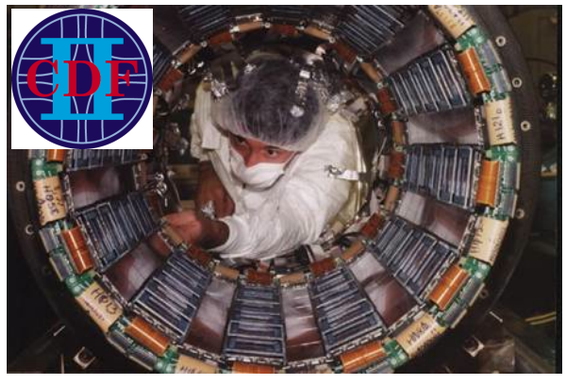
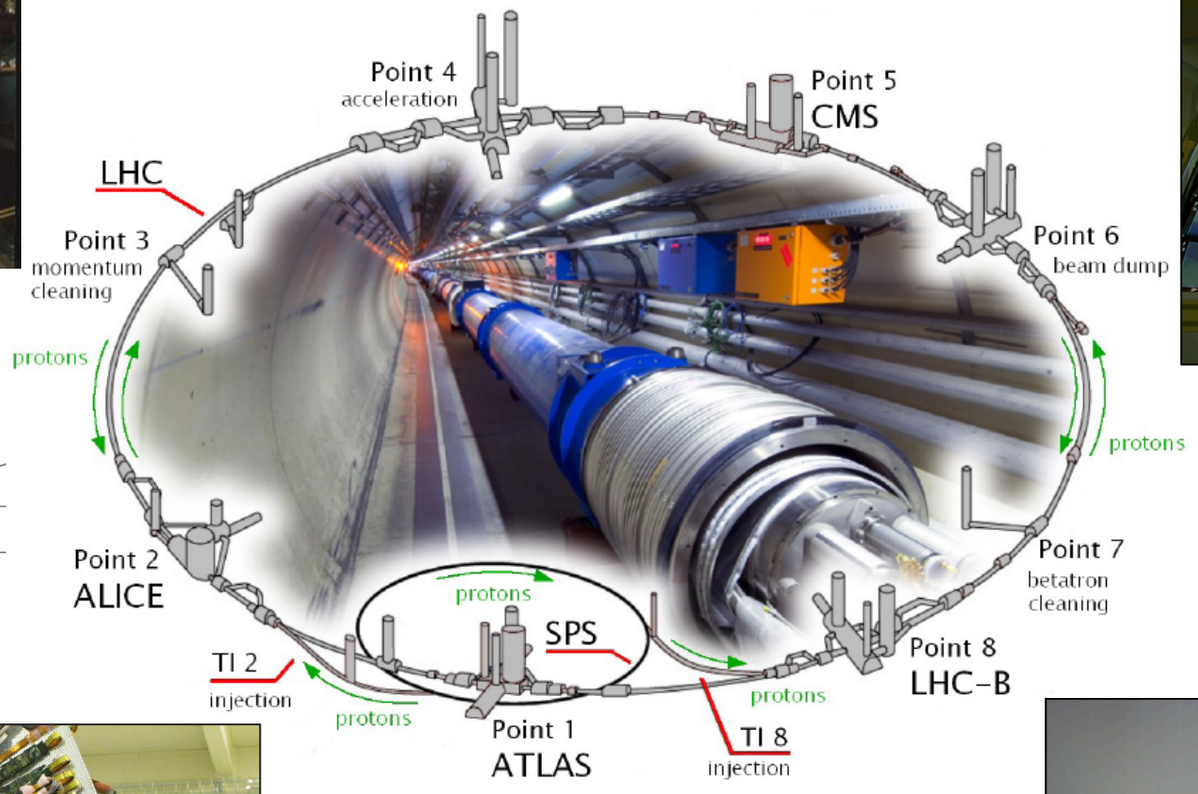
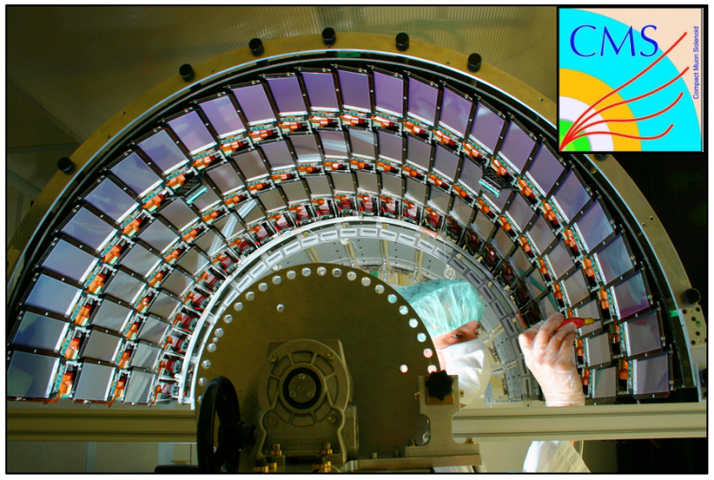
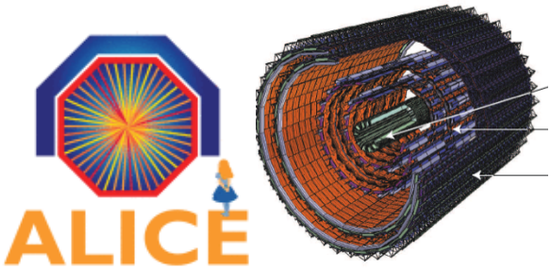
Inter-Experiment Workshop on Radiation Damage in Silicon Detectors

Common Framework and discussion

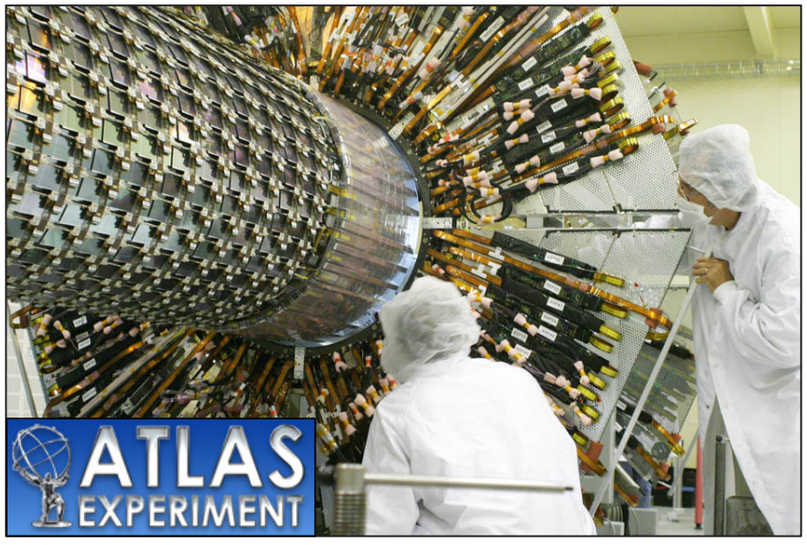








RD50 CERN

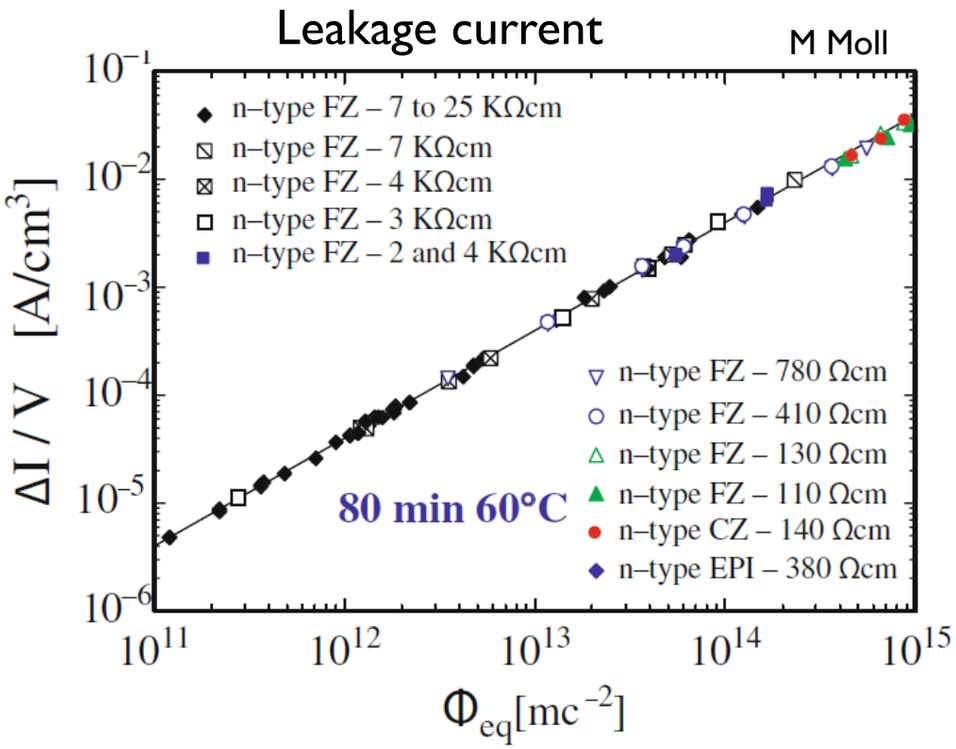


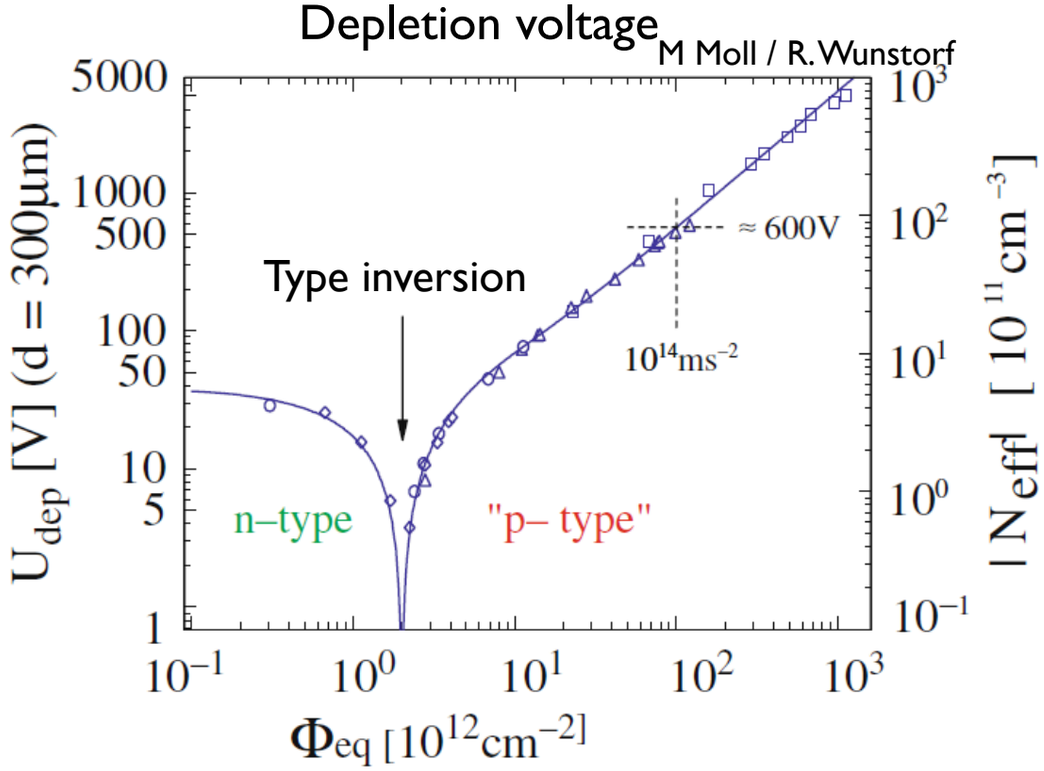
Stephen Gibson
CERN

Primers for discussion:

Overview

- Common framework for analysis and comparison
  - Units and normalization
  - Global fitting
- Census of common tools for radiation damage modelling.
  - Towards a shared implementation?
- Review of different monitoring strategies
- Further discussion points
- Next meetings and planning for 19th RD50 workshop.





Common analysis framework

- Aim to compare results quantitatively between experiments on the timescale of the 19th RD50 workshop.
- Our experiments have different detector geometries / radii, silicon volumes, detector types; strips / pixels, operating temperatures…
- How to define plots for simple comparison?
  - First step is normalise leakage current to reference Temperature and Volume.
  - Enables definition of a standard set of plots for direct, simple comparison.
- In addition, we may consider to benefit from the different geometries and fluences in multiple experiments and to combine data from all experiments into a common fit, to help over-constrain the radiation damage models (or reduce the need for modelling, as at CDF)

Normalisation: temperature

Normalisation: temperature correction

- Operating temperatures differ between experiments and also between different detector layers and modules.
  - Need to rescale current to a reference temperature:

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

E_g is the silicon band gap, 1.21 eV

RD50-2011-01 recommendation

- *Discussion*: Which reference temperature to take?
  - ATLAS Pixel + Strips scale to T_{REF} = -10 °C
  - CMS operate around 17°C, when HV is off, drops to ~10 °C
  - LHCb VELO use +21°C (Annealing model in M. Moll's thesis)

Normalisation: Volume

Normalisation of silicon volume

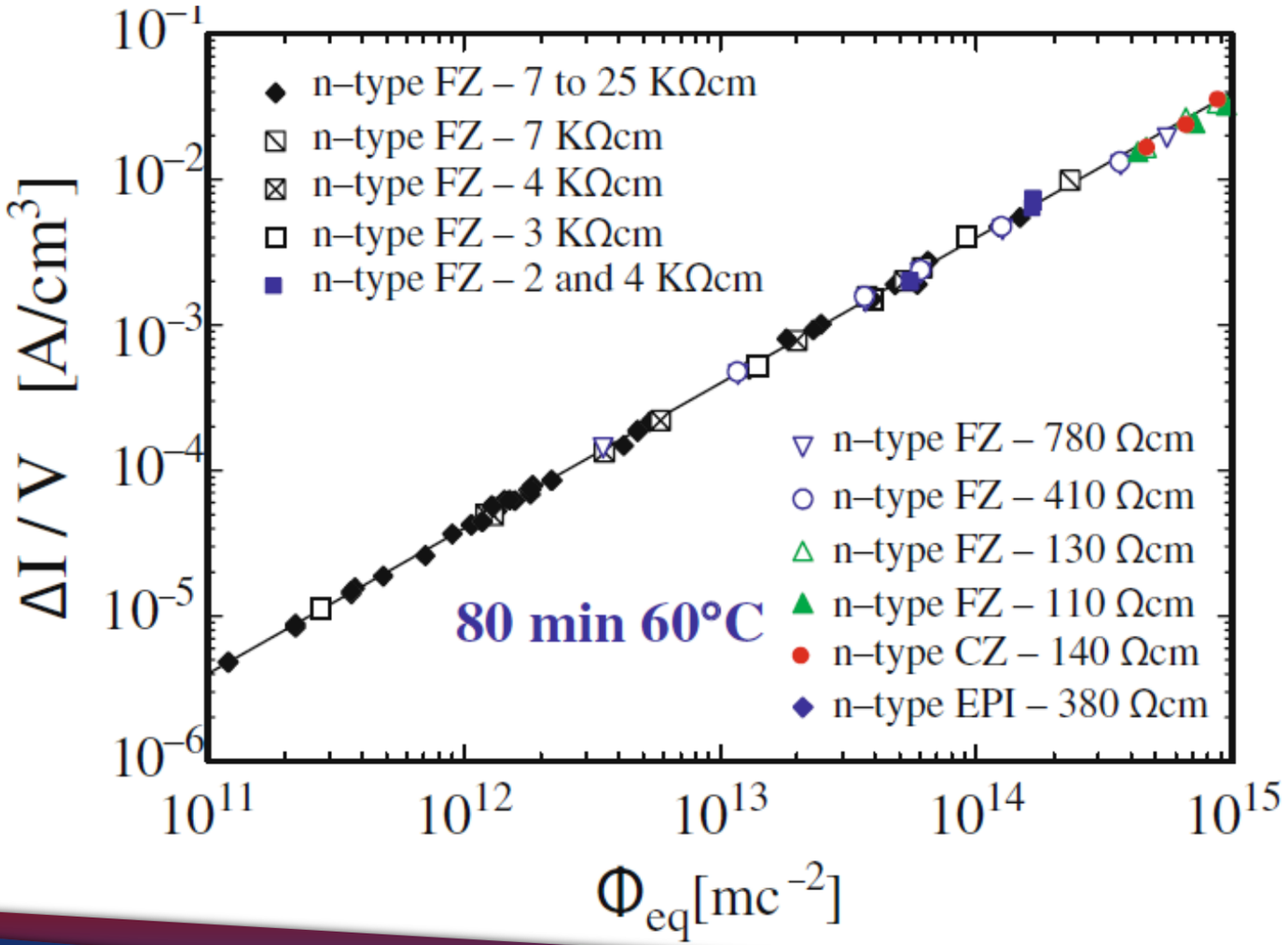
- Leakage current is typically recorded per detector module.
- Rather than plot per module leakage current, the standard procedure is to normalise by dividing by the silicon volume [in cm^3].
- Use micro Amp as standard unit as CMS?

$$\frac{\mu A}{fb^{-1}cm^3}$$

Enables standard plot to extract damage constant α (independent)

$\Delta I(t) / Vol. = \alpha(t,T_\alpha) * \Phi_{eq}(t)$

- Can we combine all experiments onto one plot after annealing correction?

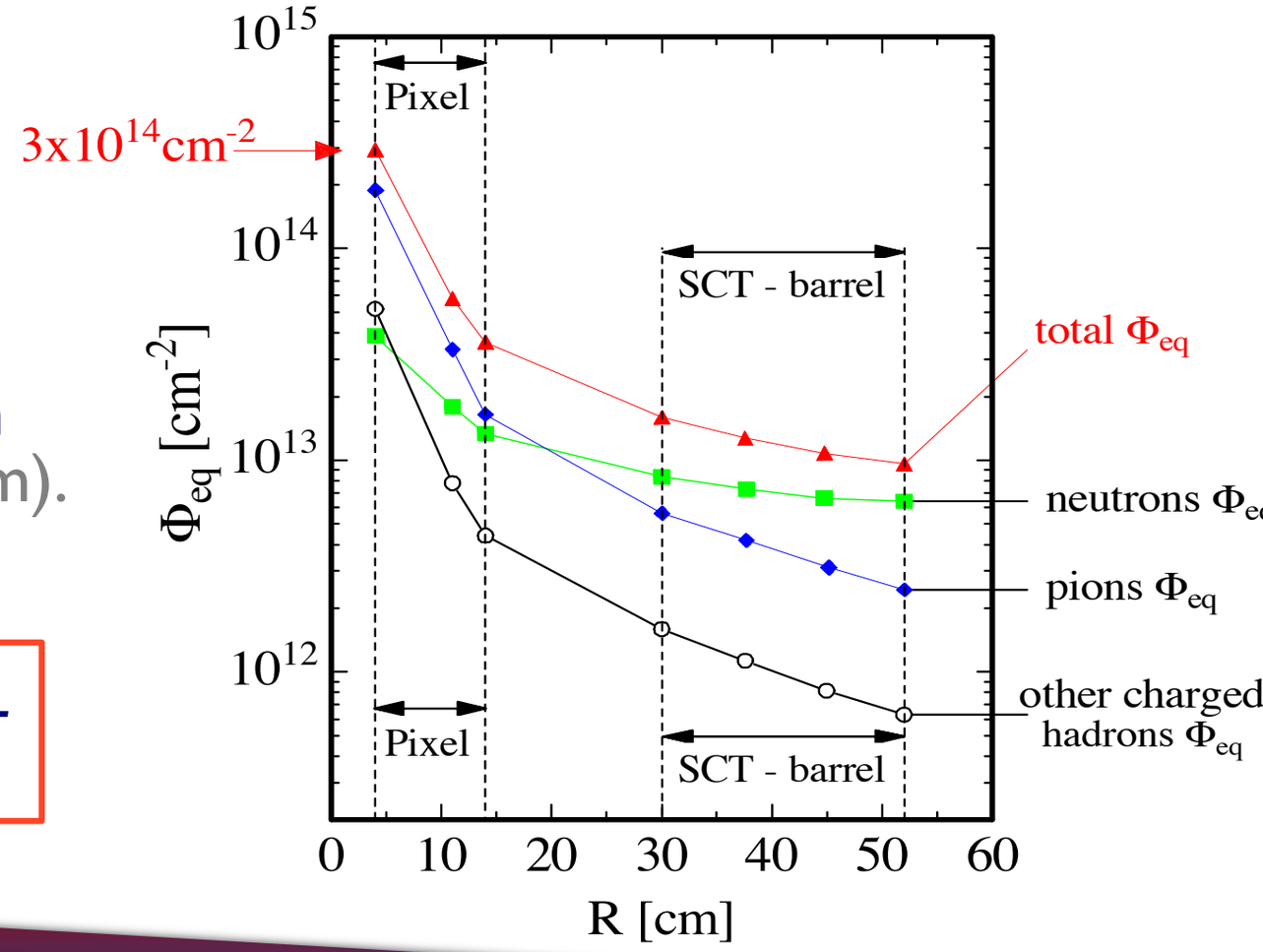


Over-constraining the model

$$\Delta I(t) / Vol. = \alpha(t,T_\alpha) * \Phi_{eq}(t, R)$$

- Which variables are known / measured / calculated?
- $\Delta I(t)$ -> measured
- Vol. -> known volume of silicon
- $\alpha(t,T_\alpha)$ -> unknown, or only estimated from test beam data, or other parametrisation. Includes annealing component from measured temperature profile.
- $\Phi_{eq}(t, R)$ -> calculated from radial (R) dependence in FLUKA 1 MeV eq simulation (damage factors) and Integrated Luminosity.
- Further correction for beam ionization current = ΔI (with beam) – ΔI (no beam).

Can we use data from all experiments to over-constrain the model?



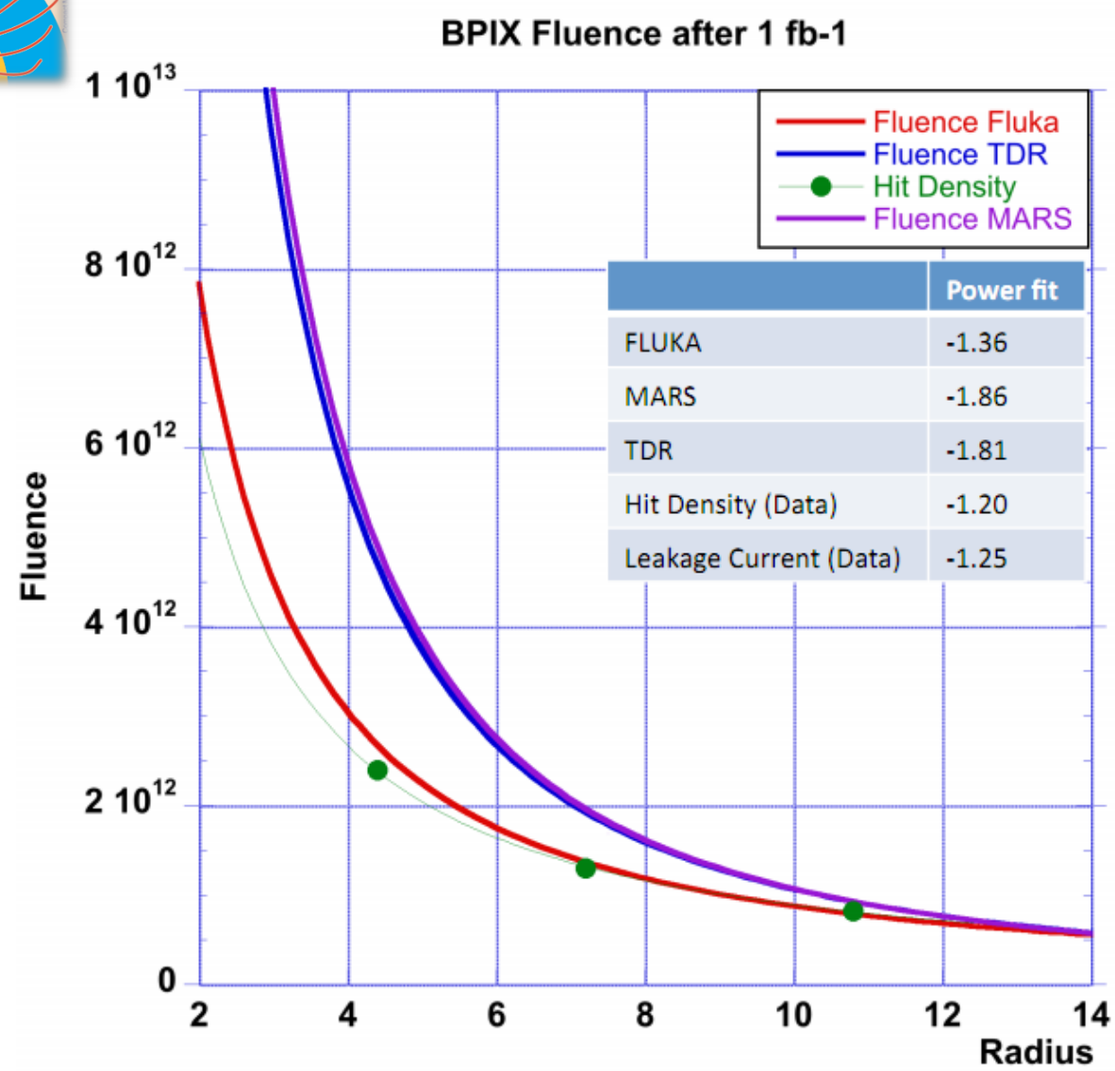
Proposal for global fit

$$\Delta I(t) / Vol. = \alpha(t,T_\alpha) * \Phi_{eq}(t, R)$$

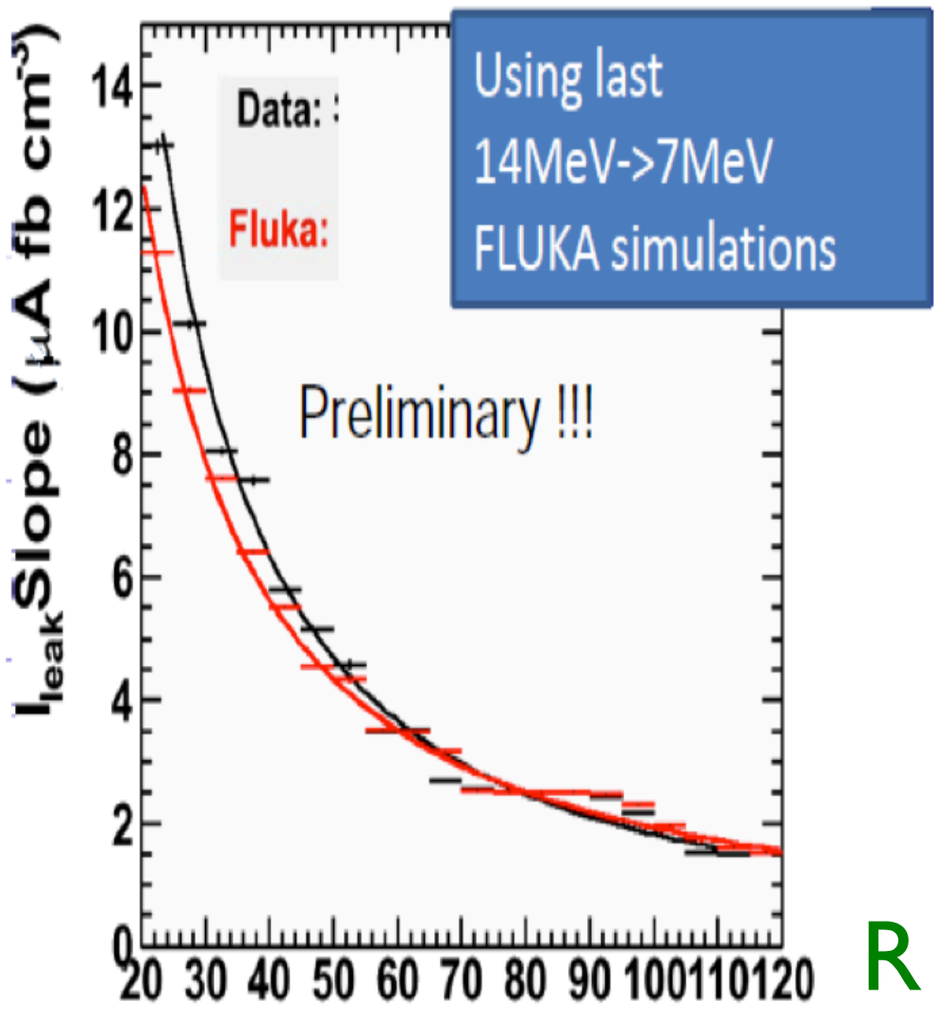
- Fluence radial dependence can be derived from FLUKA simulation and different particle damage factors.
- Can alternatively measure the radial dependence in data.
- Fluence can be parametrised by radius and integrated luminosity
- $\Delta I(t) / Vol. = \alpha(t,T_\alpha) * \Phi_{eq}(t, R)$
- $\Delta I(t) / Vol. = \alpha(t,T_\alpha) * L * (A / R + B/ R^2)$
- ***Propose to plot radial dependence of (ΔI / Vol.) at different Integrated Luminosity contours.***
- ***May then perform global fit for alpha, provided experiment dependent annealing correction can be taken into account.***
- Particle spectra from collisions should be similar - may encounter unavoidable (small?) differences due to different detector material and magnetic fields.

Over-constraining the model

$\Phi_{eq}(t, R)$ vs R



$\Delta I(t) / Vol$ vs R



- Example plot from CMS silicon strips allow comparison with Fluka model
- *Encourage all experiments to repeat plot for different luminosities.*

Census of tools

ATLAS micro-strips (SCT)

- Jack Roberts has recently arrived at CERN for 8 months to develop a general utility for calculation of leakage currents and depletion voltages as a function of integrated luminosty, temperature.
- Paul Dervan for SCT models of leakage currents predictions including annealing effects, based also on FLUKA simulations by Ian Dawson. Hamburg model.

ATLAS Pixel

- Daniel Munstermann has original Dortmund code for calculation of various parameters, including leakage currents and depletion voltage with annealing.

RD50

- Excel spreadsheet implementing Hamburg Model from Michael Moll.

LHCb VELO

- Paula Collins, NIEL parameterisation. Strong interest in common c++ version to calculate evolution of silicon parameters.

Discussion – Towards a common utitily…

Further discussion points

Raised during discussion…

RD50

1. RD50 annealing correction. Many experiments rely on 1999 thesis of Michael Moll with data to 21°C . Updated corrections for low temperature operation?
2. How experiments bridge the gap between macroscopic properites and microscopic defects to help RD50 / improve model?

"Hamburg Model works best in Hamburg..."

LHCb

1. Measurement of band gap, E_g.
2. LHCb observe slight rise of slope of IV plots with increasing fluence
3. LHCb, how to treat kaon, photons and conversions, low energy particles? What effective corrections are applied by FLUKA simulation?
4. Worrysome drop in efficiency in a few sensors – to be understood, routing line effect?
5. LHCb tracker leakage current evolution

Further discussion points

Raised during discussion…

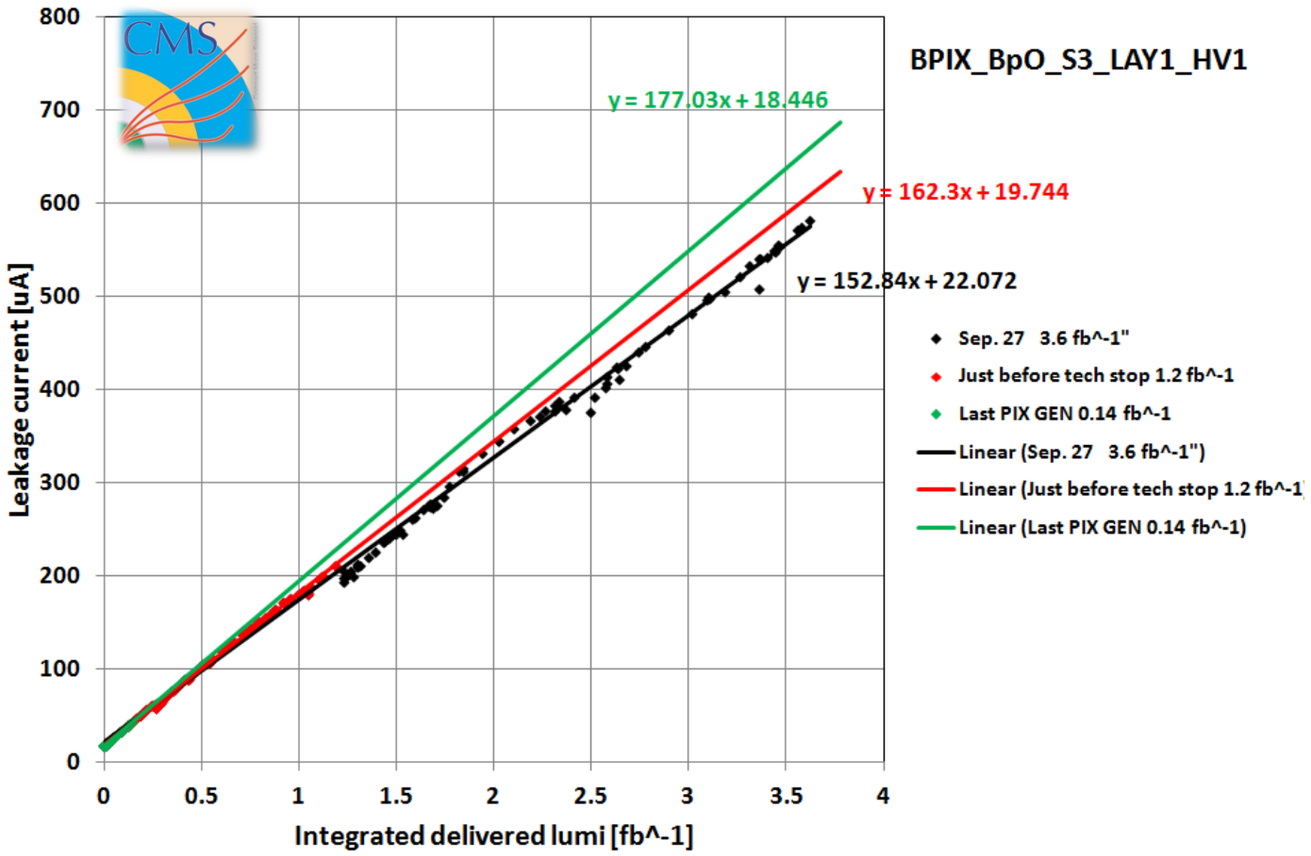
CMS

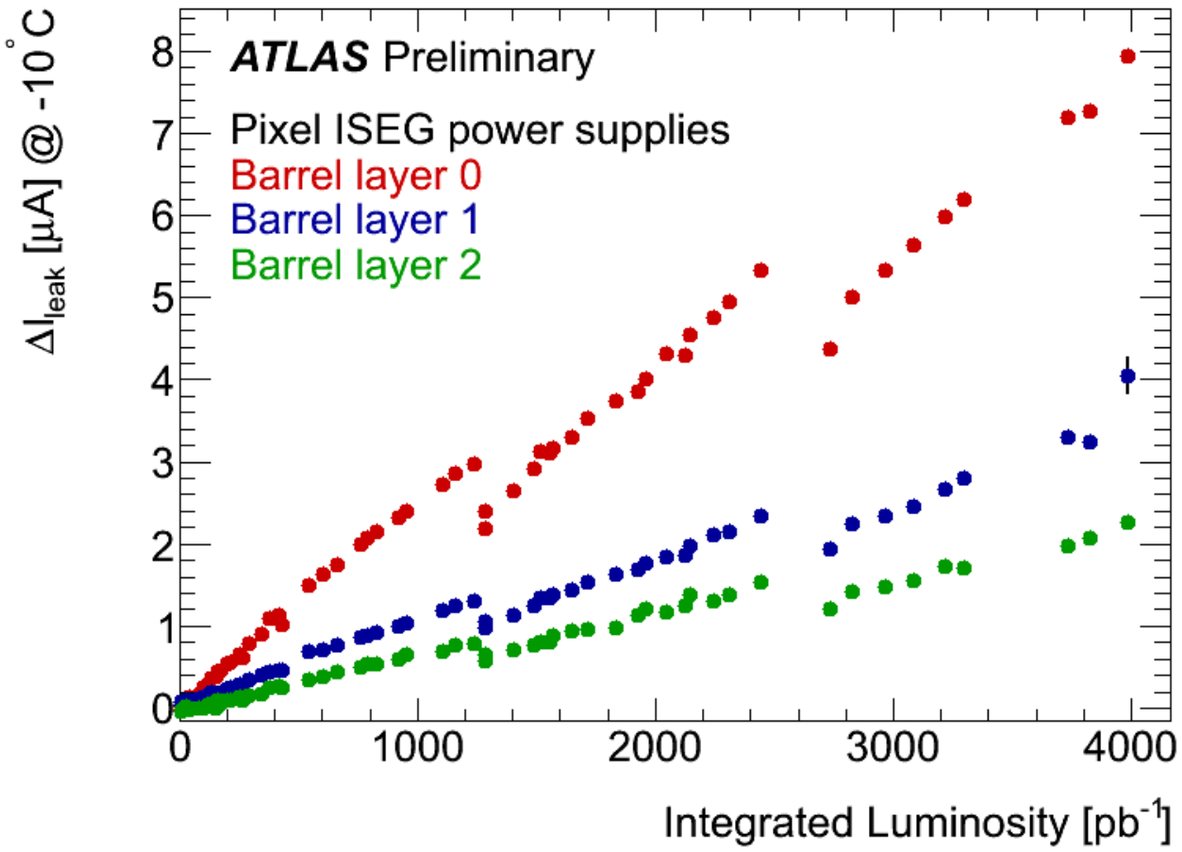
1. Measurement of alpha from data: understanding the factor of 2?
2. Normalised leakage current per volume versus radial dependence in the CMS strips.

ATLAS

1. Per pixel leakage current measurements – can these be compared with power supply current measurements? Search for patterns possilbe with per pixel results, absolute calibration may be complicated due to guard rings, etc…
2. Hamburg model change improves situation since ATLAS TDR.
3. Difference in inner modules end-cap between FLUKA and SCT predicted currents.

Impact of annealing





$$\Delta I(t) / Vol. = \alpha(t, T_\alpha) * \Phi_{eq}(t, R)$$

- Impact of annealing seen in changing slope of leakage current versus integrated luminosty:
- Observe jumps during technical stops in ATLAS due to detector cooling

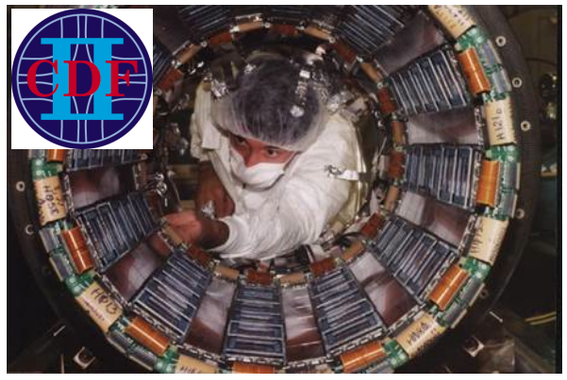
Beyond this workshop

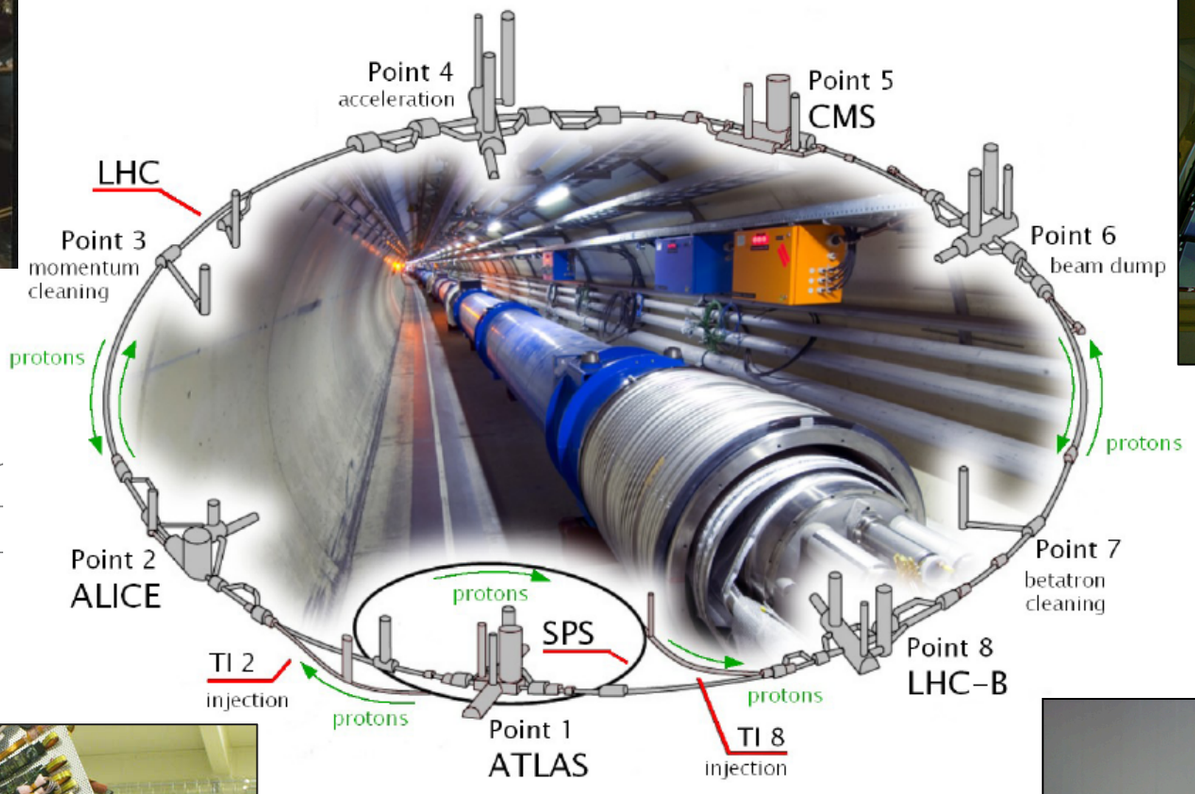
19th RD50 Workshop, at CERN, 21-23 November 2011.

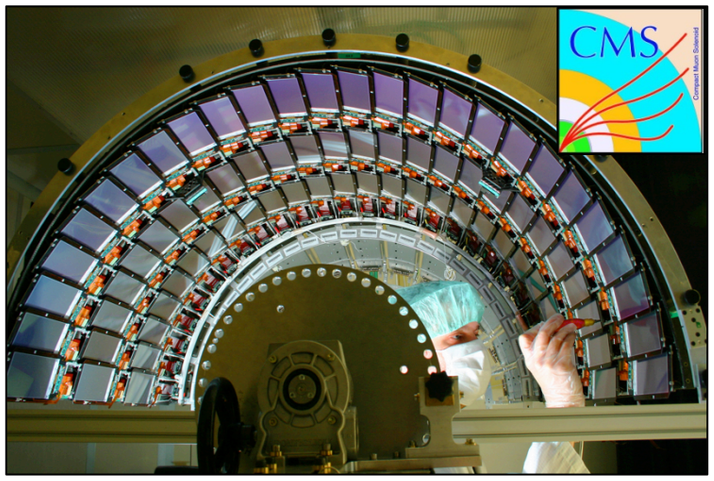
- A dedicated session is being organized on radiation damage in LHC experiments.
- Please consider to come and participate.
- We would like to aim for a common framework for simpler comparison between experiments on the timescale of the RD50 workshop.
- Meanwhile, we expect to hold interim meeting(s) of the Inter-Experiment Radiation Damage Working Group to help prepare for the 19th RD50 workshop.
- An inter-experiment operational workshop, which may include radiation damage effects, is envisaged for early 2012.

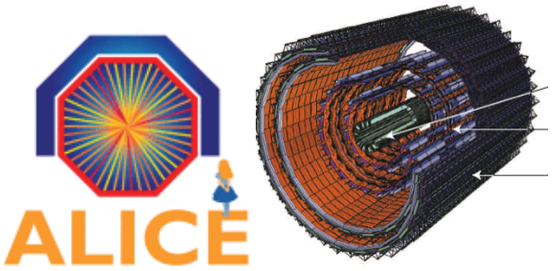
Inter-Experiment Workshop on Radiation Damage in Silicon Detectors

Thanks to all the experts who made this possible!









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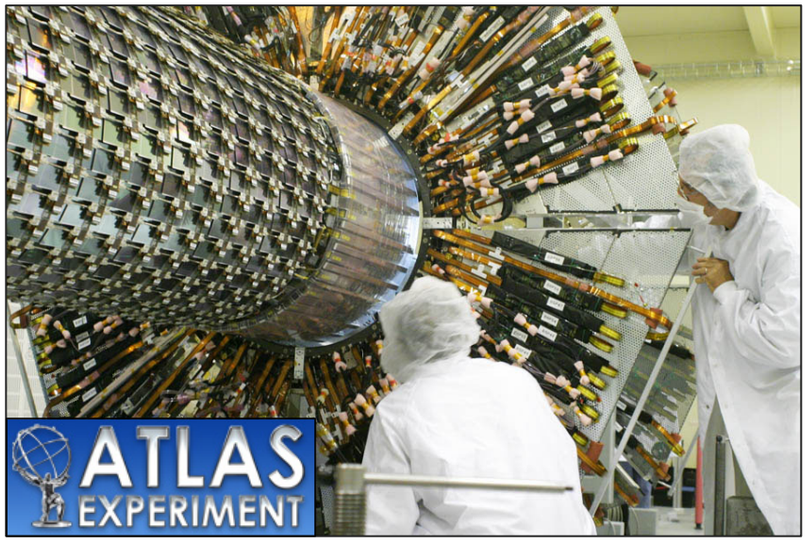

Hope to see you at 19th RD50 Workshop