CERN

Joanna Rymut

"Developing a fast simulator for irradiated silicon detectors"

(TRACS radiation upgrade)

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(Summer Student 2015)

11 - August - 2015

Project description

"Simulation and measurements of heavily irradiated silicon detectors: CMS HPK and HGC campaigns"

Expand TRACS functionality and performance

TRACS is an open source program developed by Pablo de Castro (Summer Student 2014)

Fast **TRA**nsit **C**urrent **S**imulator based on Ramo's theorem that uses external libraries for calculations FEM

Project description

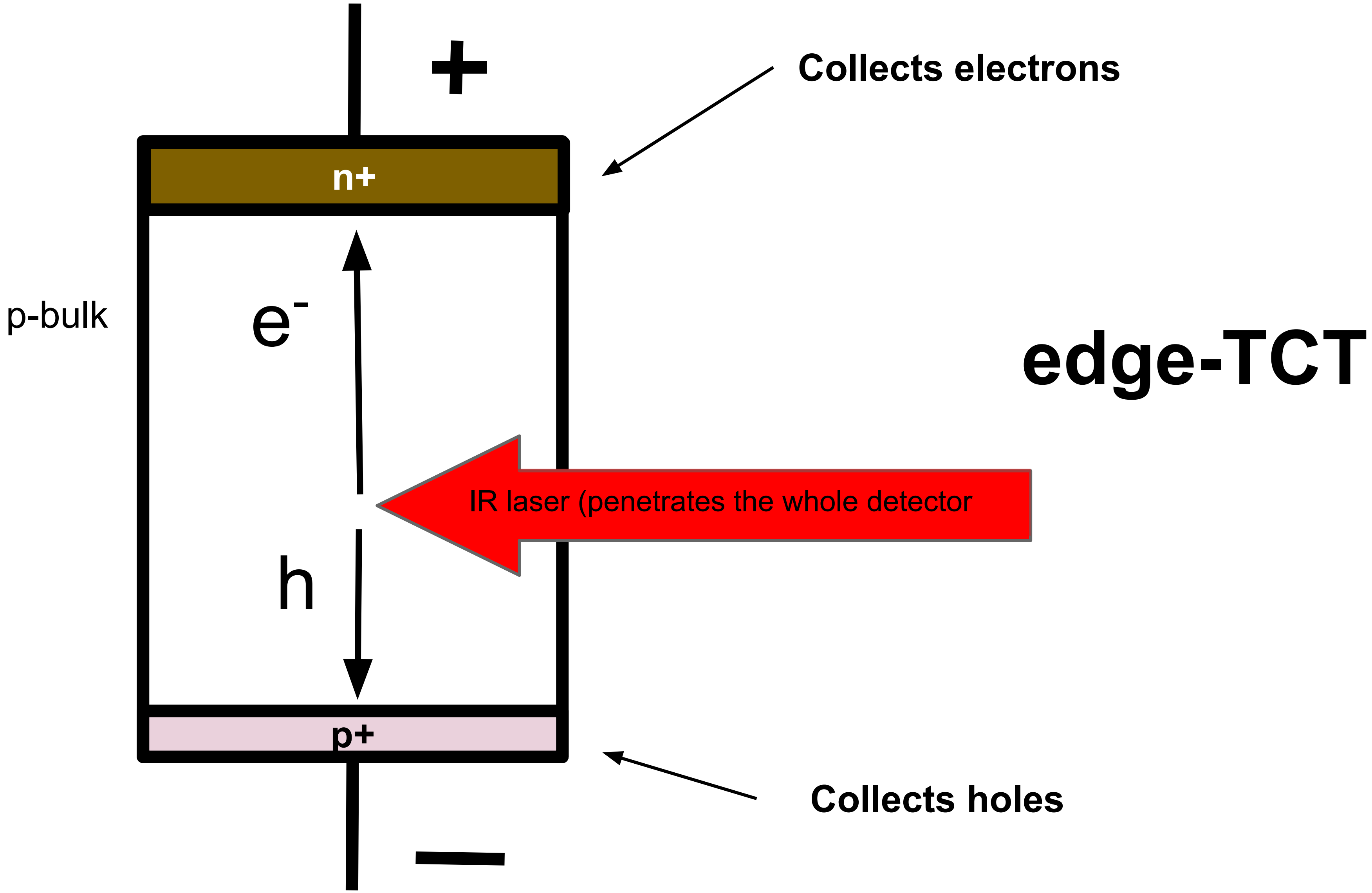
What we want to achieve:

“Fast simulation of irradiated detectors with selectable free parameters that can be fitted to measurements”

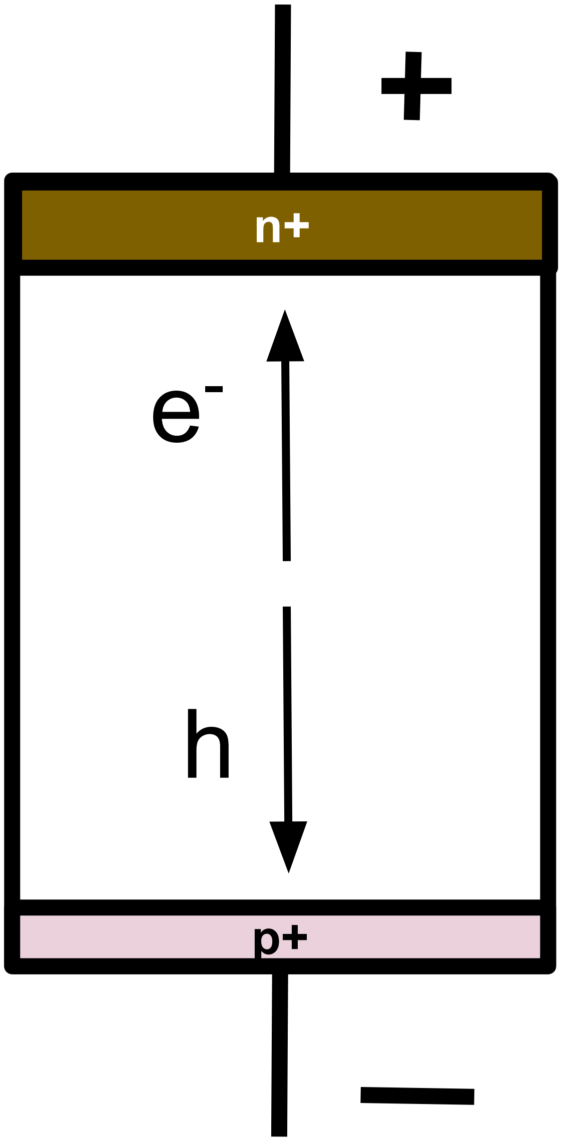
What we need to implement in TRACS

- Simulation of irradiated detectors
- Tunable Neff distribution → Our free parameters
- Simulate trapping effects
- Accurate simulation of electronics (Shaping)
- Performance improvements (parallelization?)

Basics of silicon detectors



Basics of silicon detectors



Velocity is proportional to the electric field

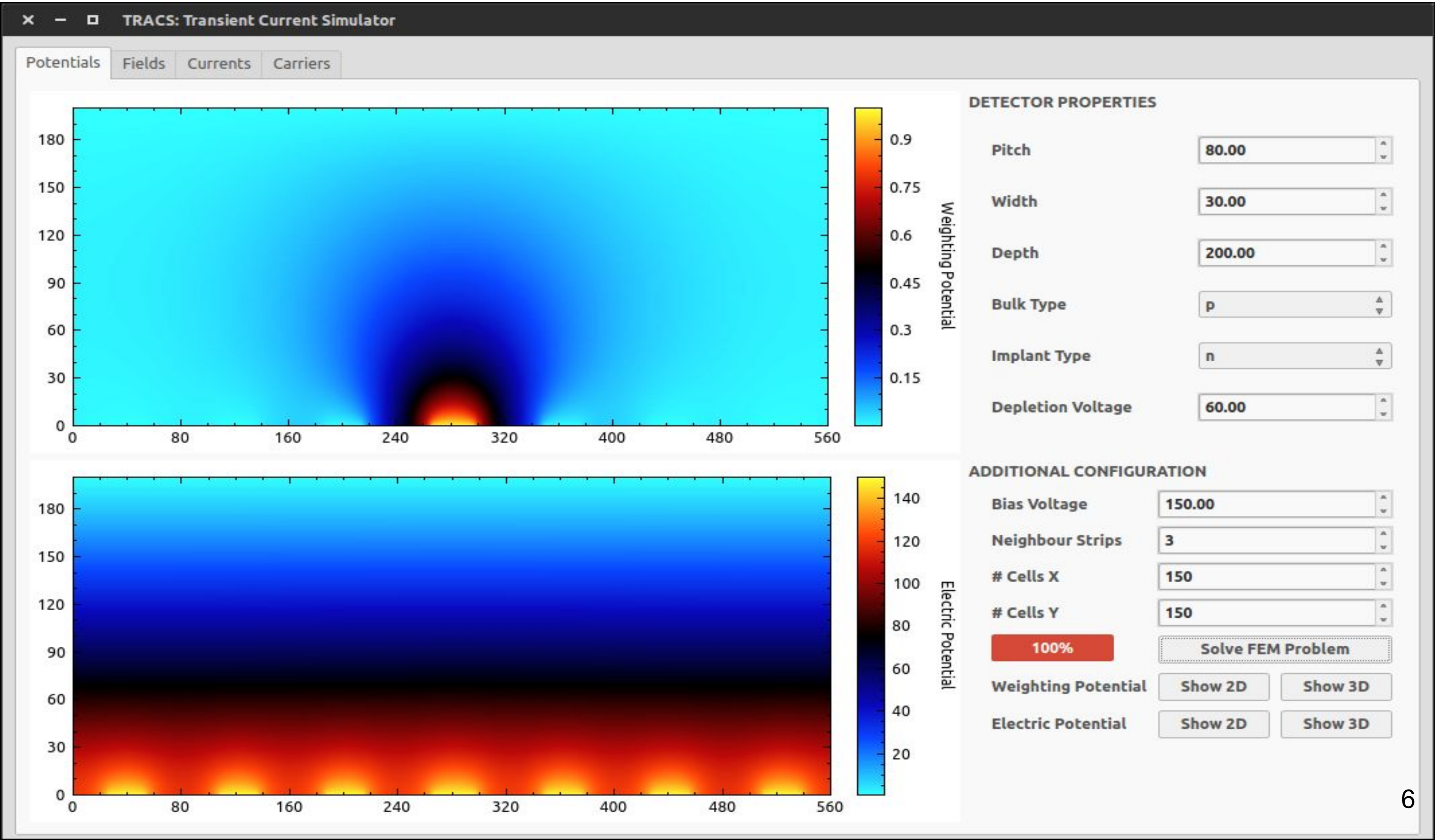
Current generated due to electric induction

i.e. its proportional to the velocity

edge-TCT illumination allows as to “see” the field inside the detector

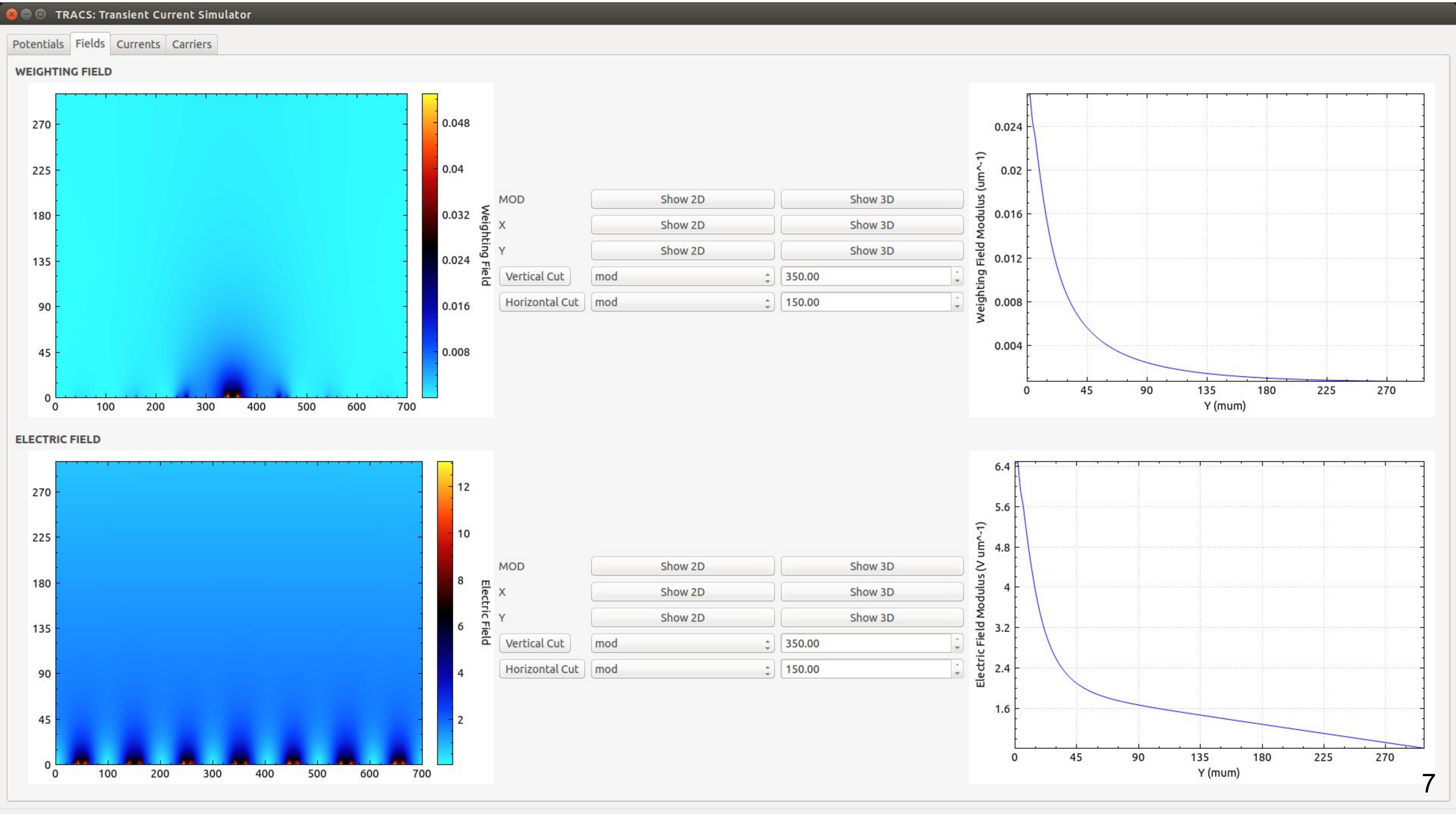
What TRACS did

Simulate diode and strip detectors



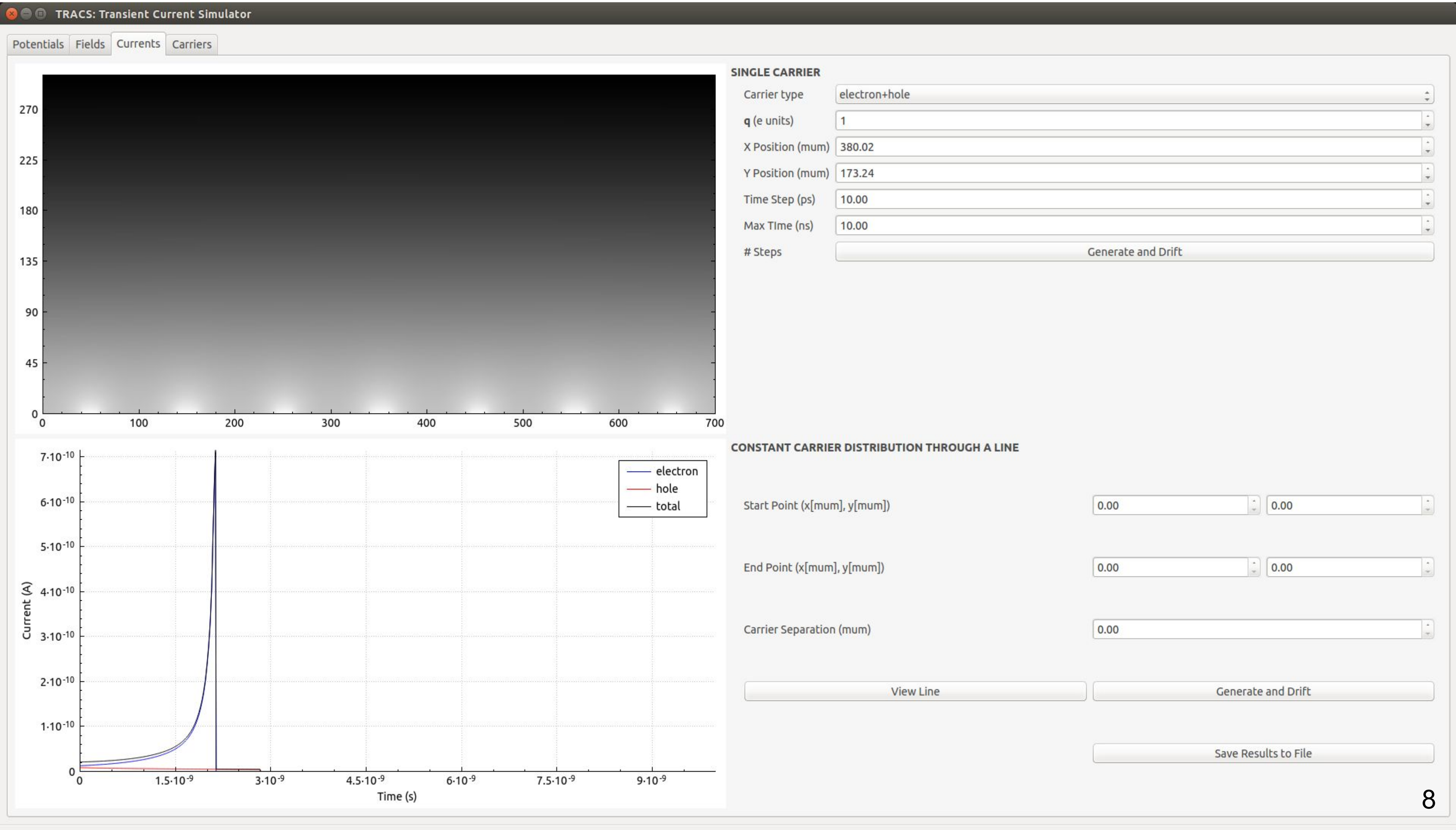
What TRACS did

Calculate weighting and electrical potentials and fields



What TRACS did

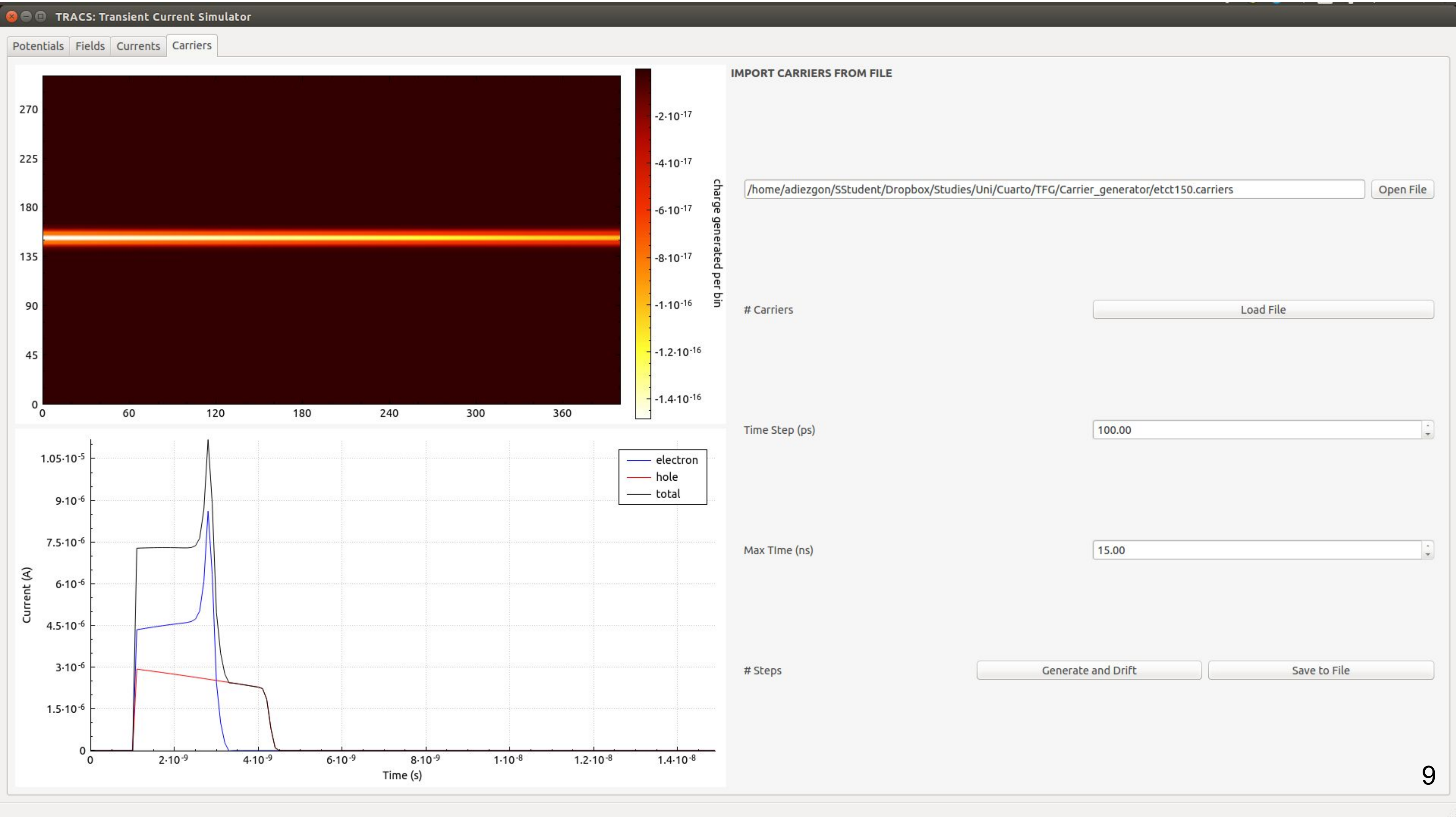
Simulate waveform due to a single e-h pair



What TRACS did

Simulate signal generated by any kind of illumination

simple RC shaping was also implemented in November



First Step - Changing Neff distribution

Why is Neff important?

$$\nabla E = \frac{\rho}{\varepsilon} \qquad \nabla \phi = \vec{E}$$

$$\nabla^2 \phi = \frac{\rho}{\varepsilon}$$

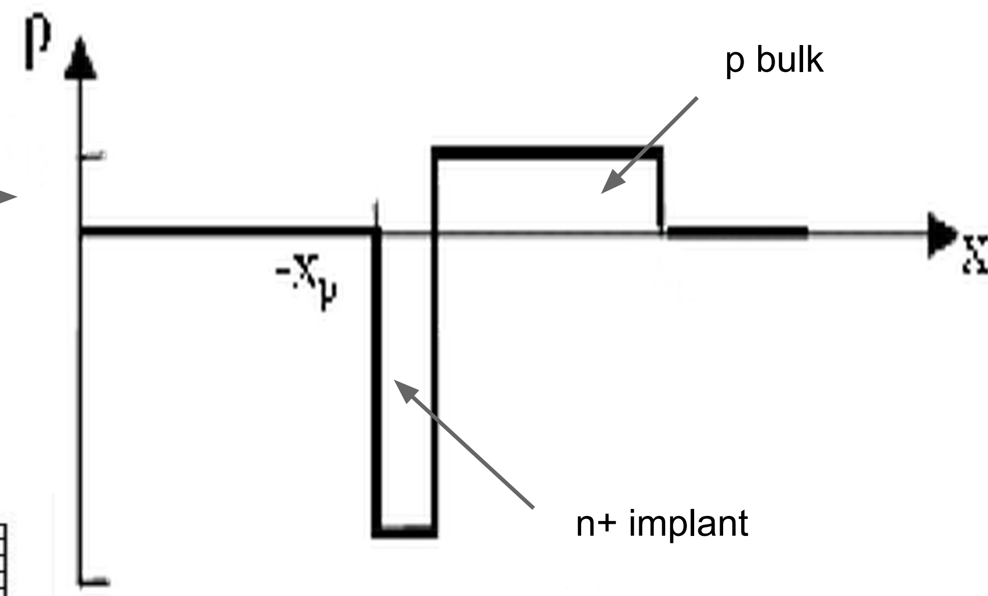
Integrate once → Get electric field

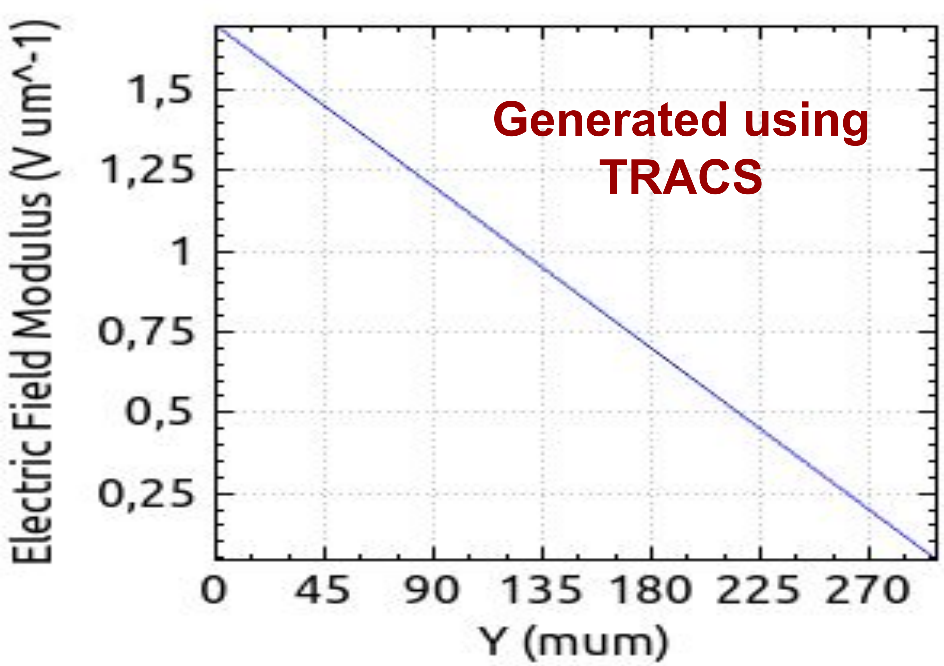
Integrate twice → Get electric potential

Neff before irradiation

Constant space charge distribution

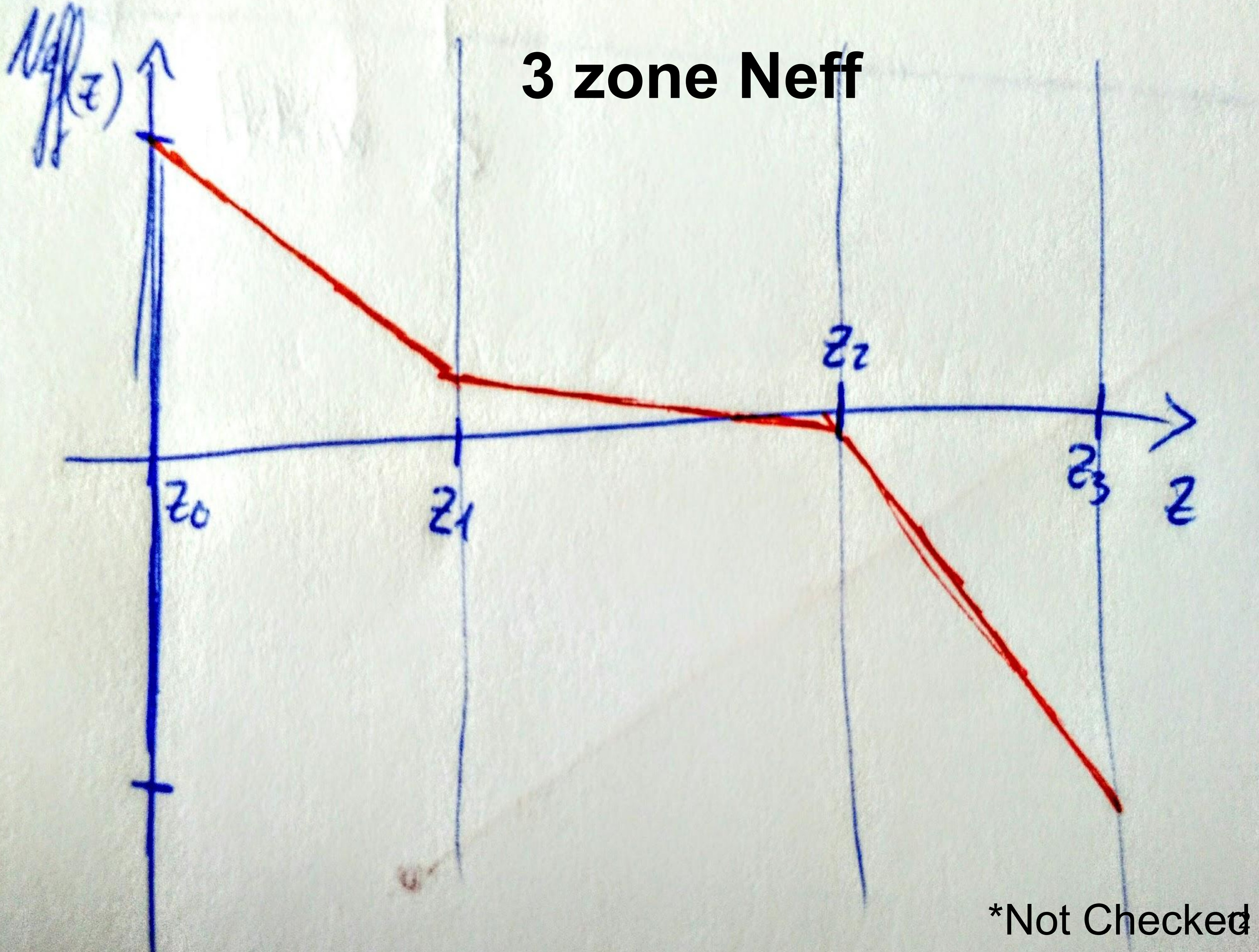
(ρ in previous slide)





Linear Electric field

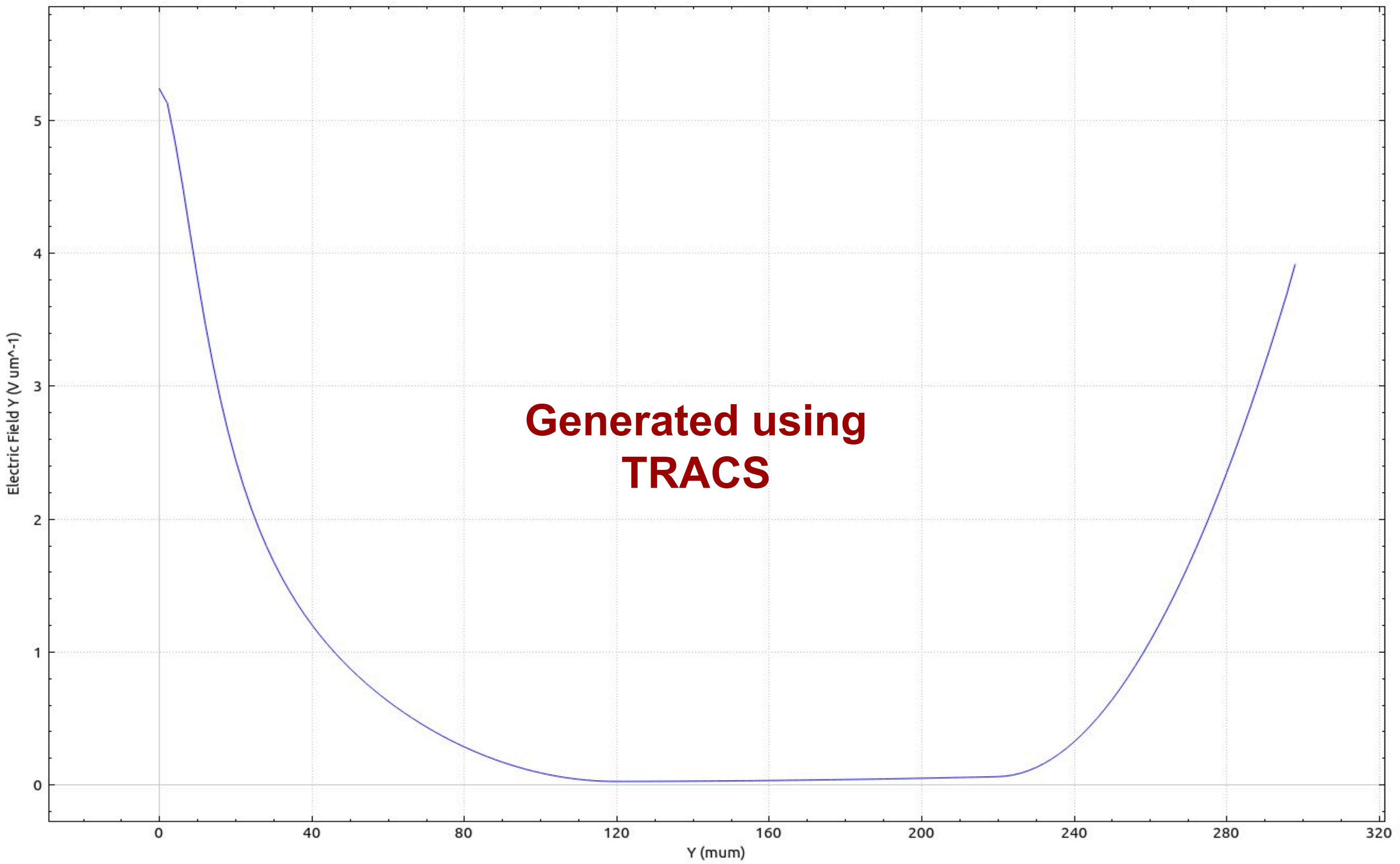
3 zone Neff



*Not Checked

Third Approach* - 3 zone Neff

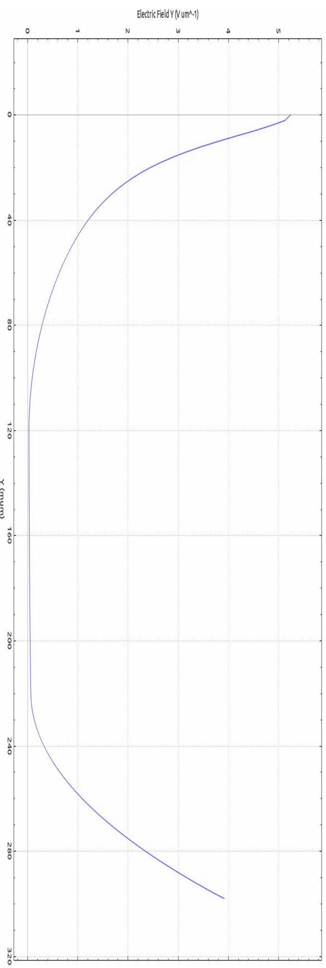
*Not Checked

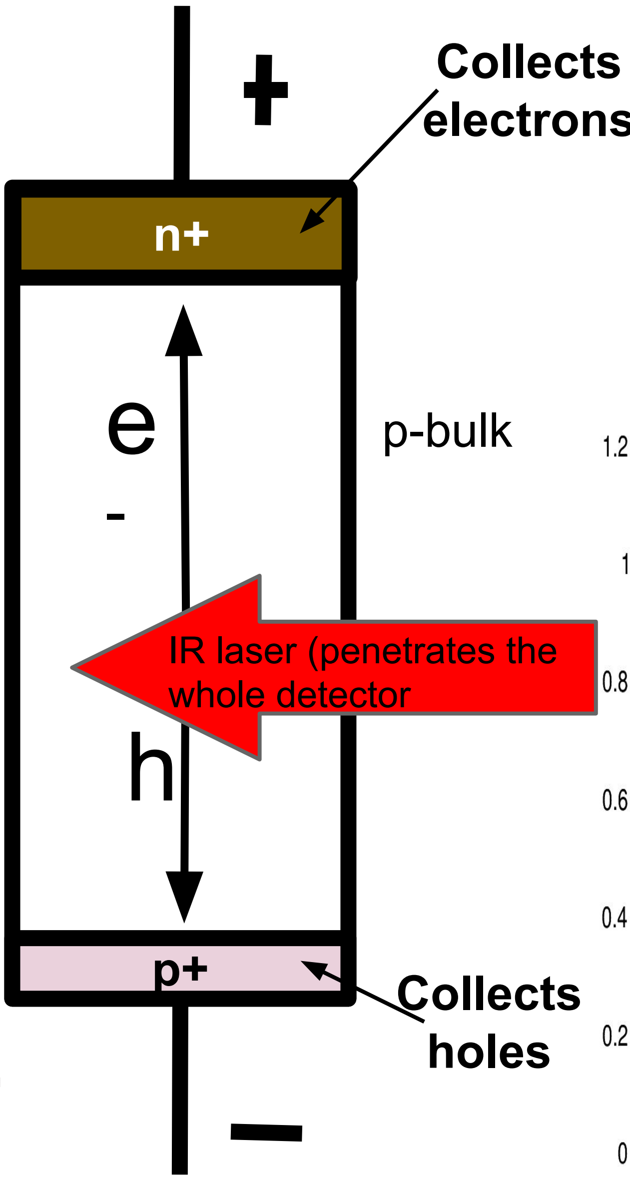


3 parabolas (one per Neff zone)

Second Approach* - 3 zone Neff

*Not Checked

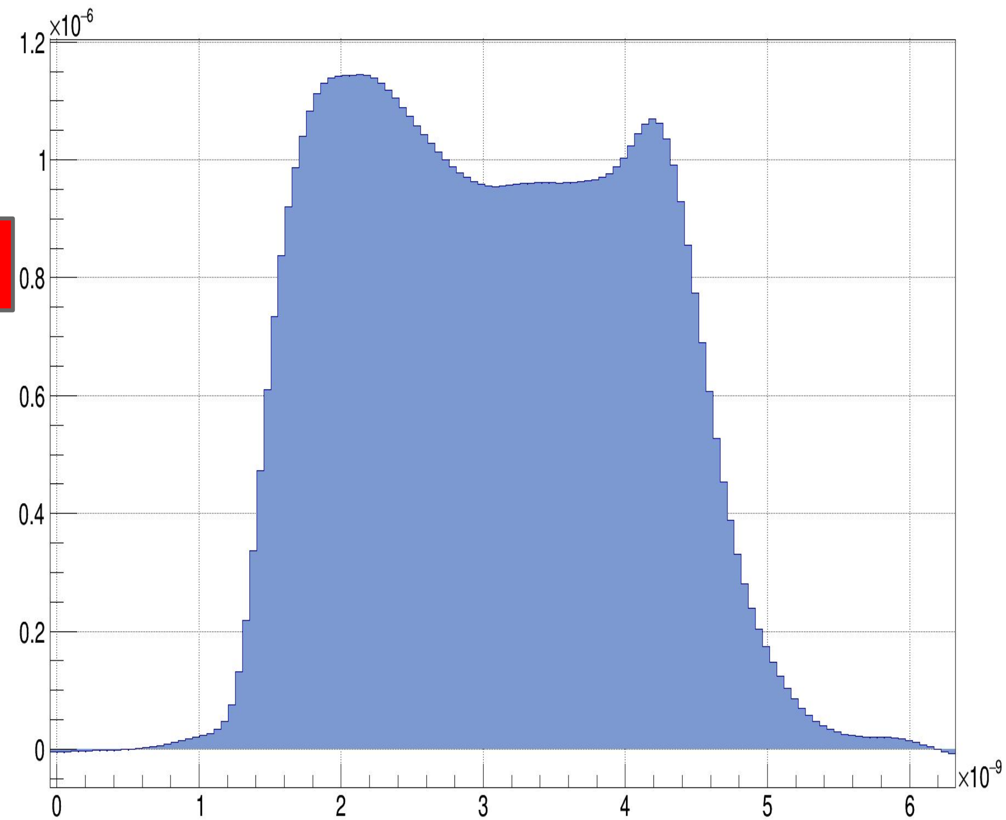




- Microstrip
- IR laser
- edge-TCT
- ~180μm

Double peak

- Bias = 500v
- Vdep = 250v
- Irradiated



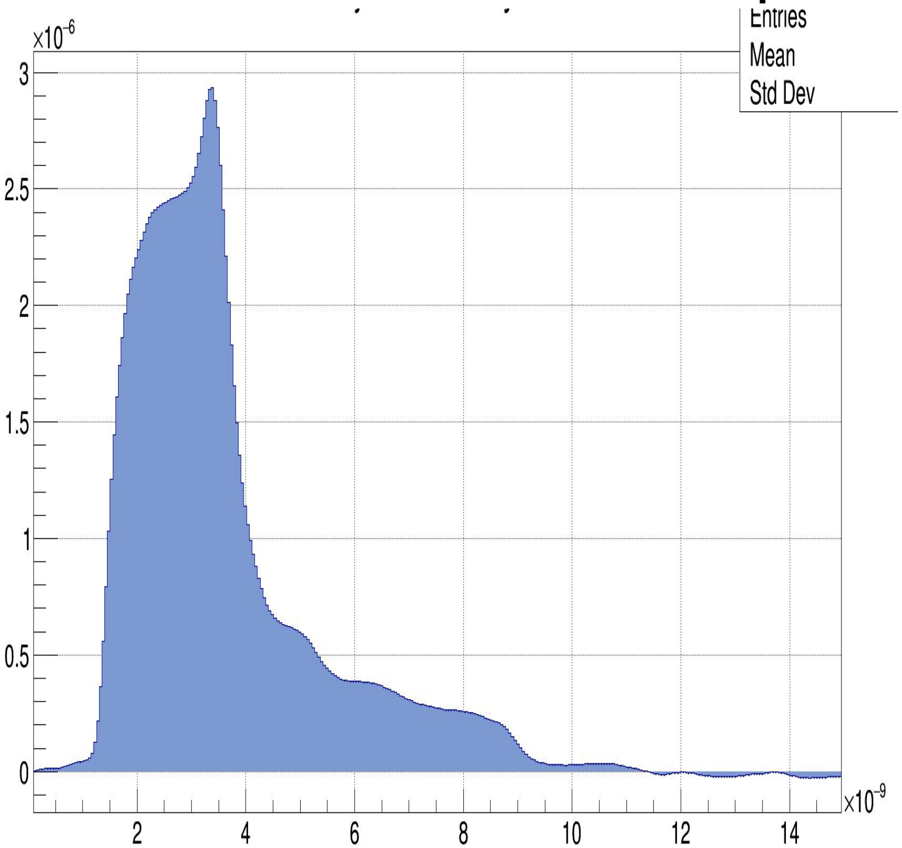
NoIRRAD vs IRRAD

- Microstrip
- IR laser
- edge-TCT (~180μm)

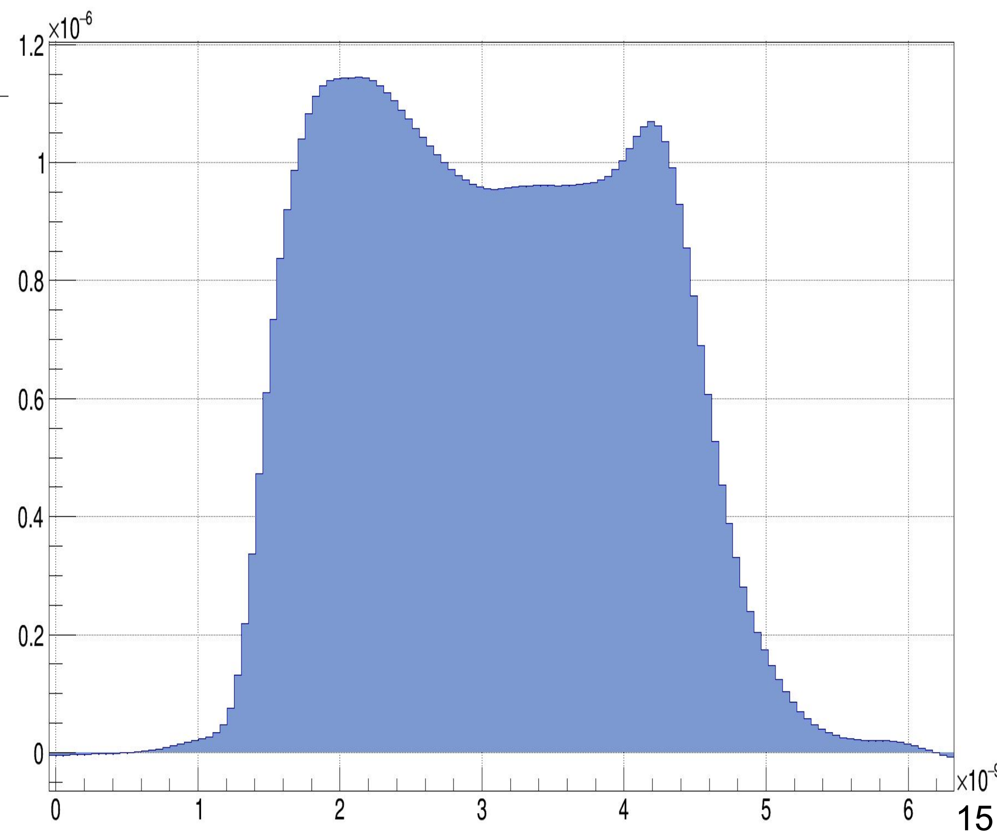
- Bias = 500v
- Vdep* = 250v

*Vdep has no relevance for irradiated simulations

Non-irradiated mirostrip



Irradiated mirostrip



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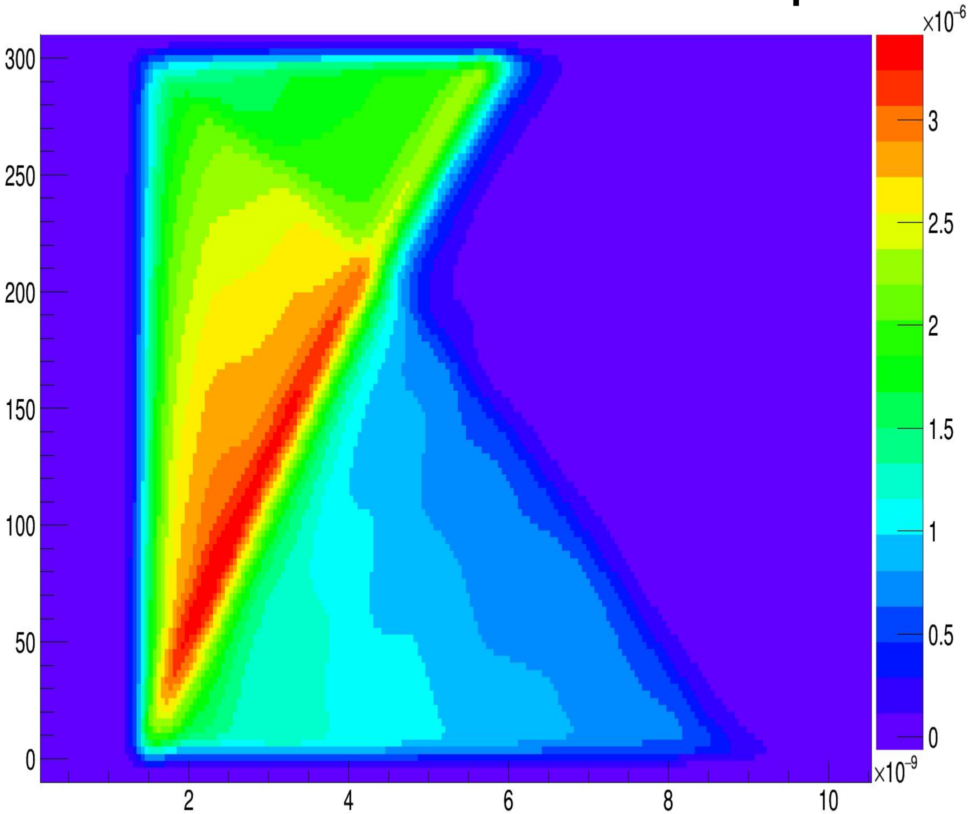
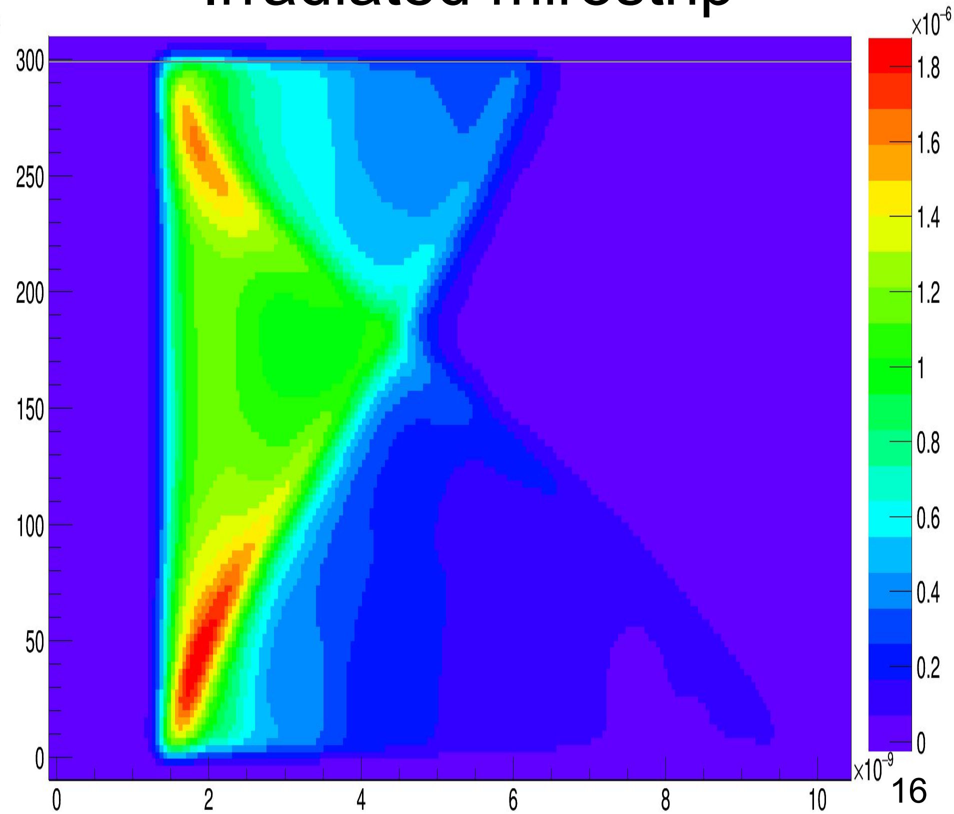


Irradiated mirostrip



Progress report

All that TRACS already does and ...

☑️ Simulation of irradiated detectors (given Neff distribution)

☑️ Include trapping effects

☑️ Improve RC shaping by means of convolution with amplifier

☑️ Output format mimicks TCT+ data format. Simulation can be analyzed with standard eTCT analysis software

☑️ Improved performance using less carriers per simulation

☐ Further performance improvements through parallelization

☐ Fit simulation to experimental data

? Irradiated simulation in GUI

? Input file to avoid recompiling all the time

Near future

Type of simulation	Before improvements	After Improvements	Expected with parallelization
edge-TCT/50ps 1-laser height	**~200s**	**~20s**	**3-10s**
edge-TCT/50ps/ 3um full detector	**~3h**	**~30min**	**4-15min**

Simulation time

Trimmed version of *.carriers file

Make "main.cpp" accept input parameters

Will call "main.cpp" with different Neff configurations searching for the best fit to measurements

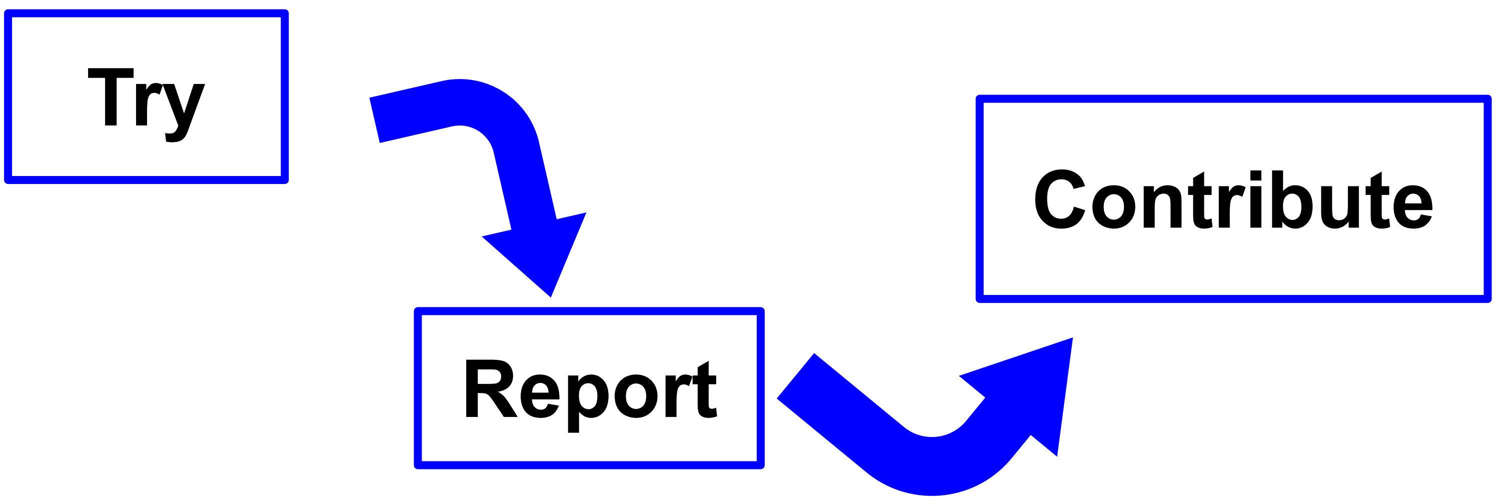
Fitting

Write minimization code χ^2

One more thing...

Code is available on GitHub → github.com/IFCA-HEP/TRACS

You are encouraged to



Thanks for your attention

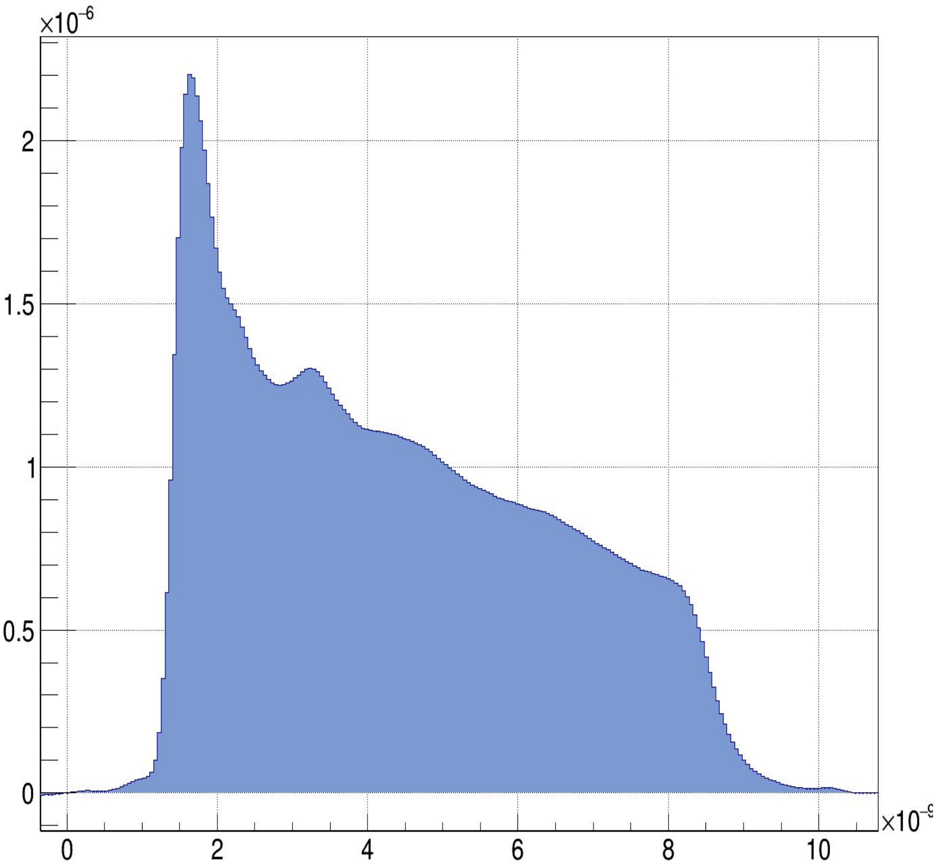
NoIRRAD vs IRRAD

- Microstrip
- IR laser
- edge-TCT (~15μm)

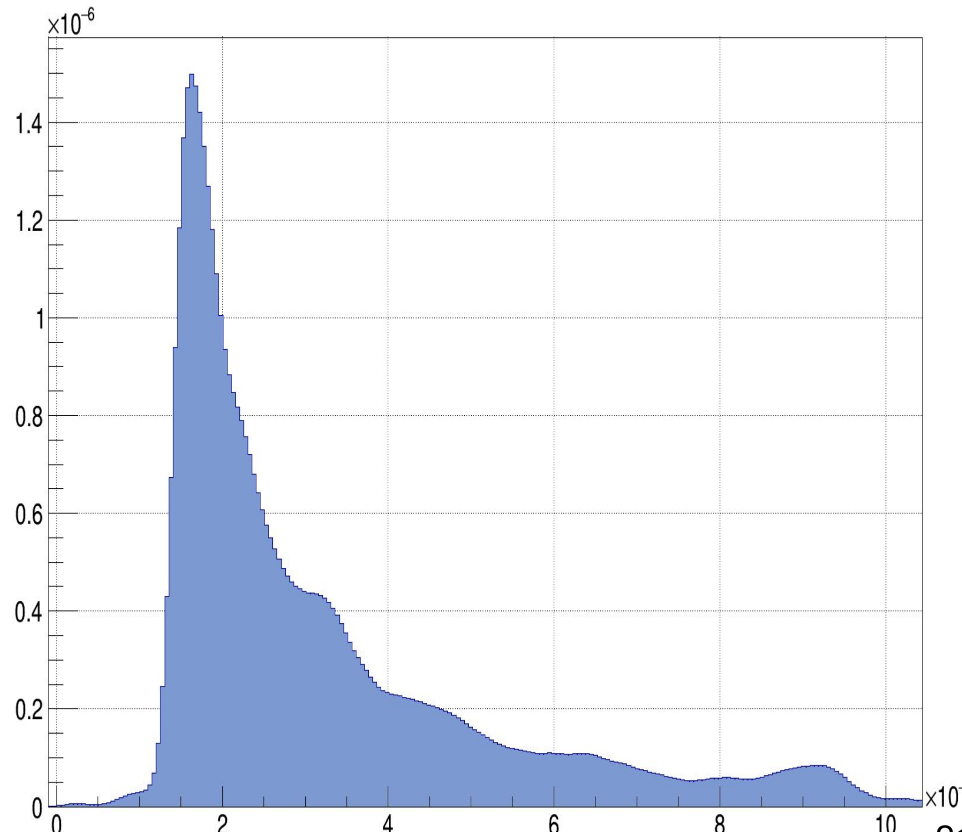
- Bias = 500v
- Vdep* = 250v

*Vdep has no relevance for irradiated simulations

Non-irradiated mirostrip



Irradiated mirostrip



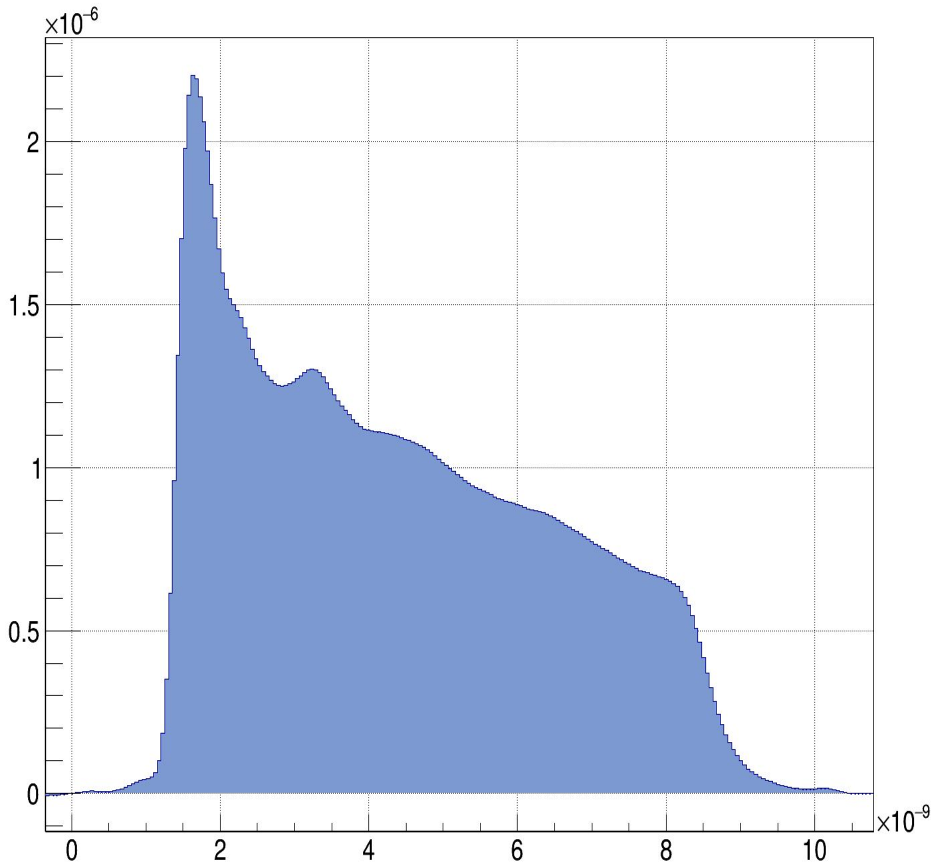
NoIRRAD vs IRRAD

- Microstrip
- IR laser
- edge-TCT (~290μm)

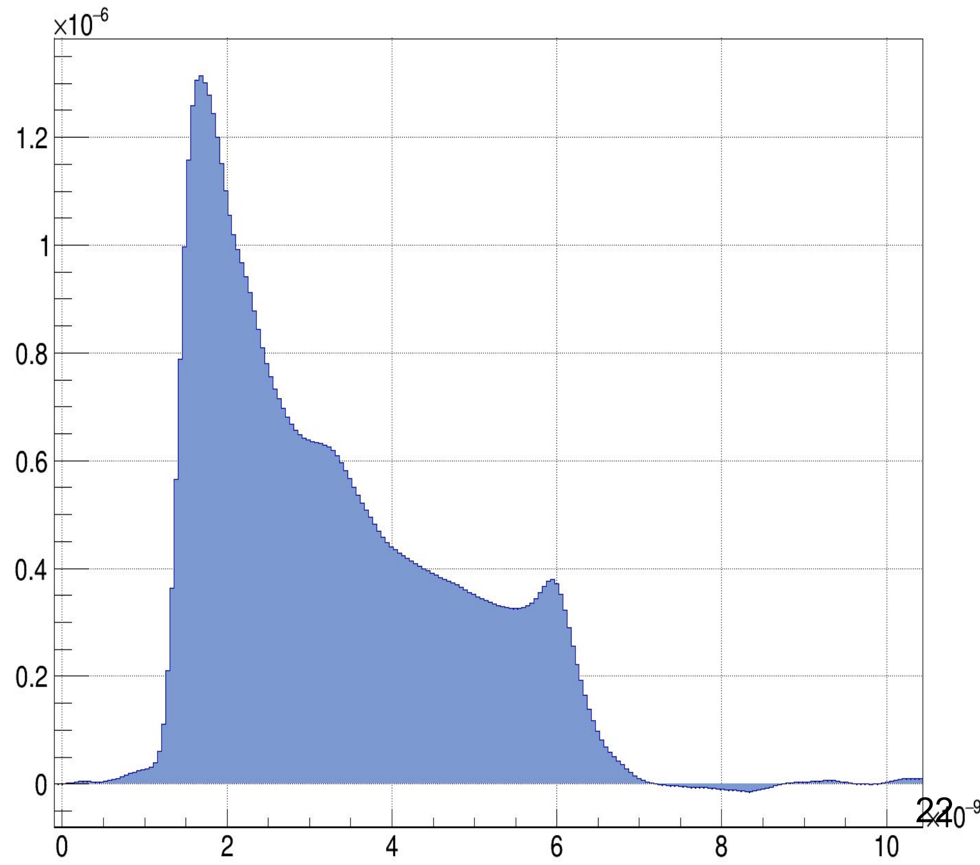
- Bias = 500v
- Vdep* = 250v

*Vdep has no relevance for irradiated simulations

Non-irradiated mirostrip

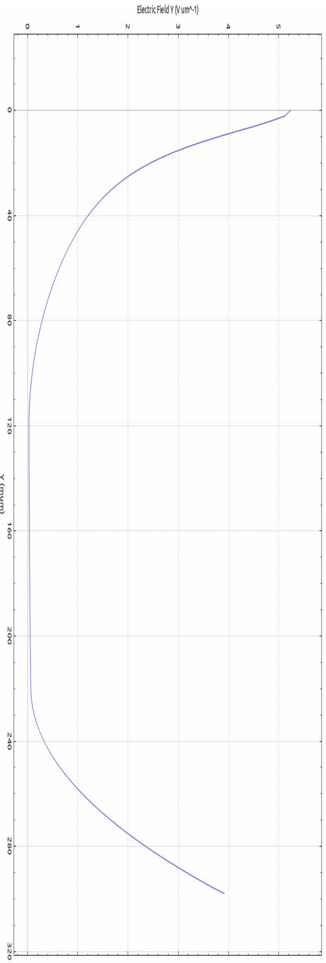


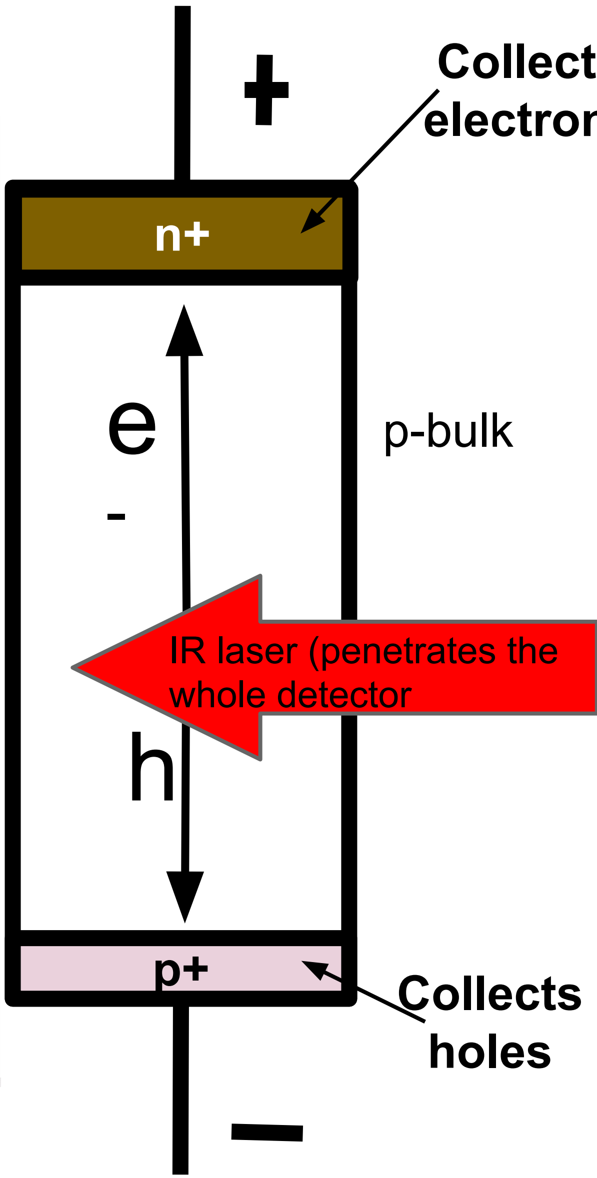
Irradiated mirostrip



Second Approach* - 3 zone Neff

*Not Checked

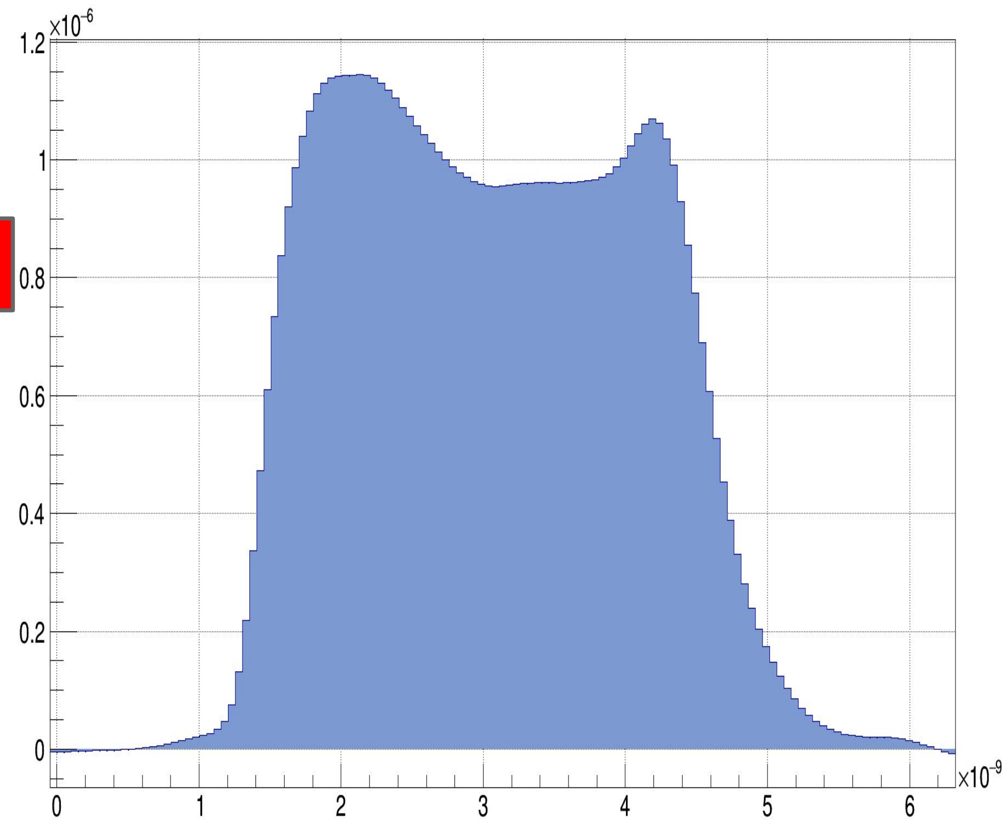




- Microstrip
- IR laser
- edge-TCT
- ~180μm

Double peak

- Bias = 500v
- Vdep = 250v
- Irradiated



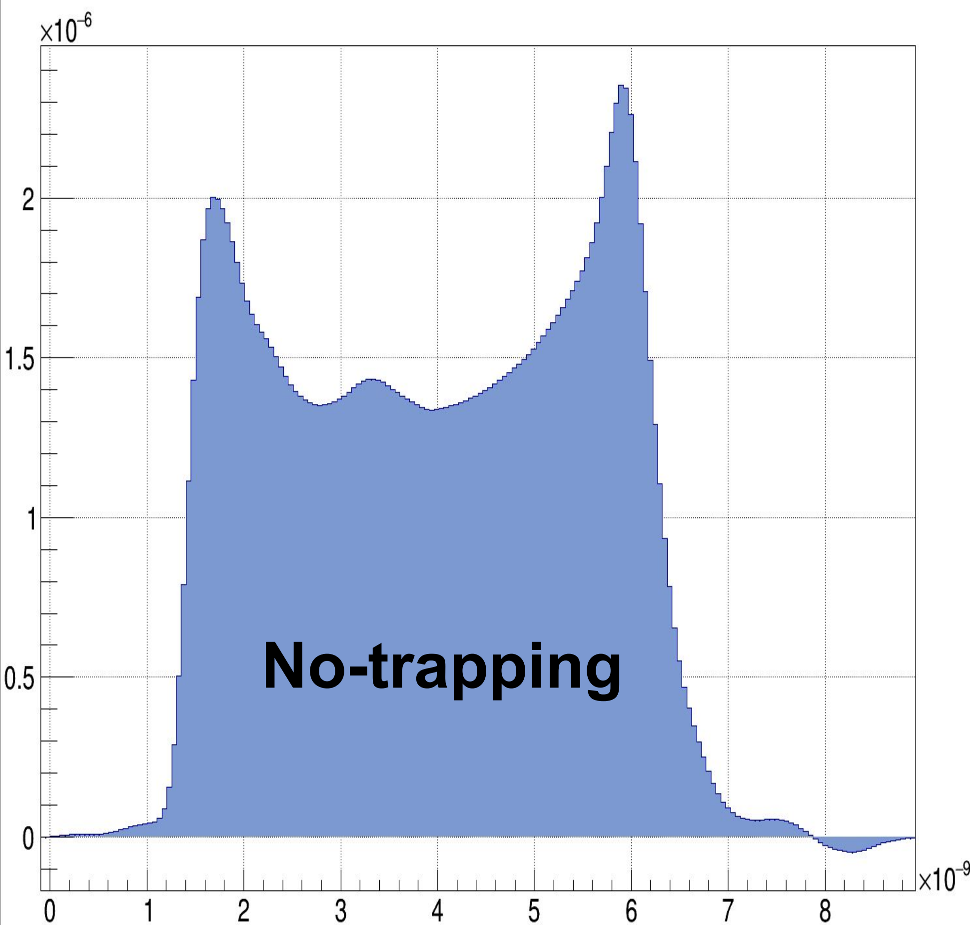
Second Step - Trapping

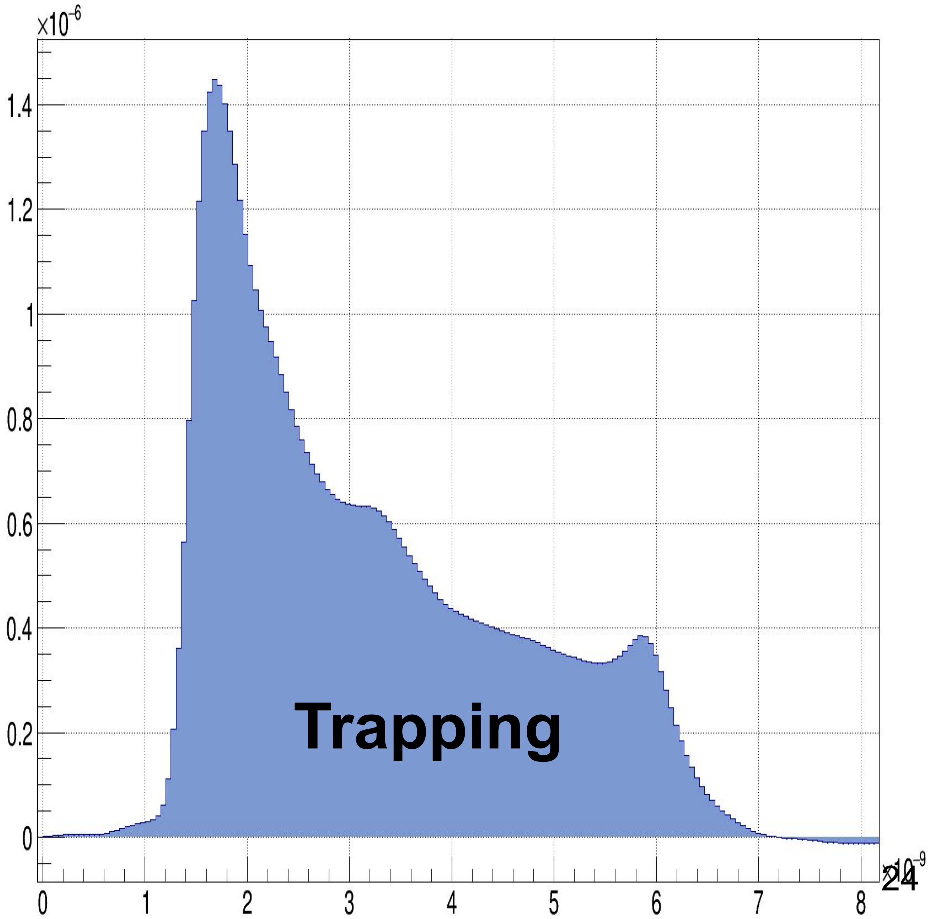
Simple exponential decay - Fast and accurate enough

- Microstrip
- IR laser
- edge-TCT (~280μm)

- Bias = 500v
- Vdep* = 250v

*Vdep has no relevance for irradiated simulations





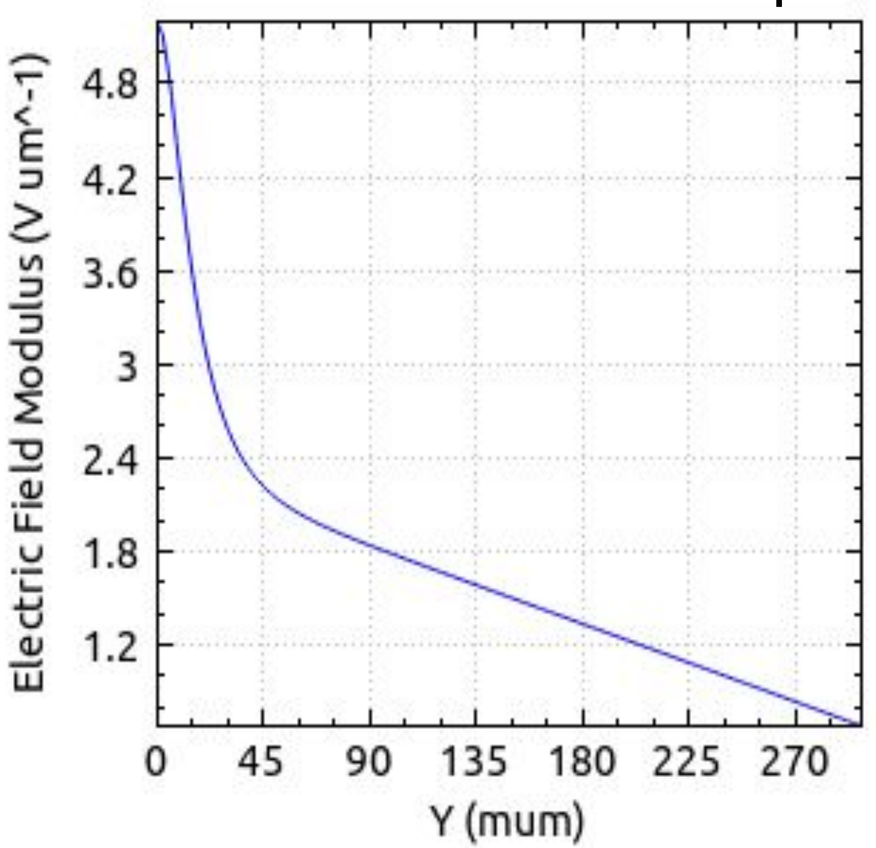
NoIRRAD vs IRRAD

FIELDS

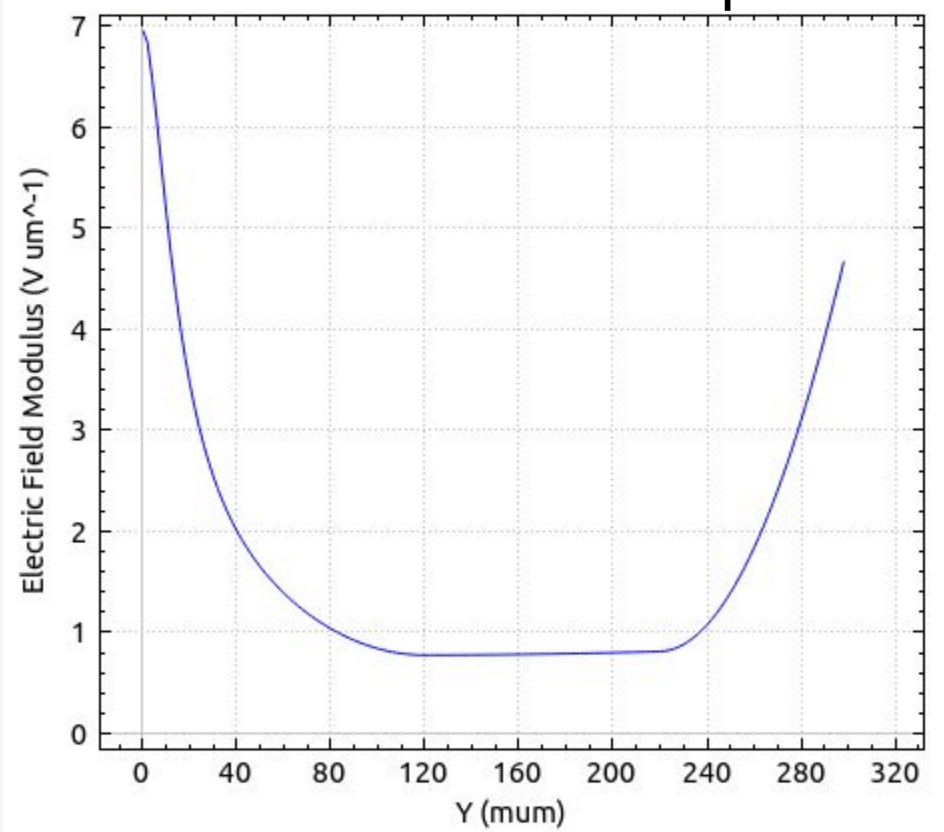
- Microstrip
- Bias = 500v
- Vdep* = 250v

*Vdep has no relevance for irradiated simulations

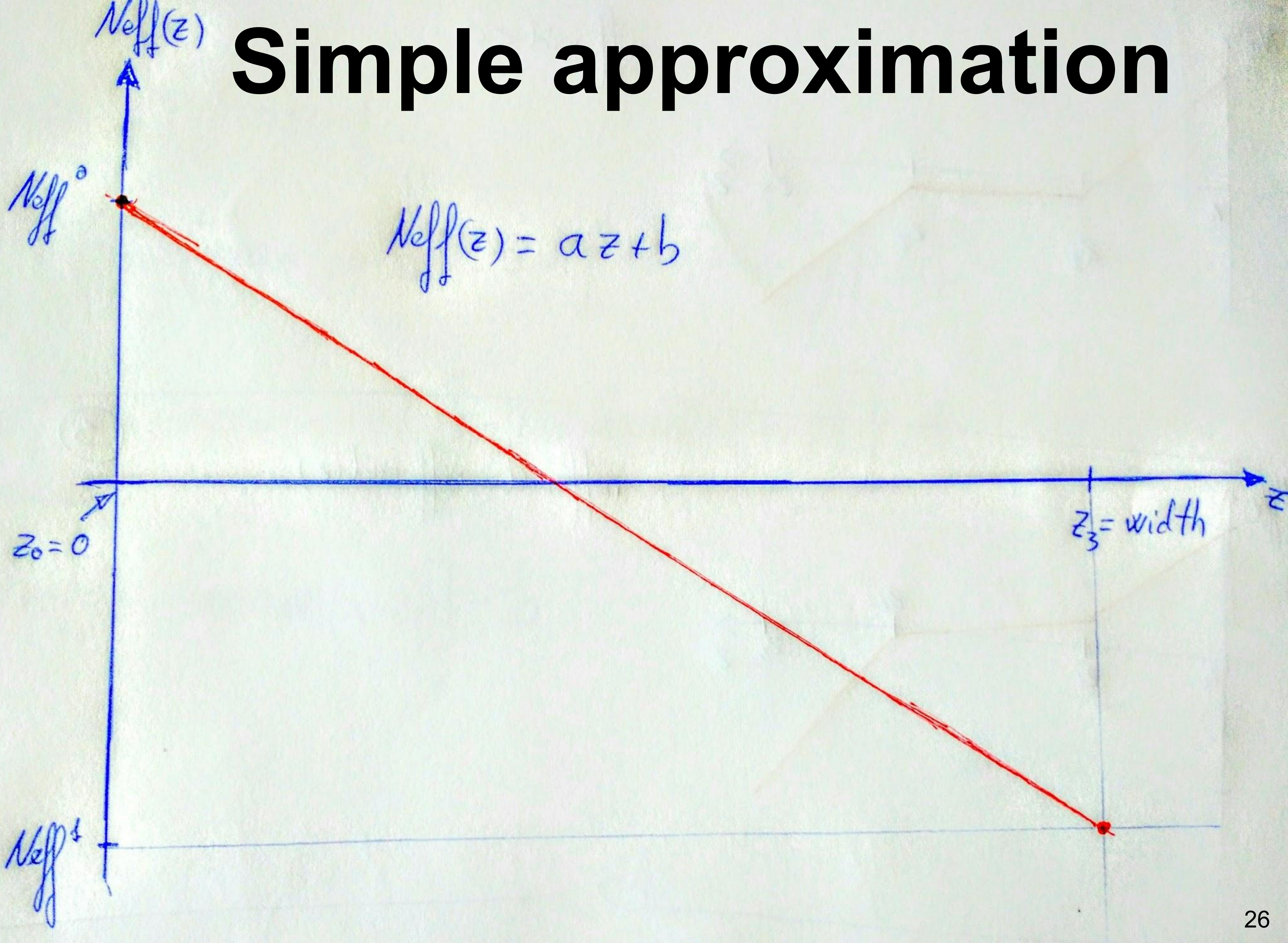
Non-irradiated mirostrip



Irradiated mirostrip



Simple approximation



Agreement with published results