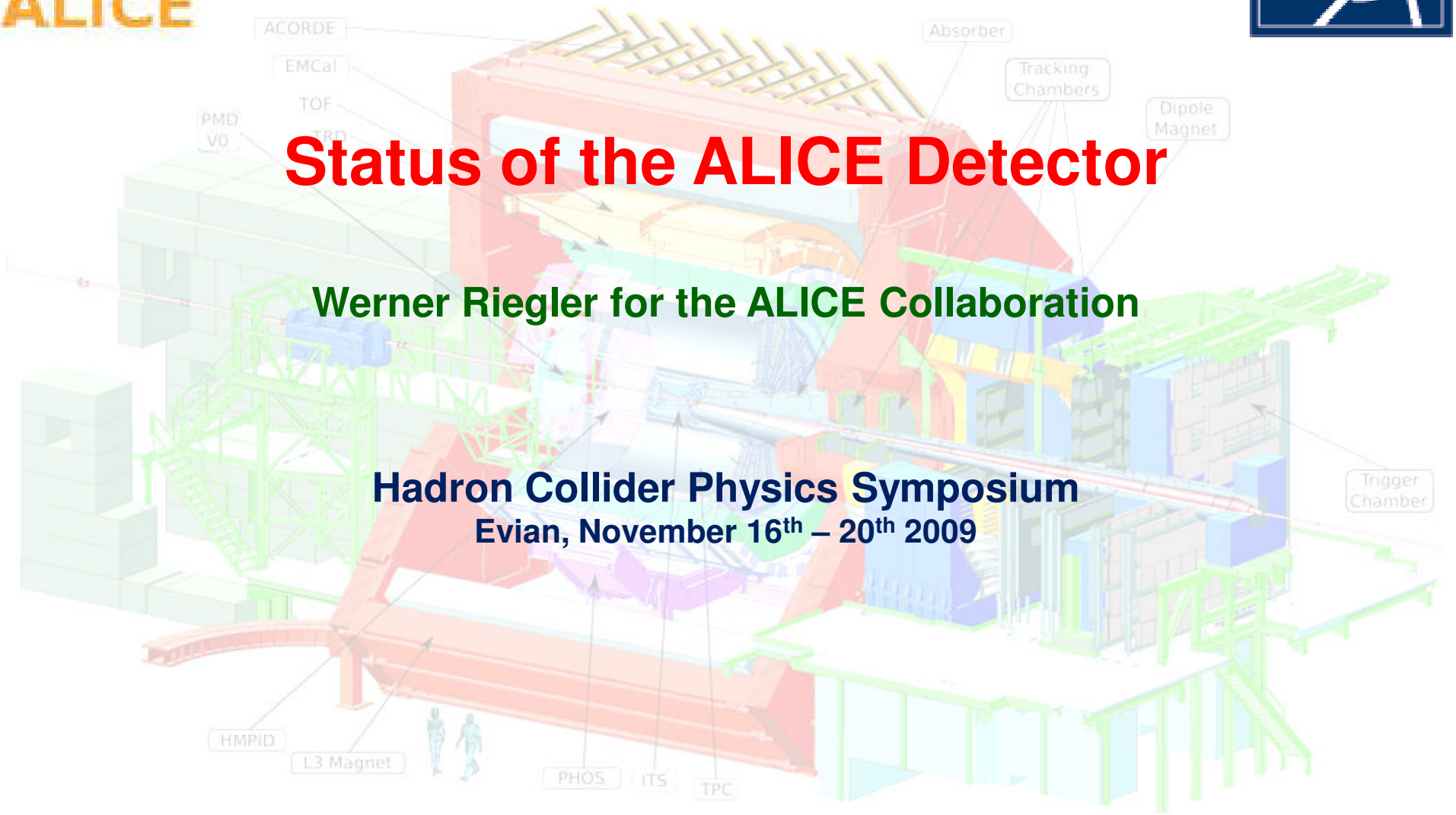


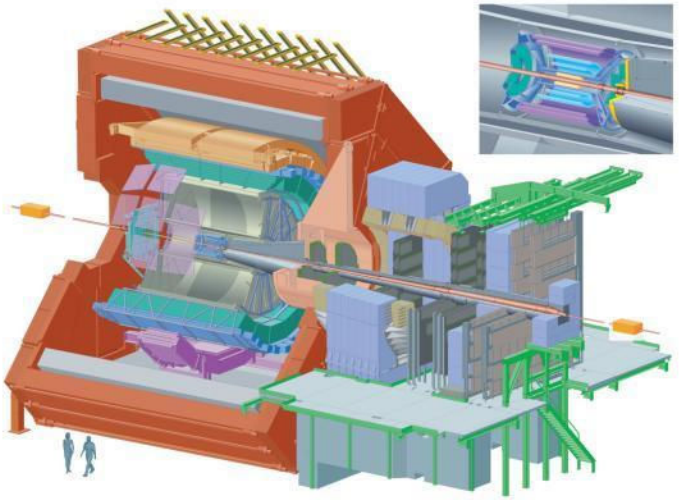
Status of the ALICE Detector

Werner Riegler for the ALICE Collaboration

Hadron Collider Physics Symposium
Evian, November 16th – 20th 2009

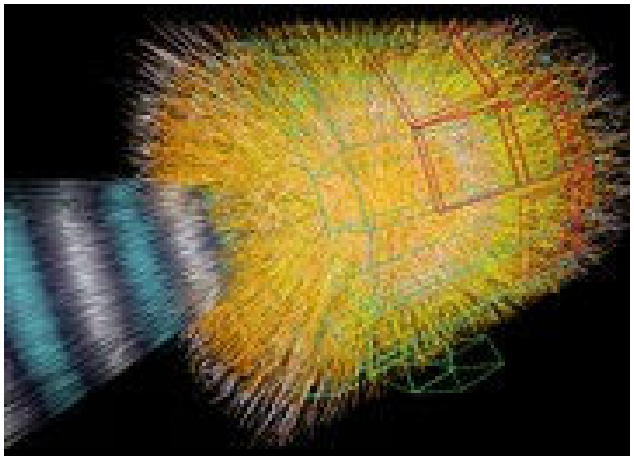
ALICE

ALICE is a dedicated heavy-ion detector to exploit the unique physics potential of nucleus-nucleus interactions at LHC energies. The aim is to study the physics of strongly interacting matter at extreme energy densities, where the formation of a new phase of matter, the quark-gluon plasma, is expected.



Alice will also study proton-proton collisions both as a comparison with lead-lead collisions and in physics areas where ALICE is competitive with other LHC experiments. ALICE has unique physics potential with p+p collisions.

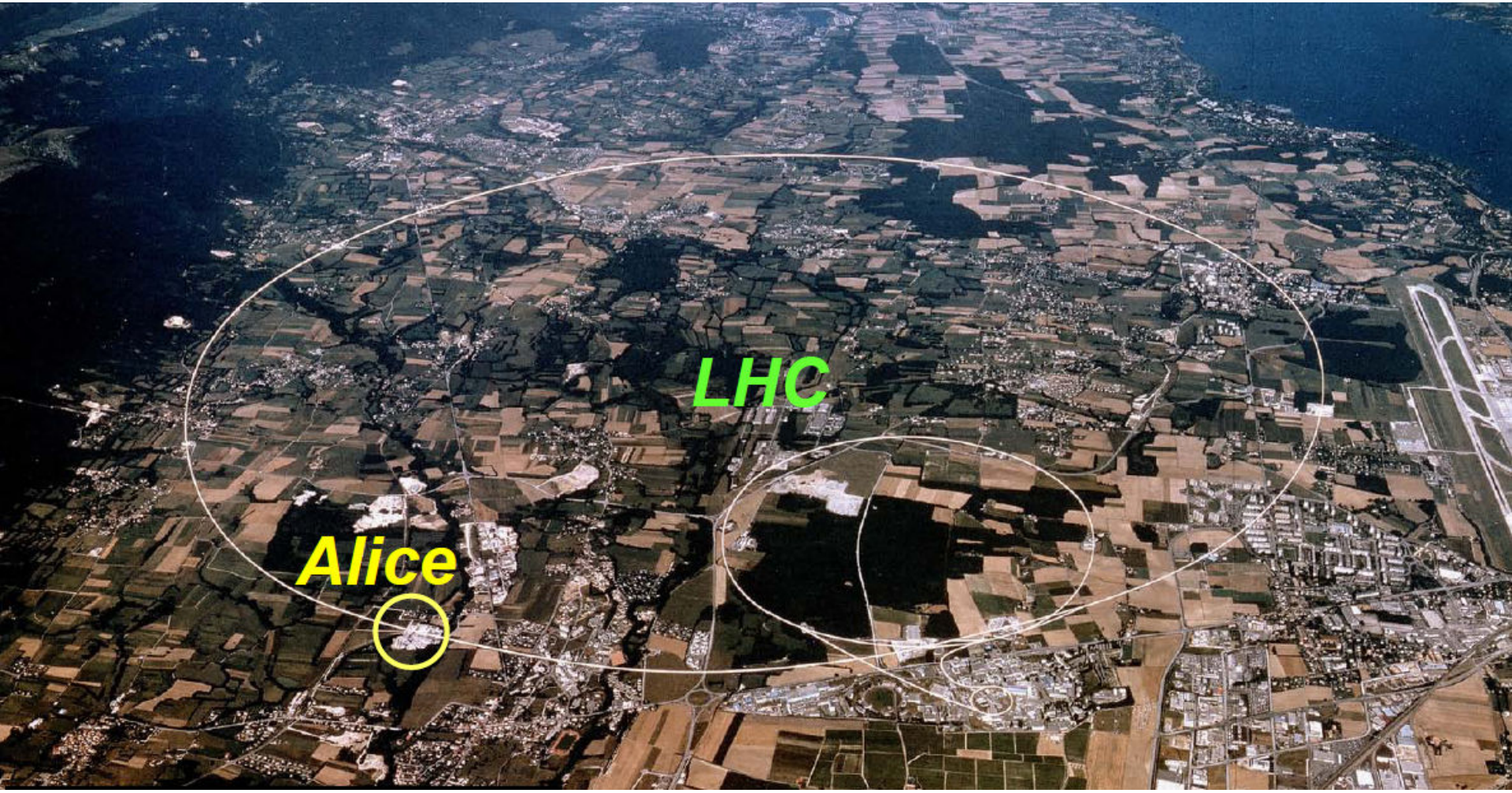
LHC will collide Pb Ions at 5.5TeV/nucleon pair, corresponding to around 30 times the Energy of RHIC.



During 2010, LHC should collect a sizeable data sample with collisions at 7TeV/proton pair, which is close to eventual energy of 5.5 TeV/nucleon pair for Pb ! → ALICE must make excellent use of these collisions.

The 2009 LHC plan includes an Ion run at the end of the year.

ALICE at LHC



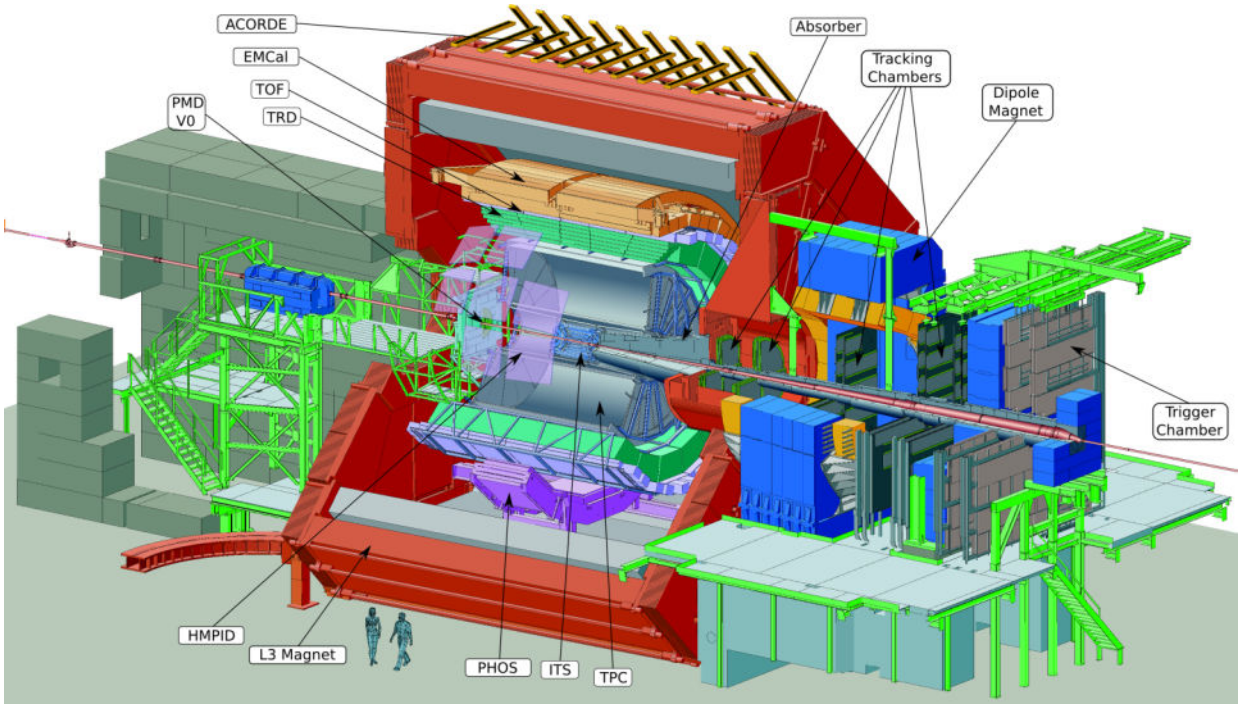
ALICE

Principle Considerations:

Tracking and identification of particles down to very low momenta of ~100 MeV/c and up to a few hundred GeV/c.

Reconstruct short-lived particles such as hyperons, D and B mesons.

Perform these tasks in an environment with large charged-particle multiplicities, up to 8000 charged particles per rapidity unit at mid-rapidity.



Hadrons, electrons and photons are detected and identified in the central rapidity region ($-0.9 < \eta < 0.9$) by a complex system of detectors immersed in a moderate (0.5 T) magnetic field.

Tracking with six layers of silicon detectors (ITS), a large-volume Time-Projection Chamber (TPC) and a high-granularity Transition-Radiation Detector (TRD).

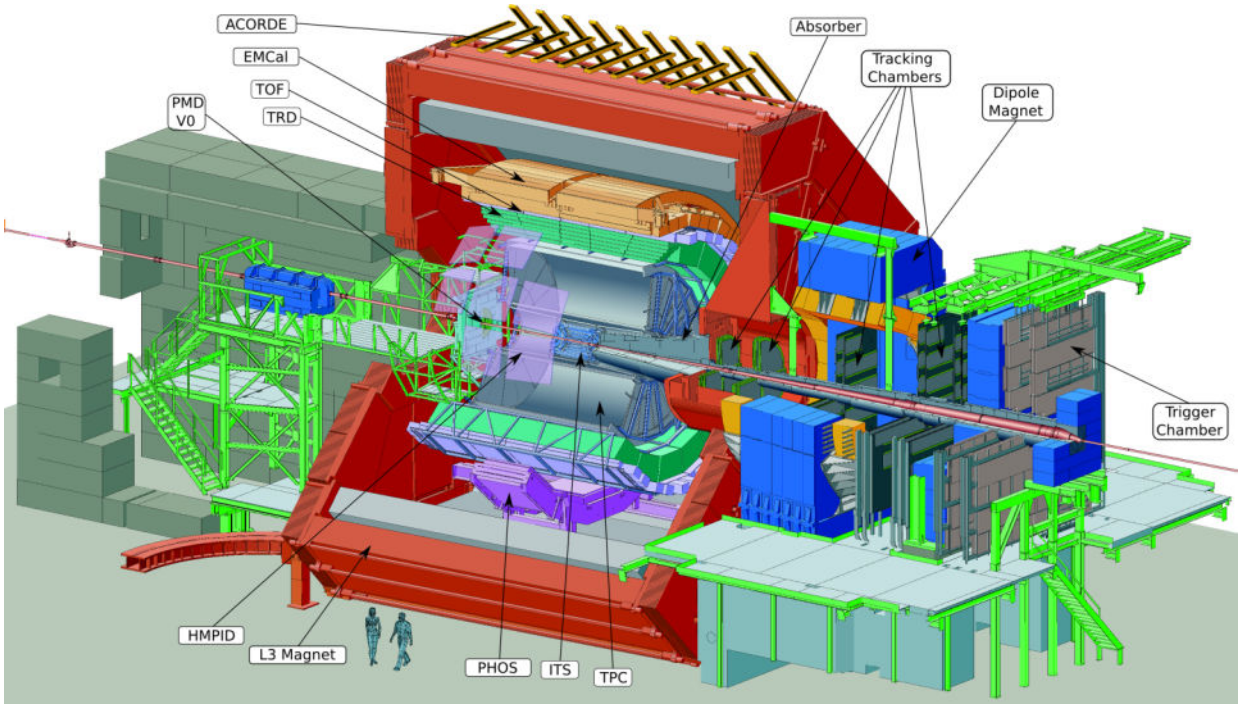
Particle identification in the central region is performed by measuring energy loss in the tracking detectors, transition radiation in the TRD, Time Of Flight (TOF) with a high-resolution array, Cherenkov radiation with a High-Momentum Particle Identification Detector (HMPID), and photons with a crystal PHOton Spectrometer (PHOS). A Lead Scintillator EMCALorimter covers the outer perimeter of the central region.

ALICE

Principle Considerations:

The detection and identification of muons are performed with a dedicated spectrometer, including a large warm dipole magnet of 0.7T field maximum and covering a domain of large rapidities ($-4.0 < \eta < -2.4$).

Additional detectors located at large rapidities complete the central detection system to characterize the event and to provide the interaction trigger.

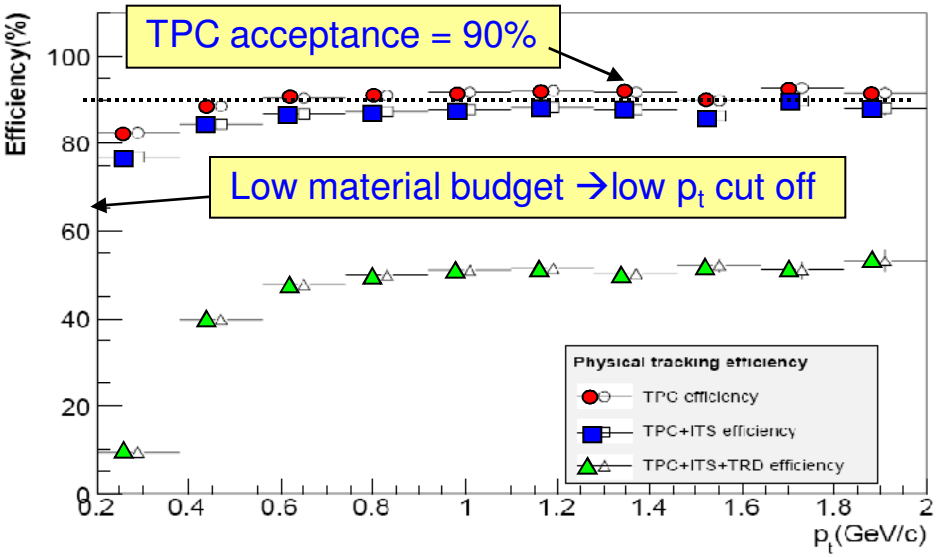


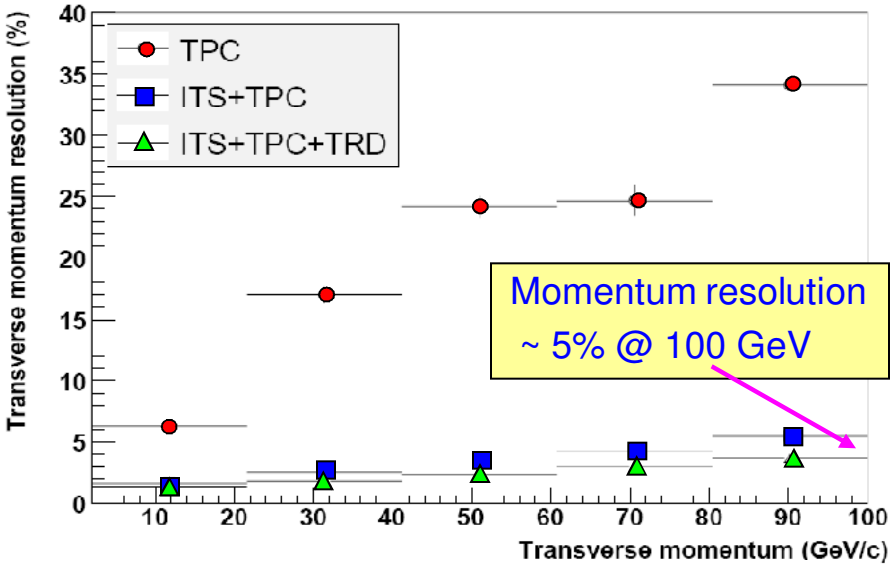
They cover:

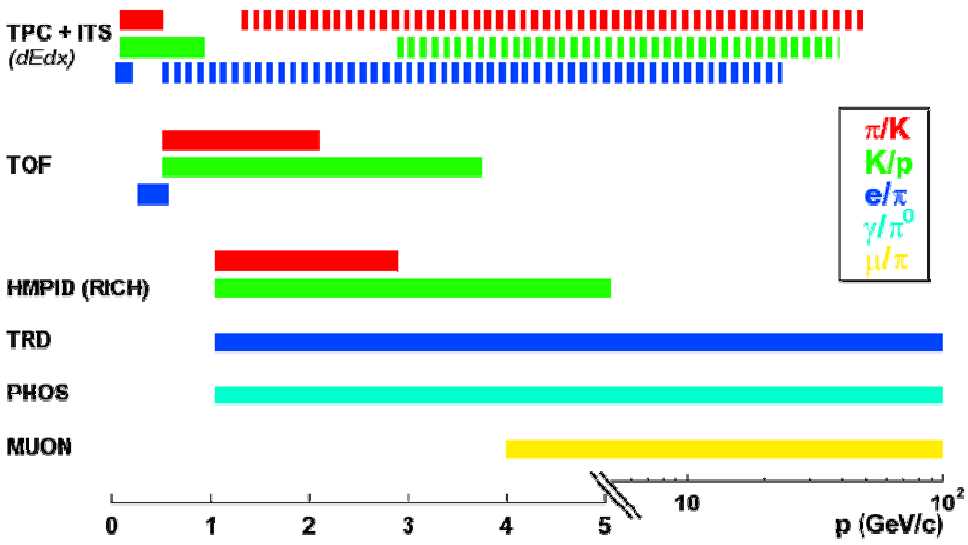
a wide acceptance ($-3.4 < \eta < 5.1$) for the measurement of charged particles and triggering (Forward Multiplicity Detector - FMD, V0 and T0 detectors),

and a narrow domain at large rapidities ($2.3 < \eta < 3.5$) for photon multiplicity measurement (Photon Multiplicity Detector - PMD), and the coverage of the beams' rapidity to measure spectator nucleons in heavy-ion collisions (Zero-Degree Calorimeters - ZDC).

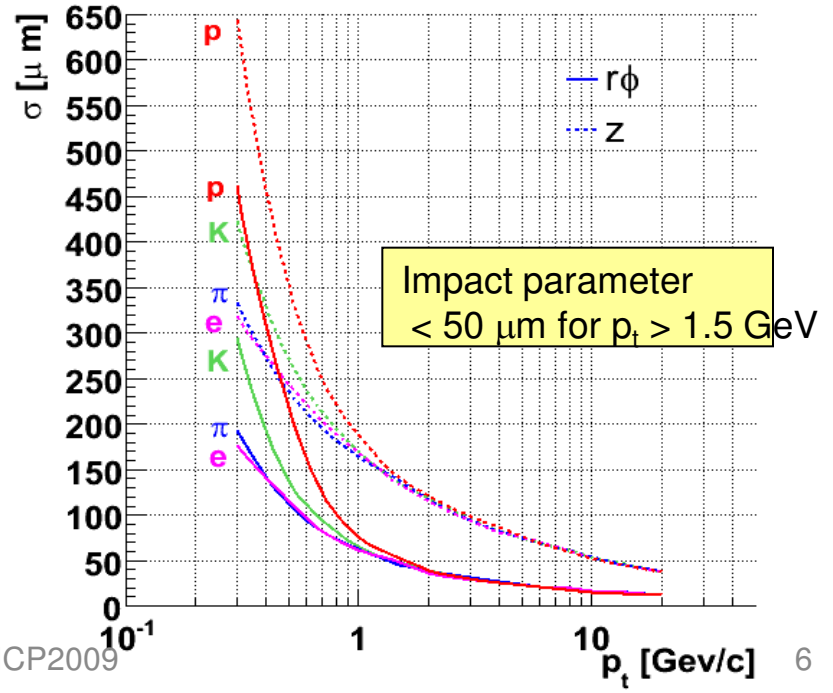
ALICE expected Performance







PID
from ~ 100 MeV to above 50 GeV



ALICE Collaboration

~ 1000 **Members**

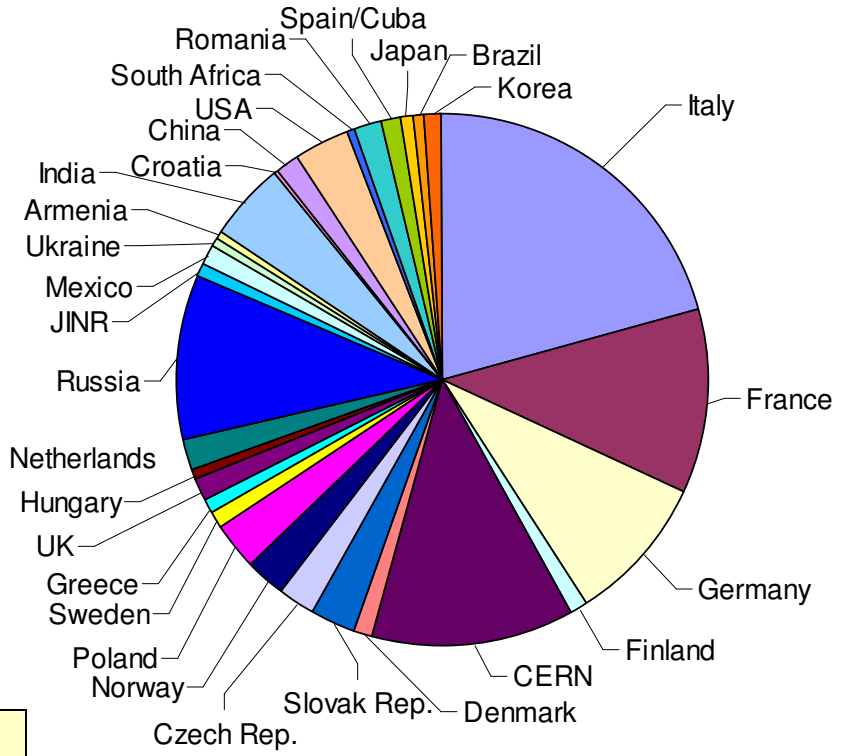
(63% from CERN MS)

~30 **Countries**

~100 **Institutes**

~ 150 **MCHF capital cost**

(+ 'free' magnet from L3)



A brief history of ALICE

1990-1996: Design
1992-2002: R&D
2000-2010: Construction
2002-2007: Installation
2008 → : Commissioning

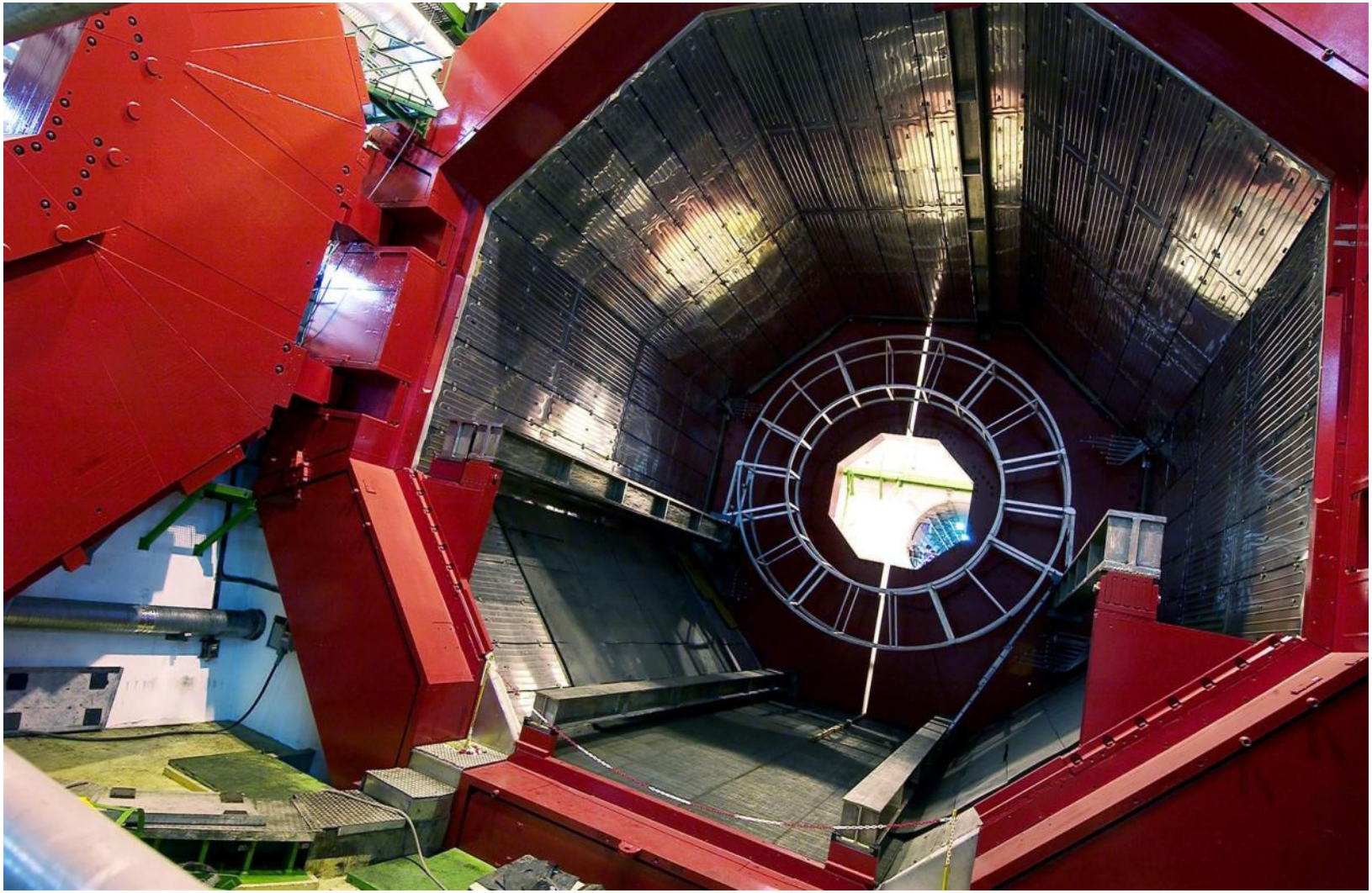
After 20 years … just days away from first collisions !

ALICE Installation

2003 Preparation of Solenoid and area after removal of the L3 experiment

ALICE Installation

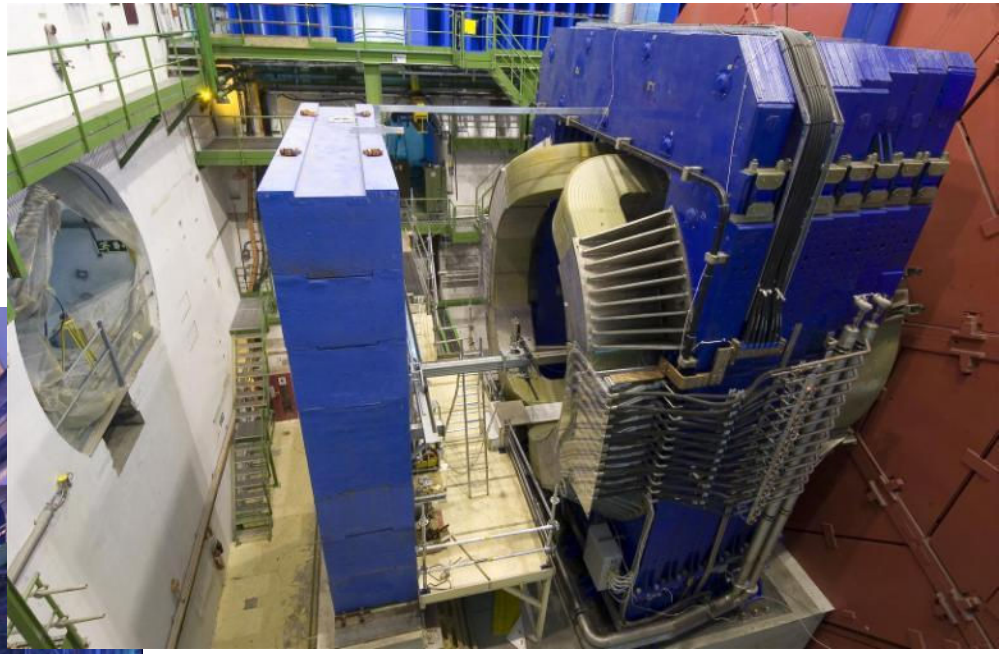
2004 Installation of support structures and infrastructure



ALICE installation

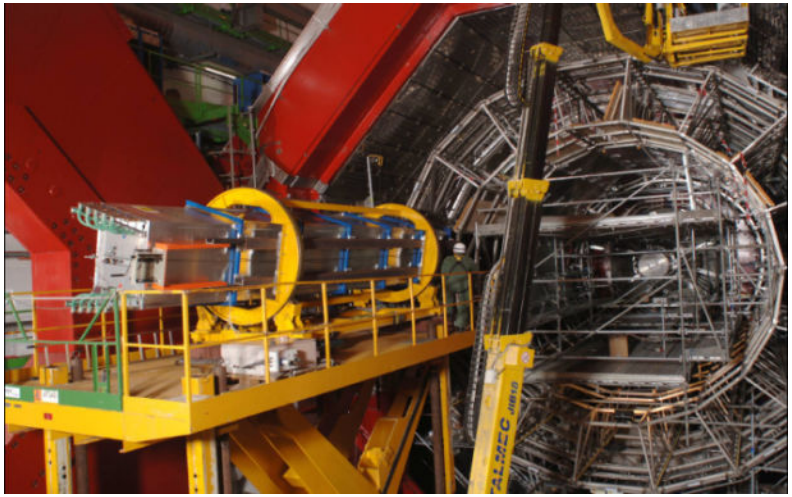
2005 **Installation and commissioning of the Dipole Magnet,**

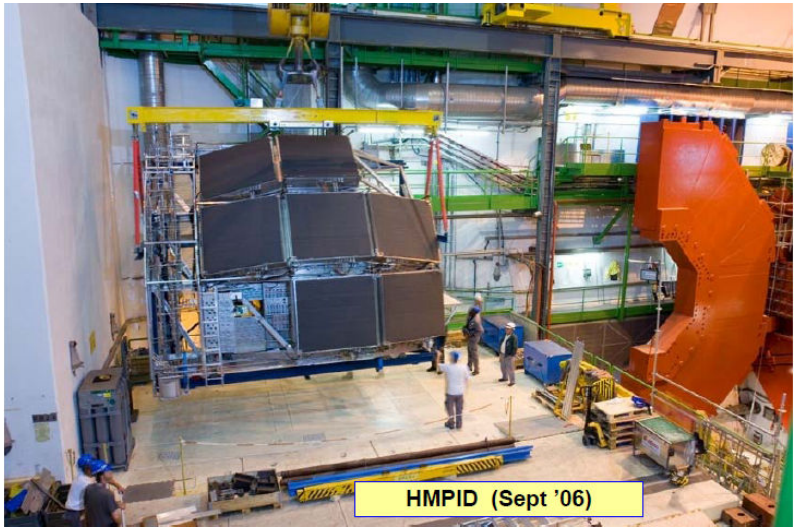
Field maps …



ALICE installation

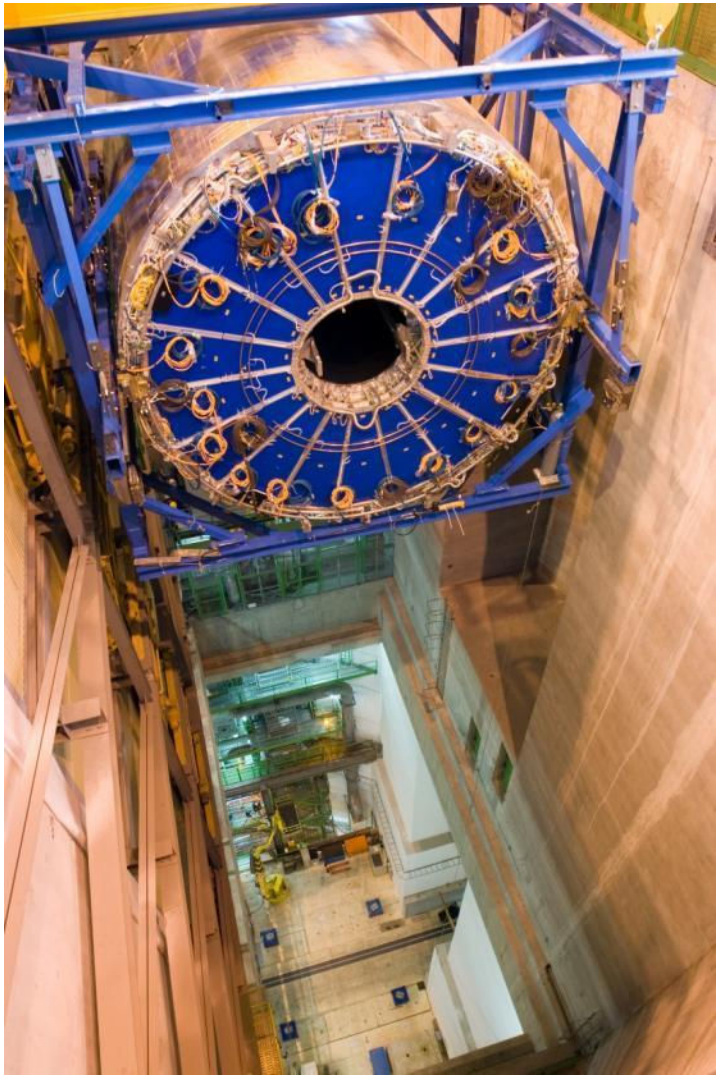
2006 Absorbers, Spaceframe, HMPID, First TOF modules, First TRD modules

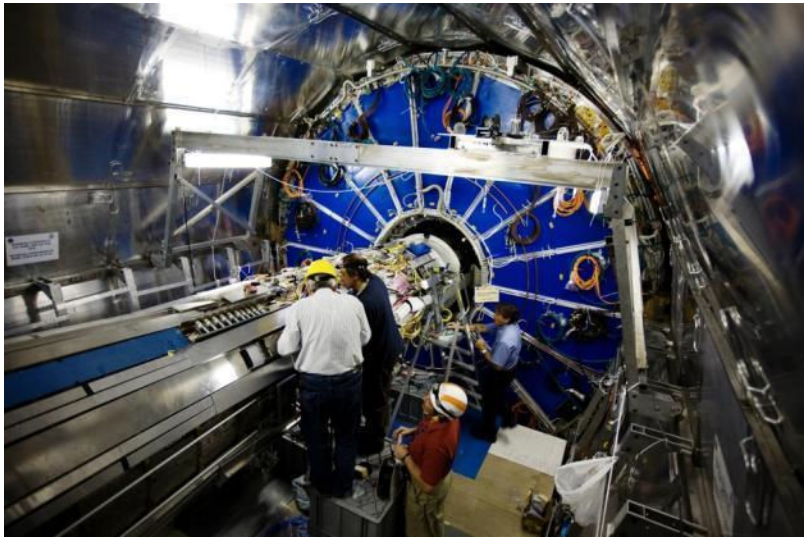


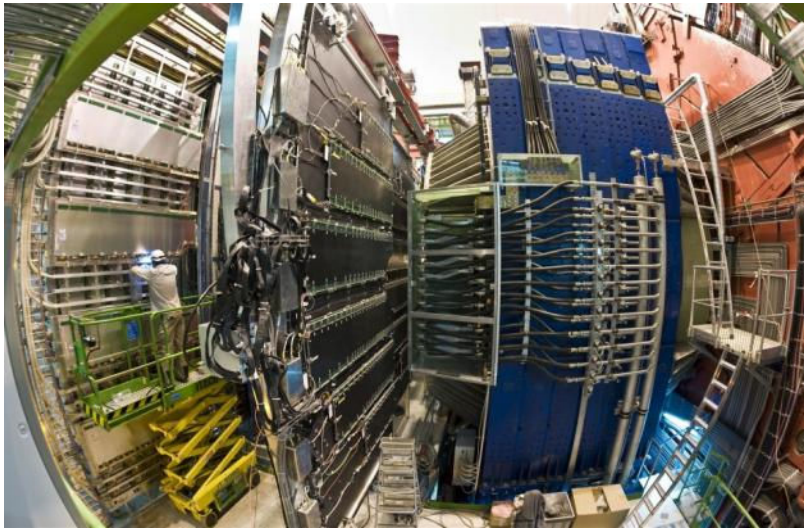


ALICE installation

2007 extremely busy year: TPC, SPD, SSD, SDD, MUON, more TOF, more TRD, Services First COSMIC run: Dec 2007 !

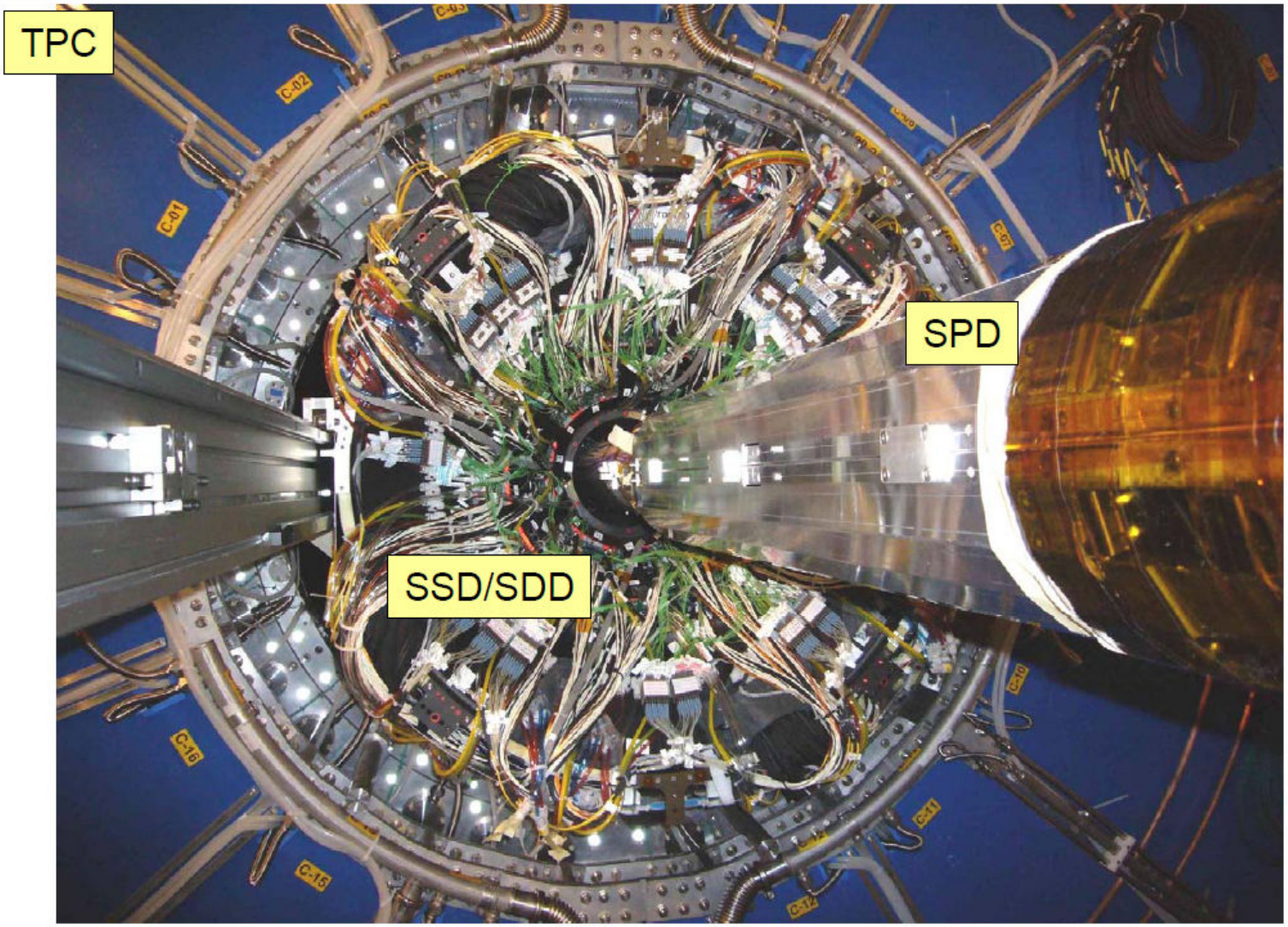






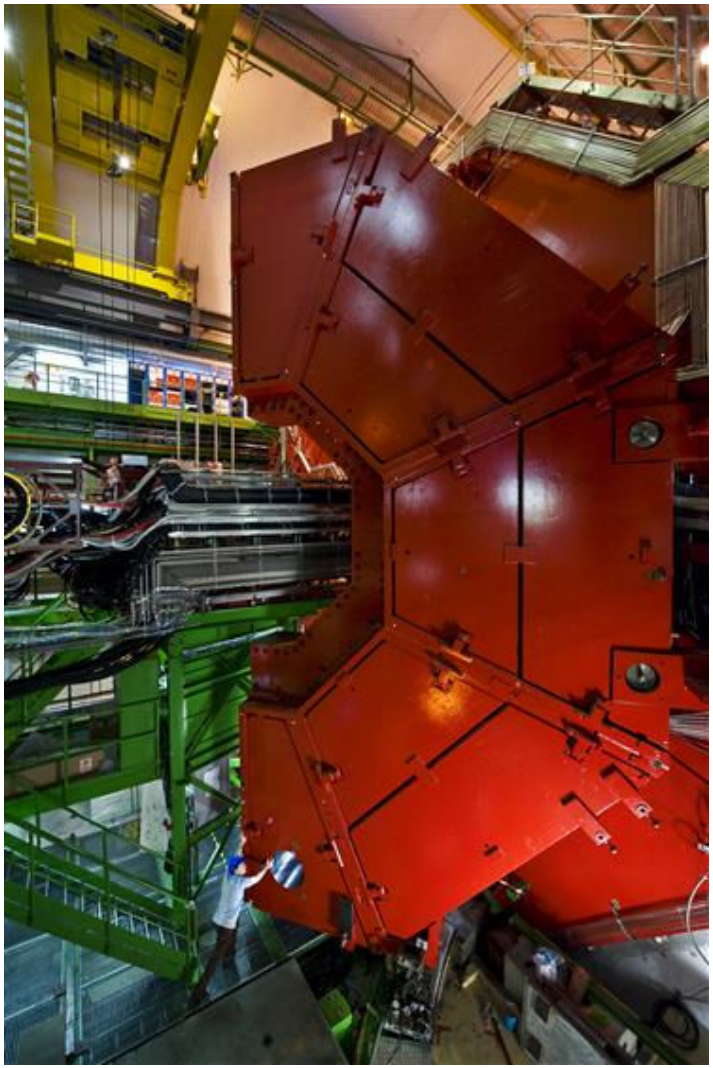
ALICE installation

2007: Beampipe, SPD, SDD+SSD, TPC, 'Russian Doll, sliding one after the other



ALICE installation

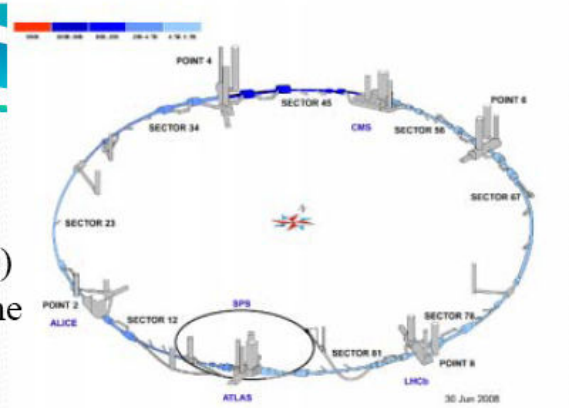
2008: All TOF, more TRD, EMCAL support, closure &

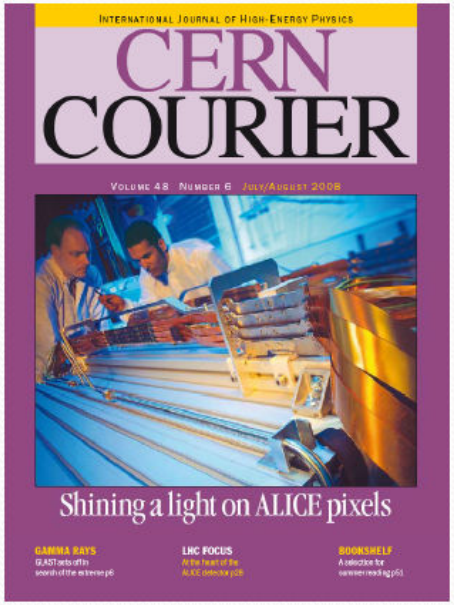


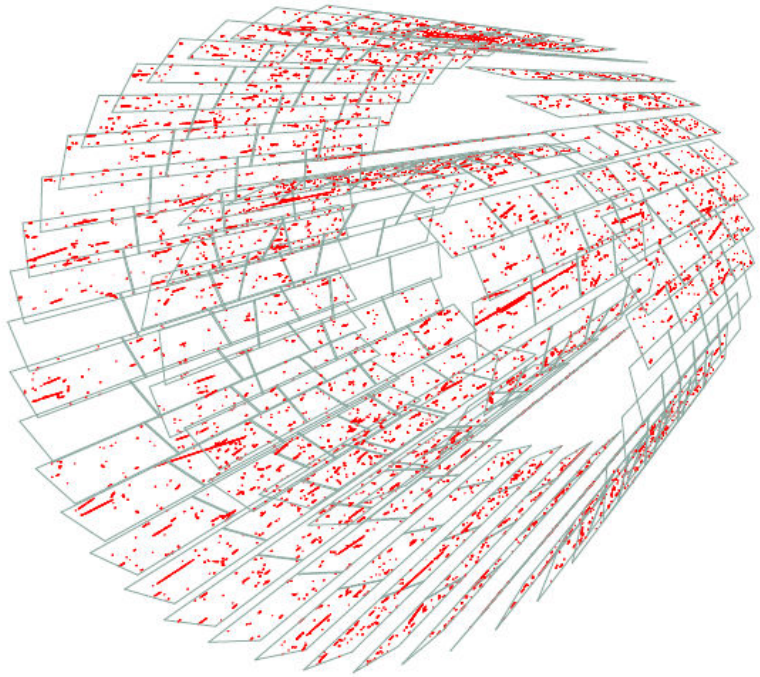
COSMIC run starting in August 2008

June 2008, First LHC induced events in ALICE

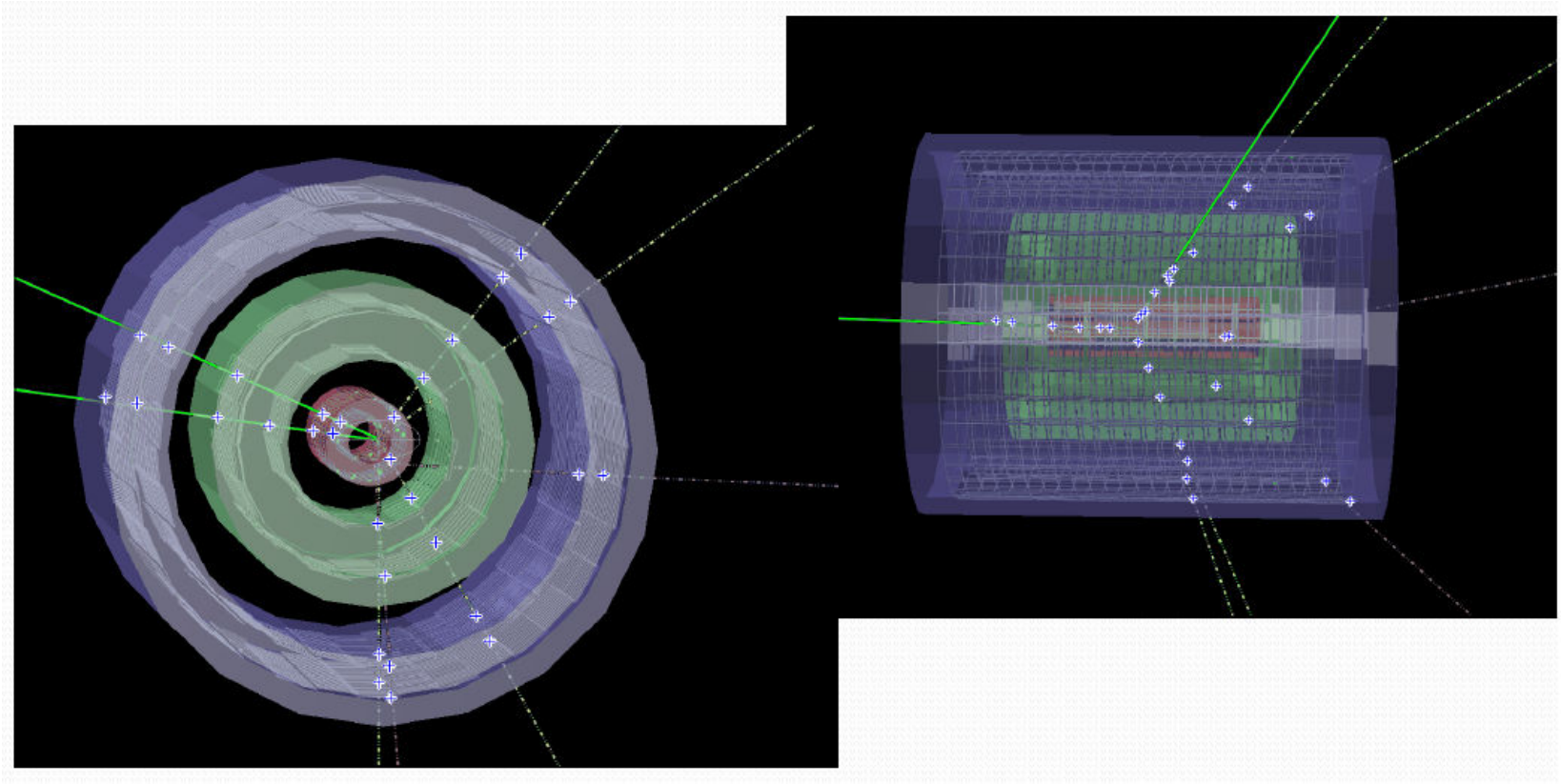
- On June 15 the SPD in self-triggering mode (L0) sees one of the first "sign of life" of LHC during the beam injection test in Tl2 - Run 38795 time 18:10







2008, First interactions 12th Sept.



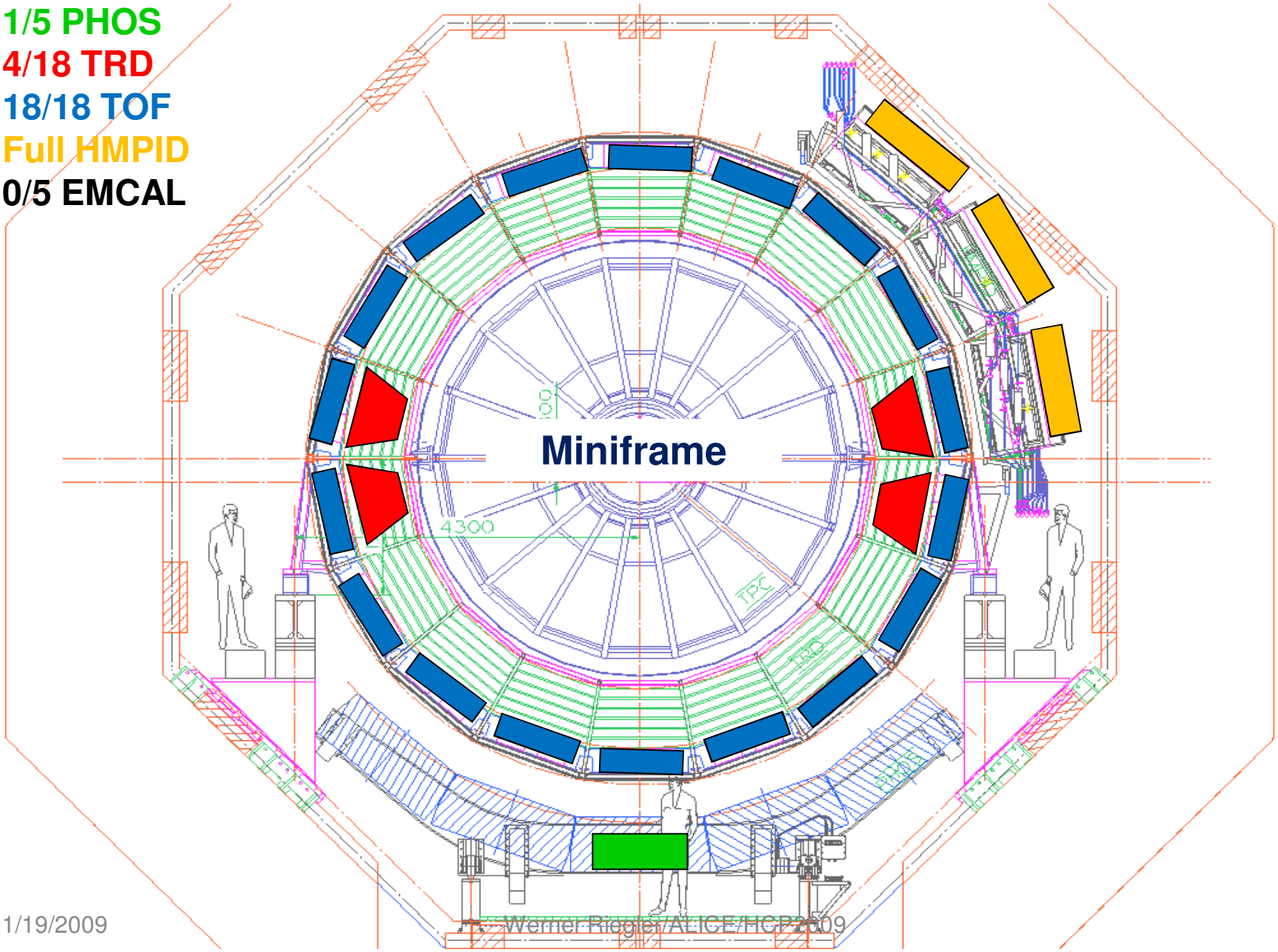
ITS tracks on 12.9.2008
7 reconstructed tracks, common vertex

Circulating beam 2:
stray particle causing an interaction in the ITS

After LHC Incident on September 19th: TRD installation, EMCAL installation, Service improvement, very busy 2009 shutdown

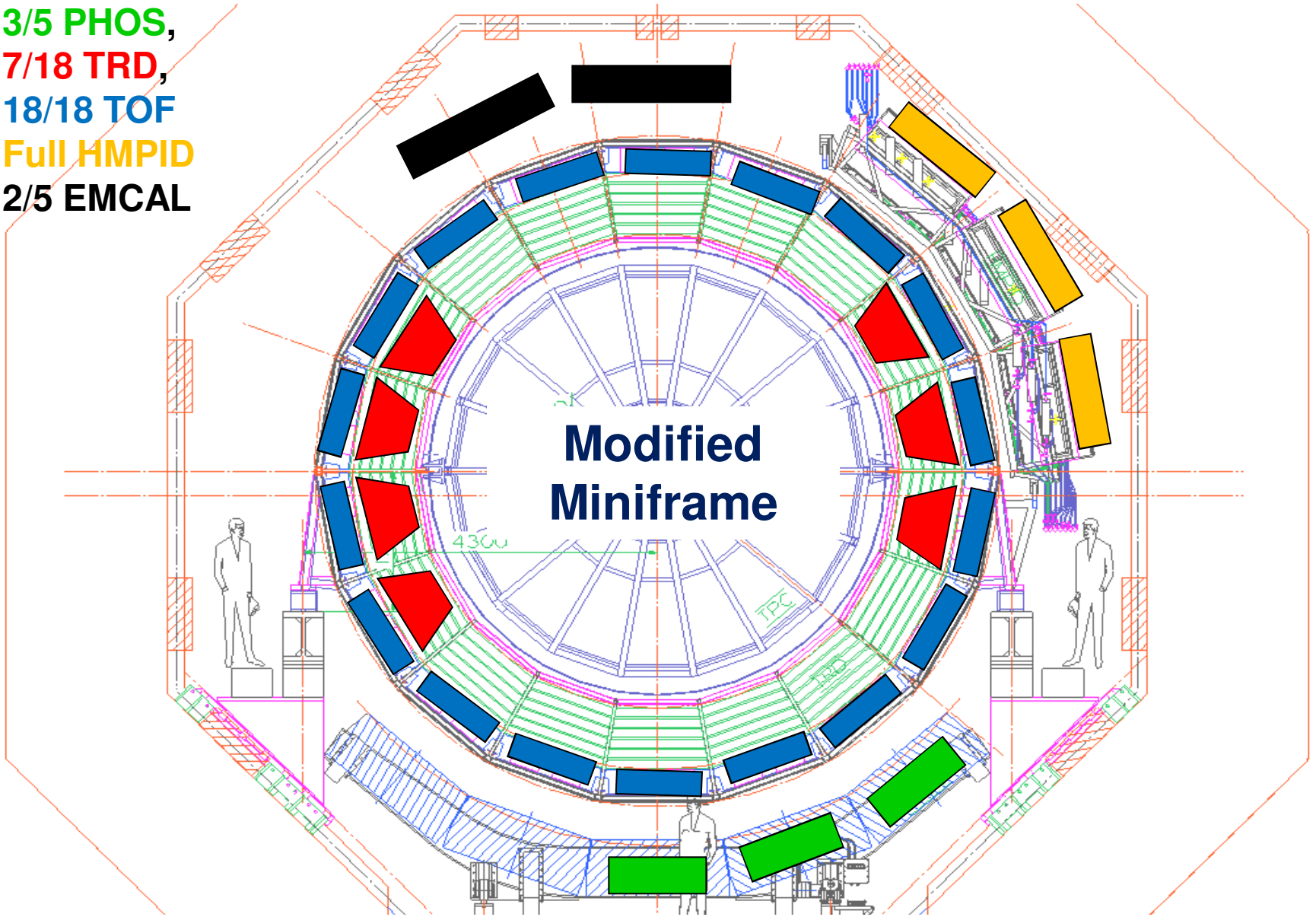
Detector Status on Sept. 10th, 2008

1/5 PHOS
4/18 TRD
18/18 TOF
Full HMPID
0/5 EMCAL



Detector Status Aug. 2009

3/5 PHOS,
7/18 TRD,
18/18 TOF
Full HMPID
2/5 EMCAL



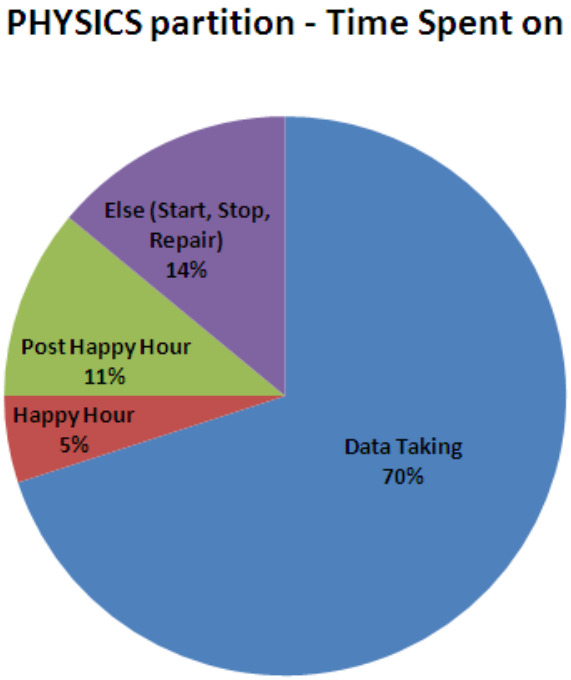
→ Restart COSMIC running in August 2009

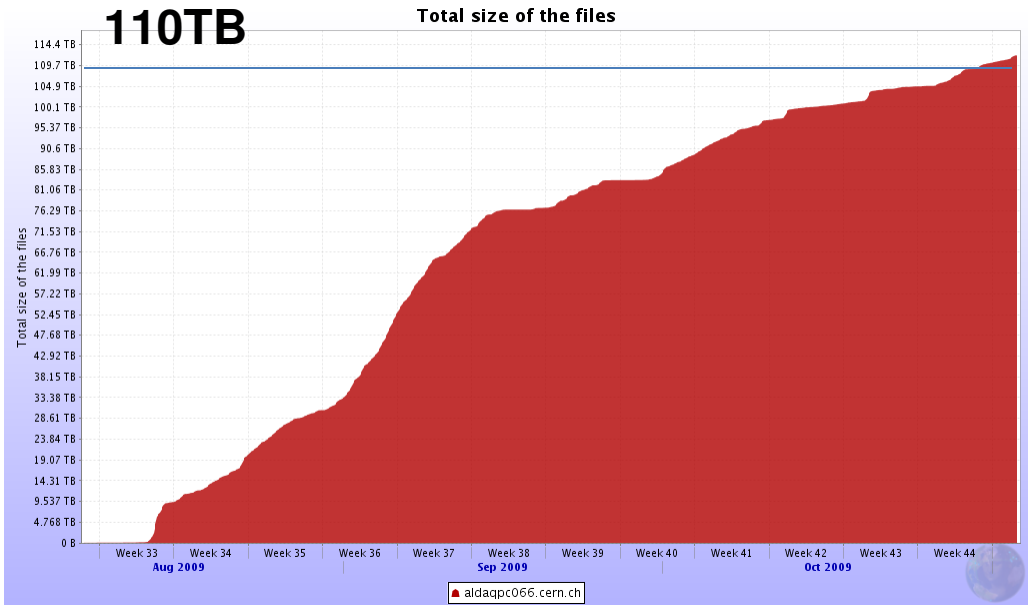
ALICE Commissioning 2009, DAQ

Continuous COSMIC running since August 15th 2009,
DAQ very stable !

PHYSICS partition at 70% usage … Where is the rest ?

- **Daily "Happy Hour" for detector calibration and development**
- **Restart after "Happy Hour"**
- **General Operations (Start/Stop Runs, Resets, …)**





7 Aug, 09 **1 Nov, 09**

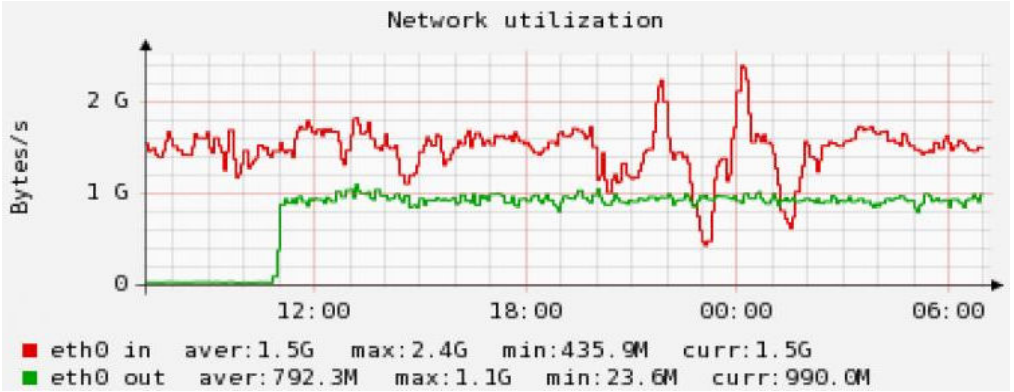
ALICE Rates -- Typical Numbers, DAQ

Collision system	$\sqrt{s_{NN}}$ (TeV)	L_0 ($cm^{-2}s^{-1}$)	$<L>/L_0$ (%)	Run time (s/year)	σ_{geom} (b)
pp	14.0	10^{31*}		10^7	0.07
PbPb	5.5	10^{27}	70-50	10^{6**}	7.7

ALICE has very large DAQ bandwidth:
Commissioning of the full DAQ including data recording in the Computing Center

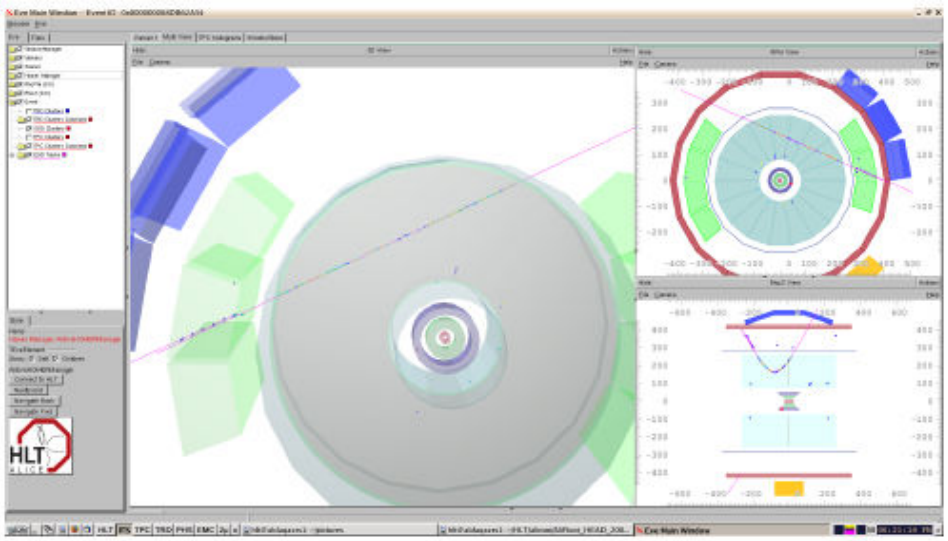
- **1 week without tapes: Peak 2.8 GB/s - 7 days at 1.275 GB/s**
- **4 days with tape: Sustained migration at 0.95 GB/s**

For p+p:
Currently around 300MB/event and maximum event rate of up to 1kHz

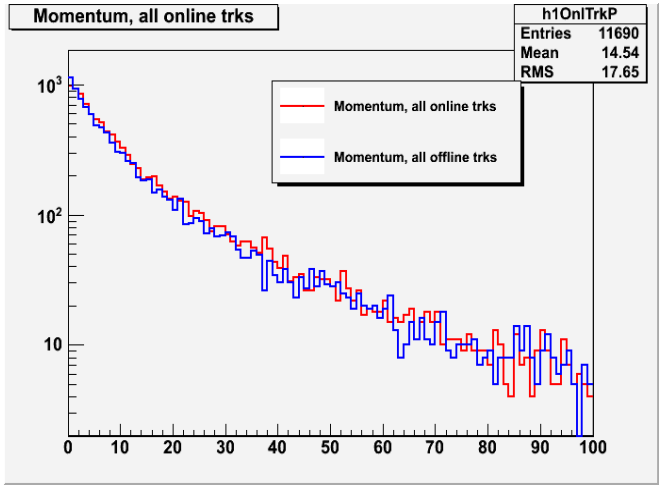


High Level Trigger

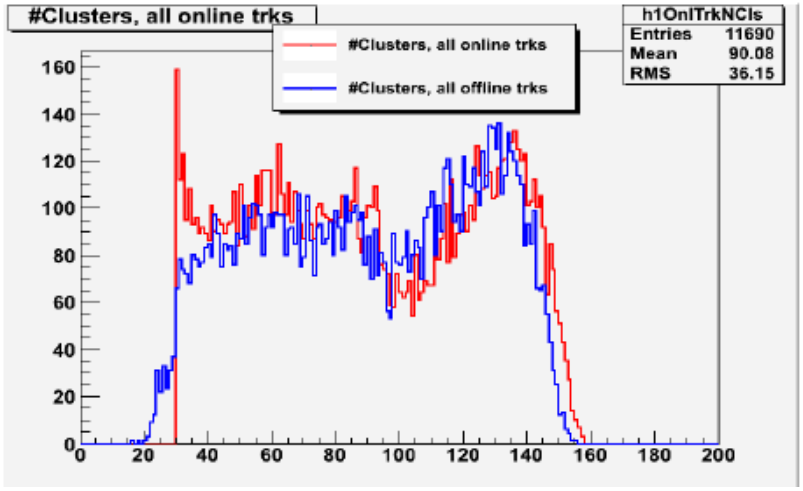
HLT Event Display



Reconstructed Momentum, online vs. offline



Number of TPC cluster, online vs. offline

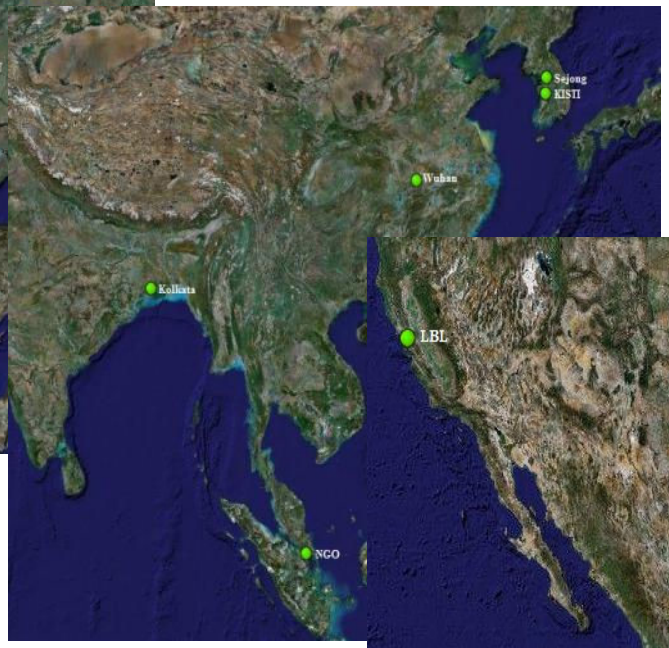


Computing: the ALICE Grid Map

Europe

15K CPUs, 5PB of tape and disk storage

Asia

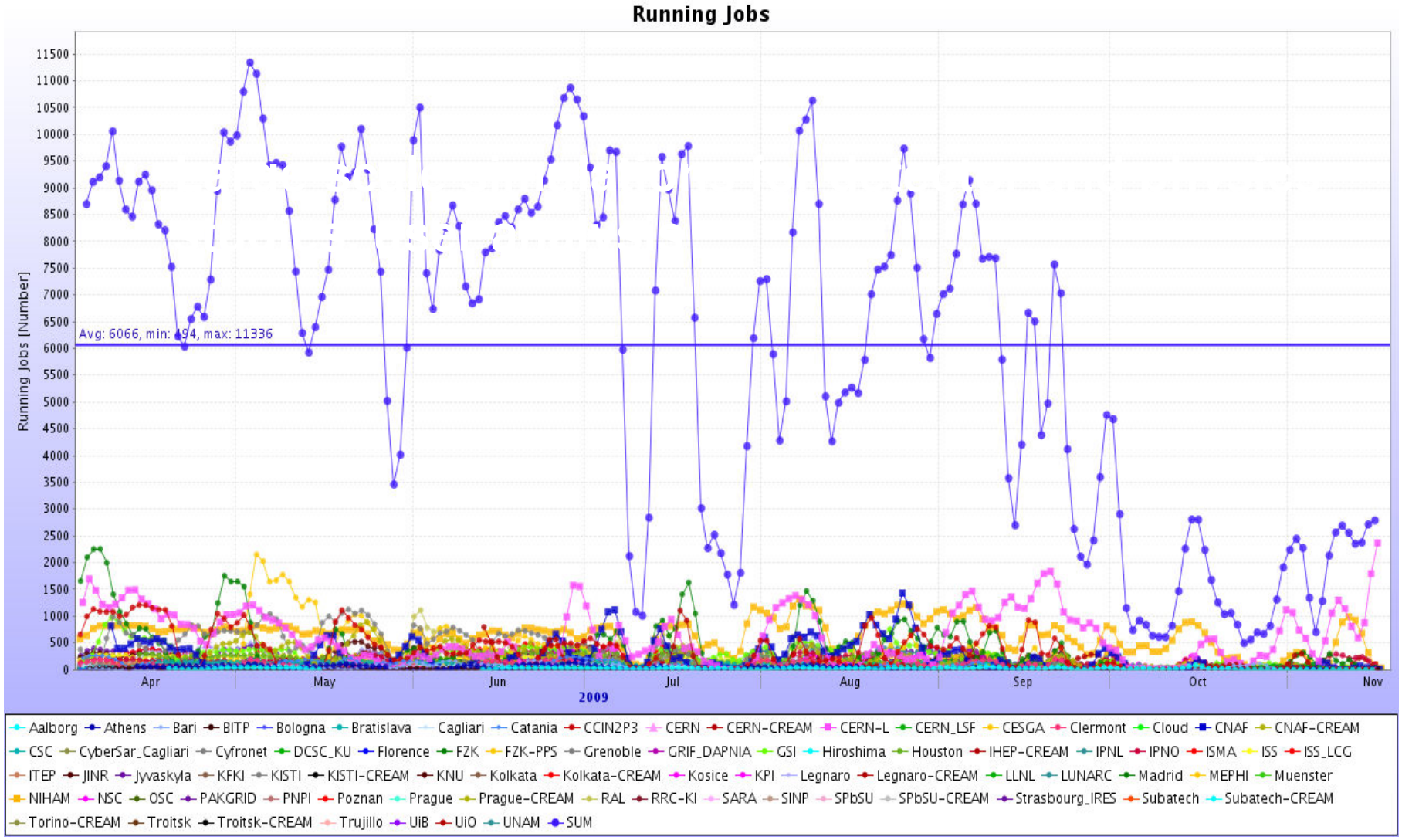


Africa

North America

90 computing centers on 4 continents

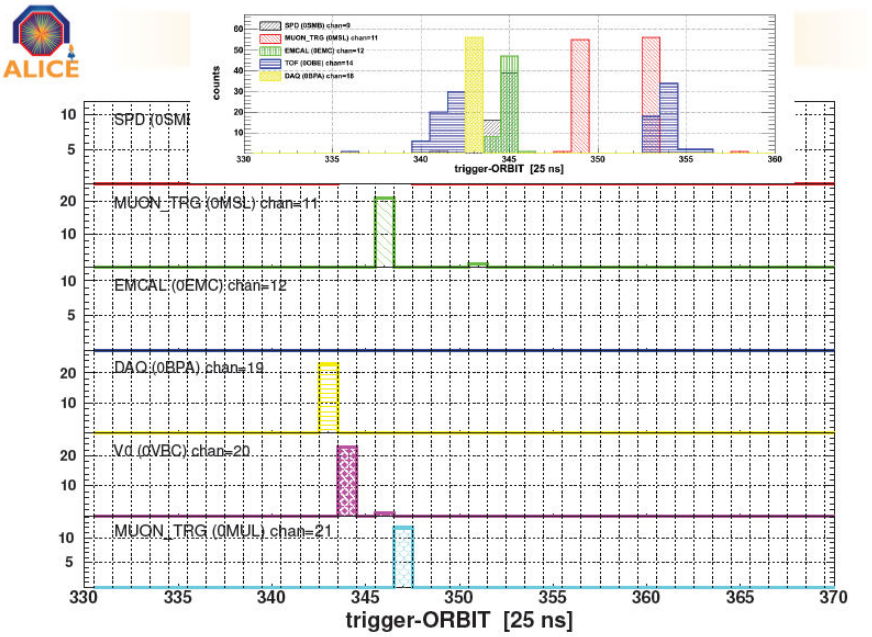
Computing: Continuous data processing

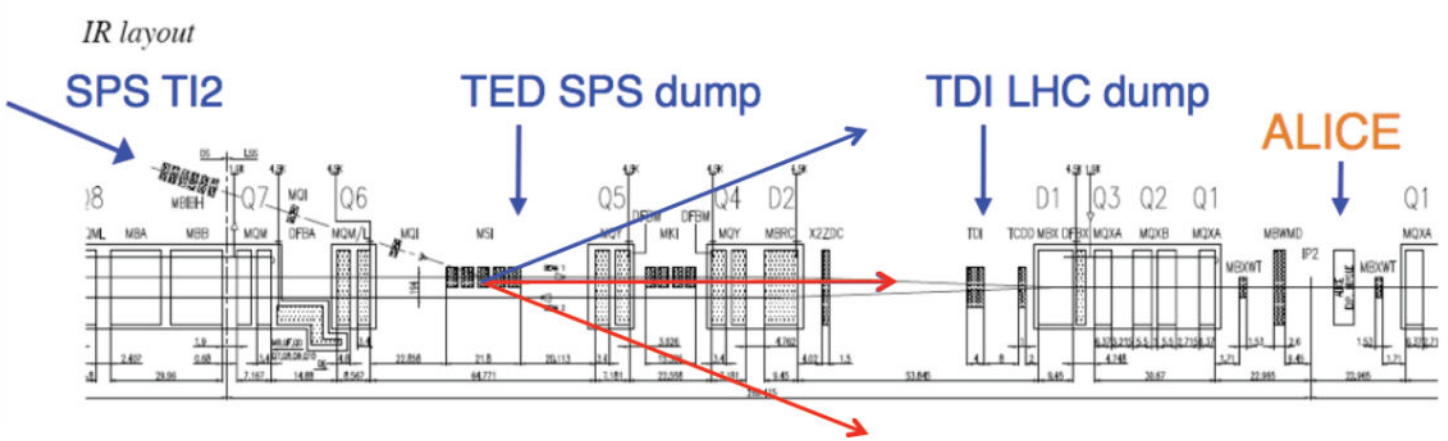


Trigger Time Alignment

During several LHC injection tests, where pilot bunches of 2×10^9 protons are dumped at the end of the injection line, we got about 1muon/cm^2 in ALICE

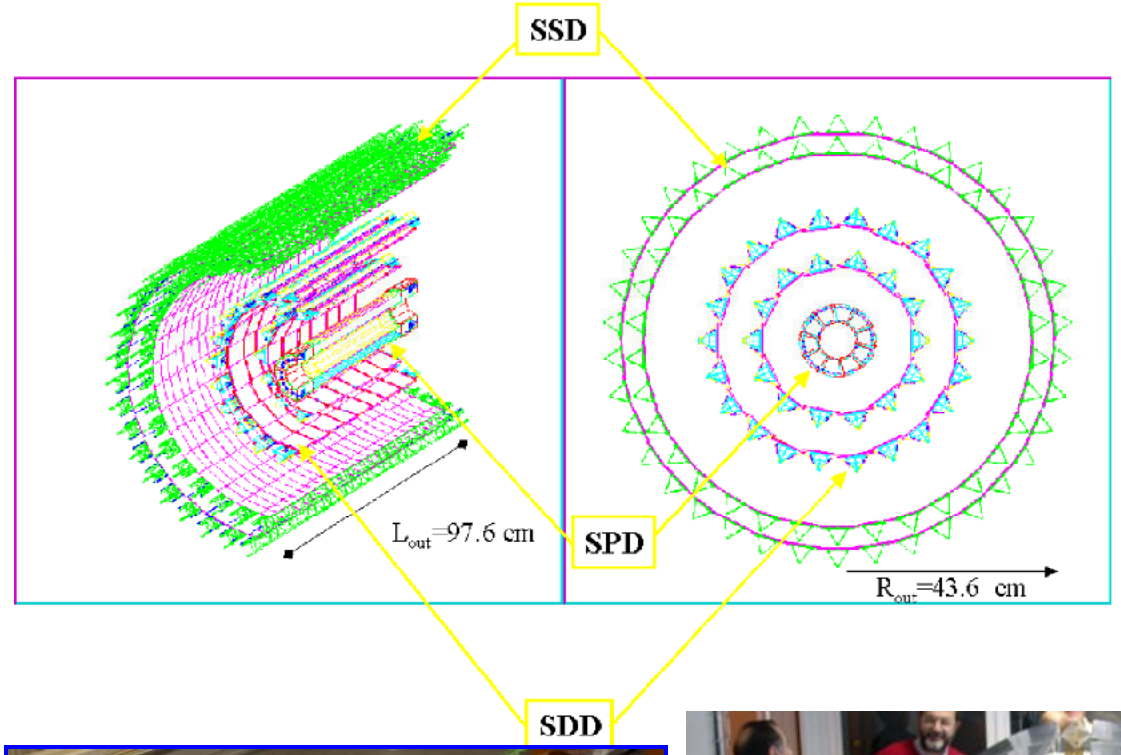
→ Time alignment of trigger detectors !





Key Figures of Subdetector Performance

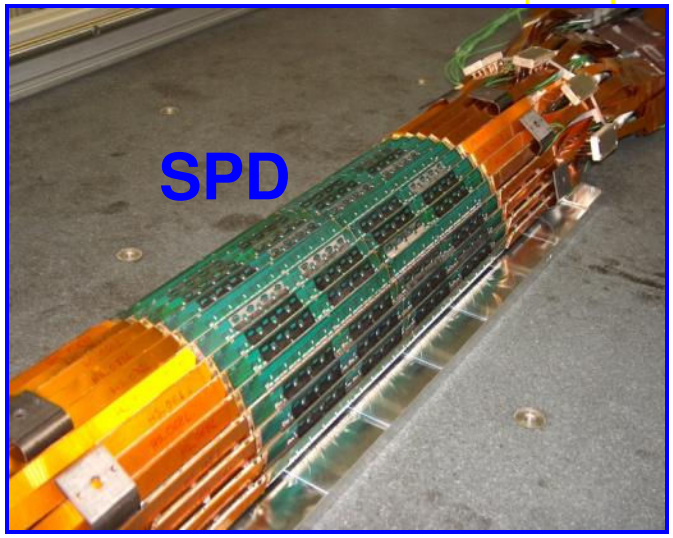
Inner Tracking System

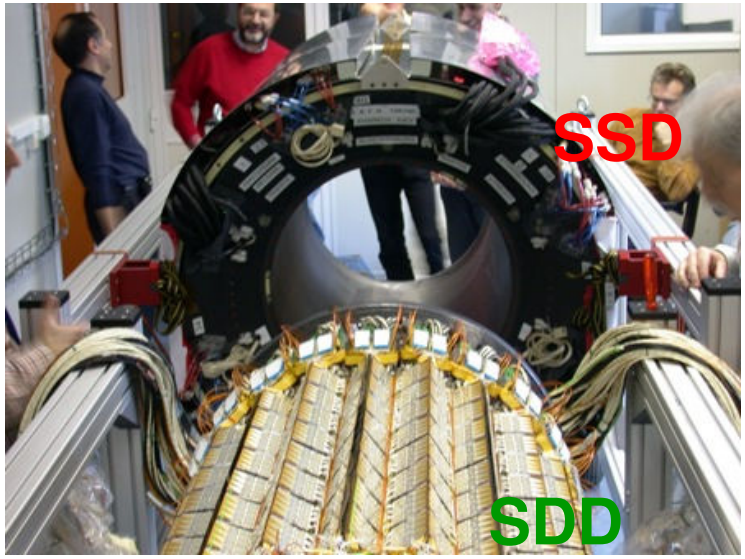


Silicon Pixel Detector (SPD):
- **~10M channels**
- **240 sensitive vol. (60 ladders)**

Silicon Drift Detector (SDD):
- **~133k channels**
- **260 sensitive vol. (36 ladders)**

Silicon Strip Detector (SSD):
- ~2.6M channels
- 1698 sensitive vol. (72 ladders)

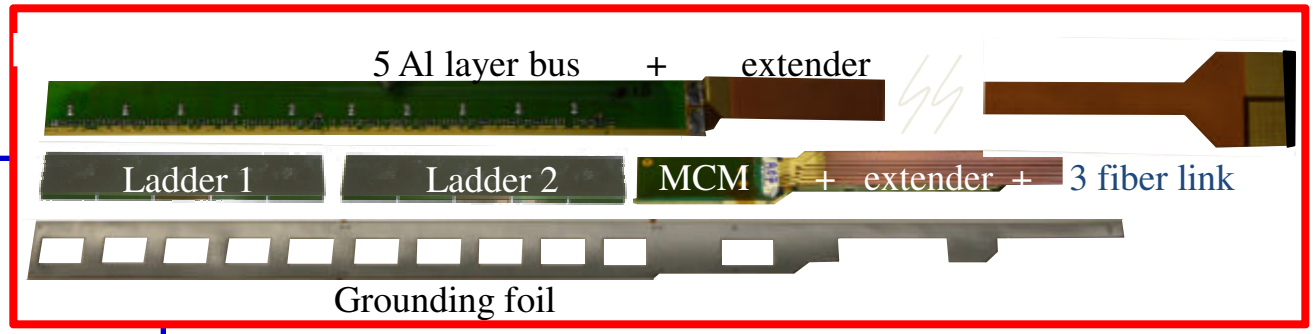




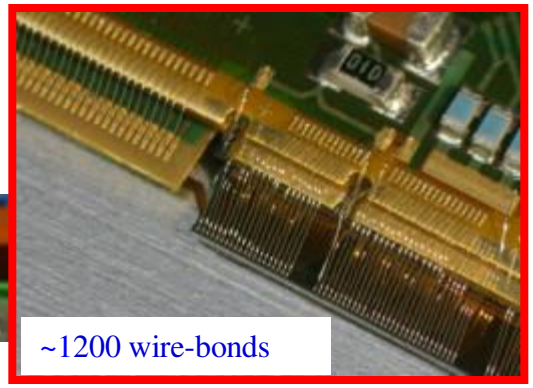
ITS total:
2198 alignable sensitive volumes
→ 13188 d.o.f.

SPD

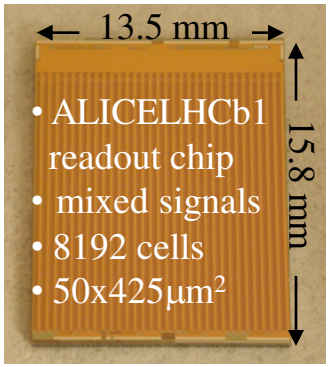
- 2 layer barrel
- Total surface: ~0.24m^2
- Power consumption ~1.4kW
- Evaporative cooling C_4F_{10}
- Operating at room temperature
- Material budget per layer ~1% X_0



Half-stave



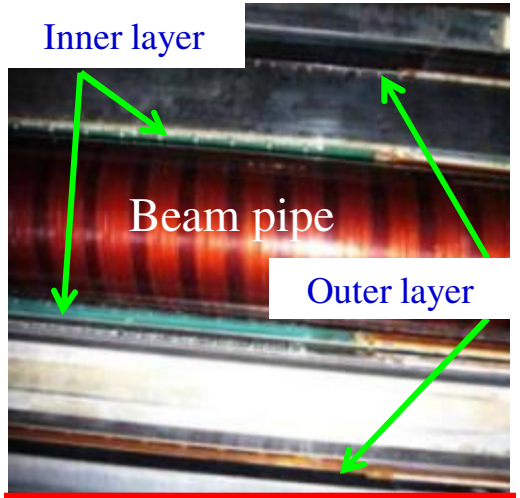
Outer surface: 80 half-staves



Inner surface: 40 half-staves

Unique L0 trigger capability

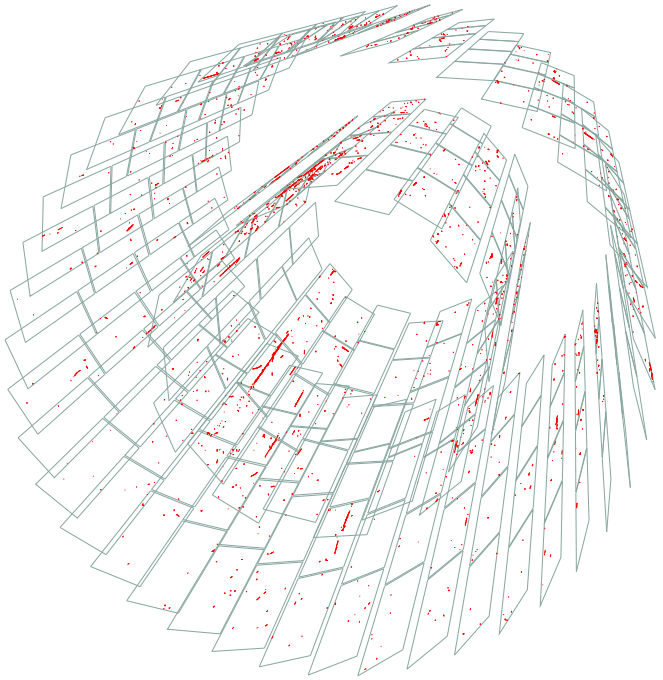
- Prompt FastOR signal from each chip
- Extract and *synchronize* 1200 FastOR signals from the 120 half-staves
- User defined programmable algorithms



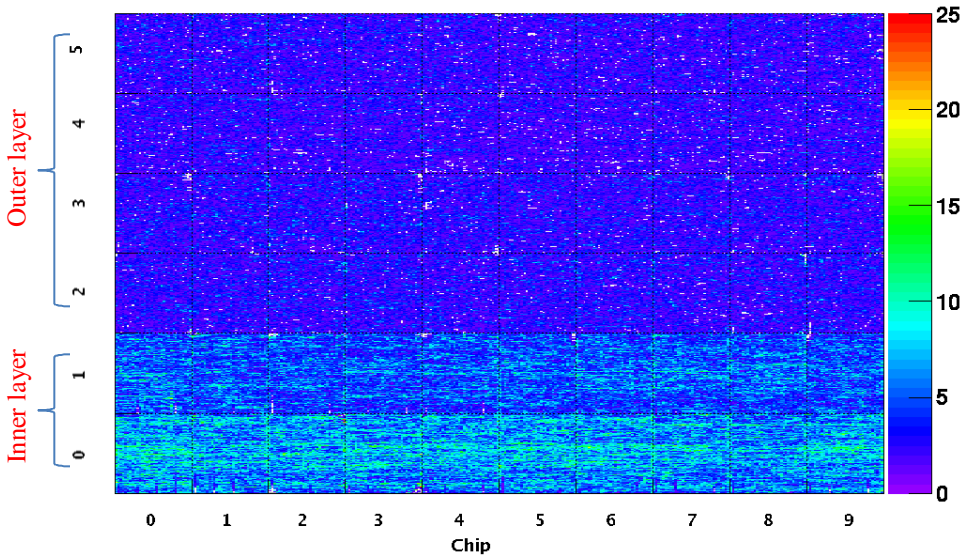
Minimum distance inner layer-beam pipe ≈5 mm

SPD- Injection Test - 23 Oct '09

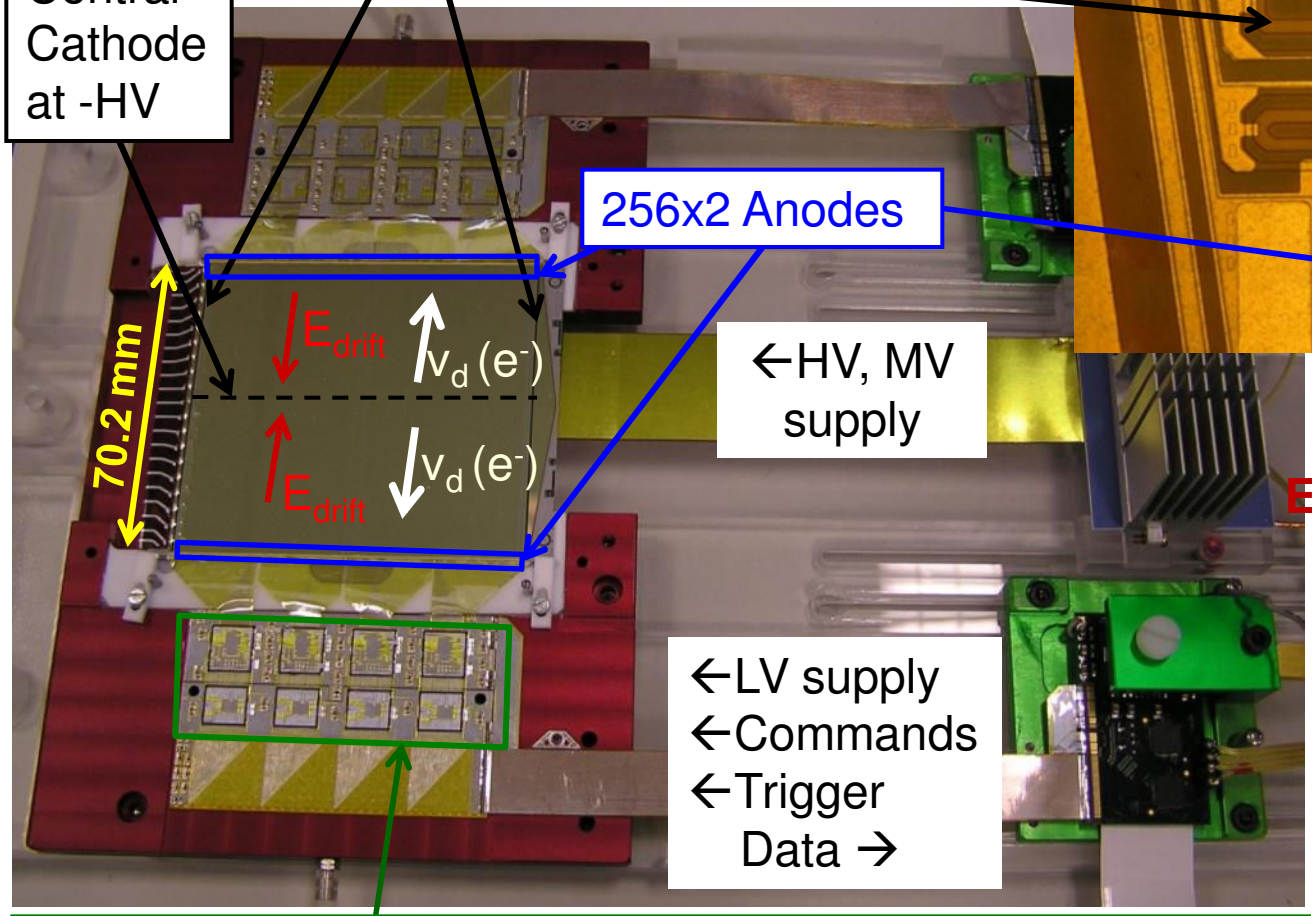
Pb beam through ALICE Interaction with beam monitoring screens 23-10-2009 at 19:06

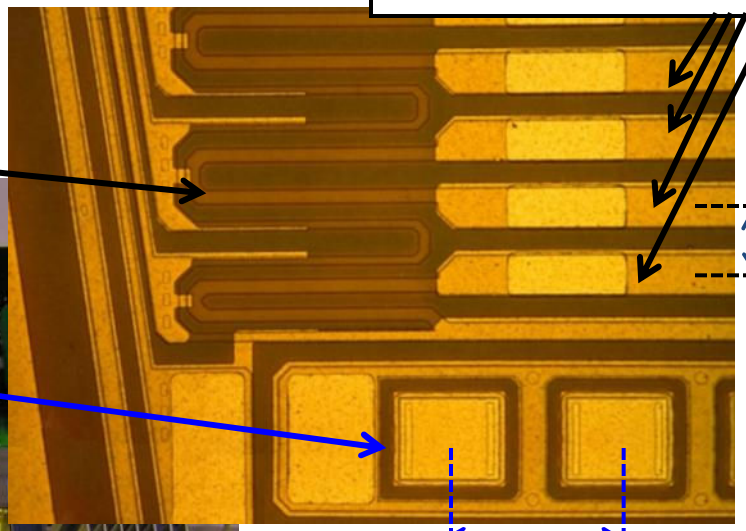


Uniformity matrix of one half-sector
Events collected during 2009 injection tests

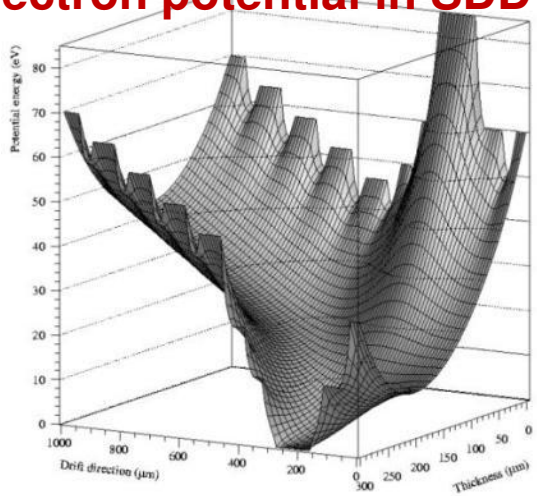


Silicon Drift Detector





Electron potential in SDD



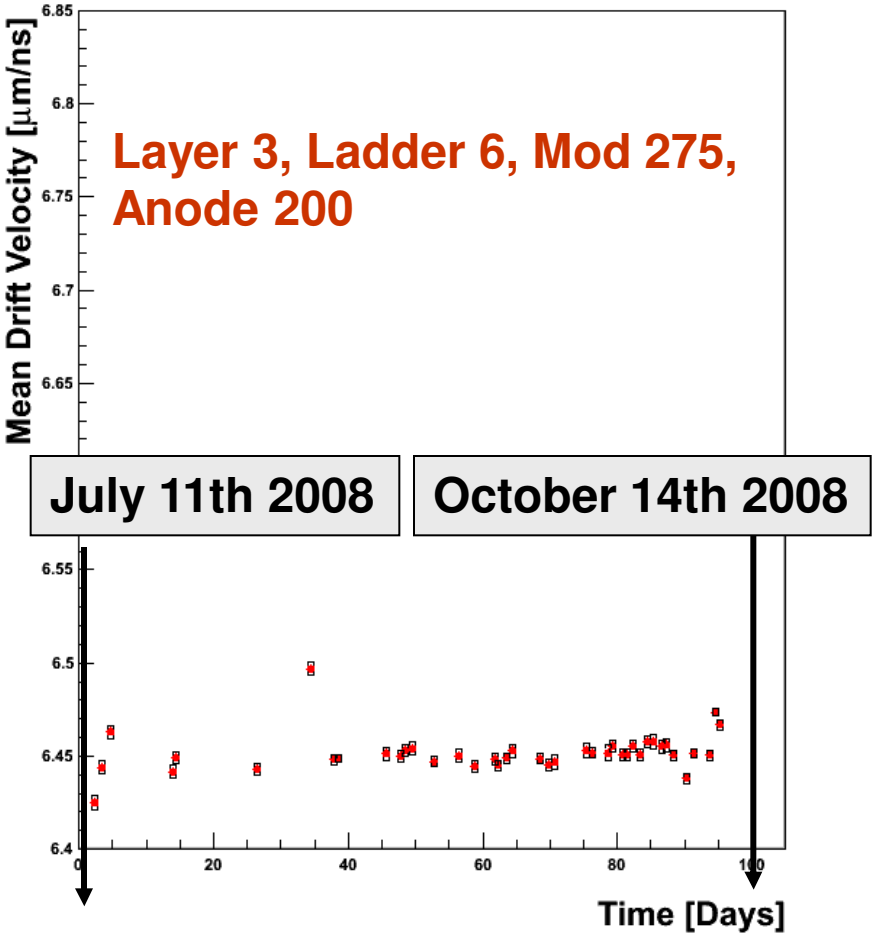
Silicon Drift Detector, Drift Speed Calibration

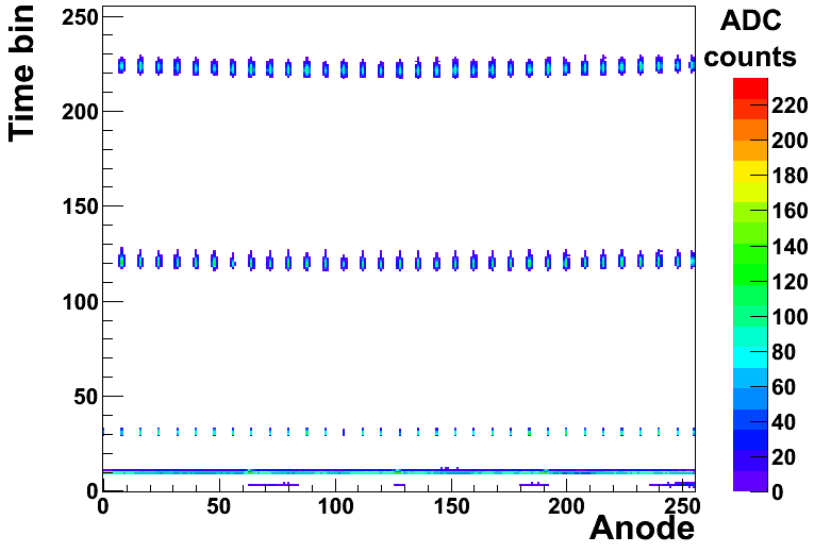
Drift Speed very sensitive to Temperature ($\alpha\ T^{-2.4}$)

33x3 MOS charge injectors implemented in known positions on each drift side (half-module)

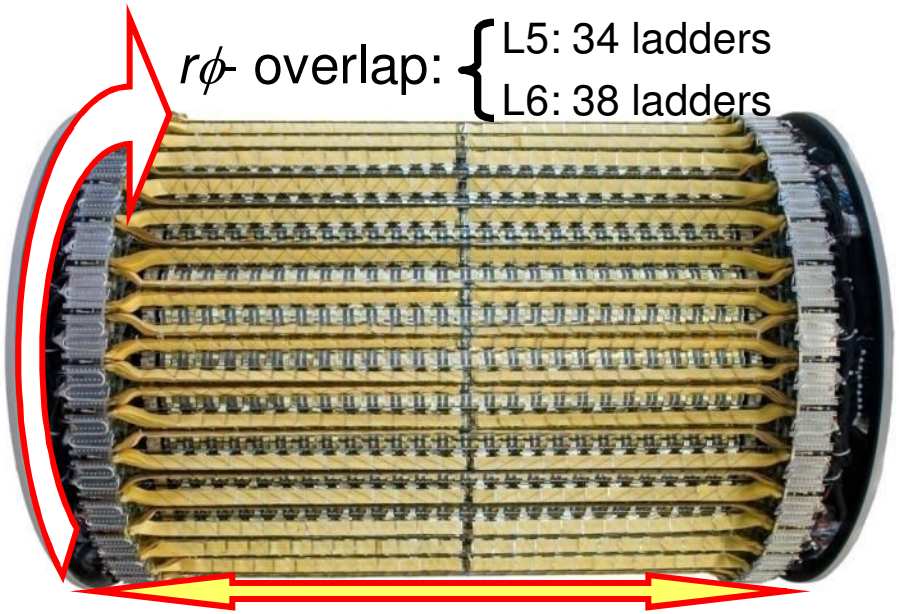
3 months of data taking during summer 2008

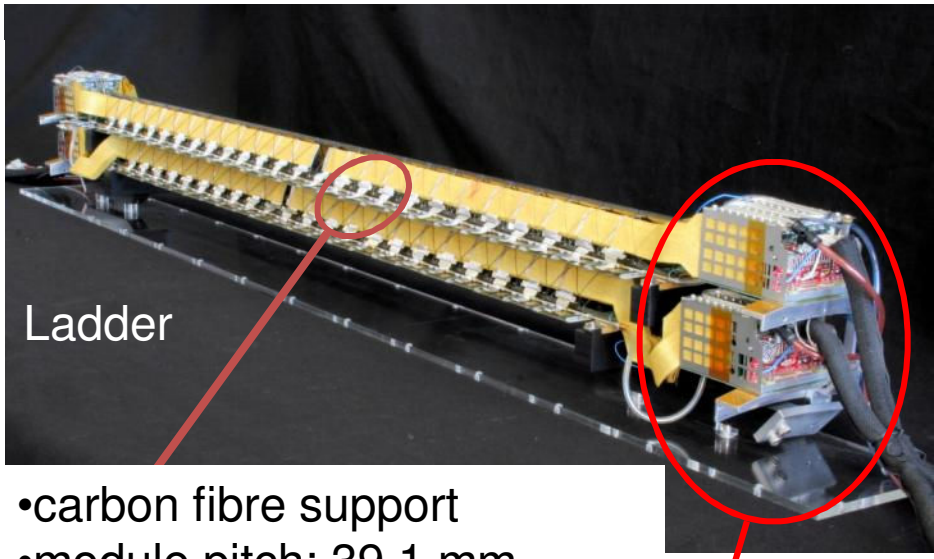
Drift speed stable within 0.2%





Silicon Strip Detector

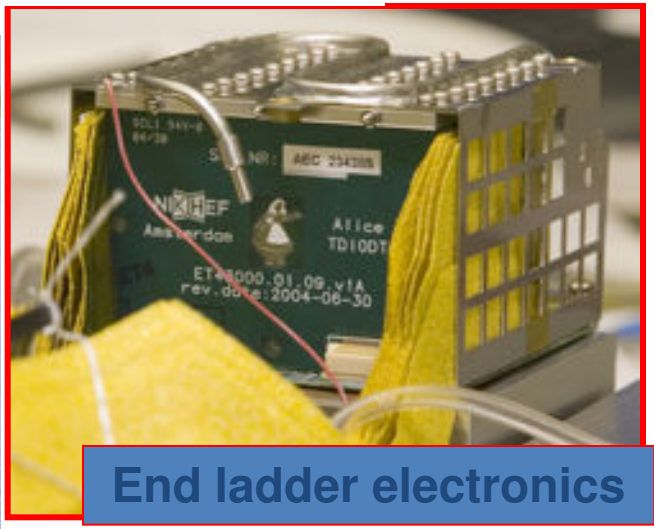




- carbon fibre support
- module pitch: 39.1 mm
- Al on polyimide laddercables

Hybrid:identical for P- and N-side
Al on polyimide connections
6 front-end chips HAL25
water cooled

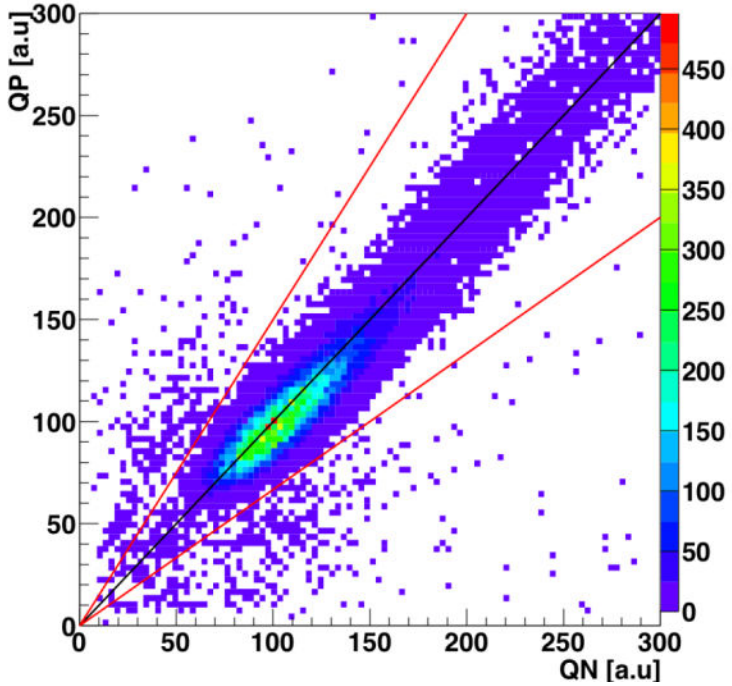
Sensor:
double sided strip:
768 strips 95 um pitch
P-side orientation 7.5 mrad
N-side orientation 27.5 mrad



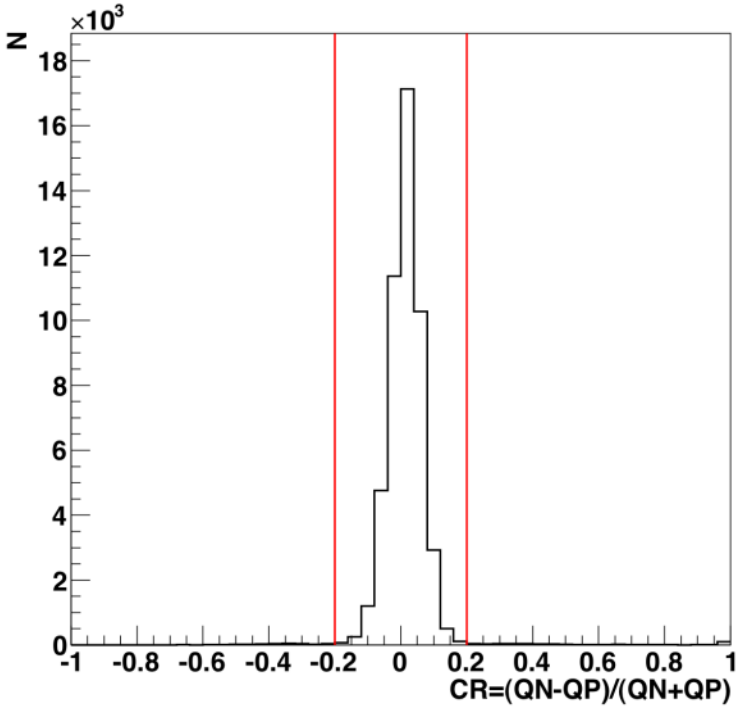
End ladder electronics

Silicon Strip Detector

- **Charge matching between p and n sides**
  - ⇨ **Relative calibration from 50k cosmic tracks**
  - ⇨ **Important to reduce noise and ghost clusters**



cluster charge (P vs N)



charge ratio

ITS operational issues

ITS detector is in very good shape and a lot of operational experience was gained during the 2008 and 2009 COSMIC runs.

Most Critical Issues:

SPD:

Efficient operation of evaporative cooling proved to be very challenging. At this moment, around 8% of the half staves are off, mainly due to due to cooling issues.

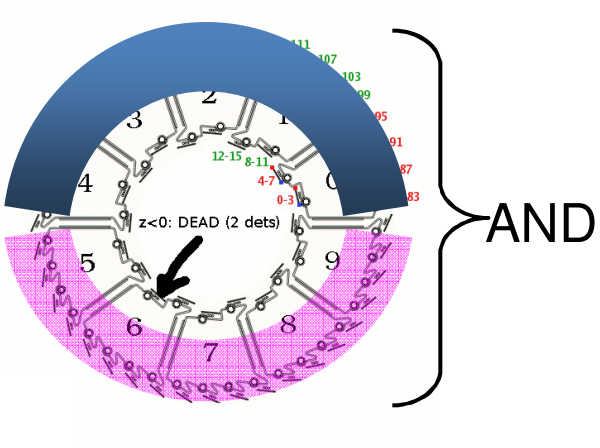
SDD:

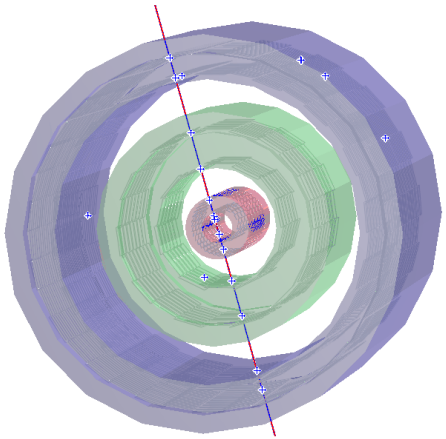
At this moment around 5% of the detector is off due to several issues not related to cooling.

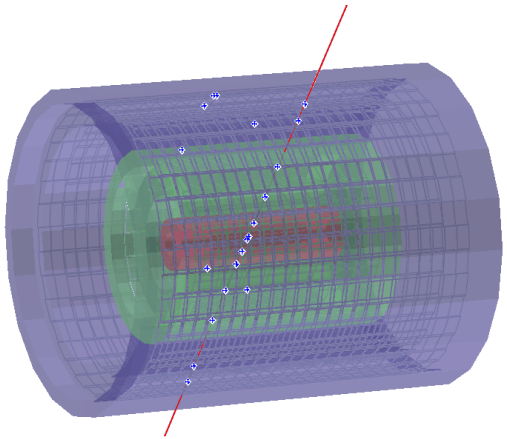
SSD:

The high level of humidity in the cavern during summer (up to 68%) caused rising leakage currents on the detectors. This was cured by installing a ventilation system with humidity controlled air. Currently around 10% of modules are off.

Triggering and Tracking the Cosmics





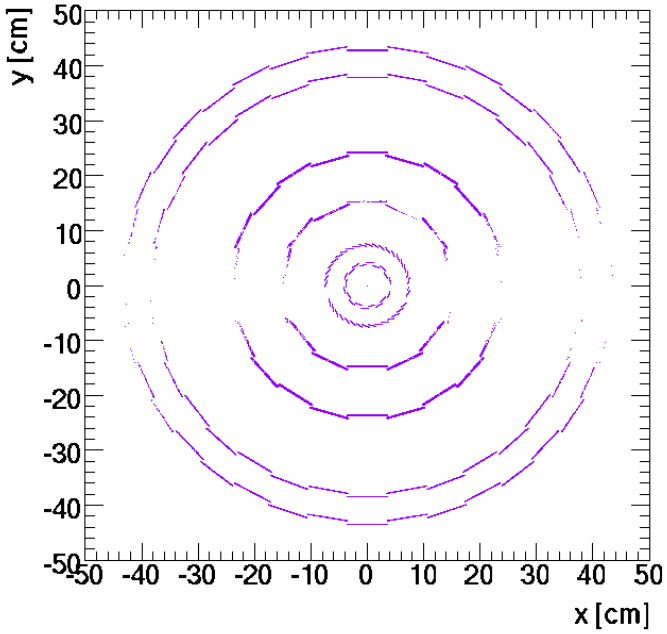


Trigger: SPD FastOR

Coincidence between top outer SPD layer and bottom outer SPD layer

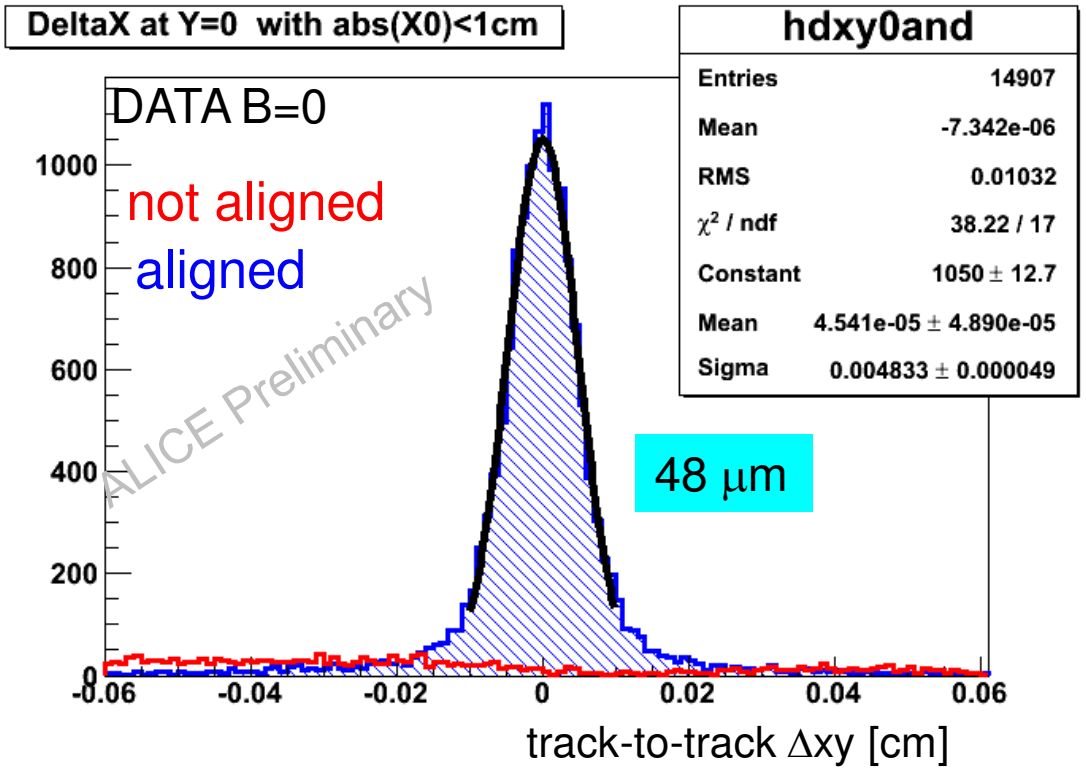
rate: 0.18 Hz

Statistics collected (after reco): ≈10^5 events with B=0 in 2008

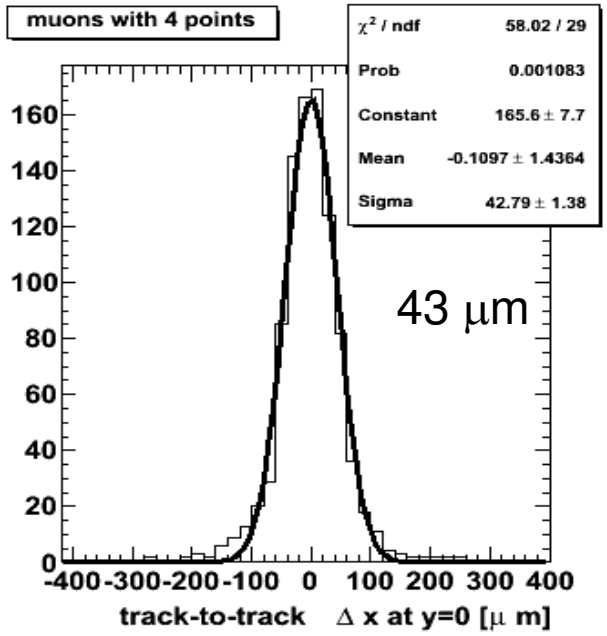


SPD alignment: Δxy at y=0

Track-to-track matching (2 points per track in the pixels)



Simulation for ideal Geometry



Expected spread

$$\sigma^2_{\Delta x} = 2*(r^2_{SPD2}+r^2_{SPD1})/(r_{SPD2}-r_{SPD1})^2*\sigma^2_{spatial}$$

→ $\sigma_{spatial}$=14 μm → σ_{misal}~9 μm

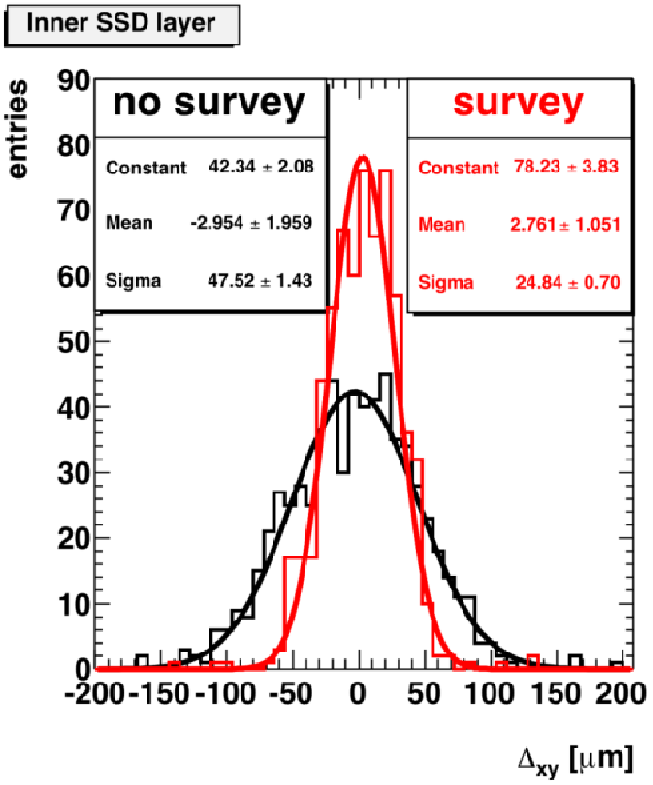
→ $\sigma_{spatial}$=11 μm (Sim)

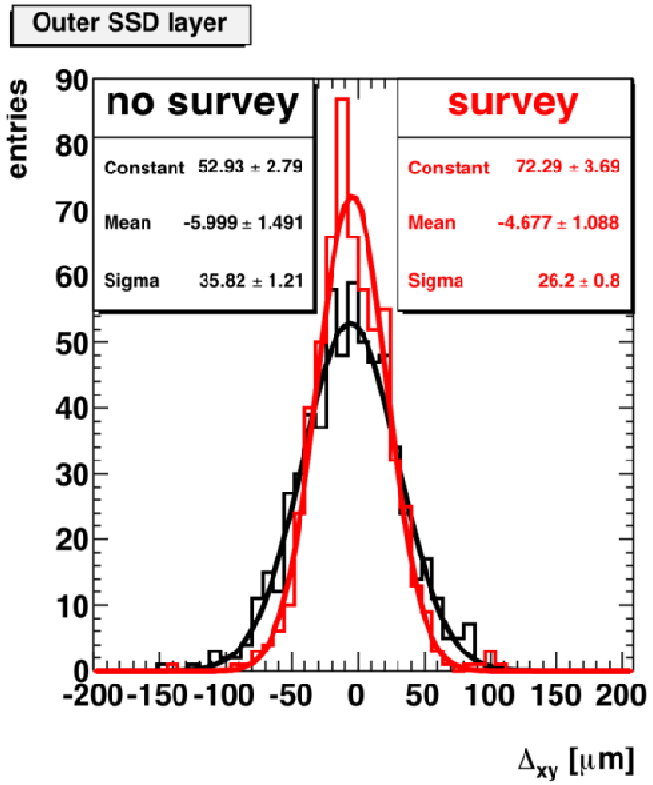
Validation of SSD Metrology with Cosmics

Extra clusters from acceptance overlaps → distance between two clusters from same track on contiguous (overlapping) modules on same ladder

Comparison between nominal positions and 'mechanically' measured position

module on ladder misalignment

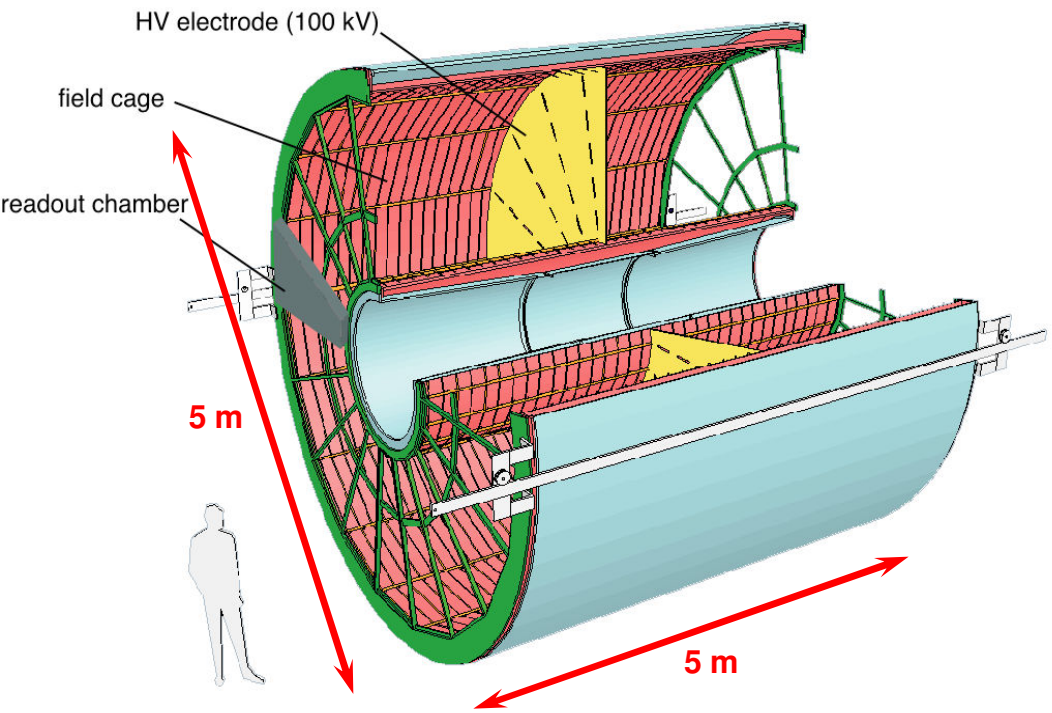




$\sigma(\Delta xy)=25\ \mu m$ **(48)**
$\Rightarrow \sigma(point)=25/\sqrt{2}=18\ \mu m$
$\Rightarrow \sigma(misal)<5\ \mu m$ **(27)**

$\sigma(\Delta xy)=26\ \mu m$ **(36)**
$\Rightarrow \sigma(point)=26/\sqrt{2}=18\ \mu m$
$\Rightarrow \sigma(misal)<5\ \mu m$ **(15)**

ALICE Time Projection Chamber



- **Data readout:**
  - Pads (3 types): 557 568
  - Samples in time direction: 1000
  - Data taking rate:
    - ~ 1kHz for p-p
    - ~ 200 Hz for Pb-Pb

General features:

- Diameter × Length : 5 m × 5 m
- Azimuthal angle coverage: 2π
- Pseudo-rapidity interval: $|\eta|<0.9$
- Readout chambers: 72
- Drift field: 400 V/cm
- Maximum drift time: 92 μs
- Central electrode HV: 100kV

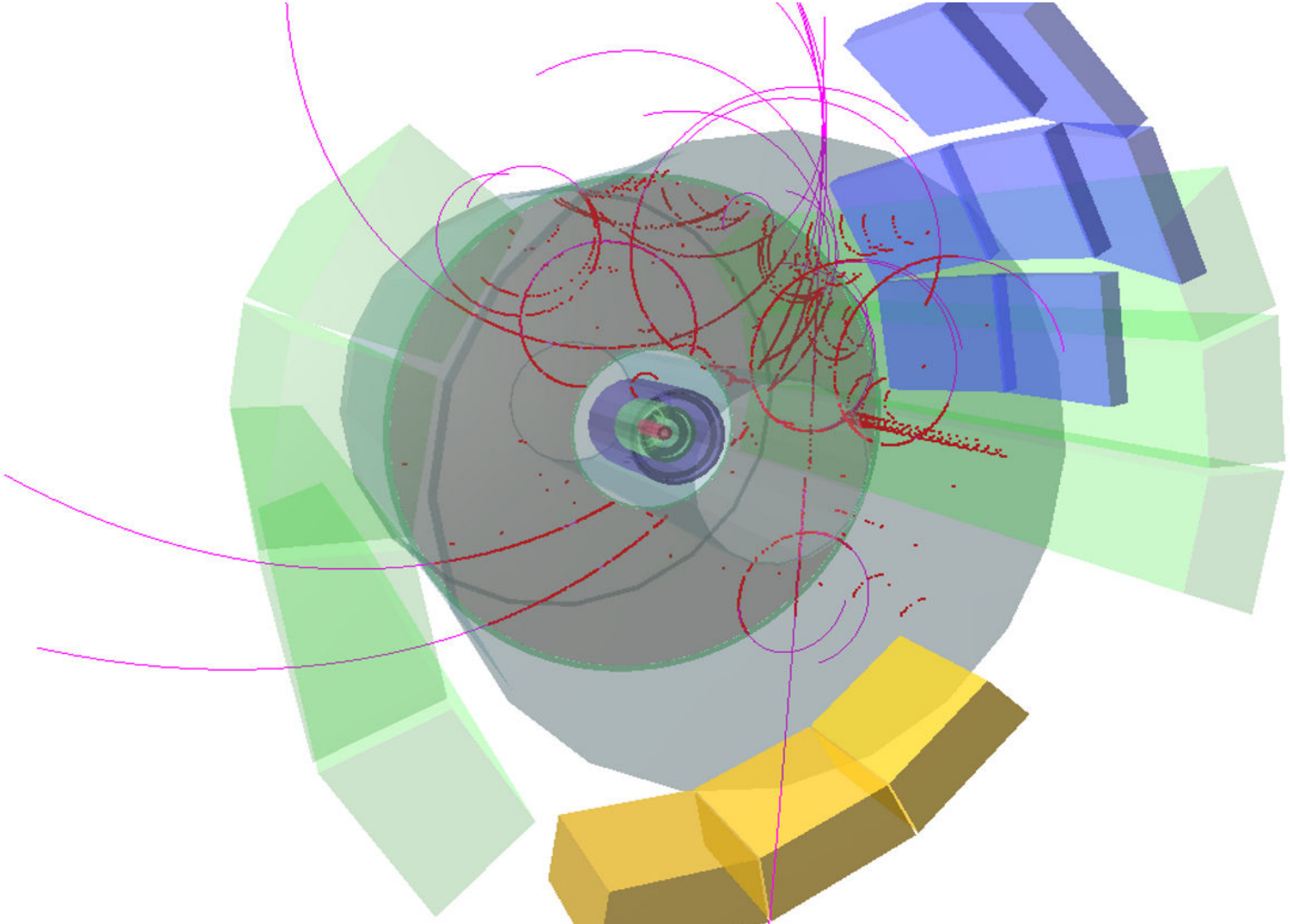
Gas:

- Active volume: 90 m^3
- Ne-CO_2-N_2: 85.7% - 9.5% - 4.8%
- Cold gas - low diffusion
- Non-saturated drift velocity

  $\Rightarrow$ temperature stability and homogeneity $\leq$ 0.1 K

TPC

HLT online reconstructed COSMIC shower event

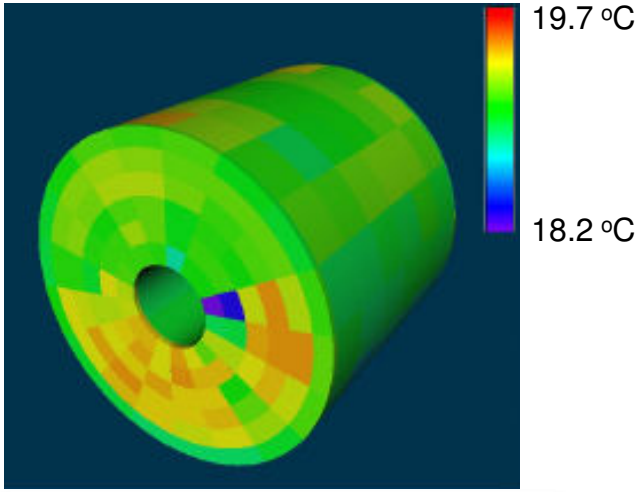


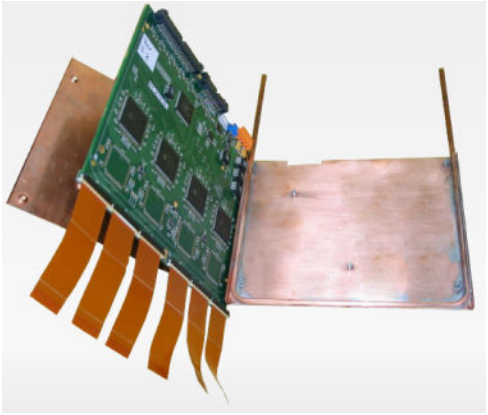
TPC Cooling

Provide temperature stability

- ~ 60 adjustable cooling circuits
- ~ 500 temperature sensors
- Thermal screening towards ITS and TRD
- Cooling of Chamber bodies
- Water cooling of FEE in copper envelope (~27 kW)

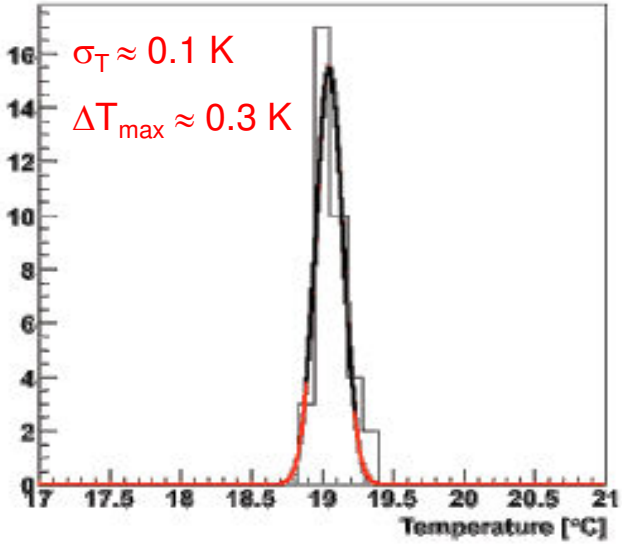
Temperature outside TPC





FEC with its cooling envelope

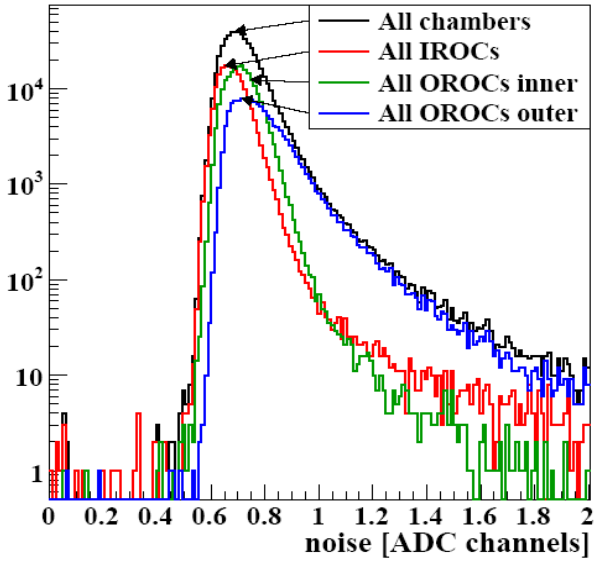
Compatible with design specifications



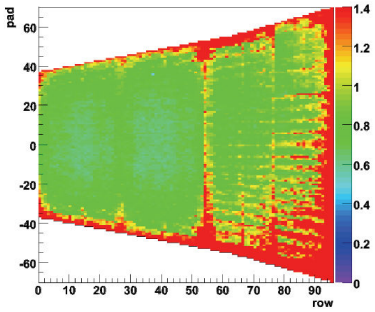
Temperature inside TPC

TPC Pedestals and Noise

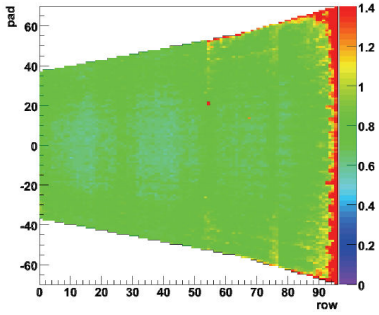
- Pedestals are very stable over time
- Average noise level:
  - Design goal: 1 ADC count (1000 e)
  - Achieved: 0.7 ADC count (700 e)



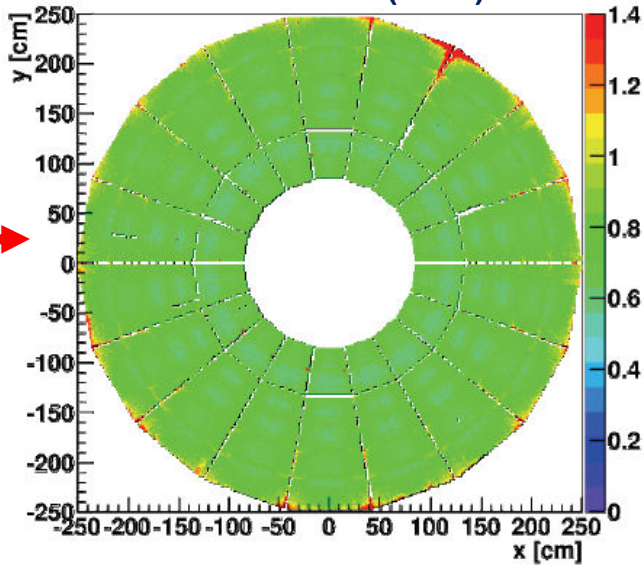
Underground (2007)



Underground (2008)



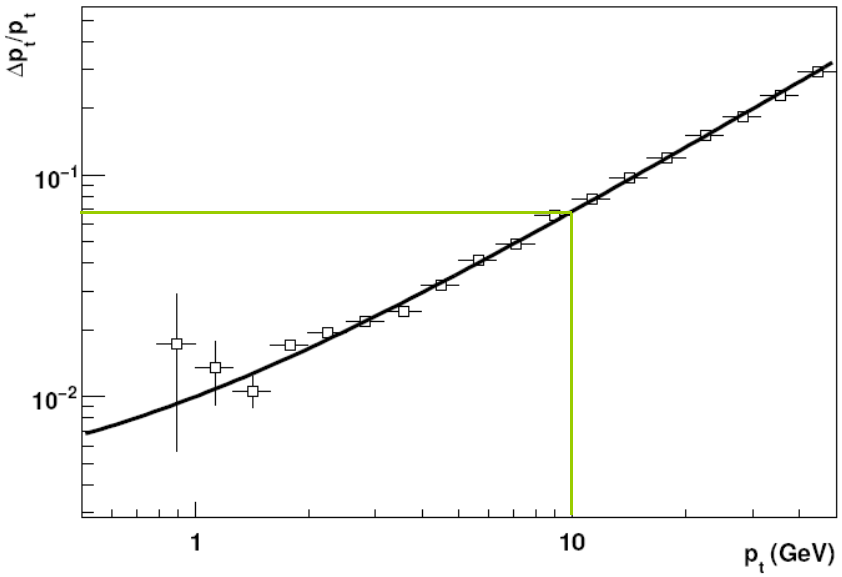
Current situation (2009)

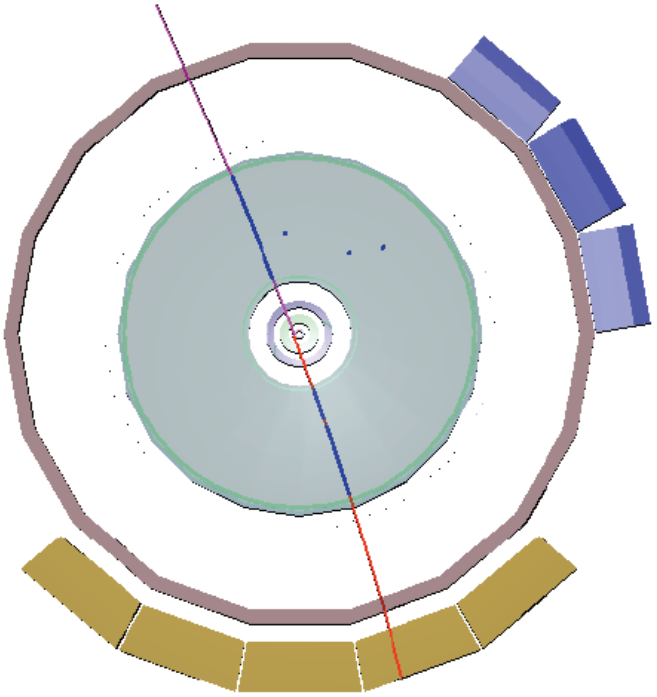


TPC Momentum Resolution

- Cosmic muon tracks treated independently in two halves of TPC
- Comparison of p_T at vertex gives resolution
- Statistics: ~ 5×10^6 events

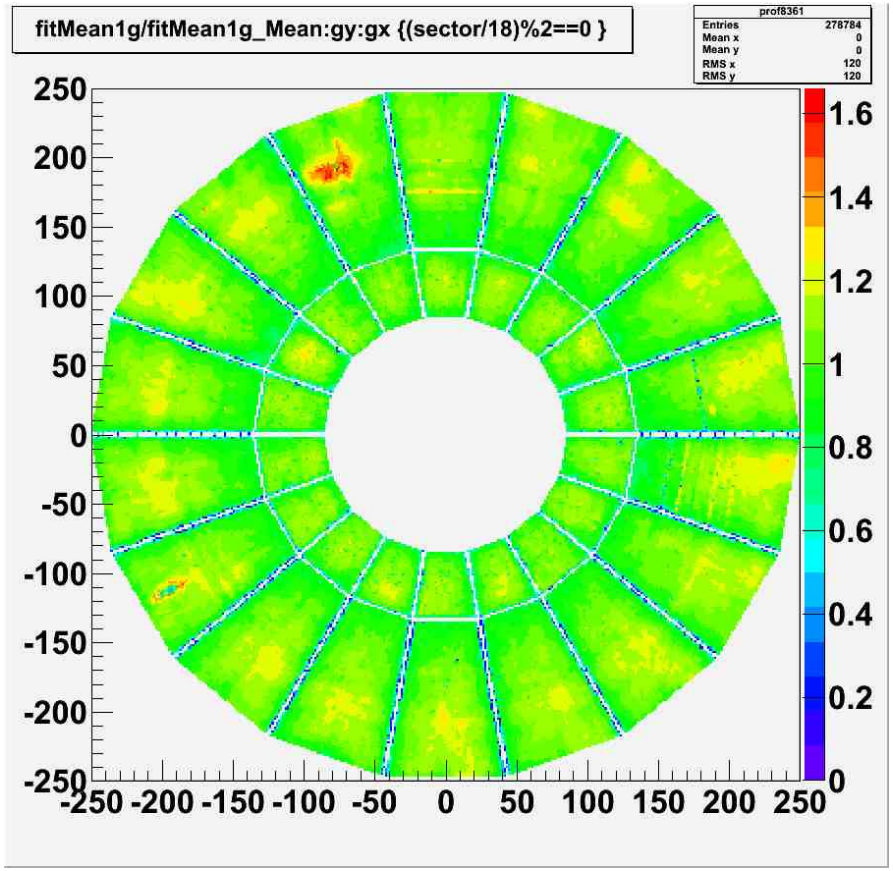
- Design goal: 4.5 % @ 10 GeV
- Achieved: 6.5 % @ 10 GeV
  ~ 1 % below 1 GeV



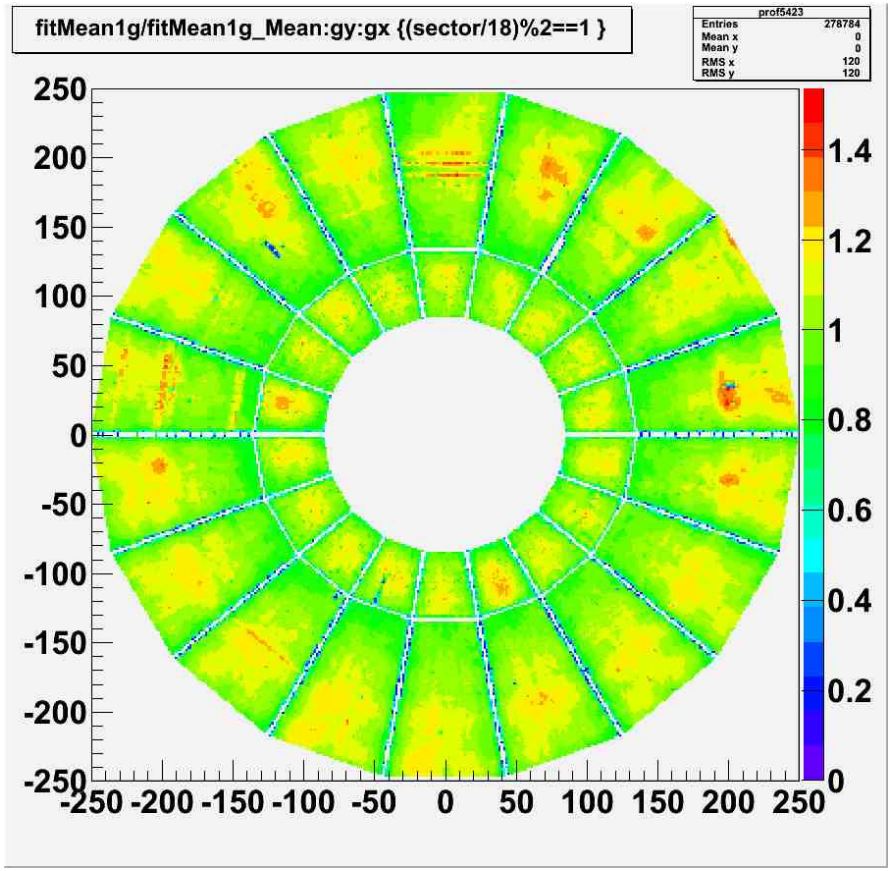


TPC Gain calibration map with Kr83 decays

Pad by Pad calibration



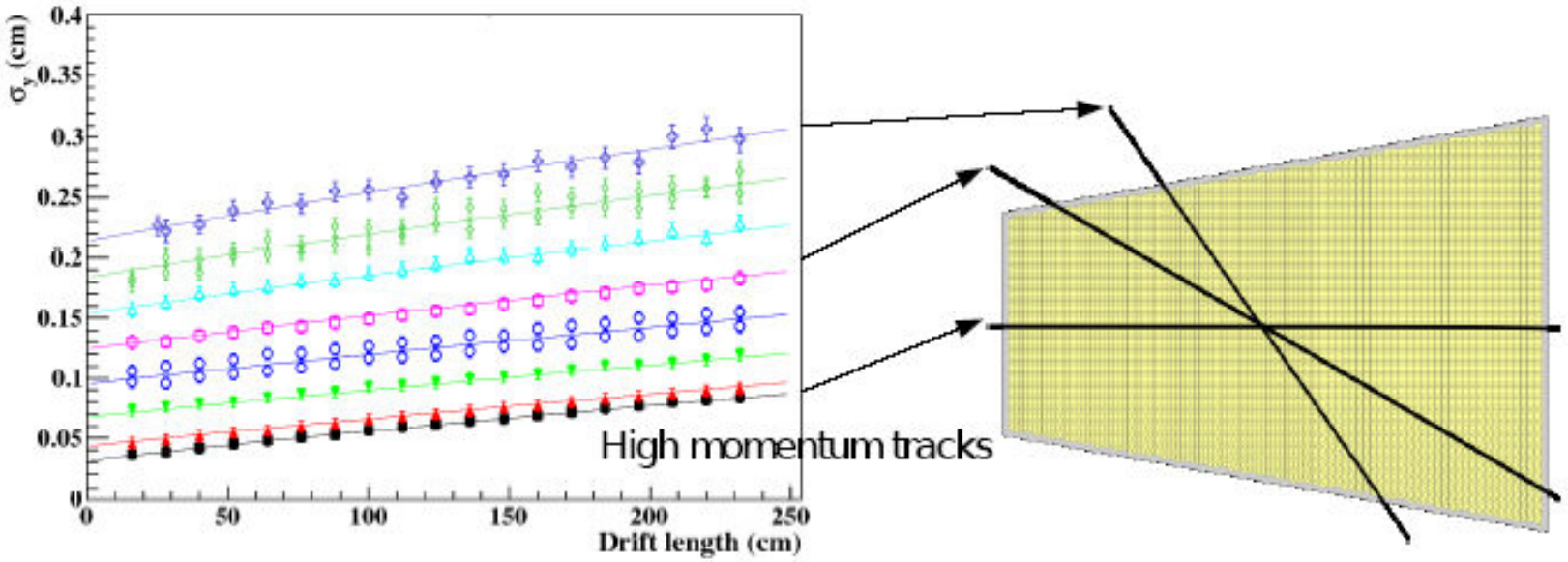
A side



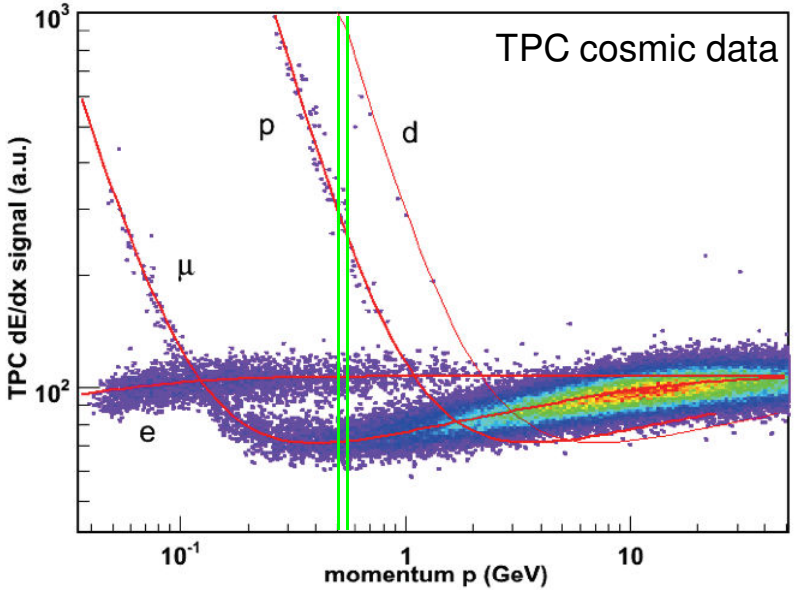
C side

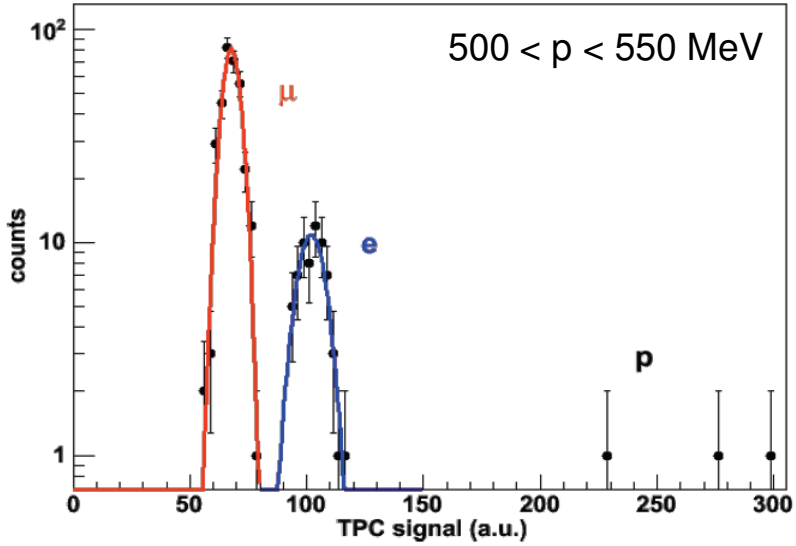
TPC Space Point Resolution

- 300 - 800 μm in rφ
  - for small inclination angles (high momentum tracks)
- Good agreement with simulations



TPC dE/dx Resolution

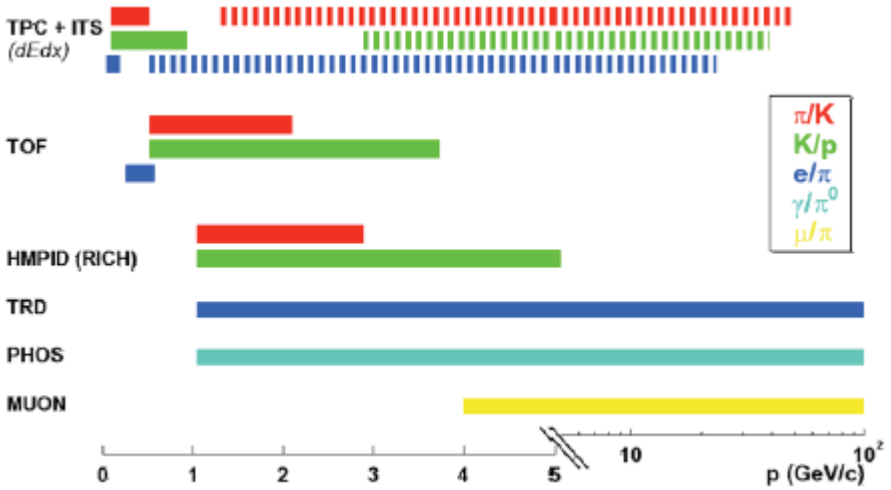




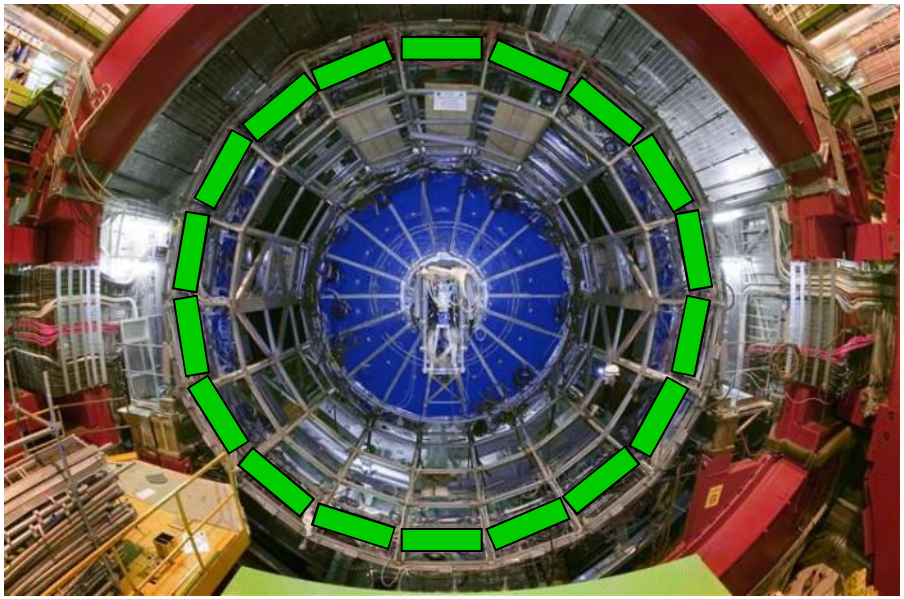
Allows particle identification up to 50 GeV/c

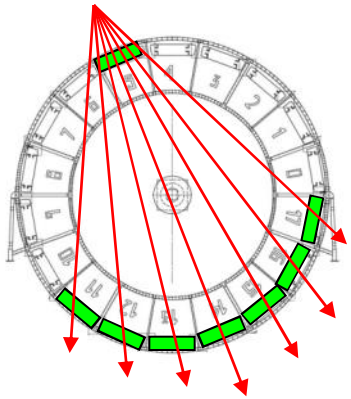
- **Statistics: 7×10^6 cosmic tracks in 2008**
- **Design goal: 5.5 %**
- **Measured: < 5.7 %**

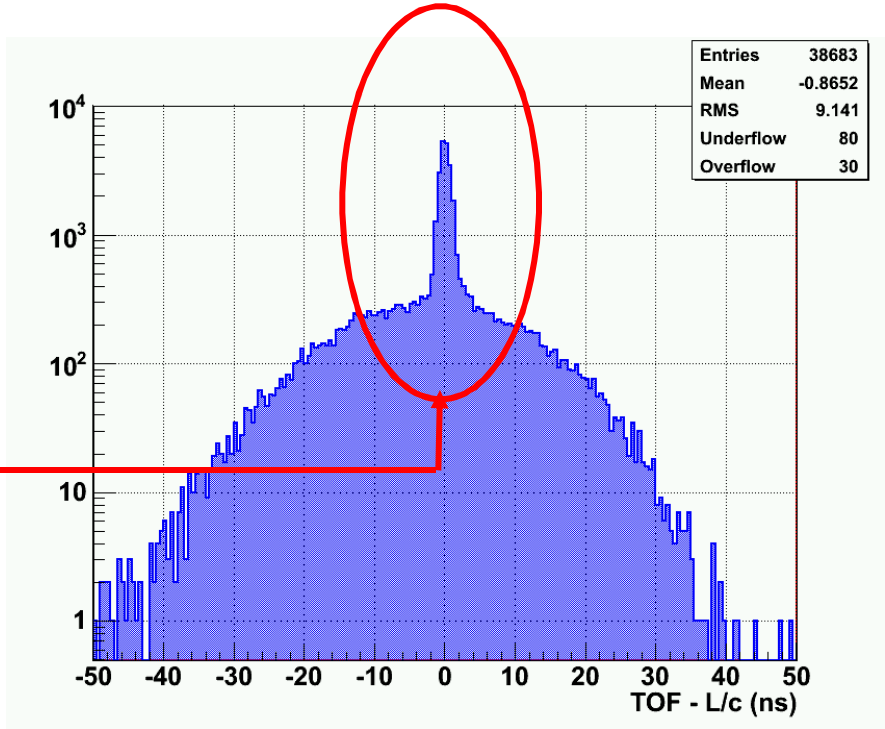
  → close to design value



TOF: Full TOF trigger – TOF "benchmark"



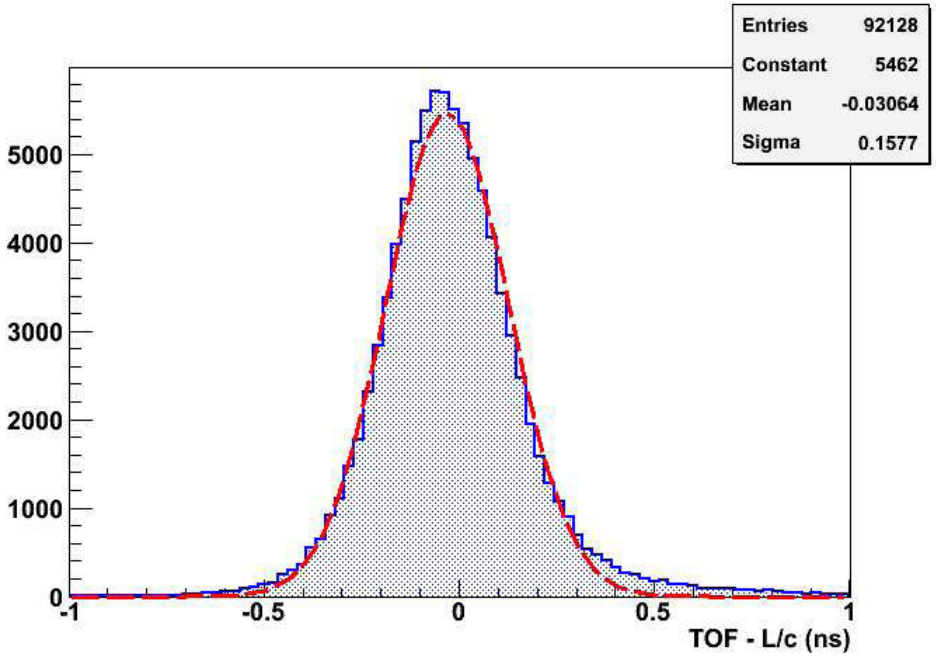




Clearly visible muon-related peak in the raw (TOF - L/c) spectrum

NO calibration
only TOF information

TOF 2009-calibration, preliminary



TOF resolution:

σ_{TOF} = 158 ps

including all contributions
poor timeslewing correction
notaligned geometry

$$\sigma_{TOF} = \sigma_t \sqrt{2}$$

Single-hit resolution:
σ_t = 111 ps

Design resolution of 80ps will be reached with p-p data calibration

TOF Current Calibration: PID Performance

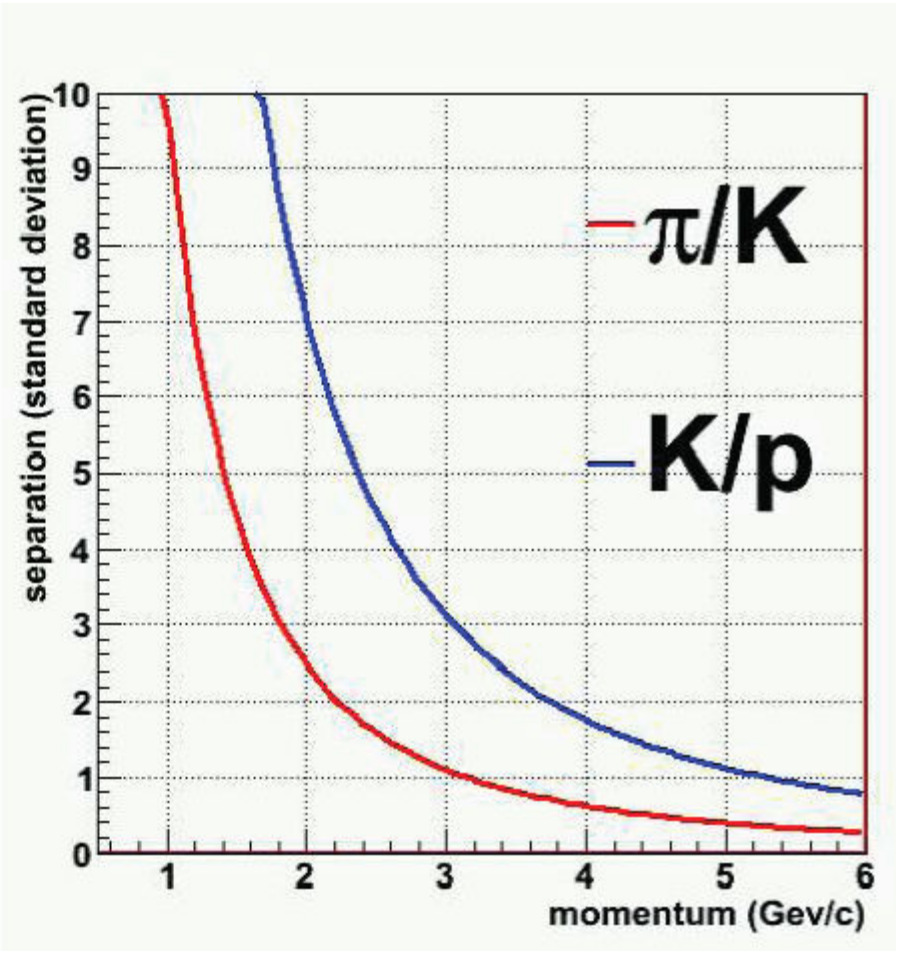
PID with first pp data and current calibration

L = 3.7 m

σ_{TOF} = 140 ps*

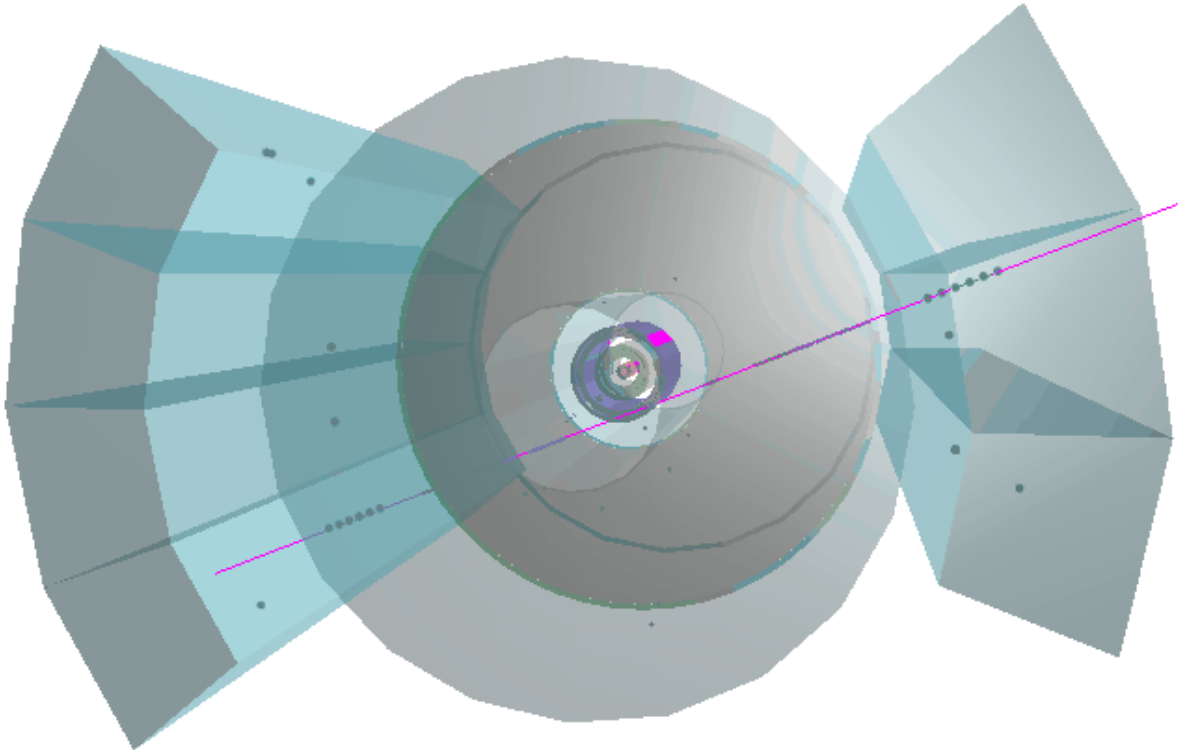
* including the event-time uncertainty σ_{T0} = 50 ps

3σ separation up to
1.8 GeV/c (π/K)
3.0 GeV/c (K/p)

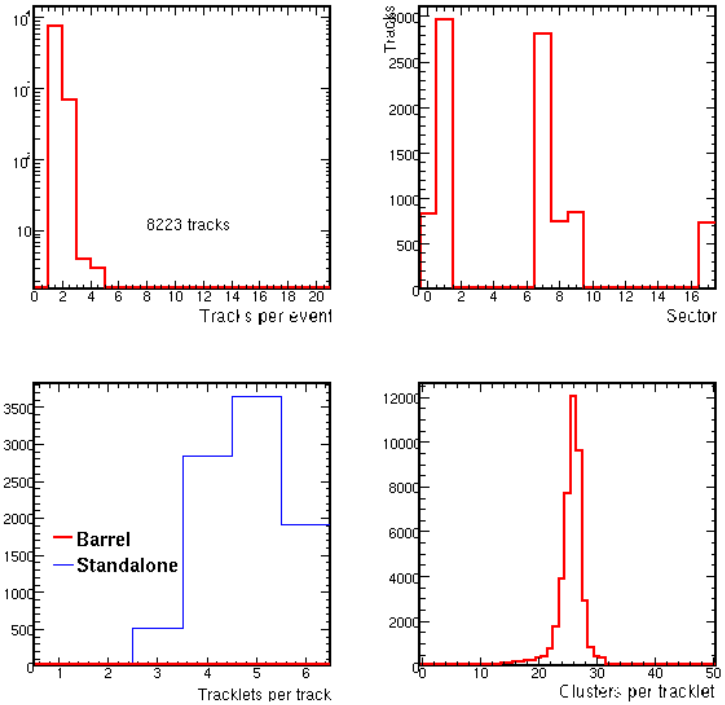


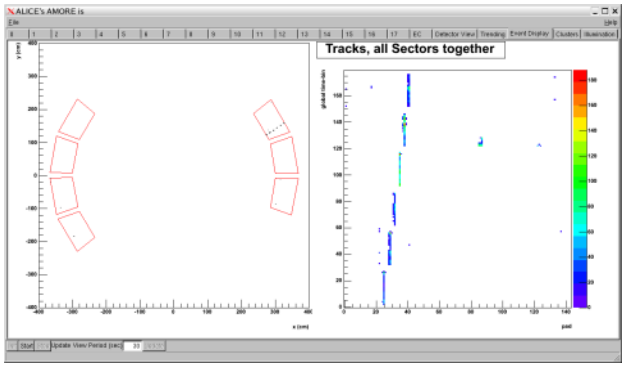
TRD: Commissioning & operation status

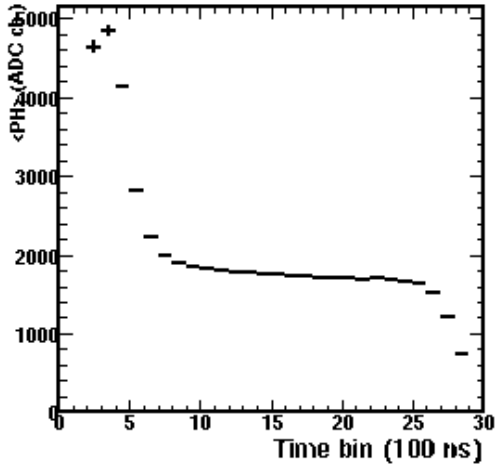
- 7 super modules with full readout chain installed in ALICE
- Successful data taking with cosmic rays and ^{83}Kr decays
- The Global Tracking Unit (GTU) as L1 trigger selects good cosmic events with ~99% purity of good tracks in TRD
- < 2 % dead channels



Cosmics: First Reconstruction Results with XeCO2







- Final Xe/CO_2 (85%/15%) gas mixture used since November 2nd 2009
- TRD standalone tracking
- track frequency of about 1 Hz (trigger rate was 2.7 Hz), with nice distribution for the nr. of tracklets per track and Nr. of clusters per tracklet.

The ALICE muon Spectrometer

Tracking

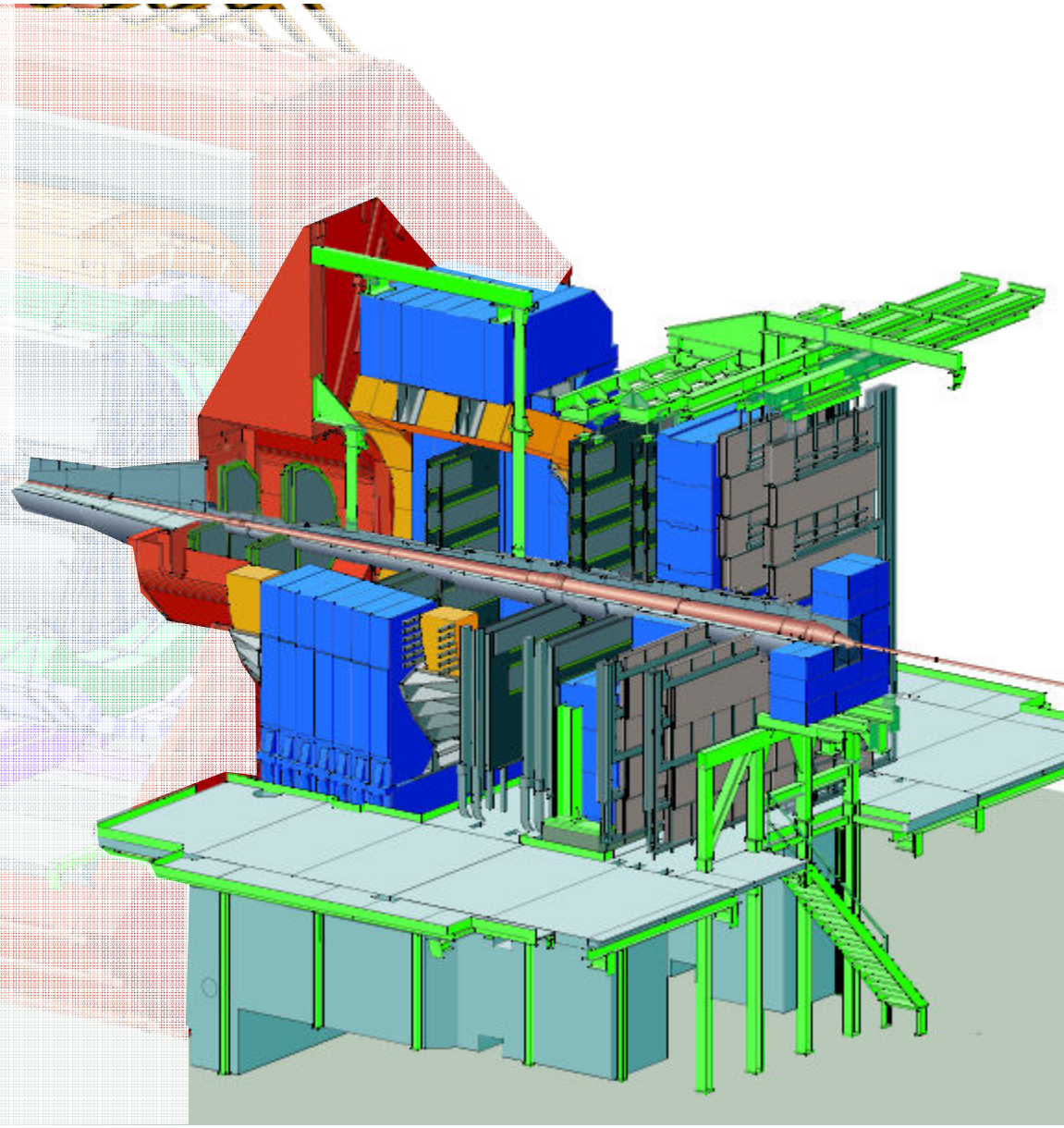
5 stations of 2 Chambers each
(Cathode Pad Chamber)
1 & 2 : quadrants
3, 4 & 5 : slats
100 m^2
1.1 10^6 electronic channels

Space resolution better than 100 µm
Geometry Monitoring System (GMS)
St. 4 and 5 used for High Level Trigger

Trigger

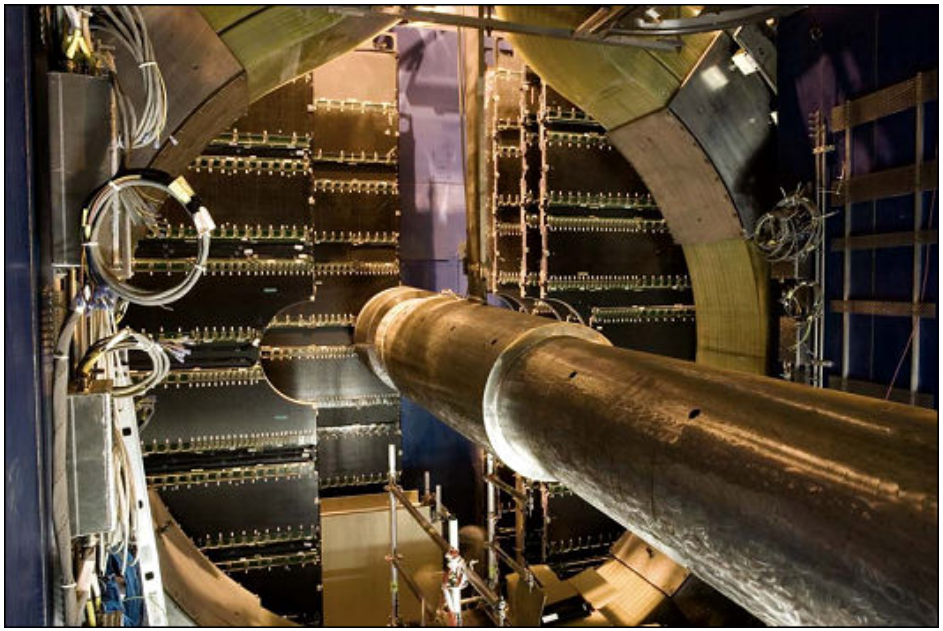
2 stations of 2 Chambers each
(72 RPCs)
150 m^2
2 10^4 channels

p_t cut on single muons
Trigger delivered in 800 ns

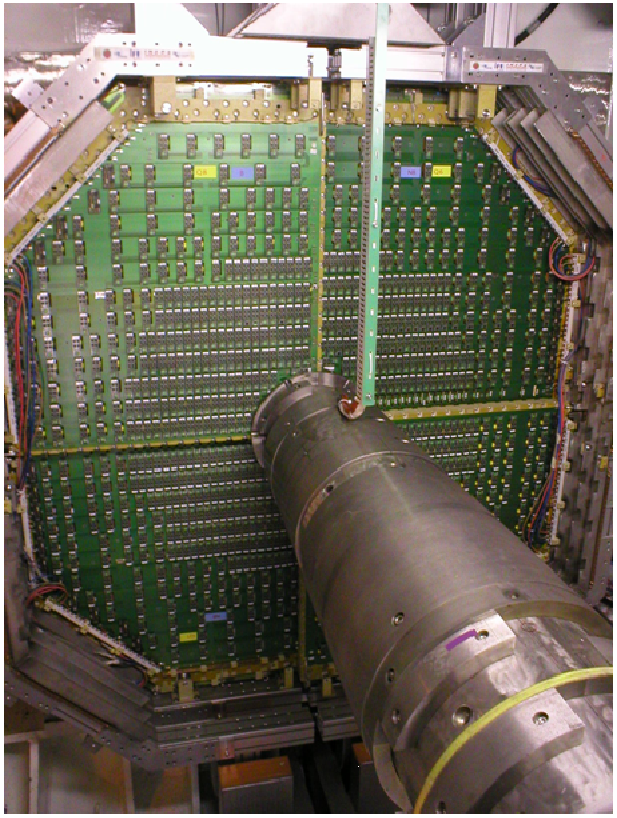


Tracking Chambers

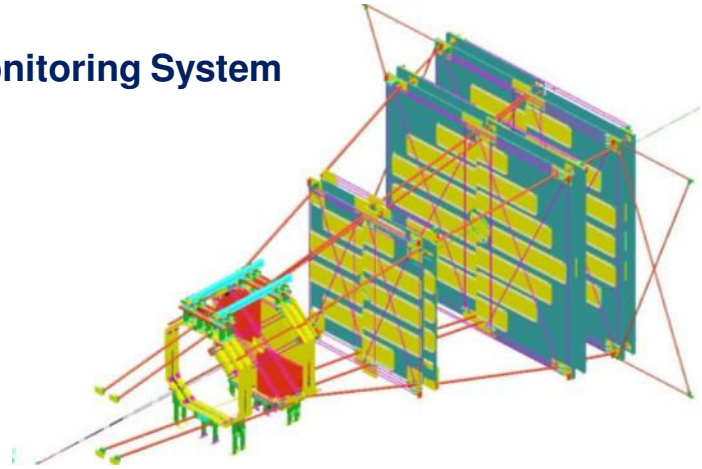
Slats on stations 3, 4 & 5



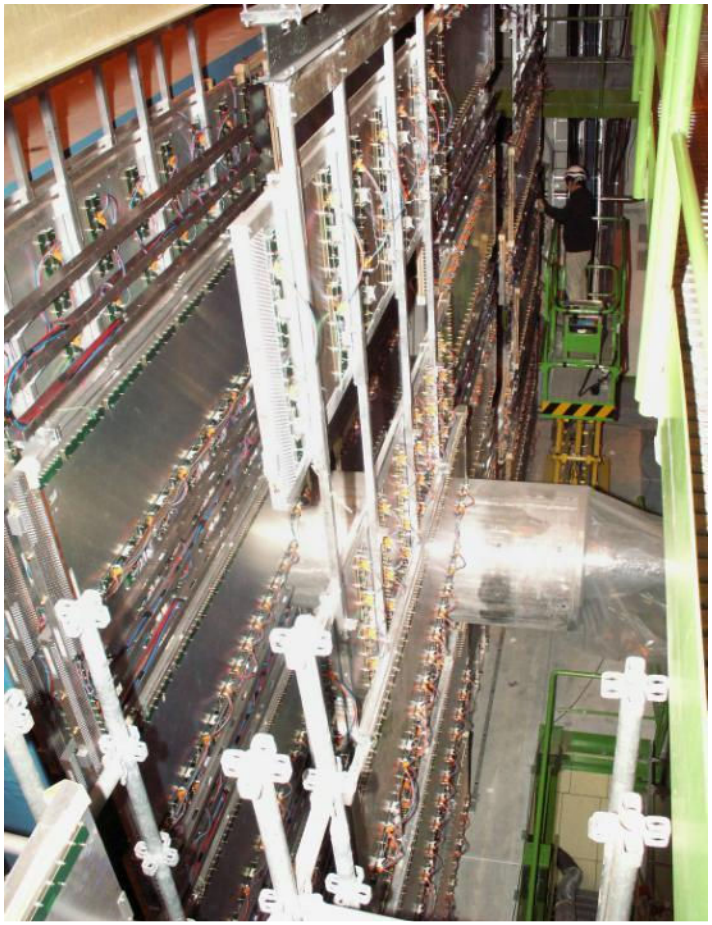
Quadrants on stations 1 & 2



Global Monitoring System

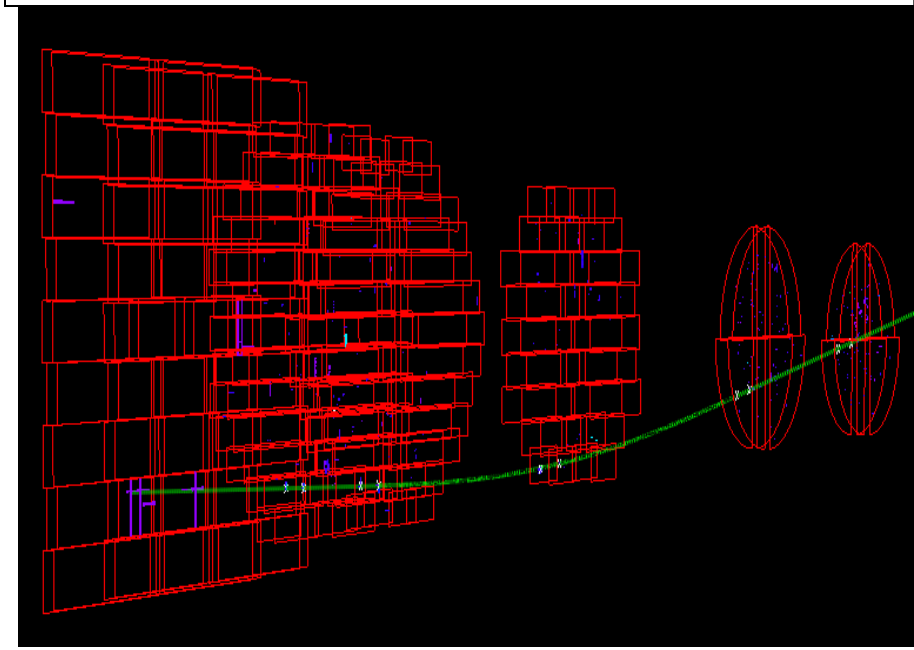


Trigger Chambers



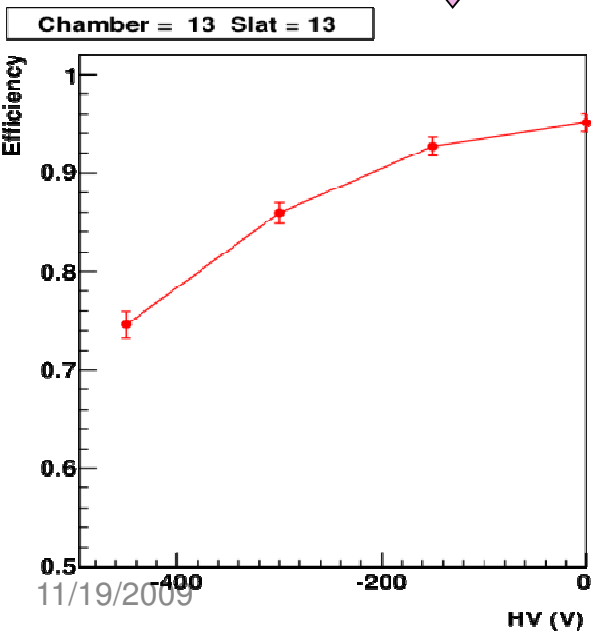
Muon Status

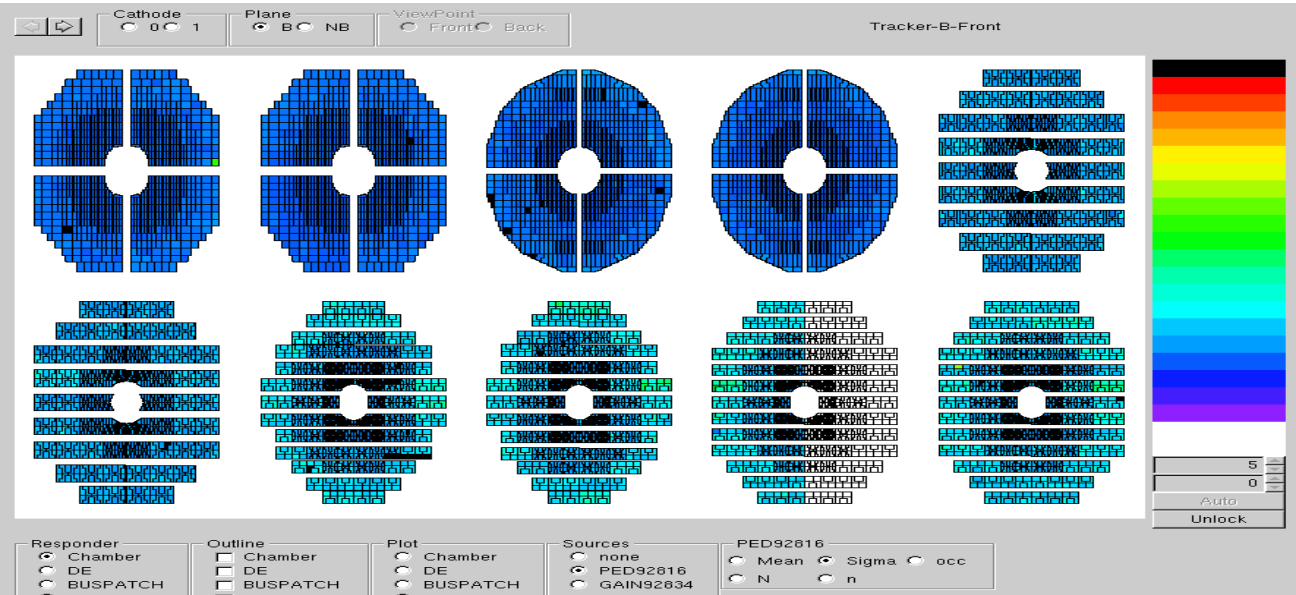
first cosmic muon in dipole magnetic field



- 4 weeks cosmic run August-September 2009
- **Stable and efficient data taking; detector configuration very close to the final one**
  - **Data taken with Dipole magnet on for the first time**
  - **Tracking: 96% of the detector operational and read-out;**
  - **Trigger: fully operational; RPCs operated in avalanche mode; HV scans to measure** chamber efficiency

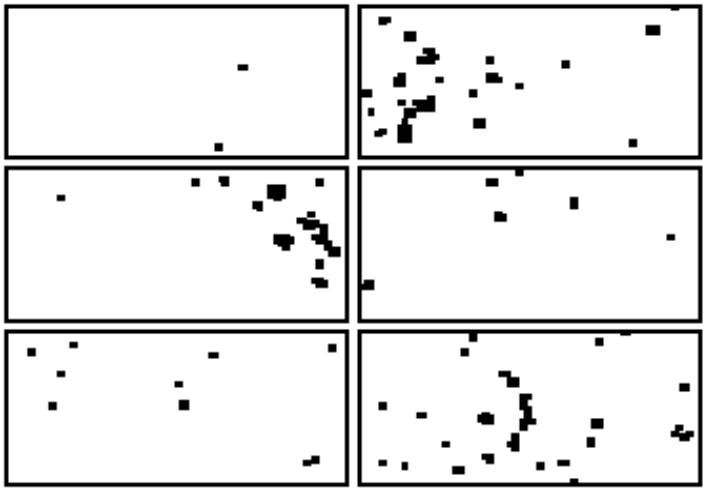
Chamber noise < 2 ADC counts (Bending plane)

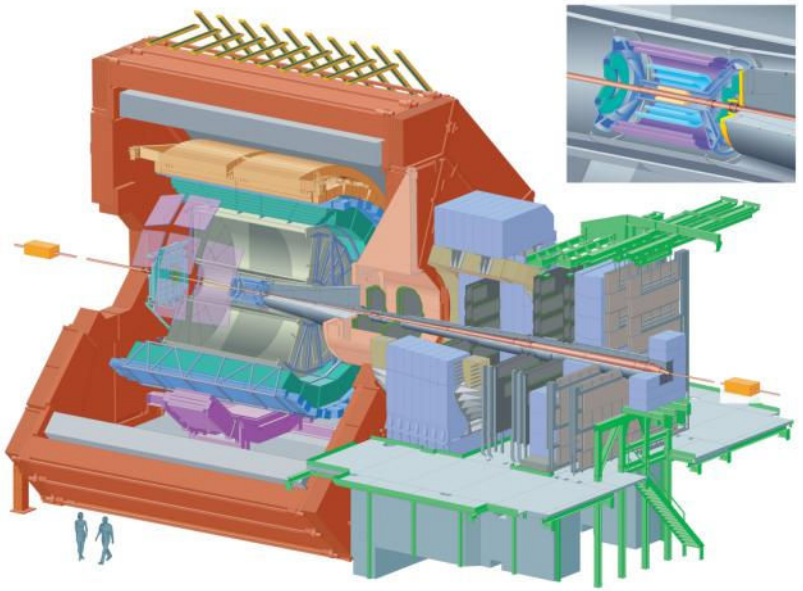




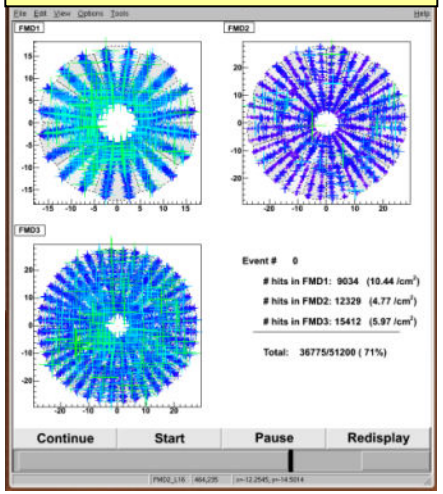
More Subsystems

HMPID cosmic event

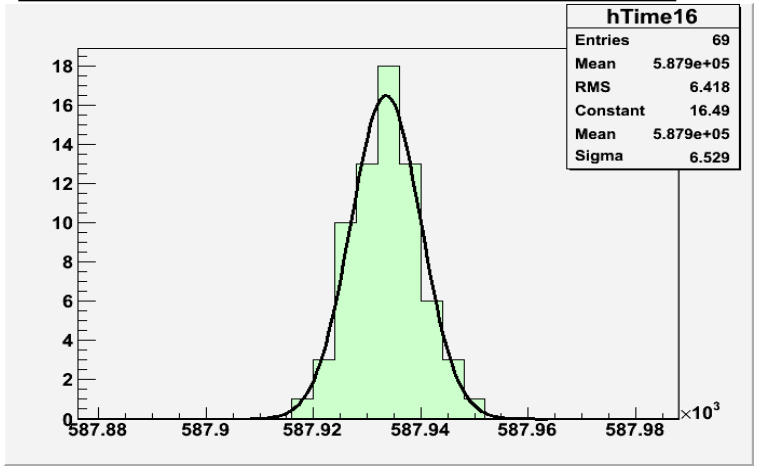




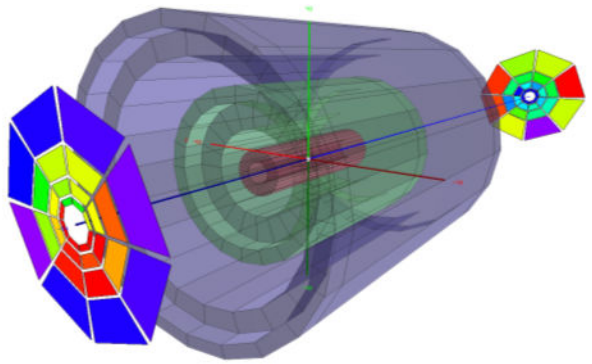
FMD event during injection tests



T0 time from injection test 6.5 channel sigma = 160ps

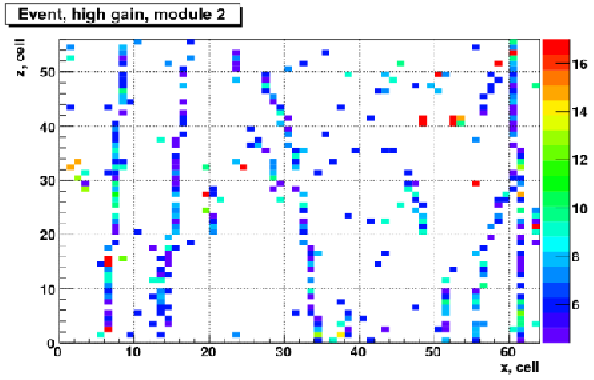


V0 event display

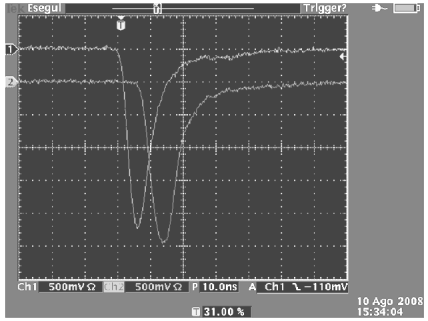


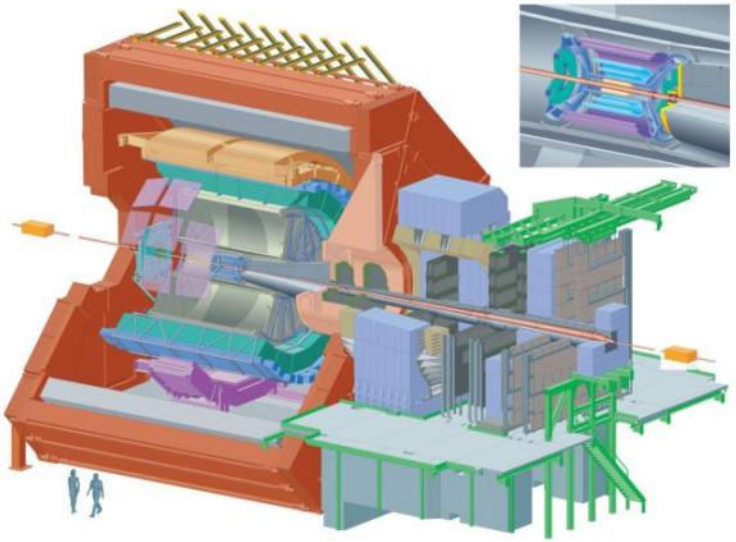
More Subsystems

Muon Tracks in PHOS module during injecton test

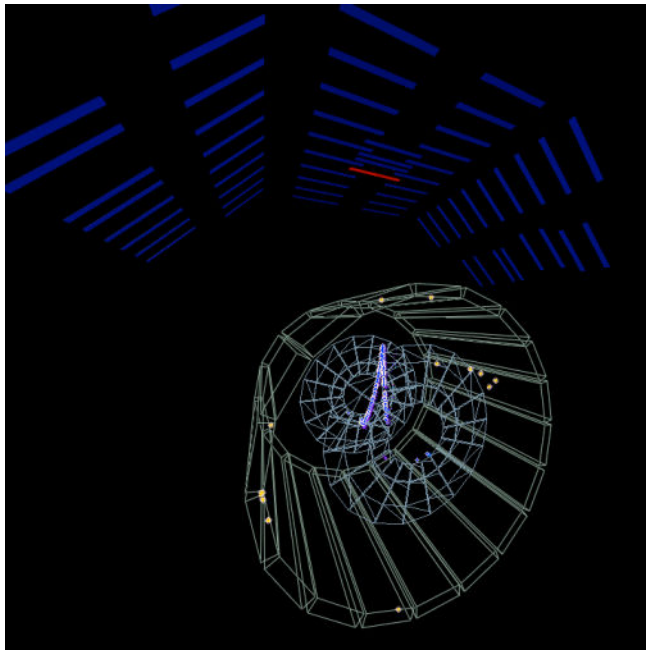


ZDC signals

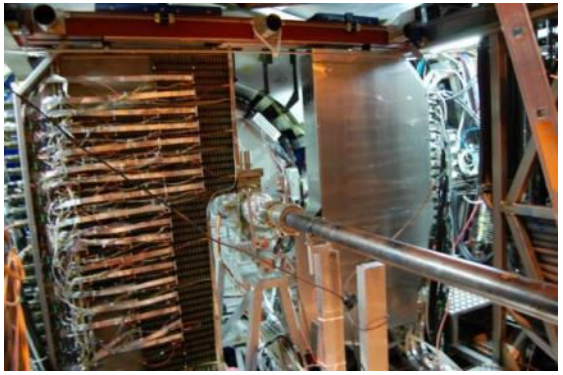




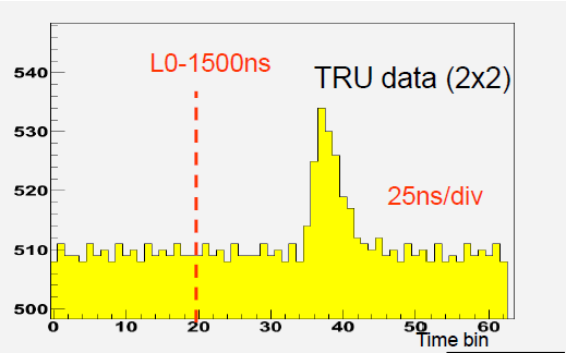
Cosmic Event Triggered by ACORDE Scintillator Array



PMD installed



First signals from EMCAL



Conclusions

ALICE is in very good shape for first collisions.

Extended Comic runs in 2008 and 2009 were performed and detector calibration is very advanced.

In addition to the Heavy Ion program ALICE also has a dedicated p+p program with unique possibilities.

We are eager to start …