Neutron Beam Profile Measurements with a Triple GEM for Thermal Neutrons at the CERN n_TOF Facility

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- n_TOF facility
- Triple GEM detector for thermal neutrons
- Set up
- Results
- Conclusions
n-TOF neutron facility @CERN

- Proton intensity: $8 \times 10^{12}$ p/pulse
- Proton beam momentum: 20 GeV/c
- Proton pulse width: 6 ns (rms)
- High instantaneous n flux: $10^5$ n/cm$^2$/pulse
- Wide energy spectrum: 25 meV : 1 GeV
- Low repetition rate: < 0.25 Hz
- Neutron time width: 160 ms

Neutrons are collimated and guided through an evacuated beam pipe to an experimental area at 185 m from the spallation target.

Neutron spectrum @n_TOF

Wide neutron spectrum spanning an energy range from meV up to the GeV region.
Contamination by gammas

Prompt $\gamma$ flash at $\sim 600$ ns

"Slow" photons from several processes

investigated TOF range

160 ms $\text{Time of Flight}$
**Triple GEM Detector**

Gas Electron Multiplier:
- 50 µm thick kapton foil
- 5 µm of Copper on each side
- high surface-density of bi-conical channels

The three functions
- Conversion, Amplification, & Readout
are well separated and decoupled

Working with different levels of gain it is possible to obtain high level of particle discrimination

F. Sauli NIM A386 531
M. Alfonsi et al., The triple-Gem detector for the M1R1 muon station at LHCb, N14-182, 2005 IEEE-NSS
Working point

The α produce an high ionization which allow a wide plateau before the γ background.

WP: 870 V ⇒ Gain ~ 300
How to detect thermal neutron

\[ n + ^{10}\text{Be} \rightarrow \begin{cases} ^7\text{Li} + \alpha + \gamma, & (97\%) \\ ^7\text{Li} + \alpha, & (3\%) \end{cases} \]

**Head-On detector**

**Side-On detector**

Glass Support (1mm)

Gas gap (Ar CO\textsubscript{2}-70\% 30\%)

\(^{10}\text{B} \text{ (350 nm)}\)

Thermal neutrons

A. Pietropaolo et al., A new \(^3\text{He}\)-free thermal neutron detector concept based on the GEM technology, conference proceeding, He-2-4, 2012 IEEE-NSS Anaheim CA
Boron multilayer cathode

First prototype made in 2012

Thermal neutron window

Naked Glass Sheets  Borated Glass Sheets
Detector linearity measurements in a fission reactor

Measurements at Triga (ENEA)
Power of 1 MW

- Gamma background free
- No electronic noise

Good linearity up to 1 MW

Eff. = 4%

Real time measurements
Signal /gammas $10^4$
FPGA data acquisition

GEM counts → FPGA → counts/slice → Real time spectrum

p+ beam \( t_0 \)
delay, #slice, \( \Delta t \)
delay = 12 ms
\( \Delta t = 150 \) ms

Slice = 1ms

counts/slice

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Beam spot

With a scan procedure it is possible to make an image of the neutron beam in the thermal region.
Results: GEM efficiency and neutron spectrum profile

From a convolution between:
- PS beam intensity
- Neutron flux by $^{235}$U fission chamber from PTB institute (GE)

\[ n(\text{Hz}) = 10^B \text{ counts} - \text{Glass counts} \]
Results: GEM efficiency and neutron spectrum profile

Expected neutrons

Fission Chamber

Measured neutrons

stat. error 3%

GEM

Efficiency %

4.2 ± 0.2 %
Results: beam image

- Scan steps: 3mm
- Sum of the two matrix bin by bin
- The entries of the new matrix are divided by 1 or 2
- Beam image!
Results: beam image

- Scan steps: 3mm
- Sum of the two matrix bin by bin
- The entries of the new matrix are divided by 1 or 2
- Beam image!
Results: beam projection

Measured horizontal profile

Simulated horizontal profile

http://pceet075.cern.ch FLUKA simulation for n_TOF collaboration by V. Vlachoudis - CERN
CONCLUSIONS

- A triple GEM for thermal neutrons was tested at 185 m from the spallation source in the experimental room of the n_TOF facility at CERN
- The mean efficiency of this detector is 4.2%
- The efficiency curve vs neutron energy was measured in the range 0.03 eV - 1.75 eV
- The projection of the beam is in fair agreement with the one obtained with simulation
- With a scan procedure it was possible to perform the beam imaging for thermal neutrons spot with almost complete rejection of γ rays
Thanks!

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• Particle conversion, charge amplification and signal induction zones are physically separated
• Time resolution: 9.7 ns for Ar-CO$_2$ (70-30)
• Spatial resolution: up to 200 $\mu$m - limited by readout
• Dynamic range: from 1 to $10^8$ particles/cm$^2$ s
• Effective gain is given by the formula: $G_{eff} \propto \sum V_{G_i}$

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### Triple GEM detector

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A Standard Triple GEM construction

The detectors described in this talk are built starting from 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

- THERMAL neutrons: 128 pads 3x6 mm$^2$
  ~ 25 cm$^2$ of sensitive area
Triple GEM detector: electronics readout

• FAST neutrons: 128 pads 6x12 mm² ~ 100 cm² of sensitive area
• THERMAL neutrons: 128 pads 3x6 mm² ~ 25 cm² of sensitive area
• 8 chip CARIOCA to set the threshold on 16 channels and reshape the signal
• FPGA-based DAQ: 128 scaler and TDC channels, in → gate and trigger, out → signals
• HVGEM power supply with 7 independent channels and nano-ammeter

Developed by G. Corradi D. Tagnani Electronic Group LNF-INFN
Developed by A. Balla and G. Corradi and Electronic Group LNF-INFN
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Time evolution

online measurement

Cumulative counts

Time spectrum (1ms/bin) 150ms $\Delta t$
N-TOF thermal neutron Beam spot

With a scan procedure it is possible to make an image of the neutron beam in the thermal region.

Time spectrum (1ms/bin) 150ms gate

Online measurement

Single event

Cumulative counts
Neutron beam has been reconstructed making an horizontal scan on the beam. 

ToF measurements: thermal energy spectrum

Slices acquisition: Time spectrum (1ms/bin), 150ms total gate.