Inter-Experiment Workshop on Radiation Damage in Silicon Detectors

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Radiation damage

and

CMS pixel

G. Bolla

bolla@cern.ch

PURDUE UNIVERSITY

Outline

I will not cover:

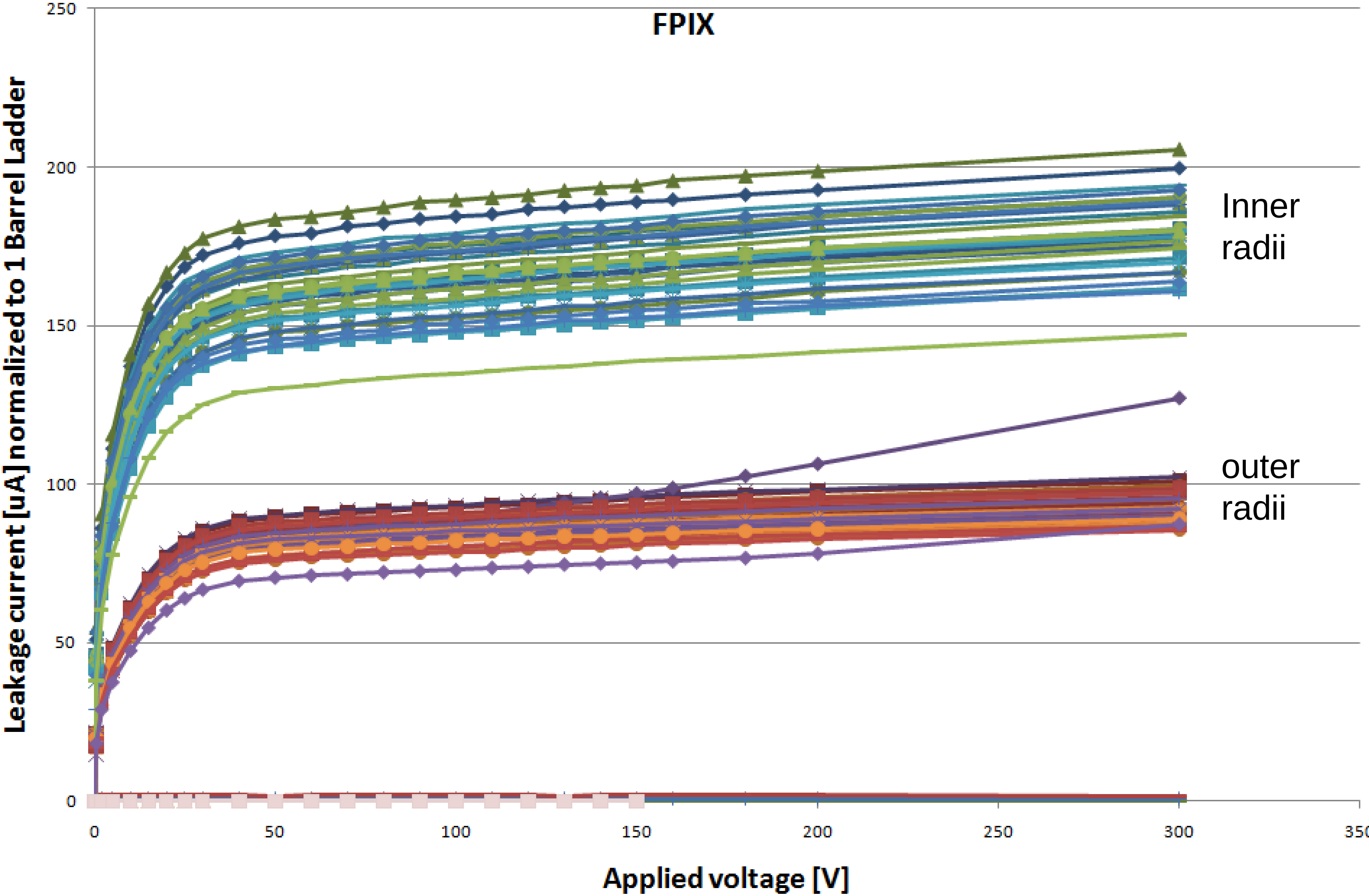
- Changes in the readout electronic (Gain, pedestal, thresholds etc...)
- SEU (quite interesting and important topic)

- Measured radiation damage so far:
  - Leakage current
    - IV curves
    - Current versus time/integrated-lumi
  - Depletion voltage
- An attempt to convert integrated luminosity to integrated fluence
- Comparison with existing models.

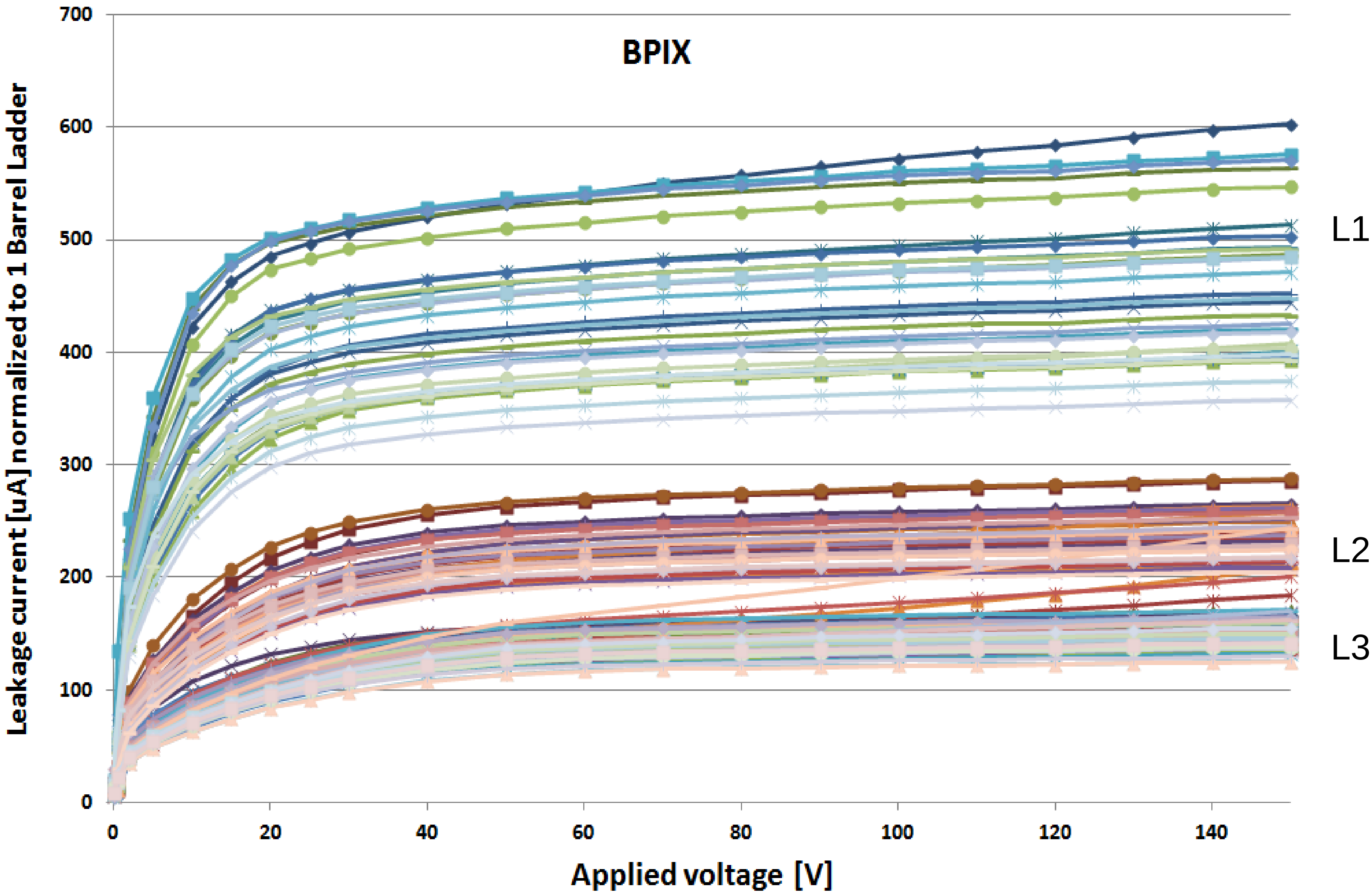
Important notes

- No temperature corrections are applied.
  - Temperature of the sensors is estimated to be 17° C for all sensors (within a few degrees).
- Only correction applied is the normalization by volume (when written) to 1.3 cm^3

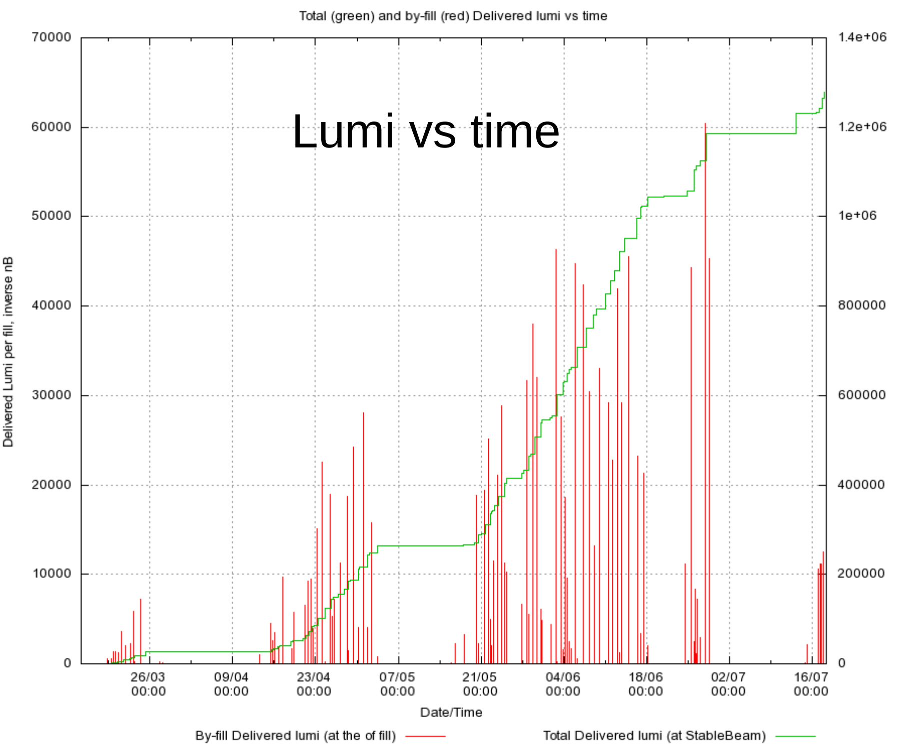
IV curves FPIX after ~2 fb^-1

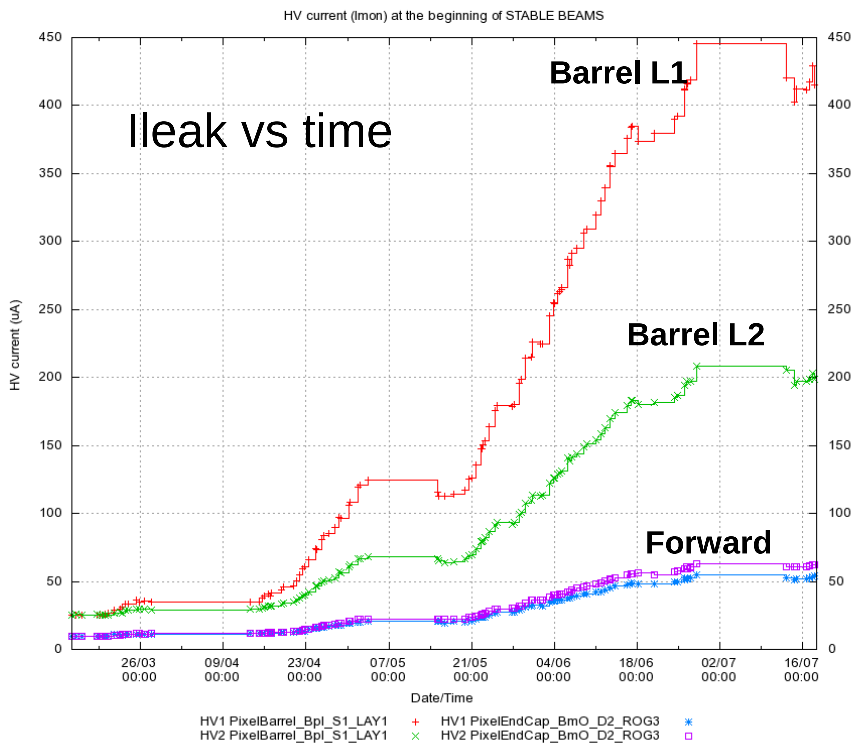


IV curves BPIX after ~2 fb^-1



Leakage current: clear signs of radiation damage





Clear the correlation between integrated lumi and leakage current increase.
Clear signs of annealing when the LHC is down.

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Current versus integrated luminosity

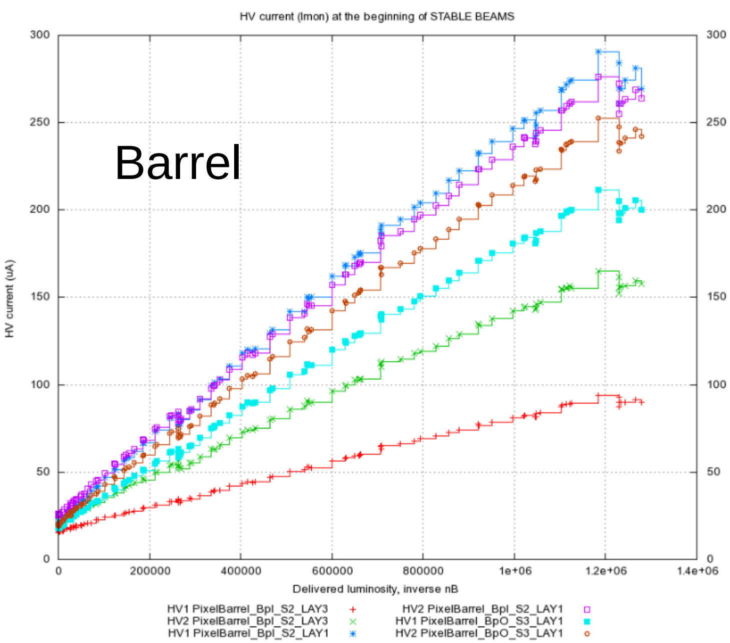
Behavior is quite linear

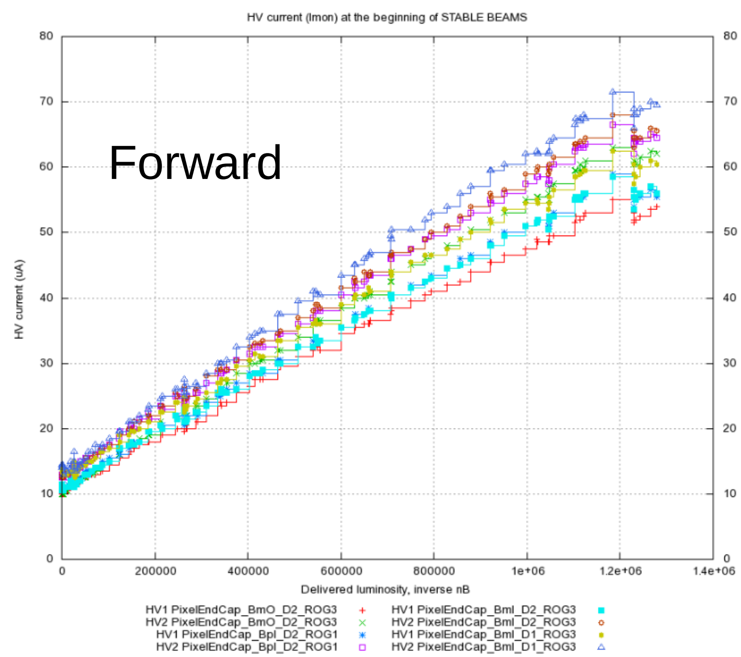
Barrel:

- Different volume of silicon attached to the same HV channel
- Different radius (three different radii)

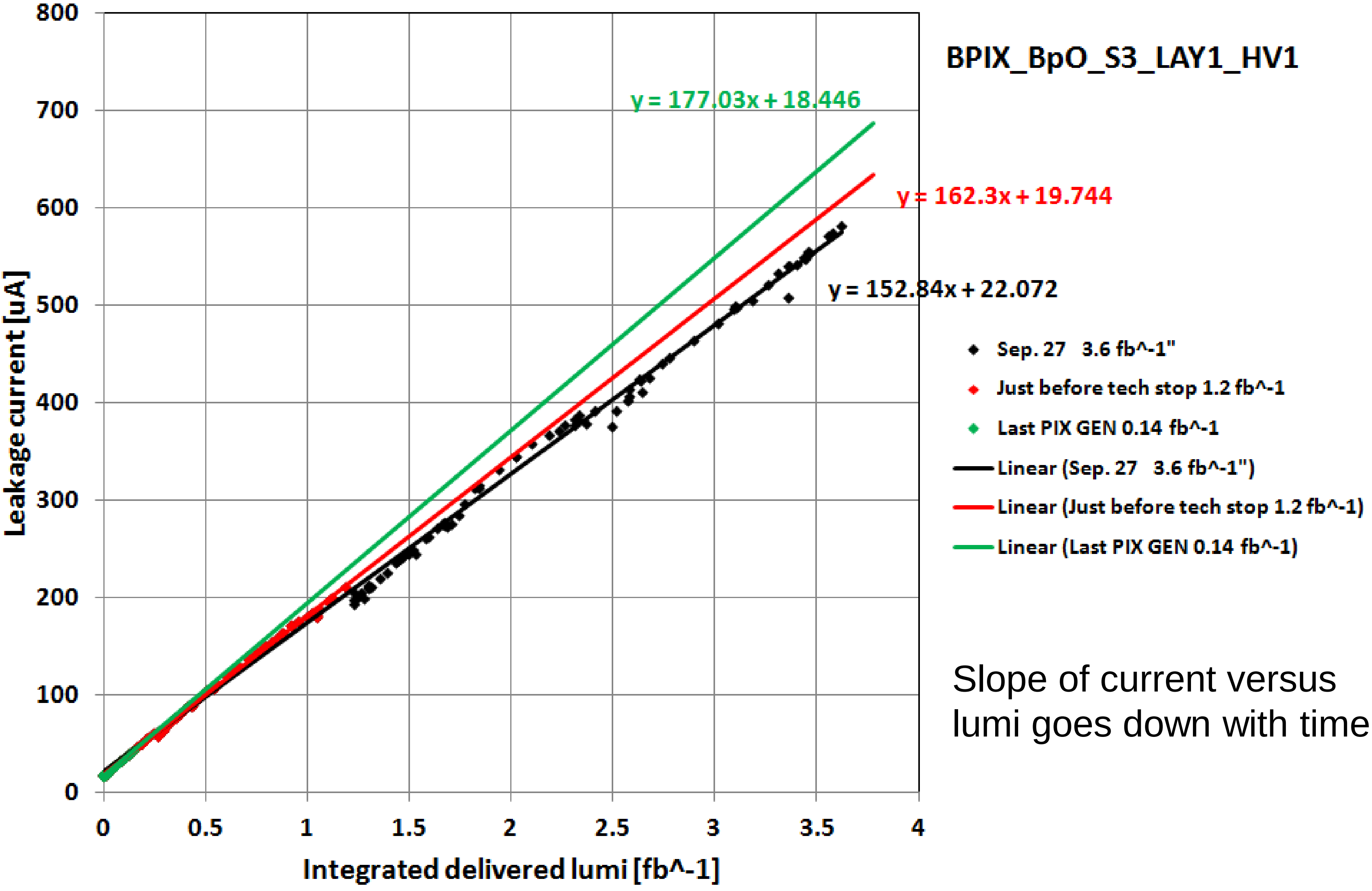
Forward

- Only two geometry: inner and outer radius
    - Two geometry were balance to have ~ the same current





How is the slope developing versus time

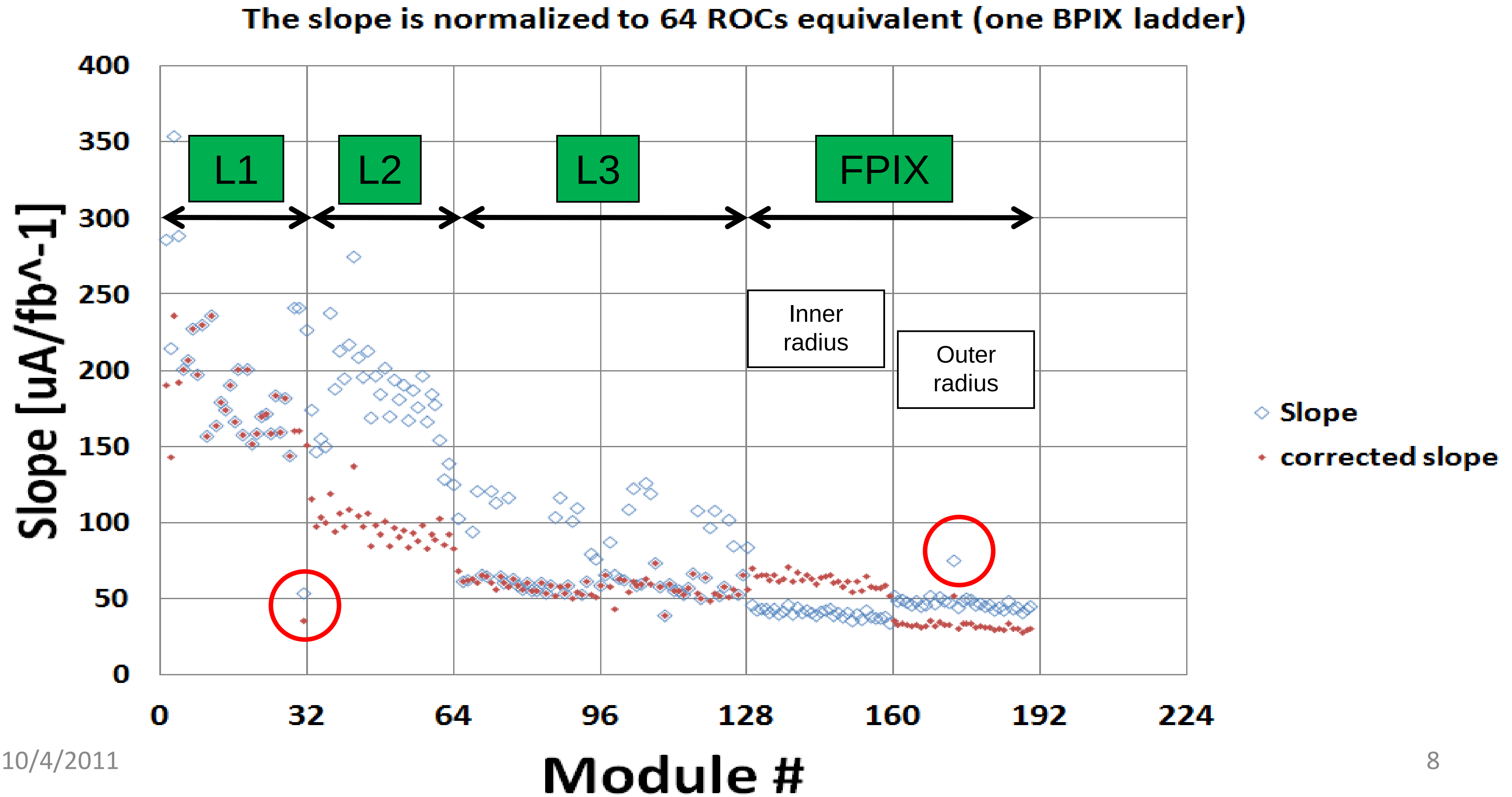


Slope of current versus lumi goes down with time.

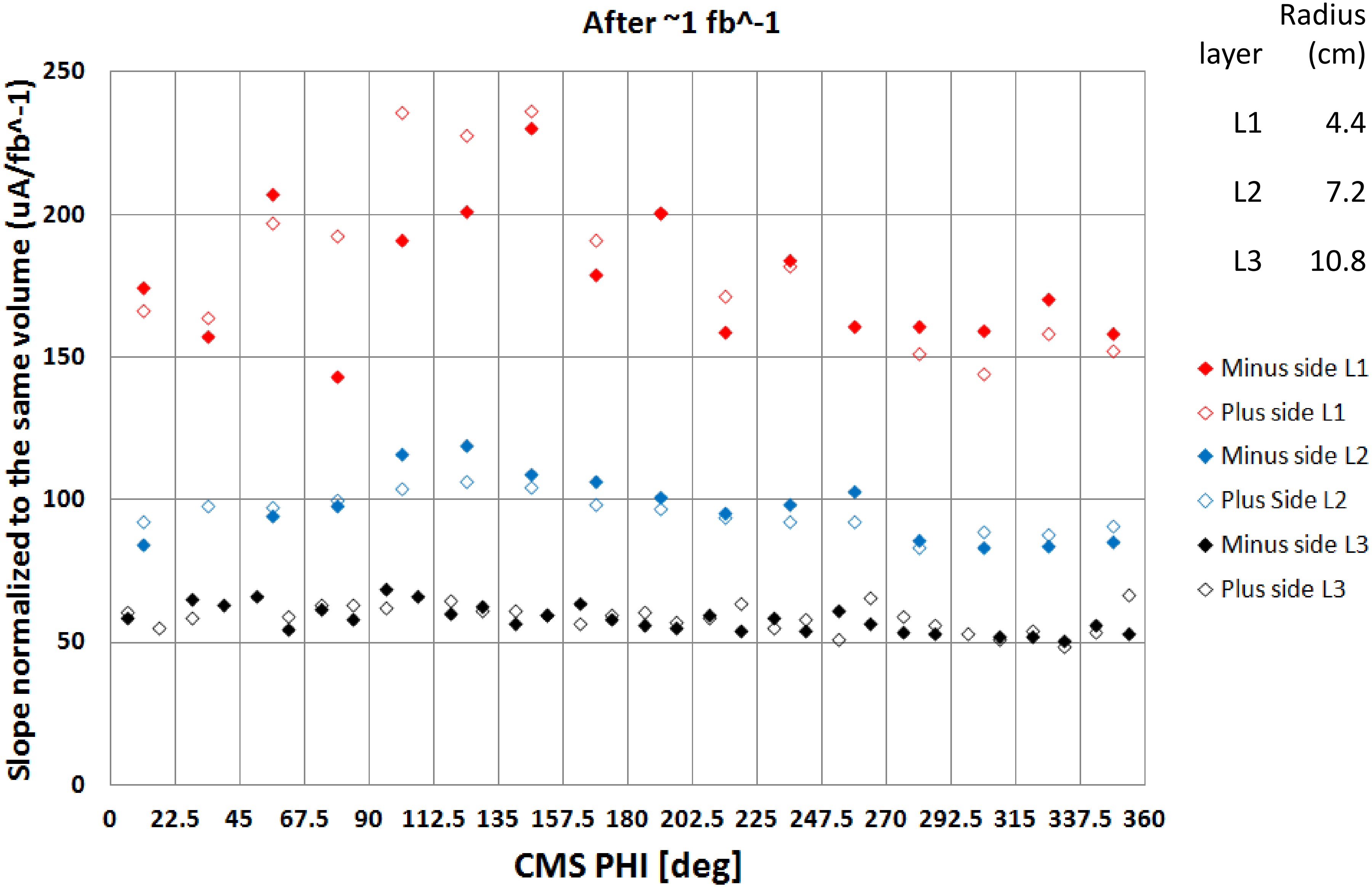
Slopes normalized by volume

The Plot below is made with the first 1 fb^-1

- Few outlier
- Clear distinction between the different layers.
- Some distinct features within a layer



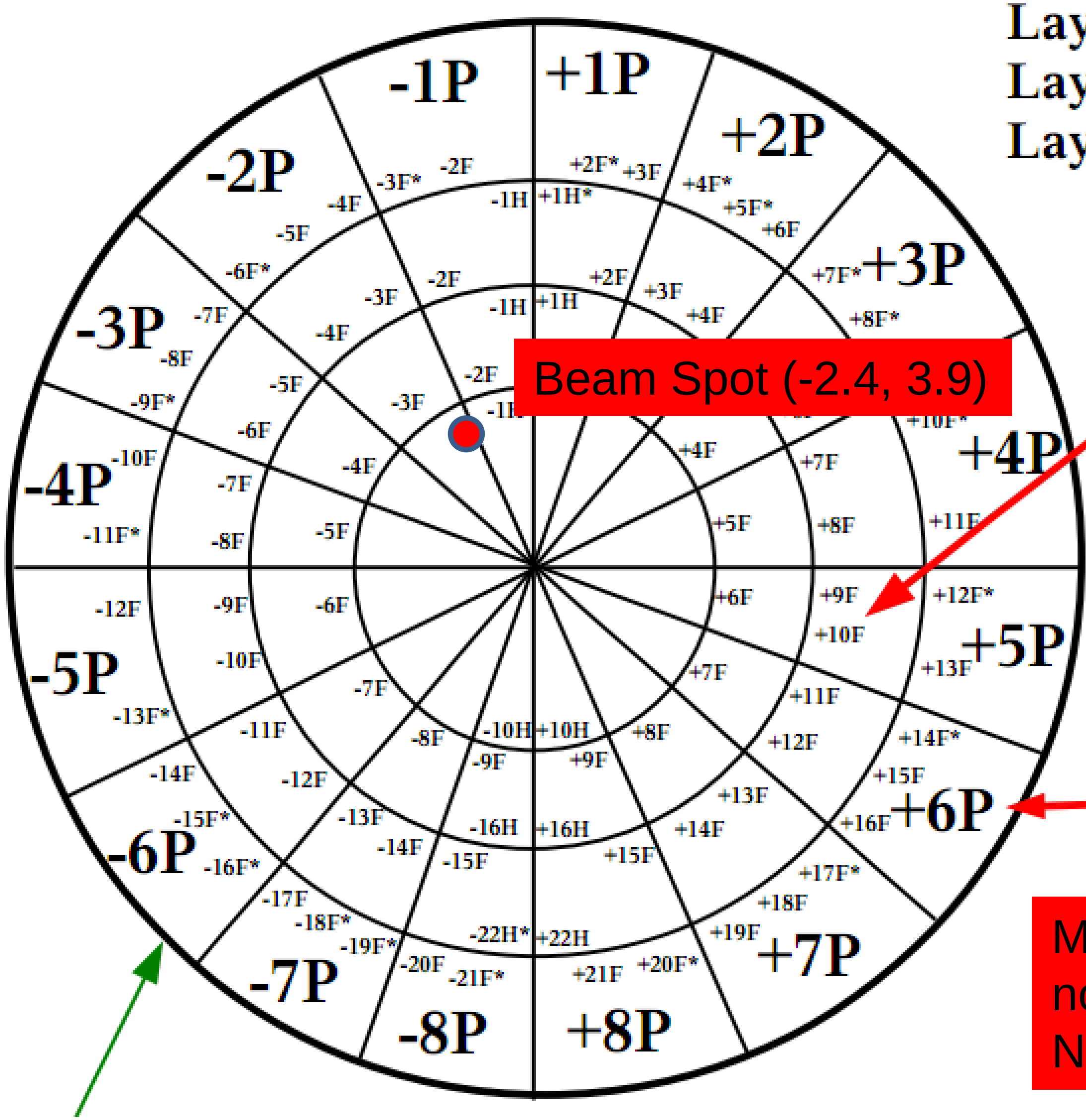
Slopes are different within the same layer



layer	Radius (cm)
L1	4.4
L2	7.2
L3	10.8

Misalignment between Pixel and Beam.

Layer-1 Channel-1
Layer-2 Channel-2
Layer-3 (*) Channel-2



ladder name

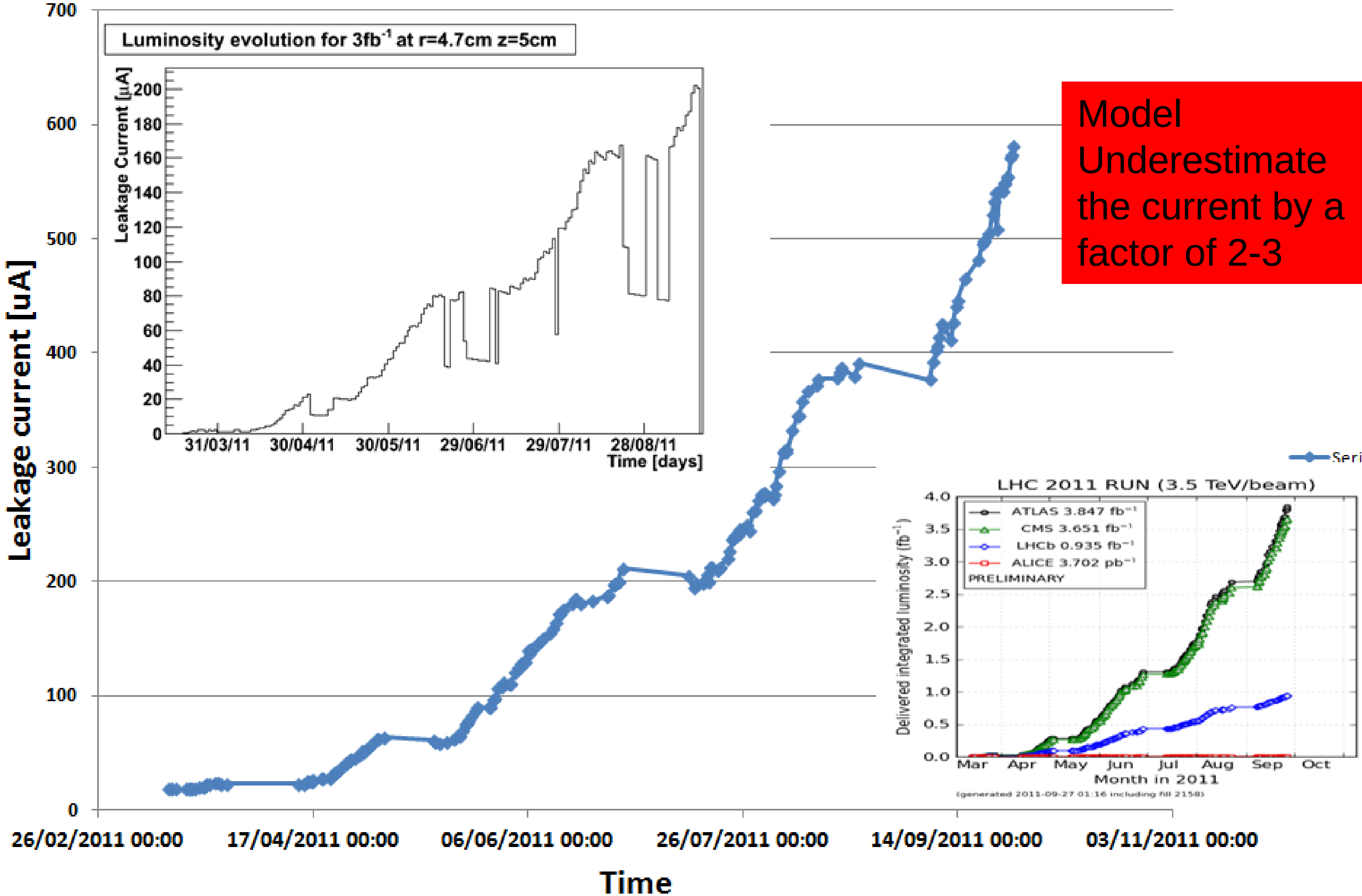
BpI

Phi = 0

sector name

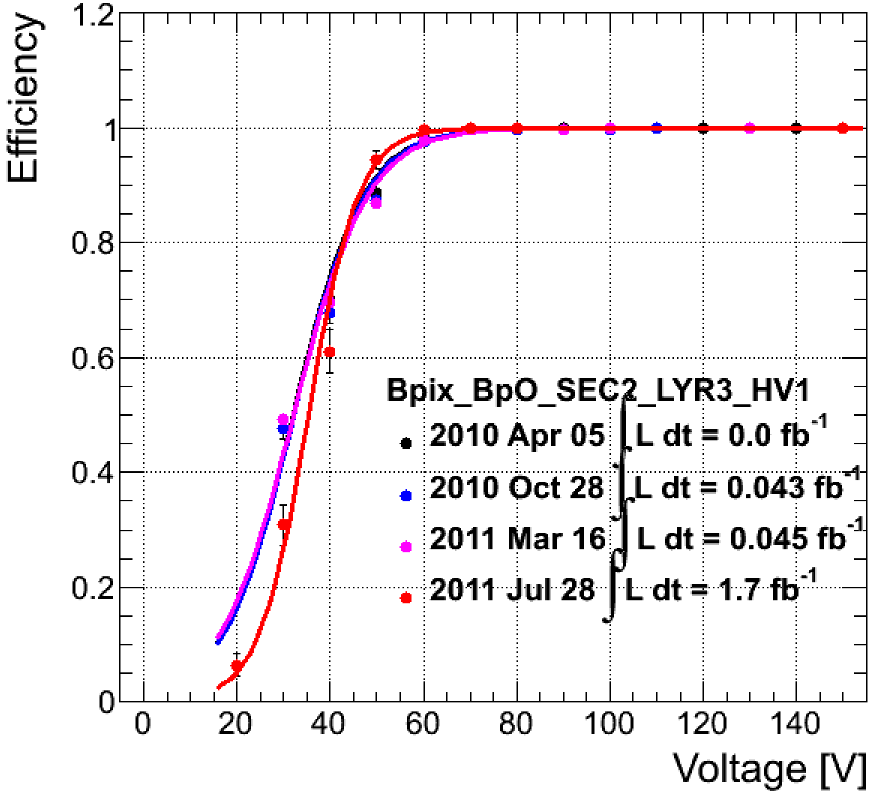
Misalignement in the drawing is not to scale.
Numbers in mm

IV behavior: comparison with the model



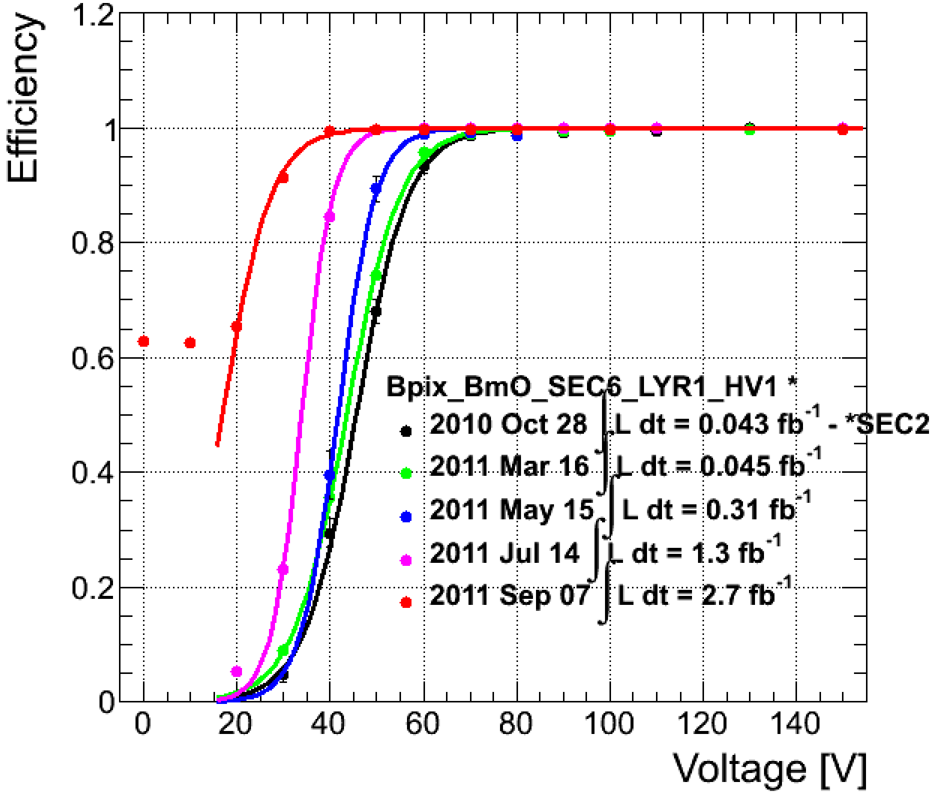
Model Underestimate the current by a factor of 2-3

All Layer 3 Scans (1 HV channel)



- First 3 measurements overlap
- Last scan (red) was done on full layer (see later)

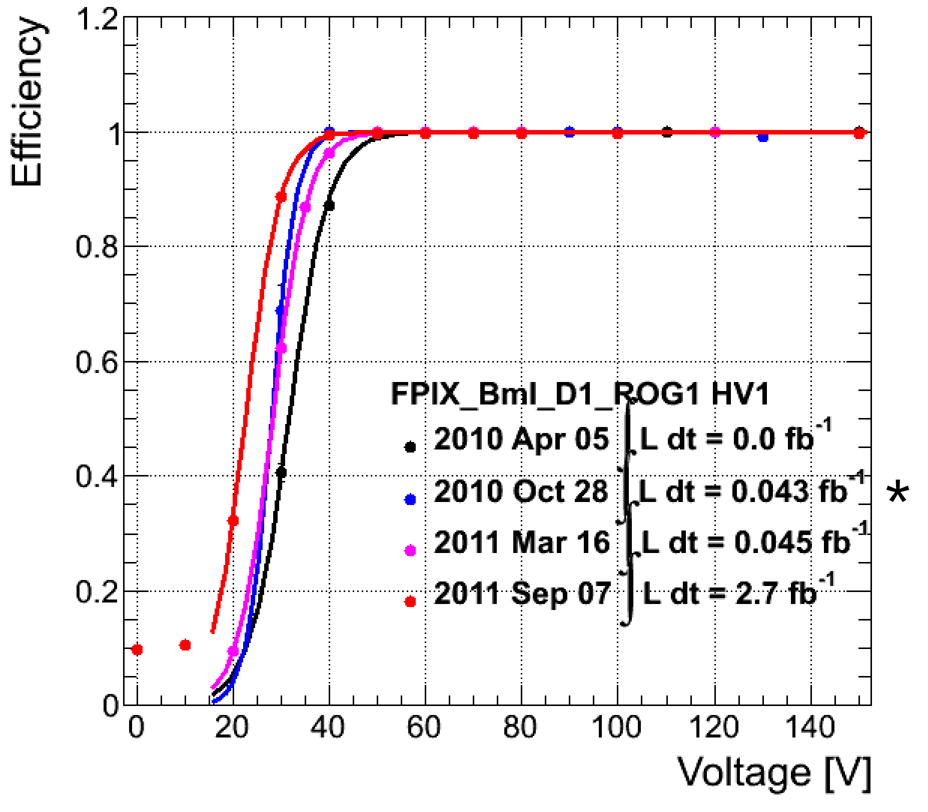
All Layer 1 Scans (1 HV channel)



- See Slide 9 for V_{95} vs integrated luminosity

* First L1 scan was done in SEC2 (which overlapped in ϕ with Fpix scan)

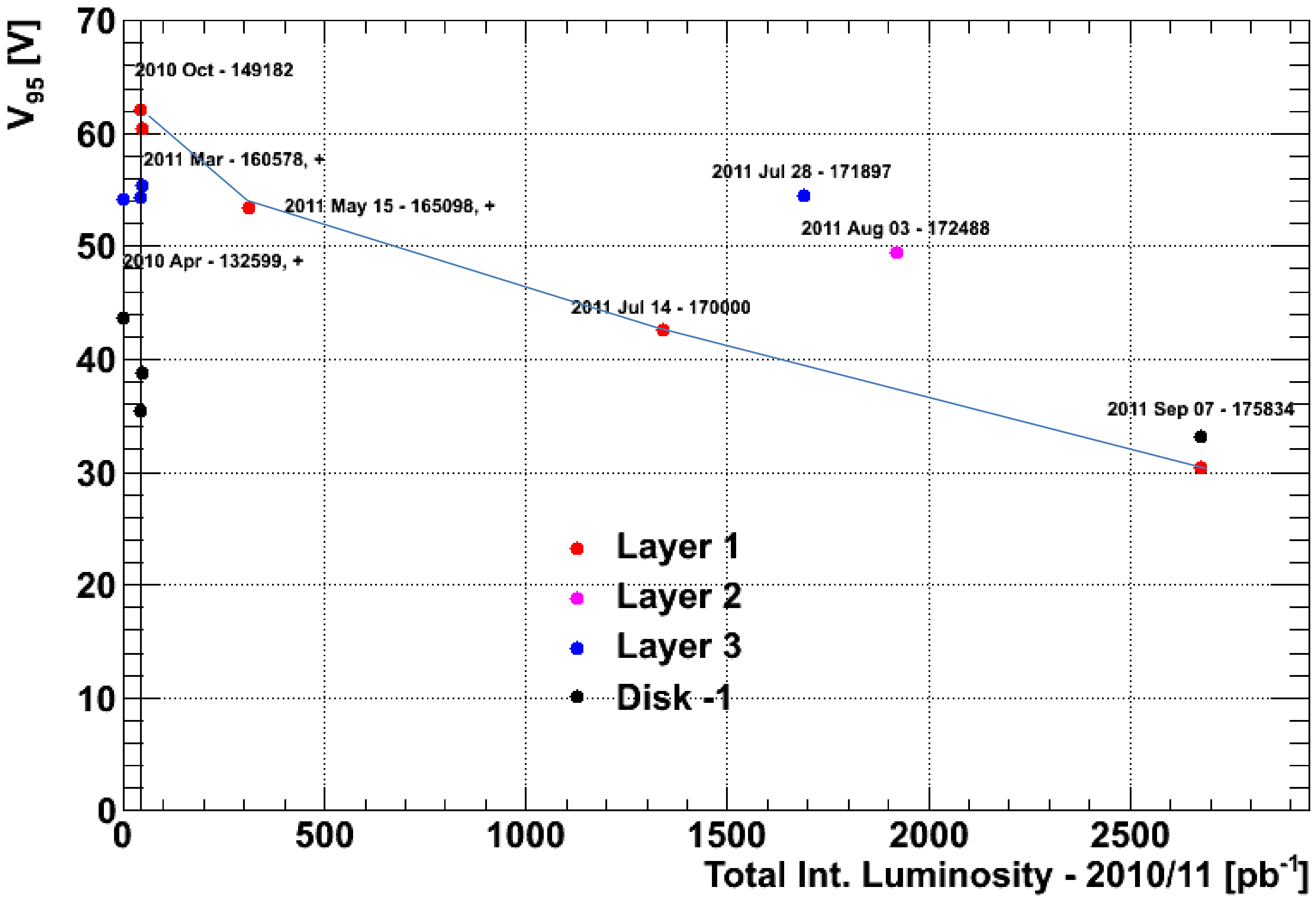
All Disk -1 Scans (1 HV channel)



- Operation point (not shown) is at 300V
- See next slide for V_{95} vs total integrated luminosity

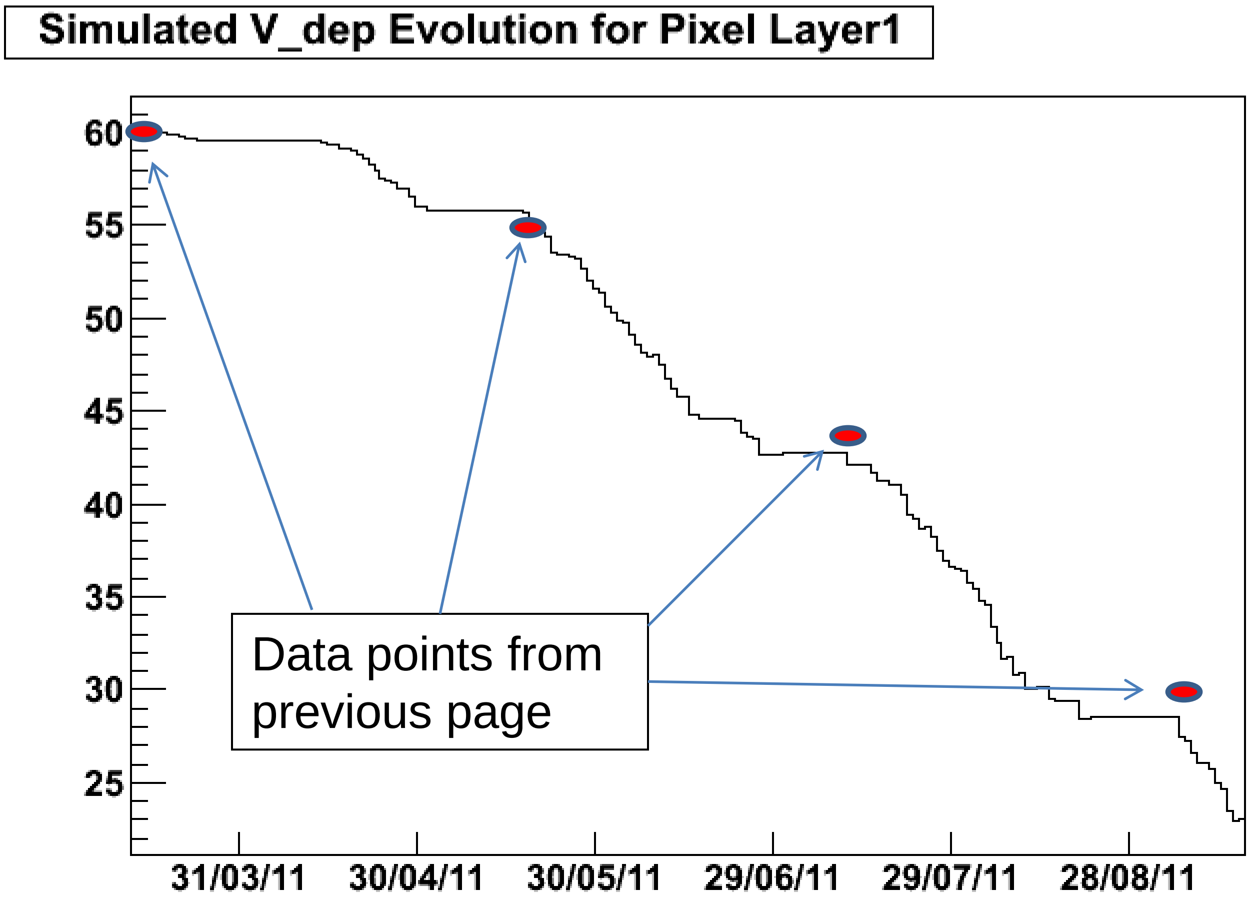
* 2nd scan point (blue) overlapped in ϕ with L1 scan

Depletion Voltage: data so far for ε=95%



Comparison with the model: depletion voltage

Data added with powerpoint on top of the output of the simulations



Plots from the model were generated after the data point were measured.
Was there a retuning of the model?

Translating fb^{-1} into fluence

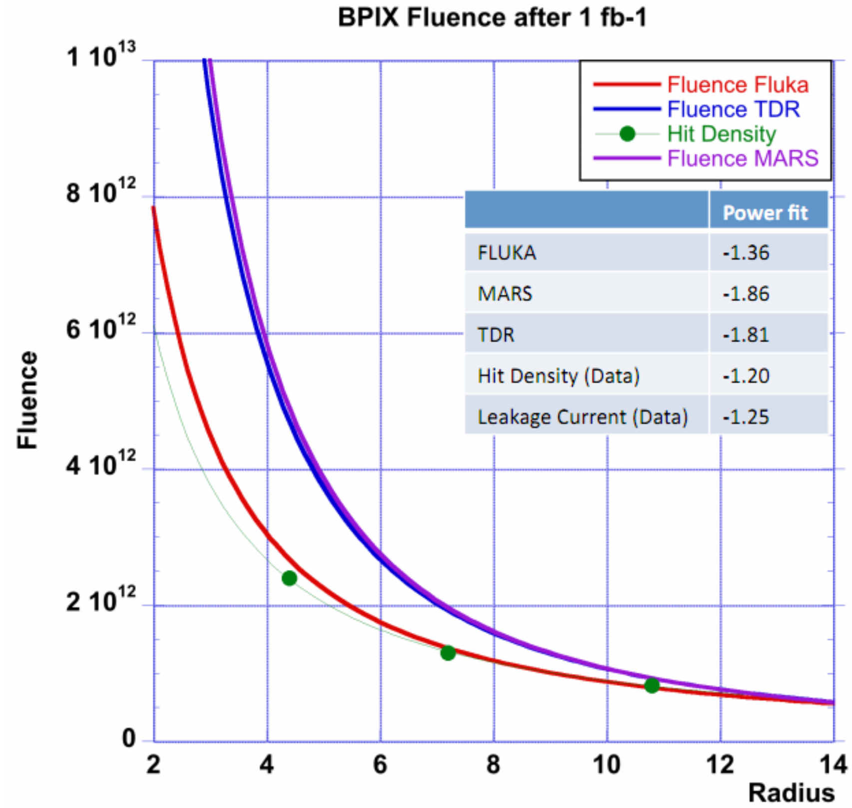
Blue and Purple are simulation that were used for the TDR
- Based on MARS at 14 TeV
- Predicted ~5E12 1 MeV neutron equivalent per fb^{-1} at the innermost layer of the barrel pixel

Red is more recent simulations from BRM.
- Based on FLUKA at 14 TeV
- Scaled to 7 TeV
- Re-scaled to match the BCM measurements.
  - Hmmm... Lot of scaling here and there.

Green is from offline analysis of pixel data
- Simple accounting of pixel hits density from zero bias trigger in a layer by layer basis.

Fluka and measured hit density matches rather well to each other (10%)

Power fit matches the leakage current measurement.



	Power fit
FLUKA	-1.36
MARS	-1.86
TDR	-1.81
Hit Density (Data)	-1.20
Leakage Current (Data)	-1.25

Note how the power low of Danek matches rather well the power law of the leakage current measurements

Translating fb^{-1} into fluence

From the previous slide we can assume 2.5E12 MeV neutron equivalent per fb^-1.

With this assumption than we are experimentally measuring α =~ 8E17 A/cm at 17˚C

OR

We can assume a reasonable α like =~ 4E17 A/cm at 20˚C than.

You conclude that the fluences are >5E12 1MeV neutron equivalent at our innermost radius (4.7 cm).

Some remarks but no conclusions

Pixel has very homogeneous temperatures (up to our knowledge) so scaling for temperature should be easy

Let's try to converge today on a common temperature to normalize to.

Most of the results of today (leakage current) are so clear just because we cannot operate the pixel detector at its nominal temperature (-20 deg C).

This is a problem that **we will solve** in LS1.

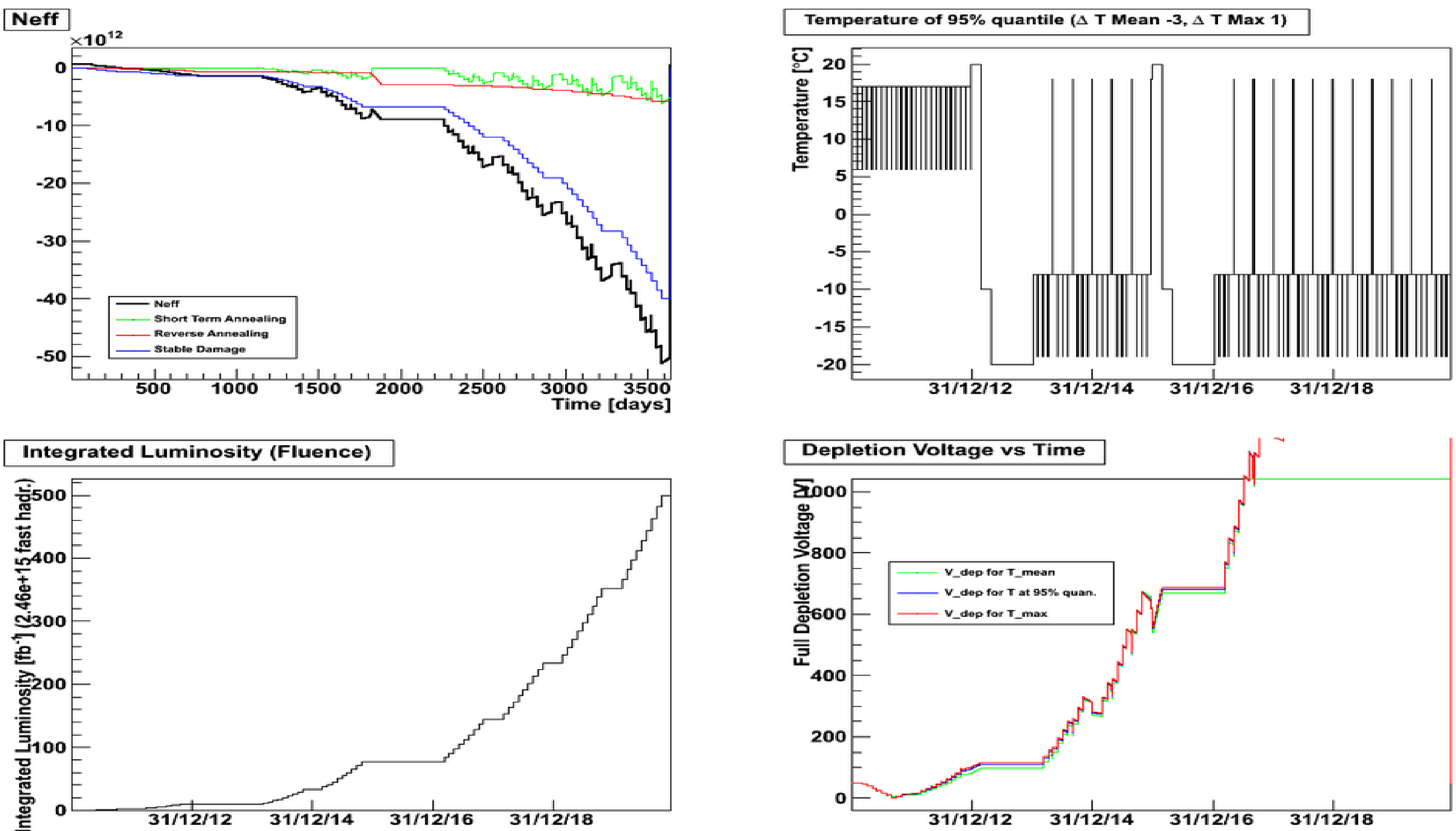
It might be reassuring to know that with the present temperature we should be able to sustain up to ~50 fb^-1 (100 fb^-1 if next year we go down by 7 deg in T as planned).

We have models for leakage current and depletion voltage (C. Barth). The matching between the models and the experimental data still needs some understanding.

Spare slides

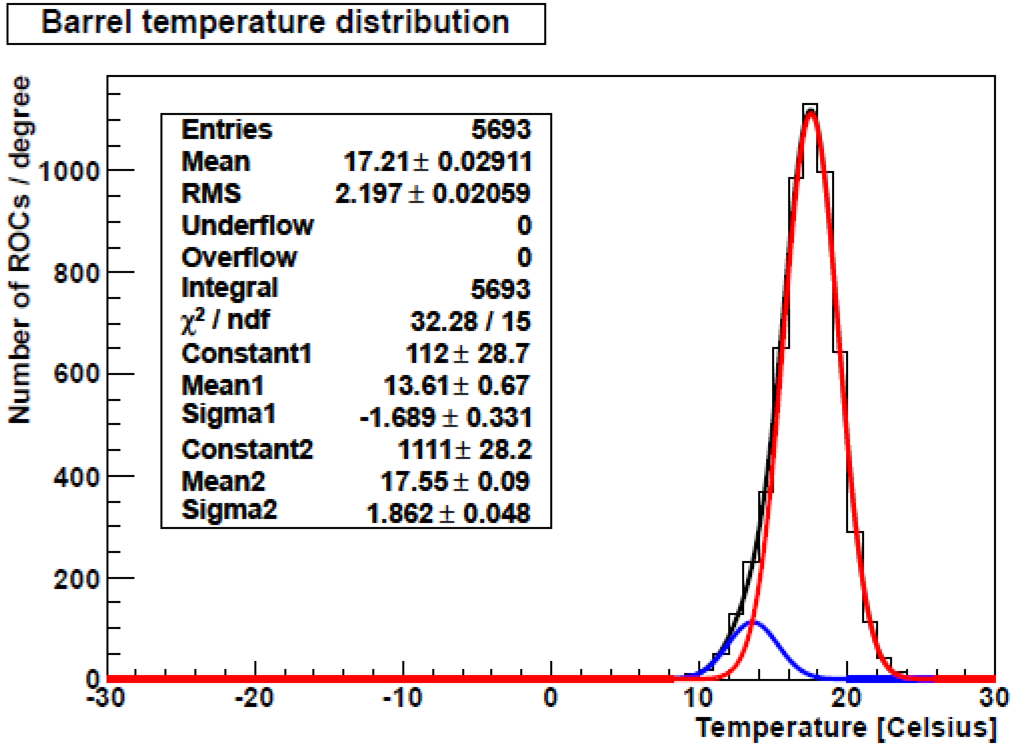
Comparison with early model: depletion voltage

Model results at the end of 2010 predicted inversion at ~2 fb^-1



Barrel temperatures

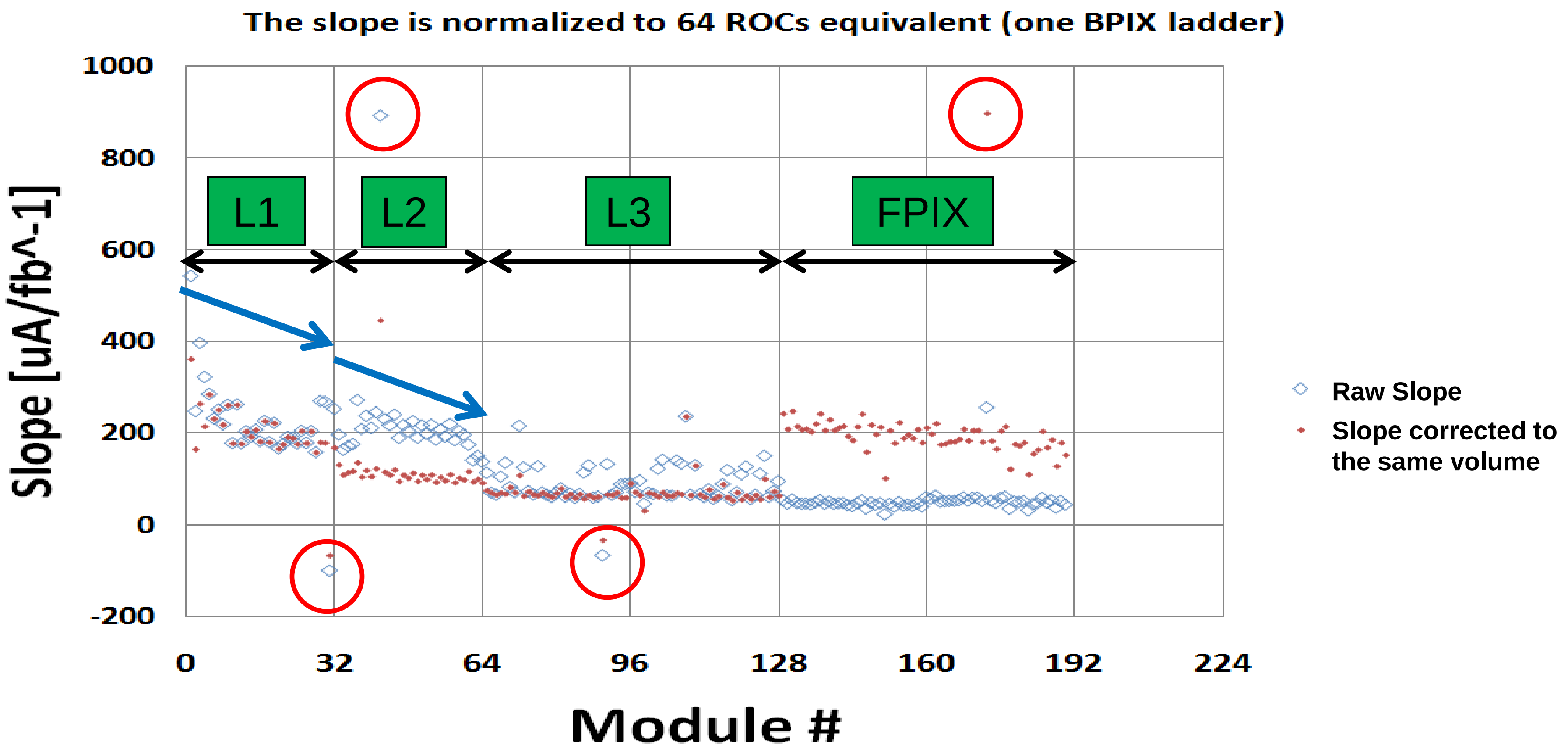
Barrel absolute temperature (?)



Slopes normalized by volume

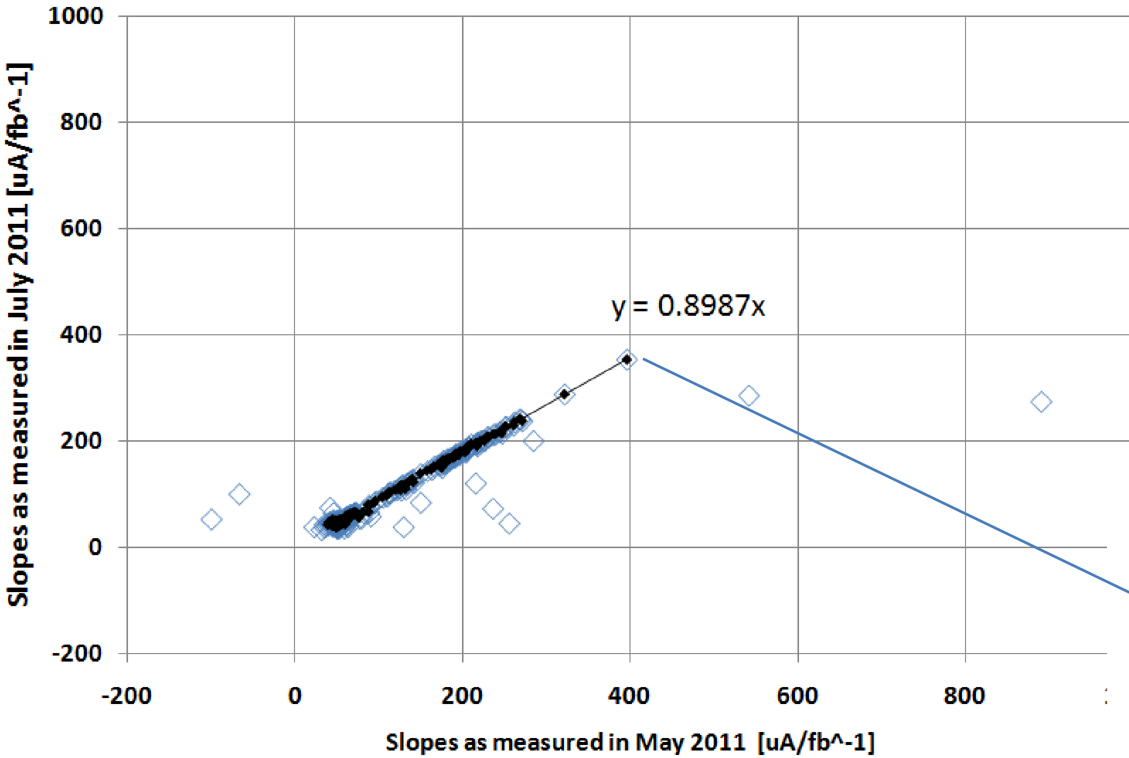
The Plot below is made with the first 0.14 fb^-1

- Several outlier
- Clear distinction between the different layers.
- Some distinct features within a layer



Comparison of slopes: (0.14 vs 1 fb^-1)

Scatter plot of slopes of July versus slope of May



Negative slopes no longer visible.

Large slopes almost back to normal values.

On overall the slopes went down by ~10%

Even the channel with the highest slope is quite linear.