Triple-GEM detectors for electron, proton and neutron beam diagnostics

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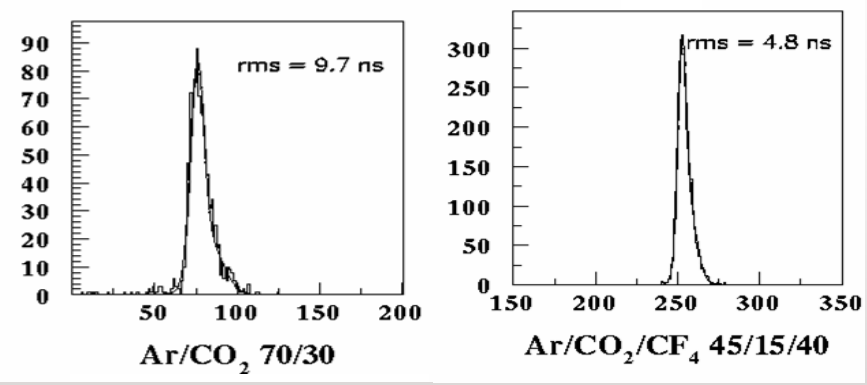
ENEA, Frascati

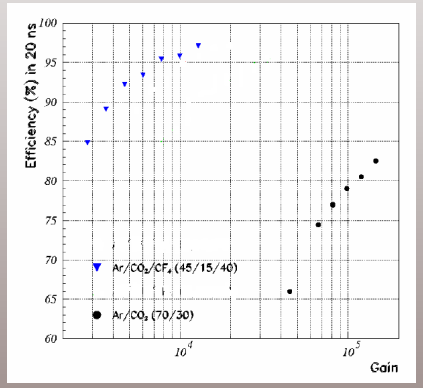
Thanks to D. Dominici (*INFN LNF*)

“Standard” triple GEM



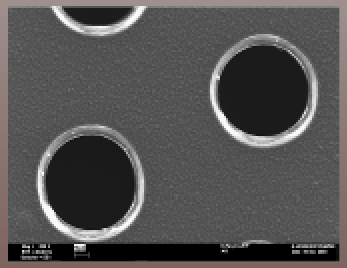
The results of several tests on 10x10 cm^2 prototype allowed us to select the Ar/CO_2/CF_4 with geometry 3/1/2/1 mm

→ **better time resolution** 4.8 ns with respect to Ar/CO_2



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

Max space resolution O(100 μm)

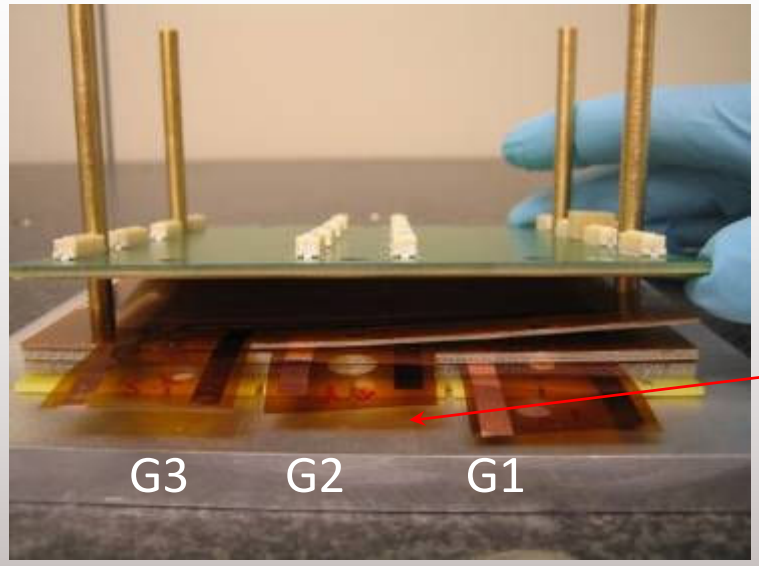


Ageing studies on whole detector area 20x24 cm^2:
25 kCi ^{60}Co source at 10 MHz/cm^2 on 500 cm^2
Integrated charge 2.2 C/cm^2

Detector performance recovered with a 15 V shift on HV

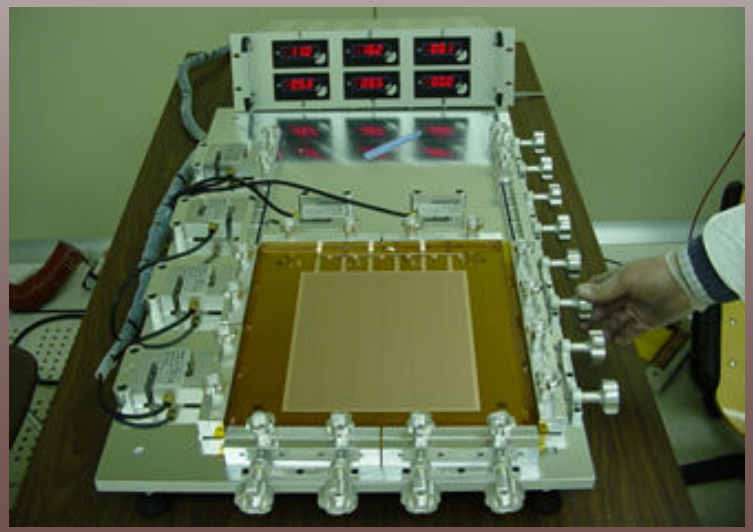
G.Bencivenni et al., NIM A 518 (2004) 106
P. de Simone et al., IEEE Trans. Nucl. Sci. 52 (2005) 2872

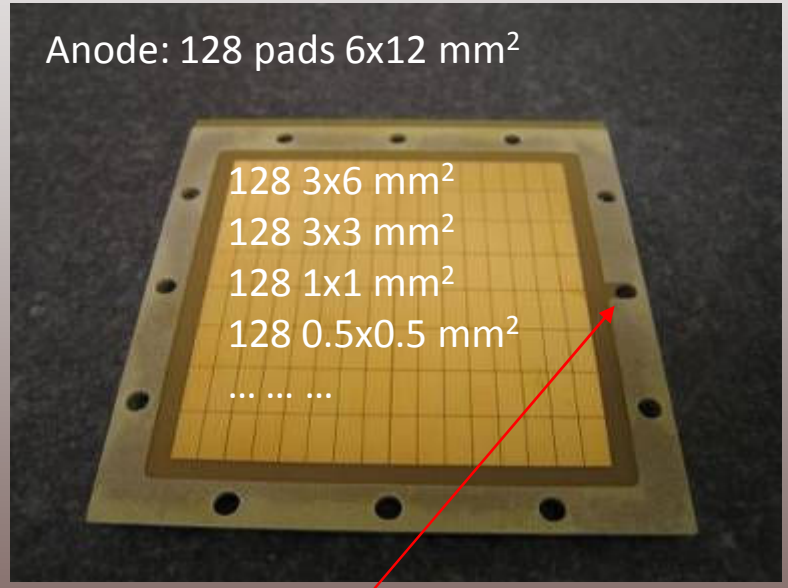
A Standard Triple GEM construction



The detectors described in this talk are built starting form the standard **10x10cm²** produced by **CERN**: 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

Where we are working now

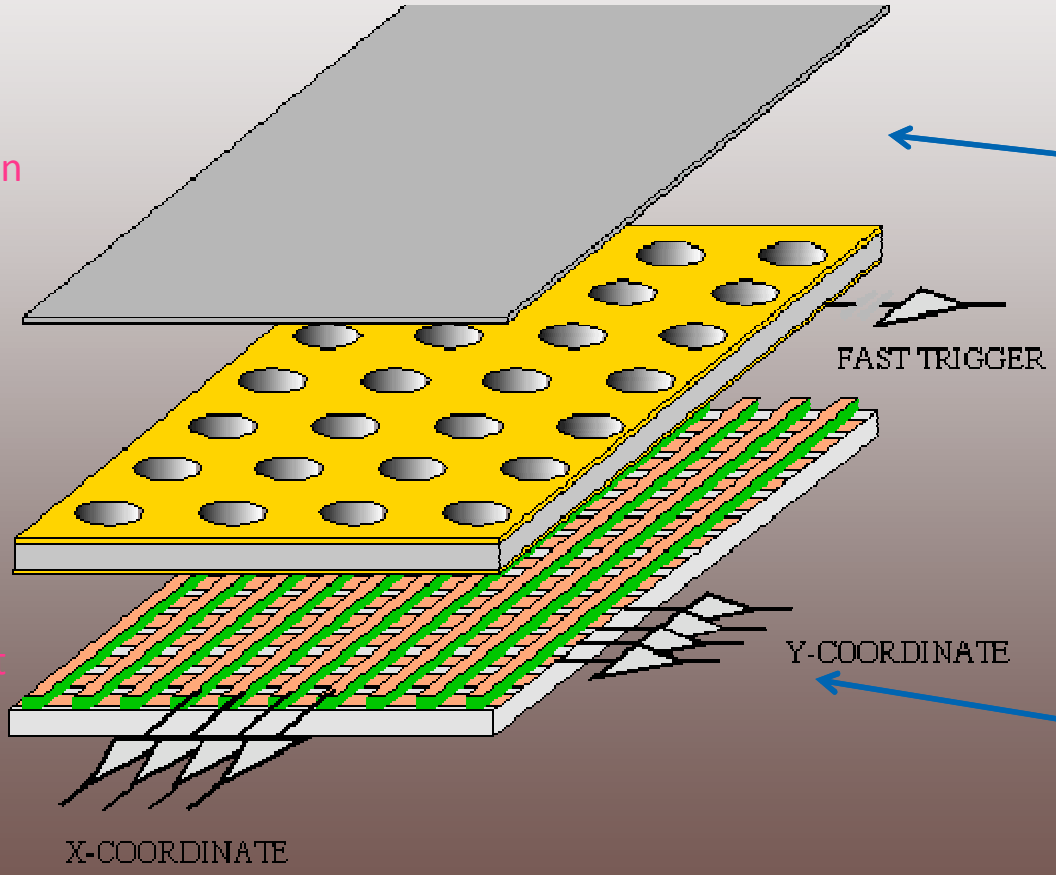
Key-advantages of GEM detectors:

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

Particle conversion

Gain

Readout



Neutron, X-ray

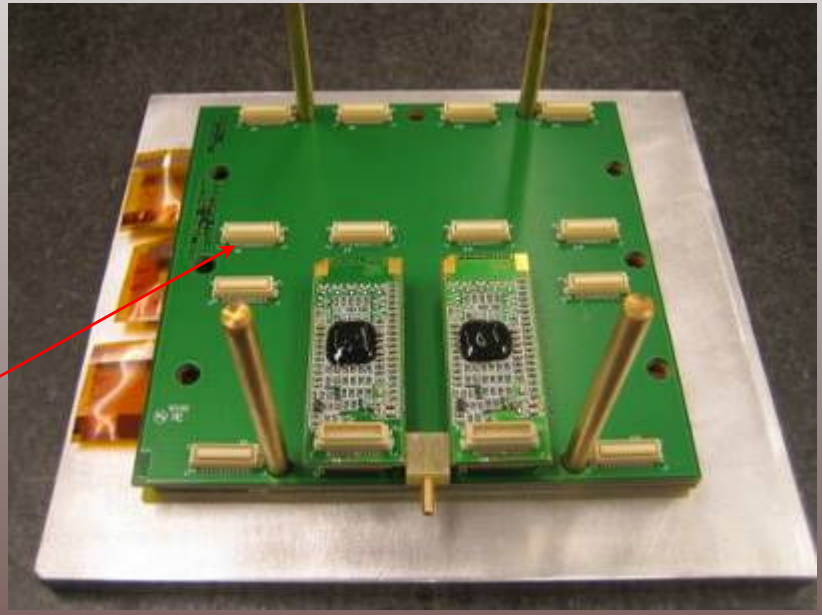
Pixel readout,
Rad-hard electronics

Electronics developments for GEM detectors

The FEE board

The card is based on *Carioca Chip and has been designed and realized in Frascati (G. Corradi). Total dimension : 3x6 cm^2

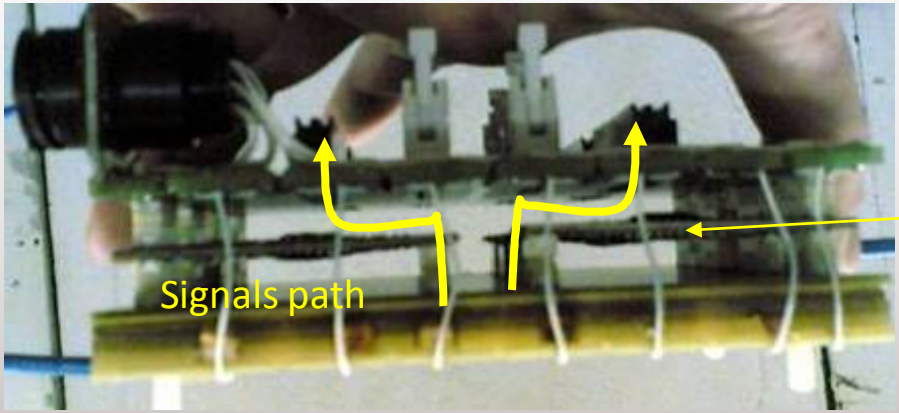
16 channels for each card: channel density of 1 channel/cm^2
Sensitivity of 2-3 fC; LVDS output (25 ns); **Rad-hard**;
Extremely modular and usable for GEM applications



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

* Development of the CARIOCA front-end chip for the LHCb muon detector. W. Bonivento, et al NIM A491:233-243,2002

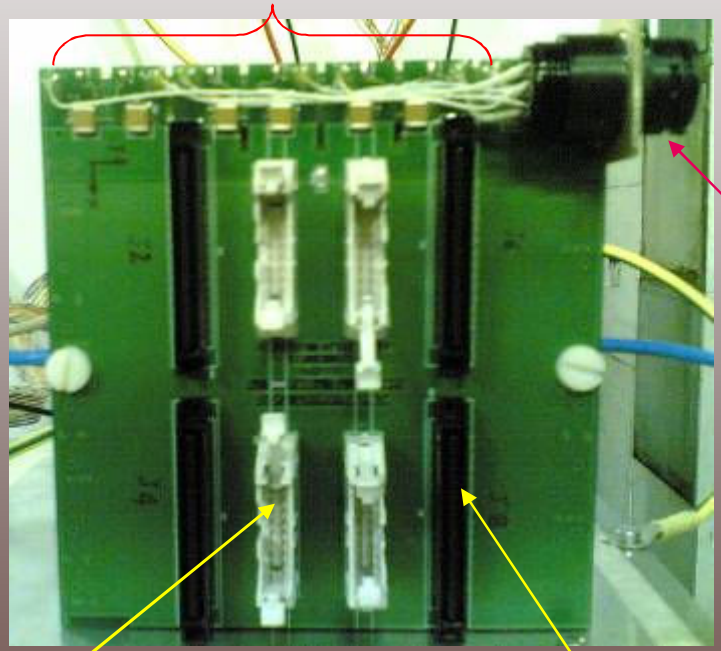
The mother board



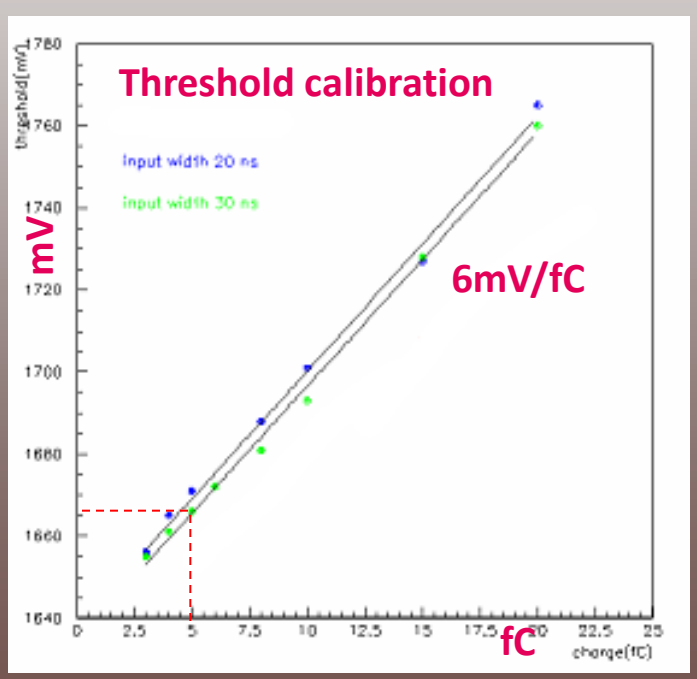
On this mother board
HV and LV ground are **connected**
through a 10 KΩ resistor

CARIOCA readout electronics

HV filters



HV in



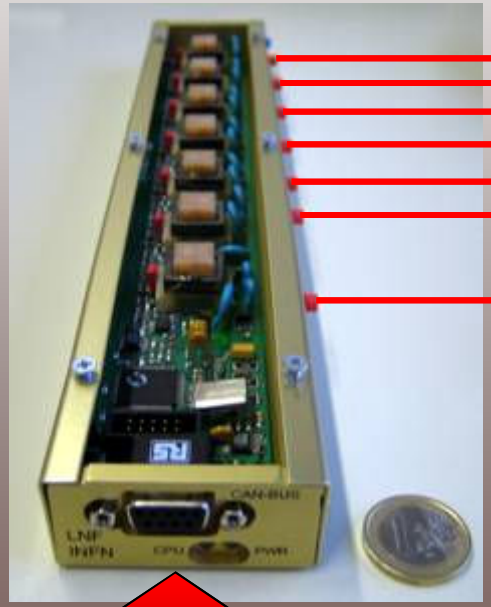
Threshold & LV inputs

4×32 LVDS outputs

HV supply for GEM detectors

HVGEM is a new device designed and realized at Frascati specifically for the HV power supply of 3GEM detectors.

G. Corradi, F. Murtas and D.Tagnani
A novel High Voltage System for a triple GEM detector
Nucl. Instrum. Meth. **A572** (2007) 96



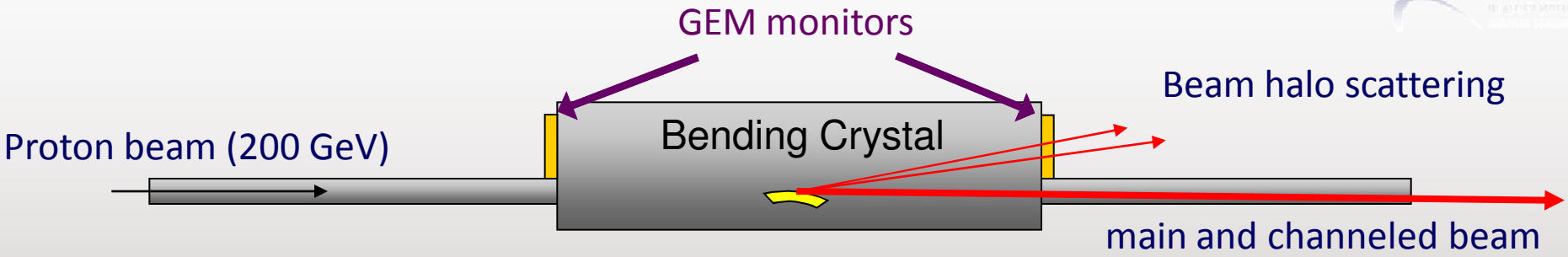
All the detectors for beam diagnostic described here have been powered with this new device

Controlled via Canbus

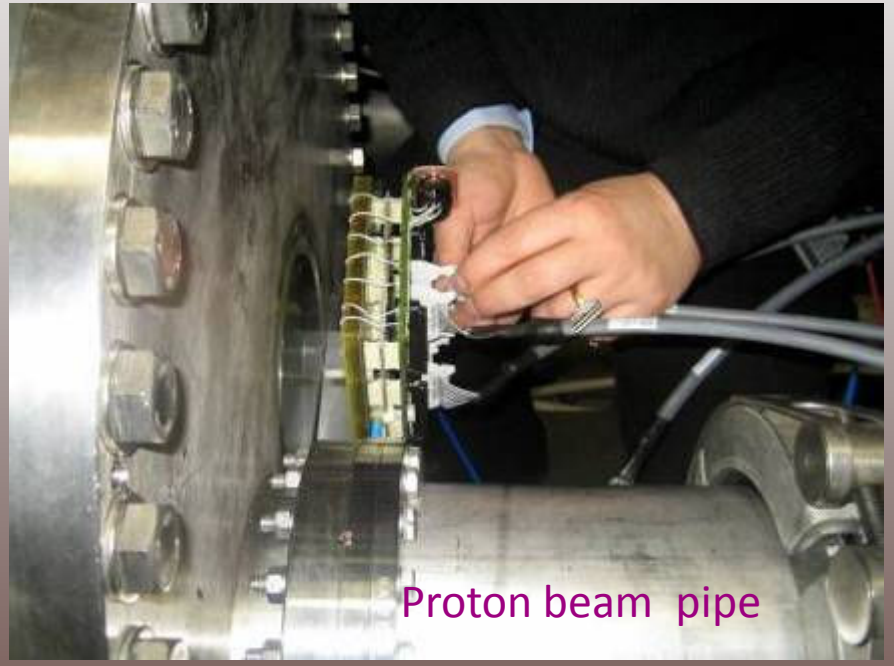
A new version with 7 nano-ammeters
one for each generator element
is now in construction

Beam monitors for UA9 experiment at SPS (CERN)

GEM monitor on UA9 Experiment at CERN

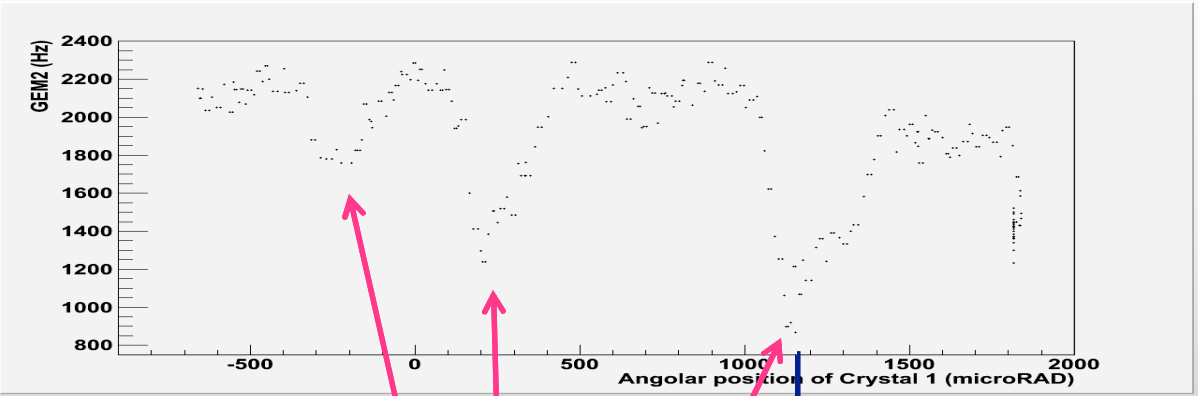


Proton beam pipe



The installation just two months after the collaboration request

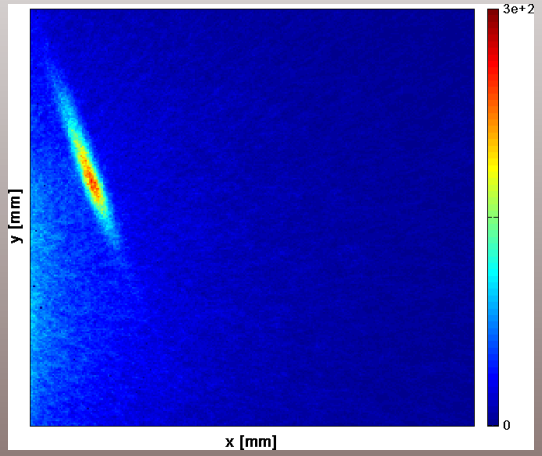
Channeling seen by GEMs at UA9



Counting rate on GEM monitor during the Crystal Angular Scan
MD on August 11th

Online display

Channeled beam seen by Medipix2 detector



Decrease **of beam halo scattering**, due to channeling

Downstream GEM (wrt crystal) **2 KHz** perfectly correlated with scintillators

Upstream GEM rate is **20Hz** (consistent with background)

Luminosity monitor at Frascati collider DAFNE

LUMI GEM Assembling

Pads : 6 x 24/32 mm^2

pads

induction gap

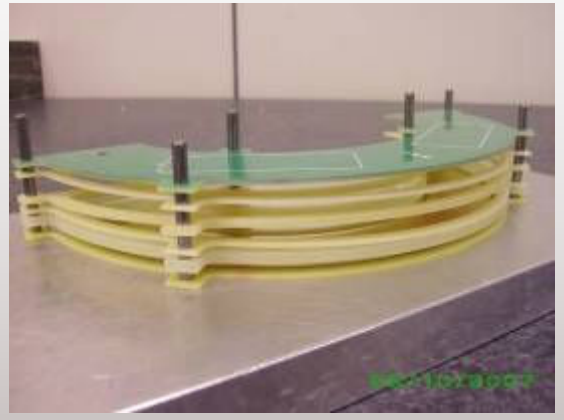
GEM 3

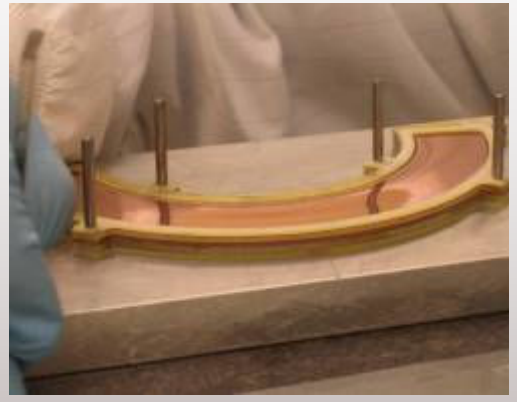
GEM 2

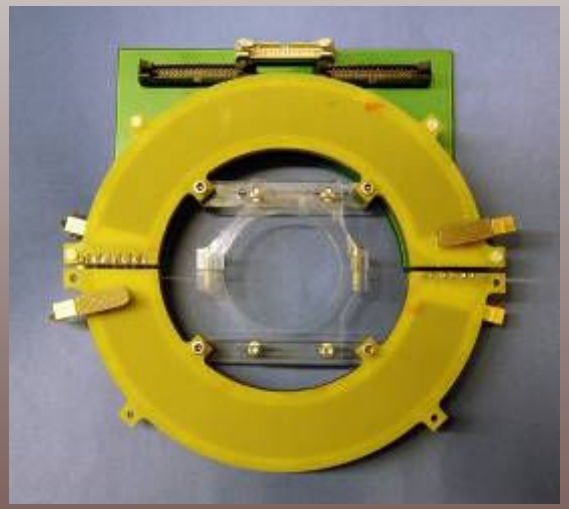
GEM 1

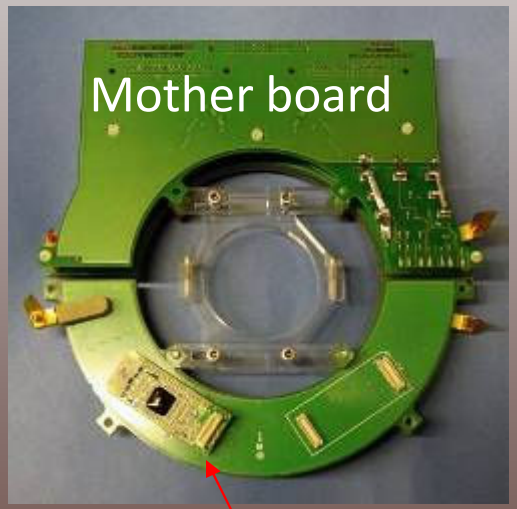
Cathode

Seven detectors have been built







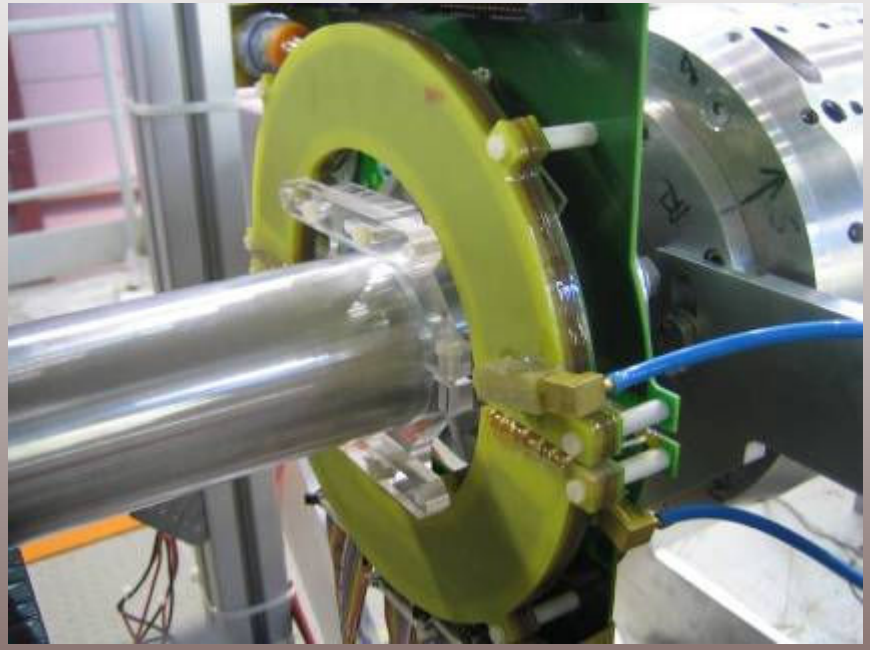


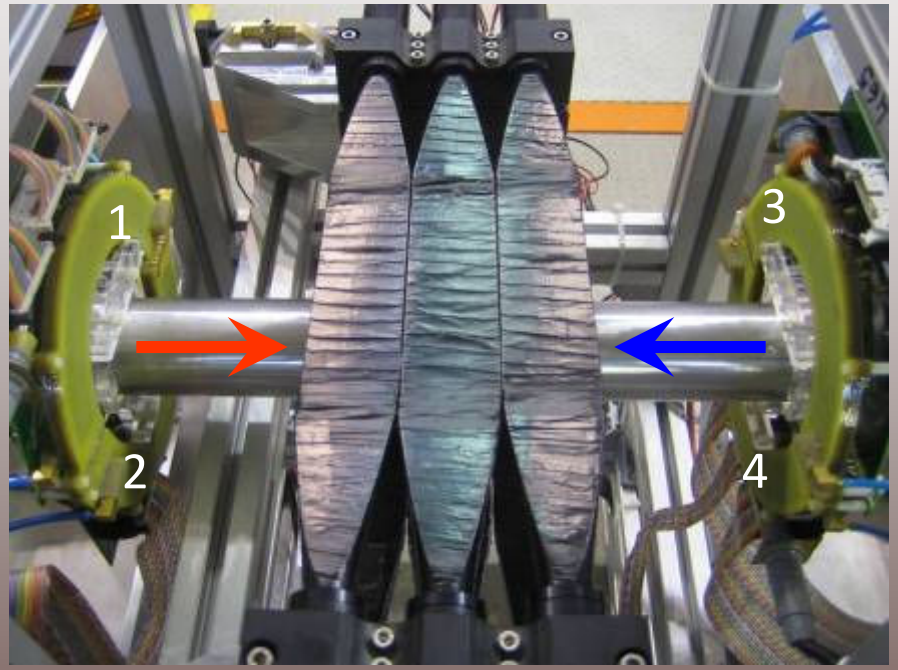
Final luminometers with Carioca FEE

GEM luminometer mounted on Dafne

Electron monitor

Positron Monitor

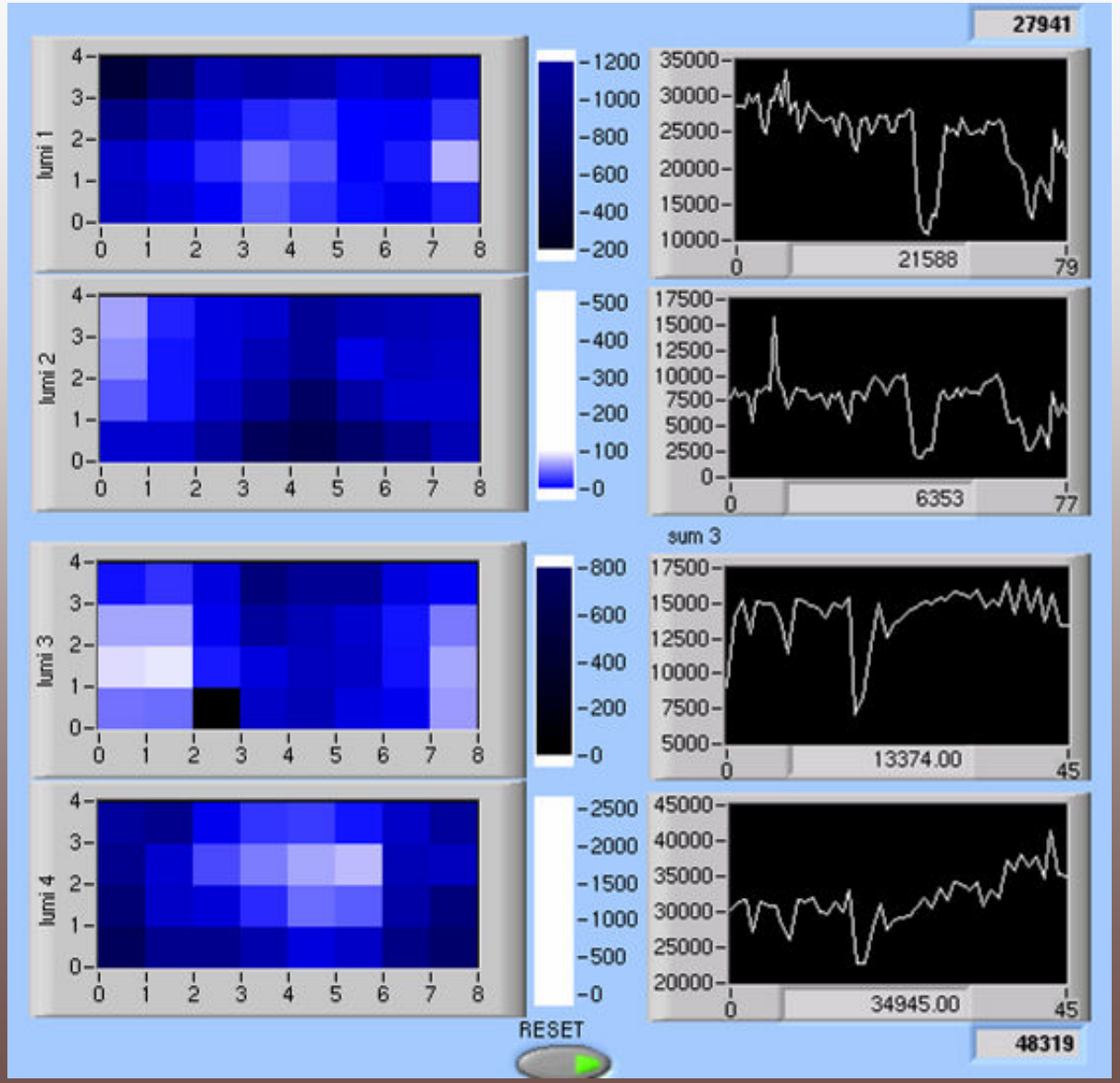




Possible developments for a Luminometer at Super B

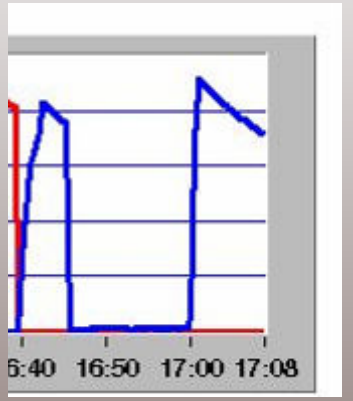
Background monitor

Readout every second with VME scalers



28 KHz

Only
Electron Beam



48 KHz

1

Electron
monitor

2

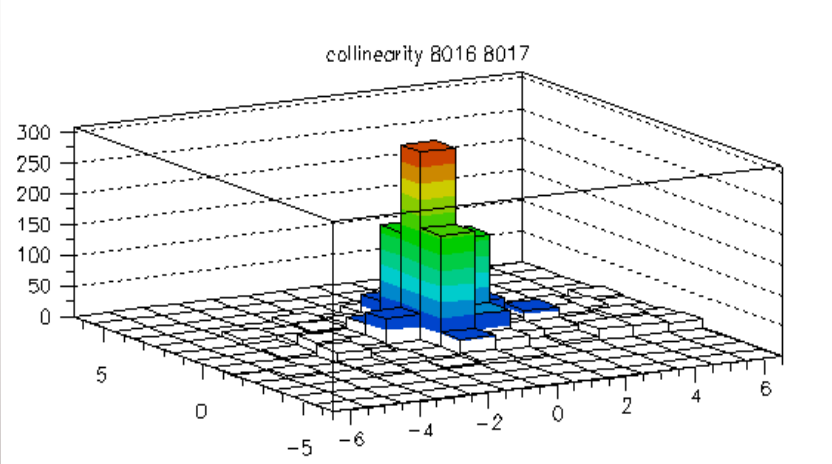
3

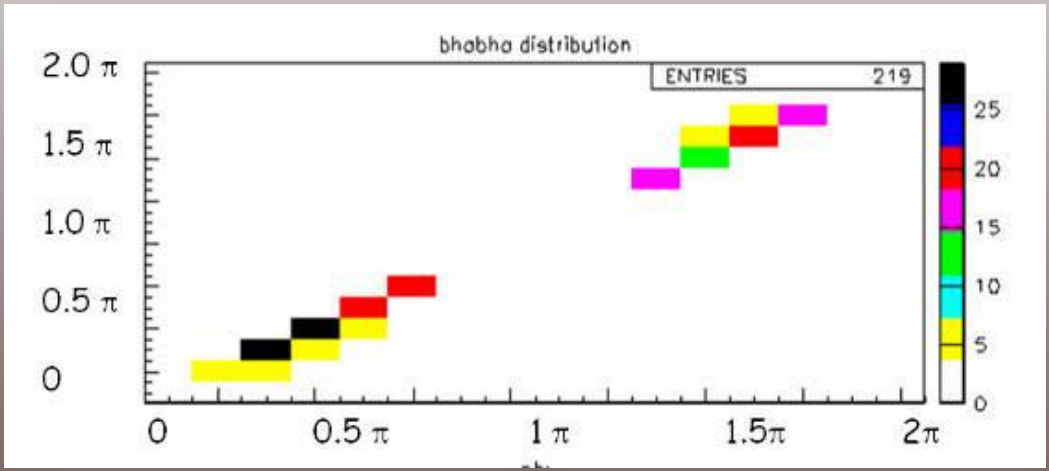
Positron
Monitor

4

Bhabha Correlation

The system is able to measure the particle impact point with a precision of 8 mm in theta



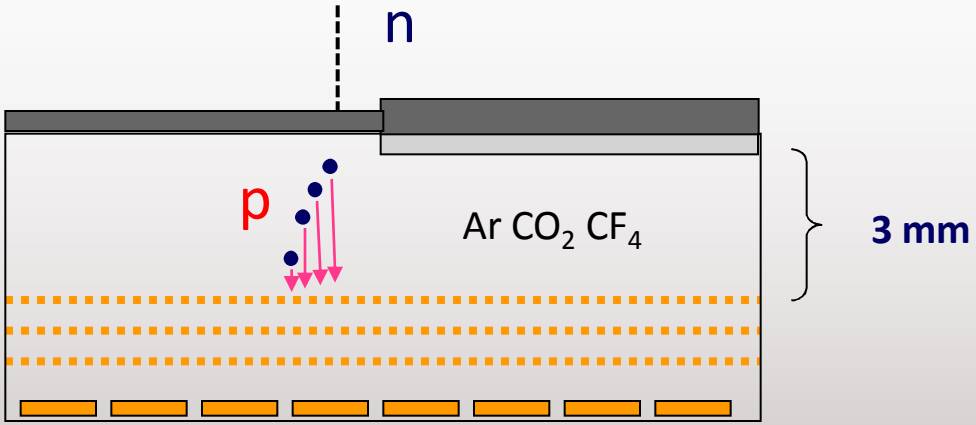


The correlation in ϕ of Bhabha events is clear.

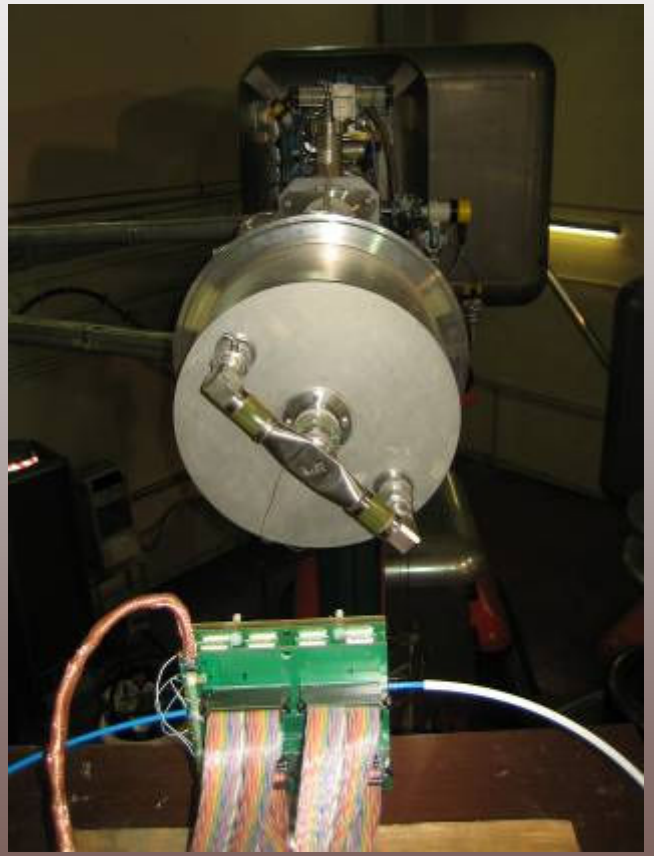
More precise analysis is in progress

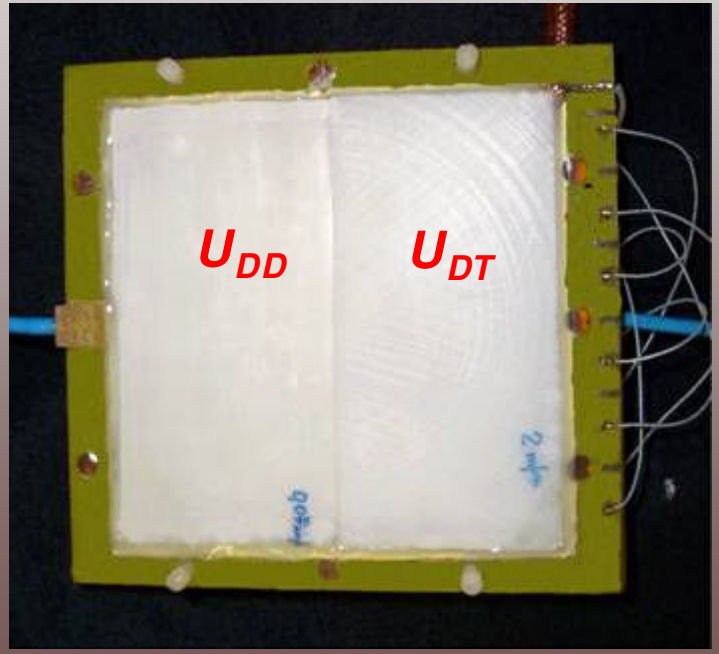
Neutron Flux Monitor for fusion reactors

Neutron flux from fusion plasma



Frascati Neutron Generator
at Enea Frascati :
2.5 (DD) and 14 (DT) MeV





Detector divided
in two zone :

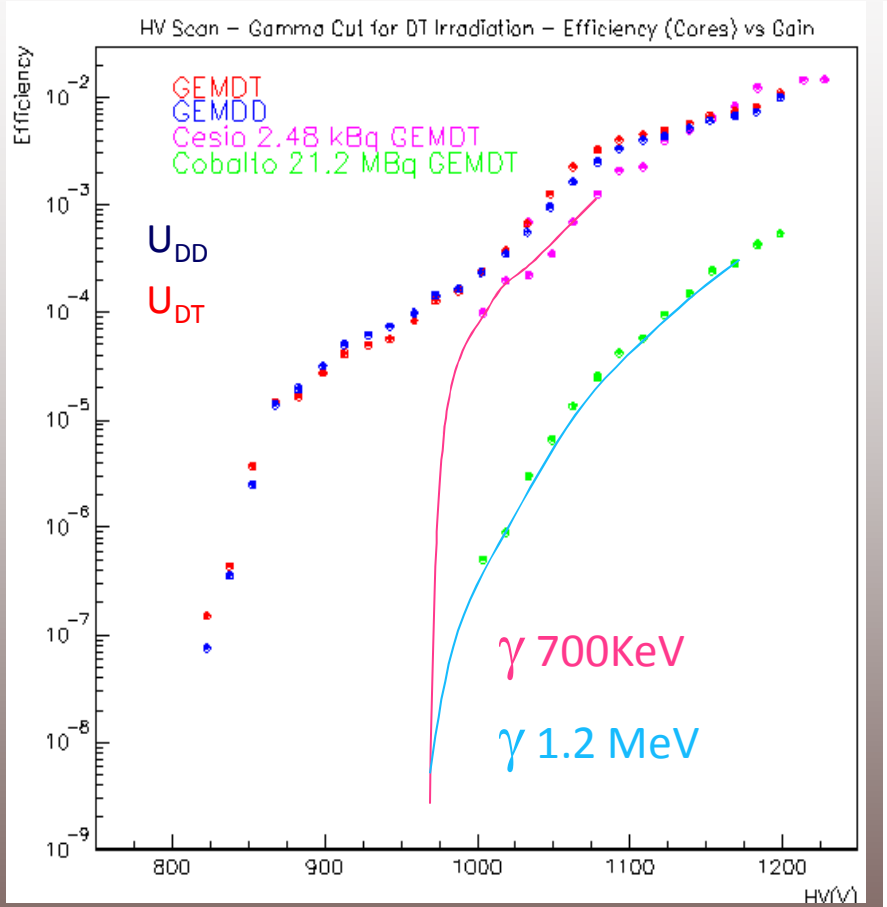
U_{DD} 700 μm Polyeth.
5 μm Al.

U_{DT} 2 mm Polyeth.
0.2 mm Al.

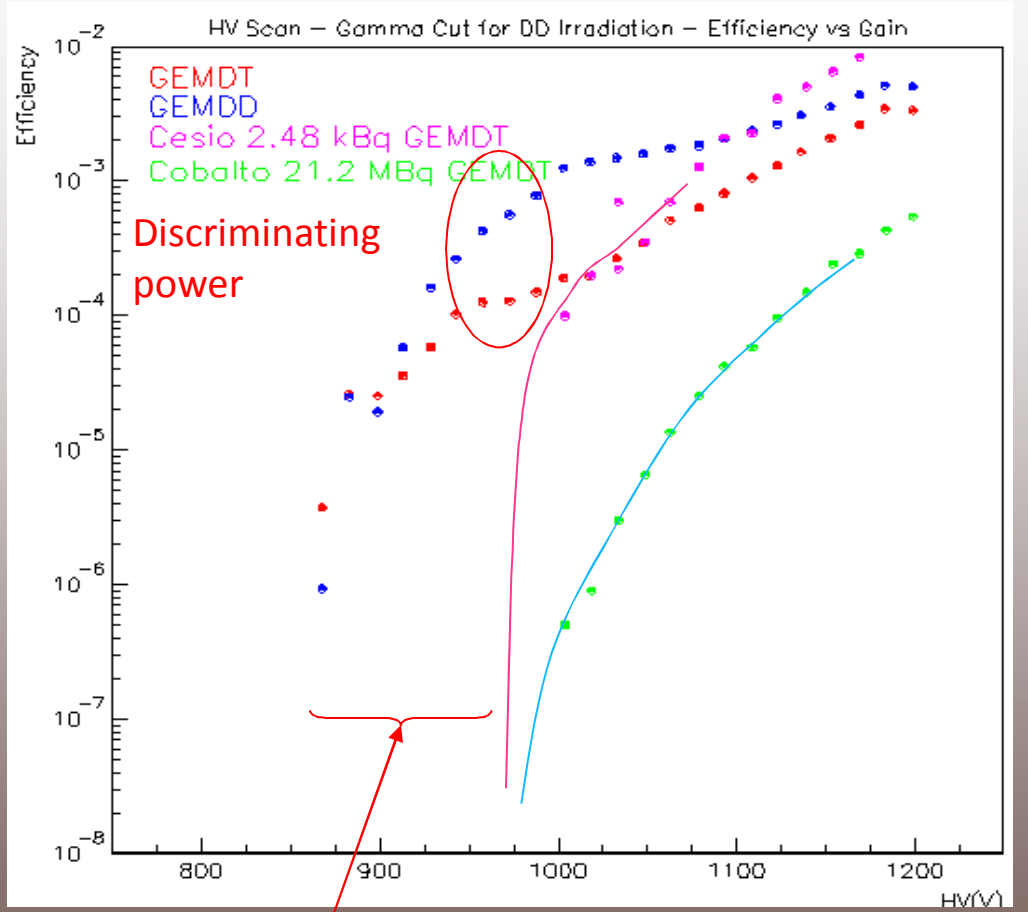
Key point: increase n/γ ratio

Efficiency vs GEM gain

14 MeV Neutron

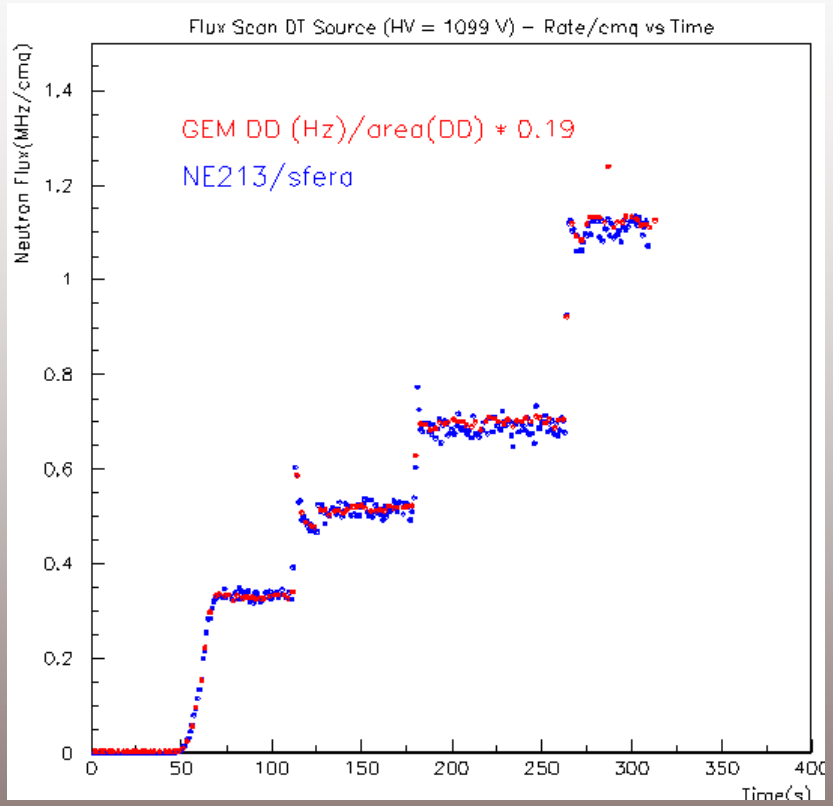


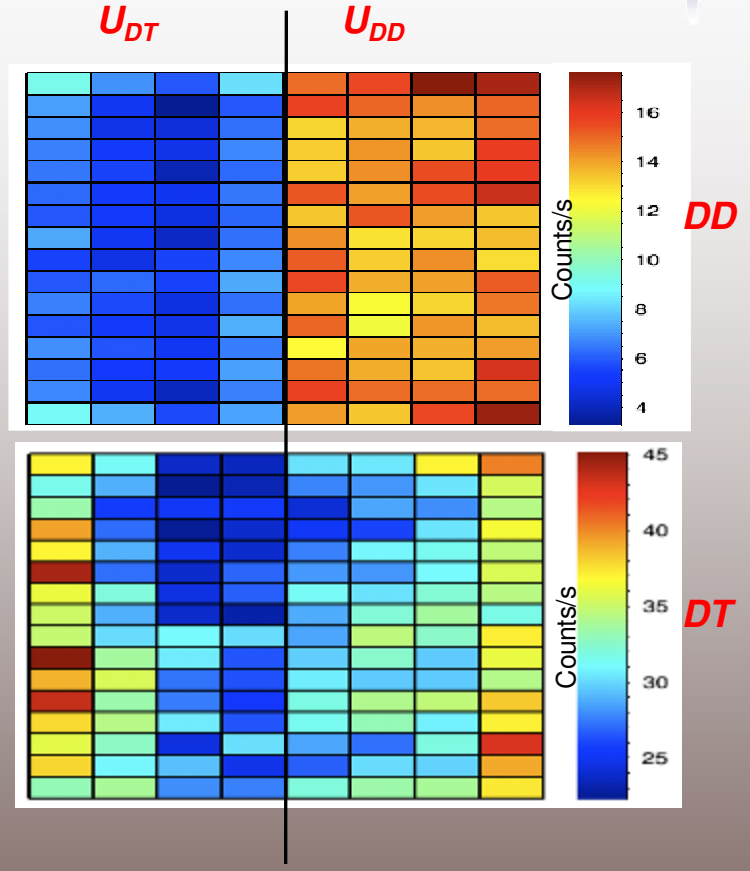
2.5 MeV Neutron



There is a working region without photon contamination with eff = 10^{-4}

Flux vs time and discrimination

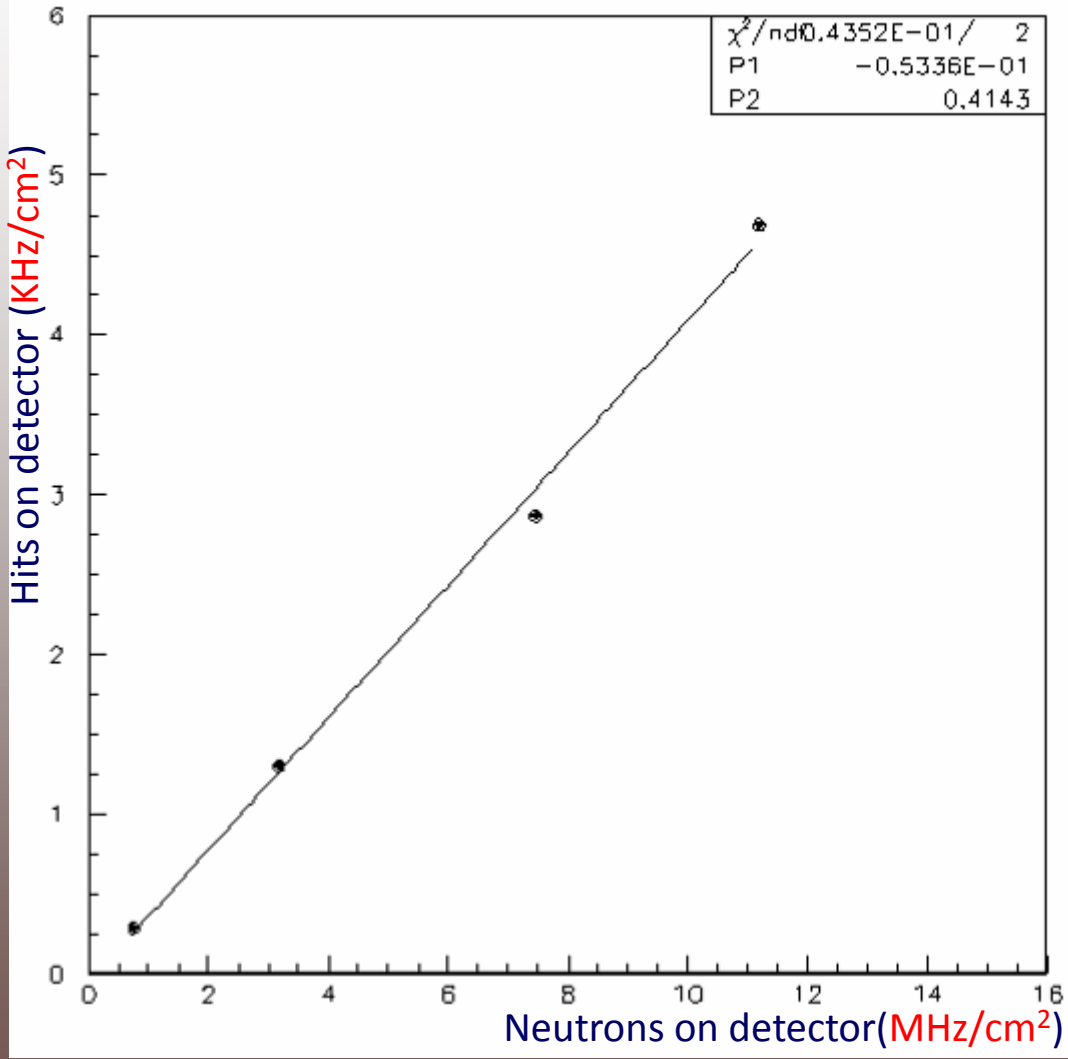




More studies on cathode materials are needed to improve discrimination

Installed at Frascati Tokamak Upgrade : measurements in progress

Calibration and Linearity

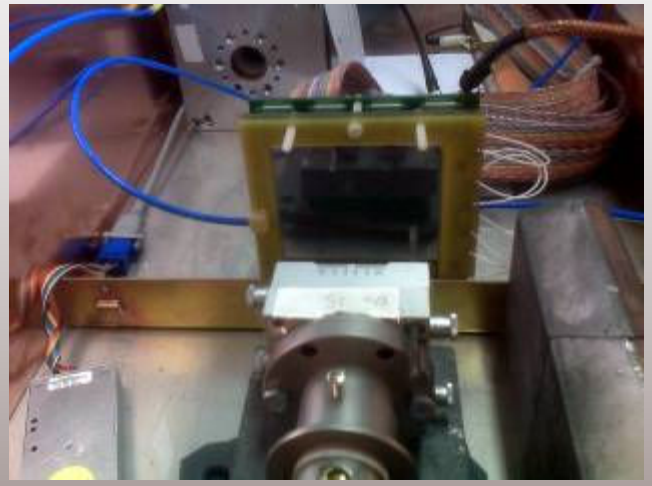


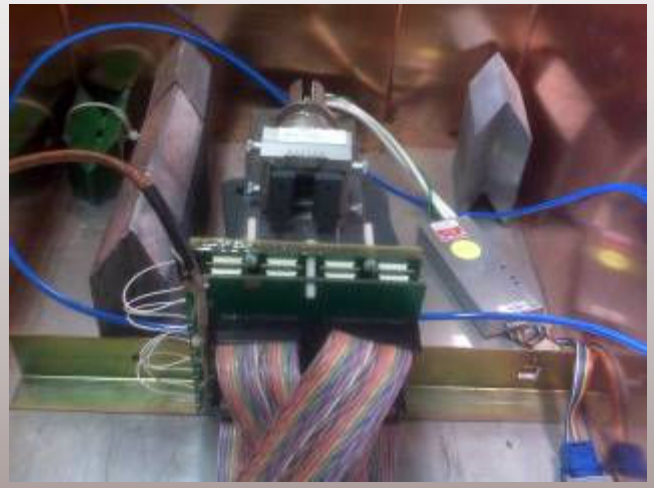
Higher neutron flux beam are needed to measure the real performance of this monitor

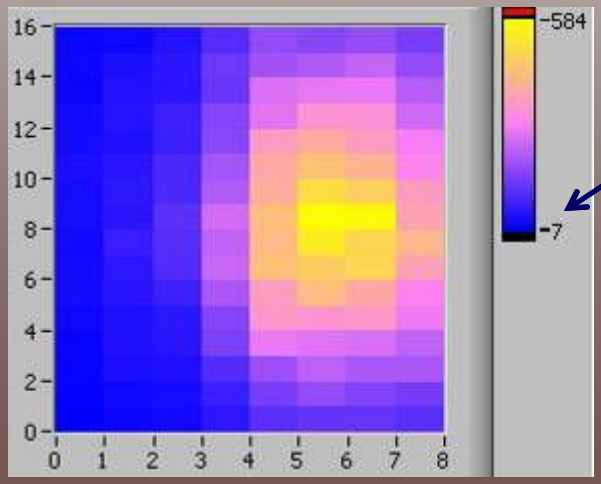
Other 3 order of magnitude in neutron flux to be explored

Triple GEM detector for X-ray

A collaboration between CEA ENEA INFN has been started to develop diagnostic for burning plasma with soft X-ray. A GEM detector with a cathode mylar window has been installed in Cadarache laboratory



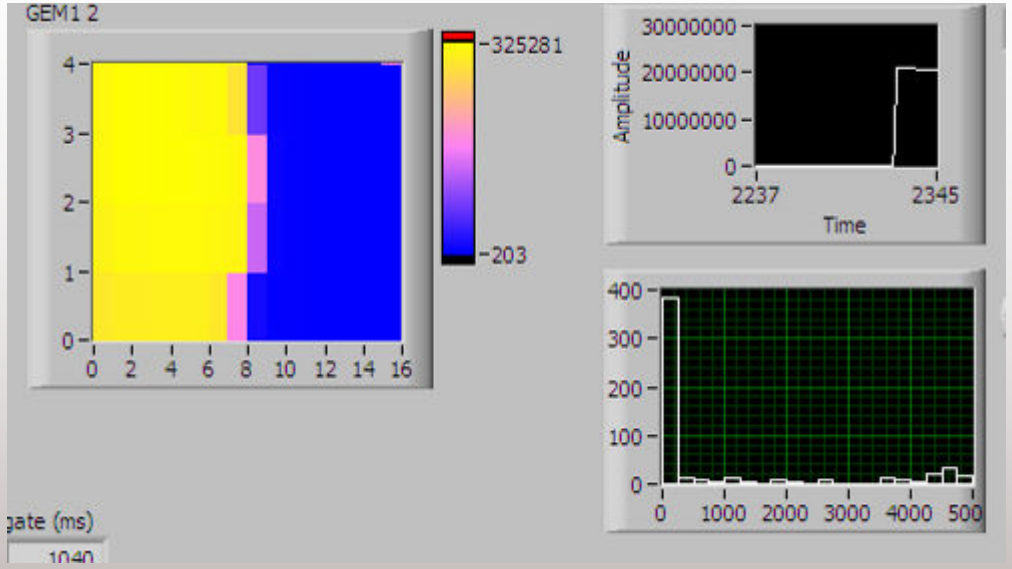




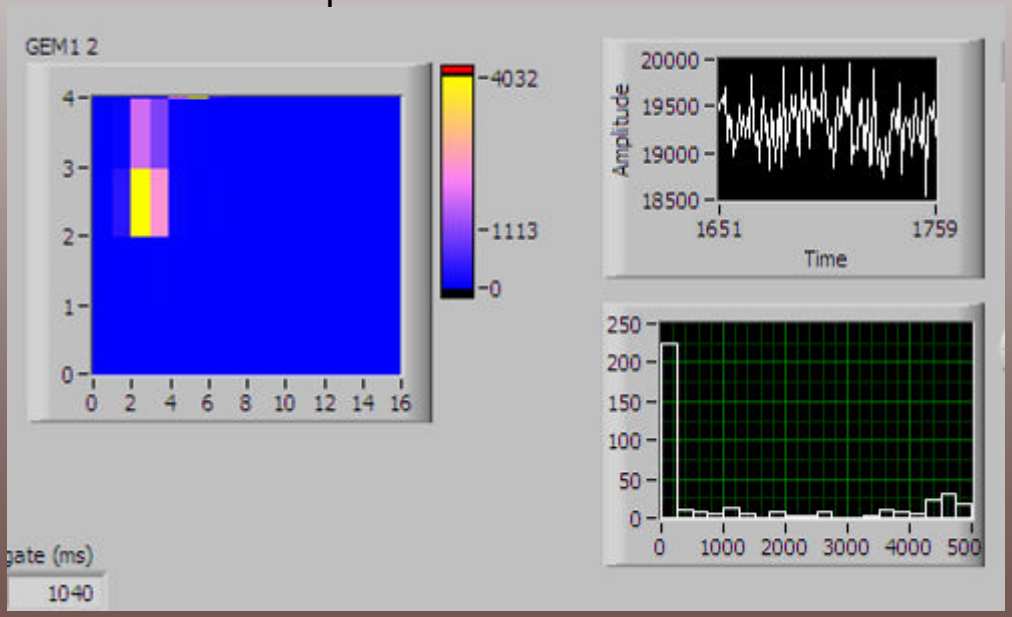
An image of the spot produced by the X-ray source.

DAQ based on a CAEN multipurpose VME module (FPGA) able to produce also fast control signals for feedback systems.

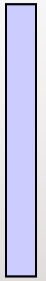
X-Ray spot with poly-capillary



3x6 mm^2 pads

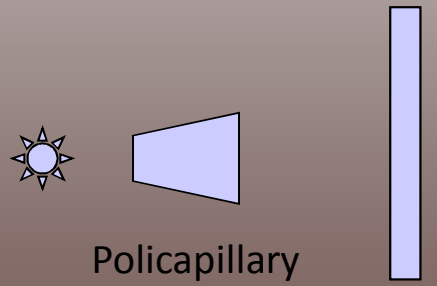


Before



First measurements with
Poly-capillary and GEM detector

After

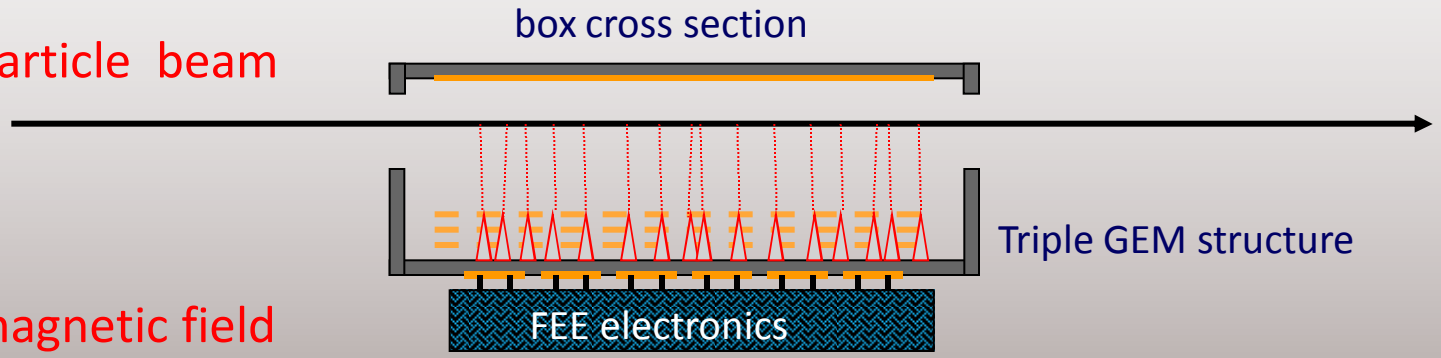


Policapillary
Lens

Compact TPC with GEM readout for high intensity beam and ion beam

TPG for beam diagnostic

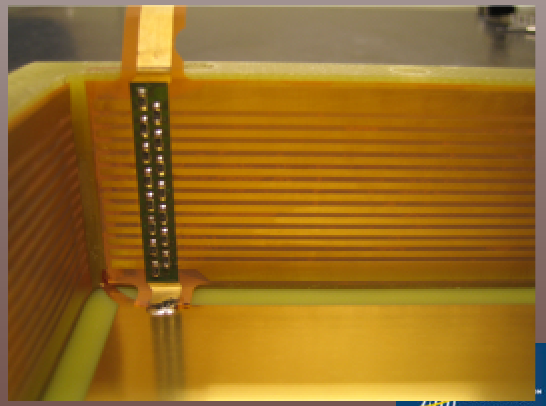
It's essentially a small TPC with a 4 cm drift and readout with triple GEM
In this way also high current beam can be monitored in position



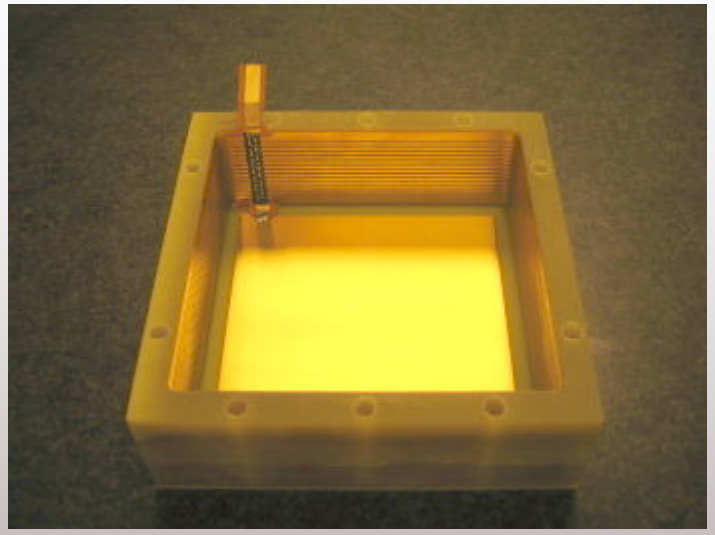
Without magnetic field

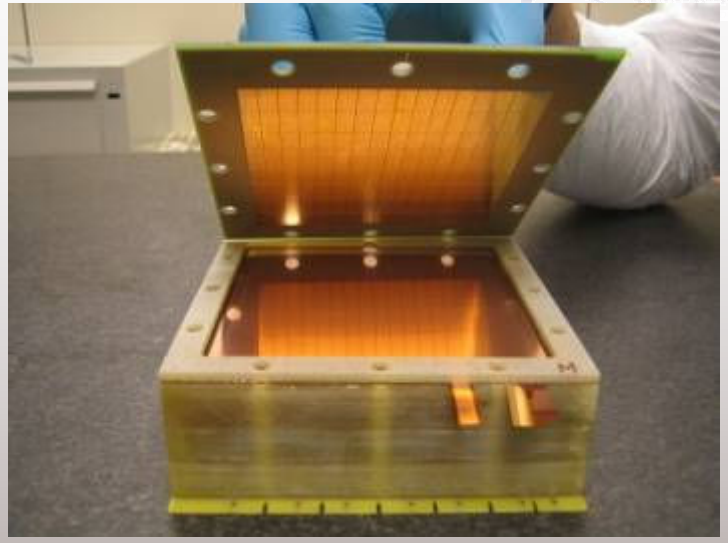
The material budget crossed by a particle is only two kapton foils (<0.2%X_0) used for the field cage necessary for the drift field uniformity

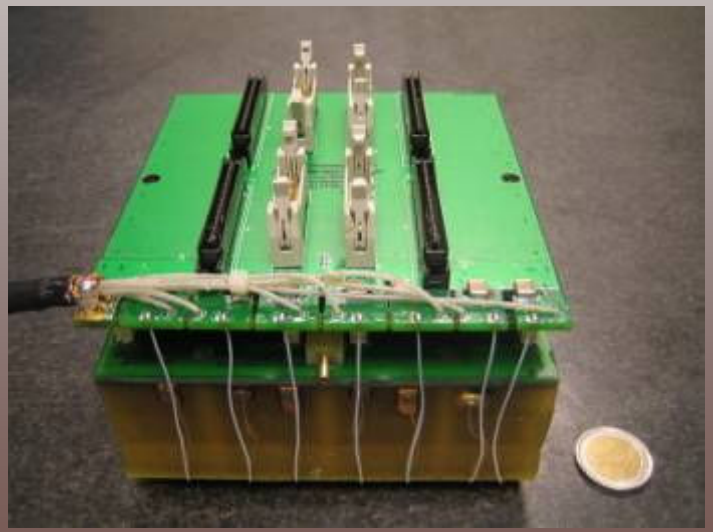
14 strips with 15 resistors (10 MΩ) for a total field cage current of 1 μA



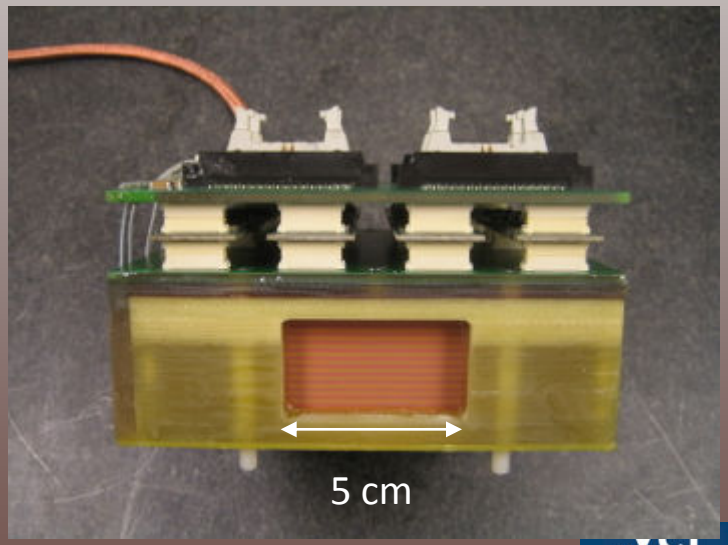
Assembling the TPG chamber



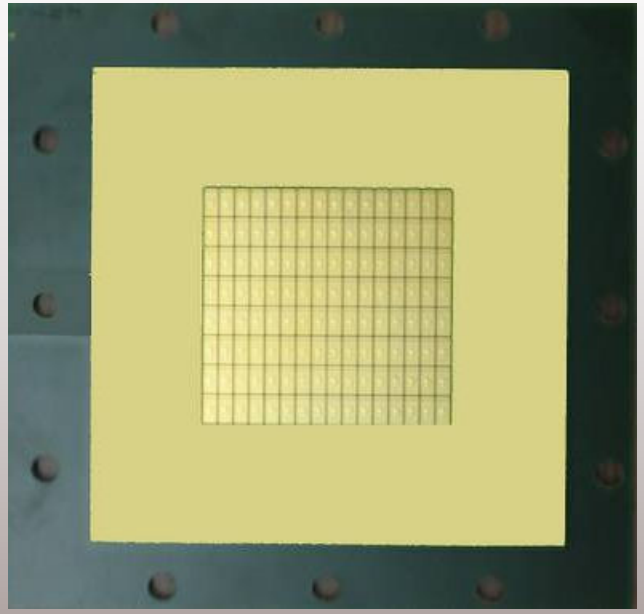


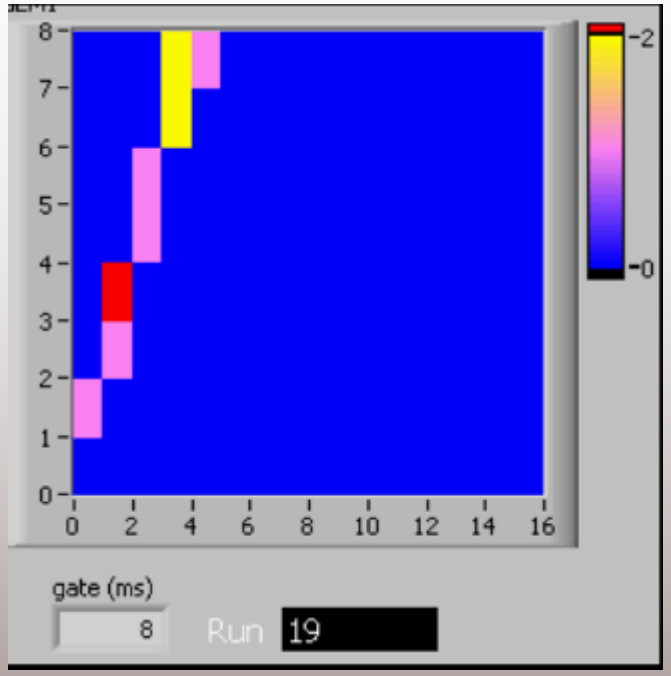


(M. Pistilli)



Cosmic rays in free running





For this type of monitor a new layout has been designed for an active volume of 5x5x4 cm^3
Pad dimension 3x6 mm^2
Threshold set at 7 fC
Gas mixture Ar CO_2 (70-30)
Triple GEM Gain at about 10^4
Sub-millimetric precision

A gate of 8ms is open randomly without an external trigger

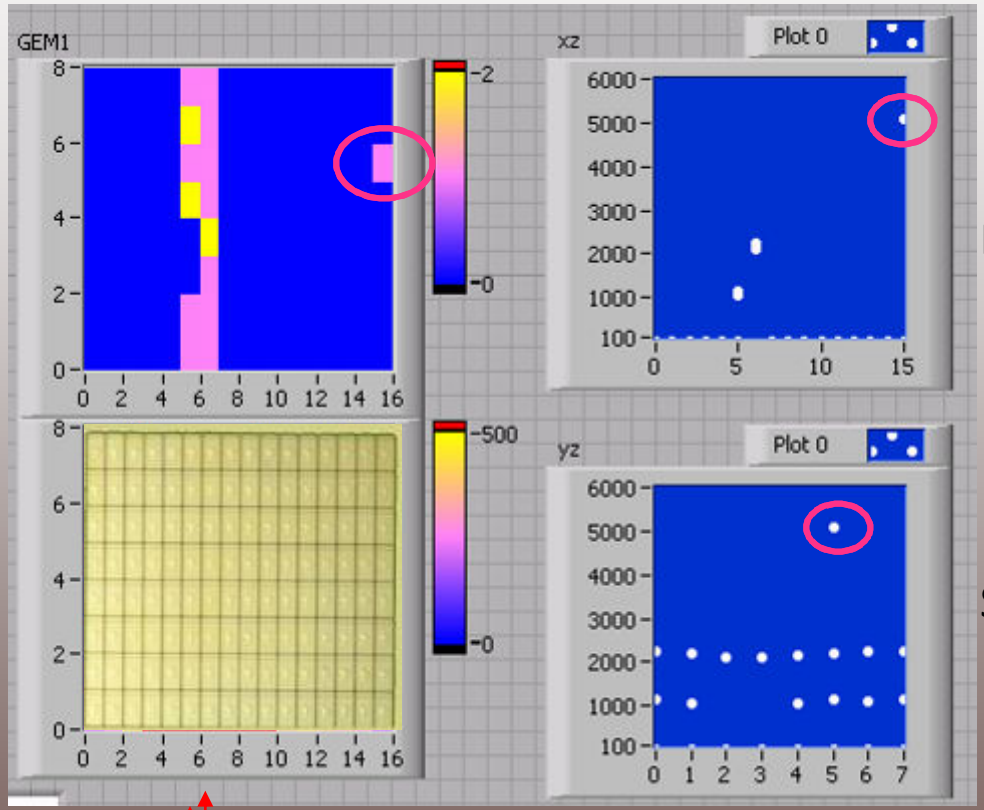
Threshold set at about 7 fC
Gas mixture Ar CO_2 (70-30)
Triple GEM Gain at about 10^4

Low intensity beam

Two electrons in 10 ns

Top view

Last event



Trigger signal

Front view

Pad layout

Side view

particles

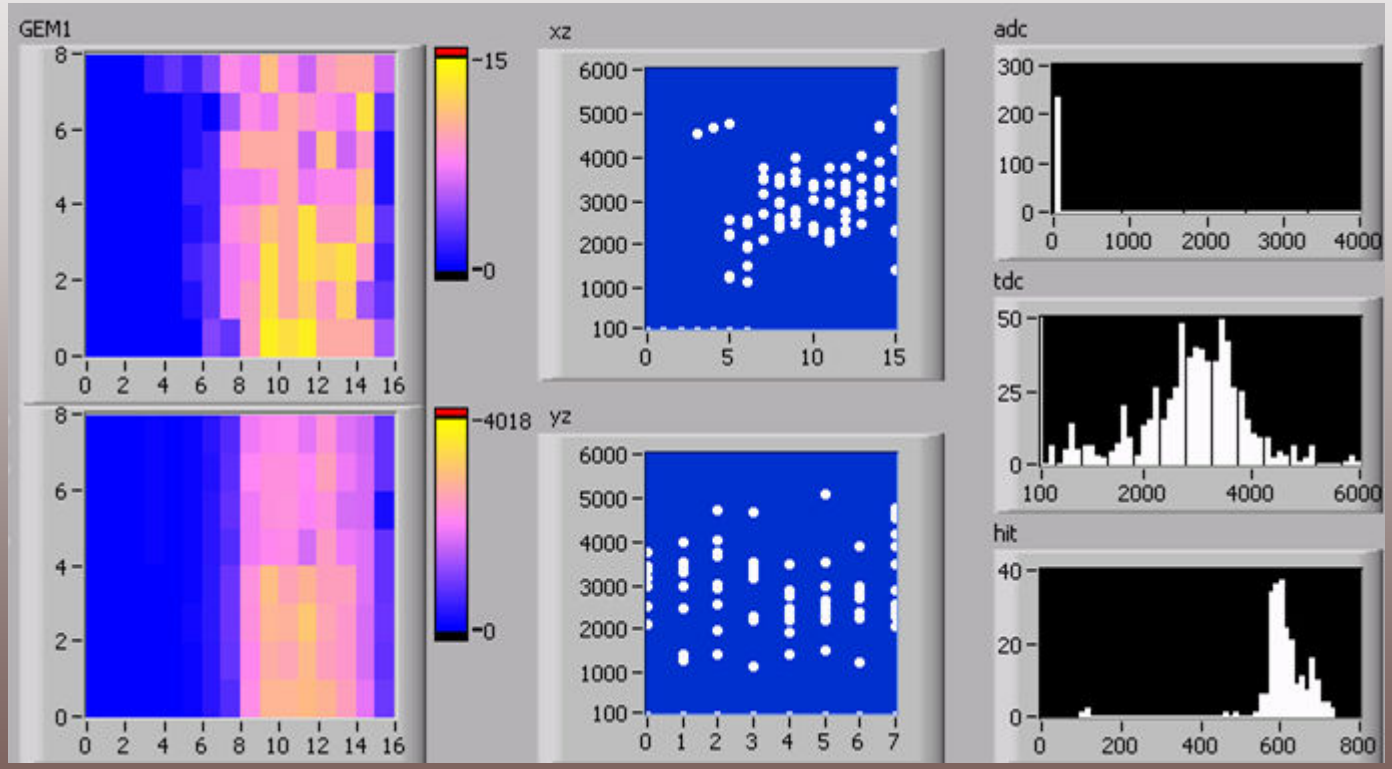
particles

High Intensity beam 4400 e^-

The time length of a single bunch was 10 ns

Top view

Side view

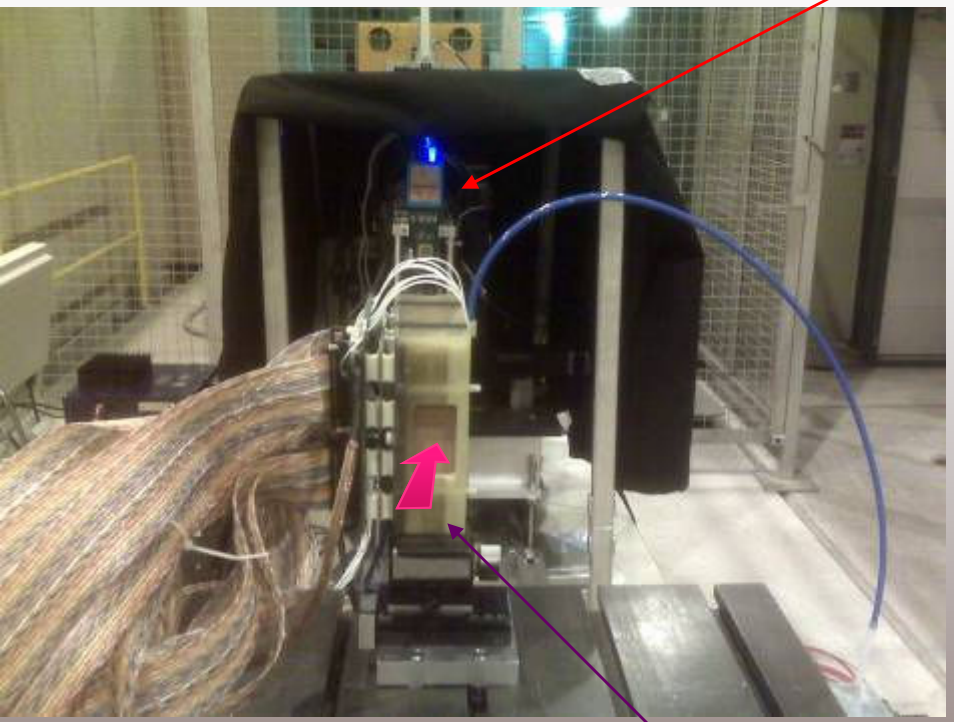


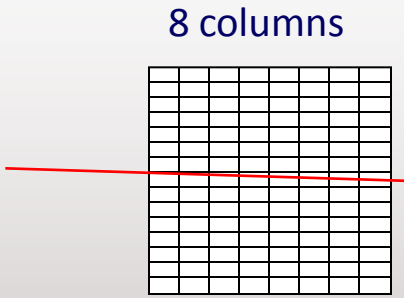
z distrib.

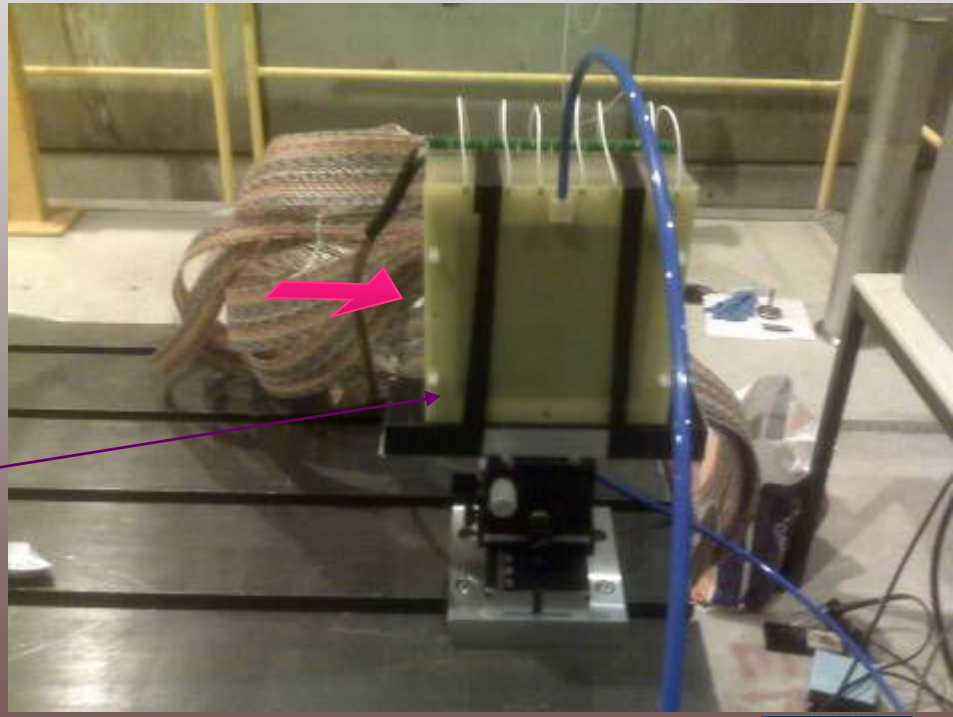
hits

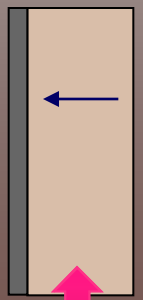
History view

Test for beam channeling at CERN







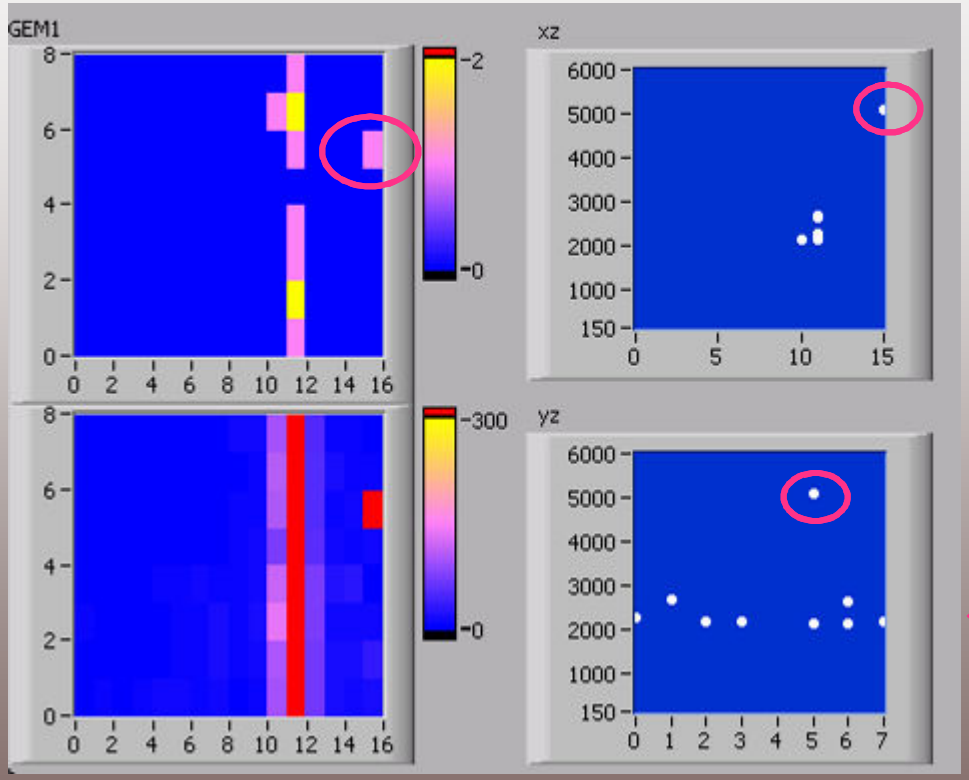


A Single Proton through the TPC

From online monitor … no offline analysis !

Side view

History view



Front view

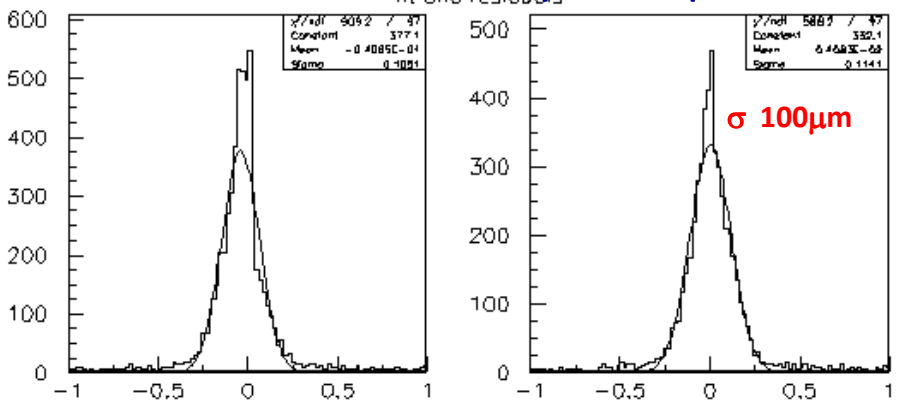
Top view

particle

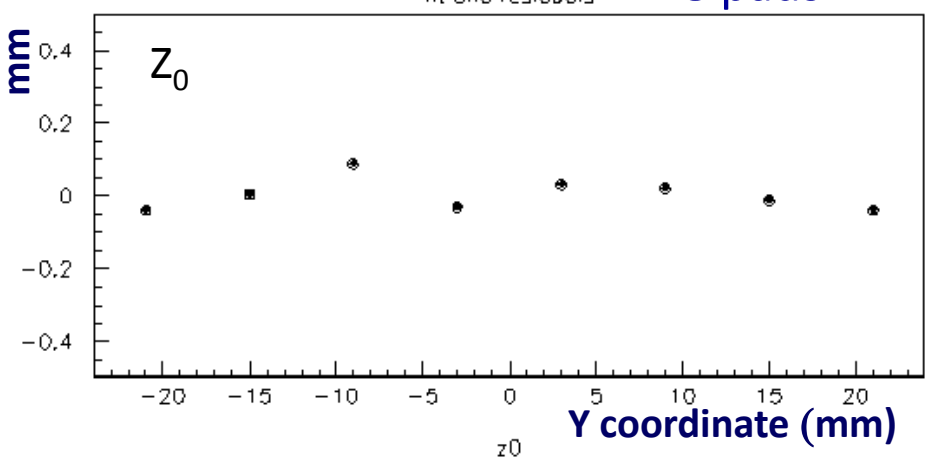
particle

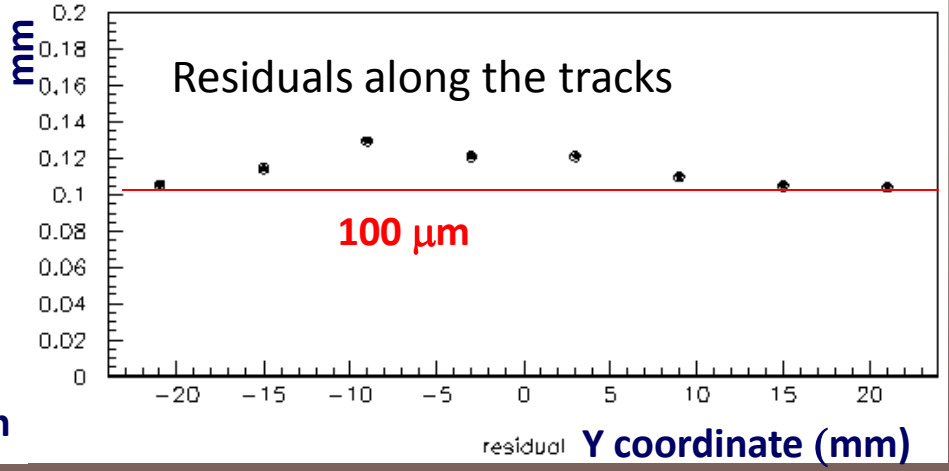
Track reconstruction

Residual measured by each pad



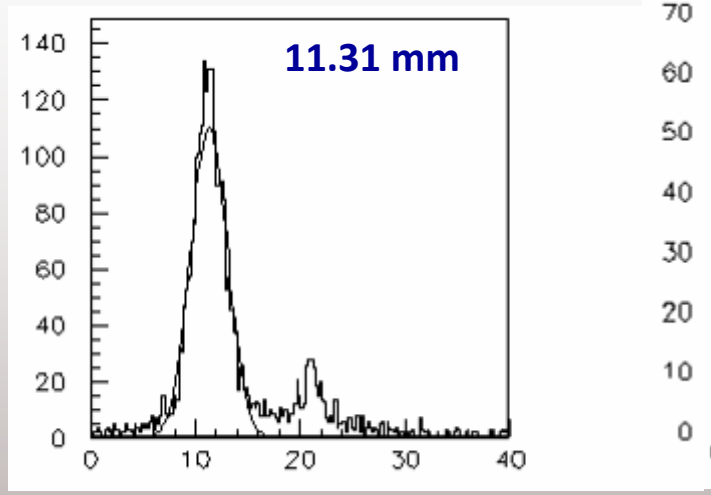
8 pads



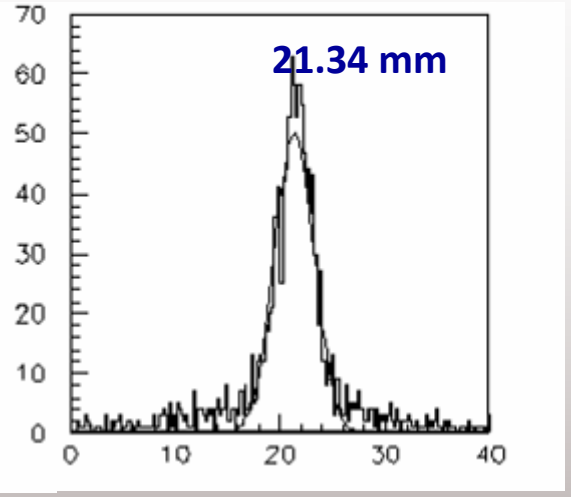


50 μm resolution in track position

Chamber calibration

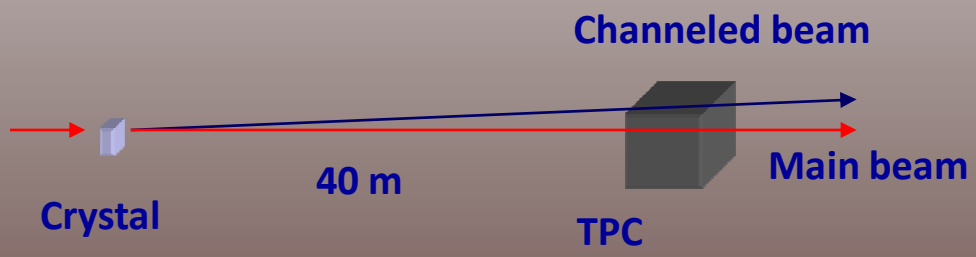


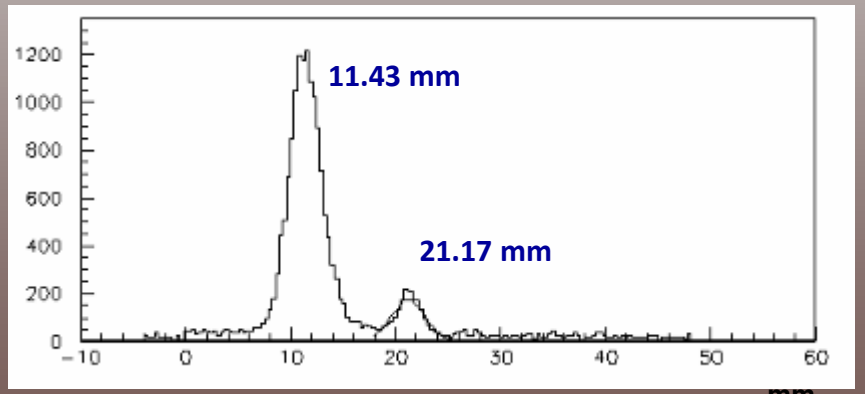
Electron drift (mm)



Electron drift (mm)

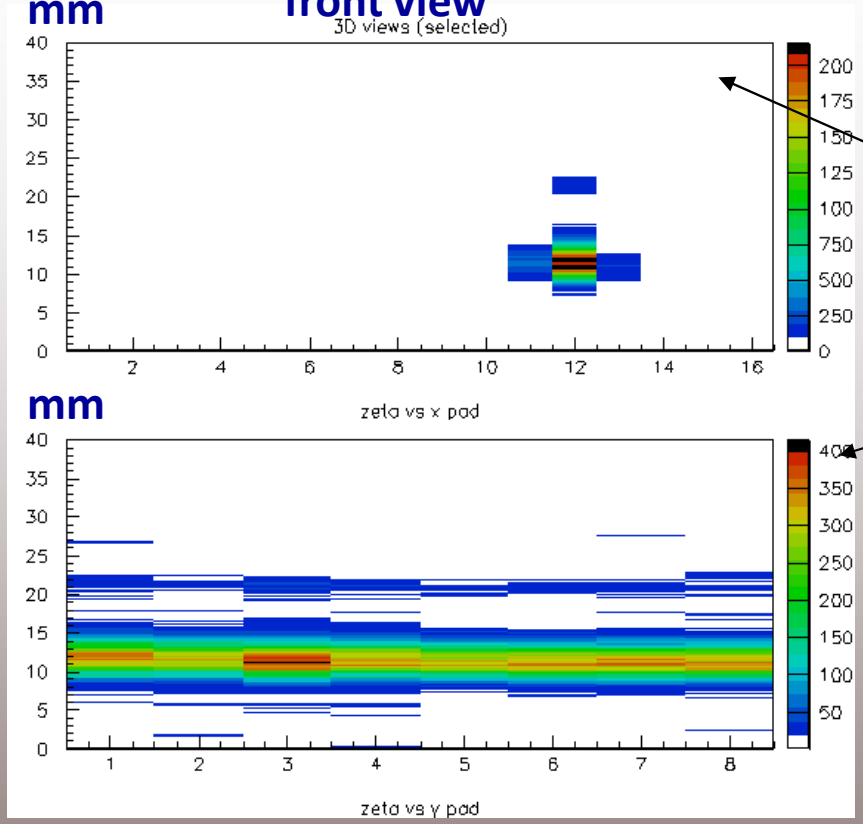
Beam position with a chamber displacement of 1 cm





Proton Channeling at CERN test

front view

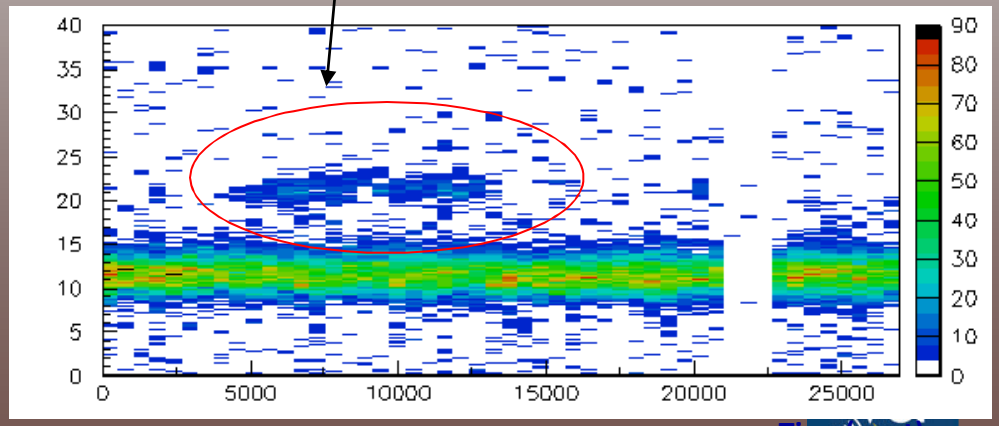


pad

pad

top view

Channeled beam



Conclusions

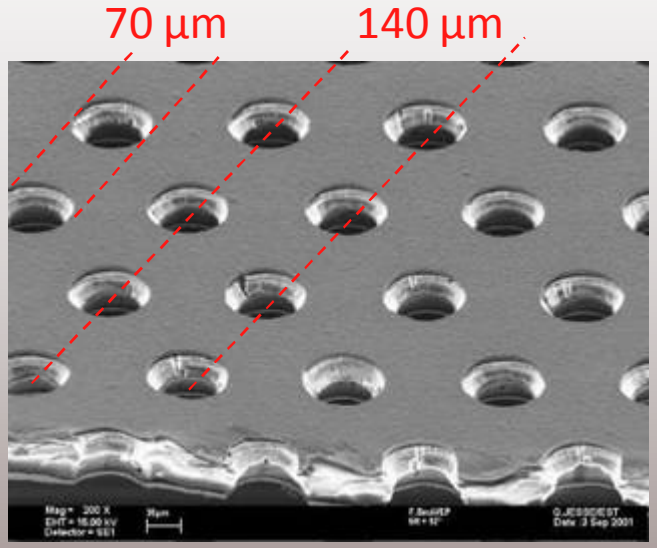
Several portable detectors based on triple GEM technology have been built in Frascati for several purpose :
Luminosity monitor, Neutron flux monitor, Xray monitors, Beam position monitors, …

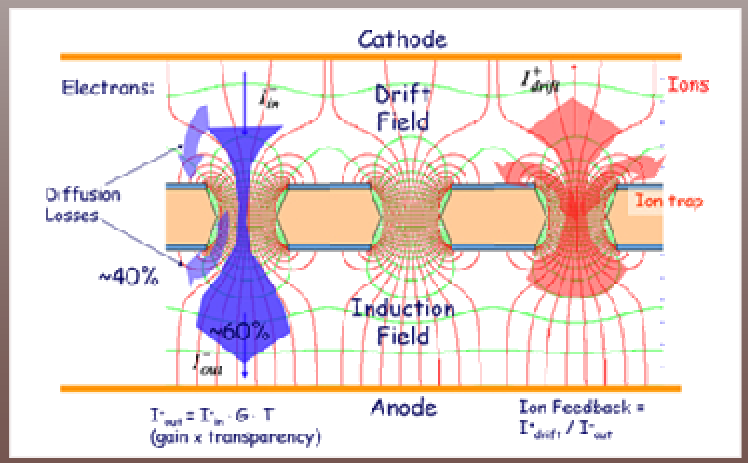
- *In all of these sectors they show good performances and confirm good radiation hardness*
- *These R&D are spreading inside and outside INFN (ENEA, CEA, ISIS, Politecnico di Milano…).*

- *Particular interest inside EFDA for burning plasma diagnostics*
- *A new R&D for X-rays monitor and imaging for high fluxes region (Nuclear Fusion Reactors) in collaboration with ENEA and CEA, using the poly-capillary technology*

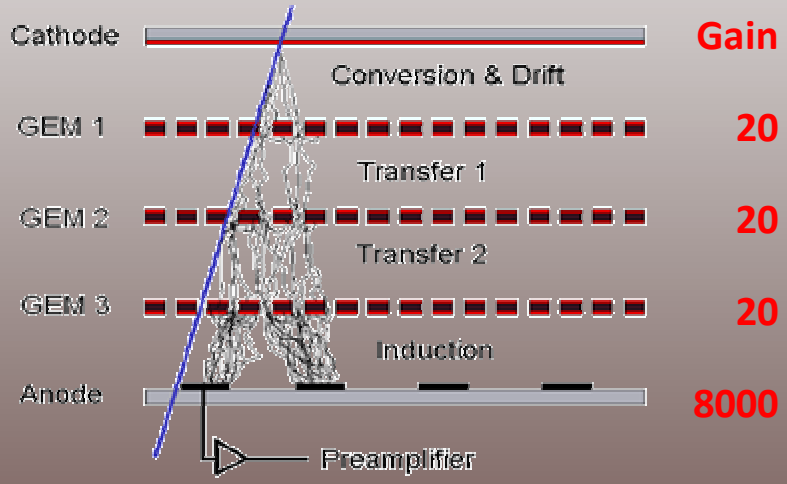
A triple GEM Detector

A **GEM** (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**;





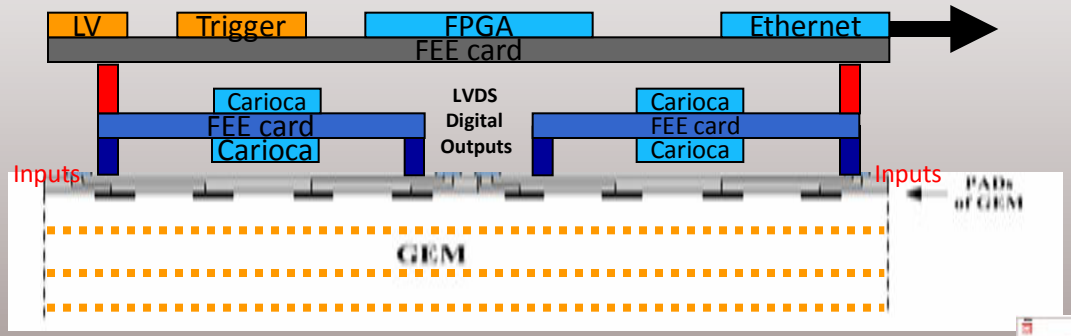
Several **triple GEM** chambers built in Frascati in the LHCb Muon Chamber framework*



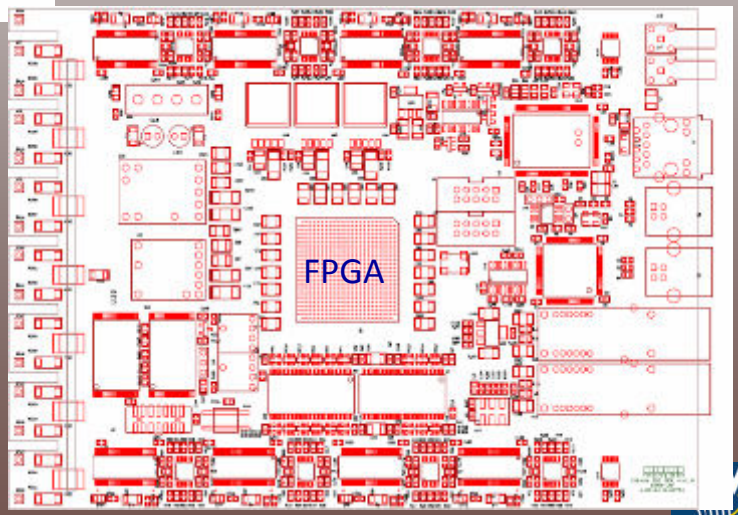
*** M.Alfonsi et al.,** The Triple-GEM detector for the M1R1 muon station at LHCb, **N14-182, 2005 IEEE NSS Conference, Puerto Rico**

“Intelligent” Mother Board

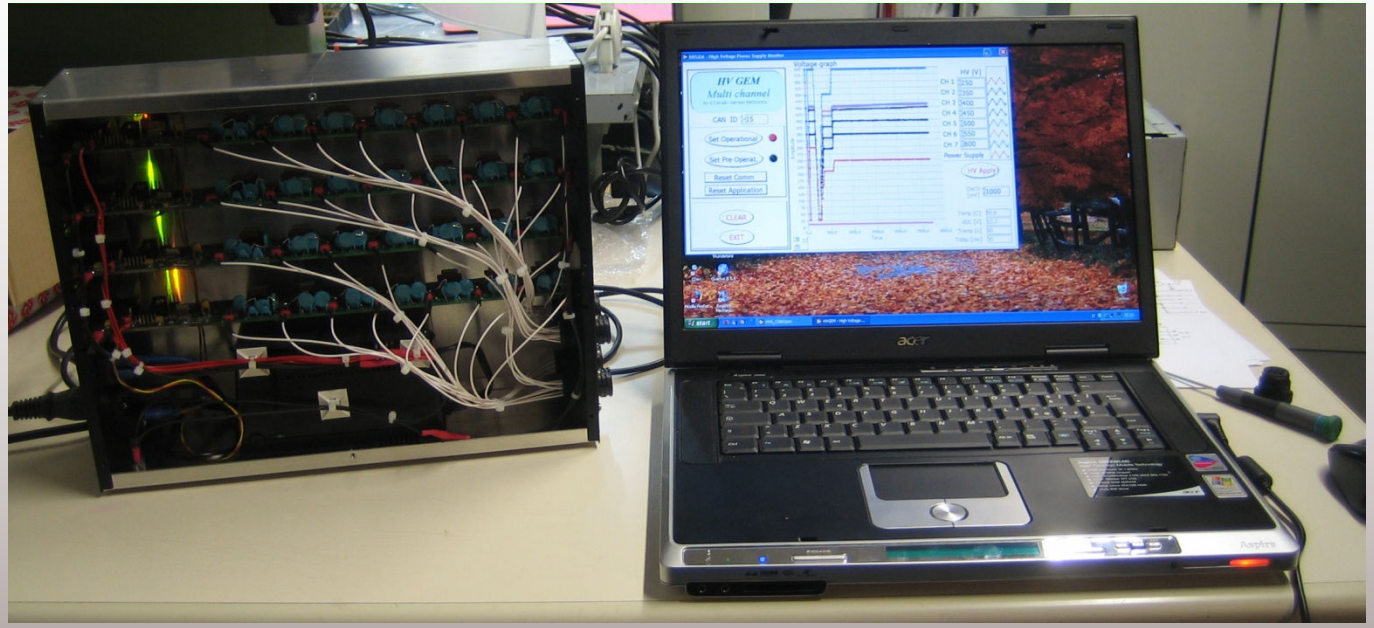
We are working on a Intelligent Mother Board with an FPGA on board able to count the 128 channel hits and/or measure the time respect to a trigger (1 ns) ; the data are readable through an Ethernet connection.



Design done (A.Balla, M.Gatta);
Ready in few weeks



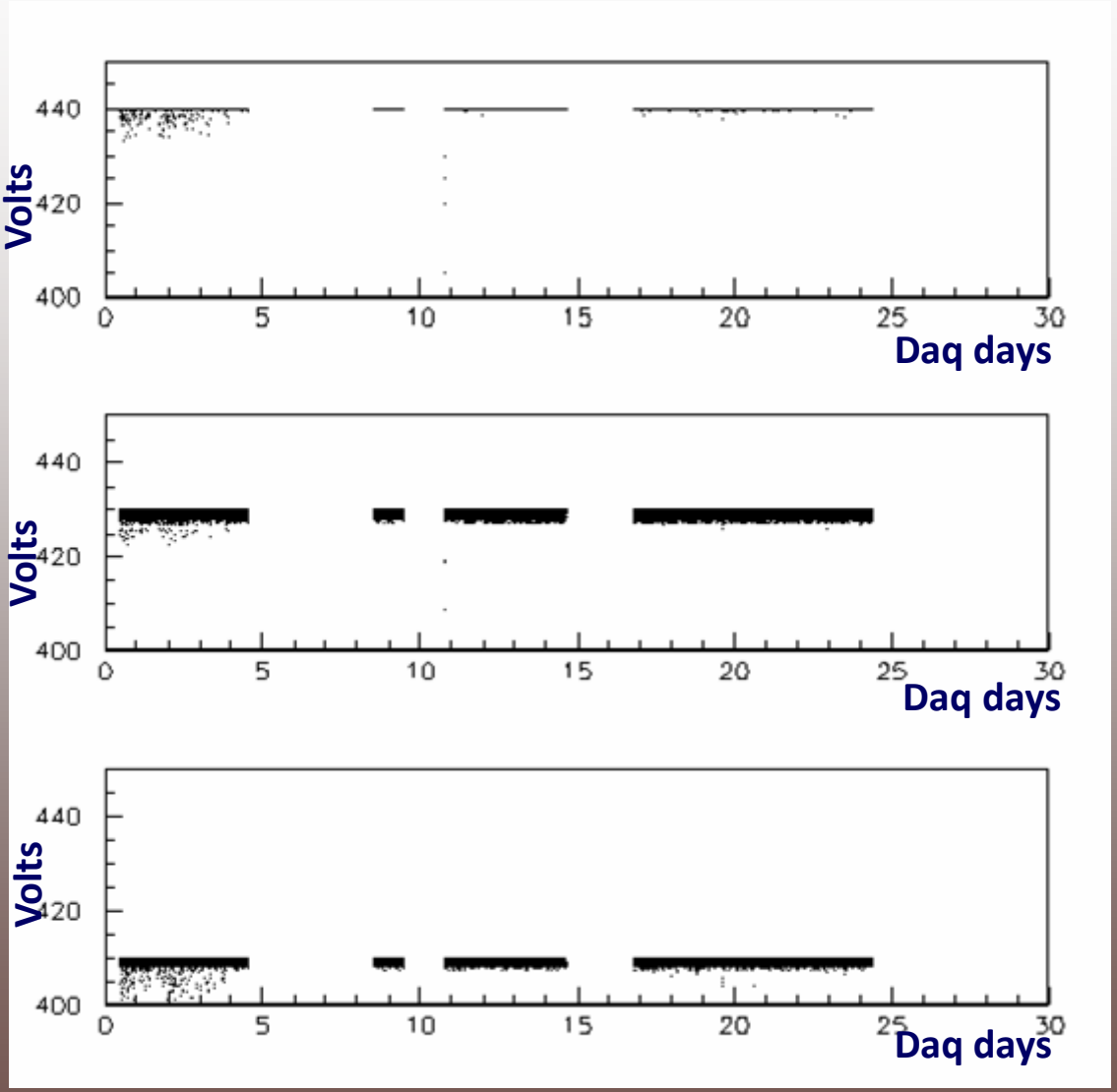
New system with 4 modules



Recently a new system with 4 modules has
been made for the luminometer power supply.
This system is actually working near the Dafne IP

A detail of 4 HV connectors

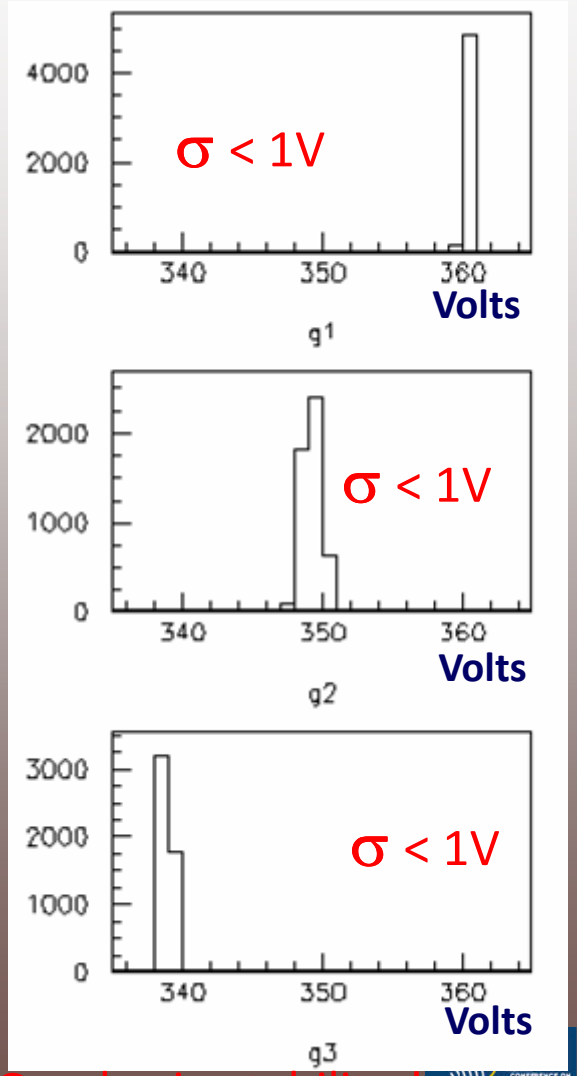
HVGEM prototype stability



g1

g2

g3



Good gain stability !

HV Online monitor and control

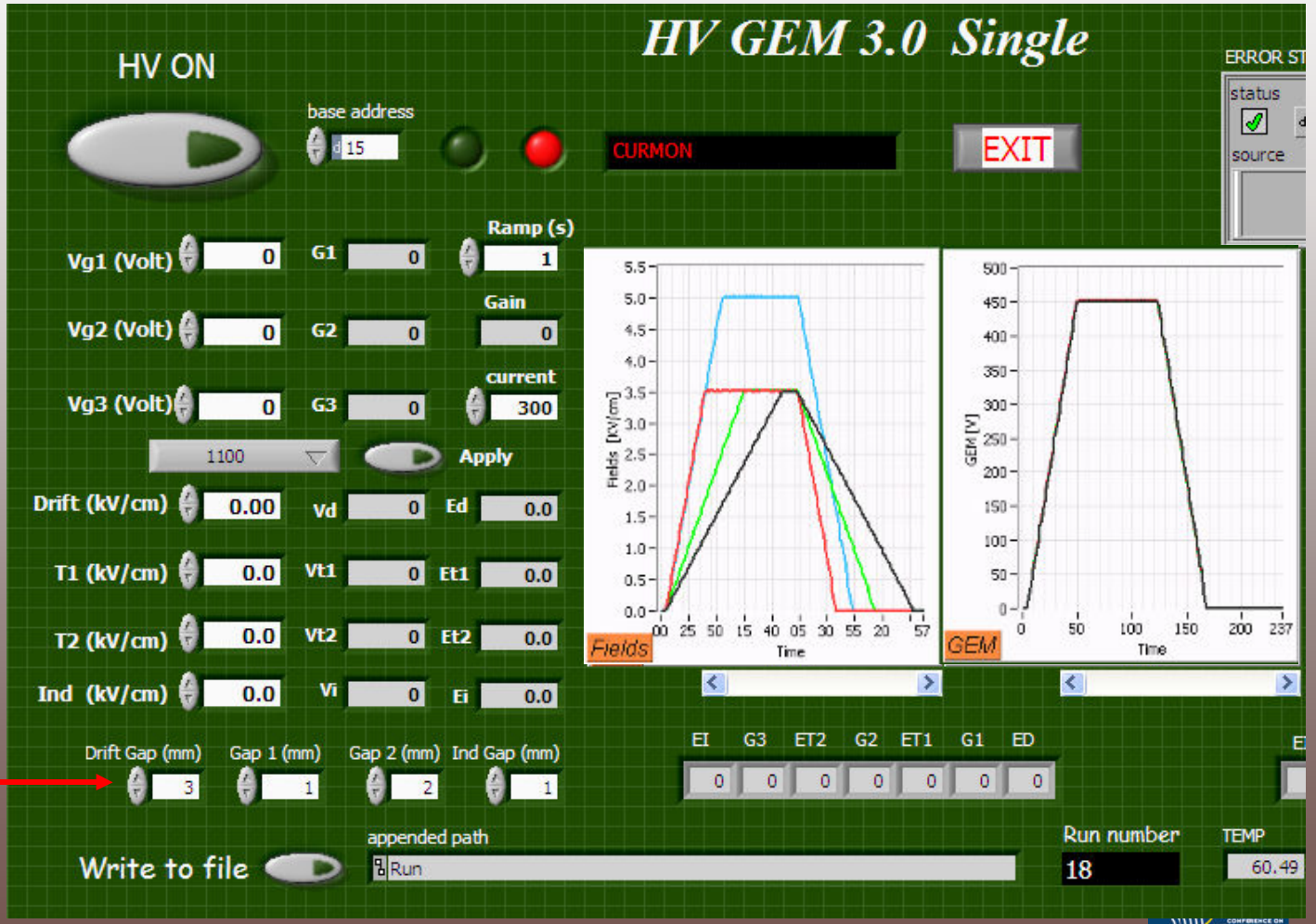
It gives the possibility to set and control directly the 4 fields and the total gain of our triple GEM chambers

Labview and PVSS programs

GEM Voltage (gain)

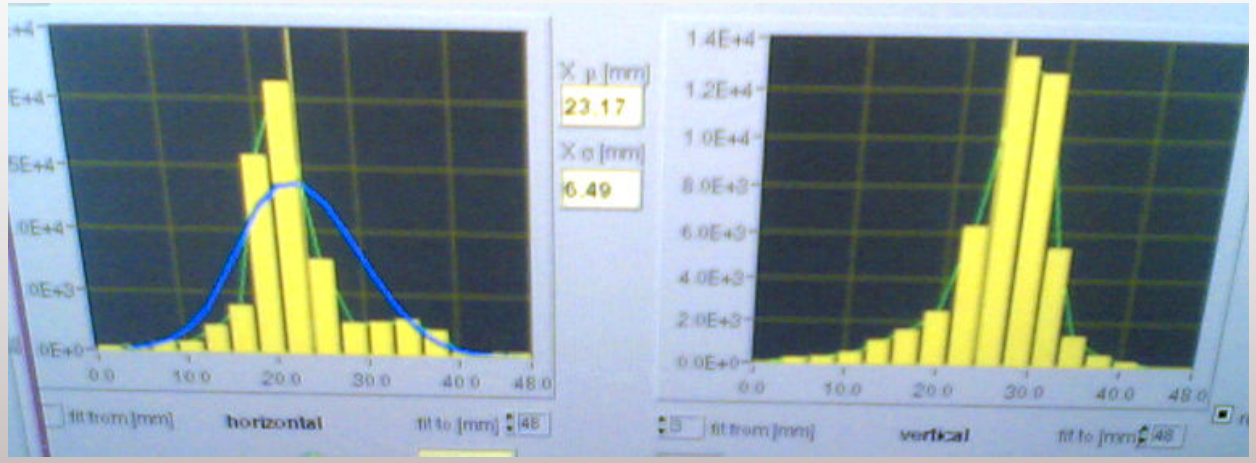
Fields

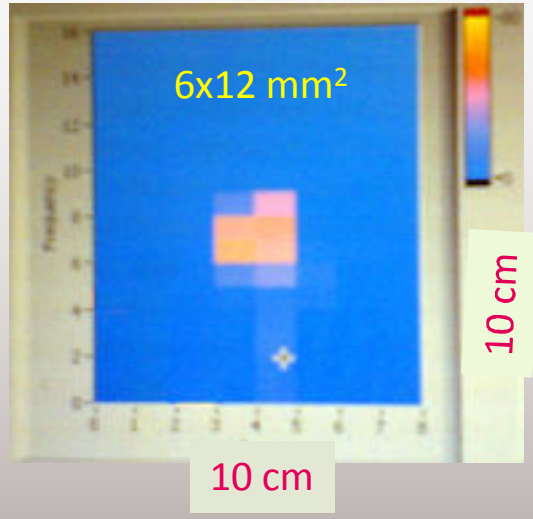
Gap dimension



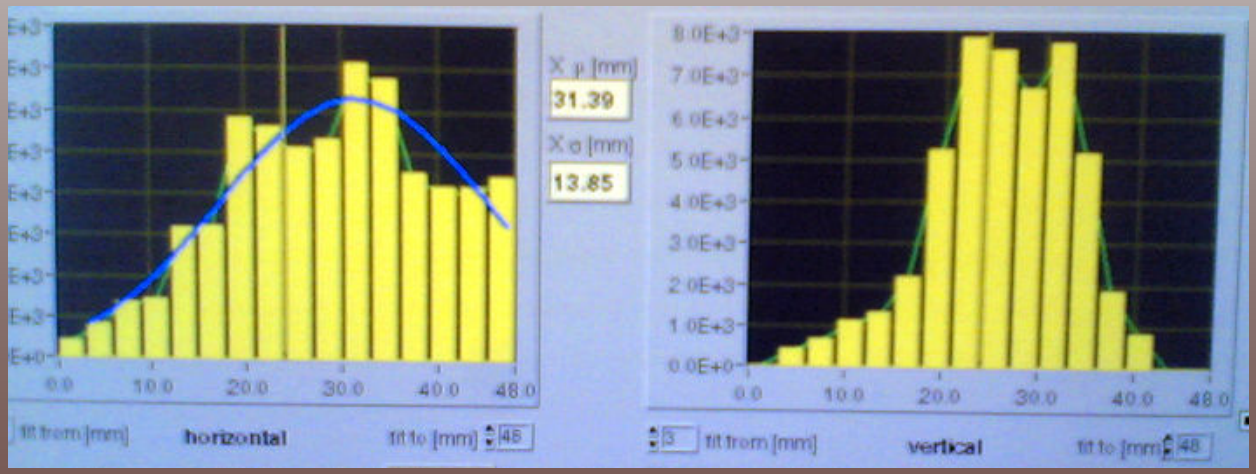
Beam monitor at BTF Frascati

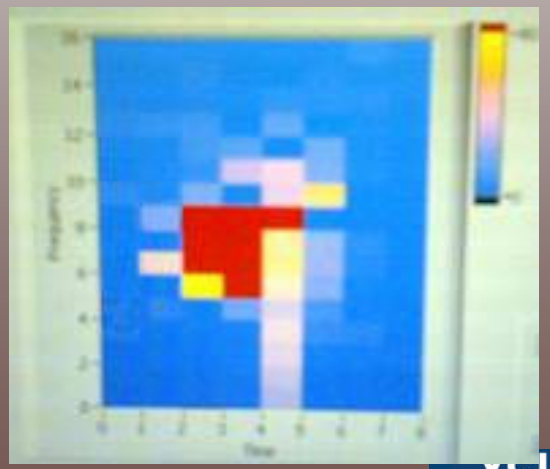
Beam profile at BTF in two configuration : narrow and wide beam





Standard diagnostic with scintillating fibers

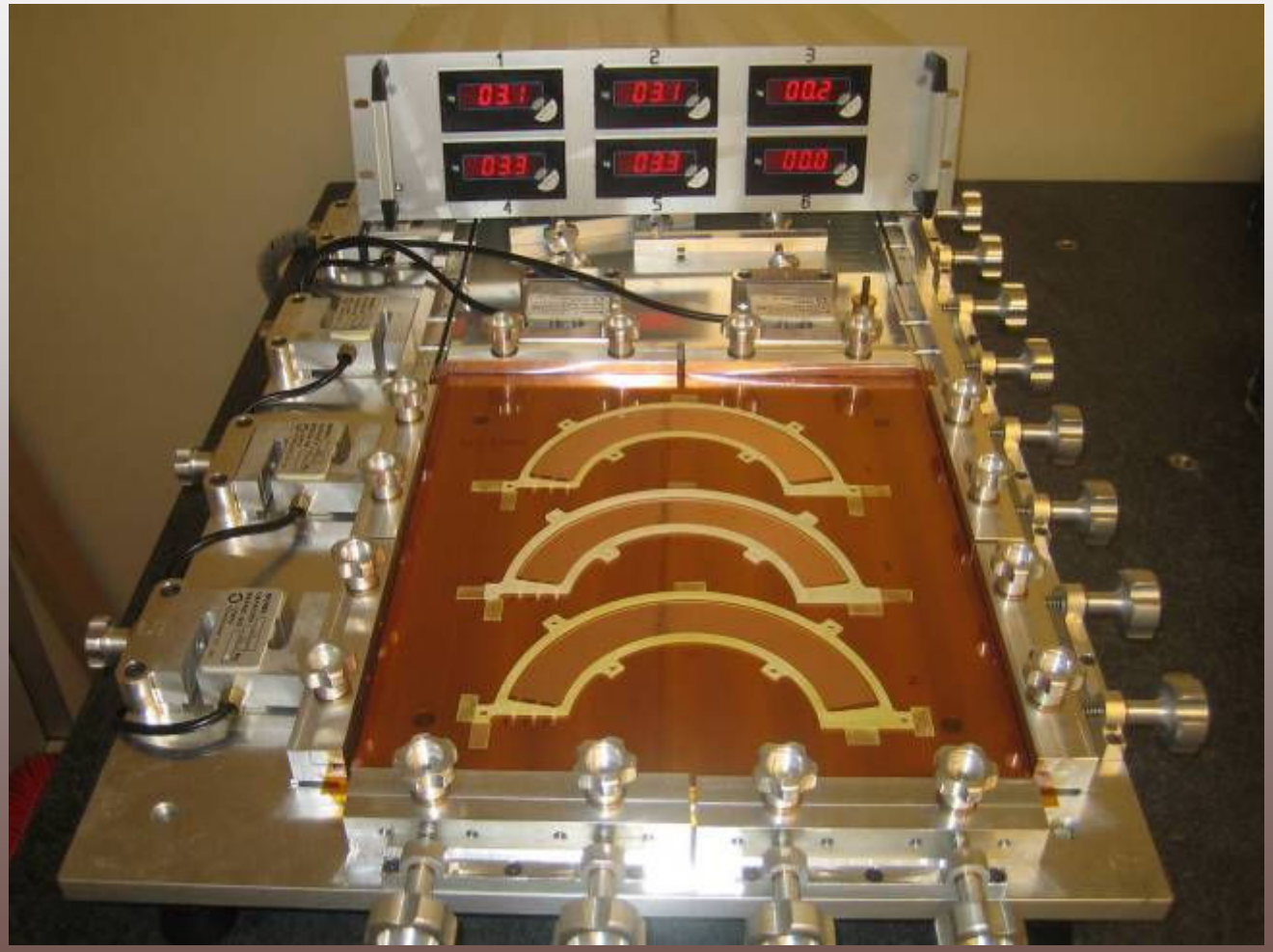




Real-time beam monitoring, from 1 to thousands electrons, 10 ns beam shot

Kapton foil with 3 lumi GEM

The construction of this type of detector has required a new GEM design (same kapton and holes structure but different electrodes shapes)

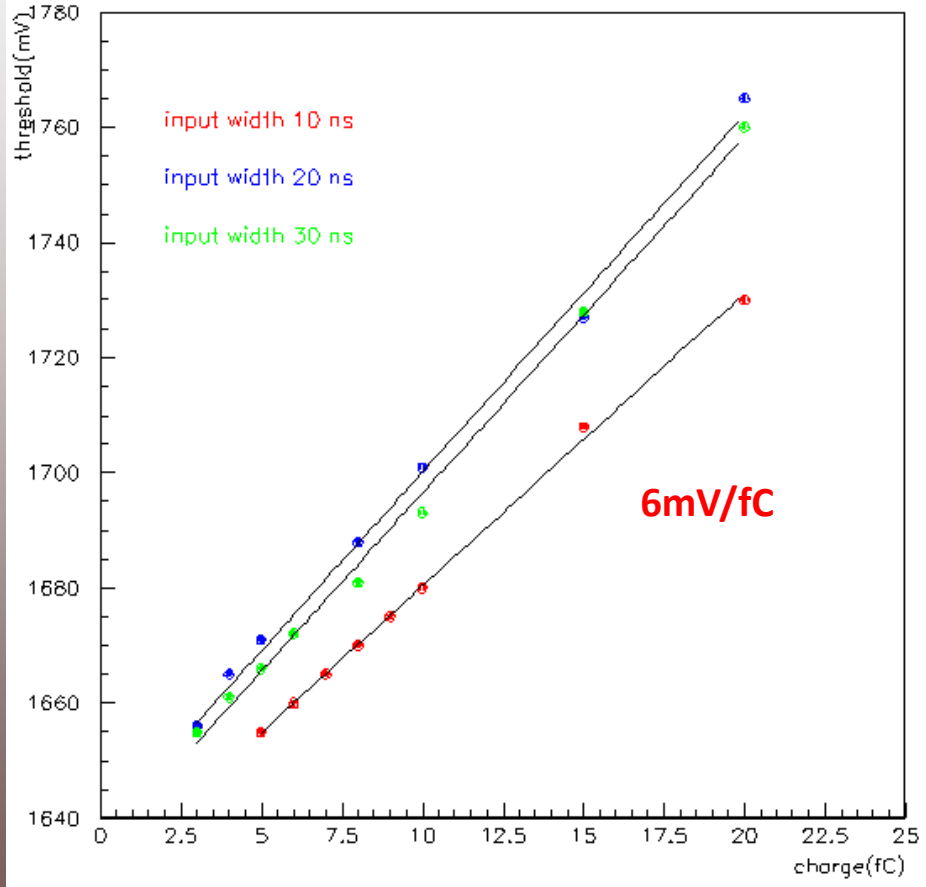


One GEM foil with the three annular structure during the stratching phase for the prototype construction

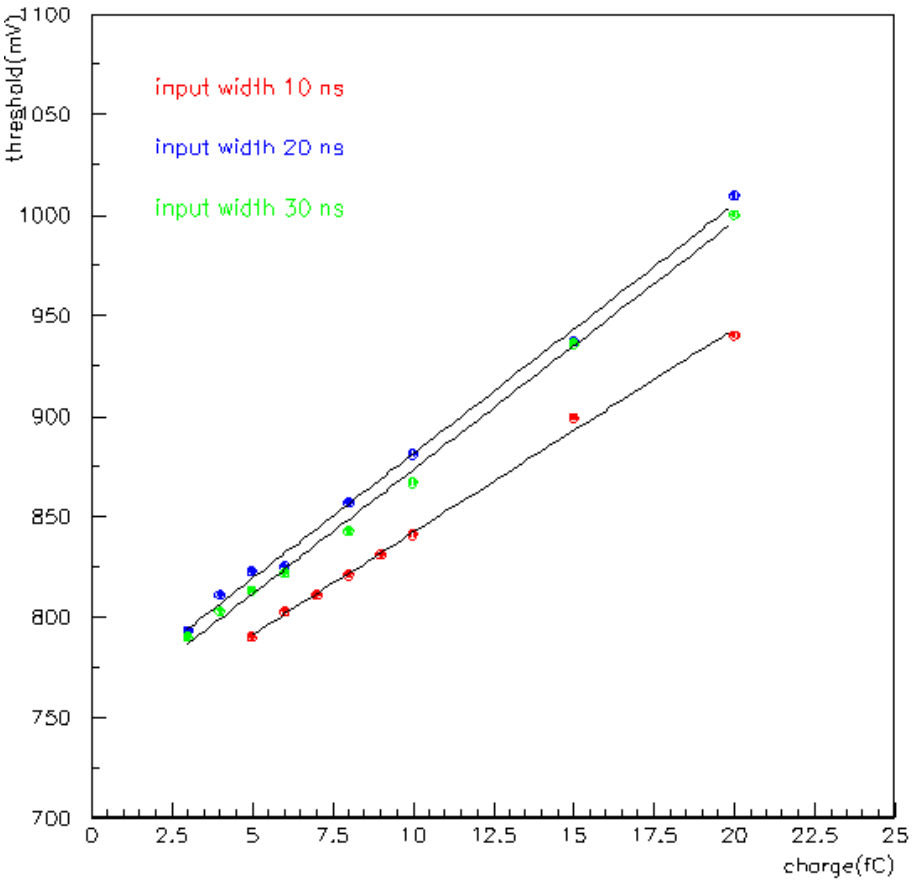
Carioca Card Sensitivity

The sensitivity is measured vs two different thresholds

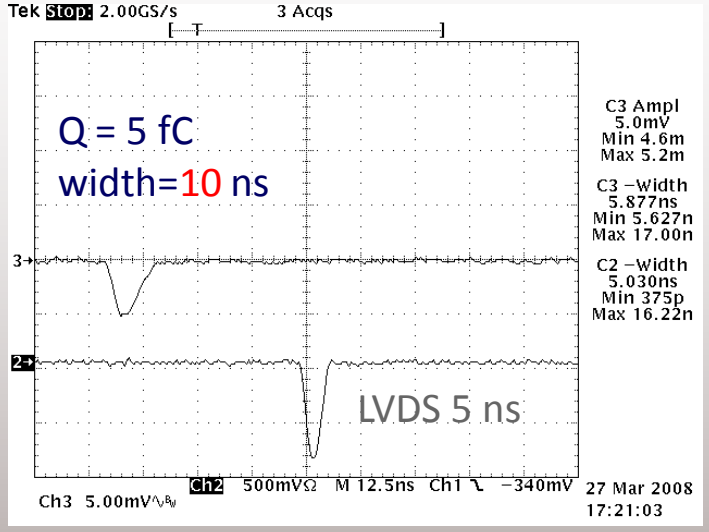
DAC Threshold on power supply

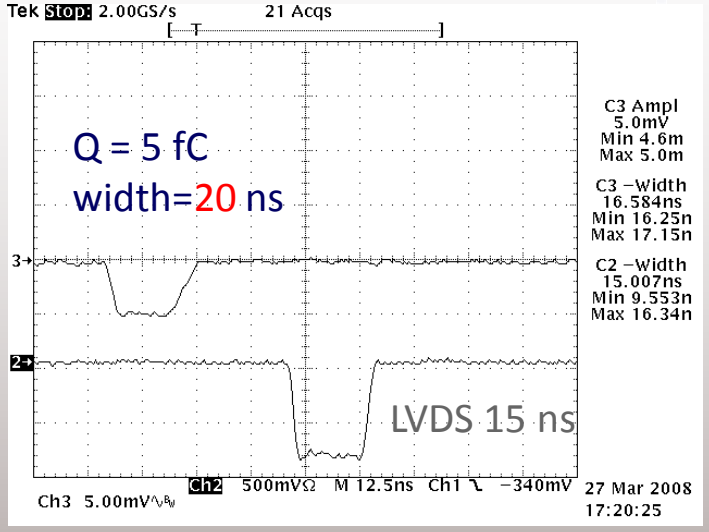


Threshold on Carioca



Carioca Card Sensitivity





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