The commissioning of ALICE's TPC

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for the ALICE TPC collaboration

CERN

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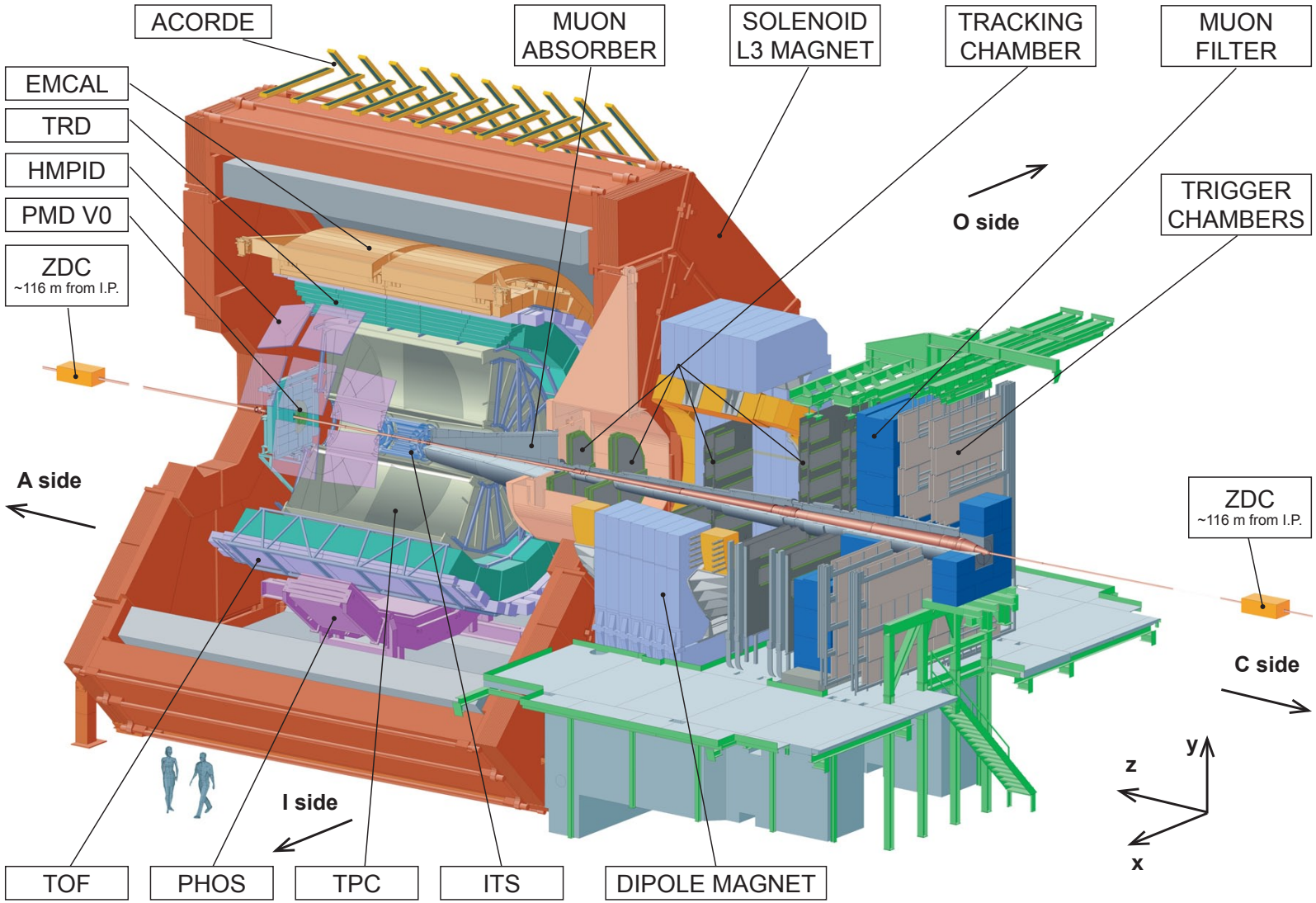
Outline

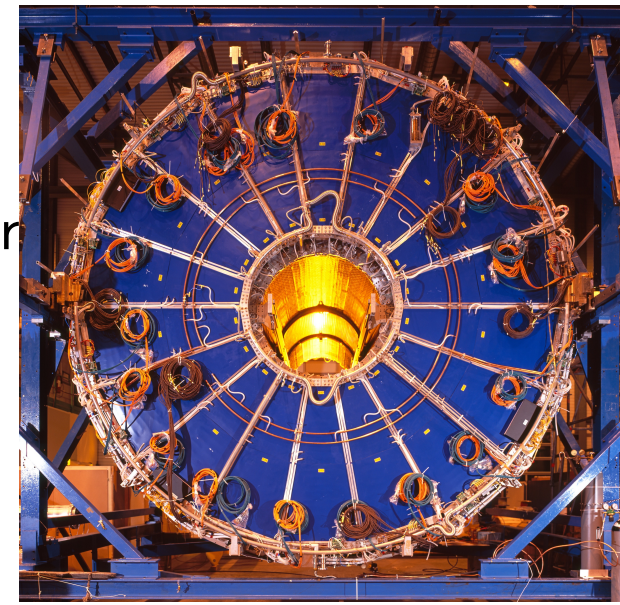
- Overview of ALICE and its TPC
- TPC subsystems and their performance
- Calibration status
- First results

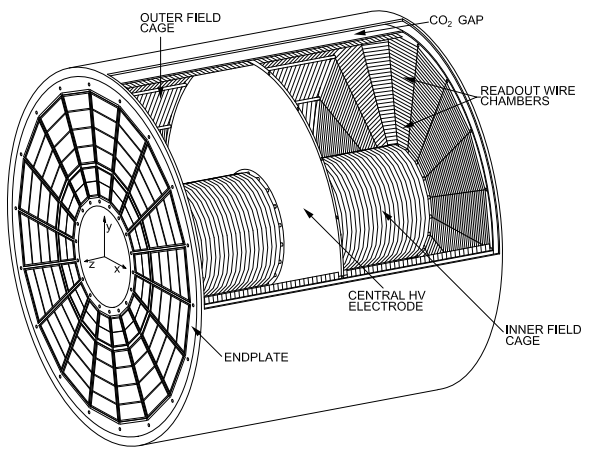
ALICE


ACORDE
MUON ABSORBER
SOLENOID L3 MAGNET
TRACKING CHAMBER
MUON FILTER
EMCAL
TRD
HMPID
PMD V0
ZDC ~116 m from I.P.
O side
TRIGGER CHAMBERS
A side
ZDC ~116 m from I.P.
C side
I side
y
z
x
TOF
PHOS
TPC
ITS
DIPOLE MAGNET

The TPC – key facts

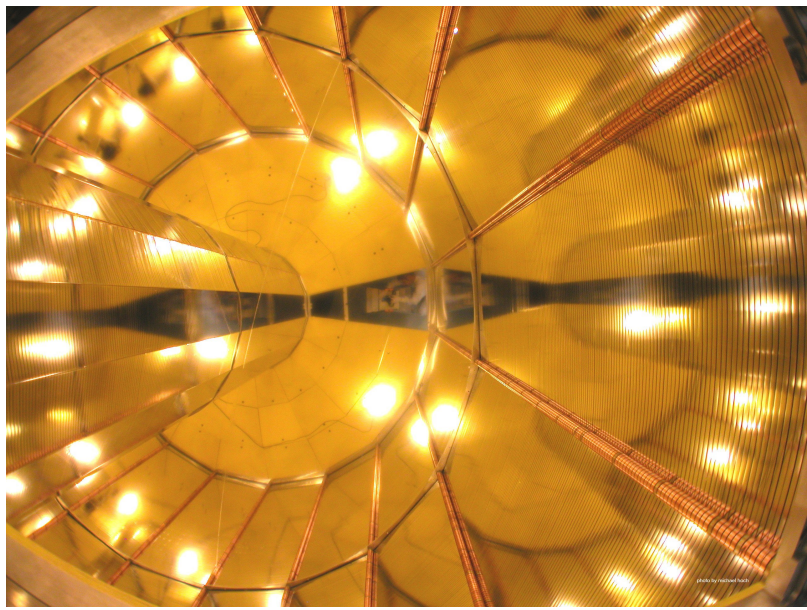
- pseudo-rapidity coverage: $|\eta| < 0.9$ or $|\eta| < 1.5$ for full and 1/3 of radial track length, respectively
- active volume: $-2497 < \mathrm{z} < 2497\ \mathrm{mm}$ times $848 < \mathrm{r} < 2466\ \mathrm{mm}$
- read-out chambers: $2 \times 2 \times 18$ (side, radial and azimuthal segmentation) multi-wire proportional chambers
- gas: Ne–CO_2–N_2 [85.7–9.5–4.8]
- number of pads: 557,568





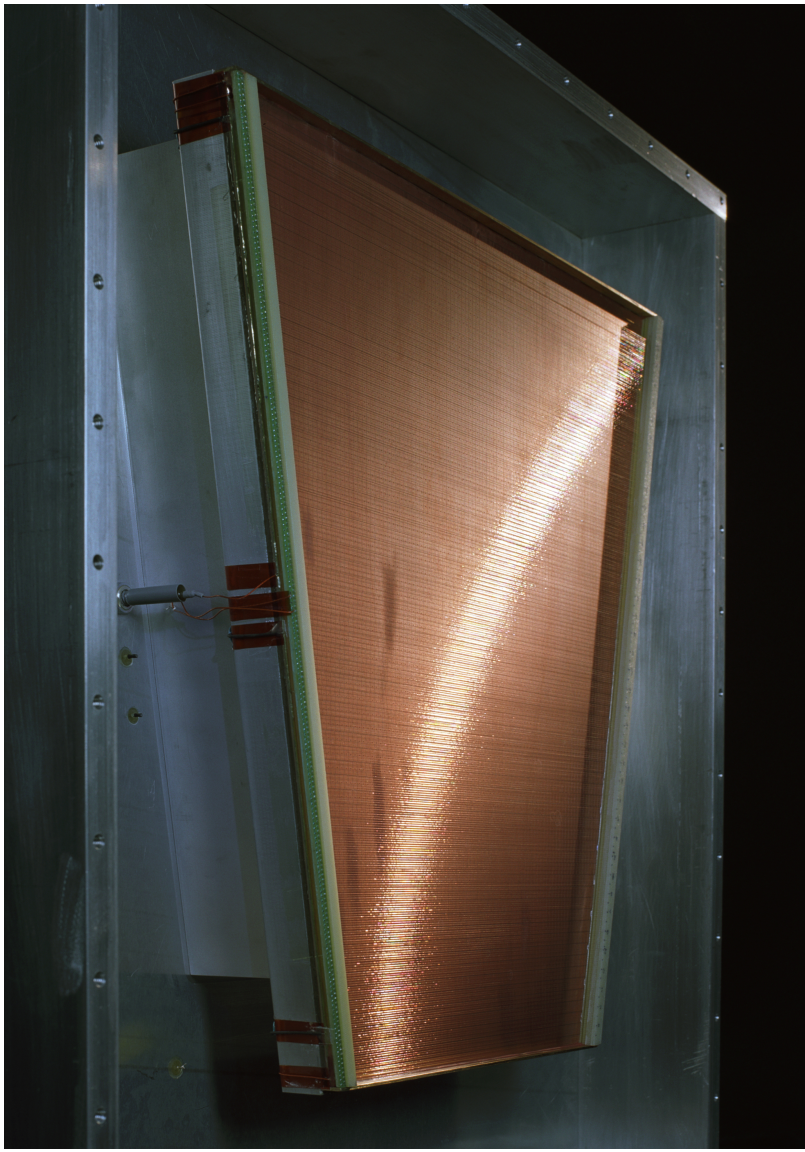
Field cage

- largest ever built for a TPC
- radiation lengths X/X_0:
  - 1.367% (inner field cage)
  - 0.607% (gas)
  - 2.153% (outer field cage)
- detailed structure modeled in MC in very nice agreement with tomographic results
- water cooled voltage divider
- potential: $100\ \mathrm{kV}$ $(400\ \mathrm{V/cm})$
- drift time: $96\ \mu\mathrm{s}$ (nominal; full length)
- very stable operation
  - few trips, but well understood
  - related to beam losses



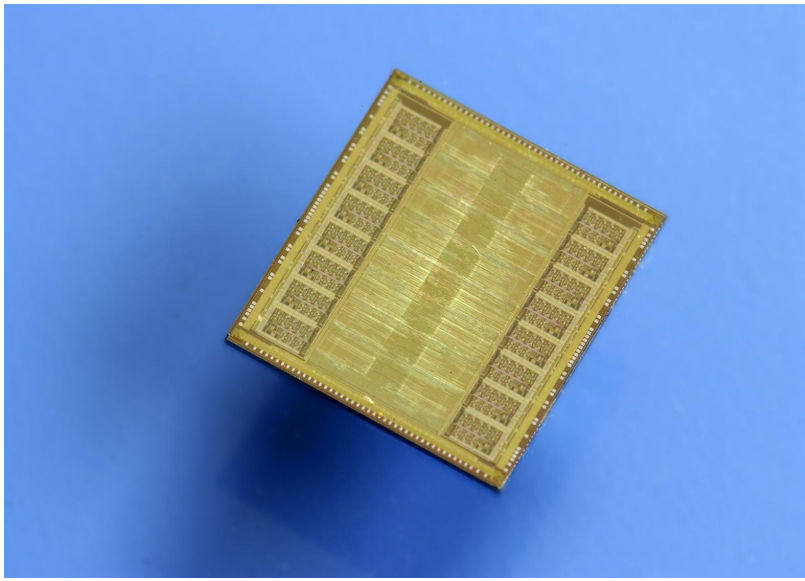
Readout chambers

- 72 multi-wire proportional chambers
  - 2×18 inner read-out chambers
  - 2×18 outer read-out chambers
- occasional trips
  - strongly correlated to LHC beam losses



Front-end electronics

- based on two custom made circuits:
  - PASA (Pre-Amplifier ShAper): 16 channel charge sensitive amplifier and pulse shaper
  - ALTRO (ALice Tpc Read-Out): 16 channel ADC with digital processing and buffering
- $10\ \mathrm{MHz}$ sampling rate: 900–1000 samples
- de-randomising multiple event buffer for 4 events
- 4,536 front-end cards with 8 PASAs and ALTROs (128 channels) each
- 216 independent partitions (6 per sector) connected via optical fibres ($160\ \mathrm{MByte/s}$) to the DAQ.

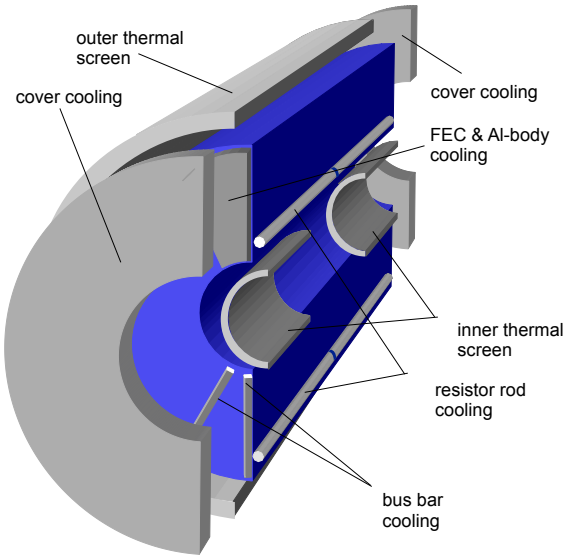


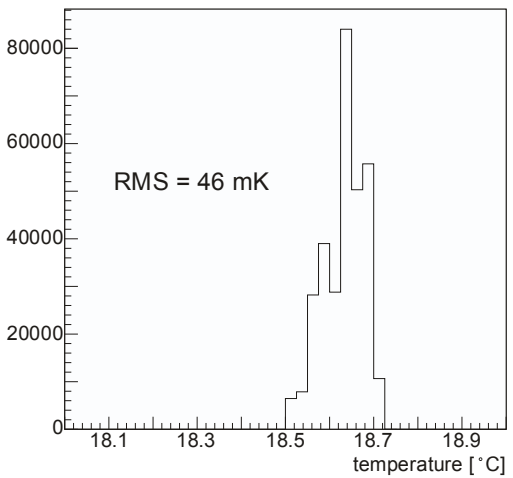
Front-end electronics (cont.)

- different readout modes:
  - full readout: for high occupancy events (PbPb) with multiple event buffer
  - sparse readout: for low occupancy events, skipping empty channels but without multiple event buffer
- attainable readout times:
  - $280\ \mu\mathrm{s}$ (empty events, including noise)
  - $500\ \mu\mathrm{s}$ ($7\ \mathrm{TeV}$ min. bias pp events), rates of $1.8\ \mathrm{kHz}$ were achieved recently at an interaction rate of $13.5\ \mathrm{kHz}$
  - $2.3\ \mathrm{ms}$ (PbPb events, estimated)

Cooling system

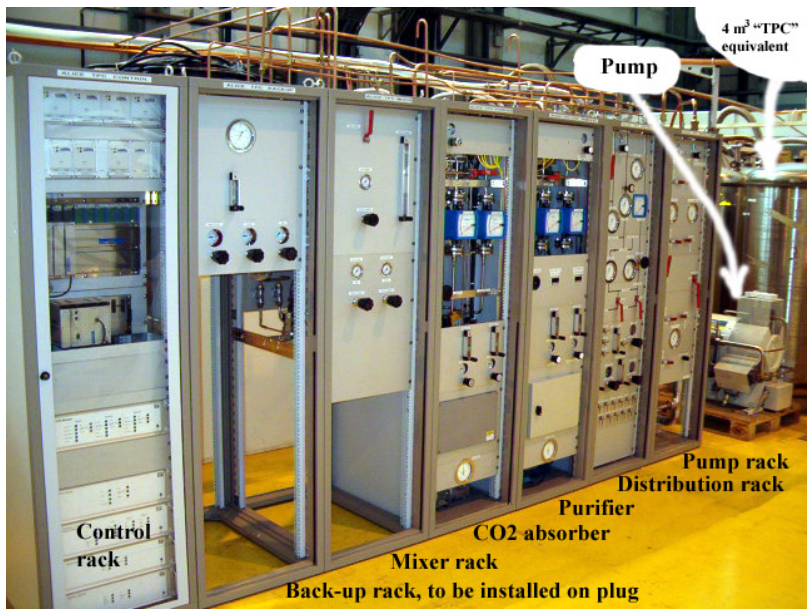
- problem:
  - gas mixture is very sensitive to temperature
  - electronics dissipate about $27\ \mathrm{kW}$
  - ITS and TRD add heat from in- and outside
- implemented solution:
  - leak-less underpressure cooling system with about 60 circuits
  - 500 temperature sensors
- obtained result: $0.046\ \mathrm{K}$ RMS temperature homogeneity





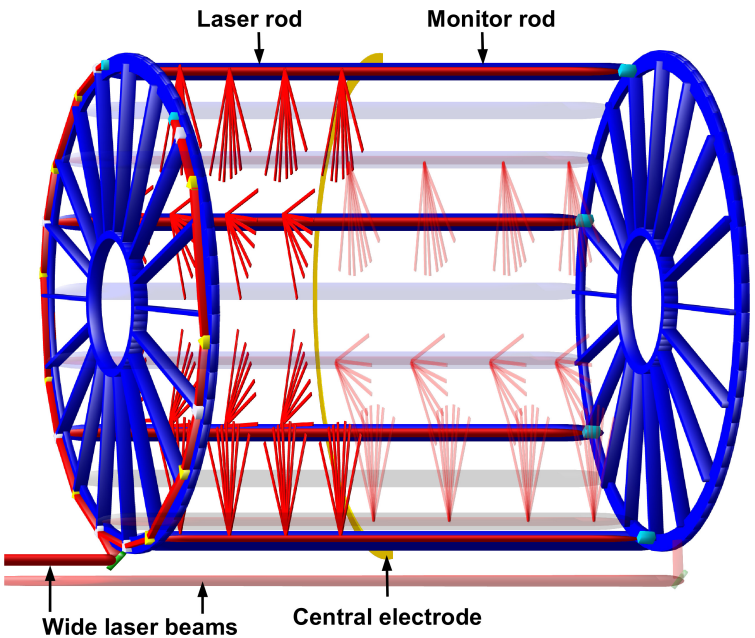
Gas recirculation system

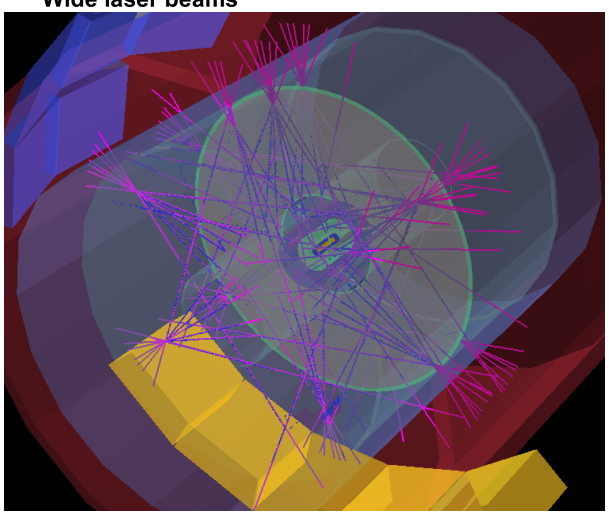
- mixture: Ne–CO_2–N_2 [85.7–9.5–4.8]
- precise control of gas mixture
- removal of Oxygen: only about $1\ \mathrm{ppm}$ left
- humidity kept at a fixed level to avoid aging of components



Laser system

- Laser specifications:
  - colour: $\lambda = 266\ \mathrm{nm}$ or $E = 4.66\ \mathrm{eV}$
  - energy: $100\ \mathrm{mJ}$ per $5\ \mathrm{ns}$
  - rate: $10\ \mathrm{Hz}$
- split into 336 beams distributed over the TPC volume
- used for (time dependent) spatial calibrations
- is run intermixed with physics data

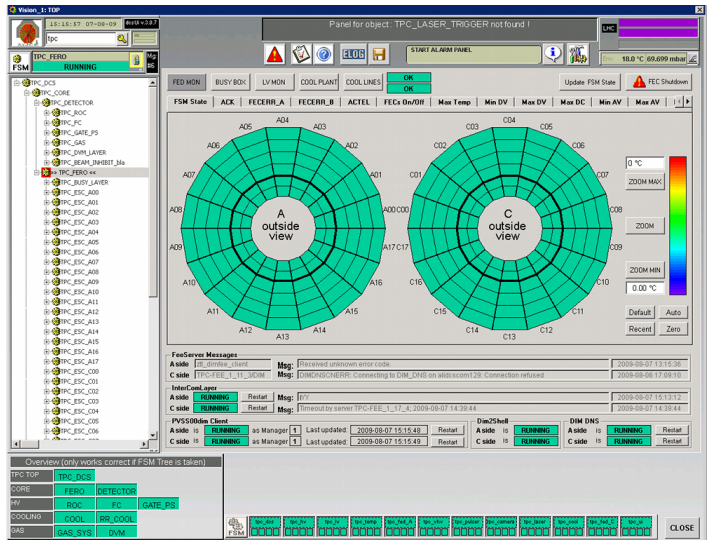


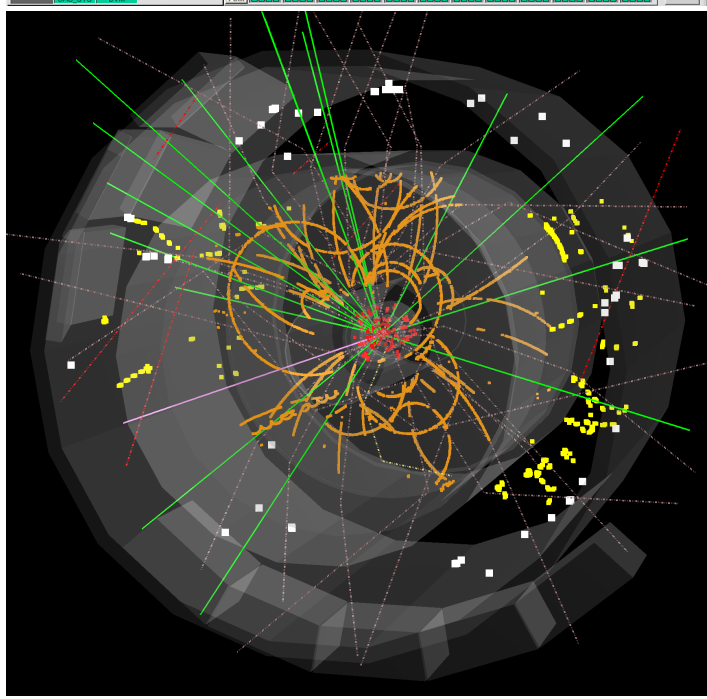


Milestones

2006	completely assembled
2007	transport to cavern
2008	commissioning with cosmics
06.12.2009	first $\sqrt{s} = 900\ \mathrm{GeV}$ collisions
30.03.2010	first $\sqrt{s} = 7\ \mathrm{TeV}$ collisions

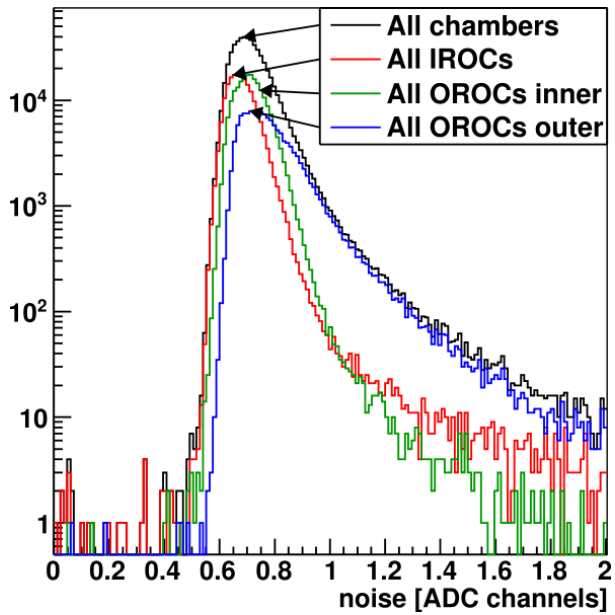
- configuration and control integrated into ALICE-wide framework
- fully controlled by central ALICE shifters

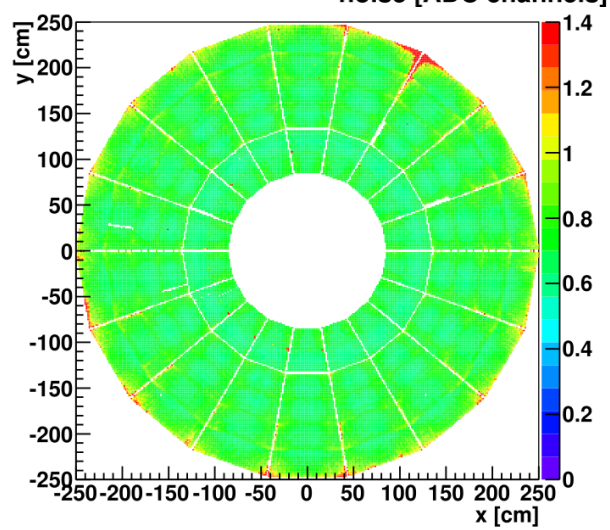




Noise figure

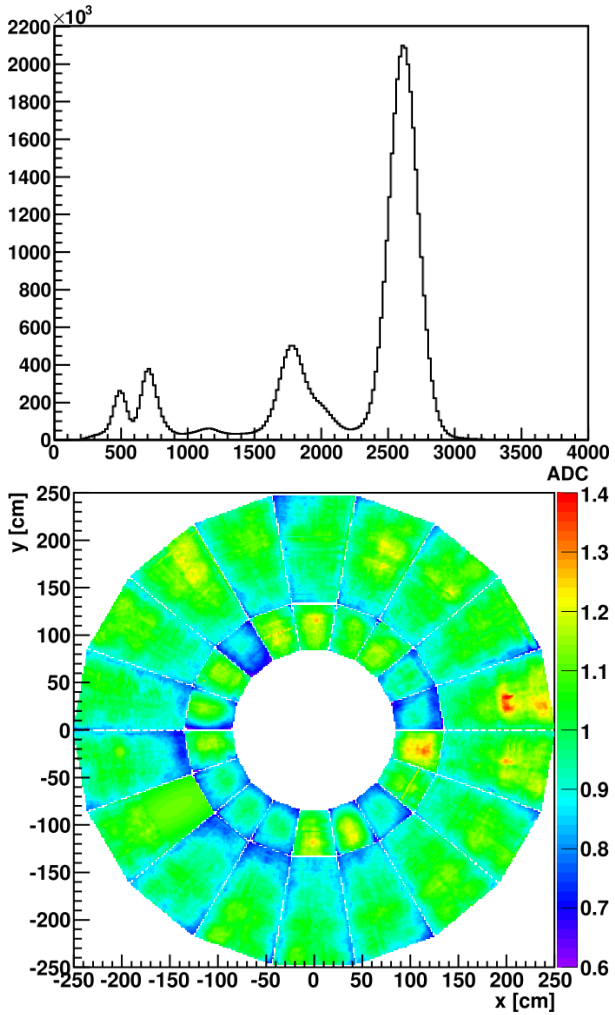
- average RMS noise: $0.7\ \mathrm{LSB}$ or $700\ \mathrm{e}$
- noisy spots identified, zero-suppression is adopted
- empty event size: $30\ \mathrm{kByte}$





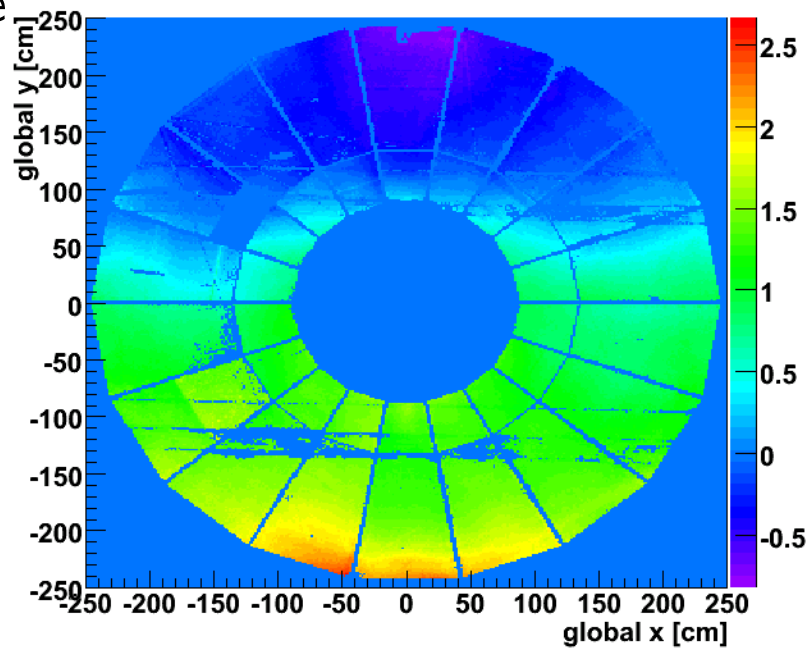
Gain

- calibration of electronic variations with injected pulses
- precise absolute calibration using ^{83}Kr decays
- gain spread is on the level of 20% and is corrected for offline



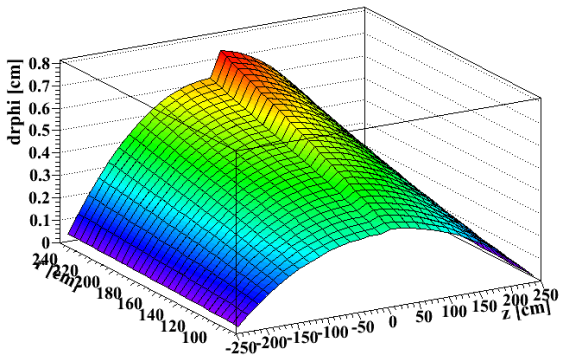
Drift velocity

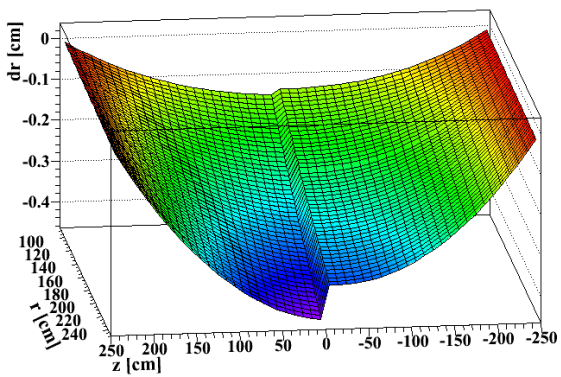
- redundant implementation:
  - photo electrons from the central electrode
  - position of laser tracks
  - track matching with inner detectors
  - dedicated gas monitor
- time dependent calibration parameters are obtained online
  - Laser runs every hour interleaved with physics data taking
  - DAQ machines calculate the calibration parameters on the fly
- achieved relative precision: 10^{-4}



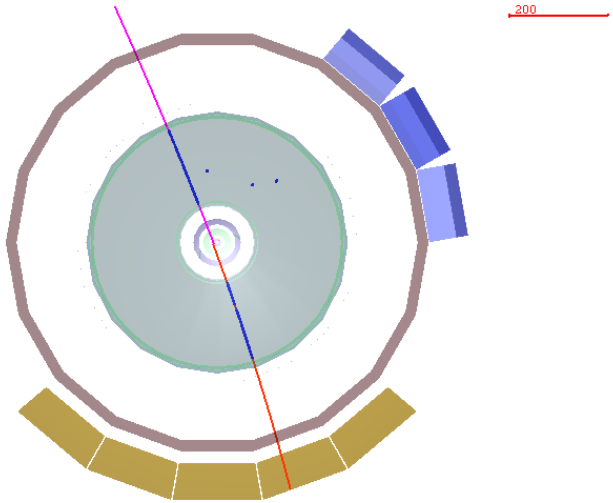
$\mathbf{E} \times \mathbf{B}$

- $\mathbf{E} \times \mathbf{B}$-effect due to:
  - imperfect $\mathbf{B}$-field
  - imperfect orientation of TPC (direction of drift field)
  - misaligned, or tilted chambers ($\mathbf{E}$-field distortions)
- overall effect: $\leq 7\ \mathrm{mm}$
- corrected to below $1\ \mathrm{mm}$
- further, detailed study ongoing

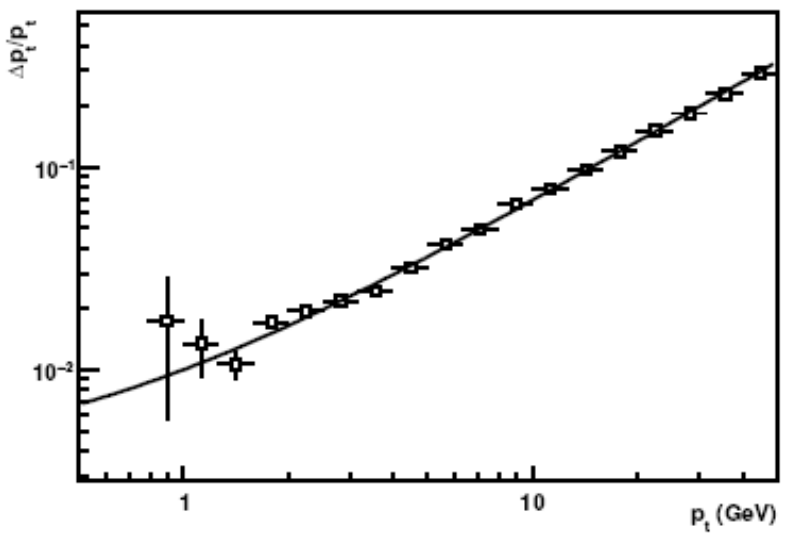




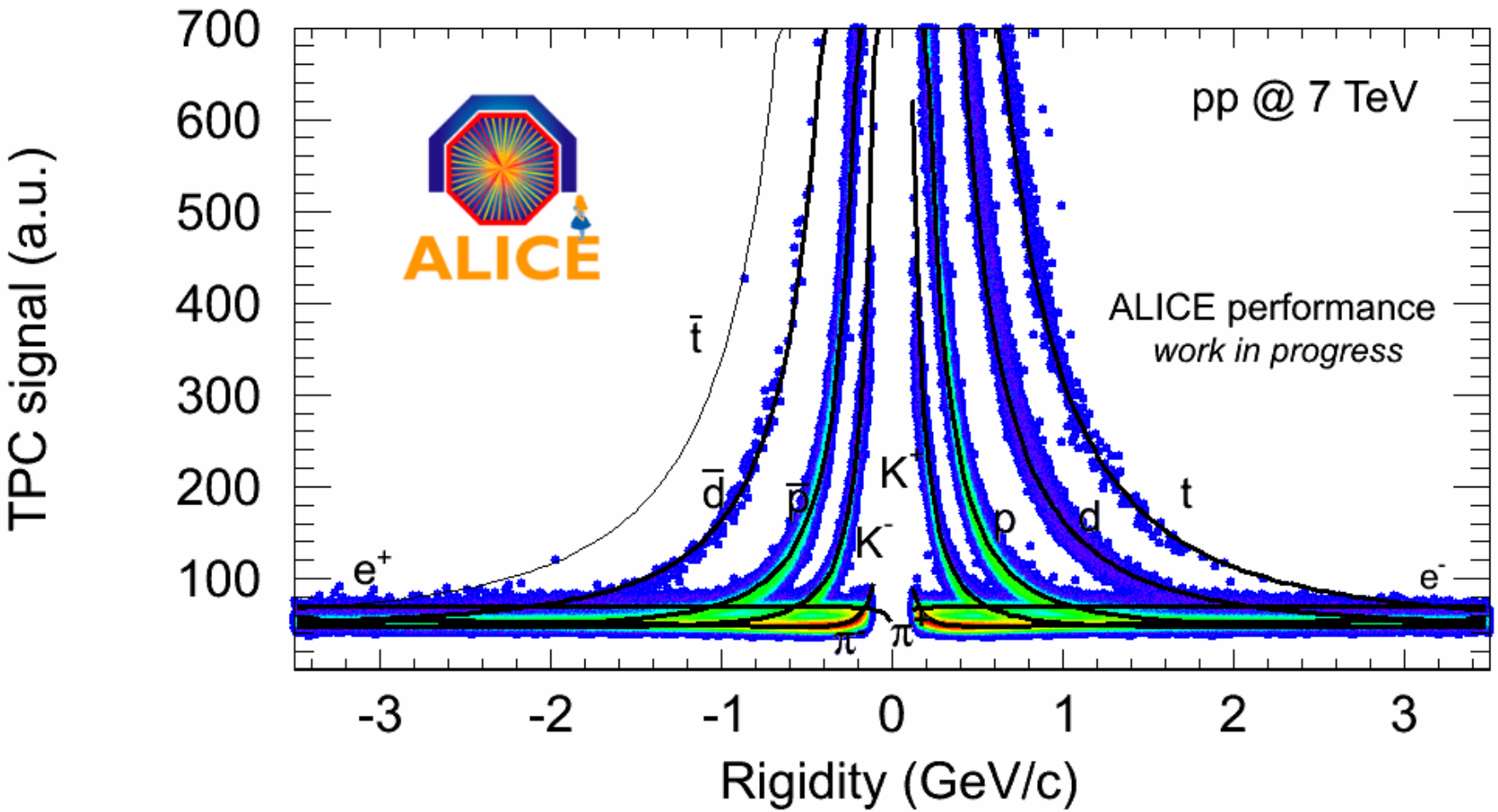
$p_\perp$ resolution



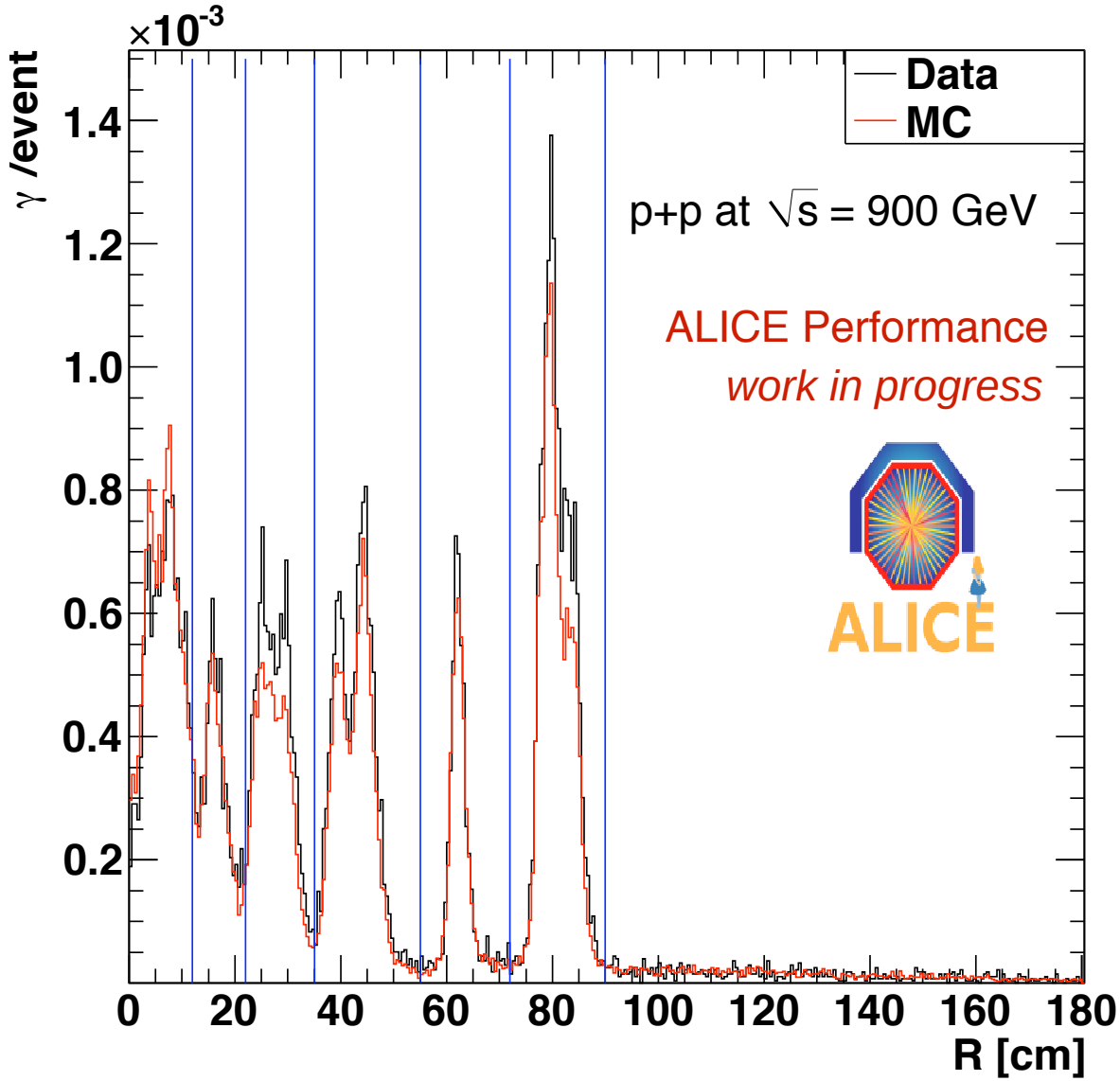
- obtained from matching upper part and lower part of a cosmic track
- current calibration:
  $(\sigma_{p_\perp}/p_\perp)^2 = (0.01)^2 + (0.007 p_\perp)^2$



dE/dx spectrum



Tomography


×10^-3
γ /event
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
20
40
60
80
100
120
140
160
180
R [cm]
Data
MC
p+p at √s = 900 GeV
ALICE Performance
work in progress
ALICE

The ALICE-TPC collaboration

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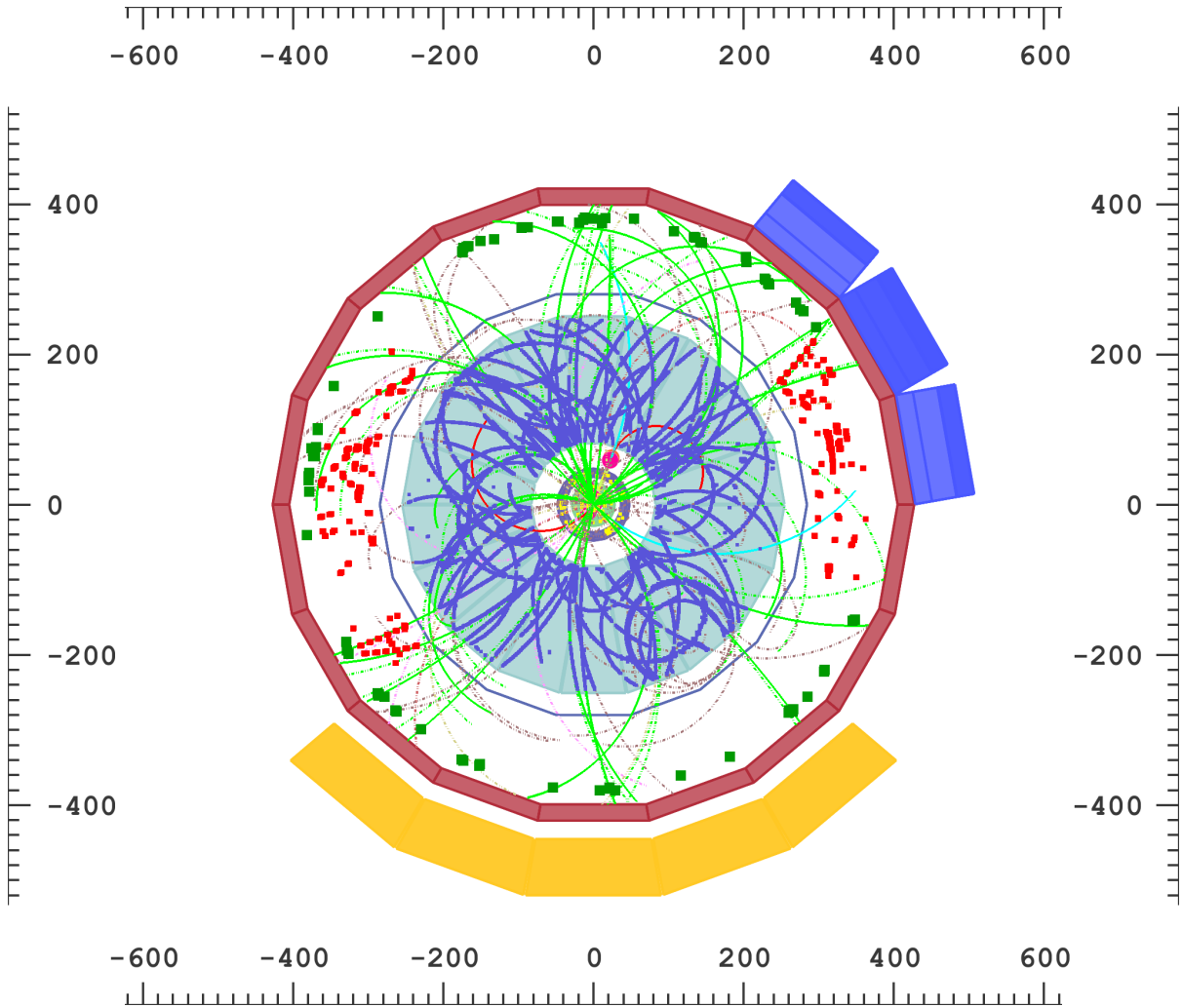
Events



Events