CMS SILICON STRIP TRACKER: RADIATION DAMAGE STUDIES

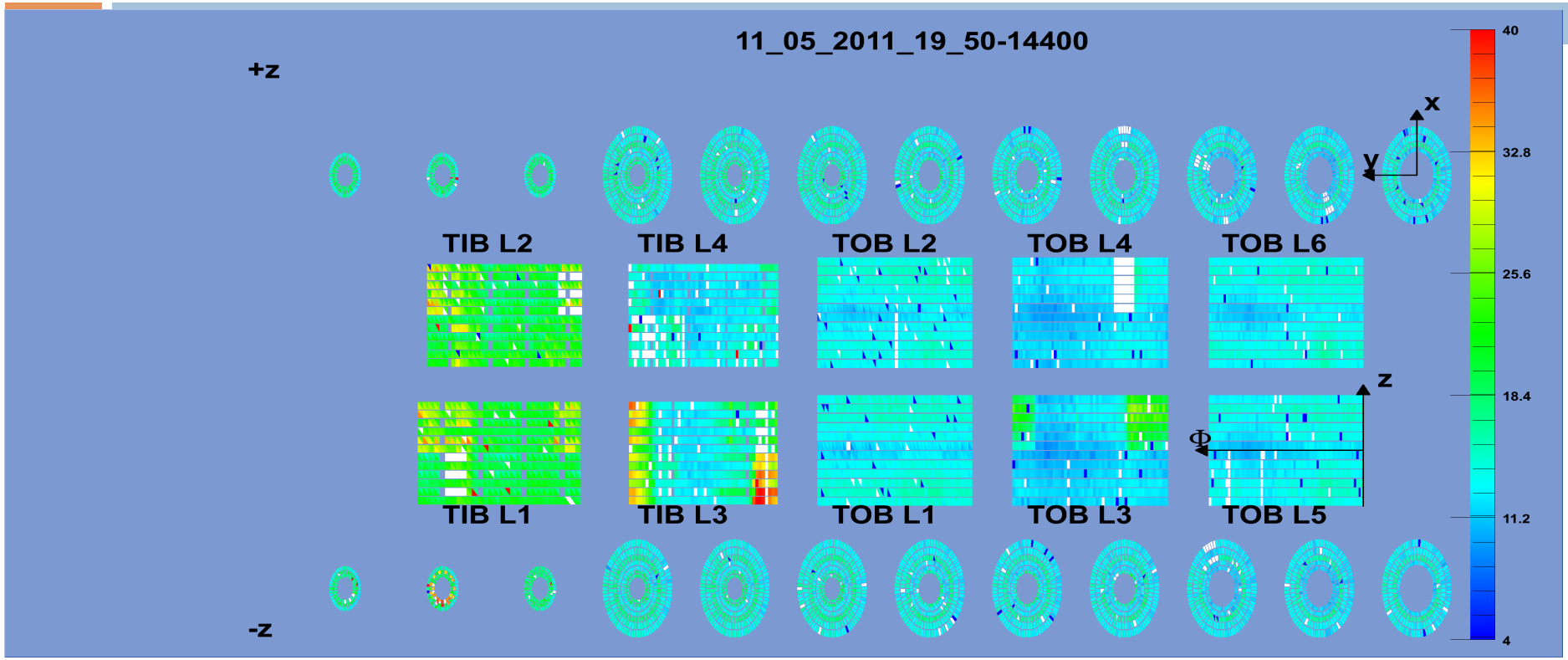
- LEAKAGE CURRENT MEASUREMENTS
- DEPLETION VOLTAGE MEASUREMENTS

Lino Demaria for CMS Silicon Tracker

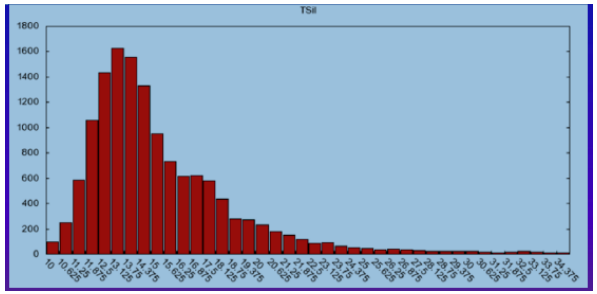
Leakage Current

- Power supply HV lines measure current supplied to several modules (3 to ~10) with < 1μA precision
- Temperature of sensors is varying across the Strip Tracker but it is measured at module level
  - large variety of modules, silicon geometries and thermal contacts with cooling pipes
  - Comparison are done for current densities (normalization with volume) scaled to a temperature of 20C
- Detector Control Unit (DCU) every module, measures Silicon Sensor Temperature and Leakage current
  - Measurements rely on calibration constant taken in lab

Silicon Detector Temperature



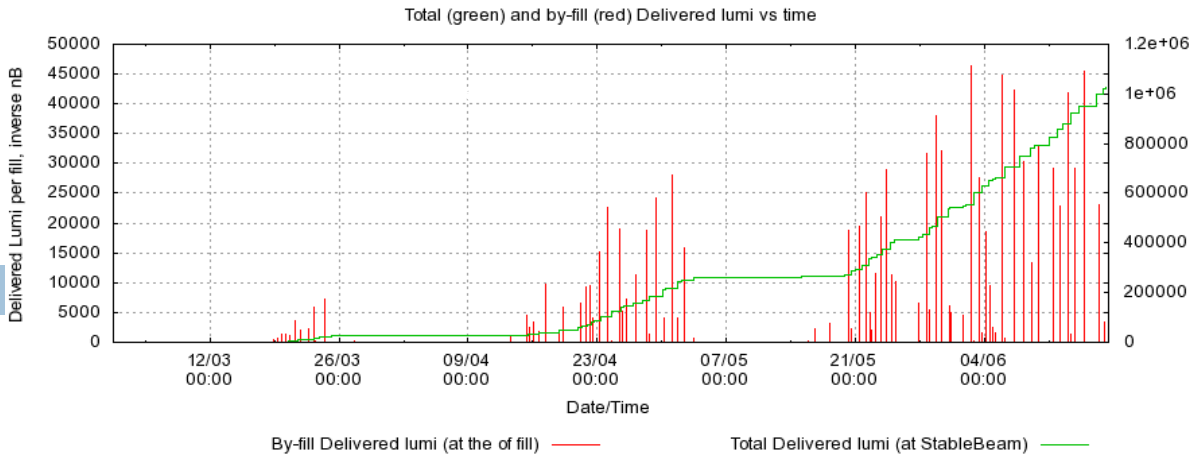
Peak at 14C, but average Temperature different among different Subdetector (TIB, TOB, TEC, TID) and higher for Back-to-Back modules. Also some uncooled parts showing higher temp [30-40C]

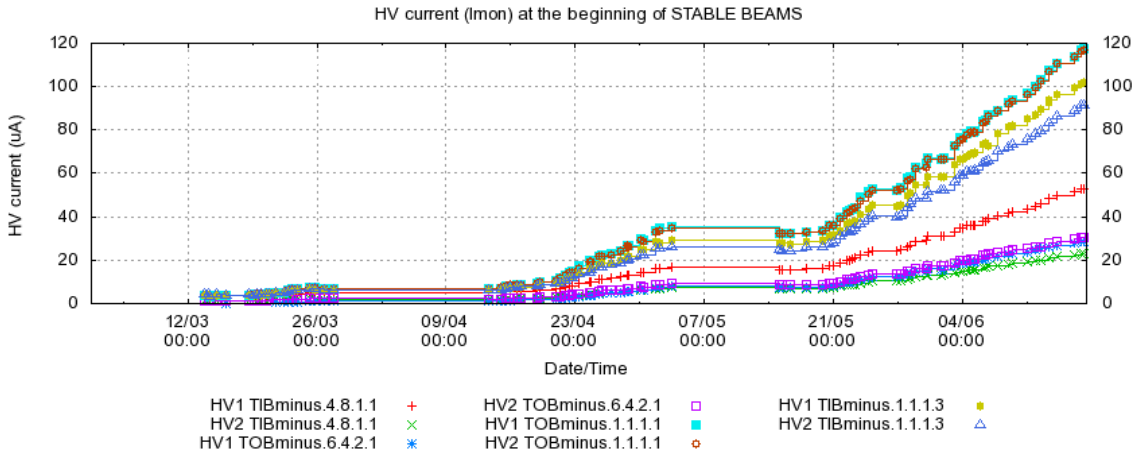


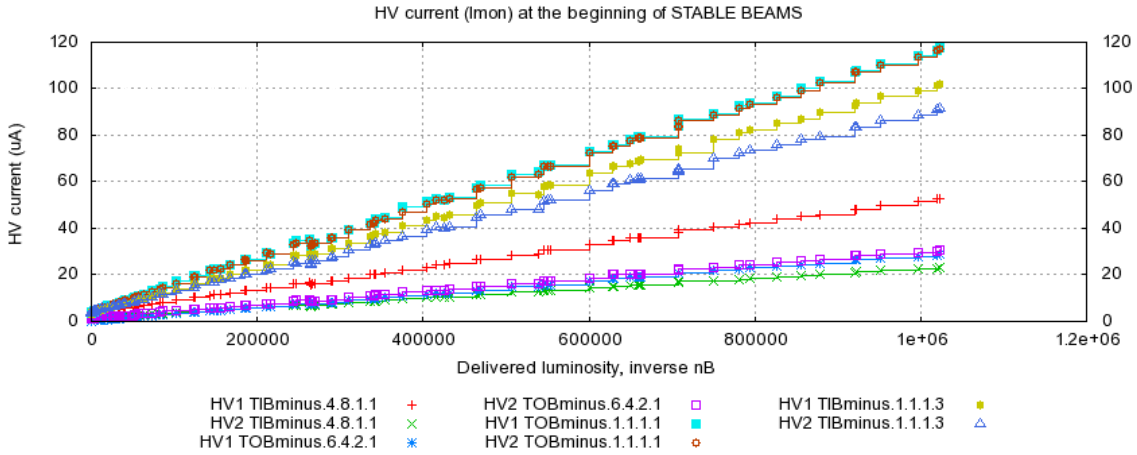
Data from PS

- WEB-based online tool
  - No dedicated measurement
  - Standard DB query
- Power supply I value, begin of each fill (10min)
  - Different layers – different ϕ
  - Different # of modules
  - Different T

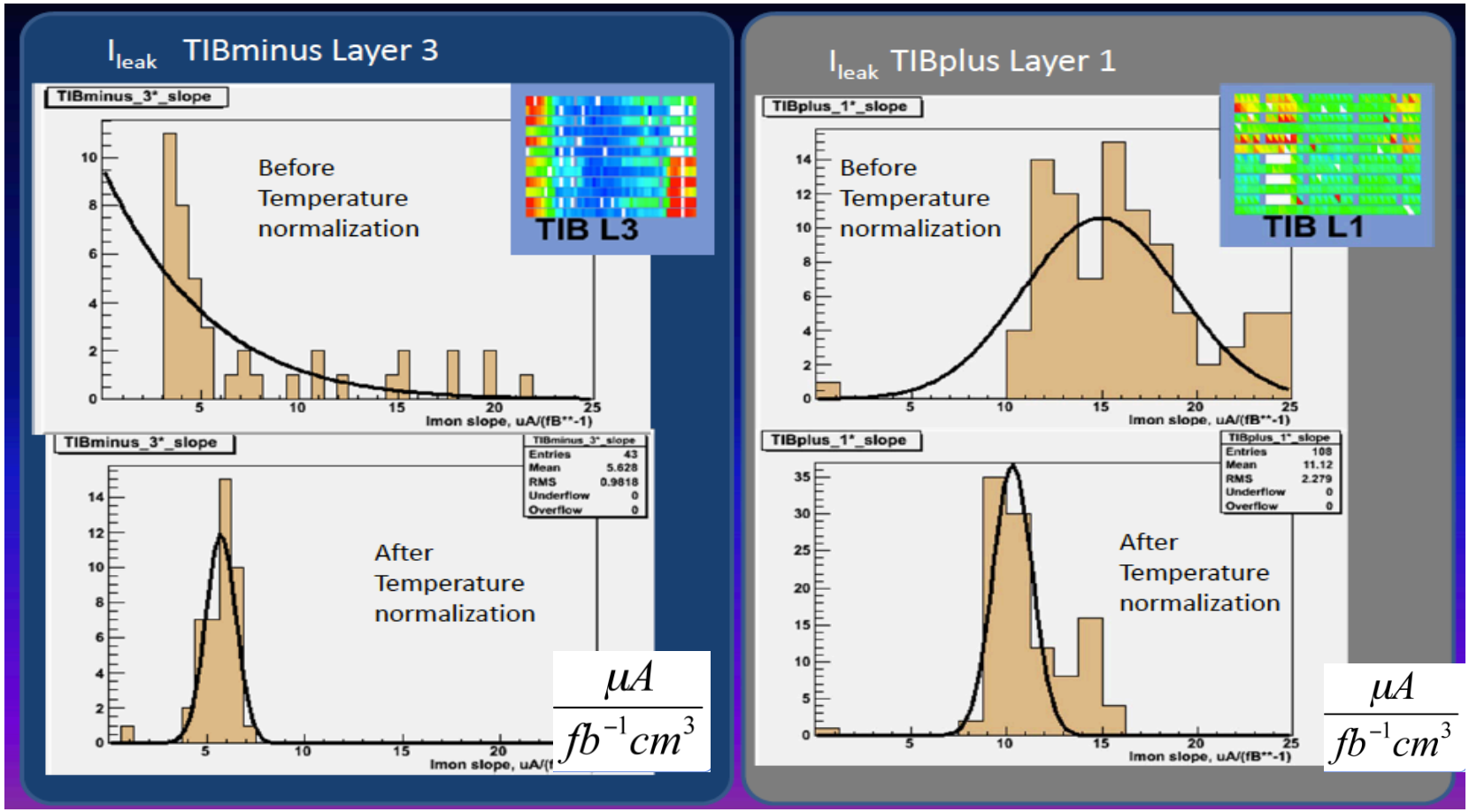
    ➔ different curves
- ➔ Offline analysis
  - Normalize volume & T
  - Normalize to slope [μA/1fb







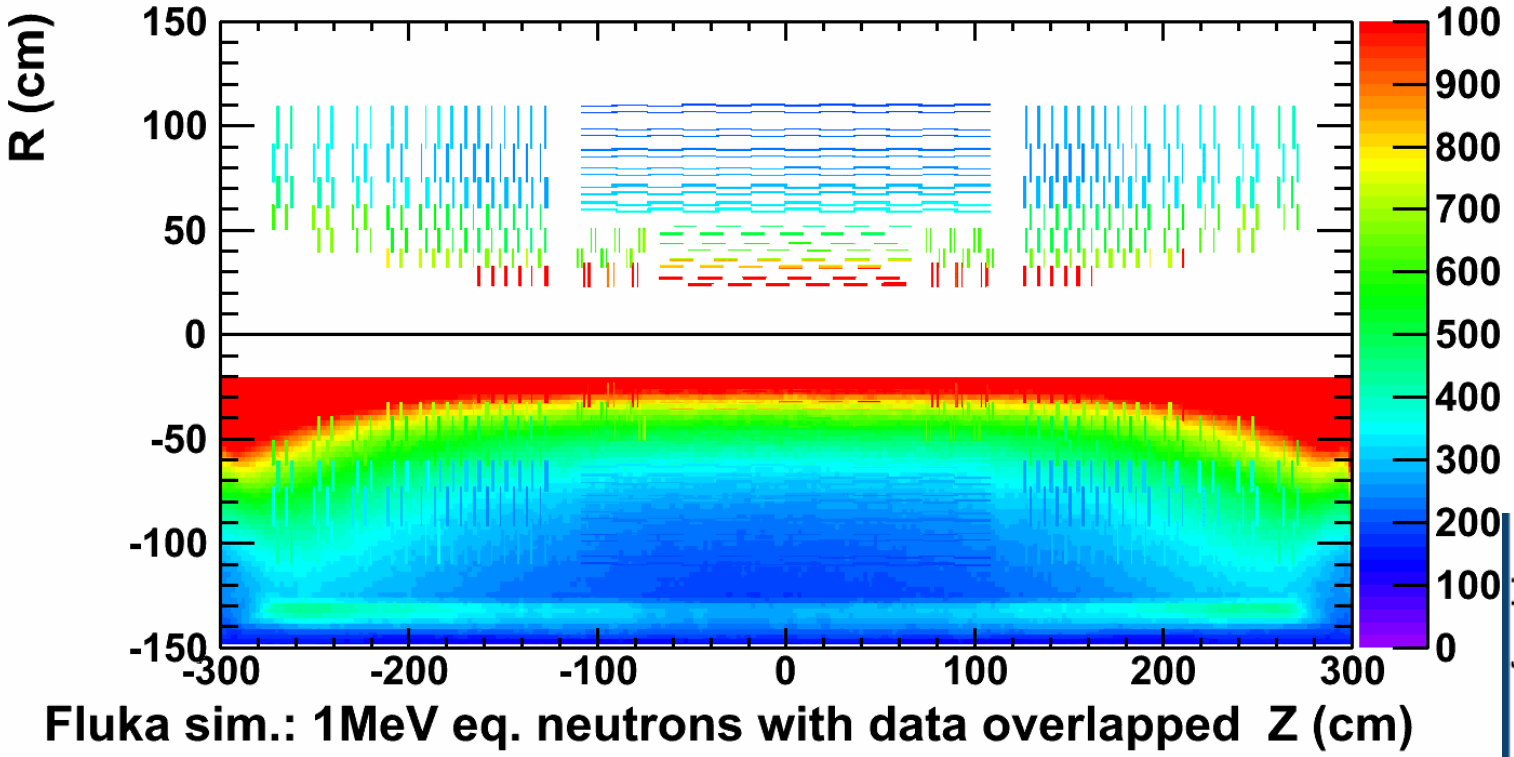
Temperature (and Volume) Normalization

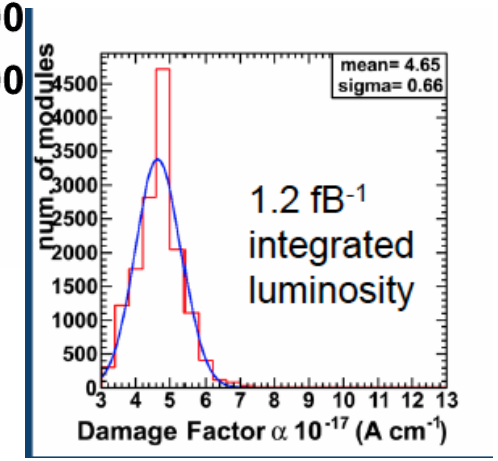


If measurements of T-sil are missing then Slope is not shown here. Some filtering on bad Measurements is done, but can be improved

Relative comparison with Simulation

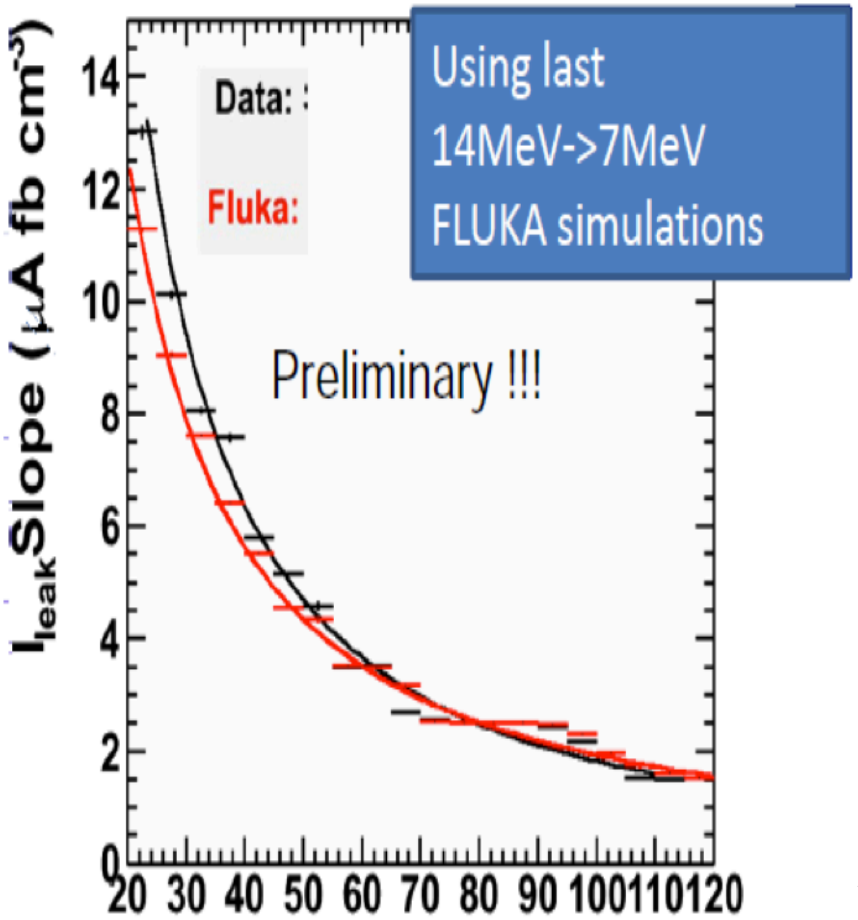
Arbitrary scale in Z

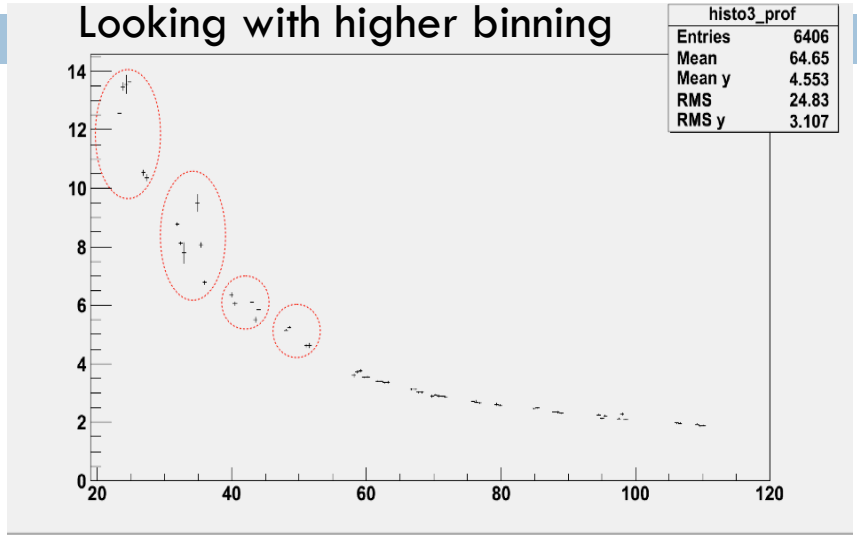




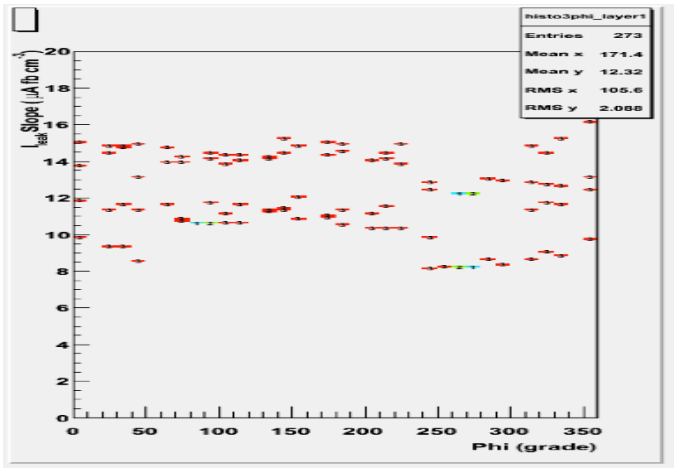
Measurements at 1.2 fb-1

Radial Dependency





Studying a Φ structure in L1 internal. Back-to-back Modules with different temp

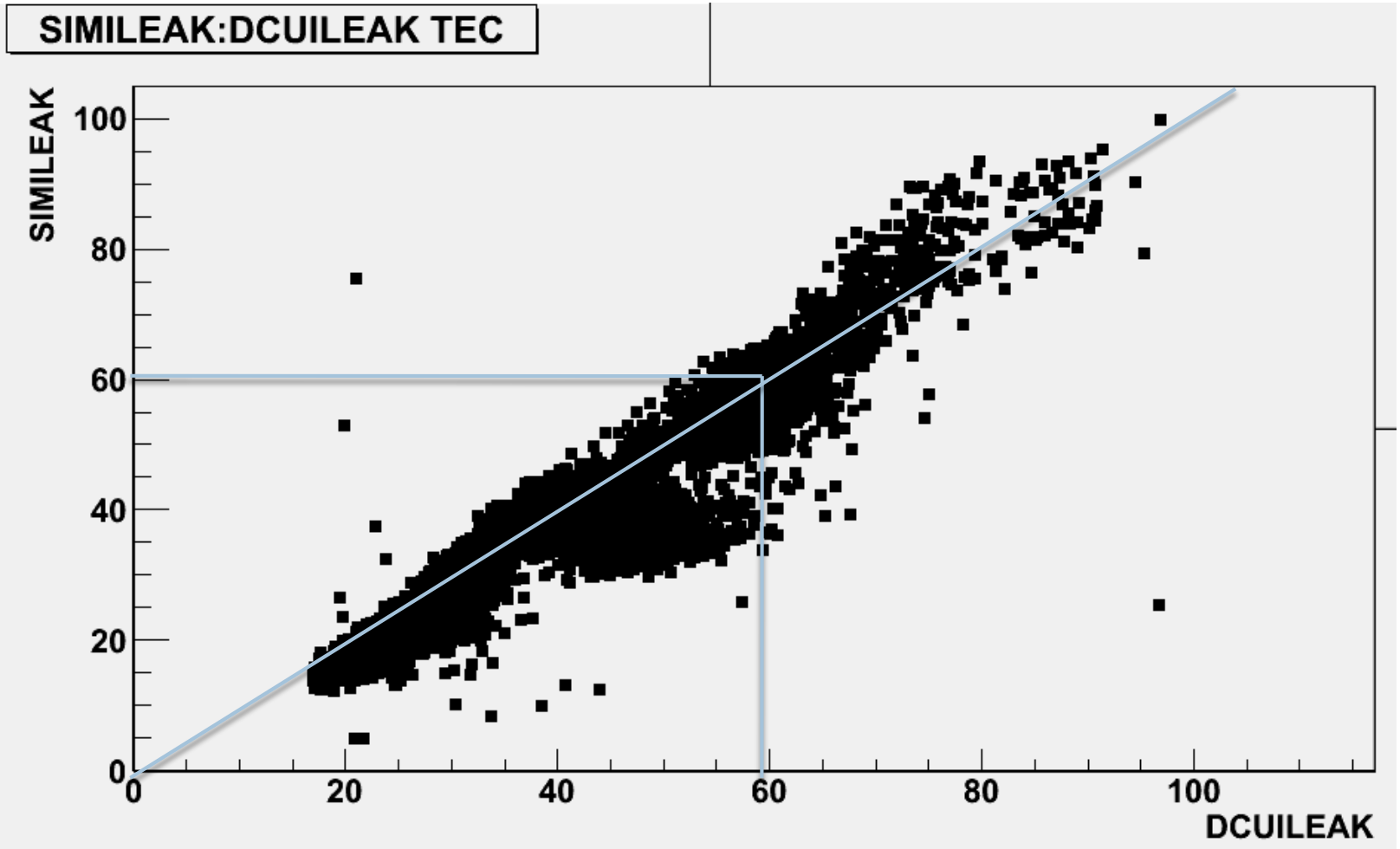


Detailed comparison Data - Simulation

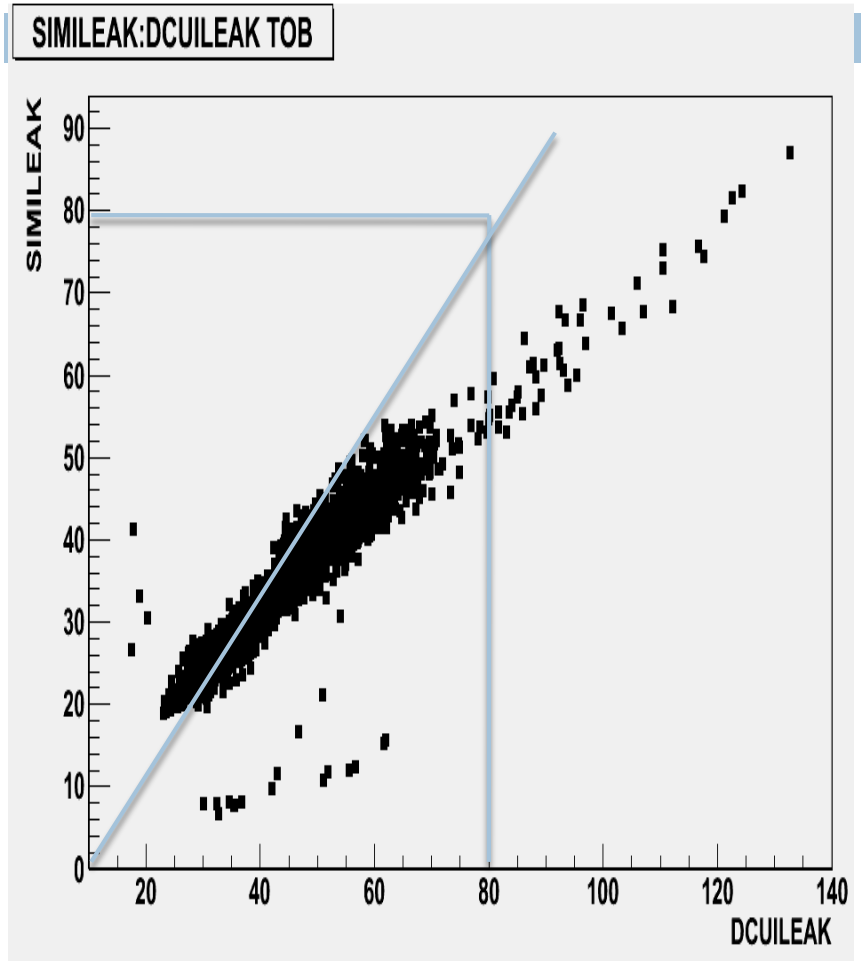
- Fluence taken from FLUKA
- Luminosity treated at per day level
  - Temperature are taken @ module level, using DCU
  - Temperature variations taken into account at per day level (Technical Stop, etc…)
- Comparison with Data using DCU leakage currents

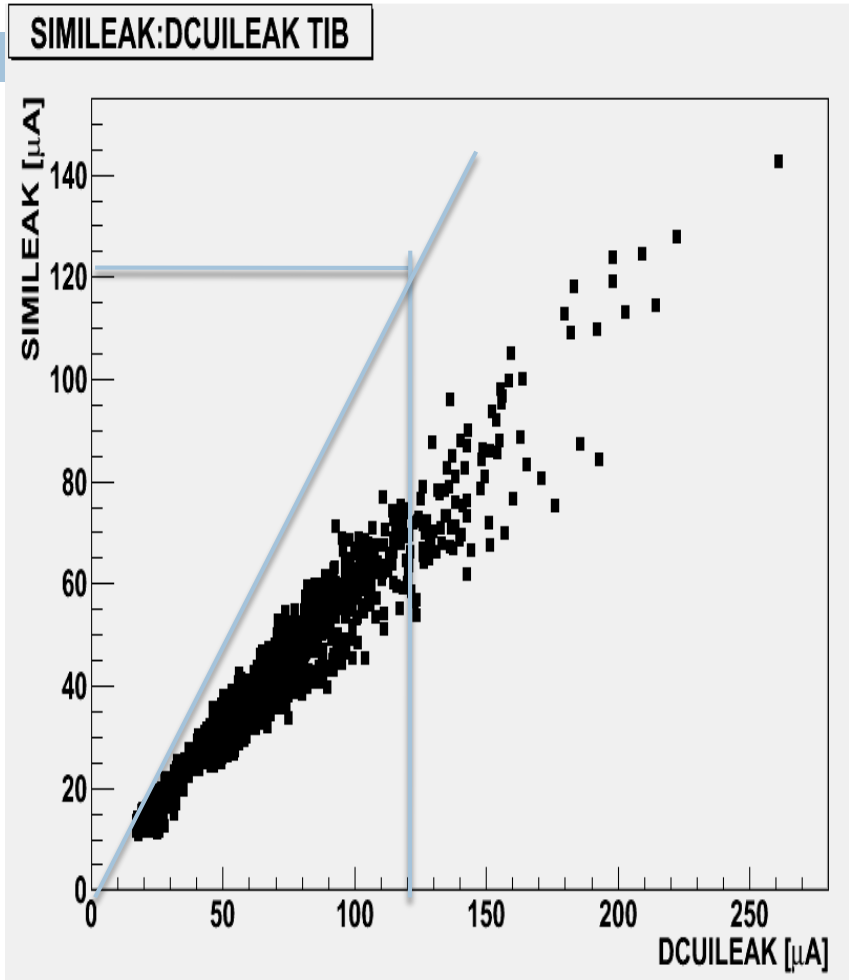
- In this study we are very dependent on DCU calibrations and of course on FLUKA simulation

Simulation vs Measurement @ modules level (uses DCU data) - TEC case



Inner and Outer Barrel



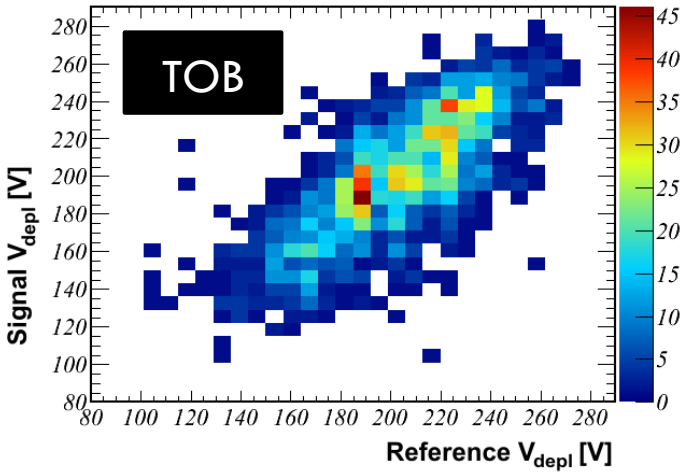


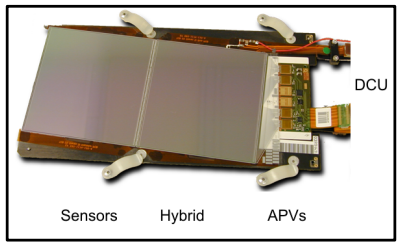
We suspect that the Temperature measurements is affected by non-linearity at the beginning of ADC range of the DCU (high temperatures with respect to measurements at lab

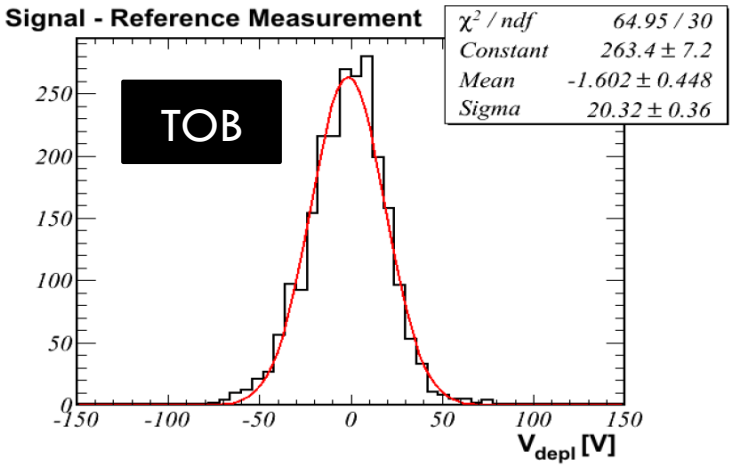
Depletion Voltage: measurements

- Signal vs Bias Voltage (HV scan)
  - Depletion voltage measurement
  - Done during collisions
- Noise vs Bias Voltage
  - Can be done during no beam activities
- **Up to 2 fb-1 no evidence of change… as expected**
  - New HV scan before HI physics

Signal vs. voltage (during STABLE BEAM)

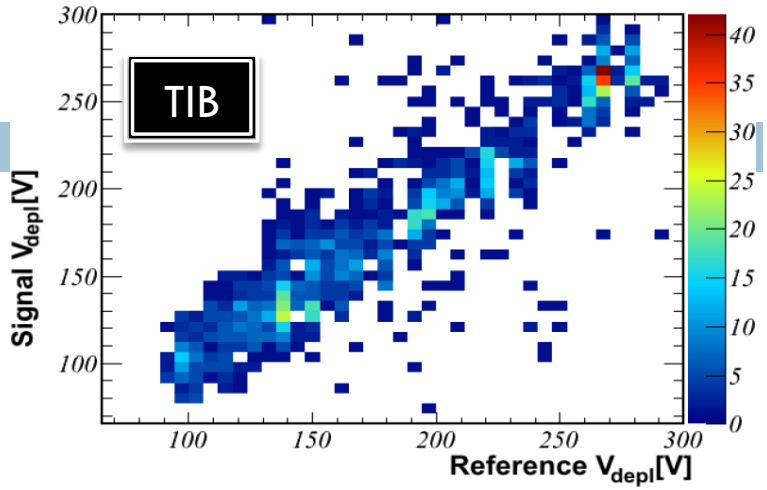


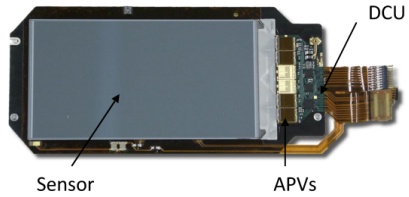


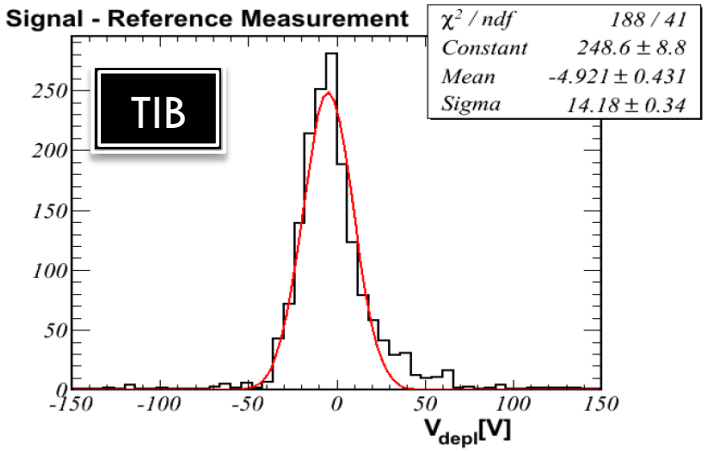


Very good agreement between the results from the signal scan and the reference measurements (especially in TIB partition with only one sensor per module)

➔ Anchor measurement for the future







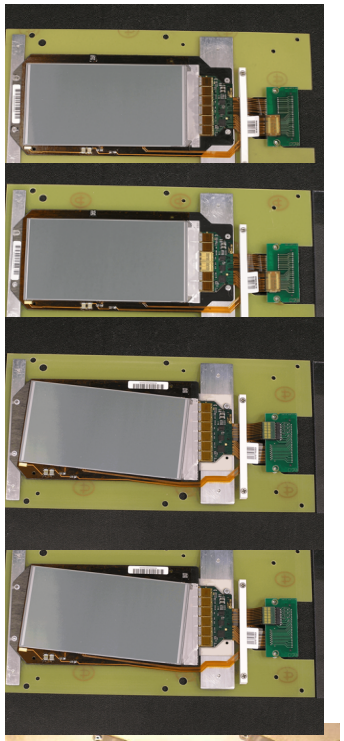
Within to the accuracy of the measurement "no" significant change in Vdep is visible so far (Feb11).

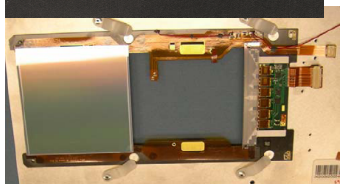
Summary and Conclusions

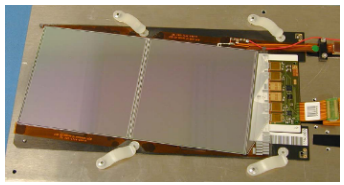
- Effects seen on Leakage current
  - Temperature variations across detector
  - Scaling for T-sil and Volume applied
  - Linear behaviour clearly seen (Ileak vs Luminosity)
  - Geometry dependence investigated
  - Firdt comparison with model done
  - Now moving to analysis per module
- Annealing studies to be done
  - Heavy Ion period will be a good period (stable conditions and little radiation
- Variation on Vdep not seen
  - New data has to be taken before the end of year

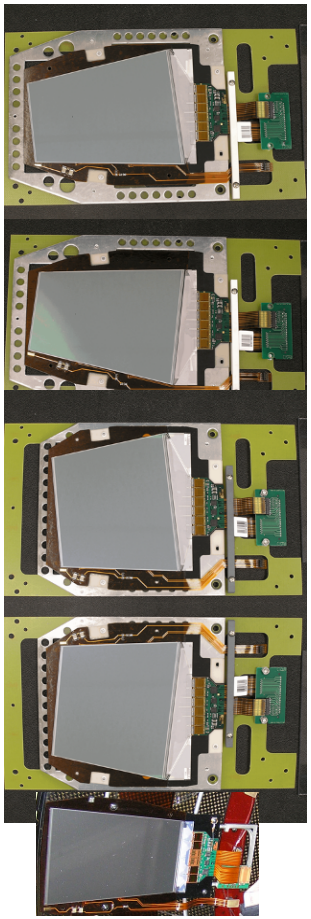
BCKUP SLIDES

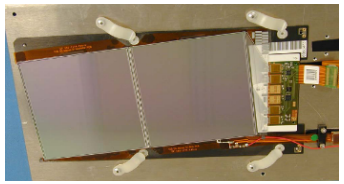
Several Different Module Geometries



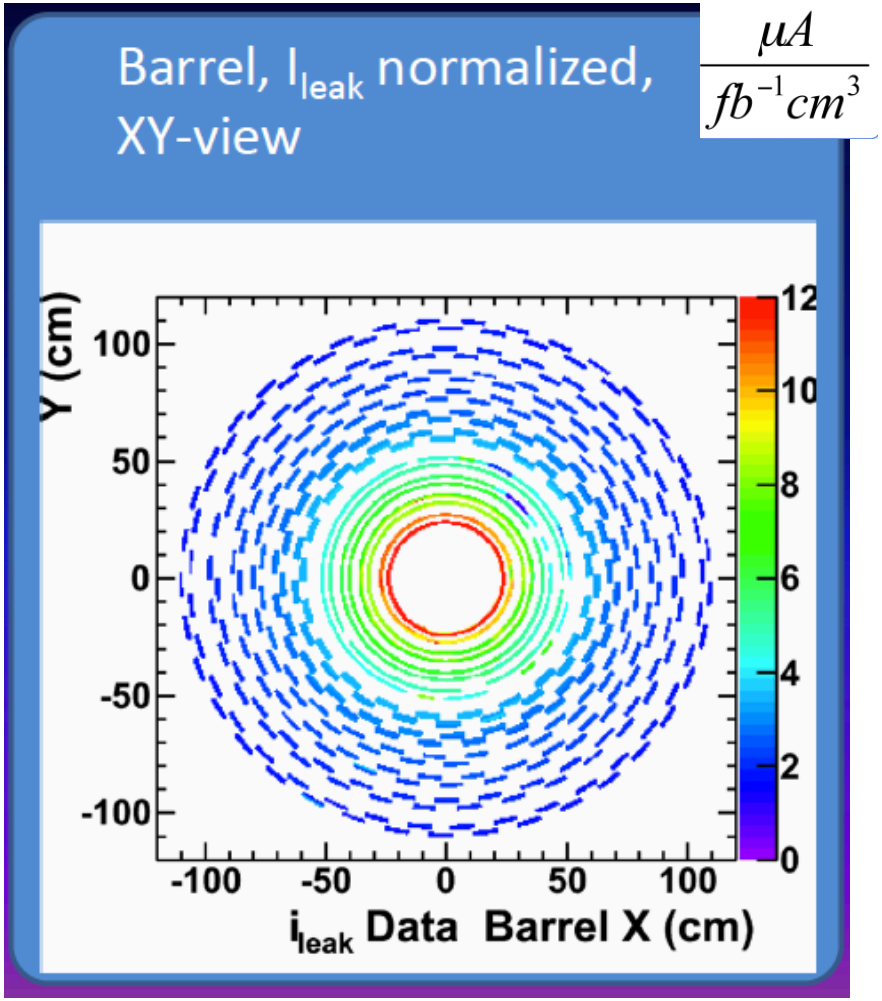


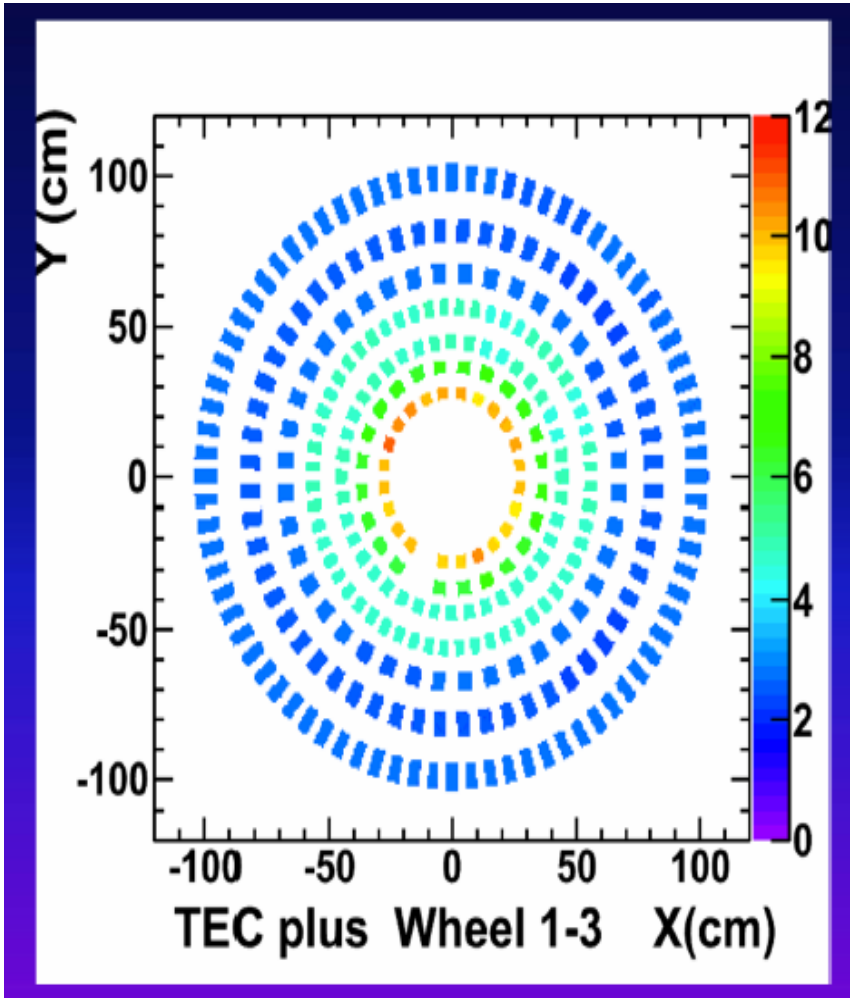




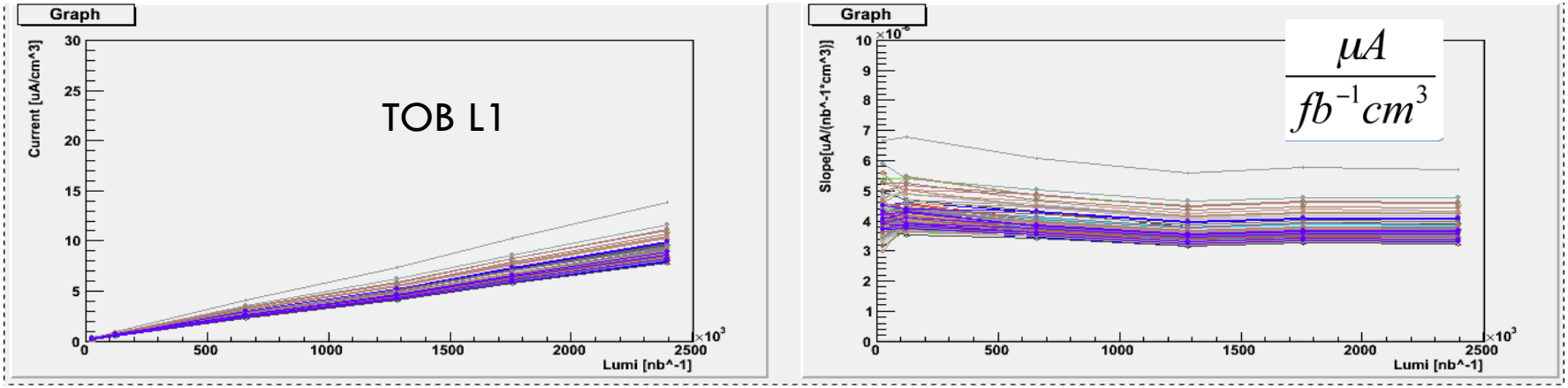


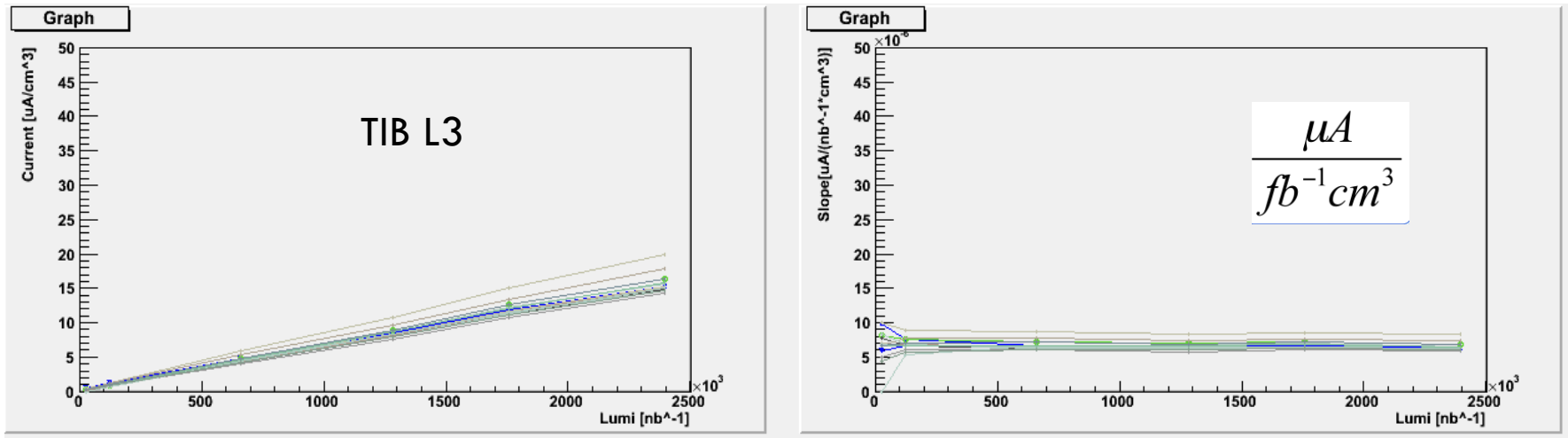
Geometry dependency of slope



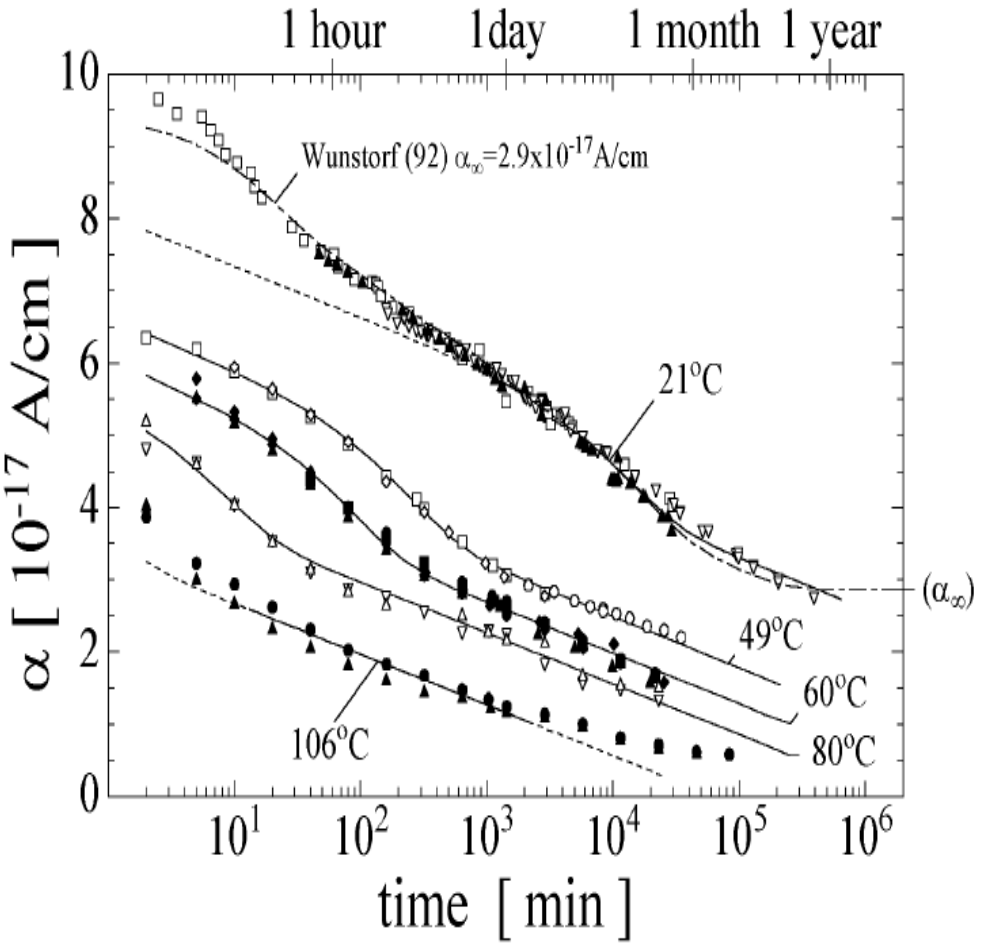


Time dependence





Annealing modeling



- CMS SST uses extensively the annealing model for a wide range of temperatures
- Damage at LHC is provided as sum of many little "pills" with a time evolution: they are summed as indipendent one / another

Formulas for Leakage Current

- Temperature Scaling

  $I(T_1)/I(T_2) = (T_1/T_2)^2 \exp(-1.21/2k_B\,(1/T_1 - 1/T_2))$

- Leakage Current Damage

  $\Delta I = \alpha\,\Phi\,V$

- Annealing taken into account:

  $\alpha = 1.23\text{e-}17\ A/cm \exp(-t/\tau_1)$
  $+ -8.9\text{e-}17\ A/cm + 4.6\ AK/cm\ e\text{-}14/T$
  $+ 3.07\text{e-}18\ A/cm \ln(t/t_0)$

and $1/\tau_1 = 1.2\text{e}13 \exp(-1.12/2k_BT)$

Formula for Depletion voltage

- Full depletion voltage:

$\Delta N_{eff} = N_A + N_C + N_Y$

with: $N_A = g_a \Phi \exp(-t/\tau_a)$

$N_C = 0.9 \ |N_{eff0}| \ * (1 - \exp(-10.9e\text{-}2/|N_{eff}| \ \Phi) + 1.77e\text{-}2 \ \Phi$

$N_Y = -g_Y \Phi (1 - 1/(1+t/\tau_Y))$

and $g_a = 1.54e\text{-}2$ 1/cm , $g_Y = 4.6e\text{-}2$ 1/cm

$\tau_a = 1/(2.3e13 \exp(-1.08/k_B T))$

$\tau_Y = 1/(1.5e15 \exp(-1.33/k_B T))$