Activities of US Chapter of CERN RD50 On the Development of Semi-3D Si Detectors

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On behalf of US RD50 members: BNL, FNAL, Purdue, Rutgers, and Syracuse and observers: CMU, JHU, OSU and UCSC

2nd RD50 - Workshop on radiation hard semiconductor devices for very high luminosity colliders, CERN, 18-20 May, 2003

Active Participation of US Institutes in RD50

Institutes	BNL	FNAL		Purdue	Rutgers	Syracuse
Team participation	DE NS	NS FDS		NS FDS	NM FDS	FDS NS
Capabilities	Simulation, design, processing and testing	Design and testing		Simulation, design and testing	Testing	Simulation, and testing

Observers: CMU, JHU, OSU, and UCSC

- Close proximity
- Largely overlapping activities
- Possibility of obtaining US funding

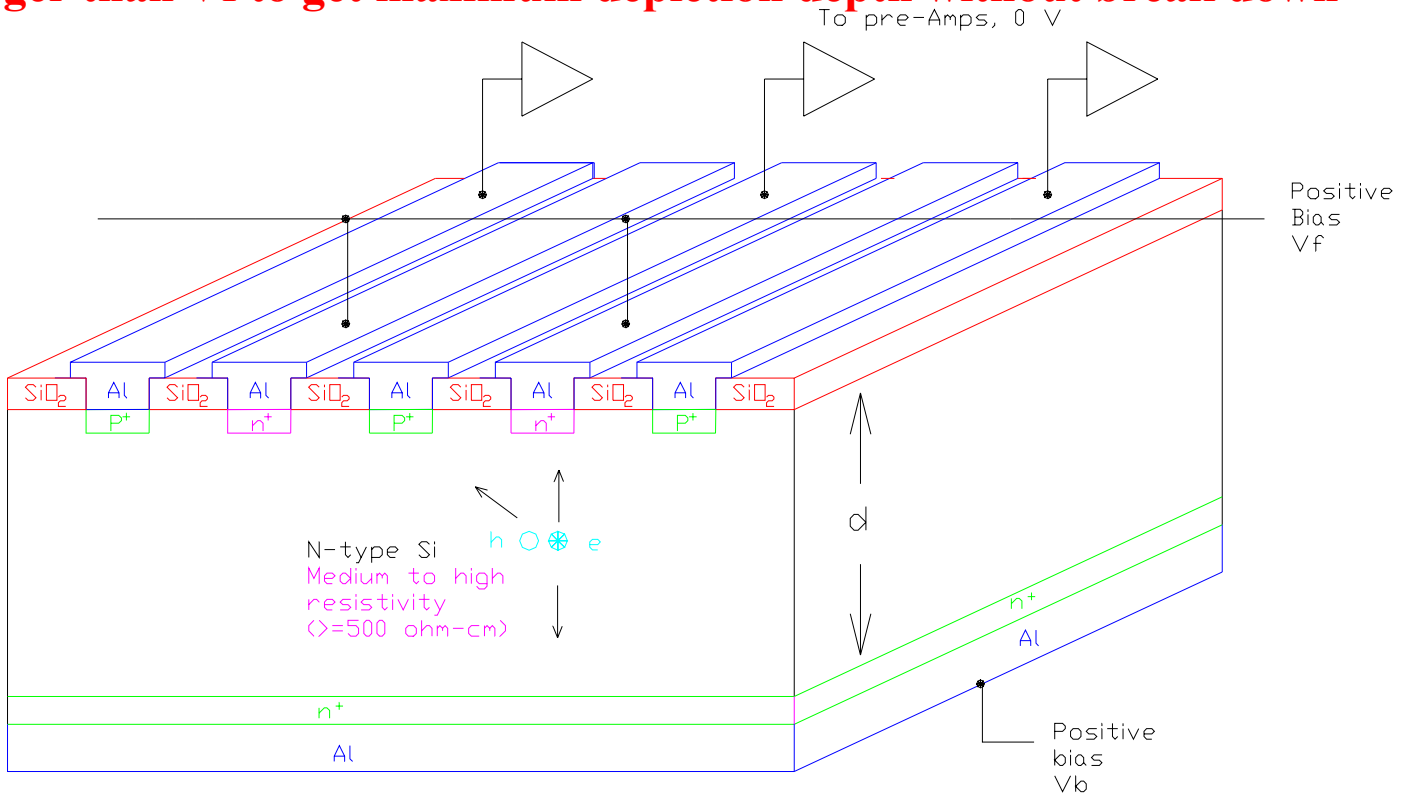
US institutes will closely collaborate (with monthly phone conference) and coordinate their work in:

- NS (semi –3D)
- FDS

Development of Medium and High resistivity n-type SSD and SPD: more radiation tolerance

- **Low bias at the beginning**
- **p^+- n^+ /n/n^+ configuration:**
  - **Depletion from one side before SCSI**
  - **Depletion from both sides after SCSI**
- **May work up to 1x10^{15} n/cm^2 rad.**
- **One sided processing**
- **Bias Vb may be larger than Vf to get maximum depletion depth without break down**

p^+- n^+ /n/n^+ configurati
(Medium resistivity)



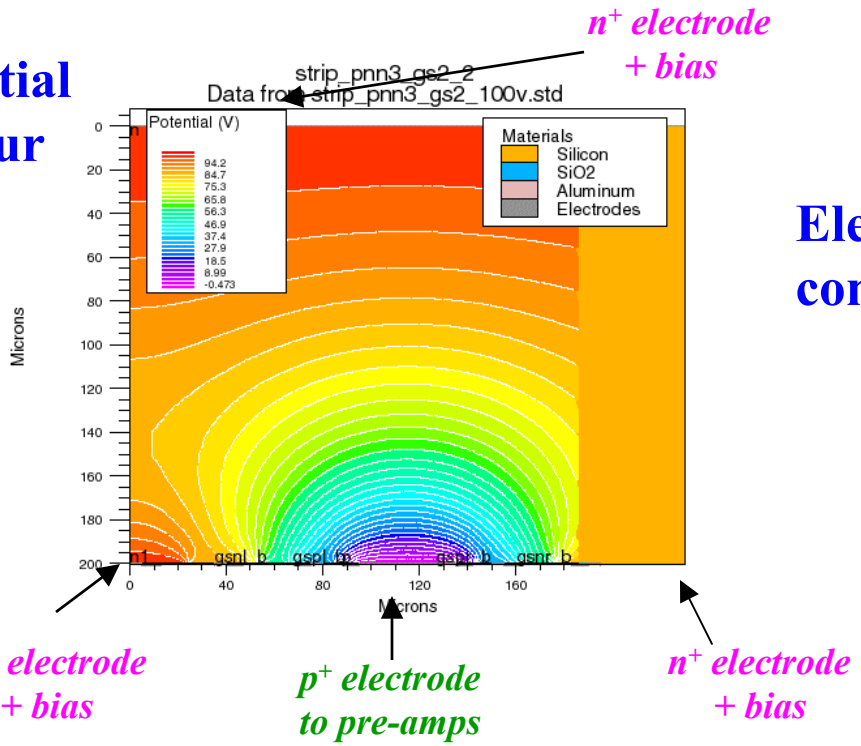
Z. Li et al., 9th Vienna Conference on Instrumentation, Vienna, Austria, February 19-23, 2001 NIM A478, (2002) 303-3110

Simulation: p^+- n^+ /n/n^+ configuration (Medium resistivity)

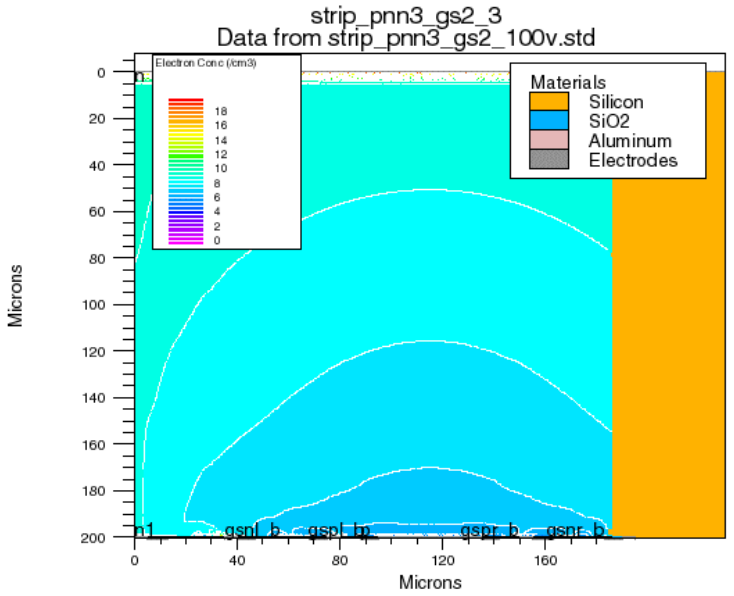
- **Before radiation, N_{eff}= +1x10^{12} /cm^3 (4 kΩ-cm)**
- **Junction on the p^+ contacts**

Simulation, V = 100 volts

Potential contour



Electron concentration



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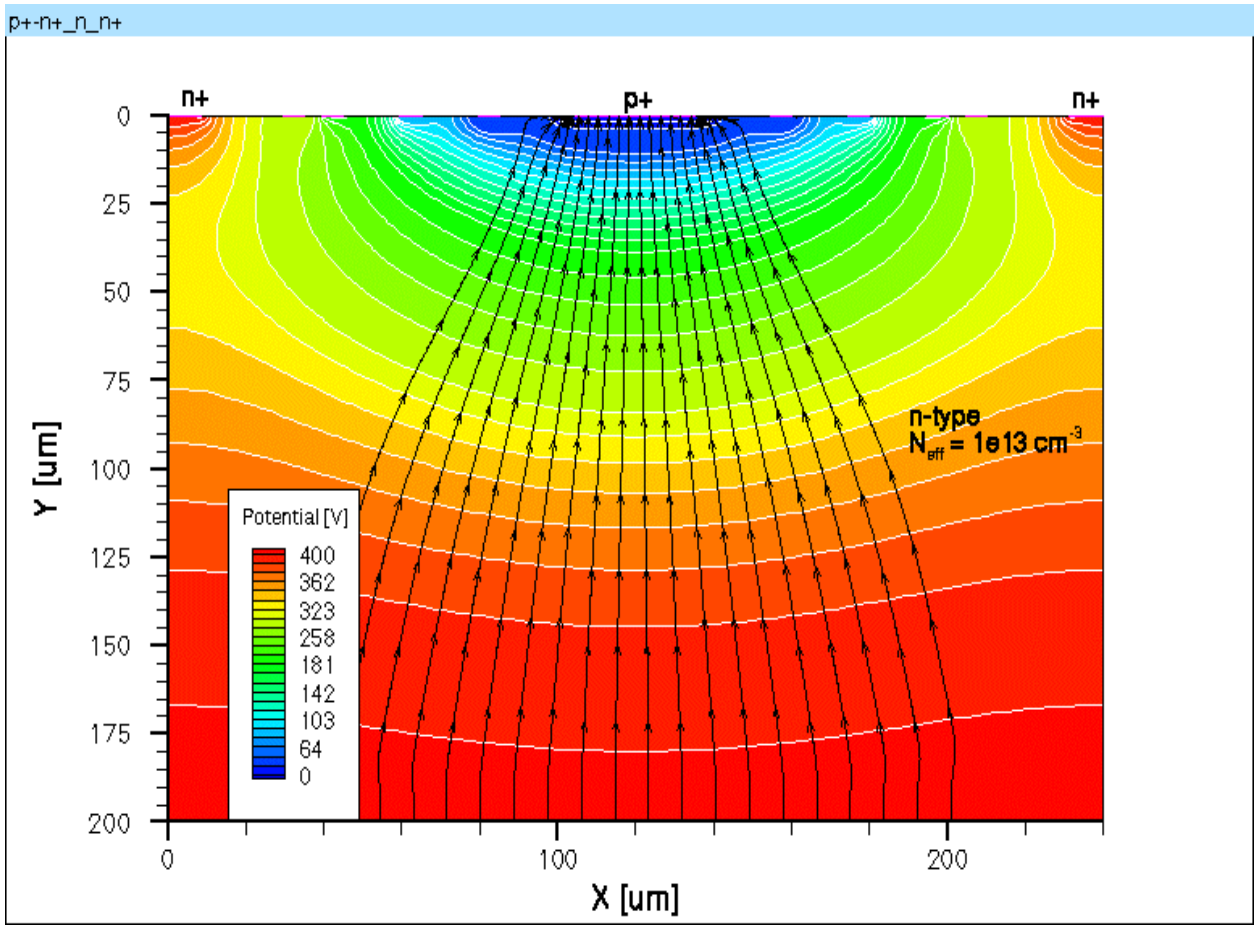
New simulation by Syracuse Univ . (Marina Artuso)

Sensor before SCSI

Field Lines

p^+- n^+ /n /n^+ configuration



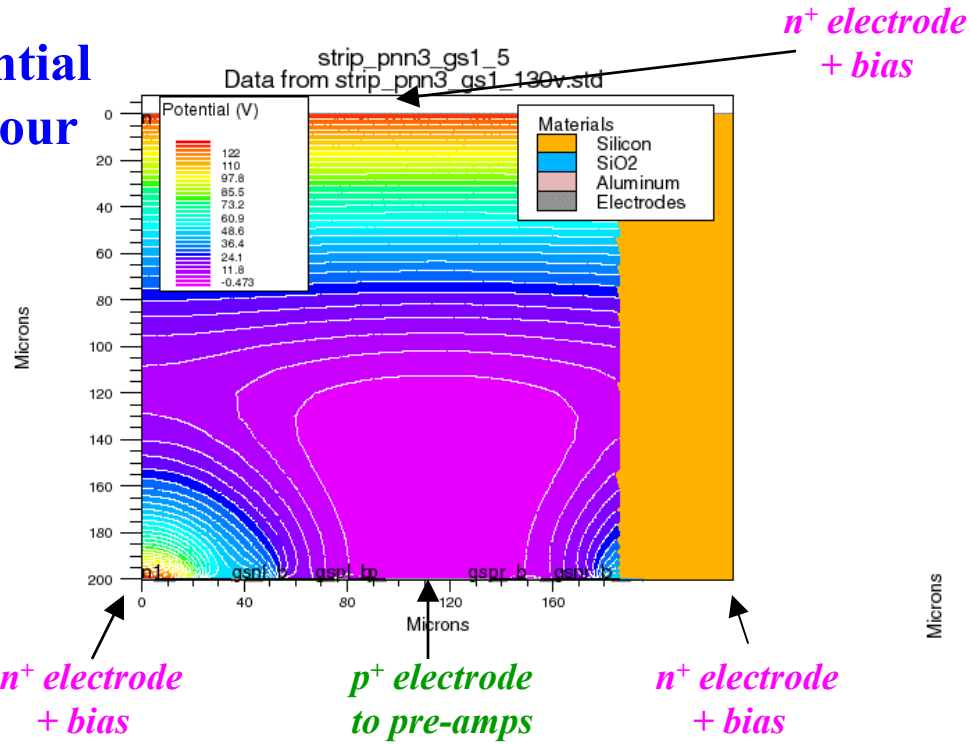
- *V (n+) = 400V*
- *V-back= 400V*
- *V (p+) = 0*

Novel p^+- n^+ /n (or p)/n^+ configuration (Medium resistivity)

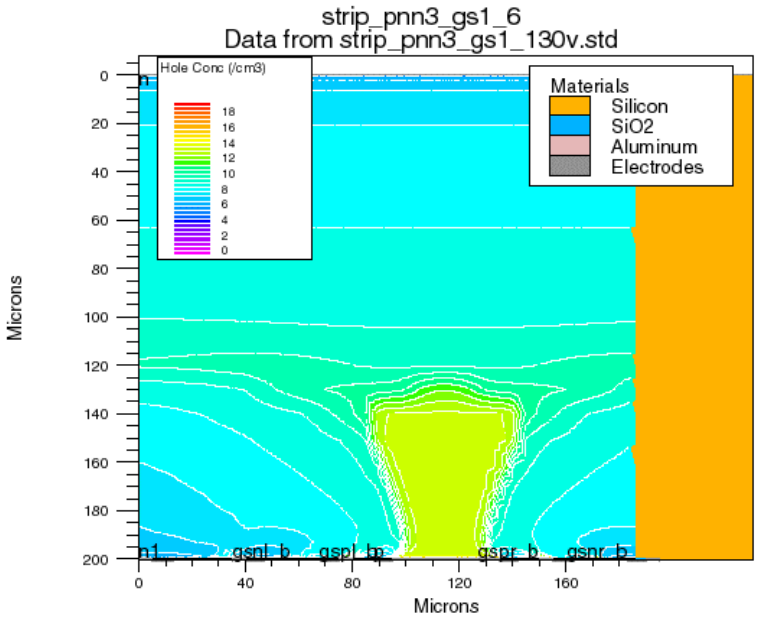
- **After radiation, N_{eff}= -1x10^{13} /cm^3 (5x10^{14}n/cm^2)**
- **Junction on the n^+ contacts, and depletion from both sides**

Simulation, V = 130 volts (<<370 volts in standard structures)

Potential contour



Hole concentration



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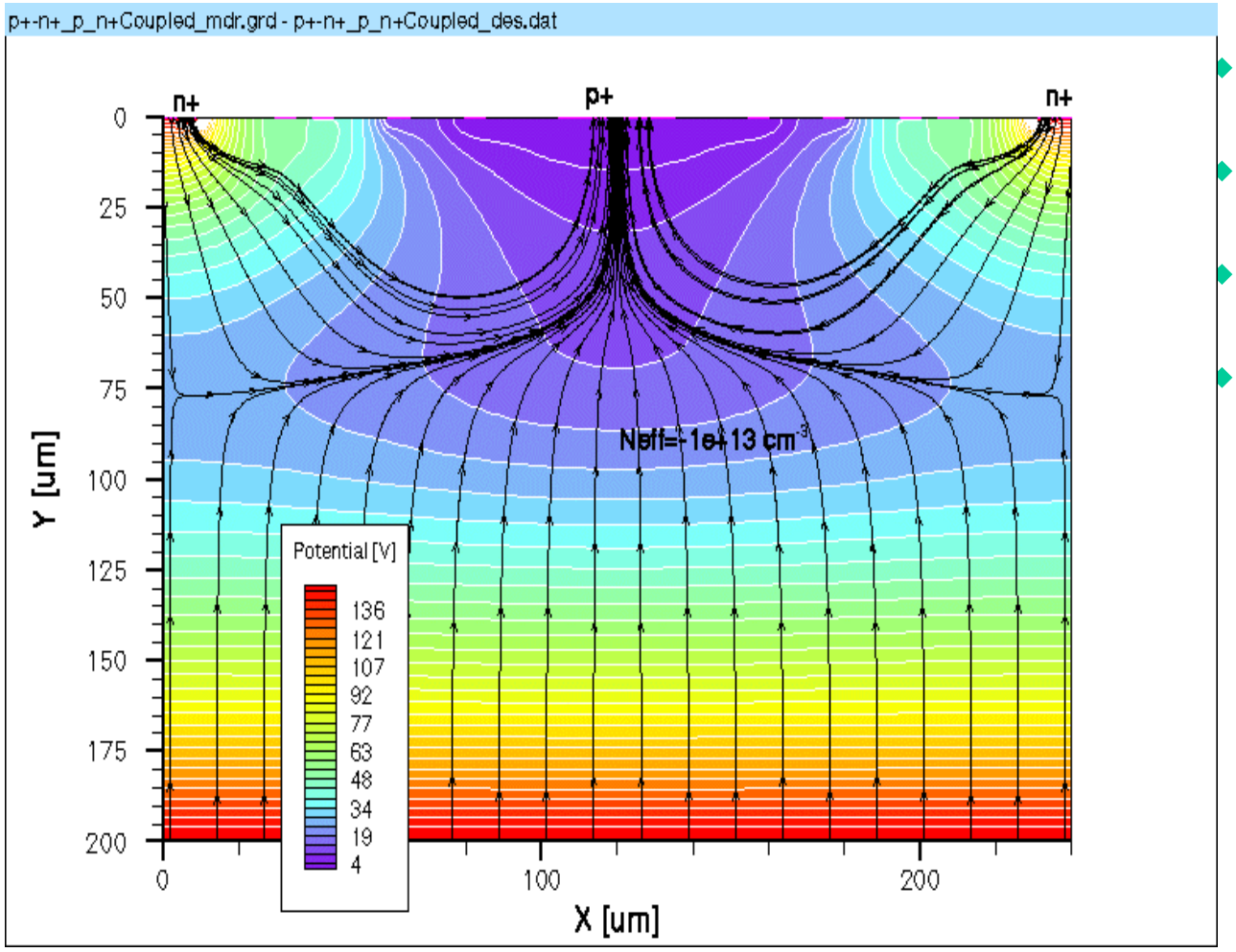
Sensor after SCSI

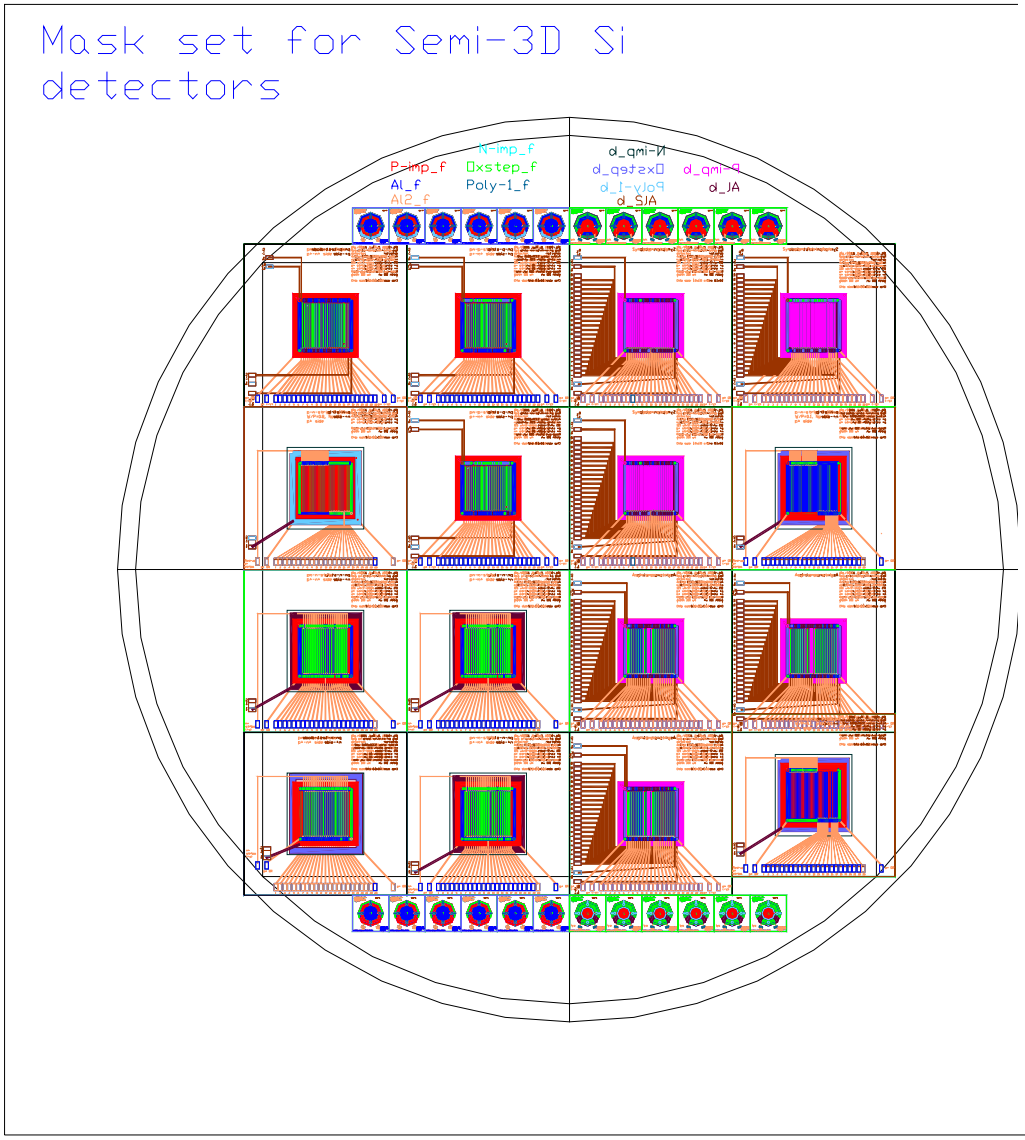
Field lines p+ - n+ /p/n+

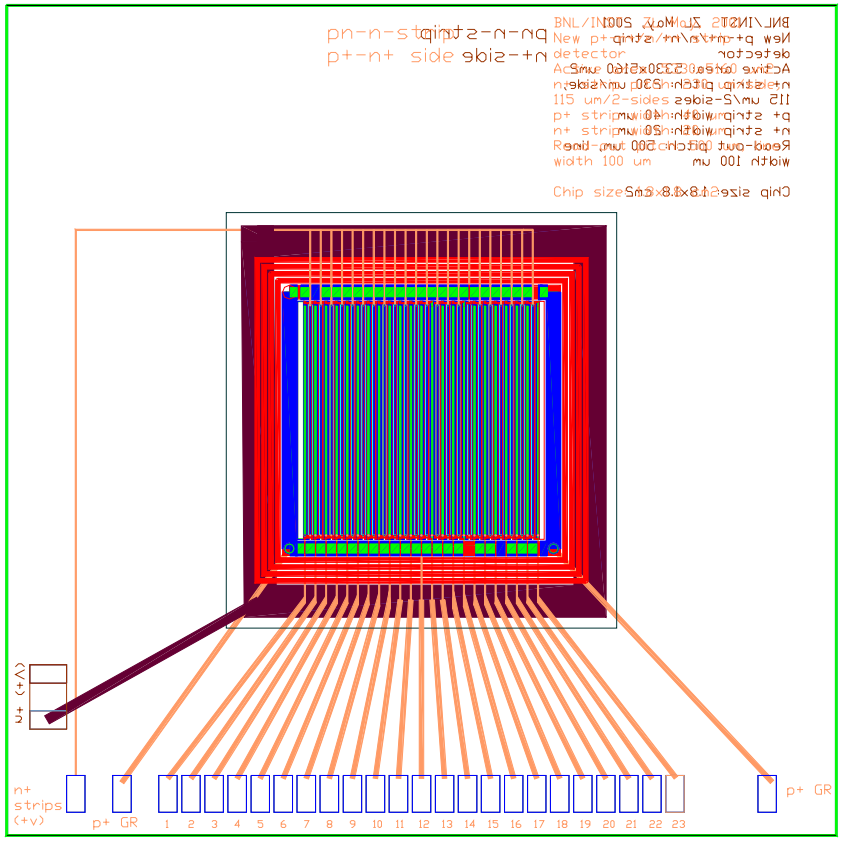


- *V (n+) = 150V*
- *V-back= 150V*
- *V (p+) = 0V*
- E_{lmax} = *150 kV/cm*

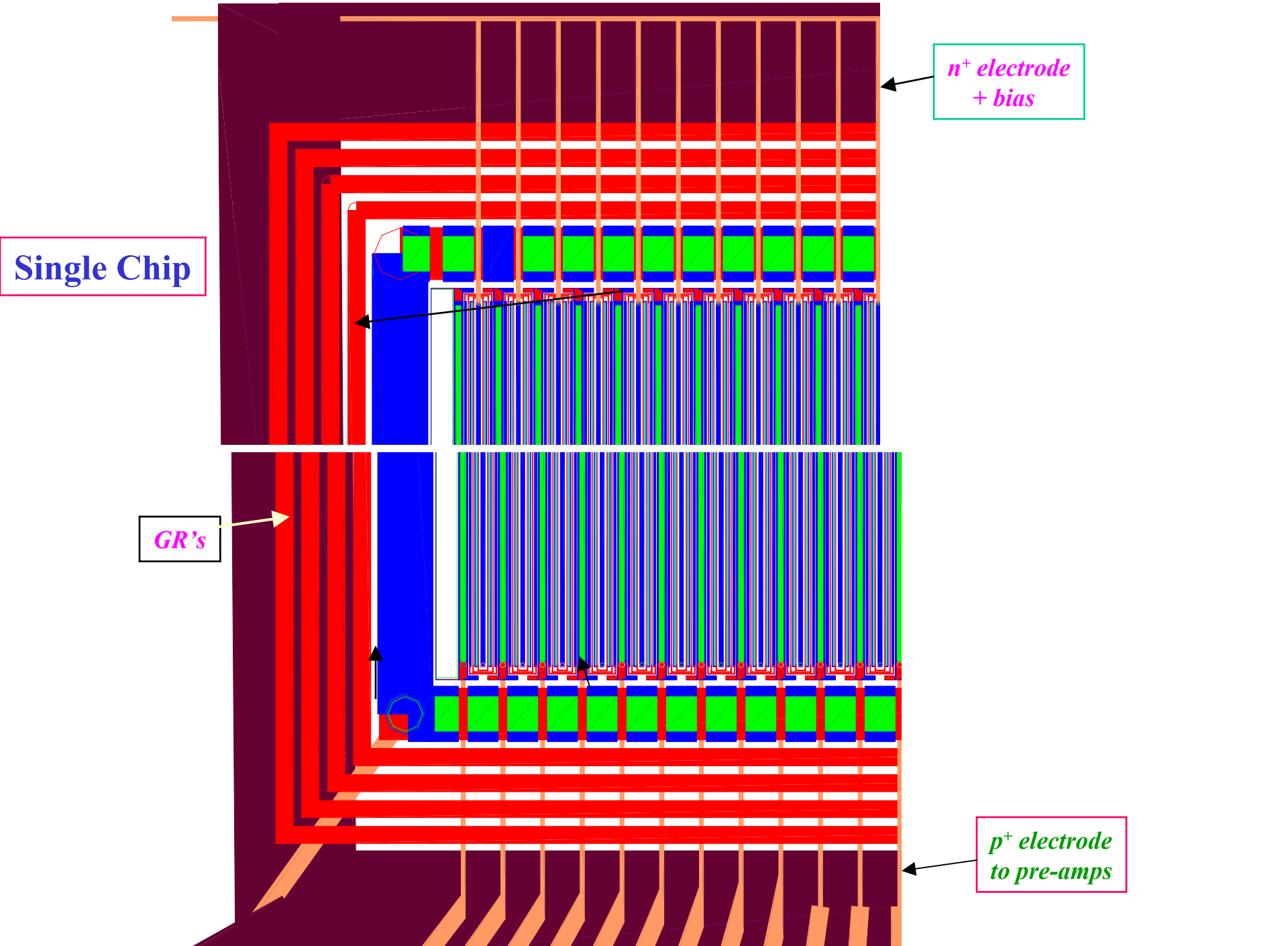
After radiation, N_{eff}= -1x10^{13} /cm^3 (5x10^{14}n/cm^2)

Mask set layout: p^+- n^+ /n/n^+ configuration (Medium resistivity)



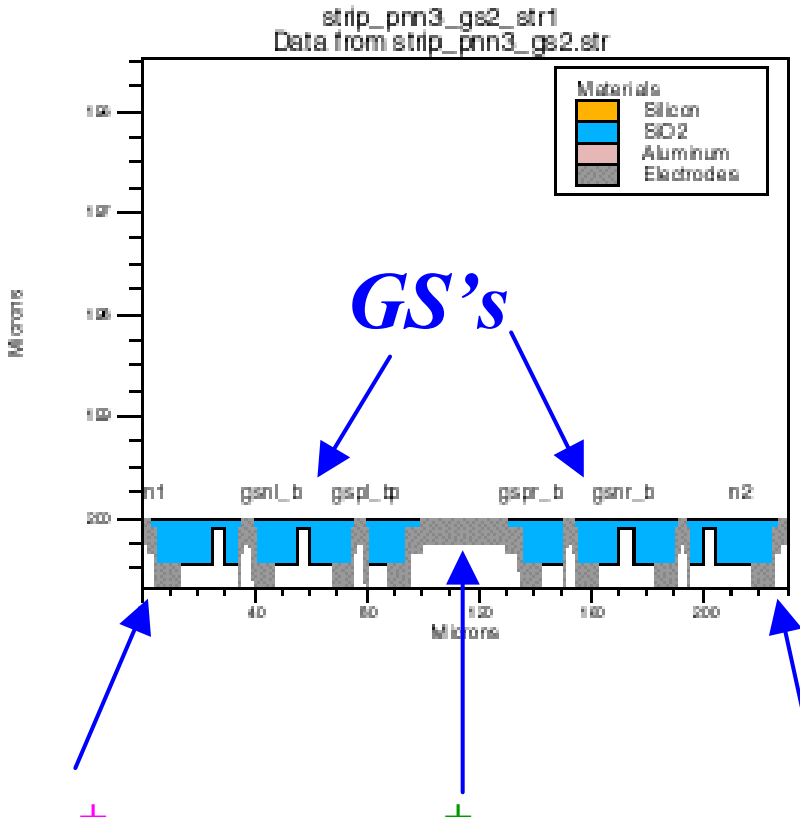


Single Chip


Single Chip
n^+ electrode
+ bias
GR's
p^+ electrode
to pre-amps

Layout of the detector structures

(Electrodes are strips on the front side)



GS's

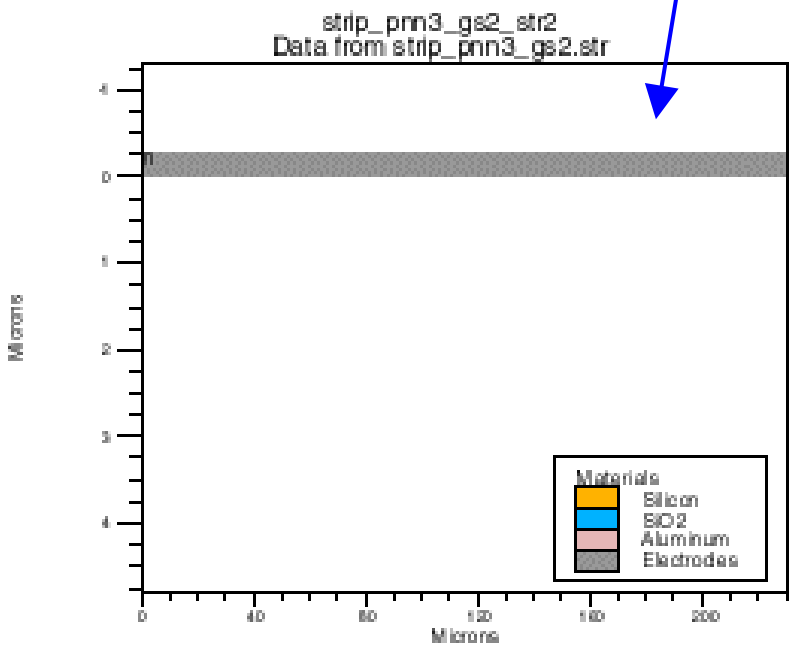
n^+ electrode

p^+ electrode

n^+ electrode

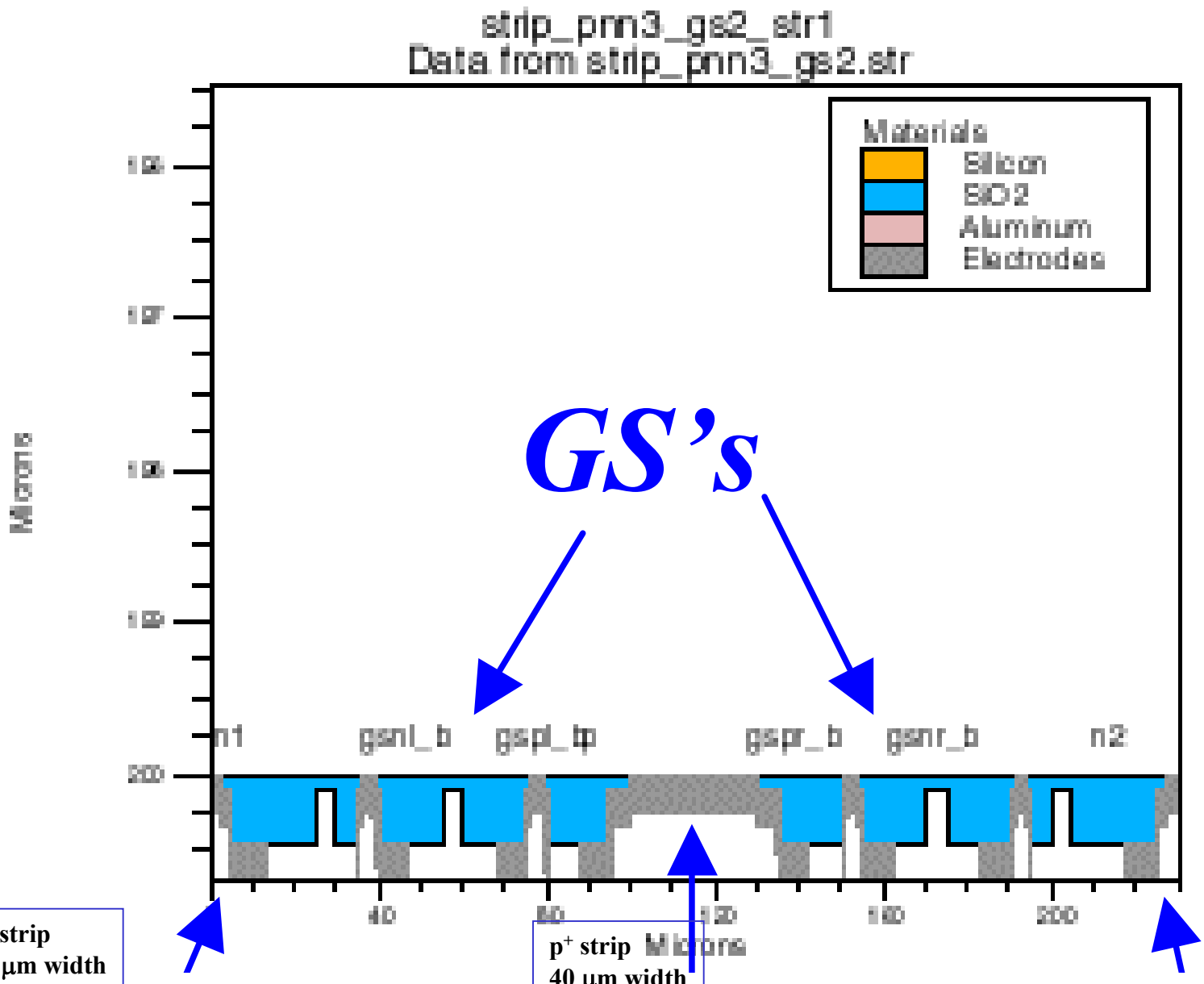
Front side

n^+ electrode

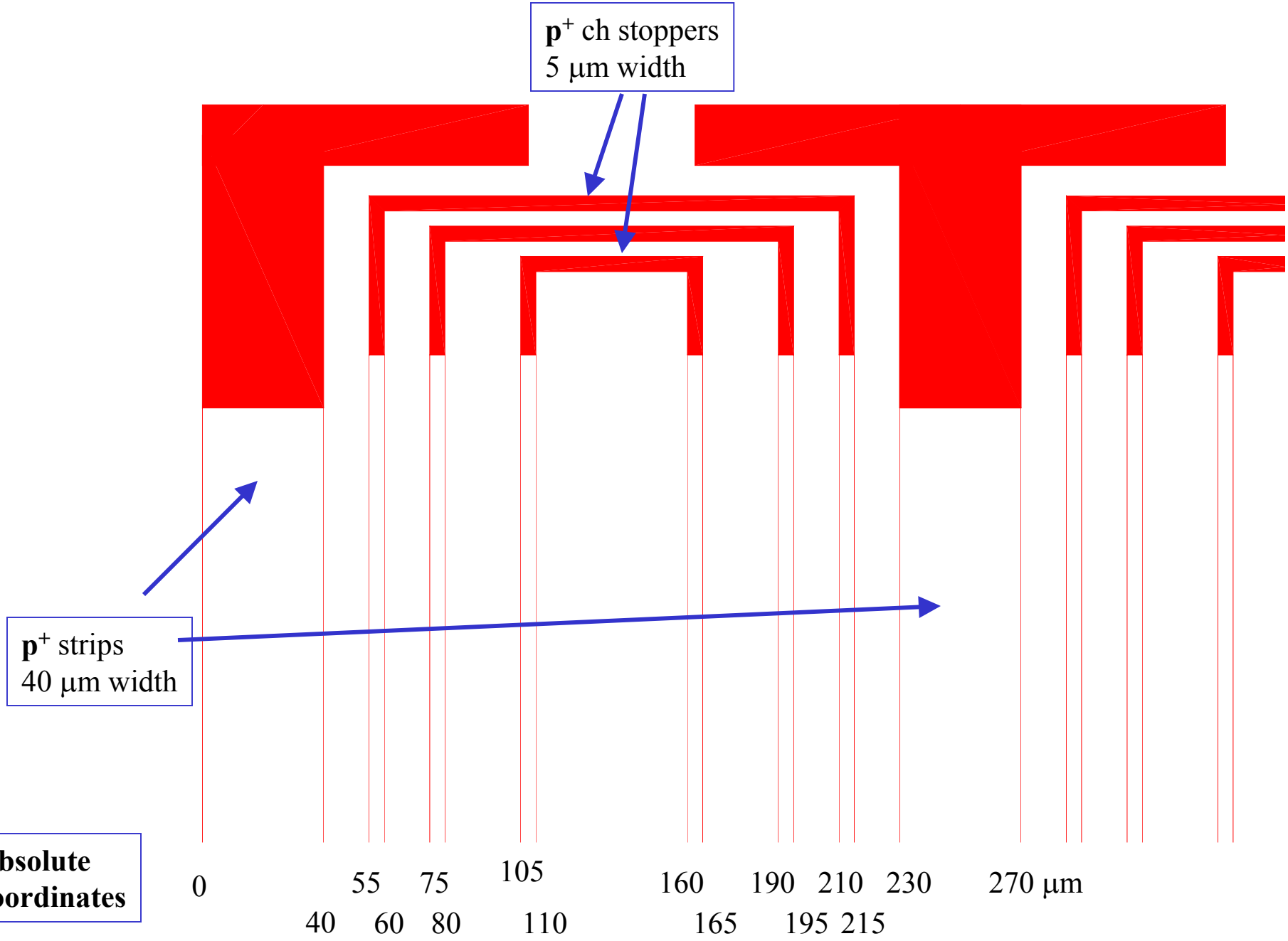


Back side

Details of front side

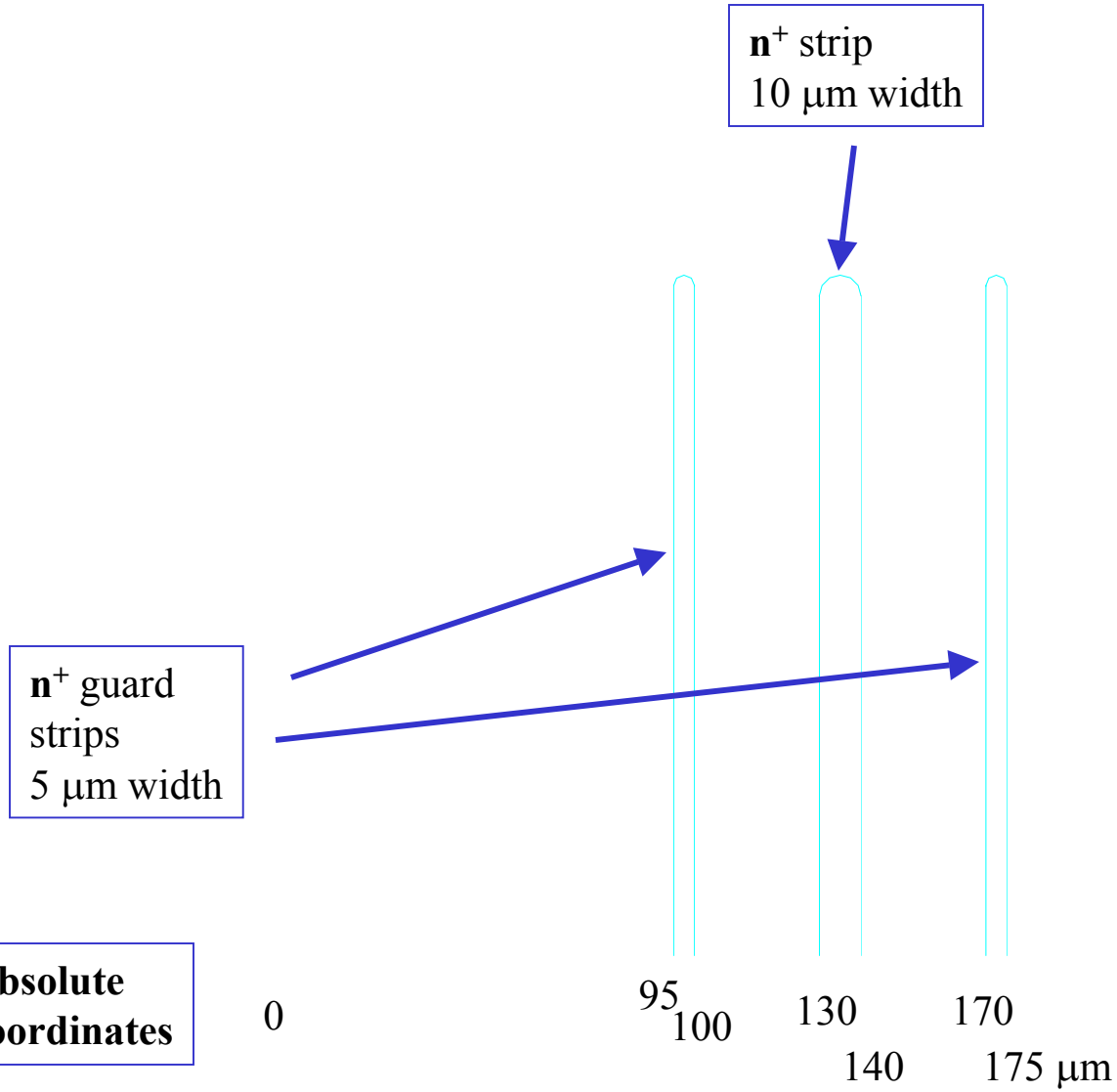


Step 1: p^+ implant through 1000 A SiO_2 (B, 40 keV, $4x10^{14}$ /cm^2)

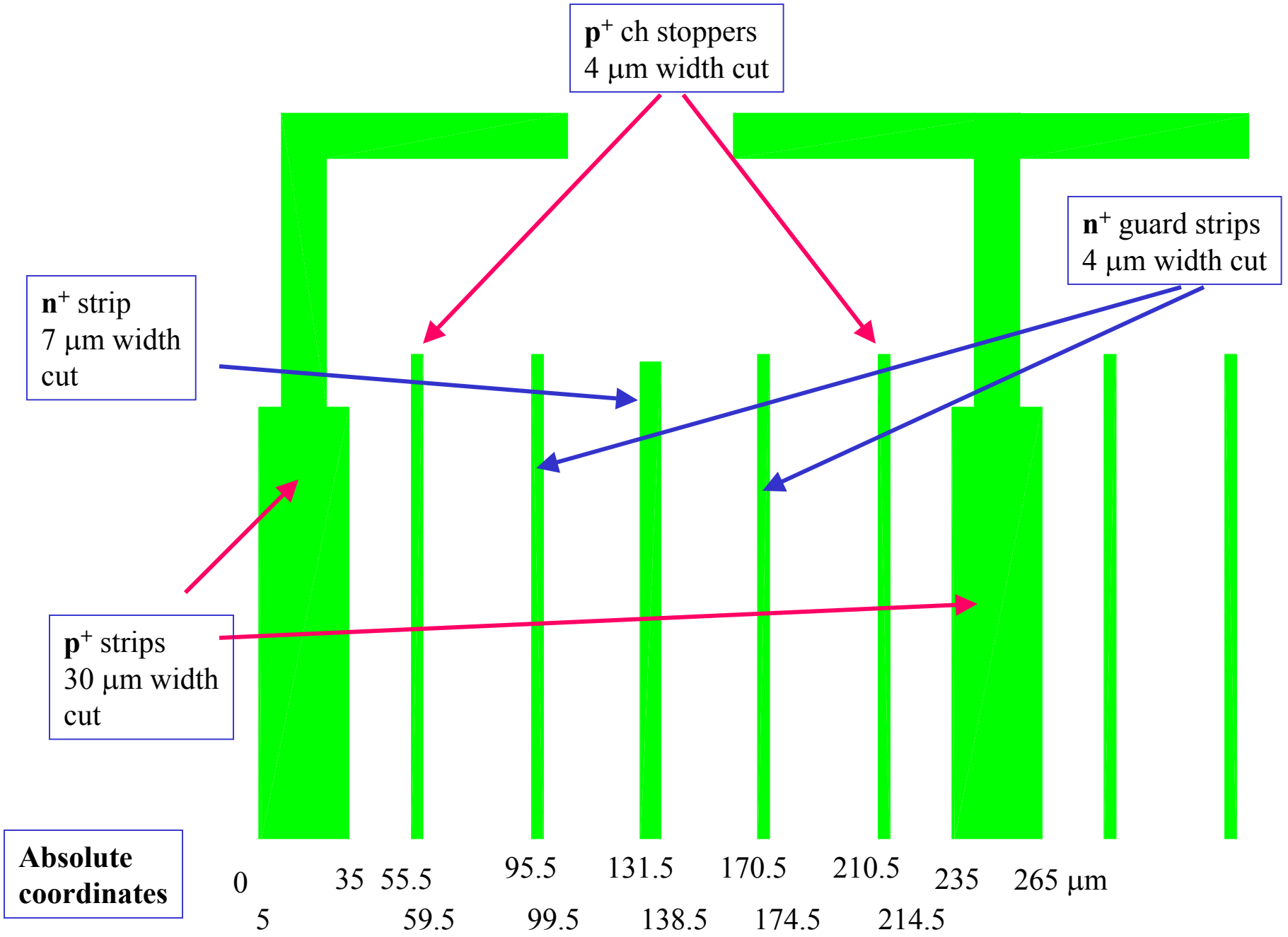


Step 2: n^+ implant through 1000 A SiO_2 for guard strips (Ph, 60 keV, $1x10^{14}$ /cm^2, and 90 keV, $1x10^{14}$ /cm^2)

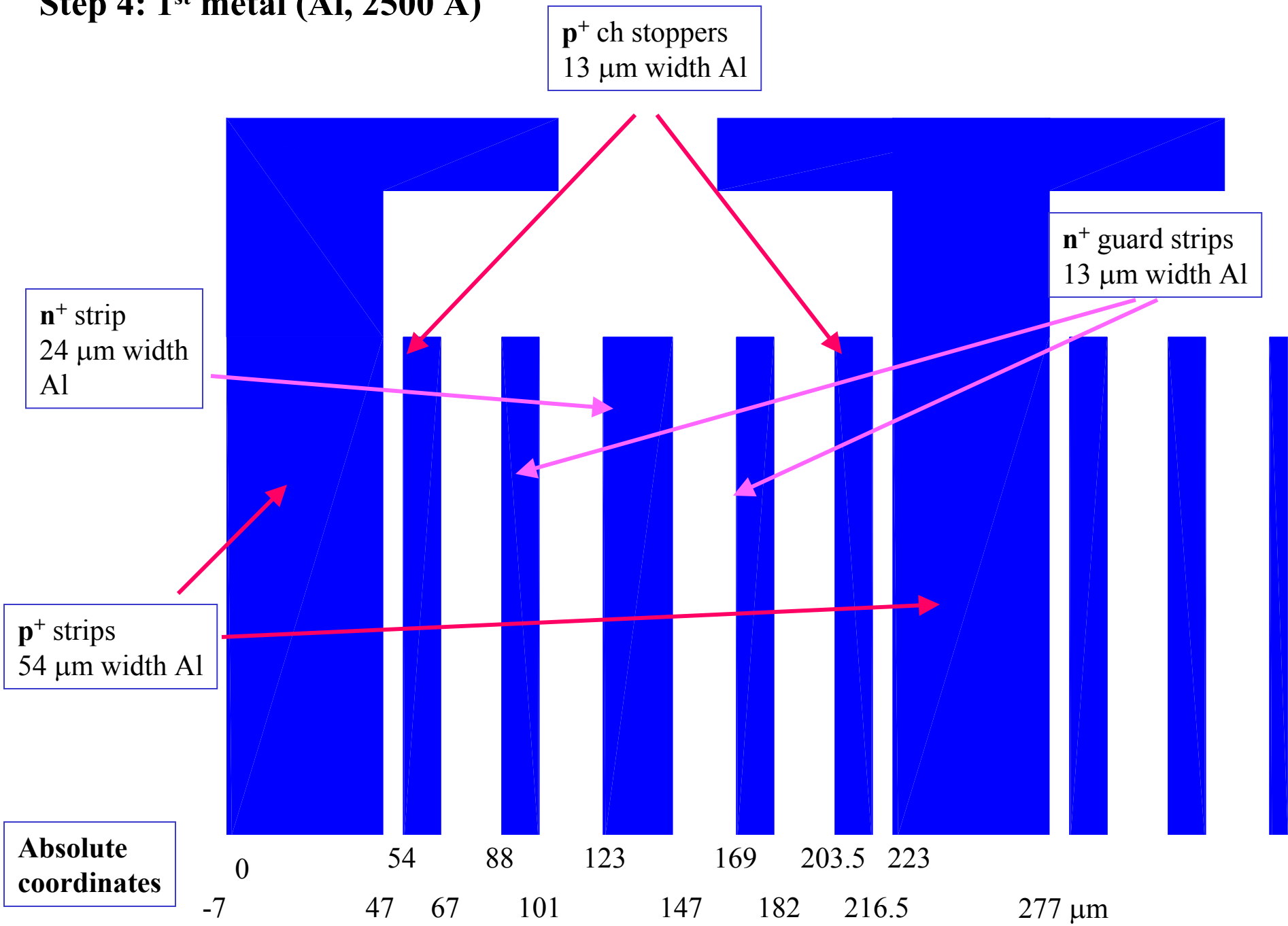
(note: during this implant, the p^+ implanted regions are covered by 3000 A of Al)



Step 3: Oxide step cut to bare Si



Step 4: 1st metal (Al, 2500 A)

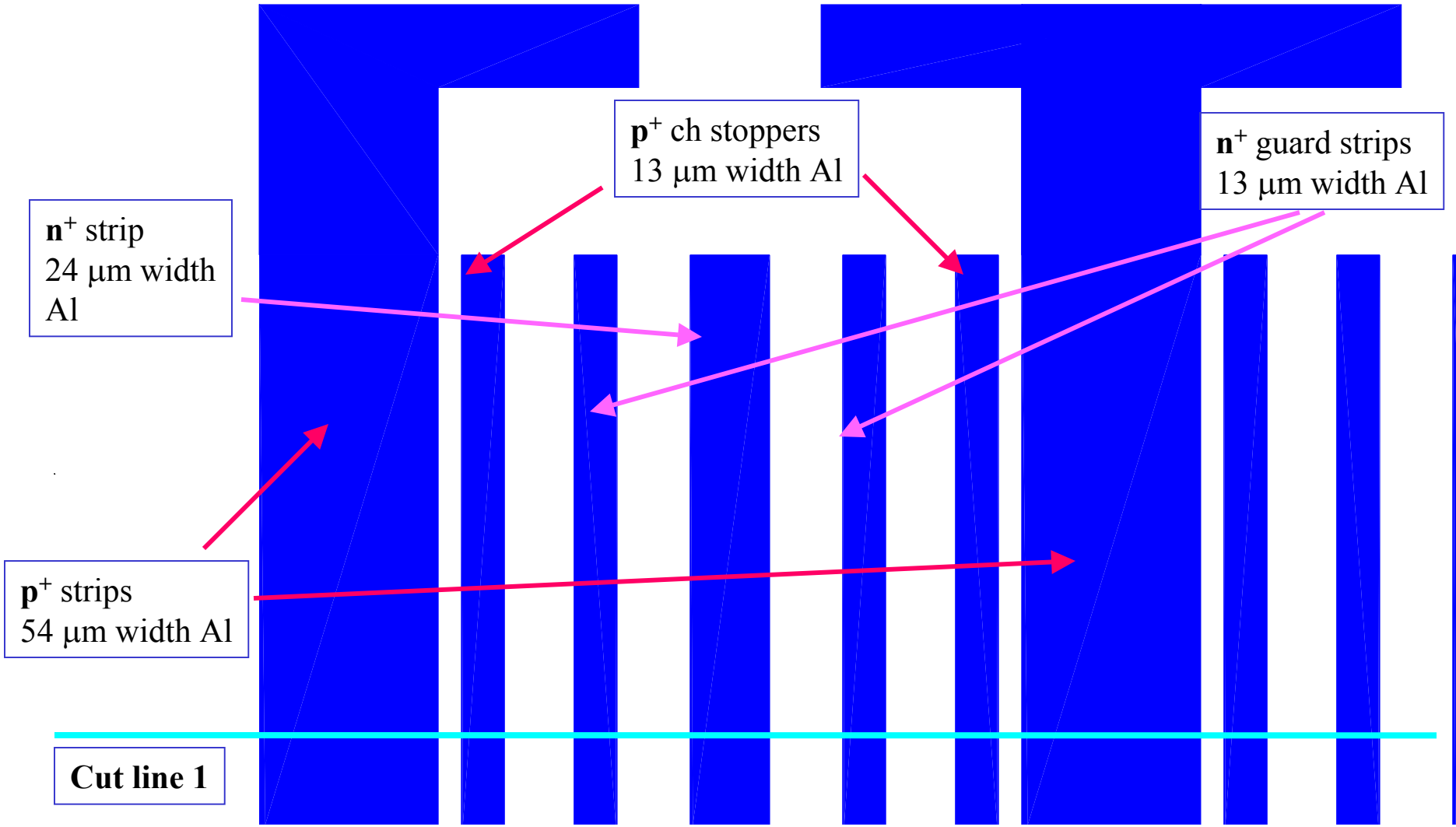


Step 5: n^+ implant on the back (uniform implantation) through 1000 A SiO_2 (Ph, 60 keV, $1x10^{14}$ /cm^2 and 90 keV, $1x10^{14}$ /cm^2)

Step 6: Etch backside to bare Si

Step 7: Deposit Al on back side (2500 A)

2d simulation along the cut line 1, and 200 μm thick wafer
n-type, N_{eff0}= 1x10^{13} /cm^3 (before rad.), and p-type, N_{eff} =- 1x10^{13} /cm^3 (after SCSI)
Biases: p$^+$ strips: 0 V (Electrodes for CCE)
n$^+$ strips and back plane: biased to the same + voltage (a few hundreds of volts)
All p$^+$ guard strips and n$^+$ ch-stoppers are floating



Future work plans

- Simulation of CCE before and after SCSI
- Fabrication of first prototype Semi-3D Si detectors
- Electrical testing
- Radiation of test structures and strip detectors
- Electrical testing and CCE testing to check the radiation harness of Semi-3D Si detectors
- Improvement in design and second batch fabrication

  Are guard strips necessary?
- Further testing