ALICE TPC commissioning results

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Outline

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

Overview

ALICE

ACORDE

EMCAL

HMPID

TRD

PMD

ZDC ~116m from I.P.

V0

T0

TPC

TOF

PHOS

ABSORBER

FMD T0 & V0

ITS

TRACKING CHAMBERS

MUON FILTER

TRIGGER CHAMBERS

ZDC ~116m from I.P.

DIPOLE MAGNET
ALICE Time Projection Chamber in numbers

General
- 5m diameter
- 2.5m + 2.5m length
- $2 \times 18$ readout chambers/side
- 90m$^3$ volume
- 92$\mu$s drift time
- 100 kV central electrode

Data readout
- 557568 readout pads
- 920 samples time axis
- $\approx 1$kHz p-p
- $\approx 200$Hz central Pb-Pb

Gas
- 85.7% Ne, 9.5% CO$_2$, 4.8% N$_2$
- cold gas—low diffusion
- non-saturated drift velocity $\Rightarrow$ temperature stability/homogeneity $<0.1$K
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

O₂ and H₂O contamination of gas causes signal loss (e⁻ attachment)

- Removed by Cu catalyst
- Achieved 1 ppm O₂ (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\times 2\times 2 \text{ 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

Leak-less under-pressure system

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

\[ \sigma_T = 0.1 \text{K}, \Delta T_{\text{max}} = 0.3 \text{K} \]

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
- \( E \times B \)

In total 336 laser beams
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

Cosmics correction

Temperature and pressure gradients cause top-bottom arrival time offset

Accuracy $10^{-4}$ ⇒ update period 1 hour
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%.
Will allow particle identification up to 50 GeV/c

- Achieved 5.7%
- Design goal 5.5%
- Determined from $7 \times 10^6$ events
Space point resolution $r \varphi \ 300–800 \mu m$

- 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
<table>
<thead>
<tr>
<th>Event samples</th>
<th>Shower</th>
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Commissioning done, stable operation

- $60 \times 10^6$ events successfully recorded
- Ready for physics runs since summer 2008
- Calibration ongoing
- Performance in accordance with specifications
- Waiting for beam
ALICE TPC collaboration

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