Applications with
Triple GEM Detector

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- Triple GEM detector as beam monitor
- Monitors for Crystal experiment at SPS
- A compact Time Projection chamber with GEM

An INFN R&D project: IMAGEM
http://www.lnf.infn.it/esperimenti/imagem/
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 a 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
The detectors described in this talk are built starting from the standard 10x10cm²:
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.
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 cm²

16 channels for each card: channel density of 1 ch/cm²
Sensitivity of 2-3 fC; LVDS output (25 ns); Radhard;
Extremely modular and usable for GEM applications

All the 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.
The mother board

On this mother board HV and LV ground are connected each other through a 10 KΩ resistor.

CARIOCA readout electronics

HV filters

Threshold calibration

6mV/fC

HV in

Threshold & LV in

4×32 LVDS signals out

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HV supply for GEM detectors

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

All the detector for beam diagnostic has been power up with this new device

Cathode (up to 5 KV)

Controlled via Canbus

A Corradi, F. Murtas and D. Tagnani
A novel HighVoltage System for a triple GEM detector
Nuclear Inst. and Methods in Physics Research, A
Reference: NIM A46 128

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Beam monitors on Crystal experiment at SPS
The first RUN foreseen on next June 18th ... in the meanwhile
Beam Test at BTF Frascati

500 MeV $e^-$

Calorimeter  GEM  Fiber detectors

Scaler  Nanoammeter

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Beam monitor at BTF Frascati

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

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If some other shapes are needed ...
LUMI GEM Assembling

Pads: 6 x 24/32 mm²

Seven detectors have been built

Final luminometers with Carioca FEE
Design by D. Tagnani

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GEM luminometer mounted on Dafne

See the Paolo Valente talk on Luminosity measurements at Dafne

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Background monitor

Readout every second with VME scalers

Electron monitor

Positron Monitor

28 KHz

Only Electron Beam

48 KHz

F. Murtas
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 zones:

- $U_{DD}$: 700 μm Polyeth., 5 μm Al.
- $U_{DT}$: 2 mm Polyeth., 0.2 mm Al.
Efficiency vs GEM gain

14 MeV Neutron

2.5 MeV Neutron

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

See Basilio Esposito Poster
Flux vs time and discrimination

More studies on cathode materials to improve discrimination in progress

Starting ENEA INFN CEA collaboration for the use of these monitors at Tokamak (Cadarache and Frascati) and Ignitor Project

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Small TPG 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%X₀) 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)

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

Threshold set at about 7 fC
Gas mixture $\text{Ar CO}_2 (70-30)$
Triple GEM Gain at about $10^4$

For this type of monitor a new layout has been designed for an active volume of $5 \times 5 \times 4 \, \text{cm}^3$
Pad dimension $3 \times 6 \, \text{mm}^2$
Threshold set at 7 fC
Gas mixture $\text{Ar CO}_2 (70-30)$
Triple GEM Gain at about $10^4$
Sub-millimetric precision
Some other events
TPG performance

The track is reconstructed using the space time relation

residual distribution

\[ \sigma_y (208 \, \mu m) \]

single event with two tracks

top view (1) (2)

side view (1)

side view (2)

Characterization with different gas mixture is in progress

Next beam test at BTF \((e^-)\) and ion beam facilities \((C^+)\)
"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
Conclusions

- Several portable detectors based on triple GEM technology have been built in Frascati for several purpose: Bhabha track position, Neutron monitor, Beam monitors, Xray, Gamma ray …

- In all of these sectors they show good performances and confirm good radiation hardness

- These R&D brought us to develop new HV systems, new front end electronics based on well known ASIC chips, new electronics for “on board DAQ” based on FPGA

- Future R&D on neutron and Xrays detection for high fluxes (Nuclear Fusion Reactors) for ITER and IGNITOR

- Future R&D on beam monitor for high intensity beams and ions beam for hadrotherapy
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.
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.
HVGEM prototype stability

\[ g_1 \quad \sigma < 1V \]

\[ g_2 \quad \sigma < 1V \]

\[ g_3 \quad \sigma < 1V \]

Good gain stability!
**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 stretching phase for the prototype construction.
Bhabha time correlation

Readout multihit TDC

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Hit multiplicity and timing

Without T0 subtraction Over 32 channels

Molteplicity

11 ns

12 ns

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**Bhabha Correlation**

The correlation in phi of bhabha events is clear.

More precise analysis is in progress.

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

The sensitivity is measured vs two different thresholds

DAC Threshold on power supply

Threshold on Carioca

6mV/fC

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