Beam test studies of silicon sensors for ALICE ITS3

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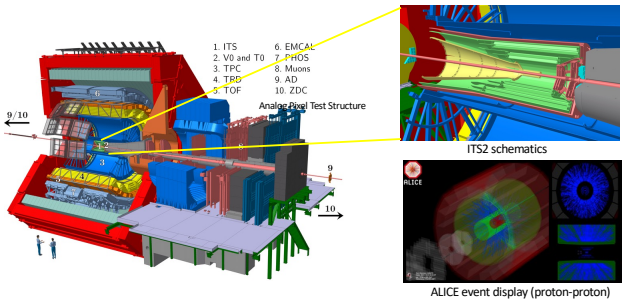
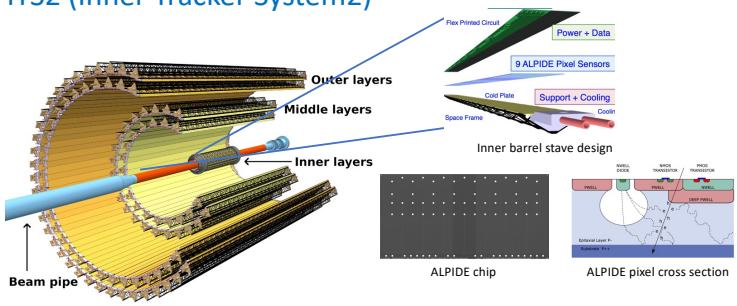
for the ALICE Collaboration

ALICE (A Large Ion Collider Experiment)



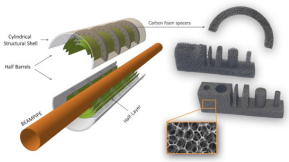
- ALICE studies nuclear matters produced from high-energy heavy-ion collisions
- ITS is able to perform precise tracking and vertexing with charged particles

ITS2 (Inner Tracker System2)



- The component of the ITS2 is the ALPIDE chip in the TowerJazz with 180 nm technology
- Pixel size is reduced from 50 μm ×425 μm(ITS1) to 29.24 μm × 26.88 μm
- The material budget of the inner layers is reduced from 1.14% X_0 (ITS1) to 0.35% X_0

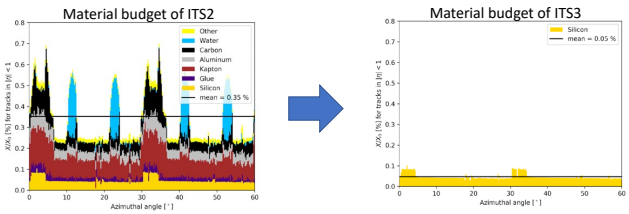
ALICE ITS3 upgrade



Beampipe inner/outer radius (mm)	16.0/16.5		
IB Layer parameters	Layer 0	Layer 1	Layer 2
Radial position (mm)	18.0	24.0	30.0
Length (sensitive area) (mm)	270	270	270

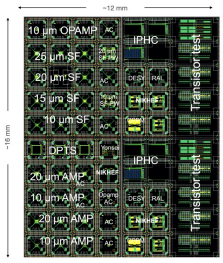
CERN-LHCC-2019-018

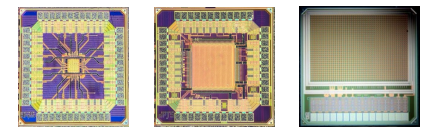
- Bent to 18, 24 and 30 mm curvature radius
- Radius and thickness of beam pipe to 16 mm, 500 μm
- To use Carbon foam for support structures
- To produce truly cylindrical, a single large wafer-scale sensor



- ITS2 material budget
  - 0.35% X_0 per layer
  - Si contributes to only 1/7th
- Removal of water cooling
  - Require the power consumption below 20mW/cm^2
  - Air cooling
- Removal of the circuit boards
  - Require integration of power and data buses on the chip
- Removal of mechanical support
  - Rely on the stiffness of large-size, bent silicon wafers
  - 0.05% X_0 per layer
  - Thinned down to below 50μm

Multi-Layer Reticle1(MLR1)

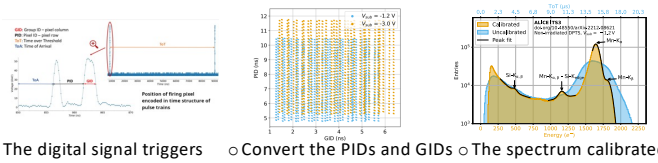




Analog Pixel Test Structure | Digital Pixel Test Structure | CE65

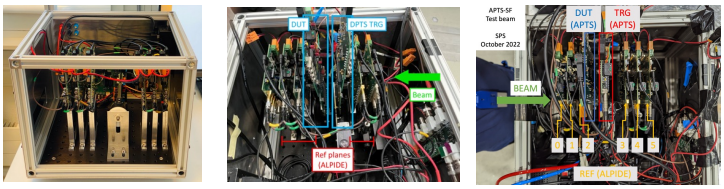
- First submission with 65 nm Imaging Sensor process
- Contained several test chips : APTS, DPTS, CE65

DPTS



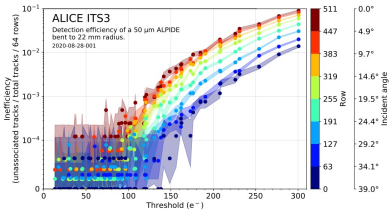
- The digital signal triggers address generator to send two pulses based on the pixel position
- Convert the PIDs and GIDs of the waveforms to pixel rows and columns
- The spectrum calibrated in the ToT resolves the two x-ray peaks, the Mn-K_α silicon escape and silicon fluorescence

Testbeam & result



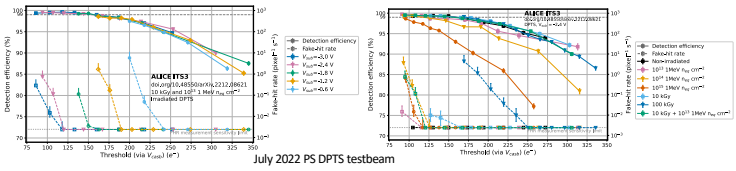
August 2020 DESY bent ALPIDE testbeam | July 2022 PS DPTS testbeam | October 2022 SPS APTS testbeam

- Performance test with reference detectors of ALPIDE at various sites (PS, SPS, and DESY)
- DUT includes bent ALPIDE chip (Geometry test), APTS, DPTS (readout test), carbon foam (multiple scattering)



June 2020 DESY Bent ALPIDE testbeam

- The inefficiency as a function of row, beam incident angle, and threshold
- Below the threshold of 100e^- the hit inefficiency is generally lower than 10^{-4} independently of the incident angle or the position on the chip



July 2022 PS DPTS testbeam

- Irradiated detection efficiency by changing threshold and FHR at different reverse biases
- The efficiency is more than 99% at the low thresholds
- By increasing the reverse bias, the fake hit rate can be reduced at the low threshold
- The effect of different irradiated levels on the detection efficiency and FHR
- Irradiated sensors show the same distribution : the detection efficiency stays above 99% up to a threshold of about 150e^- (except largest non-ionising(10^{15}), ionizing(100kGy))

Summary

- 3 inner layers of ITS2 will be replaced by ITS3
- The goal is to reduce the material budget and to get closer to the interaction point, to produce truly cylindrical layers
- The MLR1 submission includes a broad range of test structures using 65 nm process
- To evaluate the performance of bent chip and MLR1 under development, several beam tests have been performed and detection efficiency is above 99%