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

10th International Conference on Radiation Effects on Semiconductor Materials, Detectors and Devices

Weightfield 2

- Tool to study signals in UFSD
  presented at 9th Trento Workshop on Advanced Radiation Detectors
  http://indico.cern.ch/event/273880/session/4/contribution/59/material/slides/0.pdf

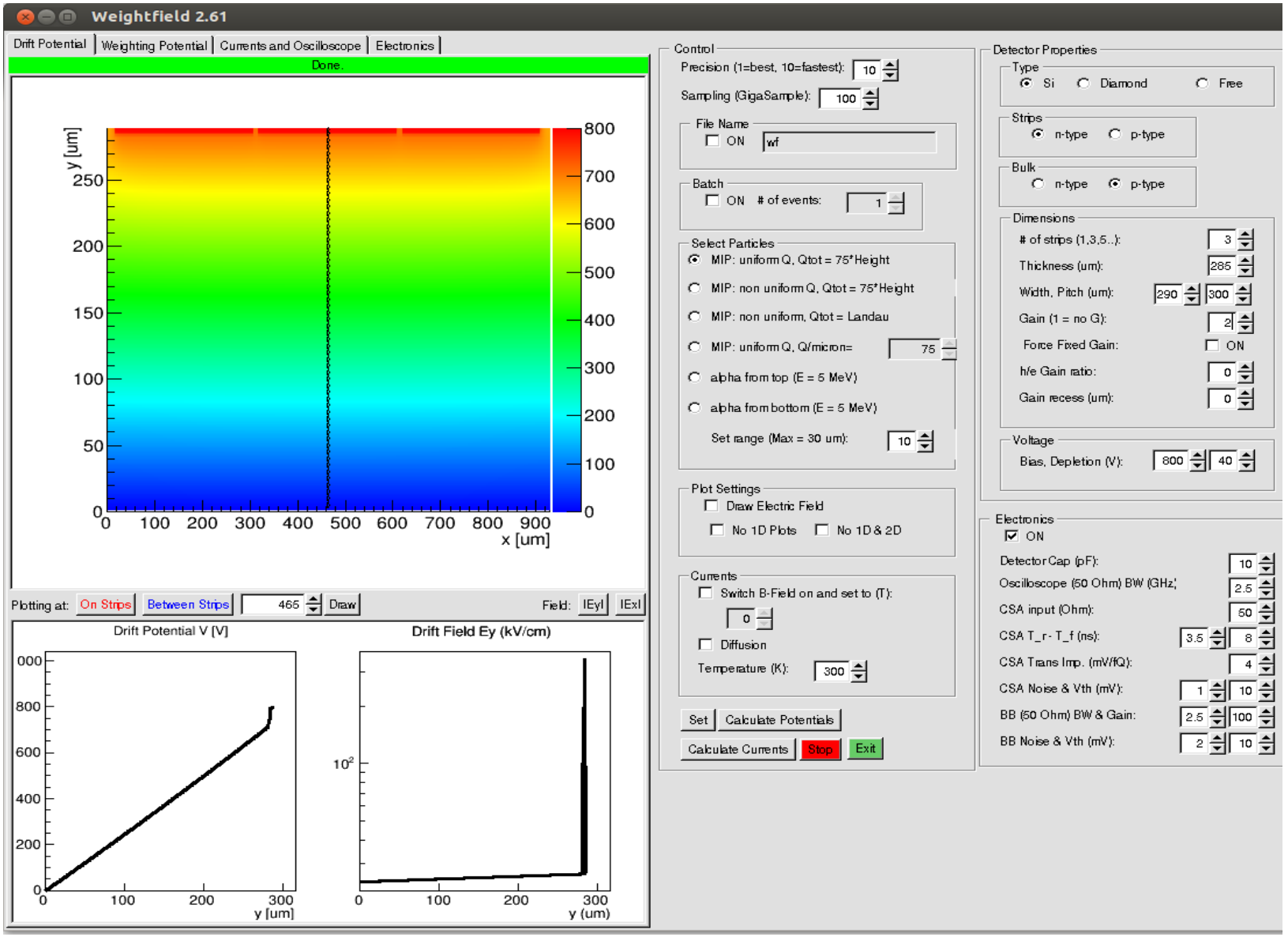
- Weightfield 2 is based on *Weightfield* by M. Friedl and B. Kolbinger (HEPHY Vienna)
  http://www.hephy.at/en/research/departments/semiconductor-detectors/detector-simulation

- Written in C++ language, uses ROOT graphical interface TGUI

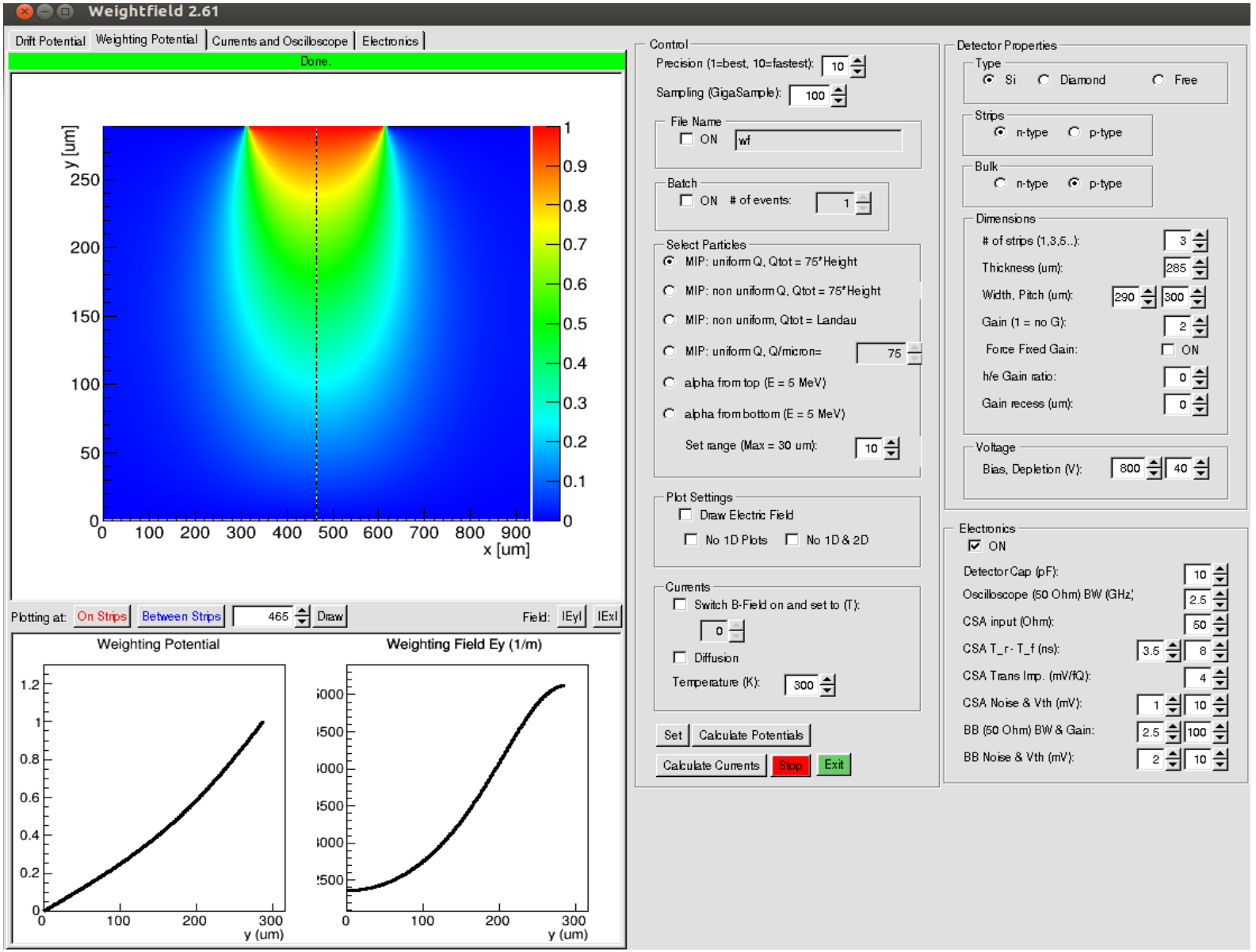
- Program features:
  - calculates induced currents with Ramo's Theorem $I = -e\,v(x)\,E_w$
  - solves Poisson's equation using Vdep (not from doping)
  - draws electric field
  - allows to set temperature and magnetic field
  - allows to simulate non uniform charge deposition
  - allows to set gain
  - simulates oscilloscope and shaper

- New features:
  - Extended electronics simulator
  - Time walk curve in batch mode
  - Updated gain mechanism
  - Diamond simulator

Graphical Interface



Graphical Interface

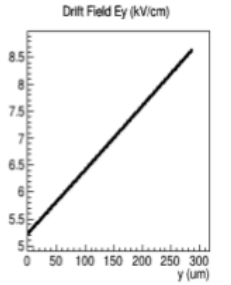


Drift Field and Currents

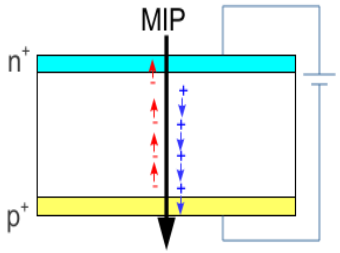
Pad geometry, sensor height 100 um

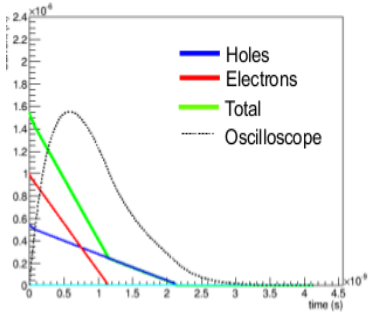
MIP

V_{bias} = 200 V
V_{depl} = 50 V

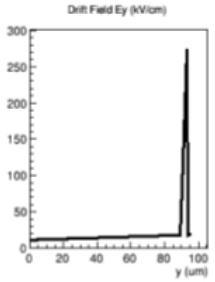


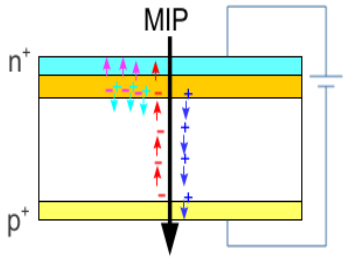
Without gain

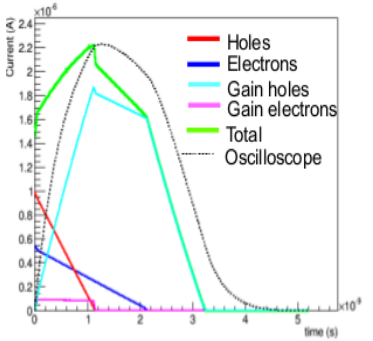




With gain

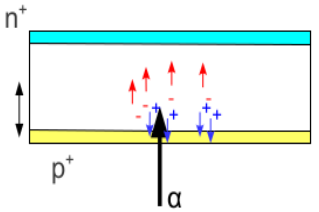


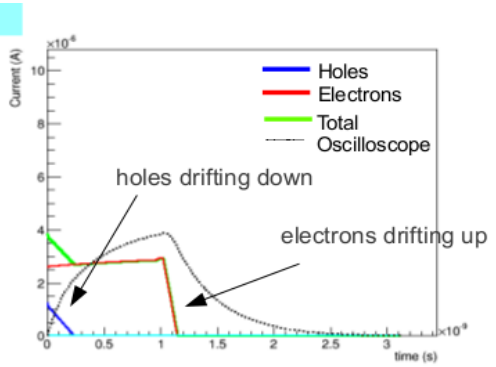




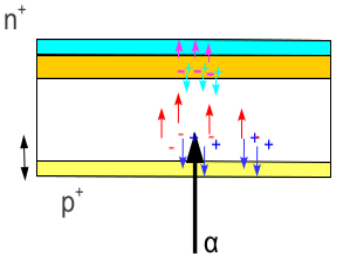
Alpha from bottom

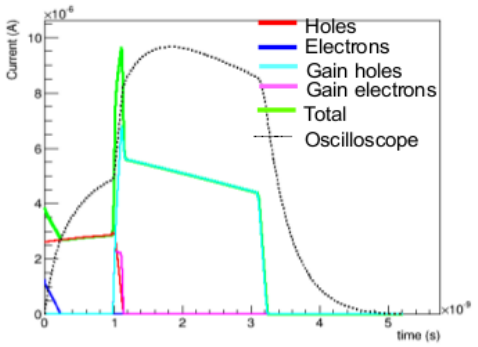
Without gain



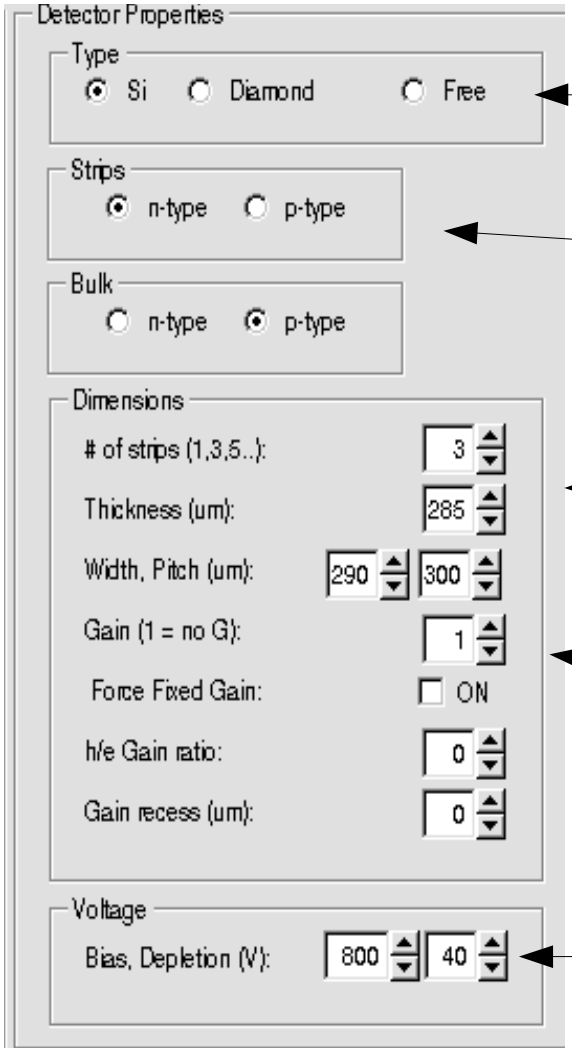


With gain





Detector Properties panel



Type of material: Silicon, Diamond (basic)

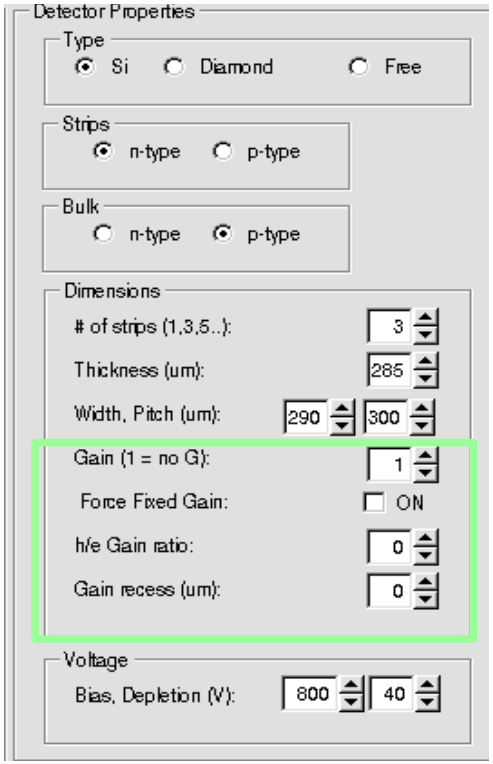
Strips/bulk doping

Geometry

Gain control

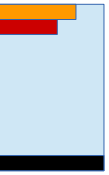
Bias and depletion voltage

Detector Properties panel – Gain Control



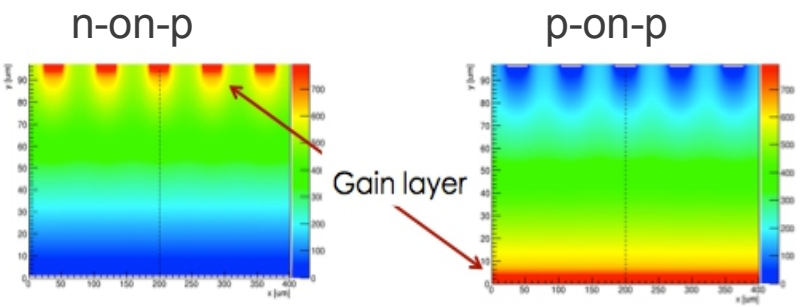
Gain control:

- 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

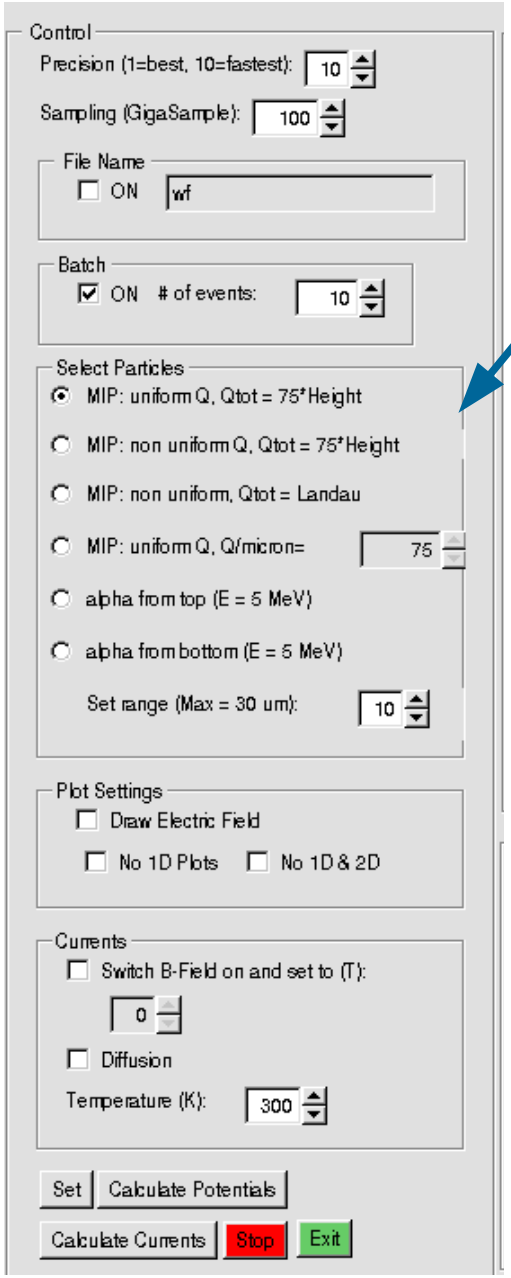


```
Temperature set to = 300
Upper detector dimension = 289
Processing event 1
Tracking one e/h pair for every 10 pairs
Incident  Angle = 0 Degrees
MIP uniform charge deposition
Total number of pairs = 21240
Detector with internal gain. Gain layer extends from 282 to 286
Ratio h/e gain = 0.01
Mobility e = 0.135 [m2/(V*s)] Mobility h = 0.048 [m2/(V*s)]
V Saturation:  e = 103494 [m/s]  h = 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

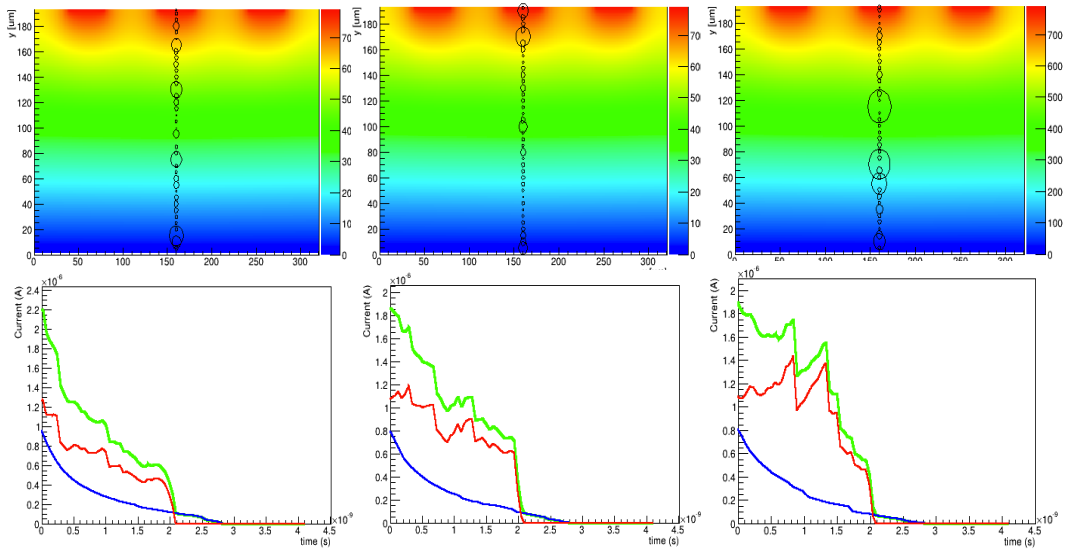


Control panel



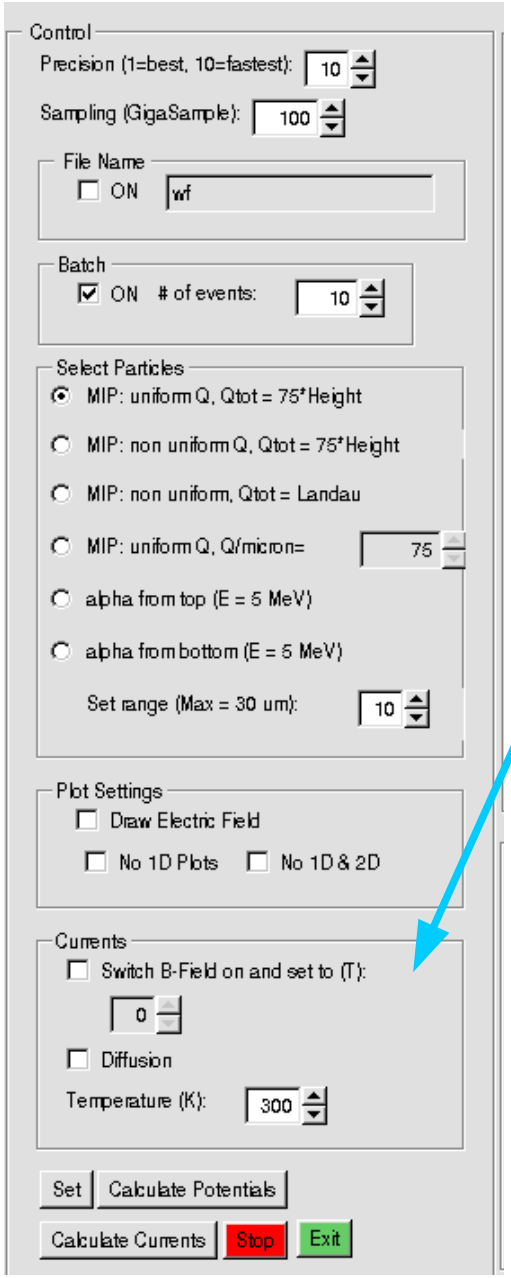
Particle type selection:

- **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

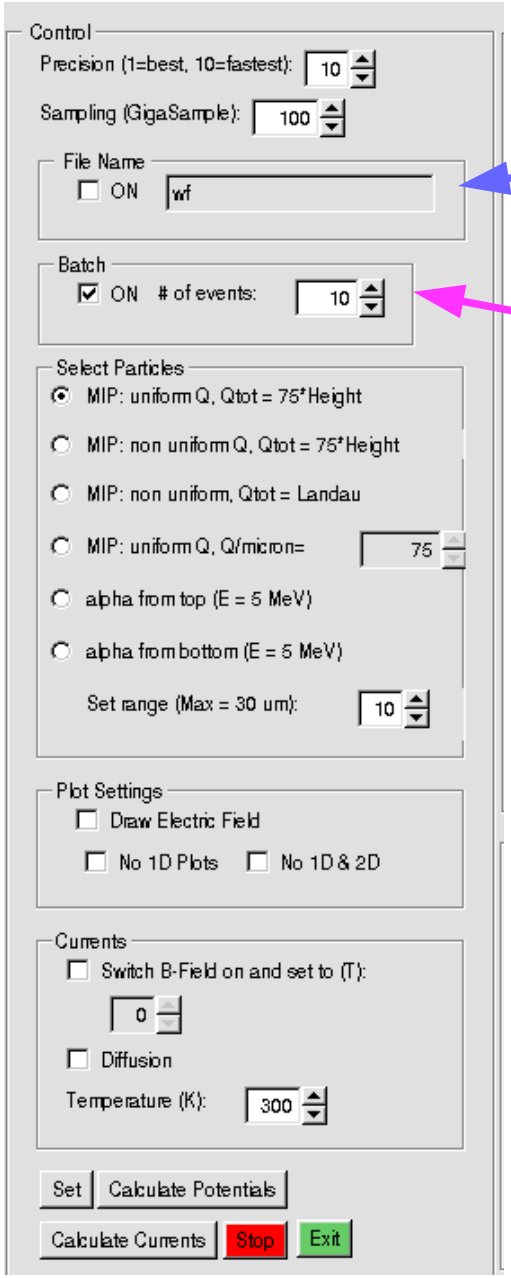


Account for

- Thermal diffusion (selectable T)
- Magnetic field (Lorentz drift)

in currents calculation

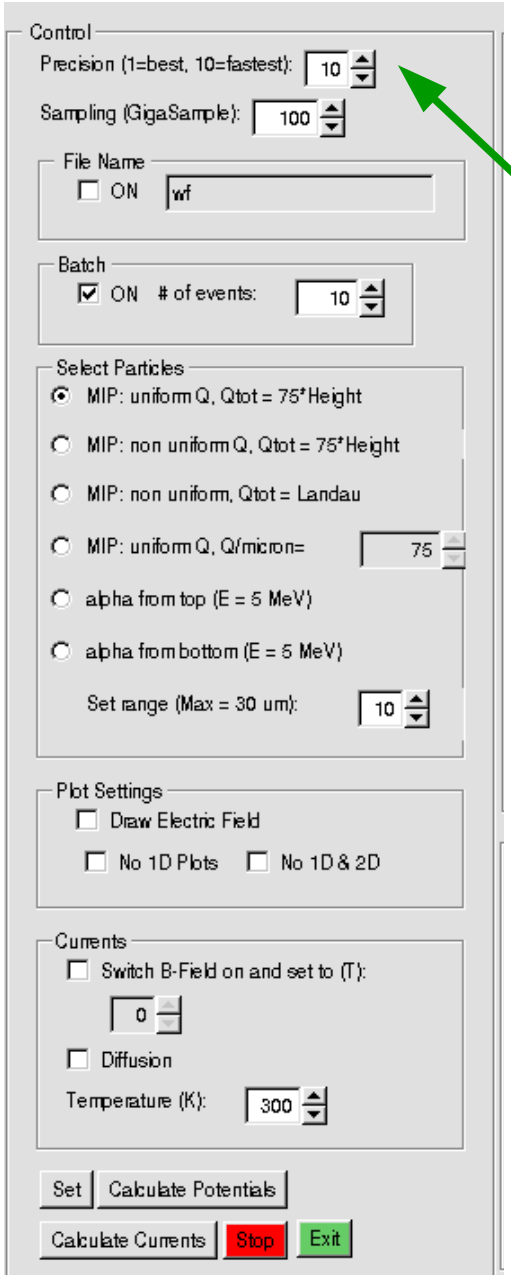
Control panel



Output file:
- writes an I(t) output file

Batch mode:
- loop of a selectable number of events

Control panel



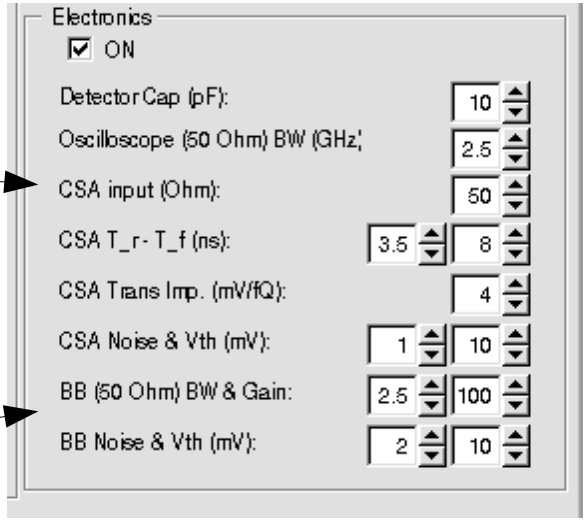
Precision:

- 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

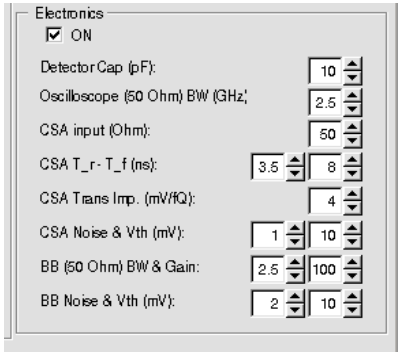
Accounting for electronics effect:

- 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

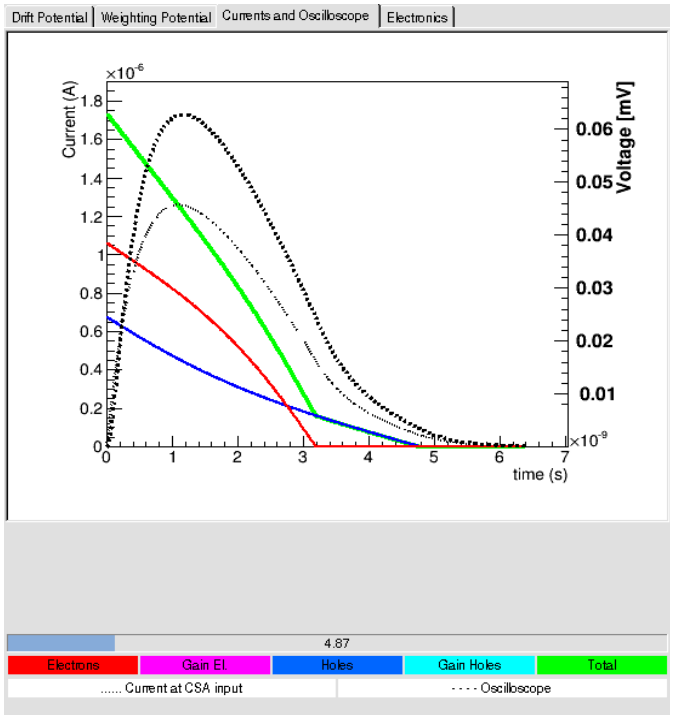


Electronics

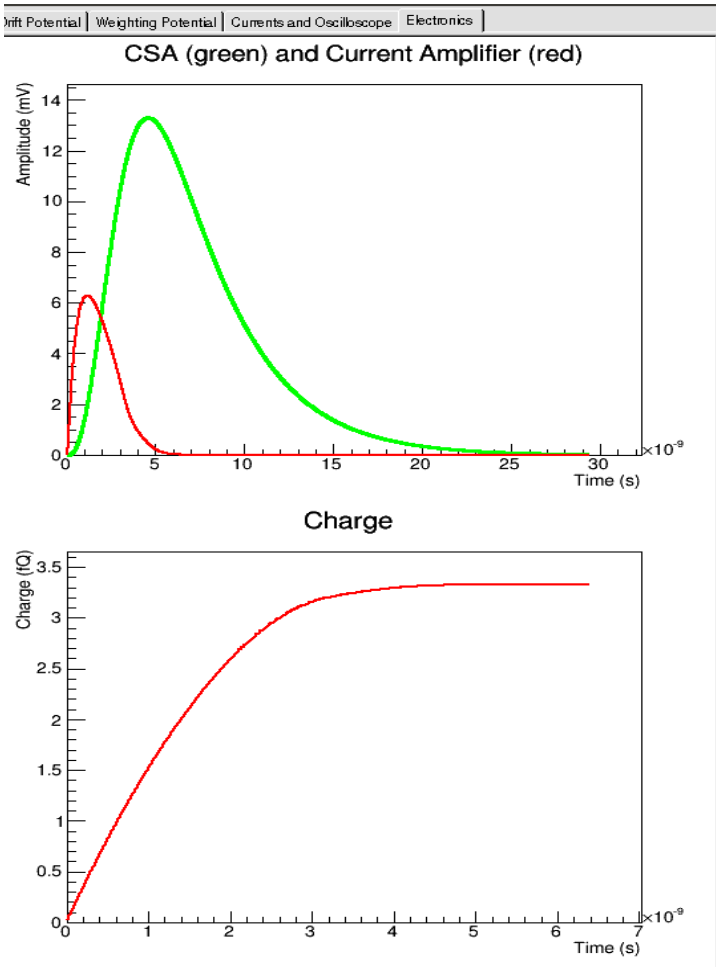
Effect of electronics on:



Currents tab



Electronics tab



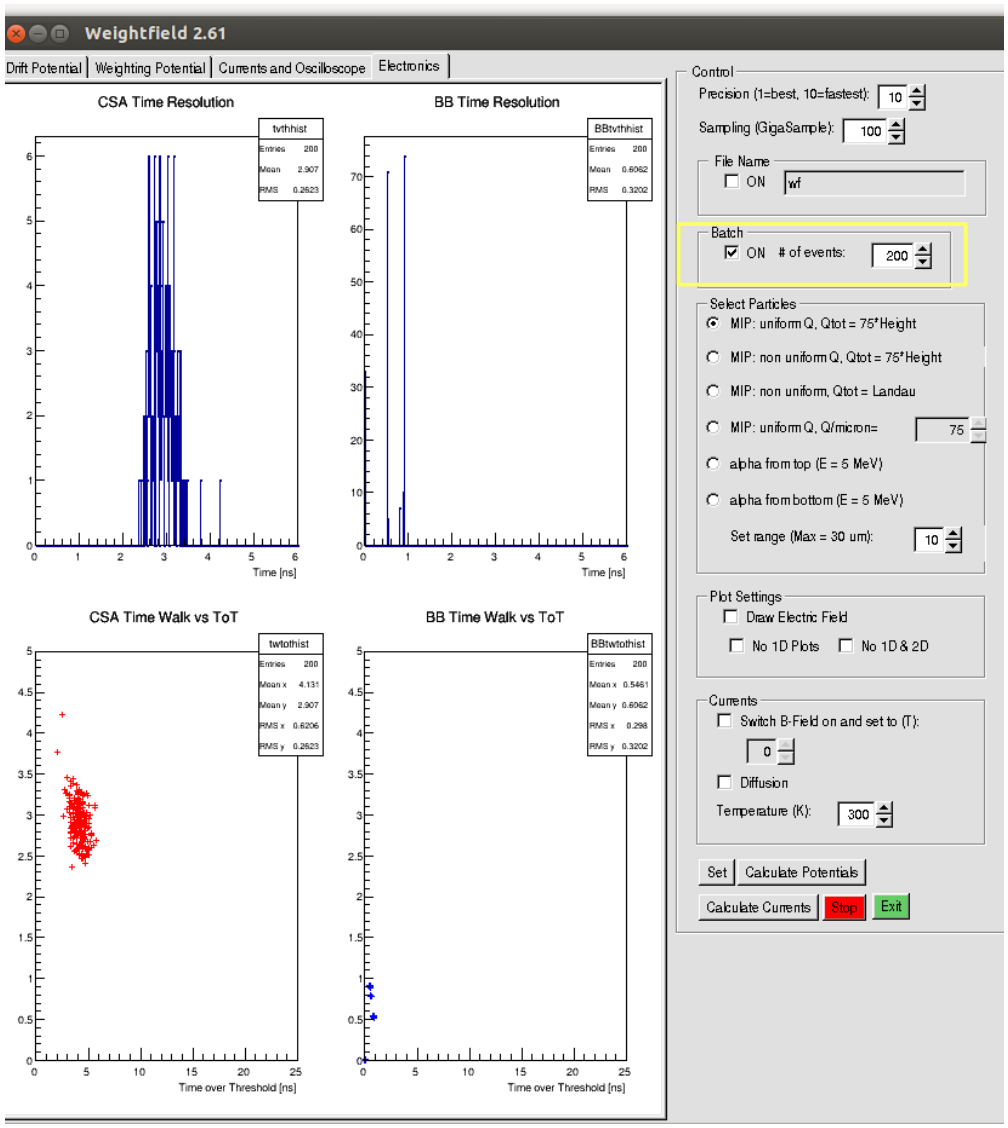
Parameters file

Detector parameter are also fixable from file Parameters.dat

parameters.dat

```
# 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



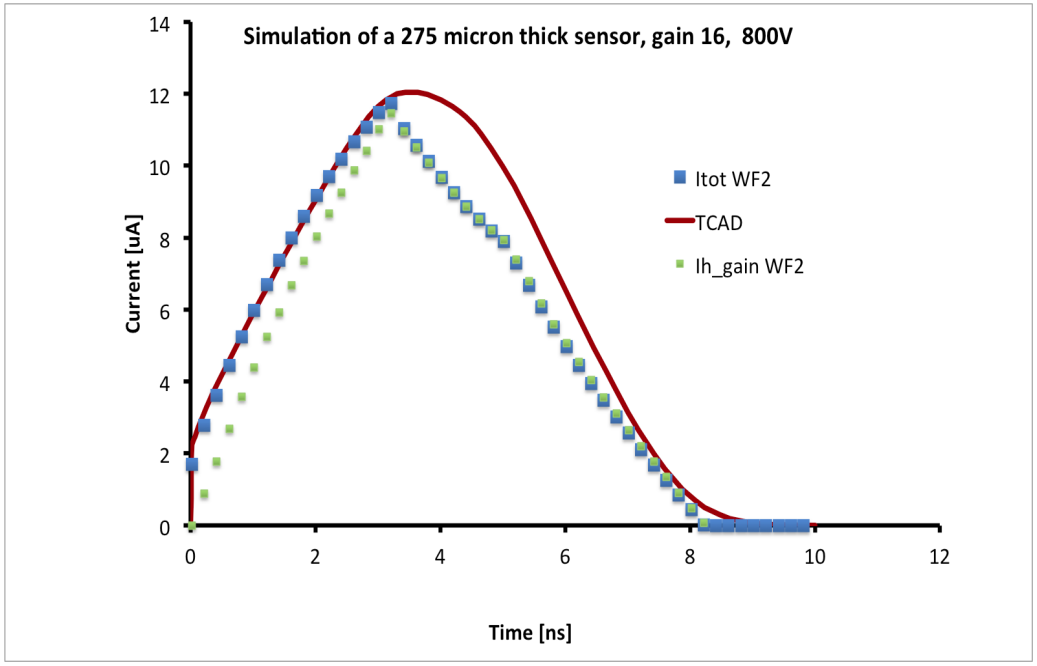
Electronics tab with Batch Mode on

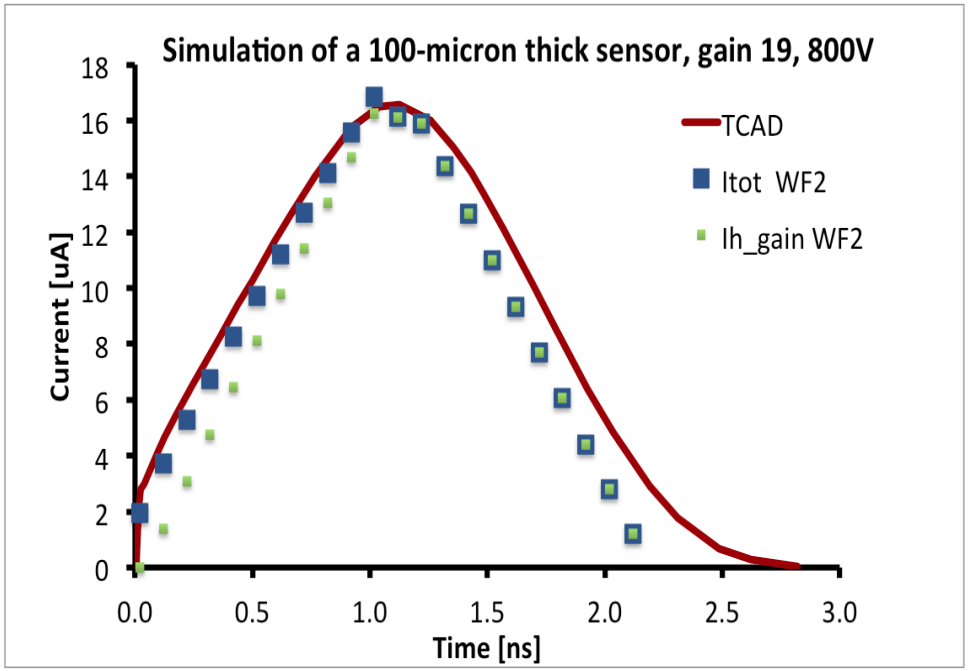
- CSA/BB time resolution
- Time walk vs Time Over Threshold plot

Console output for each event

```
Tracking one e/h pair for every 10 pairs
Incidente 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