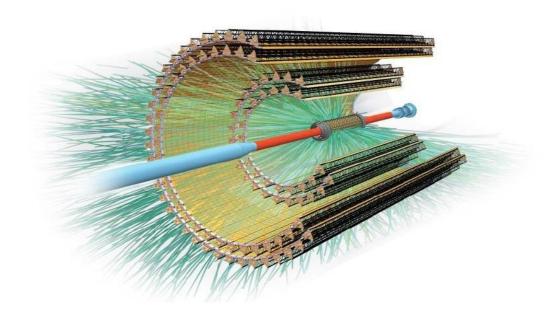


Characterization of ALPIDE silicon sensors with inclined tracks

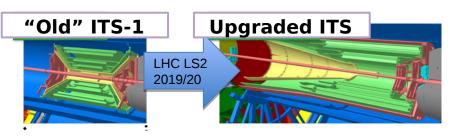


Svetlana Kushpil on behalf of the ALICE Collaboration Nuclear Physics Institute of the CAS Řež, Czech Republic





Monolithic Active Pixel Sensor (ALPIDE) for ITS upgrade

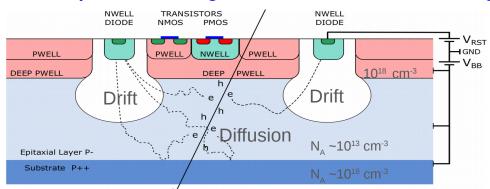


Motivations and Goals: Improved vertex & tracking precision (closer to IP, smaller pixels, less material) Faster readout

7 layers of pixel sensors (r = 23 - 400 mm) 10 m² of silicon

|n| < 1.22 for tracks from 90% of the most luminous region

ALPIDE produced using TowerJazz 180 nm CMOS Imaging Process

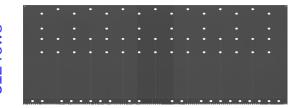


- Deep P-well allows in-pixel full CMOS (complex in-pixel circuitry without charge loss)

- Enables low-power read-out
- High granularity, low material budget
- Resistivity (>1 kΩ·cm) p-type epitaxial layer (25 μm)
- Possibility of reverse biasing (up to -6 V)

1024 pixel columns

512



Chip size: 30 mm x 15 mm Pixel pitch: 29 µm x 27 µm Chip thickness:

> 50 µm (Inner Barrel) 100 um (Outer Barrel)

> > **ICHEP 2020**

Required radiation hardness*:

2700 krad Total Ionising Dose (TID)

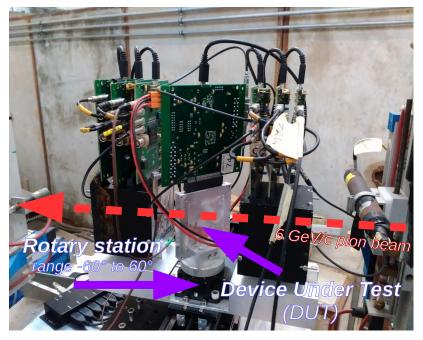
1.7×10 ¹³ 1MeV n cm⁻² Non-Ionising Energy Loss (NIEL)

Technical Design Report for the Upgrade of the ALICE Inner Tracking System J.Phys. G41 (2014) 087002, CERN-LHCC-2013-024 ALICE-TDR-017

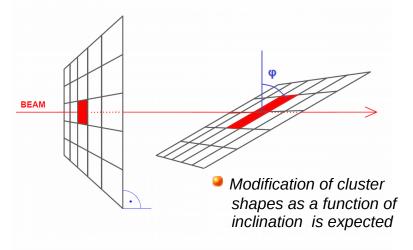
(* with safety factor)



ALPIDE characterizations at CERN PS



Measurement of ALPIDE response to tracks with different incident angles helps to tune the detector Monte Carlo model*



Setup (3 + DUT + 3 planes) highly automated:

allows to run with different settings of threshold, reverse substrate bias, incident angles

Track resolution in DUT with telescope around 2–3 µm with 6 GeV/c pions

ALPIDE performance in terms of: detector efficiency, position resolution, cluster sizes, shape

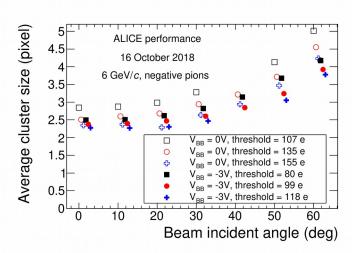
* "Monte Carlo simulation of charge collection Processes in Monolithic Active Pixel Sensors for the ALICE ITS upgrade" https://doi.org/10.1016/j.nima.2019.162882 NIMA, Volume 950, 11 January 2020, 162882

Readout and analysis is performed using the **EUDAQ/EUTelescope** framework (http://eutelescope.web.cern.ch/)

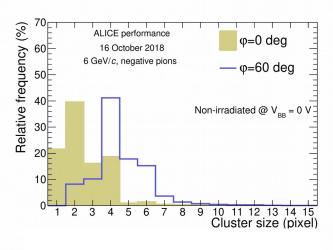


Selected results vs DUT inclination



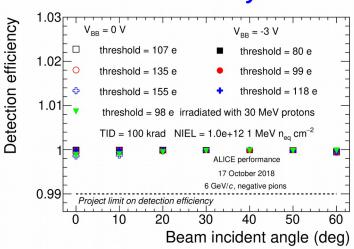


- Average cluster size increases with incident angle
- Trend is the same for different thresholds and back-bias settings



- The number of clusters with more pixels increases with inclination
- At inclination of 60 deg
 - One-pixel cluster disappears
 - 5 and 6 pixel clusters form about
 20% of the total number of clusters





- Detector efficiency stays close to 100% over a wide range of thresholds for all inclination angles
- Also in the case of the irradiated sensor 100 krad (TID) $1.0 \times 10^{-12} \text{ 1MeV n}_{\text{eq}} \text{ cm}^{-2}$ (NIEL)
- ALPIDE shows good performance and large operational margin for inclined tracks. We also tested an irradiated sensor following the test with beam. After radiation ALPIDE is fully operational and fulfills TDR requirements.