PID performance of the MRPC-based ALICE-TOF detector

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ALICE at LHC:
• The experiment devoted to the study of Quark Gluon Plasma
• (0.15 - 20) GeV/c • First pp: 2009

ALICE-TOF:
• Based on Multigap RPC technology
• Installed in 2008
• PID from 0.3 GeV/c; 3σ up to 2.5 GeV/c (π/K), 4GeV/c (p/K)

ALICE-TOF:

16 × 16 × 26 m³, 10000 t

10 YEARS IN OPERATION
ALICE-TOF

- inner/external radius: 3.7/3.99 m
- active area 141 m$^2$
- weight 26 tons
- $|\eta| < 0.9$
- full $\varphi$ $\rightarrow$ 18 SuperModules (SM)
- 5 Modules each SM
- 19(15) MRPCs per Modules
- total of 1593 MRPCs
- 152928 readout channels

120 cm

...wide area MRPC application!

In 2017, total of 2116 hours:
- $\sim$99% total time availability
- $\sim$93% average active channels

The missing 7% $\rightarrow$ due to electronics and connectors

(not to MRPC!)
ALICE-TOF MRPC

10 gas (93% C₂H₂F₂ + 7% SF₆) gaps, 250 μm, double-stack design

surface resistivity ~ MΩ/☐

bulk resistivity ~ 5 × 10¹² Ωcm

2.5 × 3.5 cm²

2 rows of 48 pickup pads
**Total current**: overall the 1593 MRPCs (without beam)

- **LHC Run1**
  - EPJ Plus (2013) 128: 44

- **LHC Run2**

- **ALICE Performance**
  - Time-Of-Flight detector
  - Total HV current without circulating beams

**stable** over the years!
Operation - Current

Small current:
- **no** ageing
- low noise

Total current: increases **linearly** with the **rate** (LHC luminosity)

**NO sign of deviations** (nor for the expected Pb-Pb Run 3 rate)
Operation - Matching Efficiency

For $p_T < 0.3$ GeV/c particles do not reach TOF (B=0.5 T)

- MRPC efficiency ($\sim 98-99\%$)
- TOF algorithmic inefficiency
- TOF geometrical acceptance (dead space)
  - Budget material (in front of TOF)
  - Hardware data taking conditions (extern.)
  - Track extrapolation

Performance stable during Run1 and Run2
(deviations due to)
Cosmic ray

Ultra-Peripheral Collisions

we expect two tracks in the central detectors with forward detectors showing no activity
PID with a TOF detector

\[ m = \frac{p}{c} \sqrt{\frac{c^2 t^2}{L^2} - 1} \]

\[
\left( \frac{\delta m}{m} \right)^2 = \left( \frac{\delta p}{p} \right)^2 + \left( \frac{\gamma^2 \delta L}{L} \right)^2 + \left( \frac{\gamma^2 \delta t}{t} \right)^2
\]

Dominant term for high momenta

\[ \Delta t \approx \frac{L c}{2p^2} \left( m_i^2 - m_j^2 \right) \]

PID capability of a TOF detector

\[ n_\sigma = \frac{\Delta t}{\sigma_{TOF}} \]

time resolution as low as possible
Time resolution

\[ \sigma \sim 84 \text{ ps} \]

\[ \sigma_{\text{TOF}}^2 = \sigma_{\text{MRPC}}^2 + \sigma_{\text{TDC}}^2 + \sigma_{\text{FEE}}^2 + \sigma_{\text{Cal}}^2 \]

\[ t_{\text{TOF}} - t_{\text{event}} - t_{\exp_i} \]

\[ \sigma_{\text{TOT}}^2 = \sigma_{\text{TOF}}^2 + \sigma_{\text{trk}}^2 + \sigma_{\text{event}}^2 \]

(negligible for \( p > 1 \) GeV/c)
Other factors that can lead to a spoiling of the ALICE-TOF time resolution:

- hit multiplicity (cluster)
- time walk
- asymmetric tails

Time resolution

\[ \sigma \sim 84 \text{ ps} \]

...improved!

\[ \sigma \sim 56 \text{ ps} \]

\[
\sigma_{\text{TOF}}^2 = \sigma_{\text{MRPC}}^2 + \sigma_{\text{TDC}}^2 + \sigma_{\text{FEE}}^2 + \sigma_{\text{Cal}}^2
\]

\[
t_{\text{TOF}} - t_{\text{event}} - t_{\text{exp}}
\]

\[
\sigma_{\text{TOT}}^2 = \sigma_{\text{TOF}}^2 + \sigma_{\text{trk}}^2 + \sigma_{\text{event}}^2
\]

(negligible for \( p > 1 \text{ GeV/c} \))
TOF time **calibration** is based on 3 components:

- global offset, common to all channels (clock)
- channel-by-channel offset (cables, …)
- **time-slewing** correction: correlation between the time and charge —> TOF system uses **Time Over Threshold**, as a proxy for the charge

~ 50% improvement (~110-130 ps in quadrature)
Time resolution - Time slewing

**single channel** upgraded calibration (2017)

~40000 channels

2017 calibration stability

88% of channels < 20 ps
mean = 14.0 ± 0.1 ps

stable during the year...
Time resolution - Time slewing

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**single channel** upgraded calibration (2017)

(before: groups of 8 channels, limited TOT range, polynomial parametrisation)

~40000 channels

2017 calibration stability

88% of channels < 20 ps

mean = 14.0 ± 0.1 ps

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stable during the year…
Time resolution - Time slewing

... and **uniform**

between **channels**
**Time resolution - \( \tau_{\text{event}} \)**


**Time event** is the event collision time:
for \( N_{\text{track}} \geq 2 \rightarrow \)
TOF can measure it independently

**OLD!**

\[
\sigma_{\text{TOF}} (\text{ps})
\]

**NEW!**

\[
\frac{\sigma_{\tau_{\text{event}}}}{\sqrt{\text{TOF track multiplicity}}}
\]

Same for different collision systems (pp, p-Pb, Pb-Pb)  
\( \rightarrow \) depends just on the track multiplicity

Improvement:
PID performance

TOF Beta vs momentum (pseudorapidity region $|\eta| < 0.5$)

$B=0.5$ T
K/π still separated

π

p/K still separated

signal (arb. units)

0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1

TOF β

0 0.8 0.82 0.84 0.86 0.88 0.9 0.95 1

ALICE Performance

Pb–Pb \( V_{SN} = 5.02 \) TeV

\( p = 3.00 \) GeV/c

\( p < 5.00 \) GeV/c

ALI-PERF-141743
Physics with TOF PID

http://dx.doi.org/10.1103/PhysRevC.88.044910

Precision measurement of the mass difference between light nuclei and anti-nucl

https://arxiv.org/abs/1712.09581
Conclusions

- The **ALICE-TOF** detector is a high performance detector based on MRPC technology; is a **large** (active area 141 m²) detector taking data for almost **10 years**

- Since its installation until today:
  - **no degradation**
  - very **stable** detector
  - **no loss** in performance
  - **no changes** in operation expected during **Run 3**

- The **time resolution** is improved thanks to 2017 calibrations (upgraded time slewing corrections): **from ~ 80 ps to less than 60 ps**

- With 2 tracks or more reaching the TOF, $t_{\text{event}}$ can be determined by the TOF itself (resolution on $t_{\text{event}}$ **below 30 ps** with 10 tracks)

- It provides a $K/\pi$ separation up to **3 GeV/c** and a $p/K$ separation up to **5 GeV/c** (PID)

- The **TOF-PID** is **extensively and successfully exploited** in many analyses in **ALICE**