Muon Detectors
@ muon shifter training

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on behalf of the 4 muon detector communities

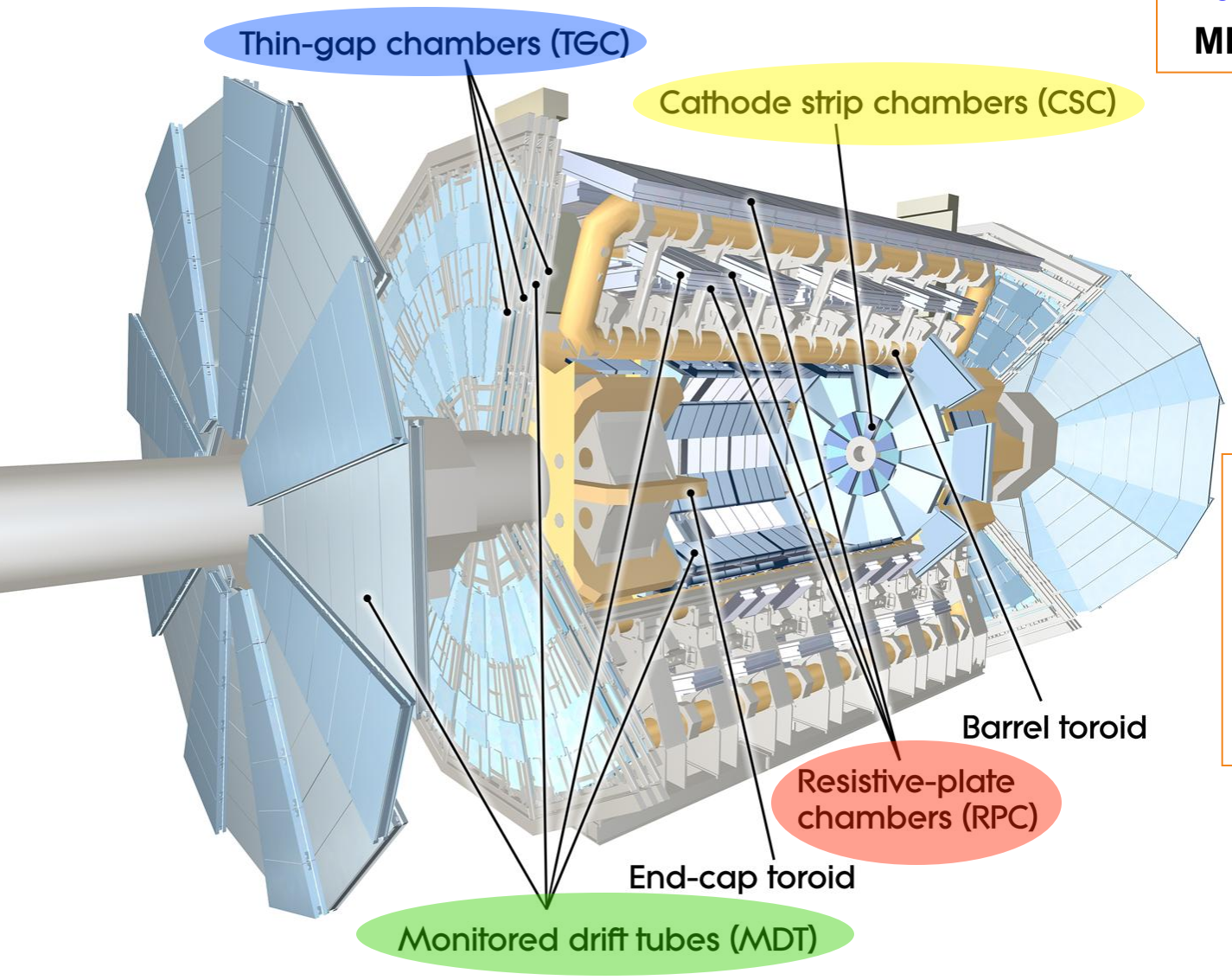
Muon System

air-core toroid magnets

4 chamber sub-systems

Trigger chambers:
RPC (~600), TGC (~3600)

Precision chambers:
MDT (~1200), CSC (32)



LV: for electronics

HV: for particle detection

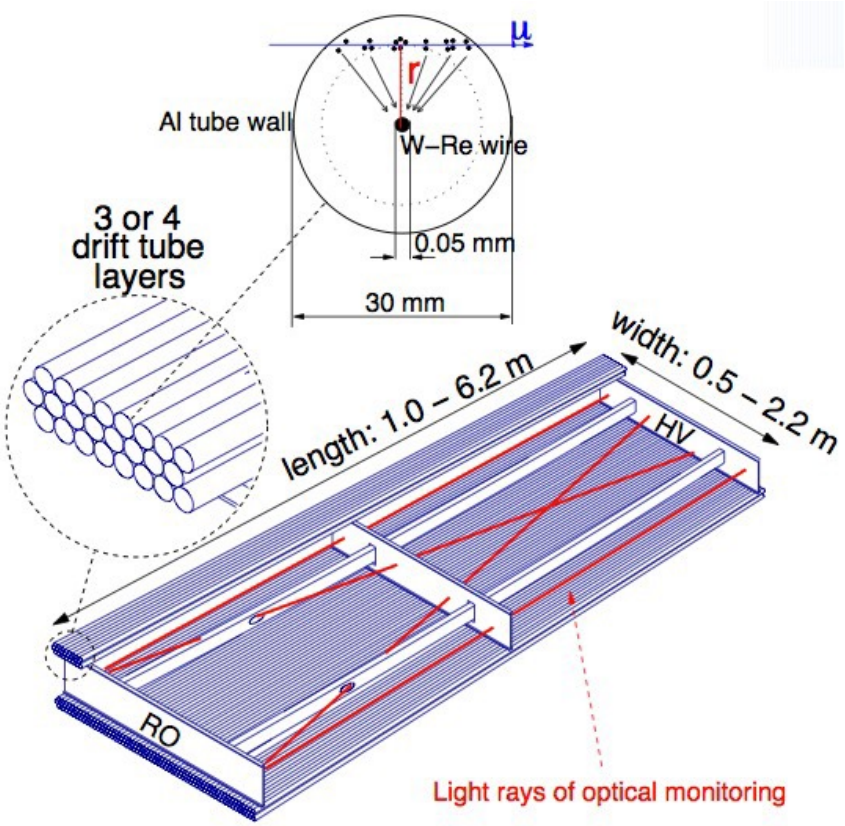
GAS: sensitive medium

B-field: momentum measurement

MDT

MDT Chambers: Principle of Operation

- MDT = Monitored Drift Tube Chambers
- Precision muon tracking detectors in both the Barrel and Endcap of the Muon Spectrometer.
- CSCs in in innermost (smallest r) region of the innermost (closest to the IP) endcap station

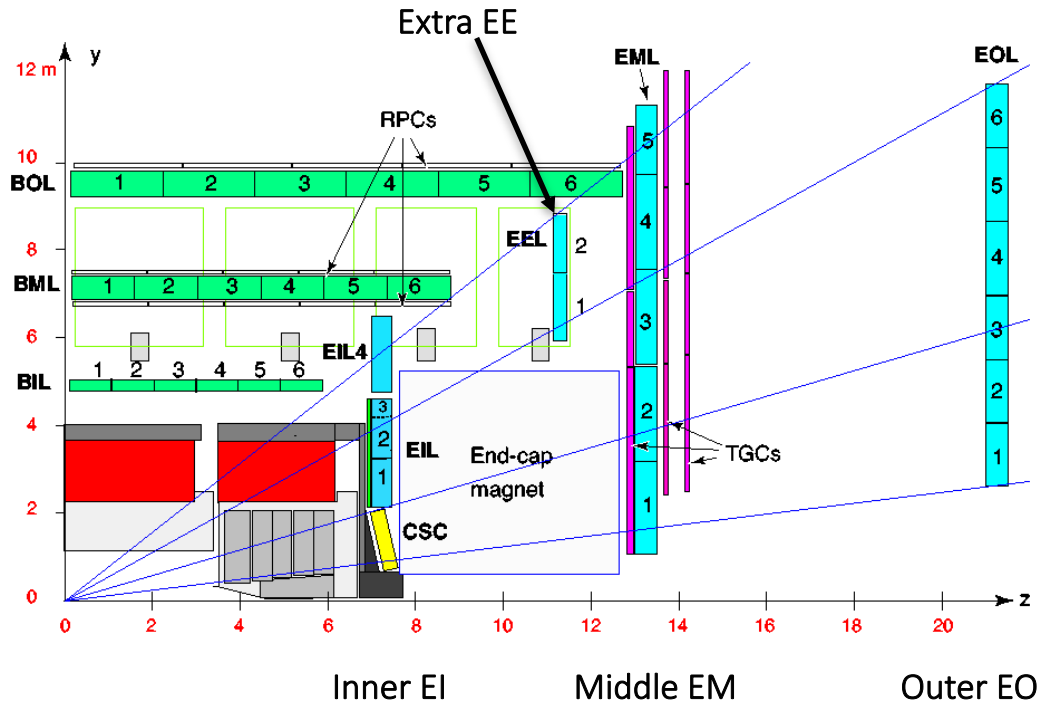


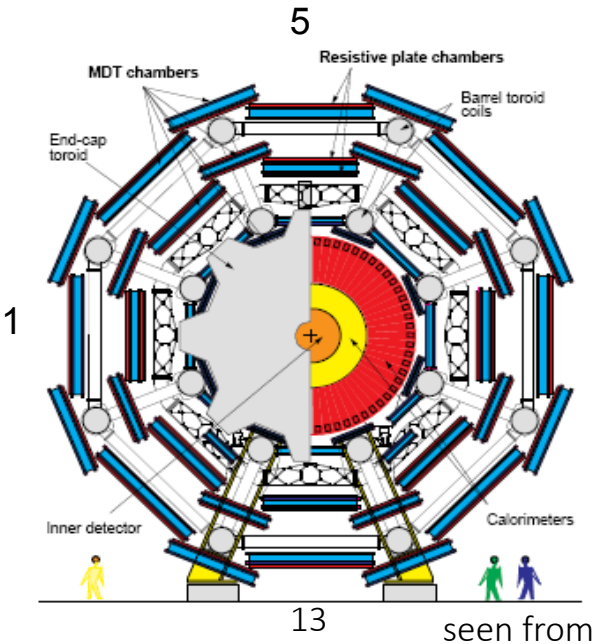
- **Drift tubes of 30 mm ∅ (15mm for BME)**
- **Gas gain $2*10^4$, nominal HV 3080 V**
- **Optical systems monitors deformation and chamber displacements: Alignment**
- **Operating gas Ar:CO_2 = 93:7, ~1000 ppm H_2O**
- **Operating pressure: 3 bar (abs.)**
- **Single tube resolution: 80 μm ⊥ to wire, no information on 2nd coordinate → RPC, TGC**

- Chambers have 2 multilayer = 2x3 or 2x4 tube layers, separated by the spacer
- Exceptions: BEE and BIS8 chambers have 1 multilayer (ML) only
- Total: 380 000 MDT tubes in ATLAS, 1154 chambers

Geometry, Detector Segmentation

Sides:
•ATLAS geometry is mirror symmetric to z = 0. Sides are names “A” and “C”
Layers:
•Muon stations are arranged in 3 Layers: Inner, Middle, Outer, (Extra)
•Barrel: Concentric Circles around the beam axis
•Endcap: Disks ⊥ beam axis

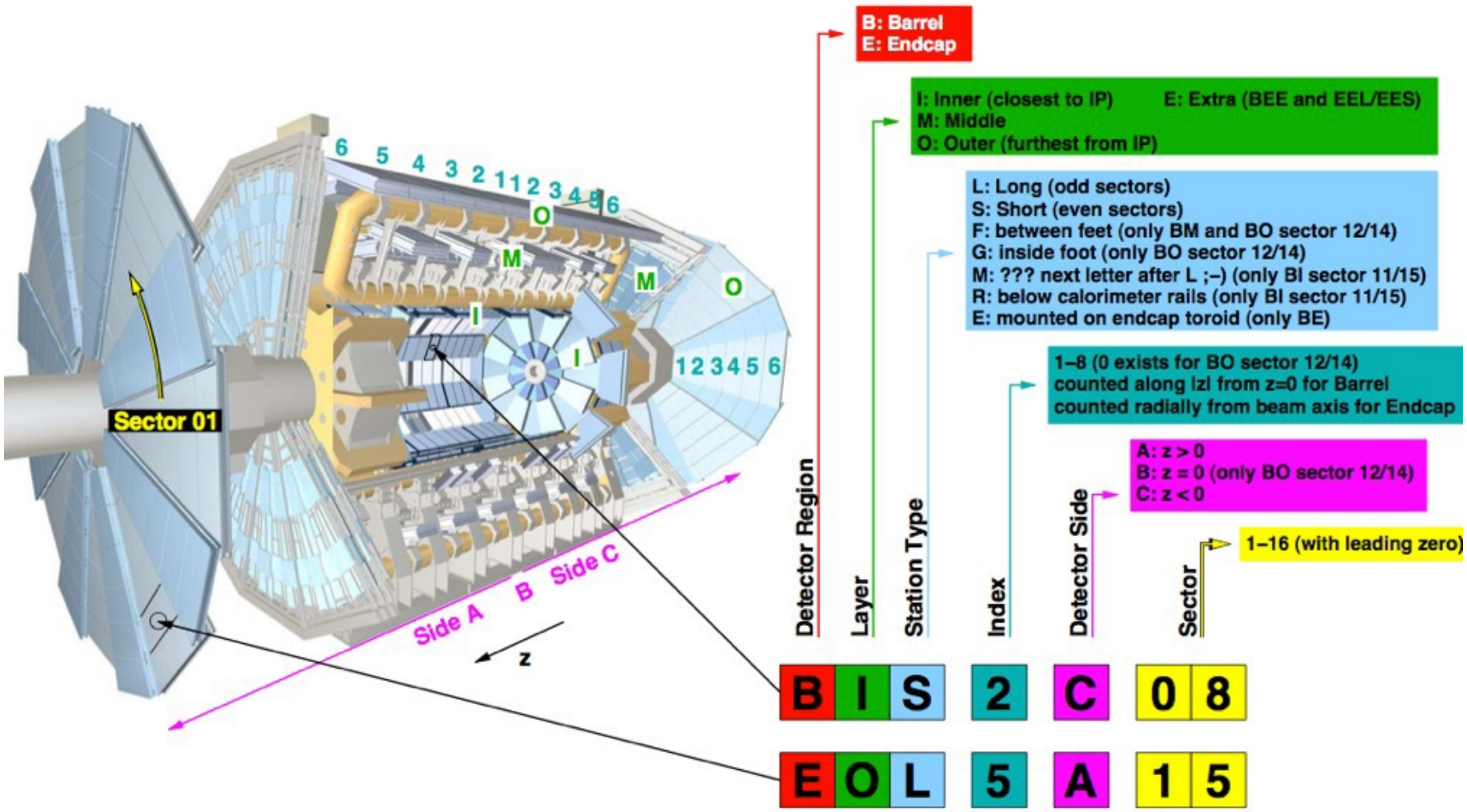




seen from the C side

Sectors:
•Azimutal position (ϕ) defines the sector
•Sectors 1-16 for MDT endcap and barrel (as for CSC, RPC. Note: TGC = 12 sectors)
Towers/Station Numbers:
•Identify a chamber within a sector
•Increasing along z for barrel chambers
•Increasing with r for endcap chambers (MDT only)

Naming Convention



- All MDT chamber names consist of 7 characters
- Chambers with same station Index (and same side) form a projective tower = crossed by tracks from the IP. Losing eg 2 MLs in the same tower = hole in coverage/momentum rec.

New stations
(BME, BOE, BMR and BOR)

BME, BOE are stations installed during the LS1 period to "plug" acceptance holes

- **2 BOE stations are BOS type MDT chambers, each with a RPC plane**
- **They are located in sector 13, below the BOL3 on sides A,C**

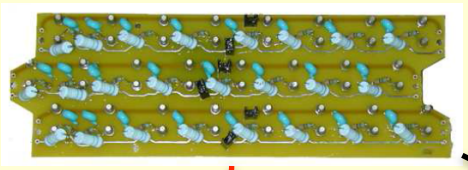
- **2 BME stations are small tube MDT (sMDT) chambers**
  - **tube diameter 15mm → drift time spectra different, different HV**
  - **2 RPC planes each**
- **They are located in sector 13 Middle layer, closing the hole of the missing BML4's**

- **BME and BOE RPCs are equipped with a double readout for Upgrade studies – 2nd readout is via MDT system DAQ**
  - **Within MDTs, these chambers are named BMR and BOR (R = RPC)**
  - **BMR and BOR issues → RPC on-call expert**

Part of MDT readout, but they are RPC chambers

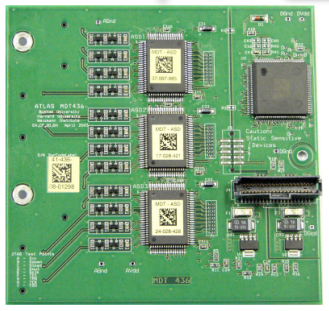
On-Chamber Electronics

Readout/Signal Chain

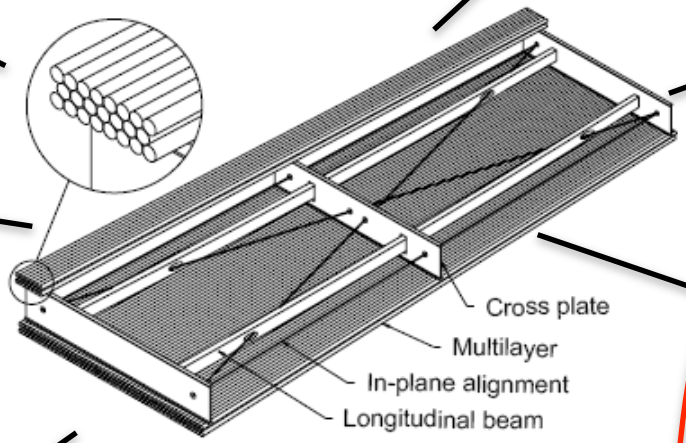


1. Hedgehog cards (passive)
HV distribution. HV decoupling. Signal routing.

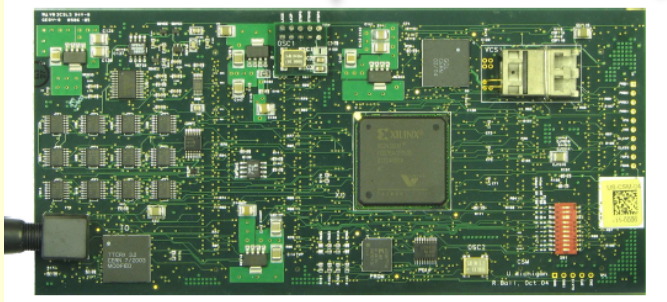
Front-End



2. Mezzanine
Amplifier-Shaper-Discriminator (ASD): 3/card, each handles 8 tubes
TDC (AMT): 1 per card, handles 24 tubes



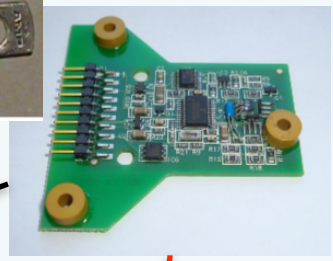
1 CSM/chamber



3. Chamber Service Module (CSM)
Multiplexes data from up to 18 mezz cards into a single data stream
Buffering of data, send data to ROD on receipt of L1 Accept.

DCS Chain

4. T/B probes



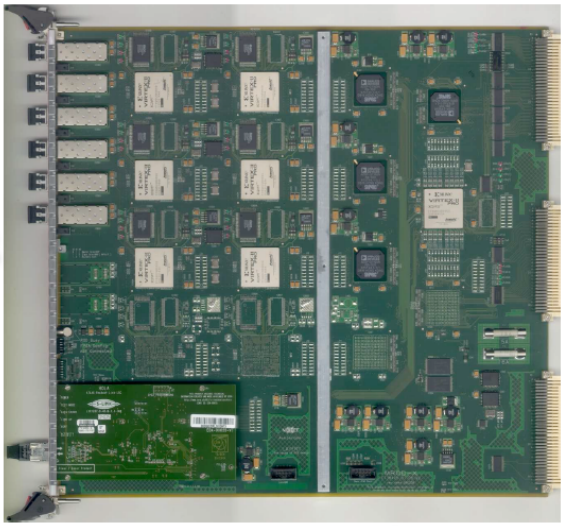
5. MDT DCS Module (MDM, ELMB)
Control/readout magnetic field and T-probes. Readout Mezz Voltage/ Temps info. Control CSM during configuration load

Off-Detector Electronics: Readout

MDT example, similar for other detectors

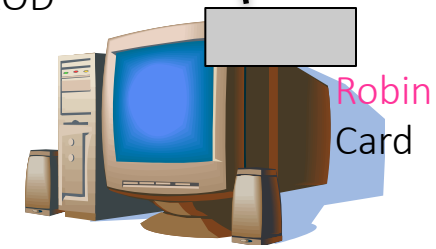
6(5) x

Optical fibers: TTC + readout



(M)ROD module (~200 total)
9U high VME card
Collect data from several chambers, build ROD fragment

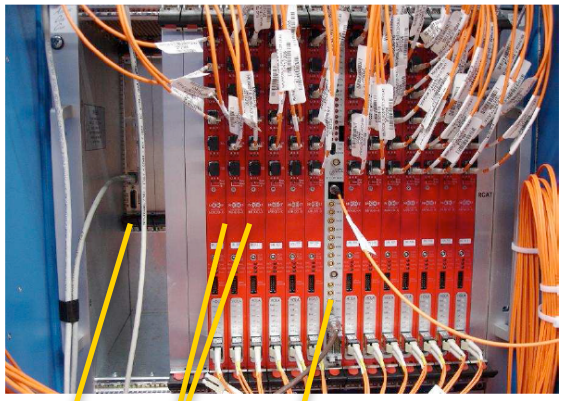
Optical 1(2) x



Robin Card

ROS

Event Fragment Building



SBC MROD TIM

ROD Crate

MROD VME Crates (16 total)

TTC Crate (Trigger and Timing Control)

Central Trigger Processor (CTP) and LHC Clock

ROD: Readout Driver
ROS: Readout system
ROBIN: Readout Buffer In

CSC

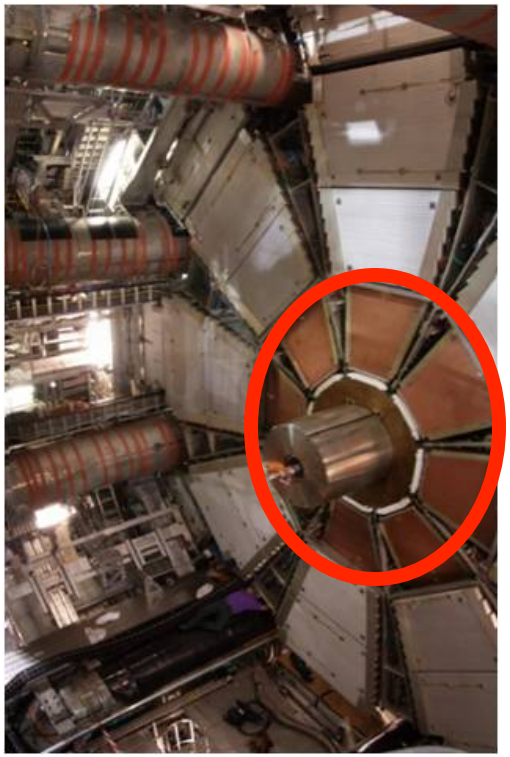
Cathode Strip Chambers (CSC)

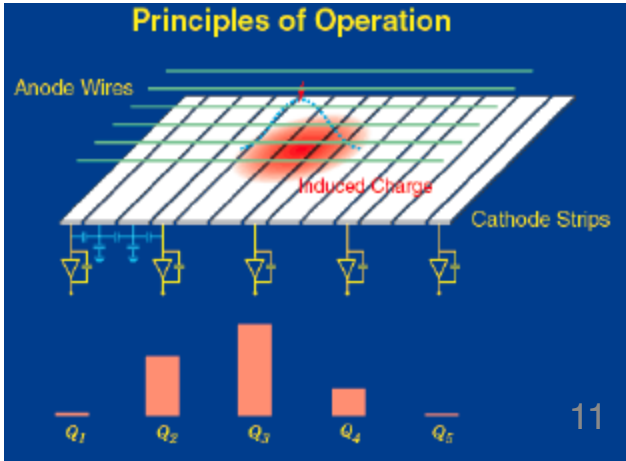
- CSC are multiwire proportional chambers and are operated using Ar/C02 (80%:20%) at atmospheric pressure

- CSC are located in the innermost layer of the EndCap system of the Muon spectrometer covering the region of $2.0 \leq \eta \leq 2.7$

- The position is measured by the induced charge on the segmented cathode strips by the avalanche formed on the anode wire

- The Front-End electronics cooling is water based and its temperature is monitored



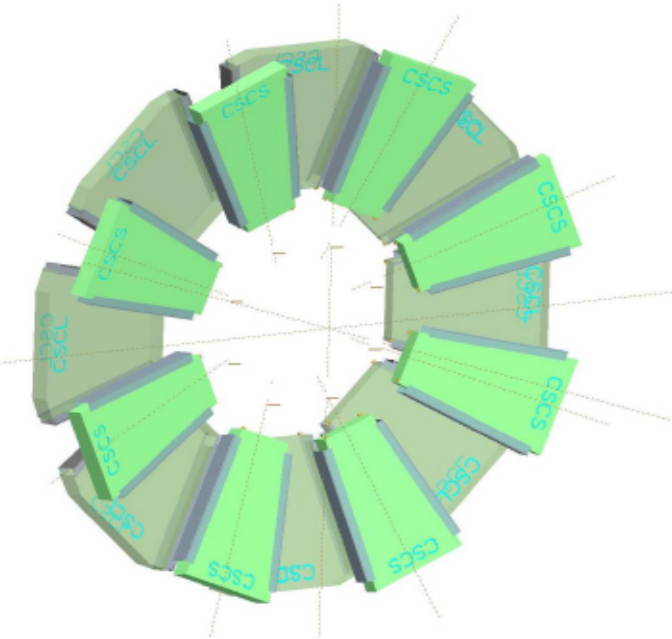


CSC (2)

- There are 16 chambers per wheel of two kinds, large and small, partially overlapping and alternating

- Each chamber has 4 precision (**η)** and 4 transverse (**φ**) layers

- Each η layer has 192 channels and each φ has 48, with different strip sizes



- Each η layer is readout by one on-detector electronic module (ASM, amplifies-shapes-transmits the information) and the 4 φ layers by one ASM board

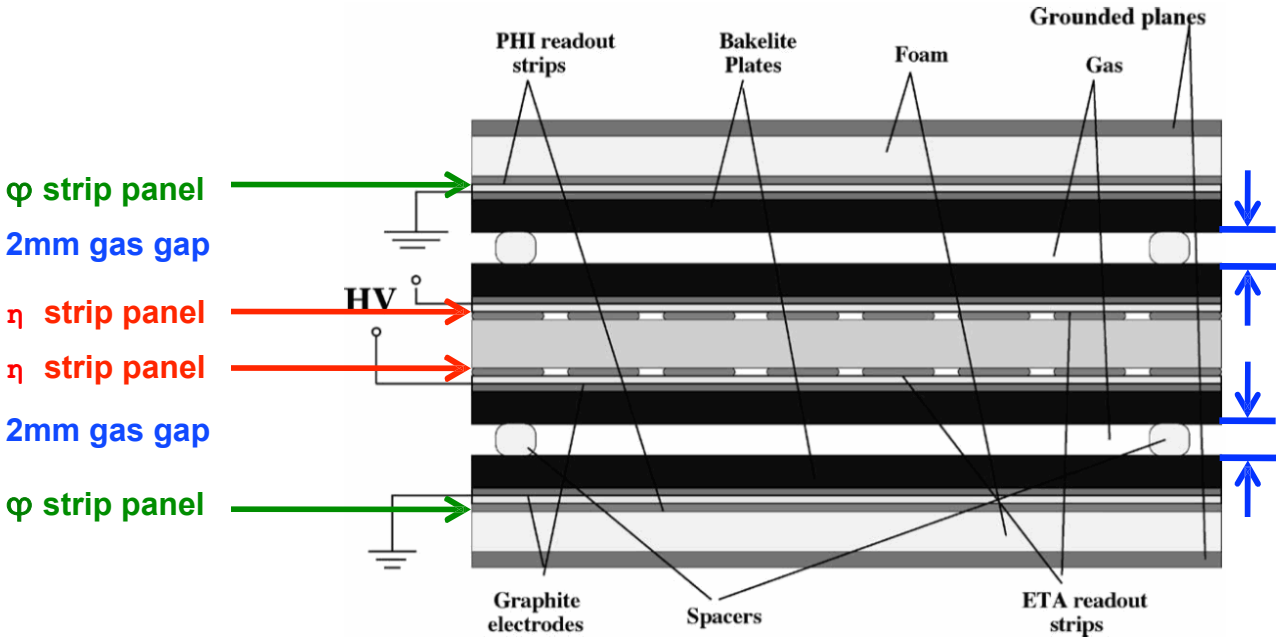
- The Low Voltage (LV) powers on the ASM boards, whereas the High Voltage (HV) powers on the chambers

- The data are transferred from the on-detector electronics to the off-detector electronics via optical links and control optical links are used for the communication of the electronics

- New off-detector readout system still needs operational experience

RPC

RPC detector description



RPC = Resistive Plate Chambers
Each chamber contains a **double-layer** of RPCs, layer 0 (closer to IP) and layer 1

Each layer is made of **gas volumes with 2mm gaps** flushed with a mixture of $C_2H_2F_4$(94.7%) : **iso-**C_4H_{10} (5%) : SF_6 (0.3%) and operated in **avalanche mode** at a nominal voltage of **9.6 kV**

Each gas volume is equipped with **2 panels of readout strips** 25-35mm wide in orthogonal coordinates (**η**,**φ**). Strip signals are read out by the front-end electronics connected at the strip edge and encapsulated in the chamber box

RPC signals are used to provide **trigger** and **azimuthal coordinate** of the muon tracks

RPC detector - LVL1 – DAQ segmentation and numbering scheme

Three layers of RPC chambers arranged in **16 barrel sectors**:

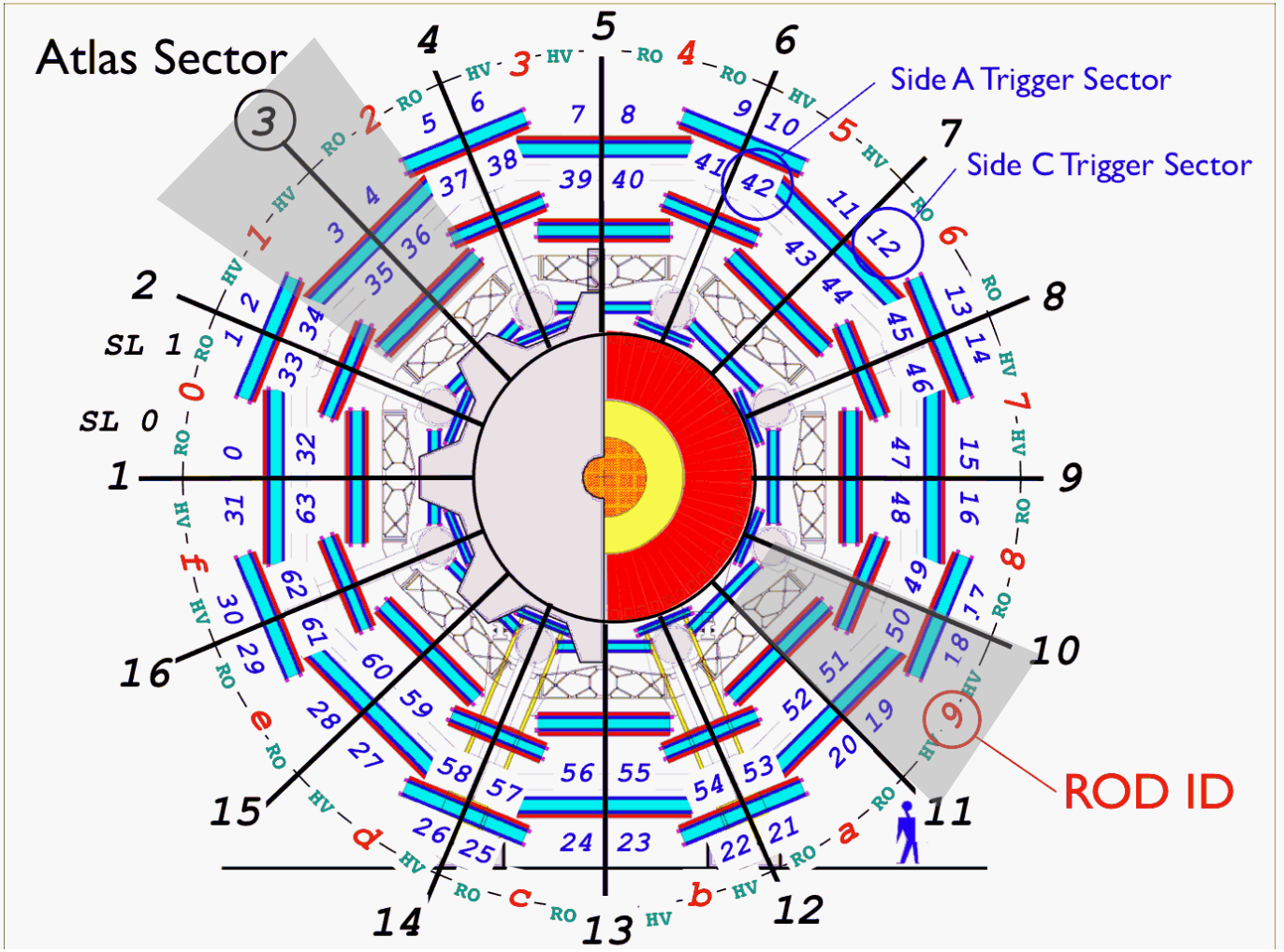
2 in BM stations

- **BM Confirm** (RPC1)
- **BM Pivot** (RPC2)

1 in BO stations

- **BO Confirm** (RPC3)

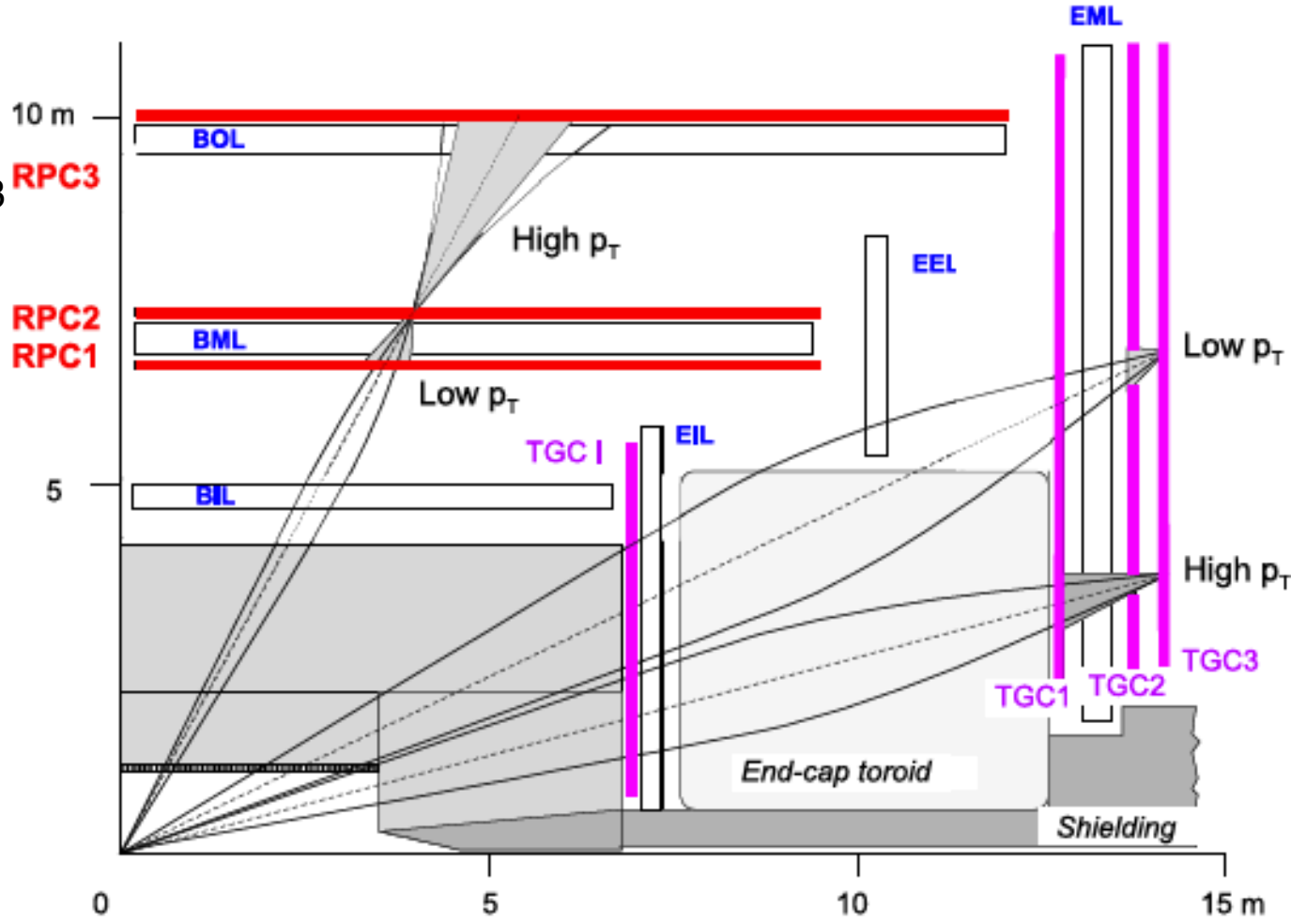
No RPC in BI stations



RPC L1 muon barrel trigger scheme

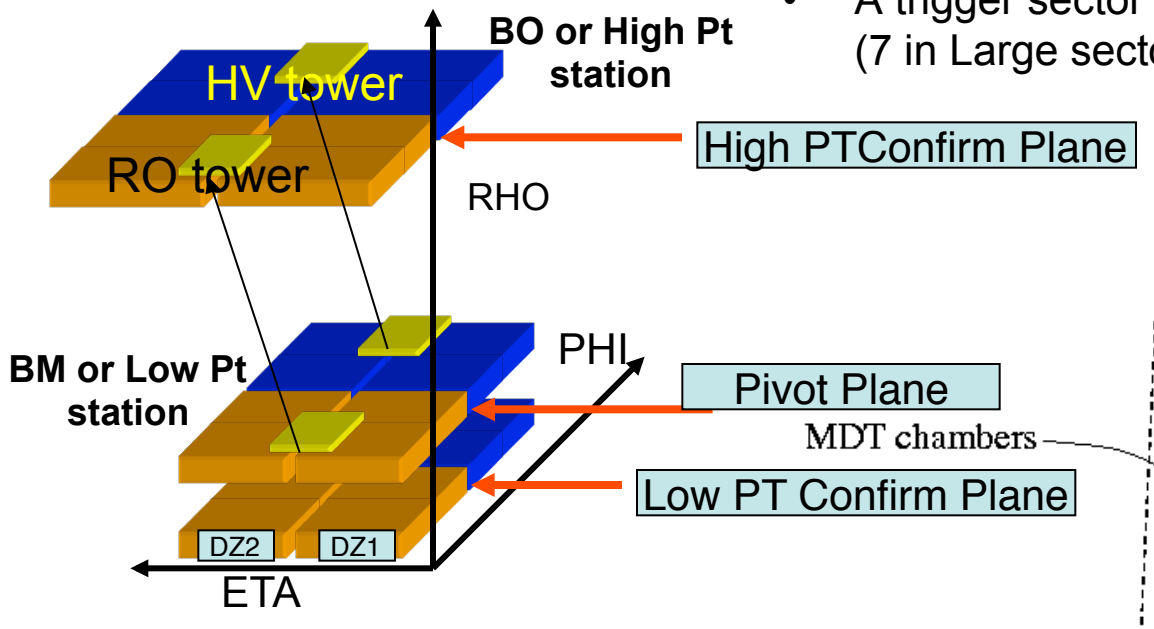
High-p_T
Low-pt && >=1 hit on RPC3

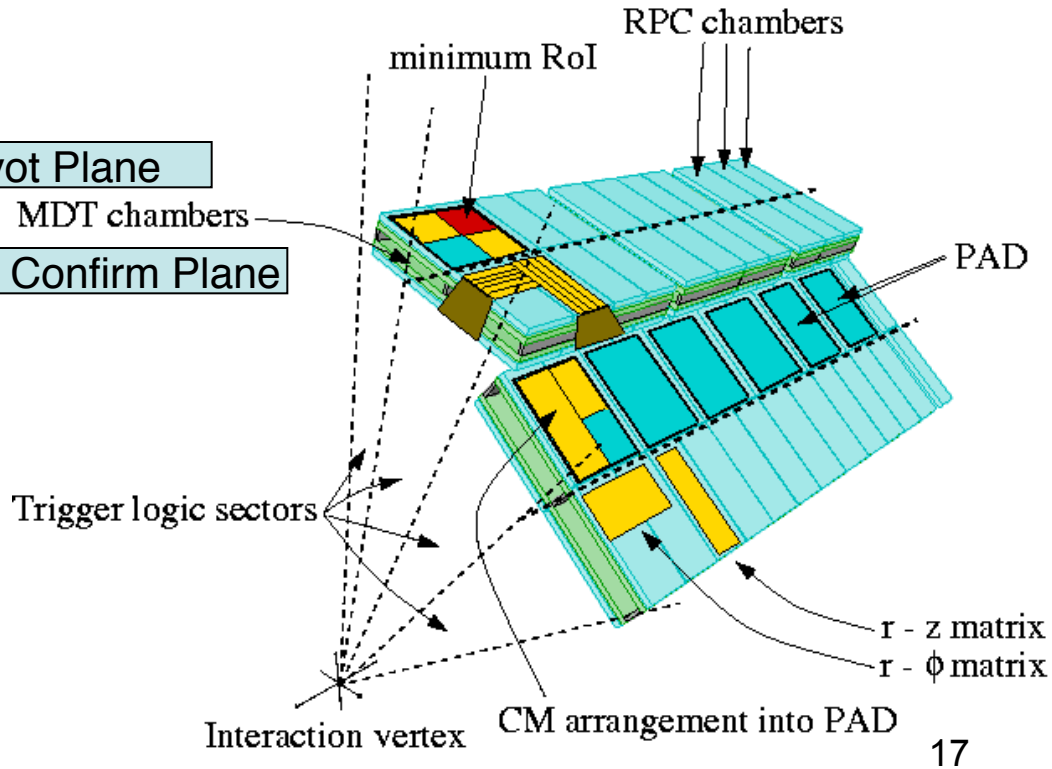
Low-p_T
3/4 hits on RPC1, RPC2



RPC reference frame in a barrel muon station

- A barrel sector is segmented in 2 **trigger sectors** / side
- A trigger sector is segmented along **η** in 6 (7 in Large sectors) **trigger towers** i.e. PADs





A **PAD** or **trigger box** corresponds to 2 **η**-CM and 2 φ-CM

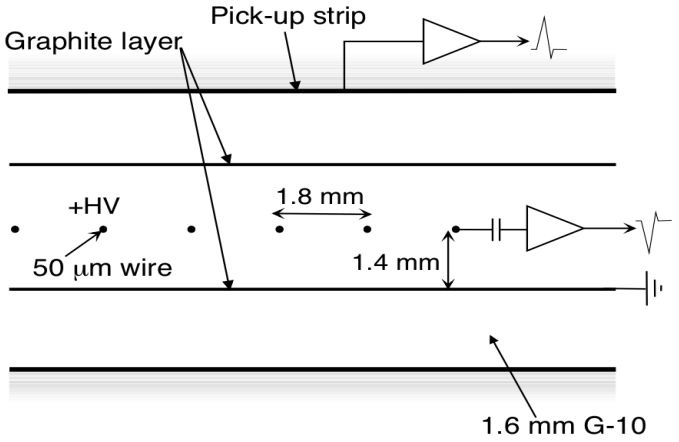
A **RoI** is defined by the overlap of an **η**-CM with a φ-CM

TGC

TGC : Principle of operation

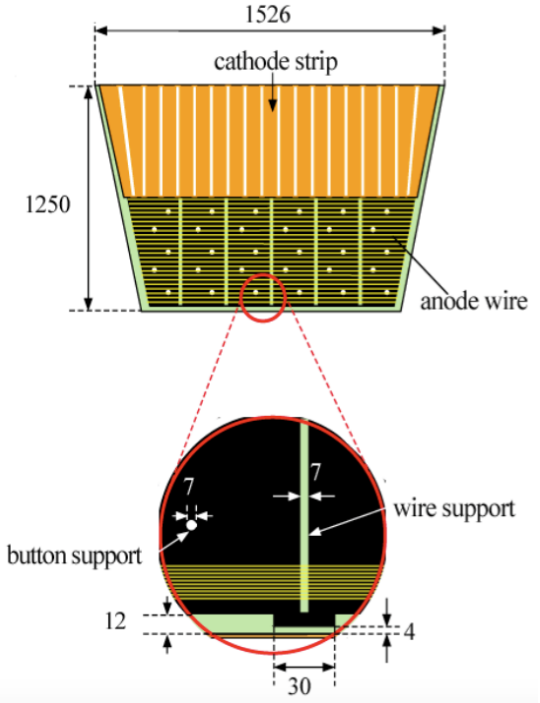
TGC : Thin Gap Chamber

- MWPC, with very thin gap
  - 1.4 mm wire-cathode gap
  - enables good time resolution
    : for Muon trigger in the endcap region



Operation parameters

- Gas gap : 2.8 mm
- Wire pitch : 1.8 mm
- Wire diameter : 50 μm
- Wire potential : 2800 V
- Gas mixture : CO_2 (55%)+ n-pentane (45%)
- Gas amplification : $3x10^5$



TGC : geometry

Layer structure

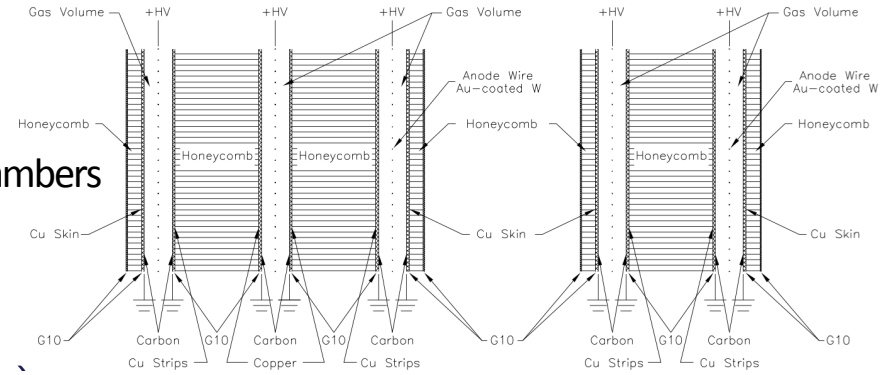
- triplet, doublet (=3, 2 gas volumes)

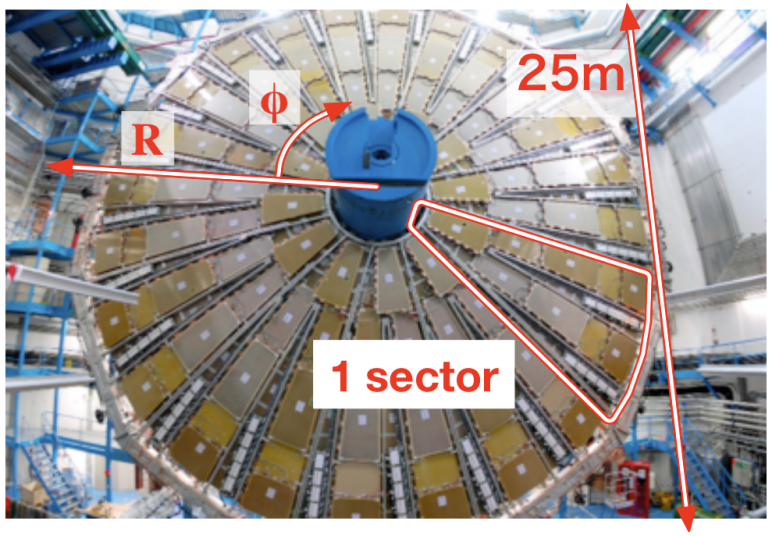
Stations (=wheels)

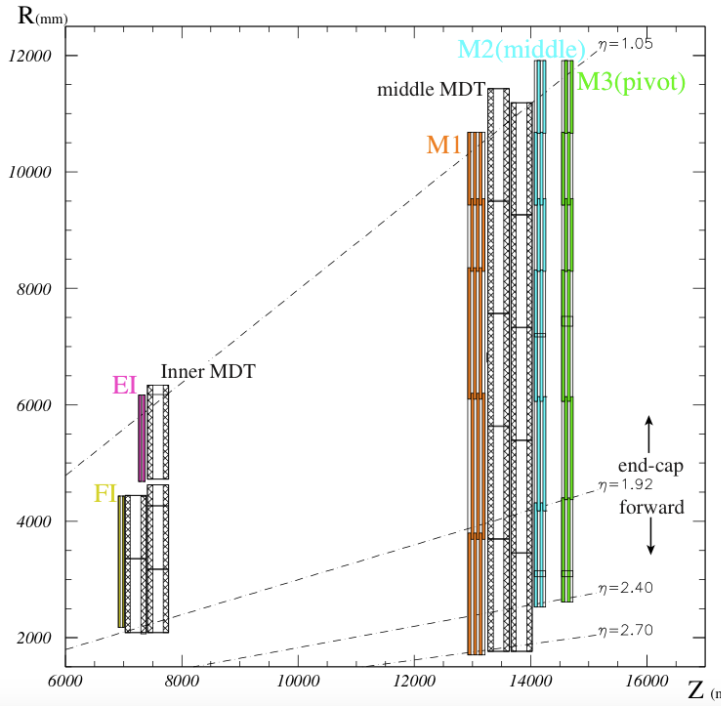
- BW
  - M1 : triplet
    - no strip in the middle layer
  - M2, M3 : doublet
- Inner Station
  - EI, FI : doublets

Segmentation

- 12 Sectors in one side
- Sub-segmentation : chambers
  - Phi : x4
    - phi0 - phi3
  - R : Endcap, Forward
    - E1, E2, E3, E4(, E5)
    - F







Muon EndCap Trigger by TGC

Trigger sectors separation

- 4 trigger sectors in Endcap, 2 in Forward for one TGC sector
- 148 sub-sectors in one trigger sector

Triggering

- Based on coincidence among M1 - M3
- Decision : 7 layer coincidence
- pT calculation : with ΔR, Δphi between M1 and M3