

Radiation Testing Techniques and Results For the ATLAS TileCal Upgrade



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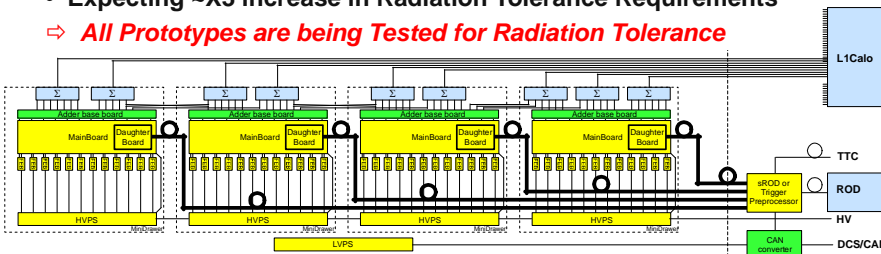
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On Behalf of the ATLAS Tile Calorimeter System

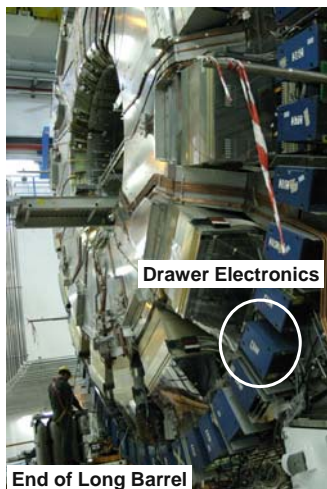
The TileCal Demonstrator

- Prototype Development Program for the Phase 2 Upgrade
 - Replacement of All Front-End & Back-End Electronics
 - Expecting ~X3 increase in Radiation Tolerance Requirements
- ⇒ **All Prototypes are being Tested for Radiation Tolerance**



System Components

- **Front-End Main Board**
 - Analog & Digital
- **3-in-1 Cards**
 - Analog & Digital
- **Daughter Board**
 - Kintex-7 FPGA
- **Luxtera Modulator**
 - Analog & Digital
- **HV Control Board**
 - Analog & Digital
- **Low Voltage Power**
 - Analog & Digital
- **COTS POL Regulators**
 - Analog & Digital



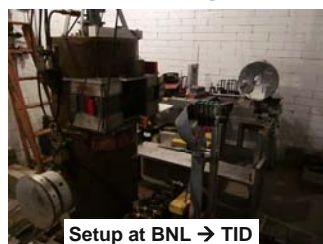
Radiation Testing Facilities & Methodology

- **TileCal Radiation Requirements**
 - 10 Years of Running, 3000 fb⁻¹ Total

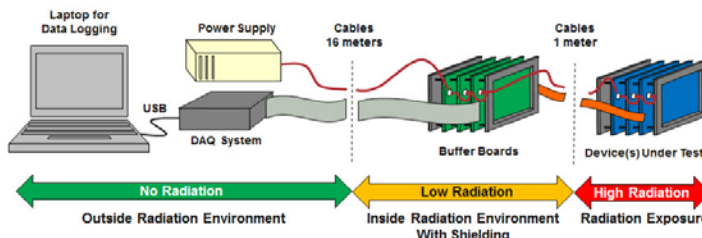
	TID (Grays)	NIEL Fluency (neutrons/cm ²)	SEE Fluency (protons/cm ²)
Lo	244	6.1x10 ¹²	1.47x10 ¹²
Hi	5368	4.5x10 ¹³	7.13x10 ¹³

- **Radiation Testing Facilities**

Facility	Location	Radiation Type	Radiation Source & Test Type
Brookhaven National Laboratory	Upton, NY	1 MeV Gammas	Decays from a ⁶⁰ Co source; Test for TID
University of Massachusetts - Lowell	Lowell, MA	1 MeV (equiv) Neutrons	Neutrons from U235 decay in a nuclear reactor; Test for NIEL
Massachusetts General Hospital	Boston, MA	10-200 MeV Protons	Cyclotron for cancer therapy; Test for SEE

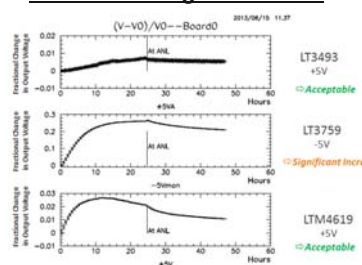


- **General Technique for Tests:**
 - Read out during irradiation
 - Shield DAQ from radiation
 - Customize DAQ for test type
 - Often requires signal buffering & remote powering



Have also used LANSCE, ANL APS, Fermilab, & CDH in Illinois

COTS POL Regulators - TID

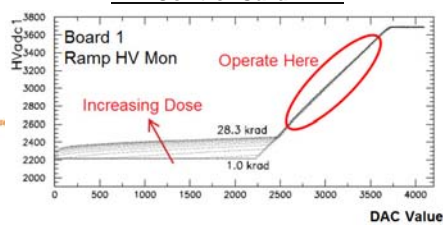


3-in-1 Cards - TID

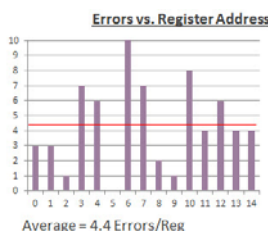
	TSSA2360 (Used in QINJ)	DG611DY (Used in Integrator)
on resistance	0.9Ω	18 Ω
turn off time	2.5ns	12ns
turn off time	6ns	16ns
charge injection	1pC	4pC
leakage current	±20nA	20nA

A Few Measurements & Results

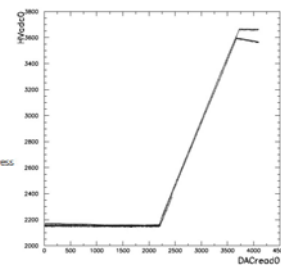
HV Control Card - TID



HV Control Card - SEU



HV Control Card - NIEL



Daughter Board - SEE

Upset type	Upset rate	Test specifications
One-bit upsets (repairable):	30/week	Proton energy: 216 MeV
Two-bit upsets (repairable):	1/week	Proton flux: 8·10 ⁴ protons/cm ² /s
Multi-bit upsets (unrepairable):	1-2/month	Test duration: ~1 hour
Gbit transmission errors:	5/month	Equivalent run time: 100 days (L=10 ³⁴ cm ⁻² s ⁻¹)

Modulator - SEE

Observed (1) SEE in TX that affected all four channels.
Observed SEEs in RX: 13.7 / CH / 1E+12 p/cm²
Tend to be 100's of bits long → Easy to identify
SEEs in the high-speed circuitry were short and did not require rebooting/resetting of the optical links

⇒ **Work in progress... Goal: Complete testing of all prototypes by end of 2015**



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