Alternative detectors: GEM and Borated MediPix

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Laboratori Nazionali Frascati & CERN
The ARDENT Marie Curie ITN project

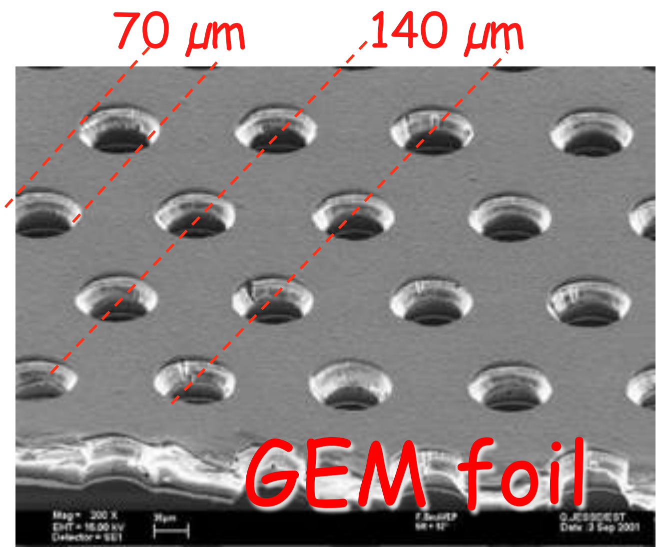
- Principia of triple GEM detector
- A triple GEM detector system
- Fast neutron Monitor
- Thermal Neutron detectors
- Borated Medipix

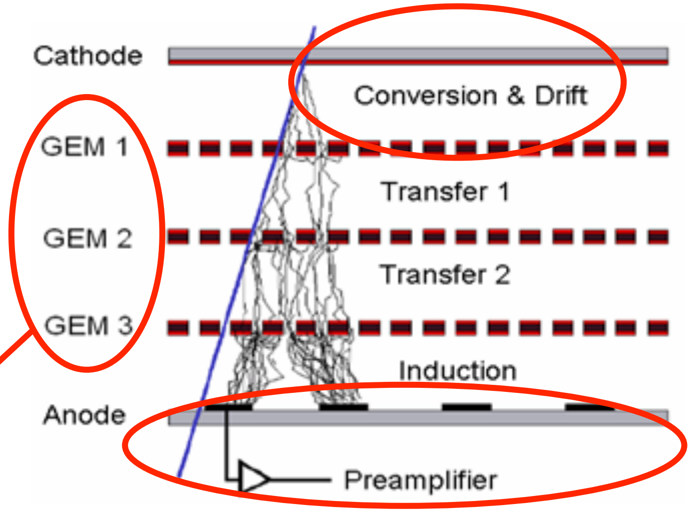
E,Aza, A.Balla, G.Claps, G.Corradi, G.Croci, A.Pietropaolo, S.Puddu, L.Quintieri, D.Raspino, M,Silari, P.Stuart, D.Tagnani (INFN, ENEA, CERN, RAL, U.BICOCCA)

A triple GEM Chamber

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

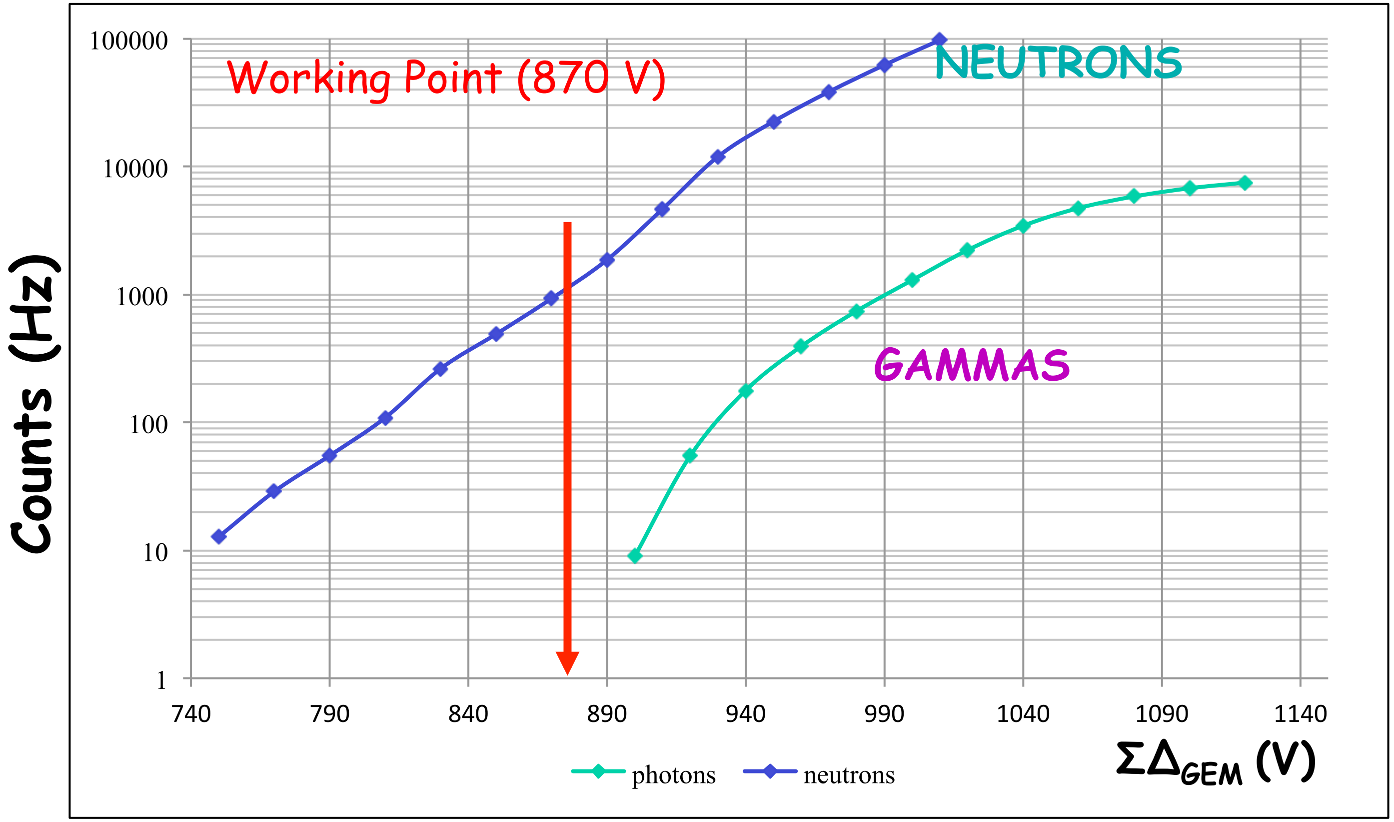
Several triple GEM chambers have been built in Frascati since 2001 (LHCb, Dafne Upgrade, KLOE2, UA9, IMAGEM, GEMINI, AIDA/BTF …





Working with different levels of gain it is possible to obtain high level of gamma- neutron discrimination

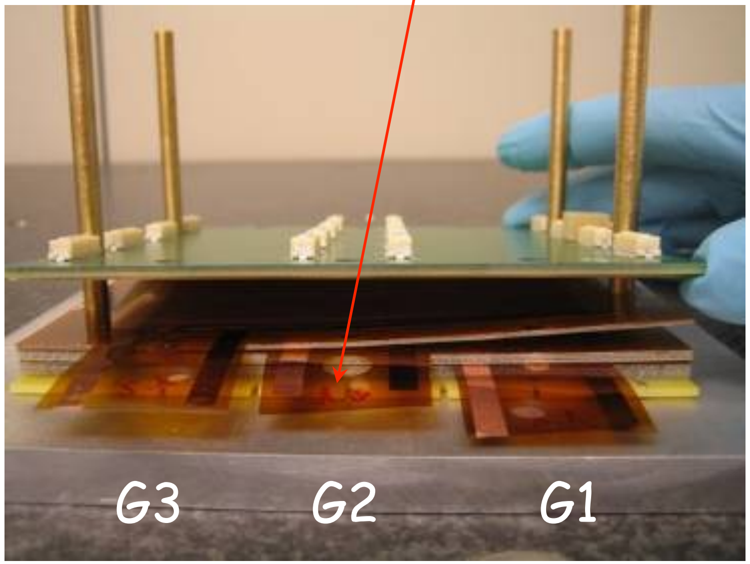
Detector Working Point

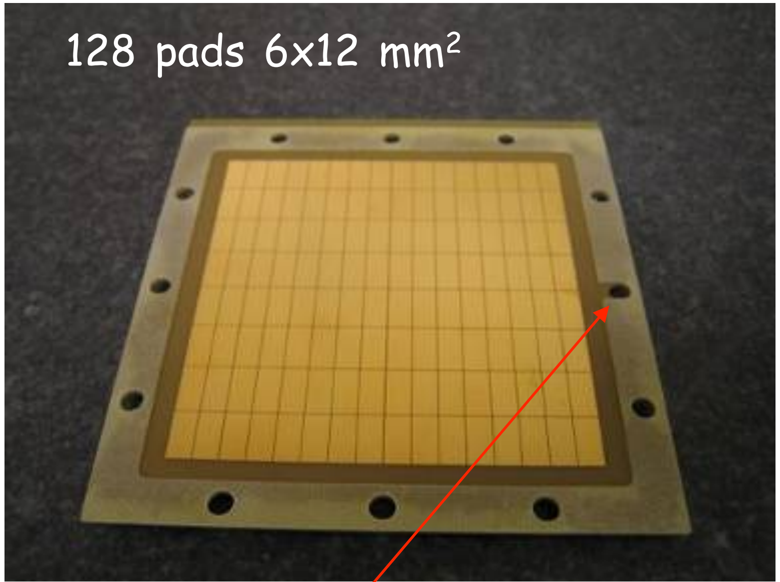


Counting rate Vs chamber gain: up **to 890 V** the chamber is sensitive to fast neutron but not to gamma rays.

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 gas mixture used is Ar CO_2 70-30 atmospheric pressure



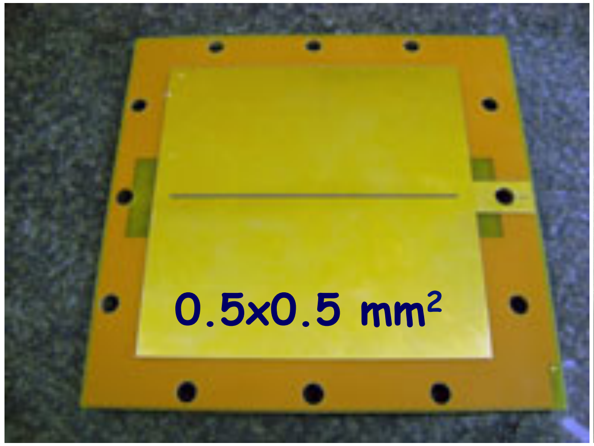


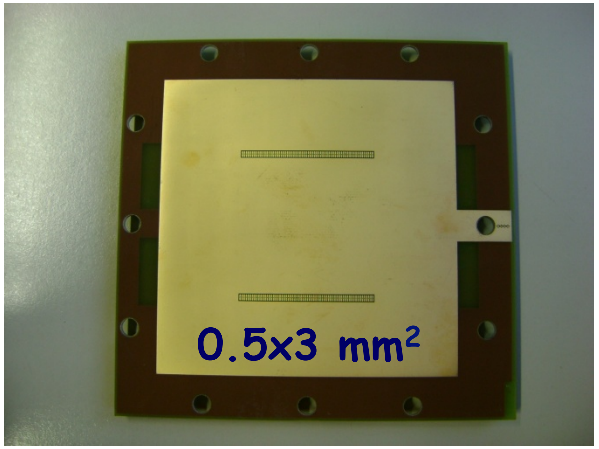
The GEM are stretched and a G10 frame is glued on top

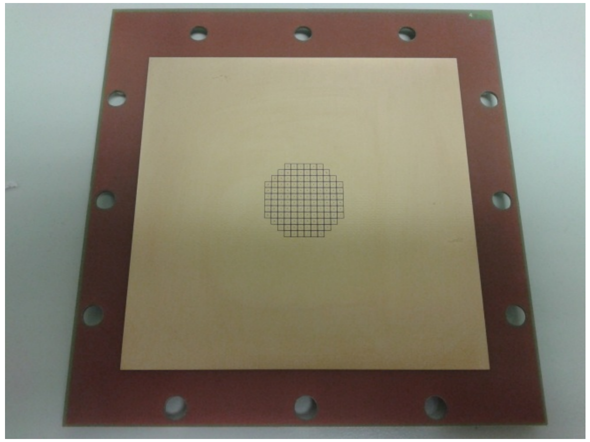
The frame for the G3 foil has been modified for the gas inlet

Pad readouts

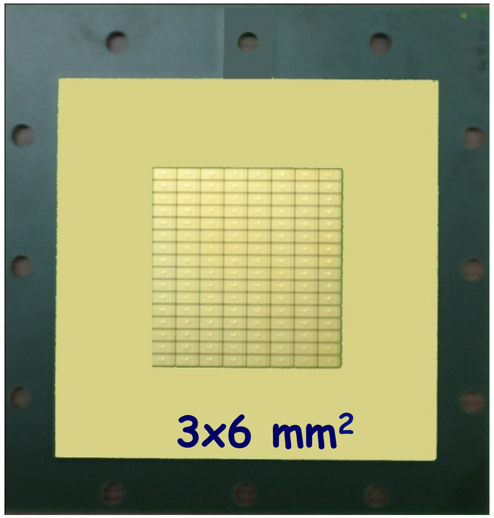
Different pad geometry but always with 128 channels

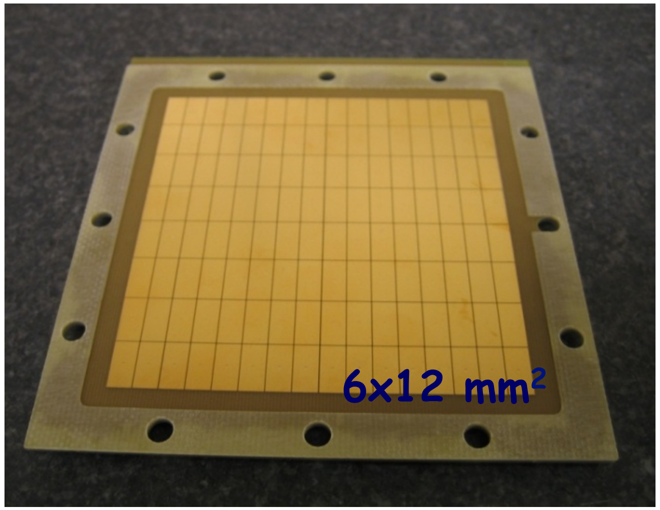


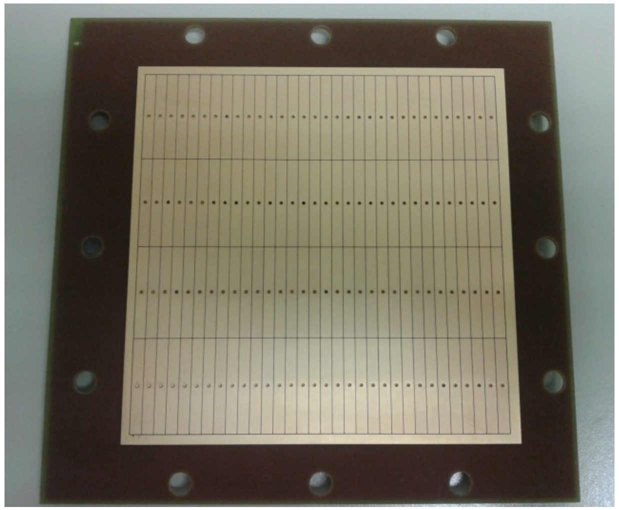




Used for beam monitors (BTF, Lead Ions UA9, CNAO, Bern Cyclotron)

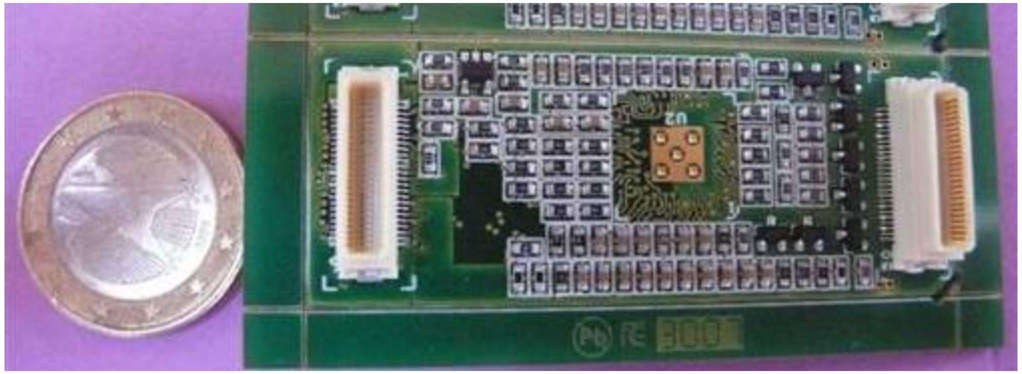


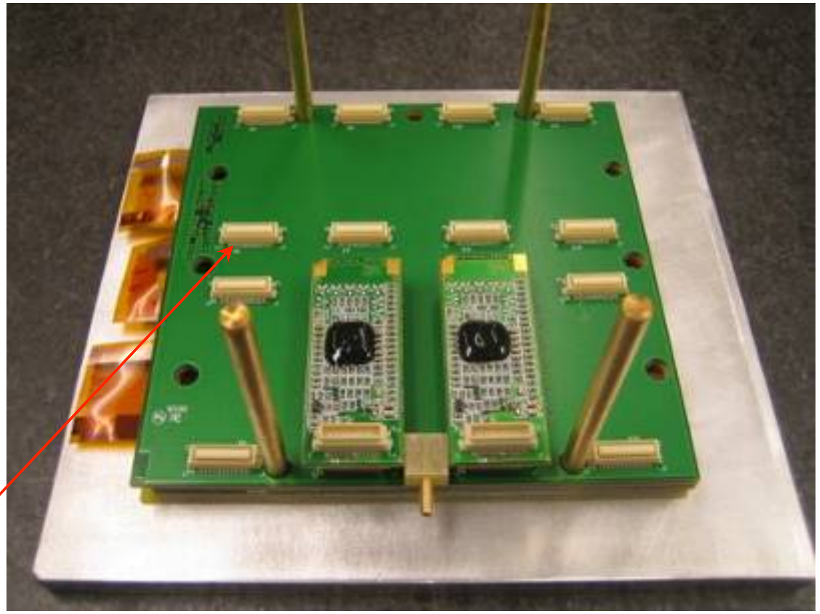




The FEE board used

The card is based on *Carioca Chip and has been designed and realized in Frascati by Gianni Corradi ; Total dimension : 3x6 cm^2





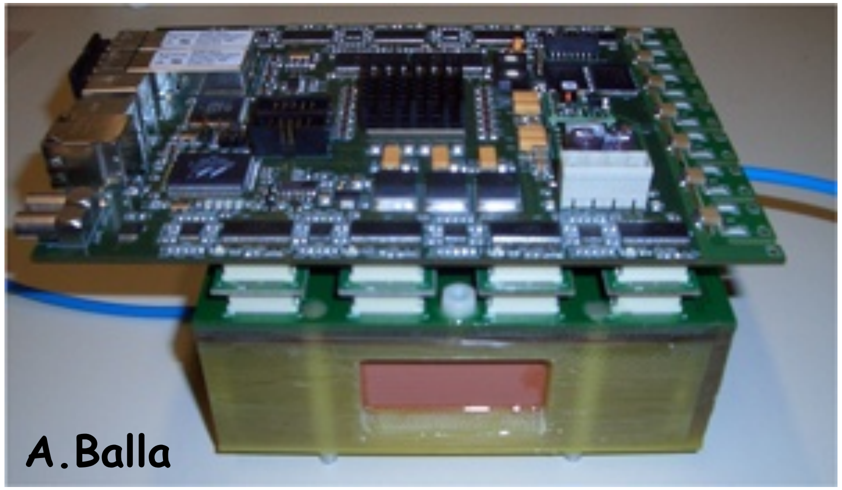
All the anode PCB have been designed with the same connector layout for a total of 128 channels (1ch/cm^2)

Now we are working with a Milano Bicocca electronic group (A. Baschirotto) for the design and construction of a chip with 8 channels able to measure also the charge released in the drift gap;
The aim is to reach an high density pixel readout (32 ch chip .. 1 ch/mm^2)
ST Microelectronics

DAQ System and Power Supply

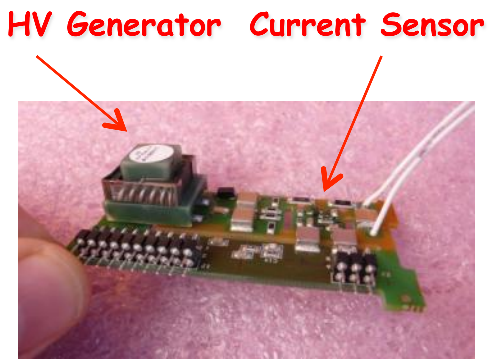
Two important devices have been developed in Frascati during 2010 :

A compact DAQ board, FPGA based
with 128 Scalers readout and
with 128 TDC channels



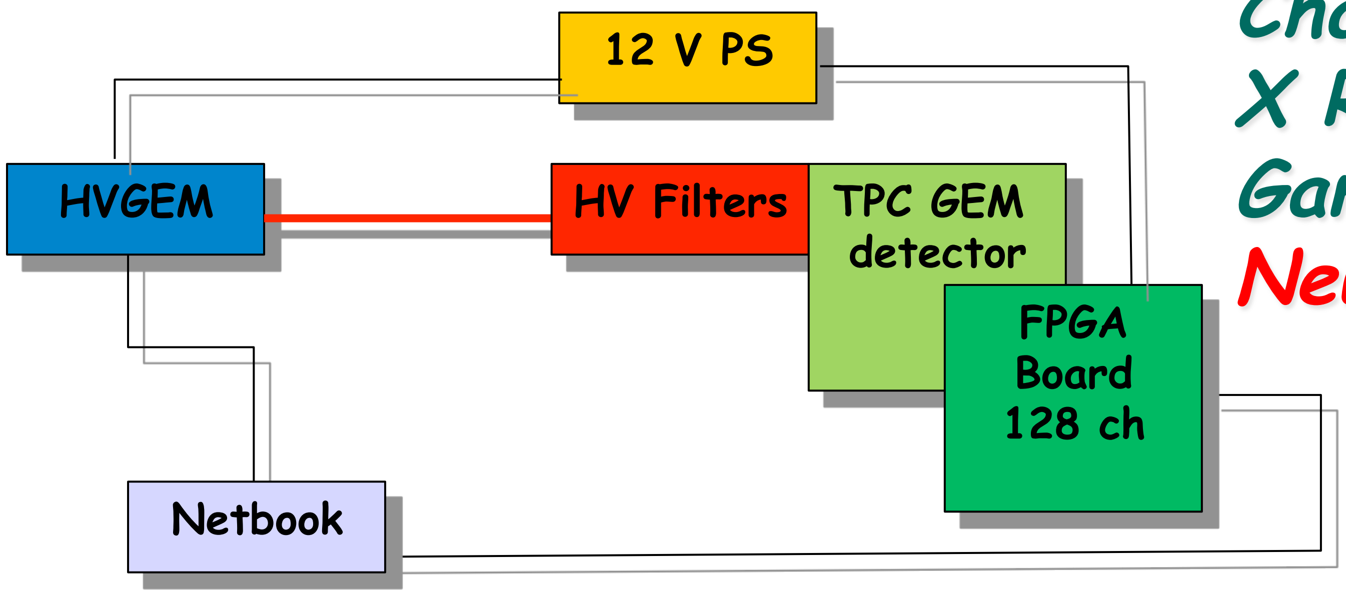
1 power supply (12V)
2 input channels: gate and trigger
3 data outputs : ethernet and USB

HVGEM : a power supply for
triple GEM detectors:
7 HV channels (0.5 V ripple)
with 7 nano-ammeters (10 nA)



Two slot NIM Module CANbus
controlled

A triple GEM detector system



Charged particles
X Ray
Gamma Ray
Neutrons

Applications in :
Medical diagnostics and tumor treatment
Industrial materials
Nuclear plants : fission and fusion
Neutron Spallation Source

Main Characteristics

The main characteristics are :
- Extended dynamic range (from single particle up to 10^8 partcles cm^{-2} s^{-1})
- Good time resolution (5 ns)
- Good spatial resolution (200 μm)
- Radiation hardness (2C/cm^2)

Thanks to these characteristics a GEM detector can be used for:
- plasma imaging for fusion reactors (tokamak) neutron and X rays,
- diagnostics for beam particles (high energy physics, hadron therapy)
- detectors for fast and thermal neutrons ,
- medical applications (diagnostics and therapy):
    - medical diagnostics medicale in gamma therapy;
    - medical diagnostics in hadro therapy;
    - steress diagnostics in industrial applications;
- environment monitoring;
- radioactive waste imaging;

Fast Neutron detection at

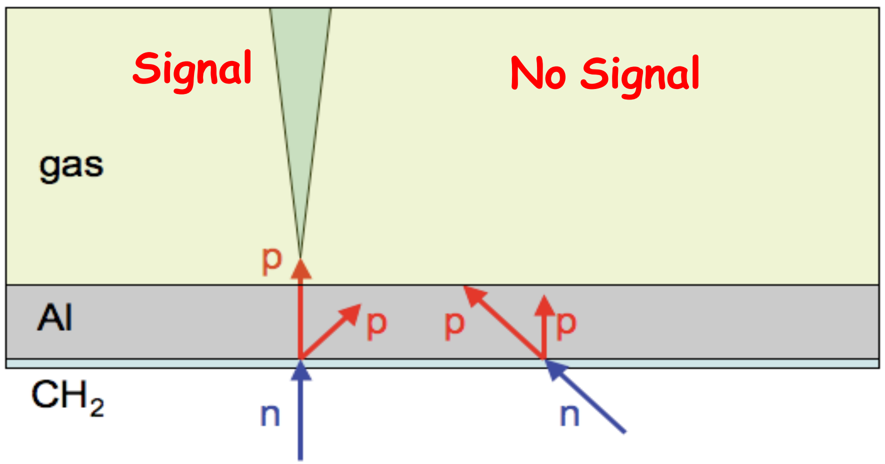
Frascati Neutron Generator (ENEA)
Neutron Spallation Source ISIS (UK)
and
n-TOF (CERN)

Polietylene Converter Cathode

2.5 MeV Neutrons interact with CH_2, and, due to elastic scattering processes, protons are emitted and enter in the gas volume generating a detectable signal.

Aluminum thickness ensures the directional capability,

stopping protons that are emitted at a too wide angle.



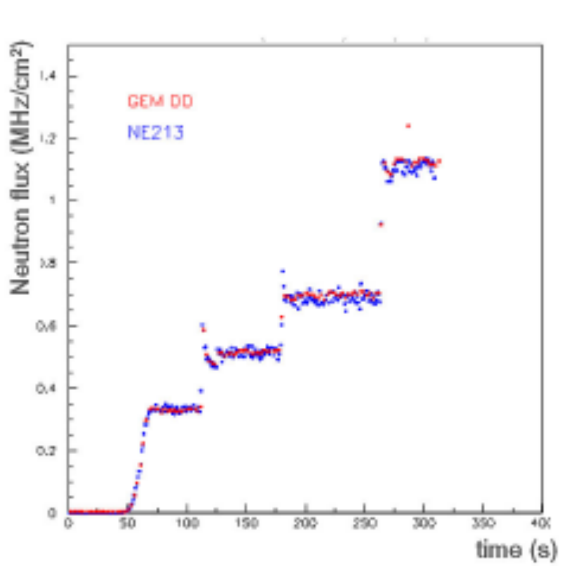
Optimized CH_2-Al thicknesses (50 μm-50 μm) determined by simulations (MCNPX-GEANT4)

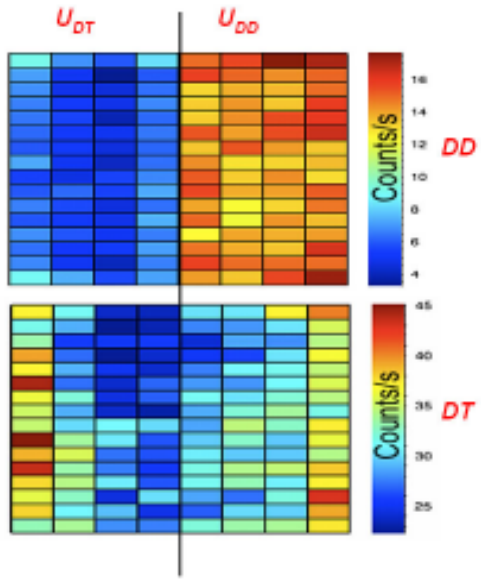
Efficiency of 4 10^{-4}

Neutron diagnostics at Frascati Tokamak

The active area of this neutron monitor has been divided into two parts with the polyethylene converter optimized for the two energies (2.4 and 14 MeV from DD and DT nuclear interaction respectively)

Measurements at Frascati Neutron Generator (ENEA)



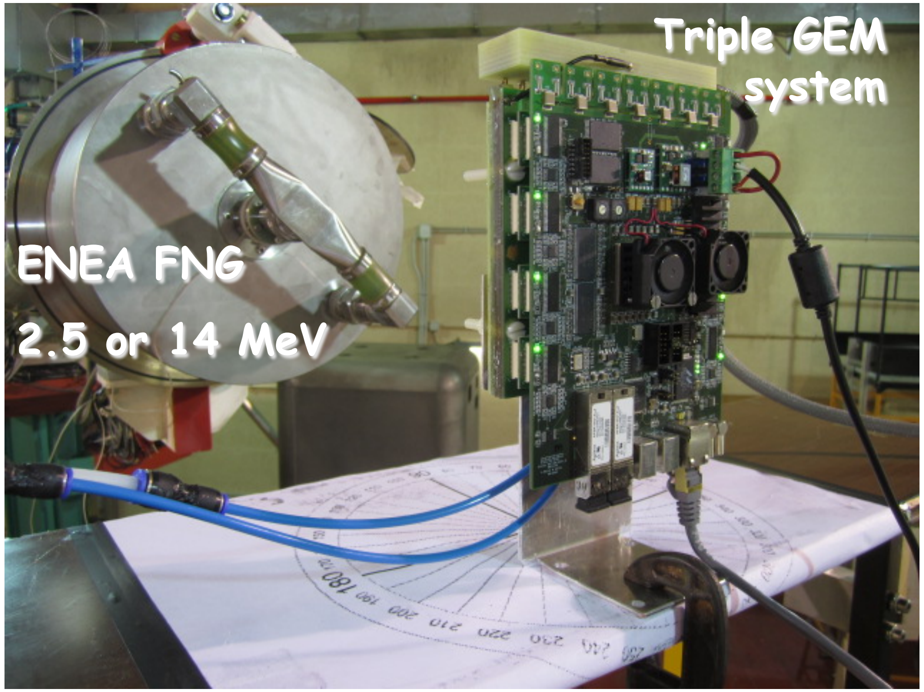


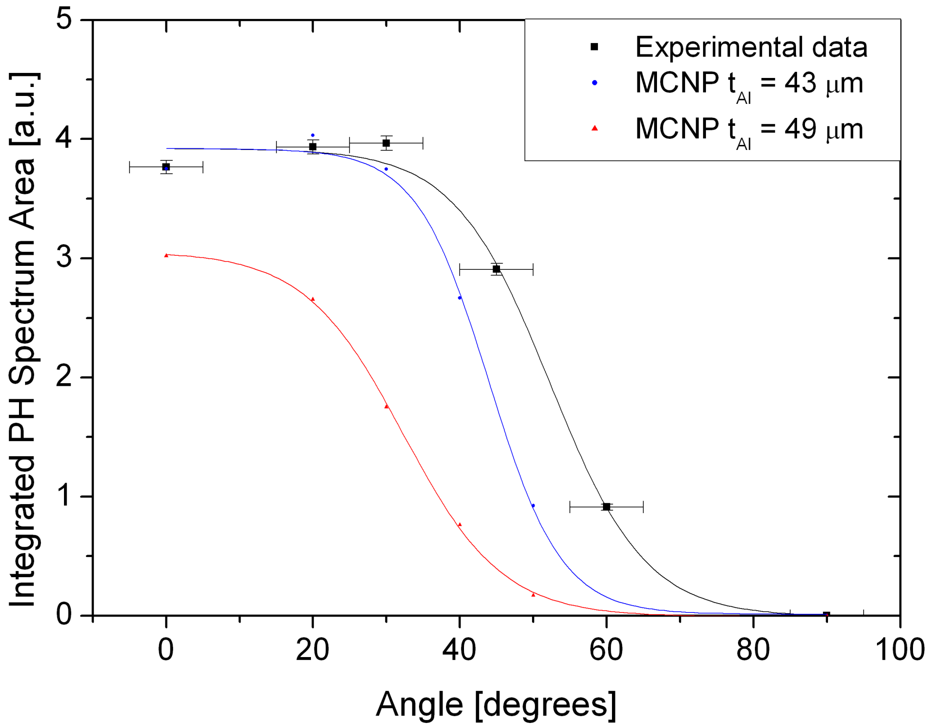
Design of a GEM-based detector for the measurement of fast neutrons
NIM A, Volume 617, Issues 1–3, 11–21 May 2010, Pages 155-157

Test at Frascati Neutron Generator

Measurement of the PH spectrum acquired under 2.5 MeV neutron irradiation at different angles with respect to beam direction and comparison with MCNP.
As expected the integrated PH counts decrease when increasing the angle.

BEAM4Fusion prototype



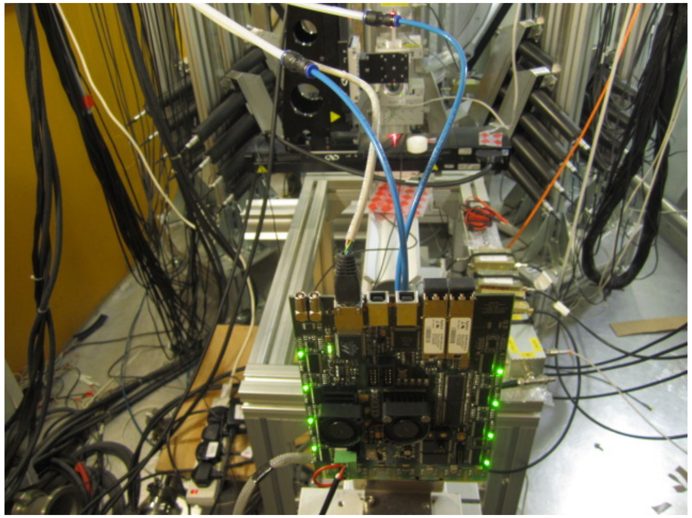


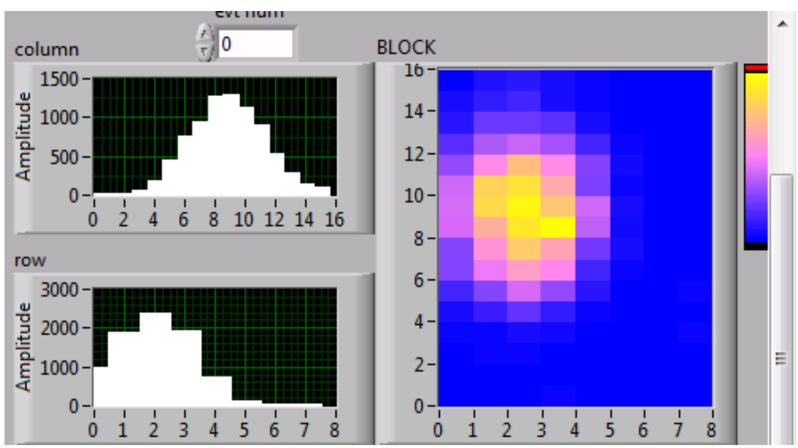
Comparison between measurements and simulations suggests that the Al thickness is less than 43 μm. Measured alluminum thikness is 40 μm.

Fast Neutron Monitor (ISIS)

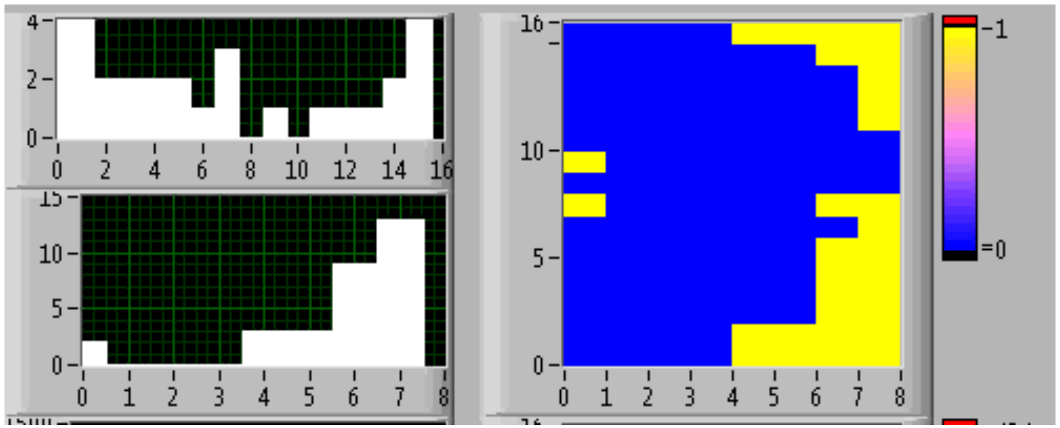
Monitor for a fast neutron beam with energies ranging from a few meV to 800 MeV

Tested at neutron beam of the Vesuvio facility at RAL-ISIS.



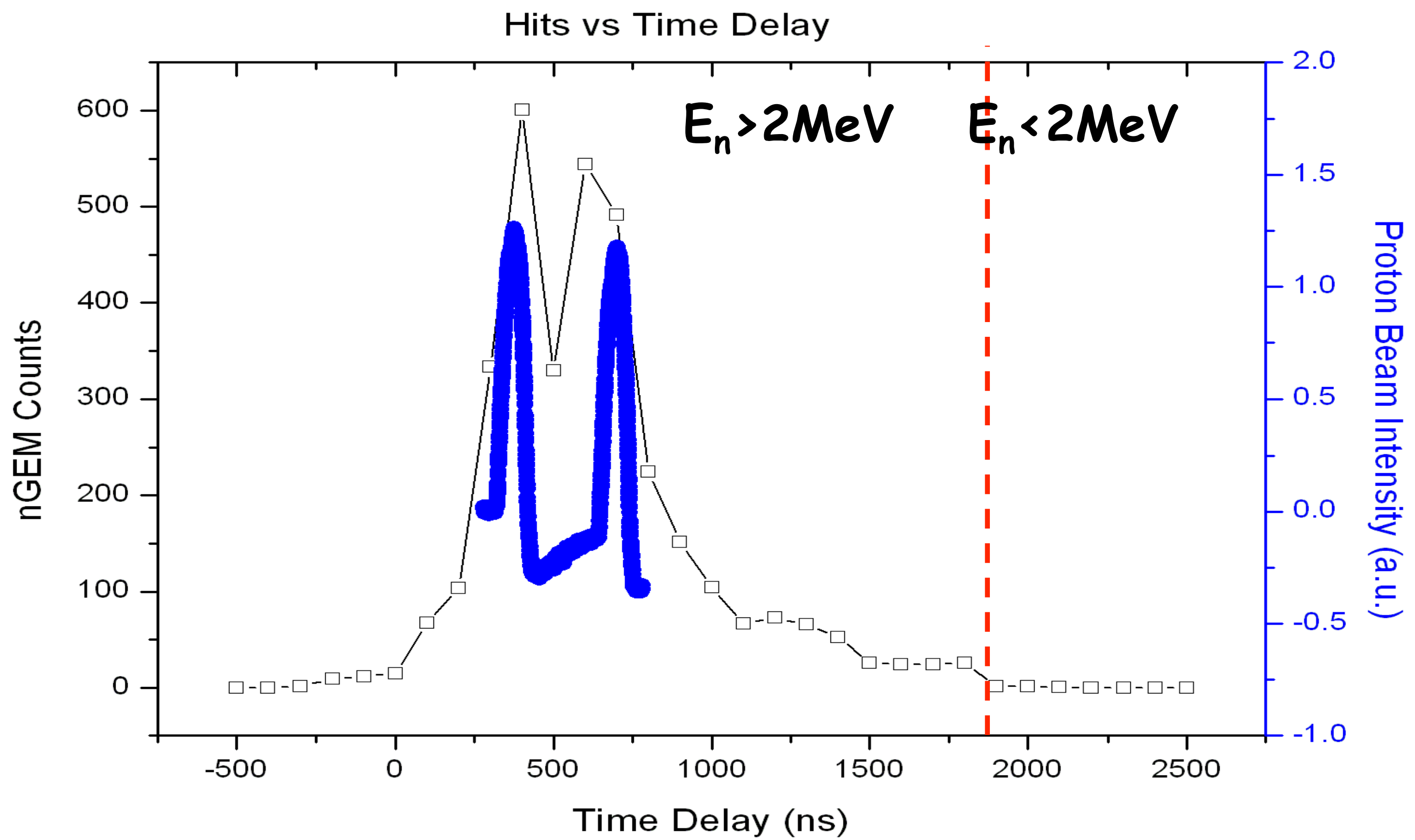


Beam profiles and intensity



Neutron beam monitorig during the shutter opening

Fast Neutron time line



Rate measurement scan on time delay from beam T_0 using GEM detector with 100 ns gate.

Comparison with proton beam profile intensity

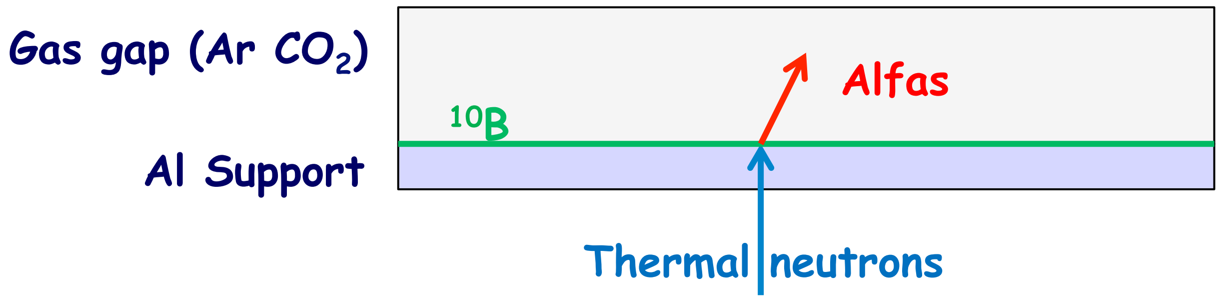
Thermal Neutron detection at

Triga Casaccia (ENEA)
Neutron Spallation Source ISIS (UK)
and
n-TOF (CERN)

^{10}B Cathode for thermal neutron

INFN-E prototype

Thermal Neutrons interact with ^{10}B, and alfas are emitted entering in the gas volume generating a detectable signal.

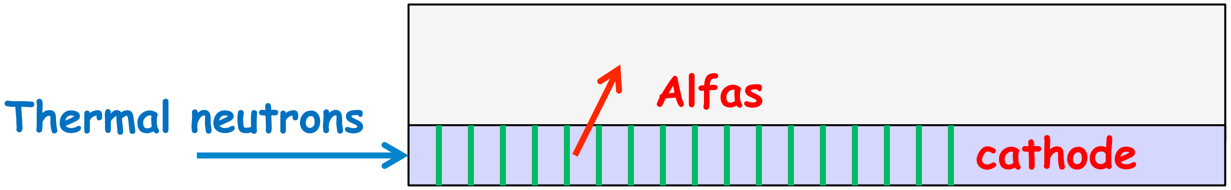


Low Efficiency

Big active area

Beam Monitor and transmission

Side-On detector



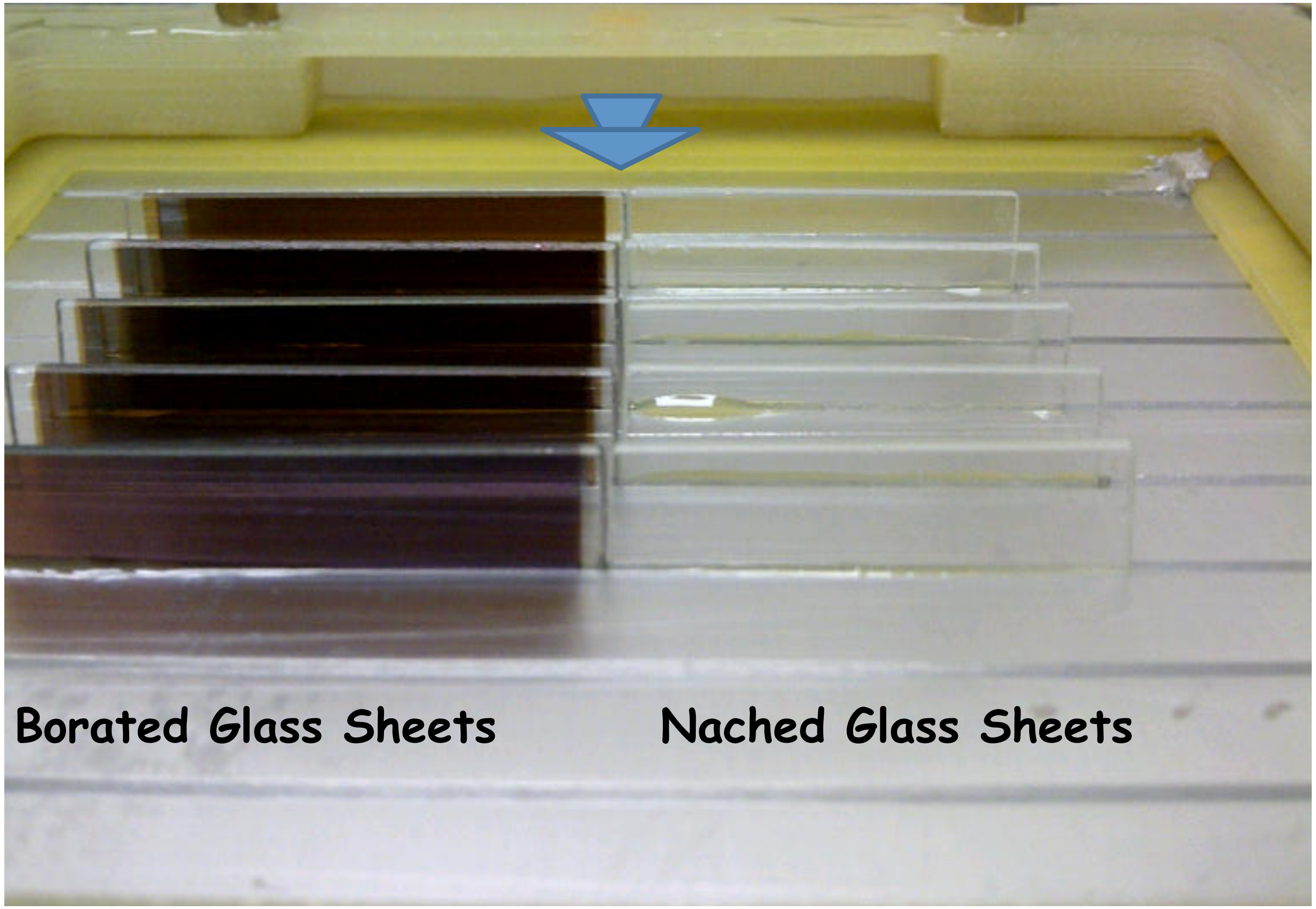
High Efficiency

Small active area

Actually 4% efficiency ... working to obtain 50%.

Boron multilayer cathode

Thermal neutron window

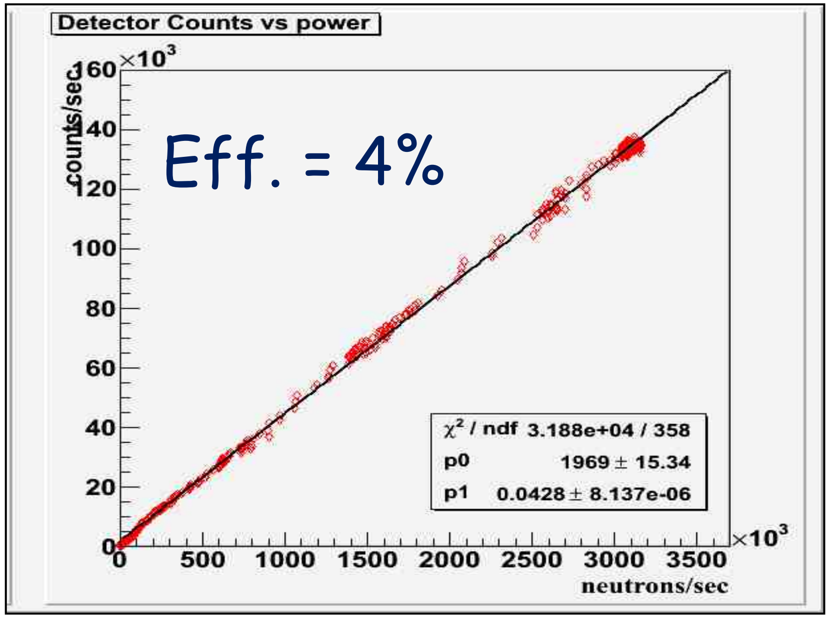


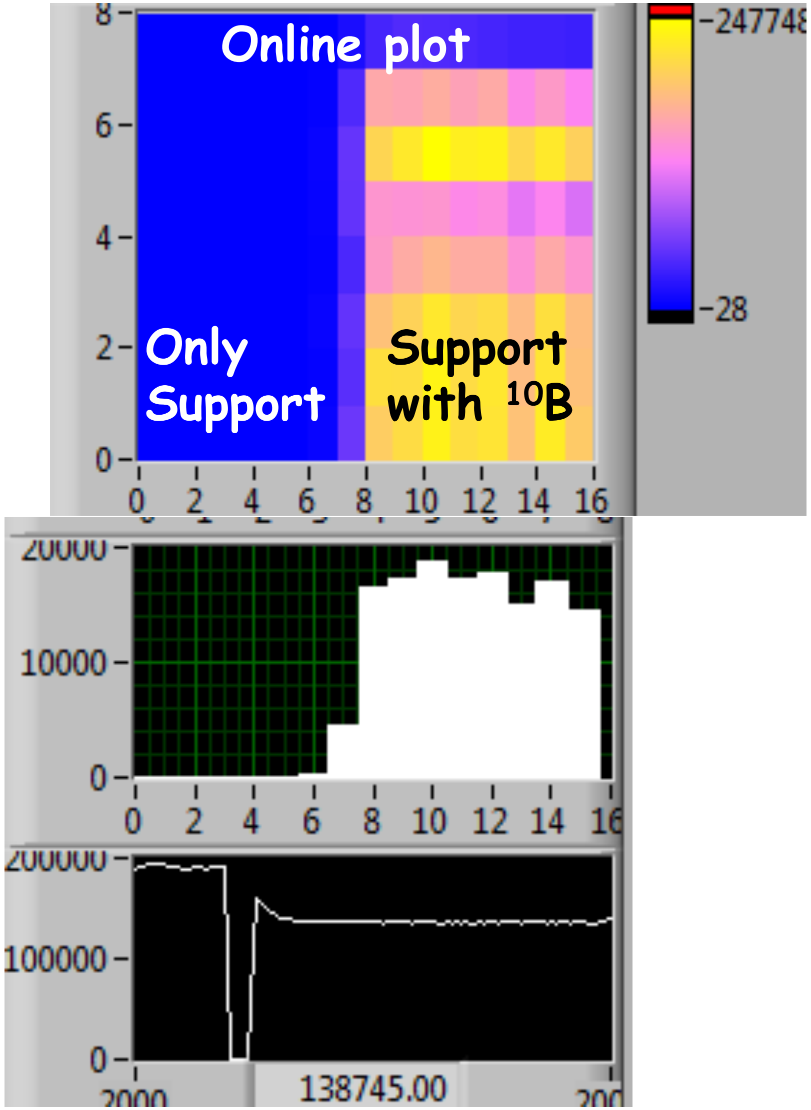
Monitor for fission reactor

Measurements at Triga (ENEA)
Power of 1 MW

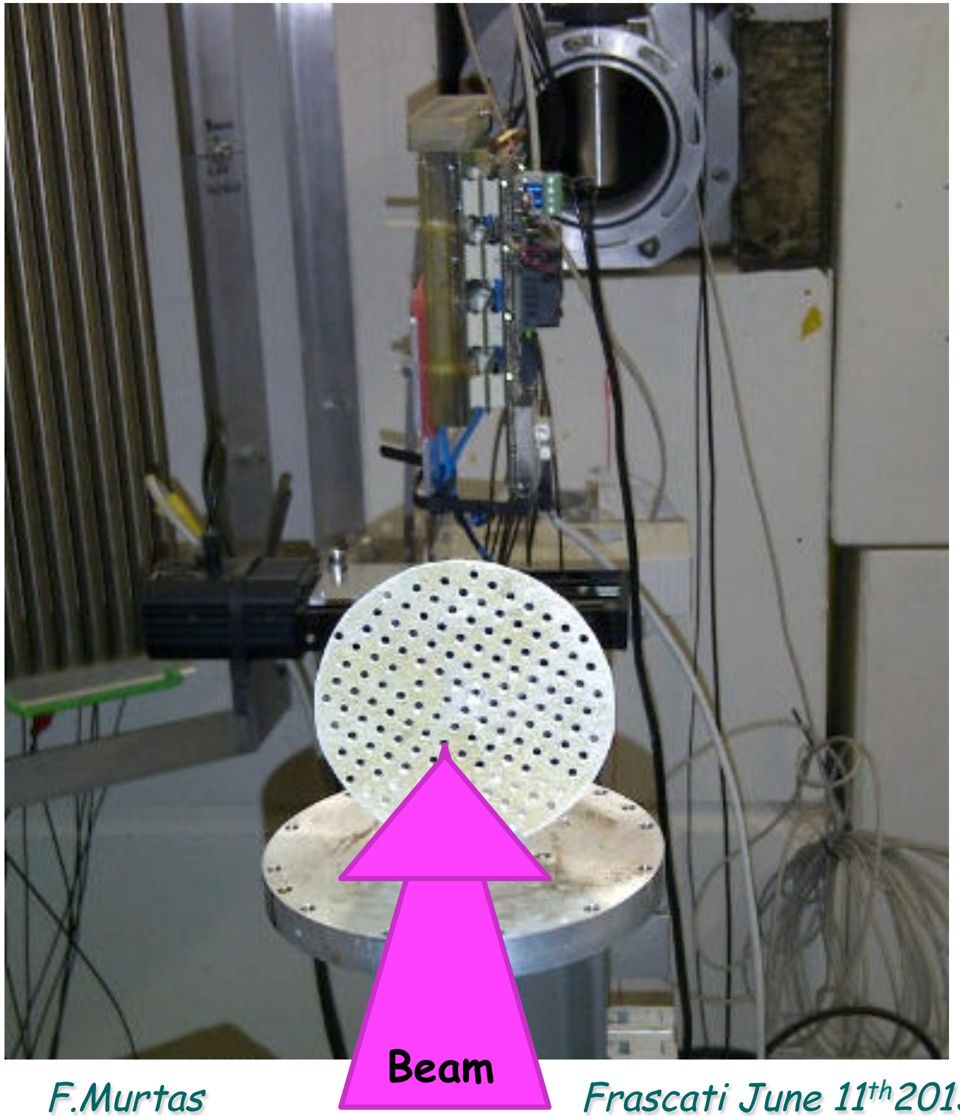
Gamma background free
Without electronic noise

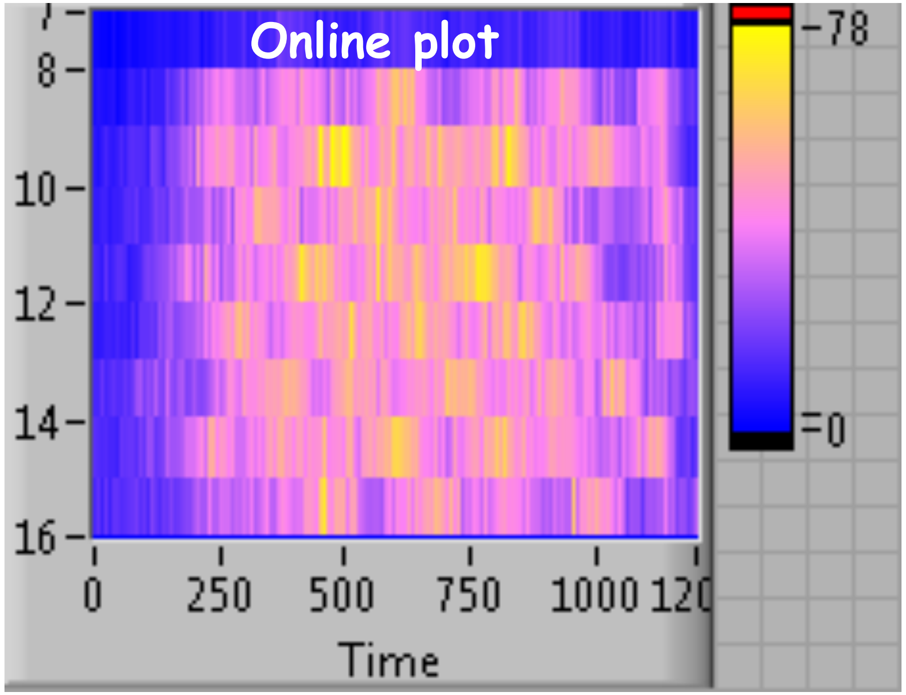
Good linearity up to 1 MW



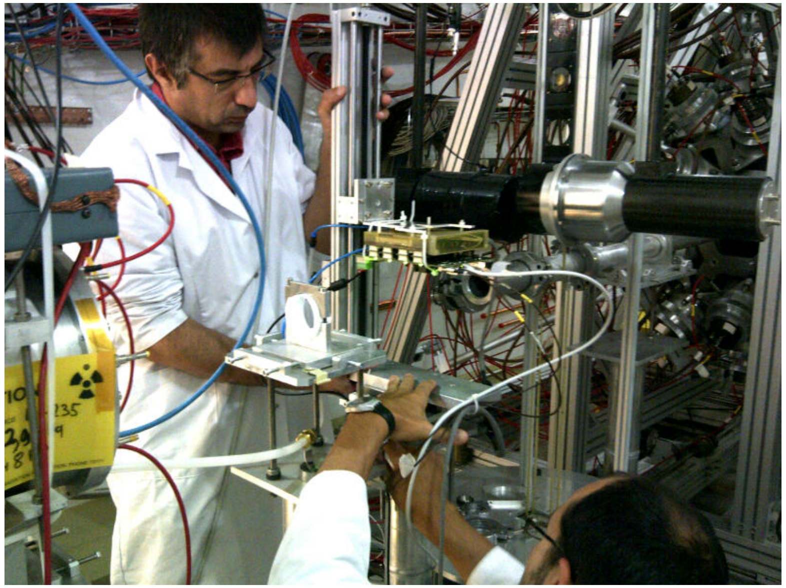


Imaging of Thermal Neutron beam through a cadmium grid (ISIS)

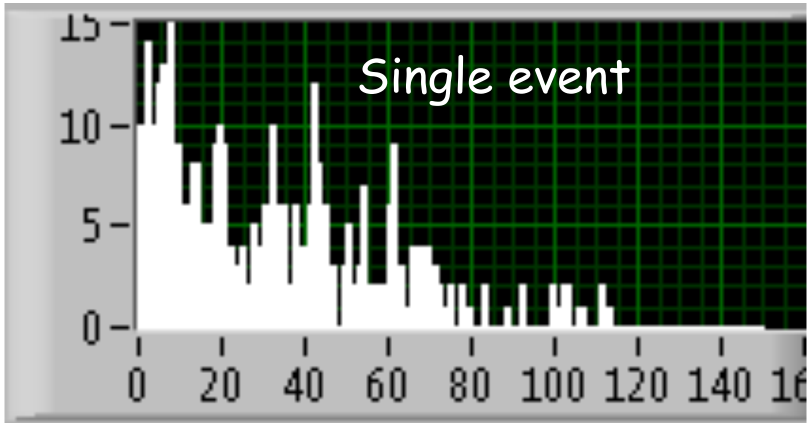


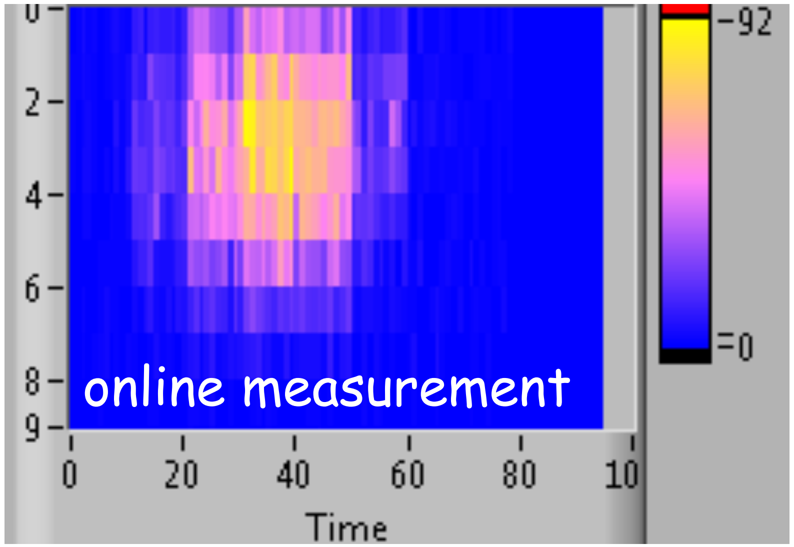


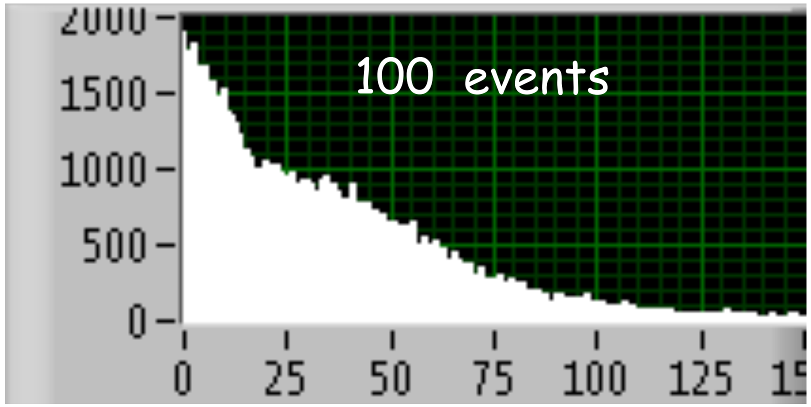
N-TOF Thermal neutron Beam spot



online measurement

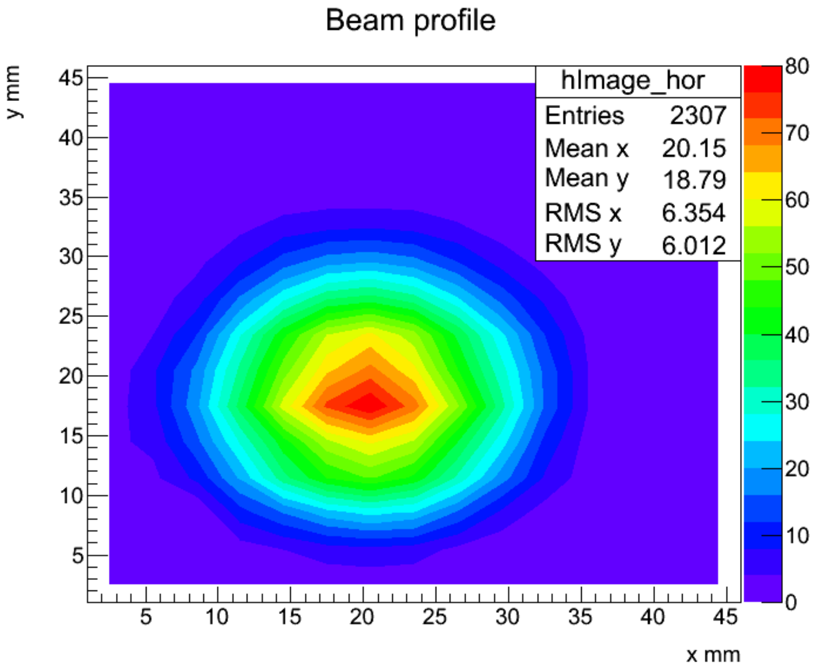


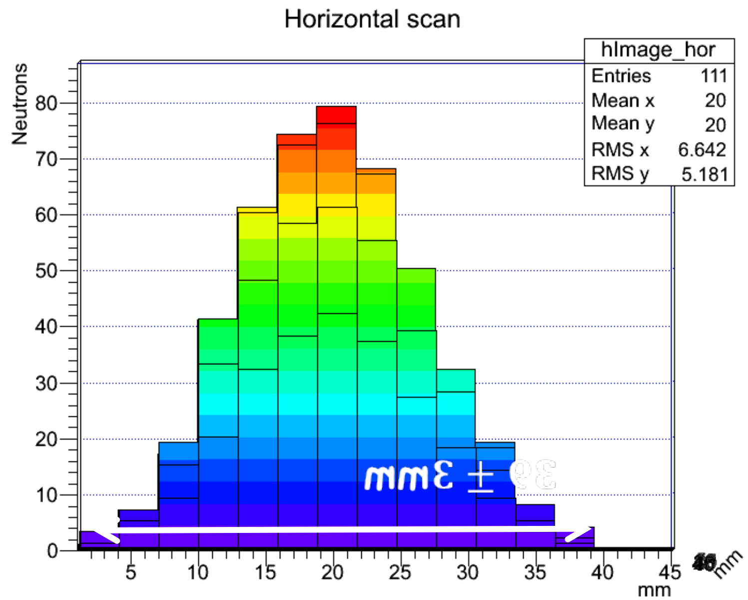


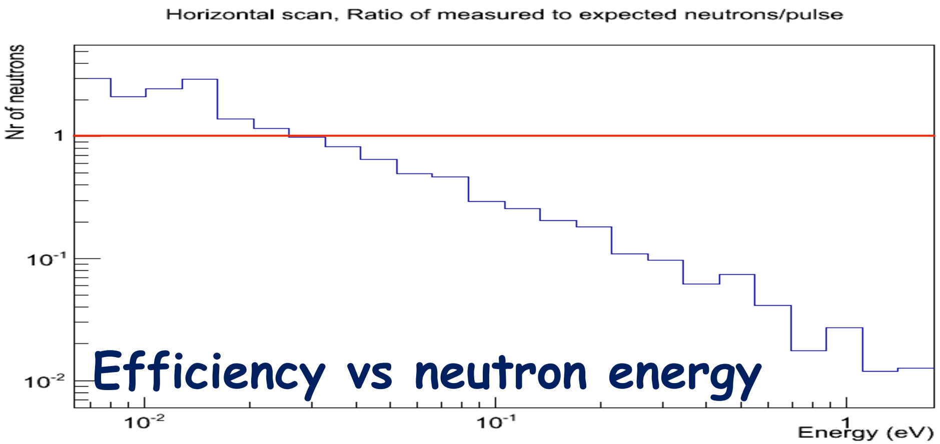


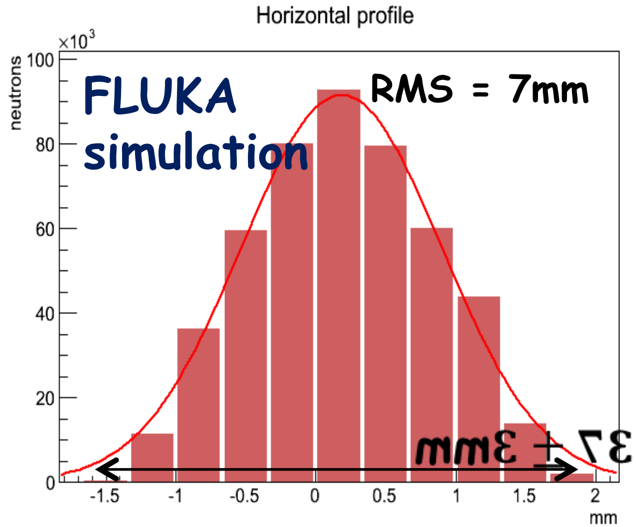
Time spectrum (1ms/bin)
150ms total gate

N-Tof Beam profile

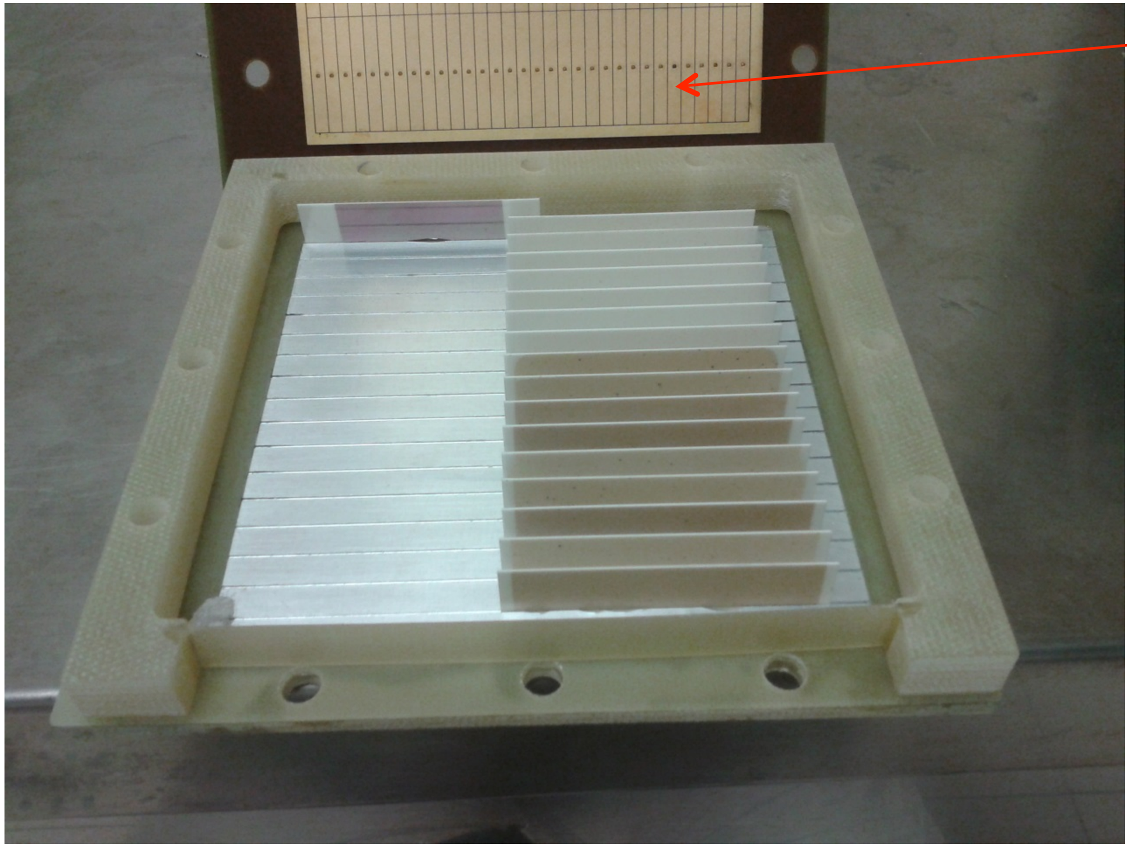








New prototype for high efficiency



Pad dimension of 3 mm

17 allumina supports
10 x 50 x 0.4 mm

34 Born depositions (1 micron)
made by G.Celentano (ENEA)

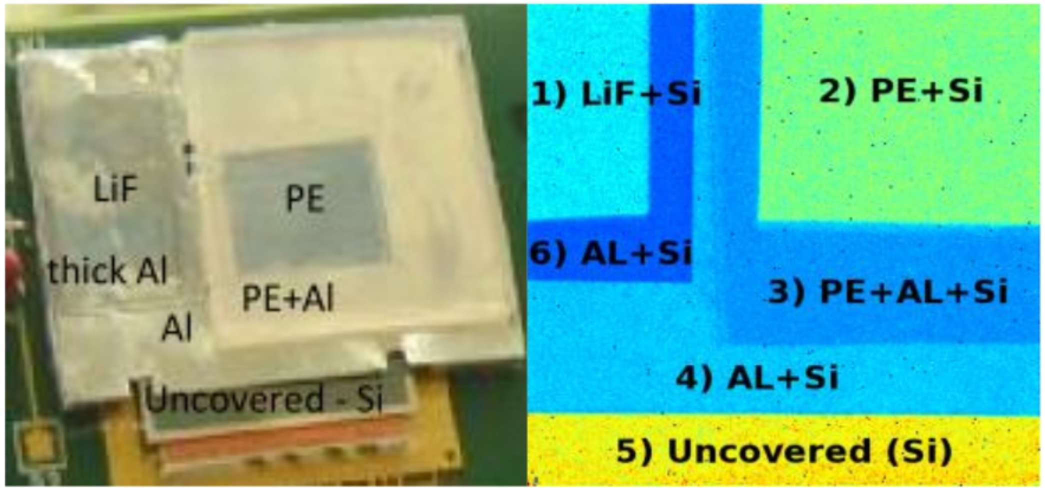
Some problems on depositions

Designed optimesd with Lina Quintieri fluka simulation

Neutron detection with high pixelated detector

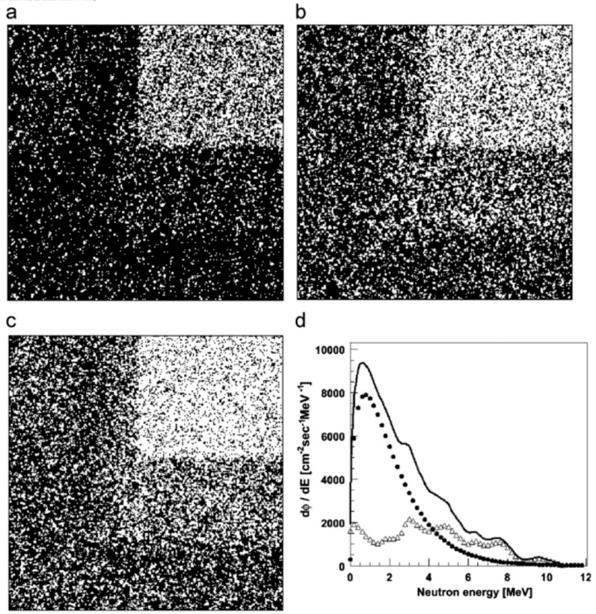
Medipix for neutron detector

Medipix is a silicon detector
with 50x50 micron pixels
Matrix of 256x256 pixels
Active area of 1.4x1.4 mm
Power supplied by USB

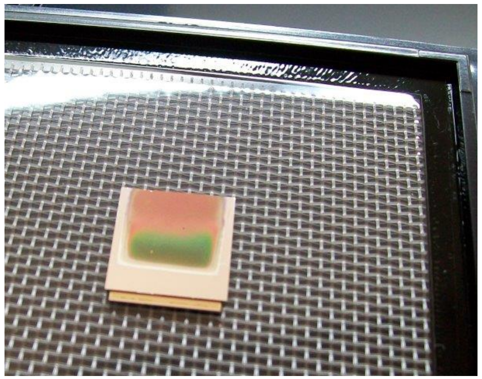


Different converters
have been placed in front of
medipix and background
measurement made around
the ATLAS experiment at CERN

Medipix for neutron detection



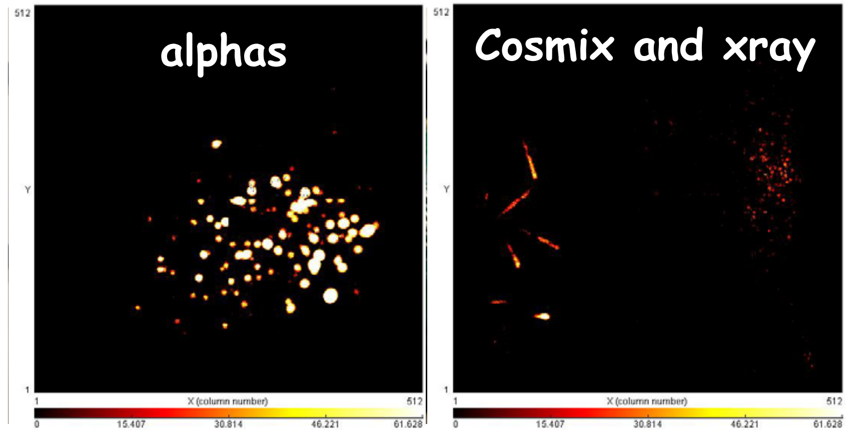
ATLAS-MPX detector located at 12cm from:
252Cf source(a),
241AmBe source(b)
andbothsources(c).
Neutron energy spectra of the sources:
252Cf source(K),
241AmBe source(D), and the solidline is the superposition of 252Cf and 241AmBe sources (d).
Theacquisitiontimeis1000s.

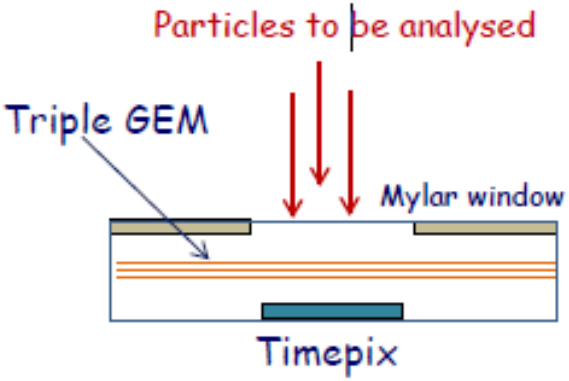


First tryals of boron deposition on Medipix made by G.Celentano (ENEA)

Wire bonding in progress at CERN.

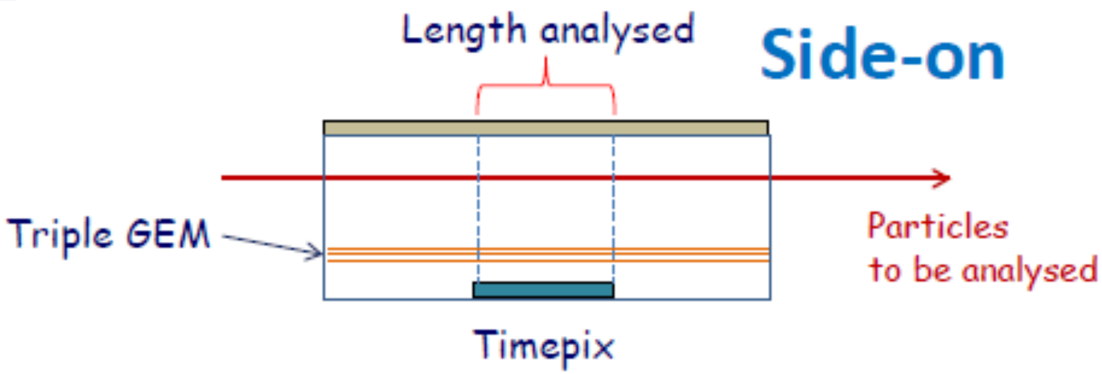
GEMPIX detector





Head-on

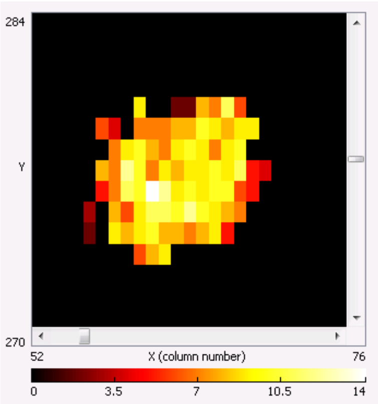
Side-on

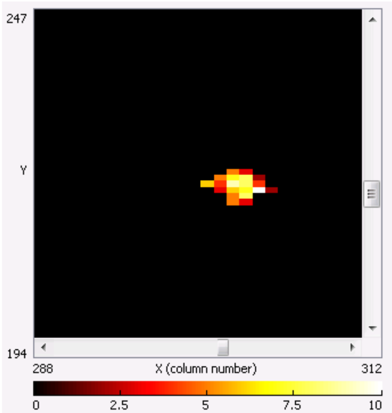


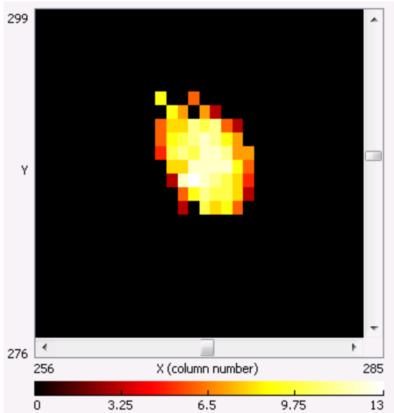
The readout is made with a Timepix chip
The active area is 9 cm^2
The particle track is analysed with 512 pixel in 3 cm length

Detailed energy deposition

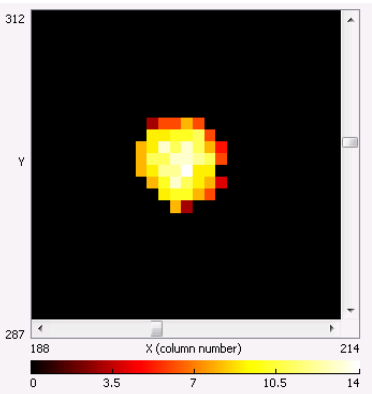
Cobalt (compton electron) 1100V **1120V**

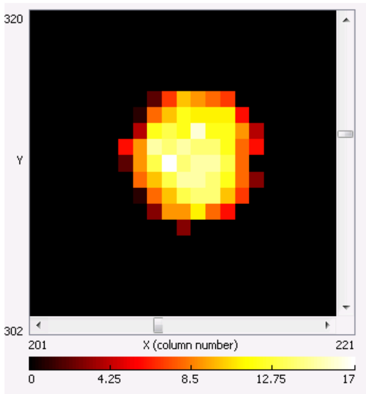


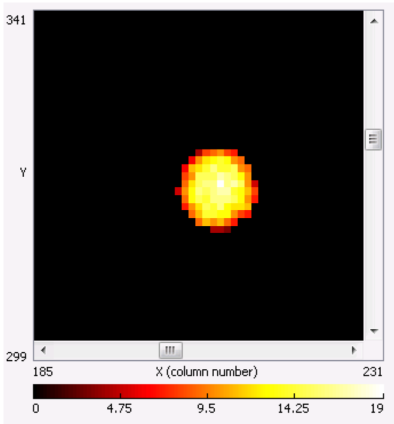




X Ray 1100V **1160V**



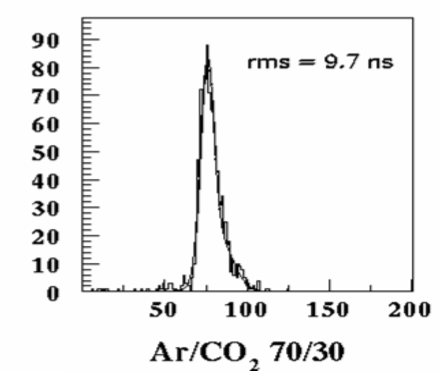


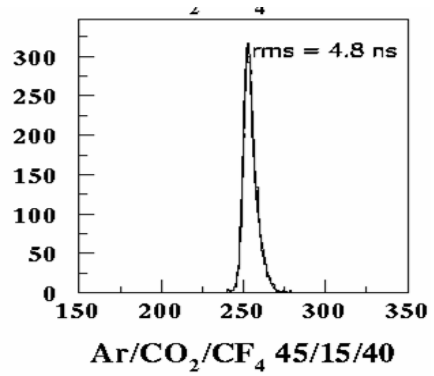


Summary

- ✓ The triple GEM tecnology is very relayable and usefull for different applications in different science and technology fields
- ✓ In Frascati has been developed a compact and complete system.
- ✓ Recently very good results have been obtained for a real time fast and thermal neutron detectors with spatial and time high resolution
- ✓ High dinamic range in rate measurements with very low gamma background.
- ✓ Working in progress for high efficiency detector
- ✓ Interesting progress on netron detection with high pixelated detector
- ✓ Slow device that require a pattern recognition program
- ✓ Other applications under studies in the framework of ARDENT project
- ✓ Boron, Litium, Gadolinium, deposition technics is an important issue

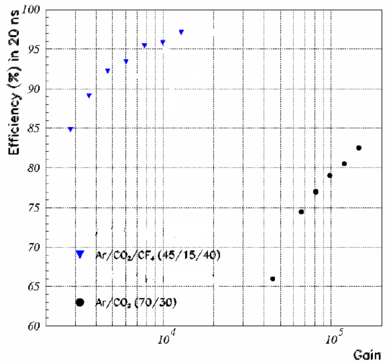
GEM Performances (2002-2006)





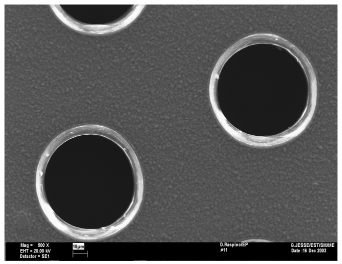
The results of several tests* on 10x10 cm^2 prototype allowed us to select the Ar/CO_2/CF_4 with geometry 3/1/2/1 mm

→ better time resolution 4.8 ns in respect of Ar/CO_2



→ higher efficiency at lower gas gain : 96% in 20 ns

Max space resolution O(100 μm)



Ageing studies on whole detector area 20x24 cm^2:

25 kCi ^{60}Co source at 10 MHz/cm^2 on 500 cm^2

Integrated charge 2.2 C/cm^2

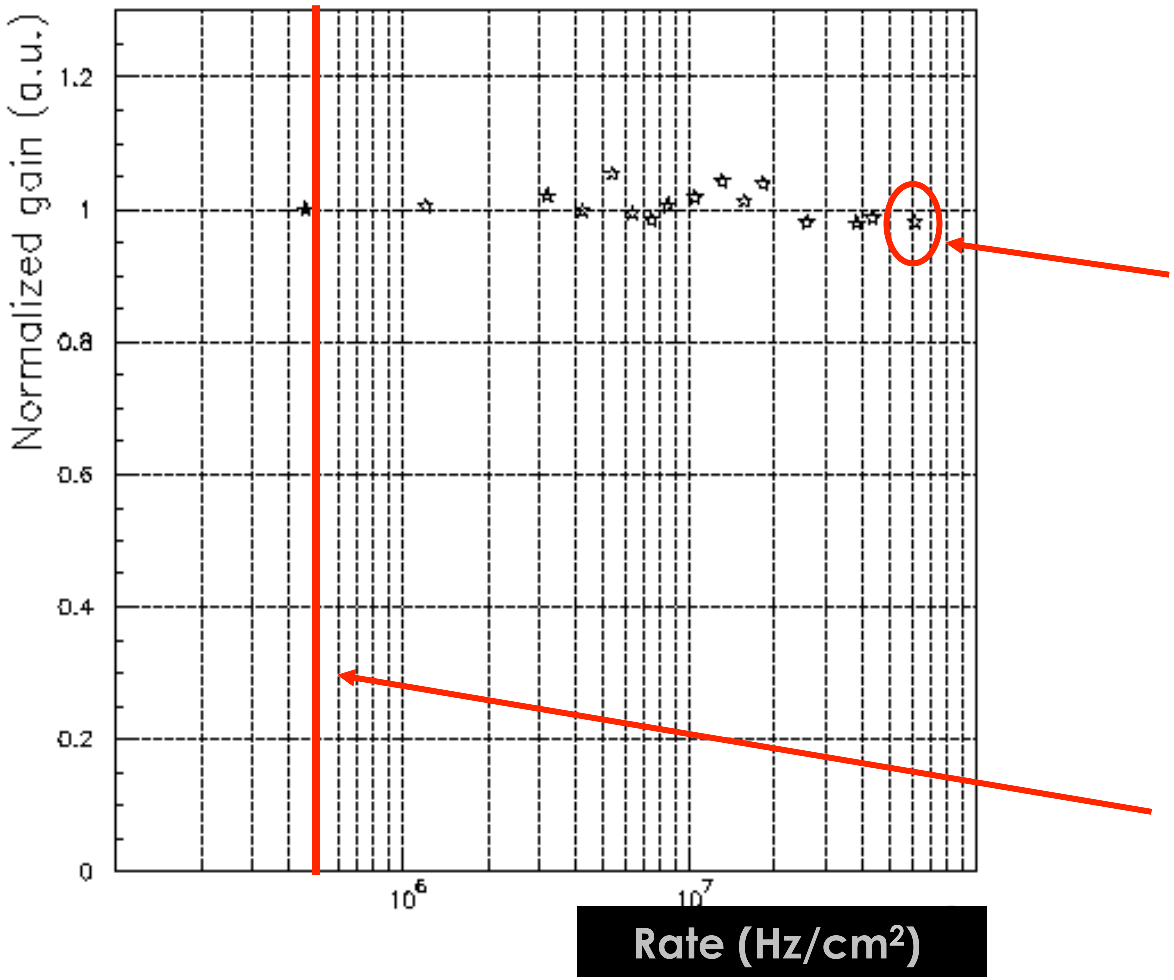
Detector performance recovered with a 15 V shift on HV

G.Bencivenni et al., NIM A 518 (2004) 106

P. de Simone et al., IEEE Trans. Nucl. Sci. 52 (2005) 2872

Linearity at very high rate

- The rate capability was measured with an X-ray (5.9 keV) tube over a spot of ~ 1 mm^2
- The detector was operated at a gain of ~ 2x10^4



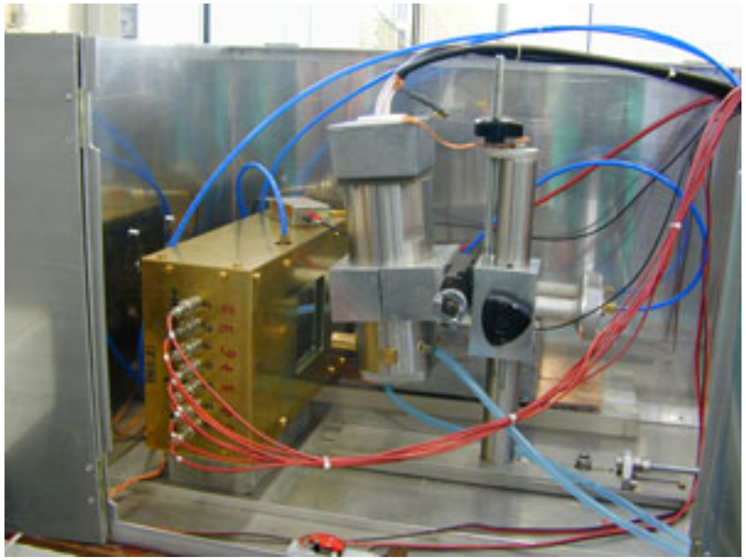
A very good gain stability was found up to a photon counting rate of 50 MHz/cm^2

LHCb M1R1 maximum rate (460 kHz /cm^2)

Gas Gain

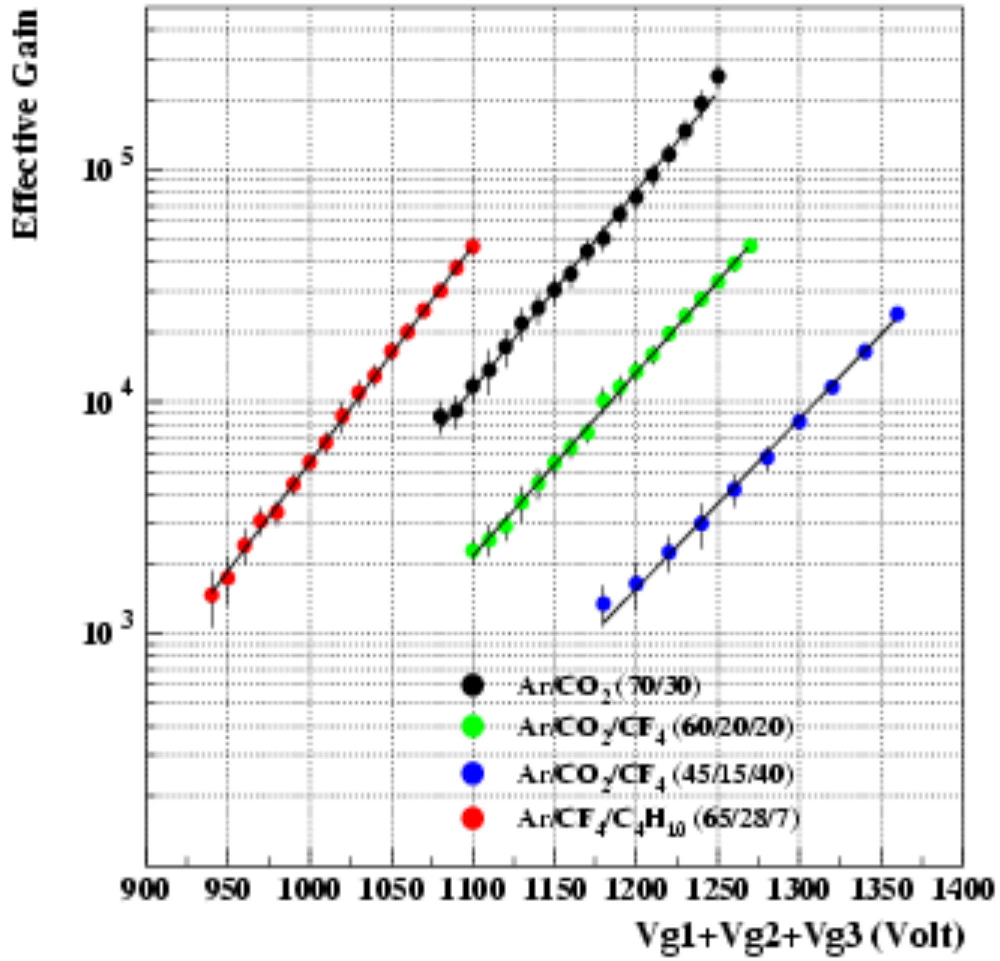
The effective GAIN G_{eff} of the detector has been measured using a 5.9 keV X-ray tube, measuring the rate R and the current i, induced on pads, by X-rays incident on the GEM detector.

$G_{eff} = i / eNR$



$$G_{eff} = A\, e^{\alpha (Vgem1+Vgem2+Vgem3)}$$

A and α depend on the gas mixture.



Discharge probability

Working region

At PSI we exposed three detectors to a particle flux up to 300 MHz.

Each detector integrated, without any damage, about 5000 discharges.

In order to have no more than 5000 discharges in 10 years in M1R1 the discharge probability has to be kept below 2.5 10^{-12} (G < 17000).

This limit is conservative because up to 5000 discharges no damage was observed.