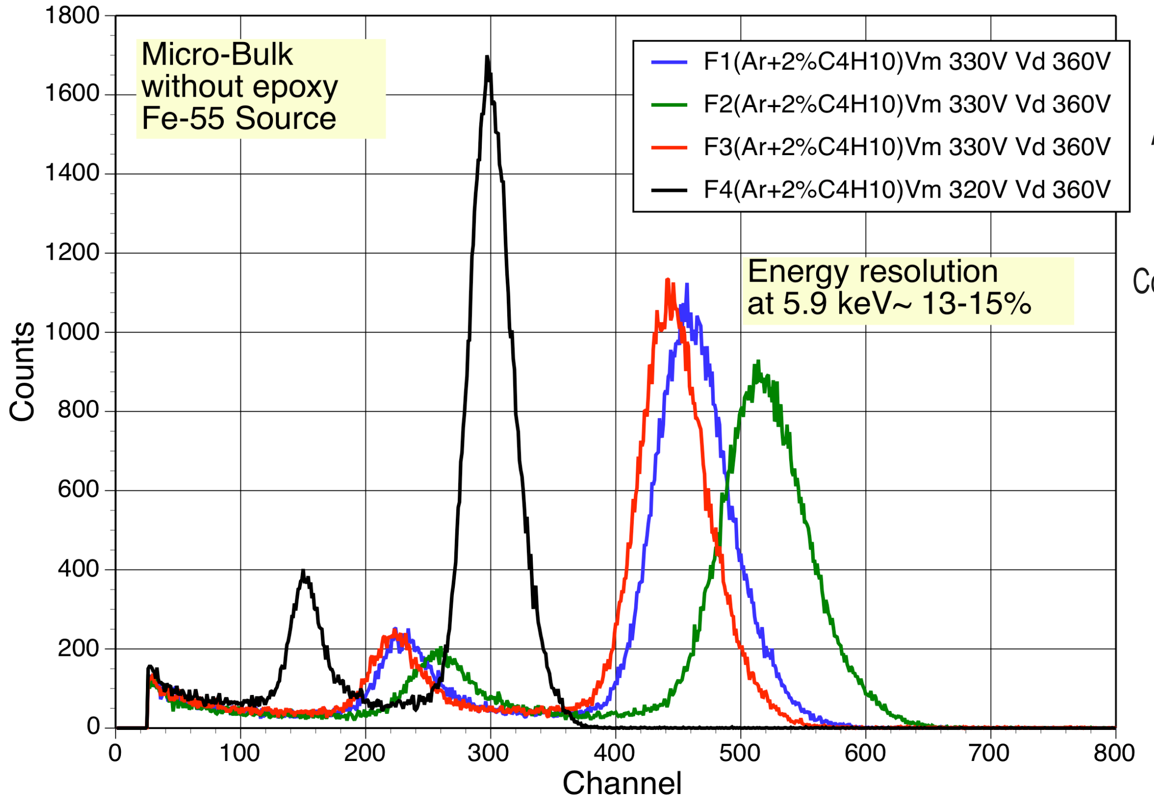
- 10.5% at 5.9 keV of the Fe-55 X- ray source,
- 5.5% at 22 keV of the Cd-109 X- ray source,
- <1.5% with Am-241 a source.

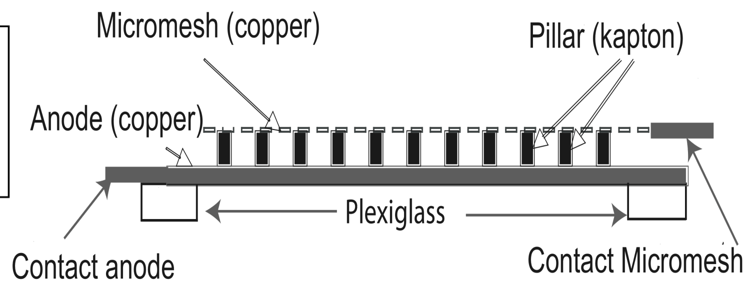
The combination of the high resolution and the fact that it is a gas detector allowed us to observe a **favourable peak/valley ratio** for the fission fragment distribution of ^{252}Cf.



New development for transparent detectors

Four new transparent (challenge) Micro-bulk (F1 to F4)*



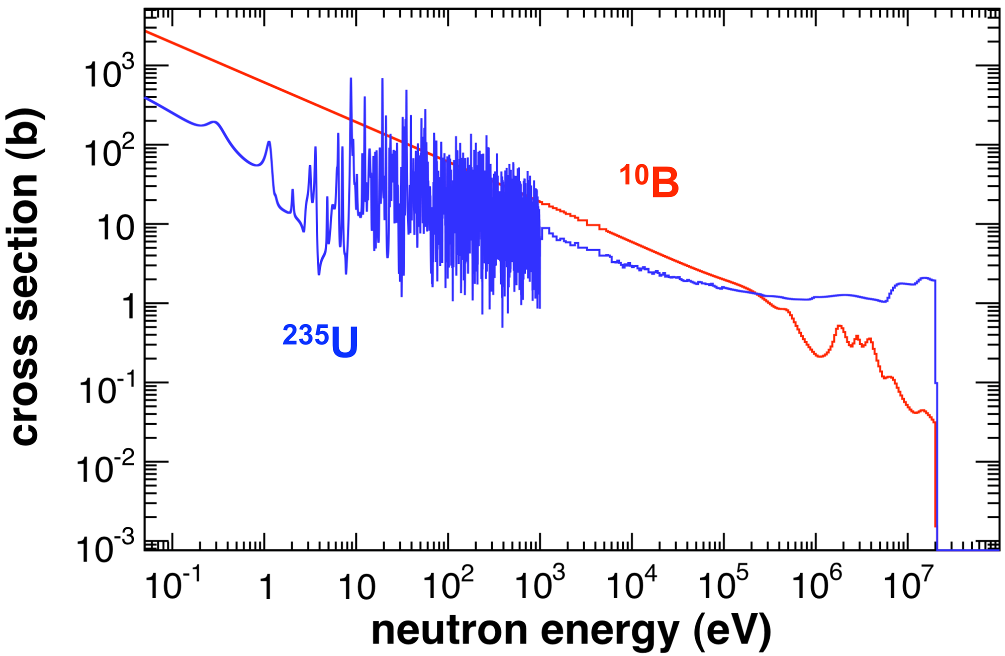


Vd is the negative High Voltage applied on the drift electrode, Vm is the negative High Voltage applied on the MicroMesh. The difference between Vd and Vm determines the gain applied on the detector

Ar-Isobutane mixed gas has been used, the percentage of 2% of the Isobutane has been chosen to have a non-flammable gas for the use in CERN tunnel.

**Ring in place of the epoxy support allows to have a detector with very thin material*

Method to cover a large range of the neutron energy



In order to cover the full range from thermal to above 1 MeV, two standard reactions have been chosen: ^{235}U(n,f) and ^{10}B(n,α).

The ^{235}U(n, f) reaction is suited above a few 100 eV.

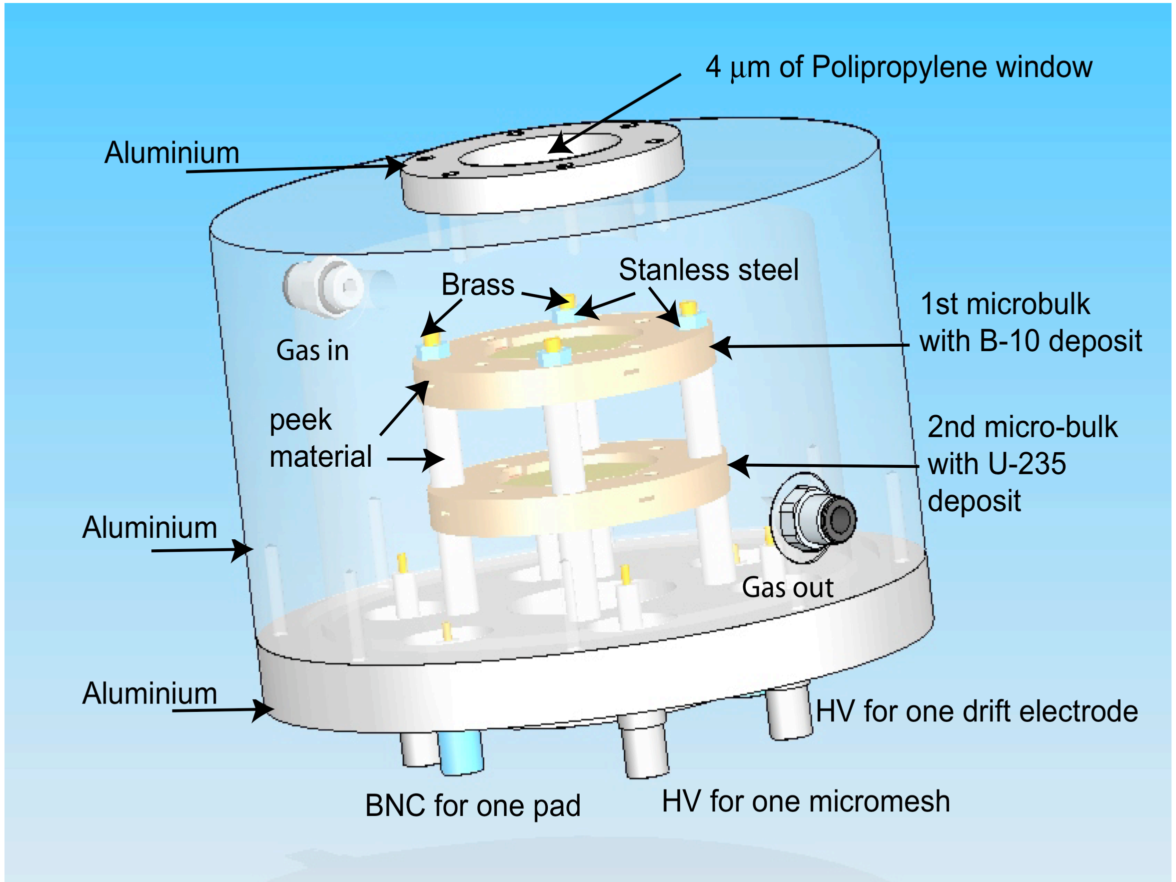
Below that energy the resonance structure of ^{235}U(n, f) does not allow a precise determination of the neutron flux without taking into account detailed and complicated corrections.

➲ use of 2nd standard reaction ^{10}B(n,α)

The combination of both elements (^{10}B and ^{235}U) makes it possible to have an excellent detector to measure the energy distribution of the neutron in a large neutron energy range from thermal to several MeV.

The Micromegas Micro-bulk for neutron beam monitoring

Two Micromegas detectors equipped with very thin material



Drift Electrode (1)

The sputtering method has been used at CERN for the ^{10}B (from B_4C) deposit (very high evaporation temperature), on a copper coated kapton, 12.5 μm of kapton and 1 μm of copper

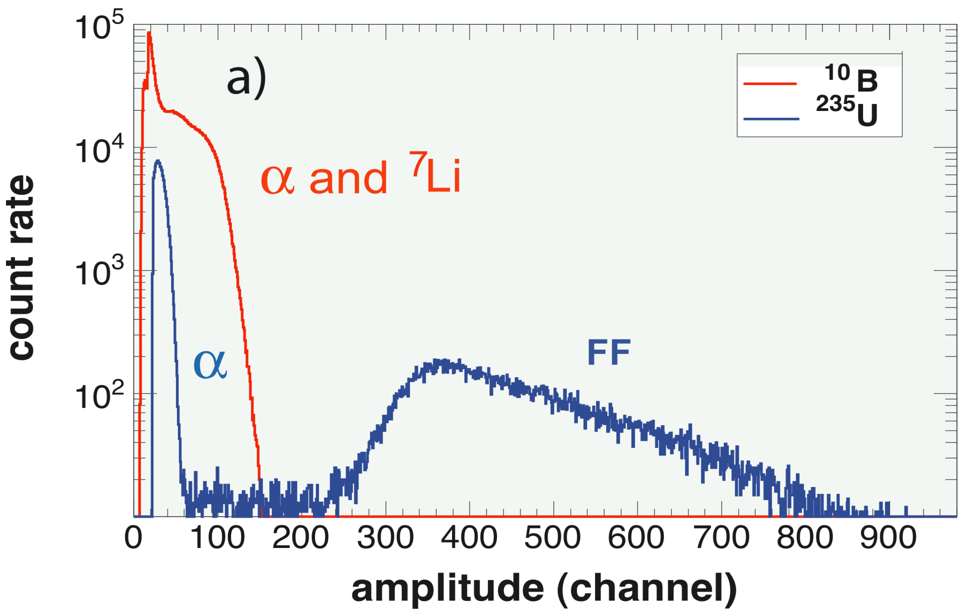
Drift Electrtode (2)

The ^{235}U (1 mg U-235 (99.94%) sample was deposited on 1.2 μm of aluminised Mylar at JRC-IRMM in Geel using the evaporation method.
To minimize the heating of the sample, a special device based on water-cooling has been fabricated.

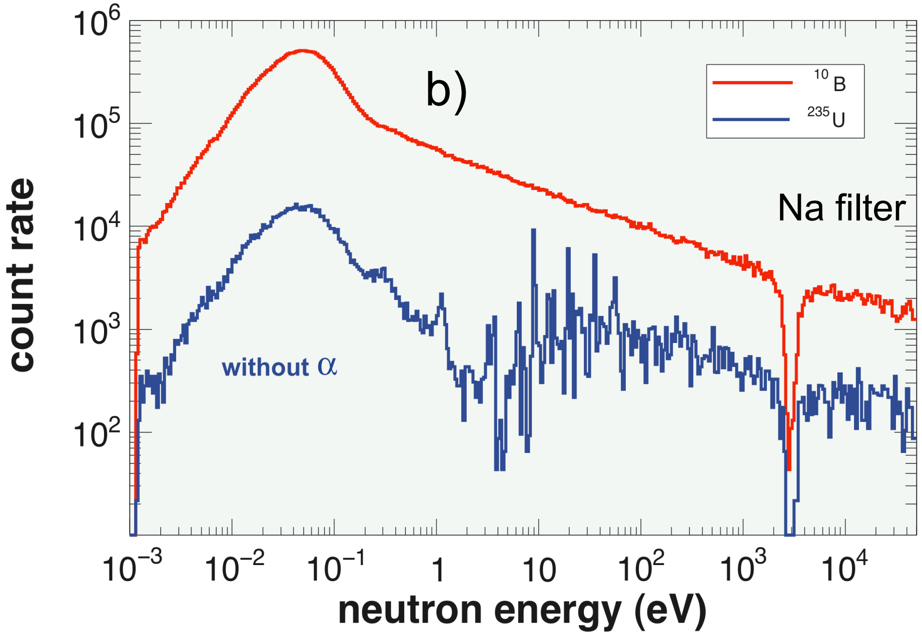
Micromesh + Anode strip = **Micro-Bulk** (5 μm Cu+ 25 μm Kapton + 5 μm Cu)

Results obtained at GELINA facility

The GELINA neutron source is based on a linear electron accelerator producing an electron beam
The accelerated electrons produce Bremsstrahlung radiation in a uranium target, which in turn, by means of photonuclear reactions, produces neutrons.



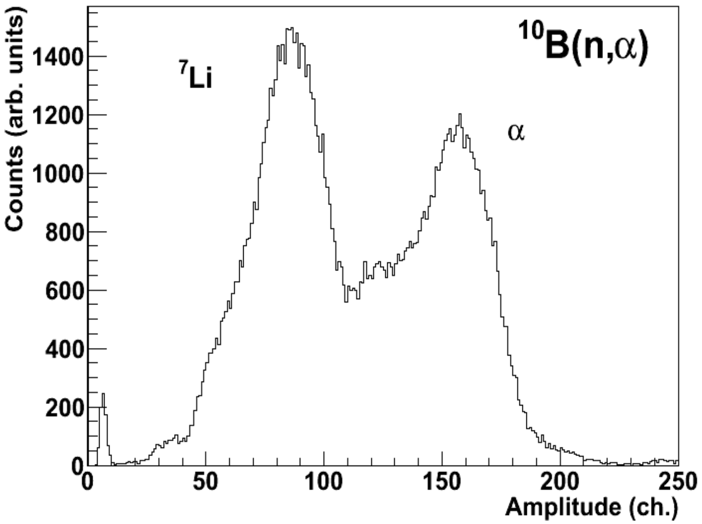
a) Neutron reaction product spectra from ^{10}B and ^{235}U

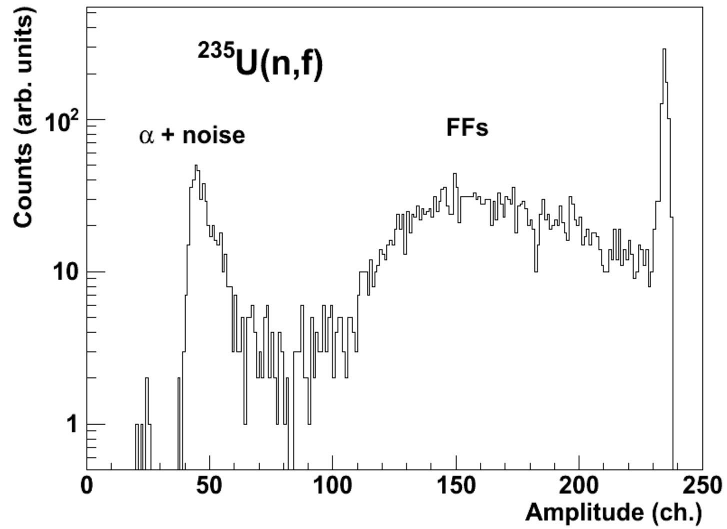


b) Reaction rate as a function of neutron energy for ^{10}B and ^{235}U

A premixed Ar + 10%CH_4 has been used

Result obtained during the short commissioning of the new target of the CERN n_TOF facility (November 2008) (1)





Neutron reaction product spectrum from ^{10}B

(the use of the premixed gas of Ar + CF_4 + C_4H_{10} allows to distinguish clearly the contribution of the two components (1.47 MeV alpha and 0.83 MeV ^{7}Li) of the reaction products of the neutrons on ^{10}B).

Neutron reaction product from ^{235}U

(the peak at ch. ~240 is due to the saturation of the flash-ADC).

Due to the very limited beam time, which was dedicated for the test of the new lead target , the statistics accumulated were rather poor but sufficient to validate that this new concept can be used as a neutron beam monitoring device.

Result obtained during the short commissioning of the new target of the CERN n_TOF facility (November 2008) (2)

^{10}B μMEGAS sample: ~1 μm, 3.5 cm ø

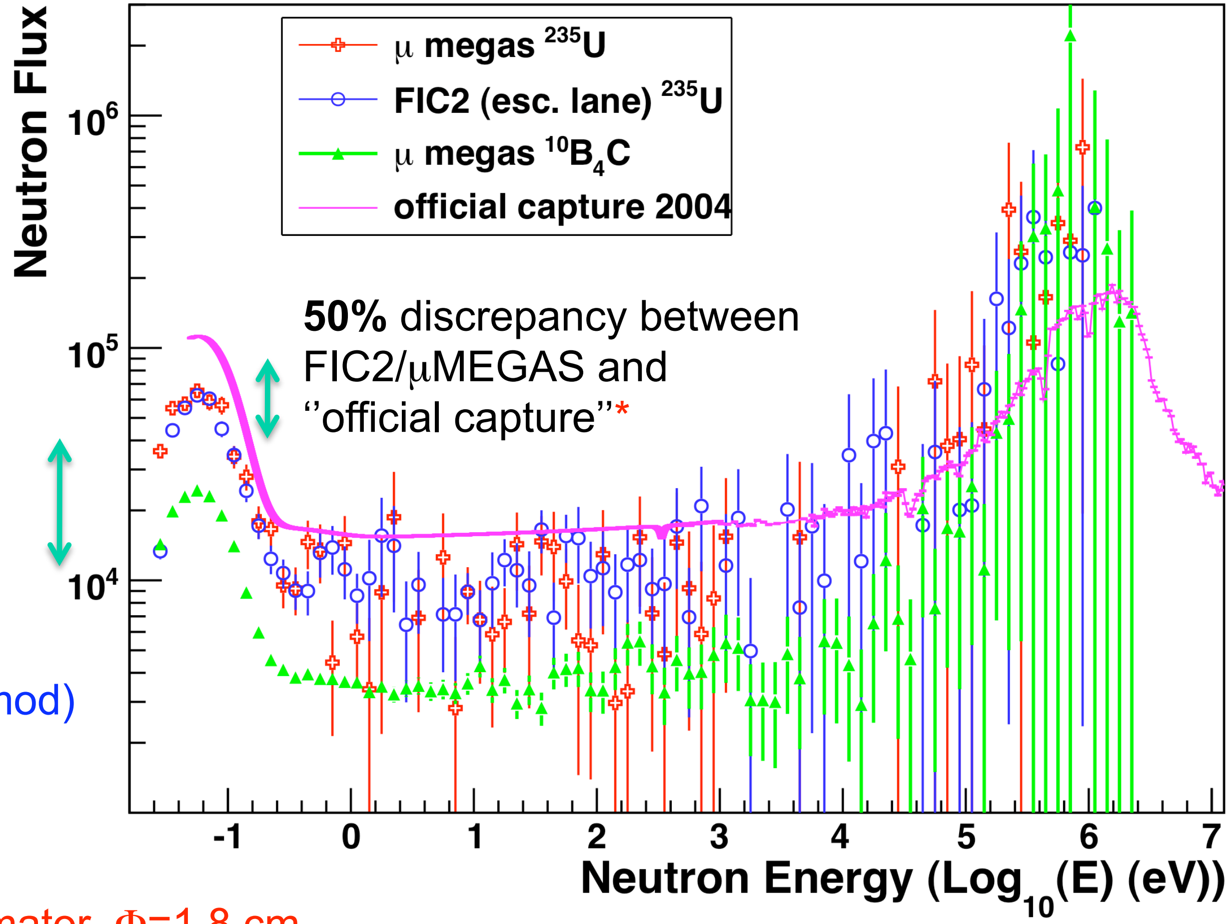
^{235}U μMEGAS sample: 1 mg, 2.0 cm ø

^{235}U FIC2 sample: 12.79 mg, 5 cm ø

Fission Ionisation Chamber (FIC)

60% discrepancy between μMEGAS ^{10}B and μMEGAS ^{235}U

(^{10}B mass uncertainty)



L_{FIC2} = 192.65 m (L_{2004} + 10 cm new mod)

$L_{\mu MEGAS}$ = 182.0 m

*bad alignment (0.9 mm) of the collimator Φ=1.8 cm

Conclusion

We have developed a new neutron detector based on Micromegas Micro-Bulk technology.

A challenge was launched to obtain a neutron transparent detector as a monitor of the neutron beam.
That concerns not only the design of the detector but also the manufacturing of the neutron/charged particle converters.

The first results show clearly the capability to use this type of detector for the future measurements on the neutron beam line.