SIMULATION WG MEETING 28.4.2015

STATUS AT HELSINKI

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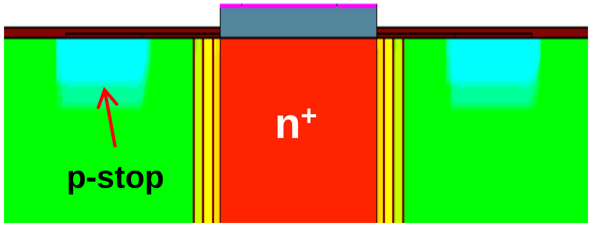
Outline

- ❑ **3D columnar detector transient & CV/IV simulations: Φ_{eq} = 1e16 cm^{-2}**
- ❑ **Phase II pixels: charge sharing at 400 V (simplified structure)**

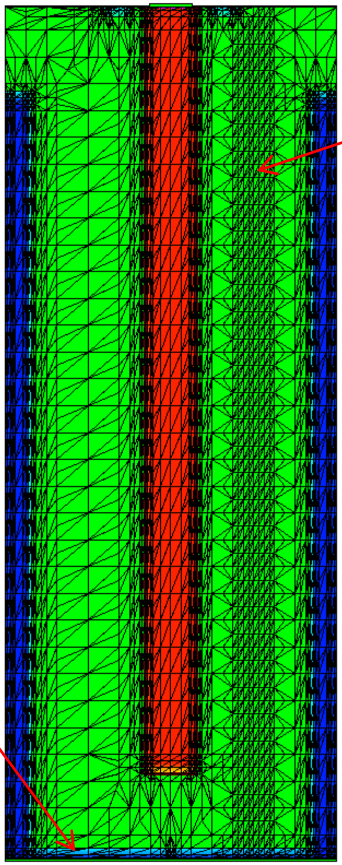
Double type column 3D-sensor simulations: structure

- **Double-side double type column 3D-sensor structure**
- 55x55x200 μm^3 structure, 250 nm oxide layer & 500 nm Al on both planes
- P-type bulk with 180 μm n^+/p^+ columns (r = 5 μm)
- All p^+ contacts connected together by the backplane Al
- p-stop depth = 1.5 μm, r_{in} = 10 μm , r_{out} = 15 μm

DC-coupled front contact (R_{bias} = 50 Ω)



Diagonal cut



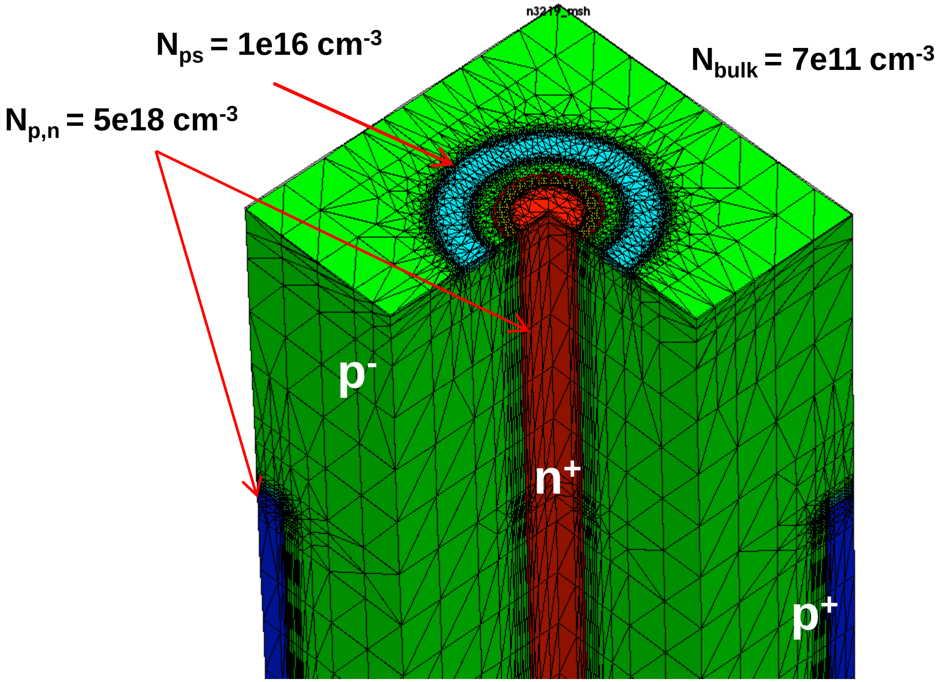
- **Reduced mesh size around MIP trajectory**

- **29 615 mesh points (> 30 k: memory allocation crash)**
- **Column doping profiles by error function**

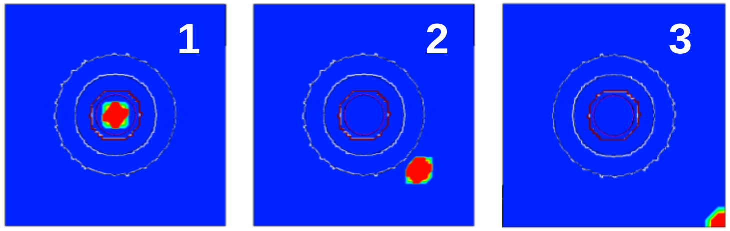
- **p^+ doping at backplane to reduce low field region**

Doping profiles

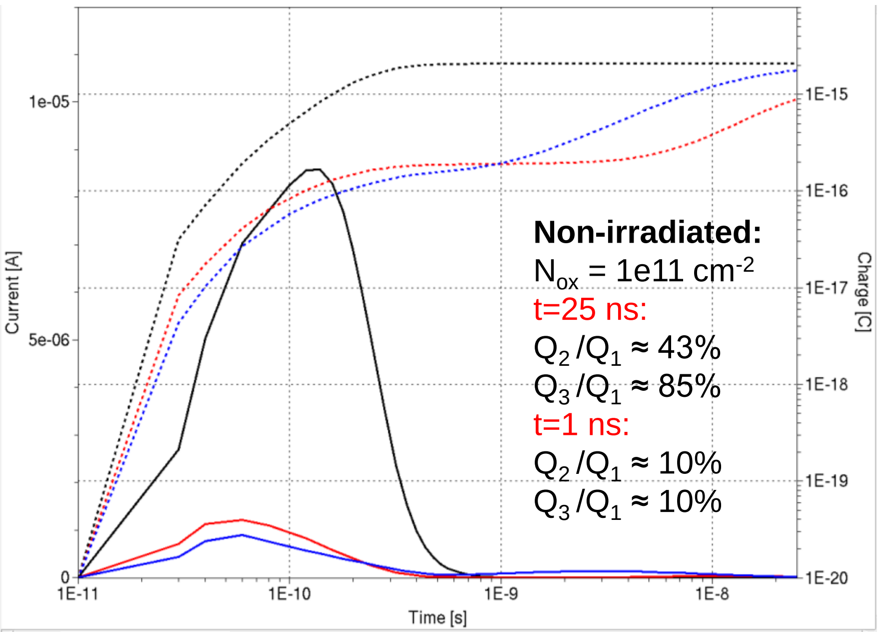
(Oxide layer transparent for clarity)

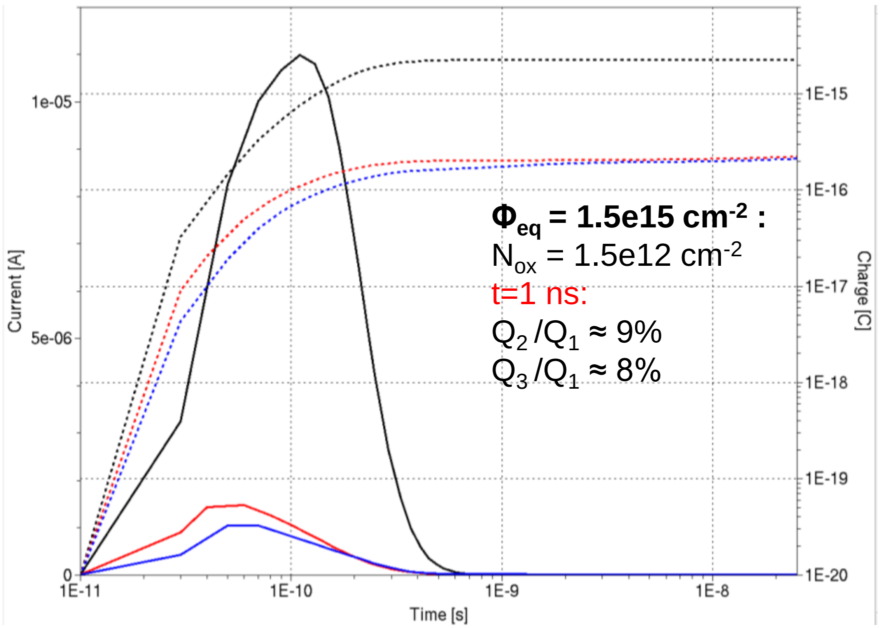


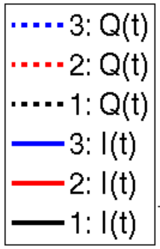
3D transient simulations: non-irradiated & protons



- ❑ **Hit position 1: n+ column (hole transient)**
- ❑ **Hit position 2: midgap (electron + hole transient)**
- ❑ **Hit position 3: p+ column (electron transient)**
- ❑ **V=-100 V, T=253 K (non-irradiated: T=293 K), MIP σ = 0.5 μm**
- ❑ **DC-coupled contacts:** $R_{front} = R_{back} = 50\ \Omega$

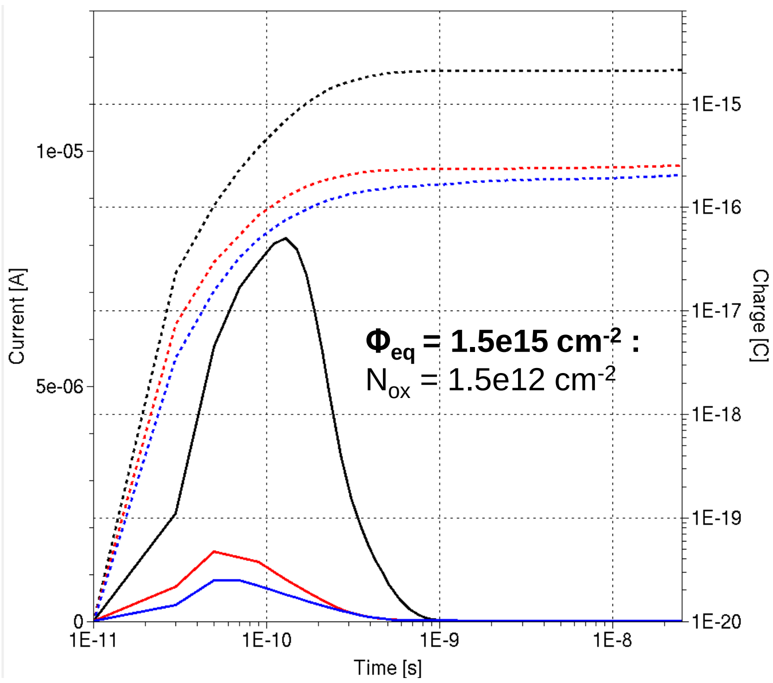


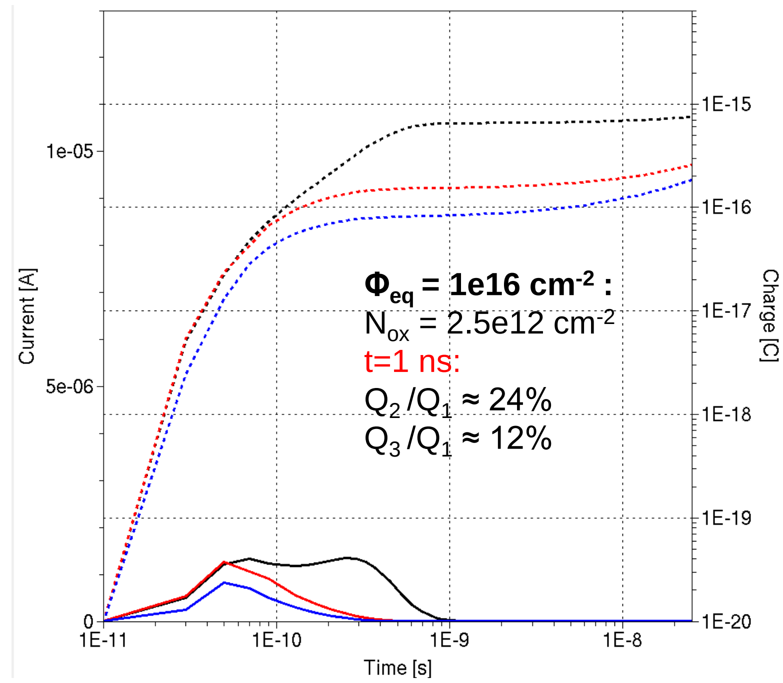


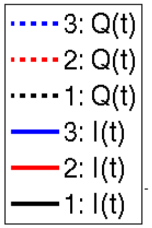


- ❑ **Defects**
  - ▪ **Bulk:** proton model
  - ▪ **Within 2 μm of surface:** proton model + shallow acceptors = non-uniform 3-level model

3D transient simulations: high Φ @ V=40 V



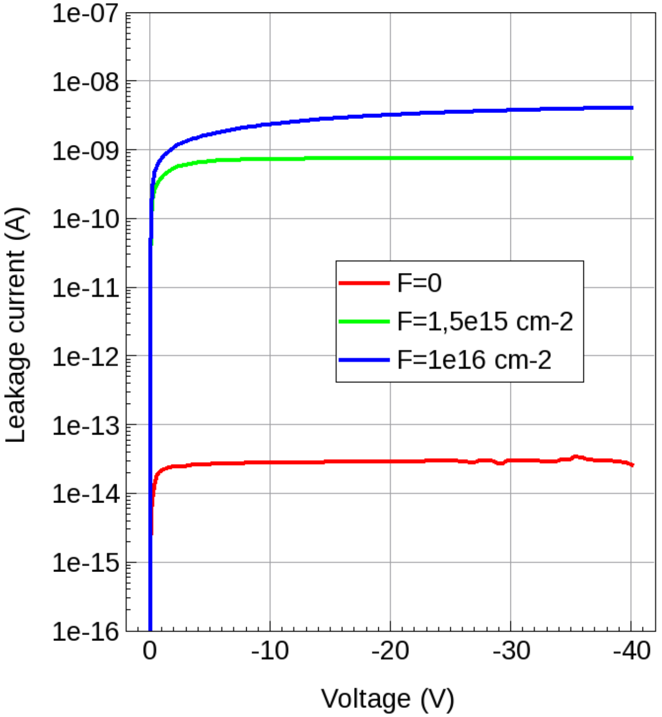


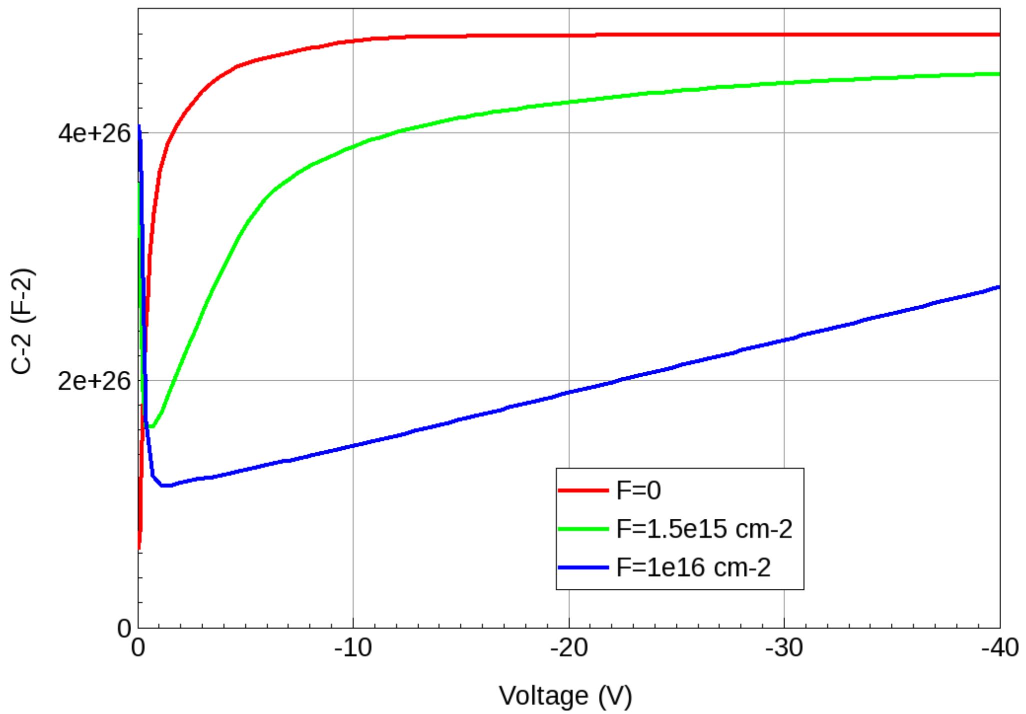


- ❑ Essentially no voltage dependence between 40 V – 100 V for Φ_{eq} = 1.5e15 cm^{-2}
- ❑ **Position 2 (midgap) most radiation hard:** ½ of max. drift distance between electrodes
- ❑ **Position 1 (n$^+$): Pros:** high E region, **Cons:** transient from holes
- ❑ **Position 3 (p$^+$): Pros: :** transient from electrons, **Cons:** low E region

Hit position	Fluence [cm^{-2}]	CCE @ 1 ns [%]
1	1.5e15	100
2	1.5e15	100
3	1.5e15	90
1	1e16	34
2	1e16	85
3	1e16	42

3D CV/IV simulations: high Φ @ V=40 V



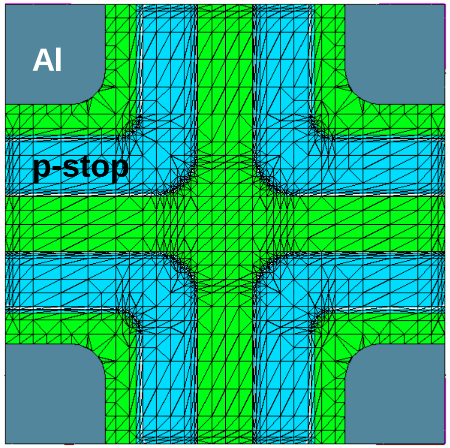


α (253K)= $8.9 \cdot 10^{-19}$ $A \cdot cm^{-1}$
I = V·α·Φ
→ I(1.5e15) ≈ 0.8 nA
I(1e16) ≈ 5.4 nA

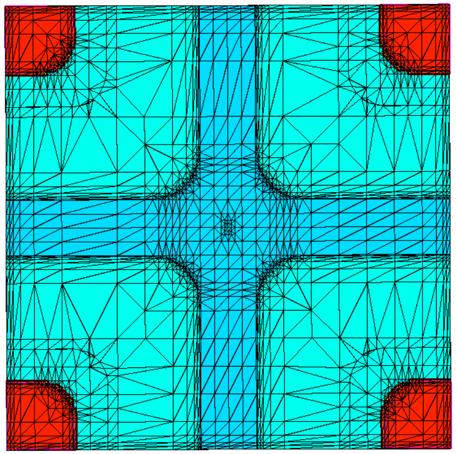
- ❑ Irradiated LC agrees with experimental also @ Φ_{eq} = 1e16 cm^{-2}
- ❑ **Φ_{eq} = 1e16 cm^{-2}:** Sensor not fully depleted @ V=40 V

Phase II pixel: Corner region structure

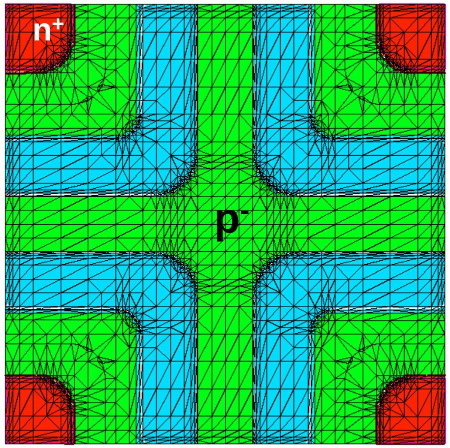
Normal: P-stop with Al



Normal: P-spray & implants



Normal: P-stop & implants



$N_n = 1e19\ cm^{-3}$

Normal (N): 23/4 = 5.75
Wide (W): 30/4 = 7.5

N: 6.0
W: 5.0

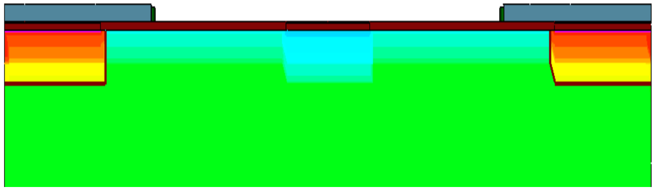
N: 5.0
W: 3.0

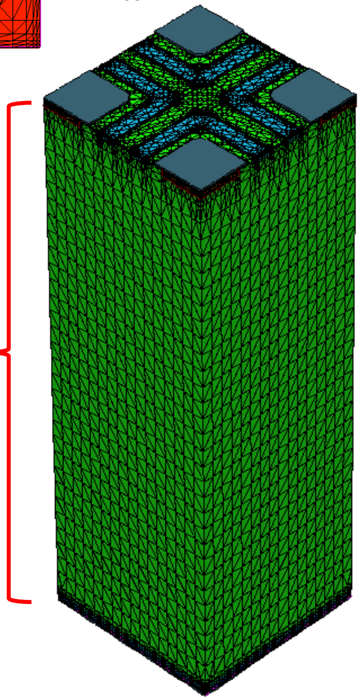
N: 5.0
W: 4.0

$N_{bulk} = 1.68e12\ cm^{-3}$

$N_{pstop} = 5e16\ cm^{-3}$

- ❑ **Corrected moderate p-spray:**
- ▪ **Center: peak=1e17 cm^{-3}, d=1.5µm**
- ▪ **Elsewhere: peak=1e15 cm^{-3}, d=1µm**





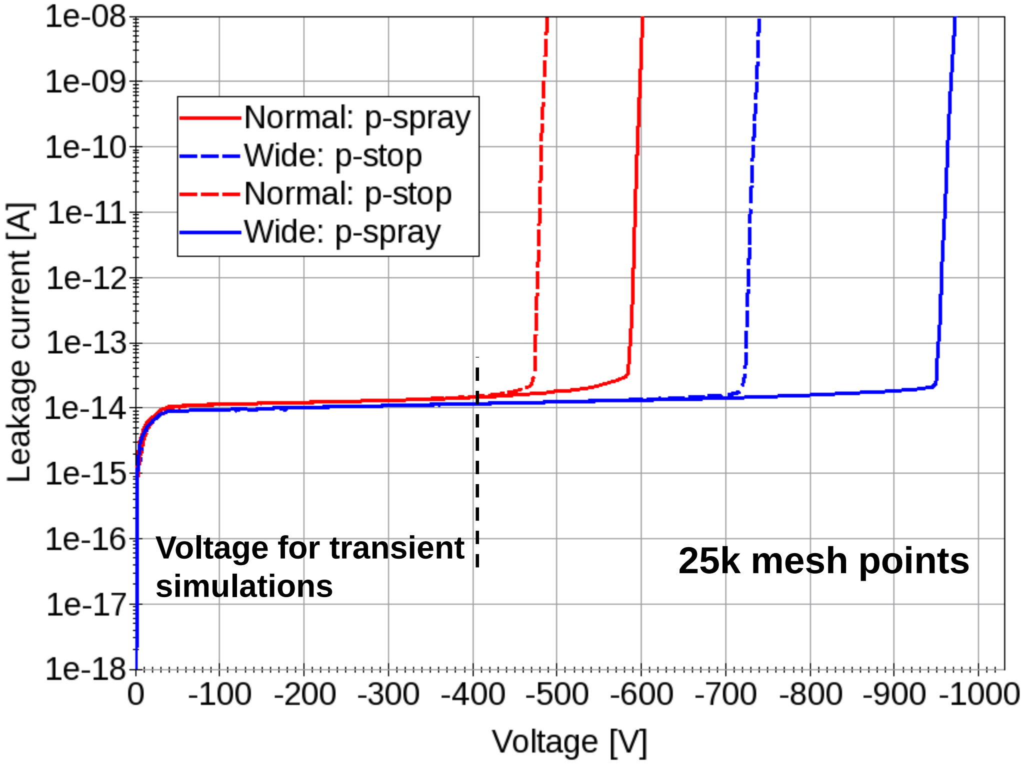
150 µm

- ❑ Normal & wide designs, MO = 3 µm
- ❑ Minimized complexity: ‘ideal’ DC-coupling (no vias/punch throughs)
- ❑ Mesh points: from ~30k to ~106k
- ❑ ¼ of implant included for corner region simulations to maximize mesh density

Normal vs wide: V_{bd} for p-bulk tuned lifetimes

- **Corrected moderated p-spray design (single high concentration region)**
- **Q_f = 1e11 cm^{-2}**

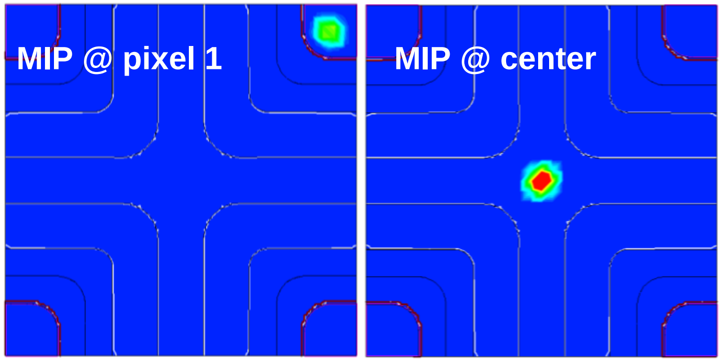
- **Tuned e & h lifetimes for p-bulk:**
  τ_e = 1e-2 s, τ_h = 1e-2 s

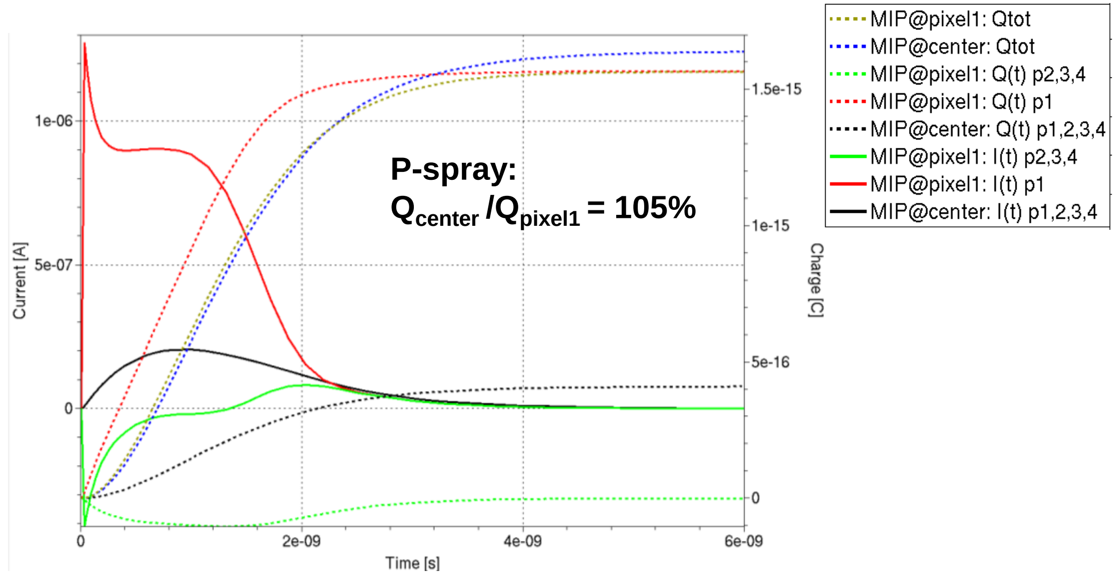


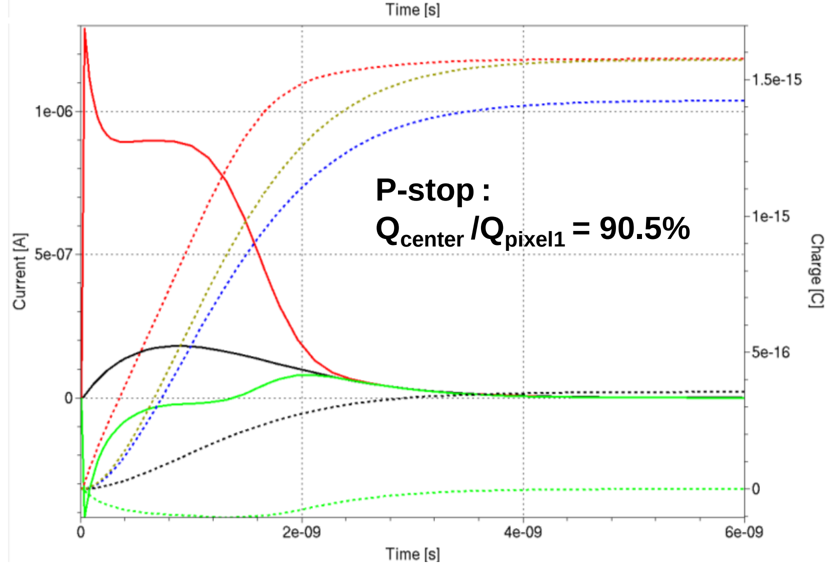
- **Normal:** V_{bd}(p-spray) ≈ 590 V, V_{bd}(p-stop) ≈ 470 V
- **Wide:** V_{bd}(p-spray) ≈ 950 V, V_{bd}(p-stop) ≈ 720 V

→ **superior V_{bd} for wide design with p-spray**

Transient simulations: charge sharing of 'Normal' design







- **MIP injection at pixel 1 & center**
- **Non-irradiated, V = -400 V, Q_f = 1e11 cm^{-2}, T = 293 K**

- **MIP @ pixel 1:**
  - Charge sharing = 0
- **MIP @ center:**
  - **P-spray:** higher cluster charge than for MIP @ pixel 1!
  - Charge loss >10% higher for p-stop with N_{ps} = 5e16 cm^{-3}, d=1.5 µm

Transient simulations: charge sharing of 'Wide' design

- **MIP injection at pixel 1 & center**
- **Non-irradiated, V = -400 V, Q_f = 1e11 cm^{-2}, T = 293 K**

- **MIP @ pixel 1:**
  - Equal collected charges between isolation methods
  - Charge sharing = 0
- **MIP @ center:**
  - Charge loss 4% higher for p-stop with N_{ps} = 5e16 cm^{-3}, d=1.5 µm

CONCLUSIONS:

- **Normal with p-stop:** Lowest V_{bd}, highest charge loss @ center injection
- **Wide with p-spray:** Highest V_{bd}, 1.3% charge loss @ center injection