A Large Ion Collider Experiment

THE UPGRADE OF THE ALICE TPC

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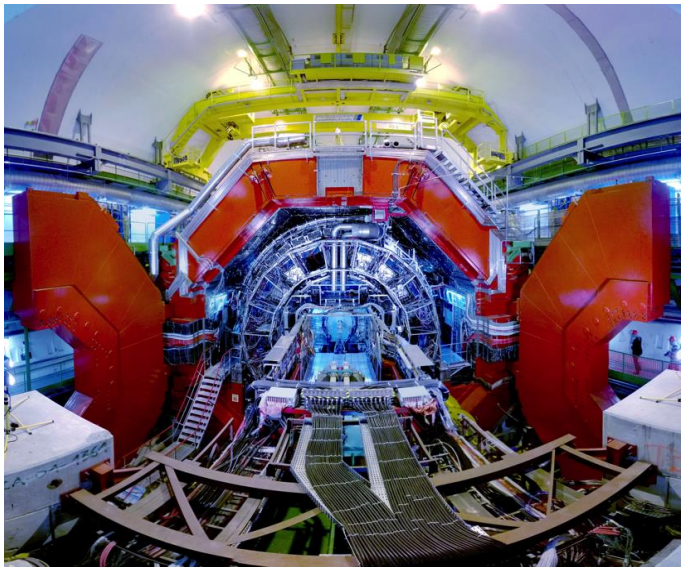
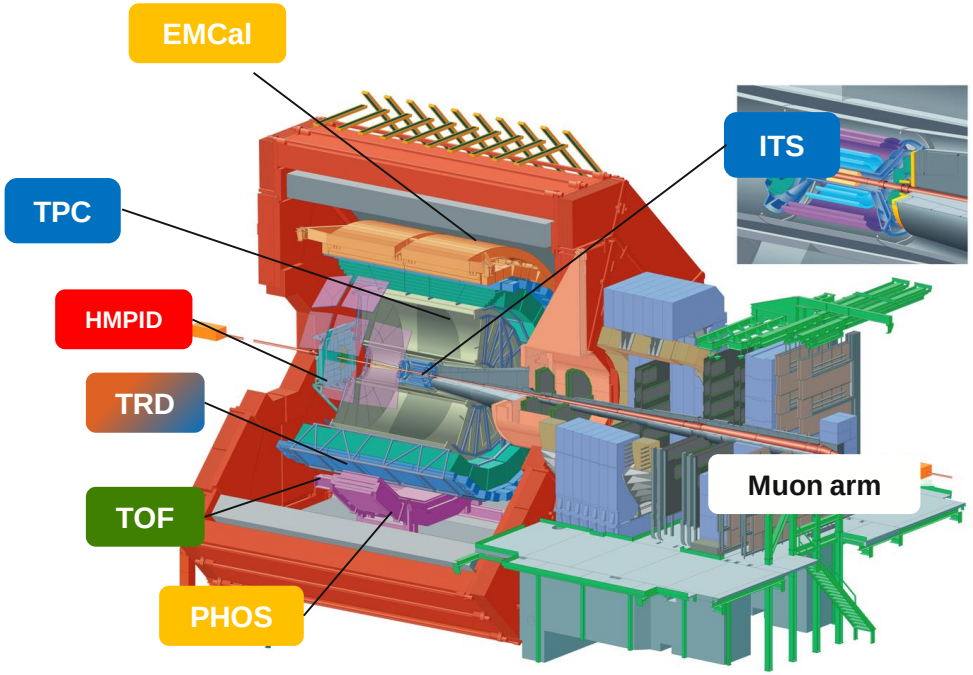
RD 51 Week

23.06.2020

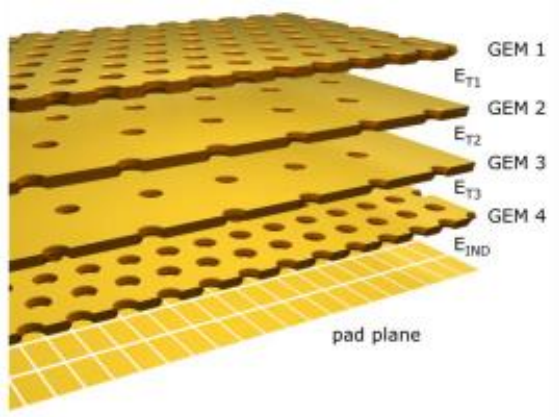
THE ALICE EXPERIMENT

- A dedicated heavy-ion experiment at the CERN LHC
- Study of a high-density, high-temperature phase of strongly interacting matter
- Unique PID capabilities
- Covers broad kinematic range

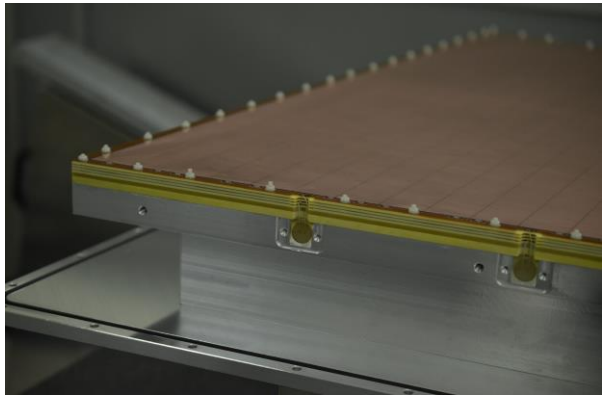




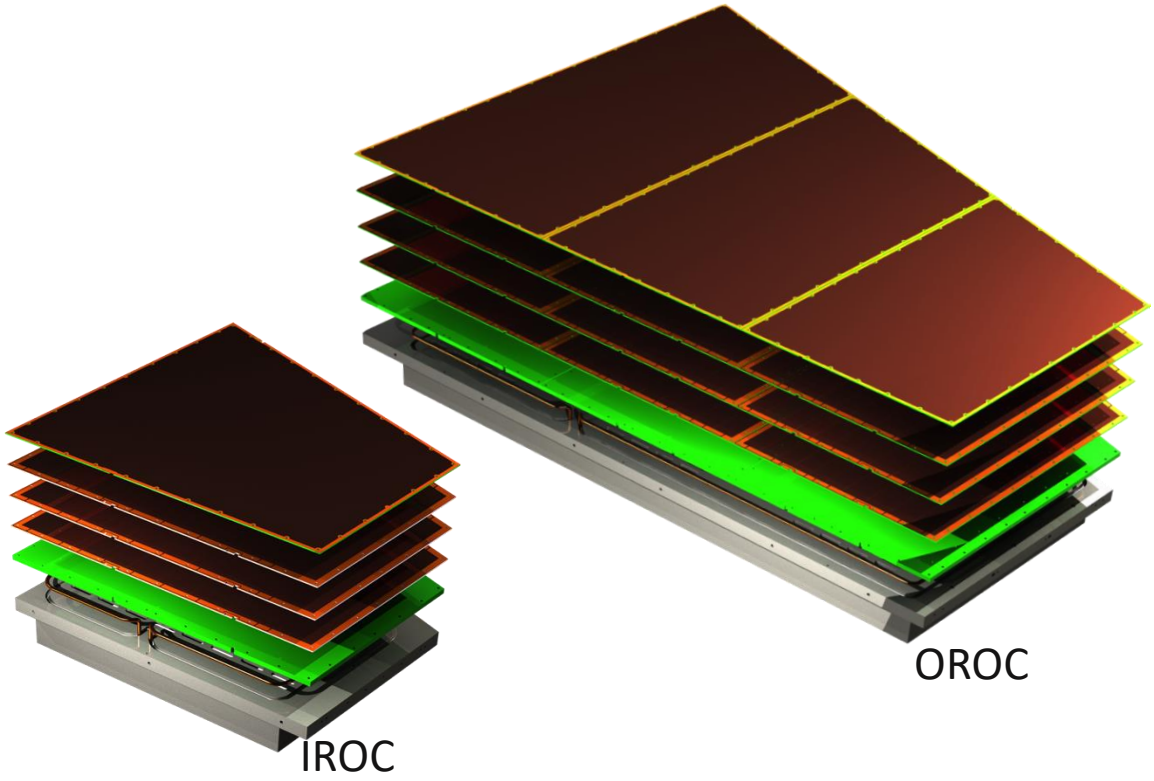
ALICE TPC UPGRADE



- Motivation: high-precision measurements of rare probes at low p_T
- Challenge:
  - Operation at 5x higher rate, record all Min. Bias events
  - No dedicated trigger → continuous readout
  - Preserve PID
- Solution:
  - Replace MWPC by GEM-based chambers
  - Quadruple GEM stacks with optimized field configuration allows to fulfil requirement:
    - Operate at the gain of 2000 in Ne-CO_2-N_2
    - IBF < 1% (at gain = 2000 → ε = 20)
    - Local energy resolution σ_E/E < 12% for ^{55}Fe
    - Momentum resolution: σ_{PT} / p_T = 1% (@1GeV/c)
    - Stable operation under LHC conditions

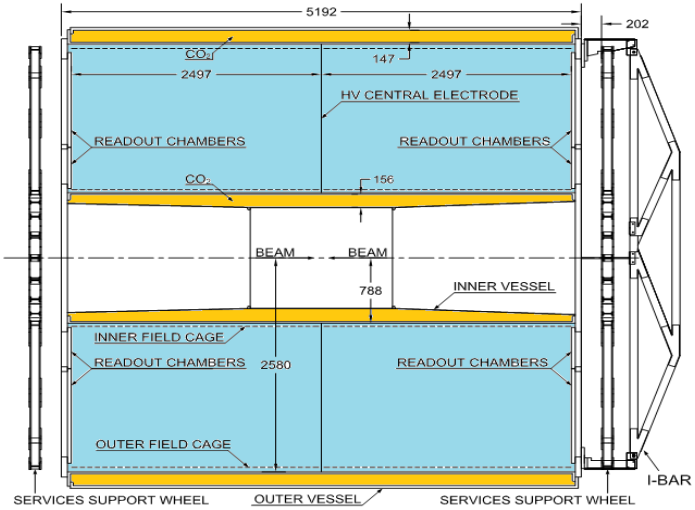


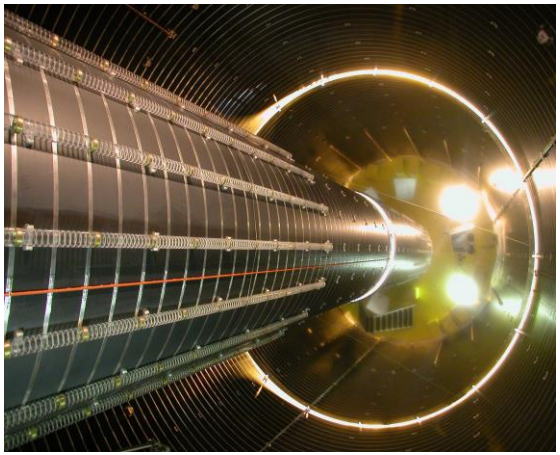
GEMS FOR THE UPGRADE



- Large-size single-mask foils from CERN PCB workshop
- 1 stack in IROC, 3 stacks in OROC

THE ALICE TPC FIELD CAGE





- Low-mass, high-precision field cage
- ~90 m^3 active detector medium
- Gas: Ne-CO_2-N_2 (90-10-5) in Run 3
- 100 kV at the Central Electrode
  - E_{drift} = 400 V/cm
  - v_{drift} = 2.7 cm/µs
  - max t_{drift} = 92 µs
- Drift Field is defined by suspended strips power through 4 removable Resistor Rods
- Field cage wall covered with guard ring strips, connect to separate resistors chain

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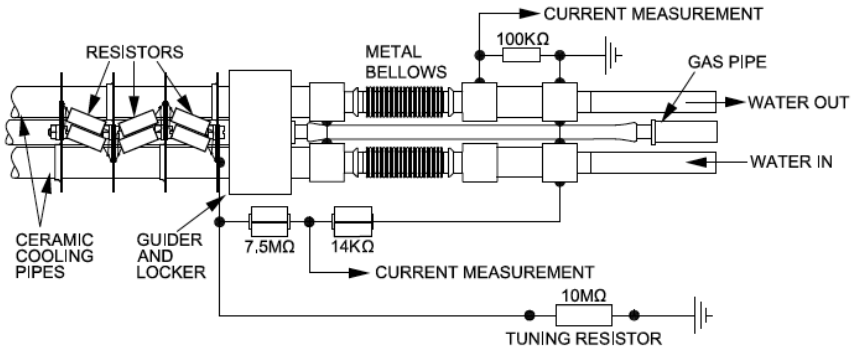

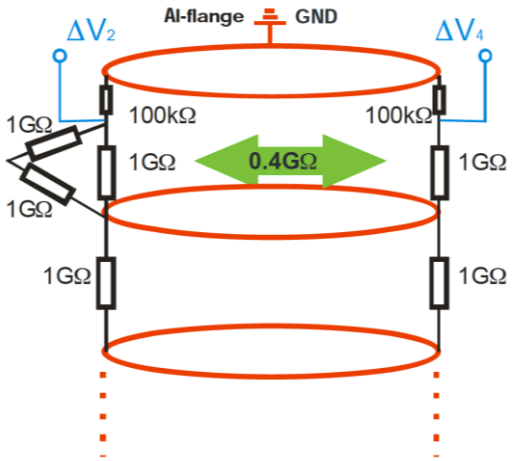

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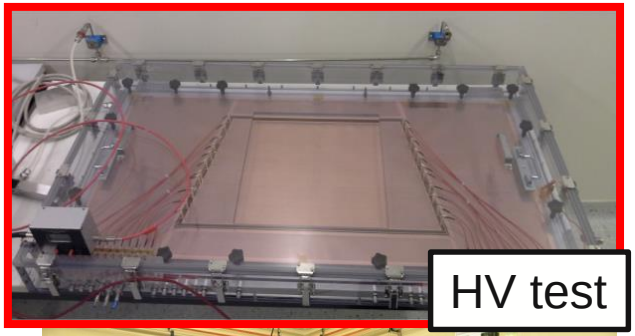
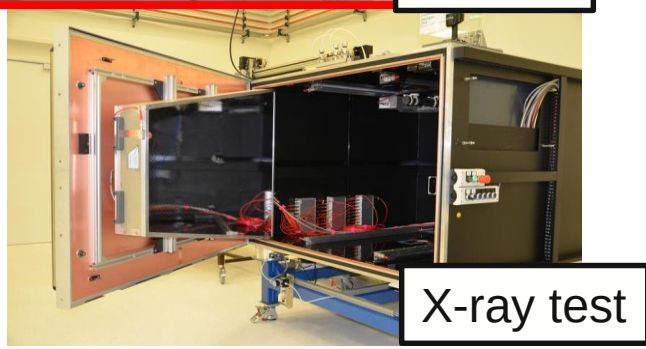
- Field cage wall covered with guard ring strips, connect to separate resistors chain
- Potential of last strip adopted to potential of ROC:
  - MWPC: passive components
  - GEM: active powering

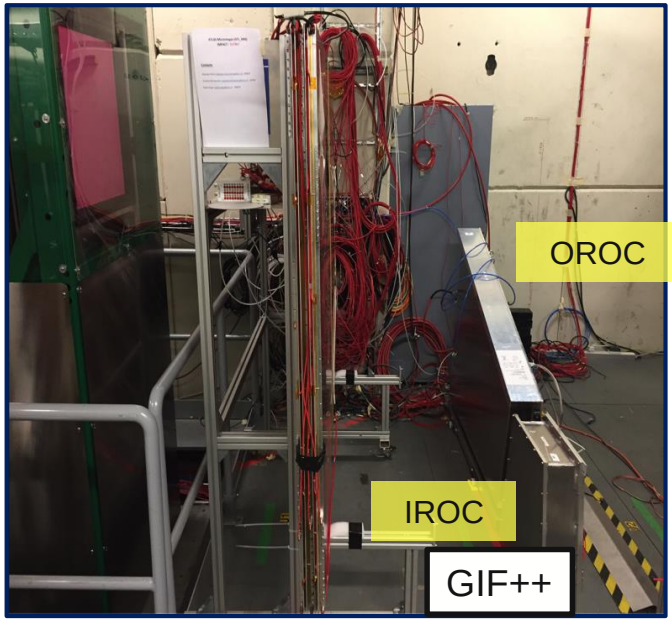
CHAMBER PRODUCTION

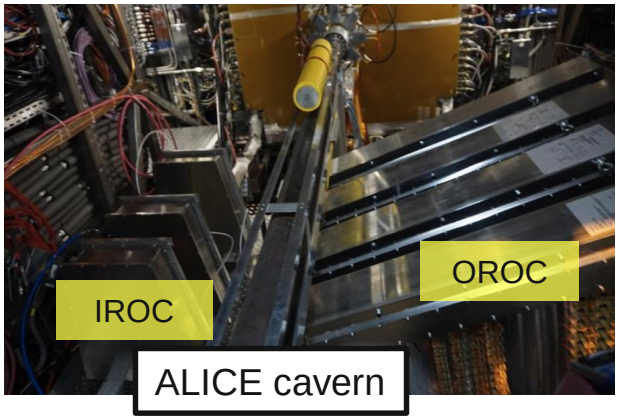
CHAMBER PRODUCTION

- Collaboration of several institutes specialized on dedicated tasks
- Production of 80 ROC (40 IROC/40 OROC)
  - Finished April 2019
- Detailed certification program (gain, IBF, stability)
- Stability tests at CERN
  - ALICE cavern
  - GIF++ @ CERN









TPC UPGRADE SEQUENCE

Remove Services and FEE (outside cleanroom)

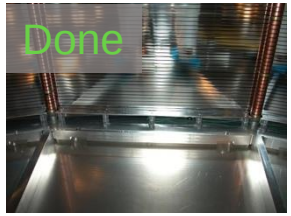
7 Mar

TPC in cleanroom. Cleaning & irradiation tests

11 Apr

Uninstall MWPC ROC

25 Apr (A)
5 Aug (C)



FC HV infrastructure modification

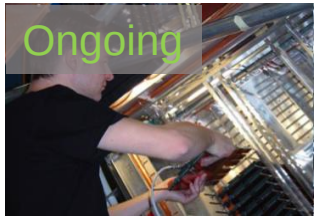
13 May (A)
16 Aug (C)

Install GEM ROC

14 Jun (A)
25 Aug (C)

Survey, shimming, sealing

5 Jul (A)
16 Sep (C)



Install new FEC + test

14 Oct (A)
31 Oct (C)

Pre-commissioning with cosmic, Laser, pulser, Xray

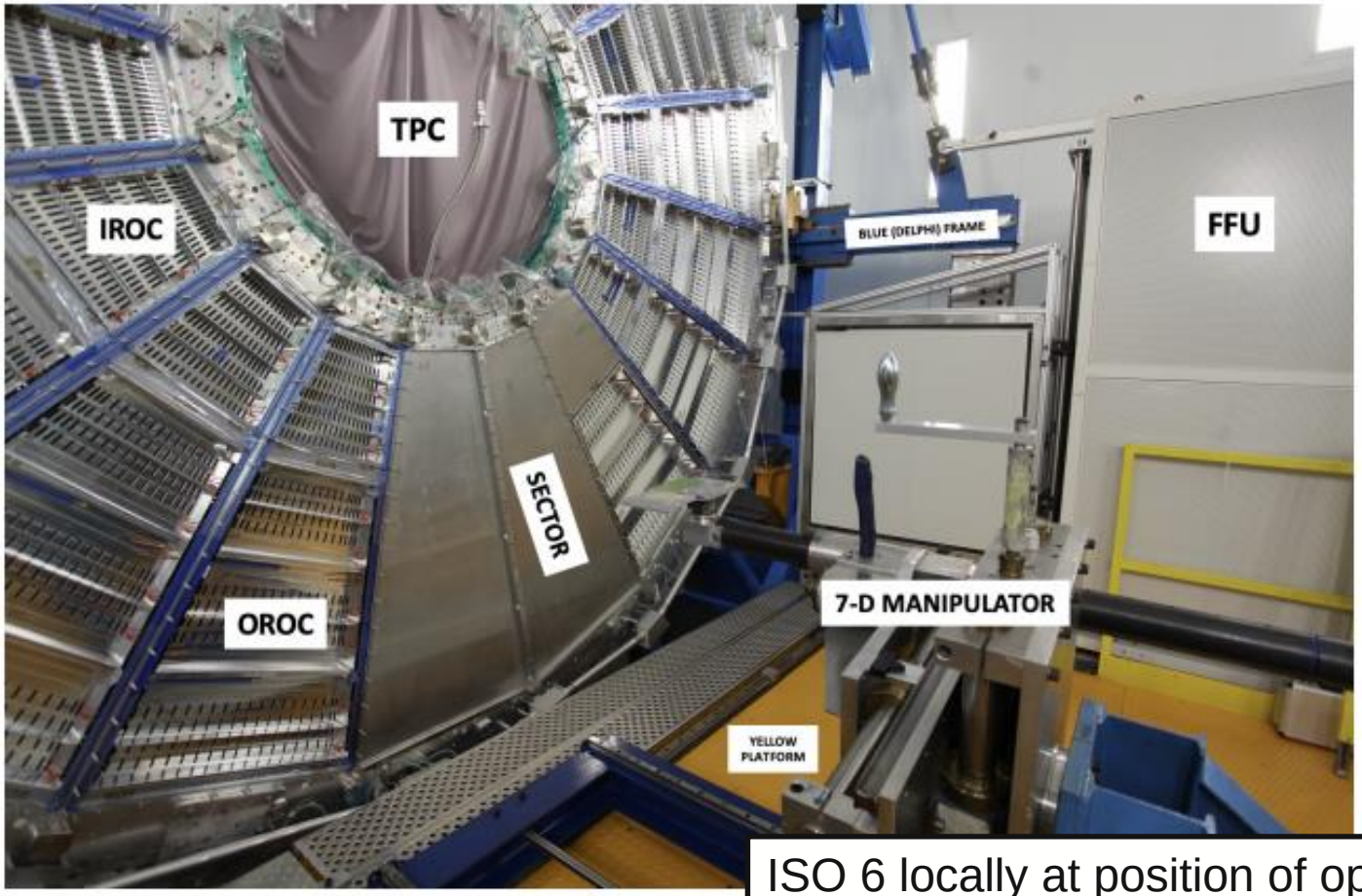
25 Nov (A)
7 Jan (C)

Ready for transportation to SX2

24 July

9

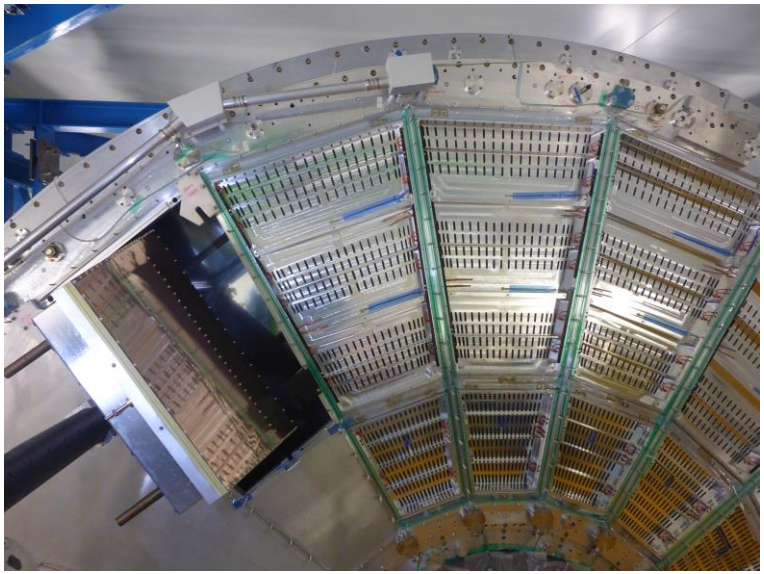
CHAMBER EXTRACTION/INSERTION

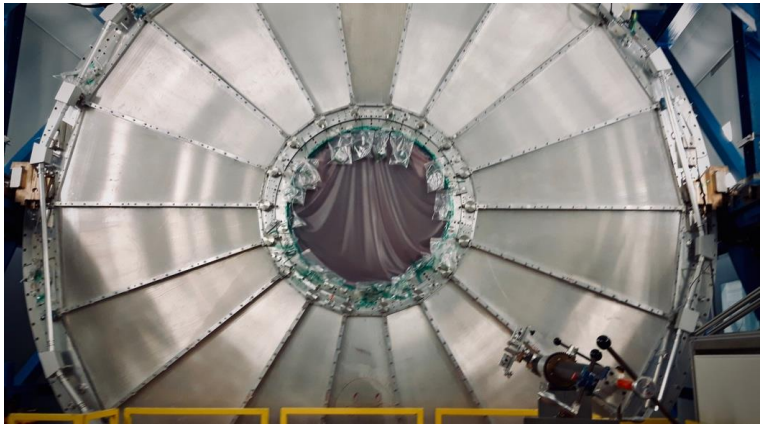


ISO 6 locally at position of operation

ROC EXCHANGE

- Step 1: All MWPC were removed form one side
  - Chambers were packed (will be re-used by DUNE)
  - Empty sector covered with plates





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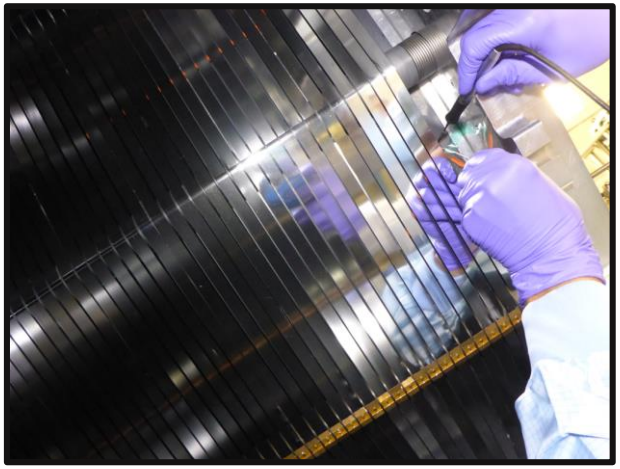
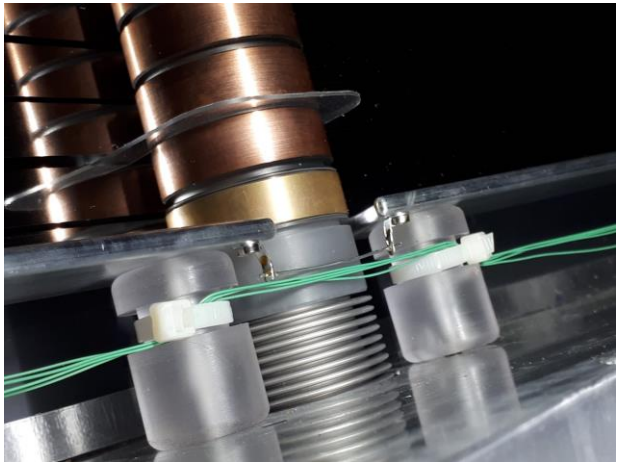
  - Active powering of last strip of Resistor Rod and Guard Rings
  - Removal of skirt electrodes





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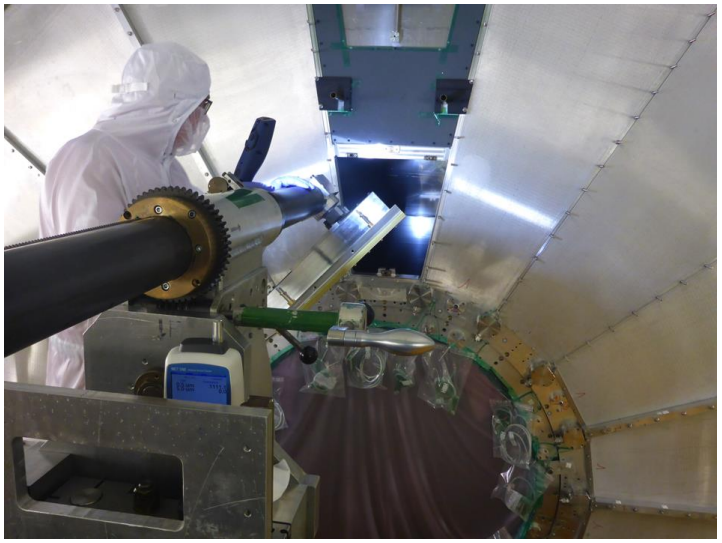
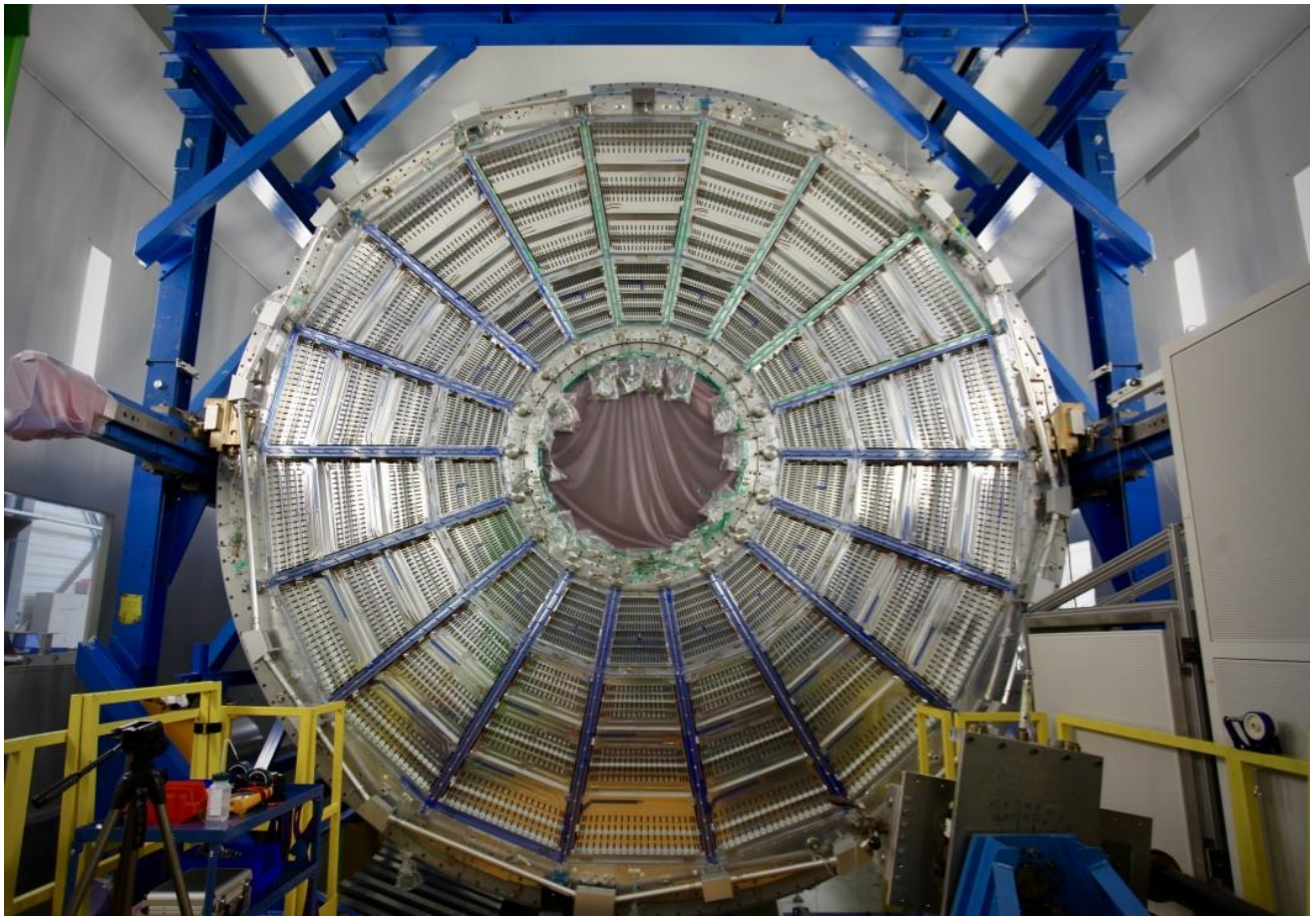
  - Active powering of last strip of Resistor Rod and Guard Rings
  - Removal of skirt electrodes
- Step 3: Installation of GEM chambers
  - Preparation of ROC for installation
  - Insertion
- Step 4: Finalization
  - Survaying and Alignment
  - Sealing
- Step 5: Filling with gas



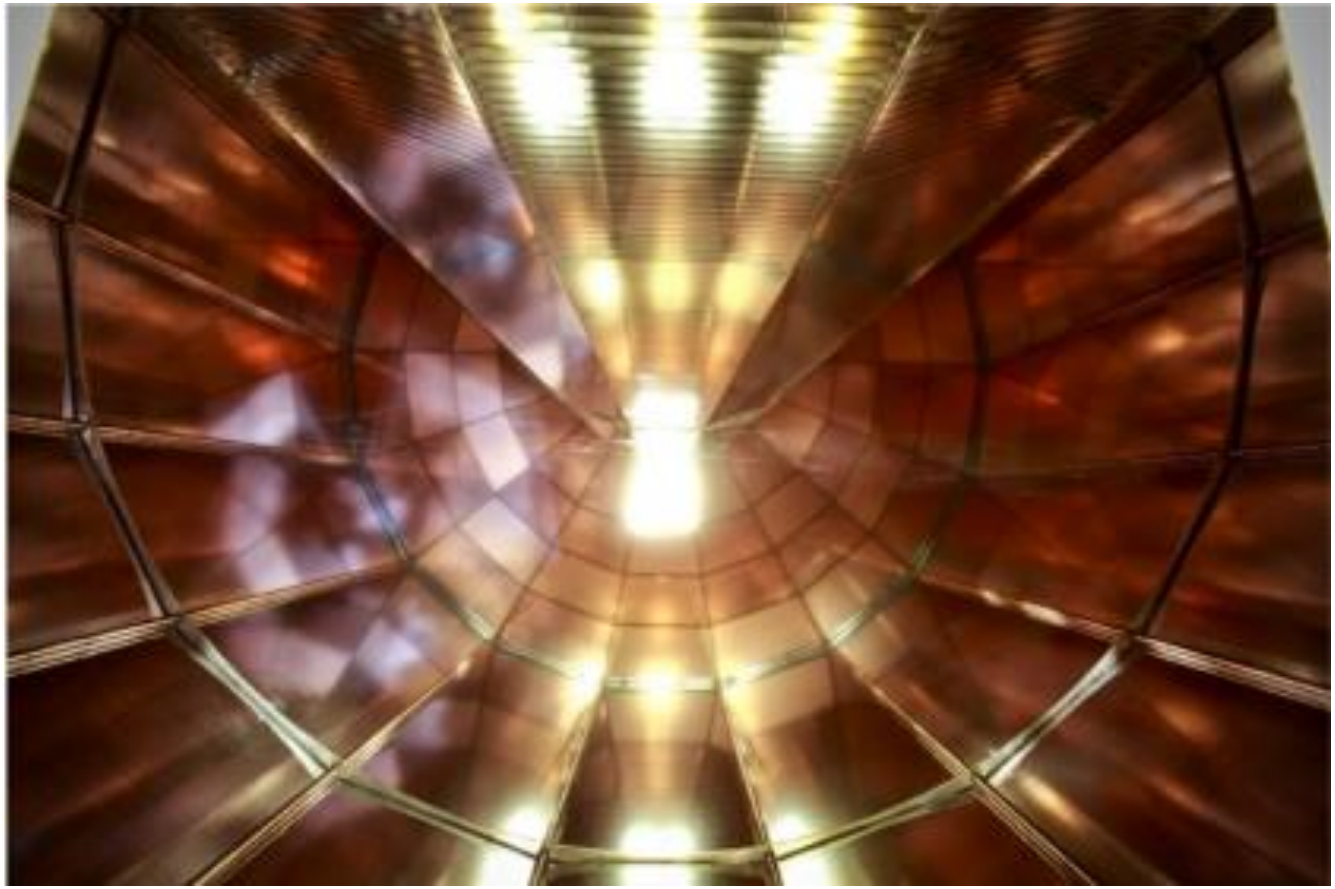
ROCS EXCHANGED

From Outside



ROC EXCHANGE

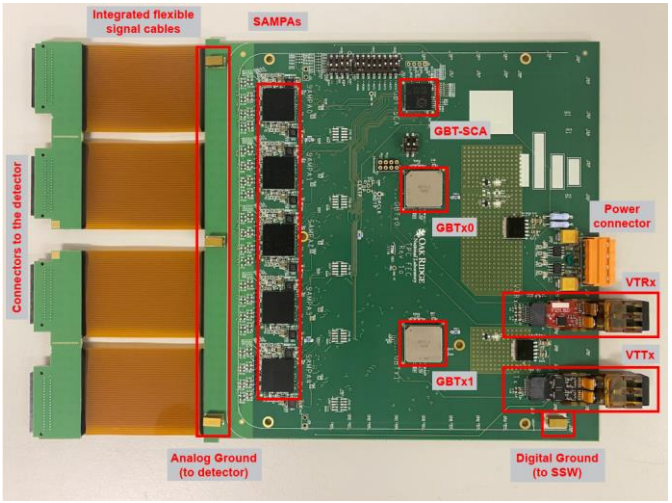
... And from inside

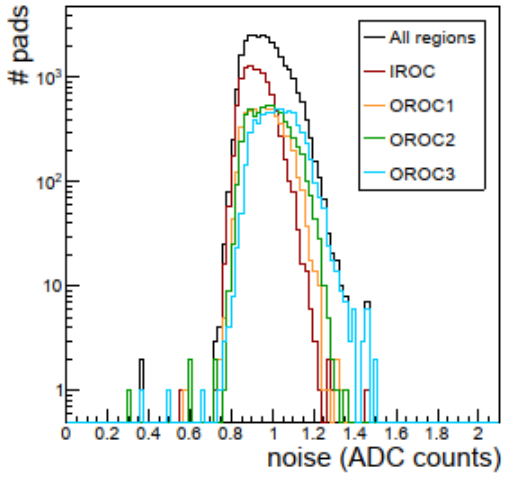


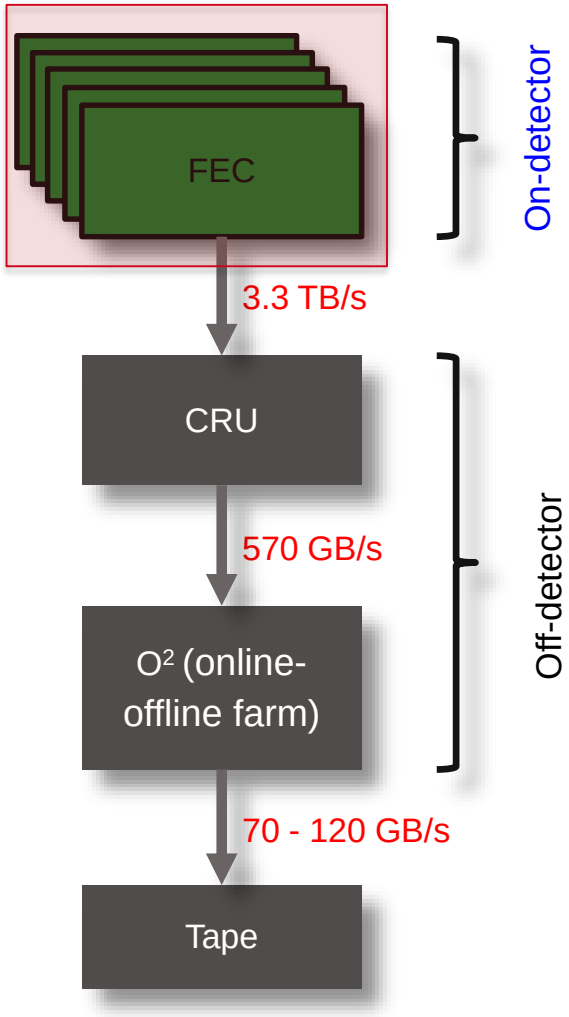
INSTALLATION OF SERVICES

TPC READOUT - FEC

- 3276 Front-End Cards (FEC)
- SAMPA ASIC (130 nm TSMC CMOS)
  - Integrated Pre-Amp
  - Shaper (t_{peak}=160ns)
  - 10-bit ADC
- Radiation hard data and control link: CERN GBT system
- System noise: 670e^-
- All ADC values are transferred at 5 MHz (no compression)





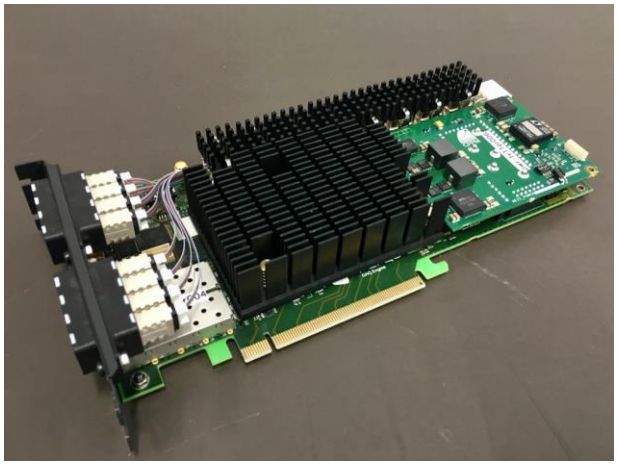


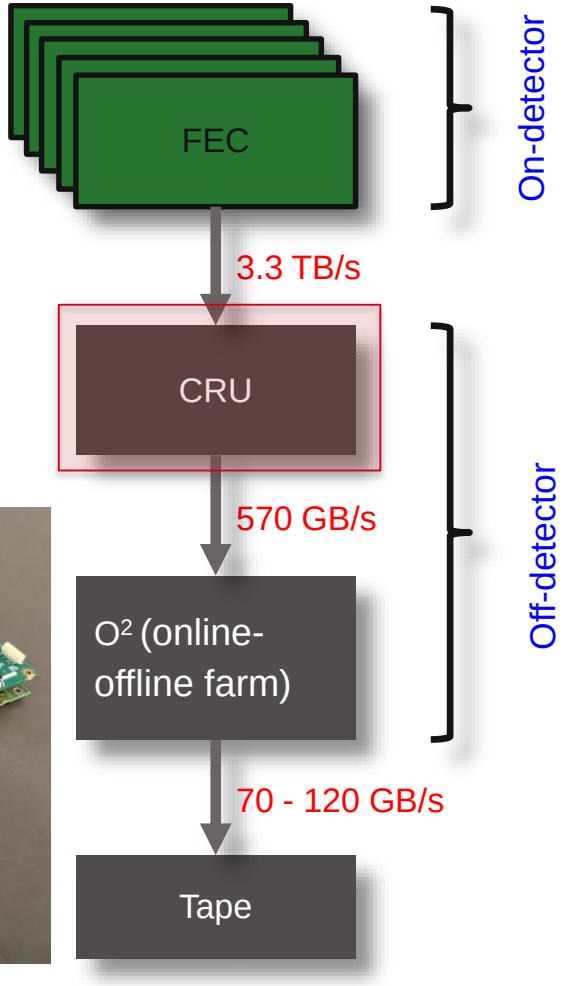
TPC READOUT

Common Readout Unit (CRU) (FPGA-based readout card):

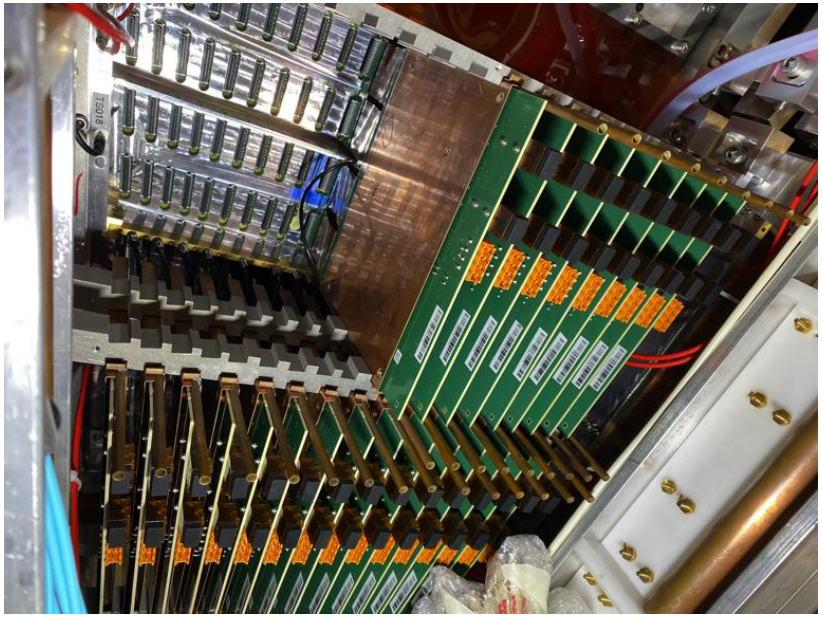
- PCI-E40 board from LHCb (designed by CPPM)
- Located in First-Level-Processors (FLPs) of the ALICE O^2 online-offline farm
- Data-processing in CRU FPGA:
  - Decoding
  - Sorting
  - Zero Suppression
  - Common-Mode Filter

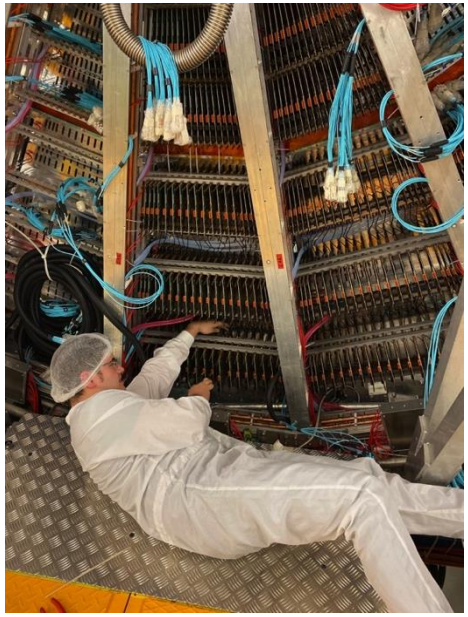
  ➔ Data compression

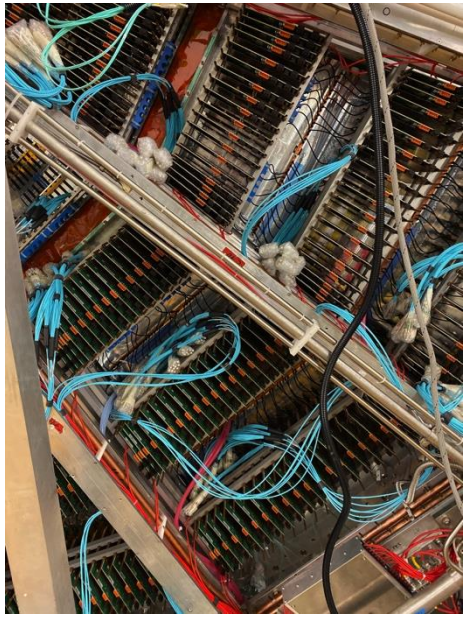




FEC INSTALLATION



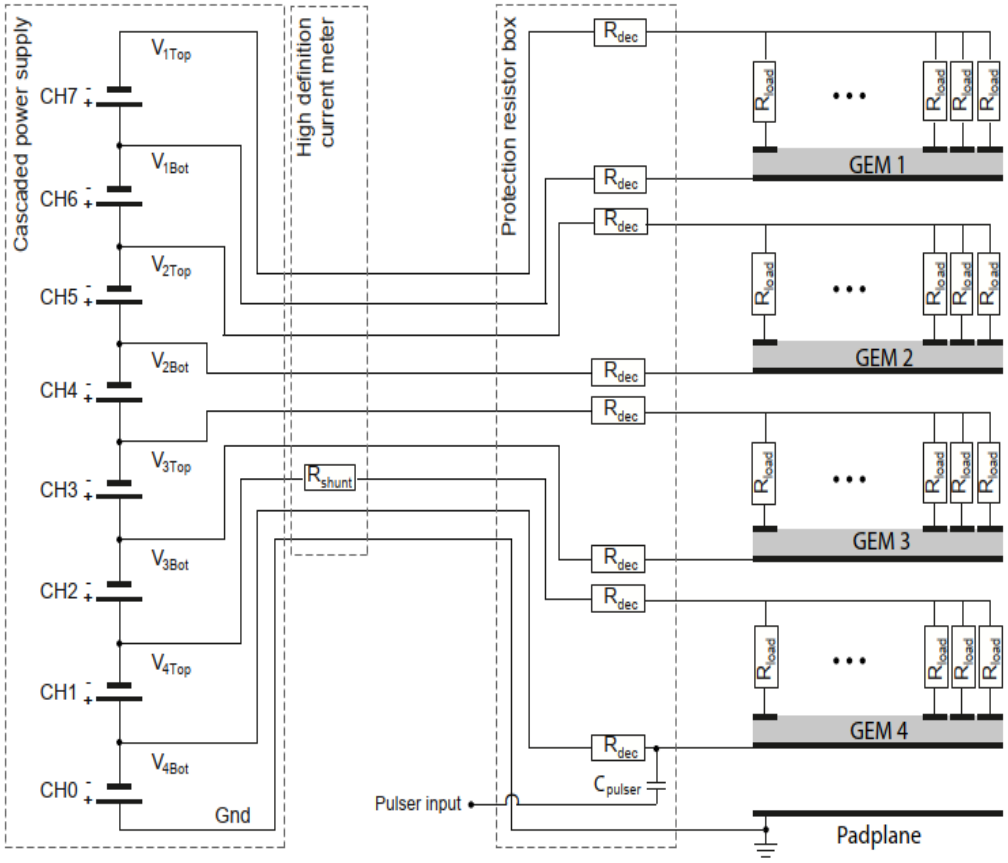




- Installation on each partition
- Connectivity tests using calibration pulser

GEM POWERING

36 seperate sectors



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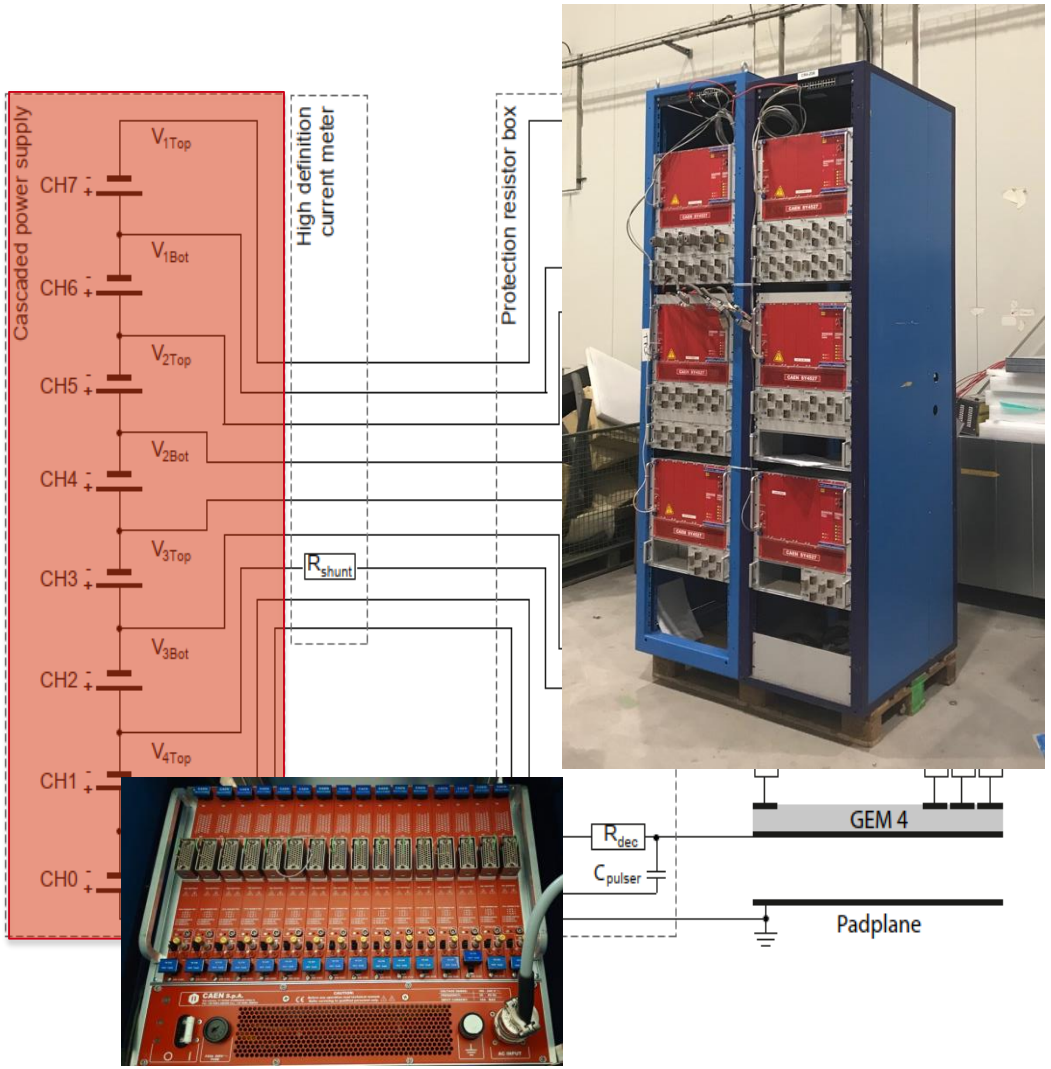
Cascaded Power Supplies (72 modules)
CAEN A1515

- Safe operation: designed to **avoid overvoltage** in case of single channel trip
- Highest possible **flexibility** (e.g. fine tuning of potential on individual electrodes)



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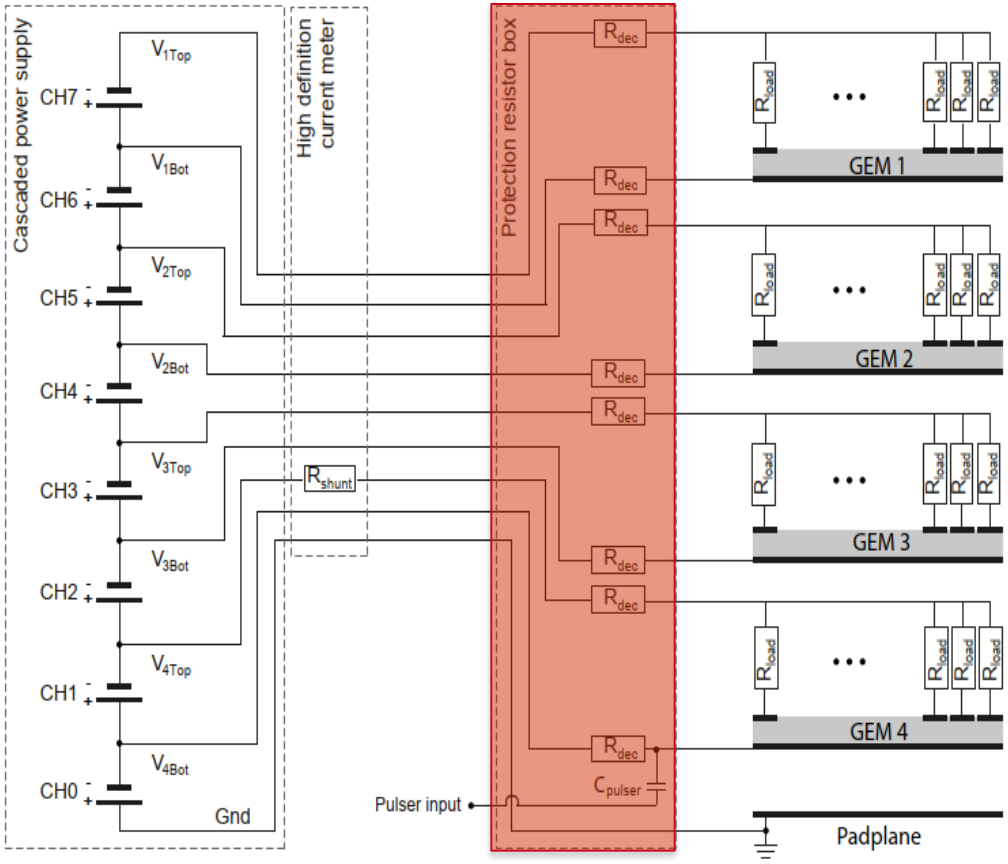
Protection Resistor Box near detector:

- Decouples GEMs from HV
- Avoid secondary dischares
- Modular design to adapt resistor value of single HV channels



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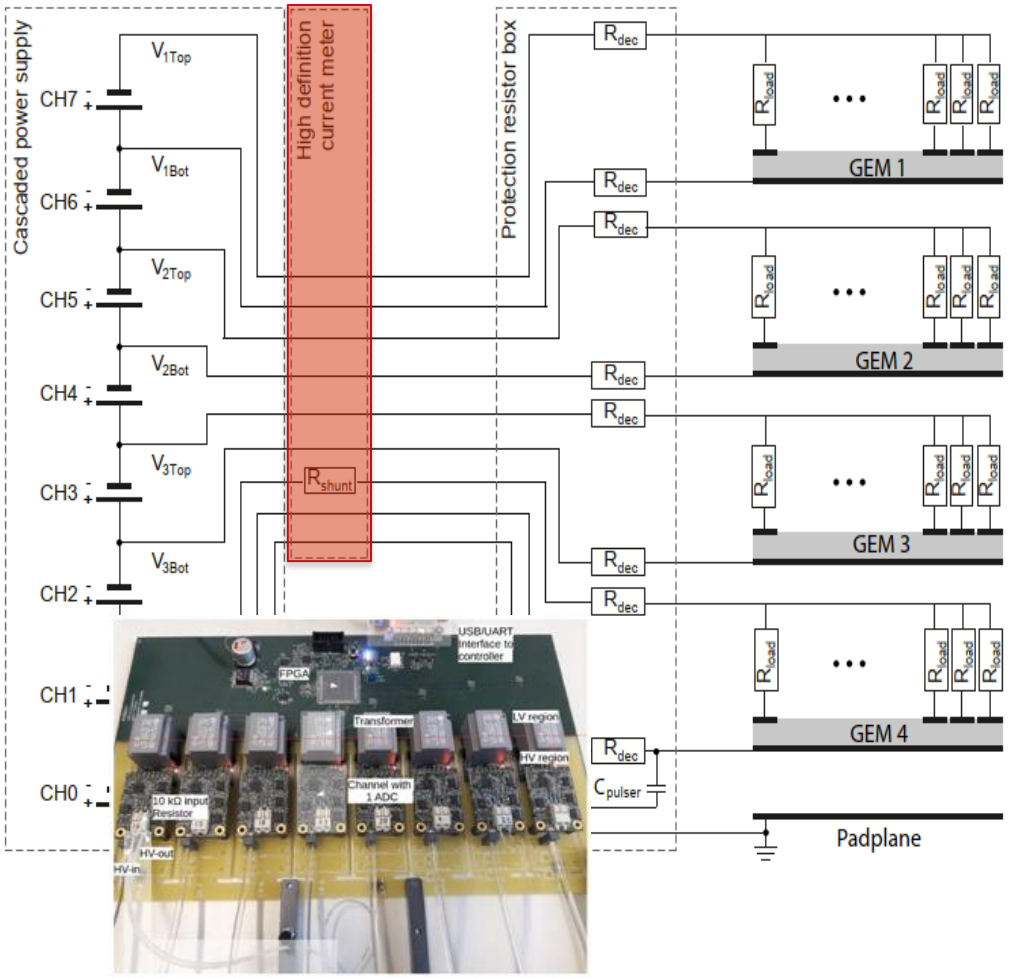
High-resolution current readout:

- High-resolution (<1 nA, 1 kHz) current monitoring (last GEM in stack) for each GEM stack
- Goal: Measure track density fluctuations (luminosity, collision centrality, geometrical) for online distortion calibration



GEM POWERING

ROC connection

Connection procedure

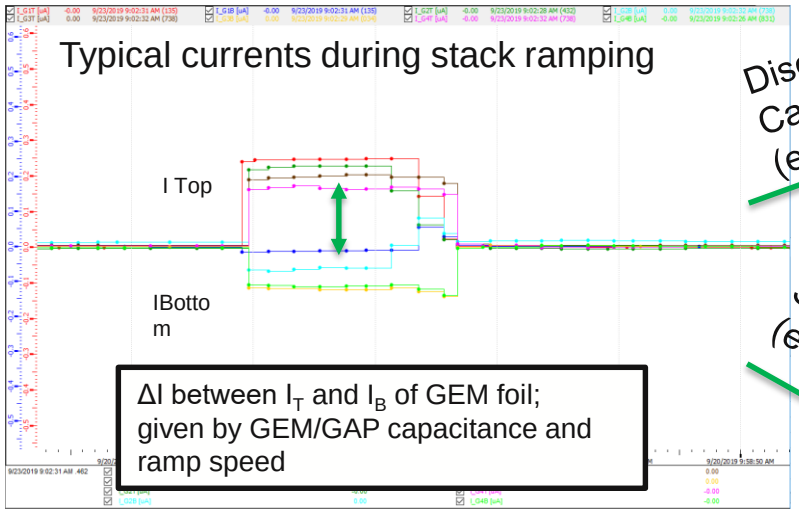
- Connect single channel cables (HV Lemo)
- 4 eye procedure to avoid mistakes
- GEM capacitance measured on PS side to confirm good connection
- Conductance test (G = 0.00-0.001 nS); humidity issue solved after flushing the TPC with CO2 at nominal flow (gas system)

- For Precommisioning temporary long cables are used

GEM SOFTWARE PROTECTION

Software detection of disconnected/swapped channels via measurement of ramp-up currents

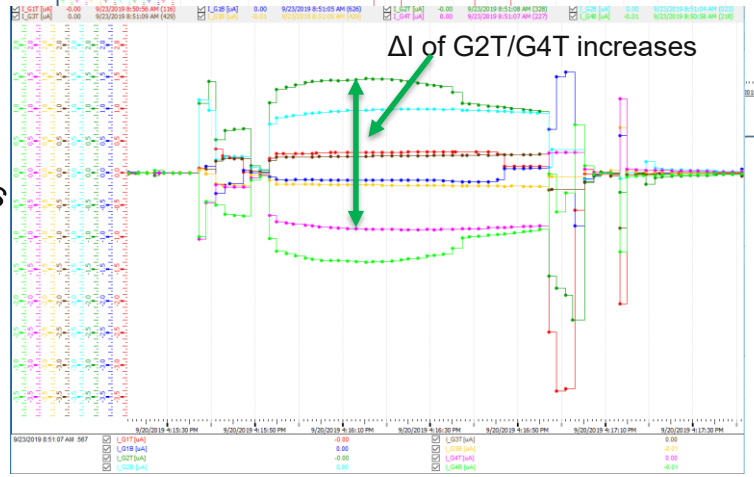
Tested with GEM stack emulator



ΔI between I_T and I_B of GEM foil; given by GEM/GAP capacitance and ramp speed

Disconnected Cable (e.g. G1T)

Swapped cables (e.g. G2B/G4B)



- During ramp currents are constantly checked;
- Ramp is aborted if currents are not correct
- Successfully tested for all disconnected channel/swapped channels
- Ramp procedure is aborted when all voltages are still in safe region.

PRECOMMISSIONING

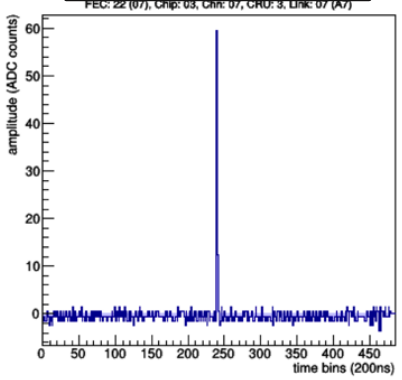
PRE-COMMISSIONING

Test of all sectors

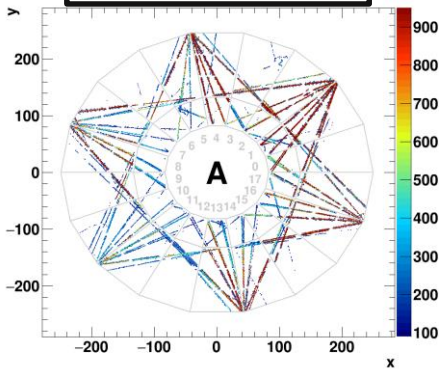
- Readout:
  - Pad connectivity (pulser)
  - Noise performance
  - Tracking (laser and cosmic)

- HV stability of ROCs and Field Cage:
  - Long term operation at full voltage
  - High load tests with X-ray generator

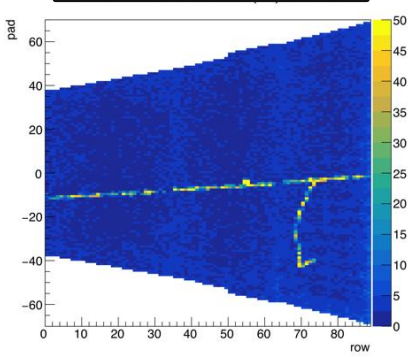
Pulser signal



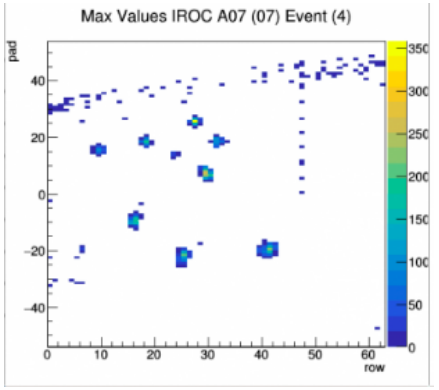
Laser tracks



Cosmic tracks

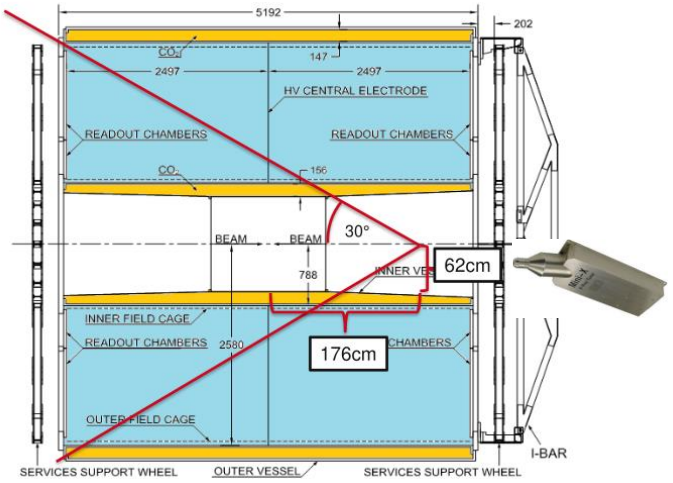


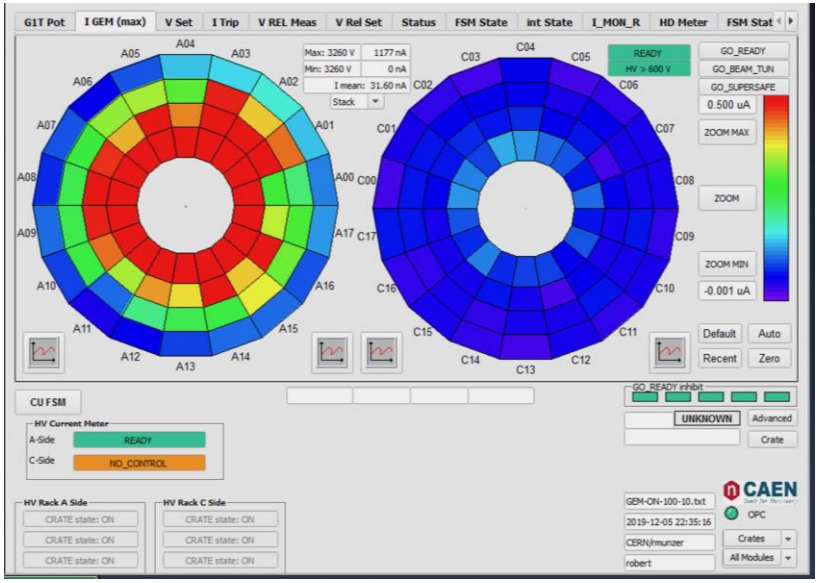
X-ray clusters

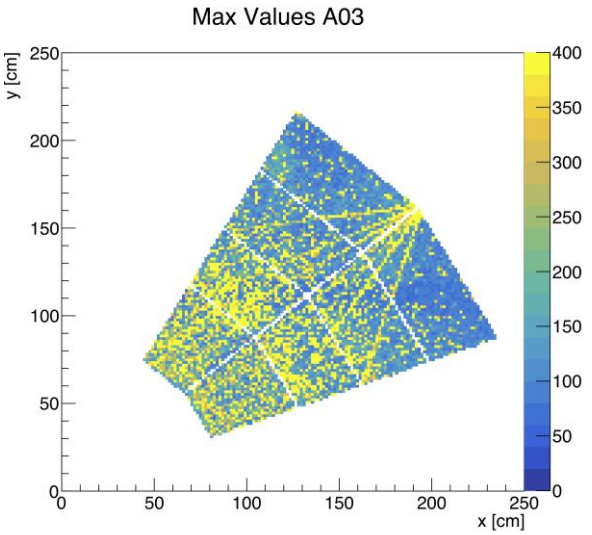


X-RAY IRRADIATION

- Amptek Mini X-ray (Ag Source) is mounted inside TPC
- ~2% conversions, enough to induce loads comparable with expected average scenario
- Studies:
  - Detector stability
  - Distortion studies using laser tracks
  - Charge up / Gain variation

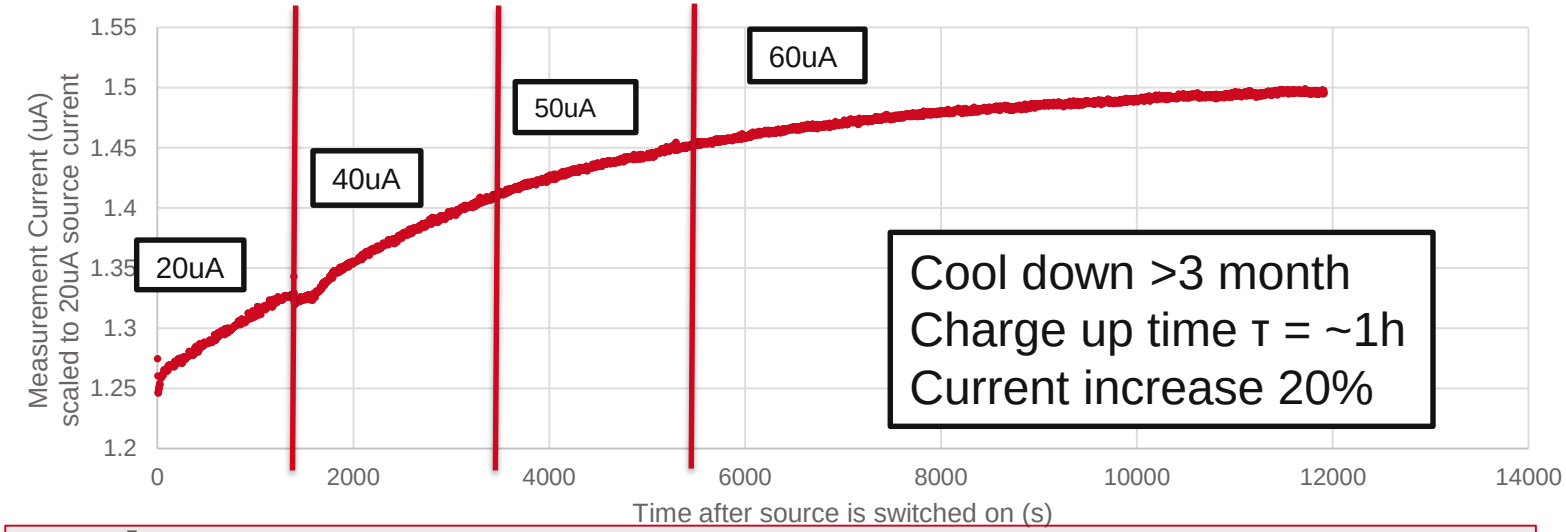


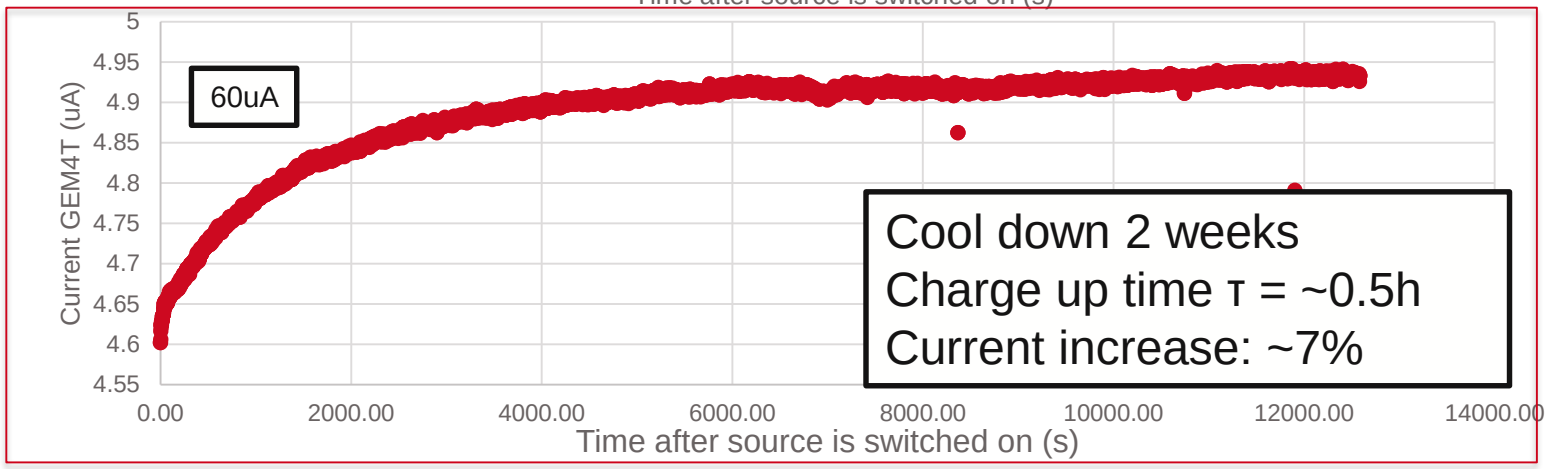




GAIN CHANGE IN GEM

Normalized Current of GEM4T during x-ray scan to 20uA Source current



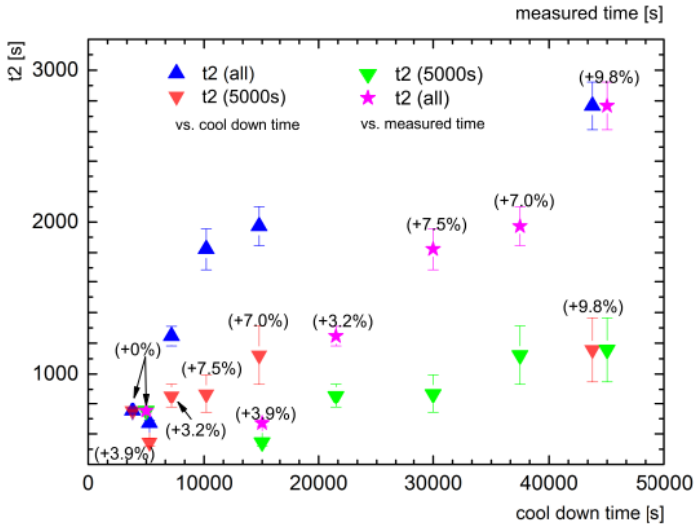


X-RAY SUMMARY

Test	Running time	Cool down (no x-ray)	Charge up time	Current increase (~3h)
1.	3 h	> 3 months (HV off)	1 h	20%
2.	6.5 h	2 weeks (HV on)	0.5 h	~7%
3.	13h 43min	2 days (HV on)	0.1 h	2%
4.	31h 20min	5.5 hours (HV on)	~1-2 min	<0.5%

- With shorter cool down time:
  - the charge-up time is shorter and the
  - gain change is smaller

➢ Small effect during standard LHC operation expected



Y. Vetter – Bachelor Thesis 2015 (Heidelberg)

ALICE

CHAMBER REPLACEMENT

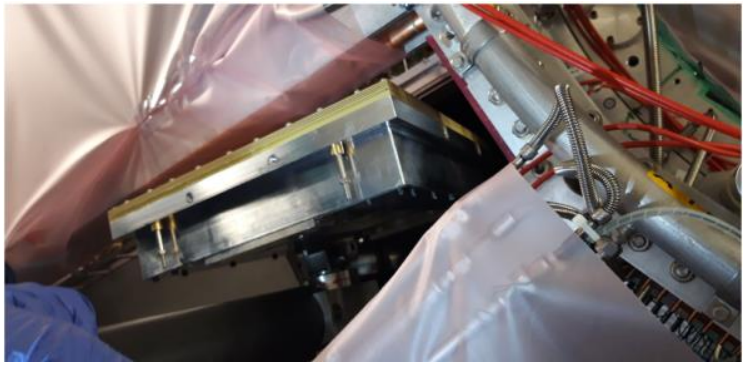
CHAMBERS

A few chambers needed to be replaced

- **A10-IROC:** HV Connection to GEM foil broke between testing and installation
- **A07-IROC:** Bad contact in HV cable.
- **A08-OROC:** Short between GEM foils due reduced tension in foil

- **A02-IROC:**
  - Temporary increase of current in GEM2 after X-ray irradiation
  - Recovered after further operation.
- **A16-IROC:**
  - Temporary increased of current in GEM2 after X-ray irradiation
  - Recovered after further operation.

IROC with extra current could have stayed inside TPC



ALICE

FURTHER PLAN

FURTHER SCHEDULE

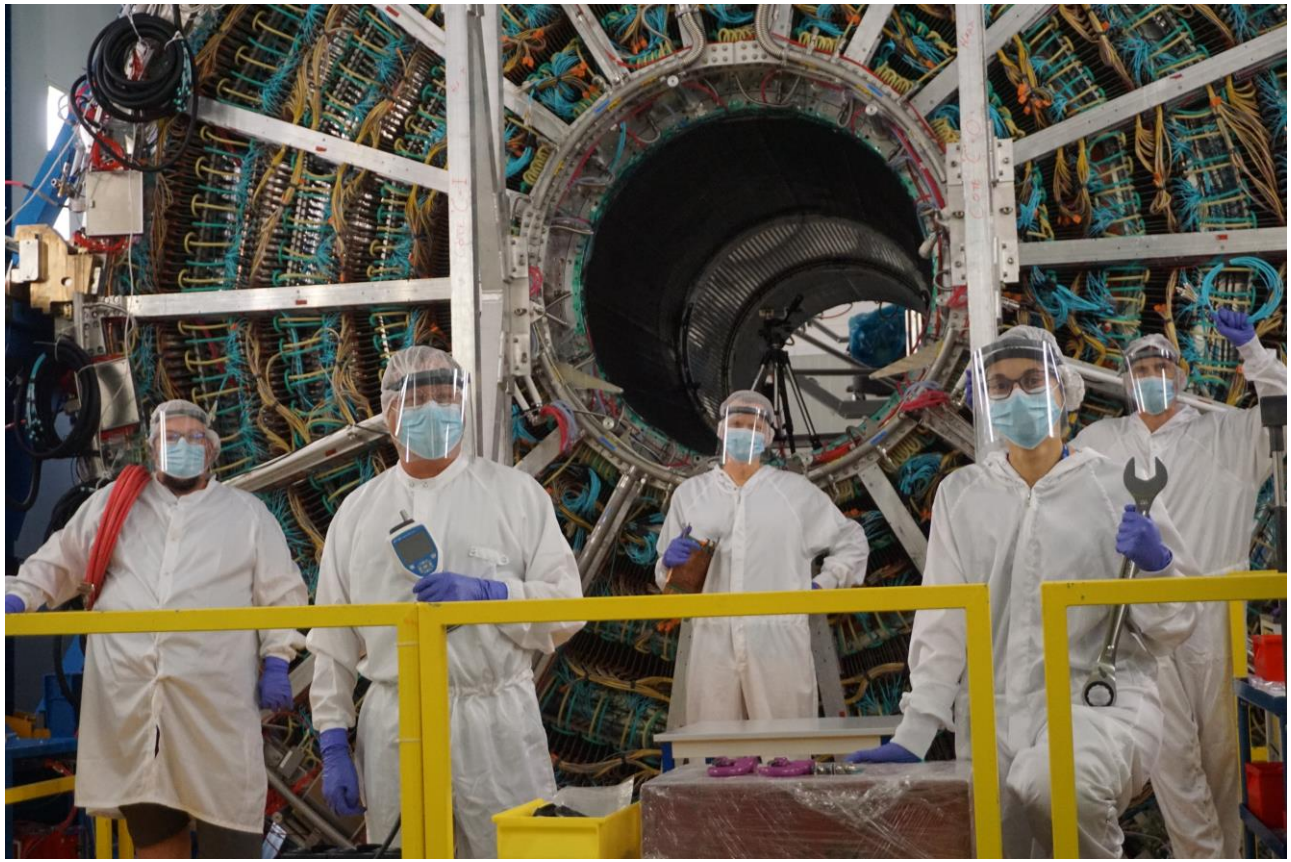
Milestones

- July 2020: TPC will be moved back to cavern
- Aug./Sep. 2020: Installation of new ITS of ALICE inside TPC
- Oct.-Dec. 2020: Connecting in cavern
- From Jan. 2021: Standalone Commissioning
- From Mar. 2021: ALICE global Commissioning
  - Jul. 2021: TPC Kr Calibration

SUMMARY

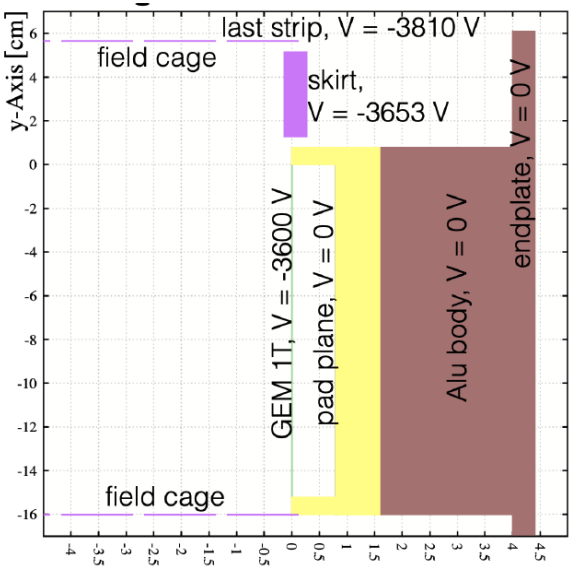
- ALICE TPC successfully upgrade with GEMs
- Field Cage adopted for different powering scheme
- Installation of services finished
- Pre-commissioning of TPC finished
- Preparation for moving back to ALICE ongoing

THANK YOU VERY MUCH

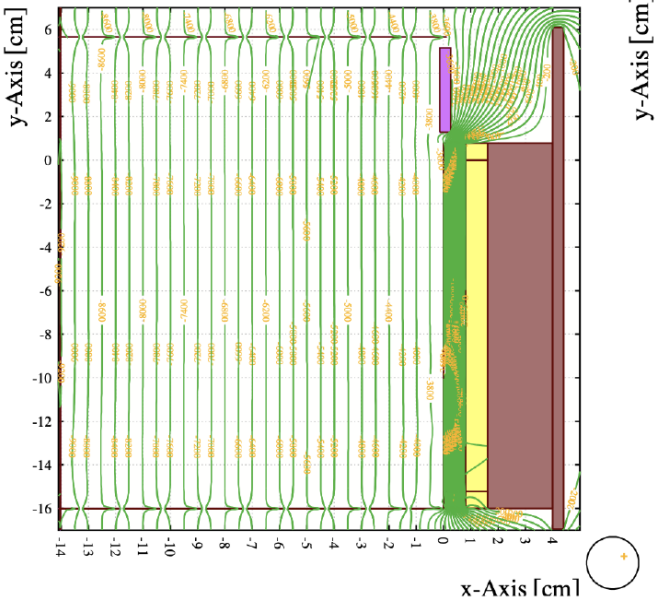


BACKUP

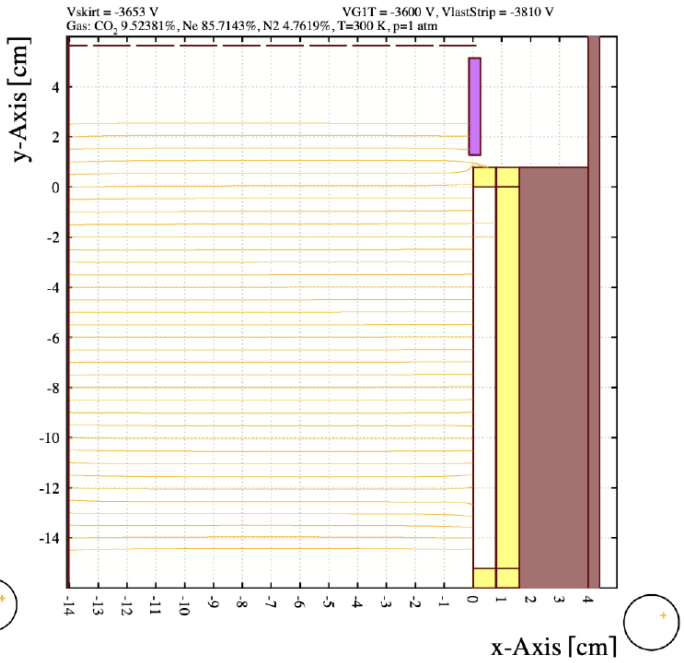
OPERATION WITH SKIRT



Equipotential lines

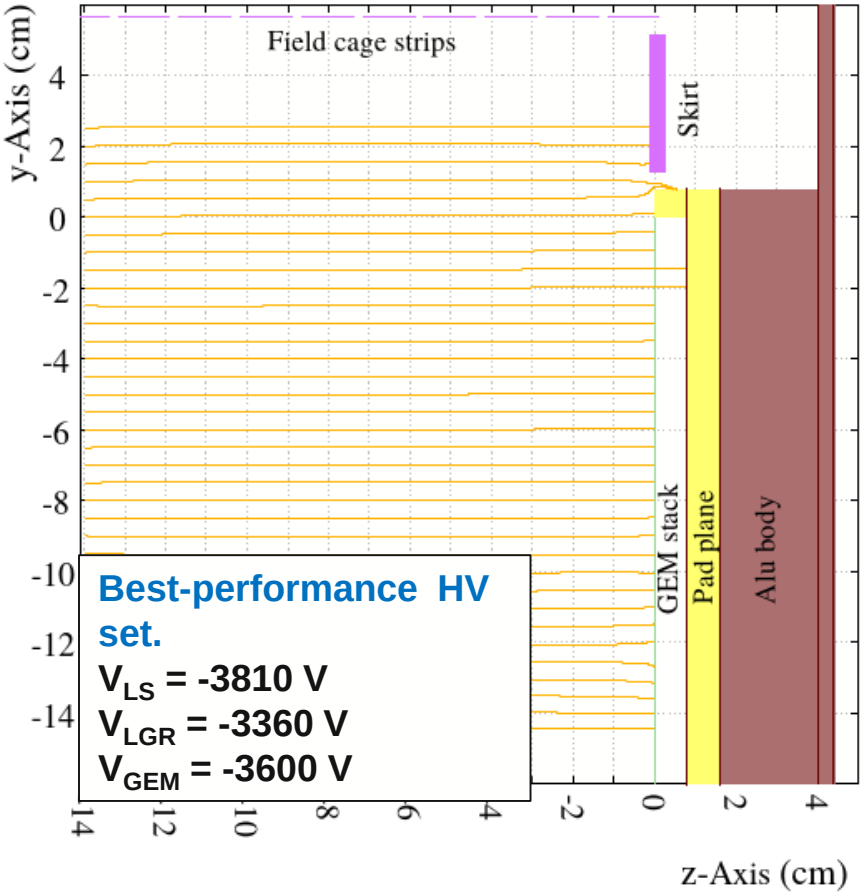


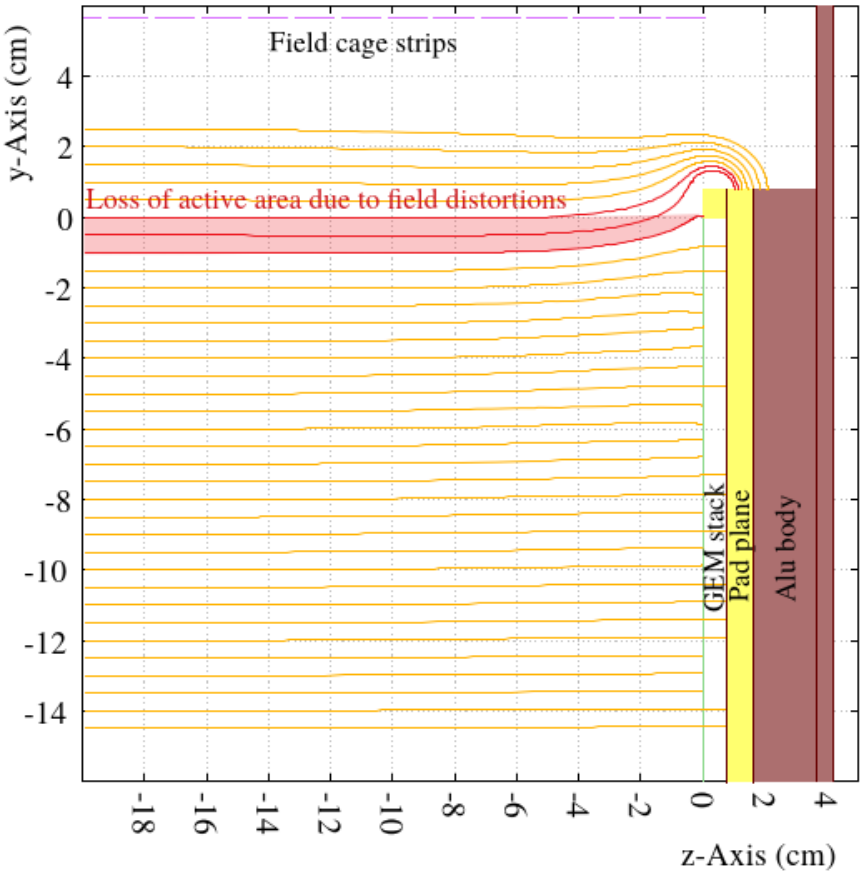
Field (drift) lines



Ernst

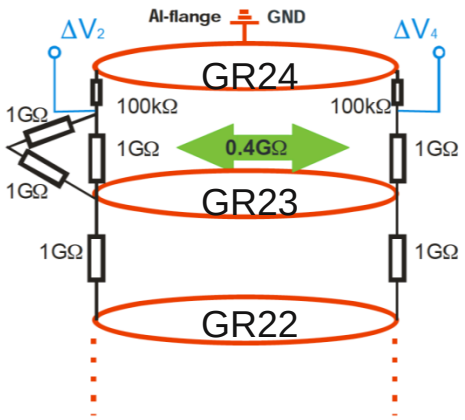
OPERATION WITHOUT SKIRT

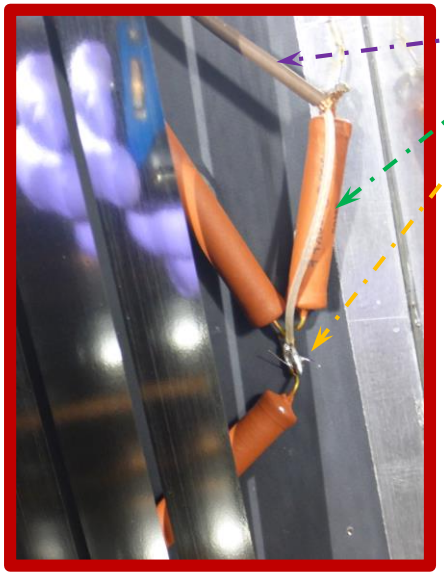




GUARD RING RESISTOR CHAIN

- Four GR resistor chains on each TPC side (2 per Inner/Outer FC)
- Implementation of the new GR powering scheme to avoid high potential gradients
- Connection of last GR resistors not suitable for the nominal voltages





Remove cable

Remove 100 k resistor

Solder HV cable and passivate

before/after

New GR HV scheme

- GRs need to be powered to match potentials of RR
- HV potential supplied to GR23
- ΔV between GR and RR at the same order like in Run1/Run2
- Coupled operation of GR and RR potential