He-free Side-on GEM detector for Thermal Neutron Counting

How it works and some results

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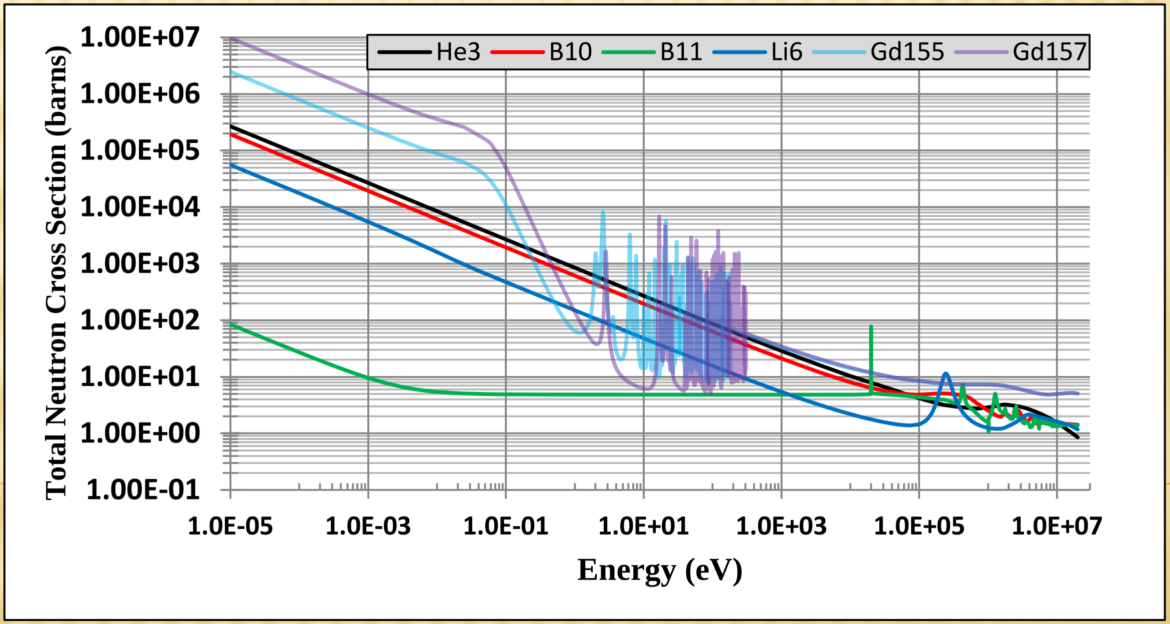
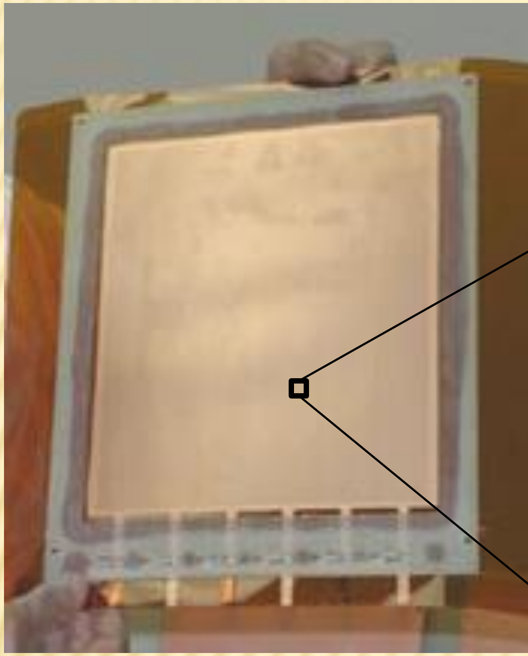
^{3}He SHORTAGE PROBLEM

- He-3 shortage noticed by US governement
- research of replacement technologies
- switch to detector based on ^{10}B solid converters and BF_3 gas
- alternative solid converters: ^{6}Li, ^{155,157}Gd

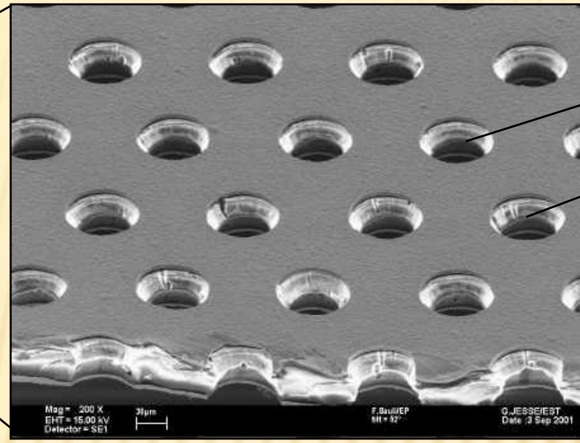


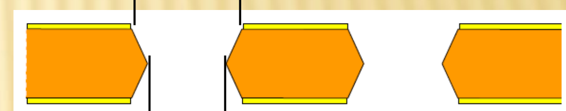
An interesting alternative:
a compact GEM detector based on solid ^{10}B-enriched layers.

WHAT IS A GEM?



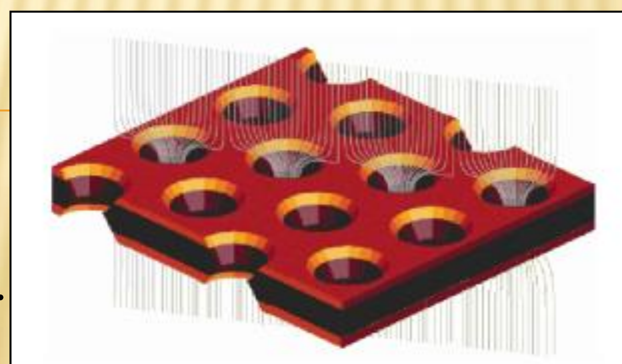
A Gas Electron Multiplier (F.Sauli, NIM A386 531) is made by 50 μm thick kapton foil, copper clad (5 μm thick) on each side and perforated by an high surface-density of bi-conical channels;

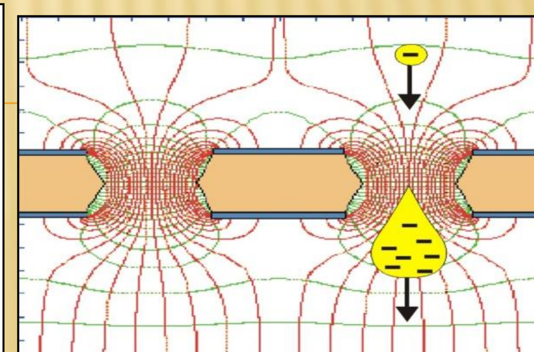




Applying a potential difference (tipycally between 300 and 500 volts) between the two copper cladding, an high intesity electric field is produced inside the holes (80-100 kV/cm).

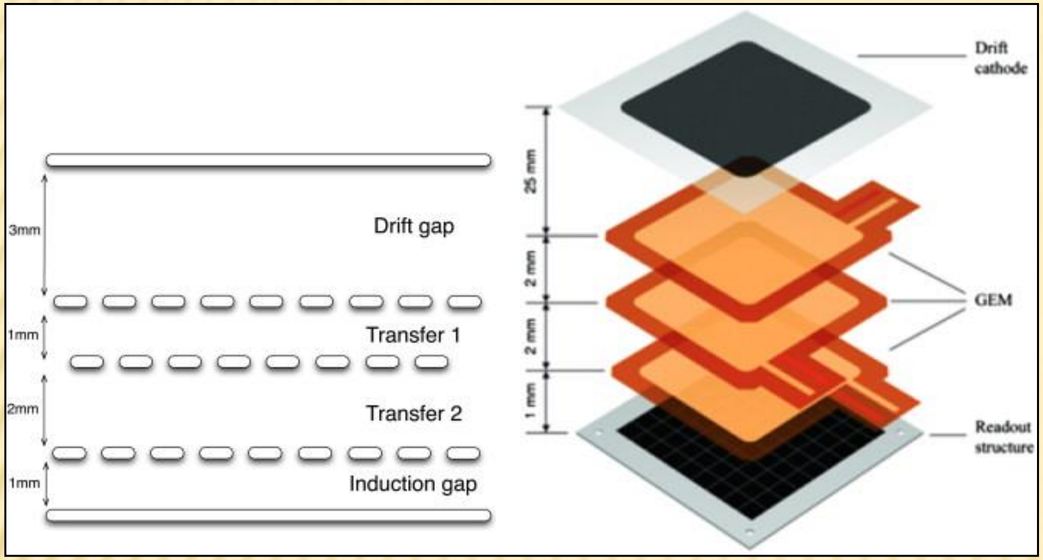
GEM is used as a proportional amplifier of the ionization charge released in a gas detector.



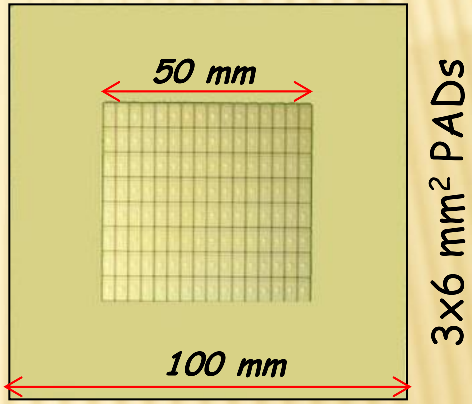


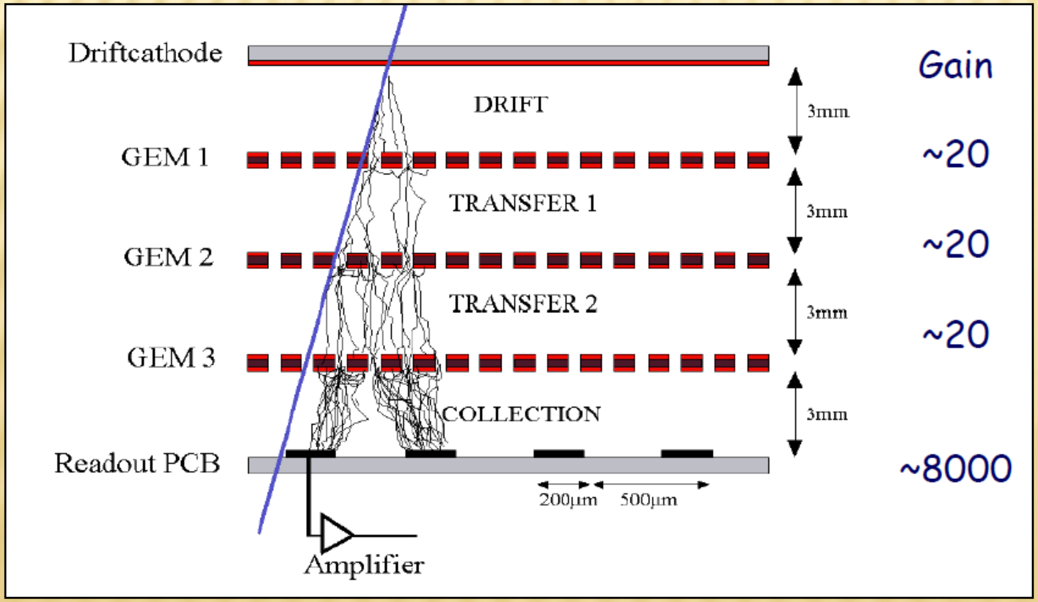
TRIPLE-GEM DETECTORS

Layout of a typical Triple GEM detector constructed with standard 10 x 10 cm².

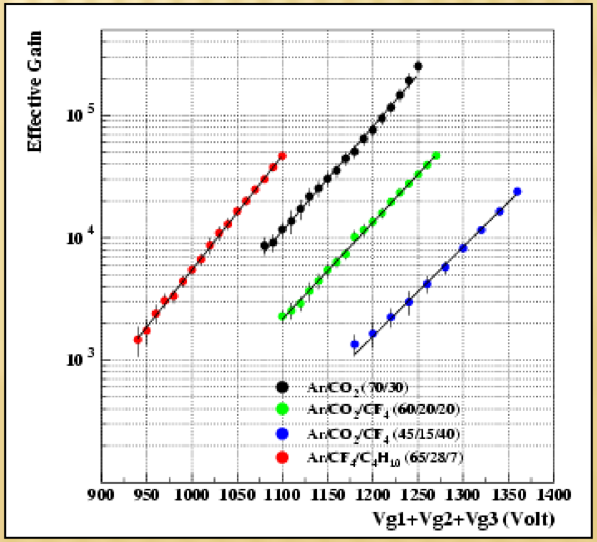


The anode has 128 pads. Each PAD can have a different geometry depending on detector applications.

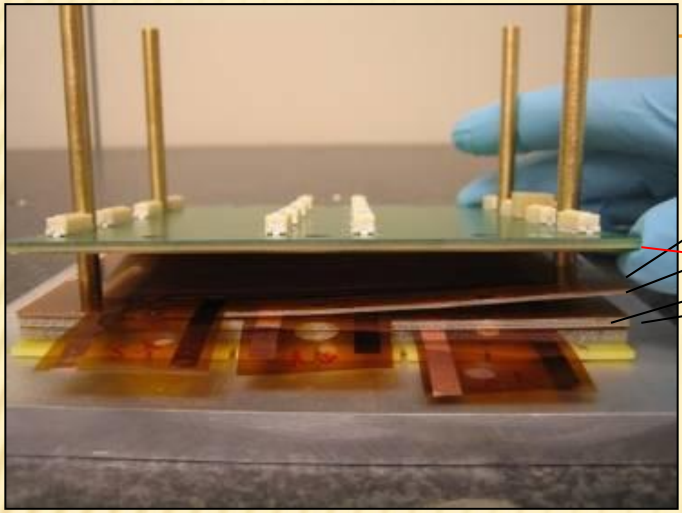


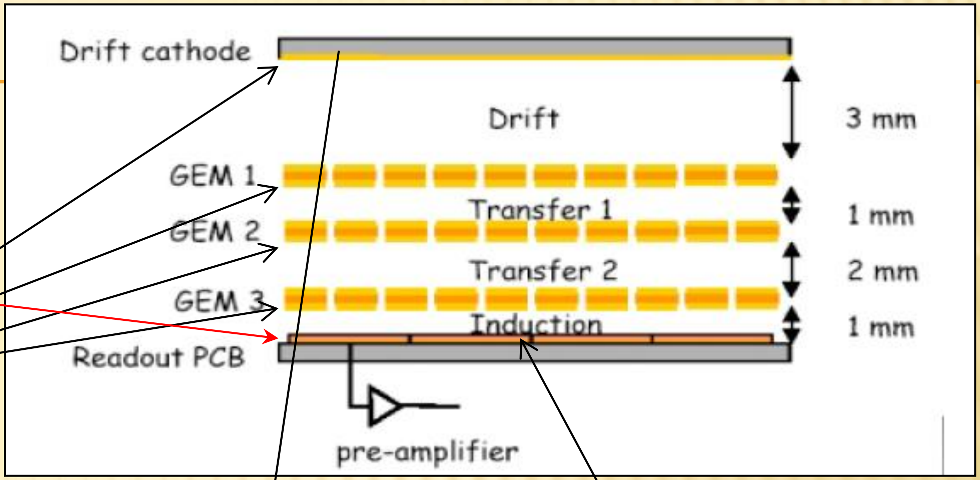


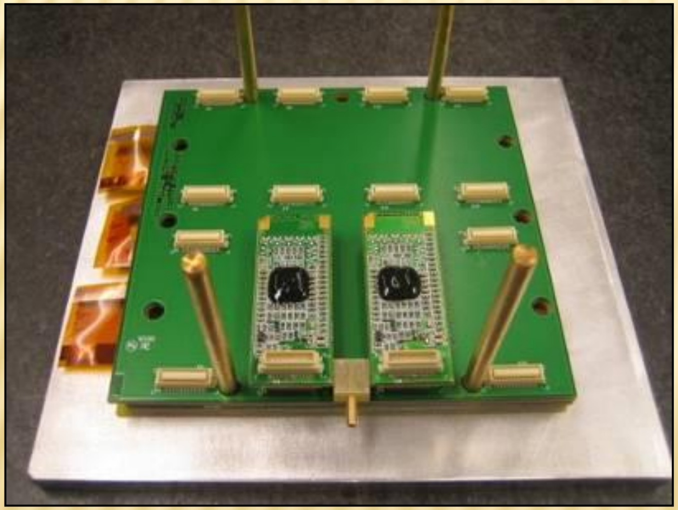
Gas Gain Curves



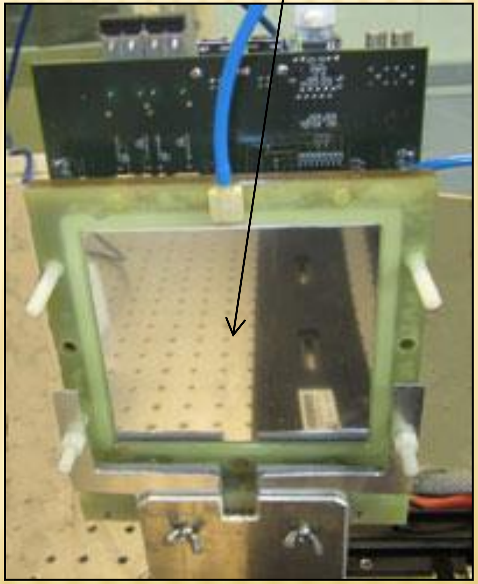
A COMPACT TRIPLE-GEM DETECTOR



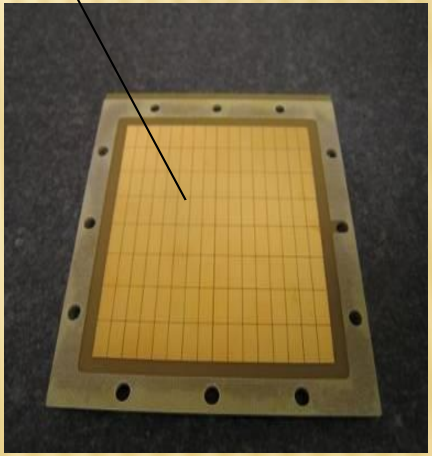




All the anode PCB have been designed with the same connector layout for a total of 128 channels.



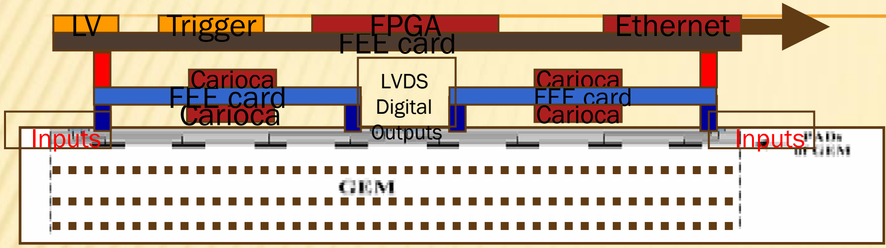
Detector window: typically made of Aluminate Mylar or Fiberglass



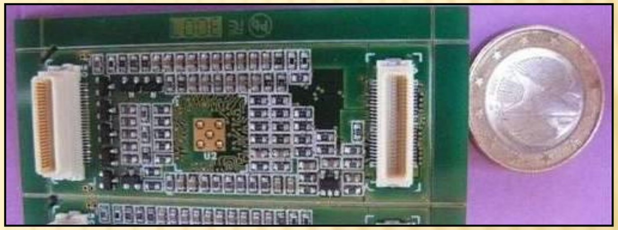
PCB anode divided in 128 PADs

PADs dimension and geometrical configuration can be chosen according to the application of the detector.

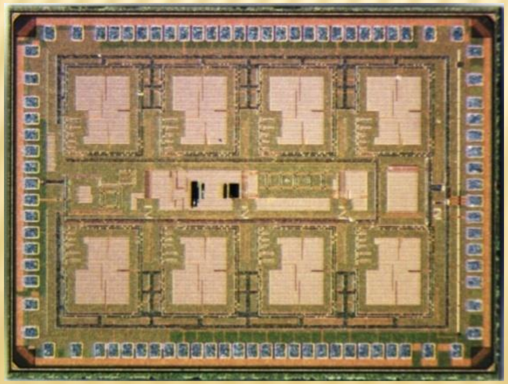
FEE: CARIOCA GEM CHIP CARDS



CARIOCA chip cards



The card is based on Carioca GEM Chip and has been designed and realized in Frascati (LNF, Gianni Corradi);
Total dimension : 3x6 cm^2
16 channels for each card: channel density of 1 ch/cm^2
Sensitivity of 2-3 fC,LVDS output (25 ns), Radhard.



We are working on a new GEMINI chip which will be able to increase the number of channels. The new chip can mange 32 channels, in comparison to the 8 channels of the old one.

It will be able to measure also the charge released in the drift gap.

FEE: FPGA MOTHER BOARD

We have an Intelligent Mother Board with an FPGA (Field Programmable Gate Array) on board able to count the 128 channel hits and/or measure the time respect to a trigger (1 ns) ; the data are readable through an Ethernet connection (LNF A.Balla, P.Ciambrone, M.Gatta).

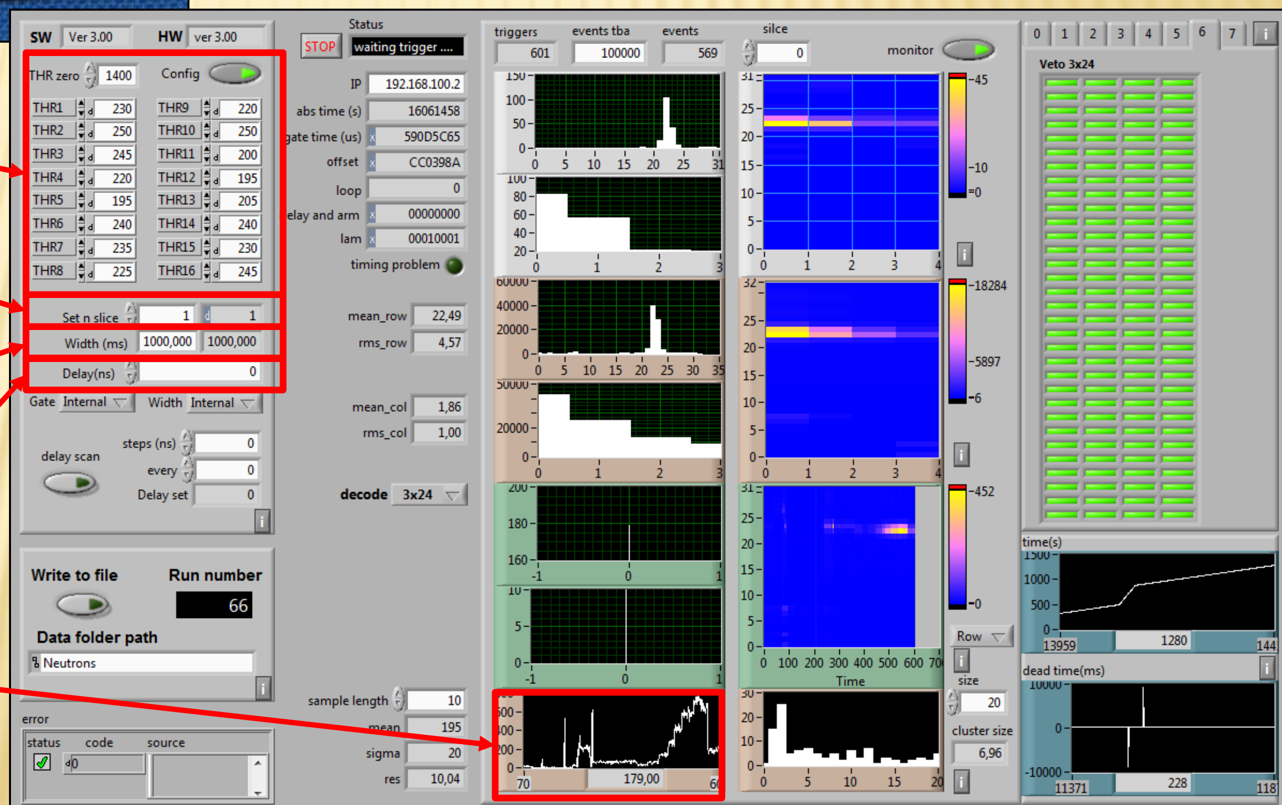
Threshlds settings

Slices acquisition

Integration time (untill 20-30 µs)

Delay to trigger

Total Counts vs time



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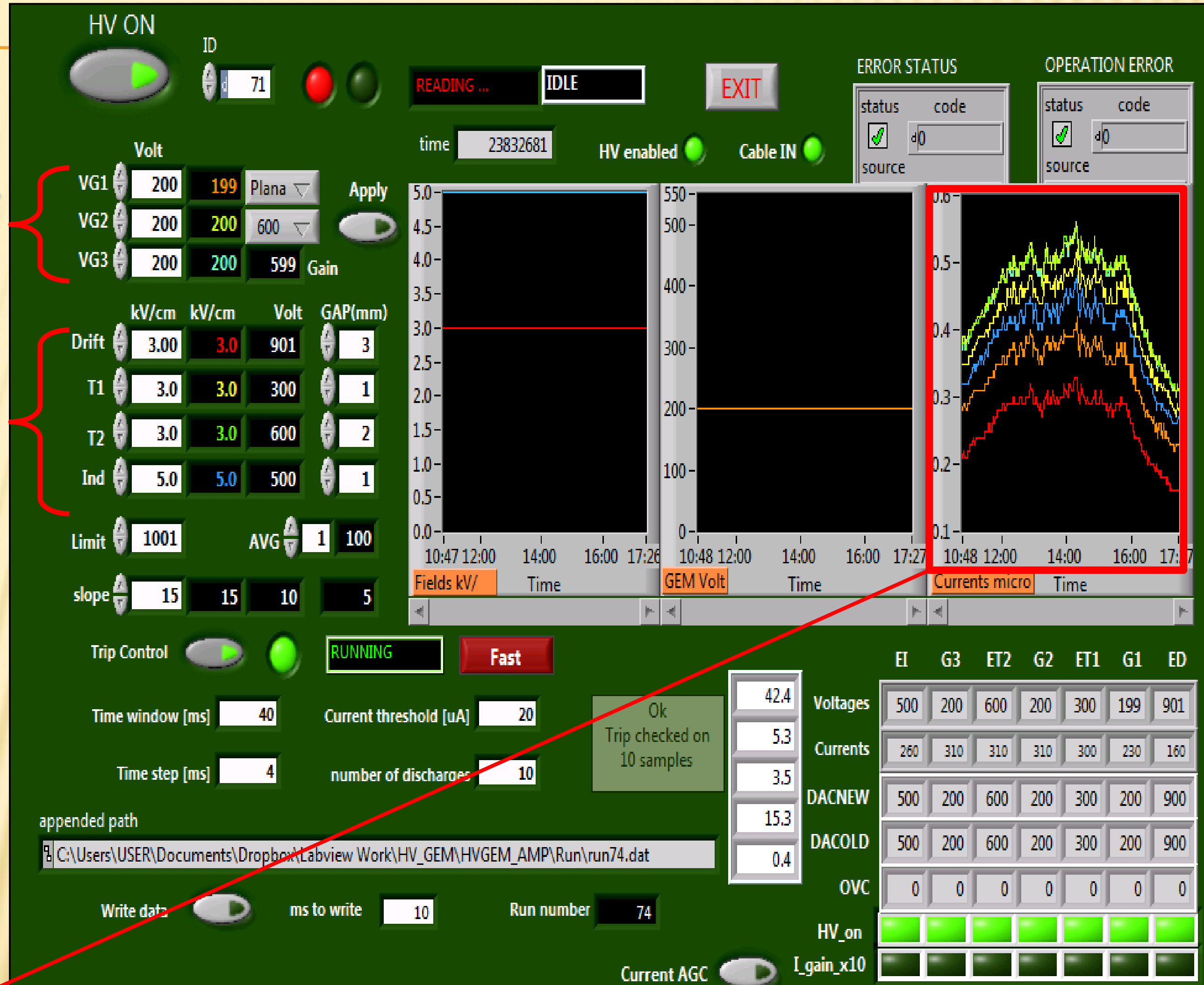
HIGH VOLTAGES: NIM STANDARD HVGEM MODULE

Labview Control Pannel for the High Voltage

GEM Voltage (gain)

Fields

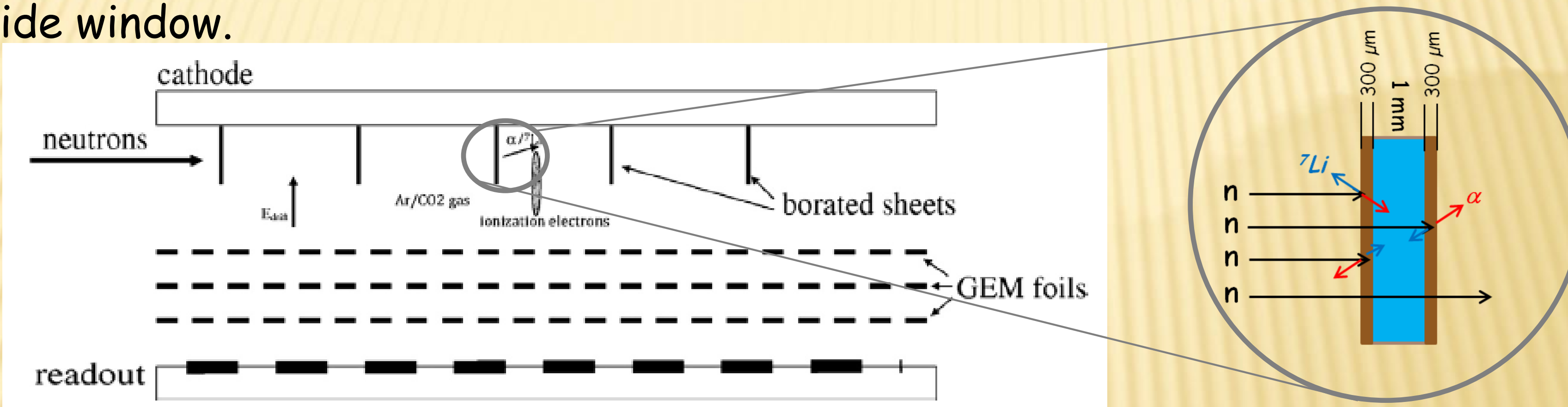


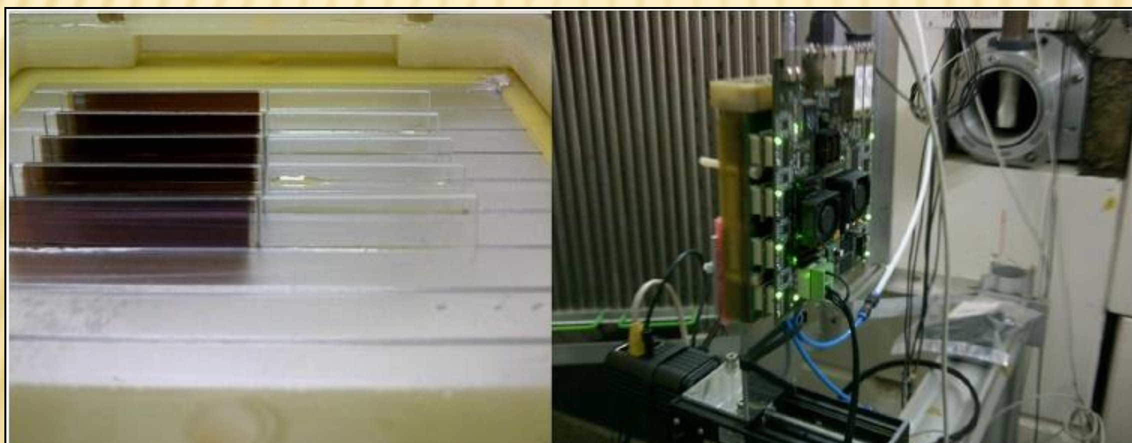
High Voltage Module for triple-GEM detector

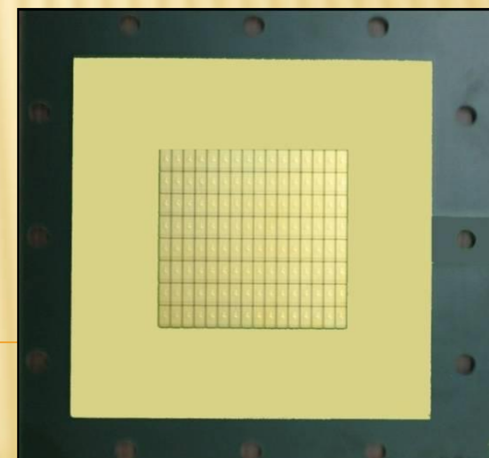
Real-time electrodes current measurements: each channel has a nano-Ammeter which measures the current with a sensitivity of 10 nA.

A GEM DETECTOR FOR THERMAL NEUTRONS

The idea was to insert a sequence of borated strips attached to the aluminum cathode. The drift region was extended and the detector was equipped with a side window.



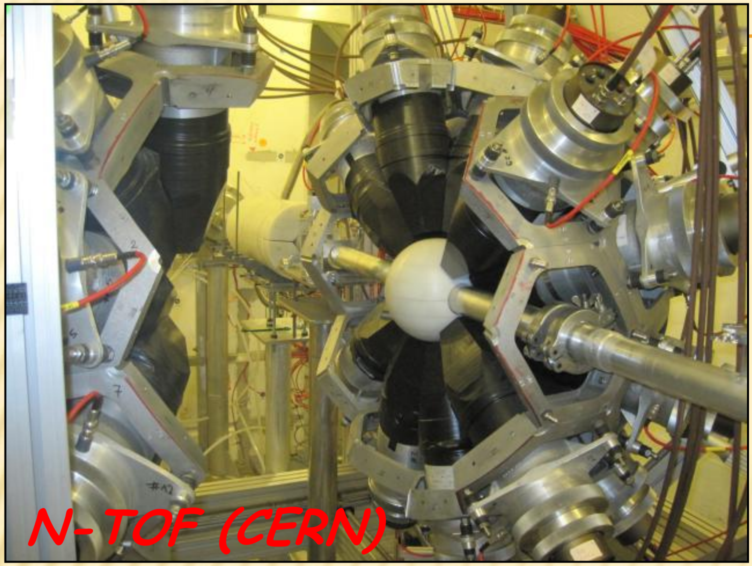




Boron Reaction: $^{10}B + n \longrightarrow \alpha + {}^{7}Li + 2.79$ MeV (6 %)

$\longrightarrow \alpha + {}^{7}Li^{*} + 2.31$ MeV $+ \gamma$ (478 keV) (94%)

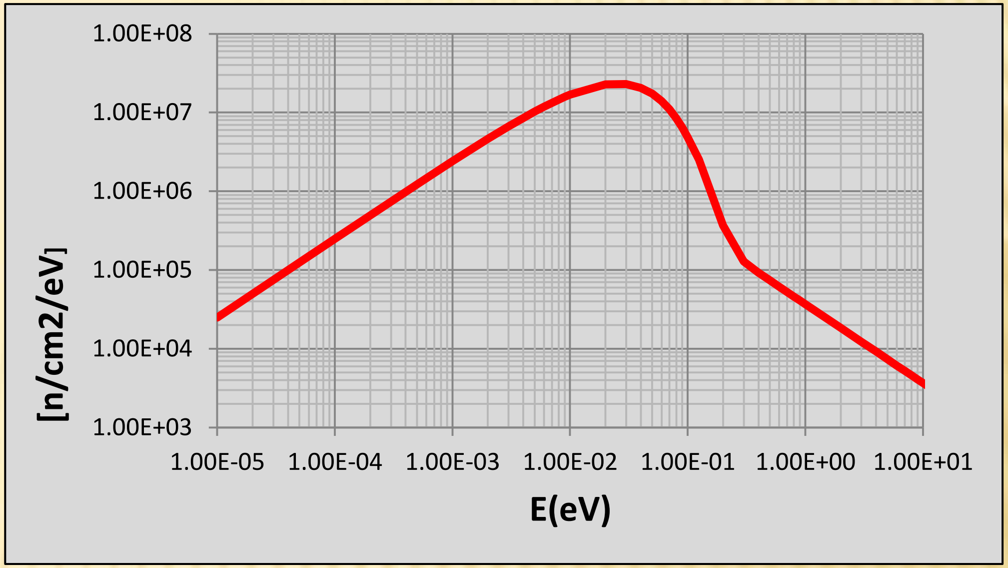
NEUTRON FACILITIES USED

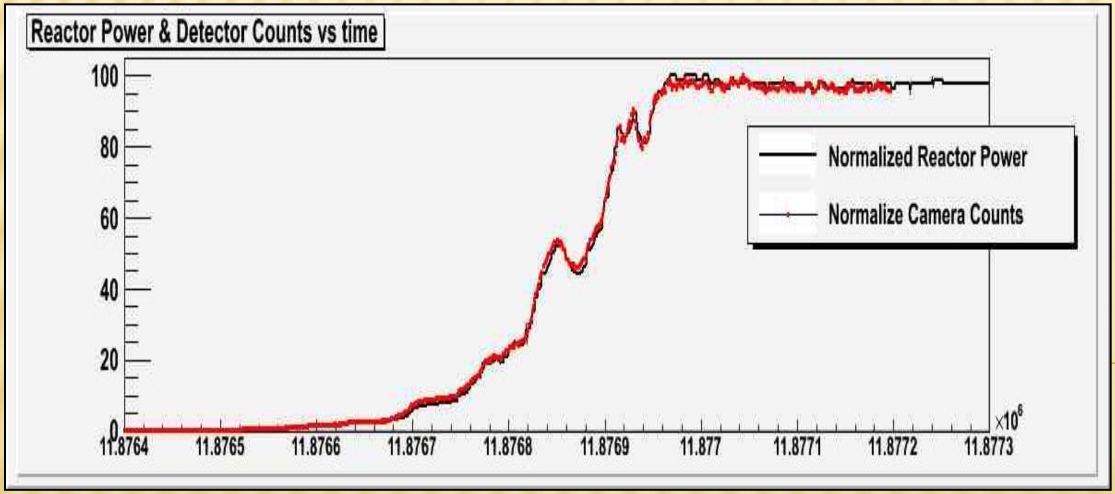


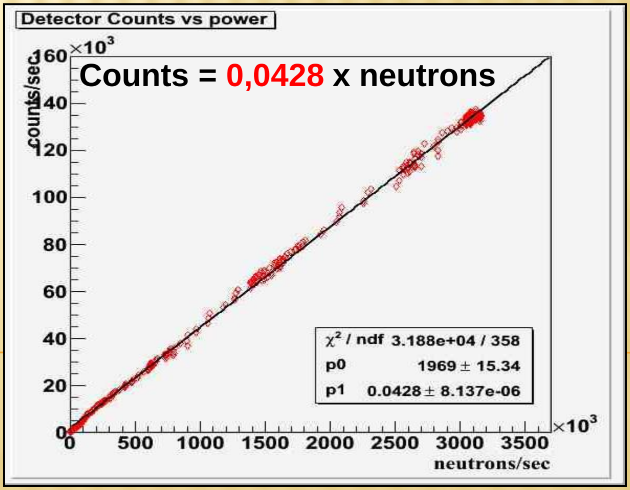
Tests @ TRIGA Reactor (ENEA)

TRIGA Reactor has a Neutron Flux Rate ϕ = (2,3 ± 0.2) x 10^6 neutrons/(cm^2·sec) at 1 MWatt of Reactor Power.

The flux was changed varying the reactor power from 100 W to 1 MW. Side-on GEM detector was able to follow these variations.





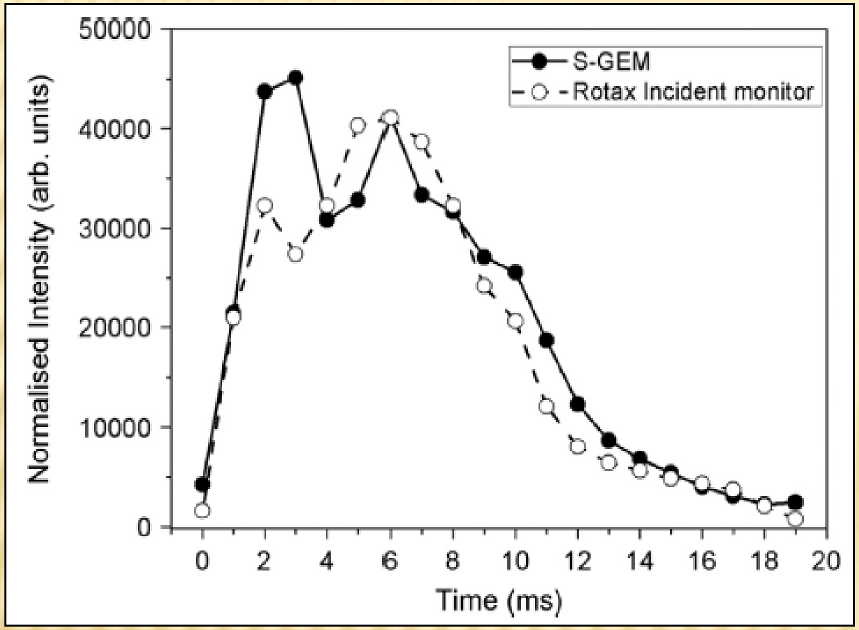


Knowing the incident flow and the detector active area of we estimated an ***absolute efficiency*** of ***4.3 ± 0,5%,*** over the whole range of reactor thermal energies.

Test @ ISIS: ToF measurements

ISIS facility is a pulsed neutron source. Energy spectrum ranges from thermal to fast neutrons.

We used our detector to make Time of Flight (ToF) measurements of thermal neutrons.



An external trigger starts the detector acquisition of the detector which records data in a time window of 1 ms.

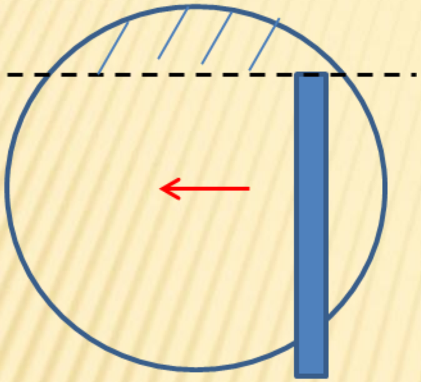
The typical ISIS double-peak profile was obtained applying a delay increasingly longer in step of 1 ms.

Results are in agreement with those obtained from the ROTAX instrument.

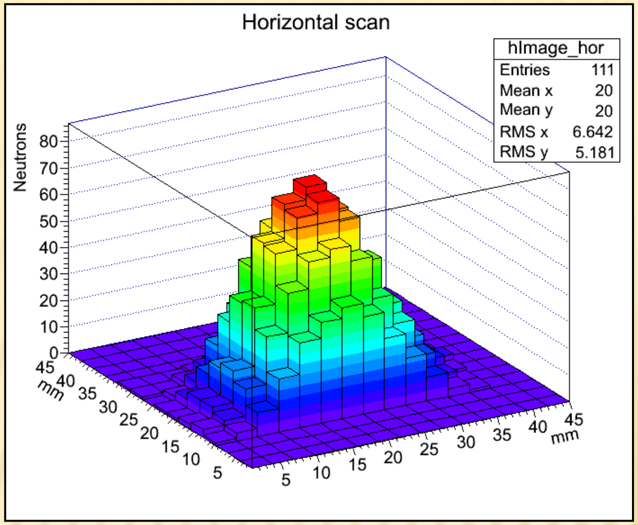
Our FEE electronics is very fast and allows ToF measurements, widely used in neutron spectroscopy. It is possible to scan using time windows which can reach a temporal amplitude a few tens of μs.

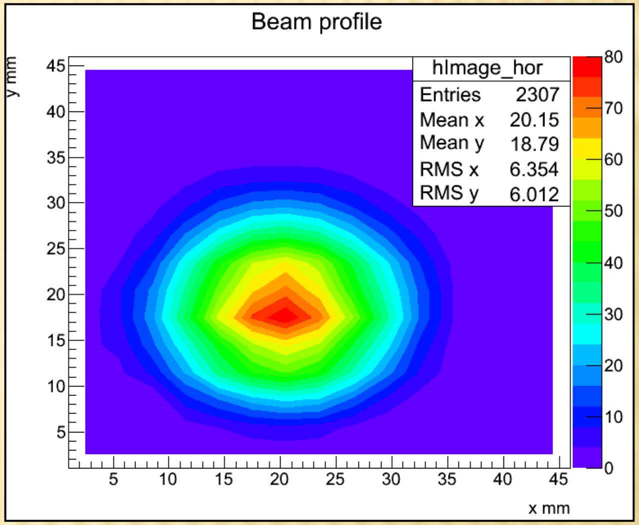
TEST @ N-TOF: MEASUREMENTS

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

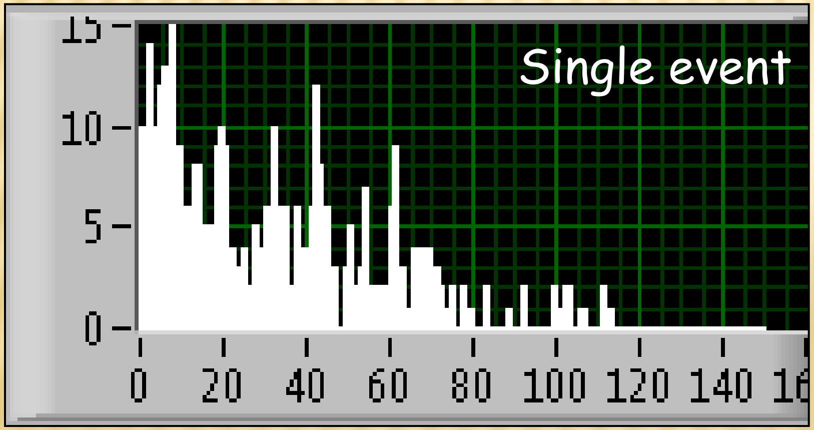


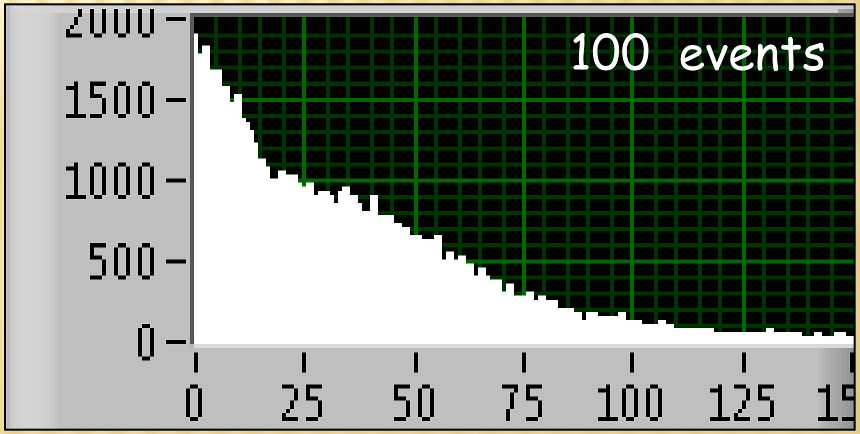
Horizontal scan





ToF measurements: thermal energy spectrum

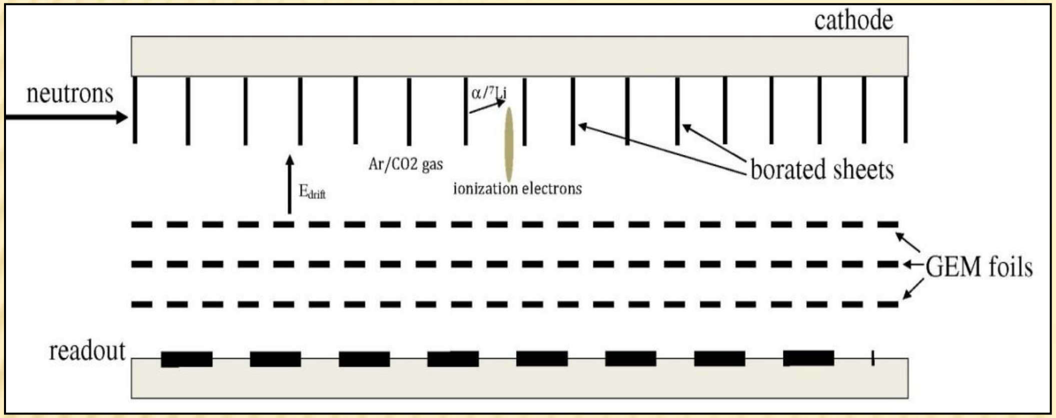


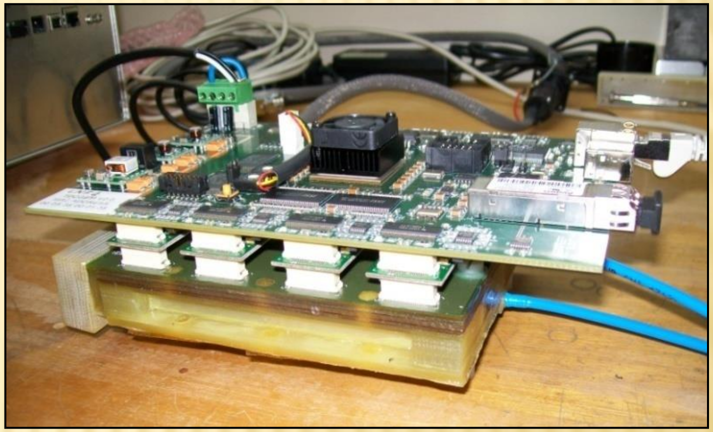


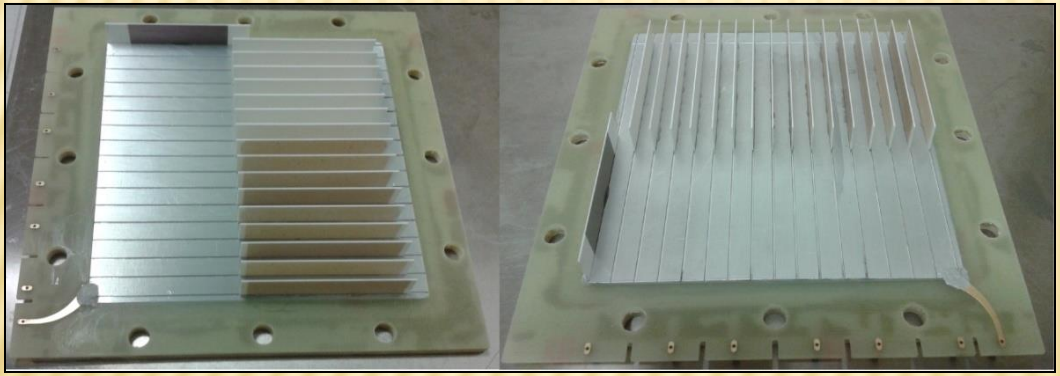
Slices acquisition: Time spectrum (1ms/bin), 150ms total gate.

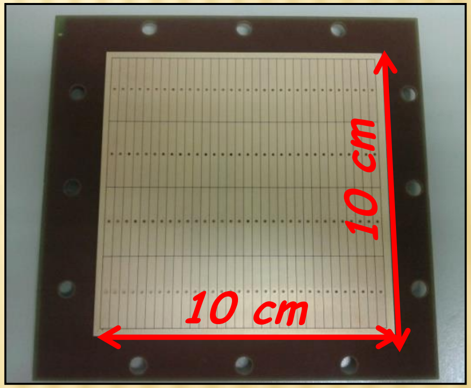
THE SECOND PROTOTYPE

We developed a new prototype increasing the number of borated strip to 16, in order to obtain an higher efficiency.









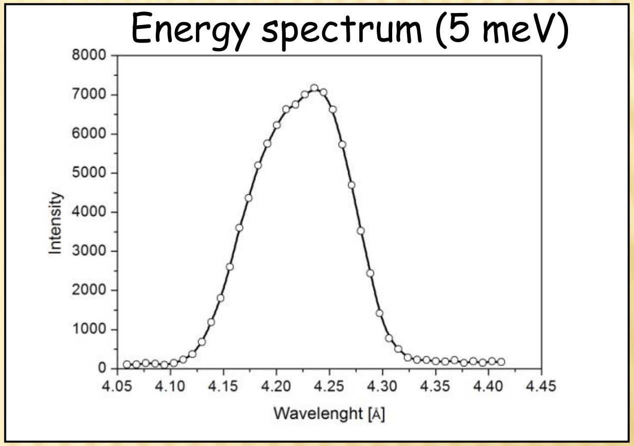
Now we used an anode with PADs having a different geometry. There are 32x4 PADs and each PAD is 3x24 mm².

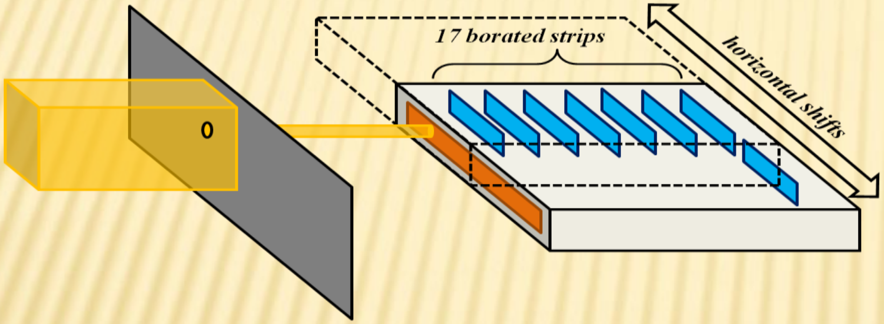
Now we used ceramic strips (Al_2O_3) 500 µm thick.

Detector window is placed on the side of the anode with 32 PADs. In this way detector is able to measure also position of small spot beams impinging on the side-on window.

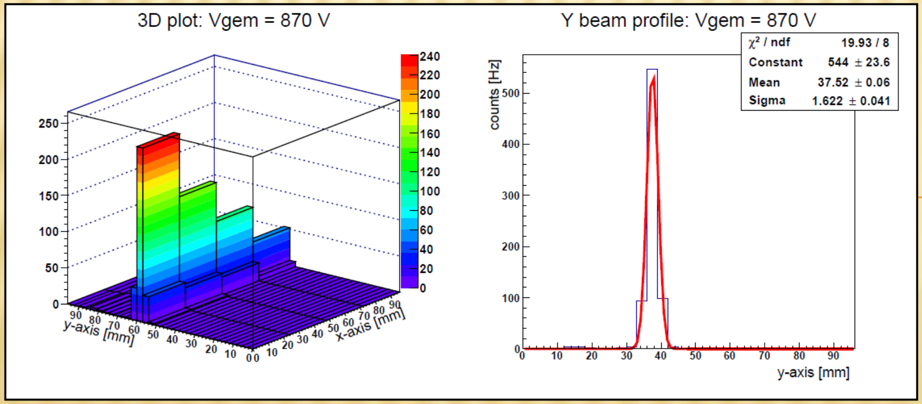
TESTS @ HFIR REACTOR (USA): POSITION SCAN

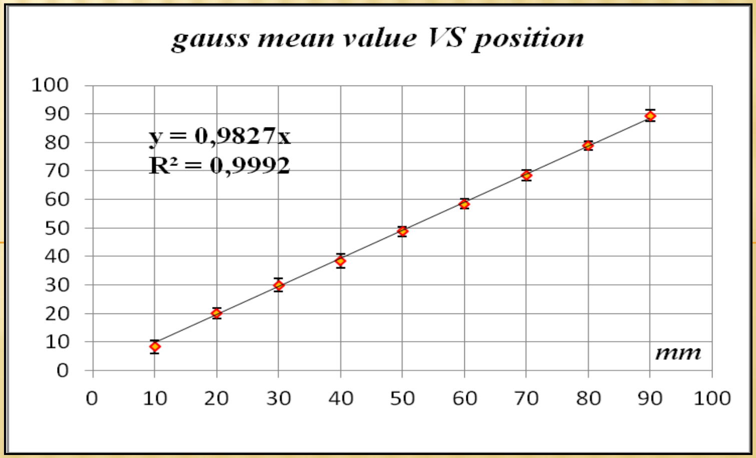
Measurements were performed on one of the beam facilities available at the HFIR reactor (ORNL). It can provide two neutron energies corresponding to 2 Å and 4 Å in wavelength. Our source worked at 4 Å and $\Delta\lambda/\lambda$ = 0,5%. The corresponding energy peak is 5,11 meV (±0.03).





Using a borated aluminum mask with a hole 2,5 mm in diameter, we made a position scan moving the GEM detector.

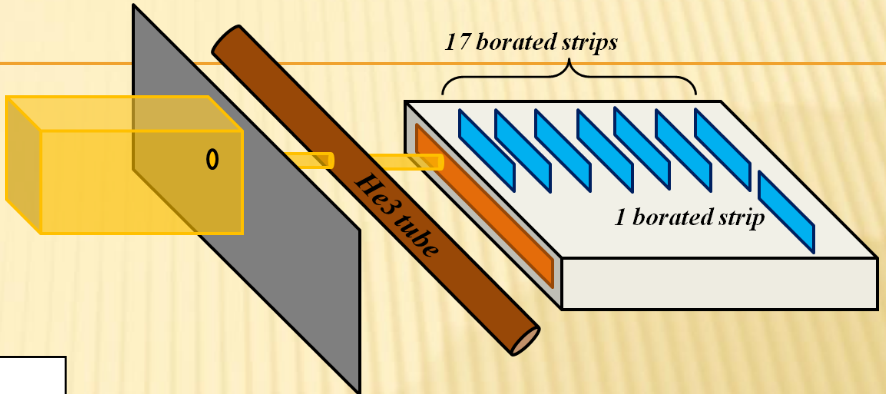


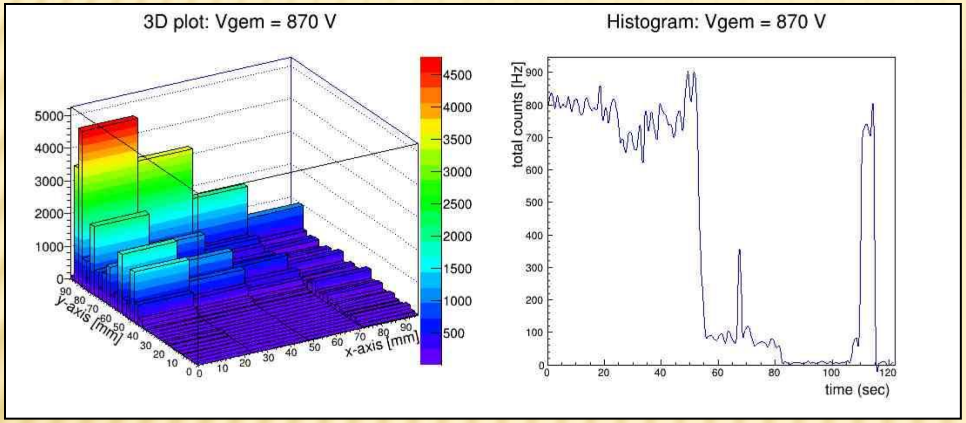


We obtain a beam position resolution of about 0.8 mm.

TESTS @ HFIR REACTOR (USA): EFFICIENCY

We estimated detector efficiency, making a comparison with an ^{3}He tube which has a 100% absolute efficiency at the used peak energy of 5,11 meV.

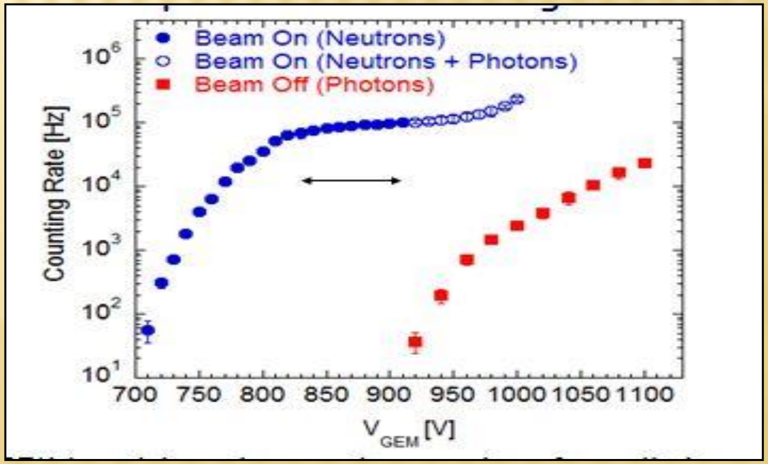




Detector efficiency was evaluated on both detector sides:

- 16 strips efficiency = ***31 ± 1 %***
- 1 strip efficiency = ***2,8 ± 0,5 %***

	S-GEM	^{3}He Tube
Overall mean counts [s^{-1}]	1863	6011
Background mean counts [s^{-1}]	21	1586
Signal/Background	87.7	2.8
Efficiency [%]	31	99



Low gamma sensitivity.

CONCLUSIONS

- ✓ Over ten years experience has showed that GEM techonology is reliable and very versatile.
- ✓ We have developed a compact and quasi portable system, with modular elements.
- ✓ Side-on GEM detector is based on GEM technology and can enjoy of consolidated knowledges.
- ✓ Side-on GEM detector can represent a valid substitute to the traditional thermal neutron detectors.
- ✓ It shows a very good linearity as thermal neutron monitor and a low gamma sensitivity.
- ✓ FEE allows ToF measurements with a time resolution of few tens of μs (spectroscopic applications)
- ✓ A suitable pad configuration allows beam position measurements with an accuracy better than 1 mm.
- ✓ Untill now we find an absolute efficiency of about 31% at 5 meV.
- ✓ With the same configuration and 1 μm ^{10}B deposition, we expect to achieve an efficiency > 70% in the thermal neutron energy region, a comparable value to ^{3}He tubes.

THANK YOU FOR YOUR ATTENTION!

- HVGEM : MPElettronica – Rome (Italy)
- CARIOCA Chips: Artel SRL – Florence (Italy)
- MB-FPGA: Athenatek – Rome (Italy)
- GEM FRAMES: Meroni & Longoni – Milan (Italy)
- GEM Foils: CERN
- Detector construction: LNF-INFN (Frascati)
- Boron layer deposition ENEA (Frascati)