Modification of the near-side jet peak at $\sqrt{s_{NN}} = 2.76$ TeV Pb–Pb collisions measured by the ALICE detector

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CERN ALICE, Utrecht University

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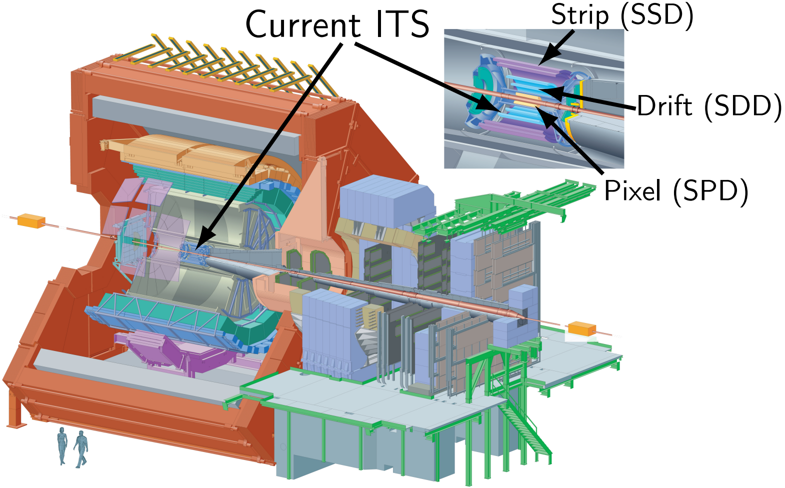
Wigner Theoretical Physics Seminar



- Current ITS has six layers
- Only two layers equipped with pixel detectors

Motivations and strategy:

- High precision measurements of **heavy flavor and charmonia at low p_{T}** and **low-mass dileptons**
  - cannot be selected by a hardware trigger
- Record large **minimum bias** samples
  - read out all Pb–Pb collisions at 50 kHz
- **Integrated luminosity of 10 nb^{-1}** in Pb–Pb (plus pp and p–A data)
  - factor 100 in statistics compared to LHC Run 1 and 2 (2009 - 2019)

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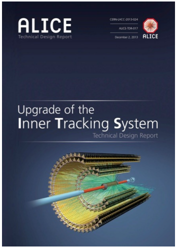
Upgrades:

- New Inner Tracking System (ITS)
- New Muon Forward Tracker (MFT)
- Smaller beam pipe
- Online and offline system
- Electronics and readout of the Time-Projection Chamber (TPC)
- Readout electronics of several detectors
- New Fast Interaction Trigger (FIT)

Design objectives for the upgrade of the ITS

- Improve impact parameter resolution by a factor of 3(5) in r-φ(z) at $p_{\mathrm{T}} = 500$ MeV/c
  - First layer closer to interaction point: 39 mm → 23 mm
  - Material budget: $\sim 1.14\%$ X_0 → 0.3% X_0 for the three innermost layers
  - Pixel size: 50µm × 425µm → 29 µm × 27 µm



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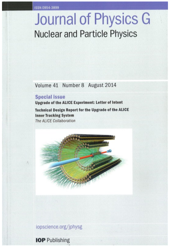

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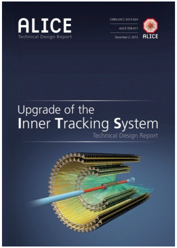
  - All layers pixel chips (instead of strip, drift and pixel layers)



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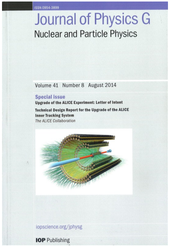

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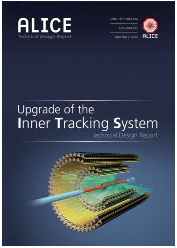
- Fast readout (present ITS is limited to 1 kHz)
  - Pb-Pb: up to 100 kHz
  - pp: several 100 kHz
- Fast insertion/removal for yearly maintenance



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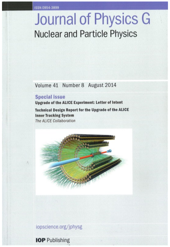

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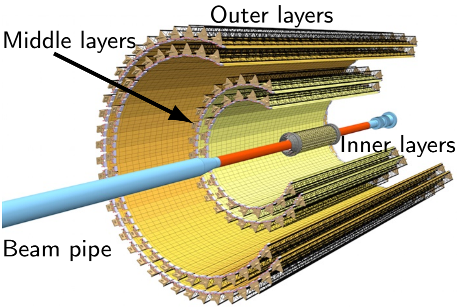
Requirements for the upgrade of the ITS



- 7 layers of pixel sensors ($r = 23 - 400$ mm)
- 10 m^2 of silicon with 12.5 Gpixels
- $|\eta| < 1.22$ for tracks from 90% of the most luminous region

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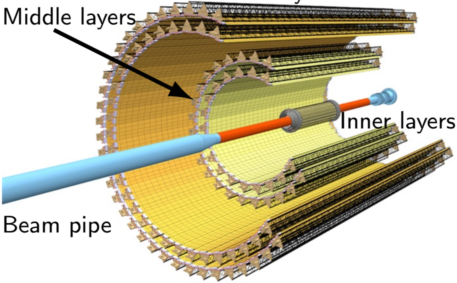

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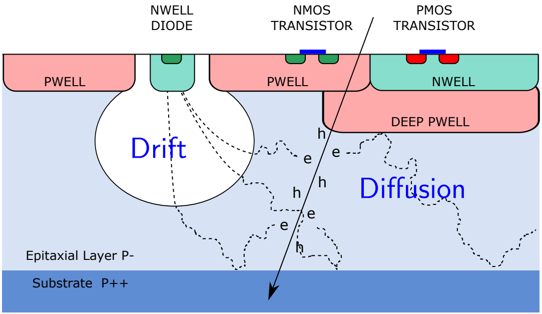
Parameter	**Inner barrel**	**Outer barrel**
Silicon thickness	50 µm	100 µm
Spatial resolution	5 µm	10 µm
Power density	< 300 mW/cm^2	< 100 mW/cm^2
Event resolution	< 30µs	
Detection efficiency	$> 99\%$	
Fake hit rate	$< 10^{-6}$ per event per pixel	
Average track density	15 - 35 cm^{-2}	0.1 - 1 cm^{-2}
TID radiation *	2700 krad	100 krad
NIEL radiation *	1.7×10^{13} 1 MeV n_{eq}/cm^2	10^{12} 1 MeV n_{eq}/cm^2

* Including a safety factor of 10

Technology choice

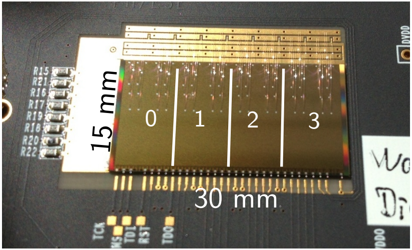
Monolithic **A**ctive **P**ixel **S**ensors using TowerJazz 0.18 μm CMOS imaging process

- High-resistivity ($> 1\text{k}\Omega$ cm) epitaxial layer on p-type substrate
- Quadruple well process: deep PWELL shields NWELL of PMOS transistors, allowing for full CMOS circuitry within active area
- Moderate reverse substrate biasing is possible, resulting in larger depletion volume around NWELL collection diode



Specification of the pALPIDE-1

- First prototype with final size ($15 \text{ mm} \times 30 \text{ mm}$)
- 512×1024 pixels
- Pixels are $28\ \mu\text{m} \times 28\ \mu\text{m}$
- Digital readout with priority encoder
- Four sectors with different pixel geometries and reset mechanisms



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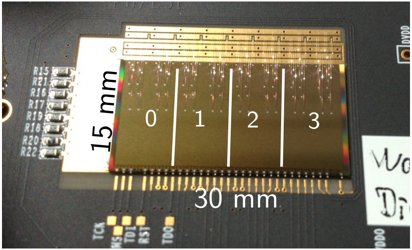

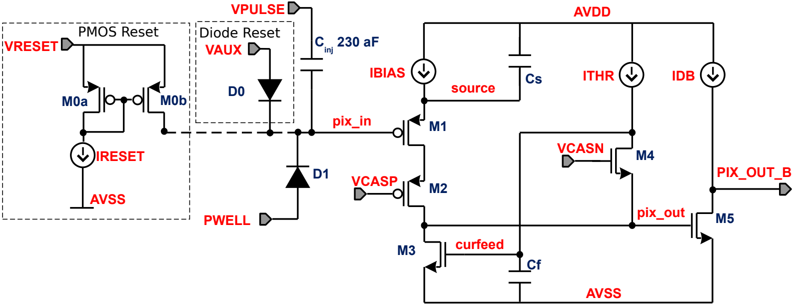

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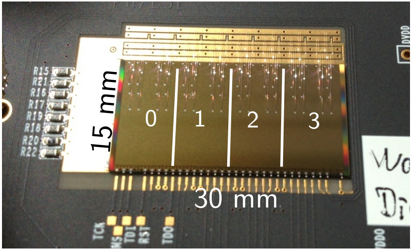

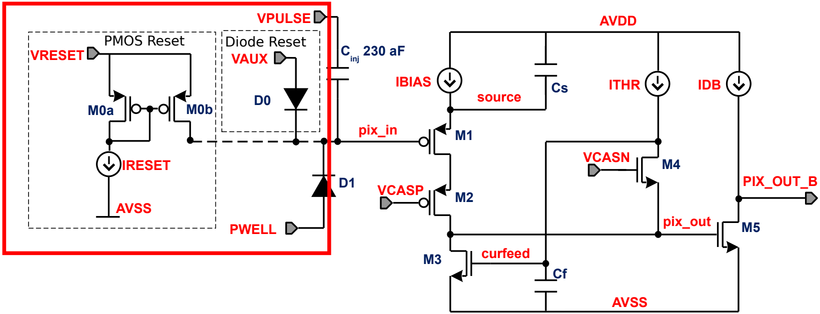

- Two types of reset mechanisms

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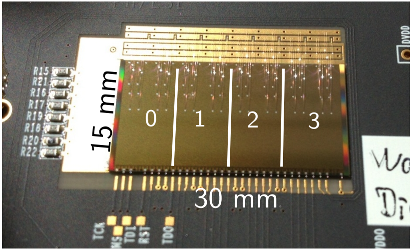

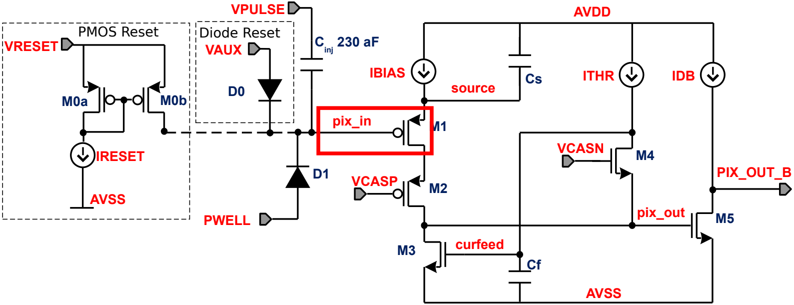

- Input node where charge is collected

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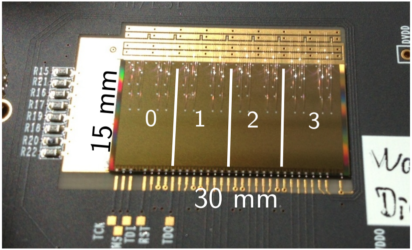

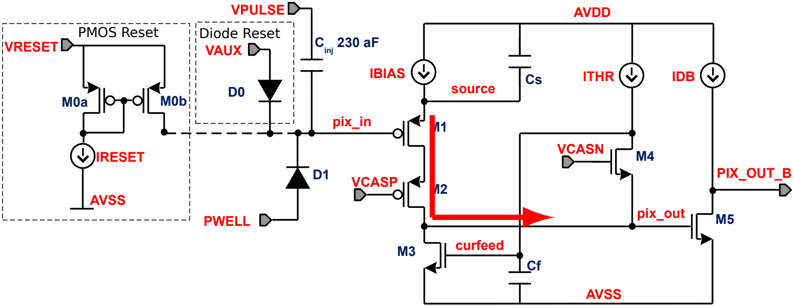

- Charge is transfered from C_S to the output node

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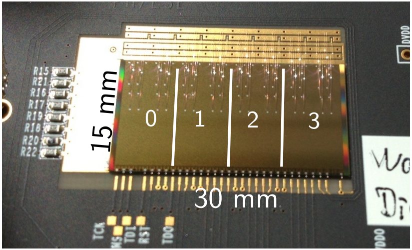

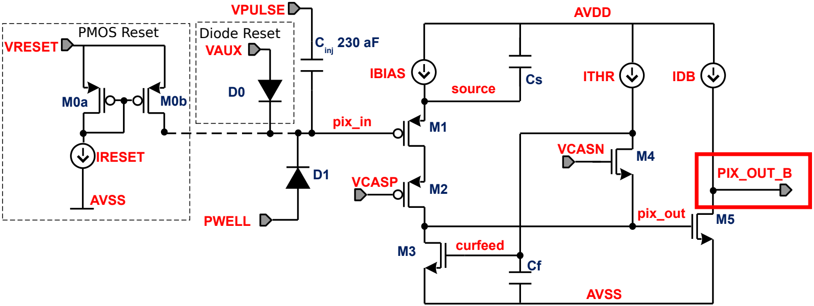

- Pixel is registered as hit

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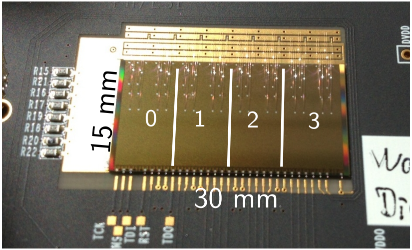

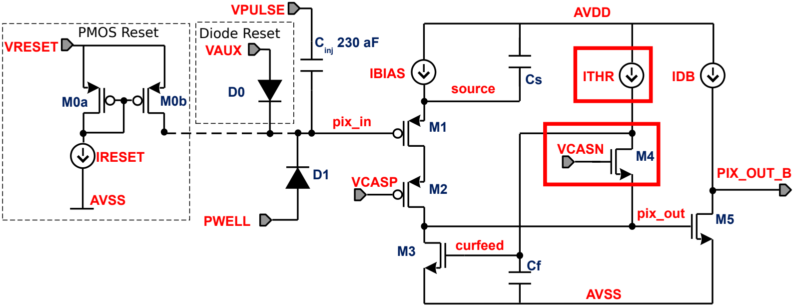

- Two main parameters to change the charge threshold

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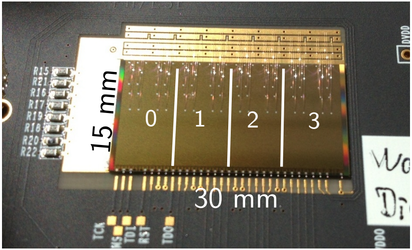
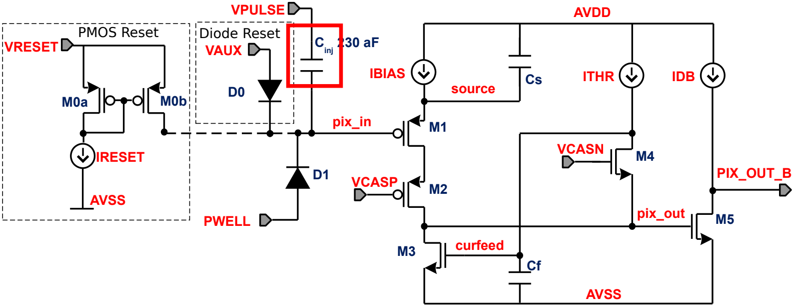
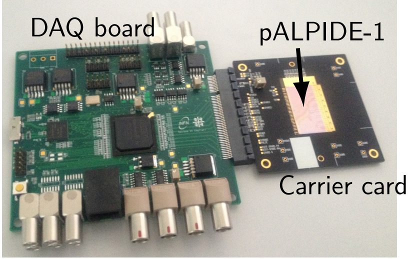
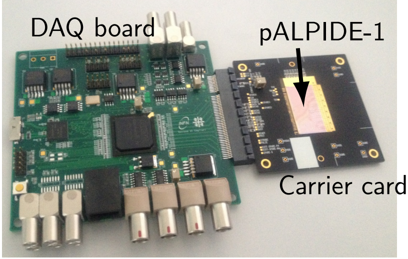




- Injection capacitance for measuring threshold

Characterization in test beam

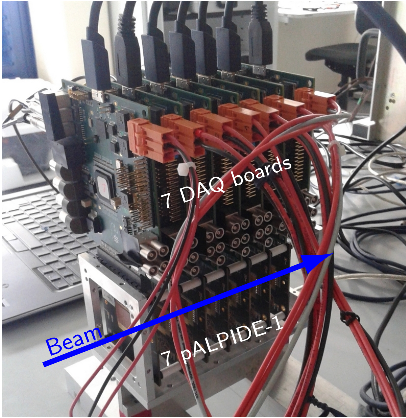


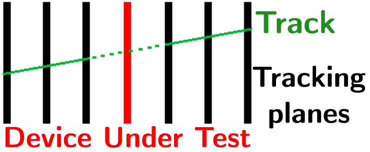


Test beam

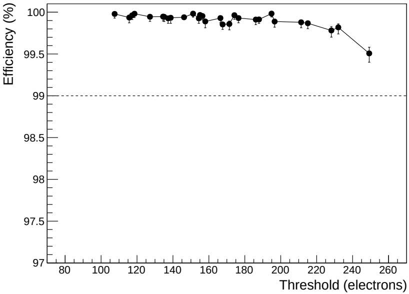
- Tracking is done by a stack of 7 layers of pALPIDE-1
- Readout and analysis is done using the EUDAQ/EUTelescope framework *
- Measurement of detection efficiency and spatial resolution

*https://eutelescope.web.cern.ch





Characterization results



- Efficiency is well above 99%

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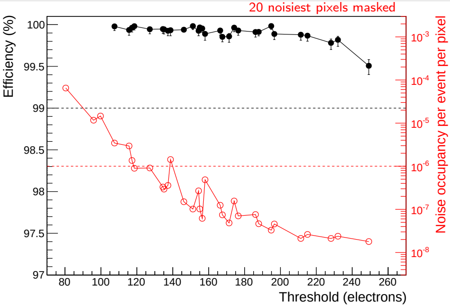

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- Noise occupancy is below 10^{-6} hits/event/pixel above ~ 140 electrons

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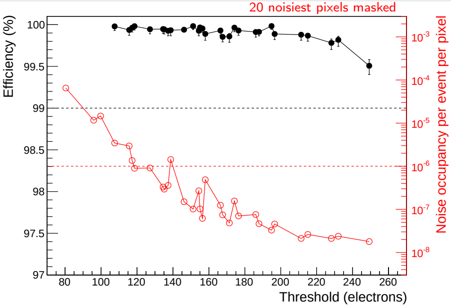

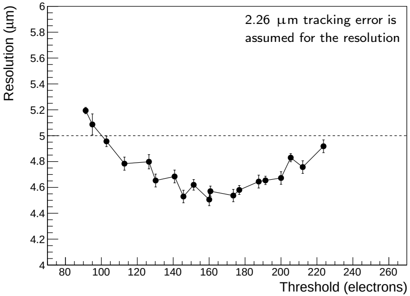

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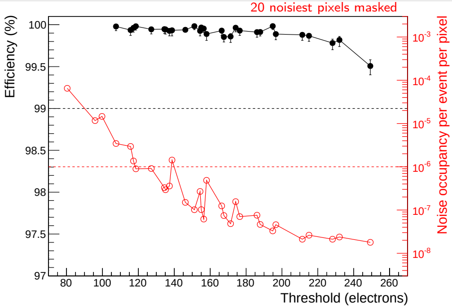

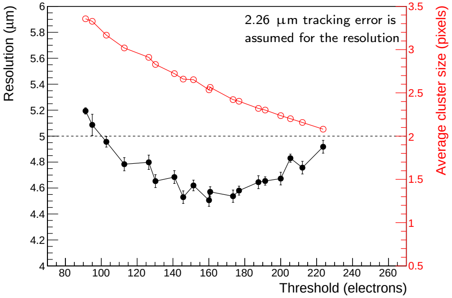

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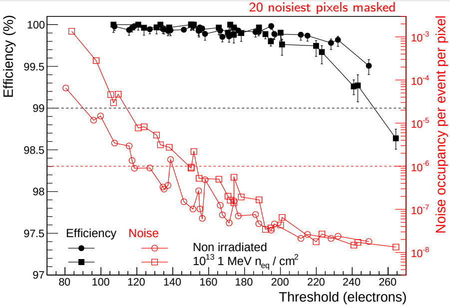

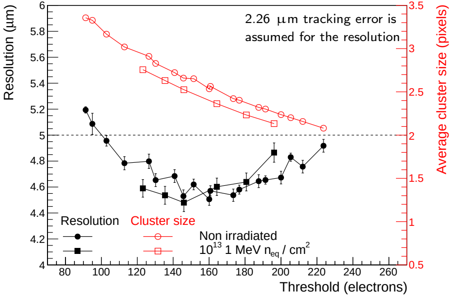

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- Resolution is below 5 µm with a large operational margin
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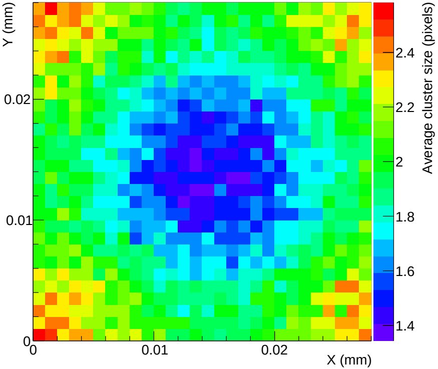
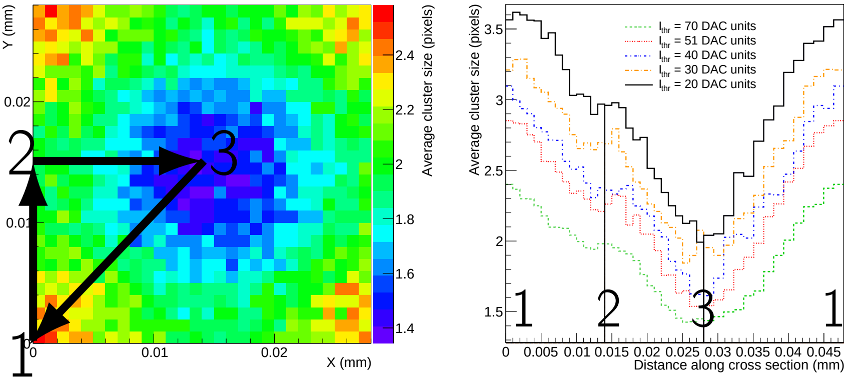
- After irradiation:
  - Efficiency and resolution does not change
  - Cluster size slightly smaller
  - Noise occupancy slightly higher

- Cluster size distribution as function of impinging point of tracks within pixel



- Average cluster size is
  - largest at the corner of pixels
  - smallest at the center of pixels

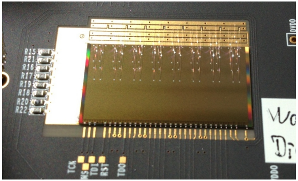
- Cluster size distribution as function of impinging point of tracks within pixel



- Average cluster size is larger at low I_{thr}
- Average cluster size changes less within a pixel at high I_{thr}

Summary and outlook

- The current ITS will be replaced in 2019–2020
- 7 layers of monolithic pixel sensors will be used
- Results from first full-scale prototype shown:
  - All requirements are fulfilled
  - Large operational margin
  - Satisfactory results also after irradiation with 10^{13} 1 MeV n_{eq}/cm^2
- Changes in newer prototypes:
  - All features needed for module integration added
  - Analog front-end optimization
  - Multi-event buffers added
  - Noise occupancy lowered by orders of magnitude
- Final chip is submitted soon



Thank you for your attention!