ATLAS Phase-II Strip Tracker Upgrade

ABC130 ASIC Total Ionizing Dose Testing

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Outline

- Insufficiency of current inner detector in HL environment
- ATLAS phase-II semiconductor tracker upgrade
- **T**otal **I**onizing **D**ose (TID) effects of radiation
- Testing details & results

Current ID

Insertable b-layer - IBL (added in long shutdown 1):

- supporting high resolution pixel detector, b-jet tagging

Pixel detector:

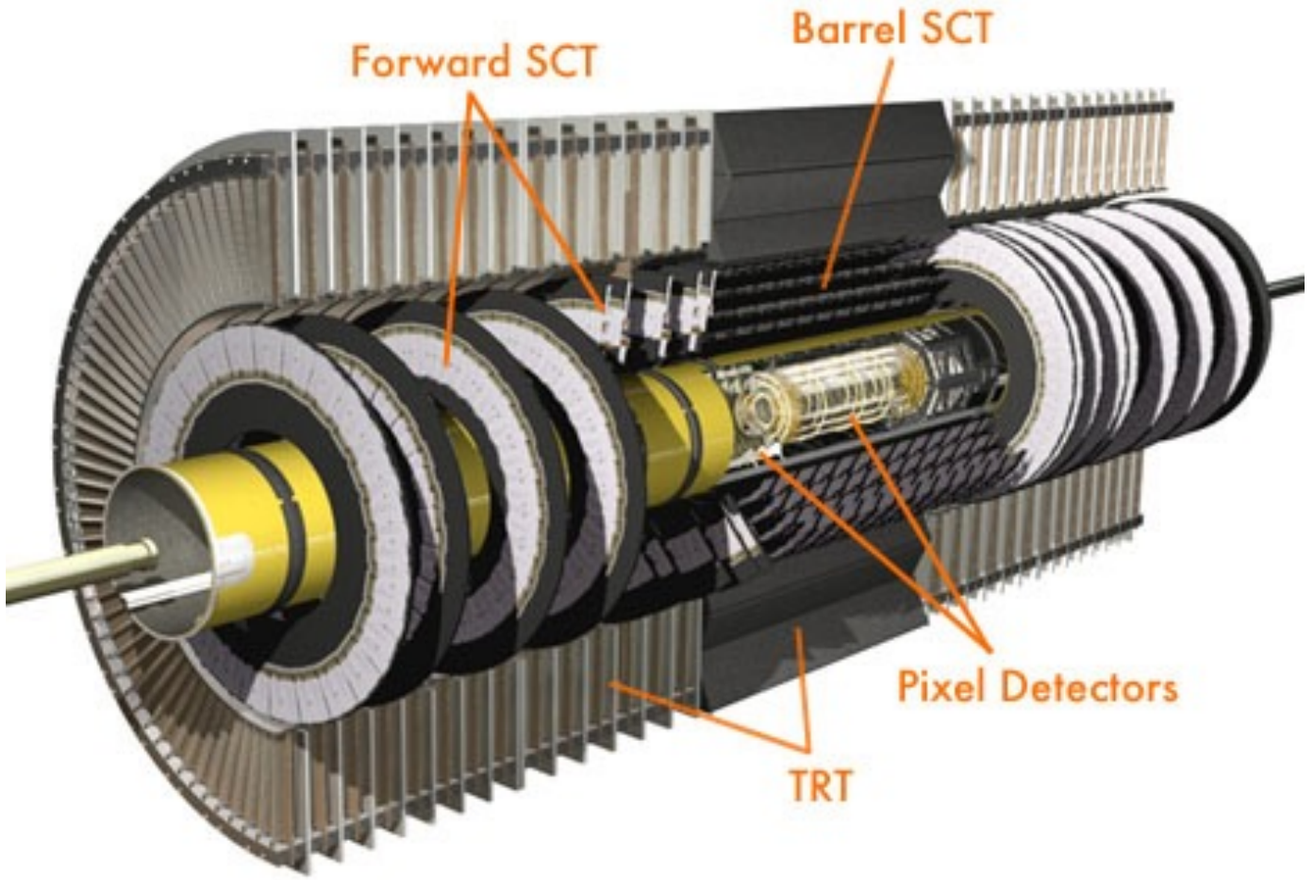
- high resolution vertex reconstruction and impact parameter measurements
- r=5-9 cm, 80 million pixels

Semiconductor tracker - SCT:

- momentum measurement
- r=30 -52 cm + end caps

Transition radiation tracker - TRT:

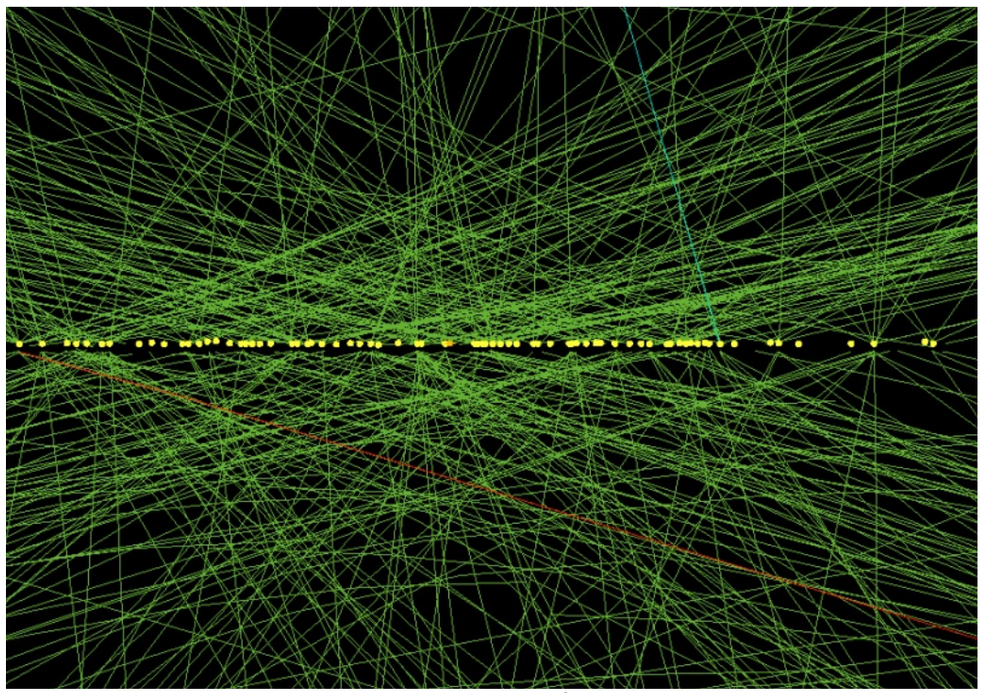
- particle tracking & electron identification
- straw tubes cover r=56-107 cm + end caps



Failure at High Luminosity

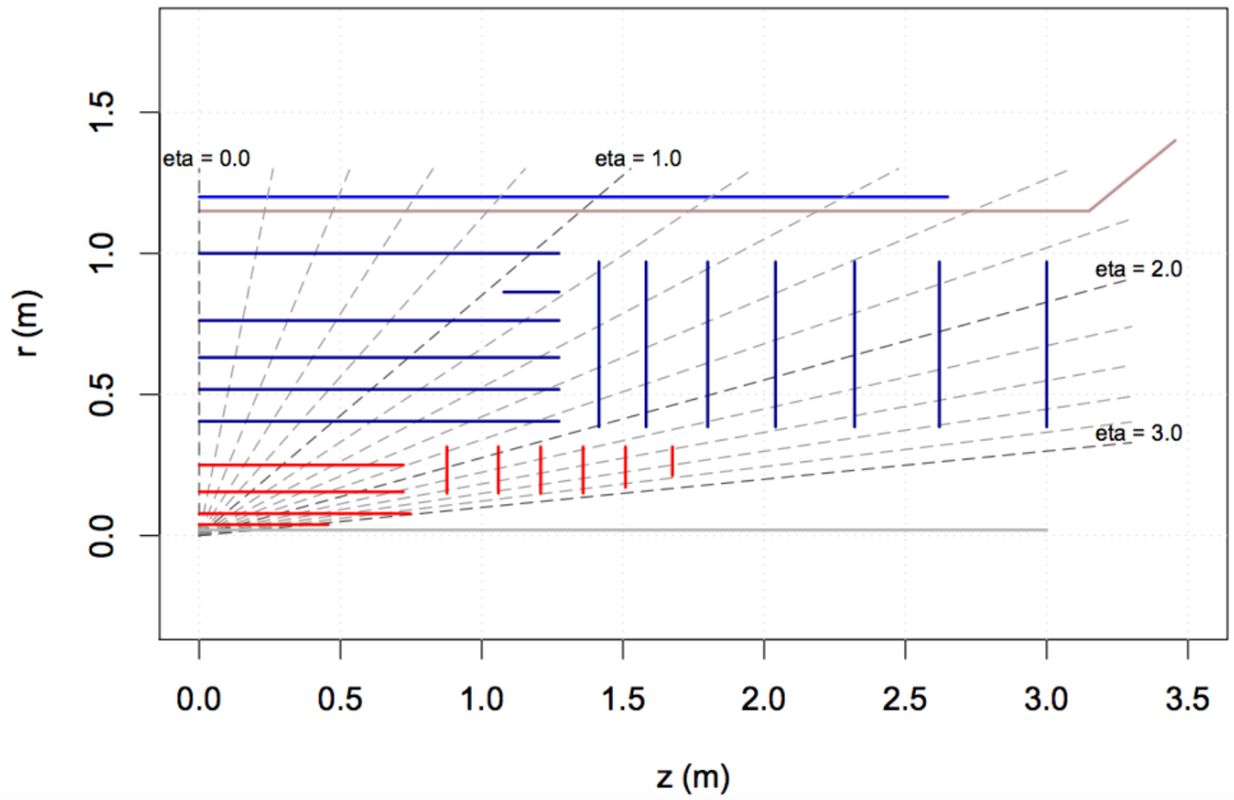
- 3000 fb^{-1} of integrated luminosity over 10 years to be accumulated at HL-LHC is 10 times what the current ID was built to endure
- luminosity of $\mathcal{L} = 5 \times 10^{34} cm^{-2} s^{-1}$ result in nearly 100% occupancy of TRT straw tubes and will surpass the capability of the SCT (Si strips) to resolve nearby particles
- higher granularity and more silicon strip detectors are needed to resolve pileup of ~140 vertices per event

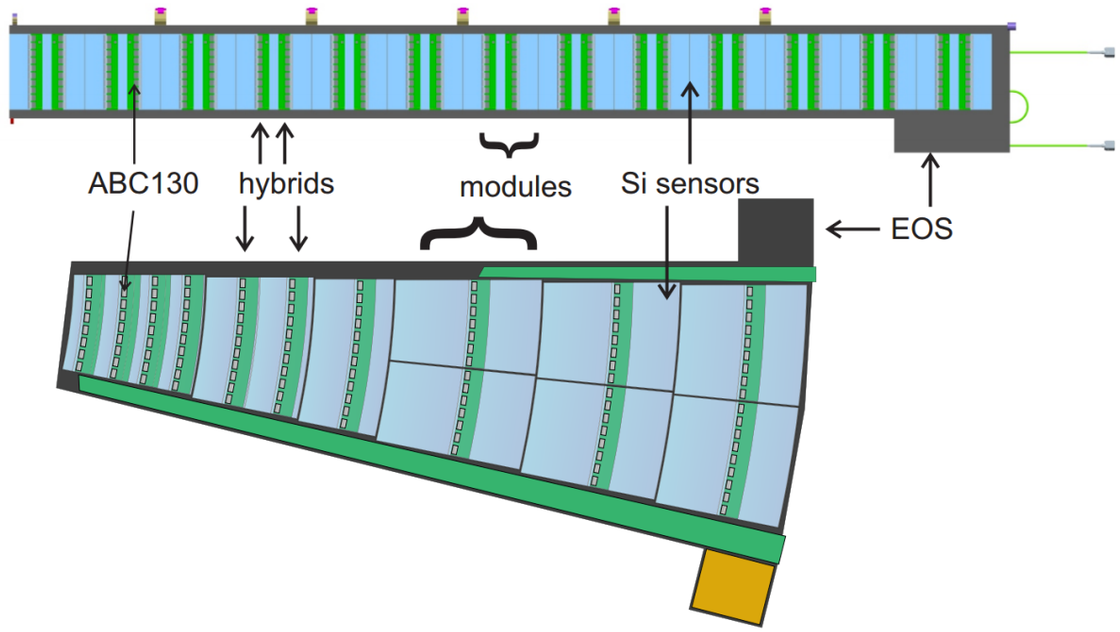
Conclusion: high performance requirements for the HL-LHC cannot be met by current ID



Phase-II ID Upgrade

- TRT replaced with silicon strip sensors
- replacement of SCT and pixel detector with higher resolution, higher bandwidth, radiation hard electronics





★barrel→stave→module→chips & strips

TID Effects of Radiation

- **T**otal **I**onizing **D**ose: effects & damage caused by total amount of ionizing energy deposited in the material of the device (contrary to **S**ingle **E**vent **E**ffects)

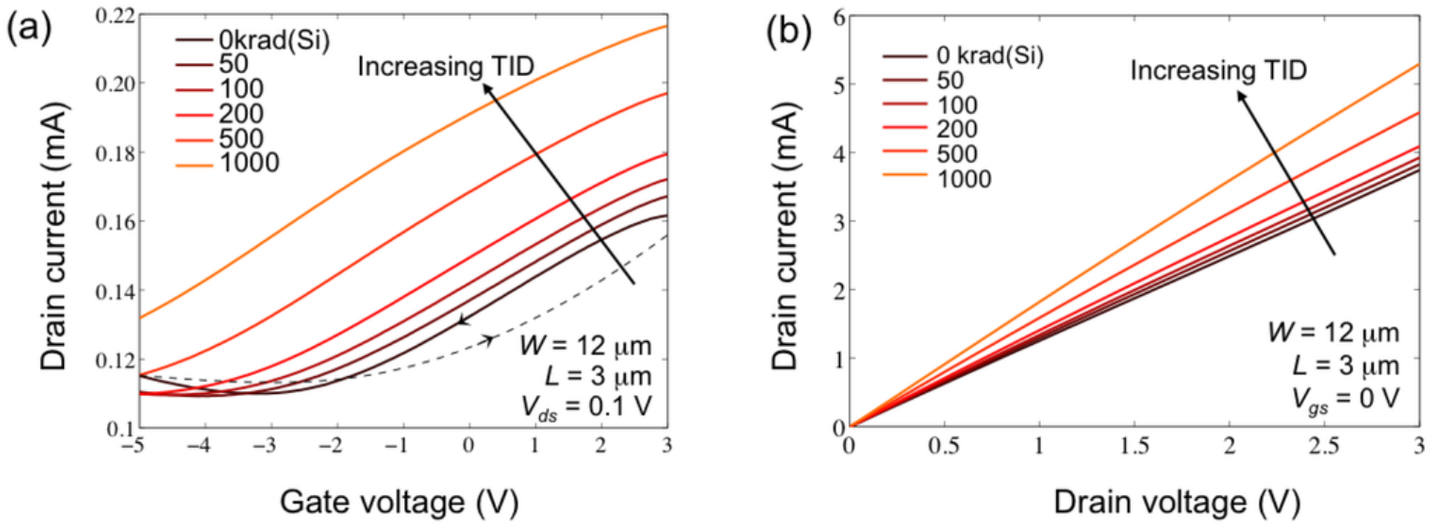
causes buildup of charge in material:

  - SiO_2 electron hole pairs do not recombine quickly, in an E field electron & hole drift
  - electrons are more mobile and dissipate, holes get trapped at defect centres and at Si-SiO_2 interface

- buildup of charge changes operating characteristics, causes leakage current and changes threshold voltage of transistors

★expect leakage current from the chip's digital & analog architecture to increase with dose

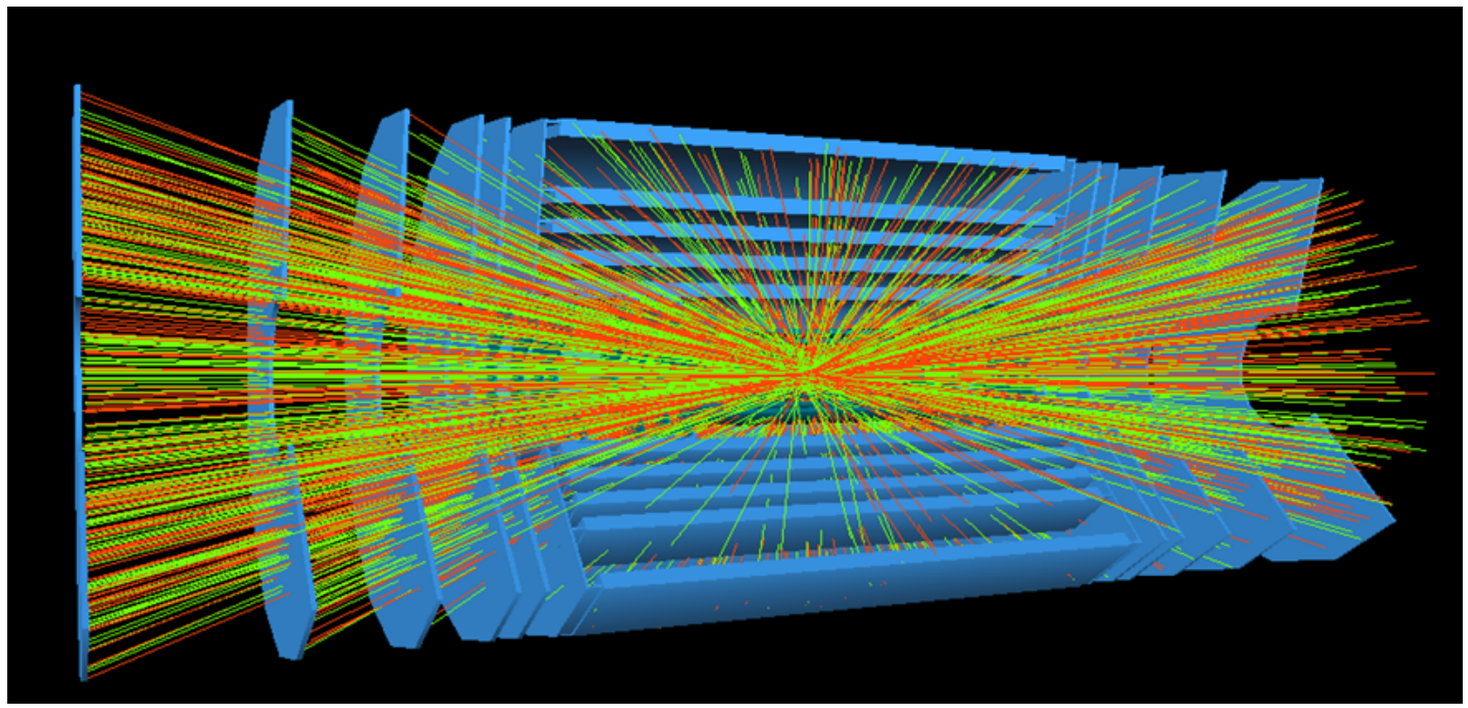
ex:



http://lhcb-elec.web.cern.ch/lhcb-elec/papers/radiation_tutorial.pdf

Radiation Tolerance

- increased current to ABC130s across entire detector can cause cooling and power supply issues
- must have a consistent threshold voltage across channels for reliable strip readout and accurate measurements
- expect ~30 Mrad = 300 kGy = 300 J/g over lifetime of ABC130 use in SCT

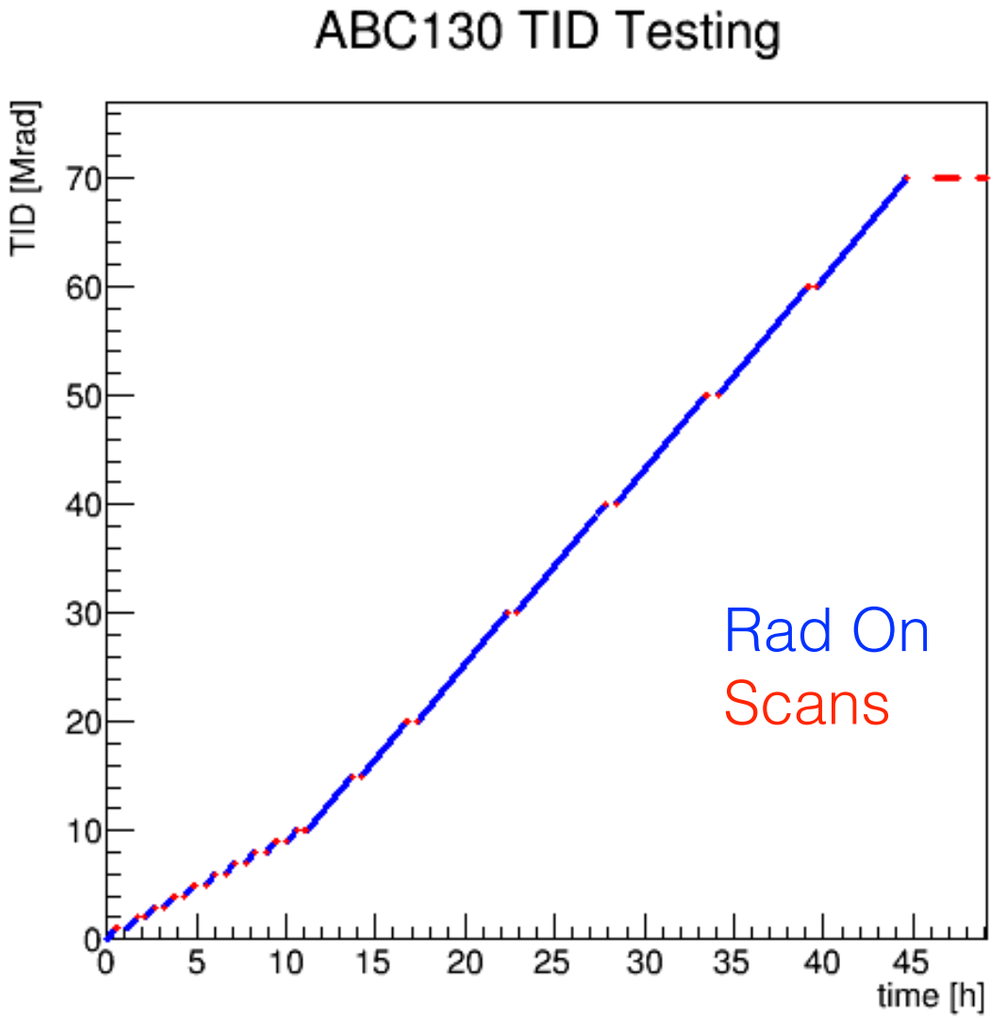


TID Procedure (1)

- constant dose rate 2 Mrad/h
- room temperature (cooling system was not available)
- exercised chip during irradiation
- 30 minute pause for scans each step
- measured I&V from power supply and V across chip throughout entire procedure

TID Delivery Scheme

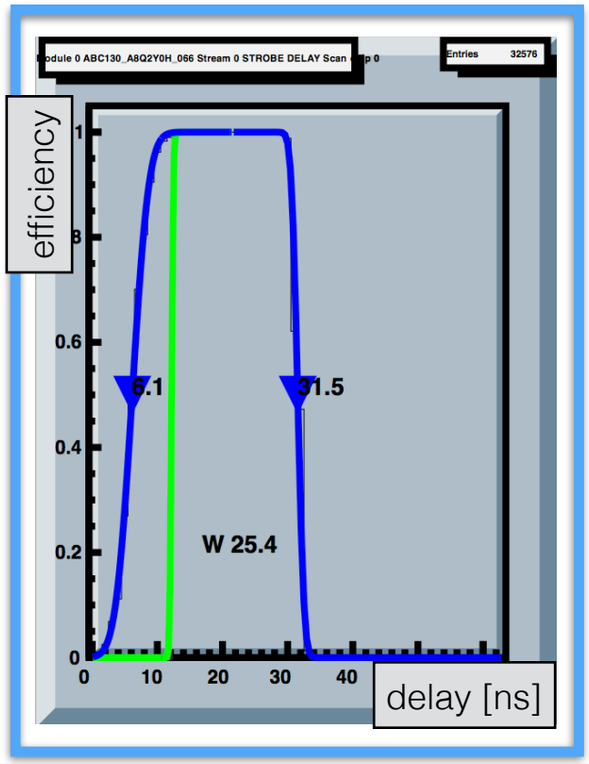
Dose Range [Mrad]	**Dose Step [Mrad]**
0-10	1
10-20	5
20-70	10

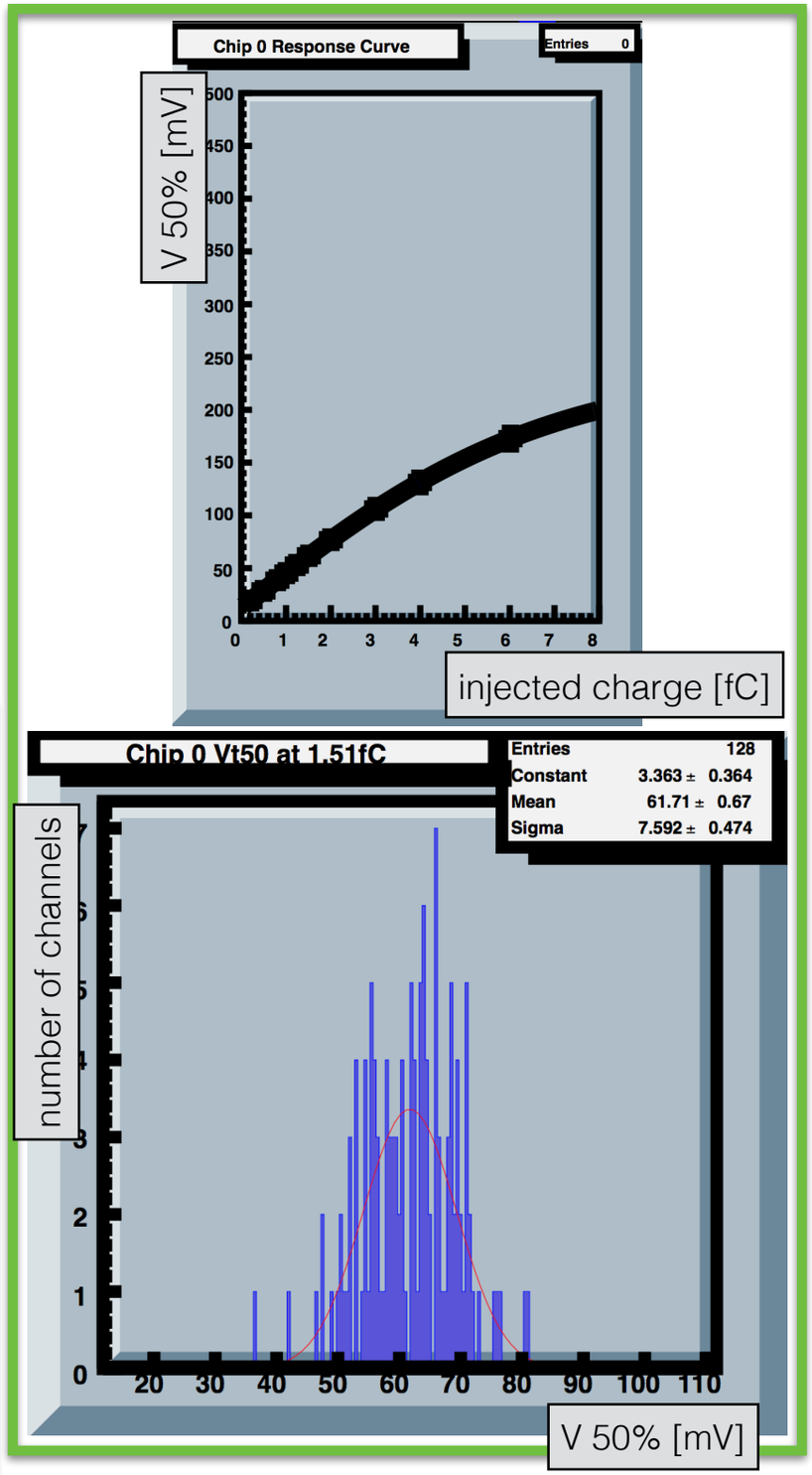


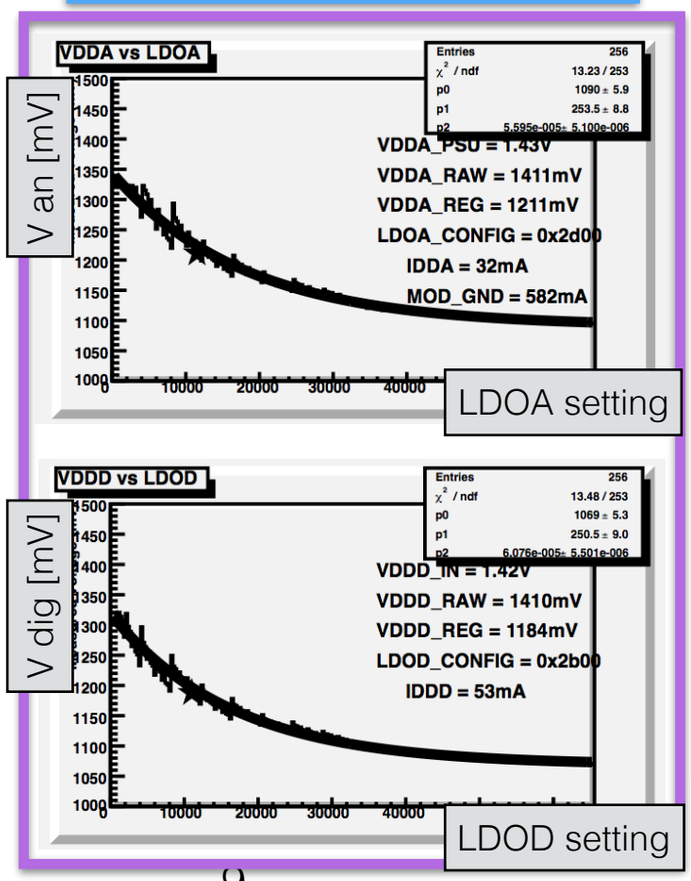
TID Procedure (2)

scans performed at each step:

- strobe delay: calibrates delay time between test charge injection and channel readout
- response curve: measures 50% threshold voltage over injected charge, gain (mV/fC) for each channel, voltage offset V(0 fC)
- scan ADC's: sets analog to digital converters to match nominal operating voltages



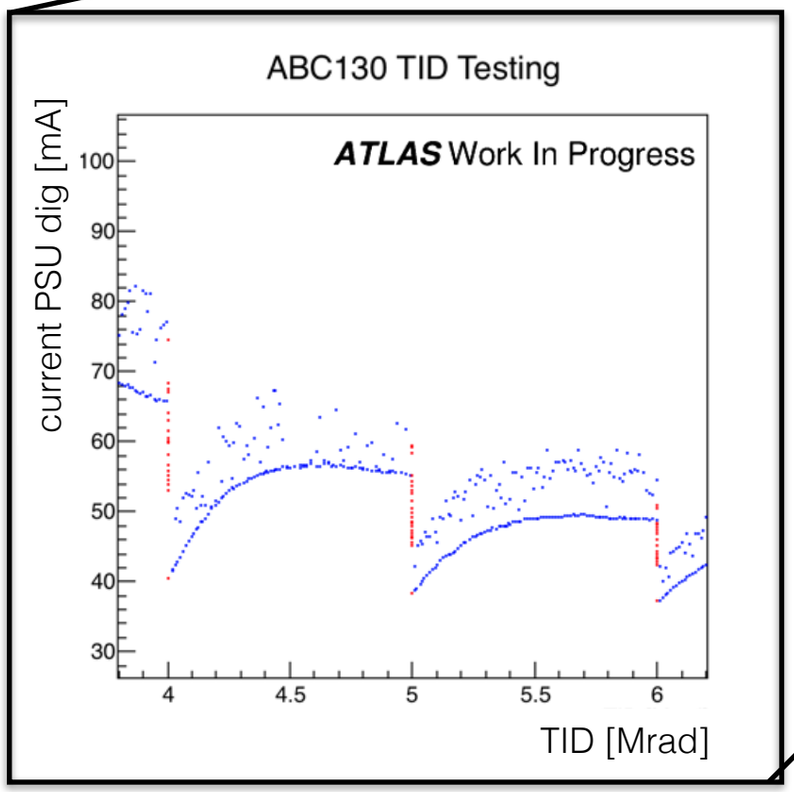


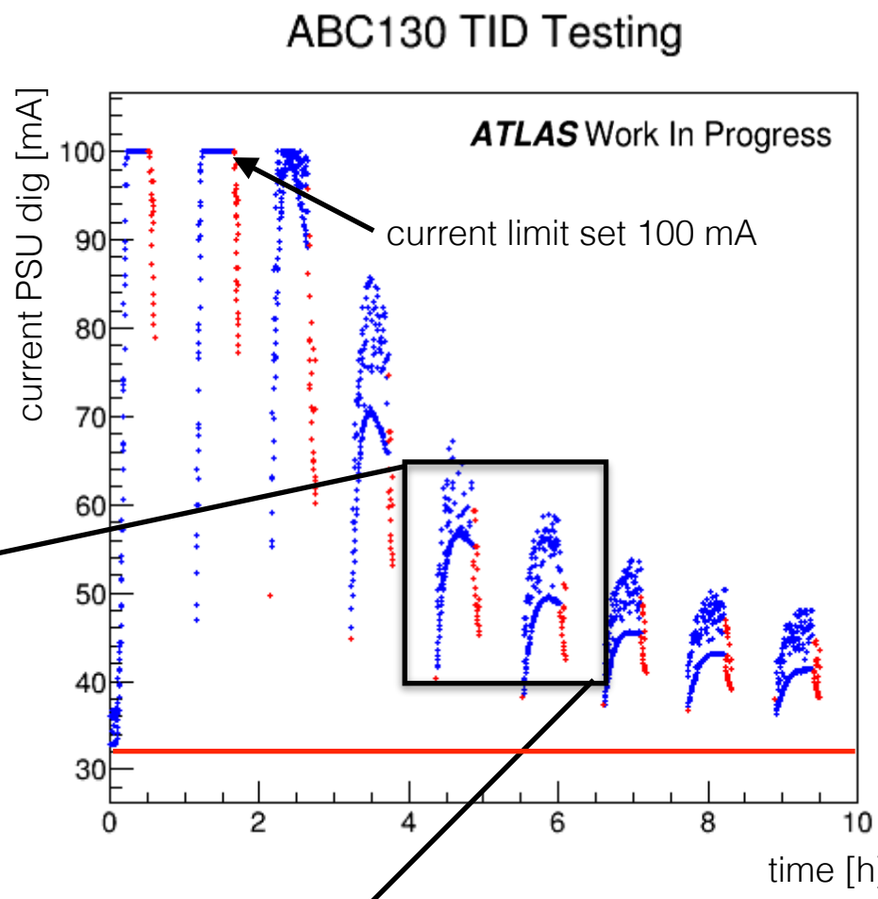


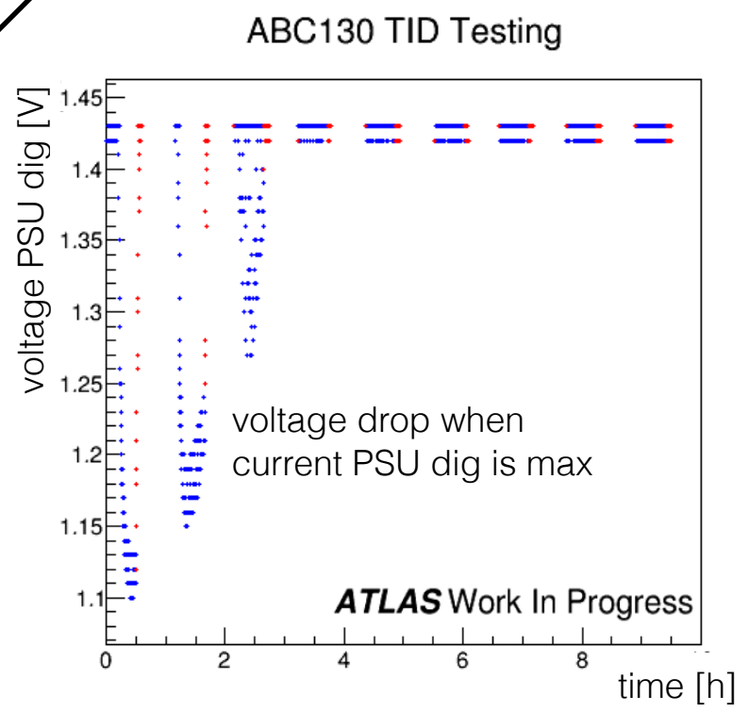
Results (1)

★preliminary results

- early & drastic increase in current to the digital components of the ABC130
- current increase damps out over time after initial changes
- effect saturation and recovery are visible both during irradiation and when radiation is paused



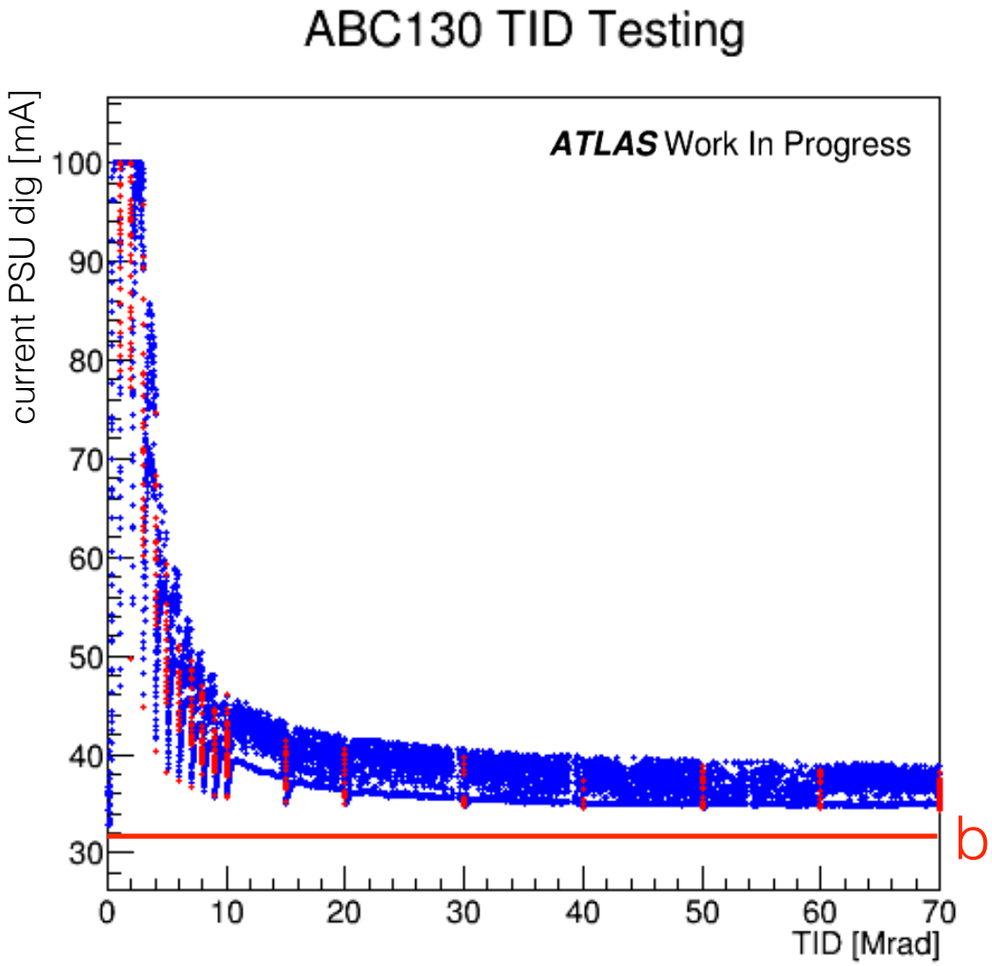


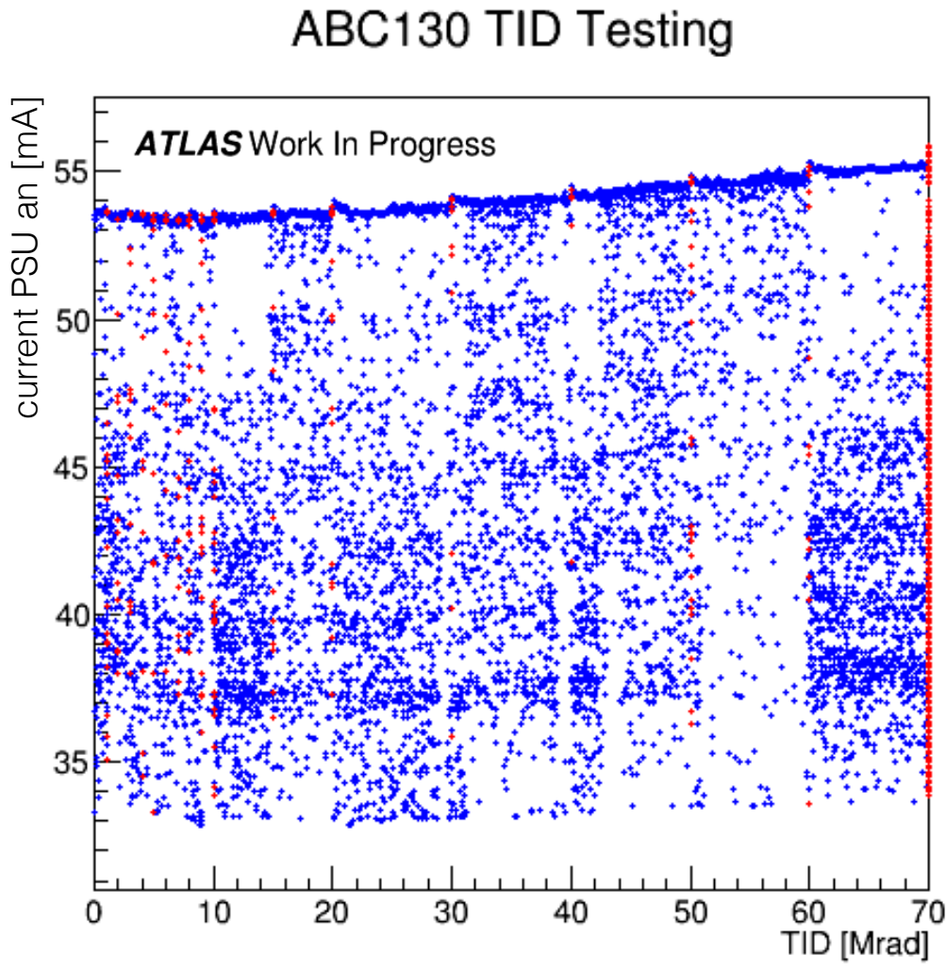


Results (2)

★preliminary results

- over full 70 Mrad effects diminish
- no extreme effects on analog part of the ABC130





★dependences to be explored: **temperature, dose rate, radiation type**

Summary

- large effect within first few Mrads
- ABC130 ASIC retained full functionality throughout & after 70 Mrad
- recovery observed throughout irradiation and pauses
- **still preliminary, needs to be tested with lower dose rate and temperature (253 K)**