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
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 \(= 100\,\mu\text{s}\)
- Multi-Wire Proportional Chamber (MWPC)-based readout with gating grid -> electron avalanche and ion backflow suppression
- The gating grid is kept closed for \(200\,\mu\text{s}\) with alternating potential to efficiently block the ions -> Limits the readout \(\sim 3.5\,\text{kHz}\)

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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

- 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

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 (140 μm pitch)
- Position 2&3: Large pitch (280 μm pitch)
- Optimizing the energy resolution and IBF

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

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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)
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!

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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
References

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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

![Graph showing HV test examples](image)

- 100nA current
- 6s time interval

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Backup

FECs with the heating system

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Transporting the TPC
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Transporting the TPC

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