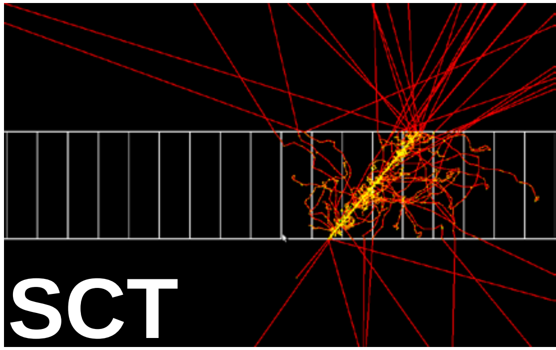
Risks Management in Detector Construction and Operation
A tool we should start using more of

Science & Technology Facilities Council



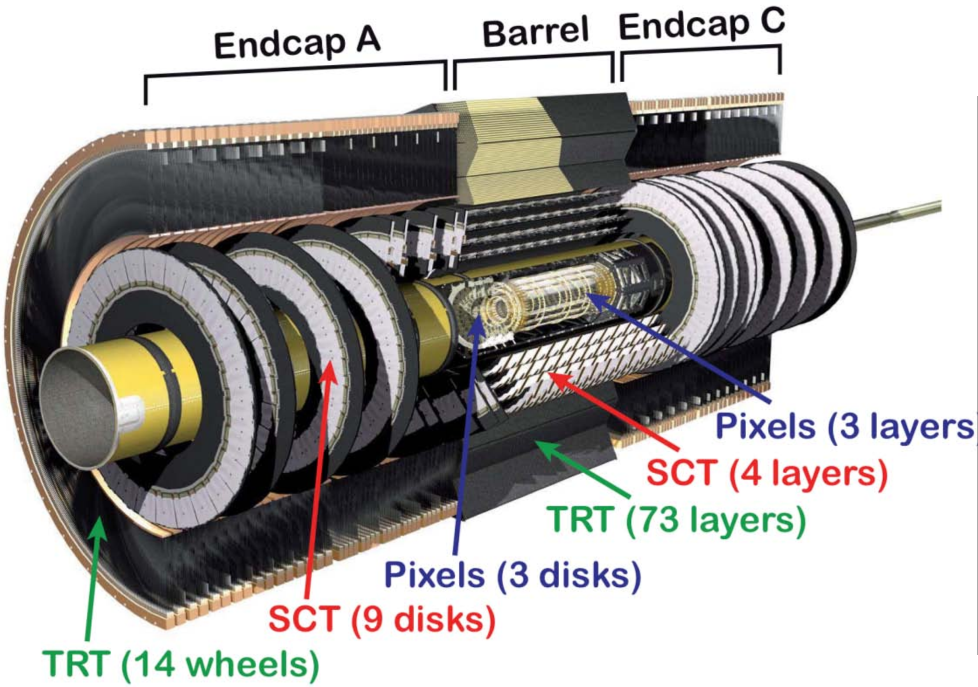
Steve McMahon

RAL

Wednesday 4th July 2011

Forum on Tracker Mechanics at CERN

The Semi-Conductor Tracker inside the ATLAS ID



Some SCT Facts & Figures

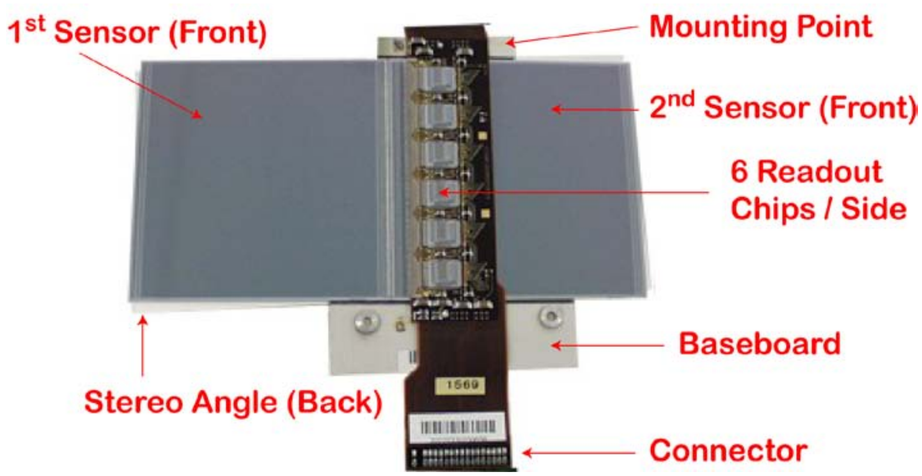
Barrel	4 layers 2112 modules
End-Caps	2 x 9 disks 1976 modules
Coverage	30 cm < r < 52 cm $\|\eta\| < 2.5$
Active Material	61 m^2 silicon
Readout	6.3 $\times 10^6$ channels

Some SCT Operational Parameters

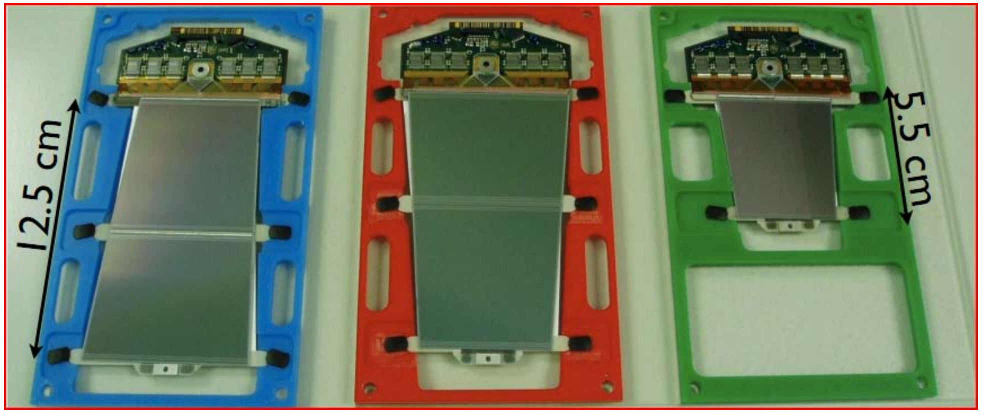
- 150 V reverse bias voltage ($U_{standby}$ = 50 V)
- Binary Readout with 1 fC/hit threshold (standard setting)
- 3 time bin readout (25ns / bin = LHC clock)
- C_3F_8 cooling: -7°C to +4.5°C (temp on the surface of silicon)

The SCT Modules (The basic detector unit)

- **Sensor Paramaters**
  - 770 (768 bonded) p-strips on n-type silicon
  - 80 μm pitch (B)
  - 285 μm thick
  - 4(2) single-sided sensors glued back-to-back
  - Stereo angle of 40 mrad
  - 83 % Hamamatsu, 17 % CiS
- **Sensor Length**
  - 12 (2x6) cm (B), 6-12 (1or2 x 6cm) cm (ECs)
- **Resolutions**
  - ~17 μm(rφ, bending plane), ~580 μm (z)
- **Baseboard**
  - Thermal Pyrolitic Graphite
  - Mechanical & thermal structure
- **Readout**
  - Rad-hard front-end readout chips (ABCD)
  - 6 chips/side, 128 channels/chip
  - 48 modules served by 1 ROD
  - 11 (12) RODs send data to 1 Atlas ROS
  - TIM provides trigger signal & clock

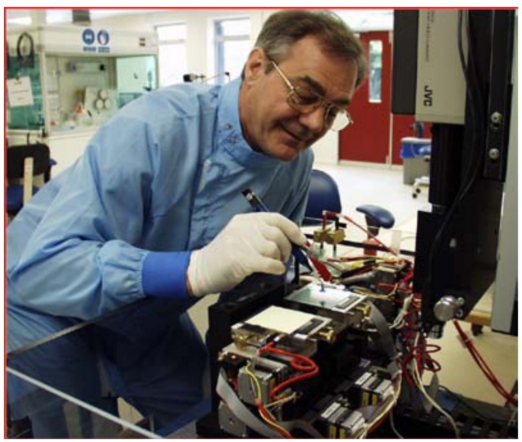


Barrel Module



End Cap Modules

Making Barrel Modules in R12 at RAL (one production site)



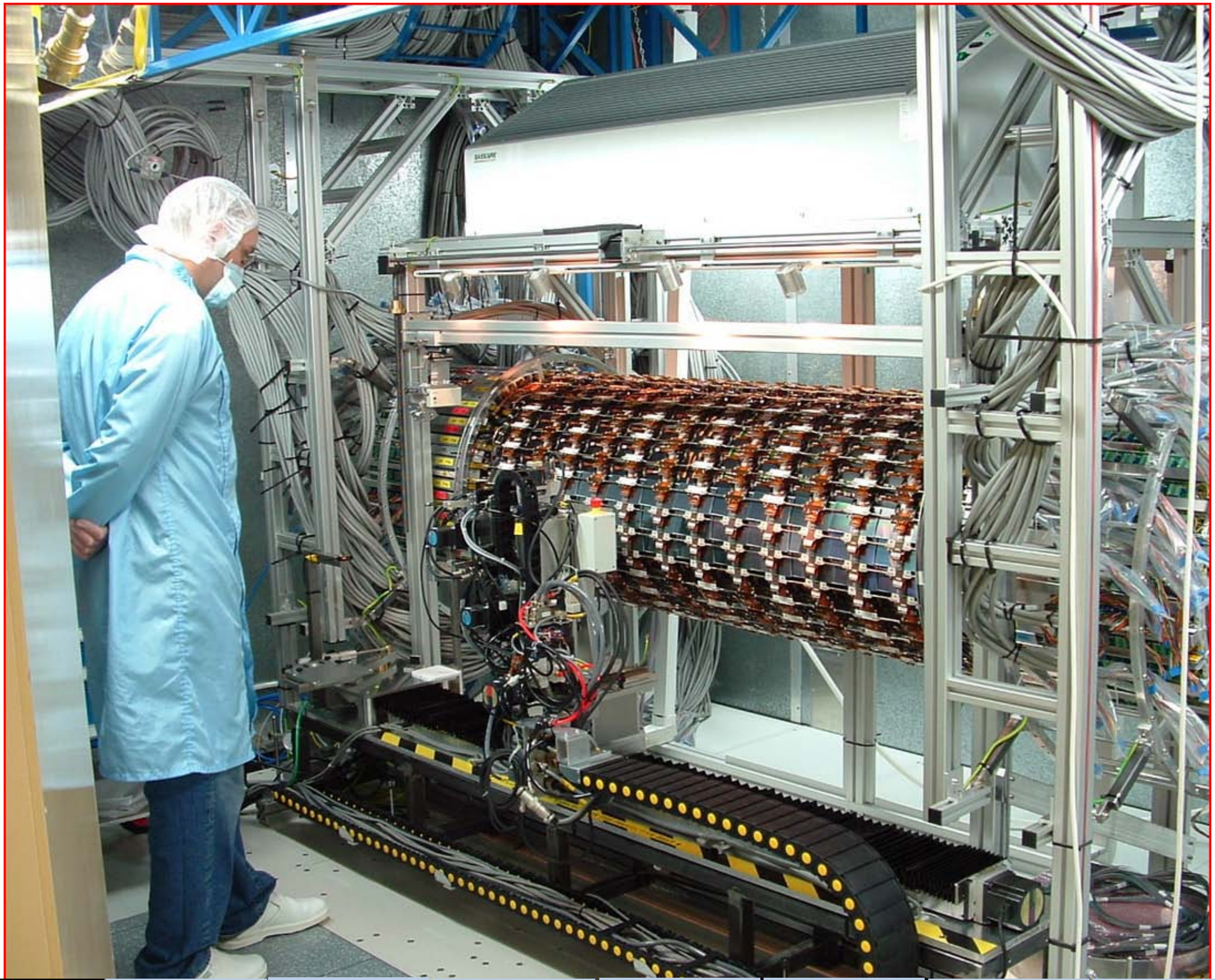
Sensor alignment

Hybrid Mounting

Wire Bonding

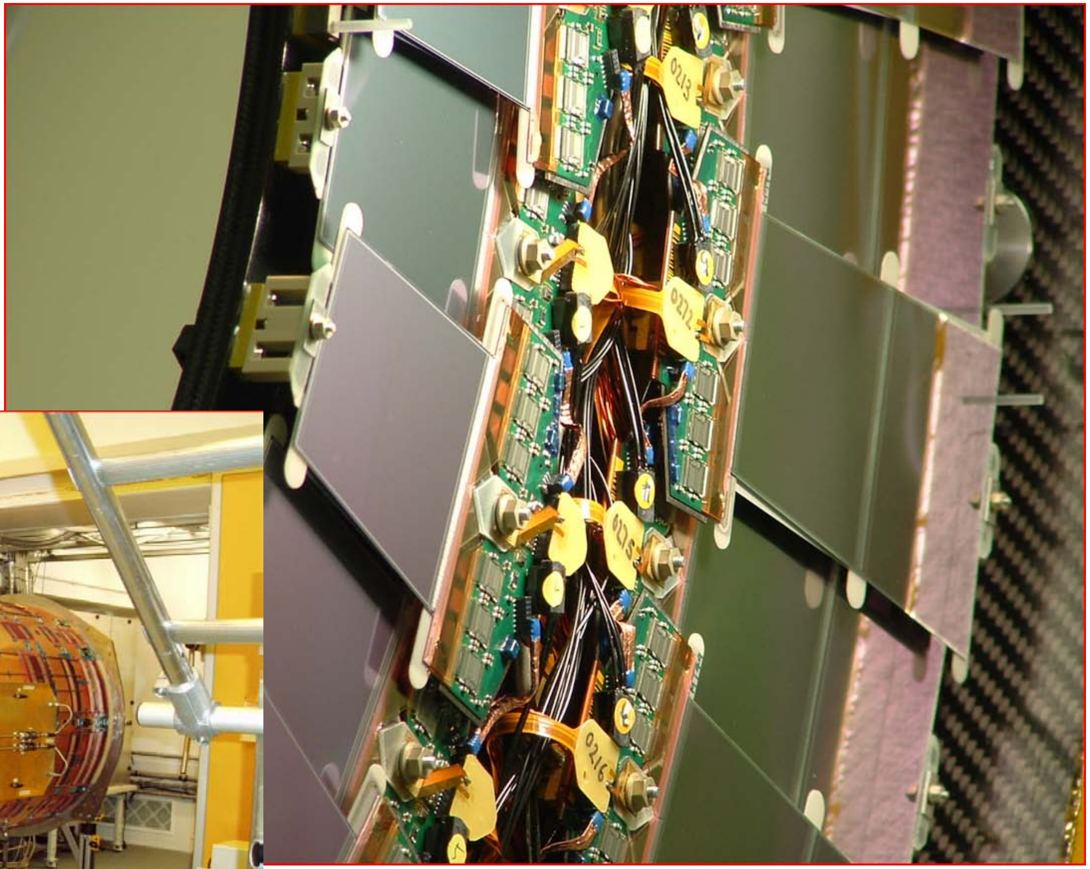
2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

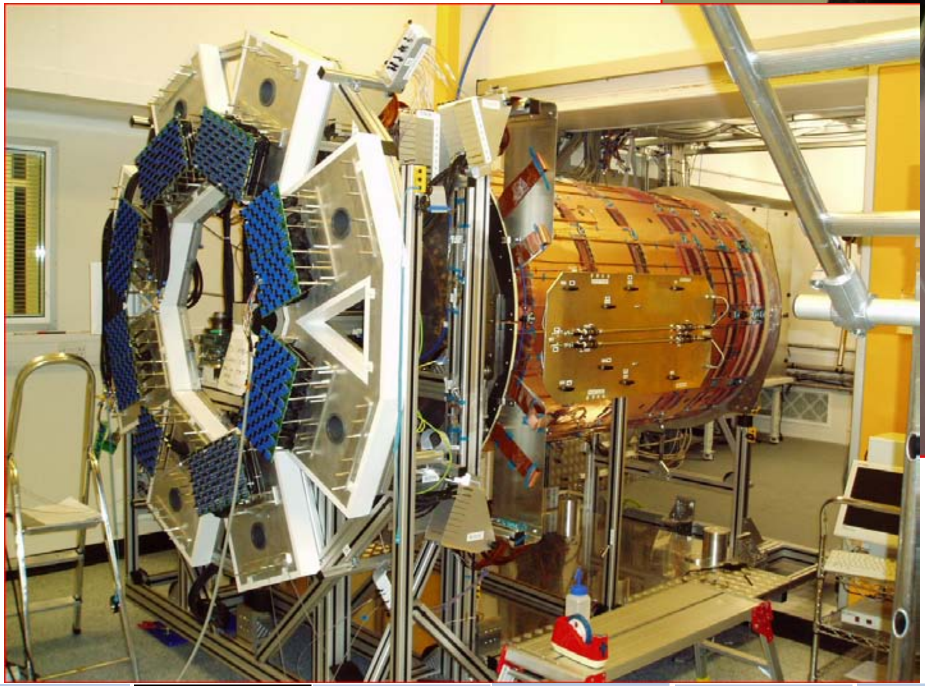
Mounting Modules to Barrels in Oxford



2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

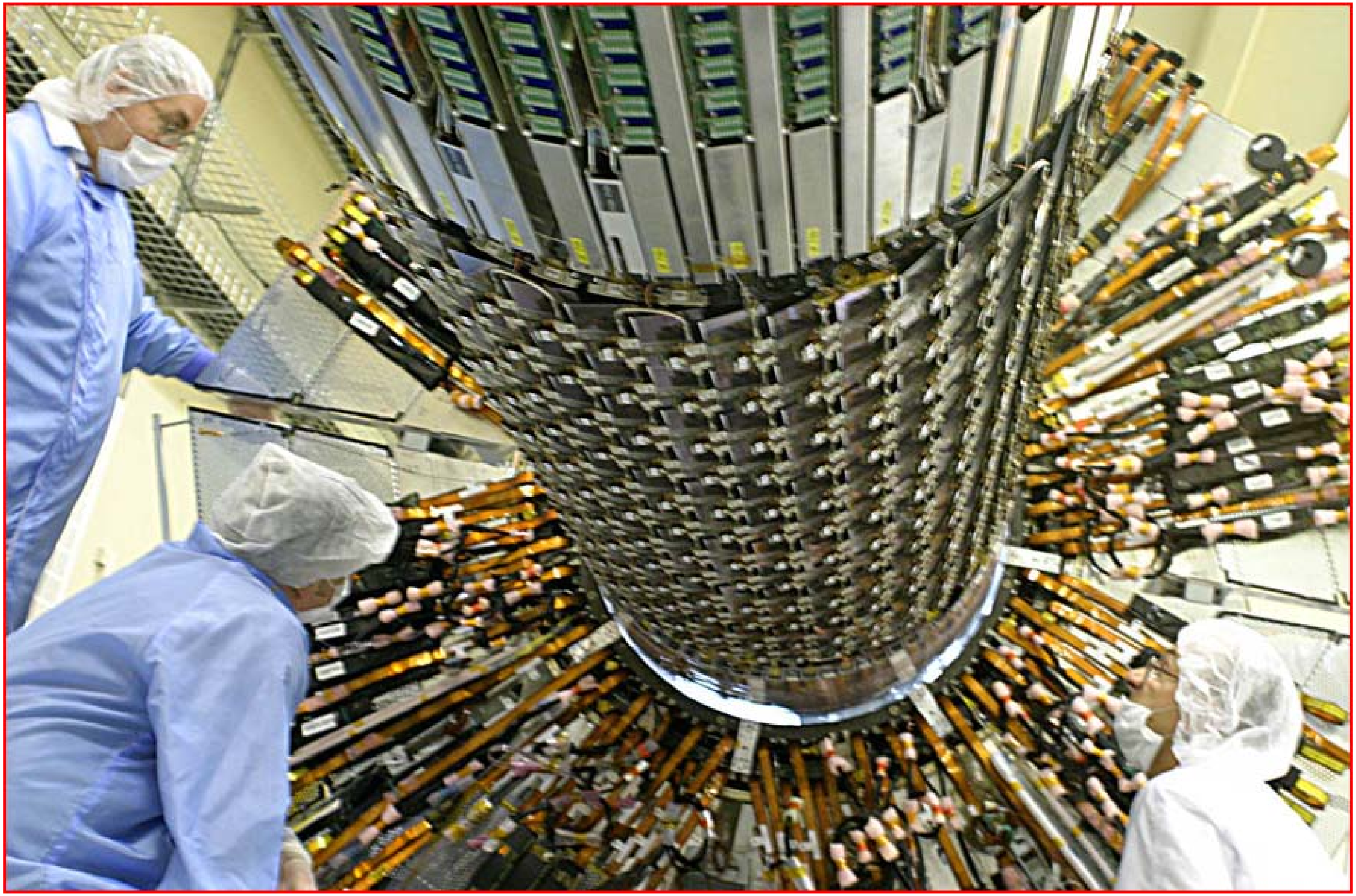
End-Cap-C construction in Liverpool (ECA in Nikhef)





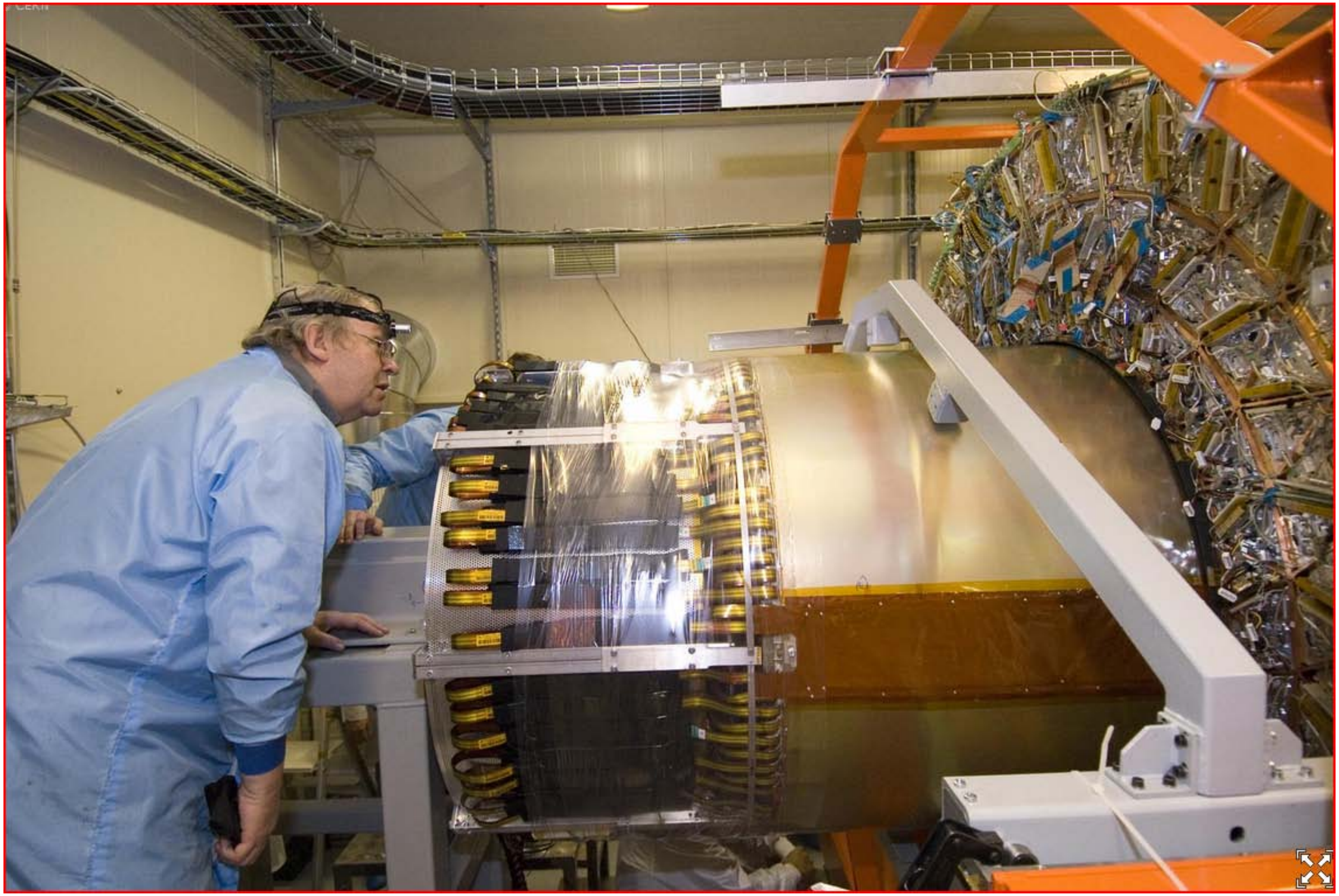
2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

Integration in SR1 (surface building at CERN)



2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

Inserting the Barrel into the TRT



2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

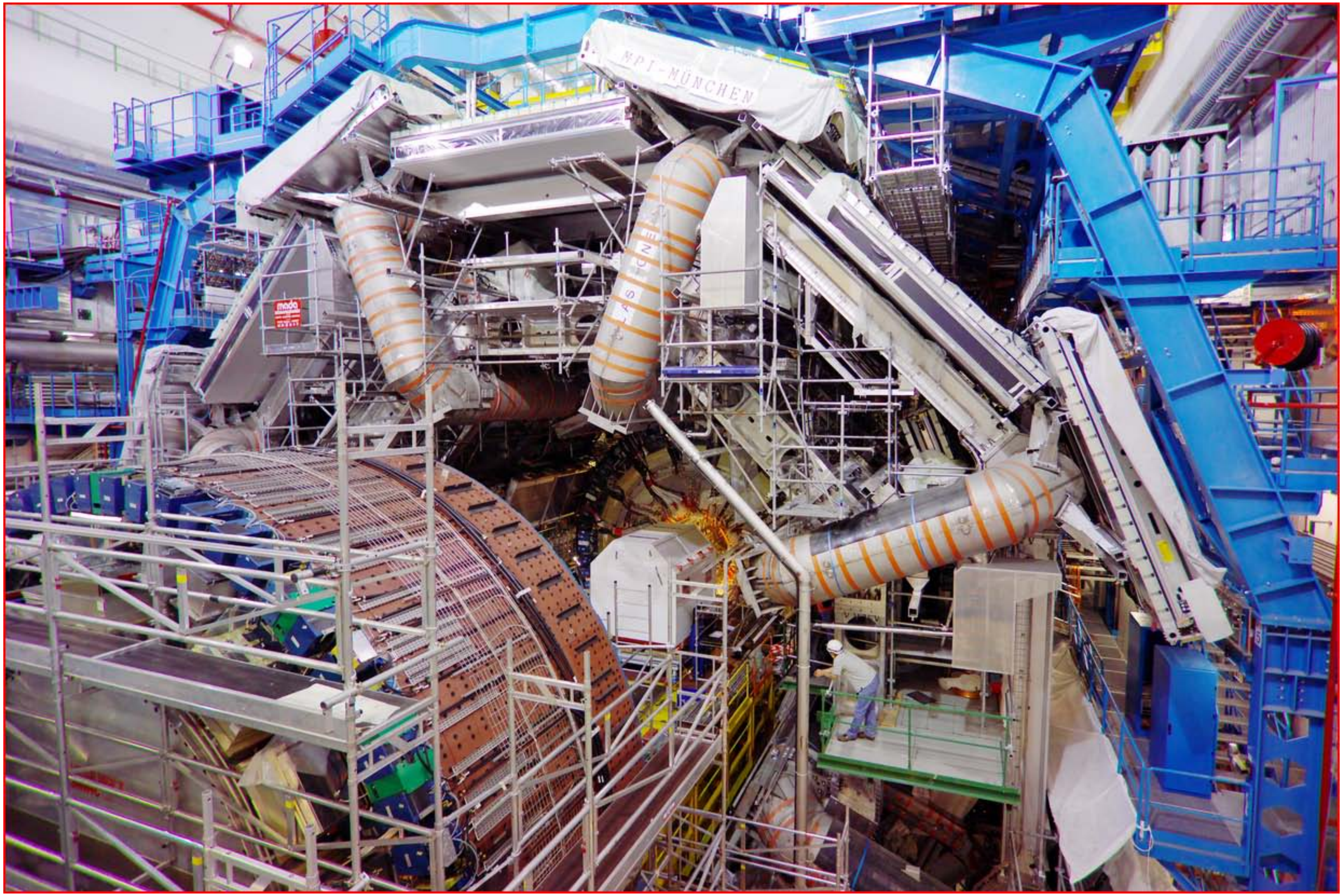
Preparing the Barrel for the Cryostat

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

Mounting Barrel to Cryostat

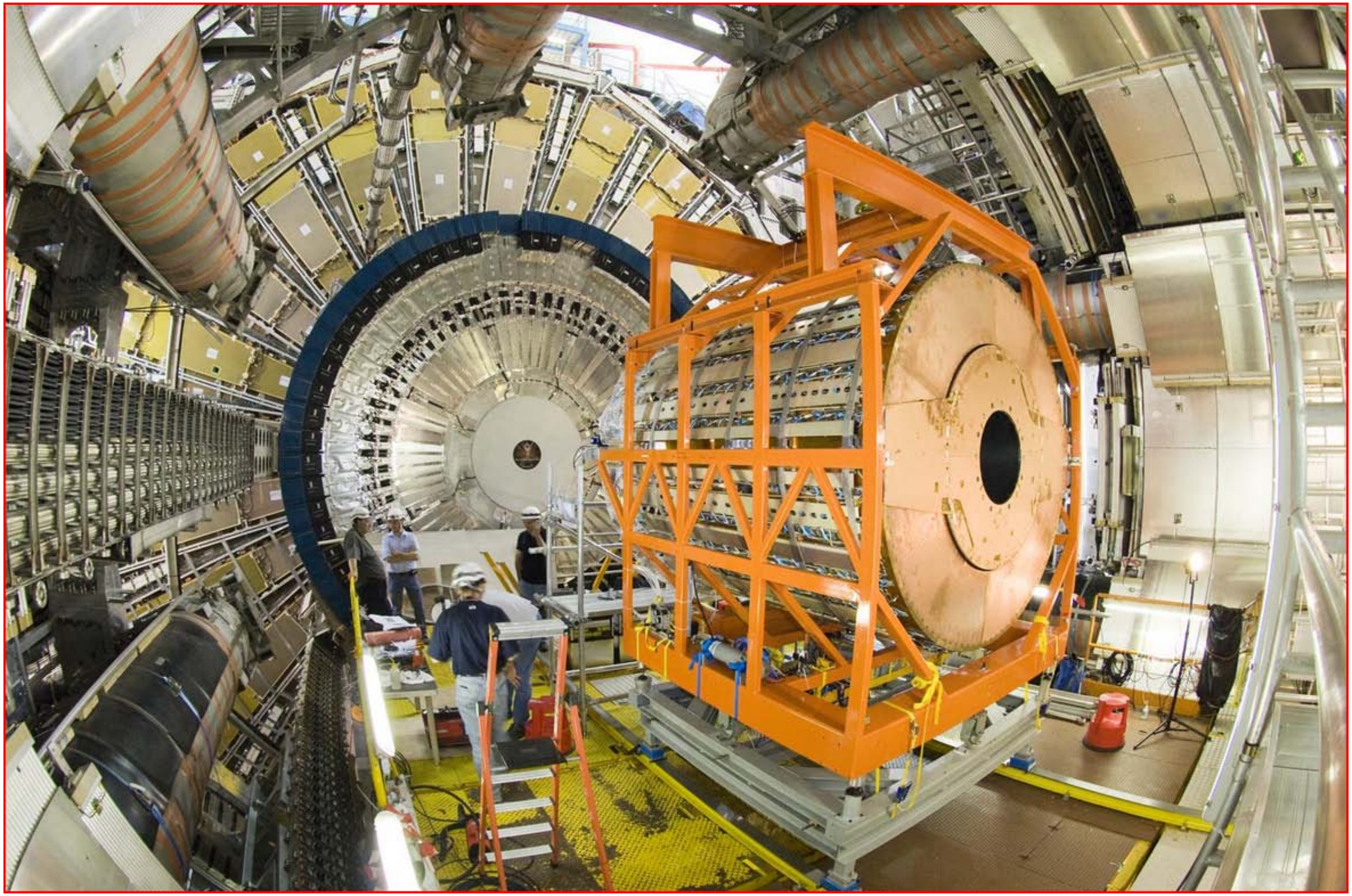
2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

Setting the scale of ATLAS



2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

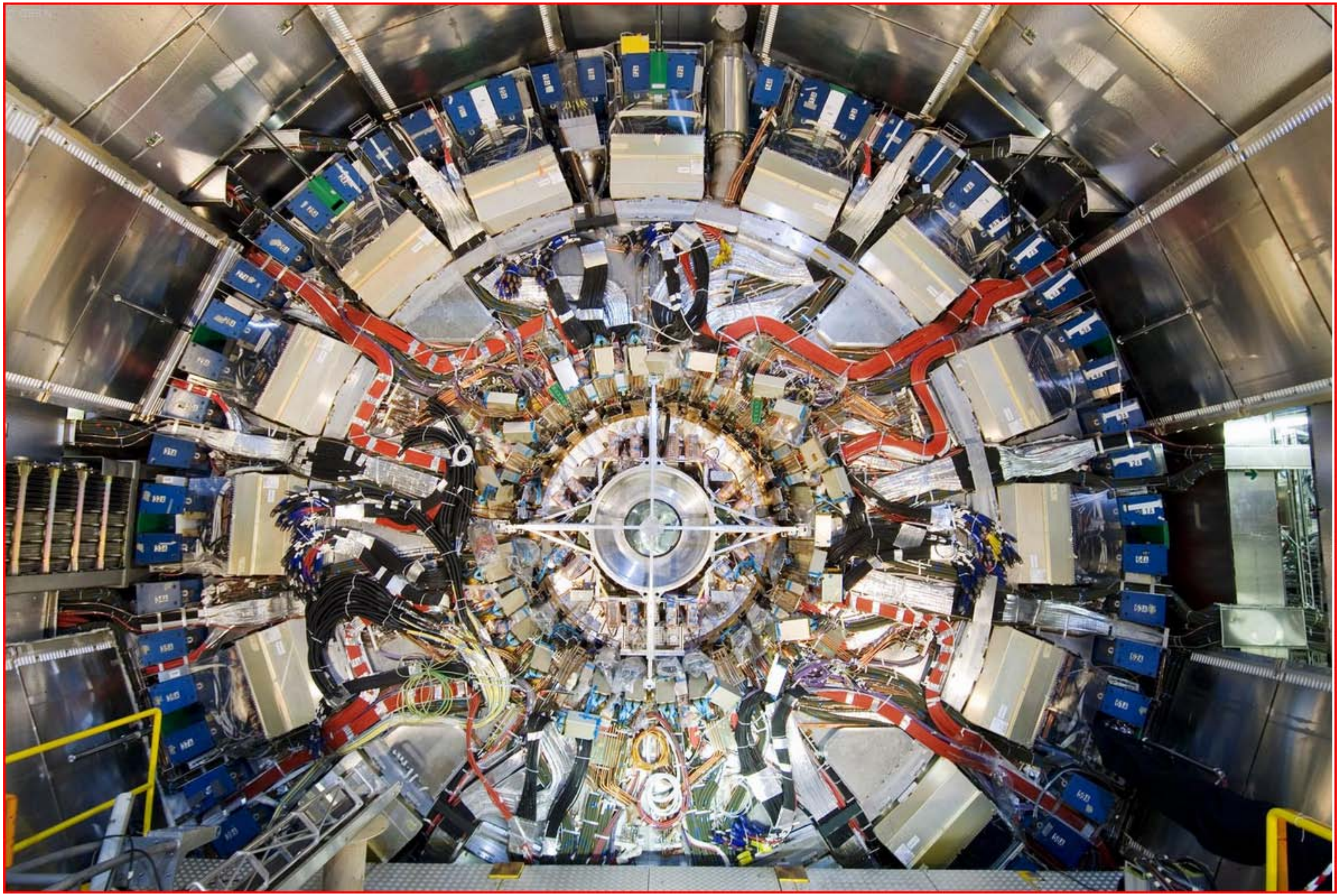
Mounting End-Caps into the Cryostat



2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

Finished : The view at the end of the ID

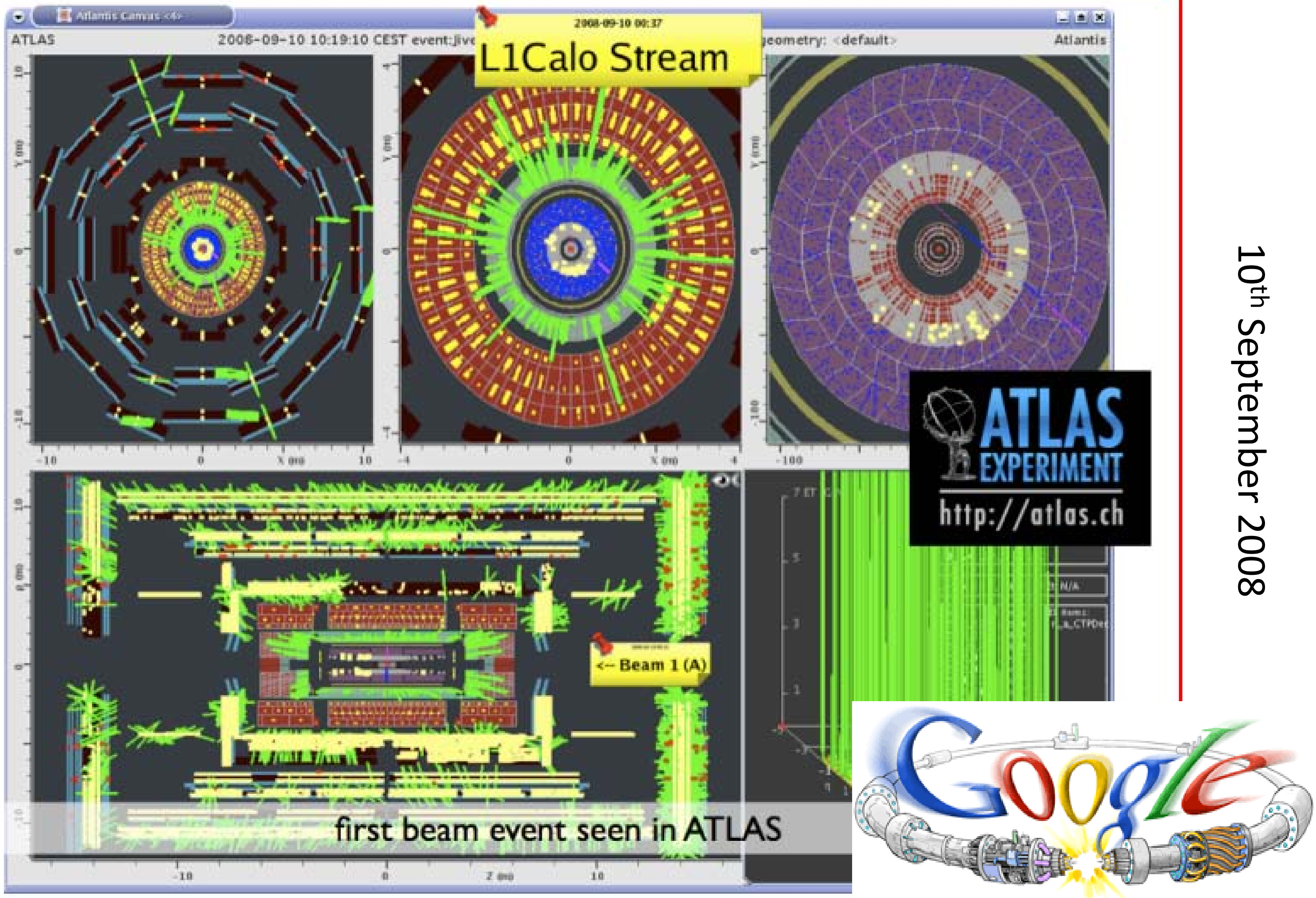
> 40,000 cables Installed on both sides



30th May 2007

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

First Beam Splash Events in ATLAS



10th September 2008

2003 2004 2005 2006 2007 **2008** 2009 2010 2011 2012

Friday 19th September 2008 : The catastrophe

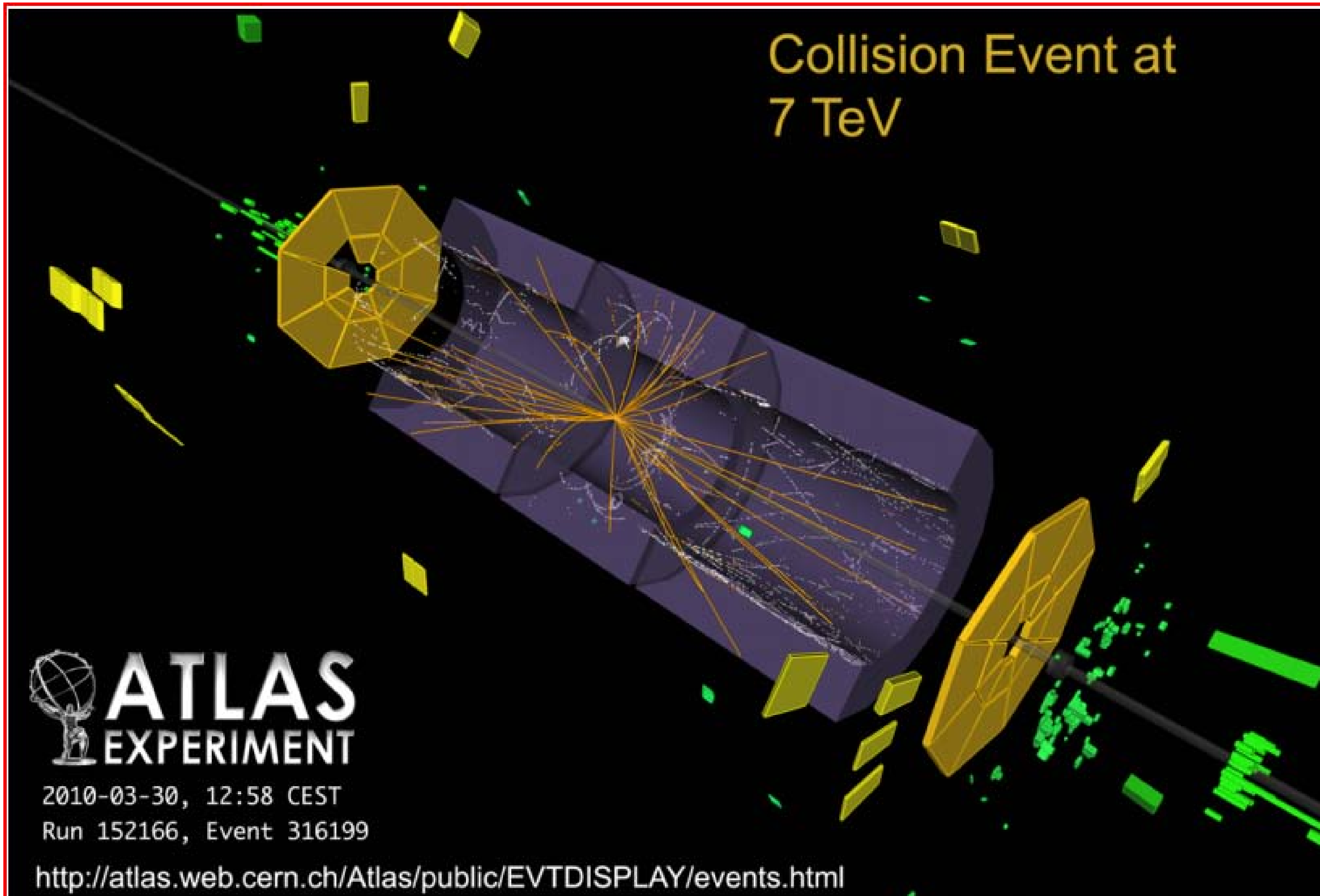
19th September 2008

2003	2004	2005	2006	2007	**2008**	2009	2010	2011	2012

First Collisions in ATLAS

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

First Collisions 7TeV collisions in ATLAS



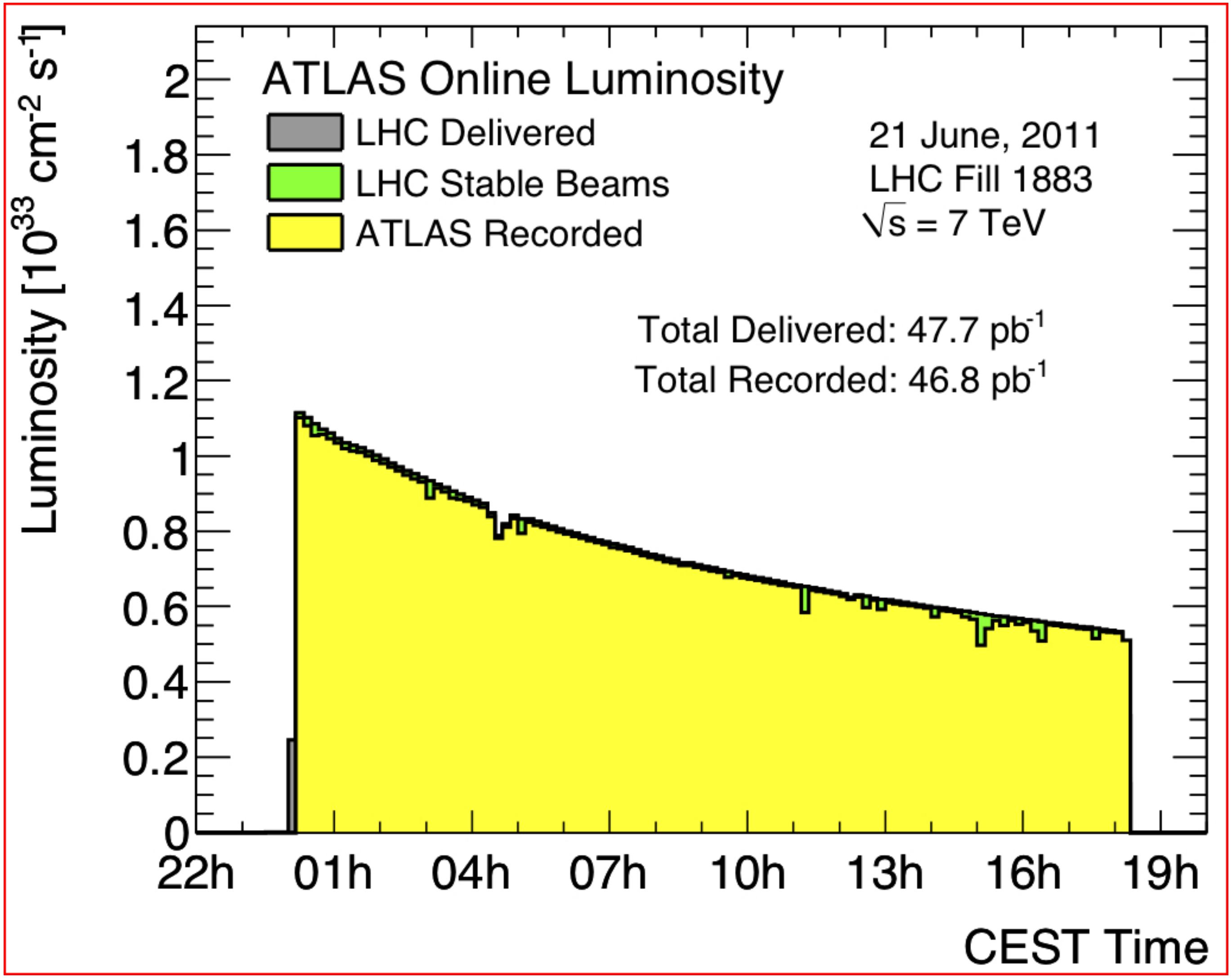
30th March 2010

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

First Collisions 7TeV collisions in ATLAS

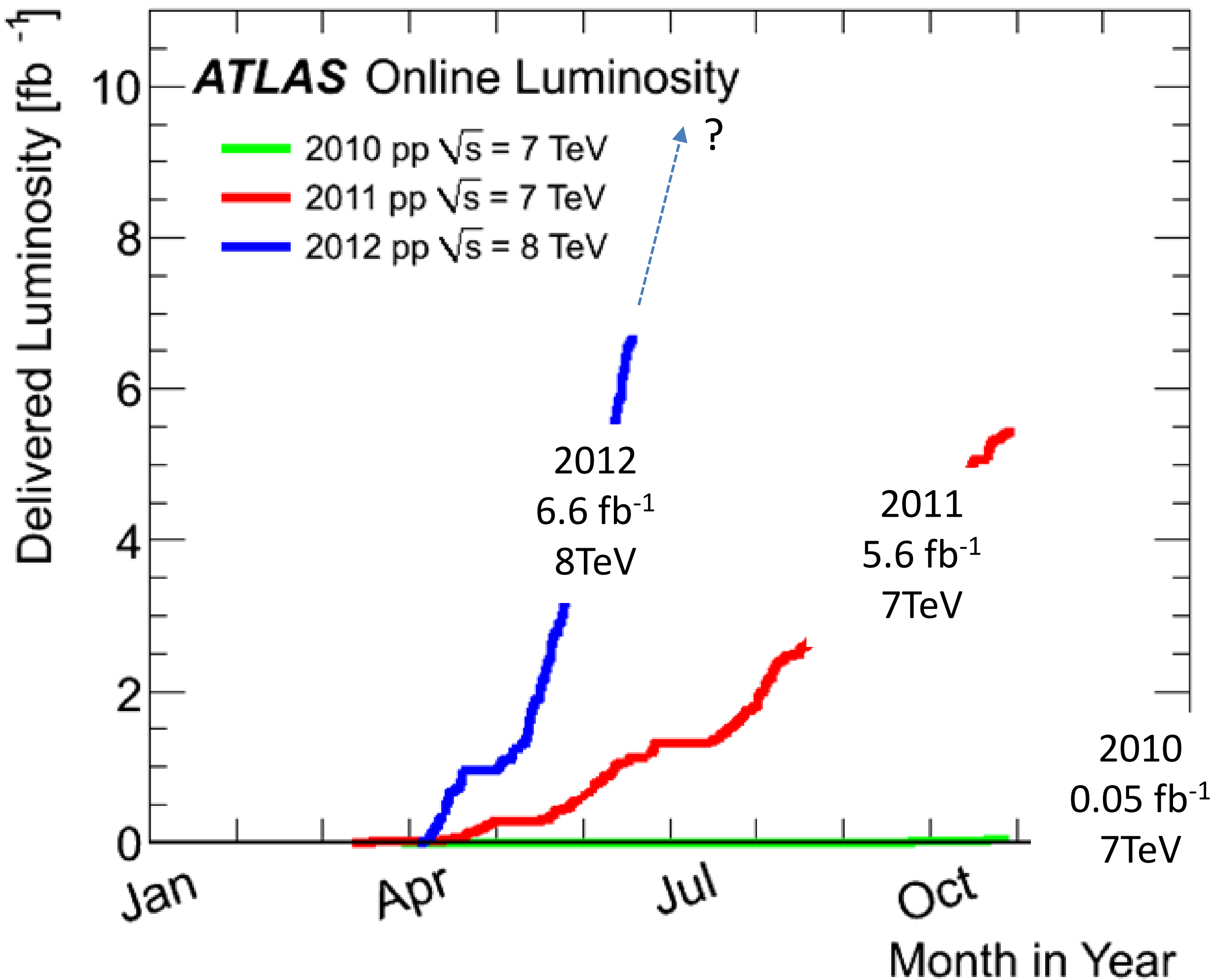
2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

Integrating luminosity in 2011



2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

Integrating luminosity in 2012



2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

The SCT Detector Configuration (snapshot in 2012)

Modules out of the physics configuration

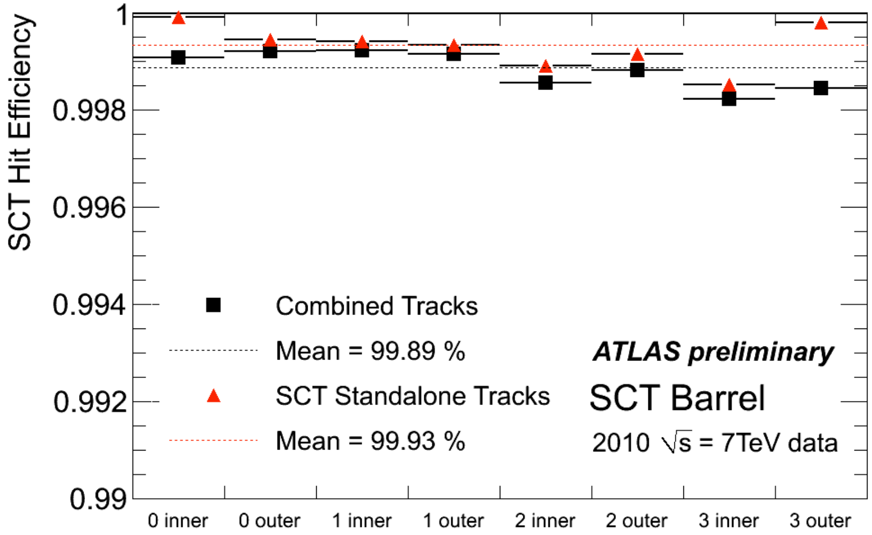
	Endcap A	Barrel	Endcap C	SCT	Fraction (%)
Total	5	10	15	30	0.73
Fraction (%)	0.5	0.2	1.5	0.7	
Cooling	0	0	13	13	0.32
LV	0	6	1	7	0.17
HV	4	1	1	6	0.15
Readout	1	3	0	4	0.10

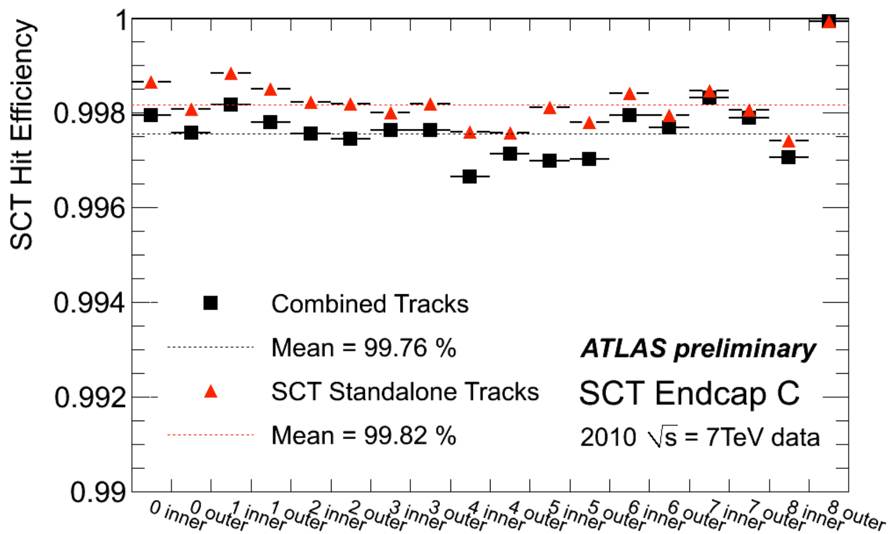
Disabled Readout Components	Endcap A	Barrel	Endcap C	SCT	Fraction (%)
Disabled Modules	5	10	15	30	0.73
Disabled Chips	5	24	4	33	0.07
Masked Strips	3,364	3,681	3,628	10,673	0.17
Total Disabled Detector Region					0.97

2003 2004 2005 2006 2007 2008 2009 2010 2011 **2012**

SCT Intrinsic Silicon Efficiency

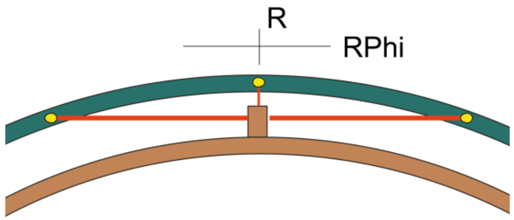
- Efficiency =
  - # of hits / # of possible hits (on tracks)
  - Dead modules & chips accounted for
- Barrel: all layers
  > 99.8% efficiency
- End-Caps: all disks
  > 99.6% efficiency
- Time stability: ± 0.1 %
  - Above design spec of 99.0 % efficiency

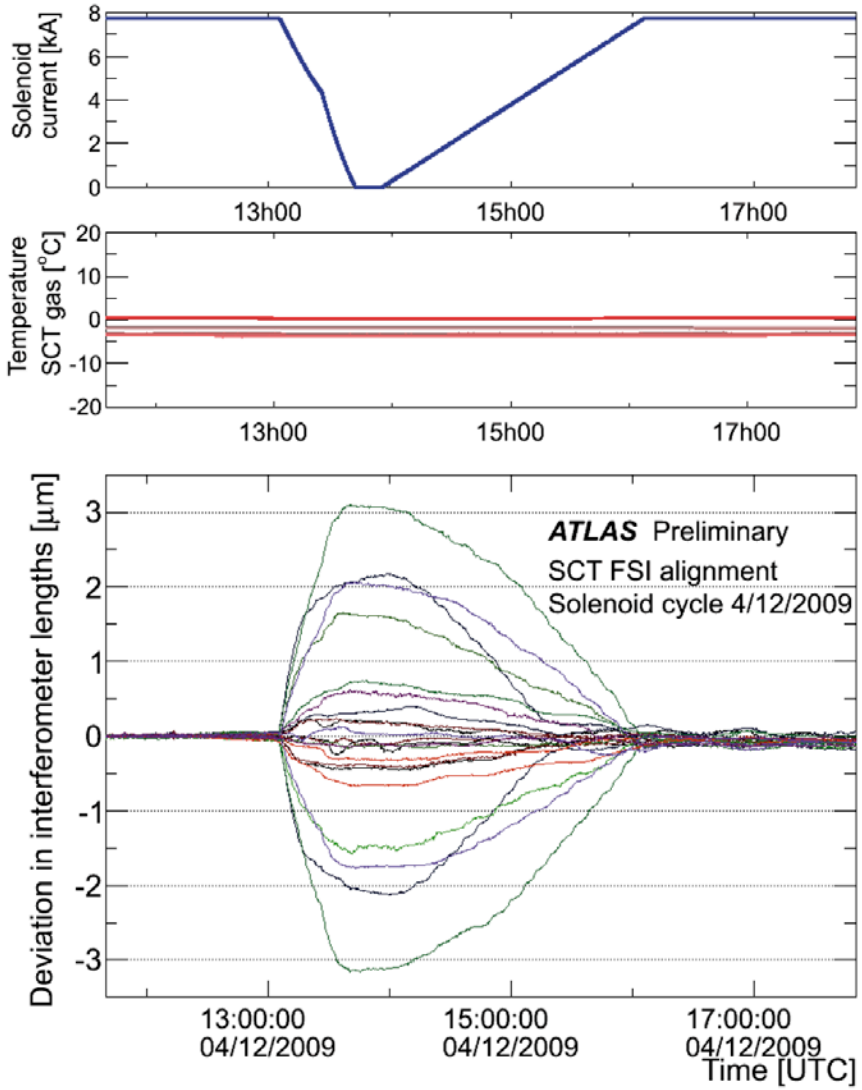




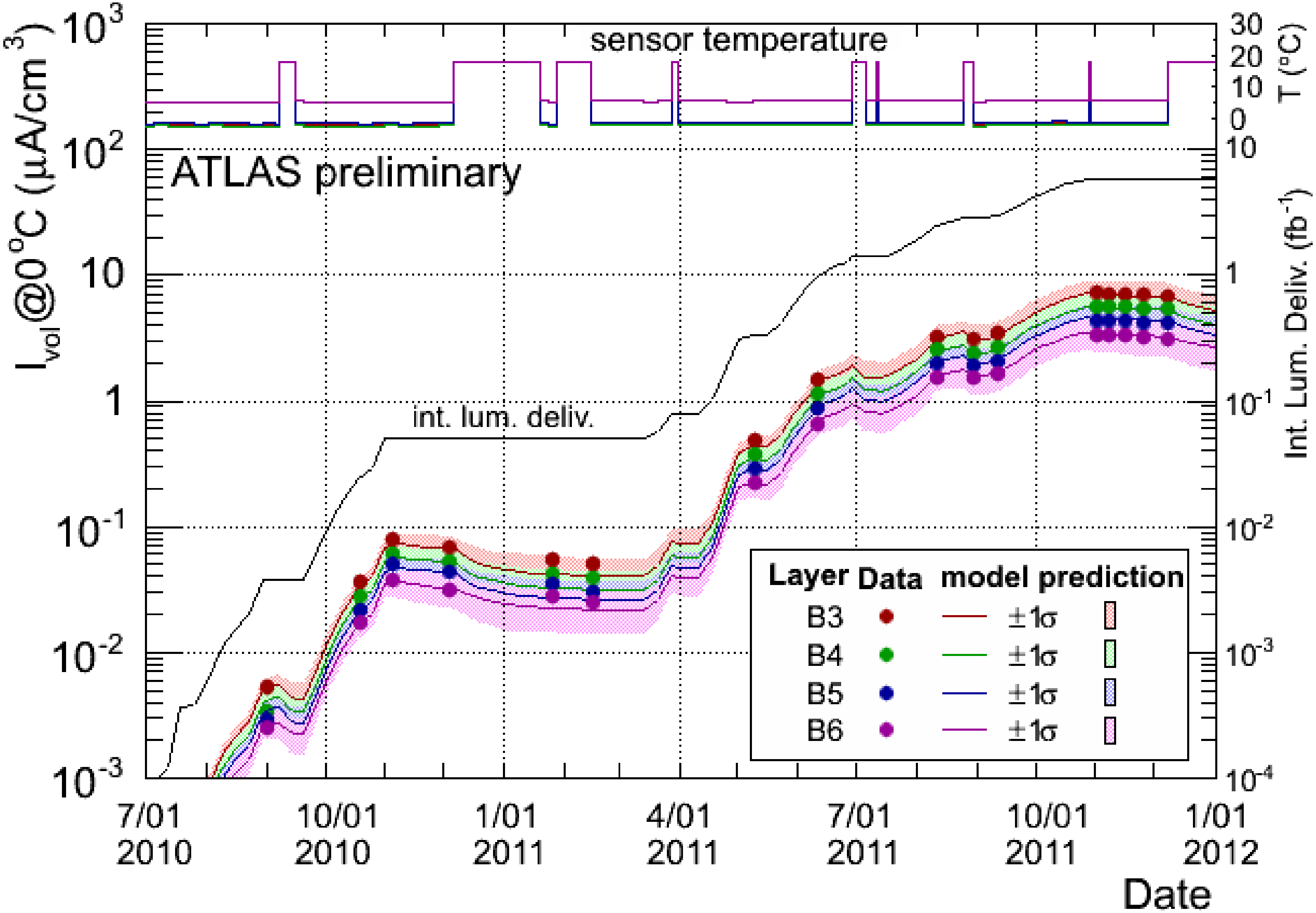
SCT Internal Alignment and Stability

- Monitor long term stability of SCT geometry
- Optical alignment system using Frequency Scanning Interferometry
- **842** interferometers form geodetic grid of distance measurements
- Detected movements
  - Before magnet ramp down: position deviations $\sigma \sim 11$ nm
  - During solenoid ramp: movements ≤ 3 μm
  - After full magnet cycle: position deviations $\sigma \sim 49$ nm





SCT Evolution of Radiation Damage (Leakage currents)



ATLAS & SCT Data Taking Efficiency and Data Quality

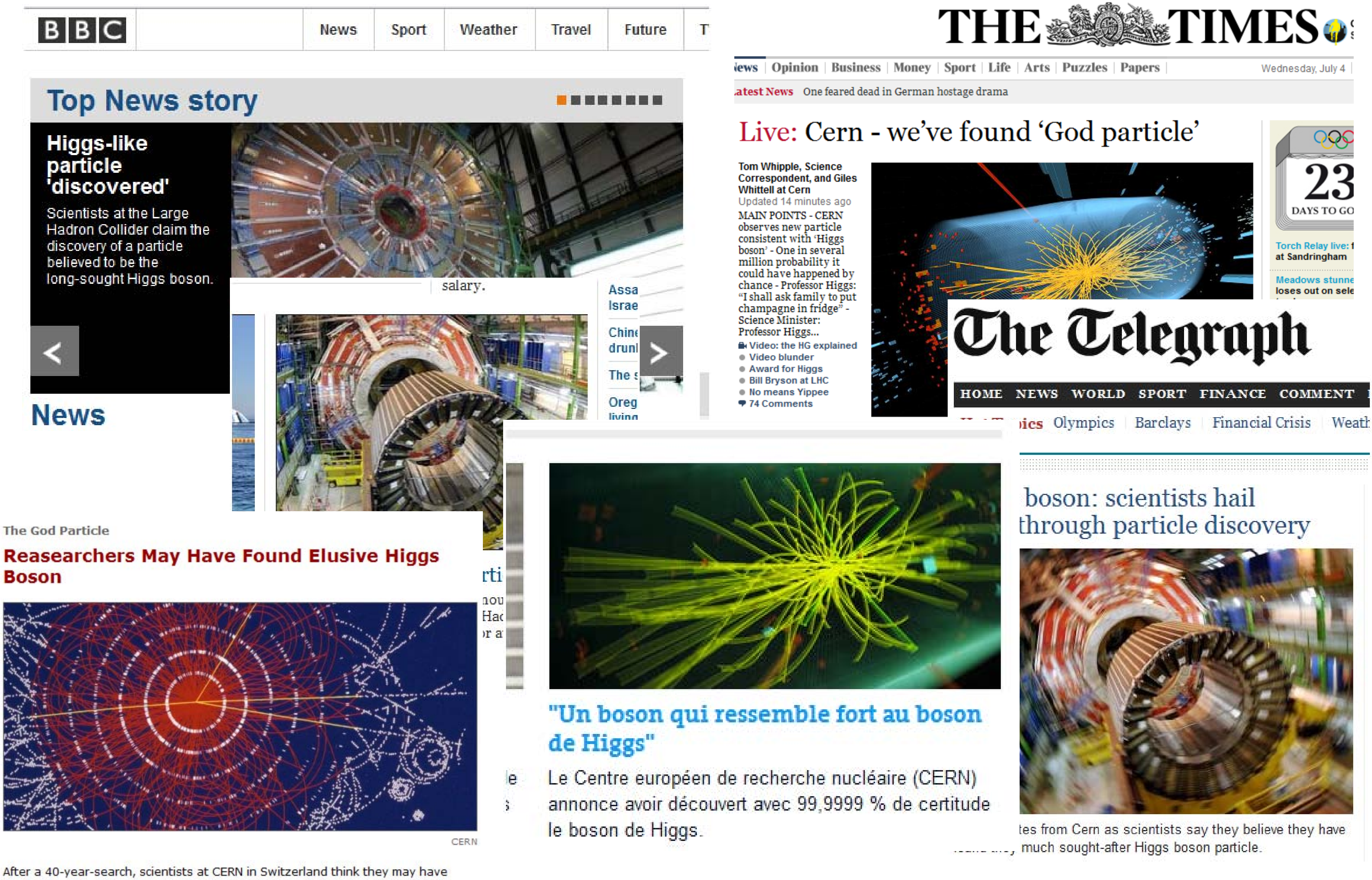
ATLAS 2011 p–p run												
Inner Tracking			Calorimeters				Muon Detectors				Magnets	
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.8	99.6	99.2	97.5	99.2	99.5	99.2	99.4	98.8	99.4	99.1	99.8	99.3

Luminosity weighted relative detector uptime and good quality data delivery during 2011 stable beams in pp collisions at √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 √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.

4^{th} July 2012



BUT !!

All of the Above is True!

However, it is a narrative that does not tell the *whole story*

We ignore the uncomfortable parts of the story at our peril.

There were a very considerable number of problems

✓ Cooling and Environment

- ✓ Multiple problems of evaporative cooling and control system during installation and commissioning.
- ✓ Evaporative Heater failures
  - ✓ Control system, connectors, feed-back-failures
- ✓ The HEX problem
  - ✓ SCT EC Heat Exchangers need in-situ design change and rebuild.
- ✓ The compressor problems
  - ✓ A long saga that led to the Thermo-siphon project.
- ✓ The heater pad problems
  - ✓ Loss of connection to 3 pads around barrel after field ON.

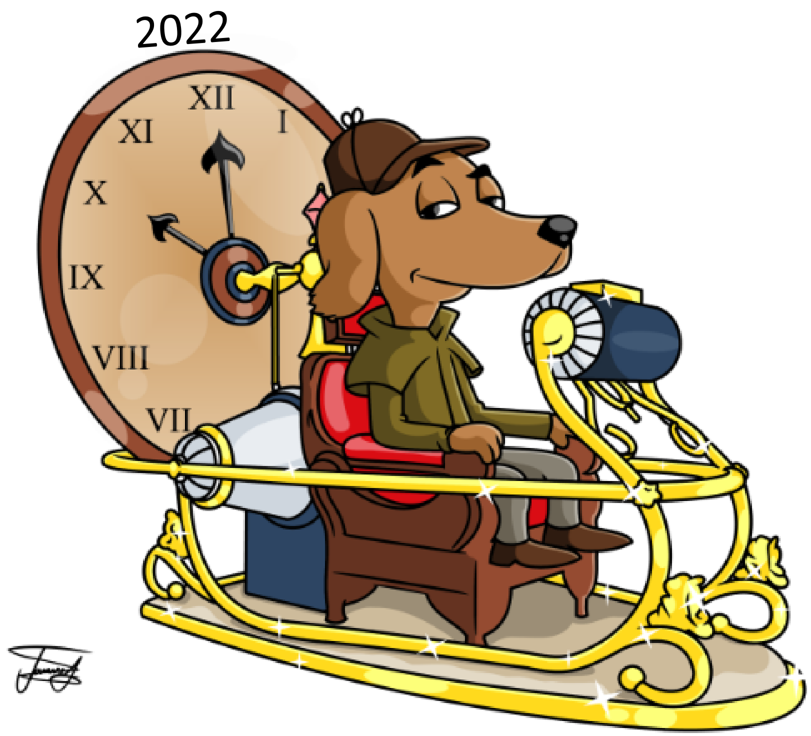
✓ Optical transmitters

- ✓ Each SCT module has 3 optical connections
- ✓ 1 of these is used to send data to the module (clock and command). These are sent from crates in the side caverns by TX transmitters
- ✓ Poor reliability and frequent failures of the *off detector* VCSELS.
- ✓ Initially thought to be due to ESD (wrong! ... not all the story)
- ✓ Eventually traced to humidity ingress (at least in part).

✓ *Considerable delays*

- ✓ It is hard to remember how much time we lost in the installation because of these problems but it was a lot.
- ✓ It is also not nice to work in a responsive mode.

Let's jump in our time machine and go to 2022



It is LS3 and we are about to install our new detectors

But the environment has totally changed

CERN RP Limits

- Experimental collective dose limit *(concept under review)*
  - Around 300 mSv/12 month period
  - This means different parts of the experimental upgrade program are tensioned against each other.
  - Delays or overruns in one system would need to be “paid back” elsewhere.
  - Probably need to keep an experimental contingency.
- Category B Radiation worker
  - CERN require less than 6mSv in a 12 month period
  - ATLAS internal dose limit = 2mSv in a 12 month period
  - Individual exposure in a single day cannot exceed 50 μSv/day
  - For activities in regions where the dose is between 20 and 50 μSv/h the maximum exposure time for an individual would be ~20-30 hrs/12 months
  - For services disconnection at the flange the dose is around 10’s μSv/h at contact.
  - Inside the barrel bore the dose is expected to be around 60 μSv/h and will require robotics (a whole new adventure)

Installations

- Installations
  - Installations that used to take thousands of man hours become impractical
    - Technician years are 10's – 100's hour long so you need a lot of them.
    - Technicians can only work for a limited number of hours per day.
  - Design for absolute minimum installation times is a must
  - Mistakes and significant in-situ repairs becomes an impossibility
  - If one foresees that a detector might need to be removed or replaced (beyond the initial installation) best to design that this can be done by Robot.
  - It is conceivable that if one meets a set of problems in the initial installation it will be necessary to take detectors out to the surface for repair. For instance if the integrated dose of the in-situ-repair is more than the remove and replace scenario.
- The working Environment
  - Important to eliminate the spread of any contamination.
  - "tent the working area and run it under-pressure" (clean room in reverse)
  - Working practices need to be defined and will be burdonsome.

Priorities for RP in coming years

- ✓ Extensive program to simulate the activation areas for various access scenarios including the tracking regions.
- ✓ Understand the measured doses (radiation maps) during the various stops
  - ✓ This is particularly true in the area close to the detector where people will want to work for extended periods during the long-stops.
  - ✓ Understand how to control the working environment to minimize the risk to personnel and of contamination and the transport of radioactive material.
- ✓ Develop robotics for the inner bore of the detector and other areas where intervention is required but cannot be done by humans.
  - ✓ Consultation started

Planning the construction/operation of a new tracker

- How to...
  - Define a GANTT chart and get cracking ......

Sceptical Look

  - This is not going to be enough!
  - We need a more systematic approach to the problem

Risk Management

- ✓ A risk is anything that could adversely effect what we are trying to do.
- ✓ The purpose of risk management is to increase the probability of a successful project outcome by an appropriate risk control process. Here successful means on-time, on-budget and meeting all requirements in terms of performance and operation (no de-scope).
- ✓ For us the project might be to build large scale detector systems on budget and on schedule that will operate and performs as specified for the lifetime of the experiment. The risk management process is for the lifetime of the experiment.
- ✓ It is pro-active process that includes (amongst other things): risk identification, processing or ranking and control.
- ✓ It is *NOT a stand alone process* but must be integrated into the overall project management structure and philosophy.
- ✓ Helps the project leader determine priorities, allocate resources, and use processes that reduce the likelihood that a project will not meet all of its targets. It can also mean that the project spends less time in responsive mode.

Risk Management

- Risk Management
  - ✓ Must be part of the overall project management process
  - ✓ Initiated when the project starts and continue for the life of the experiment
  - ✓ Participants must understand and accept risk management process and tools
- 4 Key steps in the process
  1. Establish risk project framework – accepted across the project
  2. Preliminary risk identification
  3. Risk categories & Risk Ranking (project specific)
  4. Risk response strategies & action plans

- Important to ..
  - ✓ Regularly monitor and control the risk management process
  - ✓ Communicate and control, feedback to other parts of the project
- Benefits
  - ✓ *If done properly the benefits to the project out weigh the costs*
  - ✓ Enhanced understanding, more realistic budget, project plan and less responsive project environment
  - ✓ The process must be appropriate for the benefit of the project (or sub-project)

Key Steps in the Process

- ✓ Establish the project framework
  - ✓ Understand key objectives, technologies, project and financial structure (CERN is special here as it controls/owns many of the interfaces)
  - ✓ Understand who is responsible for the risk management process at different points
- ✓ Preliminary risk identification of categories (project specific)
  - ✓ Categories, in a tracking detector, might include
    - ✓ Modules, electronics, cooling, powering, detector environment, interfaces, variability of design
    - ✓ Procurement, suppliers, new technologies, regulations and legal issues, resources
    - ✓ The ON detector risks will not be the same as the OFF detector risks
    - ✓ Construction (in house and industry), integration, installation, Operation
    - ✓ Funding, scope, schedule , organizational (distribution etc)
- ✓ Risk Ranking (Analysis)
  - ✓ How to define a risk event (and at what level of detail)
  - ✓ How to classify an event (probability and impact ratings)
    - ✓ Risk ratings will be probably different for ON and OFF detector
- ✓ Risk response strategies & action plans
  - ✓ Who are the individual risk owners
  - ✓ How risks are monitored and reviewed
  - ✓ The risk register & the appropriate risk response strategies
  - ✓ The risk management plan & organizational specific tools used to support the process
  - ✓ Frequency of risk scanning review sessions.
  - ✓ Who is responsible for testing and verification of the risk action plan?

Levels of Risk Management

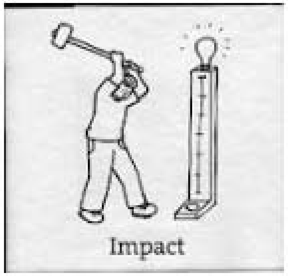
- ✓ High complexity and low risk tolerance need more risk management and hence more time needed (like installation).
- ✓ Here it is even more important to start the risk management process at the planning stage
- ✓ Good to have an Independent Verification and Validation (IV & V) process as part of the risk management

Identify Risks

- ✓ The process is Iterative and continues throughout the project
- ✓ Account for all internal and external factors
- ✓ Good to do an all encompassing first pass at the outset of the project
- ✓ Repeat regular risk sessions to review the previous analysis
- ✓ Classic form = Brainstorming
- ✓ Use a diverse team of stakeholders
- ✓ Balance “paranoia” with realism or even optimism
- ✓ Establish the right environment for discussing risk (nothing is silly)
- ✓ Separate issues *(things that have happened)* from risks
- ✓ Separate relevant and non- relevant risk
- ✓ Analyse and rank
- ✓ Update the risk register

Ranking Risks

- ✓ Define which risks are so significant that they require active management ?
- ✓ The risk register is used to prioritize, track and manage risks (and owner)
  - ✓ Describe each risk (including causes) and impact on the project
    - ✓ The risk impact could be positive or negative (positive risks are opportunities)
  - ✓ Assign each risk a *probability rating* and *impact rating*.
    - ✓ Probability rating is the likelihood that the risk will happen
    - ✓ Impact rating is the level of impact to the project if it does occur
    - ✓ This rating can be something as simple as: HIGH, MEDIUM or LOW or something more complex
    - ✓ Define priority score and priority rating
  - ✓ The risks of the highest probability score.
    - ✓ These are the risks that need management
  - ✓ Evaluate interdependences between risks
    - ✓ It is possible to cascade across or between risks, one risk causing another.
    - ✓ For risks that can trigger other risks increase their priority score to reflect interdependencies.
  - ✓ Sophisticated *quantitative* and qualitative Risk Ranking methodologies exist
    - Monte Carlo, decision trees, Failure mode effect analysis (FMEA), sensitivity analysis



Categorize Risk Events and Impact

Likelihood	Consequences				
	Insignificant *(Minor problem easily handled by normal day to day processes)*	**Minor** *(Some disruption possible, e.g. damage equal to $500k)*	**Moderate** *(Significant time/resources required, e.g. damage equal to $1million)*	**Major** *(Operations severely damaged, e.g. damage equal to $10 million)*	**Catastrophic** *(Business survival is at risk damage equal to $25 Million)*
Almost certain *(e.g. >90% chance)*	High	High	Extreme	Extreme	Extreme
Likely *(e.g. between 50% and 90% chance)*	Moderate	High	High	Extreme	Extreme
Moderate *(e.g. between 10% and 50% chance)*	Low	Moderate	High	Extreme	Extreme
Unlikely *(e.g. between 3% and 10% chance)*	Low	Low	Moderate	High	Extreme
Rare *(e.g. <3% chance)*	Low	Low	Moderate	High	High

http://www.expressbcp.com/DownloadTemplates/threatandriskassessment.htm

Quantitative Risk Analysis : When and Why

- ✓ When the output of the priority scoring outcome is too coarse
- ✓ Should only be done if it is worth spending the time and effort
- ✓ To better understand the quantitative impact of risks at the top of the risk priority rating
- ✓ Often uses past project data or expert input
- ✓ Used to change priorities, scope, quality plans etc.

Risk Analysis Techniques (Many and Varied)

Not all suited to our needs

- Preliminary Risk Analysis Evaluation
  - Undesirable events are identified first and then a decision is made about which is the best technique used to analyse them. More suited to workplace risk.
- Hazard and Operability Studies (HAZOP)
  - Developed in the 70's by ICI. More suited to production flow on process lines in large chemical works.
- **Failure Mode and Effects Analysis (FMEA/FMECA)**
  - Used for designs, processes, operation or machinery (used ahead of all!)
  - Step by step process.
  - Now used by Intel, National Semiconductor
  - Developed in the 50's by reliability engineers to study the consequences of the failure of military systems (rocket science). Each potential failure mode is analysed to see what effect its failure would have on the rest of the system. Severity classification follows.
  - FMEA can be extended to include criticality and then becomes Failure Mode Effects and Criticality Analysis (**FMECA**). This latter technique is widely used in the aerospace and military spheres.
  - Used in the nuclear power industry.
  - There is plenty of documentation, training, worksheets and software (try YouTube) on how to use FMEA/FMECA and it would seem to be an ideal tool for a lot of what we do.
  - It is possible, in some cases, to analyse entire systems inside one matrix with elements describing criticality relationships.

Risk Analysis Techniques (Many and Varied) Not all suited to our needs

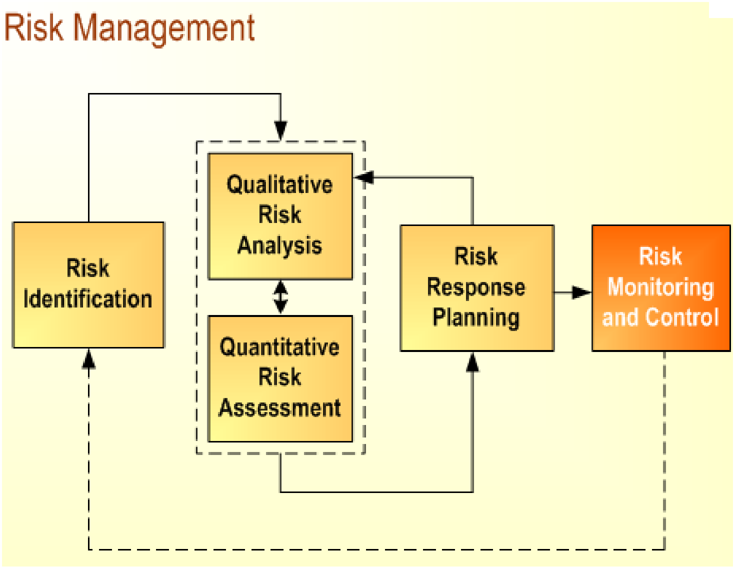
- Sometimes called Fault-Tree-Analysis (FTA), Events-Tree-Analysis (ETA), Cause-Consequence Analysis (CCA)
- Fault Tree Analysis
  - ✓ Developed in the 1960's by Bell Telephone Labs. Later adapted by Boeing.
  - ✓ Safety evaluations of ICBM launch control systems (rocket science again)
  - ✓ Logical diagrams that bring our the relationship between explicit failures and the components that lead to them. The process is to start (top of tree) with the undesired event (the failure) and see how one can "get to it"
  - ✓ The technique can be qualitative or quantitative
  - ✓ Plenty of software such as FaultTree+ and CARA.
  - ✓ http://www.weibull.com/basics/fault-tree/index.htm
- Event Tree Analysis
  - ✓ Traces the development of the consequences that can follow (or lead up to) a particular action. Uses inductive logoc
  - ✓ Has been used to test the operability of nuclear power stataions
  - ✓ Was used to analyse the failure at 3 mile Island reactor number-2.

Risk Response Action Plan

- Risk owner and project leader define strategy
- The chosen strategy must be:
  - ✓ Manageable
  - ✓ Reduce negative impact (is there a way to exploit opportunities?)
  - ✓ Make best use of available resources & be cost effective
- Strategies:
  1. **Avoidance** (*eliminate* probability or impact, e.g. use redundancy)
  2. **Acceptance** (ignore) ... possibly because it is too expensive.
  3. **Mitigation** (*reduce* probability or impact)
  4. **Transfer** (pass over risk to someone better able/suited to handle). Risk not eliminated!!
  5. **Enhance** (is it possible to enhance probability or impact of opportunities?)
  6. **Exploit** (can we actually make use of a risk)
  - ✓ The *risk-owner* has to determine which strategy is adopted but this needs to be reviewed regularly in consultation with the PL and possible change
  - ✓ One must question if the *reaction* to the risk introduces additional risks.
    - ✓ If so add to the risk register!
  - ✓ The risk owner then determines the action plan and action triggers

Monitor And Control

- ✓ Risks can/will evolve over time both in probability and impact
- ✓ Their interdependencies can also evolve and emerge
- ✓ Continually scan for new risks during brainstorming sessions
- ✓ Risk documentation is important
- ✓ Establish contingency plans and funds



The Key Points, Again

- ✓ Establish a risk management Framework
- ✓ Categorize and Identify Risks
- ✓ Analyse and Rank Risks
- ✓ Identify Risk Owners or Managers
- ✓ Develop Strategies and Plans for significant risks
- ✓ Analyse effectiveness and risk response strategies
- ✓ Update risk register and response plans regularly
- ✓ Monitor, control and report new risks
- ✓ Archive and share risk lessons

Will a formal Risk Management eliminate all Problems?

Is this the alternative

Conclusions

- ATLAS has a fantastic tracking detector that is contributing to the rich program of EW physics.

- The Installation (and parts of the construction) was not without some serious hiccups, the like to which would be a disaster, at Phase II.
- We need a more methodical / formal approach to risk management for the next tracker to avoid repeating history. There is a wealth of documentation, software and expertise out there to take advantage of. If applied correctly it is more of a benefit than a burdon.

- *History, despite its wrenching pain, cannot be unlived, but if faced with courage, need not be lived again.*
  - *Maya Angelou*

Thank You

Reading this season's fire risk assessment report.