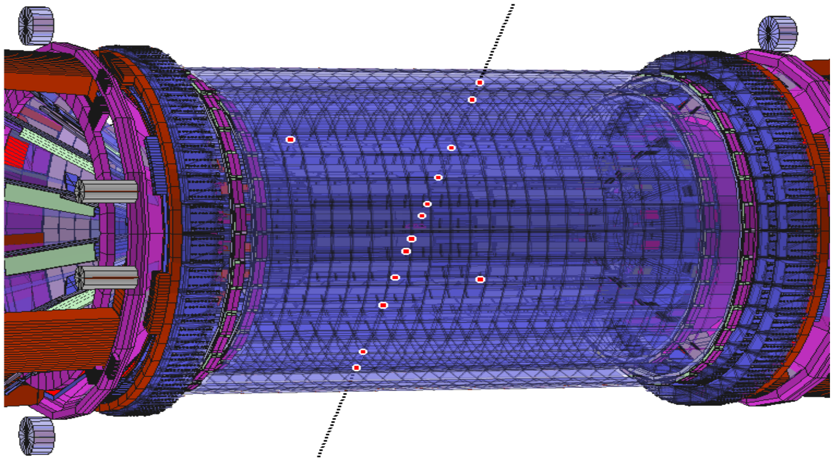
Operations and Performance of the Silicon Drift and Silicon Strip Detectors of the ALICE experiment



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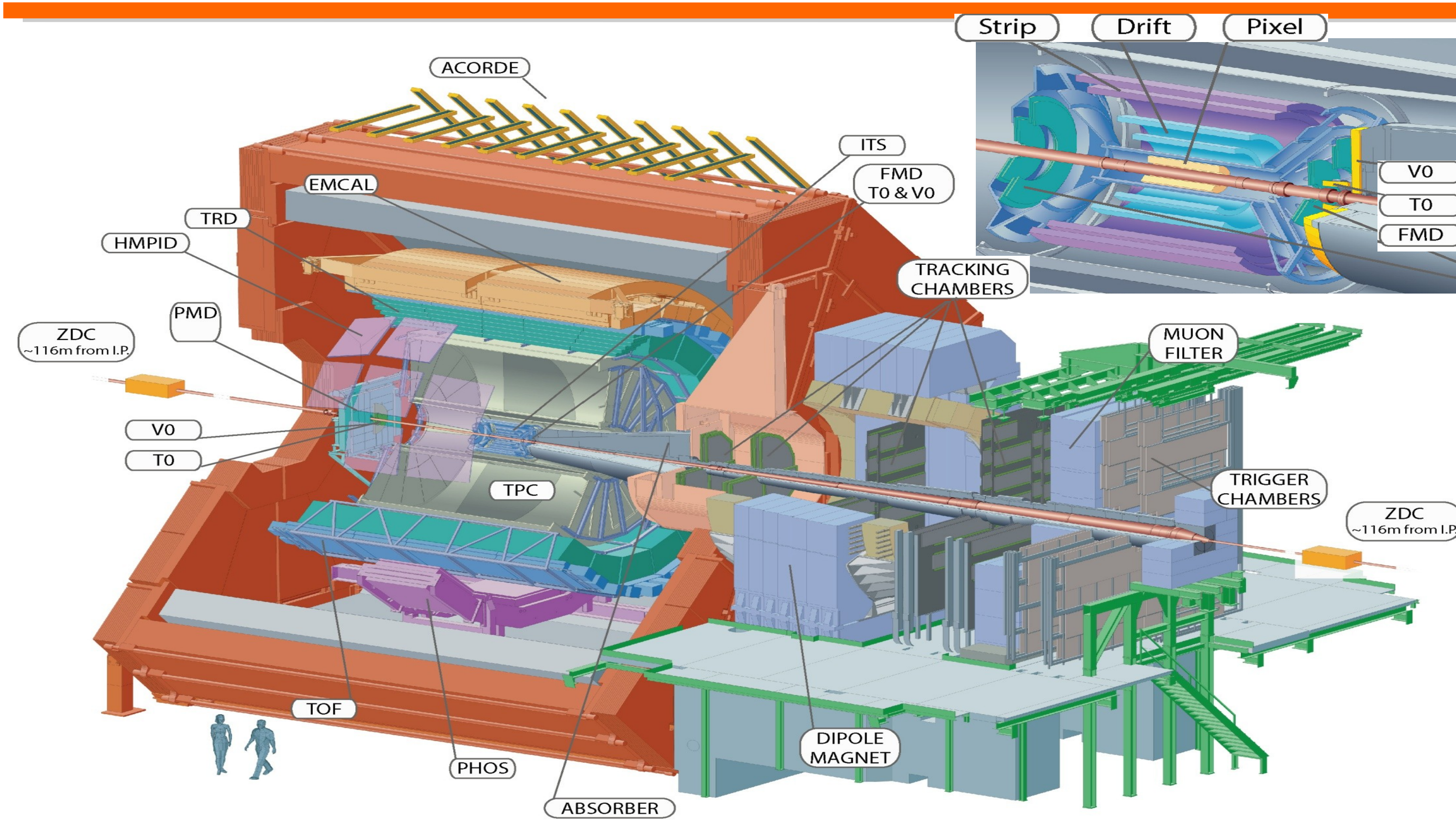
Overview

- The Inner Tracking System in ALICE
- The Silicon Drift & Strip Detectors
  - General description
  - Common and peculiar aspects
- Detector calibration during 2009-2010 data taking
  - Noise, bad channels, drift speed (SDD), L0 trigger alignment (SSD)
  - Monitoring and Quality Assurance
- Results from cosmic and pp runs
- Summary

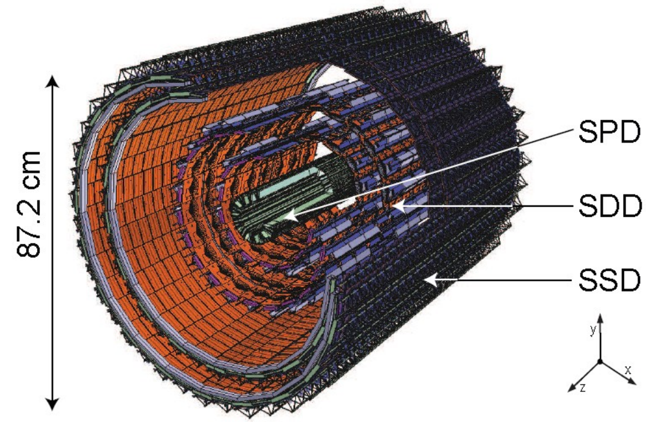
ALICE @ the LHC



Inner Tracking System

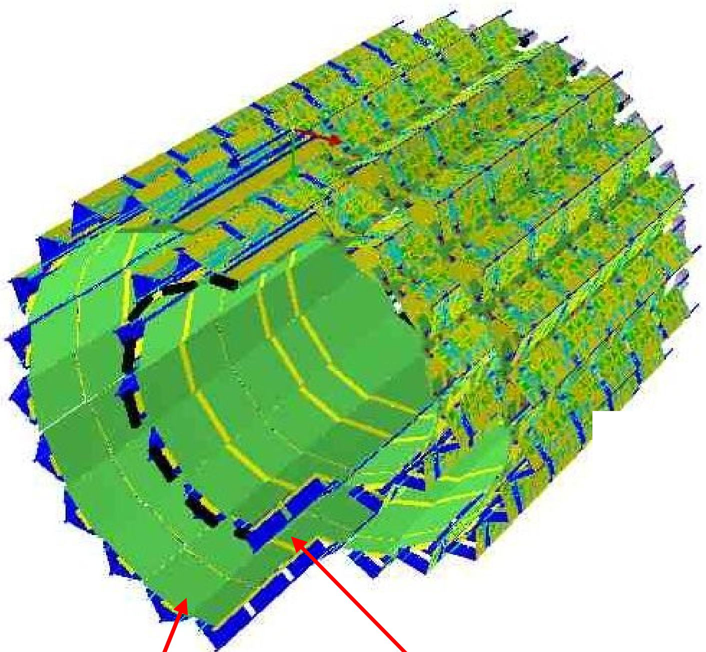
Design goals

- ❑ Optimal resolution for primary vertex and track impact parameter
  - Minimize distance of innermost layer from beam axis (<r>≈ 3.9 cm) and material budget (1.13-1.26% X0 SDD, 0.83-0.86% X0 SSD)
- ❑ Maximum occupancy (central PbPb) < few %
- ❑ 2D devices in all the layers
- ❑ dE/dx information in the 4 outermost layers for particle ID in $1/\beta^2$ region



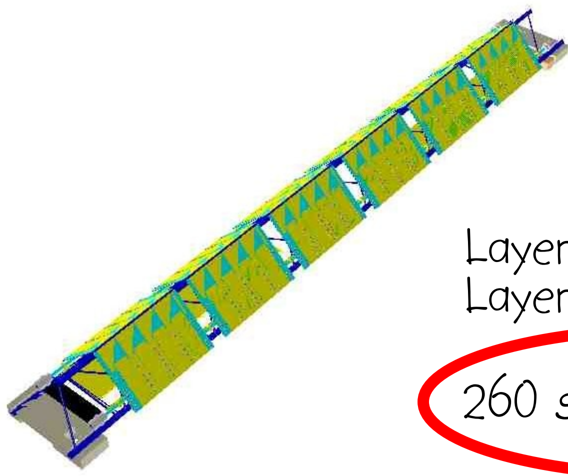
Layer	Det. Type	Radius (cm)	Length (cm)	Resolution (μm)		PbPb dN/dy=6000	
				rφ	Z	Part./cm^2	Occupancy (%)
1	SPD	3.9	28.2	12	100	35	2.1
2	SPD	7.6	28.2	12	100	12	0.6
3	SDD	15.0	44.4	35	25	3	2.5
4	SDD	23.9	59.4	35	25	1.5	1.0
5	SSD	38.0	86.2	20	830	0.6	4.0
6	SSD	43.0	97.8	20	830	0.45	3.3

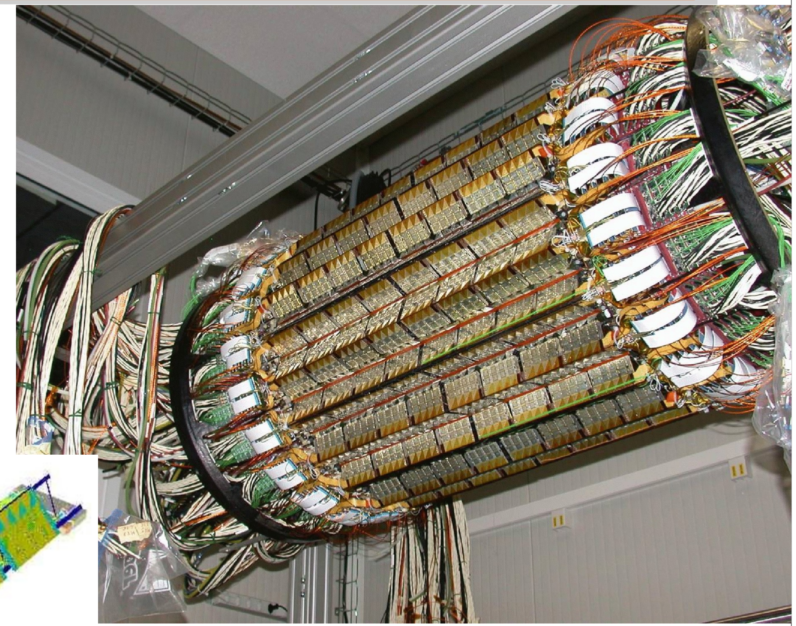
The Silicon Drift Detector



Layer 4
22 Ladders

Layer 3
14 Ladders

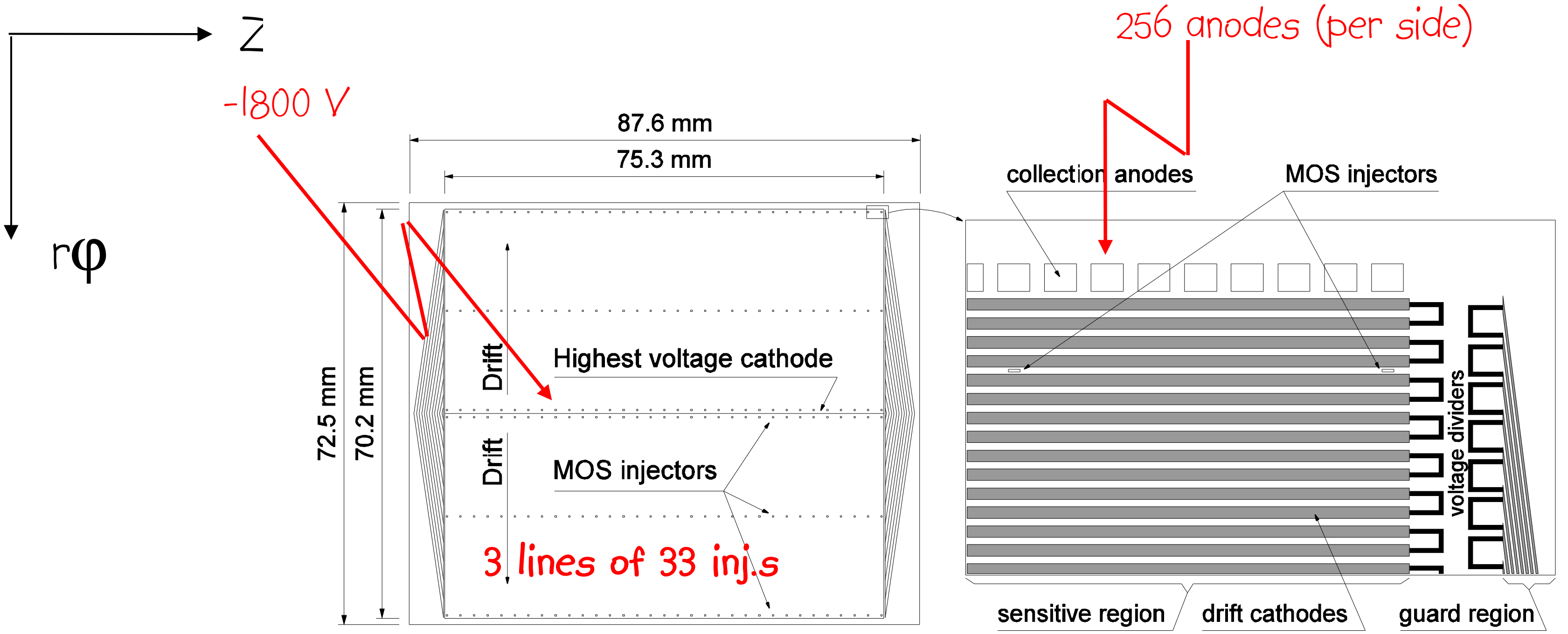




Layer 3: 6 sensors/ladder
Layer 4: 8 sensors/ladder

260 sensors in total

The SDD Sensor



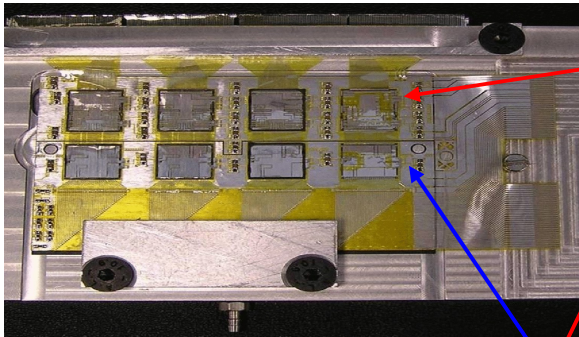
Drift speed ~ 6.5 μm/ns

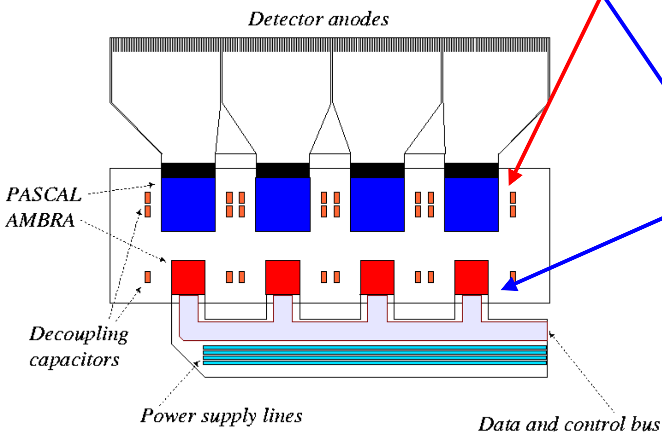
Av. resolution (z)(*) 25 μm

Av. resolution (rφ)(*) 35 μm

(*) from beam test

SDD Front-End Electronics





PASCAL (Preamplifier, Analog Storage and Conversion from Analog to digital) (64 channels each)

- preamplifier
- analog storage
- ADC
- @ 20 or 40 MHz

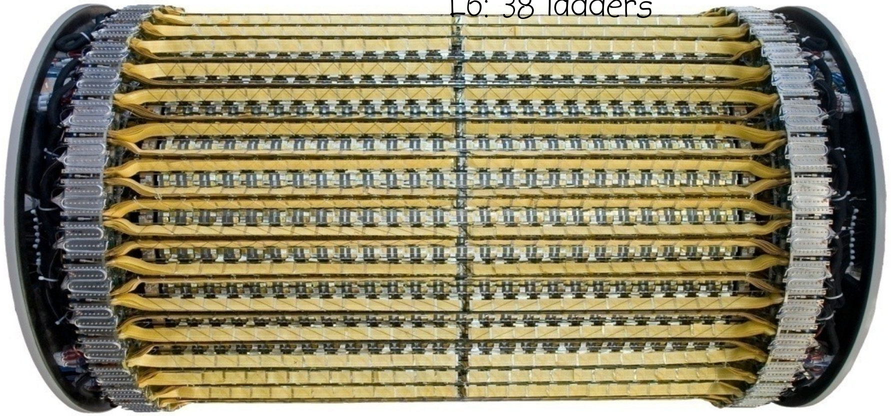
AMBRA (A Multievent Buffer Readout Architecture) (input from PASCAL)

- digital multibuffer
- anode-by-anode baseline equalization
- non-linear data compression (10 to 8 bits)

The Silicon Strip Detector (SSD)

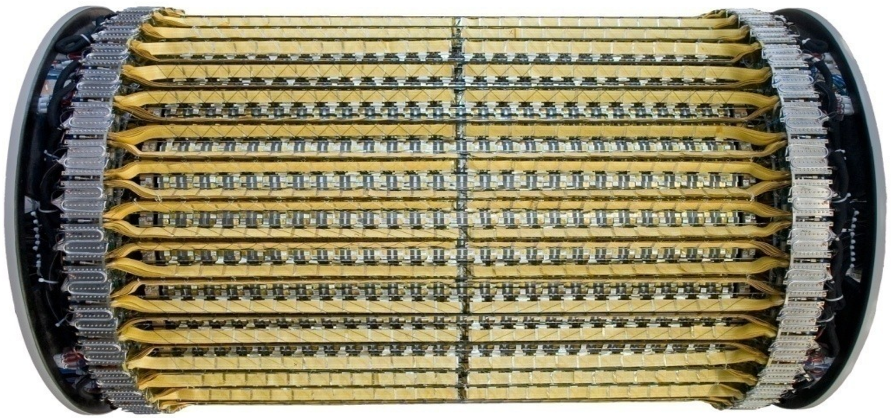
Table 3.11. SSD system parameters.

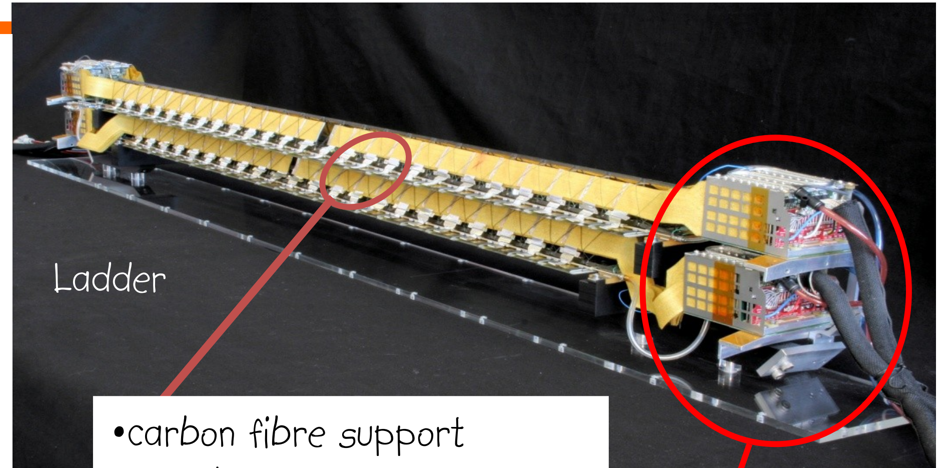
Sensor active area	73×40 mm^2
Sensor total area	75×42 mm^2
Number of strips per sensor	2×768
Pitch of sensors on a ladder	39.1 mm
Strip pitch on a sensor	95 μm
Strip orientation p side	7.5 mrad
Strip orientation n side	27.5 mrad
Spatial precision $r\varphi$	20 μm
Spatial precision z	820 μm
Two track resolution $r\varphi$	300 μm
Two track resolution z	2400 μm
Radius layer 5 (lowest/highest)	378/384 mm
Radius layer 6 (lowest/highest)	428/434 mm
Number of ladders layer 5	34
Number of ladders layer 6	38
Modules per ladder layer 5	22
Modules per ladder layer 6	25
Number of modules layer 5	748
Number of modules layer 6	950
Material budget SSD cone	$0.28X_0$
Material budget per SSD layer	$0.81X_0$ (layer 5), $0.83X_0$ (layer 6,



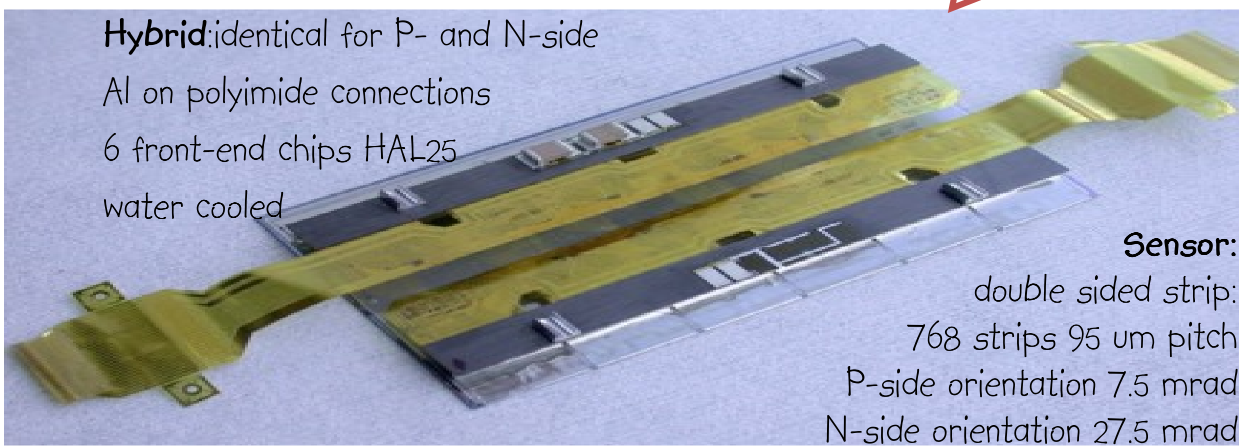
- SSD (Silicon Strip Detector): the two outer layers of the ITS
- 72 ladders (22 or 25 modules each)
- 1698 modules (> 2.5M output channels)
- Layer 5: r = 37.8 - 38.4 cm - Layer 6: r = 42.8-43.4 cm
- Acceptance $|\eta| < 1.0$ (matches the one of the TPC)

SSD: some details



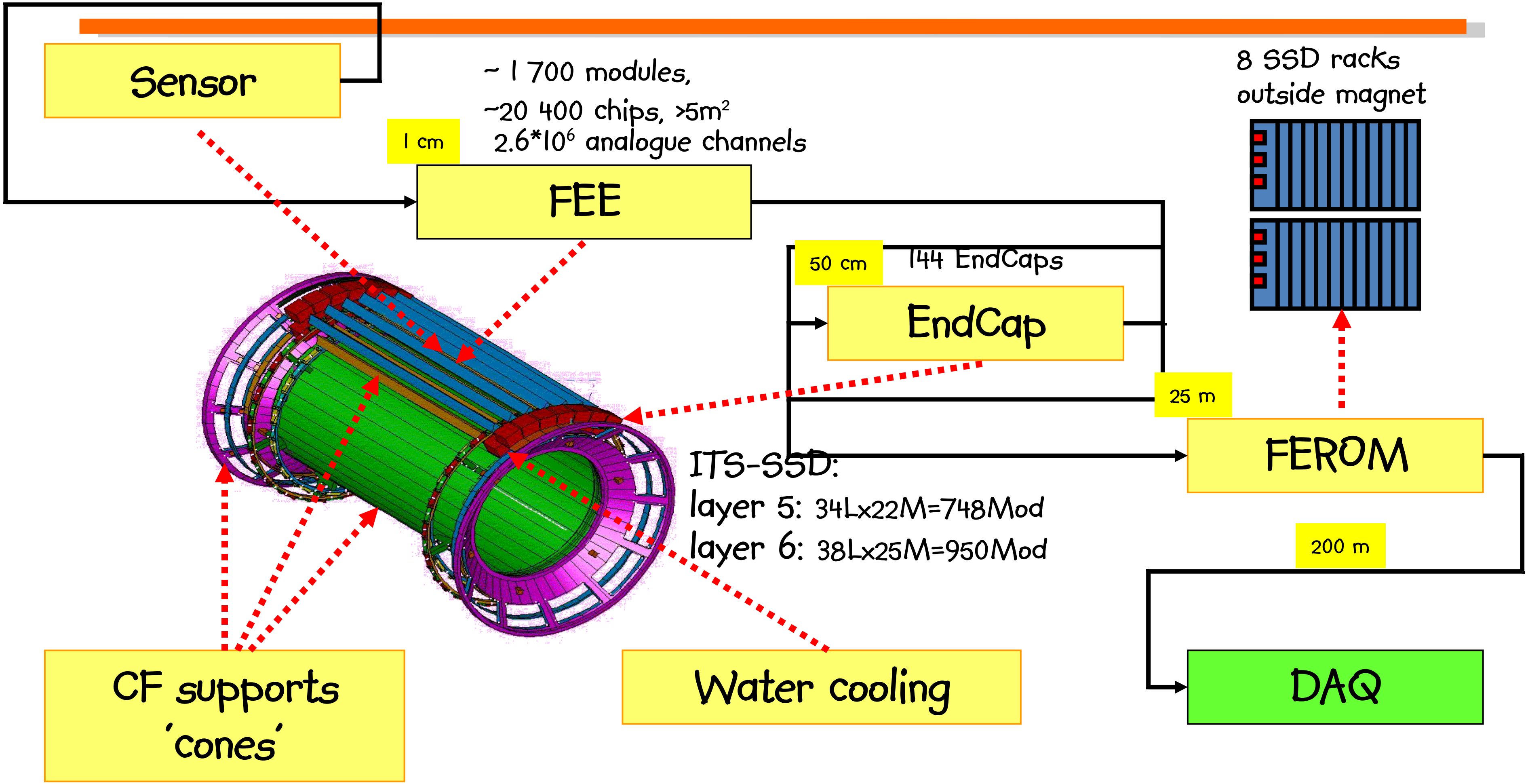


- carbon fibre support
- module pitch: 39.1 mm
- Al on polyimide laddercables



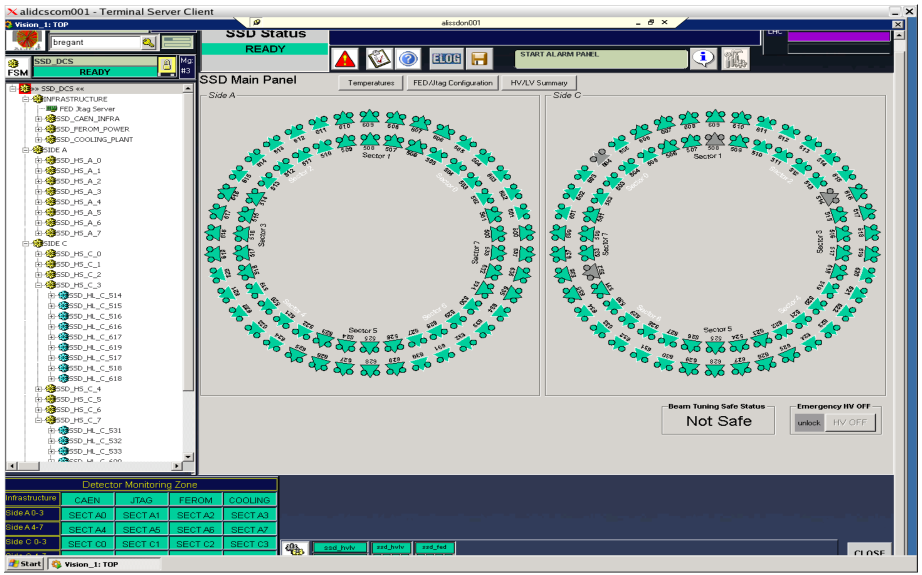
End ladder electronics

SSD General layout



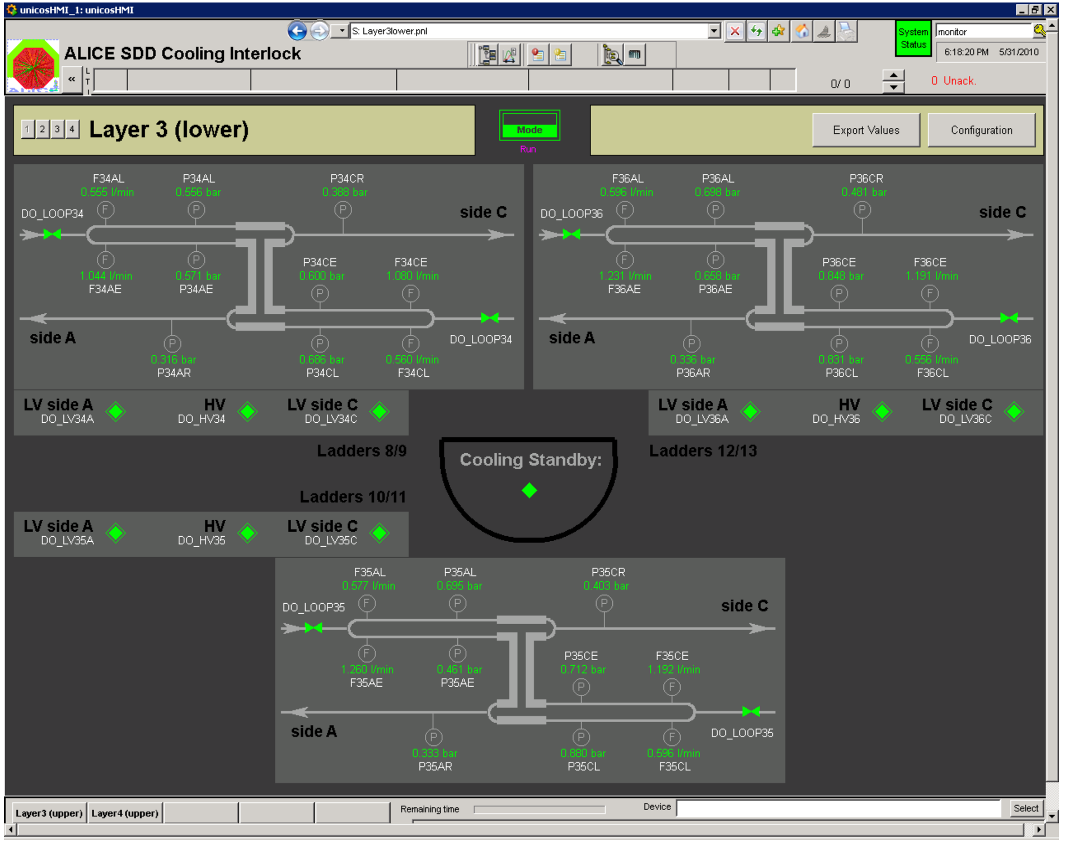
SSD Detector Control System

- ❑ The SSD was one of the first systems operated remotely via the DCS interface.
  - o Based on PVSS under a windows platform.
- ❑ Tree based structure that provides the possibility to navigate through different levels (sector, ladder, …)
  - o Automatic warnings, errors are implemented.
  - o Possibility to load different settings (bias values) apart from the default configuration.
  - o Control the main power supplies (CAEN).
  - o Monitor the performance of the cooling system.
  - o Monitor the conditions within the SSD barrel (R.H.)



Cooling system

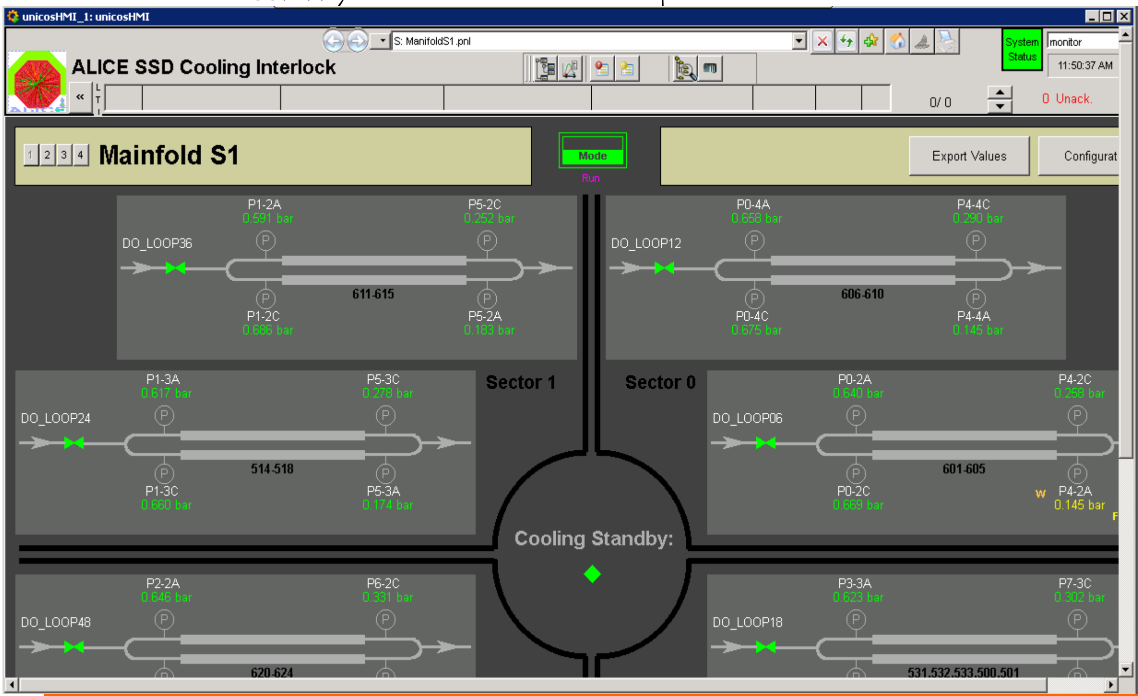
- Water cooled
- Partially common to both subsystems (heat exchanger, purifier, circulation pump, underpressured water tank)
- For the SDD:
  - inside pressure < 1 bar (leak safe)
  - flow in intermediate state between laminar and turbolent (maximum heat transfer)
  - controlled by dedicated PLC

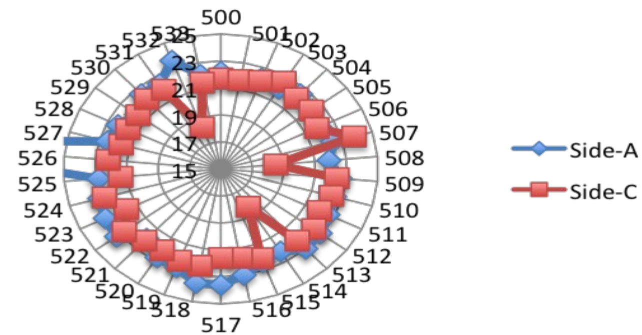


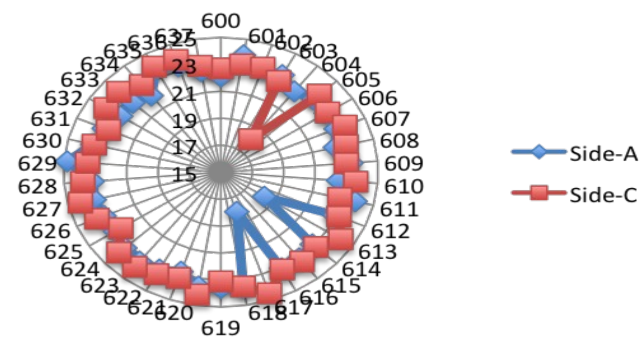
Cooling system

For the SSD:

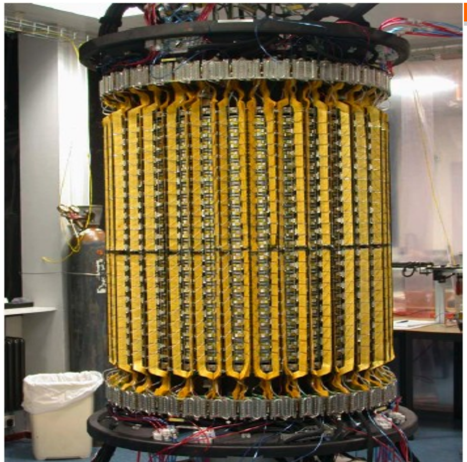
- Counter-flow on ladders in thin (40 μm) pipes
- Endcaps cooled in series
- Water supplied at 17°C – no heat transfer for the SDD and the TPC
  - Possibility to tune the water temperature







Commissioning – Milestones

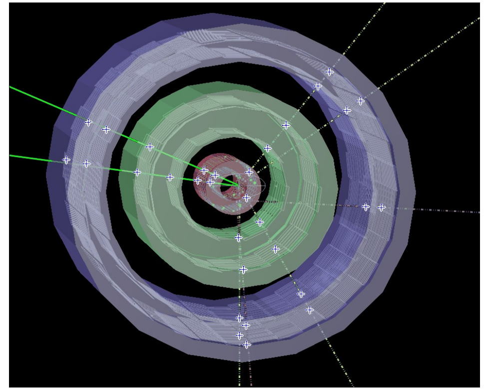


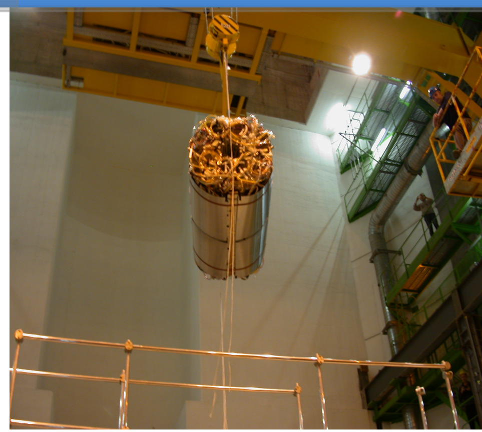
2006

- Assembly of the SDD in Turin (Jun-Dec) and transport to CERN
- Assembly of the SSD in Utrecht and transport to CERN.
- The full detector was tested at CERN in the experimental area.
  - Results showed that 16 modules of layer 5 and 9 of layer 6 were not working ➔ 25 dead modules out of 1698 (~1.3%).

2007

- SSD+SDD were moved to the interaction point (March 2007).
  - The SSD was one of the first detectors to have all systems integrated
- C/A-side connection tests (July/September 2007).
- Cosmic run I: partial cooling ➔ only part of the C-side was powered (December 2007) .





2008

- Cosmic run II: partial cooling (February 2008).
- Cooling plant upgrade (May 2008)
- Cosmic run III (June – August 2008)
  - Collected data for alignment and calibration
- Ready for first collisions (September 2008)

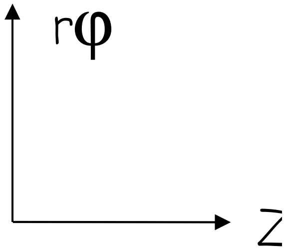
2009/2010

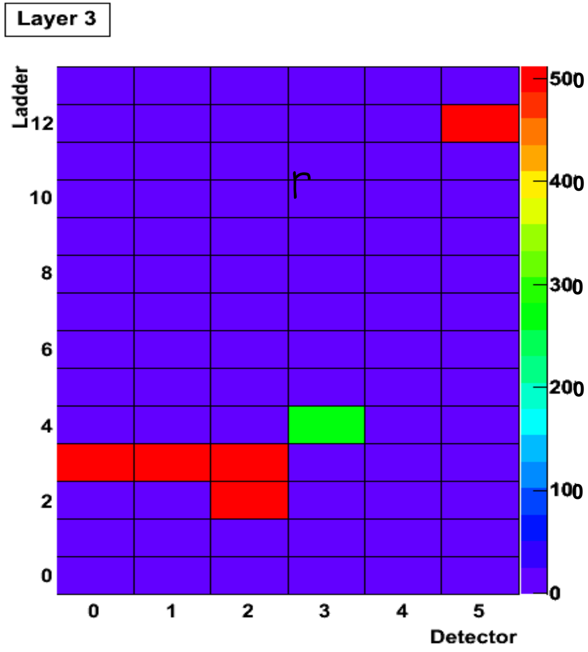
- Mini-frame upgrade (April 2009):
  - Recabling of the SSD with local tests to validate connections.
- Cooling plant/ Firmware upgrades (May 2009)
- Re-commissioning phase (June 2009).
- Cosmic run IV (August 2009).
- First collisions at 0.9 and 2.36 TeV (December 2009)
- LHC winter shutdown
- LHC back in March 2010
- pp run at 7TeV but also additional runs at 0.9TeV

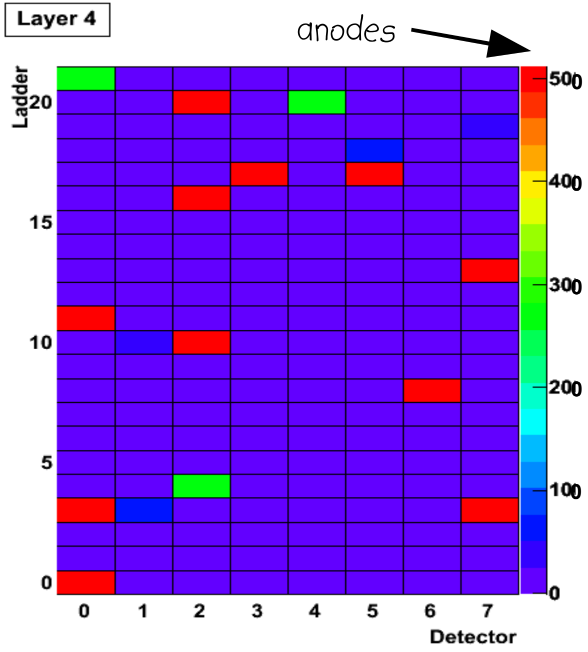
SDD Bad channels

- During p-p data taking (end of 2009)
  - 16 modules (out of 260) out of DAQ due to FEE or HV problems; ~92.5% modules in DAQ
  - 4 modules with 1 hybrid disconnected (½ of channels dead)
  - ~ 99% of good channels in good modules

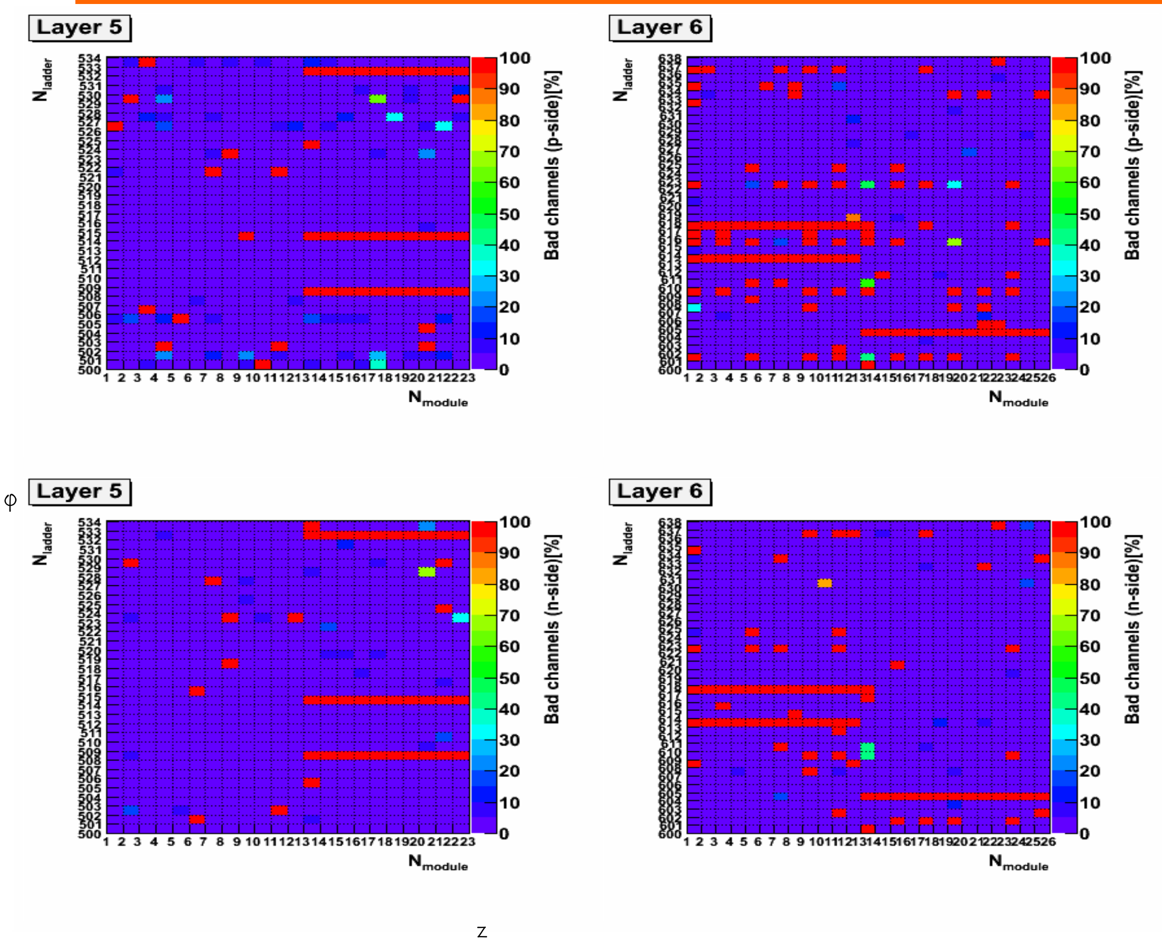
Colors represent number of bad anodes





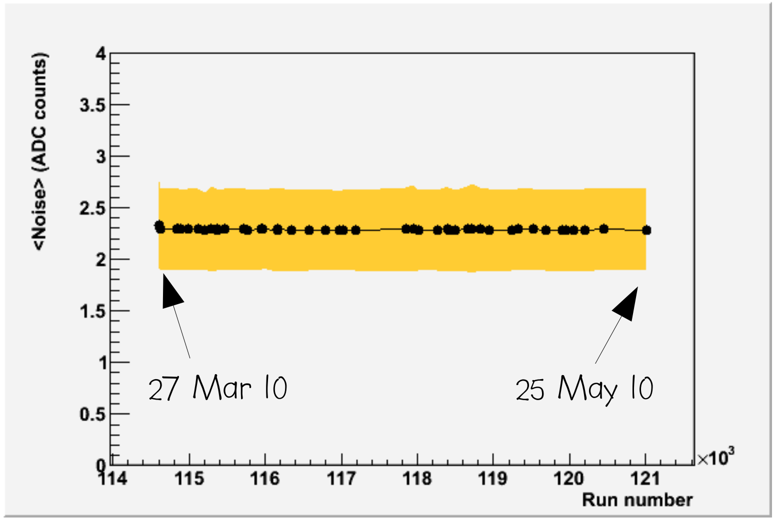


SSD Bad channels



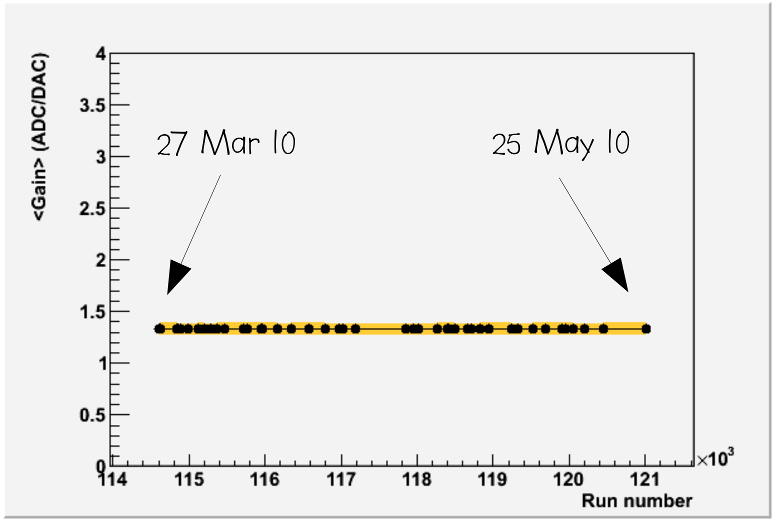
- Total of ~2.6M channels.
- ~90% of the channels are active in the DAQ.
- 6 half-ladders switched off due to electrical problems
  - ~4.2% of the total channels
- Few modules manually masked due to noisy areas.
- Detector Algorithm (DA) runs online to detect noisy channels

SDD Noise and Gain



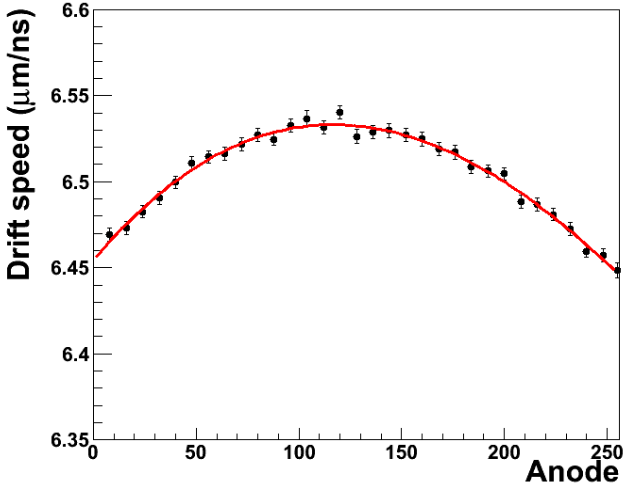
- PEDESTAL run
  - Analyzes special SDD calibration runs taken without zero suppression during LHC fill periods
  - Provides: **Baselines**, **Noise**, **Common Mode Corrected Noise**, **Noisy anodes**

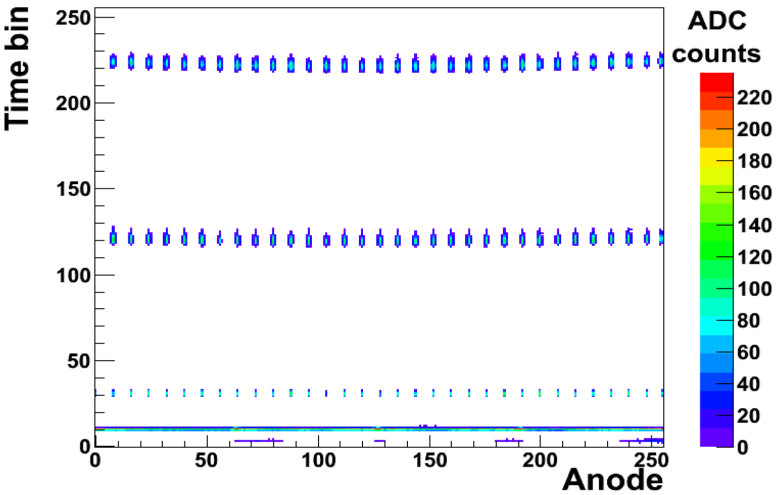
- PULSER run
  - Analyzes special SDD calibration runs taken with Test Pulse signal to front-end electronics
  - Provides: **Anode gain, Dead anodes**



SDD Drift Speed Measurement

- 33 (1 each 8 anodes) x 3 MOS injectors on each half module
- Drift speed is extracted from a fit of the measured drift time vs. the known drift distance



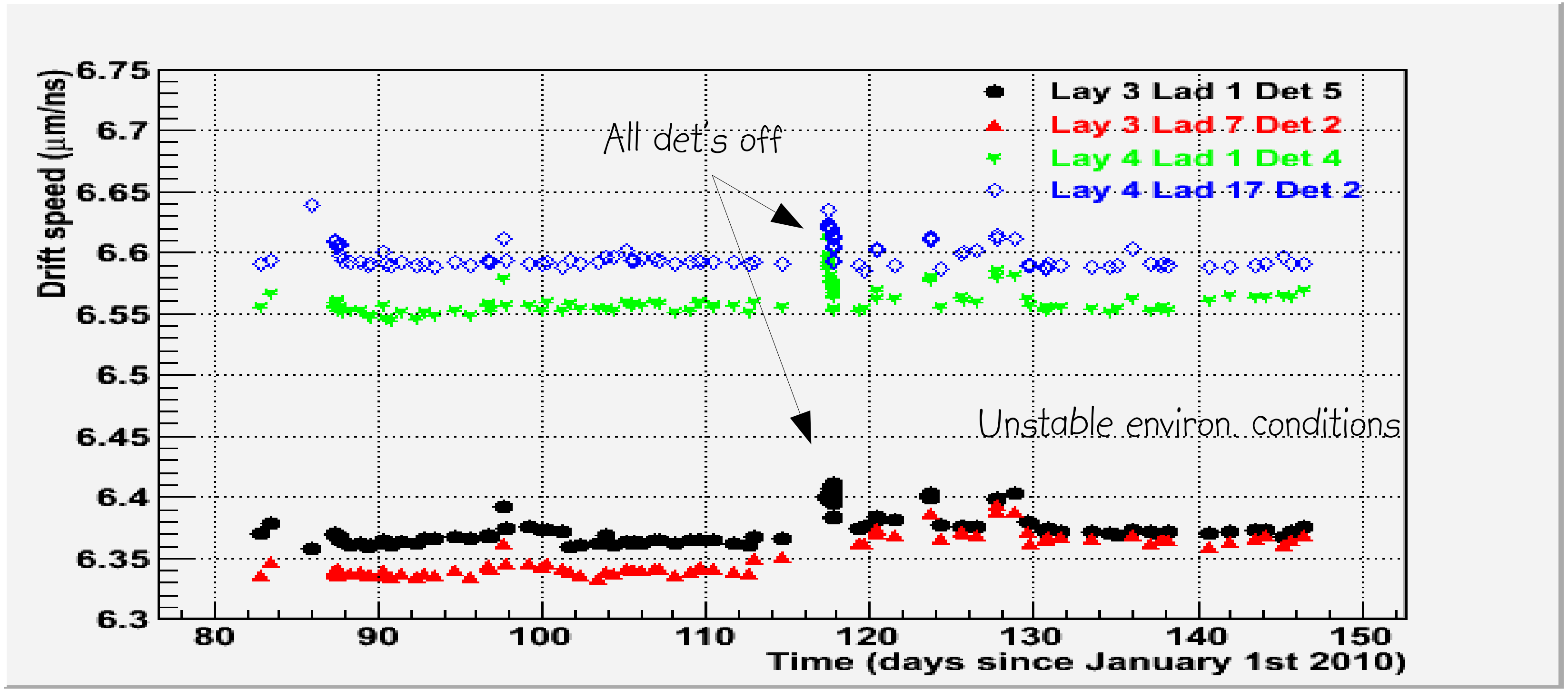


- Drift speed depends on anode number
  - ⇨ inversely proportional to temperature ($\propto T^{-2.4}$)
  - ⇨ heat sources (voltage dividers) located on module edges

SDD Drift Speed vs. Time

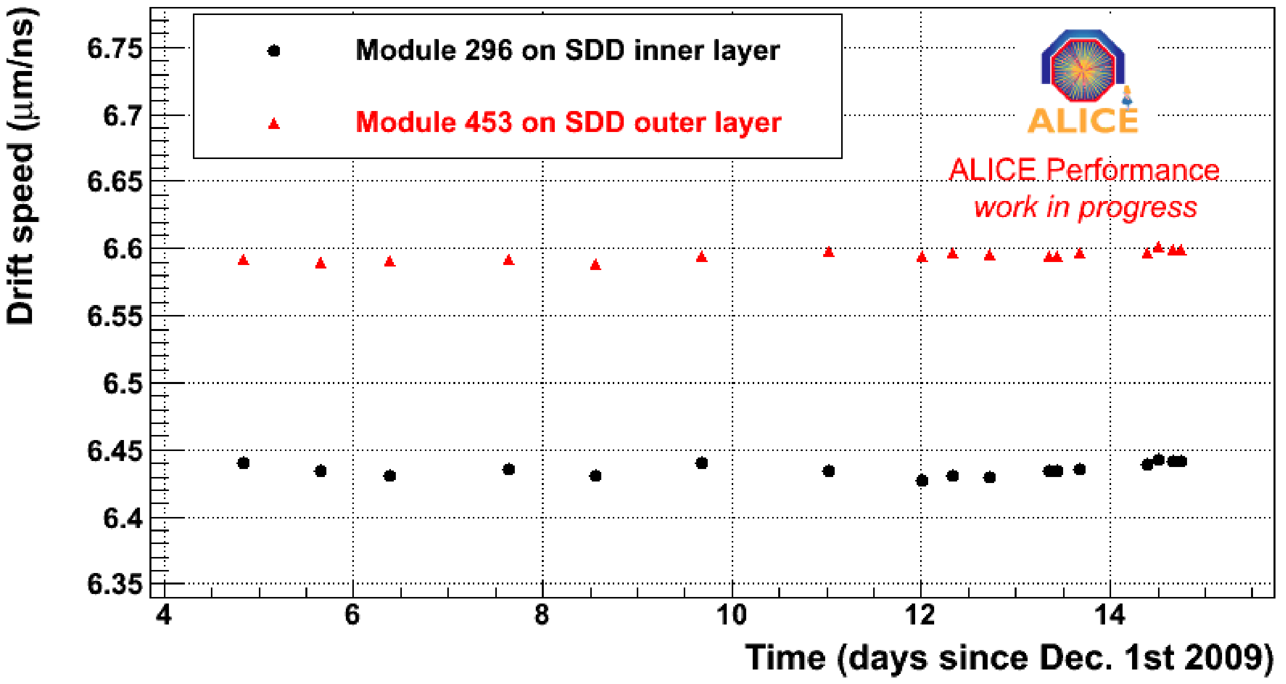
- Drift speed depends on
  - Temperature
  - Dopant concentration (module-by-module difference)

$$v_{drift} = \mu_e E \quad , \quad \mu_e \propto T(K)^{-2.4}$$

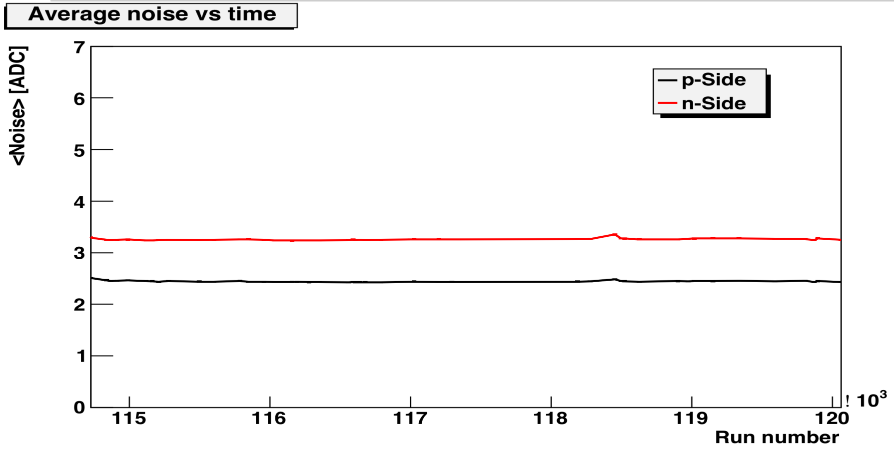


SDD Drift Speed vs. Time

- With stable conditions (2009 pp data taking) v_{drift} much more stable

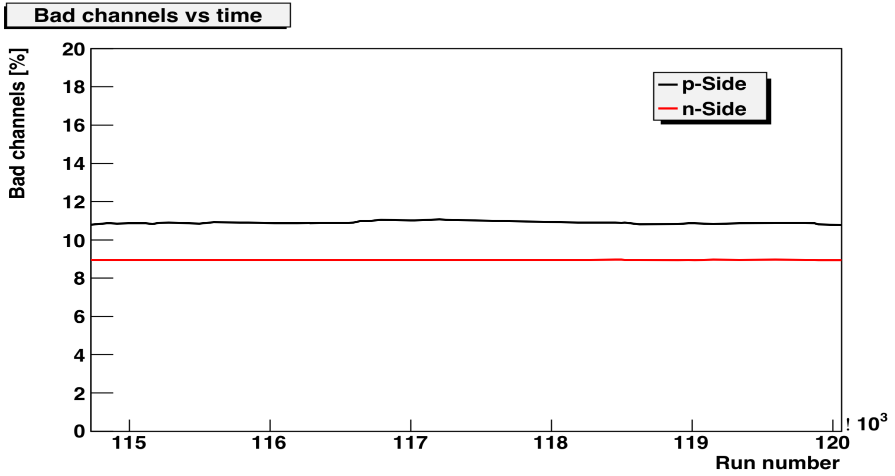


SSD: Time evolution of noise/bad channels



- Average p-side noise ~ 2.4 ADC – average n-side noise < 3.5 ADC
- Stable noise vs time

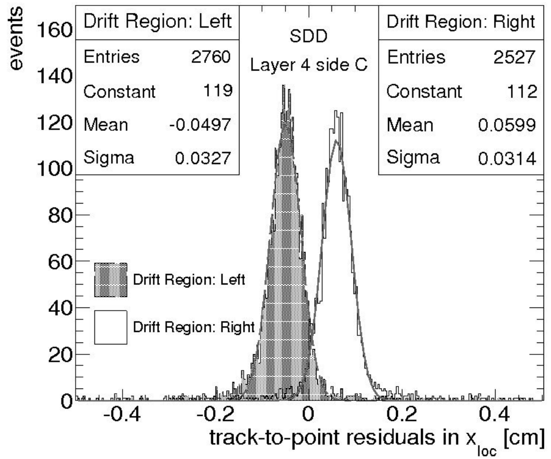
- More bad channels on layer 6 than on layer 5.
  - Mainly originating from SINTEF modules that exhibit a noise level above the average one.
- Stable bad channel map vs time

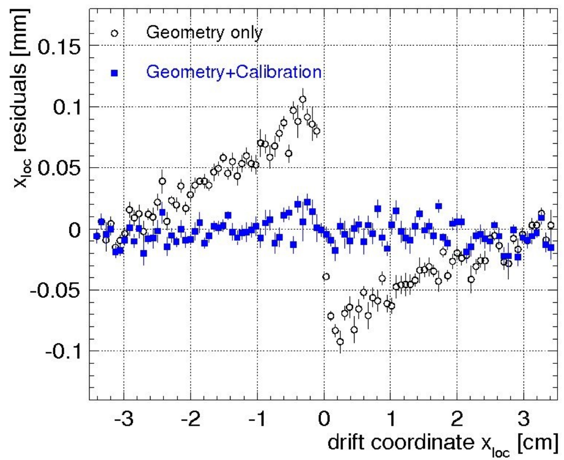


SDD Time-zero Calibration

Two strategies have been developed on simulated data

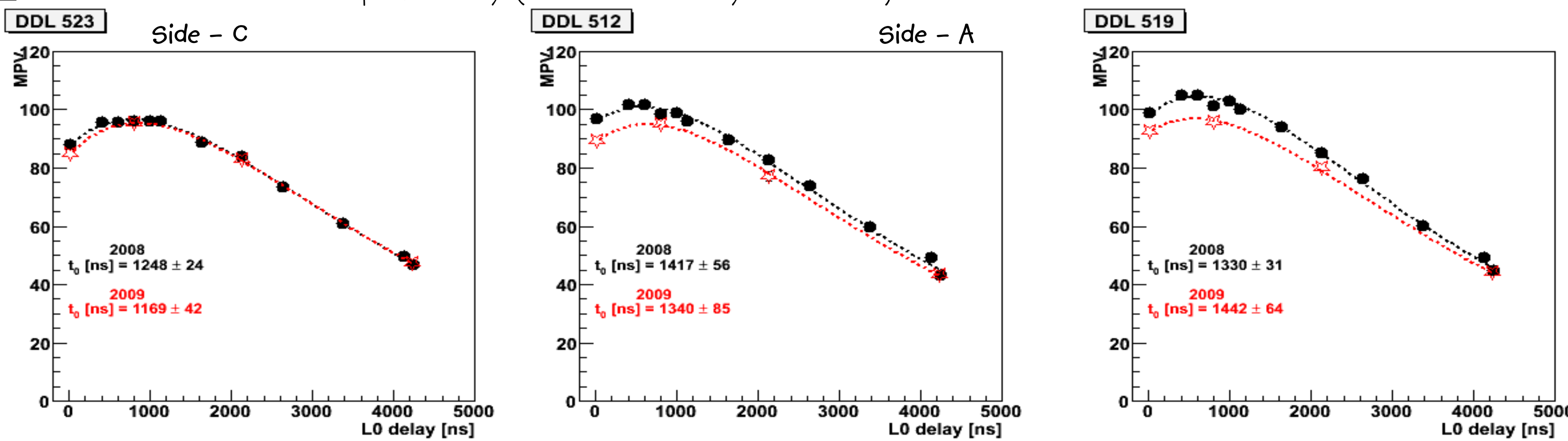
- Minimum drift time
  - Time offset extracted from time distribution of all the measured clusters
- Analysis of track-cluster residuals
  - Time offset extracted by exploiting the opposite sign of residuals in the two detector sides
- Results from the track-cluster residuals from cosmic data
  - Track fitted in SPD and SSD, residuals calculated in SDD
  - Difference between Time Zero in side A and C (partly) due to different cable lengths





SSD L0 trigger alignment

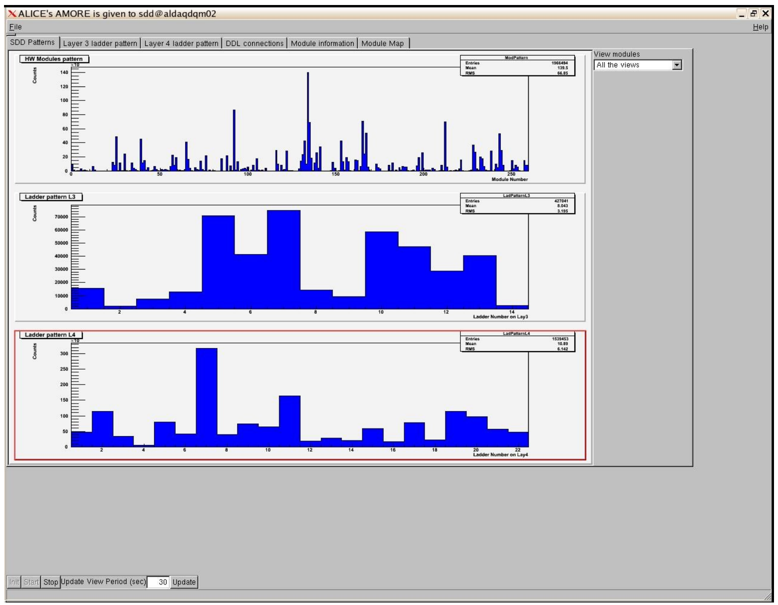
- Doesn't affect the alignment (cluster position) but rather the strength of the signal
  - Better S/N ratio when sample the signal on the peak
- FEROMs receive the L0 and send the HOLD signal to the HAL25 chip
- The delay between receiving L0 and sending HOLD is programmable (0 -> 4250ns)
- The best choice for this delay depends on:
  - cable length ("trigger detector" -> CTP, CPT->LTU, LTU->FEROM, FEROM->endcap),
  - internal electronics delays,
  - chosen shaping time.
- Needs to be measured experimentally (unless all the delays are known)



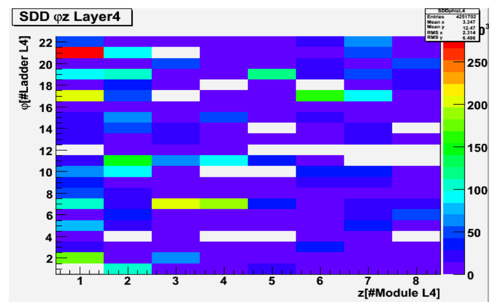
Loss of signal (~10%) due to the mini-frame upgrade (longer cables with more loss)

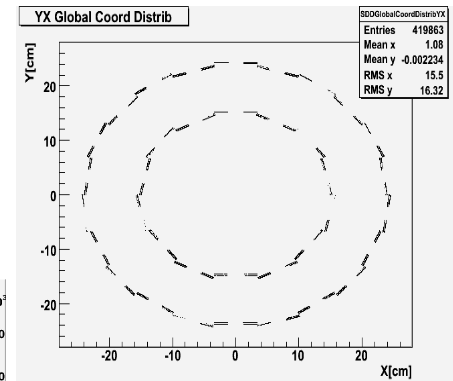
SDD Monitoring

- Online monitoring inside official AMORE framework (AMORE agents)
  - detailed histograms for SDD/ITS shifter
  - summary histograms for central DQM shifter



- Offline monitoring with same official ALICE offline code (AliRoot)
  - detailed histograms in expert mode
  - summary histograms for offline shifter
  - successfully tested during cosmic runs





SSD: Quality assurance (online/offline)

Online

- ❑ Usage of MOOD (experts) and AMORE (shifters – fast feedback).
- ❑ Monitor raw data integrity as they arrive either from the LDC or from the GDC.
- ❑ To come:
  - ❑ Quasi-online reconstruction using the HLT cluster
  - ❑ Monitor reconstructed points.
  - ❑ Implementation of the automatic checks and issuing of warnings/errors.

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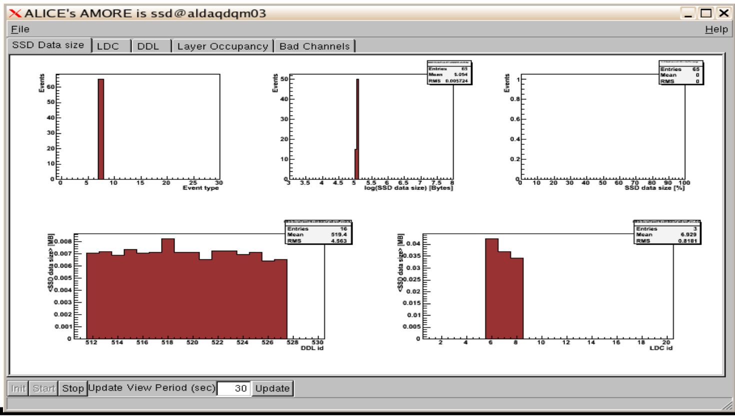
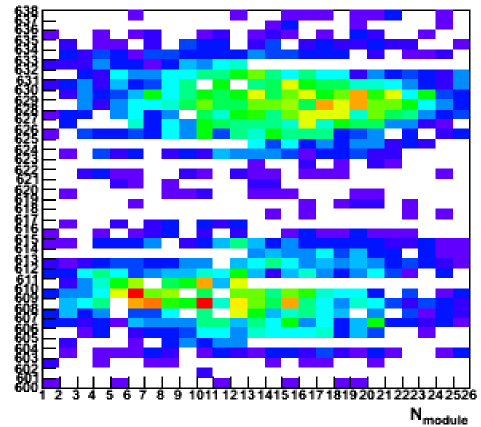
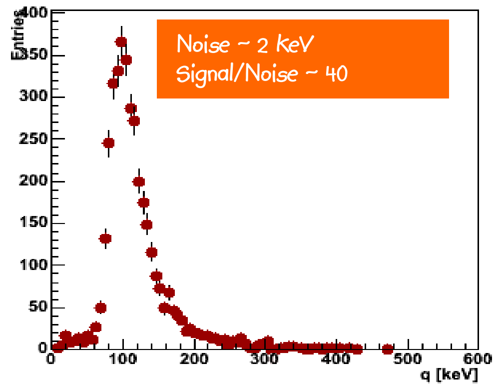


Offline

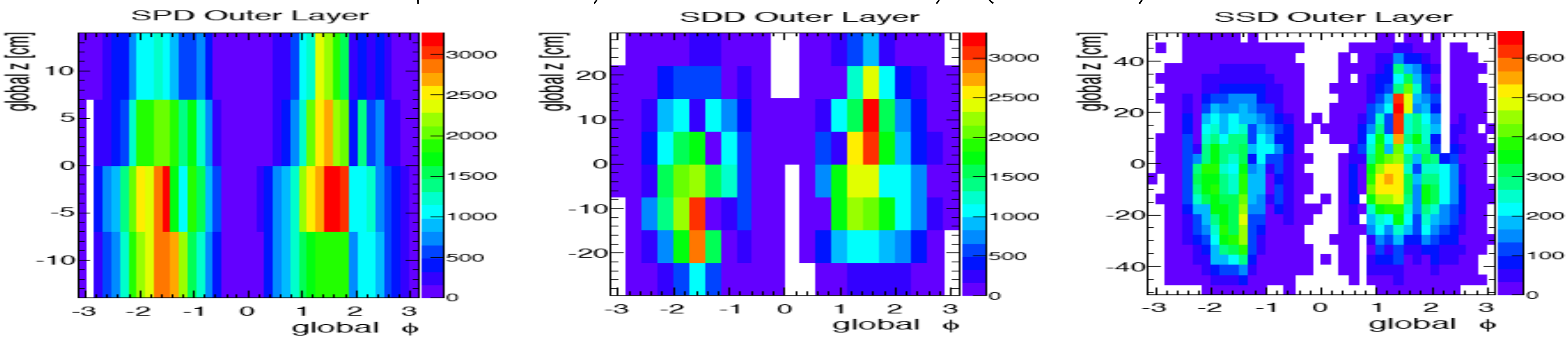
- ❑ Monitor simulation and reconstruction part.
- ❑ Code developed within the official ALICE offline framework (AliRoot).
- ❑ During the cosmic data taking feedback was provided on a regular basis (almost after the end of the run).
- ❑ Usage of pure noise runs to detect fake clusters:
  - o $\sim 10^{-4}$ noise clusters per module per event





SSD alignment

- First order alignment with cosmics using the SPD trigger
  - Coincidence between top outer SPD layer and bottom outer SPD layer (rate: 0.18 Hz)



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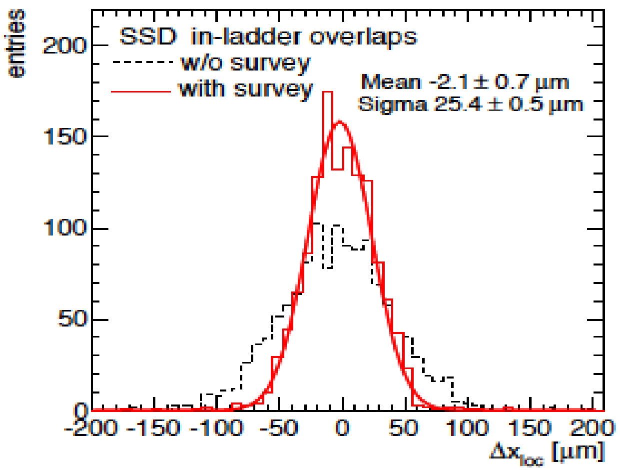
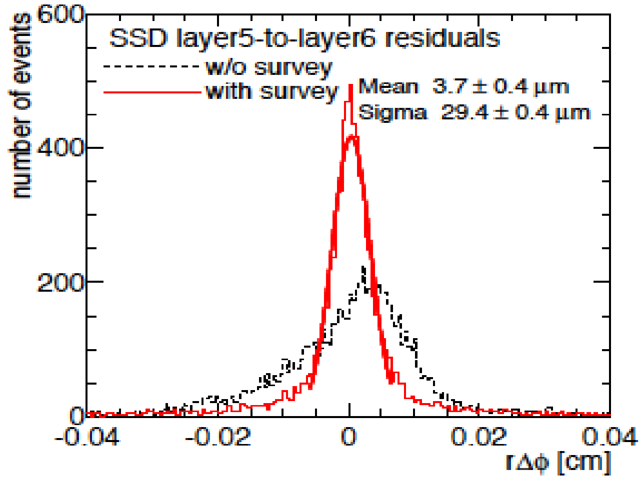
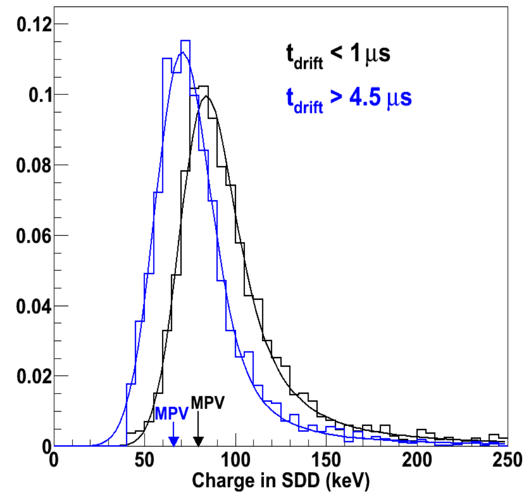
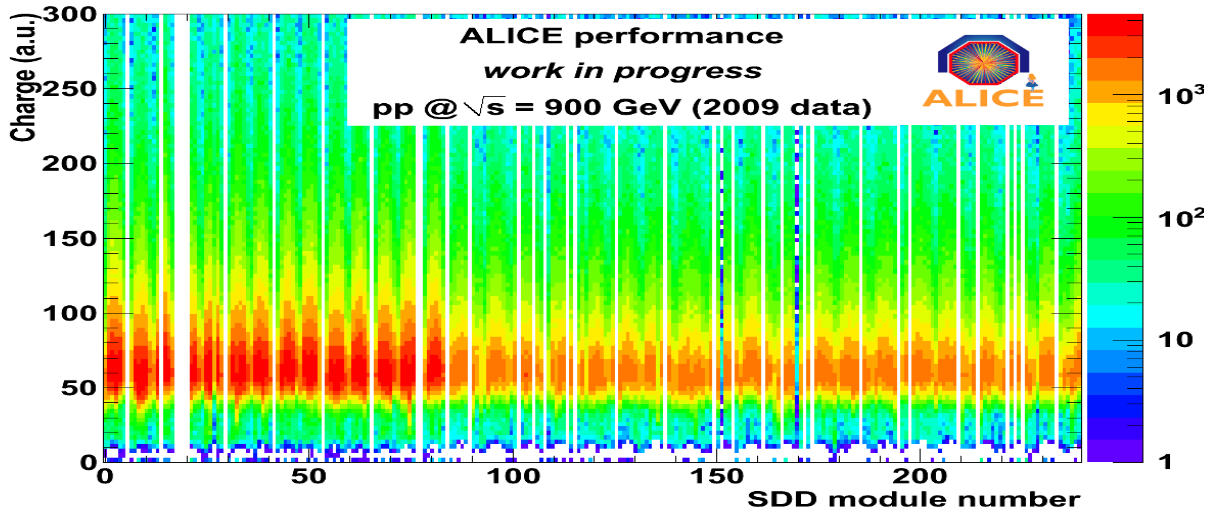




- Preliminary results show:
  - Residual misalignment spread of the SSD modules on the ladders of ~5μm

SDD charge calibration

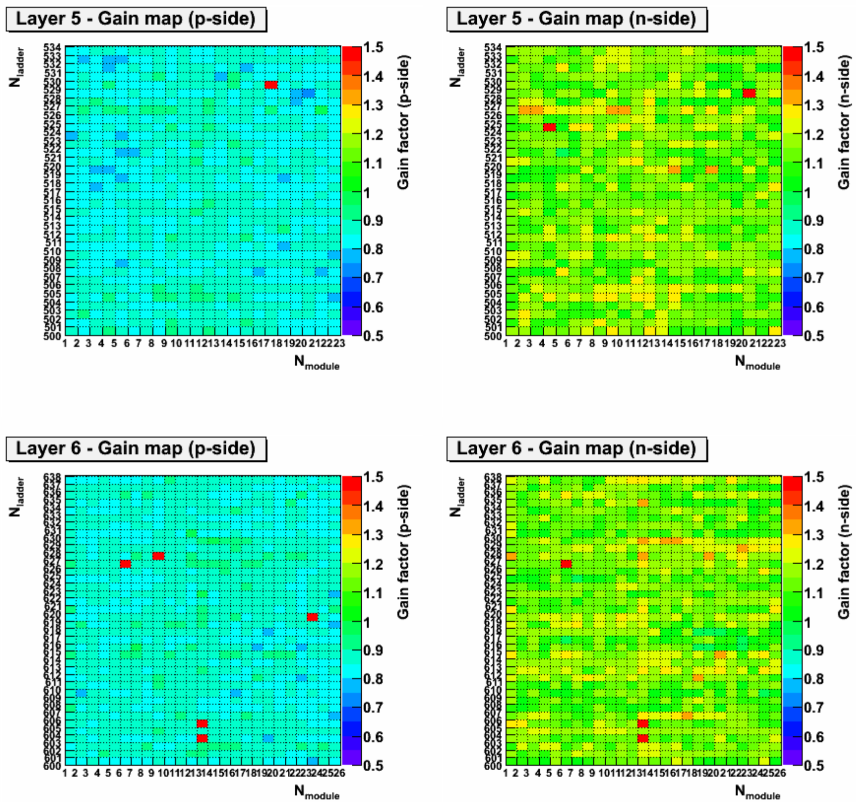




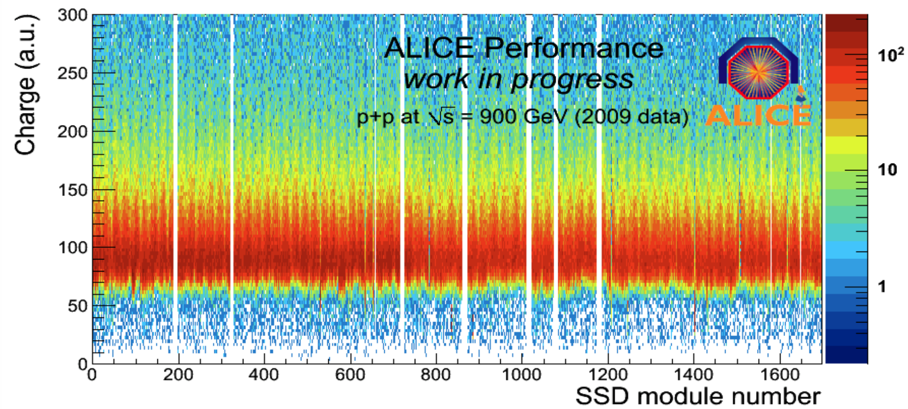
- Distribution of cluster charges from cosmic tracks, fitted with a Landau function
- Possibility to obtain with good precision the conversion factor ADC units to KeV (drift distance dependence, reproduced with MC, can be corrected at reconstruction phase)

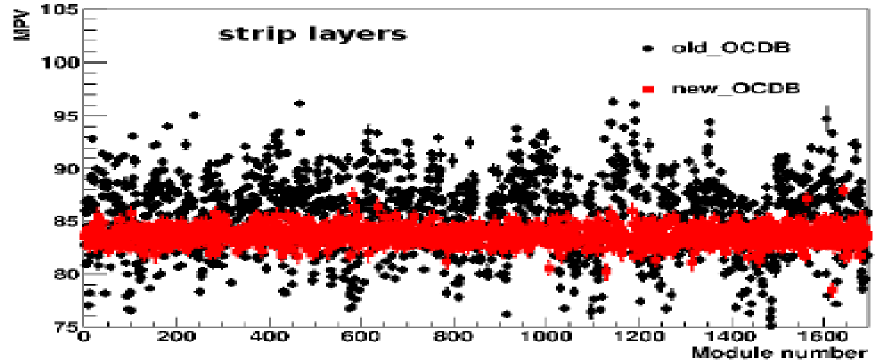
- For more than 85% of the modules, the dE/dx distributions have the MPV within 5% from the expected value of 84 KeV
  - Charge Collection Efficiency completely under control
  - Special correction needed only for 15 modules with lower CCE, all of them traced-back to hardware problems (applied voltages, silicon purity)

SSD calibration



- Gain map tuned at the module level from the collision data.

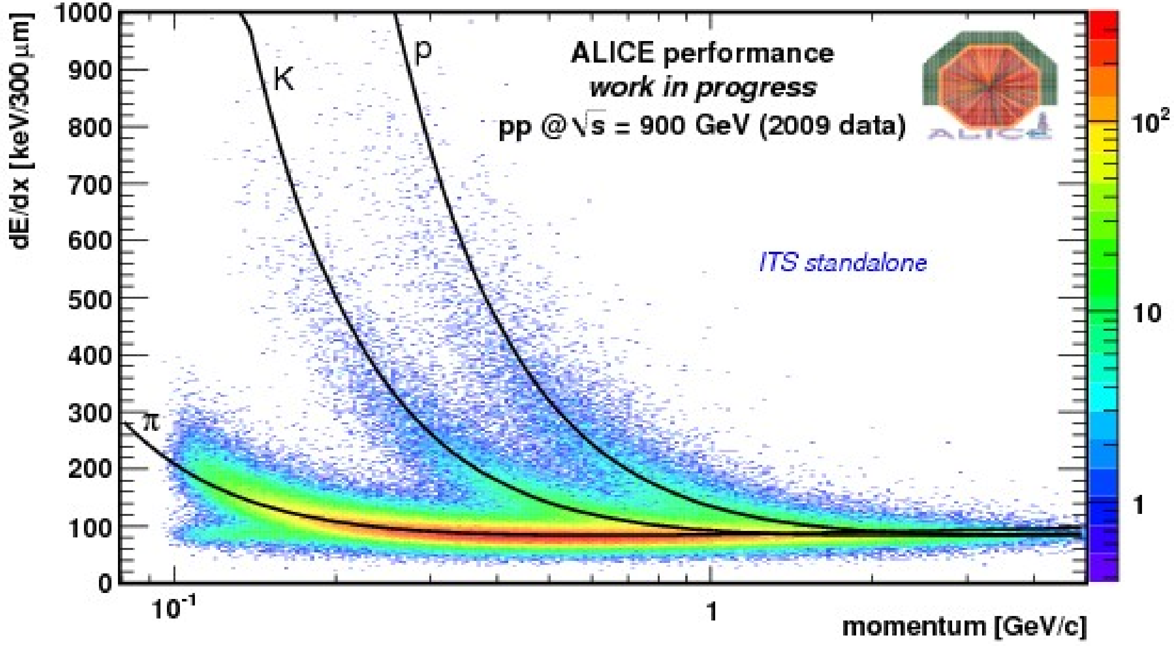




- Charge distribution measured on all the SSD modules
- MPV stable within few percent.
- SSD in excellent shape: Signal/noise ~40

SDD-SSD dE/dx measure

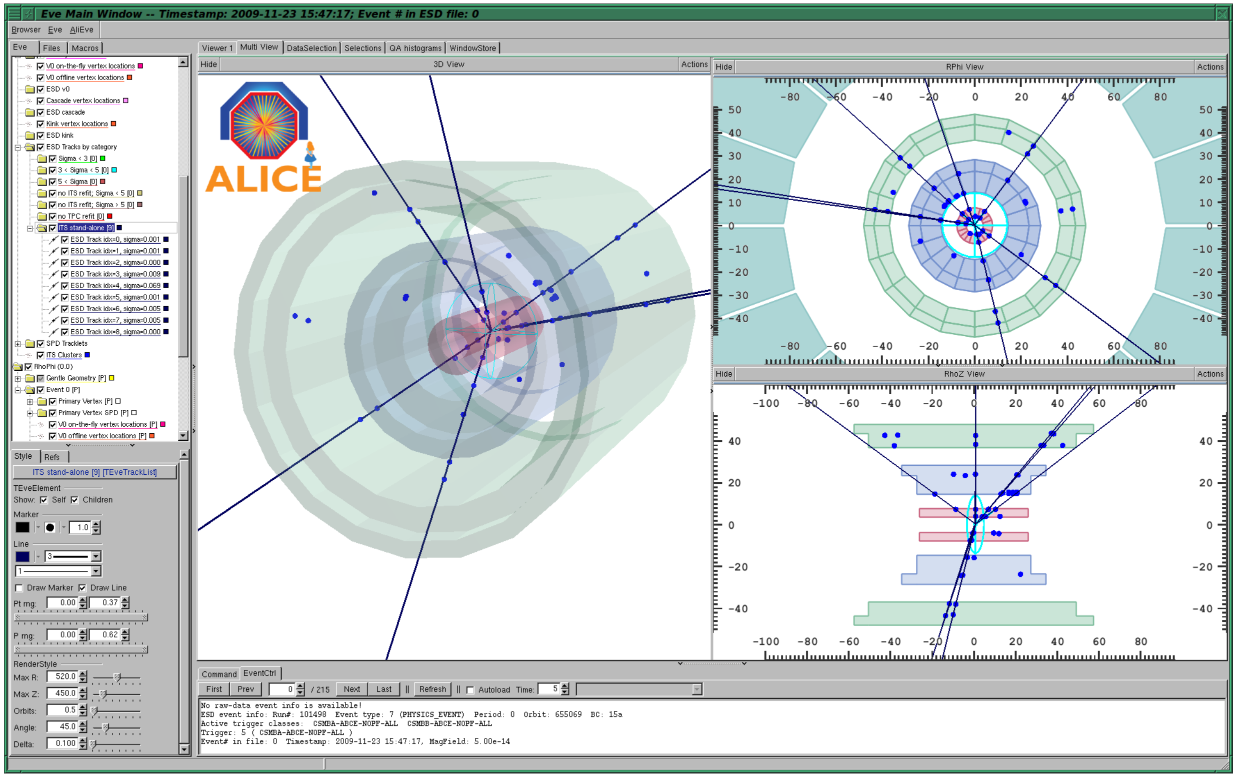
- Truncated mean from SDD+SSD dE/dx vs. track momentum (ITS standalone)



Summary - Conclusions

- More than 90 % of channels in DAQ for both Drift and Strip Detectors
- Data from cosmic events were collected to debug and monitor the system
- Frequent calibration runs are performed to proper measure relevant parameters (noise, gain, drift speed)
  - time stability of all monitored parameters
  - charge calibration and efficiency as expected
  - detectors behaviour well understood and under control
- Detector performance constantly monitored online and offline
- Both SDD and SSD were in acquisition since very first LHC collisions, and are ready for the ongoing long data taking period

SDD/SSD data taking during *pp* collisions



BACKUP

SDD Sensor Characteristics

Sensitive area	$70.17 \times 75.26\ mm^2$
Anode pitch	294 μm
HV (nominal)	-1800 V
Bias voltage (MV)	-40 V
Drift velocity	~ 6.5 μm/ns
Av. resolution (z) (*)	25 μm
Av. resolution (rφ) (*)	35 μm

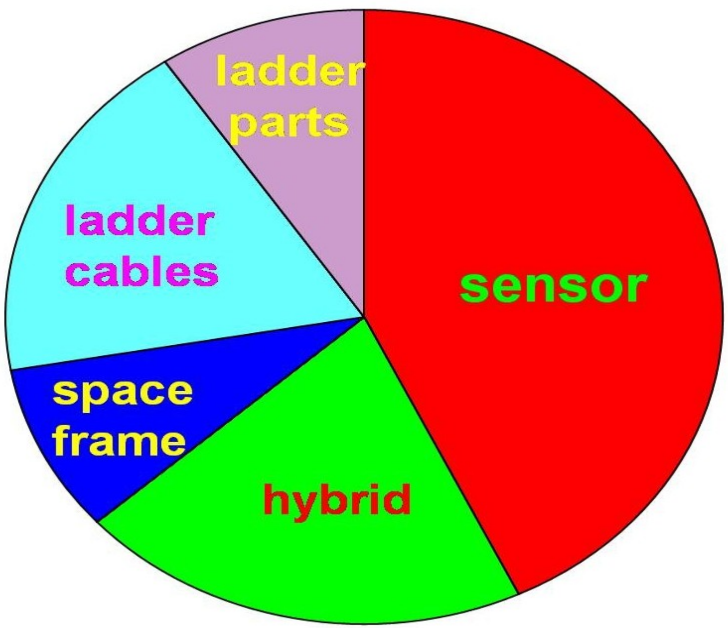
(*) from beam test

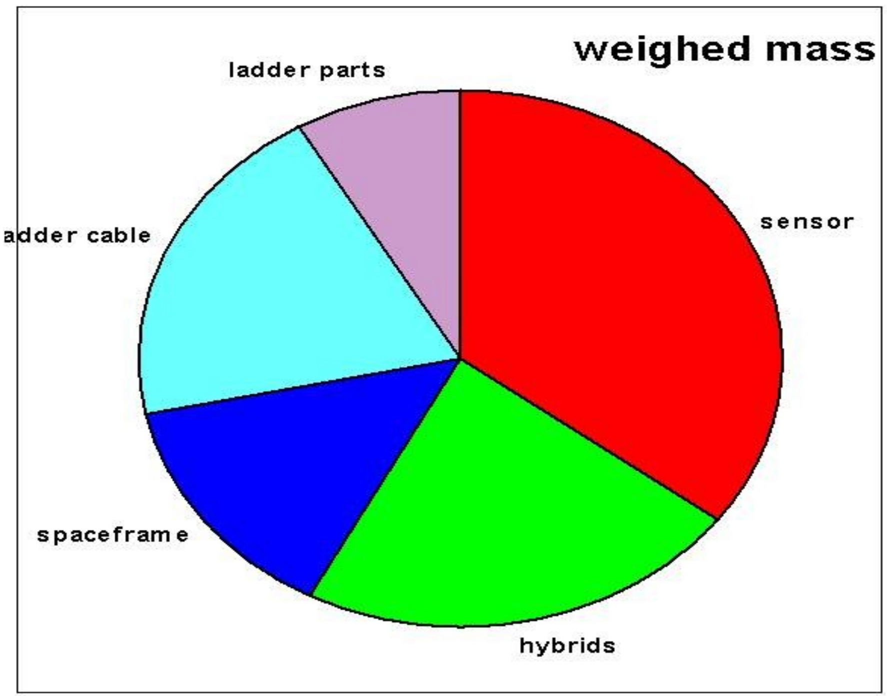
SSD: Module mass & radiation length

	Mass [g]	Radiation length
Sensor	2.2	0.36
Module on ladder	6.3	0.85

Mass of SSD on TPC 111 kg (as installed)

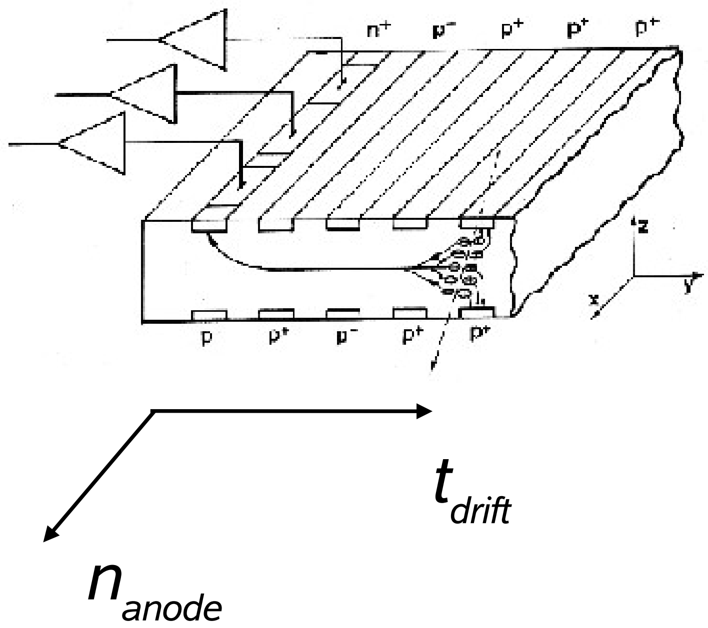
Radiation thickness

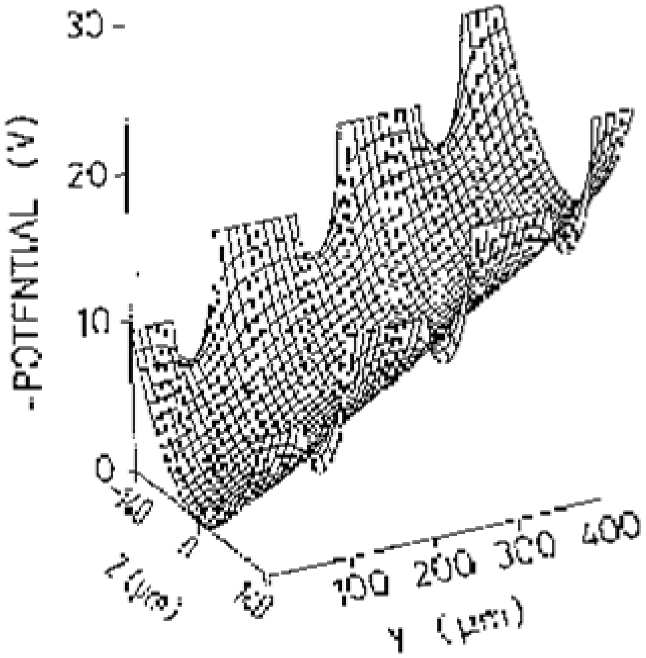




SSD: Relative humidity

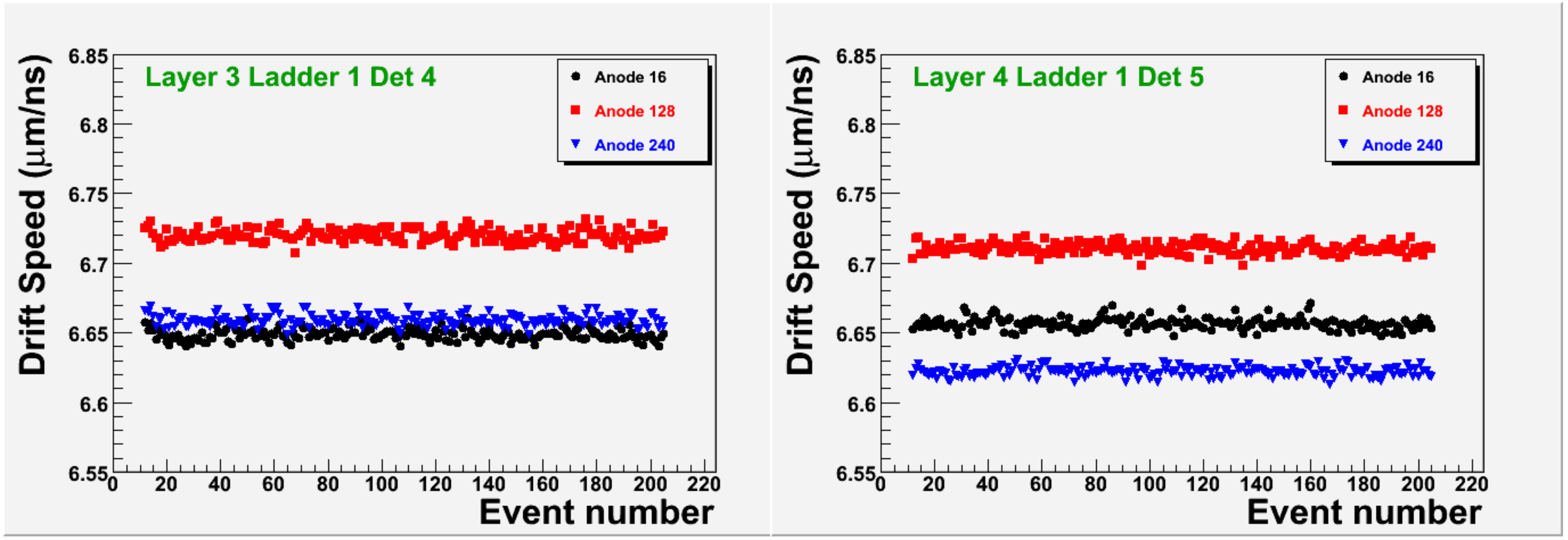
The Drift Sensor





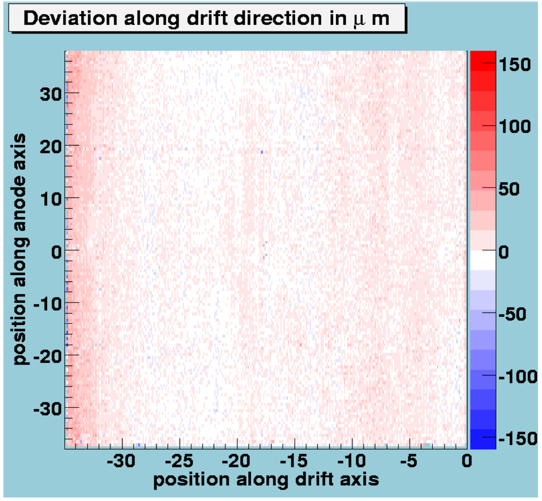
Short Timescale Drift Speed Stability

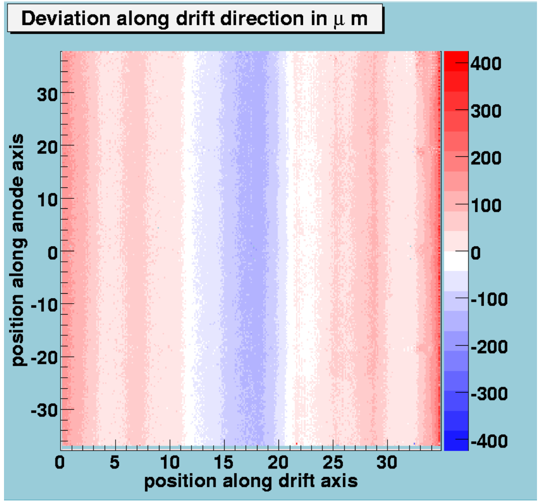
- Drift speed constant on a time scale of 1 hour of data taking
  - *about 5 triggers/minute, 200 analyzed events from a raw data file*

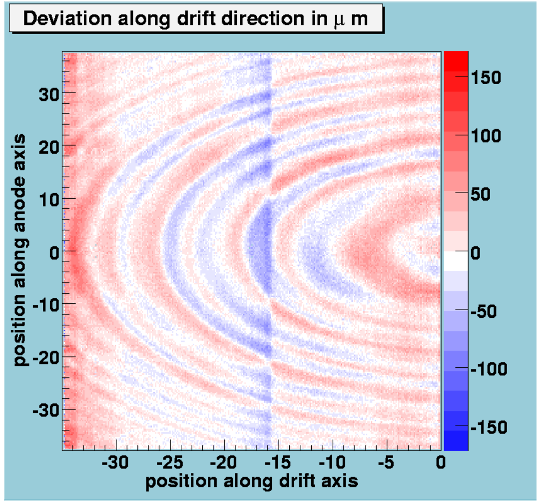


SDD Correction Maps

- All 260 modules fully characterized before assembling in ladders
  - charge injected in >100,000 positions using an infrared laser
  - for each laser shot, compute residual between reconstructed and original coordinate
  - maps of systematic deviations of drift coordinate (due to non-linear voltage divider or dopant concentration inhomogeneities) to be used to correct the time coordinate at reconstruction phase







Charge vs. Drift Distance

Cluster charge depends on drift distance

- larger drift distance ⇒ larger charge diffusion ⇒ wider cluster tails cut by the zero suppression
- quantitatively reproduced with MonteCarlo simulations
- crosschecked with cosmic muons collected with and without zero suppression with a test setup
- can be corrected at reconstruction phase