Signal formation and intrinsic time resolution

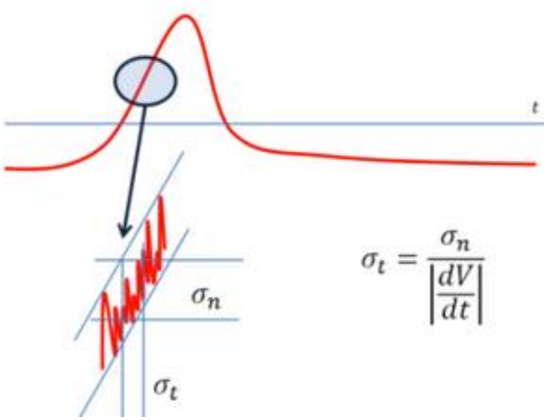
$$\sigma_t = \left(\frac{N}{dV/dt}\right)^2 + (\text{Landau Shape})^2 + \text{TDC}$$

Usual "Jitter" term

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

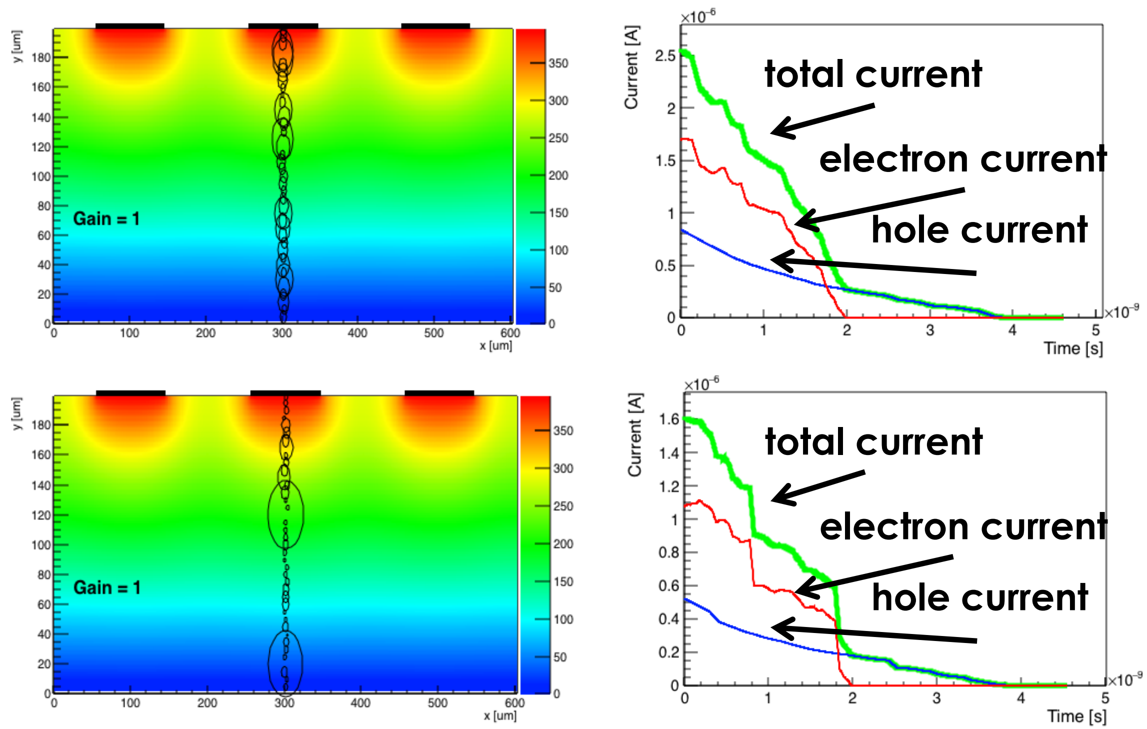
Time walk: Amplitude variation, **corrected in electronics**

Shape variations: non homogeneous energy deposition



$$\sigma_t = \frac{\sigma_n}{\left|\frac{dV}{dt}\right|}$$

Need large dV/dt



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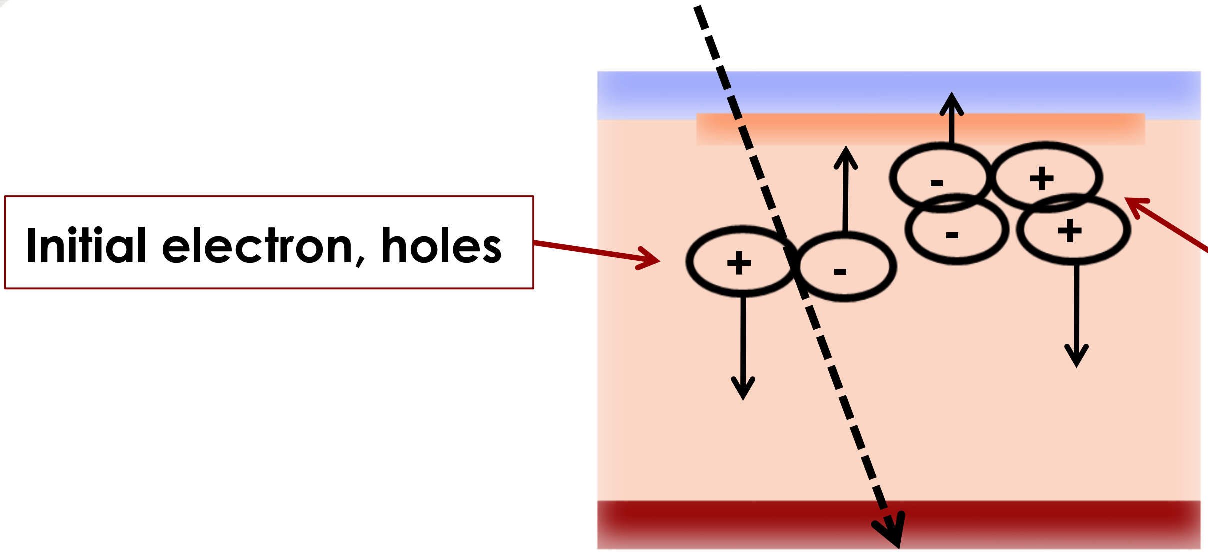
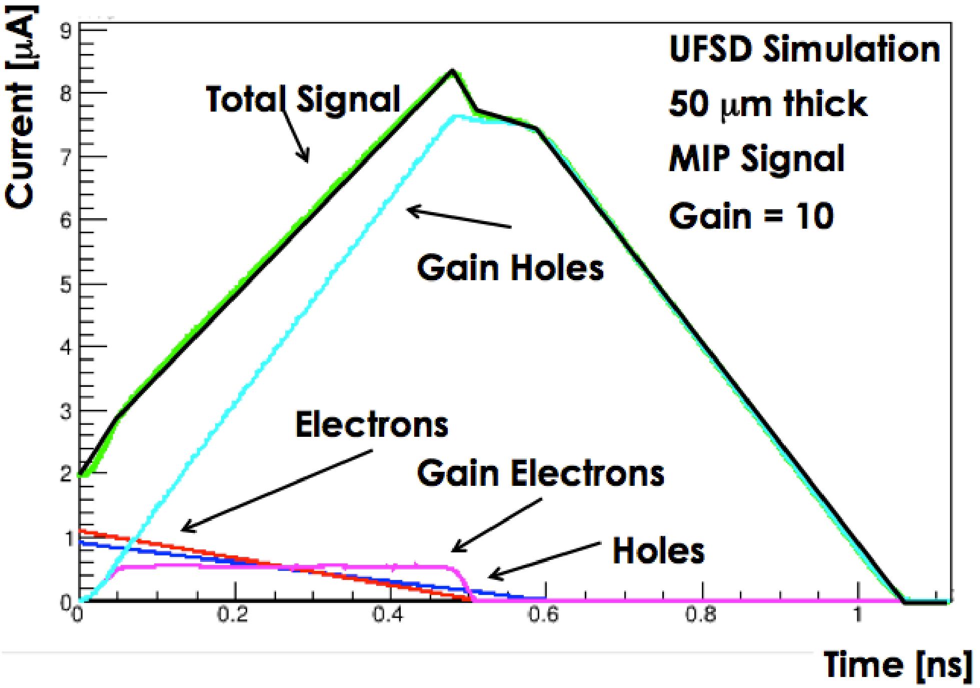
How gain shapes the signal



Gain electron: absorbed immediately

Gain holes: long drift home

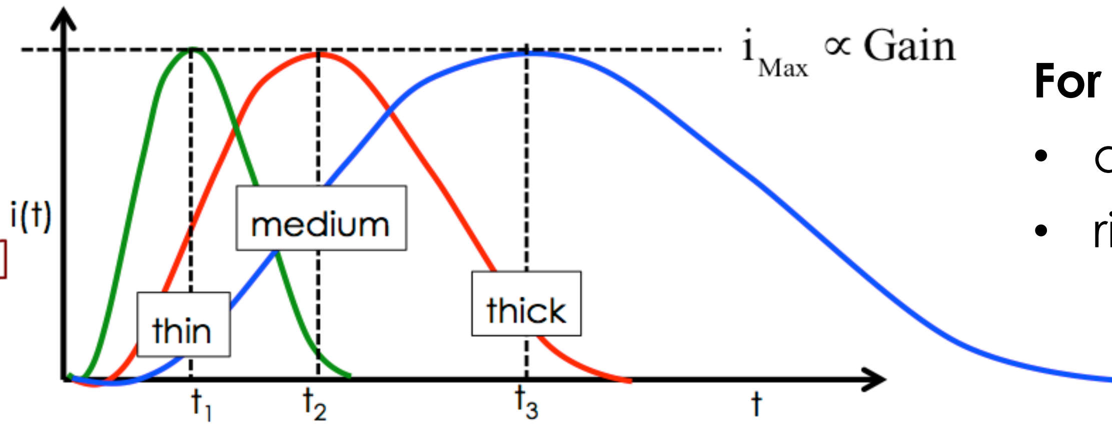


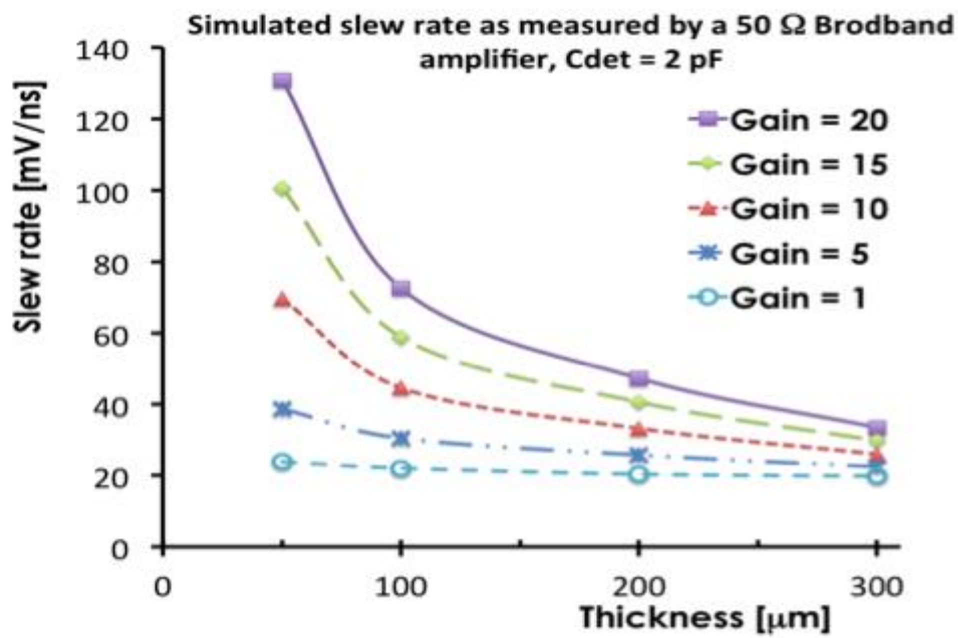
Electrons multiply and produce additional electrons and holes.

- **Gain electrons have almost no effect**
- **Gain holes dominate the signal**

➔ **No holes multiplications**

Gain and slew rate vs thickness





For a fixed gain:

- amplitude = constant
- rise time ~ 1/thickness

The slew rate:

- Increases with gain
- Increases ~ 1/thickness

➔ **Go thin!!**

Significant improvements in time resolution require thin detectors

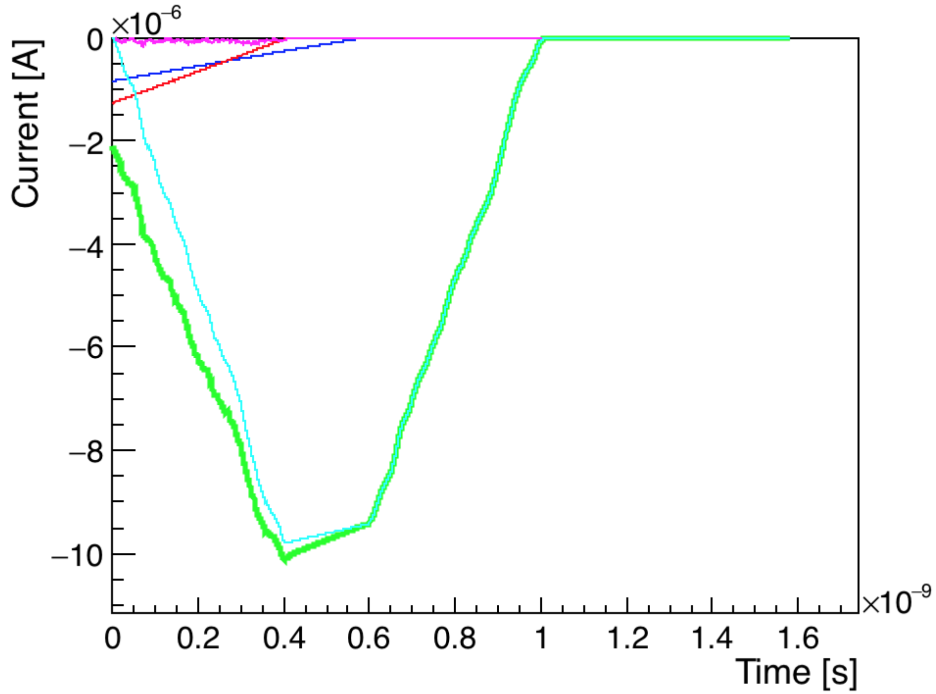
Evolution of LGAD signal shape in ETL

The signal from an LGAD is short and reaches ~ 10 uA

(gain = 13 in the plot)

Gain = 10 ➔ Q = 5 fC

The electronics needs to exploit it: needs to follow the rising edge.



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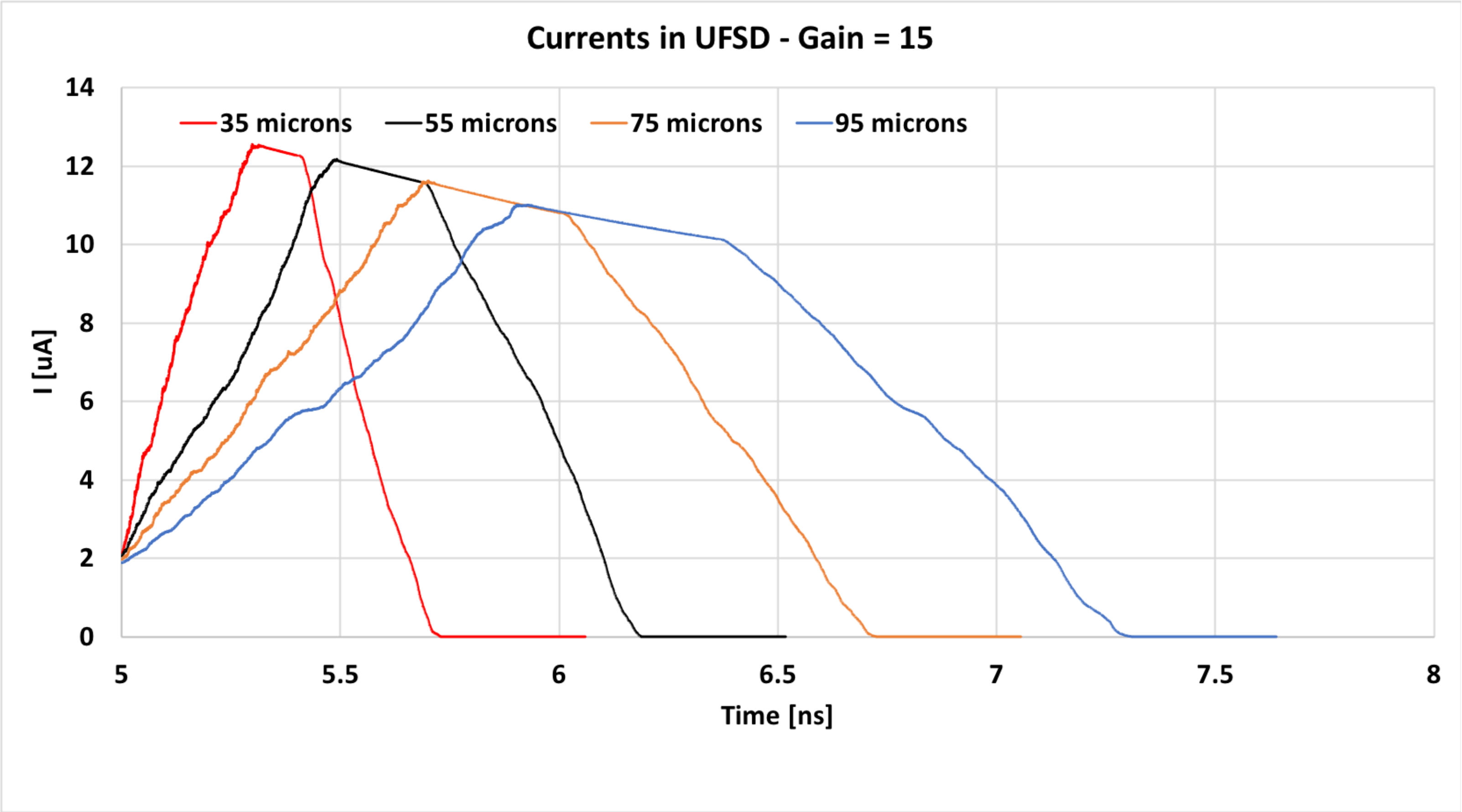
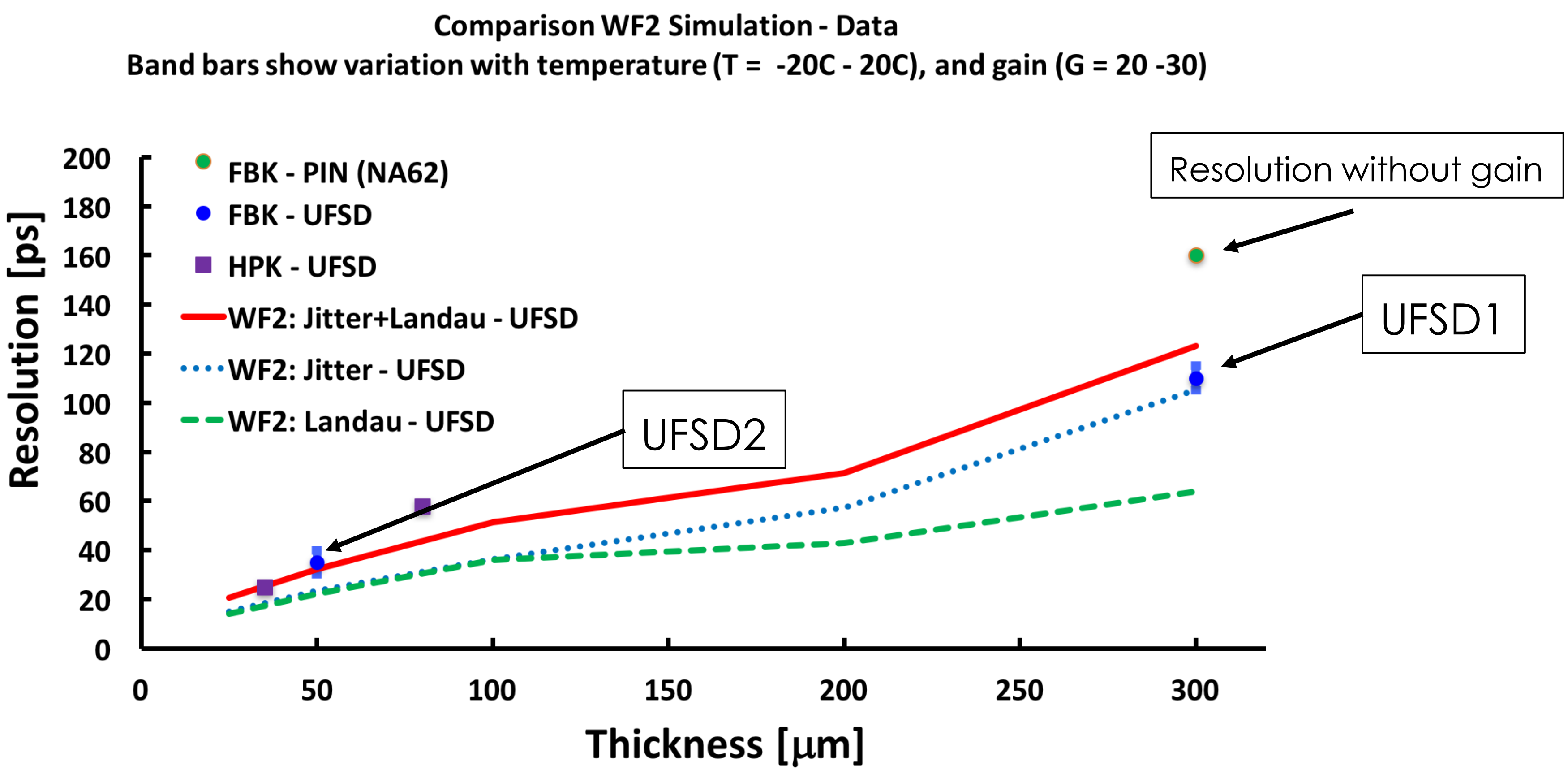
Currents for different thicknesses



UFSD time resolution summary

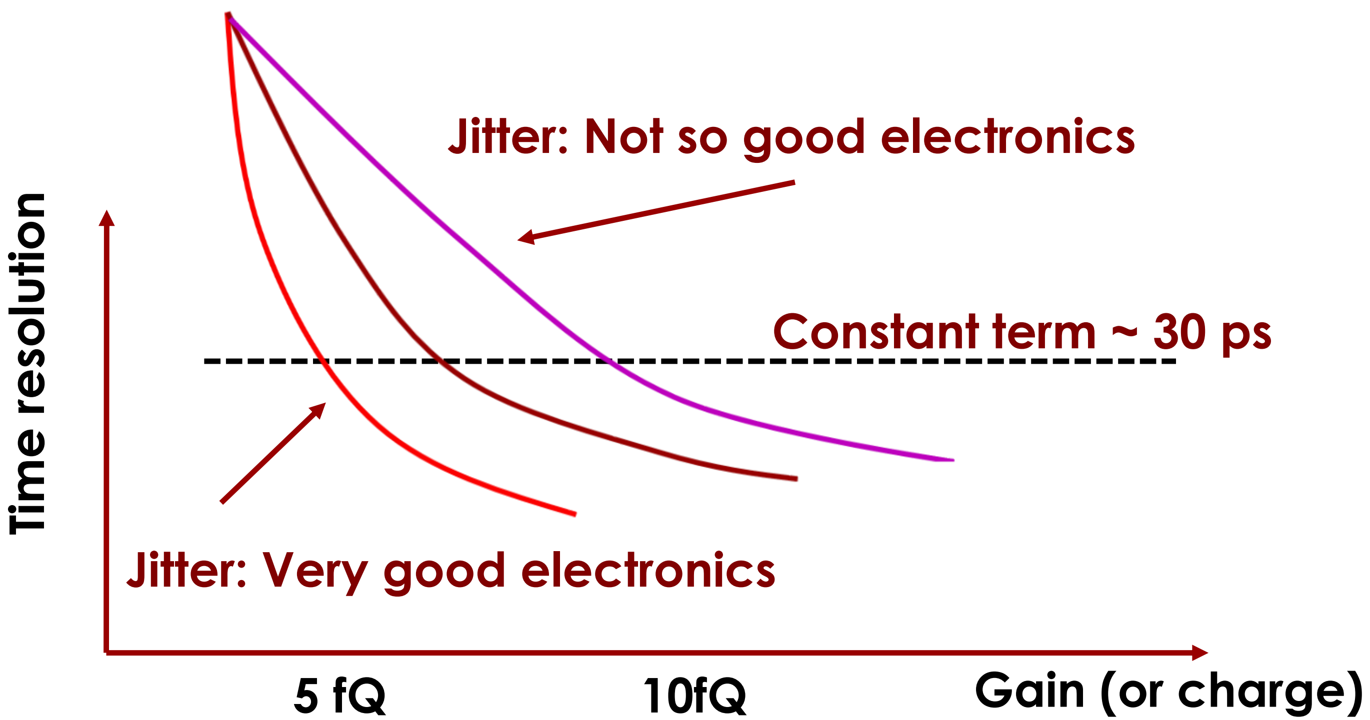


Message: the time resolution is limited by charge non uniformity

➔ Be aware: this is not time walk, it is the variability of the current pulse

Time resolution at 50 micron

$$\sigma_t^2 = \left(\frac{N}{dV/dt}\right)^2 + \sigma^2_{Non-uniform\, charge\, dep.}$$



Two components determine the time resolution:

- Non uniform charge deposition ➔ ~ constant term 25 – 30 ps
- Jitter contribution = N/(dV/dt) ~1/Gain **(controlled by electronics)**

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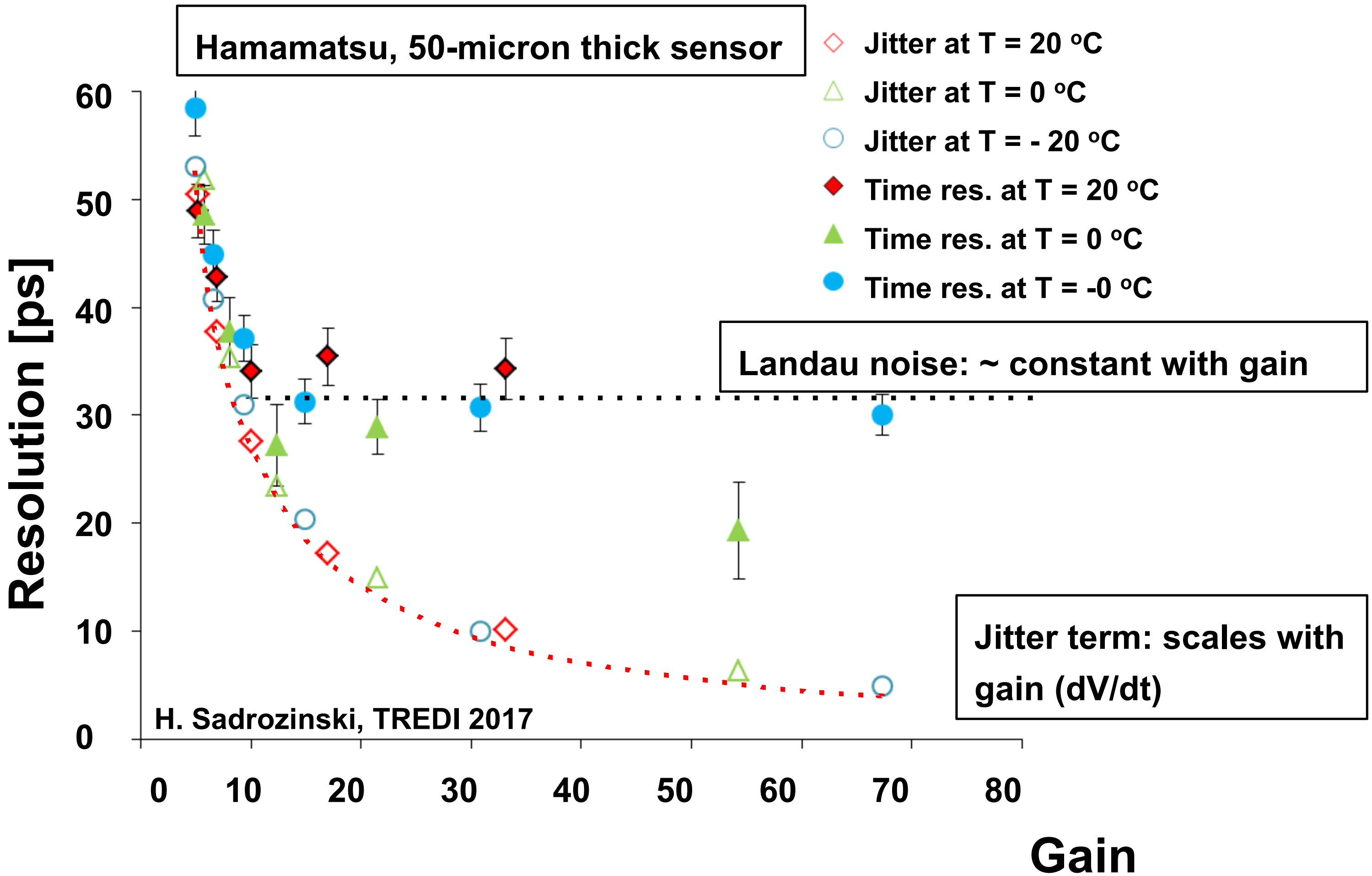
UFSD: time resolution

UFSD from Hamamatsu confirm our simulation: 30 ps time resolution, Value of gain ~ 20



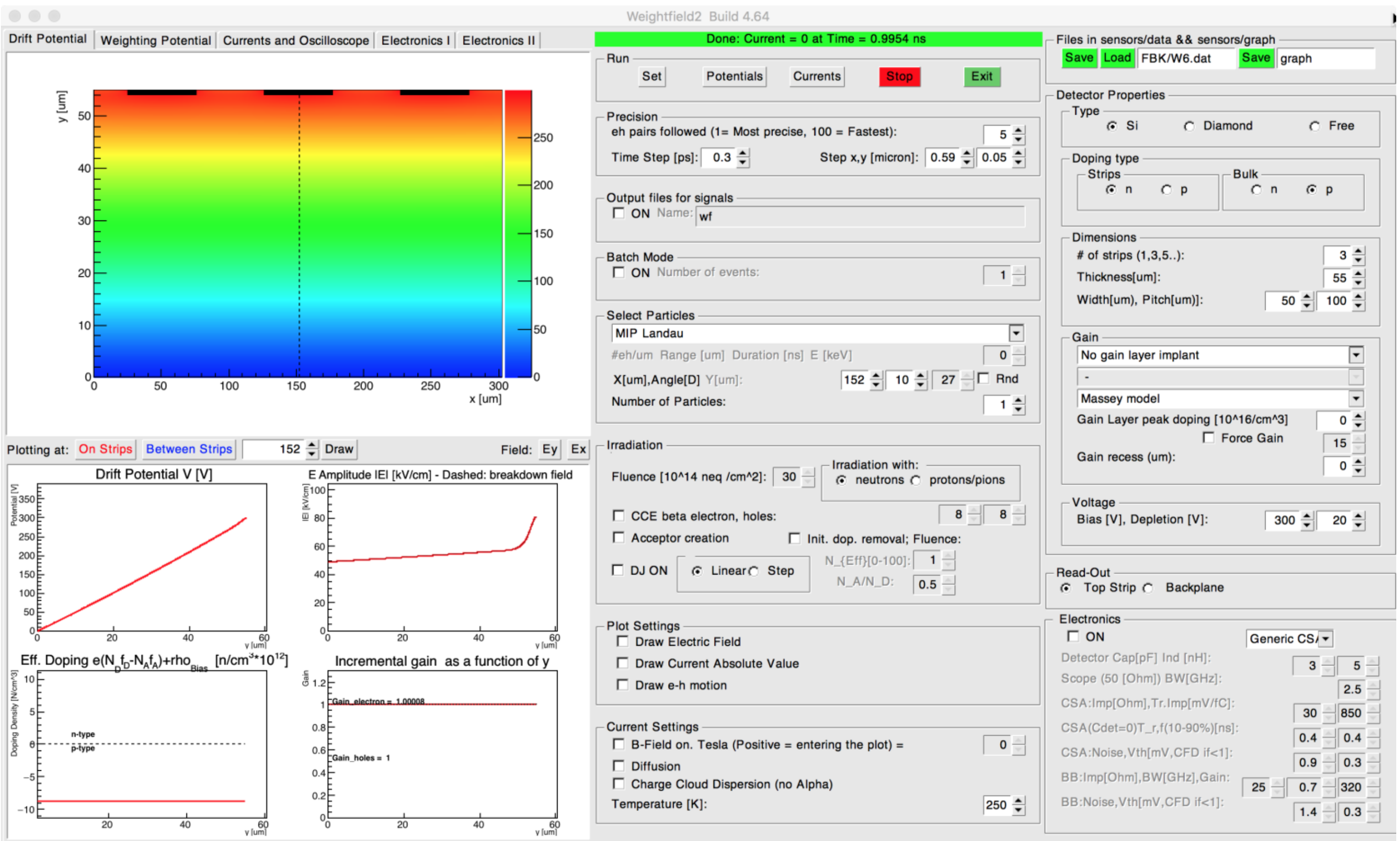
Weightfield2

Available at:

http://personalpages.to.infn.it/~cartigli/Weightfield2/Main.html

It requires Root build from source, it is for Linux and Mac.

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



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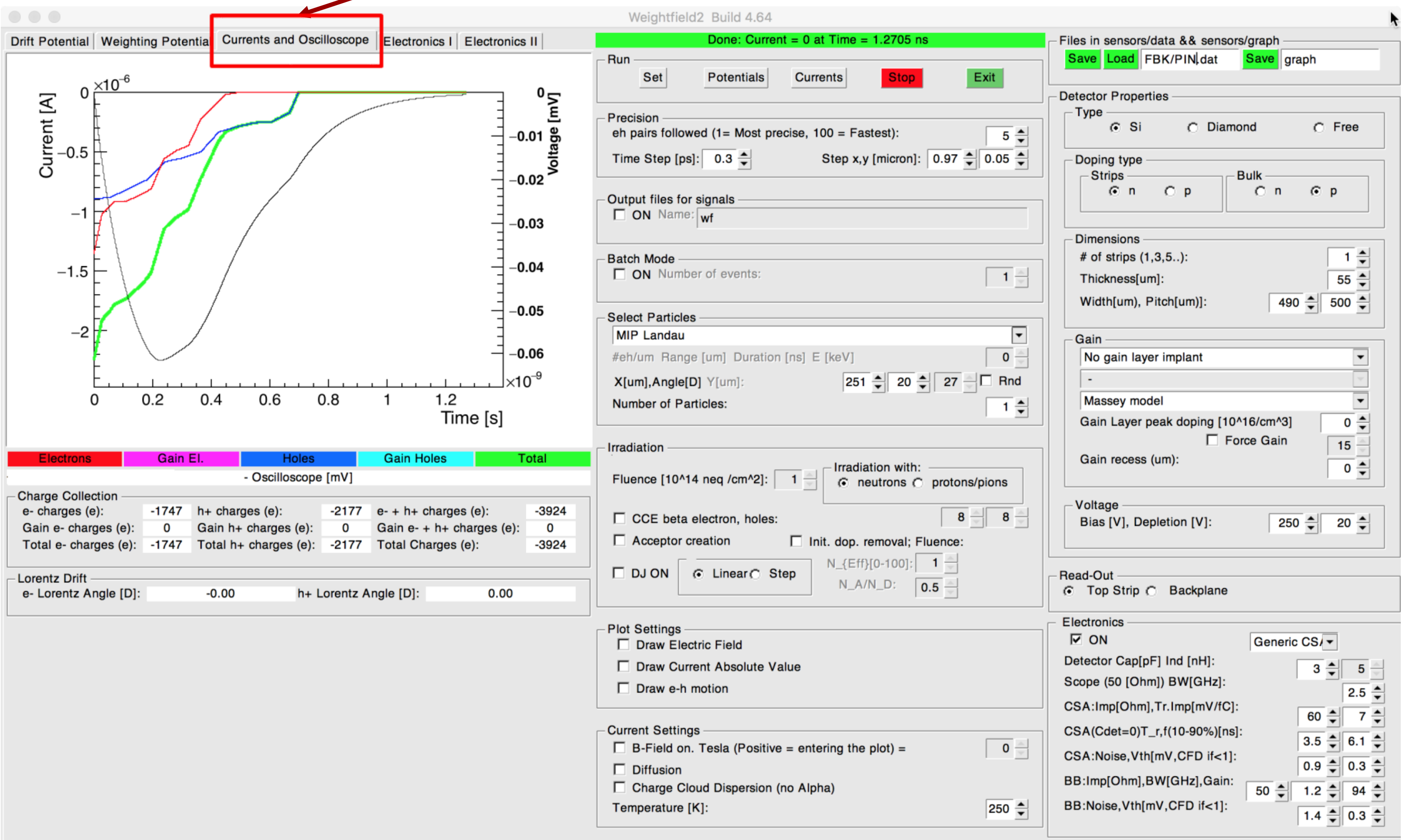
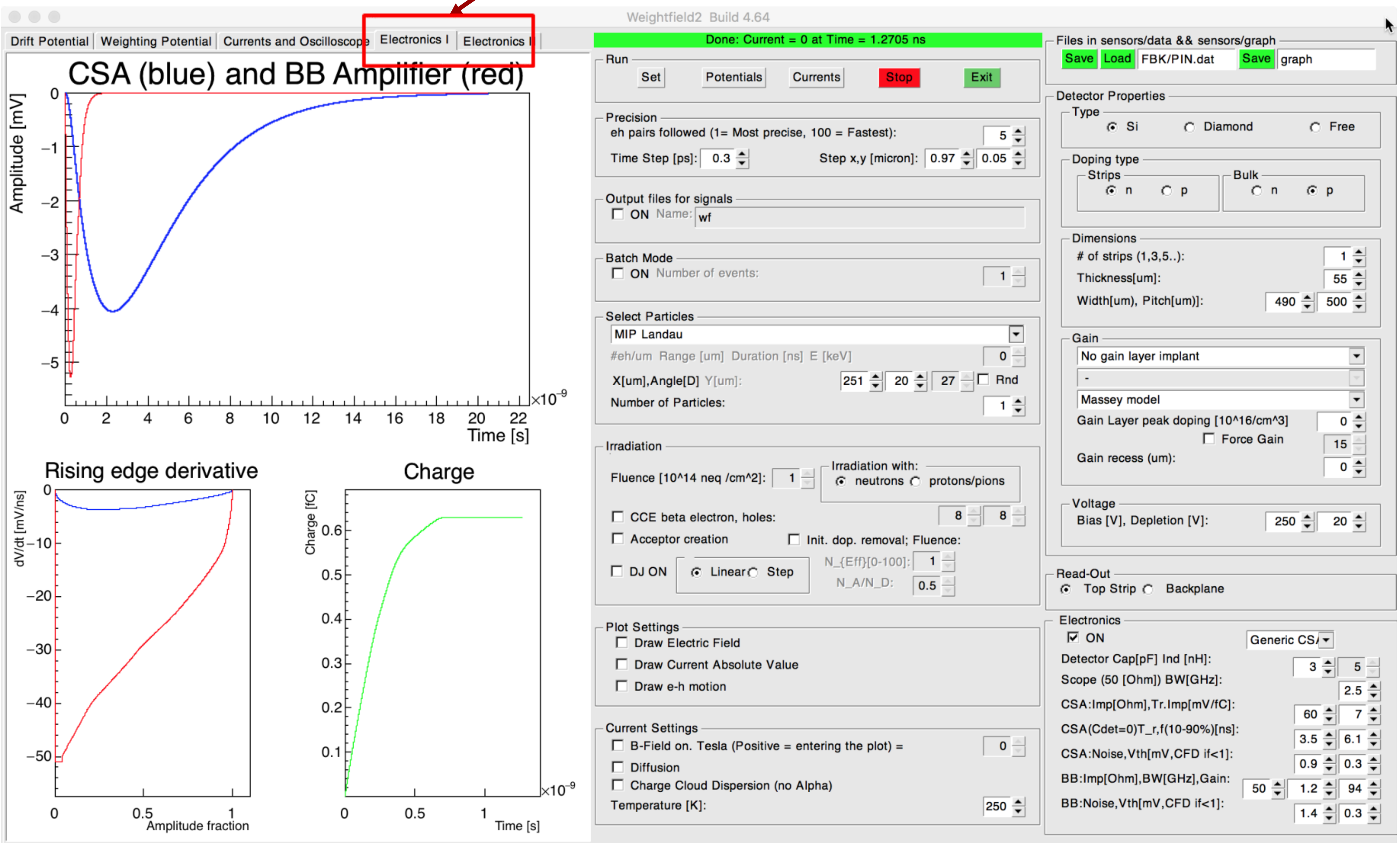
WF2: Currents

Current tabs



WF2: Electronics

Electronics tabs



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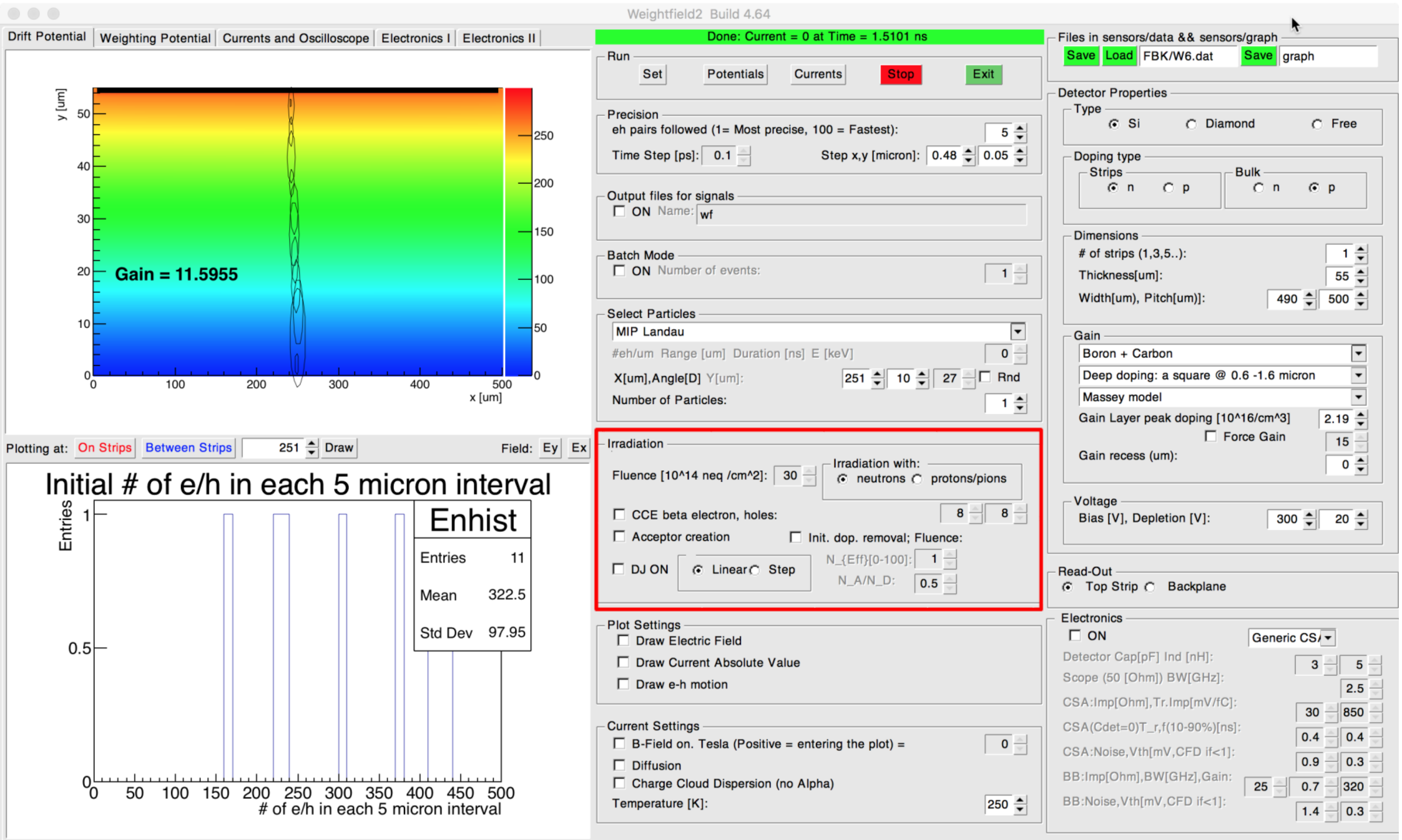
WF2: Radiation damage



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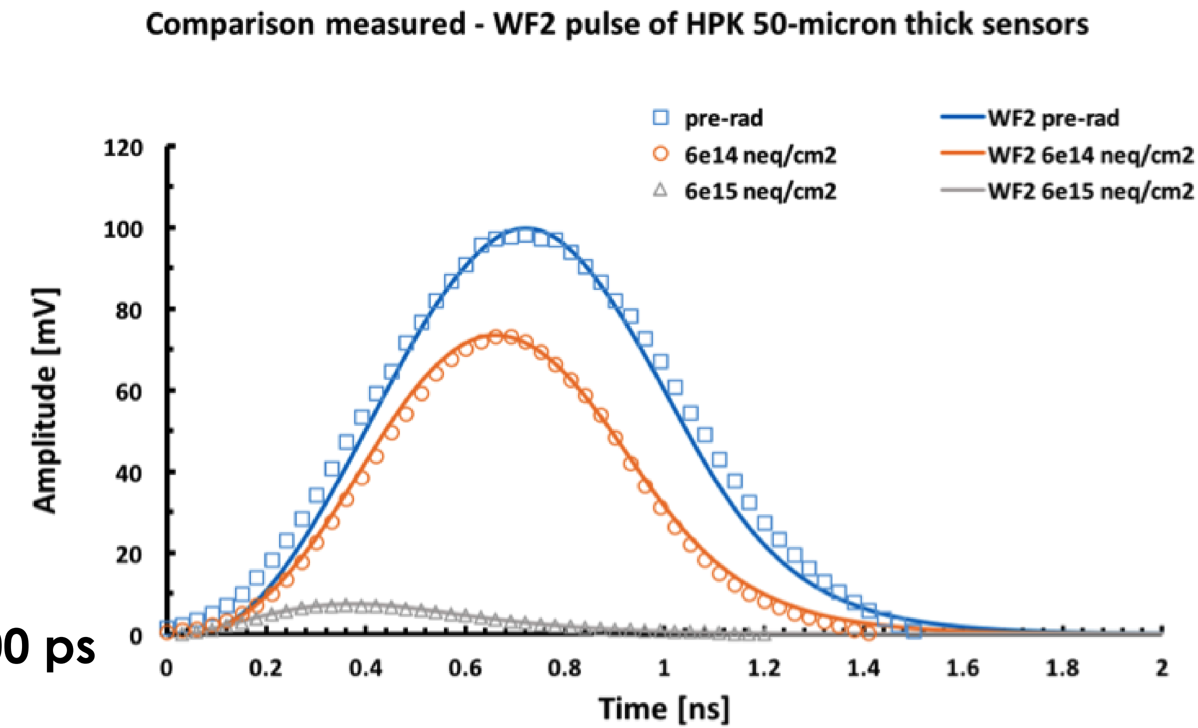
Evolution of the signal with fluence

The UFSD signal becomes

- Faster
- Shorter
- Smaller

Q: 10 fC ➔ 2 fC

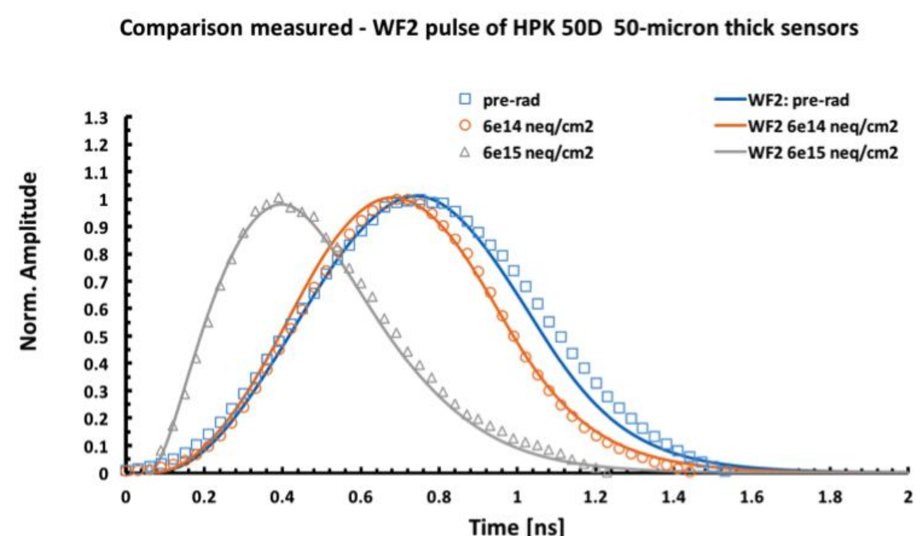
Rise time: 400 ps ➔ 200 ps



Be aware of ToT: the signal tail changes dramatically with irradiation,

ToT might not work without constant calibration

➔ Use CFD



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Summary

- The signal of UFSD for gain = 10 is 5 fC

➔ The range we need to consider is about 3 – 15 fC

- With 50-micron thick sensors we have ~ 30 ps intrinsic resolution

- Smaller intrinsic terms require thinner sensors