Simulation tools and radiation damage

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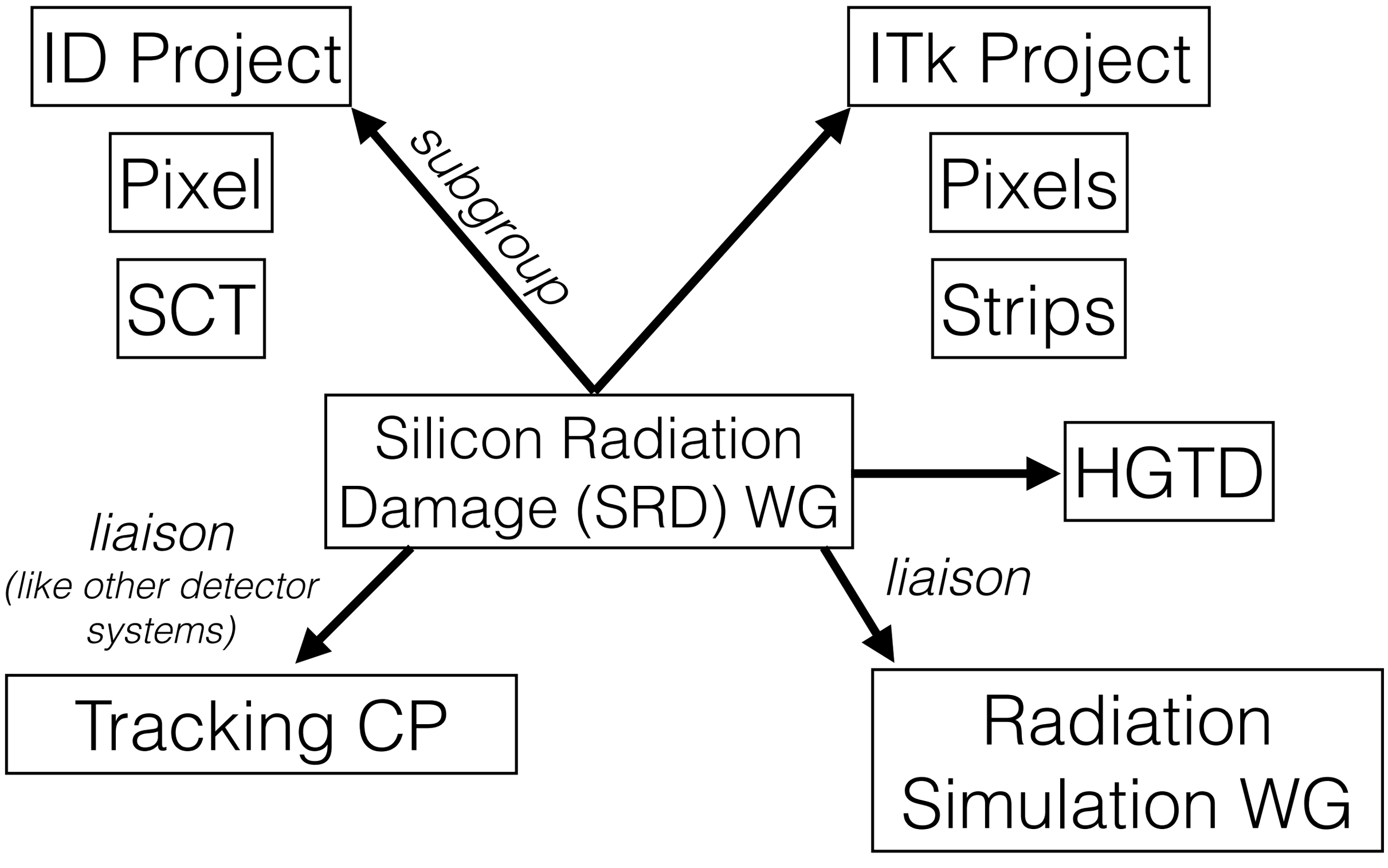
Bi-weekly IF03 Solid State Detectors and Tracking
September 17, 2020

Outline

- Current organization in ATLAS
- Challenges

Silicon Radiation Damage in ATLAS



Specific tasks

Develop and maintain radiation damage simulation (in digitization) in ATHENA

- Tune radiation damage model parameters

- Produce TCAD simulations, which are inputs to the digitizer

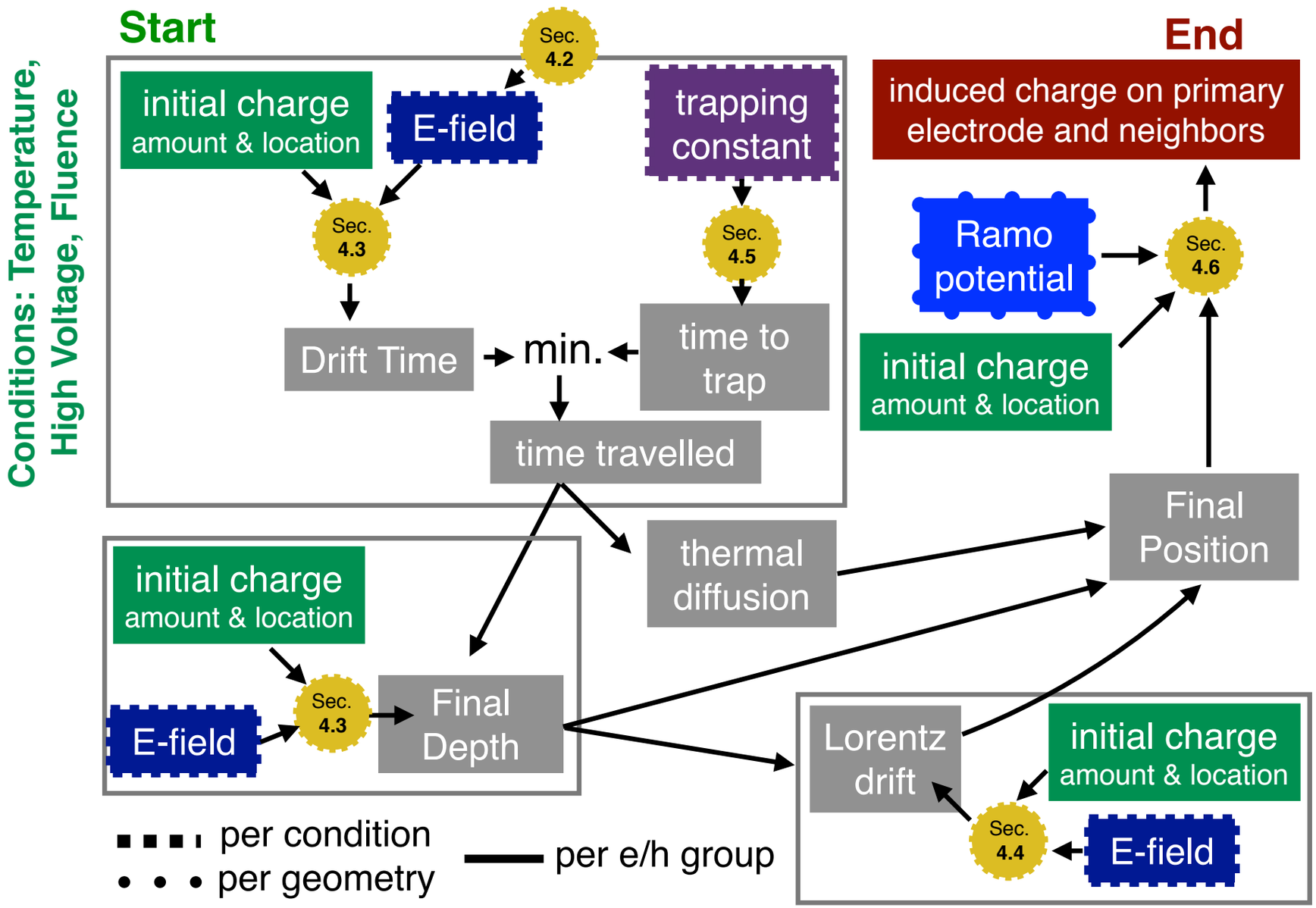
Measure the fluence and make predictions for operating conditions

- Measure leakage current and fit fluence + model params.

- Measure depletion voltage and fit fluence + model params.

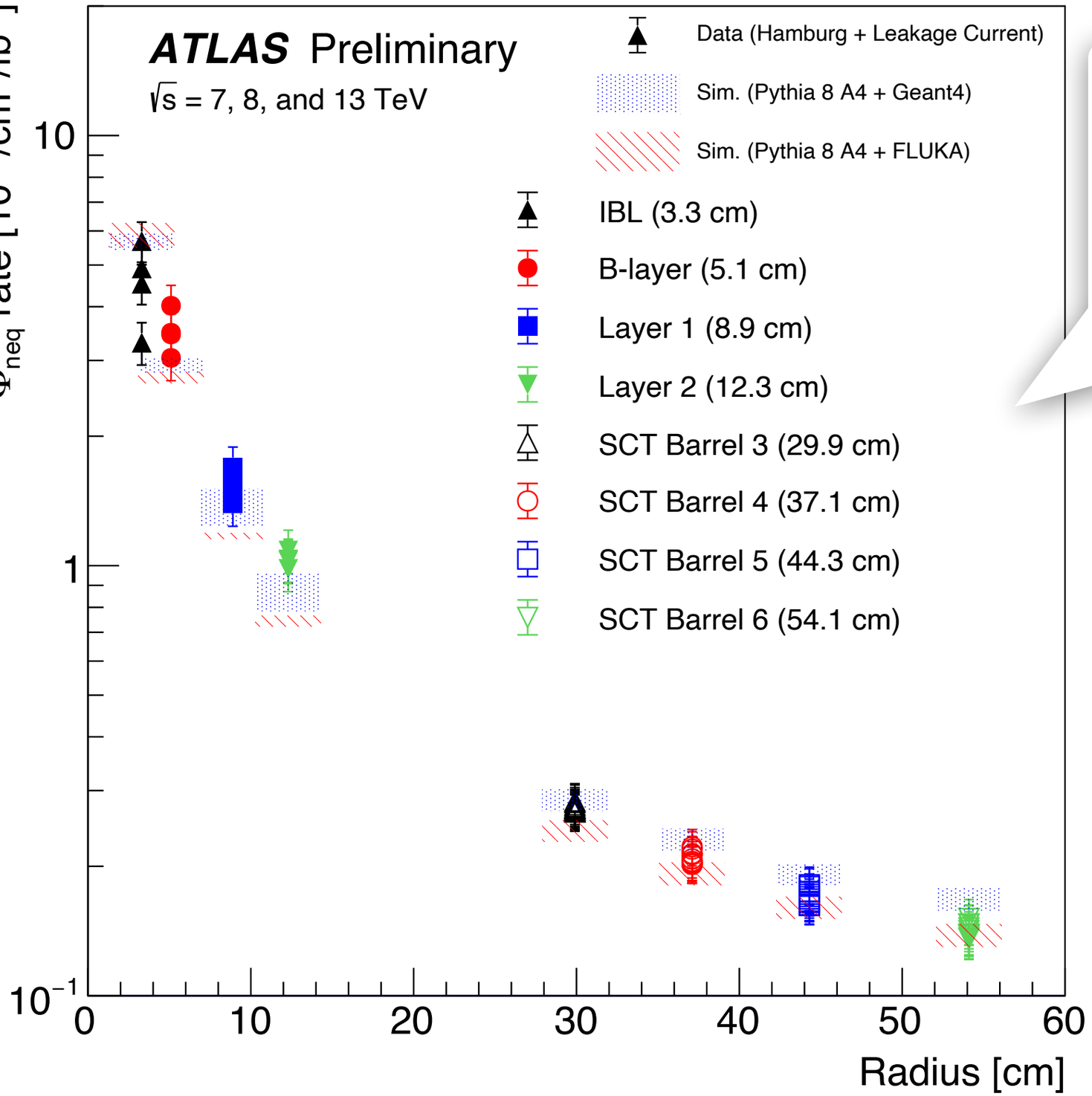
- Extract r- and z-dependence of fluence for simulation input and safety factors.

Digitization



JINST 14 (2019) P06012

Current picture: pixels and strips



data ~ sim. for innermost

data ~ 1.5 x sim. for other pixels

data ~ sim. for strips

The fluence falls off roughly as $1/r^2$

Challenges - Measurements

- Many of our methods have known biases. For example, we often don't know the actual temperature of our models. Perhaps this could be solved with detailed thermal simulations / measurements?
- Certain measurements don't make sense at high fluence e.g. what does the "full depletion voltage" mean when the E-field inside the sensor bulk has regions of near zero field?
- There are large differences between data and simulation (inner most layers, can be factor of 1.5-2). Is it the data or the simulation that is "wrong"?
- Damage factors have large uncertainty as most are "guesses" (see RD50 database). We need a dedicated measurement / simulation campaign to update these and include uncertainty (none at the moment).
- Annealing models may not be accurate beyond LHC fluences. We already see that our depletion voltage models are breaking down and there may be hints that the same is happening for leakage current.

Challenges - Simulation

- Properly accounting for radiation damage in simulation requires a significant computational overhead.
- A lot of custom code floating around - perhaps it makes sense to move to shared code? e.g. digitization in Allpix^2 (for testbeam) integrated into CMSSW and ATHENA? ATLAS radiation damage digitization is in ATHENA and Allpix 1.0 which was helpful.
- Related: model validation and tuning is usually done with testbeam data where the conditions are not as pristine and the simulation code is often a bit different. Testbeam data are notoriously hard to use long after they are taken and comparing them with collider data is hard. Can we improve this situation?
- Most radiation damage models do not come with uncertainties. We need a repository of models with uncertainties, maybe following a dedicated (global?) tuning campaign from testbeam / collision data. Maybe RD50 is the right place to host this?