INFN – SEZIONE DI MILANO-BICOCCA
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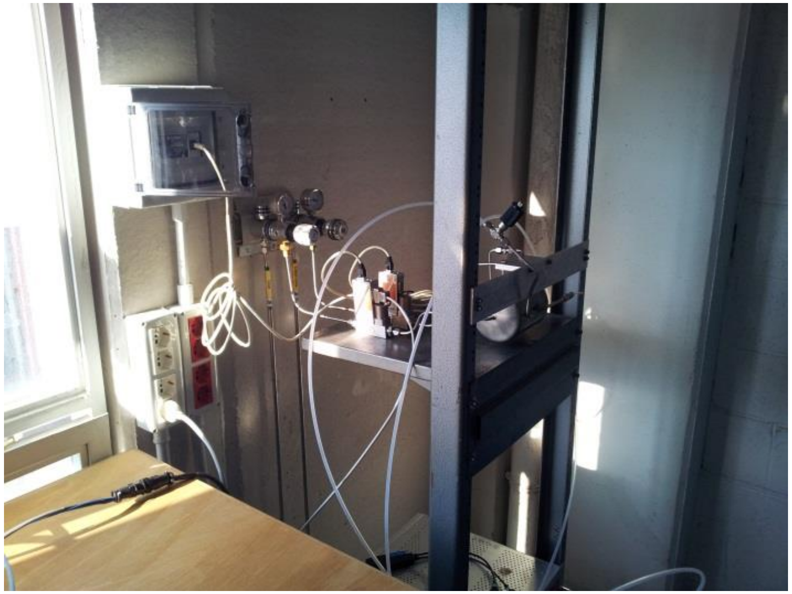
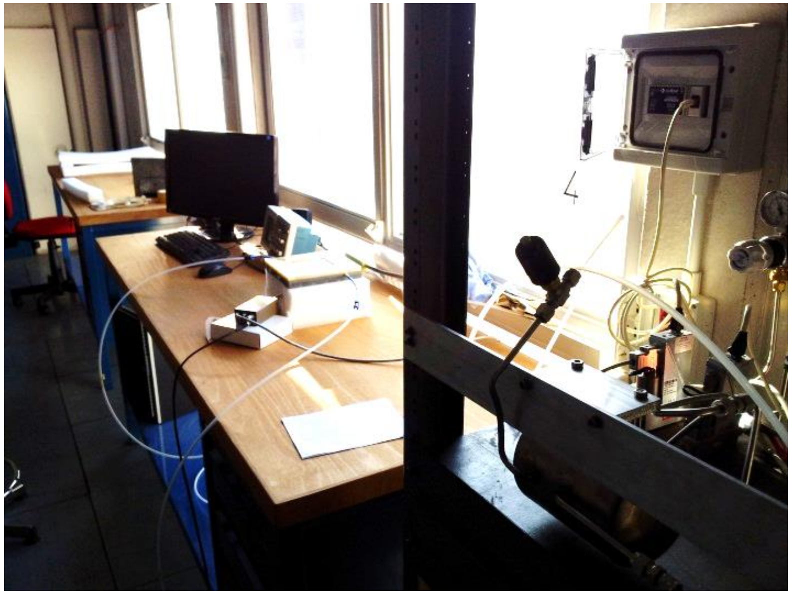
  - C. Cazzaniga
  - A. Muraro
  - G. Albani

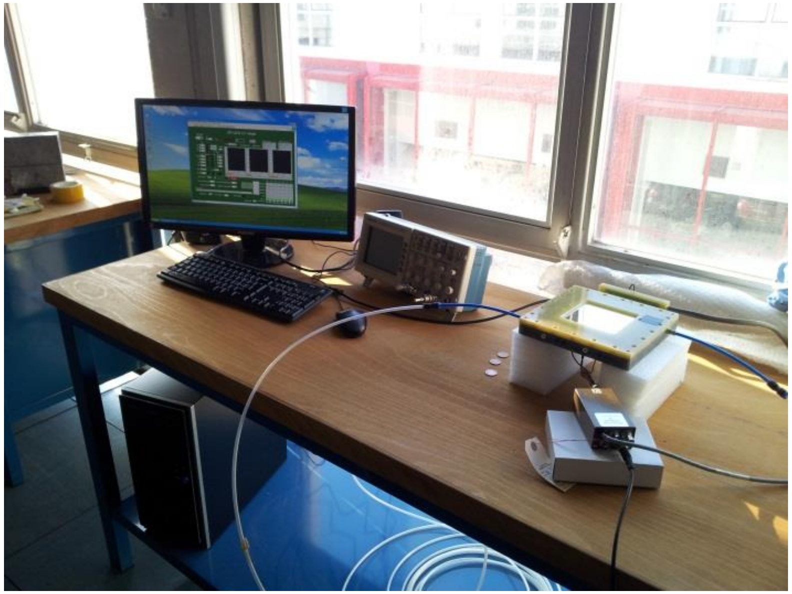
Main Activities

- Neutron and gamma spectroscopy on fusion reactors (tokamaks e.g. JET and AUG)
- General research (both theoretical and experimental) on nuclear fusion
- Fast neutron beam monitors based on GEM and diamond detector for spallation neutron sources and for fusion reactor experiments(e.g. ChipIR @ ISIS and ESS and SPIDER @ RFX-Consortium)
- GEM-based thermal neutron detectors (alternative to 3He?) for spallation neutron sources
- Diagnosis of cultural heritage artifacts
- Development of scintillation, solid-state and gas based detectors for different applications
- Development and realization of the new GEMINI chip for GEM readout

GEM laboratory







Ar-CO_2 mixing gas system
Ortec Mini-X X-Rays tube with shielding
Radioactive sources
^{55}Fe
^{137}Cs
^{60}Co
^{22}Na
^{241}Am
GEM powered using HV-GEM and readout using CARIOCA + FPGA-MB

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

UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

INFN Istituto Nazionale di Fisica Nucleare

CONSORZIO RFX

Development of GEM-based neutron beam monitors

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OUTLINE

- Why and how to use GEM-based detectors to detect neutrons

- FAST NEUTRON DETECTORS
  - Mainframe projects
  - Prototypes construction
  - Performances on neutron beams
  - Large area detector (35 x 20 cm^2)

- THERMAL NEUTRON DETECTORS
  - Mainframe projects
  - Prototypes construction
  - Performances on neutron beams

- Conclusions and Future Perspectives

WHY AND HOW TO USE GEMS TO DETECT NEUTRONS

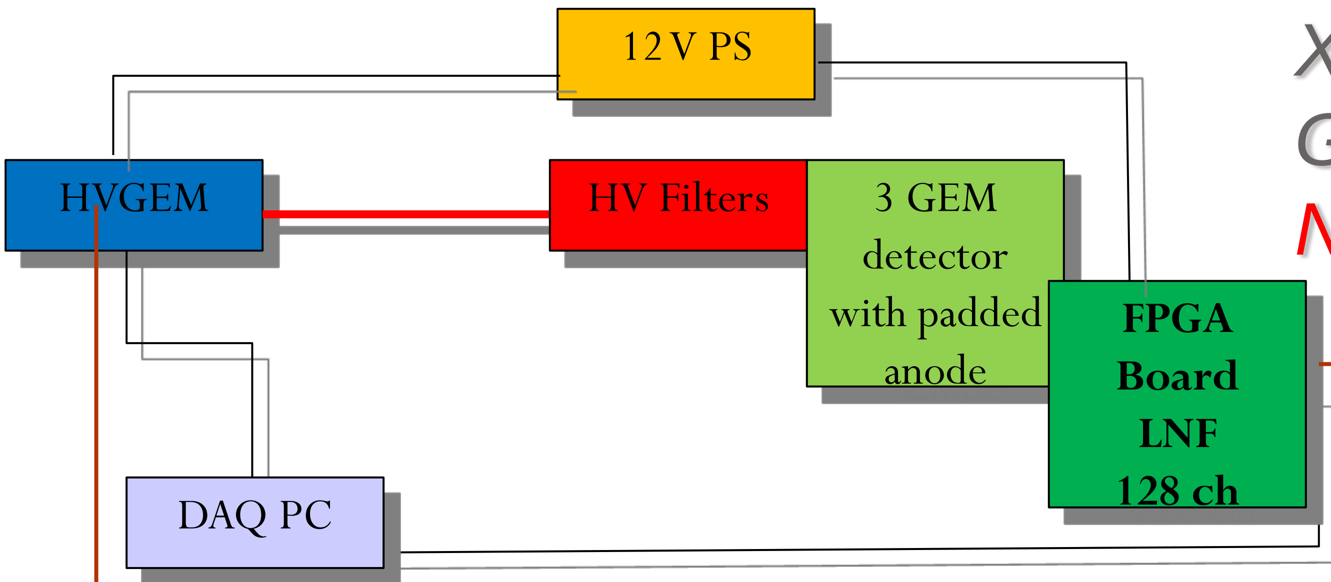
- GEM detectors born for tracking and triggering applications (detection of charged particles)

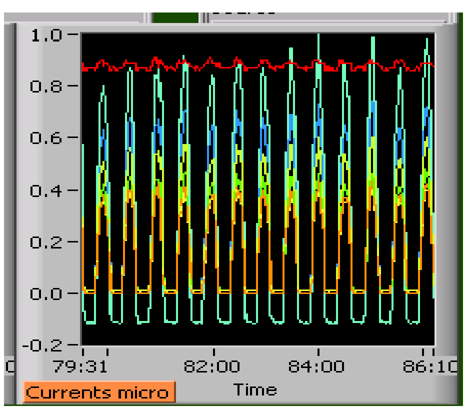
- In order to detect neutral particles you need a converter
  - Fast Neutrons: Polyethylene converter + Aluminium
    - Neutrons are converted in protons through elastic scattering on hydrogen
  - Thermal Neutrons: ^{10}Boron converter
    - Neutrons are detected using the productus (alpha,Li) from nuclear reaction ^{10}B(n,alpha)7Li

- GEMs offer the following advantages
  - Very high rate capability (MHz/mm^2) suitable for high flux neutron beams like at ESS
  - Submillimetric space resolution (suited to experiment requirements)
  - Time resolution from 5 ns (gas mixture dependent)
  - Possibility to be realized in large areas and in different shapes
  - Radiation hardness
  - Low sensitivity to gamma rays (with appropriate gain)

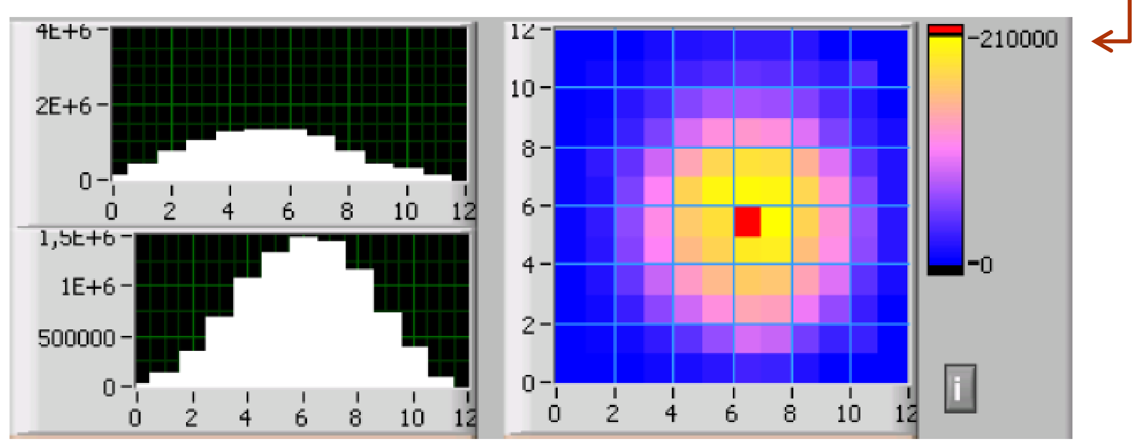
Complete GEM detector system

Charged particles
X Ray
Gammas
Neutrons





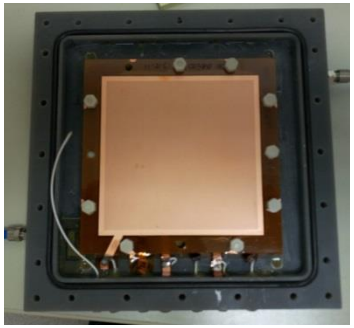
Current Monitor



2D monitor with pads readout
Possibility to set time slices from 5 ns up to 1 s

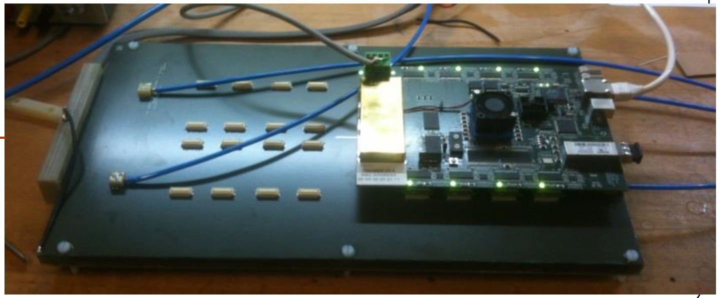
nGEM (fast neutrons GEM) prototypes

4 Prototypes of nGEM have been built and tested so far with Gas Mixture Ar/CO_2 & $Ar/CO_2/CF_4$



- **1 «Analogue» Prototype (nGEM-S-1)**
  - 100 cm^2 active area
  - Cathode: Aluminium (40 μm) + Polyethylene (60 μm)
- **2 Small area Digital Prototypes** (10x10 cm^2 – nGEM-S-2/3)
  - nGEM-S-2
    - Cathode: Aluminium (40 μm) + Polyethylene (60 μm)
    - Gas Ar/CO_2 & $Ar/CO_2/CF_4$
  - nGEM-S-3 (same cathode as full size prototype)
    - Cathode: Aluminium (50 μm) + Polyethylene (100 μm)

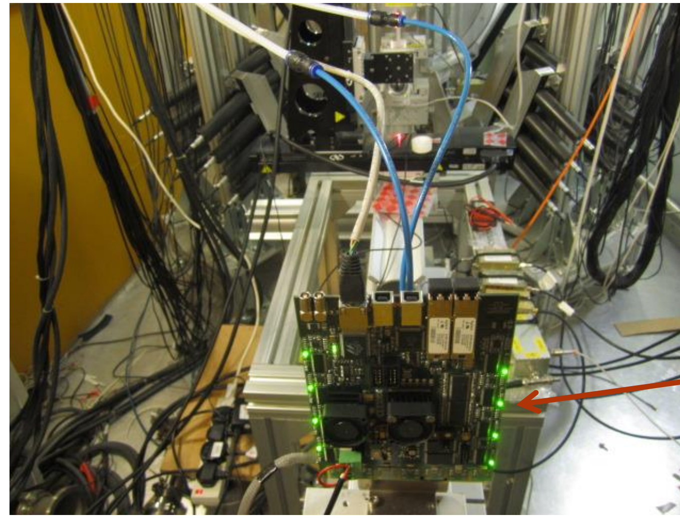
- **1 Full-Size SPIDER prototype (nGEM-FS-1)**
    - Cathode: Aluminium (50 μm) + Polyethylene (100 μm)
    - 20 x 35 cm^2 active area



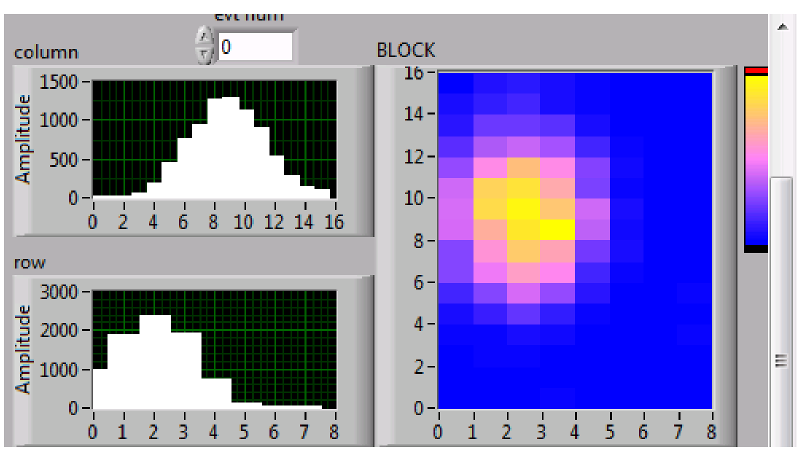
Real-time 2D beam map measurements

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

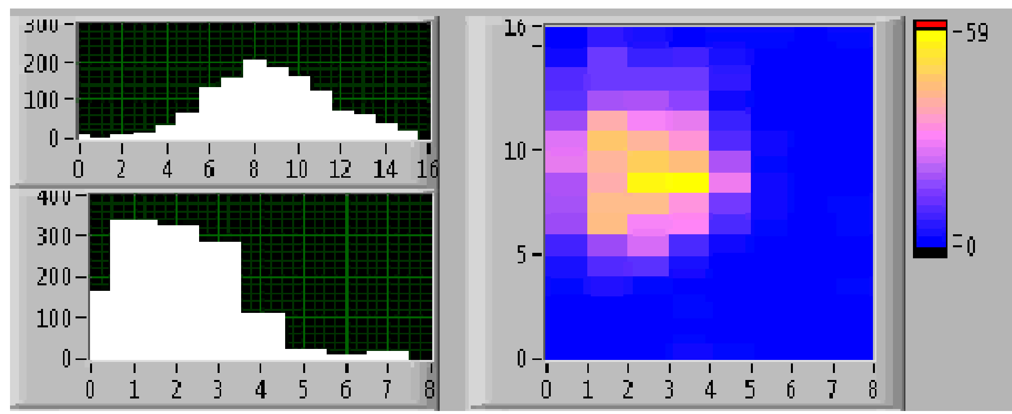
Tested at neutron beam of the Vesuvio facility at RAL-ISIS



nGEM-S-2

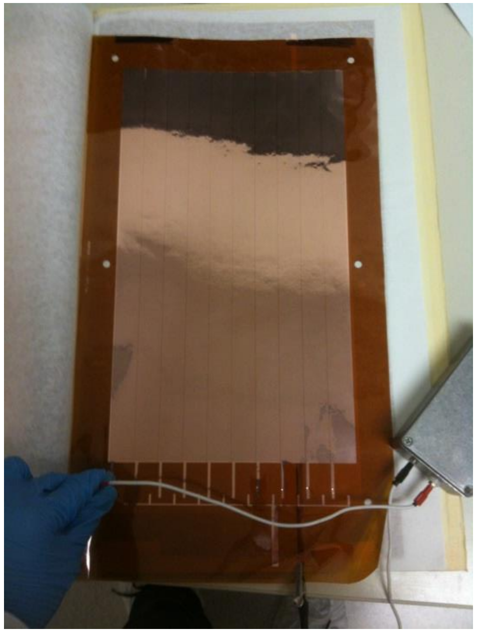


2D Beam profiles and intensity in real time

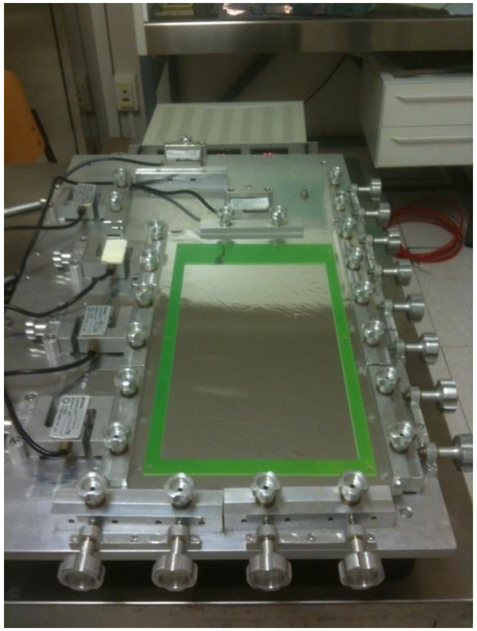


Neutron beam monitorig during the shutter opening

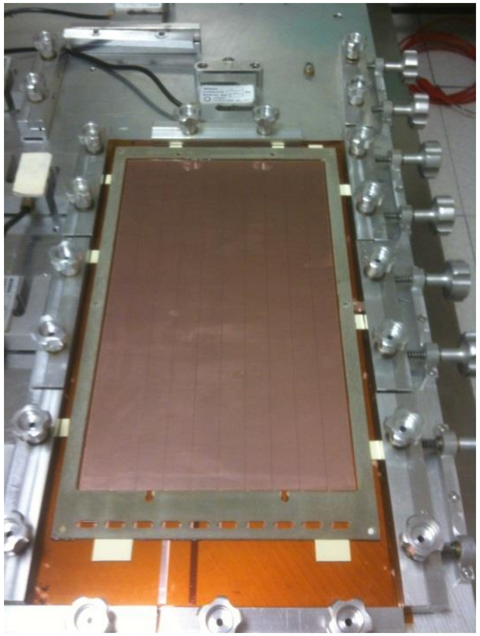
First nGEM full size prototype for SPIDER



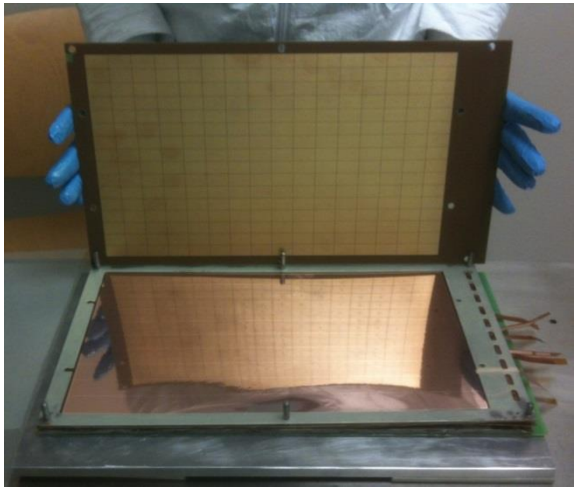
GEM Foil HV Test



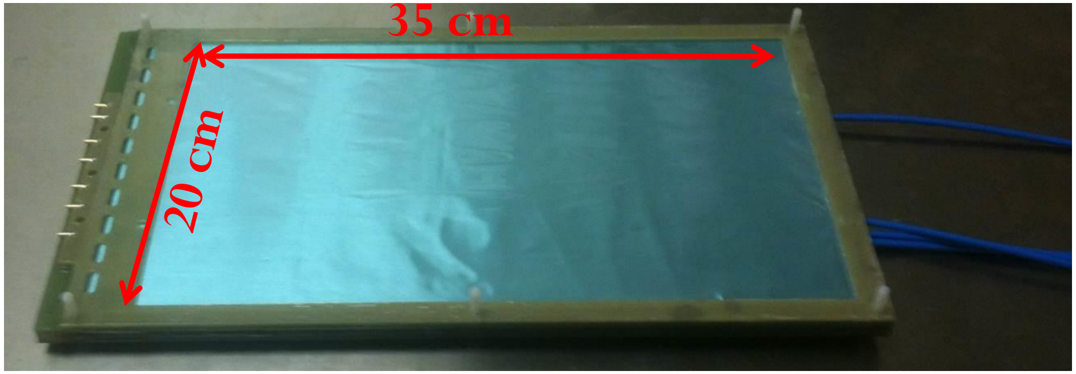
Cathode Stretching and Framing



GEM Stretching and Framing



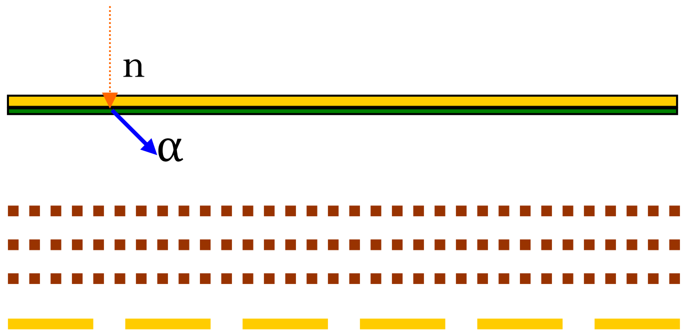
Assembly 256 Pads



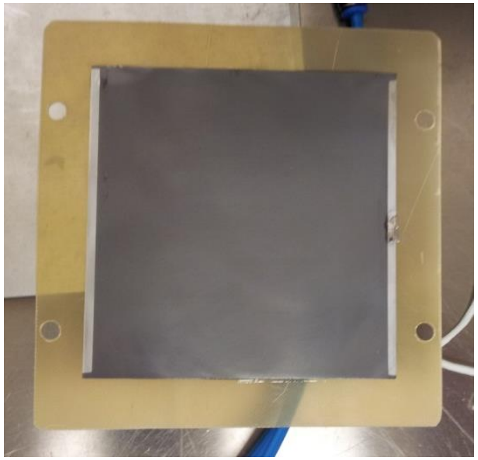
At the moment it is the largest area GEM-based fast neutron detector!!!!

bGEM prototype of thermal neutron beam monitor

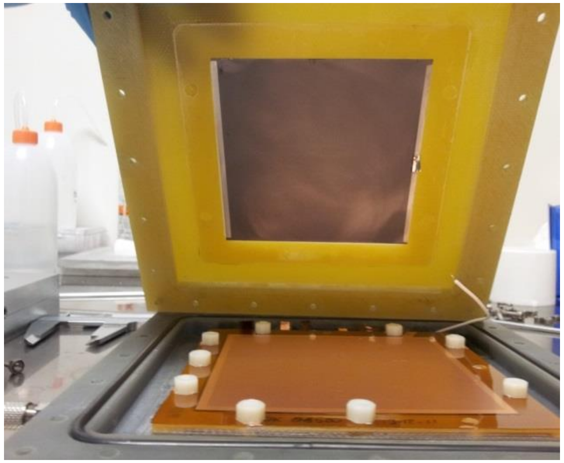
- Triple GEM detector equipped with an aluminum cathode coated with 1μm of B_4C: first bGEM prototype
- Exploit the $^{10}B(n,\alpha)^7Li$ reaction in order to detect thermal neutrons



Detector Schematics



B_4C coated aluminium cathode mounted on its support



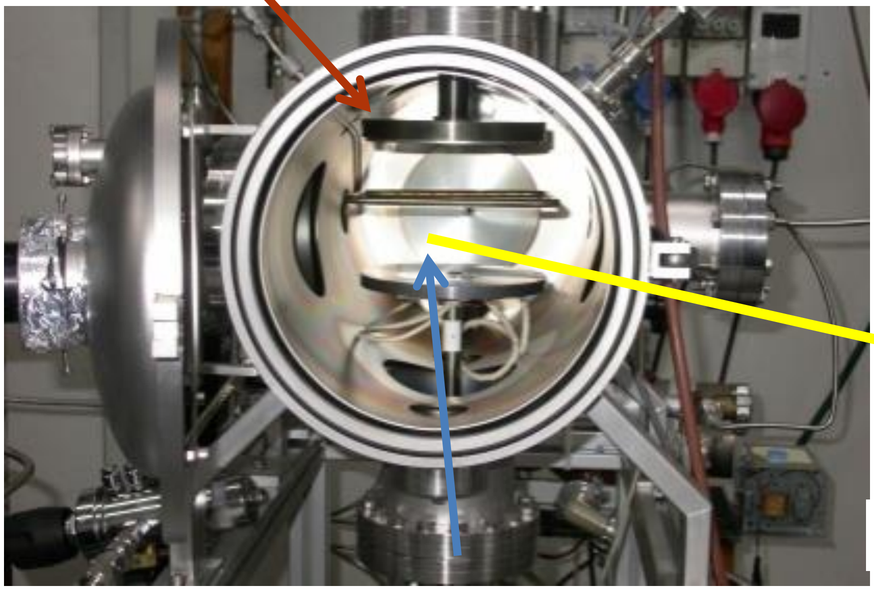
B_4C coated aluminium cathode assembled inside the bGEM chamber layout

Low efficiency detector →

1% is sufficient since the neutron flux is very high ($>10^6 n/cm^2\,s$)

RF plasma sputtering system for B_4C coating at IFP-CNR (Milano,Italy)

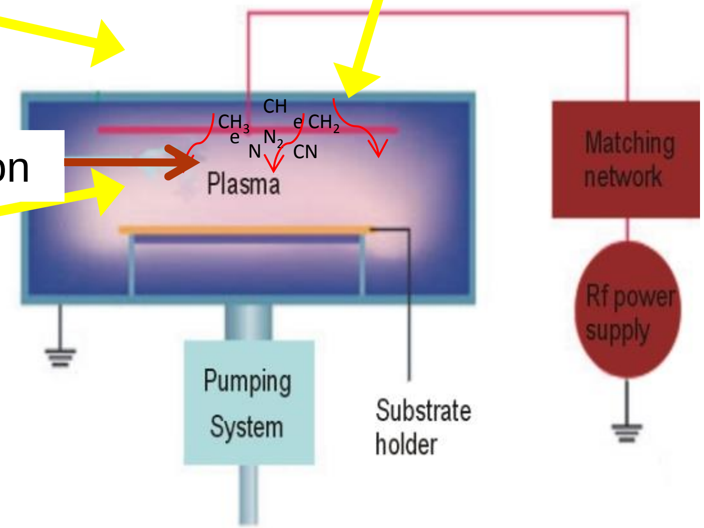
B_4C target



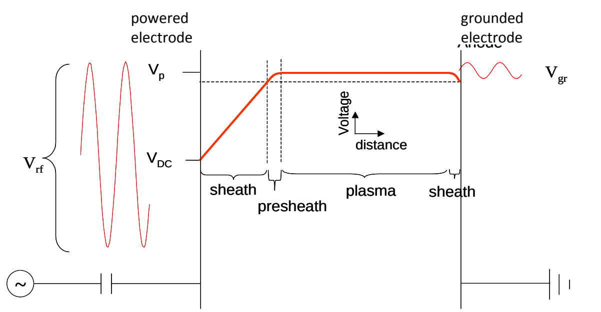
Courtesy of E. Vassallo (IFP-CNR)

Atoms, Radicals Molecules , Ions and Electrons

Gas Injection

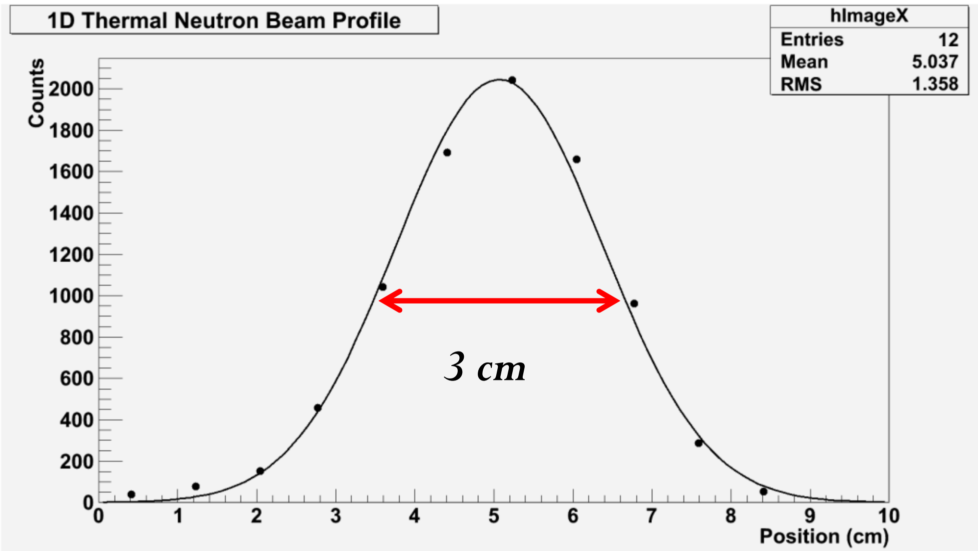


Plasma deposition area



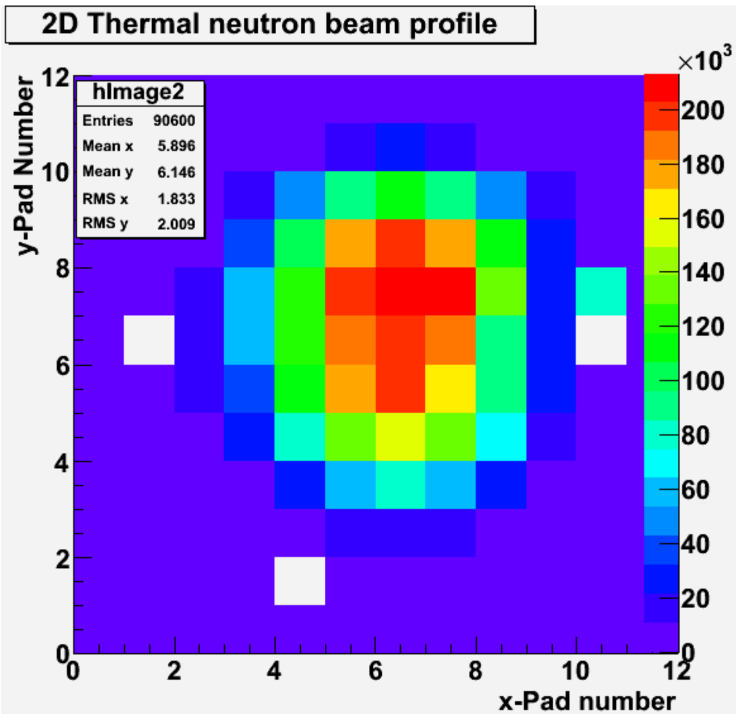
Time-average voltage profile across electrodes in rf discharge

Measurement of ISIS-vesuvio 2D thermal neutron beam profile



G. Croci et Al, NIMA (2013), In Press

The measured FWHM is around 3 cm compatible with ISIS-Vesuvio data



Future Perspectives

- **A new larger area nGEM neutron** detector for MITICA (the evolution of SPIDER) is under design and will be developed next year
- **A new high efficiency (>50%?)** thermal neutrons GEM-based detector - based on a 3D cathode of thin lamellas - for future spallation neutron sources has been designed and is currently been built. Results will be presented in the next months. This detector can represent a valid alternative to ^{3}He detectors
- We are working on a **new GEMINI chip** which will be able to increase the number of channels. The new chip can manage 32 channels, in comparison to the 8 channels of CARIOCA. This new GEMINI chip will be used to upgrade all these detectors