



# Simulation of Gain Optimized Sensors



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# Intro: 4D Detection



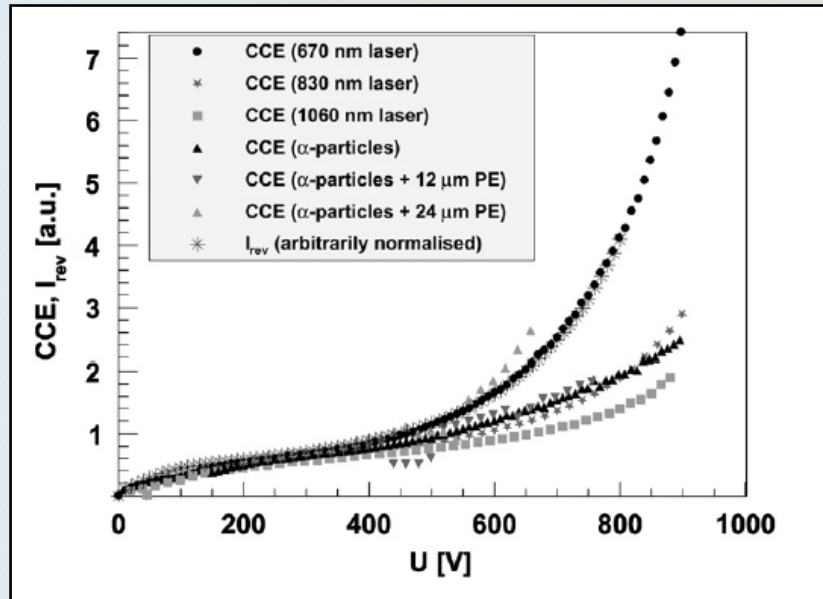
- What is 4D detection?
  - Fast timing and precise spatial resolution (10's of ps /  $\mu\text{m}$ ) (Hartmut F.-W. Sadrozinski: UFSD 20<sup>th</sup> RD50 workshop Bari 2012)
- Necessarily thin ( $<100\mu\text{m}$ )
  - MIP ionizes less mobile charge.
  - How to increase signal? Charge Multiplication!



# Charge Multiplication

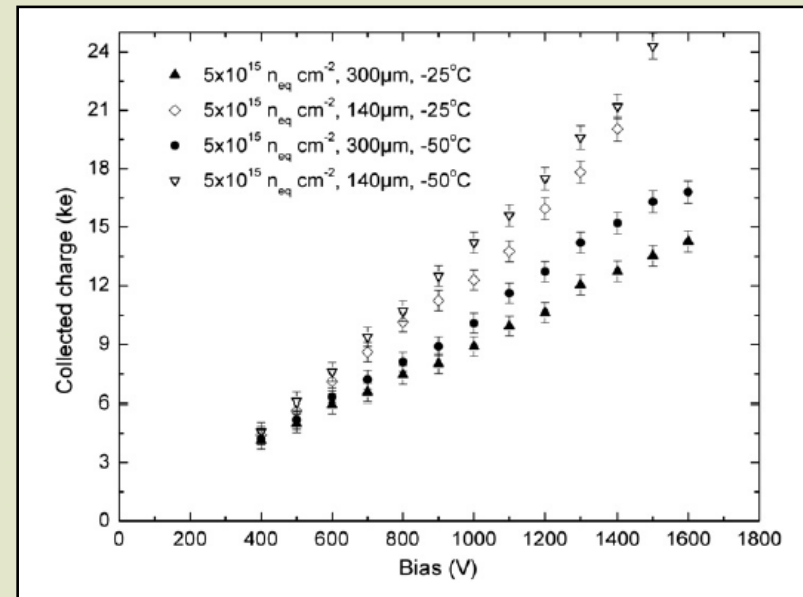


J. Lange et al, NIMA622 (2010) 49-58

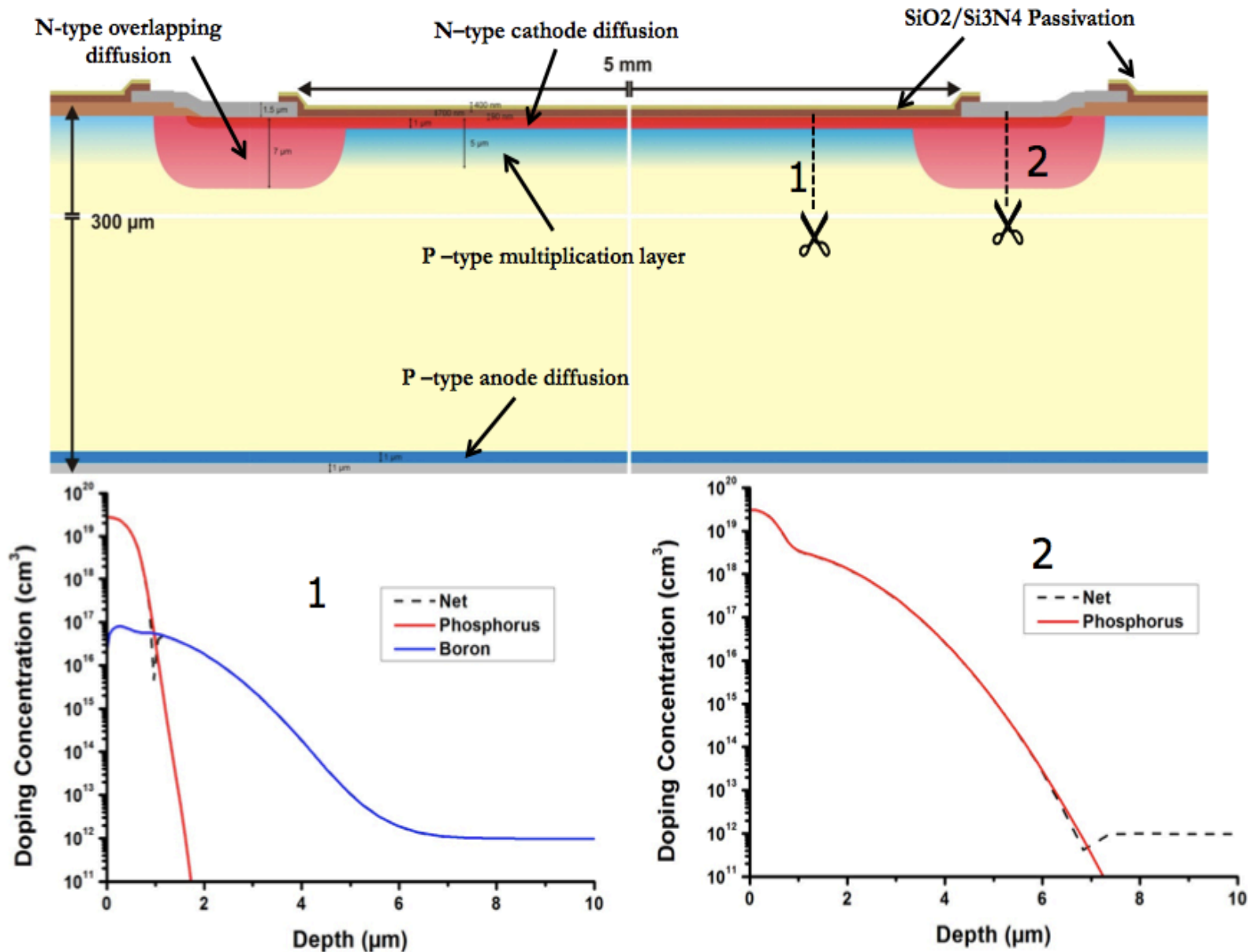


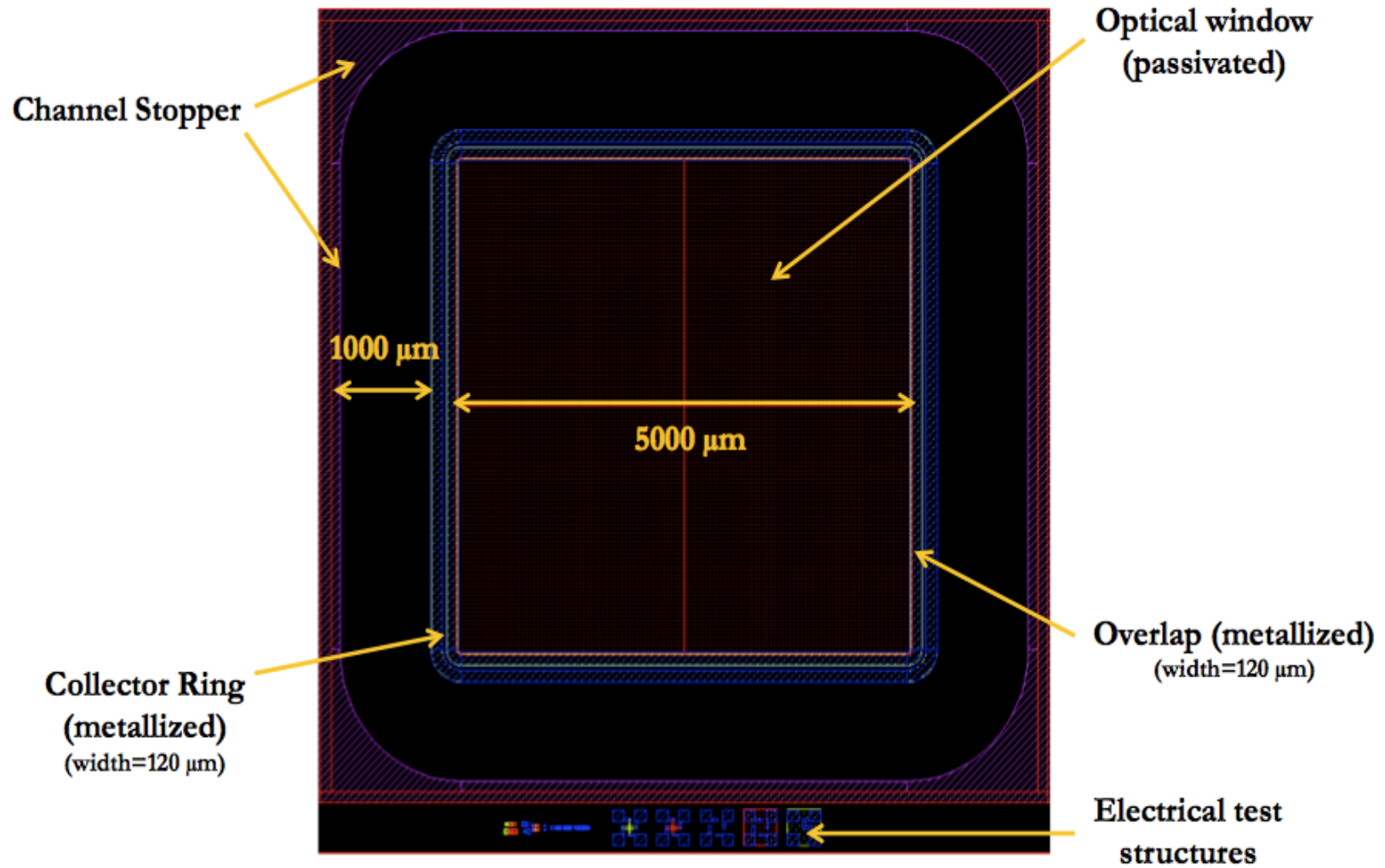
- Observed in irradiated detectors in 2010!
- Recently observed in non-irradiated pad sensors
  - Baselga / Pellegrini
  - Kramberger
  - Sadrozinski / Ely

G. Casse et al, NIM A 624, 2, (2010) 401–404



- How does it work?
  - Bulk defects affect resistivity / space charge
  - Electric field is amplified as a result
- Can we control doping profile to tune field without irradiation?



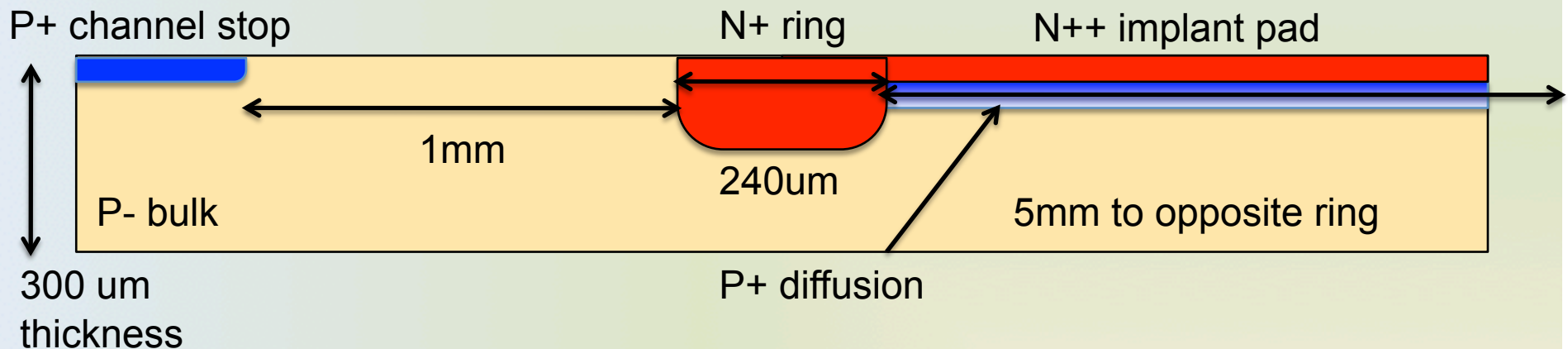




# Device Model



- Device simulation using Synopsis TCAD
- Symmetry simplifies the real device into a 2D model
- From this we analyze 3 distinct regions



1) Edge Region

near P channel stop  
at each end

2) Ring Region

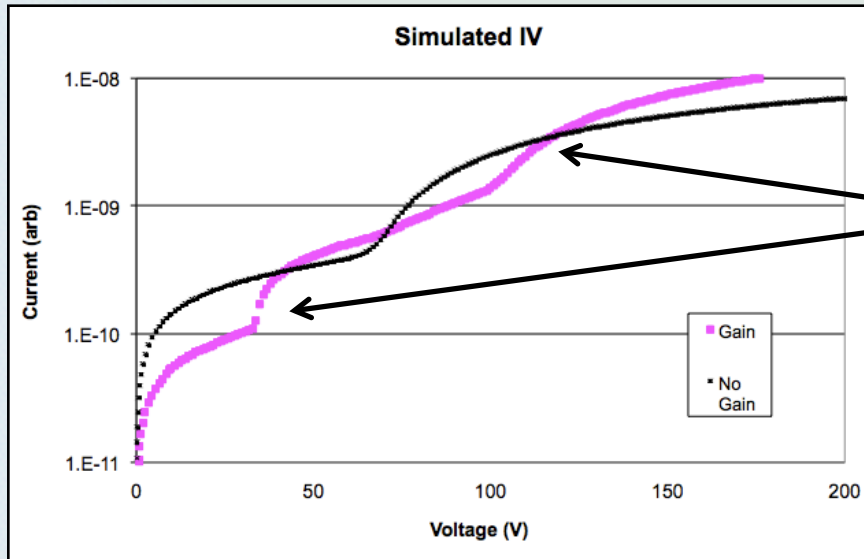
N+ ring surrounds  
implant pad and P+  
diffusion

3) Central Region

High field region  
under implant pad



# IV Results



← Simulation Results

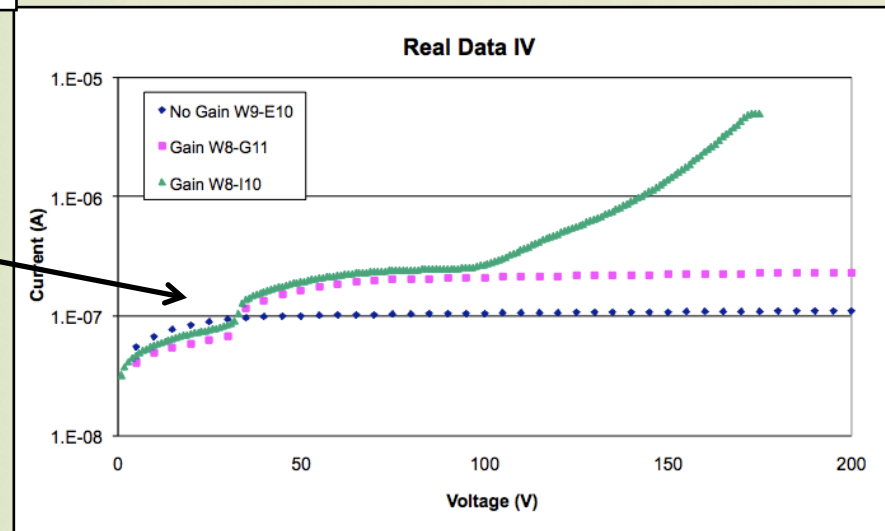
- Gain diode curve shows strange shape, can the "humps" be explained?

- No Gain Diode also shows similar feature

Real Diode Data →

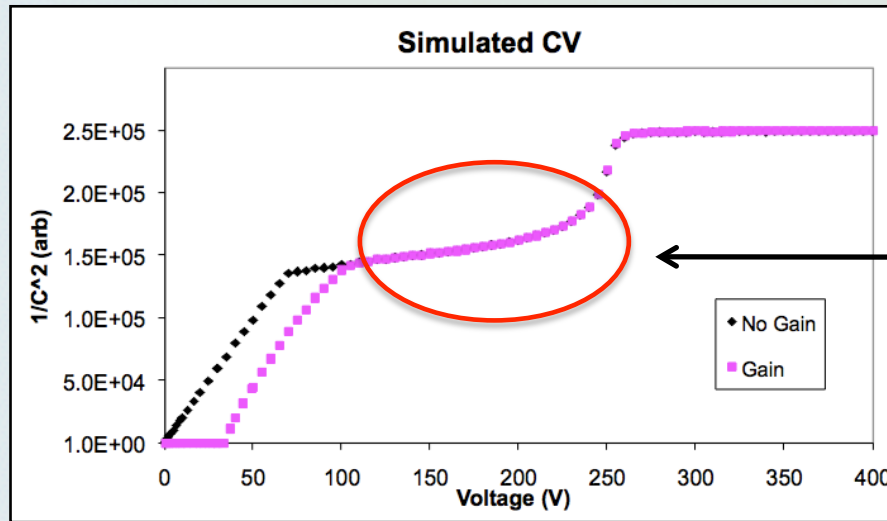
- Gain Diode curve shows humps, though not as many

- No Gain Diode shows no such feature





# CV Results

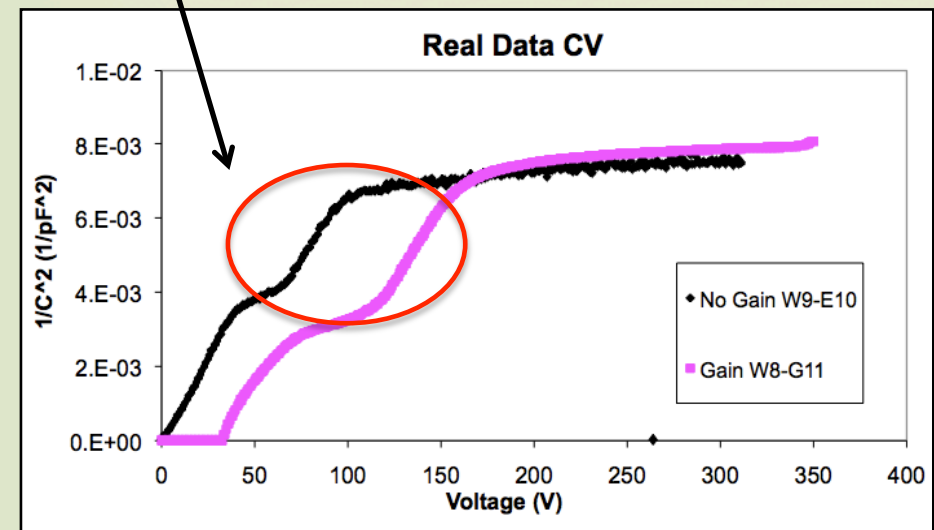


← Simulation Results

- Agreement low / high voltage range, not in mid
- Could sensor depletion offer some insight?

Real Diode Data →

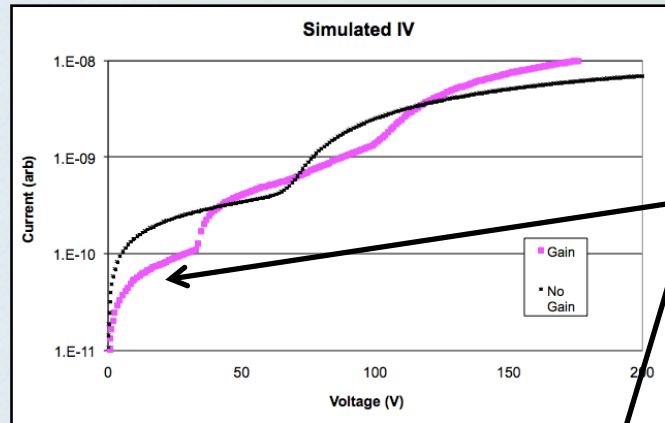
- No Gain Diode has no P+ diffusion yet CV shows kink?



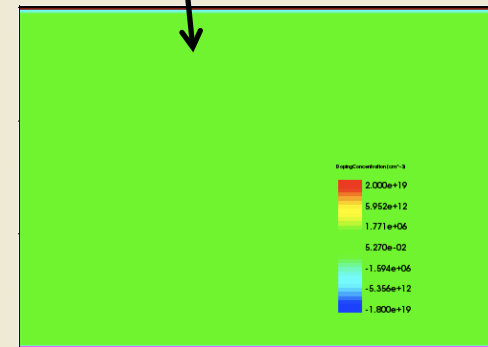
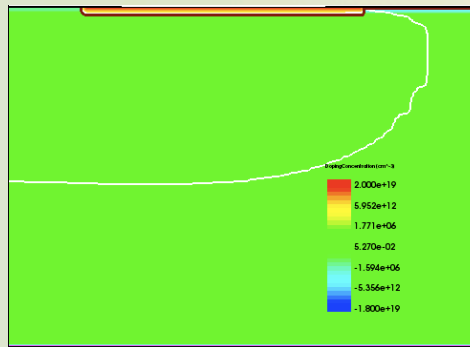
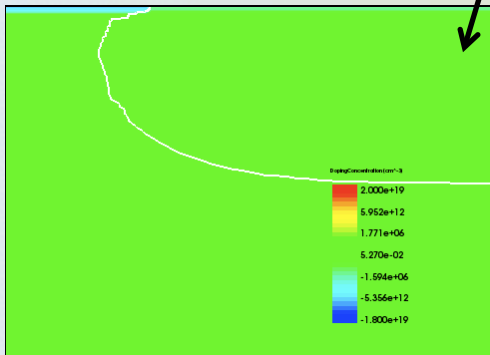
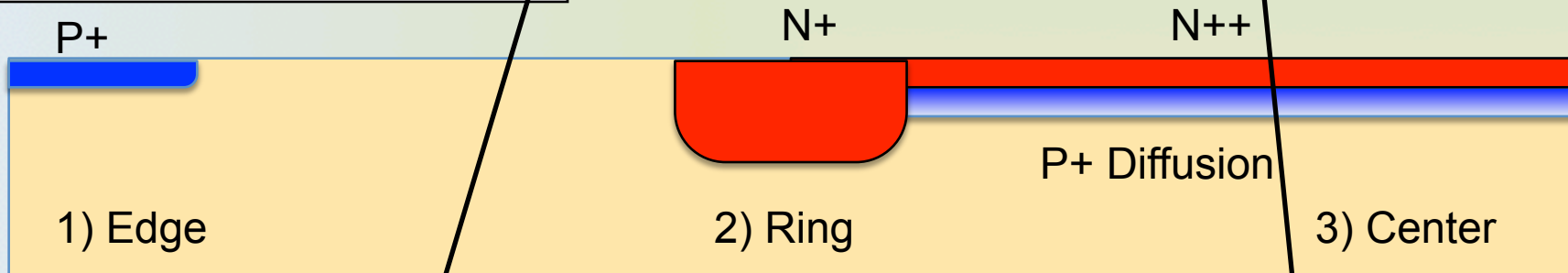




# 20V Depletion Region Profile

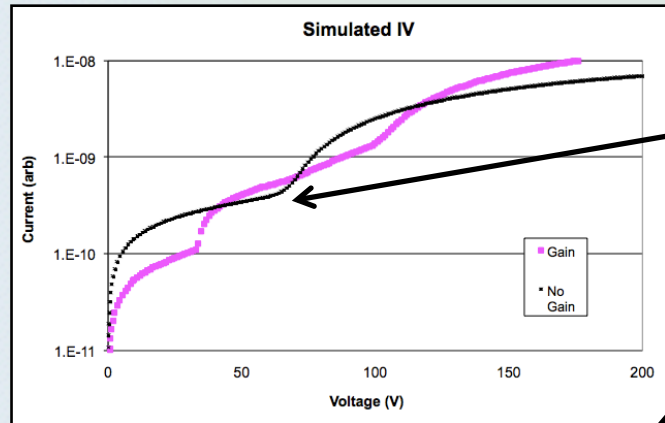


- 2D Device region maps shown below
- Sides of sensor depleting → first plateau
- Central region does not collect



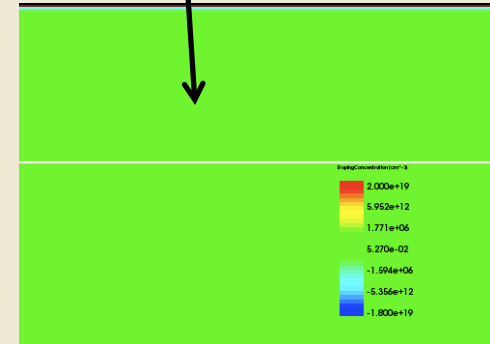
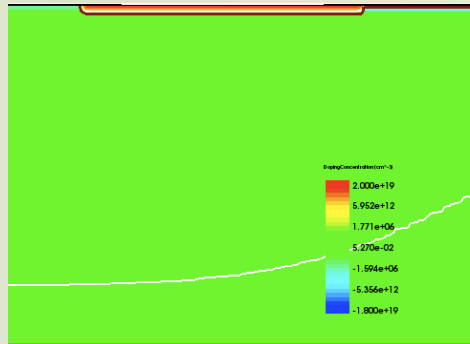
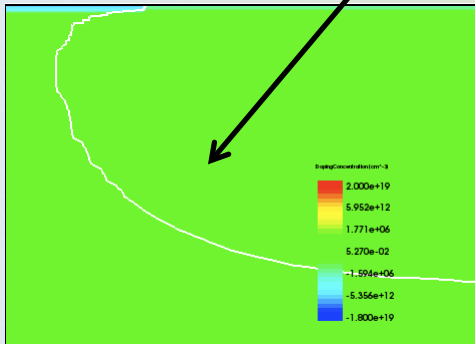
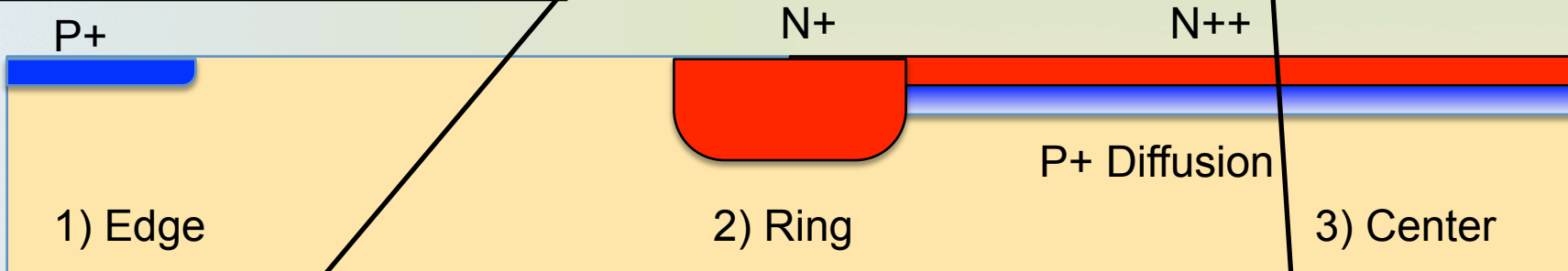


# 50V Depletion Region Profile



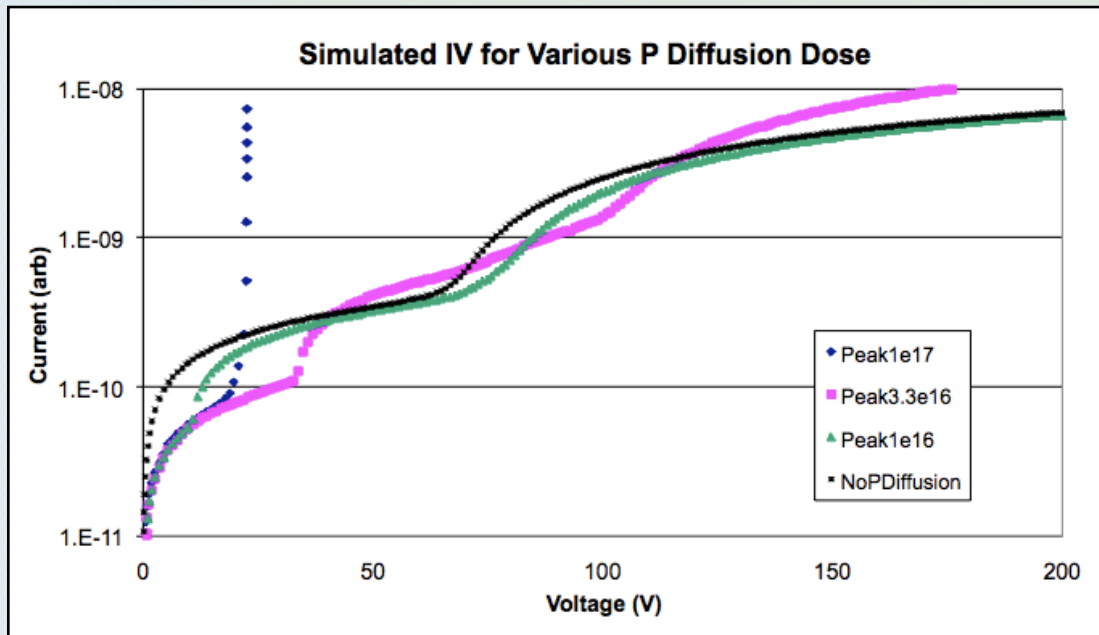
- Central region begins depleting after first hump

- Edges not yet fully depleted





# Varying P+ Diffusion Dose

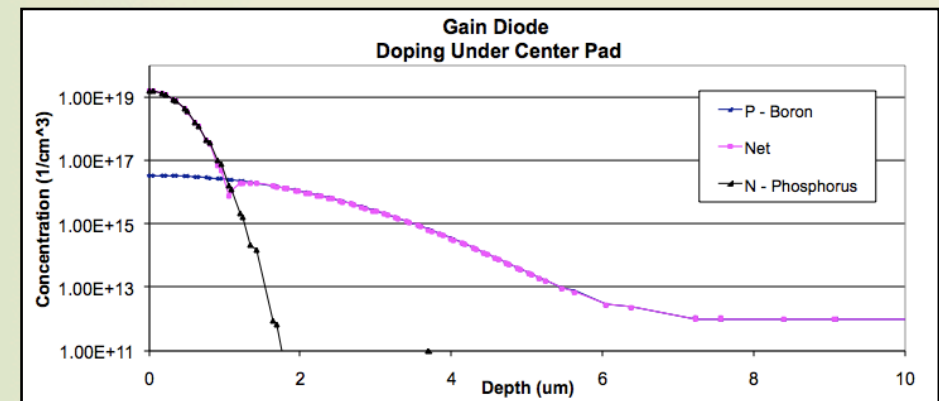


-P+ Diffusion profile peak (value @ 0um) is altered

- Choose the peak value that most closely resembles real data (3.3e16)

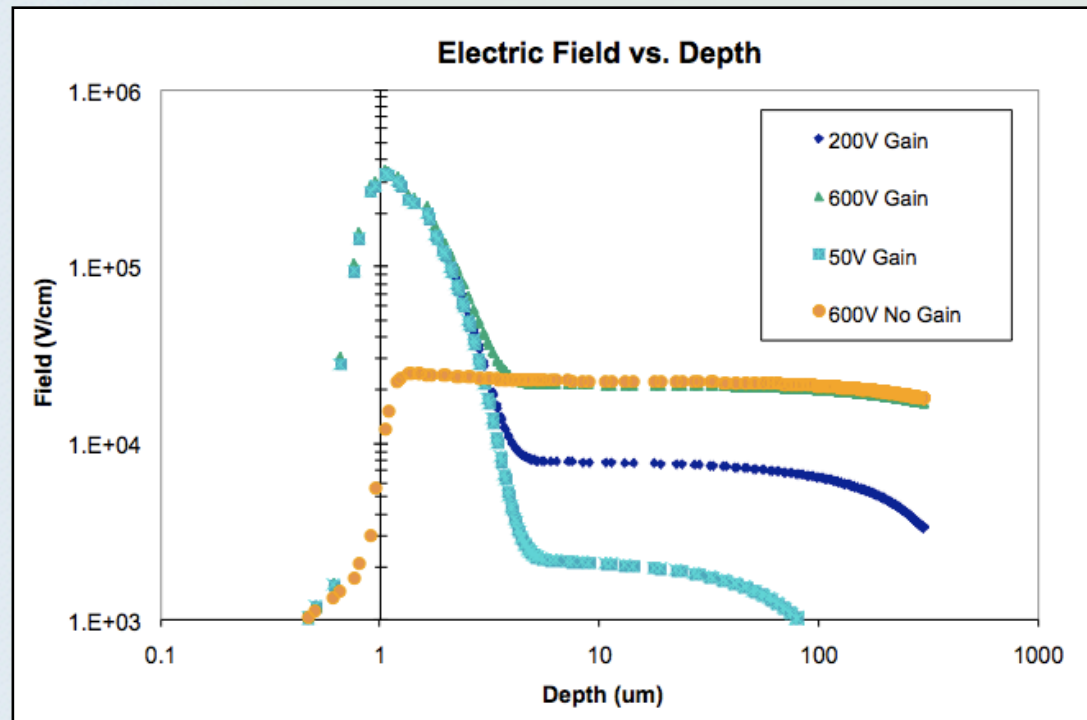
- Can't go too high or else avalanche!

- Humps and plateaus vary with P+ Diffusion Dose





# Electric Field

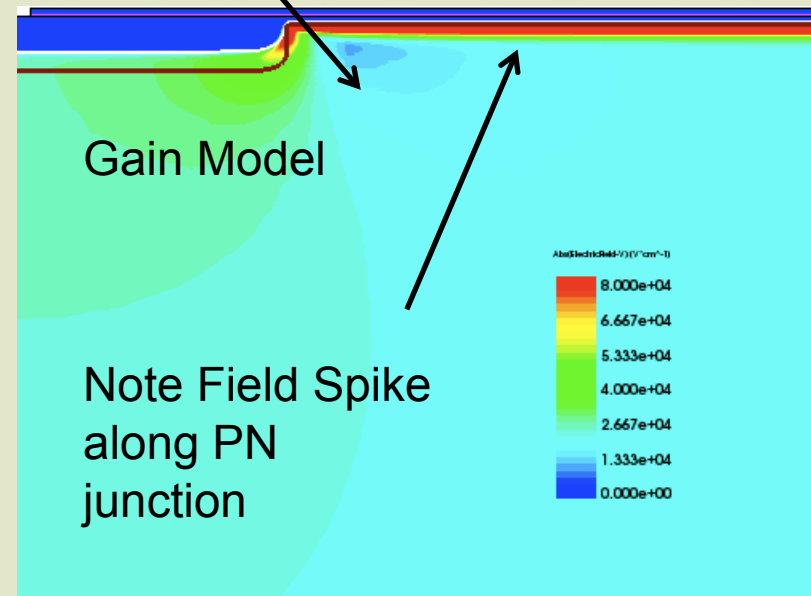
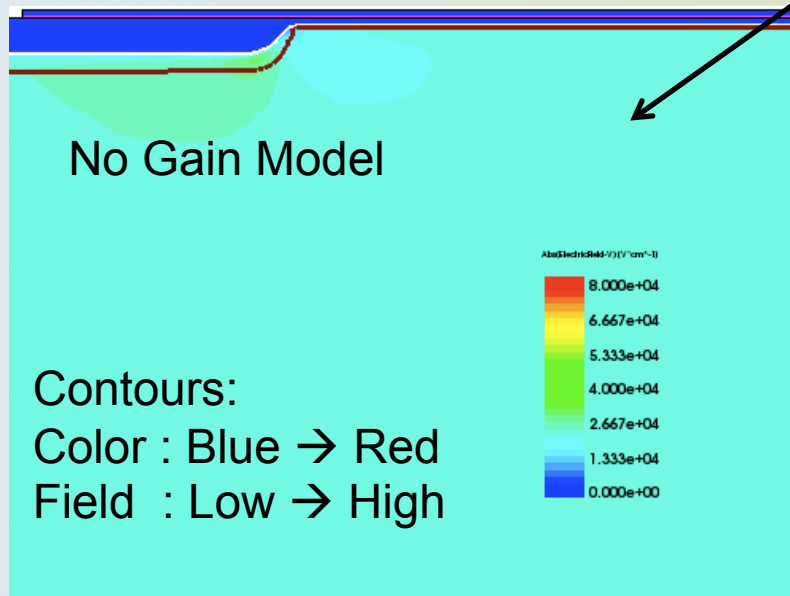
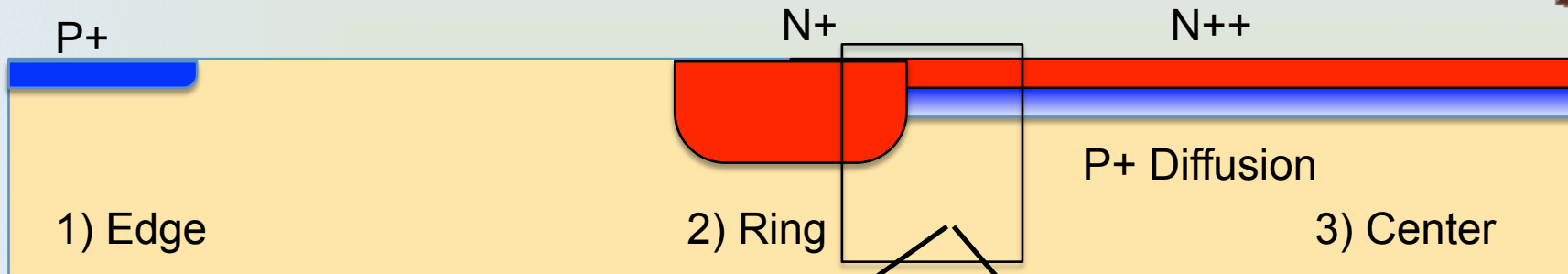


- Slice under central implant pad
- Field peaks sharply at PN junction
- Peak is relatively constant vs. bias voltage

- Deeper into detector field varies strongly with bias
- At large bias, carrier terminal velocity ( $\sim 20\text{kV/cm}$ ) is theoretically still possible in gain diodes



# 2D Electric Field Maps





# Future Studies



- Simulate incident radiation / dynamic signals
- Understand IV humps, fit better match to real data
- Optimize P-diffusion profile / dose for high field