ALICE TPC commissioning results

Dag Toppe Larsen

for the ALICE TPC collaboration

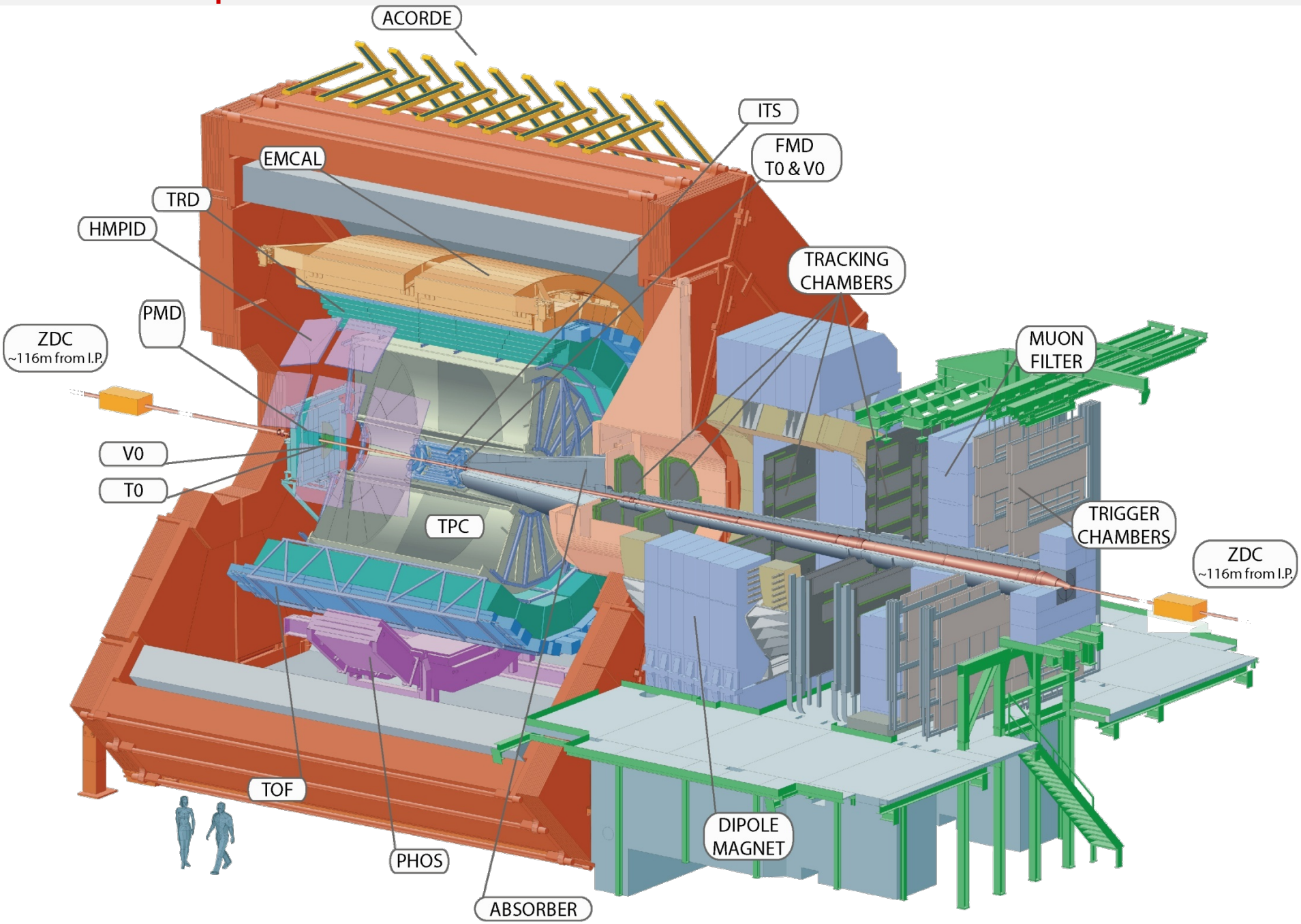
Institute of physics and technology
University of Bergen

May 25, 2009

Outline

- Components
  —the building blocks of the TPC
- Calibration
- Performance

ALICE experiment



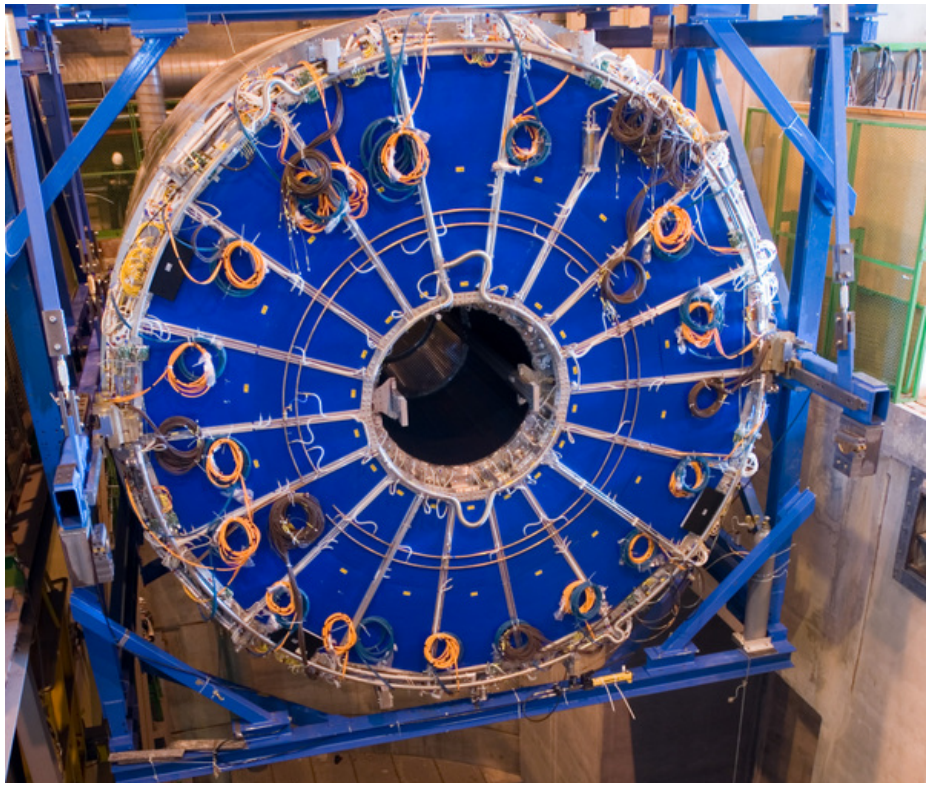
ALICE Time Projection Chamber in numbers

General

- 5m diameter
- 2.5m+2.5m length
- 2×18 readout chambers/side
- 90m^3 volume
- 92μs drift time
- 100 kV central electrode

Data readout

- 557568 readout pads
- 920 samples time axis
- ≈1kHz p-p
- ≈200Hz central Pb-Pb



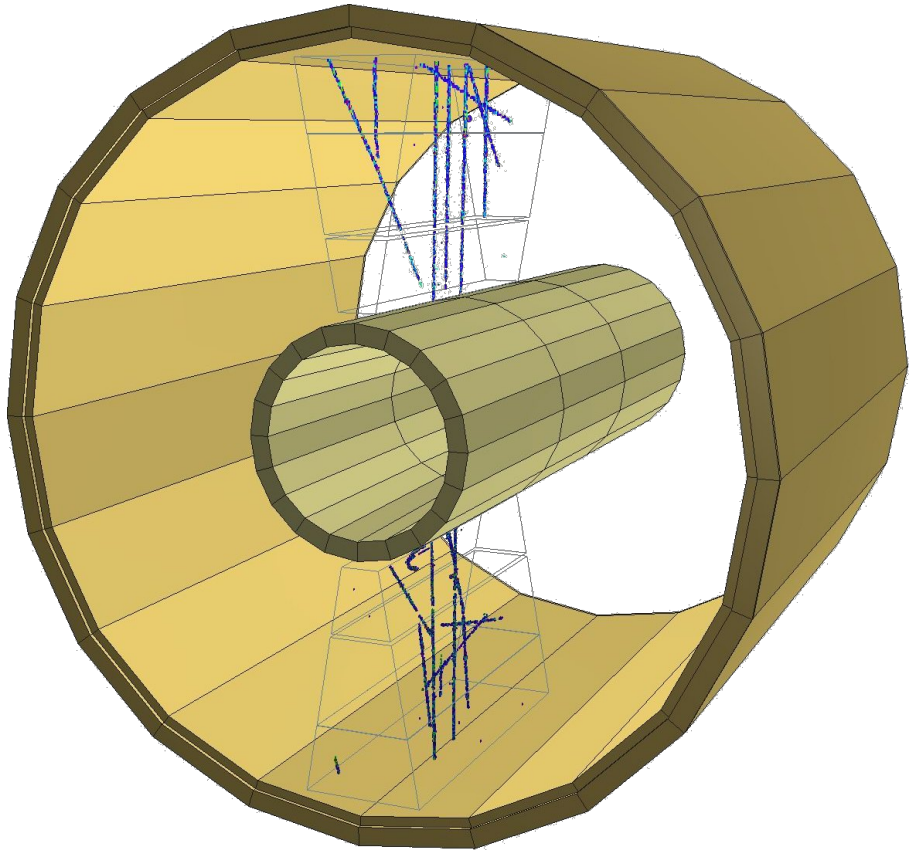
Gas

- 85.7% Ne, 9.5% CO_2, 4.8% N_2
- cold gas—low diffusion
- non-saturated drift velocity⇒temperature stability/homogeneity <0.1K

TPC sub-systems

Components needed by TPC

- Drift volume
  - Gas
  - E-field
- Read-out
  - Multi-wire proportional chamber
  - Read-out electronics
- Cooling
- Control

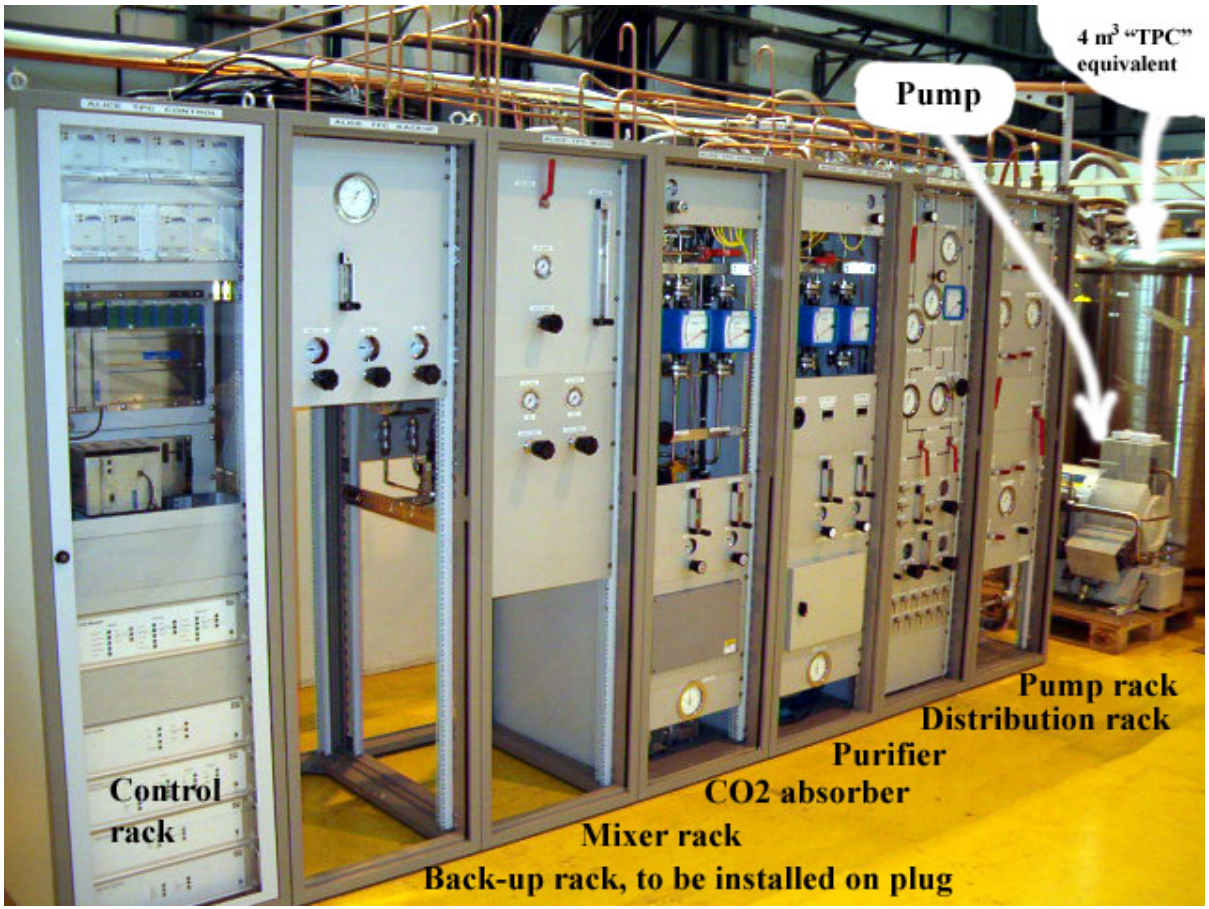


First cosmic tracks detected by the ALICE TPC during the pre-commissioning on the surface in 2006. The fraction of the electrical power and of the corresponding water-cooling plant available at the test site was sufficient for operating only two sectors at a time.

Gas recirculation system

O_2 and H_2O contamination of gas causes signal loss (e^- attachment)

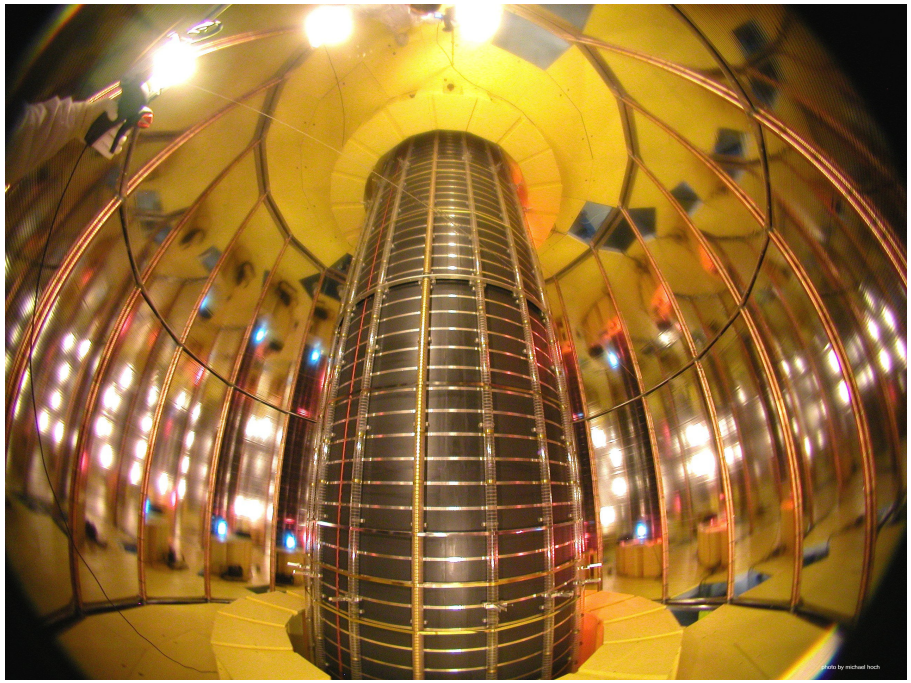
- Removed by Cu catalyst
- Achieved 1 ppm O_2 (design goal 5 ppm)



Voltage dividers

Provides homogeneous drift field

- Water cooled
- Control of water conductivity
- Under-pressure system (leak-less)

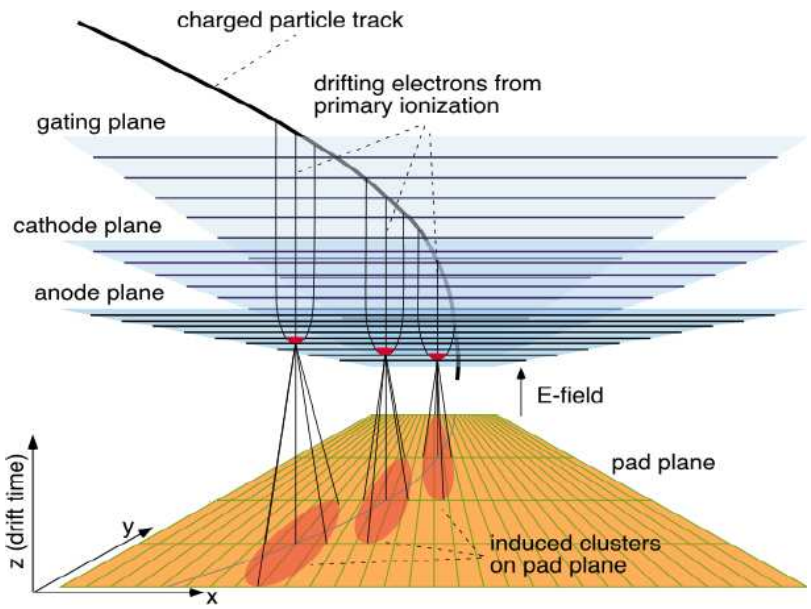


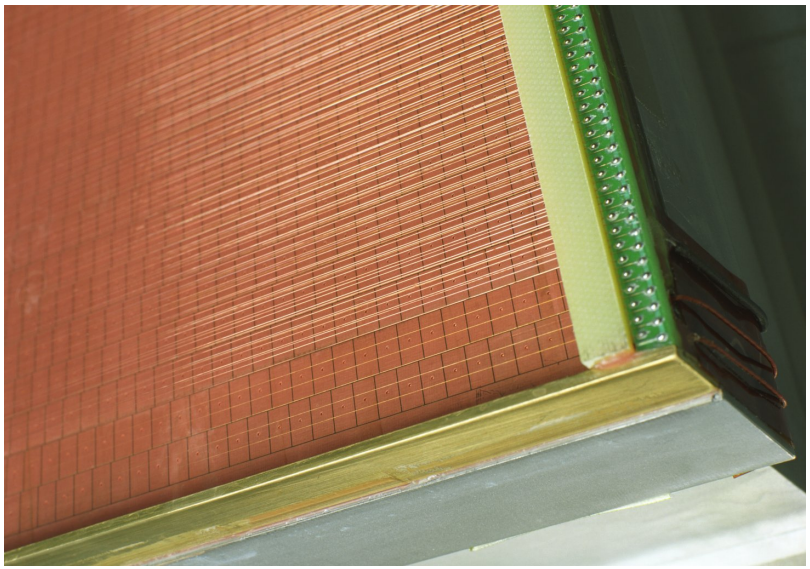
Signal read-out

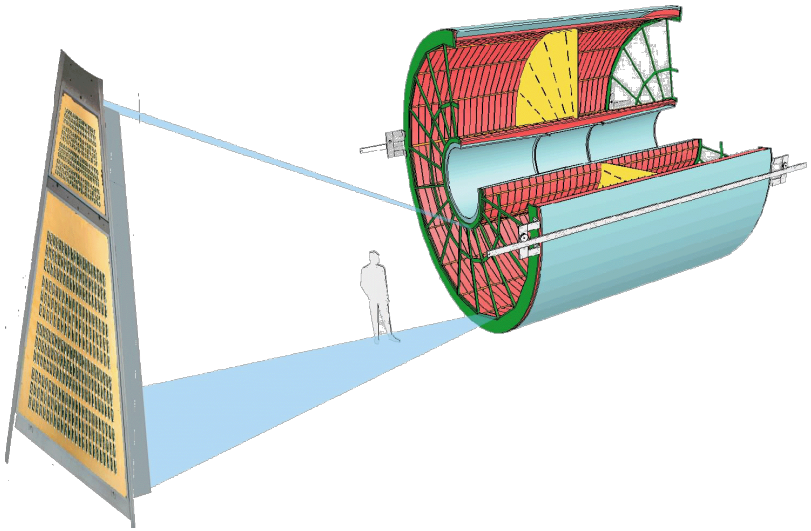
18×2×2 read-out chambers

- 2 sides with 18 sectors each
- Each sector divided in inner and outer chamber (IROC/OROC)
- Pad read-out via multi-wire proportional chambers

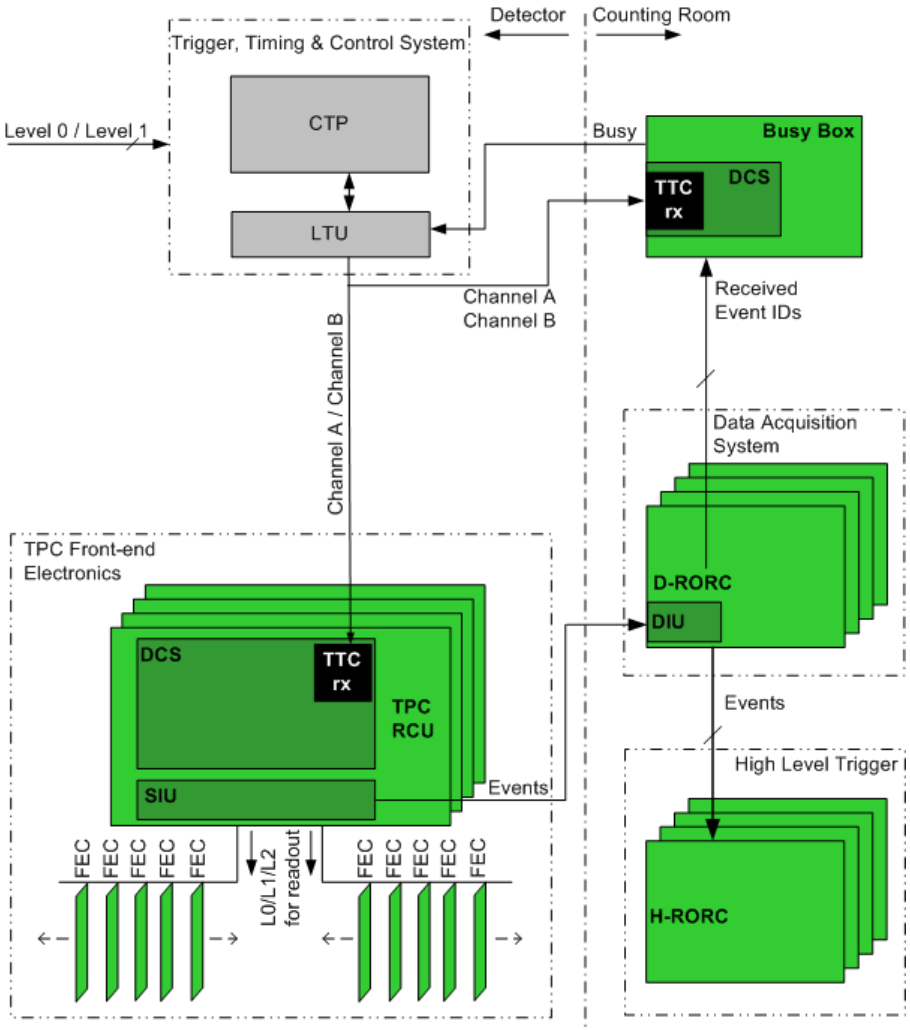
Trip-free, stable operation







Read-out electronics



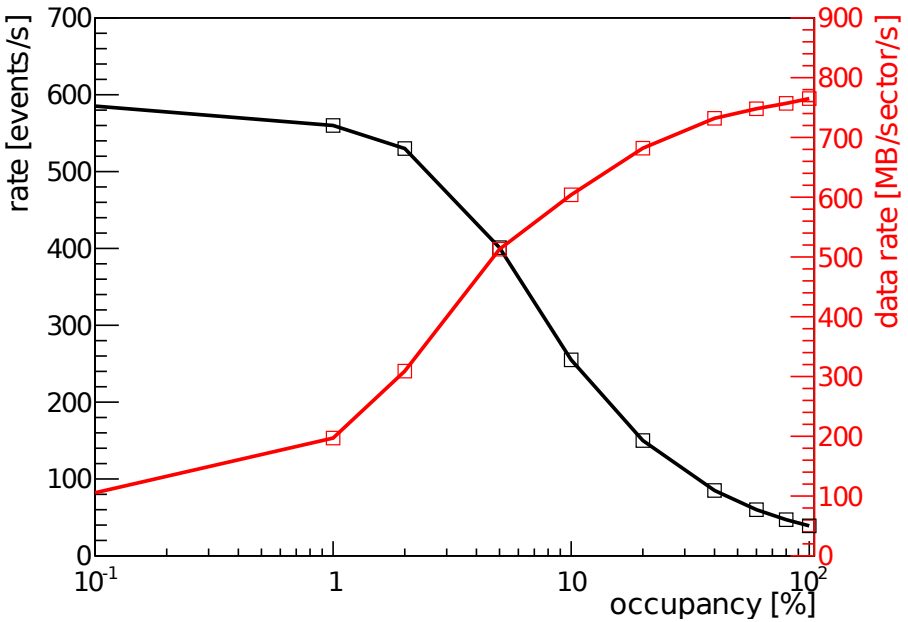
6 read-out partitions per sector

- Mounted on end plates
- Radiation tolerant
- Controlled by embedded ARM Linux system
- Up to 25 front-end cards for data readout
- Central trigger handling
- BUSY system signals when ready

Data readout performance

1 fibre link per read-out partition (216 total)

- 160 MB/s transfer rate per fibre
- 770 MB/s per sector (not all partitions have 25 front-end cards)



Performance test with varying occupancies (left plot)

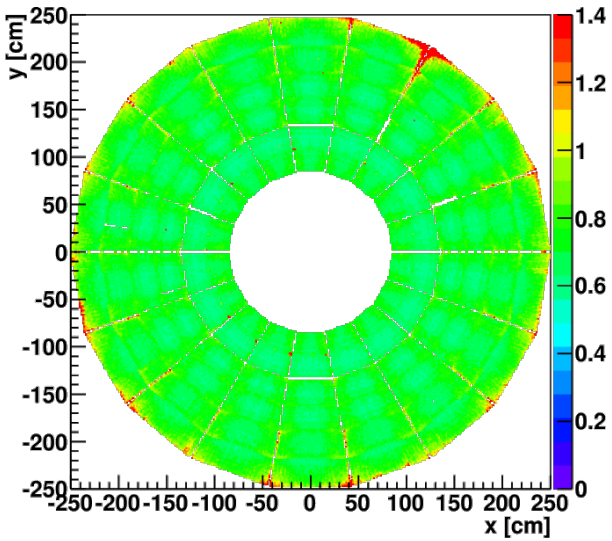
- 1000 time bins
- Same data in all channels

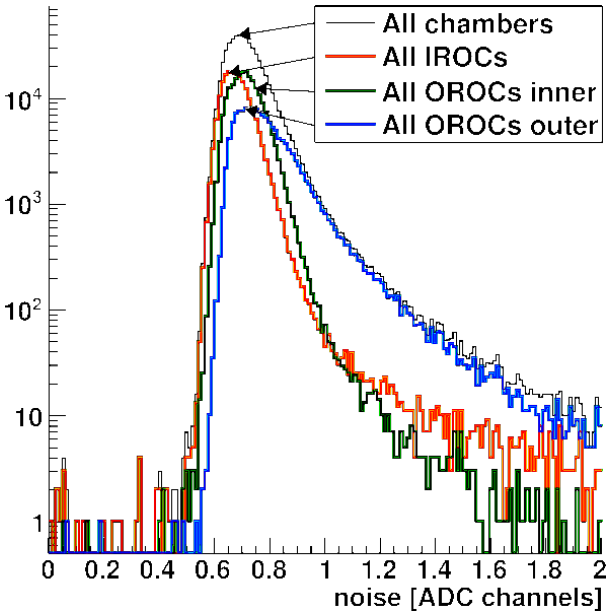
Performance @ 0% occupancy

- Full readout: 595Hz (70MB/s)
- Sparse readout (empty channels stripped): 1386Hz (927kB/s)

Noise level

Currently measured noise

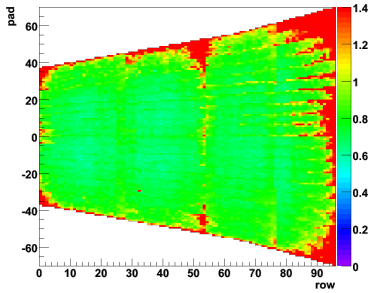




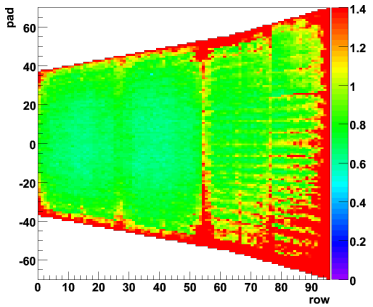
Noise figures much improved during commissioning

- Mean noise level 0.7 ADC count (700e$^-$), design goal 1 ADC count
- Data volume for zero-suppressed empty event <70kB (non-ZS 10000 larger)

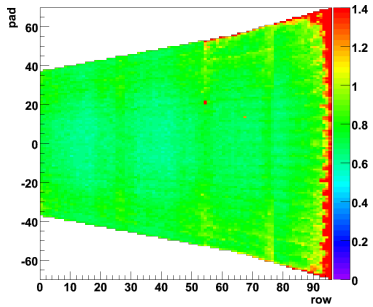
Noise development



Clean room - 2006



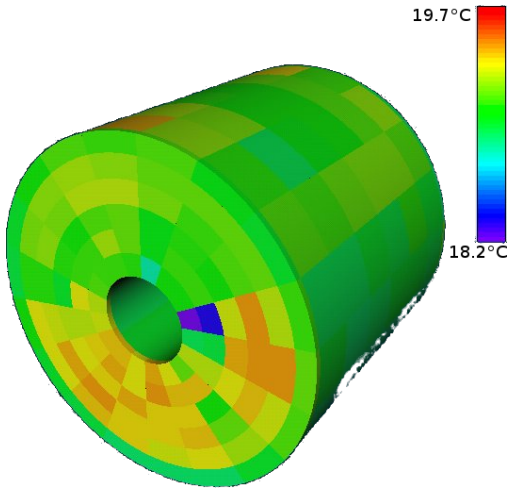
Installed - 2007



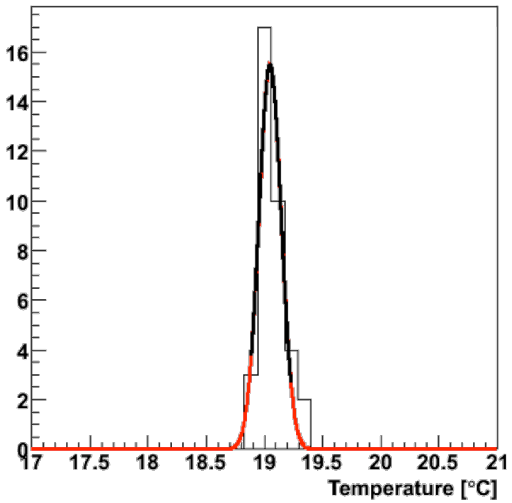
Installed - 2008

Cooling system

Temperature distribution TPC



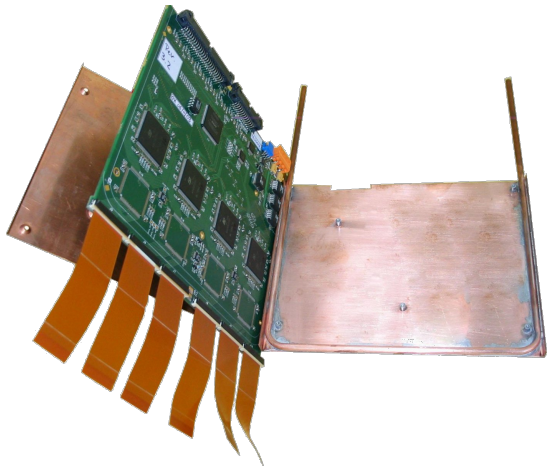
Temperature TPC in/outside



Temperature TPC inside
σ_T=0.1K, ΔT_{max}=0.3K

Leak-less under-pressure system

- ≈60 independently adjustable circuits
- ≈500 temperature sensors
- Readout chamber bodies also cooled
- Temperature variations <0.1K required
- Front end electronics outputs 27kW heat
  ⇒ water cooled copper envelopes
- Screening: towards environment (service support wheel) and detectors (TRD, ITS)

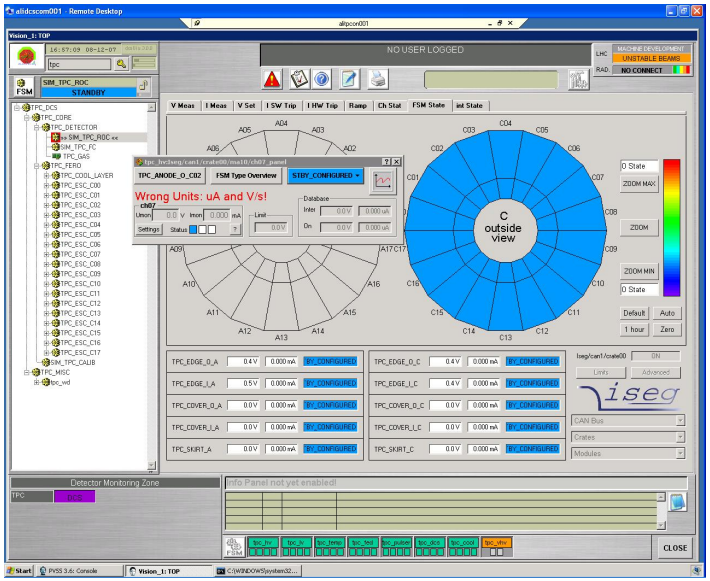


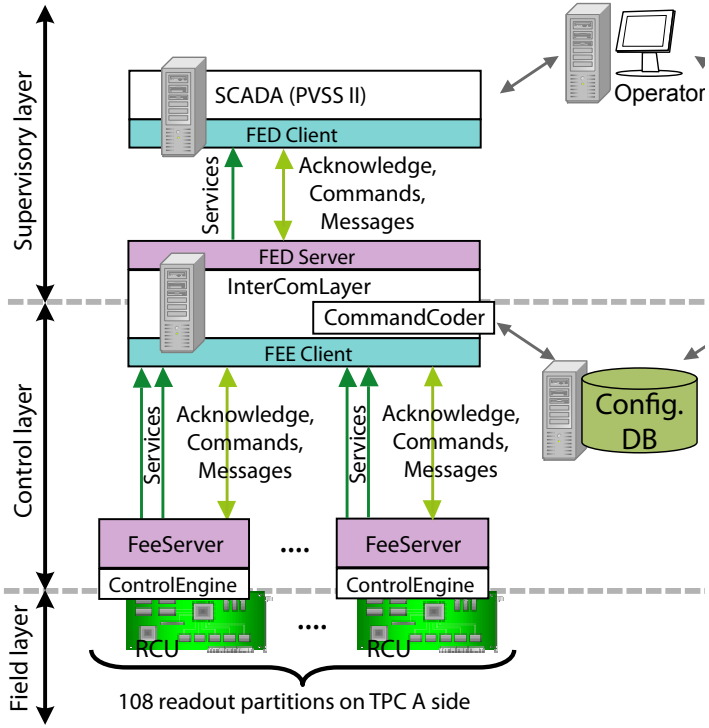
Water cooled copper envelope for front-end card

Detector control system

Distributed hierarchical control system

- Supervisory—user interface
- Control—hub, retrieve/distribute configuration, collect monitoring
- Field—running directly on electronics, control/monitoring of HW

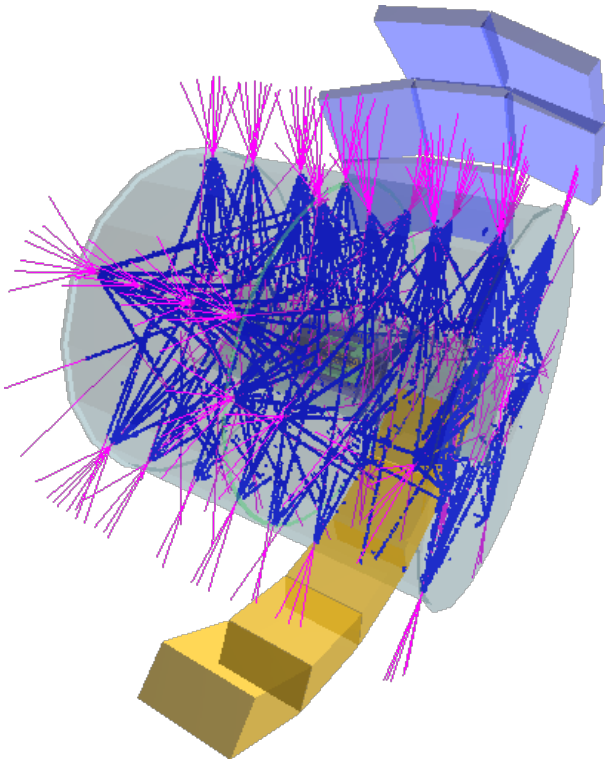


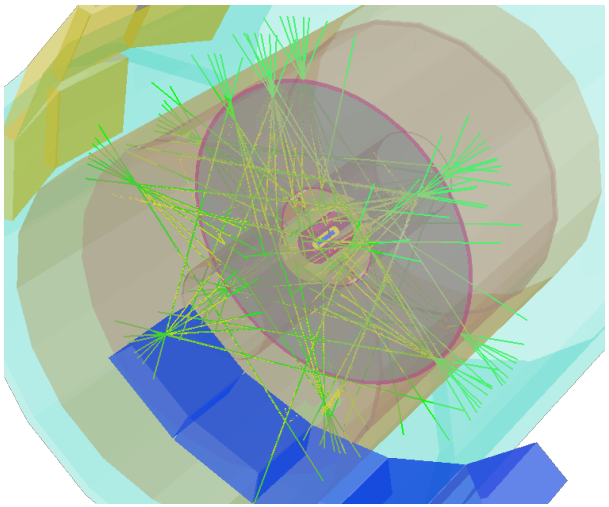


Graphical user interface for shifters

- Controls "everything"
- Integrated with Experiment control system

Laser system



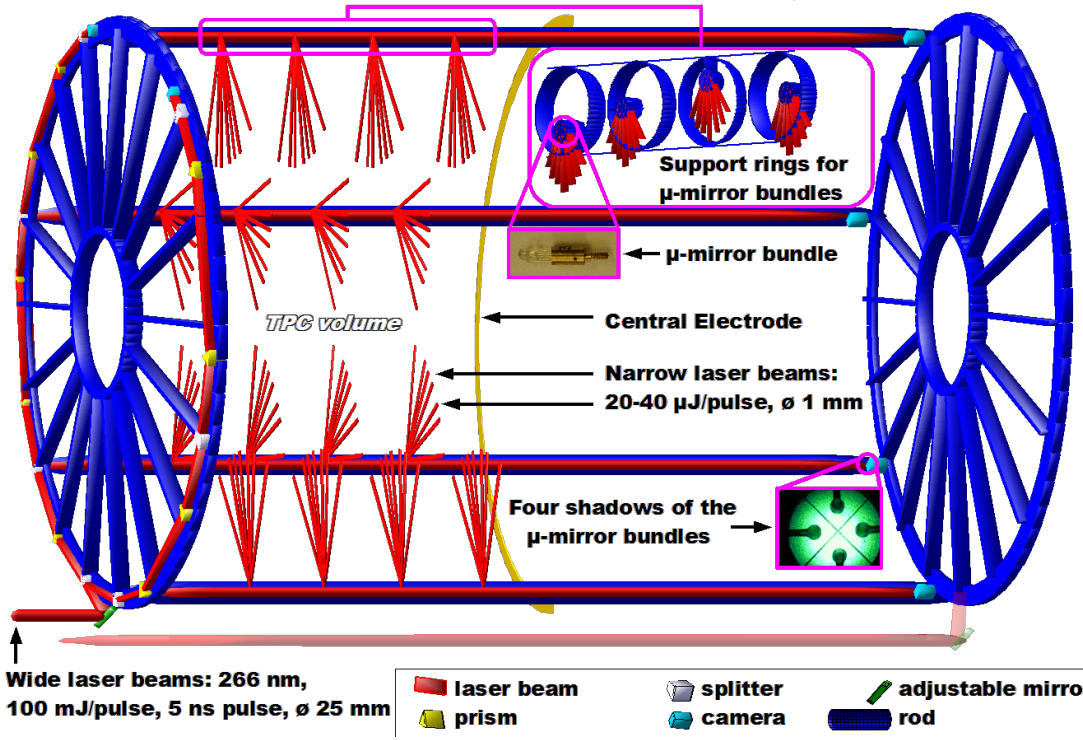


Important tool for calibration/correction

- Alignment
- Drift velocity
- E×B

In total 336 laser beams

Principle of the TPC laser system



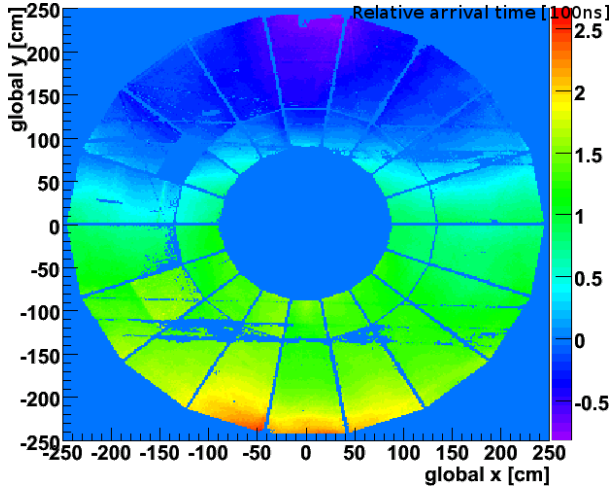
Drift velocity correction

Obtainable from multiple sources

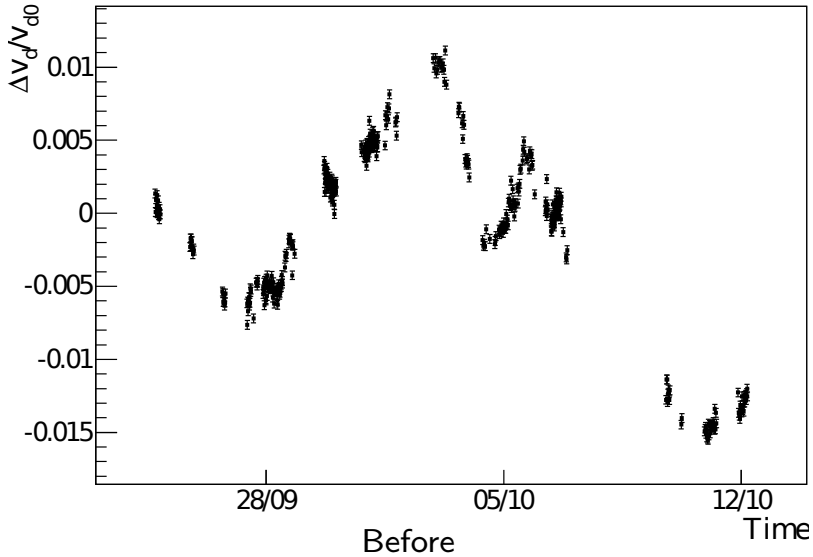
- Match tracks passing through centre membrane —both cosmics and beam collisions
- Laser events
- Match TPC-ITS tracks
- Separate drift velocity monitor

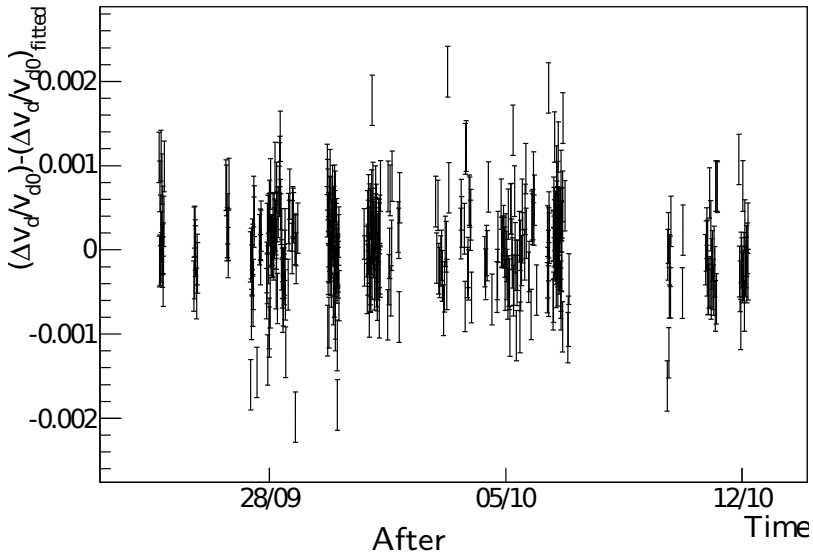
Approaches may be combined to increase accuracy

Temperature and pressure gradients cause top-bottom arrival time offset



Cosmics correction



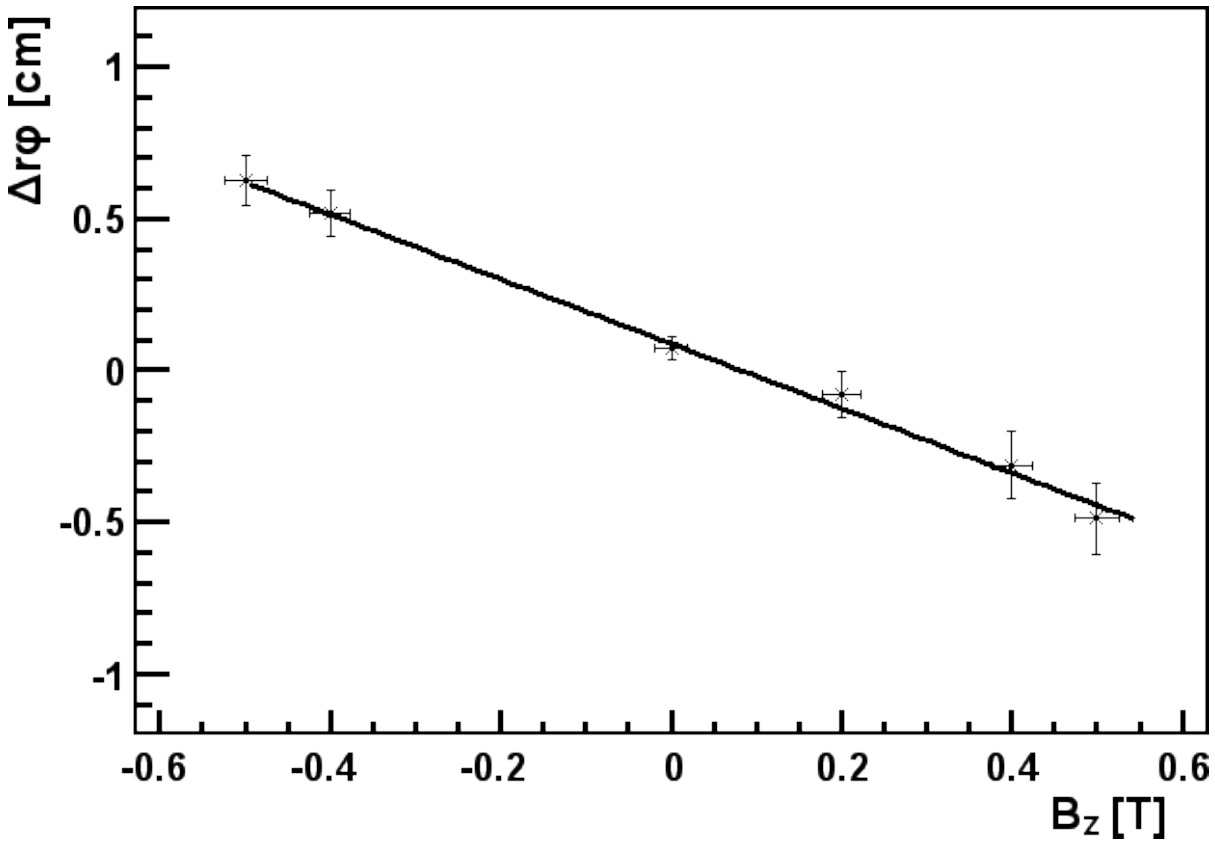


Accuracy 10^{-4} $\Rightarrow$ update period 1 hour

E×B correction

Correction maps from laser tracks

- Measure $\Delta r\varphi$
- for each track
- for multiple field strengths



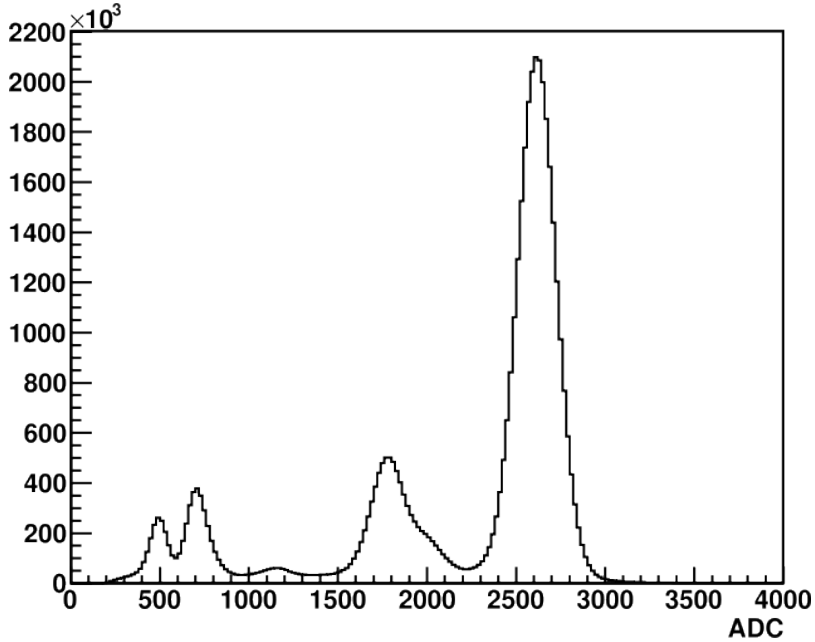
For longest drift in nominal field, $\Delta r\varphi$=0.7

Krypton gain calibration

Radioactive ^{83}Kr injected into drift gas

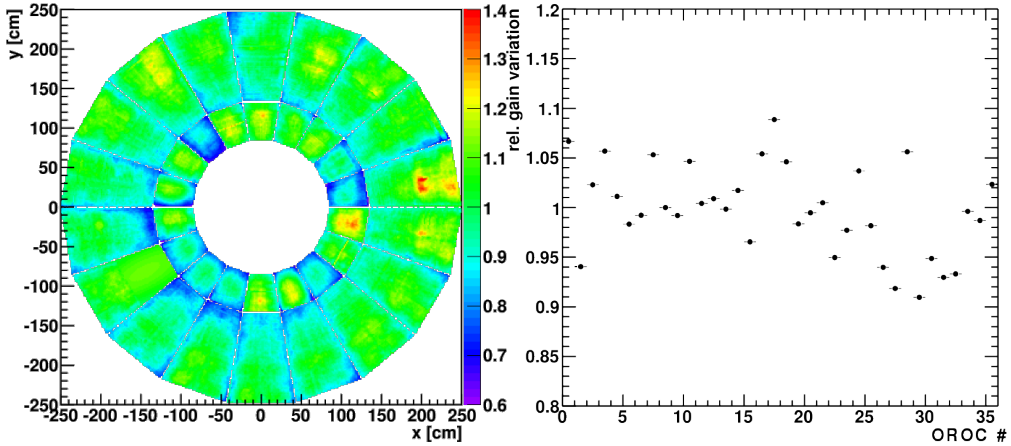
- Recorded at 3 different gains
- Direct gain calibration for each readout pad independently
- To be repeated after work on electronics/end-plates (1 day)

Gain variations within design criteria

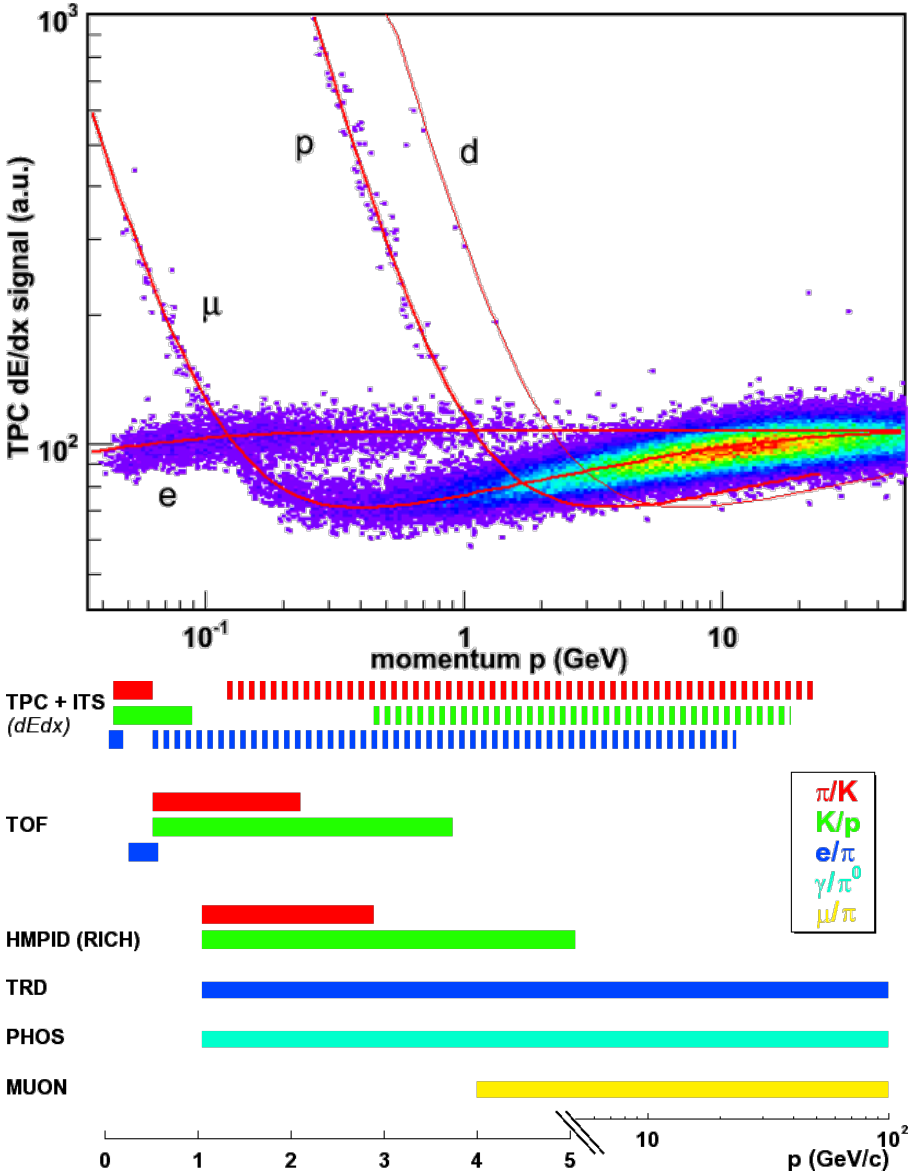


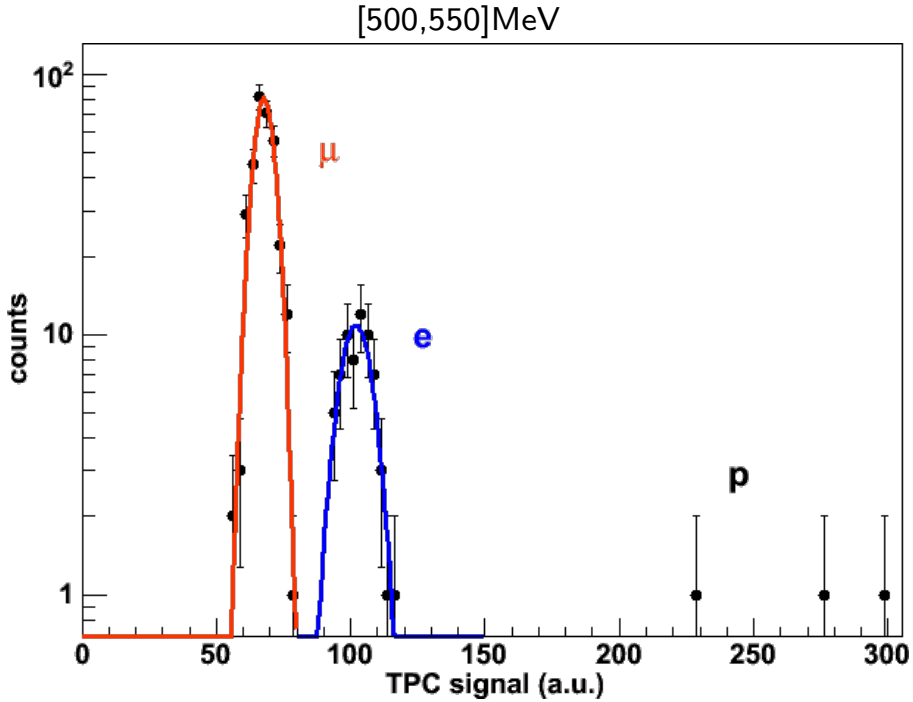
Main peak 41.6 keV. Position 1%.
Resolution IROC 4.2%,
OROC 4.0%.

Relative gain, C side



dE/dx cosmic resolution

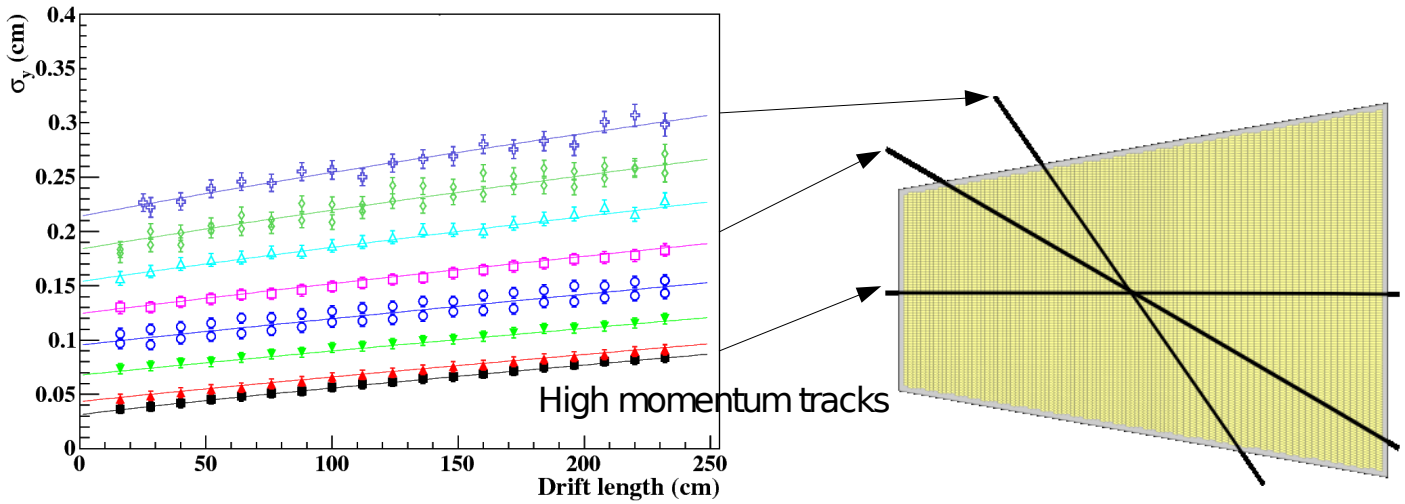




Will allow particle identification up to 50 GeV/c

- Achieved 5.7%
- Design goal 5.5%
- Determined from 7×10^6 events

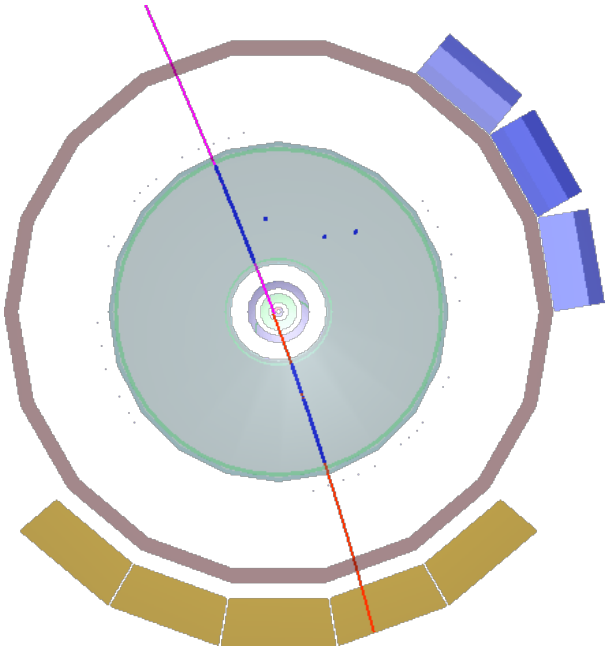
Space point resolution



Space point resolution rφ 300–800μm

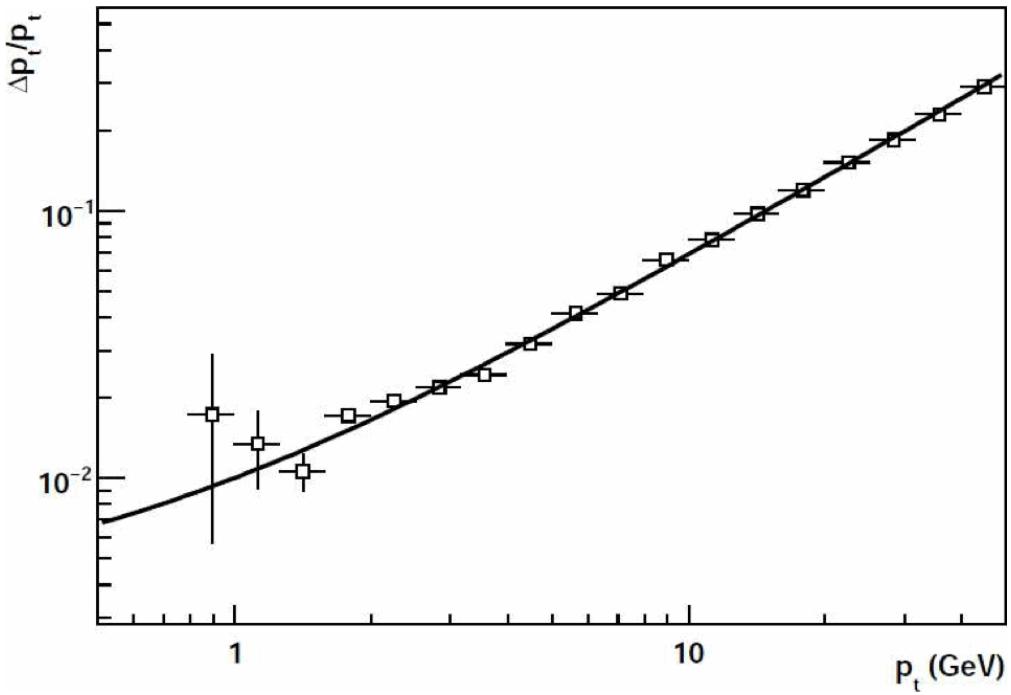
- For high-momentum tracks (small inclination angles)
- Agrees with simulations

Momentum resolution

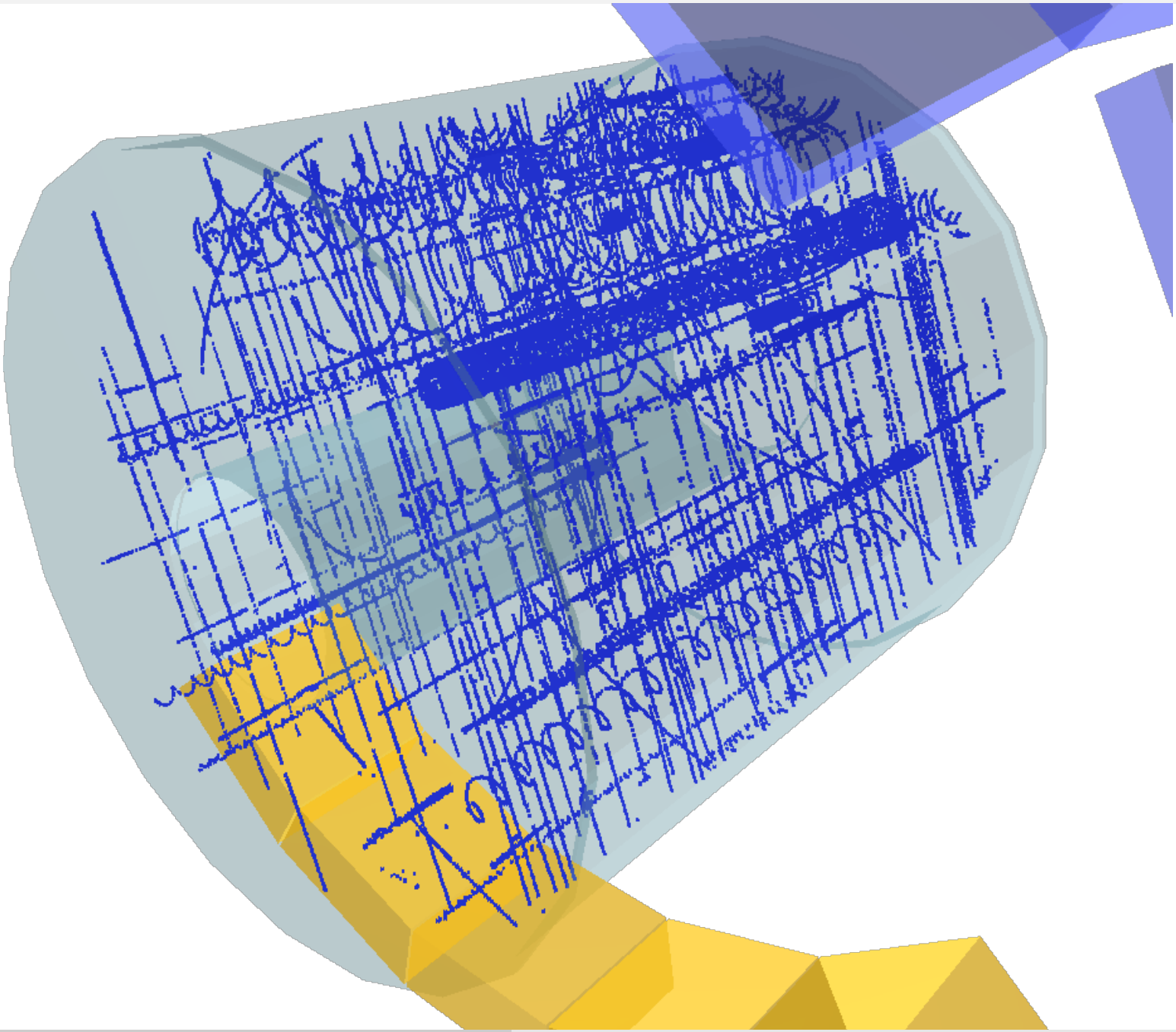


Cosmic muons reconstructed as independent tracks in upper and lower halves of TPC

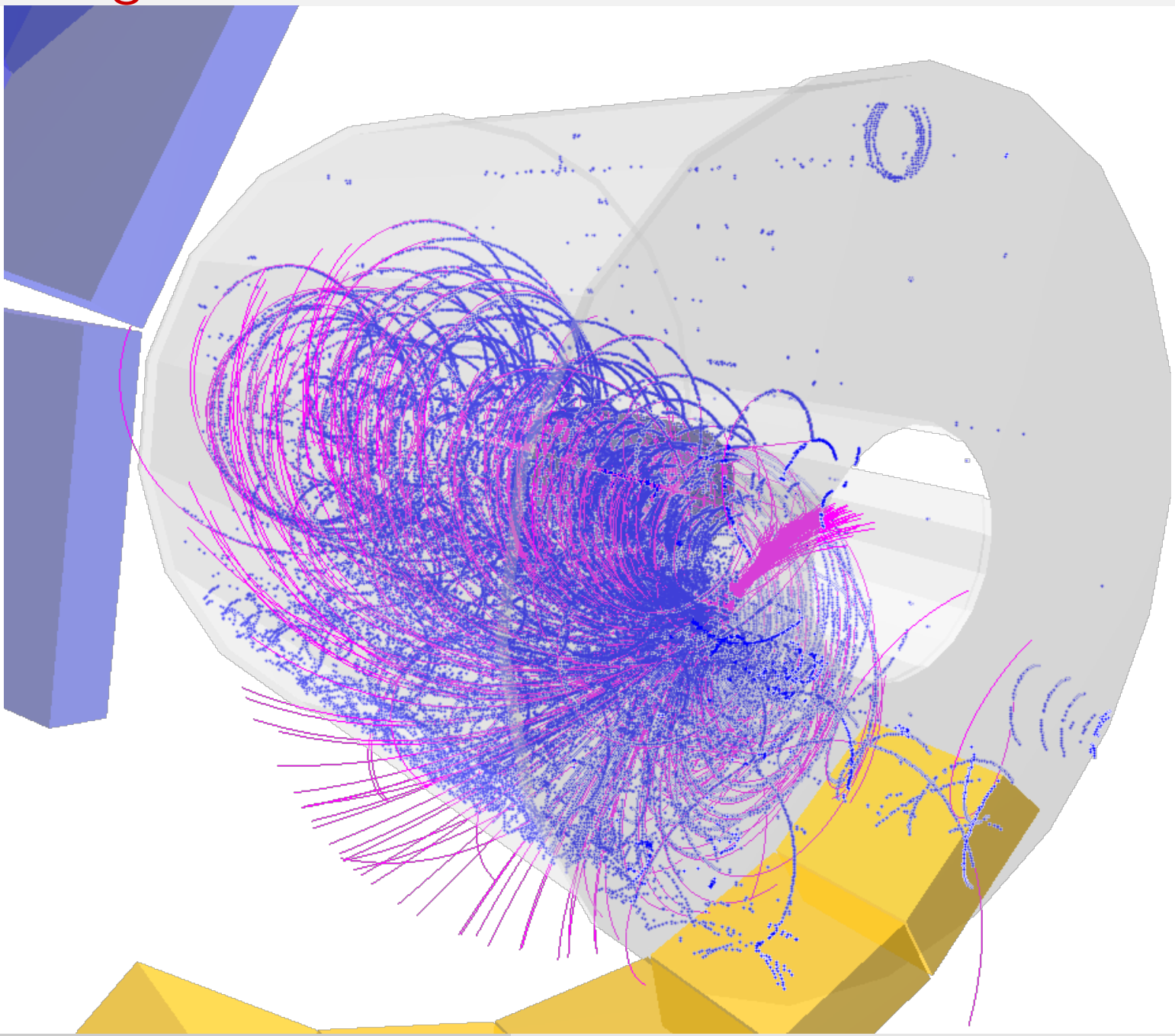
- Comparing P_t at vertex gives resolution
- Design goal 4.5% @ 10 GeV
- Achieved resolution 6.5% @ 10 GeV
- Expected to match design goal soon



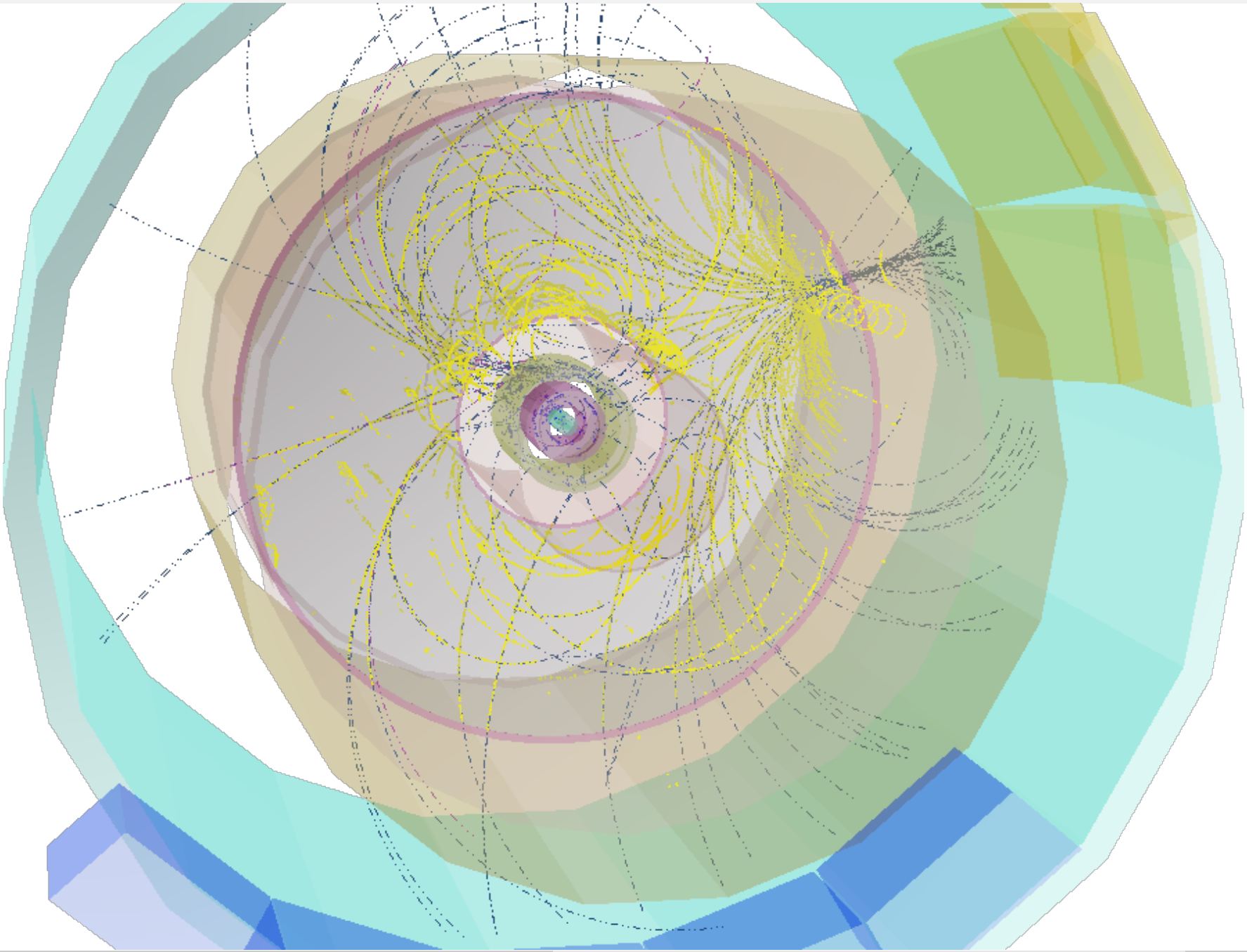
Muon shower



Electromagnetic shower



Shower



ALICE TPC ready for physics!

Commissioning done, stable operation

- 60×10^6 events successfully recorded
- Ready for physics runs since summer 2008
- Calibration ongoing
- Performance in accordance with specifications
- Waiting for beam

ALICE TPC collaboration

Dieter Roehrich[1], Haavard Helstrup[1], Dag Toppe Larsen[1], Dominik Felhker[1], Brano Sitar[2], Miro Pikna[2], Martin Siska[2], Rudolf Janik[2], Peter Strmen[2], Imrich Szarka[2], Luciano Musa[3], Christian Lippmann[3], Magnus Mager[3], Attiq Rehamn[3], Stefan Rossegger[3], Borge Nielsen[4], Carsten Soegaard[4], Helmut Oeschler[5], Alexander Kalweit[5], H. Appelshaeuser[6], Rainer Renfordt[6], Peter Braun-Munzinger[7], Hans-Rudolf Schmidt[7], Danilo Vranic[7], Chilo Garabatos[7], Uli Frankenfeld[7], Marian Ivanov[7], Yiota Foka[7], Johanna Stachel[8], Peter Glassel[8], Jens Wiechulla[8], Hans-Ake Gustafsson[9], Peter Christiansen[9], Anders Oskarsson[9], Philippe Gros[9], Alexandru Flori Dobrin[9], Marek Kowalski[10], Adam Matyja[10]

1. Department of Physics and Technology, University of Bergen, Bergen, Norway
2. Faculty of Mathematics, Physics and Informatics, Comenius University, Bratislava, Slovakia
3. European Organization for Nuclear Research (CERN), Geneva
4. Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
5. Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany
6. Institut für Kernphysik, Johann-Wolfgang-Goethe Universität Frankfurt, Frankfurt, Germany
7. Gesellschaft für Schwerionenforschung mbH (GSI), Darmstadt, Germany
8. Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
9. Division of Experimental High Energy Physics, University of Lund, Lund, Sweden
10. The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Cracow, Poland