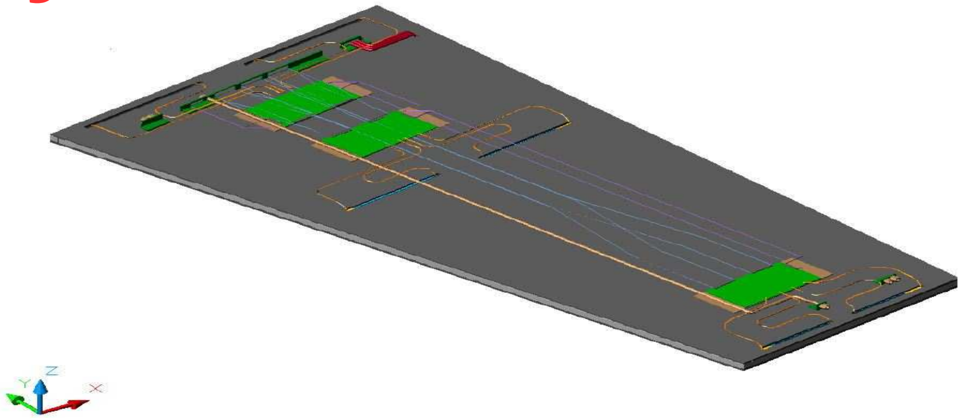
RPC Muon System

612 total chambers
Six barrel stations in radius

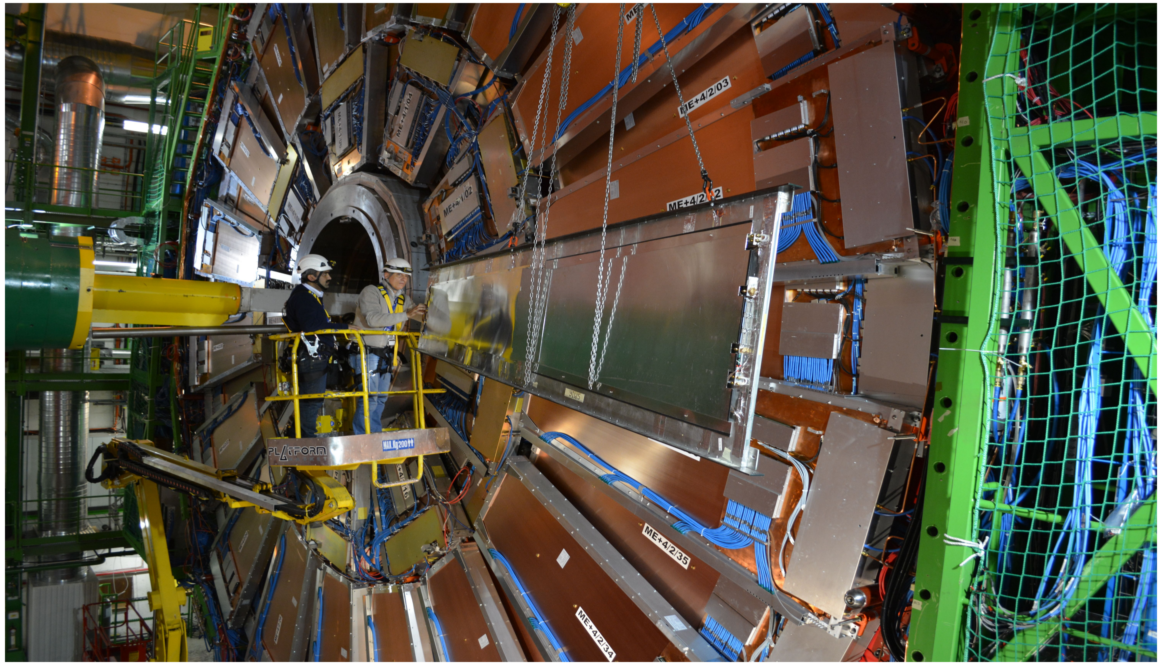
- **Long strips in barrel ⇒ high intrinsic noise rate (~50 Hz/cm^2)**
- **Linseed oil applied to surfaces to reduce noise**
- **Trigger makes use of all 6 stations**

Four endcap stations in z

- **Rate capability to 1 kHz/cm^2 using avalanche mode**

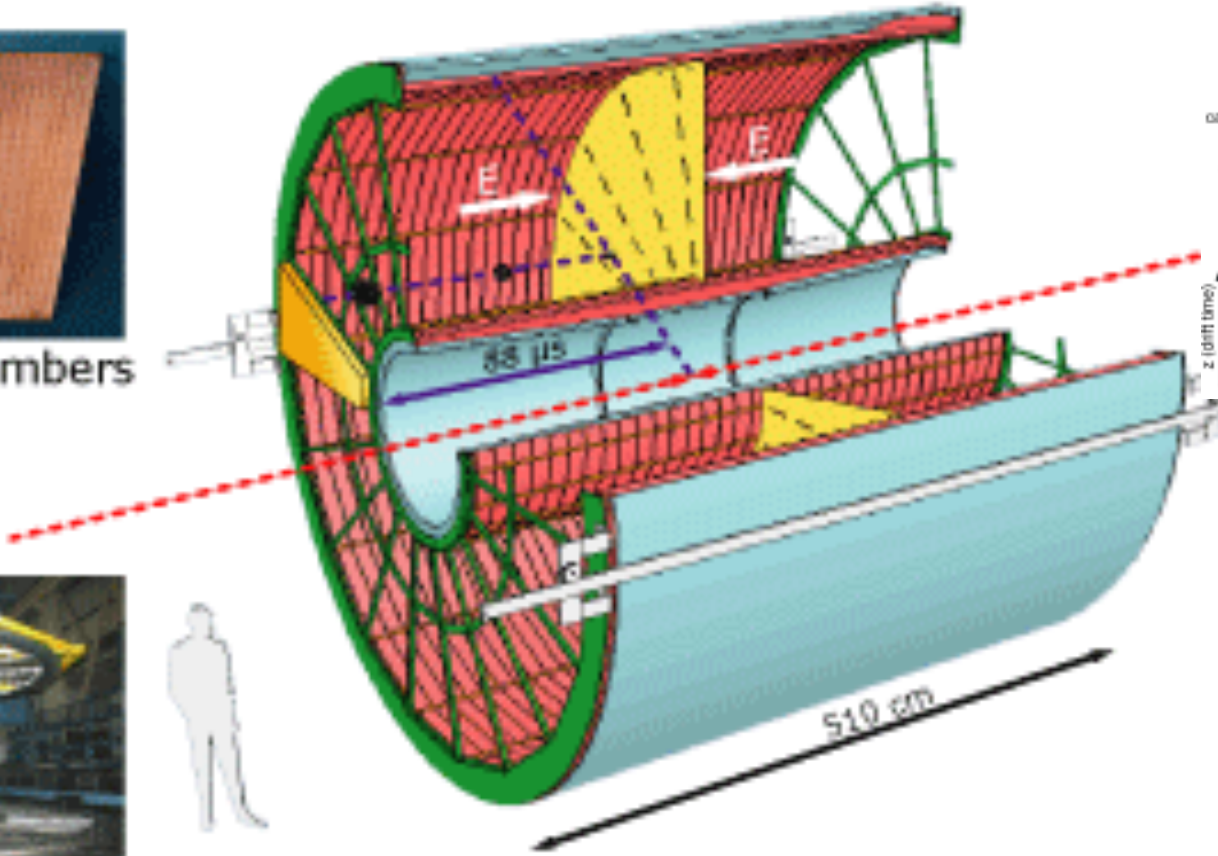


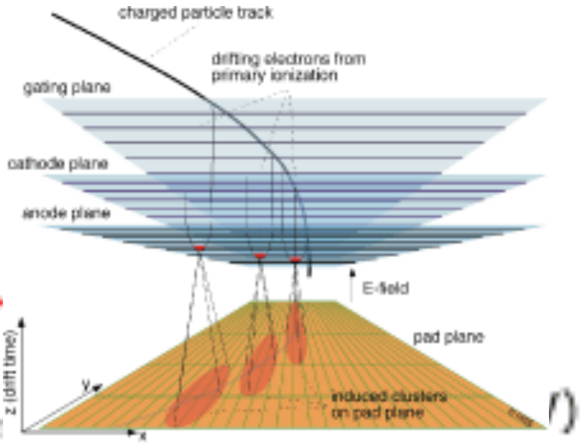
Schematic layout of an endcap chamber



ALICE MWPC TPC ENDCAP

Readout Chambers





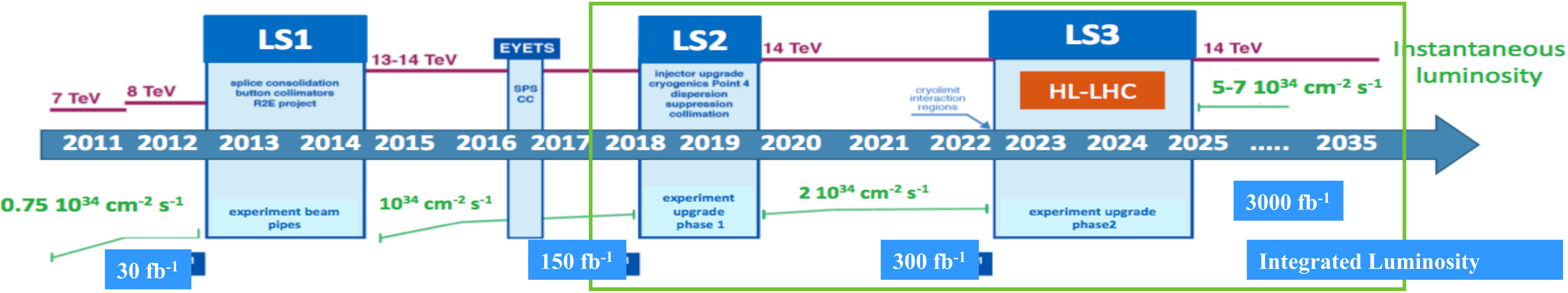
End Plate

GAS VOLUME: 88 m3

DRIFT GAS 90% Ne - 10% CO2

Field Cage

Phase 2 Upgrades towards HL-LHC



A new machine, for high luminosity, to measure the H couplings, H rare decays, HH, Vector boson scattering, other searches and difficult SUSY benchmarks, measure properties of other particles eventually discovered in Phase1.

Goal: keep the same performance as in Run 1 at least !

CMS Upgrades

- New tracker (4 pixel layer +3 disks), Track information at L1
- Calorimeters with higher granularity

$|\eta| < 3$

+ Muon : Gaseous detector upgrades

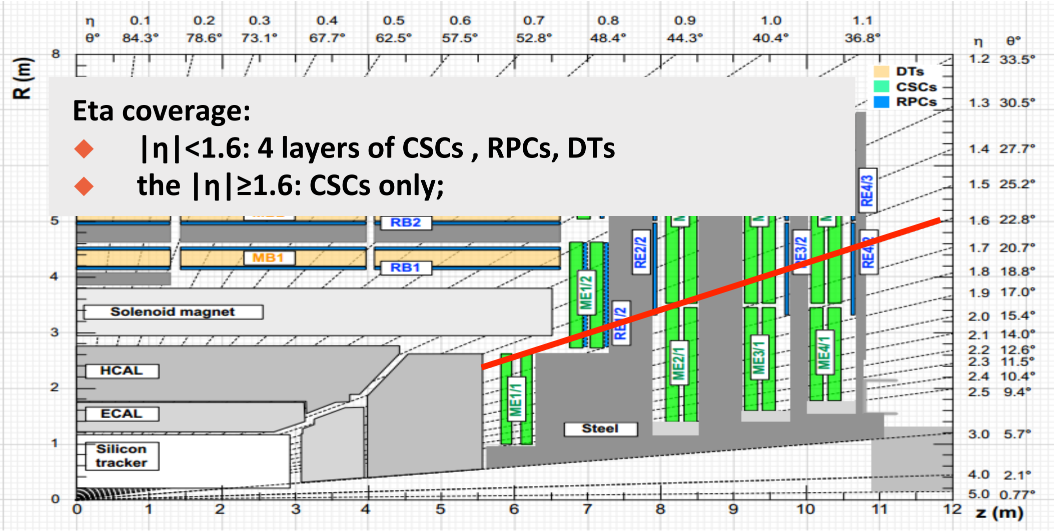
Forward muon system challenges

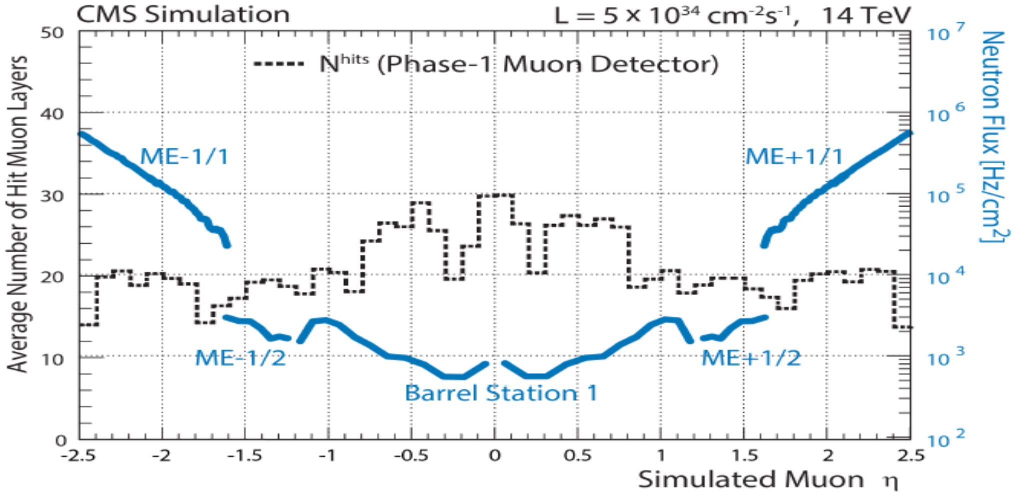
The forward region |η|≥1.6 is very challenging

- **Redundancy**: the highest rates in the system vs fewest muon layers
- **Rate** : in 100's of kHz/cm^2 and higher towards higher eta and worse momentum resolution

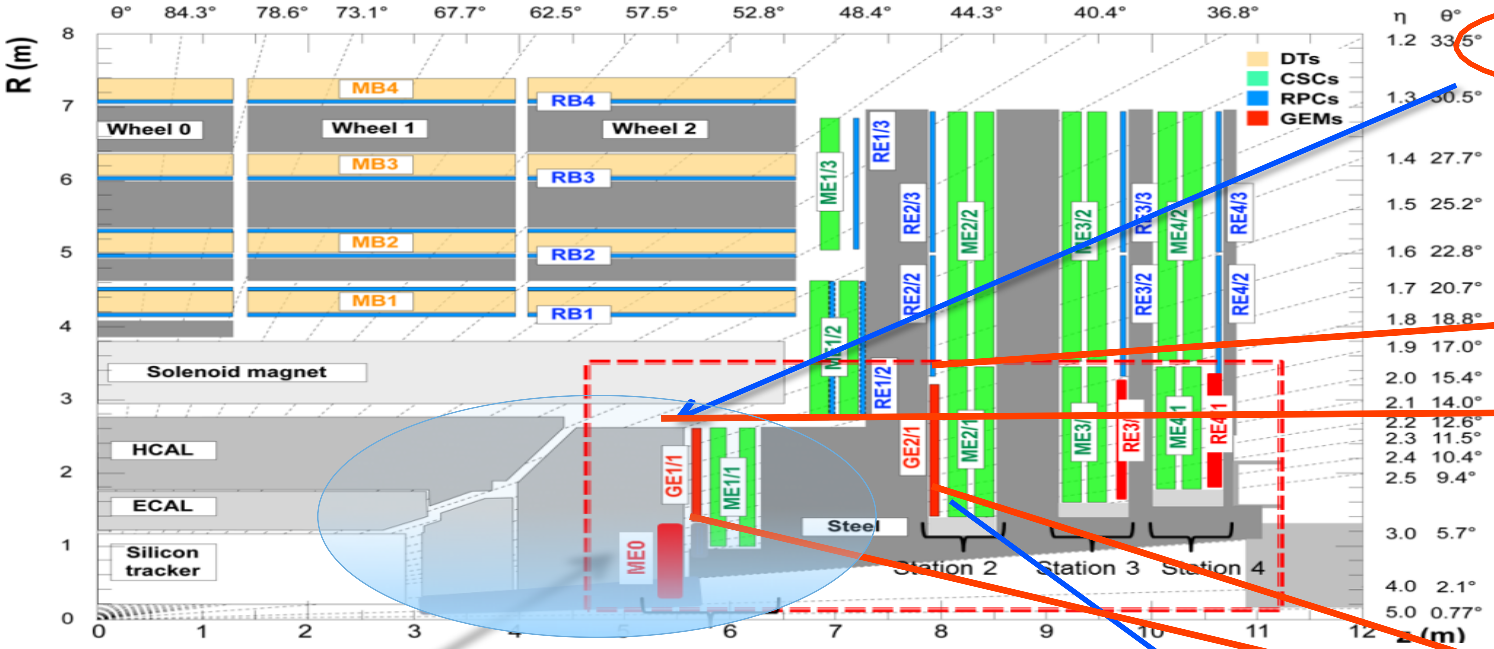
  → already a challenge post LS2.

- **Longevity:** Accumulated charge ~C/cm after many years of LH operation
- **Electronics:** High occupancy/rate and latency increases exce capabilities of the existing electronics





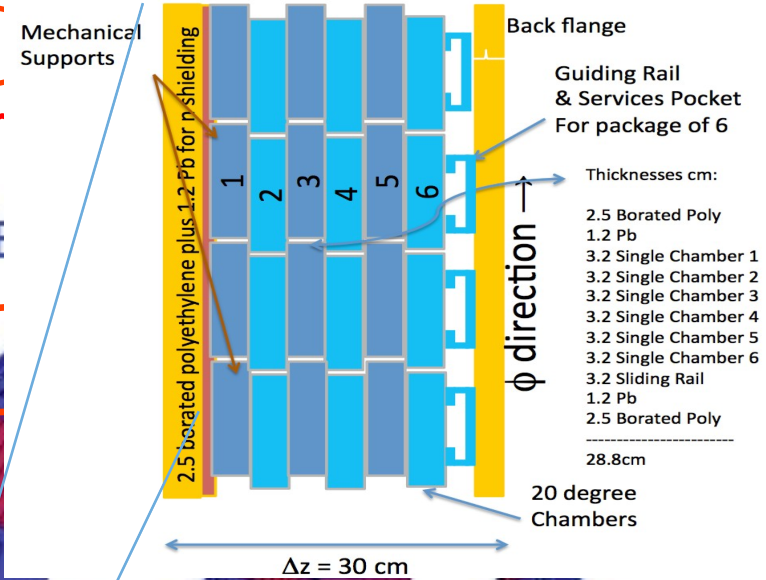
Forward muon system enhancement

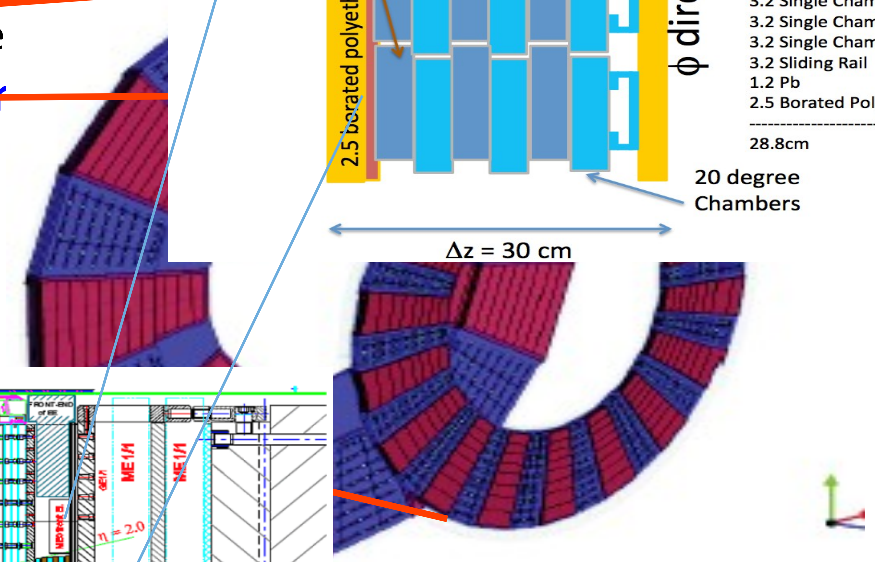


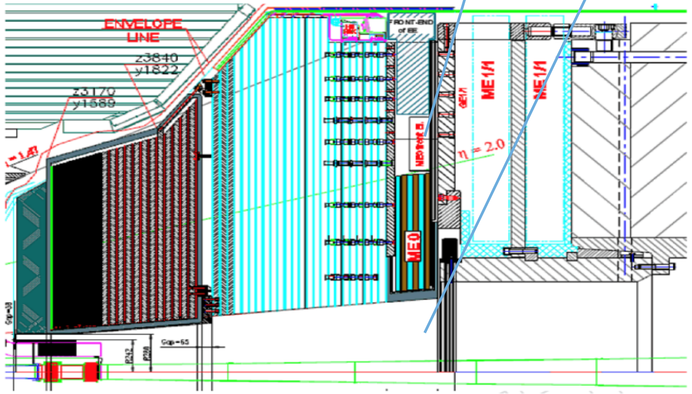
GE1/1:

Trigger and r

- 1.55 < |η
- b
- 3(
  e
- Ir







h chamber

ME0:

Triggering and reconstruction

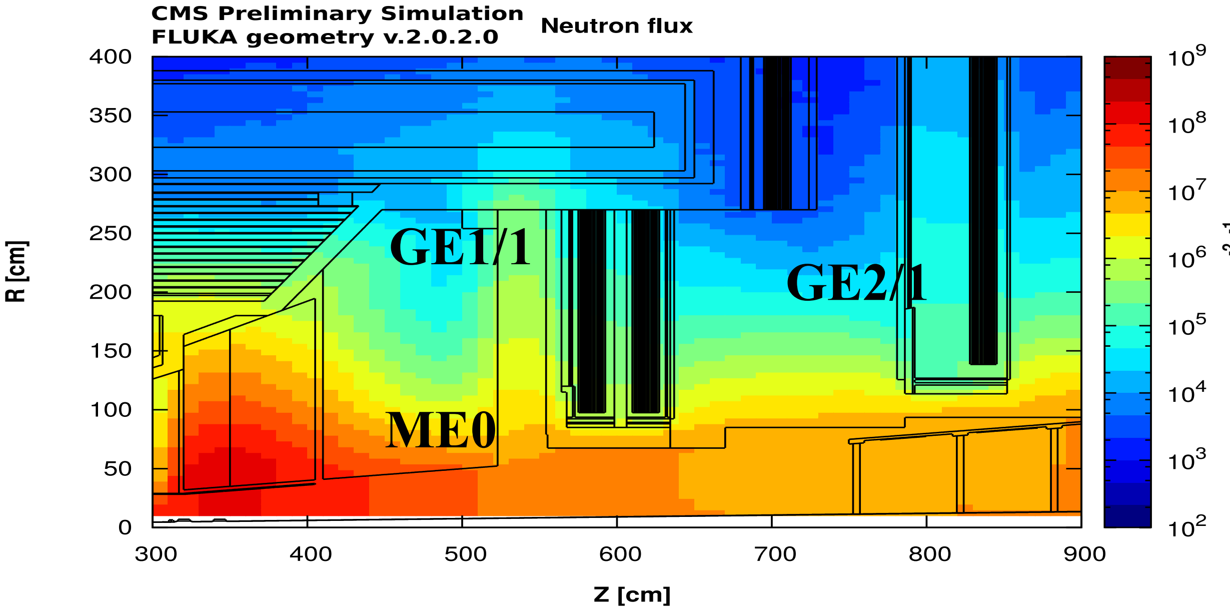
- at highest η: 2 < |η| < 3
- 6 layers of Triple-GEM
- each chamber spans 20°
- Installation: LS3 (2022-24)

- Installation: LS3 (2022-24)

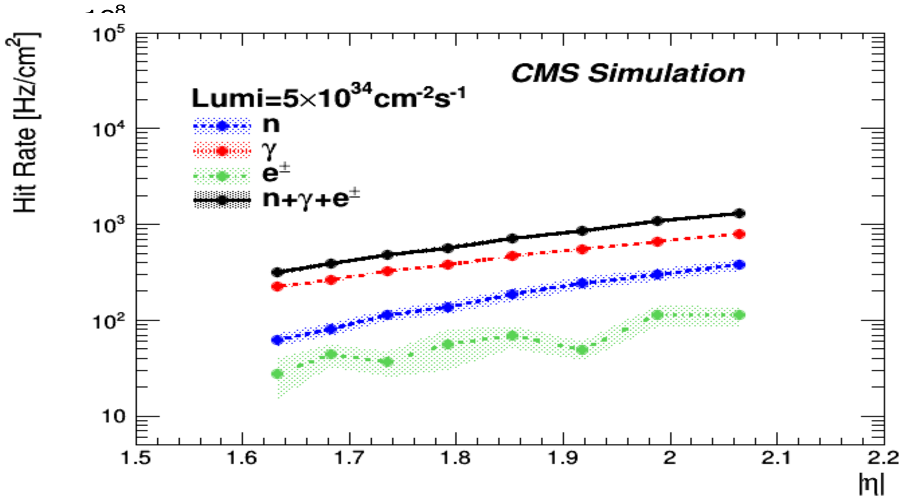
The background in forward region

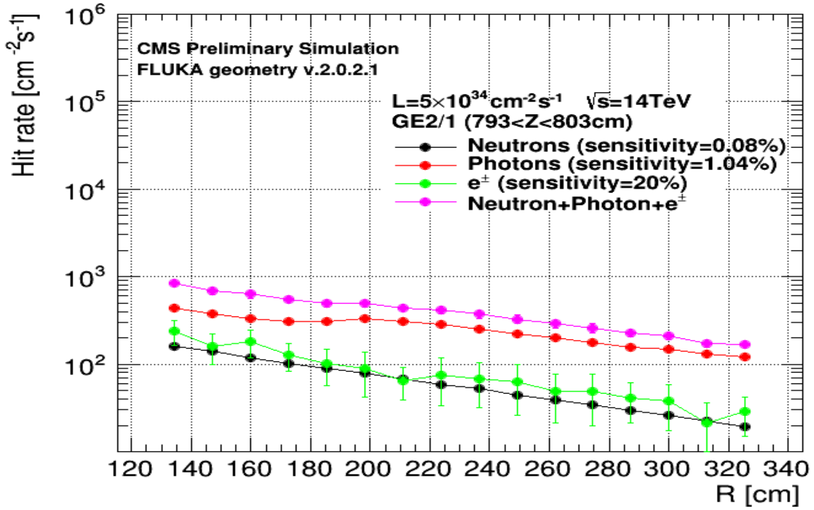
Hadronic interactions lead to activation of materials and give rise to neutron backgrounds. Long living neutrons can interact with nuclei and produce photons which further decay to electrons/positrons with some possibility to generate fake signals.

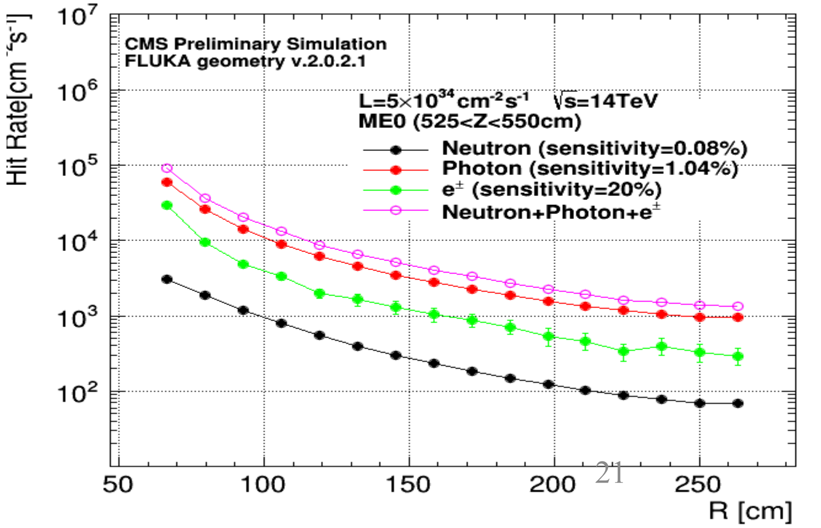
- very high flux→ low detector sensitivity to the neutron and photons required



- **Expected hit rate 250 Hz – 100's kHz/cm²**

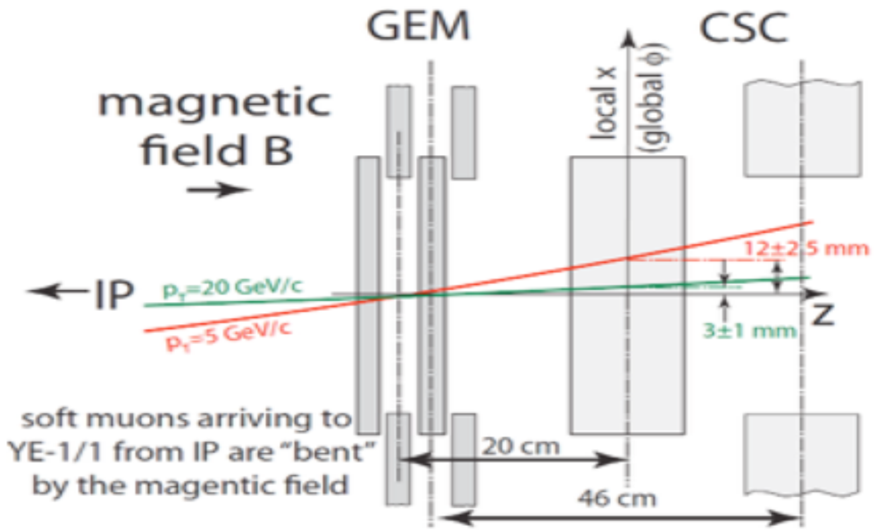






Performance: forward Muon Trigger

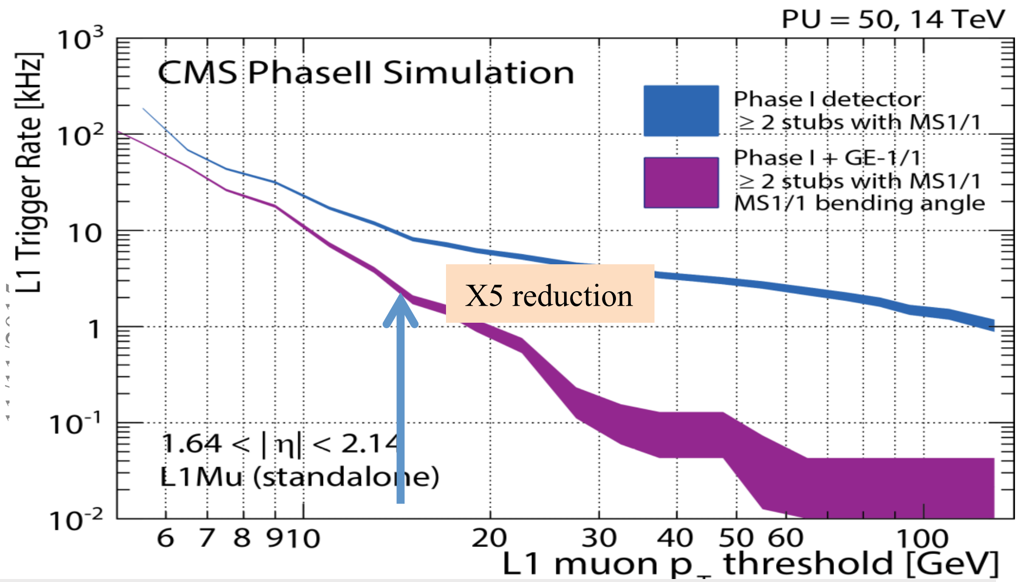
Forward trigger for $|\eta|>1.6$ relies entirely on the CSC system:

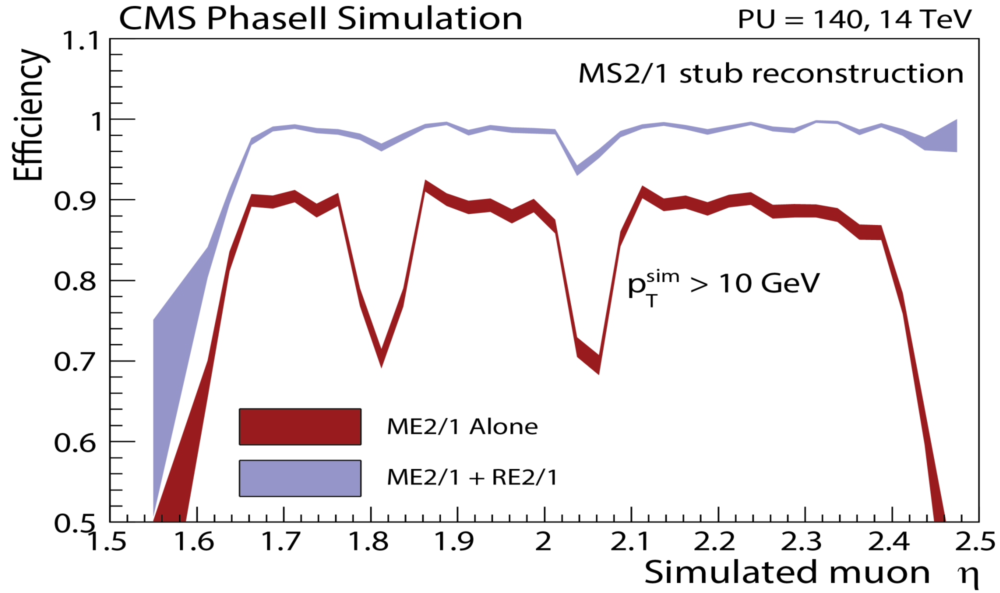


Adding detector in front of CSC to measure the muon bending angle in magnetic field in the each station, keeps the rate under control and adds redundancy:

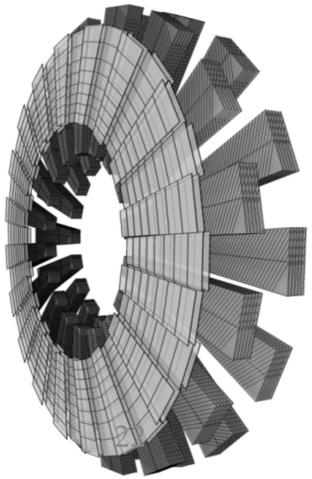
<u>**Large improvement from GE1/1 and GE2/1 stations**</u>

✓ Requirement precise $\Delta\phi$ meas.→spatial resolution





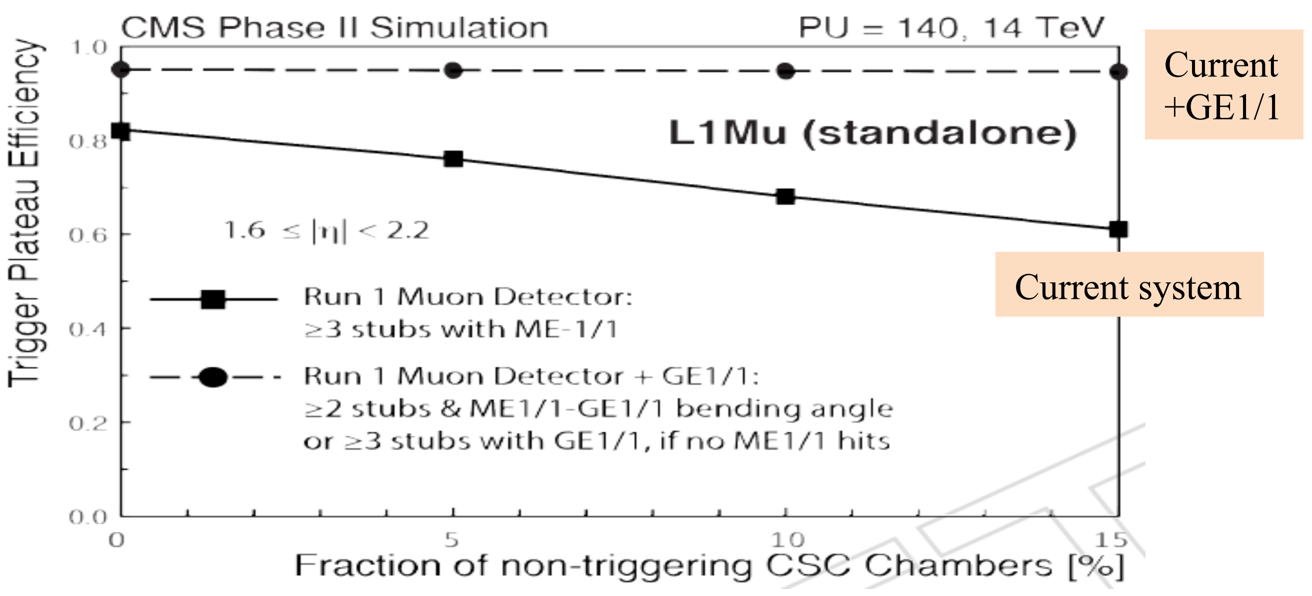
Lever arm - trigger

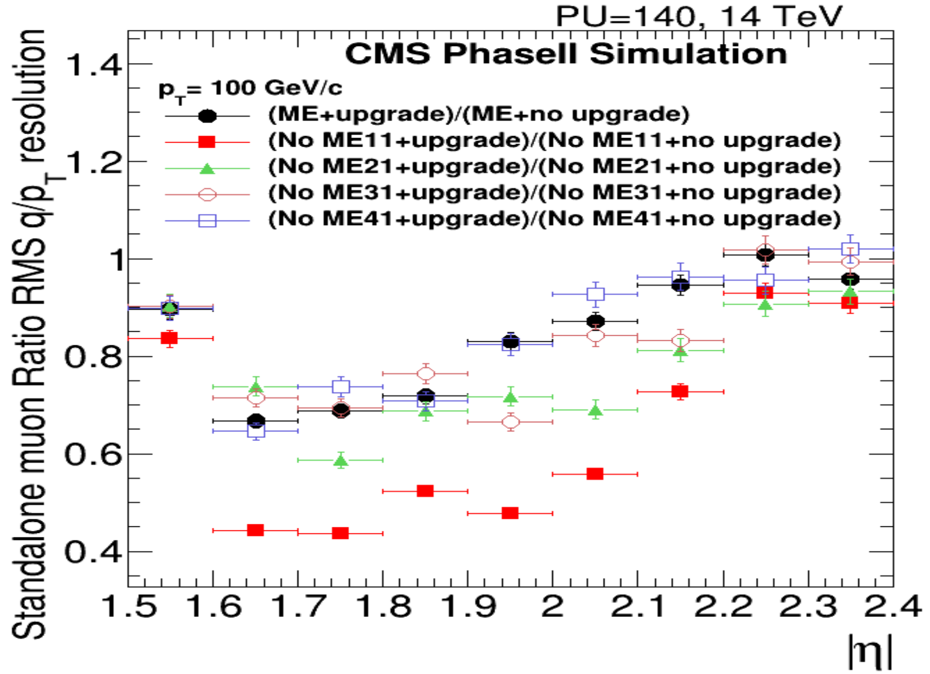


maintain 15 GeV online threshold, keep < 5 kHz rate, high efficiency

Longevity vs redundancy

Potential degradation in performance due to the aging of CSC chambers is a concern:





Redundancy assured by the GEM helps in:

- Reducing the deterioration of Level-1 muon trigger performance
- Reducing the large degradation in momentum resolution
- Mitigating otherwise large efficiency losses if a sizeable fraction of CSC chambers becomes partially or fully irresponsive

Detector requirements

• Maximum geometric acceptance within the given CMS envelope :

• Rate capability up to 100's kHz/cm2 .

• Single-chamber efficiency > 98 % for mips

• Gain uniformity of 10% or better across a chamber and between chambers and no loss due to aging effect after 3000 fb^{-1}

• High spatial and good time resolution

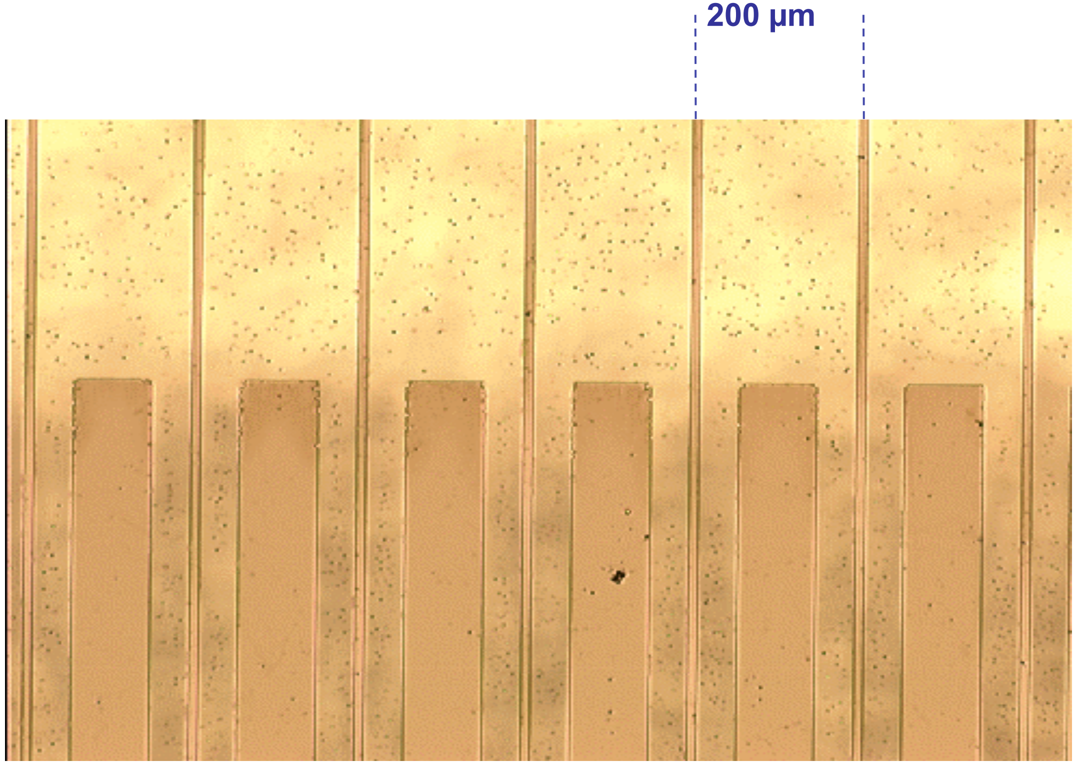
Micro-Pattern Gas Detectors (MPGD) due to their proven performance at HEP experiment (high rate capability and fine space resolution, high gain stability) are ideal tools.
Dedicated studies for the application !!

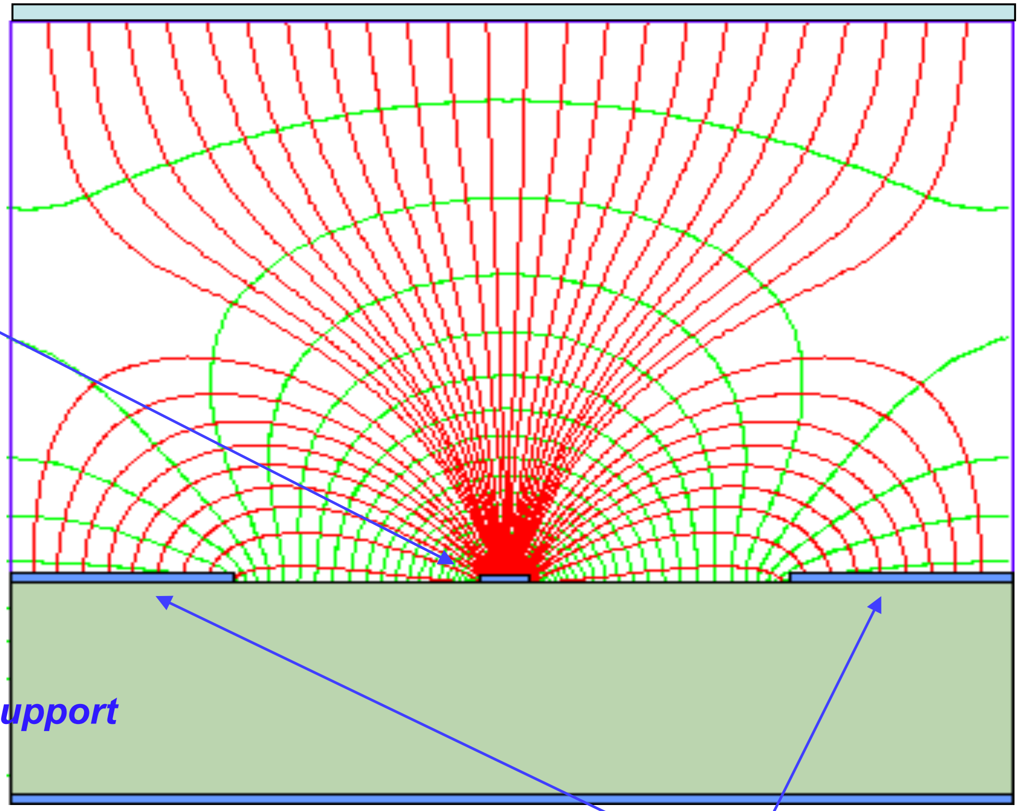
- New construction techniques and monitoring tools
- Discharge issue (due to their micrometric distance and large surface) under irradiation
- Performance in terms of time and space resolution

MSGC : Getting rid of wires

MICRO-STRIP GAS CHAMBER (MSGC)

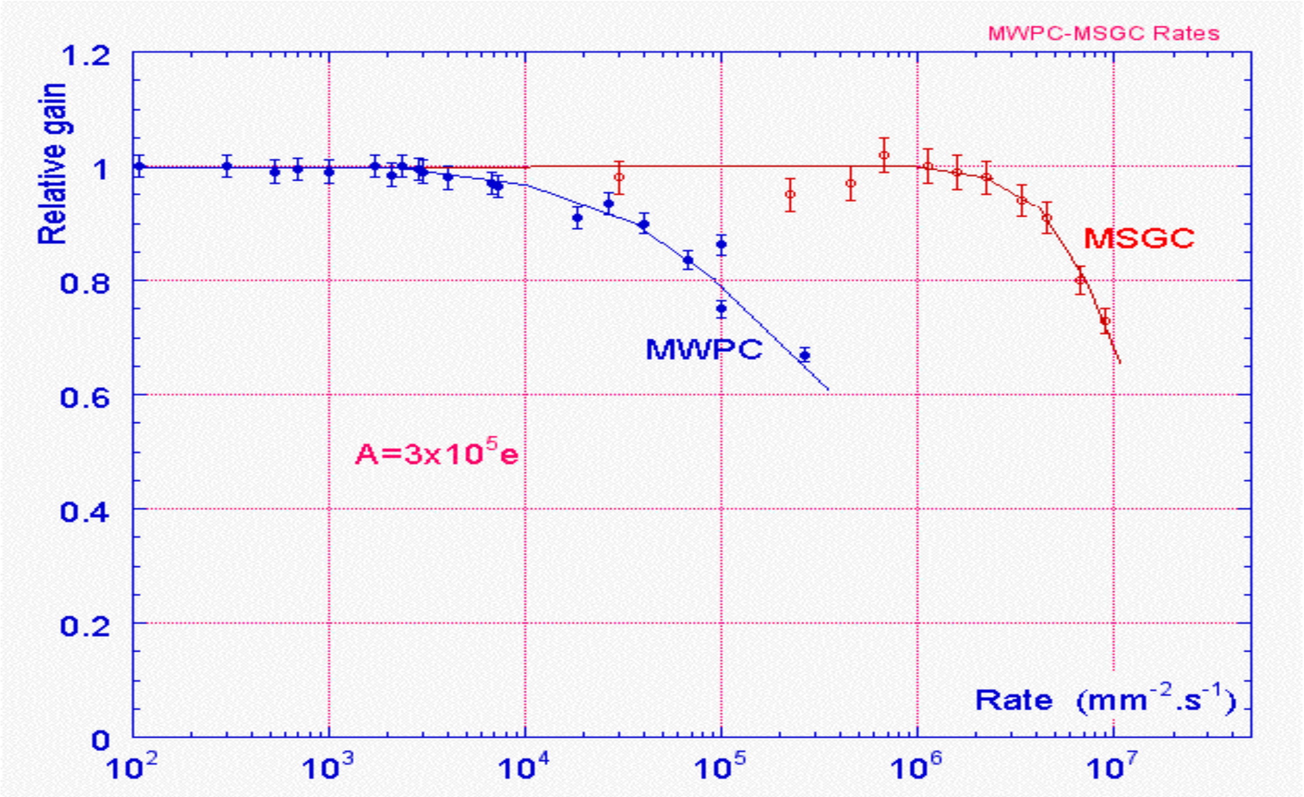
THIN ANODE AND CATHODE STRIPS ON AN INSULATING SUPPORT





Ref: A. Oed
Nucl. Instr. and Meth. A263 (1988) 351.

MSGC



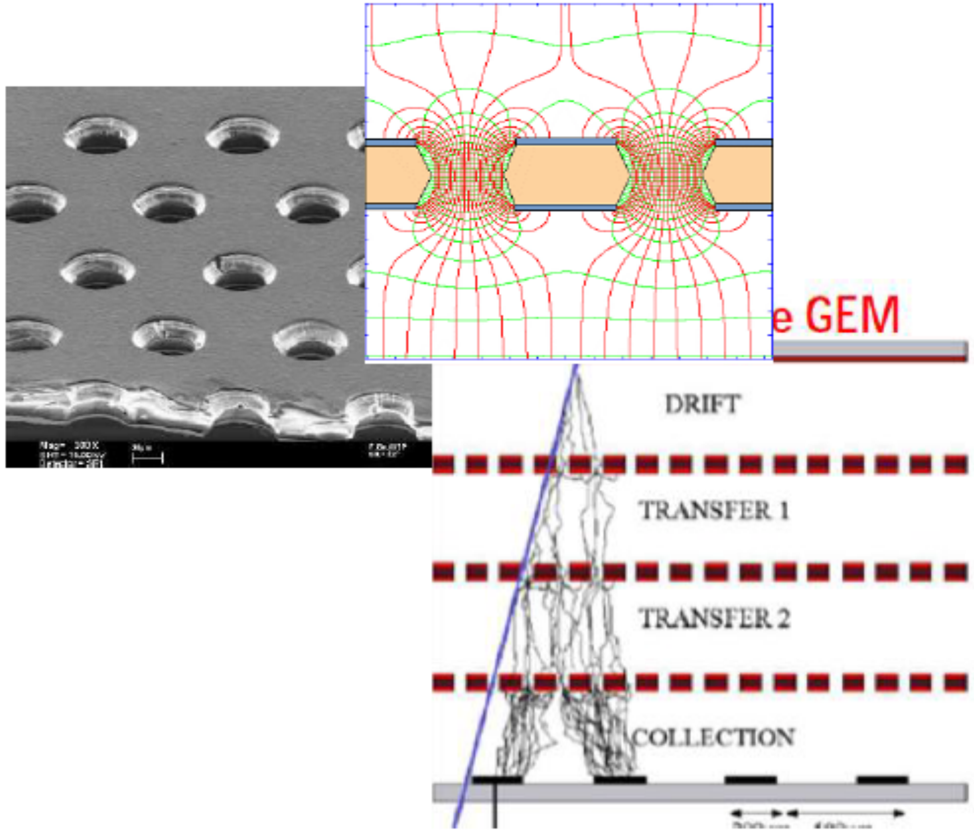
MSGC PERFORMANCES

EXCELLENT RATE CAPABILITY AND MULTI-TRACK RESOLUTION

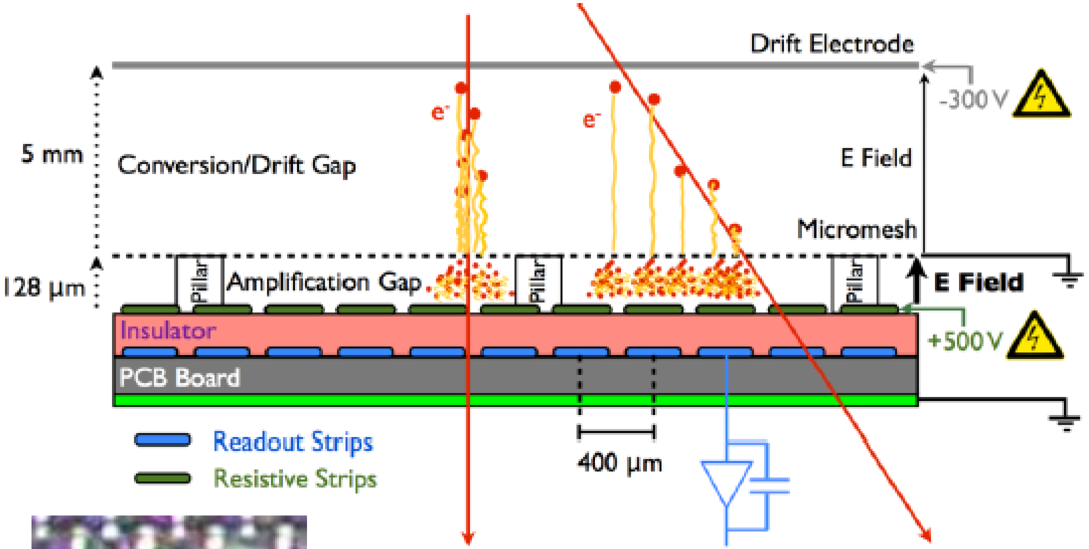
RATE CAPABILITY > 10^6/mm^2 s
SPACE ACCURACY ~ 40 μm rms
2-TRACK RESOLUTION ~ 400 μm

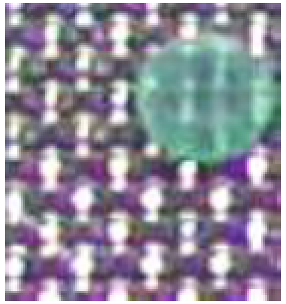
Classical MPGD: GEM and Micromegas

Gas Electron Multiplier (GEM)



Micromegas





MICROMEGAS : ATLAS PROTOTYPES

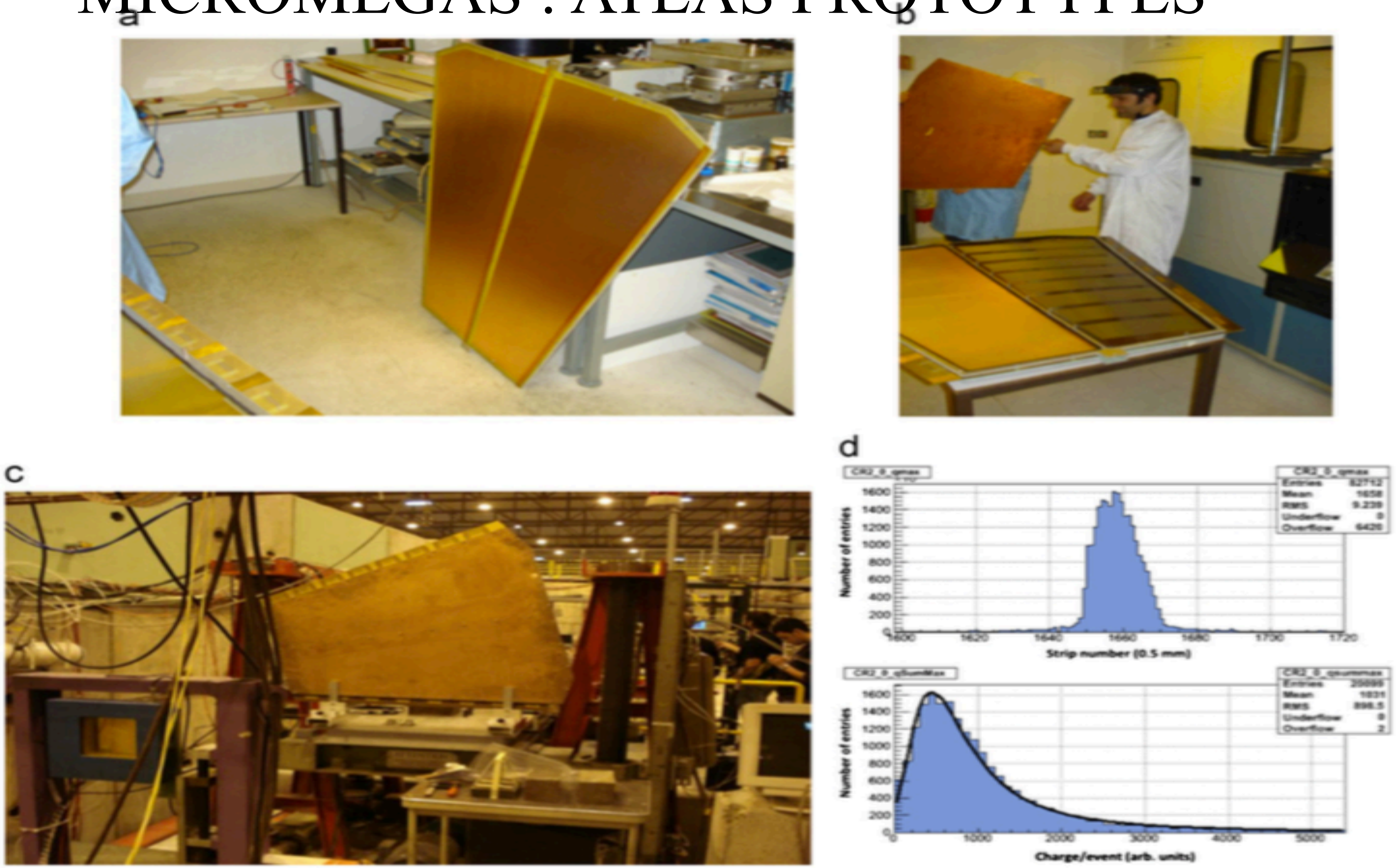
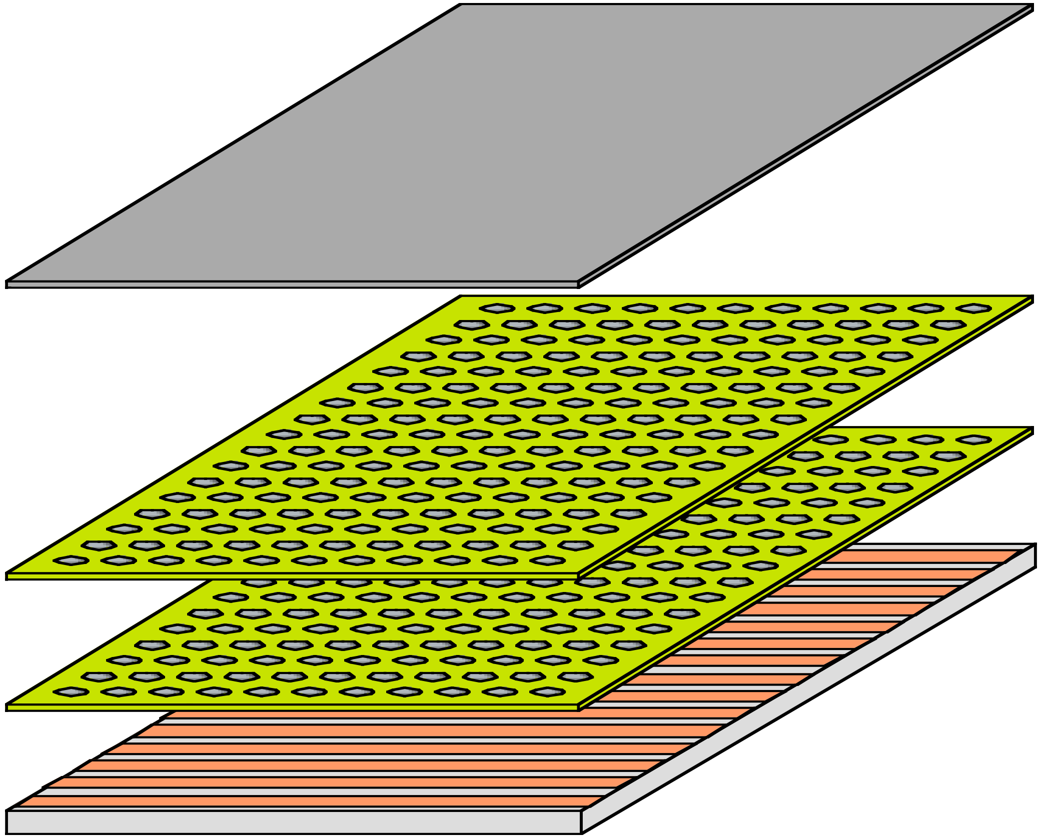


Fig. 38. (a) A large area module made with resistive Micromegas by the MAMMA collaboration. (b) Assembly of large resistive micromegas only the right half is instrumented. (c) Large resistive micromegas chamber in H6 test beam at CERN (d) hit distribution (on top) showing the beam profile and the charge distribution (bottom), adding all charges, showing essentially a Landau shape.

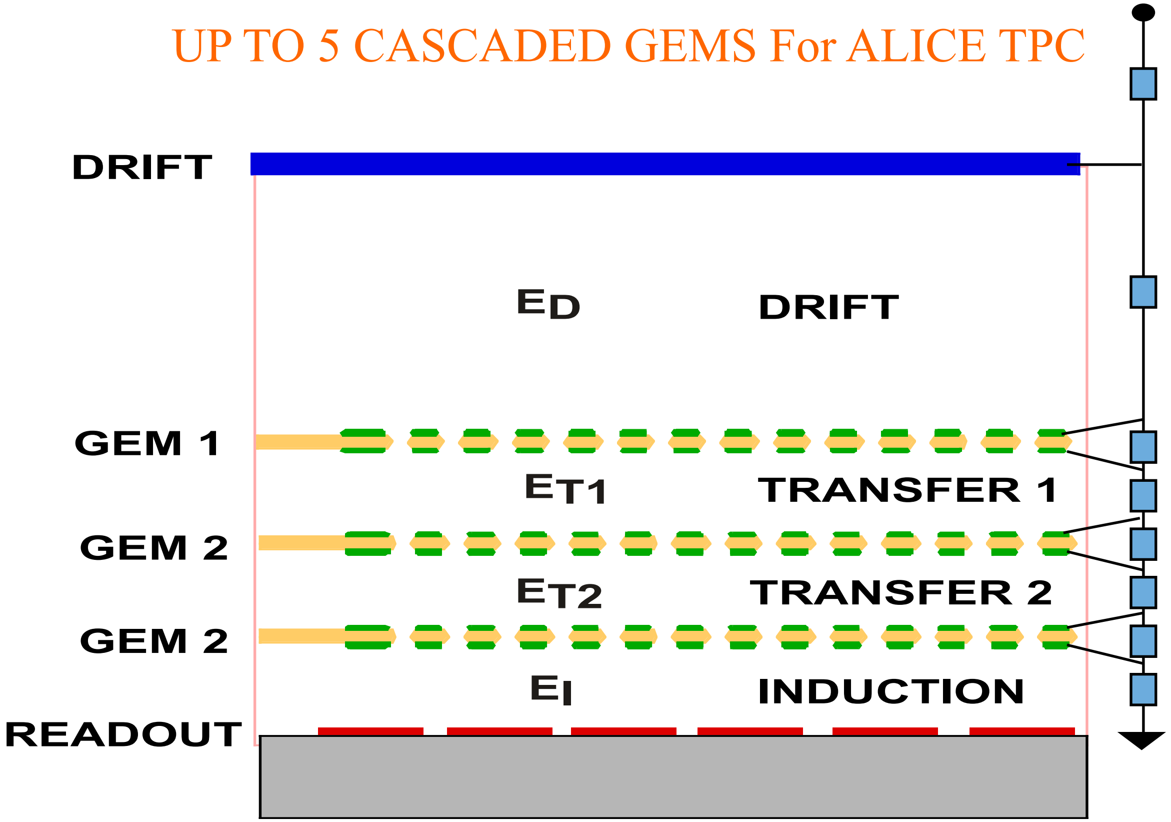
MULTIGEM

MULTIPLE GEM DETECTORS:
- HIGHER GAIN
- LOWER OPERATING VOLTAGE AND/OR SAFER OPERATION

UP TO 5 CASCADED GEMS TESTED
(for single photoelectron detection)
Voltages provided by resistor chain

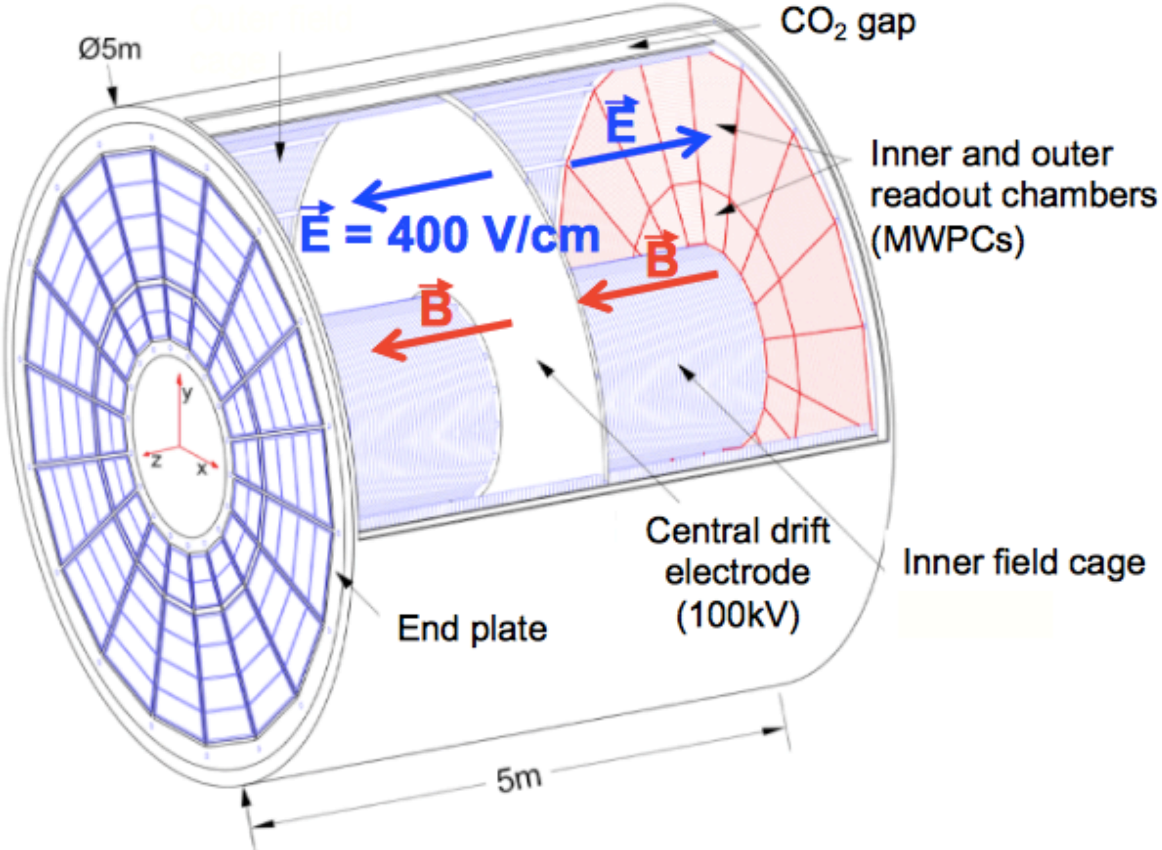


UP TO 5 CASCADED GEMS For ALICE TPC



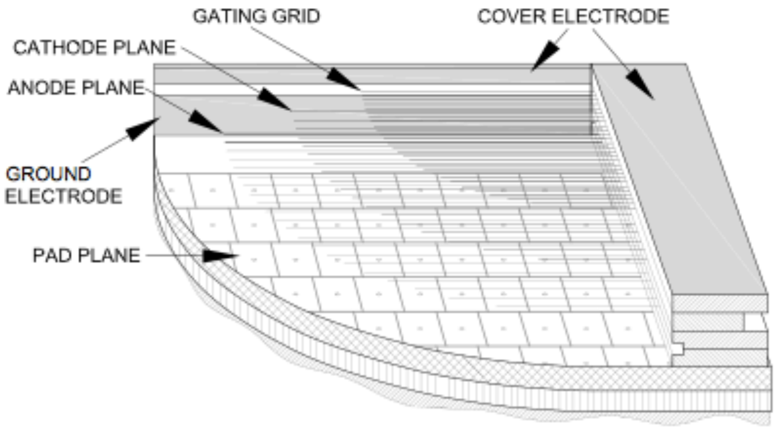
Archana Sharma - Outlook Web App | ALICE TPC GEM and chamber UE EDR (4 November... | https://indico.cern.ch/event/448484/contribution/... | Google Calendar - Week of Nov 9, 2015

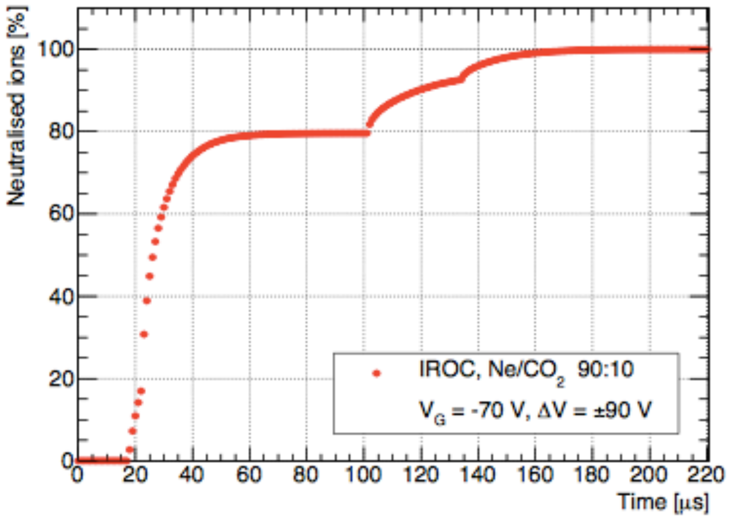
ALICE TPC IN NUMBERS



- Length 5 m
- Diameter 5 m
- Active volume 88 m^3
- B = 0.5 T
- Readout area 32 m^2
- Channels ~570 000

LIMITATIONS OF THE PRESENT SYSTEM





Present MWPC-based readout chambers employ a gating grid:

After 100 μs of electron drift time, the gating grid needs to be kept close for ~200 μs to prevent back-drifting ions into the drift region

→ Total time ~300 μs limits maximal readout rate to ~3 kHz

Ignoring the GG closure time (i.e. keeping it open all the time) leads to excessive space point distortion due to space charge accumulation in drift volume.

→ Novel technology required to block ions: multiple-GEM stacks

→ Allows for ungated („continuous") readout
N.B.: on average 5 events pile up in the TPC at 50 kHz and $t_{d,max}$ = 100 μs