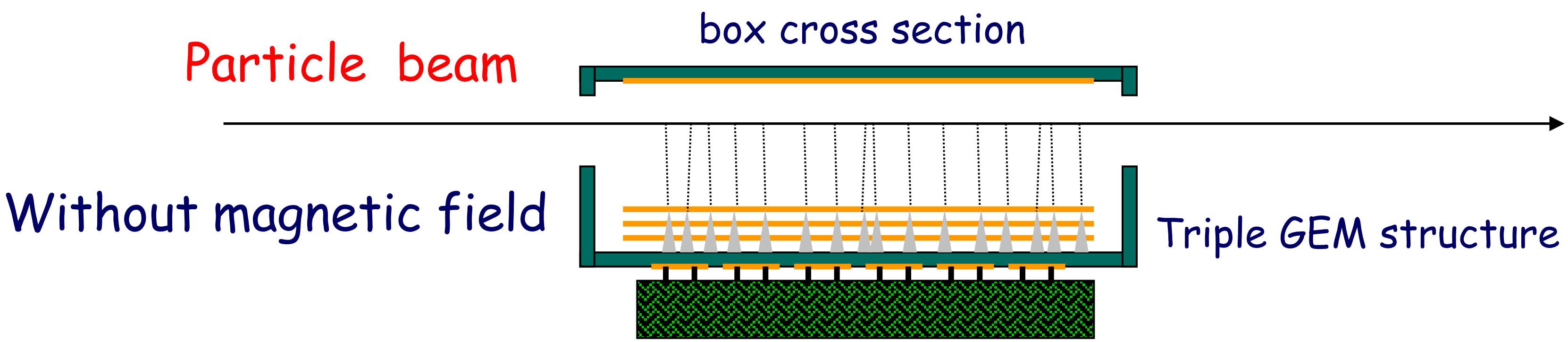
GEM Based Beam Monitors
GEMINI R&D Status Report

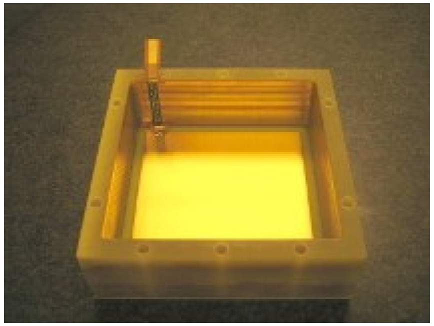
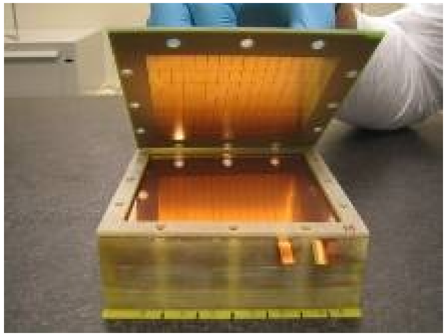
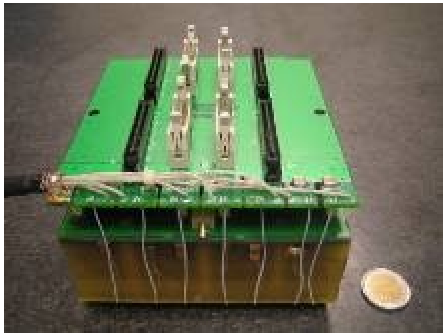
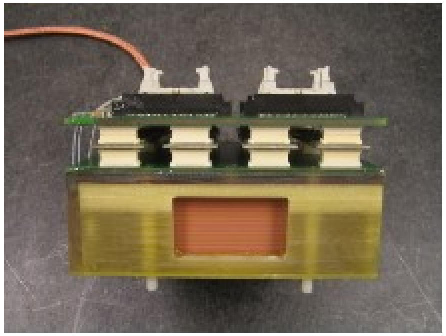
- Introduction
- TPC GEM Beam monitor
- Fast neutron detector
- Thermal neutron detector
- HVGEM Nim module
- Electronics for beam monitors: Development of a new ASIC for GEM readout

TPC GEM for beam diagnostic

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



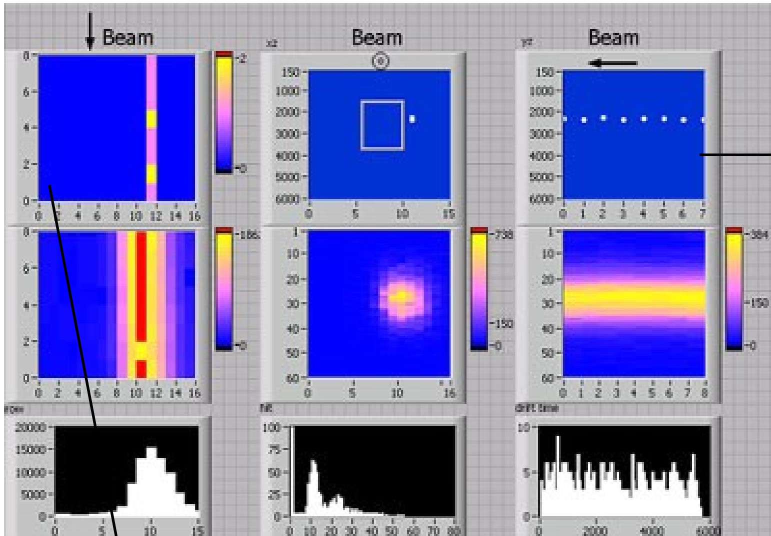
The material budget crossed by a particle is only two kapton foils ($<0.2\%X_0$) used for the field cage necessary for the drift field uniformity

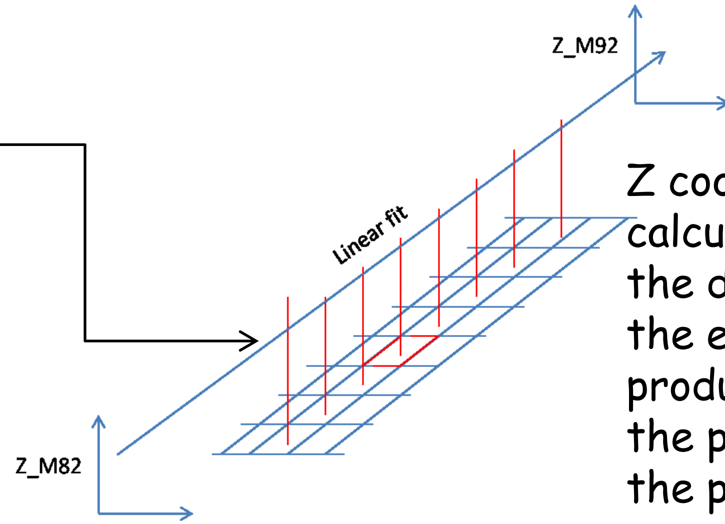





As a beam monitor at H8 for high intensity beams

3D beam reconstruction for bunched beam (up to 100 KHz)

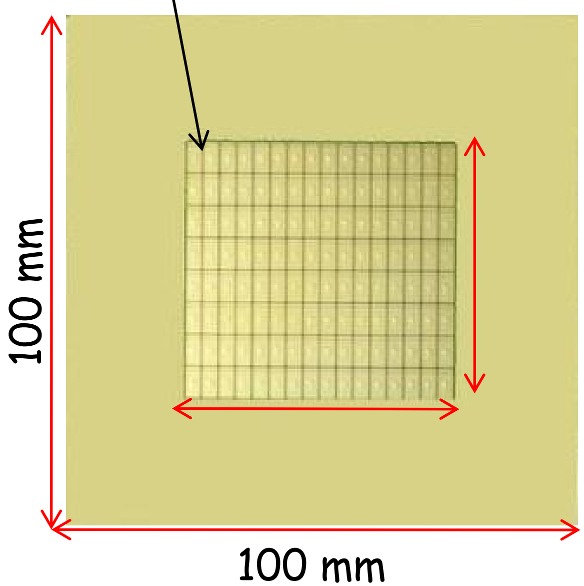
3D reconstruction : TPC track

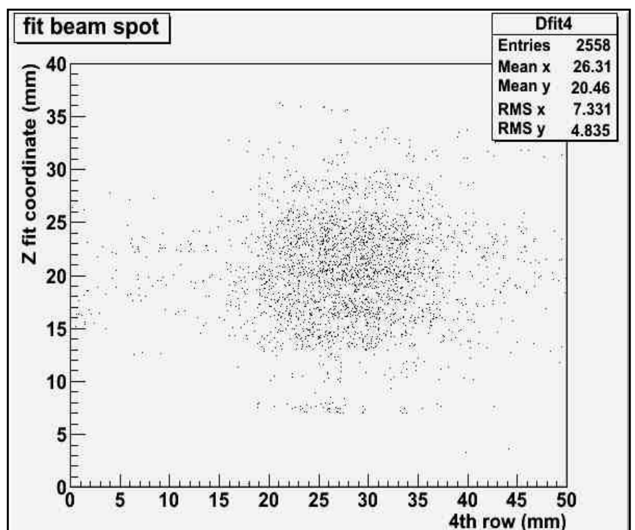


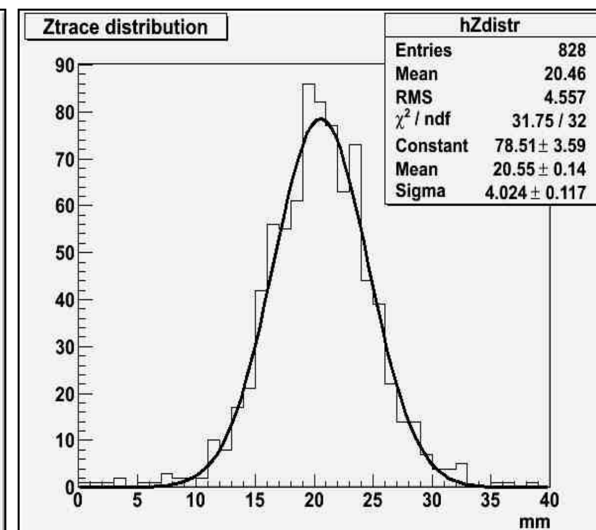


Z coordinate is calculated from the drift time of the electrons produced after the passage of the particles.

We fit the 8 points of the Chamber trace with a line. Considering the values of this line, we can recostruct the beam spot at the center of the Chamber



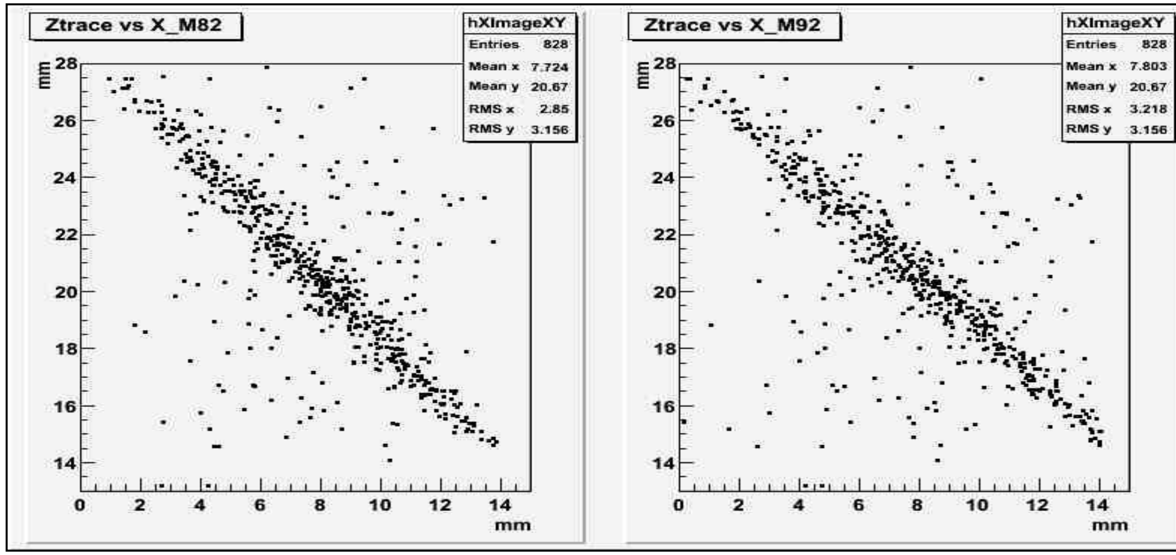




Beam Z profile

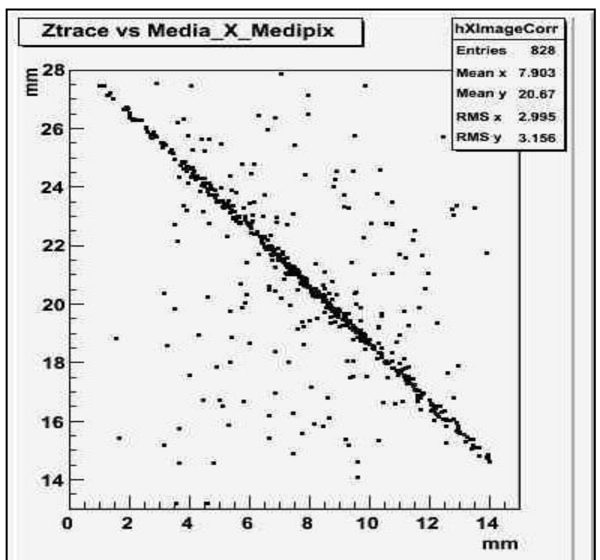
Correlation between TPC GEM & Medipix

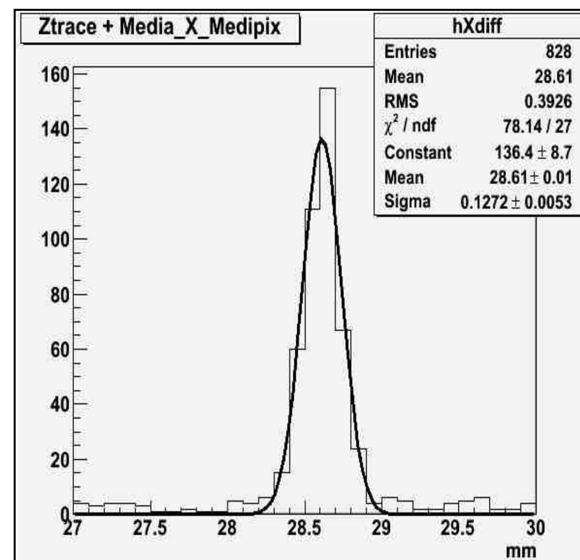
Correlation between the Z obtained at the center of the Chamber from the linear fit and the y coordinate of the beam on the two medipixes.



Left: Correlation between the Z obtained at the center of the Chamber from the linear fit and the media of the y coordinates of the two medipixes.

Right: Distribution of residuals (Z-media Y medipixes).

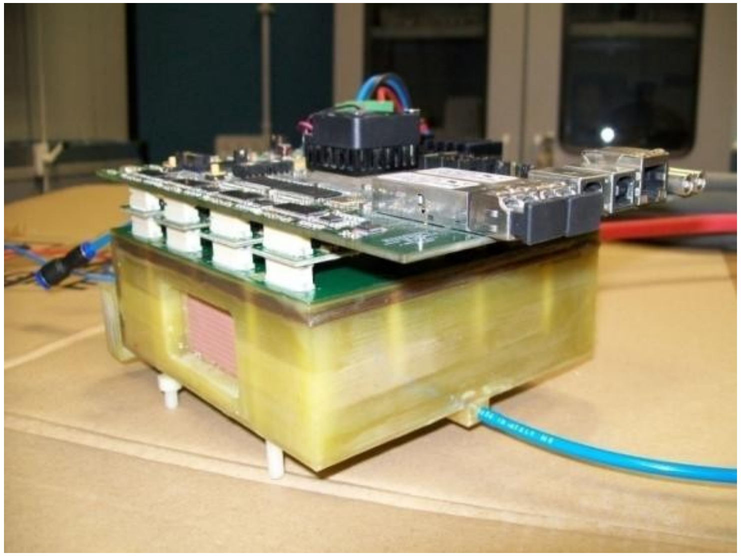




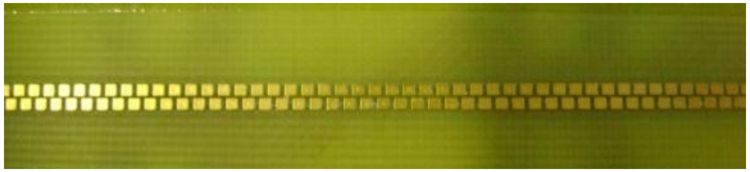
Beam Profile Reconstruction for continuos beam

TPC GEM for beam profiles

Now Low Voltage (LV) supply and readout electronics are substituted by an FPGA Mather Board, with an Ethernet connection so that LV control and data readout can be made directly on line.



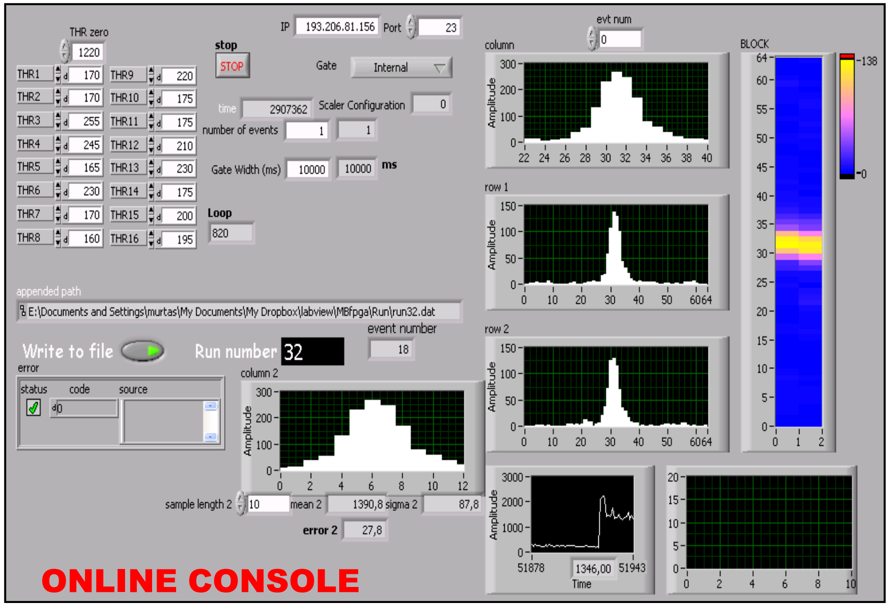
FPGA Mather Board

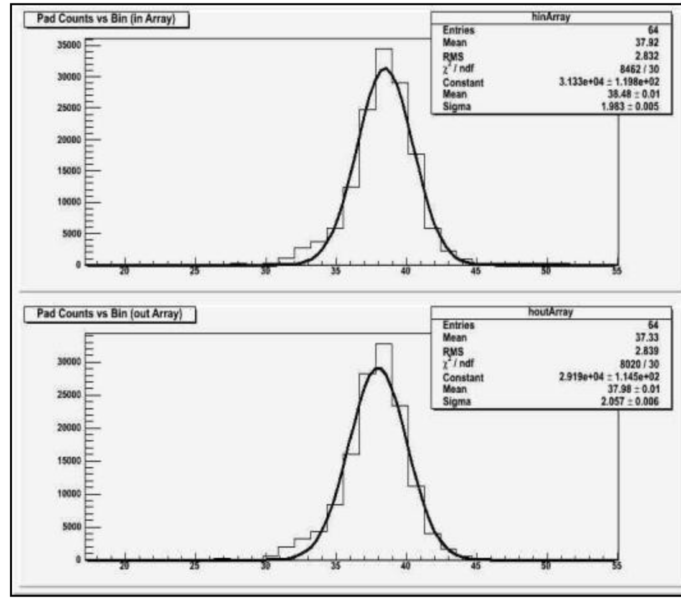


PADs are distributed along two lines. Each line contains 64 square PADs. A single PAD has an dimension **of 1x1 mm^2 and a pitch of 1.15 mm**.

The FPGA Mather Board is able to count the hits for all the 128 PAD channels sending the data **directly through ethernet**.

Beam profile reconstruction

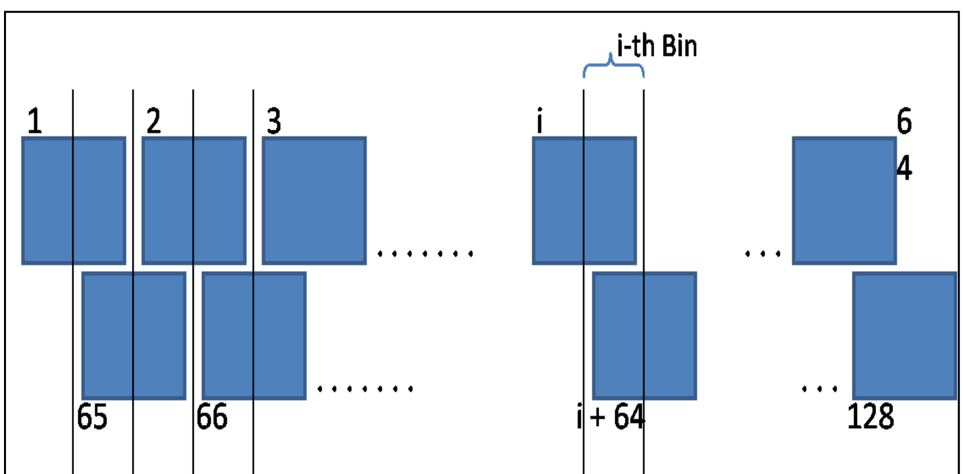


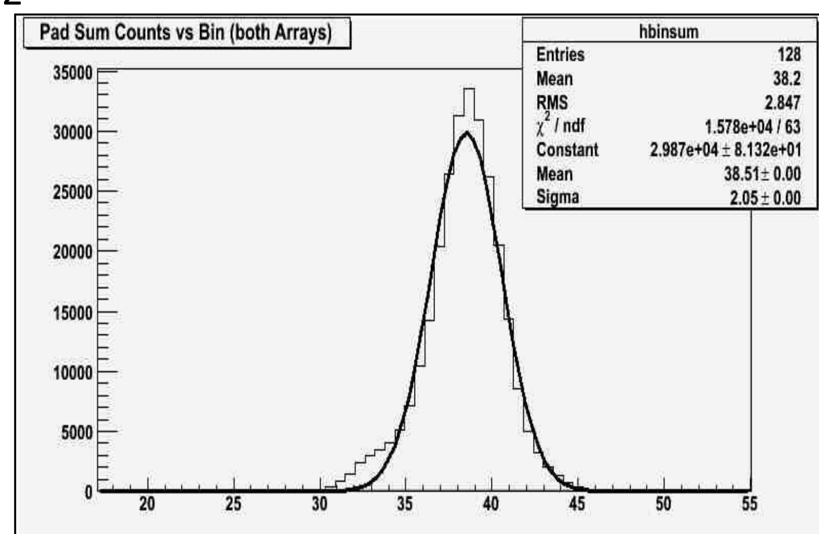


In Array (mm)

Out Array (mm)

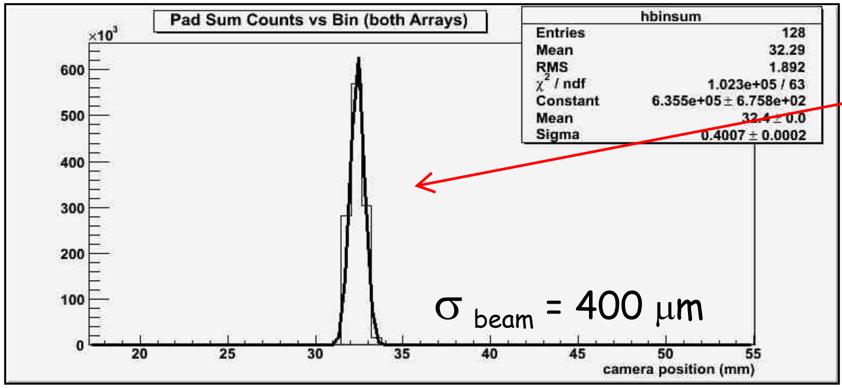
i-th bin Counts = (pad i Counts)/2 + (pad (i + 64) Counts)/2



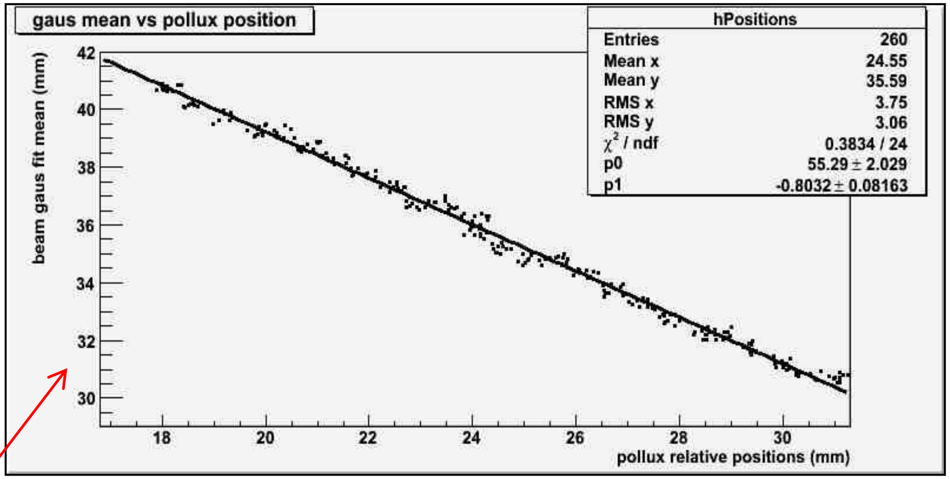


Beam Position Measurements

For this measurement we use a policapillary semilens in order to obtain a thin beam of X rays.

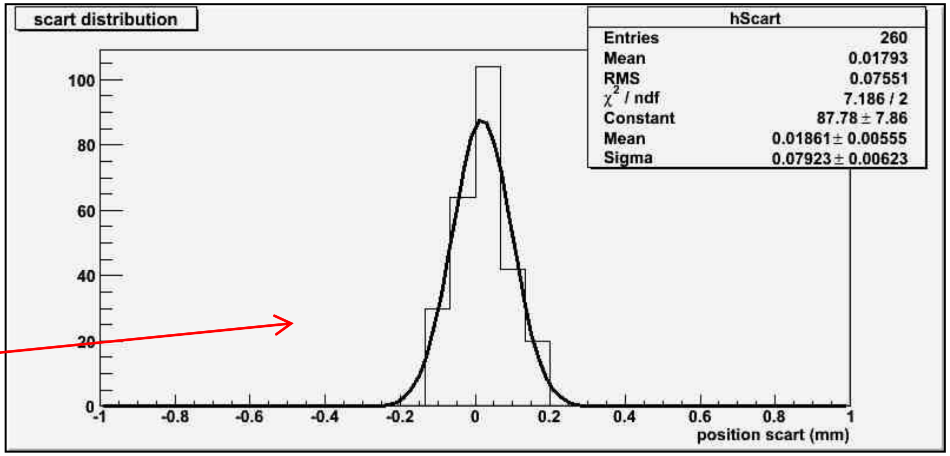


The Chamber is mounted on a mobile support. Moving it at regular steps of 0.50 mm, the event is detected at each position.



Given the thin beam profile, we make a gaussian fit and we take its mean value as a measurements of the beam position detected by the Chamber.

The distributions of the differnce between the detected position and theoretical position resulting from the linear fit.

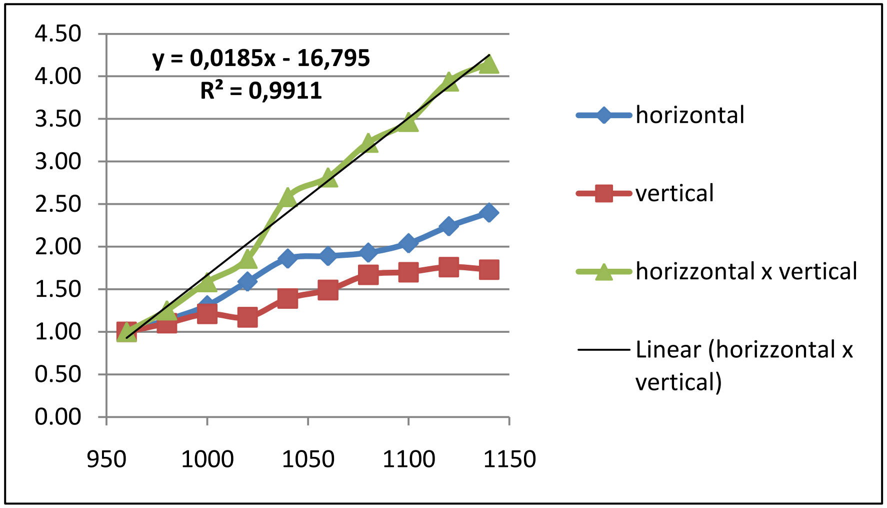


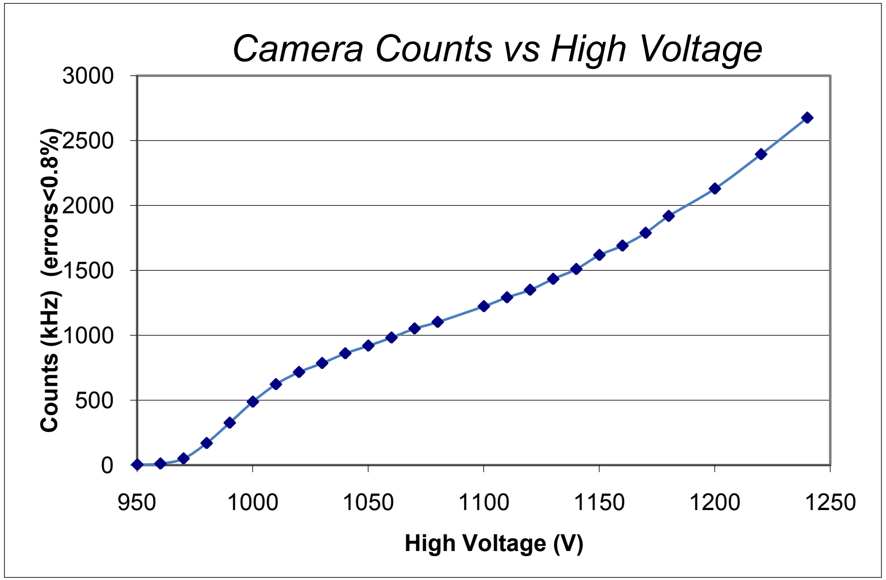
As a result we obtain a spatial resolution of about 80 μm.

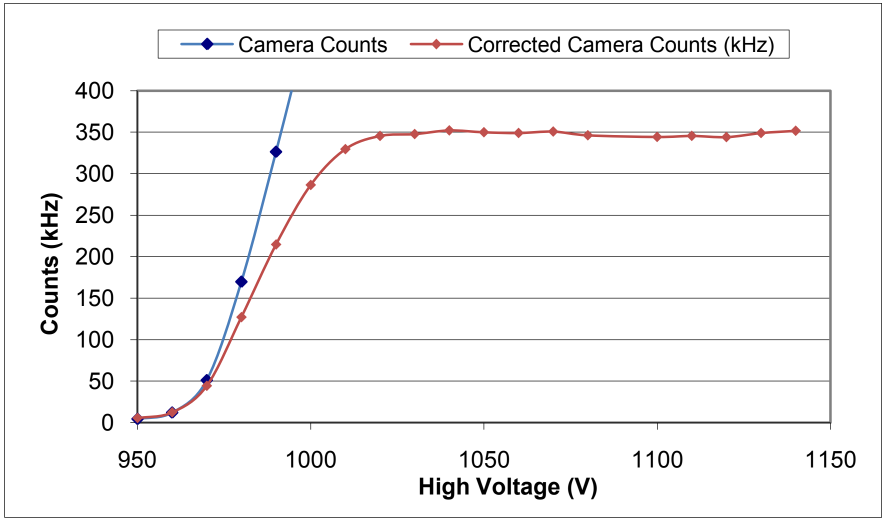
Plateau with $ArCO_2$

Cluster size: an event can cause more than one count on a PAD (vertical cluster size) and lighting of more than one PAD (horizontal cluster size).

To obtain the correct Camera counts, it is necessary to divide these counts by the total cluster size (vertical x horizontal).



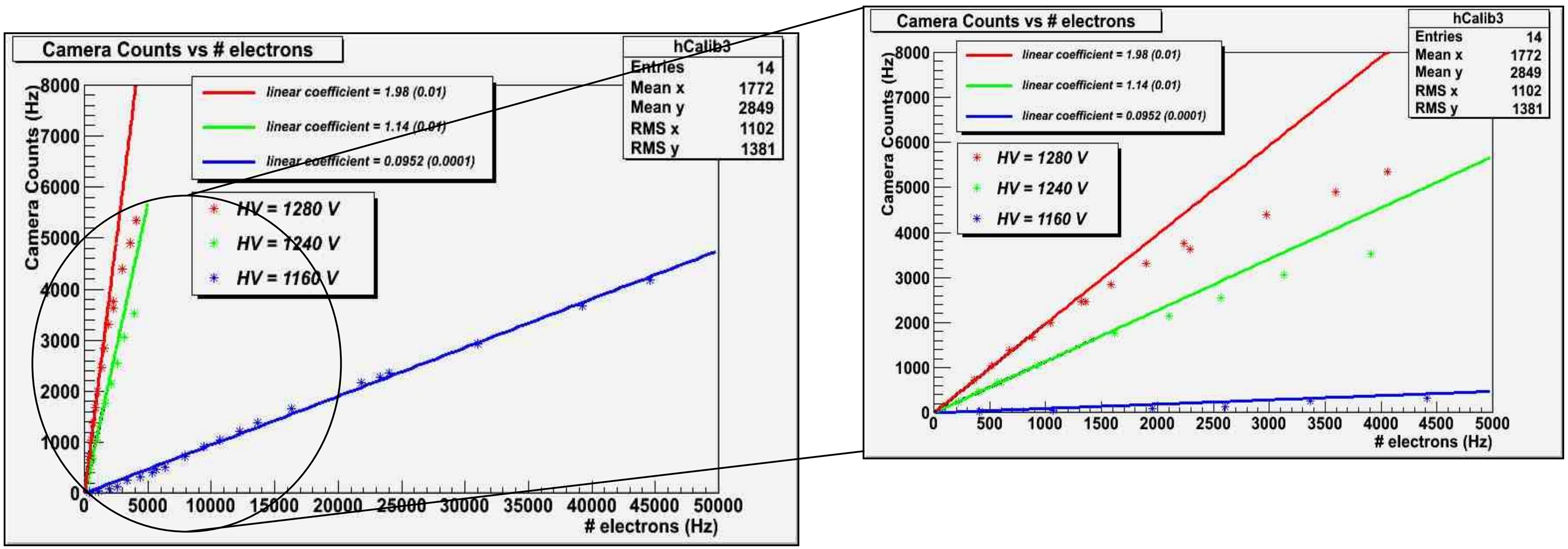




Chamber counts reach a plateau at 1020 V

Beam Flux Correlations at BTF

An electron bunched beam of 300 MeV electrons has been sent on the TPC measuring the total counting rate with three different High Voltages.

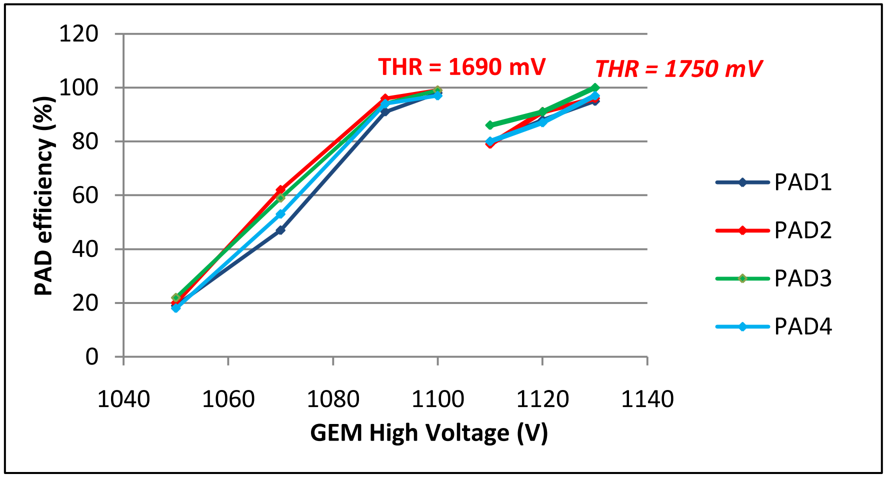


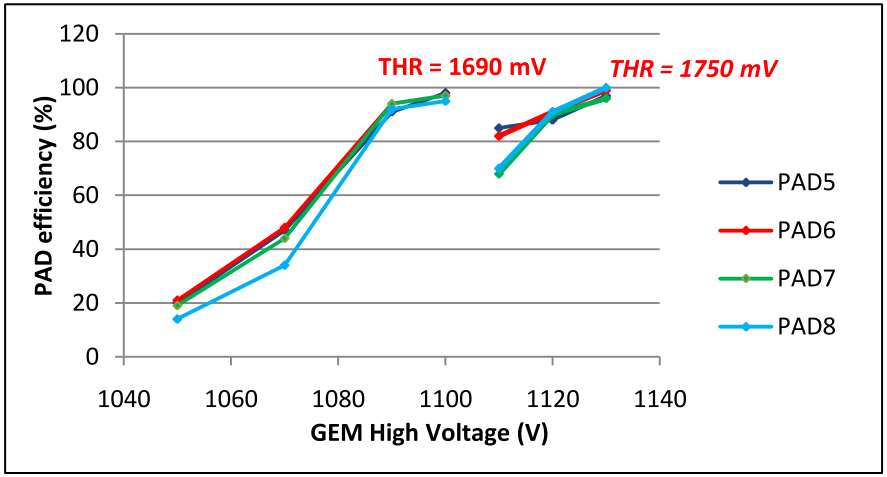
At high voltage, linearity is observed only for low beam fluxes.

Thus we operate a linear fit only on the first part of the plot in order to obtain the linear calibration coefficient of the Chamber from the linear coefficient of the fit.

PAD efficiencies with electrons

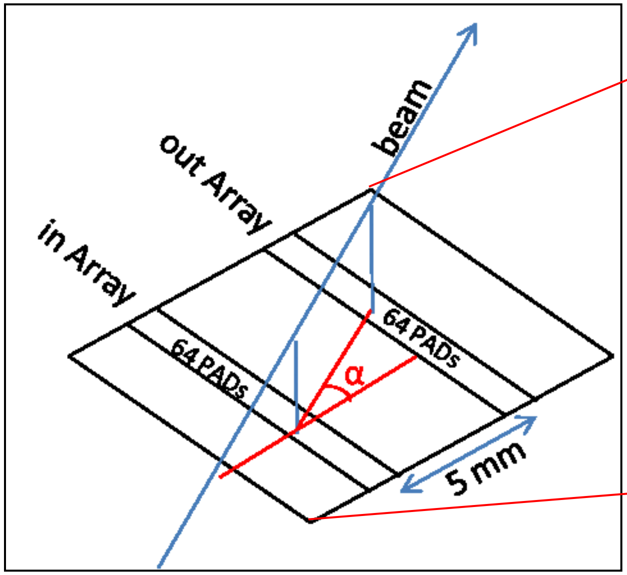
PAD efficiency is determined for the 8 PADs where beam flux is maximum.
We obtain two curves at two different values of threshold: **1690 mV** and **1750 mV**.

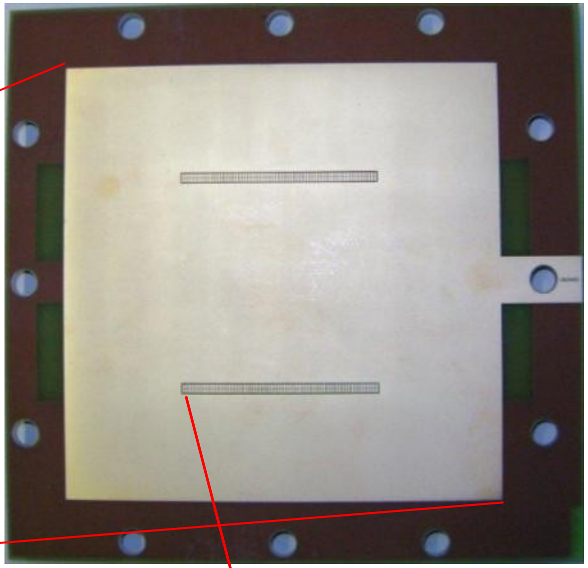


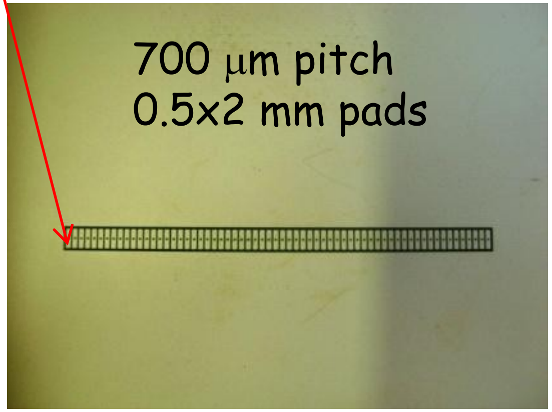


Next developments

We are going to realize 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 Monitor Summary

- ✓ TPC GEM is a versatile compact detector wirh negligible effects on detected beam (only 0.2% X_0)
- ✓ the FPGA based Mather Board semplifies the Data Acquisition and its power supply can be provided by a simple portable swicth pawer pack with a noise lower than the linear power supplier
- ✓ with a 16x8 PADs matrix, in bunched beam it is possible a 3D track recostruction with 80 μm resolution in Z coordinate
- ✓ with 2x64 PADs row lines, it is possible to reconstruct a contiunuos beam profile, determine the position with 80 μm resolution and 14 mrad angular resolution
- ✓ the beam intensity has been measured with a good linearity up to 2000 electrons per bunch (the maximum allowed at BTF)
- ✓ read-out electronics shows a low Carioca Card sensitivity (< 10 mV/fC)
- ✓ with the new pad layout it possible to measure the beam direction with an angular resolution of about 15 mrad

Neutron Detectors

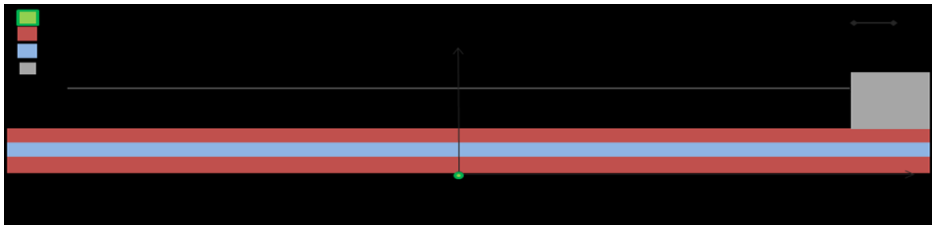
-Fast Neutron Detectors

-Thermal Neutron Detectors

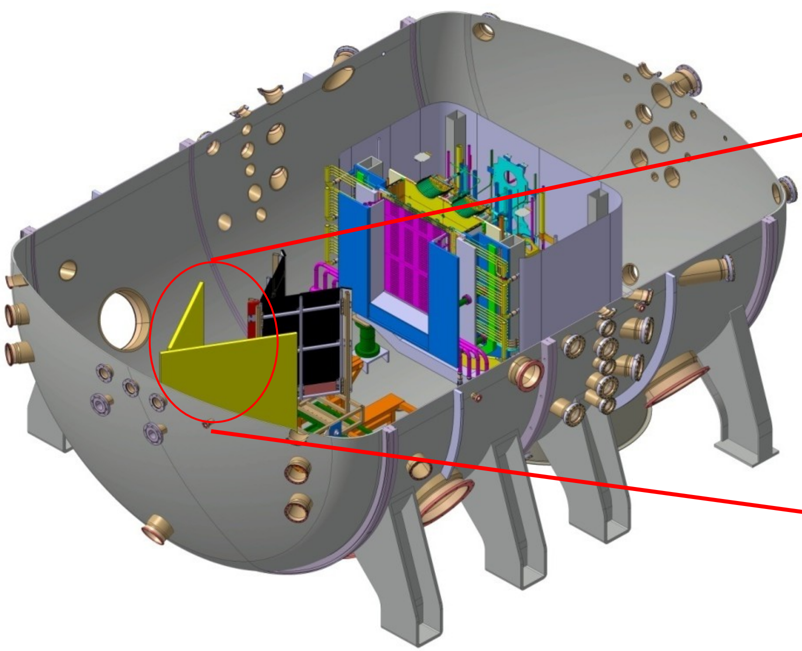
Fast Neutron Detectors

The SPIDER Facility Beam Dump

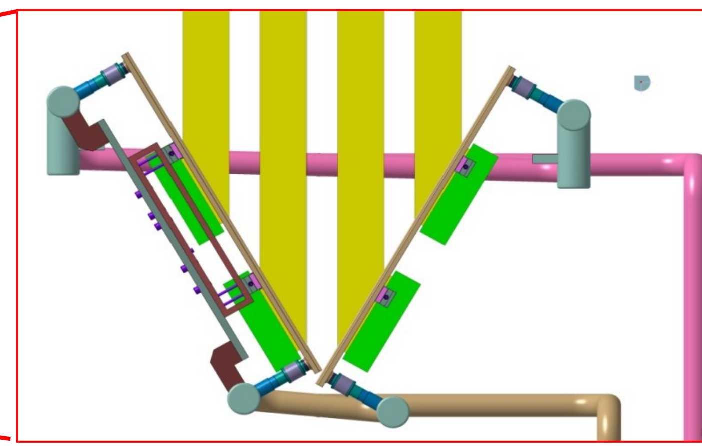
The SPIDER beam dump is composed by three layers: the two external layers are composed by CuCrZn alloy (99% Cu) and the central one contains water. The beam dump is inclined by 30 degrees with respect to the deuterium beam direction.



First CuCrZn thickness = 5.8 mm
Water layer thickness = 6.2 mm
First CuCrZn thickness = 5.8 mm



The SPIDER facility

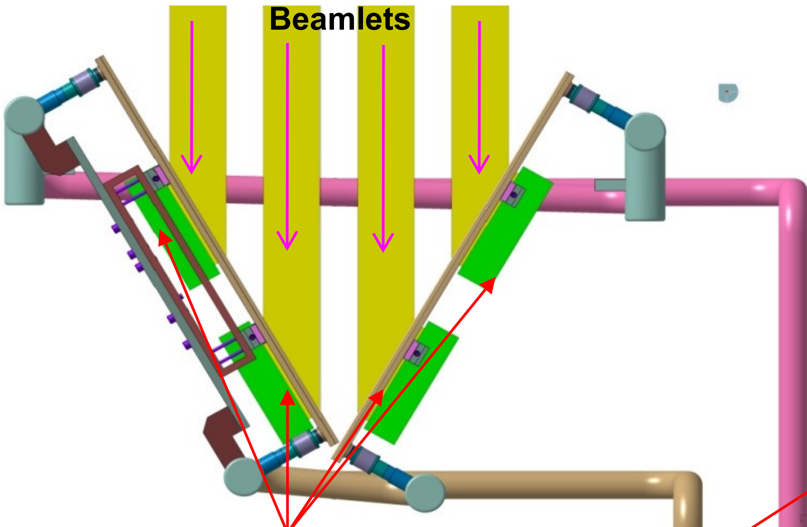


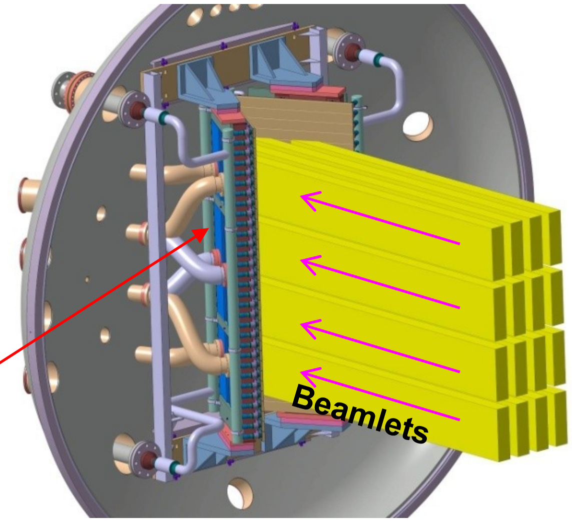
The beamlets composition of the deuterium beam

The Diagnostic system: the nGEM detectors

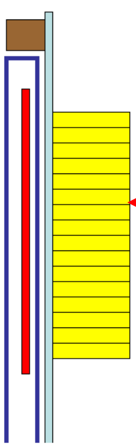
- Triple GEM detector (standard GEM foil)
- GEM foil dimensions : 35.2 cm x 20 cm
- 3 mm/ 1 mm / 2 mm/ 1 mm Gaps
- Pads readout with 16*10 = 160 pads
- Pad dimensions 20 x 22 mm^2 → 2 pads per beamlet
- Al or Cu Cathode equipped with a polyethene (CH_2) layer used to convert neutrons into protons
- Gas mixture Ar/CO_2 70%/30%
- Active LHCb type power supply (HV GEM)
- FE Electronics: CARIOCA (open to other counting chip solution)
- Installed behind the beam dump in a tank at room pressure, at a 30 cm from the neutron sources *(the beam dump is in vacuum)*
- Gas pipes and HV cables reach the detector passing into a tube that connects the tank with outside

Localization of the detectors units

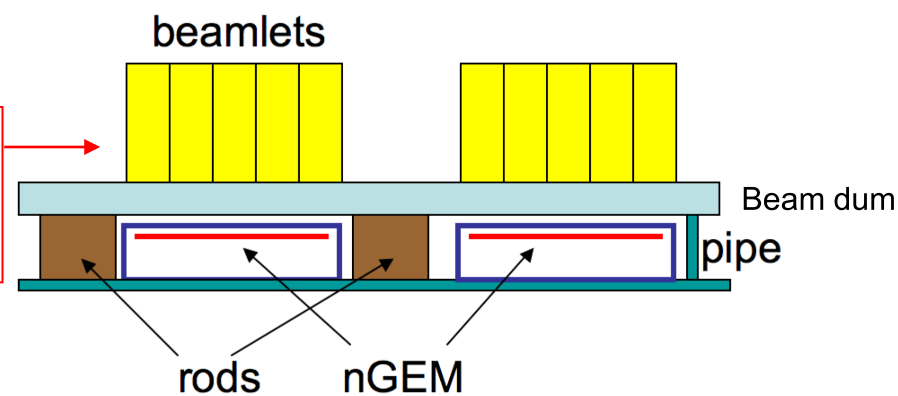




Detector boxes just behind the beam dump

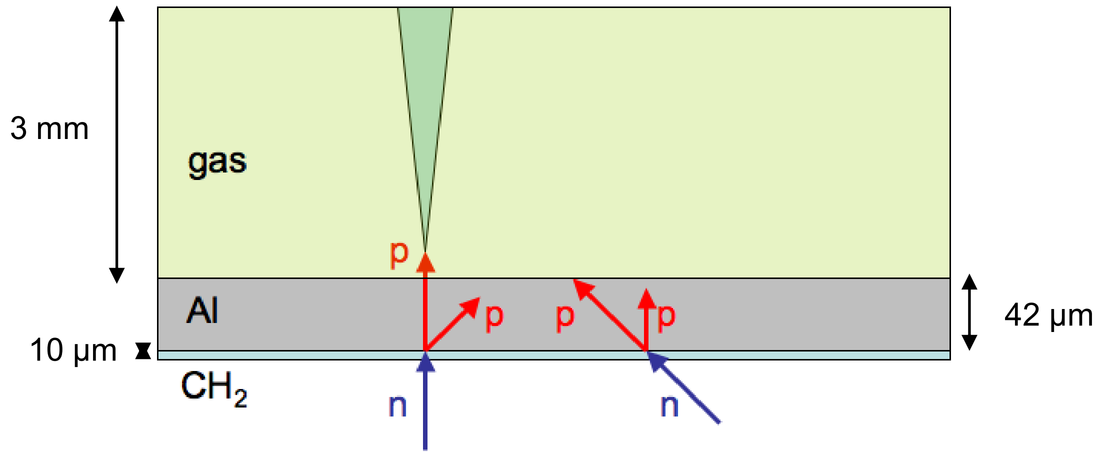


Side and top views of the nGEM location facing the beamlet footprints on the SPIDER beam dump.



The new Cathode (Al-CH_2) n/p converter

CH_2 converts neutron into protons due to the high hydrogen relative concentration (n-p reaction)



The energy cut is needed in order to preserve the beamlets composition of the original beam

Intensity flux variation measurement
2 pads associated with one beamlet

Only protons, that are emitted perpendicularly to the CH_2 layer and that are generated by neutrons impinging normally to the CH_2 surface, give information about intensity variation

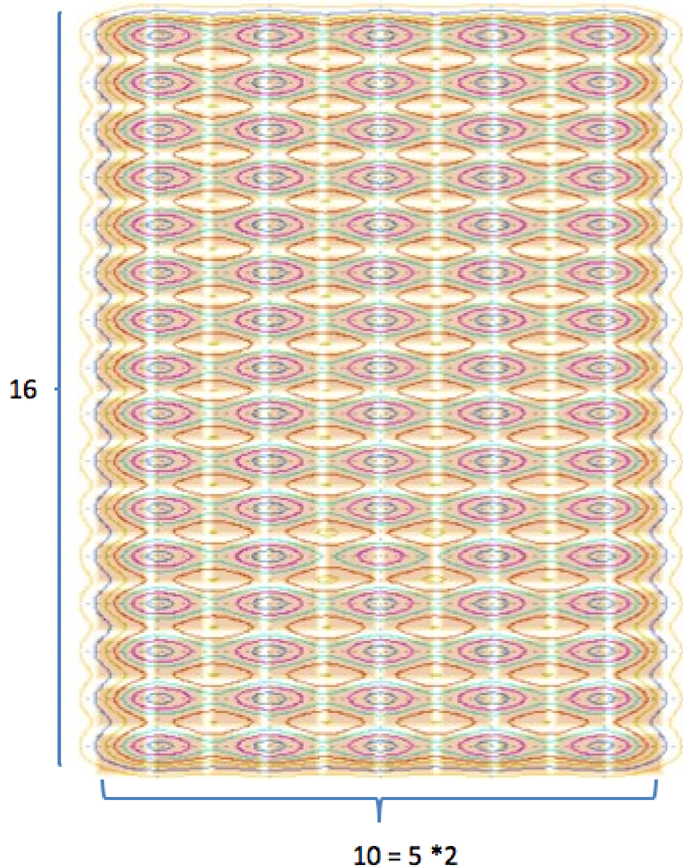
The Al layer thickness is optimized in order to stop all the protons that are not normally emitted → When entering the gas, "good" protons have a residual energy of 1.42 MeV (from neutrons of 2.45 MeV) → A track is created into the gas and in 3 mm gap an average energy of about 60 keV is released.

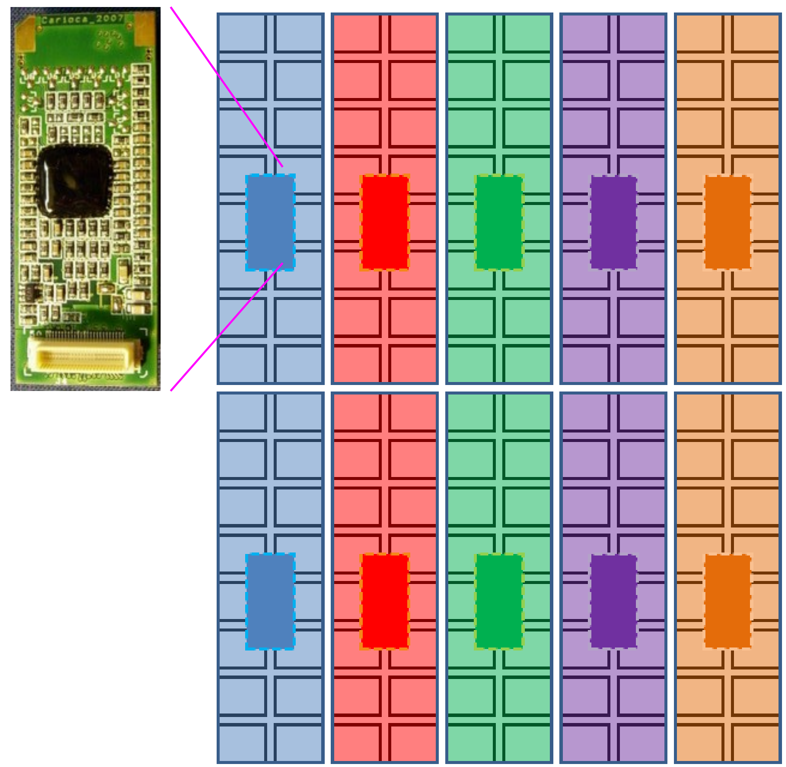
<u>Simulation are in progress in Frascati (ENEA) and Milano (CNR – University of Milano Bicocca)</u>

Sketch of the first prototype: Readout

Read-Out Pads – Dimensions
Distance between pads 0.1 mm

Read-Out Pads – CARIOCA Sectors
Each Carioca reads a sector made by 16 pads
10 Cariocas used to read-out 10 sectors

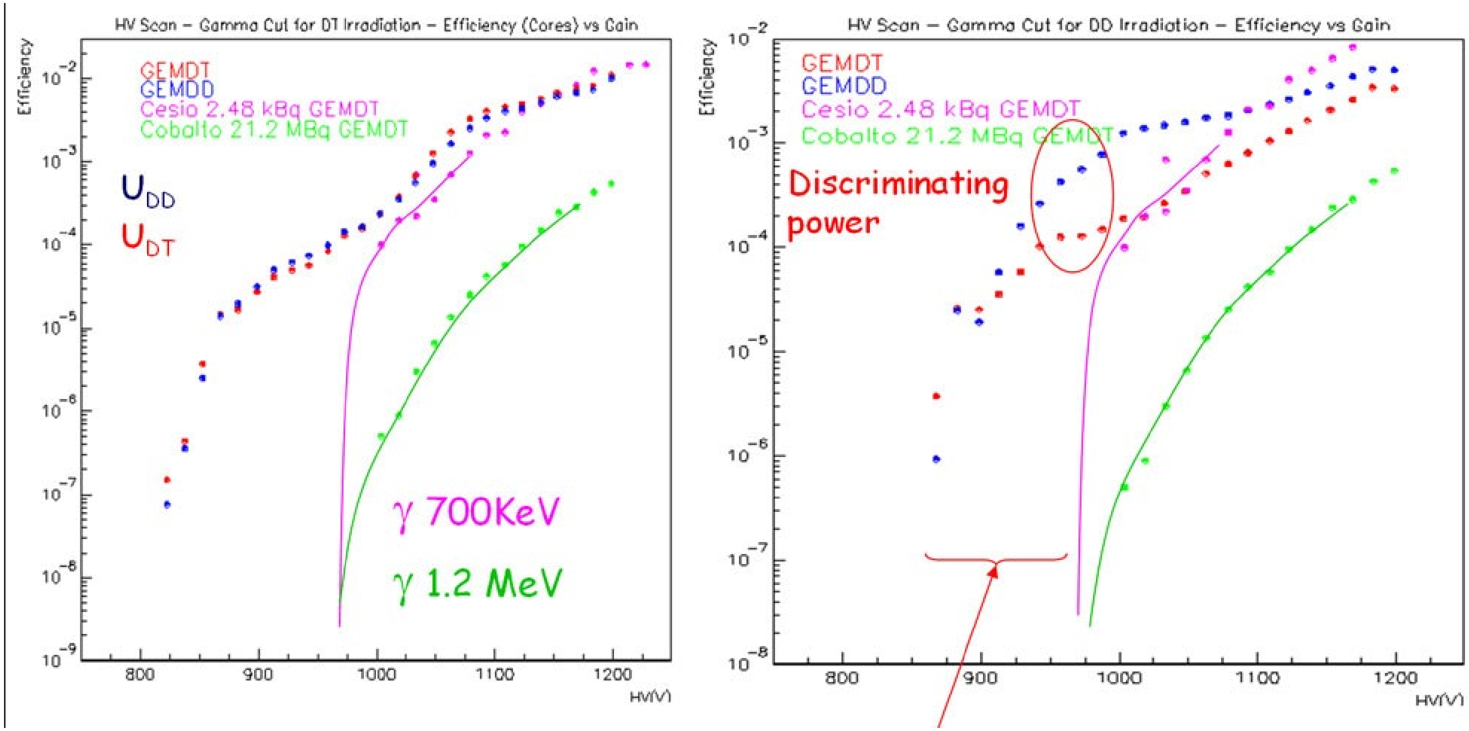




Each beamlet is facing two pads

Previous measurements with a nGEM detector prototype for fusion application

The active area of this monitor has been divided into two parts with the neutron converter optimized for the two energies 2.4 and 14 MeV: the efficiency measurements (see the figure below) shows not only a zone at low gain with no photons contamination but also a good discrimination between the two types of neutrons.



B. Esposito et Al, “Design of a GEM-based detector for the measurement of fast neutrons”, NIM A, 617 (2010), 155 - 157

Gain Region in which the nGEM is able to fully discriminate between neutrons and gammas

Thermal Neutron Detectors

Beam Monitor for high flux neutron beam at ISIS

Istituto di Fisica del Plasma "Piero Caldirola" — Consiglio Nazionale delle Ricerche

INFN Istituto Nazionale di Fisica Nucleare — Laboratori Nazionali di Frascati

Triple GEM detector equipped with an aluminium cathode coated with few microns of B_4C

Active area:

-5 cm x 5 cm

-10 cm x 10 cm

128 channels

Exploit the 10B(n,alfa)7Li reaction in order to detect thermal neutrons

Low efficiency detector → 1% is sufficient since the neutron flux is very high (>10^6 n/cm^2 s)

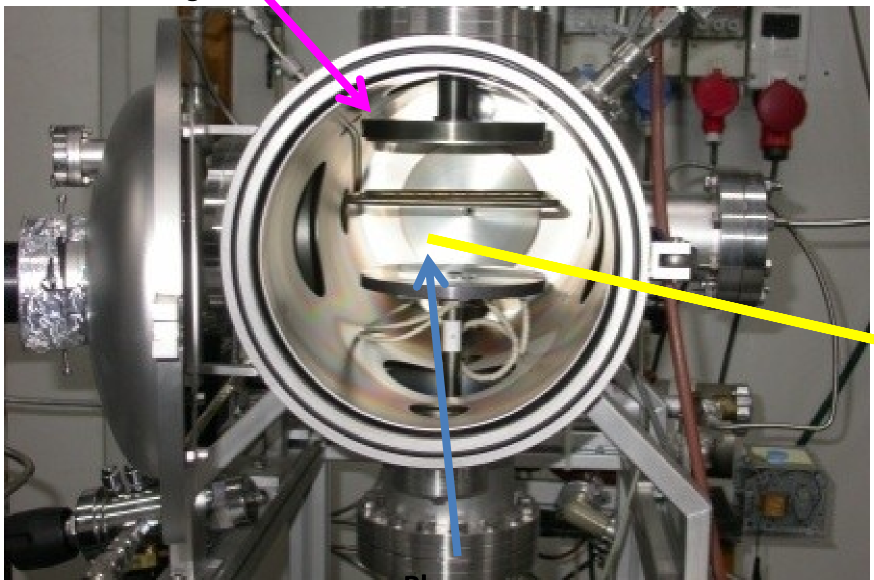
Boron Carbide deposition technique developed at IFP (Istituto di Fisica del Plasma) - CNR

Istituto di Fisica del Plasma "Piero Caldirola" Consiglio Nazionale delle Ricerche

RF plasma sputtering system

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati

B_4C target

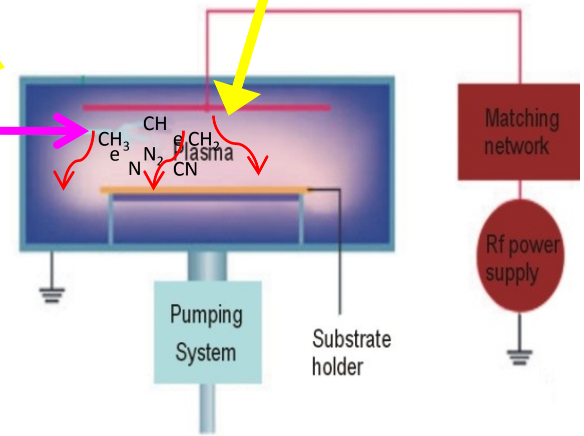


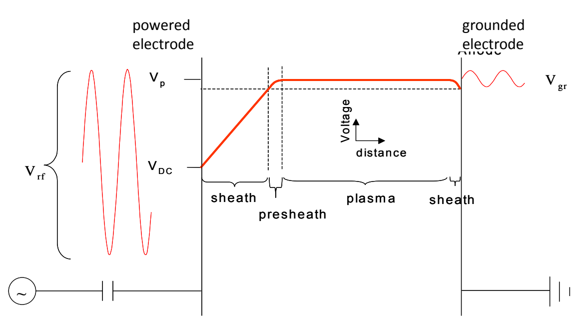
Plasma deposition area

Courtesy of E. Vassallo (IFP-CNR)

Atoms, Radicals Molecules , Ions and Electrons

Gas injection





Time-average voltage profile across electrodes in rf discharge

Istituto di Fisica del Plasma "Piero Caldirola"
Consiglio Nazionale delle Ricerche

First results

Fig 1-2 show a cross-sectional view of the B-based coating grown at a power of 200 W and at a pressure of 0.8 Pa. The thickness of the multilayered coating is about 400 nm. The thickness for every single layer is about 100 nm. The multilayered coating exhibits a good interlayer contact and a compact structure with dense and fine grained structure without columnar geometry which is important for the layer properties such as hardness or corrosion resistance.

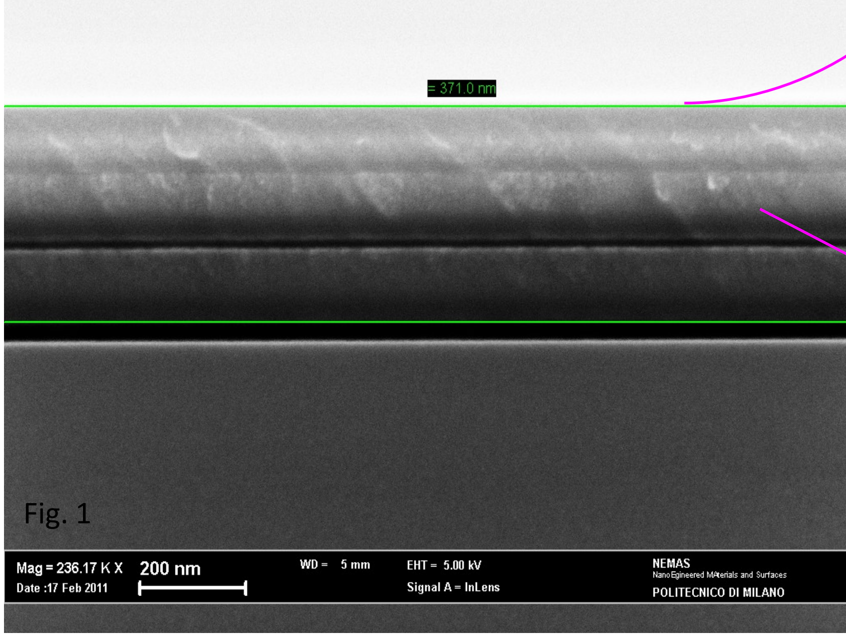


Fig. 1

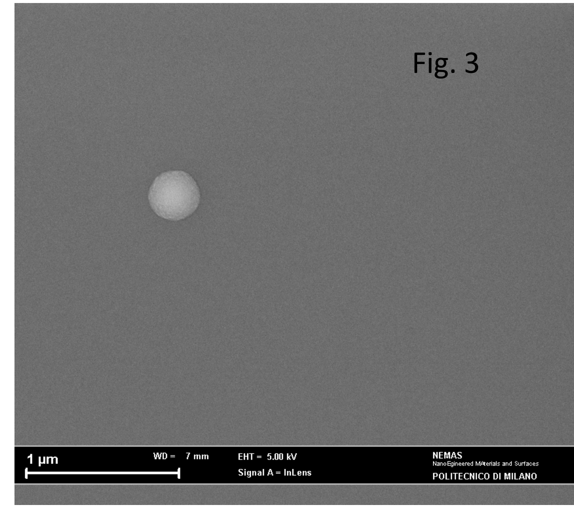


Fig. 3

The surface morphology of the coating (Fig. 3) exhibits a fine grain sizes and a dense structure.

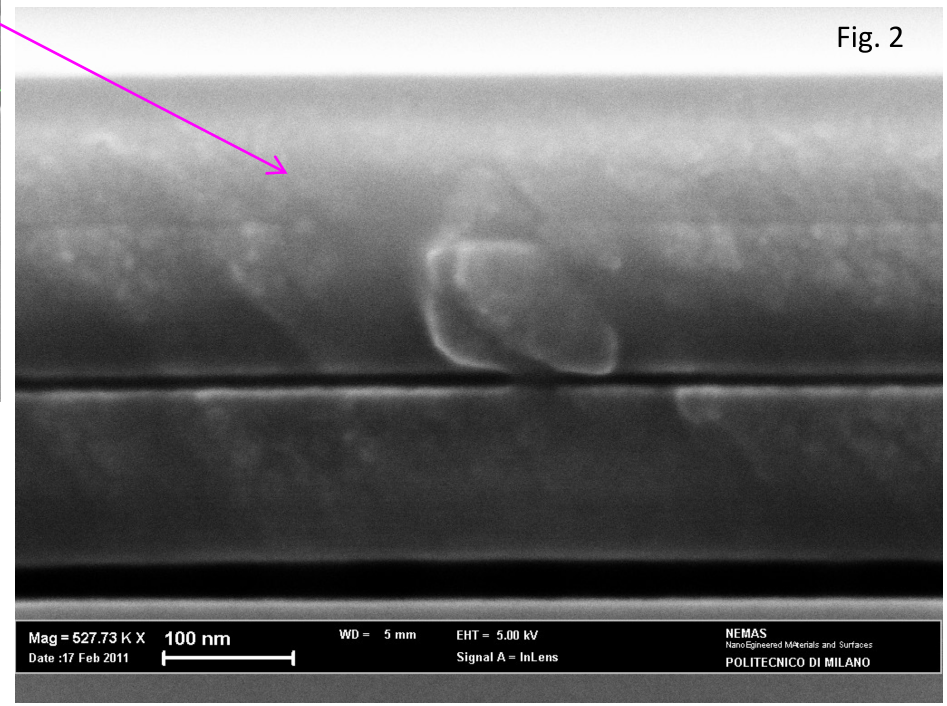


Fig. 2

IFP Istituto di Fisica del Plasma "Piero Caldirola" Consiglio Nazionale delle Ricerche

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati

Possible electronics for these detectors

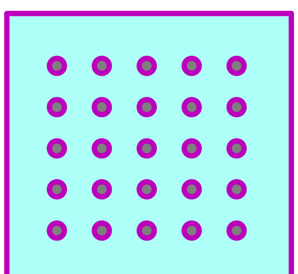
1) Carioca
2) Development of a new chip
3) Evolution of SPACIROC

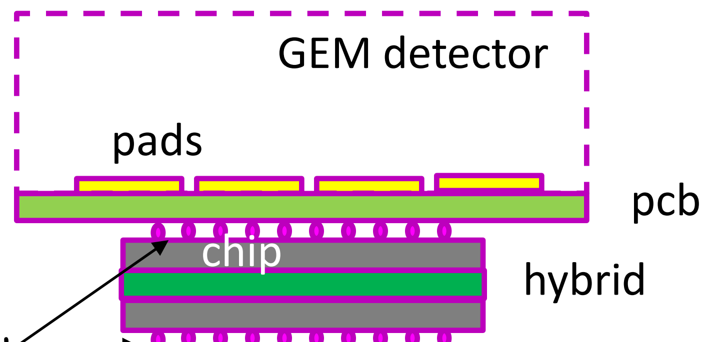
New electronics for GEM detectors

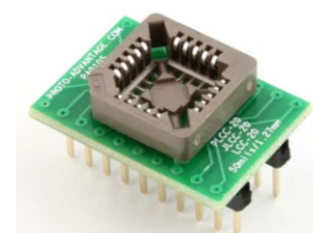
It should be a counting device similar to Medipix but with a channel density of about 1ch/mm^2 :

- Optimized for GEM detector (generally from silicon detector or wire chambers)
- Sensitivity between 10 fC up to 1 pC
- Time gate between 1 μs and 10 sec (internal or external)
- Preamp, Discrimination and counting
- Double threshold for energy measurements
- Matrix structure for low assembling cost
- input channel pins (through a socket)
- output channels pins (through a socket)
- First stage of the project : 16-25 channels in a 16x16 mm^2 → the goal is to reach 64 ch

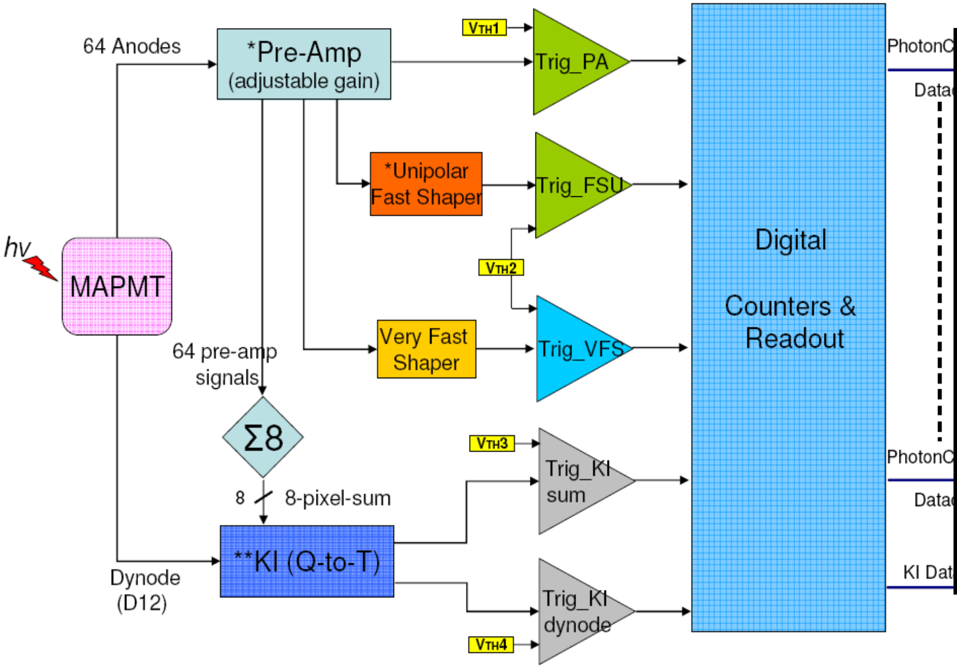
In collaboration with A. Baschirotto (Università di Milano Bicocca)







SPACIROC Architecture



64 Channels Counting & Charge Integrators

Photon Counting Triggers: FSU,VFS,PA

KI : 8-pixel-sum , Last Dynode (used with PMT)

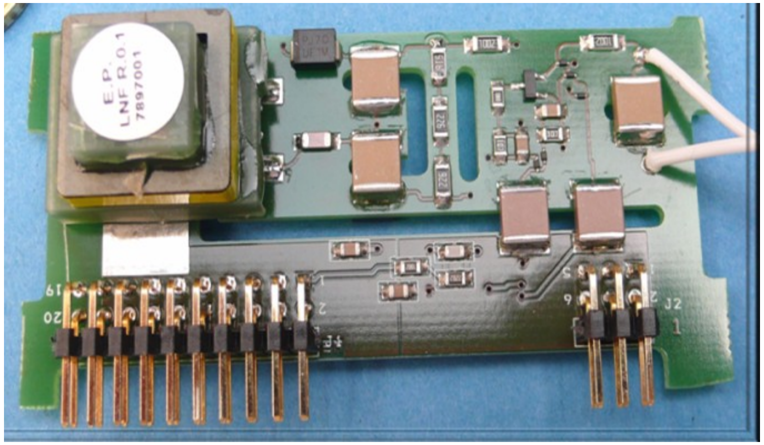
1mW/Channel

576-bit counters data

Courtesy of Pierre Barrillon (IN2P3-OMEGA LAL Orsay, France)

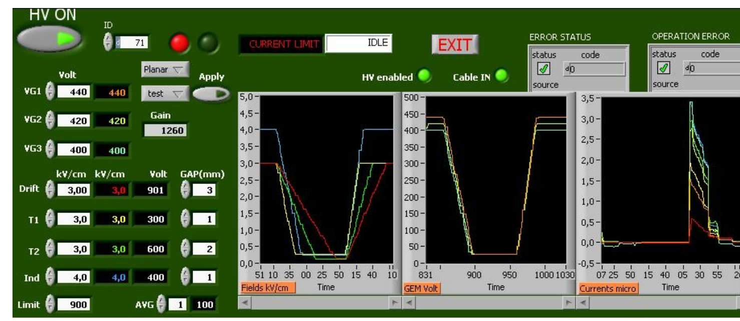
HV GEM NIM Module

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati



- 7 independent channels full isolation at 5kV vs GND.
- Standard NIM, Mechanical and Power Supply.
- USB & CAN-OPEN protocol communication.
- Programmable HV

6CH	0 to 700V	max 150μA
1CH	0 to 1400V	max 100μA



- Limit current protection programmable common for all channels.
- 7 independent channel of current readout High Sensitivity

  low scale: from 10nA to 6μA
  high scale: from 100nA to 40μA

Conclusions – Neutrons and Electronics

Fast Neutrons:

Proposal (T3.22/d1) already presented to RFX concerning the use of nGEM detectors in spider → Accepted!!

Building and test of a 10x10 chamber equipped with the new kind of n/p converter cathode → Efficiency measurements at FNG in Frascati (2011)

Ongoing MCNPX and GEANT4 simulations

Thermal Neutrons:

Deposition system being optimized for deposition over aluminium

Building of a test chamber (5cm x 5cm) once the cathode is ready

Laboratory and beam tests

Ongoing MCNPX and GEANT4 simulations

R&D on new counting chips is going to start very soon → we are open to everybody that is interested in joining efforts!!

If interested please contact me (gabriele.croci@mib.infn.it) or F. Murtas (fabrizio.murtas@lnf.infn.it)