Commissioning and testing of large size GEM chamber in mCBM experiment at GSI

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For CBM-MUCH

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Outline

- CBM experiment, MUCH system
- Challenges in muon detection
- mCBM experiment
  - mCBM layout, Free-streaming DAQ
    - mMUCH (GEM) modules
- Preliminary results
- Summary and Next steps
Compressed Baryonic Matter (CBM) experiment is a fixed target heavy ion experiment. Aim of CBM experiment is to explore the properties of nuclear matter at high net baryon densities and at moderate temperature.

- Energy range 2-35 AGeV

**CBM physics program:**
- Equation of state at high net baryonic density
- De-confinement phase transition
- QCD critical endpoint
- Chiral symmetry breaking

**Diagnostic probes of the high density phase:**
- Open charm, charmonia
- Low mass vector mesons
- Multistrange hyperons
- Flow, fluctuations, correlations
Muon Chamber (MUCH) of CBM

Aim is to measure dimuon arises from:
1. Low mass vector mesons and
2. Charmonia

Design criteria:
- High interaction rate: 10 MHz
- The first plane have a high density of tracks
  High granularity in the inner region ~ average hit rate ~ 200 kHz/cm²
- Should be radiation resistance
  (~10^{12} \, n_{eq}/cm² and for Gamma is ~30 krad
  => equivalent to 10 year operation of CBM)
- Data to be readout in a self triggered mode
  -- must for all CBM detectors
  -- events reconstruction will be done off-line by grouping the time-stamps of the detector hits

Trapezoidal shaped triple GEM chambers will be used in the first two stations of MUCH.

<table>
<thead>
<tr>
<th>Absorber</th>
<th>C</th>
<th>Fe</th>
<th>Fe</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (cm)</td>
<td>60</td>
<td>30</td>
<td>30</td>
<td>20</td>
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</tbody>
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Angular coverage ~ 5° to 25°
Sector Layout Of MUCH

=> SIS100 setup => 4 station + 4 absorbers
=> First two stations:
  --> GEM detector technology
    --> due to high particle rate

Number sector for 1\textsuperscript{st} station: \textbf{16} / layer = 48
Rmax – Rmin = \(\sim\) 80 cm

Number of sector for 2\textsuperscript{nd} station: \textbf{20} / layer = 60
Rmax – Rmin = \(\sim\) 100 cm

Readout channel: \(\sim\)2231 per module
\(\Rightarrow\) 107k for 1\textsuperscript{st} station

Typical dimension

\begin{itemize}
  \item Area \(\sim\) 1900 cm\(^2\)
  \item \(\sim\)7.5 cm
  \item \(\sim\)80 cm
  \item \(\sim\)40 cm
\end{itemize}
mCBM --> A CBM full system test setup at SIS18 facility of GSI/FAIR. The mCBM experiment will allow to test and optimize the performance of the detector subsystems including the software chain under realistic experiment conditions which will significantly reduce the commissioning time for CBM

— Operation of the detector prototypes in a high-rate nucleus-nucleus collision environment
— Free-streaming data acquisition system including the data transport
— Online track and event reconstruction as well as event selection algorithms
— Offline data analysis and
— Detector control system
— $\Lambda^0$ reconstruction
Diamond detector was placed just before the target

Z-position of MUCH

<table>
<thead>
<tr>
<th>Detector</th>
<th>Distance</th>
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<tr>
<td>GEM1</td>
<td>~84 cm</td>
</tr>
<tr>
<td>GEM2</td>
<td>~106 cm</td>
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Transverse distance

~16 cm to 48 cm for GEM1
Total FEB connected per module = 12

Channels per FEB = 128

Minimum pad size = 3.2 mm
Maximum pad size = 17.2 mm
mMUCH Modules (Triple GEM detector)

Readout PCB
--> ~2200 pad with gradually increasing sizes
--> total front end board needed = 18

Drift PCB designed at VECC
fabricated at CERN
more PCB fabricated in India

Two chambers were assembled using “NS2” technique at VECC (Thanks to CPDA lab of VECC for clean)
Handling Short Segment

Conventional approach

Optocoupler based design:

24 segments

⇒ 72 optocoupler switches/ module

Ref: https://doi.org/10.1016/j.nima.2019.162905
Testing large size chamber in mCBM experiment

<table>
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<tr>
<th>Beam information</th>
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<tbody>
<tr>
<td>Beam                      : Ag 45+</td>
</tr>
<tr>
<td>Energy                    : 1.59 AGeV</td>
</tr>
<tr>
<td>Beam Intensity            : $5 \times 10^5$ to $7 \times 10^8$</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Target information</th>
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</thead>
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<tr>
<td>Target                    : Au</td>
</tr>
<tr>
<td>Thick                     : ~ 2.50 mm</td>
</tr>
<tr>
<td>Thin                      : ~ 0.25 mm</td>
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mCBM DAQ

Specifications:

- self triggered electronics
- can handle data rate up to 32 MHz
- Dynamic range = 1-100 fC
- provides both timing and energy information
- 5 bit flash ADC
Results: Spill Structure

Run number: 160 (2.5 mm target)

- Spill On time ~ 4-5s
- Spill Off time ~ 2-3s

Data acquired in time slice manner
Size of one Time Slice ~ 10ms

Ajit Kumar
Results: Time Correlation

Time correlation between T0 and one of GEM1

Variation of sigma (ns) for different FEBs pof GEM
Results: Digi Correlation

Digi correlation between GEM1 and diamond in time slice

Digi correlation between GEM1 and GEM2 in time slice
Results: Particle Rate

- Particle Rate

This is not normalized with area

Intensity increase factor $\sim 4.4$

Target effect

0.25 to 2.5 $\Rightarrow \sim 3-4$ factor

$\chi^2$/ndf: 267.6/234
Constant: $127 \pm 1.1$
Mean: $1906 \pm 8.7$
Sigma: $744.1 \pm 8.3$

Nb digit per TS

Run Nb

GEM1

GEM2

Intensity increase factor $\sim 4.4$
Results: Event Building

**Algorithms**: 
- Consecutive time gap between the digis.
- Fixed time gap.

- **Diamond digi**
- **Tof digi**
- **Much digi**
- **Sts digi**
- **Other subsystem**
- **Combine d digi**

**time gap < 200 ns (say)** => Count as one event

*With minimum TOF and T0 trigger condition*
Results: Event Building and Hit Reconstruction

Offset correction

![Graph showing mean position w.r.t T0 for GEM1 and GEM2.
FEB Number is on the x-axis, and position is on the y-axis.
Mean (ns) and Sigma (ns) are represented by dots and triangles, respectively.
Run 159 is indicated by a vertical dashed line.

Algorithm:
Fixed time window = 200 ns
with a condition of 10 TOF + 1T0 digi
Results: Event Building and Hit Reconstruction

# events per TS

# events vs TS number

Hit distribution with time
Results: Spatial Correlation

Clear spatial correlation between hits of GEM with TOF

TOF – Time of Flight detector (MRPC)

Preliminary
Summary

- Two real size triple GEM chambers (mMUCH) commissioned in mCBM experiment at GSI, Darmstadt.
- First beam test with MUCH-XYTER and a first tests with novel Optocoupler based HV biasing scheme has been done
- mCBM data taken in a free streaming mode in a common DAQ chain which included all the subsystems
- Data taken for a range of detector/electronics settings, for two different target thickness and different beam intensities to study rate effects
- With a crude event algorithm, clear spatial correlations of mMUCH with mTOF observed

Next Steps

- A detailed data analysis
- Event reconstruction optimization
- Performance of detector with full acceptance
- Commissioning of a third mMUCH chamber
- Upgraded version of MUCH-XYTER and eventually to a CRI-based DAQ in mCBM 2020
Thank you for your kind attention!

We would like to thank GSI colleagues for their help in the beam time.

Thank you for your kind attention!
Backup
The opto-coupler indigenously designed & interfaced with the drift PCB connector with Rui's help
Results: 2

Beam
Intensity = 10^7/sec
Target thickness: 0.25mm
GEM1

Beam
Intensity = 10^7/sec
Target thickness: 2.5mm
GEM1

Factor of ~2 increase in the particle rate for 2.5 mm target thickness
Cluster size: Simulation

Detector gain = 2000
Threshold = 5fc

With same acceptance as data

Looks similar to the data
ADC and Channel hit distribution