# Neutron Beam Profile Measurements with a Triple GEM for Thermal Neutrons at the CERN n_TOF Facility

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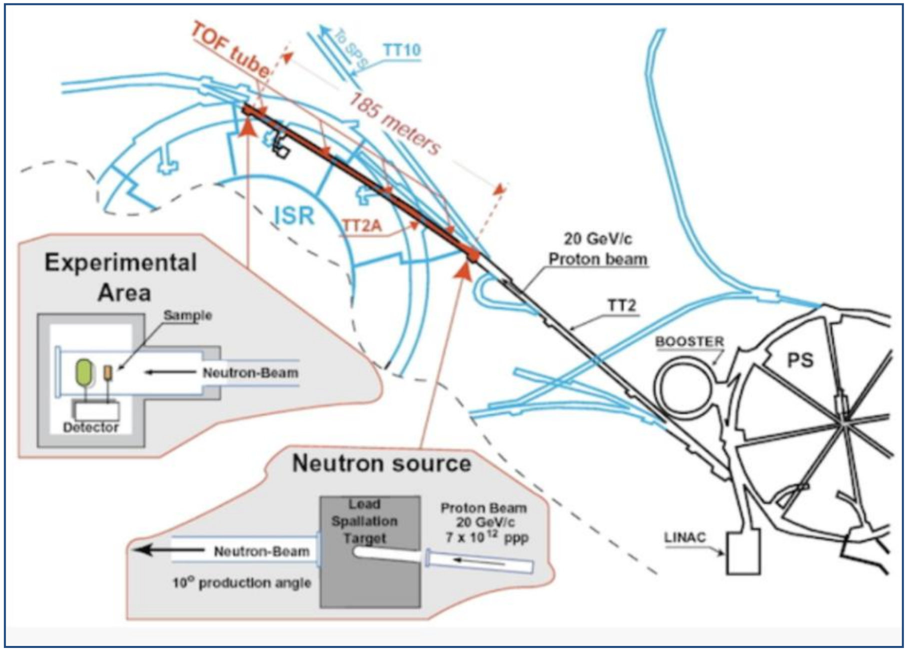
- n_TOF facility
- Triple GEM detector for thermal neutrons
- Set up
- Results
- Conclusions

# n-TOF neutron facility @CERN



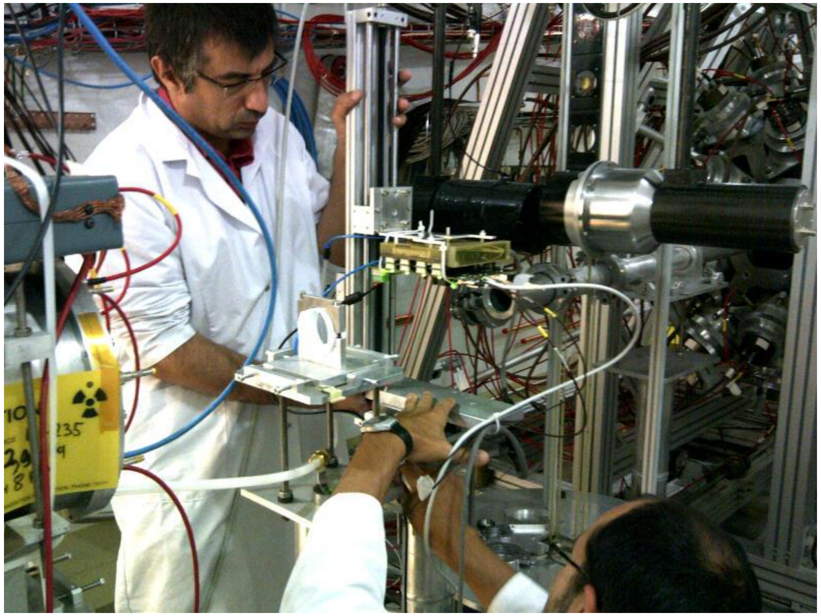

| | |
|---|---|
| ▪ Proton intensity | *$8x10^{12}$ p/pulse* |
| ▪ Proton beam momentum | *20 GeV/c* |
| ▪ Proton pulse width | *6 ns (rms)* |
| ▪ **high instantaneous n flux** | *$10^5$ n/cm$^2$/pulse* |
| ▪ **wide energy spectrum** | *25 meV : 1 GeV* |
| ▪ **low repetition rate** | *< 0.25 Hz* |
| ▪ **neutron time width** | *160 ms* |

Neutrons are collimated and guided through an evacuated beam pipe to an experimental area at **185 m** from the spallation target.

C. Guerrero et al, Performance of the neutron time-of-flight facility n_TOF at CERN, Eur. Phys. J. A (2013) 49: 27

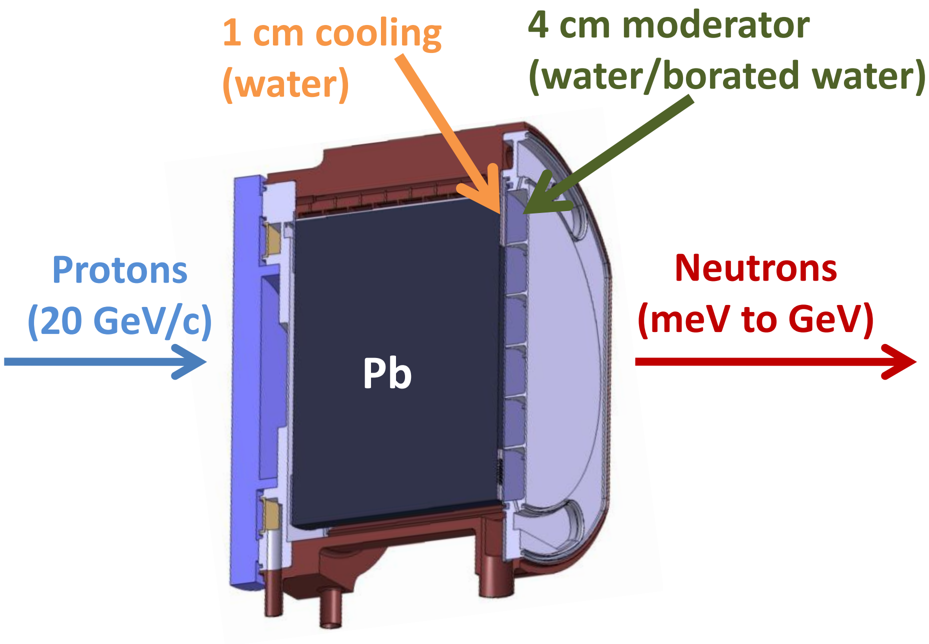
**Experimental area**

**neutron beam**

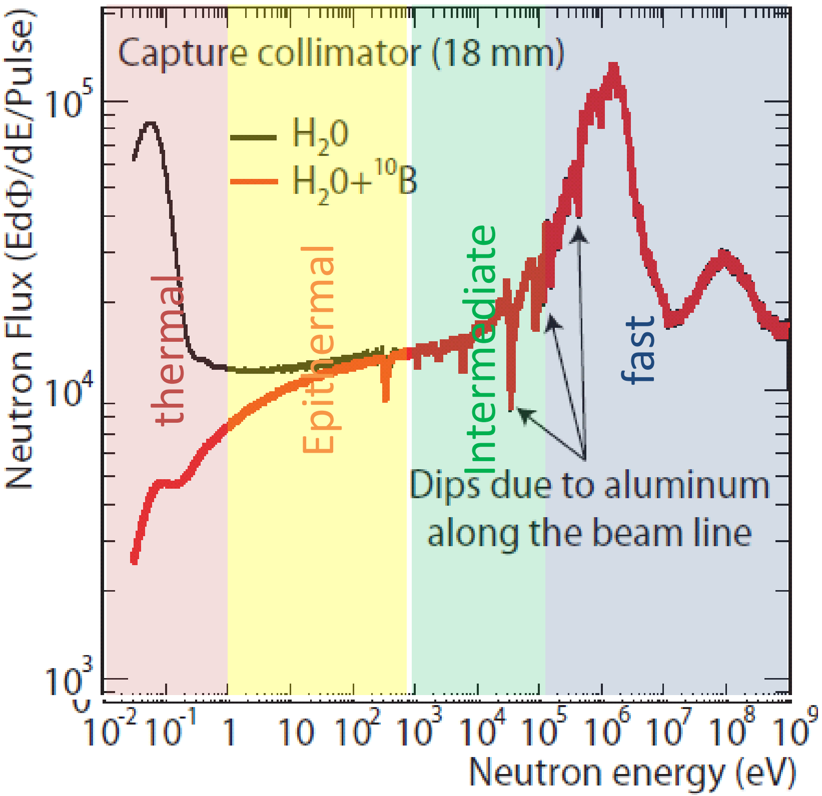


# Neutron spectrum @n_TOF

Wide neutron spectrum spanning an energy range from meV up to the GeV region.



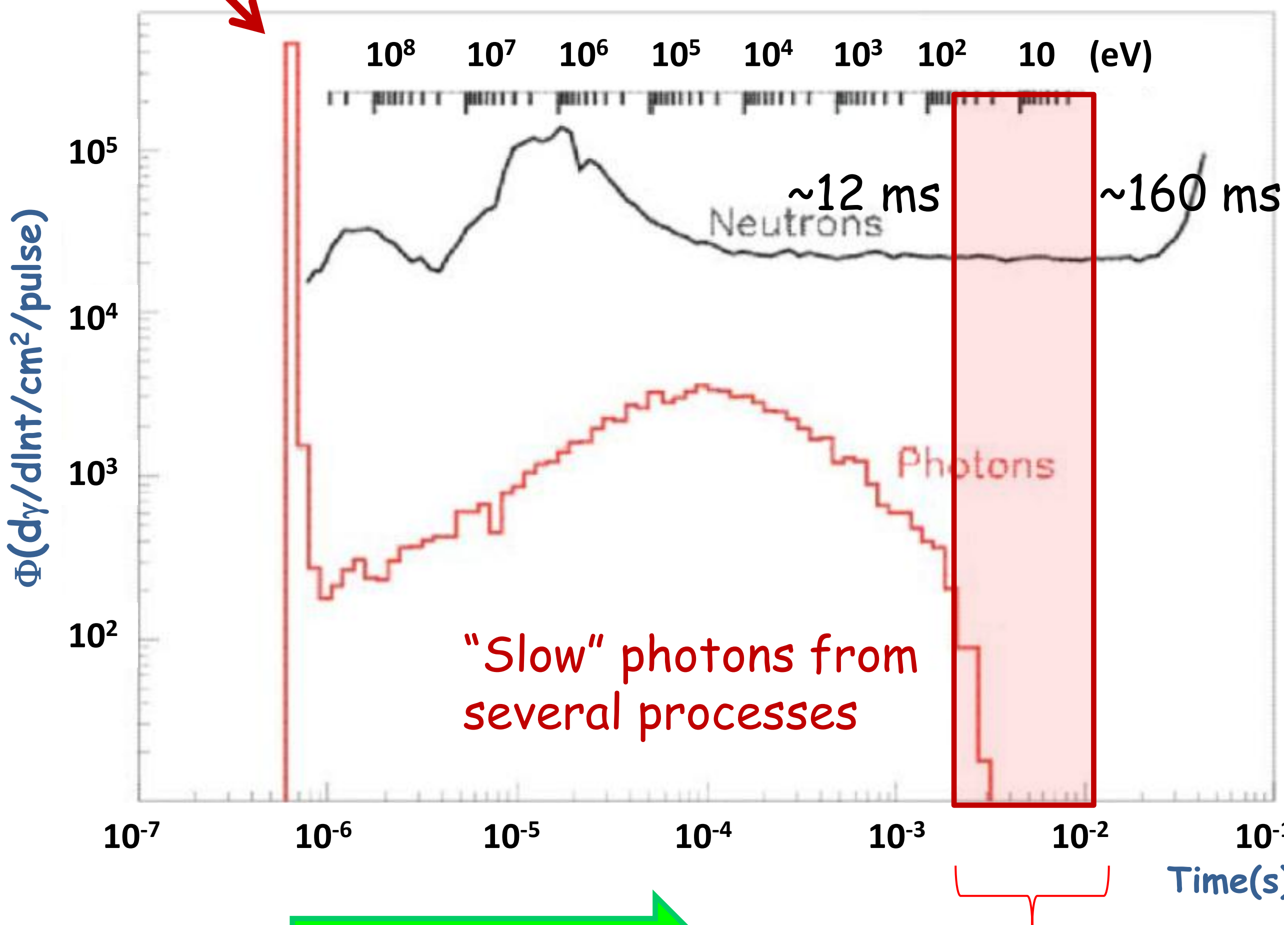

Lead spallation target




160 ms Time Of Flight

# Contamination by gammas

Prompt γ flash at ~ 600 ns



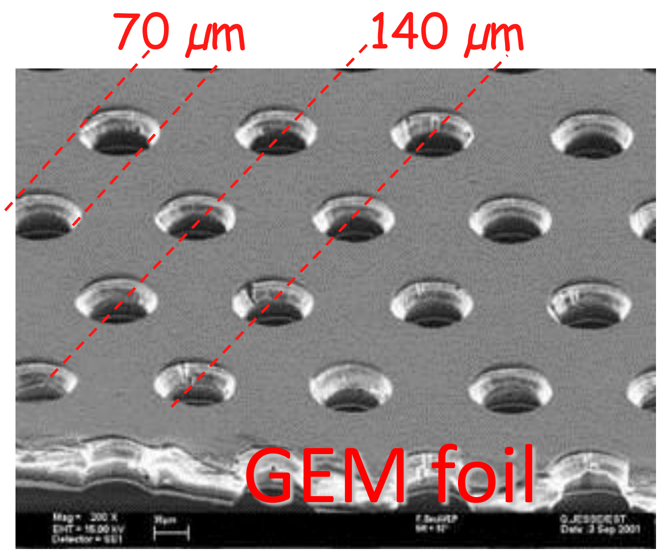

investigated TOF range

160 ms Time Of Flight

# Triple GEM Detector

Gas Electron Multiplier:

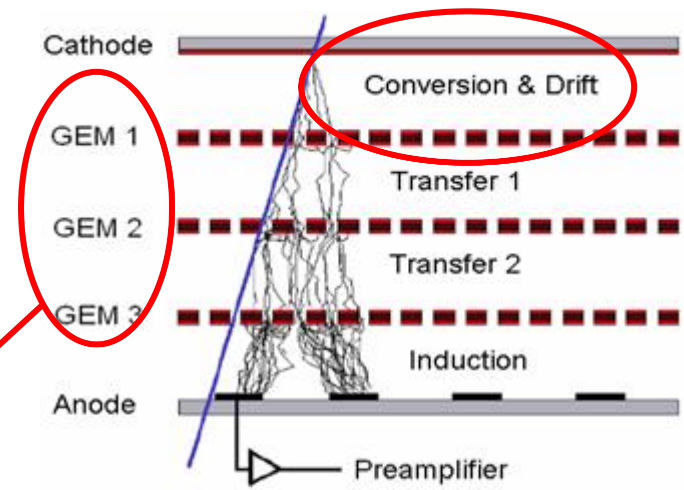
- 50 μm thick kapton foil
- 5 μm of Copper on each side
- high surface-density of bi-conical channels




The three functions

Conversion, Amplification, & Readout

are well separated and decoupled



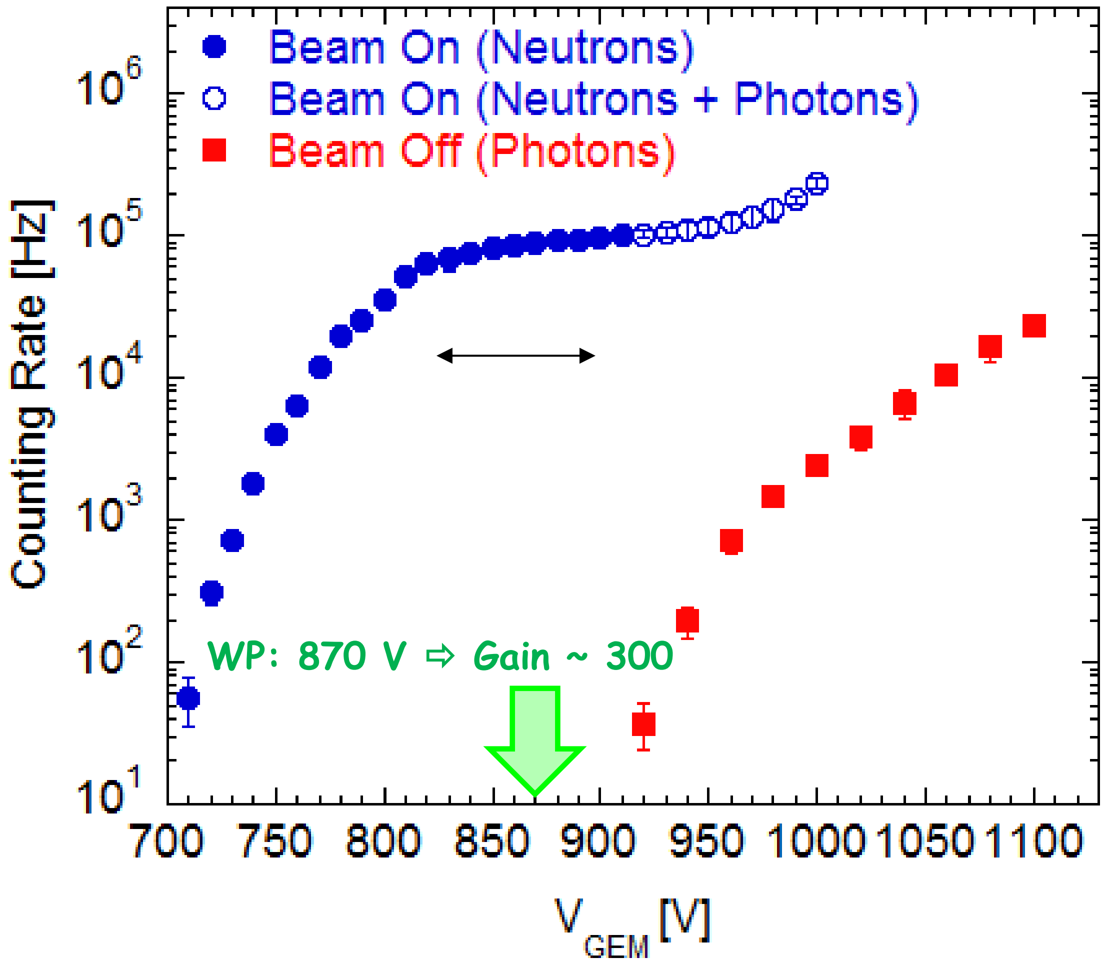

Working with different levels of gain it is possible to obtain high level of particle discrimination

F. Sauli NIM A386 531

M. Alfonsi et al., The triple-Gem detector for the M1R1 muon station at LHCb, N14-182, 2005 IEEE-NSS

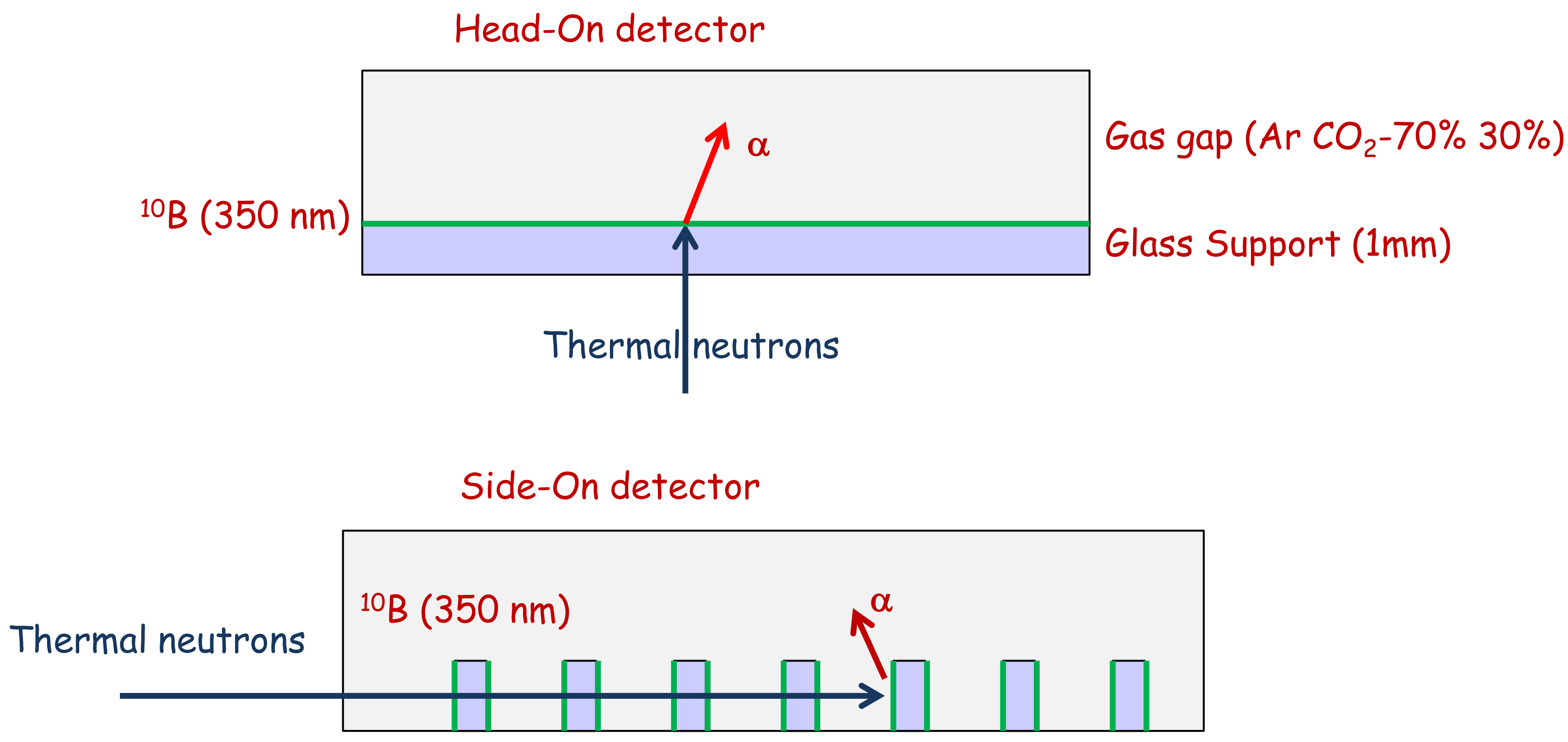
# Working point

The α produce an high ionization which allow a wide plateau before the γ background



# How to detect thermal neutron

$$n + {}^{10}Bo \rightarrow \begin{cases} {}^{7}Li + \boldsymbol{\alpha} + \gamma, & (97\%) \\ {}^{7}Li + \boldsymbol{\alpha}, & (3\%) \end{cases}$$

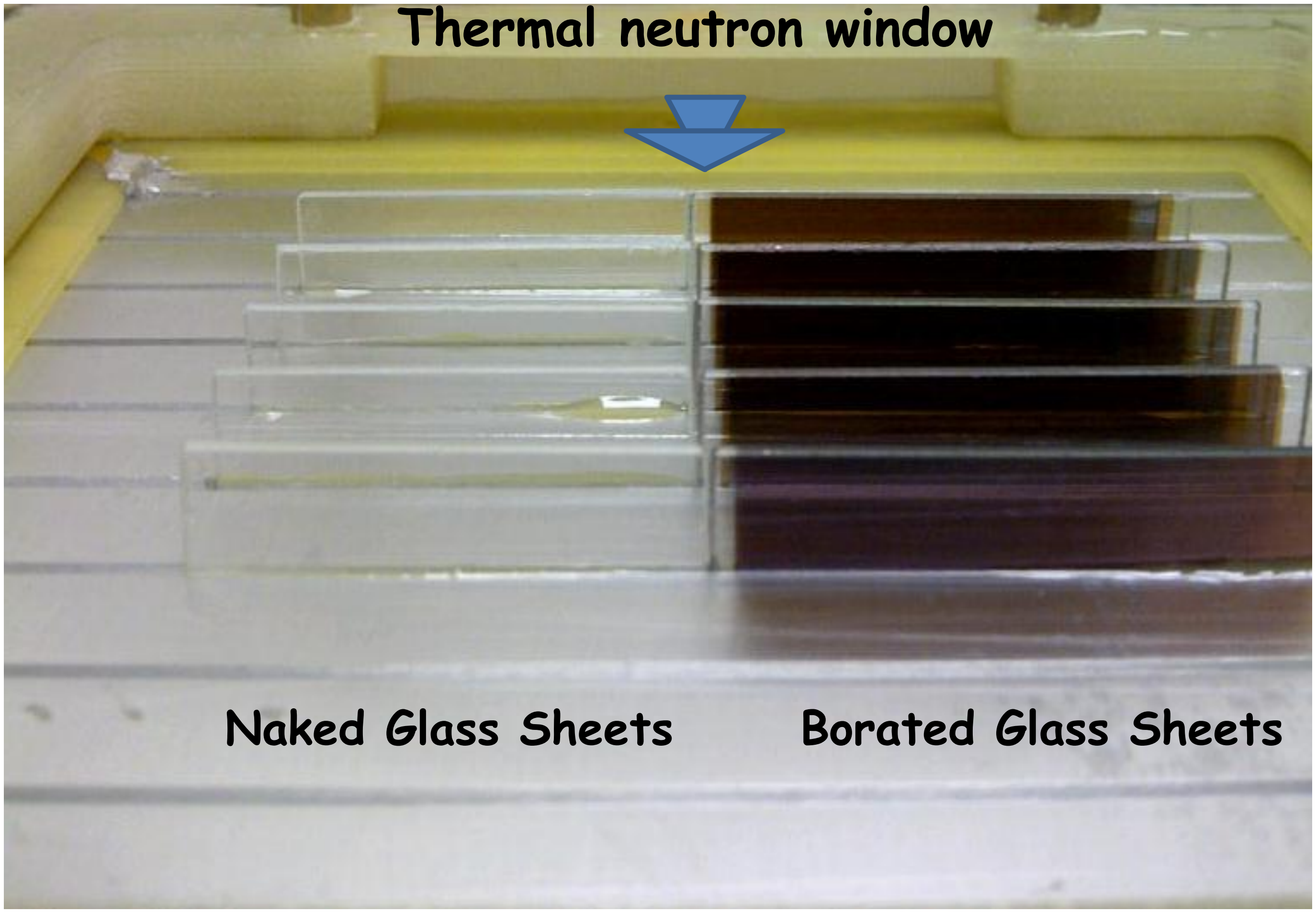



Higher efficiency

A. Pietropaolo et al., A new $^{3}$He-free thermal neutron detector concept based on the GEM technology, conference proceeding, He-2-4, 2012 IEEE-NSS Anaheim CA

# Boron multilayer cathode

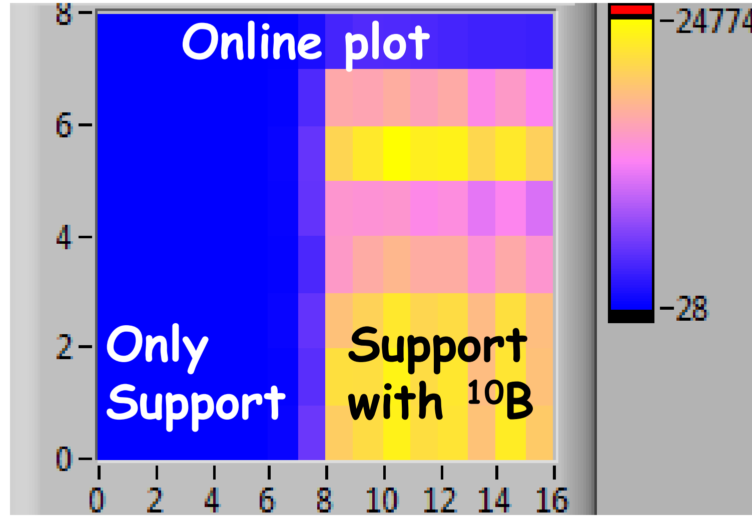
First prototype made in 2012

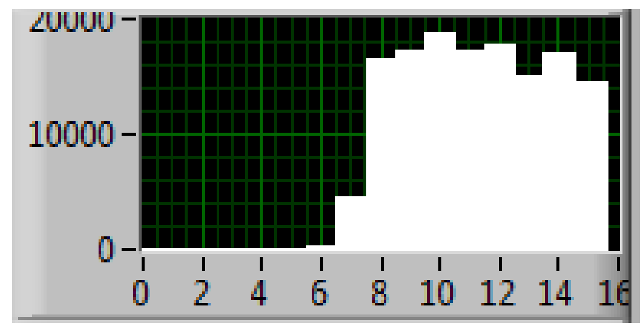


# Detector linearity measurements in a fission reactor

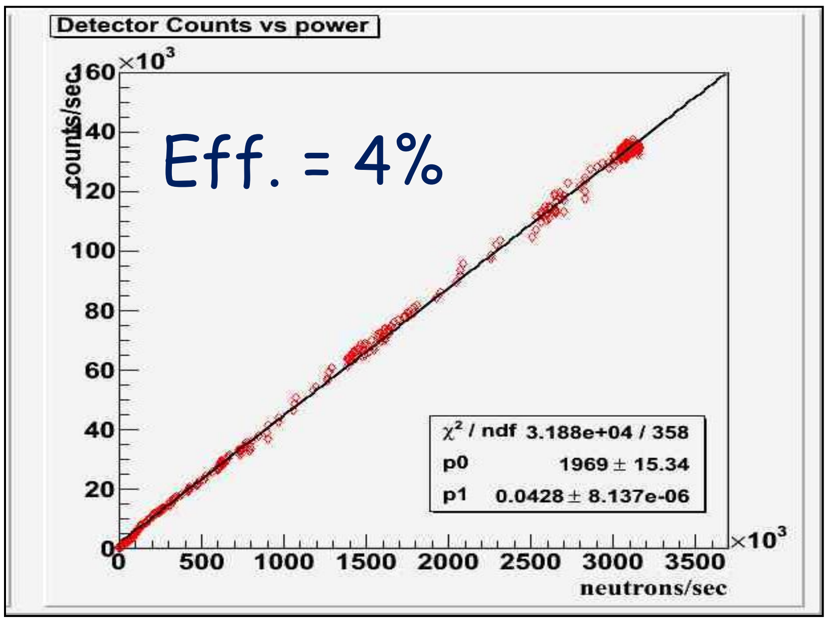
Measurements at Triga (ENEA)
Power of 1 MW

- Gamma background **free**
- **No** electronic noise



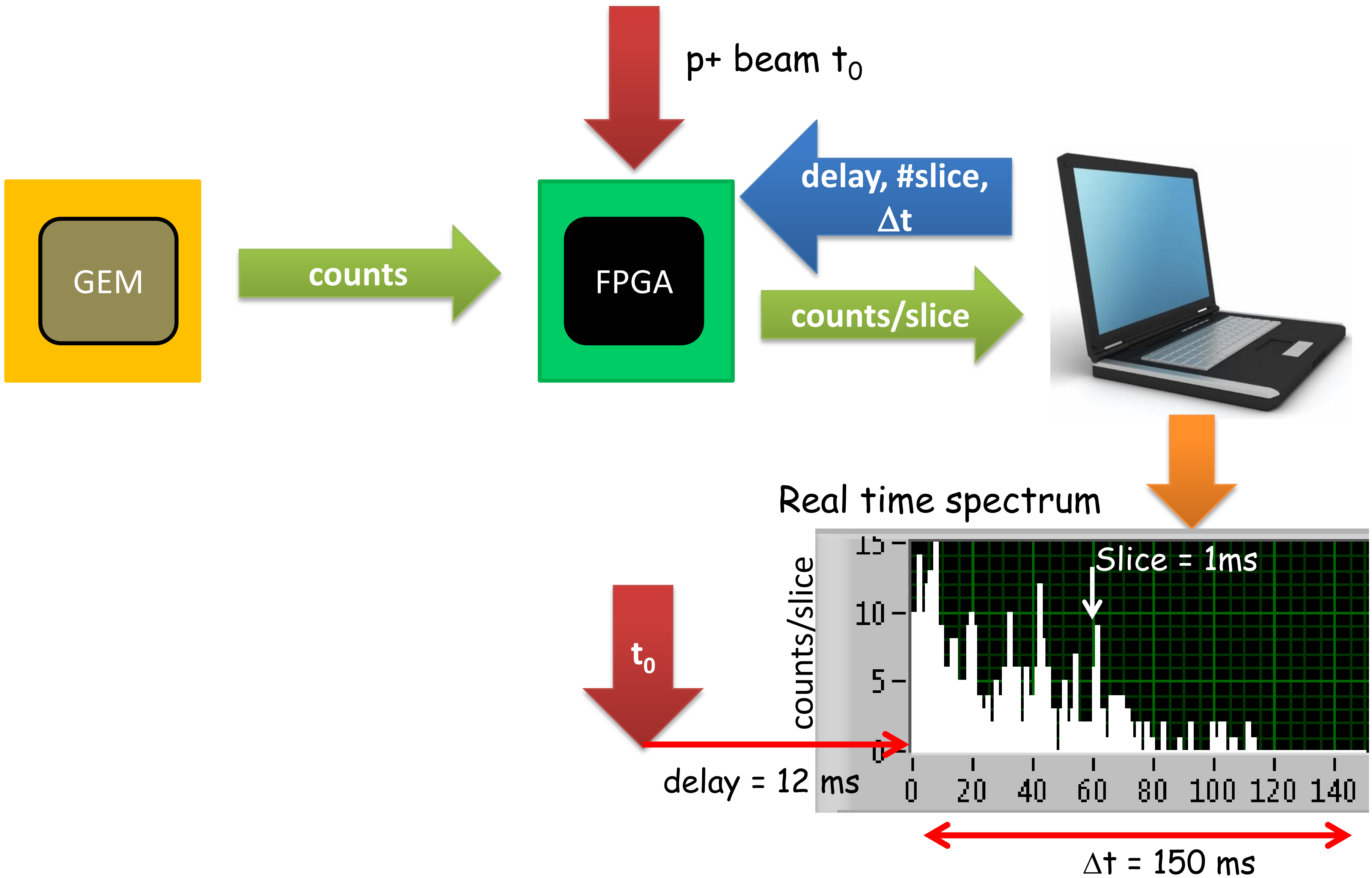




## Good linearity up to 1 MW

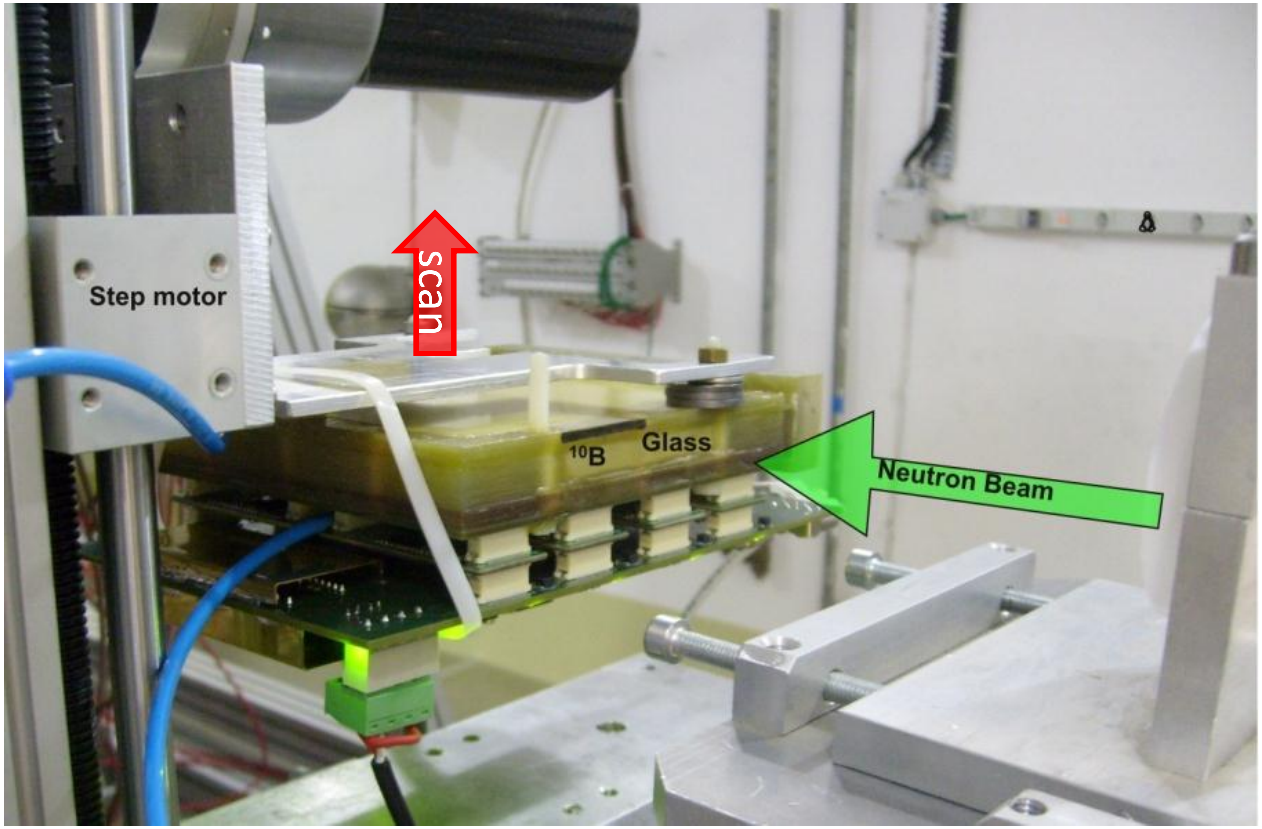


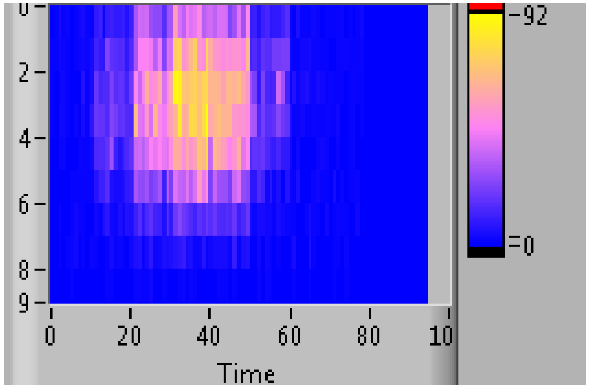

Real time measurements
Signal /gammas $10^4$

# FPGA data acquisition



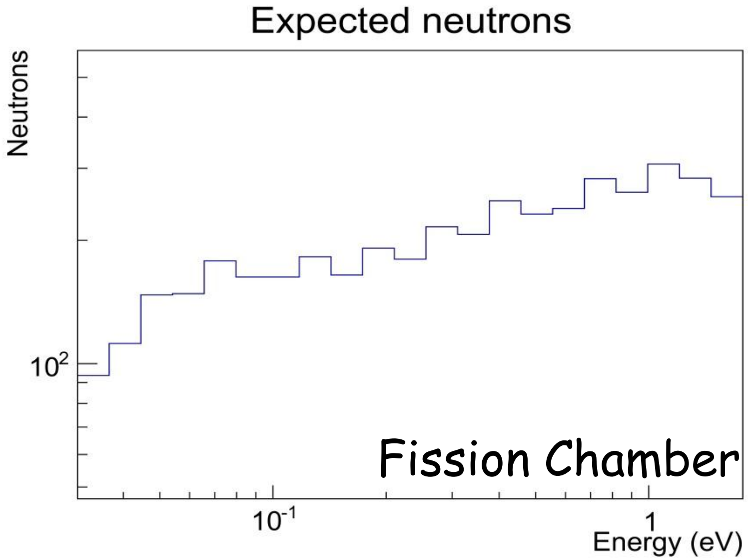
# Beam spot

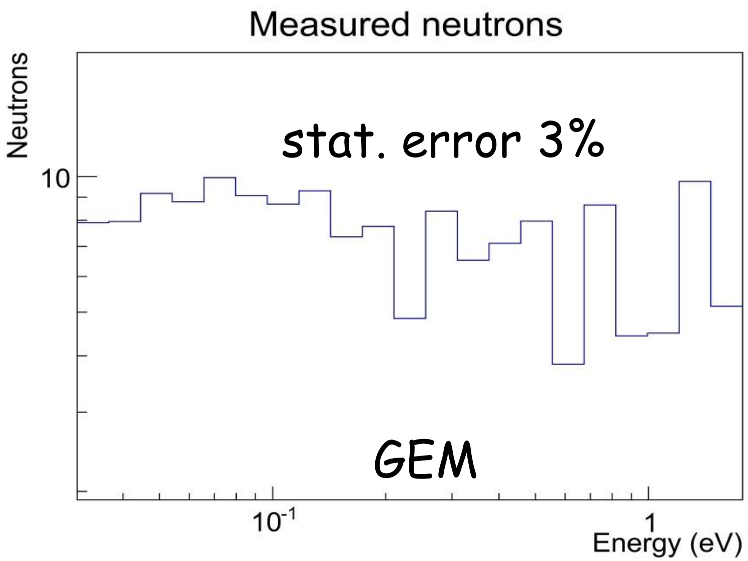



With a scan procedure it is possible to make an image of the neutron beam in the thermal region

# Results: GEM efficiency and neutron spectrum profile



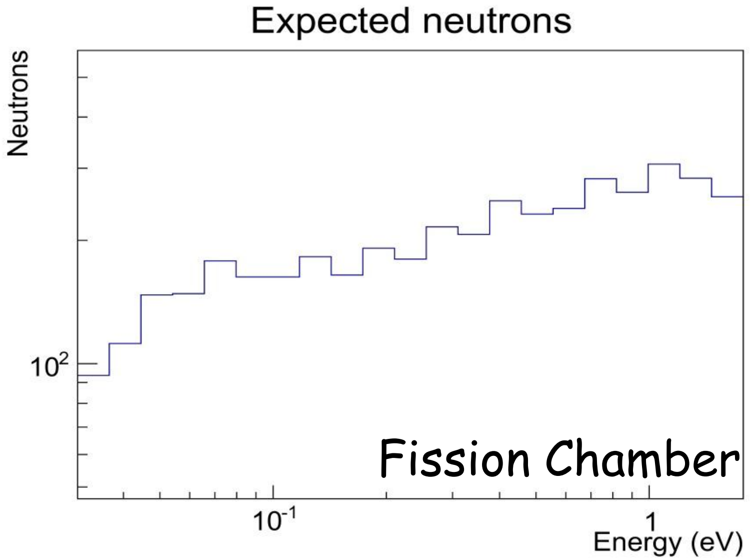

From a convolution between:

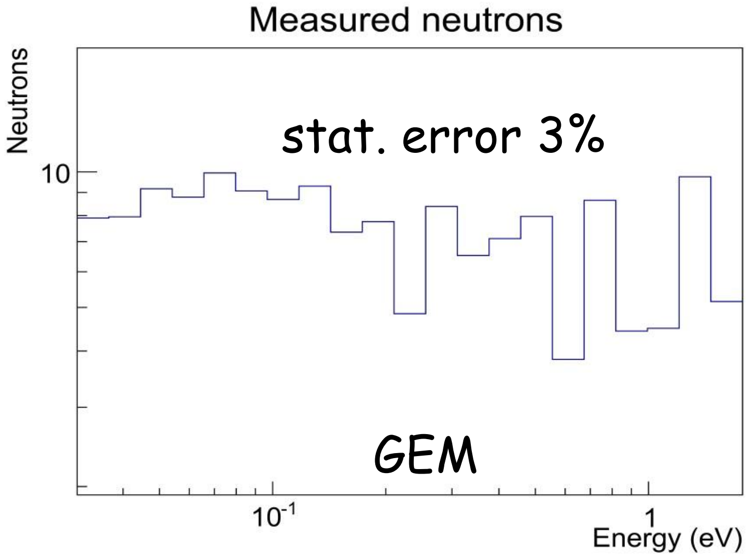
- PS beam intensity
- Neutron flux by $^{235}U$ fission chamber from PTB institute (GE)

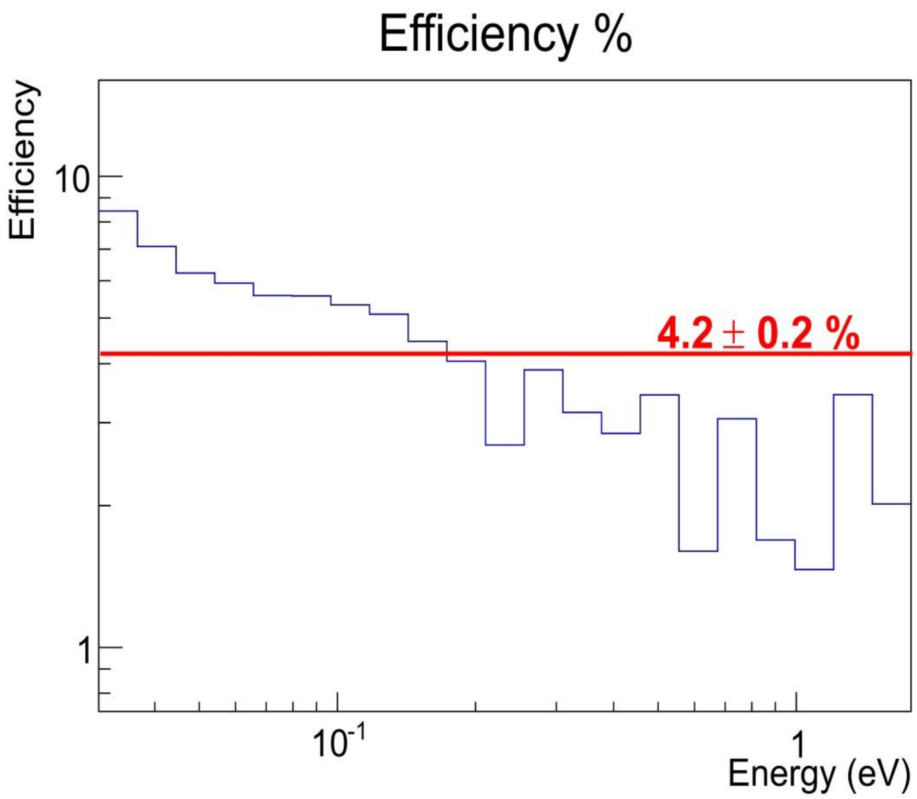
$$counts = \frac{\#\ hits}{PAD\ Cluster\ size}$$

$$n(Hz) = {}^{10}B\ counts - Glass\ counts$$

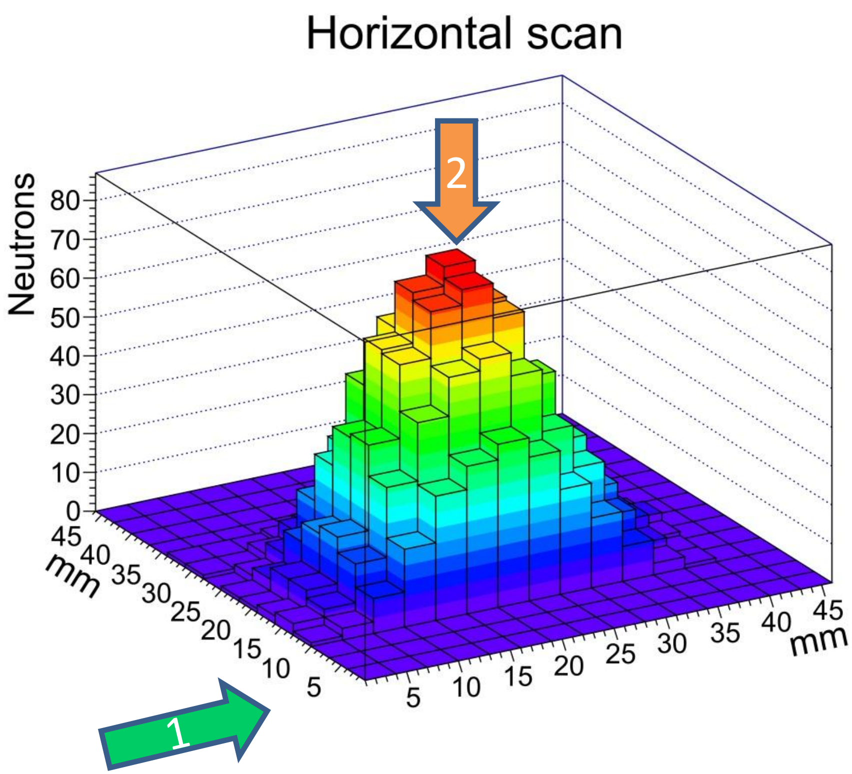
# Results: GEM efficiency and neutron spectrum profile

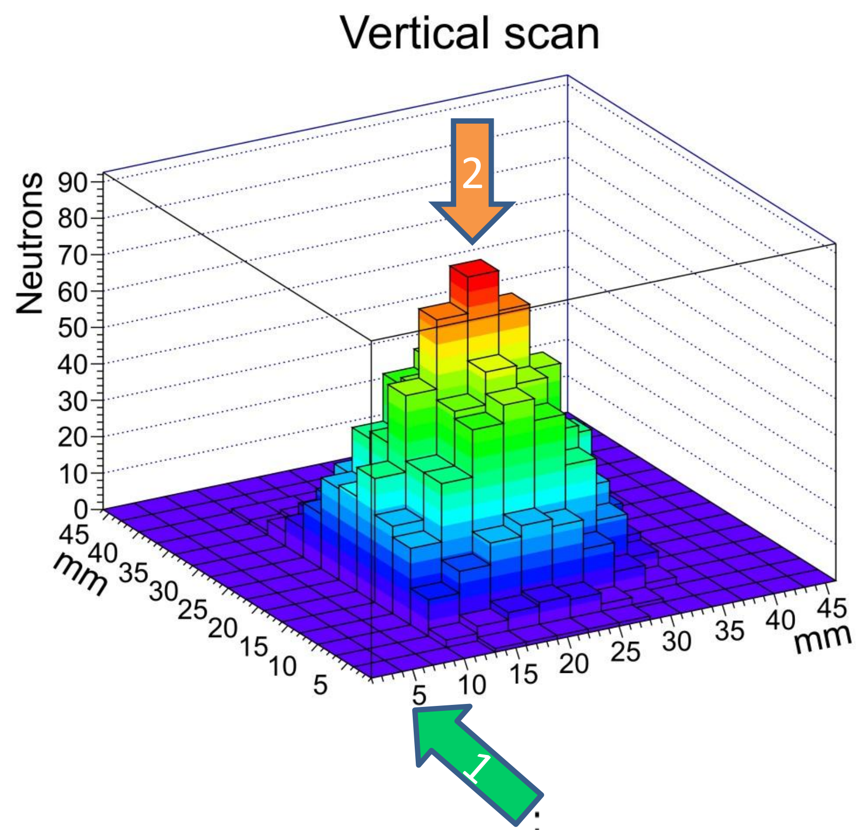


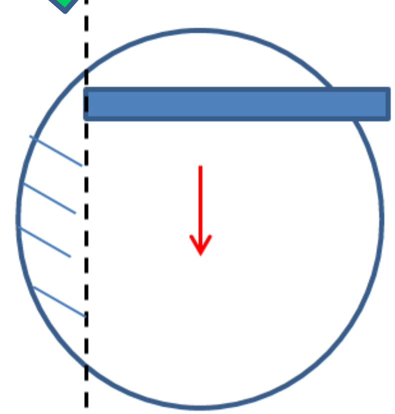



# Results: beam image

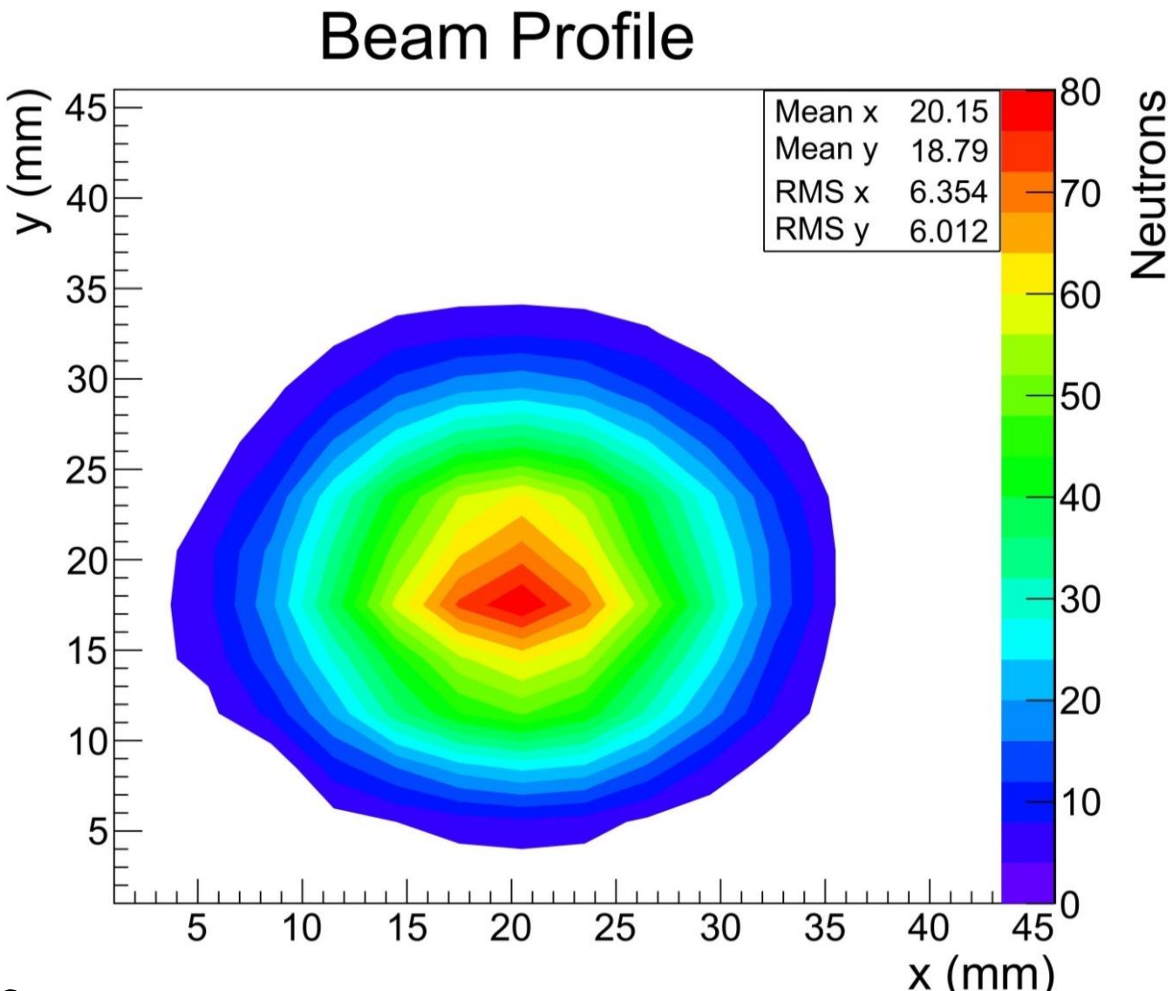


- Scan steps: 3mm
- Sum of the two matrix bin by bin
- The entries of the new matrix are divided by 1 or 2
- Beam image!

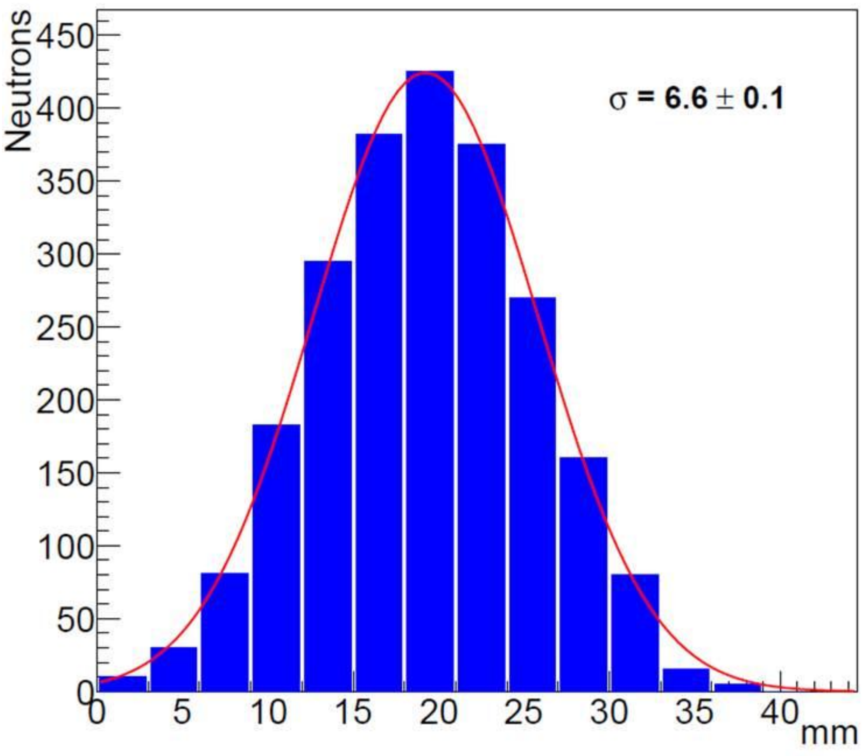
# Results: beam image



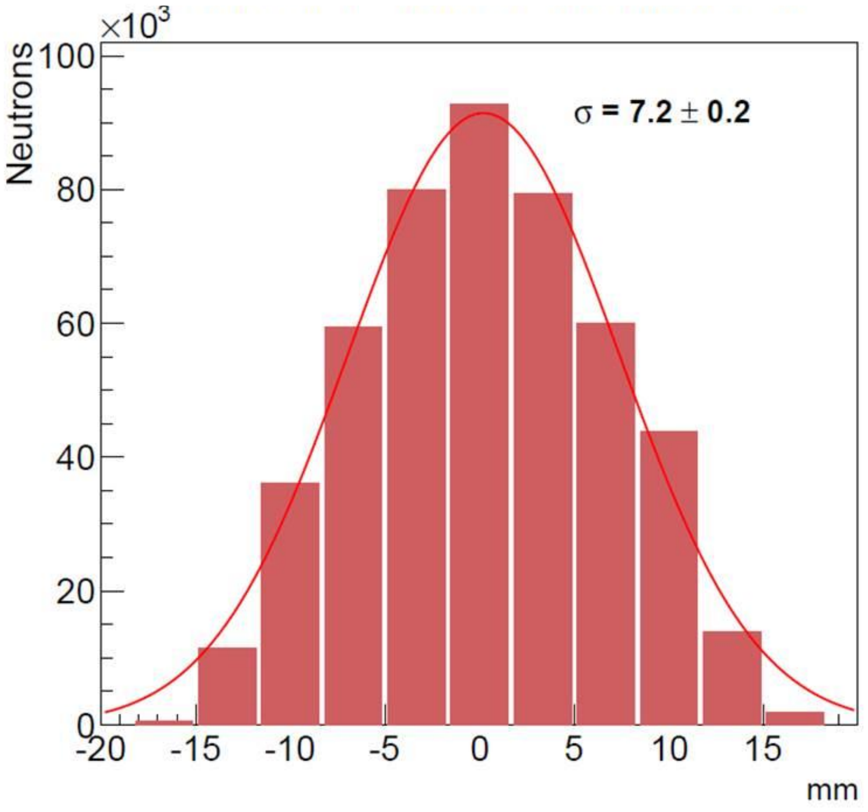

- Scan steps: 3mm
- Sum of the two matrix bin by bin
- The entries of the new matrix are divided by 1 or 2
- Beam image!

# Results: beam projection

**Measured horizontal profile**




**Simulated horizontal profile**




http://pceet075.cern.ch FLUKA simulation for n_TOF collaboration by V. Vlachoudis - CERN

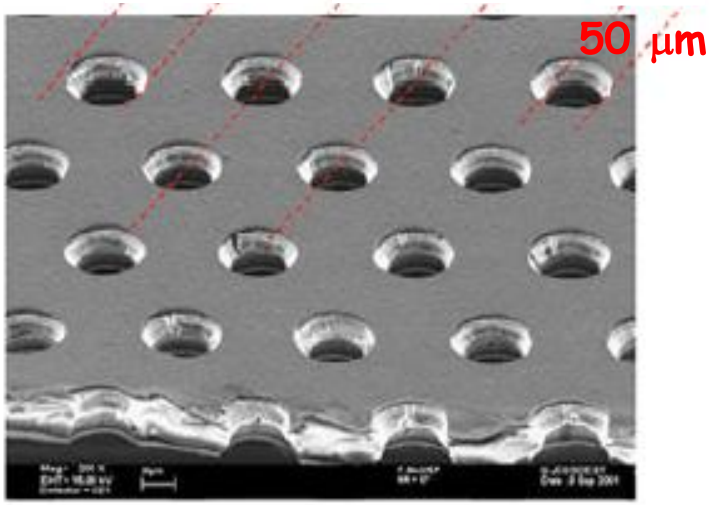
# CONCLUSIONS

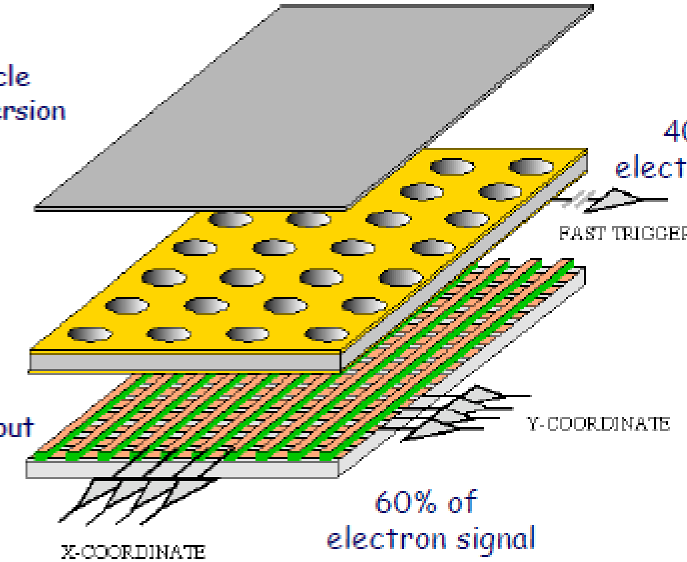
- **A triple GEM for thermal neutrons** was tested at 185 m from the spallation source in the experimental room of the n_TOF facility at CERN
- The mean efficiency of this detector is **4.2%**
- The efficiency curve vs neutron energy was measured in the range 0.03 eV- 1.75 eV
- The projection of the beam is in **fair agreement** with the one obtained with simulation
- With a scan procedure it was possible to perform the **beam imaging** for **thermal neutrons** spot with **almost complete rejection** of $\gamma$ rays

# Thanks!

This work was supported by ARDENT Marie Curie Initial Training Network funded by the European Commission 7th Framework Program under Grant Agreement 289198

# Triple GEM detector




- Particle conversion, charge amplification and signal induction zones are physically separated
- Time resolution: **9.7 ns** for Ar-$CO_2$ (70-30)
- Spatial resolution: up to **200 μm** - limited by readout
- Dynamic range: **from 1 to $10^8$ particles/$cm^2$ s**
- Effective gain is given by the formula: $G_{eff} \propto \sum V_{G_i}$

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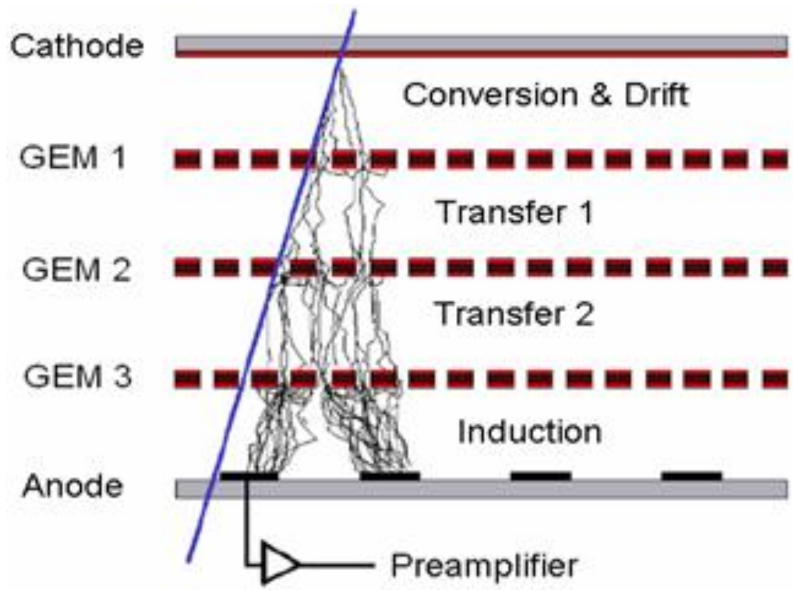
M. Alfonsi et al., The triple-Gem detector for the M1R1 muon station at LHCb, N14-182, 2005 IEEE-NSS

# Triple GEM detector

ARDENT

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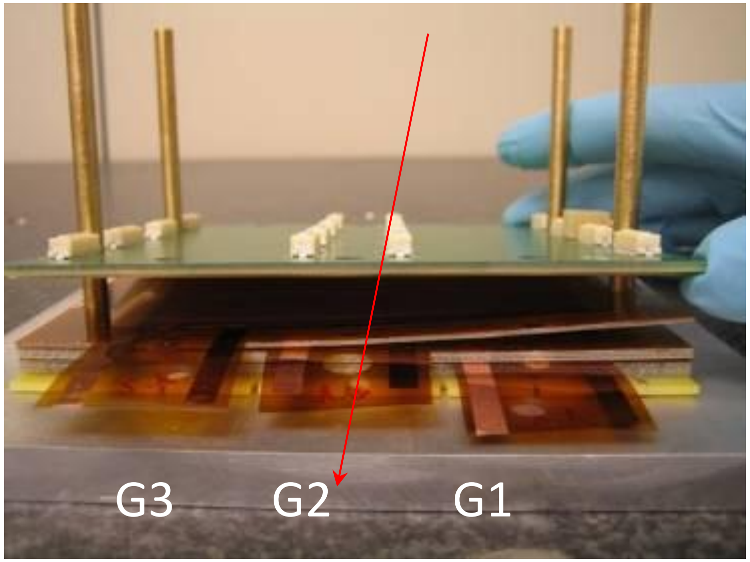
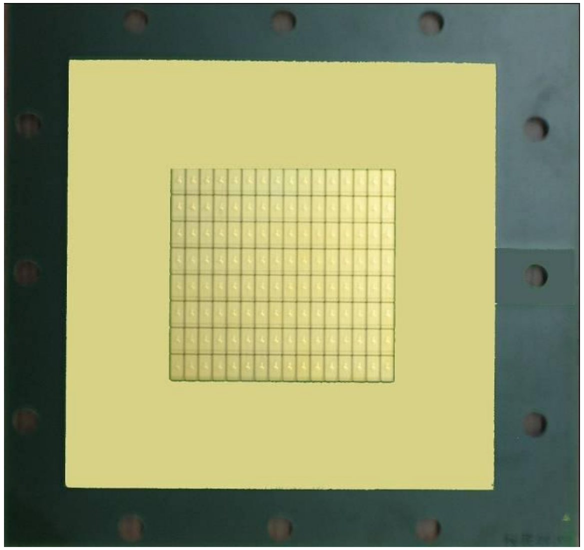
# A Standard Triple GEM construction

The detectors described in this talk are built starting form the standard 10x10cm$^2$ : only one GEM foil has been modified to have central electrodes.

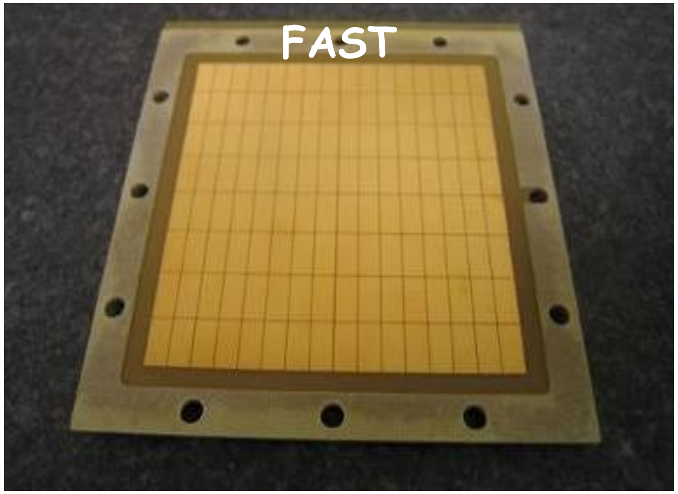


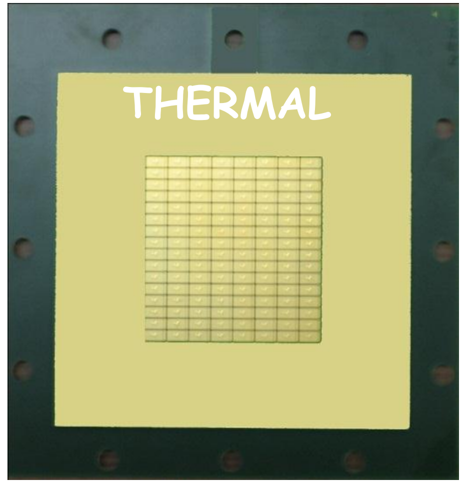



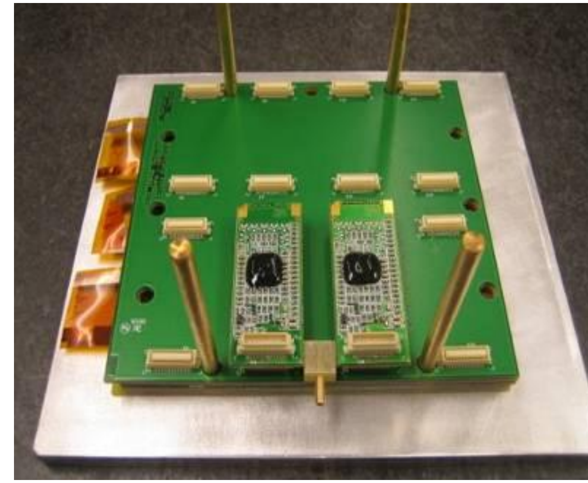
The GEM are stretched and a G10 frame is glued on top

- THERMAL neutrons: 128 pads **3x6 mm$^2$** **~ 25 cm$^2$** of sensitive area

# Triple GEM detector: electronics readout



- FAST neutrons: 128 pads 6x12 $mm^2$ ~ 100 $cm^2$ of sensitive area
- THERMAL neutrons: 128 pads 3x6 $mm^2$ ~ 25 $cm^2$ of sensitive area
- 8 chip CARIOCA to set the threshold on 16 channels and reshape the signal
- FPGA-based DAQ: 128 scaler and TDC channels, in → gate and trigger, out → signals
- HVGEM power supply with 7 independent channels and nano-ammeter

Developed by G. Corradi D. Tagnani Electronic Group LNF-INFN

Developed by A.Balla and G. Corradi and Electronic Group LNF-INFN

# Triple GEM detector: electronics readout

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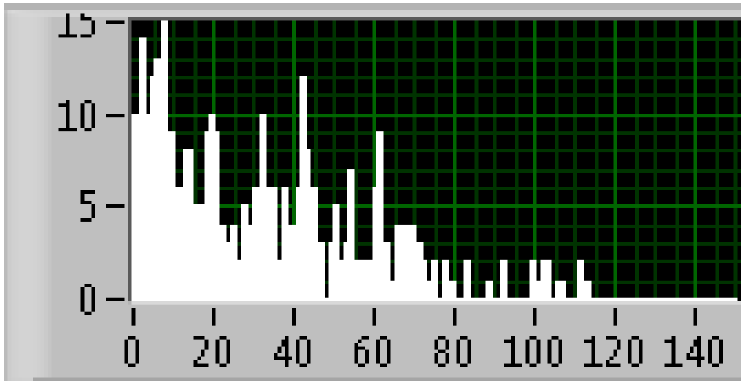
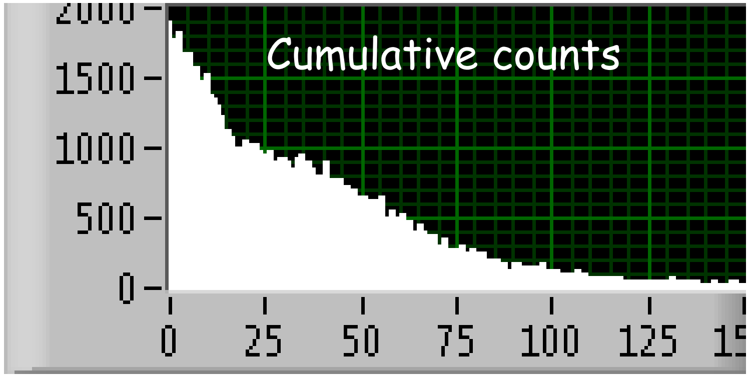
# Time evolution

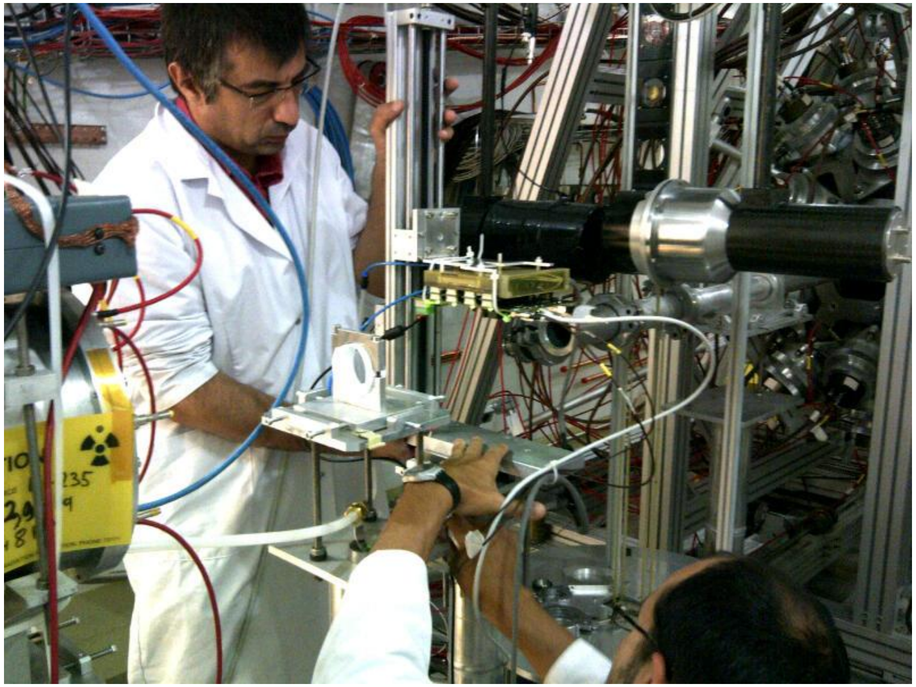
online measurement



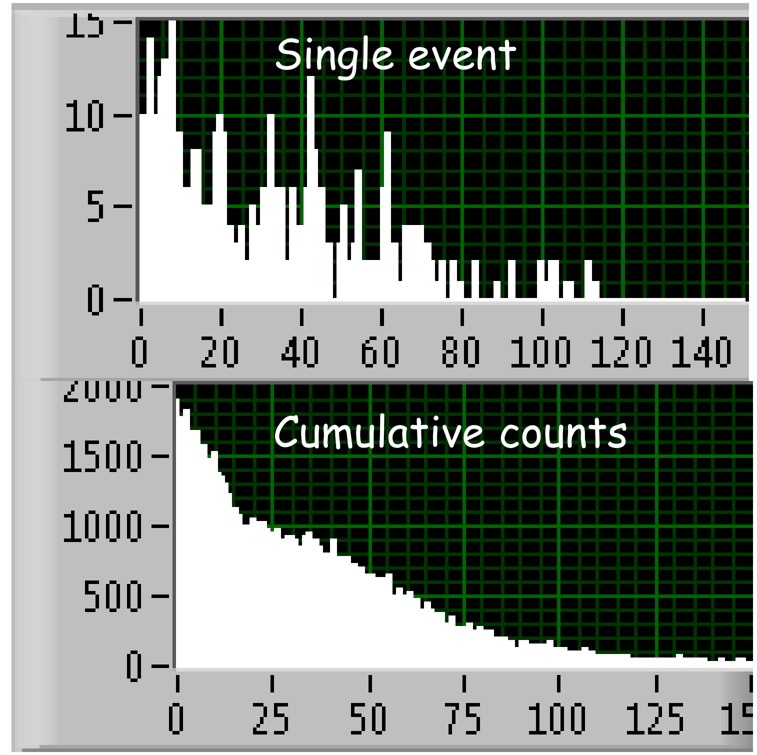




Time spectrum (1ms/bin) 150ms Δt

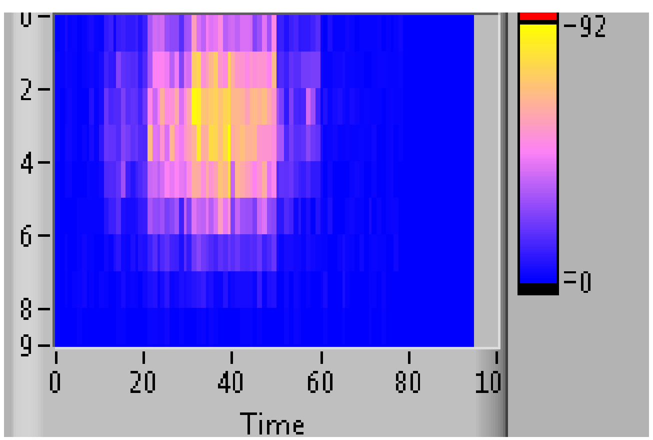
# N-TOF thermal neutron Beam spot



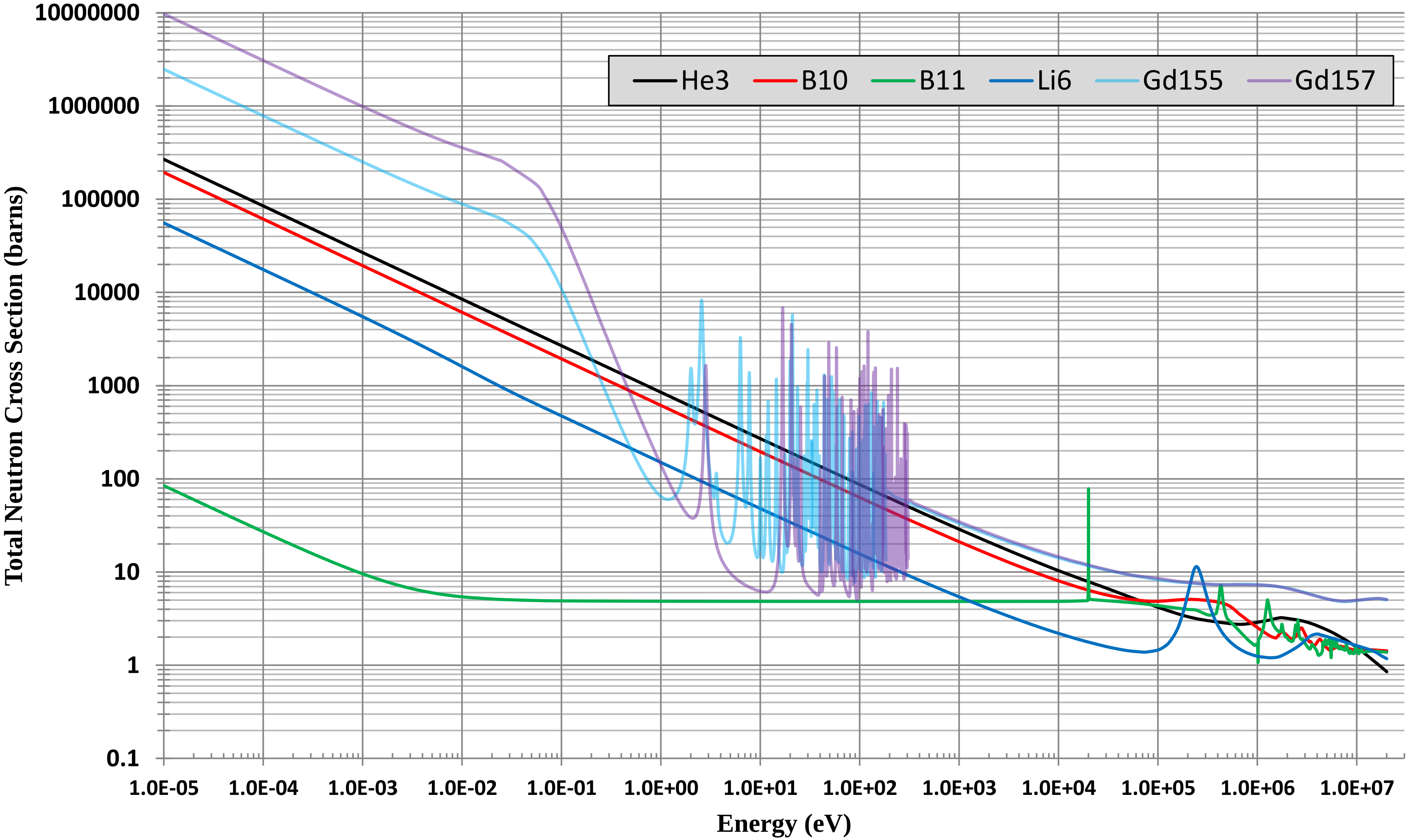
online measurement




Time spectrum (1ms/bin) 150ms gate

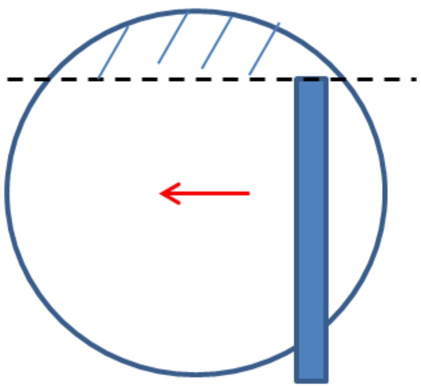



With a scan procedure it is possible to make an image of the neutron beam in the thermal region

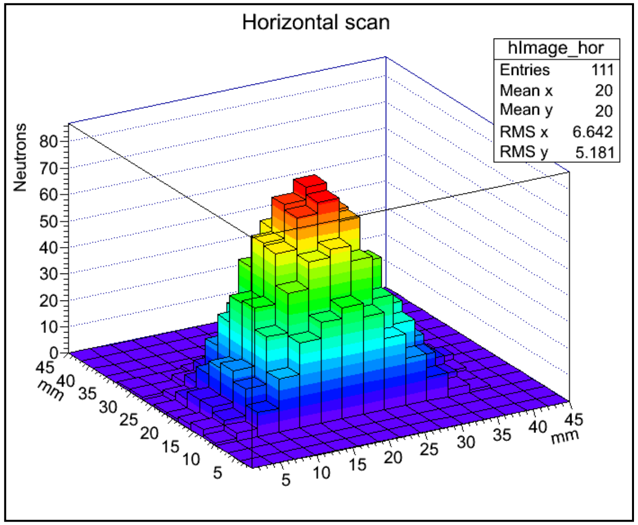

He3
B10
B11
Li6
Gd155
Gd157
10000000
1000000
100000
10000
1000
100
10
1
0.1
Total Neutron Cross Section (barns)
1.0E-05
1.0E-04
1.0E-03
1.0E-02
1.0E-01
1.0E+00
1.0E+01
1.0E+02
1.0E+03
1.0E+04
1.0E+05
1.0E+06
1.0E+07
Energy (eV)

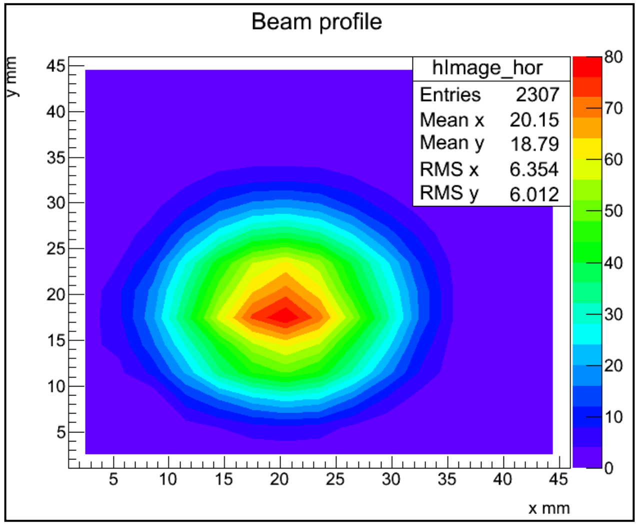
# TEST @ N-TOF: MEASUREMENTS

Neutron beam has been reconstructed making an horizzontal scan on the beam.

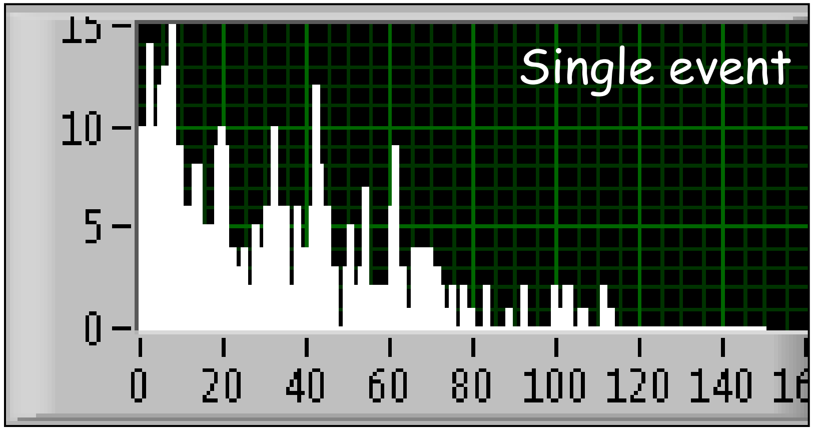


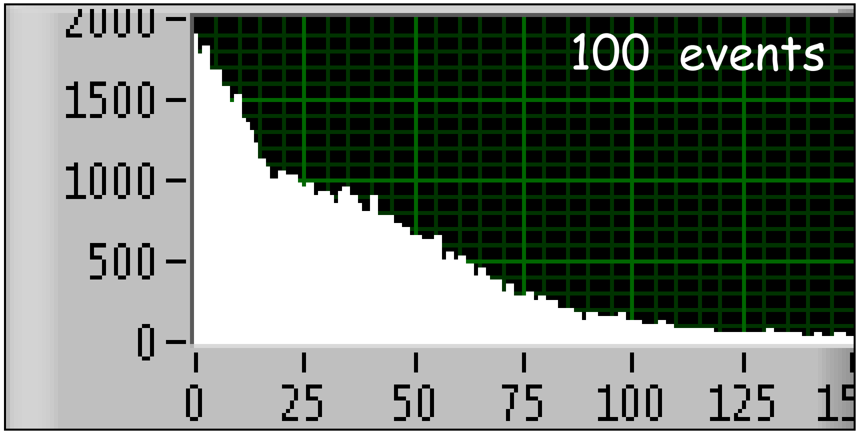
Horizontal scan




ToF measurements: thermal energy spectrum




Slices acquisition: Time spectrum (1ms/bin), 150ms total gate.