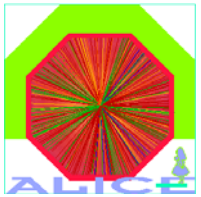


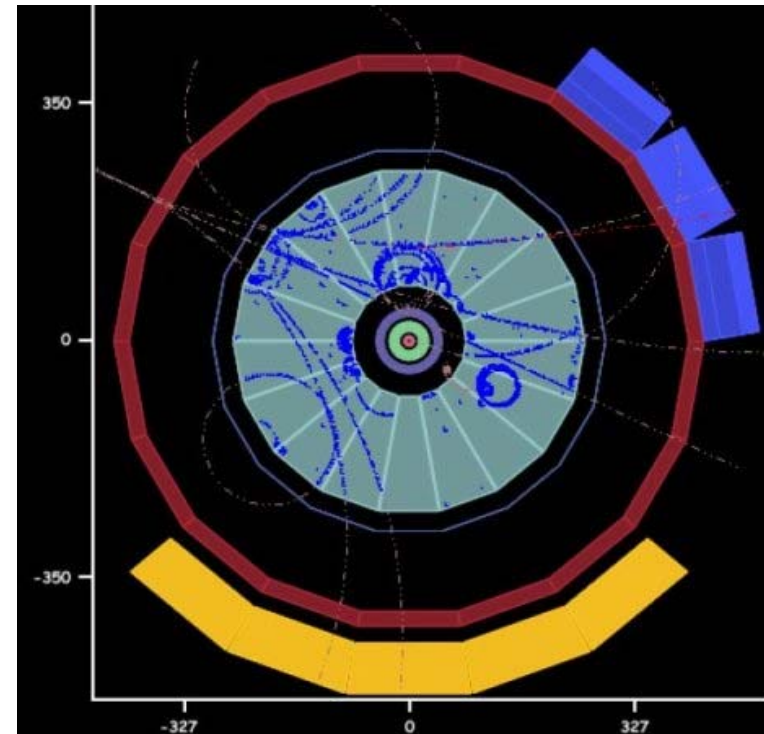


# ALICE Commissioning: Getting ready for Physics



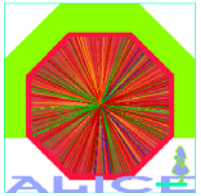
Christian Lippmann, CERN  
for the ALICE Collaboration

Moriond QCD and High Energy Interactions  
March 14th - March 21st 2009





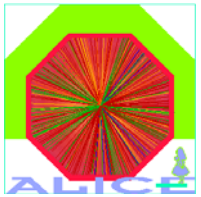
# Outline



- Introduction to ALICE
- ALICE Commissioning in 2007-09.
- Status and some selected results:
  - 1) ITS,
  - 2) TPC,
  - 3) ACORDE,
  - 4) 'Outer' Central Detectors: TRD, TOF, HMPID, PHOS, EMCAL,
  - 5) Muon Spectrometer,
  - 6) 'Forward Detectors': FMD, T0, V0, ZDC, PMD.
- Status of Trigger, HLT, DCS, DAQ.
- Summary & Outlook.

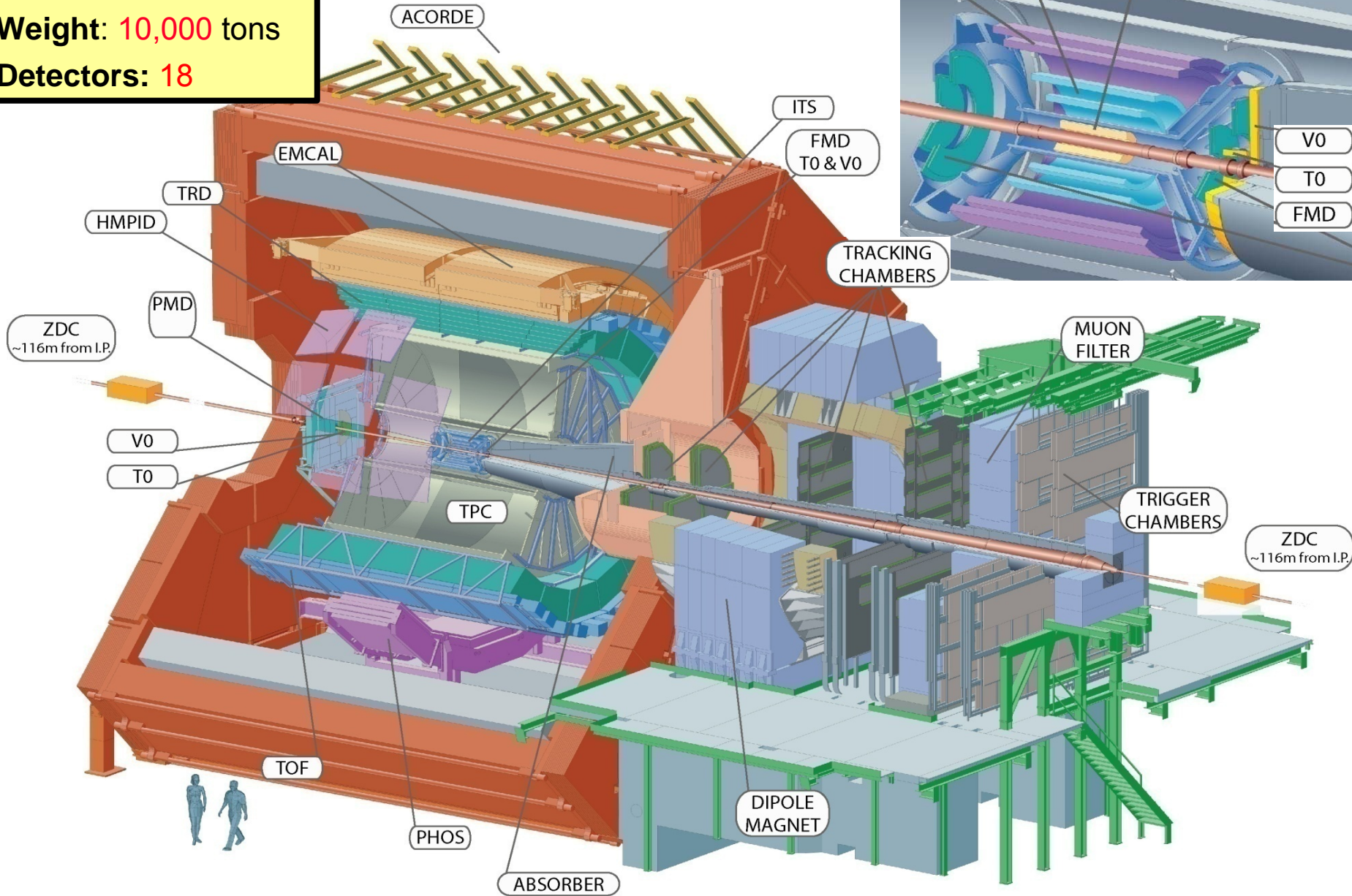


# ALICE: A Large Ion Collider Experiment



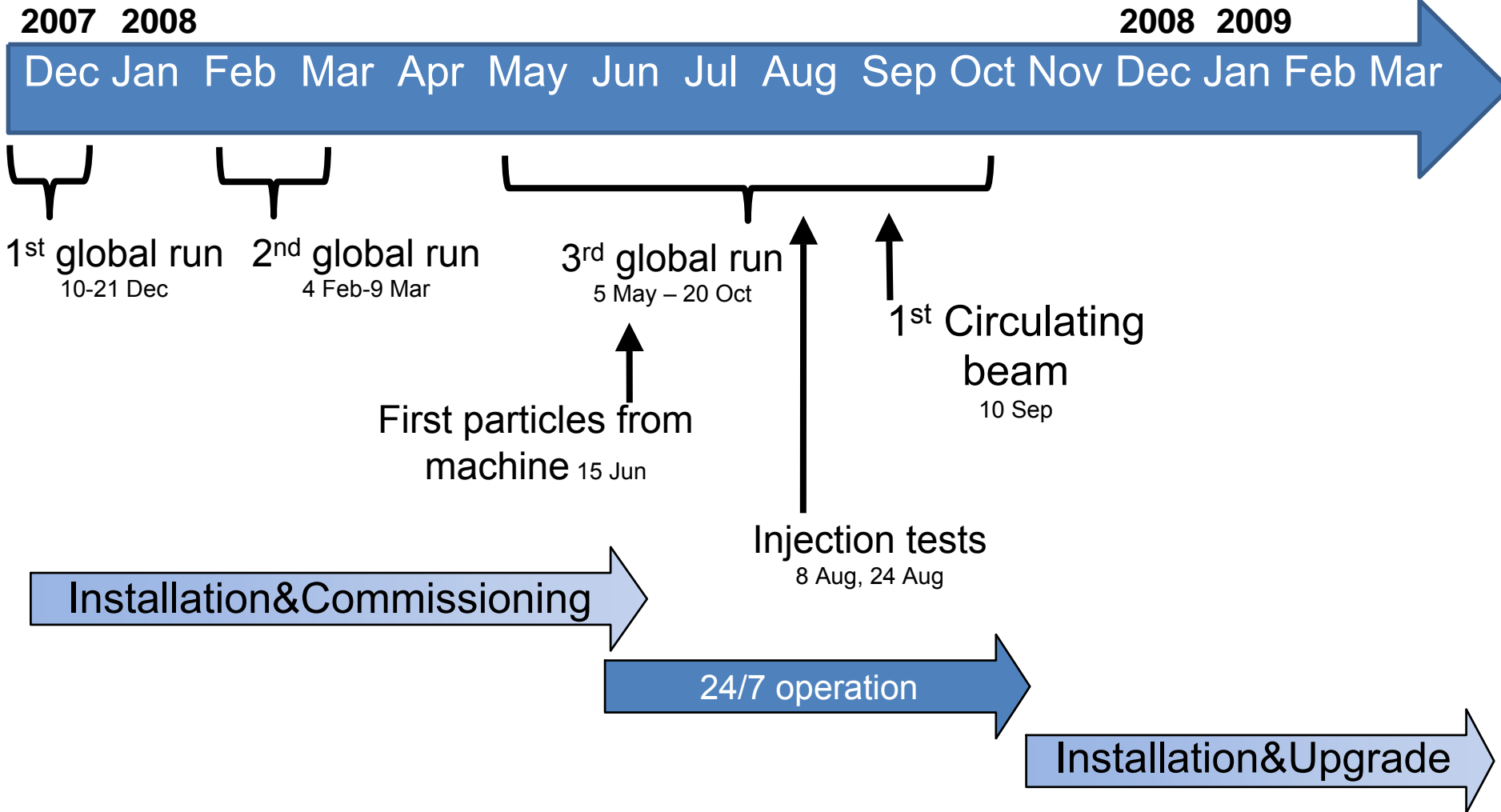
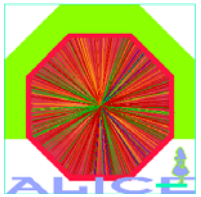
- ALICE is the dedicated **heavy ion experiment** at LHC:
  - Study **Pb-Pb collisions** at 5.5 TeV per nucleon pair.
  - Study the physics of strongly interacting matter at extreme energy densities (formation of quark-gluon plasma).
  - Carry out detailed studies of the *hadrons, electrons, muons and photons* produced in the collisions.
  - **High multiplicities**  $\Rightarrow$  high granularity;
  - **low momenta**  $\Rightarrow$  low material budget.
  - Chose TPC as main tracking detector (slow as compared to other LHC experiments).
- ALICE will also study **p-p collisions** at 14 (10) TeV:
  - For comparison with Pb-Pb collisions and
  - in physics areas where Alice complements the other LHC experiments.

**Size:** 16 x 26 meters  
**Weight:** 10,000 tons  
**Detectors:** 18



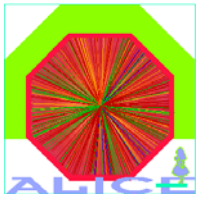


# ALICE commissioning in 2007-09





# 1) ITS: Inner Tracking System



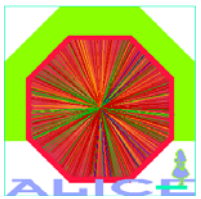
- 3 different silicon detector technologies (2 layers each):

Detector	Technology	Acceptance ( $\eta, \phi$ )	Radial position (m)	N. of channels
SPD	Pixel	$\pm 2$ ( $\pm 1.4$ ), $2\pi$	0.039, 0.076	9.8 M
SDD	Drift	$\pm 0.9$ , $2\pi$	0.15, 0.239	133000
SSD	Strip	$\pm 0.97$ , $2\pi$	0.38, 0.43	2.6 M

- Fully installed and commissioned.
- 'Pixel trigger':
  - Fast-OR of 1200 SPD chips; available for Level 0;
  - Different programmable algorithms: High multiplicity, minimum-bias, cosmics, ...
  - ALICE is the only LHC experiment including the vertex detector in the first trigger decision from startup.
- Operational.



# Lowering the ITS into the Cavern (March 2007)



# ITS Alignment (1)

## Silicon Pixel Detector (SPD):

- ~10M channels
- 240 sensitive vol. (60 ladders)

## Silicon Drift Detector (SDD):

- ~133k channels
- 260 sensitive vol. (36 ladders)

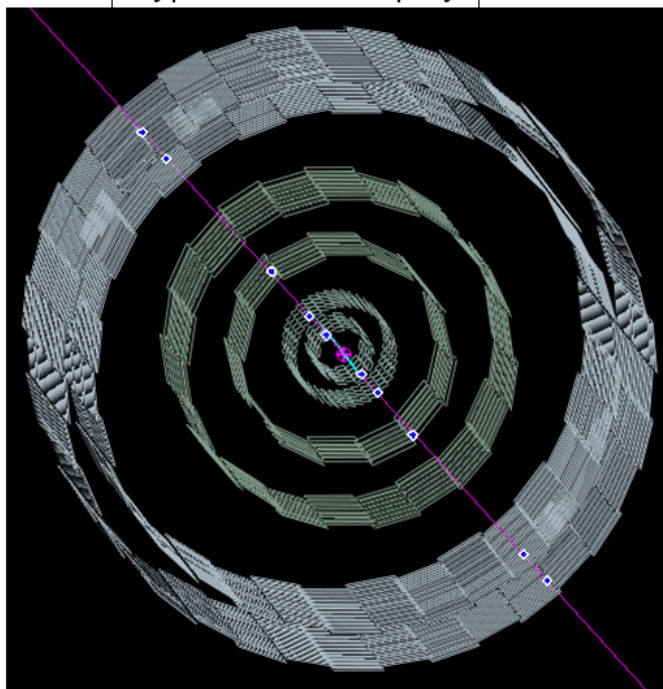
## Silicon Strip Detector (SSD):

- ~2.6M channels
- 1698 sensitive vol. (72 ladders)

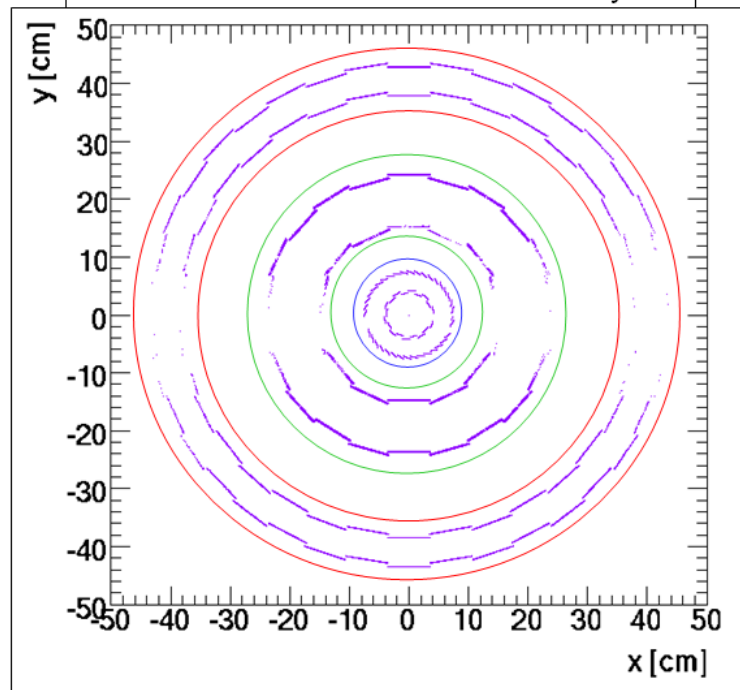
**ITS total: 2.2k alignable sensitive volumes → 13k degrees of freedom**

- ◆ Alignment using tracks and Millepede program in a hierarchical approach
- ◆ ~50k cosmic  $\mu$  for alignment collected since end of May, using Pixel trigger

Typical event display



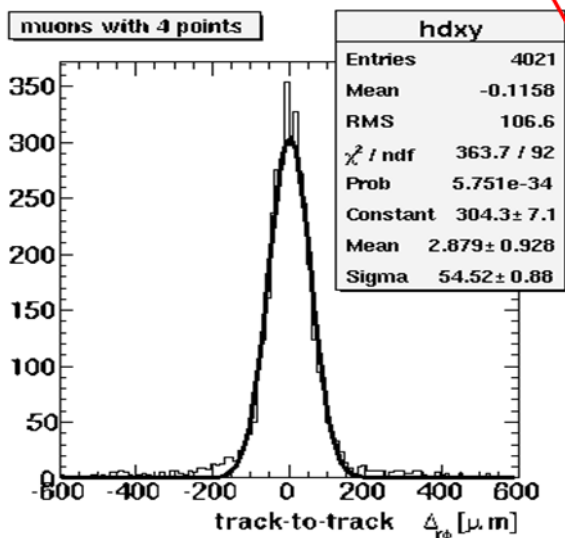
Distribution of **clusters** in the 6 layers



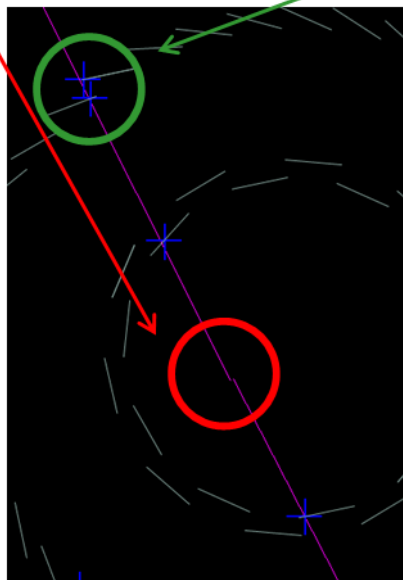


- ◆ Preliminary results for SPD (Pixels):

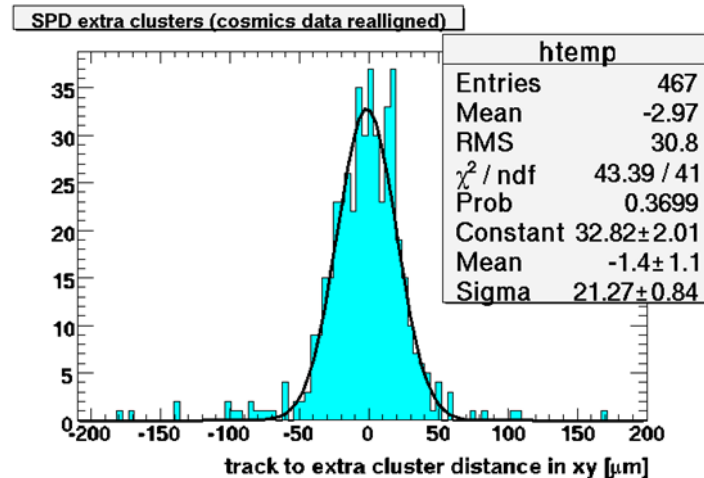
## Track-to-track (top vs bottom) distance in transv. plane



$\sigma = 55 \mu\text{m}$  (vs  $40 \mu\text{m}$  in simul. without misalignment)



## Track-to-“extra clusters” distance in transv. plane

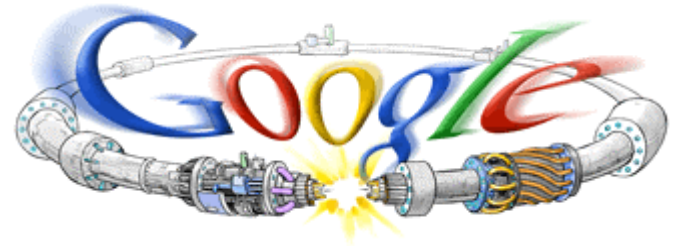
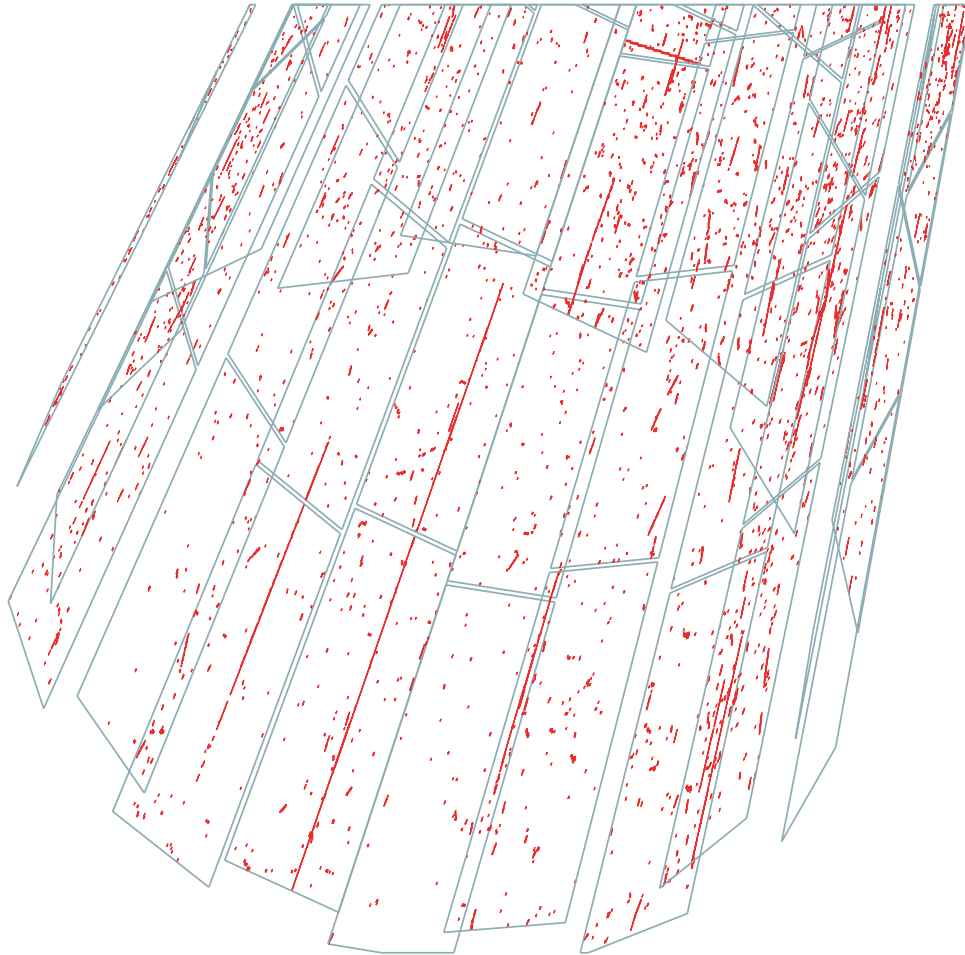
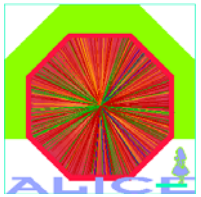


$\sigma = 21 \mu\text{m}$  (vs  $15 \mu\text{m}$  in simul. without misalignment)

- These results indicate a residual misalignment of  $< 10 \mu\text{m}$ , after realignment with cosmics.
- This is to be compared to a detector position resolution of  $12 \mu\text{m}$  in  $r\phi$ .



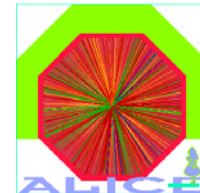
# LHC Beam Related Particles in SPD



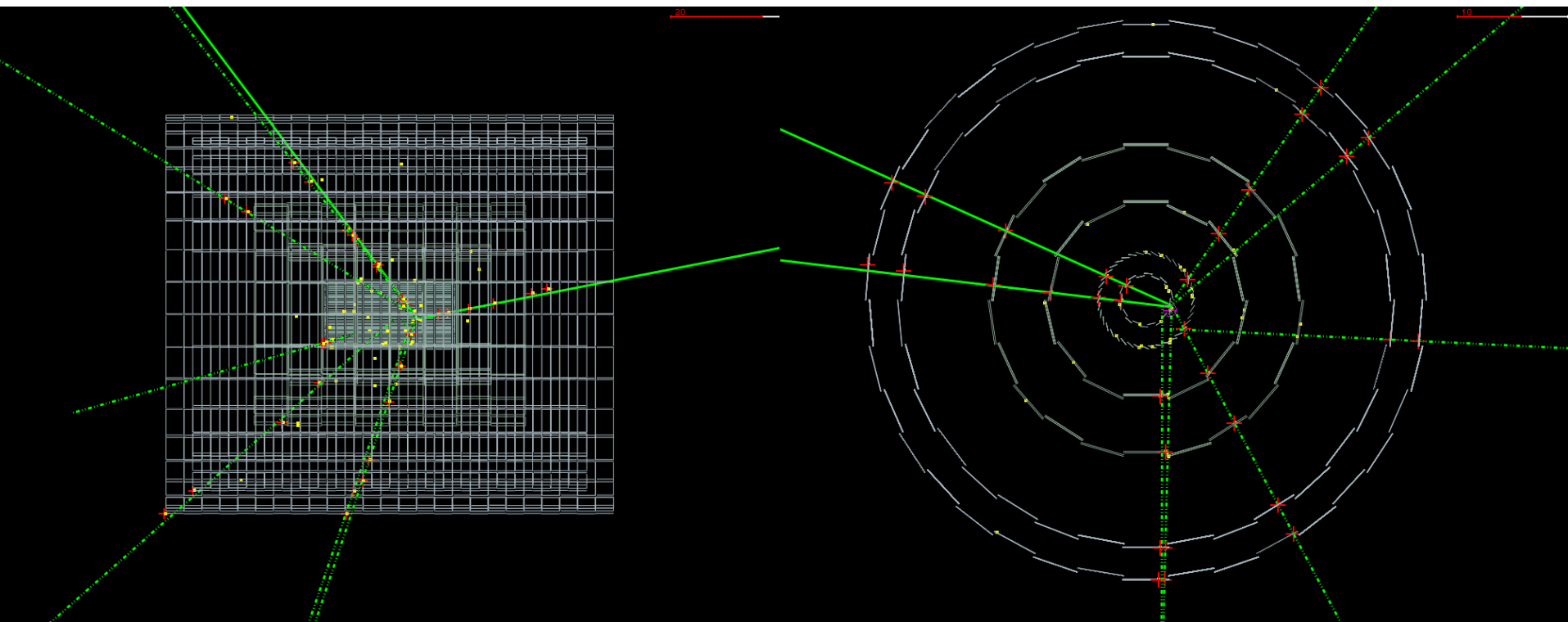
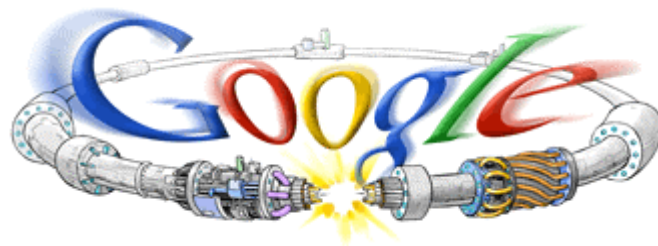
- Event from very first injection tests in August 2008.
- Self-triggering with the Pixel Trigger.
- In general ITS, V0 and FMD (and often Muon) were on during injection tests.



# First Interaction in ALICE

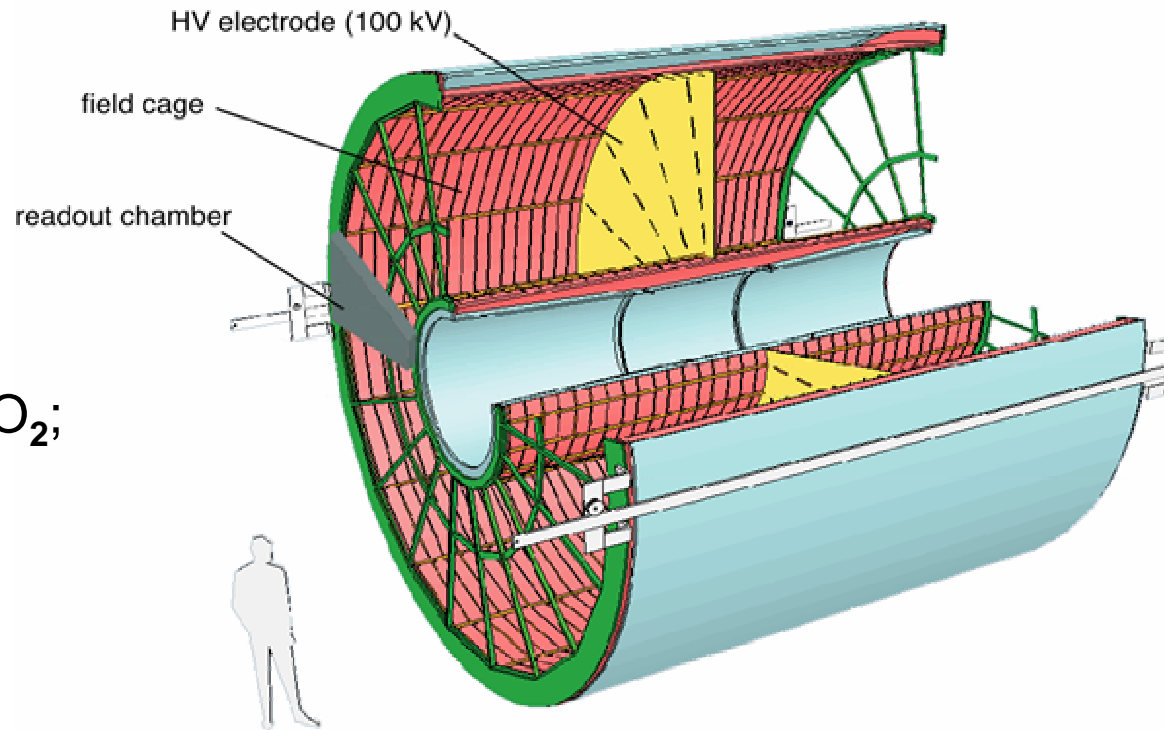


- LHC beam circulation tests on 11.09.2008.
- Collision of beam-halo particle with SPD.

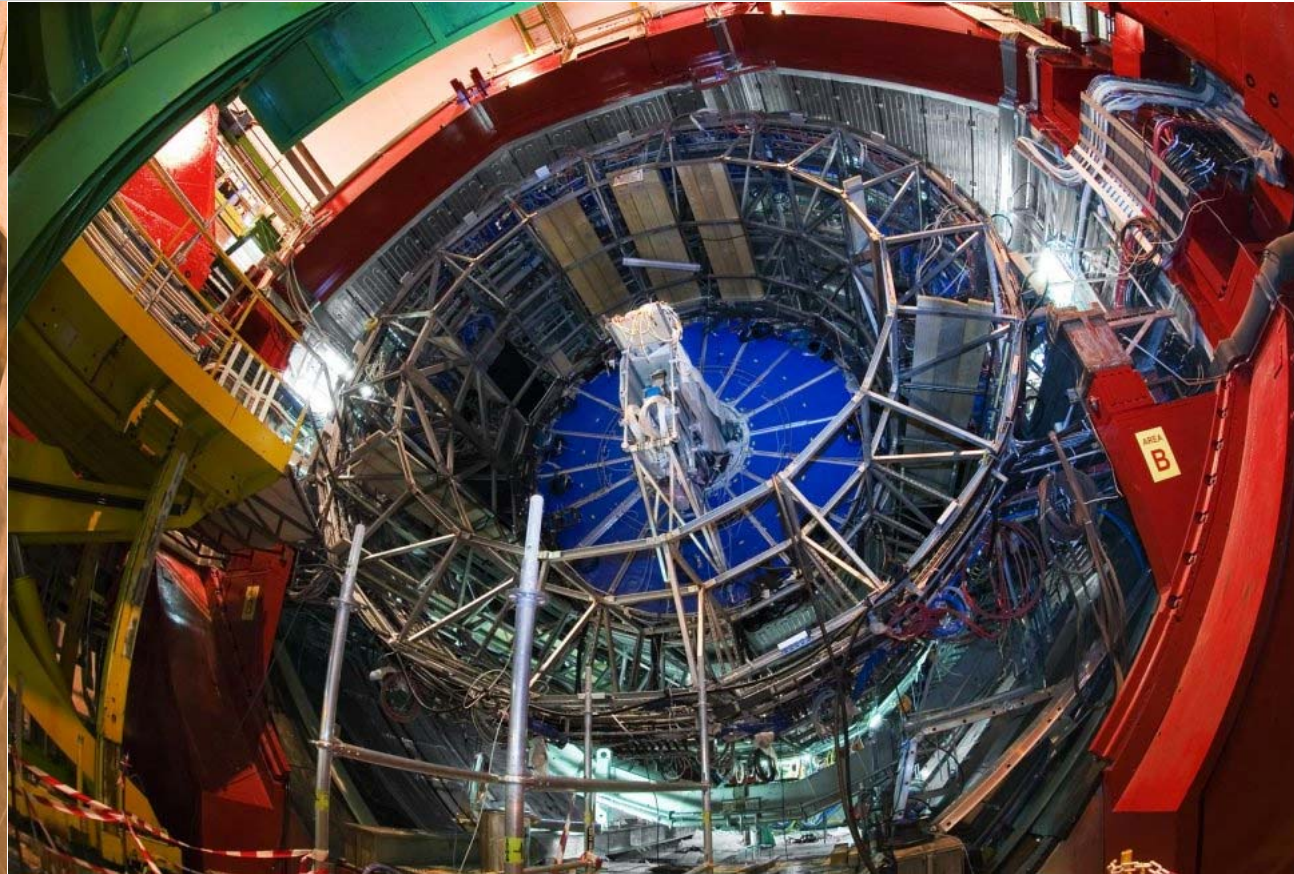


## 2) TPC: Time Projection Chamber

- The largest TPC ever;
- Optimized for  $dN/d\eta \approx 8000$ ;
- $L=5$  m,  $\varnothing = 5$  m,  $88$  m<sup>3</sup>;
- Material ( $\eta=0$ ):  $3\% X_0$ ;
- Drift gas: Ne/CO<sub>2</sub>/N<sub>2</sub> (86/9.5/4.5%) +  $\sim 1$ ppm O<sub>2</sub>;
- Drift time:  $92$   $\mu$ s;
- $\sim 570$  000 pads  
( $\Rightarrow \sim 570$  Mio pixels),
- Highly integrated digital electronics (ALTRO chip);
- Laser calibration system;
- **Installed and commissioned.**



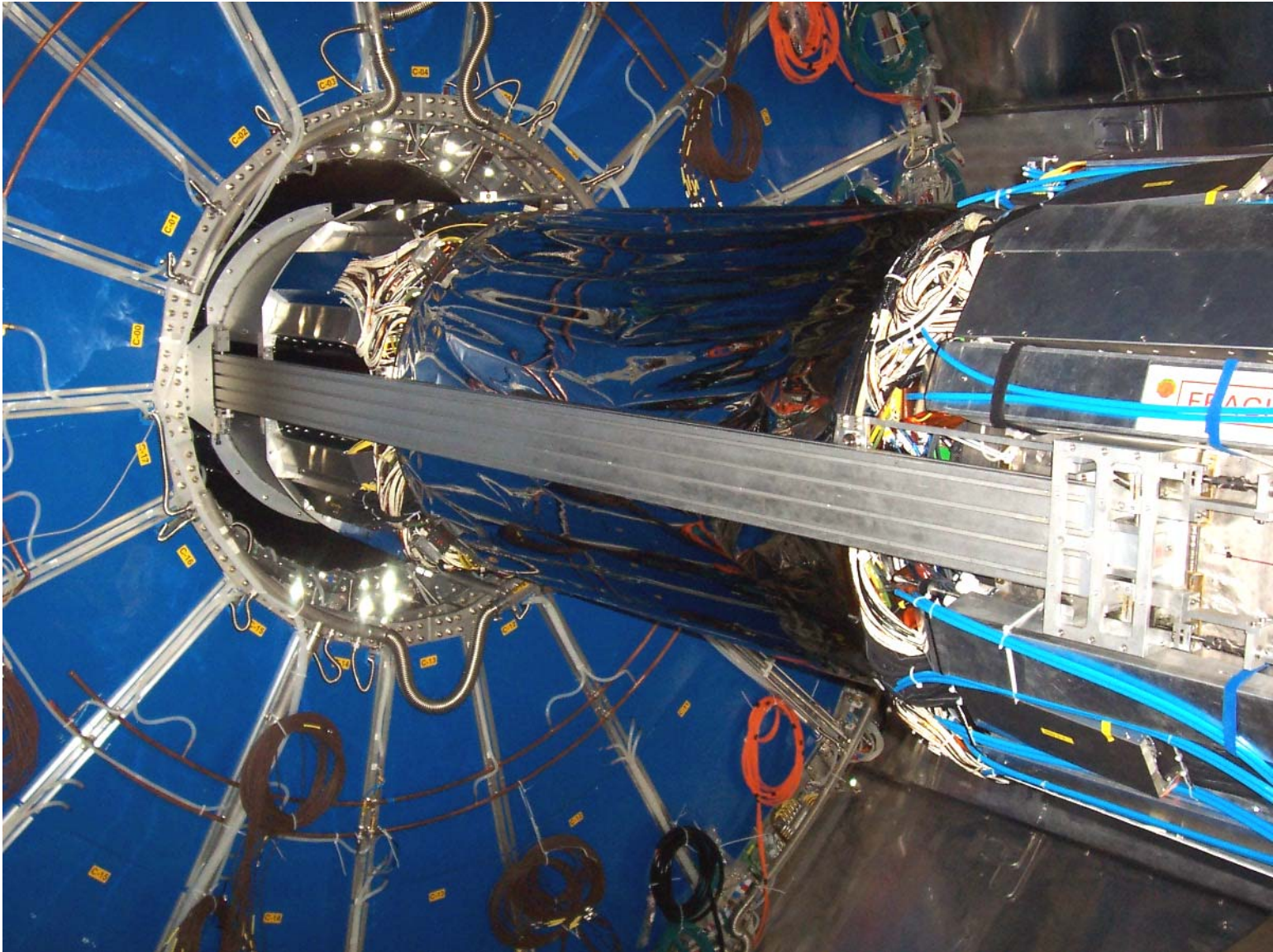
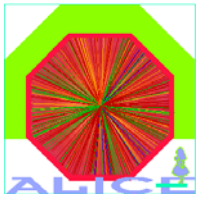
# Installation of the ALICE TPC



- Field Cage Assembly: 2002-04
- Readout Chamber Installation: 2005
- Electronics Installation: 2006
- Installation in cavern: 2007
- Commissioning/Calibration: 2007-09

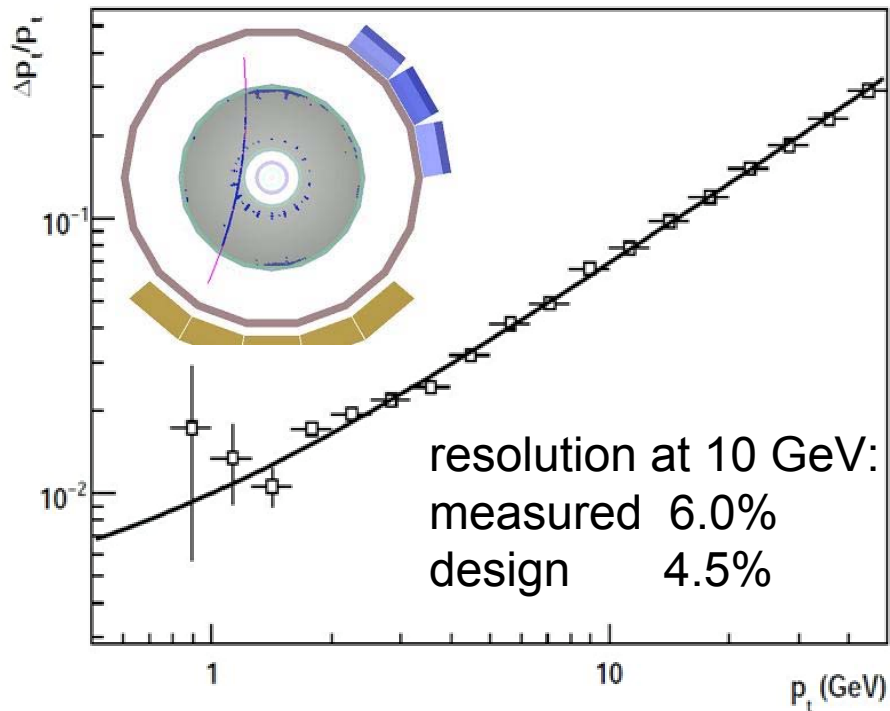


# Moving the TPC over the ITS (September 2007)

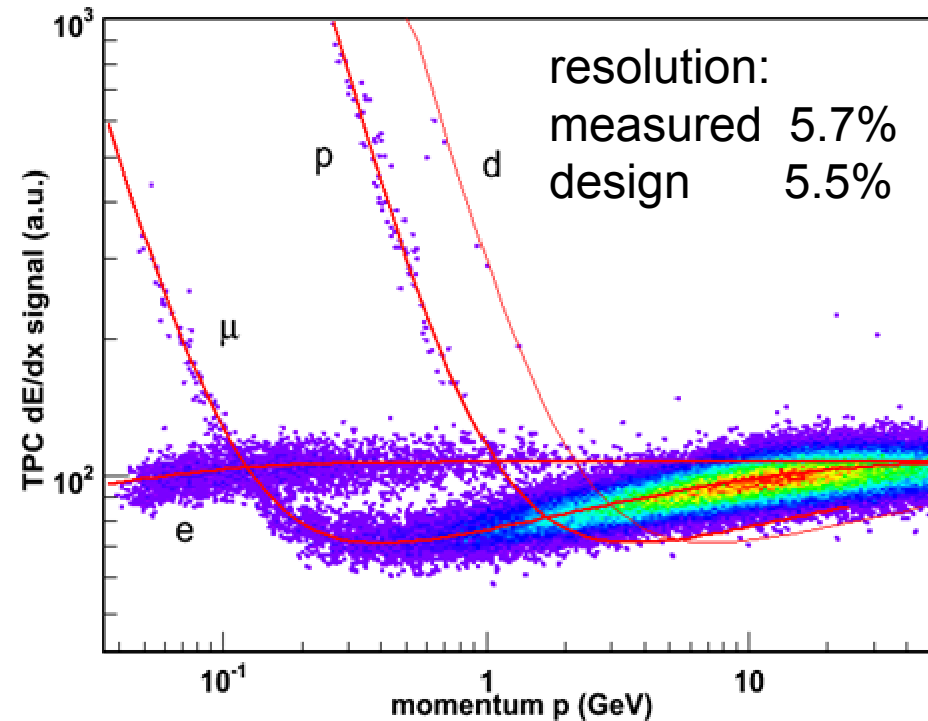


- TPC was running continuously May-October 2008.
- 60 million events (Cosmic, krypton and laser) recorded.
- First round of calibrations completed.

transverse momentum resolution,  $B=0.5$  T



particle identification via  $dE/dx$



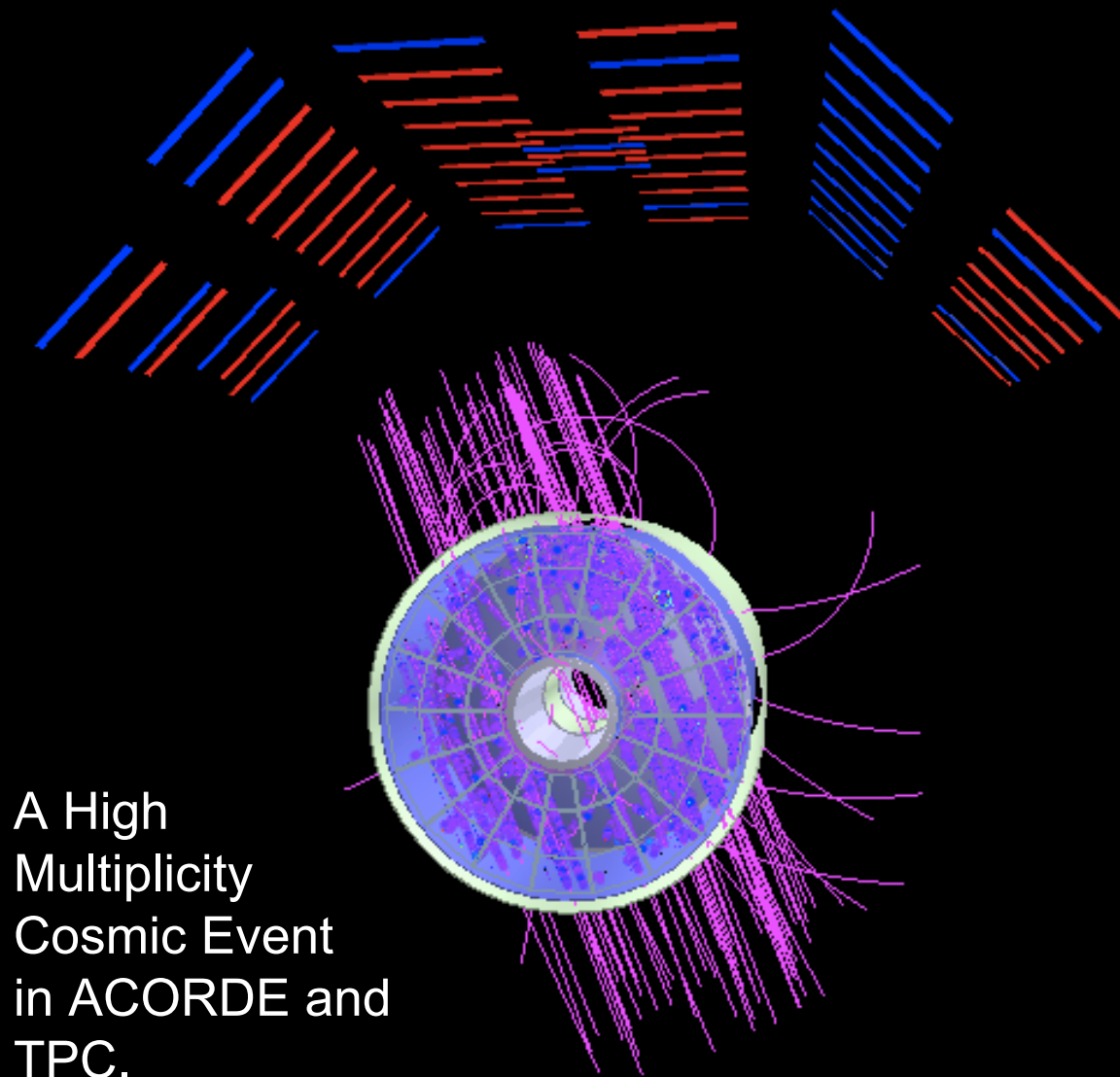
**performance close to design value, TPC ready for collisions**



# 3) ACORDE: Alice COsmic Ray Experiment



- Provides cosmic ray trigger.
- 60 modules with two plastic scintillator paddles with  $190 \times 19.5 \text{ cm}^2$  effective area.
- Cosmic  $\mu$  ( $E \geq 10 \text{ GeV}$ ) reach ACORDE at  $\leq \sim 5 \text{ Hz/m}^2$ .
- Multi- $\mu$  events at  $\leq 0.1 \text{ Hz/m}^2$ .
- **Operational.**

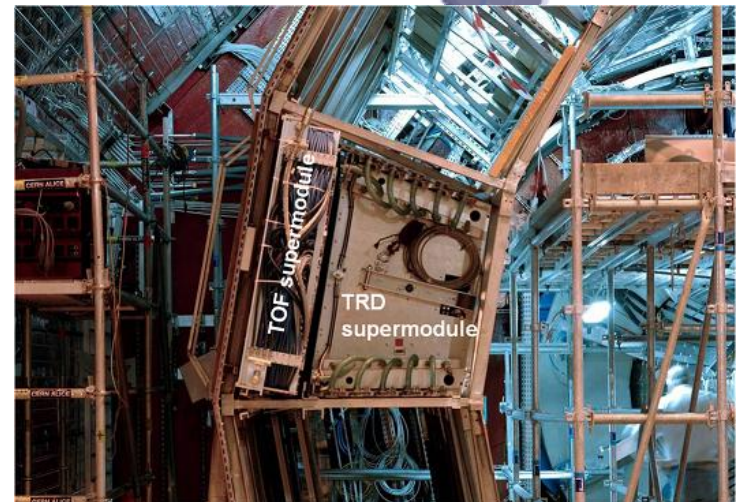
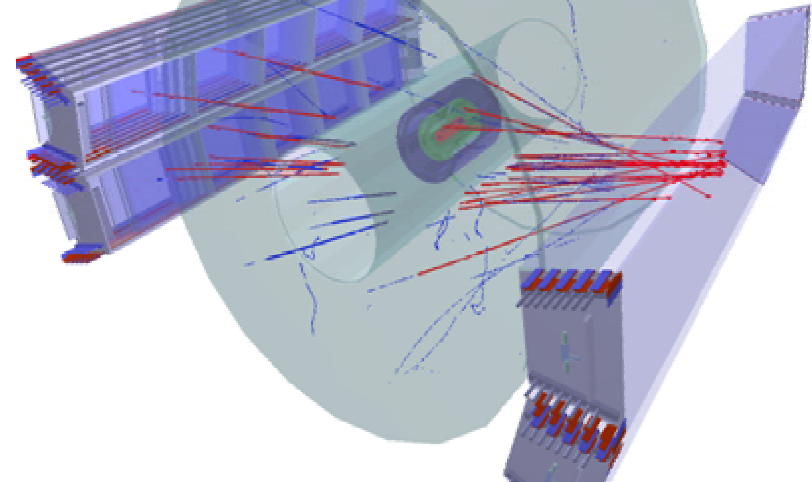




## 4) 'Outer' Central Detectors (1)

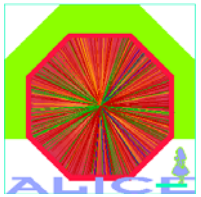
- **TRD: Transition Radiation Detector.**
  - Drift chambers filled with Xe, CO<sub>2</sub>;  
~1 180 000 pads;
  - $|\eta| < 0.9$ ;  $\Delta\phi = 2\pi$ ;  $R \geq 295\text{cm}$ ;
  - *Electron ID* for  $1 < p < 10\text{ GeV}/c$ ;  
*trigger* on high momentum particles.
  - 20% now installed & commissioned.  
Up to 45% for 2009 run.
  
- **TOF: Time Of Flight detector.**
  - MRPCs (a revolution in TOF PID!);  
~160 000 pads;
  - System resolution: <100 ps;
  - $|\eta| < 0.9$ ;  $\Delta\phi = 2\pi$ ;  $R \geq 370\text{cm}$ ;
  - *Particle ID* ( $\pi/K$  up to 2.5 GeV/c, p/K up to 5 GeV/c), *timing and triggering*.
  - Fully installed & commissioned.

Cosmic event in TPC and TRD;  
triggered by TRD L1

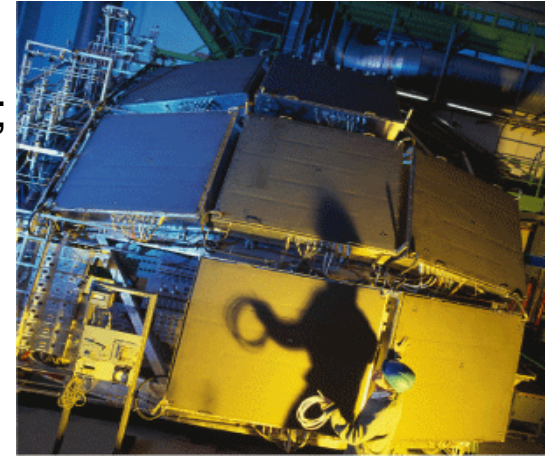




## 4) 'Outer' Central Detectors (2)



- **HMPID: High Momentum Particle ID.**
  - Proximity focused RICH, 7 modules, ~16 100 pads;
  - Acceptance:  $|\eta| < 0.6$ ;  $\Delta\phi = 58\text{deg}$ ;  $R \geq 450\text{cm}$ ;
  - *Particle ID* ( $\pi^\pm/K^\pm$  for  $1 < p < 3$  GeV/c, p for  $2 < p < 5$  GeV/c).
  - Fully installed and commissioned.



- **PHOS: PHOton Spectrometer.**
  - $\text{PbO}_4\text{W}$ - crystal calorimeter, 5 modules; ~18 000 crystals; APD read out;
  - Acceptance:  $|\eta| < 0.12$ ;  $\Delta\phi = 100\text{deg.}$ ;  $R \geq 460\text{cm}$ ;
  - *Particle ID* ( $\gamma, \pi^0, \eta$ ) up to 10 GeV/c, possibly higher momenta; Level 0 *trigger*;
  - Will be partially installed for 2009 Run.

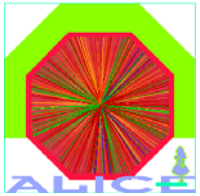
## 4) 'Outer' Central Detectors (3)

- **EMCAL: ElectroMagnetic CALorimeter.**
  - Pb-Scintillators; 12 modules; ~13 000 projective towers in 'Shashlik' geometry; APD read out.
  - Acceptance:  $|\eta| < 0.7$ ;  $\Delta\phi = 107^\circ$ ;  $R \geq 430\text{cm}$ ;
  - *Jet physics* (in conjunction with tracking and particle ID). Level 0 *trigger* (high- $p_T$  jets, photons, electrons).
  - Project approved in December 2007. 8% to be installed in March 2009. Possibly 25% for 2009 Run.



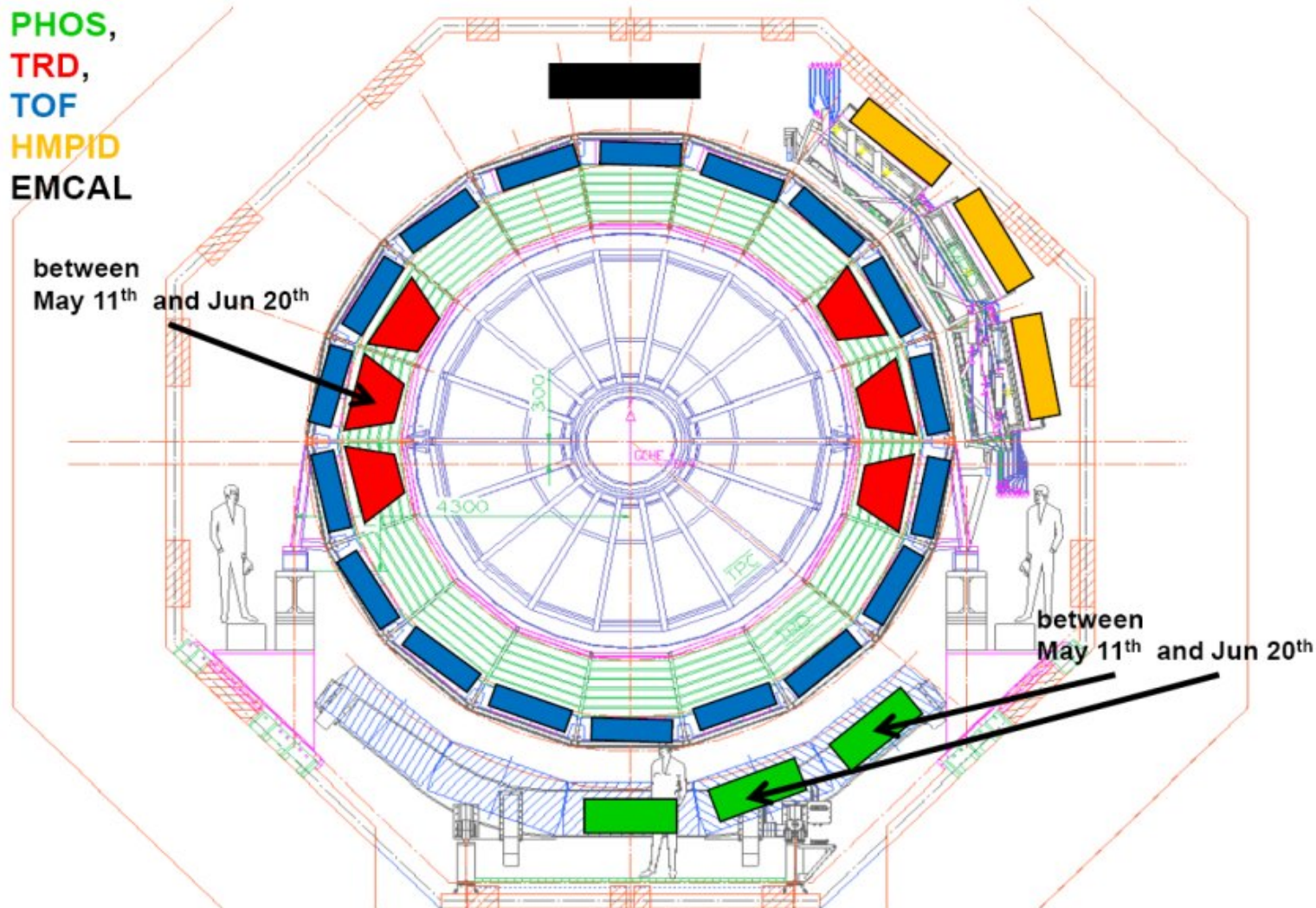


# Planned Status for Central Detectors for 2009 Run



PHOS,  
TRD,  
TOF  
HMPID  
EMCAL

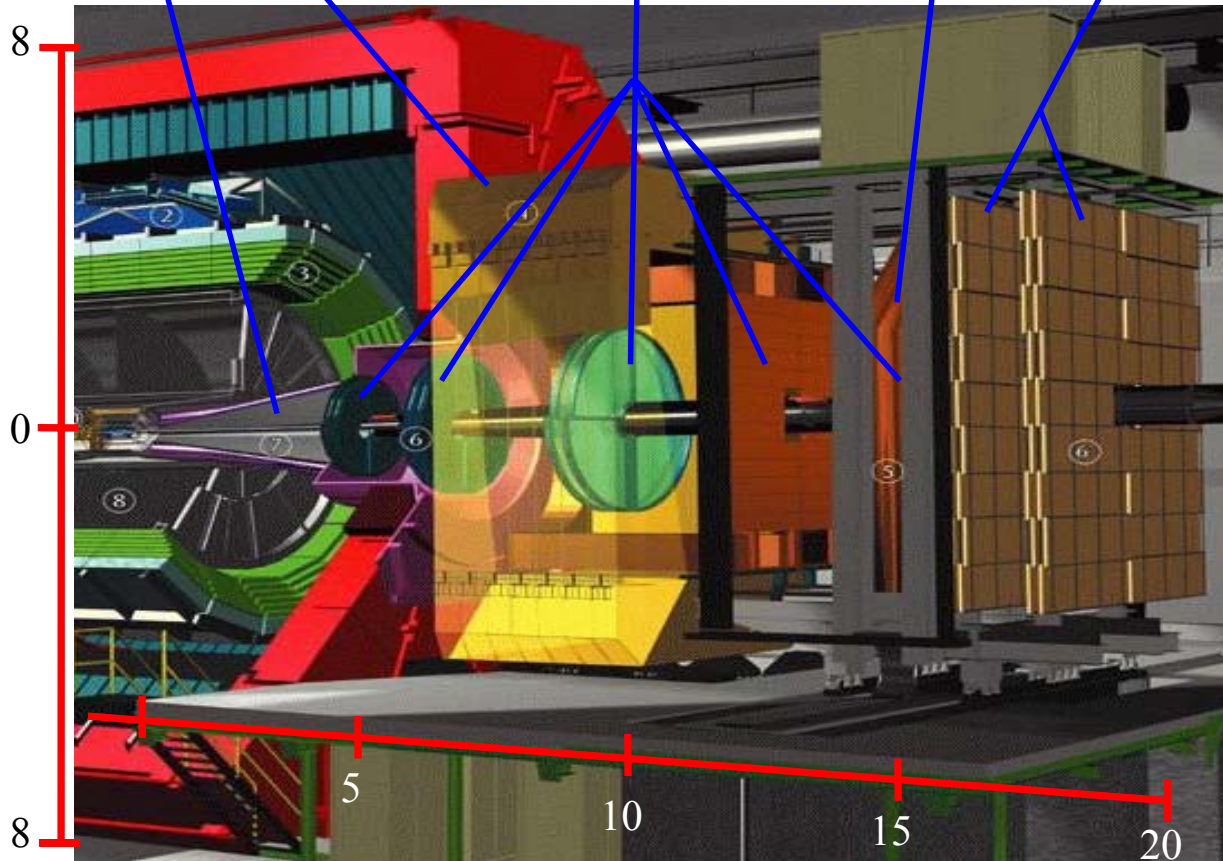
between  
May 11<sup>th</sup> and Jun 20<sup>th</sup>



between  
May 11<sup>th</sup> and Jun 20<sup>th</sup>

# 5) Muon Spectrometer

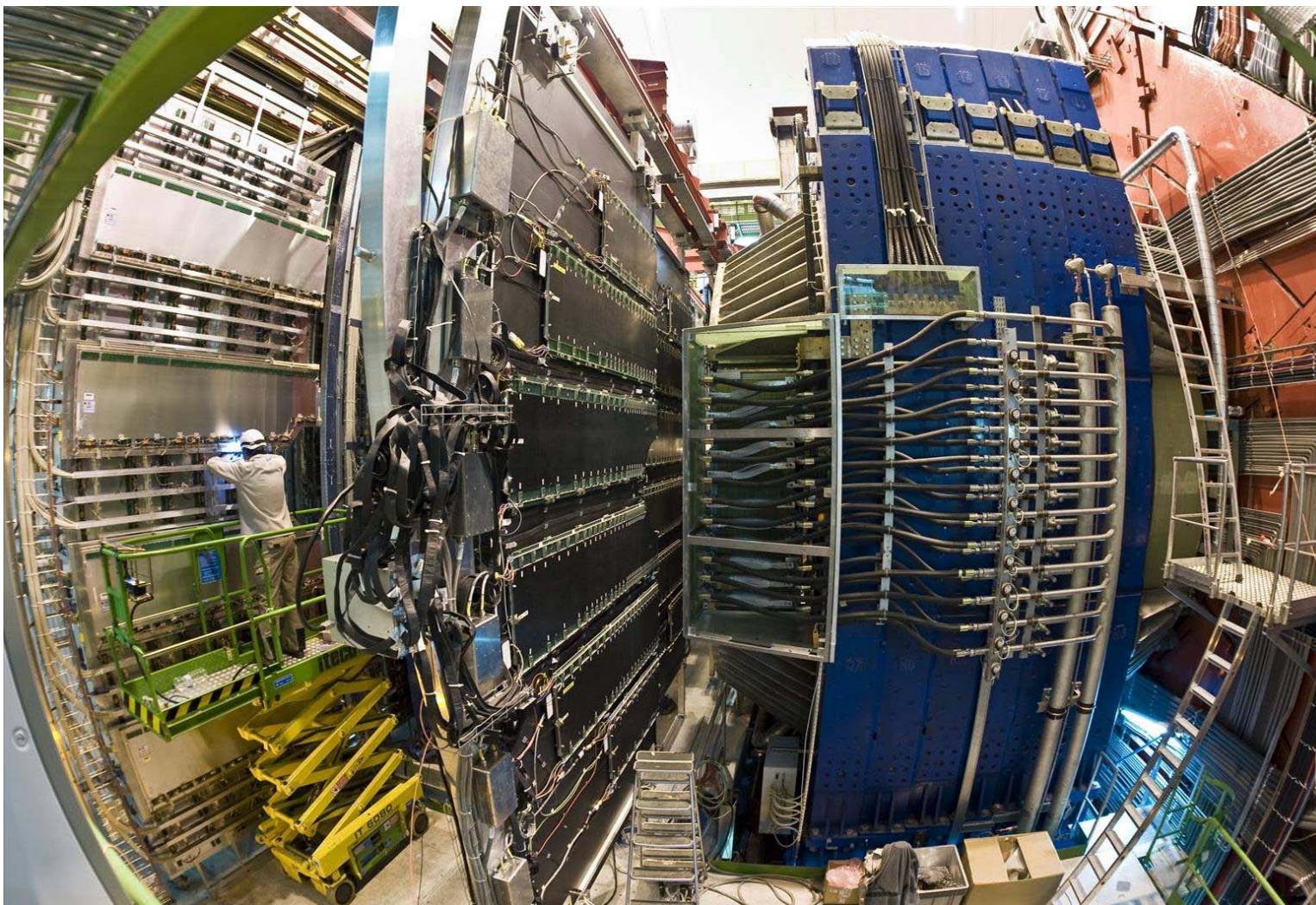
Absorber    Dipole    Tracking chambers    Absorber    Trigger stations



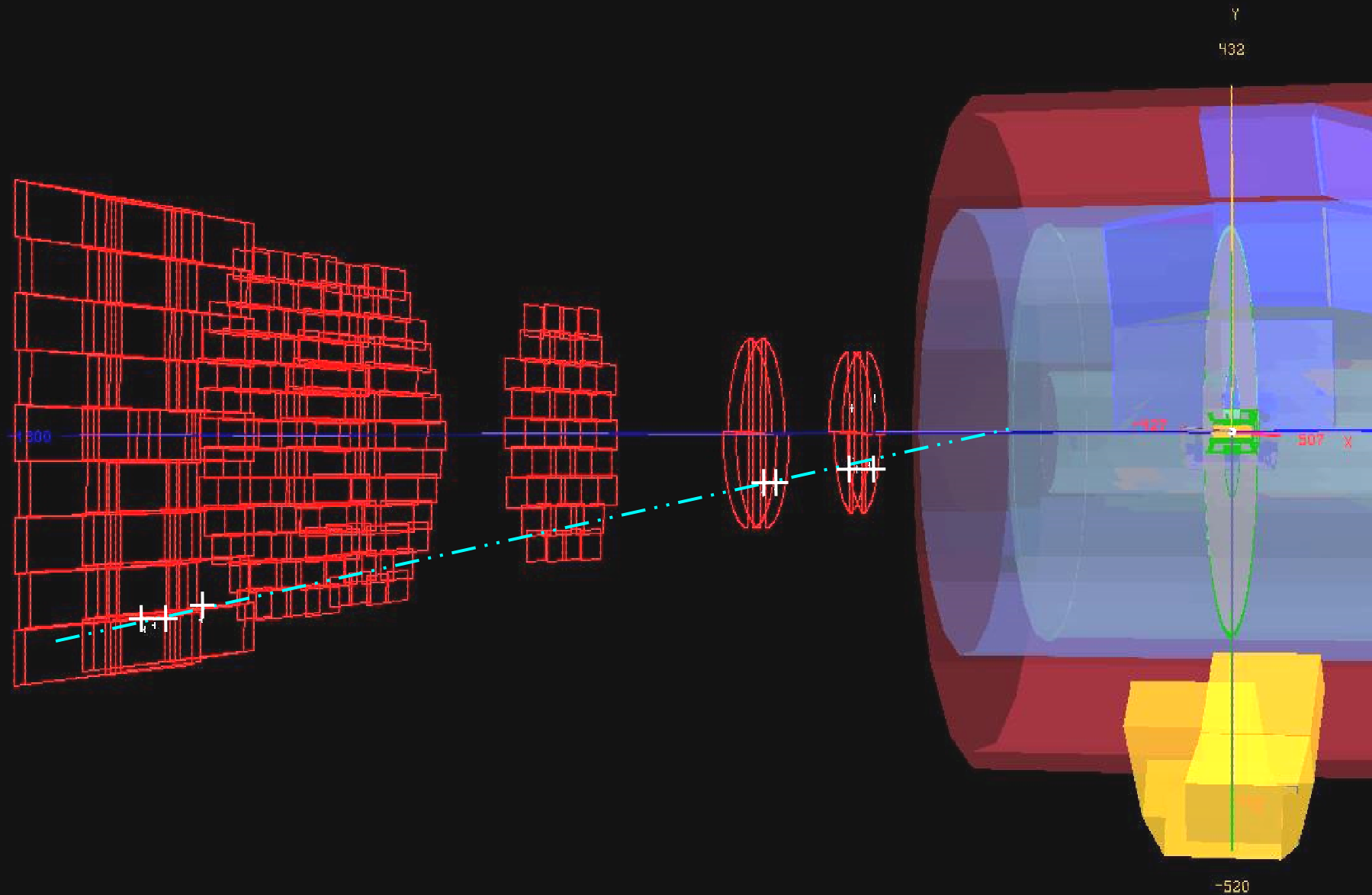
- Acceptance on single  $\mu$ :
  - $p > 4\text{GeV}/c$ ;
  - $-0.4 < \eta < -2.5$ .
- Tracking:
  - 5 tracking stations; two planes each.
  - Cathode pad chambers;  $60\mu\text{m}$  space resolution.
- Triggering:
  - 2 Trigger stations; two planes each.
  - RPC technology; avalanche or limited streamer mode.

- Fully installed & commissioned.

# Partial view of Muon chambers

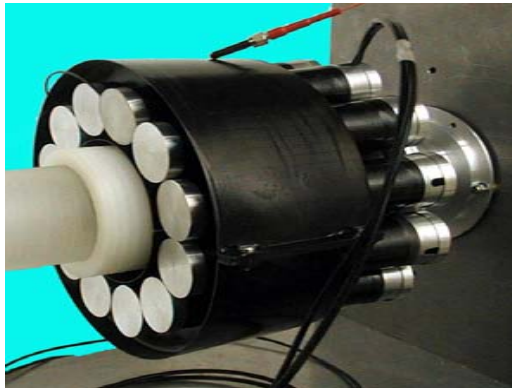
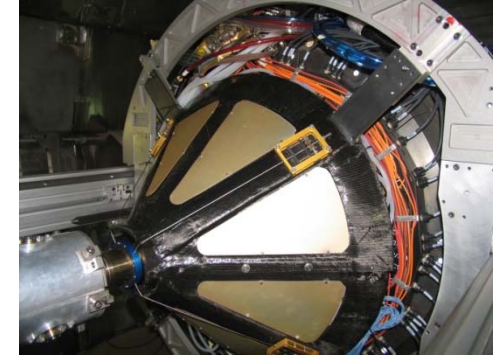


# A Rare Horizontal Particle



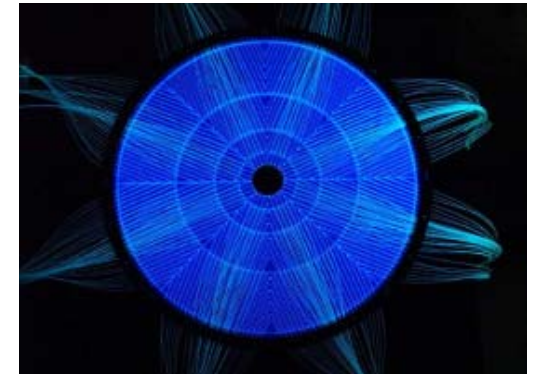
## 6) 'Forward Detectors' (1)

- **FMD: Forward Multiplicity Detector**
  - 3 planes of Si-pad detectors;
  - *Charged particle multiplicities and elliptic flow;*
  - Acceptance:  $-3.4 < \eta < -1.7$ ;  $1.7 < \eta < 5.03$ .
  - Fully installed for 2009 Run.



- **T0:**
  - 2 arrays of 12 PMTs with quartz radiators;
  - *Time reference for TOF (30 ps resolution) and vertex measurement.*
  - Fully installed for 2009 Run.

- **V0:**
  - 2 arrays of 32 scintillator tiles (600ps resolution);
  - Level 0 *centrality trigger & luminosity monitor, beam-gas rejection.*
  - Fully installed for 2009 Run.





## 6) 'Forward Detectors' (2)

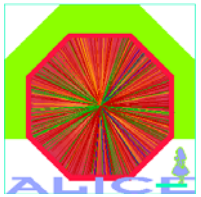
- **ZDC: Zero Degree Calorimeter.**
  - 2 neutron and 2 proton calorimeters at  $\pm 116$  m;
  - *Measure spectators;*
  - Fully installed for 2009 Run.



- **PMD: Photon Multiplicity Detector.**
  - Pre-shower detector;
  - $\sim 220\,000$  channels;
  - *Measure photon multiplicities;*
  - Acceptance:  $2.3 < \eta < 3.7$ .
  - Fully installed for 2009 Run.



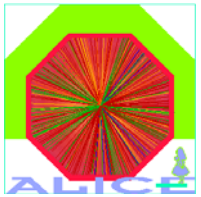
# Trigger, DAQ, DCS, HLT



- **CTP: Central Trigger Processor.**
  - Hierarchy of three levels ( L0, L1, L2 ).
  - [Operational.](#)
- **DAQ: Data AcQuisition.**
  - Data rate adequate for p-p collisions: Up to 400 MB/s sustained, 1.3GB/s for short periods.
  - 1.2 GB/s sustained data rate planned for LHC luminosity increase.
  - 2.5 PB/year.
  - [Operational.](#)
- **HLT: High-Level Trigger.**
  - Currently 1 000 processors; scalable to 20 000.
  - Data pre-processing and compression; trigger decisions.
  - [Operational.](#)
- **DCS: Detector Control System.**
  - [Operational.](#)

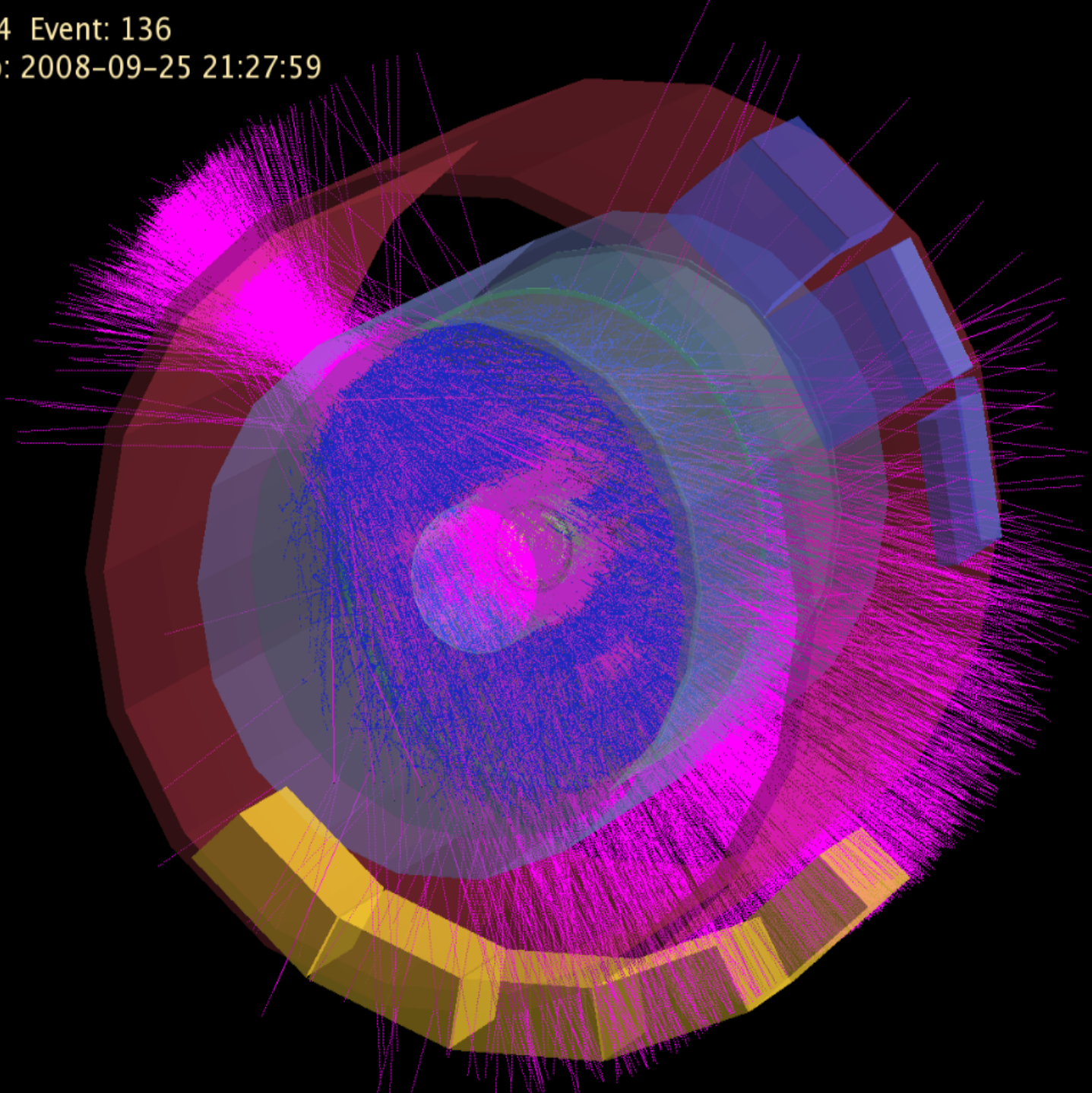


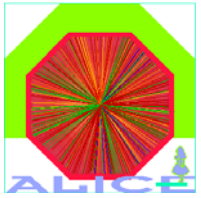
# Summary and Outlook



- ALICE is the general purpose *Heavy Ion experiment* at LHC.
- Now reality after 15 years of planning and construction.
- At start-up ALICE will have
  - *full hadron and muon capabilities.*
  - *partial electron and photon capabilities.*
- 3 commissioning runs (calibration data taking) in 2007/08.
- Were ready for measuring first pp collisions in september 2008.
- **Current shutdown is used for repairs, upgrades and further installations.**
- Next commissioning run scheduled for summer 2009 until first beams.
- ALICE will be ready for taking first p-p collisions and we eagerly await Pb-Pb collisions at the end of the upcoming run!

Run: 60824 Event: 136  
Timestamp: 2008-09-25 21:27:59



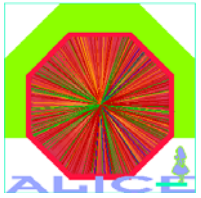


---

Backup slides



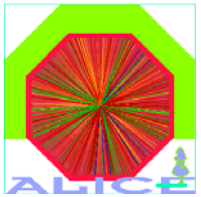
# ALICE offers:



- 
- Particle ID for  $100 \text{ MeV}/c < p < 100 \text{ GeV}/c$ ;
  - Precision tracking for  $100 \text{ MeV}/c < p < 100 \text{ GeV}/c$ ;
  - Excellent determination of secondary vertices;
  - Low material thickness;
  - Low magnetic field;
  - Measurement of hadrons, leptons and photons at mid-rapidity and
  - muons at forward rapidity.



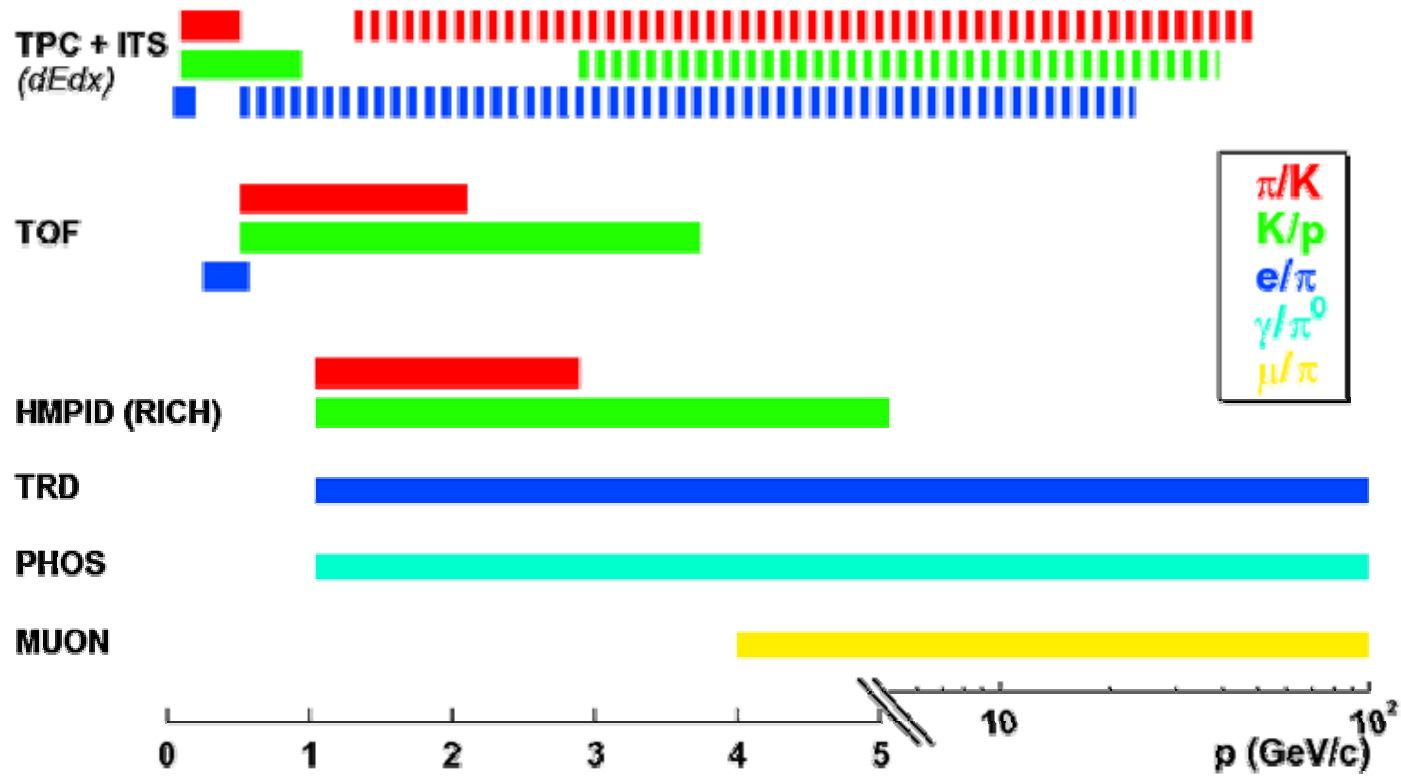
# Particle ID in ALICE



- **Stable hadrons ( $\pi$ , K, p):**  
⇒  $dE/dx$  in silicon (ITS) and gas (TPC) + **Time-of-Flight** (TOF) + **Cerenkov** (HMPID)
- **Leptons ( $e$ ,  $\mu$ )**  
⇒ **transition radiation** (TRD), Muon spectrometer
- **Photons,  $\eta$ ,  $\pi^0$**   
⇒ **e.m calorimeters** (PHOS, EMCAL)
- **Decay topology ( $K^0$ ,  $K^+$ ,  $K^-$ ,  $\Lambda$ ,  $D^+$ , ..), secondary vertices (c,b)**

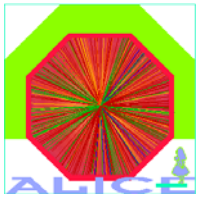
PID  
from  $\sim 100$  MeV  
to above 50 GeV

Alice uses ~ all  
known techniques!

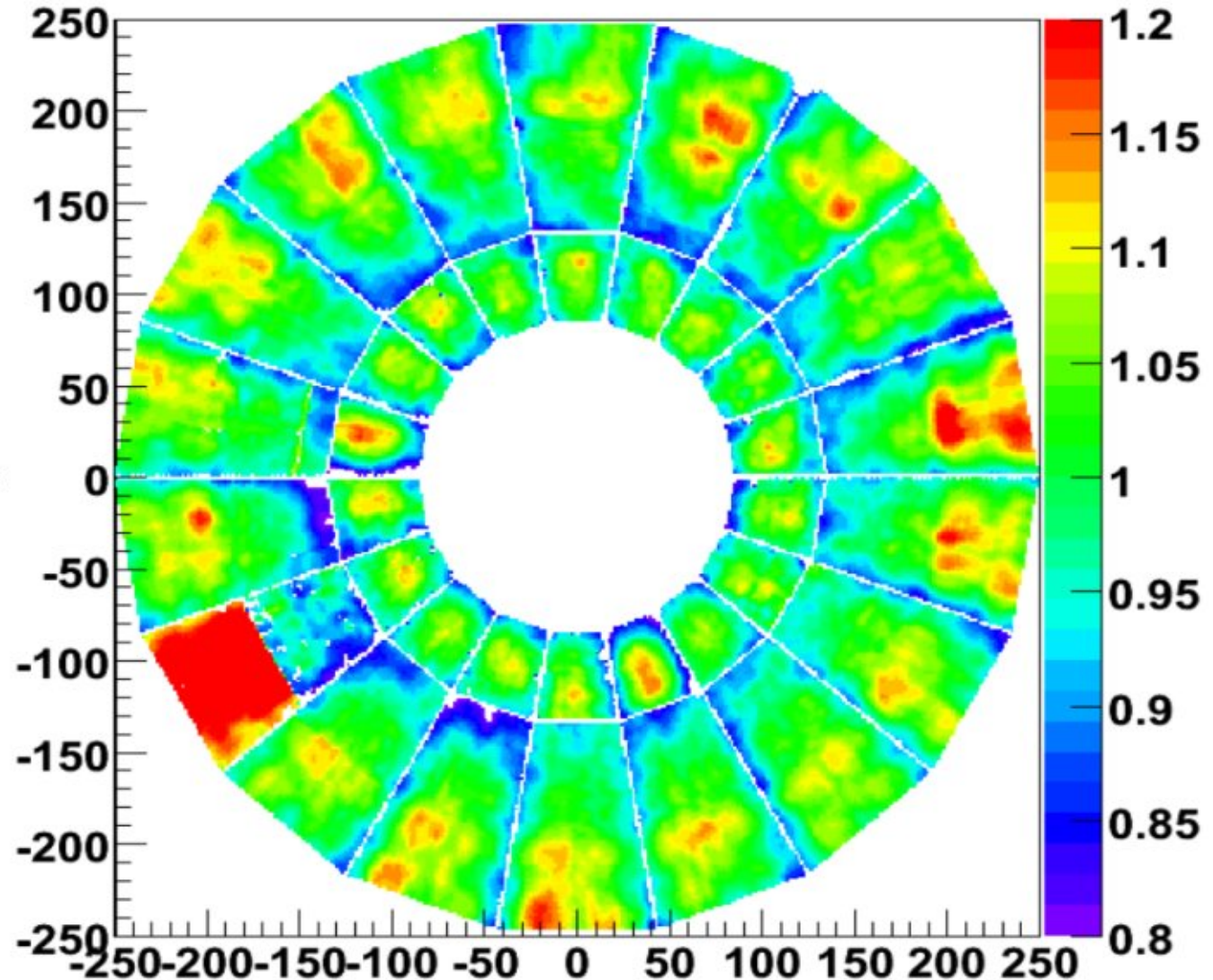




# ALICE TPC Krypton Gain Calibration



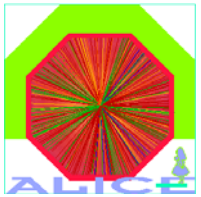
- $^{83}\text{Kr}$  isotopes released into the gas.
- Relative resolution of main peak:  $\sim 5\%$ .
- Pad to pad calibration.







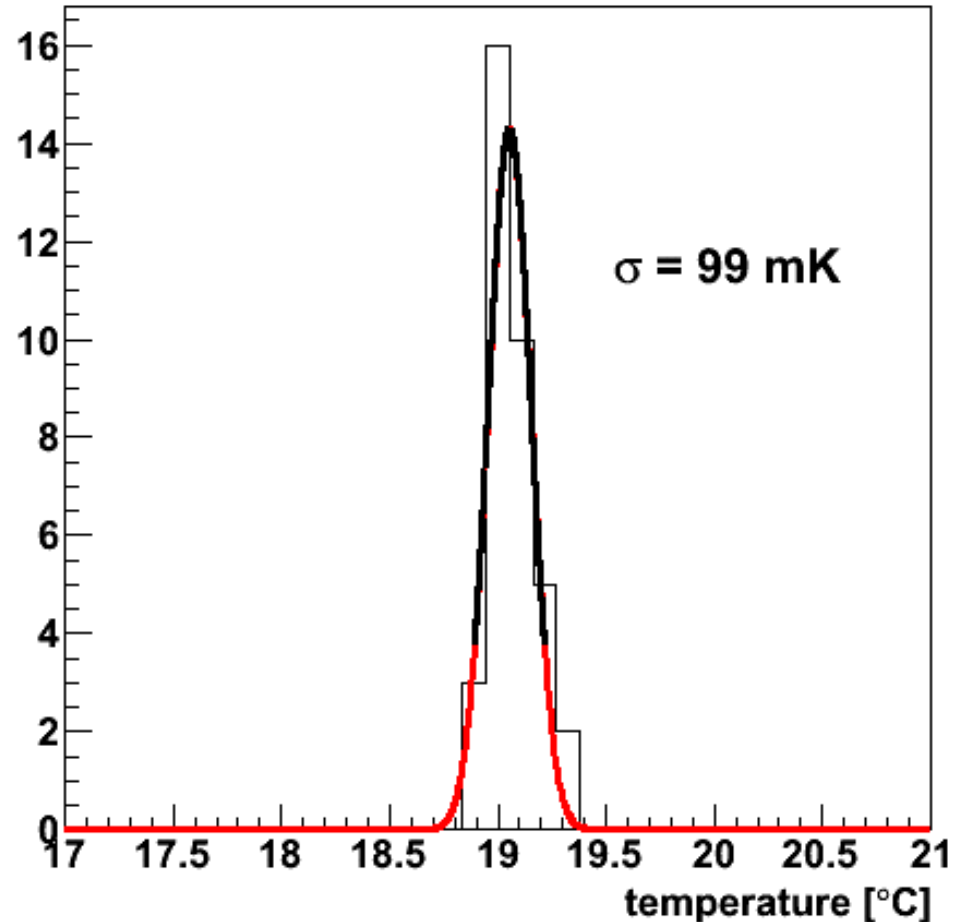
# Temperature homogeneity in TPC



Requirement:  $\sigma < 0.1$  K

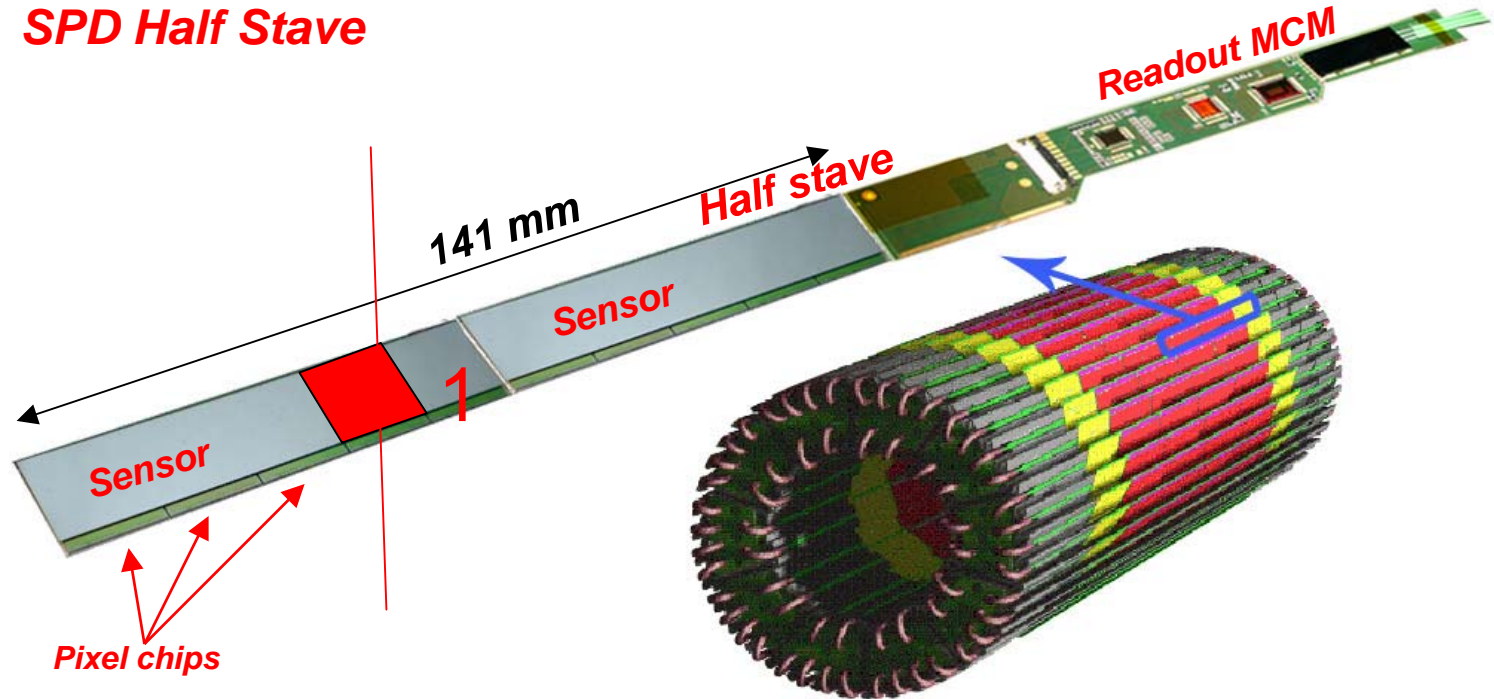
Achieved by actively stabilizing 50 cooling loops using information from 500 temperature sensors (36 inside gas volume).

Further improvements down to 80 mK in progress.



# Pixel Trigger (1)

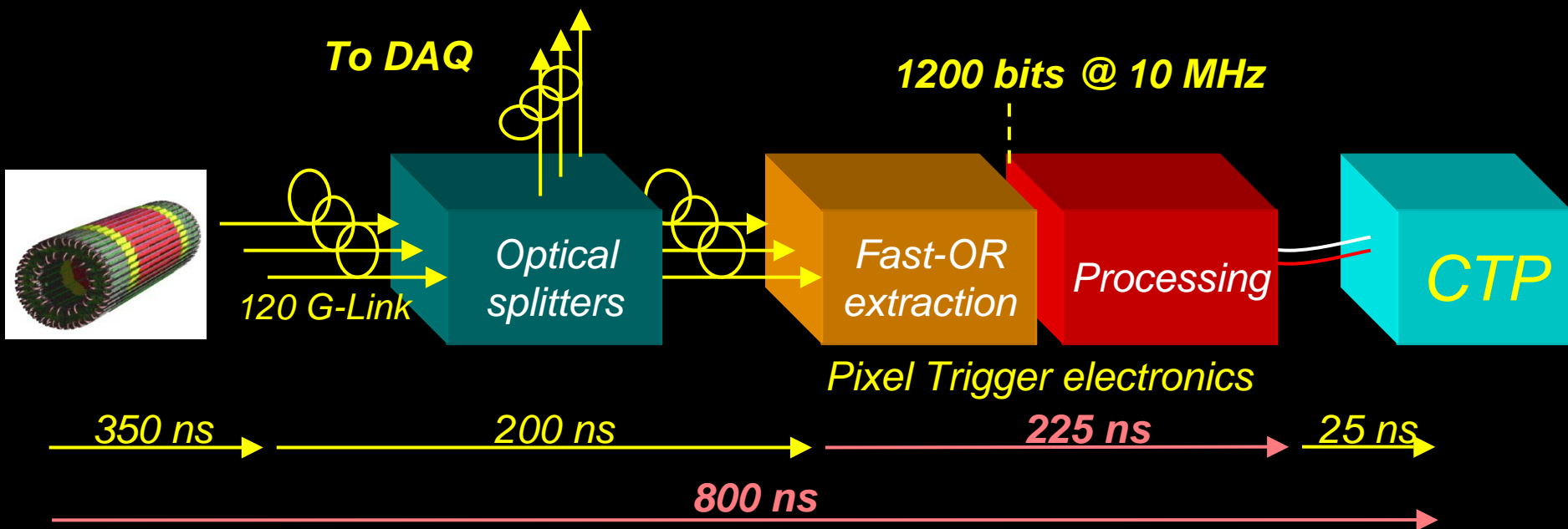
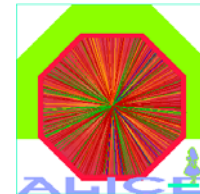
## SPD Half Stave



- Pixel chip prompt fast-OR.
  - Active if at least one pixel hit in the chip matrix.
  - 10 chips each per optical link, transmitted at 10MHz.
  - Different programmable algorithms: High multiplicity, minimum-bias, cosmics, ...

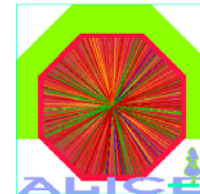


# Pixel Trigger (2)

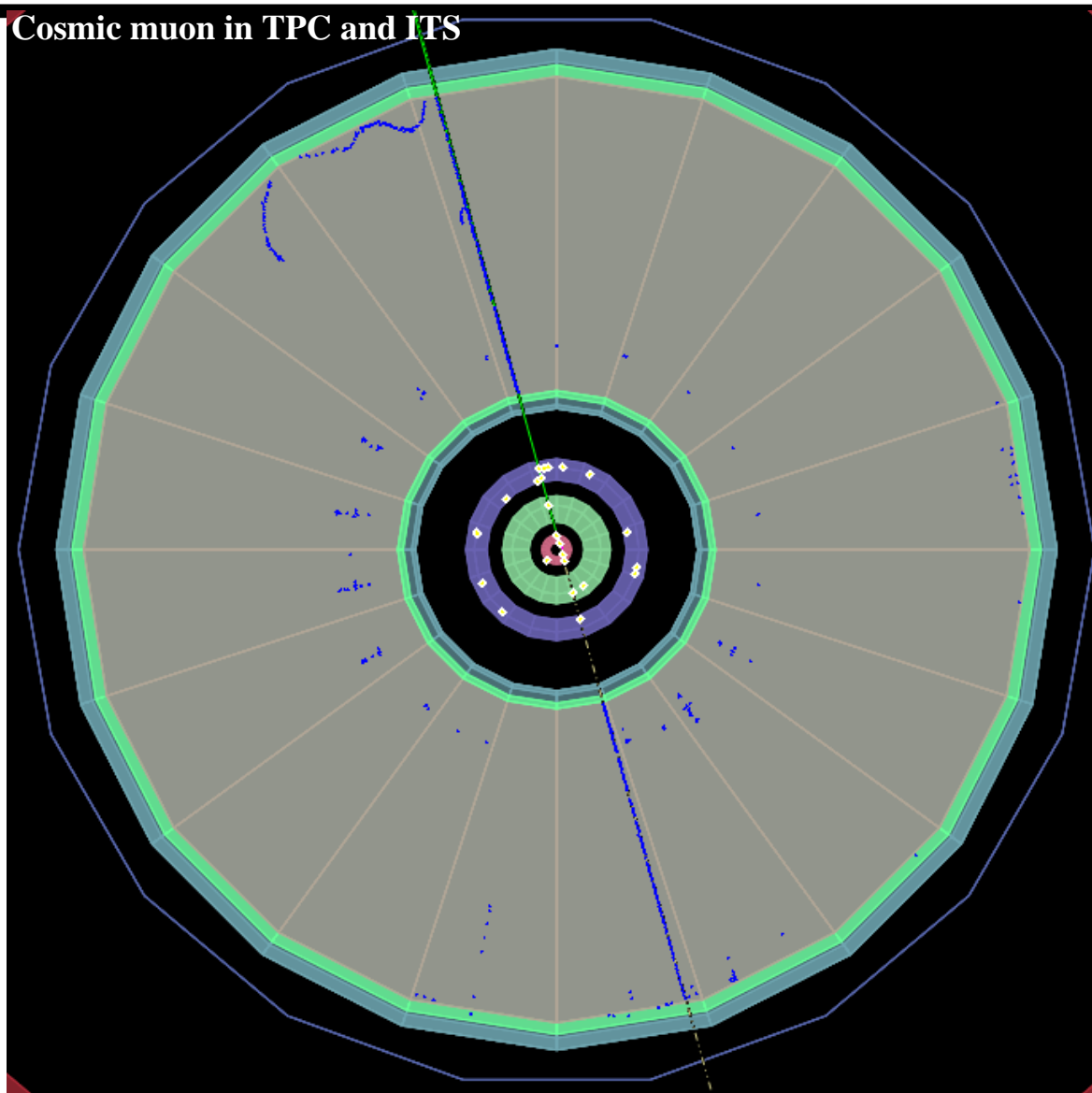




# ITS-TPC Alignment

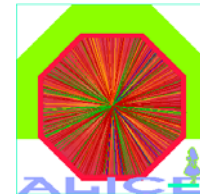


Cosmic muon in TPC and ITS





# ALICE Commissioning in 2007/08: Data taking activity



## Cumulated amount of data readout from detectors

