Radiation hardness of the ITkPixV1 chips

Maria Mironova (University of Oxford) for the RD53 collaboration

Motivation

- Study the ATLAS/CMS readout chip for the HL-LHC upgrades
- Understand impact of TID damage at the doses expected in the lifetime of HL-LHC (approximately 1 Grad)
- Deliver radiation in a controlled way using X-ray systems

X-ray irradiation setup

- X-ray setup at Oxford:
  - Comet MXR-160/22 tube
  - Tungsten target
  - Calibrated using cross-calibrated diode and Medipix detector
  - Beamspot 10 cm from source:

High dose rate

- Irradiation to 1 Grad at 4 Mrad/h
- Delay degradation:
  - 70% for strength 0 gates
  - 40% for strength 4 gates

Low dose rate effects

- In ITk the total dose will be delivered over a much longer period of time (i.e. lower dose rate)
- Damage to small transistors increases with lower dose rate and introduces non-linear behaviour at high total doses (see also Aleksandra’s talk)

Rates of relative increase in gate delay for different dose rates:

- Approximately factor 2 increase in damage for low dose rate
- Plateau for both low & high dose rates
- Effect less severe for strength 4 gates
- Strength 0 gates not used in chip design

ITkPixV1

- Latest prototype of ATLAS readout chip
- Designed by RD53 collaboration in 65 nm technology
  - Used in pre-production and close to final chip for ITk

Ring oscillators

- 42 ring oscillators in RD53B, made with different logic cells and different transistor sizes (strength 0 or 4)
- Oscillator drives a 12-bit counter, enabled for a given period of time
  - Calculate frequency f or delay \( T_D = 1/(N \cdot f) \)

Analog Front-End (AFE)

- Study impact of radiation damage on AFE
- Increase in threshold dispersion with irradiation, but threshold tuneable for most chip settings after 1 Grad

- Dispersion of tuned threshold distribution as measure of damage
- No significant difference in threshold dispersion for low and high dose rates

Conclusions

- Tested radiation tolerance of ITkPixV1 chips up to total doses of 1 Grad
- Ring oscillator measurement show delay degradation of up to 40% for strength 4 gates (corresponding to gates used in chip)
- Low dose rate increases damage by approximately a factor of 2
- AFE of ITkPixV1 experiences no significant issues up to total doses of 1 Grad & no dose rate effect on AFE