Development & Testing of High Rate RPC for CBM experiment at FAIR

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Outline

- CBM @ FAIR
- RPC at CBM-MuCh
- Working principle of RPC
- RPC R&D at VECC
- Cosmic Muon tests
- GIF++ beam test
- Summary
CBM at SIS 100 (start version/30 GeV/c (protons) and SIS 300 (future/90 GeV/c)

- Explore the QCD phase diagram in high net baryon densities
- very high rate (fixed target) HI-experiments (> $10^7$ interactions/s), access to rare probes (dileptons, (open) charm....)
CBM – Muon Setup

Muon Chamber

Tracking Detector

Silicon Tracking System

Micro Vertex Detector

Dipole magnet

Projectile Spectator Detector (Calorimeter)

Resistive Plate Chambers (TOF)
CBM-MuCh (Muon Chamber)

- Measurements of di-muons which are decay products of low mass vector mesons, charmonium etc.

- Alternate detector-absorber layout for muon tracking.

- 3 detector stations between the absorbers.

- First two stations GEM, Last two stations RPC

- **Main issues for detector requirements:**
  - high rate handling capability
  - good position resolution
  - Should be radiation resistant
  - Large area detector – modular arrangement

Fig 2: Simulation Implementation of the CBM-MuCh Experimental set up
Resistive Plate Chambers in 3\textsuperscript{rd} & 4\textsuperscript{th} Stations of MuCh

3\textsuperscript{rd} Station Particle Rate: 15 kHz/cm\textsuperscript{2}

4\textsuperscript{th} Station Particle Rate: 5.6 kHz/cm\textsuperscript{2}

Challenge to develop such high rate RPCs
Resistive Plate Chamber (RPC)

- Gaseous Parallel Plate detector
- Developed by R. Santanico and R. Cardarelli in 1981
- Working principle ~ gas ionisation
- Resistivity of electrode plates, \( \rho = 10^9 – 10^{12} \ \Omega \text{-cm} \)
- Surface Resistivity of Graphite painted electrodes, \( \rho = 100 \text{ k}\Omega – 1 \text{ M}\Omega/\square \)
RPC detector: Bakelite resistivity

The detector rate capability is strongly dependent on the Bakelite resistivity. At high particle rate ($r$) the current through the detector can become high enough to produce an important voltage drop ($V_d$) across the electrode:

$$V_d = 2\langle Q_e \rangle rs \rho$$

$s$: electrode thickness
$\langle Q_e \rangle$: average pulse charge
$\rho$: bakelite resistivity

The time constant of an elementary cell is lower at lower resistivity: the cell is recovering faster (it is quicker ready again) after a discharge took place inside it.

$$\tau = \varepsilon_0 (\varepsilon_r + 2) \rho$$

Operate RPC at low gain avalanche mode
we have tested a single gap 30 cm x 30 cm bakelite RPC prototype.

• Gas Gap ~ 2 mm

• Inner surfaces of bakelite electrode (2 mm thick) was double layer linseed oil coated.

• Bulk Resistivity of bakelites ~ $3 \times 10^{10} \Omega$-cm

• Cosmic Ray test and beam test at GIF++ has been done.
First Test Results using cosmic muons

Efficiency ~ 95% at 10.5 kV

Noise Rate ~ 1 Hz/cm²

Stable dark current over a time period at 10.2 kV

Avalanche mode Gas Mixture R134a : iC₄H₁₀ : SF₆ :: 94.2 : 4.7 : 1.1

Scintillator Corrected
Time resolution ~ 1.1 ns
Criteria for Electronics compatible with CBM RPC

- We have operated the RPC prototype with ALICE TOF electronics NINO FEE as well as CBM TOF electronics PADI.

- Both of the electronics has been fabricated for MRPCs which need good timing properties of electronics.

- In CBM, we need to record hit even with relatively worse timing.

- **Aim being**: to operate the RPC with the MUCH-XYTER electronics which are being used as the front end electronics (FEE) for the first two MuCh stations detector, GEM.
MUCH - XYTER (Muon Chamber - X - Y - Time - Energy Read-out) Electronics

1. 128 Charge Processing Channels
2. Charge sensitive Preamplifier-discriminator board
3. Low power consumption (6.2mW/channel)
4. Good noise performance
5. Rate Capability 150 kHz Input
6. Dynamic Range ~ 100 fC
7. Requires very low gain operation of RPC
Lab Test at VECC with a commercial CSA

R134a : iC₄H₁₀ : SF₆ :: 94.2 : 4.7 : 1.1

Efficiency ~ 95 % at 9900 V

- Reduction of Required high voltage from 10.5 kV to 9.9 kV.
- Accessed the lower region of avalanche mode by CSA.
- Dark Current Rate is higher due to noise as well as lower threshold.
- CSA Gain ~ 1 mV/fC

Block Diagram of RPC Cosmic Muon setup with CSA 142 IH

Dark Count Rate at 95 % efficiency = 21 Hz/cm²
Testing of the RPC Chamber at GIF++

- $E_g = 0.66$ MeV; max. dose-rate $\sim 0.5$ Gy/h @ 1m from source ($\pm 37^\circ$ angle) and 2.5 Gy/h @ glass contact
- Several attenuation factors available (up to $\sim 50,000$)
- $\mu$-beam from T2 on H4 beam-line (100 GeV; $\sim 10^4$ /spill.

**Aim being:**

- to test the response of the detector to charged particles in presence of high gamma irradiation.

- efficiency, cluster size, rate capability

- testing with actual electronics for CBM: MuCh- XYTER

- testing with the actual DAQ

- The RPC prototype, Strip dimension $\sim 28$ cm x 2.3 cm. Total Strips – 11

- 2 mm gap between two strips.

- Gas: humidified CMS RPC mixture $95.2\%$ R134a + $4.5\%$ iC$_4$H$_{10}$ + $0.3\%$ SF6 (humidity 60%)
The RPC detector under test was placed at ~ 167 cm from the source point (D1 position)

- The detector is directly in front of the irradiator and is operating under a particle flux ~ $4 \times 10^7 Hz/cm^2$

- 11 RPC strips connected to 11 channels of MuCh Xyter

- One muon trigger Channel consisting of three fold of finger scintillator (3 cm x 12 cm) located in front of TRD detectors and two big paddle scintillators placed outside GIF++ bunker connected to one channel of Much-Xyter.
Preliminary Analysis of RPC data at GIF++

- Efficiency of the chamber has been measured when 100 GeV muon beam was present.
- Humidified CMS RPC mixture: 95.2% R134a + 4.5% iC₄H₁₀ + 0.3% SF₆ (humidity 60%).
- Efficiency is > 95% and plateau starts from 9000 V (Lower voltage than lab test at VECC due to lower percentage of SF₆).

- Time correlation of RPC with the trigger pulse (3F of Scs) has been done.
- Nice peak with sigma ~ 12 ns - time resolution of RPC.
- Here, we are operating RPC in low gain region of the avalanche mode.
- Threshold in MuCh Xyter ~ 60 fC
Detection of Muon under Photon irradiation

Data Rate inside the box tells photon flux falling on the detector.

As the photon flux was quite high, though RPC has very low photon detection efficiency, it is affecting the detector efficiency severely.
Rate Plots

- Core of the muon beam ~ 10 cm x 10 cm
- First peak is pedestal peak
- Second peak is due to muon beam
- Approximate muon rate falling on the detector ~ 1 kHz/cm²
Summary

• The prototype standard bakelite RPC has been tested with 95 % efficiency using voltage sensitive preamplifier based electronics.

• We could operate it to even lower gain by using charge sensitive preamplifier based electronics. Time resolution degrades at lower gain. But our requirement for time resolution ~ 10 ns.

• The RPC has been tested in highly irradiated photon background in presence of μ beam.

• The detector has shown promising behaviour upto 1 kHz/cm² which was expected.

• The detector has shown promising behaviour upto a high level of photon background.

• More R&D is going on to meet the CBM requirements.
Back Up Slides
Operation with Charge Sensitive Preamplifier 142IH

- Aim is to operate our RPC with very low gain, option is reduce high voltage
- Since MUCH-XYTER is a charge sensitive preamplifier (CSA) based electronics, we have first operated our RPC with commercial CSA 142IH.

![Block Diagram of RPC Setup with CSA](image)
What factors decide the rate handling capability of RPC???

\[
\text{Rate Capability} = \frac{1}{\rho \ t \ <Q>}
\]

where, \( \rho \) and \( t \) are bulk resistivity and total thickness of the electrodes respectively, \( <Q> \) is the Average charge of each signal.

High Rate Experiment

1. Low Resistive Electrode
2. Need Less charge content \( (\langle Q \rangle) \) in signal

1. Low resistive Bakelite RPC
2. Avalanche mode is feasible \( (\langle Q \rangle \sim 1 \text{ pc}) \)
CBM Experiment at FAIR

Fixed Target Experiment 4 - 25 AGeV

Physics Topics
Exploring QCD Phase Diagram in high net baryon densities, $\mu_B$

Observables
Hadrons, Hyperons, Mesons, $J/\Psi$, Low Mass Vector Mesons $\omega, \rho, \phi \rightarrow e^+ e^- \text{ and } \mu^+ \mu^-$

Rare Probes ➔ High Interaction Rate, 10 MHz

Requirements
- fast and radiation hard detectors and FEE
- free-streaming readout electronics
- high speed data acquisition and online event selection

Fig 1: Schematic view of the CBM experiment: Muon set up
Installation Inside GIF++ bunker