Upgrade of the ALICE Time Projection Chamber for the LHC Run3

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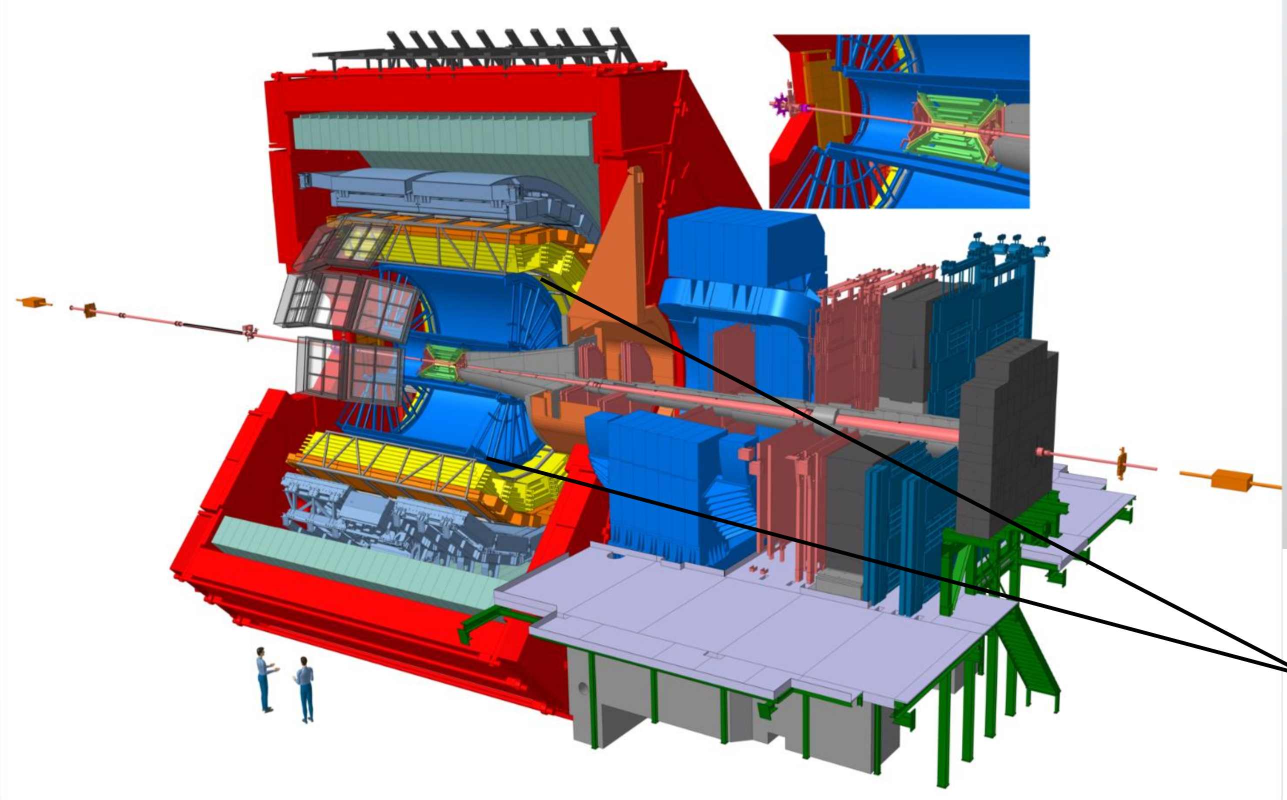
On behalf of the ALICE Collaboration

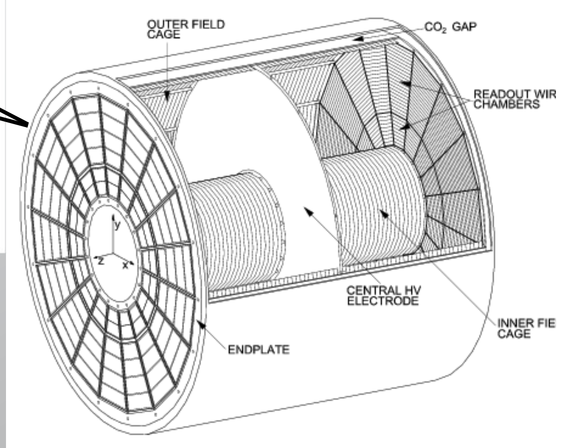
July 10-17, 2019

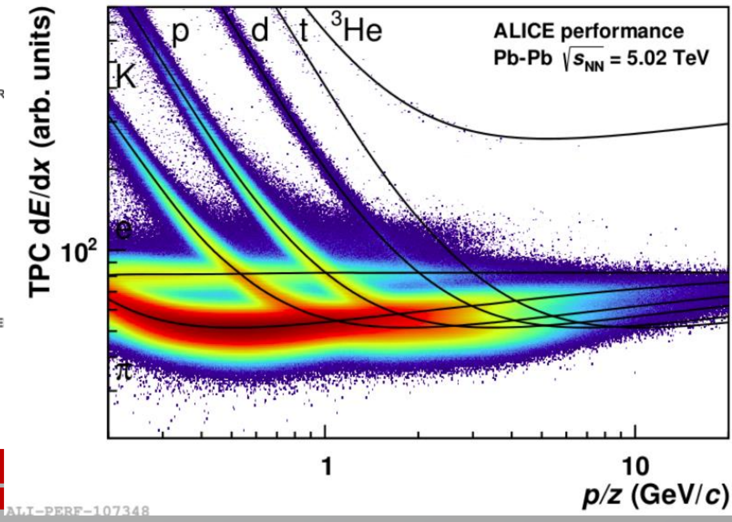
OTKA: NKFIH K120660

The ALICE detector

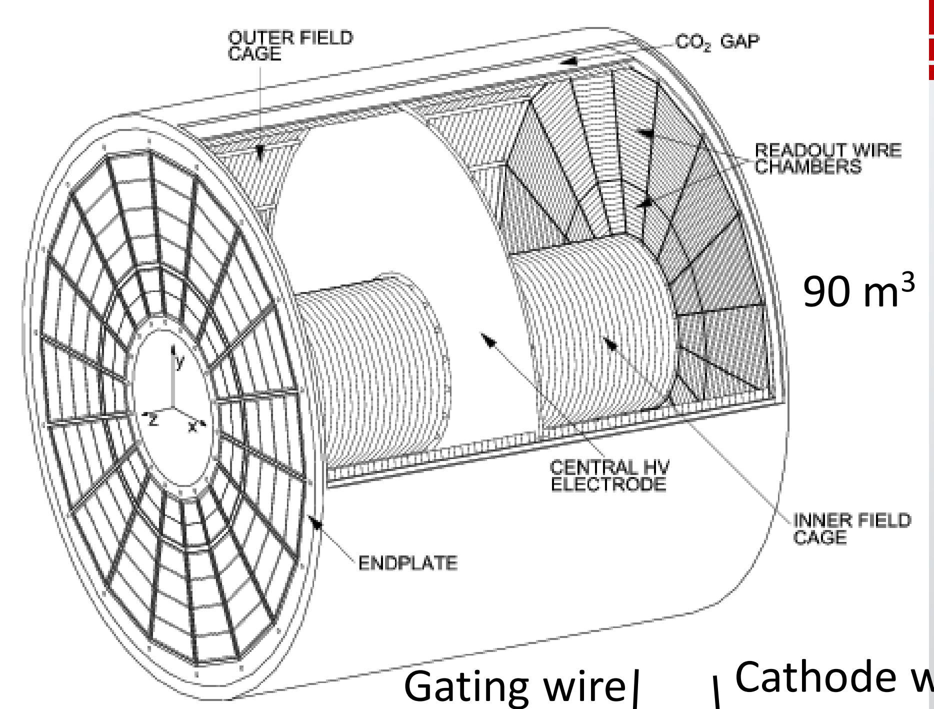


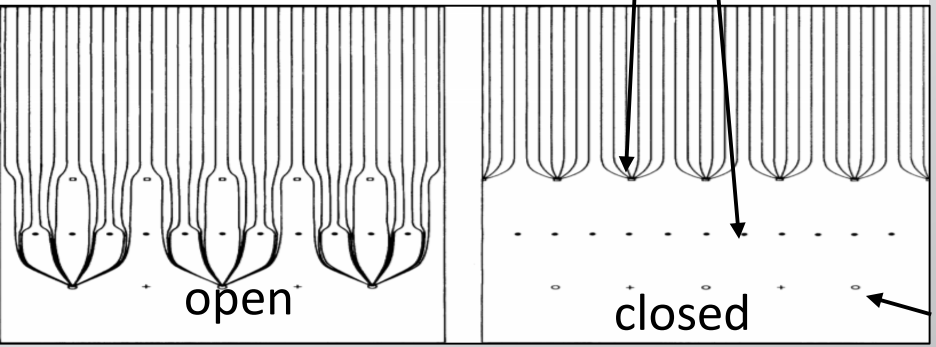
- Quark-Gluon Plasma (QGP) is a state of matter at extremely high temperature and energy density
- ALICE experiment: Study the physics of strongly interacting matter, especially where QGP forms
- The ALICE detector has demonstrated excellent tracking and particle identification (PID) capabilities in RUN 1 and 2





The ALICE Time Projection Chamber





- The main tracking and particle identification detector in the central barrel, 3D tracking with a $800\mu\text{m}$ precision
- Filled with Ar-CO_2 (88-12), Ne-CO_2-N_2 (90-10-5)->Run 3 ,Ne-CO_2 (90-10) ->Run 1
- The drift voltage is 100kV with 400 V/cm drift field
- Maximum electron drift time $\approx 100\mu s$
- Multi-Wire Proportional Chamber(MWPC)-based readout with gating grid -> electron avalanche and ion backflow suppression
- The gating grid is kept closed for $200\mu s$ with alternating potential to efficiently block the ions ->Limits the readout ~3.5 kHz

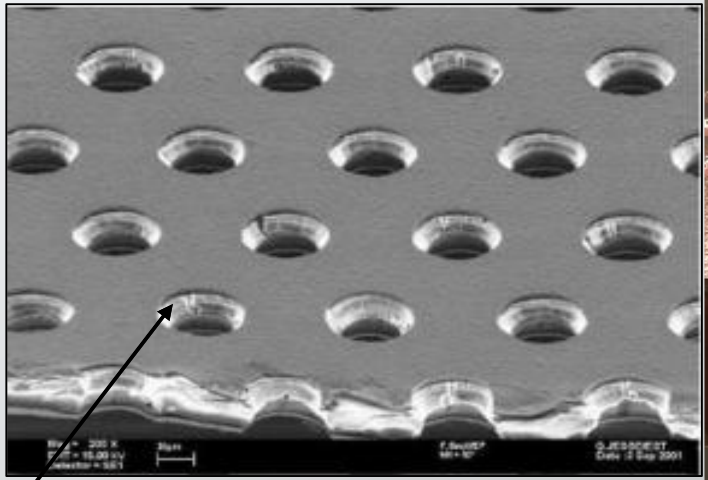
The objectives and requirements for Run3

- Increase of the LHC luminosity after LS2 to 50 kHz in Pb-Pb ->operation with gating grid is not an option
- New readout chamber is needed: The choice of Gas Electron Multipliers (GEM)
  - Intrinsic ion-blocking capabilities to avoid massive charge accumulation
  - Keep space-charge distortions at a tolerable level (ion backflow<1%)

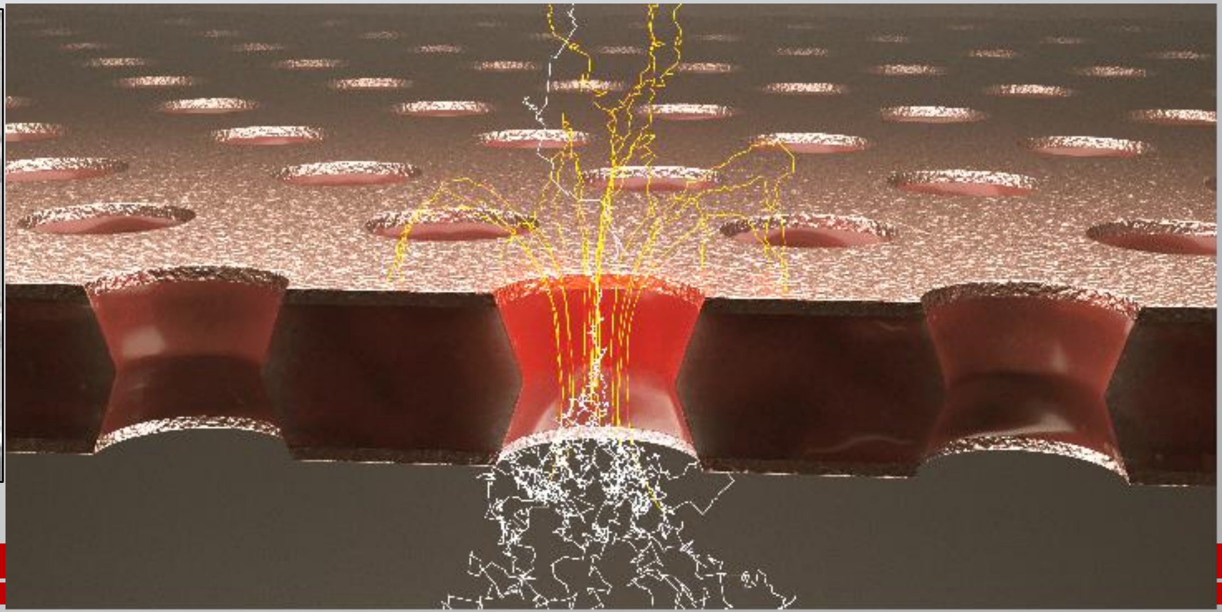
    -> Distortions are less than 10 cm in the drift volume and can be calibrated
- New readout electronics which enables continuous readout
- High data rate -> Data compression by a factor of 20
- Online pattern recognition and data format optimization
- The dE/dx and combined momentum resolution shall remain the same

GEM operation

- Novel Micro Pattern Gaseous Detectors (MPGD) – RD51 collaboration (http://rd51-public.web.cern.ch/rd51-public/)
- Result of a major R&D effort: Gas Electron Multiplier(GEM)
- A thin, metal-clad Kapton foil, chemically pierced with a high hole density
- Difference of potential between top and bottom side, high electric field inside the holes
- Electrons drift into the holes and multiply (avalanche), the GEMs can be cascaded



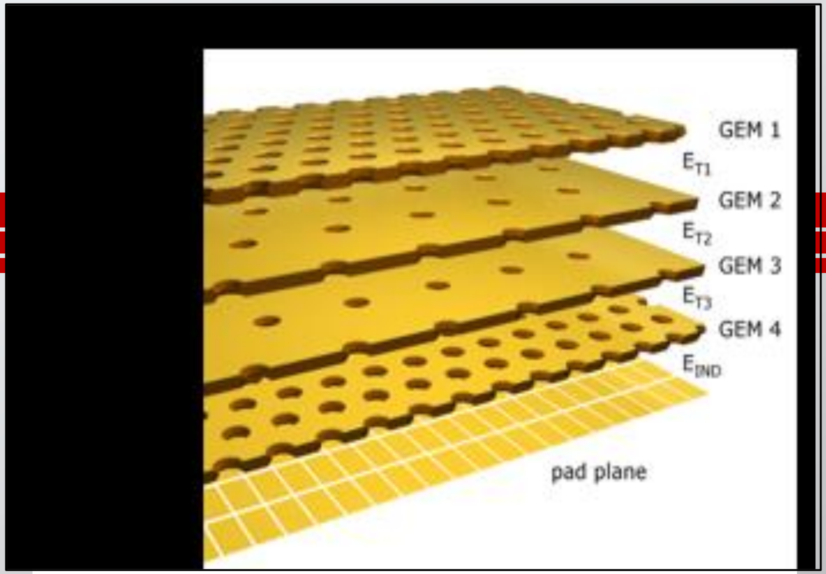
$50\mu m$ Credit: RD51 collaboration

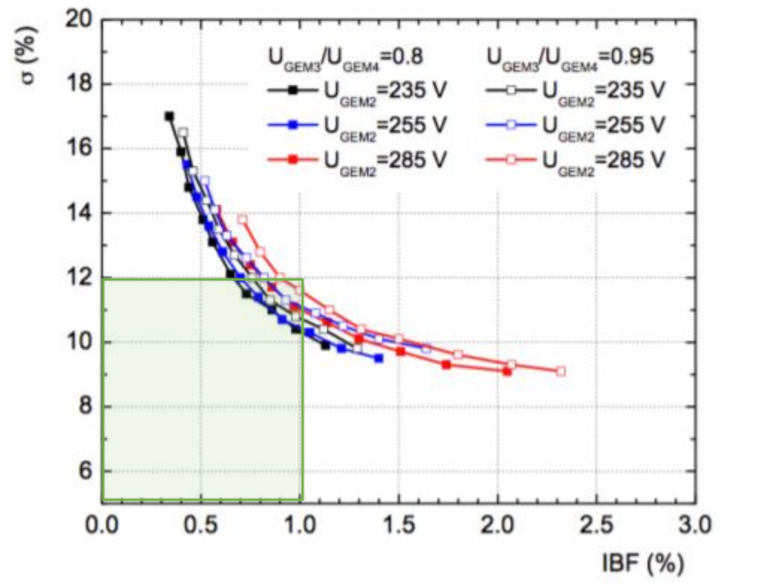


Erik Brücken, Timo Hildén: Garfield simulation

Readout Chambers

- Inner and Outer Readout Chambers (IROCs and OROCs)
- The result of several years of extensive R&D lead to quadruple GEM stacks, which have proven to provide sufficient ion blocking capabilities
- Upper limit of 1% for the fractional ion backflow(IBF)
- Preserve the intrinsic dE/dx resolution and keep the space-charge distortions at a tolerable level
- Total effective gain ~ 2000
- Position 1&4: Standard GEMs (140μm pitch)
- Position 2&3: Large pitch (280 μm pitch)
- Optimizing the energy resolution and IBF

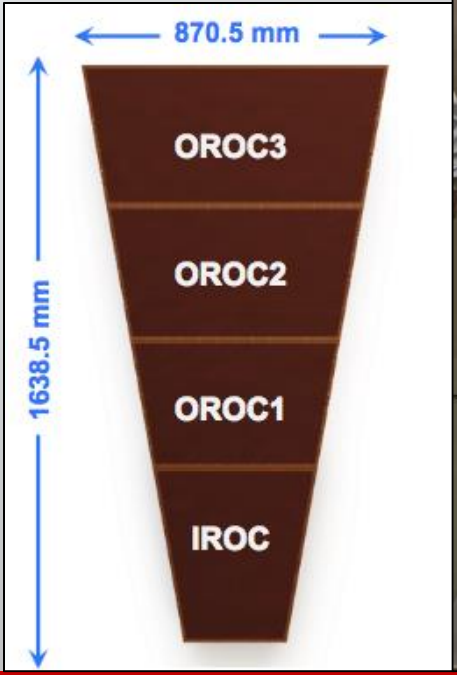


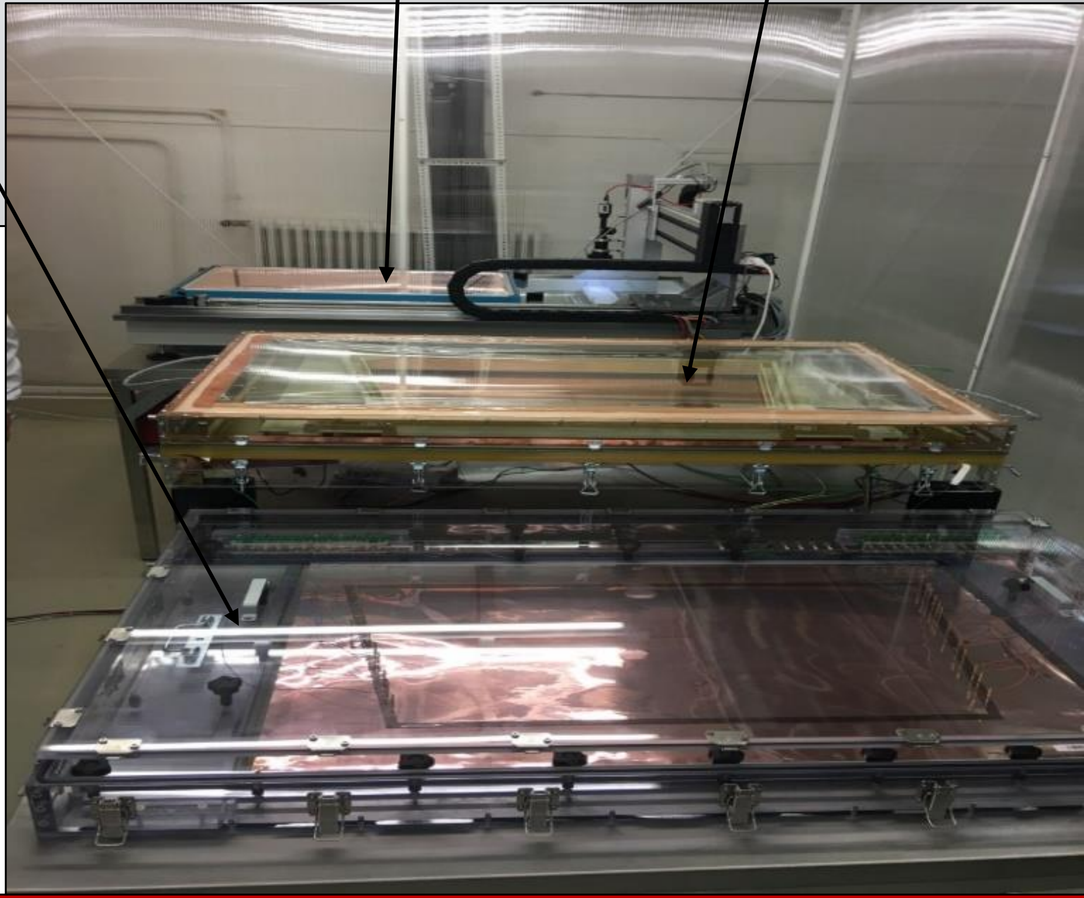


Reference: **Technical Design Report for the Upgrade of the ALICE Time Projection Chamber, The ALICE Collaboration, 2014.**

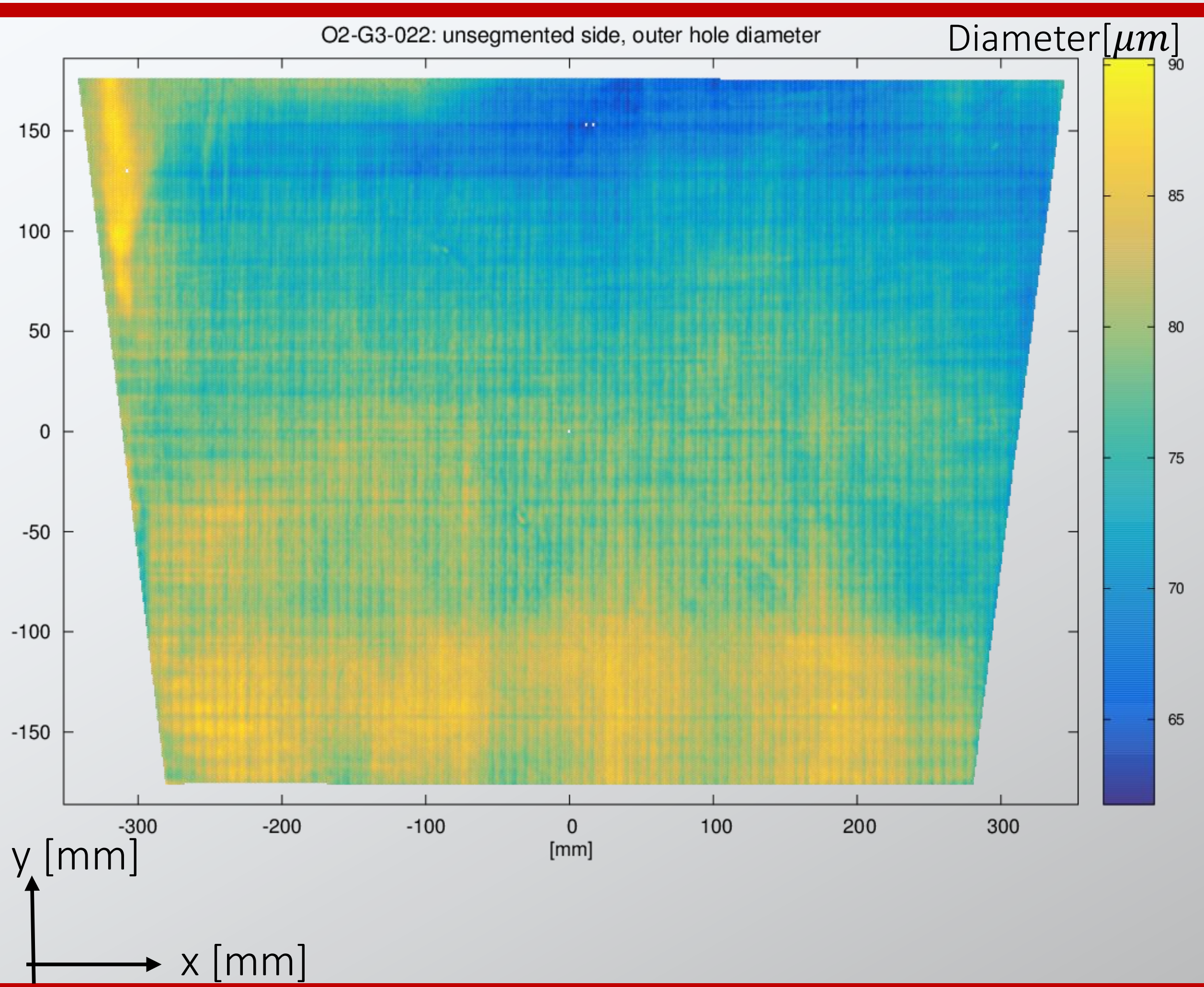
GEM Quality Assurance

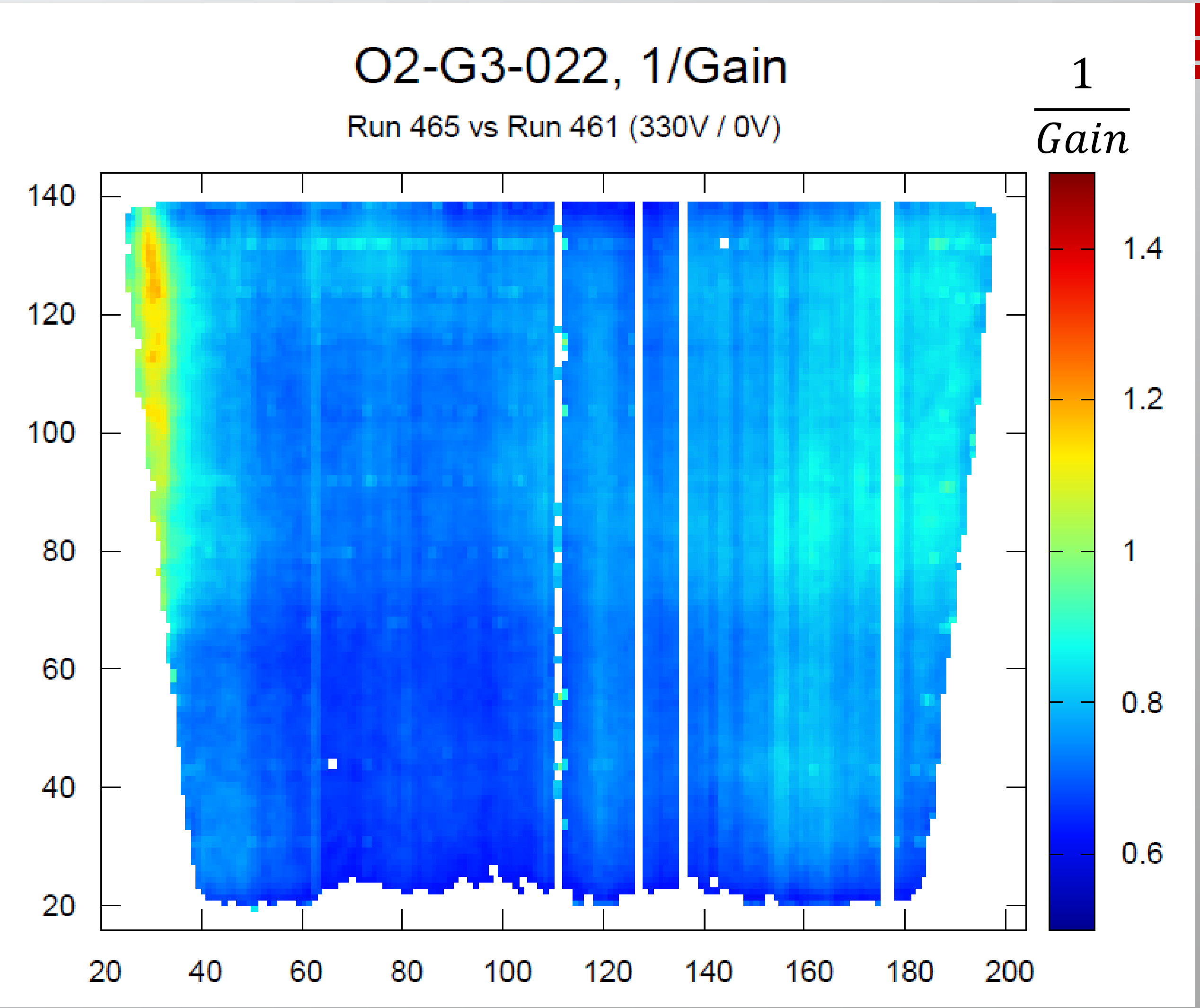
- Cannot be repaired during operation
- Production issues/limits (chemical etching)
- Cutting edge technology
- Quality selection (Basic and Advanced)
  - Imperfections
  - Hole size, gain uniformity
  - Long-term stability (electrical)
- Feedback for production
- Four types of GEMS:
  - Budapest QA center: IROC,OROC2
  - Helsinki QA center: OROC1,OROC3
- 720 Foils → 1.5 years (2017-2018)





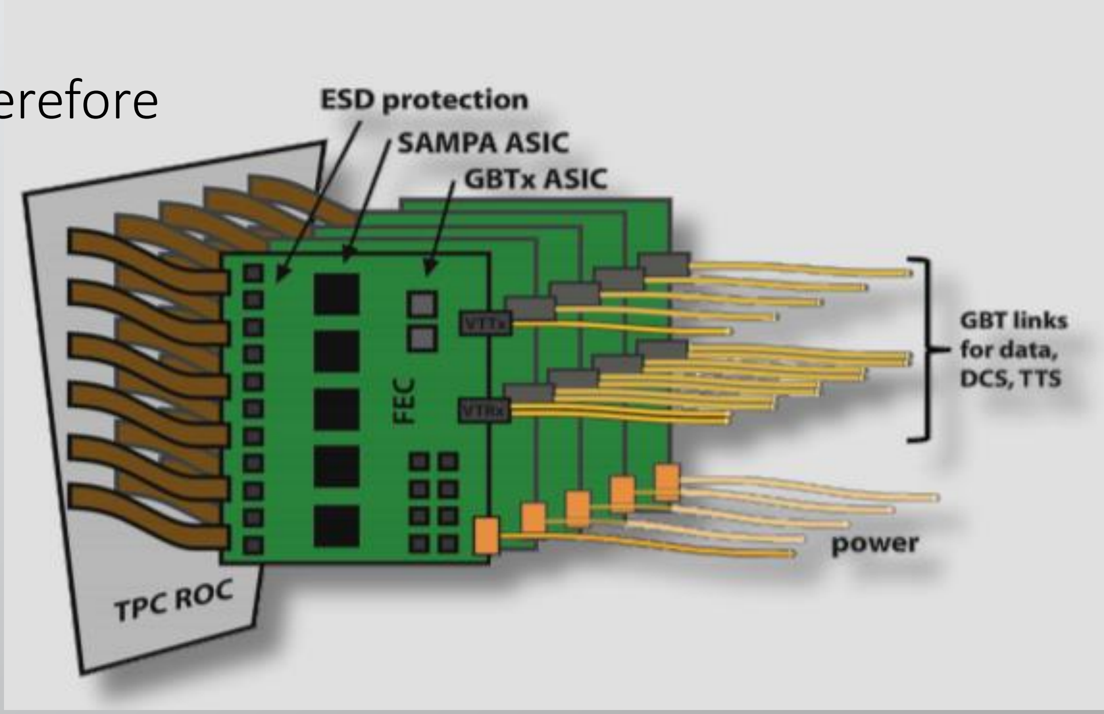
GEM Quality Assurance examples





New readout electronics

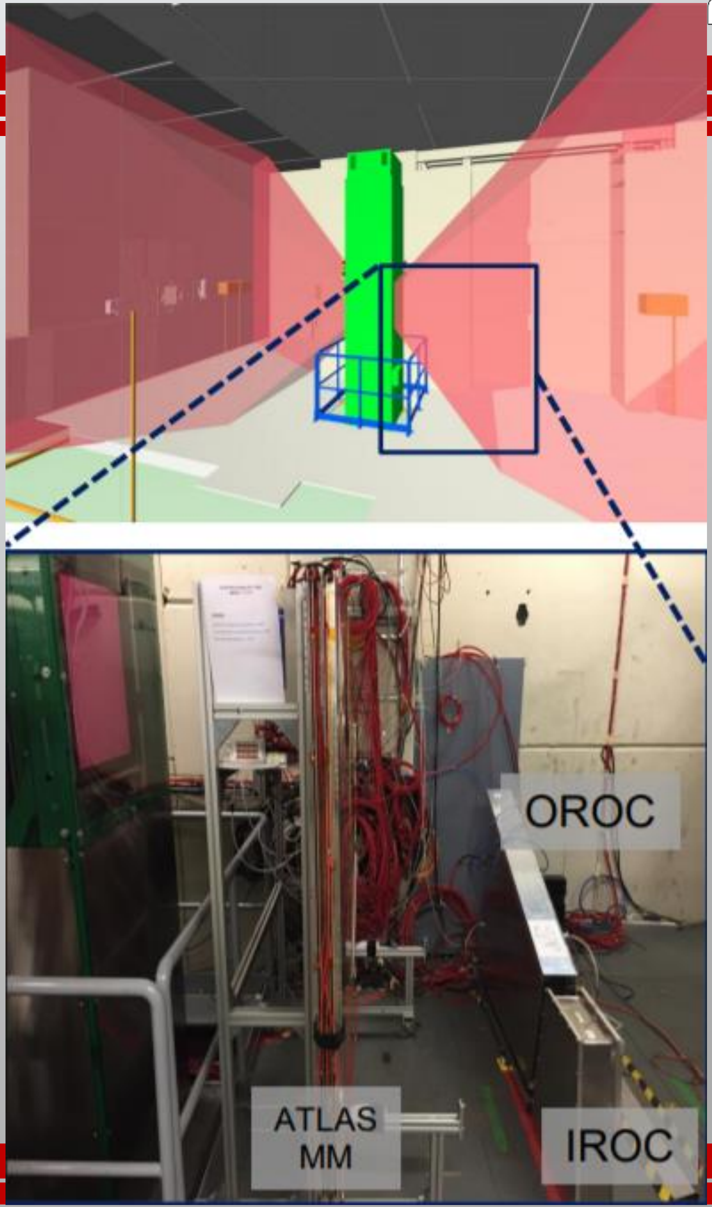
- The increased luminosity implies continuous readout therefore higher readout rate is necessary
- New FE ASIC SAMPA has been developed
  - Positive or negative input
  - Programmable conversion gains and peaking times
  - Digital signal processing



- See **Andrea Ferrero**'s talk (Muon spectrometry)

Front-End Cards → (3.3 TB/s) → Common Read-out Unit → (500 GB/s) → Online Farm → (20 GB/s) → Tape

ROC tests in ALICE cavern and at GIF++



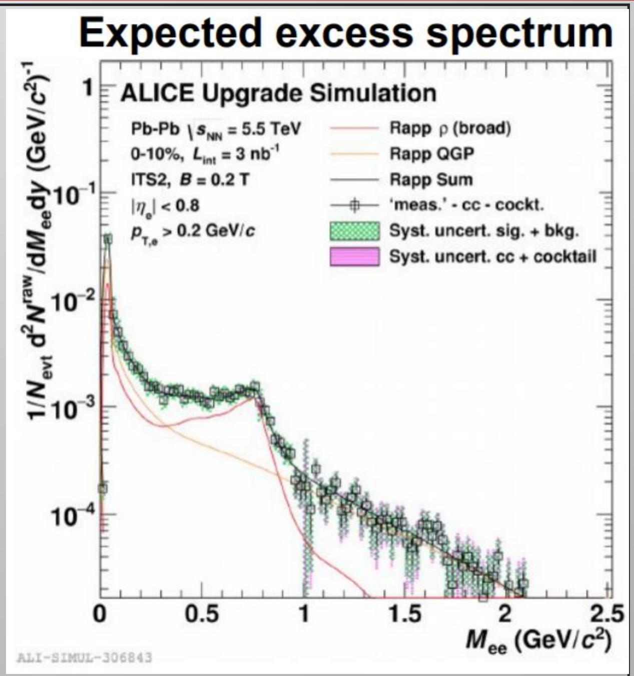
- Before the end of Run 2 the ROCs were tested in ALICE cavern under radiation comparable to Run 3 but not all!
- Continue testing at the Gamma Irradiation Facility (GIF++) at CERN
    - 13 TBq ^{137}Cs source
    - Radiation conditions comparable to cavern tests
- Tested up to 8 ROCs per week and this is completed now
- Some ROCs showed instabilities related to the imperfections of some soldering points
- After repairing and retesting these are OK!

Status

- TPC was disconnected just after the end of Run 2 (Dec, 2018) ✓
- TPC relocated to the surface (Mar 4-5, 2019) ✓
- Leak tests were done and the upgrade could be started in the cleanroom ✓
- Service removal and initial cleaning (Mar 7-11, 2019) ✓
- Front-End Electronics removal (Mar 12-14, 2019) ✓
- Service Support wheels removal ✓
- TPC entered clean room (Apr 5, 2019) ✓
- Full sector tests and exercising installation ✓
- By October 2019 **ready for data taking** in clean room
- **Ready for transportation** (Feb 4, 2020)

Summary

- ALICE upgrade during LS2
- TPC with continuous readout at 50 kHz in Pb-Pb
  - No gating grid, low ion backflow, good resolution
- GEM TPC
  - Quadruple GEM, optimized for low IBF < 1%
- Quality Assurance was successful
- Successful beam test
- Successful ROC testing at GIF++
- Ongoing ROC reinstallation
- Stay tuned!



See **Raphaelle Bailhache**'s talk

Thank you for Your attention!

Acknowledgements:
ALICE TPC Upgrade group
REGARD group
RD51 collaboration
Wigner RCP
Helsinki QA center
Budapest QA center

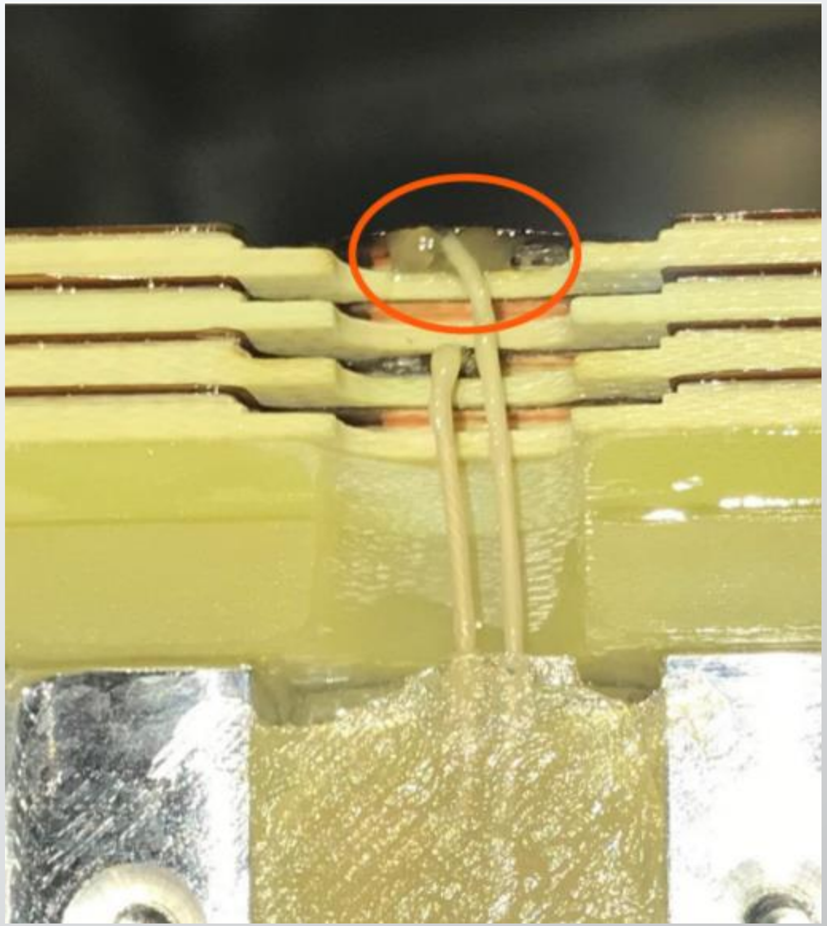
July 10-17, 2019

OTKA: NKFIH
K120660

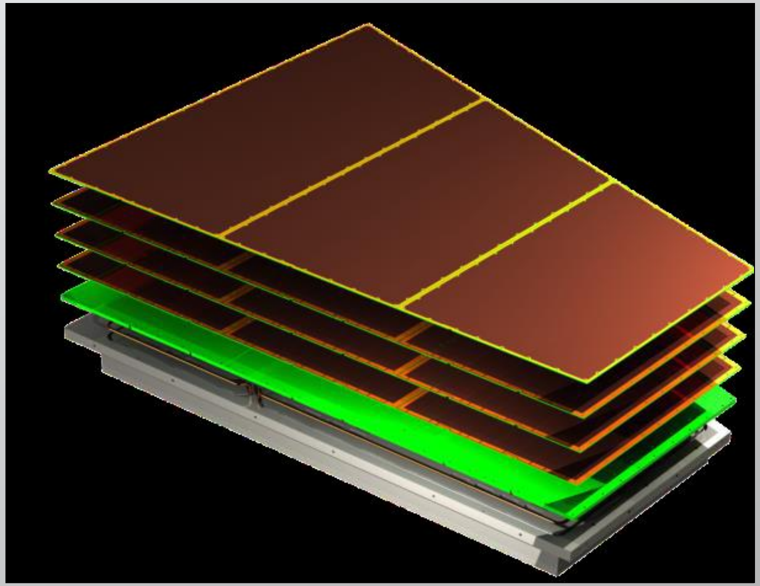
References

1. The ALICE Time Projection Chamber and its upgrade, Alexander Deisting, 2019.01.30, Seminar
2. Technical Design Report for the Upgrade of the ALICE Time Projection Chamber, The ALICE Collaboration, 2014.
3. A continuous-readout TPC for the ALICE upgrade, Christian Lippmann, 2017, EPS-HEP
4. ALICE TPC Upgrade test beam at T10, Christian Lippmann, Chilo Garabatos, 2017
5. Overview of the ALICE TPC upgrade towards a continuous readout TPC From R&D to Installion, Markus Ball, Piotr Gasik, 2019

Backup



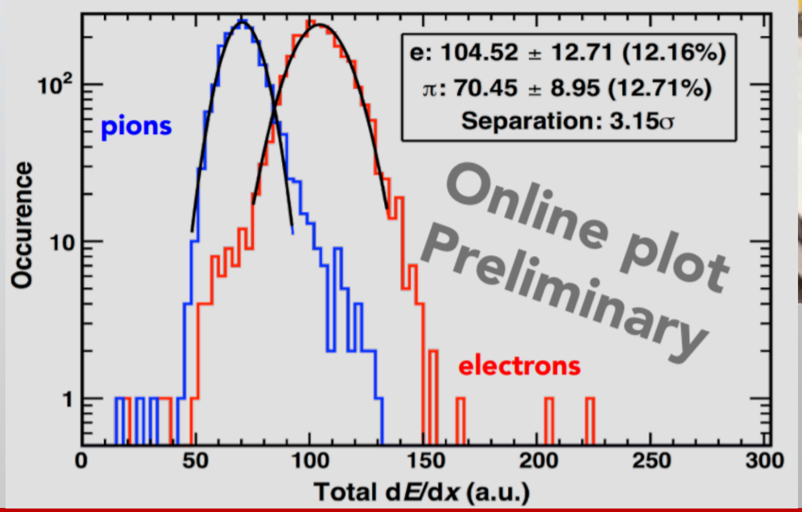
Imperfection at the soldering point

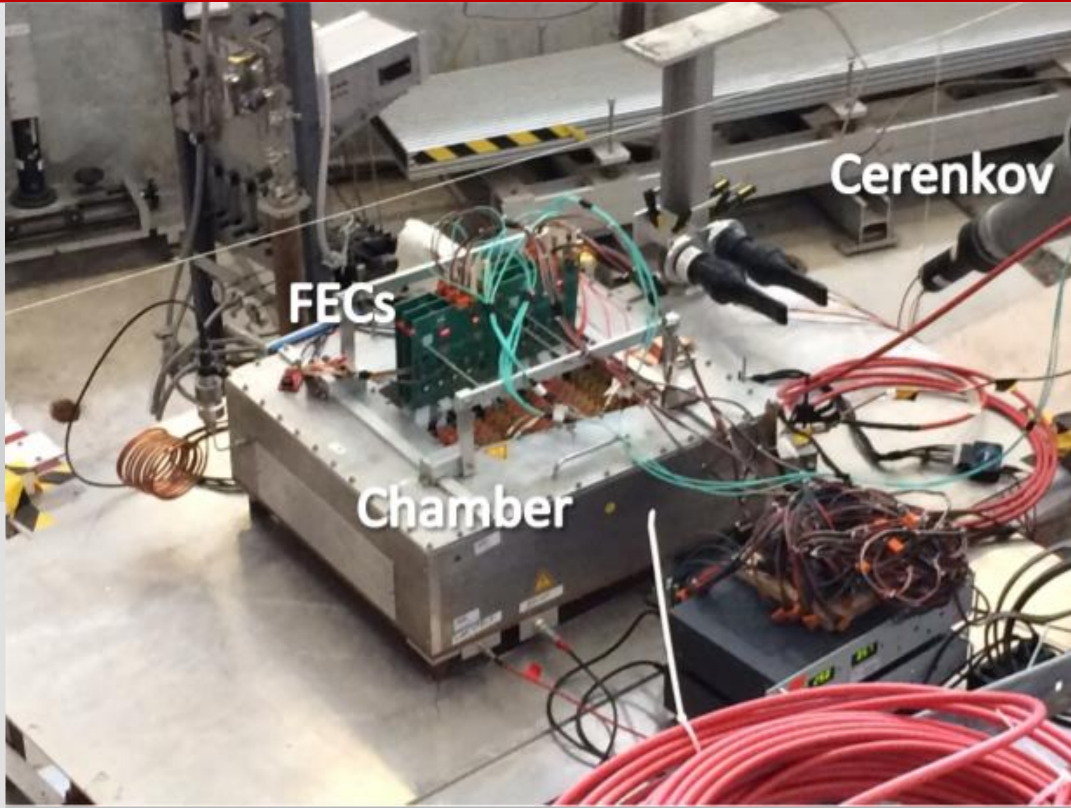


Gems cascaded

Backup performance in beam test

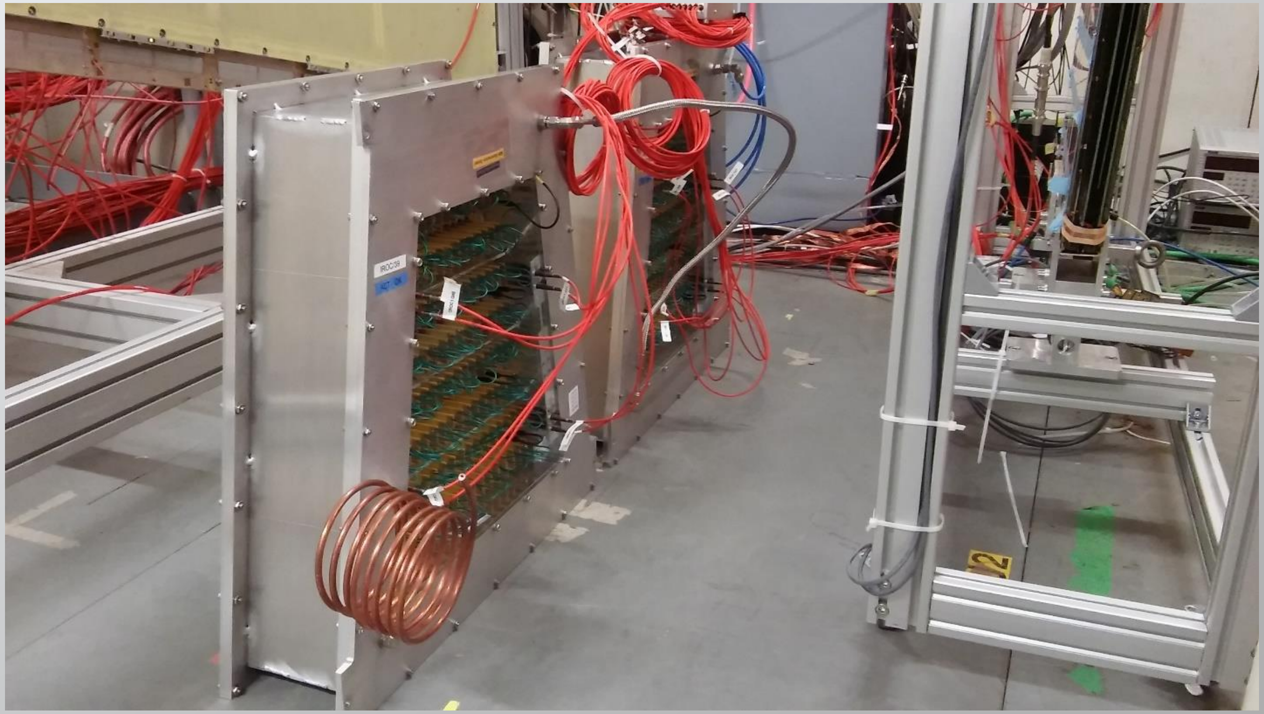
- Successful beam test at CERN PS in May 2017 with an IROC prototype
- Good separation between electrons and pions as expected
- Stable High voltage operation with two prototypes of power supplies
- The energy resolution and the IBF criteria are achieved





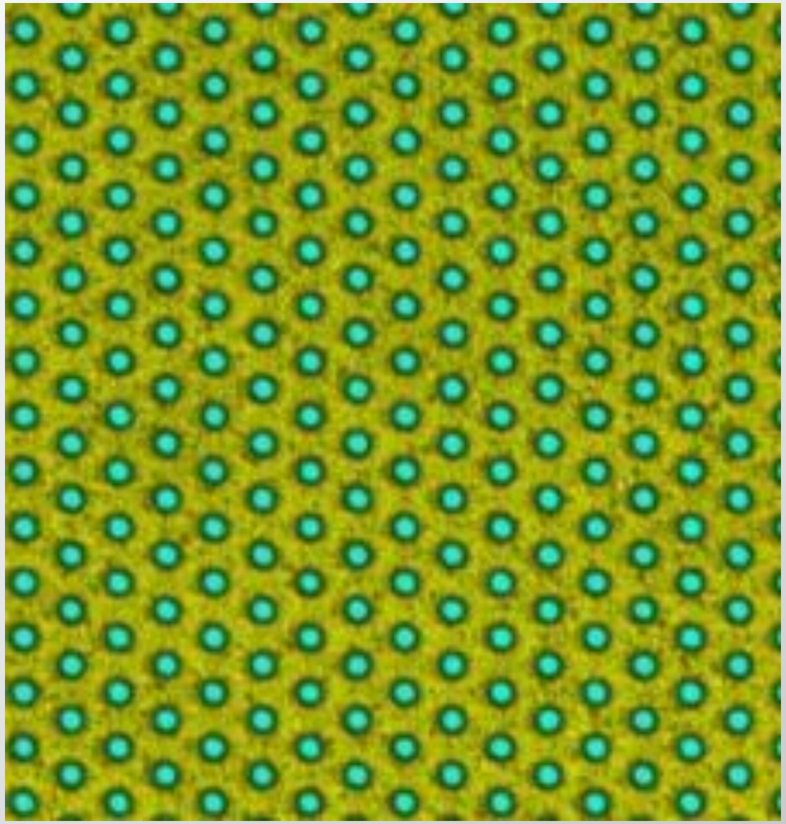
Backup

ROCs in the cleanroom

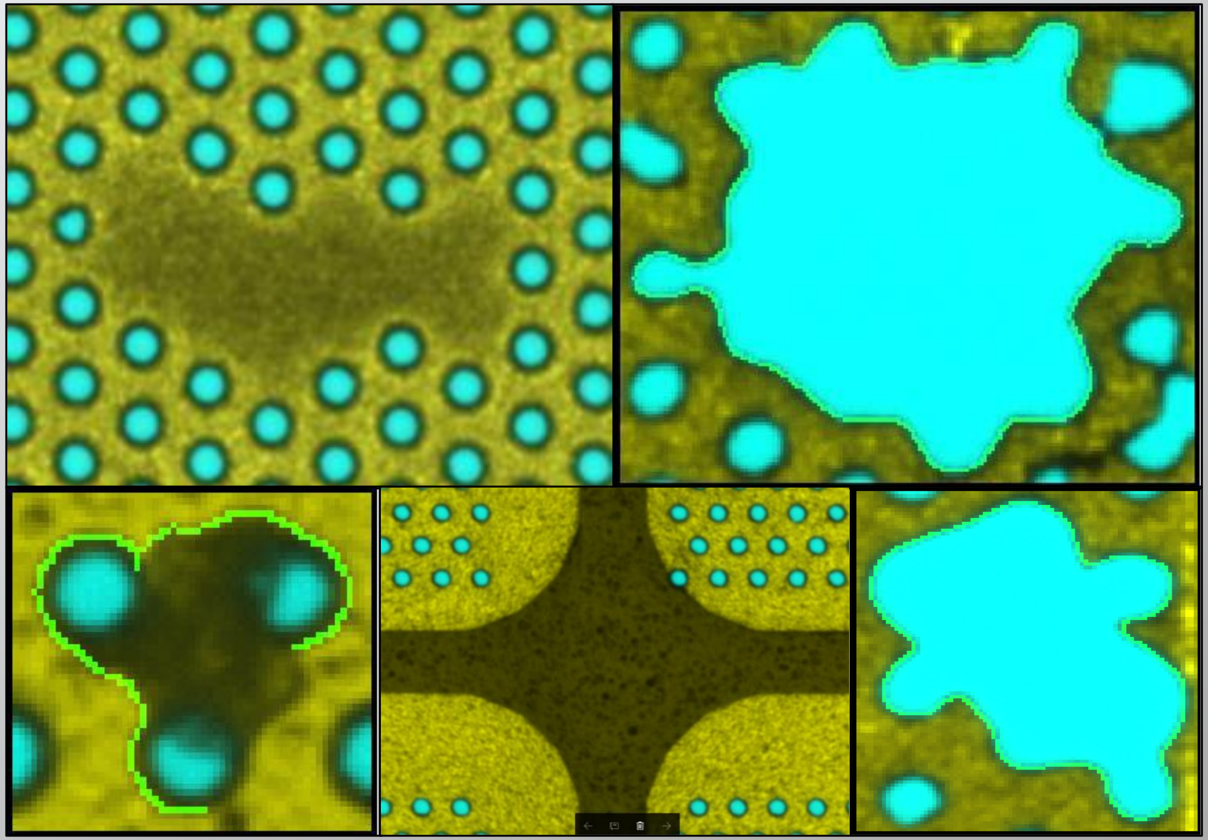


ROCs testing at GIF++

Backup



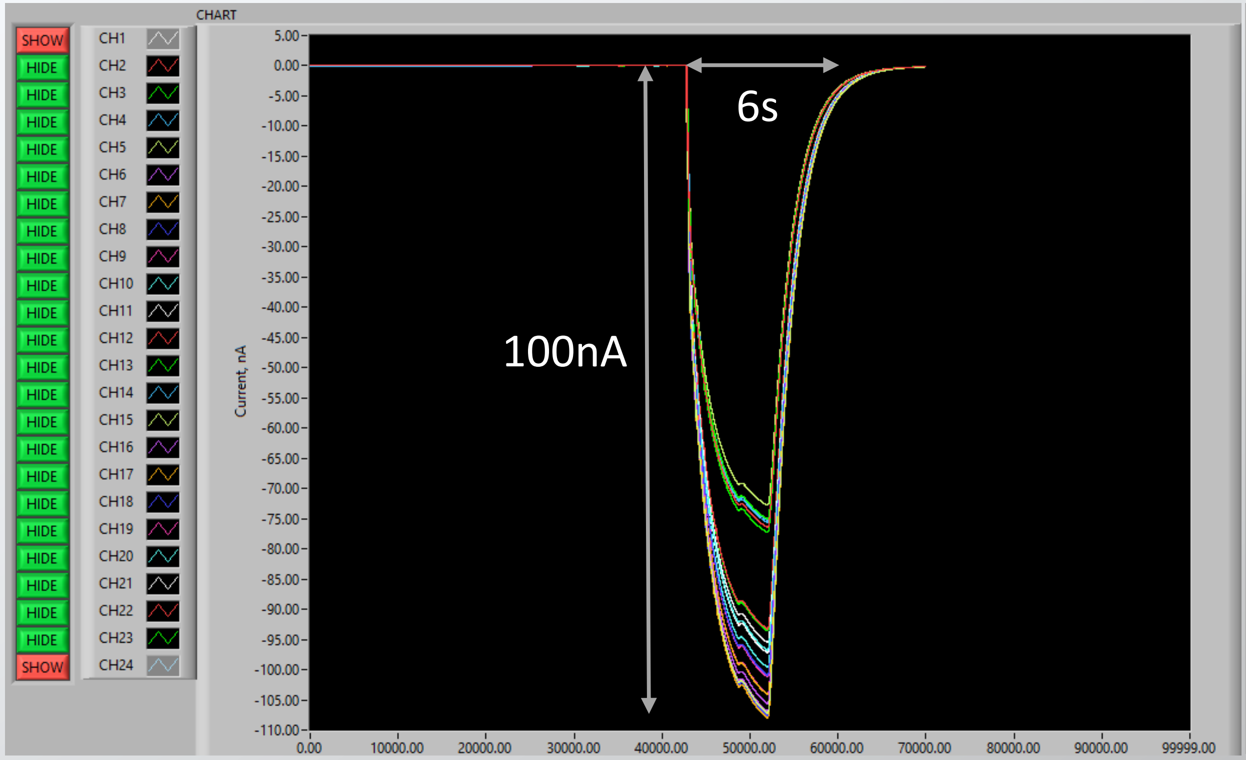
Normal foil

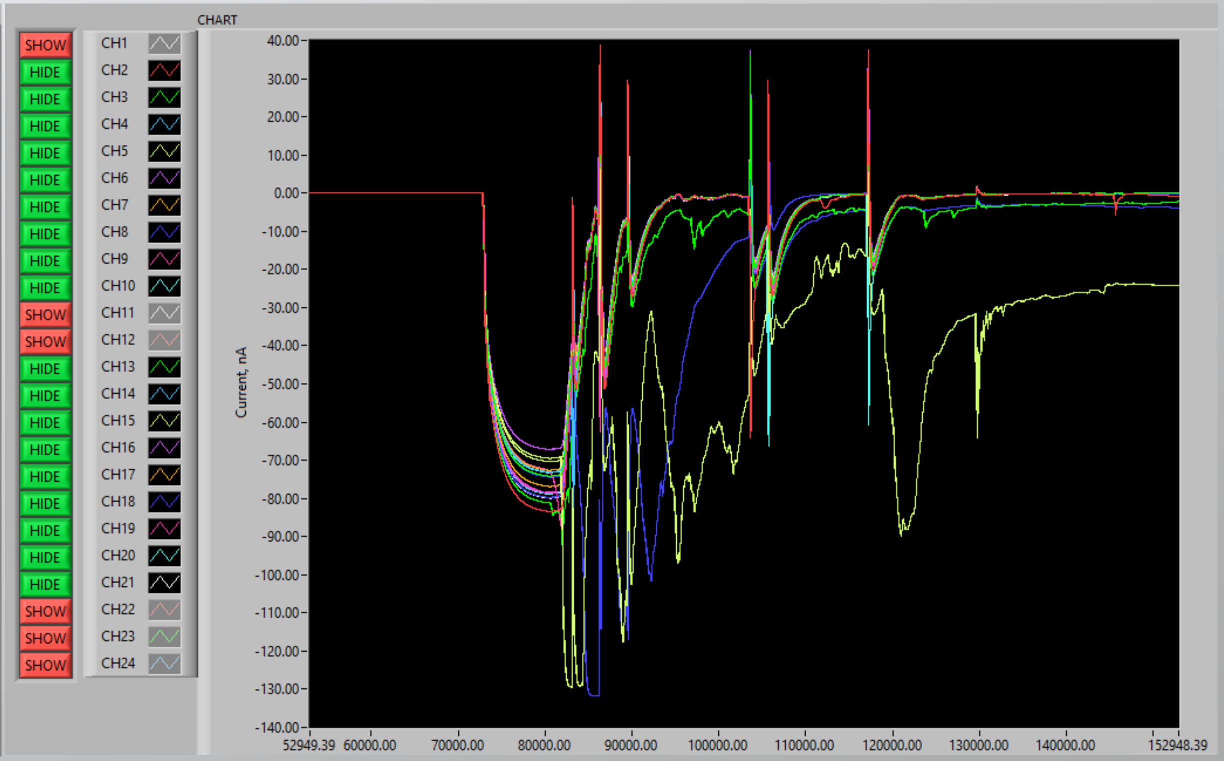


Defects example

Backup

Long term HV test examples





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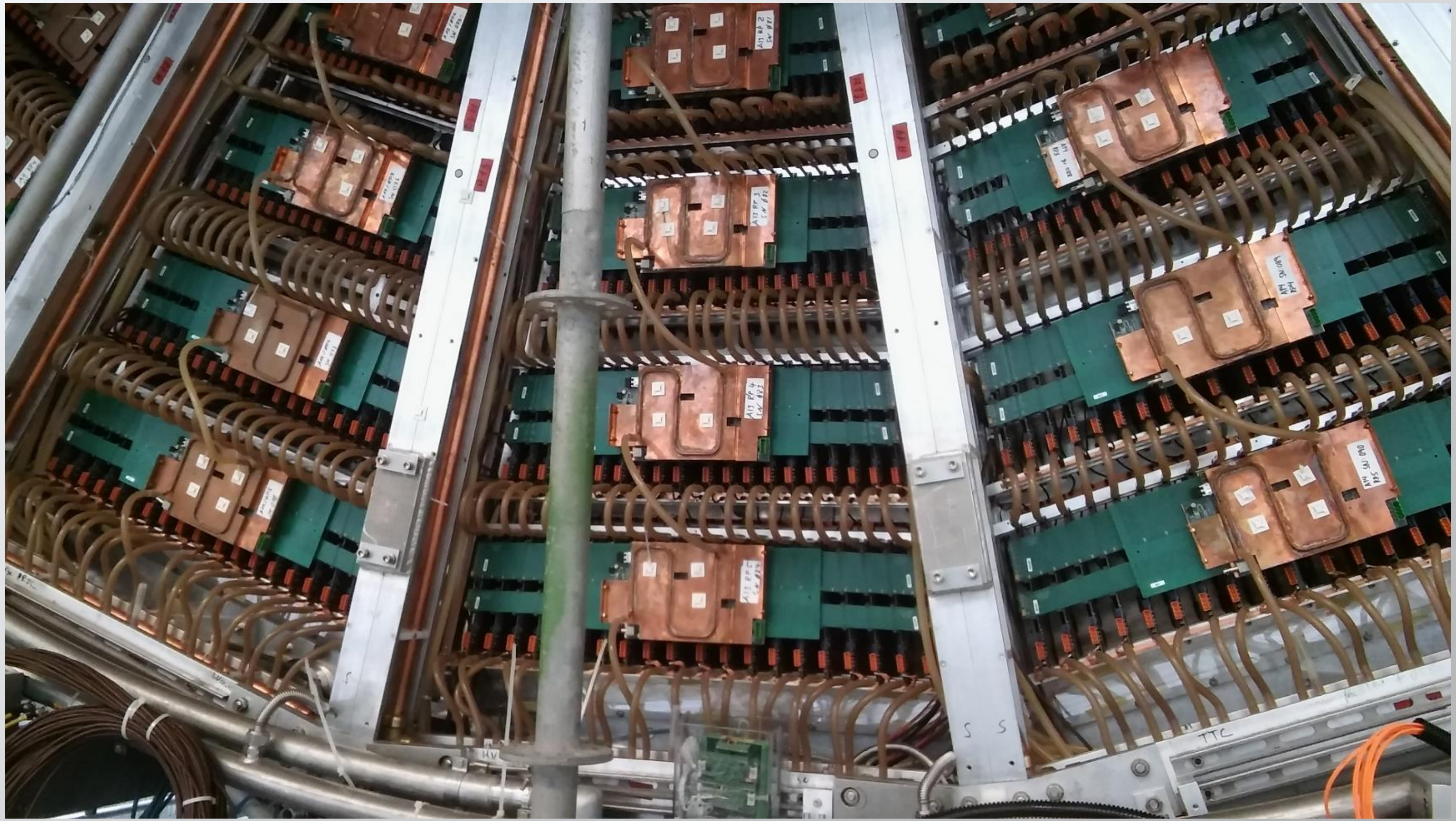

FECs with the heating system

Backup

Transporting the TPC

Backup

Transporting the TPC