ALICE Muon Trigger upgrade

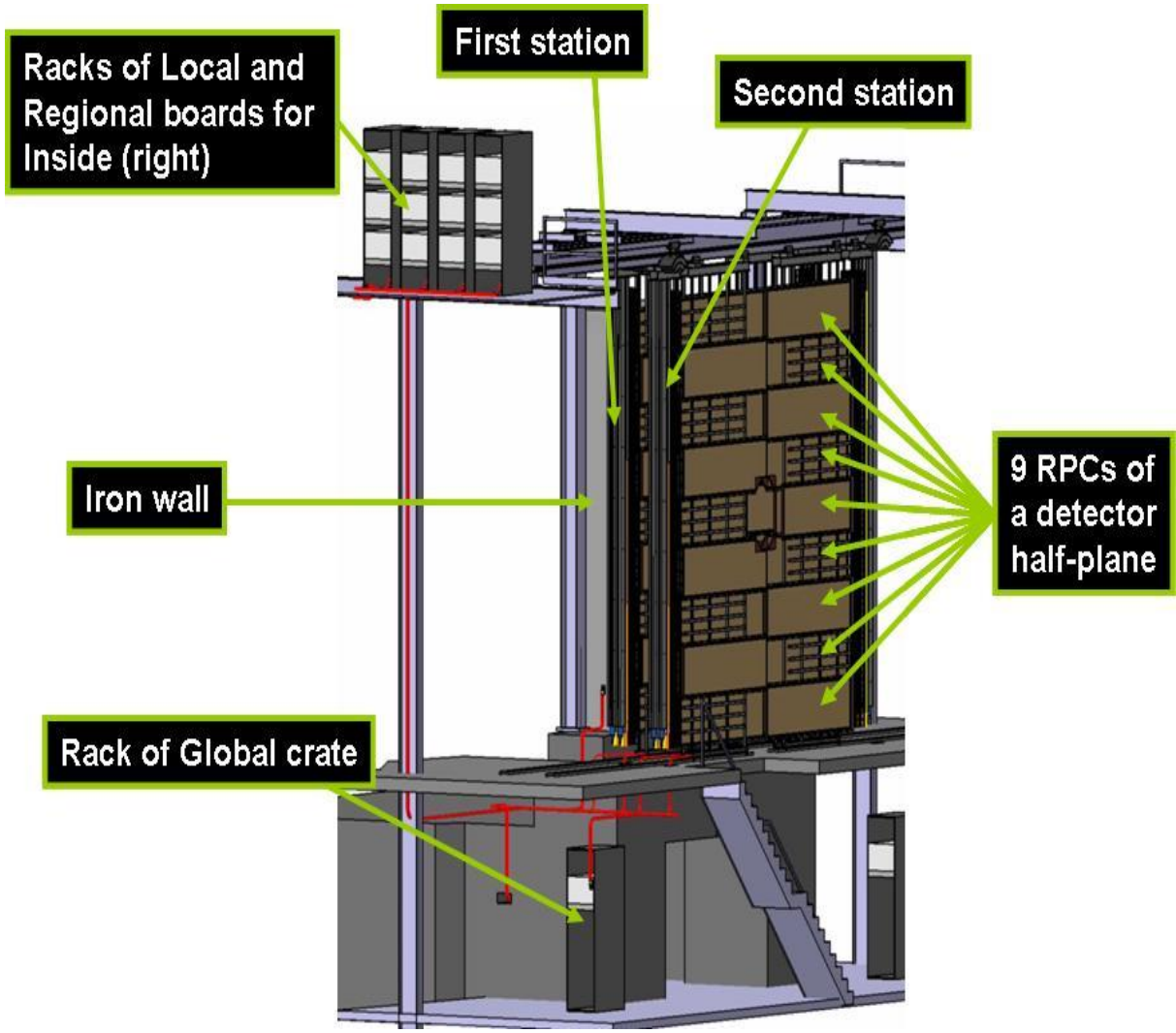
Context
RPC Detector Status
Front-End Electronics Upgrade
Readout Electronics Upgrade
Conclusions and Perspectives

Context

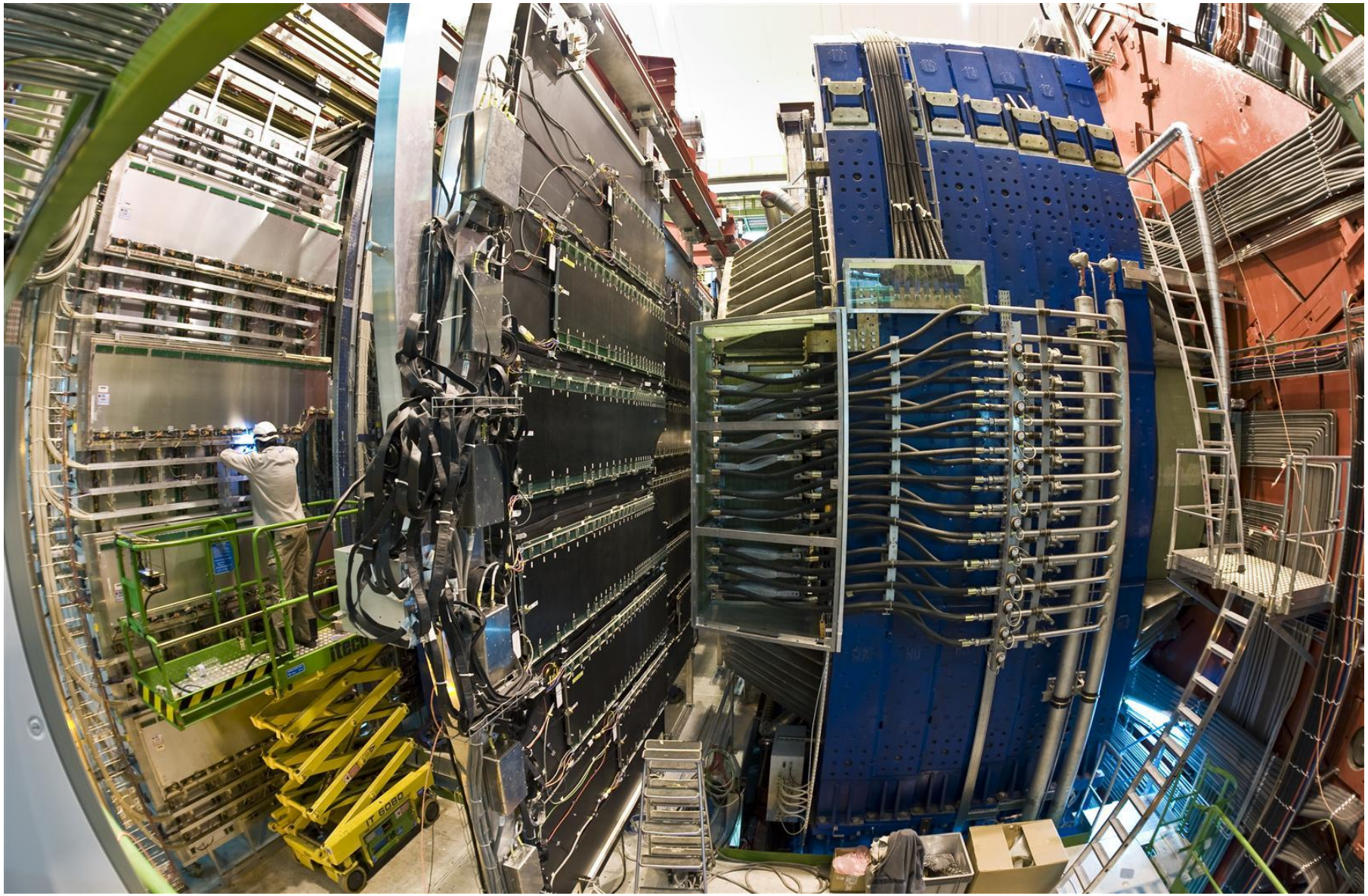
- The Muon Spectrometer needs an important upgrade in view of operating in the context of the high luminosity expected at the LHC after 2018 (run 3)
  - Larger signal + background rates
  - Larger trigger rates
- For the Muon Trigger, two main upgrades are presently considered
  - Front-End Electronics
  - Readout Electronics
  - No detector upgrade foreseen so far

The ALICE Muon Trigger

- 4 planes of 18 single gap Resistive Plate Chambers (RPC) each, arranged in 2 stations
- Total surface ~140 m^2
- Total # of readout/FEE channels ~21000
- Trigger electronics (decision, readout)
- Decision on single muons, unlike-sign and like-sign muon pairs
- p_T-based muon selection

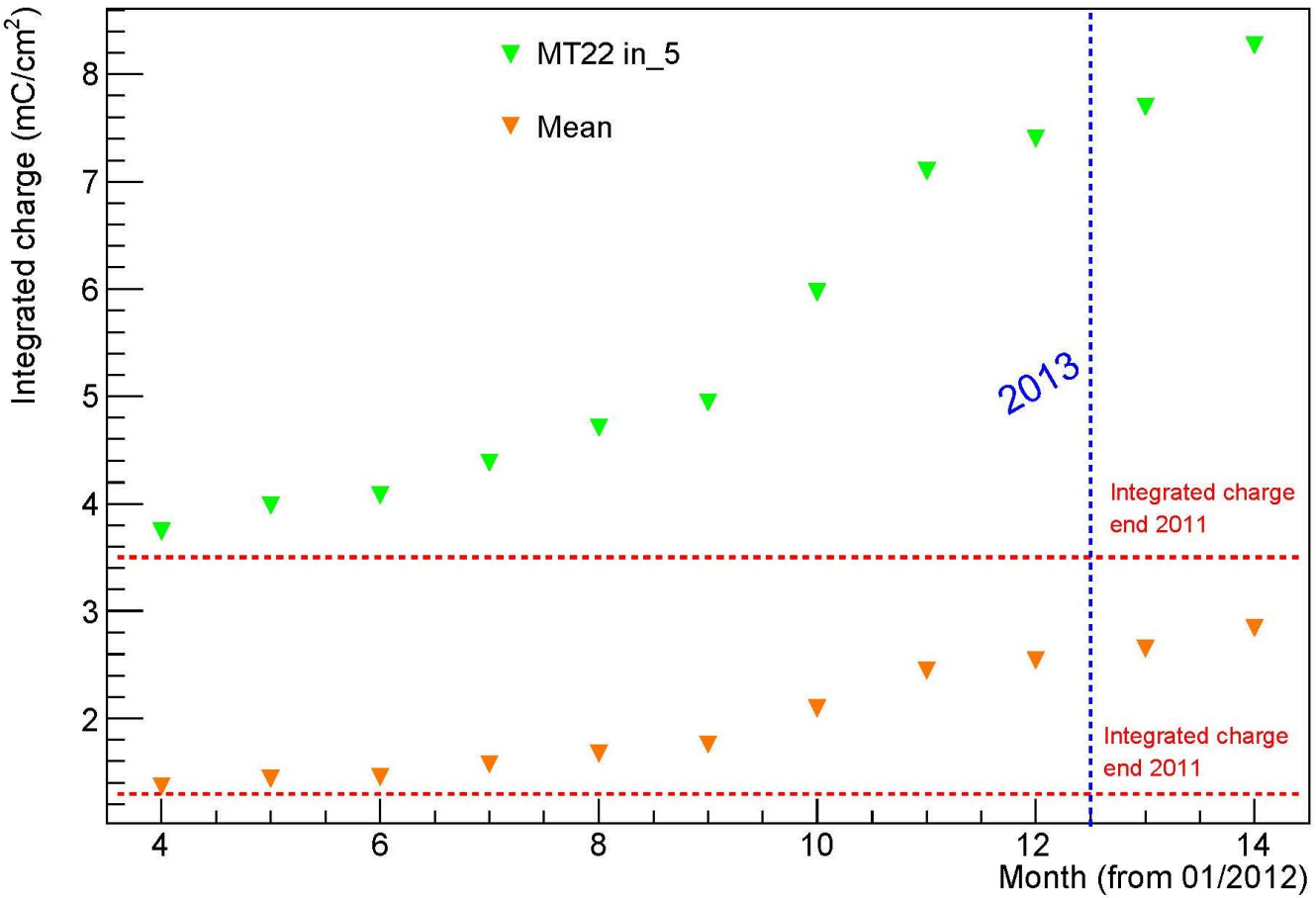


The ALICE Muon Trigger



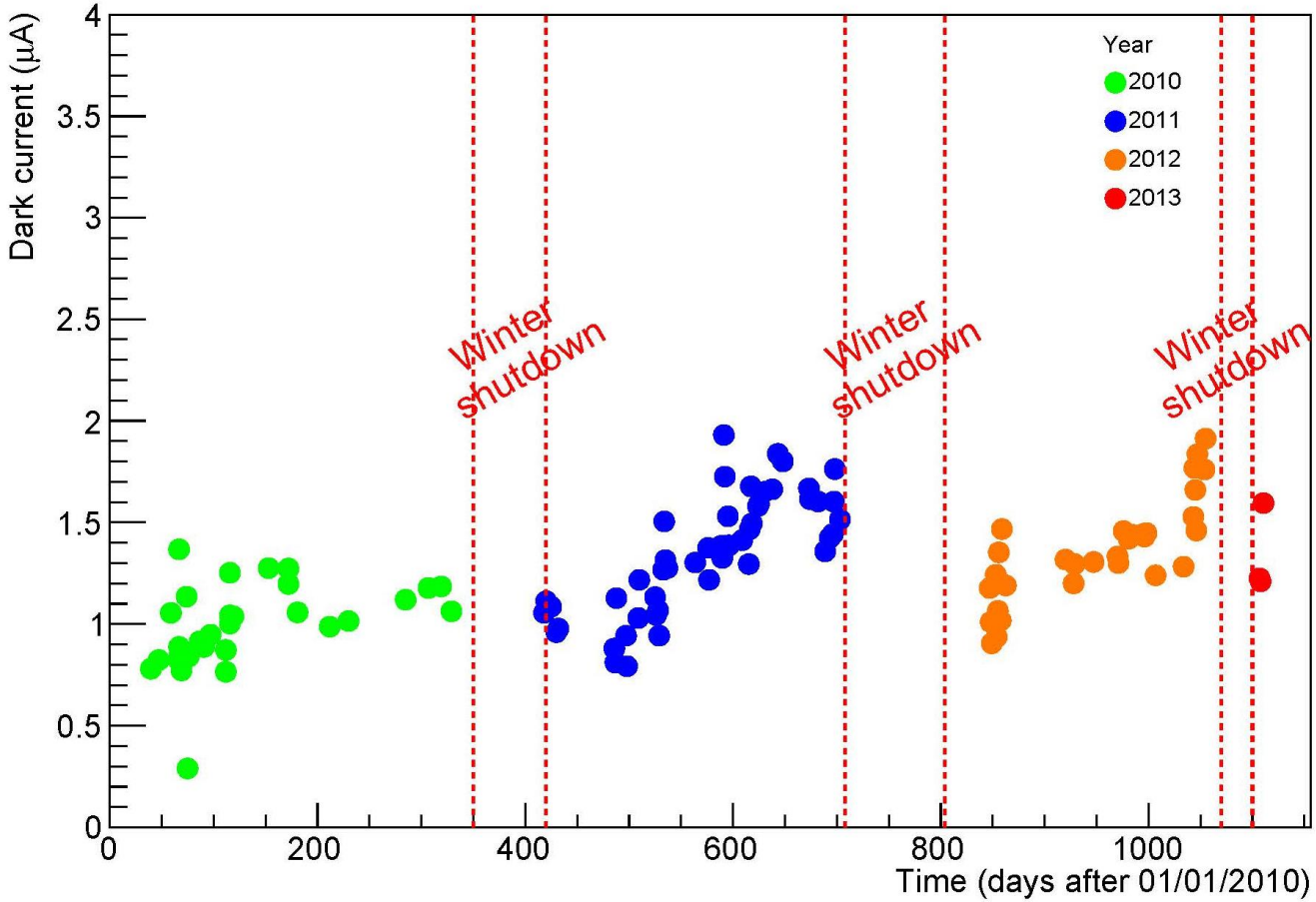
RPC detector status

RPC Detector Status: Integrated Charge



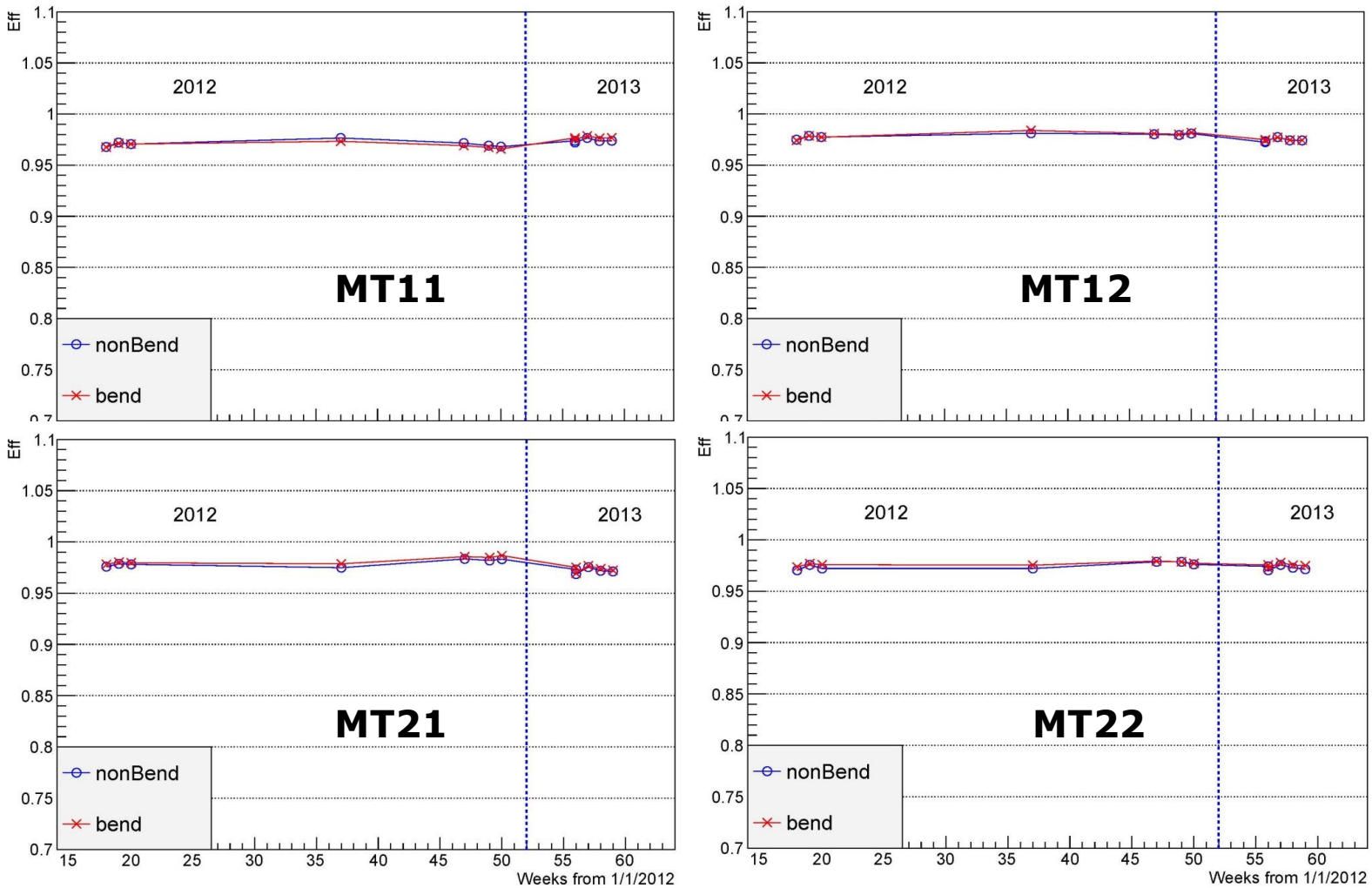
- Integrated charge so far : 3 (8) mC/cm^2 mean (peak)
- During our R&D : up to 50 mC/cm^2

RPC Detector Status : Dark Current



Low and stable dark current so far

RPC Detector Status: Efficiency

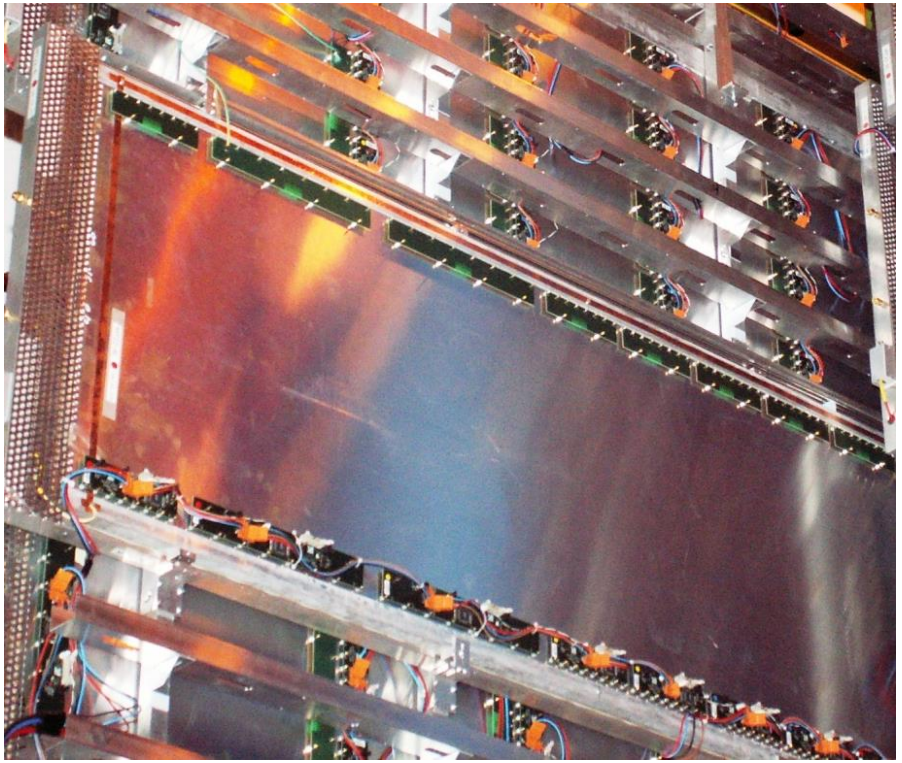


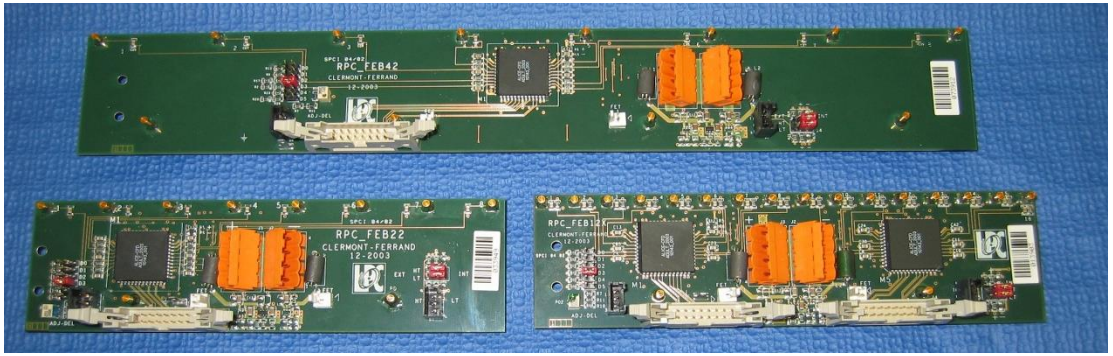
High and stable efficiency so far

UPGRADE of the Muon Trigger Front-End Electronics

Present Front-End Electronics

- **20992 strips**
- **2384** (+ spares) **FE Boards**
  - 10 types of FEB (8 or 16 ch/board)
  - For 2 different signal polarities
  - 5 possible delays to compensate for cable lengths between 14 and 20 m
  - 8 ch **ADULT ASIC** designed at LPC-Clermont
- Main functionalities of ADULT
  - Discrimination (two thresholds)
  - Signal delay (compensation of the different cable lengths)
  - LVDS driver
  - **No amplification**





FEE Upgrade Goal

- **Limit RPC aging** in the severe expected conditions of the future operations at LHC

- Improve present RPC (short term) counting rate limitation
  => Typically from ~50 Hz/cm^2 to ~200 Hz/cm^2

Pb-Pb √s=5.5 TeV, 100 KHz		p-p √s=14 TeV, 200 kHz	
RPC counting rate (mean)	**RPC counting rate (peak)**	**RPC counting rate (mean)**	**RPC counting rate (peak)**
75 Hit/s/cm^2	**125 Hit/s/cm^2**	6 Hit/s/cm^2	15 Hit/s/cm^2

Expected counting rates of the RPCs

FEE upgrade Strategy

- Possible Solution => **FEE with amplification** (RPC in avalanche mode, like in ATLAS & CMS)
  - Total charge (mean): Q~10-30 pC (goal) vs. 100 pC presently
  - Fast charge on the strip @FE-threshold: q ~ 100 fC (goal)

  ⇒ **RPC aging expected to be reduced**

- No existing ASIC with all requested functionalities

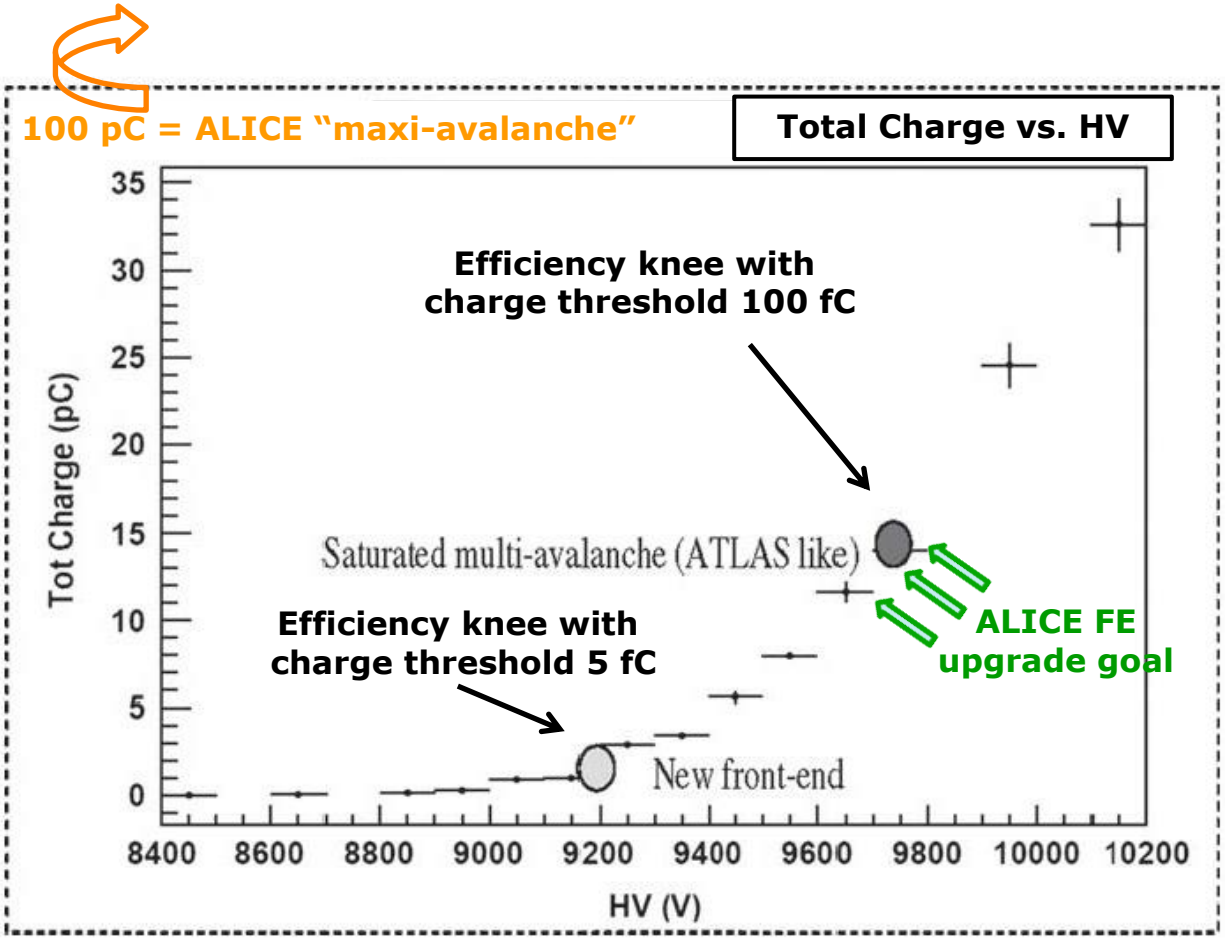
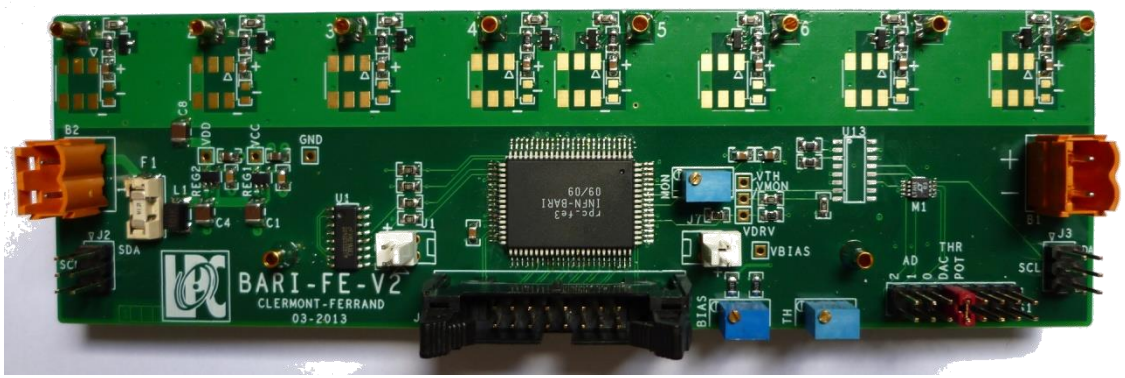


Fig. 4. Average total charge per pulse delivered in the gas vs. applied voltage.

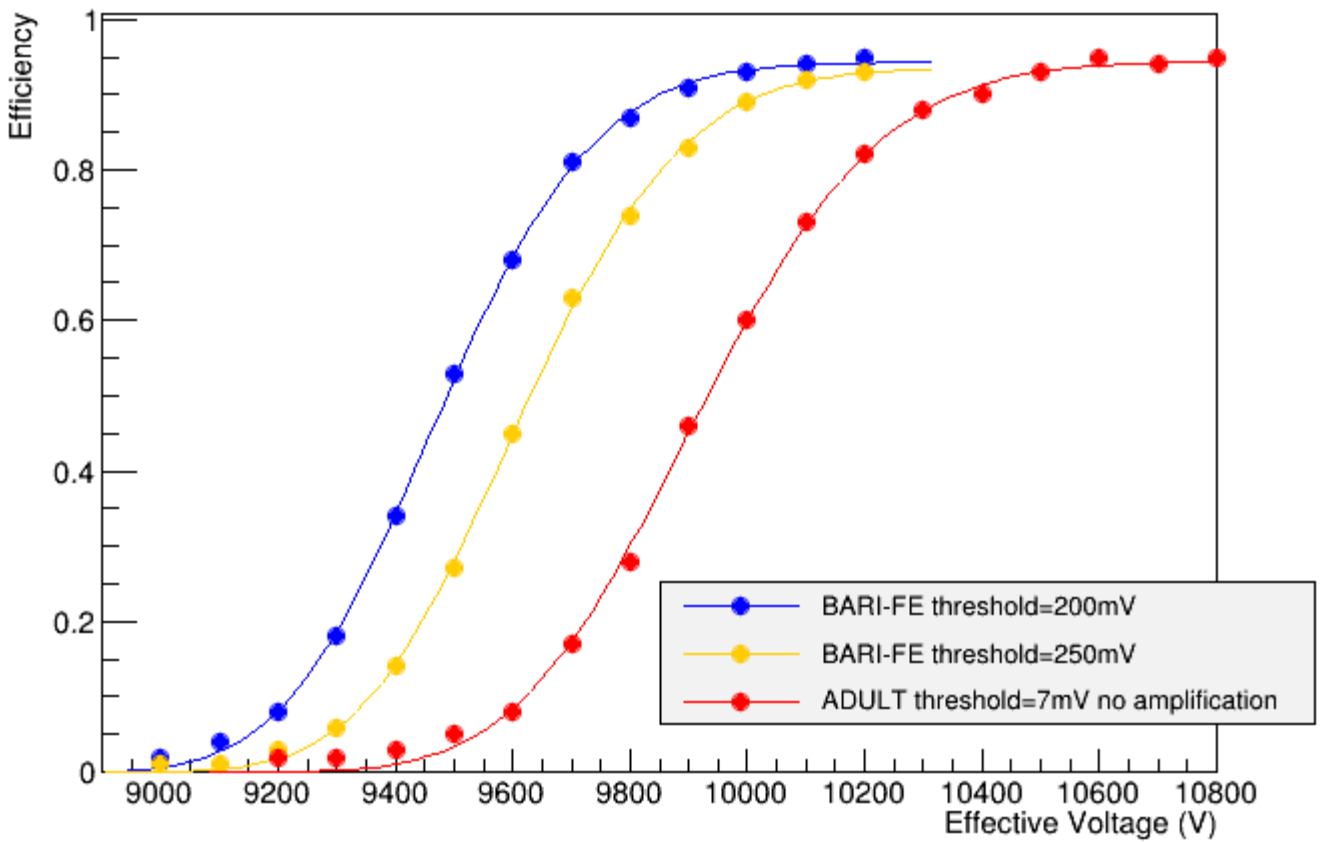
FEE upgrade R&D status (1)

- **Measurement of the background level in ALICE cavern in actual RPC signal pickup conditions**
  - Threshold just above noise < 50 fC
  - Almost similar noise level if FE card is disconnected from RPC
  - => promising …

- **Design of FE card prototypes (called BARI-FE) with the ASIC of CMS RPCs**
  - Performance evaluated on the Torino RPC test bench



FEE upgrade R&D status (2)

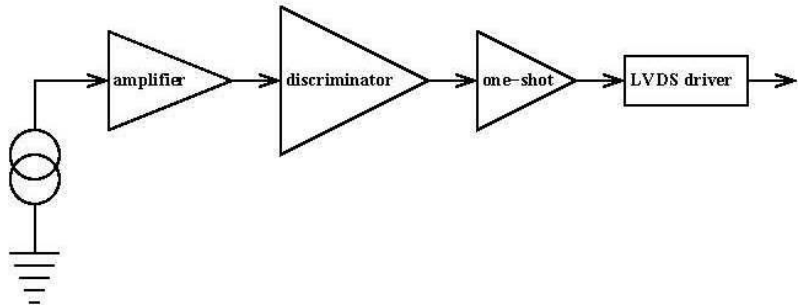


Efficiency plateau for RPCs equipped with BARI-FE (thr=200 mV and 250 mV corresp. roughly to 100 pC and 125 pC, respectively) and ADULT (thr=7 mV=standart operating value) cards

=> Efficiency curves shifted towards much lower voltages with BARI-FE as expected

FEE upgrade R&D status (3)

- **Design of the ASIC, so called "FEERIC" => 0,35 µm CMOS technology**
  - Main performance (better than requirements) from simulation
    - ✓ Dynamic range 20 fC < q < 5 pC; noise < 2 fC
    - ✓ Power consumption 70 mW/ch
    - ✓ Time resolution better than 300 ps for q > 50 fC
    - ✓ Bipolar input signals
    - ✓ LVDS output signals
    - ✓ 8 channels
  - first prototype delivered recently to LPC, qualification tests ongoing



- **Design of the production test bench**
  - Design will benefit from our experience gained with the ADULT test bench
  - Speed up the test of the FEE production: few cards tested in parallel
  - Portability: FE card support, LVPS, pulse generator, output signal analyzer, visualization, … integrated on the test bench
  - PC running Labview for measurement/archiving

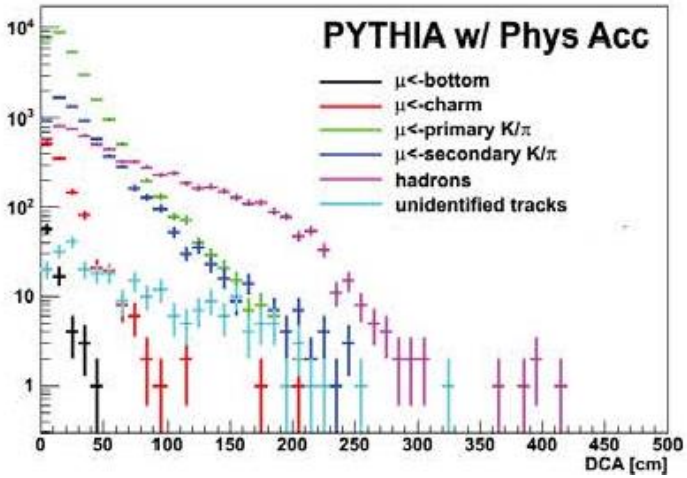
UPGRADE of the Muon Trigger Readout Electronics

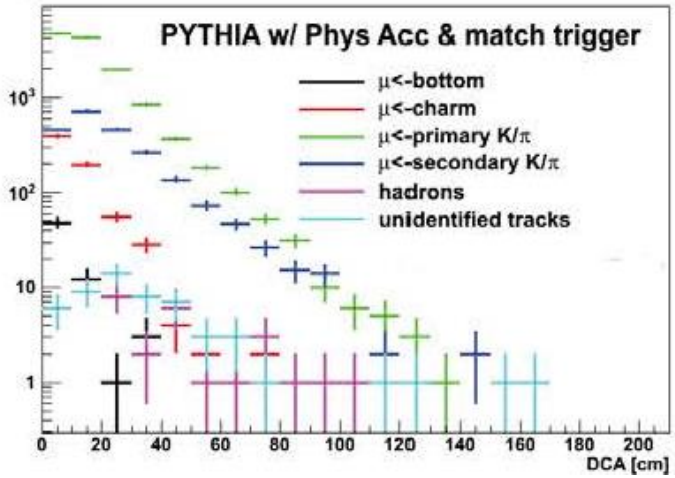
Readout Upgrade (1)

- **<u>Goal</u> => Dead Time free readout at high rate**

- **Readout the Muon Spectrometer at the Mbias rate i.e. up to 100 kHz in Pb-Pb**
  - **Hardware-based (fast) Muon Trigger decision is not needed anymore**
  - **Muon Trigger => Muon Identifier**
    - ✓ All present "muon" analyses require matching conditions
    - ✓ Drastic reduction of the hadron contamination in the muon spectrometer for matched tracks (~20-30% => less than 2%)
    - ✓ Event pile-up suppression in the muon spectrometer when matching is required, thanks to the excellent RPC timing properties which allow to separate 2 BCs @25 ns interval

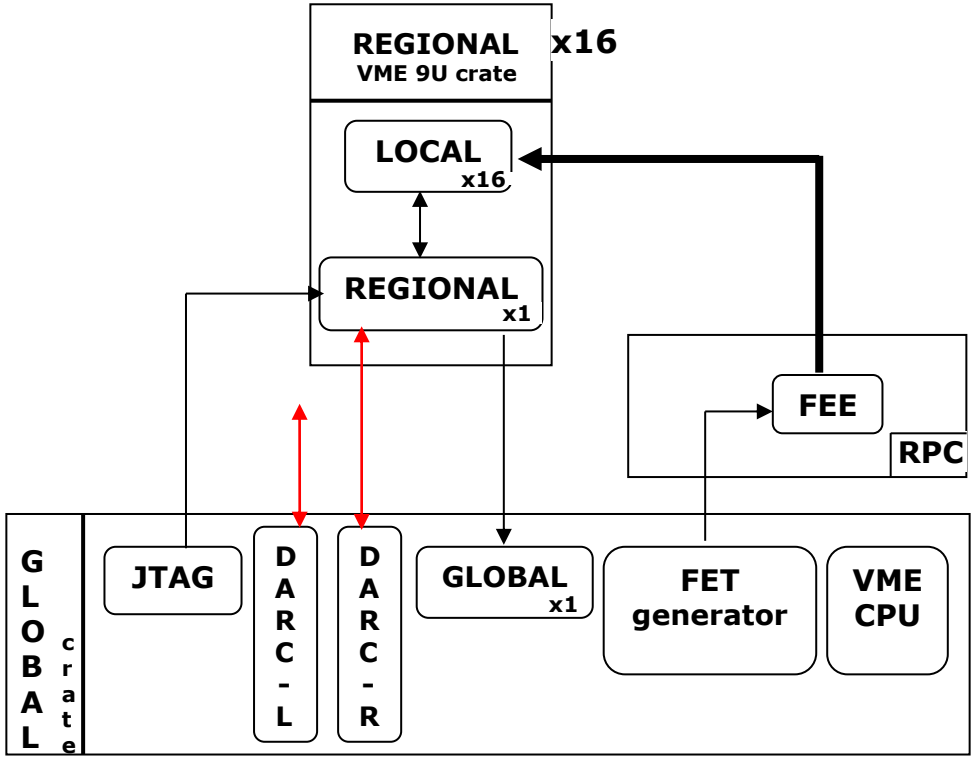
DCA distribution of reconstructed tracks in the Muon Spectrometer w (right)/wo (left) matching condition (extracted from the thesis of X. Zhang)





Present Electronics Architecture

The LOCAL cards are the most numerous cards (× 234)



LOCAL event info

- Strip-patterns X and Y => 4 × 32 bits
- Decision + board address => 32 bits

} => **7 kB/evnt, no zero-suppression**

- Scalers (readout only with software triggers)

Readout Upgrade Proposed Solution

- The 16 Regional cards are replaced by **16 CRU** (Common Readout Unit) developed by ALICE

- **New LOCAL cards (×234 + spares)**
  - Receipt and Latch signals from FEE, masks, scalers, delays, zero-suppression, MEBs, …
  - Communication via DTC e-links (RJ45, tbc) with CRU: data, trigger, clock, config.
  - 8 large front connectors per LOCAL => proposal to **keep VME 9U crates** for LOCAL card support and powering

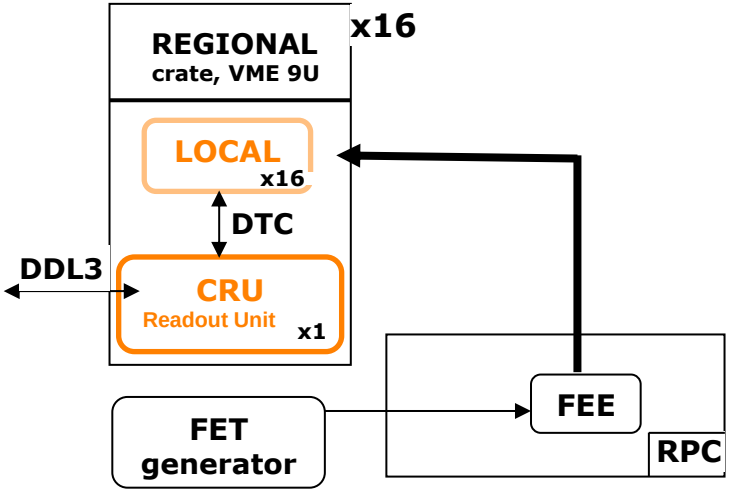
Pb-Pb √s=5.5 TeV, 100 KHz	
Total data flow to DAQ	**MAX data flow per link LOCAL => CRU**
300 MB/s (zero DT@10 Gbit/s !)	**1 MB/s (zero DT@1 Gbit/s !)**

Advantages

- Dead time free
- Simple architecture (reliability, test, ..)
- New electronics => less risks of breakdown from e.g. aging and radiation damages

Drawbacks

- **Muon Trigger hw decision lost**

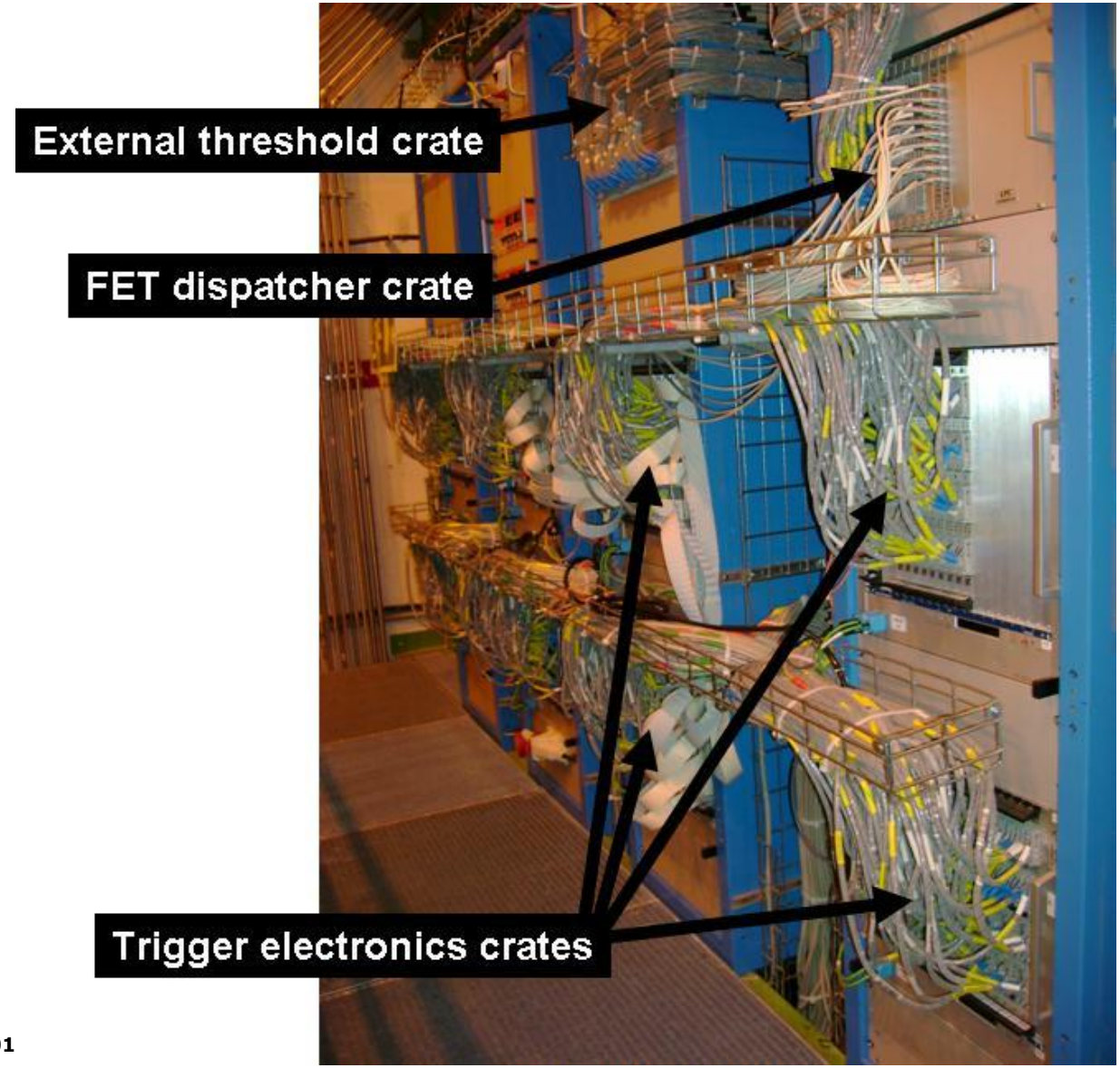


Conclusions and Perspectives

- **R&D relative to the upgrade of the FEE (2400 cards + spares) ongoing**
  - Planning (prel.)
    - ✓ Short term : FEERIC qualification, FE card design, test bench prototype
    - ✓ Summer 2014 : FE card prototypes with FEERIC (pre-production)
    - ✓ Before end of LS1: equip 1 RPC in ALICE cavern (pre-production test)
    - ✓ 2015-2016 : production
- **Dead time free readout electronics**
  - Need to change the LOCAL cards (×234 cards + spares)
  - Muon Trigger hw decision lost => **Muon Identifier**
  - Planning (prel.)
    - ✓ 2014-2016 : R&D and production of the new LOCAL
- **TDR Muon Identifier**
  - **Draft available, discussed with ALICE editors**
  - http://svnweb.cern.ch/world/wsvn/alicetdrrun3
- **Involved institutes (open)**
  - FEE : Clermont+Torino+Gangnung-Konkuk
  - LOCAL cards + CRU interface : Subatech
  - RPC/gas : Torino

Backup slides

Upgrade Cost (prel. estimates)

	R&D	Pre-prod	Prod		Instal	kCHF
	2013	2014	2015	2016	LS2	Total
RPC + FE		80	170	110		360
Readout		40	130	130		300
Total		120	300	240		660

Photos Trigger Electronics