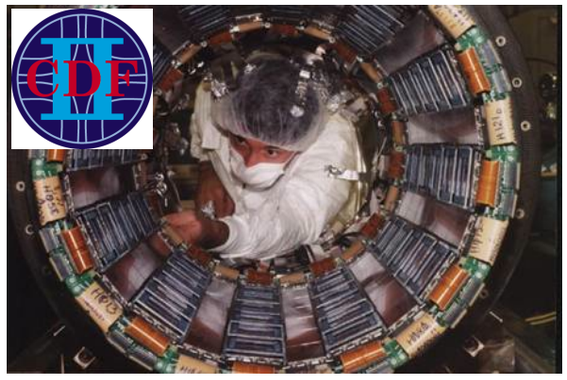
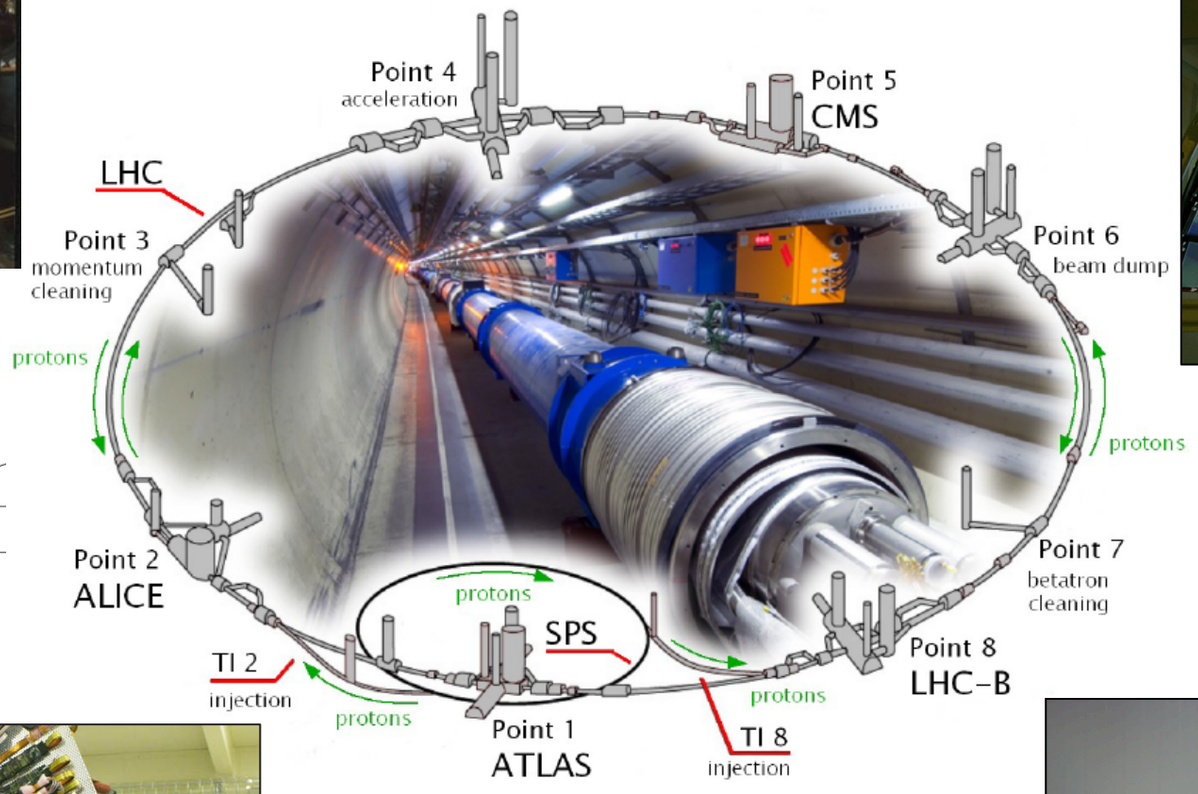
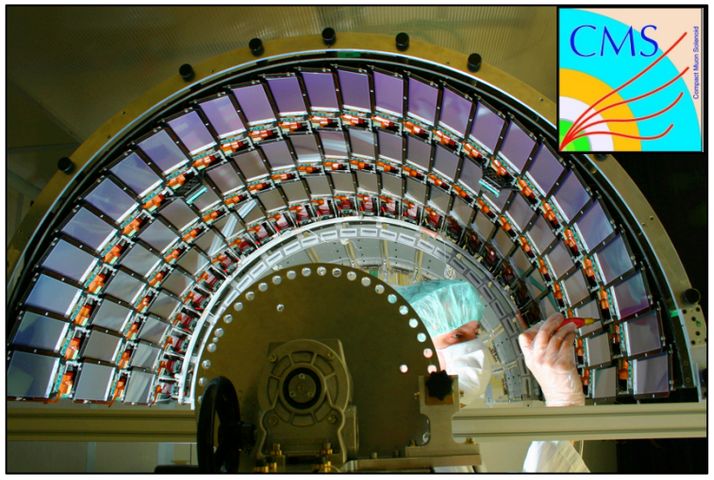
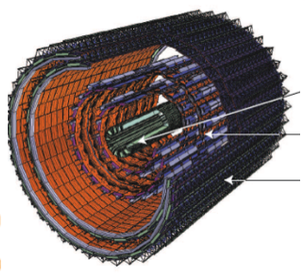
RD50 Special Session on Inter-Experiment Silicon Radiation Damage

Bringing together the experts…



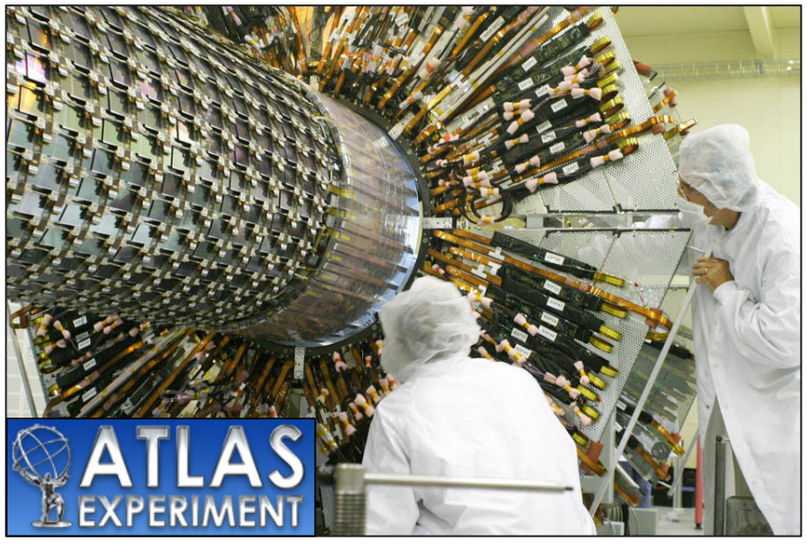






ALICE

RD50 CERN



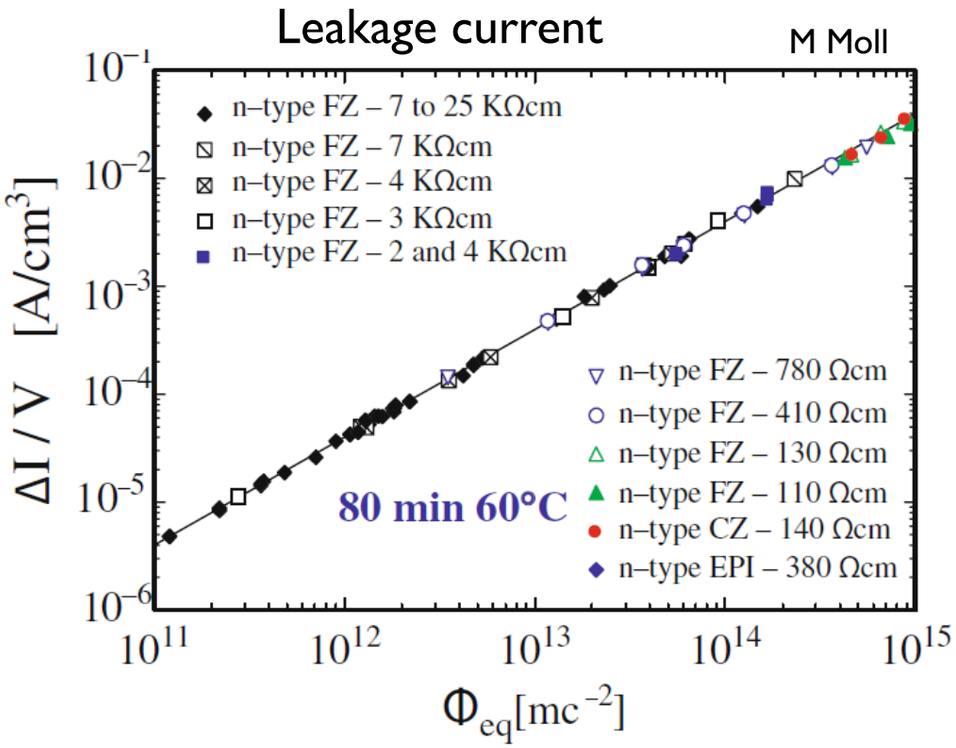
Stephen Gibson
CERN

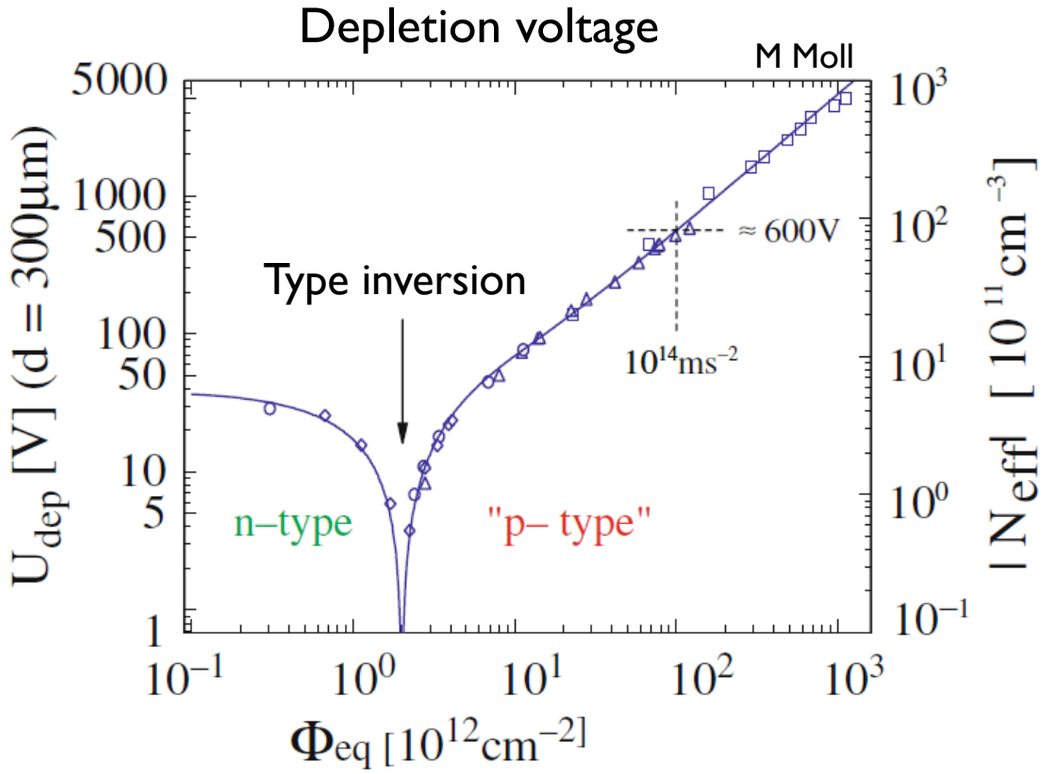
with many thanks to
Gianluigi Casse
& Michael Moll

Welcome

Outline

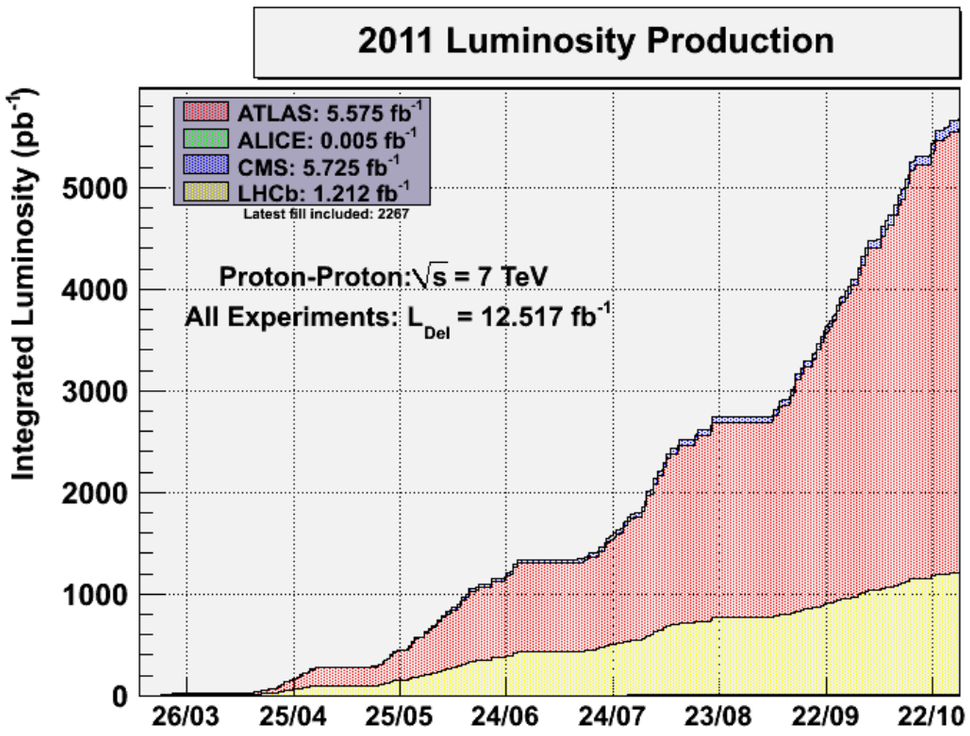
- Motivation - a common interest
- Inter-Experiment Radiation Damage Working Group
- Common analysis framework
- Recent progress and beyond.





Motivation – a common goal

- With the rapidly increasing fluence at the LHC, initial signs of radiation damage are now clearly visible in the first 5 fb^{-1}.
- Our experiments all aim to quantify and understand the macroscopic effects of radiation damage in our silicon detectors, in light of recent measurements.
  - Do the new measurements match model predictions?
  - Mitigation of reverse annealing and optimising detector performance.
  - Future extrapolations: how long will our detectors last?



Expected radiation levels for Si detectors

	TID [kGy]	Fluence 1 MeV neq [cm-2]	Time [y]
ATLAS Pixel	500	1.0E+15	10
ATLAS Strips	100	2.0E+14	10
CMS Pixel	840	3.0E+15	10
CMS Strips	70	1.6E+14	10
ALICE Pixel	2.7	3.5E+12	10
LHCb VELO	50	1.3E+14	1

Working Group Announcement

- ***Radiation Damage Inter-Experiment Working Group*** was set up this summer.
- The new Inter-Experiment Working Group focuses on recent measurements and modelling of radiation damage in silicon detectors, particularly first results at the LHC.
- The aims are distinct from and complement RD50, whose main mandate is to develop super-radiation hard sensors for future upgrades.
- ***History***: the working group was initiated following conversations at RD11 in July.

- Over the summer, several sub-detector experts from ATLAS, LHCb and CMS started to meet informally for discussion, together with Michael Moll for RD50.
- The group was formally launched at the *Inter-Experiment Workshop on Radiation Damage in Silicon Detectors*, 4 October, which aimed to trigger further collaboration between all interested silicon sub-detector communities:
- https://indico.cern.ch/conferenceDisplay.py?confId=156565
- Fruitful discussion led to several inter-experiment agreements and we have since met regularly to exchange ideas / tools and prepare a common approach for this RD50 workshop. Further collaborators are welcome - please join us!

Aims of group

Why a Radiation Damage Inter-Experiment Working Group?

- The monitoring strategies and methods differ slightly among experiments, though with a common aim. It's clear we mutually benefit from each other's experience.
- Rate of acquired dose and annealing is now as measured, rather than initial prediction of LHC profile: time to revive and check our models.
- Differing fluences, detector types and geometry can also help to constrain our radiation damage models.
- Agree on a coherent way of preparing results for a simpler comparison.
- Validation of software tools to allow to minimize the work and converge towards the calculation of the models for predictions based on our realistic dose and rate.
- Benefit for operation of current detectors and planning for future upgrades.

The working group sharepoint has been set up for exchange of ideas / tools:

- https://cern.ch/rad-damage-iewg/
- Meetings are announced via e-group mailing list: rad-damage-iewg
- Please join and contribute – just ask to be added to the access lists, all welcome.

Common analysis framework:

- At the October workshop, we agreed on a coherent way of preparing results for a simpler comparison.

1. Correct leakage currents to a common reference temperature of T_{REF}=0 °C
   Chosen to suit the range of sub-detector operating temperatures.
2. Use the same temperature correction:

$$I(T_{\mathrm{REF}}) = I(T)\left(\frac{T_{\mathrm{REF}}}{T}\right)^2 . \exp\left[-\frac{E_g}{2k_{\mathrm{B}}}\left(\frac{1}{T_{\mathrm{REF}}}-\frac{1}{T}\right)\right]$$

E_g is the silicon band gap, 1.21 eV

RD50-2011-01 recommendation

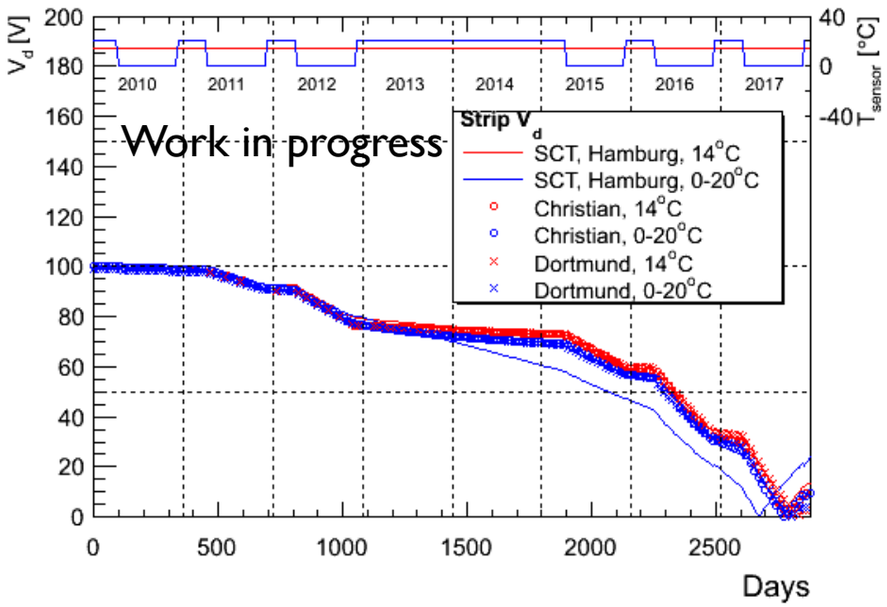
3. Normalize current to the volume of silicon [cm^3] rather than per module.
4. Standard units: $\dfrac{\mu A}{fb^{-1}cm^3}$

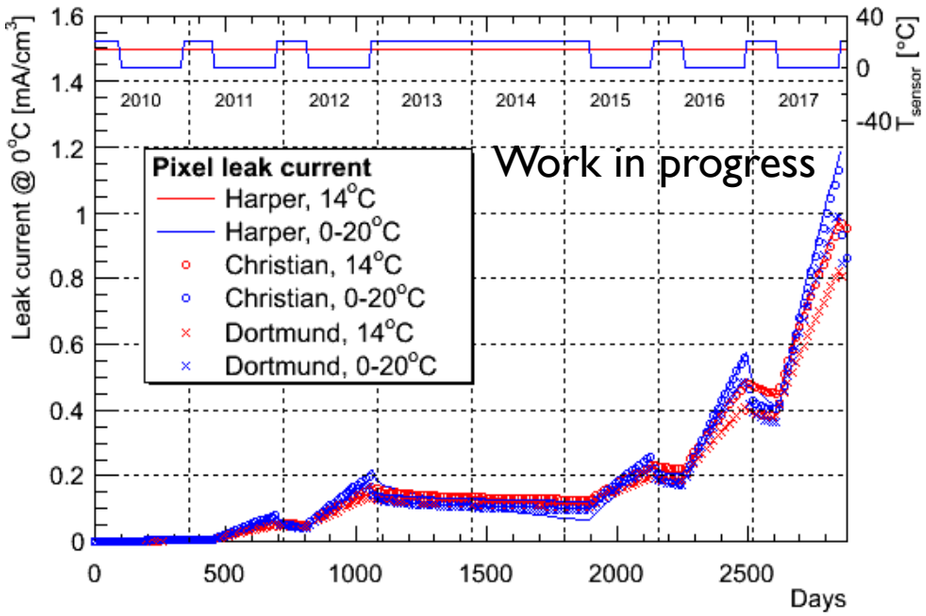
- Today's presentations are based on agreed analysis recommendations.

Examples of recent progress

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:

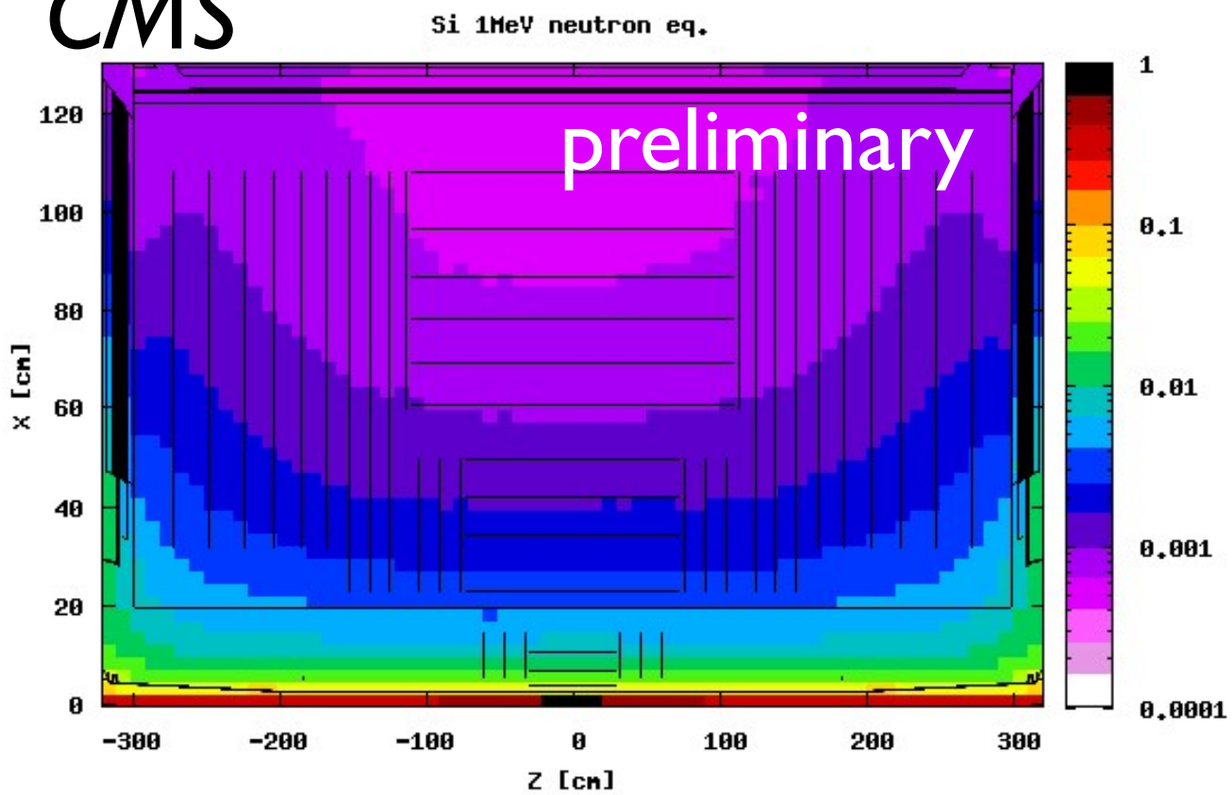




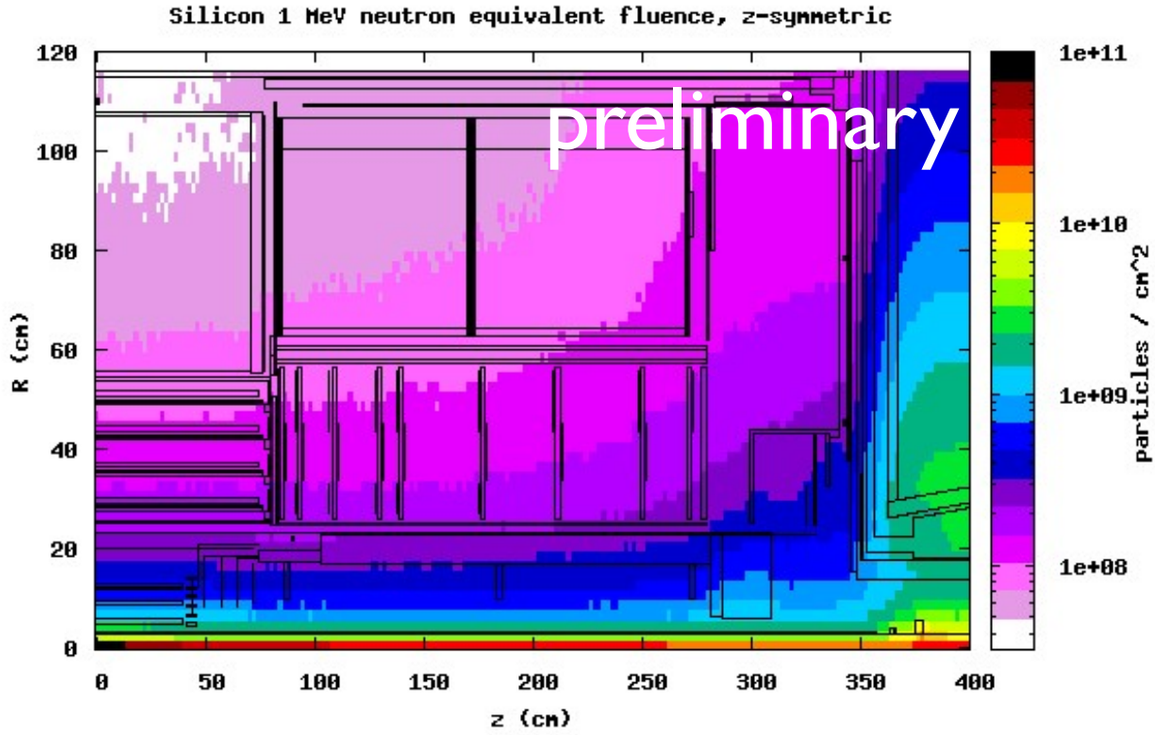
- The next step is to use a baseline model to validate the software then check the effect of different models and changes in the parameters.
- May consider to converge towards a common implementation in future.

E.g.2: FLUKA fluence comparison

CMS



ATLAS



Recent 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).
- FLUKA model is a vital input for leakage current / depletion voltage predictions.
- Detailed inter-experiment comparisons are now starting.

Today's menu

14:00 - 18:20 Special Session on Radiation Damage in LHC Silicon Detectors

14:00 **Introduction** *20'*
Speaker: Stephen Gibson (CERN)

14:20 **Measurements of rad damage at Tevatron** *20'*
Speaker: Michelle Stancari (Fermi National Accelerator Laboratory)

14:40 **measurements of radiation damage in the CMS Pixel detector with the first few invers femptobarns** *20'*
Studies of radiation damage to the CMS Pixel Detector during LHC running are presented. Leakage current and depletion voltage are monitored with increasing fluence. Methods for addressing the challenges of these measurements in the context of ongoing detector operations are discussed. These include the derivation of depletion voltage from hit efficiencies, the measurement of silicon temperature and extrapolation of current as a function thereof, and determination of the total fluence from LHC luminosity. The results allow for validation of existing radiation damage models of radiation damage and an improved understanding of the anticipated lifetime of the Pixel Detector.
Speakers: Seth Zenz (Princeton University (US)), Tilman Rohe (Paul Scherrer Institut (CH))

15:00 **Radiation Damage in the CMS Strips Tracker** *20'*
In this talk I give an overview of the radiation damage the strips tracker has suffered so far. These results are compared to the established model predictions. Finally an outlook is given for the future evolution of the detector properties within the next ten years.
Speaker: Christian Barth (KIT - Karlsruhe Institute of Technology (DE))

15:20 **Measurement of rad damage in ATLAS pixels** *20'*
Speaker: Markus Keil (Georg-August-Universitaet Goettingen (DE))

15:40 **Measurement of rad damage in ATLAS strips** *20'*

16:00 **Coffee break** *30'*

16:30 **Measurement of rad damage of LHCb silicon** *30'*
Speaker: Dr. Chris Parkes (Glasgow)

17:00 **Summary of RD50 results** *20'*
Speaker: Gianluigi Casse (University of Liverpool (GB))

17:20 **Discussion** *20'*
Speaker: Stephen Gibson (CERN)

17:40 **Departure** *20'*

Lessons from the Tevatron

15mins talk + 5mins discussion per sub-detector

Masterclass from RD50

Time for discussion towards the end.

Today's topics

Summary of suggested guidelines circulated to the speakers:

1. Normalized comparisons of leakage current evolution measured in each detector
2. Fluence from FLUKA models and comparison with leakage current measurements.
3. Radiation monitoring within detector volume (see I. Mandic's talk this morning)
4. Depletion voltage: methods, measurements and predictions.
5. Charge collection efficiency, noise effects.
6. Predictions for the long term future based on LHC forecast.

To be followed by discussion … we value input from the RD50 experts!

Beyond this workshop:

- An inter-experiment operational workshop, which may include radiation damage effects, is envisaged for early 2012 as a follow up of one in early 2011.