ATLAS SemiConductor Tracker and Pixel Detector: Status and Performance

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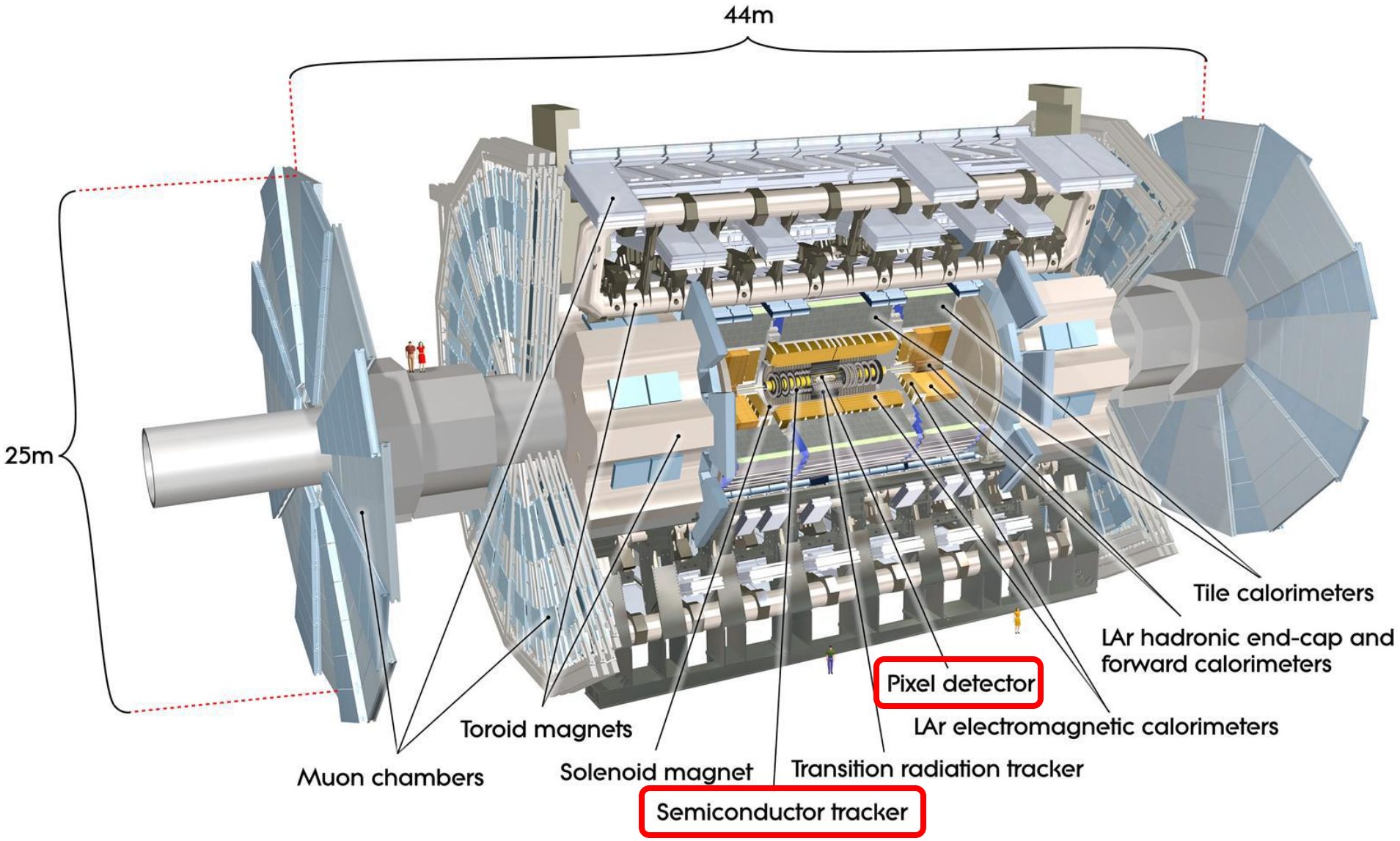
On behalf of the ATLAS Collaboration

Outline

- The ATLAS SemiConductor Tracker and Pixel Detector
- Operational Performance
- Status of the Detectors
- Monitoring of Radiation Damage
- Conclusions

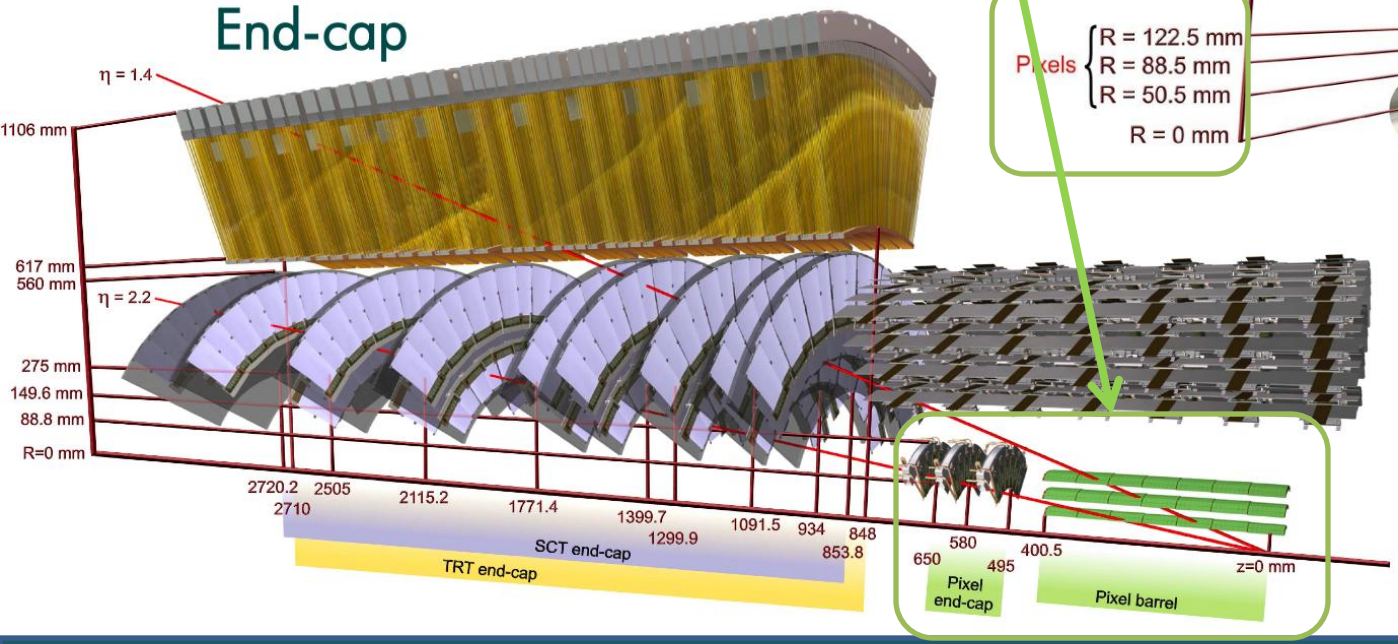
ATLAS Spectrometer

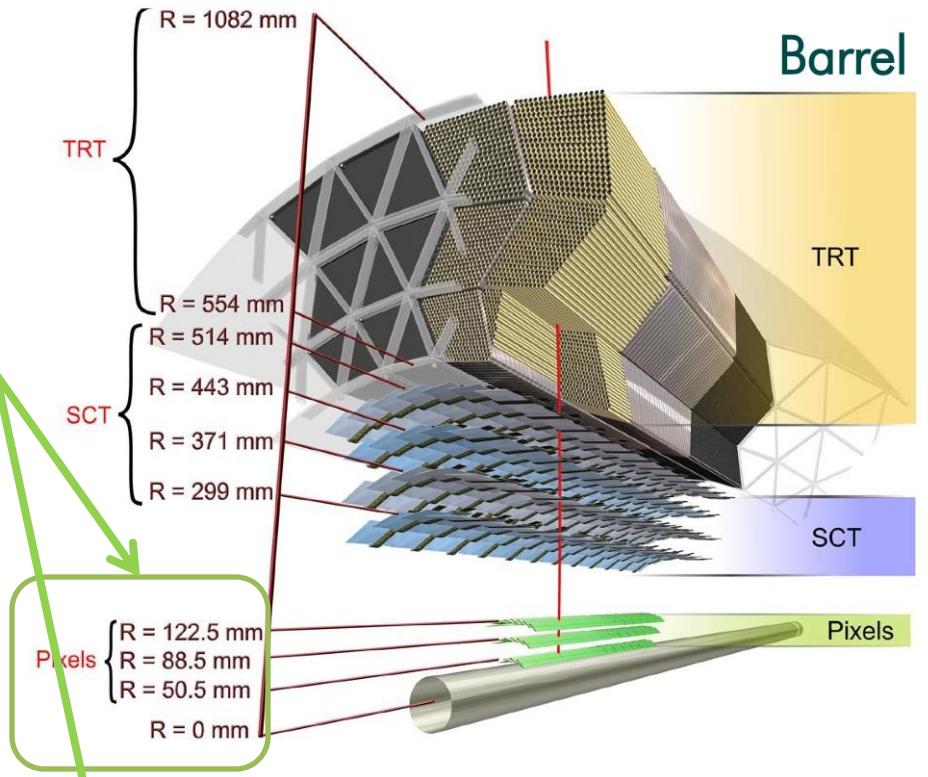


The Inner Detector

Silicon tracking detectors provide high granularity hit information for $|\eta| < 2.5$

Pixel detector:
- 3 barrel layers, 2 x 3-layer end-cap disks
- 1744 pixel modules, 80M+ channels
- Intrinsic Resolution = 10 μm/115 μm ($r\phi/z$)
- Cooled to average T = -13C
- C_3F_8 Evaporative Cooling, reliable (barring power cuts)





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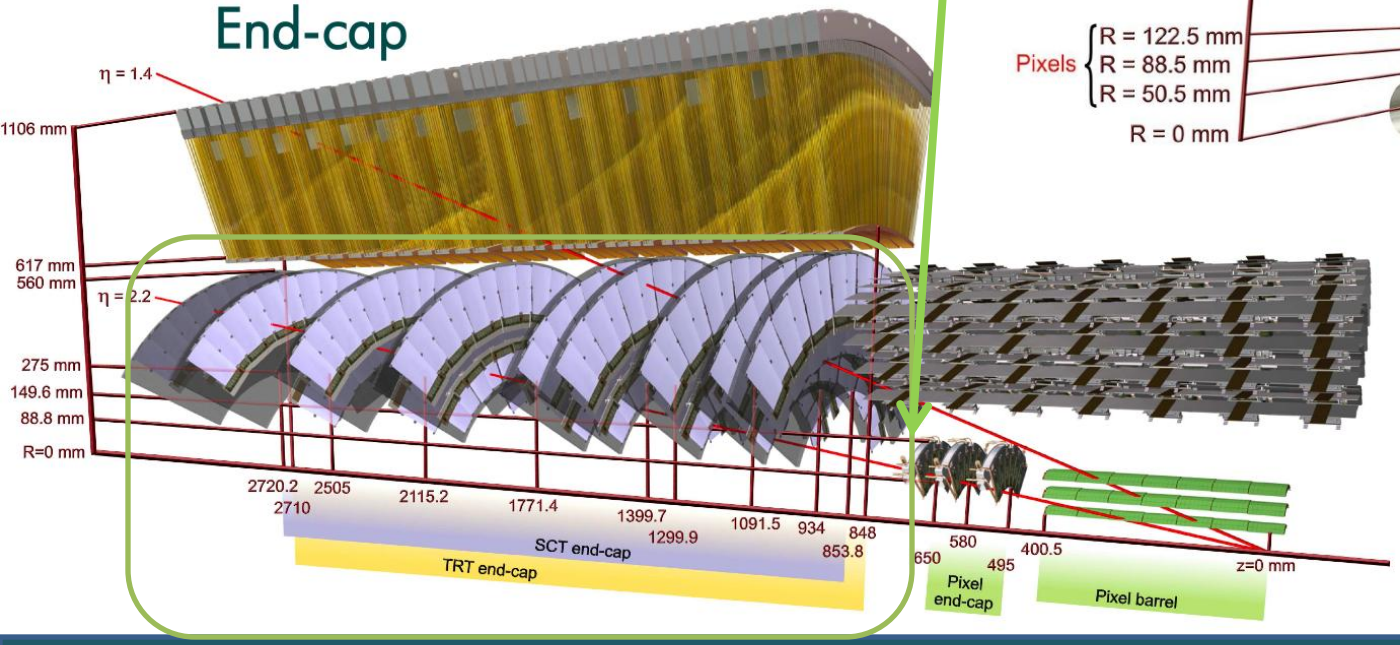
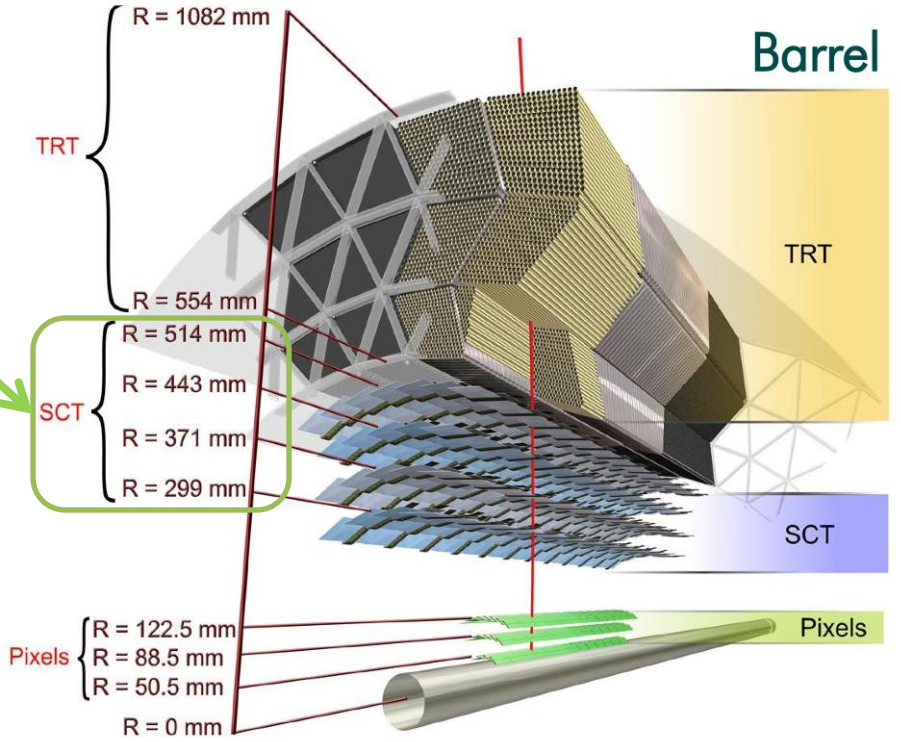
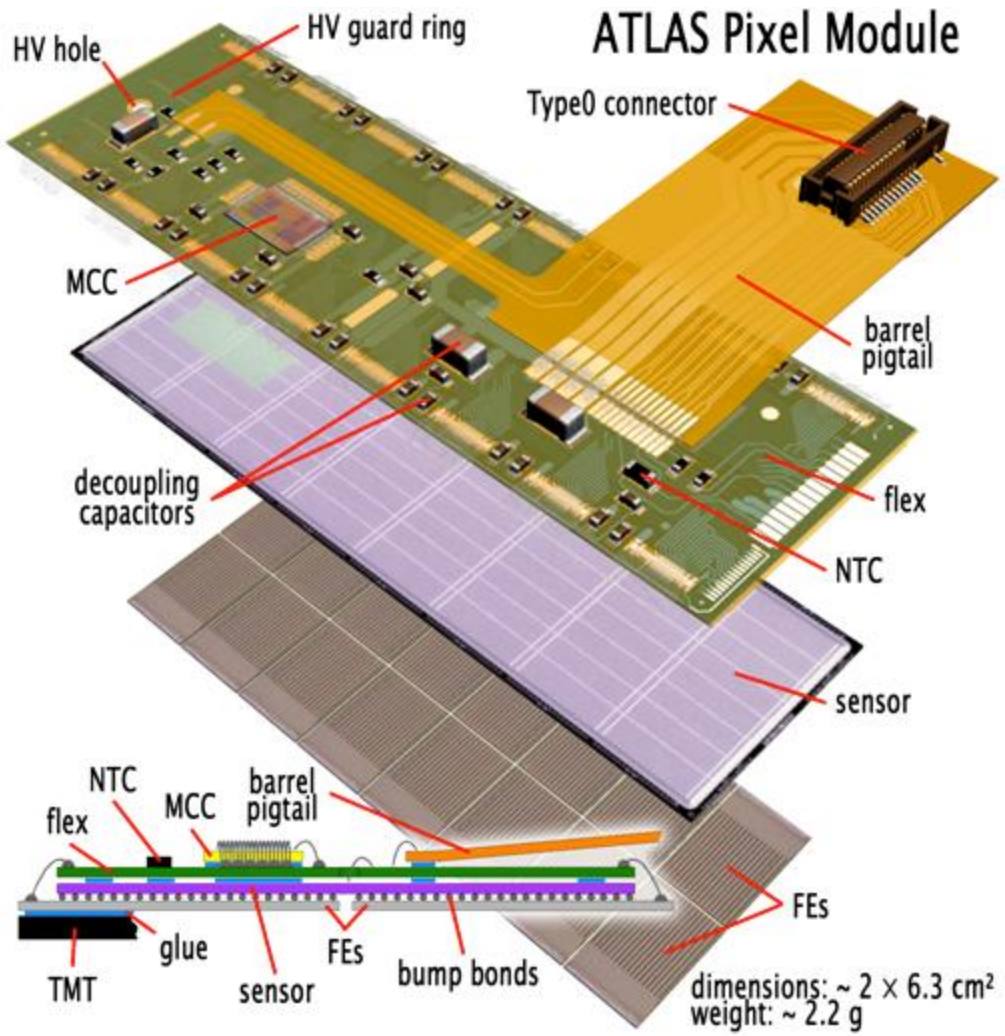
SCT:
- 4 barrel layers, 9 disks per end-cap
- 4088 modules, 6.3M channels (61 m^2)
- Intrinsic Resolution = 17 μm / 580 μm ($r\phi$/z)
- Operational T = -8C to ~5C
- C_3F_8 Evaporative Cooling, same as Pixels





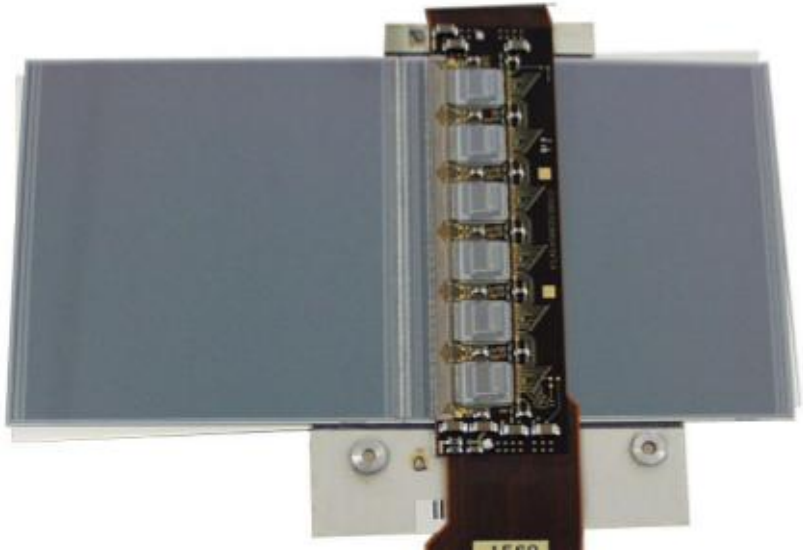
The Pixel Detector

- 250 μm thick n^+-in-n sensor with standard pixel dimension 50x400 μm
- 47232 pixels (46080 readout channels), 16 Front End chips bump bonded
- Flex hybrid glued to backside of sensor, voltage distribution, clock and configuration via MCC, event building via MCC, readout
- Radiation tolerance: 500 kGy, 10^{15} 1MeV n_{eq} cm^{-2}
- 1744 modules in total



The SemiConductor Tracker (SCT)

- Barrel Modules
  - 1 design
  - 80 μm pitch
  - 2112 in total
- End-cap Modules
  - 5 different designs
  - 57 – 90 μm pitch
  - 1976 in total
- 2 planar sensors glued onto a thermally conductive support
- 40 mrad stereo angle
- 1536 channels per module
- Binary readout, 132 bit deep buffer



Operational Performance

- Excellent performance for both detectors during 2010 and 2011
- SCT – 99.6% (2011) availability during periods of luminosity
- Pixel – 99.8 % (2011) availability
- Values are luminosity weighted → later periods more relevant

ATLAS 2011 p–p run

Inner Tracking			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.8	99.6	99.2	97.5	99.2	99.5	99.2	99.4	98.8	99.4	99.1	99.8	99.3

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at $\sqrt{s}$=7 TeV between March 13th and October 30th (in %), after the summer 2011 reprocessing campaign

ATLAS 2012 p-p run

Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.4	100	95.0	98.7	100	99.2	100	99.9	100	100

Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at $\sqrt{s}$=8 TeV between April 4th and May 31st (in %) – corresponding to 3.5 fb^{-1} of recorded data. The inefficiencies in the LAr calorimeter will partially be recovered in the future.

Detector Status: SCT

SCT disabled elements – total value is 0.97%

Disabled Readout Component	Barrel	End-Cap A	End-Cap C	Sum	Fraction (%)
Modules	10	5	15	30	0.73
Chips	24	5	4	33	0.07
Strips	3681	3364	3628	10673	0.17

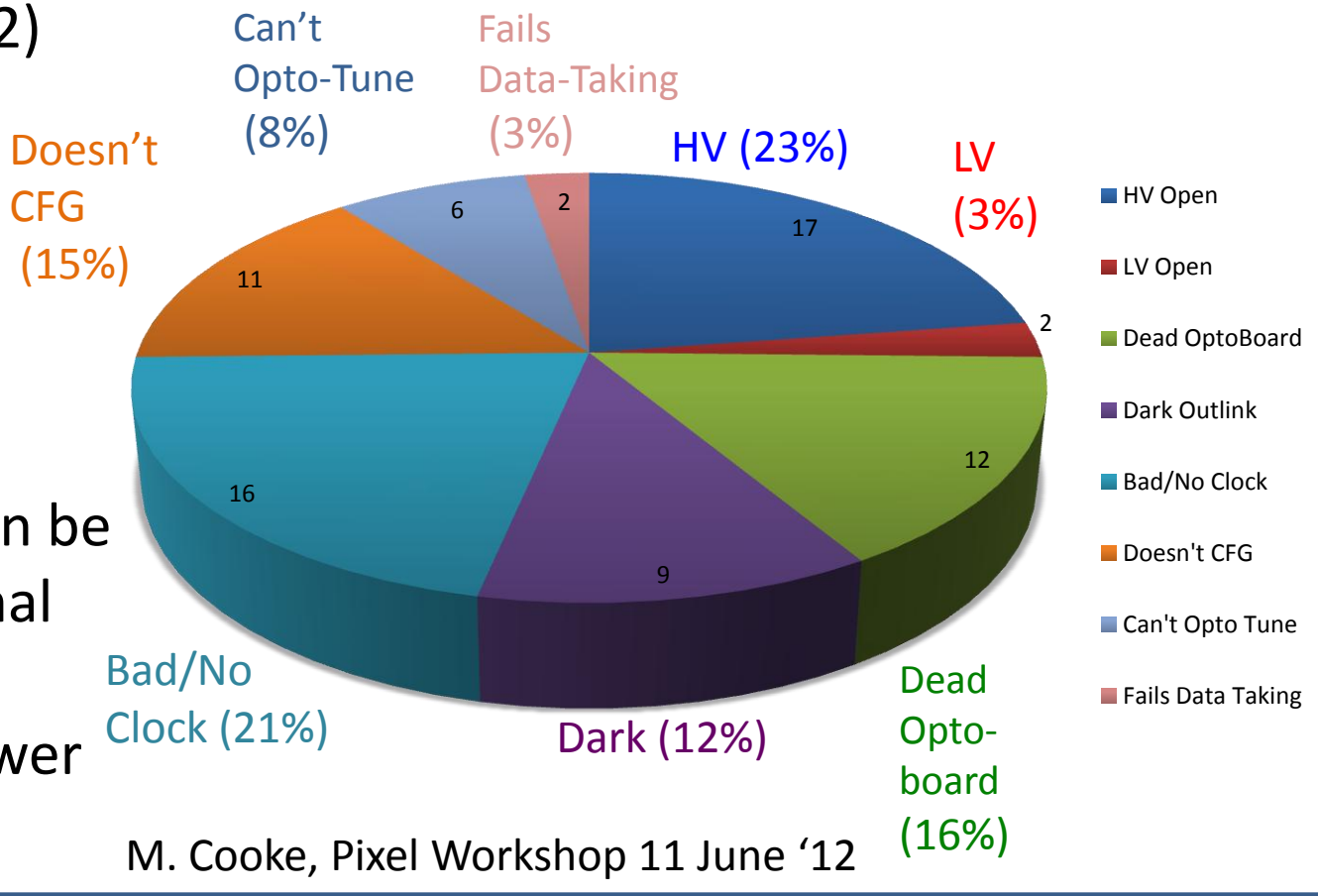
Breakdown of disabled modules. The 13 modules in End-Cap C are on 1 faulty cooling loop.

	Barrel	End-Cap A	End-Cap C	Sum	Fraction (%)
Cooling	0	0	13	13	0.32
LV	6	0	1	7	0.17
HV	1	4	1	6	0.15
Readout	3	1	0	4	0.10

Detector Status: Pixel

As of 11 June 2012, 74 pixel modules disabled, distribution of causes indicated in the pie chart below. Main causes:

- Open high voltage connections
- Loss of clock on modules
- Lost optoboard (x2)
- Can't configure
- No data return



4.2% of modules disabled

Almost all losses can be attributed to thermal shock from loss of cooling system (power cuts)

M. Cooke, Pixel Workshop 11 June '12

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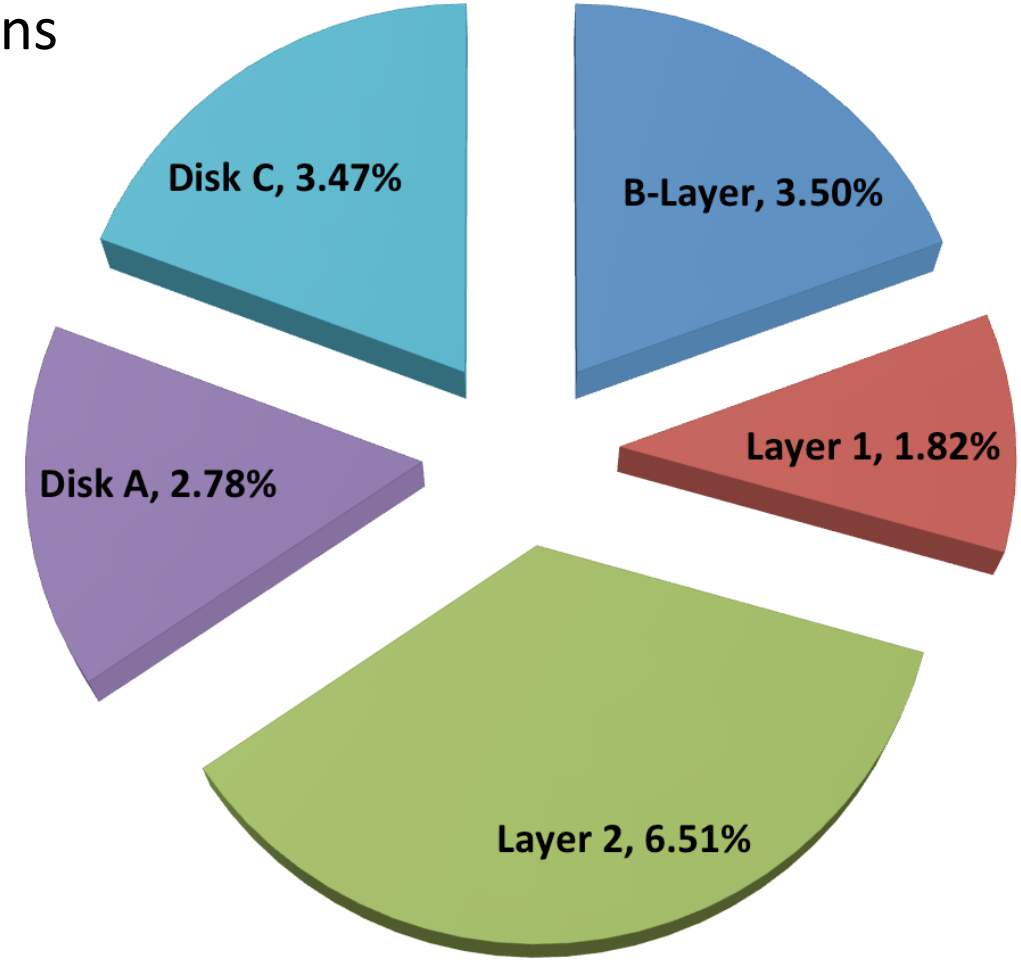

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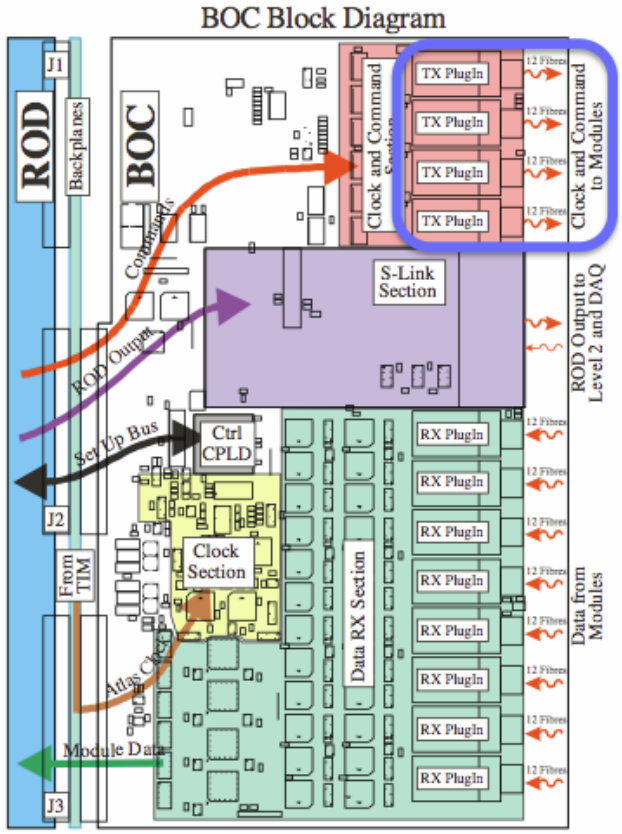
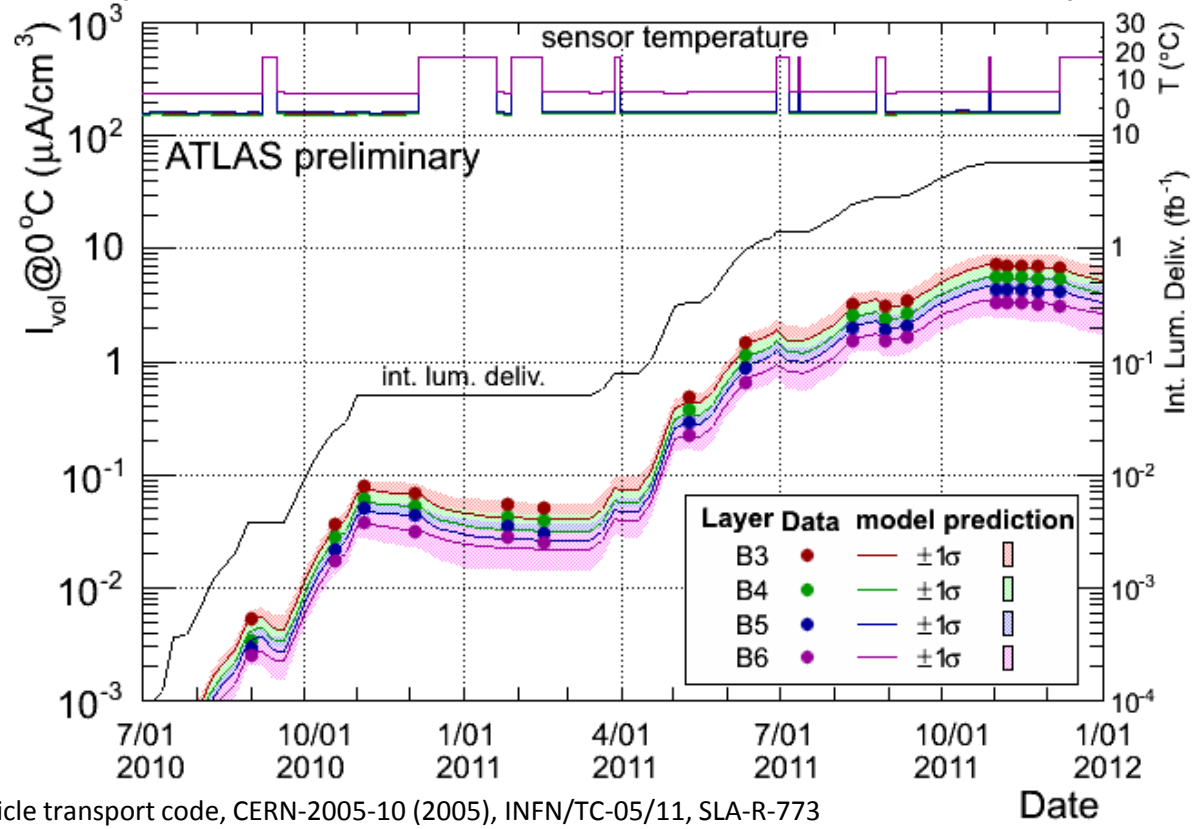
Off-Detector VCSEL Replacement

- VCSEL transmitters (TX) are common to Pixel and SCT
- Lifetime issues observed during 2010/2011 running periods → losses on the O(few)/week
- Overhead of replacing failed units opportunistically – module inactive during interim
- Less problematic for SCT, redundancy scheme for clock distribution
- Winter 2011 shutdown, all TX plugins replaced with units from new VCSEL vendor (Truelight → AOC)
- Dry air flow into DAQ racks
- Losses so far: 6 SCT, 2 Pixel



Radiation Damage, SCT

- LHC luminosities great for physics – not so much for proximal sensors and electronics
- Monitoring of radiation damage via sensor leakage current
- We observe a leakage current increase: in excellent agreement with prediction of the model using FLUKA*
- Harper model predictions (bands) and data for the SCT barrel layers
- Approximately 10% underestimate, still within uncertainty bands

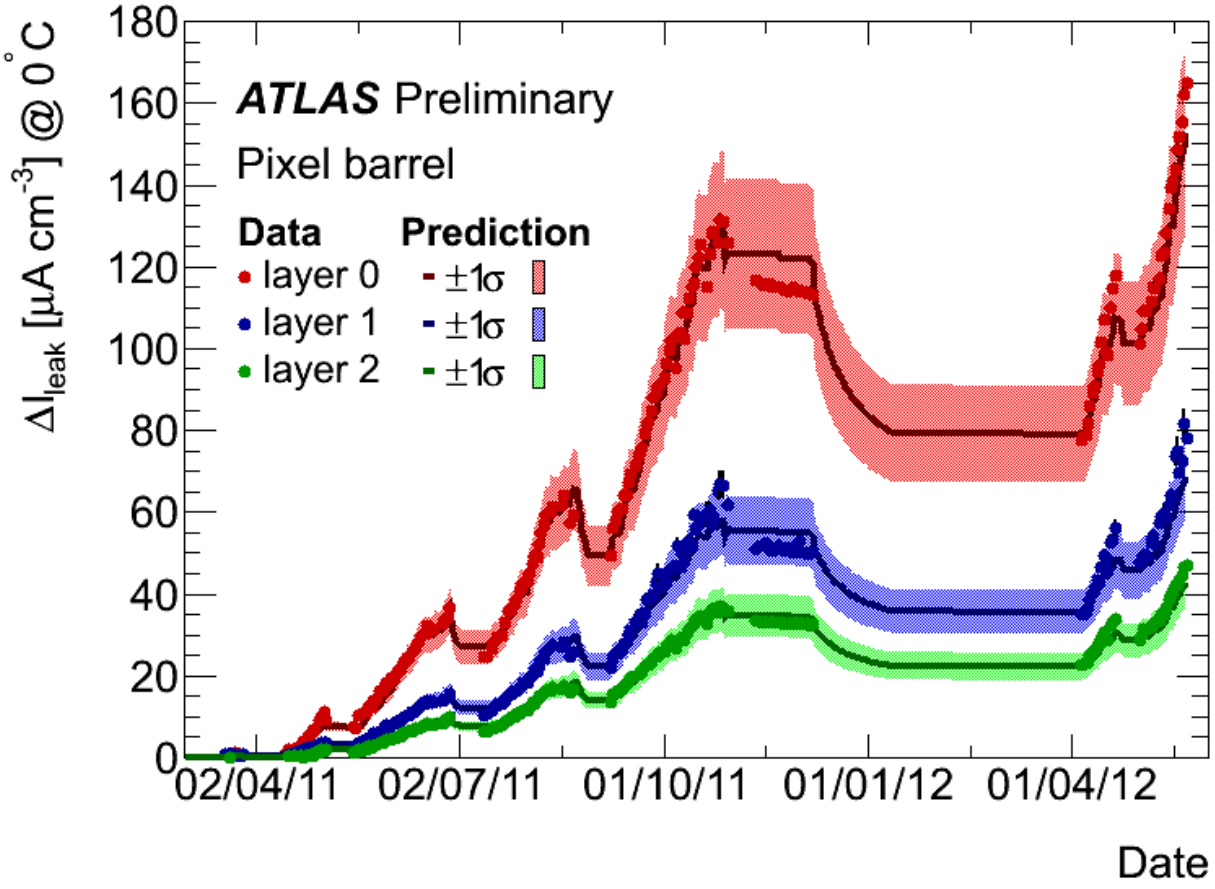


T. Kondo,
RD50 Workshop,
30 May 2012

*FLUKA: A multi particle transport code, CERN-2005-10 (2005), INFN/TC-05/11, SLA-R-773

Radiation Damage, Pixels

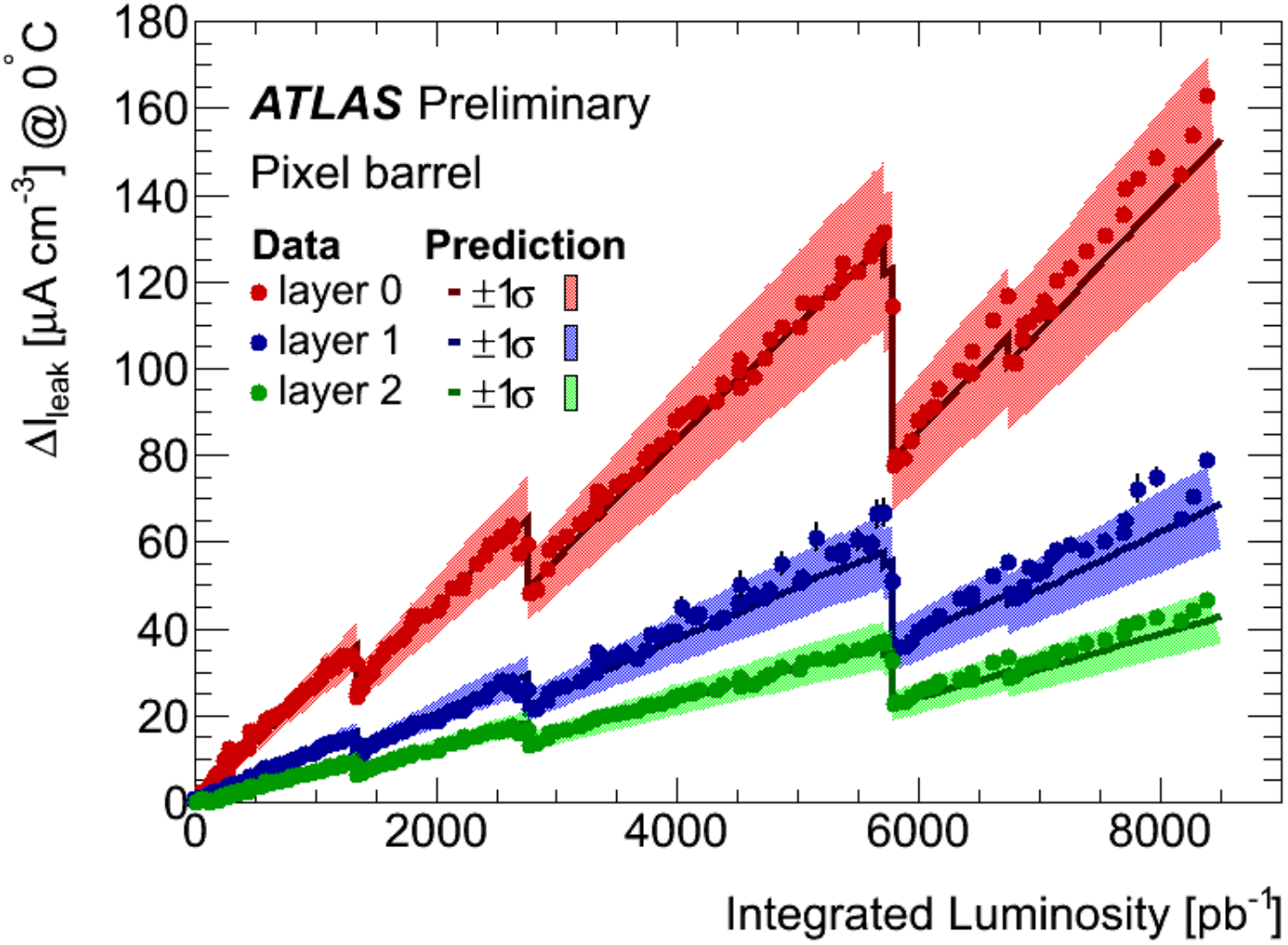
- Similar plot for the 3 pixel barrel layers – model predictions (bands) and data
- Data well described qualitatively, including the discontinuities from cooling stops → annealing.
- Model rescaled by 15% (layer 0) and 25% (layers 1 & 2)



M. Keil,
RD50 Workshop,
30 May 2012

Radiation Damage, Pixels

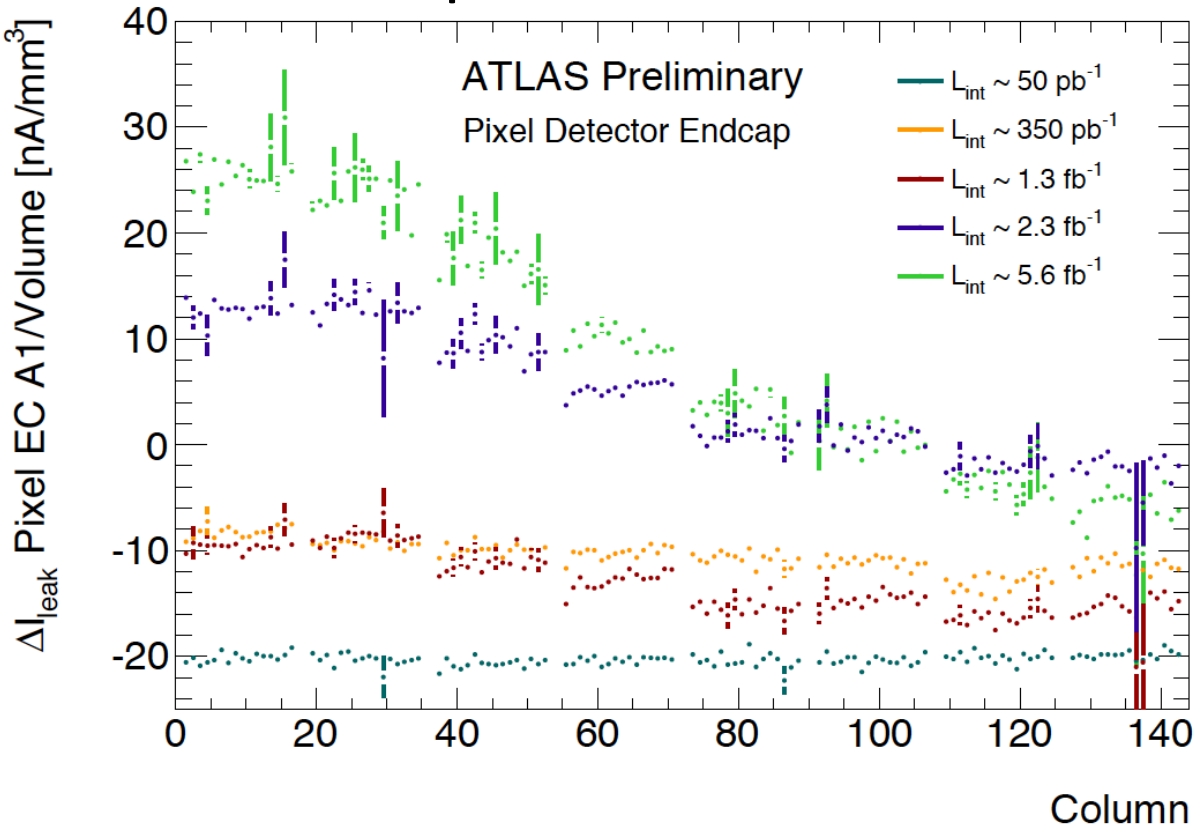
- Same as previous slide, but now functionally dependent on integrated luminosity



M. Keil,
RD50 Workshop,
30 May 2012

Radial Dependence

- Leakage current plotted for increasing values of luminosity
- Increasing column number corresponds to larger radial distance from the beamline
- Clear radial dependence



M. Keil,
RD50 Workshop,
30 May 2012

Conclusions

- The SCT and Pixel detector are both performing exceptionally well, having demonstrated better than 99% availability during luminosity periods for 2011
- DAQ and the Detector Control System (DCS) for both systems working very well
- The SCT has proven to be remarkably robust
- It is expected that many of the losses (currently at 4.2%) in the Pixel detector can be recovered in the long shutdown beginning in 2013
- The long-standing problem with off-detector optical transmitters has, hopefully, been resolved
- We see clear signs of radiation damage in both detectors which is qualitatively well described by models, not affecting detector performance or reliability
- Type inversion for the innermost layer of Pixels is expected later this year
- All indications are that detector performance will continue to impress through the 2012 run