Diagnostics with neutrons and X-Rays with GEM and Medipix

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- GEM technology
- Medipix detectors
- New GEMPIX
- Diagnostics with neutrons and X-Rays

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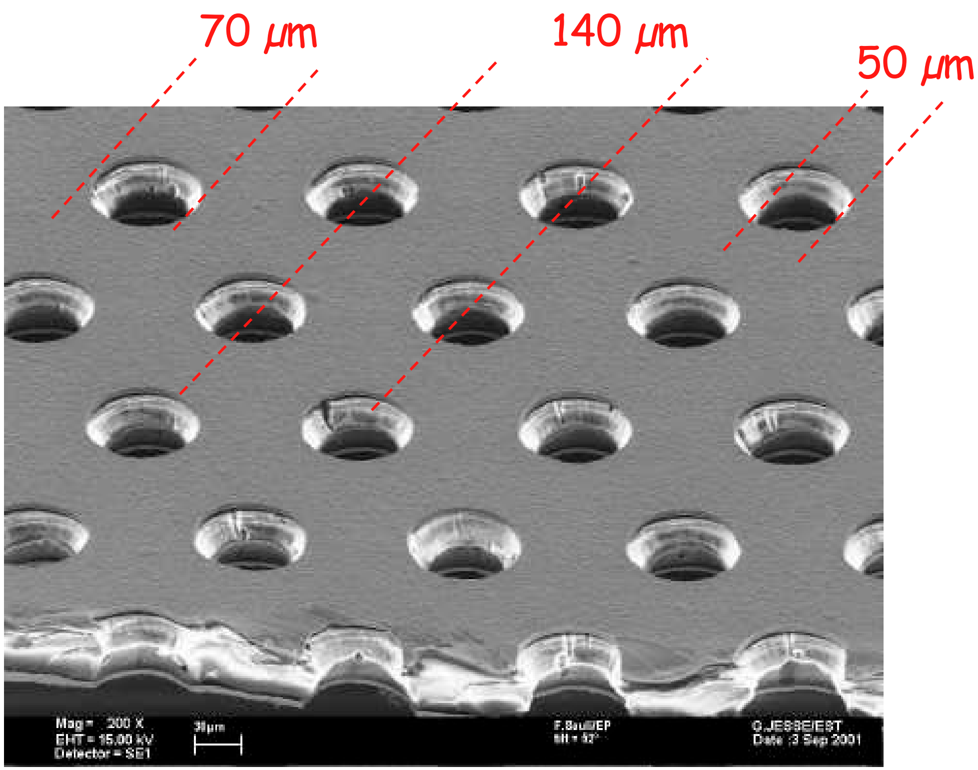
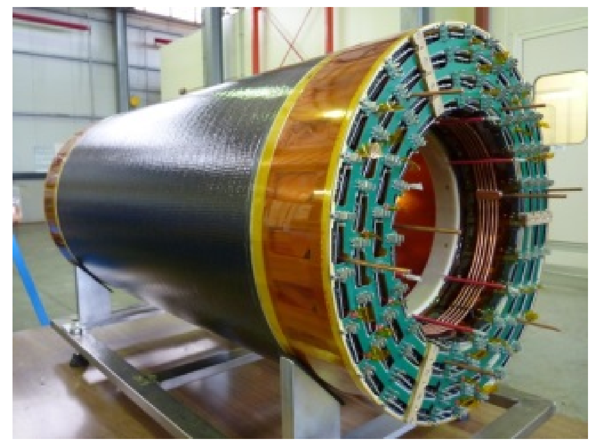
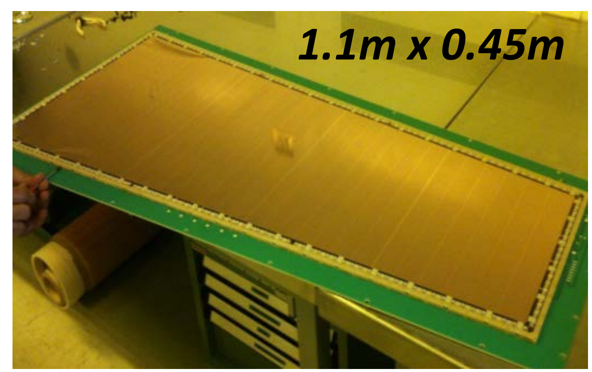
Gas Electron Multiplier

A Gas Electron Multiplier (F.Sauli, NIM A386 531 **1997**) is made by 50 μm thick kapton foil, copper clad on each side and perforated by an high surface-density of bi-conical channels;



different shapes





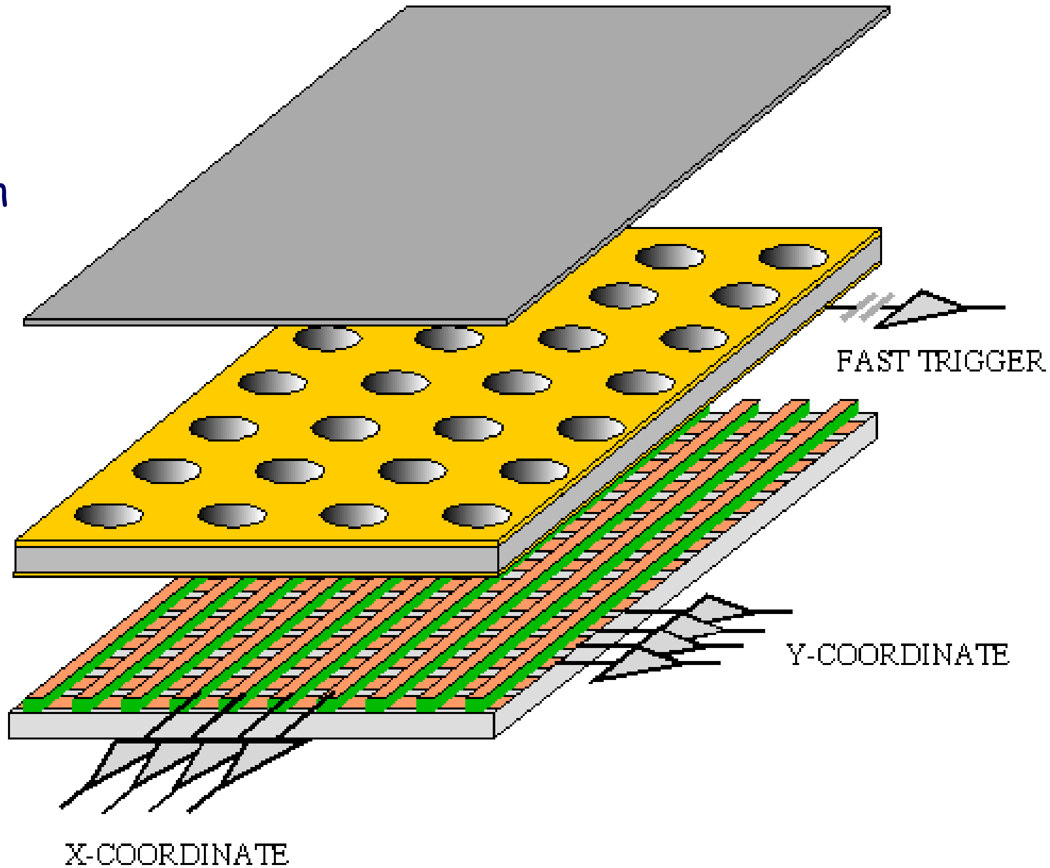
GEM Structure

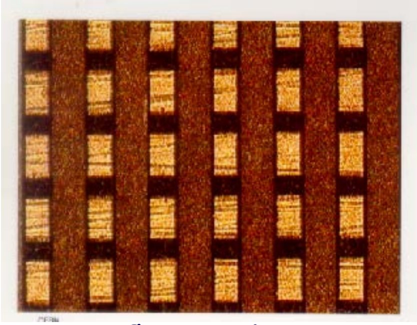
- Gain and readout functions on separate electrodes
- Fast electron charge collected on patterned anode

Particle conversion

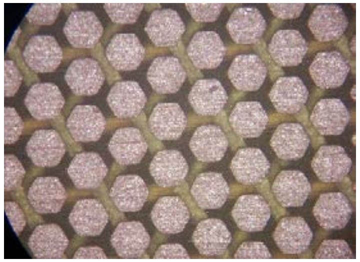
Gain
From 1 to 10^4

Readout





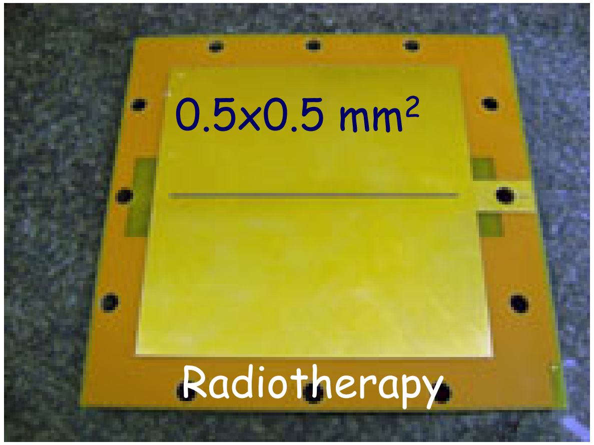
Cartesian

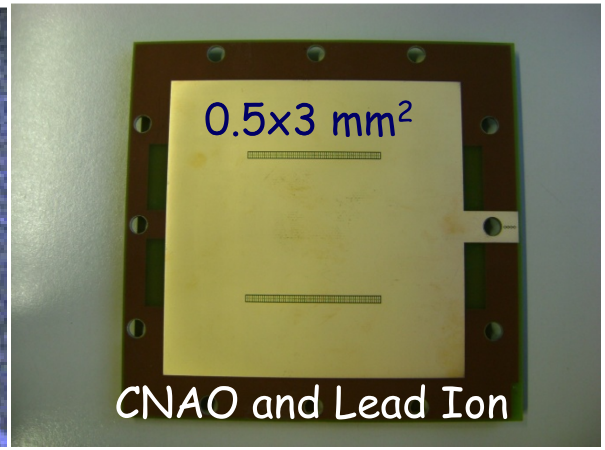


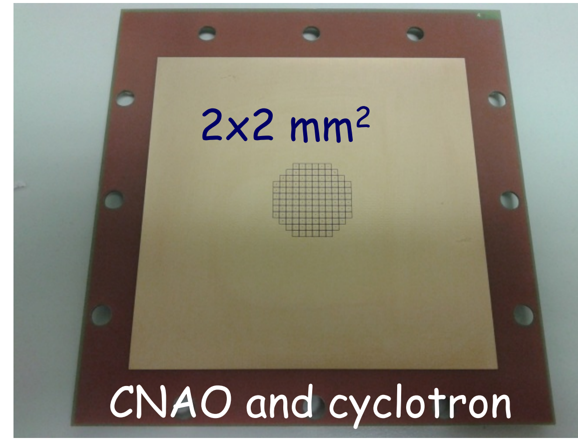
Pads

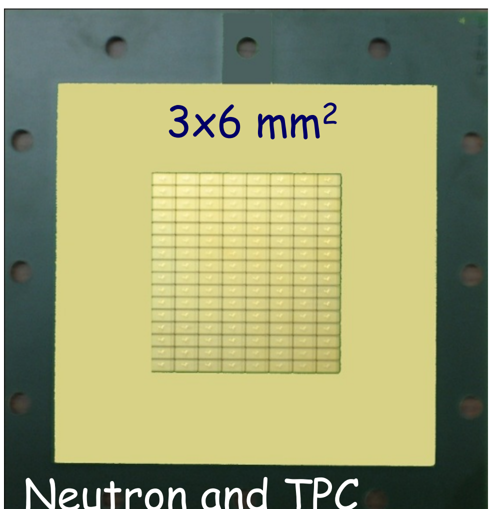
Pad readouts

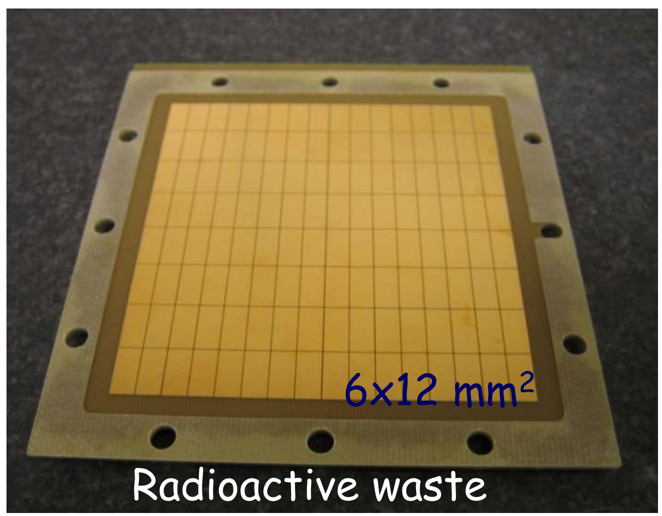
Different pad geometry **but always with 128 channels**

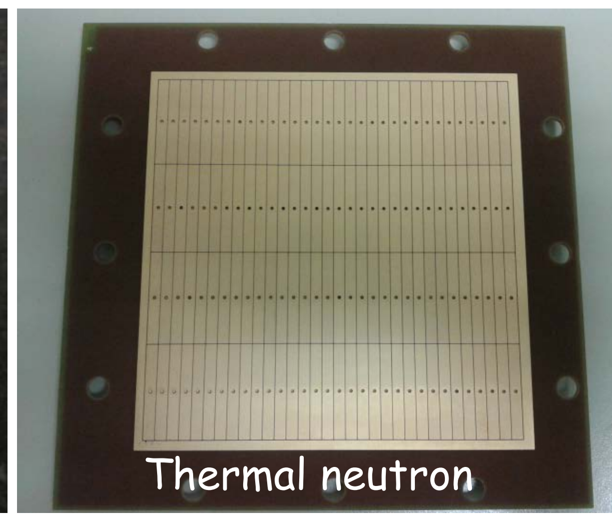






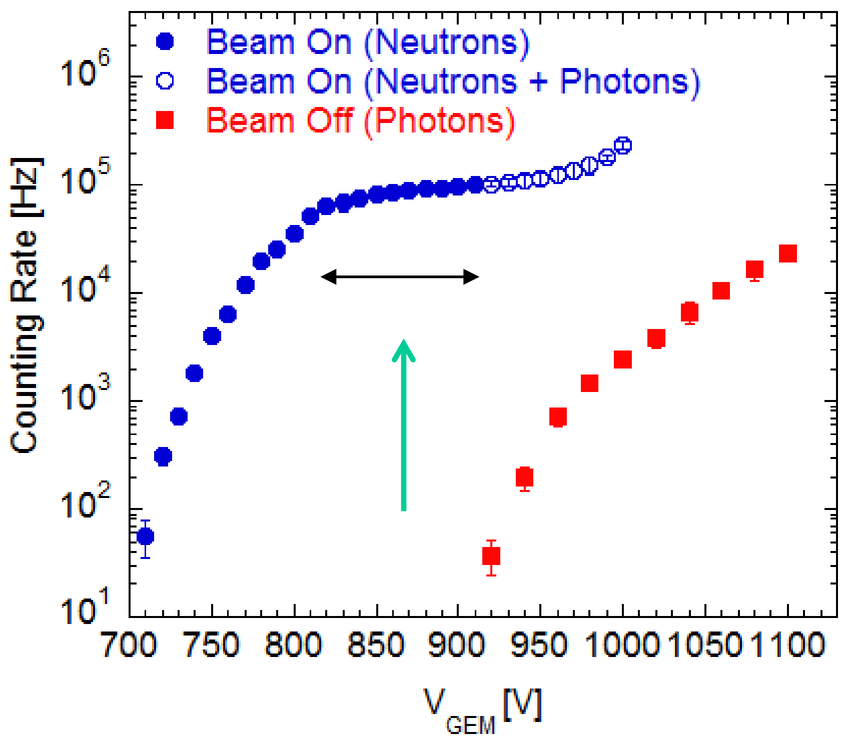


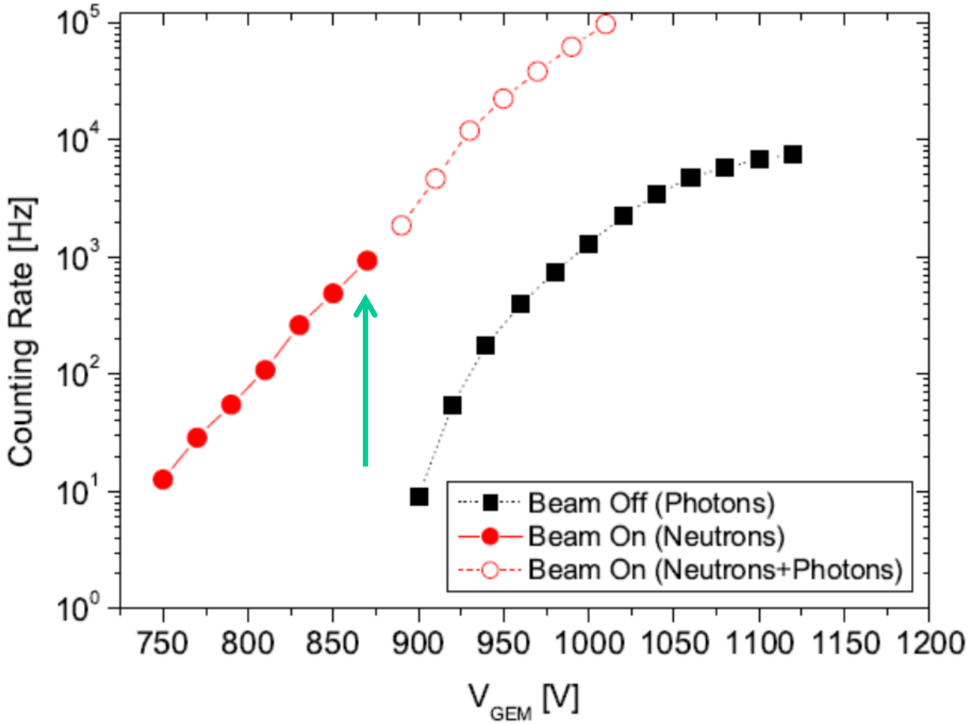




Working point for GEM detectors

The alfas produce an higher ionization respect to protons that allow a wider plateau before the gamma background





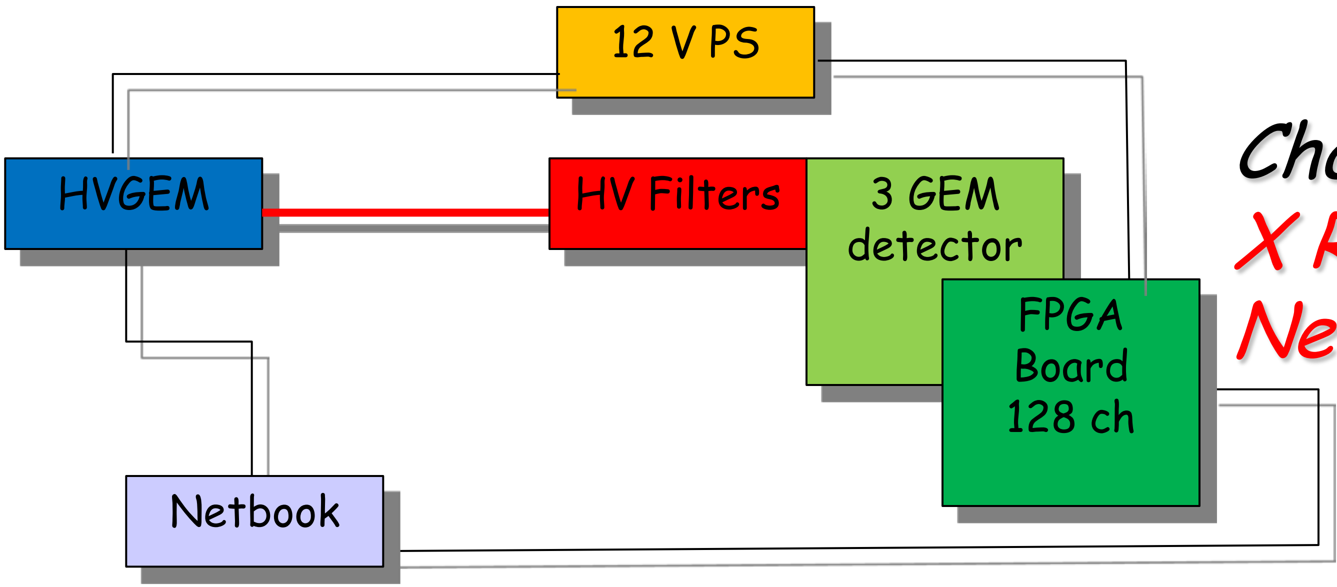
Really low level of gamma background !

GEM 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;

A triple GEM detector system

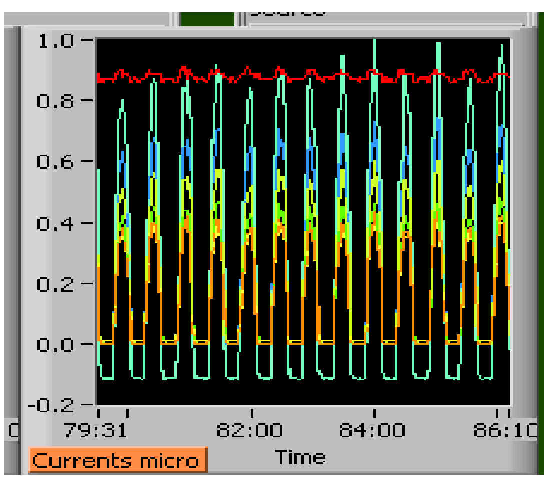


Charged particles

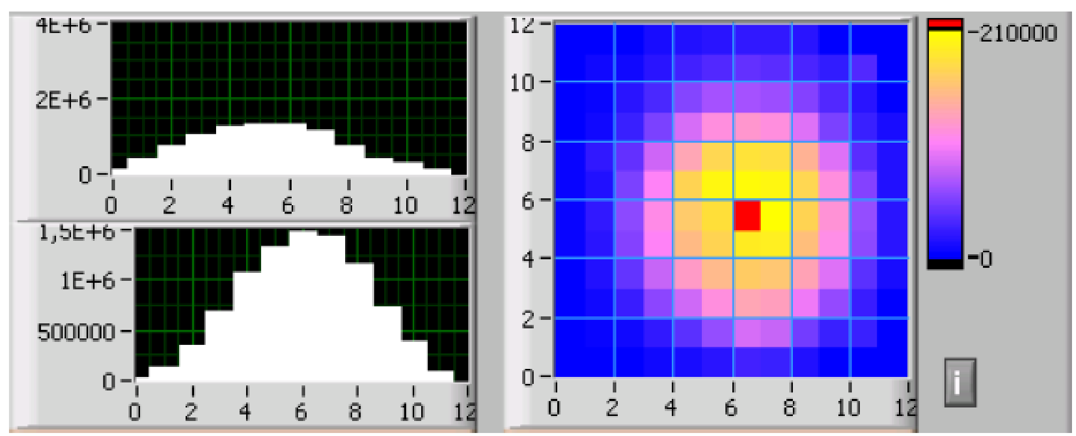
X Ray

Neutrons

Intensity

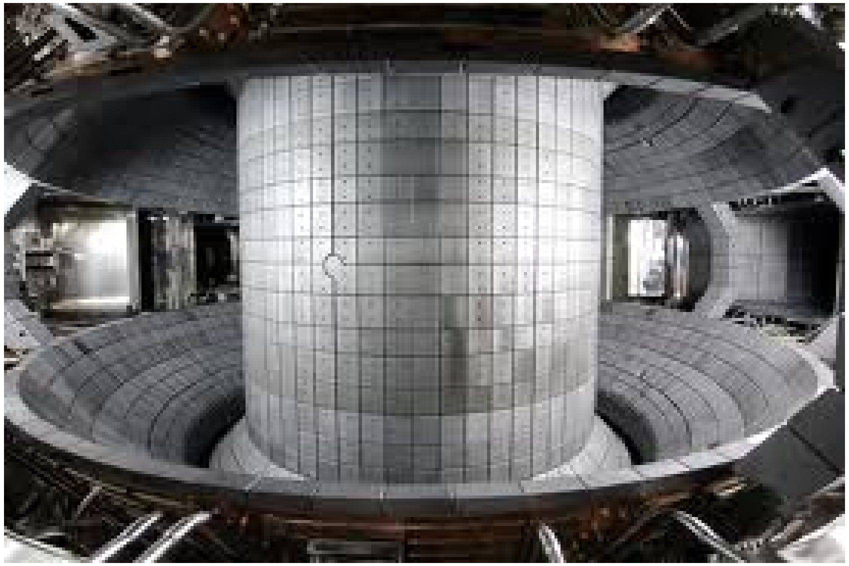


Imaging 2D



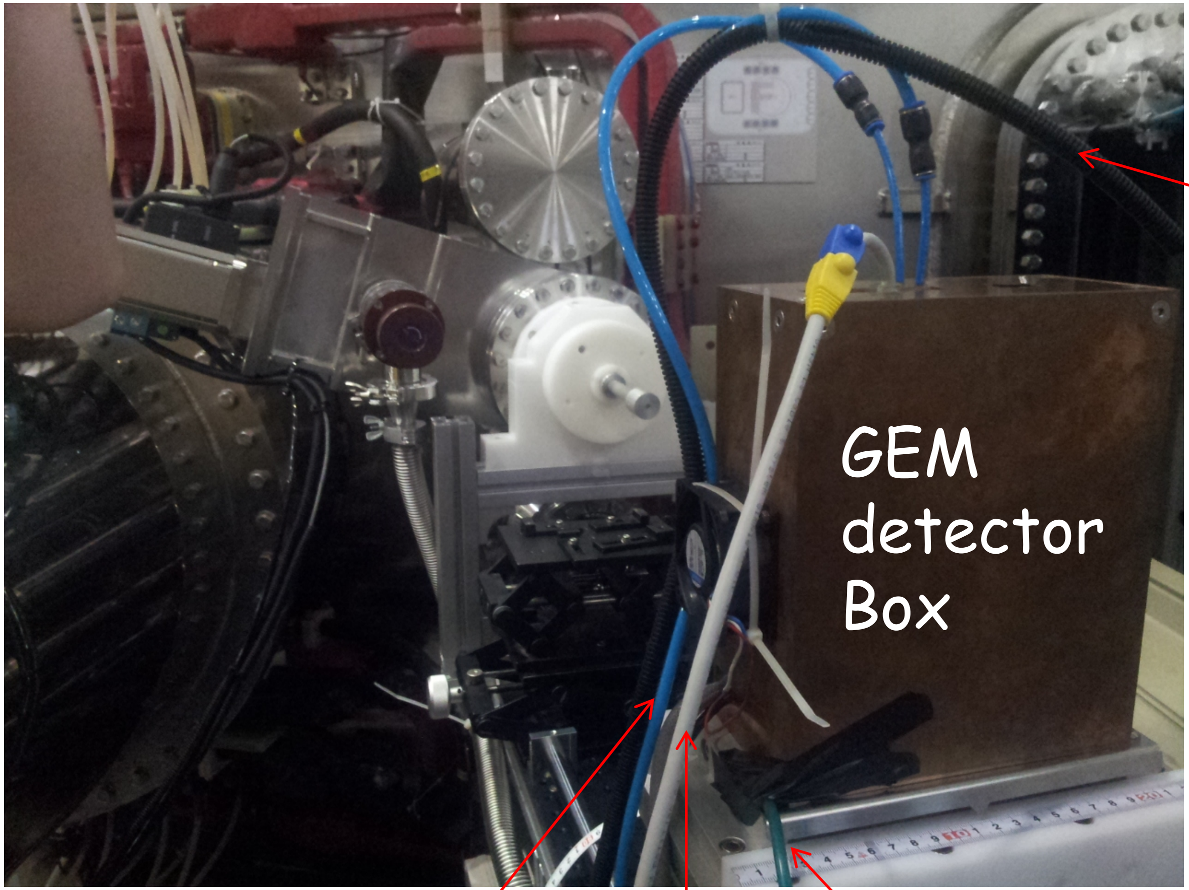
X-ray tangential imaging at KSTAR

The KSTAR XRAY diagnostic group has bought a complete system
(HVGEM – FPGA - Detector)
for a new installation in the Korean Tokamak.



The installation had been done in June 2013 in collaboration with ENEA Frascati.
A campaign of 8 weeks of data taking just ended in September.

Installation at KSTAR

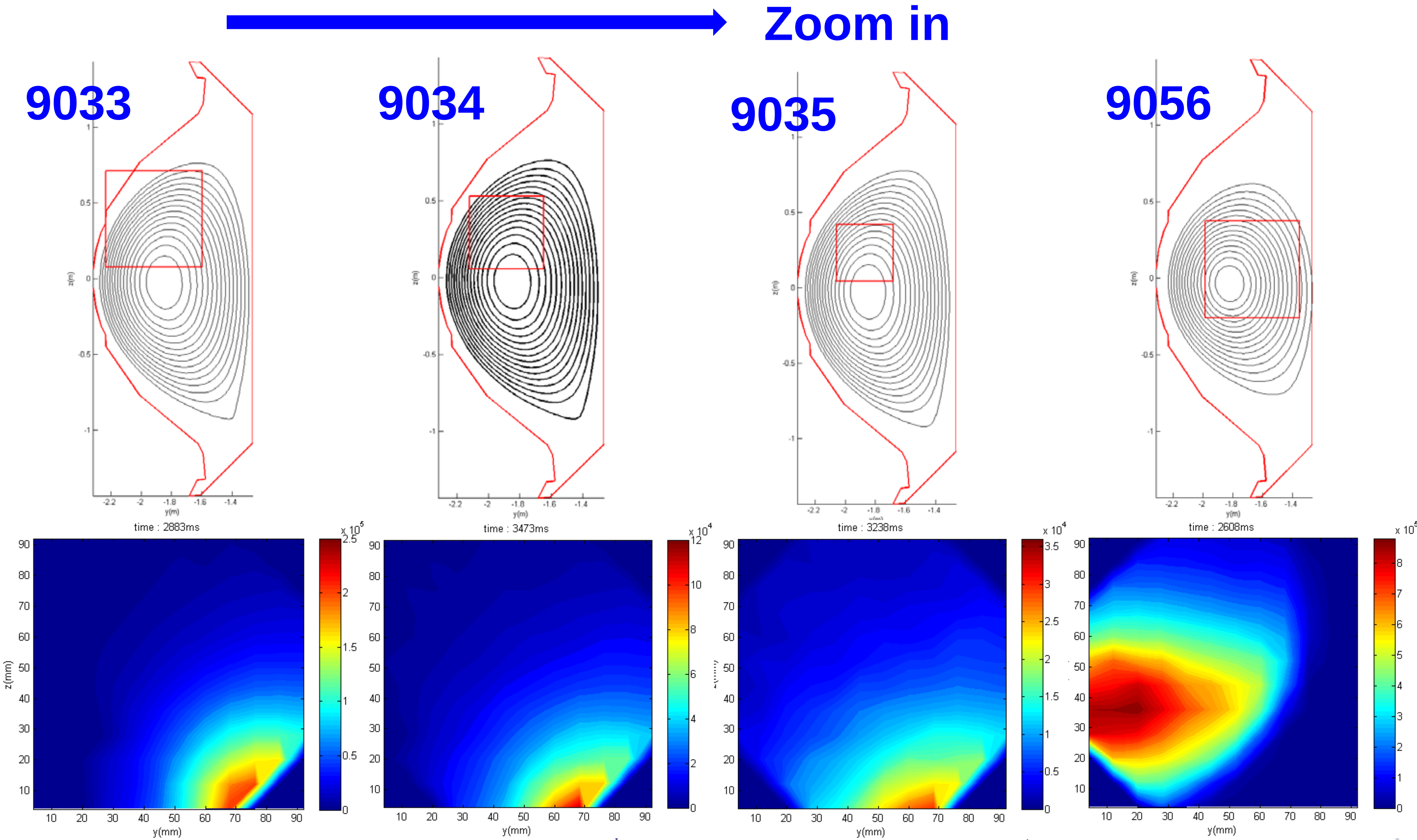


HV Cable

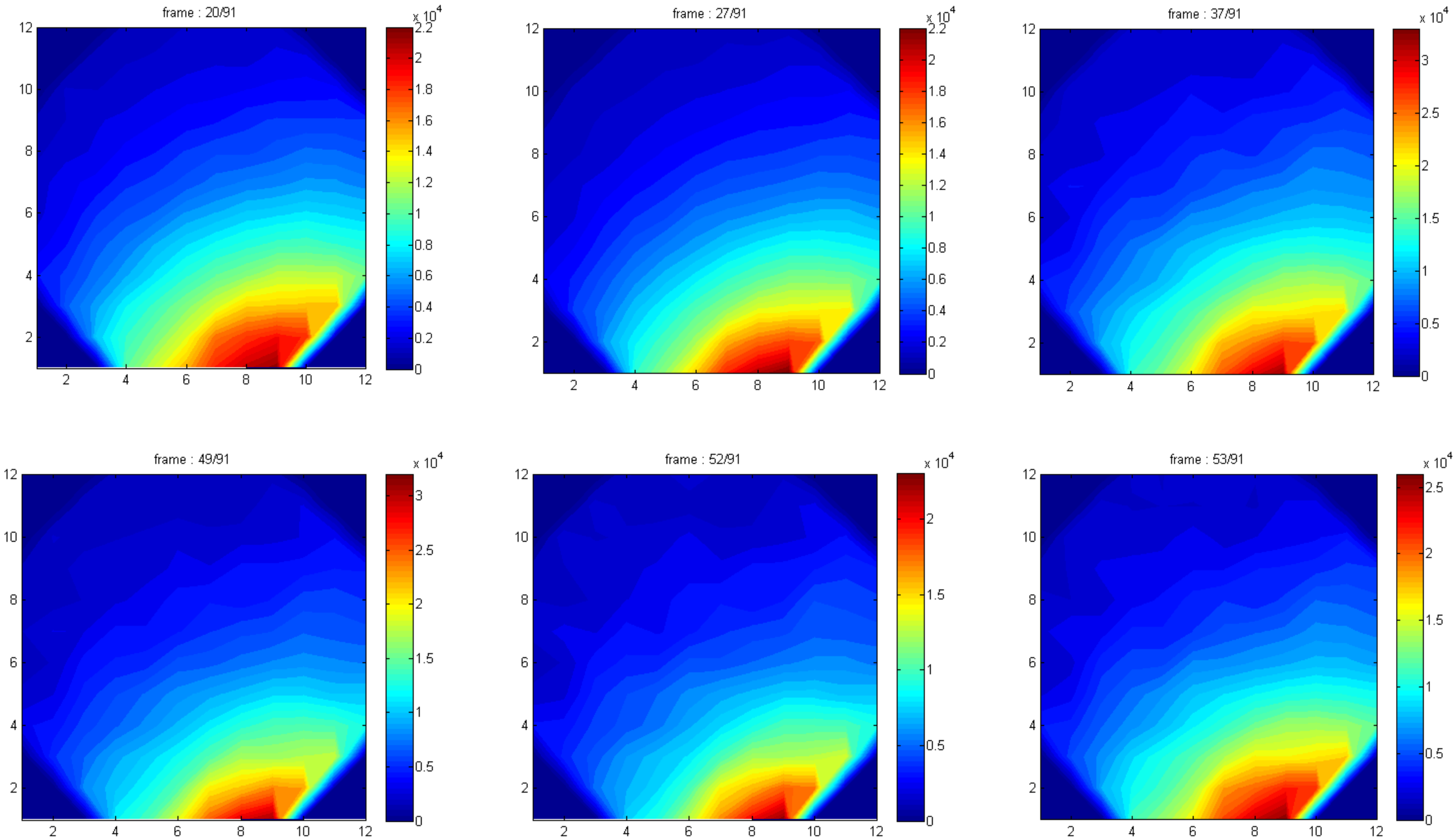
Gas pipes Ethernet LV Cable

X-ray imaging at KSTAR

Shots taken during summer 2013 (D. Pacella ENEA)

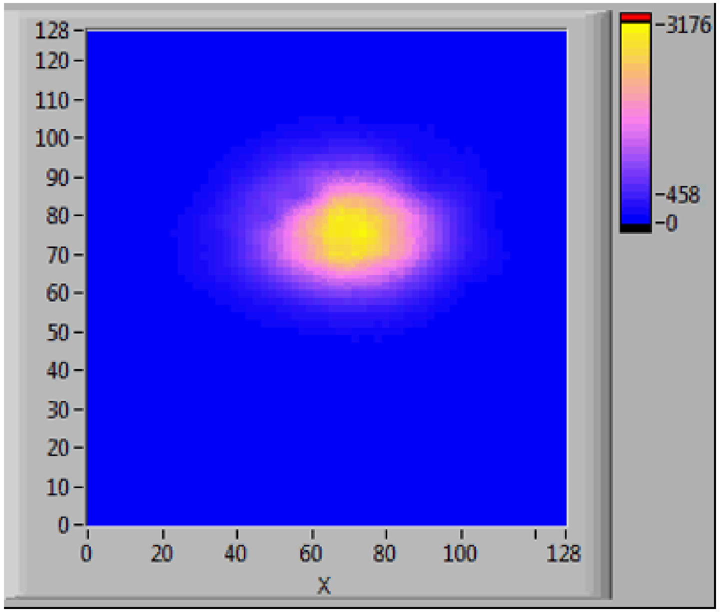


Shot 9035 : time history (frame 1 ms)

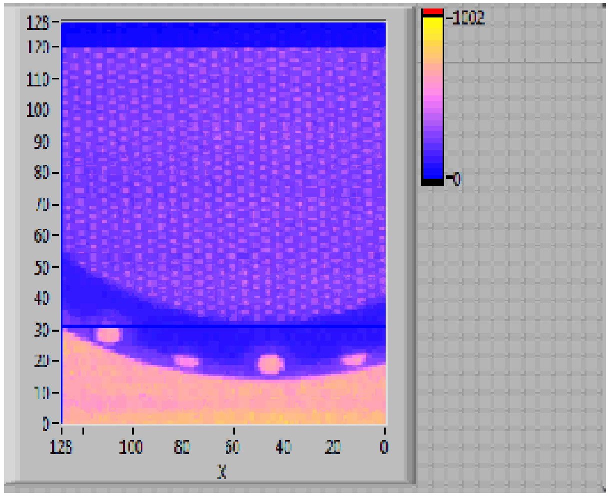


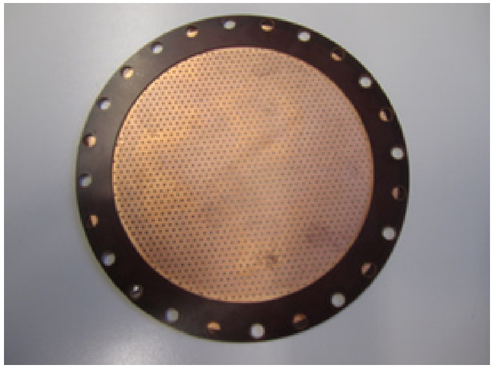
Low energy X-Ray Images

X-Ray beam of 6 KeV



X-Ray 6 KeV
With a mesh of 600 micron holes
Pitch of 2 mm

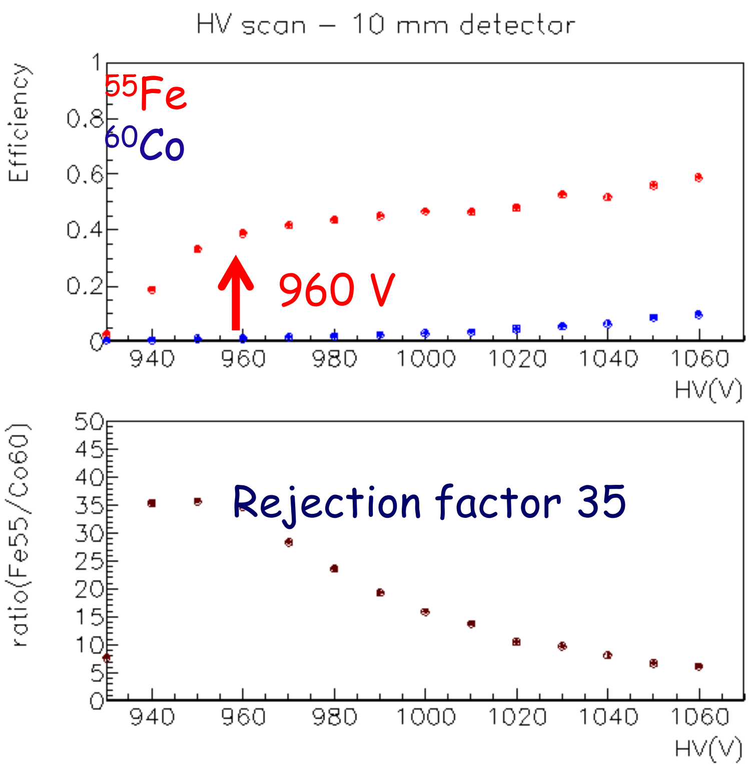


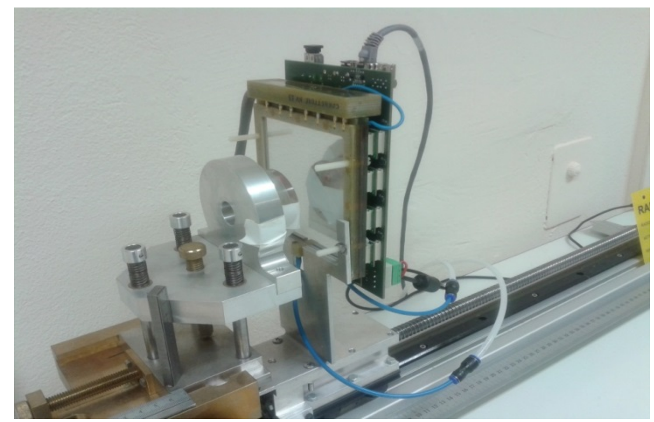


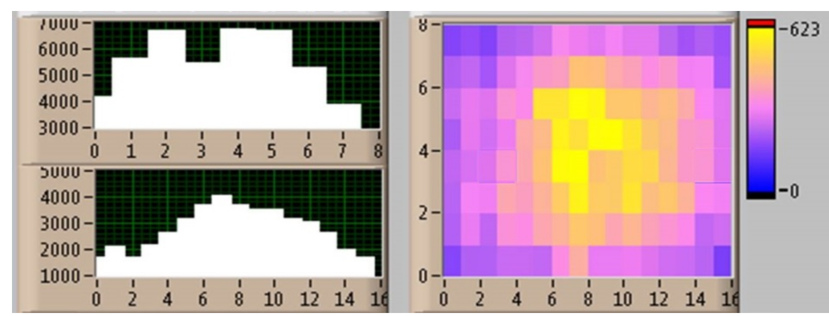
These images was realized in real time moving a triple gem with an array of 128 pads 0.5x0.5 mm crossing the beam

Radioactive waste : ^{55}Fe vs ^{60}Co

At CERN, there are cavities and beam pipes from LEP with residual radiactivity
Some one are candidate for a free release but there is a really stringent limit on ^{55}Fe activity .... The chemical analysis is slow ...
Gas chambers could be a good monitor for this type of radioactivity



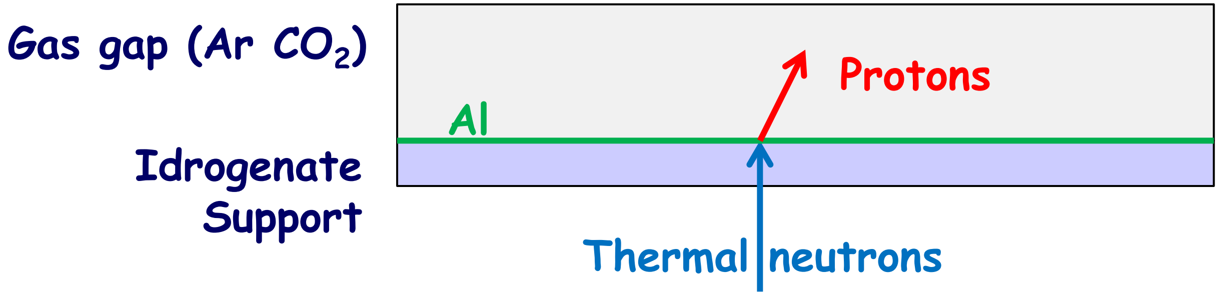




Possibility to find the hot spot

Polyethilene for fast neutron

Fast Neutrons interact with H, and protons are emitted entering in the gas volume generating a detectable signal.

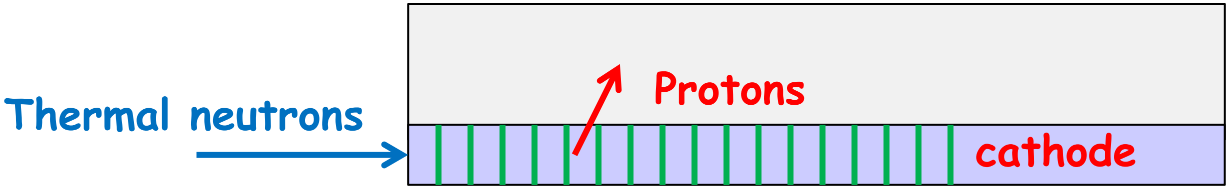


Low Efficiency

Big active area

Beam Monitor and transmission

Side-On detector



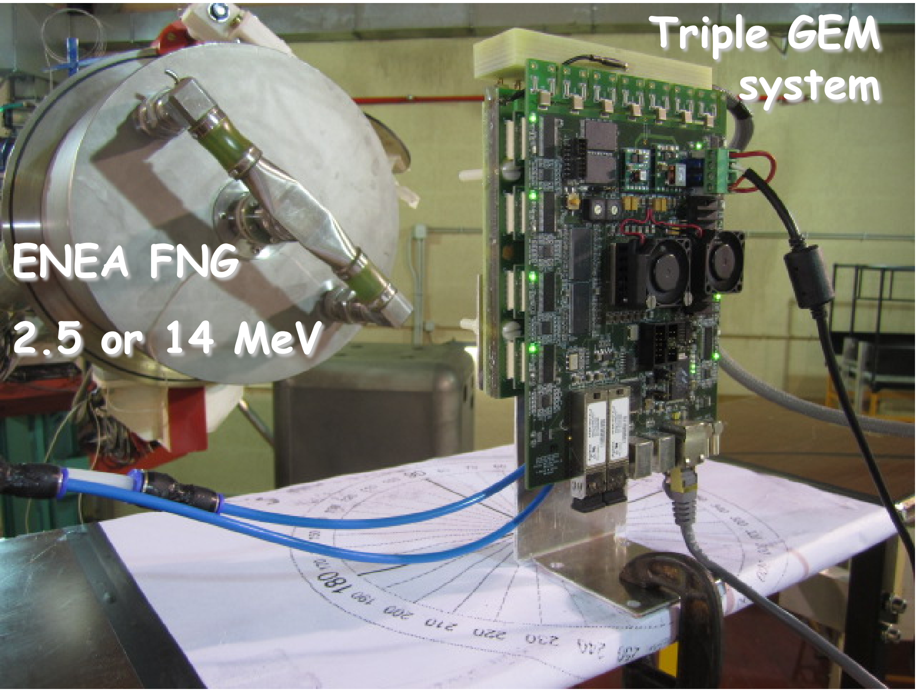
High Efficiency

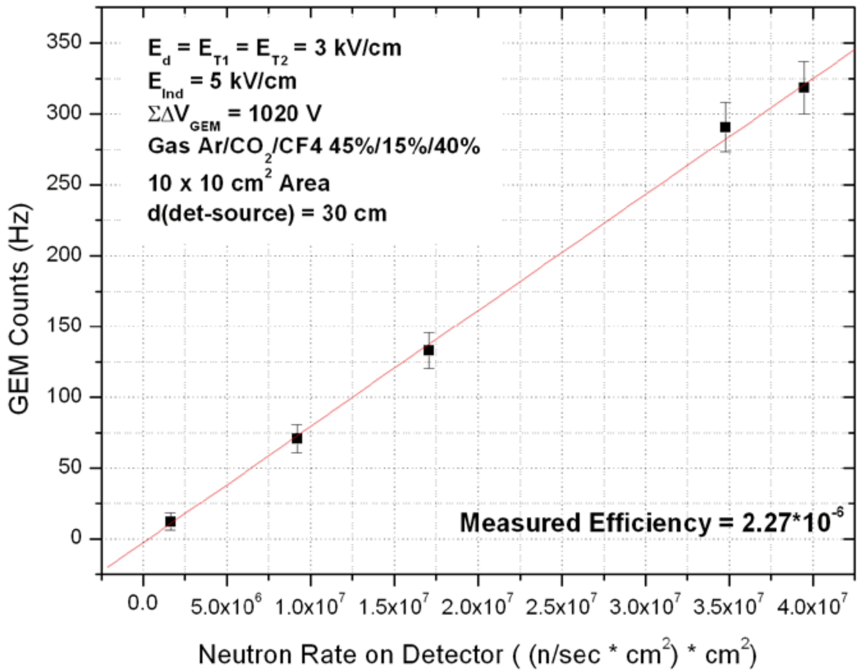
Small active area

Actually 0.1% efficiency ... working to obtain few %.

Test at Fast 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.



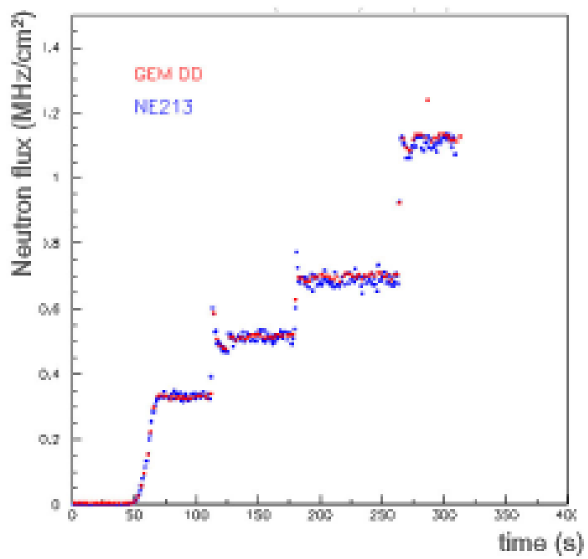


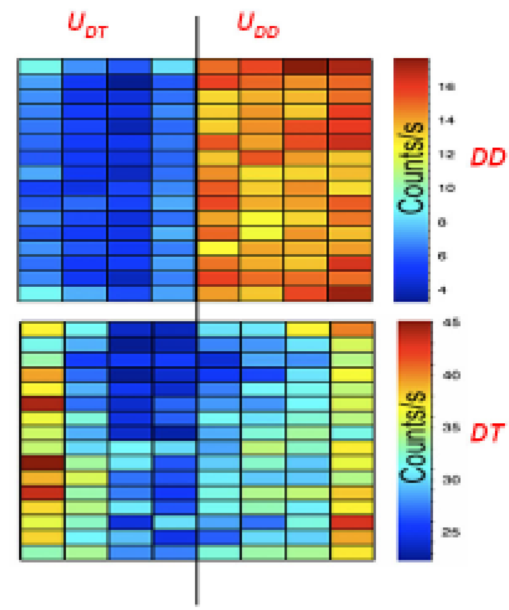
Good linearity measured up to 4×10^7 neutron/sec cm^2
the maximum rate reached by this facility

Neutron discrimination

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)



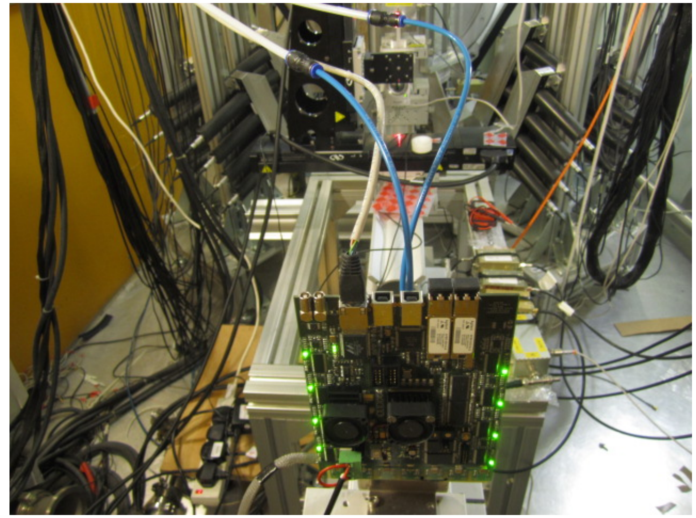


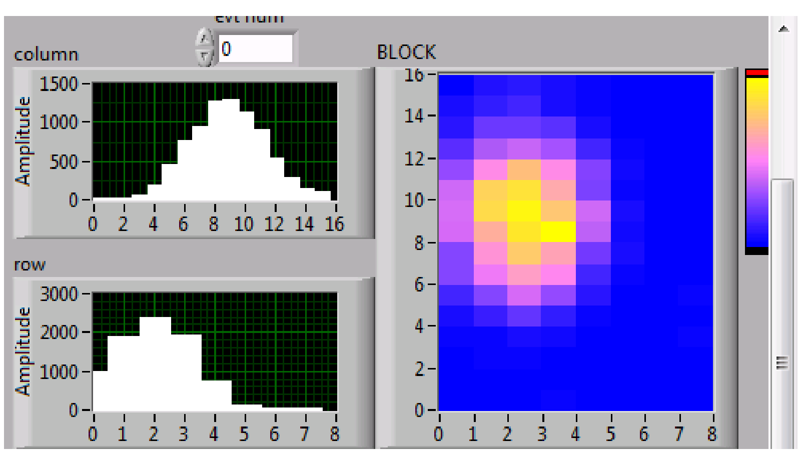
Design of a GEM-based detector for the measurement of fast neutrons
B.Esposito et al NIM A, Volume 617, Issues 1–3, 11–21 May 2010, Pages 155-157

Fast Neutron Monitor

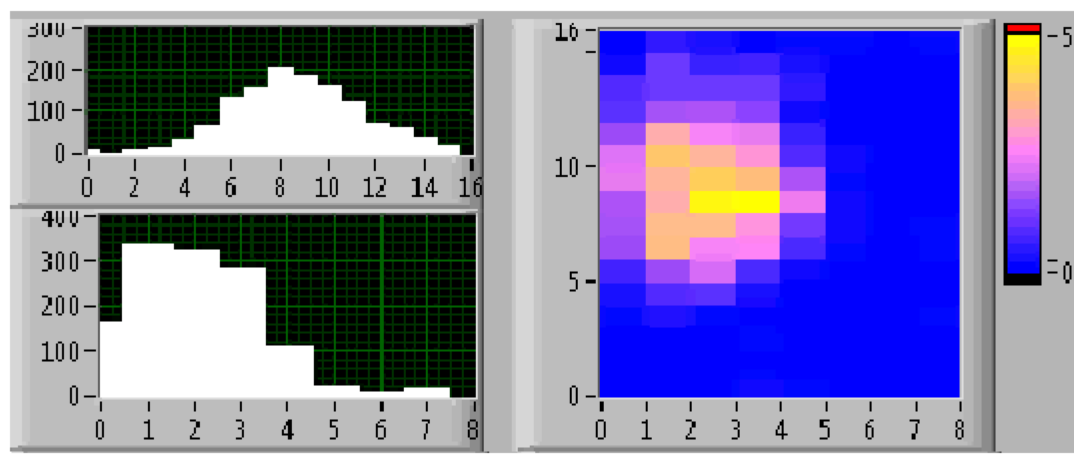
Monitor for a fast neutron beam with energies ranging from a few meV to 800 MeV

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





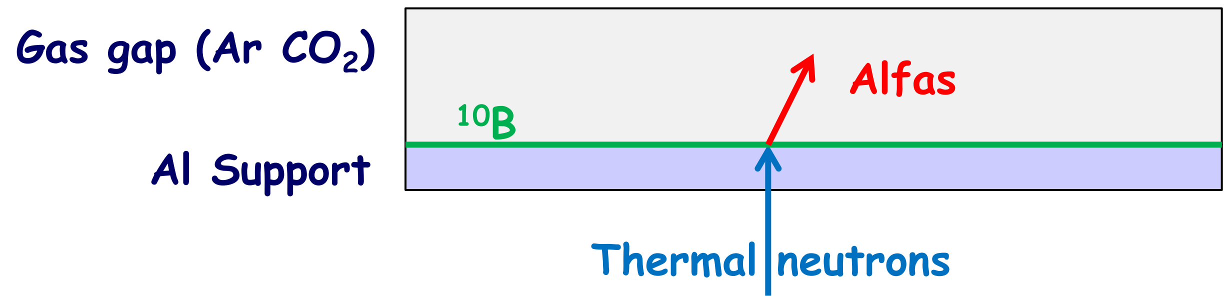
Beam profiles and intensity in real time



Neutron beam monitorig during the shutter opening

^{10}B Cathode for thermal neutron

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

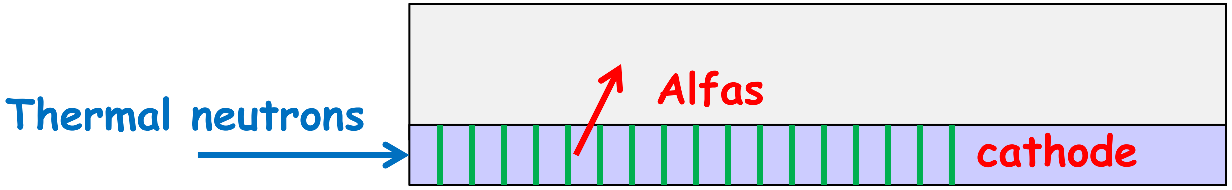


Low Efficiency

Big active area

Beam Monitor and transmission

Side-On detector



High Efficiency

Small active area

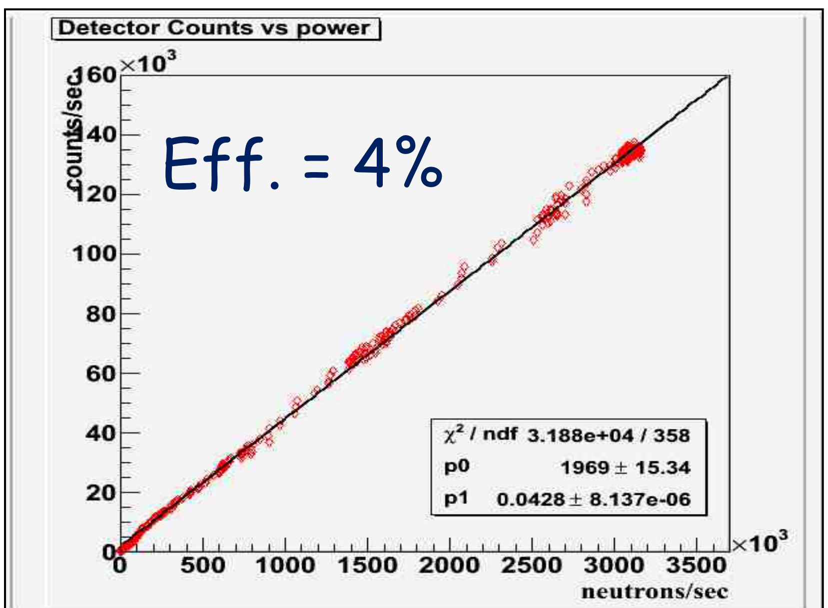
Actually 4% efficiency ... working to obtain 70%.
Good candidate as ^{3}He replacement detector

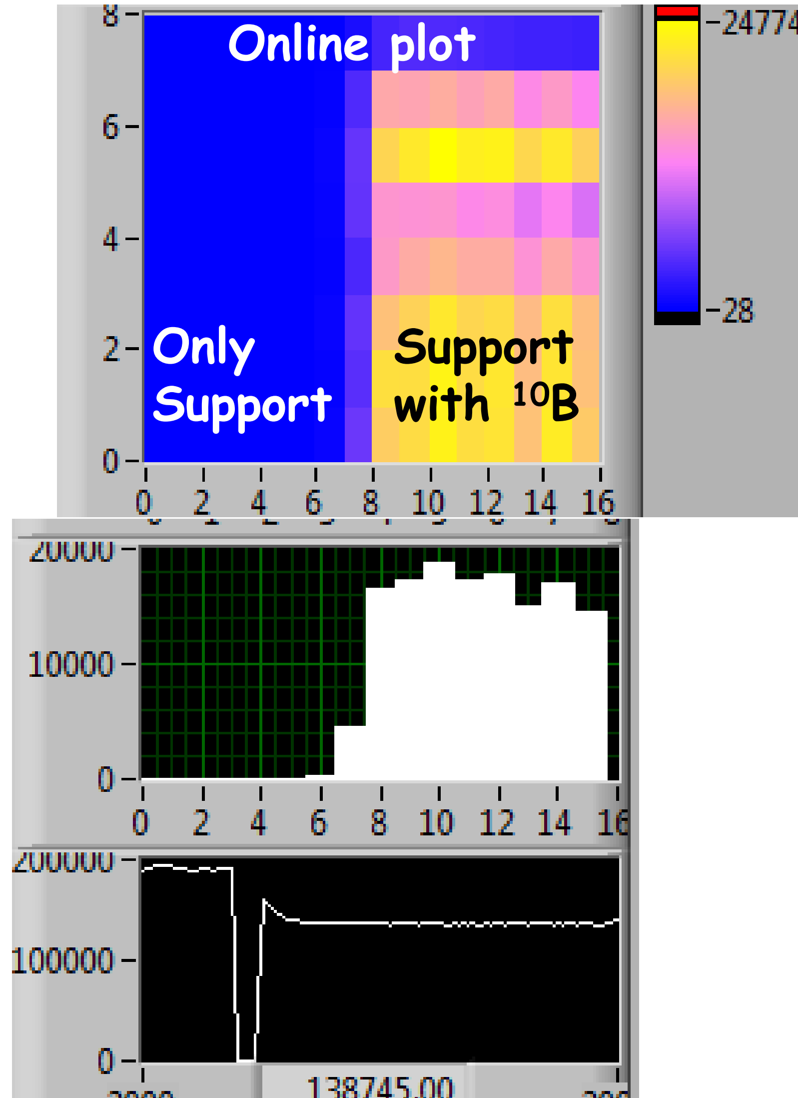
Monitor for fission reactors

Measurements at Triga (ENEA)

Gamma background free
Without electronic noise

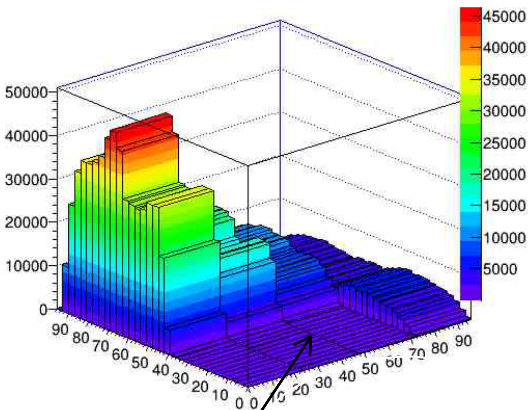
Good linearity up to 1 MW
6 order of magnitude

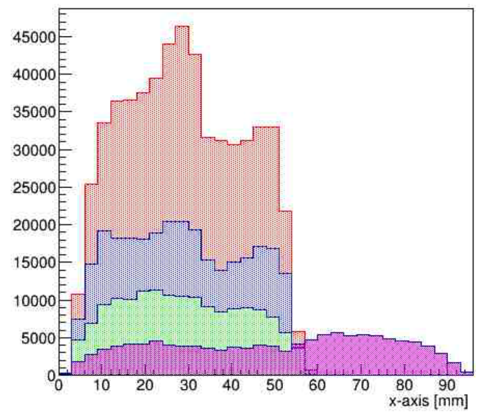




Measurements on efficiency

New prototype with 34 Boron layers and new pad layout

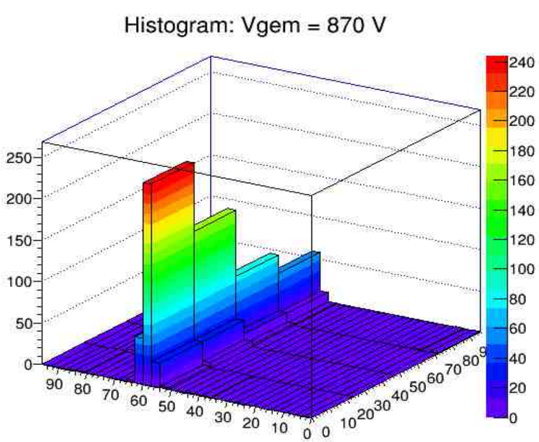


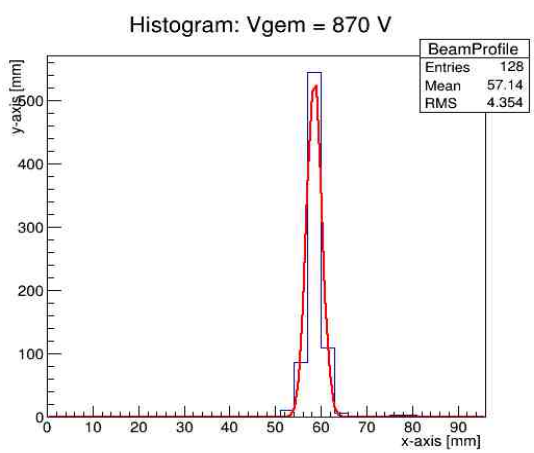


Non borated zone

Wide Beam

efficiency = 31 %

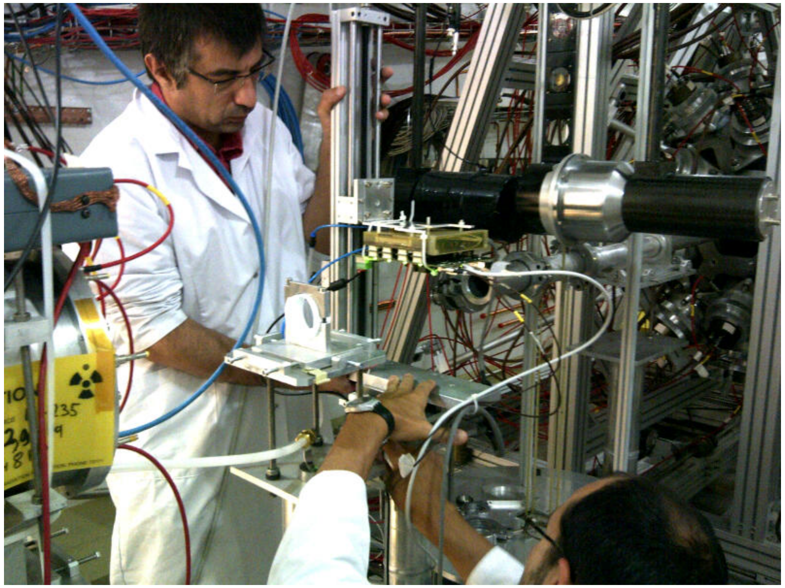




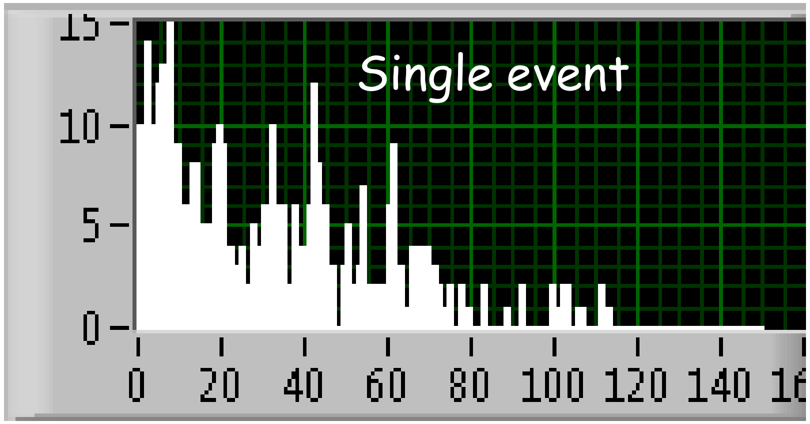
Narrow Beam

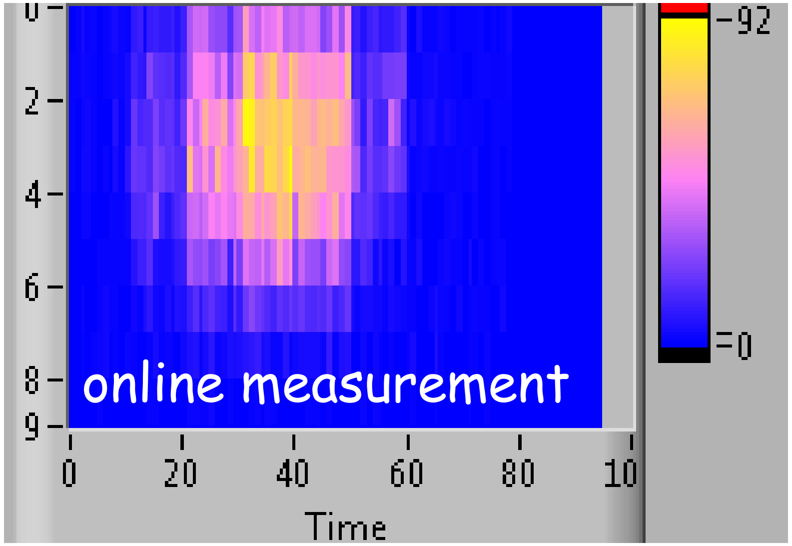
resolution =0.7 mm

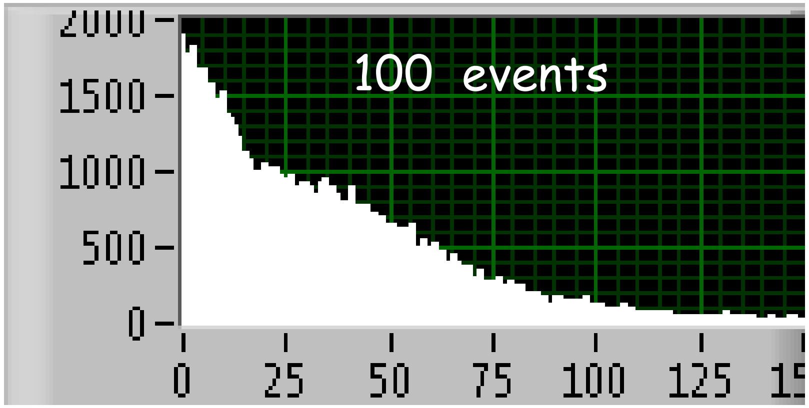
Diagnostics with thermal neutron @NTOF



online measurement





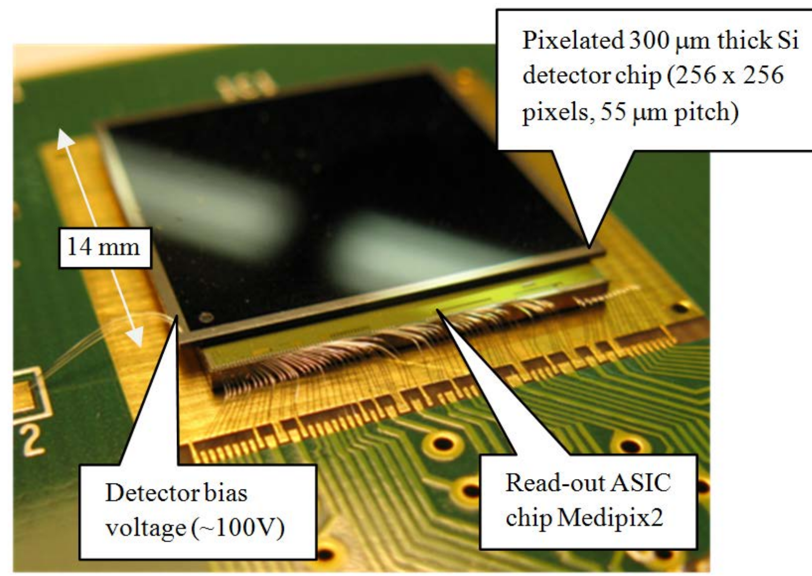


Time spectrum (1ms/bin)
150ms total gate

MEDIPIX detector

Medipix for X-Rays

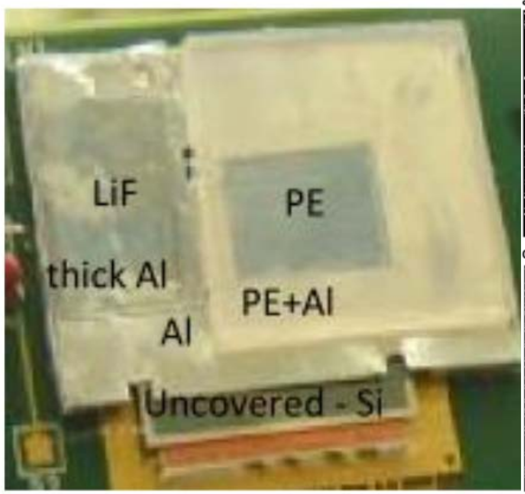
The Medipix is a silicon detector
with 50x50 micron pixels
Matrix of 256x256 pixels
Active area of 1.4x1.4 mm
Power supplied by USB

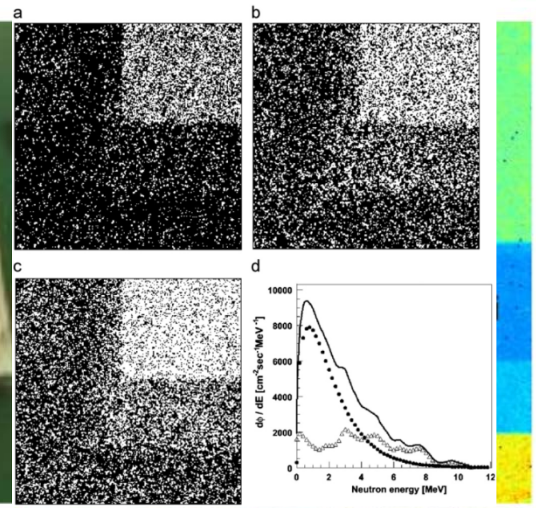


The idea is to use the readout *ASIC Chip without the Si sensor*
to measure the electron clusters produced by the GEM

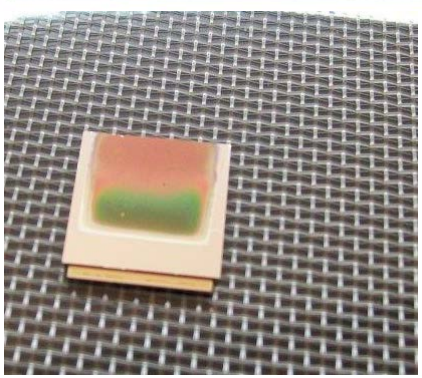
Medipix for neutron detector

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



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

Test in progress at CERN.

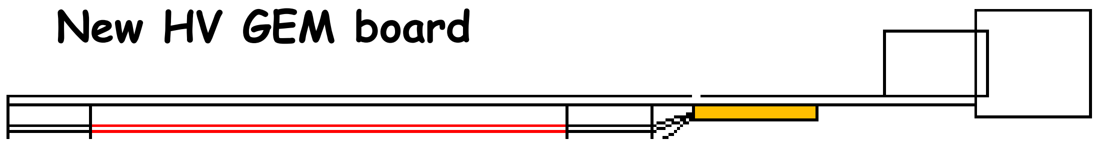
GEMPIX detector

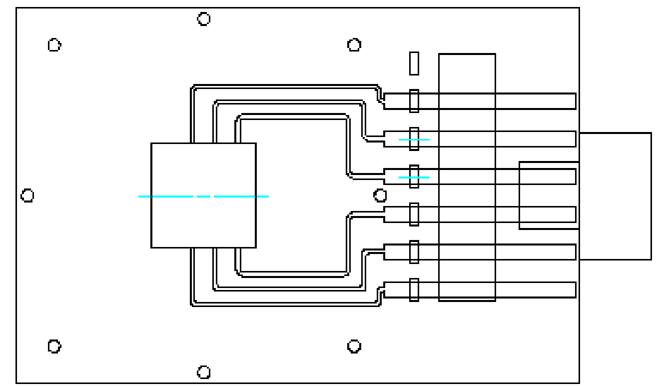
GEMpix Assembling

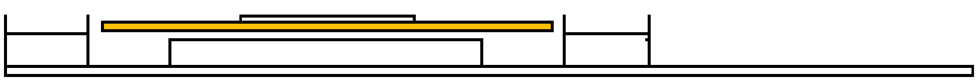
The detector has two main parts :

- The quad medipix with a naked devices
- The triple gem detector with HV filters and connector

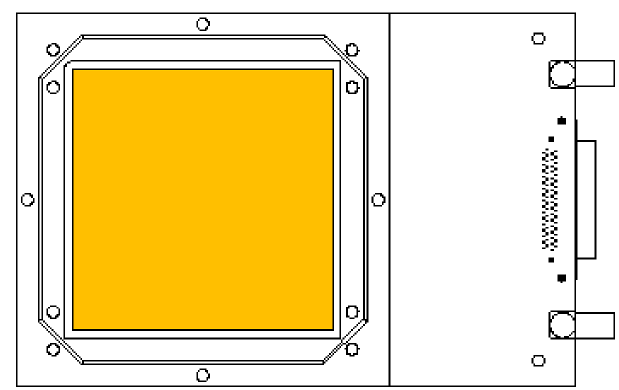
New HV GEM board







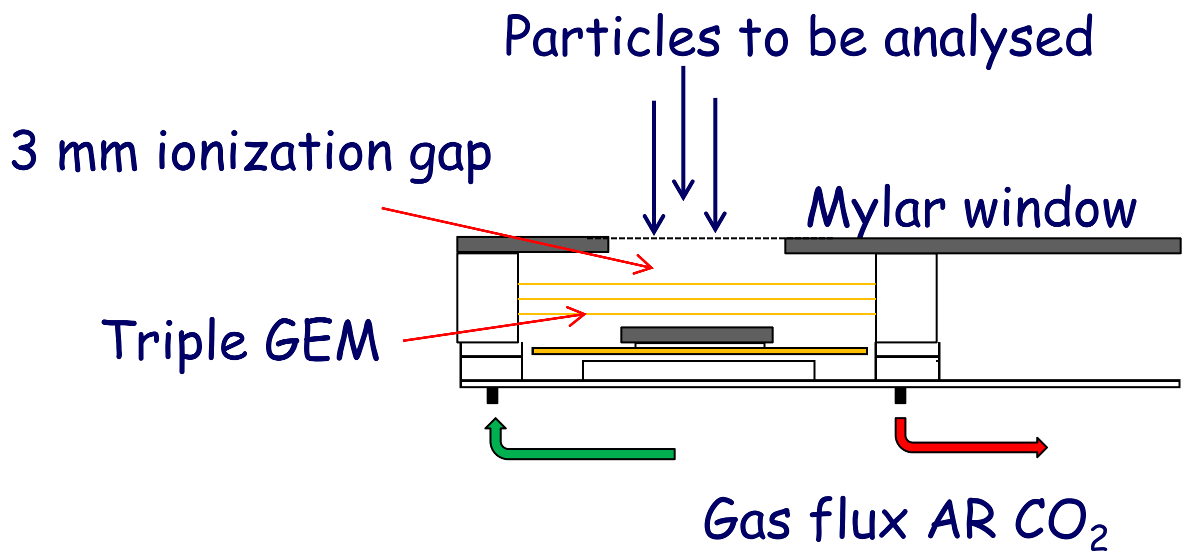
Quad medipix board



M.Campbell, J.Alzoy

Top view

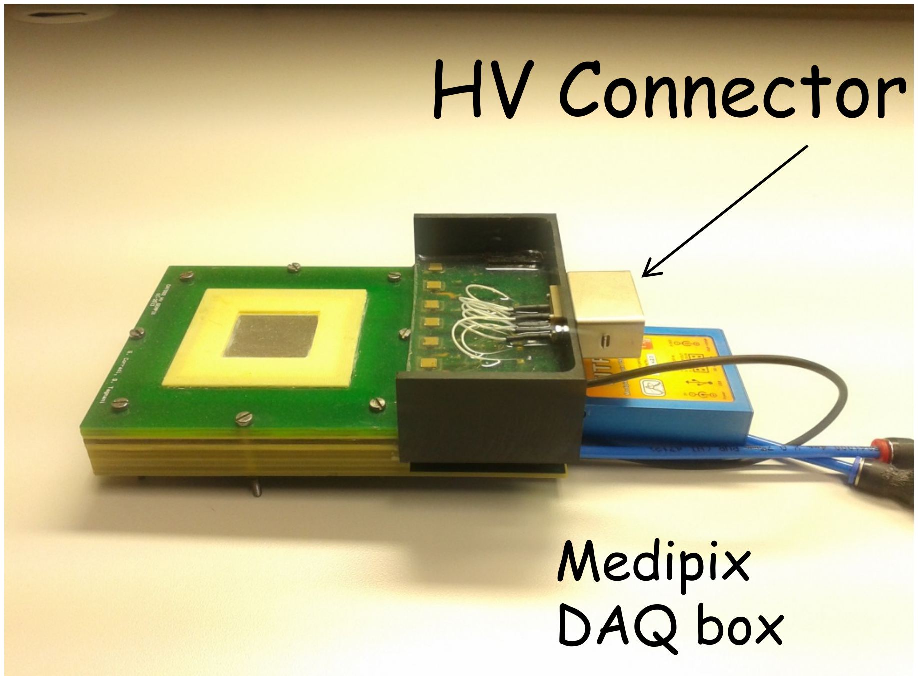
Head on detector



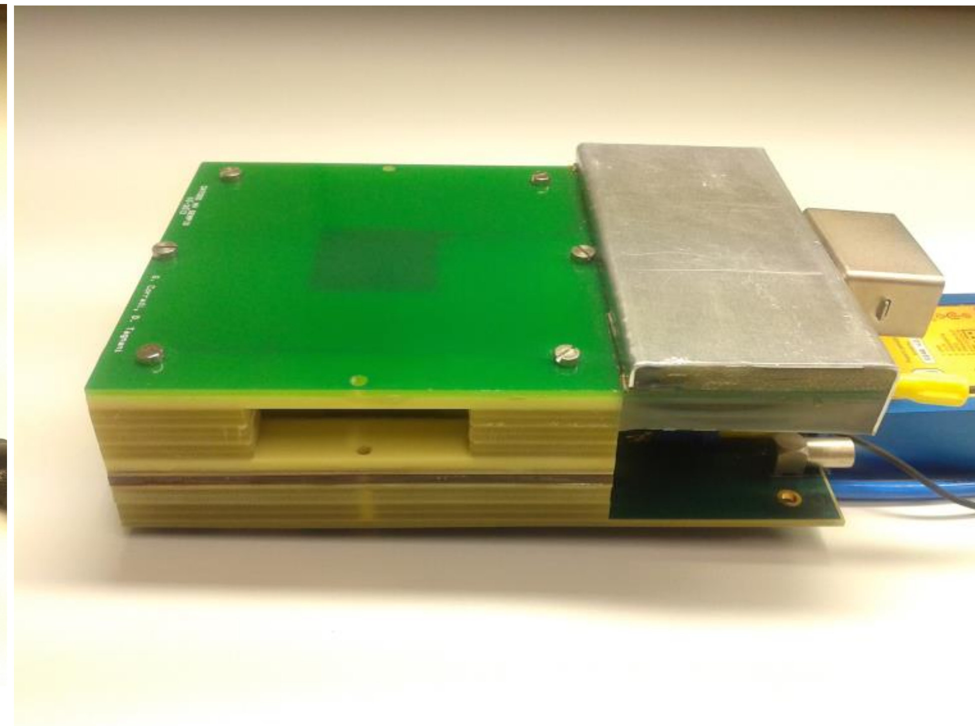
The detector is a quad naked medipix :
The active area is 9 cm^2

This type of device can be used also for neutron detection
if a film of polyethylene or Boron is deposited on the cathode

Two prototype of GEMPIX

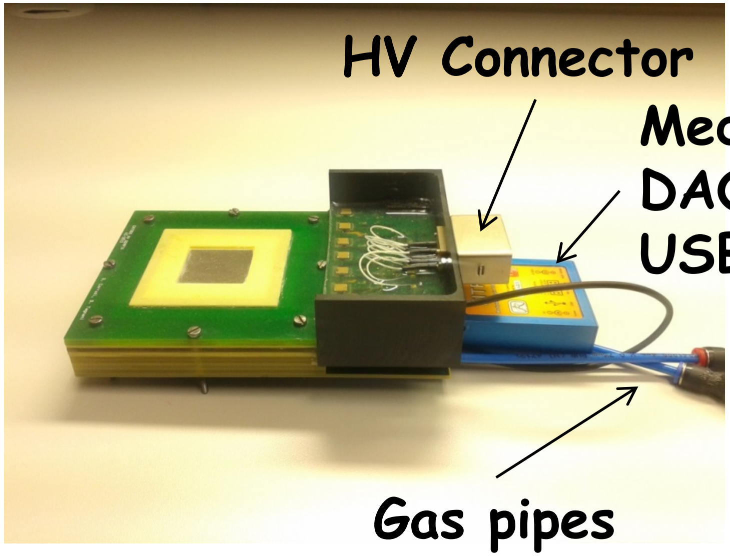


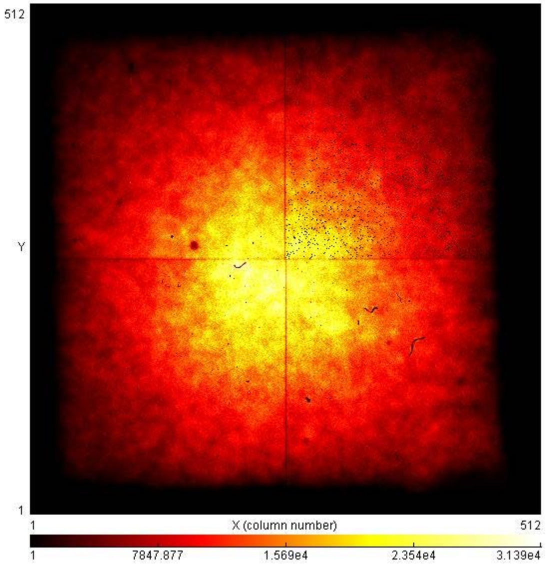
Head-on detector



Side-on detector

GEMPIX for inertial fusion



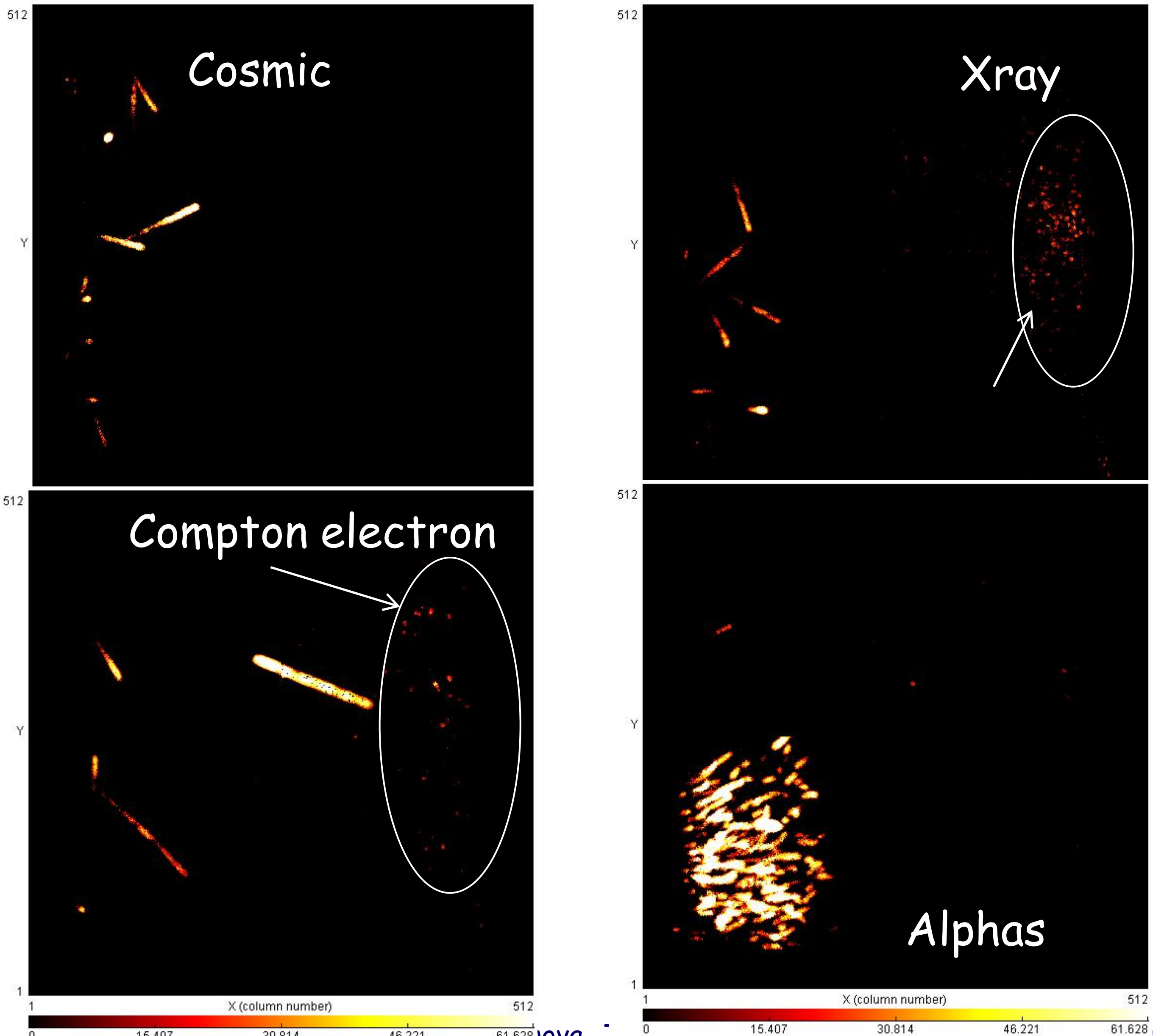


X-Ray source image

Monitor for laser produced plasmas and inertial fusion (proposed by G.Gorini & D.Pacella)

Burst of X-Rays of few ns
Next tests on ABC (Frascati ENEA) and then at PETAL (FRA)

Dosimetry and microdosimetry

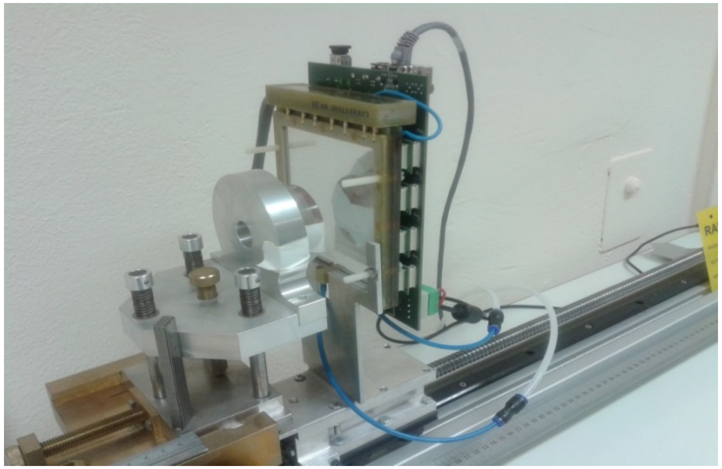


These pictures were taken with radiactive sources of ^{55}Fe Cesium and Americium

Using a gas mixture of $Ar/CO_2/CF_4$ 45/15/40

With a gain of 6000 and an induction field of 2 kV/cm

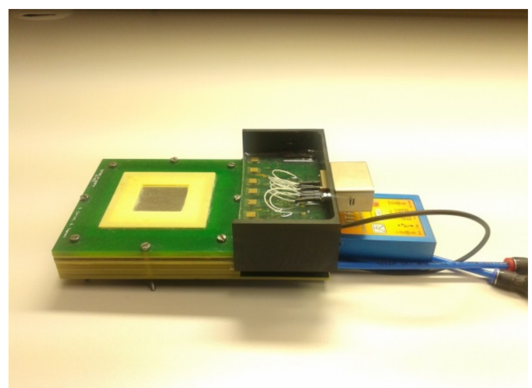
CNAO
CERN
ARDENT
INFN

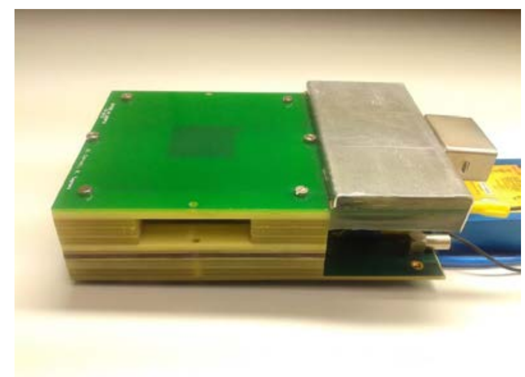


Thanks !


MEDIPIX PROBE CARD
Medipix2 USB Interface


Timepix
USB Lite
Interface





FPGA Board : Realtime DAQ

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).

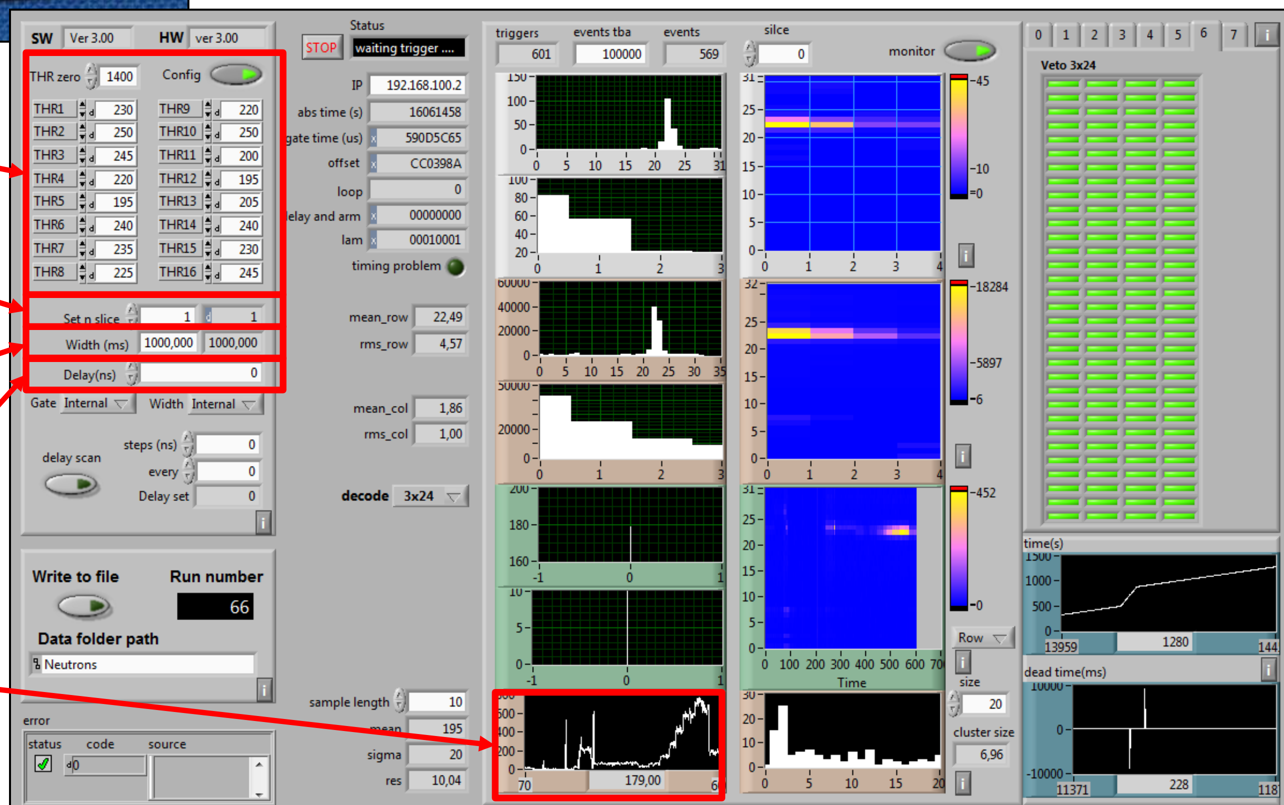
Threshlds settings

Slices acquisition

Integration time (untill 20-30 µs)

Delay to trigger

Total Counts vs time



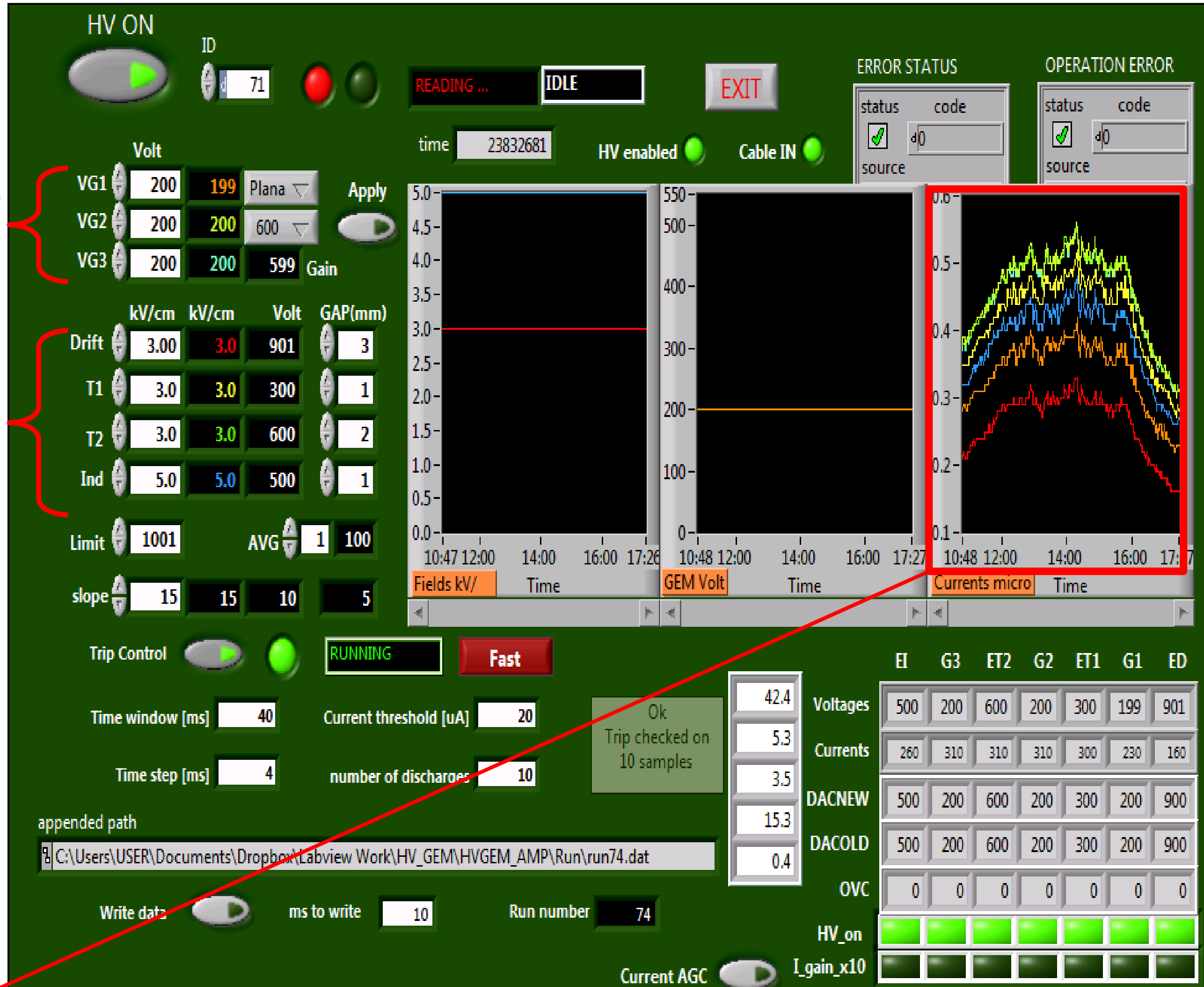
NIM standard HVGEM Modlue Power Supply

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.