The upgrade of the RPC-based ALICE Muon Trigger

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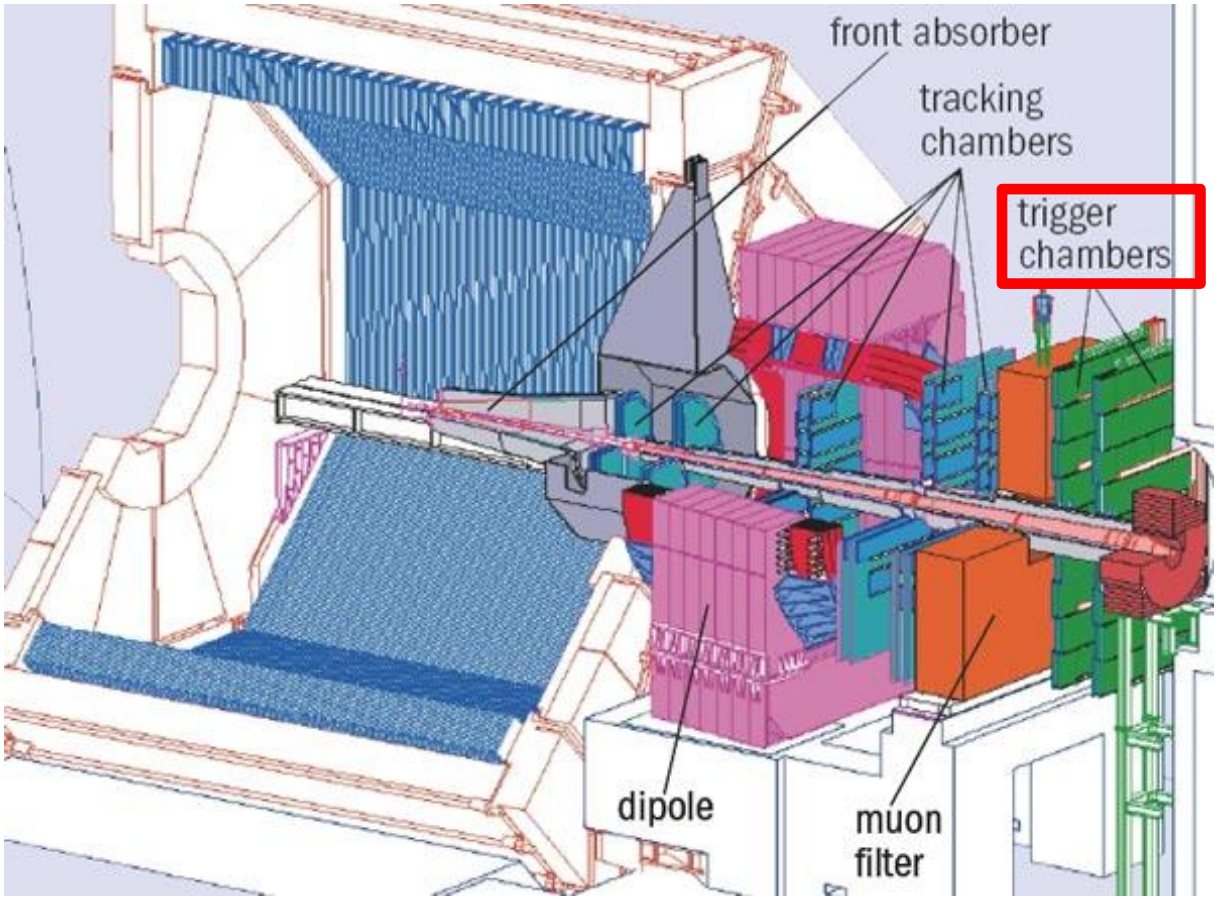
for the ALICE collaboration

RPC 2018 - THE XIV WORKSHOP ON RESISTIVE PLATE CHAMBERS AND RELATED DETECTORS

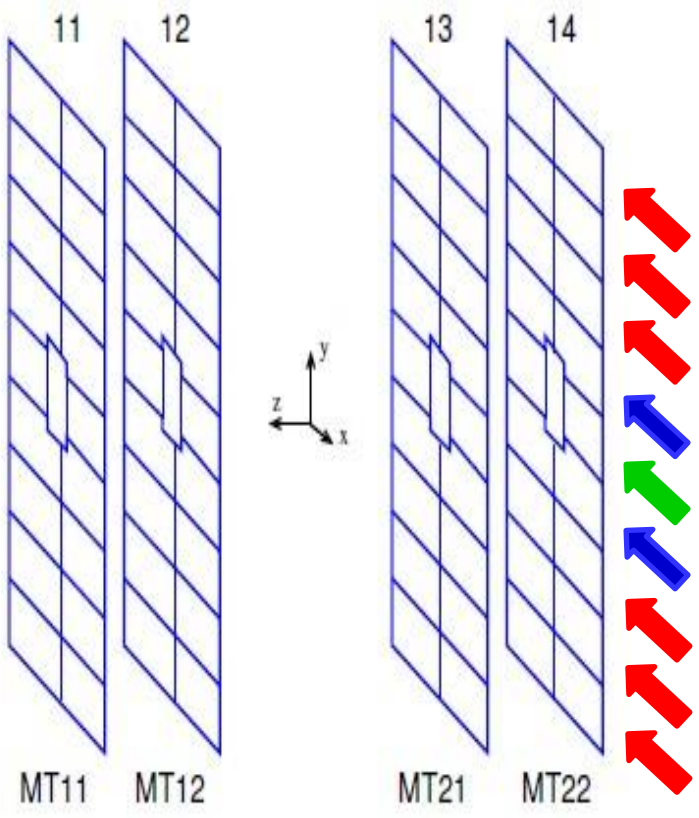
The ALICE dimuon trigger

- The ALICE experiment at CERN studies proton and ion collisions at LHC energies
- The ALICE Muon Trigger system is designed to perform a transverse momentum cut in order to select high-p_T muons that traverse the ALICE muon spectrometer



Muon trigger setup

- 72 RPCs, arranged in 2 stations of 2 planes each
- 3 different RPC shapes (Long, Cut, Short) in order to accomodate the beam pipe and its shielding
- The stations are arranged in projective geometry, i.e. with different dimensions, strip pitch and length
- 21k strips (~ 1,2,4 cm pitch) read out by FE discriminators

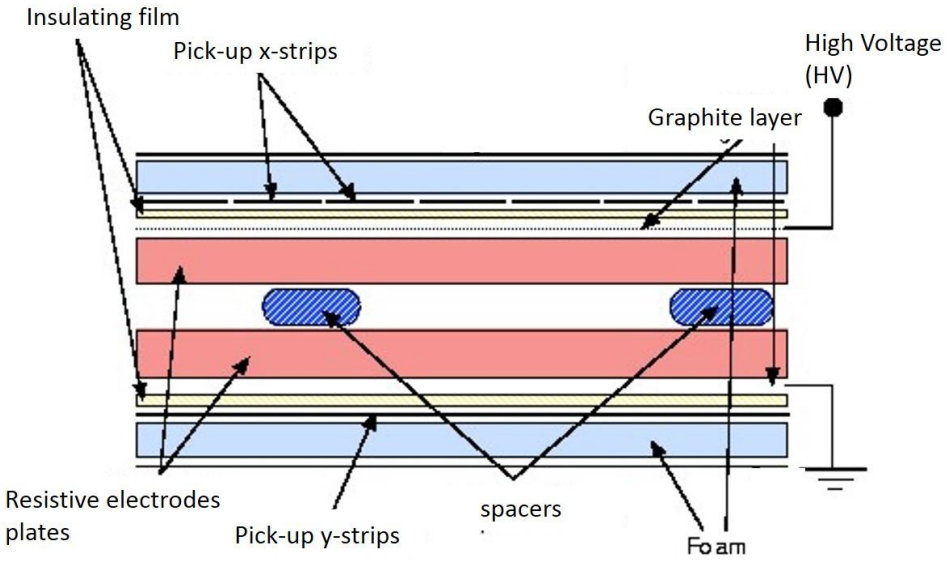


Long
Cut
Short

The detector planes are mounted on a mechanical frame that can be moved in order to allow access to the chambers for maintenance purposes

ALICE RPCs

ALICE RPCs are single-gap **bakelite** detectors: electrodes and gas gaps are 2 mm thick, **resistivity** between $3 \cdot 10^9$ and $1 \cdot 10^{10}$ $\Omega \cdot$cm



Gas gaps manufactured at General Tecnica in 2004-2005 and working in ALICE since 2010 (Run I 2010-2013, Run II 2015-2018)

Segmented strip planes manufactured at INFN technological lab in Torino

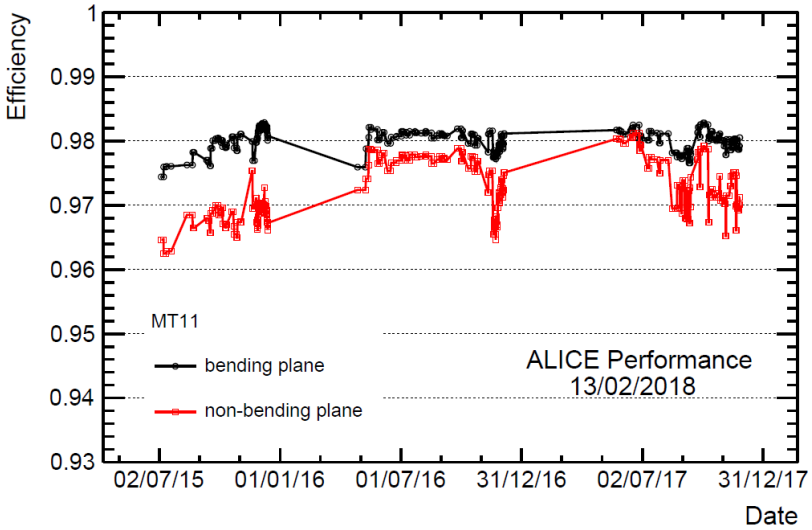
Operating **gas mixture** consists of 89.7% $C_2H_2F_4$, 10% i-C_4H_{10} and 0.3% SF_6 (R&D on ecologic gas mixtures ongoing, see A. Bianchi talk!)

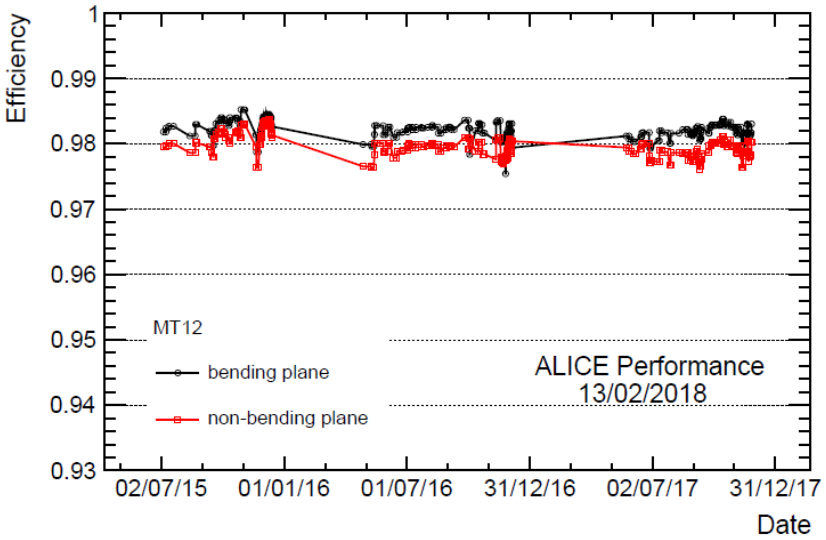
Readout electronics are ADULT FE discriminators without pre-amplification, with a threshold of 7 mV ("maxi-avalanche" operating mode)

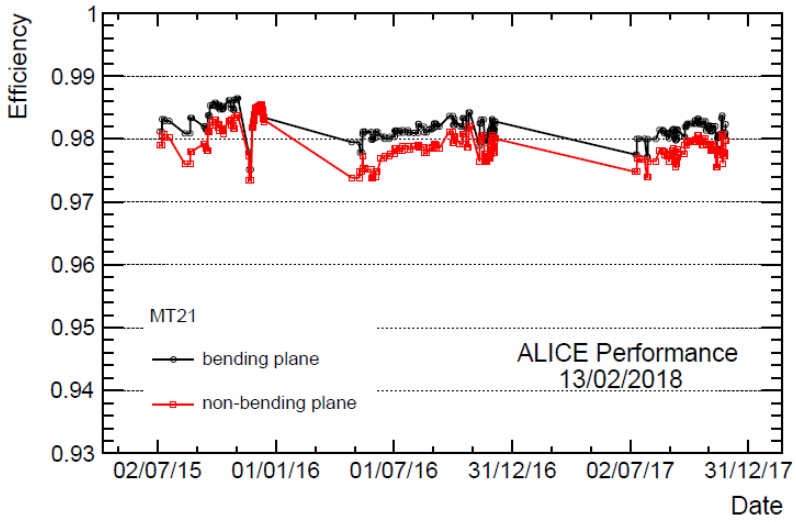
The effective **HV** applied is about 10400-10500 V at 970 mbar and 20 °C

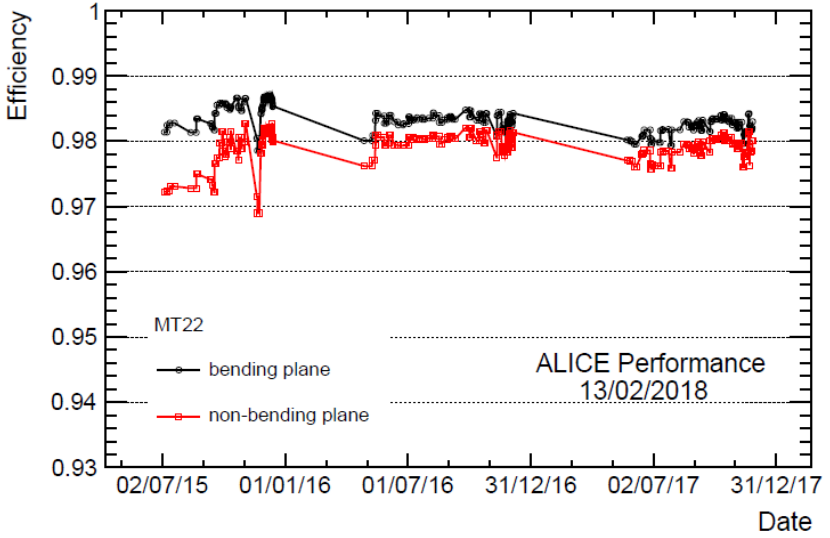
Average charge per hit is 100 pC, max. **rate capability** is about 100 Hz/cm^2

ALICE RPC efficiency 2015-2017



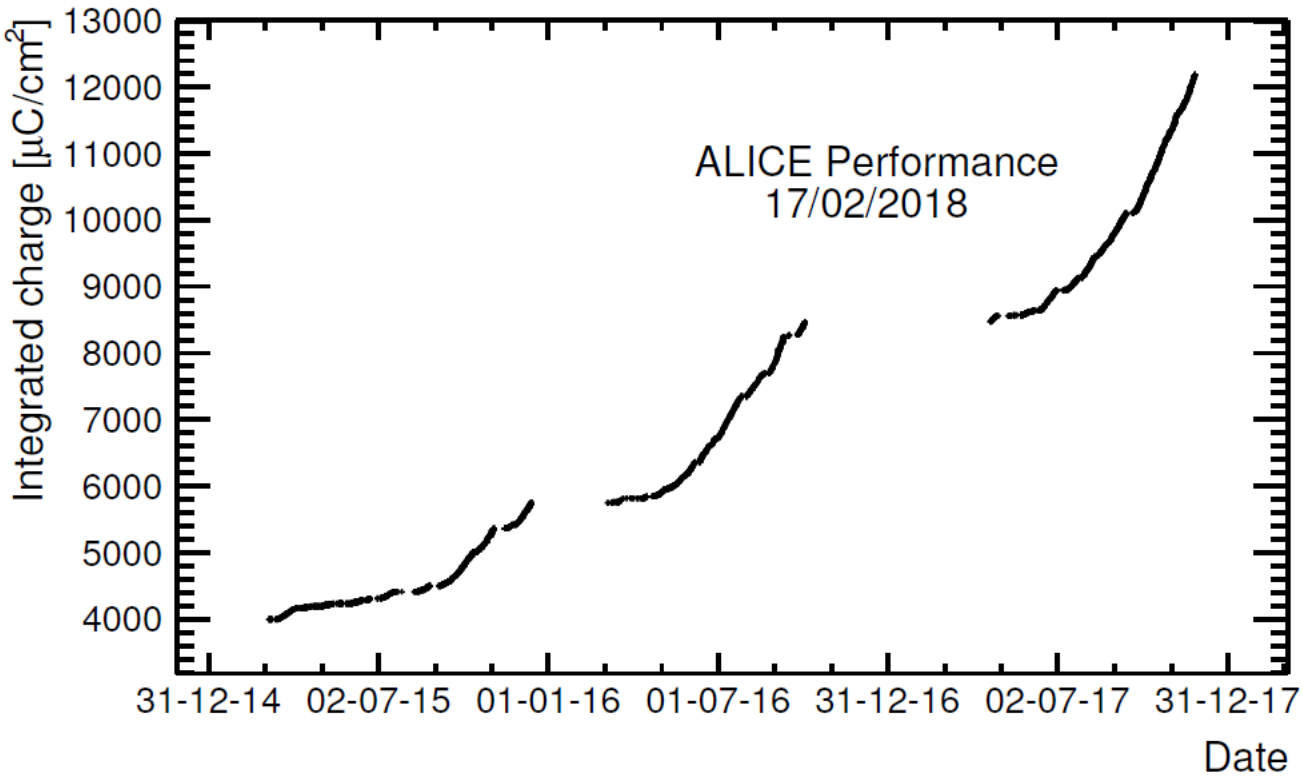






Average efficiency of the four RPC planes (> 97%) well within requirements and stable during Run II (2015-)

Total integrated charge



Average integrated charge is about 12 mC/cm^2, the most exposed gaps reached 30 mC/cm^2

ALICE RPCs were ageing-tested up to 50 mC/cm^2, so this is their certified lifetime

Upgrade: from Muon TRigger to Muon ID

From Run III (2021 -) onwards, the ALICE experiment will run in *continuous mode* (i.e. without trigger) and Muon Trigger will switch to Muon IDentification

Moreover, increased luminosity and collision rate planned for RUN-III and RUN IV will induce a large increase in counting rate (higher than current rate capability)

Run 2

pp average	pp maximum	Pb-Pb average	Pb-Pb maximum
2 Hz/cm^2	5 Hz/cm^2	4 Hz/cm^2	7.5 Hz/cm^2

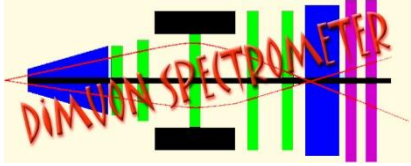
Run 3+ 4

pp average	pp maximum	Pb-Pb average	Pb-Pb maximum
5 Hz/cm^2	13 Hz/cm^2	48 Hz/cm^2	90 Hz/cm^2

To reduce ageing effects and meet the rate capability requirements, charge per hit has to be limited. This can be obtained operating RPCs with the same gas mixture but at **lower gain** with a **new front-end electronics** that provide **signal amplification** (**FEERIC ASIC**).

RPCs which have already cumulated a large integrated charge (i.e. the 24 gaps closest to the beam pipe) will be replaced during the long shutdown.

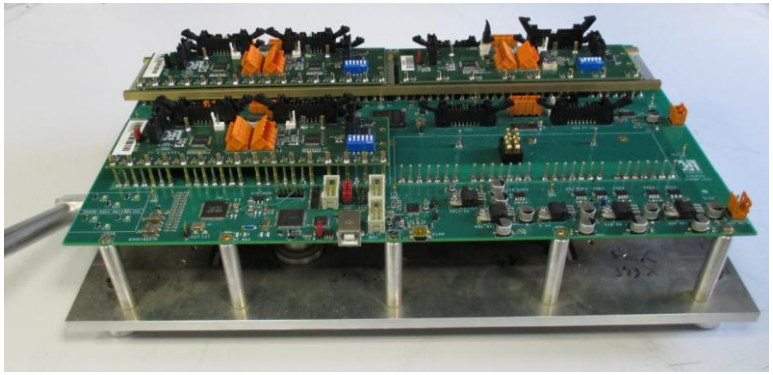
MID Upgrade



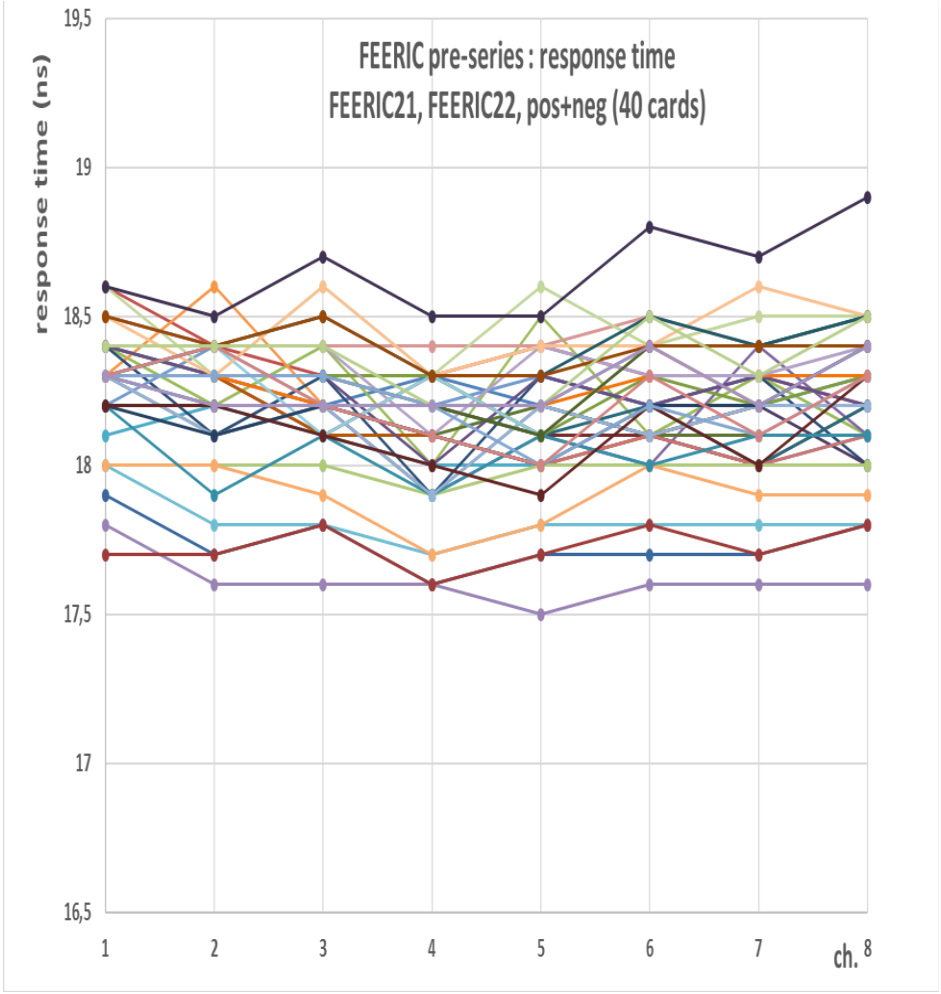
- ***FEE for the RPCs (FEERIC)***
- ***Wireless FEE threshold distribution***
- ***Readout Electronics***
- ***New gas gaps made with new bakelite***

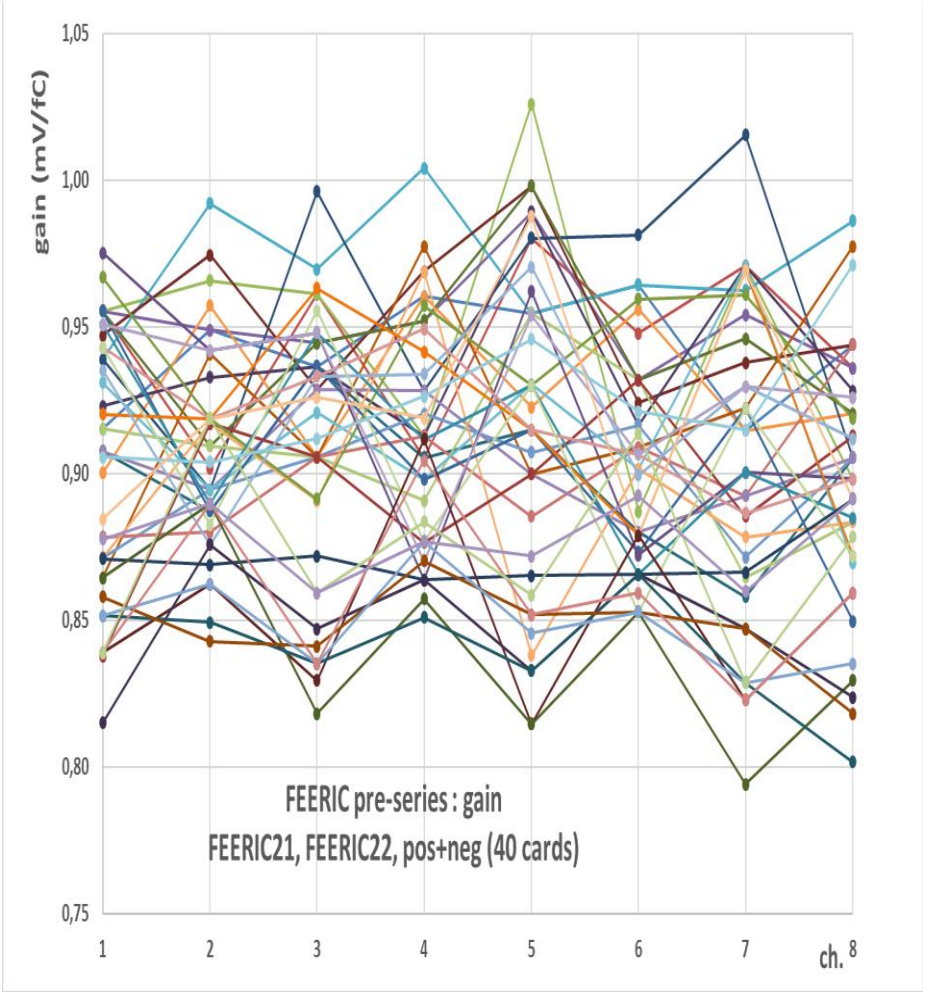
MID Upgrade : FEERIC project
FE Electronics for the RPC detectors

- ***Goal: slow down RPC aging after LS2***
  - 20992 ch., **2384 FE cards** (+14% spares)
  - Present ASIC ADULT: no amplification
  - Future ASIC **FEERIC with amplification**
- ***Production test bench fully operational***
- ***ASIC production (x5000) validated in 2 weeks in June 2016 using the test bench***
  - **Yield > 98%**
- ***Card production***
  Production completed (from **Sept.** to **Jan. 2018)**



FEERIC pre-series performance
ex. of Response Time and Gain dispersion

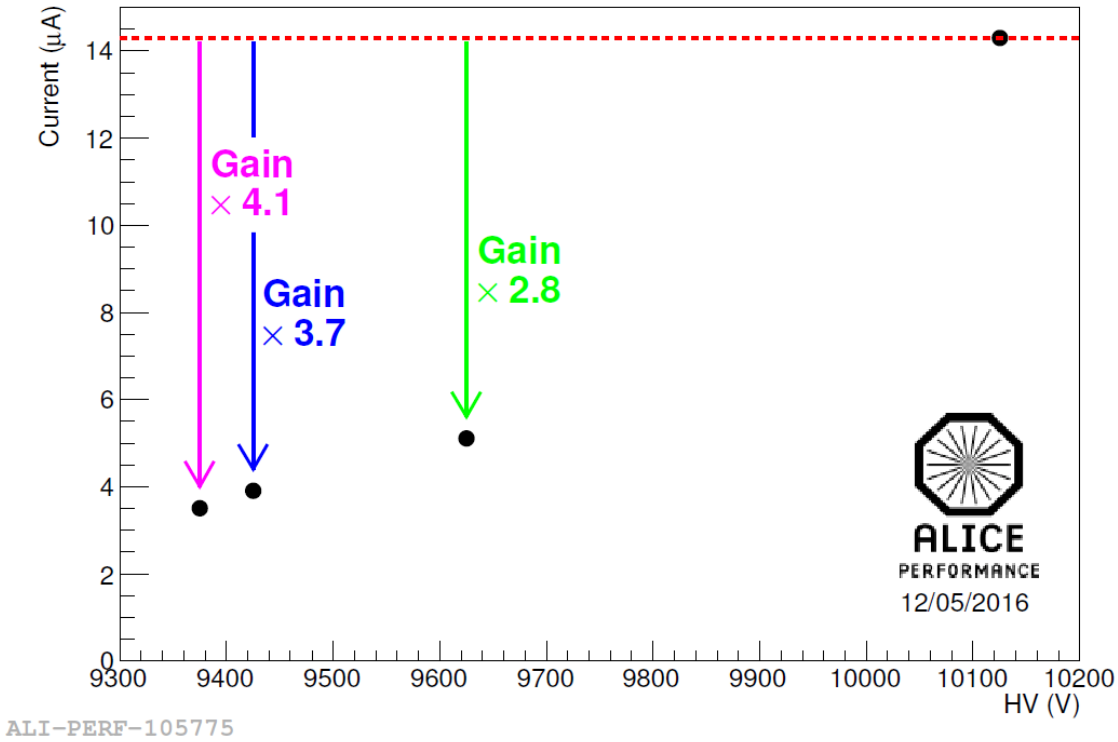




- Pre-series response time dispersion < 1.5 ns
- Response time dispersion requirement was 3 ns (for full prod.)

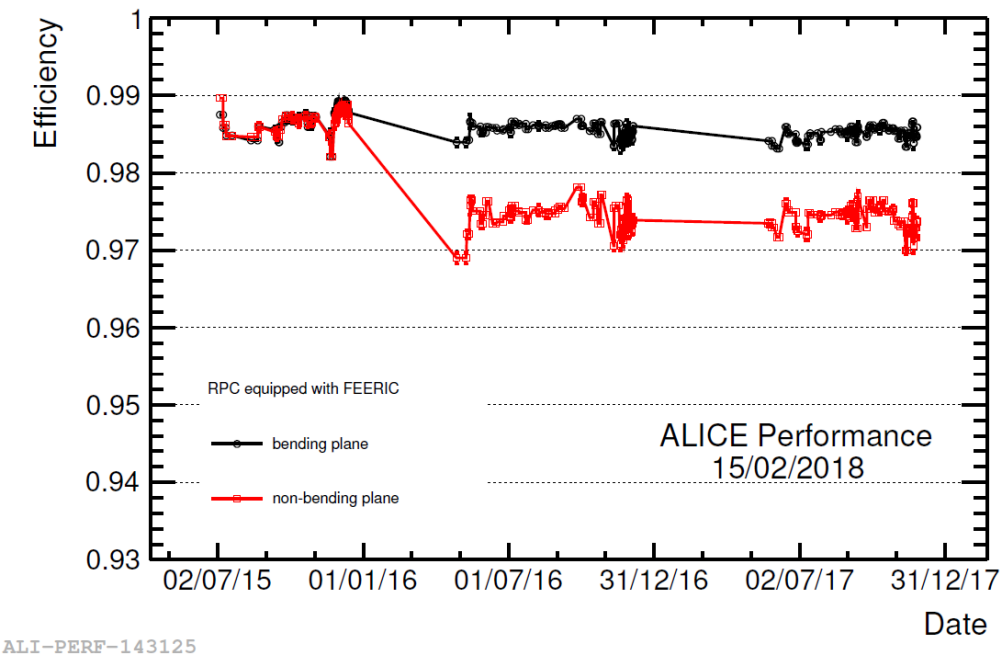
- Pre-series gain dispersion ~ ±10%

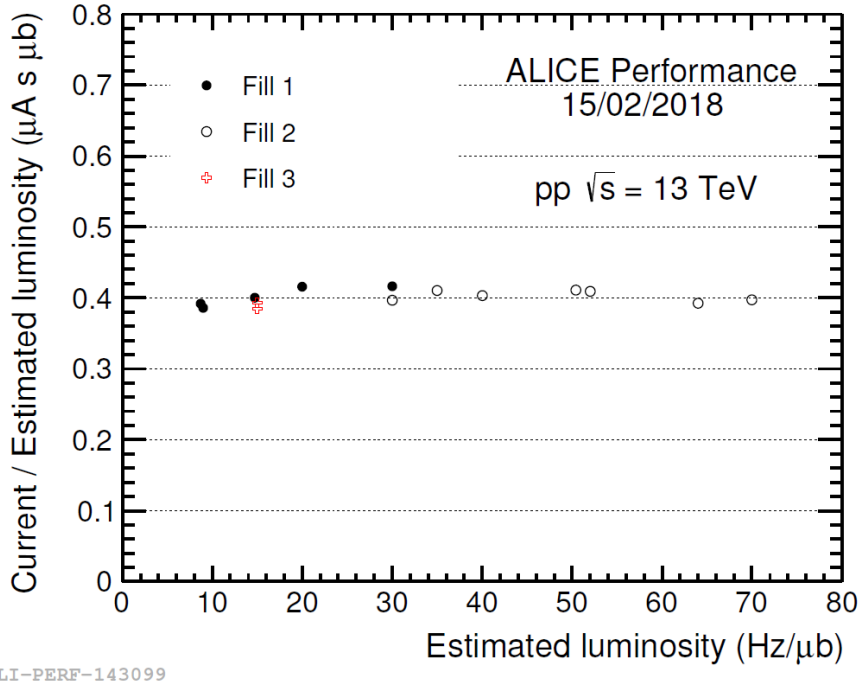
First results of FEERIC in ALICE (1)



- 39 FEERIC cards on 1 (/72) RPC in ALICE cavern since Feb. 2015
  - **Factor 4 less charge released in the RPC gas with FEERIC (lower RPC HV)=> reduced aging and increased rate capability**
  - Very satisfactory performance and stability (next slide)

First results of FEERIC in ALICE (2)

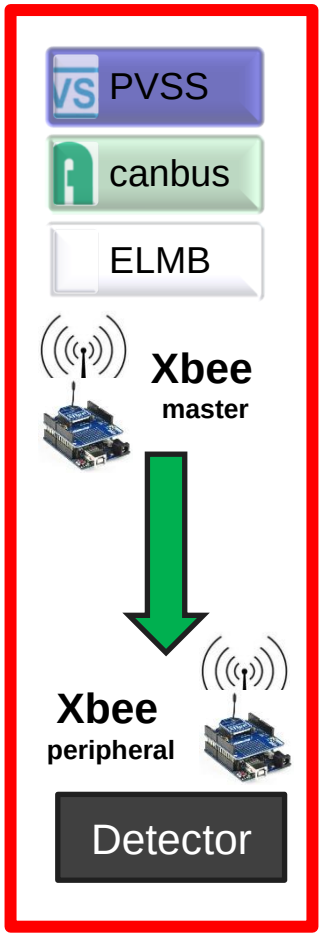




Efficiency is stable (the drop in the non-bending plane is due to a non-perfect synchronization of the downstream trigger electronics which performs the coincidence between readout planes) as well as the current.

MID Upgrade
Wireless FEERIC threshold distribution (1)

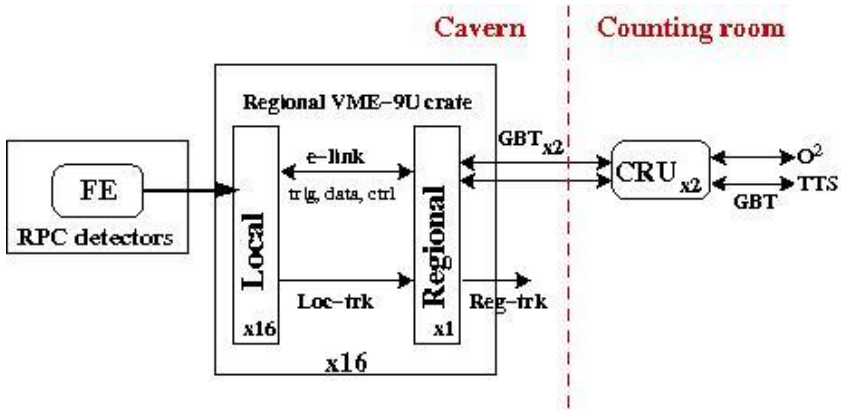
- ***Why go to wireless threshold distribution ?***
  - Threshold setting per FEERIC card (vs. per RPC side in the present setup)
  - Possibility of minimizing RPC operating HV, by tuning thresholds locally => optimize FEERIC goal to reduce RPC ageing
- ***Zigbee technology used***
  - High level protocol
  - Suitable for required data bandwidth and speed
  - Bandwidth 2.4 Ghz/Radio Communication
  - Based on Microcontroller Atmel SAMD21 core Cortex M0+
  - SoftWare based on Arduino libraries (I2C, SD cards and Xbee)
  - API mode used, checksum for guaranteeing data transmission
  - One full line has been installed during YETS 2017 on the RPC already equipped with FEERIC cards in the cavern, 2018 will be devoted to long term stability tests.

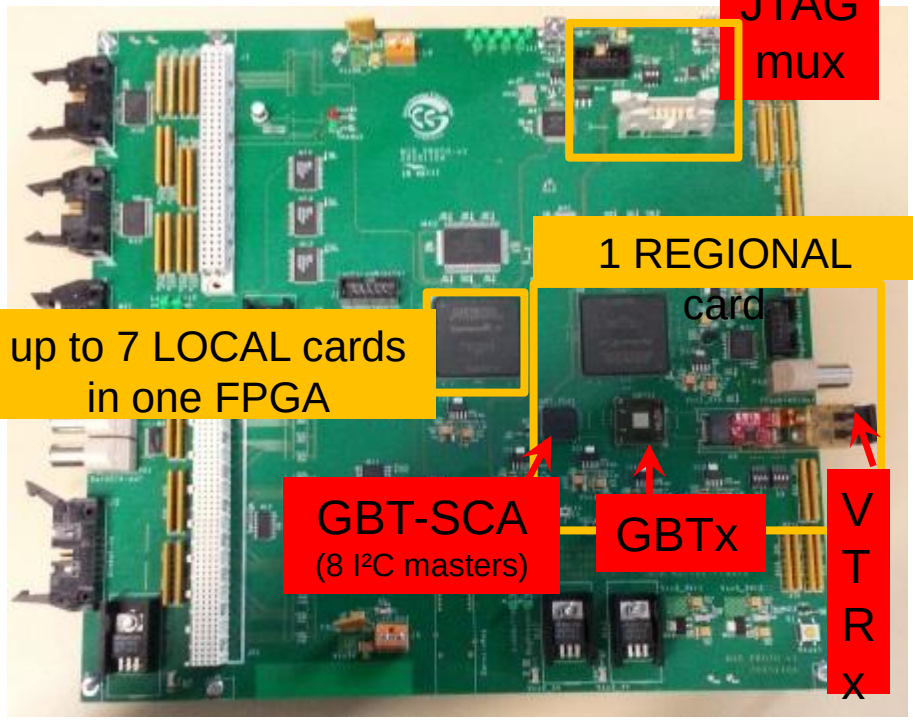


Xbee peripheral card (24 peripheral + 2 master cards needed in total)

MID Upgrade
Readout Electronics

- ***Readout electronics for continuous mode***
- ***Replacement of the 234 Local and the 16 Regional cards presently in operation***
- ***Interfaced with the Common Readout Unit (CRU) developed for LHCb/ALICE***
- ***Readout card prototype ready end 2015***
  - Emulate, on the same card, 7 Local cards connected by e-links@320 Mb/s to one Regional card implementing 1 GBT@3.2 Gb/s (GBTx, GBT-SCA, VTRx)
  - **Fully operational**
- ***Readout card pre-series => full chain, 1/16 of complete project***
  - 16 Local => 3 cards produced
  - 1 Regional => 3 cards produced
  - 1 J2 bus from Local-Regional => 3 cards produced
  - Pre-series validation ongoing, Production Readiness Review expected in March 2018





Test of the new RPCs

RPCs made with new bakelite (produced by Puricelli with smoother surface w.r.t PanPla bakelite) are being manufactured at General Tecnica and are currently tested in order to replace the most exposed ones.

The tests are performed with cosmic rays in the INFN Torino lab and include:

The detection of gas leaks;

Check of the absence of ohmic leakage currents;

The efficiency vs. HV curve in cells ≈ 20 x 20 cm^2 to select working HV;

The noise map of the detector;

The efficiency map at working HV, with a granularity of ≈ 2 x 2 cm^2.

RPC Test station

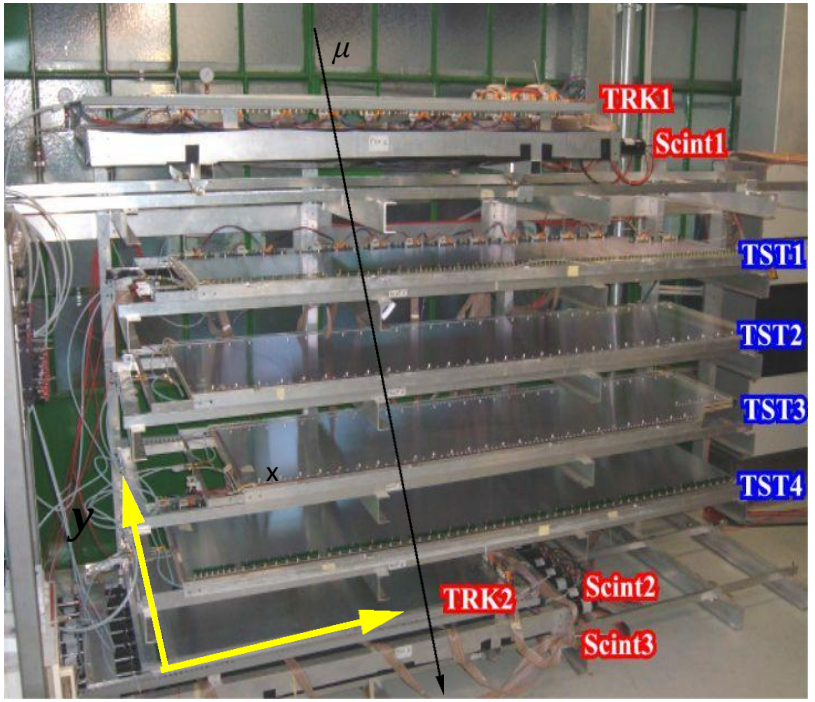
- Test station with cosmic rays composed of:
  - 3 planes of 9 scintillators each in a moving support;
  - 2 tracking RPCs in a moving support;
  - 4 test slots where the RPCs to be tested are placed.
- Streamer mixture:

Ar	$C_2H_2F_4$	$i-C_4H_{10}$	SF_6
50.5 %	41.3 %	7.2 %	1 %

ADULT front-end discriminators with internal threshold of 80 mV.

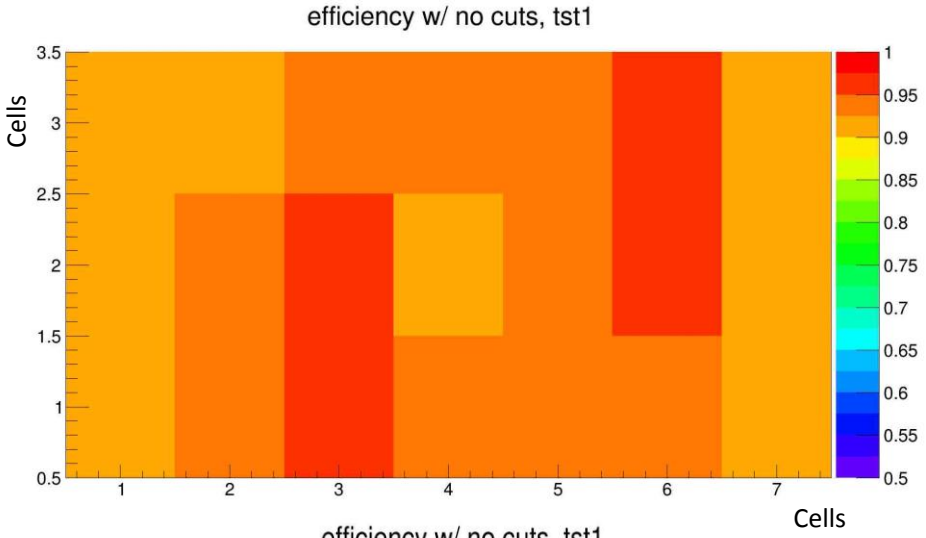
- 2 half-RPCs at a time can be tested.
- Trigger and DAQ performed via three FPGA modules (V1495)

16 RPCs of the new production batch have been tested.

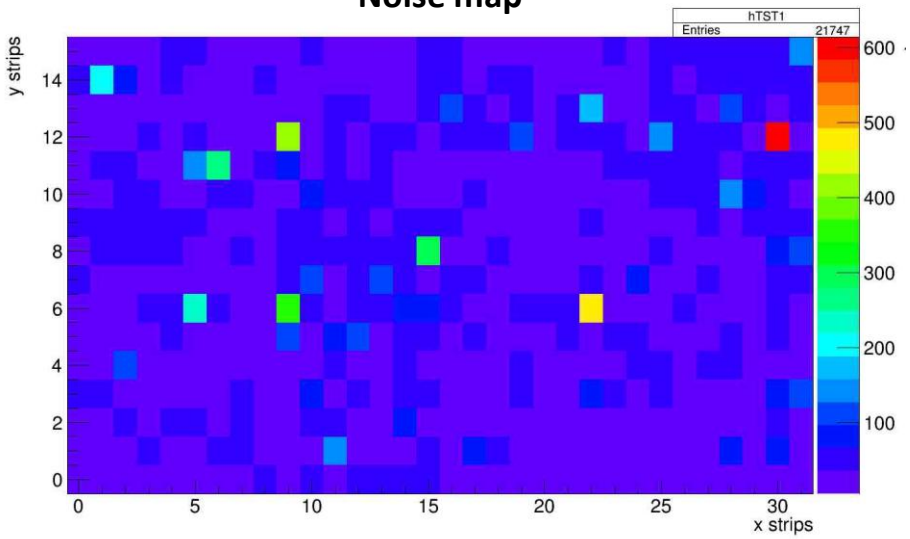


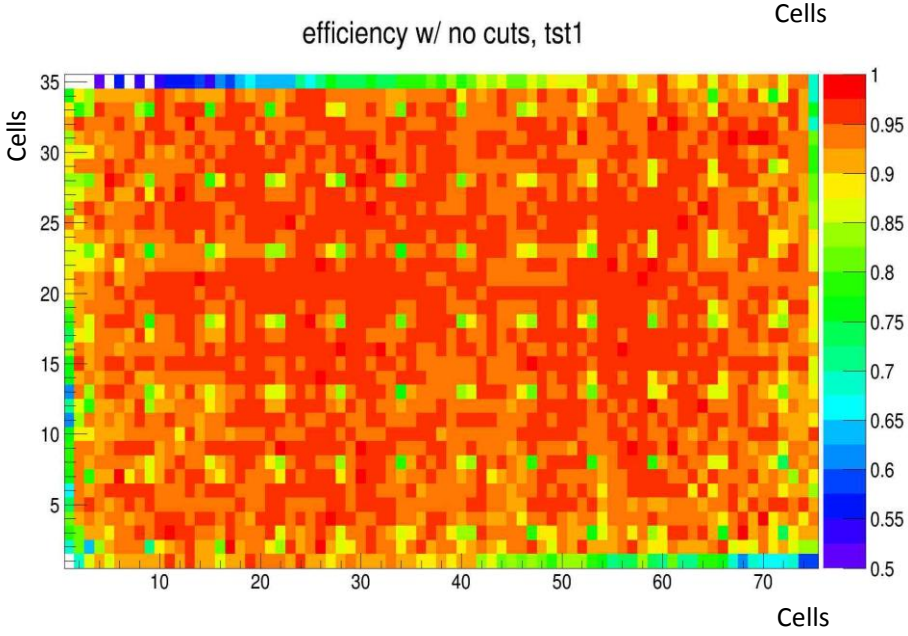
Efficiency and noise maps

Efficiency and noise maps at working HV for RPC half-planes



Noise map



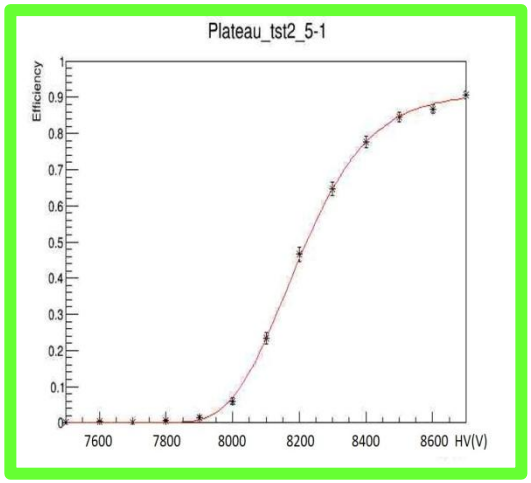


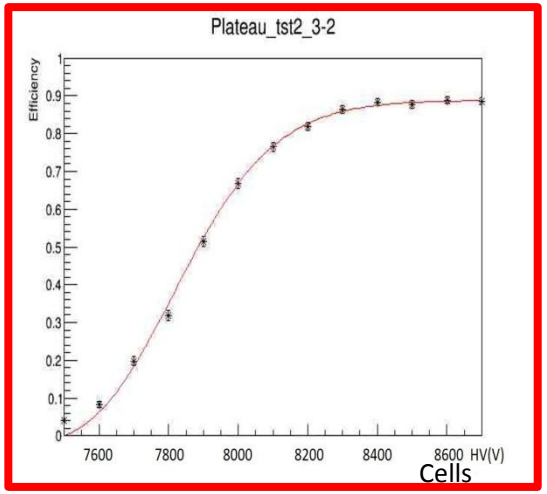
Red color corresponds to 6 Hz/cm^2

Efficiency-HV curve

In some detectors, 95% efficiency is reached at higher HV values (up to 8800 V, instead of customary 8300 V) and sometimes it is not uniform over their entire surface.

Efficiency at 8600 V

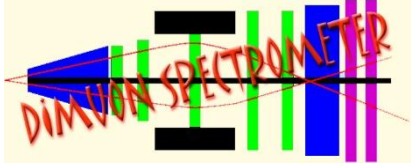




This RPC starts to be 95% efficient at 8400 V in the central region while other zones of the chamber need about 8600 V and others up to 8800 V. Causes of this phenomenon are under investigation.

However, this does not affect the RPC global efficiency at working point (efficiency does not decrease in zones with a slight local overvoltage: t.b.c. with higher rates).

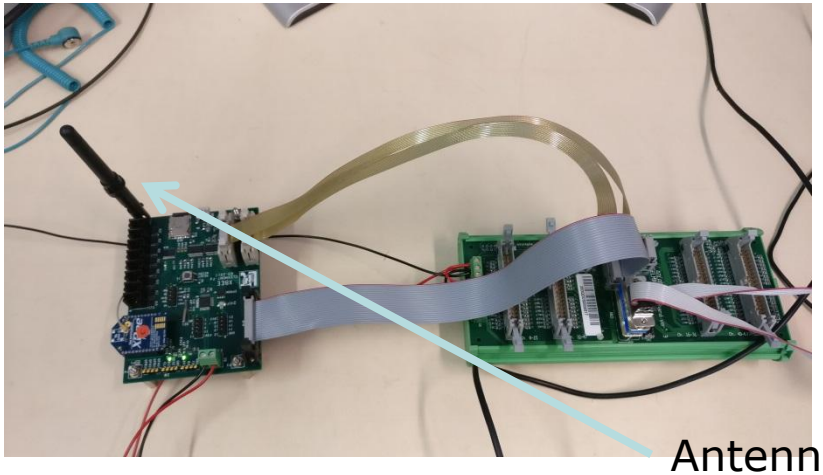
Conclusions and future goals



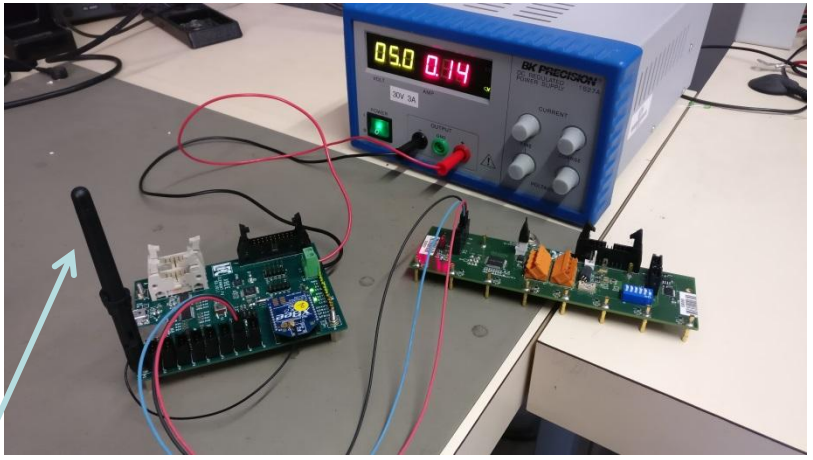
- ALICE Muon Trigger is running smoothly since the start of data-taking and its performance is fully satisfactory
- FEERIC in good shape: *in situ* test proved fully satisfactory, cards have been delivered and are ready for installation
- RPC tests ongoing: some detectors show efficiency nonuniformities but this phenomenon does not affect the RPC global efficiency at working point.
- Installation of FEERIC and of new RPCs will take place on schedule starting in 2019

MID Upgrade
Wireless FEERIC threshold distribution (2)

- ***Xbee card description and functionalities***
  - Same Xbee card for master and peripheral cards (1->12 in ALICE)
  - One single FirmWare: master/peripheral role is assigned by SoftWare configuration. By default, a board acts as peripheral
  - SD Card for initialisation
  - EEPROM for storing/re-loading last used values in case of power cycle
  - Whole chain, hw+sw, operational in lab
  - One full line has been installed during YETS 2017 on the RPC already equipped with FEERIC cards in the cavern, 2018 will be devoted to long term stability tests.



Antennas



Xbee master + ELMB

Xbee peripheral coupled to FEERIC board
(threshold setting via I2C)