CMS Muon System Upgrade During LS1

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CMS – CERN (current)

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On behalf of:

CMS Collaboration

RPC-CMS Commissioning Team

Outline

1. LHC Schedule of Upgrade
2. CMS Description
3. RE+4 Installation
4. RE-4 Installation
5. Summary

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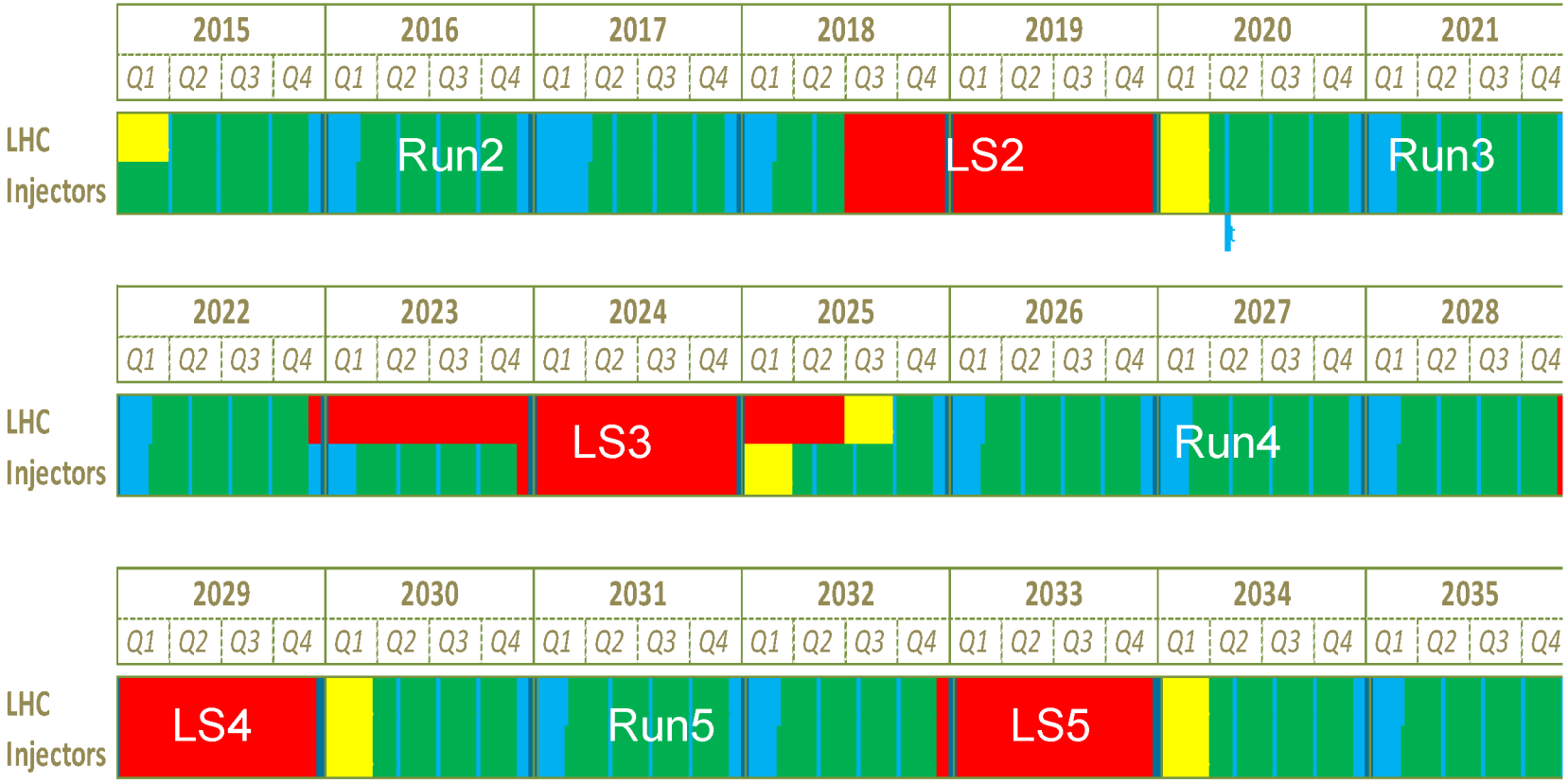
LHC schedule beyond LS1

Only EYETS (19 weeks) (no Linac4 connection during Run2)

LS2 starting in 2018 (July) 18 months + 3 months BC (Beam Commissioning)

LS3 LHC: starting in 2023 => 30 months + 3 BC

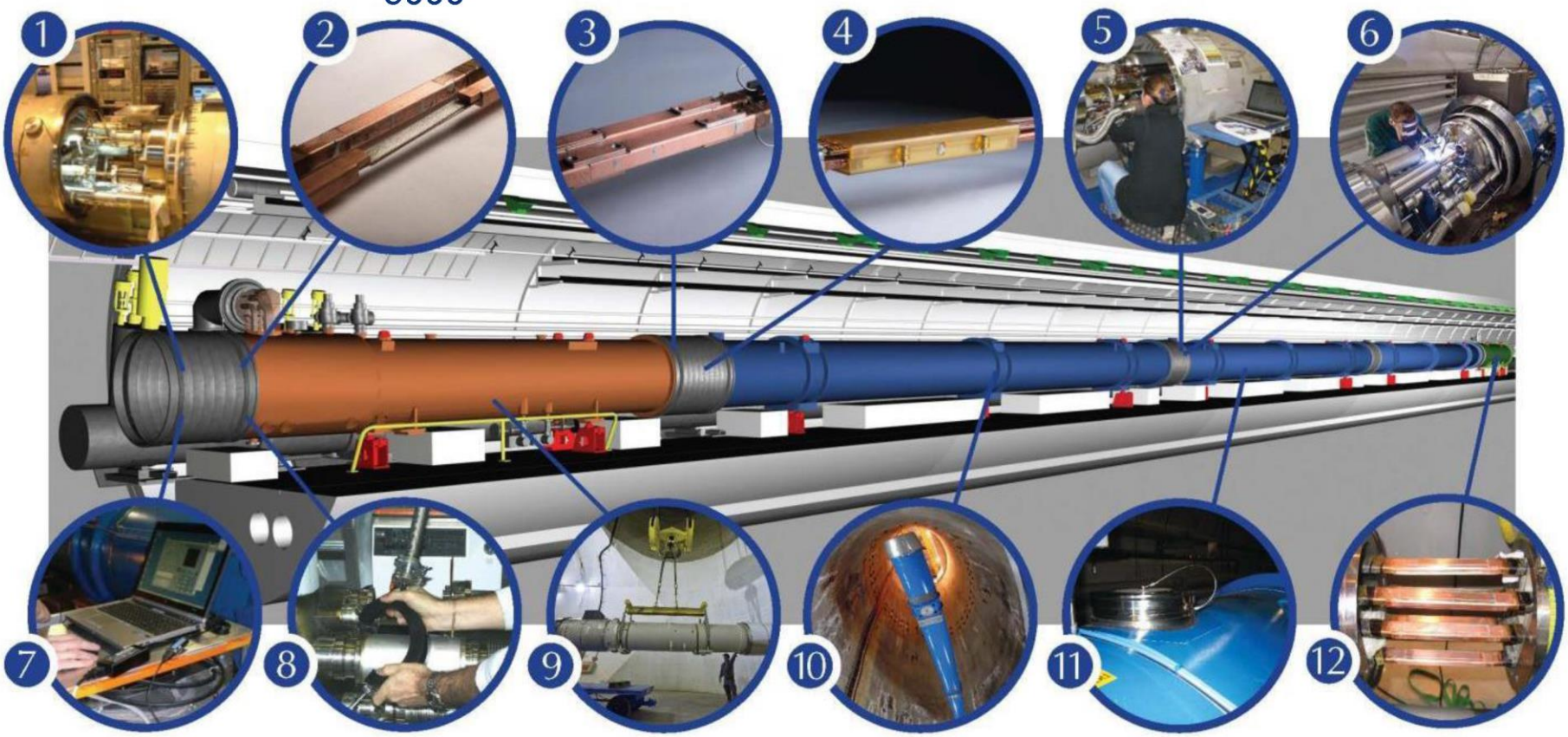
injectors: in 2024 => 13 months + 3 BC



LHC schedule approved by CERN management and LHC experiments

The main 2013-14 LHC consolidations

60% done



1695 Openings and final reclosures of the interconnections

Complete reconstruction of ~~1500~~ 3000 of these splices

Consolidation of the 10170 13kA splices, installing 27 000 shunts

Installation of 5000 consolidated electrical insulation systems

300 000 electrical resistance measurements

10170 orbital welding of stainless steel lines

18 000 electrical Quality Assurance tests

10170 leak tightness tests

3 quadrupole magnets to be replaced

15 dipole magnets to be replaced

Installation of 612 pressure relief devices to bring the total to 1344

Consolidation of the 13 kA circuits in the 16 main electrical feedboxes

Is the upgrade limited to CMS or even LHC?

Answer: Of course NO.

Booster

- Access system installed
- Cabling complete

- Beam dump replacement in progress
  - New dump installed
  - Re-installation of the BTM & BTY lines
- Maintenance of different equipment on schedule

- Already preparing for LS2: cranes renovation, new cable trench

PSB beam dump

27/09

01/11

15/11

29/11

PS

- Access system
- Ventilation renewal progressing well
  - Dismantling finished
  - Automation test in progress
- Septum 16 shielding
  - Piling work complete
  - Formworks going on
- Cabling campaign (and it starts with de-cabling !!)
- Magnet maintenance in progress
  - 6/7 main units are being overhauled in the workshop
- Renovation of the power house in progress

Septum 16 shielding - formworks

CV cabling works

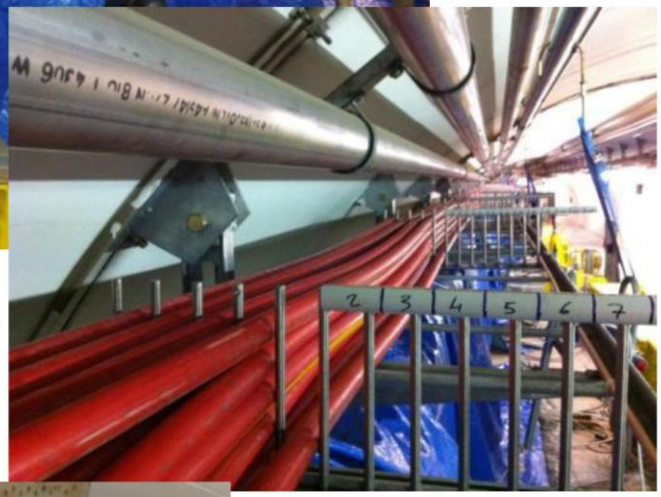
TT2 decabling

6th MU being consolidated in workshop

SPS

- BA1 - Irradiated cabling campaign
  - Progressing very well
  - slightly ahead of schedule
- TT10 – repair of the vault ongoing
  - Beam supports in place
  - Installation of protective mesh in progress
- Refilling of the primary circuits started
- Septa replacement in BA23 in progress
- Kickers conditioning in progress
- Magnet exchange
- Cabling and optical fibers campaign ongoing

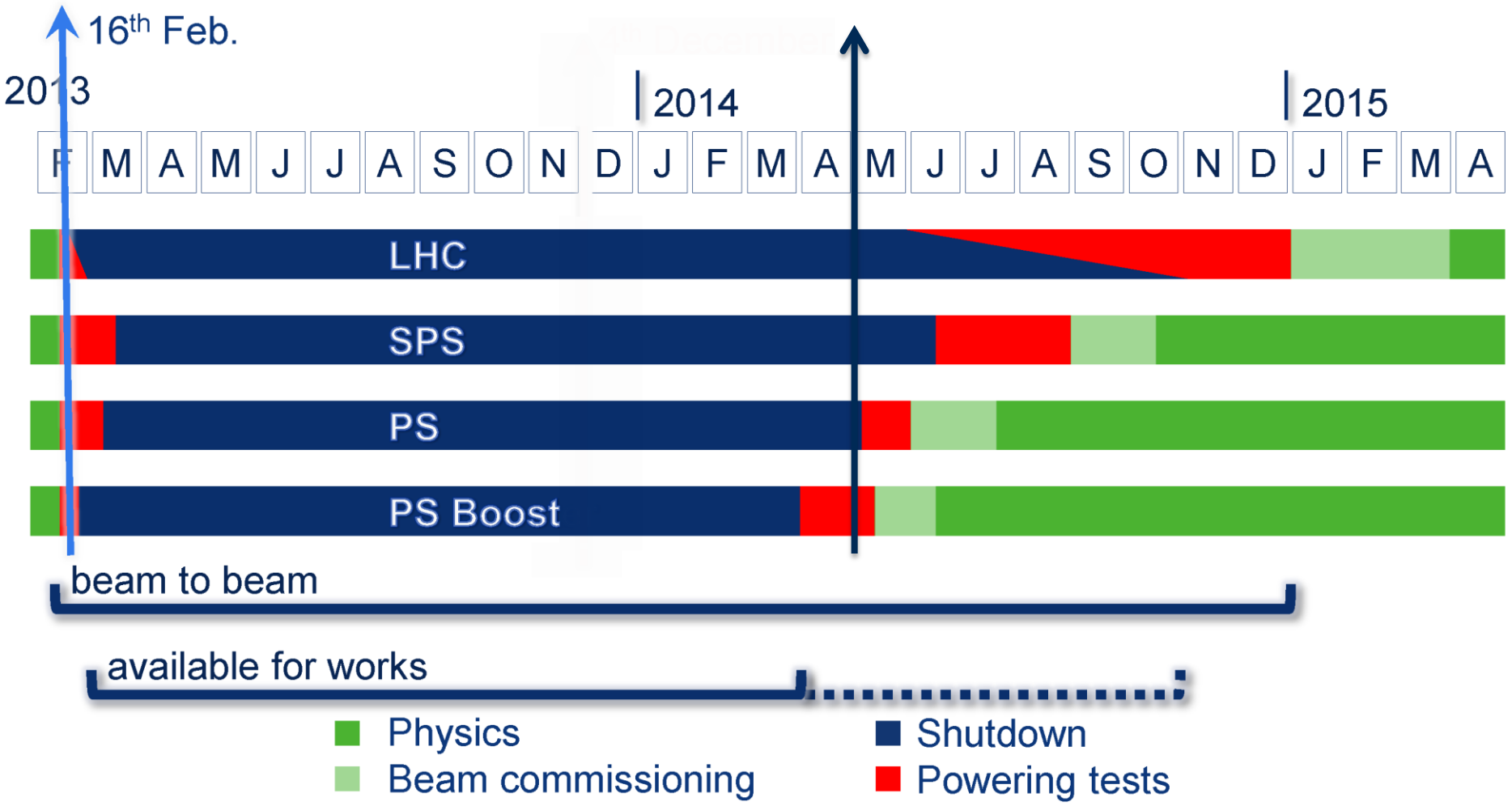
BA1 -irradiated cabling campaign



TT10 vault

SPS magnet exchange

LS1 from 16th Feb. 2013 to Dec. 2014

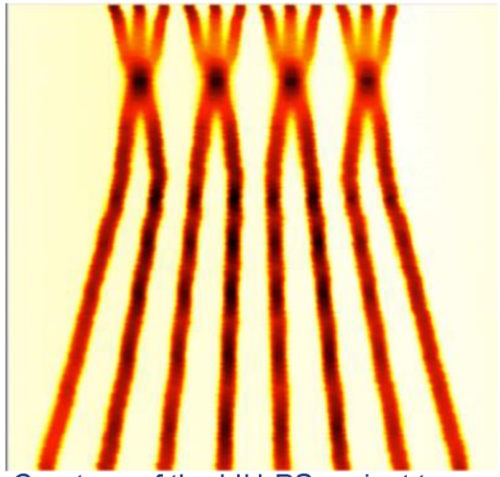


Expectations after LS1 (2015)

- Collisions at **13 TeV** c.m.
- **25 ns** bunch spacing

  Using new injector beam production scheme (BCMS), resulting in brighter beams.

Batch Compression and Merging and splitting (BCMS)



Courtesy of the LIU-PS project team

- **$\beta^* \leq 0.5$ m** (was 0.6 m in 2012)
- Other conditions:
  - Similar turn around time
  - Similar machine availability
- Expected maximum luminosity: **1.6×10^{34} cm^{-2} s^{-1}** ± 20%
  - Limited by inner triplet heat load limit, due to collisions debris

	Number of bunches	Intensity per bunch	Transverse emittance	Peak luminosity	Pile up	Int. yearly luminosity
25 ns BCMS	2508	1.15×10^{11}	1.9 μm	1.6×10^{34} cm^{-2}s^{-1}	~43	~42 fb^{-1}

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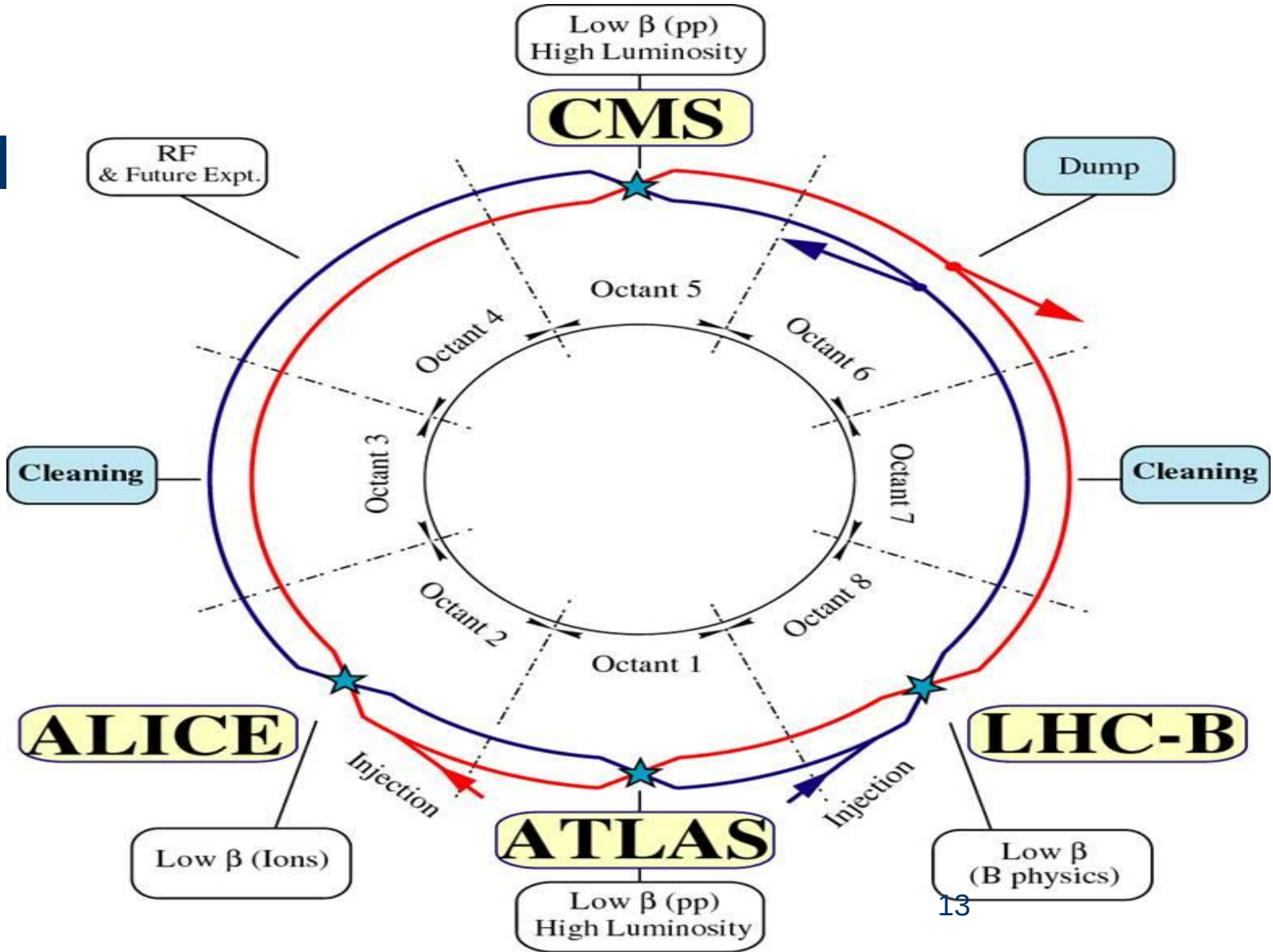
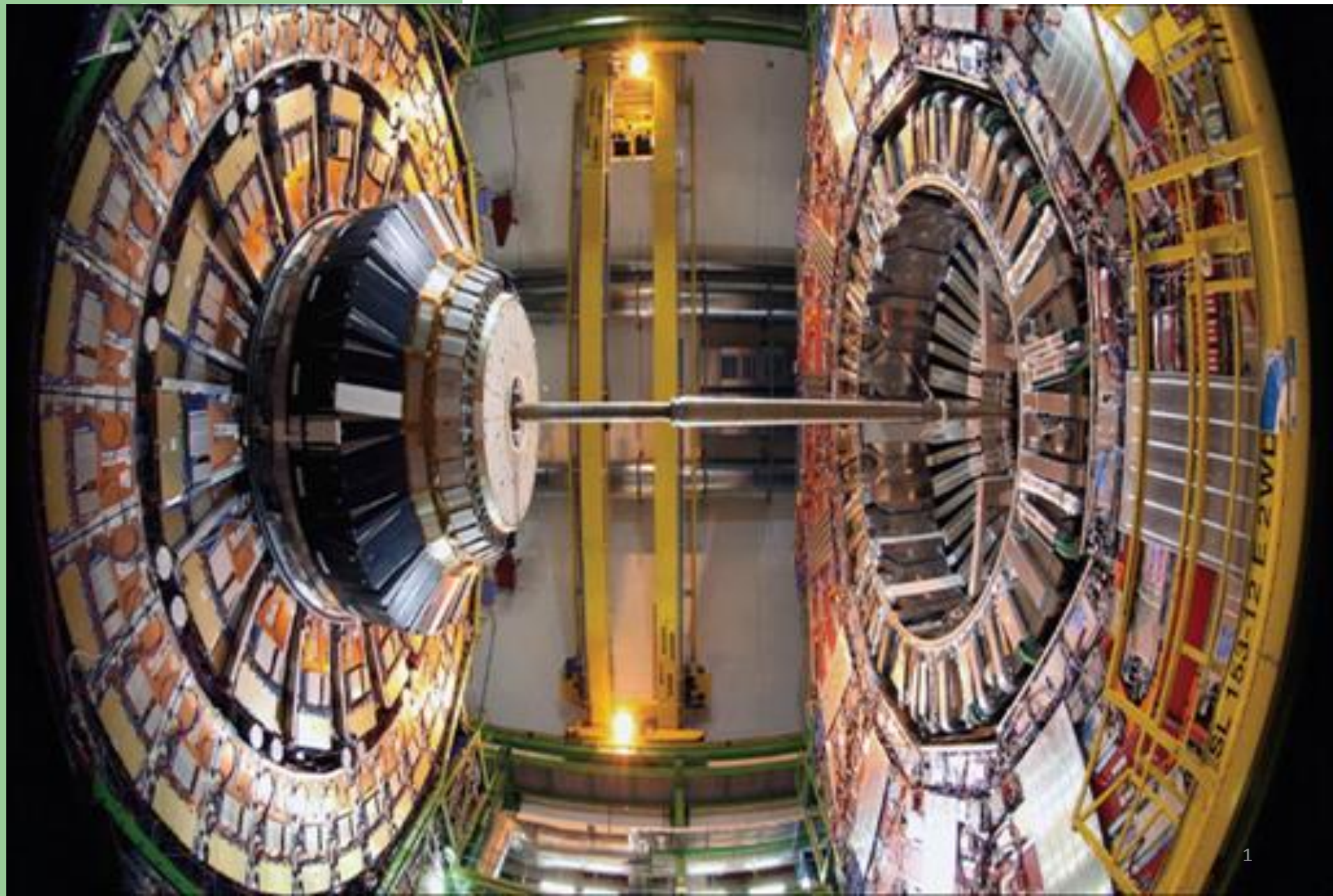
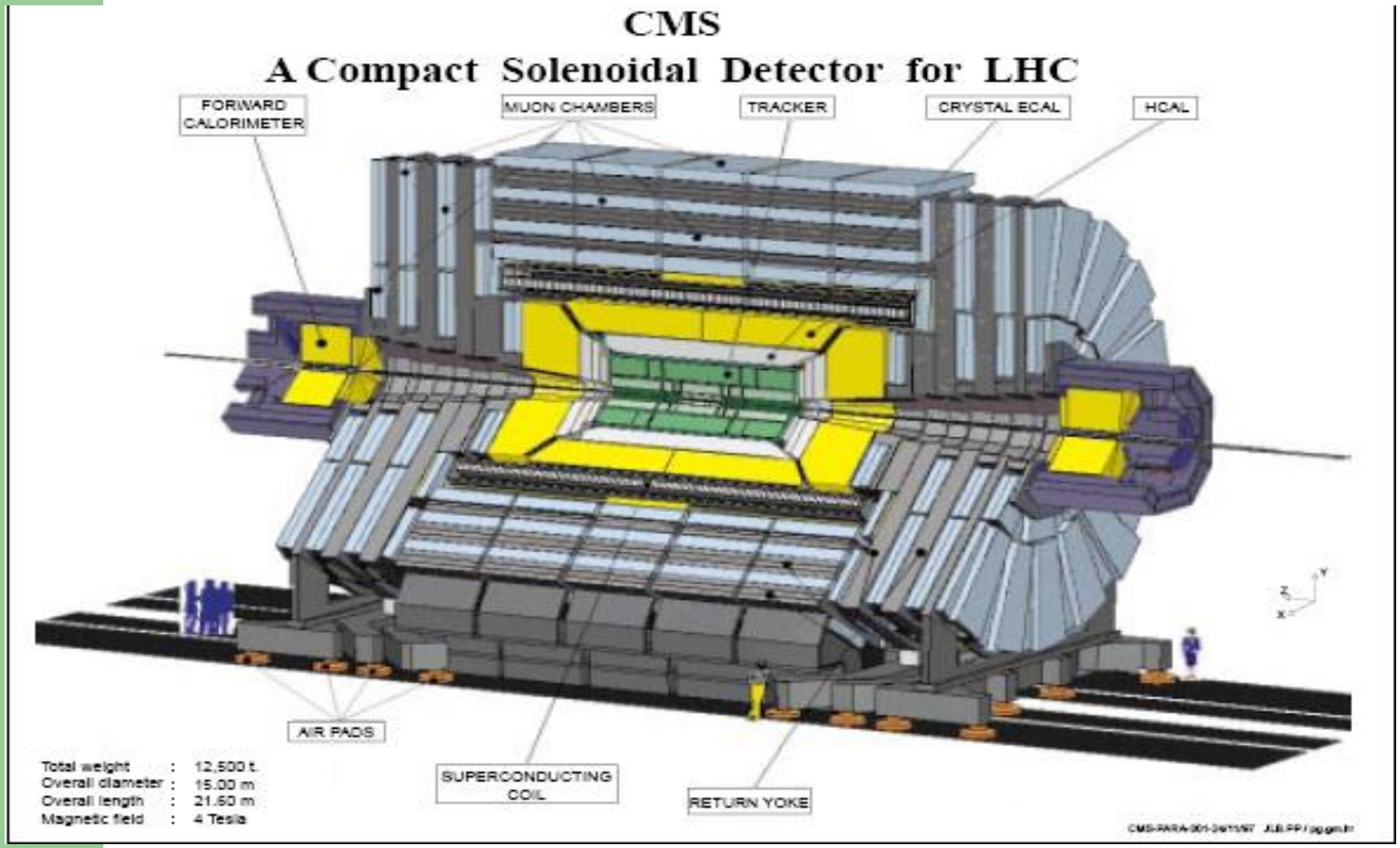
Large Hadron Collider (LHC)



Barrel vs. Endcap



THE CMS DETECTOR (Closed)



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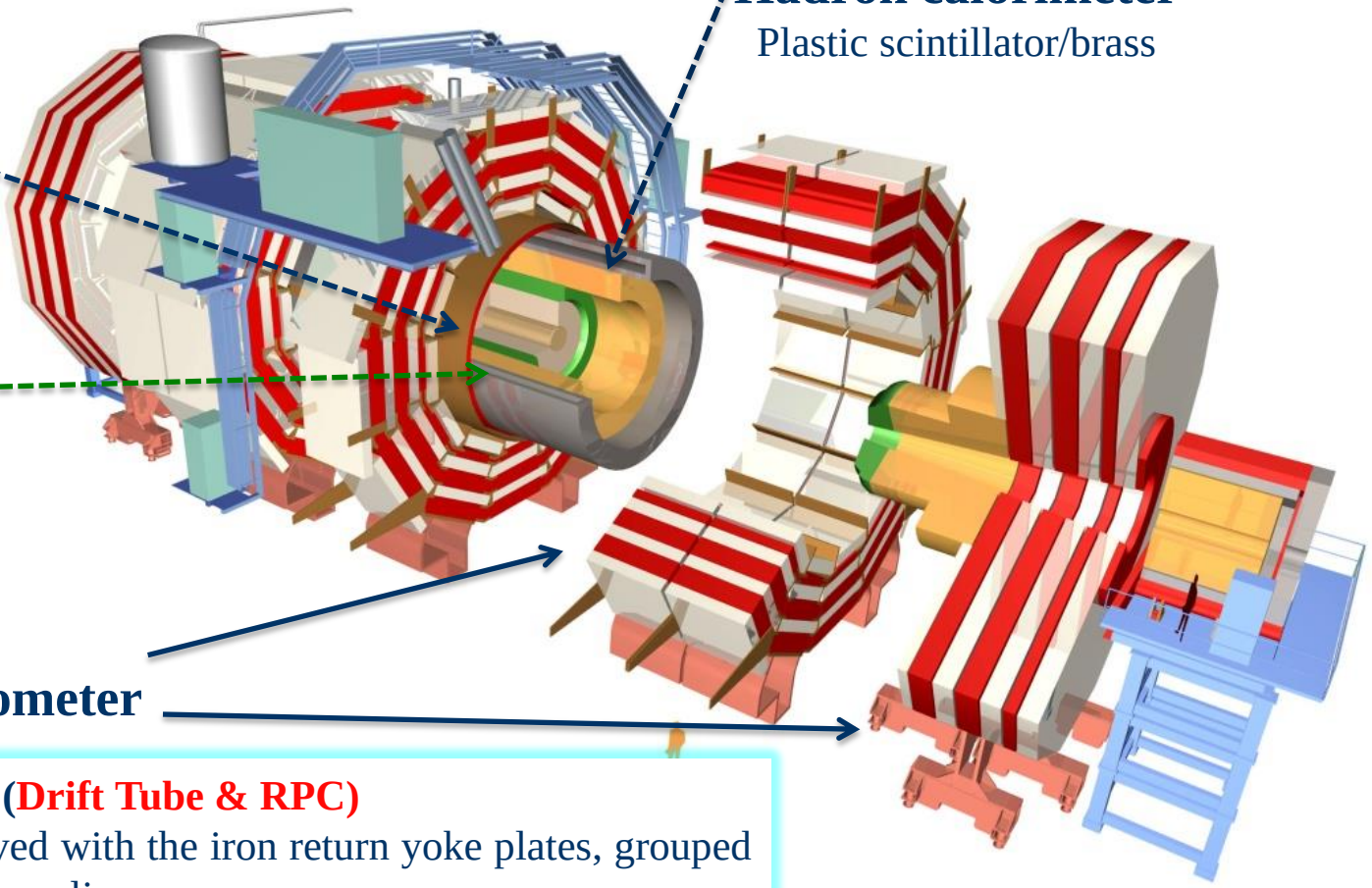
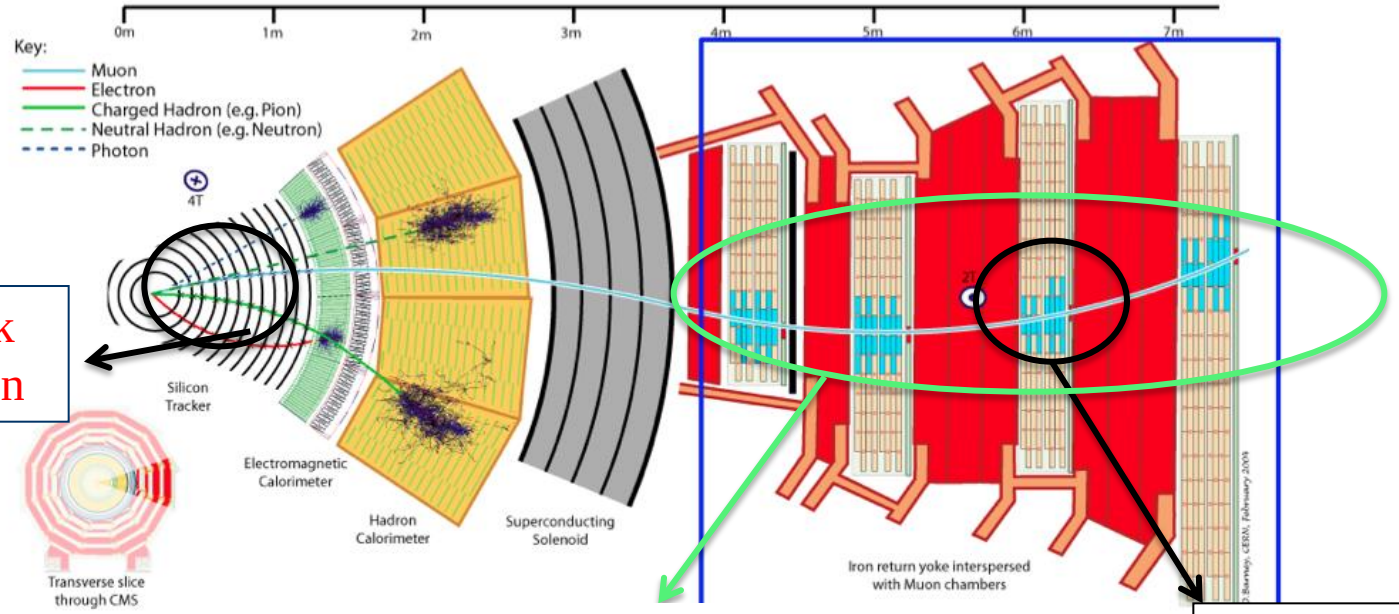


Cylindrical barrel region (Drift Tube & RPC)
4 coaxial stations interleaved with the iron return yoke plates, grouped into **5 wheels** around the beam line

Planar endcap region (Cathode Strips Chambers & RPC)
4 planar stations (disks) interleaved with the iron return yoke plates. RE-4 has been installed while RE+4 is now being built.

Weight: 12000 t
Length: 21.6 m
Diameter: 15 m
Magnetic field: 3.8 T

Cross-Sectional Sector of CMS at Barrel region (Center)



Tracker track reconstruction

Standalone Muon reconstruction

Performed using DT/CSC segments & RPC hits

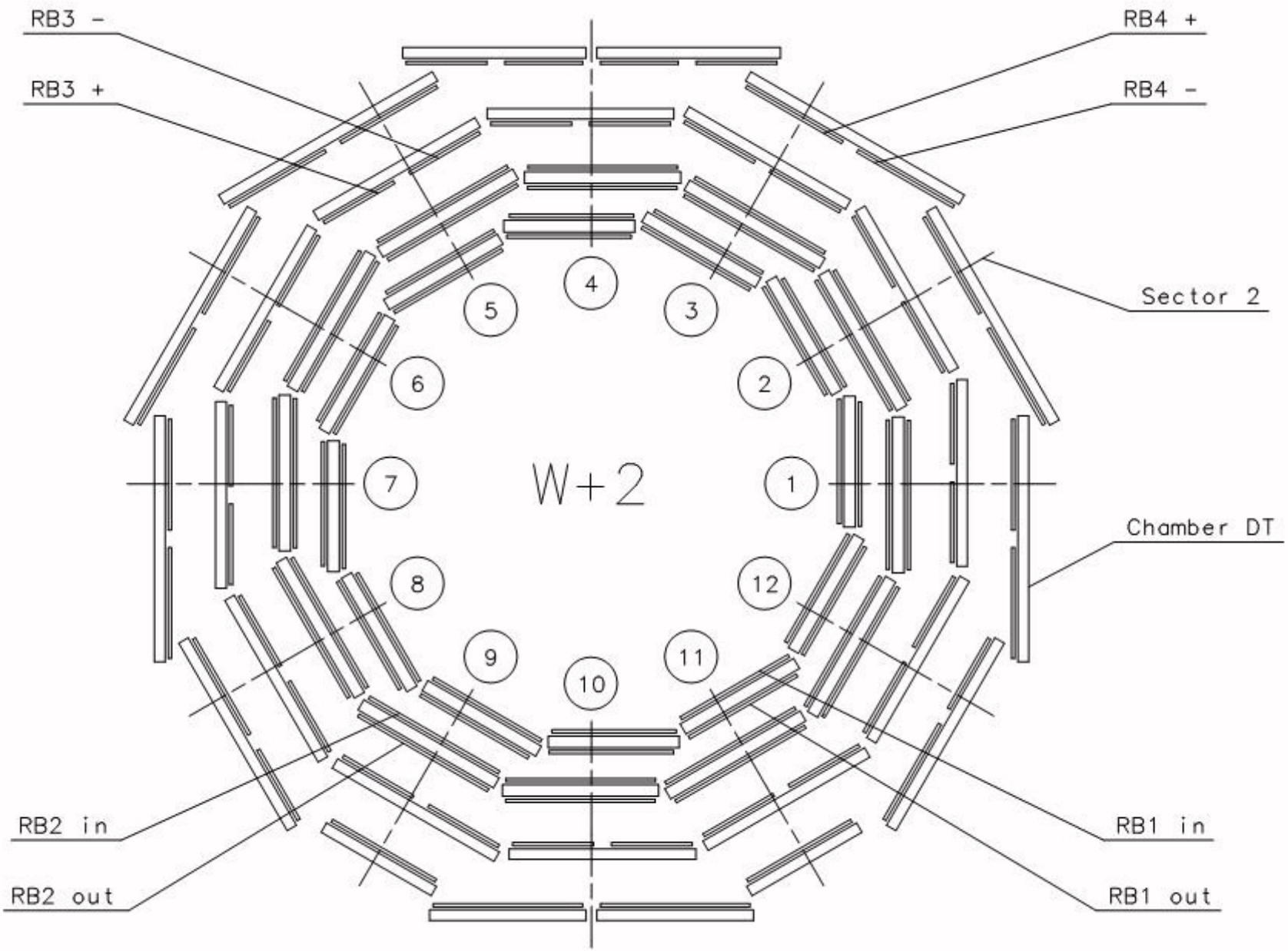
Local reconstruction

Performed within single chamber

Global muon reconstruction (out side –in): a standalone muon is propagated to match a tracker track. If matching is positive a global fitting is performed.

Tracker Muon (inside – outside): a tracker track is propagated to muon system and qualified as muon if matching with standalone or one segment.

Barrel


RB3 −
RB3 +
RB4 +
RB4 −
Sector 2
Chamber DT
RB2 in
RB2 out
RB1 in
RB1 out
W+2
1
2
3
4
5
6
7
8
9
10
11
12

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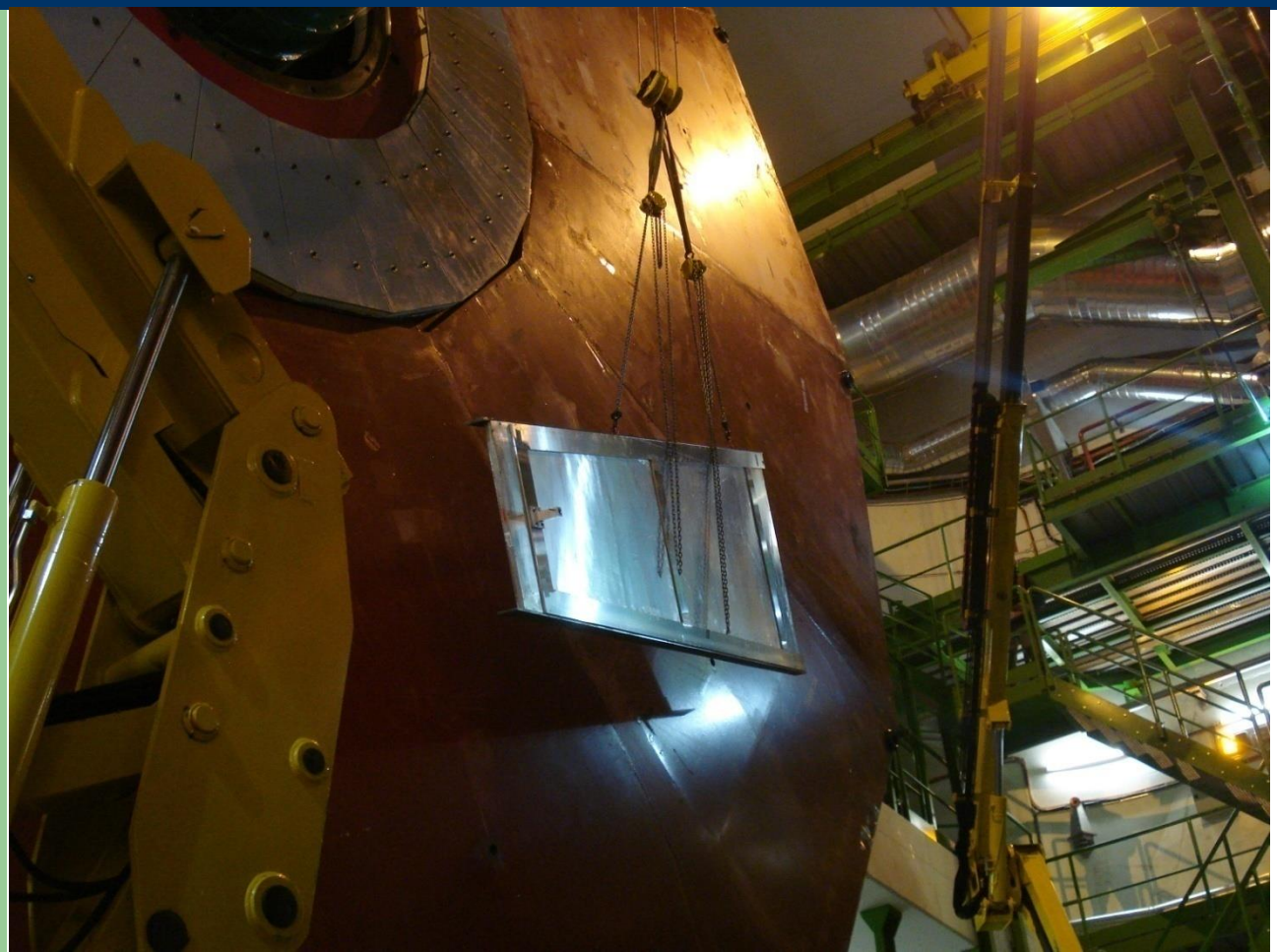
RE+4 Installation: Dec., 2013



RE+4 Installation: Dec., 2013

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RE-4 Installation: April 25-26, 2014

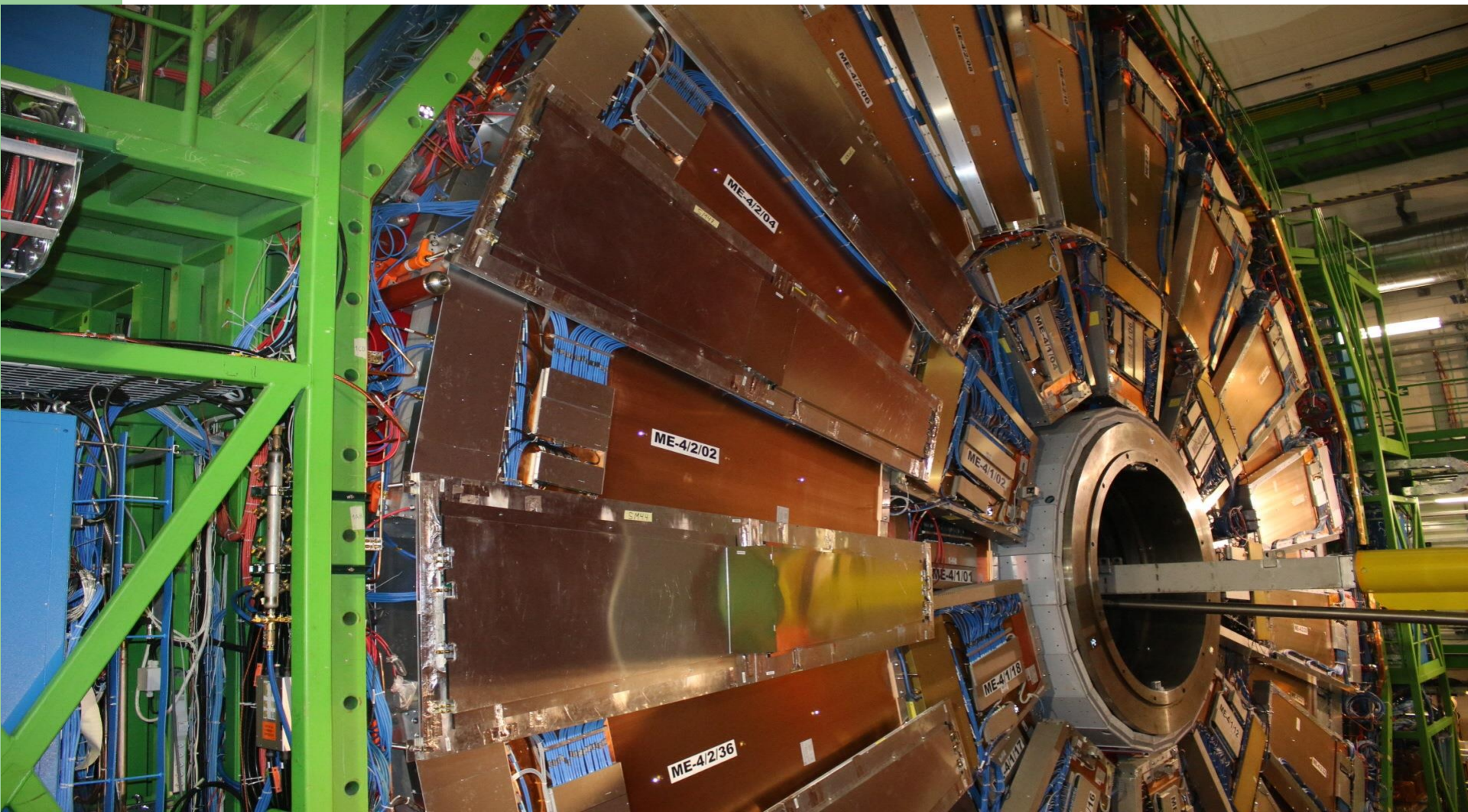
Installation of 36 RPC super modules (SM) finally underway since Friday (April 25). The installation team is working under difficult conditions:

- With a 3.5 m gap between YE+3 & YE+4.
- YE+4 is on the push back system with 4 long screws, air pads and on the far side tracks for the air pad.

On Friday (April 25) due to very limited available time in the evening, only one SM was installed until 7:00 pm.
On Saturday (April 26) even with 90 min problem with the crane and exercise by CERN firemen, installation team worked very efficiently and managed to install 7 more SMs.

All 8 SM are installed on yoke towards the near side. The number and location is as follows:
SM40 (29), SM57 (31), SM46 (33), SM45 (35), SM44 (01), SM47 (03), SM59 (05) & SM38 (07) - numbers in the brackets refer to CSC slot numbers.

RE-4 Installation: April 25-26, 2014



RE-4 Installation: April 27-28, 2014

7 SMs have been installed yesterday (ON yoke).

SM39 (27), SM52 (25), SM64 (23), SM11 (21), SM60 (19), SM63 (17), SM?? (09)

SM61 on CSC slot 15 doesn't fit, so brought down and need bit of fixing.

Reinforcement bars have been placed on

SM40 (29), SM57 (31), SM46 (33), SM45 (35), SM44 (01), SM47 (03), SM59 (05), SM38 (07), SM39 (27), SM52 (25), SM64 (23)

In addition, there was a small accident at 18:15 on April 27; one of the cooling valves was opened but closed immediately (for about 10 sec). No damage happened except for some water on YE+4.

RE-4 Installation: April 29, 2014

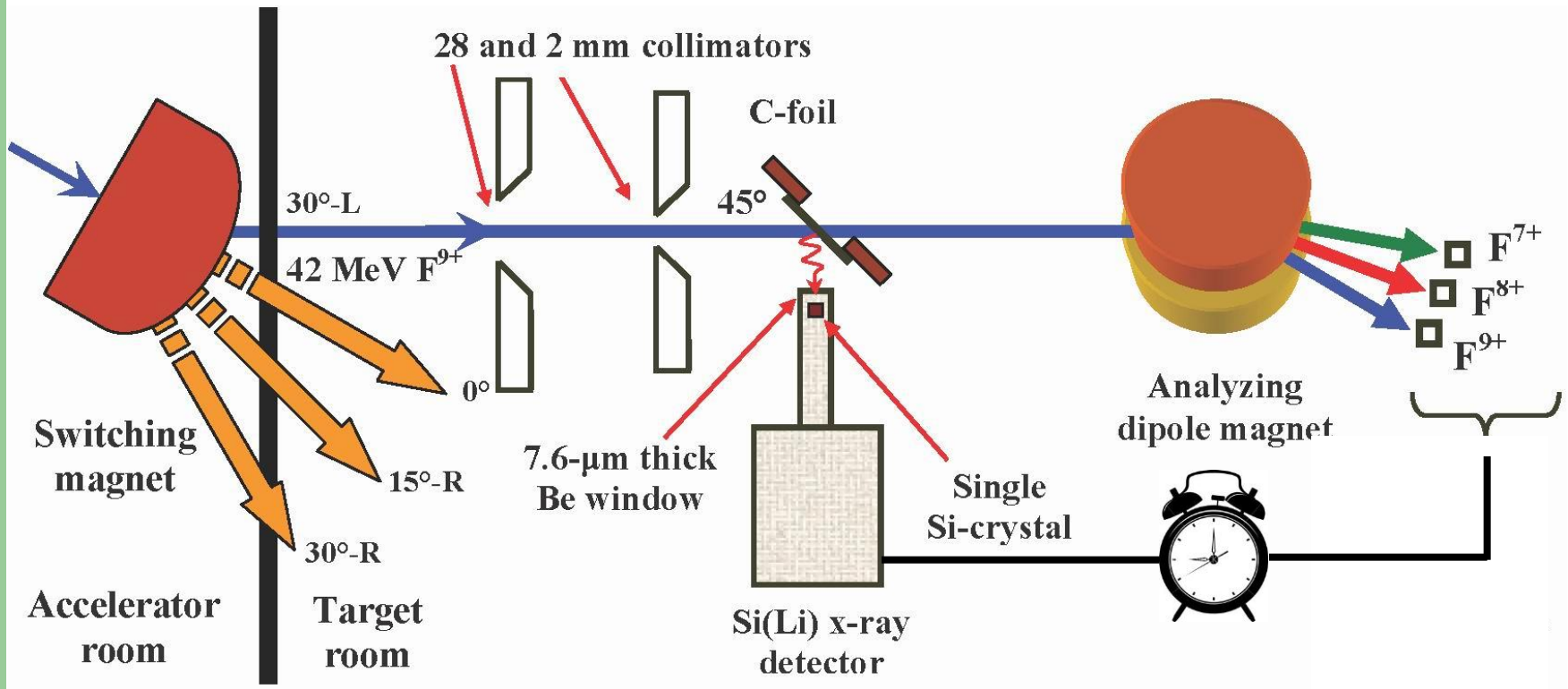
Total of 21 SM have been installed

ON-yoke SMs
The remaining three SM have been installed.
SM61 (15), SM65 (13), SM62 (11)
This completed the ON yoke SM.

OFF-yoke SMs
Following OFF yoke chambers have been installed.
SM54 (24), SM55 (26), SM53 (20)

Reinforcement Bars for ON-yoke SMs
Following SMs have been left without reinforcement bars
SM62 (11), SM65 (13), SM61 (15)
Done for otherwise

Triggering: Example

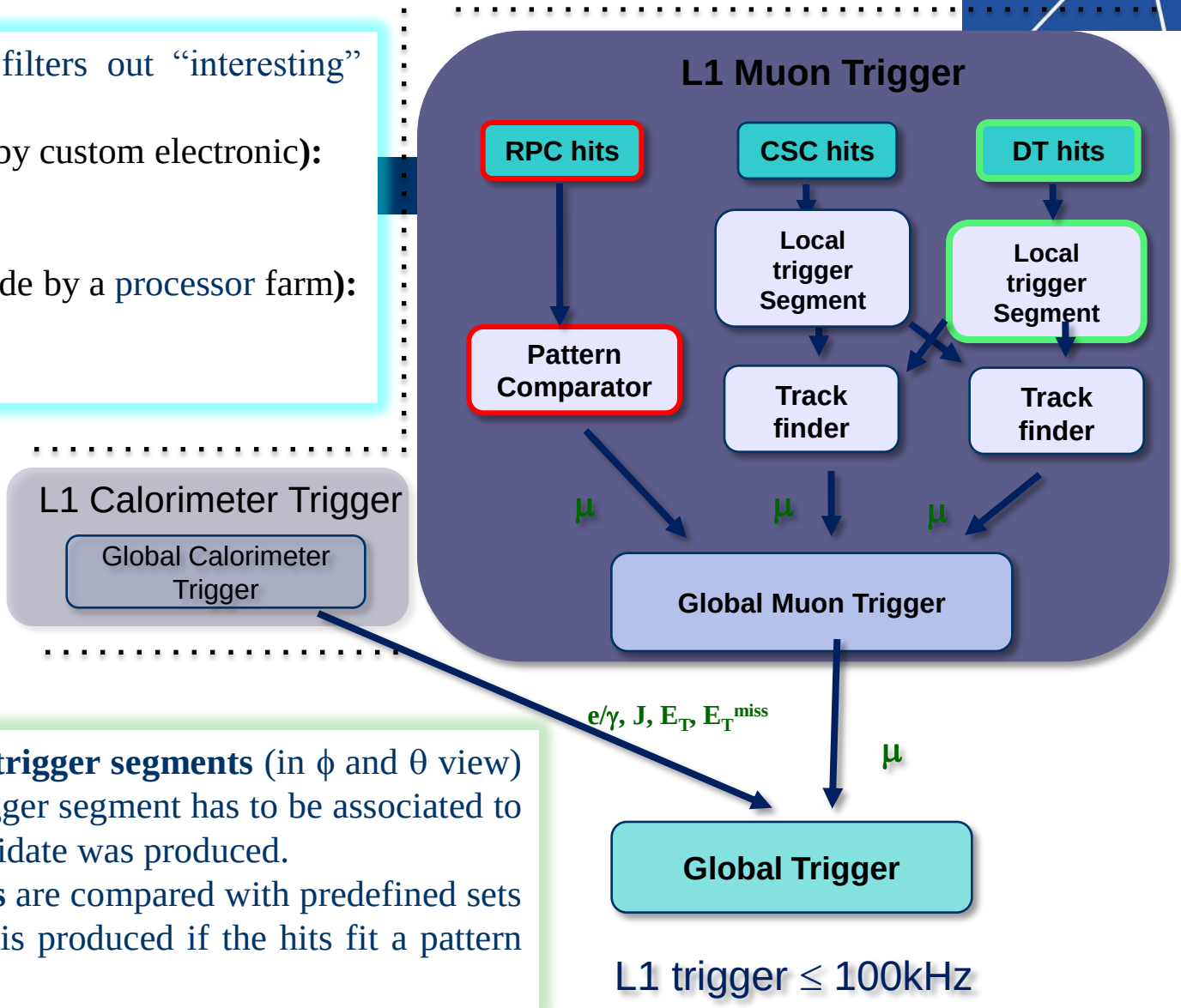


CMS Trigger System

Two level trigger system filters out "interesting" events:

Level 1 trigger (made by custom electronic):
40 MHz → 100 kHz
latency < 3.2 μs

High Level trigger (made by a processor farm):
300 Hz
decision made in 1s

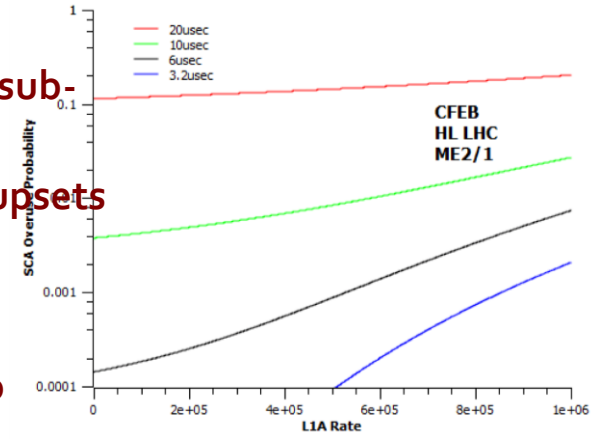


DT local trigger: provide **trigger segments** (in ϕ and θ view) for each chamber. Each trigger segment has to be associated to the BX at which the μ candidate was produced.

RPC trigger: the **RPC hits** are compared with predefined sets of patterns. A μ candidate is produced if the hits fit a pattern and are in the same BX.

Longevity R&D for Existing Muon Detectors

- Common plans: typically late-2014 to 2017
  - Detector and electronics radiation tests at GIF++ (all three sub-detectors plan tests with source and beam)
  - Neutron and/or proton beams for electronics single event upsets



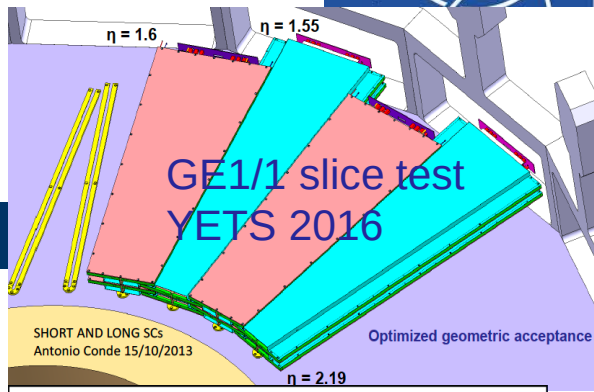
- DT specific plans:
  - Replacement of the mini-crates: electronics design 2015-20

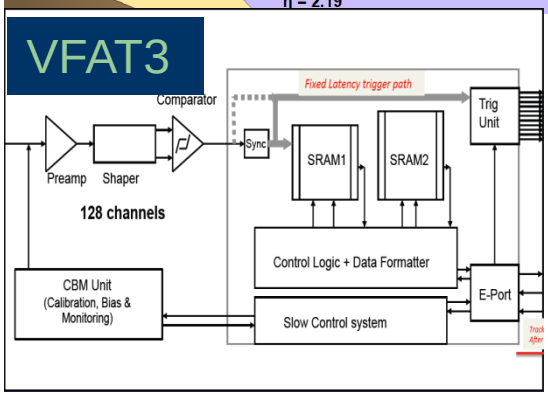
- CSC specific plans:
  - CFEB rate capabilities at various latencies – verify expectations with data

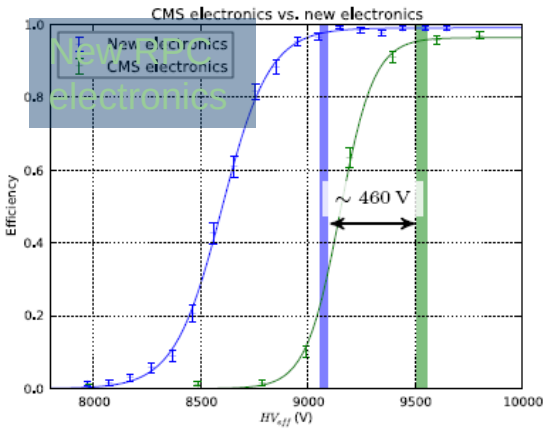
- RPC specific plans:
  - R&D on Freon-less gas mixtures (LHC- and CERN-wide project) includes tests at GIF++

New Muon Detector (GEM)

- **GEM detectors (proposed for GE1/1, GE2/1, and ME0**
  - **Chambers: well-advanced in context of GE1/1**
    - **5th generation prototypes, assembly techniques optimized**
    - **GE2/1 very similar to GE1/1 but 2x larger, ME0 about the same size but more layers; further industrialization, QC, and other studies ongoing**
  - **Front-end electronics: existing VFAT2 (digital), VFAT3 (analog/digital) needed for CMS and under design**
  - **Back-end, DAQ, and trigger electronics R&D: under development for slice test and GE1/1**
- **Improved RPC detectors**
  - Glass: 6 chambers to be tested at GIF++
    - High rate capability and time resolution to be studied
  - Bakelite:
    - Lower resistivity, smaller gap for lower HV being developed (CMS-ATLAS-ALICE) during 2014-16
    - New FE electronics with ATLAS chip 2014-16
- **Muon Fast Track Tag (MTT) for barrel**
  - **Fast scintillator tiles read out with SiPMs and combined with DT/RPC in L1 trigger**
  - **Study ghost suppression, efficiency and timing in HO 2014-16, develop prototypes 2014-20**







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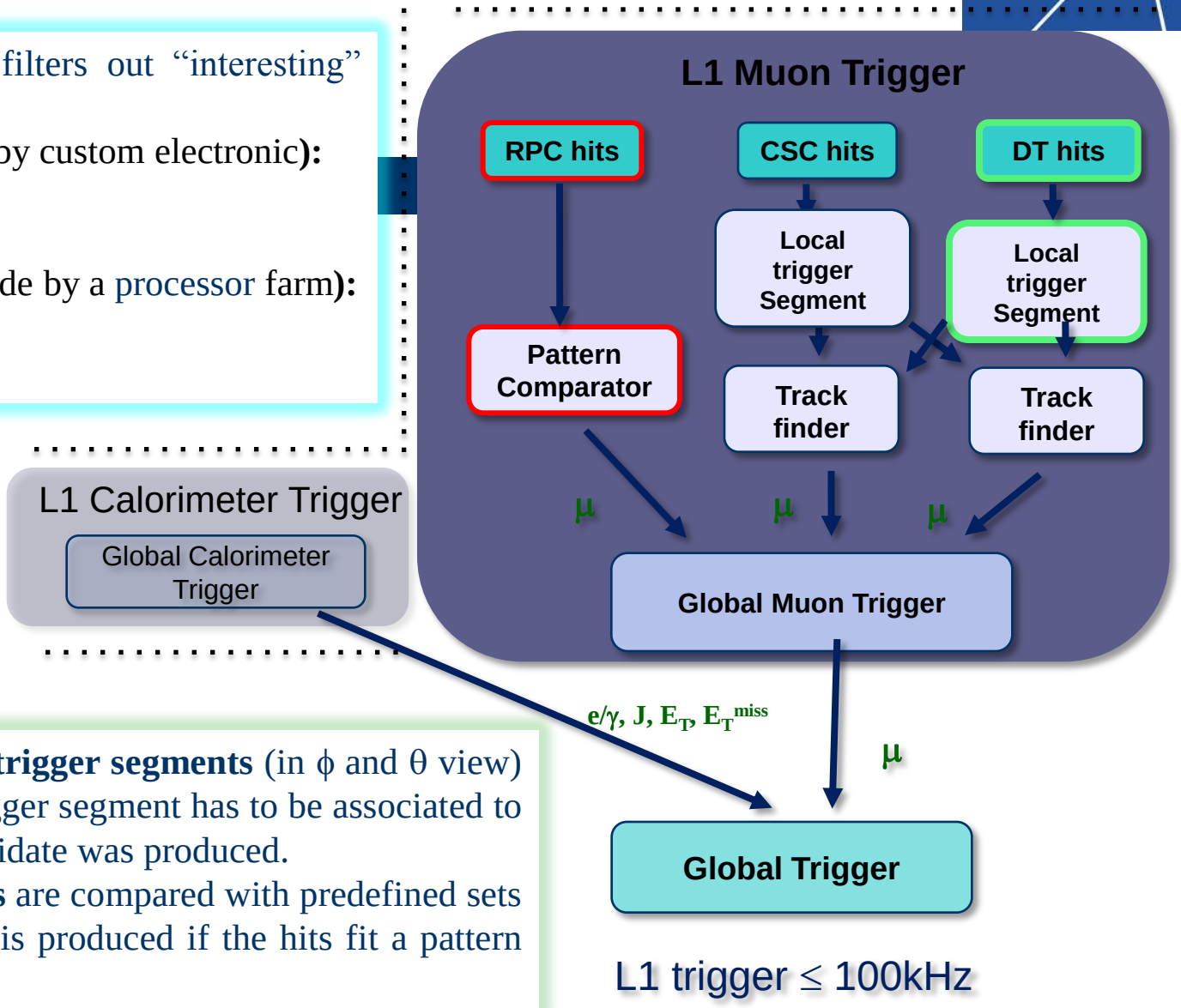

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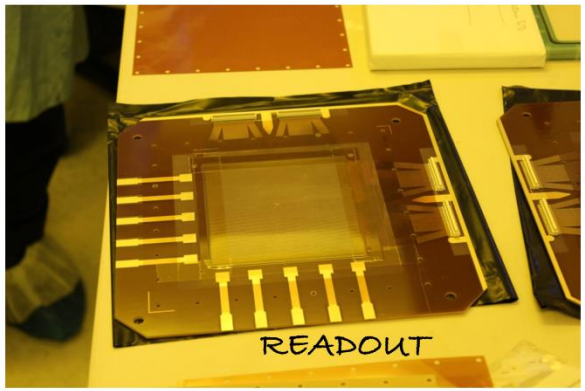
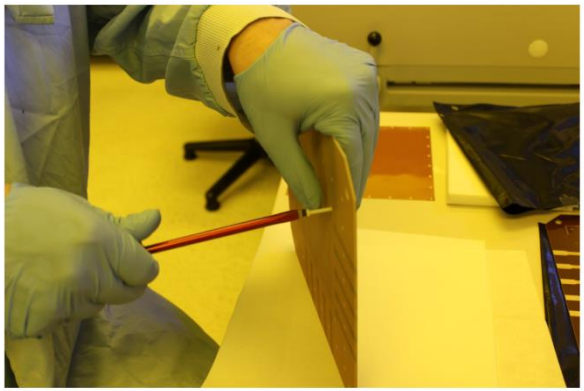
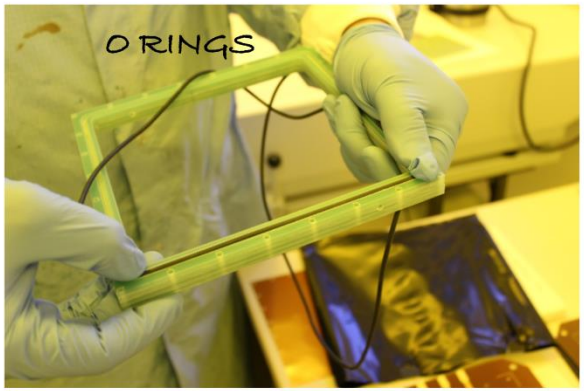
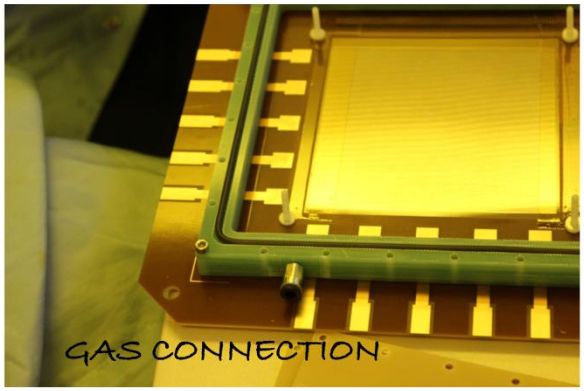
GEM Assembly-1

10X10 small prototype



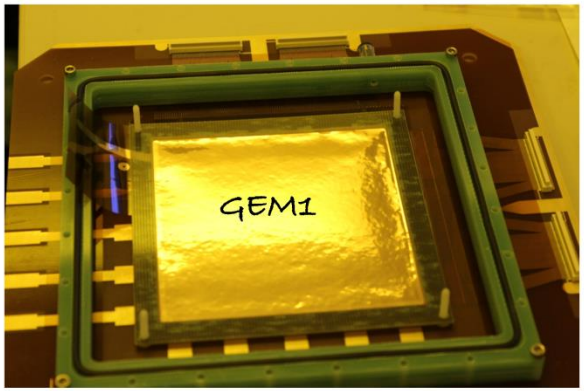


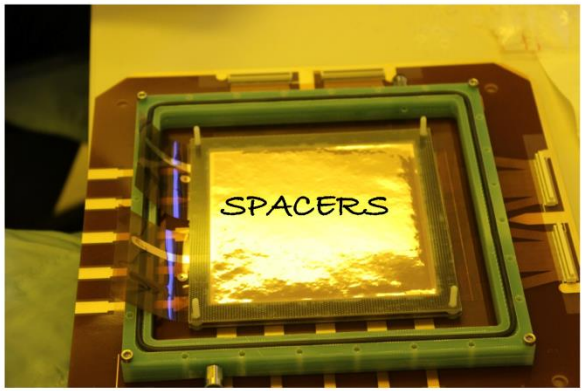


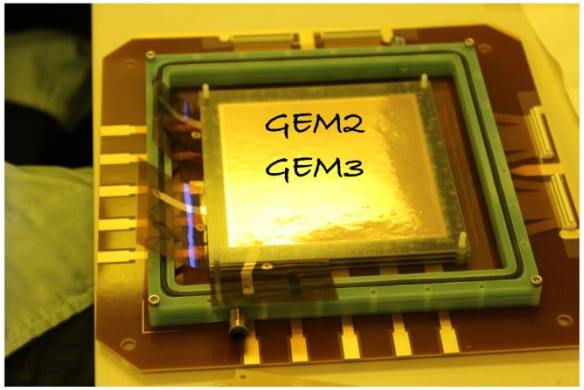


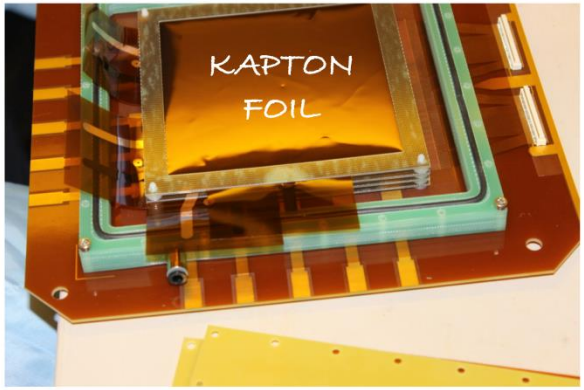
GEM Assembly-2

Building the "sandwich"





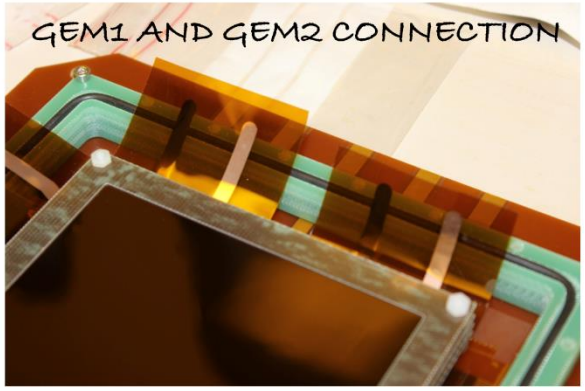




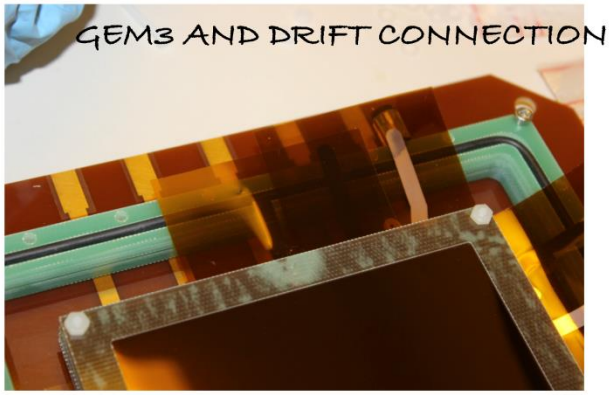
GEM Assembly-3

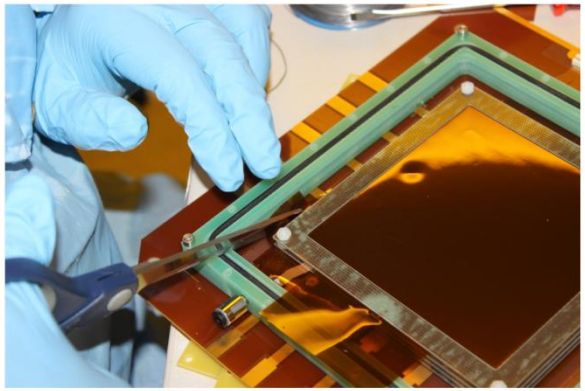
Soldering connections

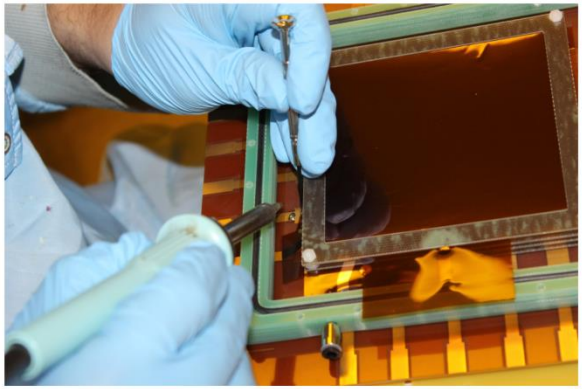
GEM1 AND GEM2 CONNECTION



GEM3 AND DRIFT CONNECTION

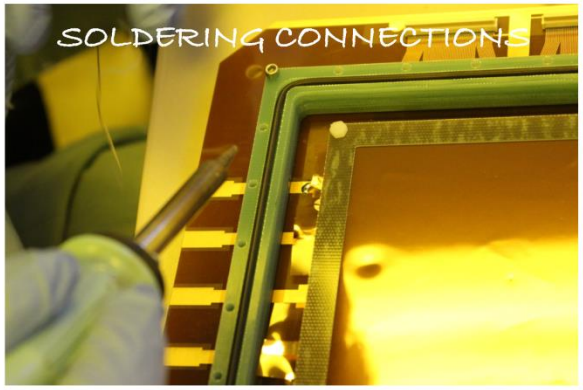


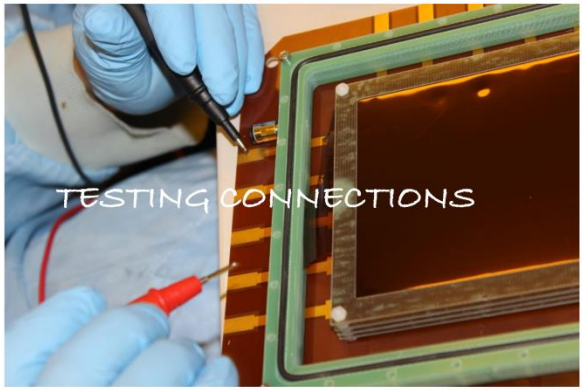


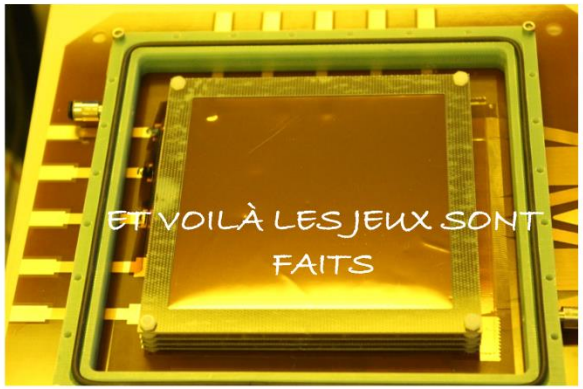


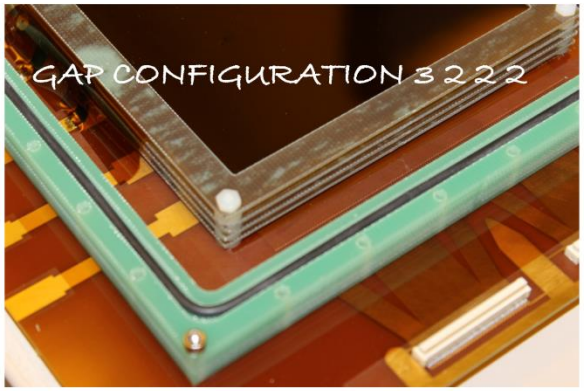
GEM Assembly-4

Testing connections

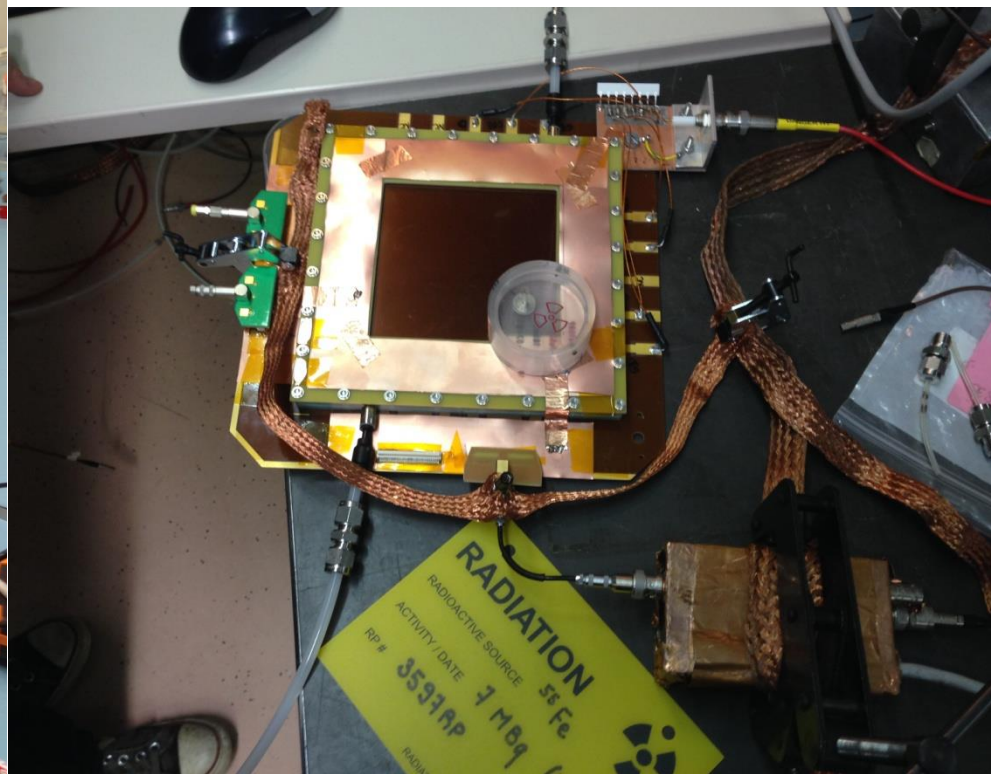








GEM Prototype for Egypt



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Summary

Interventions and maintenance of Barrel is DONE.

RE+4 is installed, cabled and intervened .

RE-4 is being installed starting April 25, 2014.

New Muon Detectors (GEM) are to be installed during LS2.

A GEM prototype has been assembled and tested for Egypt.

Thanks for attention