The ATLAS SCT: Commissioning Experience and SLHC Upgrade

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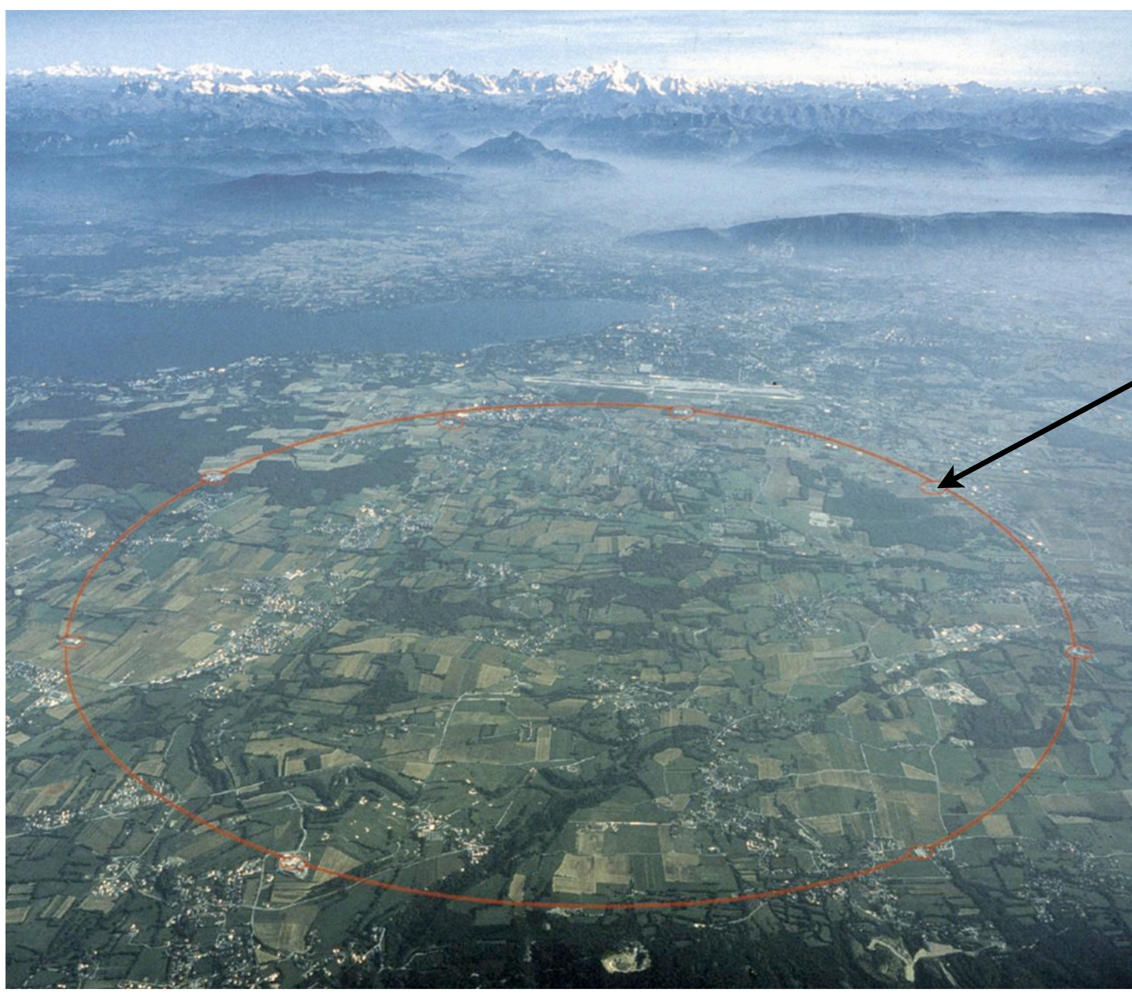
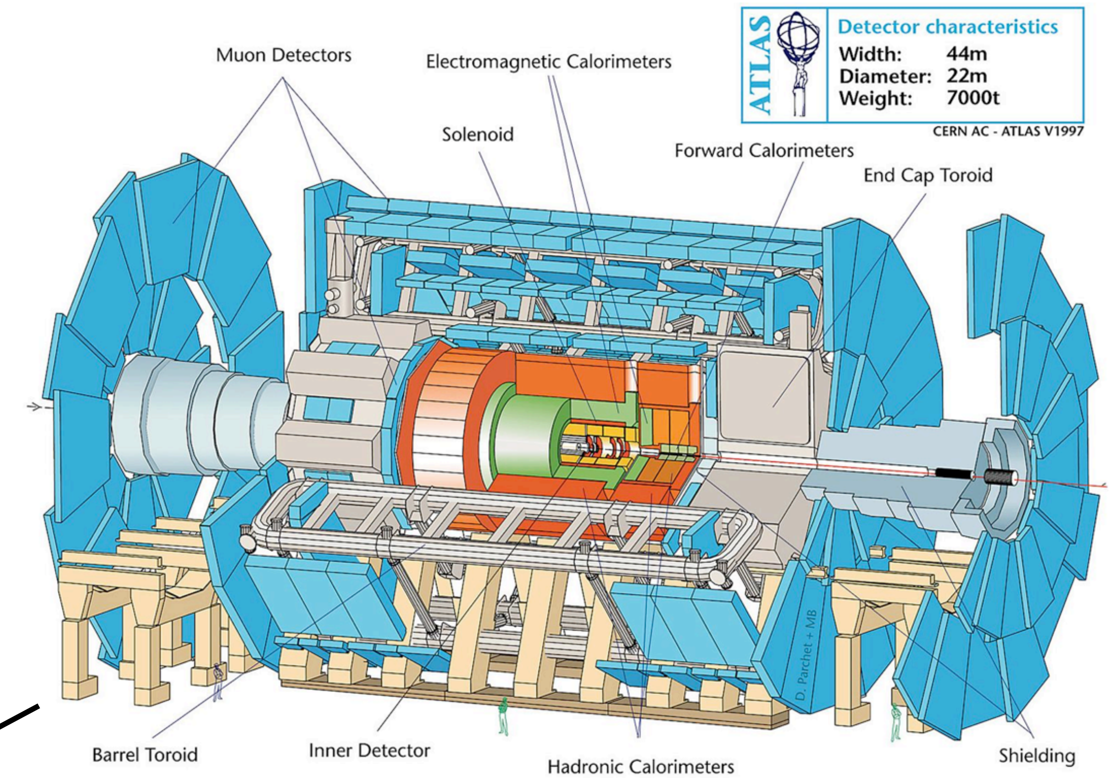
The LHC and ATLAS

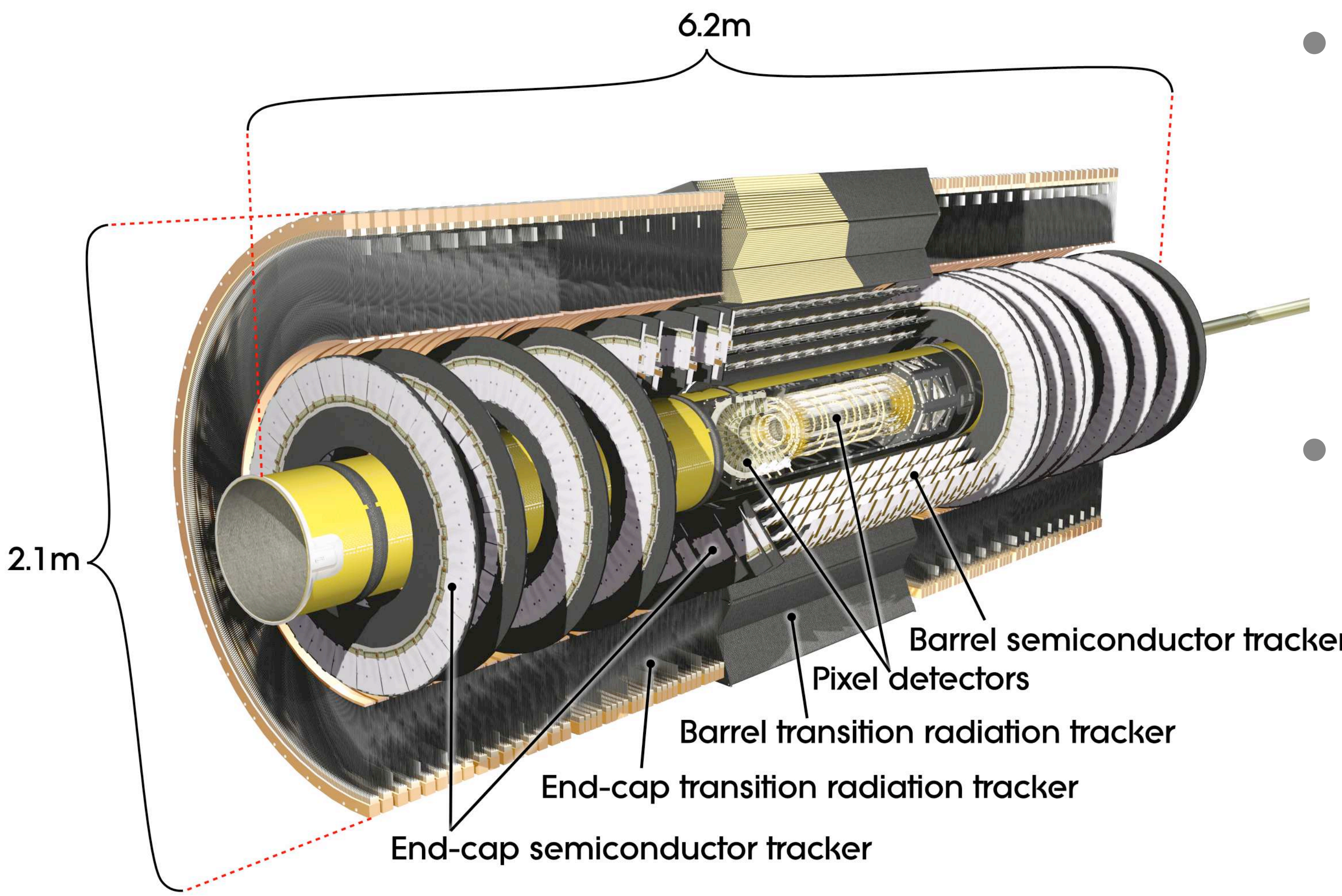
- The Large Hadron Collider (LHC) is a p-p collider with $\sqrt{s}$ = 14 GeV
- Design luminosity of 10^{34} $cm^{-2}s^{-1}$.
- First circulating beam planned for 10/9





- ATLAS is a general-purpose detector
  - Inner detector for tracking, inside 2T Superconducting Solenoid
  - LAr EM and forward hadronic calo
  - Steel and scintillator tile hadronic calorimeter.
  - Air core toroid in muon system.

The Inner Detector

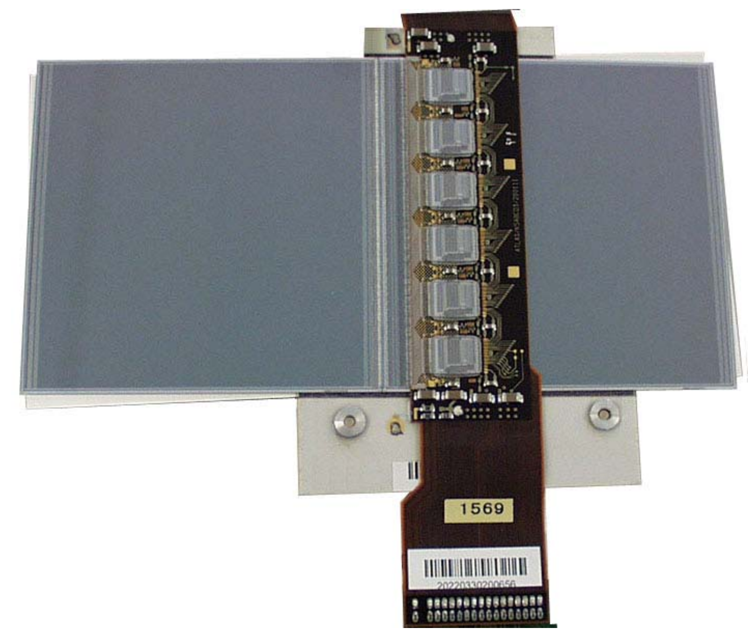


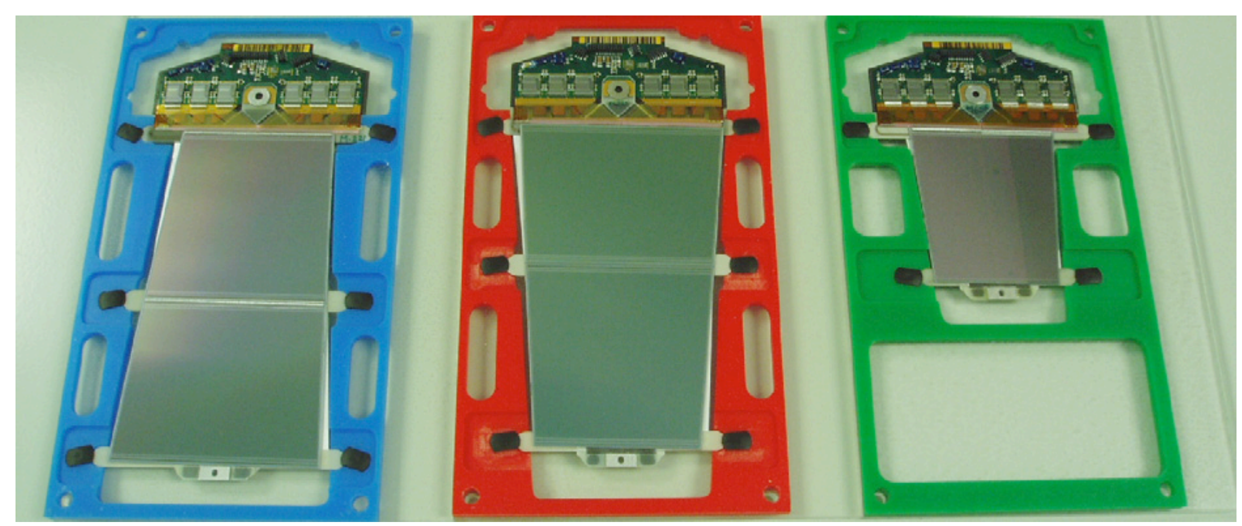
- The Inner Detector is made up of:
  - Pixels
  - SemiConductor Tracker (SCT)
  - Transition Radiation Tracker (TRT)
- The SCT is made up of
  - four barrel layers 1.5 m in length with radii of 30 cm to 52 cm
  - nine disks on each side of the barrel, at $z = \pm$ 84 to 279 cm.

- Barrel consists of 2112 modules, for a surface are of 34.4 m^2.
- End Cap consists of 1976 modules, for a surface area of 26.7 m^2.
- Coverage is $|\eta| < 2.5$, with the barrel covering $|\eta| < 1.1$ to 1.4.

SCT Modules

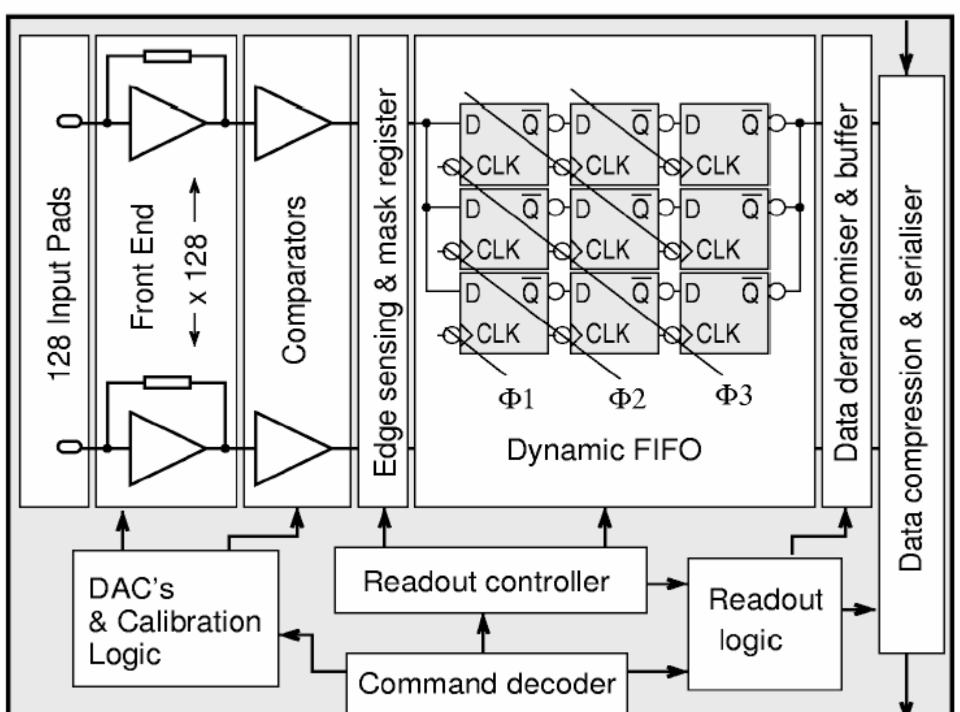
- Single-sided p-in-n microstrip sensors, 285 μm thick, manufactured by Hamamatsu and CiS.
- Strips with 80 μm pitch for barrel sensors, 57-94 μm for end cap sensors, AC-coupled
- Two sensors back-to-back (except in inner end-cap, short middles) result in about 12 cm strips.
- Two pairs of sensors are attached to each module at 40 mrad stereo.
- Binary readout of 1536 channels
- 17 μm $r\phi$, 580 μm r or z nominal resolution
- able to withstand a dose of $2{\times}10^{14}$ 1 MeV-neutron-equivalent / cm^2
- Sensors operated at -7C to freeze out reverse annealing



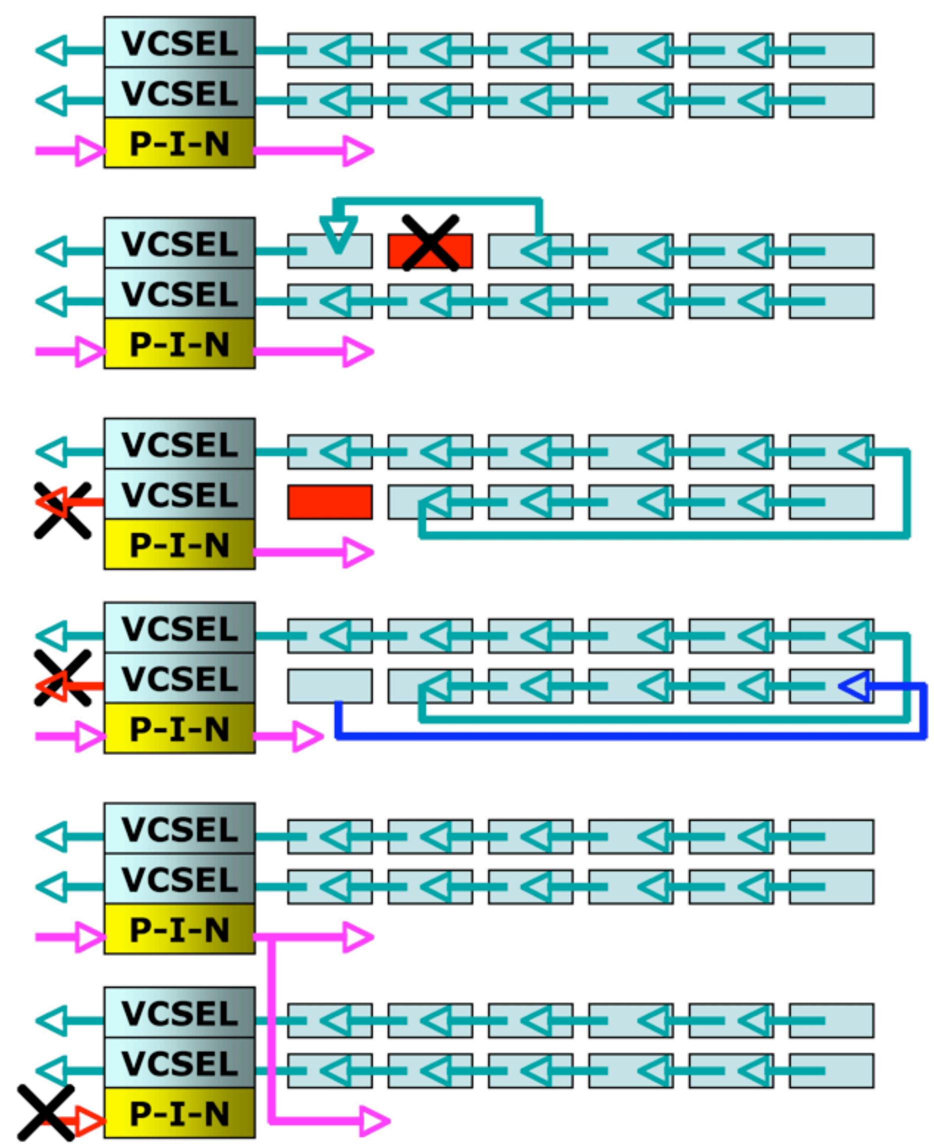


Front-End Electronics

- A hybrid contain 12 ABCD3TA chips, six on each side, to read out 128 strips each.
- ABCD3TAs fabricated in DMILL technology,
- Binary readout: need to tune threshold
  - Can trim the thresholds per channel
  - Can inject test charges
- Optical communication off-module



- Fault-tolerance schemes

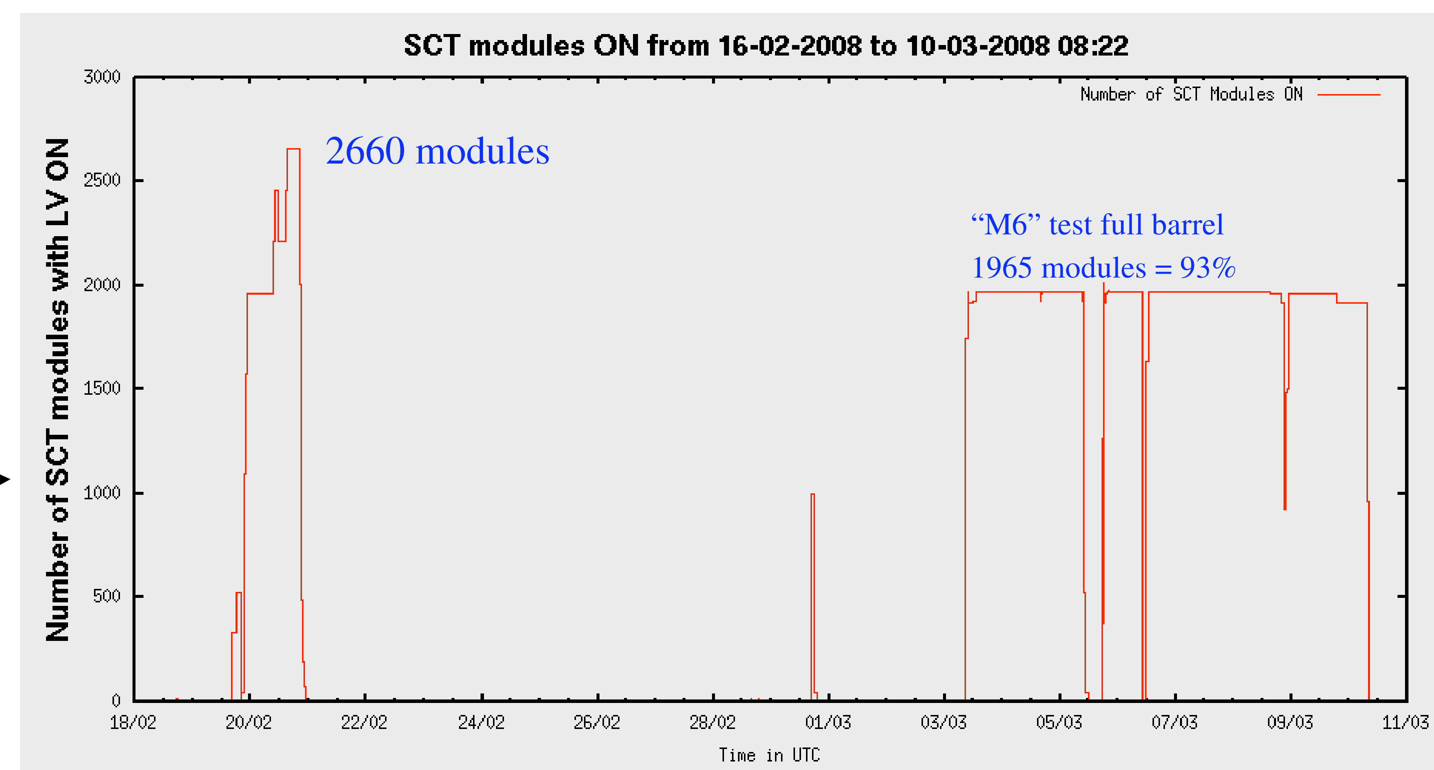


Detector Control System and Cooling

- Each module has LV and HV power controlled individually from power supplies in the service caverns.
- An evaporative cooling system using C_3F_8 cools the modules so that the sensors can be kept at -7C.
- The SCT is filled with dry N_2 gas to prevent condensation; the humidity is monitored by radiation-hard sensors.
- Temperatures are monitored on the modules, cooling loops, mechanical structure, and the gas.
- A hardware-based interlock system cuts the power to the modules if the cooling loop temperature is outside a chosen range.
- A sophisticated control system based on PVSS-II and a Finite State Machine provides detector control, software interlocks, alarm handling.

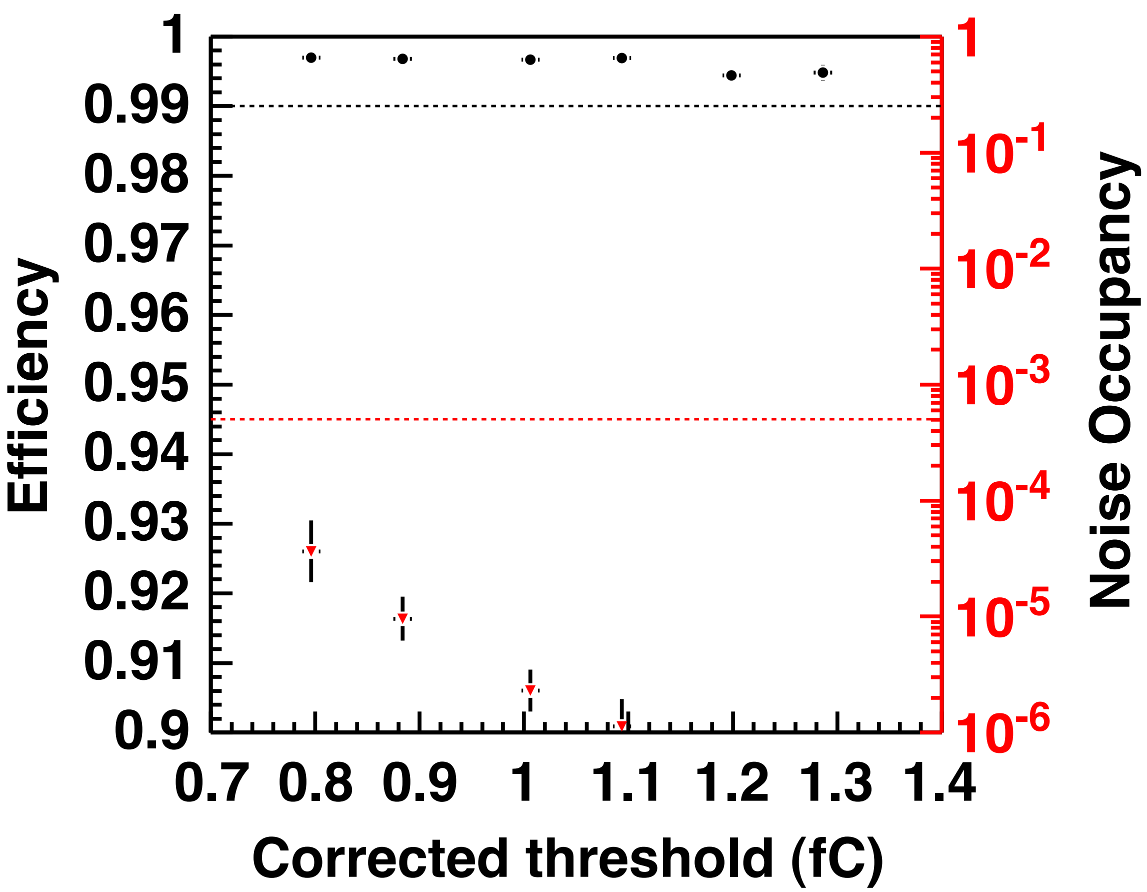
Construction and Testing

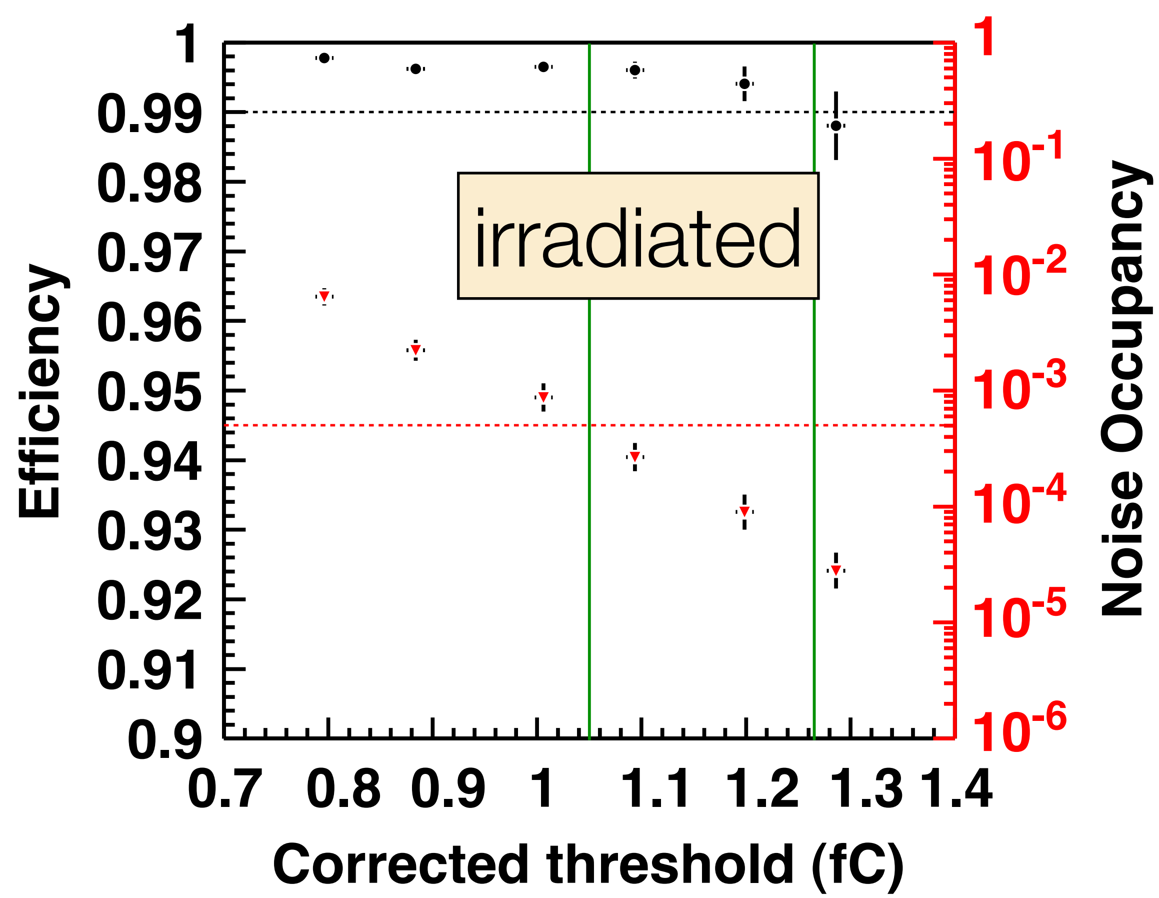
- The sensors were checked on a sampling basis, and modules built.
- A small number of sensors were irradiated at the CERN PS.
- Acceptance tests performed on the modules.
- Assemble barrels on the surface, place inside TRT. Perform Cosmic Tests.
- Install Barrel in pit. Continuity checks and sign-off **April-May 2007**.
- Install End Caps in pit and test connectivity **May-Nov. 2007**.
- EC A sign-off **Jan. 2008**.
- EC C sign-off **Feb. 2008**.
- In pit combined tests **M6**.
- Tuning and preparing for running **now!**



Noise Occupancy and Threshold

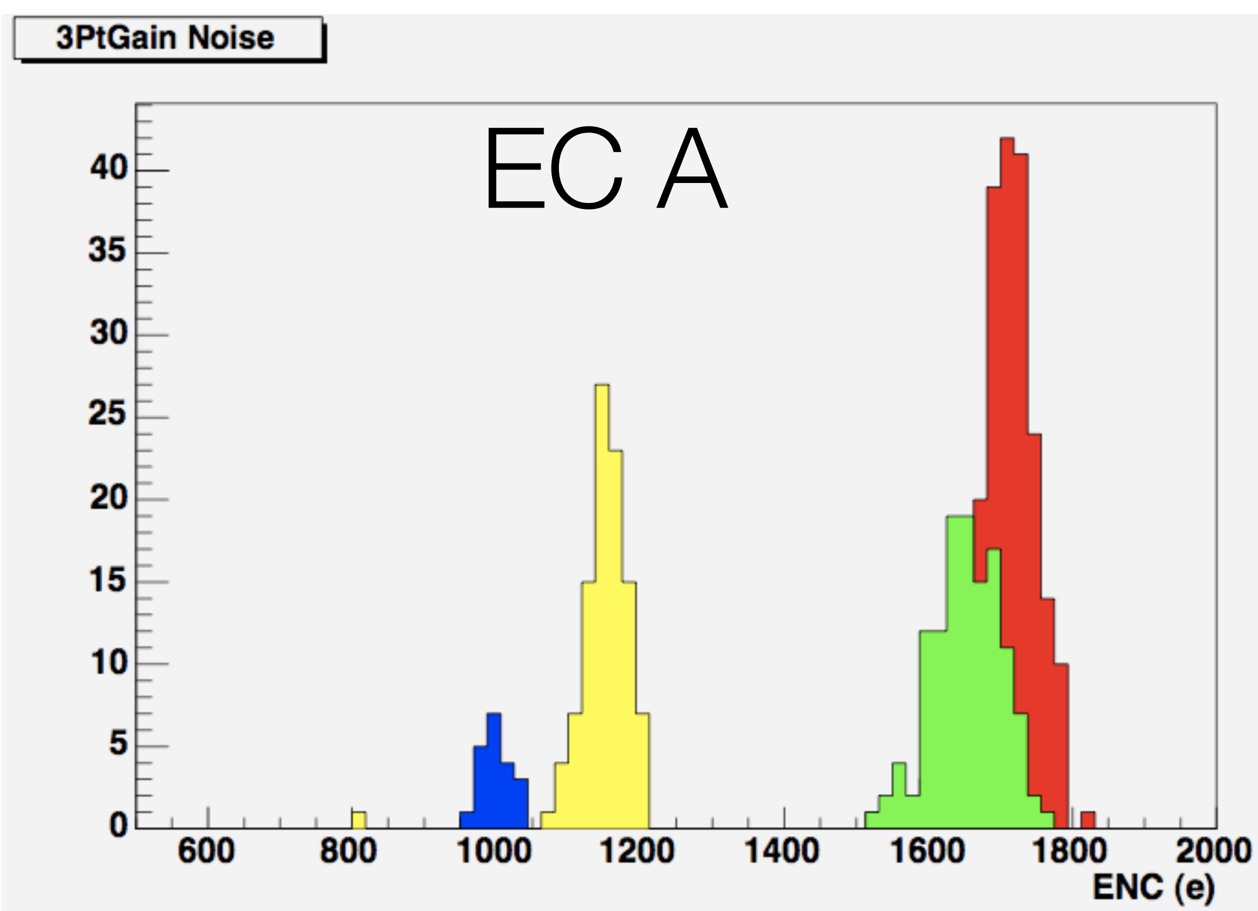
- Need to have greater than 99% hit efficiency while maintaining less than 5×10^{-4} noise occupancy.
- Right plot is after irradiating with 3×10^{14} protons/cm^2 from CERN PS.

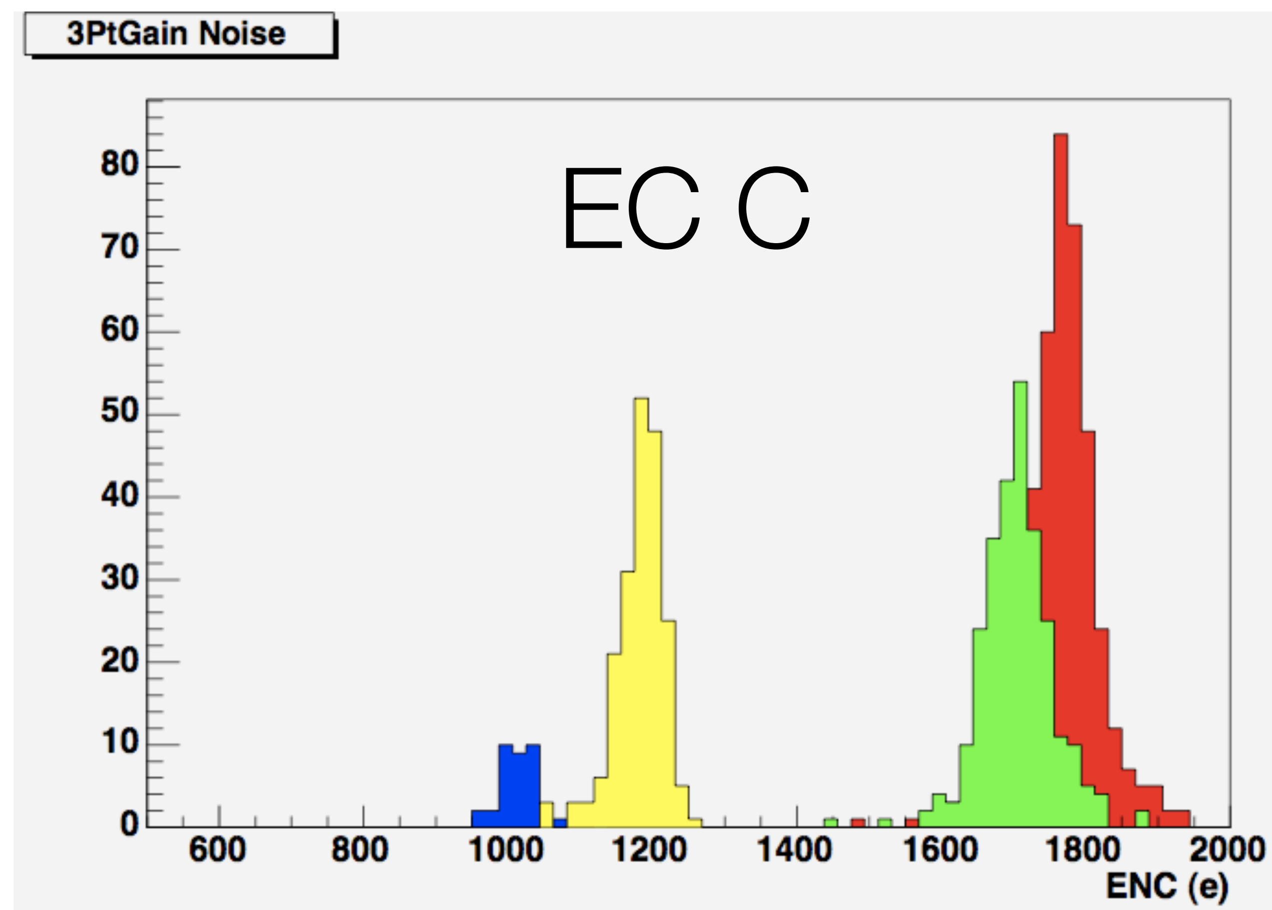




Noise Measurements in End Cap during Sign-Off at 25C

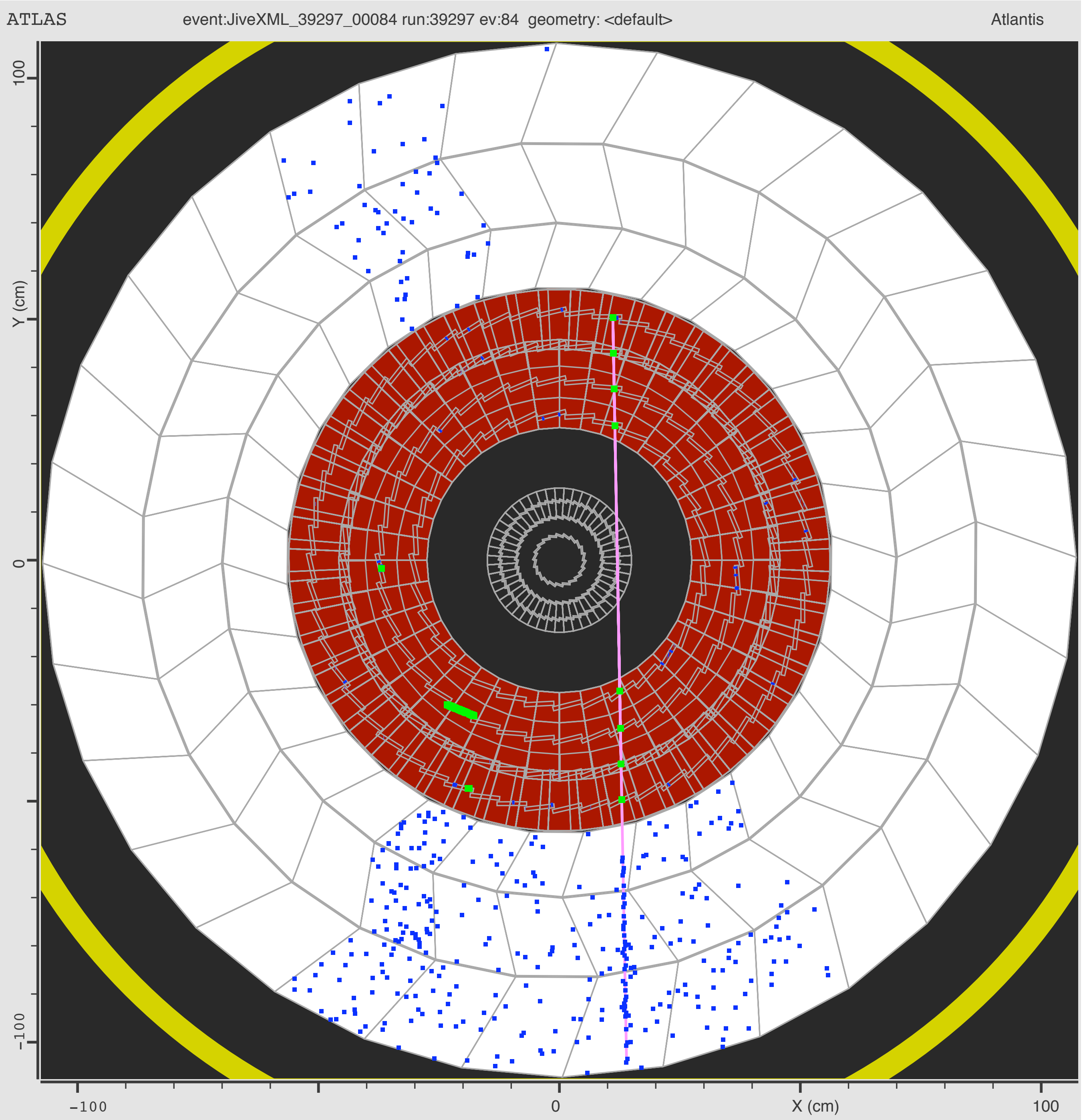
Module Type	End Cap A ENC (electrons)	End Cap C ENC (electrons)
Outers	1707	1767
Middles	1653	1704
Inners	1149	1182
Short Middles	1002	1013



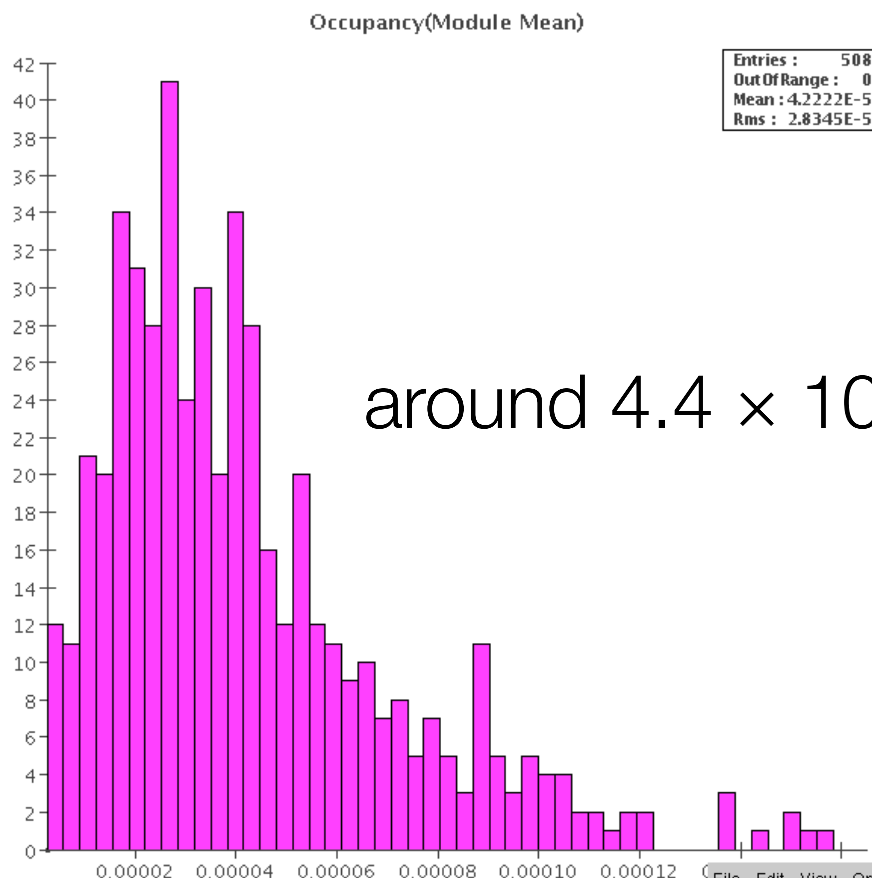


First SCT Cosmic Event in the Pit

- Combined running has been useful to set up the timing and test the DAQ system.
- Also useful to test the offline software, monitoring, reconstruction
- Cosmics have been used for alignment
  - In the surface tests
  - In M6, the statistics were lower

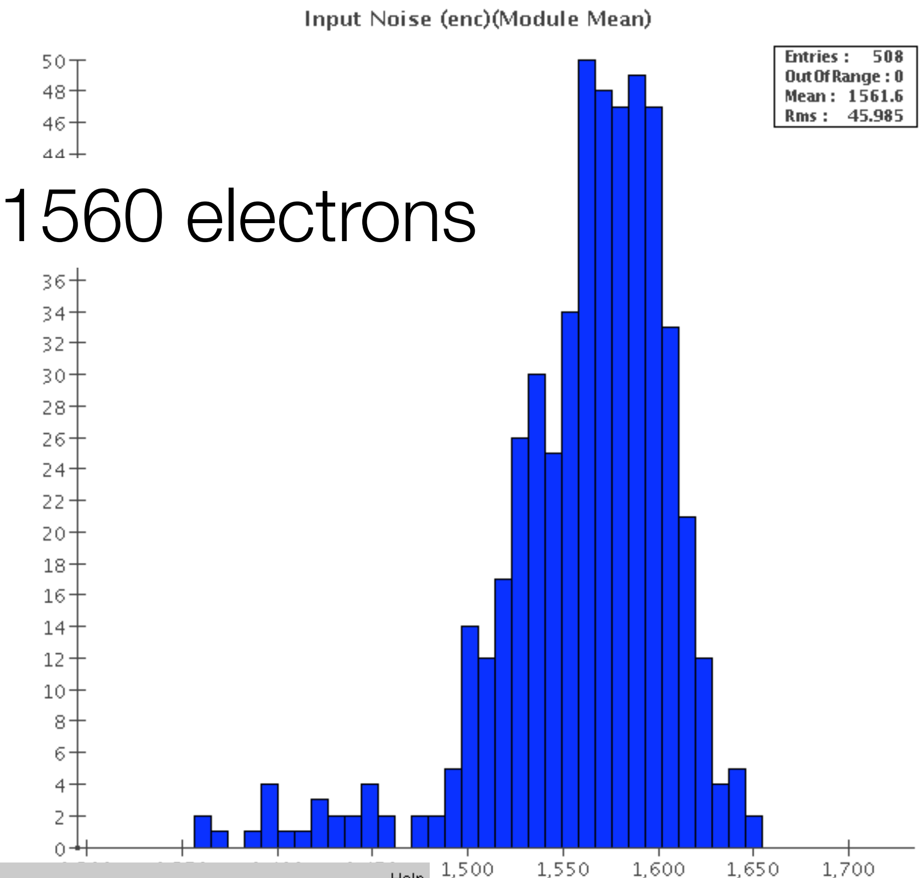


Made first round of calibration scans in Barrel



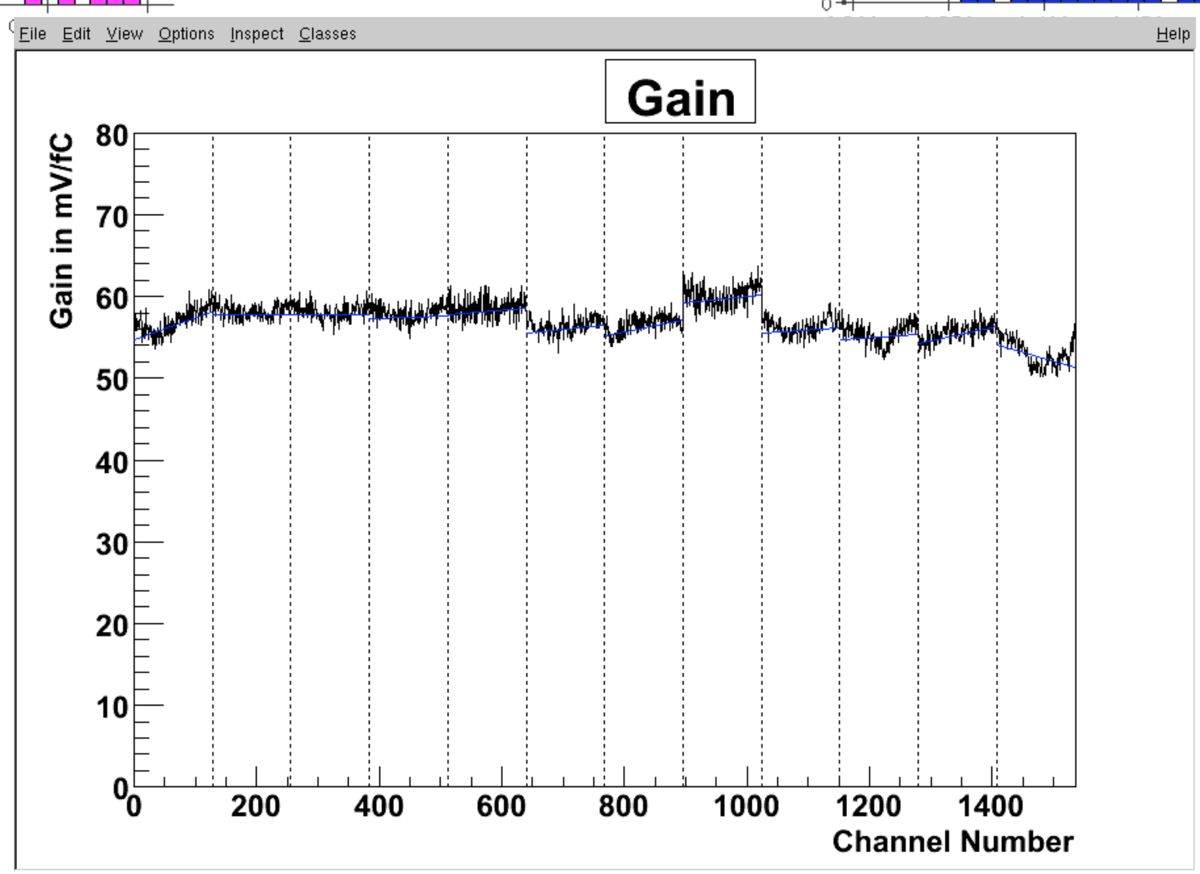
around 4.4 × 10^{-5}

Noise Occupancy



around 1560 electrons

ENC (electrons)



Latest Status

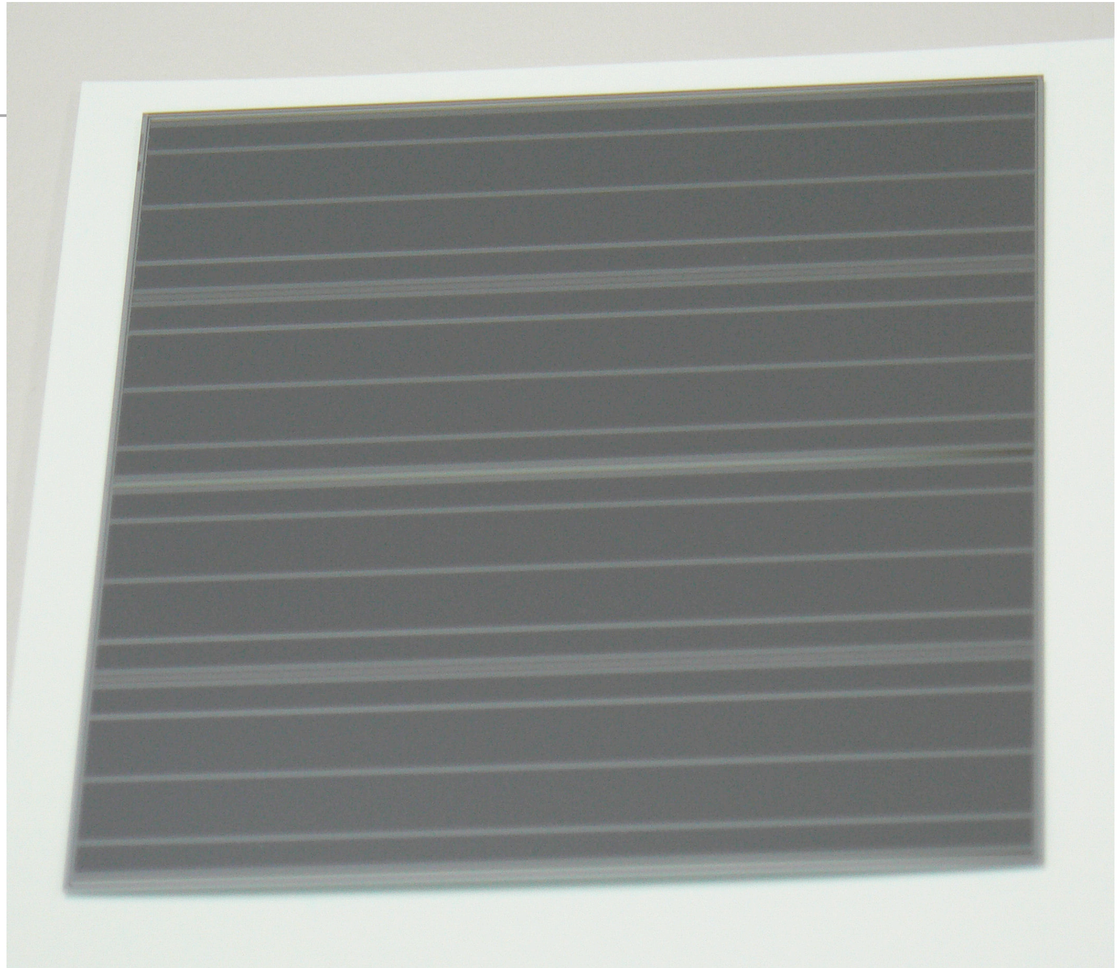
- Tuning the optical communication parameters to the modules.
- Setting up redundant control as necessary.
- Running the full detector (except for the 2 cooling loops)
- Put in global run starting 3 September. Working on trying to solve remaining issues with running at high rate.
- Trying to run stably overnight for monitoring
- Plan is to run with lower voltage originally.
- Getting ready for beam!

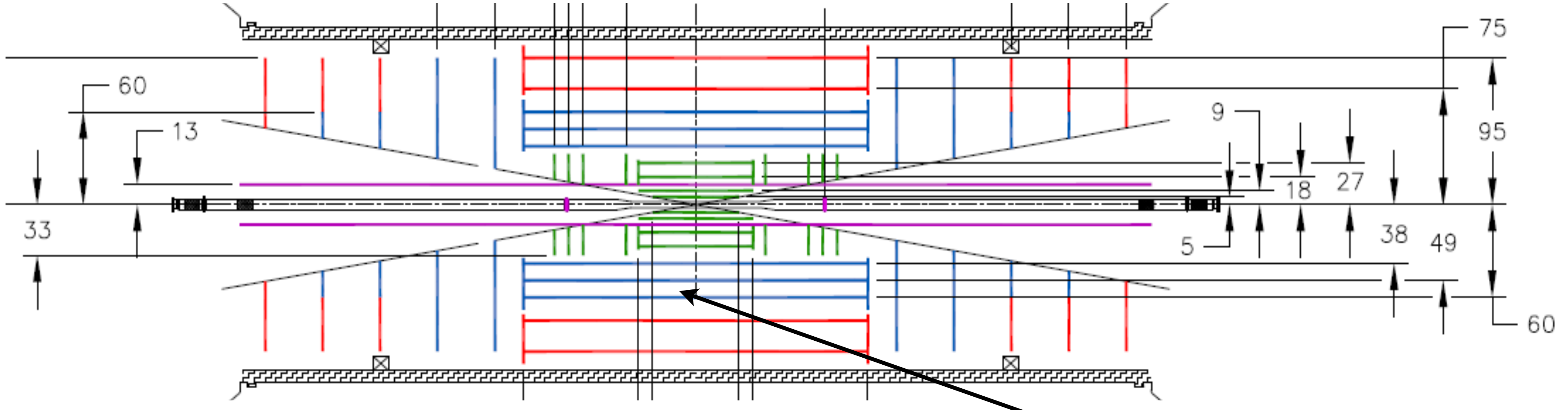
The Super LHC

- The Super LHC (SLHC), planned to start in 2018, will have a peak luminosity ten times that of the LHC
- The TRT would have too high of an occupancy; increased SCT occupancy would degrade performance.
- The SCT and Pixel detectors would have suffered radiation damage.
- Therefore, a new Inner Detector is need.
- Current plan is for an all-silicon system consisting of (in the barrel)
  - 4 pixel layers (instead of the current 3)
  - 3 layers of short strips (25 to 35 mm)
  - 2 layers of long strips (90 to 120 mm)
- More radiation-hard n-in-p sensors.

Short Strips in the Straw Man Proposal

- To the right is an n-in-p sensor made by Hamamatsu with 4 rows of 23.8 mm strips
- 1280 channels per row
- Includes both axial strips (74.5 µm pitch) and 40 mrad stereo strips (71.5 µm pitch)
- 130 detectors were ordered last year

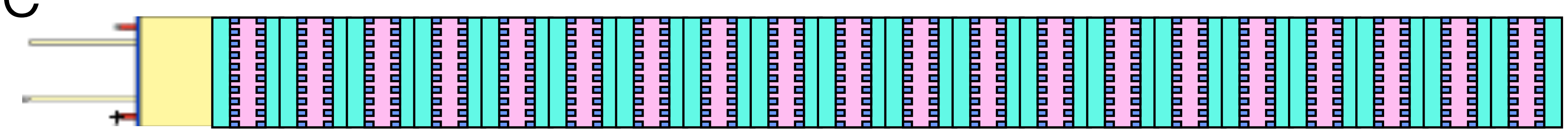




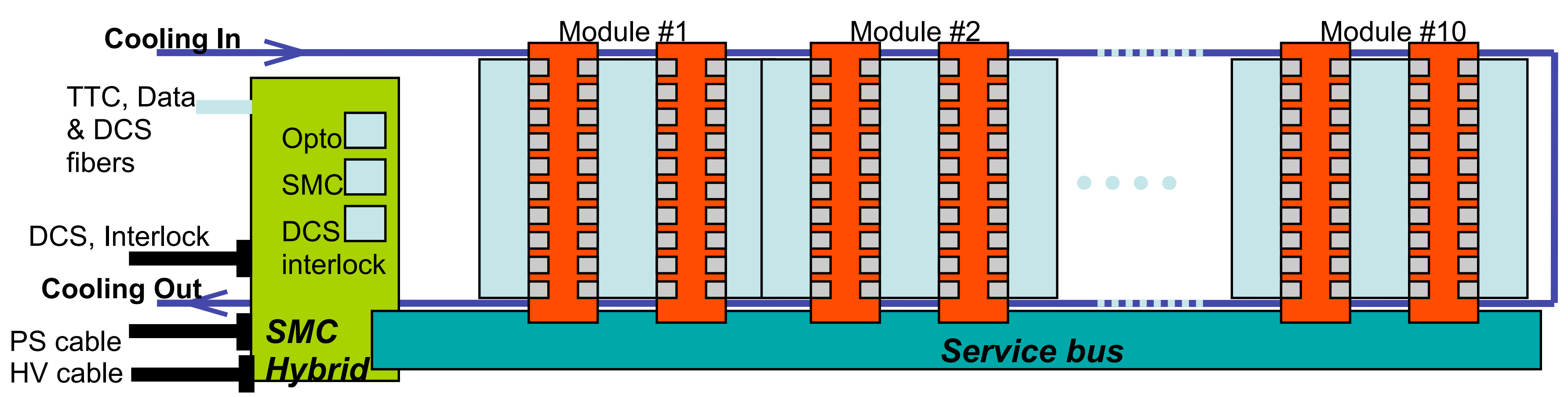
Module Integration

- Plan is to combine multiple modules into a *supermodule* or *stave*
- Will allow for simpler assembly with more work going on in parallel
- Potentially easier replacement of faulty modules

Stave

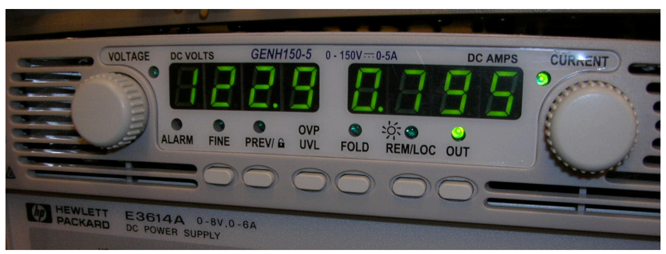


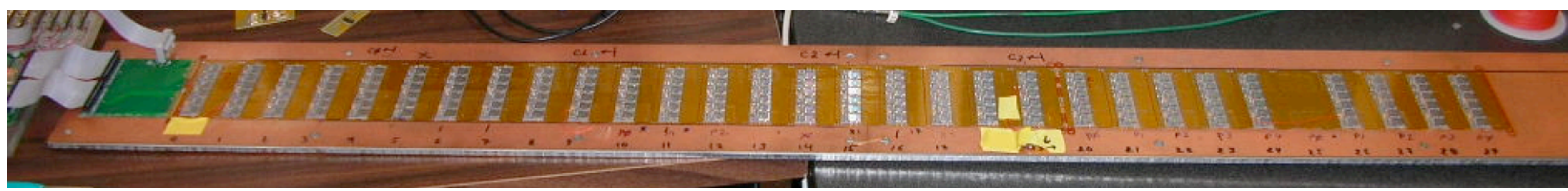
Supermodule



New Power Distribution Scheme

- Current independent power scheme is not scalable enough for the SLHC.
- One potential scheme is to have serial power, where the modules are fed in series, and each module steps down the voltage. The prototype below supplies 30 hybrids with 4V by providing 120V to the chain.





- Another scheme, DC-DC, sends higher voltage, which needs to be stepped down at the module.
- HV distribution options include:
  - Decrease granularity, and allowing for faulty sensors to be bypassed.
  - local HV generation with a step-up transformer.

Other Issues

- Deep submicron front end ASIC, the ABCD-N, supporting n-in-p sensors, increased bandwidth, and the various power schemes is being designed.
- Cooling capacity will have to be increased, so there are proposals to change to CO_2 cooling.

SLHC Conclusion

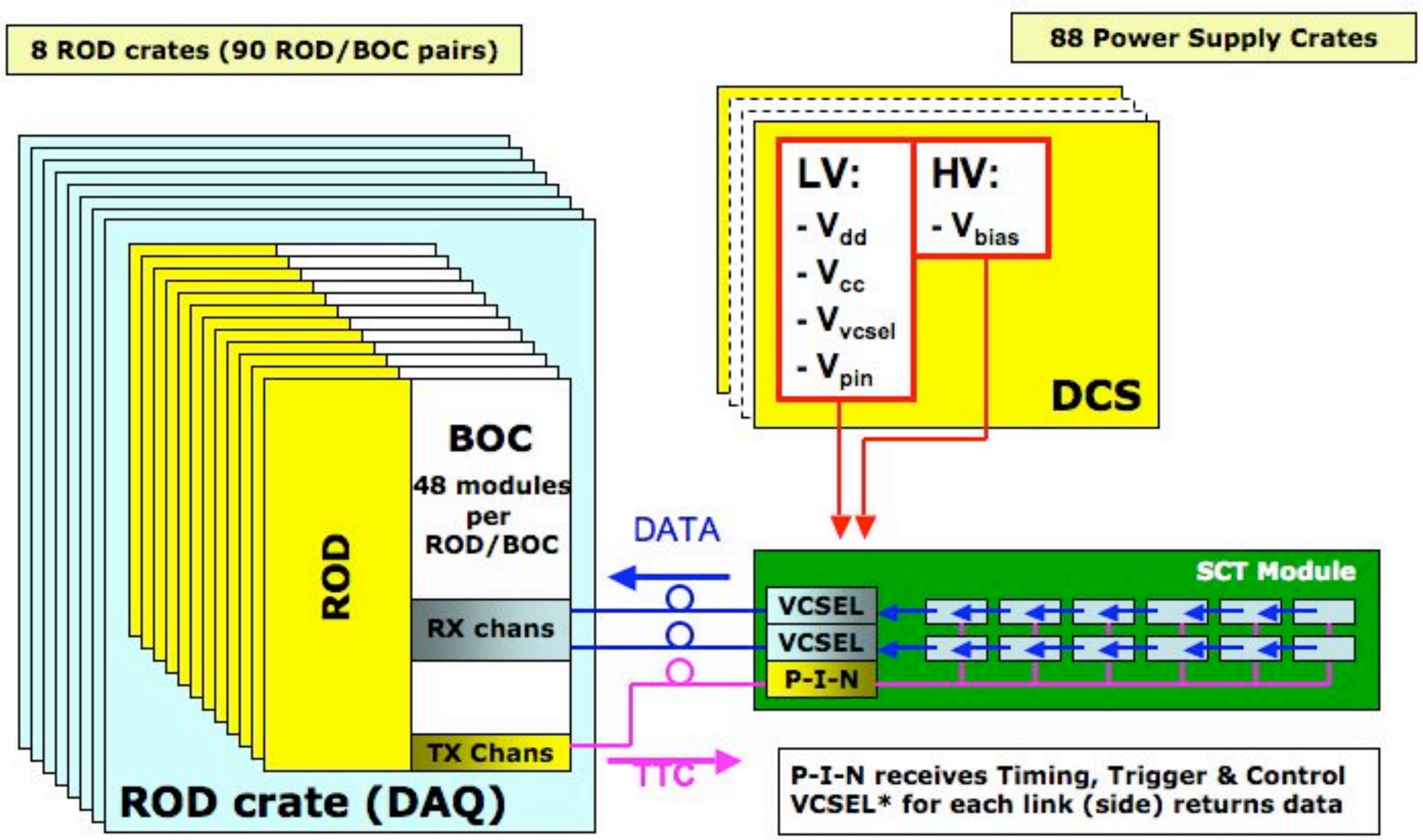
- There have been yearly workshops working on the upgrade starting from 2005.
- 10 countries are working on the upgrade of the tracker.
- Nevertheless, even though the LHC is only now starting, 2016 or 2018 is not far away, so the schedule is very tight.

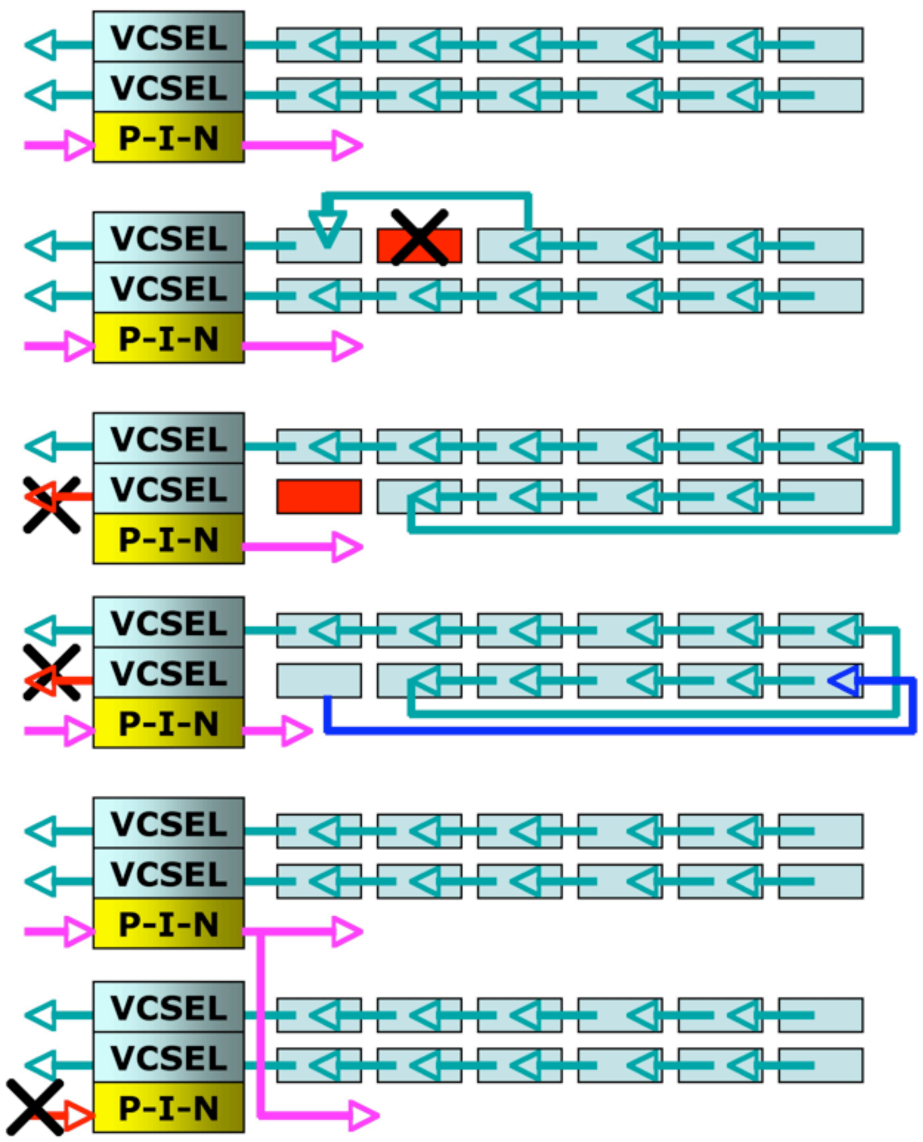
Looking Forward

- In six days (10 September) the LHC will attempt to circulate beam.
- A week or two later the plan is to have 900 GeV collisions.
- 10 TeV collisions afterwards.
- Lots of work my many people has gone into getting the machine and the detectors ready.
- Very exciting time is coming up, requiring lots of effort by many people.
- (But it is not too early to think about the SLHC upgrade.)

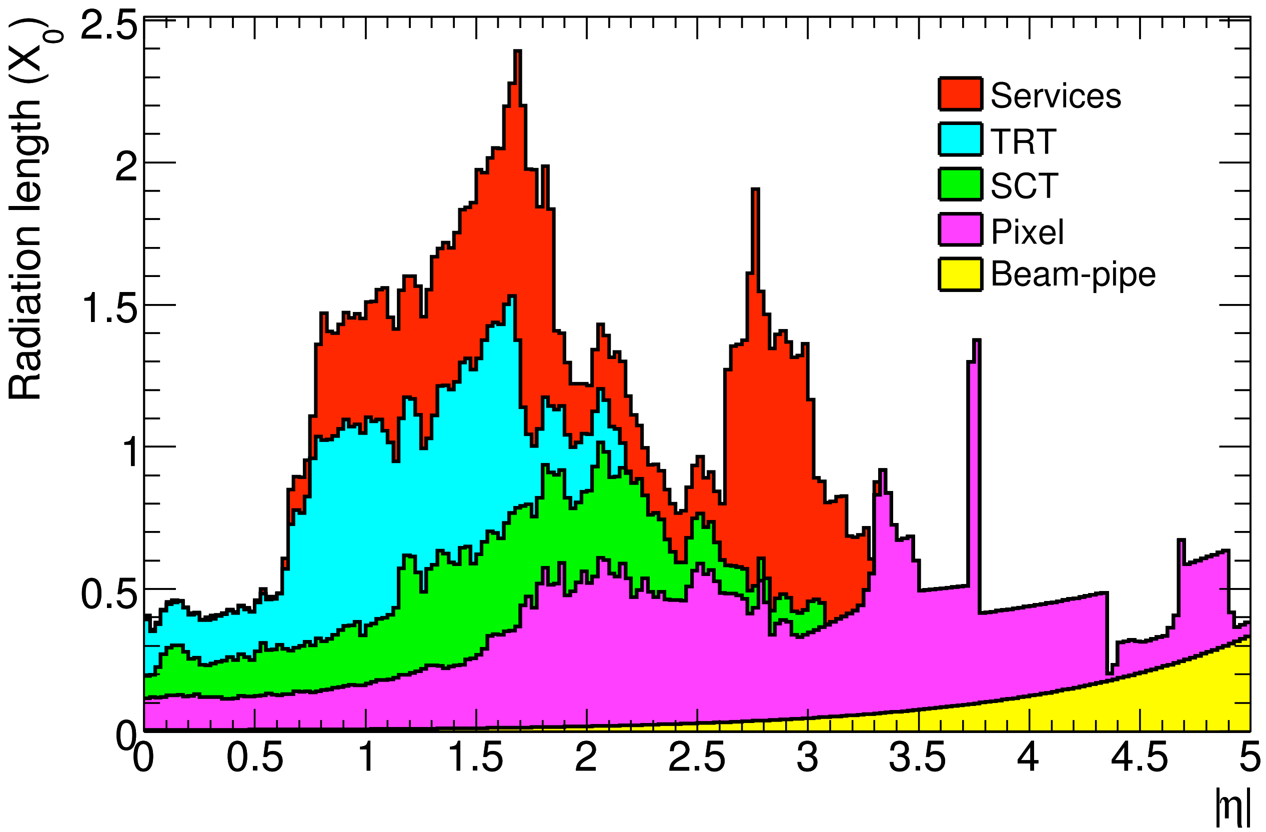
Backups

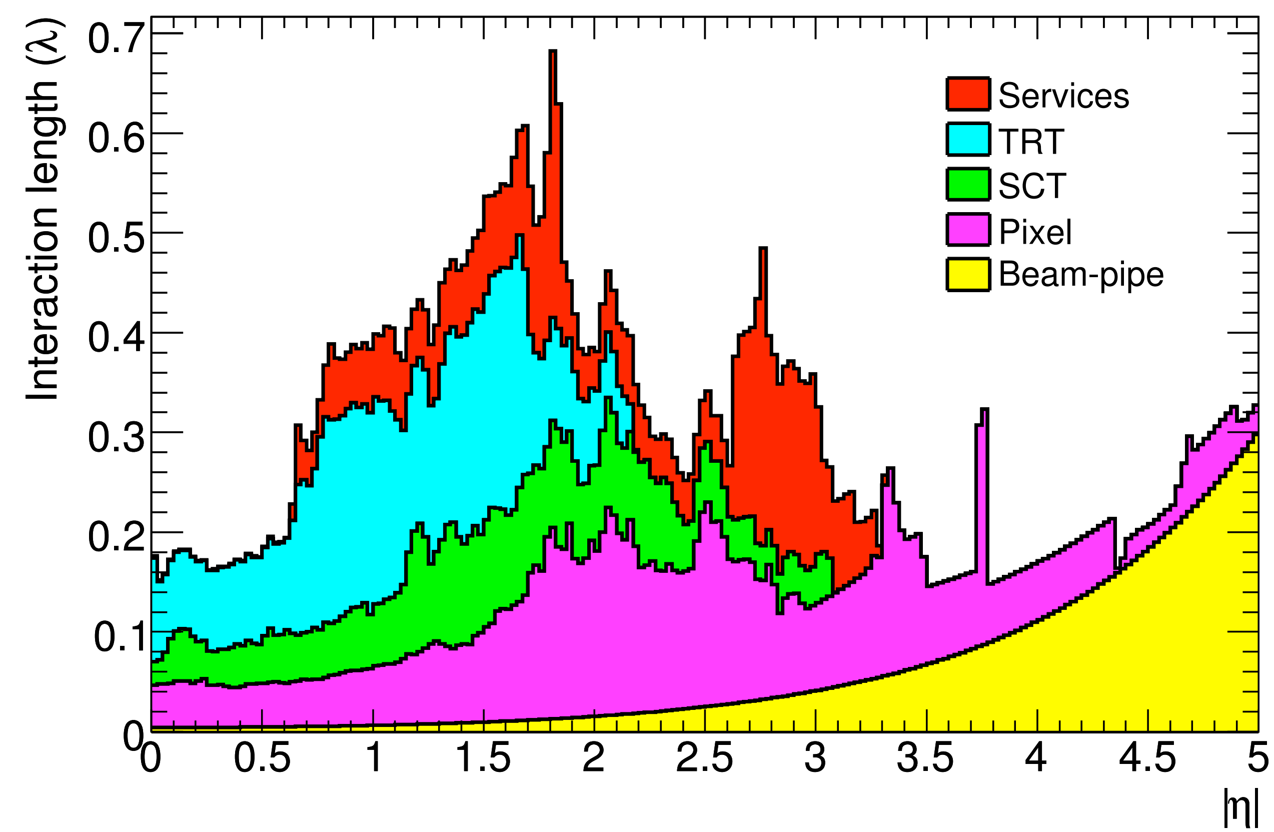
Module Communication





Radiation and Interaction Lengths

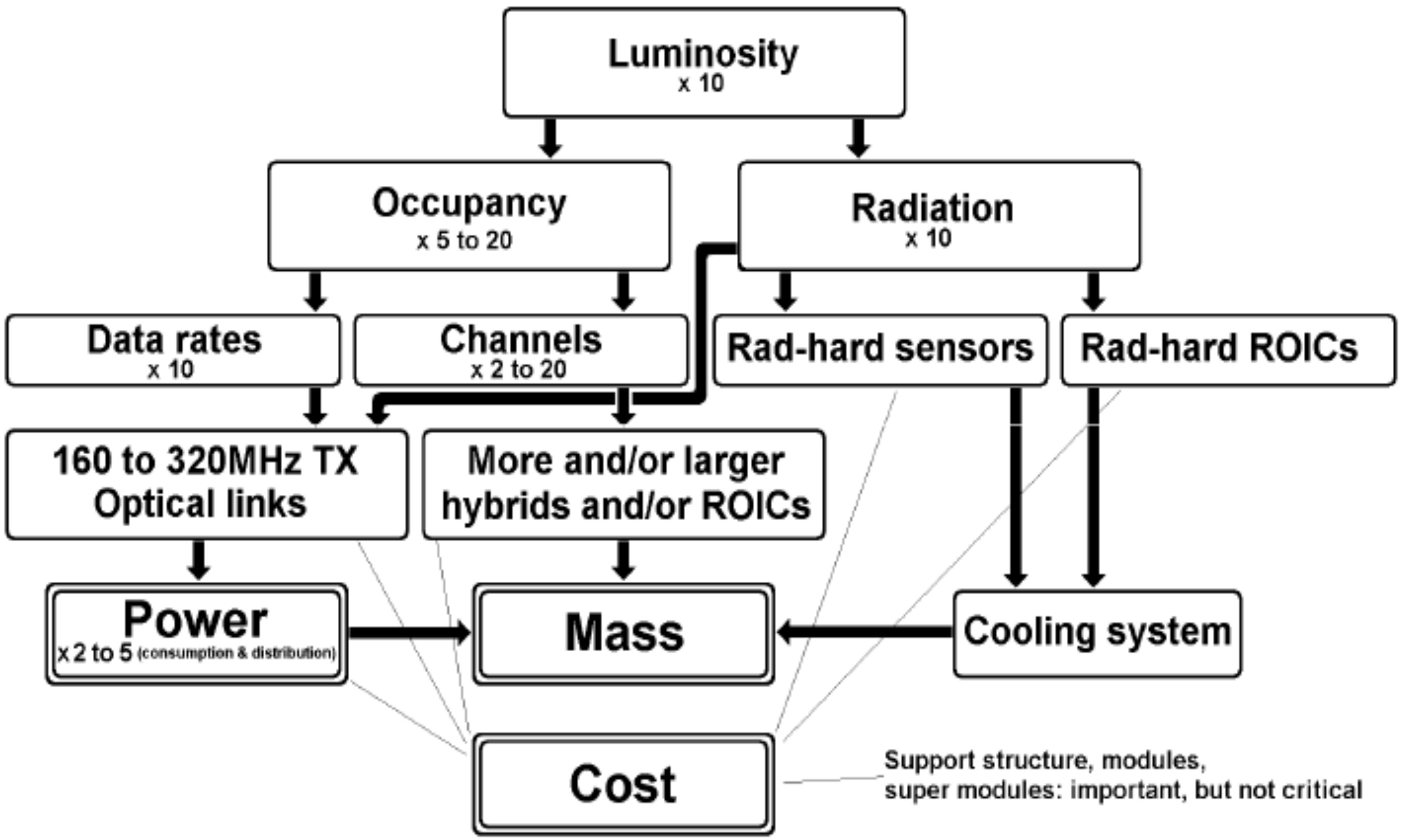




Performance Requirements

- 95% efficiency for isolated leptons with $p_T > 5$ GeV, $|\eta| \leq 2.5$
- momentum resolution better than 30% at $p_T = 500$ GeV
- track to vertex z-coordinate with better than 1 mm
- two-track resolution better than 200 μm at 30 cm radius
- no more than 20% X_0 total
- able to withstand a dose of 2×10^{14} 1 MeV-neutron-equivalent / cm^2

The Inner Detector at the SLHC



from M. Weber