

# **Weightfield2: a Fast Simulator for Silicon and Diamond solid state detector**

- Explanation of the program
- Graphical interface and currents calculation
- Base and new features

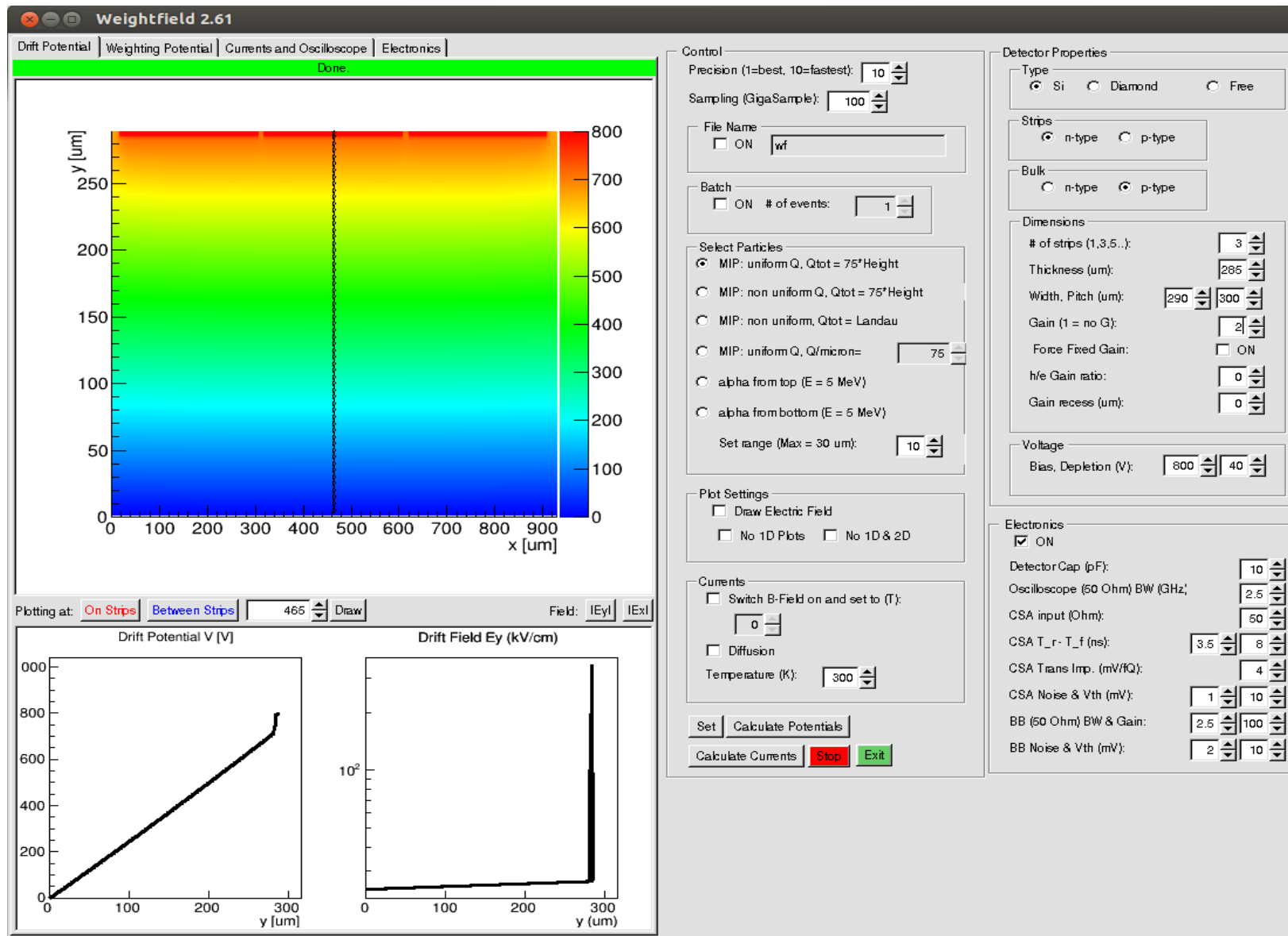
**Francesca Cenna**  
with

**N. Cartiglia, V. Fadeyev, M. Friedl, B. Kolbinger, F. Marchetto,  
A. Picerno, F. Ravera, H. Sadrozinski, A. Seiden, A. Solano, Anton Zatserklyaniy,  
Andriy Zatserklyaniy**

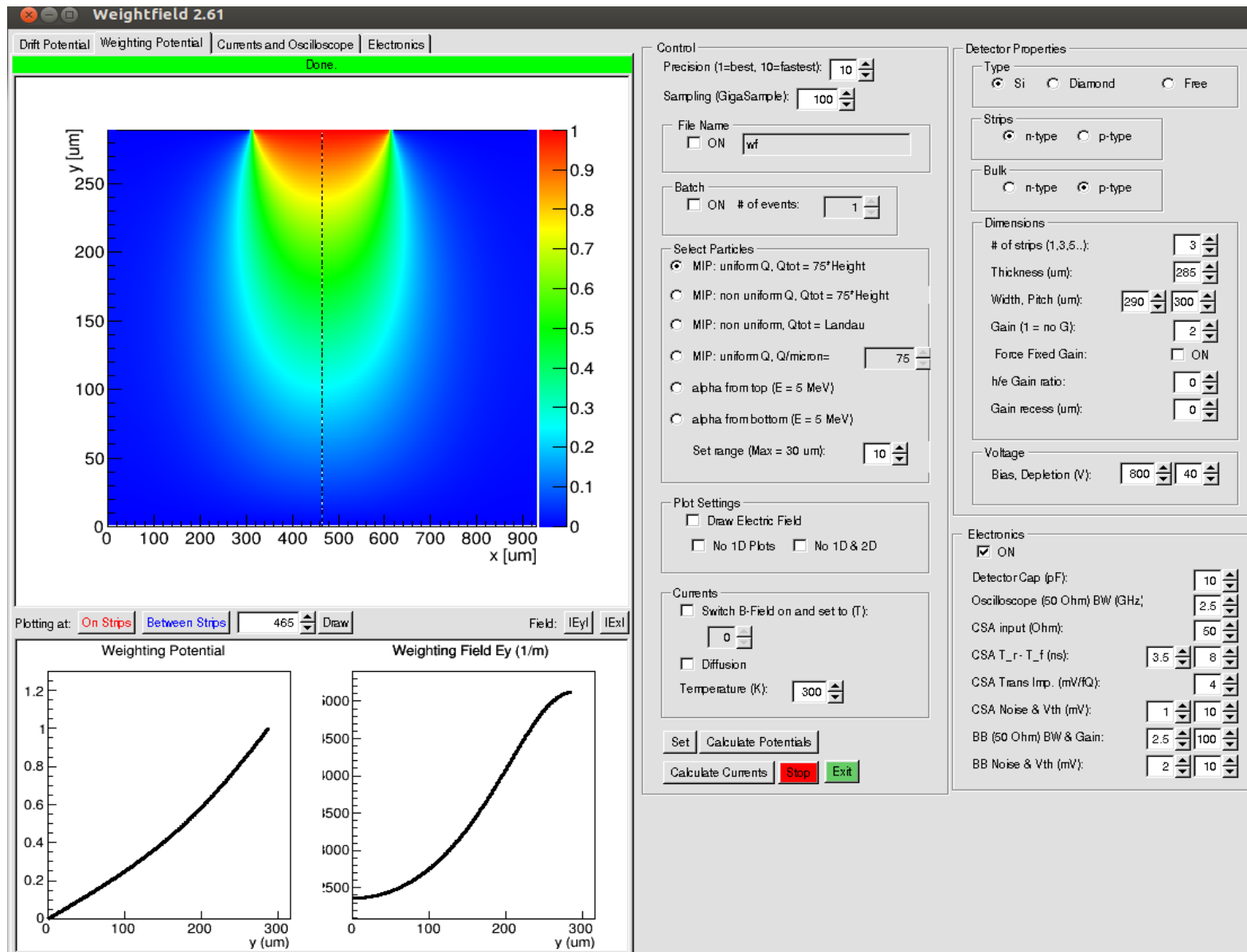
# Weightfield 2

- Tool to study signals in UFSD  
presented at 9<sup>th</sup> Trento Workshop on Advanced Radiation Detectors  
<http://indico.cern.ch/event/273880/session/4/contribution/59/material/slides/0.pdf>
- Weightfield 2 is based on *Weightfield* by M. Friedl and B. Kolbinger (HEPHY Vienna)  
<http://www.hephy.at/en/research/departments/semiconductor-detectors/detector-simulation>
- Written in C++ language, uses ROOT graphical interface TGUI
- Program features:
  - calculates induced currents with Ramo's Theorem  $I = -e v(x) E_w$
  - solves Poisson's equation using Vdep (not from doping)
  - draws electric field
  - allows to set temperature and magnetic field
  - allows to simulate non uniform charge deposition
  - allows to set gain
  - simulates oscilloscope and shaper
- **New features:**
  - Extended electronics simulator
  - Time walk curve in batch mode
  - Updated gain mechanism
  - Diamond simulator

# Graphical Interface

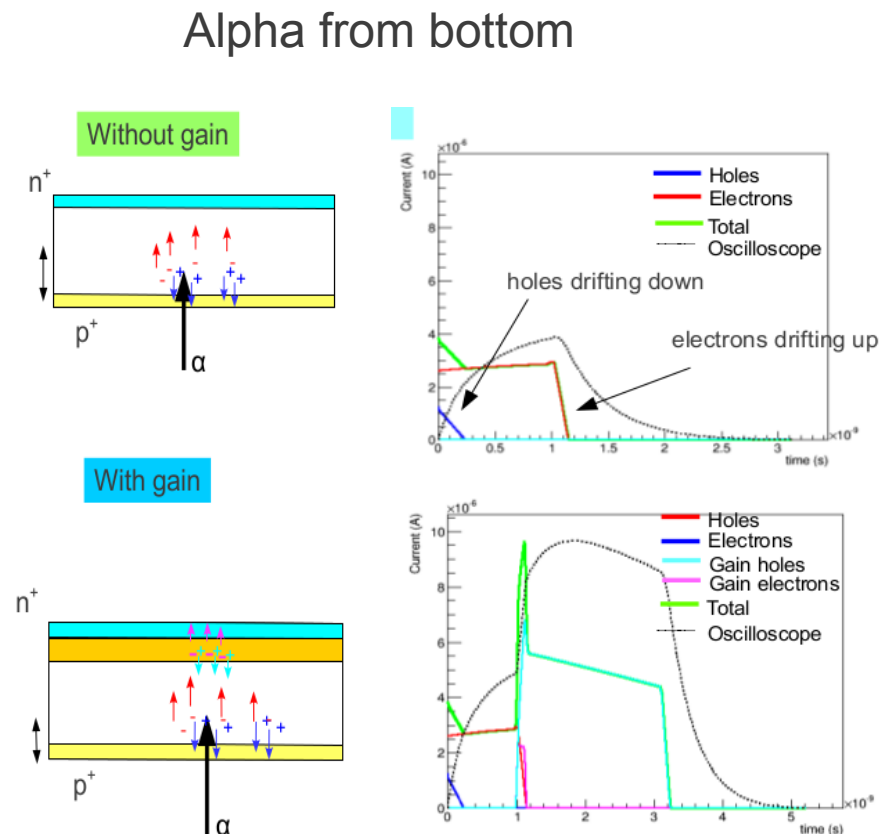
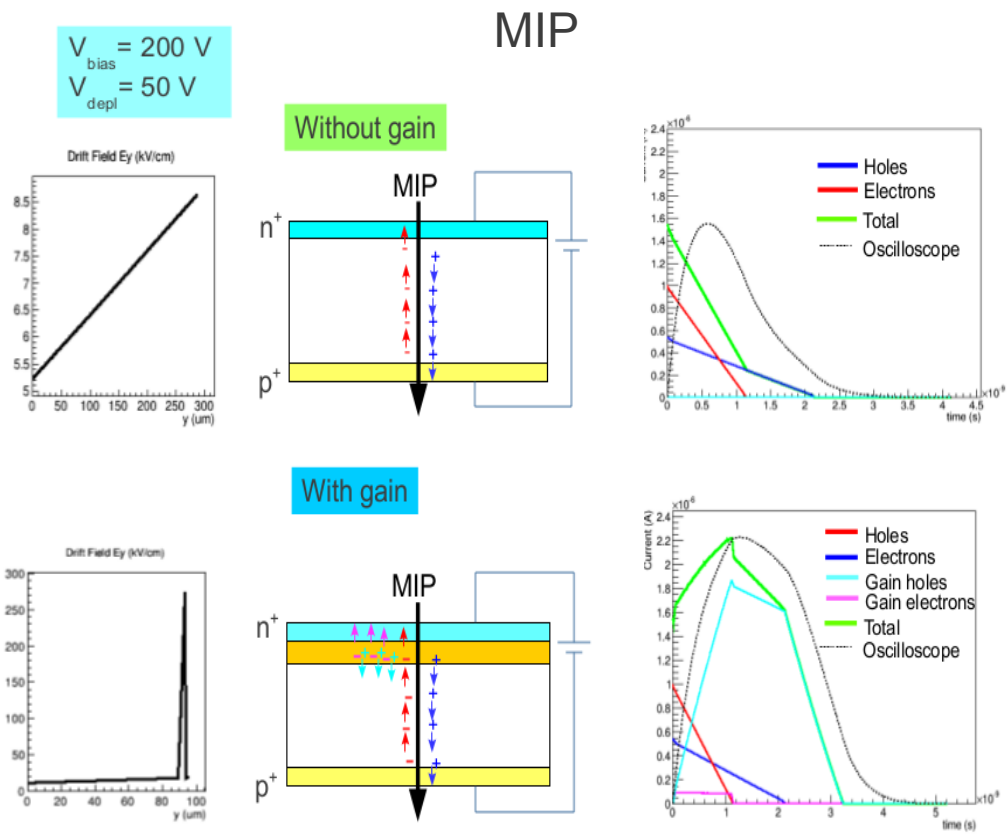


# Graphical Interface

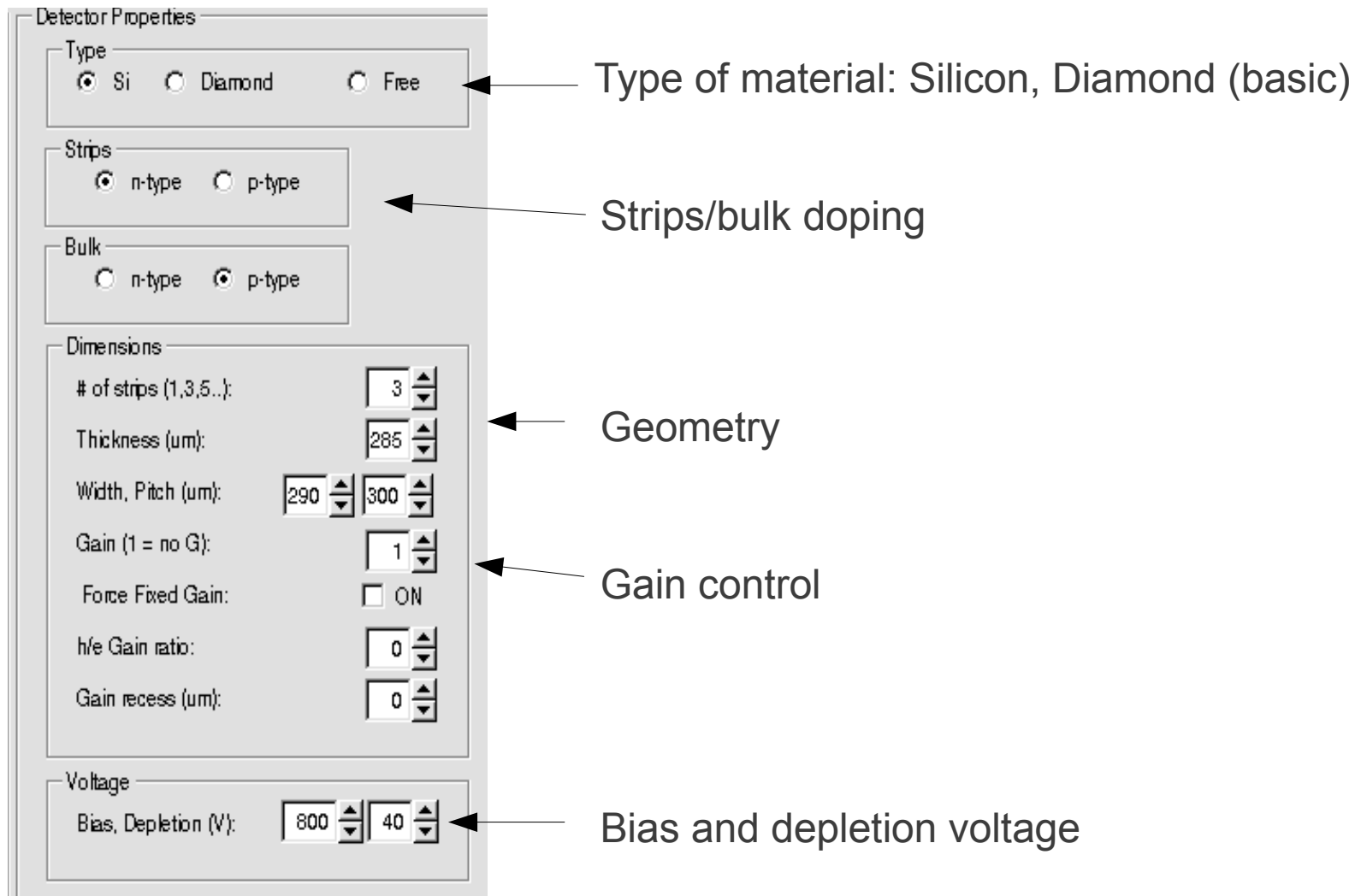


# Drift Field and Currents

Pad geometry, sensor height 100  $\mu\text{m}$



# Detector Properties panel

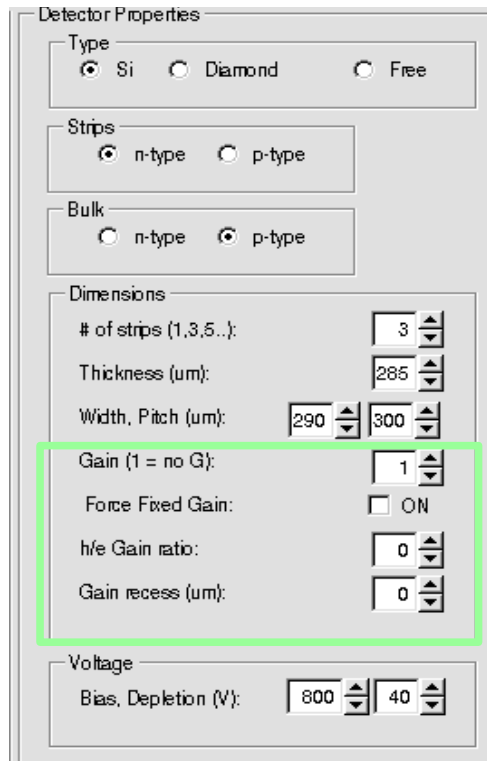


The image shows a software interface for configuring detector properties. The panel is titled "Detector Properties" and is divided into several sections:

- Type:** Radio buttons for "Si" (selected), "Diamond", and "Free". An arrow points to this section with the label "Type of material: Silicon, Diamond (basic)".
- Strips:** Radio buttons for "n-type" (selected) and "p-type". An arrow points to this section with the label "Strips/bulk doping".
- Bulk:** Radio buttons for "n-type" and "p-type" (selected).
- Dimensions:** A group of controls including:
  - "# of strips (1,3,5..):" with a spinner set to 3.
  - "Thickness (um):" with a spinner set to 285.
  - "Width, Pitch (um):" with two spinners set to 290 and 300.
  - "Gain (1 = no G):" with a spinner set to 1.
  - "Force Fixed Gain:" with a checkbox labeled "ON".
  - "h/e Gain ratio:" with a spinner set to 0.
  - "Gain recess (um):" with a spinner set to 0.An arrow points to the "Gain (1 = no G)" spinner with the label "Gain control".
- Voltage:** Two spinners for "Bias, Depletion (V)" set to 800 and 40. An arrow points to these spinners with the label "Bias and depletion voltage".

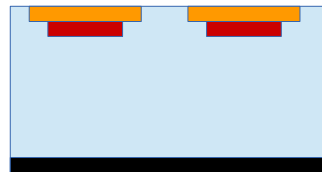
The label "Geometry" is positioned to the right of the "Dimensions" section, with an arrow pointing towards the "Thickness" and "Width, Pitch" controls.

# Detector Properties panel – Gain Control



## Gain control:

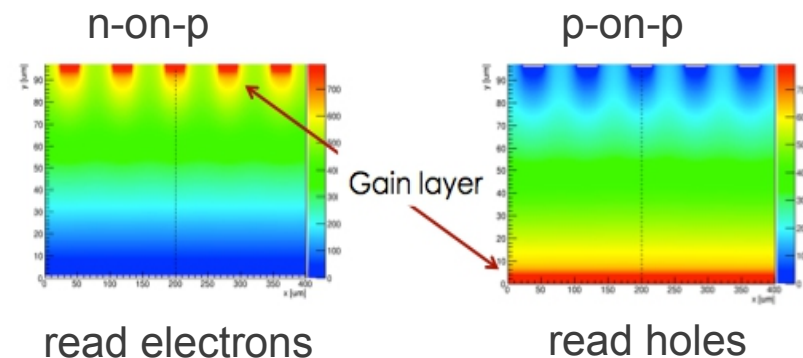
- Set gain value
- Account for holes multiplication → **h/e ratio** (e.g. 0.01)
- When multiplying holes, gain may vary → force gain value
- **Gain recess** → control strip/gain layer overlap



```

Temperature set to = 300
Upper detector dimension = 289
Processing event 1
Tracking one e/h pair for every 10 pairs
Incident Angle = 0 Degrees
MIP uniform charge deposition
Total number of pairs = 21240
Detector with internal gain. Gain layer extends from 282 to 286
Ratio h/e gain = 0.01
Mobility e = 0.125 [m2/V*s] Mobility h = 0.048 [m2/(V*s)]
V Saturation: ve = 103494 [m/s] vh = 89381.1 [m/s]
Maximum time limit simulated 29.99 nanoseconds
Oscilloscope BW = 2.5 GHz
Shaper Int. Time (10-90 %) = 3.5 ns
Shaper Fall Time = 8 ns
Noise (Assuming square pixel) = 337.101 ENC
CSA Threshold set at VTh = 10 mV
===== Results =====
Current at 0 in = 8.32 nanoseconds
Gain = 4.639 Gain requested = 4
Signal Area = 0.771406 [pvs]
Collected charge = 15.4281 [fF]
Average Current = 1.56949 [uA]
CSA dV/dt = 8.75694 [mV/ns]
CSA Jitter = 0.114195 [ns]
dV/dt (Cividec BB) = 4.5052 [mV/ns]
dV/dt (Cividec BB t < 0.4 ns) = 11.2918 [mV/ns]
Jitter (Cividec BB t < 0.4 ns) = 1771.2 [ns]
Simul. System Rise time 10%-90% (R = 50 Ohm) = 1.98 [ns]
System Rise tau: predicted (from RC) = 0.5 simulated = 0.9 [ns]
Simul. System Rise BW = 0.176768 [GHz]
Scope Rise time 10%-90% (RC+BW) = 1.98 [ns]
Rising Jitter [ns] = 0.0910472 Falling Jitter = 0.413663
VTh Time Crossing [ns] = 1.96 and 16.61
Total number of e-h pair simulated = 9691
Total number of e-h pair = 96910
    
```

- Gain layer position varies with strips/bulk doping → always at the junction



# Control panel

Control

Precision (1=best, 10=fastest):

Sampling (GigaSample):

File Name

ON

Batch

ON # of events:

Select Particles

MIP: uniform Q, Qtot = 75\*Height

MIP: non uniform Q, Qtot = 75\*Height

MIP: non uniform, Qtot = Landau

MIP: uniform Q, Q/micron=

alpha from top (E = 5 MeV)

alpha from bottom (E = 5 MeV)

Set range (Max = 30 um):

Plot Settings

Draw Electric Field

No 1D Plots  No 1D & 2D

Currents

Switch B-Field on and set to (T):

Diffusion

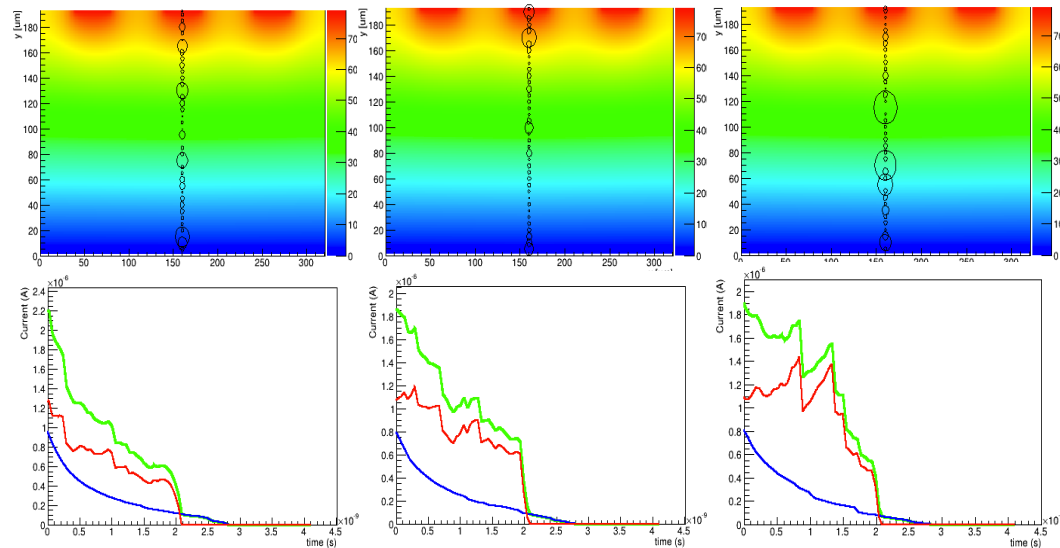
Temperature (K):

Set Calculate Potentials

Calculate Currents Stop Exit

Particle type selection:

- **MIP w/ uniform** charge deposition (75 pairs/um)
- **MIP w/ non uniform** charge deposition, fixed charge energy deposition is generated by GEANT 4 simulation → we created a library of energy deposition in 5 um
- **MIP w/ non uniform** deposition, **Landau** distributed charge → total charge is randomly extracted from Landau distribution



- **Alpha (5 MeV)** from top/bottom w/ selectable range



# Control panel

Control

Precision (1=best, 10=fastest):

Sampling (GigaSample):

File Name

ON

Batch

ON # of events:

Select Particles

MIP: uniform Q, Qtot = 75\*Height

MIP: non uniform Q, Qtot = 75\*Height

MIP: non uniform, Qtot = Landau

MIP: uniform Q, Q/micron=

alpha from top (E = 5 MeV)

alpha from bottom (E = 5 MeV)

Set range (Max = 30 um):

Plot Settings

Draw Electric Field

No 1D Plots  No 1D & 2D

Currents

Switch B-Field on and set to (T):

Diffusion

Temperature (K):

Set Calculate Potentials

Calculate Currents Stop Exit

Account for

- Thermal diffusion (selectable T)
  - Magnetic field (Lorentz drift)
- in currents calculation



# Control panel

The control panel is organized into several sections:

- Control:** Precision (1=best, 10=fastest): 10; Sampling (GigaSample): 100.
- File Name:**  ON; File name: wf.
- Batch:**  ON; # of events: 10.
- Select Particles:**  MIP: uniform Q, Q<sub>tot</sub> = 75\*Height;  MIP: non uniform Q, Q<sub>tot</sub> = 75\*Height;  MIP: non uniform, Q<sub>tot</sub> = Landau;  MIP: uniform Q, Q/micron = 75;  alpha from top (E = 5 MeV);  alpha from bottom (E = 5 MeV); Set range (Max = 30 um): 10.
- Plot Settings:**  Draw Electric Field;  No 1D Plots;  No 1D & 2D.
- Currents:**  Switch B-Field on and set to (T): 0;  Diffusion; Temperature (K): 300.

Buttons at the bottom: Set, Calculate Potentials, Calculate Currents, Stop, Exit.

Output file:

- writes an I(t) output file

Batch mode:

- loop of a selectable number of events

# Control panel

Control

Precision (1=best, 10=fastest): 10

Sampling (GigaSample): 100

File Name

ON wf

Batch

ON # of events: 10

Select Particles

MIP: uniform Q, Qtot = 75\*Height

MIP: non uniform Q, Qtot = 75\*Height

MIP: non uniform, Qtot = Landau

MIP: uniform Q, Q/micron= 75

alpha from top (E = 5 MeV)

alpha from bottom (E = 5 MeV)

Set range (Max = 30 um): 10

Plot Settings

Draw Electric Field

No 1D Plots  No 1D & 2D

Currents

Switch B-Field on and set to (T): 0

Diffusion

Temperature (K): 300

Set Calculate Potentials

Calculate Currents Stop Exit

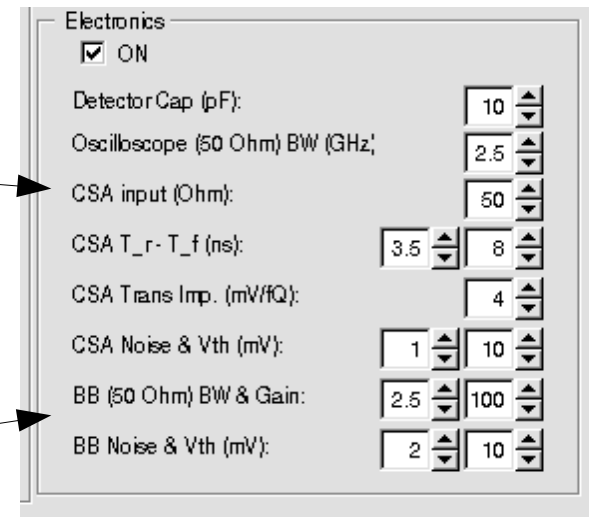
Precision:

- speed up currents calculation by tracking only 1 e-h pair every N (1 to 10)
- current induced by 1 pair is multiplied by N

# Electronics

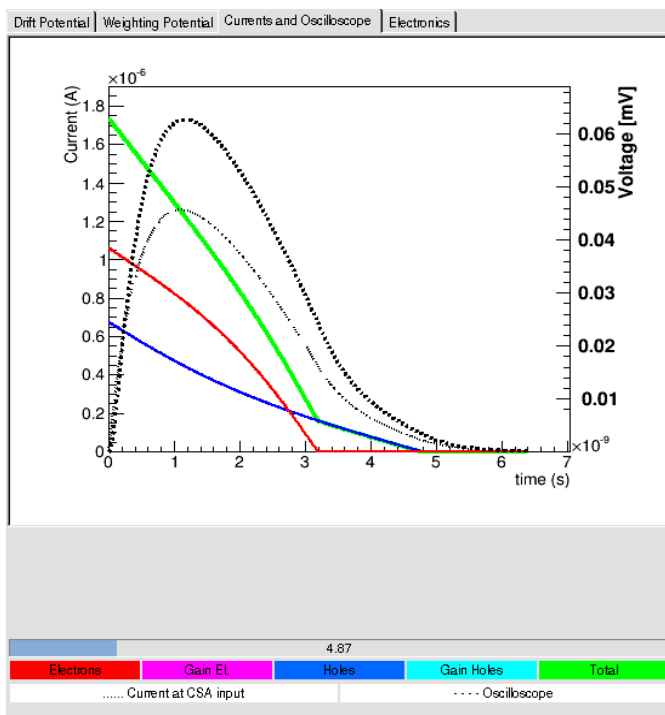
Accounting for electronics effect:

- Detector capacitance
- Oscilloscope bandwidth
- Charge Sensitive Amplifier
  - Input resistance
  - Rise time/ fall time
  - Trans-impedance
  - Noise and threshold voltage
- Broad Band amplifier
  - Bandwidth and gain
  - Noise and threshold voltage

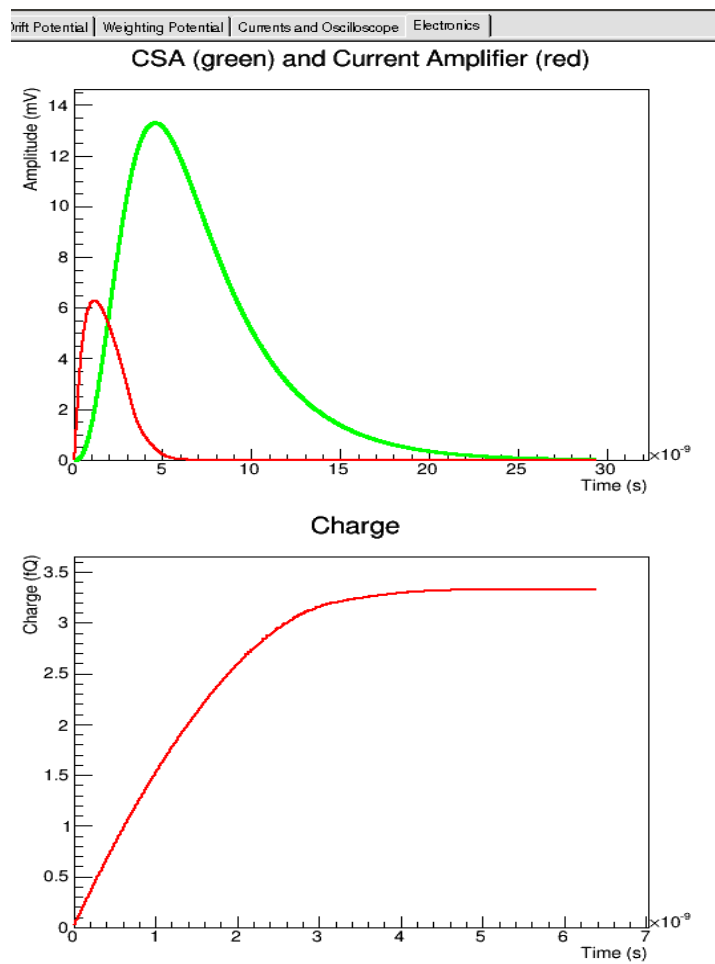


Effect of electronics on:

## Currents tab



## Electronics tab



Electronics

ON

Detector Cap (pF): 10

Oscilloscope (50 Ohm) BW (GHz): 2.5

CSA input (Ohm): 50

CSA T<sub>r</sub>-T<sub>f</sub> (ns): 3.5 8

CSA Trans Imp. (mV/fQ): 4

CSA Noise & V<sub>th</sub> (mV): 1 10

BB (50 Ohm) BW & Gain: 2.5 100

BB Noise & V<sub>th</sub> (mV): 2 10

# Parameters file

Detector parameter are also fixable from file Parameters.dat

```
parameters.dat x
# this is a comment
#####
#--Detector Properties--#
#####
#--Dimensions--
STRIP_NUMB          3          number of strips (1,3,5..)
DETECT_HEIGHT      285        Detector height (um)
STR_PITCH          300        Strip pitch (um)
STR_WIDTH          290        Strip width (um)
GAIN_SCL           1          Gain Scale (1 = no G)
HE_GAIN_RAT       0.0        h/e Gain ratio
GAIN_LYR_RSS       0          Gain layer recess (um)

#--Voltage--
BIAS_VOLTAGE       800        Bias Voltage (V)
DEPL_VOLTAGE       40         Depletion Voltage (V)

#--Electronics--
CAPACITANCE        10.        Det. Capacitance (pF)
OSCOPE_BW          2.5        Oscilloscope BW (GHz)
SHPR_INT_TIME      3.5        Shaper Int. Time (ns)
SHPR_DCY_TIME      8          Shaper Decay Time (ns)
VTH                10         Vth (in noise unit)
SHPR_TRANS         4          Shaper TransImpedance
SHPR_NOISE         1          Shaper Noise
IMPEDANCE          50         Shaper Impedance

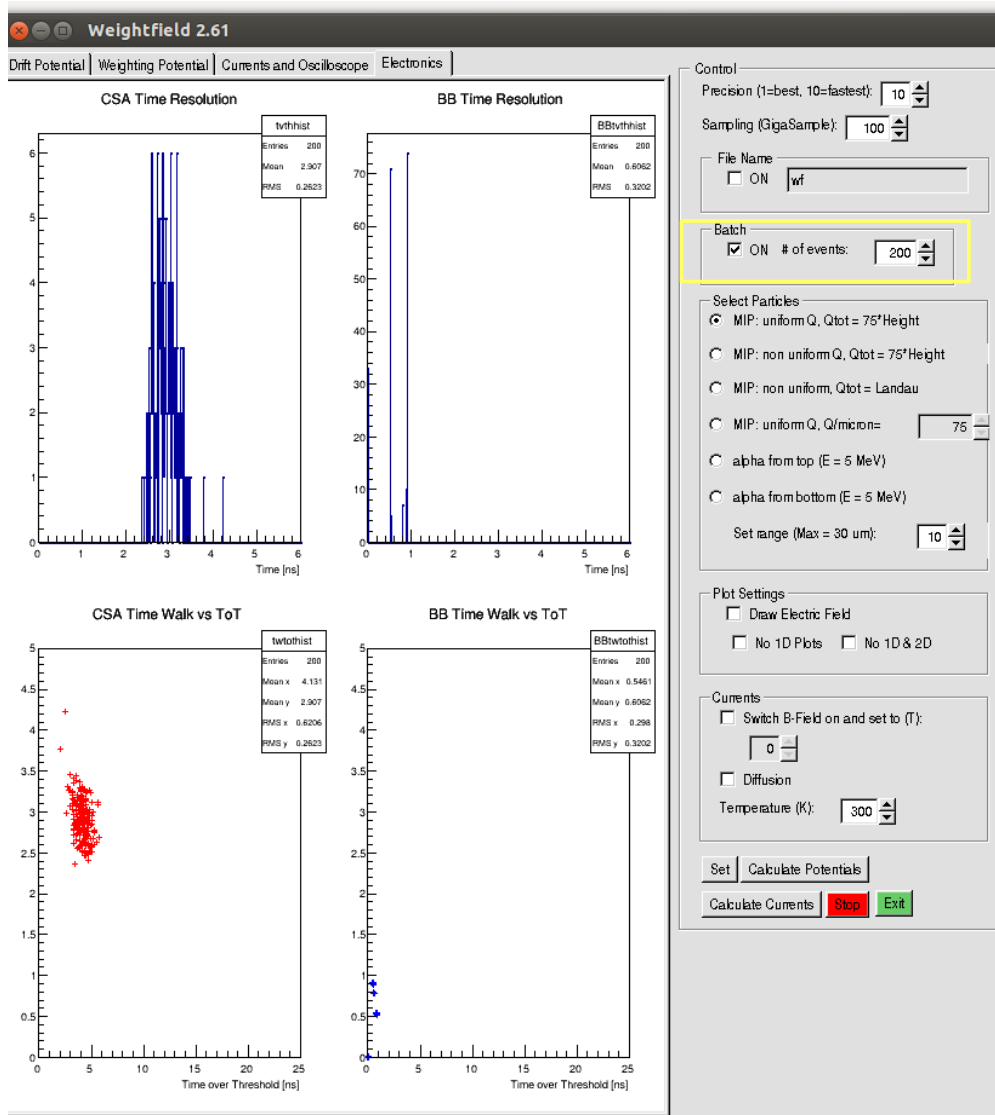
#####
#--Control--#
#####
PRECISION           10         Precision (1=best, 10=fastest)

#--Select Particles--
SET_RANGE           10         Set range (um)

#--Currents--
TEMPERATURE        300        Temperature (K)

#ALL PARAMETERS ARE IN "WFGUI.cxx"
```

# Electronics in Batch Mode



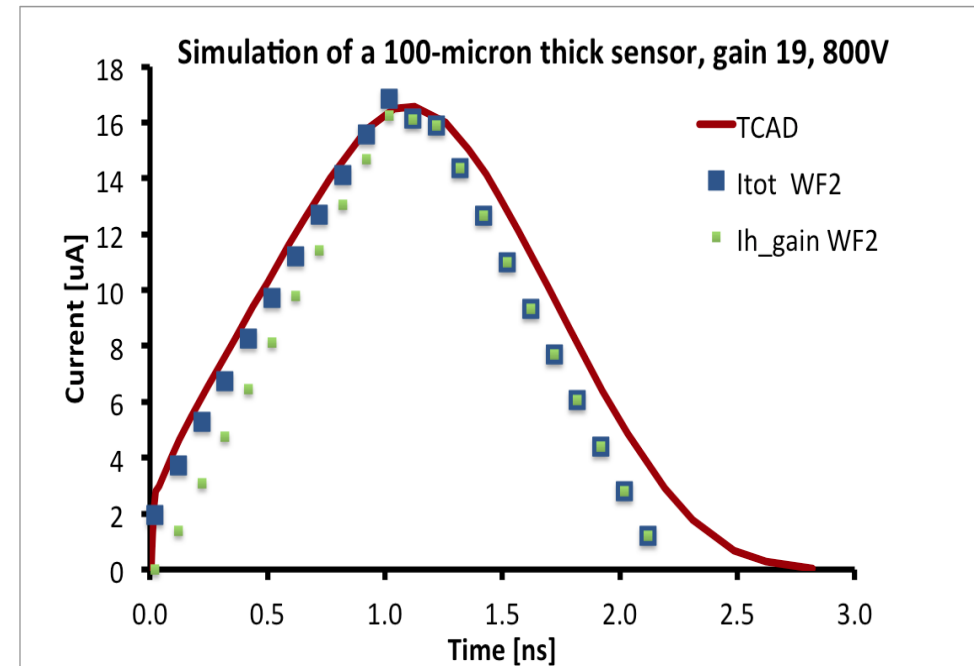
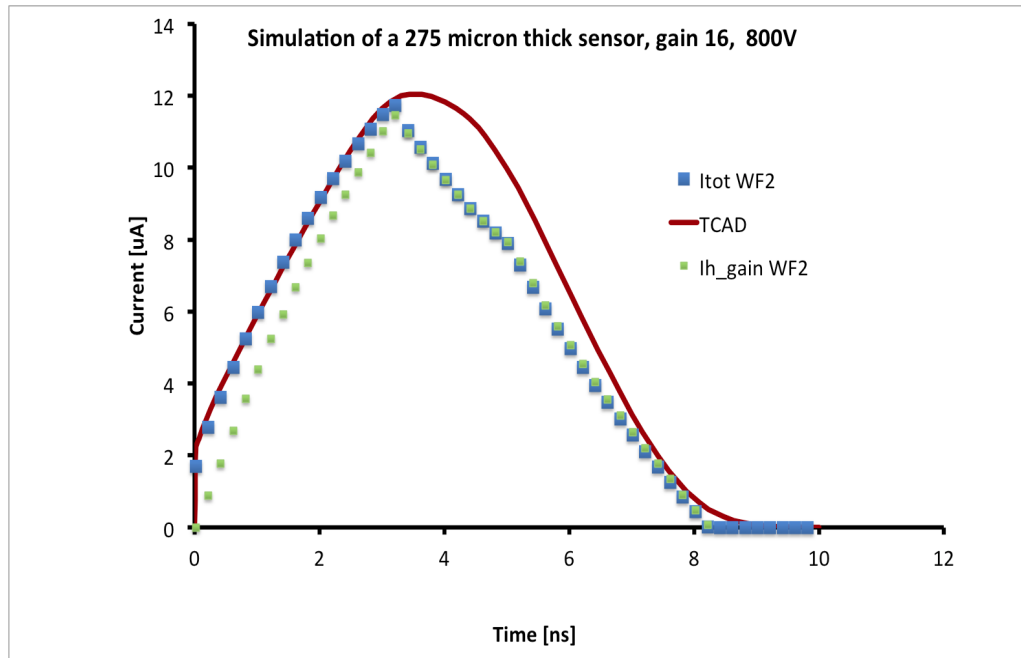
Electronics tab with Batch Mode on

- CSA/BB time resolution
- Time walk vs Time Over Threshold plot

Console output for each event

```
Tracking one e/h pair for every 10 pairs
Incident Angle = 0 Degrees
Event Number: 200
Current at 0 in... = 4.89 nanoseconds
Gain = 1 Gain requested = 1
Signal Area = 0.166203 [pVs]
Collected charge = 3.32407 [fF]
Average Current = 0.519386 [uA]
CSA dV/dt = 2.91706 [mV/ns]
CSA Jitter = 0.342811 [ns]
dV/dt (Cividec BB) = 5.36484 [mV/ns]
dV/dt (Cividec BB t < 0.4 ns) = 9.96874 [mV/ns]
Jitter (Cividec BB t < 0.4 ns) = 2006.27 [ns]
Simul. System Rise time 10%-90% (R = 50 Ohm) = 0.61 [ns]
System Rise tau: predicted (from RC) = 0.5 simulated = 0.277273 [ns]
Simul. System Rise BW = 0.57377 [GHz]
Scope Rise time 10%-90% (RC+BW) = 0.62 [ns]
Rising Jitter [ns] = 0.346684 Falling Jitter = 0.543018
VTh Time Crossing [ns] = 3.34 and 6.59
```

# Comparison Weightfield - TCAD





# Conclusions and Outlook

- *Weightfield 2* is a reliable open-source tool to predict the signal of detectors with low gain we obtained good agreement between simulations and measurements
- Many institutes interested on the program and contributed to its development
- The program is available at the page <http://personalpages.to.infn.it/~cartigli/weightfield2>
- We wish to thank anyone who contributed to its development

- Thank you for your attention

