Silvaco simulation studies of primary BPW and nested well structures
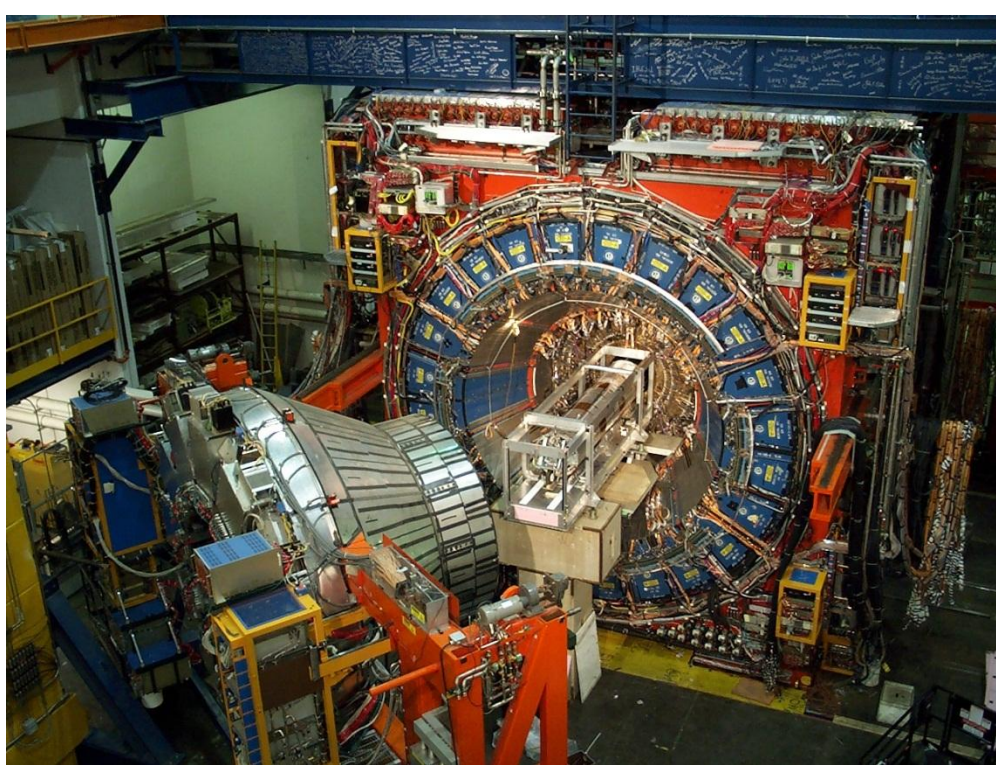
Michelle Salvador

Under the mentorship of Grzegorz Deptuch and Farah Khalid
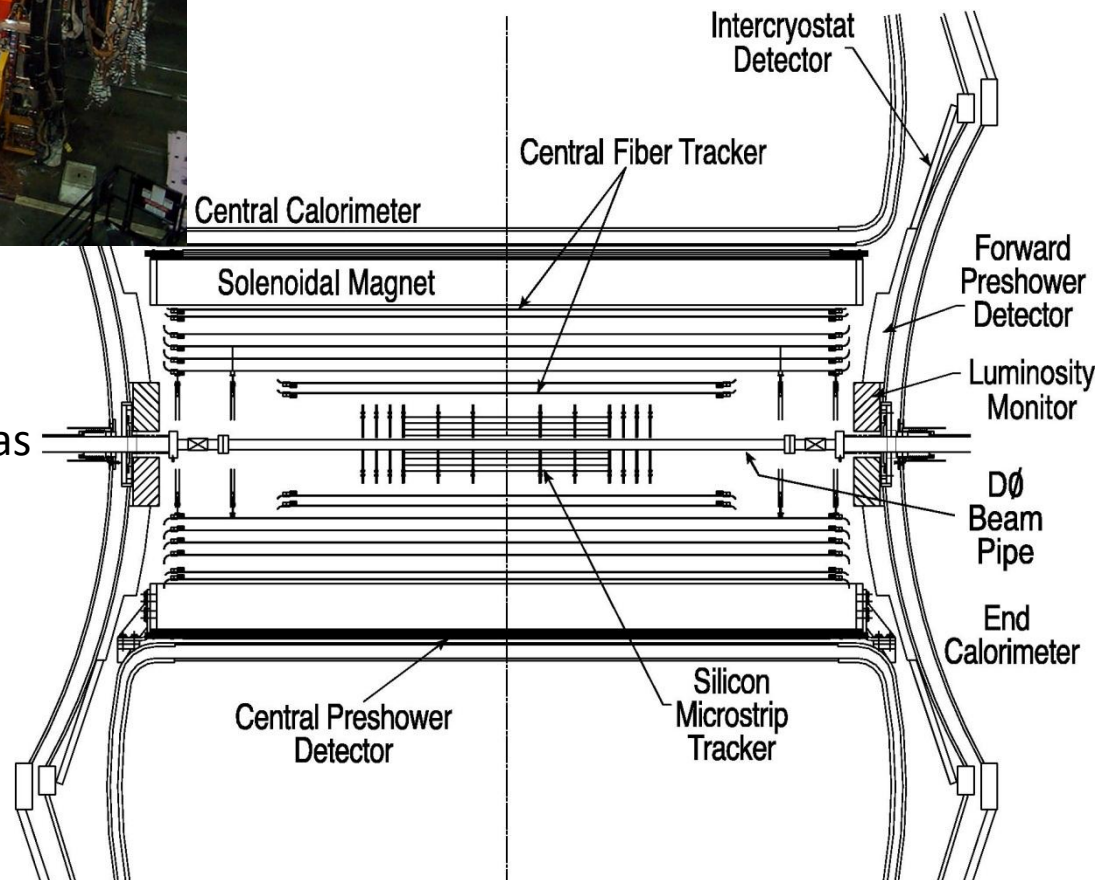
SIST Fermilab
The University of Texas at El Paso

Silicon Detectors
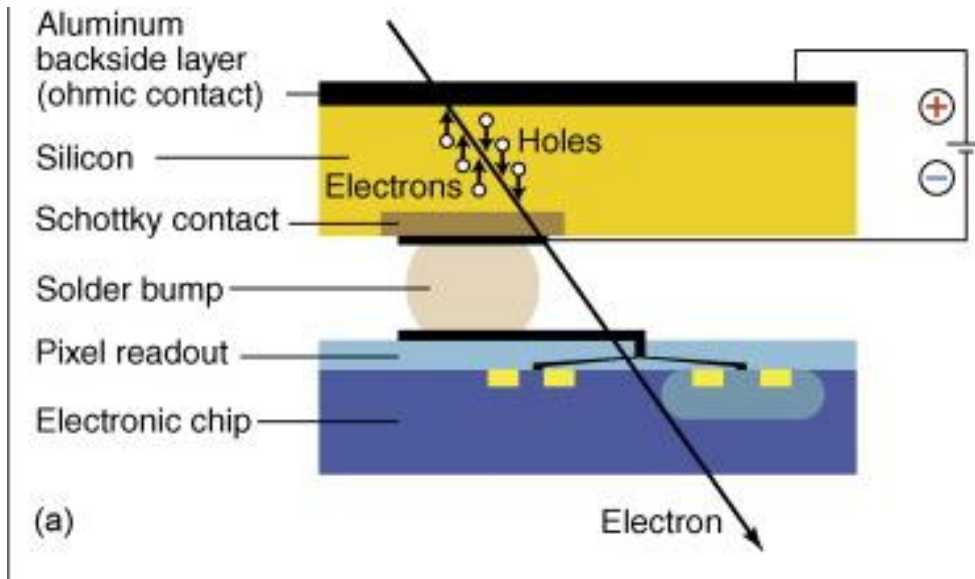

http://www-cdf.fnal.gov/cdfphotos/dcp_0723.jpg

- Same concept as commercial cameras
- Multipixel
- Silicon detectors reside at the center of experiments

http://www-d0.fnal.gov/Run2Physics/WWW/drawings/run2_nim/figure2.jpeg

General Silicon Detectors

Aluminum backside layer (ohmic contact)

Silicon

Schottky contact

Solder bump

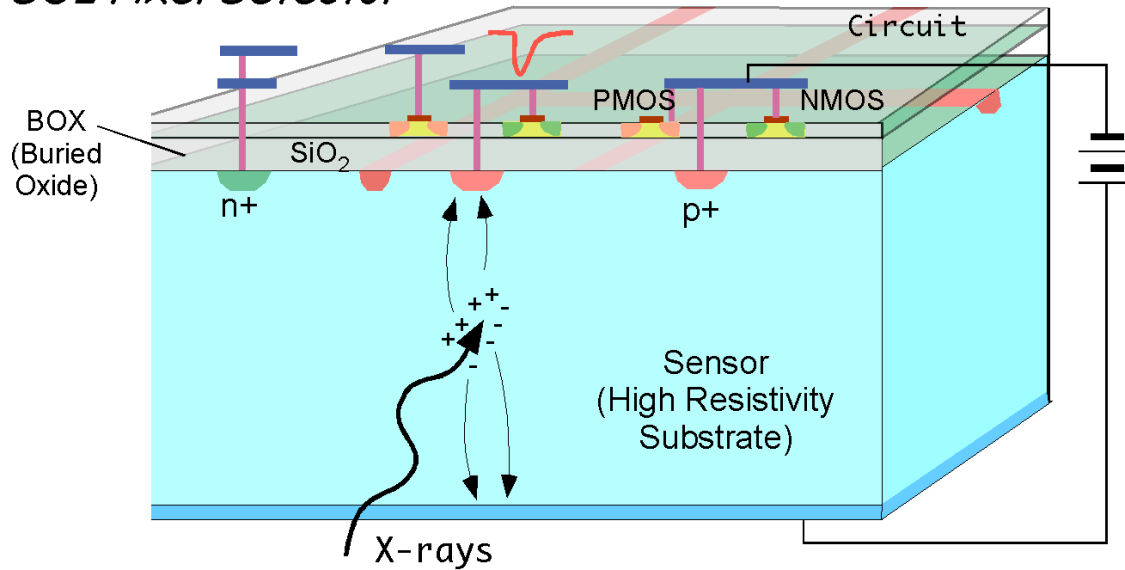Pixel readout

Electronic chip

Holes

Electrons

(a)

Electron

-Consist of two separate structures joined through solder bump

-Detector and Pixel readout

-Separated through layers of metal
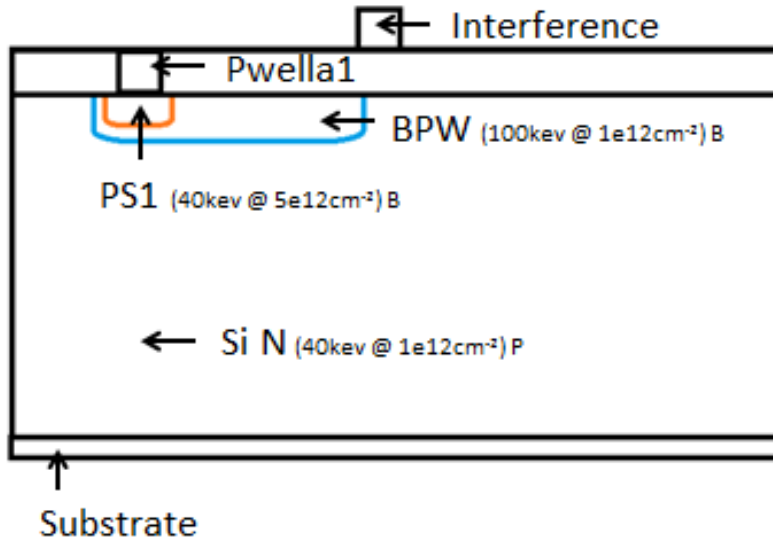
(silicon on insulator) SOIPIX

SOI Pixel Detector

-photons come in and generate charge
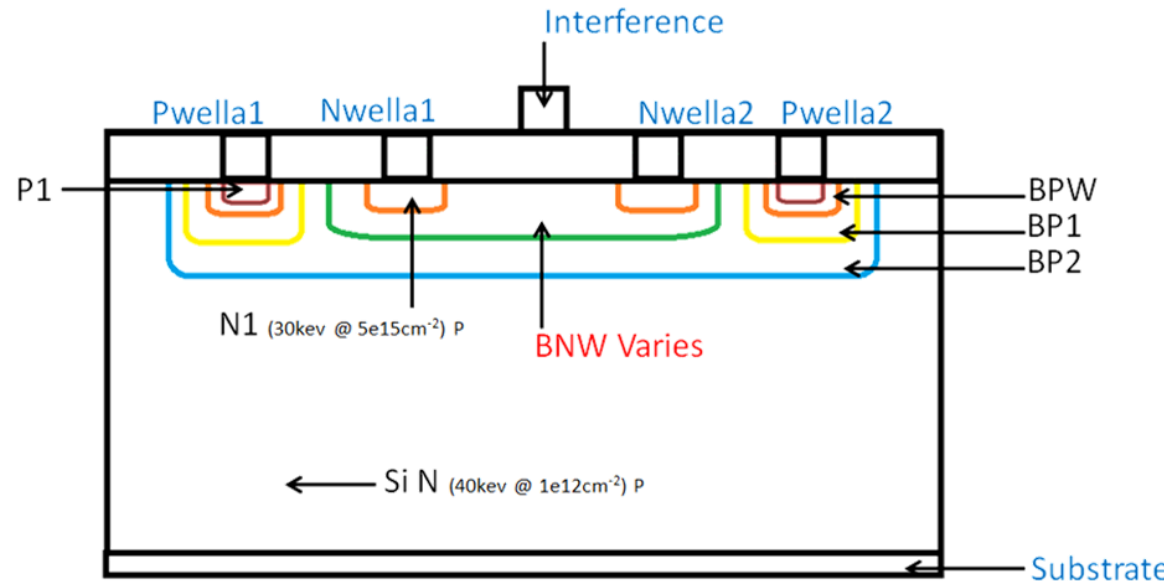example to generate in

Si energy needed 3.6 ev
X-ray 6 Kev

$$\approx \frac{6kev}{3.6ev} \approx 1667e^-$$

-charge is detected at p+ well and amplified

Primary BPW and Nested Well Structures

Goal: Quantify electrical characteristics between aggressor and victim.
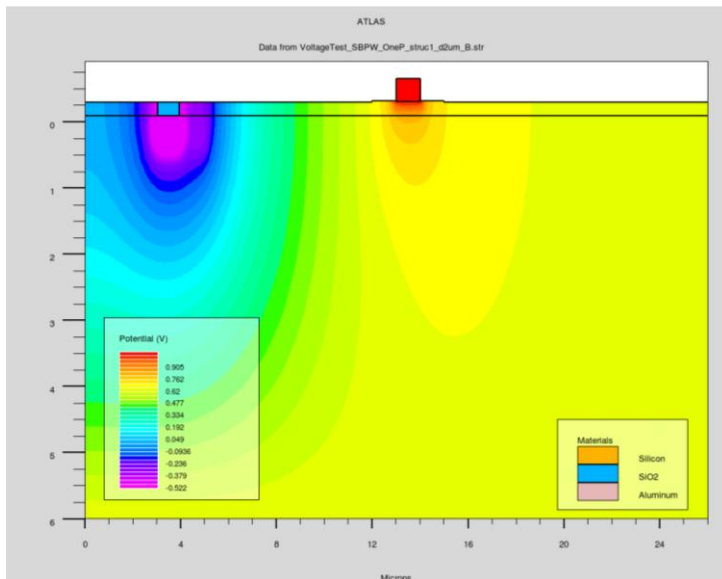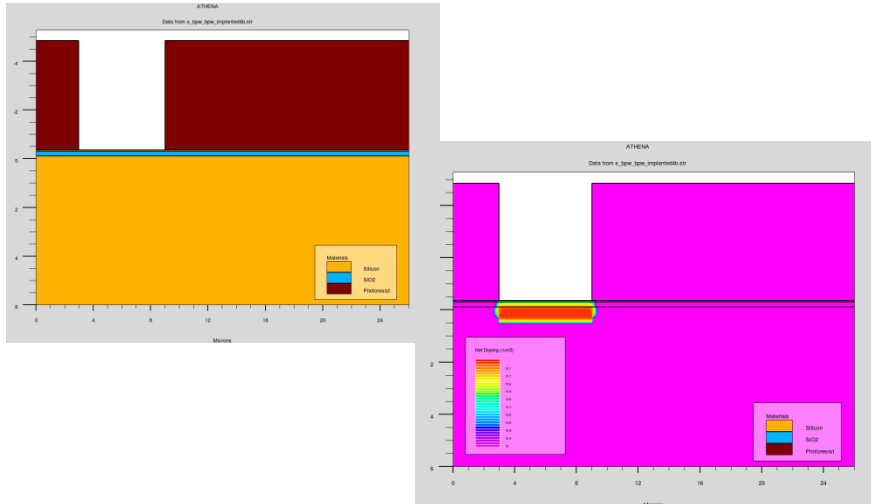Initial study of (2D cross sections)

– widely used

ATHENA

- Process Simulation

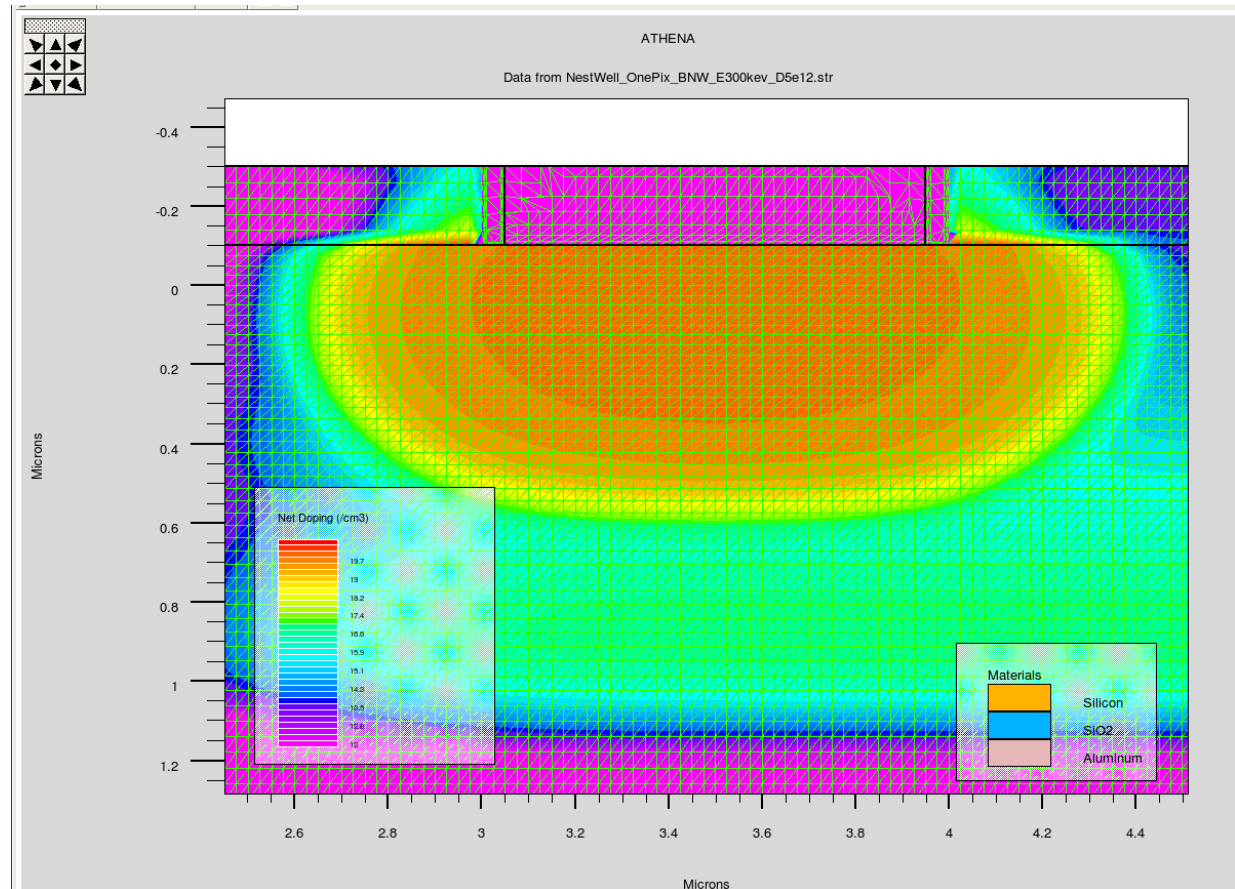 Predicts physical outcomes in structure fabrication

ATLAS

- Device Simulation

  Predictions in the

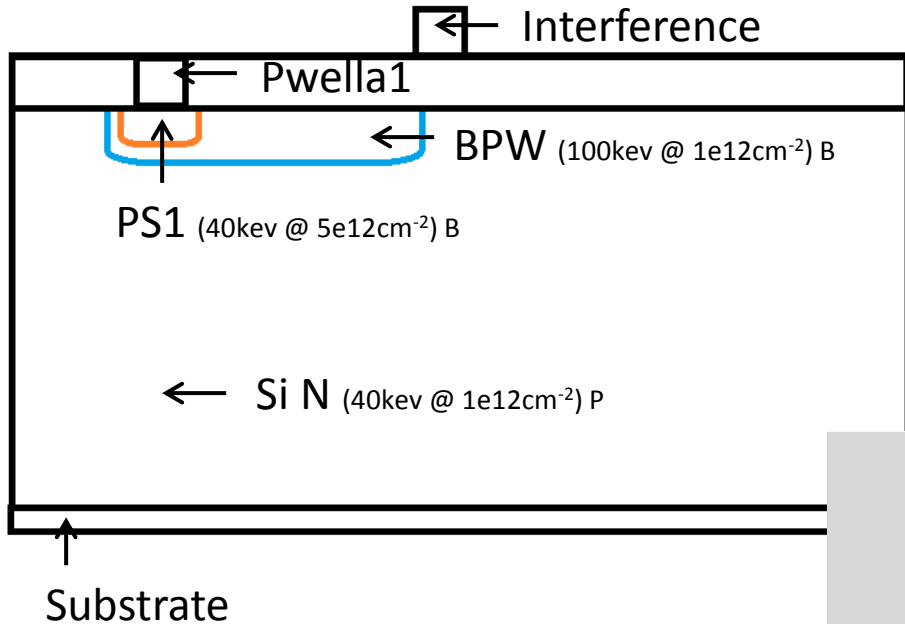 Structure's electrical characteristic

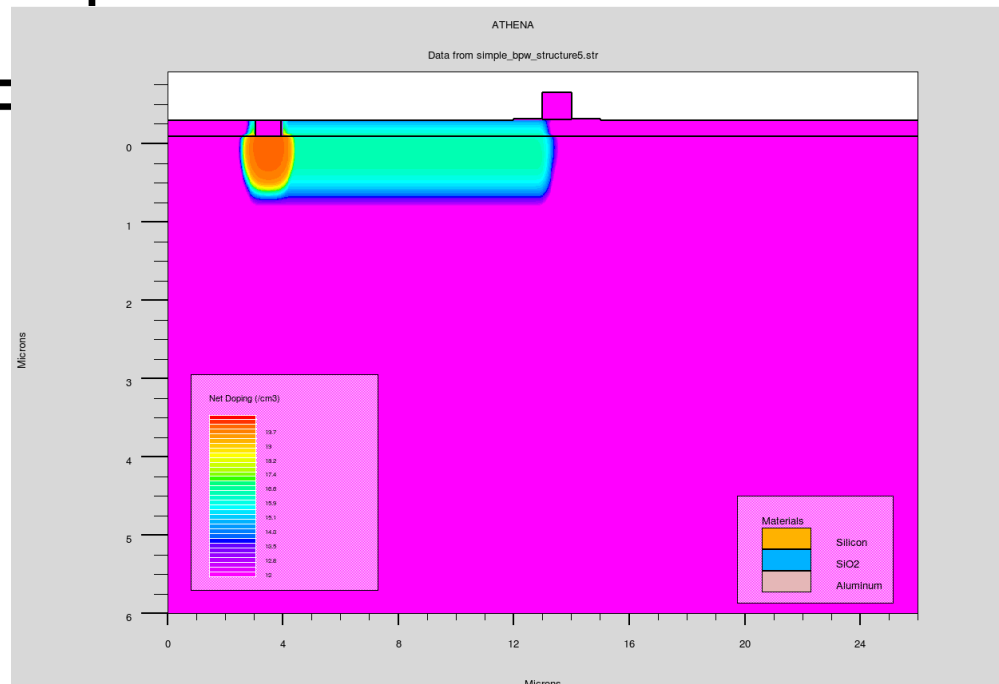# Important to define Mesh and Parameters well in Silvaco!!

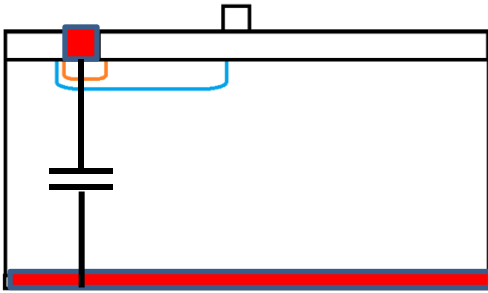-Balance between accuracy and
 efficiency

Primary BPW Structure

Interference

Pwella1

BPW (100kev @ 1e12cm^{-2}) B

PS1 (40kev @ 5e12cm^{-2}) B

Si N (40kev @ 1e12cm^{-2}) P

Substrate

-Change BPW width (2um-20um)
-Investigate amount of capacitance and charge injected
due to interference
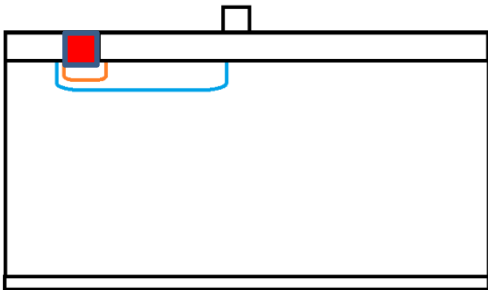

ATHENA

Data from simple_bpw_structure5.str

C_B

– Capacitance between pwella1 and die pad (substrate) electrodes
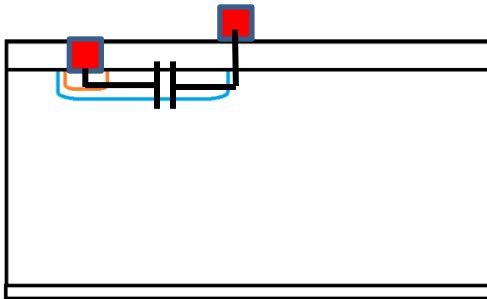
C_P

– Capacitance between aggressor (interference) and pwella1 electrodes

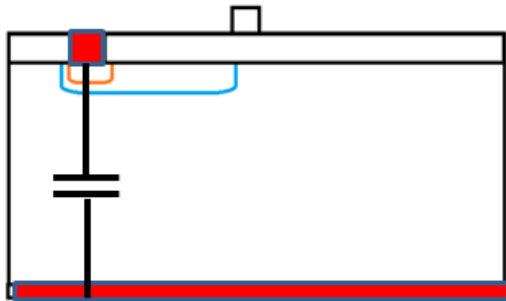# Q_P

– Charge accumulation at Pwella1 electrode

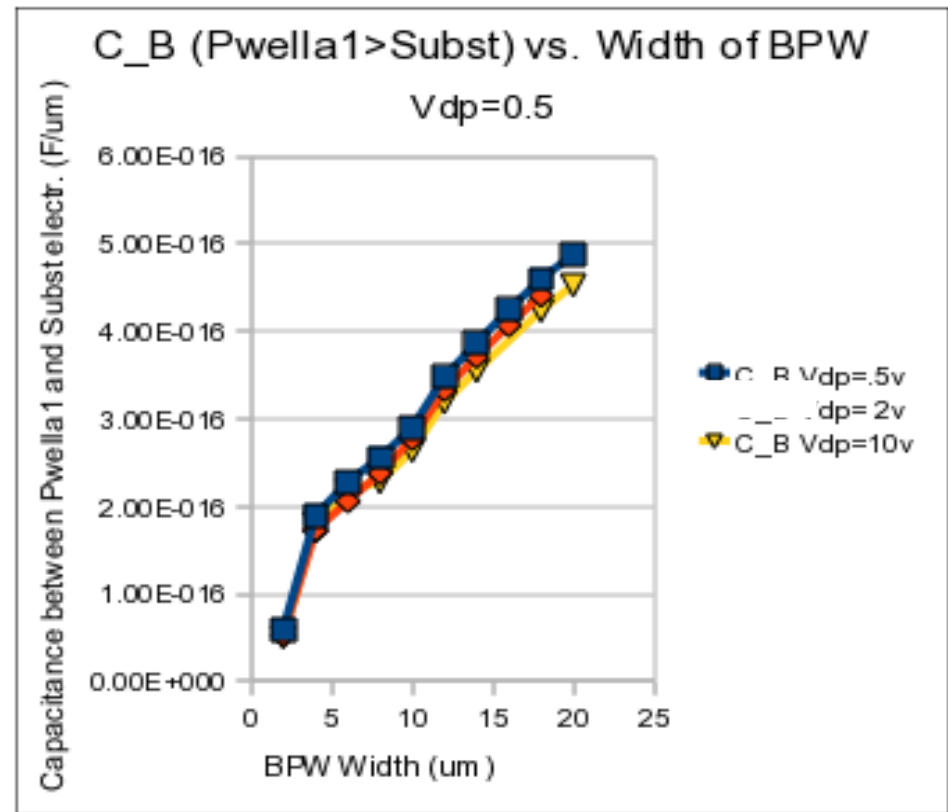Variables:

*BPW Width

*V_dp (voltage applied at substrate)

Results C_B
Capacitance across Pwella1 and Substrate electrodes

- Direct correlation with increase of BPW width
- BPW acts as capacitive plate
- Minimum change due to applied die pad voltage

$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$

C_B (Pwella1>Subst) vs. Width of BPW
Vdp=0.5

Capacitance between Pwella1 and Subst electr. (F/um)
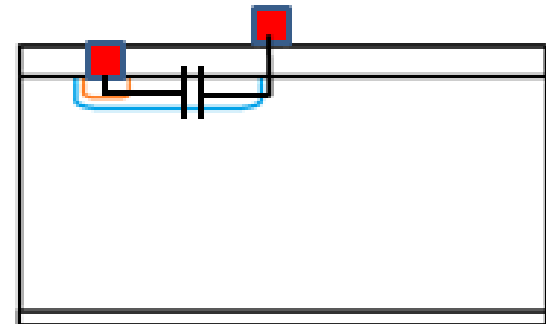BPW Width (um)

C_B Vdp=.5v
dp= 2v
C_B Vdp=10v

C_P
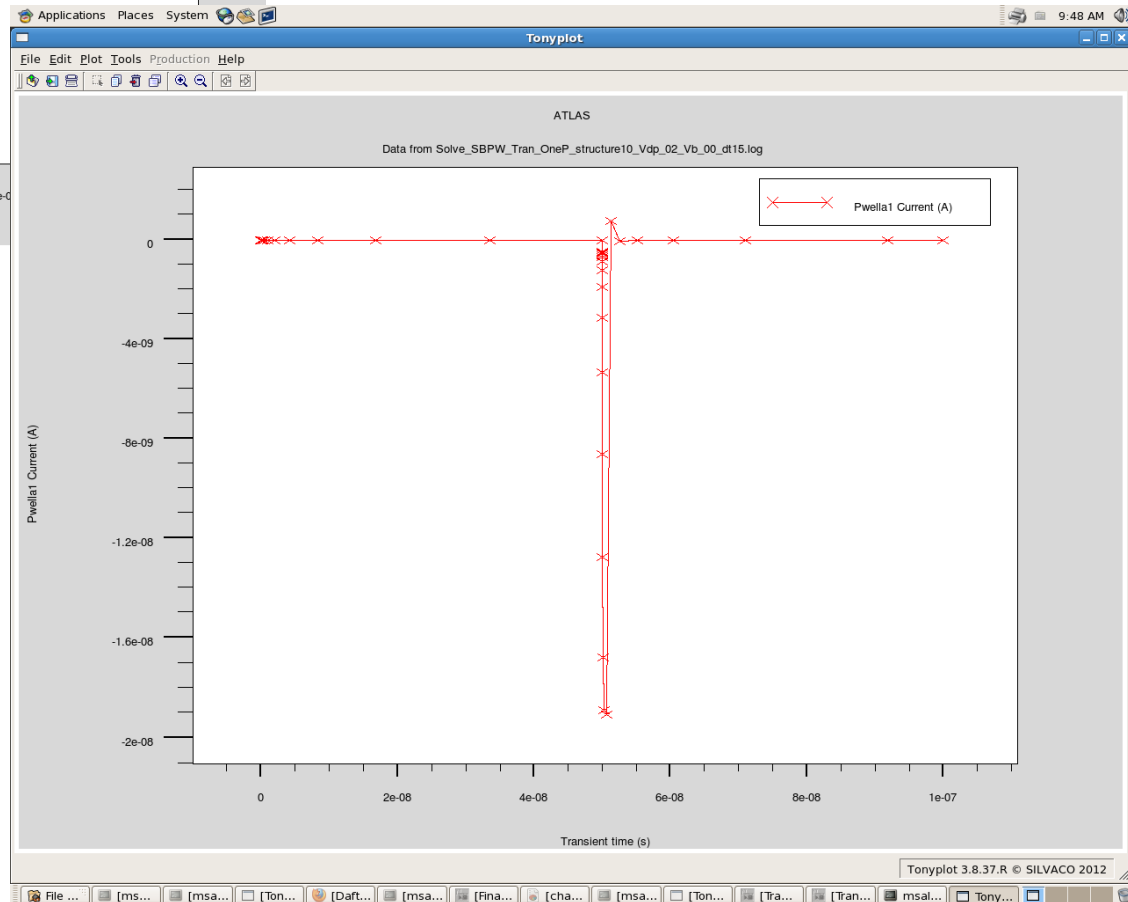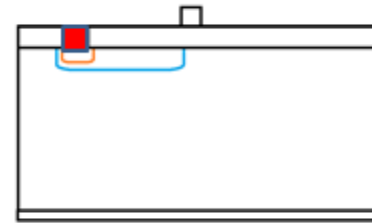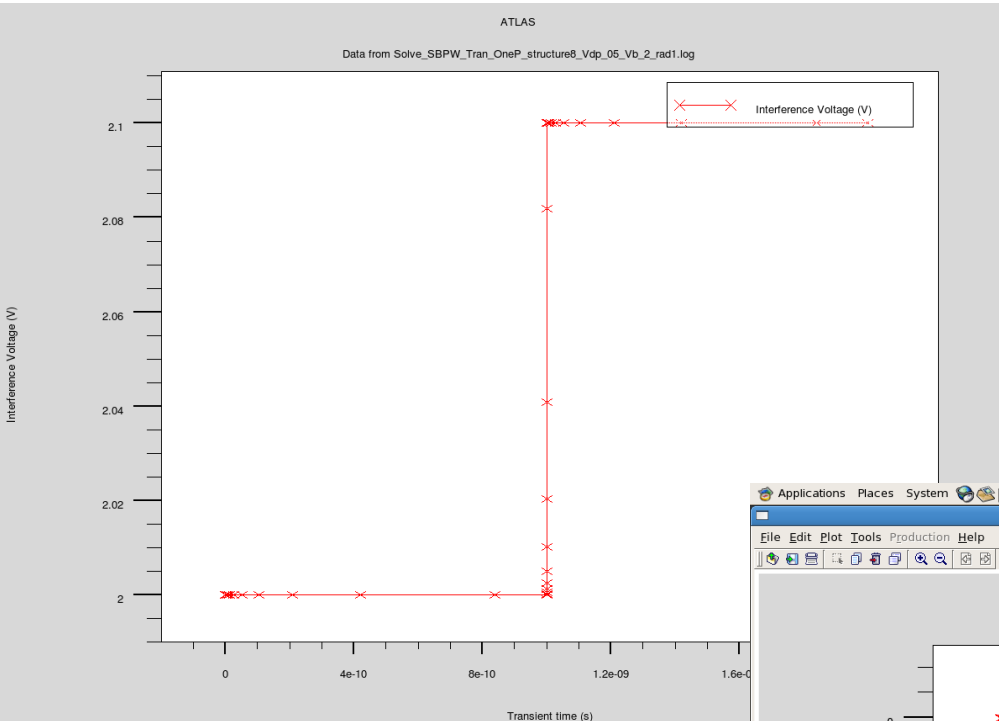## Capacitance across Pwella1 and Interference electrodes

-Increment in capacitance as
BPW widens
-Saturates when bpw
reaches Interference electrode

C=Q/V implies charge injected by
Interference will reach a maximum
value after reaching aggressor

C_P (Interf>Pwella1) vs. Width of BPW
Vdp ranges overlayed
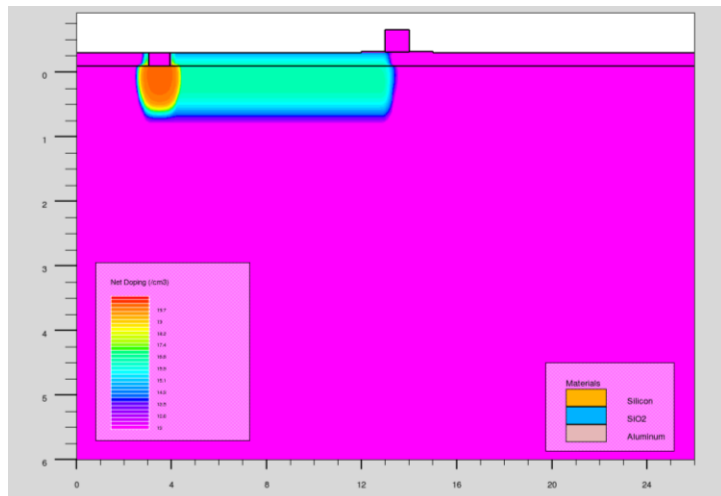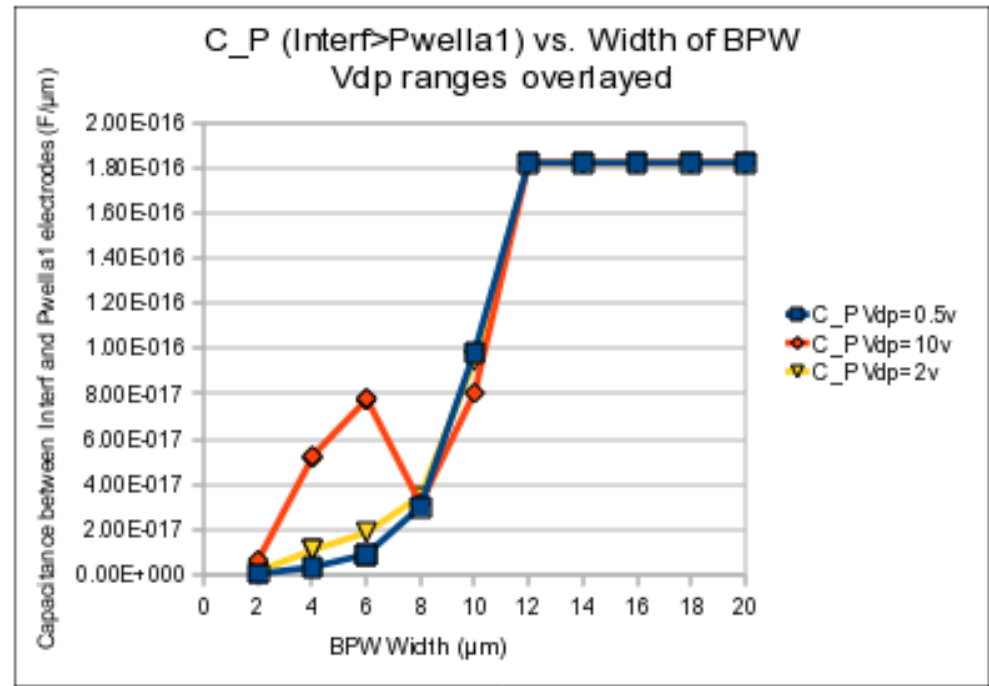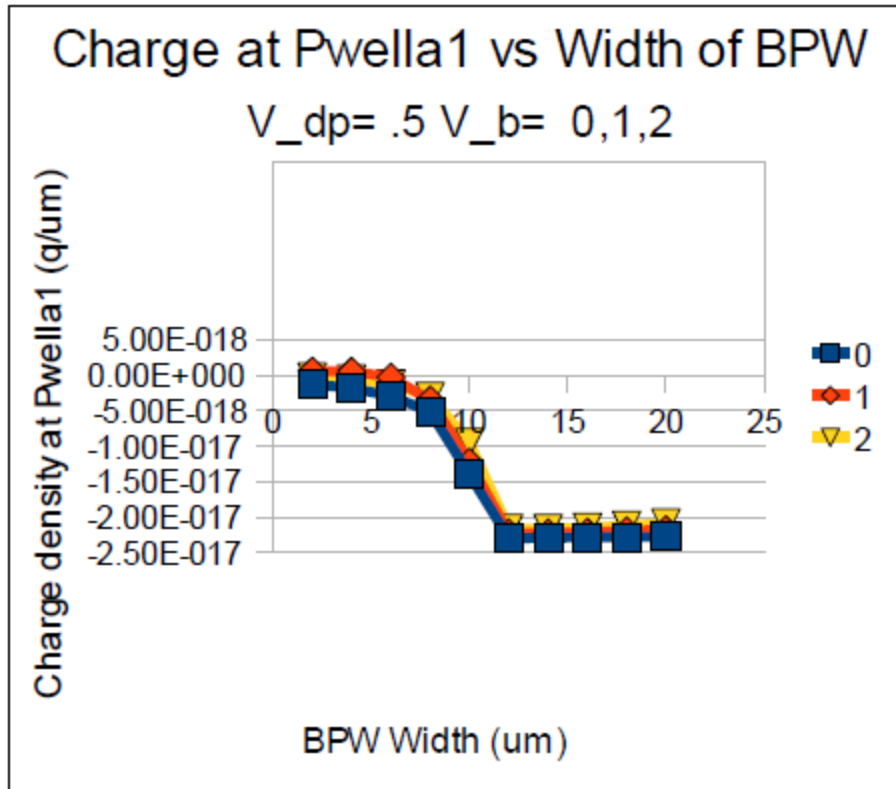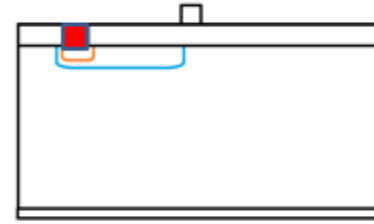

$$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$$

Charge Injection
-created through transient step voltage applied at the interference

-observe current generated

-agreement with capacitance observed in structure?
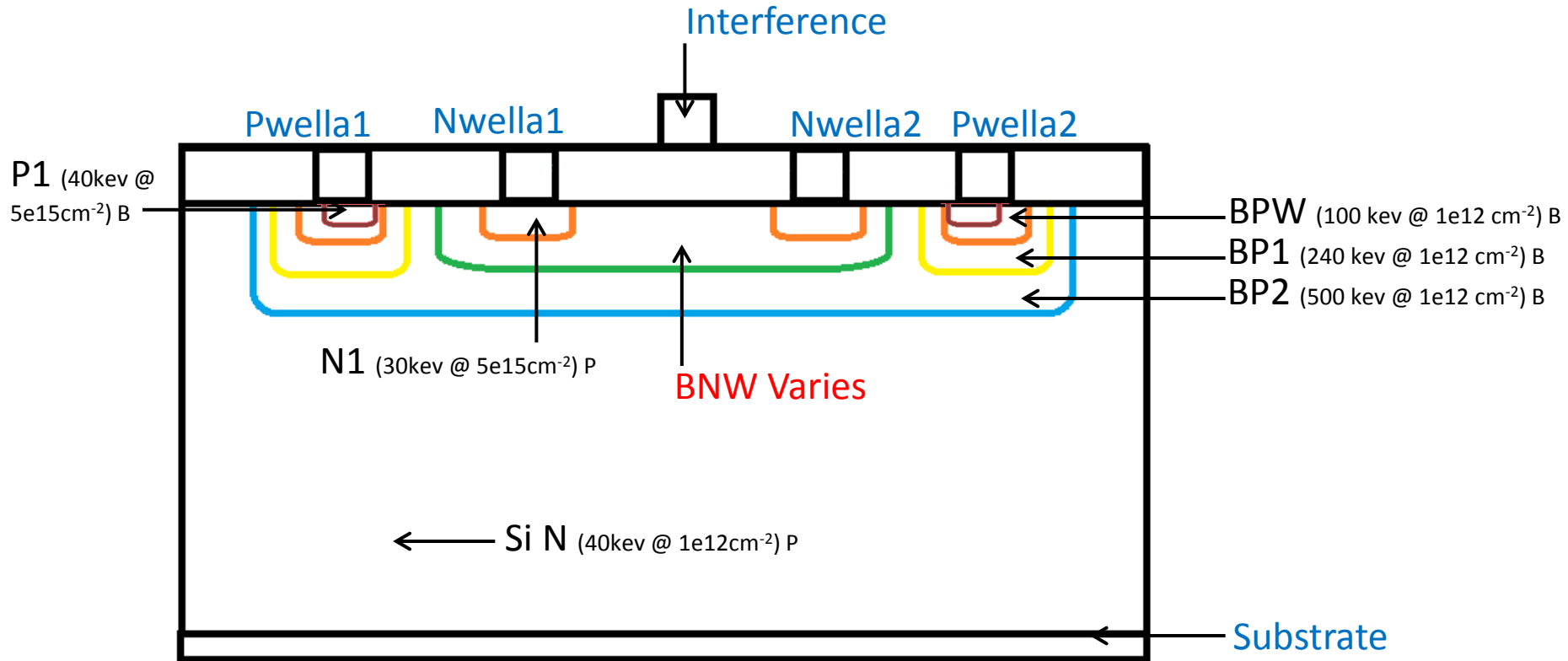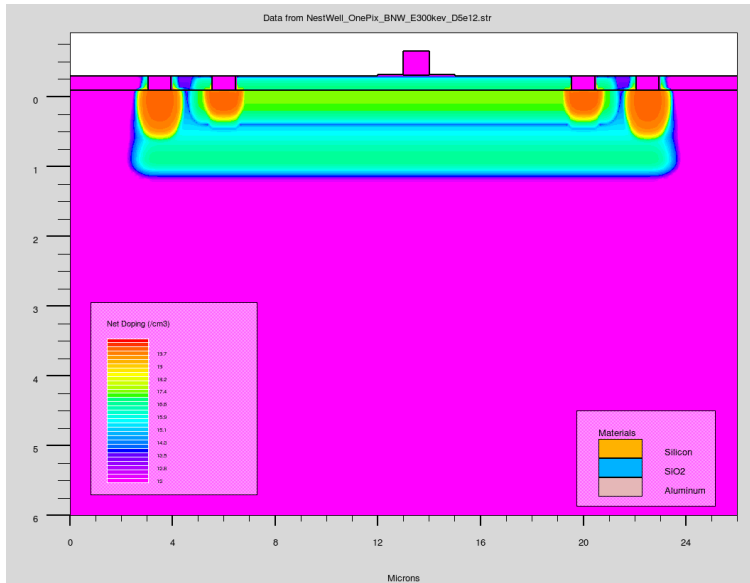
Q_P Charge accumulated at Pwella1

Charge at Pwella1 vs Width of BPW
V_dp= .5 V_b= 0,1,2

Charge density at Pwella1 (q/um)

5.00E-018
0.00E+000
-5.00E-018
-1.00E-017
-1.50E-017
-2.00E-017
-2.50E-017

0   5   10   15   20   25

BPW Width (um)

- 0
- 1
- 2

Maximum charge injected saturation as BPW reaches interference electrode

~ - 2.5e-17 maximum charge

$$\approx \frac{-2.5 * 10^{-17} q / \mu m}{1.6 * 10^{-19} q / e^{-}} \approx 156 e^{-} / \mu m$$
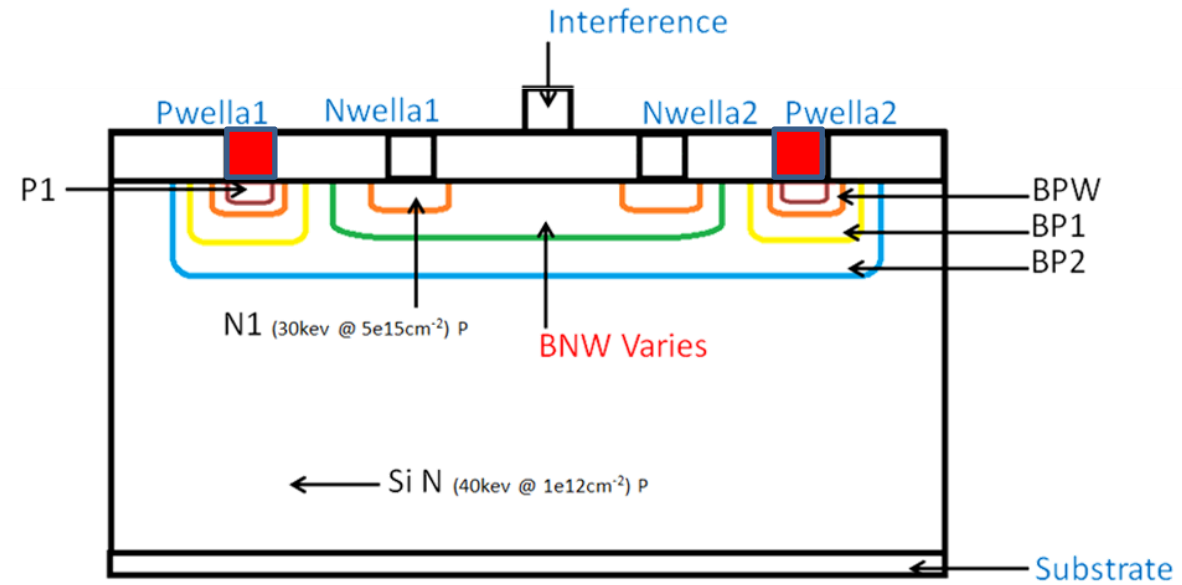
Nested Well Structure

Interference

Pwella1   Nwella1   Nwella2 Pwella2

P1 (40kev @ 5e15cm^{-2}) B

BPW (100 kev @ 1e12 cm^{-2}) B

BP1 (240 kev @ 1e12 cm^{-2}) B

BP2 (500 kev @ 1e12 cm^{-2}) B

N1 (30kev @ 5e15cm^{-2}) P

BNW Varies

Si N (40kev @ 1e12cm^{-2}) P

Substrate

Data from NestWell_OnePix_BNW_E300kev_D5e12.str

-Observe electrical characteristics as BNW dosing and energy of implantation changed

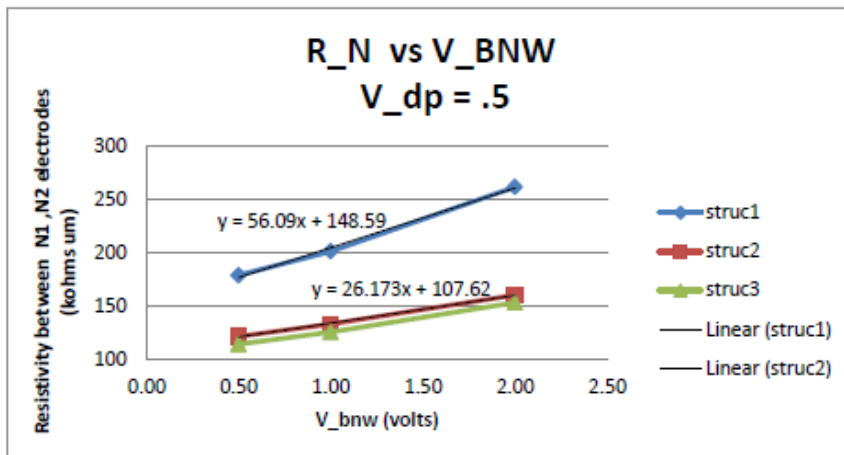|		Dose		
	Structure	1e12 cm-2	5e12 cm-2	1e13 cm-2
Energy	220 Kev	1	4	7
	300 Kev	2	5	8
	380 Kev	3	6	9
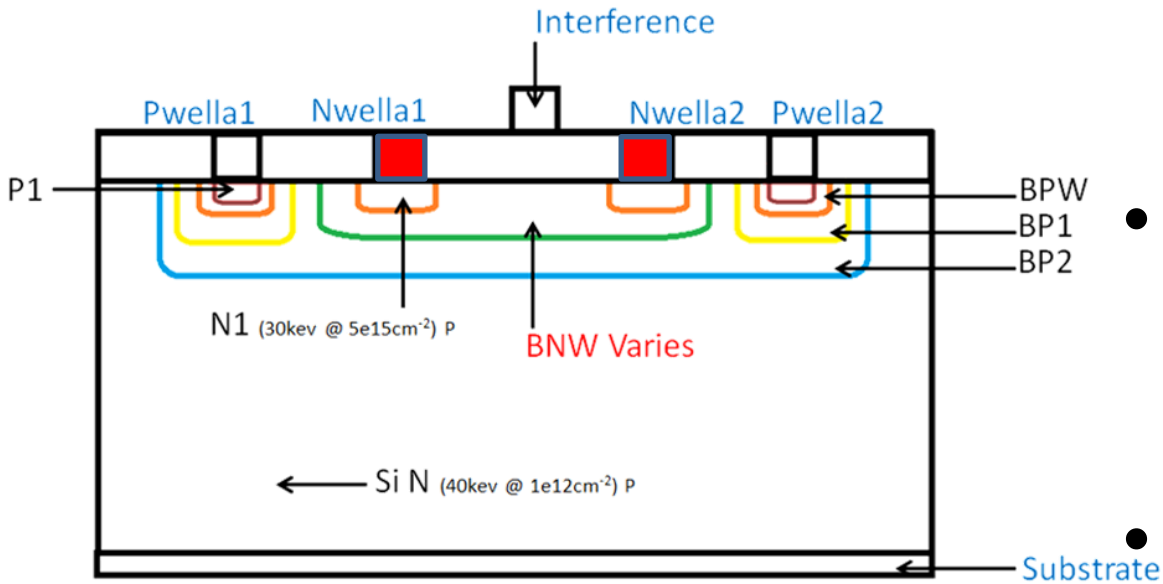
- R_N
  - Resistance across Nwella1 Nwella2
- R_P
  - Resistance across Pwella1 Pwella2

R_N vs V_BNW
V_dp = .5

$y = 56.09x + 148.59$

$y = 26.173x + 107.62$

R_N vs V_BNW
V_dp = .5

$y = 0.3728x + 15.834$
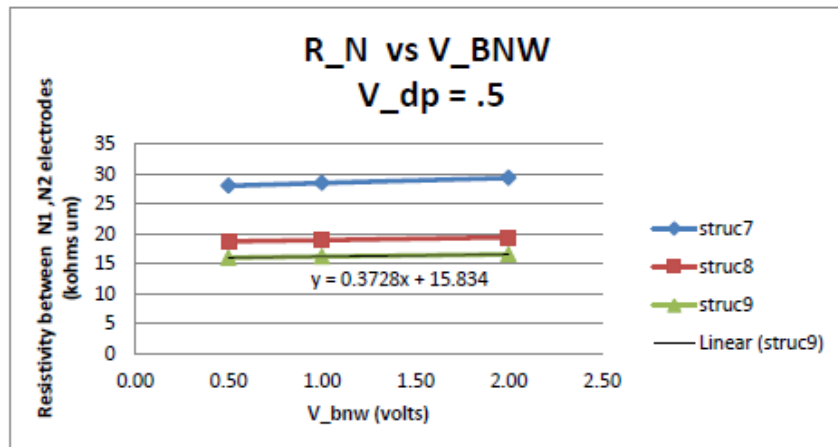
		Dose		
	Structure	1e12 cm-2	5e12 cm-2	1e13 cm-2
Energy	220 Kev	1	4	7
	300 Kev	2	5	8
	380 Kev	3	6	9

-Shallow and lower concentration produces higher resistance across N electrodes

-Here shown for 2D cross section simulation

R_N vs V_dp (.5v, 2v, 10v)
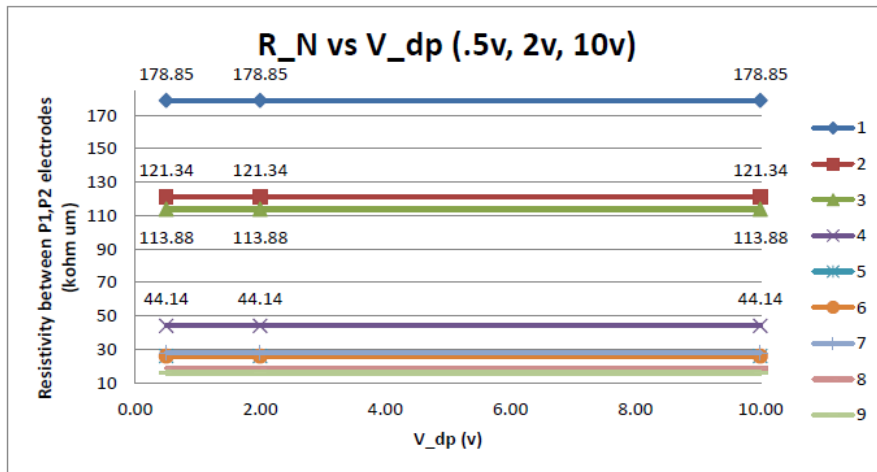
-Shows independence of R_N to changes in V_dp , isolation

R_P vs V_dp (.5v, 2v, 10v)
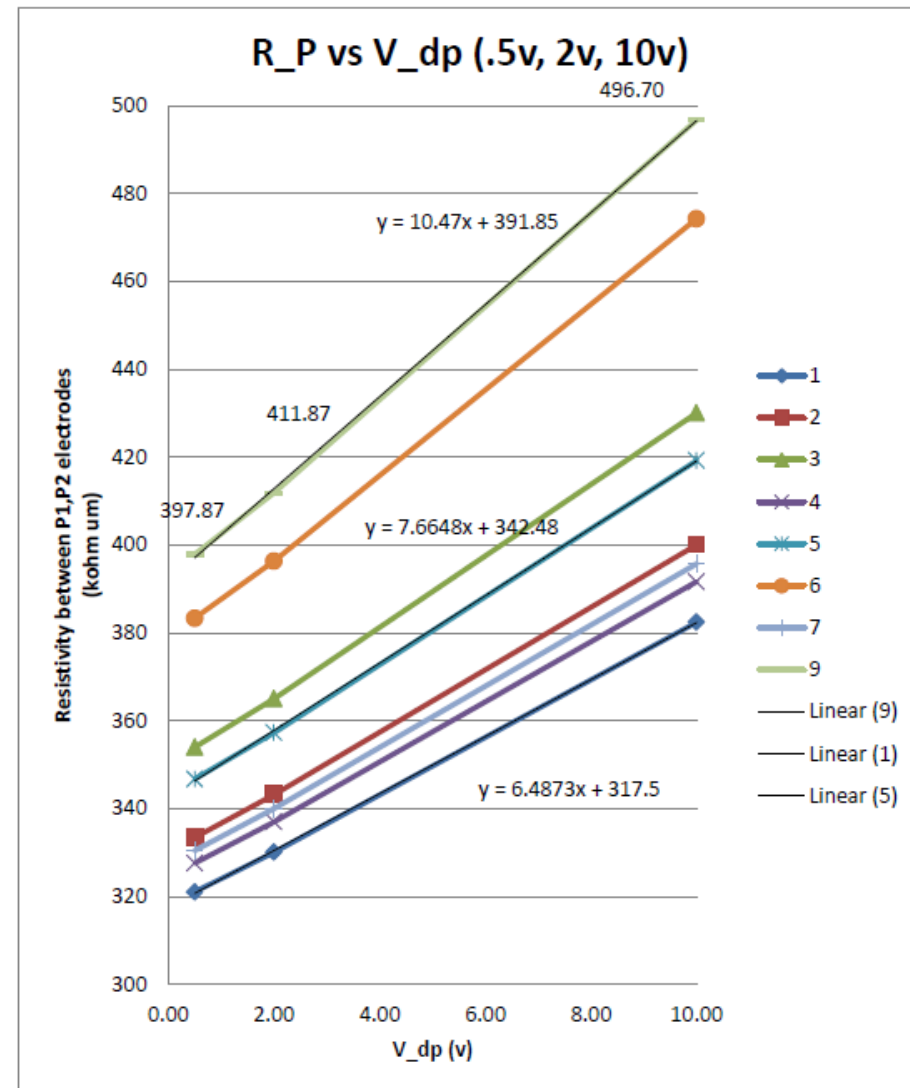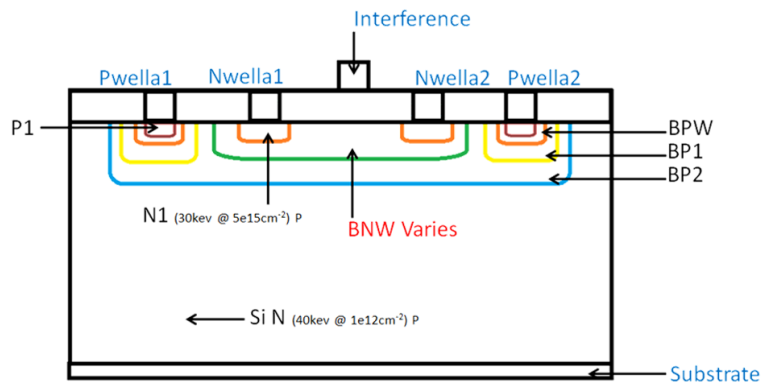
Capacitive Coupling
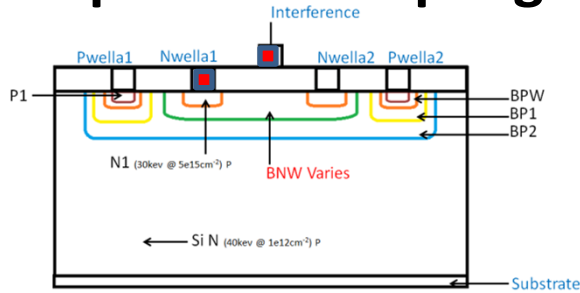
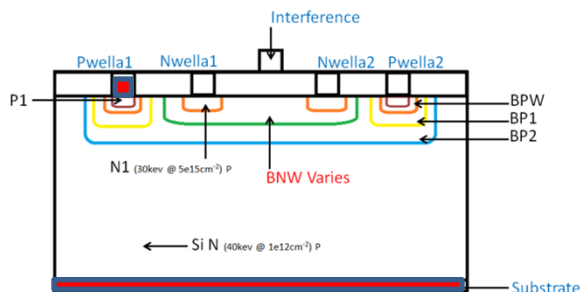## C_N

– Capacitance across Nwella1 and Aggressor

C_P
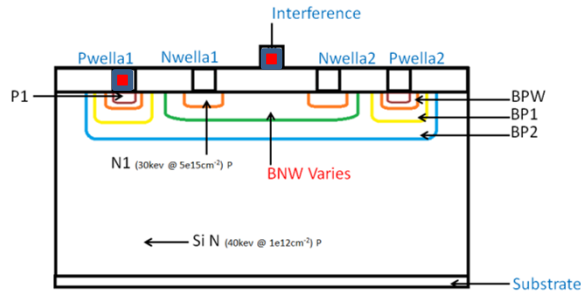
– Capacitance across Pwella1 and Aggressor
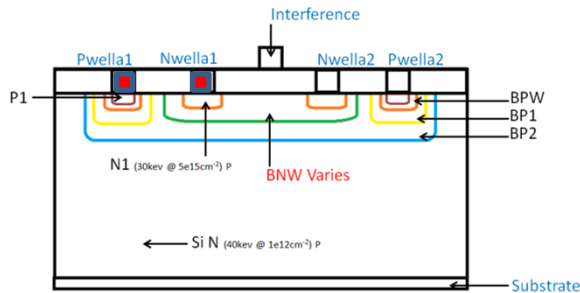
C_W

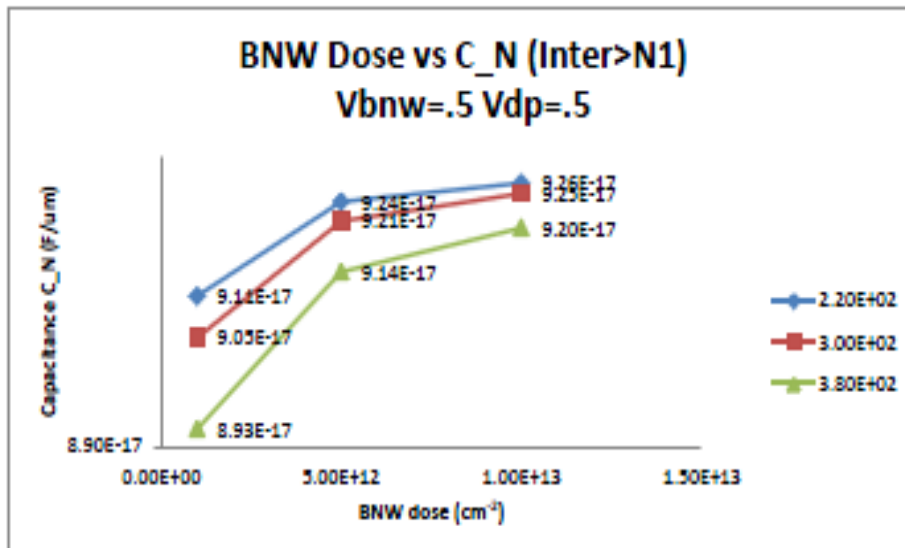– Pwella1 and Nwella1
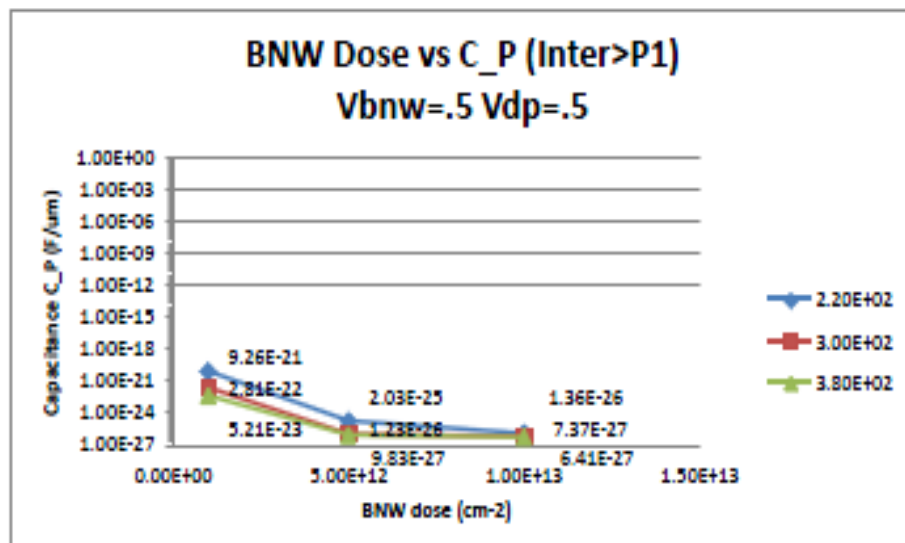
C_B

– Pwella1 and Substrate

BNW dose and energy Increment effect

BNW Dose vs C_N (Inter>N1)
Vbnw=.5 Vdp=.5

BNW Dose vs C_P (Inter>P1)
Vbnw=.5 Vdp=.5

-Capacitance increase for Inter>N1 decrease for Inter>P1

-Capacitance Inter>P1 lower when compared to primary BPW

-Less interaction from interference to pwella1, readout electronics

Future Work

3D structures

- compare observed 2D characteristics with 3D structure simulations
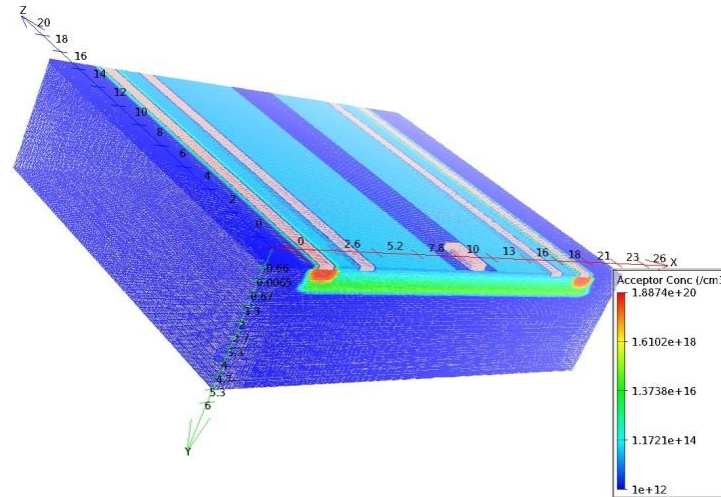
Prepare files for ease of future studies

Documentation

Shell script – "semi-automated structure tester"