CMS Tracker Optical Links Radiation Effects Measurement & Prediction

Jan Troska, Erik Butz

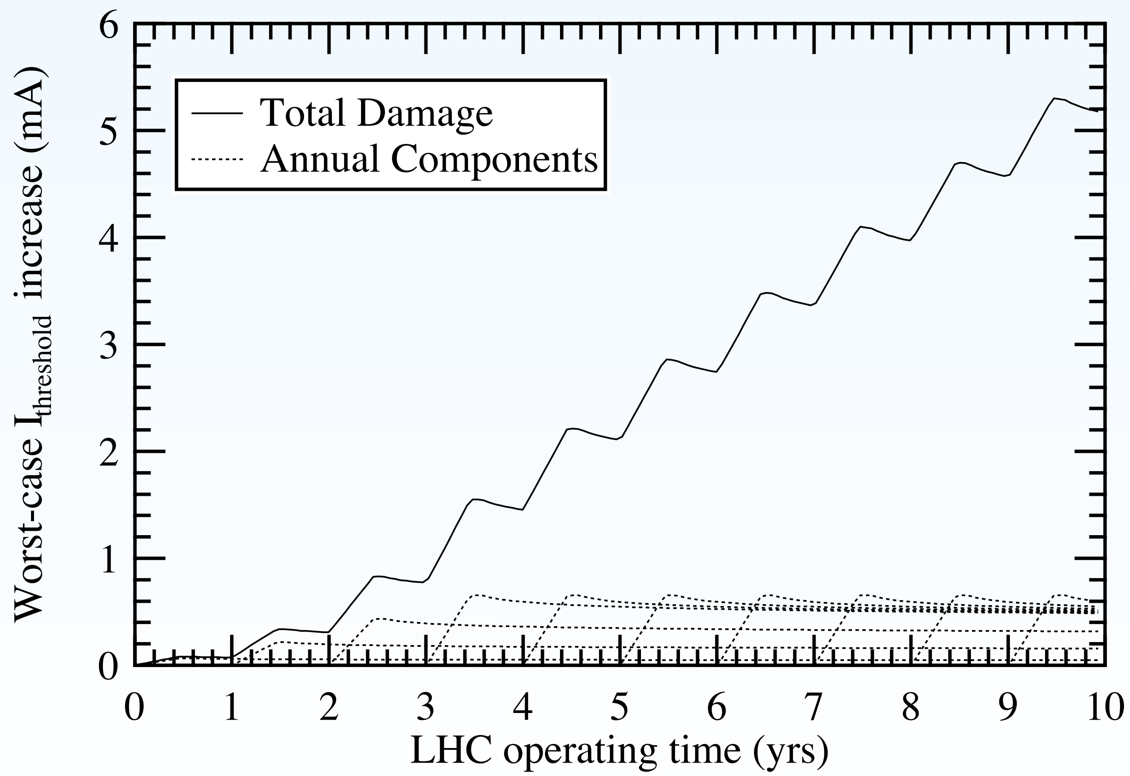
on behalf of the CMS Tracker group and EP-ESE

Background

- Radiation Qualification of optical links during development and production provided rich dataset to determine survivability of links during nominal 10 years of operation in the Tracker

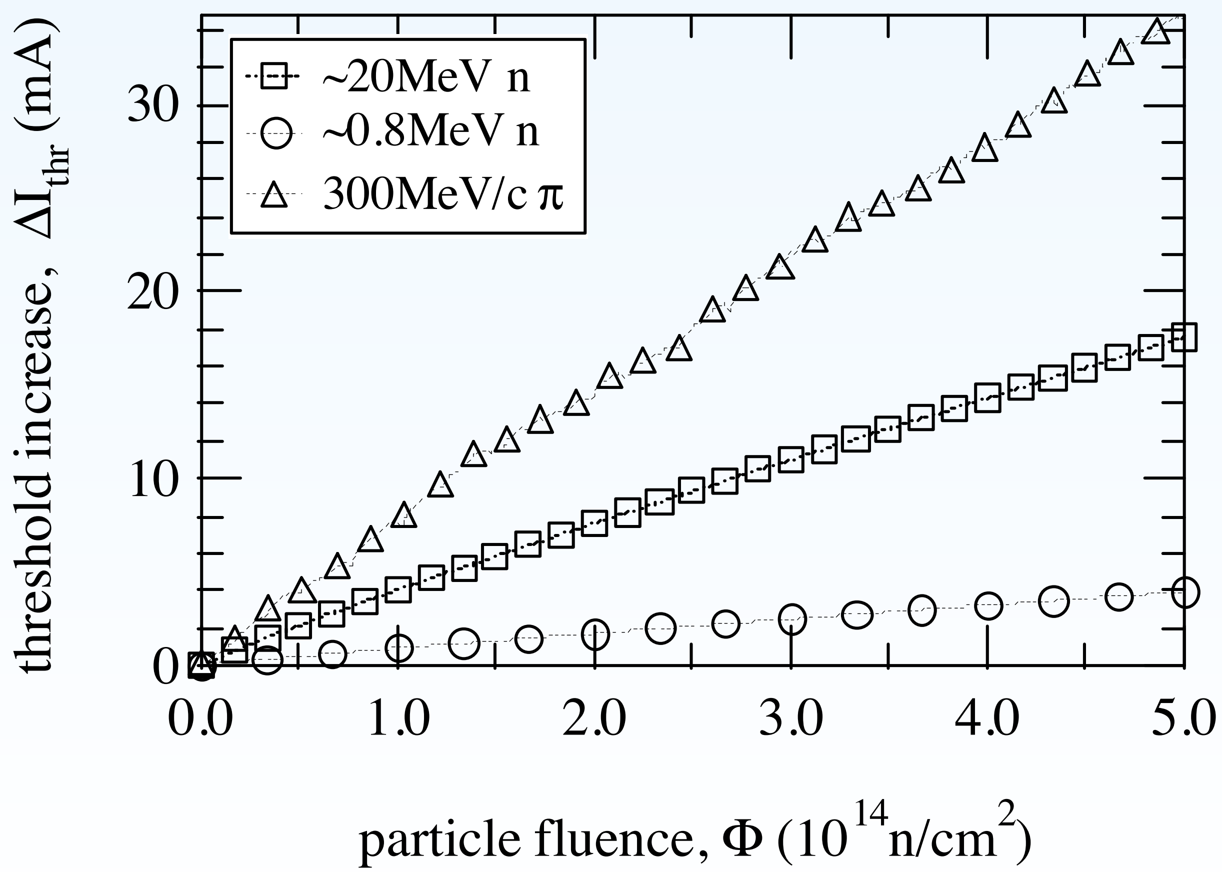
K. Gill, R. Grabit, J. Troska and F. Vasey, "Radiation hardness qualification of InGaAsP/InP 1310 nm lasers for the CMS Tracker optical links," *IEEE Transactions on Nuclear Science*, vol. 49, no. 6, pp. 2923-2929, Dec 2002.

- Predictive model used to extrapolate accelerated test data to 10 years of operation
  - Conclusion limits laser threshold increase to reasonable level



Details of damage prediction (2002)

- Radiation environment simulation for 500 fb-1 from Tk TDR (1998) produced Particle fluences split into:
  - Neutrons > 100 keV
  - Other fast hadrons
- Did radiation testing of laser diodes at different sources to determine relative damage factors of different particle species and energies:
  - Gammas : 0.8 MeV neutrons : <u>20 MeV neutrons</u> : 300 MeV pions
  - Relative damage factors are 0 : 0.12 : <u>0.53</u> : 1

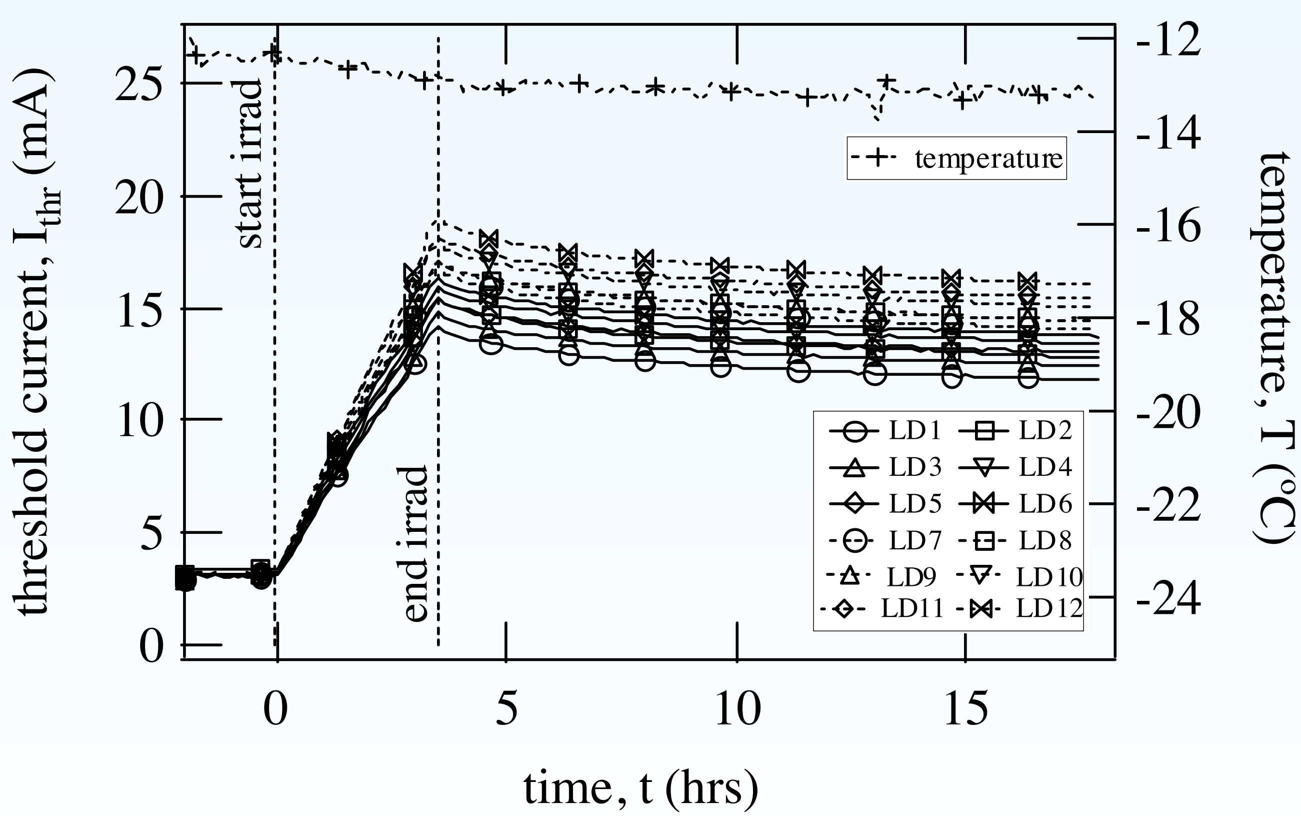


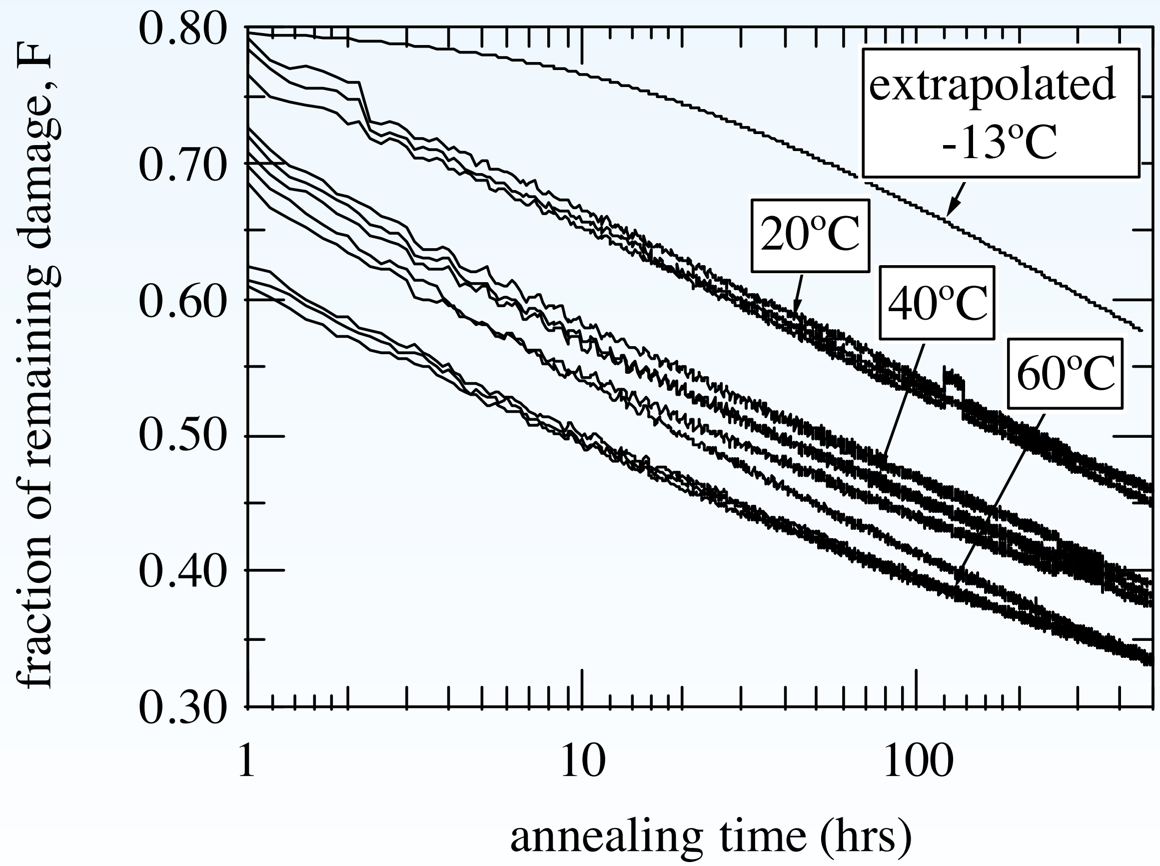
→ Define radiation qualification level (for 500 fb-1) at 20 MeV neutron source for laser diodes from Tracker TDR fluences as follows:

- (1x Neutrons > 100 keV + 2x Other fast hadrons) * 1.5 [safety factor]

Details of damage prediction (2002)

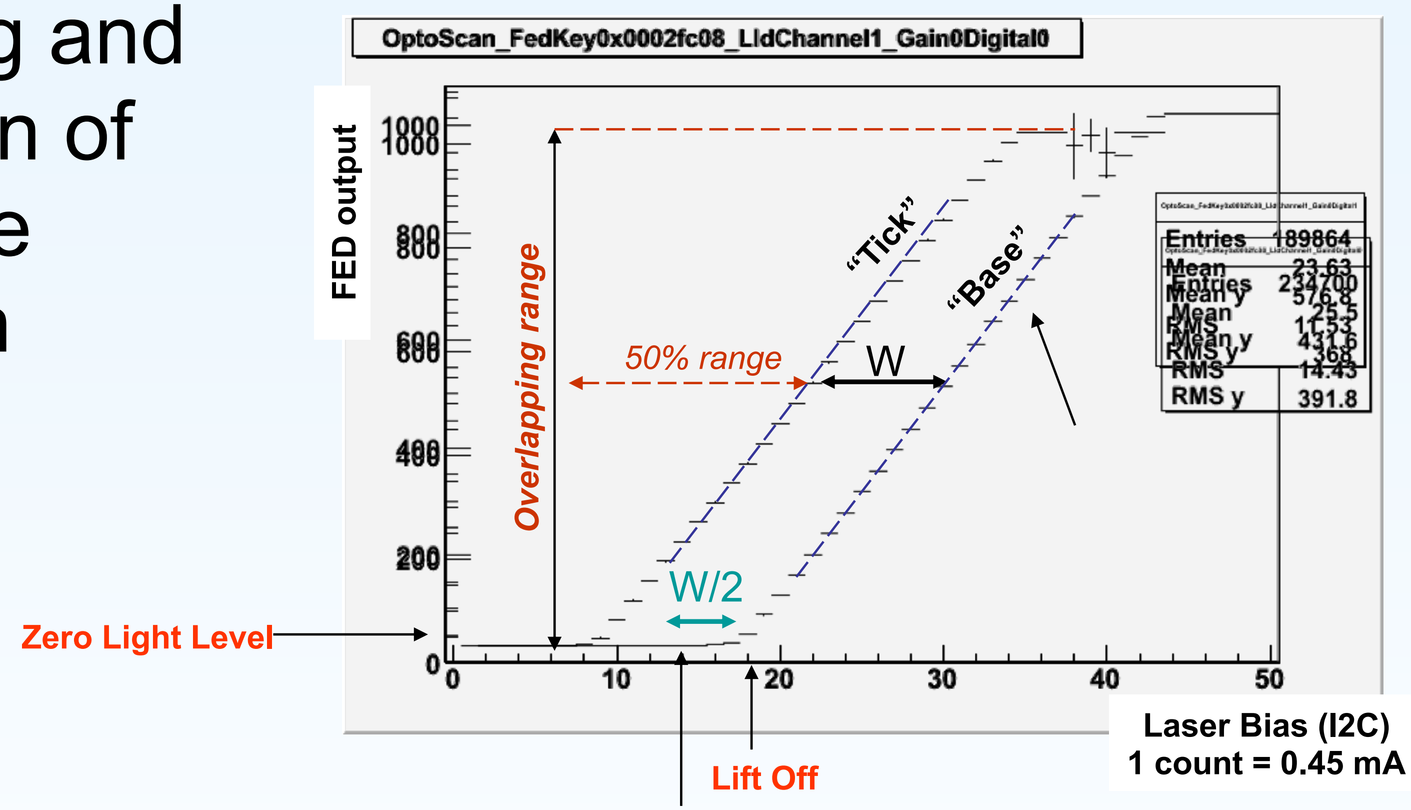
- Measured radiation damage (threshold increase) at neutron source to radiation qualification level + annealing at elevated temperature to confirm long-term annealing behaviour
- Use measured data for damage and annealing, scaled linearly to annual estimated lumi profile, to predict in-system laser threshold increase





Optical Link Gain Calibration

- “Optoscan” procedure is run periodically to set-up correct operating points for the *analogue* optical links in the tracker (2 or 3 links per detector module)
- Varying laser bias setting and gain allows determination of laser threshold and slope efficiency which are both expected to change with irradiation



Laser Current = (Laser Thr * 0.45) mA ⟵ **Laser Threshold** = Lift Off –W/2

Tick Mark hight = W * Base Slope

Measured Gain = Tick Mark * (1/0.8) * (1.024/1024)

Best Gain ~= 0.8

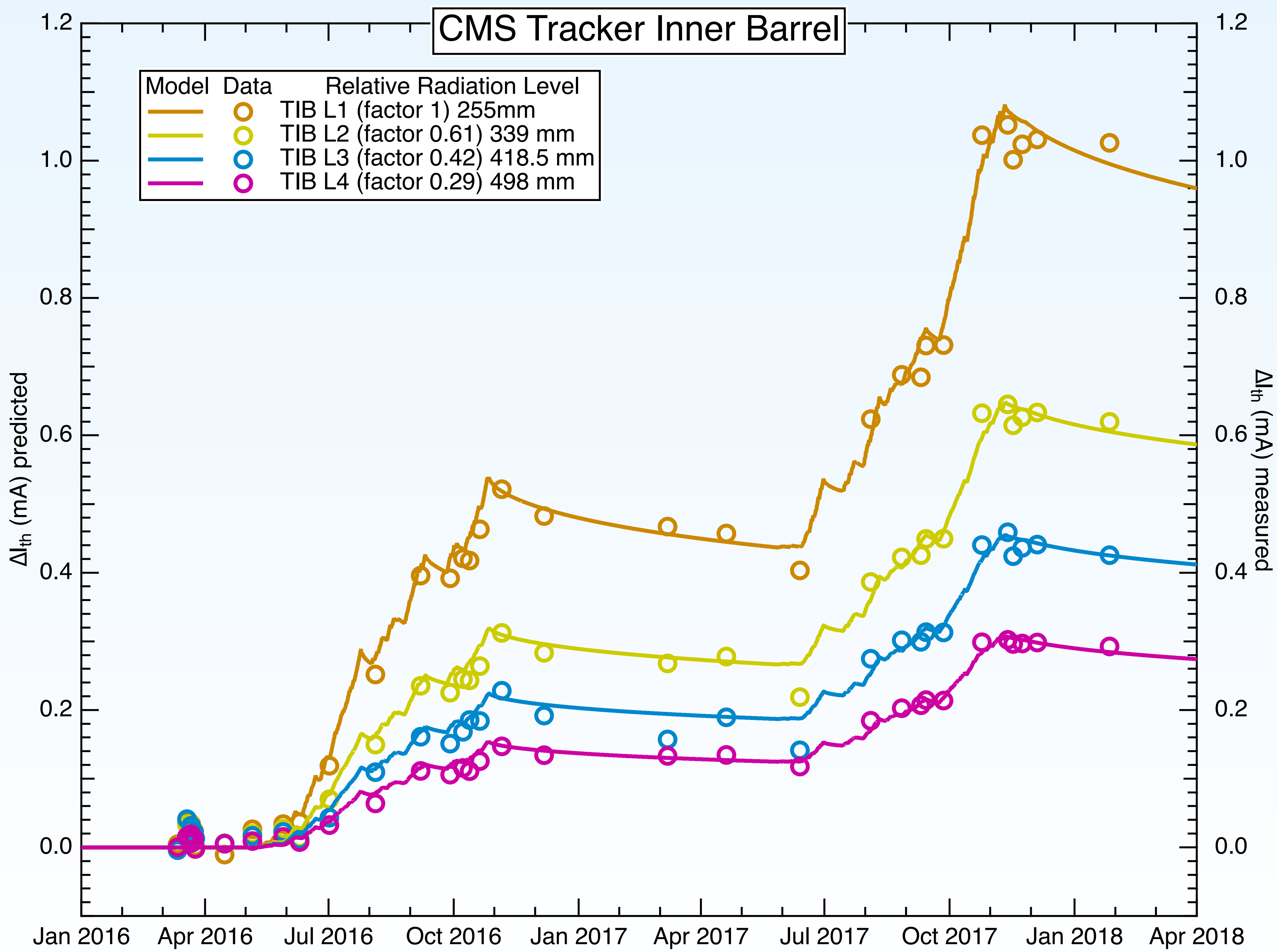
Bias setting = Lift off + 2

Comparison of Data to Prediction

- Take laser threshold measured in-system by averaging per-layer in Tracker Inner Barrel as a function of time
  - Highest level of damage yields most interesting data…
- Take CMS delivered lumi data from LPC website
- Split lumi data into 3.5 hr segments corresponding to original irradiation duration.
- Scale amplitude of measured threshold increase after qualification level fluence (500 fb-1) linearly to actual delivered lumi
- Sum irradiation steps with ongoing annealing based on measured annealing behaviour
- Adjust relative lumi scaling to “fit” fine-grain prediction to measured threshold increase.

Comparison of data vs model

- Model matches (remarkably) well with average observation
- Comparison with TDR radiation map is within original 1.5x safety factor



Conclusion

- Analogue optical links provide unique means to track radiation effects on the laser threshold and slope efficiency
- Assessing required level of safety factor is useful for future upgrades
  - We had lots of margin for radiation effects at Phase 0, whereas we are uncomfortably close to the ultimate limits at Phase 2
  - This is needed *now* to guide detector design choices
- Will continue monitoring as fluence accumulates