Triple GEM detectors : Beam monitoring for beam profile and intensity measurements.

F.Murtas CERN and LNF-INFN

- Construction of a triple GEM detector
- A triple GEM system
- Beam Monitor
- Intensity measurements
- Conclusions

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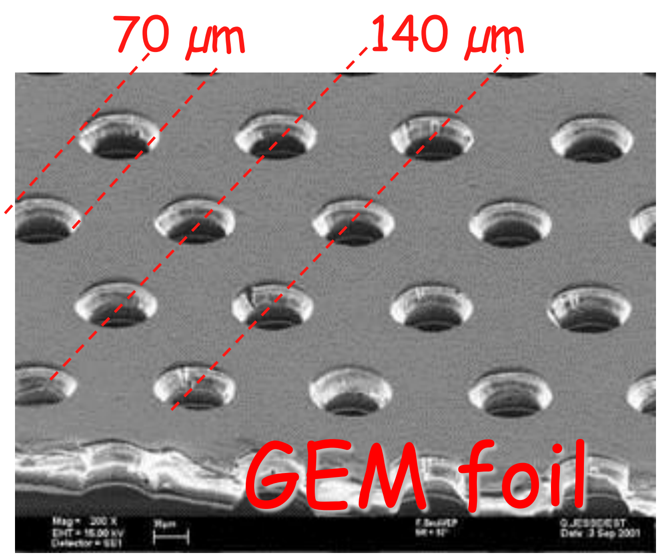
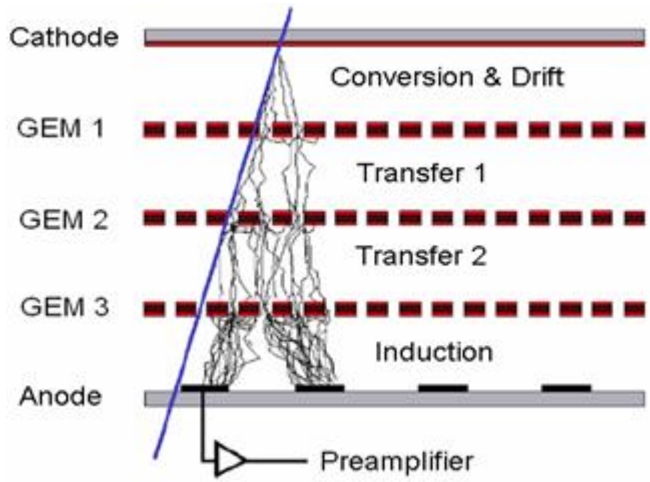
A triple GEM Chamber

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 in the LHCb Muon Chamber framework*





*** M.Alfonsi et al., The Triple-GEM detector for the M1R1 muon station at LHCb, N14-182, 2005 IEEE NSS Conference, Puerto Rico**

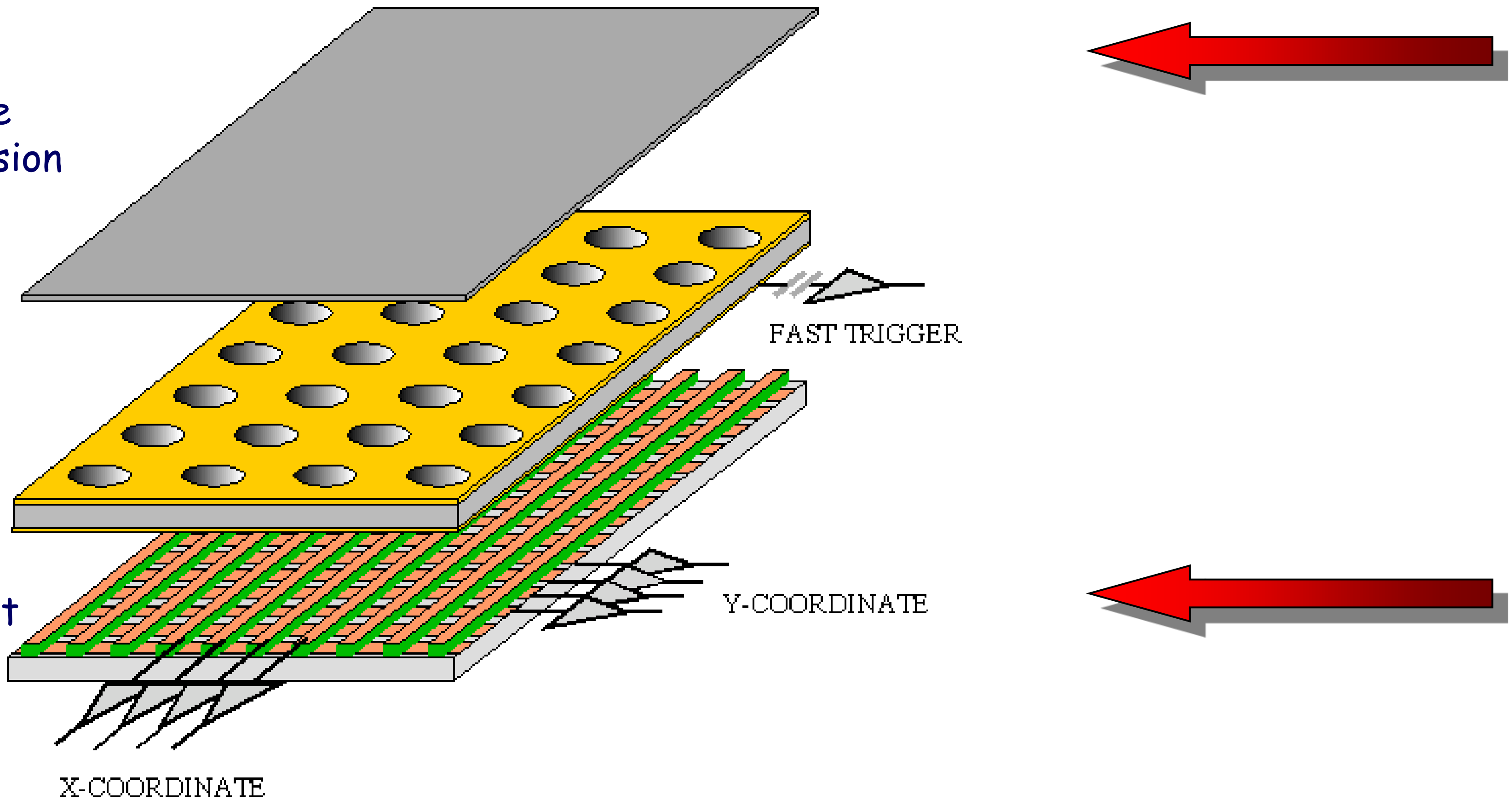
Where we are working now

- Gain and readout functions on separate electrodes
- Fast electron charge collected on patterned anode
- High rate capability and radiation tolerant

Particle conversion

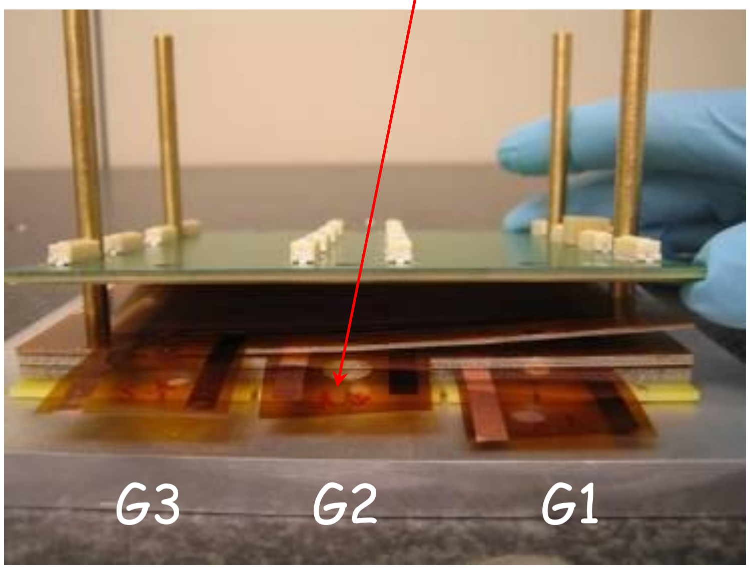
Gain

Readout

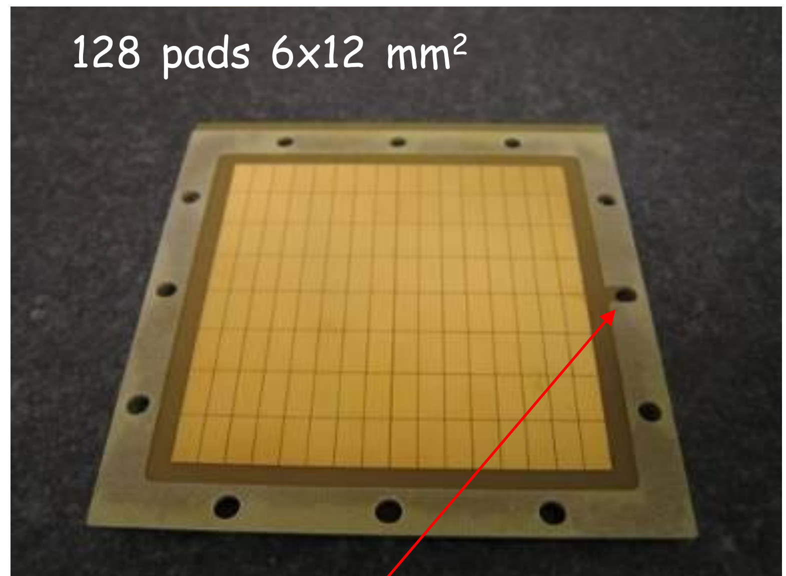


A Standard Triple GEM construction

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.



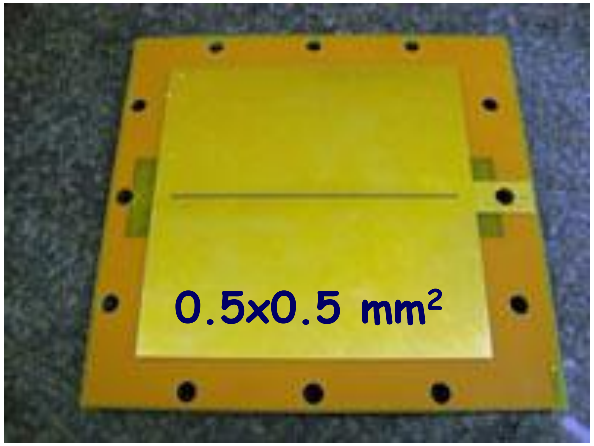
The GEM are stretched and a G10 frame is glued on top

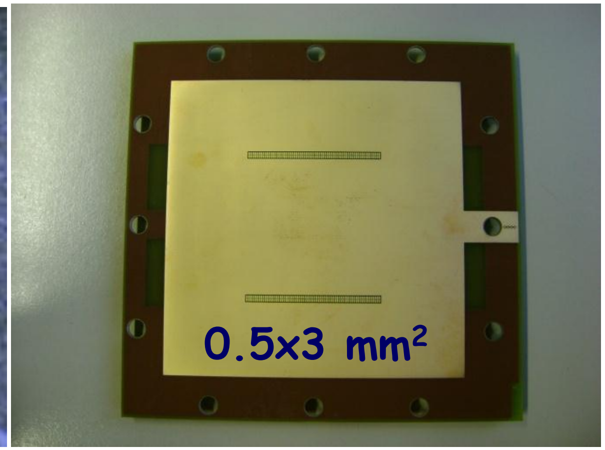


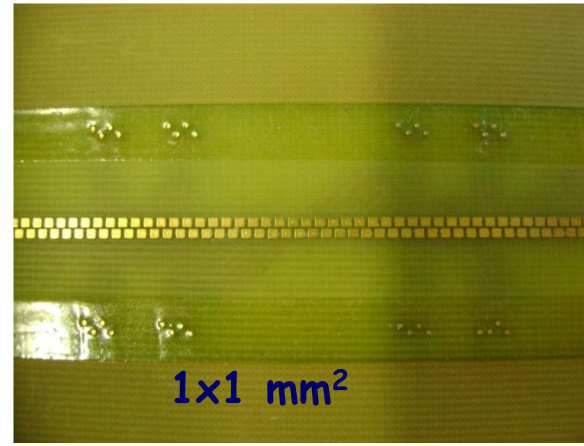
The frame for the G3 foil has been modified for the gas inlet

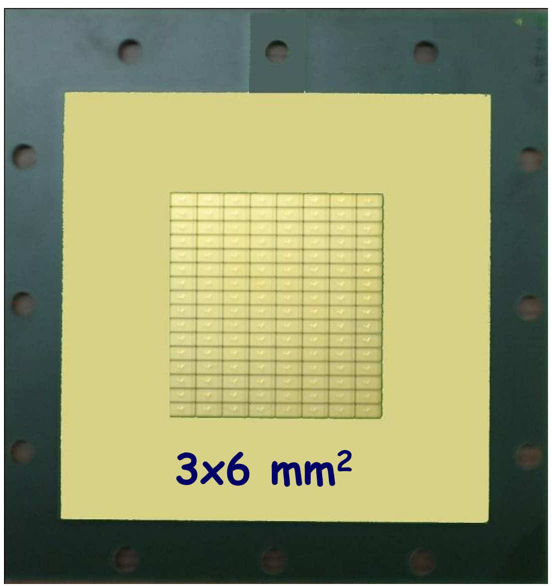
Pad readouts

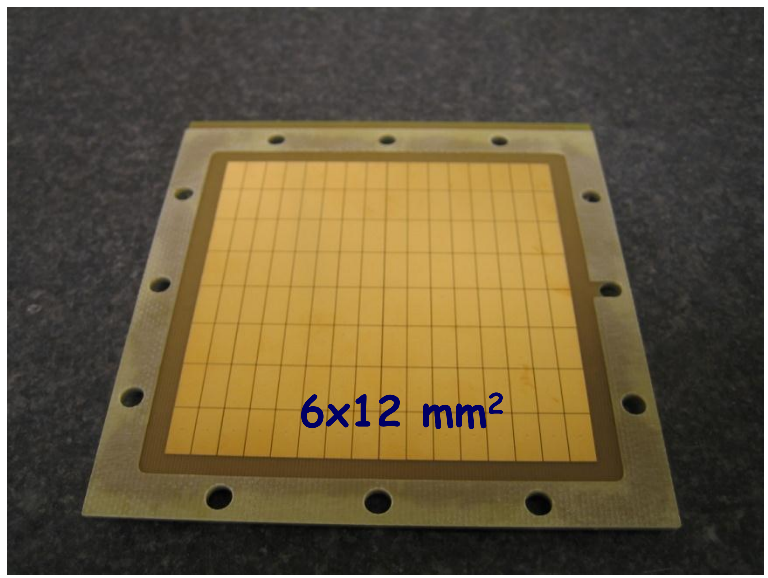
Different pad geometry but always with 128 channels





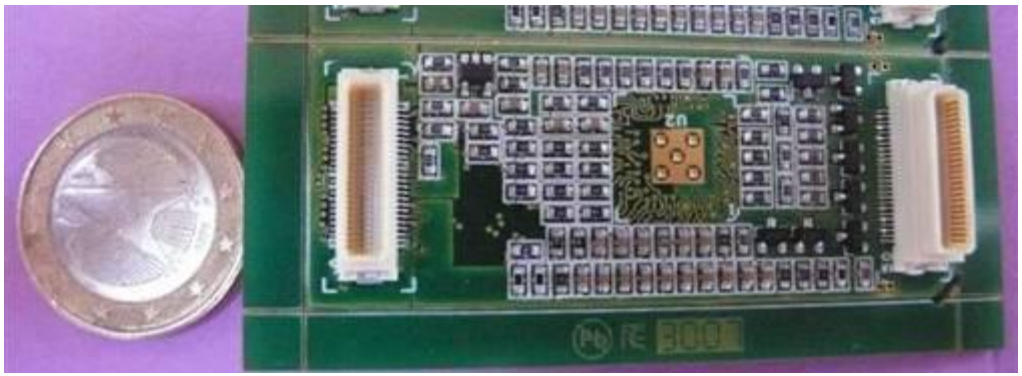




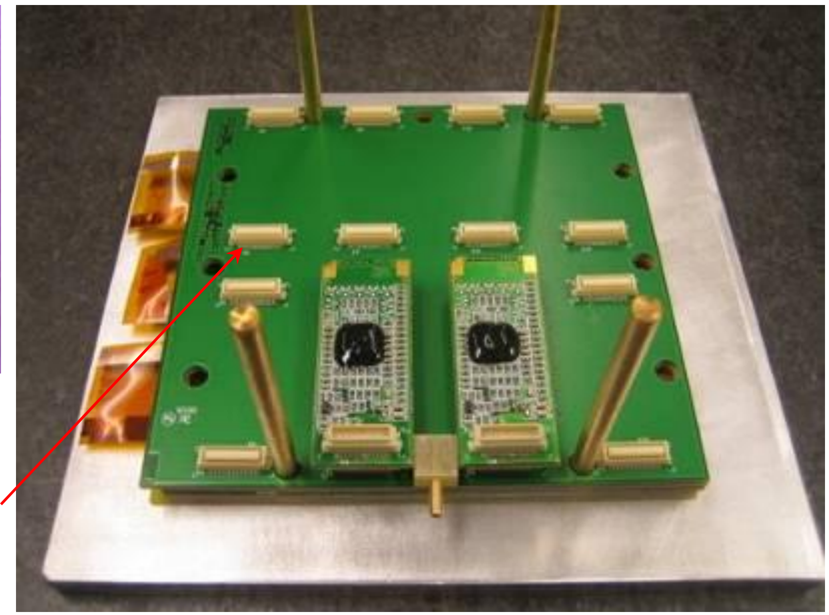


The FEE board used

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)

DAQ System and Power Supply

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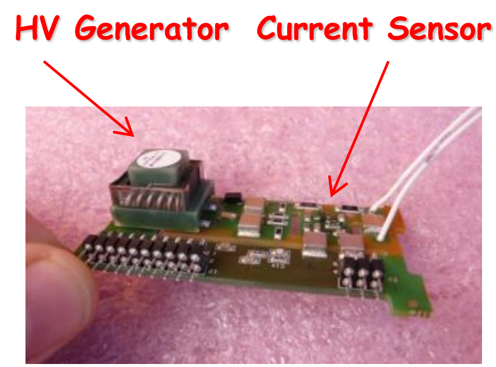
Two important devices have been developed in Frascati during 2010 :

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

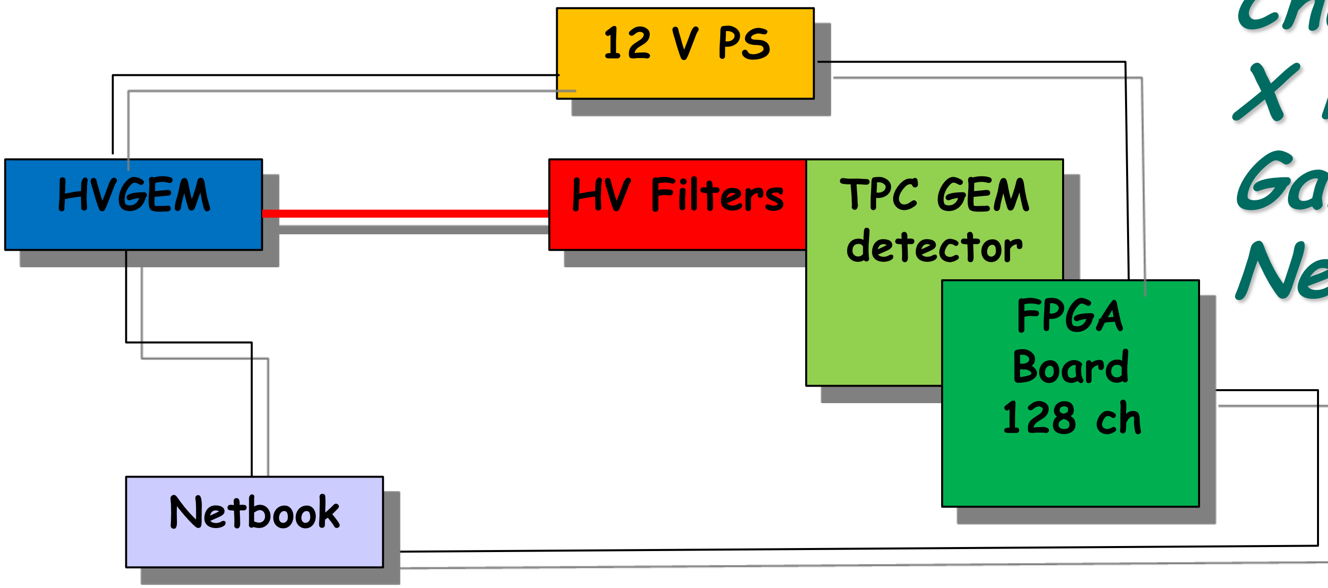
HVGEM : a power supply for triple GEM detectors:
7 HV channels (0.5 V ripple)
with 7 nano-ammeters (10 nA)



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

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

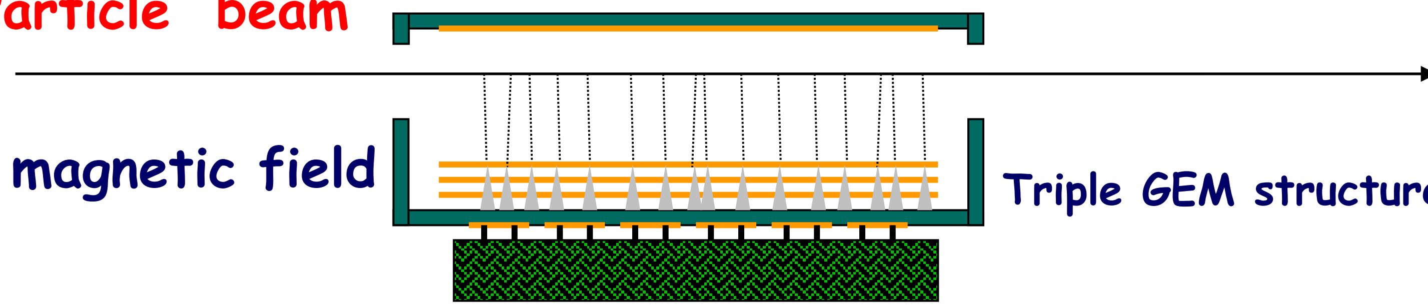
The main characteristics are :
- Extended dynamic range (from single particle up to 10^8 partcles cm^{-2} s^{-1})
- Good time resolution (5 ns)
- Good spatial resolution (200 μm)
- Radiation hardness ($2C/cm^2$)

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)
- detectors for fast and thermal neutrons ,
- medical applications (diagnostics eand therapy):
  - medical diagnostics medicale in gamma theray;
  - medical diagnostics in hadro therapy;
  - steress diagnostics in industrial applications;
- environment monitoring;

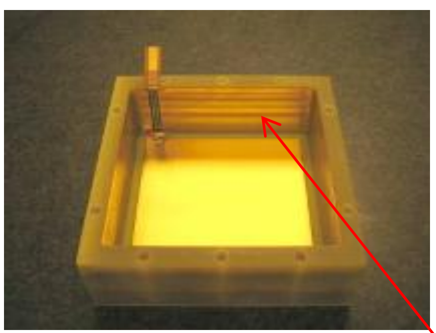
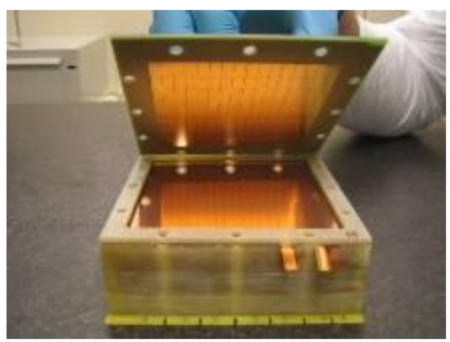
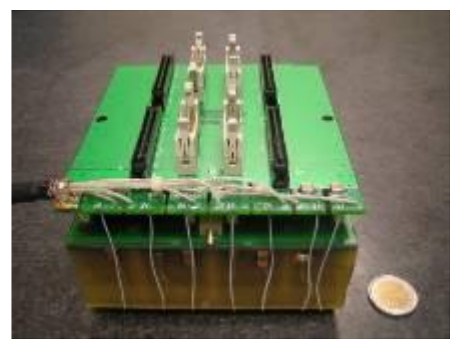
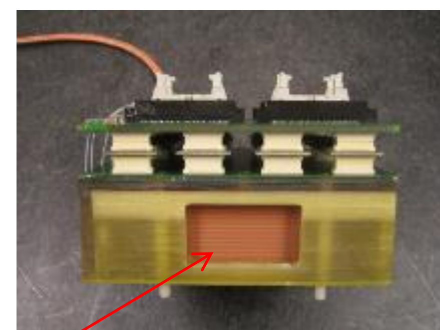
Beam Monitor : from single particle to high intensity beam

A Triple GEM beam monitor

It's essentially a small TPC with a 4 cm drift and readout with triple GEM
With this detector also high current beam can be monitored in position



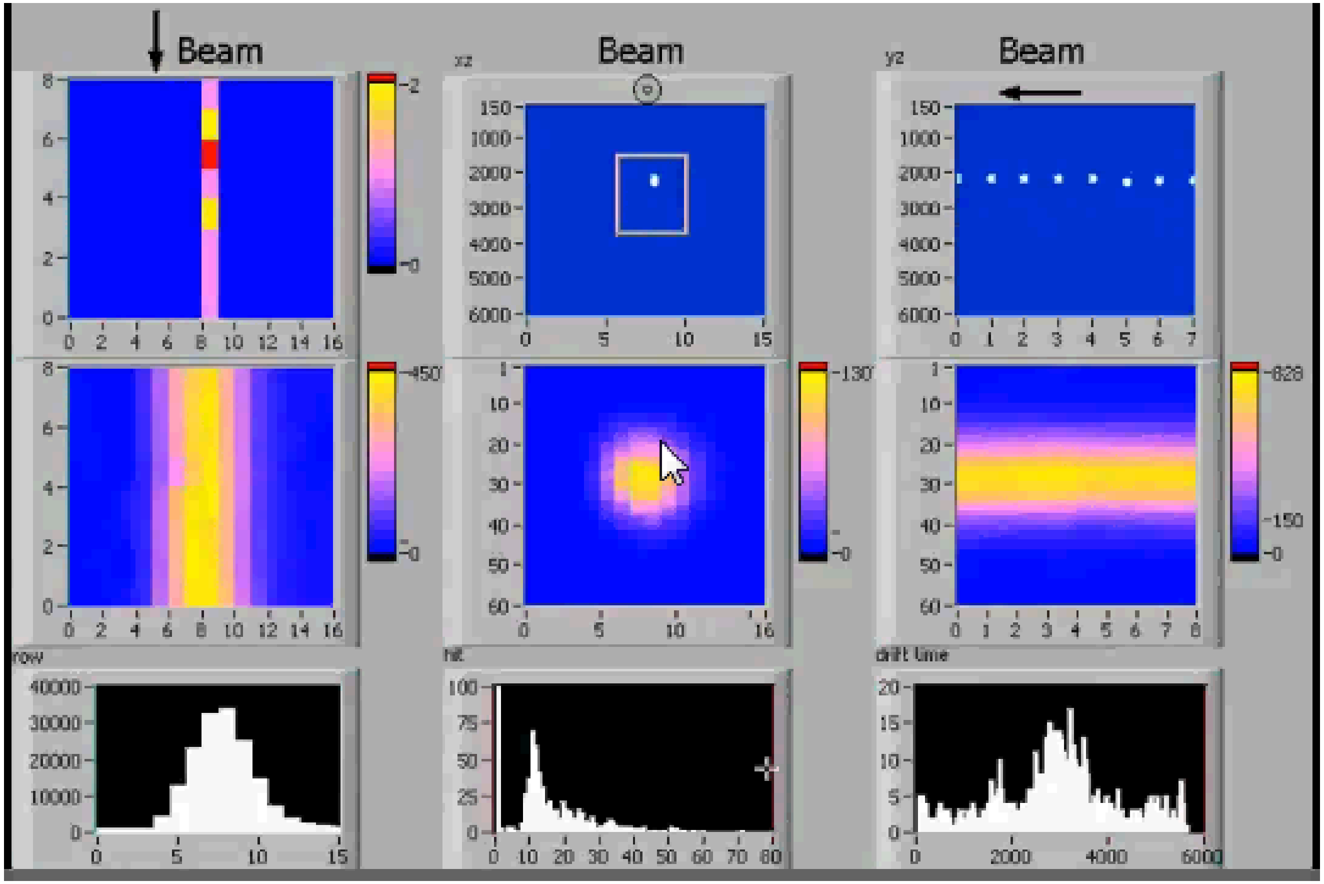
The material budget crossed by a particle is only two kapton foils (<0.2%X_0) used for the field cage necessary for the drift field uniformity

The kapton field cage with 14 strips

Real time track reconstruction

... thanks to this good efficiency ....



Single event

History

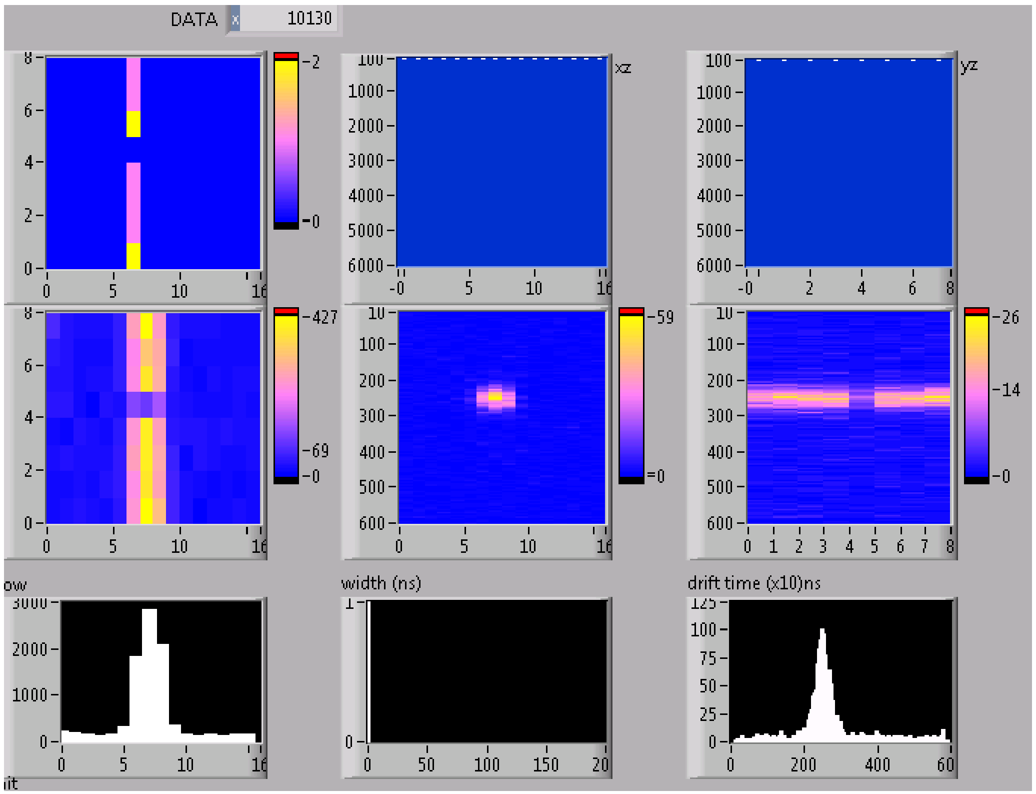
Profiles

This is a screen shot of the TPC GEM Online Console

This chamber has been used at Lead Ions test at CERN UA9

Frascati Beam Test Facility

In July this beam monitor has been installed and used for beam optimization



5 cm
Horizontal profile

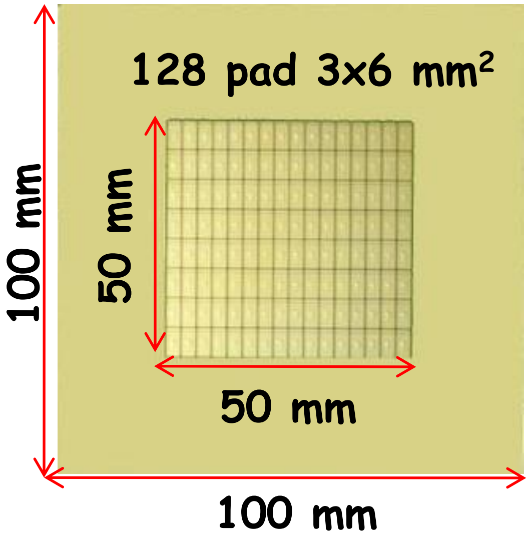
Front view

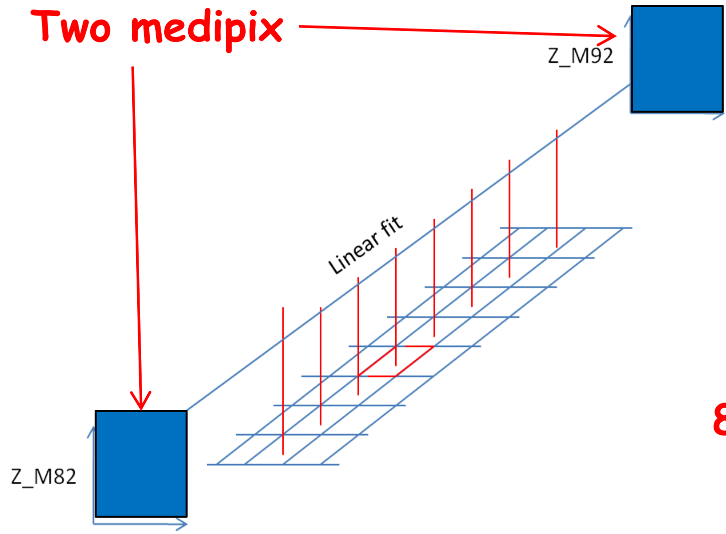
4 cm
Vertical profile

50 Hz of electron or postron beam 500 MeV

A pulsed beam can be reconstructed in 3D

3D track reconstruction

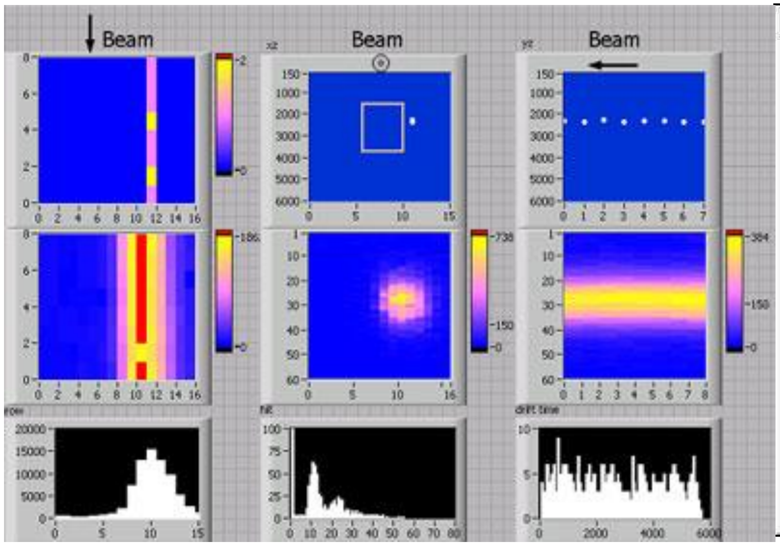




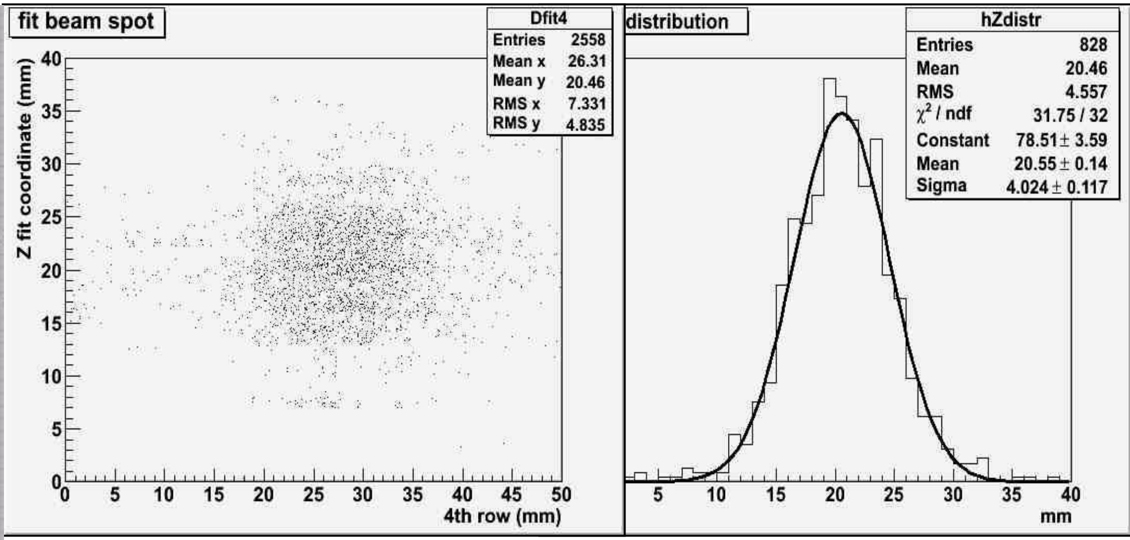
Z coordinate is measured from the drift time of the electrons produced by the particle track.

80 microns resolution

Beam Z profile

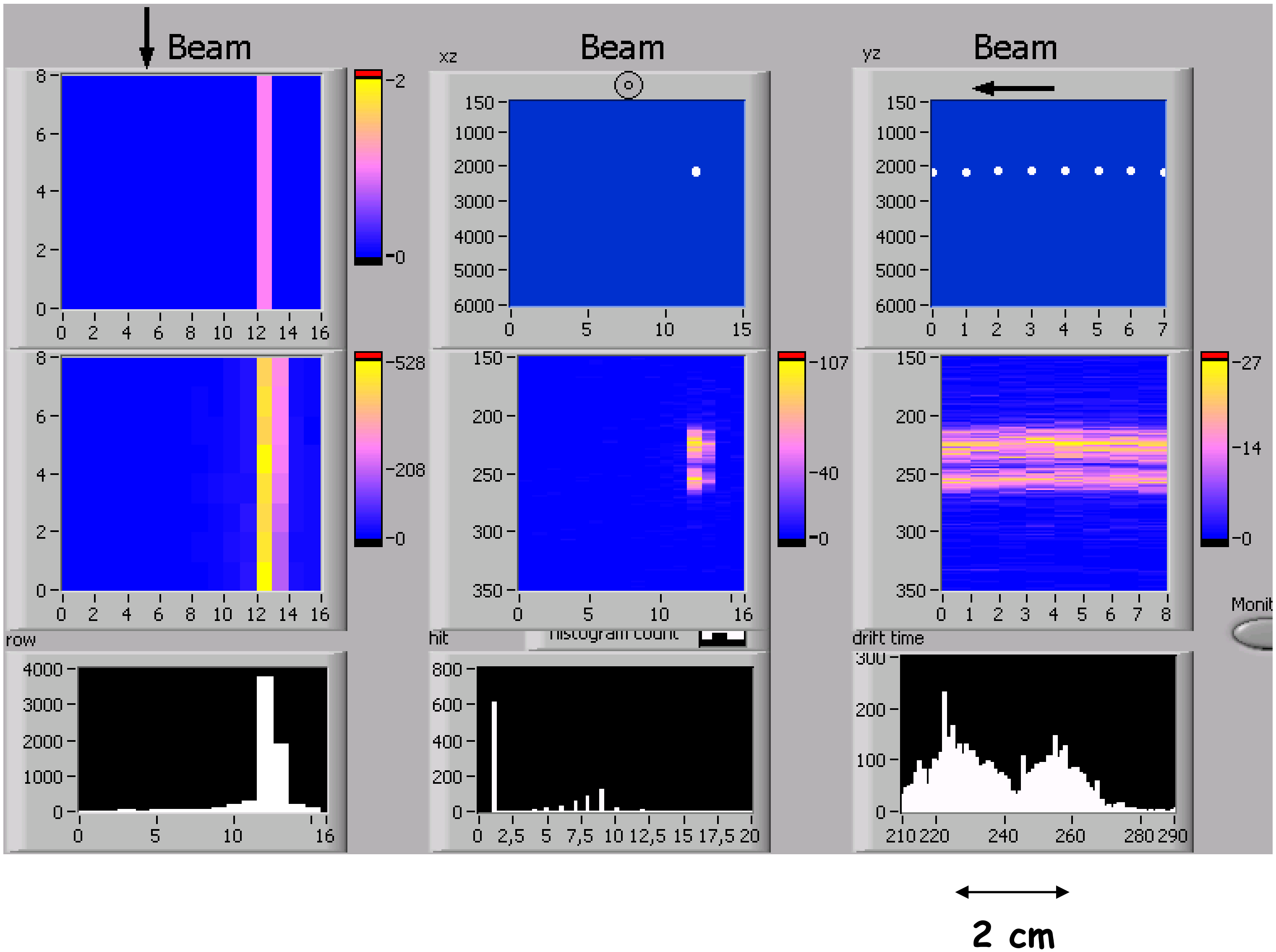


ONLINE CONSOLE



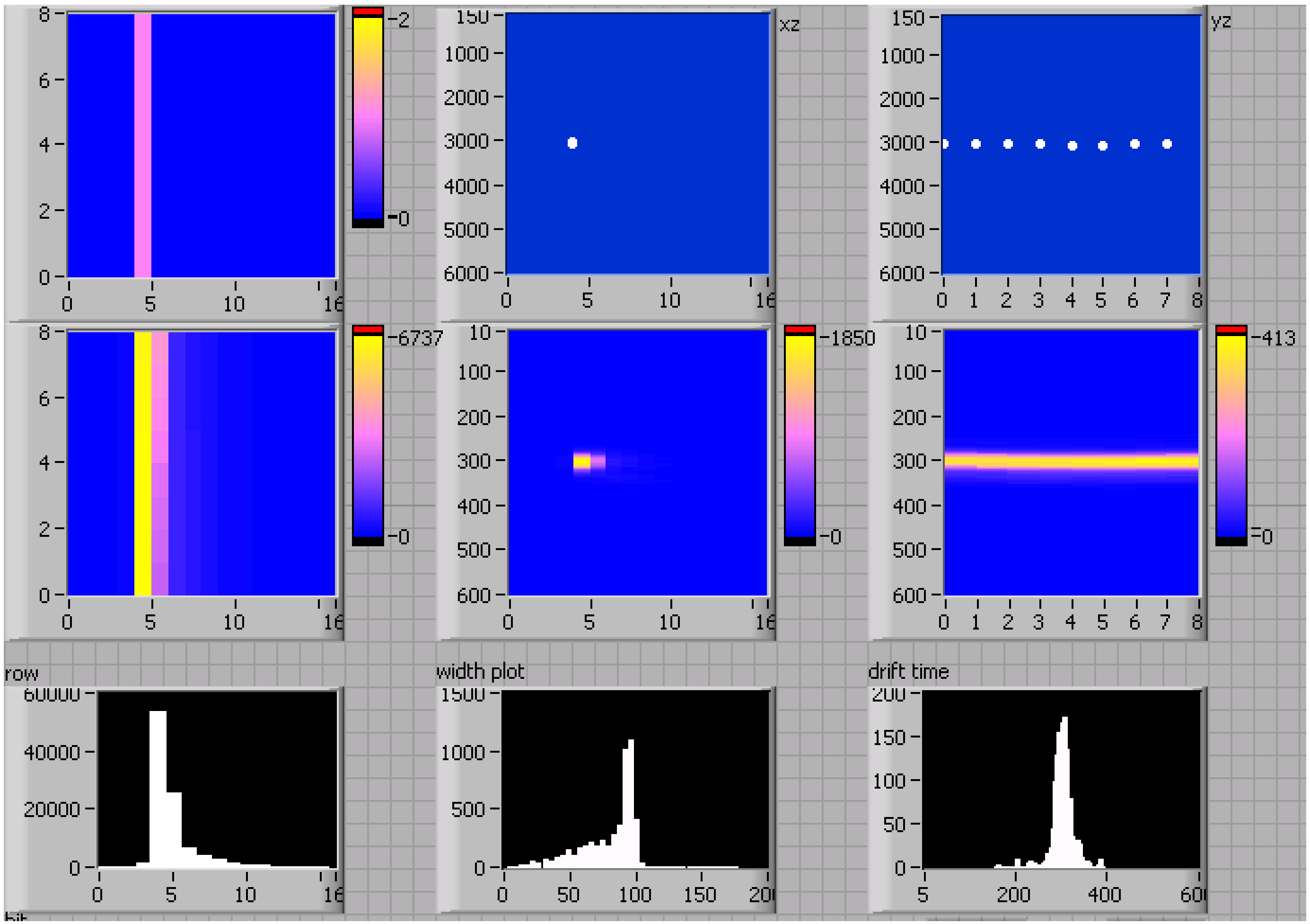
The hits are linearly fitted, and the beam spot at the center of the chamber is recostructed

How to see channeled beam



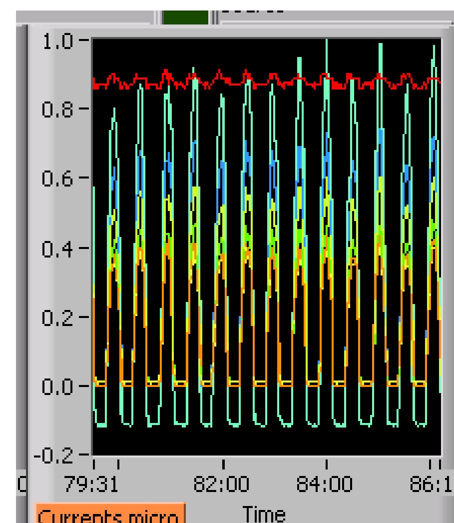
Lead Ions at CERN H8

The test was performed in November 2011



Time zero for 3D reconstruction taken with a Scintillator

The ion beam is spilled in 12-17 sec (currents from HV)



Beam profile TPC GEM

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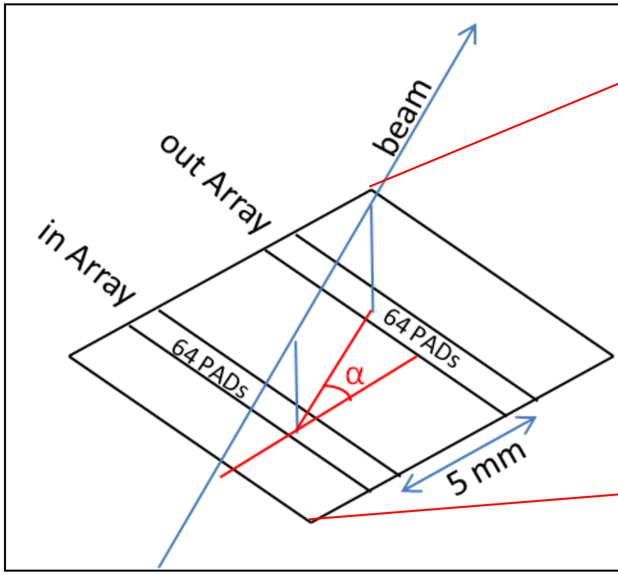
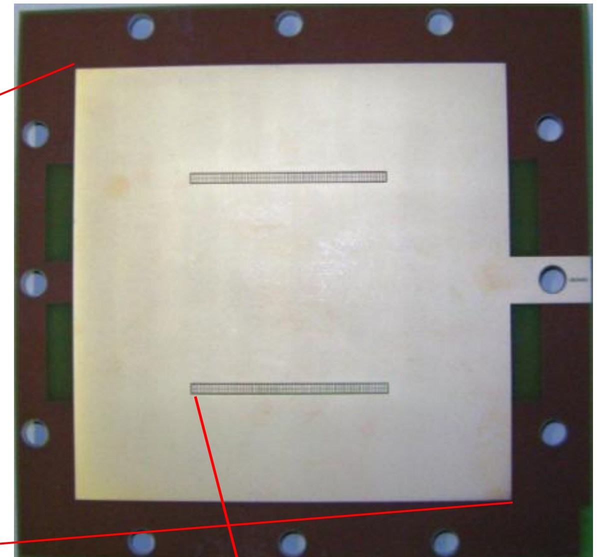
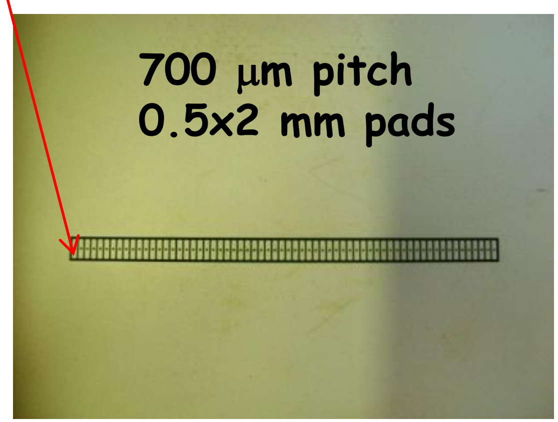
We realized a new TPC GEM having two separated 64 PADs lines. The distance between the lines is 5 mm long.







This configuration will permit us to measure the angle α of a thin beam which crosses the chamber with a resolution of about 15 mrad .

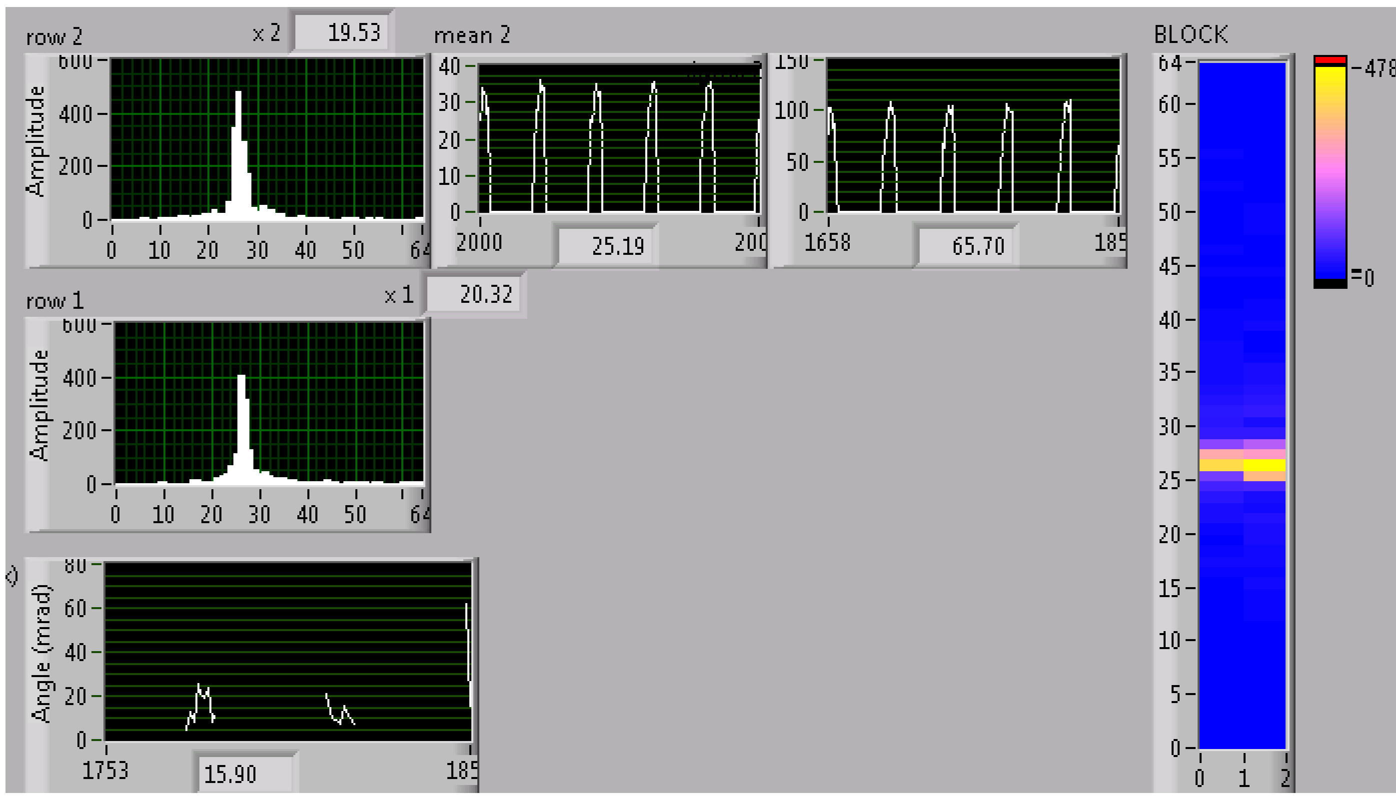
Beam Profile at H8 October 2012

With continuous beam without possibility to trigger the particles, only a profilometer can be used.

Horizontal profile 1

Horizontal profile 2

Incident angle (mrad)

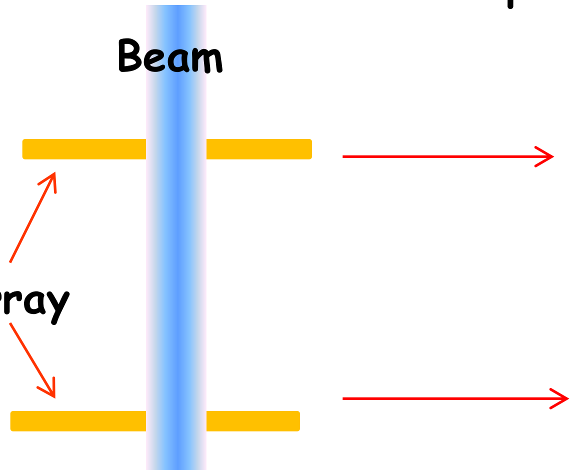


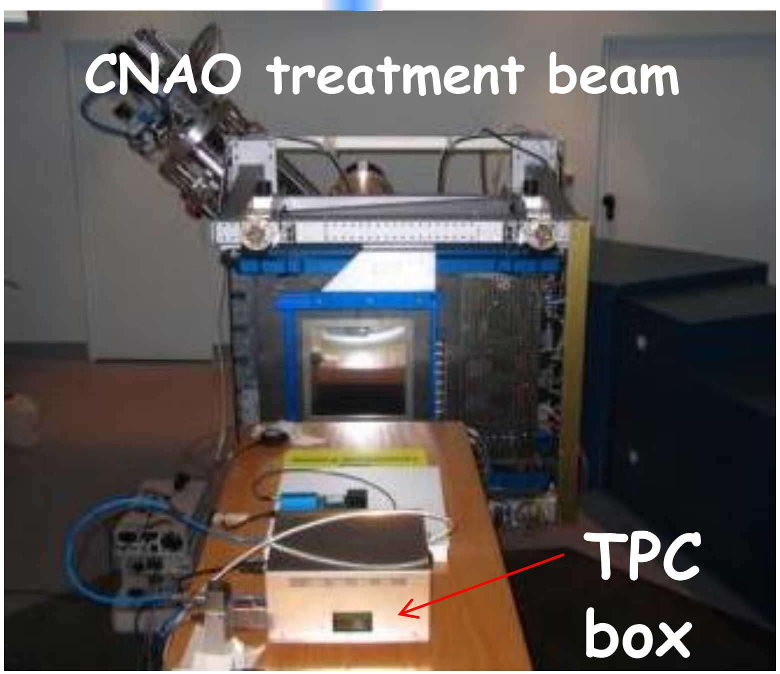
Test at CNAO: 10^8 protoni/sec

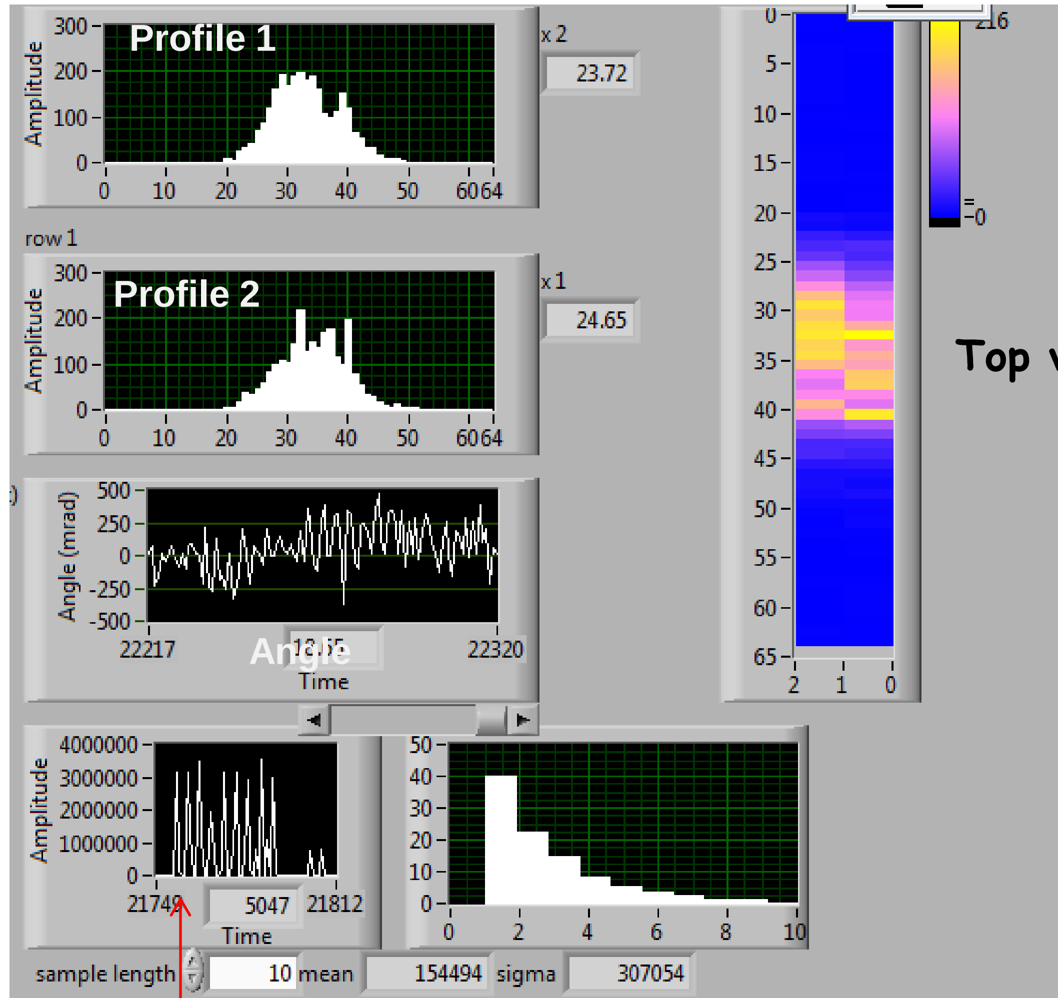
Centro Nazionale di Adroterapia Oncologica (Pavia)

Beam

Pads Array







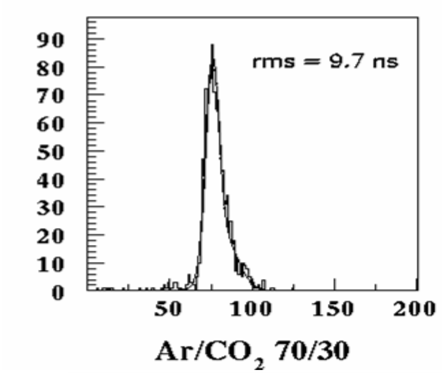
Top view

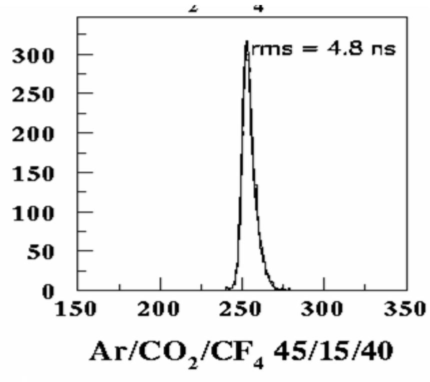
Bunches vs time

Summary

- ✓ The triple GEM tecnology is very relayable and usefull for different applications in different science and technology fields
- ✓ With different pad configurations and drift, different spatial resolutions can be obtained, up to 80 micron.
- ✓ In Frascati has been developed a compact and complete system
- ✓ The FPGA based Mather Board semplifies the Data Acquisition and the HVGEM allow a very fine tuning of the detector; their power supply can be provided by a simple portable swicth power pack
- ✓ Two GEM Beam Monitors have been made, one for 3D reconstruction and the other for profile measuremts
- ✓ The two chambers have ben used in different beams, protons, lead ions, electrons and positrons.
- ✓ Developments are in progress for high intensity beam using Nitrogen

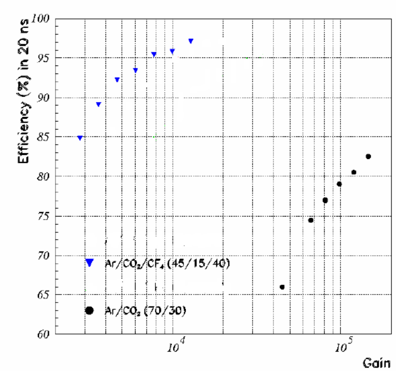
GEM Performances (2002-2006)





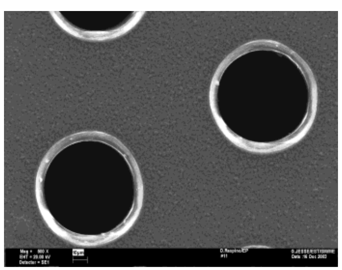
The results of several tests* on 10x10 cm^2 prototype allowed us to select the $Ar/CO_2/CF_4$ with geometry 3/1/2/1 mm

→ 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

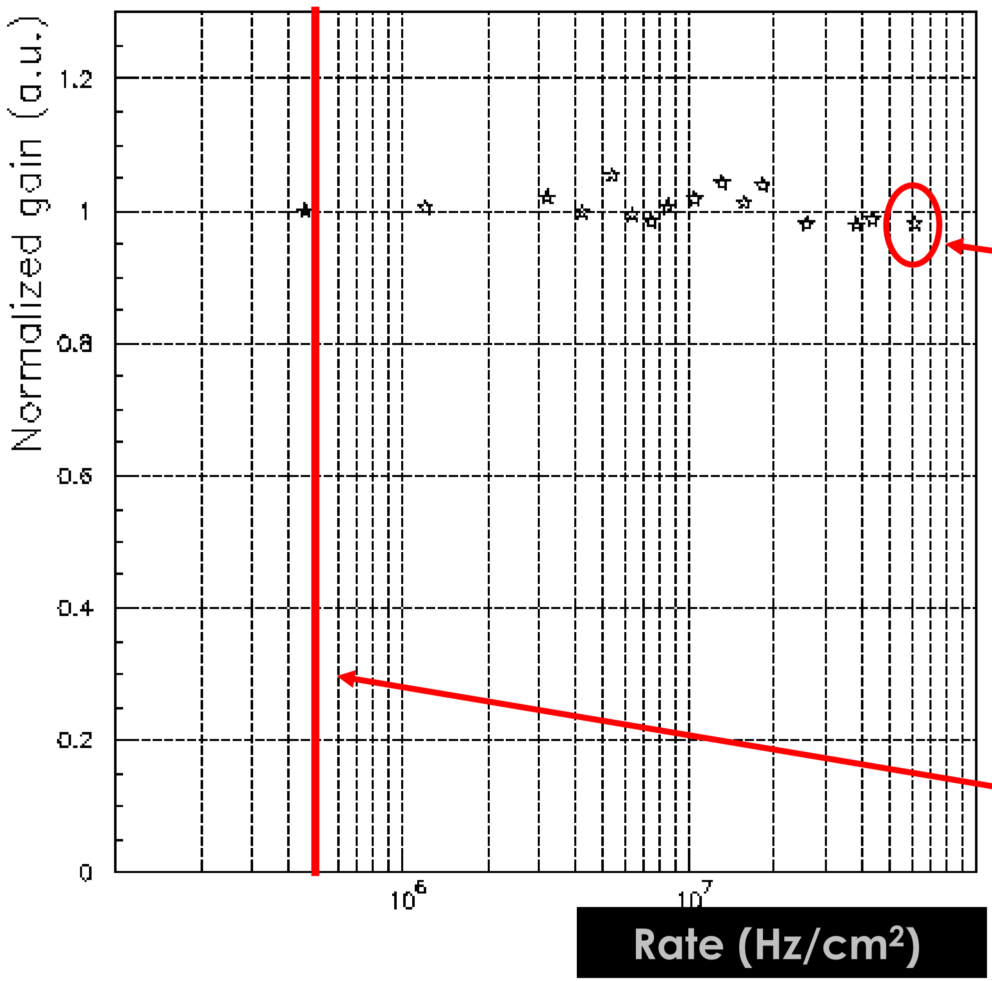
Detector performance recovered with a 15 V shift on HV

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 ~ $2x10^4$



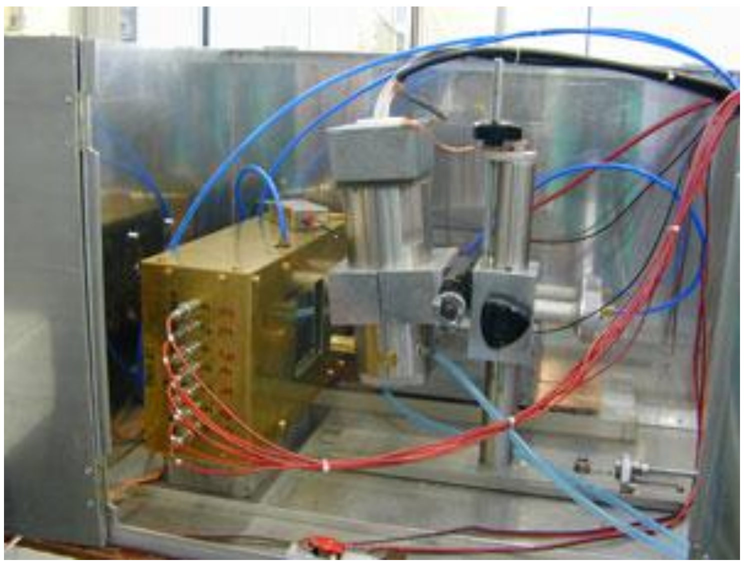
A very good gain stability was found up to a photon counting rate of 50 MHz/cm^2

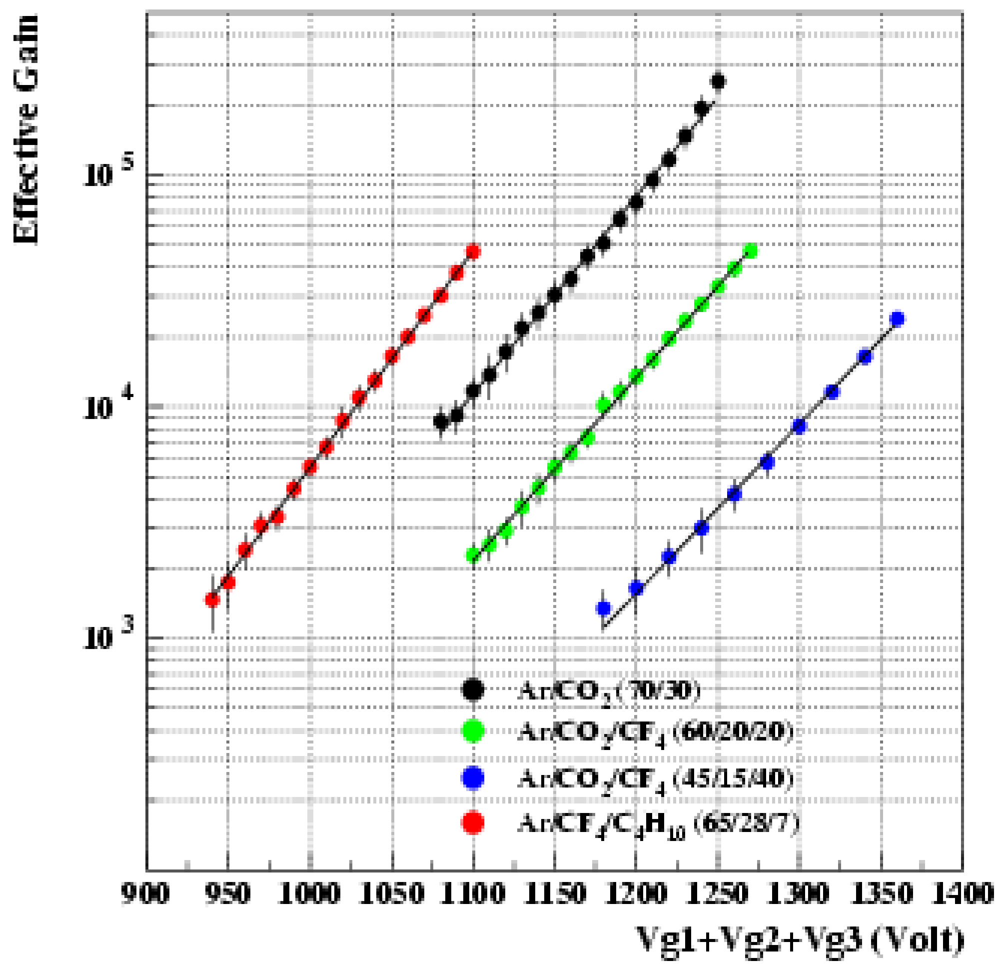
LHCb M1R1 maximum rate (460 kHz /cm^2)

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

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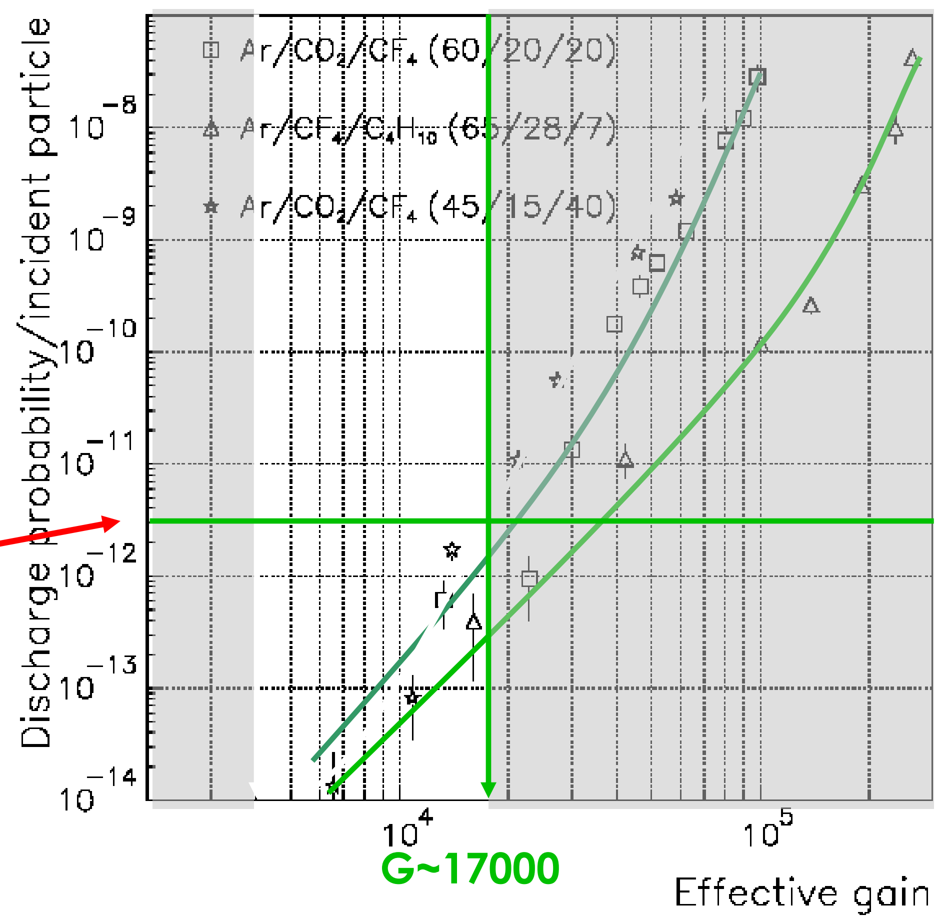
At PSI we exposed three detectors to a particle flux up to 300 MHz.

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.

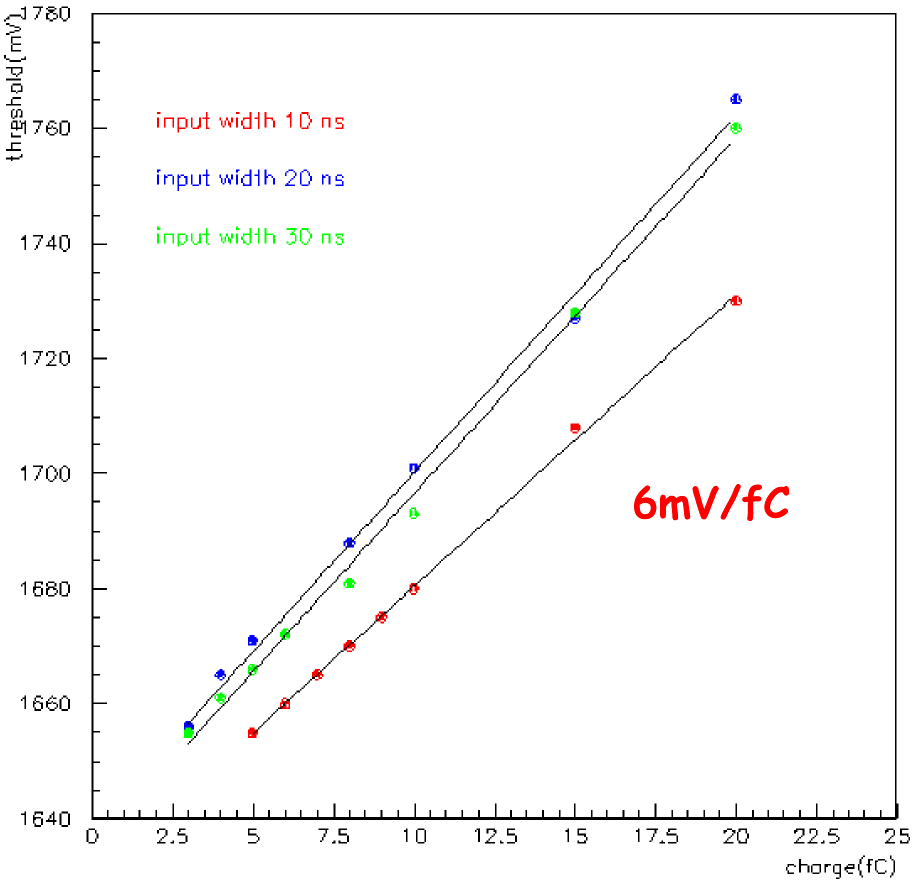
Working region



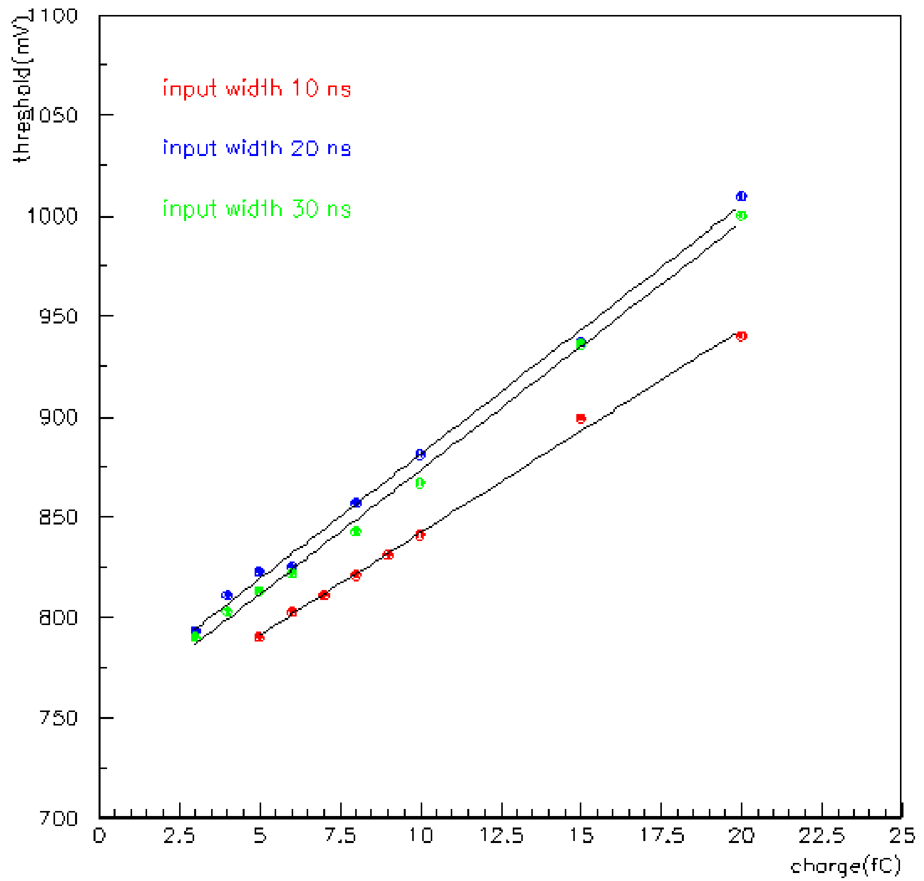
Carioca Card Sensitivity

The sensitivity is measured vs two different thresholds

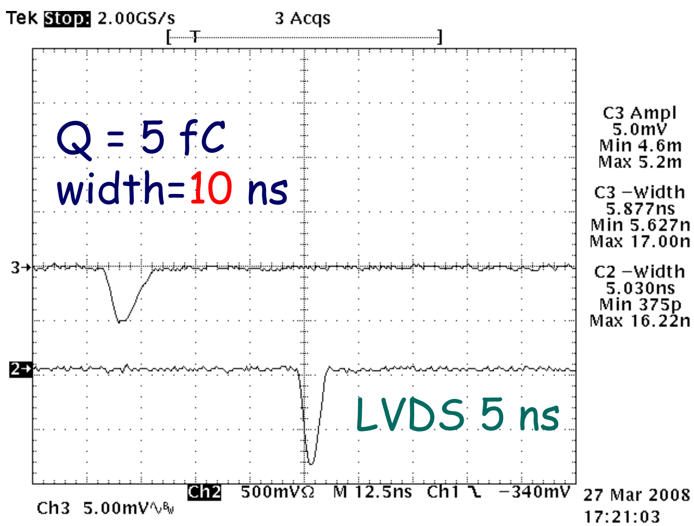
DAC Threshold on power supply

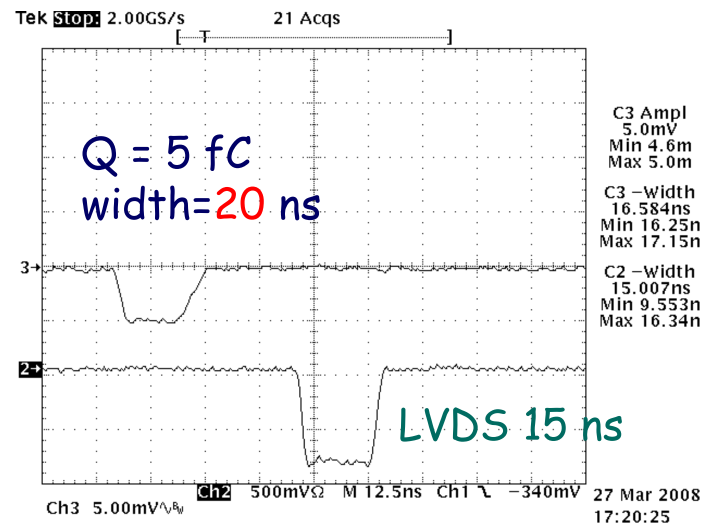


Threshold on Carioca



Carioca Card Sensitivity





The sensitivity has been measured injecting a charge between 5 and 20 fC with different width