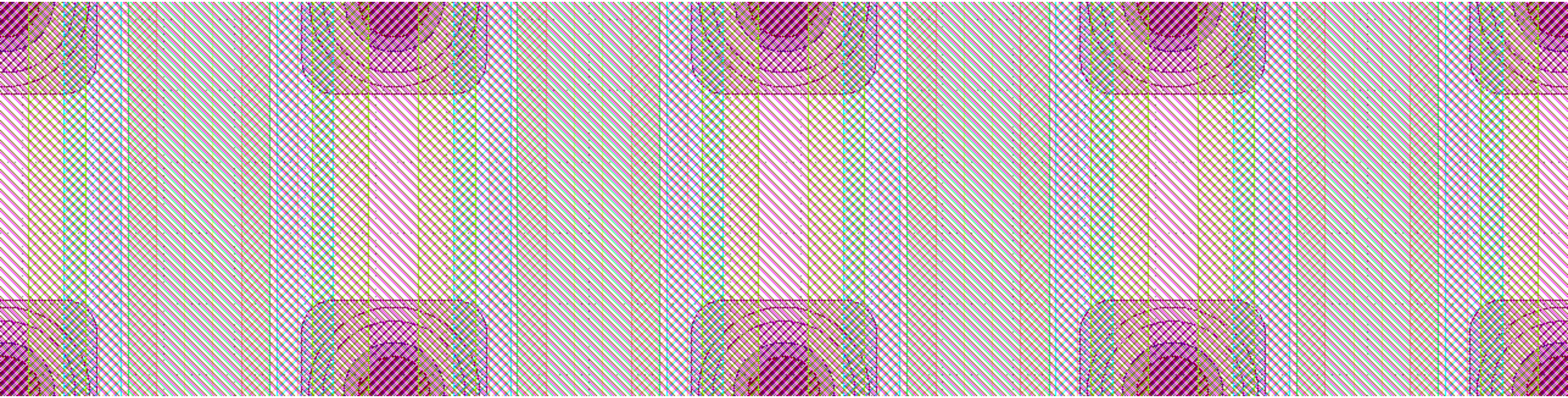
Enhanced Lateral Drift Sensors

Improving resolution with enhanced lateral drift (ELAD) sensors



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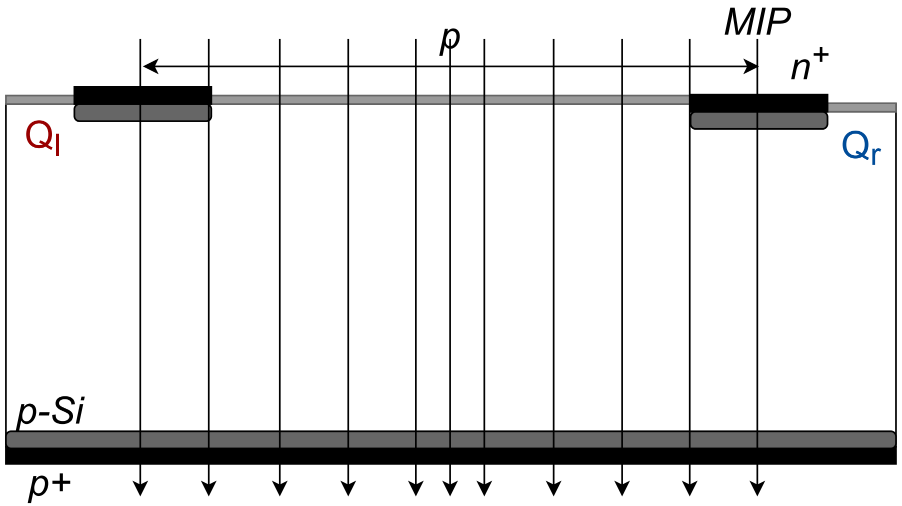
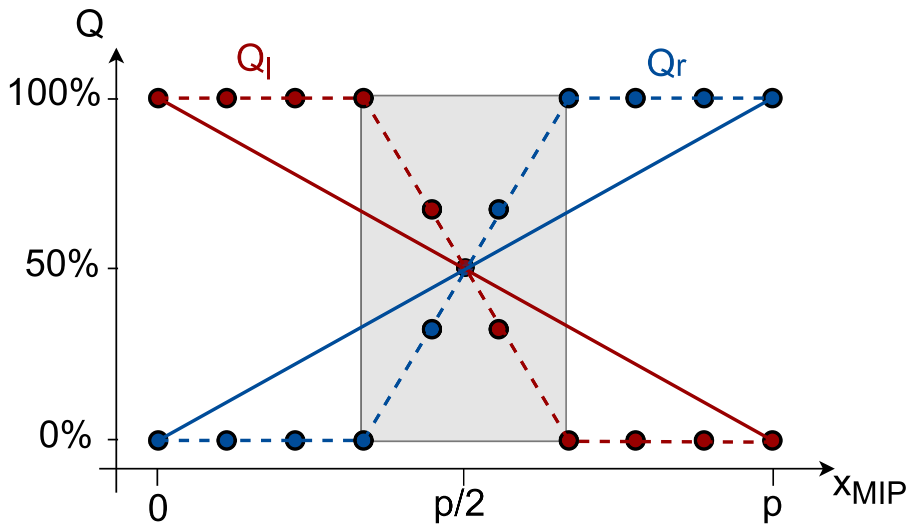
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES PIER DESY Strategy Fund CiS Forschungsinstitut für Mikrosensorik GmbH Fraunhofer EMFT DESY.

Charge sharing

Towards the theoretical optimum of position resolution



$$\eta = Q_l/(Q_l+Q_r)$$



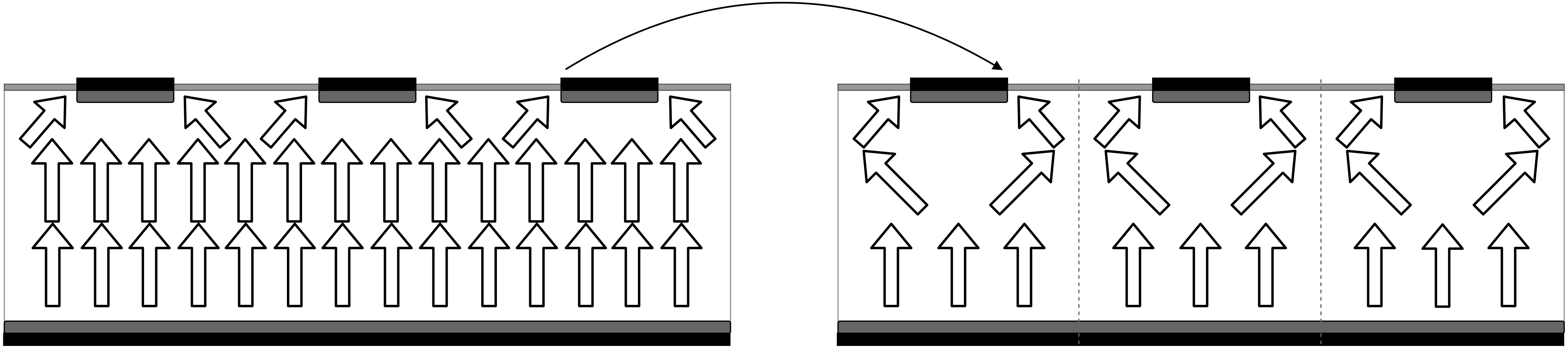
- Standard sensor design:
  - charge in the left part of pitch collected by 1st strip
  - charge in the right part of pitch collected by 2nd strip
- In an ideal case:
  - charge distribution between 1st and 2nd strip is **linear** → best charge sharing

Concept of an Enhanced Lateral Drift Sensor

Manipulating the electric field

- Charge carriers in sensor follow the electric field lines
- **How to achieve improved position resolution of charged particle sensors?**

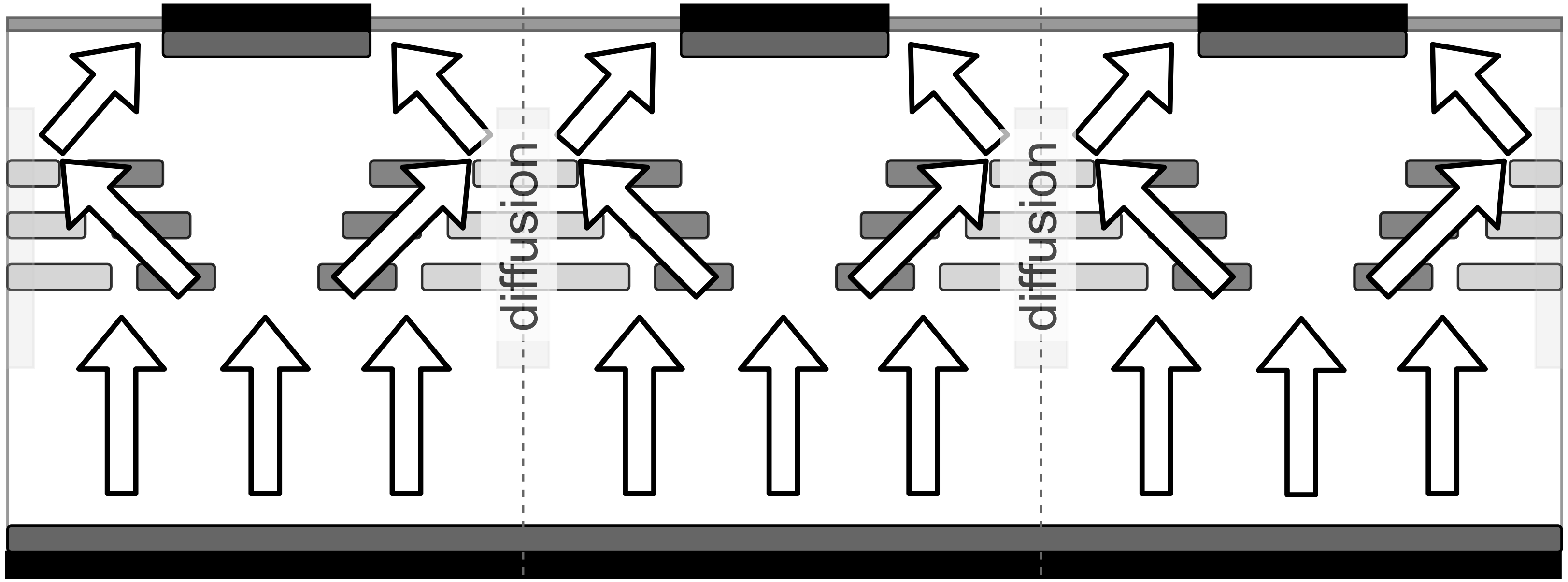
  → Induce lateral drift by locally engineering the electric field
- Introduce a lateral electric field inside the bulk



Concept of an Enhanced Lateral Drift Sensor

Manipulating the electric field

- **Buried implants → regions of additional doping**

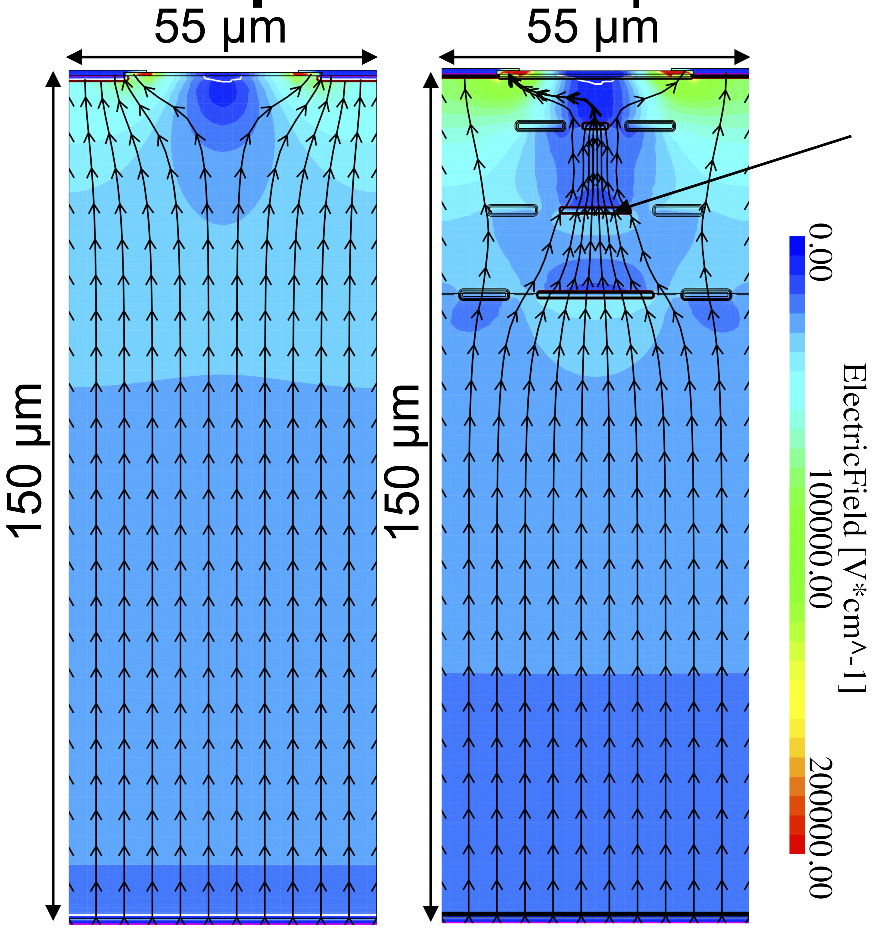


- Lateral electric field → repulsive/attractive areas inside the bulk
- **Modified drift path of the charge carriers**

Simulations of the ELAD Sensors

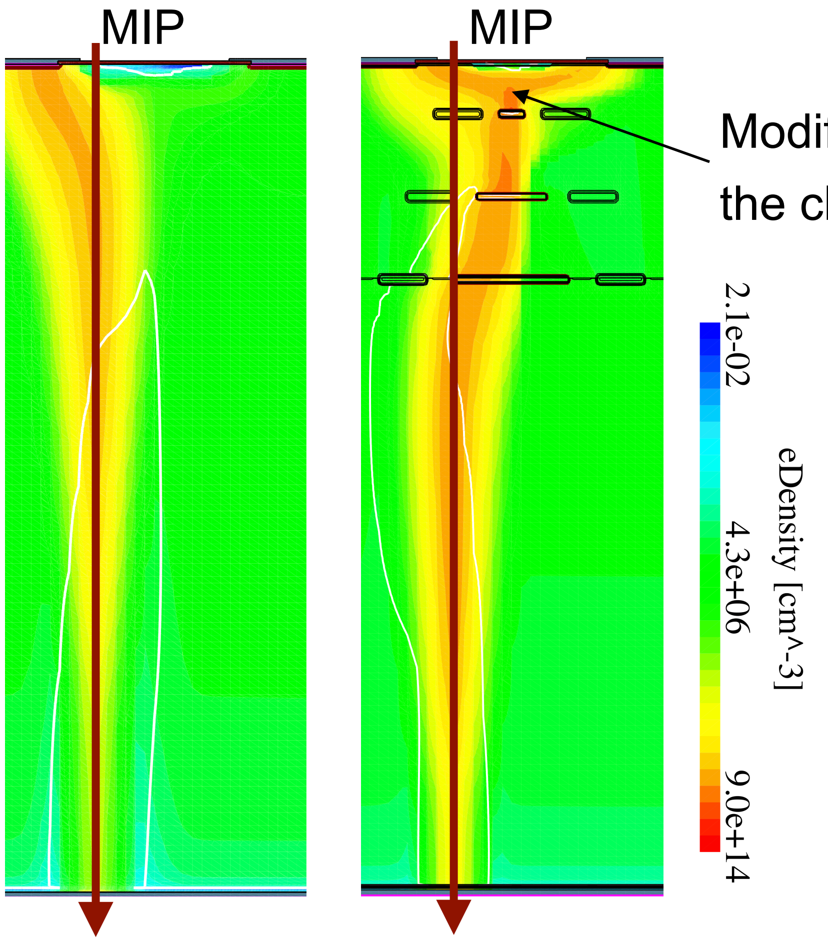
TCAD Electric Field & Transient Simulations

- Buried **p⁺**- and **n⁺**-implants create the lateral electric field in the bulk.



Electric field lines move to the centre

Planar sensor *p-ELAD*

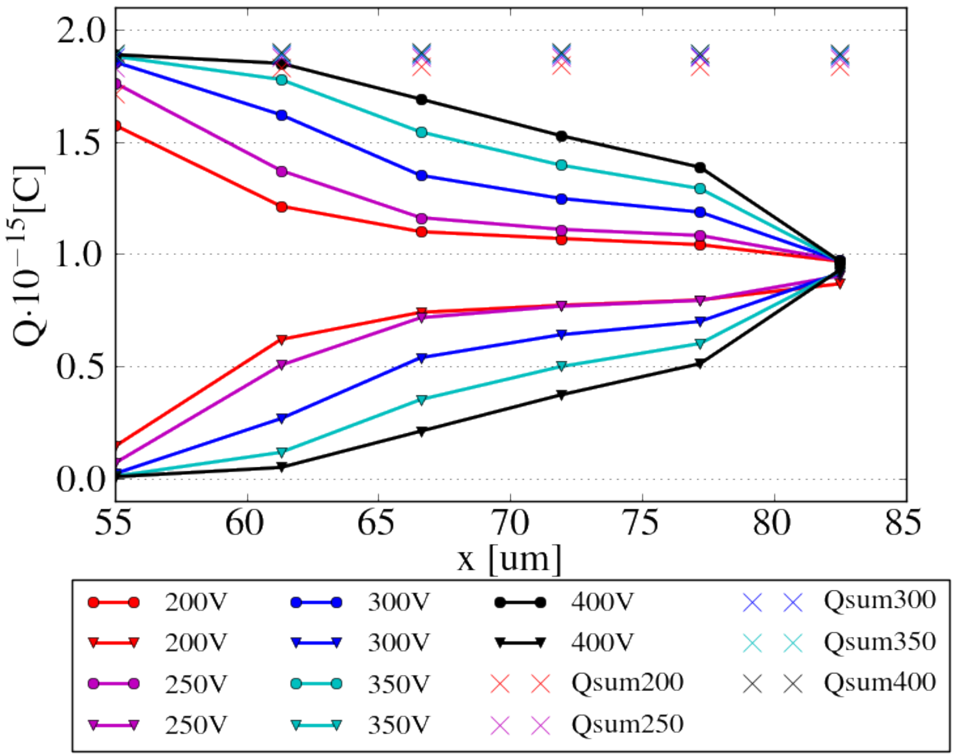


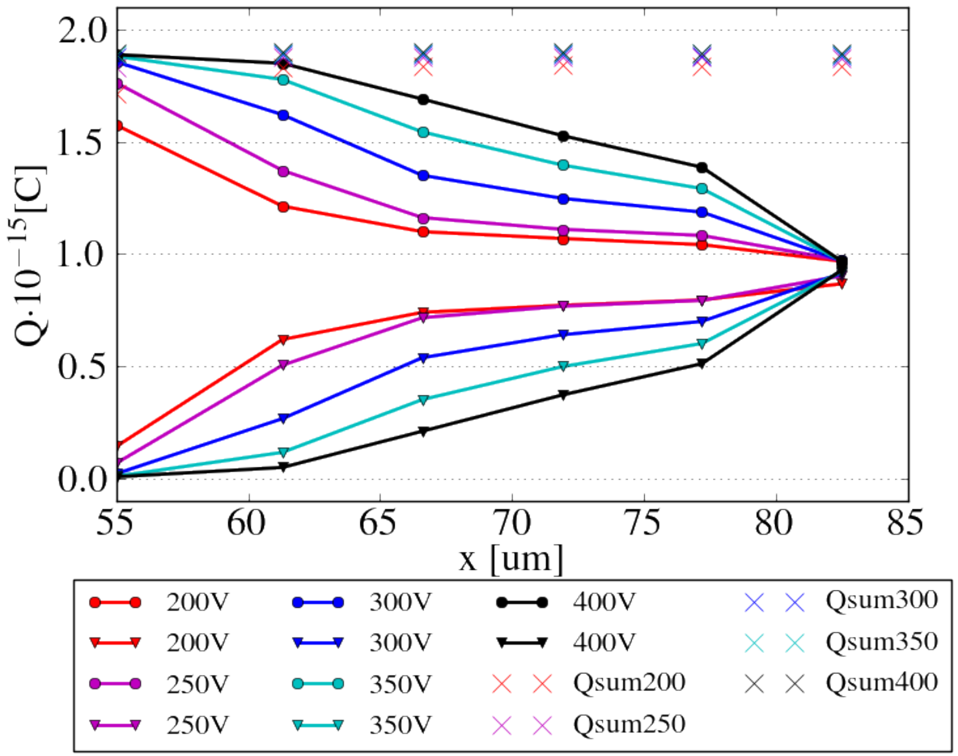
Modified drift path of the charge carriers

Planar sensor *p-ELAD*

Simulations of the ELAD Sensors

TCAD η - function 150 μm ELAD $n_{di}=3 \times 10^{15}\ cm^{-3}$



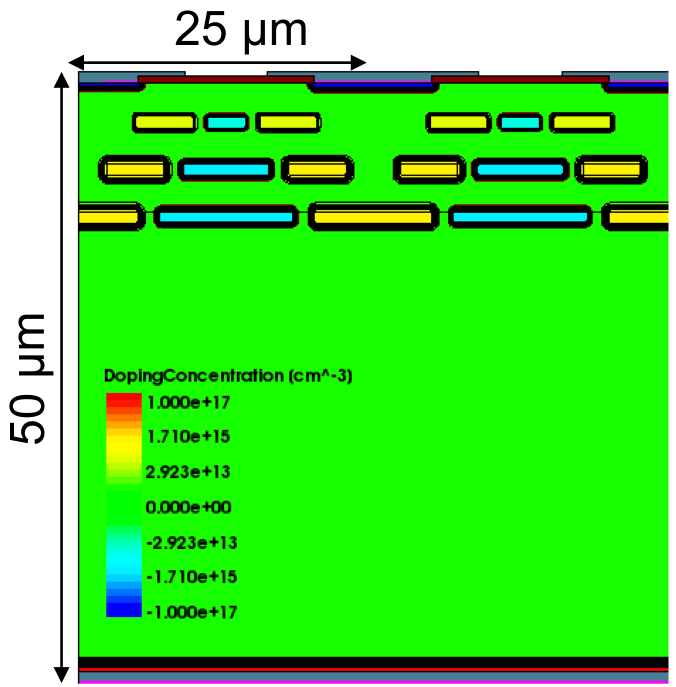


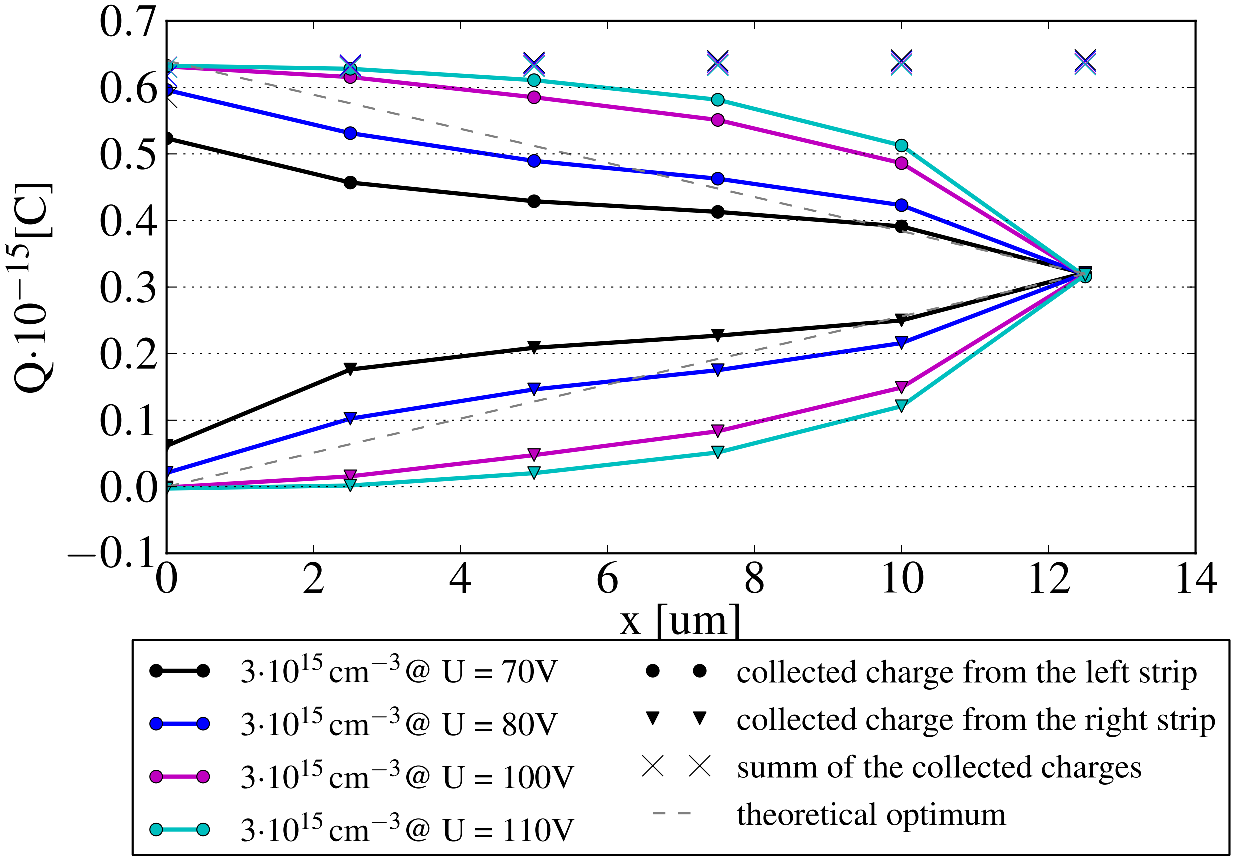
- p-ELAD: optimal voltage → 300V and 350V
- n-ELAD: optimal voltage → 250V and 300V
- **tuning** of the **lateral** and **longitudinal** components of the electric field

nELAD CP2

TCAD simulations | 50 µm thick CP2 n-ELAD sensor $n_{di}=3 \times 10^{15}$ cm^{-3}

- smaller distance between the buried implants layers
- wider buried implants



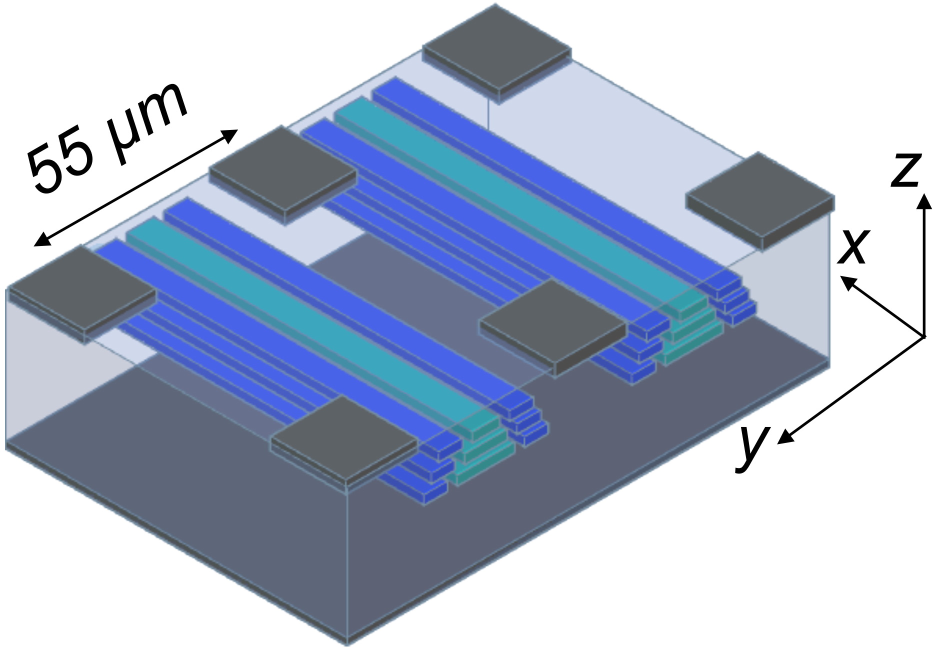


- ELAD design optimised to the read-out pitch and thickness

Simulations of the ELAD Sensors

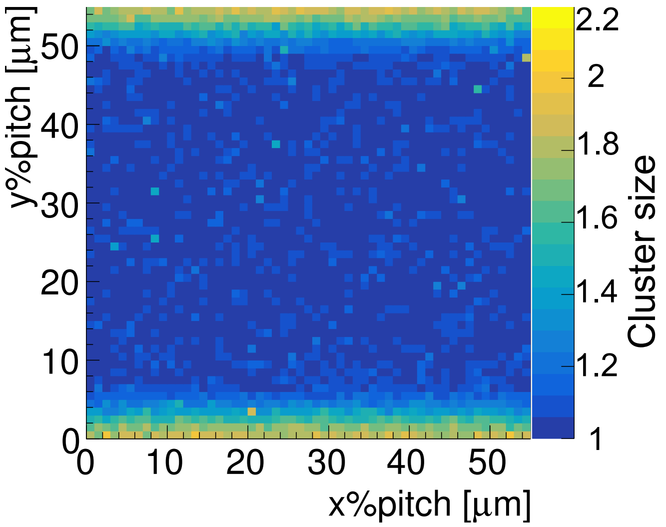
Allpix² resolution studies

- To estimate the position resolution → AllPix² simulations
- Allpix² - generic simulation framework for silicon tracker and vertex detectors
- Simulations with MC particles
- Based on Geant4 and ROOT
- Uses TCAD electric field

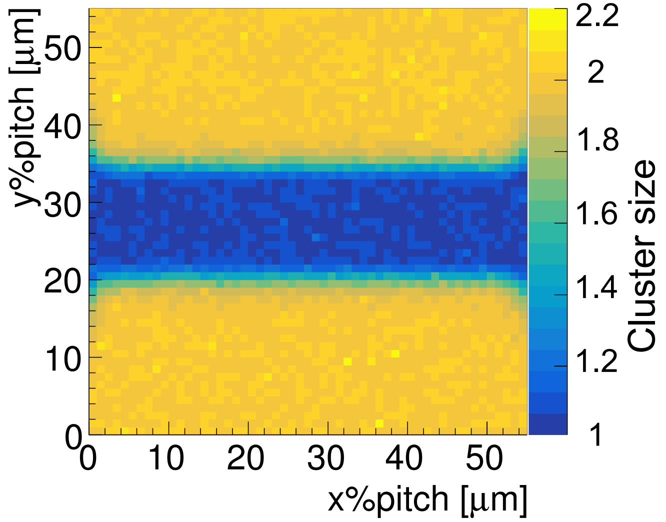


Simulations of the ELAD Sensors

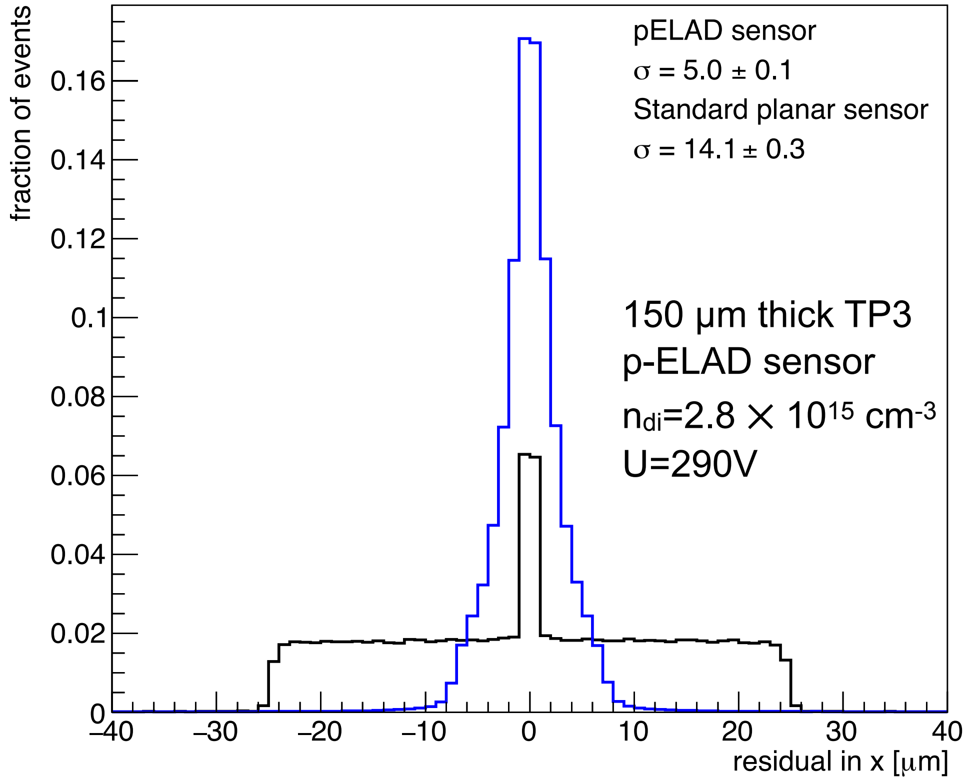
Allpix² resolution studies



- Cluster size in *x* ~1
- Edges of the pixel ~2
- no ELAD effect



- Cluster size in *y* ~2
- Center of the pixel ~1
- ELAD charge sharing

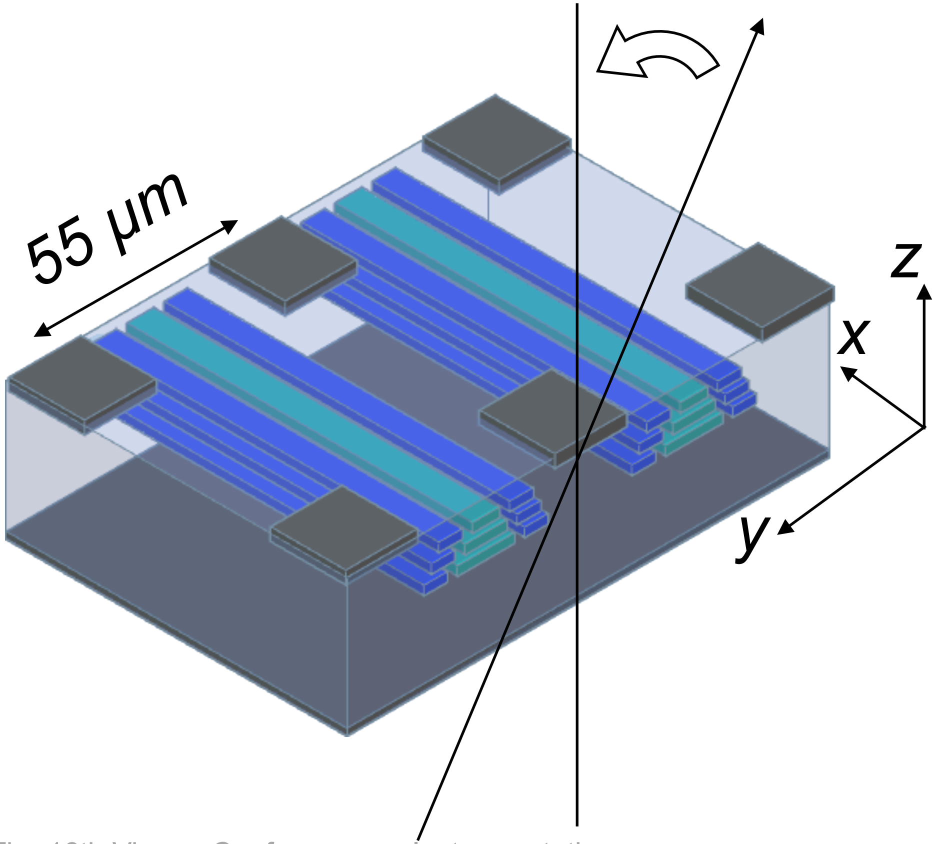


Simulations of the ELAD Sensors

Allpix² resolution studies. Rotation scans.

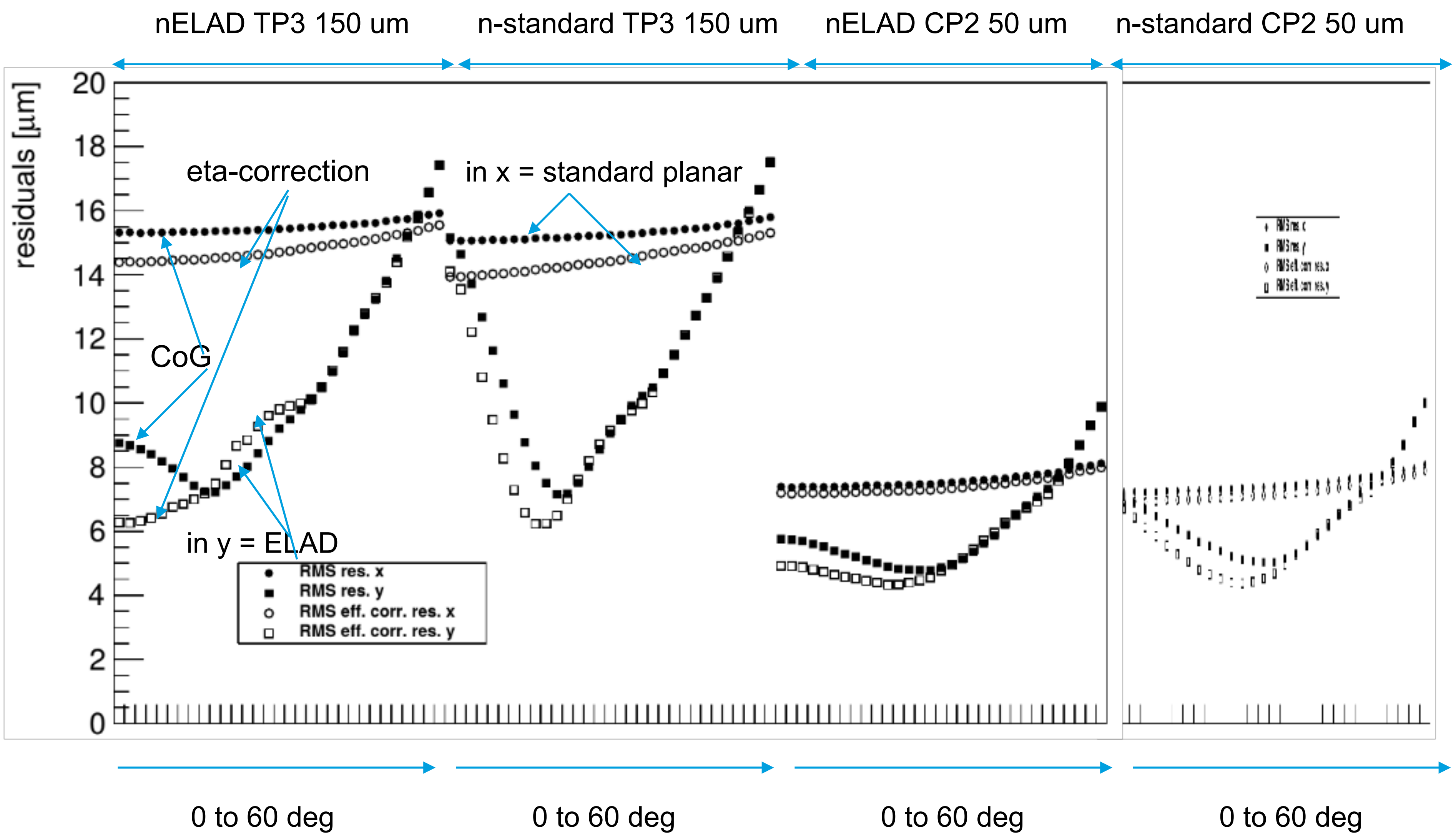
- Goal
  - Understand ELAD behaviour for non-perpendicular tracks
- Object under study
  - 150 um thick n-ELAD with TP3
  - 50 um thick n-ELAD with CP2
- Compare with
  - 150 um thick n-standard TP3
  - 50 um thick n-standard CP2
- Methodology
  - Scan incidence angle from 0 to 60 degrees in the y-direction!

→ Superimpose effect of 'geometrical' charge sharing with ELAD-charge-sharing (→ many data points, even more plots, …)



Simulations of the ELAD Sensors

Allpix² resolution studies. Rotation scans.

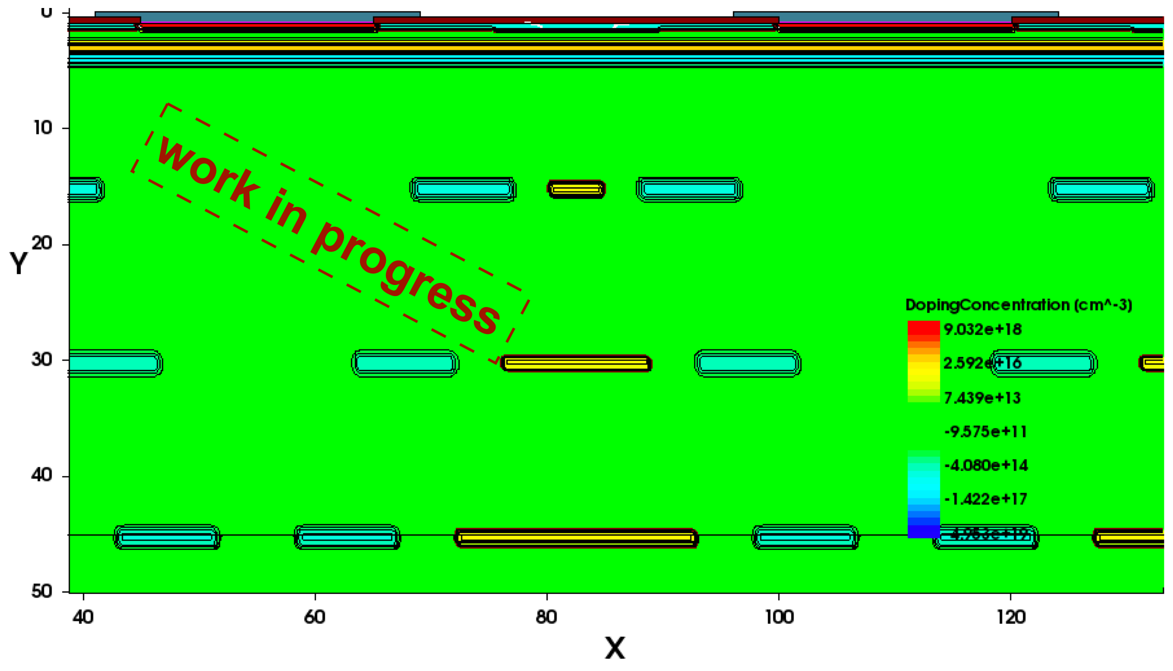


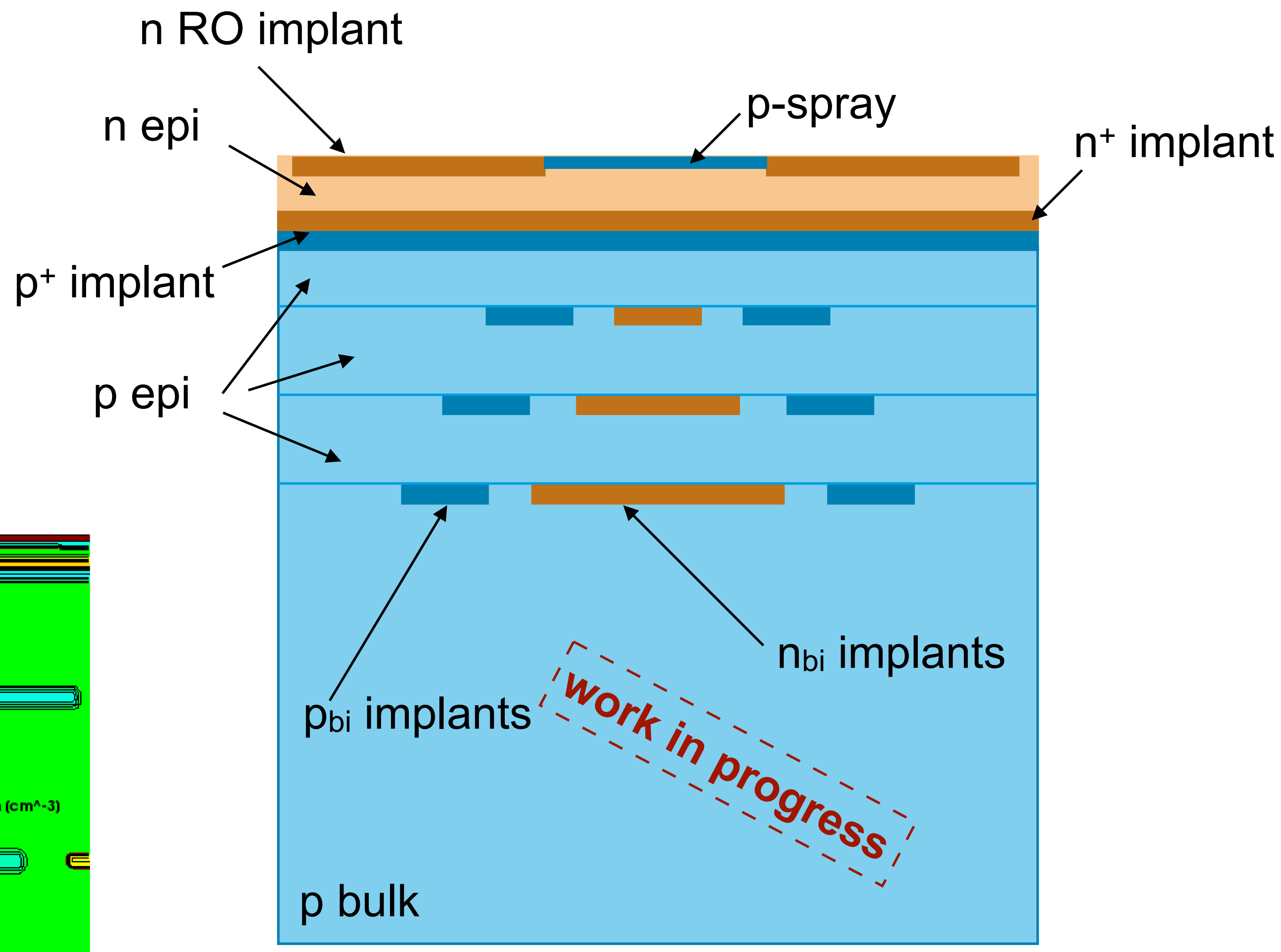
ELAD with multiplication layer

First attempt

- extra n⁺ p⁺ multiplication layer
- n-epi on top of the multiplication layer
- ELAD structure with p-epi layers

beneath the multiplication layer

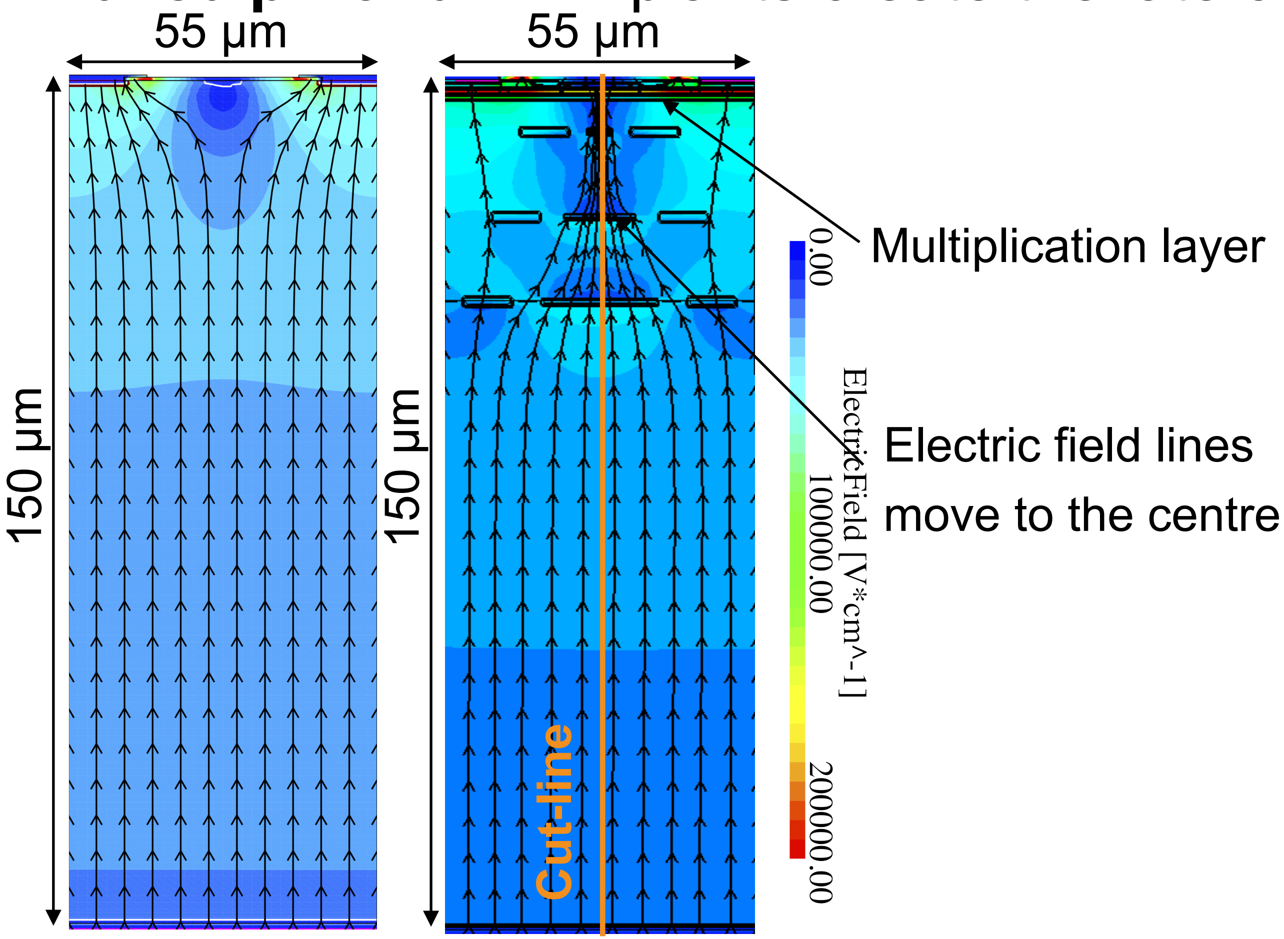




ELAD with multiplication layer

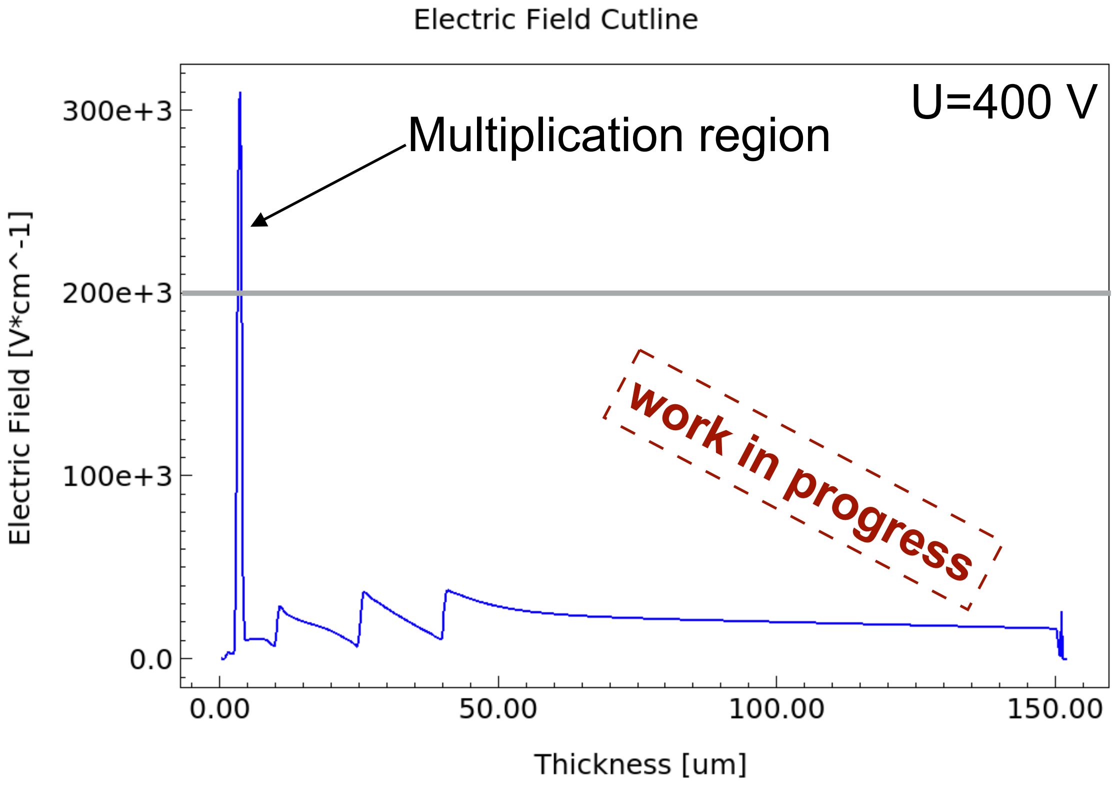
TCAD Electric Field

- Buried **p⁺**- and **n⁺**-implants create the lateral electric field in the bulk.



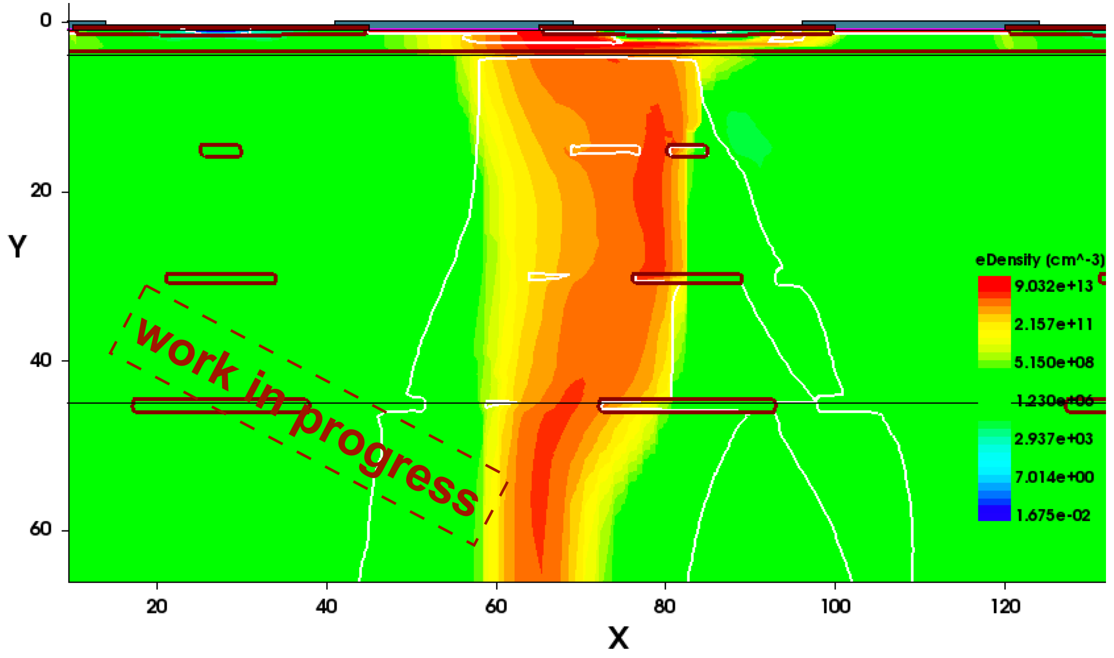
Planar sensor *p-ELAD with multiplication*

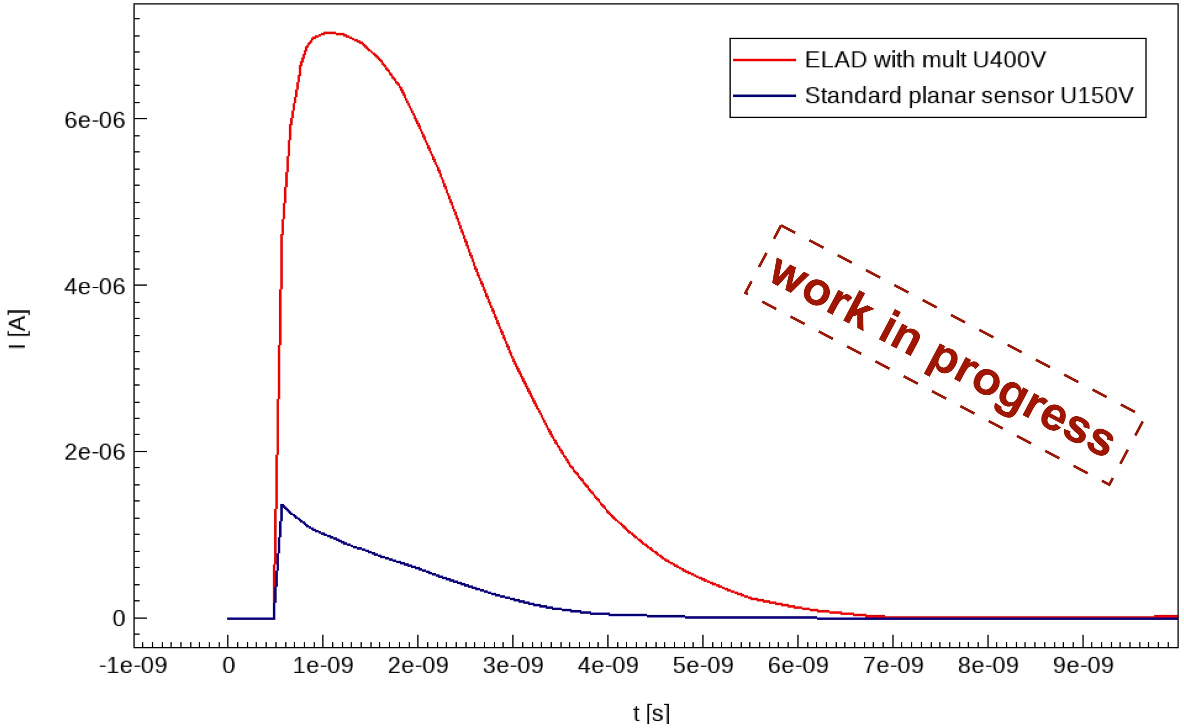
- Buried **p⁺**- and **n⁺**- layers create the multiplication region.



ELAD with multiplication layer

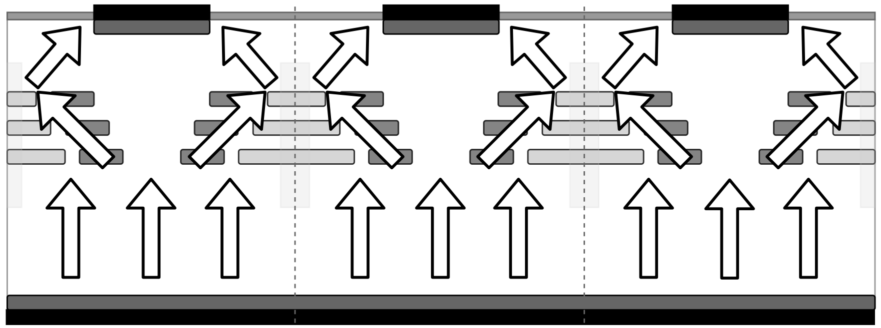
TCAD Transient Simulations





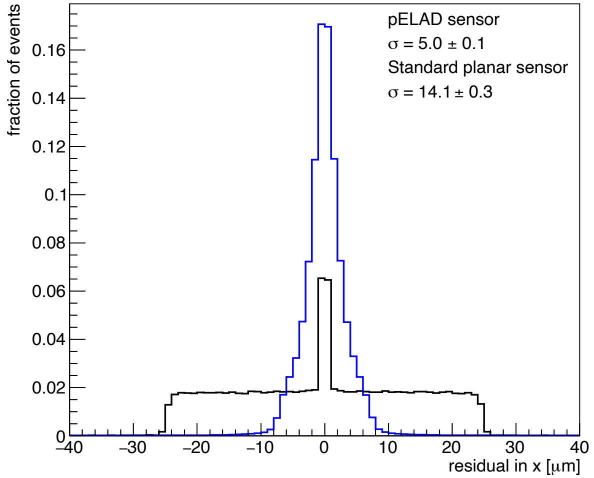
- multiplication of the charge is achieved (~9x)
- more tuning needed
- aiming for 3 um spatial resolution at 55 um pitch combined with sub 100 ps timing resolution (with appropriate ASIC).

Summary & Outlook



Summary:

- Technologically challenging project aiming to reach the theoretical optimum of position resolution
- Interesting technology for future HEP detectors: RMS residual of 4.9 um @ 25 um pitch
- Bulk engineering opens new possibilities in sensor design



Outlook:

- Looking further into buried multiplication layer, especially concerning gain, depth and electric field close to read-out electrodes