RPC project at the CMS experiment

from the present system to the upgrade

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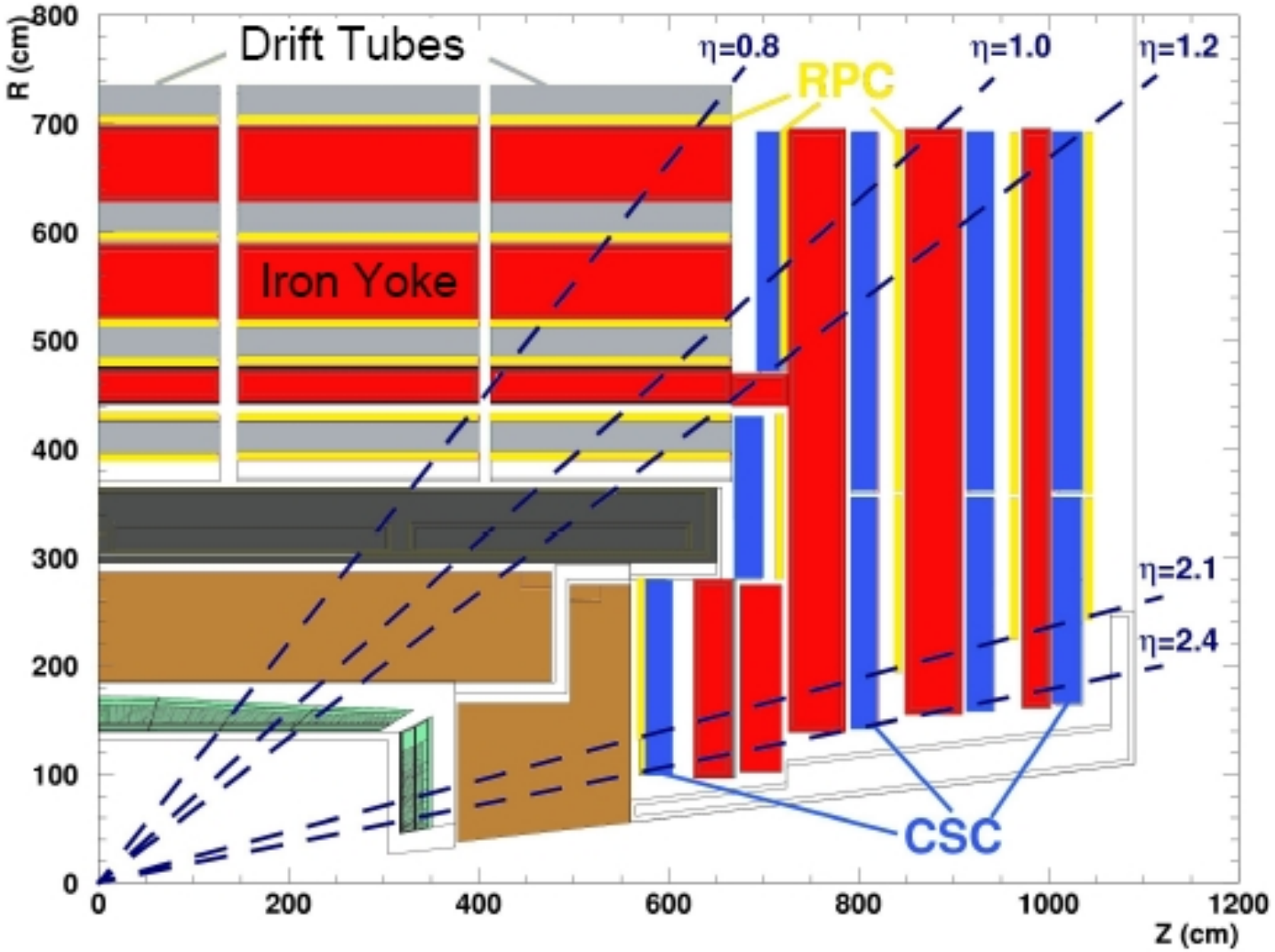
Outline

- Muon system description
- RPC collaboration
- Organization chart
- Results 2010-2011 with collision data
  - Efficiency studies
  - Background studies
- 2012-2013 Upgrade
- Conclusions

Muon system

2 detector regions but 3 trigger regions: Endcap, Barrel and Overlap

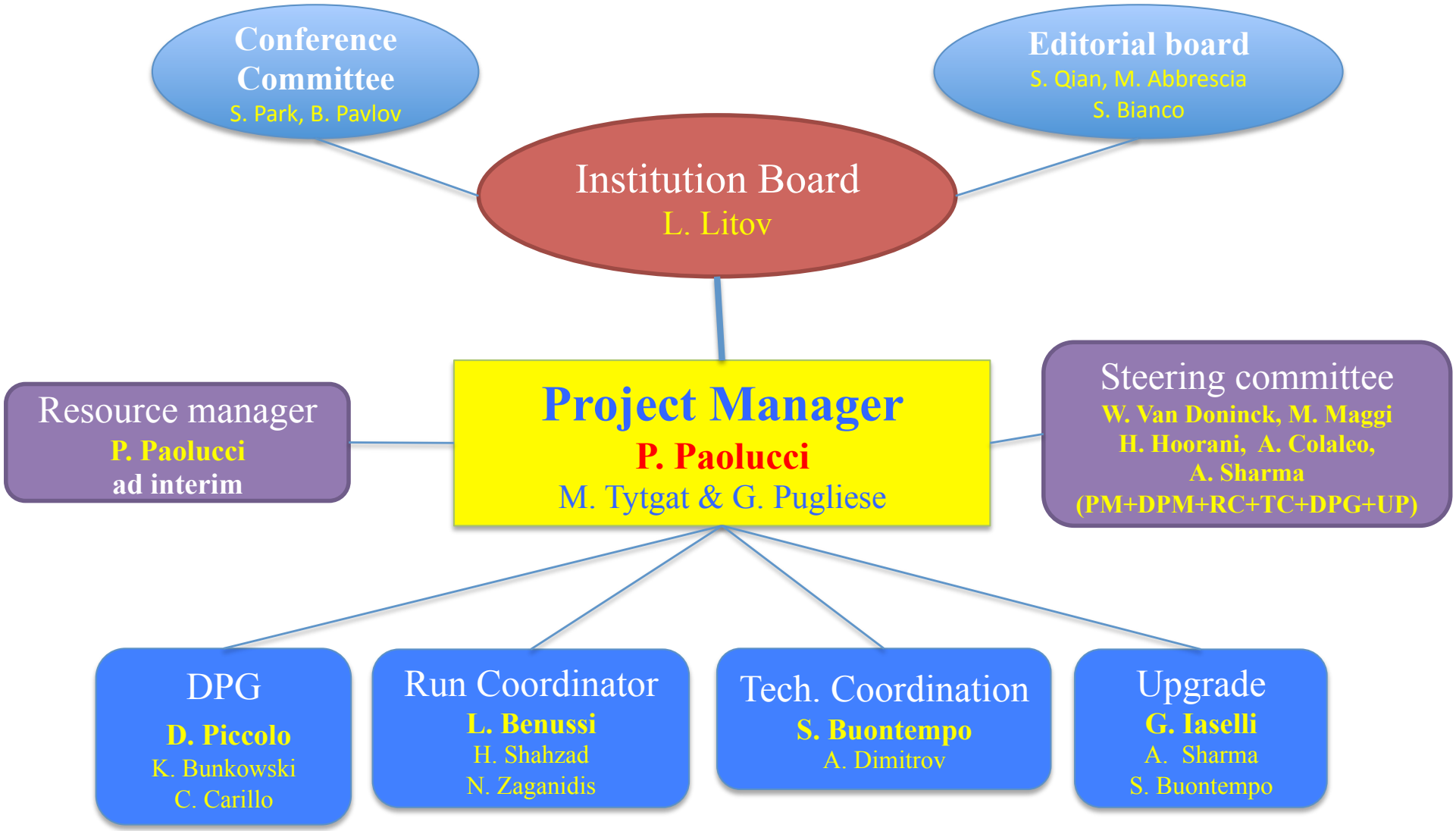


RPC collaboration

Barrel	Italy	Bulgaria	China	Colombia	
Endcap	Korea	Pakistan	China	Belgium	CERN
Upgrade	Italy	Pakistan	India	Colombia	CERN
	Korea	China	Belgium	Finland	Egypt

CHINA	2
KOREA	16
INDIA	4
BELGIUM	10
COLOMBIA	2
PAKISTAN	6
EGYPT	3
CERN	4
ITALY	28
BULGARIA	12
TOTAL	84

Organization Chart



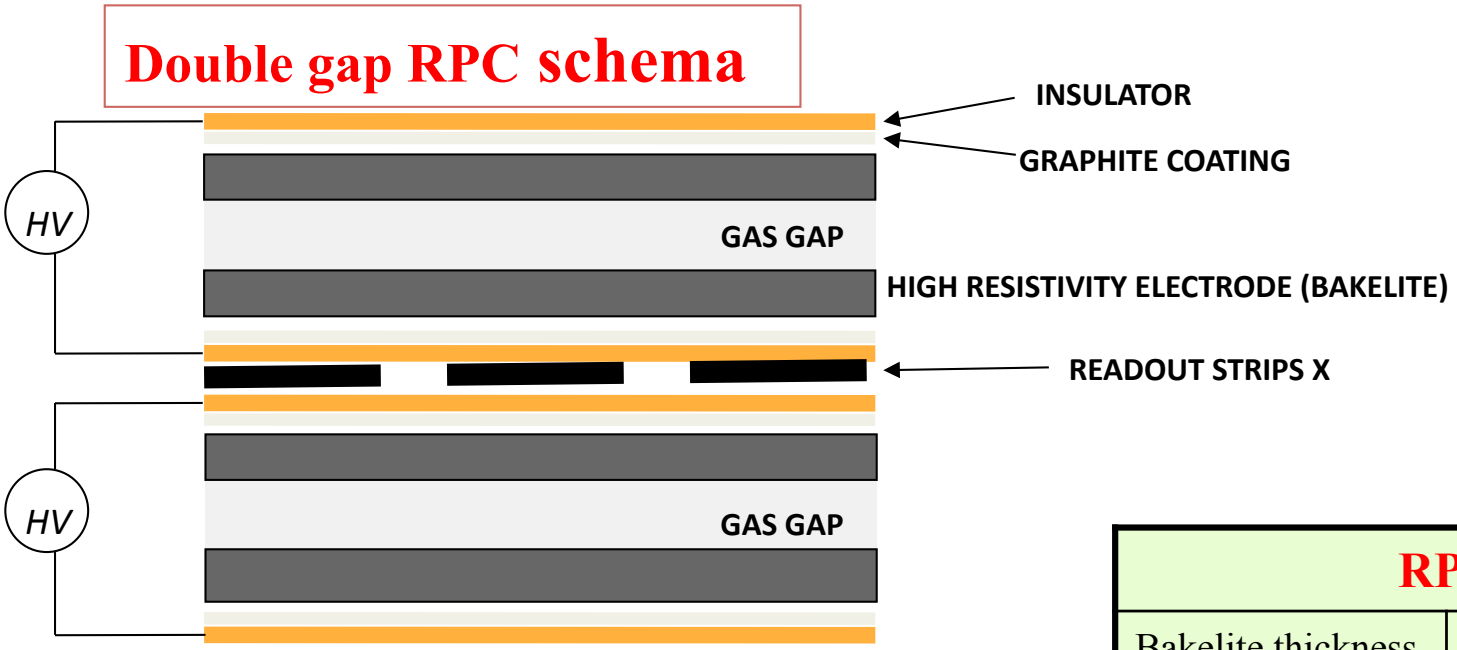
Gruppo di Napoli

- Le persone coinvolte nel progetto RPC e nel suo Upgrade sono:
  - Pierluigi Paolucci – Project Manager
  - Salvatore Buontempo – Technical coordinator
  - Camilo Carillo – Data Physics Group

  - 1 PhD student coinvolto nel progetto upgrade

  - SER – sviluppo scheda di acquisizione per l'upgrade
  - PM/OM – manutenzione ed installazione upgrade

RPC detector

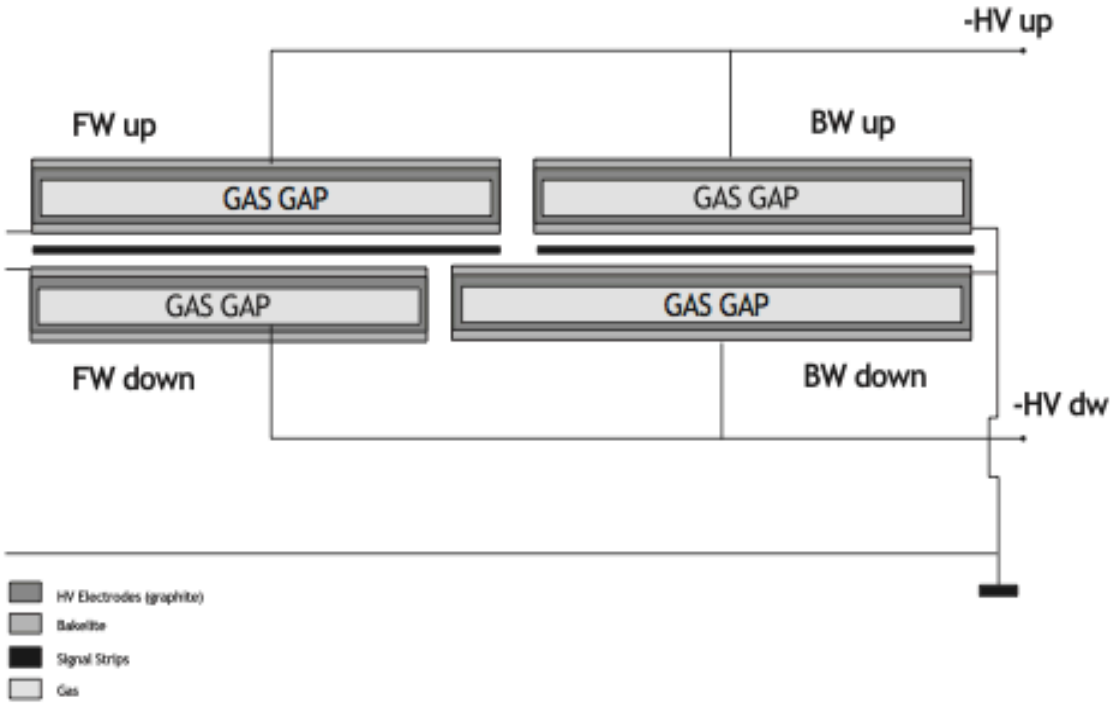


- **Streamer mode (LEP and BaBar)**
- **Avalanche mode (LHC)**
  - high rate capability → 1 KHz/cm^2
  - spatial resolution (~ 8 mm)
  - time resolution < 3ns (BX identification)
  - plateaux more than 300 Volt long
  - Cluster size ≈ 2 (trigger pattern)

RPC info	
Bakelite thickness	2 mm
Bulk resistivity	1-2 10^{10} Ω cm
Gap width	2 mm
Gas mixtures	96.2%C2H2F4 + 3.5%C4H10 + 0.3%SF6
Operating HV	9.4 – 9.8 kV
No.Gaps	two

RPC system: few numbers

Double Gas gap RPC. Operating in avalanche mode HV ≈ 9.5kV.



CMS RPC

- Chambers = 912
  - Barrel = 480
  - Endcap = 432

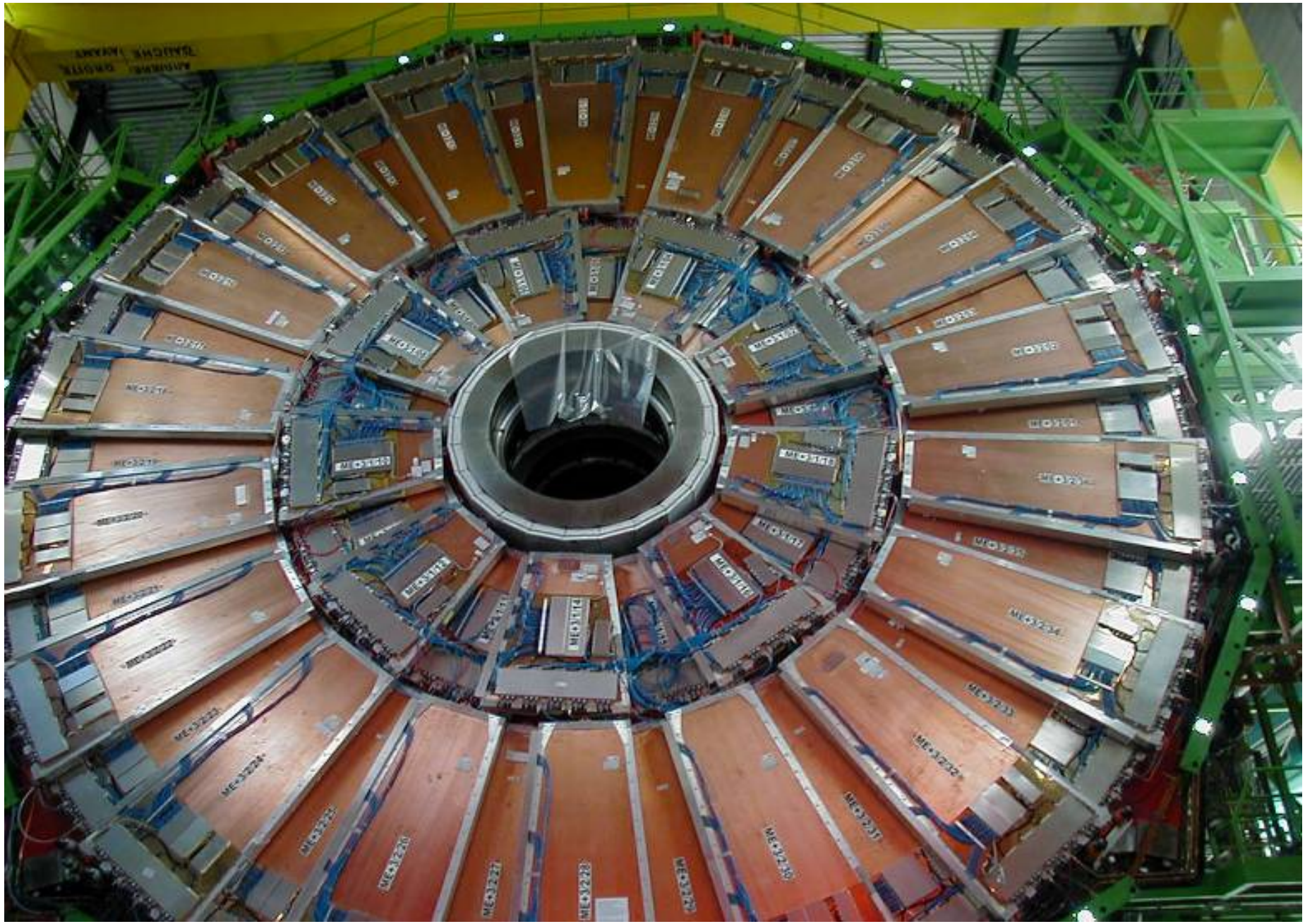
RPC Strips (Channels)

- Total = 109608
  - Barrel = 68136
  - Endcap = 41472

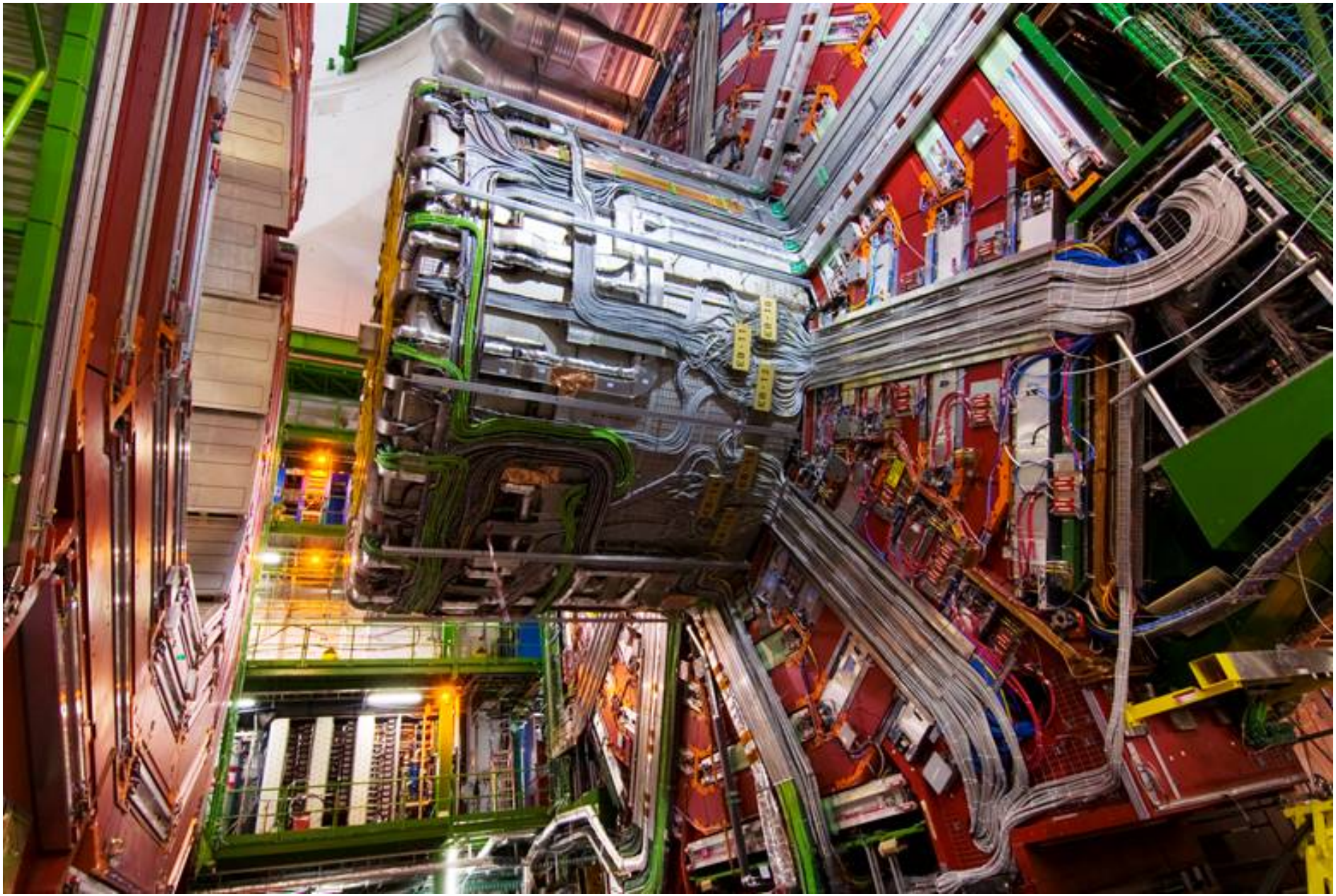
Active Area ≈ 2953 m^2

- Barrel ≈ 2285 m^2
- Endcap ≈ 668 m^2

Endcap disk



Barrel wheel



RPC monitor system

CMS central tools only

- Detector Control System (Napoli): G. Polese & A. Cimmino
  - Current, voltage and environmental parameters
  - Front-end and trigger electronic configuration
- Web Based Monitoring (Korea):
  - Offline analysis of online data
- Data Quality Monitor (Napoli): A. Cimmino & D. Lomidze
  - Offline analysis (reconstruction)
- Results are stored in CMS database
  - To be used in offline analysis

How judge the RPC muon system ?

① Detection efficiency and stability
- Plateau curves
- Overall efficiency

② Background:
- Noise rate & Dark current

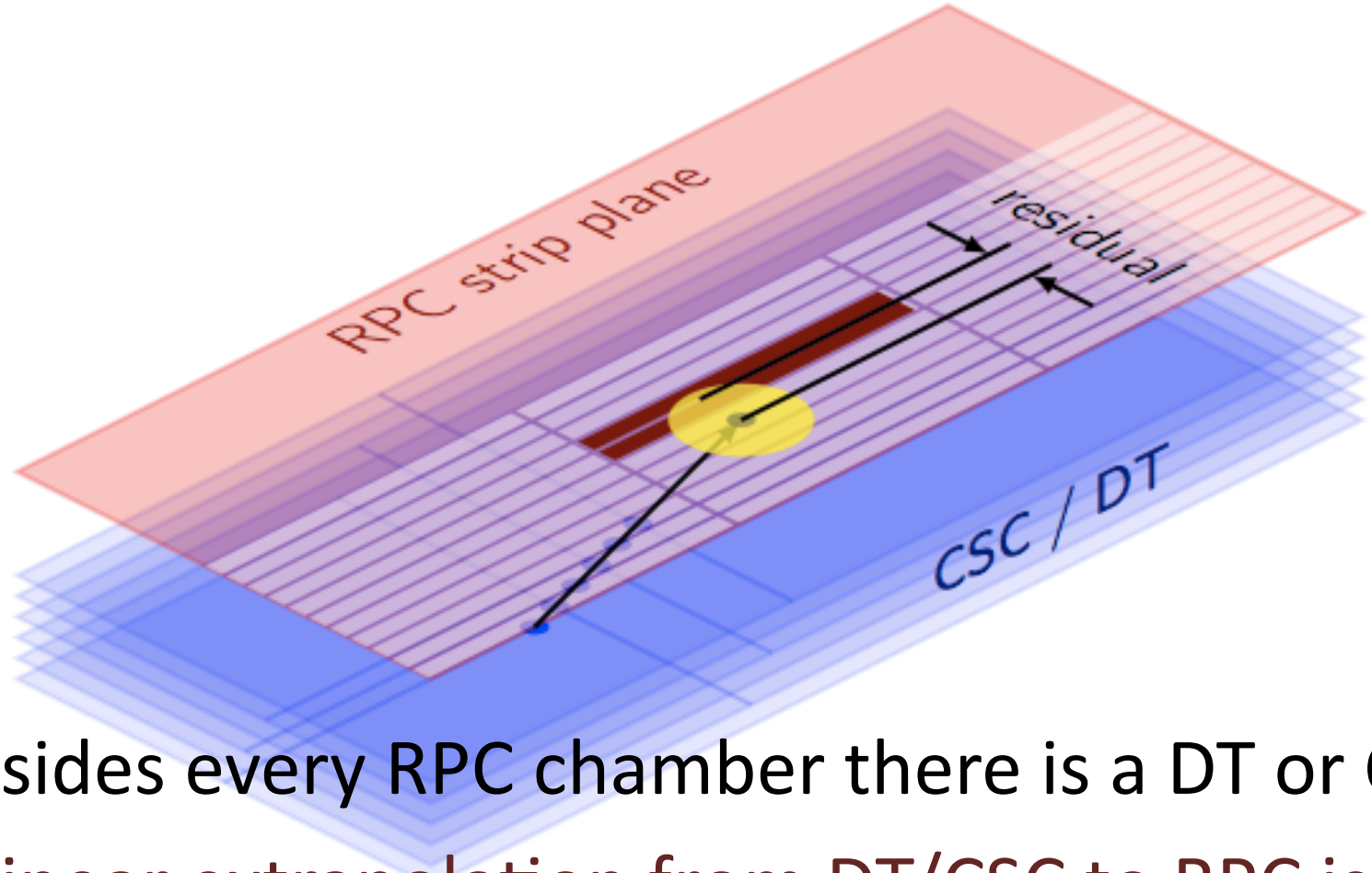
③ Trigger rate & efficiency stability

- High Luminosity 10^{33}
- Millions of muons
- Many runs (time)

④ Aging effect:
- Dark current & noise rate
- Plateau position (HV at 50% eff)
- Efficiency uniformity

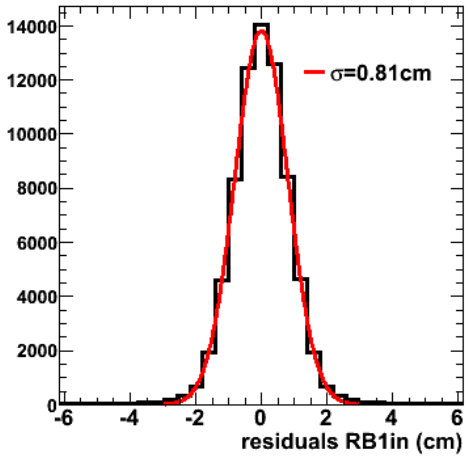
- High Luminosity
- High beam intensity
- time
- sophisticated analysis

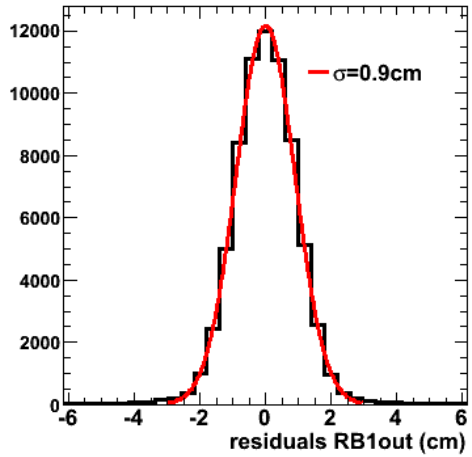
① Plateau/Efficiency measurement

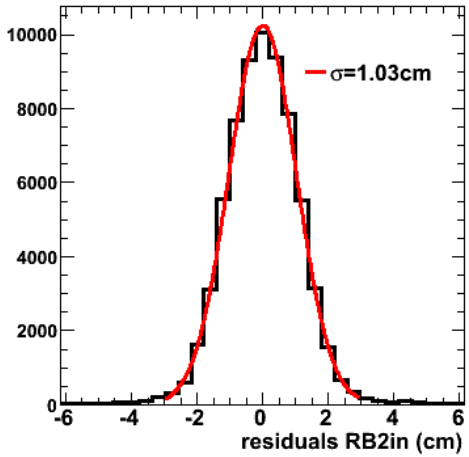


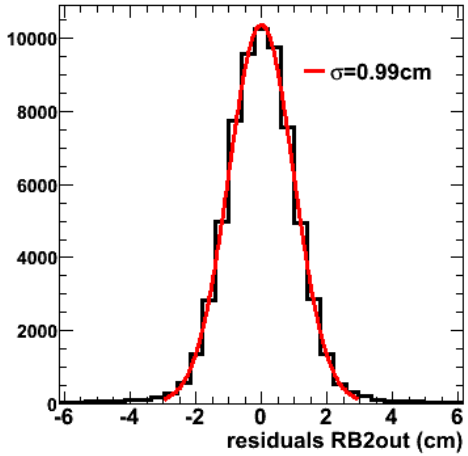
- Besides every RPC chamber there is a DT or CSC
- A linear extrapolation from DT/CSC to RPC is used
- Z/W muon impact point technique is under study

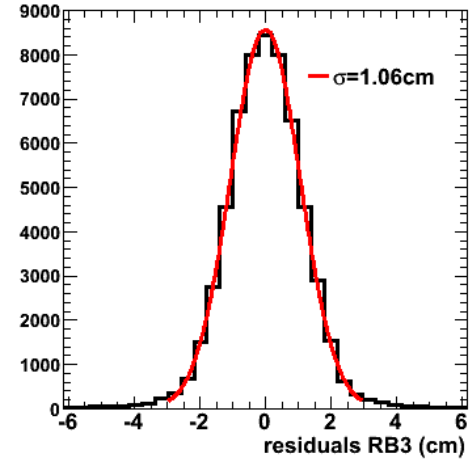
① Barrel resolution

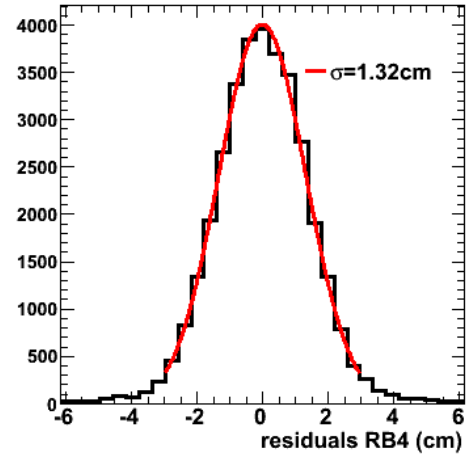












- **Resolutions range**: σ = 0.81 cm (inner) σ = 1.32 cm (outer)
- Strip widths range from 2.28 cm to 4.10 cm.

RPC system: requirements

① Redundant muon system (trigger and identification)

② Fast detector for bunch crossing identification

③ Cheap technology to cover a so large area

④ Dark current 10 μA (max 100 μA) per chamber

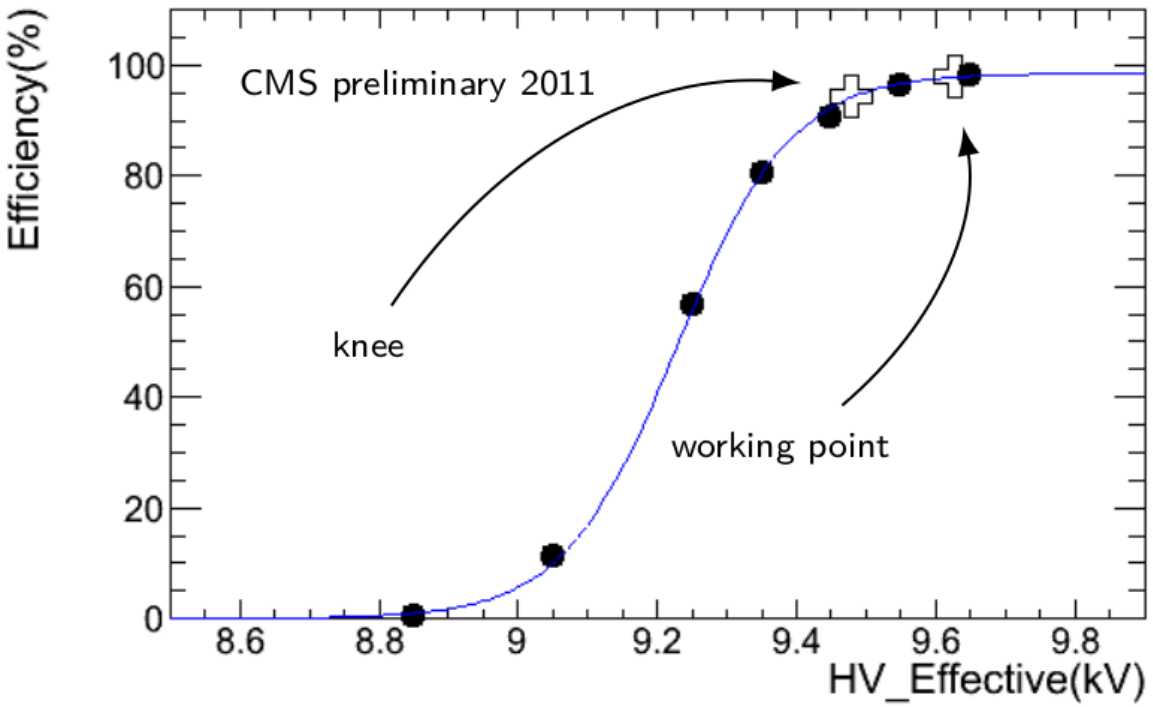
⑤ Background rate (1-100 KHz/cm^2) capability

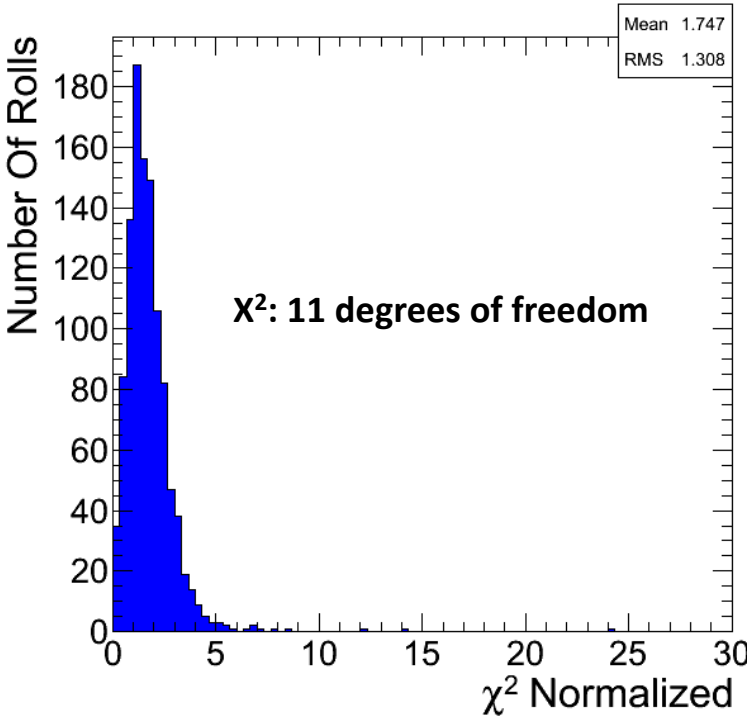
⑥ Spatial resolution ≈ 5-10 mm Approved

⑦ High stability and detection efficiency > 95%

⑧ Muon trigger rate and efficiency

① efficiency: HV scan 2011



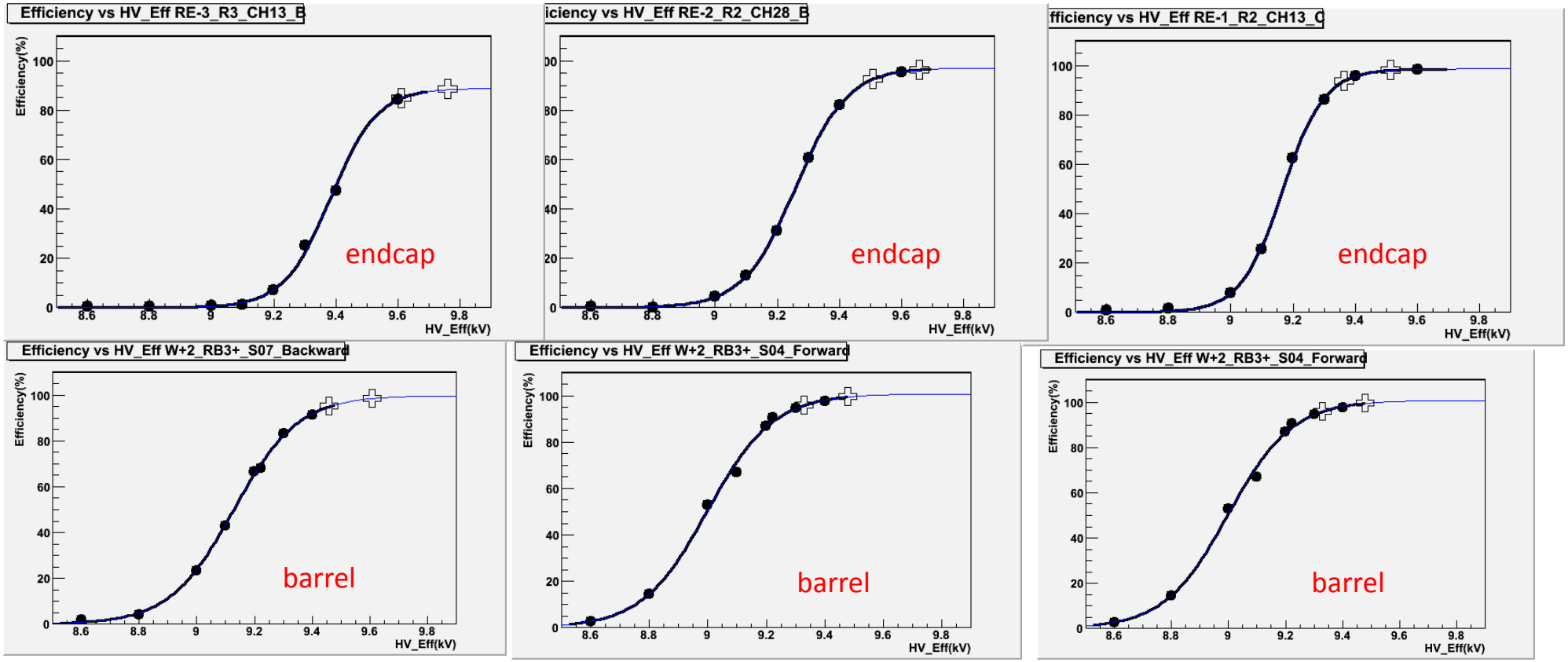


$$Eff = \frac{Eff_{max}}{1 + e^{s(HV - HV_{50})}}$$

All efficiency curves are nicely sigmoidal in shape

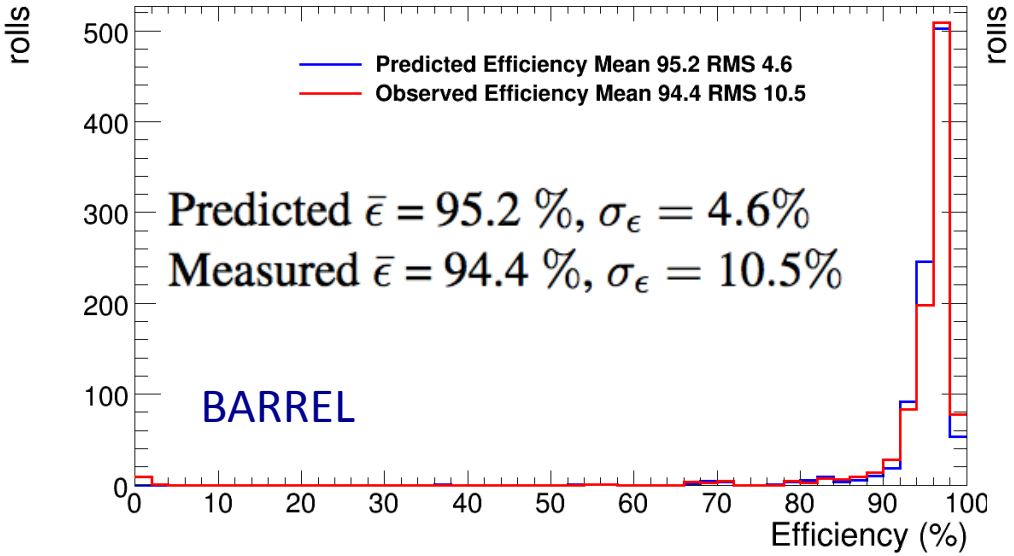
- Eff_{max} is the maximum efficiency; asymptotic value when HV → ∞
- HV_{50} is the HV applied such that the efficiency is $Eff_{max}/2$
- s is just a scale factor, determines how "horizontal" is the sigmoid.

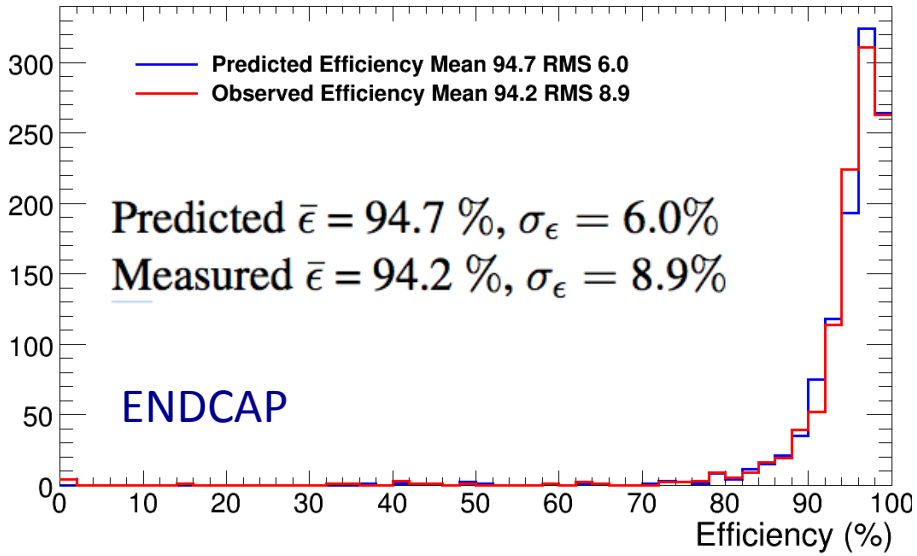
① efficiency: 2172 plateau

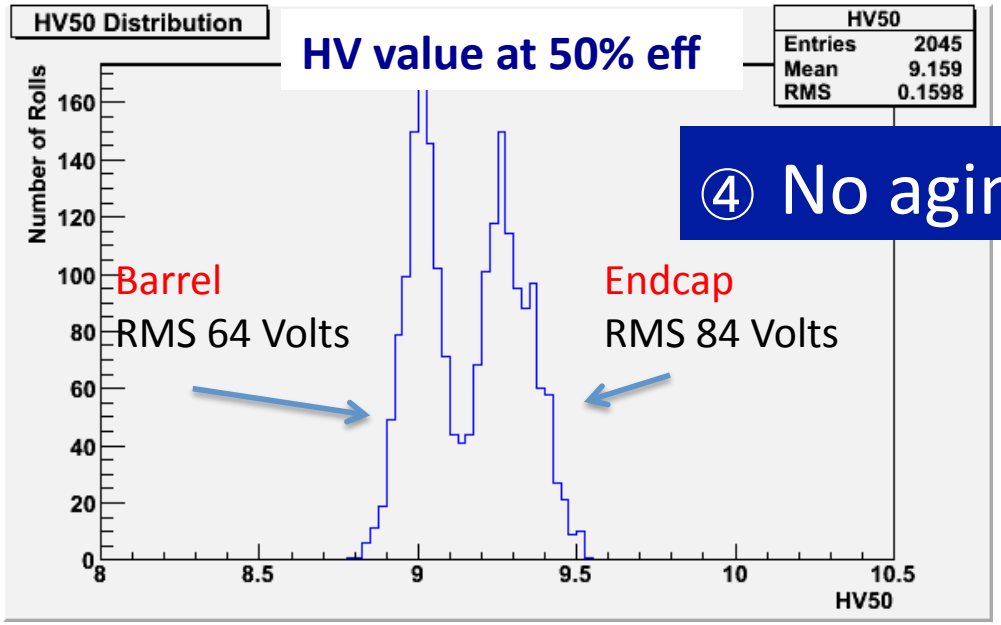


- **99% of the 2172 rolls (half-chamber) have a perfect plateau**
- After about 5-7 years from the gap construction and 3 years of data taking
- This is already a great success – never seen in other experiments with RPC

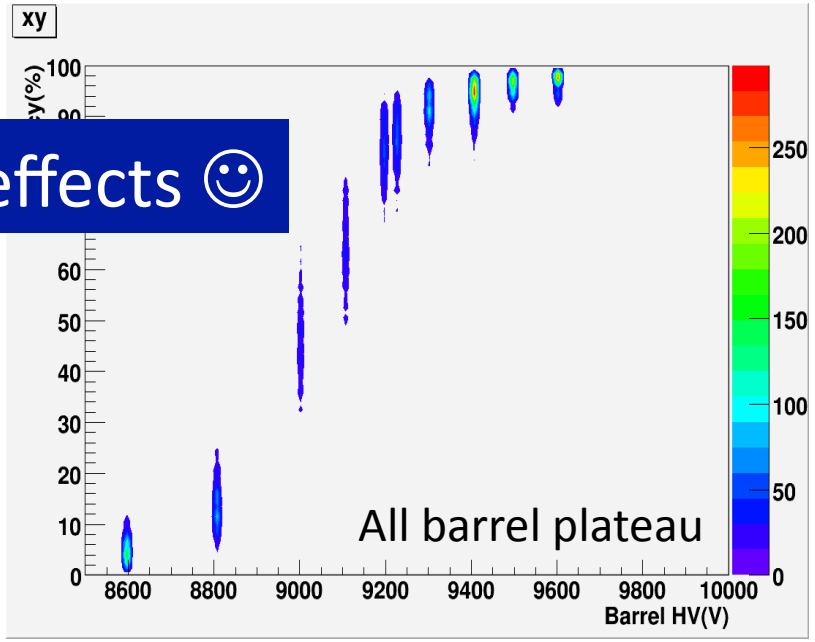
① efficiency: 2172 plateau analysis



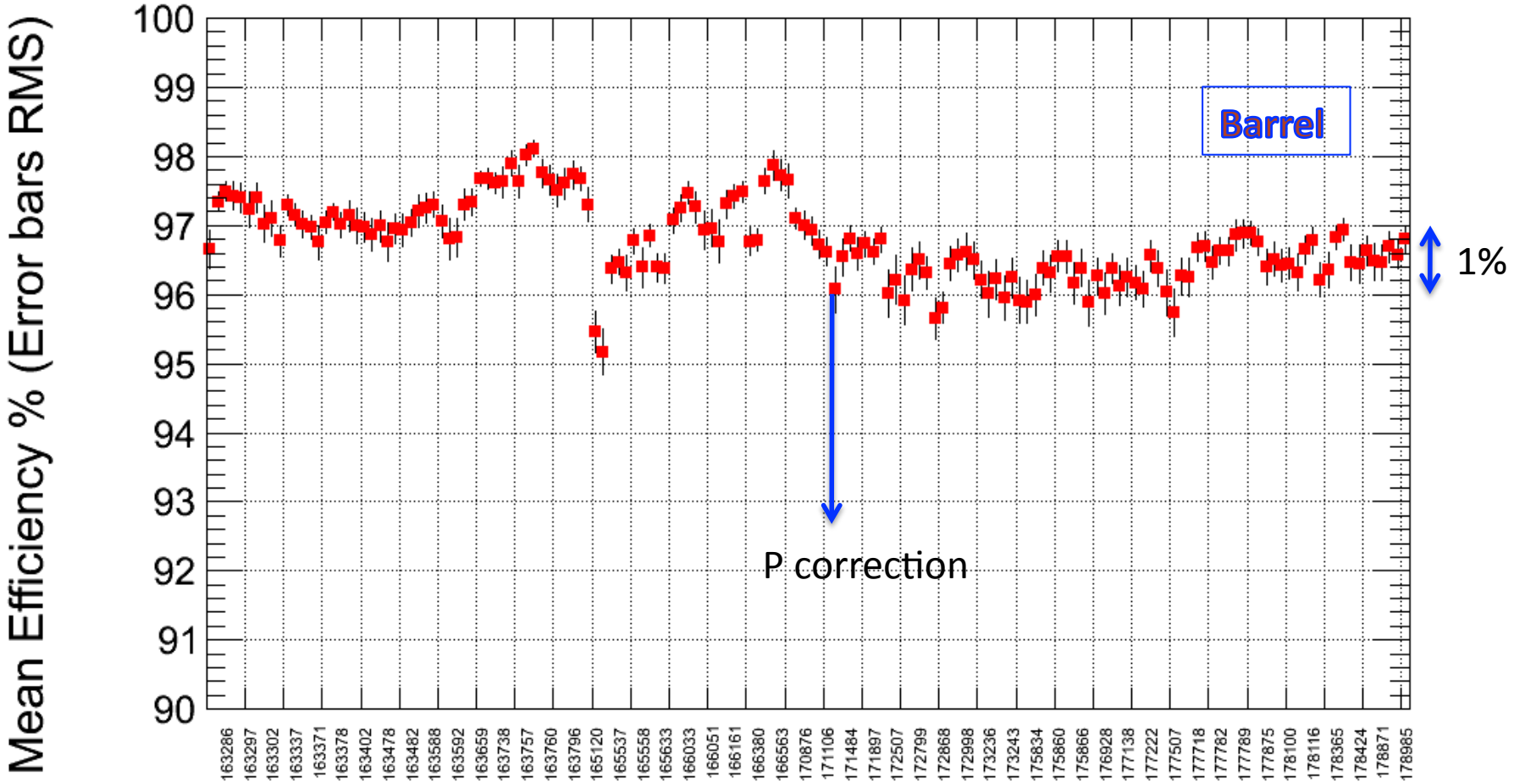




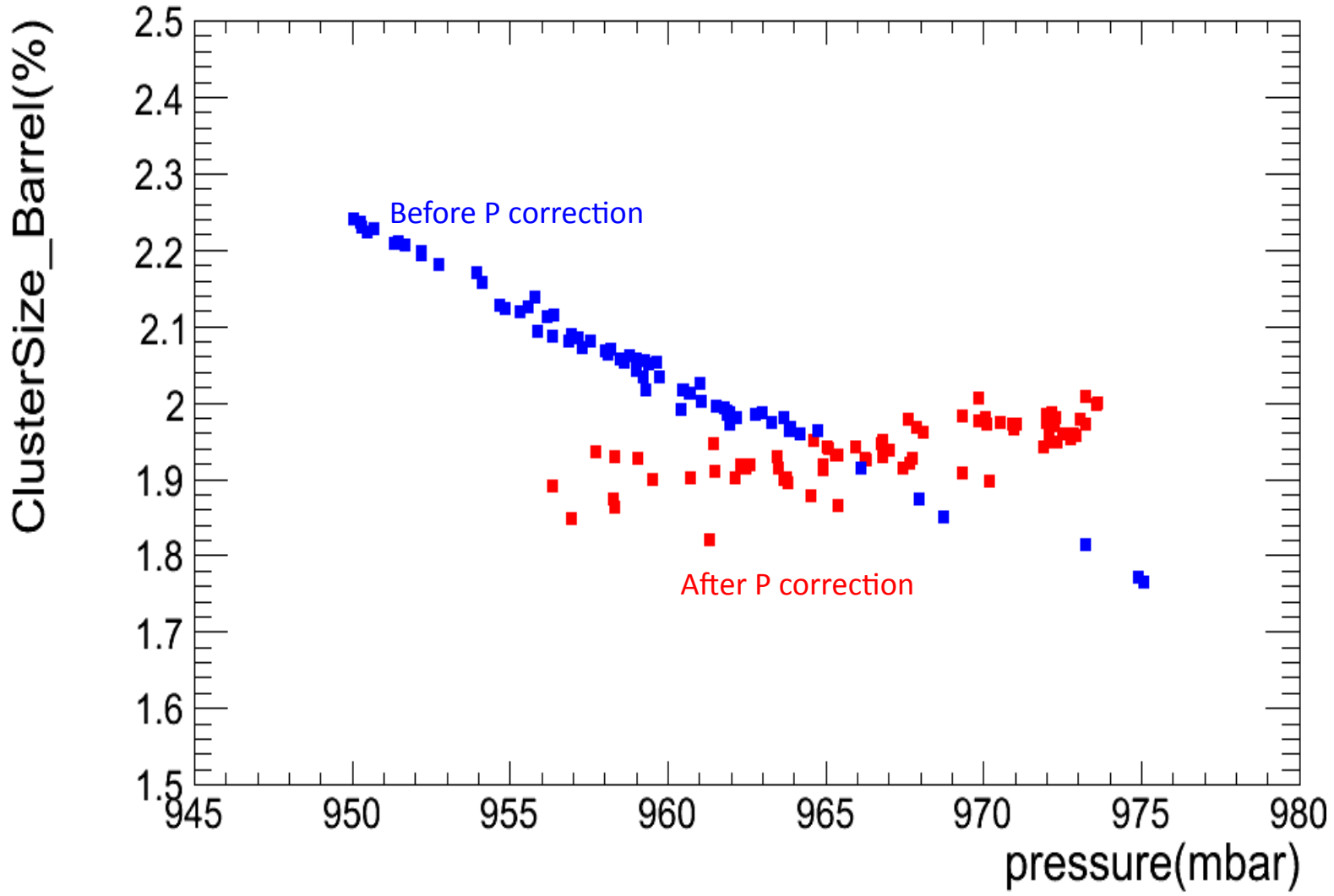
④ No aging effects ☺



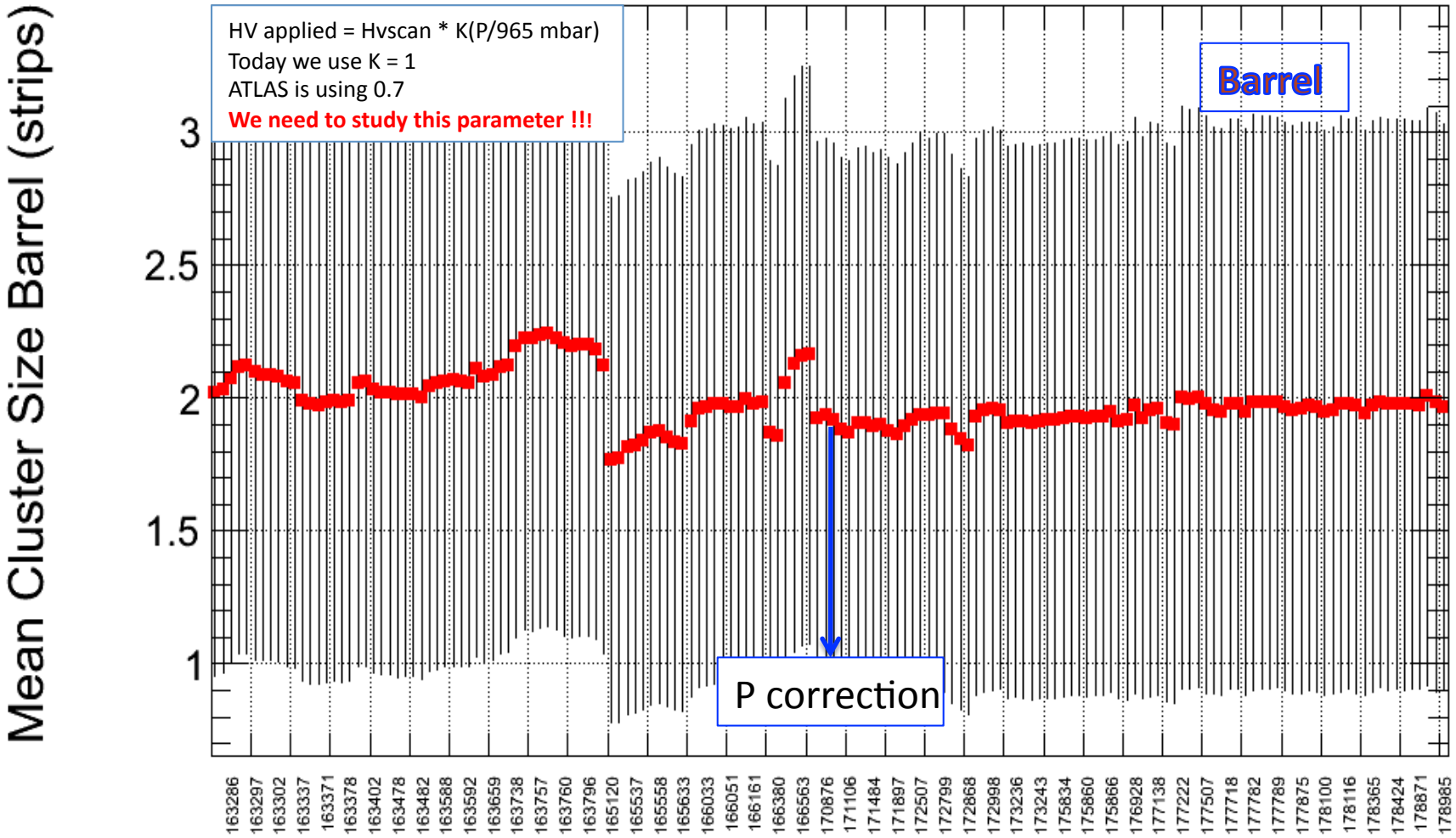
① Stability in time (efficiency 2011)



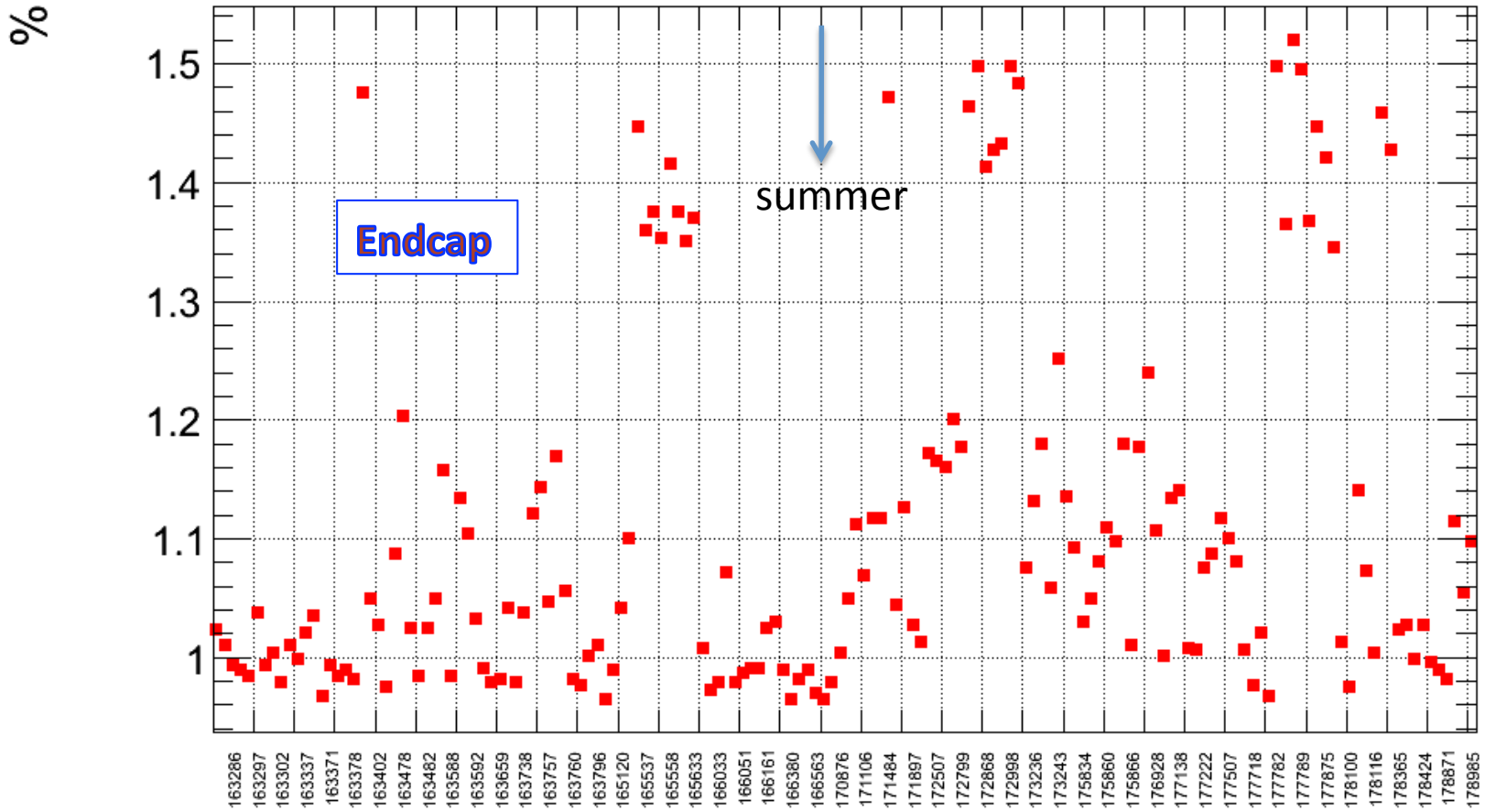
① Stability: cluster size .vs. pressure



① Stability in time (cluster size 2011)



Dead channel history plot



We should try to improve more and more the masking strategy
Anton is working very well on that

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⑤ Background rate (1-100 KHz/cm^2) capability

⑥ Spatial resolution ≈ 5-10 mm

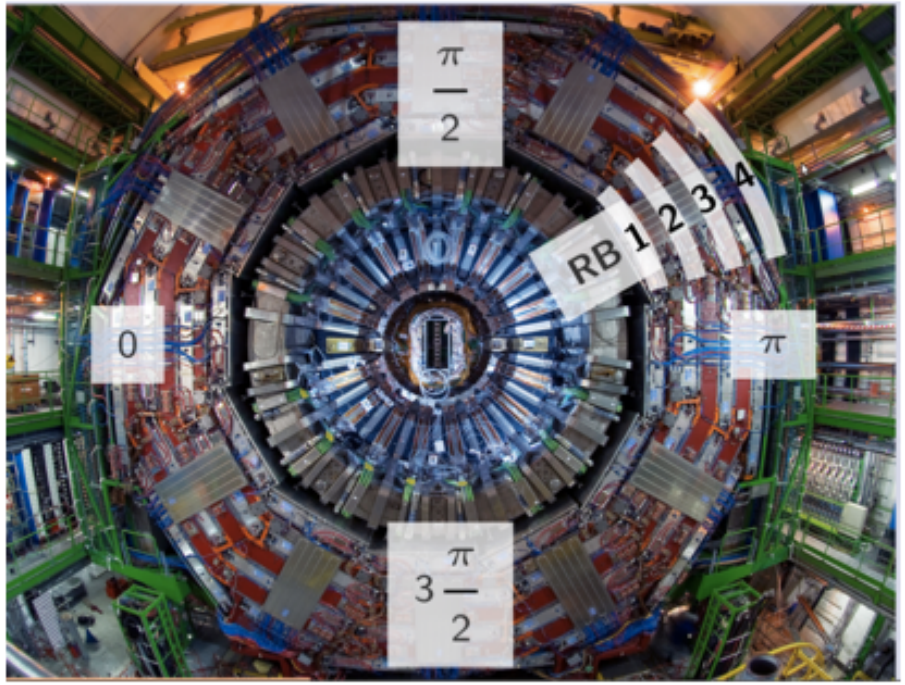
⑦ High stability and detection efficiency > 95%

⑧ Muon trigger rate and efficiency

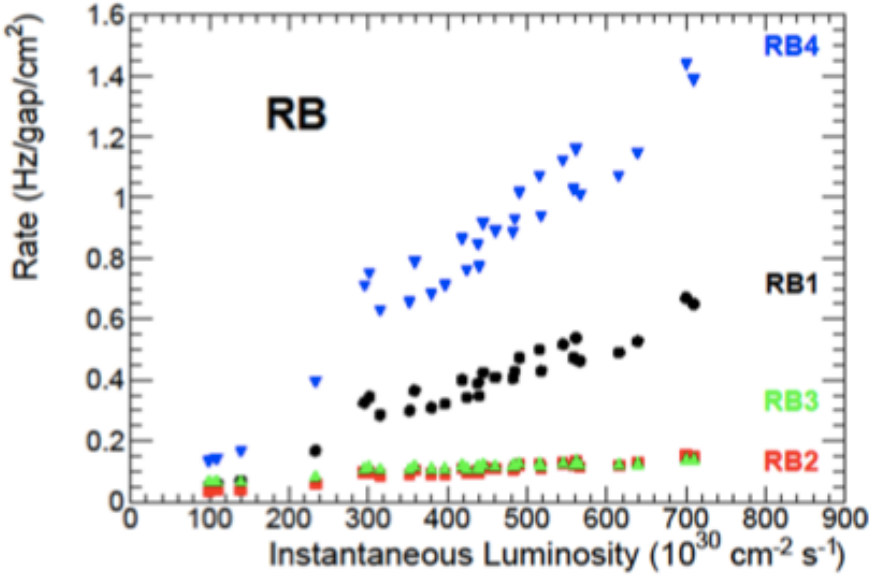
Approved

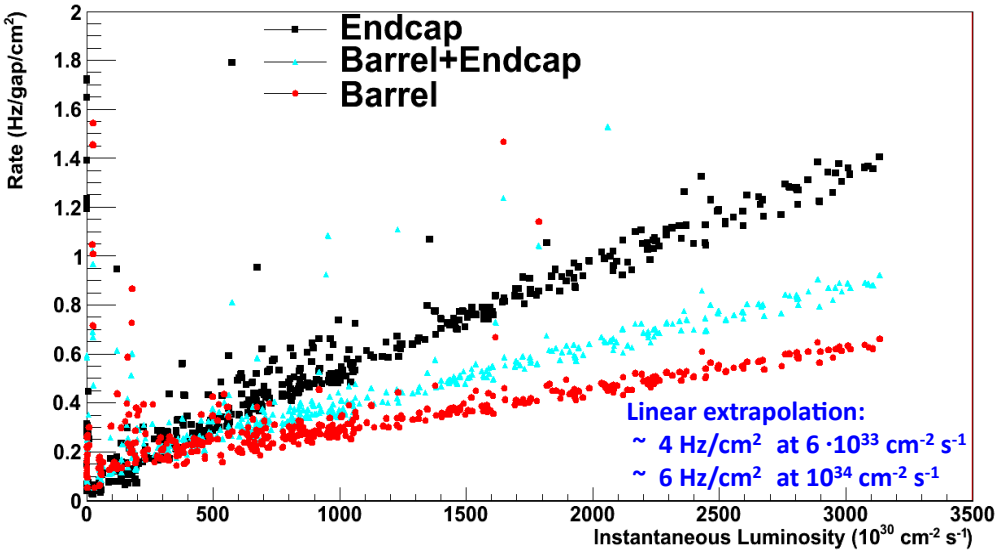
② Background .vs. luminosity

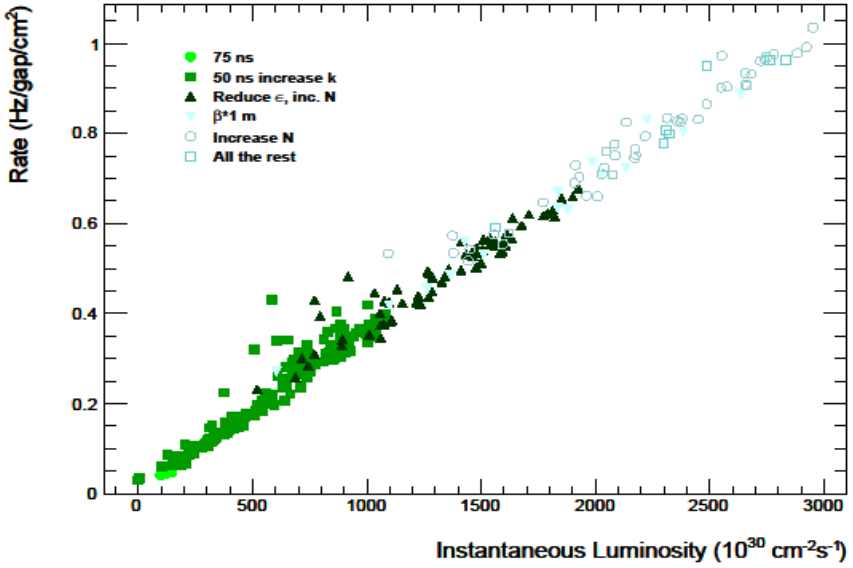
Chambers position in CMS



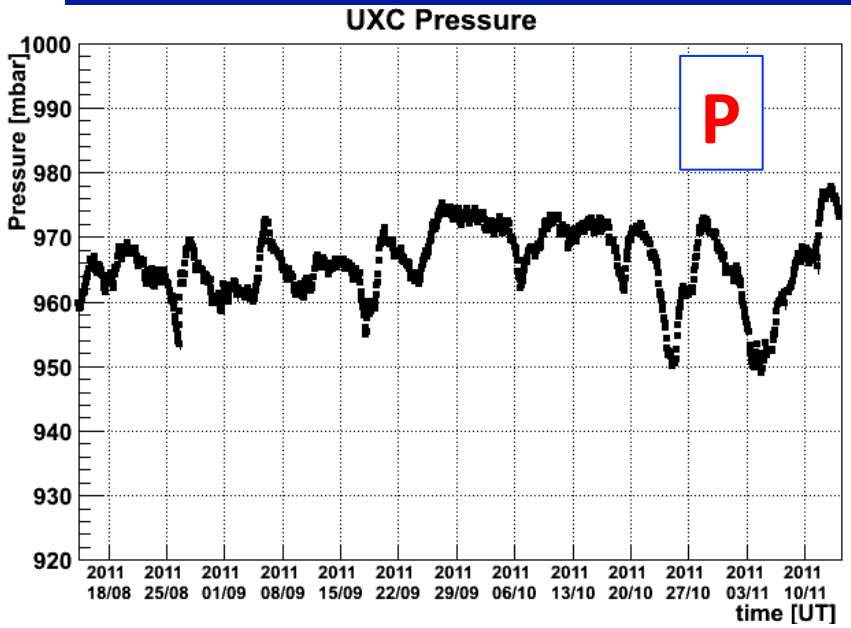
Barrel *r* dependency.

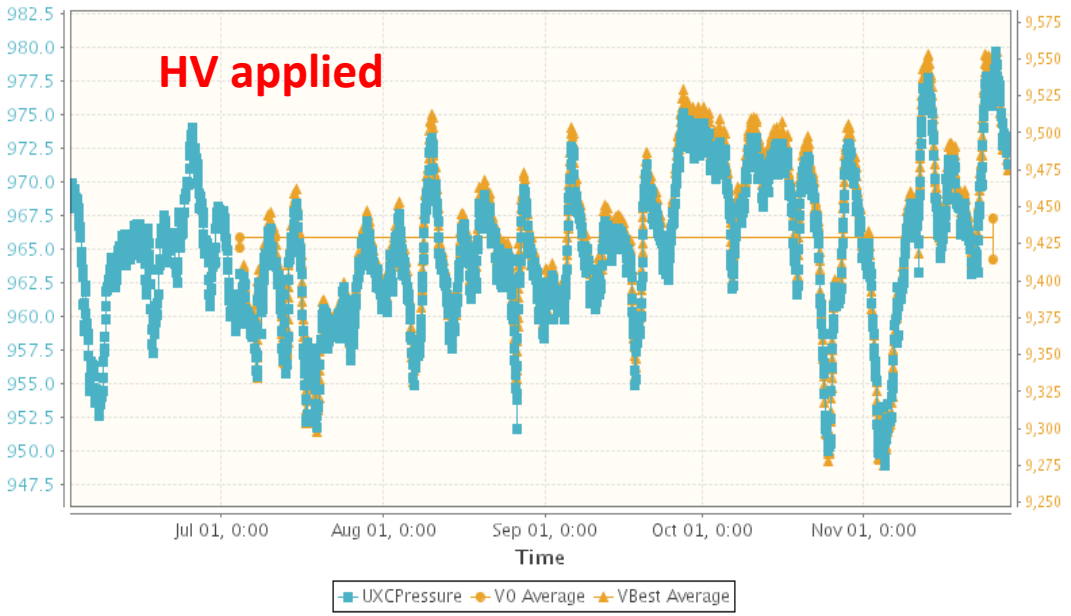


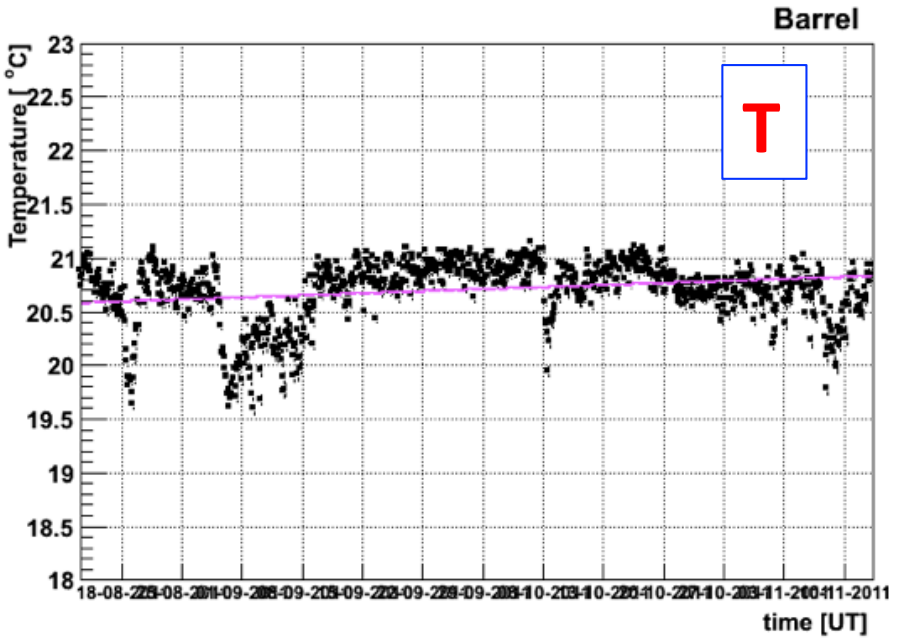


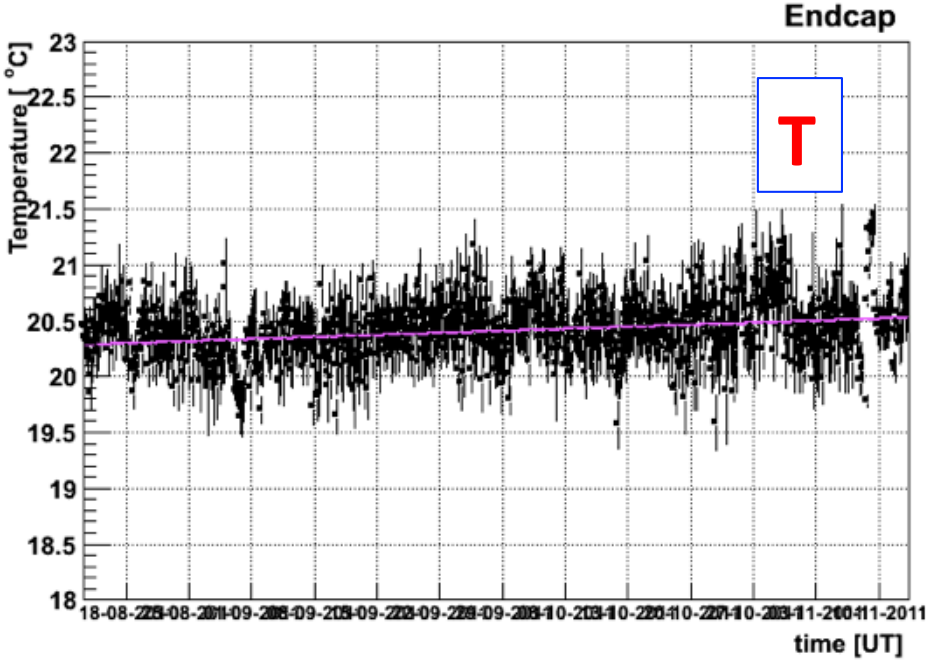


Environmental parameters (last 3 months)



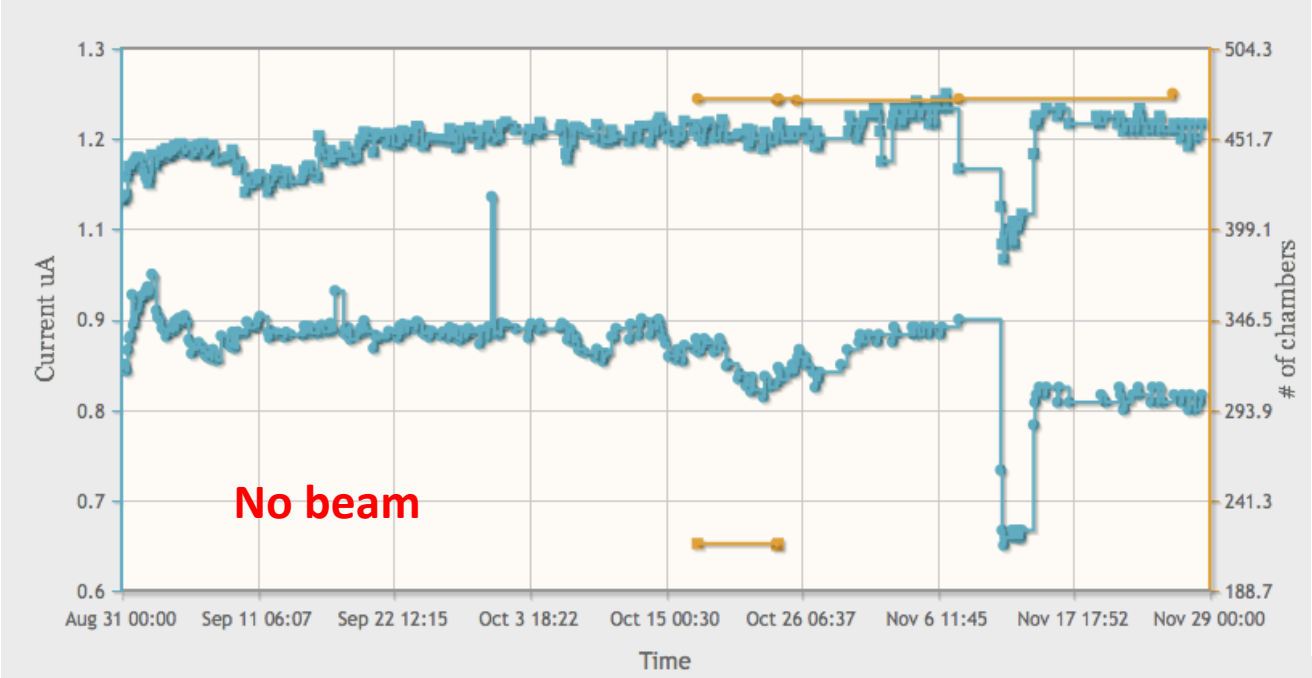






Average Current (last 3 months)

From Giovanni



No beam:

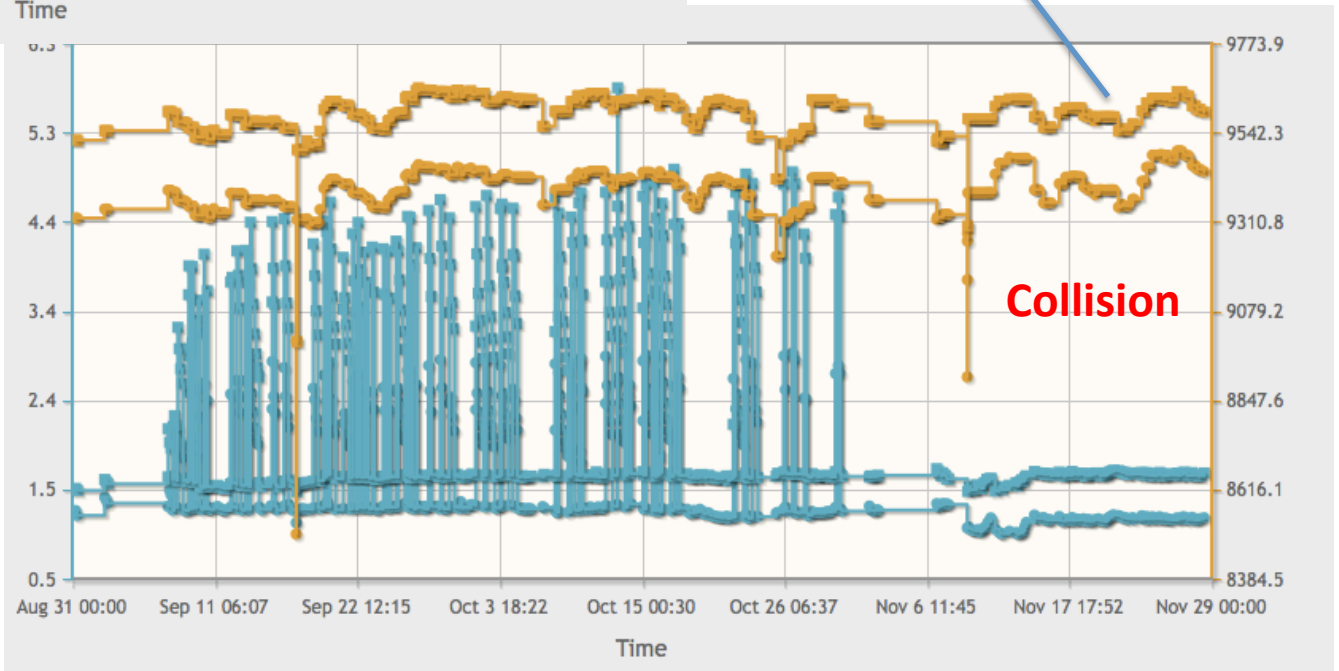
- <I> = 1 μA
- <noise> = 0.1 Hz/cm^2

Voltage correction with P

Collisions:

<Max I> = 1.5 μA

Few chambers I > 5 μA



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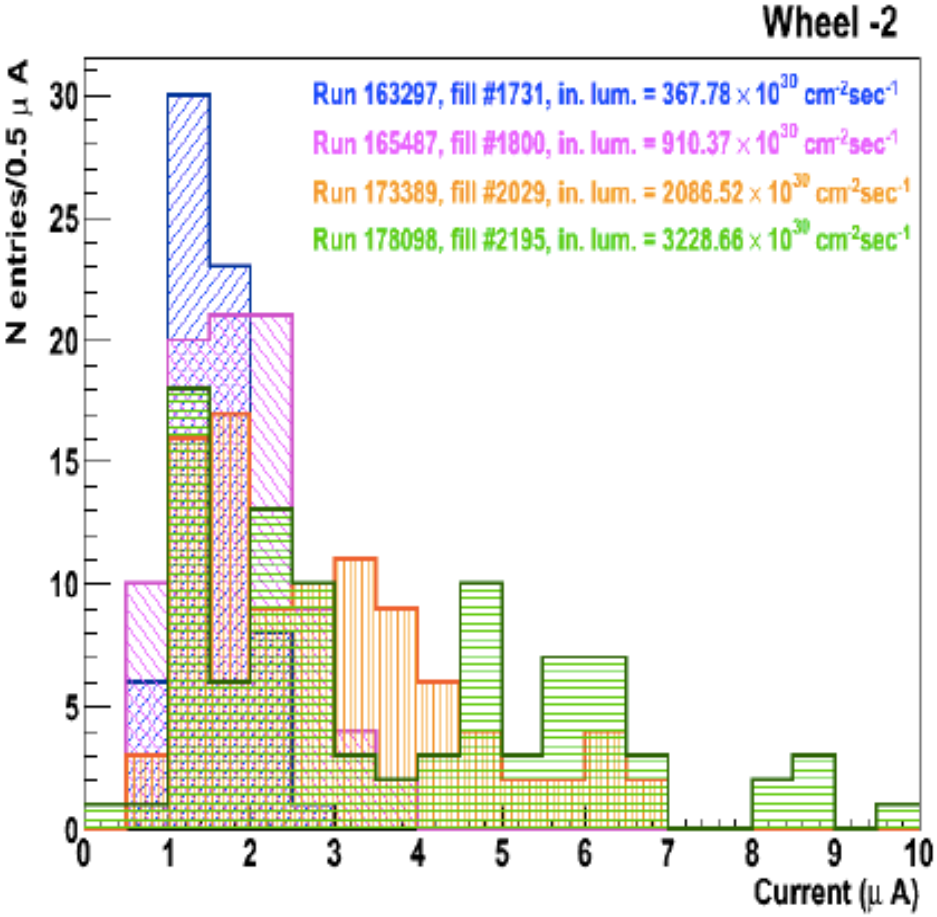
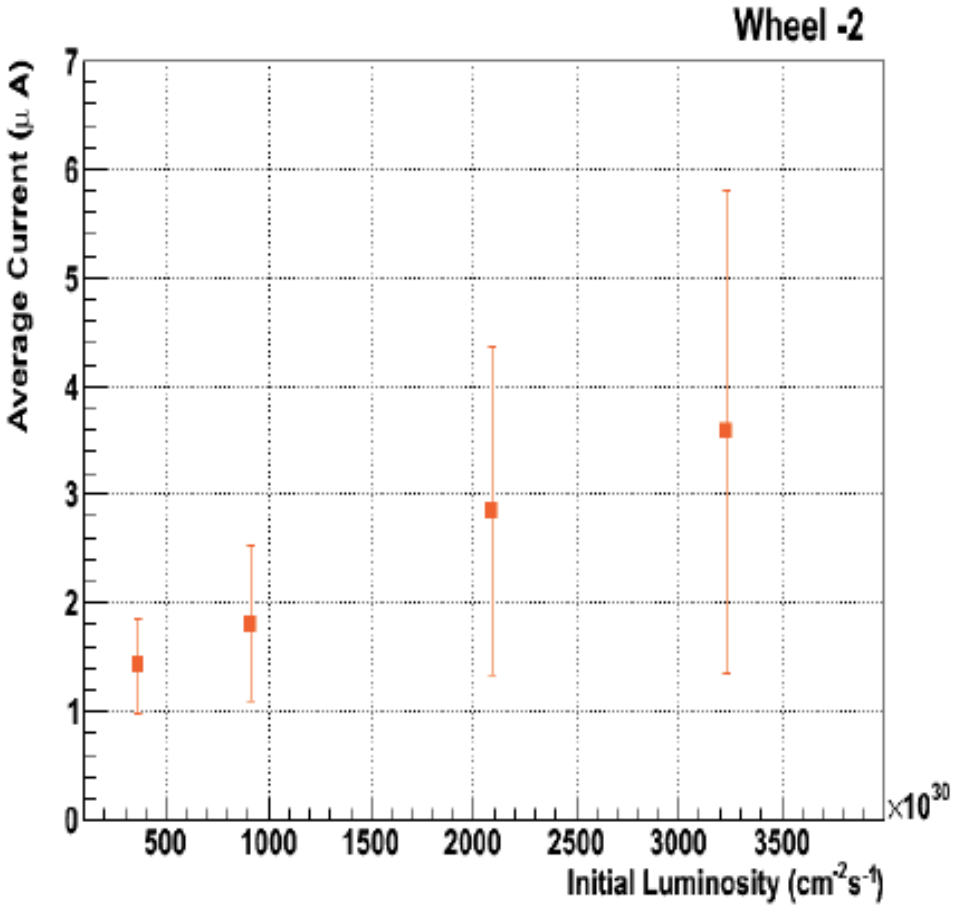
Current vs Luminosity





PLOTS FROM WBM TOOL

RPC system: requirements

① Redundant muon system (trigger and identification)

② Fast detector for bunch crossing identification

③ Cheap technology to cover a so large area

④ Dark current 10 μA (max 100 μA) per chamber

⑤ Background rate (1-100 KHz/cm^2) capability

Approved

⑥ Spatial resolution ≈ 5-10 mm

⑦ High stability and detection efficiency > 95%

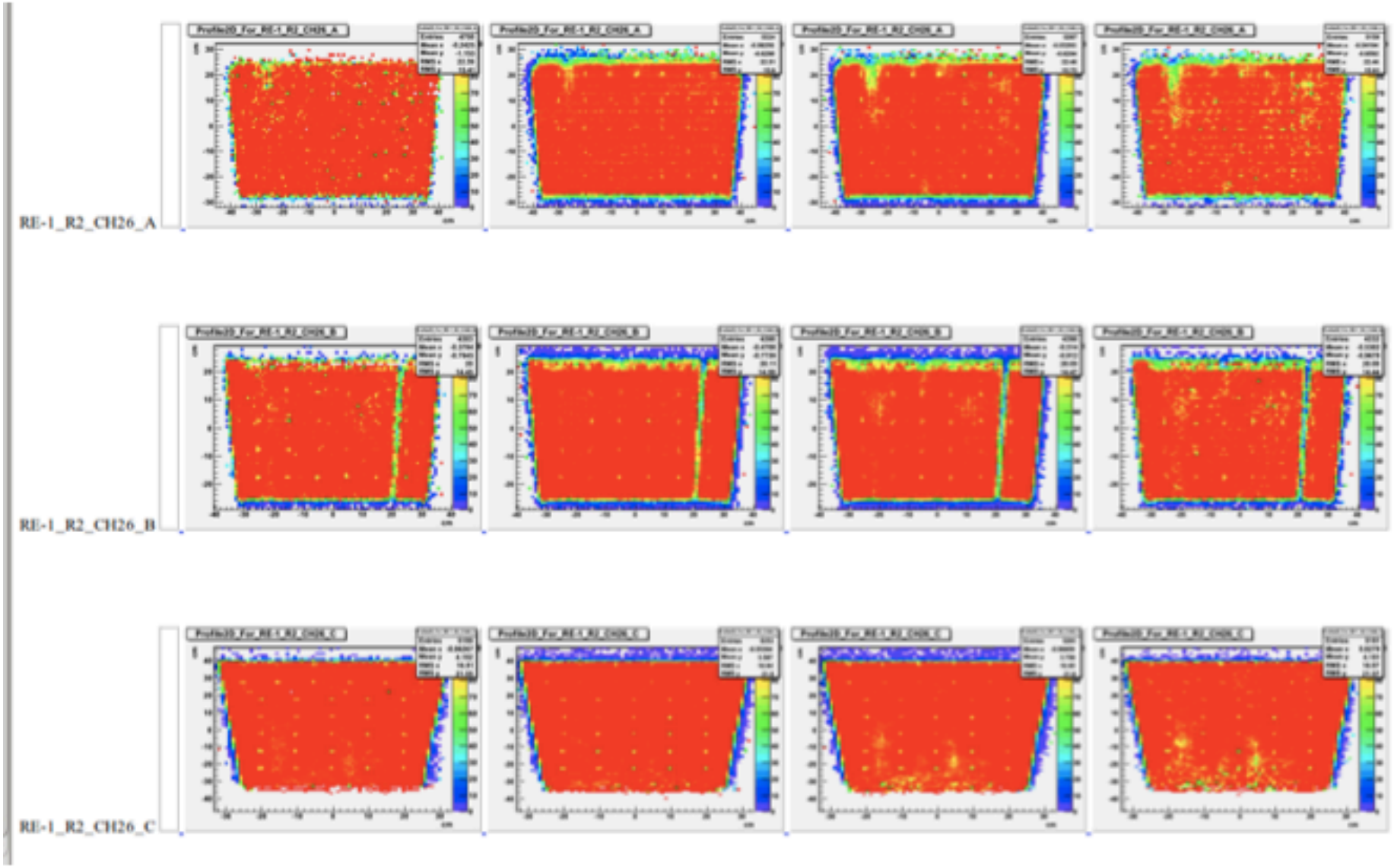
⑧ Muon trigger rate and efficiency

Summary table

	Single gap	Dead chamber	No TH control
Barrel	**7**	**5**	**13** chambers
Endcap	**24**	**3**	**0**

- Data Loss for RPC — 19 pb^{-1} – 0.37%
- Overall Operating Channels — 98.4%
- Average Efficiency — 95%
- Average Cluster Size — < 2
- Average Noise rate ($3 \cdot 10^{33}$ cm^{-2} s^{-1}) — 1.3 Hz/cm^2
- Max Noise rate ($3 \cdot 10^{33}$ cm^{-2} s^{-1}) RE-2/2/C — < 7 Hz/cm^2
- Average intrinsic noise (no-beam) — ~ 0.1 Hz/cm^2
- Average current (no-beam) — ~ 1 μA
- Average current (with beam) — ~ 1.5 μA
- Temperature — < 21.5 °C

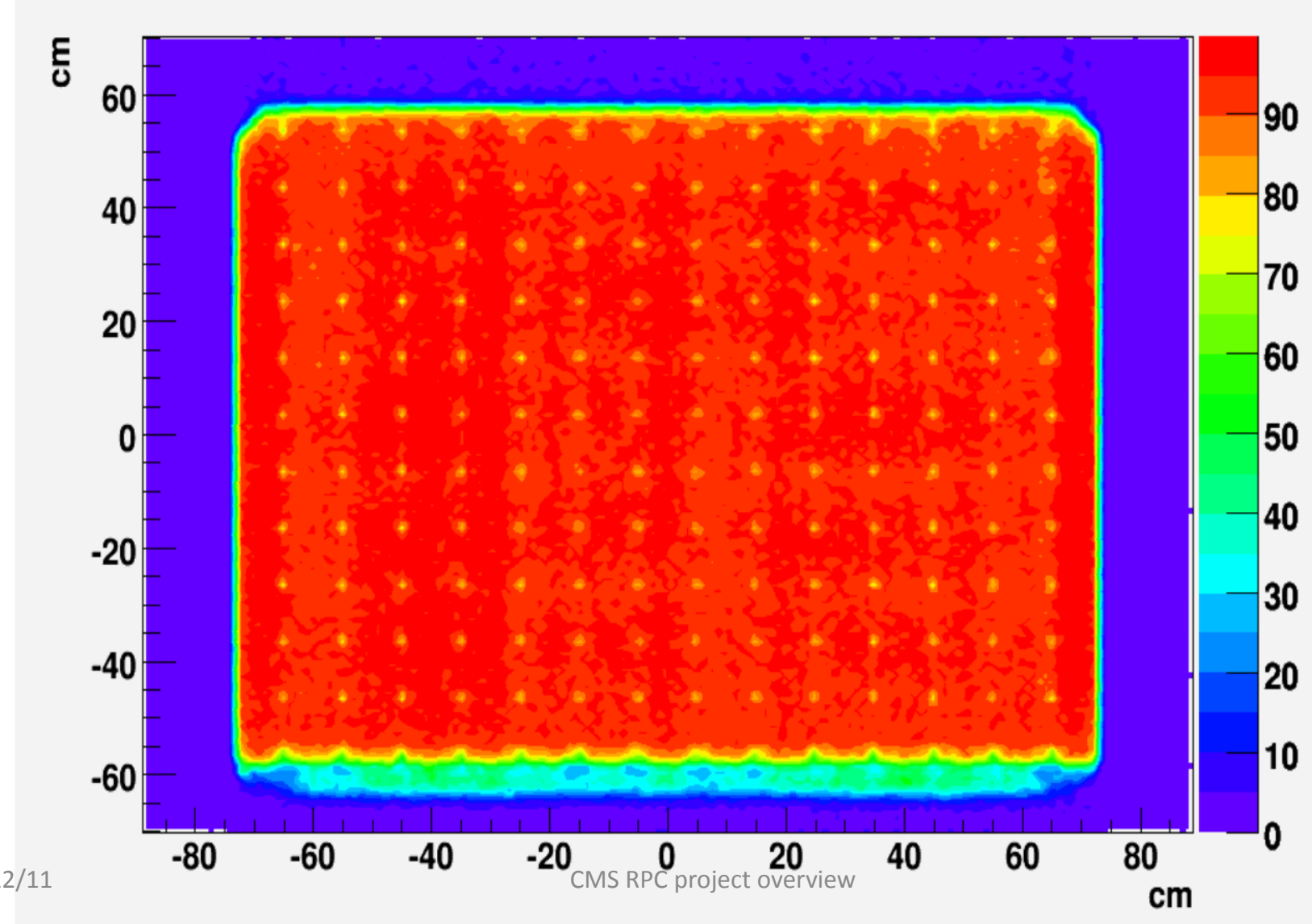
Visual inspection of the chambers



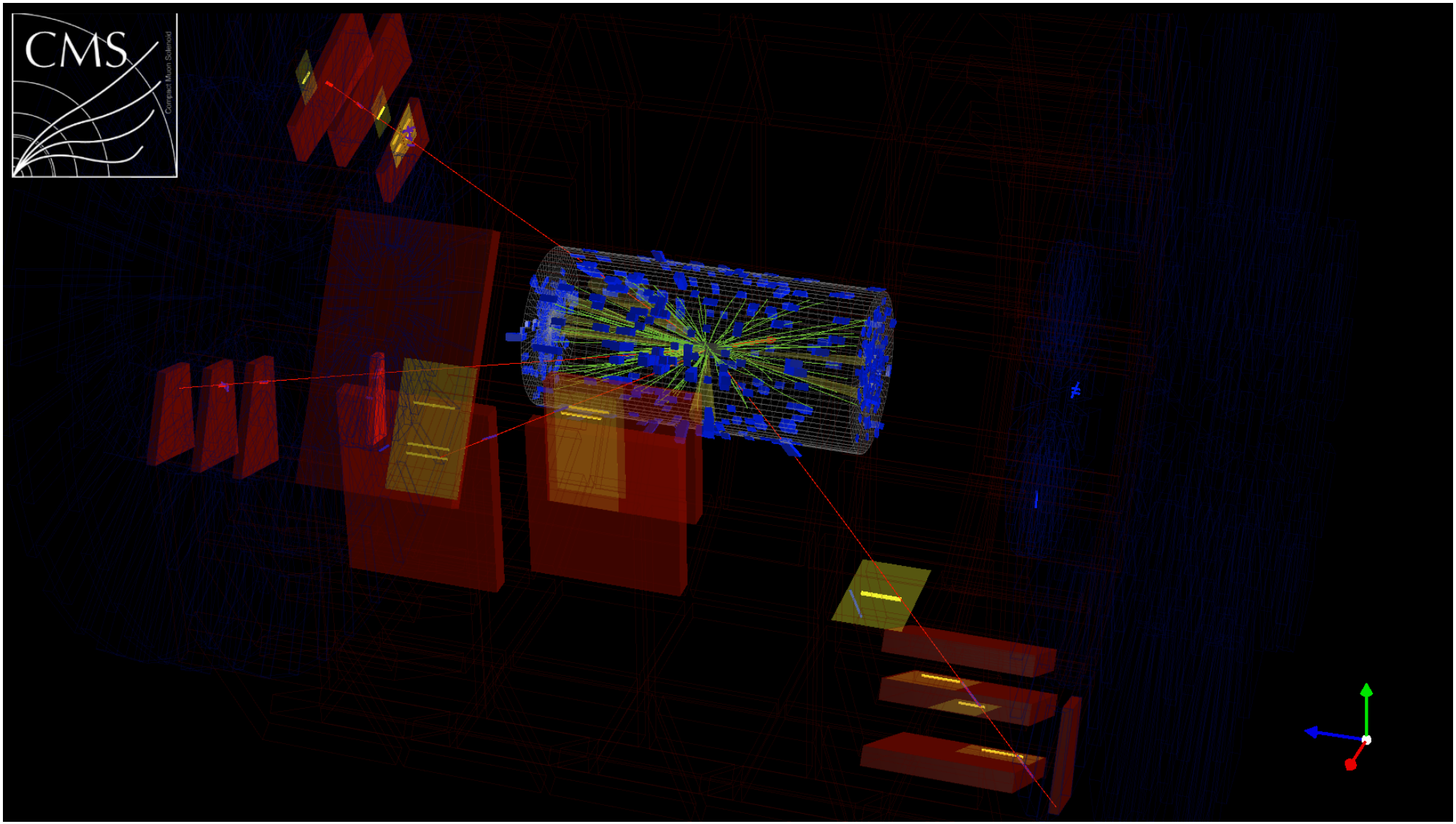
Even with the visual inspection it is clear we are running very well
Our system and no aging effect are visible until now

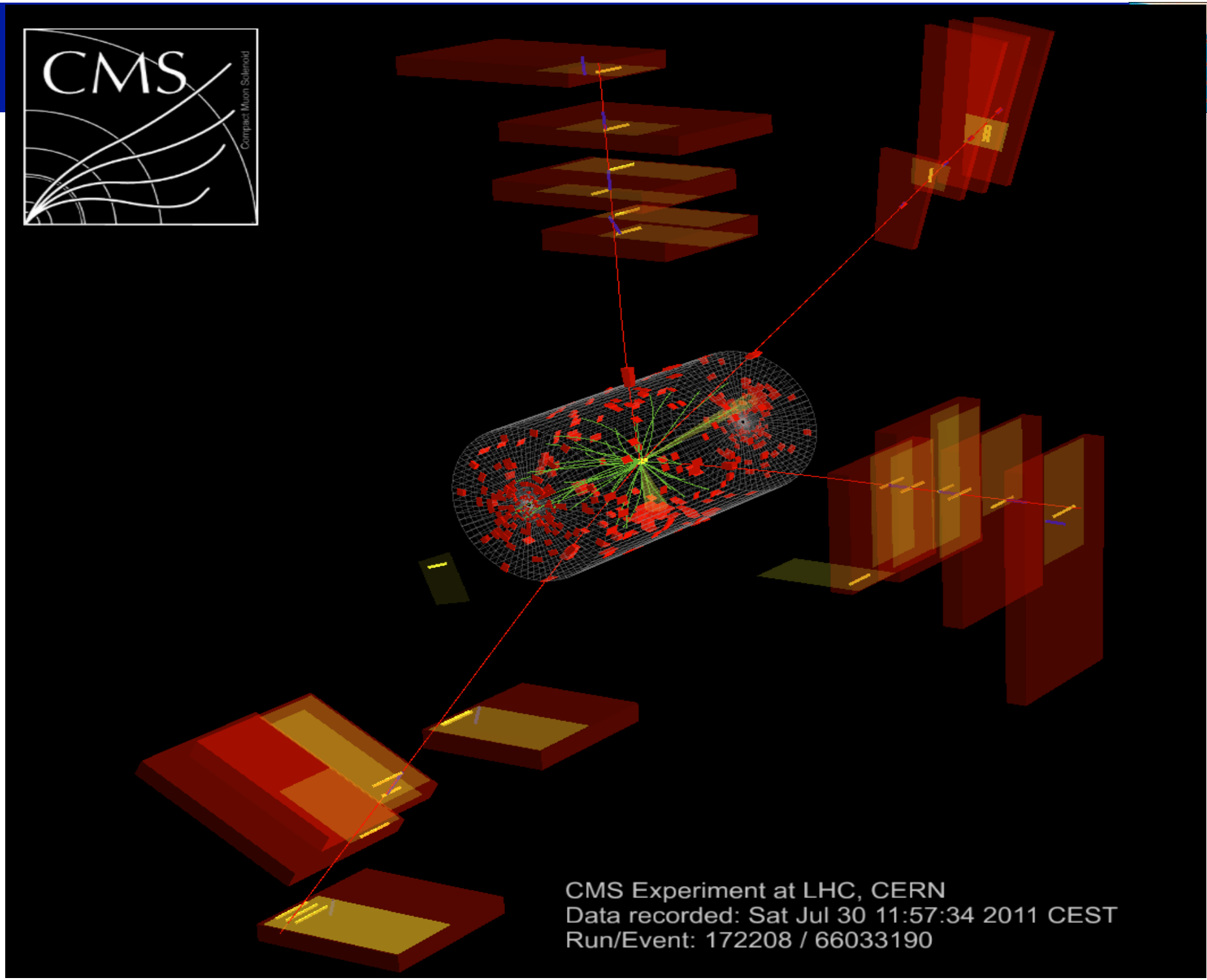
Visual inspection of the chambers

Here you see the spacers and the corner ☺



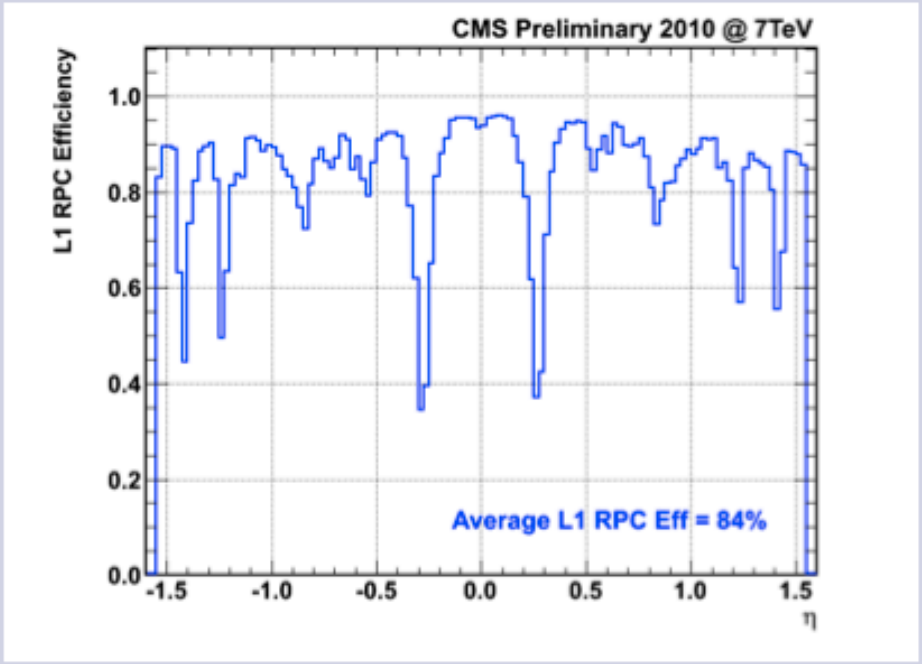
4 muon events with RPC




CMS
Compact Muon Solenoid
CMS Experiment at LHC, CERN
Data recorded: Sat Jul 30 11:57:34 2011 CEST
Run/Event: 172208 / 66033190

③ RPC trigger results

L1 RPC Trigger Efficiency at $\sqrt{s} = 7$ TeV



2010 data

- Reconstructed muons with $p_T \geq 7\,\mathrm{GeV}/c$
- Associated L1 CSC or DT trigger

2011

- Changed majority rule from 4/6 to 3/6 in Barrel
- Improved detector performance

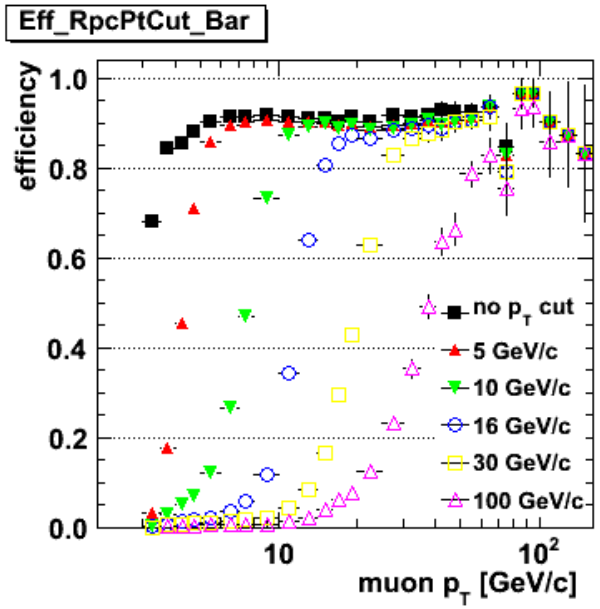
future

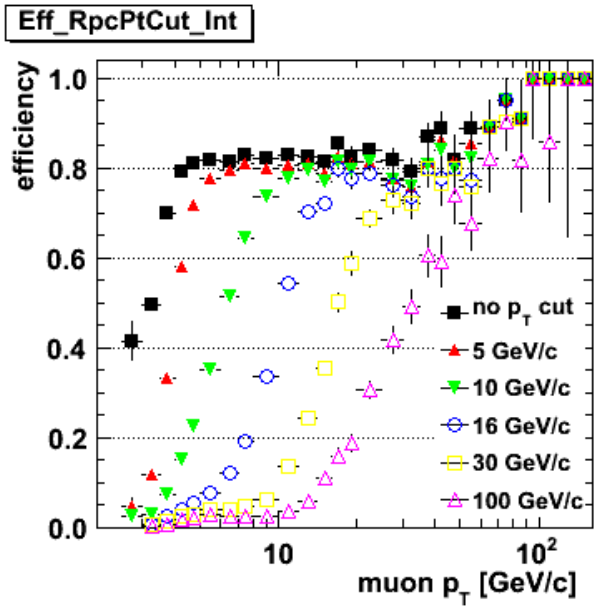
- Addition of the 4th Endcap plane

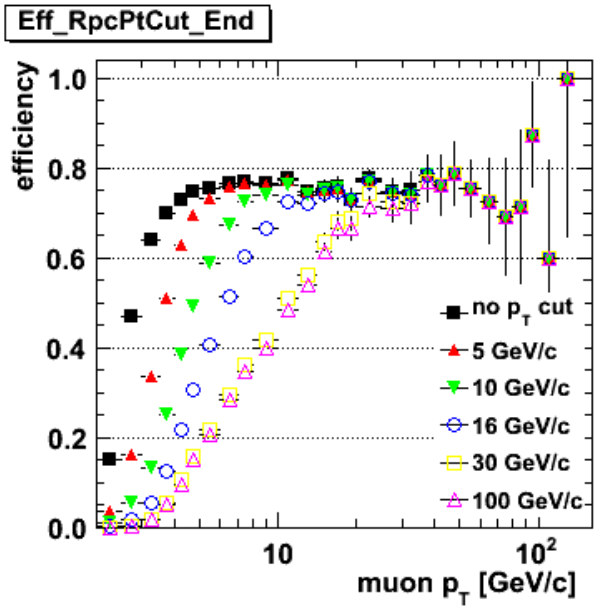
Combination of	Approximate contribution to inefficiency	
	Barrel	Endcap
	($\lvert\eta\rvert < 0.8$)	($1.25 < \lvert\eta\rvert < 1.6$)
Geometrical acceptance	7 %	8 %
Hit efficiency	6 %	12 %
Intrinsic PAC efficiency	3 %	<1 %

(estimation accuracy limited due to track association uncertainty ($\sim$ 1 %))

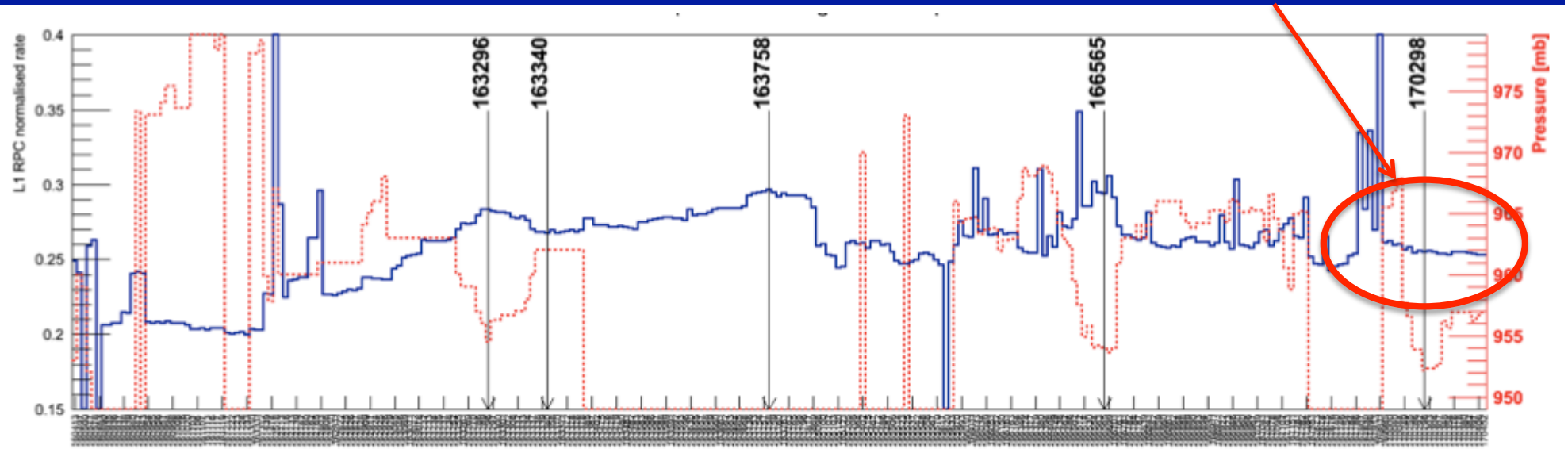
③ RPC trigger results







RPC Trigger rate is much more stable after pressure correction of the WP



RPC Upgrade: station 4 + Ring 1

Baseline TDR: 4 disks equipped with 3 rings of chambers

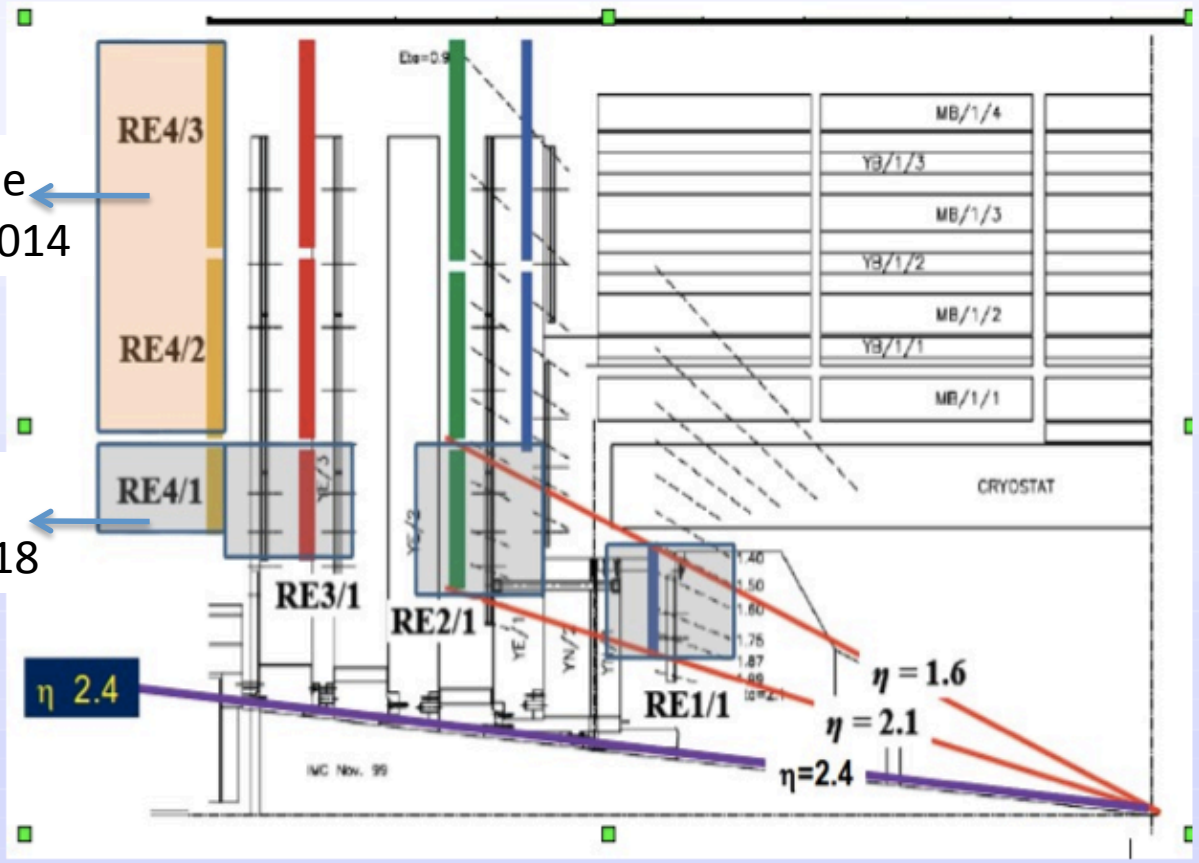
Forward trigger is now de-scoped due to insufficient budget

1) Restoration 4th stations

RPC trigger requires nov
algorithm -
with 2/3: rate is just too high
due to noise and wrong pt
assignment- **shutdown 2013**

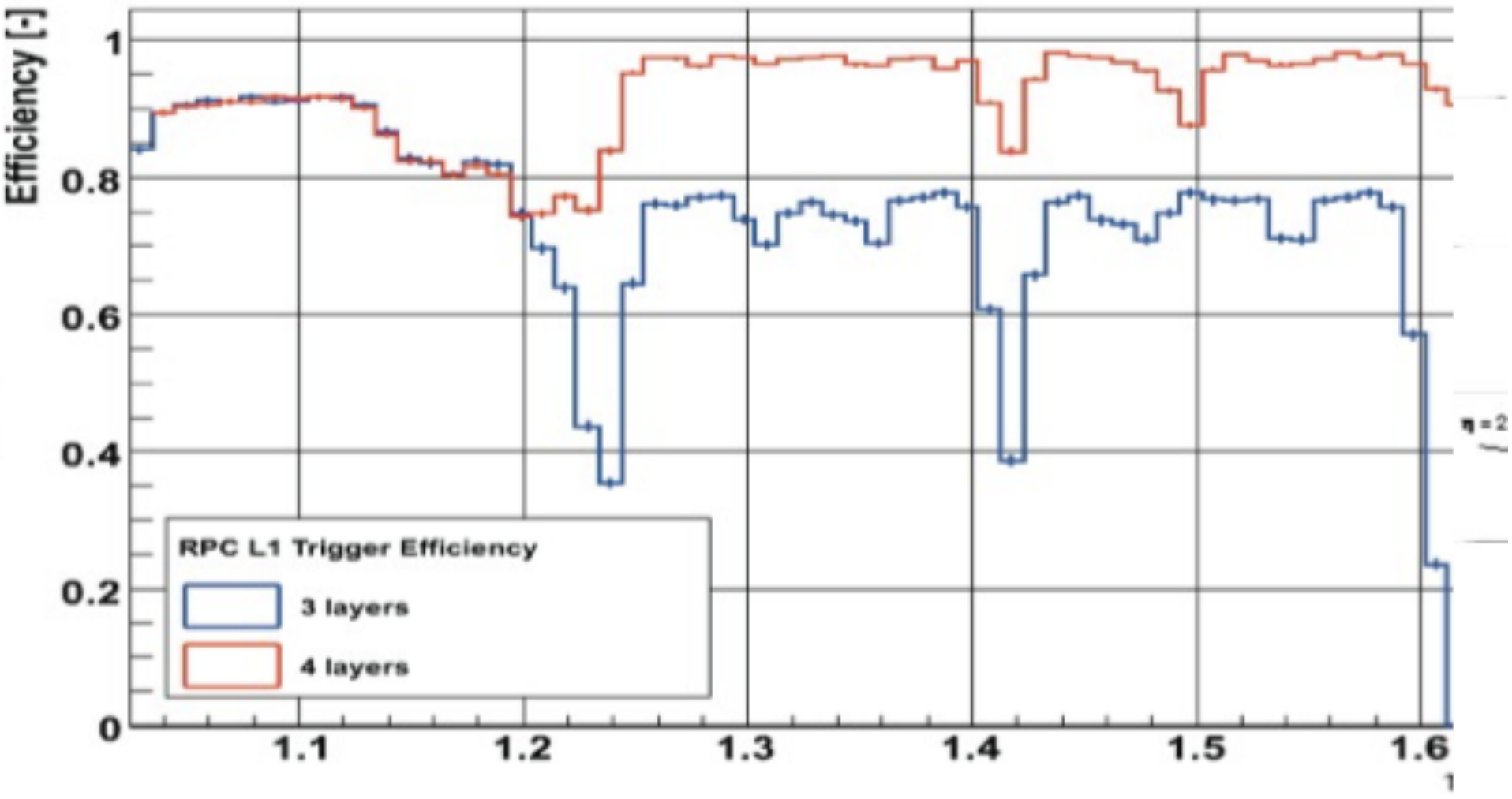
Upgrade
2013-2014

Upgrade
2017-2018



2) Missing all 1rd rings (no coverage for $|\eta| > 1.6$)

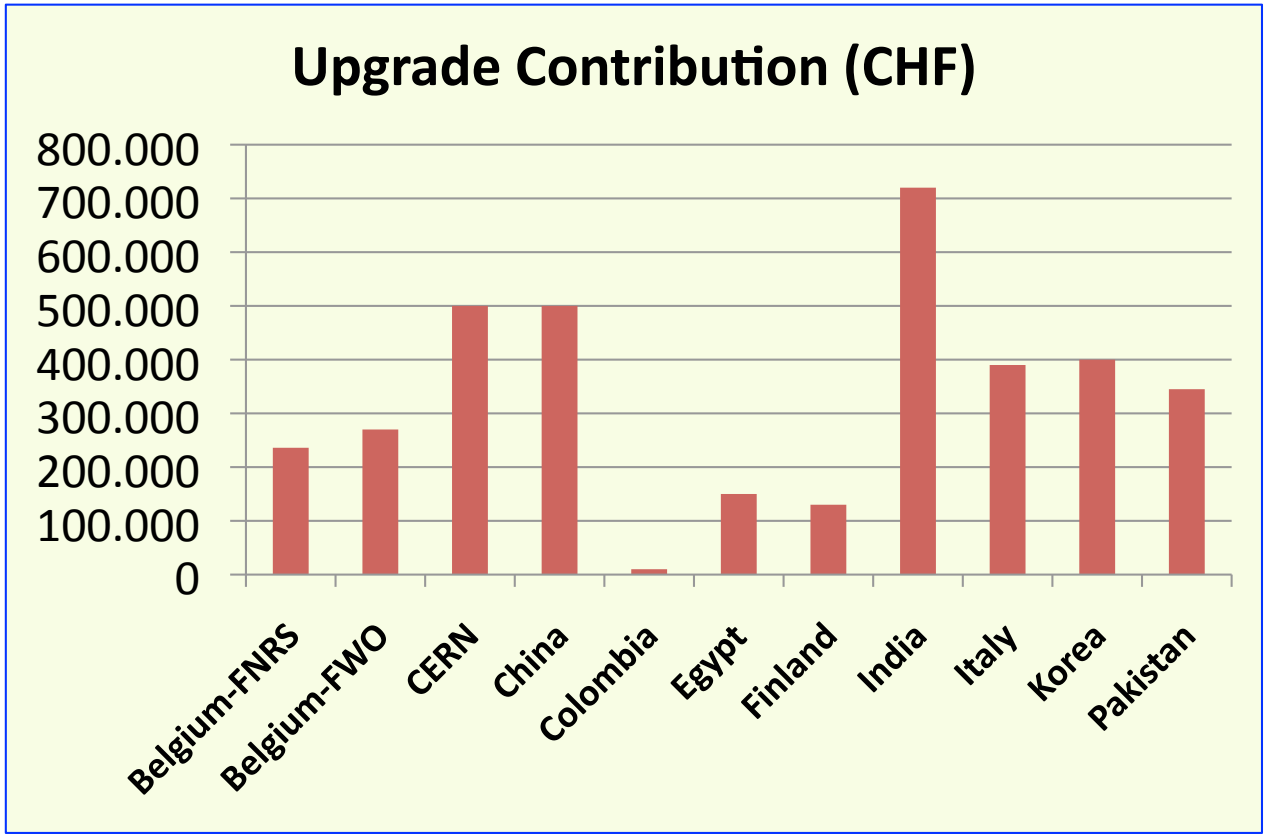
Upgrade Trigger improvements



RPC Upgrade RE4 (2011-2013)

- Belgium, China, CERN, Colombia, Egypt, Finland, India, Italy, Korea, Pakistan.
- Total estimated cost is 4.2 MCH but available are 3.7 MCHF

It is a very big effort to be done in 3 years 2011-2013



Upgrade: who is doing what ?

- Bakelite production — Italy (2011)
- 600 Gaps — Korea (2011-2012)
- 200 chambers — India, CERN & Belgium (2012-2013)
- Services for chamber — India (2012-2013)
- Front-end electronics — Pakistan (2011-2012)
- 200 chamber test at CERN — All
- Off chamber electronics — Italy (2011-2013)

- Power system and services — All
- Installation and Commissioning — All (2013-2014)

Conclusions (I)

- RPC detector and trigger is working very well
- **2011** has been an important year; thanks to the millions of muon we were able to study in details our system and learn a lot about it.
- All the requirement have been fulfilled
- Ready for the upgrade 2013-2014
- 15 institutions and many PhD students
- Budget has been consolidated