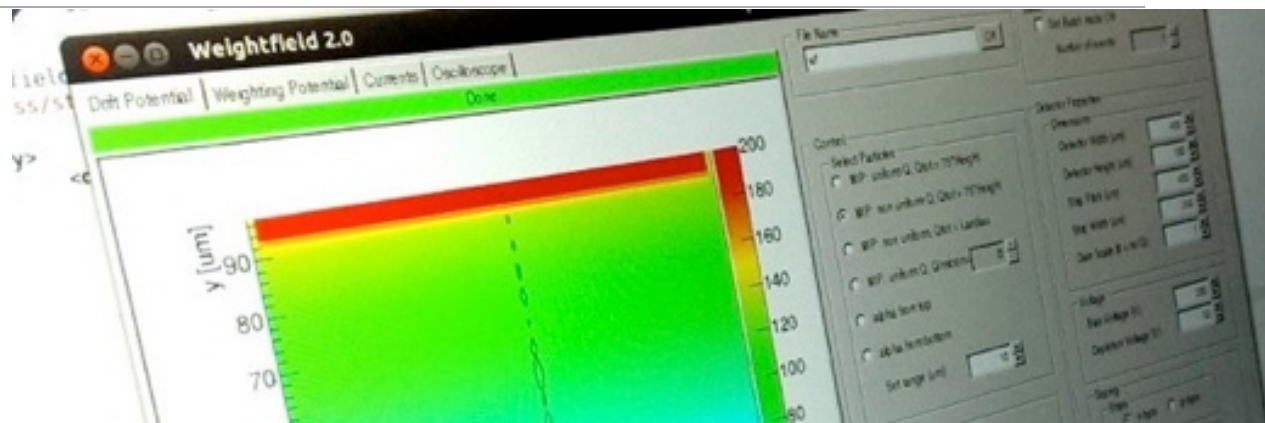


Weightfield2

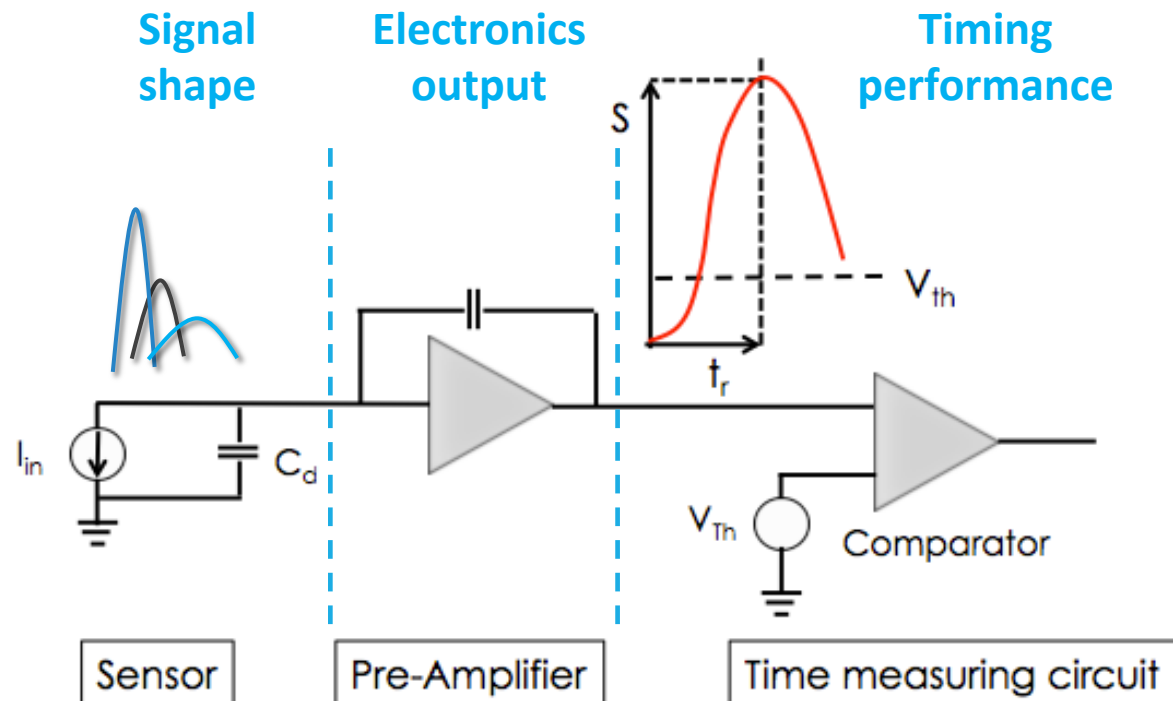
A friendly simulator for silicon detectors

V. Sola



Weightfield2 at a Glance

- ▷ A fast simulator program to study the performance of silicon and diamond detectors
- ▷ It simulates the entire signal chain

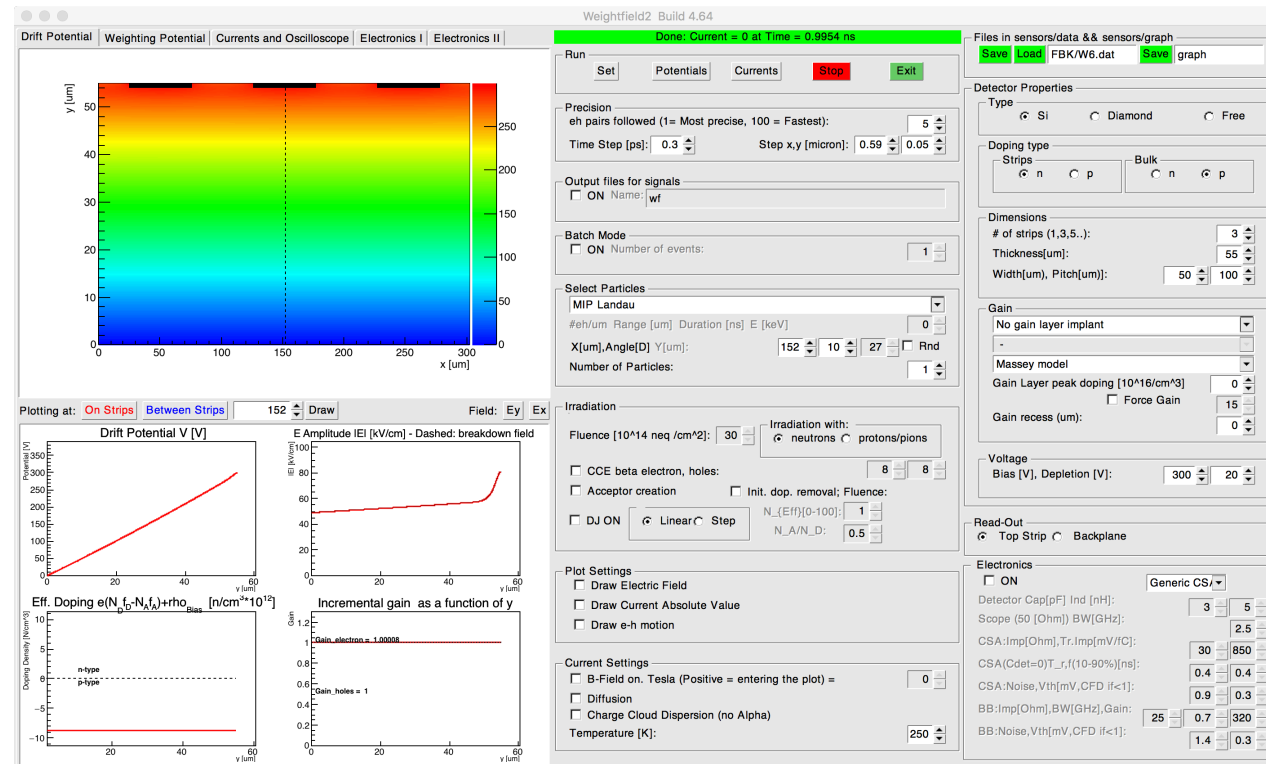


Weightfield2 at a Glance

Available at l.infn.it/wf2

It requires root(.cern.ch) build from source, it is for Linux and Mac-OS

It does not replace TCAD, but it helps in understanding the sensors response



Weightfield2 Highlights

- ▷ It is open source
- ▷ It is fast
- ▷ It generates the signal from several sources (MIP, alpha, lasers..)
- ▷ It runs in batch mode writing output file
- ▷ It loads/save configurations
- ▷ It performs basics electronics simulation

How to get it

1. Obtain the last version from l.infn.it/wf2
2. Unzip it
3. In a terminal, type "make" or "make -f Makefile_MacOS10.10_root6"
4. In the same terminal, type "./weightfield"

The [Manual](#) page explains the basic features of the program

Weightfield2 Layout

Controls

4 tabs: field, Weighting field, currents, and electronics

The screenshot displays the Weightfield2 software interface with several key components highlighted by red boxes:

- Top Tabs:** Drift Potential, Weighting Potential, Currents and Oscilloscope, Electronics I, Electronics II.
- Plot:** A 2D plot showing a color-coded field distribution over a 300x300 micrometer area. The y-axis ranges from 0 to 30, and the x-axis ranges from 0 to 300. A color scale on the right indicates values from 0 to 300.
- Run Panel:** Shows a status bar with "Done: Current = 0 at Time = 0.9954 ns". Below are buttons for "Set", "Potentials", "Currents", "Stop", and "Exit".
- Output Files:** A section for "Output files for signals" with a checkbox for "ON" and a text field for "Name" containing "wf".
- Batch Mode:** A section for "Batch Mode" with a checkbox for "ON" and a numeric field for "Number of events" set to 1.
- Select Particles:** A section for "Select Particles" with a dropdown menu set to "MIP", a numeric field for "#eh/u" set to 0, and a "Number of Particles" field set to 1.
- Irradiation:** A section for "Irradiation" with a "Fluence [10^14 neq/cm^2]" field set to 30, and options for "neutrons" and "protons/pions".
- Plot Settings:** A section for "Plot Settings" with checkboxes for "Draw Electric Field", "Draw Current Absolute Value", and "Draw e-h motion".
- Current Settings:** A section for "Current Settings" with checkboxes for "B-Field on. Tesla (Positive = entering the plot)", "Diffusion", and "Charge Cloud Dispersion (no Alpha)", and a "Temperature [K]" field set to 250.
- Files in sensors/data && sensors/graph:** A section with "Save", "Load", and "Save graph" buttons.
- Detector Properties:** A section for "Detector Properties" with options for "Type" (Si), "Doping type" (n), and "Dimensions" (# of strips, Thickness, Width, Pitch).
- Gain:** A section for "Gain" with a dropdown for "No gain layer implant" and various gain-related parameters.
- Voltage:** A section for "Voltage" with "Bias [V]" and "Depletion [V]" fields set to 300 and 20.
- Read-Out:** A section for "Read-Out" with a dropdown for "Top Strip" and "Backplane".
- Electronics:** A section for "Electronics" with a checkbox for "ON" and various electronic parameters like "Detector Cap", "Scope", "CSA", "BB", and "Noise".

The program can save/load your configuration and the plots

Batch and output file

B field, diffusion, charge cloud, temperature

Step 1: Select your sensor

The screenshot displays the Weightfield2 software interface (Build 4.64) with a focus on the 'Detector Properties' panel, which is highlighted with a red border. The interface includes a main plot area on the left showing a color-coded field distribution over a 300x50 micrometer area. The 'Detector Properties' panel contains the following settings:

- Run:** Done: Current = 0 at Time = 0.9954 ns. Buttons: Set, Potentials, Currents, Stop, Exit.
- Precision:** eh pairs followed (1= Most precise, 100 = Fastest): 5. Time Step [ps]: 0.3. Step x,y [micron]: 0.59, 0.05.
- Output files for signals:** ON Name: wf.
- Batch Mode:** ON Number of events: 1.
- Select Particles:** MIP Landau. #eh/um Range [um] Duration [ns] E [keV]: 0. X[um],Angle[D] Y[um]: 152, 10, 27. Rnd. Number of Particles: 1.
- Irradiation:** Fluence [10^14 neq /cm^2]: 30. Irradiation with: neutrons (checked), protons/pions. CCE beta electron, holes: 8, 8. Acceptor creation. Init. dop. removal; Fluence: N_{(Eff)}[0-100]: 1. DJ ON. Linear (checked), Step. N_A/N_D: 0.5.
- Plot Settings:** Draw Electric Field, Draw Current Absolute Value, Draw e-h motion.
- Current Settings:** B-Field on. Tesla (Positive = entering the plot) = 0. Diffusion. Charge Cloud Dispersion (no Alpha). Temperature [K]: 250.
- Detector Properties (highlighted):** Type: Si (checked), Diamond, Free. Doping type: Strips: n (checked), p. Bulk: n, p (checked). Dimensions: # of strips (1,3,5..): 3. Thickness[um]: 55. Width[um], Pitch[um]: 50, 100. Gain: No gain layer implant. Massey model. Gain Layer peak doping [10^16/cm^3]: 0. Force Gain. Gain recess (um): 0. Voltage: Bias [V], Depletion [V]: 300, 20.
- Read-Out:** Top Strip (checked), Backplane.
- Electronics:** ON. Detector Cap[pF] Ind [nH]: 3, 5. Scope (50 [Ohm]) BW[GHz]: 2.5. CSA:Imp[Ohm],Tr.Imp[mV/fC]: 30, 850. CSA(Cdet=0)T_r,f(10-90%)[ns]: 0.4, 0.4. CSA:Noise,Vth[mV,CFD if<1]: 0.9, 0.3. BB:Imp[Ohm],BW[GHz],Gain: 25, 0.7, 320. BB:Noise,Vth[mV,CFD if<1]: 1.4, 0.3.

Fields Computation

- ▷ The program loads your geometry
- ▷ It compute the silicon resistivity from the depletion voltage
- ▷ It uses an iterative method to compute:
 - The electric field
 - The weighting field

Step 1: E field

Weightfield2 Build 4.64

Done: Current = 0 at Time = 0.9954 ns

Run: Set Potentials Currents Stop Exit

Precision: eh pairs followed (1= Most precise, 100 = Fastest): 5

Time Step [ps]: 0.3 Step x,y [micron]: 0.59 0.05

Output files for signals: ON Name: wf

Batch Mode: ON Number of events: 1

Select Particles: MIP Landau

#eh/um Range [um] Duration [ns] E [keV]: 0

X[um],Angle[D] Y[um]: 152 10 27 Rnd

Number of Particles: 1

Irradiation: Fluence [10¹⁴ neq /cm²]: 30 Irradiation with: neutrons protons/pions

CCE beta electron, holes: 8 8

Acceptor creation Init. dop. removal; Fluence: N_{(Eff)}[0-100]: 1 N_A/N_D: 0.5

DJ ON Linear Step

Plot Settings: Draw Electric Field Draw Current Absolute Value Draw e-h motion

Current Settings: B-Field on. Tesla (Positive = entering the plot) = 0 Diffusion Charge Cloud Dispersion (no Alpha) Temperature [K]: 250

Files in sensors/data && sensors/graph: Save Load FBK/W6.dat Save graph

Detector Properties: Type: Si Diamond Free; Doping type: Strips n p Bulk n p; Dimensions: # of strips (1,3,5..): 3 Thickness[um]: 55 Width[um], Pitch[um]: 50 100; Gain: No gain layer implant Massey model Gain Layer peak doping [10¹⁶/cm³]: 0 Force Gain 15 Gain recess (um): 0; Voltage: Bias [V], Depletion [V]: 300 20

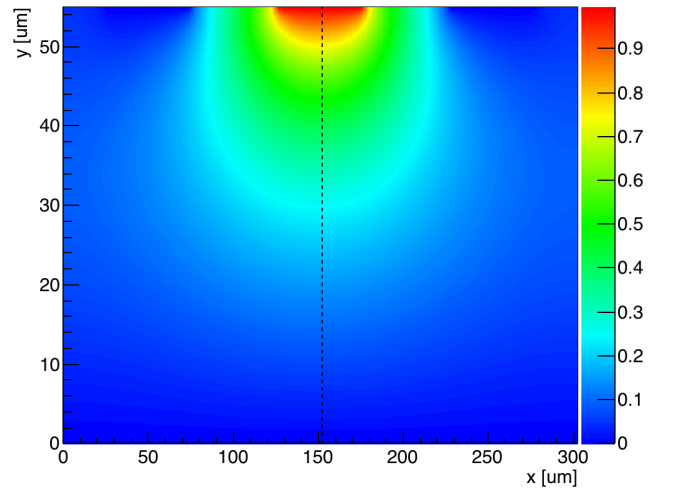
Read-Out: Top Strip Backplane

Electronics: ON Generic CS; Detector Cap[pF] Ind [nH]: 3 5; Scope (50 [Ohm]) BW[GHz]: 2.5; CSA:Imp[Ohm],Tr.Imp[mV/fC]: 30 850; CSA(Cdet=0)T_r,f(10-90%)[ns]: 0.4 0.4; CSA:Noise,Vth[mV,CFD if<1]: 0.9 0.3; BB:Imp[Ohm],BW[GHz],Gain: 25 0.7 320; BB:Noise,Vth[mV,CFD if<1]: 1.4 0.3

Step 1: W field

Weightfield2 Build 4.64

Drift Potential | Weighting Potential | Currents and Oscilloscope | Electronics I | Electronics II



Run: Done

Set Potentials Currents Stop Exit

Precision
eh pairs followed (1= Most precise, 100 = Fastest): 5

Time Step [ps]: 0.3 Step x,y [micron]: 0.59 0.05

Output files for signals
 ON Name: wf

Batch Mode
 ON Number of events: 1

Select Particles
MIP Landau

#eh/um Range [um] Duration [ns] E [keV] 0

X[um],Angle[D] Y[um]: 152 10 27 Rnd

Number of Particles: 1

Irradiation
Fluence [10¹⁴ neq /cm²]: 30 Irradiation with: neutrons protons/pions

CCE beta electron, holes: 8 8

Acceptor creation Init. dop. removal; Fluence: N_{(Eff)}[0-100]: 1

DJ ON Linear Step N_A/N_D: 0.5

Plot Settings
 Draw Electric Field
 Draw Current Absolute Value
 Draw e-h motion

Current Settings
 B-Field on. Tesla (Positive = entering the plot) = 0

Diffusion
 Charge Cloud Dispersion (no Alpha)
Temperature [K]: 250

Files in sensors/data && sensors/graph
Save Load FBK/W6.dat Save graph

Detector Properties

Type Si Diamond Free

Doping type
Strips n p Bulk n p

Dimensions
of strips (1,3,5..): 3
Thickness[um]: 55
Width[um], Pitch[um]: 50 100

Gain
No gain layer implant
-
Massey model
Gain Layer peak doping [10¹⁶/cm³]: 0
 Force Gain 15
Gain recess (um): 0

Voltage
Bias [V], Depletion [V]: 300 20

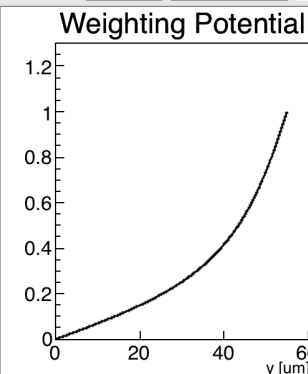
Read-Out
 Top Strip Backplane

Electronics
 ON Generic CS/

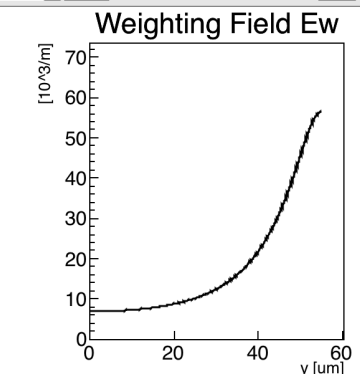
Detector Cap[pF] Ind [nH]: 3 5
Scope (50 [Ohm]) BW[GHz]: 2.5
CSA:Imp[Ohm],Tr.Imp[mV/fC]: 30 850
CSA(Cdet=0)T_r,f(10-90%)[ns]: 0.4 0.4
CSA:Noise,Vth[mV,CFD if<1]: 0.9 0.3
BB:Imp[Ohm],BW[GHz],Gain: 25 0.7 320
BB:Noise,Vth[mV,CFD if<1]: 1.4 0.3

Plotting at: On Strips Between Strips 152 Draw Field: IEyl IExl

Weighting Potential

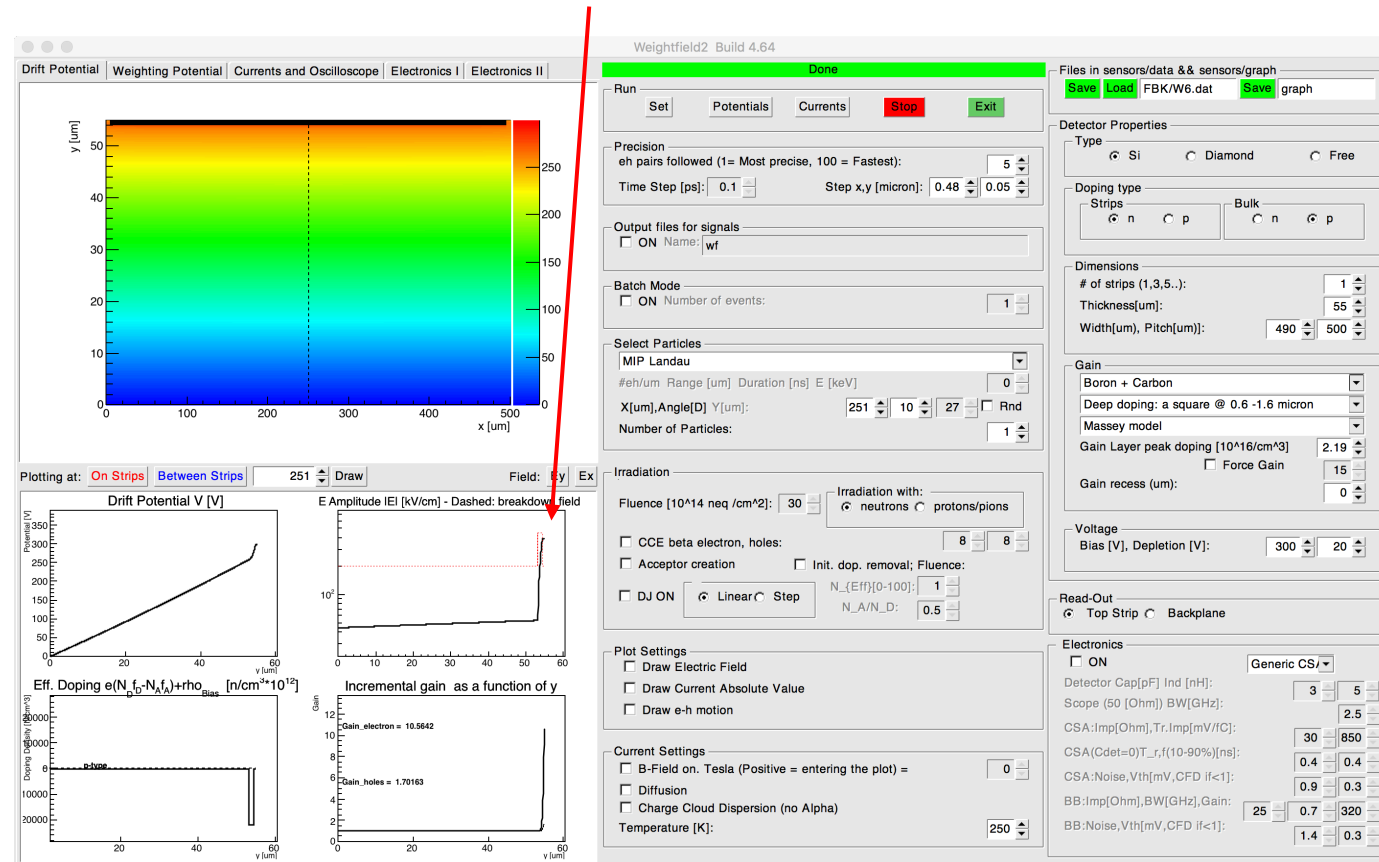


Weighting Field Ew



Select your sensor: does it have gain?

- ▶ The program implements a gain layer – LGAD design
- ▶ It computes the contribution from the additional doping to the electric field



Step 2: Select the particle

Weightfield2 Build 4.64

Drift Potential | Weighting Potential | Currents and Oscilloscope | Electronics I | Electronics II

Run: Done

Set Potentials Currents Stop Exit

Precision
eh pairs followed (1= Most precise, 100 = Fastest): 5

Time Step [ps]: 0.1 Step x,y [micron]: 0.48 0.05

Output files for signals
 ON Name: wf

Batch Mode
 ON Number of events: 1

Select Particles

- MIP Landau
- MIP: uniform Q, Qtot = $q \cdot [\#eh/um] \cdot Height$
- MIP: NON uniform Q, Qtot = $q \cdot [\#eh/um] \cdot Height$
- MIP Landau
- Laser (1064 nm): Top-TCT, $Q = q \cdot [\#eh/um] \cdot Height$
- Laser (1064 nm): Edge-TCT, $Q = q \cdot [\#eh/um] \cdot Height$
- Edge MIP Landau

Files in sensors/data && sensors/graph
Save Load FBK/W6.dat Save graph

Detector Properties

Type Si Diamond Free

Doping type
Strips n p Bulk n p

Dimensions
of strips (1,3,5..): 1
Thickness[um]: 55
Width[um], Pitch[um]: 490 500

Gain
Boron + Carbon
Deep doping: a square @ 0.6 -1.6 micron
Massey model
Gain Layer peak doping [$10^{16}/cm^3$]: 2.19
 Force Gain 15
Gain recess (um): 0

Voltage
Bias [V], Depletion [V]: 300 20

Read-Out
 Top Strip Backplane

Electronics
 ON Generic CS/
Detector Cap[pF] Ind [nH]: 3 5
Scope (50 [Ohm]) BW[GHz]: 2.5
CSA:Imp[Ohm],Tr.Imp[mV/fC]: 30 850
CSA(Cdet=0)T_r,f(10-90%)[ns]: 0.4 0.4
CSA:Noise,Vth[mV,CFD if<1]: 0.9 0.3
BB:Imp[Ohm],BW[GHz],Gain: 25 0.7 320
BB:Noise,Vth[mV,CFD if<1]: 1.4 0.3

Plotting at: On Strips Between Strips 251 Draw Field: Ey Ex

Drift Potential V [V]

E Amplitude |E| [kV/cm] - Dashed: breakdown field

Eff. Doping $e(N_D - N_A) + \rho_{Bias}$ [$n/cm^3 \cdot 10^{12}$]

Incremental gain as a function of y

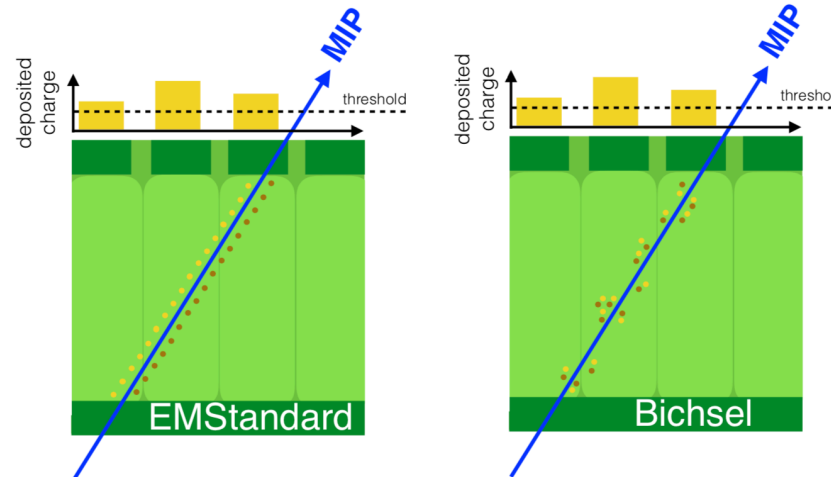
Irradiation
Fluence [10^{14} neq /cm²): 30 Irradiation with: neutrons protons/pions
 CCE beta electron, holes: 8 8
 Acceptor creation Init. dop. removal; Fluence:
 DJ ON Linear Step $N_{\{Eff\}[0-100]}$: 1
 N_A/N_D : 0.5

Plot Settings
 Draw Electric Field
 Draw Current Absolute Value
 Draw e-h motion

Current Settings
 B-Field on. Tesla (Positive = entering the plot) = 0
 Diffusion
 Charge Cloud Dispersion (no Alpha)
Temperature [K]: 250

Step 2: Charge deposition – Landau

The program uses GEANT4 with the photo-absorption ionization (PAI) model to generate non-uniform charge depositions



Results cross-checked with several publications, for example:

The Impact of Incorporating Shell-corrections to Energy Loss in Silicon

F. Wang, D. Su, B. Nachman, M. Garcia-Sciveres, and Q. Zeng

arXiv:1711.05465v2 [physics.ins-det]

“The ionization energy loss fluctuation in very thin silicon sensors significantly deviates from the Landau distribution. Therefore, we have developed a charge deposition setup that implements the Bichsel straggling function, which accounts for shell-effects.”

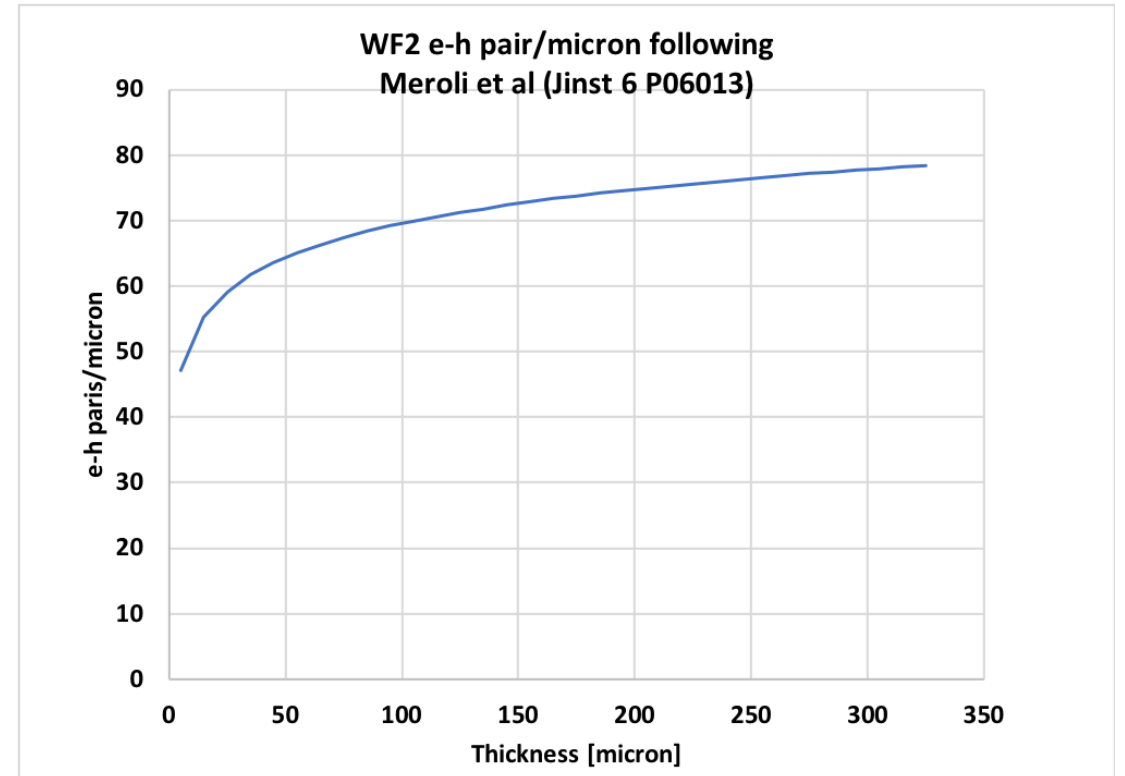
Step 2: Charge deposition – Landau

Landau distribution

$$\text{MPV} = d * [0.027 * \ln(d) + 0.126]$$

$$\text{FWHM} = 0.31 * d^{0.81}$$

$$\frac{\text{FWHM}}{\text{MPV}} = 2.1 * d^{-0.3}$$



Following Meroli et al (Jinst 6 P06013), these are the parameterizations of the MPV and FWHM as a function of the sensor thickness d for the Landau distribution in silicon

Step 2: Charge carriers drift

Weightfield2 Build 4.64

Done: Current = 0 at Time = 1.5101 ns

Run: Set Potentials Currents Stop Exit

Precision: eh pairs followed (1= Most precise, 100 = Fastest): 5

Time Step [ps]: 0.1 Step x,y [micron]: 0.48 0.05

Output files for signals: ON Name: wf

Batch Mode: ON Number of events: 1

Select Particles: MIP Landau

#eh/um Range [um] Duration [ns] E [keV]: 0

X[um],Angle[D] Y[um]: 251 10 27 Rnd

Number of Particles: 1

Irradiation: Fluence [10^14 neq /cm^2]: 30 Irradiation with: neutrons protons/pions

CCE beta electron, holes: 8 8

Acceptor creation Init. dop. removal; Fluence: N_{(Eff)}[0-100]: 1 N_A/N_D: 0.5

DJ ON Linear Step

Plot Settings: Draw Electric Field Draw Current Absolute Value Draw e-h motion

Current Settings: B-Field on. Tesla (Positive = entering the plot) = 0 Diffusion Charge Cloud Dispersion (no Alpha) Temperature [K]: 250

Files in sensors/data && sensors/graph: Save Load FBK/W6.dat Save graph

Detector Properties: Type: Si Diamond Free

Doping type: Strips: n p Bulk: n p

Dimensions: # of strips (1,3,5..): 1 Thickness[um]: 55 Width[um], Pitch[um]: 490 500

Gain: Boron + Carbon Deep doping: a square @ 0.6 -1.6 micron Massey model Gain Layer peak doping [10^16/cm^3]: 2.19 Force Gain: 15 Gain recess (um): 0

Voltage: Bias [V], Depletion [V]: 300 20

Read-Out: Top Strip Backplane

Electronics: ON Generic CS/ Detector Cap[pF] Ind [nH]: 3 5 Scope (50 [Ohm]) BW[GHz]: 2.5 CSA:Imp[Ohm],Tr.Imp[mV/fC]: 30 850 CSA(Cdet=0)T_r,f(10-90%)[ns]: 0.4 0.4 CSA:Noise,Vth[mV,CFD if<1]: 0.9 0.3 BB:Imp[Ohm],BW[GHz],Gain: 25 0.7 320 BB:Noise,Vth[mV,CFD if<1]: 1.4 0.3

Drift Potential Weighting Potential Currents and Oscilloscope Electronics I Electronics II

Plotting at: On Strips Between Strips 251 Draw Field: Ey Ex

Initial # of e/h in each 5 micron interval

Statistic	Value
Entries	11
Mean	322.5
Std Dev	97.95

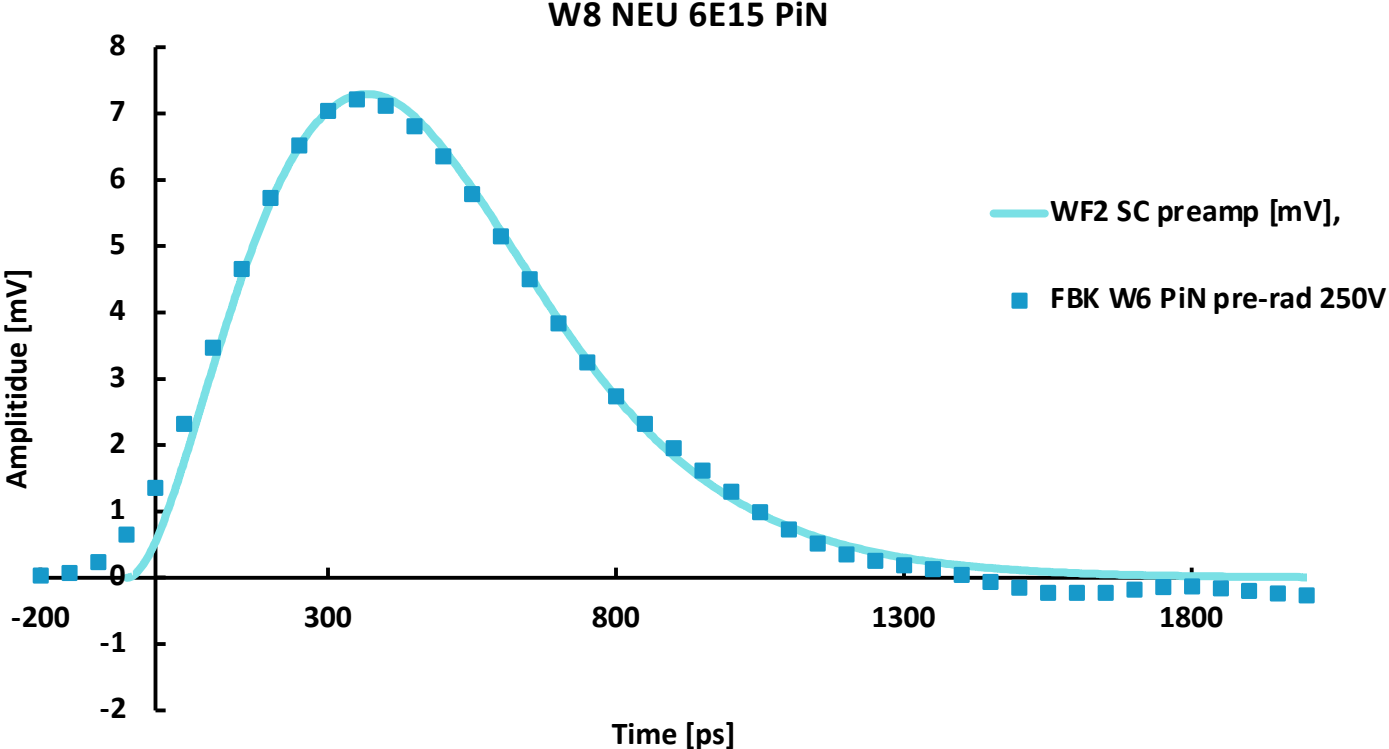
Drift of the charge carriers – Ramo's theorem

Current is generated using Ramo's theorem: $i(t) = qv(t)E_w$

$$I_{tot}(t_j) = \sum_{k=1}^n I_k(t_j) = -q \sum_{k=1}^n \overrightarrow{v_k}(t_j, x_k) \cdot \overrightarrow{E_w}(x_k)$$

	Electrons	Holes
$\mu(T) \text{ [m}^2/\text{Vs]}$	$0.1414 \left(\frac{T}{300K}\right)^{-2.5}$	$0.0470 \left(\frac{T}{300K}\right)^{-2.2}$
$\beta(T)$	$1.09 \left(\frac{T}{300K}\right)^{0.66}$	$1.213 \left(\frac{T}{300K}\right)^{0.17}$
$v_{Sat}(T) \text{ [m/s]}$	$1.07e5 \left(\frac{300K}{T}\right)^{0.87}$	$8.35e4 \left(\frac{300K}{T}\right)^{0.52}$
$v(x, T) \text{ [m/s]}$	$\frac{\mu_e(T)E_d(x)}{\frac{1}{\beta_e(T)} \sqrt{1 + \left(\frac{\mu_e(T)E_d(T)}{v_{e,Sat}(T)}\right)\beta_e(T)}}$	$\frac{\mu_h(T)E_d(x)}{\frac{1}{\beta_h(T)} \sqrt{1 + \left(\frac{\mu_h(T)E_d(x)}{v_{h,Sat}(T)}\right)\beta_h(T)}}$

WF2 – Data: current in PiN



Gain modelling

If the electric field is high enough, carriers generate secondary ionization along the drift path

$$N_e(x) = N_e e^{\beta x}$$

$$N_h(x) = N_h e^{\alpha x}$$

$$\alpha = A_n \exp\left\{-\frac{B_n}{E}\right\}$$

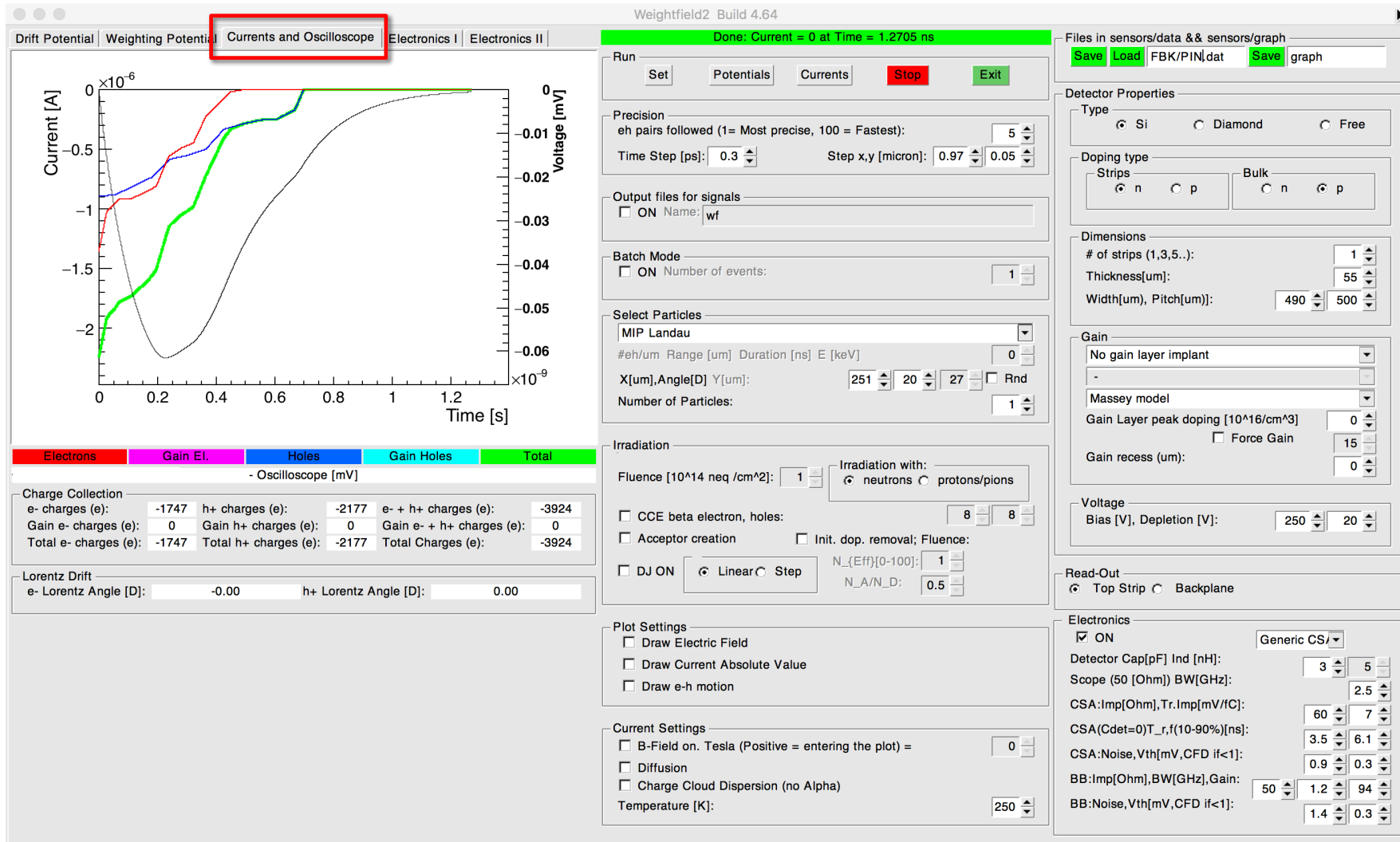
$$\beta = A_p \exp\left\{-\frac{B_p}{E}\right\}$$

$$B_{n,p}(T) = C_{n,p} + D_{n,p} T$$

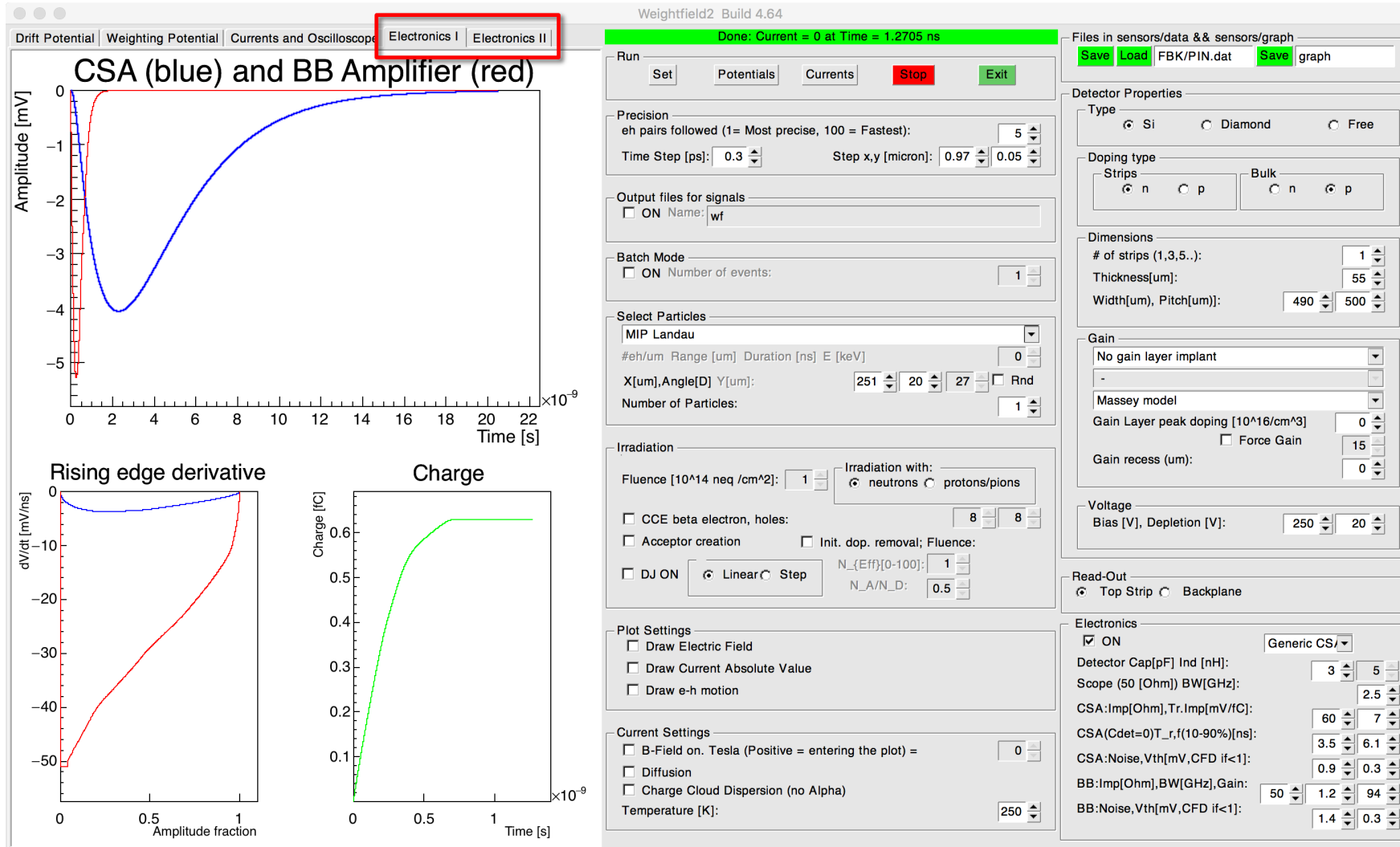
Different impact ionisation models can be selected:

- Massey
- van Overstraeten-de Man
- Okuto-Crowell
- Bologna

WF2 – Currents



WF2 – Electronics



Step 4: Radiation damage

Weightfield2 Build 4.64

Done: Current = 0 at Time = 1.5101 ns

Run:

Precision
eh pairs followed (1= Most precise, 100 = Fastest):

Time Step [ps]: Step x,y [micron]:

Output files for signals
 ON Name:

Batch Mode
 ON Number of events:

Select Particles
MIP Landau

#eh/um Range [um] Duration [ns] E [keV]

X[um],Angle[D] Y[um]: Rnd

Number of Particles:

Files in sensors/data && sensors/graph
 FBK/W6.dat graph

Detector Properties
Type: Si Diamond Free

Doping type
Strips: n p Bulk: n p

Dimensions
of strips (1,3,5..):
Thickness[um]:
Width[um], Pitch[um]:

Gain
Boron + Carbon
Deep doping: a square @ 0.6 -1.6 micron
Massey model
Gain Layer peak doping [$10^{16}/\text{cm}^3$]:
 Force Gain
Gain recess (um):

Voltage
Bias [V], Depletion [V]:

Read-Out
 Top Strip Backplane

Electronics
 ON Generic CS/
Detector Cap[pF] Ind [nH]:
Scope (50 [Ohm]) BW[GHz]:
CSA:Imp[Ohm],Tr.Imp[mV/fC]:
CSA(Cdet=0)T_r,f(10-90%)[ns]:
CSA:Noise,Vth[mV,CFD if<1]:
BB:Imp[Ohm],BW[GHz],Gain:
BB:Noise,Vth[mV,CFD if<1]:

Plotting at: On Strips Between Strips Draw Field: Ey Ex

Initial # of e/h in each 5 micron interval

Enhist

Entries	11
Mean	322.5
Std Dev	97.95

Irradiation
Fluence [10^{14} neq/cm²]: Irradiation with: neutrons protons/pions

CCE beta electron, holes:
 Acceptor creation Init. dop. removal; Fluence:
 DJ ON Linear Step N_(Eff)[0-100]:
N_A/N_D:

Plot Settings
 Draw Electric Field
 Draw Current Absolute Value
 Draw e-h motion

Current Settings
 B-Field on. Tesla (Positive = entering the plot) =
 Diffusion
 Charge Cloud Dispersion (no Alpha)
Temperature [K]:

Radiation damage effects

Charge trapping with fluence ϕ :

$$i(t) = i(t)_{new} e^{-t/\tau}$$

$$\tau = \beta\phi$$

Acceptor removal:

$$N(\phi) = N(0) * e^{-c\phi}$$

Acceptor creation:

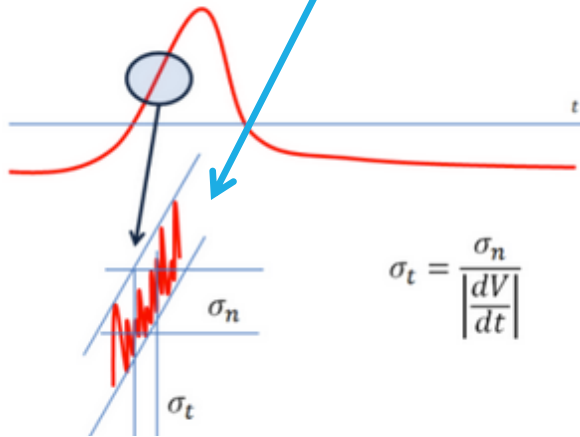
$$N(\phi) = \beta\phi$$

Time resolution

$$\sigma_t = \left(\frac{N}{dV/dt} \right)^2 + (\text{Landau Shape})^2 + \text{TDC}$$

Usual "Jitter" term

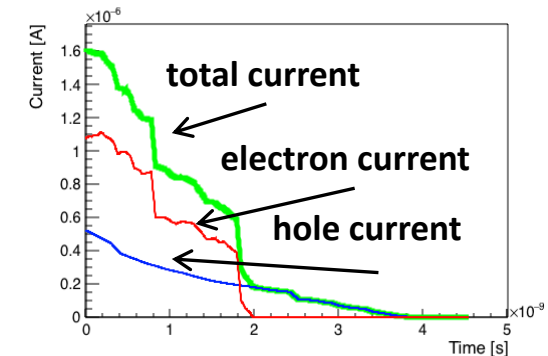
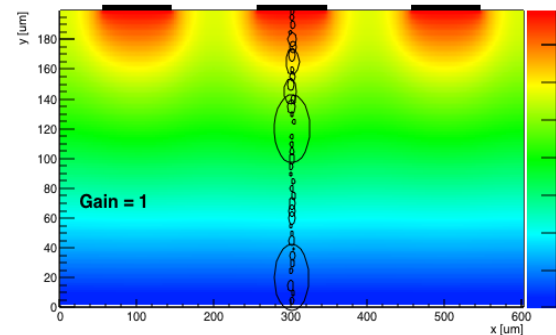
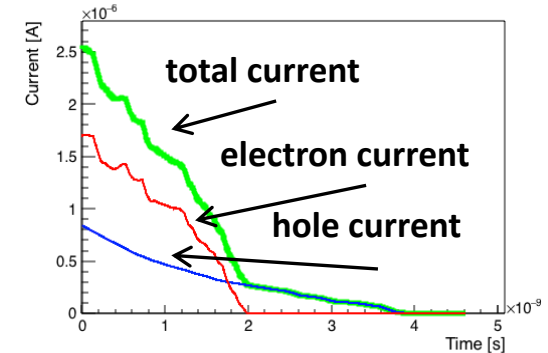
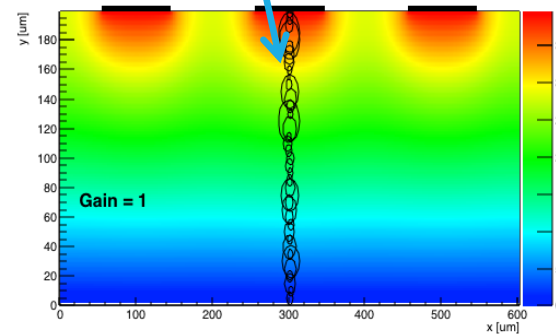
Here enters everything that is "Noise"
and the steepness of the signal



Need large dV/dt

Time walk: Amplitude variation, corrected in electronics

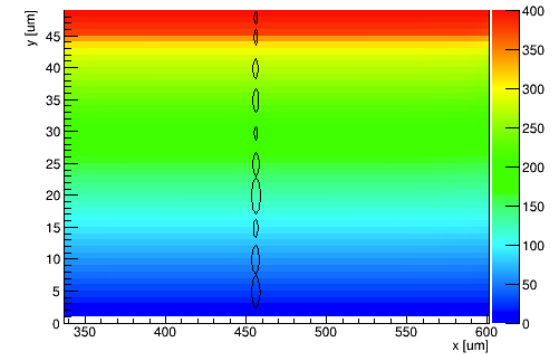
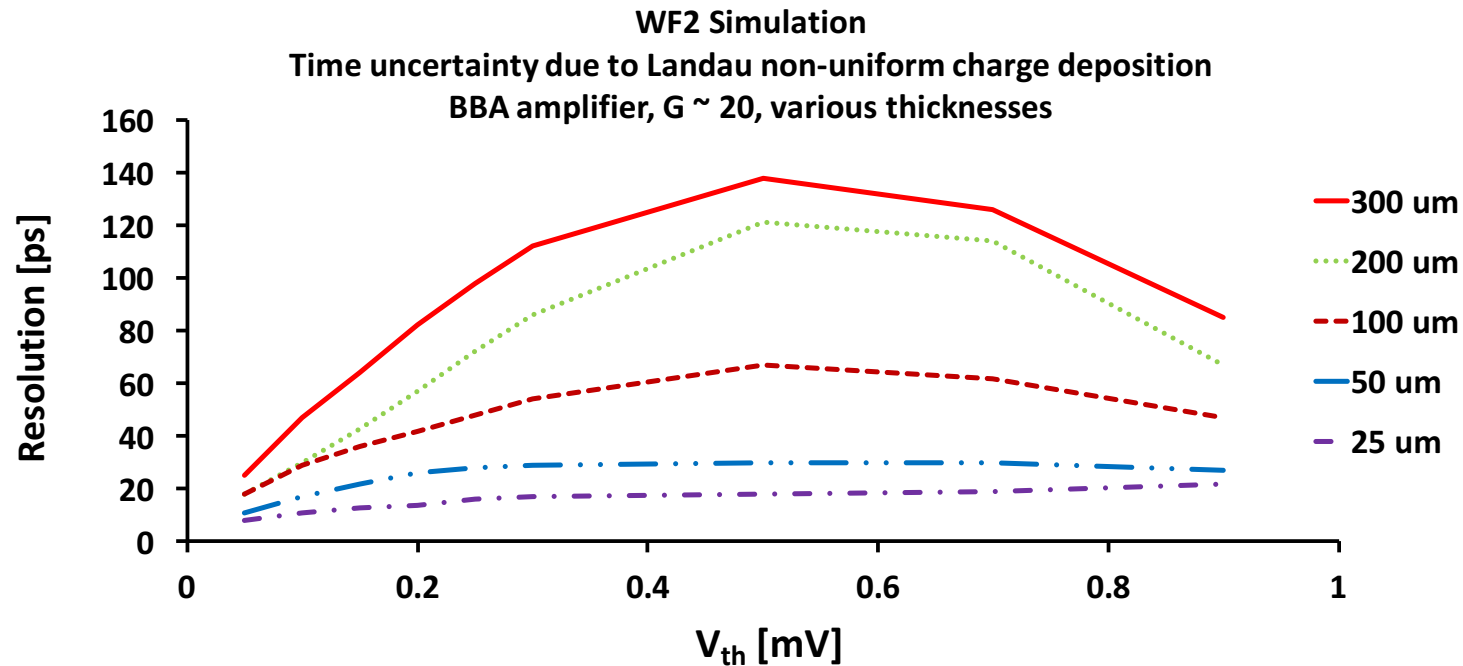
Shape variations: non-homogeneous energy deposition



Non-uniform charge deposition

This is a physical limit to time resolution

Need to use thin detectors and low comparator threshold



- ➔ Set the comparator threshold as low as you can
- ➔ Use thin sensors

Batch mode: deposited & collected charges

Weightfield2 Build 4.64

Done running in batch.

Run: Set Potentials Currents **Stop** Exit

Precision: eh pairs followed (1= Most precise, 100 = Fastest): 5

Time Step [ps]: 0.1 Step x,y [micron]: 0.97 0.05

Output files for signals: ON Name: wf

Batch Mode: ON Number of events: 100

Select Particles: MIP Landau

#eh/um Range [um] Duration [ns] E [keV]: 0

X[um],Angle[D] Y[um]: 251 20 27 Rnd

Number of Particles: 1

Files in sensors/data && sensors/graph: Save Load FBK/W6.dat Save graph

Detector Properties: Type: Si Diamond Free

Doping type: Strips: n p Bulk: n p

Dimensions: # of strips (1,3,5..): 1 Thickness[um]: 55 Width[um], Pitch[um]: 490 500

Gain: Boron + Carbon Deep doping: a square @ 0.6 -1.6 micron Massey model Gain Layer peak doping [$10^{16}/\text{cm}^3$]: 2.19 Force Gain Gain recess (um): 15 0

Voltage: Bias [V], Depletion [V]: 300 20

Read-Out: Top Strip Backplane

Electronics: ON CSA SC Detector Cap[pF] Ind [nH]: 3 5 Scope (50 [Ohm]) BW[GHz]: 2.5 CSA:Imp[Ohm],Tr.Imp[mV/fC]: 30 880 CSA(Cdet=0)T_r,f(10-90%)[ns]: 0.4 0.4 CSA:Noise,Vth[mV,CFD if<1]: 1.3 0.3 BB:Imp[Ohm],BW[GHz],Gain: 50 1.2 94 BB:Noise,Vth[mV,CFD if<1]: 1.4 0.3

Drift Potential | Weighting Potential | Currents and Oscilloscope | Electronics I | Electronics II

Gain = 12.8626

Plotting at: On Strips Between Strips 251 Draw Field: Ey Ex

Generated average # of e-h per micron

Enhist	
Entries	100
Mean	97.7
Std Dev	52.49
χ^2 / ndf	11.64 / 15
Constant	114.2 ± 20.0
MPV	70.51 ± 1.86
Sigma	8.438 ± 1.301

Measured average # of e-h per micron

MeasEnhist	
Entries	100
Mean	1198
Std Dev	653.3
χ^2 / ndf	16.83 / 29
Constant	36.81 ± 5.87
MPV	873.1 ± 33.0
Sigma	138 ± 21.3

Fluence [10^{14} neq/cm²]: 1 Irradiation with: neutrons protons/pions

CCE beta electron, holes: 8 8

Init. dop. removal; Fluence: N_{Eff}[0-100]: 1 N_A/N_D: 0.5

Plot Settings: Draw Electric Field Draw Current Absolute Value Draw e-h motion

Charge Cloud Dispersion (no Alpha): entering the plot = 0

Temperature [K]: 250

Deposited charge

Collected charge

Batch mode: time resolution

The screenshot displays the Weightfield2 software interface (Build 4.64) in batch mode. The main window is titled "Done running in batch." and contains several panels:

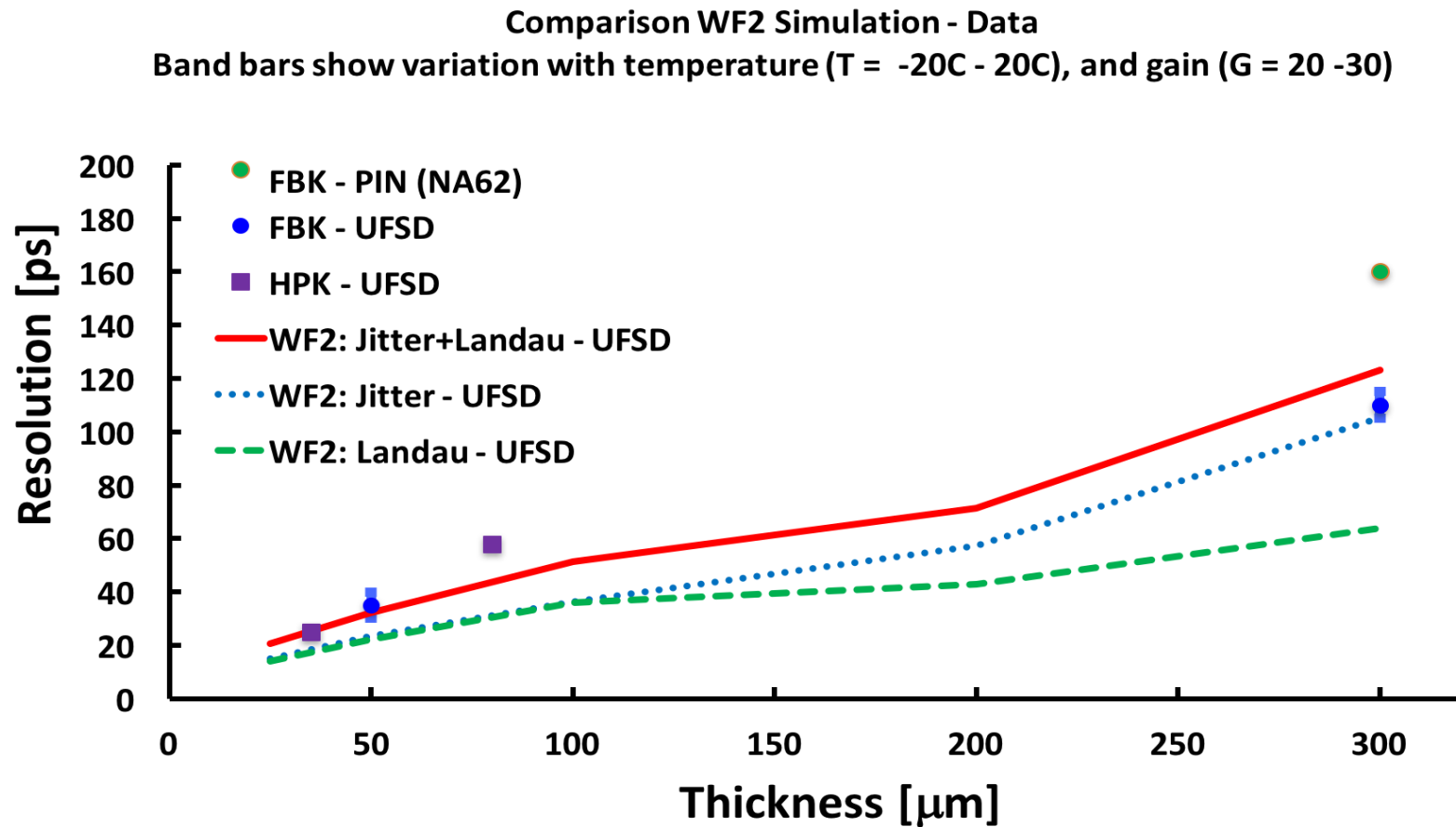
- BB Time Resolution:** A histogram showing the distribution of time resolution. The x-axis is "Time [ns]" (0 to 0.6) and the y-axis is "Entries" (0 to 15). A red curve is overlaid on the histogram. A table titled "BBtvthhist" provides summary statistics:

Parameter	Value
Entries	100
Mean	0.2151
Std Dev	0.03226
χ^2 / ndf	13.23 / 12
Constant	9.989 ± 1.535
Mean	0.2115 ± 0.0045
Sigma	0.03674 ± 0.00525
- BB Time Over Threshold:** A scatter plot showing the relationship between time over threshold and time of arrival. The x-axis is "Time over Threshold [ns]" (0 to 1.6) and the y-axis is "T_{arrival}" (0 to 0.7). The plot shows a cluster of blue data points.
- Configuration Panels:**
 - Run:** Includes buttons for "Set", "Potentials", "Currents", "Stop", and "Exit".
 - Precision:** "eh pairs followed (1= Most precise, 100 = Fastest):" set to 5. "Time Step [ps]:" set to 0.1. "Step x,y [micron]:" set to 0.97 and 0.05.
 - Output files for signals:** Includes a field for "ON Name:" and a "100" value.
 - Select Particles:** "MIP Landau" selected. "#eh/um Range [um] Duration [ns] E [keV]" set to 0. "X[um],Angle[D] Y[um]:" set to 251, 20, 27. "Number of Particles:" set to 1.
 - Irradiation:** "Fluence [10¹⁴ neq /cm²):" set to 1. "Irradiation with:" set to "neutrons". "CCE beta electron, holes:" set to 8 and 8. "Acceptor creation" and "Init. dop. removal;" are unchecked. "DJ ON" is checked with "Linear" selected. "N_{(Eff)}[0-100]:" set to 1. "N_A/N_D:" set to 0.5.
 - Detector Properties:** "Type" set to "Si". "Doping type" set to "Bulk" with "n" selected. "Dimensions" include "# of strips (1,3,5..):" set to 1, "Thickness[um]:" set to 55, and "Width[um], Pitch[um]:" set to 490 and 500. "Gain" includes "Boron + Carbon" selected, "Deep doping: a square @ 0.6 -1.6 micron", "Massey model", "Gain Layer peak doping [10¹⁶/cm³]" set to 2.19, "Force Gain" unchecked, and "Gain recess (um):" set to 0. "Voltage" includes "Bias [V], Depletion [V]:" set to 300 and 20.
 - Read-Out:** "Top Strip" selected.
 - Electronics:** "ON" checked. "CSA SC" selected. "Detector Cap[pF] Ind [nH]:" set to 3 and 5. "Scope (50 [Ohm]) BW[GHz]:" set to 2.5. "CSA:Imp[Ohm],Tr.Imp[mV/fC]:" set to 30 and 880. "CSA(Cdet=0)T_r,f(10-90%)[ns]:" set to 0.4 and 0.4. "CSA:Noise,Vth[mV,CFD if<1]:" set to 1.3 and 0.3. "BB:Imp[Ohm],BW[GHz],Gain:" set to 50, 1.2, and 94. "BB:Noise,Vth[mV,CFD if<1]:" set to 1.4 and 0.3.

Time resolution

ToA vs ToT

Time resolution vs thickness

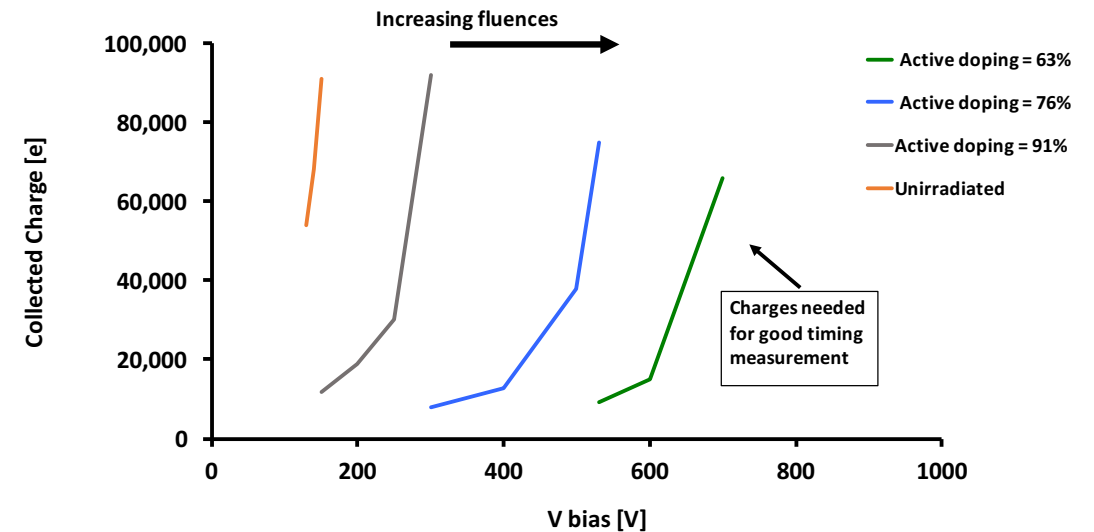
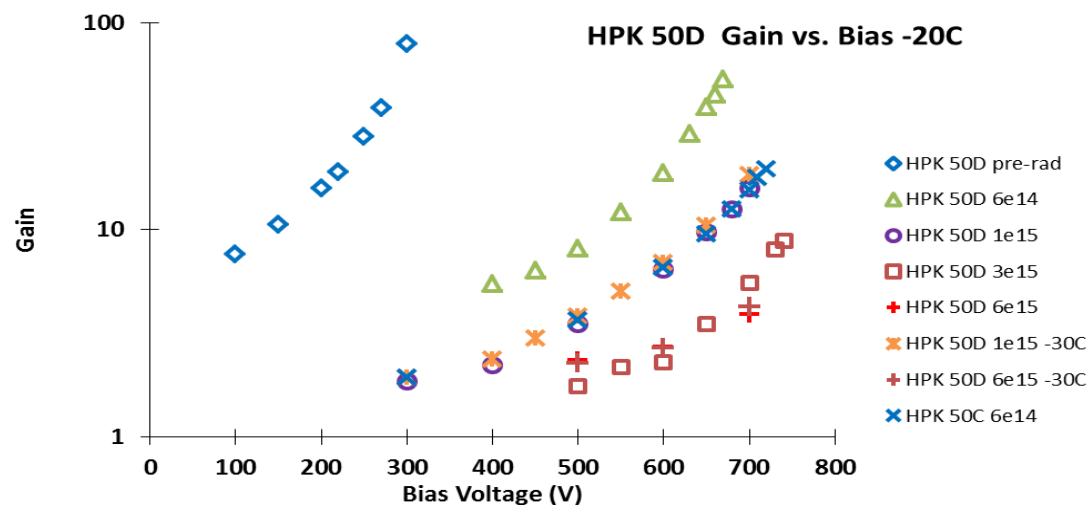


Compensation with V_{bias}

Due to irradiation, the gain layer atoms get deactivated (acceptor removal)

The necessary field can be recovered by increasing the external V_{bias} :

proven to work up to $5 \cdot 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$

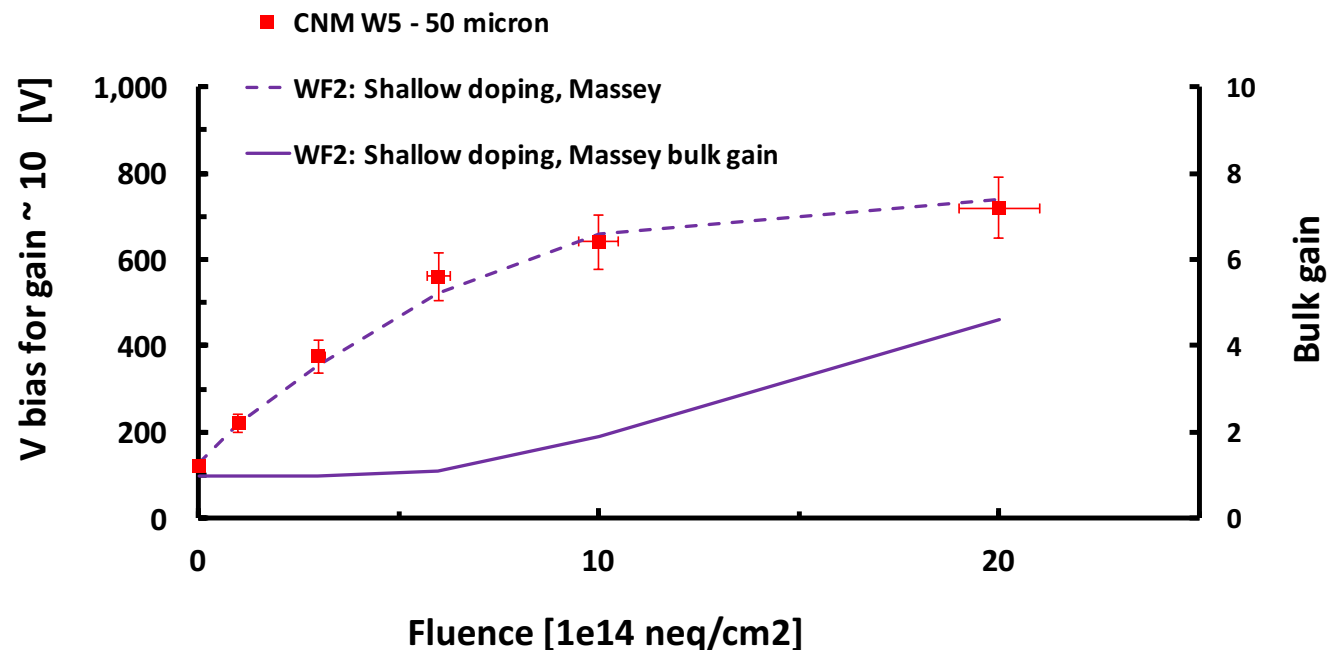


Compensation with V_{bias}

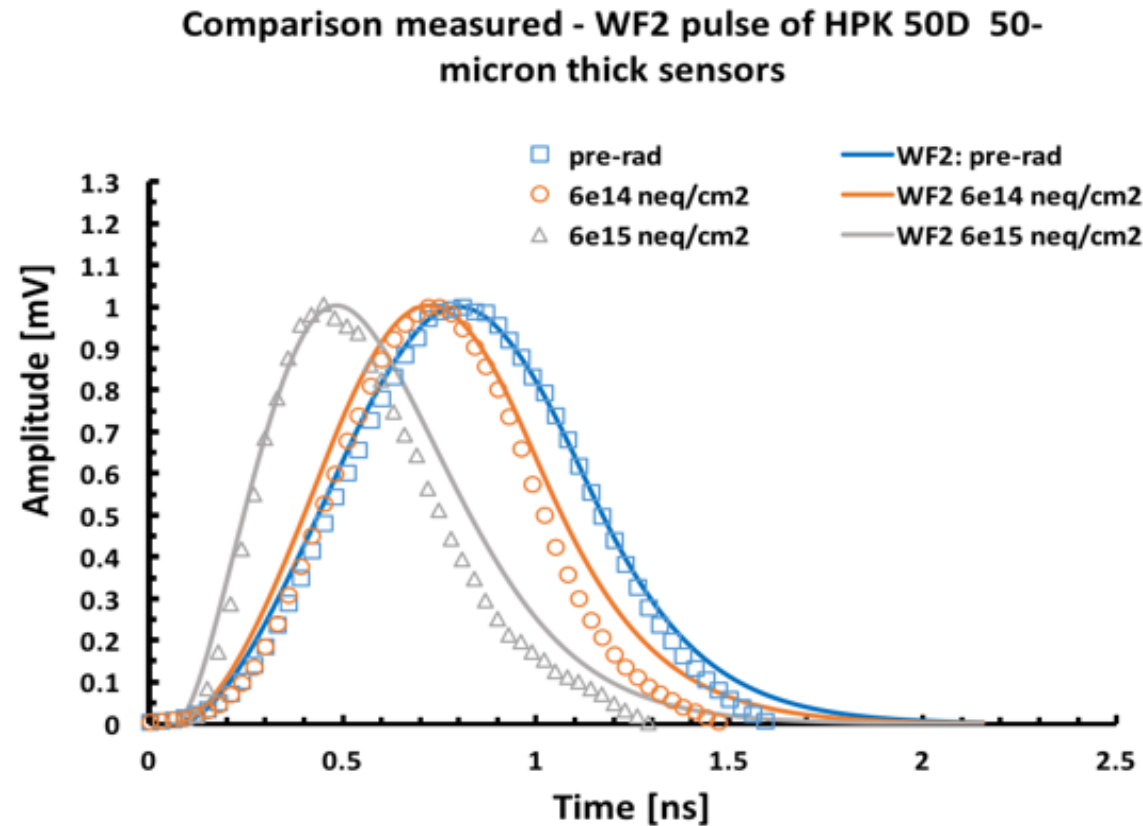
As the gain layer density decreases, we need to increase the external voltages to create the E_{field} needed for multiplications

In so doing, the gain moves from the gain layer to the bulk

Bias voltage to obtain Gain ~ 10 as a function of fluence



Pulse shape in irradiated sensors



With irradiation the signal changes: it becomes shorter and steeper

Summary

- ▷ Weightfield2 is a rather easy to use simulator for silicon sensors
- ▷ It can help the user's intuition in deciding the best solutions
- ▷ It is fully configurable by the user

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