The CMS RPC system overview

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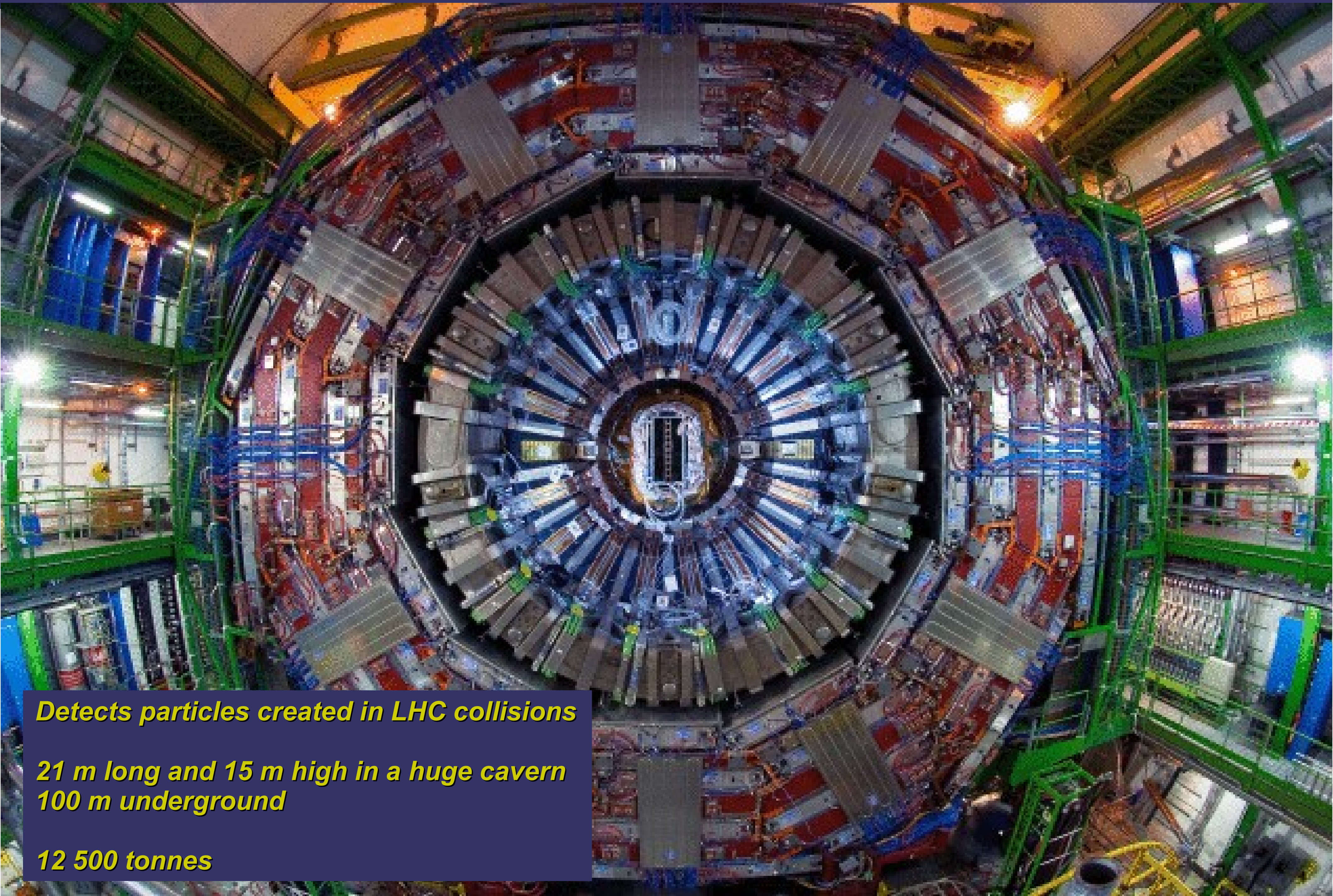
The Compact Muon Solenoid (CMS) experiment is one of the two general-purpose detectors observing at the CERN Large Hadron Collider (LHC).

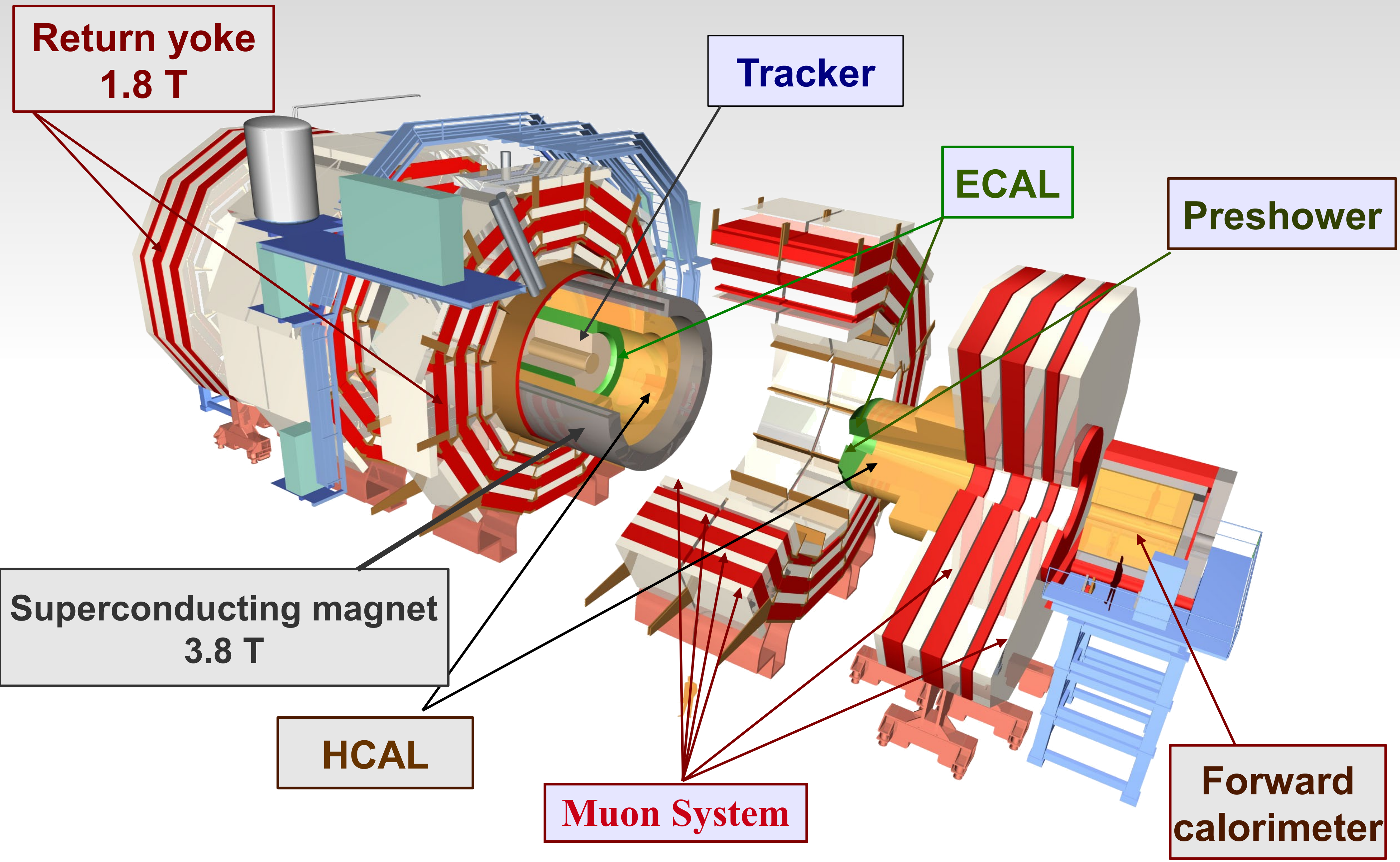


Detects particles created in LHC collisions

21 m long and 15 m high in a huge cavern 100 m underground

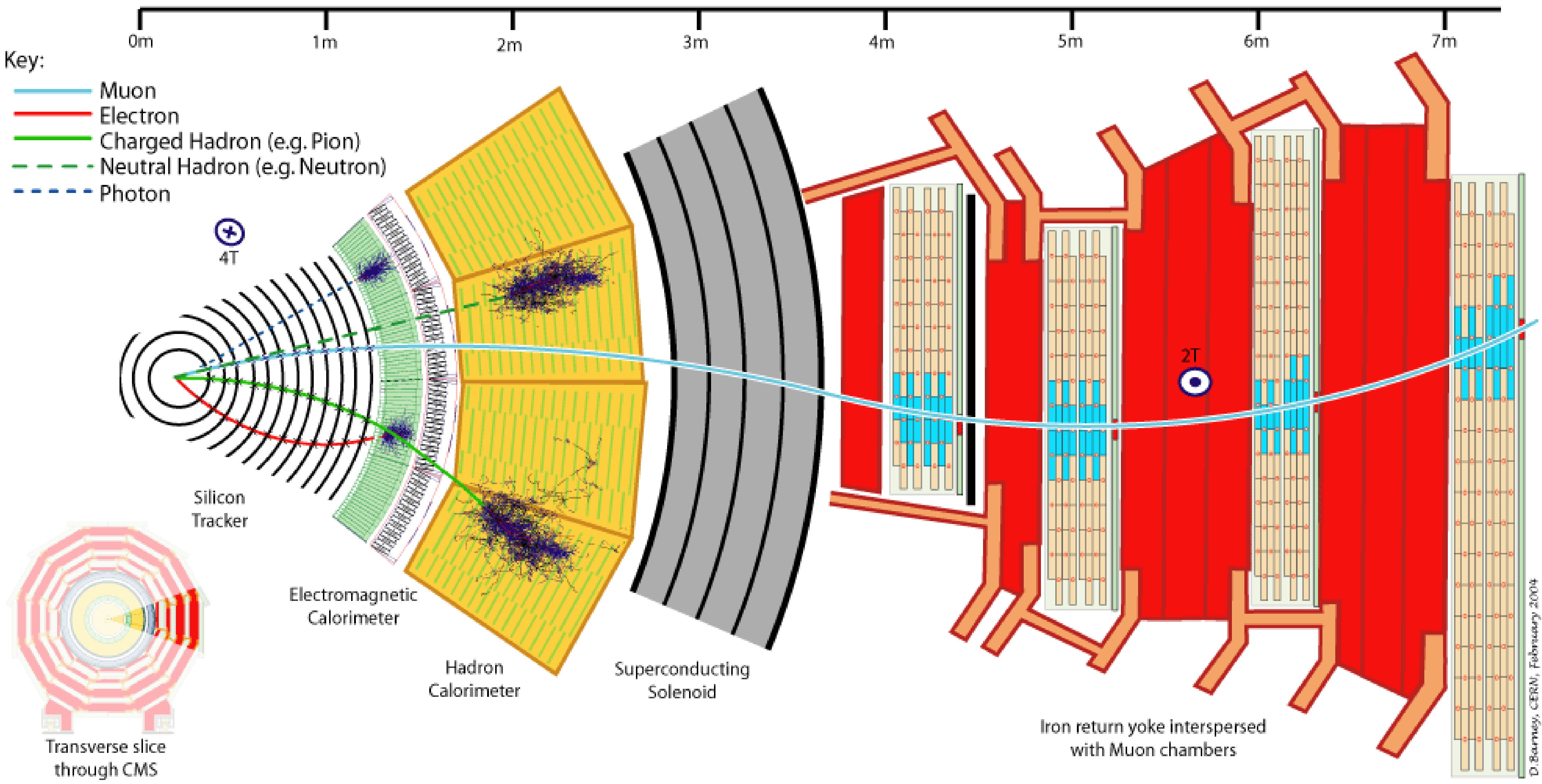
12 500 tonnes

CMS design



Return yoke
1.8 T
Tracker
ECAL
Preshower
Superconducting magnet
3.8 T
HCAL
Muon System
Forward
calorimeter

Particle identification in CMS



CMS detector requirements for the muon system

- *In CMS, high energy muons can only originate from the decay of a heavier particle – something that might be potentially interesting!*
- *Muons are easy to identify - Can quickly decide if we want to keep data from a collision or throw it away*
- *CMS uses multiple layers of muon detectors*

- ***High detection efficiency***

- ***A good muon identification and momentum resolution over a wide range of momenta in the region $|\eta| < 2.5$;***

- ***A good dimuon mass resolution (1% at 100 GeV/c^2);***

- ***The ability to determine unambiguously the charge of muons with $p < 1$ TeV/c;***

Three different gaseous detector technologies are used to trigger and reconstruct muons

CMS Muon System

Barrel

DT & RPC

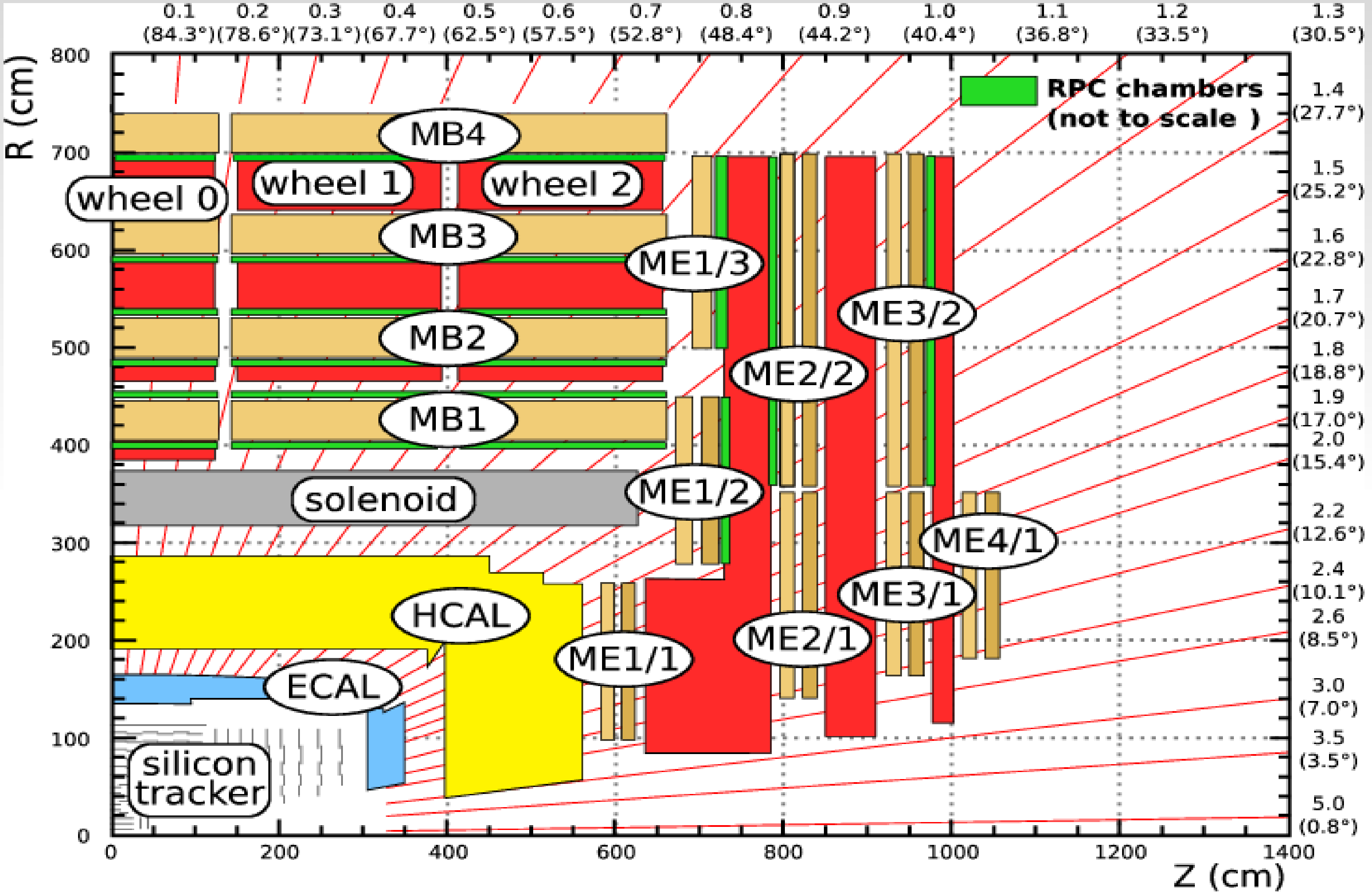
|η| < 1.2

η = -ln tg(θ/2)

EndCap

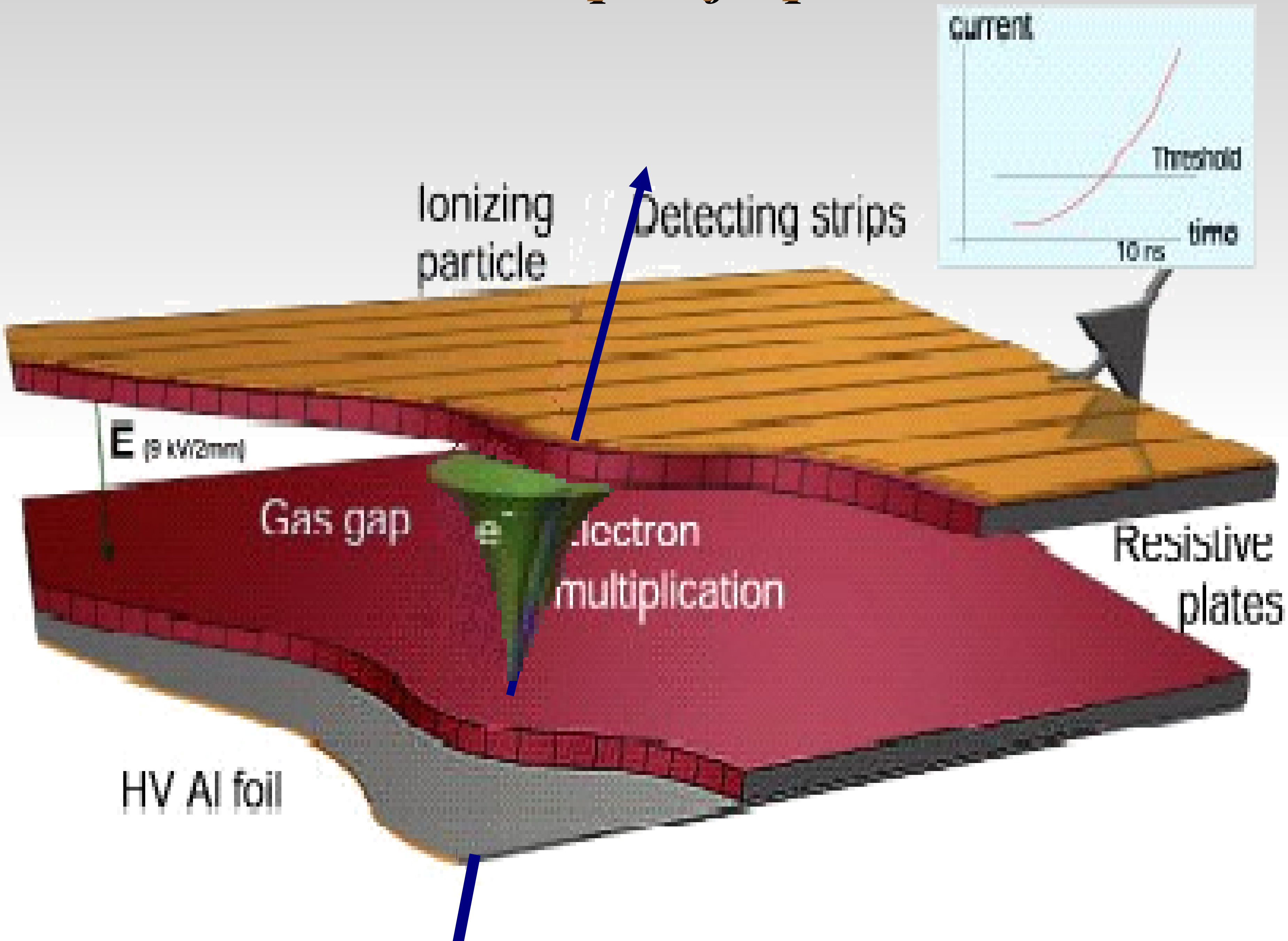
CSC & RPC

0.9 < |η| < 2.4

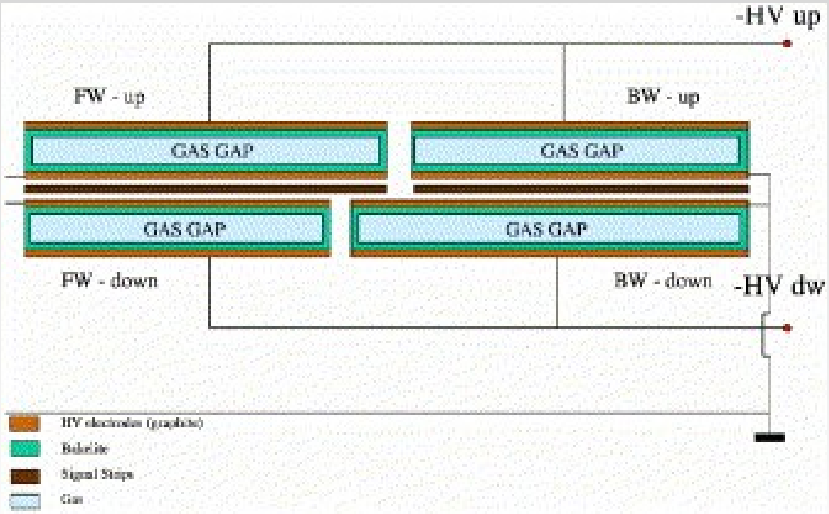


DT – Drift Tubes;
CSC – Cathode Strip Chambers;
RPC – Resistive Plate Chambers

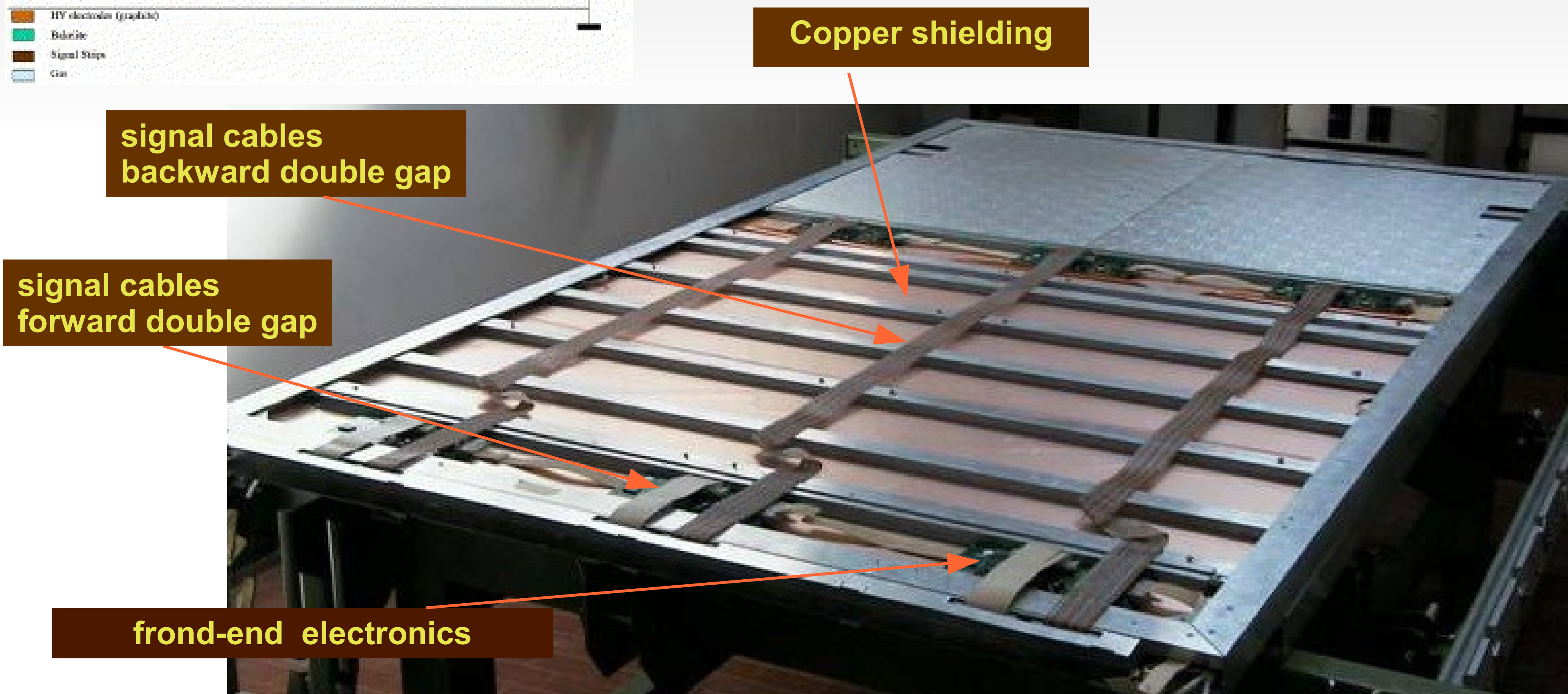
RPC - Principle of Operation



RPC – the largest detector on CMS



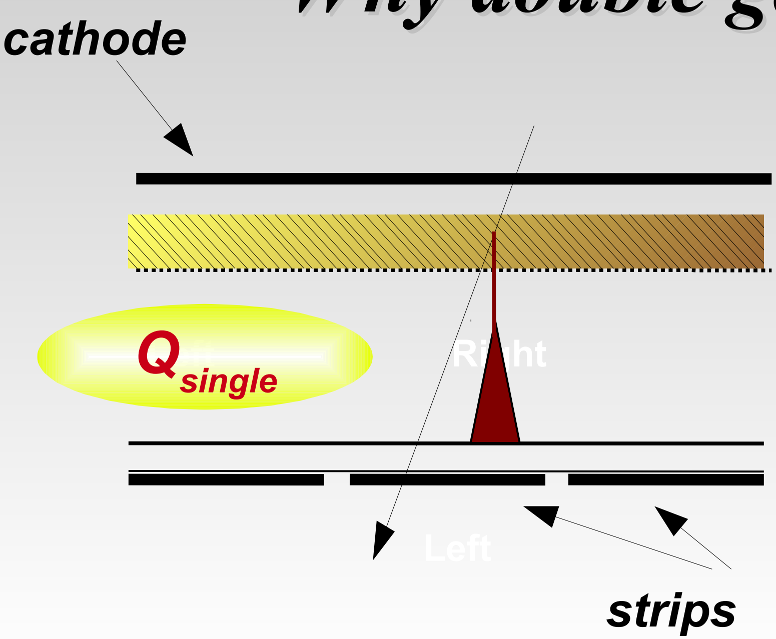
- *RPCs cover active area of ~2953 m^2*
- *More than 100 000 signal strips*
- *Two different geometry*
  - ✓ *rectangular in the barrel*
  - ✓ *trapezoidal in the endcap*



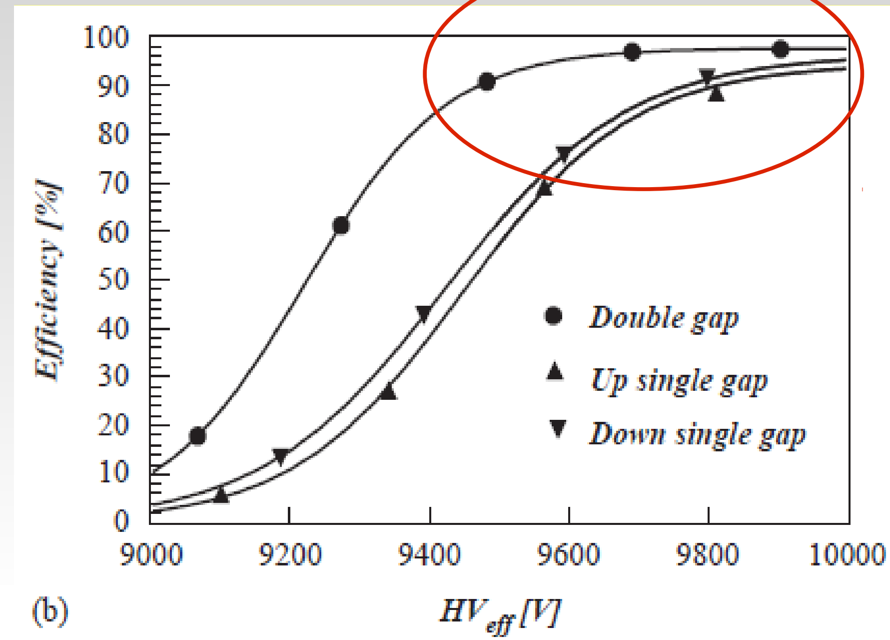
Resistive Plate Chambers in CMS
Double gap design

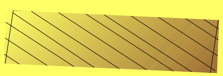
Resistive Plates	Bakelite with bulk resistivity (1 - 2). 10^{10} Ωcm
Gas gap	2 mm ± 20 µm wide
Gas mixture	95,2% $C_2H_2F_4$(Freon), 4,5 % iC_4H_{10} (Isobutan), 0,3 % SF_6
Graphite HV electrodes	resistivity 300 kΩ / cm^2
Insulating PET film	0.3 mm thick
Detecting copper strips	40 µm thick, pitch 2.3 – 4.1 cm (barrel); 1.7 – 3.6 cm (endcap)
Avalanche mode	ability to work at a high rate of ionizing particles ~ 1 kHz/cm^2
Trigger	time resolution ~1 ns – bunch crossing assignment
Operating HV	9.4 - 9.8 kV
Spacers	⌀ = 8 mm
Copper shielding	
Linseed oil treatment	

Why double gap



stable efficiency in the plateau
cluster size and noise as low as possible





Only avalanches starting in these areas will give signal sufficiently large, that it may be detected

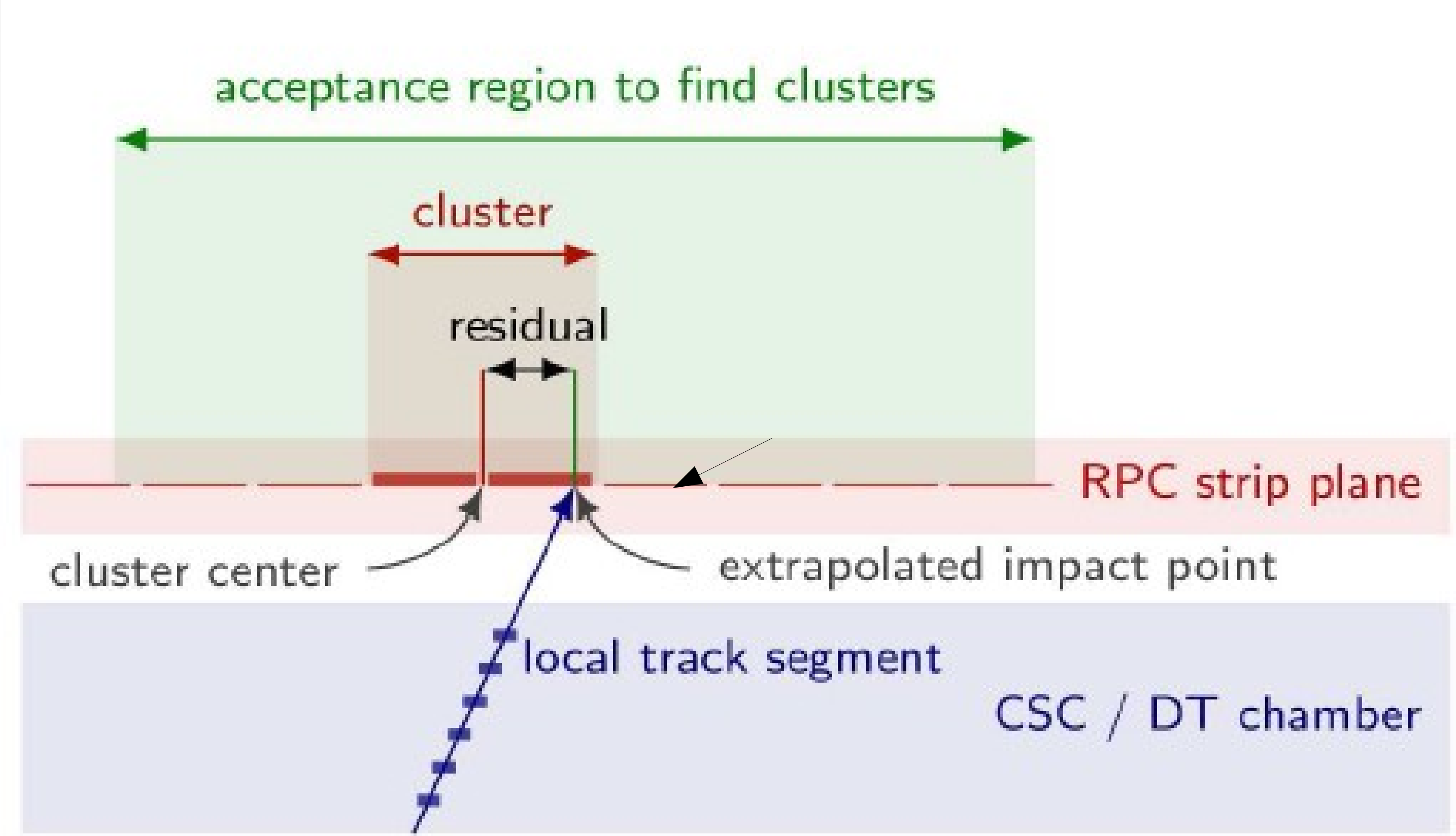
$$\varepsilon\left(HV_{eff}\right)=\frac{\varepsilon_{max}}{1+e^{-S\left(HV_{eff}-HV_{50\%}\right)}}$$

$$Q_{multi} = \Sigma_j \, Q_{multi,j}$$

Improve:
Time resolution
efficiency

Efficiency estimation

The segment extrapolation method is used for RPC efficiency estimation from real data

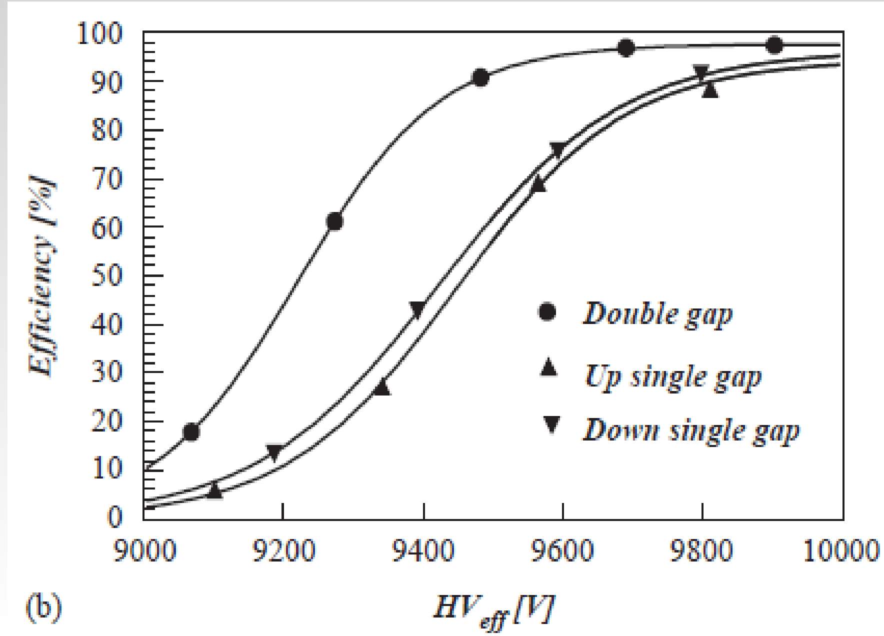


efficiency = number of RPC responses / number of expected RPC responses

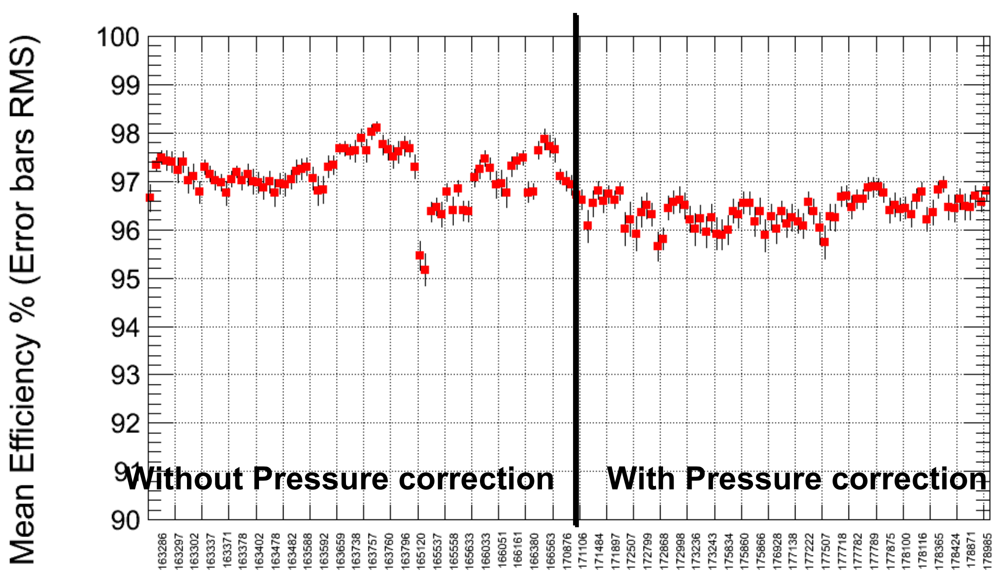
Setting of the optimal working point

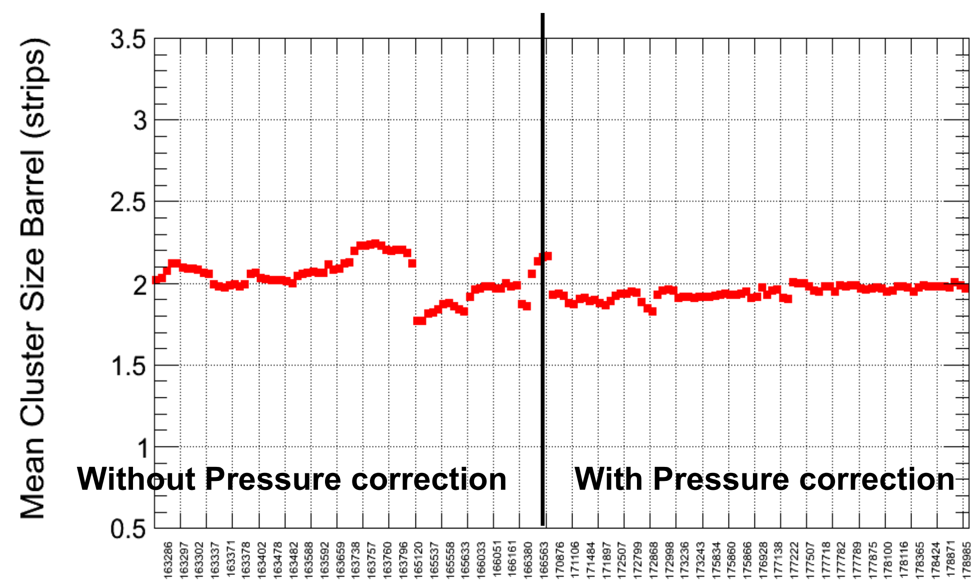
The HV working point depends on temperature and pressure in the cavern

$$HV_{eff}(p,T) = HV\frac{p_0}{p}\frac{T}{T_0}$$

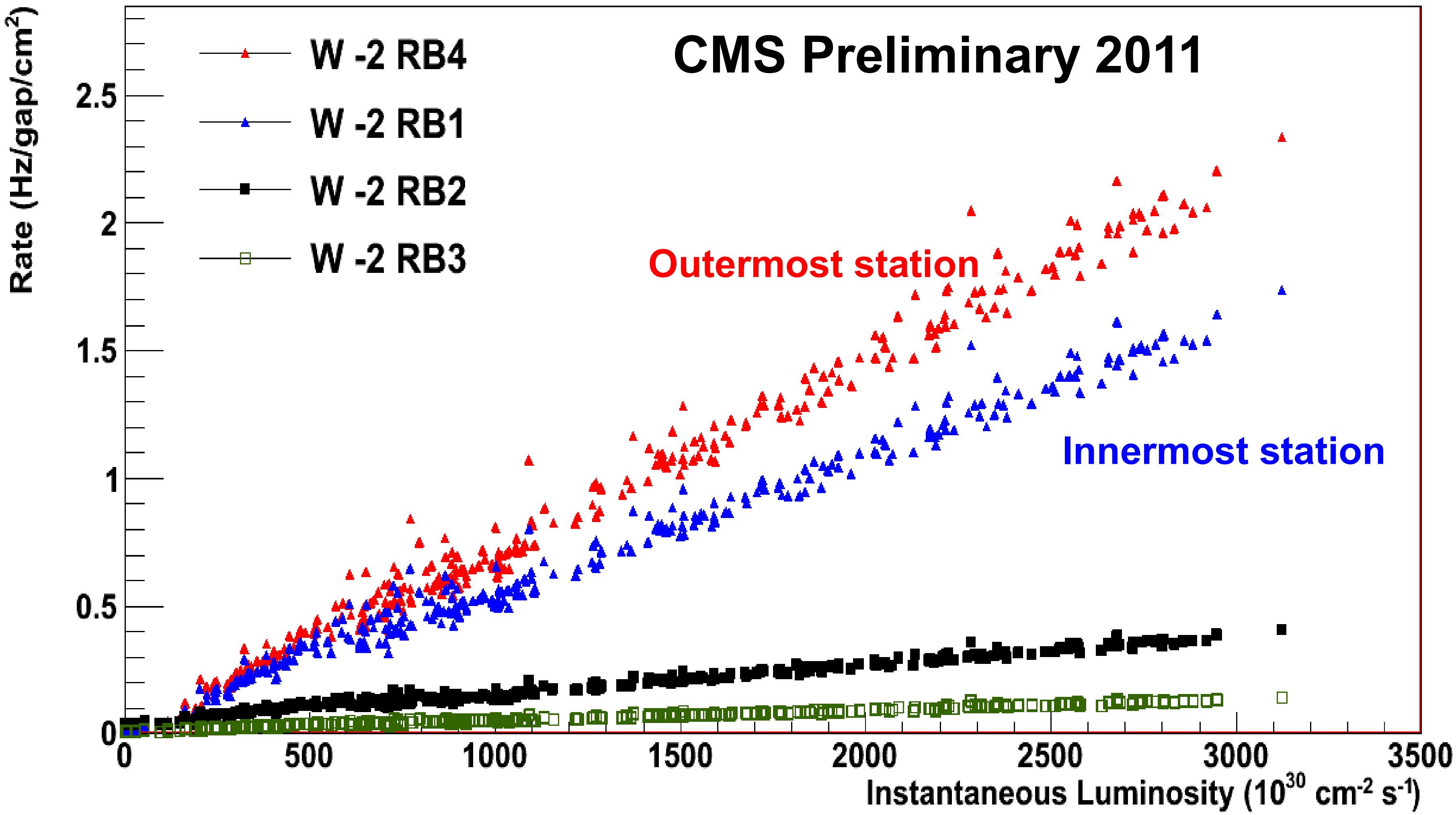


The effect of the automatic pressure correction



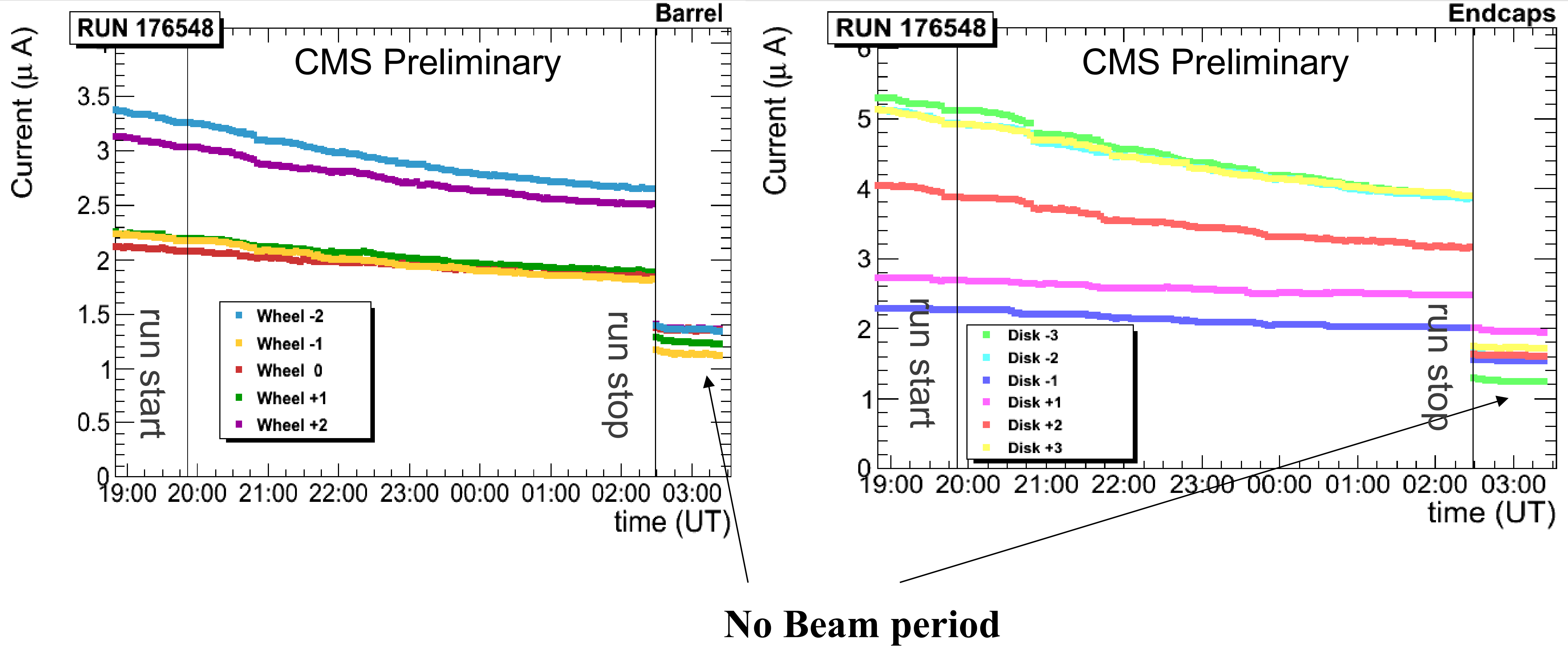


Radiation Background studies



RPC Background rate as a function of the instantaneous luminosity, for four radial stations of Barrel wheel W-2. Outermost station affected mainly by neutron background, innermost mainly affected by particles coming from the vertex.

Current versus luminosity



History plot for mean current in a wheel for a given run, the current is correlated to the beam intensity that decreases in time.

Detector response simulation

During the data taking MC is updated regularly

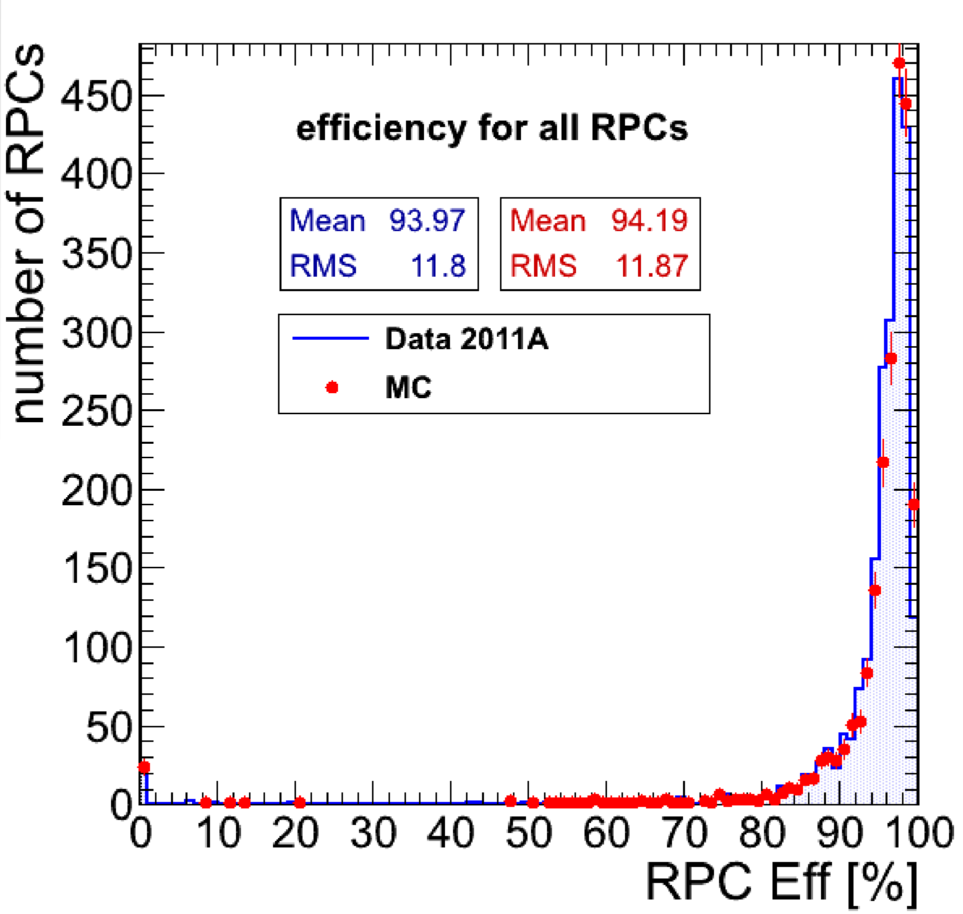
- Data collected in the first part of 2011 have been used to simulate the efficiency in MC

- Intrinsic RPC noise is measured during cosmic runs and used to model the MC response

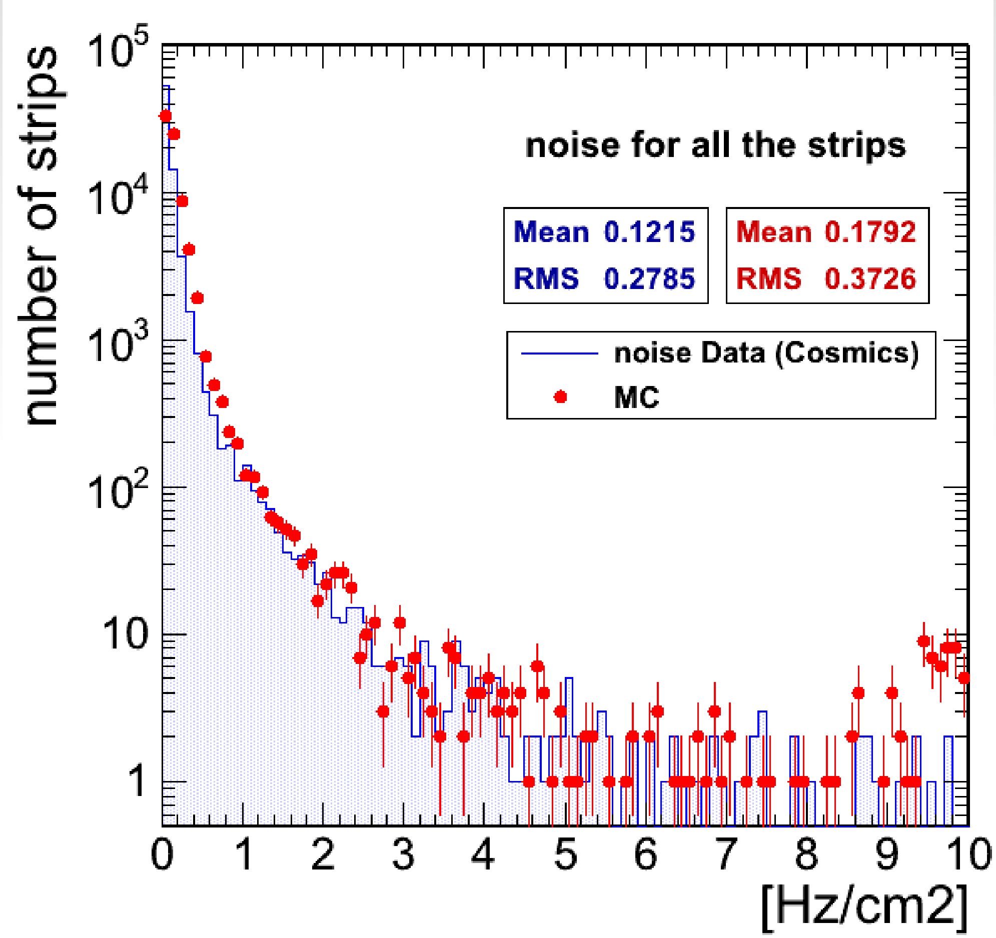
- Cluster Size of RPC – the number of consecutive strips fired in response of a single particle
experimentally measured cluster distributions from data collected with cosmic rays is used to parametrize the MC

-Timing
the delay of signal along the cables for each chamber, the time of flight of the particle and the signal propagation speed on the strip are taken into account in order to estimate the total time for response

Detector response simulation

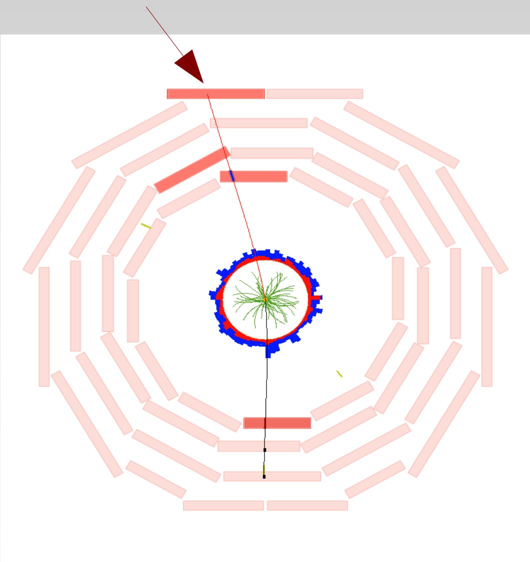


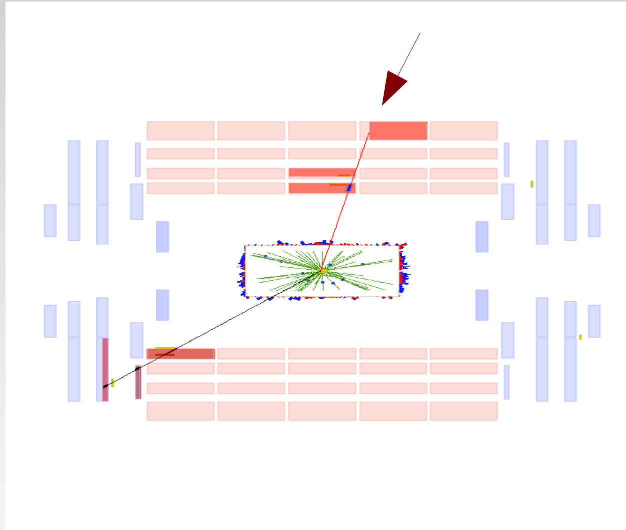
Efficiency distribution for all the RPCs (data in blue, MC in red)



Intrinsic noise distribution for all the RPCs signal electrodes (data in blue, MC in red)

RPC hits in the muon reconstruction





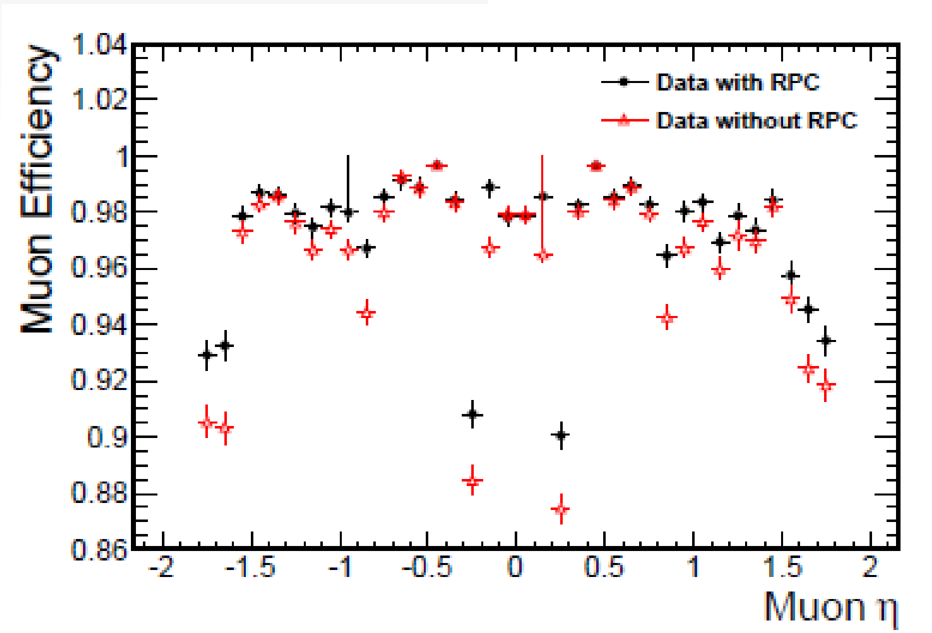
example of muon recovered by

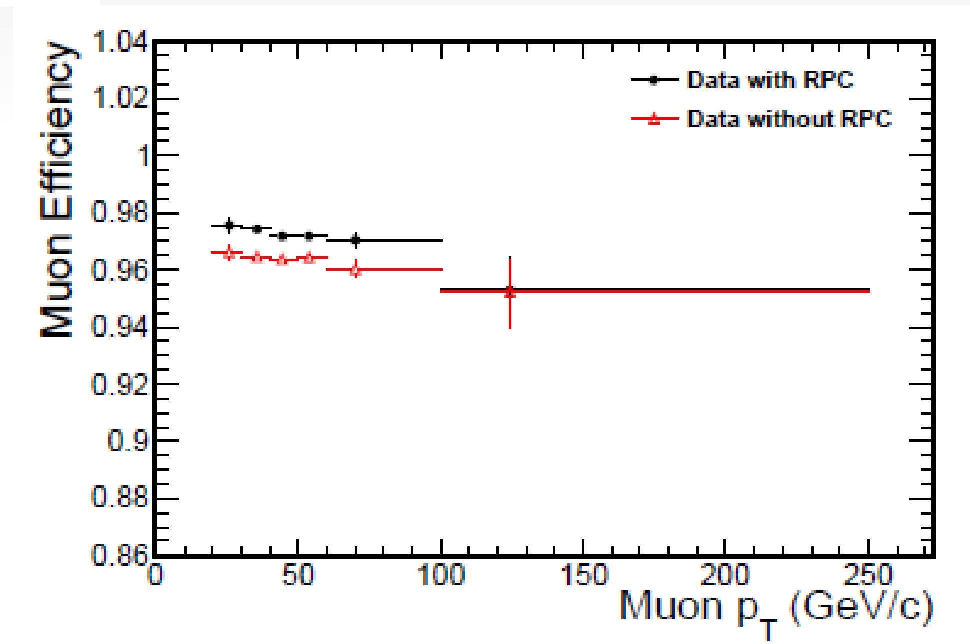
RPCs - 1 DT segment + 2 RPC hits

The red track, crossing the gaps of the DT

will fail in reconstruction when the RPC

hits are removed in the track fitting





Efficiencies measured on data for muons as a function of η and pT
with (black dots) and without (red triangle) the use of RPC in the track reconstruction.

An efficiency gain by RPC is 1% on average and 3% in certain eta region.

Summary

The CMS RPC system operates successfully for more then two years and participate successfully in the cosmic and collision data taking.

RPCs performance is studied using dedicated collision and cosmic runs and it is well understood.

The RPCs are stable and reliable sub-detector and fulfills the requirements for the trigger and reconstruction capabilities necessary for the CMS physics program.

References

[1] http://cms.web.cern.ch/org/cms-public

[2] CMS Collaboration, The Muon Project Technical Design Report, CERN/LHCC 97-32 (1997);

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[5] M. Kim, The RPC hits in the CMS muon reconstruction, PoS(RPC2012)045;

[6] S. Constantini, Calibration of the RPC working voltage in the CMS experiment, PoS(RPC2012)005;

[7] U. Berzano, RPC monitoring tools in the CMS experiment, PoS(RPC2012);

[8] M. Rodozov, Analysis of the radiation background in the CMS RPCs, PoS(RPC2012)045

Thank You!!!

BACK SLIDES

Summary of CMS detector requirements

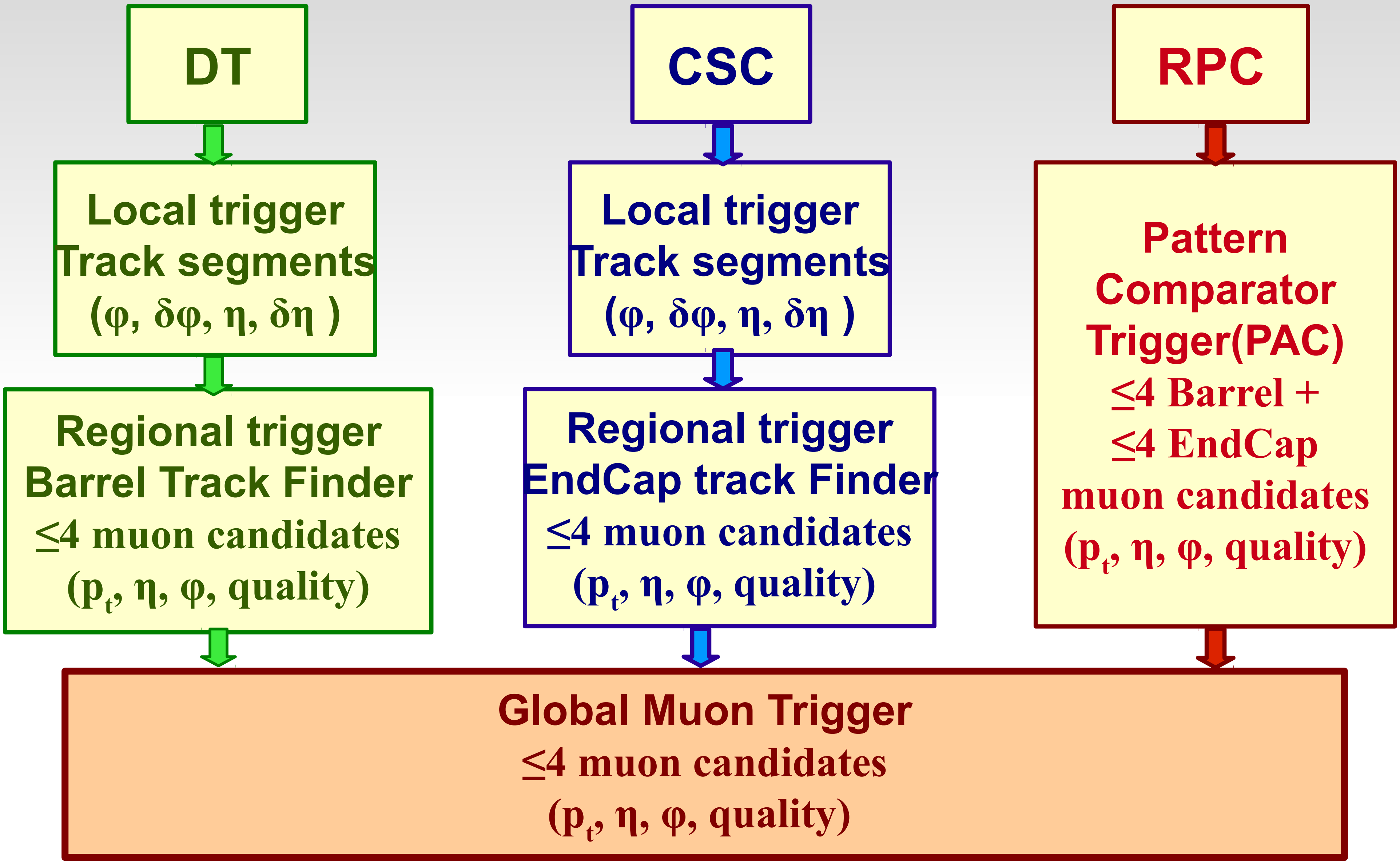
Good muon identification and momentum resolution over a wide range of momenta in the region $|\eta| < 2.5$; good dimuon mass resolution (1% at 100 GeV/c^2); and the ability to determine unambiguously the charge of muons with $p < 1$ TeV/c;

Good charged particle momentum resolution and reconstruction efficiency in the inner tracker. Efficient triggering and offline tagging of τ's and b-jets, requiring pixel detectors close to the interaction region;

Good electromagnetic energy resolution, good diphoton and dielectron mass resolution (1% at 100 GeV/c^2), wide geometric coverage ($|\eta| < 2.5$); measurement of the direction of photons and/or correct localization of the primary interaction vertex, π^0 rejection and efficient photon and lepton isolation at high luminosities.

Good E_T^{miss} and dijet mass resolution, requiring hadron calorimeters with a large hermetic geometric coverage ($|\eta| < 5$) and with fine lateral segmentation ($\Delta\eta \times \Delta\phi < 0.1 \times 0.1$).

L1 Muon Trigger



Output data rate: ~ 75 kHz

Trigger : every 25 ns – BX; 20 events 10^9 int/s

Trigger decision:
"trigger primitive" objects:
e.g. γ,e, μ and jets above
E_t and p_t tresholds
Decision period – 3.2 μs
Output data rate: 50 kHz
(design rate 100 kHz)

HLT

L1

PC farm ; HLT software code
Main purpose:
Output data ~ 100 Hz

HLT selection criteria :
Ignore:
Soft hadrons with Pt ~ few GeV;
Muon background
from b, c, π and K decays

Hcal & Ecal trigger

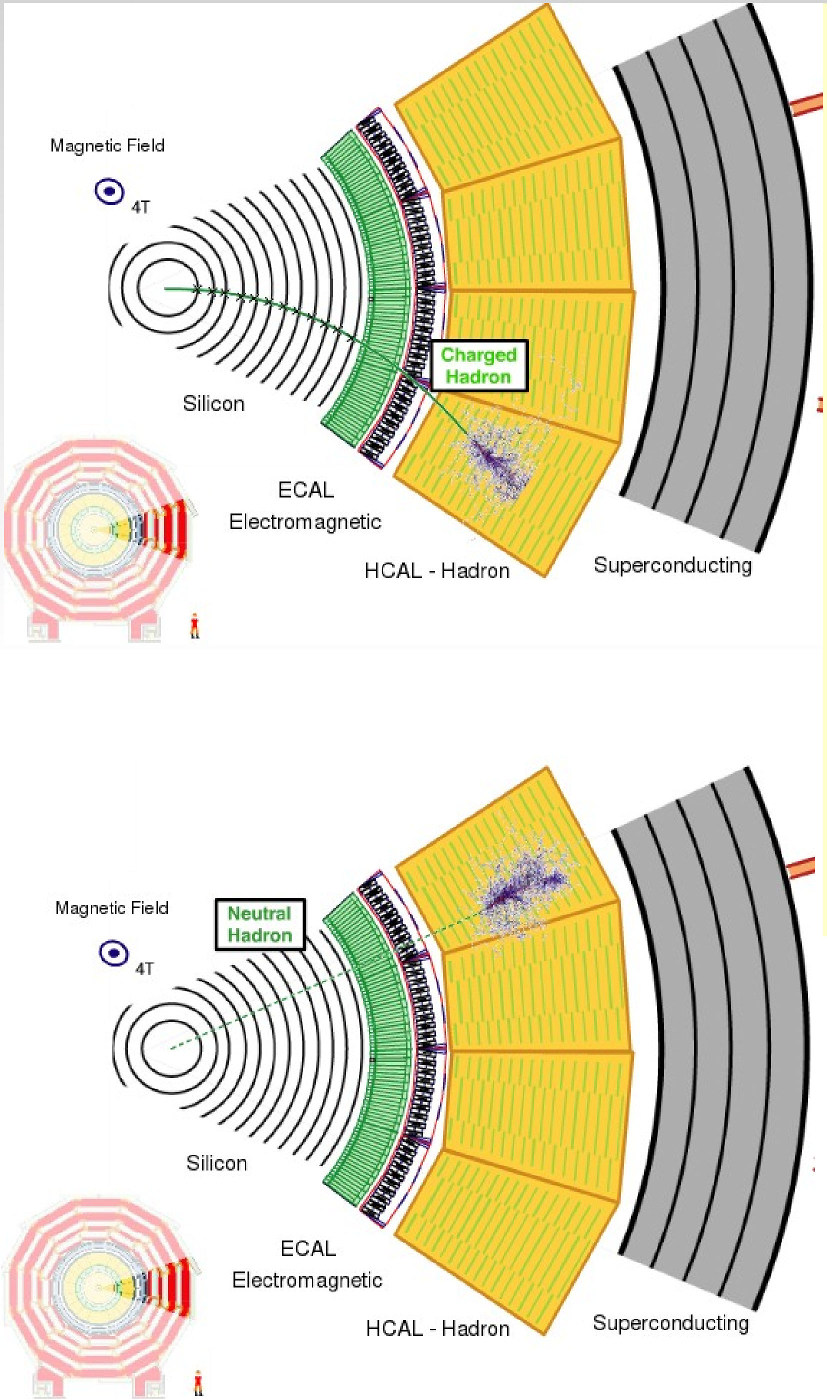
Muon trigger

The best 4 candidates,

Global trigger

Software setting conditions

Solenoidal magnetic field



- **The CMS solenoid is designed to provide an axial magnetic field of 3.8 T – about 100000 times that of the earth;**
  ~1.8 T in the return yoke
- **The current required is ~17 kA → need to use a superconducting wire (zero resistance)**
- **The superconductor chosen is Niobium Titanium (NbTi) wrapped with copper – needs to be cooled to ~4K**
- **The CMS solenoid is 13m long with an inner diameter of 5.9m**
- **The solenoid is sufficiently large that the tracking and all central calorimeters can fit inside**
- **Charged particles only bend in one projection (looking along the beam line)**
  - **Makes life easier for the physicist!**