Studiul dependentei parametrilor functionali ai detectorilor RPC si TRD pentru CBM functie de fluxul de particule incidente

Proiect PN 09 37 01 03

Director Proiect: Prof. Dr. Mihai Petrovici
OUTLINE

- **Motivation**
- **SIS18 – GSI, April 2014 experimental setup**
- **Experimental results**
  - Current & HV for RPC 2013 & RPCref @ counting rate
  - Current & HV for TRD2012 & RPC2012 @ counting rate
- **Conclusions and Outlook**
Mariana Petris, Seminar DFH, 08.12.2014

Motivation

The RPC rate capability is limited with the time interval needed for the localized charge avalanche to dissolve from the glass electrode. The drop of the electric field in the gas gap at high particle rates affects efficiency and time resolution. For a single gap of width $b$ the average field reduction is:

$$<\Delta E> = \rho \frac{a}{b} \Phi <Q>$$

$\rho = \text{glass resistivity}$

$a = \text{glass thickness}$

$\Phi = \text{the particle flux}$

$Q = \text{the avalanche charge}$

$$<\Delta V> = IR = \rho a \Phi <Q>$$

Timing RPC – in present: intensive R&D activity for high counting rate performance:
- time resolution better than 100 ps ,
- high efficiency (> 95%)

ALICE-MRPC: Resistive electrodes - float glass of $10^{12} - 10^{13} \Omega \text{cm}$ resistivity

ALICE-TOF TDR CERN/LHCC 2000-12
**Motivation**

**The CBM-TRD requirements**

**TRD subdetector – possible scenario:**
- 3 stations @ 4.5, 6.75, 9 m from target
- Highly granular and fast detectors which can stand counting rates up to $10^5$ part/cm$^2$·sec
- Tracking of all charged particles with a position resolution of:
  - 200 – 300 $\mu$m across the pads
  - 3 – 30 mm along the pads
- Identification of high energy electrons ($\gamma > 1000$) with a pion rejection factor $> 100$ @ 90% electron efficiency

*585 m$^2$ surface*
*708 modules*
*785,408 channels*

*Matching STS & TOF acceptance*
Motivation

TRD High Counting Rate Effect
Ion space charge with consequences on

Pulse Height – e/πi discrimination

Position Resolution

M. Petris et al., Nucl. Instr. and Meth. A 581(2007), 406
M. Petrovici et al., Nucl. Instr. and Meth. A 579(2007), 961

Mariana Petris, Seminar DFH, 08.12.2014
Motivation

- Proper choice of the HV power supplies for both CBM-TOF & CBM-TRD detectors
Photo of the Experimental Setup

1.5 GeV/u Ni beam on 1 mm Pb target
Photo of the Experimental Setup

RPC 2013:
FEE - PADI8
Converter: TRB3

RPC Reference:
FEE – PADI3 + splitters
Converter: TRB3

4 counter RPC 2012:
FEE - NINO
Converter: CAEN TDC
TRD gas mixture: 80% Ar + 20% CO₂

RPC gas mixture:
85% C₂F₄H₂ + 10% SF₆ + 5% iso-C₄H₁₀

Scaler 2: Pl.1 & Pl.2 (1.6 cm x 8 cm)
Scaler 3: Pl.3 & Pl.4 (1.6 cm x 8 cm)
Scaler 4: Pl.5 & Pl.6 (2 cm x 9 cm)

HV power supply: CAEN A1526
N/P polarity, 10 nA current resolution
0 – 15 kV HV range, 100 µA/1 mA full scale
Current & high voltage protection
Time evolution of current and high voltage were recorded during the measurements. Detector current data have been combined with the DAQ scalers for rate estimation in the off-line analysis. The scalers were the plastic scintillators. The mean value of the two scalers was considered in the counting rate estimation.
Current & HV evolution for RPC2013
Run230414_2204

ΔVₚ = 5500 V – 5420 V = 80 V
ΔVₙ = 5500 V – 5250 V = 250 V

Negative & positive current have almost the same values
Negative and Positive HV have different behaviour @ the same current
Current protection setting?
Current & HV evolution for RPCref
Run230414_2204

Stable behaviour of reference RPC
Active area = 532 cm²
I ≤ 12 nA/cm² @ ~4 kHz/cm²

DAQ didn’t work more for the time period of this csv file
Current & HV evolution for TRD2012
Run230414_2204

$I_{TRD} = 15 - 35 \mu A @ V_{ANODE} = 1950 \text{ V} - 1630 \text{ V} = \Delta V = 320 \text{ V}$

HV variations due to the current protection setting
Current & HV evolution for RPC2012
Run230414_2204

\[ \Delta V_P = 5500\,V - 4290\,V = 1210\,V \]
\[ \Delta V_N = 5500\,V - 3510\,V = 1990\,V \]

Large HV variations due to the current protection setting;
Smaller variations could be due to the counting rate.
Current/rate estimation for

**TRD2012**

Active area 54 cm x 56 cm = 3024 cm²
I > 12.6 nA/cm² @ ~0.8 – 0.9 kHz/cm²

**RPC2012**

Active area = 1090 cm²
I > 9 nA/cm² @ ~0.8 – 0.9 kHz/cm²

- the exposure was not uniform,
- larger on the side closer to the target
- linear rate extrapolation at the TRD edge: 4.21 kHz/cm²
Current & HV evolution for RPC2013
Run230414_2336

Current protection setting was not reached

\[ \Delta V_P = 5500 \, \text{V} - 5450 \, \text{V} = 50 \, \text{V} \]
\[ \Delta V_N = 5500 \, \text{V} - 5410 \, \text{V} = 90 \, \text{V} \]

HV variations due to the high counting rate
Current & HV evolution for RPCref

Run230414_2336

ΔV_P = 5500 V – 5450 V = 50 V
ΔV_N = 5500 V – 5435 V = 65 V

HV variations due to the high counting rate
Current/rate estimation for

**RPC2013**

Active area = 532 cm$^2$
$I = 25 - 30$ nA/cm$^2$ @ $\sim 35 - 40$ kHz/cm$^2$

**RPCref**

Active area = 84 cm$^2$
$I = 55 - 60$ nA/cm$^2$ @ $\sim 35 - 40$ kHz/cm$^2$
 Current & HV evolution for TRD2012
Run230414_2336

\[ \Delta V_{\text{ANODE}} = 1950 \text{ V} - 1825 \text{ V} = 125 \text{ V} \]

HV variations due to the current protection setting
Current & HV evolution for RPC2012
Run230414_2336

$\Delta V_P = 5500 \text{ V} - 5305 \text{ V} = 195 \text{ V}$

$\Delta V_N = 5500 \text{ V} - 5335 \text{ V} = 165 \text{ V}$

HV variations due to the high counting rate?

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Current/rate estimation for

**TRD2012**

- Active area 54 cm x 56 cm = 3024 cm²
- \( I > 12.6 \text{ nA/cm}^2 \) @ 4 kHz/cm²

**RPC2012**

- Active area = 1090 cm²
- \( I = 31 \text{ nA/cm}^2 \) @ ~4 kHz/cm²

- the exposure was not uniform,
- larger on the side closer to the target
- linear rate extrapolation at the TRD edge: 42.4 kHz/cm²
Current & HV evolution for RPC2013

Run240414_0041

\[ \Delta V_P = 5503 \text{ V} - 5500 \text{ V} = 3 \text{ V} \]

\[ \Delta V_N = 5500 \text{ V} - 5460 \text{ V} = 140 \text{ V} \]

HV variations due to the high counting rate

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Current & HV evolution for RPCref

Run240414_0041

ΔVₚ = 5505 V – 5500 V = 5 V
ΔVₙ = 5499 V – 5503 V = 4 V

Stable behaviour

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Current/rate estimation for **RPC2013** & **RPCref**

**Active area = 532 cm\(^2\)**

Highest current RPC2013 = 20 \(\mu\)A; 
\(I = 37.5 \text{nA/cm}^2 \) @ 65 kHz/cm\(^2\)

**Active area = 84 cm\(^2\)**

Highest current RPCref = 7 \(\mu\)A; 
\(I = 83 \text{nA/cm}^2 @ 65 \text{kHz/cm}^2\)
Current & HV evolution for TRD2012

Run240414_0041

I_{TRD} = 38 - 43 \, \mu A; \quad V_{ANODE} = 1950 \, V - 1785 \, V = \Delta V = 165 \, V

HV variations due to the current protection setting
Current & HV evolution for RPC2012
Run240414_0041

\[ \Delta V_P = 5500 \text{ V} - 5120 \text{ V} = 380 \text{ V} \]

\[ \Delta V_N = 5500 \text{ V} - 4940 \text{ V} = 560 \text{ V} \]

Large HV variations due to the current protection setting, smaller variation when the protection was removed.

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Current/rate estimation for TRD2012

Active area: 54 cm x 56 cm = 3024 cm²
I > 15 nA/cm² @ ~4 kHz/cm²

Current evolution for the Positive HV of TRD_BUC

Current evolution for the Positive HV of BUC_2012

RPC2012

Active area = 1090 cm²
I = 41 nA/cm² @ ~4 kHz/cm²

- the exposure was not uniform,
- larger on the side closer to the target
- linear rate extrapolation at the TRD edge: 69 kHz/cm²

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Current & HV evolution for RPC2013
Run240414_0244

Stable behaviour of RPC 2013

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Current & HV evolution for RPC2013

Run240414_0244

Stable behaviour of RPC 2013

Mariana Petris, Seminar DFH, 08.12.2014
Current & HV evolution for RPCref
Run240414_0244

Stable behaviour of reference RPC

Mariana Petris, Seminar DFH, 08.12.2014
Current & HV evolution for RPC ref
Run240414_0244

Stable behaviour of reference RPC
Current/rate estimation for

**RPC2013** & **RPCref**

Active area = 532 cm$^2$
$I = 16$ nA/cm$^2$ @ ~24 kHz/cm$^2$

Active area = 84 cm$^2$
$I = 42$ nA/cm$^2$ @ ~24 kHz/cm$^2$
Current & HV evolution for TRD2012
Run240414_0244

HV variations due to the current protection setting

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Current & HV evolution for TRD2012
Run240414_0244

HV variations due to the current protection setting

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Current & HV evolution for RPC2012
Run240414_0244

Stable behaviour of RPC2012

Mariana Petris, Seminar DFH, 08.12.2014
Current & HV evolution for RPC2012
Run240414_0244

Stable behaviour of RPC2012

Mariana Petris, Seminar DFH, 08.12.2014
Current/rate estimation for

**TRD2012**

- Active area: 54 cm x 56 cm = 3024 cm²
- $I > 15 \text{nA/cm}^2$ @ ~4 kHz/cm²

**RPC2012**

- Active area = 1090 cm²
- $I = 41 \text{nA/cm}^2$ @ ~4 kHz/cm²

- the exposure was not uniform,
- larger on the side closer to the target
- linear rate extrapolation at the TRD edge: 25.37 kHz/cm²
\[
<V_{\text{drop}}> = <I(\text{nA/cm}^2)> \times \rho(\Omega\text{cm}) \times (nd)
\]

- \(n\) = number of glass plates
- \(d\) = glass thickness
- \(\rho\) = glass resistivity

The largest measured current value was of about 0.037 \(\mu\text{A/cm}^2\) at the highest counting rate of 105 kHz/cm\(^2\). The total voltage drop on the all five gaps is 165 V. For a counting rate of 25 kHz/cm\(^2\), the calculated voltage drop on all five gaps is 50 V. As the detector is supposed to be operated within the efficiency plateau, this voltage drop has no consequences on the detector performances.
Dissipated power in RPC counters due to the high current

<table>
<thead>
<tr>
<th>Counter</th>
<th>Strip width (w) (mm)</th>
<th>Strip gap (g) (mm)</th>
<th>64 x (w+g) (L) mm</th>
<th>Strip length l (mm)</th>
<th>I (μA)</th>
<th>S = L x l (cm²)</th>
<th>I (μA/cm²)</th>
<th>R (MΩ)</th>
<th>Dissipated power (mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPC2013</td>
<td>2.16</td>
<td>2.03</td>
<td>266</td>
<td>200</td>
<td>20</td>
<td>532</td>
<td>0.04</td>
<td>17</td>
<td>6.765</td>
</tr>
<tr>
<td>MRPC2</td>
<td>2.18</td>
<td>2.54</td>
<td>299.8</td>
<td>200</td>
<td>22.54</td>
<td>599.64</td>
<td>0.04</td>
<td>15</td>
<td>7.62</td>
</tr>
<tr>
<td>MRPC1</td>
<td>2.18</td>
<td>2.54</td>
<td>299.8</td>
<td>100</td>
<td>11.27</td>
<td>299.82</td>
<td>0.04</td>
<td>30</td>
<td>3.81</td>
</tr>
</tbody>
</table>

\[ R \ (\Omega) = \rho \times (l/S) = 1.5 \times 10^{10} \Omega \text{cm} \times (6 \times 0.1 \text{cm})/S \]

6 = number of glass plates

0.1cm = glass thickness

M1: 24 x 7.62 mW + 8 x 3.81 mW = 213 mW
M2: 15 x 7.62 mW + 12 x 3.81 mW = 160 mW
M3: 42 x 7.62 mW = 320 mW
**Summary**

**RPC**
Not identical behaviour off positive and negative voltage
Detectors recovered even after large HV trips

**TRD**
Non-uniform exposure of the TRD surface -> the rate for TRD & RPC2012 was underestimated due to the position of the plastics used as scalers!
Large anode HV variations due to the current protection setting
It would be better to apply anode HV on groups of anode wires (split anode configuration)
Insignificant drift voltage variations

**General remarques:**
FEE was not affected by the large variations of the detector high voltage.
Further systematic studies are needed in the upcoming beam times.

The obtained results were reported in:
M. Petris et al., CBM Collaboration Meeting, 8-12 September 2014, Krakow, Poland
CBM Collaboration, CBM-TOF TDR