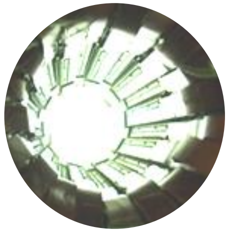
PAUL SCHERRER INSTITUT PSI
PIXEL 2010 Grindelwald, Switzerland
5th International Workshop on Semiconductor Pixel Detectors for Particles and Imaging, September 6–10, 2010

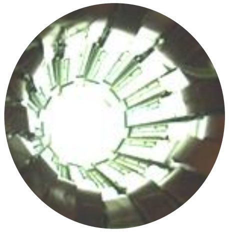
The ALICE Silicon Pixel Detector – Commissioning, Operation and Performance with Proton-Proton Beams

Petra Riedler on behalf of the ALICE Silicon Pixel Detector Project in the ALICE Collaboration



OUTLOOK

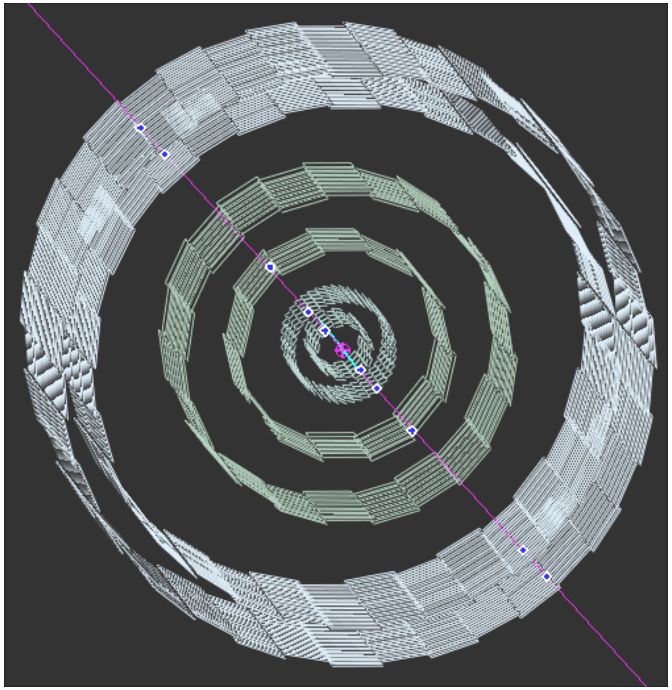
- The ALICE SPD
- Operation with cosmics and in p-p collisions
- Preparation for heavy ion run

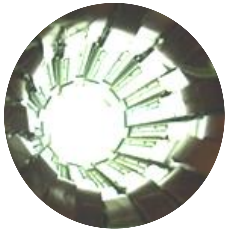


ALICE Inner Tracking System

- ITS (Inner Tracking System) consists of 2 layers of silicon pixel (SPD), 2 layers of silicon drift (SDD) and 2 layers of silicon strip detectors (SSD)

6 layer ITS



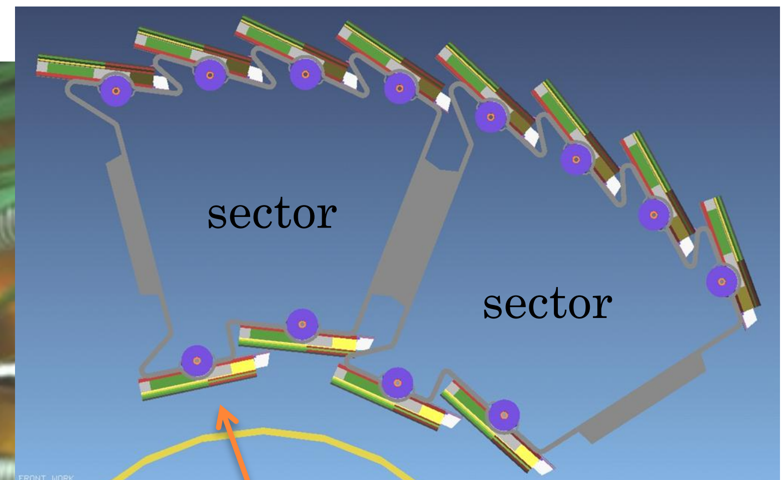


ALICE Silicon Pixel Detector

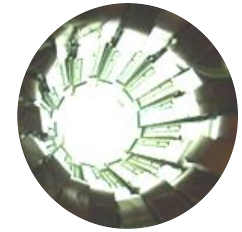
2 barrel layers formed by 10 carbon fiber sectors

$R_{inner\ layer}$: 3.9 cm

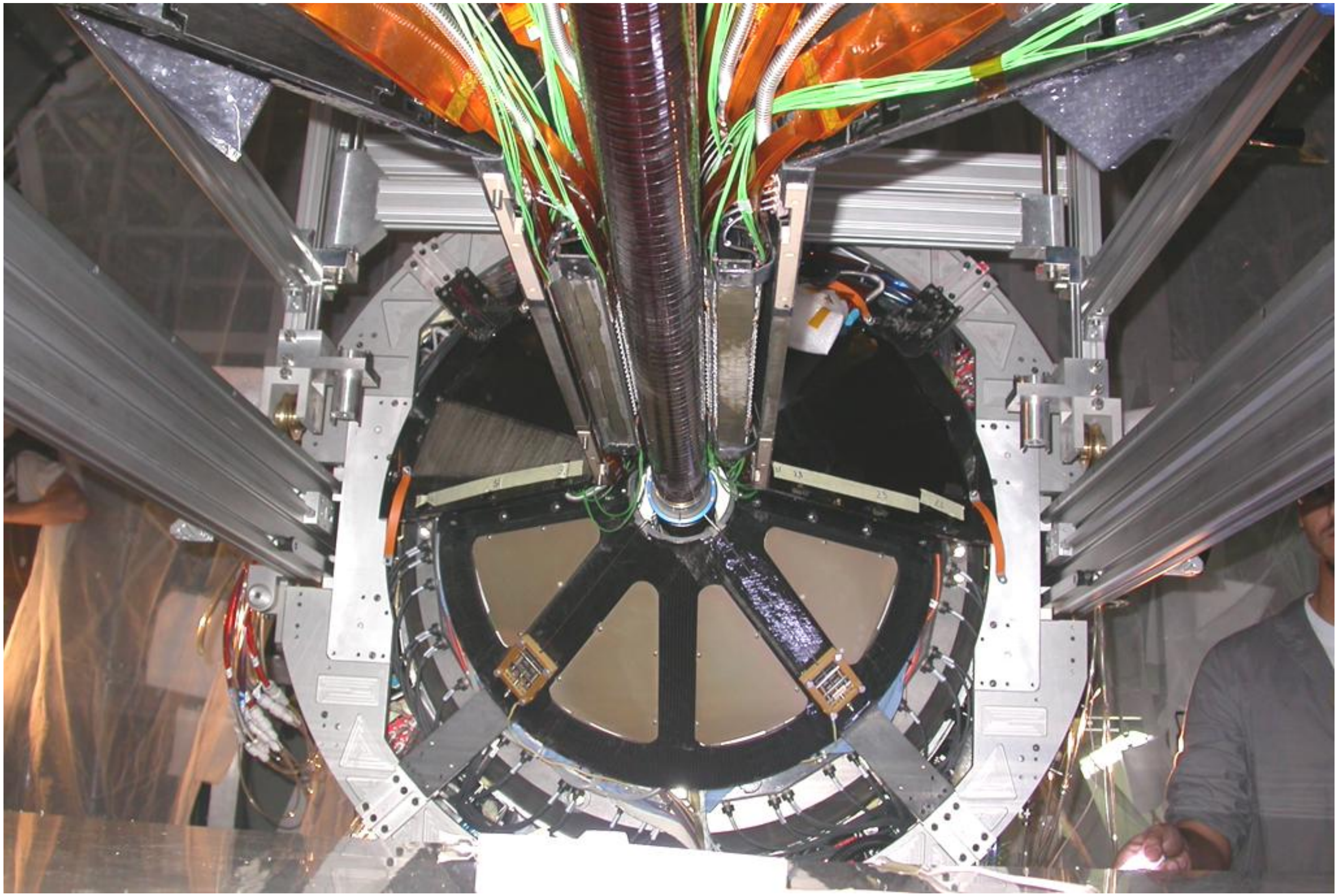
$R_{outer\ layer}$: 7.6 cm

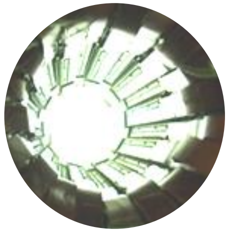


Minimum clearance of closest component to beam-pipe ~ 5 mm



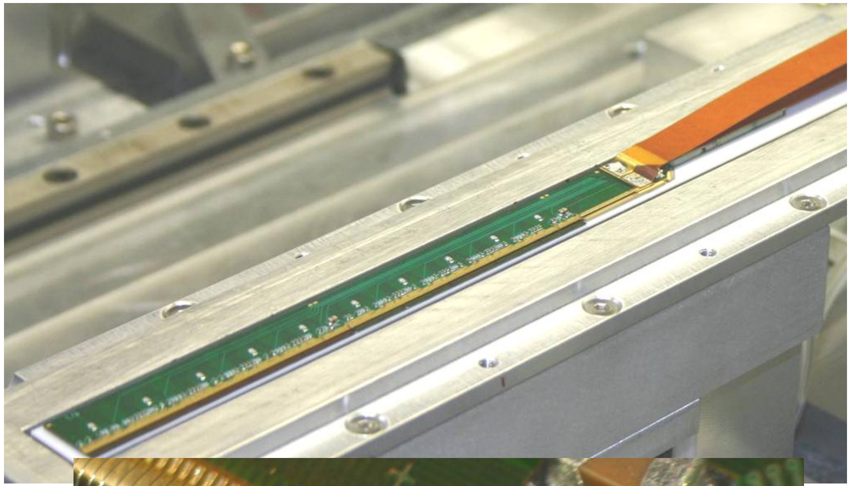
ALICE Silicon Pixel Detector

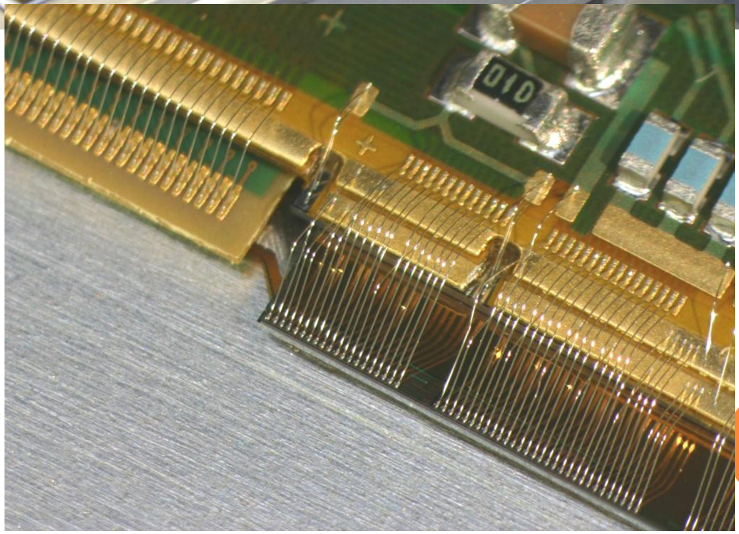


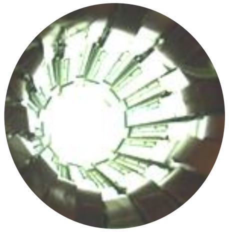


ALICE Silicon Pixel Detector

- Smallest building block: half-stave
- 120 half-staves (40 inner +80 outer)
- Each half-stave consists of:
  - 1 MCM
    - max. height: 5 mm
  - 2 fc bonded ladders
    - 5 chips + 1 sensor
  - 1 multilayer bus
- 1200 pixel chips
- 9.83 x 10^6 pixels

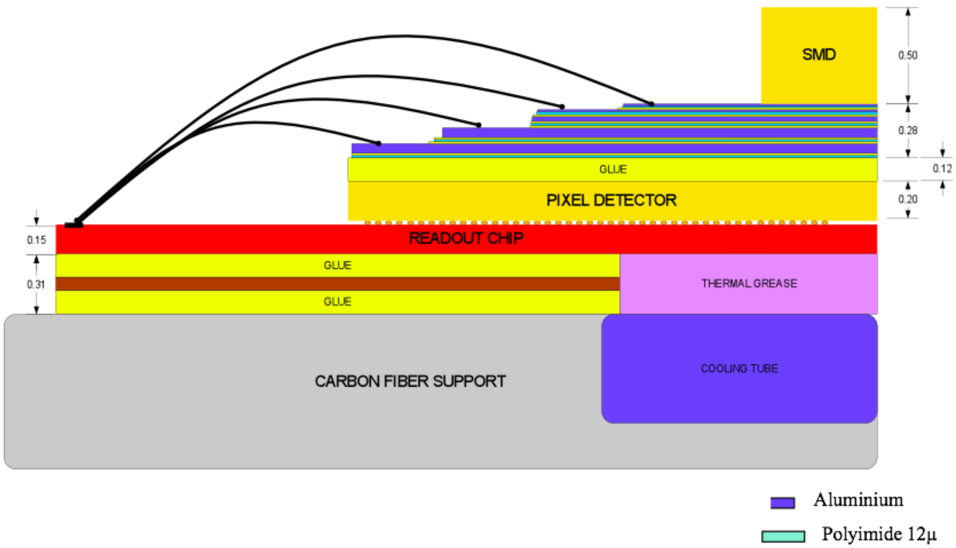






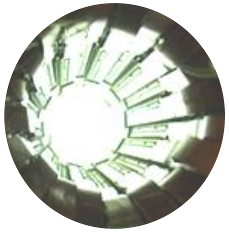
ALICE SILICON PIXEL DETECTOR

HALF STAVE CROSS SECTION

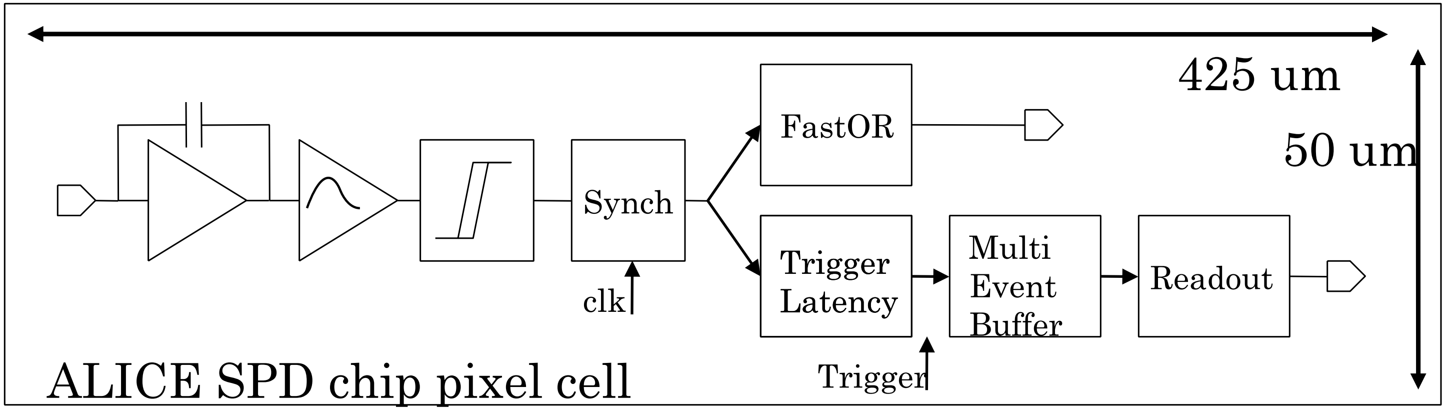


Optimize material budget:
~1.1% X_0 per layer

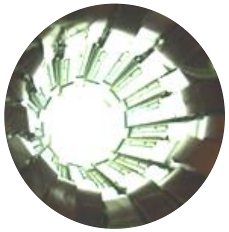
- Carbon fibre: 200 µm
- Cooling tube (Phynox): 40 µm wall thickness
- Grounding foil (Al-Kapton): 75 µm
- Pixel chip (Silicon): 150 µm
- Bump bonds (Pb-Sn): diameter ~15-20 µm
- Silicon sensor: 200 µm
- Pixel bus (Al+Kapton): 280 µm
- SMD components
- Glue (Eccobond 45) and thermal grease



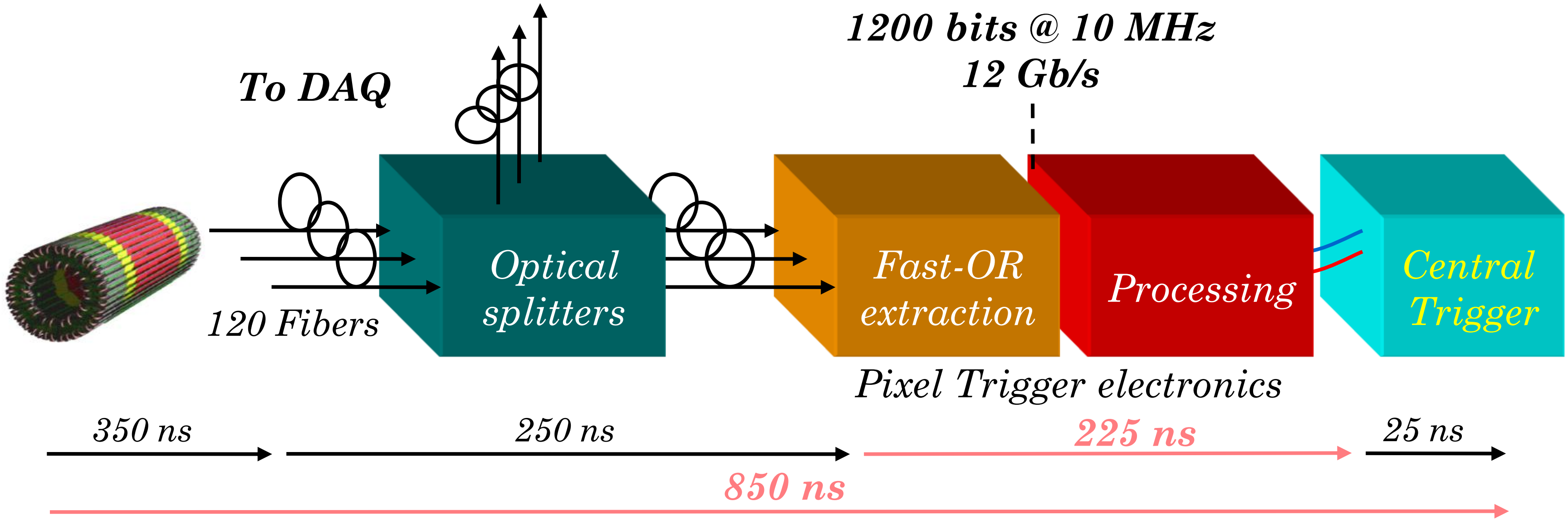
PIXEL TRIGGER



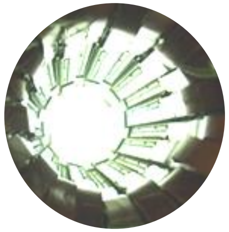
- Dedicated FastOr (FO) circuitry in each pixel cell
- Active if at least one pixel per chip is hit
- Transmitted every 100 ns
- Two data streams: data + FO
- Low latency pad detector with 1200 pads
- Used for L0 trigger decisions (cosmics, pp, HI)



PIXEL TRIGGER

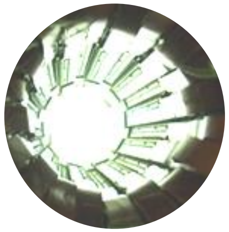


- Extract and synchronize 1200 FO bits every 100 ns
- User defined and programmable algorithms (MB, topological trigger, high multiplicity trigger,..)
- Overall latency: 850 ns



COMMISSIONING

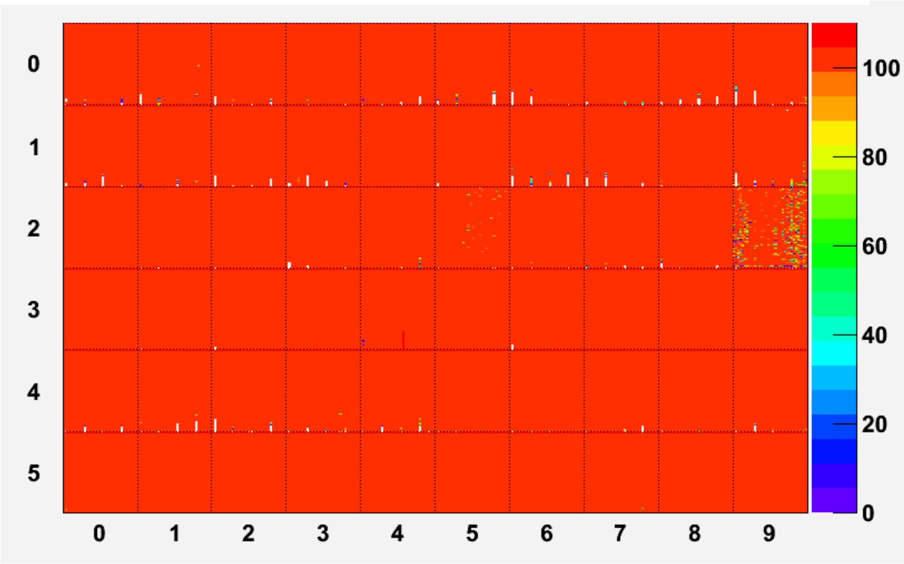
- SPD fully commissioned in the lab (CERN DSF) prior to installation in the pit
- Installed in summer 2007 in ALICE
- First switch-on of half of the detector: December 2007 (no connection of one side possible due to ongoing installation work)
- Fully connected and operated in 2008: data taking with cosmics
- SPD trigger used to trigger ALICE during cosmic runs



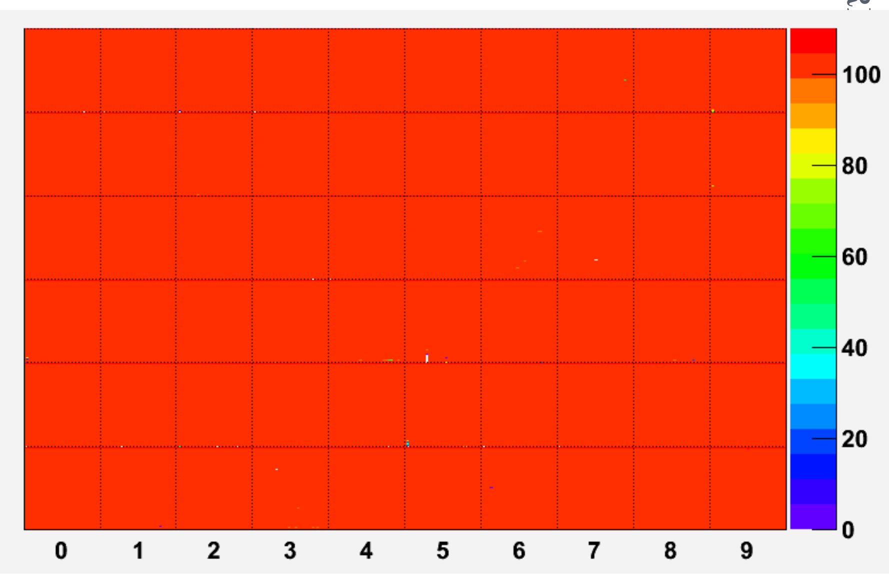
Performance Optimization

- Tuning of the chip settings using the internal test-pulse to optimize the matrix response
- Noisy pixels (masked)<10-4
- Dead pixels (in working chips): 1.2%

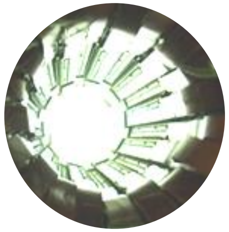
Half-sector hit map



Before tuning

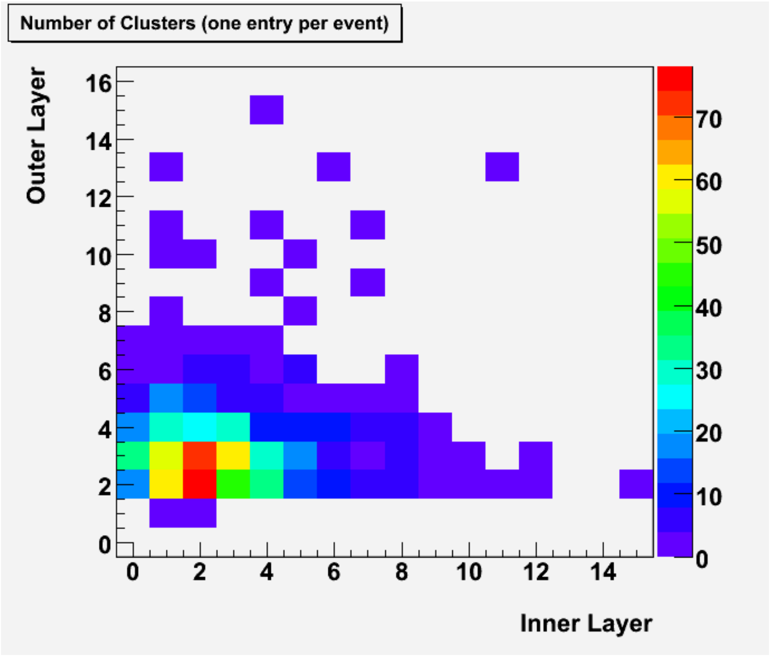


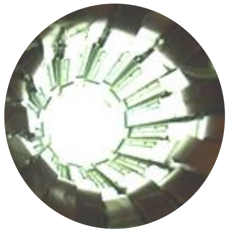
After tuning



Cosmic Data Taking

- SPD Trigger: require coincidence between one cluster in top half-barrel and one cluster in bottom outer half barrel
- Rate: 0.18 Hz in agreement with muon flux measured in the cavern and with MC
- Very high purity: 99.5% of events with at least two clusters in the outer layer

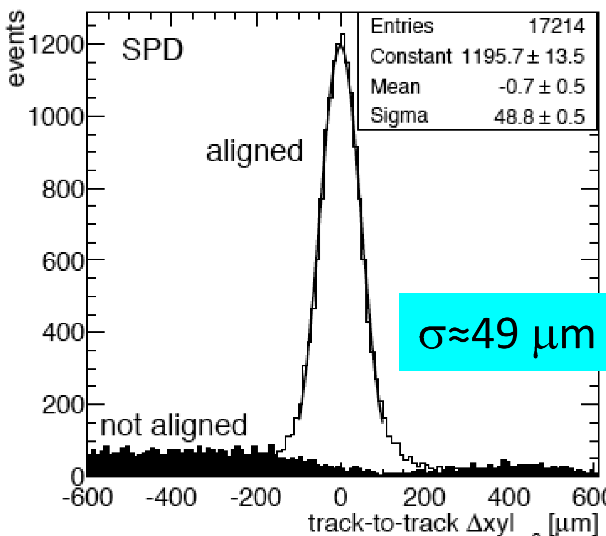




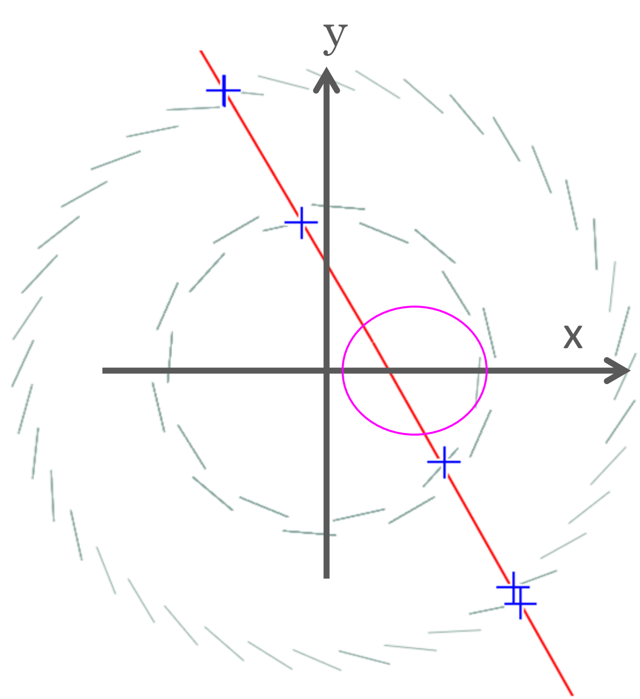
ALIGNMENT WITH COSMICS

- Track-based alignment with MillePede2 (global residuals minimization)
- Cosmics with SPD trigger: ~10^5 B=0, ~10^4 B=±0.5T
- Alignment quality:
  - matching of top-bottom "half tracks"

ALICE Coll. JINST 5 (2010) P03003



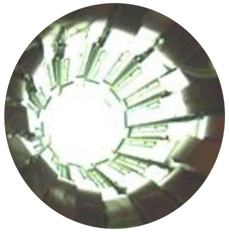
σ≈49 μm



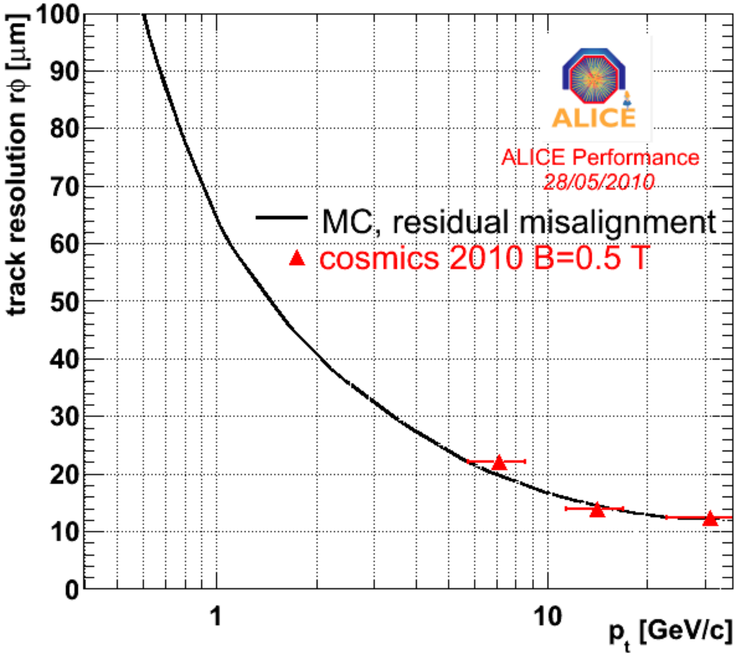
Expected spread

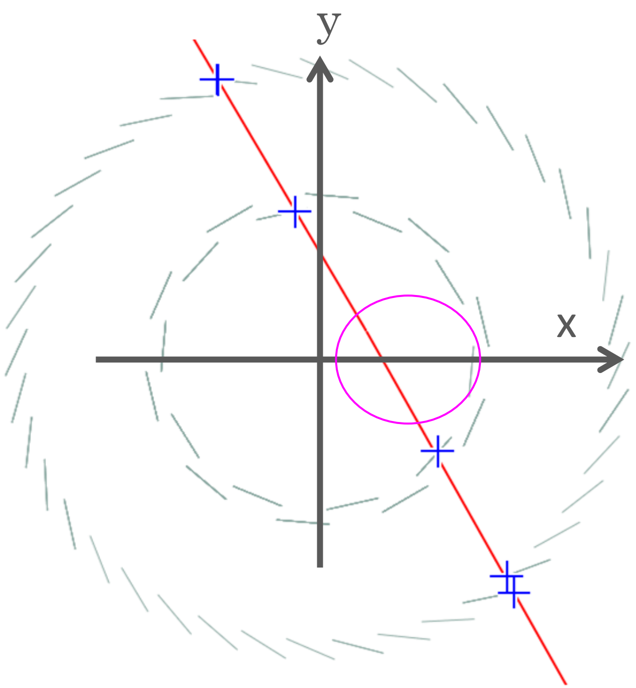
$$\sigma^2_{\Delta x} = 2*(r^2_{SPD2}+r^2_{SPD1})/(r_{SPD2}-r_{SPD1})^2*\sigma^2_{spatial}$$

→ $\sigma_{spatial}$≈13 μm → σ_{misal}~7 μm → $\sigma_{spatial}$=11 μm (Sim)

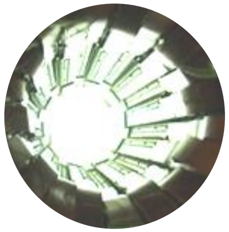


Alignment with Cosmics



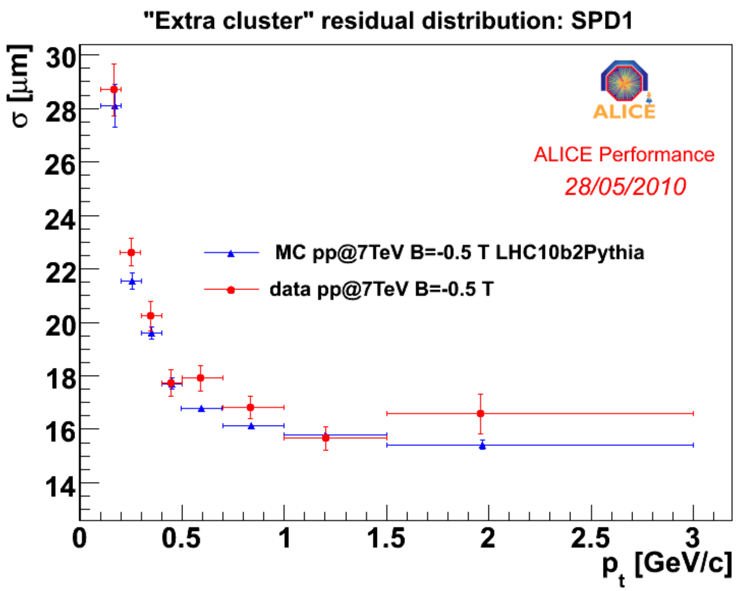


single track position resolution matches well the MC expectation
(statistics not sufficient to go to low transverse momentum)

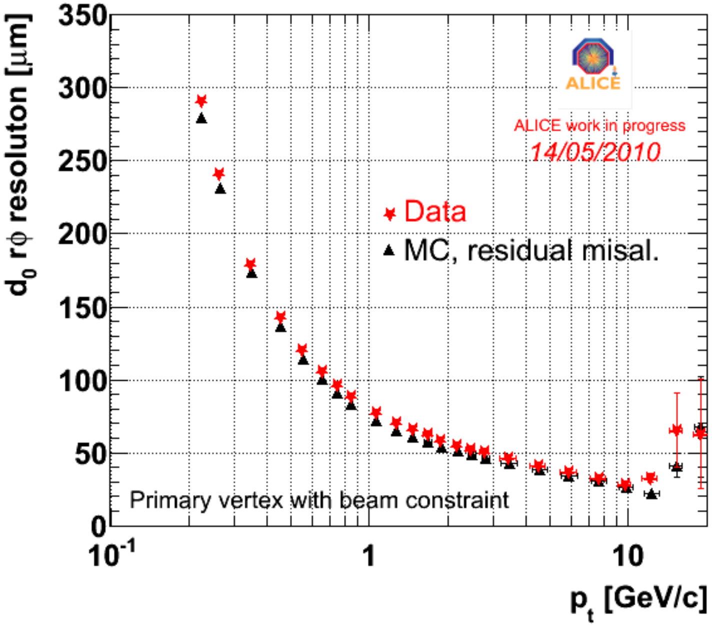


ALIGNMENT WITH PP-COLLISIONS

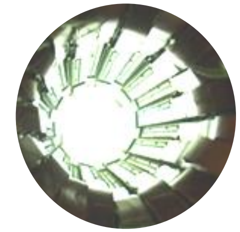
Rϕ distance between two clusters in overlapping modules



track-to-primary-vertex distance of closest approach vs p_t : close to MC; improving…

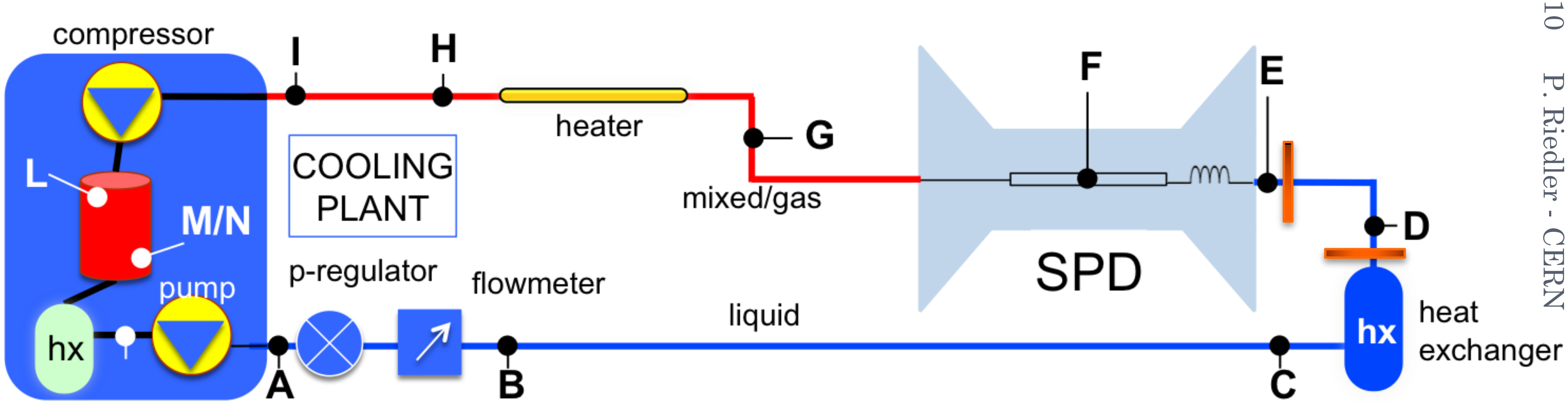


Using full ITS

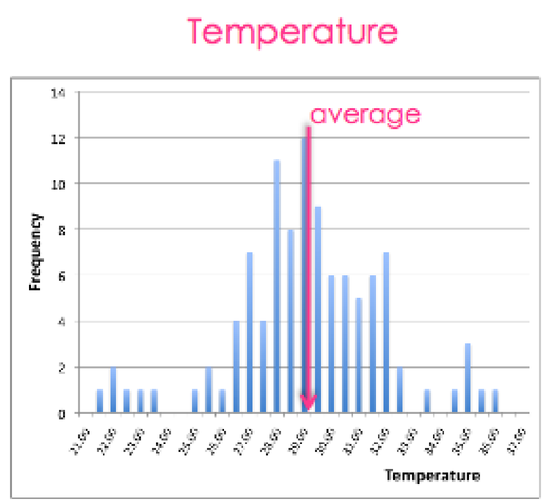


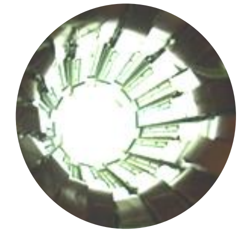
Cooling System

- Evaporative 2-phase system using C_4F_{10}



- Average temperature: 29°C



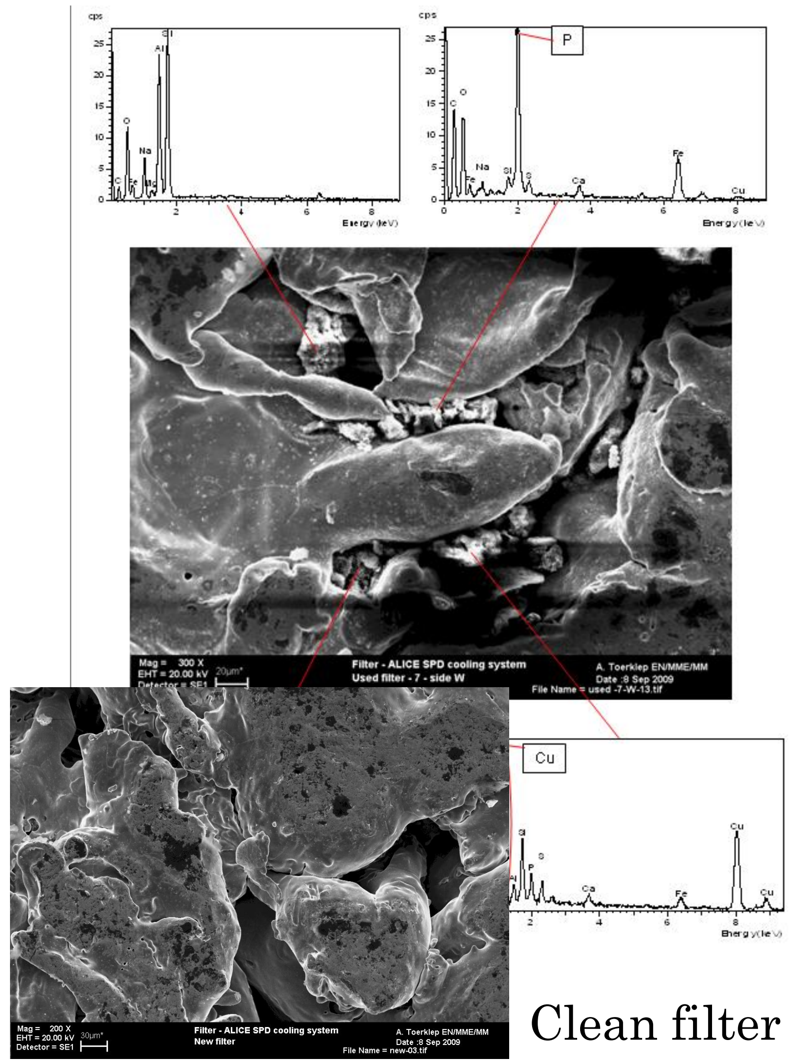


Number of half-staves

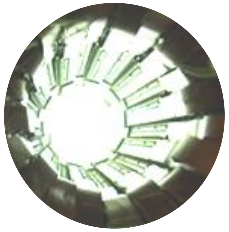
Number of operational HSs changed with time:

- During commissioning in DSF: 120 (100%)
- October 2008: 103
- August 2009: 85
- SEM analysis of micro-filter shows clogging >> counter-flushing of lines
- November 2009: 110
- One patch-panel with filters only accessible during long shutdown (move TPC)

Used filter

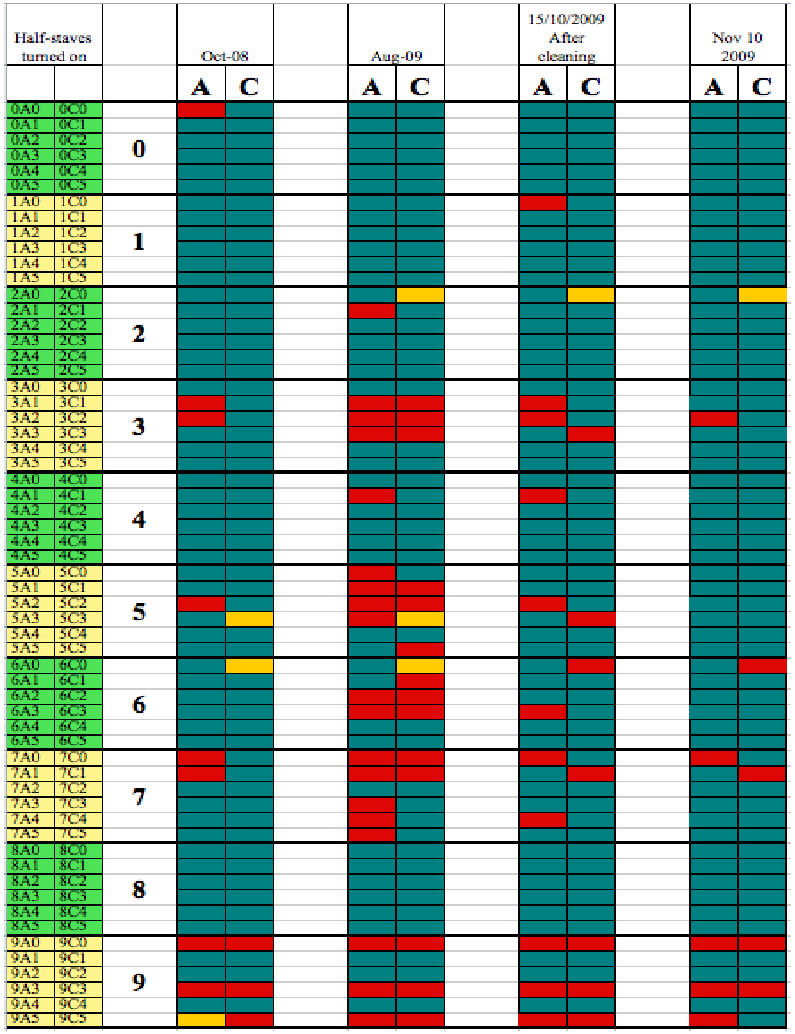


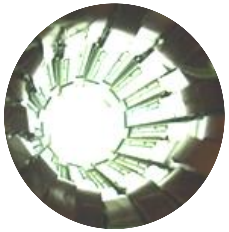
Clean filter



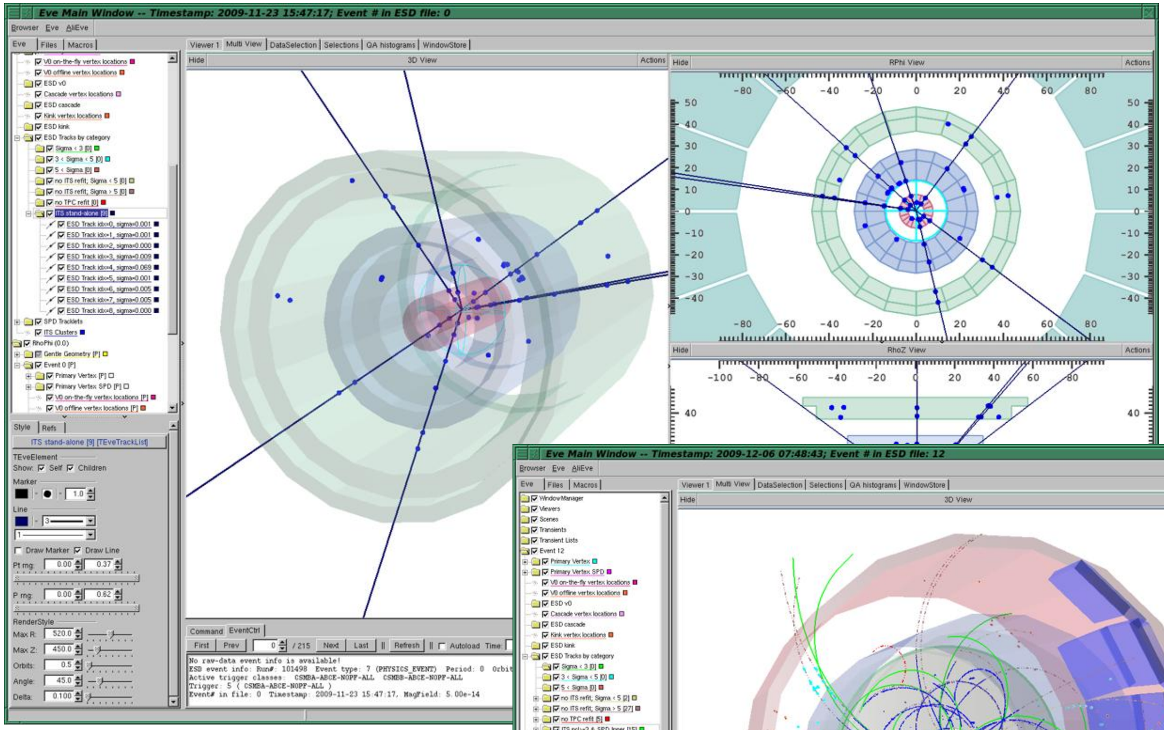
NUMBER OF HALF-STAVES

- Impact on tracking not negligible: efficiency reduced by 15% if single SPD-point required and ~40% if 2 points required
- Flow could be partially improved, pressure valves and flow meters on every of the 10 cooling lines
- Further improvement expected during next long access (>filters)
- In the meantime the SPD works very well:

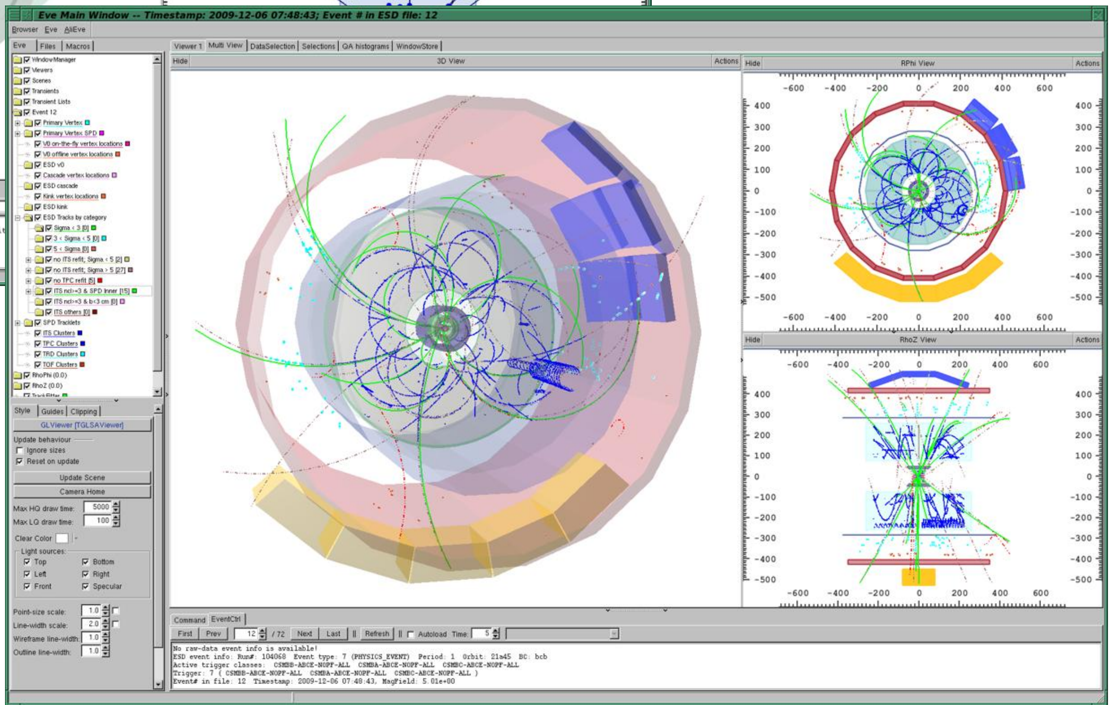




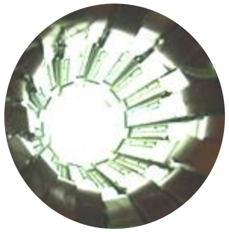
FIRST EVENTS …



900 GeV

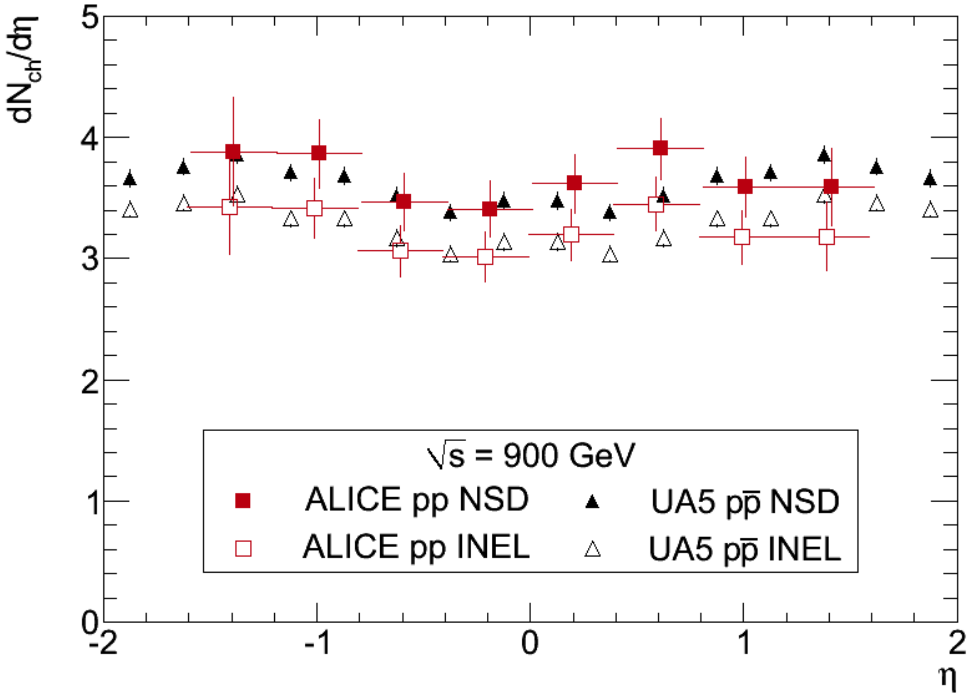


7 TeV



First Physics results

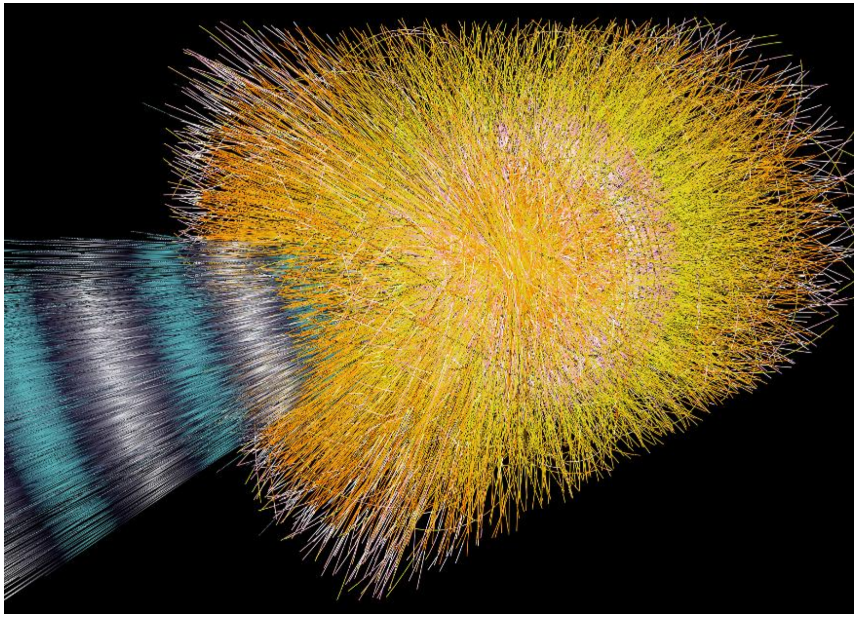
- First LHC paper shows pseudorapidity density based on SPD data and 900 GeV (and using SPD trigger in L0 decision)
- SPD data also key for next publications (2.36 TeV and 7 TeV)

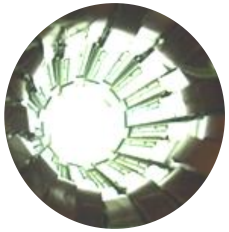


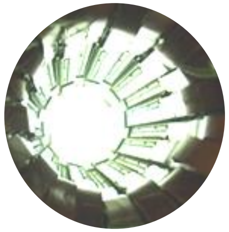
EPJ C: Vol.65, 1 (2010)
284 events, 23/11/2009

Preparation for Heavy ion run

- LHC HI run: week 44-48 2010
- Test runs of ALICE in HI configuration
- Check if DAQ/Detectors/Trigger can cope with the rates and data volume
- Up to dN/dη ~8000 (Pb-Pb central collisions)

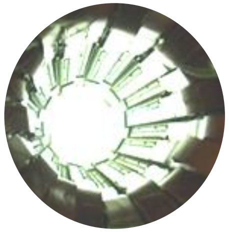






PREPARATION FOR HEAVY ION RUN

- SPD:
  - No difference in the operation of the readout in pp and ion-ion runs
  - Frontend ASICs were designed to cope with expected HI rates and occupancy
  - Zero suppression and formatting is done off detector in the control room – no inefficiencies (loss of hits) of the readout up to average pixel occupancy of 12.5%
- Specific tests carried out using the SPD and the setup in the test-facility (small scale SPD):
  - Increase data size to expected 246kB/event on real detector by lowering threshold on full detector
  - Dedicated tests in the test-facility: increase data volume by injecting test charge



SUMMARY AND OUTLOOK

- The ALICE SPD has proven to be very robust and able to provide key data and trigger information for the first running at LHC
- Further improvements of the cooling system are foreseen for the next long shutdown
- In the meantime several publications are based on SPD data and trigger and more are in preparation
- Different options for a future pixel detector in ALICE are being explored:
    - Thinning studies
    - Novel sensors (epi, edgeless, …)
    - Monolithic pixels (LePix)
    - First results from tests in the next PIXEL workshop