Preparazione del Run 2017:
Muoni

…e anche preparazione di altre cose…

Luigi Guiducci

Riunione CMS Italia 2016
Spoleto
14-16 Dicembre 2016

Outline

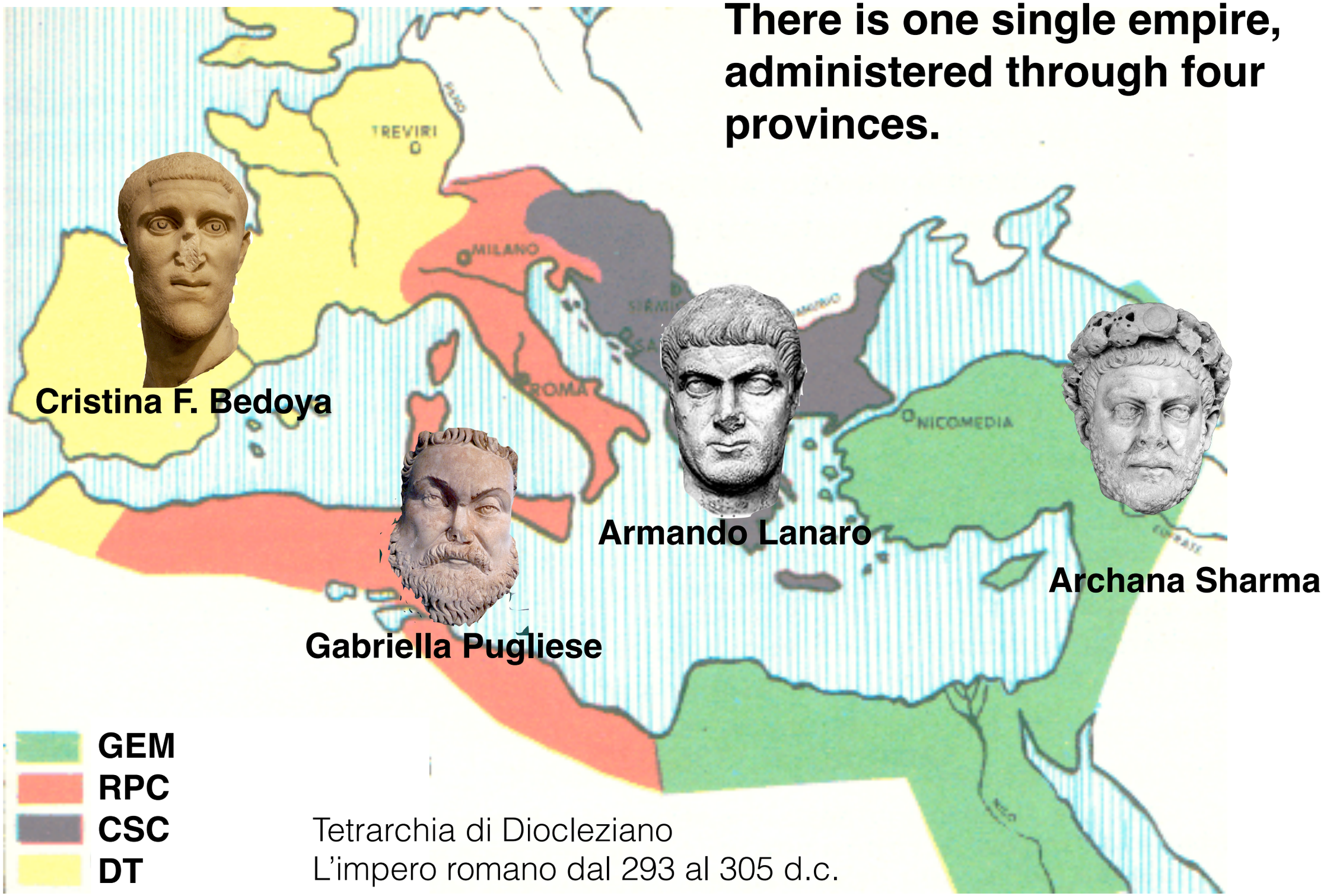
- **Highlights from 2016 running**
  - Status of the detector, operational efficiency and data quality
  - New DT+RPC combination algorithm in the barrel
  - New RPC efficiency tool

- **EYETS activities and plans for 2017 run**
  - EYETS DT and RPC activities
  - GE1/1 Slice Test installation and commissioning + GE1/1 production
  - Development and deployment of new DT readout (uROS)
  - Longevity studies performed in P5

- **Phase2 TDR and R&D plans**
  - Phase2 Muon TDR timeline
  - iRPC R&D and eco-gas studies
  - Phase2 DT electronics: demonstrator in P5, cooling studies
  - ME0 & GE2/1 R&D

The new muon system organization

There is one single empire, administered through four provinces.



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GEM Proj.Eng
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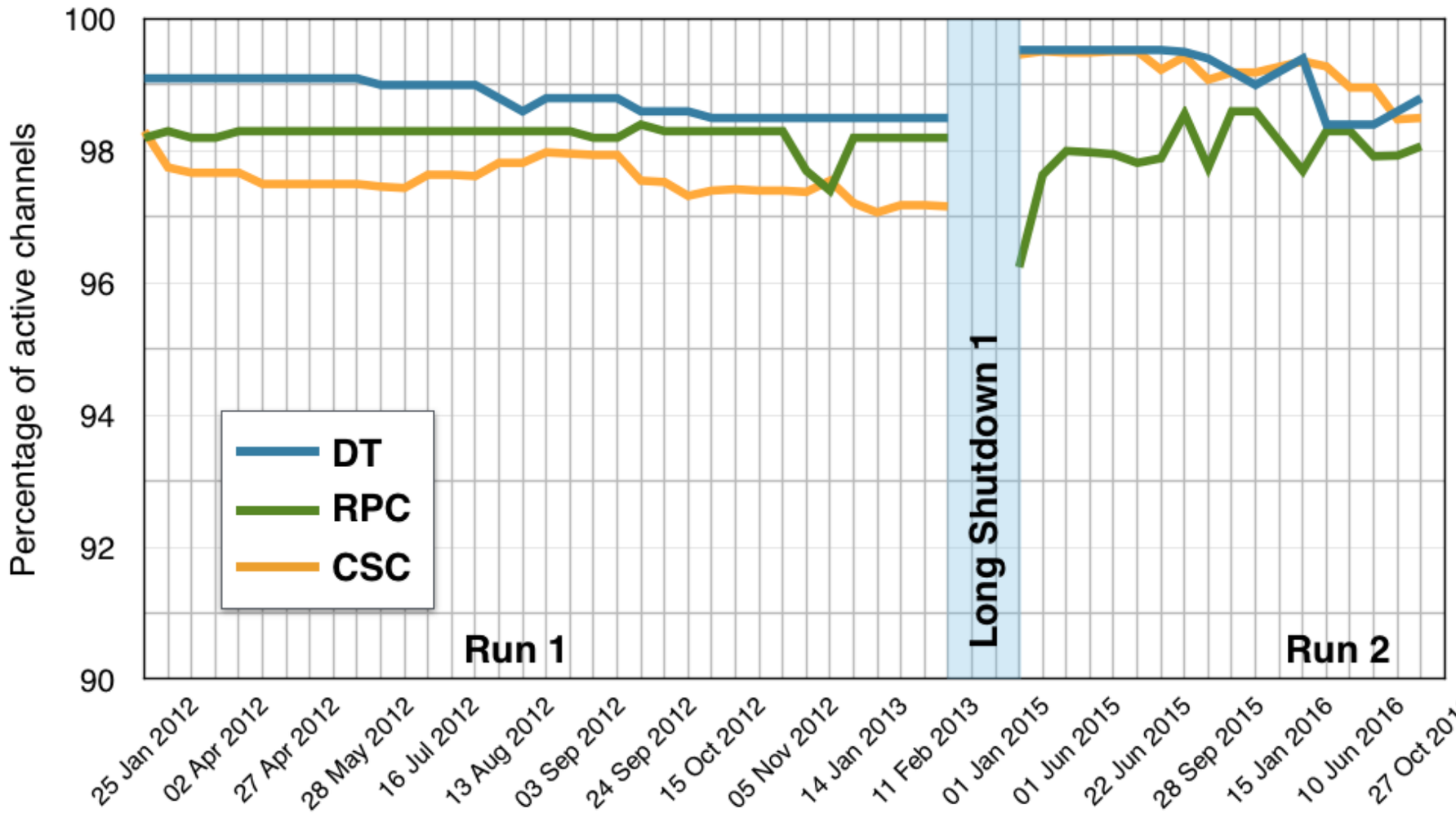
Italians hold 26 positions

CMS MUON ORGANIZATION (NOV 24, 2016)

Highlights from 2016 running

Status of the muon detectors at the end of 2016



Fraction of active channels

- CSC: ~ **98.5%**
- DT: ~ **98.8 %**
- RPC: ~ **98.1 %**

Inactive channels are mainly caused by
failure of the electronics located near or inside the chambers.

- Plan to **recover a fraction (0.5-1%)** in each muon system **during EYETS.**
- Necessary to maintain **access to the detector** and **expert availability** during Technical Stops

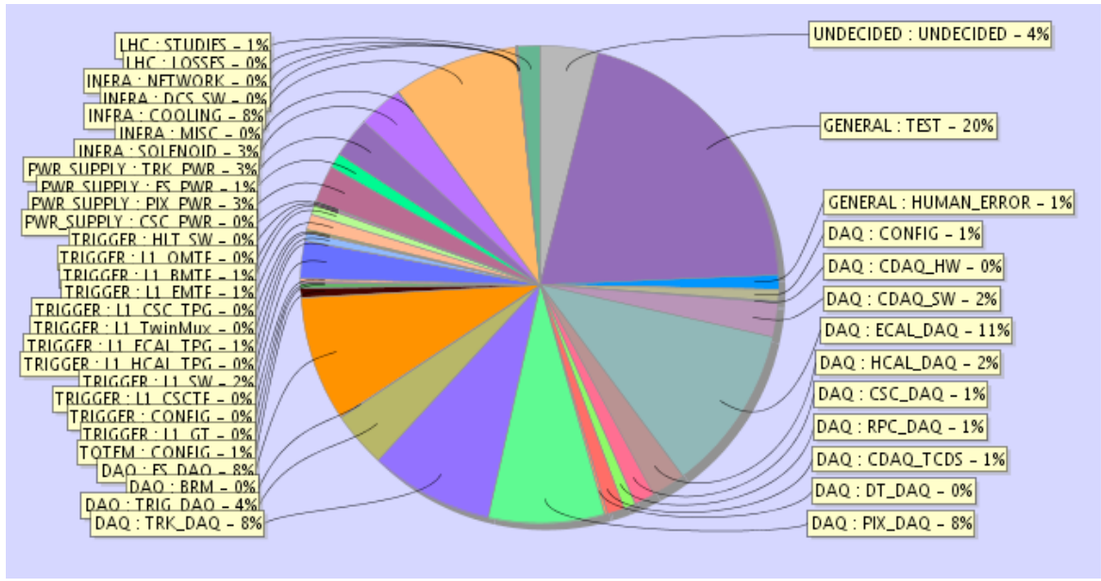
Operations and data quality during 2016

Very low contribution to **CMS downtime: 2.4 %**

CSC: 1.5% SEU on chamber electronics boards forcing to reconfigure CSC (happened 23 times)

DT: 0.15% transmission error between FED and DAQ

RPC: 0.76% CCU errors caused crash of the LB workers (happened 2 times). RPC SW updated to fix this problem



CMS preliminary results: April 22nd - October 27th 2016								
Tracker		**Calorimeters**			**Muon Spectrometer**			**Operational Issue**
Pixel	SST	ECAL	ES	HCAL	CSC	DT	RPC	Tracker HV ramp
99.6	98.9	99.2	99.6	99.5	99.9	99.8	99.5	99.3
All good for physics: 96%								

Luminosity weighted fraction (in %) of data certified as good for physics analysis relative to 38.1 /fb of data recorded by the CMS experiment during 2016 proton-proton collisions at 13 TeV with magnet at 3.8T.

Small amount of bad quality data:

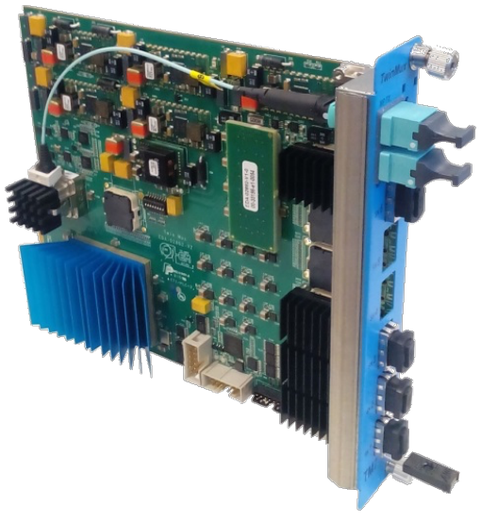
- RPC:145 pb^{-1} luminosity lost because of an hardware failure on RPC system (48 V PS of the LV FEB of half wheel).
- DT < 2 pb^{-1}
- CSC: 13 pb^{-1}

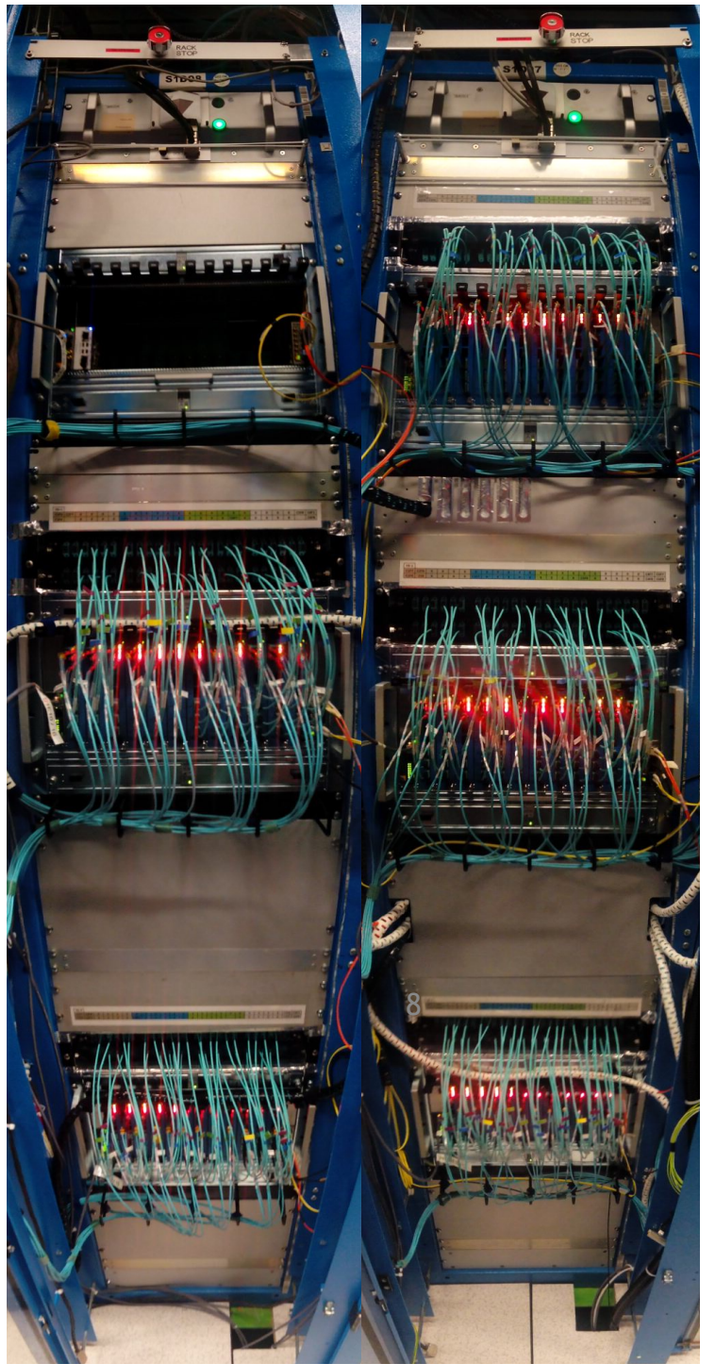
Key of the success:

- **detector expert availability guaranteed 24/7**
- **well defined procedures for prompt intervention during all beam-off and access time**

DT TwinMux: 2016 achievements, 2017 plans

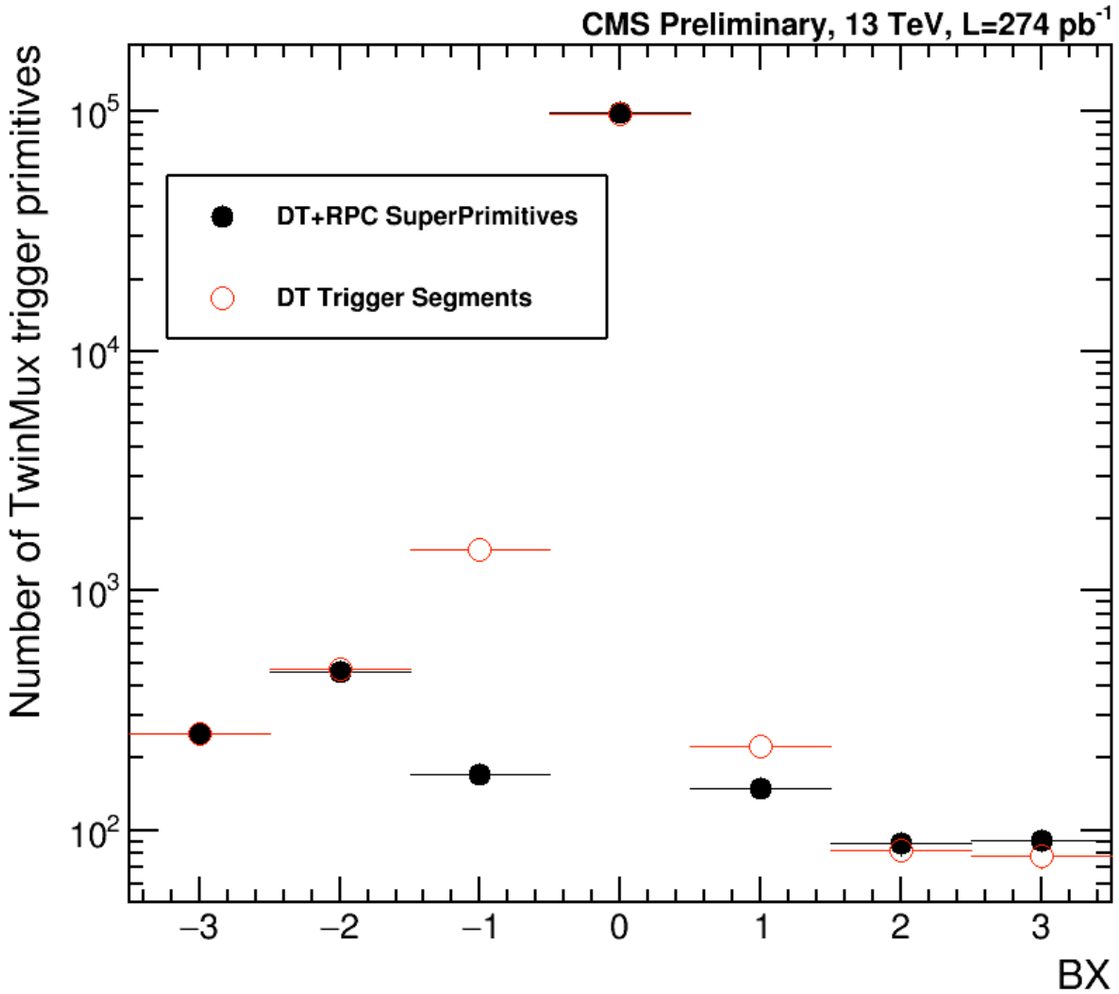
- **Final production: 60 boards**
  - Installed in 5 crates at the beginning of 2016
  - 2720+720 optical fibers
  - **Fully operational during 2016**
- **Firmware capabilities**
  - Rx of DT, RPC, HO, Tx to BMTF and OMTF
  - RPC clustering, DT+RPC synchronisation
  - DT-RPC SuperPrimitives: BX-assignment via phi-matching
- **Next steps (in 2017)**
  - Optimisation of RPC synchronisation and tuning of the DT+RPC combination algorithm
  - Generation of RPC only primitives (first test in HI run)
  - HO inclusion in the SuperPrimitives algorithm

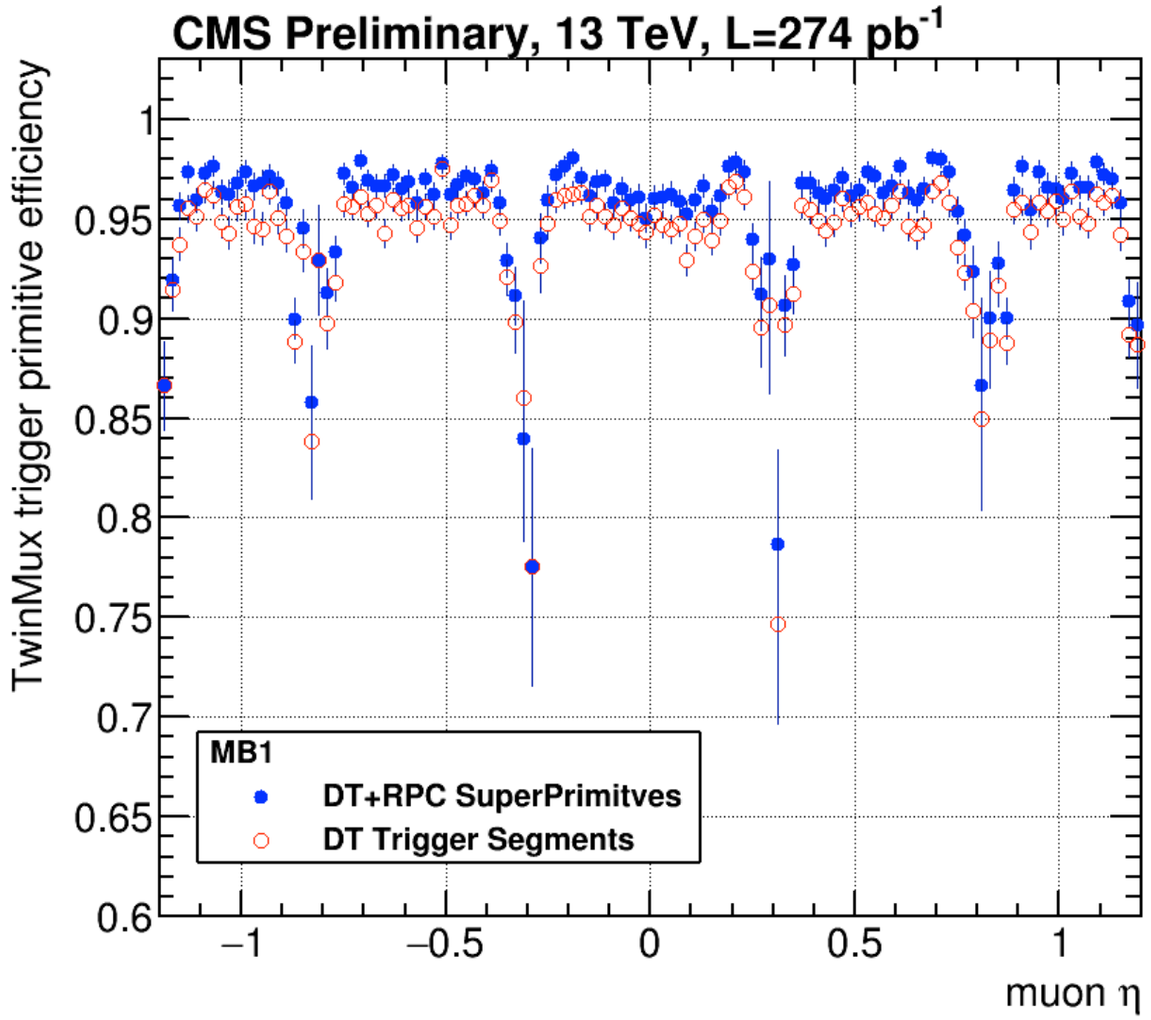




DT TwinMux: (end of) 2016 DT-RPC algorithm

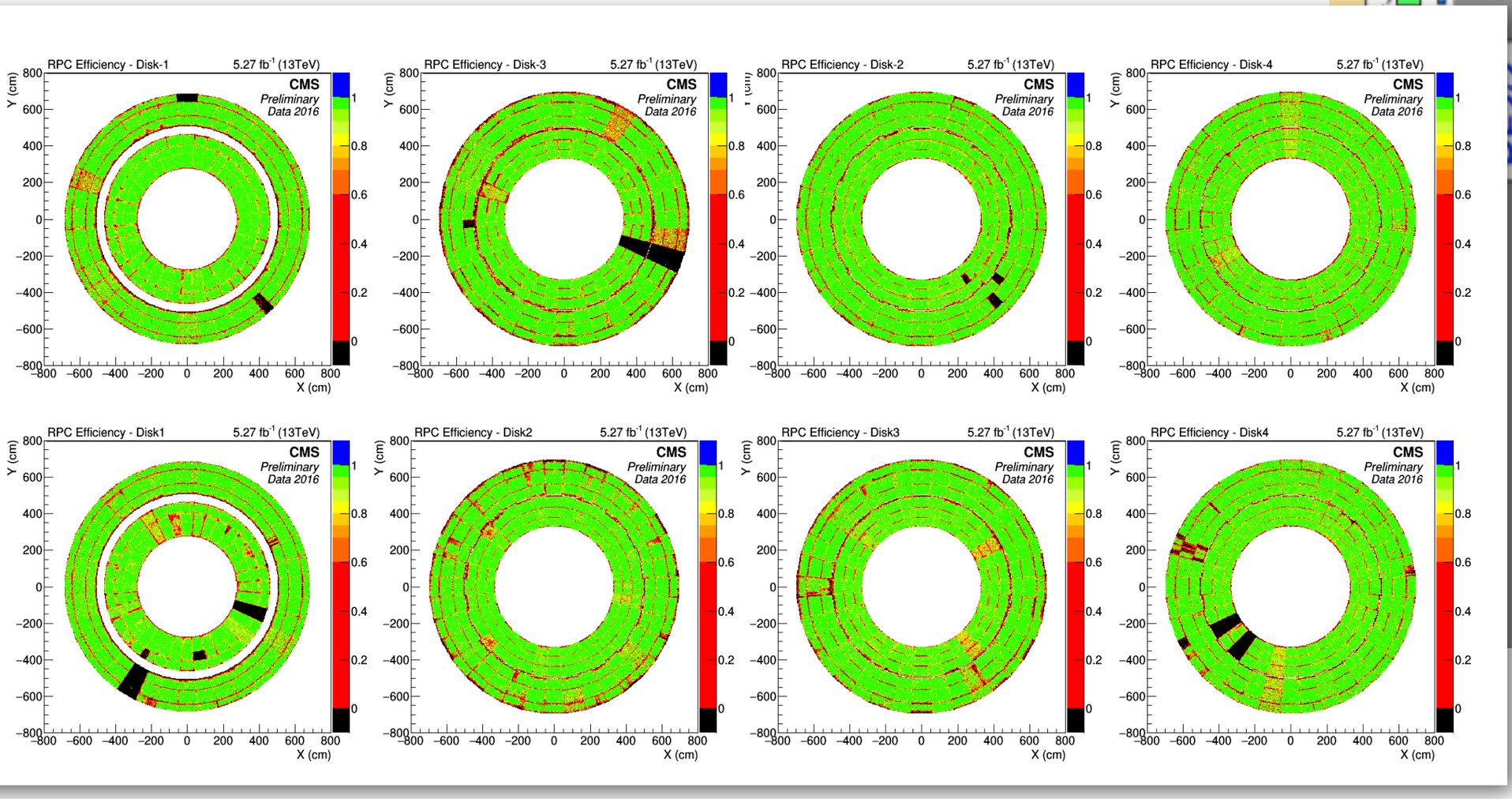
- **RPC clusters close in ϕ to DT Trigger Segments** from the same chamber are searched for, in a **± 1BX time window** centred around the DT Trigger Segment BX.
- The closest RPC cluster is selected; **if Δϕ≤15 mrad, RPC and DT are considered matched.**
- If the DT Trigger Segment was built with less than 8 DT ϕ layers, the **Trigger Segment BX is shifted to match the RPC cluster BX.**

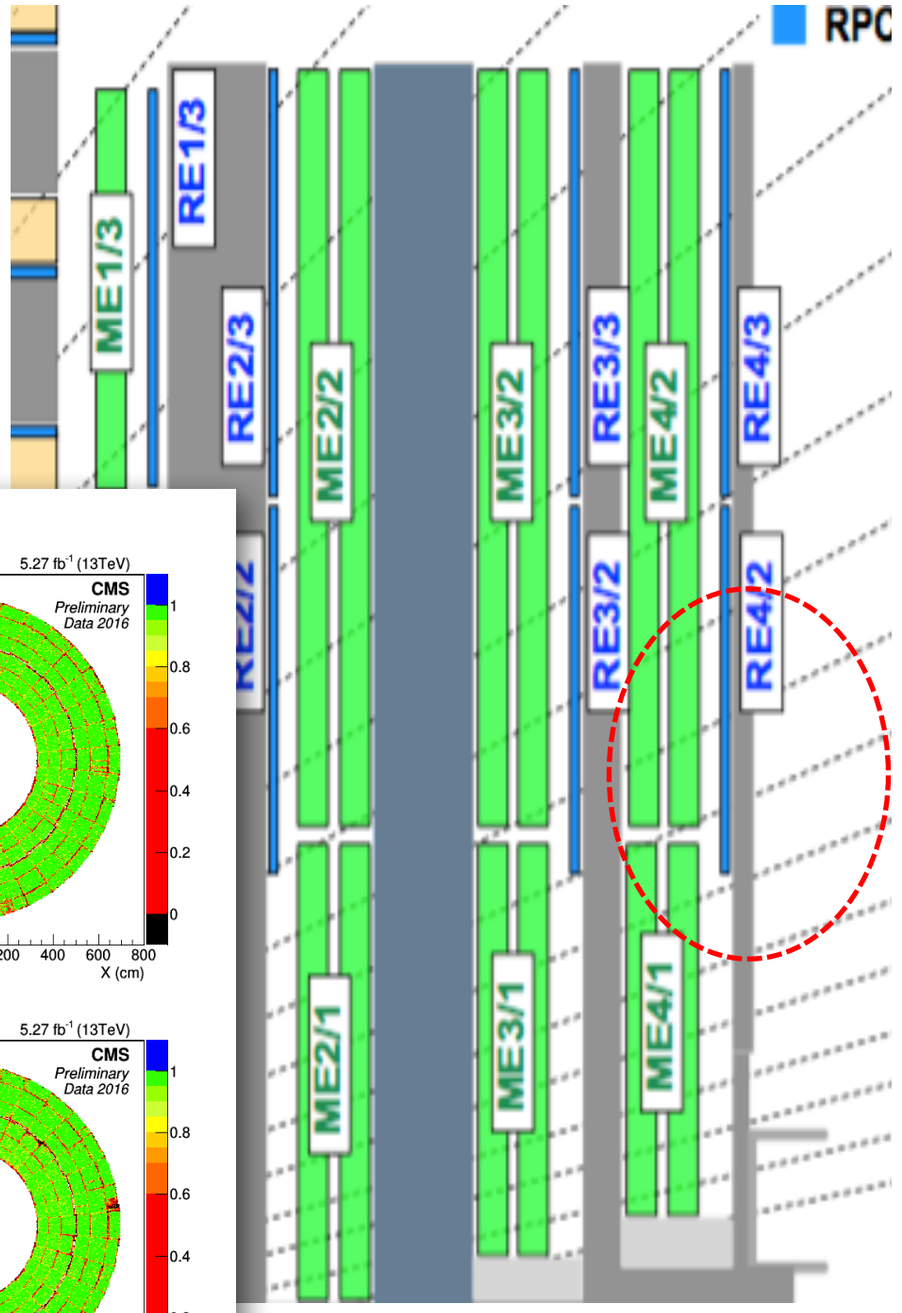




New algorithm for RPC performance study

New method has been developed for RPC efficiency calculation based on tracker muons and tag & probe method. The “old” method based on CSC/DT segment extrapolation was not providing sufficient coverage to RPC chambers because of geometry limitation.





EYETS activities and plans for 2017

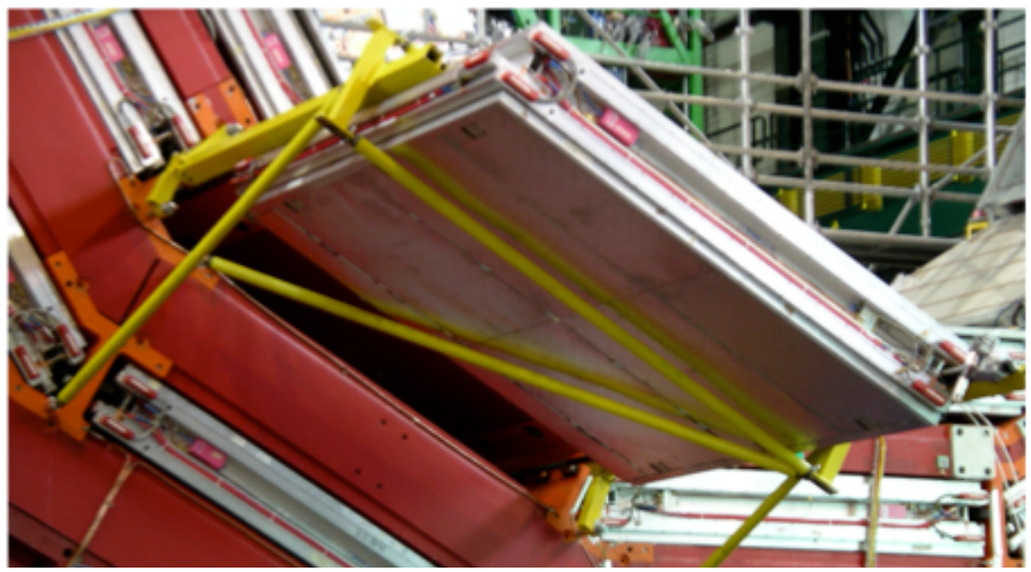
EYETS DT activities

- Replace HV mainframe:
  - the old one is more then 10 year old
  - easier maintenance of the new system
- Take the opportunity that the detector is open to repair few minicrates accessible in the external wheels.
- Extract in situ DT/RPC chambers for RPC repairs: still under discussion
- Improve neutron shielding for the external chambers of top sectors (for external wheels only).
  - Test during LHC operation shown that a layer of borated polyethylene + a layer of lead can reduce the single-hit background of a factor 2.
  - We will install the shielding to more MB4 chambers during LS2

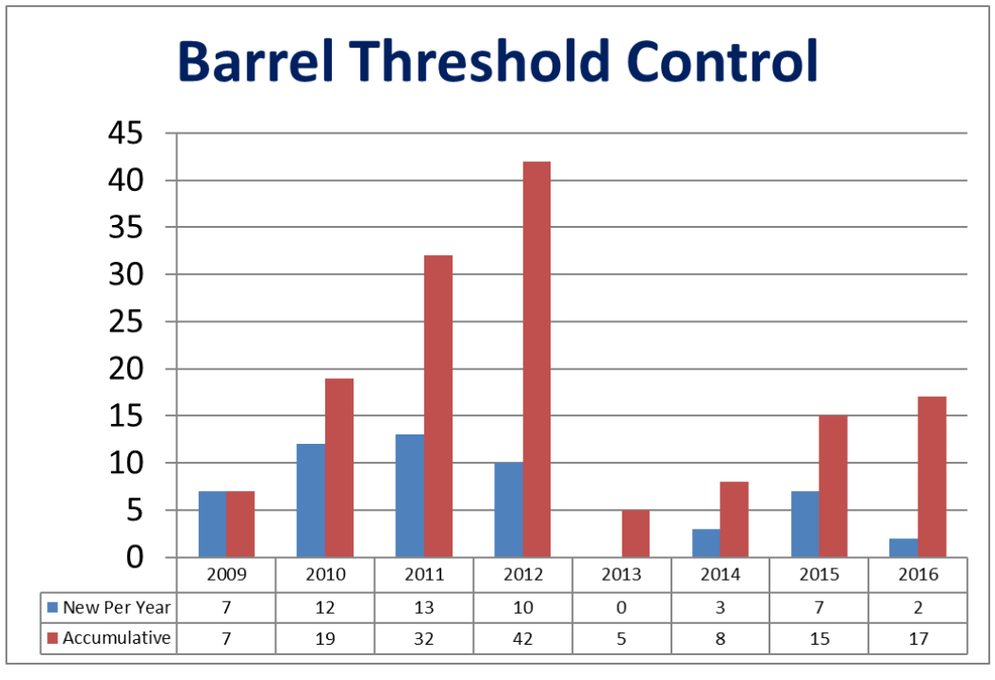
EYETS RPC activities

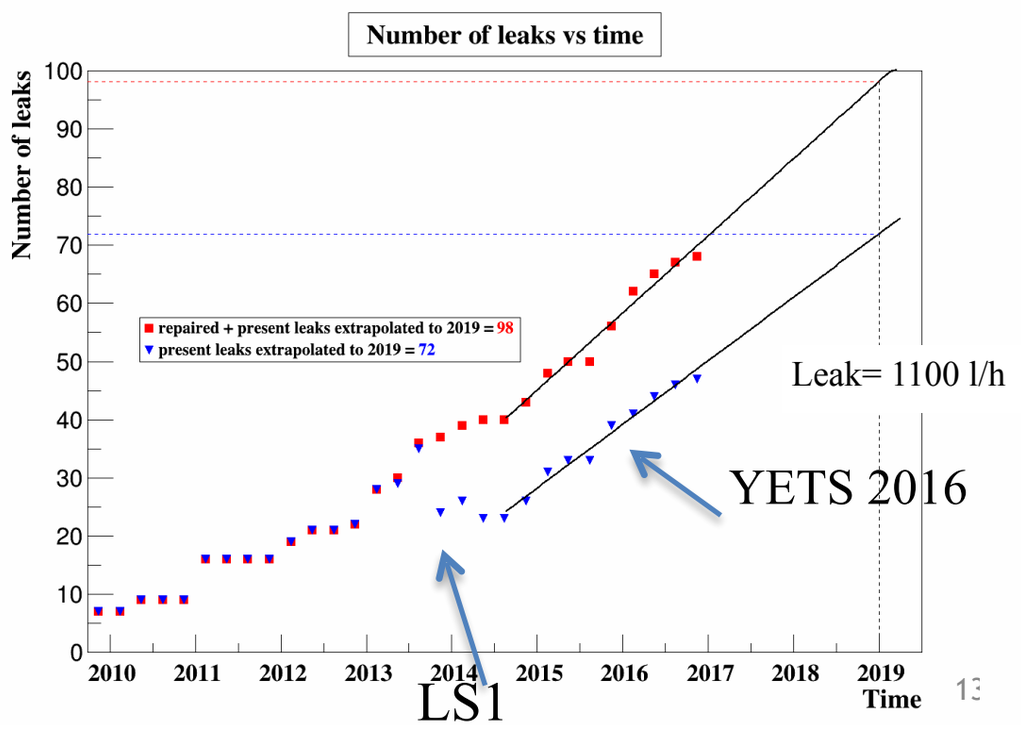
➢ **Maintenance on barrel (W+&-2 wheels) and endcap**
(in background of main CMS activities)

1. Threshold Board repairs: it requires partial extraction of the chamber.
2. HV connector repairs
3. LV repairs
4. Leaking chamber repairs: aim to reduce the leaks by 20 %



➢ **RE31 mockups installation test**

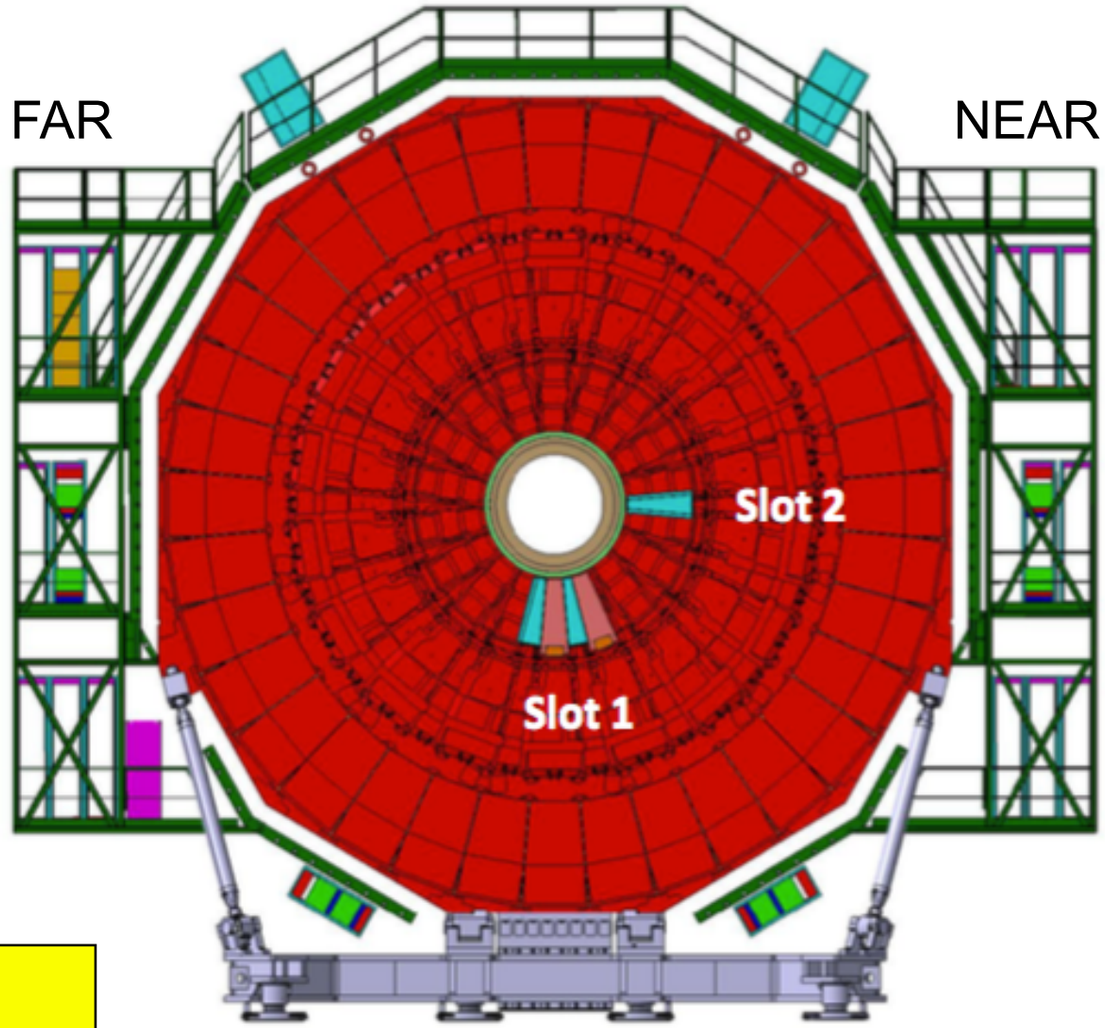




GEM GE1/1 Slice Test Installation

Main goals of the test:

1. Gain installation and integration experience
2. Reduce the GE1-1 commissioning period in LS2
3. Trigger commissioning
4. Study GEM chamber, HV, electronics under realistic background conditions



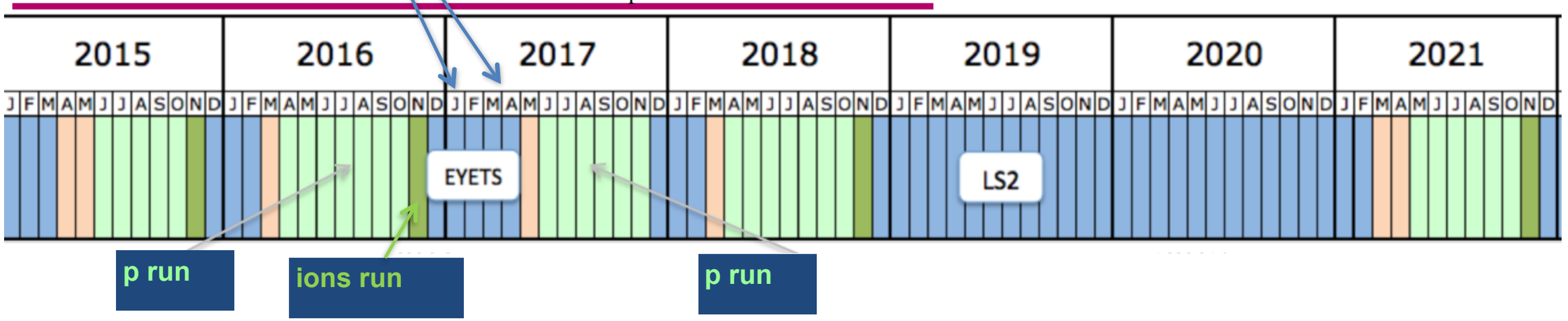
10 triple-GEM in 5 SC

Installation : January

Test in cavern : March

EYETS 2016-17

Extended Year End Technical Stop



HV System for GE1/1

USC

S1H12

A1526N

RPC type HV cable, installed during LS1

A1515

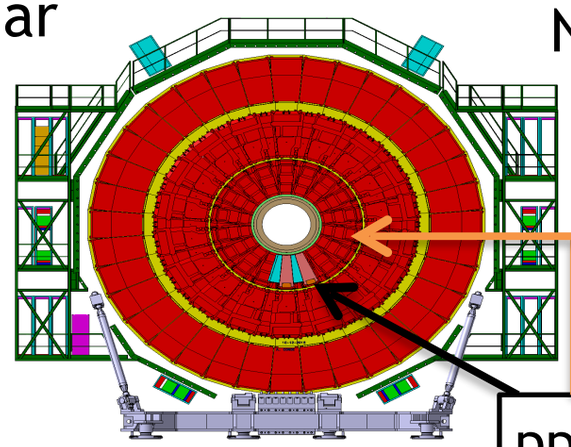
GEM Type HV Multiconductor cable diam 2x~18mm

INFN-NA + CAEN

UXC YE-1

Far

Near



One chamber will have the INFN HV system

pp

Via the upper minus trigger tunnel

4 HV ch. (long cable)

Feet Panel

1 HV ch. Short cable

1
7

filter GEM 1

1
7

filter GEM 2

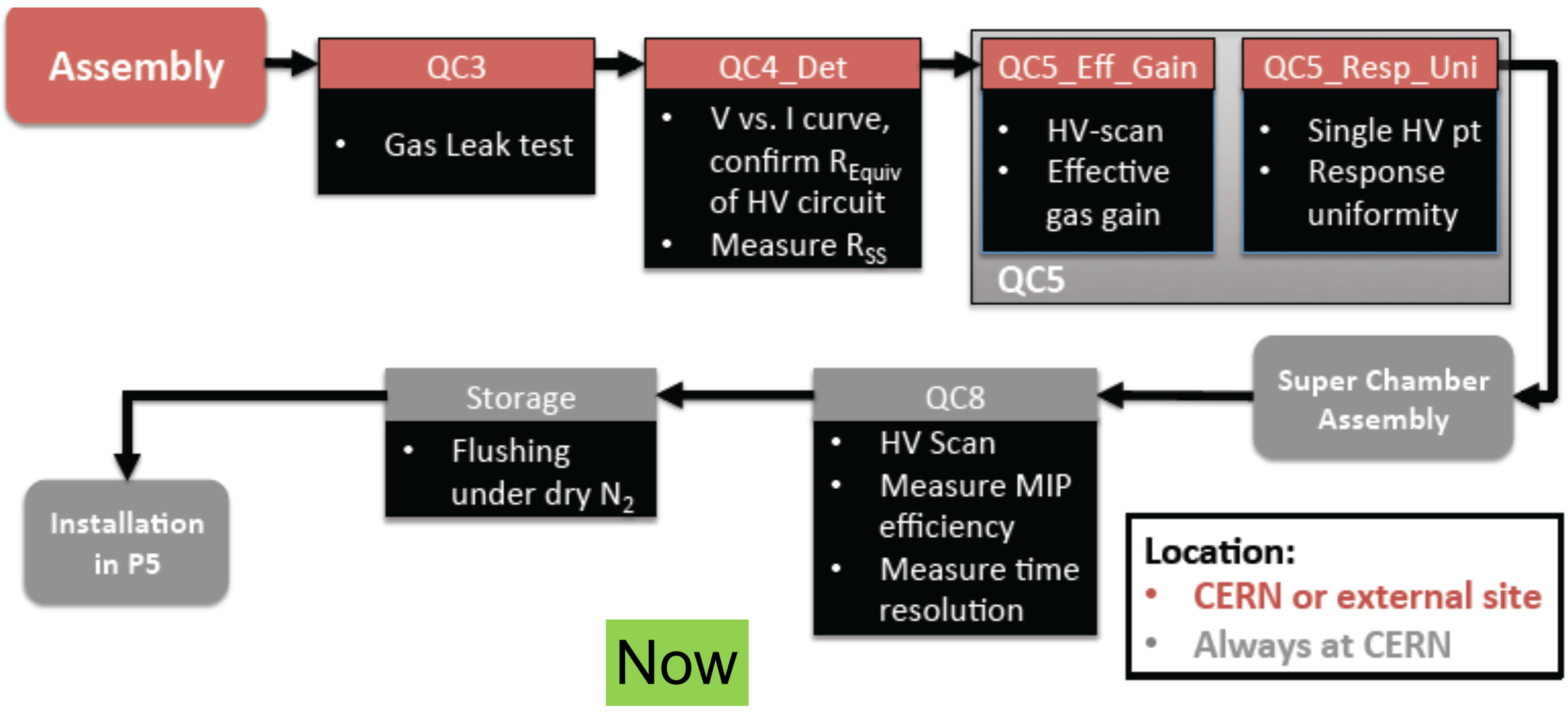
1
7

filter GEM 4

Quality control for Slice Test GE1/1 chambers

- Assembled 10 Slice Test Chambers
- Single detector QC completed
- Super Chamber assembly completed
- Last checks ongoing

QC2 Fast: Current and sparks measurements in air for 10 minutes
QC2 Long: Current and sparks measurements in N_2 30 min → 98% good



GE1/1 production commitments

GE1/1 Chamber Production and QC (2015-2017) (BARI, LNF)

- **Production of 30 chambers /161 (144 +spares)**

Front-end electronics (BARI)

- Participation in chip design
- Responsibility of the Control Bias Monitoring and Slow Control electronics

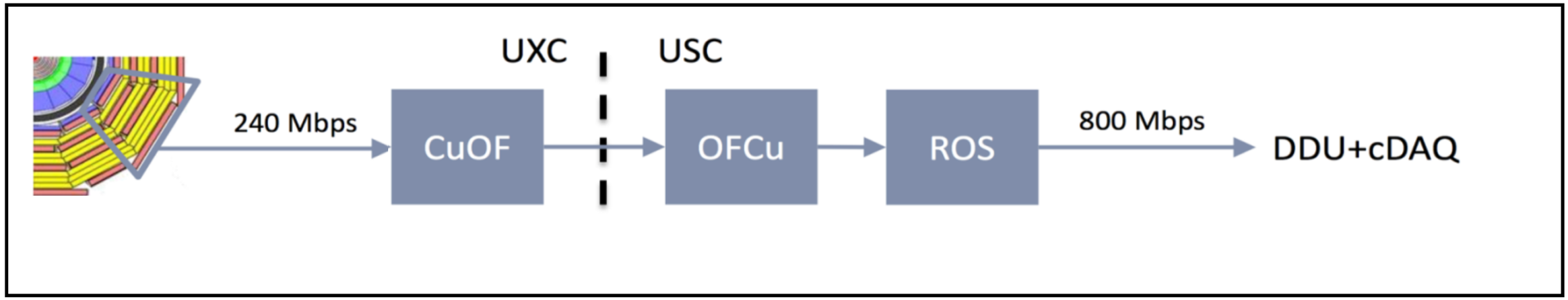
HV Power system (NAPOLI)

- Design and production in collaboration with CAEN.
- Development & production of prototypes (board and cables), test in Naples, commissioning at CERN and installation, development of multichannel HV filter

Further involvement for Slice Test and more

- Slice test installation, QC development
- DAQ and DCS development and integration in CMS (PV, BA)
- Temperature sensors test and development of monitoring tool (LNF)
- Simulation of background, muon reconstruction and id (BA, PV)
- Physics analisys (BA, BO)

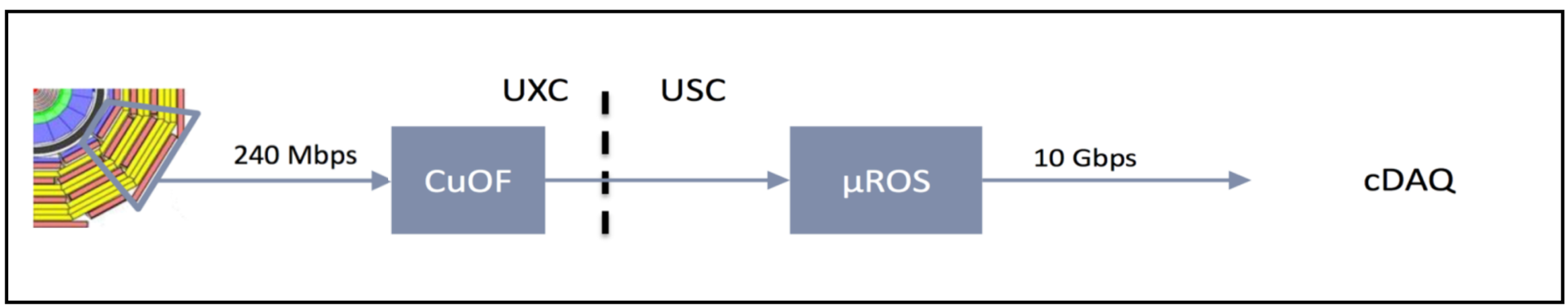
DT: transition to uROS readout system



end of 2017

- More robust and powerful electronic based on µTCA (same board used for the DT trigger chain)
- More bandwidth to DAQ

Test crate already installed



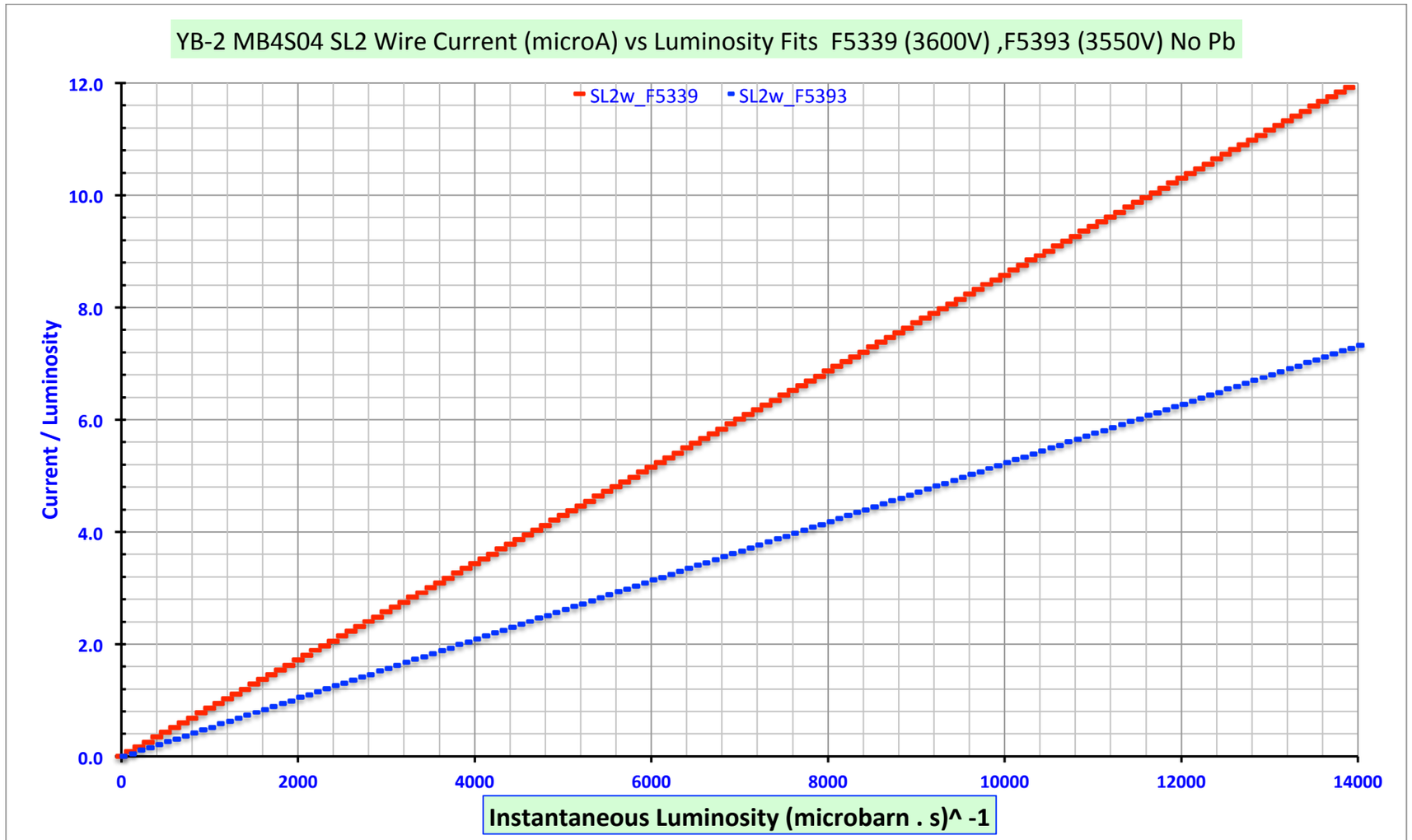
uROS test setup

Optical splitter

- TwinMux board receiving (through Optical Splitter) data from 72 ROBs, from 3 DT sectors
- Firmware dev. and commissioning in 2017
- Installation of final system: end of 2017

uTCA crate

DT Longevity Studies in CMS

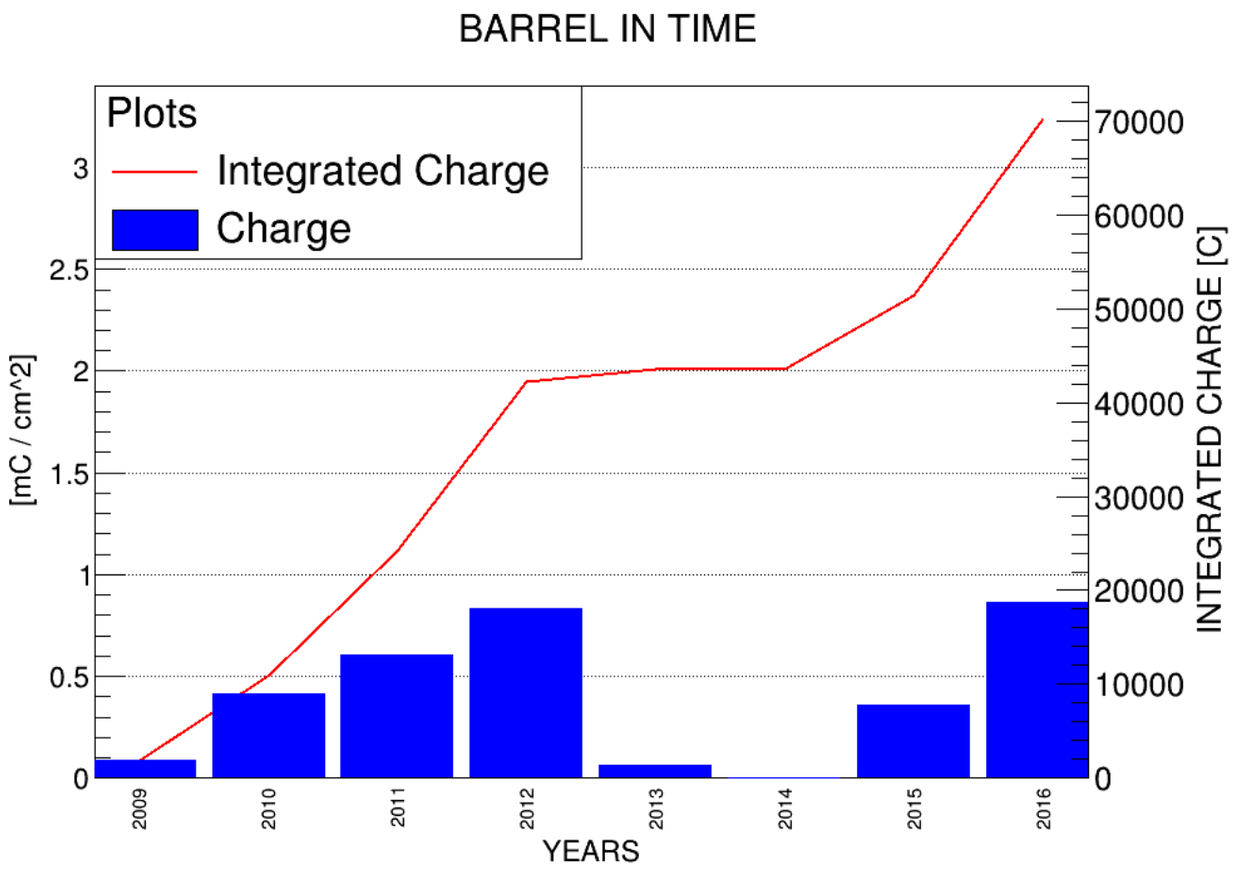


- Lower the DT anode HV by 50V in the stations most affected by background:
  - test done during 2016 data taking shown a current reduction of 1.6 at a cost of 1% of hit efficiency (negligible for the system)
- Annual HV scan during cosmic data taking: repeat in 2017 and following years in order to spot any sign of ageing

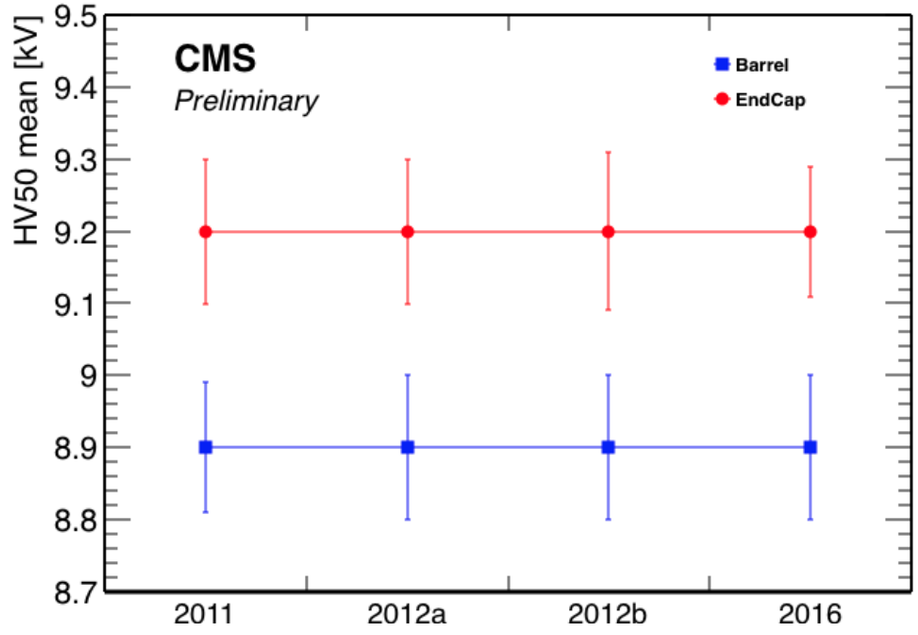
RPC Longevity Studies in CMS

RPC performance is carefully monitored and correlated with external conditions like luminosity, background, environment conditions, gas flow rate etc…

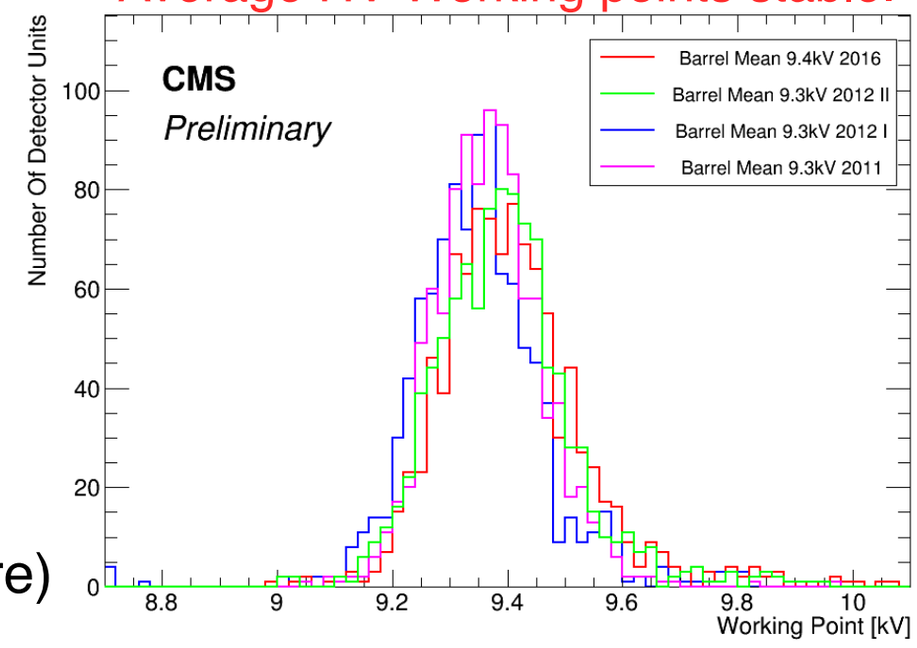
-> in order to improve performance stability and spot any sign of ageing.



Integrated Charge in RUN 1 and RUN2: 3 mC/cm^2



Average HV Working points stable.



Plan for 2017:

- ➢ 2017 HV scan at higher luminosity
- ➢ Applying HV Temperature correction (as for the pressure)

Phase2: TDR and R&D

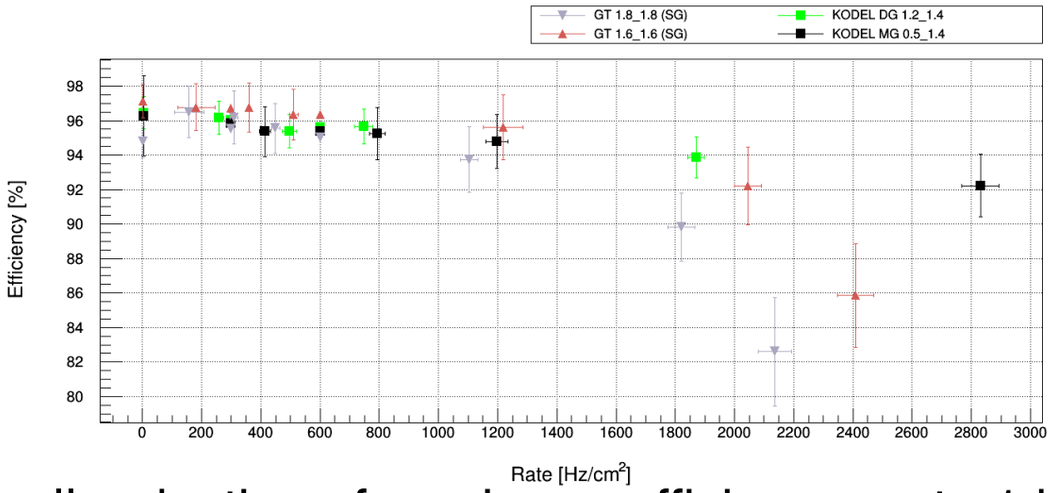
Muon Phase2 TDR timeline

- **Oct. 2016** **set up procedure and contributors** ✓
- **Nov. 2016** **content specified via bullet list / keywords** ✓
- **Dec. 2016** **preliminary versions of all chapters except 8 (cost)**
  to verify suitability of proposed outline and to identify problems
- **Jan 2017** **1st version of chapters 2 – 7**
- **Feb 2017** **1st version of chapters 1 and 9**
- **Mar 2017** **1st version of chapter 8 (cost, schedule)**
- **May 2017** **semifinal version for muon internal review**
- **May 2017** **muon internal review**
- June 2017 comprehensive review
- **June 2017** **final version for CMS review**

Several italian editors!

Sandro (DT), Davide (RPC), Cesare (GEM), Luigi (Trigger&Physics)

Status of R&D for iRPC baseline



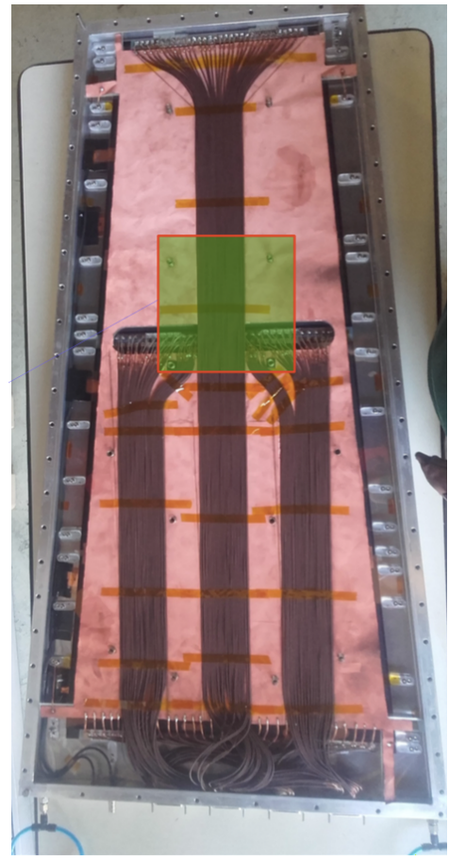
Small reduction of maximum efficiency up to 1 kHz/cm^2

1. General Tecnica production:

- Two RPC: gas and Bakelite thickness 1.8 and 1.6 mm.
- Detector dimension ~ 0.7 m^2

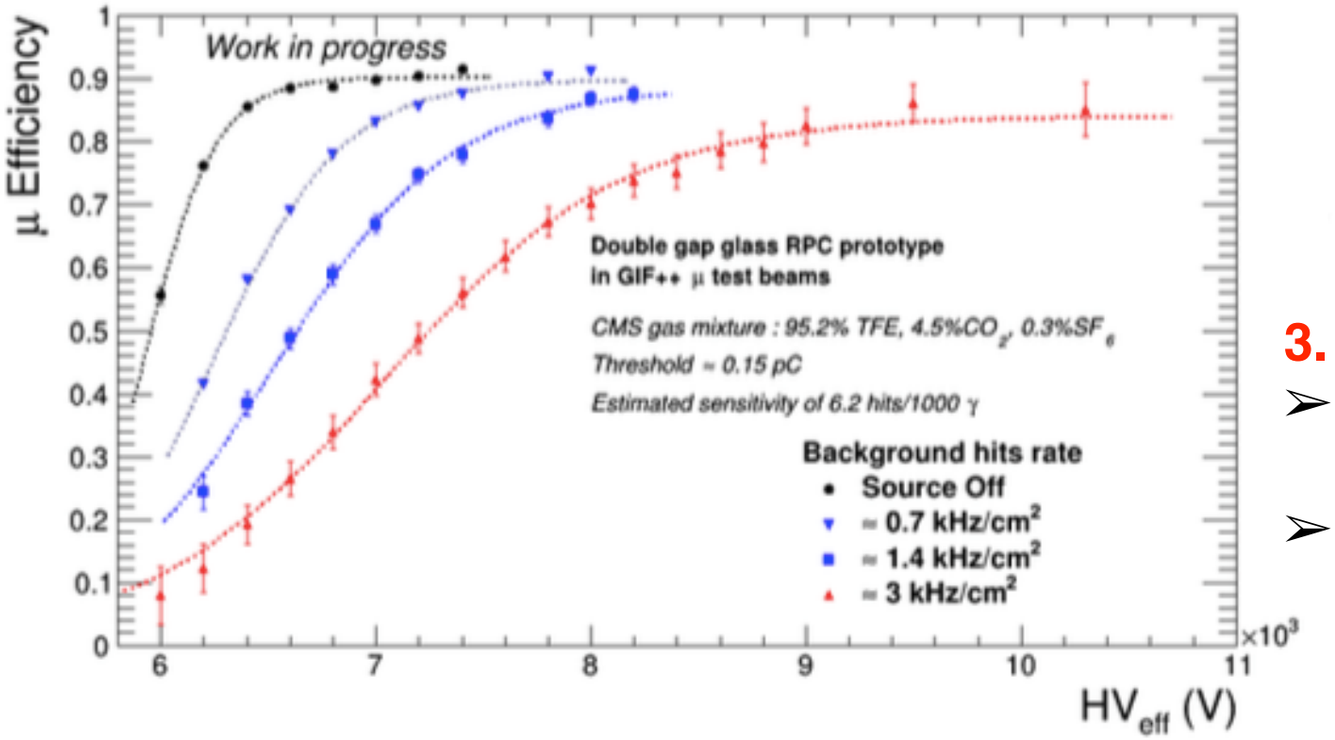
2. Korea production:

- 1.2 mm double-gap RPCs
  0.5 mm 4-gap(multi-gap) RPCs
- Detector dimension ~ 0.7 m^2



For 2017:

- Continue small prototypes testing at GIF++
- Build full size prototypes (2x double gap bakelite, 1x double gap glass, 1x multi gap glass)



3. Lyon production:

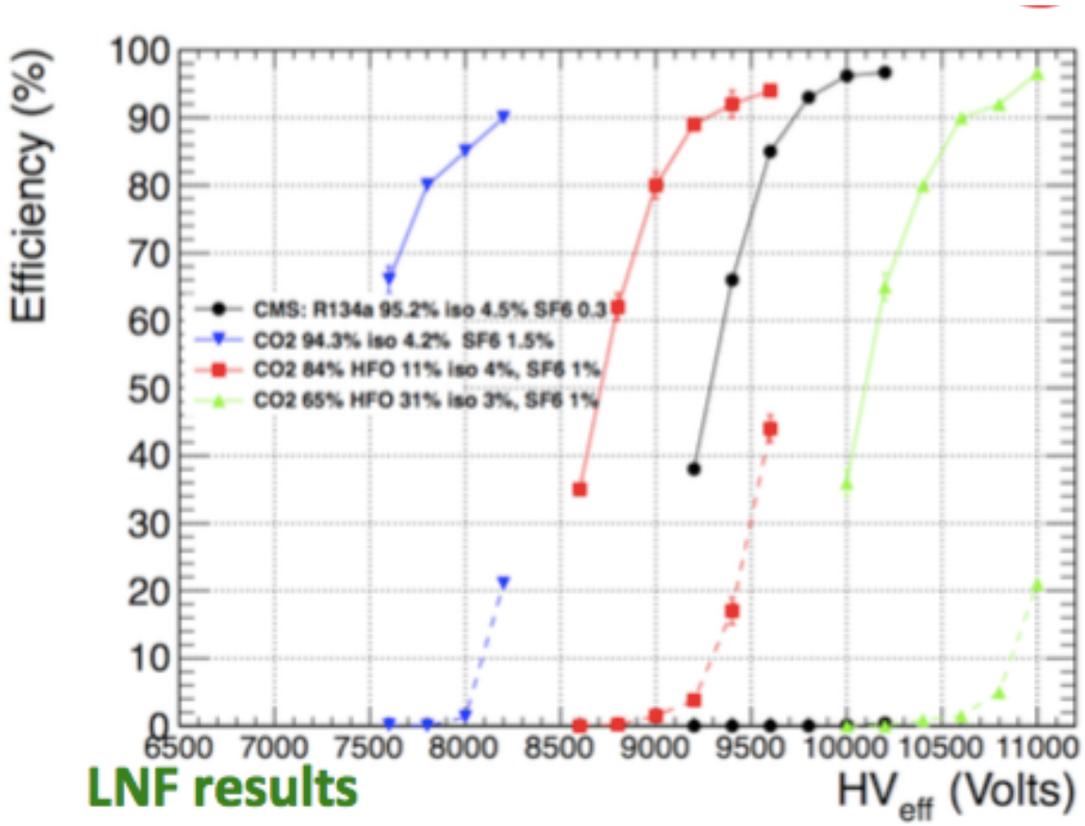
- Mosaic of 30 x 30 cm^2 glasses.
- Detector dimension ~ 1 m^2

- Test full size prototypes with semi-final electronics in test beam in June

RPC Eco-gas R&D Status

Several gas mixtures tested to find a gas mixture with reduced GWP

1. **Replacing $C_2H_2F_4$ with $C_3H_2F_4$:** $C_3H_2F_4$ (HFO) added in order to contain smaller (x2) concentrations of R134a. The HFO shows interesting quenching properties but when used in larger percentages it requires shifting significantly the HV working point to higher values (~12kV).
2. **CO_2 – $C_3H_2F_4$ based gas mixtures:** Four components (adding CO_2) gas mixtures also tested. The CO_2 goes in the right direction (green line GWP=242 but producing a factor ~5 more ch)
3. **CF_3I based mixtures:** very promising but much expensive at the moment.



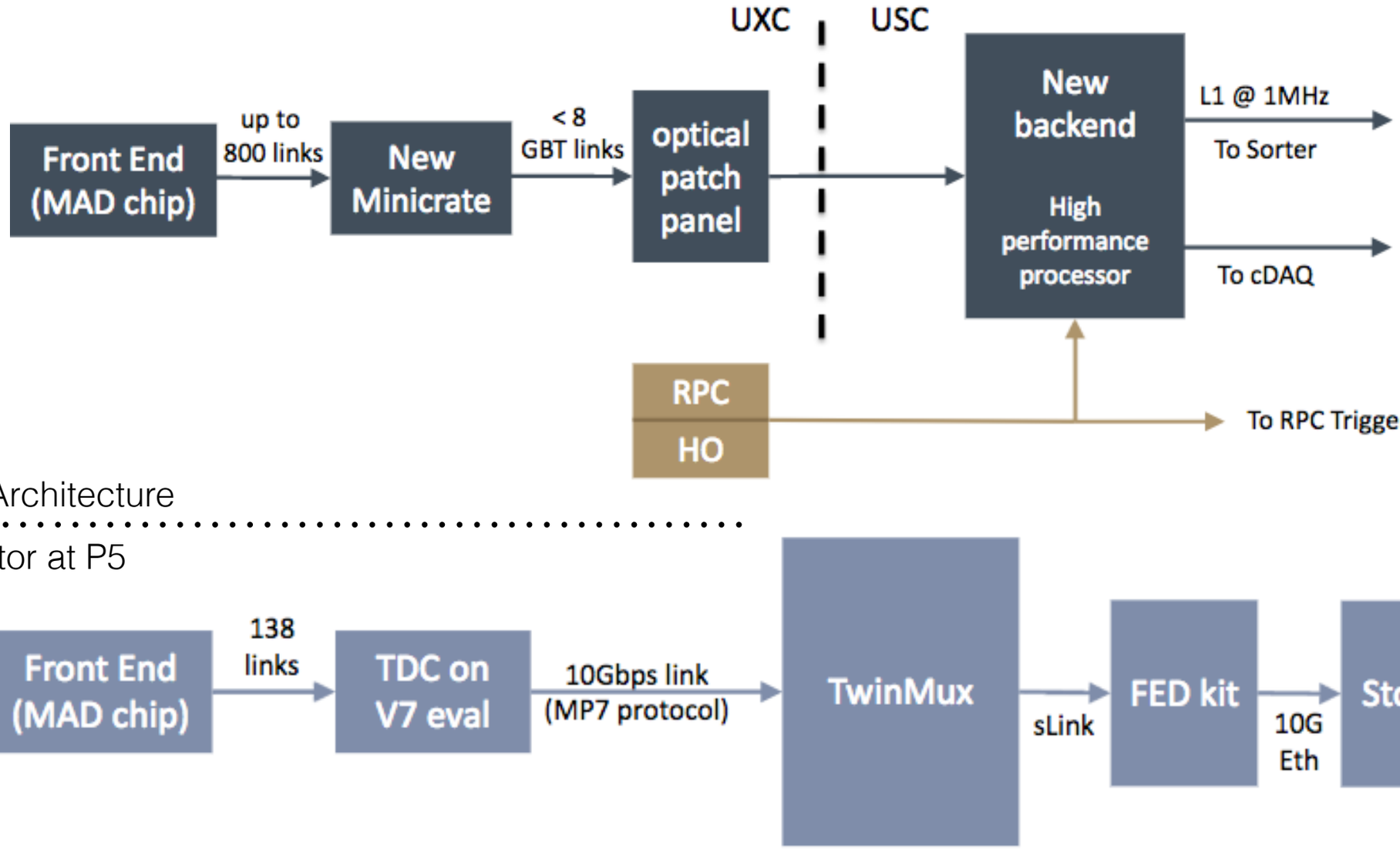
Next year, will continue testing mixtures in lab, select two best options to test at GIF++.
If we will not find a second **"magic gas mixture":** we are evaluating the impact on the detector longevity and performance by:

1. Reducing the efficiency plateau
2. Increasing the streamer probability
3. Lower efficiency

25

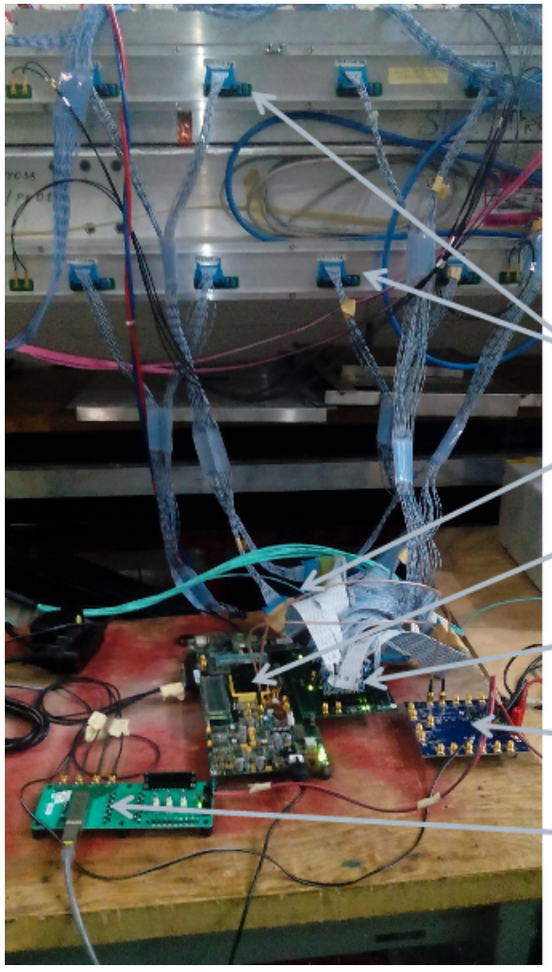
DT Phase2 demonstrator in P5

A MB1 chamber has been equipped with a full electronics chain modelling the Phase 2 architecture

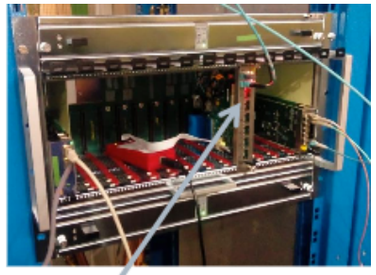


Based on presently available boards and links, the system will allow to validate the firmware performances, evaluate design choices and assess the final requirements through real data taking (cosmics)

First results from the DT demonstrator in P5



SX5 Setup



LVDS cables from Front End

10Gbps link to TwinMux

Virtex 7 Evaluation Board (138 TDCs)

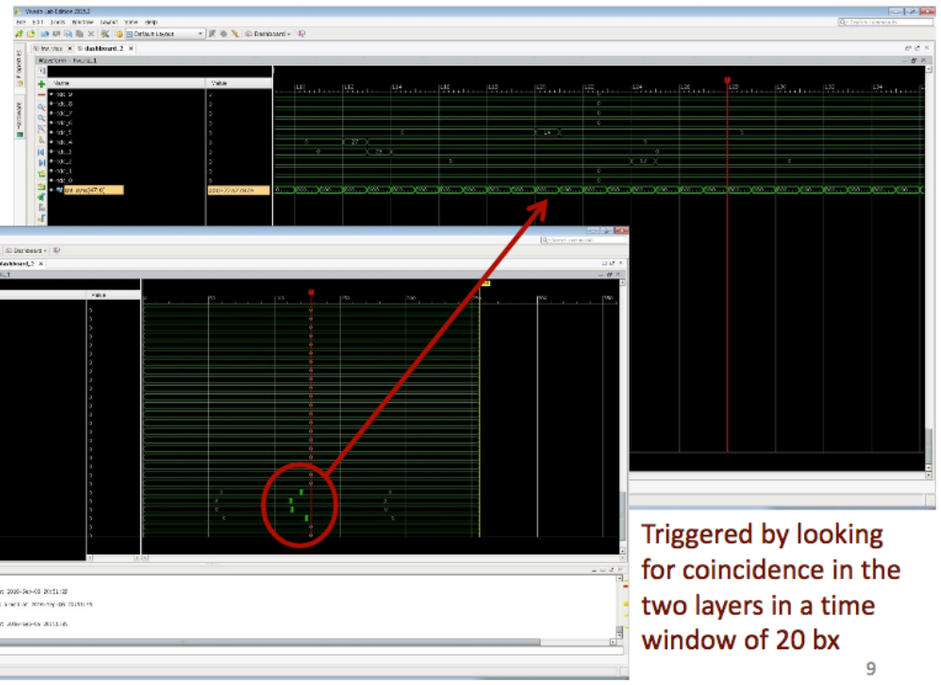
Input FMC mezzanines

LHC clock PLL (not conneted to TCDS yet)

Slow Control (Ipbus)

First Cosmic Ray Events

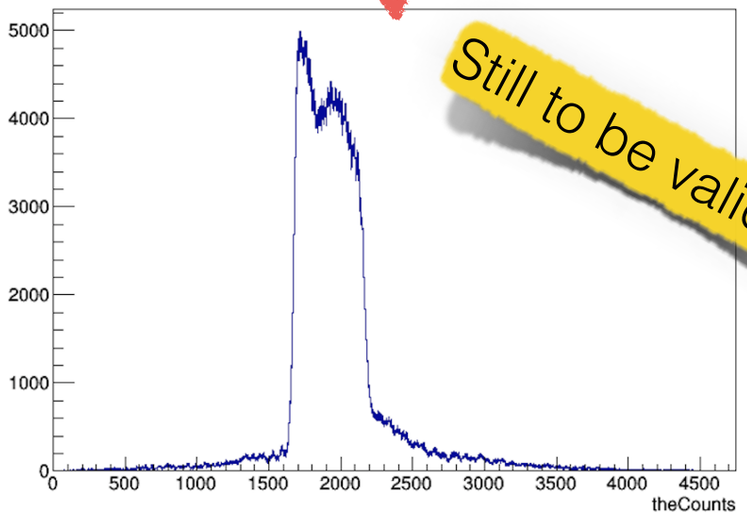
Caught by the TDC and readout by Vivado Hardware Monitor



Triggered by looking for coincidence in the two layers in a time window of 20 bx

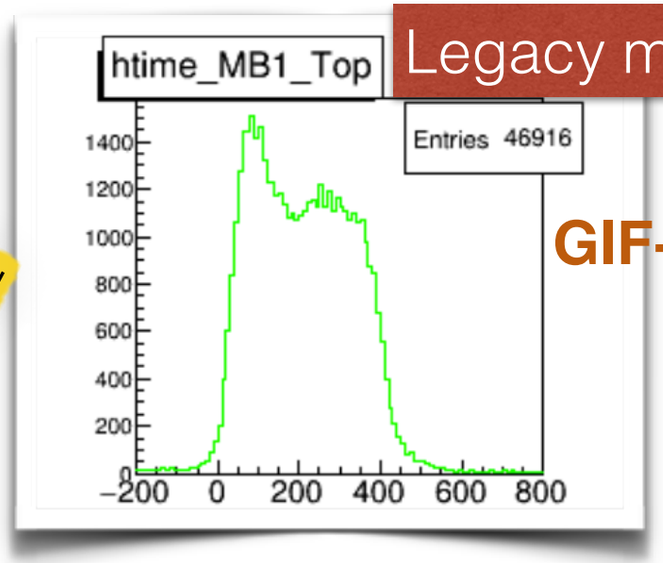
Demonstrator readout data processing integrated in the standard CMSSW workflow

Next step: integration and performance evaluation of BX-ID from the TDC stream



Still to be validated

Legacy minicrate:

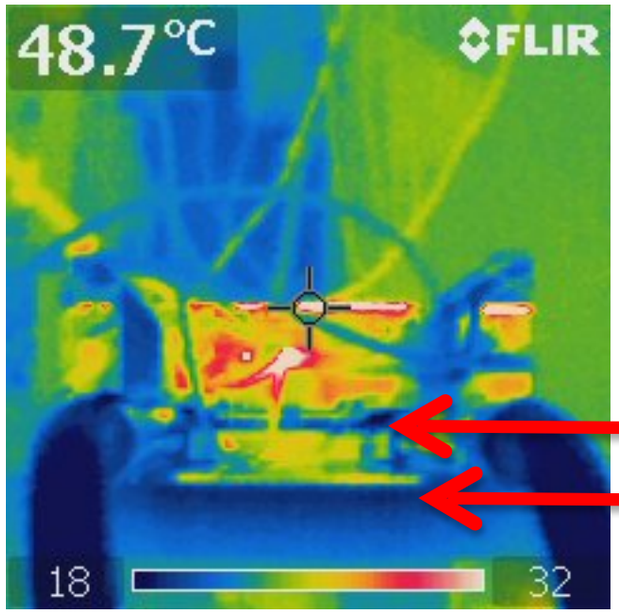


GIF++ MB1

DT MiC2 cooling tests (Bologna)

Trying to address the question:
If current minicrates (MiCs) are left in place, **can we use the present cooling to cool MiC2 electronics?**
To which extent?

Built MiC2 simulator, PCBs with 0.8ohm resistors thermally connected with copper bands along both sides of the boards



IR camera: Xsectional view

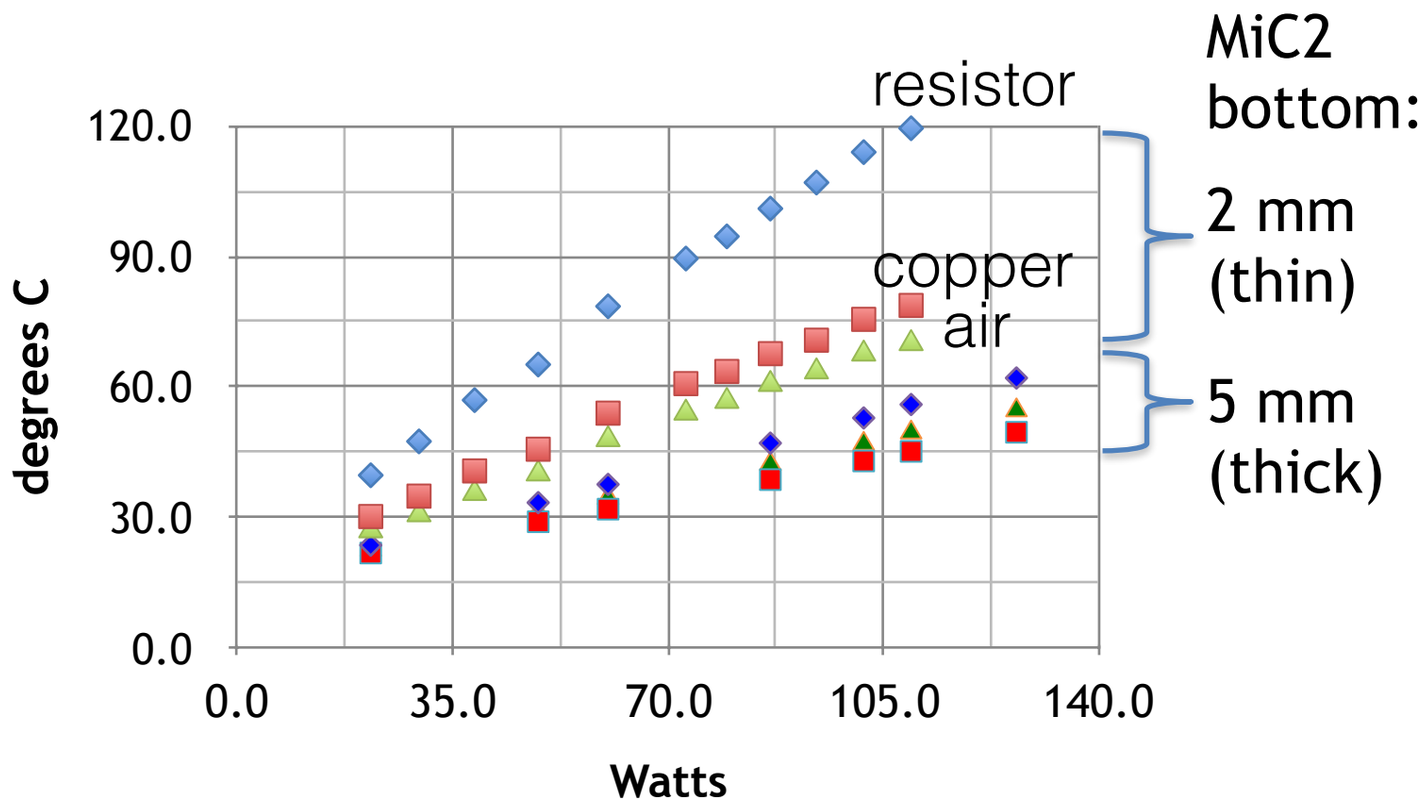
MiC2 bottom

MiC bottom

Copper bands in contact with MiC2 aluminium bars, in turn in contact with MiC cooling channels (water cooling)

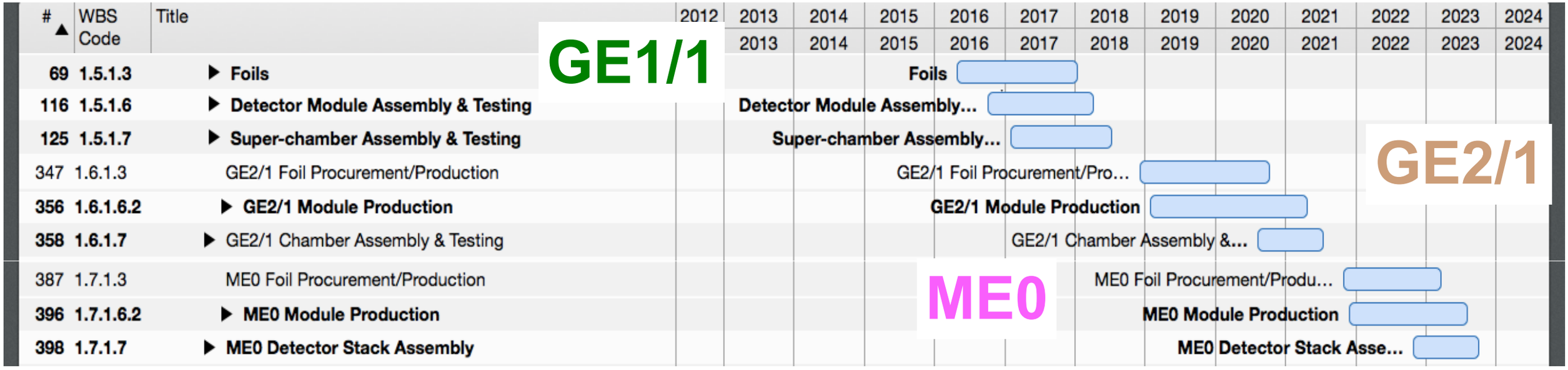
Several configurations tested:
cooling through MiC seems feasible.

Next step: check cooling capability if **MiC2 installed on top of present MiC** (rather then inside)



Timeline of GEM detectors for Phase2

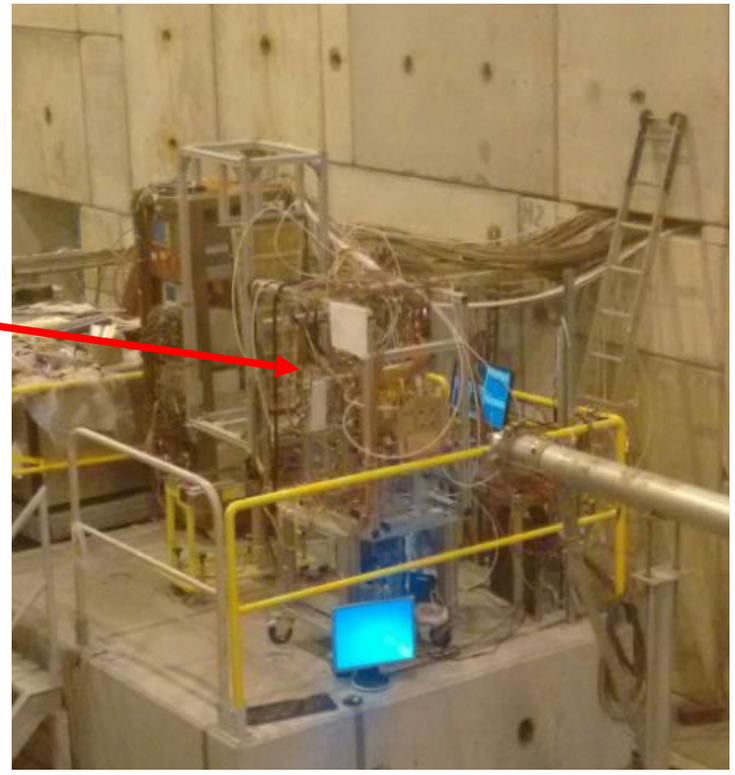
Q3 2017 TDR
Q2 2018: Decision on GE21 technology
Q1 2019: Decision on ME0 technology

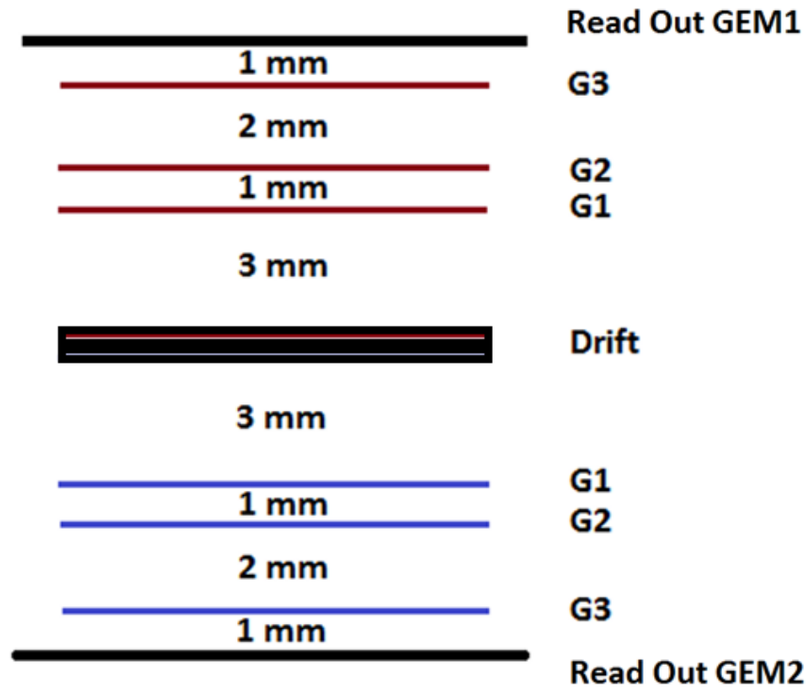


ME0 Status

ME0 baseline (back to back GEM): Test beam 19Oct-9Nov 2016 SPS H8 (μ 150 GeV)
Time resolution, efficiency, spatial resolution; neutron test @ CHARM Facility

Stand with trackers, PMTs and B2B GEM



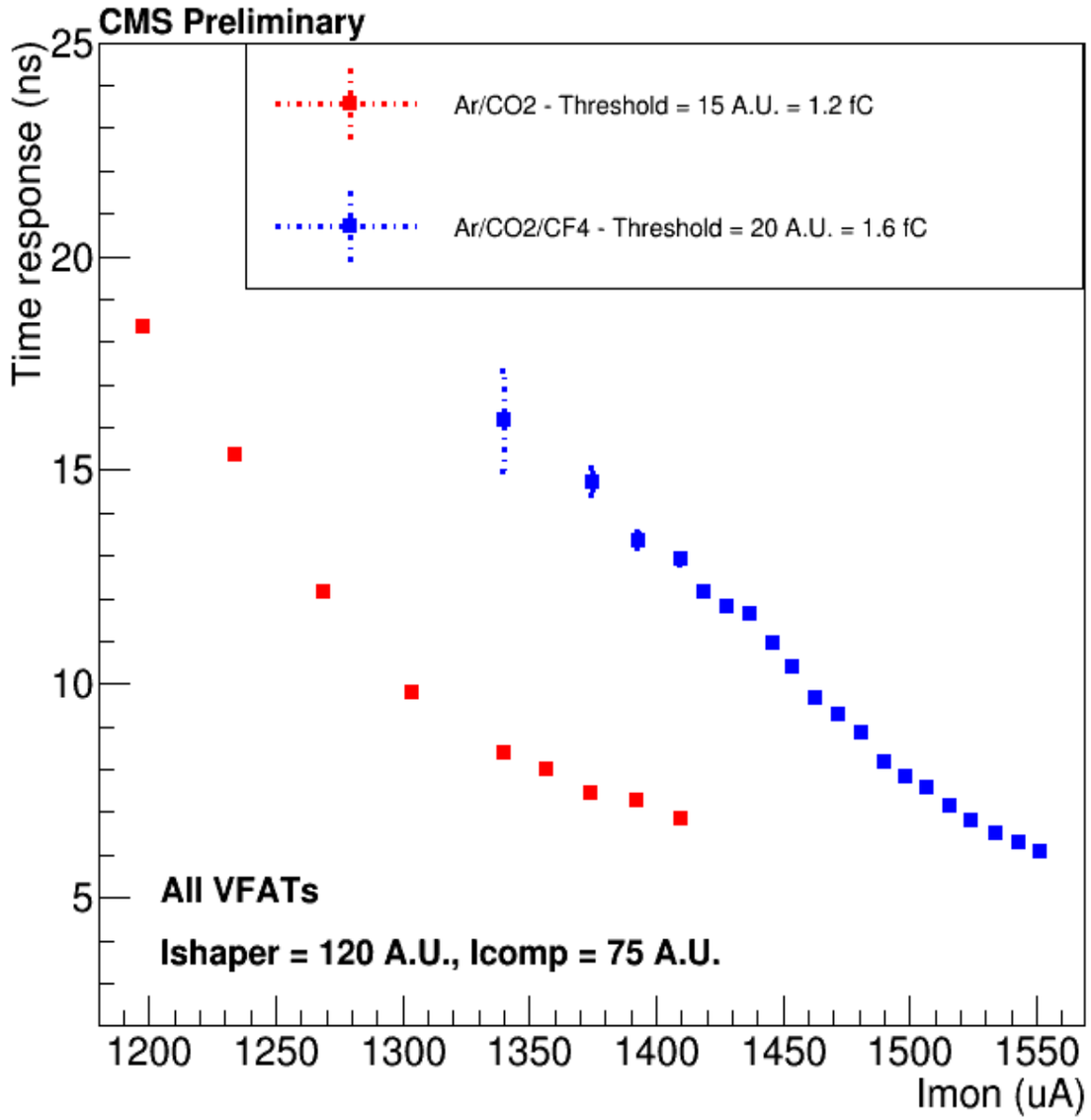


ME0 electronics (charge sensistive amplifier): the ASIC with 2 branches: one “slow” for reading charge and one “fast” for time measurement with <1ns capability.
First chip version submitted 7/12/2016
30 prototypes available end February 2017

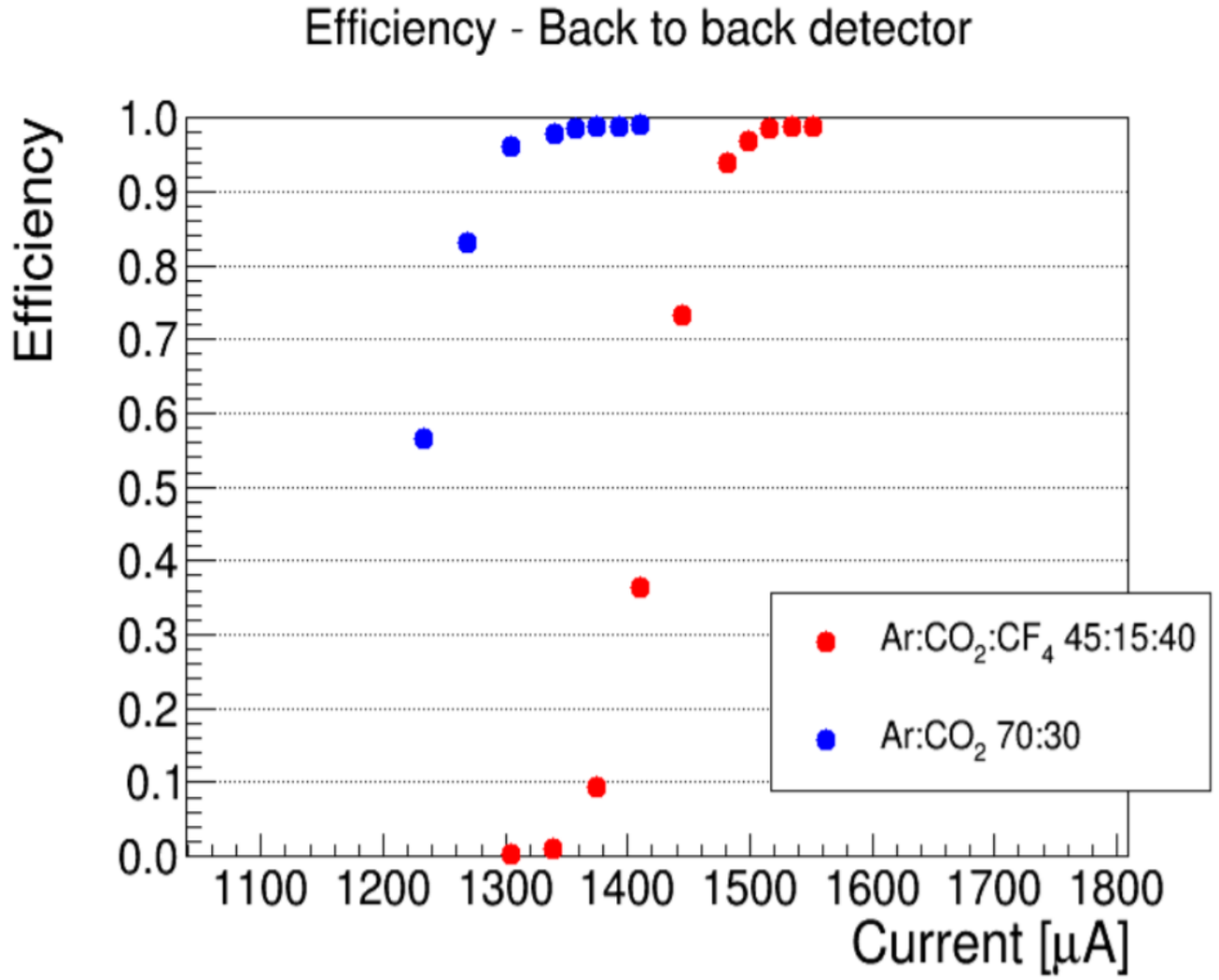
(F. Licciulli, De Robertis, Loddo, INFN BA)

Technology	TSMC 130nm
Charge sensitivity	54 mV/fC
ENC	187e- + 16.5e-/pF
Power consumption	≈ 1.5 mW
Time jitter	@ 1fC ≈ 245ps

ME0 B2B GEM prot.: test beam (prelim) results



Time resolution with Ar/CO2 is ~6 ns, while with Ar/CO2/CF4 ~5 ns is possible. Both these values are compatible with previous estimations from GE1/1.



Efficiency at plateau close to 100% (98.5%-99%) for both gas mixtures ($Ar:CO_2$ 70:30, $Ar:CO_2:CF_4$ 45:15:40)

GE2/1 prototype: GE1/1-sized uRWELL

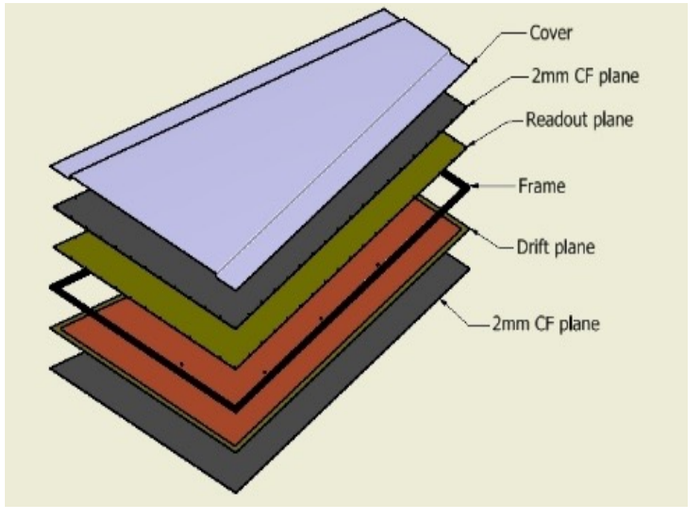
- April 2016 : Design completed
- July 2016 : Material procurement
- September 2016: Assembly
  (delay due to the etching procedure)

- November @ H8 test beam:
  Efficiency , Rate capability , Time resolution , Spatial resolution (with $Ar/CO_2/CF_4$)

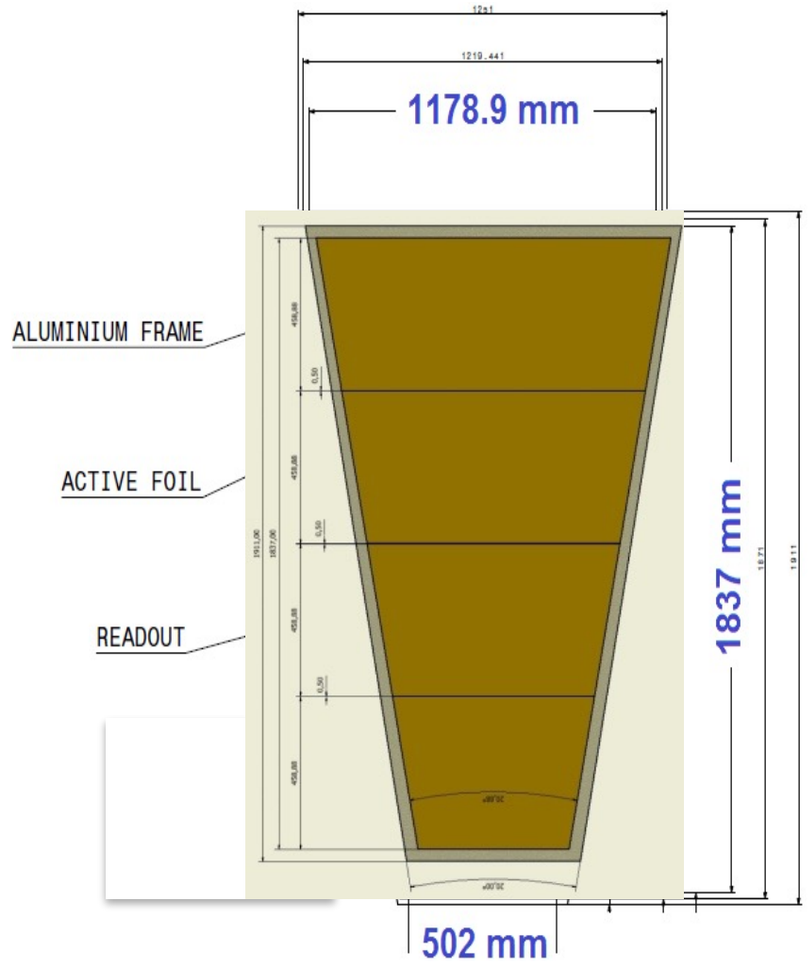
- Jan-Nov 2017: GIF++ test (longevity and uniformity under irradiation) with both Ar/CO_2 and $Ar/CO_2/CF_4$ (using the prototype tested @ H8)

- Mechanical design & assembly of
  full-size detector started

- Four PCB μ-RWELL modules + only one cathode PCB closing entire chamber is under study, with dummy and uRWELL modules.



GE2/1 μ-RWELL exploded view

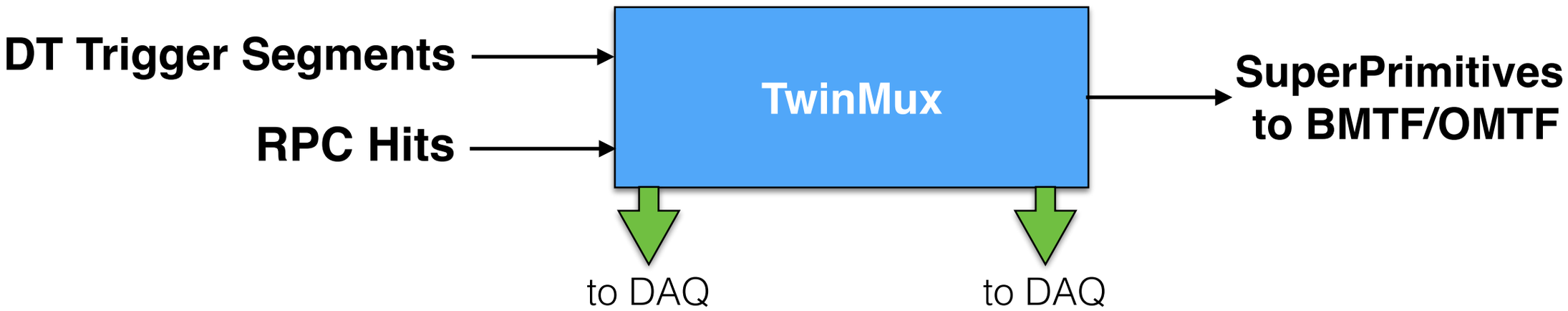


Conclusioni

- Ottimi risultati nel 2016, in termini di stato dei detector, efficienza nella presa dati e qualità dei dati. Il lavoro per migliorare i sistemi di trigger e readout e le analisi online/offline delle performances non si è mai fermato
- L'upgrade di Fase1 del trigger è completato dal punto di vista hardware, i nuovi algoritmi hanno prodotto i primi risultati, su questi il lavoro continuerà
- Durante l'extended technical stop, ci sarà un'intensa attività per riparare detector/elettronica, e per l'installazione dello slice test di GE1/1
- Diventa sempre più importante comprendere se vediamo effetti di ageing dei detector, sia a P5, che con irraggiamento alla GIF++
- Nei prossimi mesi gli sforzi saranno dedicati non solo alla manutenzione e alle operations dei detector, ma anche, in misura notevole, agli upgrade: la produzione di GE1/1 e la scrittura del TDR di Fase2 e le attività di R&D sui nuovi detector, sul gas, sulla nuova elettronica

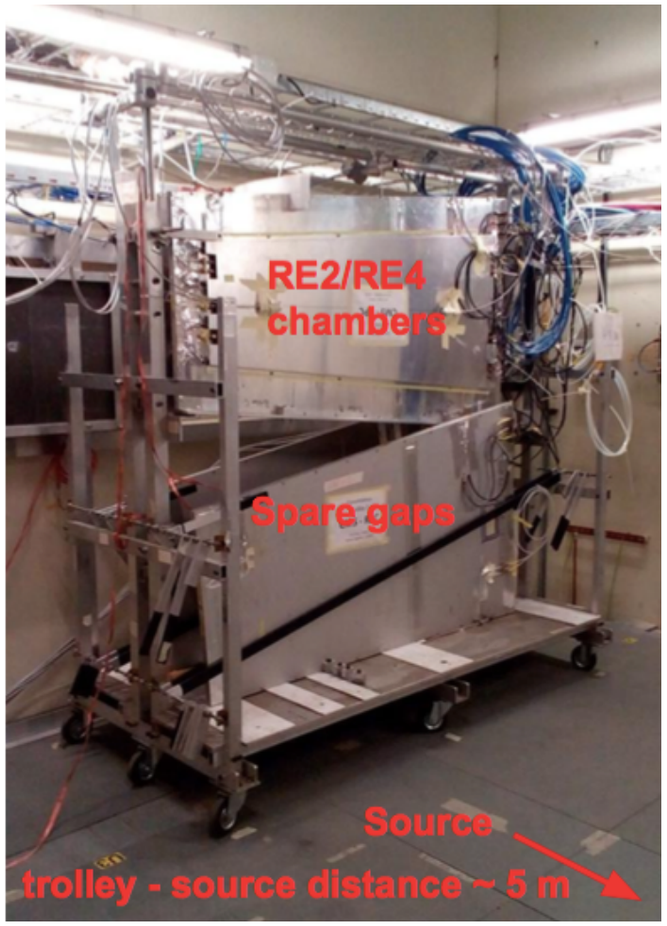
Backup

DT+RPC SuperPrimitive TwinMux algorithm in 2016



- Each TwinMux processor receives DT and RPC links from one sector of the barrel muon detector
- DT consists of Trigger Segments, including position, direction, quality and BX information
- RPC consists of Hits, including position and BX information
- Output data to the Barrel Muon Track Finder use the same data format as the DT Trigger Segments and are obtained with the following algorithm
- Input data are deserialised and synchronised.
- A clustering algorithm is applied to RPC Hits: neighbouring Hits are merged and the resulting cluster position is assigned with half-strip resolution and converted into DT coordinates.
- In case the same RPC cluster fires in two consecutive BXs, the second one is suppressed.
- RPC clusters close in ϕ to DT Trigger Segments from the same chamber are searched for, in a ± 1BX time window centred around the DT Trigger Segment BX.
- The closest RPC cluster is selected; if the Δϕ with respect to the DT Trigger Segment satisfies Δϕ≤15 mrad, RPC and DT are considered matched and the SuperPrimitive quality bit is set.
  - If the DT Trigger Segment was built with less than 8 DT ϕ layers, the Trigger Segment BX is shifted to match the RPC cluster BX; if the DT Trigger Segment was built with all 8 DT ϕ layers, its BX is not changed.
- If no match with an RPC cluster was found, the original DT Trigger Segment is output to the Barrel Muon Track Finder, and the SuperPrimitive quality bit is not set.

RPC longevity studies



Set-up:

➢ 2 RE2 and 2 RE4 chambers (one for irradiation the other as reference)

➢ 6 spare gaps (w/o electronics)

- trolley can be moved to scan each partition during TB

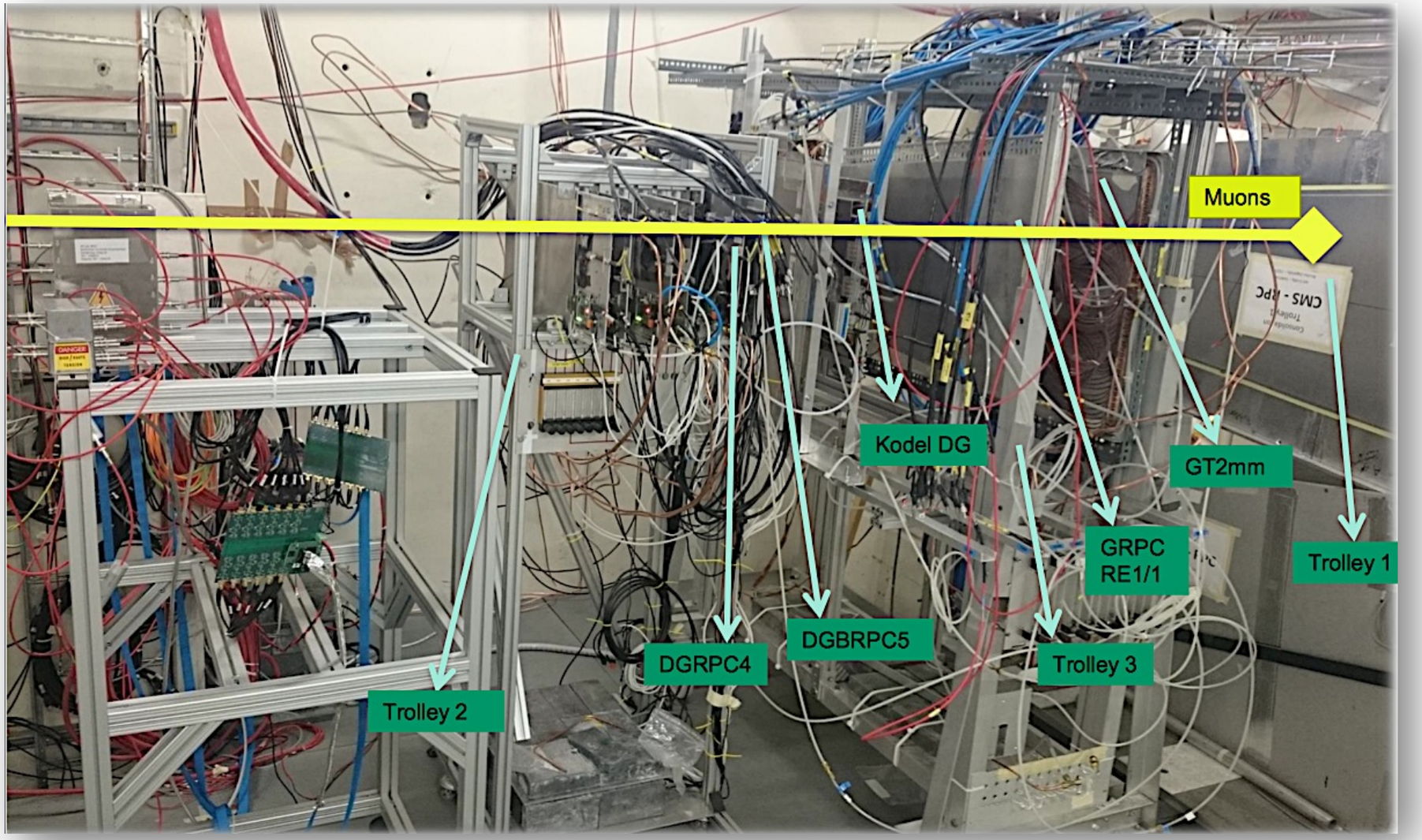
Delay starting irradiation of all chambers:

- Gas flux limitation up to ~30 l/h (enough only for two chambers)
- new MFCs installed end of October. Ready to start the irradiation test to all system.
- closed loop still not available

Procedure:

1. Continuous monitoring of the currents.
2. Daily measurement of current and rate at Working Point and at stand-by both in SG and DG mode
3. Weekly current and rate scan
4. Few time/year detector performance with muon & Resistivity measurements.

Backup: RPC R&D status on baseline



2016 test beams at GIF

- 5 periods of two weeks over the year
- several prototypes tested with different thickness of gas gap and Bakelite, electrode material (Glass & Bakelite) and electronics.

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Backup: RPC Link System Upgrade

The RPC group is working in defining the best solution and cost for the Link system Upgrade.

- ➢ The preferred solution for the RPC Link System upgrade is to keep the legacy LinkBox (crate) and the power supply system.
- ➢ The requirements for the new system have been defined.
- ➢ It would be good to use as much as possible "standard" CMS hardware/ firmware/software solutions developed for the upgrades as much as it is possible.
- ➢ It would be good share the hardware/firmware/software solutions between the RPC/muon upgrade projects.

Teheran colleagues joined the activity and they have already some preliminary ideas.

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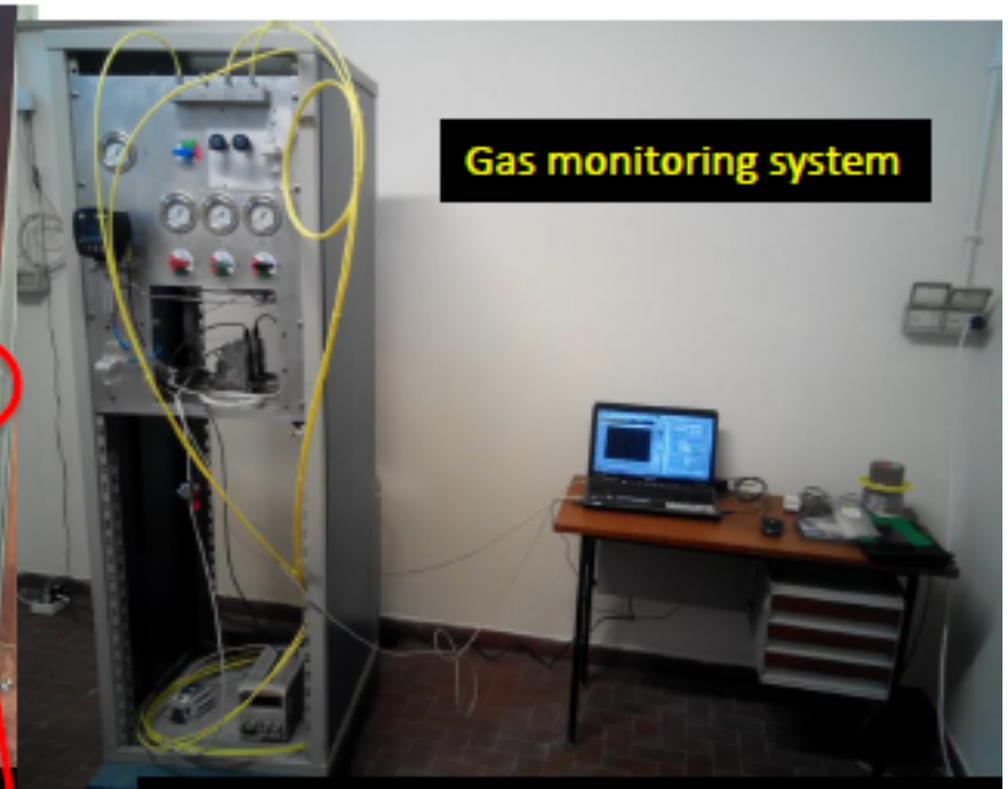
QC4 and QC5 in Bari

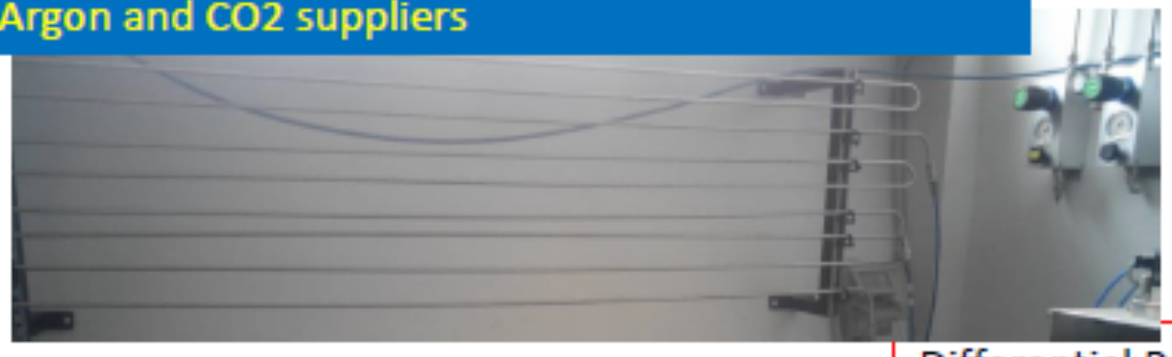
X ray gun with xyz-movement
MCA8000D-AMPTEK

X-ray Box with GE11/IV
(we will use it for the exercise)



•Bronkhorst Flow-Meter
mod. EL-FLOW® metal seal USB controlled
(3 lines)
•HygroPro from Gen. Electric
•Weather station for pressure
measurements with logging capapbility

Gas thermalization stainless steel pipes connecter to
Argon and CO2 suppliers



Differential Pressure Transmitters
(Dwyer Series 616, 0.25% accuracy, Max. Press. 350 mBar)
controlled by computer with logging capability

INFN GEM sites

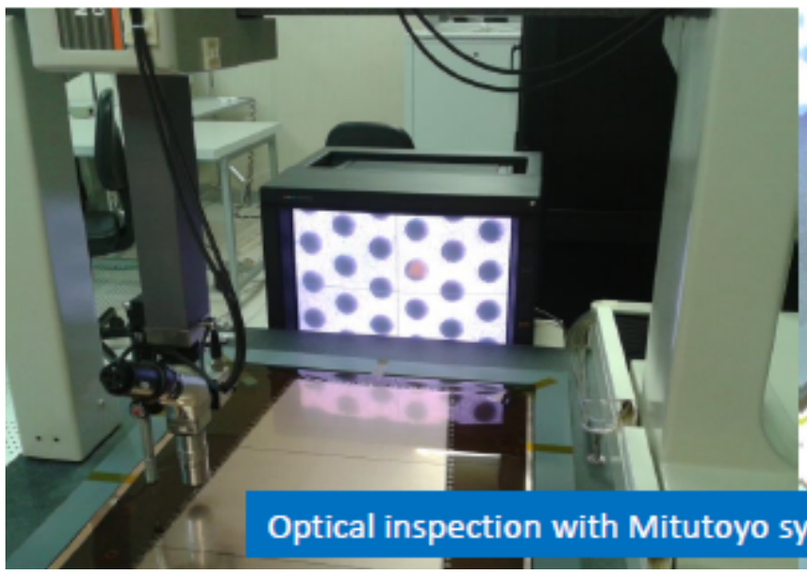
The Assembly site: the clean room (class 1000)(BA)

- Clean room is almost completed. List of equipment:

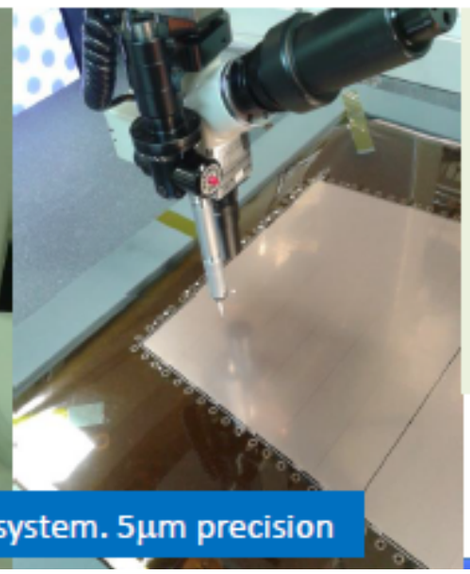
Optical bench for chamber assembly

Gas-tight box for foils current leakage test

Retro-illuminated table for first foil inspection



Optical inspection with Mitutoyo system. 5µm precision



1. HV CAEN N1471H power supply
2. HV CAEN NDT1470 p.s.
3. Megger MIT420
4. N/CO_2 gas lines
5. Keithley 6487 Picoammeter
6. Pressurized air line
7. One NIM crate

Box for QC2 test (LNF)

Phase2 “GEM” activities 2015-2016-2017

Sviluppo dei rivelatori Fase2:

- Studio prototipi small & large **size GE21(μRwell) e ME0 (FTM,GEM)** (**BA,LNF,PV,BO**)
  - Misure di guadagno, efficienza, risoluzione spaziale e temporale, rate capability (TB,GIF++)
- Test ageing **ME0** (**BO,PV**)
- Test con neutroni **ME0** (**BA,PV,NA**)
  - Currents ,gain, charge and rates measurements
  - Discharges studies
  - Test of the new HV Caen module for GEM
- Elettronica **ME0** (**BA**)
- Studio e disegni della meccanica per **GE21 (uRwell & GEMbaseline)** (**BA, LNF,NA)**
- Mockup **GE21** e **ME0** (**NA**)
- Realizzazione di moduli **GE21** e **ME0** full size (**BA,LNF,PV,BO**)

Simulazioni e Analisi Fase2:

- Simulazioni fondi, ricostruzione, identificazione muoni: **BA,PV**
- Analisi canali di fisica**:** **BA,BO**

(+ contributo di G.Bencivenni, M.PoliLener (LNF) per uRwell)

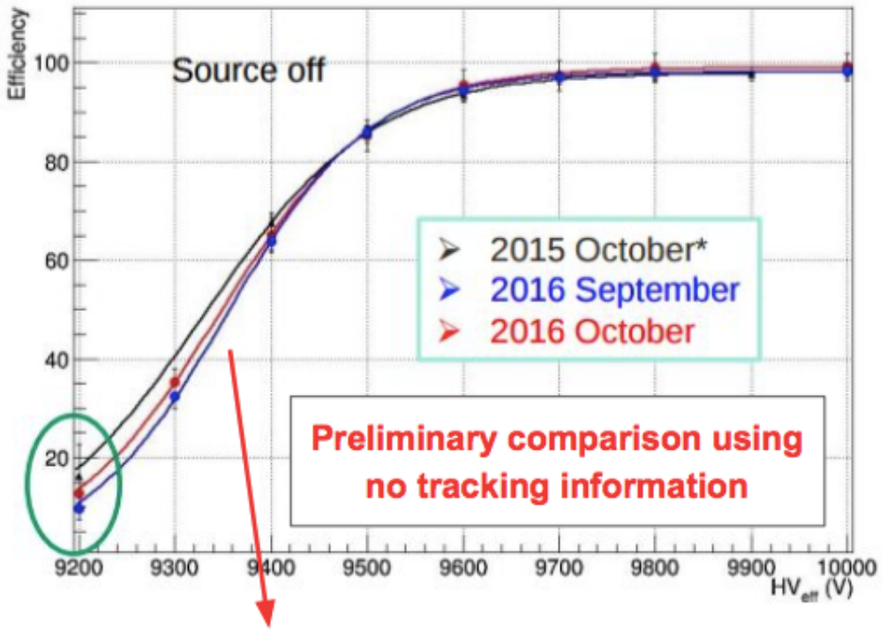
Comments on 2016 DT Operations

- Stable behaviour of the minicrates during 2016. Only 2 board failures observed during the year.
- Fraction of dead channels stable during 2016. The main problem is due to RO links in the CMS balcony and in the counting room.
  - The problem should improve when the new uROS board will be installed (end of 2017)
- Despite the trigger system was almost completely replaced at the beginning of 2016, the operation of the detector and the quality of the data was not affected:
  - in 2017 we will fully exploit the potentiality of the Twinmux

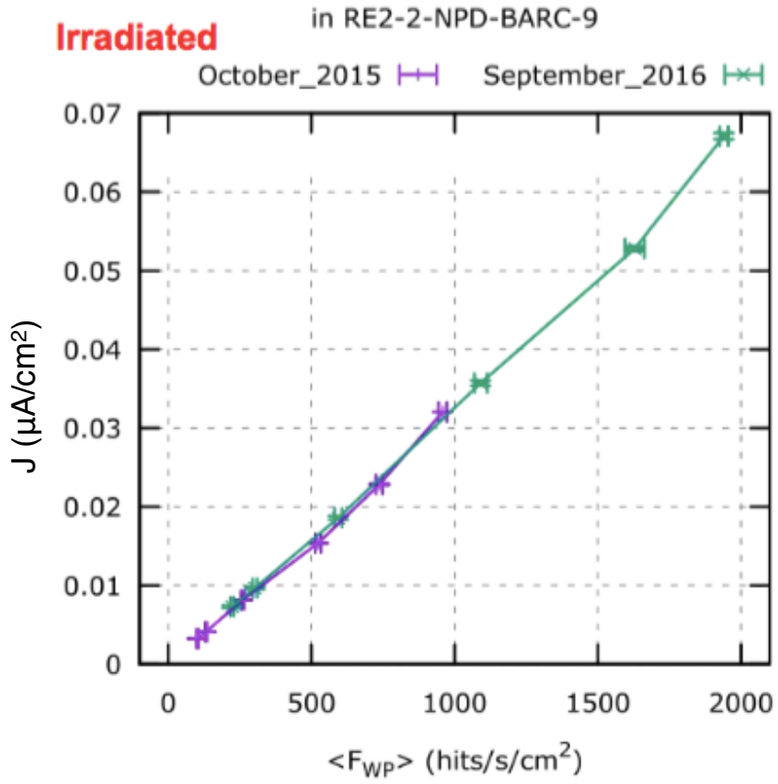
RPC Longevity Studies at GIF++

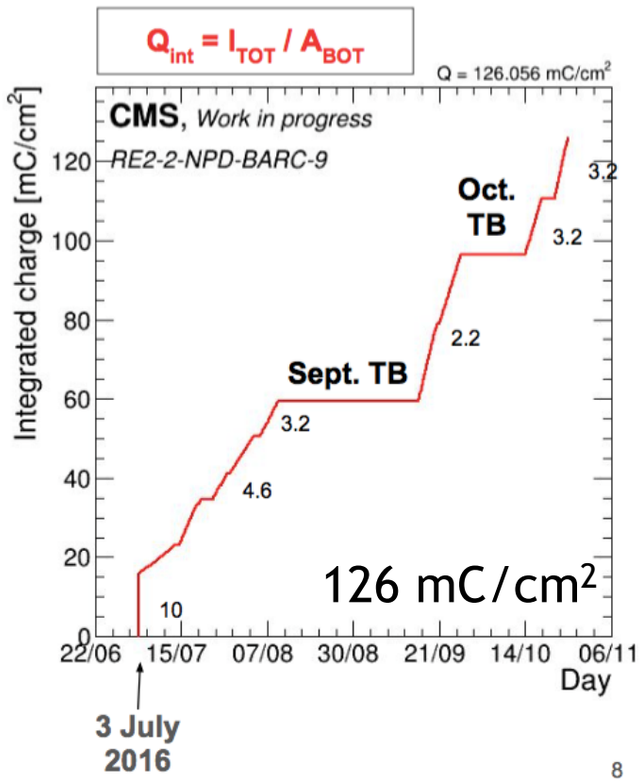
Irradiation test started on the 3th of July 2016 on RE2 chambers

Conservatively started with high absorption factor, gradually lowered up to a maximum rate of ~ 1.2 kHz/cm². This rate correspond to about a factor 2 of the expected HL-LHC rate.



No variation of the chamber performance





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HL_LHC requirements:

- integrated charge for 3000 fb^{-1}: 1 C/cm² (with a Safety factor 3)
- Maximum rate ~ 600 Hz/cm²