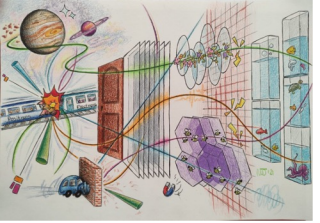# WP4 - TCAD simulations

Proposal for workplan and milestones

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on behalf of the WP4 preparation/proposal group

ECFA
European Committee for Future Accelerators

Technology Computer-Aided Design (TCAD):

- Is a decisive tool for the detector community for the:
  - Sensor designs and optimization
  - Radiation damage understanding and modeling
  - Electrical field calculation for Monte-Carlo tools
  - Is integral part of full detector system simulation (ATLAS,CMS)
- Mainly commercially available (Synopsys TCAD, Silvaco TCAD)

Companies implement device physics in different ways:

- Cross calibration required, partially performed for Synopsys and Silvaco TCAD

**Protocols to transfer electric field from TCAD to Monte-Carlo tools:**

- Ready for Allpix2
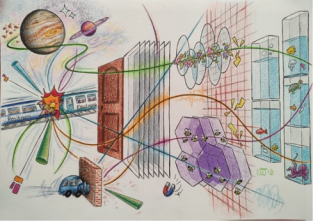
TCAD as part of full detector simulation:

- LHC Run1/2/3 pixel detectors:
  - Both ATLAS and CMS rely on TCAD simulations to include radiation damage effects into their Monte-Carlo simulated events
  - The model used is based on EVL 2 traps one
  - M. Swartz and colleagues expanded it over the years
  - It is now validated on testbeam data till 2.4e15, on collision data till ~ 1e15

- HL-LHC i.e. fluence >~ 3e15:
  - Perugia model (includes surface damage - see next talk)
  - HPTM
  - LHCb model (developed on irradiated Velo pixels modules, till 8e15)

- e+e- machines
  - Surface damage -> Perugia model

Outreach/Training:

- Europractice Training Course
- Biannual TCAD school SIMDET

Directions of research
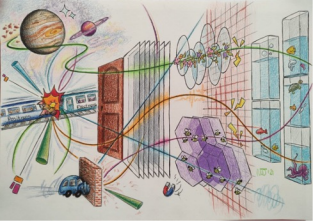
Charge collection time optimization
- 2D and 3D sensors

## Implementation and validation of physics models of non Si materials
- Focus on SiC, GaN, diamond (?)

Cluster defect simulation in TCAD
- Occupation-dependent ionization energy
- NIEL scaling

Further development of physics models:
- Fluence dependence of the IR absorption length
- Effects of mobility reduction due to scattering by ionised defects at high fluences
- Impact-ionisation via local-level at high fluences
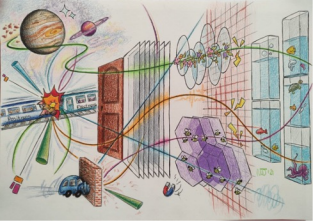
Cooperation with TCAD companies

Silvaco

- fruitful interaction since years with engineers
- open/eager to discuss new physics models to be implemented
- support for missing/wanted features (e.g. extraction of 3D field)

Synopsys

- Synopsys provides a physical model interface allowing to modify generation-recombination, mobility, band structure models etc
- implementation of more sophisticated models need support from the company
- direct contact to software developer/engineers not yet established

Contact other companies e.g. Global TCAD Solutions™?

Whatever the company, **build good relations with it!**
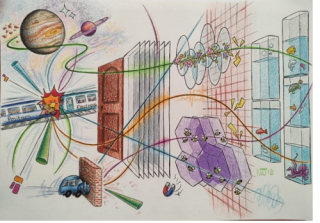
Milestones & Deliverables

S=short (3 years), M=Medium (6 years), L=Long (>> 6 years)
*M=milestone D=deliverable*

Protocols to transfer electric field from TCAD to Allpix2 (~ ready but need to be validated to all sorts of structures maybe)

SM: Flexible CMOS simulation of 65 nm to test design variations in 1 year?

SM CCE vs fluence vs voltage for HL-LHC (depends on RD53C chip)

SD: Model for 1e17? (includes mobility models and more)

MM: TCAD for different WBS ?

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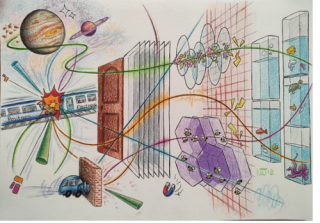
FTEs: 5 in ~ 10 institutes

Licenses for this: ~ 50k€/year (+/- 50%)