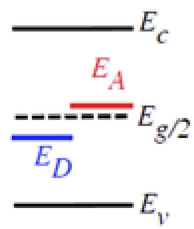
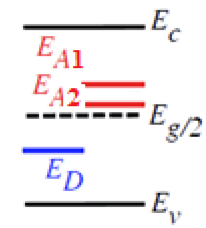
Simulation/modeling group – discussion session

Models of radiation damage in TCAD

EVL model
A single donor in bottom half of the bandgap and a single acceptor in the upper half of the bandgap



Perugia model
Three levels associated to donor CiOi, 1st acceptor to V_2 and 2nd acceptor to V_3

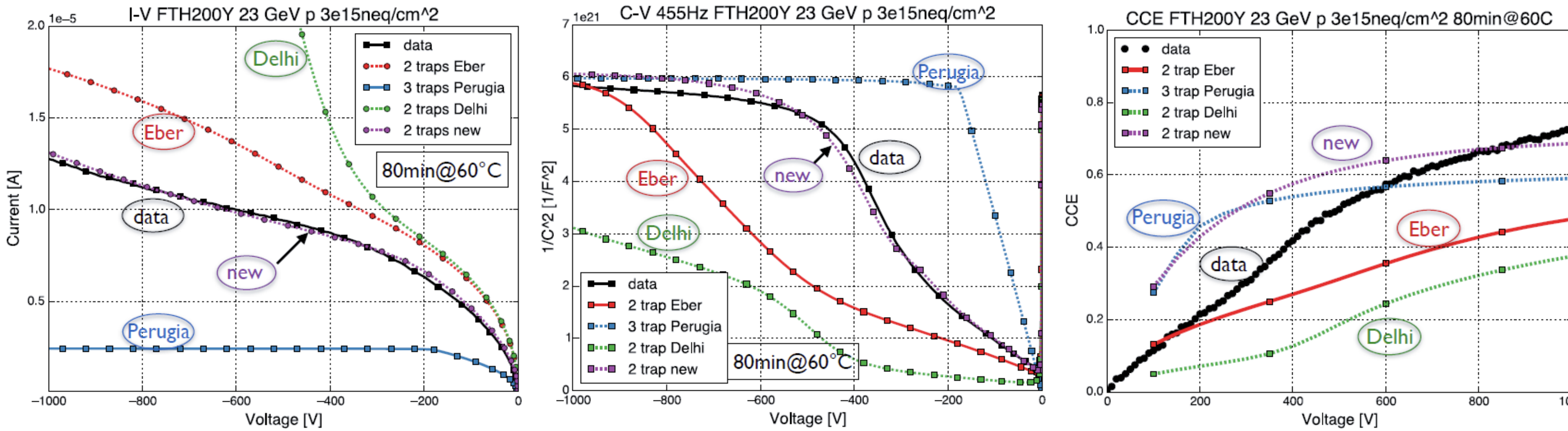


Model	E [eV]	g_{int} [cm^{1}]	σ_e[cm^2]	σ_h [cm^2]
EVL	Ev+0.48	6	1e-15	1e-15
Neutrons	Ec-0.525	3.7	1e-15	1e-15
Delphi	Ev+0.48	4	2e-15	2.6e-15
23 MeVp	Ec-0.51	3	2e-15	2e-15
KIT (Eber)	Ev+0.48	5.598 (-3.949e14)	2e-15	2.6e-15
23 MeVp	Ec-0.525	1.198 (+6.5434e13)	2e-15	2e-15
HIP	Ev+0.48	5.598 (-3.949e14)	1e-14	1e-14
23 MeVp	Ec-0.525	1.198 (+6.5434e13)	1e-14	1e-14
2 μm from surface only	Ec-0.40	14.417 (+3.168e16)	8e-15	2e-14
Hamburg (new)	Ev+0.48	1.51-2.75	8.37e-15	2.54e-15
	Ec-0.525	0.36-0.93	6.3e-15	8.37e-15

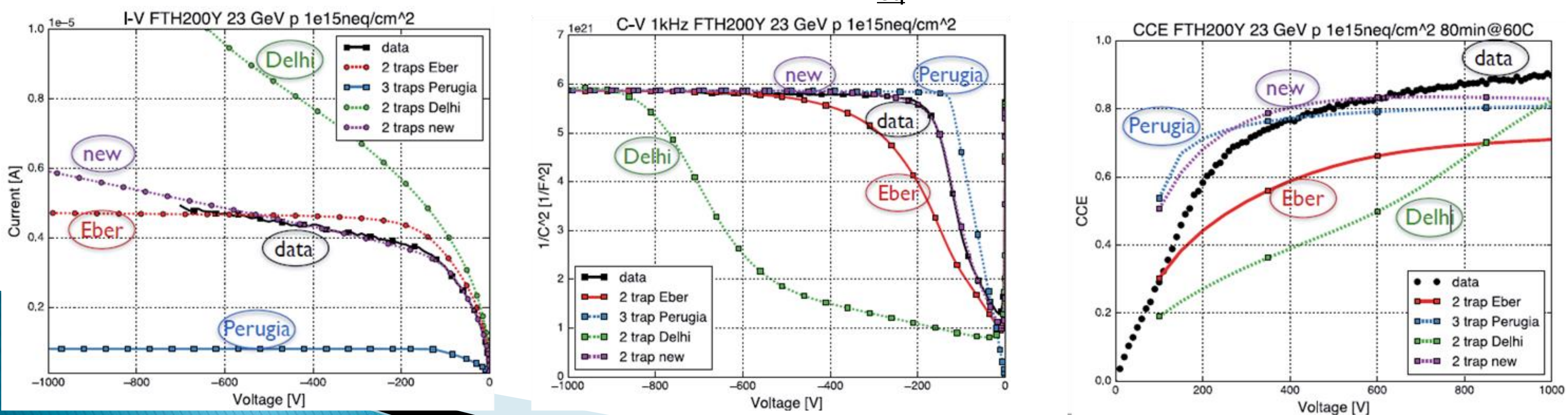
Model	E [eV]	g_{int} [cm^{1}]	σ_e[cm^2]	σ_h [cm^2]
Perugia	Ev+0.36	0.9	2.5e-13	2.5e-15
p-type	Ec-0.42	1.6	2e-15	2e-14
	Ec-0.46	0.9	5e-15	5e-14
Perugia	Ev+0.36	1.1	2e-18	1.2e-14
n-type	Ec-0.42	13	2.5-15	1.2e-14
	Ec-0.50	0.08	5e-15	3.5e-14
Peniccard	Ev+0.36	0.9	3.23e-13	3.23e-14
	Ec-0.42	1.613	9.5-15	9.5e-14
	Ec-0.46	0.9	5e-15	5e-14
Perugia new	Ev+0.36	0.9	3.23e-13	3.23e-14
(<7e15 cm^{-2})	Ec-0.42	1.6	1e-15	1e-14
	Ec-0.46	0.9	7e-15	7e-14

Comparison of models (synopsis)

200 μm thick p-type pad detector Φ_{eq}(23 GeV p)=3e15 cm^{-2}, annealed 80min@60°C, T=-20°C
Simulation same device with different models – **a clear disagreement between different models**



Somewhat better agreement for lower fluences Φ_{eq}(23 GeV p)=1e15 cm^{-2}



Calibration stage

1. **Cross calibrate the simulation tools in a most basic cell** (large p^+-n pad detector with only shallow dopants) in the similar way we did for our "custom made" simulation packages (https://indico.cern.ch/event/456679/contributions/1126330/). Not really ambitious, but showing that the drift times and induced current pulses calculated with TCAD and Silvaco agree to certain precision (we need both in order not to blindly trust one!). It may be a starting point to select suitable parametrizations for : mobility, impact ionization (simulate the large abundance of LGAD measurements – already done by CNM). It is essential that the induced currents agree, not only the charge, which is mostly shown. Note the choice of boundary conditions at the surface should be the same for all attempts. Have a look at C-V simulation.
2. **Test signal calculation also for multi-electrode system**. Try to simulate as single infinitely long strip - 2D problem (e.g. atlas geometry pitch-width-thickness = 80-20-300 um) and see what effects it has – double, quadruple the basic cell … and see if Ramo's theorem is correctly accounted for. Maybe a comparison with "custom made" tools should be done.
3. **Try to introduce a single level in a band-gap** and calculate its contribution to the current and space charge and CV. This is crucial to do – a single level 1D problem should be easy to implement and the data between different tools should agree (M. Benoit gave a comprehensive review of the tools at Trento workshop in Paris, but it is not in the indico). See if this matches expectations.
4. With 1,2,3 fulfilled a **cross-calibration with double level** should be done in the same way as for c).

At all above stages I would leave out the electronics and look at induced currents only. Simulation of electronics, needed of course in the end, can cause a lot of confusion at this point.

I know people have done these steps before , but we should have a kind of official reference results. So, a document where a standard set of parameters is defined and what should come when one uses it. This is the starting point for every group involved in simulations to "calibrate" their tools. Once we have our anchor set then we can start looking where the differences come from, what is their origin and why …

Working stage

After 1,2,3,4,5 comes the interesting part of:

- including P ad B removal
- including more traps
- varying the parameters of traps
- modifying mobility and impact ionization models for irradiated silicon
- study of surface effects
- exploration of convergence/no-convergence of simulation tools

simplification of simulations (separate calculation of fields and drift currents) and making them Monte Carlo ready

- setting up the “ultimate“ model describing irradiated devices with different particles.
- Electronics

Tool to export fields from TCAD to KDetSim, WF2, TRACS…