Kick off of topical working groups

At our second workshop in March 2012, it was proposed to organize ourselves into working groups to help focus on various topics in more detail:

- *Fluence predictions and comparison with leakage current data. Aiming to understand the differing data/prediction ratio with radius.*
- *Tuning and comparison of radiation damage models and annealing effects (Hamburg/ Harper / Dierlamm / Krasel. etc). Aiming to achieve a consistent model / understanding of the model parameters between experiments.*
- *Depletion voltage measurement methods, results and modelling; before and after type inversion, for different sensor types.*
- *Temperature dependent measurements, errors and extraction of the effective band gap.*
- *Anomalous sensor effects; perhaps in the form of a discussion forum for other experts to comment.*

Kick off of topical working groups

Group	Interest so far	Others who may be interested:
Fluence predictions and leakage current comparison with radius	Seth Zenz, Anna Elliot-Peisert, SG	Ian Dawson, Paul Miyagawa, CMS/FLUKA experts?
Radiation damage modelling and annealing effects	Taka Kondo, Christian Barth, Seth Zenz, SG	Jack Roberts, Daniel Muenstermann, Andre Rummler
Depletion voltage measurement and modelling	Taka Kondo, Christian Barth, Seth Zenz, Anna Elliot-Peisert, SG	Andre Schorlemmer
Temperature and effective band gap	Alex Chilingarov, Seth Zenz, Anna Elliot-Peisert	Paula Collin/ LHCb, ATLAS?
Anomalous sensor effects (forum)	Anna Elliot-Peisert	Steve McMahon for SCT / Chris Parkes et al, VELO 2nd metal layer. All.

- Interest so far based on replies received to date.
- Not exclusive – you are very welcome to join the effort!
- For discussion:
  - Topical / membership overlap between first three groups
  - Aims of each group and timescale (next slide)

Previous and Forthcoming Workshops

Sharepoint for Radiation Damage Inter-Experiment Working Group:
Access enabled by signing up to e-groups: rad-damage-iewg
https://cern.ch/rad-damage-iewg/

First Inter-Experiment Radiation Damage Workshop [CERN, 4 Oct 2011]
https://indico.cern.ch/conferenceDisplay.py?confId=178194

Special session at the 19th RD50 workshop: [CERN, 23 Nov 2011]
https://indico.cern.ch/conferenceOtherViews.py?confId=148833

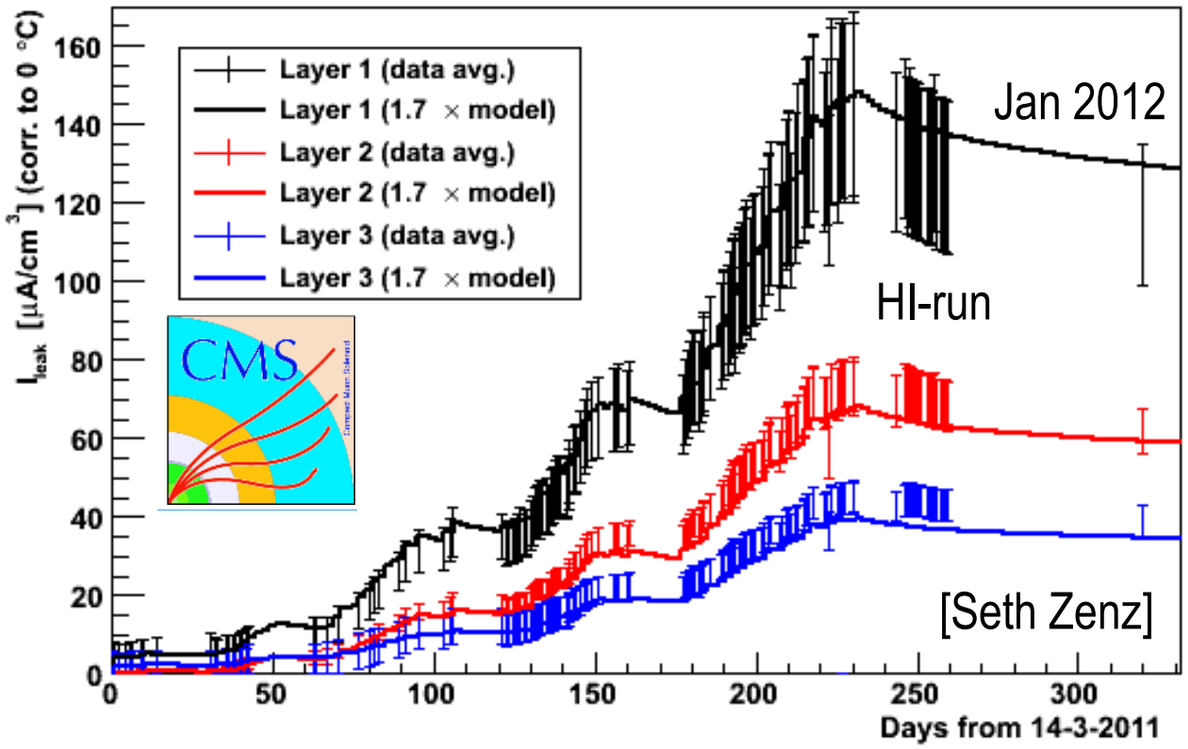
Second Inter-Experiment Radiation Damage Workshop [CERN, 7 March 2012]
https://indico.cern.ch/conferenceDisplay.py?confId=178194

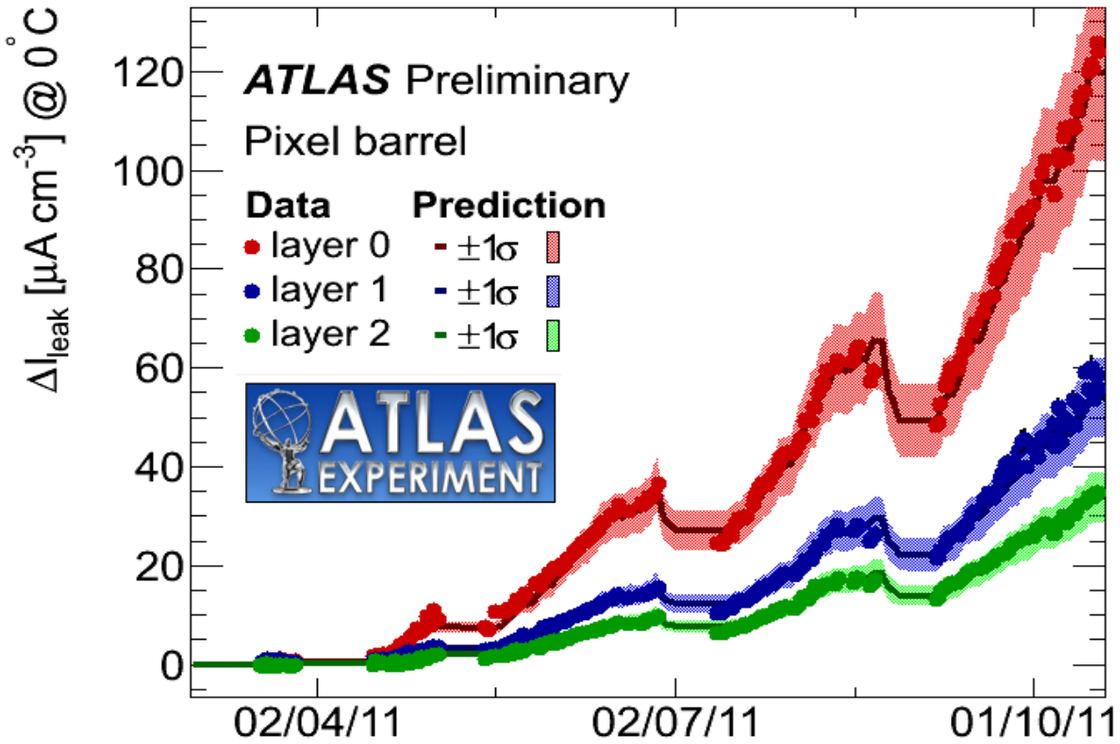
Special session at the 20th RD50 workshop [Bari, Italy, 30 May 2012]
https://indico.cern.ch/conferenceDisplay.py?ovw=True&confId=175330

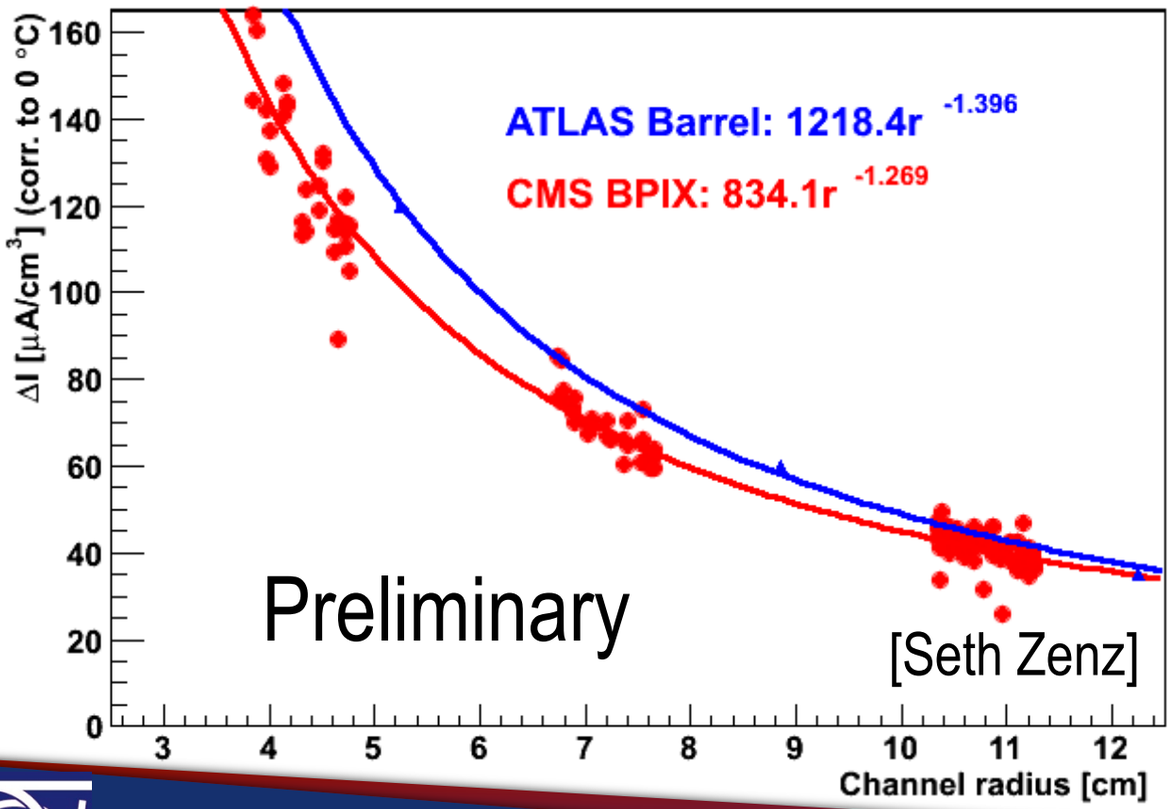
Aim for topical groups to report at 20th RD50 workshop in two months…

FLUKA predictions and leakage current comparisons with radius

Leakage current







L0 +15%, L1, L2 + 30%

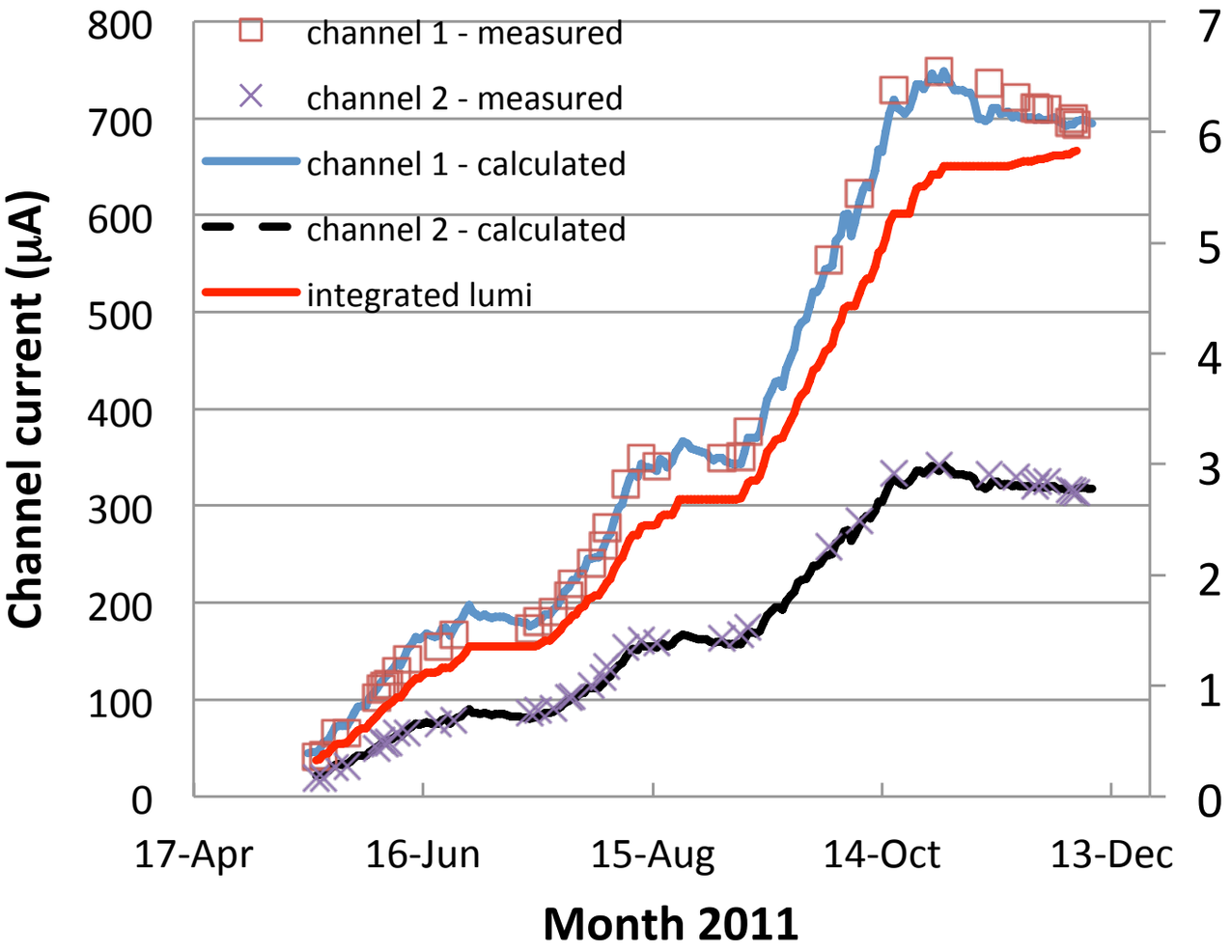
Pixel barrel	radial position (cm)	1 MeV neq (x 10^8 cm^{-2})	Dose (Gy)
1	5.09	21.50	1.06
2	8.89	8.91	0.44
3	12.29	5.57	0.27

FLUKA 1MeV neq fluence in ATLAS

SCT barrel	radial position (cm)	1 MeV neq (x 10^8 cm^{-2})	Dose (Gy)
1	29.9	1.66	0.069
2	37.1	1.30	0.049
3	44.3	1.07	0.036
4	51.4	0.90	0.027

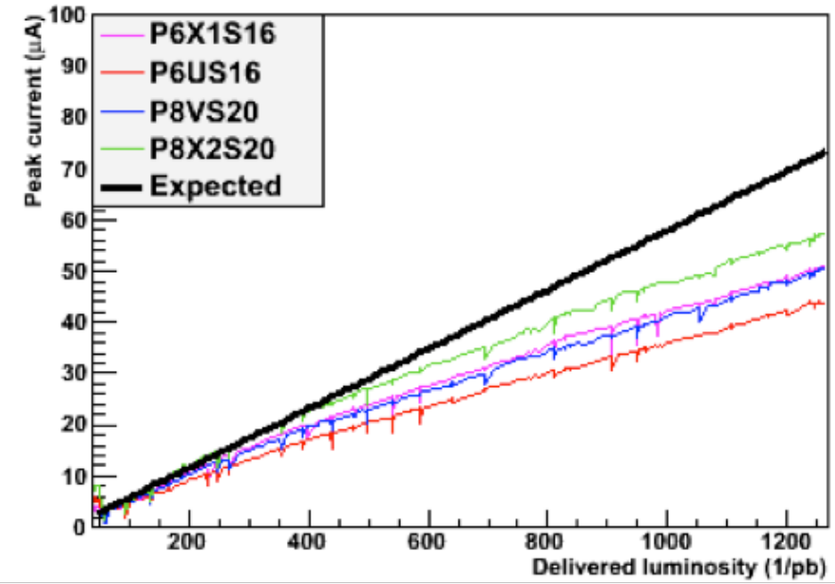
Leakage current

Preshower

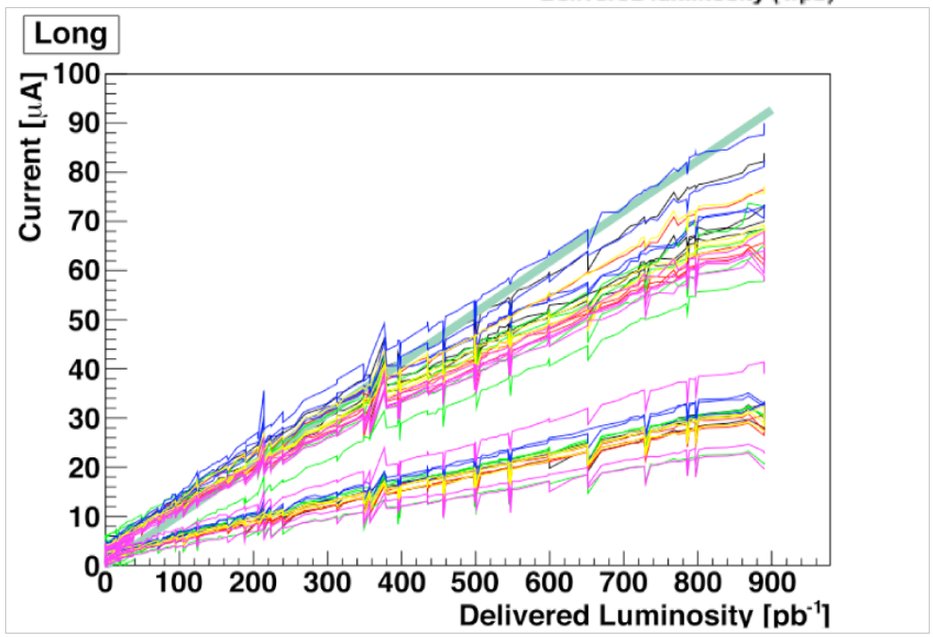


Good agreement, after scaling
(data 13% lower than prediction)
radii ~40 to 120 cm,

TT:



IT:



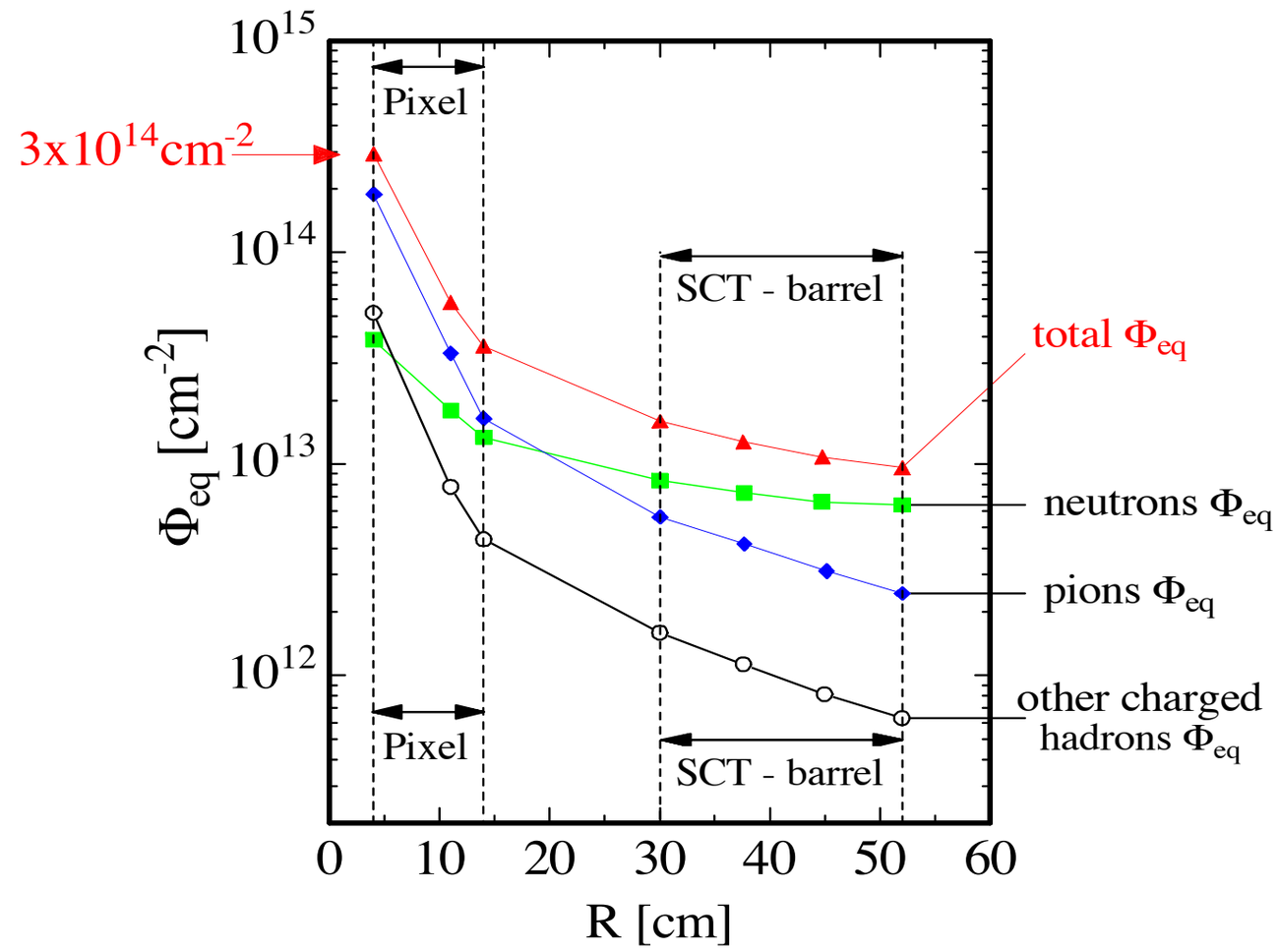
- Improvements to simulations on-going

Leakage current

- In general the agreement between model and data is remarkably good; *"within a factor of 2 is already amazing"*, Marko Mikuz, at last week's 7th "Trento" workshop.
- Agreement between model and data is better at the larger radii of the strip detectors in ATLAS and CMS, where the fluence is neutron dominated:
  - For the Pixel detectors, the models needs to be scaled up by less in the inner layers than for the outer layers:

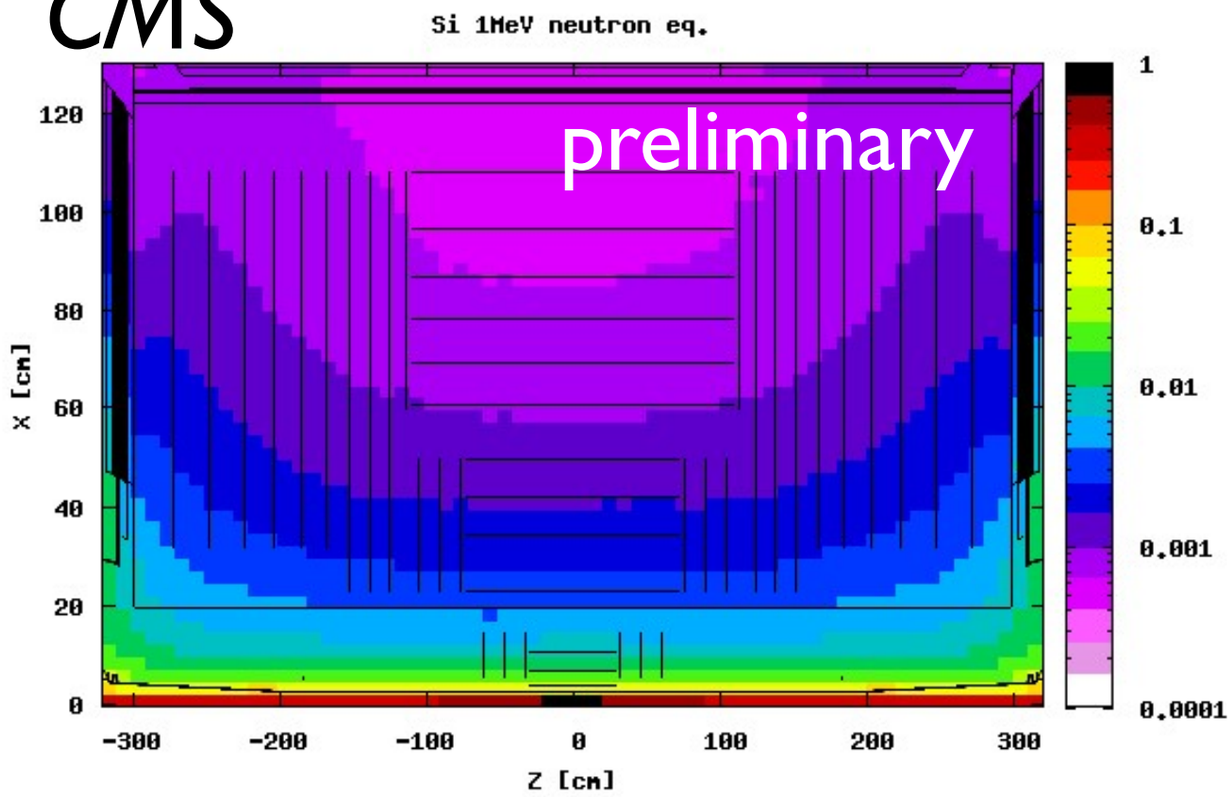
For discussion:

- *Why do the experiments see this ~15% discrepancy increase in the outer Pixel radius?*
- *ALTAS uses Phojet, CMS uses* DPMJet III
- *Secondaries? Low pT Loopers? Charge fraction?*

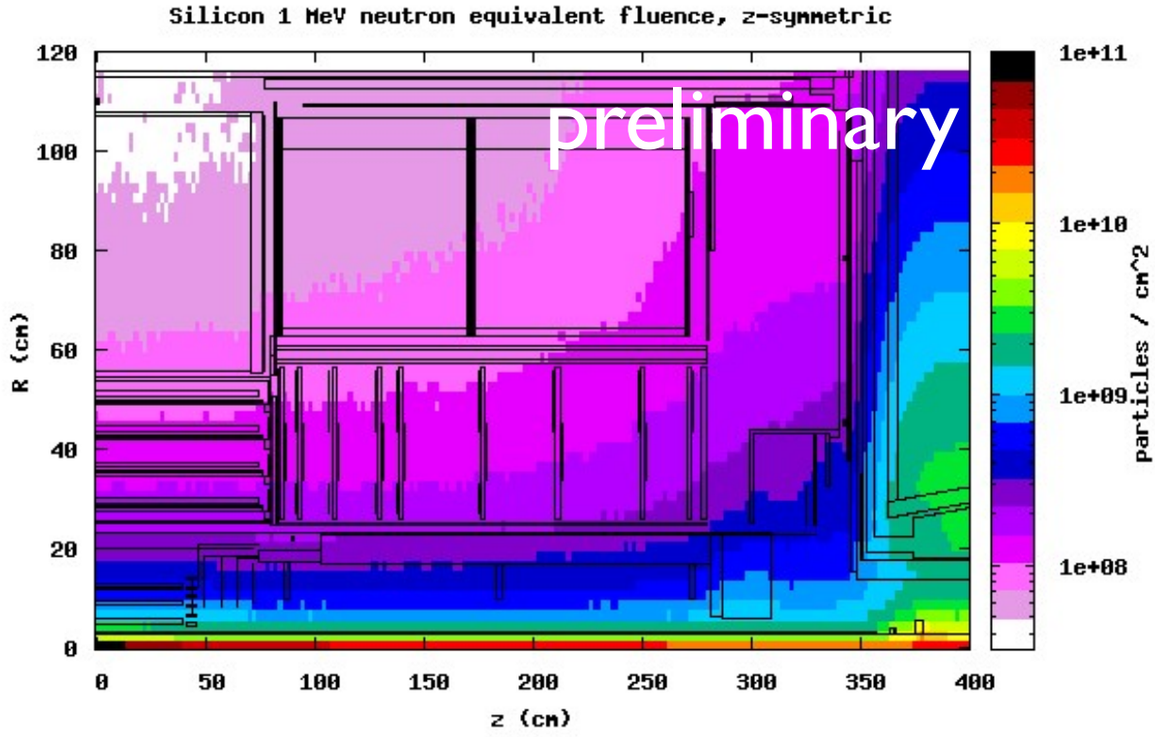


FLUKA fluence comparison

CMS



ATLAS



Earlier work toward checking FLUKA models between experiments:

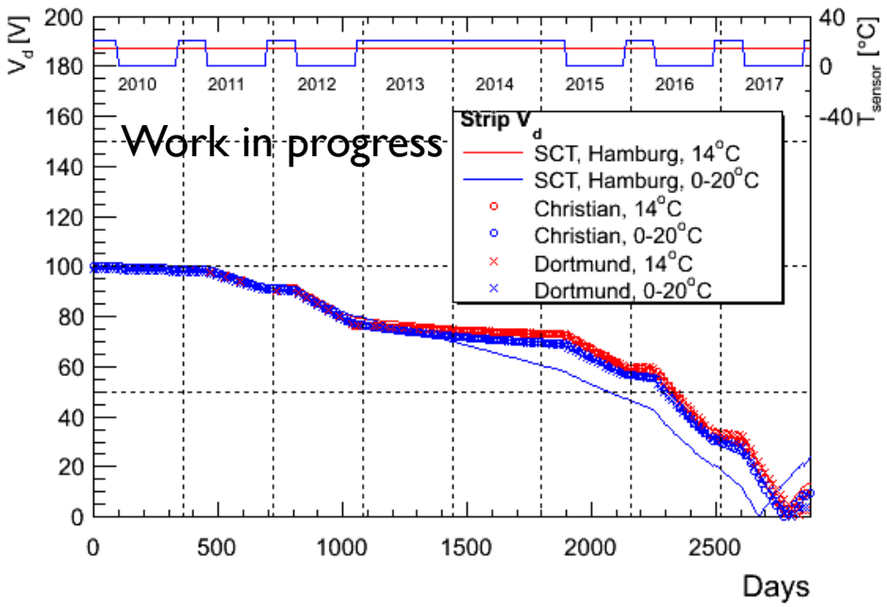
- Radial dependence at different Z slices being compared for 7 TeV and 14 TeV FLUKA simulations in CMS and ATLAS.
- Initial studies show reasonable agreement at low radii, despite effects of material and different magnetic fields (low p_T loopers).
- Aim for a more detailed comparison of 7 TeV fluence predictions?

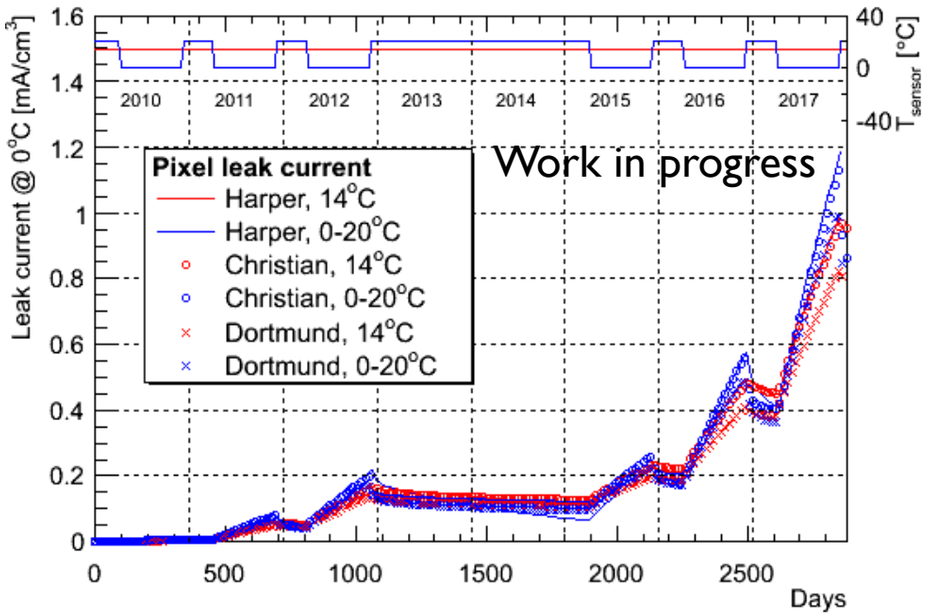
Radiation damage modelling and annealing effects

Radiation damage tools

E.g.1 Radiation damage tool comparison:

- Each experiment has software tools to predict leakage current and depletion voltage evolution.
- The underlying model is typically a subtle variant of the models in Michael Moll / R. Wunstorf thesis: e.g. R. Harper (2001) / A. Dierlamm (2003) / O. Krasel (2004).
- We have begun comparing the output of such tools based on a common fluence and temperature profile as input:

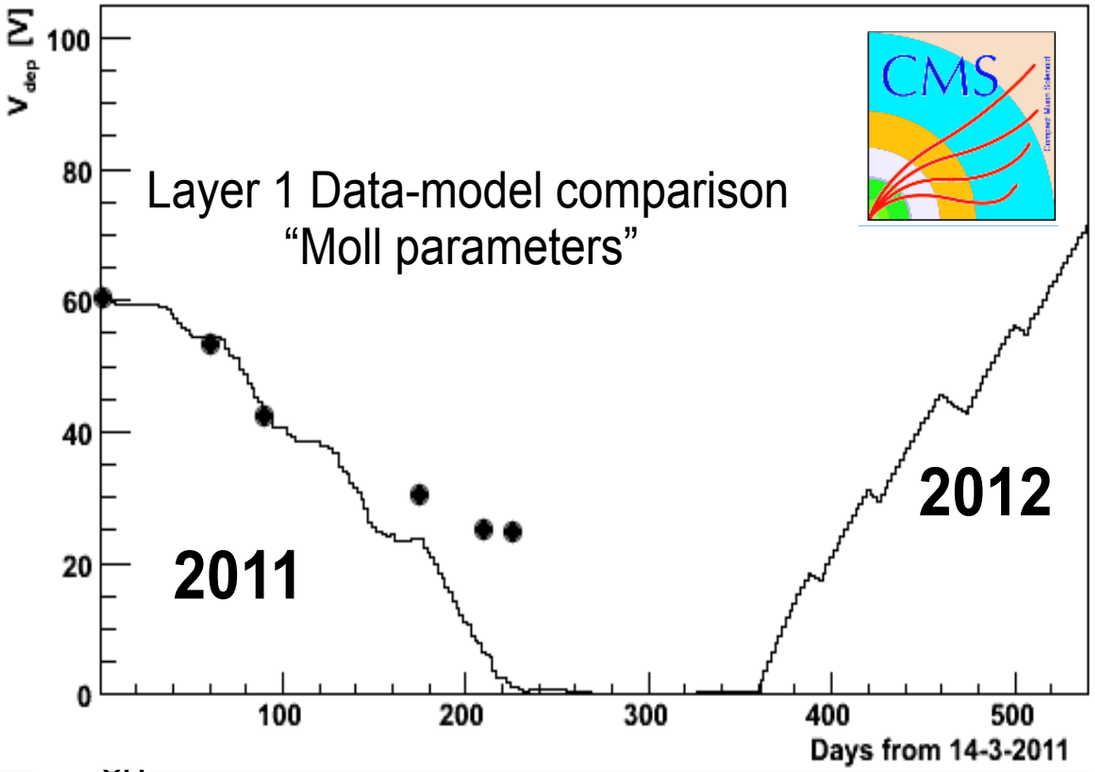


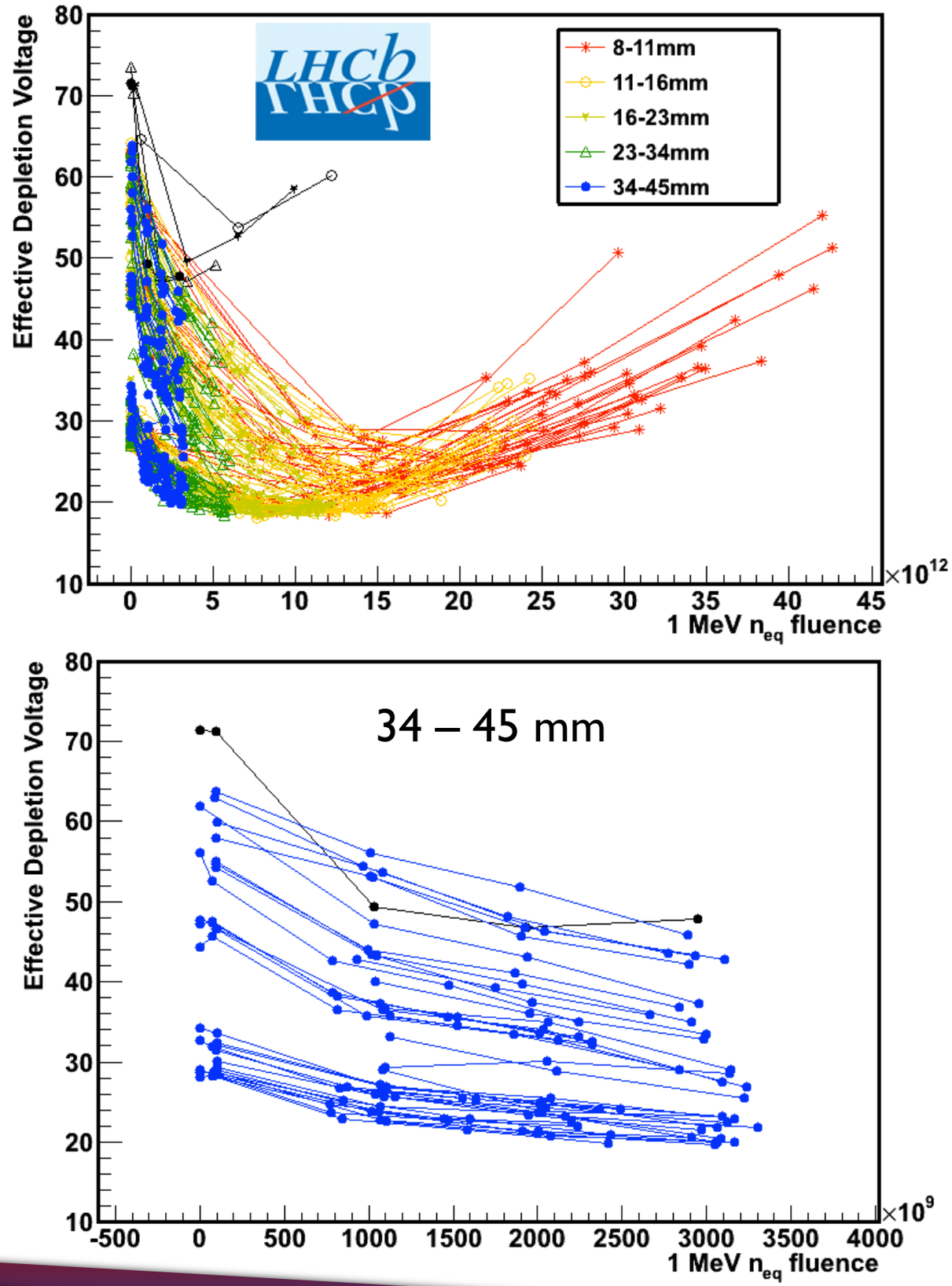


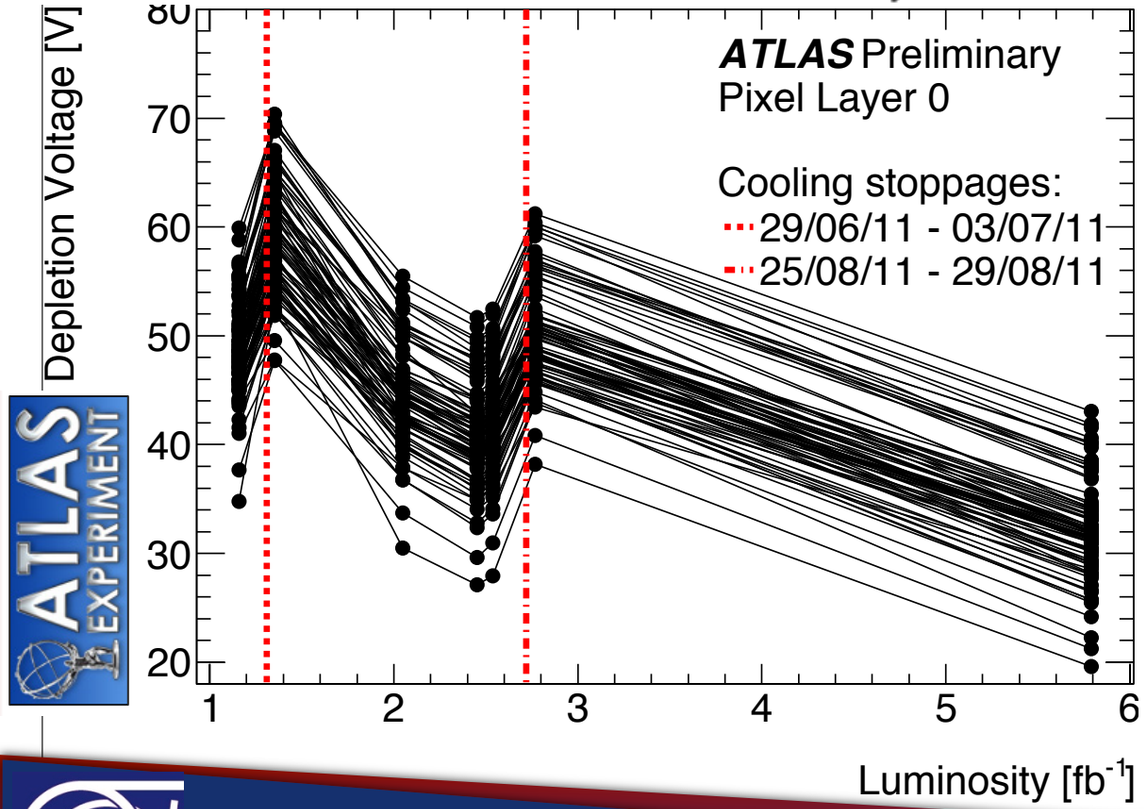
- The next step is to use a baseline model to validate the software then check the effect of different models and changes in the parameters.
- May consider to converge towards a common implementation in future.

Depletion Voltage measurement and modelling

Depletion voltage

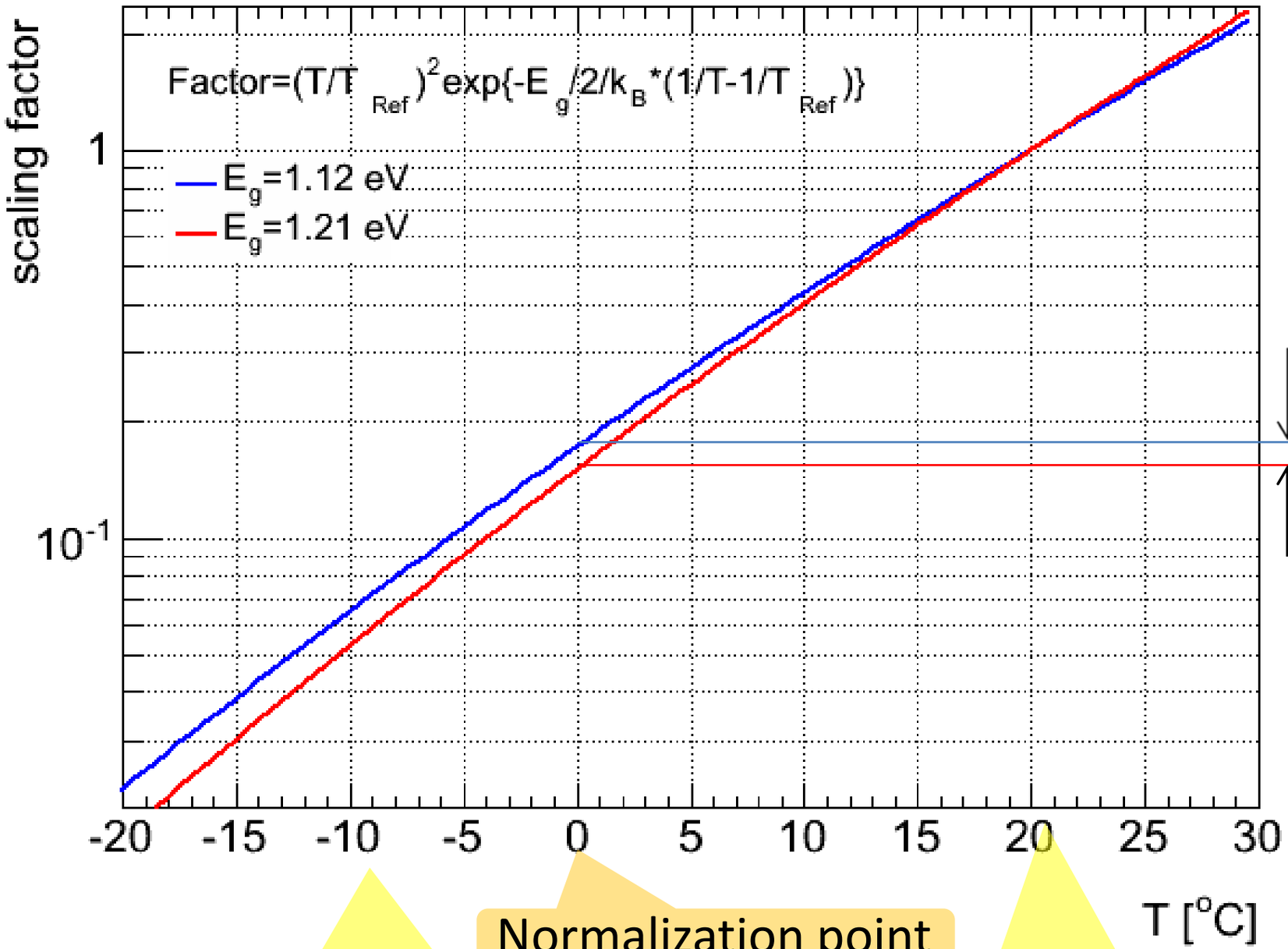






Temperature and effective band gap

Temperature scaling



E_g ➔ E_{eff}

14 % difference at 0°C with T_{ref} = 20°C.

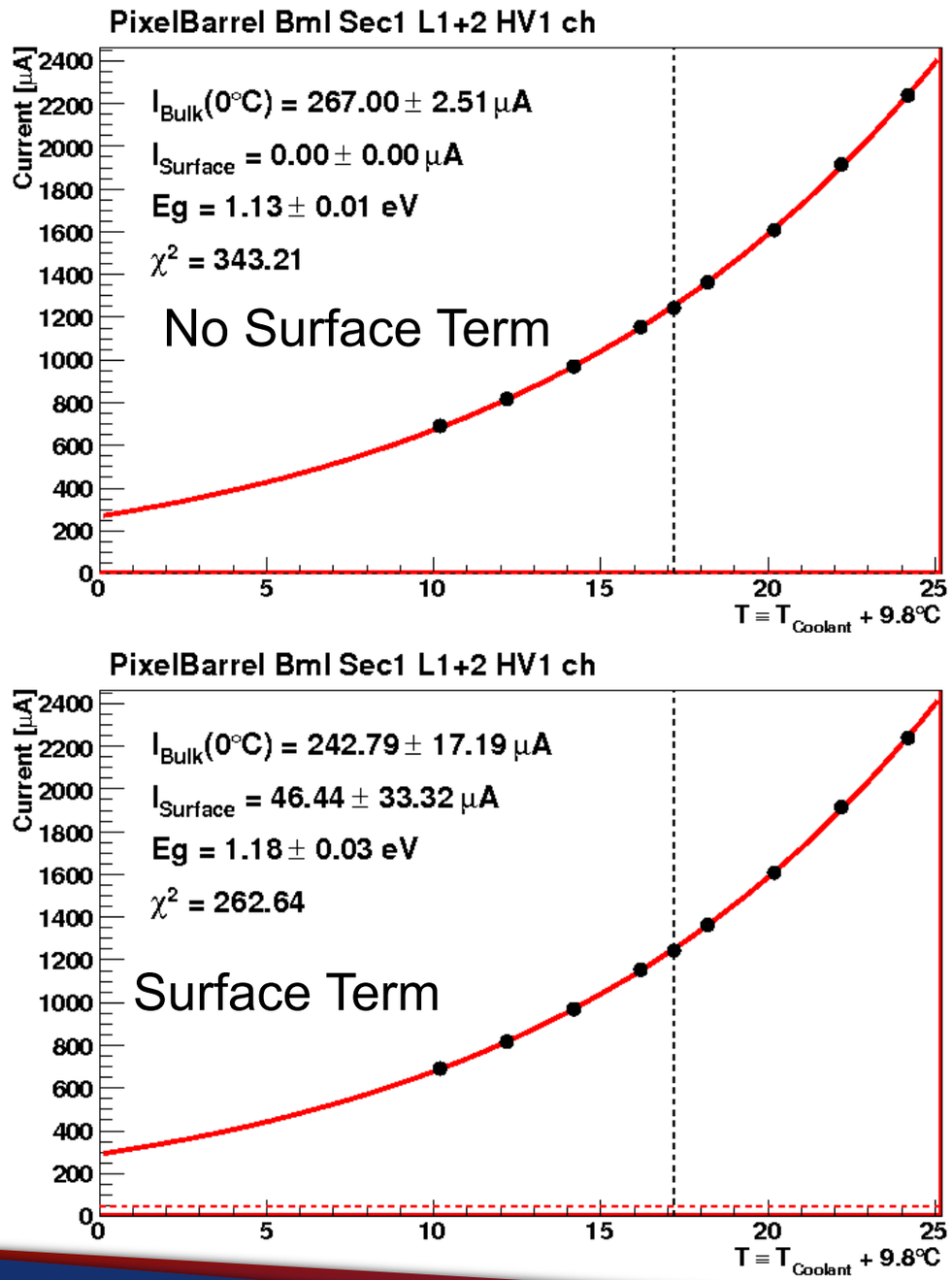
Normalization point

Harper model is based on experiments at -10°C ~ -8°C.

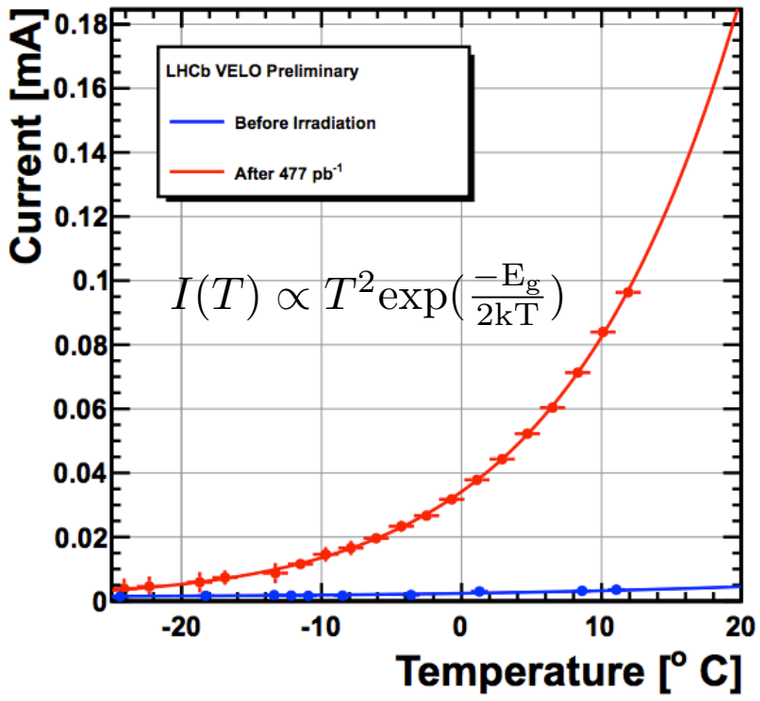
Hamburg/Dortmund model is given with T_{ref}= 21°C

Effective band gap

- Temperature dependence
  - Fitted E_a compatible with literature value (1.21 eV)
  - Only if constant term is allowed (else 1.13 eV)



Bulk Bulk before after



Preliminary	"effective band gap E_g"
100V 480 pb^{-1}	1.12 +- 0.06 eV
150V 480 pb^{-1}	1.11 +- 0.07 eV
150V 821 pb^{-1}	1.10 +- 0.04 eV
150V 1204 pb^{-1}	1.14 +- 0.04 eV

$$I(T) \propto T^2 \exp(\frac{-E_g}{2kT})$$