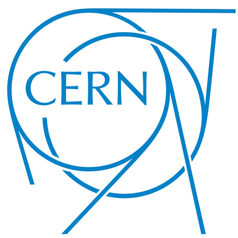


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# First laboratory results of CLICTD on Czochralski substrate

## Vertex and tracker meeting

20/05/2021

Katharina Dort

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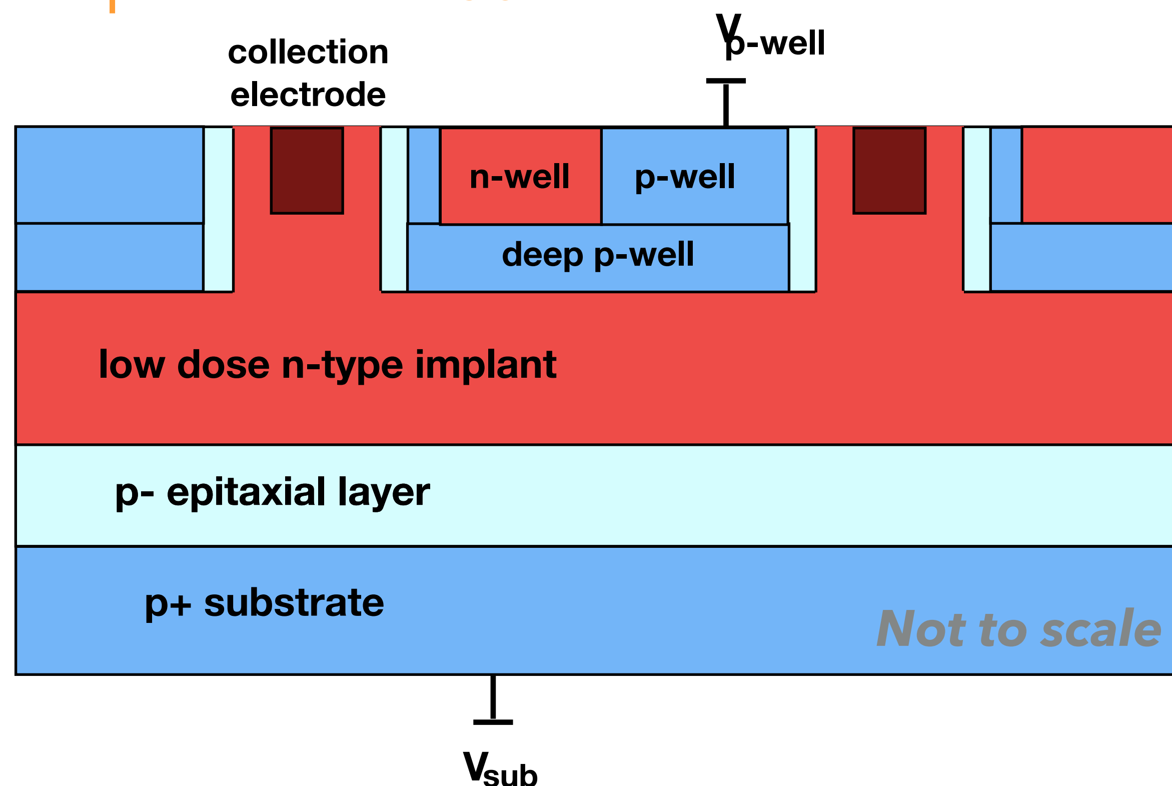
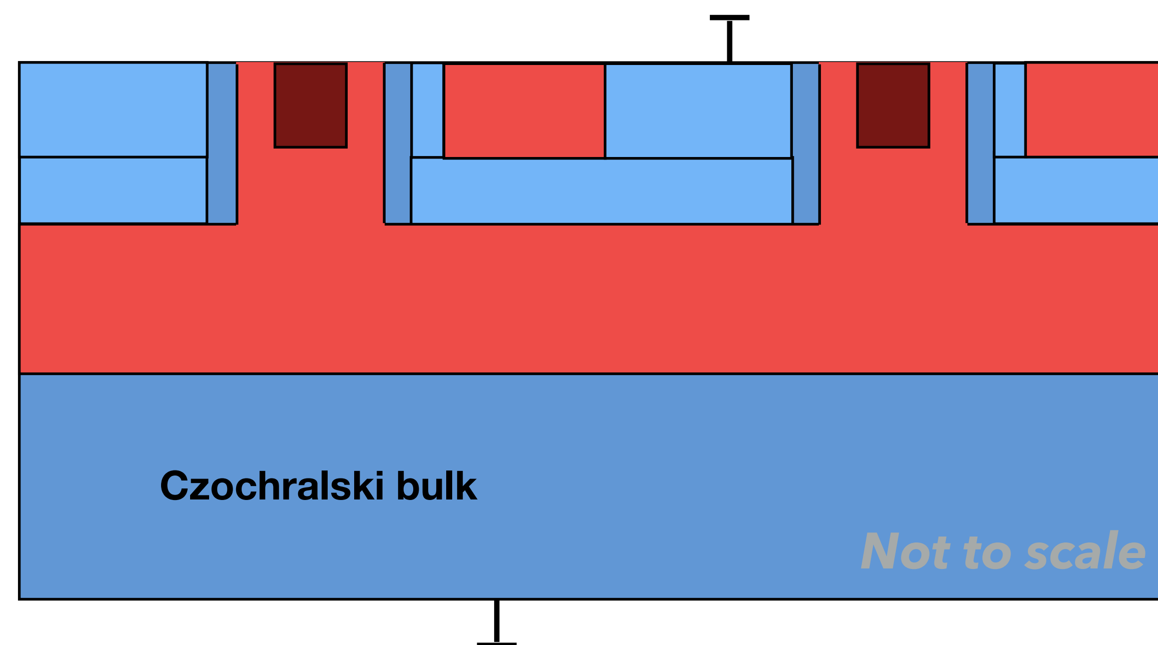
# CLICTD on Czochralski wafer material

- Limited thickness of epitaxial layer -> High-resistivity Czochralski (> 800 Ωcm) starting material allows for larger depleted volume NIM A 986 (2021) 164381

Epi thickness: 30 um




Total thickness: 100 um




https://indico.cern.ch/event/921920/

- New CLICTD samples received spring 2021
  - Different n-type doses
    (High, intermediate, low)
  - Different pixel flavours
    (continuous n-implant, segmented n-implant, additional p-implant)
  - Different starting material
    (Epi, Czochralski)

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# CLICTD - 1st submission

## Epitaxial layer / low n-type dose

### Continuous n-implant

| SAMPLE | Bias voltages [V] | Thickness [um] | Cluster size | Time resolution | Position resolution | Efficiency | Rotation scan |
|---|---|---|---|---|---|---|---|
| **A1 (no cut-out)** | -6, -3 | 300 | Yes | Yes | Yes | Yes | No |
| **A4** | -6 | 300 | Yes | No | Yes | Yes | Yes (both directions) |
| **A6** | -6 | 50 | Yes | No | Yes | Yes | Yes |

### Segmented n-implant

| SAMPLE | Bias voltages [V] | Thickness [um] | Cluster size | Time resolution | Position resolution | Efficiency | Rotation scan |
|---|---|---|---|---|---|---|---|
| **B1 (no cut-out)** | -6 | 300 | Yes | Yes | Yes | Yes | No |
| **B2 (no cut-out)** | -6 | 300 | Yes | No | Yes* | Yes* | No |
| **B4** | -6 | 300 | Yes | No | Yes | Yes | Yes |
| **B5** | -6 | 100 | Yes | No | Yes | Yes | Yes |
| **B6** | -6 | 50 | Yes* | No | Yes* | Yes* | Yes* |

- Overview of TB measurements performed on CLICTD samples from the 1st submission
- Only tested in the lab: A2, A3, B3, A5, A7, B7, A8, B8, A9, B9, A10, B10

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# CLICTD on Czochralski wafer material

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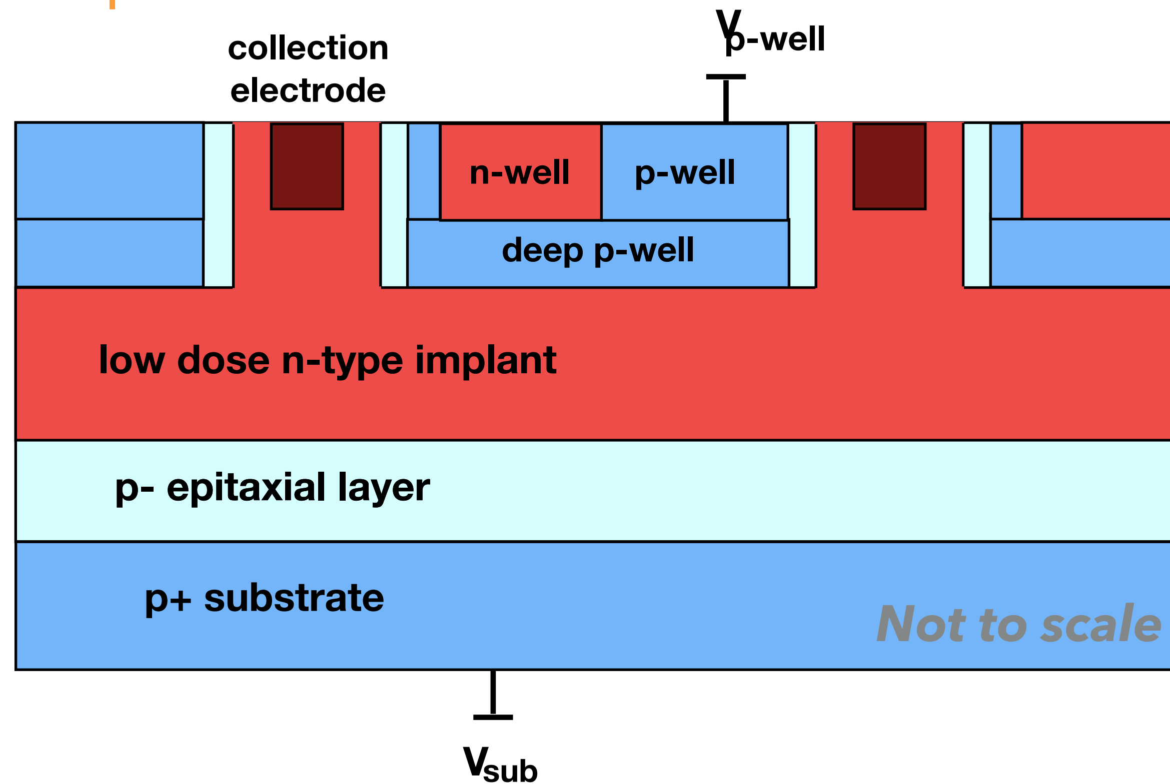
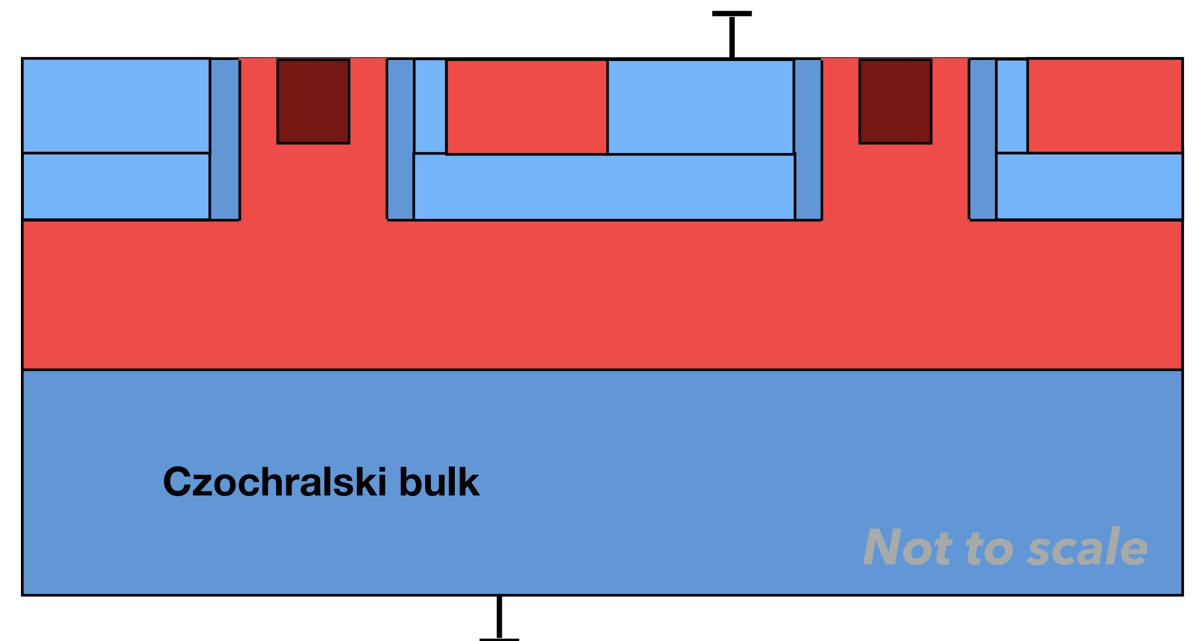



Total thickness: 100 um

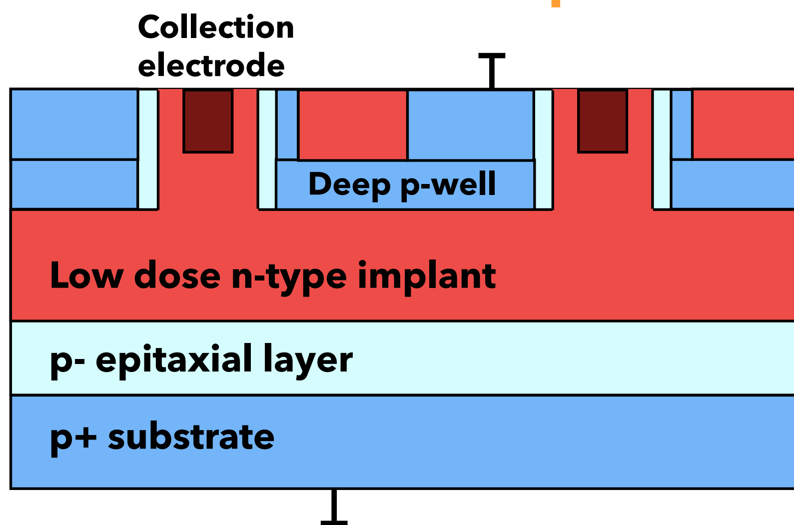



https://indico.cern.ch/event/921920/

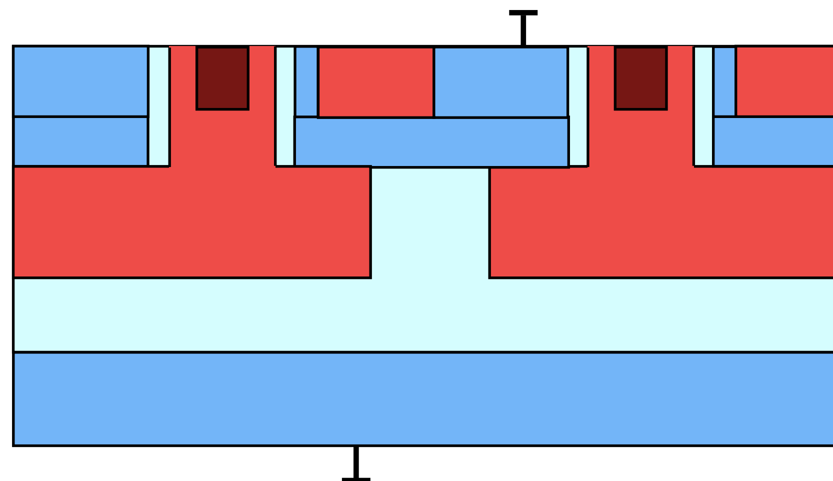
- New CLICTD samples received spring 2021
  - Different n-type doses (High, intermediate, low)
  - Different pixel flavours (continuous n-implant, segmented n-implant, additional p-implant)
  - Different starting material (Epi, Czochralski)

# Pixel flavours used for CLICTD

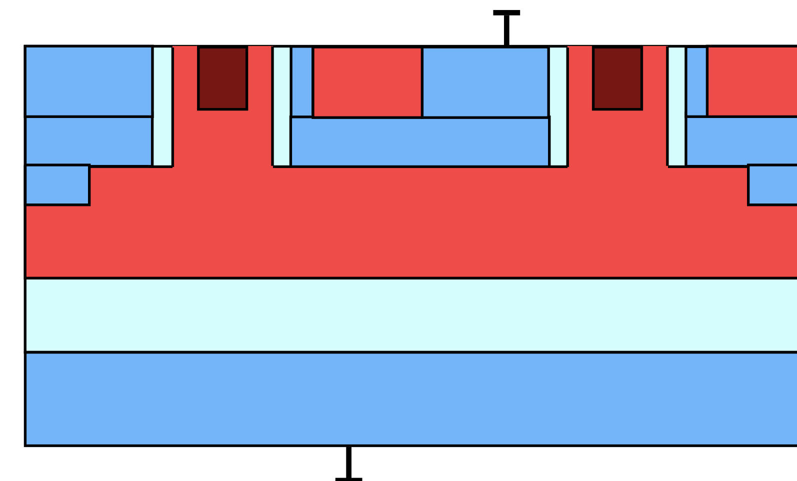
**Continuous n-implant**




**Segmented n-implant**



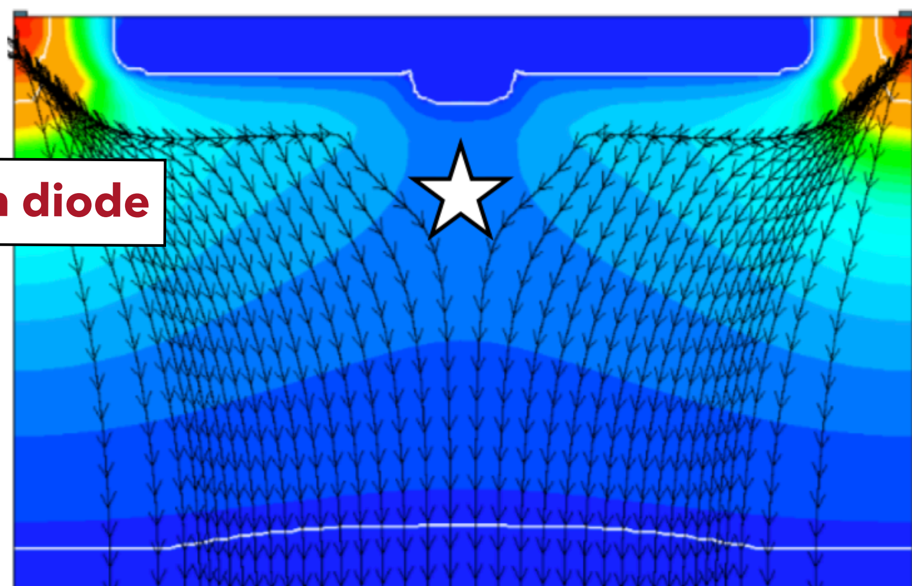
**Additional p-implant**



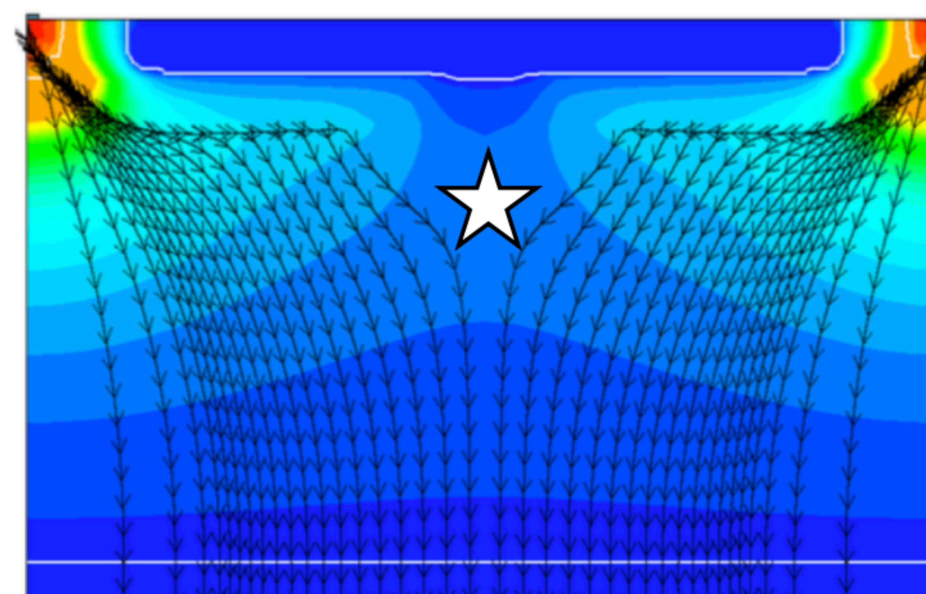
- Introducing lateral doping gradient "bends" streamlines towards the collection diodes

➡ Accelerated charge collection

**E-static potential, additional p-implant:**




**E-static potential, gap in N-implant:**



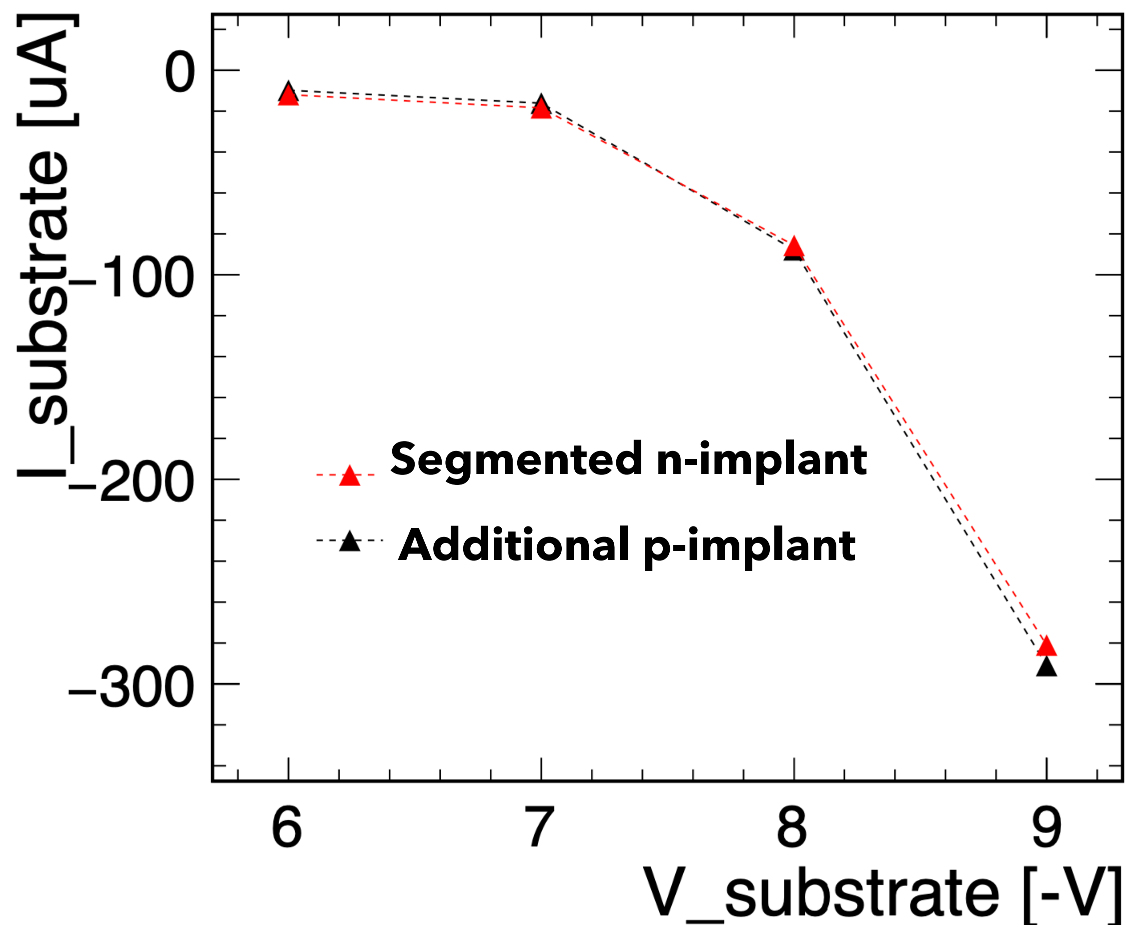
M. Munker et. al: doi:10.1088/1748-0221/14/05/c05013

# IV Curves for different pixel flavour

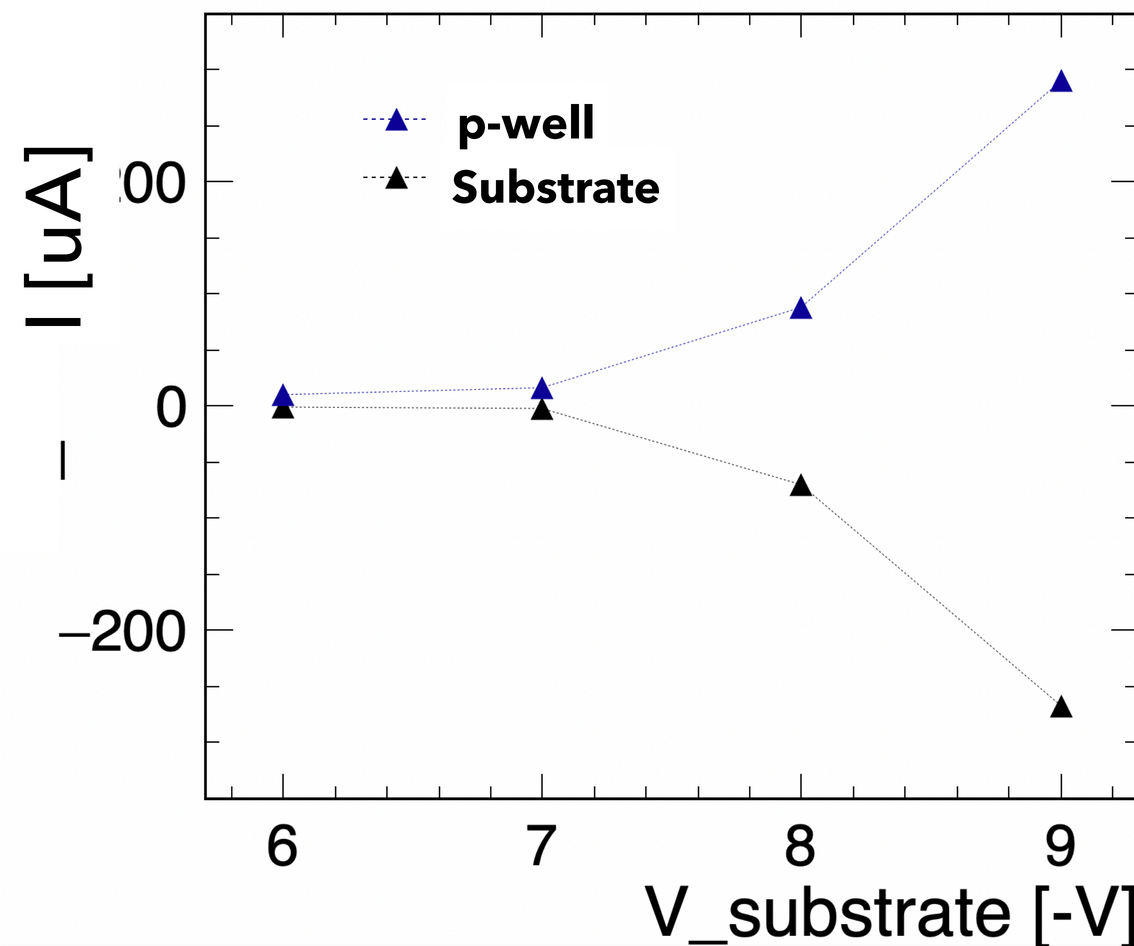


**P-well voltage : -6 V**

**Low n-dose / Epi**




**Additional p-implant / low n-dose / Epi**



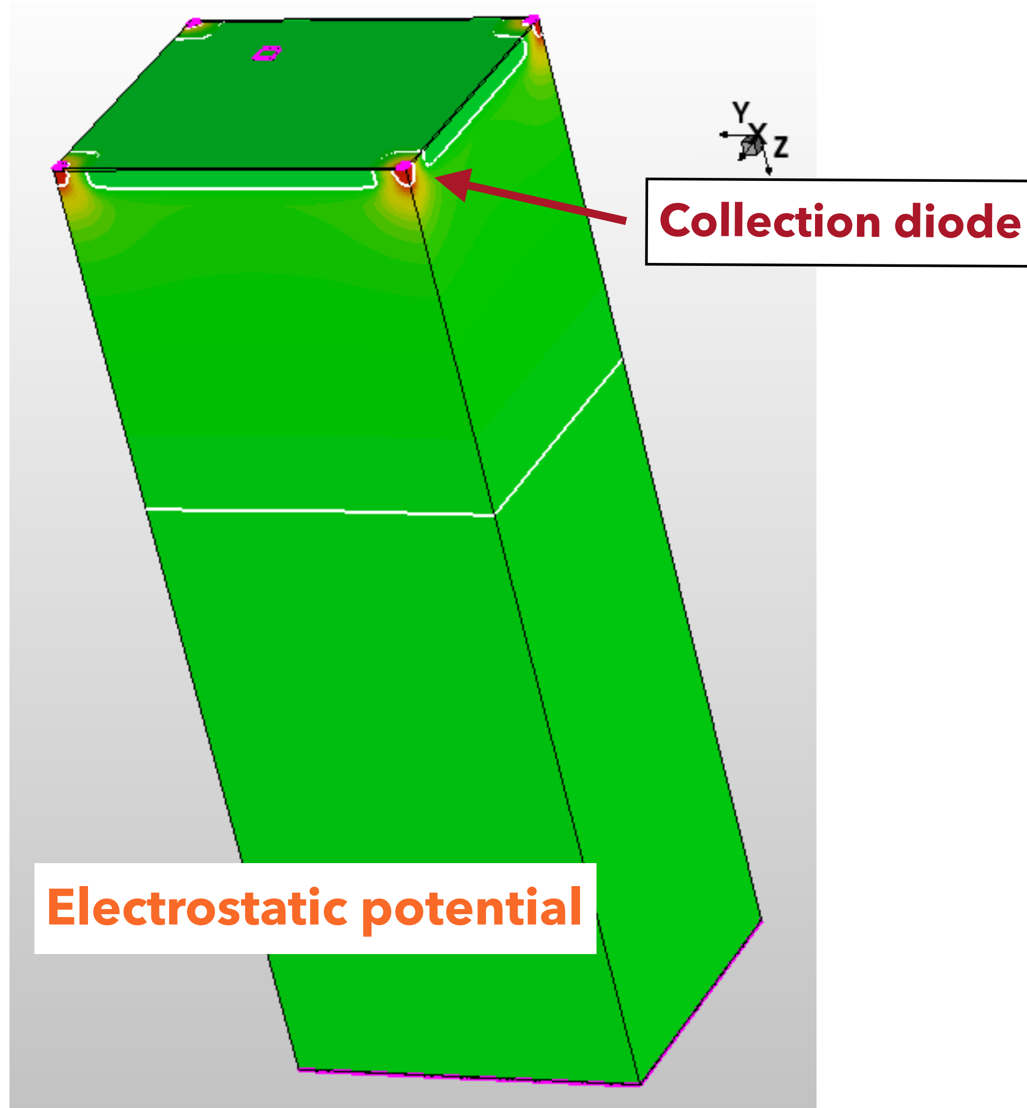

- P-well and substrate current are measured as a function of substrate voltage:
  - Determine stable operation window
  - Comparison to simulation
- Similar IV curves for flavour with segmented n-implant and additional p-implant

# Substrate voltage

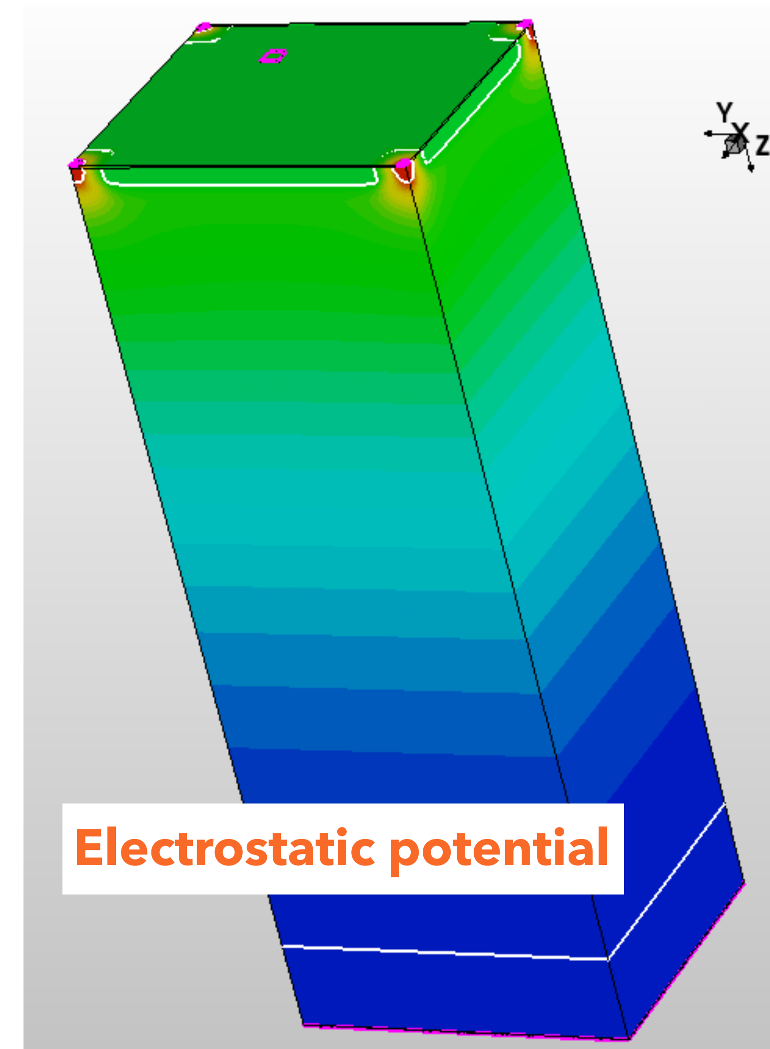
## Czochralski substrate

**Low n-dose / segmented n-implant**
**P-well voltage : -6 V**

**Substrate voltage: -6V**




**Substrate voltage: -12 V**



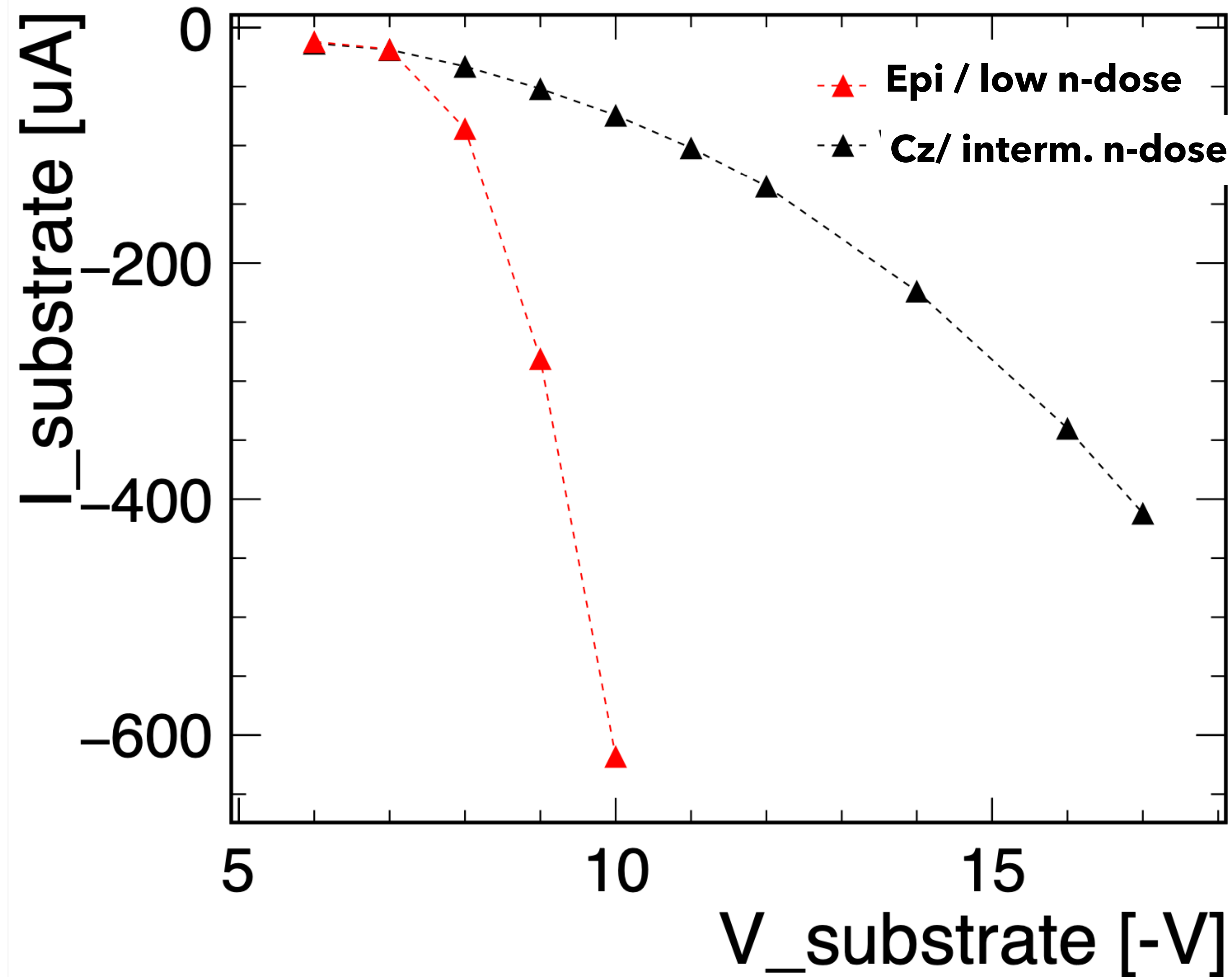

- Higher substrate voltage due to high-resistivity Czochralski substrate
  -> larger depleted volume
  ➡ Improved signal/noise ratio, larger cluster size (position resolution), larger efficient operation window

# IV - Curves for different starting materials



**Pixel flavour : Segmented n-implant**

**P-well voltage : -6 V**

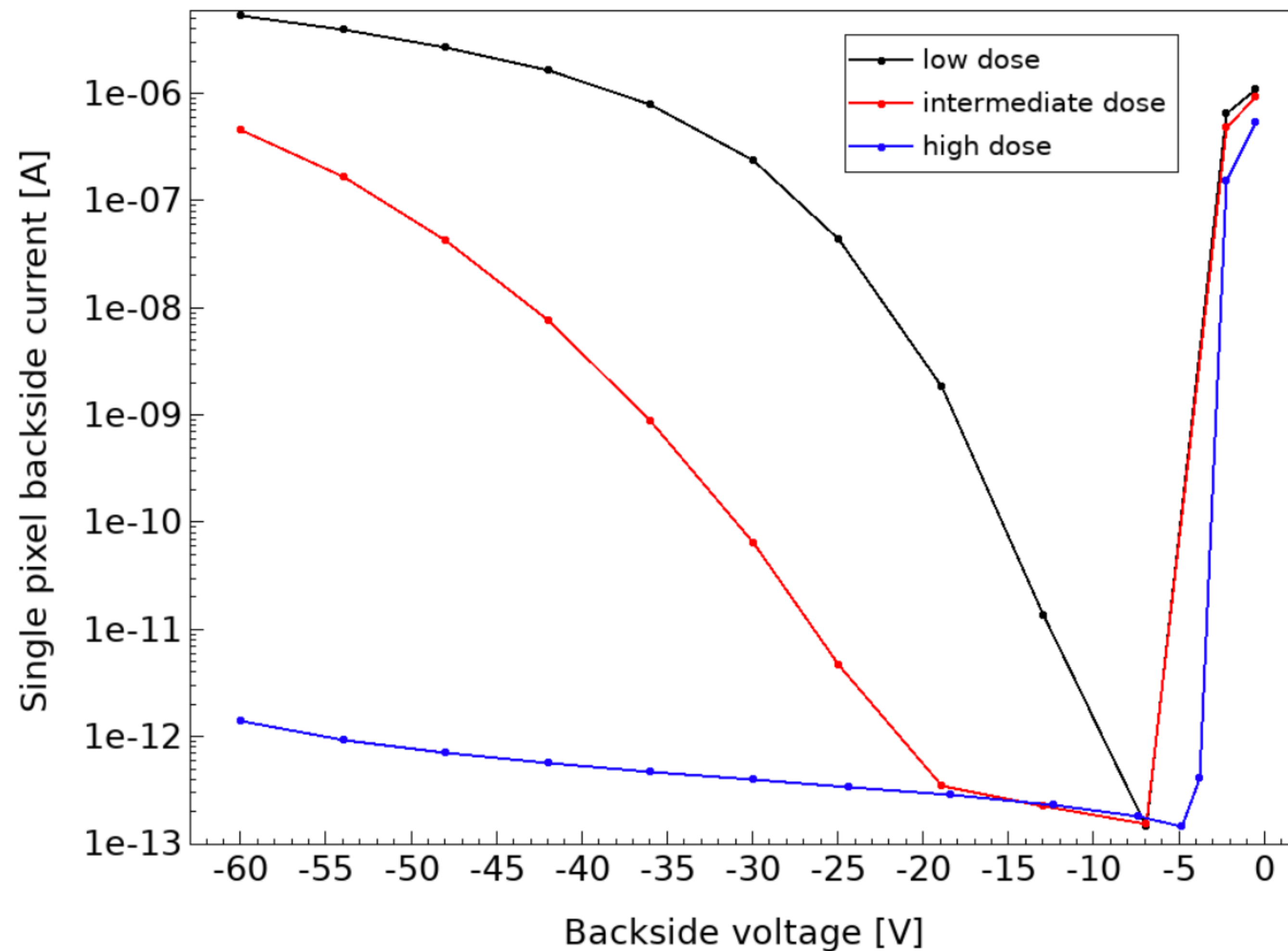



- Substrate current significantly lower for Czochralski sample with intermediate n-implant dose

# Different n-implant dose

*From Magdalena's vertex and tracker talk 21/07/2020*

## Hole current between backside and p-wells




- Higher punch-through current for lower deep n-implant dose
- Better isolation between p-wells and substrate for higher n-implant doses

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# IV - Curves for different starting materials

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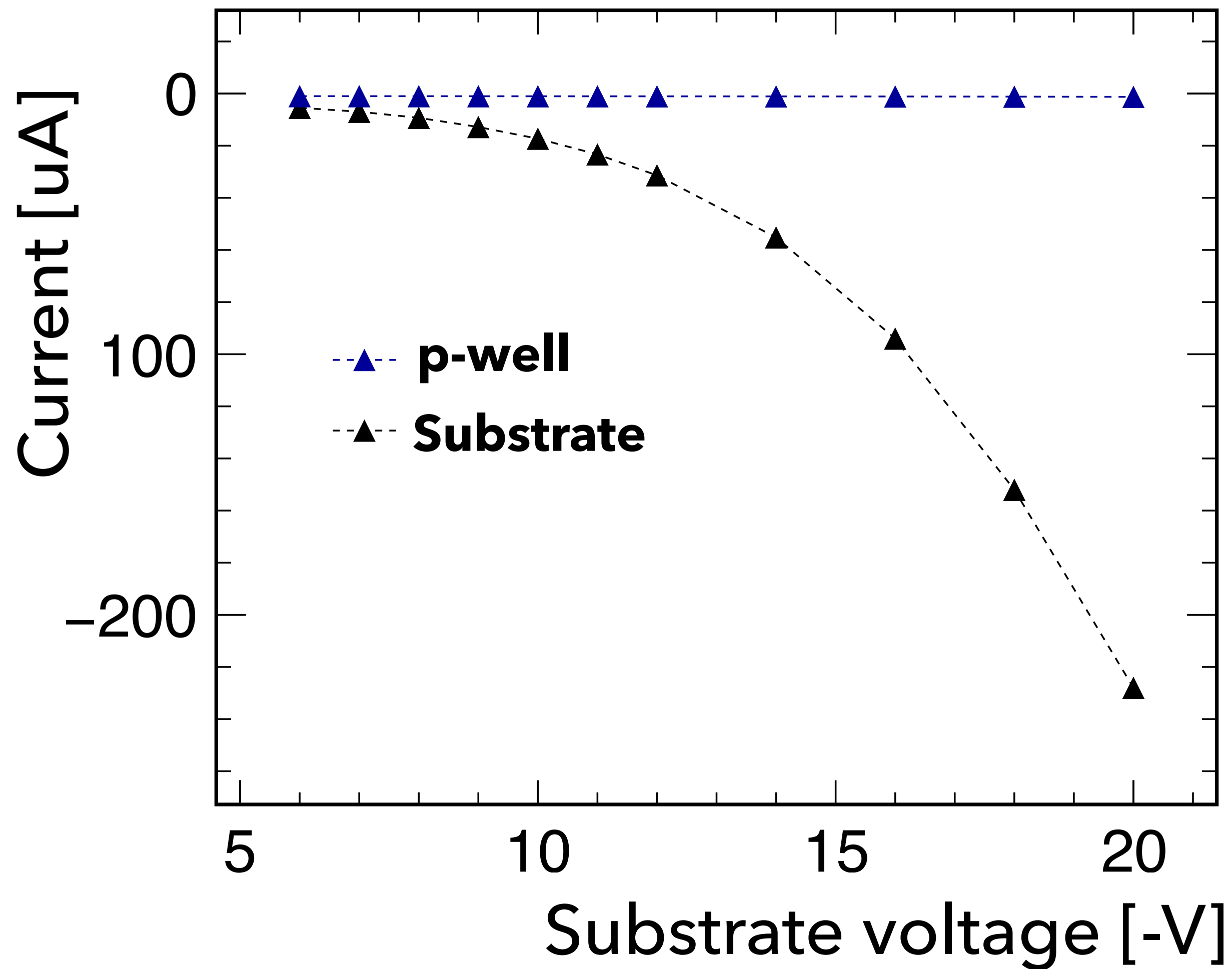
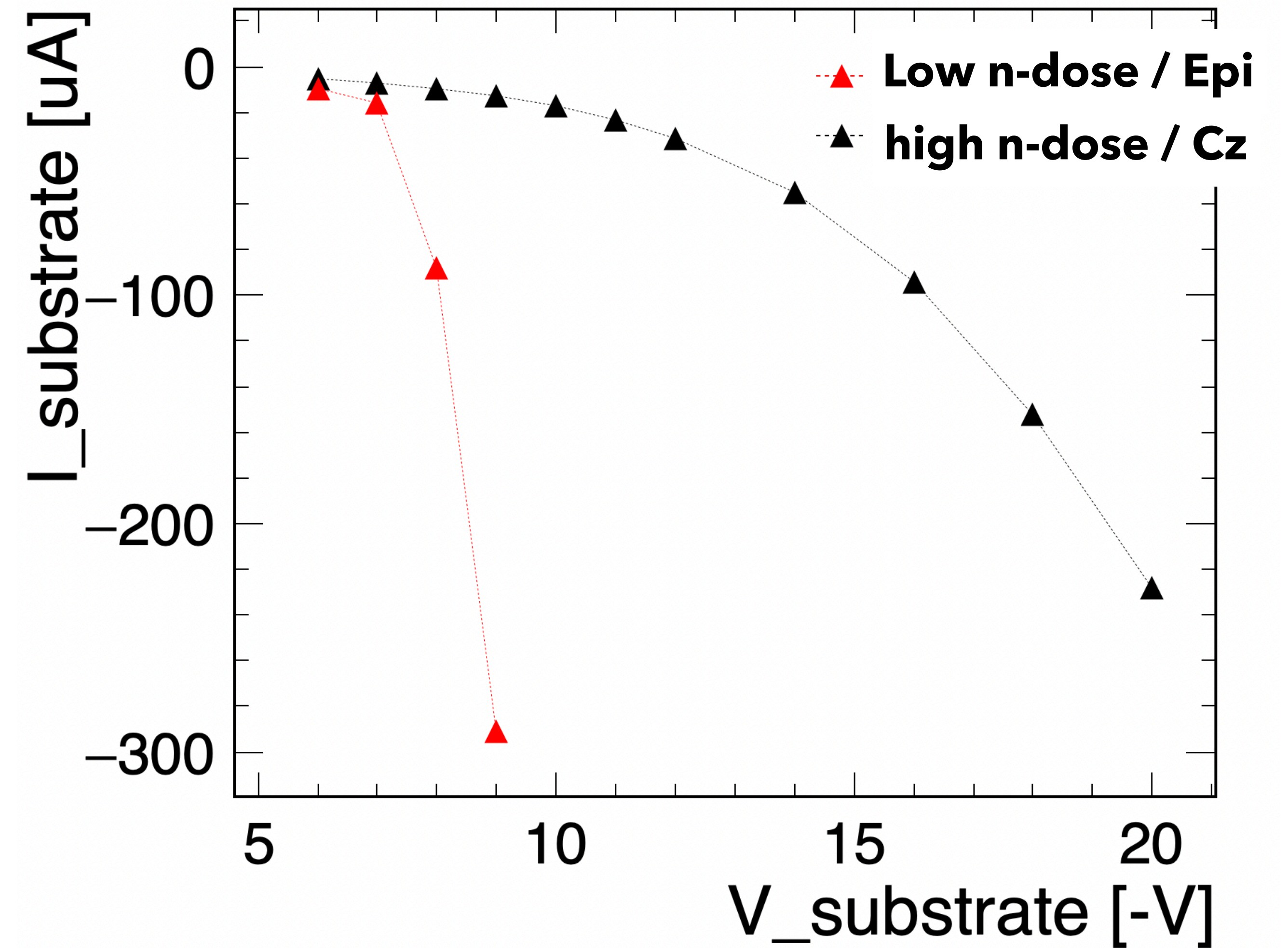
**Extra p-implant / high n-dose / Czochralski**




**Extra p-implant**

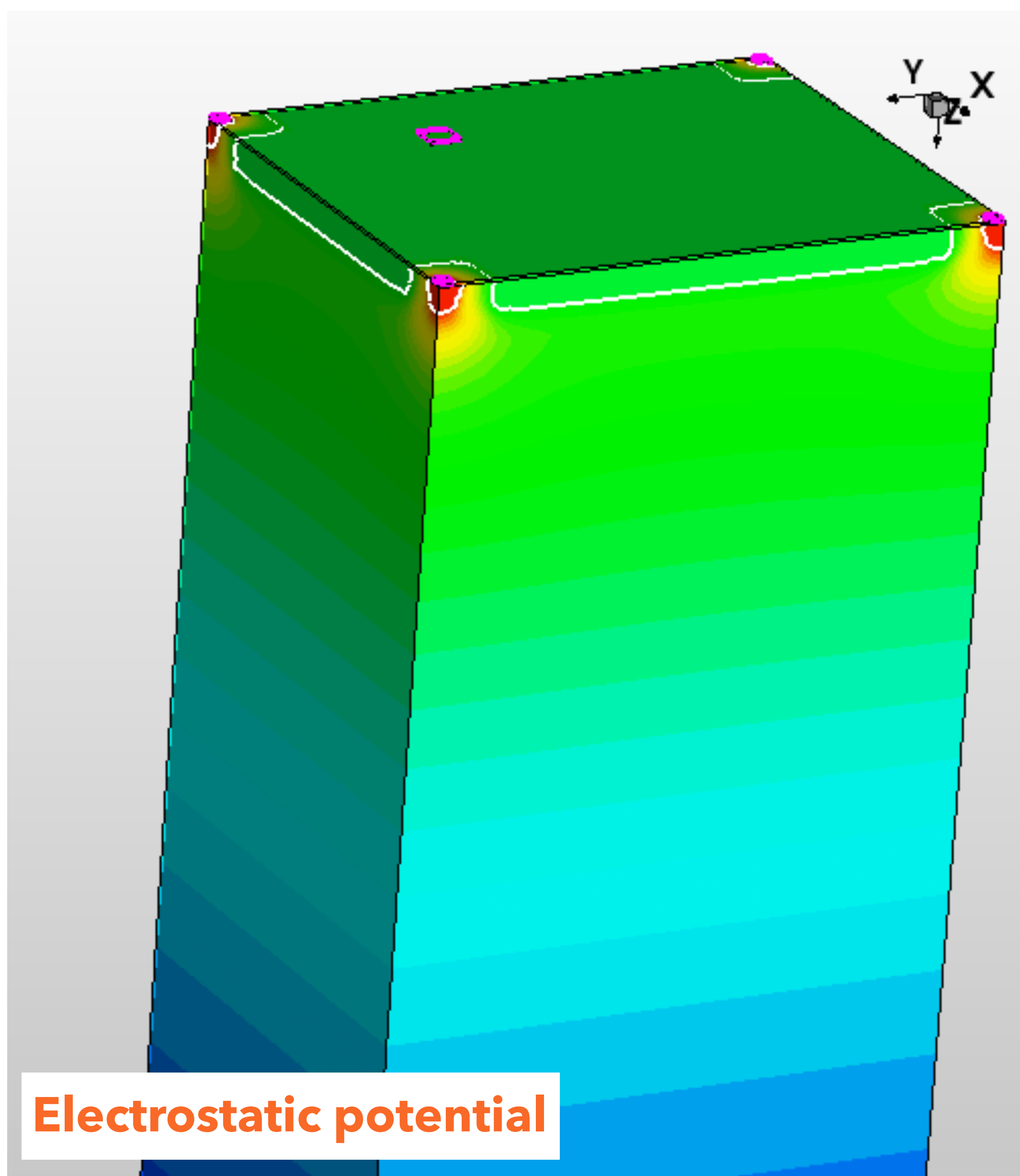


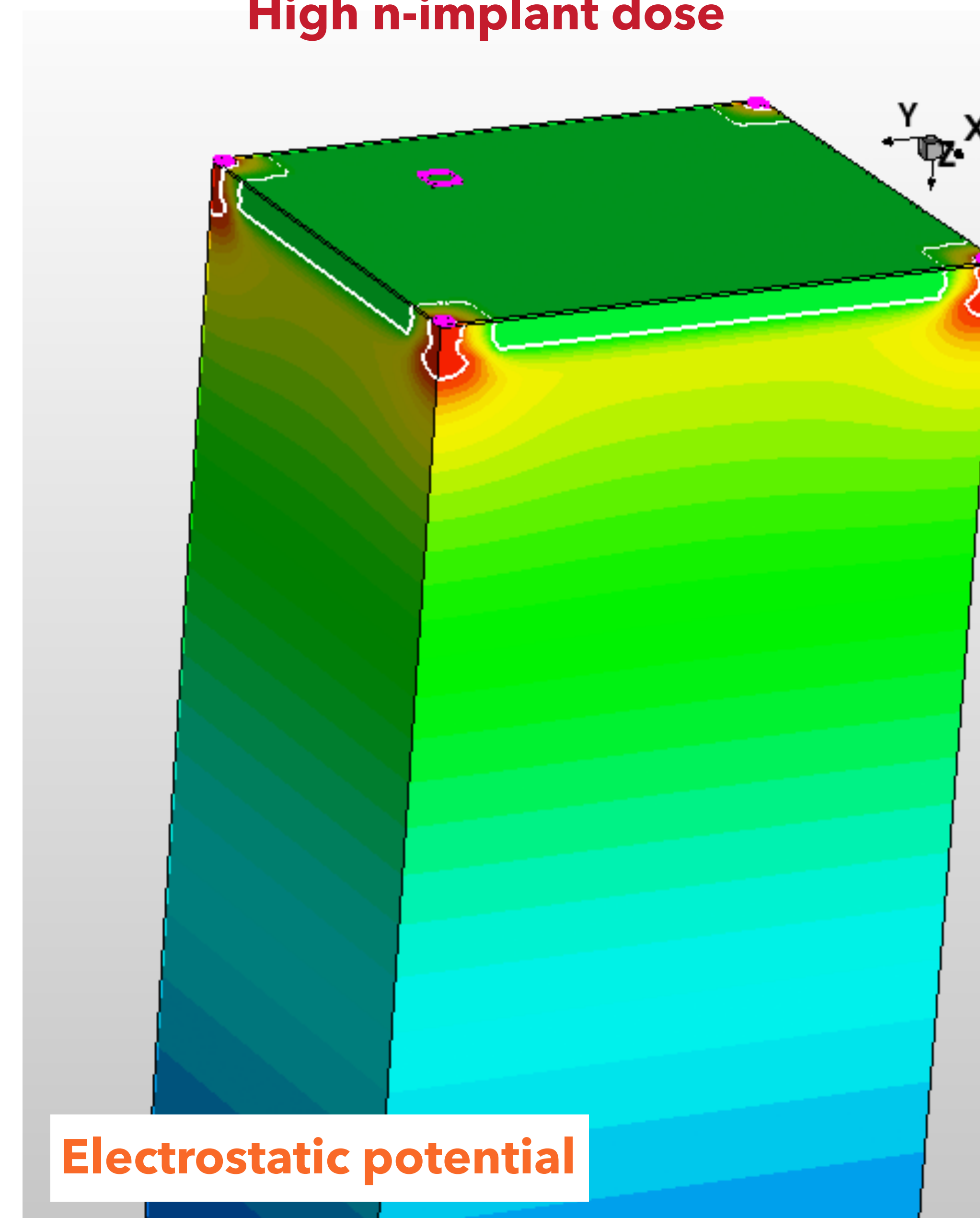

- Increase in substrate current while p-well current remains stable
- Substrate current related to substrate damages?

# Different n-implant dose



**Substrate voltage : -12 V**

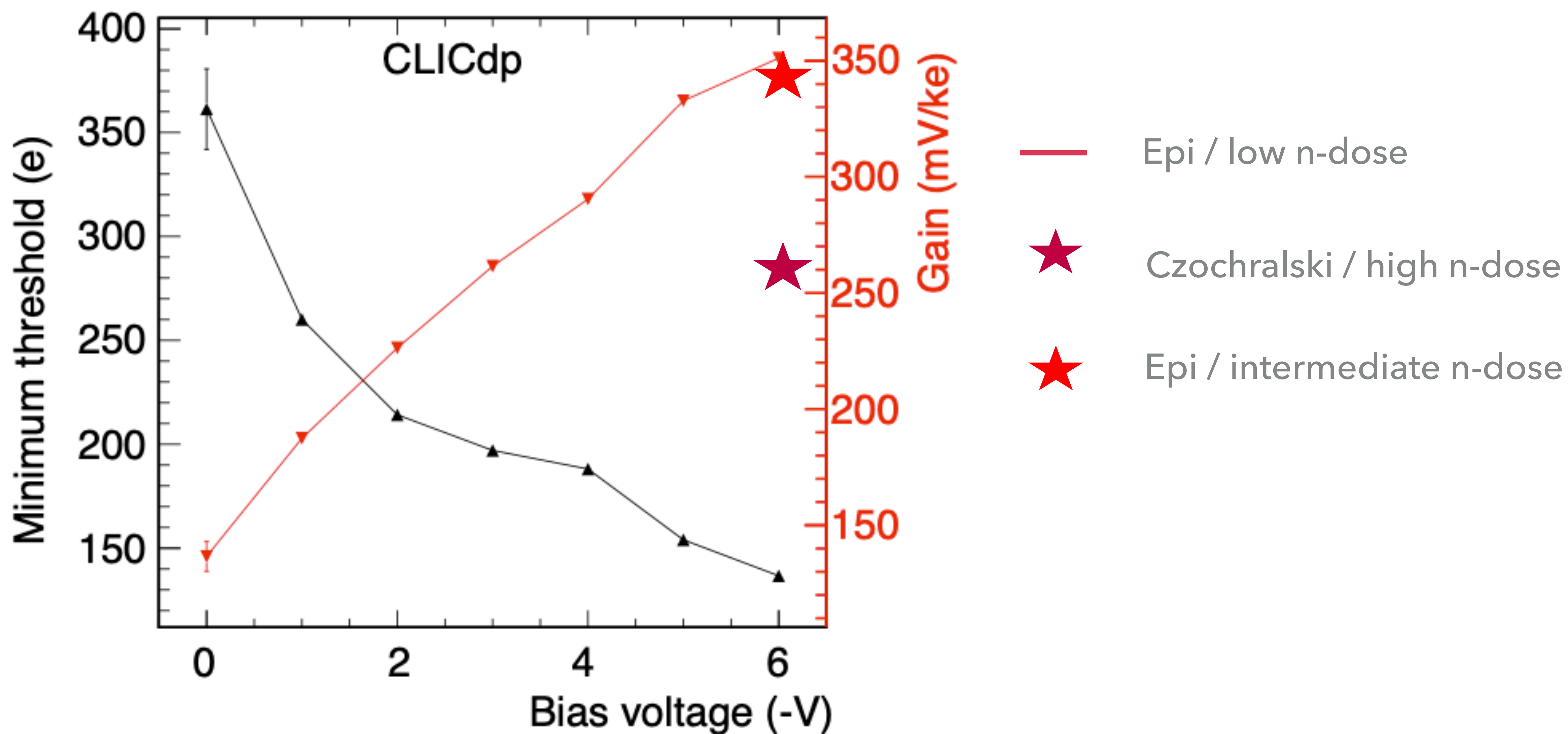



- Not fully depleted around collection diode for high n-implant dose (depletion grows into lower doped region) -> increased capacitance (~ 2.5 higher)
  - Could be compensated by smaller opening: **https://indico.cern.ch/event/921920/**

# Gain measurements






- As expected, decrease in gain for higher n-implant dose

# Summary and Outlook

- New CLICTD submission with different:
  - Pixel flavours
  - Starting materials
  - N-implant doses

➡ Large parameter space

- Effect of Czochralski substrate and higher n-implant dose observable in IV-scans and gain measurements

- Test-beam measurements at DESY in ~ 1 week
  - Possible improvements in position/time resolution and efficiency will be investigated

# Back-up

# IV Curves

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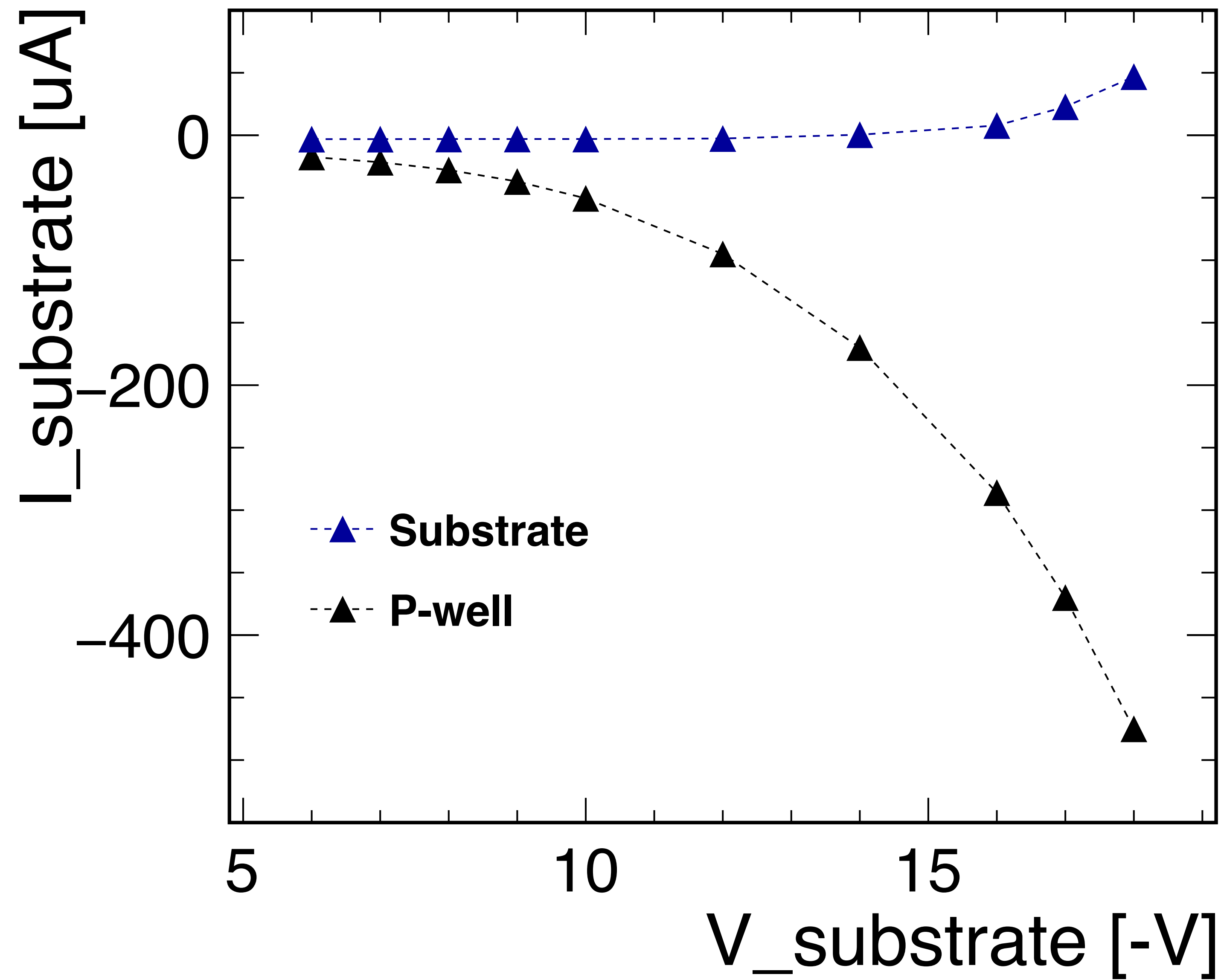
CERN EP R&D

### Continuous n-implant / low n-dose / Epi



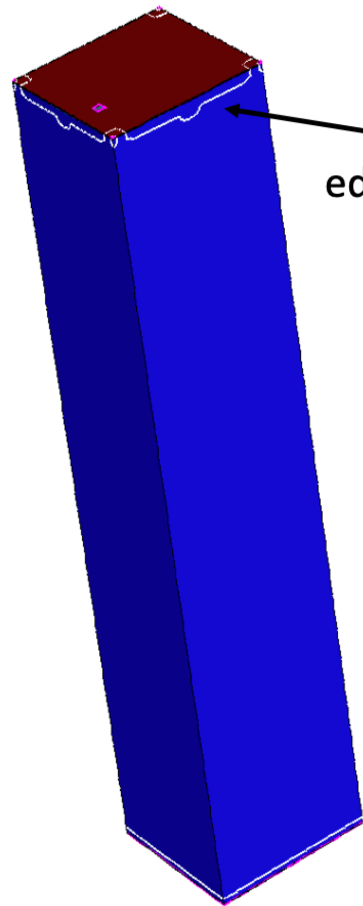
# Equalisation



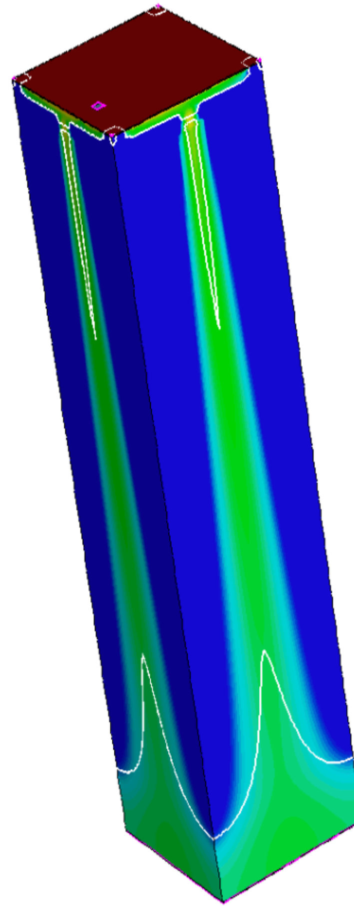
## Punch through for different Cz doping

**Hole current density at -60V** on the backside (red = high, blue = low):

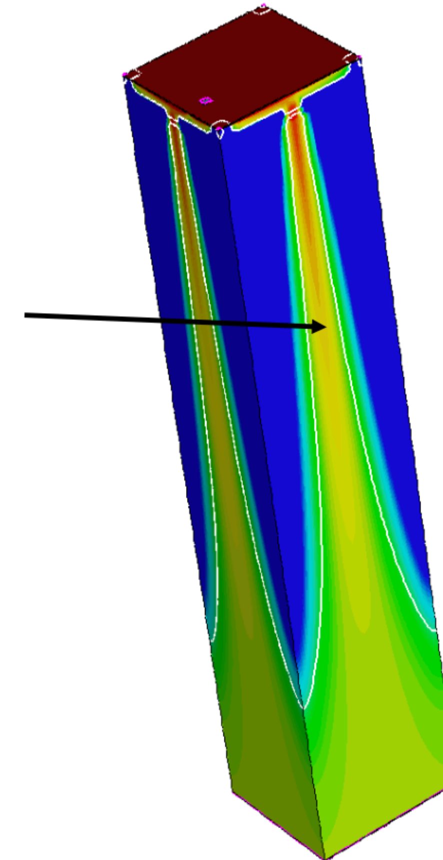
Cz doping = $2*10^{12}$ / $cm^3$:



Cz doping = $4*10^{12}$ / $cm^3$:



Cz doping = $6*10^{12}$ / $cm^3$:



White lines = edges of depleted region

Higher current at high backside voltages since depletion reaches backside (no backside implant)

Punch through hole current

→ ***Higher punch through for higher Cz doping***

# Equalisation