mTOF performance during mCBM beamtime at GSI

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Facility for Antiproton and Ion Research (FAIR) is under construction in Darmstadt, Germany. Compressed Baryonic Matter (CBM) is one of the experiments at FAIR to explore the QCD phase diagram in the region of high baryon densities at highest interaction rates up to 10 MHz.

A CBM full system test-setup called mini-CBM (mCBM) has been installed for testing under CBM conditions.

Hadron PID is done with CBM-TOF wall: 120 m$^2$, 5 kinds of MRPC with rate capability from 1 kHz/cm$^2$ to 25 kHz/cm$^2$. 
Introduction: High-rate MRPC2

Structure parameters

| Parameter           | Value                  |
|---------------------|------------------------|
| Dimension           | 360 × 338 × 26 mm³     |
| Weight              | 3.3 kg                 |
| Gas gap number      | 4×2 stacks             |
| Gas gap width       | 0.25 mm                |
| Glass dimension     | 330 × 276 × 0.7 mm³    |
| Strip dimension     | 270 × 7 mm²            |
| Strip pitch         | 3 mm                   |
| Strip number        | 32                     |
| Electrodes          | low resistive glass    |

Equipped with low resistive glass (~10¹⁰ Ω cm), the rate capability of MRPC2 meets the requirement of CBM-TOF at corresponding high rate area (1-10 kHz/cm²).
Prototype test
Rate: 70 kHz/cm²
Efficiency: >90%
Time resolution: ~ 80 ps
(J. Wang et al., Nucl.Instrum.Meth. A713 (2013) 40-51)

Cosmic test
Gas: 5% i-C₄H₁₀, 5% SF₆, 90% C₂H₂F₄
Efficiency: > 95%
Time resolution: < 90 ps
After applying HV @ ± 5600 V for ~ 2 days in Tsinghua University Lab,
Dark current < 50 nA
Noise < 5 Hz/cm²
Cosmic test is low rate test and it is limited to statistics. The real performance of
MRPCs for CBM should be finally tested with high-rate beam and CBM system
under full illumination condition.
Structure parameters

| Parameter          | Value                      |
|--------------------|----------------------------|
| Gas gap number     | 5×2 stacks                 |
| Gas gap width      | 0.23 mm                    |
| Strip length       | 270 mm                     |
| Strip width        | 7 mm                       |
| Strip pitch        | 10 mm                      |
| Strip number       | 32                         |
| Electrodes         | ultra-thin float glass     |
| Thickness of glass | 0.28 mm                    |

Developed and produced by University of Science and Technology of China (USTC) for CBM-TOF area where rate < 1 kHz/cm². Should be tested with CBM condition, too.
Data driven readout chain

- PreAmplifier Discriminator (PADI): amplification (~250), threshold (10~20 fC)
- GSI Event-driven TDC with 4 channels (GET4): signal arriving time and TOT are measured
- Radiation hard ASIC GBTx: collects and combines GET4 data. Signal changed to optical signal
- Data Processing Board (DPB): collects data from GBTx and builds μ-time slices (data package)
- First Level event selector Interface Board (FLIB): combines μ-time slices for data selection and storage
- 1600 channels: 32*2(sides)*5(MRPCs)*5(modules) + 128 channels: 32*2(sides)*2(MRPCs)
mTOF at mCBM experiment

❖ mTOF modules+testing counters

Top view of experiment layout

Double layer is closer to beam for rate investigation. Triple layer is meant for better track quality. Prototypes of some other counters are put behind mTOF modules to use mTOF modules as reference counter.
# Experiment conditions

| Gas mixture       | 90% C₂H₂F₄, 5% i-C₄H₁₀, 5% SF₆ |
|-------------------|---------------------------------|
| Gas flow          | 110 ml/min in total             |
|                   | Gas flows in parallel           |
| HV                | ± 5.3 kV for MRPC2 (106 kV/cm)  |
|                   | ± 6.4 kV for MRPC3 (116.4 kV/cm)|
| PADI threshold    | -300mV for MRPC2                |
|                   | -250mV for MRPC3                |
| Beam condition    | ¹⁰⁷Ag+ empty target             |
|                   | ¹⁰⁷Ag+thin target (0.25 mm)     |
|                   | ¹⁰⁷Ag+thick target (2.5 mm)     |

Run 159: beam intensity: 2*10⁵ thin target (1% interaction probability)
Particle flux on counters is ~10 Hz/cm²
mTOF performance

- **Steps of analysis**

  - **Step 1: Unpacking and event building**
    - Digi info: logical address (layer, MRPC, strip, side), TOT, time
    - Event: At least 10 counters fired within 50 ns

  - **Step 2: Calibration and hit finding**
    - Position calibration (different cable length)
    - TOT calibration (amplifier differences)
    - Walk correction (slewing correction)

  - **Step 3: Tracking**
    - Track-finding in events (as shown in example)

  - **Step 4: Performance evaluation**
    - Derive counter properties by comparing measured hits to track fit expectations
Performance evaluation

- Analysis within groups:
  - Diamond and MRPCs (same geometry acceptance)

- Efficiency:
  \[
  \frac{N_i(\text{Hit})}{N_i(\text{Hit}) + N_{i-1}(\text{Miss})}
  \]
  
  \(N_i\): Number of tracks with \(i\) hits

- Time resolution:
  - \(\sigma\) (Expected time from track fit – Measured time)
mTOF performance

- mTOF position distribution

The active area of the detectors is shown after calibration.

Only $1/(1600+128)$ dead channel.

Structures are visible due to problems in data acquisition system (firmware in DPB) leading to partial data loss.
mTOF performance

- **Position resolution**
  - project MRPC-based tracks to target plane

- **Evident phenomenon:**
  - Different track sources
  - Position of second source caused by geometry
  - Hypothesis: a third source (T0 diamond counter) is close to target and causes elliptical shape
  - Position resolution is quiet good

Extrapolated intercept with z=0 plane (target plane)
Preliminary time resolution of mTOF

Time resolution of mTOF counters is \( \sim 65 \pm 5 \) ps.
mTOF performance

Preliminary efficiency

Efficiency of MRPC2 (layer 1 row 2) above 90% in DAQ error free regions

Efficiency of MRPC3 (Front) above 90%
Summary and next steps

- The time resolution of mTOF is better than 80 ps.
- Effective area efficiency above 90% is demonstrated.
- Beam test with higher particle flux, new glass material, and stable DAQ is scheduled in Q2 2020.
- Aging tests will be finished this year.

Thank You!
MRPC2 with eco-friendly gas mixtures is ongoing

See Botan Wang's talk:
https://indico.gsi.de/event/7101/session/8/contribution/85/material/slides/1.pdf

PADI threshold
Noise of MRPC2 and MRPC3 tested in Heidelberg

Noise Rate vs. Field strength

- **MRPC3a (Low resistive glass)**
- **MRPC3b (Float glass)**

Tested by Dennis Sauter