Operation of the ALICE Silicon Drift Detectors during cosmic data taking

Francesco Prino

INFN – Sezione di Torino

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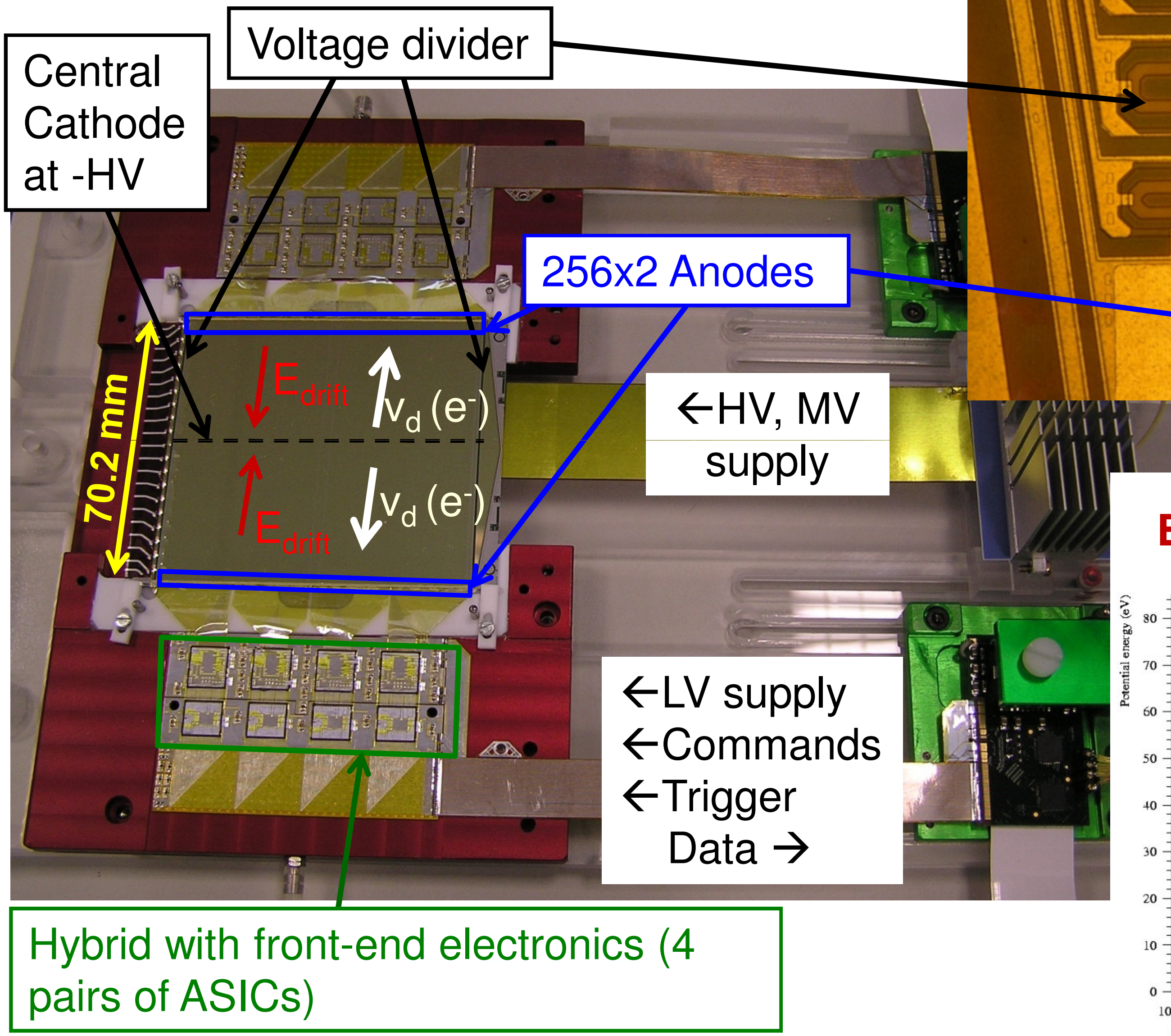
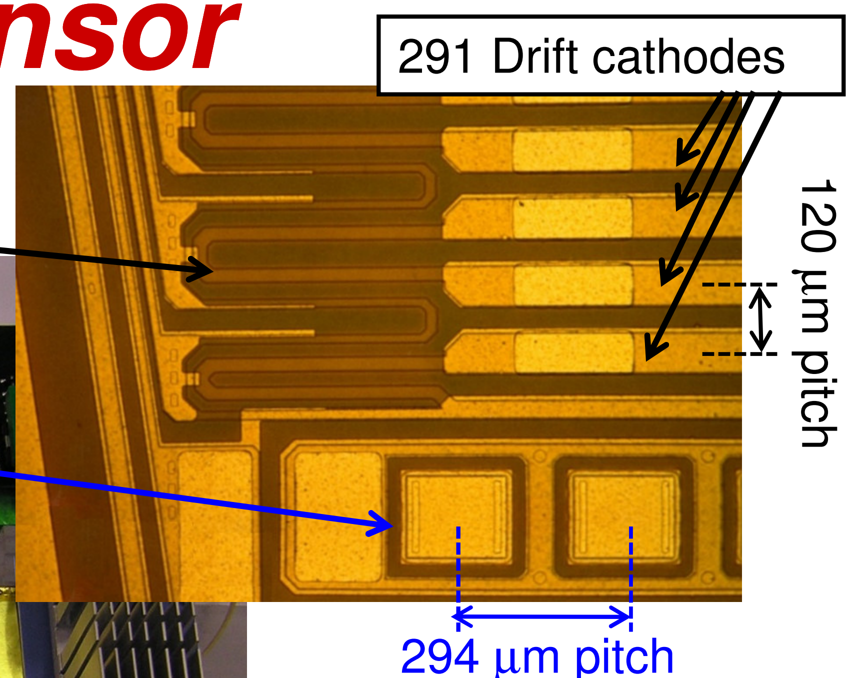
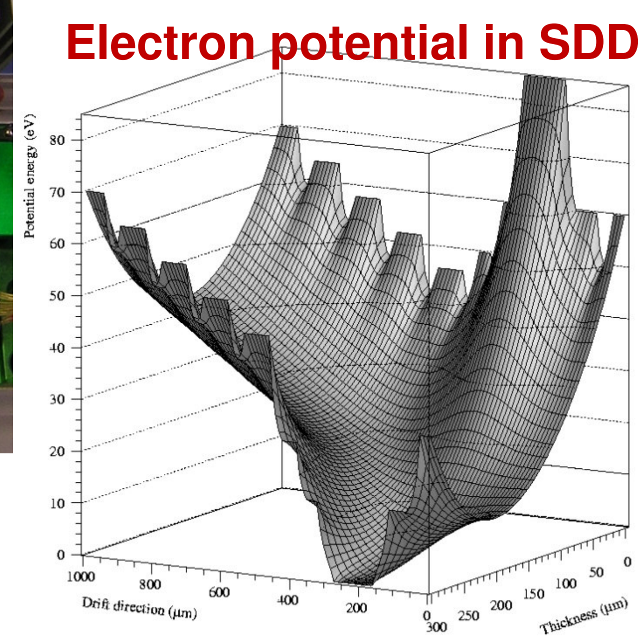
SDD sensor



Central Cathode at -HV
Voltage divider
256x2 Anodes
E_{drift}
v_d (e^-)
E_{drift}
v_d (e^-)
70.2 mm
←HV, MV supply
←LV supply
←Commands
←Trigger
Data →
Hybrid with front-end electronics (4 pairs of ASICs)

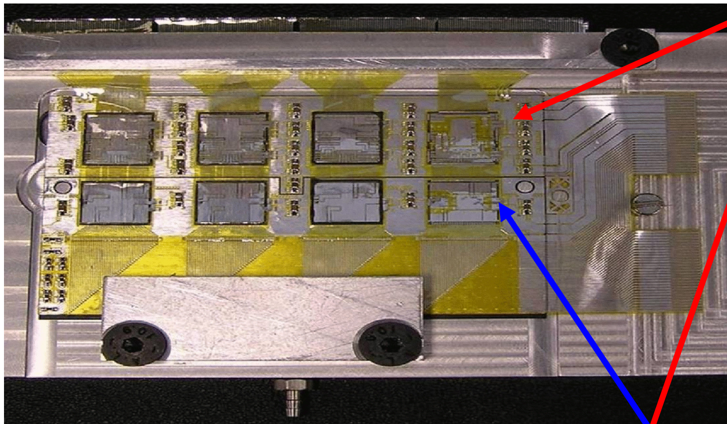


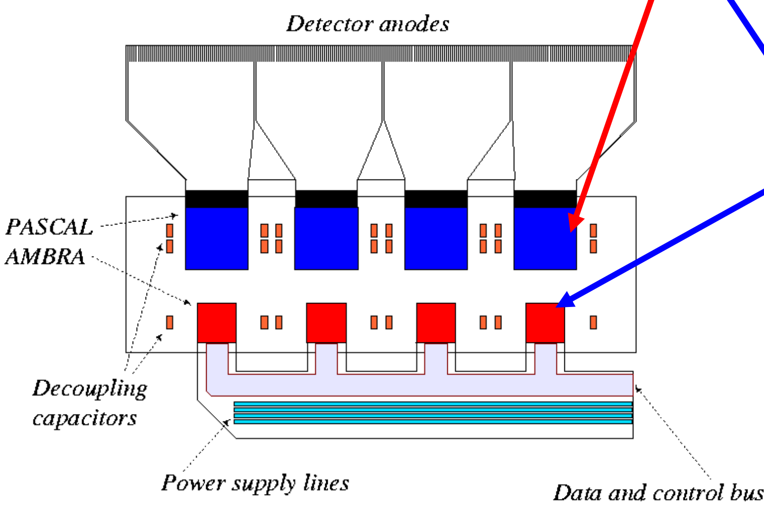
291 Drift cathodes
120 μm pitch
294 μm pitch



Electron potential in SDD
Potential energy (eV)
Drift direction (μm)
Thickness (μm)

SDD Front-end electronics

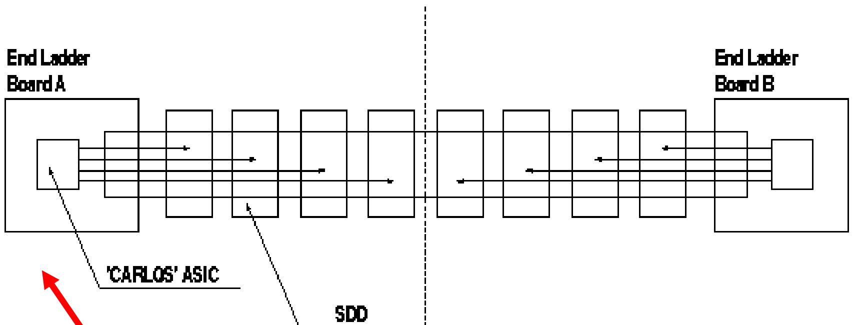




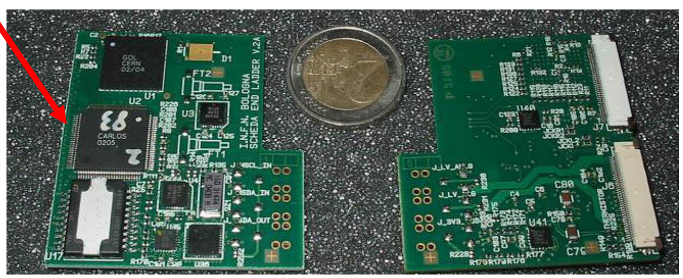
<Power dissipation> ≈ 6 mW / channel

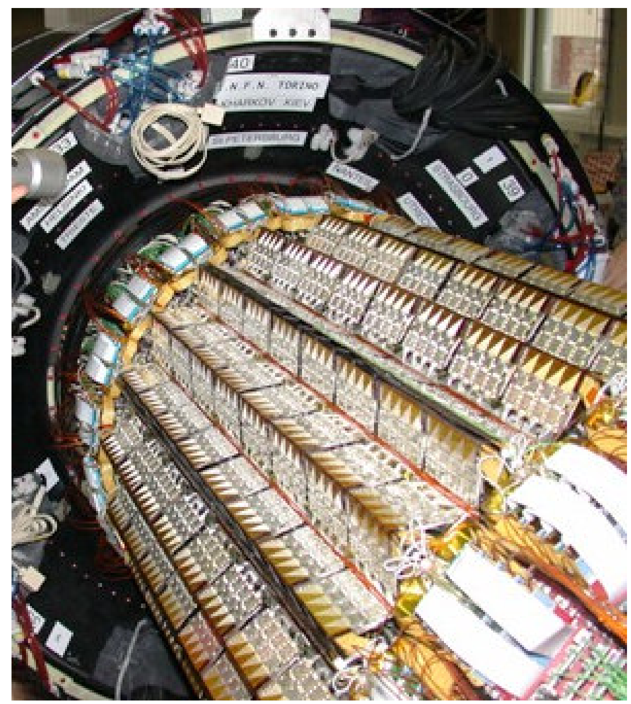
- **PASCAL**
  - ⇨ Reads signals from 64 anodes
  - ⇨ Preamplifier
  - ⇨ Analog Storage (256 cells/anode)
    - ✓ ***Analog Memory sampled at 40 MHz (default) or 20 MHz***
  - ⇨ Conversion Analog->digitaL
    - ✓ ***10-bit linear successive-approx. ADC***
- **AMBRA**
  - ⇨ Digital four-event buffer
  - ⇨ Anode-by-anode baseline equalization
  - ⇨ Non-linear data compression
    - ✓ ***From 10 to 8 bit per cell***

SDD ladders and layers



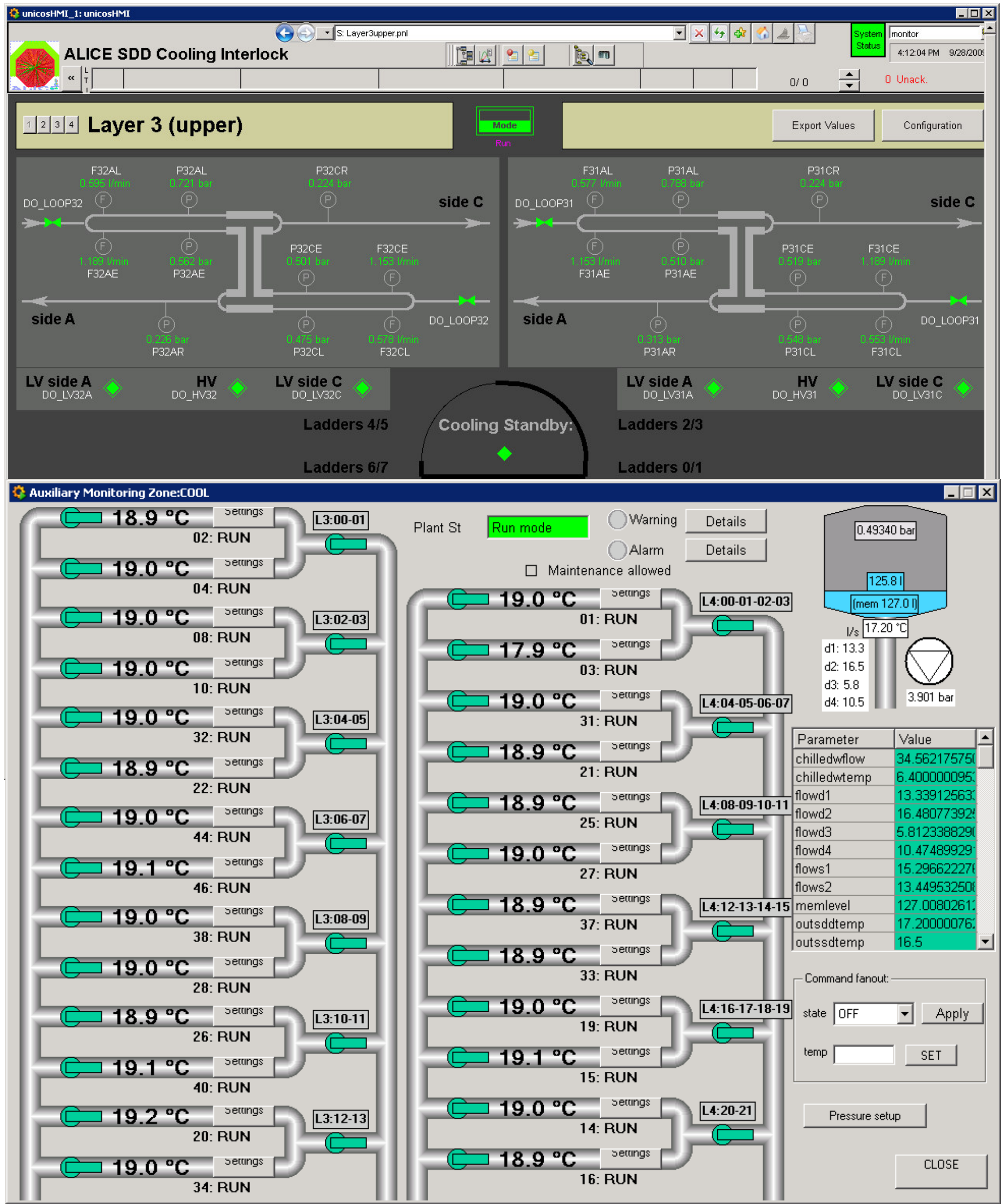
Layer	# ladders	Modules /ladder	# modules	Material Budget (% of X_0)
3	14	6	84	1.13
4	22	8	176	1.26





- CARLOS board
  - 8 inputs fed in parallel by 8 AMBRAs
    - ✓ *1 Carlos per SDD module*
  - 2D 2-threshold zero suppression
  - Formats data and sends to DAQ

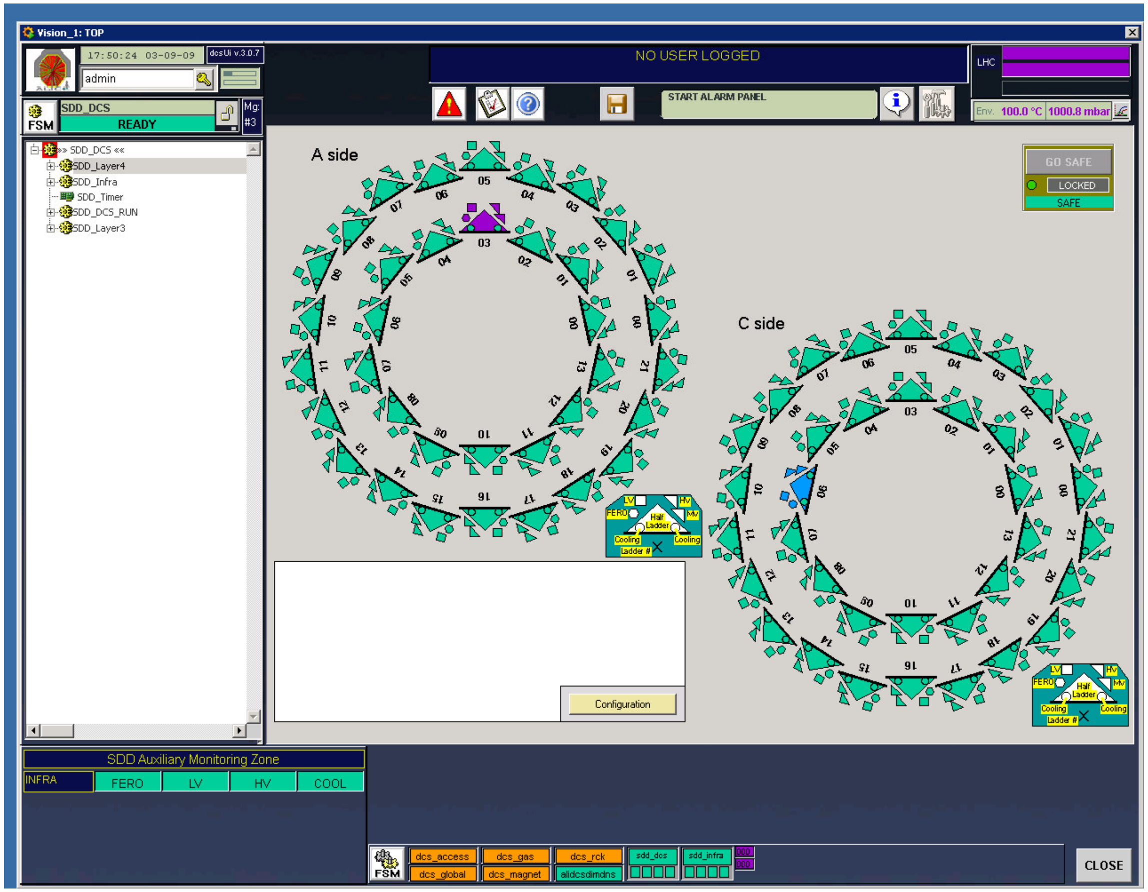
Cooling the SDD



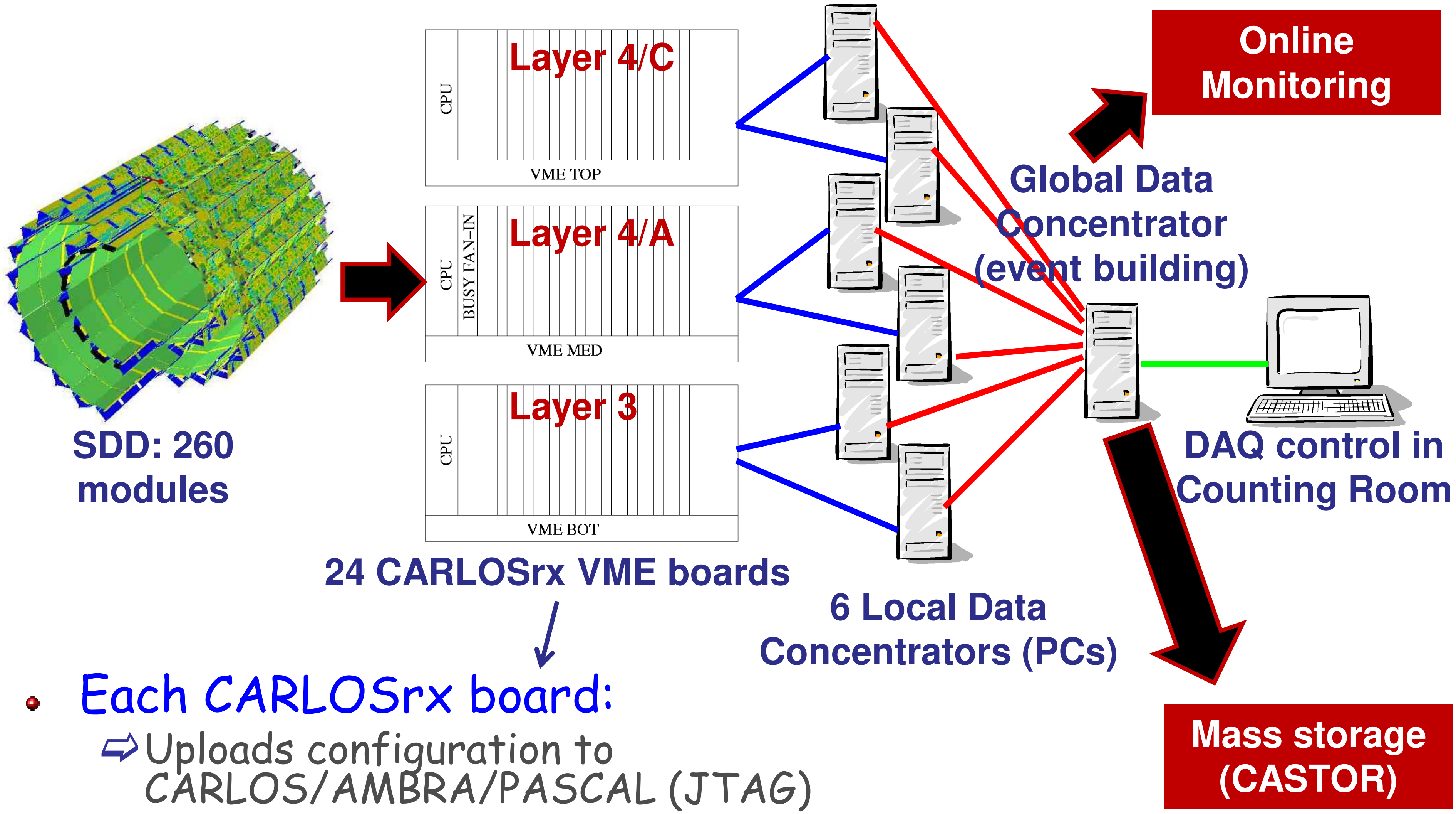
- Cooling agent: water
- Pressure inside barrel <1 bar
  - ⇨ Leak safe
- Flow adjusted to stay in intermediate state between laminar and turbulent regime
  - ⇨ Maximum heat exchange
- 13 (sectors) * 2 (A/C side) *2 (Ladder/End-ladder)circuits with independent flow and pressure control
- Safe operation controlled by dedicated Programmable Logic Controller:
  - ⇨ Overpressure control to guarantee leak safety
  - ⇨ Flow control to give the clearance for FEE operation.

SDD Detector Control System

- Systems controlled by DCS:
  - LV power for Front-End Electronics
  - HV and MV supplies for SDD detectors
  - Cooling plant
  - State of readout cards
- Finite States Machine (FSM) provides simple control of the whole system by well defined sequence of states
  - FSM communicates to DAQ and gives permission to start data-taking when detector is in ready state
  - Alarms and warnings logging system
  - Archiving of all system parameters
    - ✓ ***HV, MV, temperature recorded by thermistors …***



Readout and DAQ

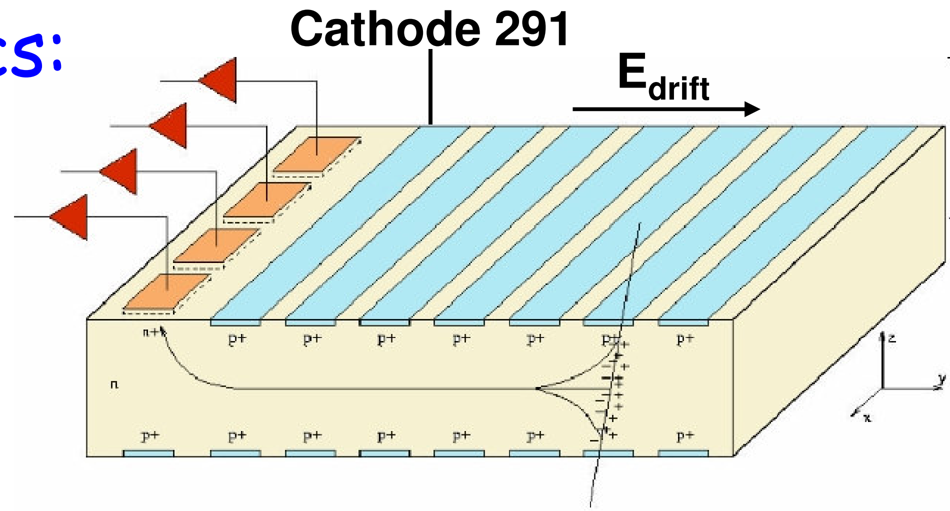


- Each CARLOSrx board:
  - ⇨ Uploads configuration to CARLOS/AMBRA/PASCAL (JTAG)
  - ⇨ Sends trigger to CARLOS and busy to CTP
  - ⇨ Reads data from up to 12 modules, apply data format compression and sends to DAQ

Running conditions

- Detector characteristics:

Parameter	Value
HV (central cathode)	1800 V
MV (cathode 291)	40 V
Drift field	500 V/cm
Resolution (z x rφ)	25x35 μm



- Readout and DAQ parameters
  - ⇨245 (out of 260) modules stably in DAQ

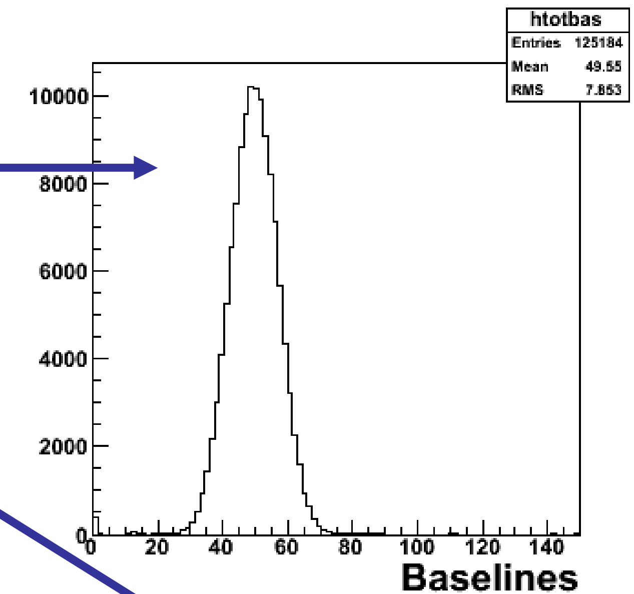
Parameter	20 MHz AM sampling	40 MHz AM sampling
Time bin size	50 ns	25 ns
Number of time samples	128	256
Readout dead time	1 ms	2 ms
Max. event rate	1 kHz	500 Hz
Event size (cosmics)	12 kB	25 kB

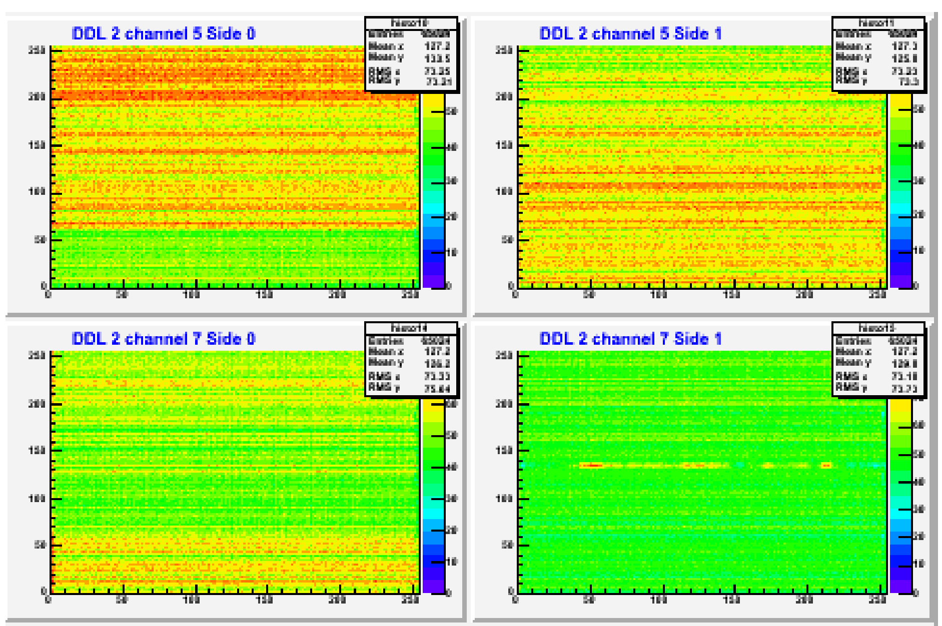
Calibrating the SDD

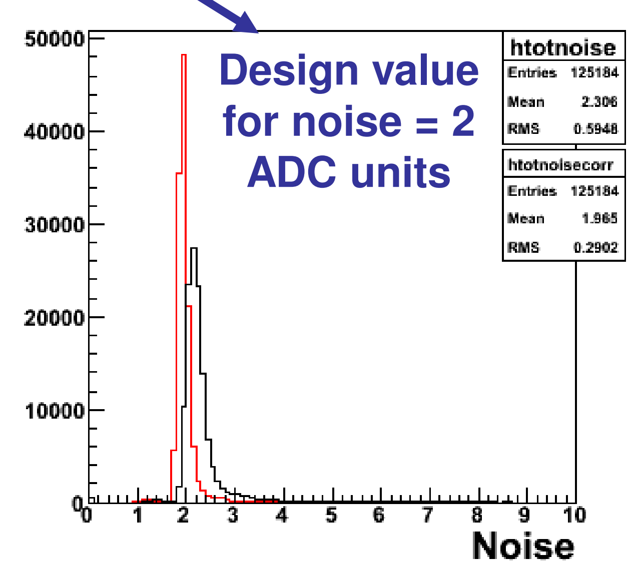
- Three SDD specific calibration runs collected every ≈24h to measure calibration parameters
  - ⇨ Run Type: PEDESTAL
    - ✓ ***Analyzes special SDD calibration runs taken without zero suppression***
    - ✓ ***Provides: Baselines, Noise, Common Mode Corrected Noise, Noisy anodes***
  - ⇨ Run Type: PULSER
    - ✓ ***Analyzes special SDD calibration runs taken with Test Pulse signal to front-end electronics***
    - ✓ ***Provides: Anode gain, Dead anodes***
  - ⇨ Run Type: INJECTOR
    - ✓ ***Analyzes injector events collected every ≈ 10 min. during physics runs***
    - ✓ ***Provides Drift speed (anode dependent)***
- A detector algorithm (DA) runs automatically at the end of each calibration run
  - ⇨ Analyzes raw data and extracts relevant calibration quantities
  - ⇨ Files with calibration parameters are stored in the Offline Condition DataBase and used in the offline reconstruction

Pedestal runs

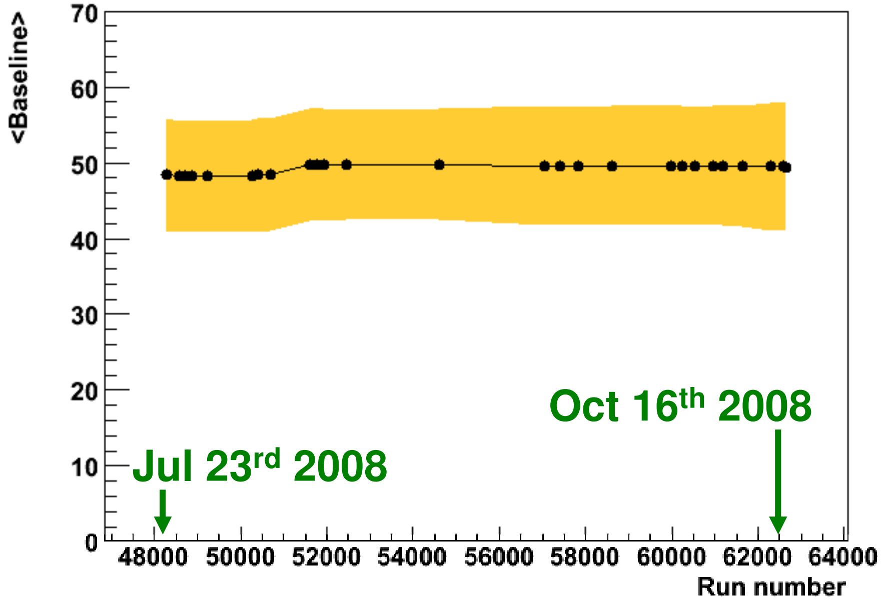
- Measure for each anode:
  - ⇨ Baselines
    - ✓ *Extract baseline equalization constants applied anode-by-anode in AMBRAs*
  - ⇨ Noise (raw and common mode corrected)
    - ✓ *Tag noisy anodes (masked out in physics runs)*

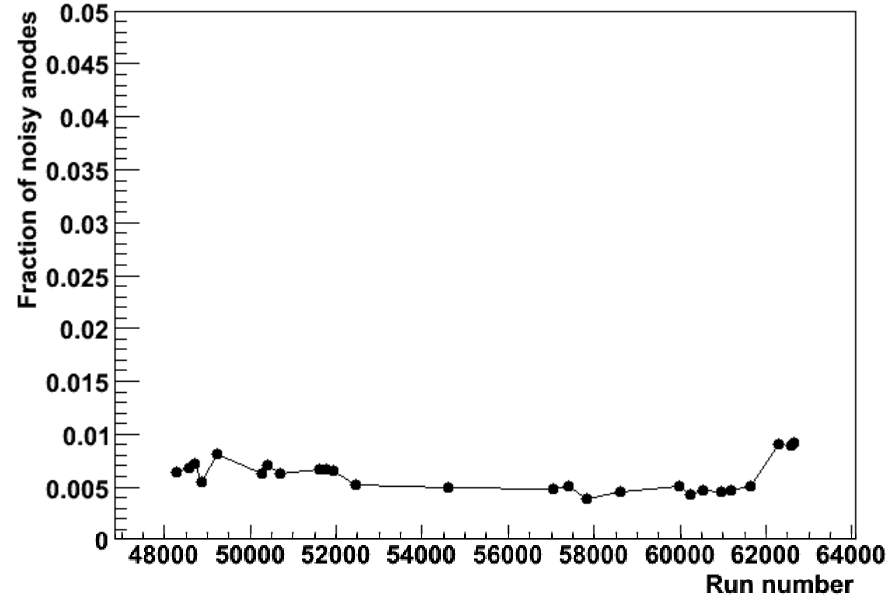


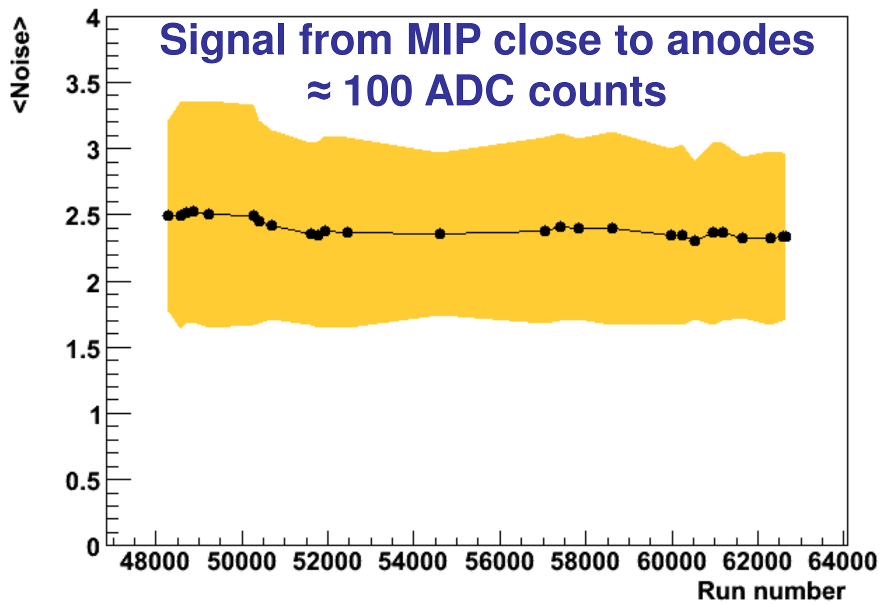


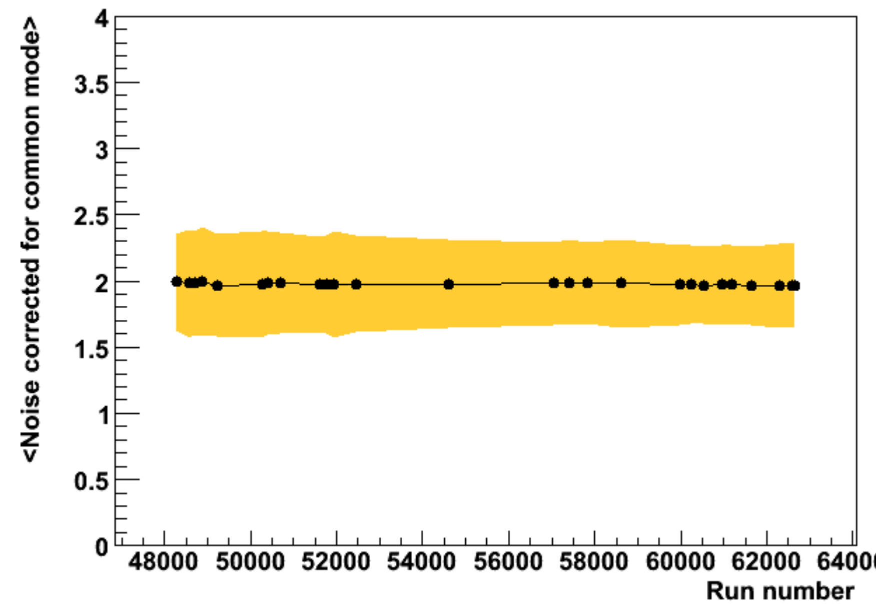


Pedestal results vs. time (2008)



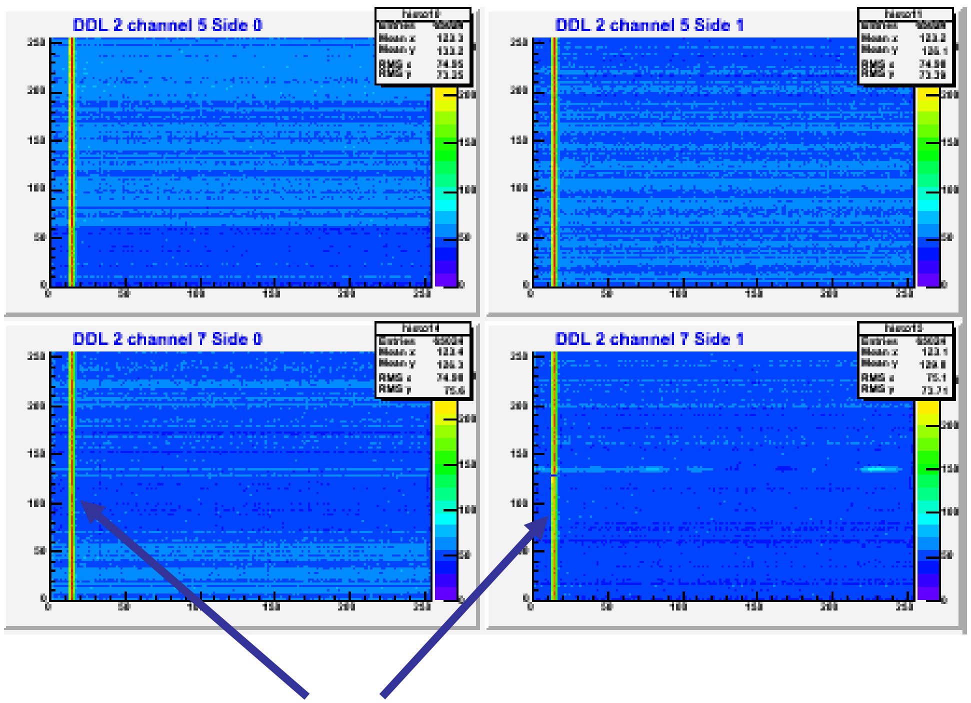




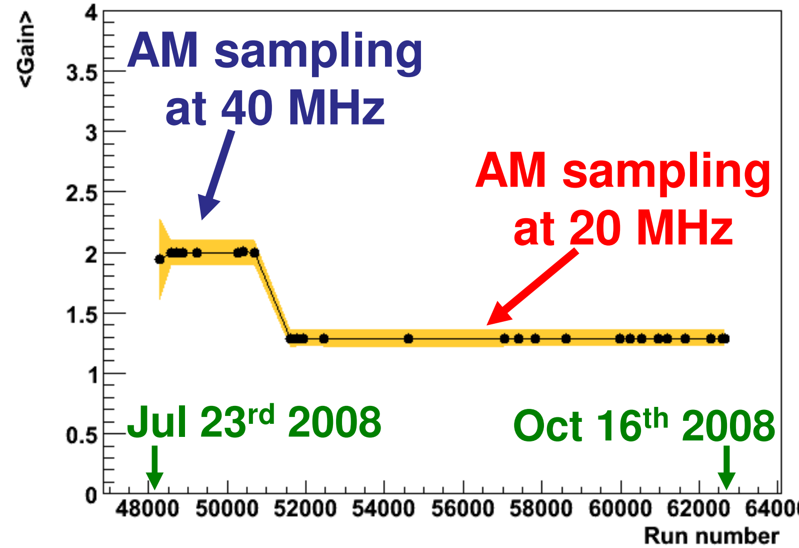


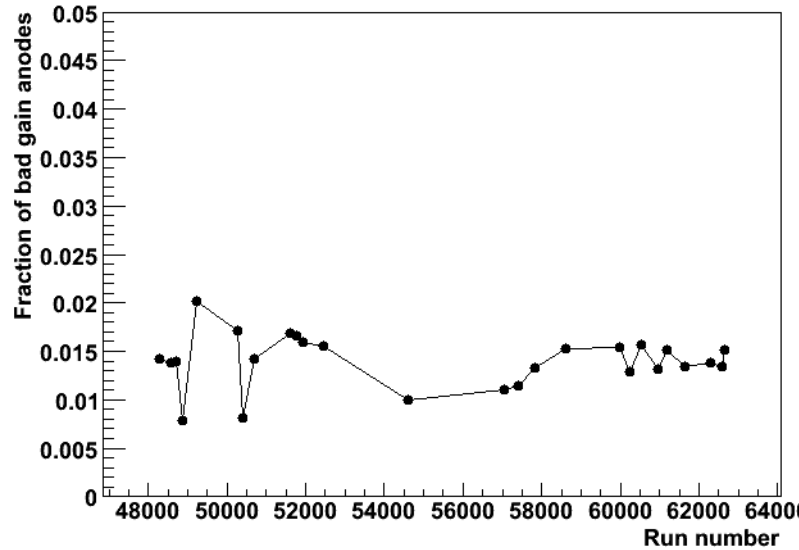
Pulser runs in 2008

- Measure gain for each anode sending Test Pulse to the input of front-end electronics
  - ⇨ Used for anode-by-anode gain equalization in cluster finder



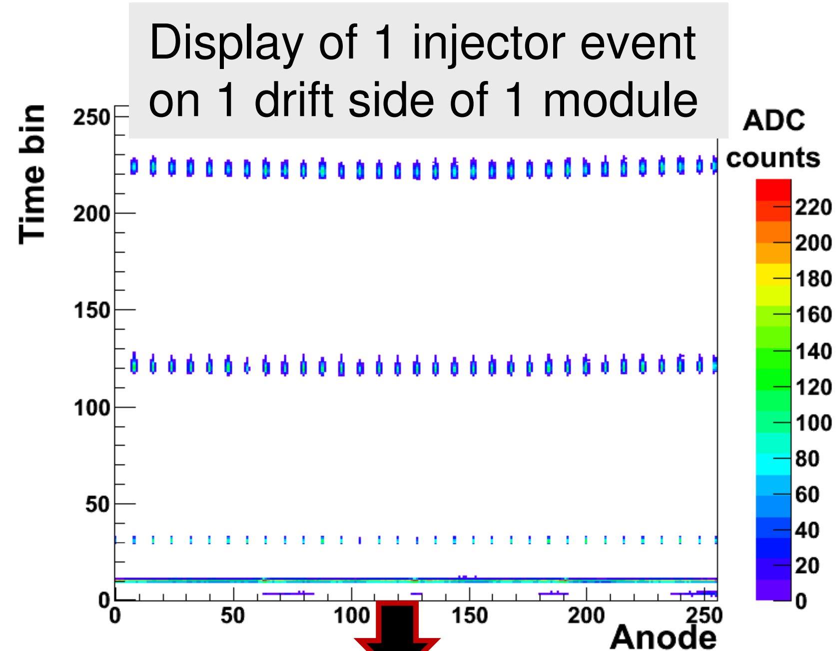
Test Pulse Signal

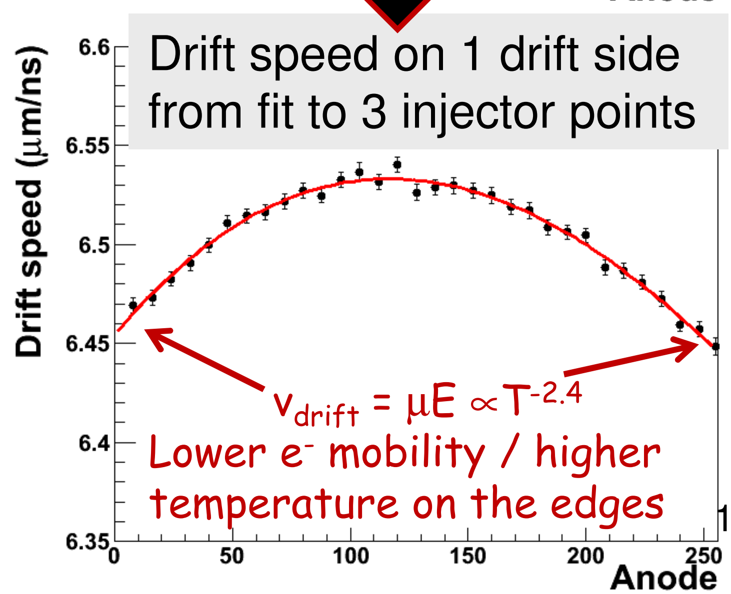




Drift speed from injectors

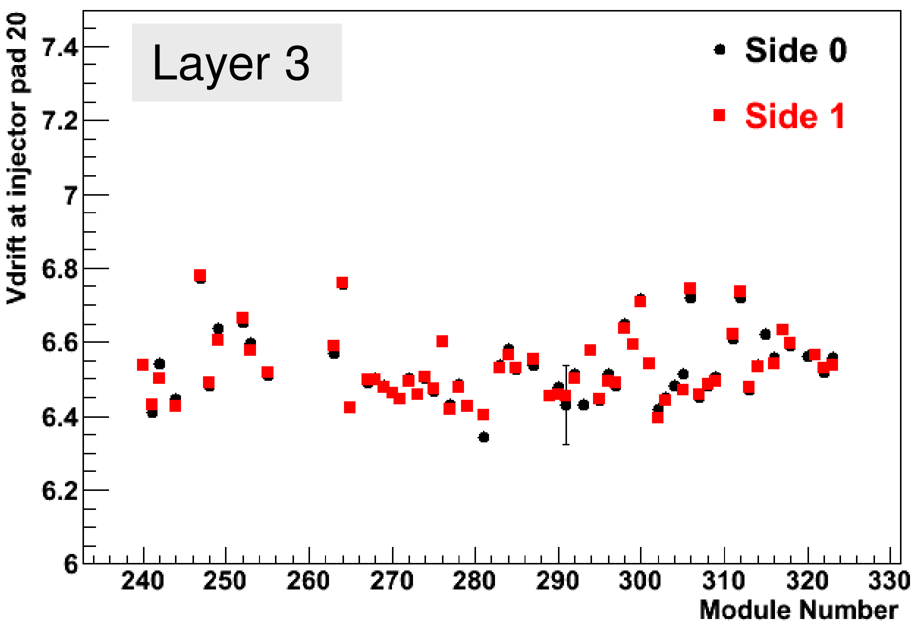
- From INJECTOR runs (acquired every 24 hours)
  - ⇨ 33x3 MOS charge injectors implemented in known positions on each drift side (half-module)
    - ✓ ***33 determinations of drift speed along anode coordinate for each drift side***
  - ⇨ Drift speed extremely sensitive to temperature ($\propto T^{-2.4}$)
    - ✓ ***0.8%/K variation at room temperature***
  - ⇨ Need 0.1% accuracy on drift speed to reach the design resolution of 35 μm along rϕ
- Max. drift time ≈ 3.5 cm / 6.5 μm/ns ≈ 5.4 μs

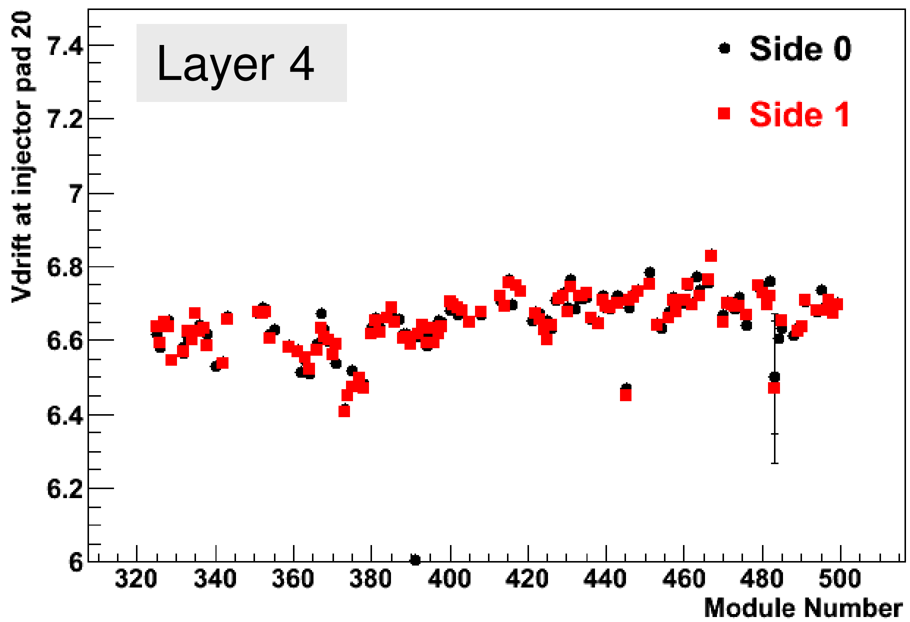




Drift speed vs. module

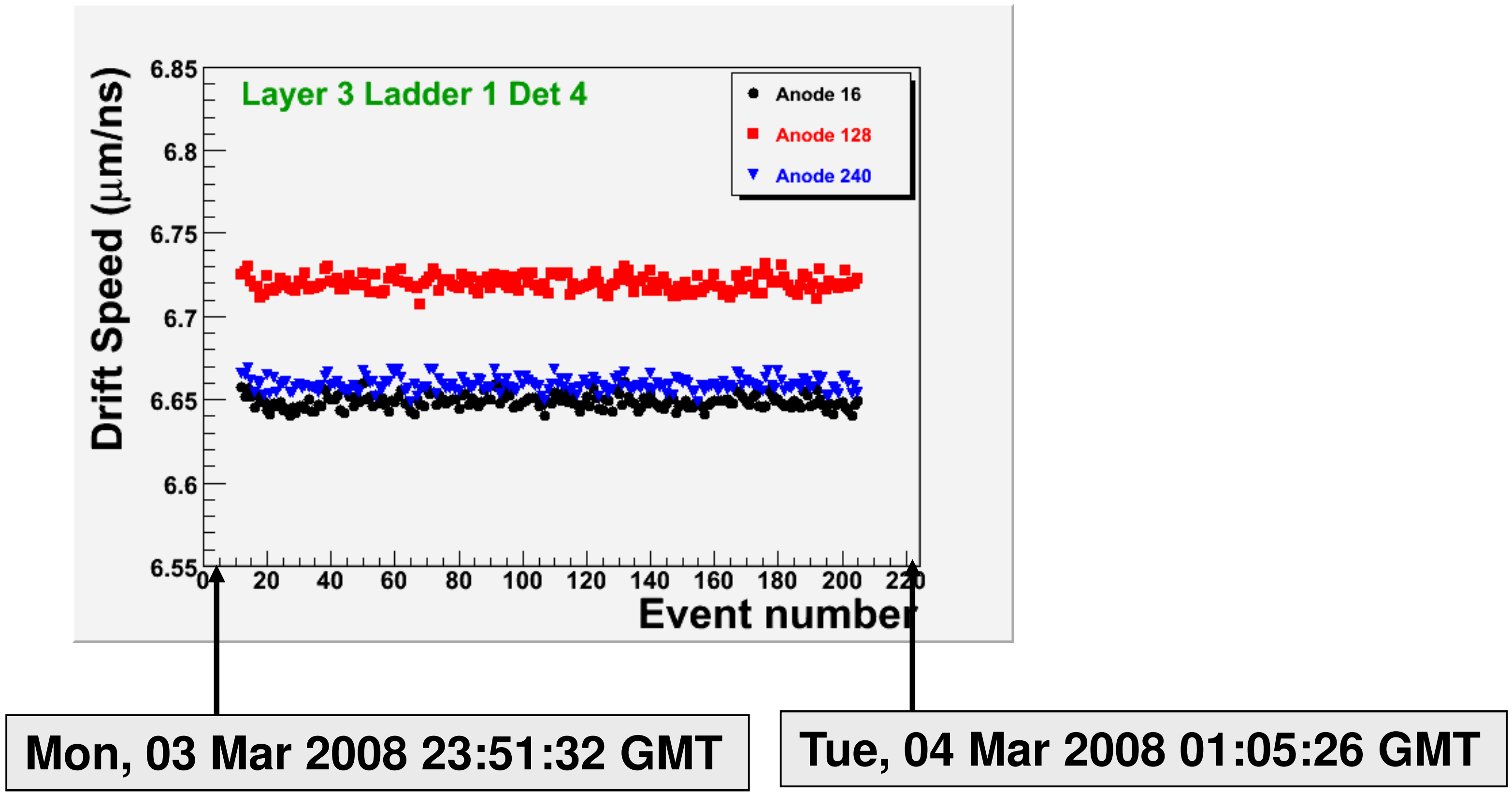
- Drift speed (electron mobility) depends on:
  - ⇨ Temperature
    - ✓ *Higher drift speed on average on Layer 4 ⇒ Lower temperature on layer 4*
    - ✓ *Estimated temperatures ≈ 24 ℃ on Layer 3 and ≈ 21 ℃ on Layer 4*
  - ⇨ Doping concentration (to a much lesser extent)
    - ✓ *Resistivity: 3000-4000 Ω·cm ⇒ Doping concentration ≈1.2-1.5 10^{12} cm^{-3}*





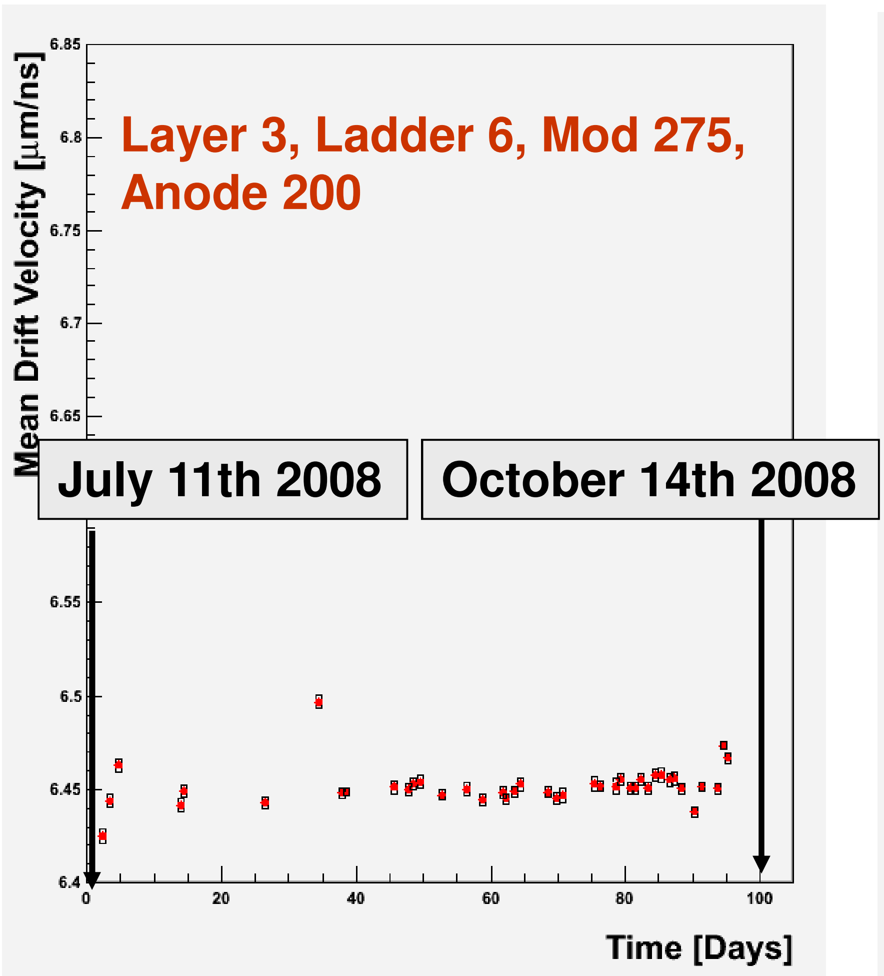
Drift speed stability – first test

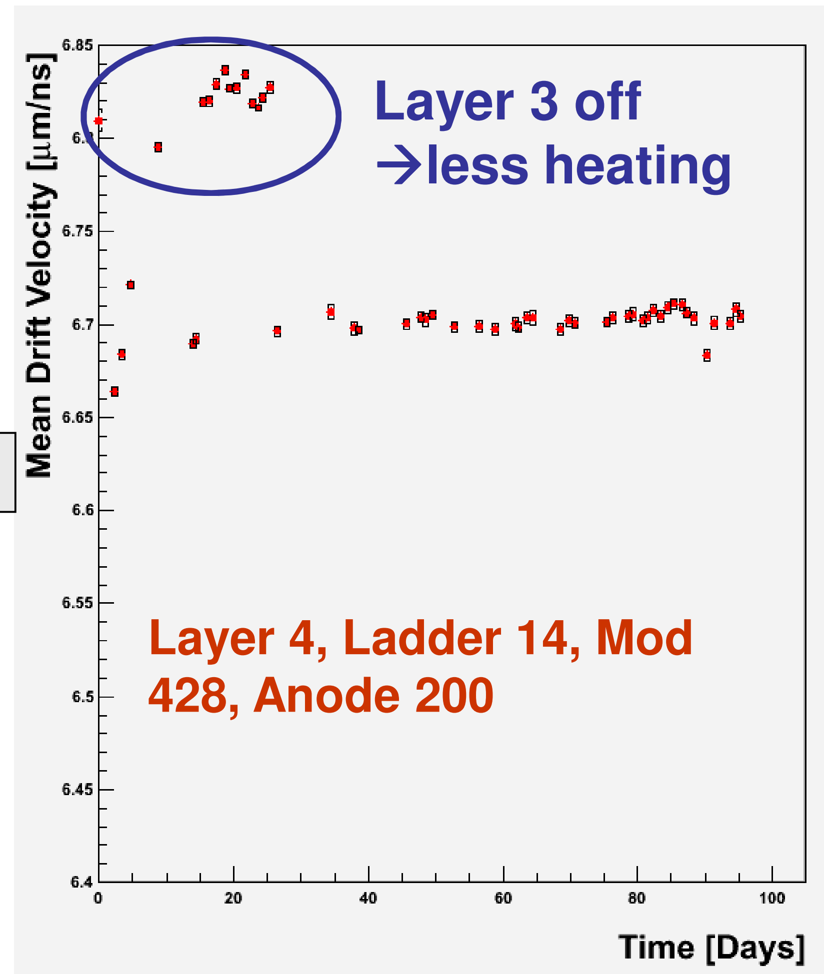
- Short term stability
  - ➯Check stability during ≈ 1 hour, rate ≈ 2 triggers/minute
  - ➯Fluctuations: r.m.s./mean ≈ 0.07%



Drift speed stability in 2008

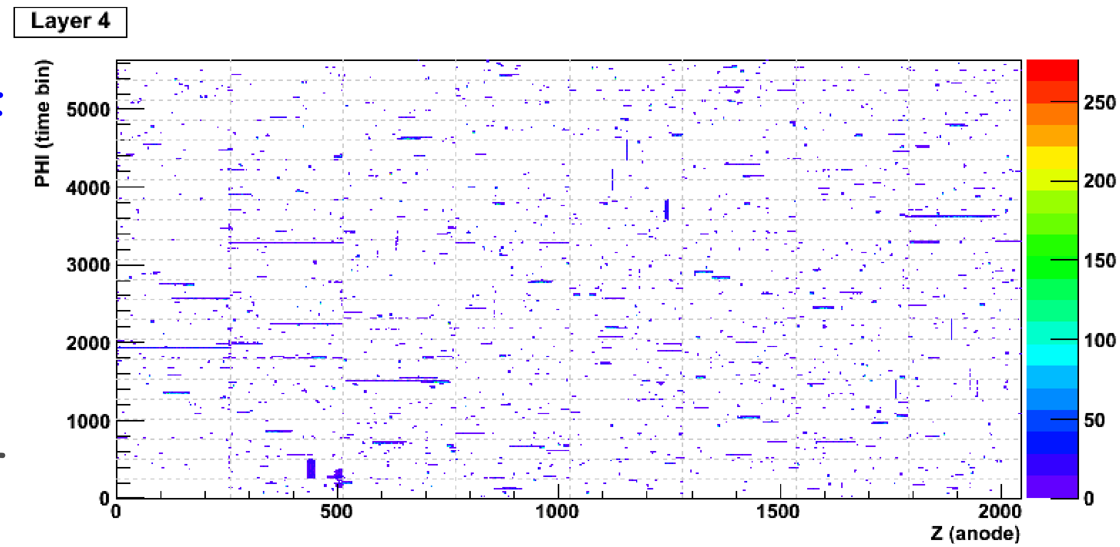
- Long term stability
  - 3 months of data taking during summer 2008
  - Drift speed stable within 0.2%

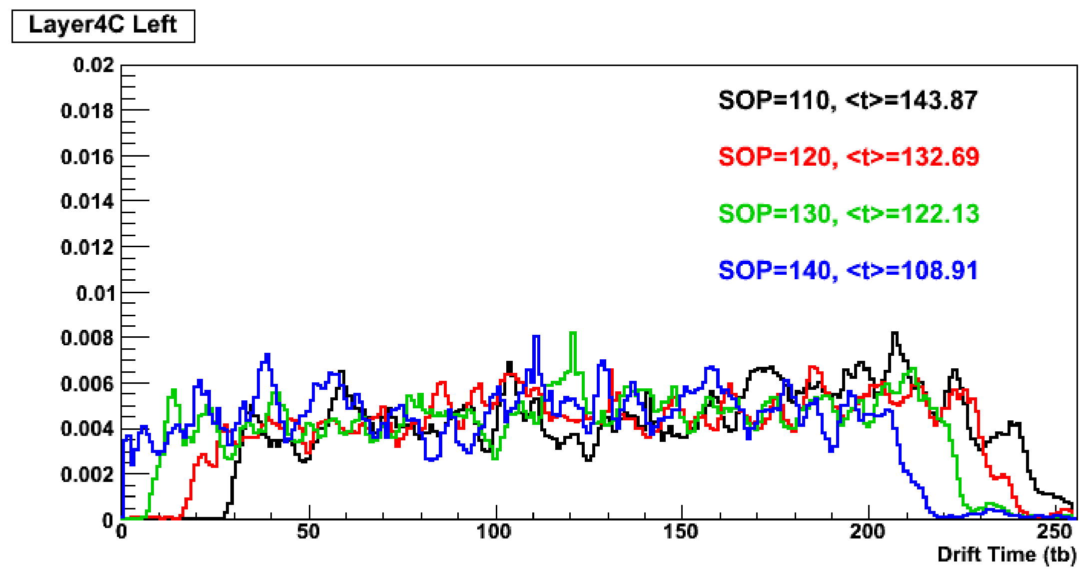




SDD timing

- Start-Of-Payload delay (= the number of clock-cycles after which the AM is frozen and read-out)
  - Tuned to accommodate the 5.4 μs of max. drift time into the 6.4 μs time window defined by the memory depth
  - Done with SOP delay scans during LHC injection tests
    - ✓ ***SPS proton beam dumped close to ALICE***
    - ✓ ***Showers of secondary particles illuminate the ALICE detectors***

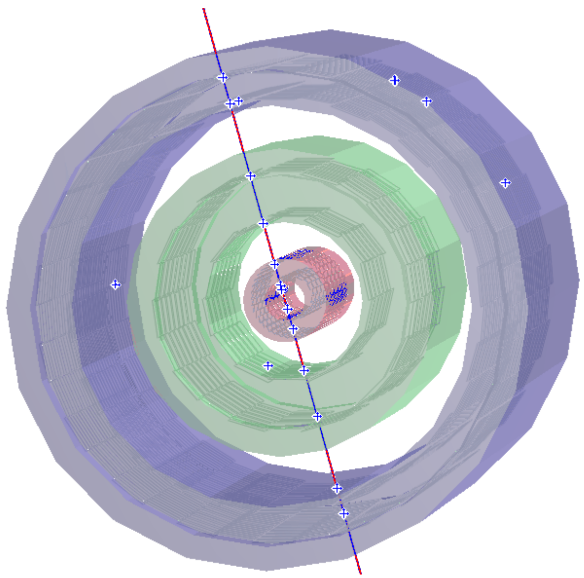




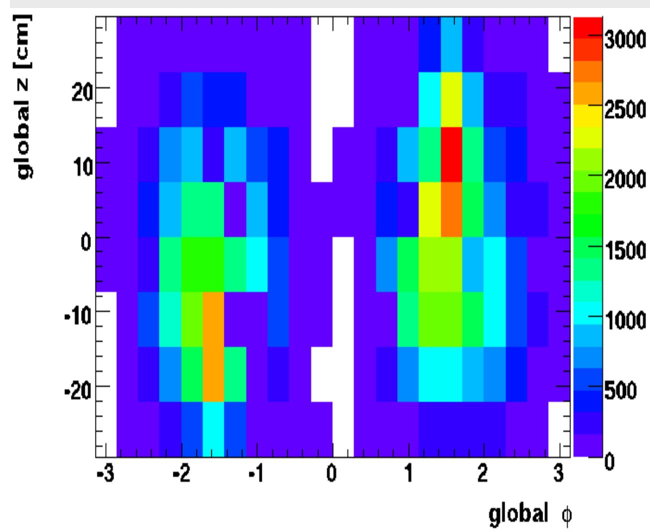
Analyses on cosmic data sample

Talk by G. Aglieri

- Statistics collected with SPD FastOr trigger:
  - ⇨ 2008: ≈ 10^5 good cosmic tracks with full ITS, without B-field
  - ⇨ Goal for 2009: ≈ 10^5 tracks with B-on + 10^5 tracks with B-off
- Goals from analysis of cosmic data:
  - ⇨ Align the 2198 ITS sensors with precision < than their resolution
    - ✓ ***Specific for SDD: calibrate the Time Zero***
    - ✓ ***Time Zero = time after the trigger for a particle with zero drift distance***
  - ⇨ dE/dx calibration in SDD and SSD

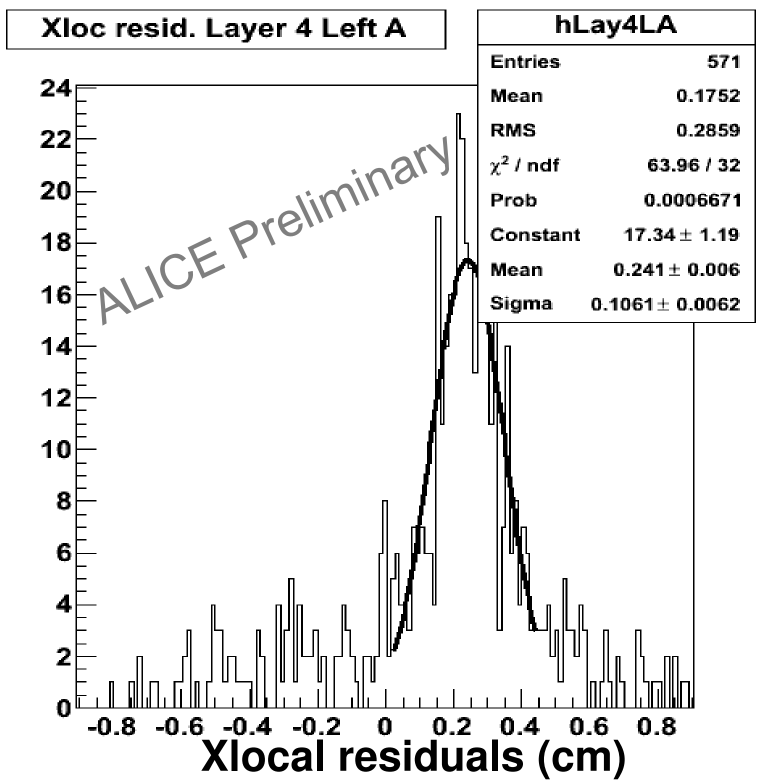


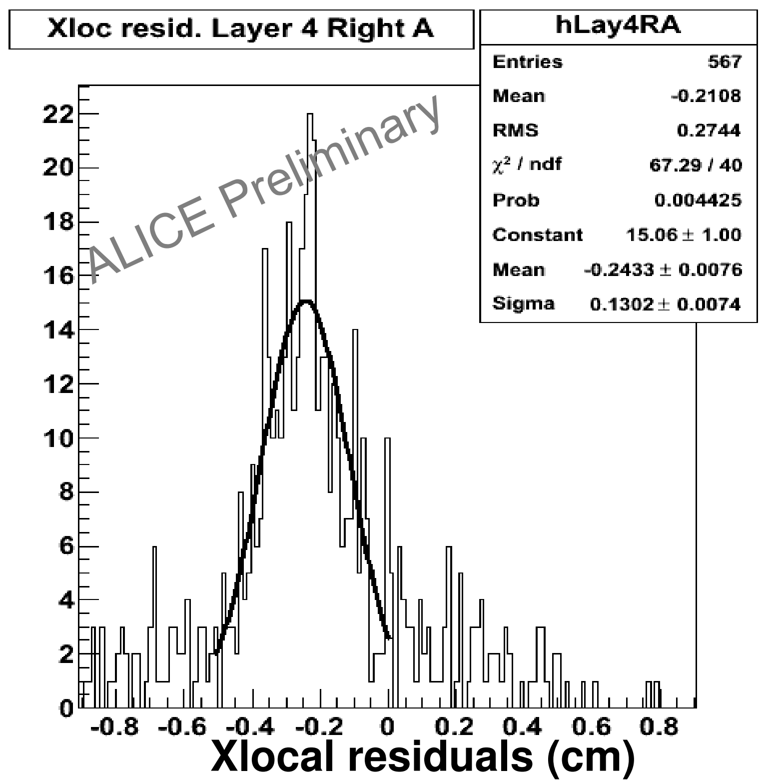
Statistics collected on Layer 4



Time Zero – method 1

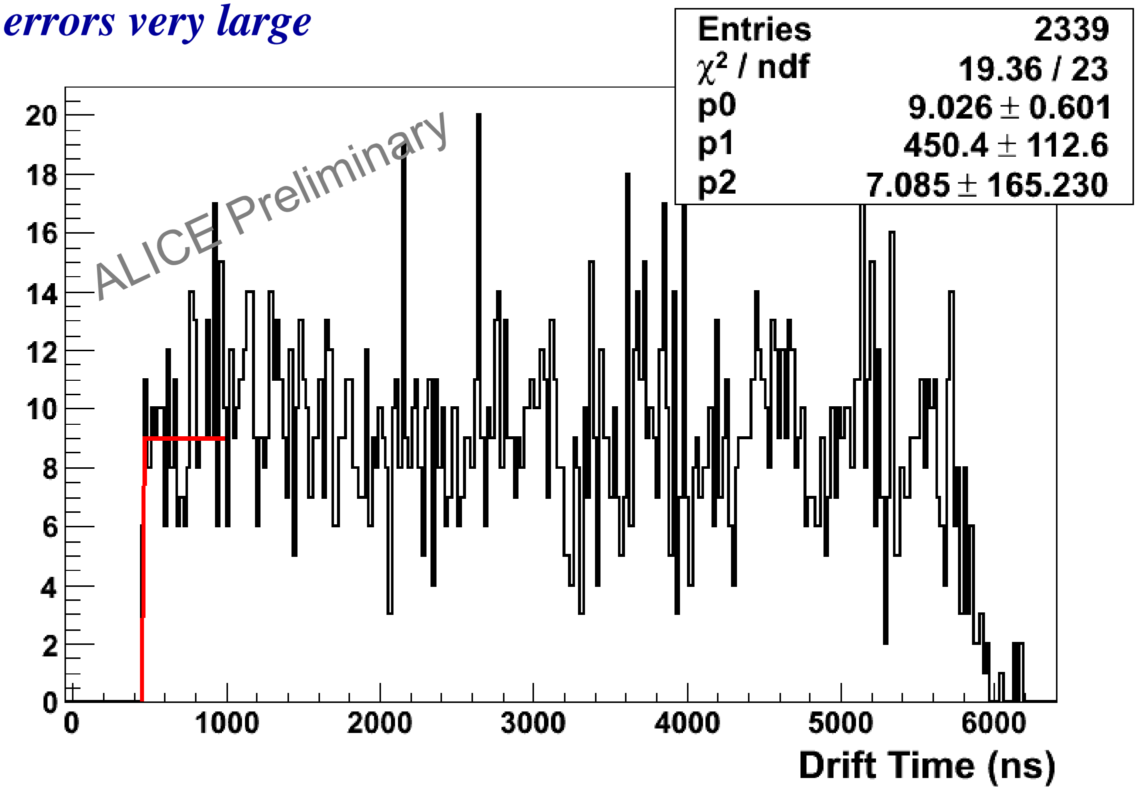
- Cosmic track fitted in SPD and SSD layer
- Track-to-point residuals along drift coordinate in the two drift regions of each SDD module
  - ⇨ Show opposite signed peaks in case of mis-calibrated time zero
  - ⇨ TimeZero = DeltaXlocal / 2. / v_{drift} = 434±6 ns
    - ✓ ***NOTE: preliminary value for 2009 data, averaged over all modules of layer 4 side A***





Time Zero – method 2

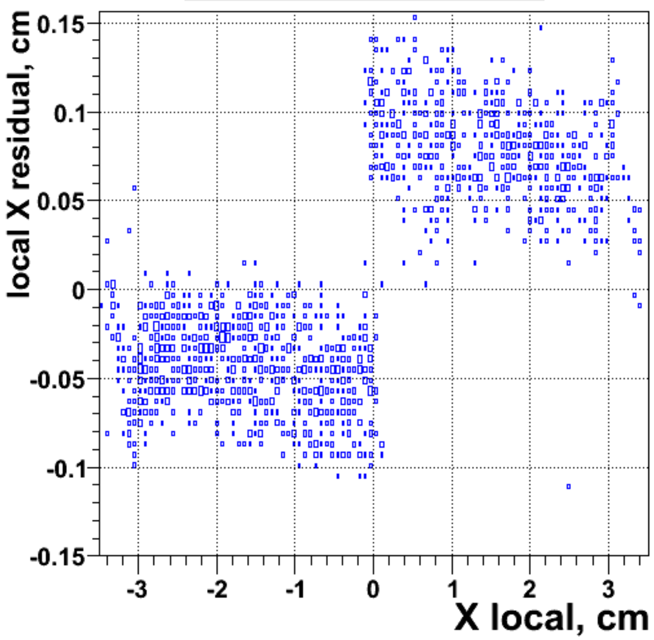
- Extract TimeZero from the minimum measured drift time for SDD reconstructed points associated to tracks
  - ⇨ PROS: no dependence on SDD calibration parameters (drift speed)
  - ⇨ CONS: requires more statistics
  - ⇨ First results from 2009 data analysis look promising
    - ✓ ***TimeZero from fit with error function of the rising edge = 434 ns (Layer 4 side A), BUT errors very large***



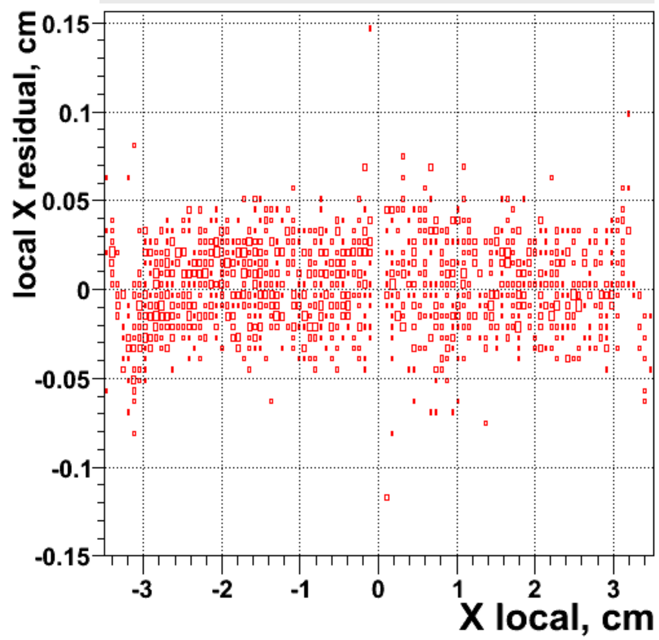
Geometrical alignment of SDD

- Interplay between alignment and calibration
  - TimeZero for each module included as free parameter in Millepede-based alignment together with geometrical rotation and translation
    - ✓ ***Drift speed added as fit parameter for modules with mal-functioning injectors***
  - Resolution along drift direction affected by the jitter of the SPD FastOR trigger (at 10 MHz → 4 SDD time bins) with respect to the time when the muon crosses the SDD sensor

Geometry only

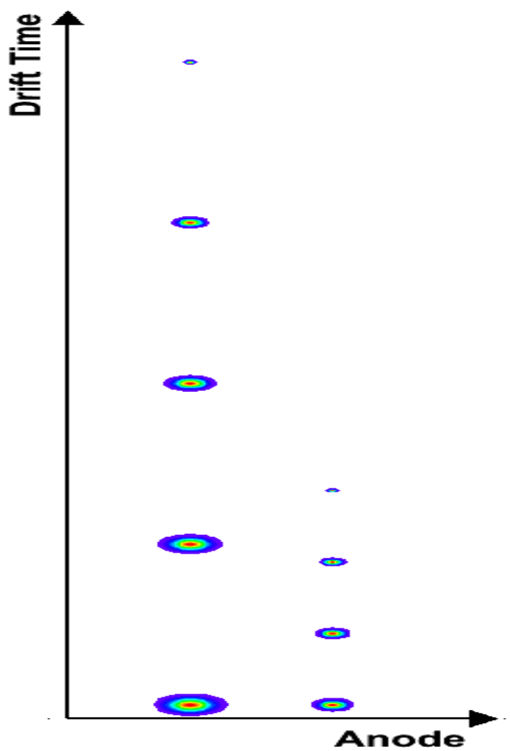


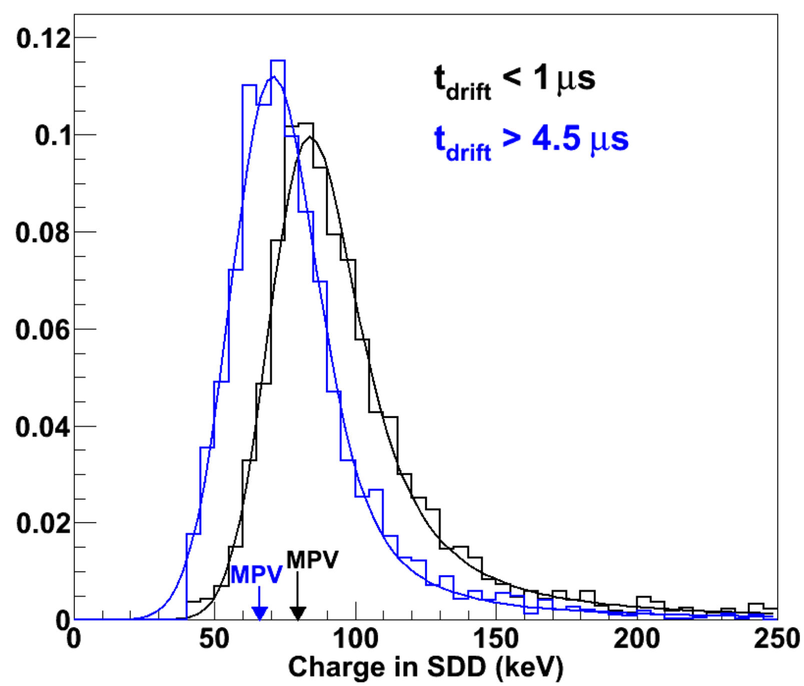
Geometry + calibration



Charge calibration (I)

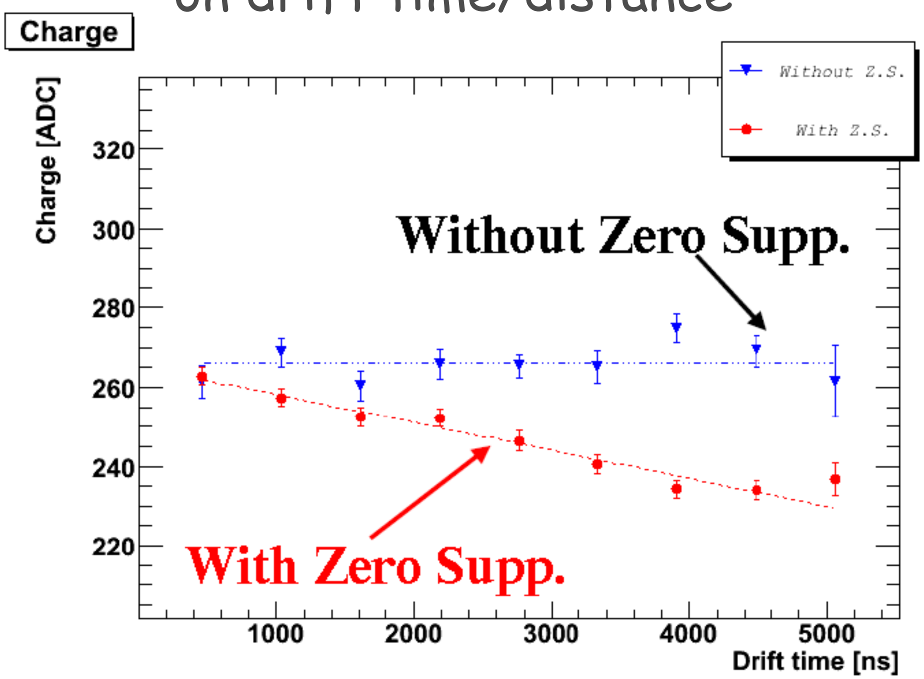
- Cluster charge distribution fitted with Landau+Gauss convolutions
- Most Probable Value of collected charge depends on drift distance/time
  - ⇨ Larger drift distance ⇒ larger charge diffusion ⇒ wider cluster tails cut by the zero suppression



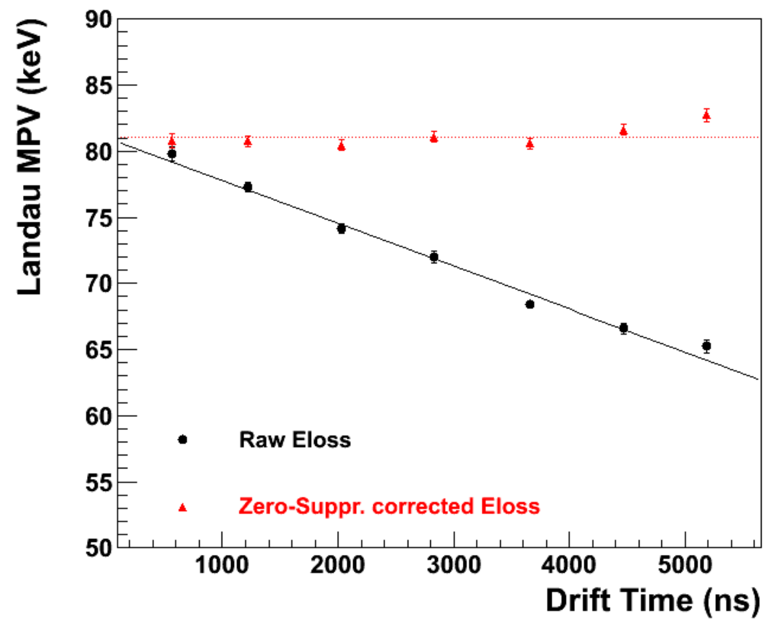


Charge calibration (II)

- Cross check with cosmics collected on few SDDs in test station with and without zero suppression
  - Data without zero suppression show no dependence of Landau MPV on drift time/distance



- Apply linear correction of charge vs. drift time to cosmic data collected in 2008 by ALICE
  - Correction extracted from detailed MC simulations of SDD response



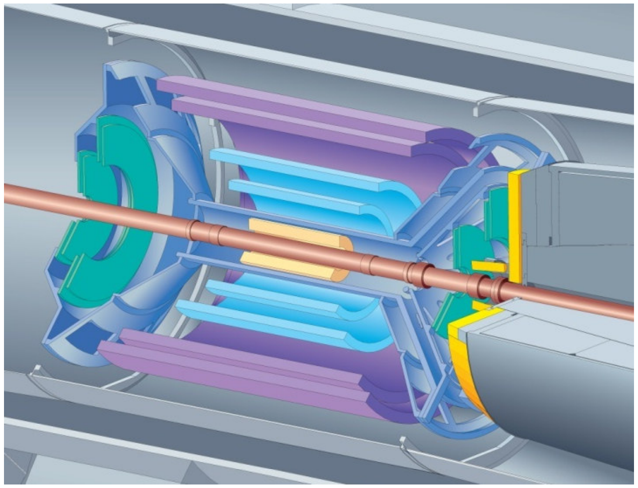
Conclusions

- SDD successfully operated during ALICE cosmic data takings in 2008 and 2009
  - ⇨ 245 SDD modules (out of 260) stably in acquisition during both the data takings, fraction of good anodes > 97.5%
  - ⇨ Calibration strategy deeply tested and tuned
    - ✓ ***Good knowledge of the detector reached***
    - ✓ ***Noise level within the design goal (S/N for MIP close to anodes ≈ 50)***
    - ✓ ***Drift speed stable with 0.2% during stable operation of ITS detectors***
- Results from cosmic data sampled allowed for
  - ⇨ Develop tools for attacking the SDD alignment which is correlated with calibration quantities
    - ✓ ***Tuning of TimeZero module-by-module using Millepede***
    - ✓ ***Recovering drift speed for modules with mal-functioning injectors***
  - ⇨ Calibrate the charge collection efficiency as a function of drift time
    - ✓ ***Good results by applying the correction based on MC simulation of Zero Suppression algorithm***
- SDD ready for the forthcoming p-p collisions at LHC

Backup

Inner Tracking System

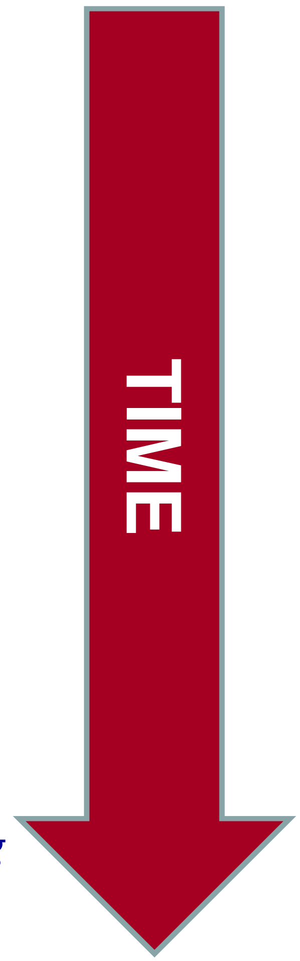
- Design goals
  - ⇨ Optimal resolution for primary vertex and track impact parameter
    - ✓ ***Minimize distance of innermost layer from beam axis (<r>≈ 3.9 cm) and material budget***
  - ⇨ Maximum occupancy (central PbPb) < few %
  - ⇨ 2D devices in all the layers
  - ⇨ dE/dx information in the 4 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./cm²	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

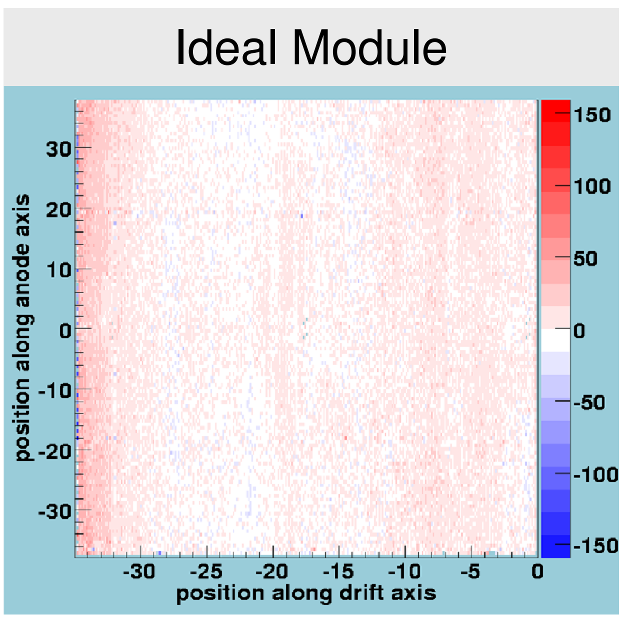
ITS Commissioning data taking

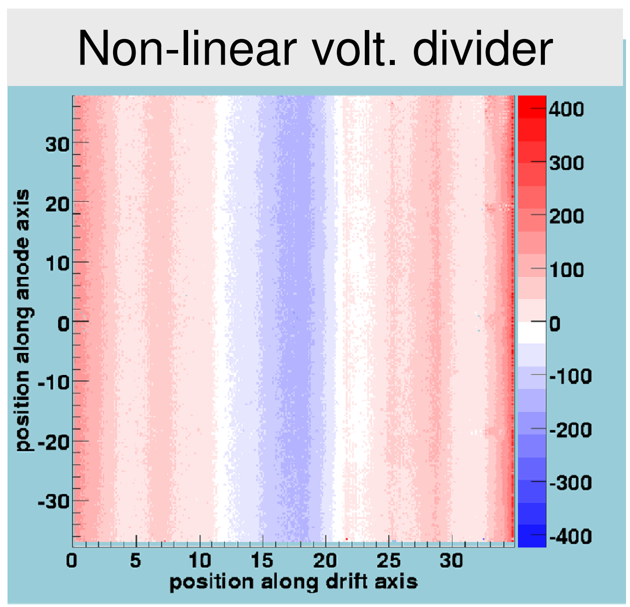
- Detector installation completed in June 2007
- Run 1 : December 2007
  - ⇨ First acquisition tests on a fraction of modules
- Run 2 : Feb/Mar 2008
  - ⇨ ≈ 1/2 of the modules in acquisition due to cooling and power supply limitations
  - ⇨ Calibration tests + first atmospheric muons seen in ITS
- Installation of services completed in May 2008
- Run 3 : June/October 2008
  - ⇨ Subdetector specific calibration runs
    - ✓ ***Frequent monitoring of dead channels, noise, gain, drift speed …***
  - ⇨ Cosmic runs with SPD FastOR trigger
    - ✓ ***First alignment of the ITS modules + test TPC/ITS track matching***
    - ✓ ***Absolute calibration of the charge signal in SDD and SSD***
- Run4 : started on mid August 2009

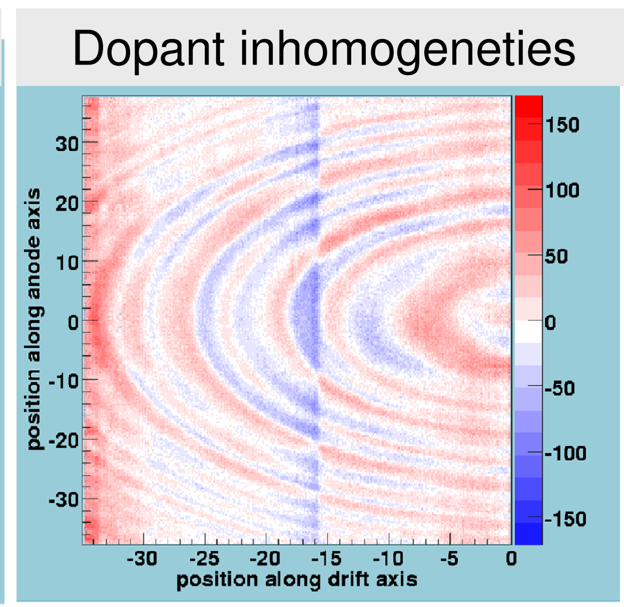


SDD correction maps

- All the 260 SDD modules have undergone a complete characterization (map) before assembling in ladders
  - ⇨ Charge injected with an infrared laser in > 100,000 known positions on the surface of the detector
  - ⇨ For each laser shot, calculate residual between the reconstructed coordinate and the laser position along the drift direction
  - ⇨ Systematic deviations due to:
    - ✓ *Non-constant drift field due to non-linear voltage divider*
    - ✓ *Parasitic electric fields due to inhomogeneities in dopant concentration*

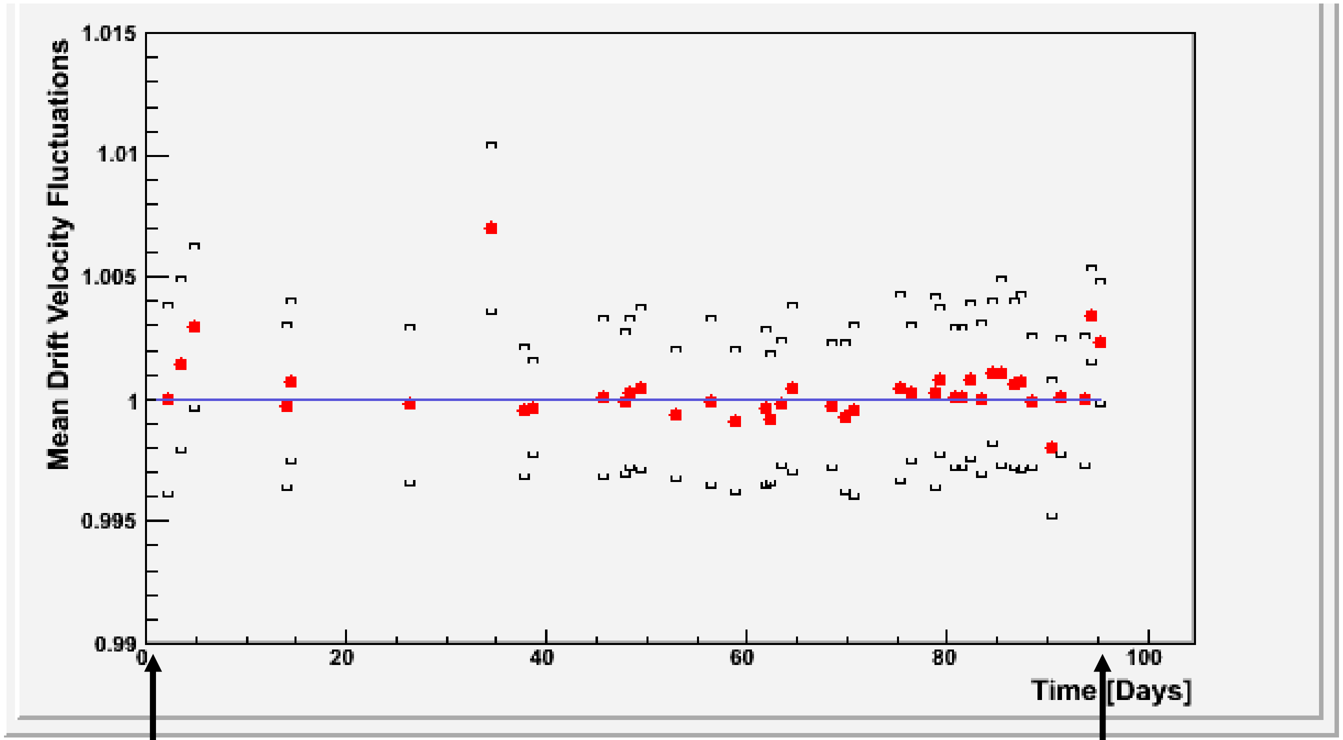






Drift speed vs. time

Layer 3, Ladder 6, Mod 275, Anode 200

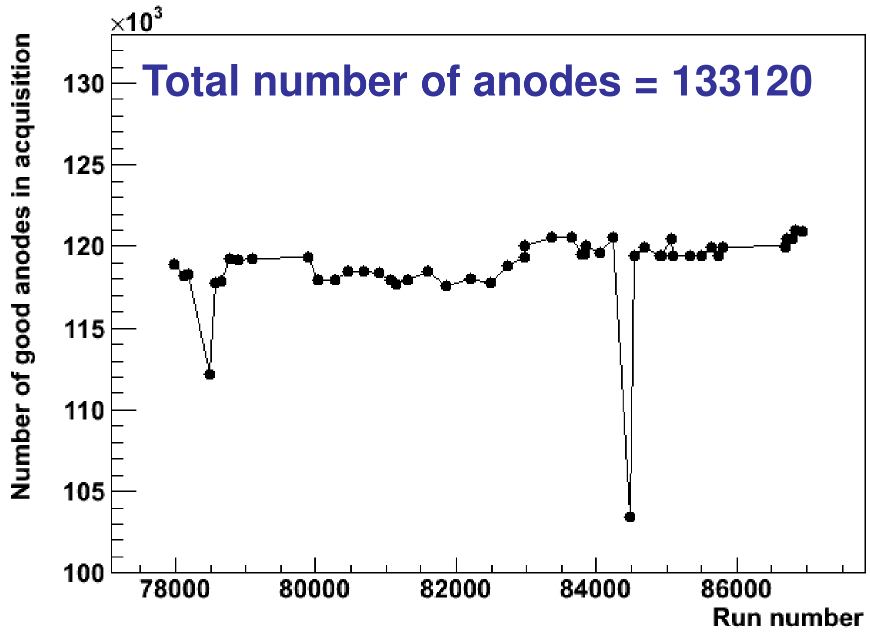


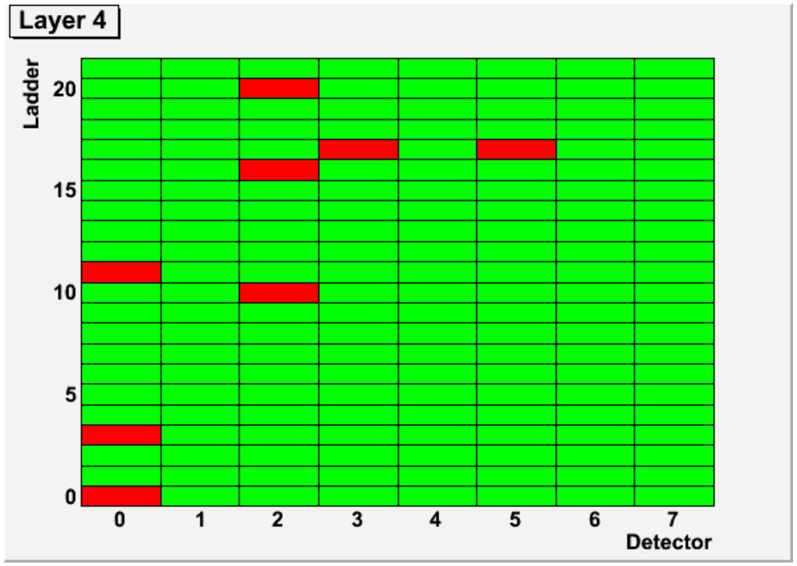
July 11th 2008

October 14th 2008

SDD during 2009 cosmic run

- SDD constantly took cosmic data from Aug 17 to Sep 13
  - ⇨ 93% of modules included in DAQ
  - ⇨ Fraction of good anodes in the good modules = 97%
  - ⇨ <Event size> ≈ 10 kB / event (@ 20 MHZ AM sampling)
    - ✓ ***Factor 50 improvement w.r.t. 2008***





ITS Alignment

- Two track-based methods to extract the alignment objects (translations and rotations) for the 2198 ITS modules:
  - ⇨ Millepede (default method, as for all LHC experiments)
    - ✓ ***Determine alignment parameters of "all" modules in one go, by minimizing the global χ^2 of track-to-points residuals for a large set of tracks***
  - ⇨ Iterative approach
    - ✓ ***Align one module at a time by fitting tracks in the other modules and minimizing the residuals in the module under study***
- Plus and hardware (based on collimated laser beams, mirrors and CCD cameras) alignment monitoring system
  - ⇨ Monitor physical movements of ITS with respect to TPC
- Strategy for the track-based alignment:
  - ⇨ Use geometrical survey data as a starting point
    - ✓ ***Measurements of sensor positions on ladders during SDD and SSD construction***
  - ⇨ Hierarchical approach:
    - ✓ ***Start from SPD sectors (10) , then SPD half staves (120), then SPD sensors (240)***
    - ✓ ***After fixing SPD, align SSD barrel (w.r.t. SPD barrel), then SSD ladders (72) …***
    - ✓ ***After fixing SPD and SSD, move to SDD (which need longer time for calibration)***
  - ⇨ Include SDD calibration parameters:
    - ✓ ***Time Zero = time after the trigger for a particle with zero drift distance***
    - ✓ ***Drift speed for modules with mal-functioning injectors***