Commissioning and first performance of the ALICE MID RPCs

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Outline

- A Large Ion Collider Experiment (ALICE)
  - Muon Spectrometer (MS)
  - Muon Identifier (MID)
- MID upgrade for Run 3:
  - MID Resistive Plate Chambers (RPCs)
  - New front-end electronics FEERIC
  - New read-out architecture
  - RPC status at INFN Torino laboratory
  - MID status at CERN
- Conclusions
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A Large Ion Collider Experiment (ALICE)

- A Large Ion Collider Experiment (ALICE) at the CERN Large Hadron Collider (LHC) is the experiment specifically designed to study the Quark Gluon Plasma (QGP) in heavy-ion (Pb-Pb) collisions.

- During the Long Shutdown 2 of LHC, ALICE achieved a major upgrade of its apparatus:
  - to cope with the increased Pb-Pb collision rate foreseen for Run 3
  - to allow a new ambitious program of high-precision measurements

<table>
<thead>
<tr>
<th>Run 2</th>
<th>Run 3</th>
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<td>10 kHz</td>
<td>50 kHz</td>
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The ALICE Muon Spectrometer (MS)

- It detects muons in the polar angular range $2^\circ - 9^\circ$, i.e. it covers the pseudorapidity range $2.5 < \eta < 4$

- It consists of:

1. Absorbers
   - front hadrons absorber
   - filter iron wall

2. Dipole magnet

3. Muon Chambers (MCH)
   - 5 stations of 2 planes of
     Cathode Pad Chambers (CPC) and Cathode Strip Chambers (CSC)

4. Muon TRigger (MTR), now Muon IDentifier (MID)
   - 2 stations of 2 planes of
     Resistive Plate Chambers (RPCs)
Muon IDentification (MID) (1)

- The MID consists of **72 Resistive Plate Chambers** arranged in 2 stations of 2 planes each.
- Each plane is 5.5 x 6.5 m², with 1.2 x 1.2 m² central hole to allow the beam pipe and shielding.
- The RPCs are equipped with **orthogonal strips** in order to provide the spatial information along the X and Y directions, for a total of 21k strips with 1, 2 and 4 cm pitch.
Starting from Run 3, ALICE is running in continuous readout mode (i.e. without trigger) and the Muon Trigger has become a Muon IDentifier (MID) → this required an upgrade of the read-out electronics which was completed during the Long Shutdown 2

- to cope with the increased counting rate and to reduce aging effects, RPC detectors are now operated at lower gain thanks to a new front-end electronics (FEERIC ASIC) including a pre-amplification stage

- some RPCs have integrated a non-negligible charge and aging effects might lead to sub-optimal performance for some RPCs → new production of RPCs in order to replace ~25% of the detectors currently installed in ALICE
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MID Resistive Plate Chambers (1)

- **ALICE MID RPCs:**
  - **2mm single** gas gap detectors
  - resistive **bakelite** electrodes, 2mm thick, $\rho \approx 3 \times 10^9 - 1 \times 10^{10} \Omega \text{ cm}$
  - the signal is picked-up inductively by means of copper strips with 50 $\Omega$ impedance

- **During Run 1 and 2** ALICE RPCs worked with:
  - effective applied HV of about 10.2 – 10.5 kV at 970 mbar of pressure and 20° C
  - maxi-avalanche mode (average charge per hit of 100 pC)
  - gas mixture: 89.7% $\text{C}_2\text{H}_2\text{F}_4$, 0.3% $\text{SF}_6$, 10% $\text{i-C}_4\text{H}_{10}$, humidified at 35-40%
MID Resistive Plate Chambers (2)

- For Run 3:
  
  → **same gas mixture** as Run 1 and 2: 89.7% $\text{C}_2\text{H}_2\text{F}_4$, 0.3% $\text{SF}_6$, 10% $\text{i-C}_4\text{H}_{10}$, humidified at 35-40%
  
  → **lower effective applied HV** (thanks to the new FEE), at 970 mbar of pressure and 20° C. New HV working point values definition **ongoing**
  
  → **avalanche mode** instead of maxi-avalanche

![Diagram of MID Resistive Plate Chambers](image-url)
The new front-end electronics: FEERIC

- **Goal:** slow down RPC aging after LS2 and **improve rate capability**
  - FEERIC has a pre-amplification stage for RPCs
  - 20992 channels, 2384 FEERIC cards (2720 spare included)
  - installation completed in July ‘19
  - **now under commissioning with pp Run 3 data**

- **One RPC was equipped with FEERIC during Run 2**
  - **factor 3-5 less charge** released in the RPC gas volume with FEERIC
  - lower HV working point w.r.t. to Run 2
  - **efficiency higher than 97%** in both bending and non bending plane, for different collision system
  - **very satisfactory performance and stability**
New wireless threshold distribution:

- Thresholds adjustable for each single FEERIC card instead of per RPC side like in Run 1 and Run 2
- Present Xbee system slow and unstable
- Agreement from TC+CERN-IT in June 2021 to upgrade to WiFi (band 2.4 GHz)

### Production (26 cards + spares) started

- 1 wifi router per side, connected to DCS via ethernet
- 12 wifi stations per side, connected to FEERIC via $I^2C$

### Installation foreseen during winter shutdown

(December 2022 – January 2023)
Readout architecture

- **New readout electronics for continuous mode**

- Replacement of all the cards in operation during Run 1 and Run 2
  - 234 Local cards, up to 16 per VME crate
  - 16 Regional cards, interfaced with the new CRU via 2 GBTx links
  - 16 J2-bus between the Local and Regional card

- One full crate: up to 16 Local, 1 Regional, 1 J2-bus

- In total: 16 similar crates for the full project
RPC production and status in INFN-TO lab (1)

- RPC production before 2019 highly unsatisfactory
  → inefficiency holes at the HV working point (WP)
  → high currents (several tens of $\mu$A)
  → general carelessness in the production process
  → not possible to use them in ALICE

- New pre-production batch of 3 RPCs at the end of 2019, after several interactions with the firm
RPC production and status in INFN-TO lab (2)

- All 3 RPCs tested in 2020 showed:
  → an **efficiency higher than 95%** around the WP (~ 8400V for streamer)
  → **low currents** (lower than 1μA)
  → can be used in ALICE

- New production batch of 30 RPCs in 2021
  → delay due to the commissioning of the brand **new INFN-TO laboratory**

- 4 RPCs tested so far. All of them show:
  → an efficiency even higher than the 2019 pre-production batch (WP at ~8100V)
  → **slightly higher currents**, between 2μA and 10μA (causes under investigation)
  → can be used in the ALICE cavern
Several hardware interventions during the commissioning without BEAMS:

- **gas leakage**, solved after recovery on RPCs side
- **HV trips**, solved after replacement of several faulty cables and connector on chamber side
- 1 HV board (for 6 RPCs) replaced

Average current value at 9500 V:

- 1.92 μA in 2018
- 4.59 μA in 2021
- 2.23 μA in 2022 (after the intervention in cavern)
MID status at ALICE at CERN (2)

- The entire system was **READY** when first Run 3 STABLE BEAMS at top energy arrived on July 5th

- Commissioning with first pp collisions ongoing

- Up to now, MID is always **READY and taking data** with ALICE when there are collisions
MID status at ALICE at CERN (2)

- **Online Quality Control:**

  → single-hit level quality control QC done  
  → MID tracks development ongoing  
  → matching between the MID and the other muon detectors ongoing
HV scan for efficiency measurements

- HV scan performed both with cosmics and pp data to compute the efficiency of the 72 RPCs.

- Scan performed at step of 100V, with an offset with respect to Run 2 HV working point from -500V to -1400V.

- Analyses of data taken with cosmics ongoing.
  - for some RPCs statistics is not enough to compute the efficiency only with cosmics data.

- The HV scan data taking for pp collisions is still ongoing.
  - stopped for the moment due to the LHC NO BEAM status which lasted for more than 4 weeks.
  - the HV scan with pp will be completed in few days as soon as stable beams will be back.
Conclusions

- **MID has been upgraded** with new front-end and readout electronics to cope with the higher interaction rates in Run 3
- **FEERIC** FE electronics in good shape, *in situ* tests proved fully satisfactory
- New **RPC gas gap** tests ongoing in Torino laboratory: promising results so far
- All the components for the **MID data readout chain** have successfully been tested and installed
- HV working point and threshold optimisation is **ongoing**
- **System status summary at CERN:**
  - all ALICE MID 72 RPCs are operational
  - readout electronics ok
  - stable participation in data-taking
  - QC under development
References


Thank you for your kind attention!