Compilation of the results on test beam characterization of ADVACAM edgeless sensors

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Outline

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  - Samples to test;
  - Test beam telescope setup;
- Results
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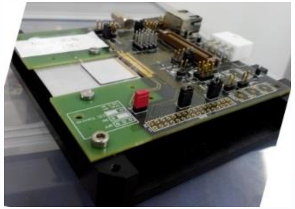
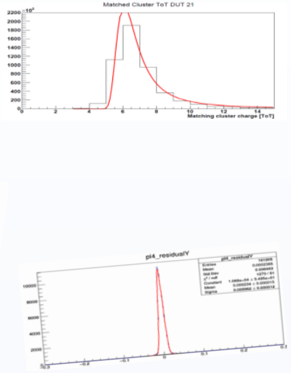
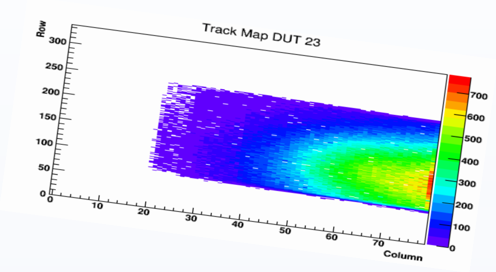
    - Inclined position case;
  - Slim edge sensor design study, irradiated and non-irradiated case;
  - Comparison of the performance for active and slim edge designs ;
- Summary

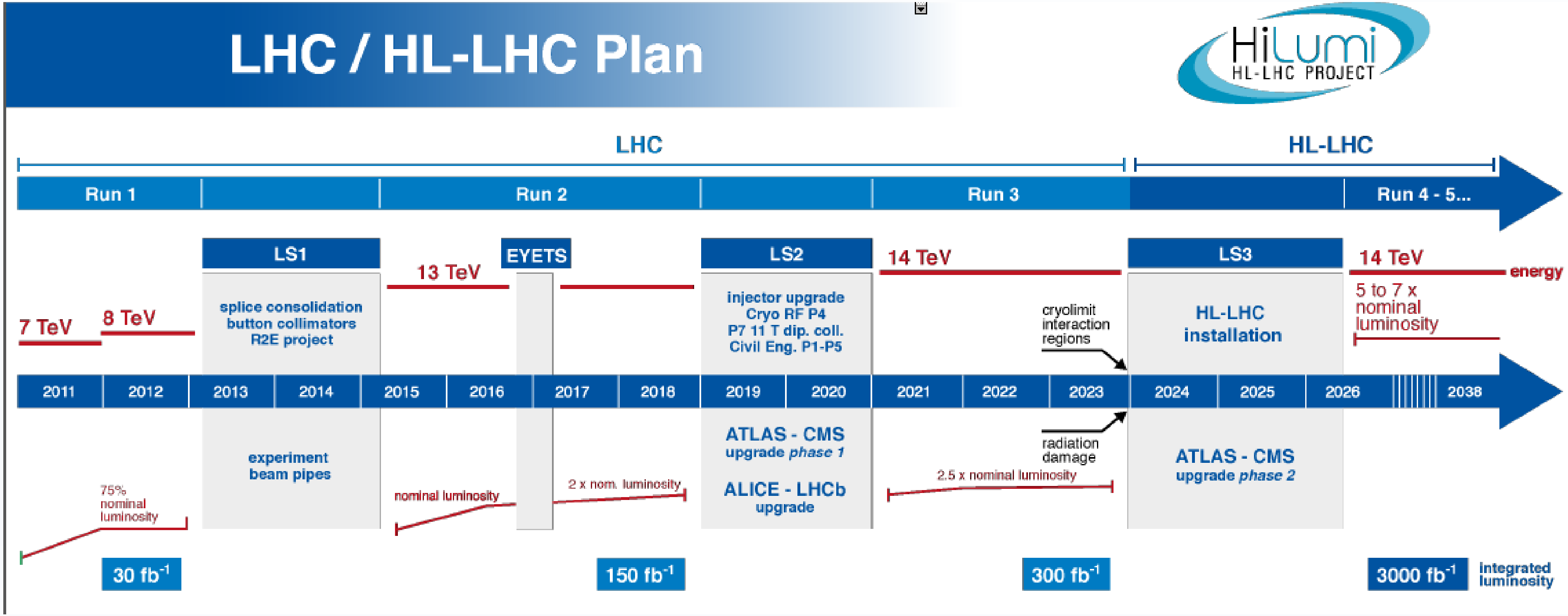






Introduction

Motivation of the R&D work on pixel detectors



Introduction

Motivation for ATLAS Inner Detector upgrade

Name of the upgrade	Date	Luminosity	Energy $\sqrt{s}$
LHC startup	2009	6×10^{33} $cm^{-2}s^{-1}$	7-8 TeV
Phase- 0	2014	1×10^{34} $cm^{-2}s^{-1}$	13 TeV
Phase- 1	2018	2×10^{34} $cm^{-2}s^{-1}$	13-14 TeV
Phase- 2	2023	$7{,}5 \times 10^{34}$ $cm^{-2}s^{-1}$	14 TeV

Very severe pile-up conditions expected:

Corresponding num. of inelastic **pp** collisions per beam-crossing (25 ns) will increase : **25 -> 200**

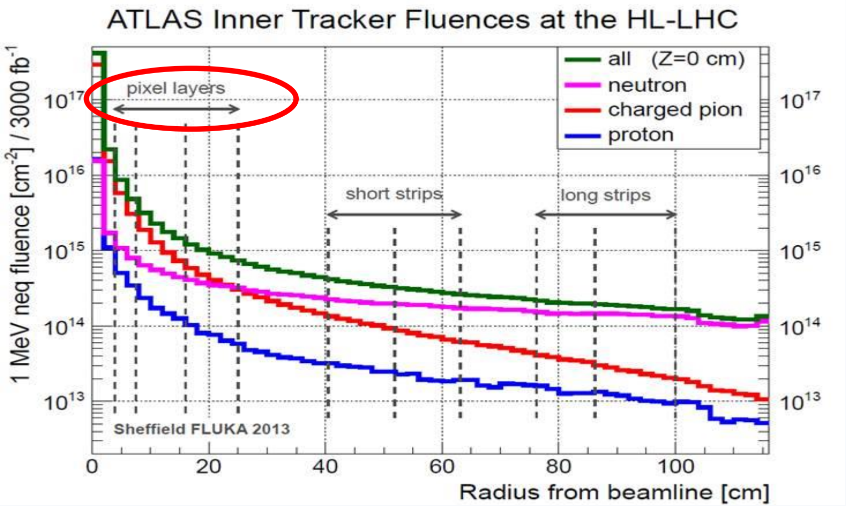
New Tracking detectors must fulfill the conditions:

- Fast (40MHz), high granularity & good pattern recognition capabilities (10^3 tracks/25 ns).

Introduction

Motivation for ATLAS Inner Detector upgrade

- Increased luminosity also leads to increasing of radiation load.



Aim is **3-4k fb^{-1}** integrated luminosity

ID (Inner Detector) has limited lifetime:

Expected: $1.6 \cdot 10^{16}$ n_{eq} cm^{-2} ⇒ **1.7 GRad**

Designed : 10^{14} n_{eq} cm^{-2} → estimated to correspond to **400 fb^{-1}**

Radiation Effects:

- Creation of lattice defects (loss in the charge collection due to charge capture).
- Change of depletion voltage (due to type inversion).
- Rise of leakage current (additional energy levels are being formed in the band gap region)

Samples to test

Samples to study: FE-I4 compatible thin **n-in-p** planar pixel sensors with *the active and slim edge design* produced by ADVACAM.

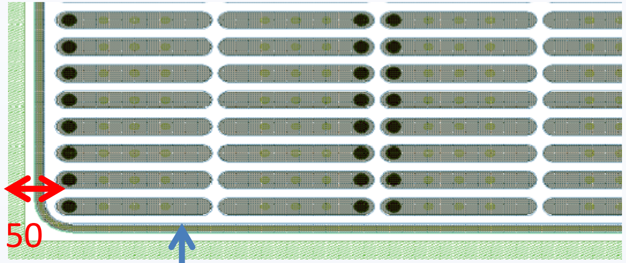
- Radiation hard (no type inversion, thin);
- Single side processing;
- Thickness : 50 um, 100um, 150um;
- Maximized active area (Deep Reactive Ion Etching (DRIE));

It is particularly interesting for the innermost layers where it is important to reduce geometrical inefficiencies.

Goal:

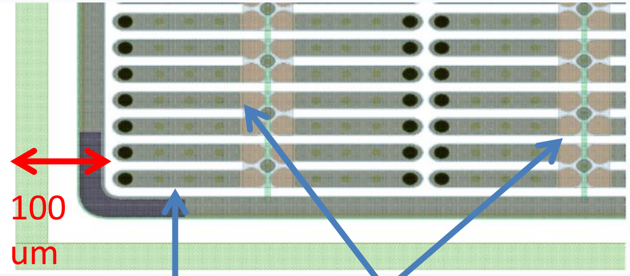
➢ Study the overall and edge hit efficiency with normal and inclined tracks before and after irradiation;

Active edge



ADV-50-3-1D , ADV-NP50-3-1A, ADV-NP150-6-1A

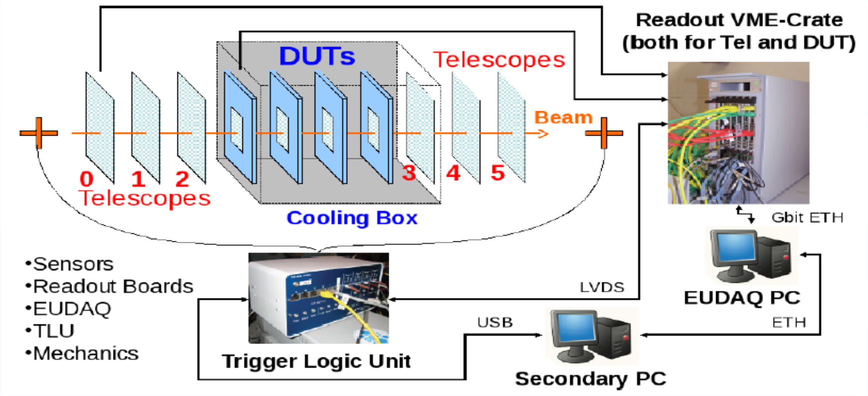
Slim edge



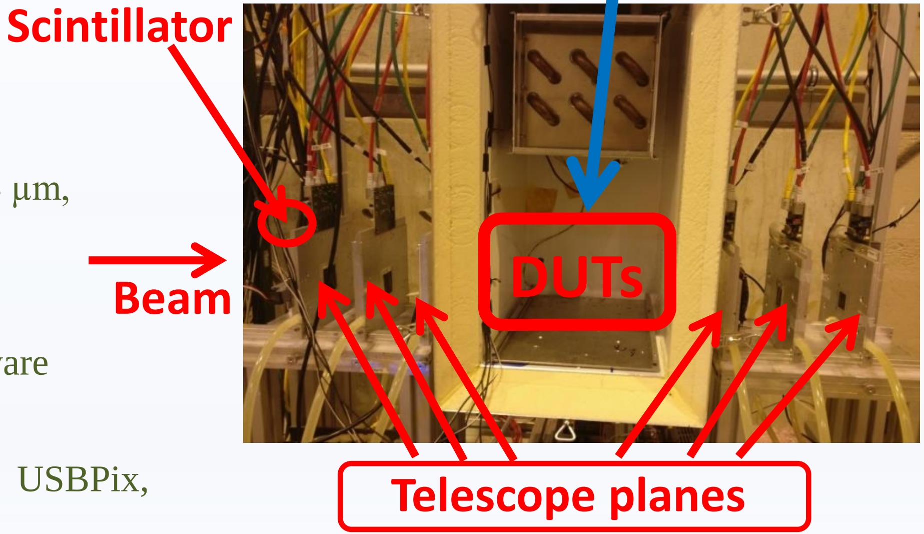
ADV-50-3-3A , ADV-NP50-3-3B, ADV-NP100-7-2A

Overview of the setup

Test Beam telescope setup:



EUDET telescope ACONITE (H6A) :



- Mimosa26 sensors (1152 x 576) with a pixel pitch of 18.4 μm,
- 50μm thick;
- Spatial resolution up to 2 um;
- Pixel read-out systems fully integrated into EUDAQ software framework;
- Multiple DAQ systems for lab tunings and measurements: USBPix, RCE, etc

Goals

- Efficiency for **50µm-thick ADVACAM samples** with **active edge** and **slim edge** design
  - with and without irradiation **1×10^{15} n_{eq}/cm^2 ;**
  - on different side edges;
  - with **normal** and **inclined** incident (DUT tilted at 30˚, 45˚ (around y-axis));
- Efficiency for **100µm-thick ADVACAM sample** with **slim edge** design before and after irradiation **2×10^{15} n_{eq}/cm^2 ;**
- Efficiency for **150µm-thick ADVACAM sample** with **active edge** design before and after irradiation **2×10^{15} n_{eq}/cm^2 ;**

Beam: CERN SPS 120 GeV pions, DESY 4 GeV electrons;

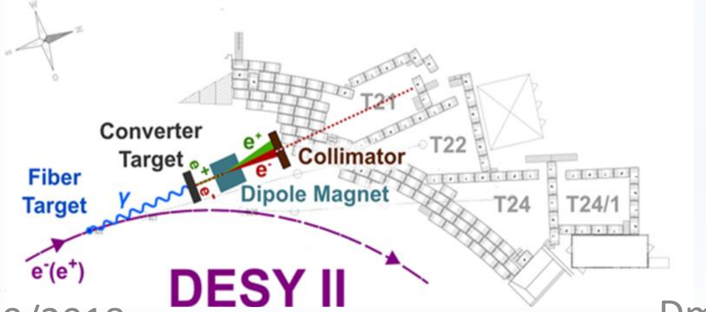
Telescopes: DURANTA (TB22) , ACONITE (H6A) and AIDA (H6B);

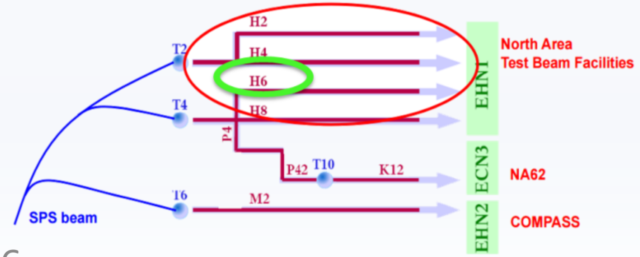
Cooling: Cooling box (-40ºC to -44ºC), Dry ice cooling (approx. -40 to -50 ˚C);

Bias voltage points:

from 50 V to 120 V (for 50um);

from 50V to 200V (100um,150um)





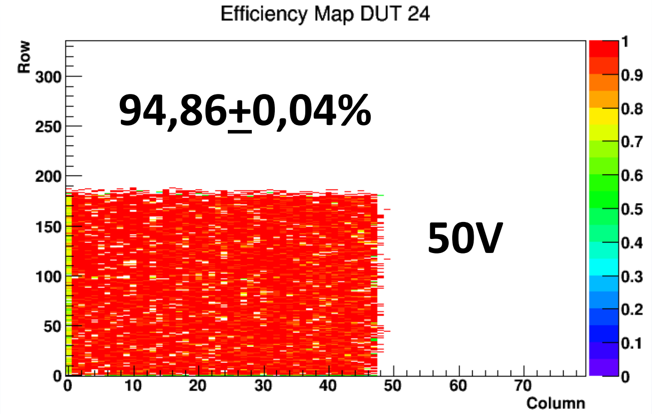
- Efficiency study for the **<u>50µm-thick</u>** ADVACAM edgeless sensors

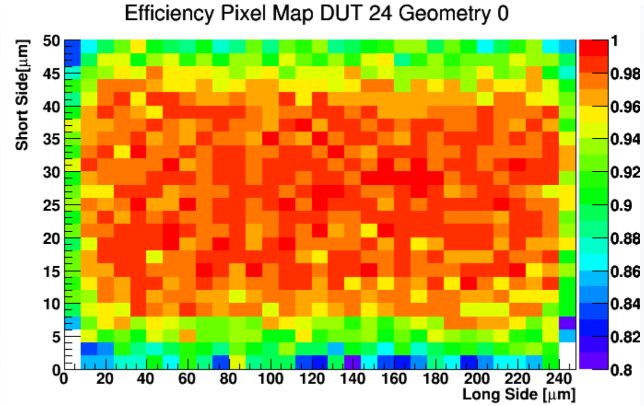
  - **<u>ACTIVE EDGE</u>** design
    - with and without irradiation on different side edges;
    - Normal and Inclined tracks;

Results

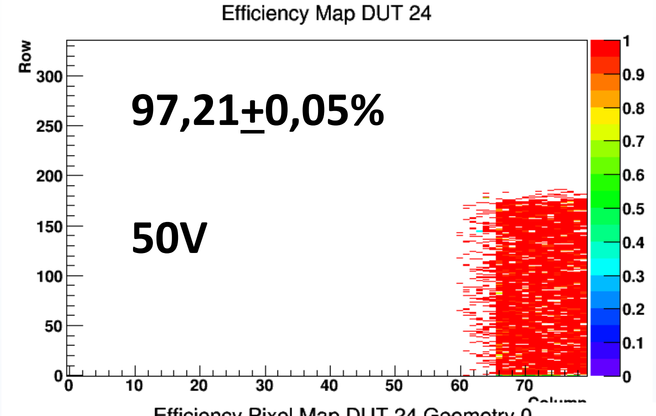
ADV-50-3-1D (active edge)
non-irradiated

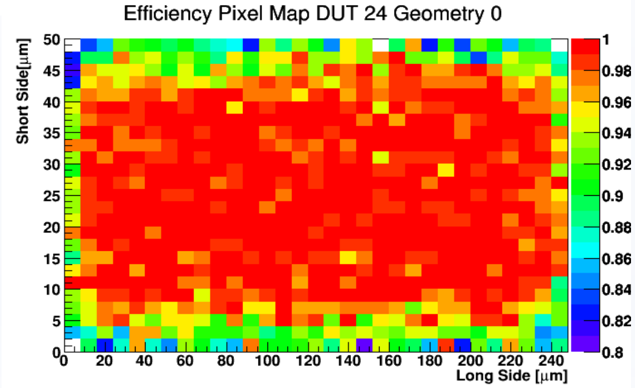
Left Edge





Right Edge





Overall efficiency

$$Efficiency = \frac{Number\ of\ Matched\ Tracks}{Number\ of\ Total\ Tracks}$$

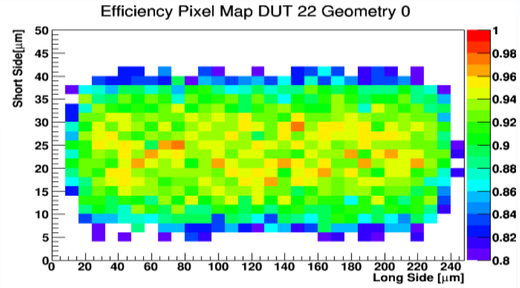
In-pixel efficiency

Results

ADV-50-3-1A (active edge), irradiated 1e15 n_{eq}/cm^2

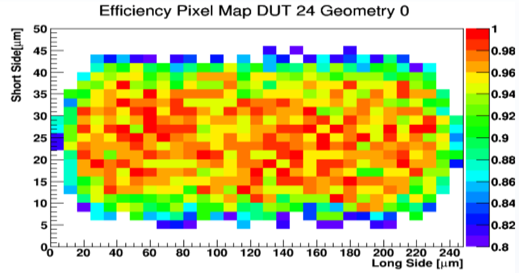
In-pixel efficiency maps

Left Edge

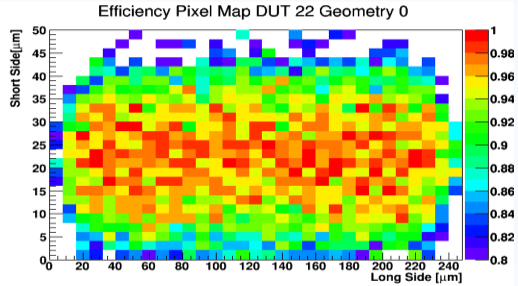


81,90±0,07% 50V

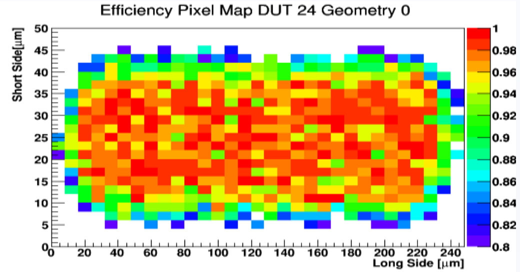
Right Edge



84,78±0,11% 50V

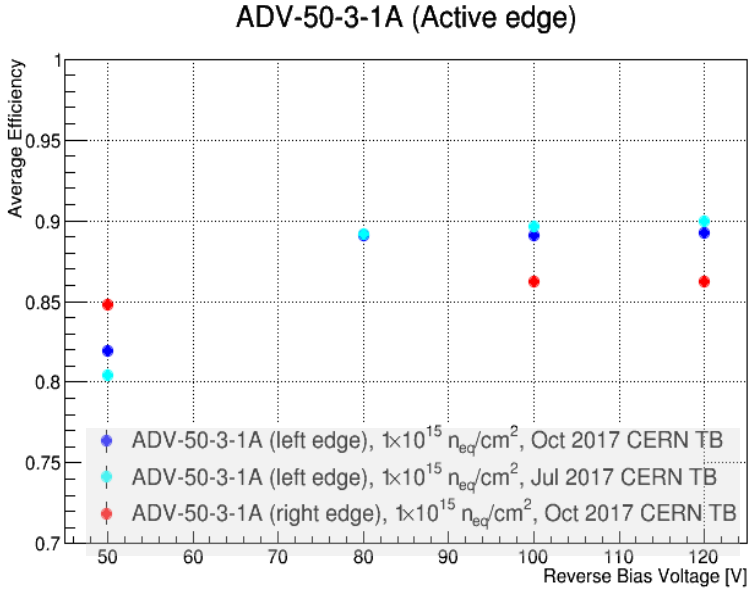


86,90±0,12% 120V



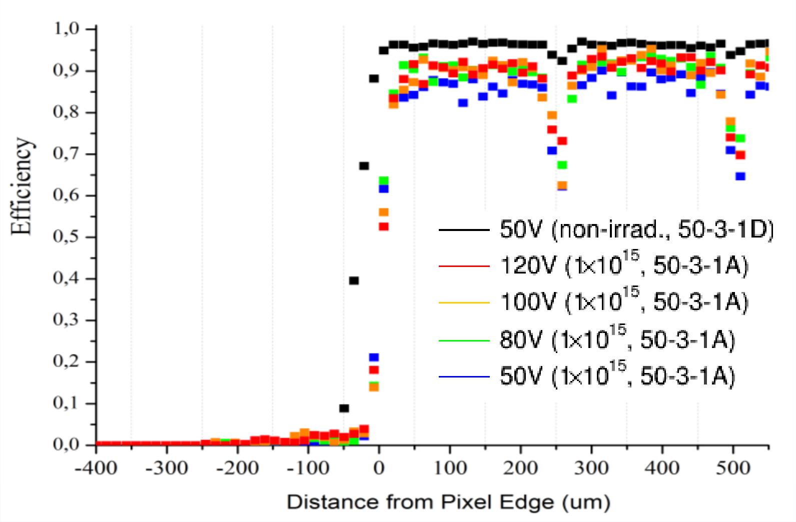
89,27±0,09% 120V

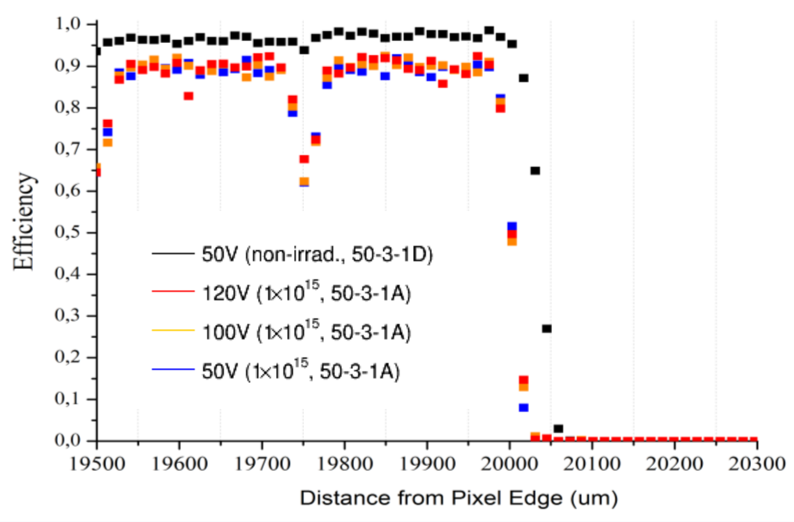
Global **efficiency vs bias voltage**



Results

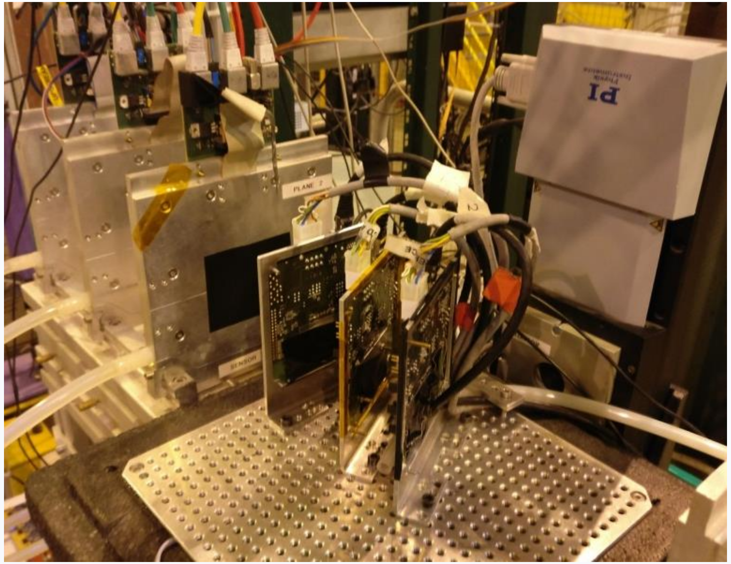
Edge efficiency:
ADV-50-3-1D (non-irrad.) and ADV-50-3-1A (1e15 n_{eq}/cm^2)

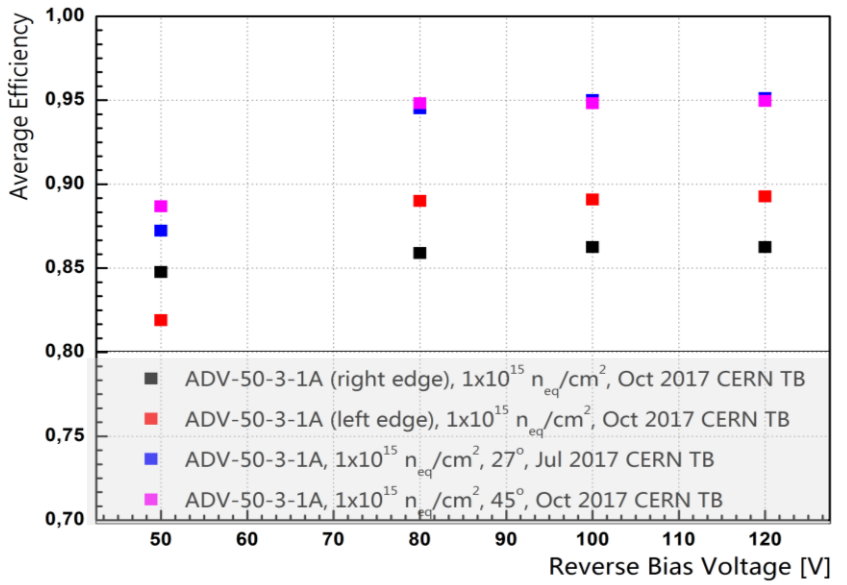




Results

- Efficiency vs bias voltage: irrad. **$1x10^{15}$ n_{eq}/cm^2**, and **tilted (45^o and 27^o)**



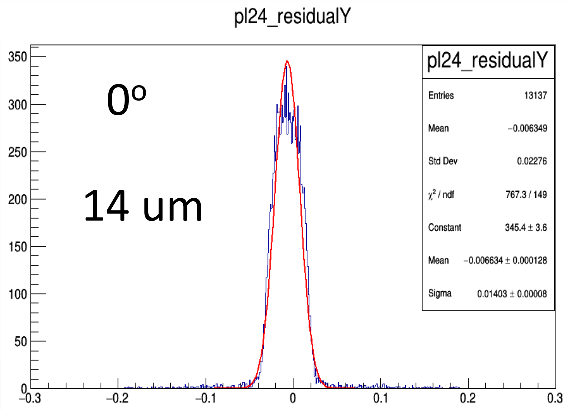


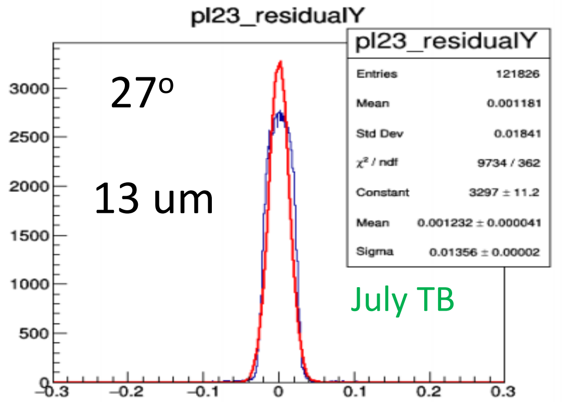
At a <u>tilted angle of 45˚, the efficiency performance improved</u>, reaching 95% at 80V bias voltage.

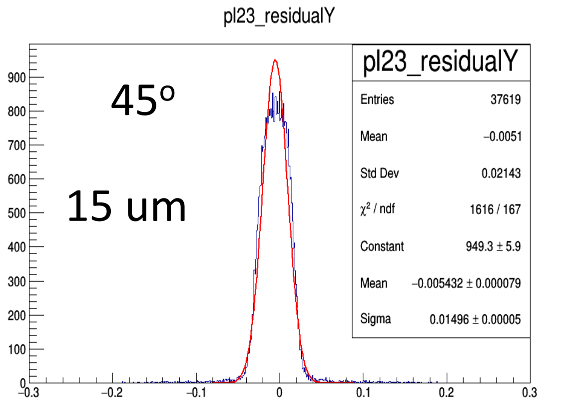
Results

- Residuals comparison for normal and inclined tracks

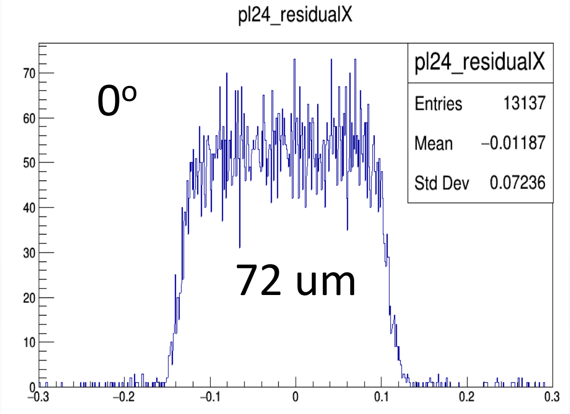
Short side:

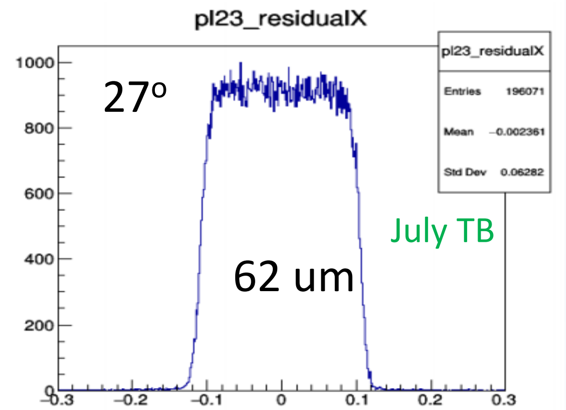


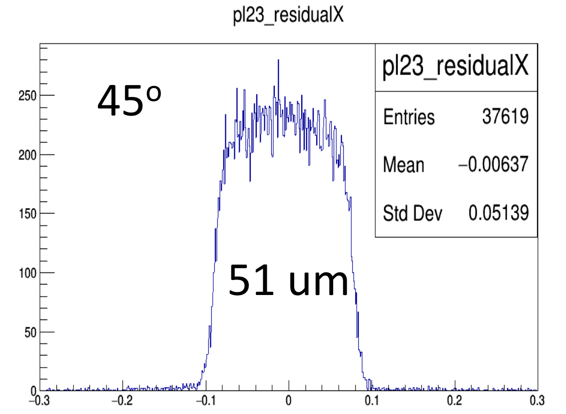




Long side :







- Efficiency study for the **50µm-thick** ADVACAM edgeless sensors

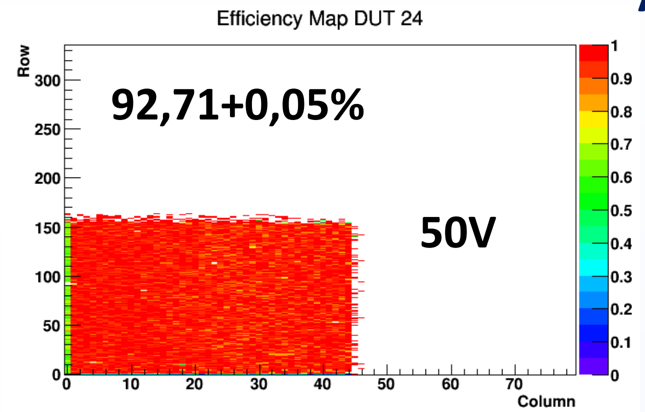
  - **SLIM EDGE** design
    - with and without irradiation on different side edges;

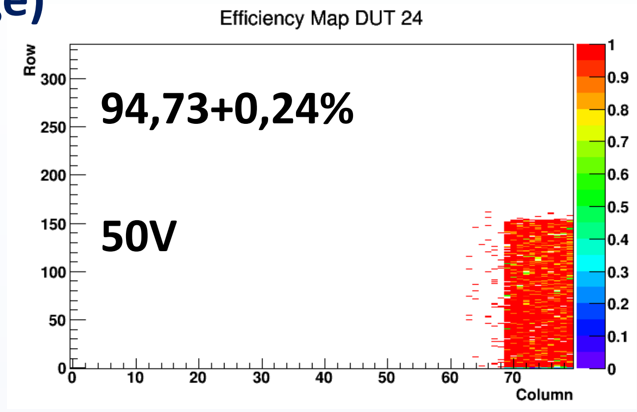
Results

Left Edge

ADV-50-3-3A (slim edge) non-irradiated

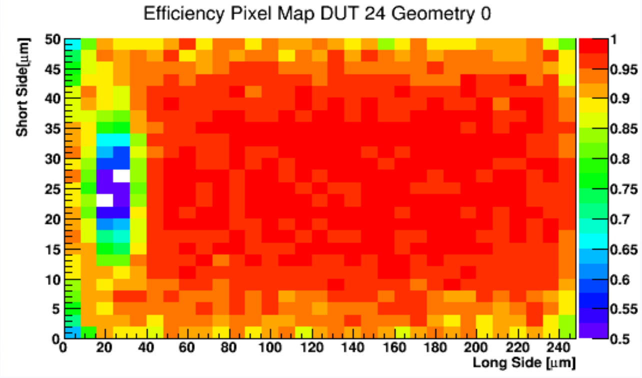
Right Edge

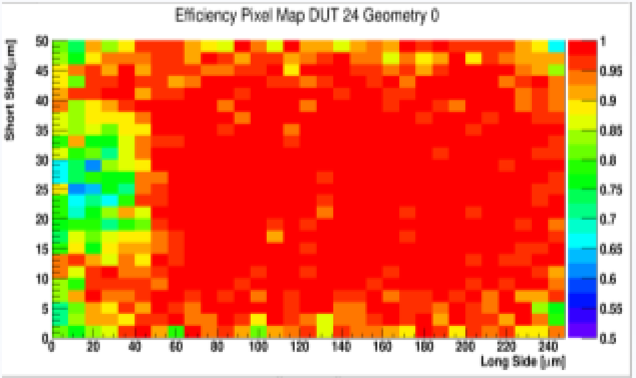




Overall efficiency

$$Efficiency = \frac{Number\ of\ Matched\ Tracks}{Number\ of\ Total\ Tracks}$$





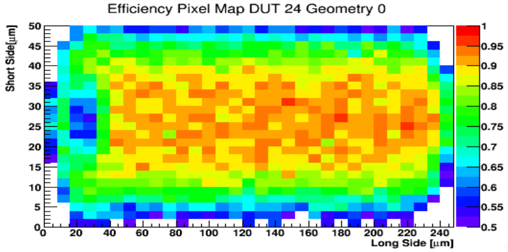
In-pixel efficiency

Results

ADV-50-3-3B (slim edge), irradiated 1e15 n_{eq}/cm^2

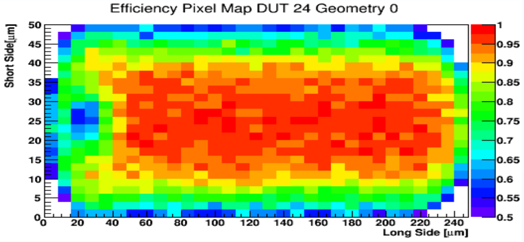
- In-pixel efficiency maps

Left Edge

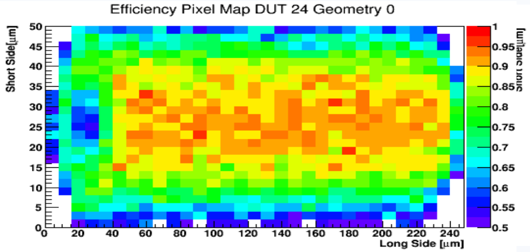


76,93±0,09% 50V

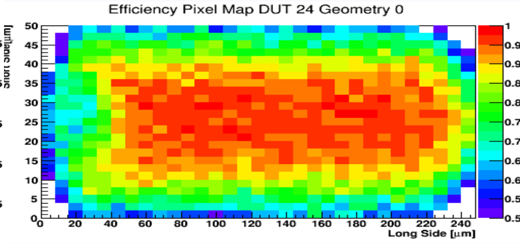
Right Edge



82,56±0,3% 50V

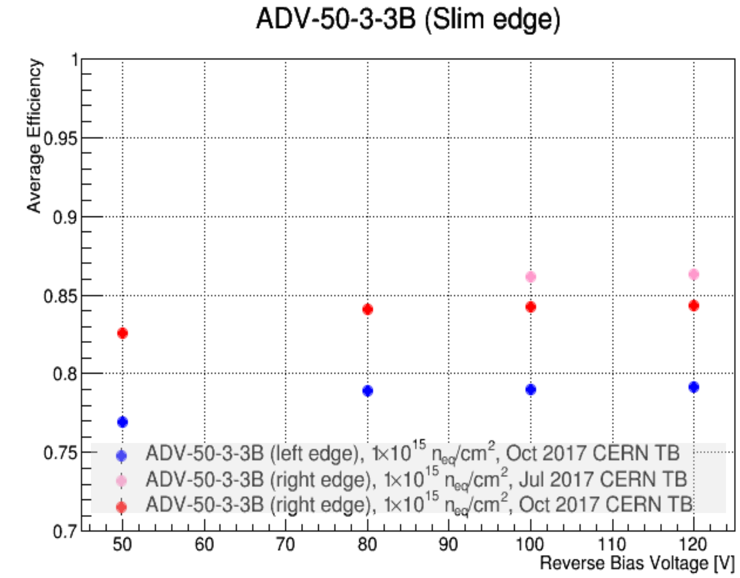


79,27±0,1% 120V



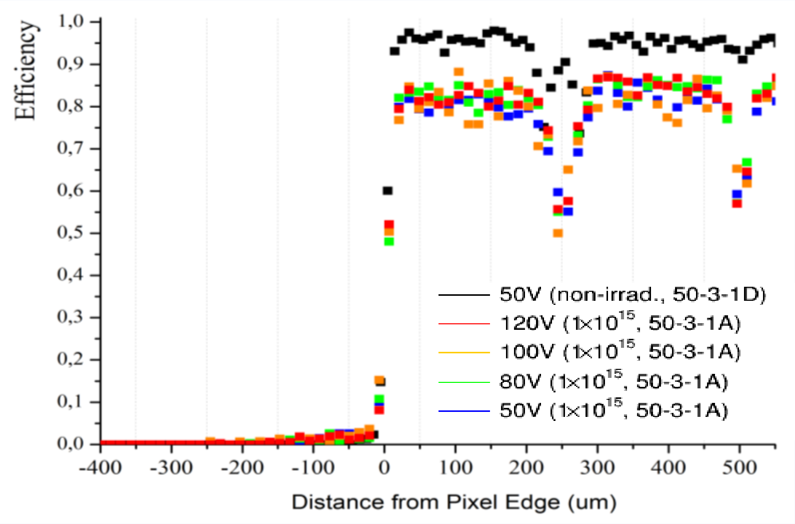
84,33±0,09% 120V

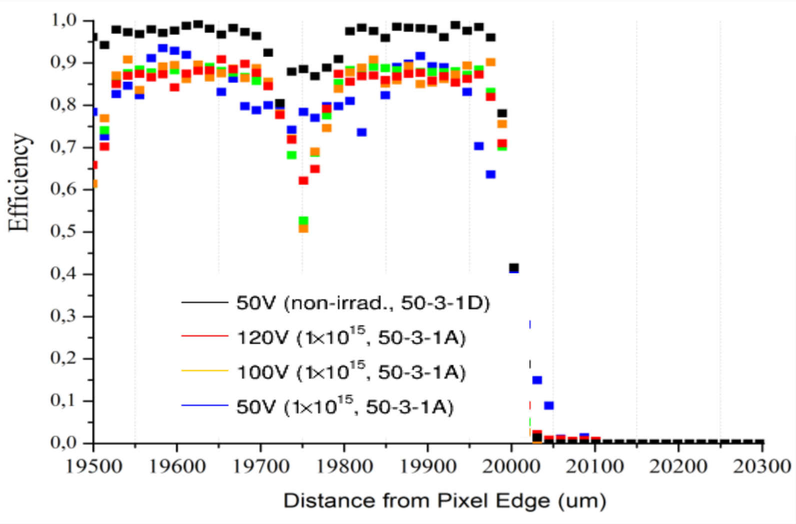
Global efficiency vs bias voltage



Results

Edge efficiency:
ADV-50-3-3A (non-irrad.) and **ADV-50-3-3B** (1e15 n_{eq}/cm^2)





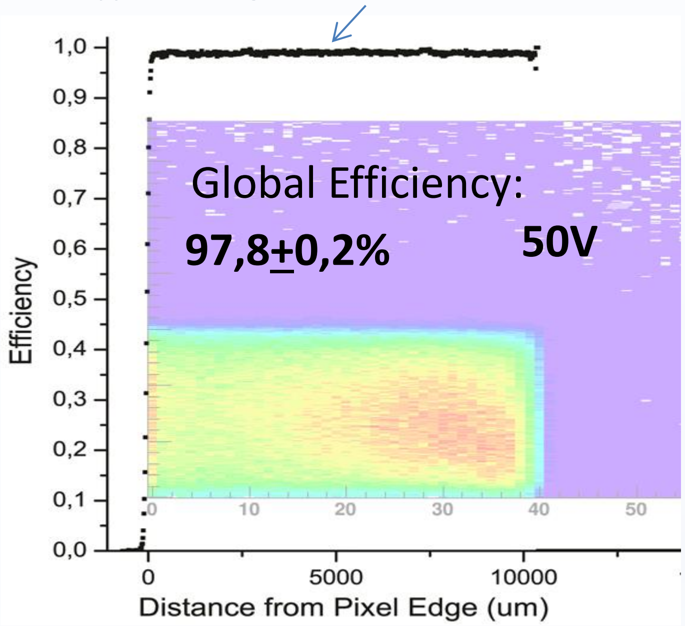
- Efficiency study for the **150µm-thick active edge and 100µm-thick slim edge** ADVACAM sensors.

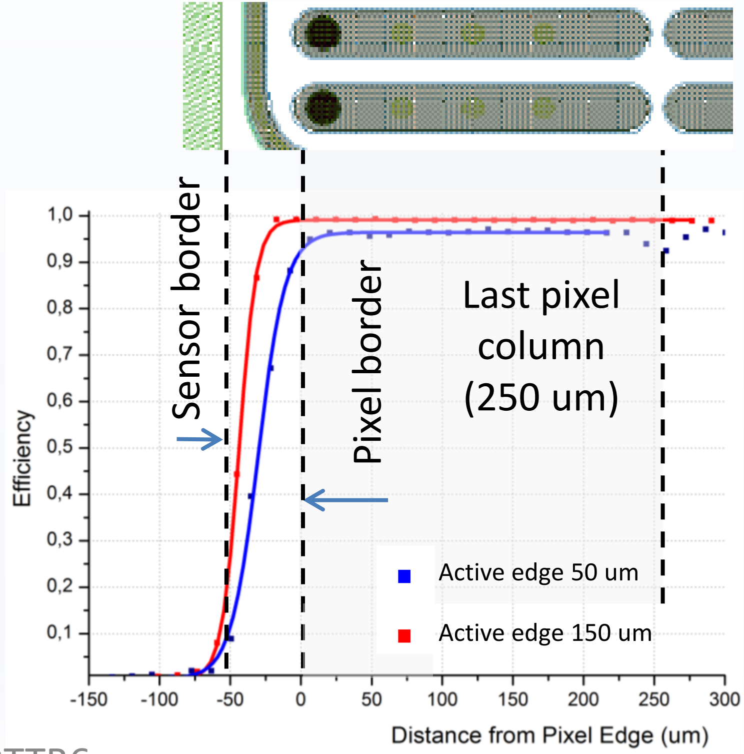
    - Non-irradiated (tested at CERN and DESY)
    - Irradiated to **$2x10^{15}$ n_{eq}/cm^2** (tested at DESY)

Results

Edge efficiency performance for the non-irradiated **active edge** samples of **150 um** thickness and comparison with ***50um-thick*** sensor of the same design (*ADV-50-3-1D, ADV-NP150-6-1A*)

- *Efficiency vs track impact position*

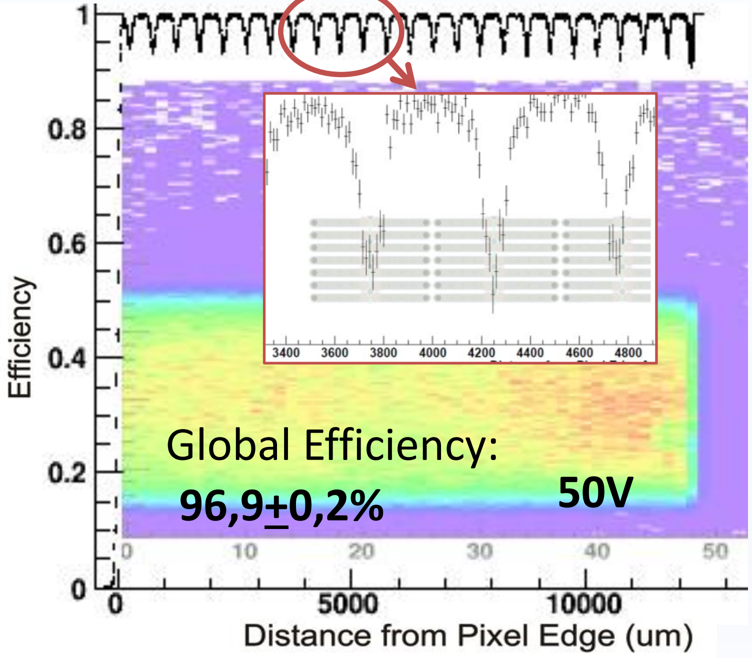


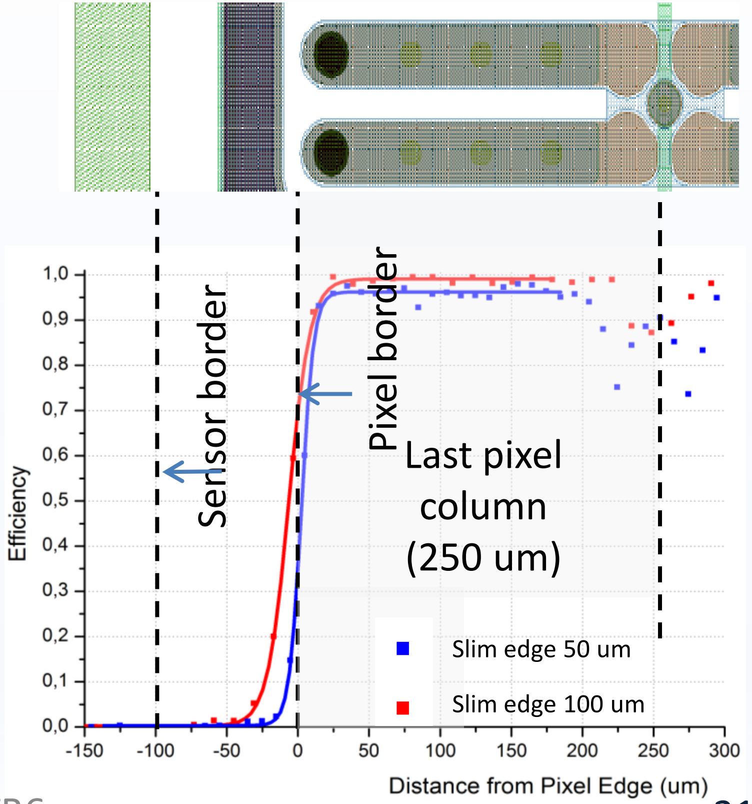


Results

Edge efficiency performance for the non-irradiated **slim edge** samples of **100 um** thickness and comparison with ***50um-thick*** sensor of the same design *(ADV-50-3-3A, ADV-NP100-7-2A)*

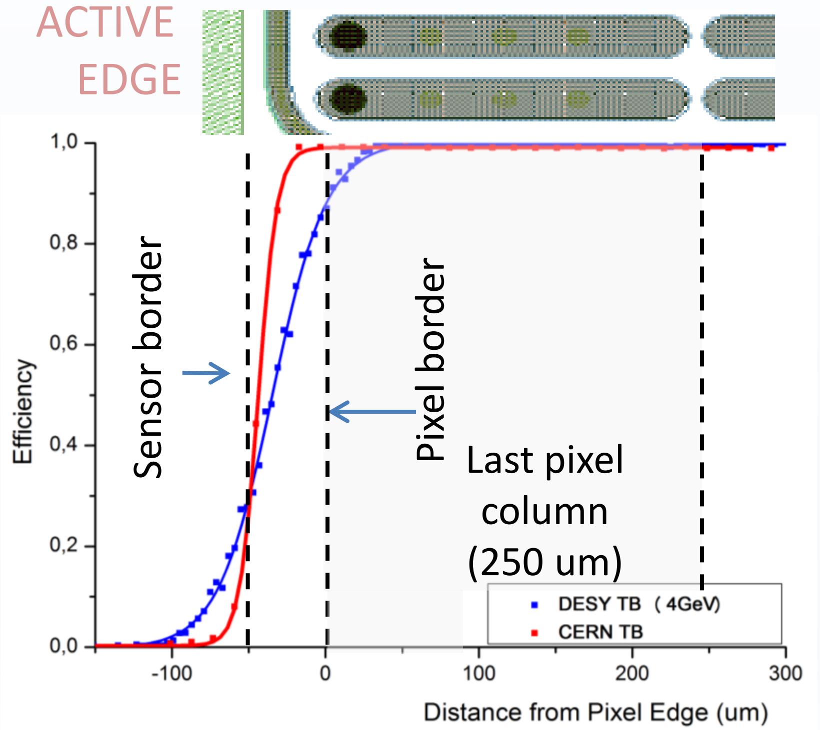
- *Efficiency vs track impact position*

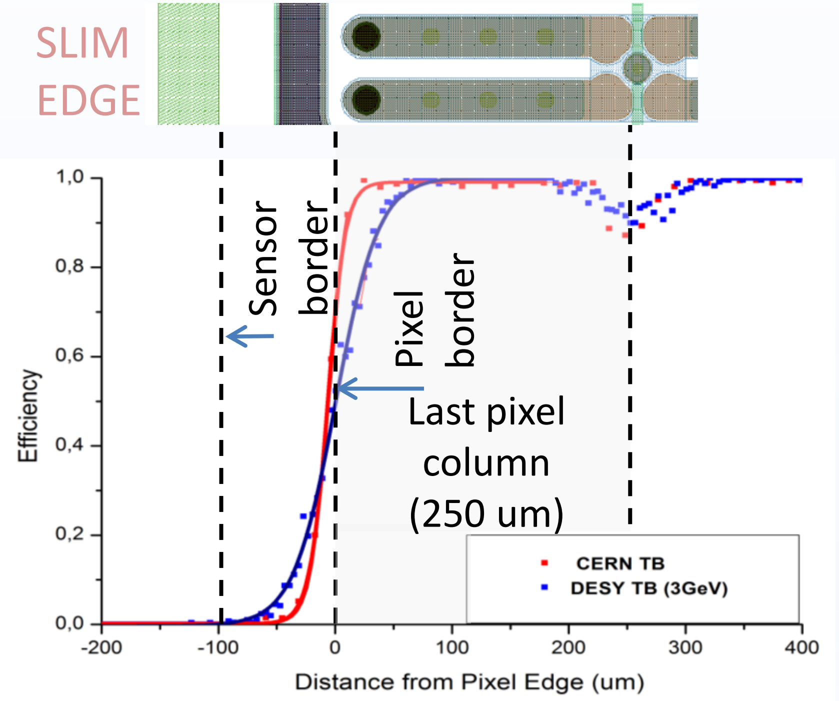




Results

Comparison of the **CERN** and **DESY** test beam results for the <u>non-irradiated</u> (*ADV-NP150-6-1A and ADV-NP100-7-2A*) samples.





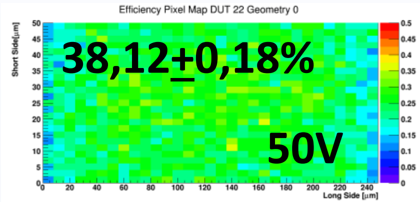
Results

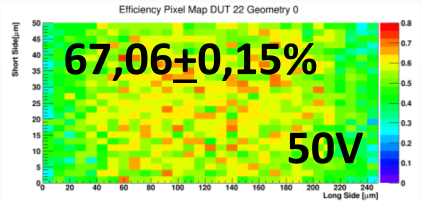
Efficiency performance for the **active edge** and **slim edge** **150 um** and **100 um** thickness (*ADV-NP150-6-1A, ADV-NP100-7-2A*) after irradiation **$2x10^{15}$ n_{eq}/cm^2** at different bias voltages.

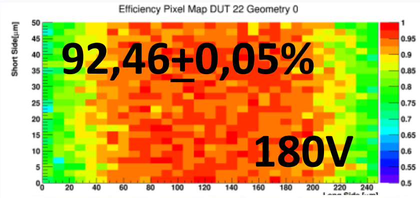
- In-pixel efficiency maps

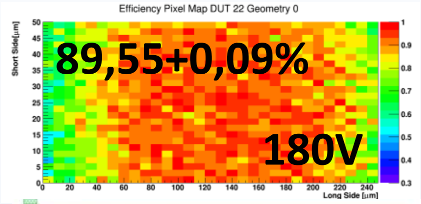
Active edge

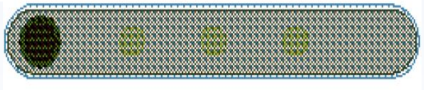
Slim edge

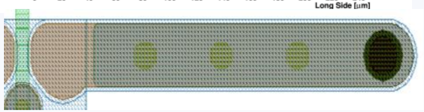




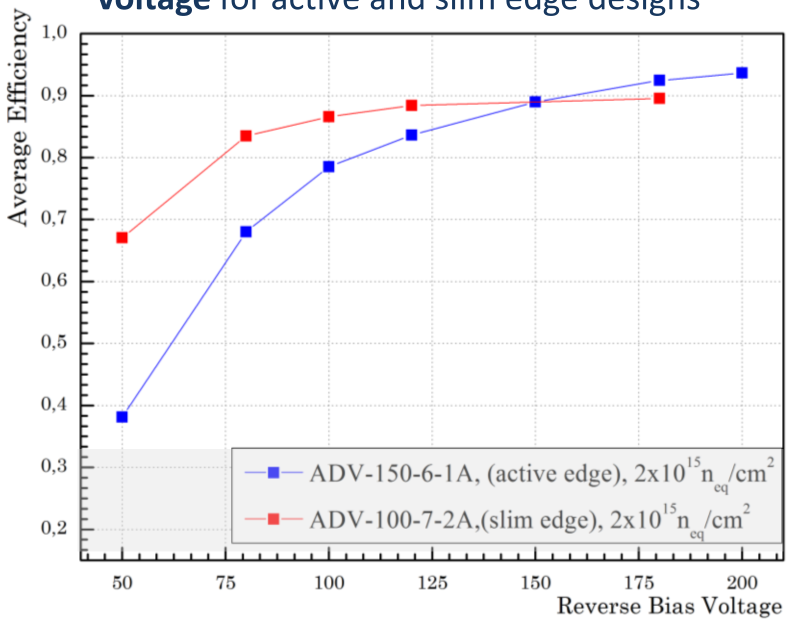






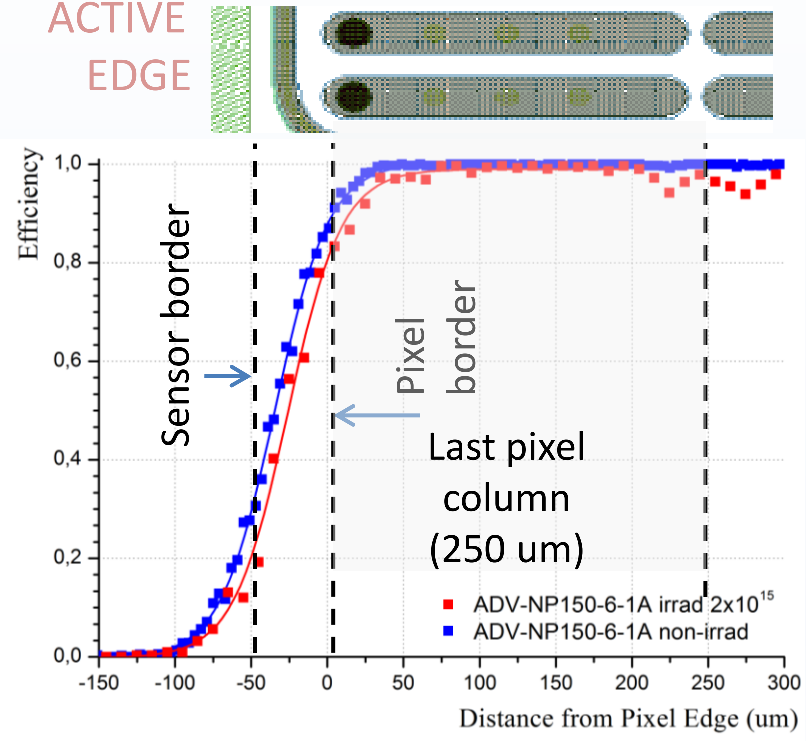


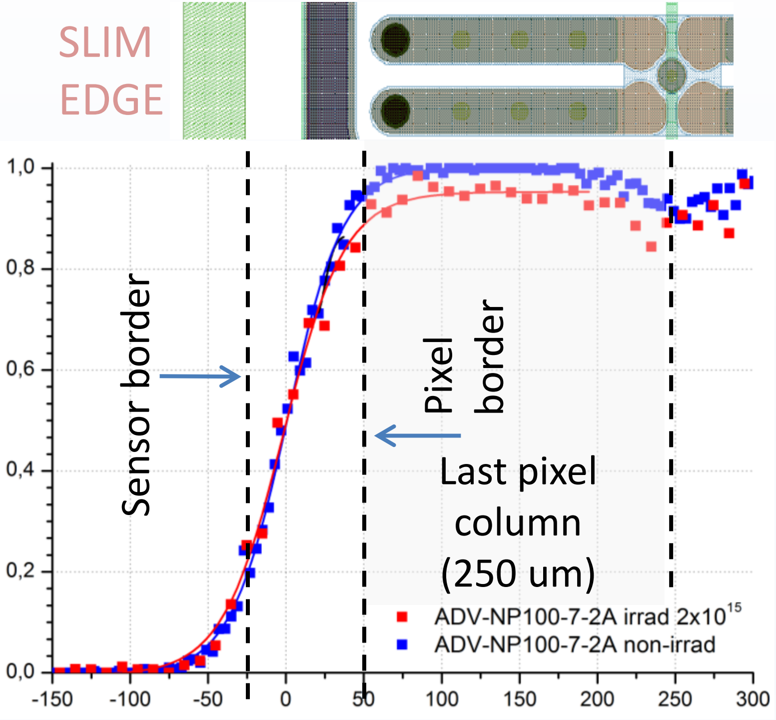
Comparison of the **Global efficiency vs bias voltage** for active and slim edge designs



Results

Efficiency performance for the **active edge** and **slim edge** **150 um** and **100 um** thickness before and after irradiation.





Results

Comparison of the performance of active and slim edge design sensors:

- 50 um – thick sensors:
  - Before irradiation **active edge** shows better efficiency 97,2% while **slim edge** has 94,7%;
  - At $1e15\ n_{eq}/cm^2$, the efficiency of **active edge** is 86-89%, while **slim edge** is 79-84% at 120V.
- 100 um **slim edge** sensor :
  - Before irradiation provides 96,8% of hit efficiency;
  - After irradiation at $2e15\ n_{eq}/cm^2$ the efficiency can recover 89.5% at 180V;
- 150 um **active edge** sensor:
  - Before irradiation provides 97,8% of hit efficiency;
  - After irradiation at $2e15\ n_{eq}/cm^2$ the efficiency can recover 93.6% at 200V;

Both designs have a problem with the achievement of high voltage (breakdown starts)

Summary and Conclusions

- 50 µm-thick samples (two are non-irradiated and two are at $1x10^{15}$ n_{eq}/cm^2 irradiation level) of active and slim edge design have been measured at CERN test beam (Oct-2017) .
- 150 and 100 µm-thick samples of active and slim edge design respectively have been measured at DESY facility (March, Dec-2017) before and after irradiation $1x10^{15}$ n_{eq}/cm^2 .
- The efficiencies (global, in-pixel, edge) were calculated for various sensor conditionals including : before and after irradiation case, the horizontal position of the sensor being illuminated, and tilted angle to the beam.
- The efficiency performance is generally better in sample with active edge design compared to the one with slim edge design. Thicker sensors show better performance.

Thank you for your attention!