Performance of the Multigap Resistive Plate Chambers of the Extreme Energy Events Project

D. De Gruttola* for the EEE Collaboration

* Centro Fermi, Rome and Salerno INFN - Italy
Extreme Energy Events (EEE) Project

- array of MRPC telescopes covering more than $3 \times 10^5$ km$^2$
- clusters and standalone stations
- stations are hosted in Italian Secondary Schools, INFN sections and CERN
- each station is made of 3 MRPC chambers
- project started in 2004
- array composed of 56 telescopes at the moment (continuously growing) (see M. Abbrescia’s talk about the EEE upgrade)
- long-living MRPC-based system (14 years)
- 60 billion tracks currently collected
- unconventional working sites:
  - mainly school buildings
  - non-professional electrical lines
  - non-controlled environmental parameters
  - heterogeneous maintenance conditions
Extreme Energy Events (EEE) Project

- array of MRPC telescopes covering more than $3 \times 10^5 \text{ km}^2$
- clusters and standalone stations
- stations are hosted in Italian Secondary Schools, INFN sections and CERN
- each station is made of 3 MRPC chambers

- Project started in 2004
- 57 telescopes at the moment (continuously growing)
- see M. Abbrescia’s talk about the EEE upgrade
- MRPC-based system (14 years)
- 60 billion tracks currently collected

Working sites:
- mainly school buildings
- non-professional electrical lines
- non-controlled environmental parameters
- heterogeneous maintenance conditions
EEE MRPC

- 6 gas gaps (300 µm)
- 2 external glass sheets (anode and cathode) – 160 cm x 85 cm, 1.9 mm thick (resistive paint 5-20 MΩ/☐)
- 5 intermediate (electrically floating) glass sheets - 158 cm x 82 cm, 1.1 mm thick
- 24 copper strips (anode and cathode) to pick up the signal – 158 cm x 25 cm, spaced by 7 mm
- Honeycomb panels to ensure mechanical stability – 182 cm x 90 cm
- Gas-tight aluminum box – 200 cm x 100 cm
- Gas mixture 98% R134a (C₂F₄H₂) - 2% SF₆
  (see S. Pisano’s talk about new gas mixtures)
- HV up to 20 kV (avalanche mode) supplied by 2 DC/DC converters
MRPC details:

- glasses
- 300 μm fishing line as spacer to create gas gaps
- vetronite panel
MRPC details:

- 24 copper strips to pickup the signal
- pitch 3.2 cm


- 6 Front-End boards (FEAs) with 24 channels to process readout signal (pre-amplification + discrimination)
- 2 Multi-hits Time to Digital Converters (TDCs 128 + 64 channels)
- 1 Trigger Card: a six-fold coincidence of both FEAs of the three MRPCs generates the Data AcQuisition (DAQ) trigger
- GPS unit provides the event time stamp (UTC time) to record and synchronize information
- weather station to monitor the temperature and the pressure inside and outside the telescopes building
Telescope and electronics

particle impact point reconstructed by:
- fired strip in one direction (y)
- difference of signal arrival times at the strip ends measured by TDCs in the other direction (x)

- 100 ps time resolution of the TDC bin
- ~1 cm spatial resolution along both coordinate
- > 95% MRPC efficiency at the operating voltage of 18 kV
- few tens ns GPS time resolution

19/02/2018                    D. De Gruttola (Centro Fermi Roma and Salerno INFN, Italy) - XIV RPC 2018, Puerto Vallarta, Jalisco, Mexico
Telescope and electronics

Particle impact point reconstructed by:
- Fired strip in one direction (y)
- Difference of signal arrival times at the strip ends measured by TDCs in the other direction (x)

- 100 ps time resolution of the TDC bin
- ~1 cm spatial resolution along both coordinate
- > 95% MRPC efficiency at the operating voltage of 18 kV
- Few tens ns GPS time resolution
Telescope and electronics

- 100 ps time resolution of the TDC bin
- ~1 cm spatial resolution along both coordinate
- > 95% MRPC efficiency at the operating voltage of 18 kV
- few tens ns GPS time resolution

Particle impact point reconstructed by:
- fired strip in one direction (y)
- difference of signal arrival times at the strip ends measured by TDCs in the other direction (x)
Students involvement

- one week to build 3 chambers (activity at CERN)
- secondary school students work under researchers’ supervision (activity at CERN)
- setup of the telescope (activity at school)
- chamber efficiency measurements (activity at school)
- all chambers are correctly working in each single telescope (daily monitor)

<10 students + 2-3 teachers per school involved in the chamber construction at CERN

Thousands of students and hundreds of teachers participating to the project
Performance
Periodic coordinated data taking periods (Runs) are performed.

All telescopes take data, with a central system of online shift and data quality monitor.

Pilot Run, Run 1, Run 2, Run 3 have been completed in the last 4 years.

Run 4 ongoing.

Data are sent to CNAF (data storage center in Bologna, Italy) to be stored, reconstructed and analyzed.

60 billion tracks collected.
**Time resolution**

- cut on reconstructed tracks $\chi^2 < 10$
- results will be published soon

*Time slewing* correction:
- the hit time depends on the signal amplitude, or equivalently the Time Over Threshold (TOT)
- the effect of its jitter has to be corrected in order to get the real hit time

$$\Delta t_{\text{hit}} = (t_{\text{bot}} + t_{\text{top}})/2 - t_{\text{mid}}$$

$$\sigma_t = \sqrt{3/2} \sigma_{\Delta t} \approx 240 \text{ ps}$$

- time slewing correction to be applied (soon)

**average time resolution** ~240 ps

- resolution within expectations (order of $10^2$ ps) and compatible with requirements
Spatial resolution (long side)

- cut on reconstructed tracks $\chi^2 < 10$
- results will be published soon

$\Delta x = (x_{\text{bot}} + x_{\text{top}})/2 - x_{\text{mid}}$

$\sigma_x = \sqrt{3/2} \sigma_{\Delta x} \sim 1.49 \text{ cm}$

$\sigma_{\text{exp}} \sim \sqrt{\sigma_{TDC}^2 + \sigma_{TDC}^2 v_{\text{drift}} / 2} \sim 1.1 \text{ cm}$

average spatial resolution (long side) 1.49 cm
resolution compatible with requirements
- cut on reconstructed tracks $\chi^2 < 10$
- results will be published soon

average spatial resolution (short side) 0.92 cm
resolution compatible with requirements

$\Delta y = (y_{bot} + y_{top})/2 - y_{mid}$

$\sigma_y =\sqrt{3/2}\sigma_{\Delta y} \sim 1\text{ cm}$

$\sigma_{yexp} \sim pitch/\sqrt{12} \sim 0.92\text{ cm} \ (pitch\ 3.2\ cm)$
Efficiency

- External chambers used as trigger
- Efficiency of the middle chamber measured on all telescopes
- Students involved in the measurement (well defined procedure for the HV scan)
- Procedure to measure efficiency of the external chambers ready (and applied in a few cases)

Average efficiency of the telescope network \( \sim 93\% \)

- Compatible within expectations and with the results from beam-tests performed at CERN
- Efficiency better than 93\% is reached by 77\% of the network
Results from beam-tests at CERN

- Efficiency vs HV for a single MRPC chamber
- Events triggered by scintillators

Efficiency plateau ~100%

TDCs 25 ps bins, scintillators system time resolution 30 ps

σ_t ~ 100 ps in the center of the strip

Spatial resolution along the strip 0.8 cm
Long term stability

average track $\chi^2$ – computed as the best track in the event if at least one hit on each chamber is recorded
Long term stability

DAQ rate – raw acquisition rate
**Long term stability**

**multiplicity** – average number of hits on the three chambers for each event
Long term stability

reconstruction efficiency - percentage of raw events where at least one candidate track has been found
Long term stability

Time Of Flight – average track TOF between top and bottom chambers
Long term stability

**track rate** - rate of events with at least one candidate track
telescope coincidences
- search for anisotropies
- Forbush decrease
- muon decay
- long distance coincidences
- many others
Conclusions

- network continuously growing and successfully operating since 14 years
- excellent performance in terms of time and spatial resolution
- very high efficiency
- High School students strongly involved in the Project
- coordinated data taking periods ongoing (central data storage and reconstruction)
- more than 60 billion tracks collected

<table>
<thead>
<tr>
<th></th>
<th>Pilot Run</th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>starting date</td>
<td>27/10/2014</td>
<td>27/02/2015</td>
<td>07/11/2015</td>
<td>01/11/2016</td>
</tr>
<tr>
<td>ending date</td>
<td>14/11/2014</td>
<td>30/04/2015</td>
<td>20/05/2016</td>
<td>31/05/2017</td>
</tr>
<tr>
<td>number of days</td>
<td>19</td>
<td>63</td>
<td>196</td>
<td>212</td>
</tr>
<tr>
<td>tracks/day (M)</td>
<td>~ 27</td>
<td>~ 53</td>
<td>~ 69</td>
<td>~ 85</td>
</tr>
<tr>
<td>purity (%)</td>
<td>75</td>
<td>84</td>
<td>83</td>
<td>80</td>
</tr>
</tbody>
</table>

Table 1: Statistics from the four coordinated runs. The number of active telescopes in Pilot Run, Run 1, Run 2 and Run 3, is respectively 15, 28, 38 and 46. The purity is calculated as candidate tracks/triggers.