Title: Current state of ATLAS and the LHC

Date: Oct 30, 2009 09:00 AM

URL: http://pirsa.org/09100157

Abstract: TBA

Current State of the LHC and ATLAS

- The LHC and 2008 commissioning
- State of the ATLAS experiment
- Current status of the LHC and plans
- What to be watching in the coming months

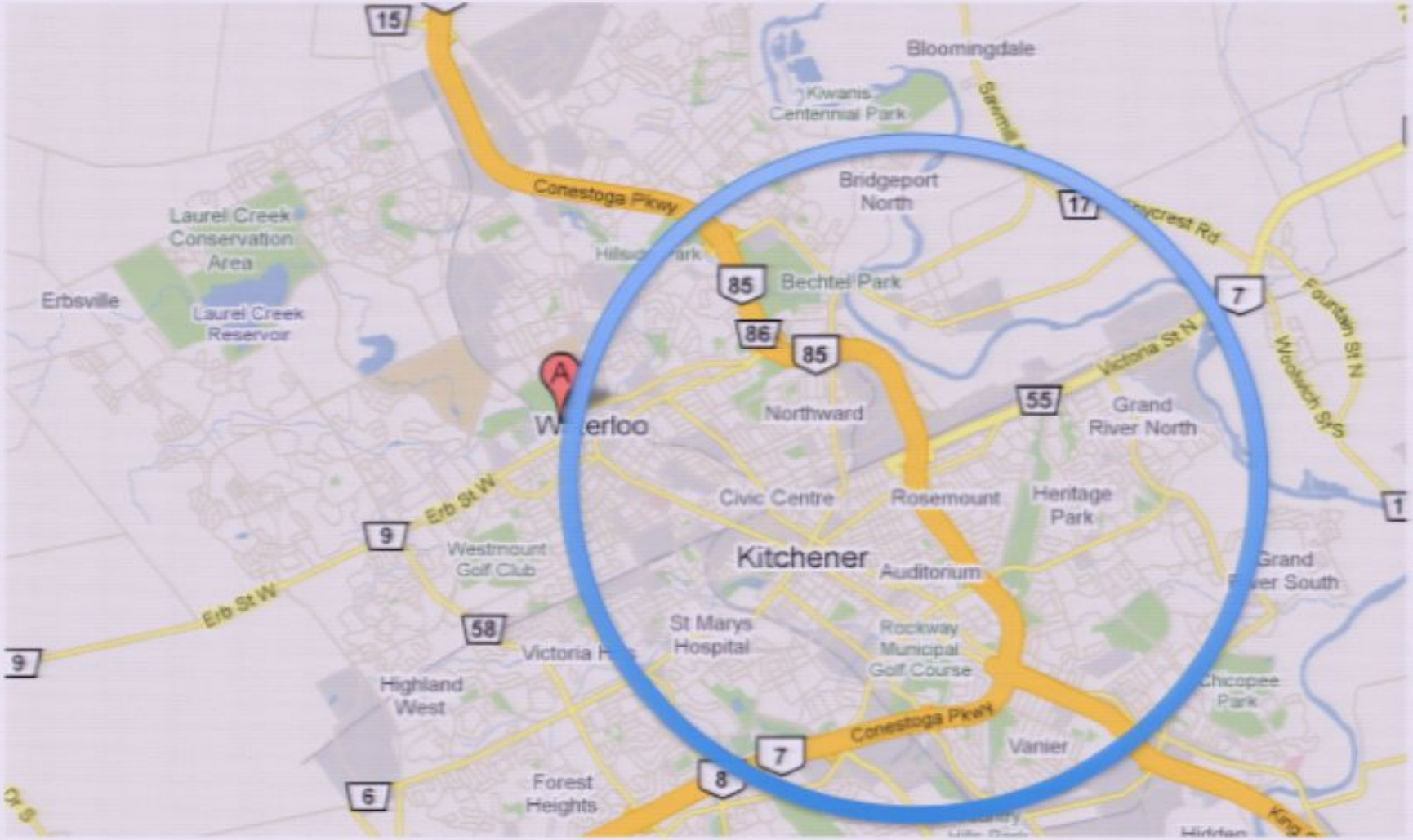
William Trischuk
University of Toronto
October 30, 2009

Geneva, CERN and the LHC

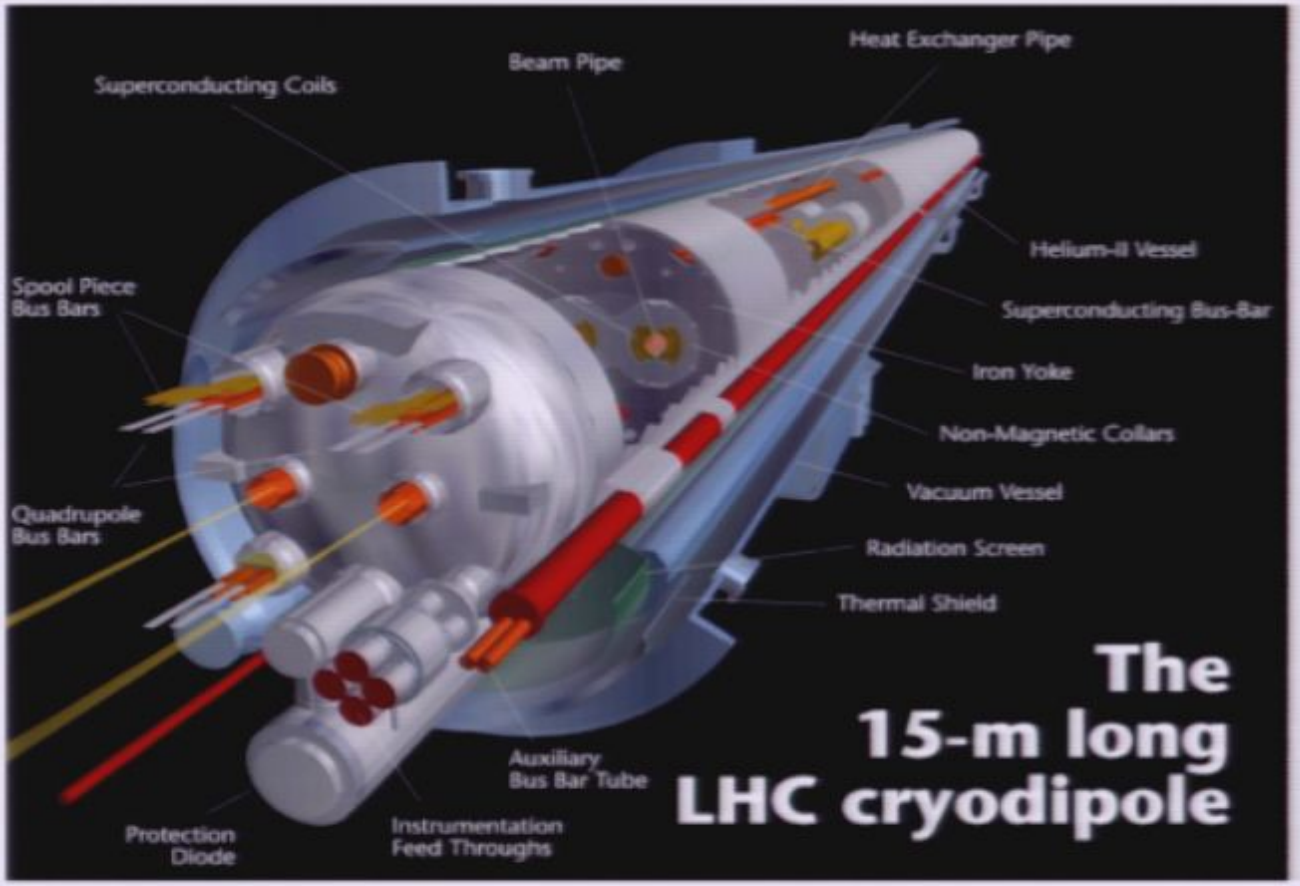
- The largest scientific instrument ever built
- The accelerator is 100 m underground
- The tunnel is 28 km in circumference

The Scale of the LHC

The Scale of the LHC



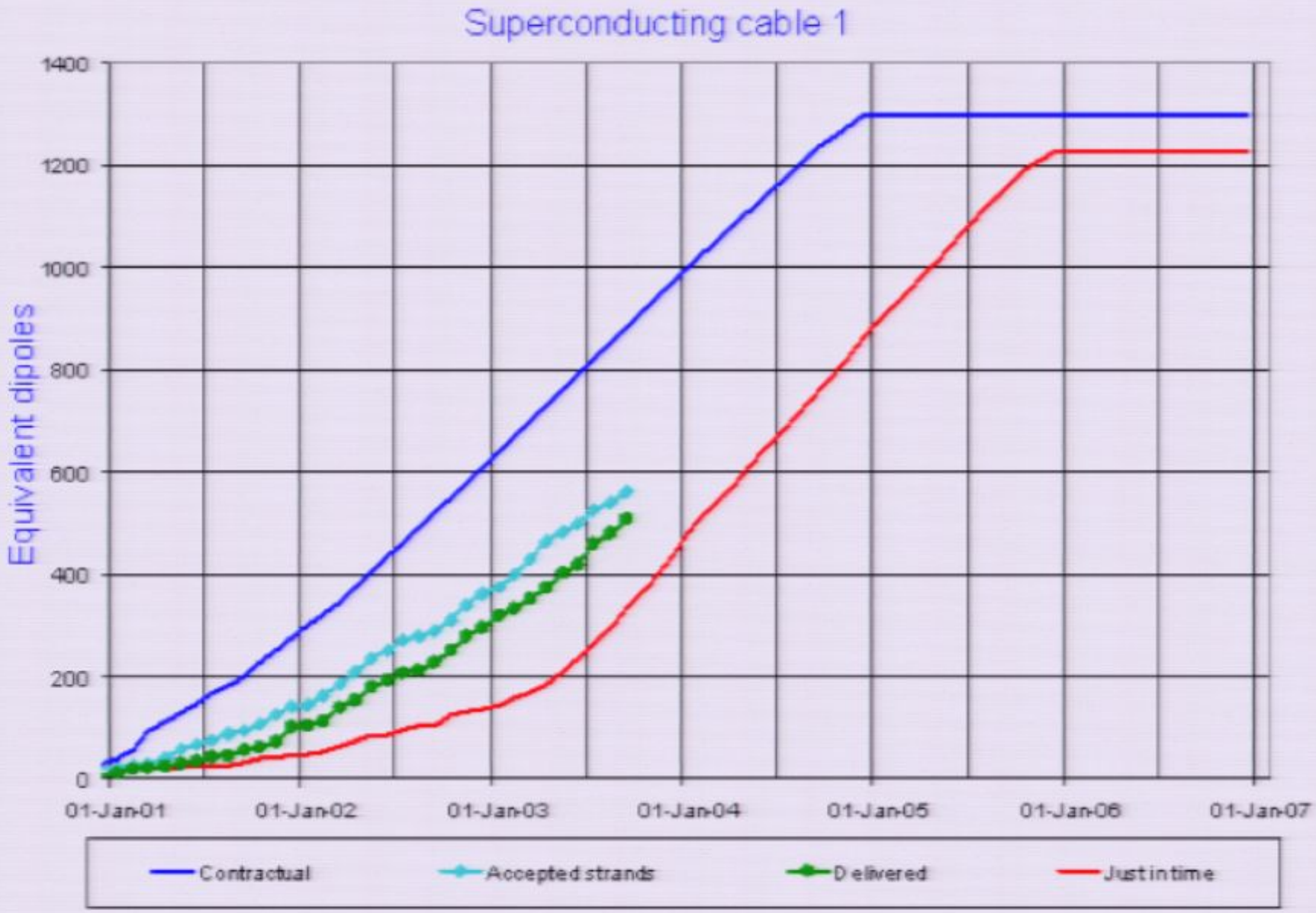
Twin Aperture 8T Superconducting Magnets



- 1200 magnets made in 3 European companies
- Aggressive design for maximum energy in LEP tunnel

LHC Progress Dashboard

Accelerator Technology Division

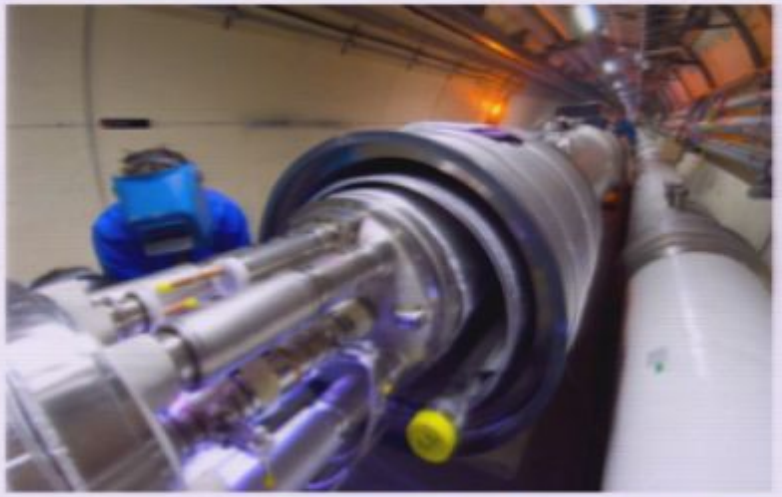


Updated 30 Sep 2003

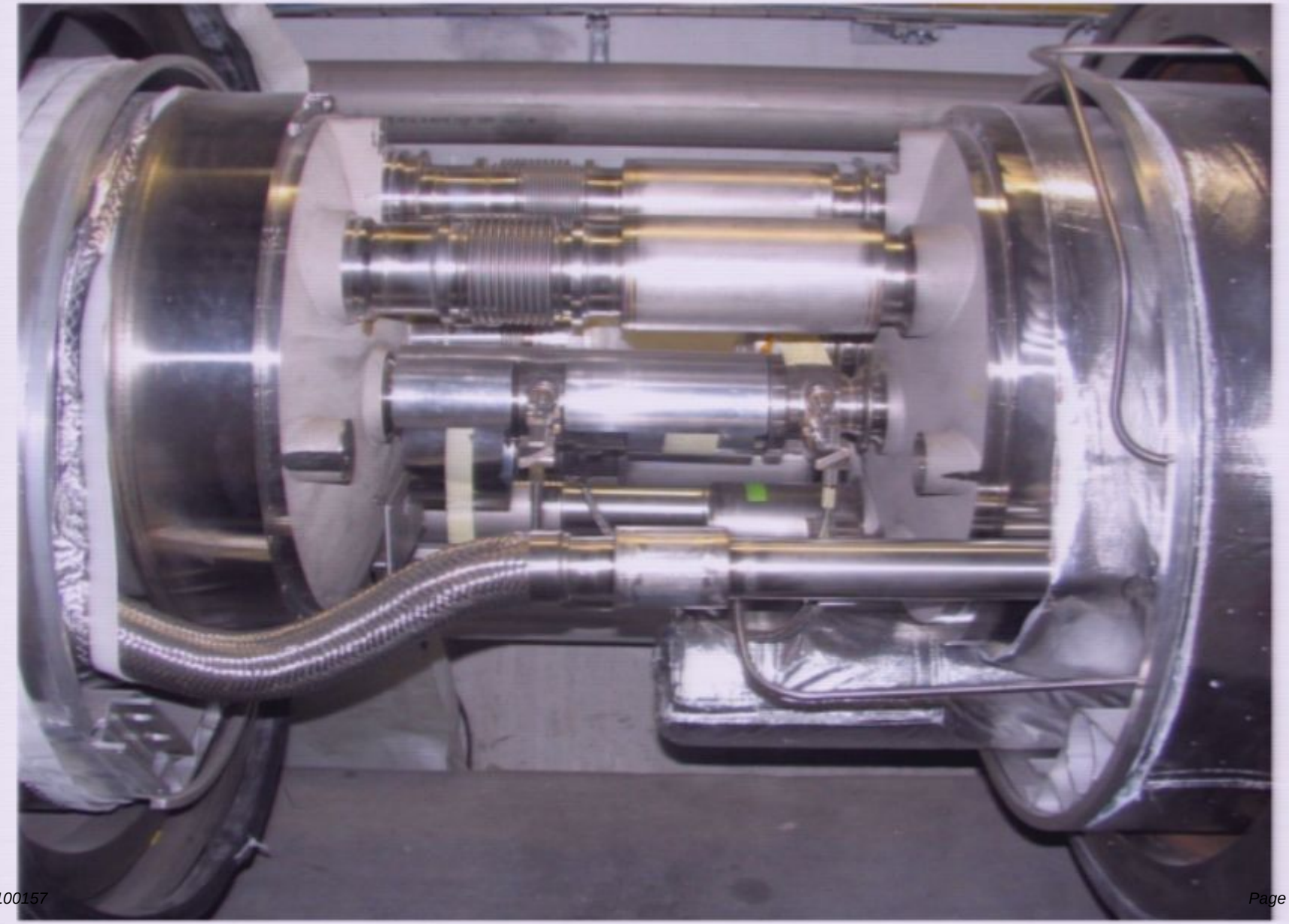
Data provided by A. Verweij - AT-MAS

Dipole Cold Masses

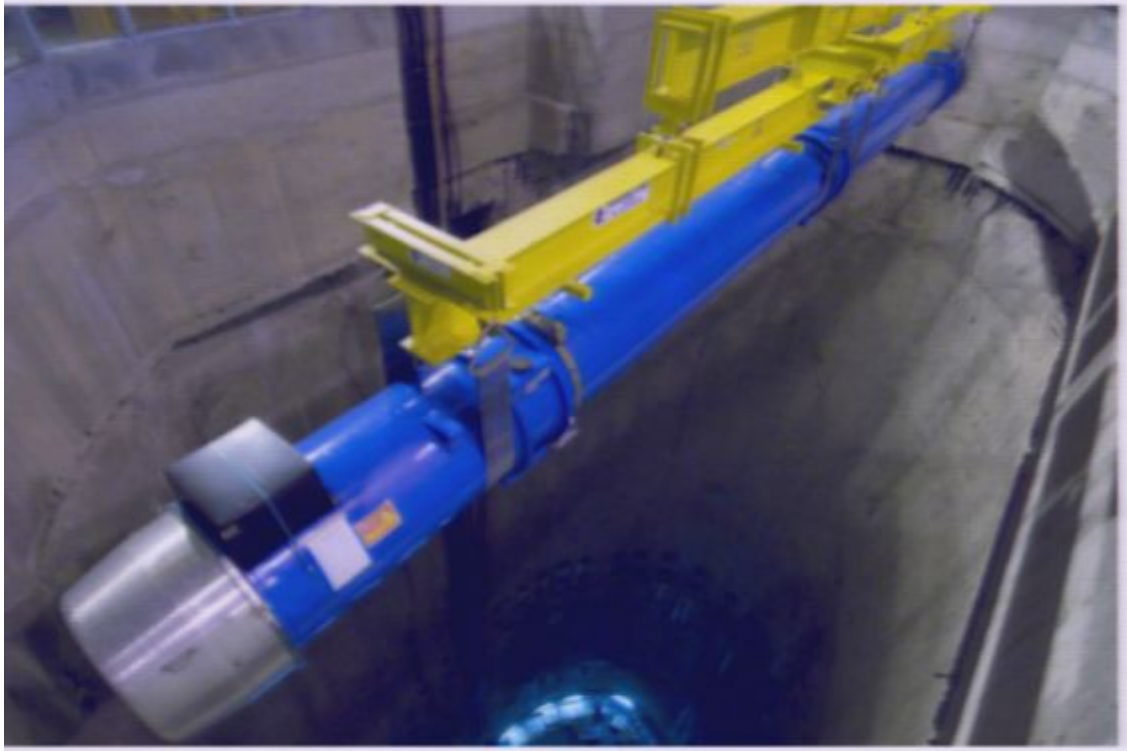
Underground



Dipole interconnection (~1200 done over two years)



Last Magnet Installation (April 2007)



- 15000 km at 2 km/hr!

Beam 2 Injection Sequence (September 2008)

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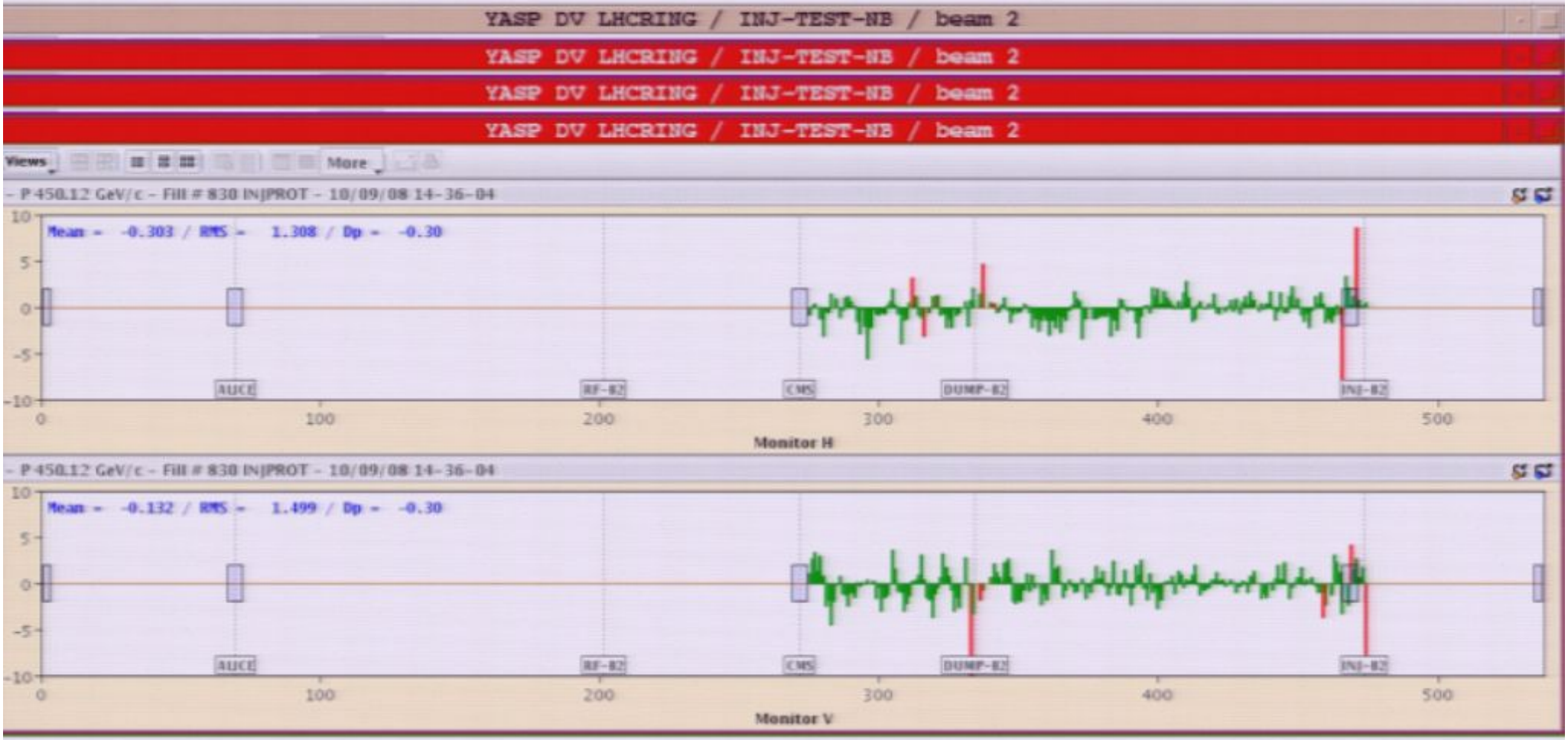

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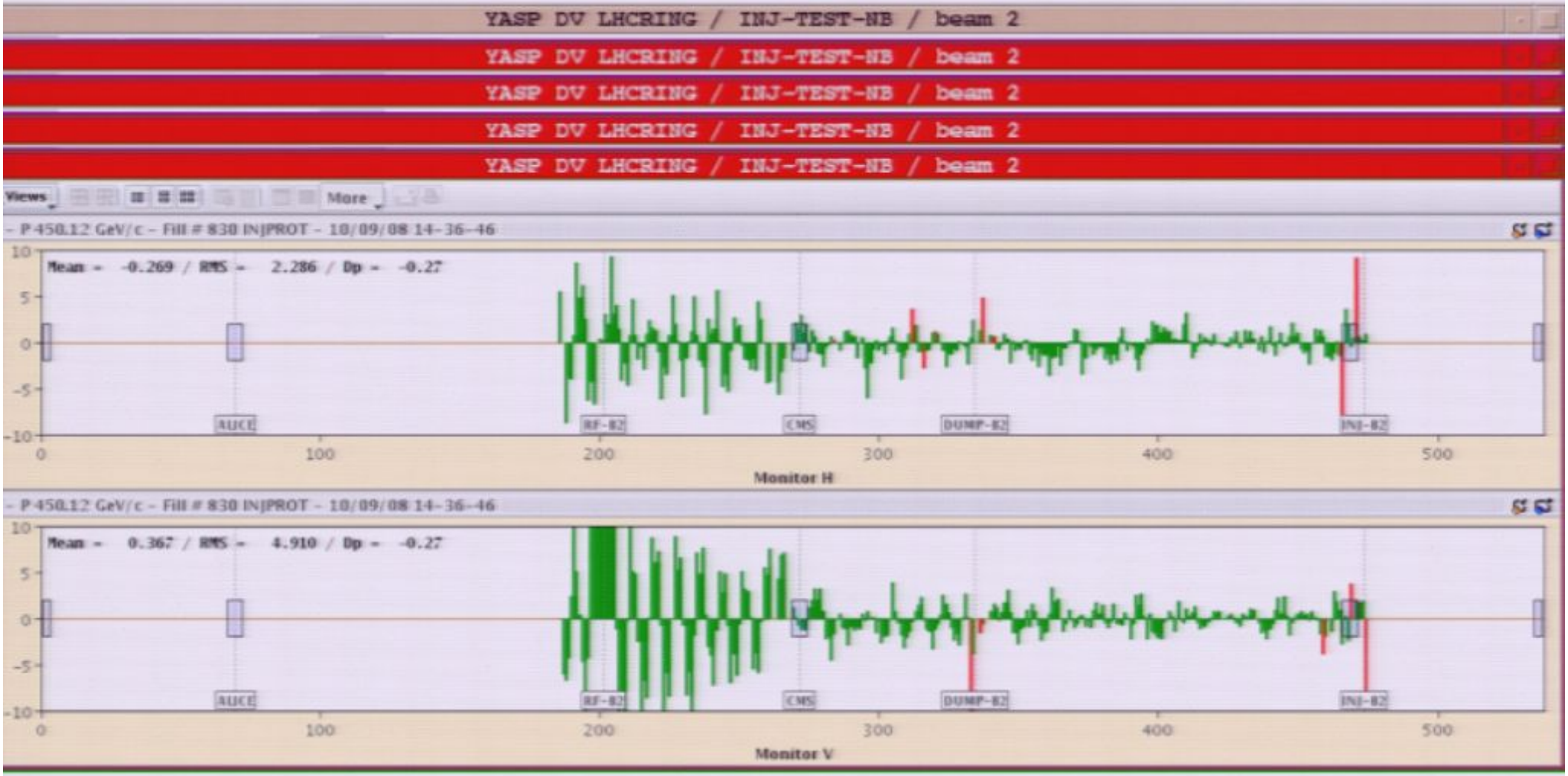

Beam 2 Injection Sequence (September 2008)

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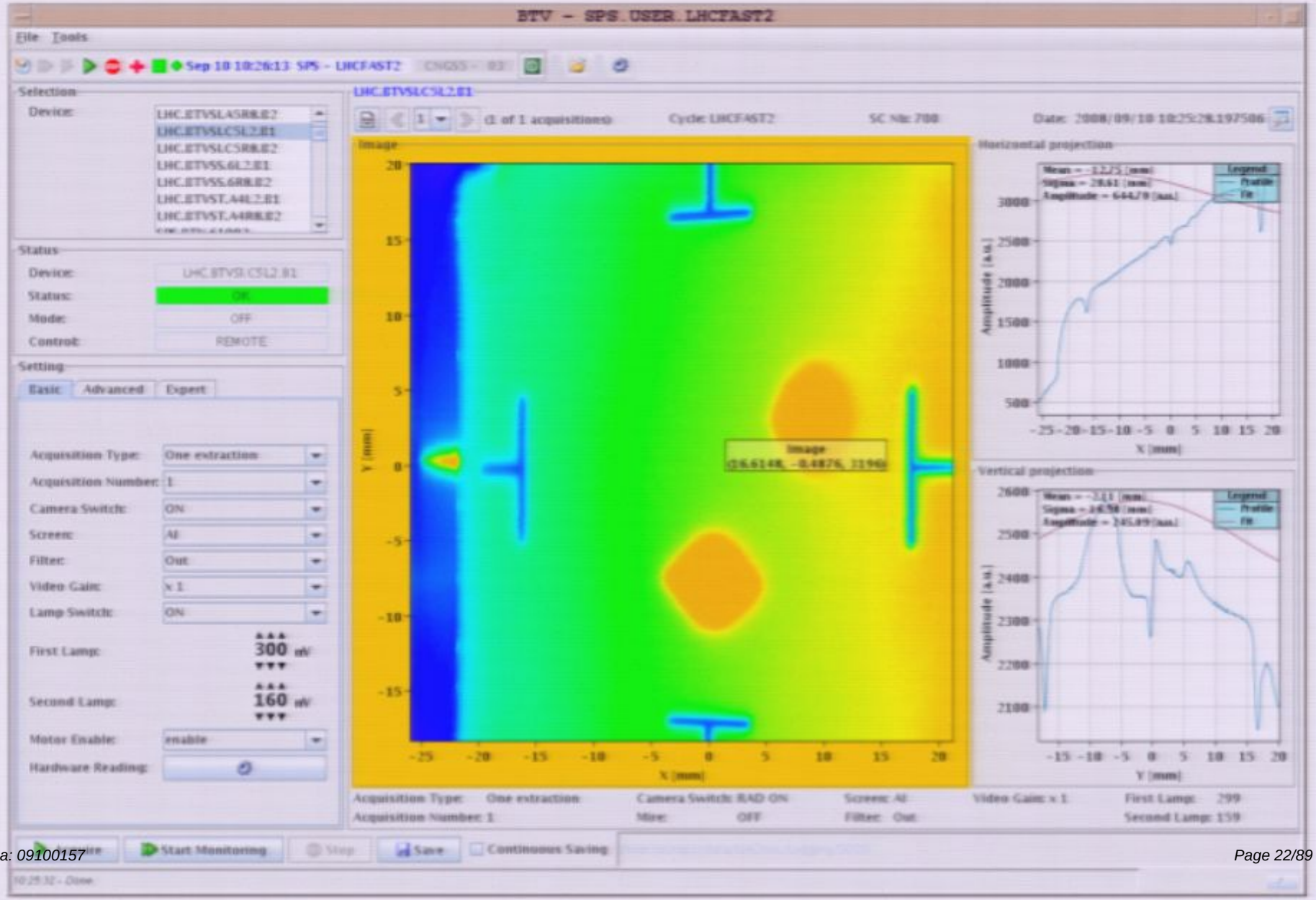
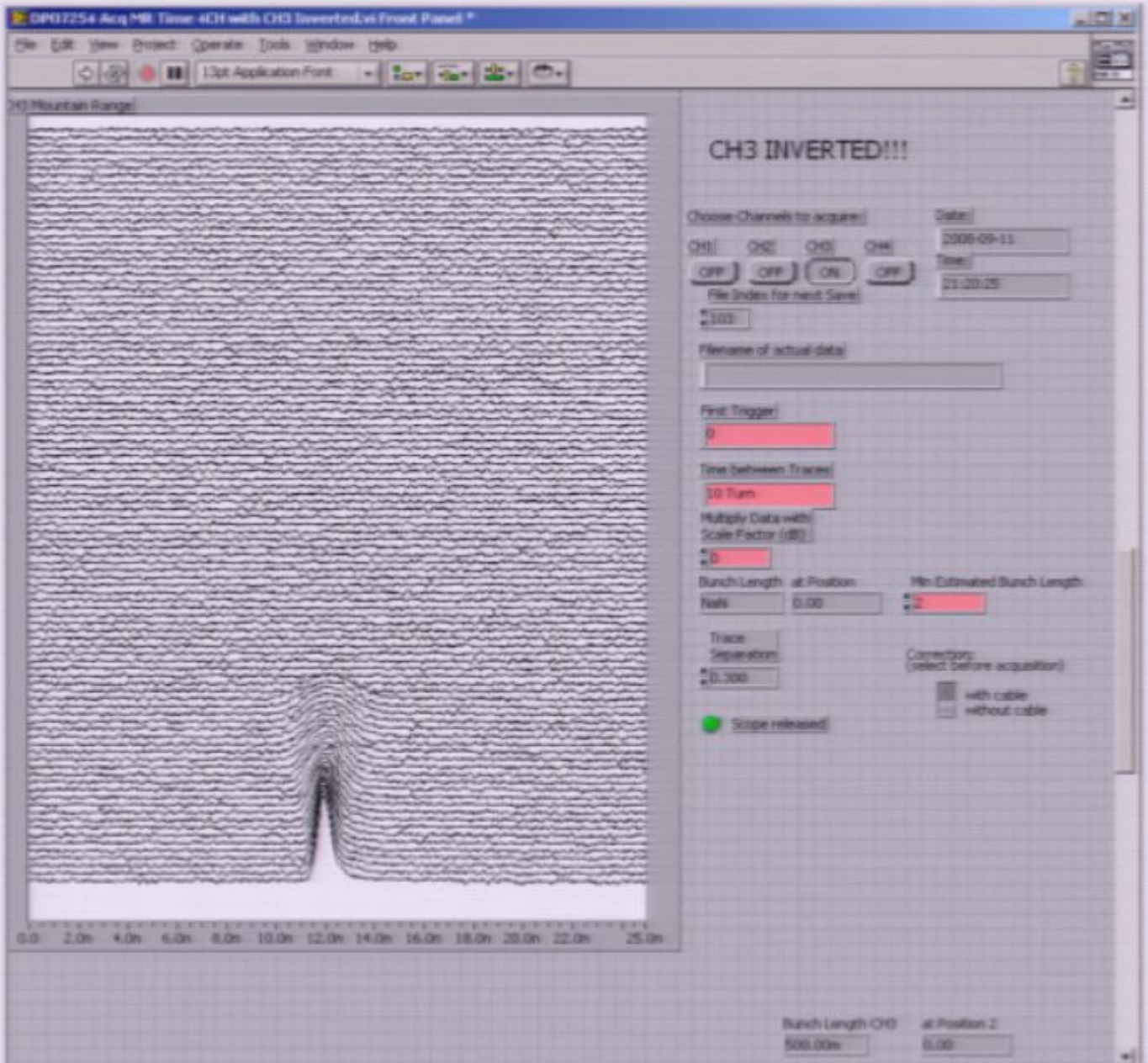
Beam 2 Injection Sequence (September 2008)

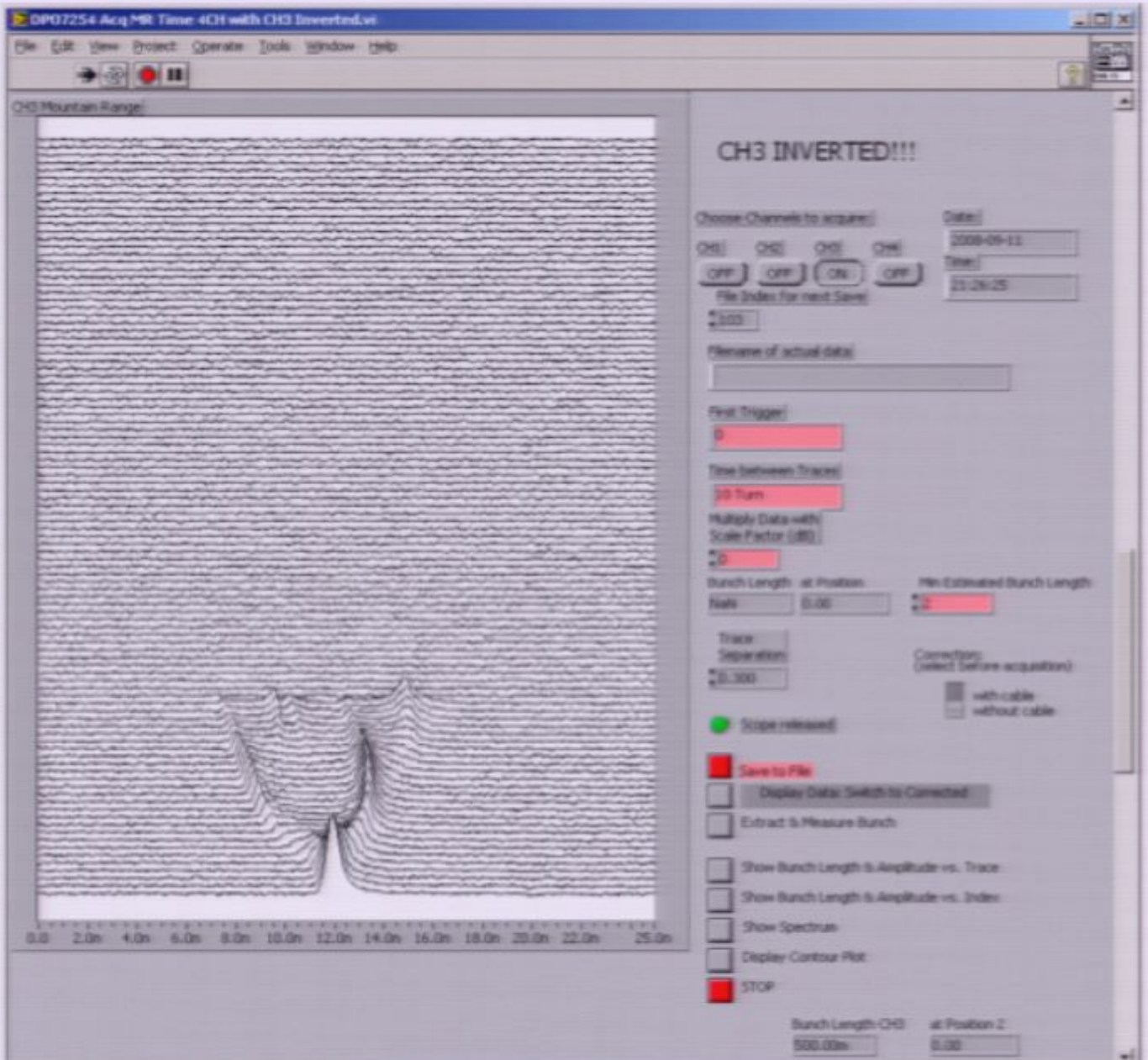
Beam on Consecutive Turns (September 2008)



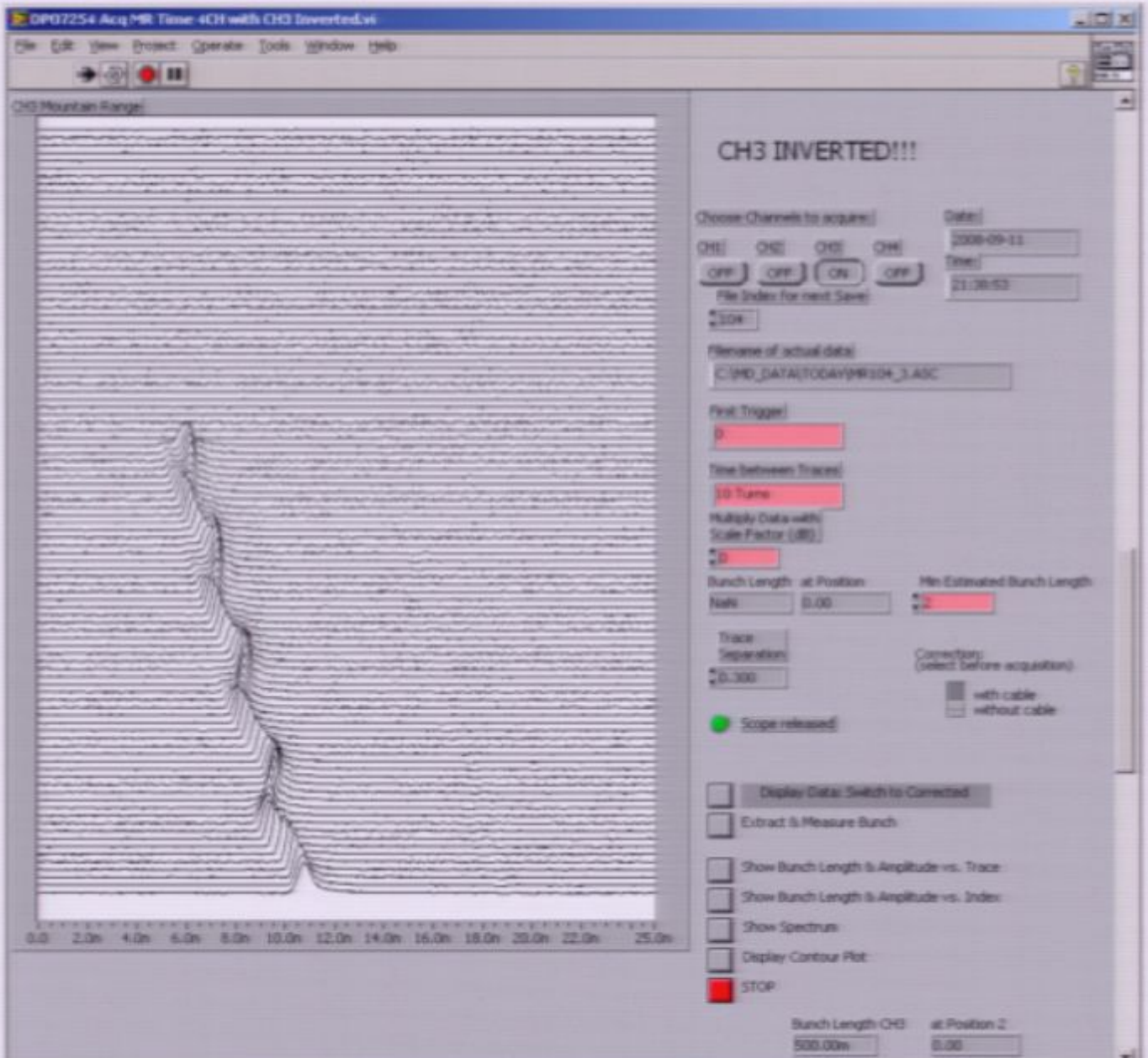
Beam Capture – RF-off (25 ms ~300 turns)



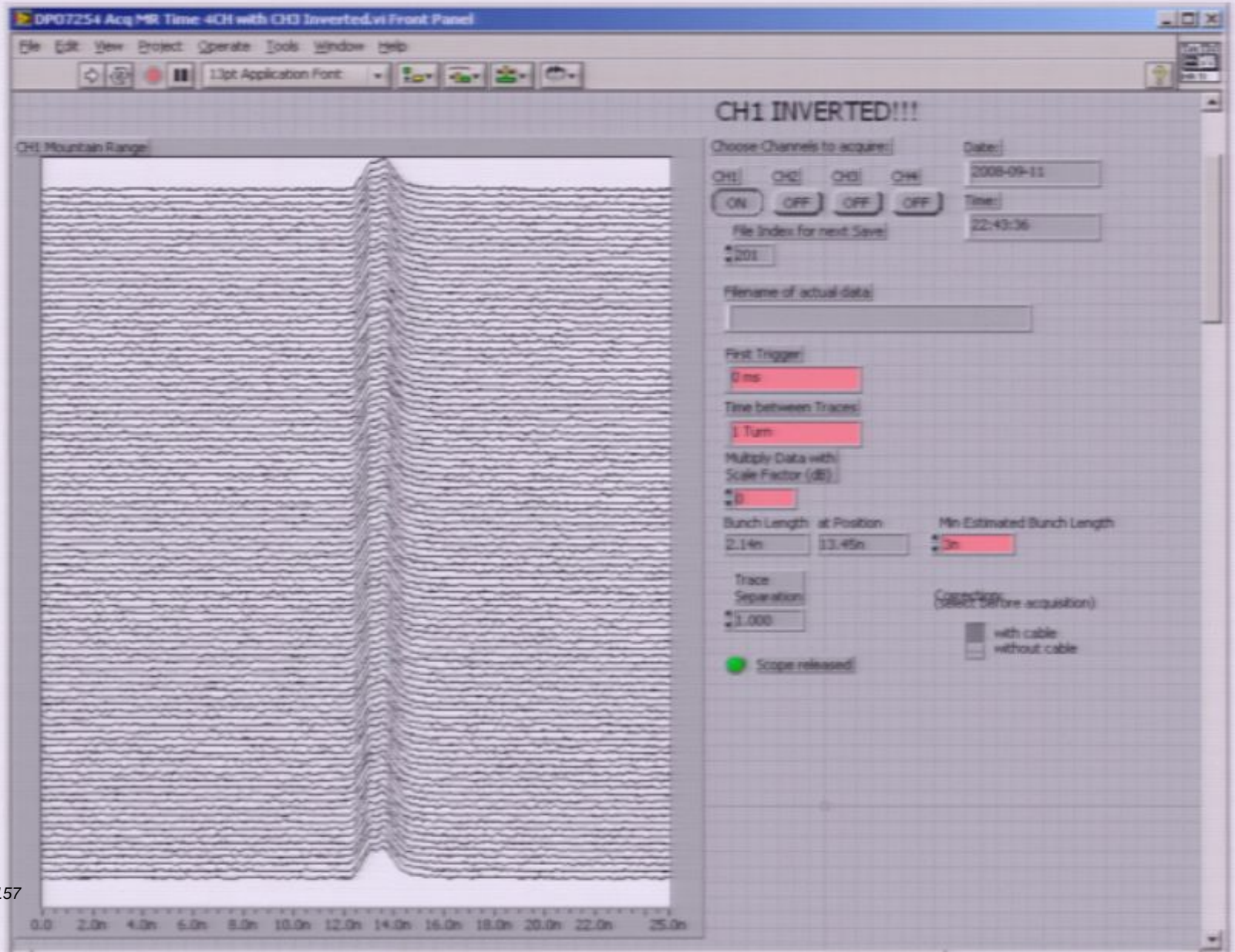
First Attempt at Beam Capture – RF-phase 180° off



Beam Capture – injection phasing



Beam Capture – Correct Phase (3rd shift)



Status of ATLAS (October 2009)

Exercised all possible interventions on detector and infrastructure

3 periods of cosmic ray runs
-Oct-Nov '08
-Jun-Jul '09
-Oct-Nov '09

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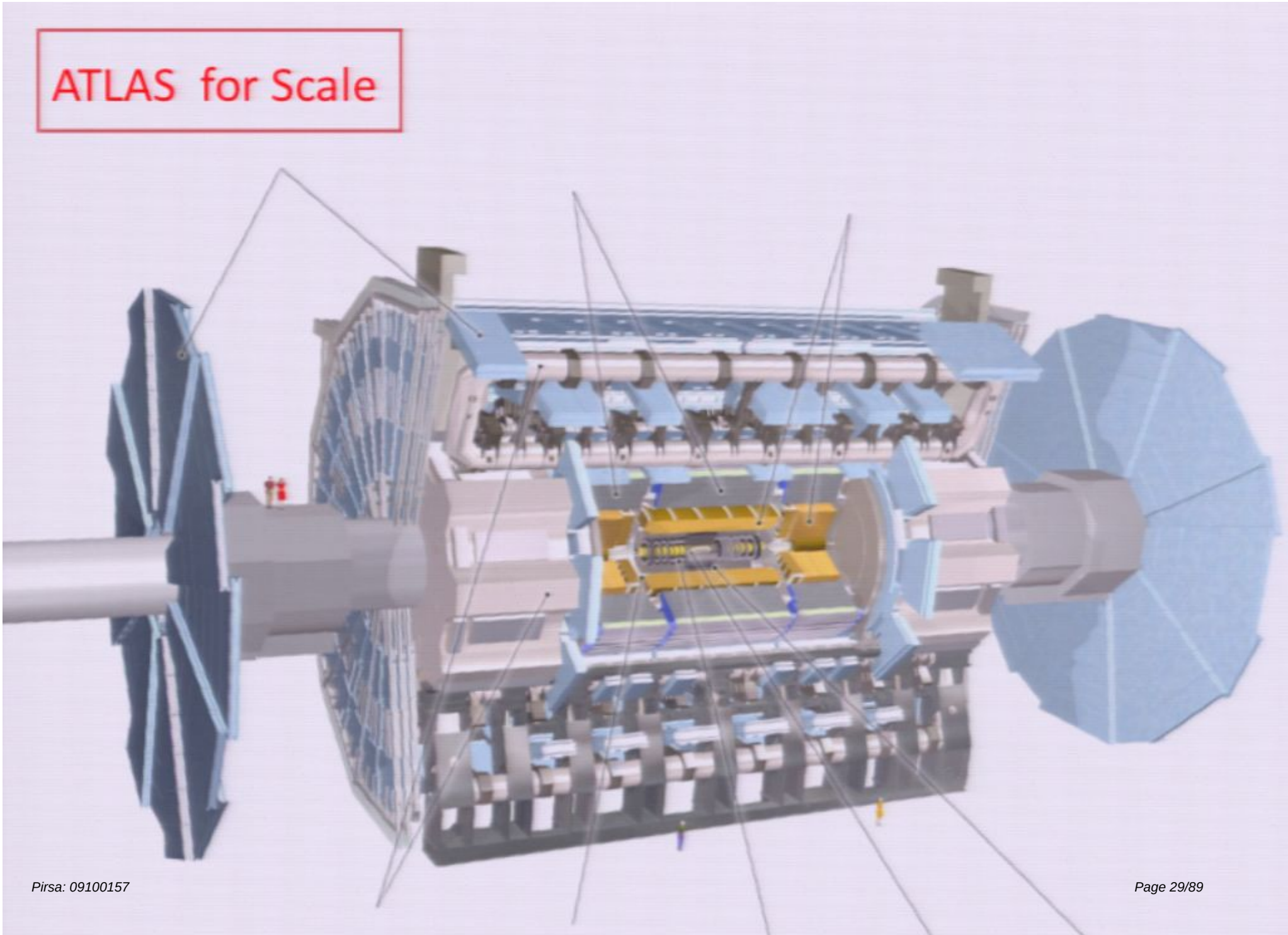
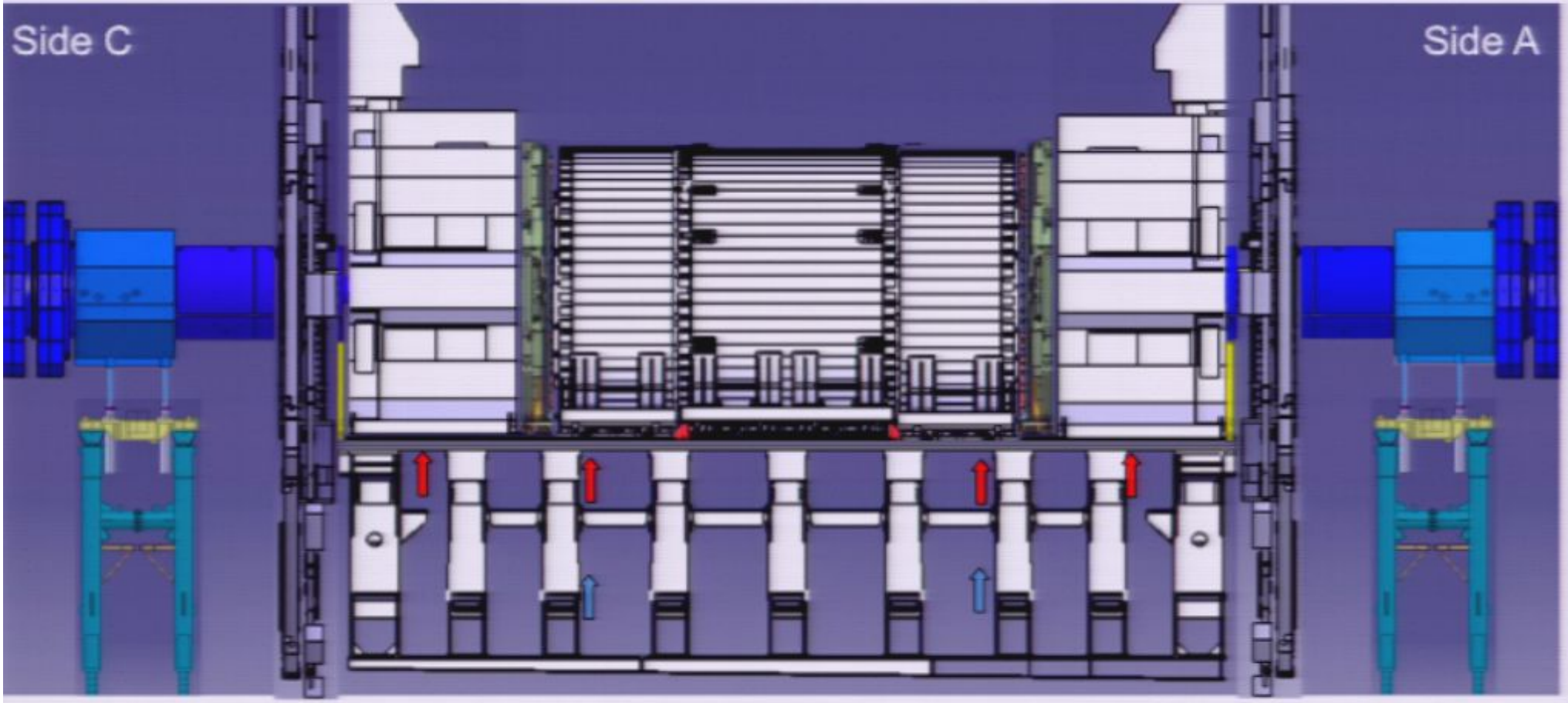


ATLAS for Scale

ATLAS Maintenance Procedures



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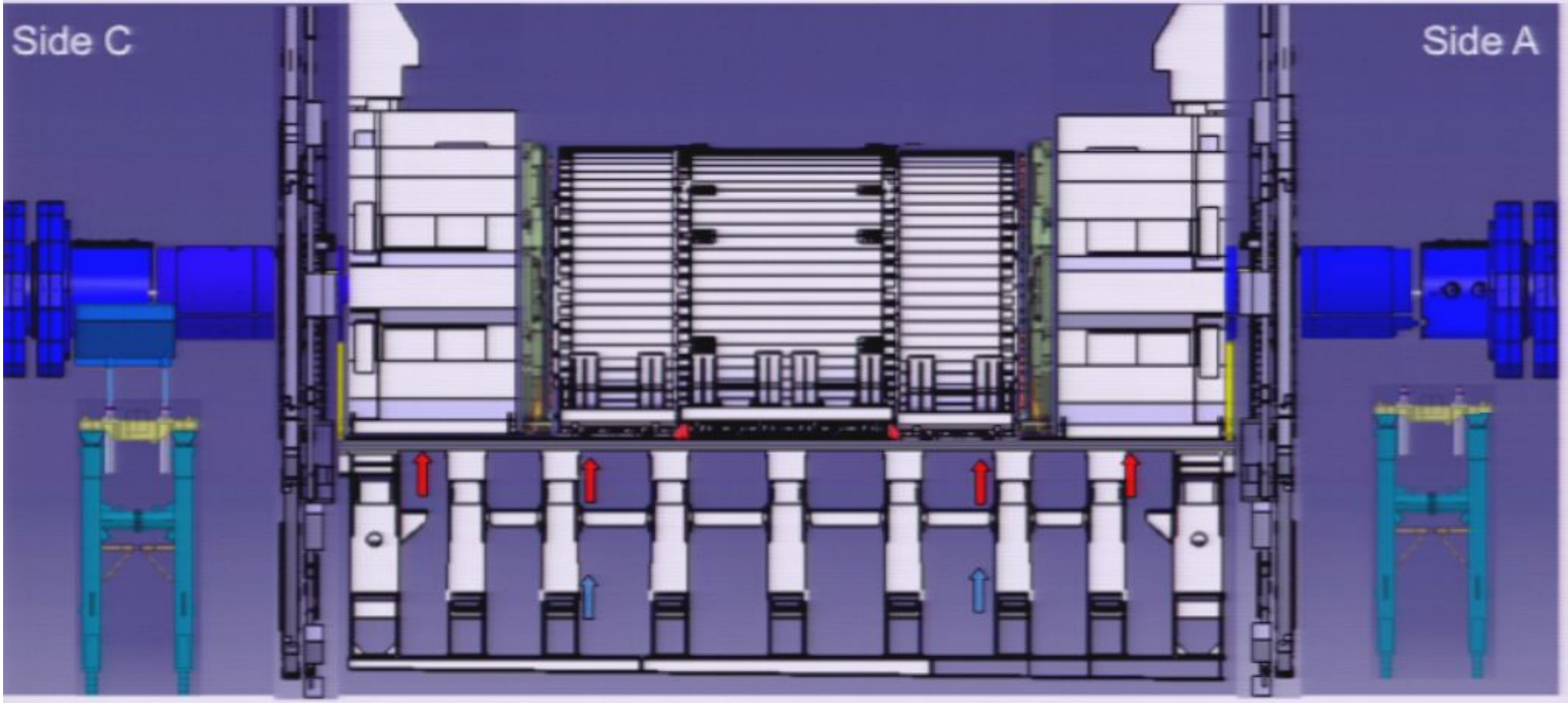
  - Partially exercised during first half of 2009
  - Anticipate full overhaul during 2010-11 shutdown

ATLAS Maintenance Procedures



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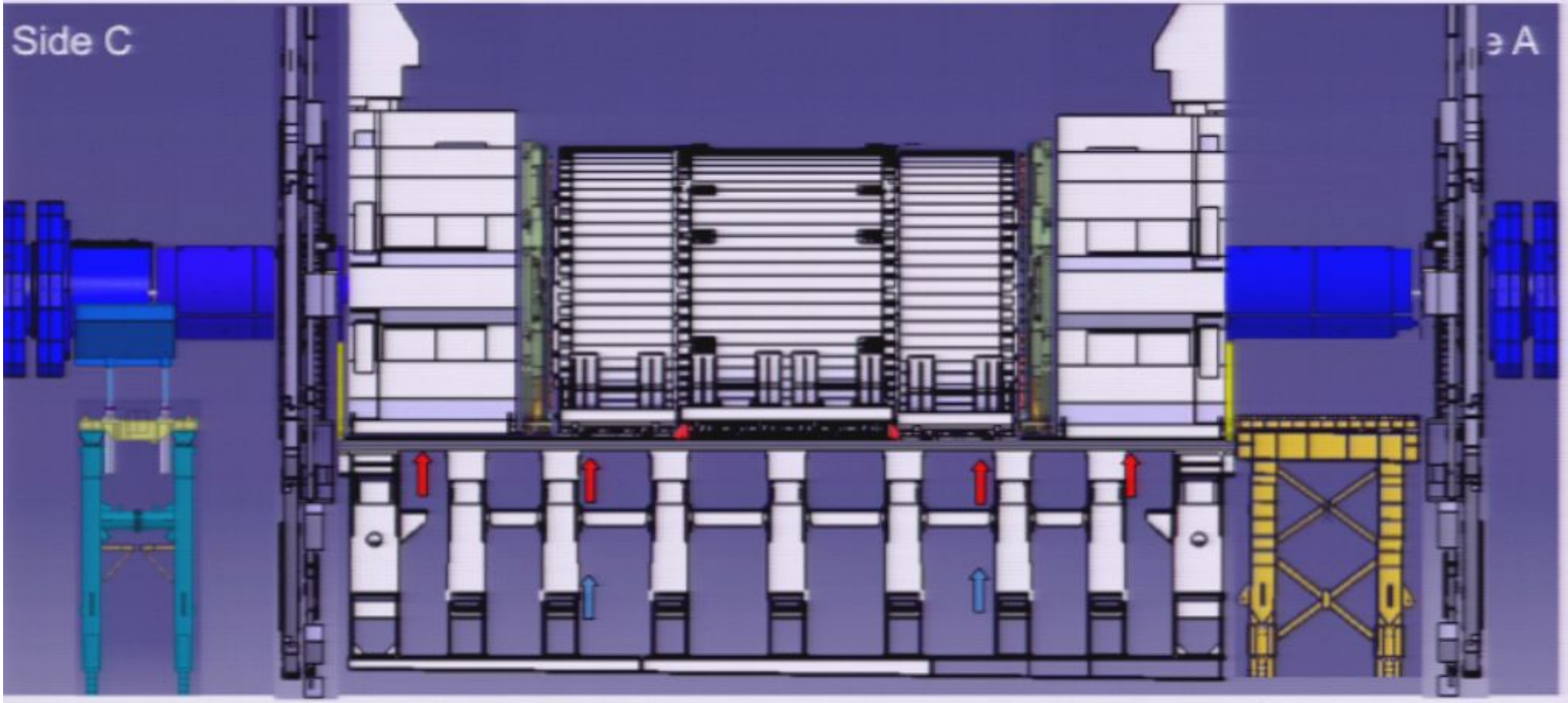

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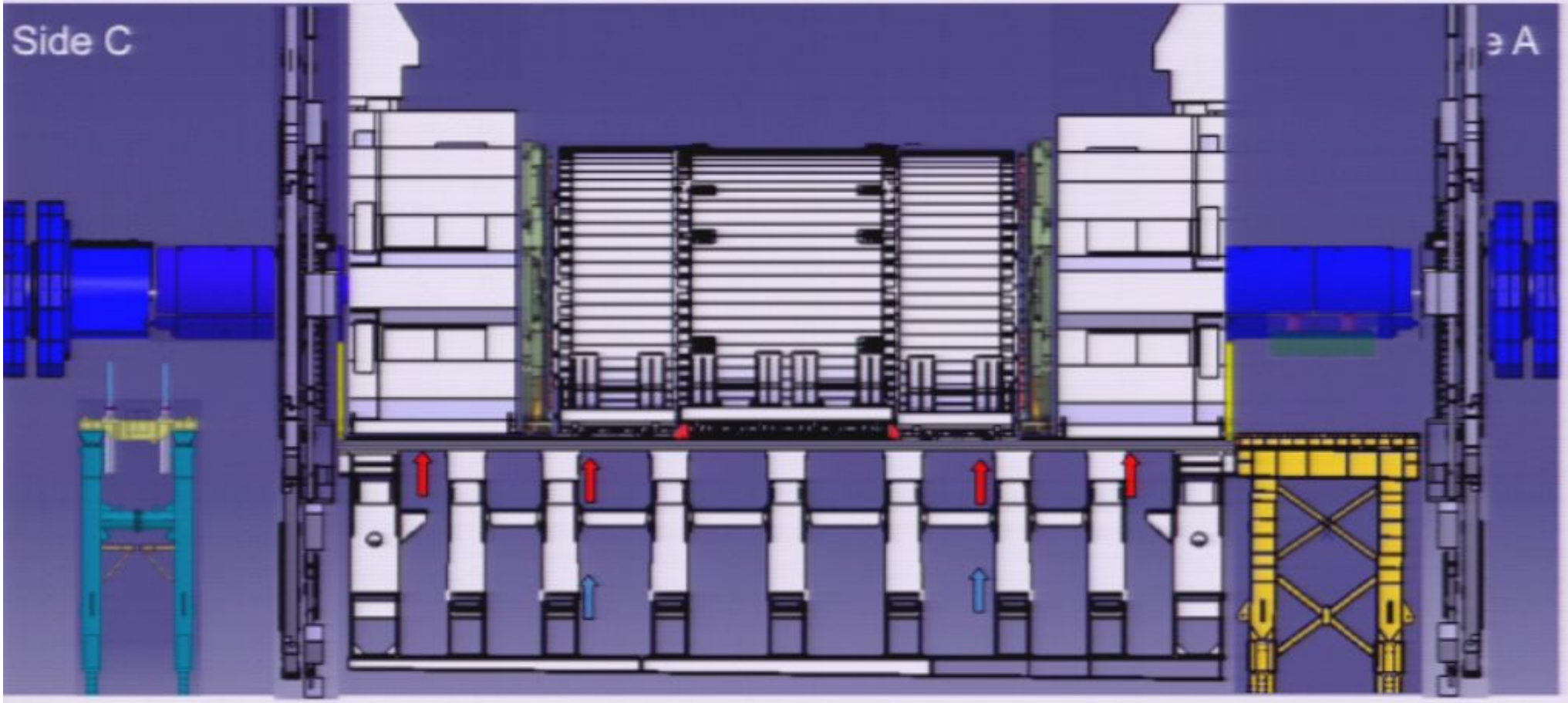

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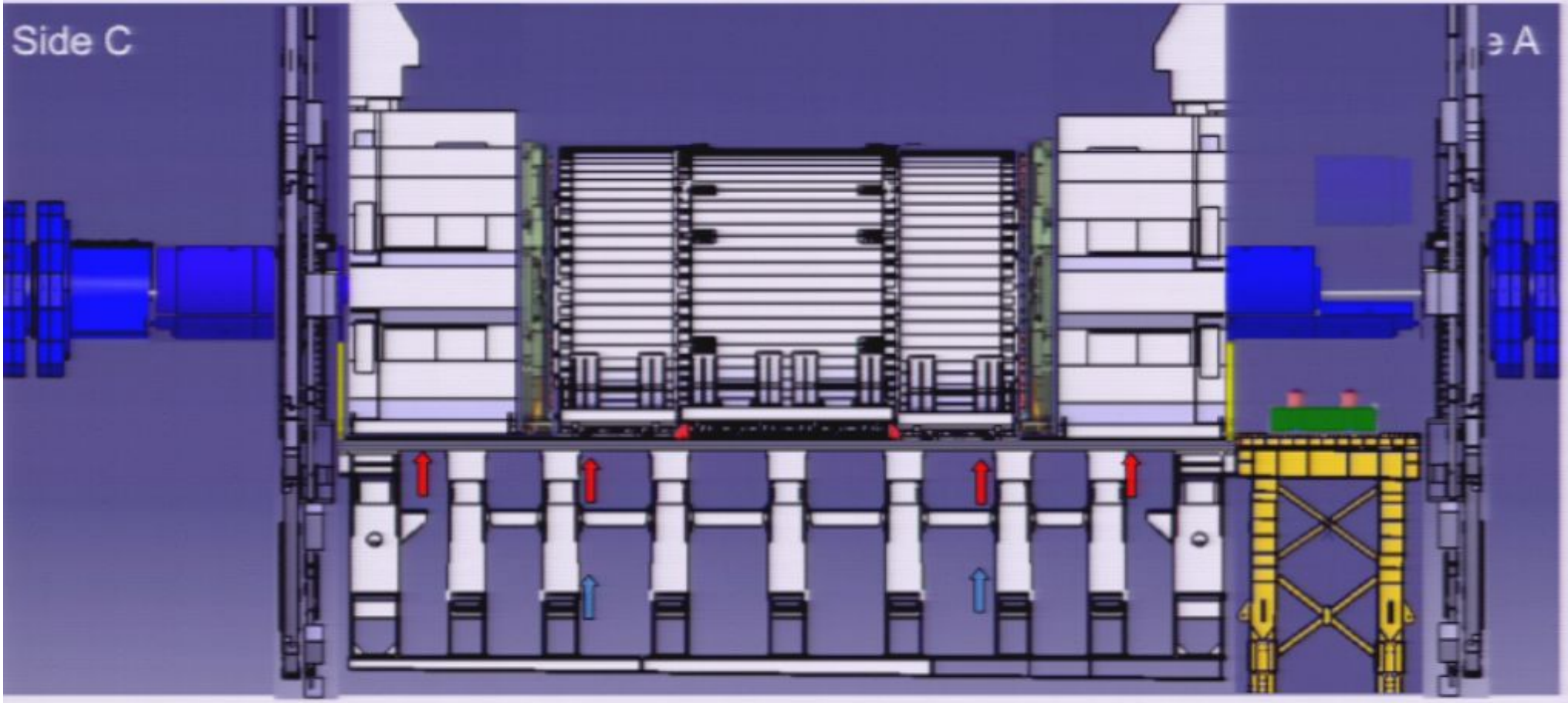

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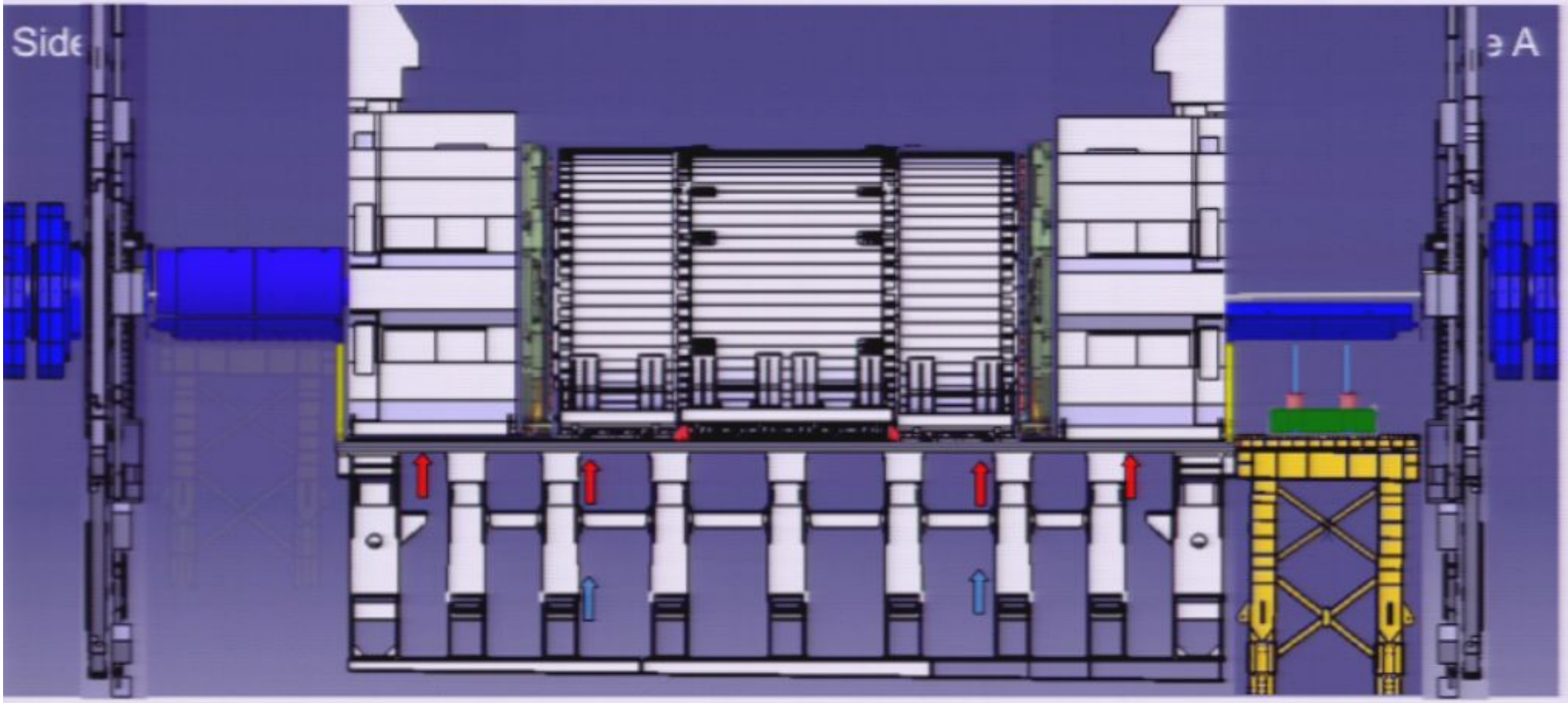

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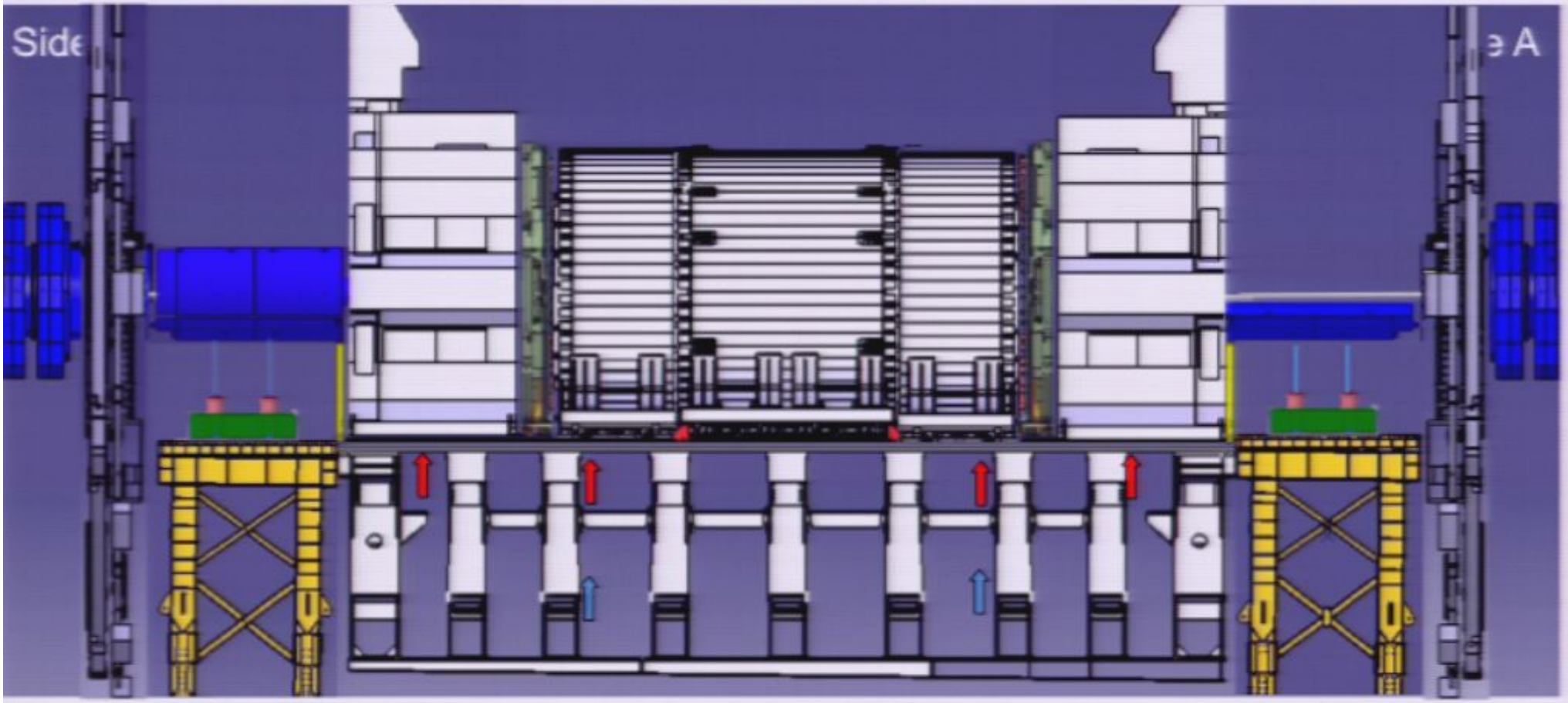

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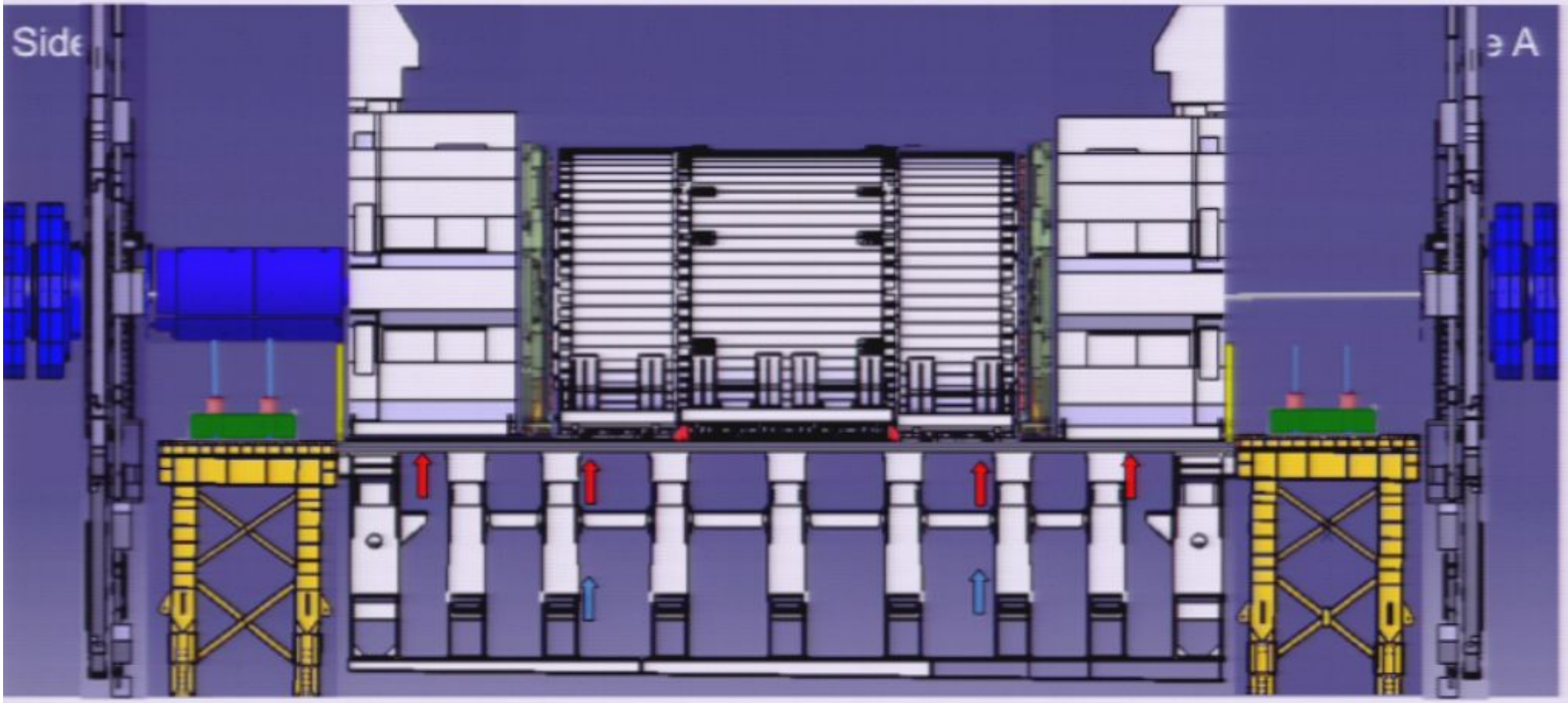

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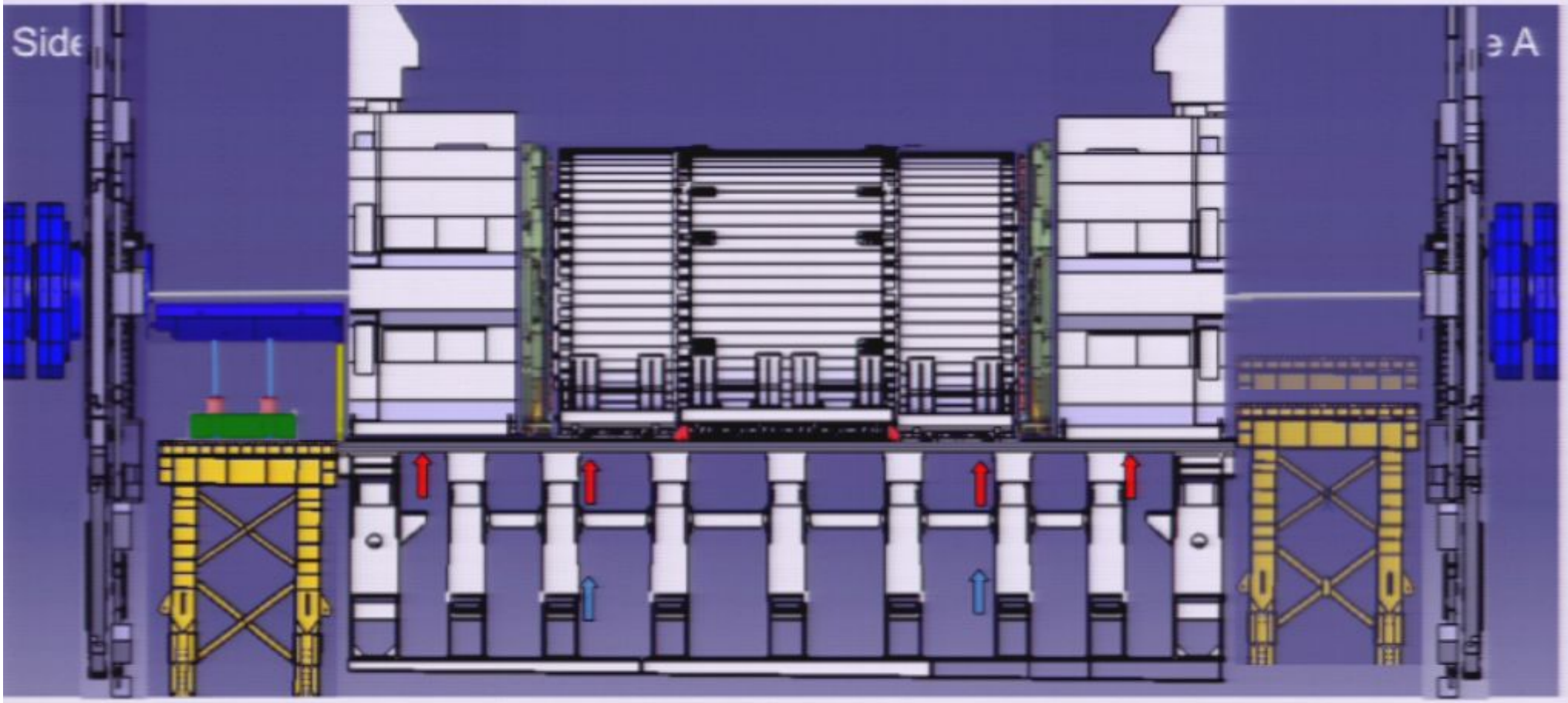

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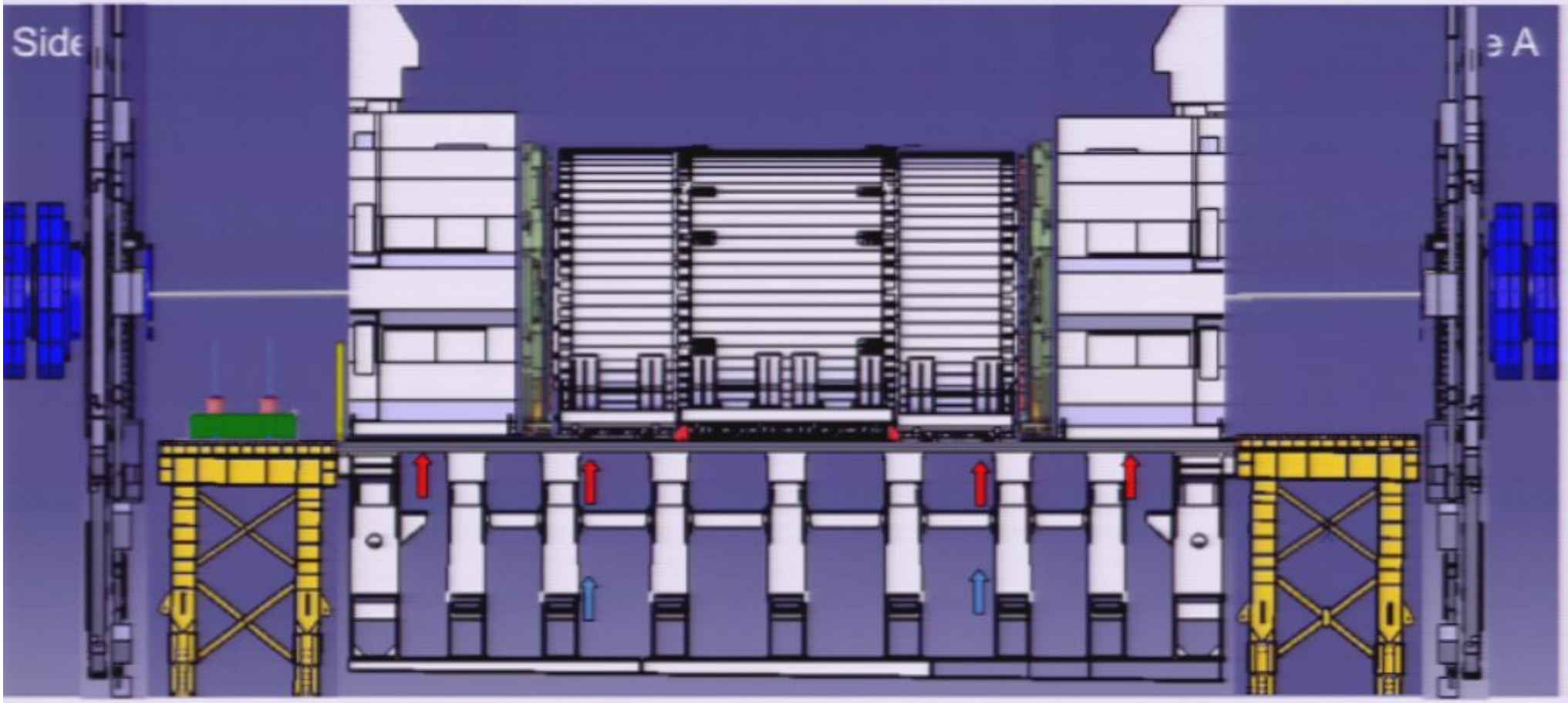

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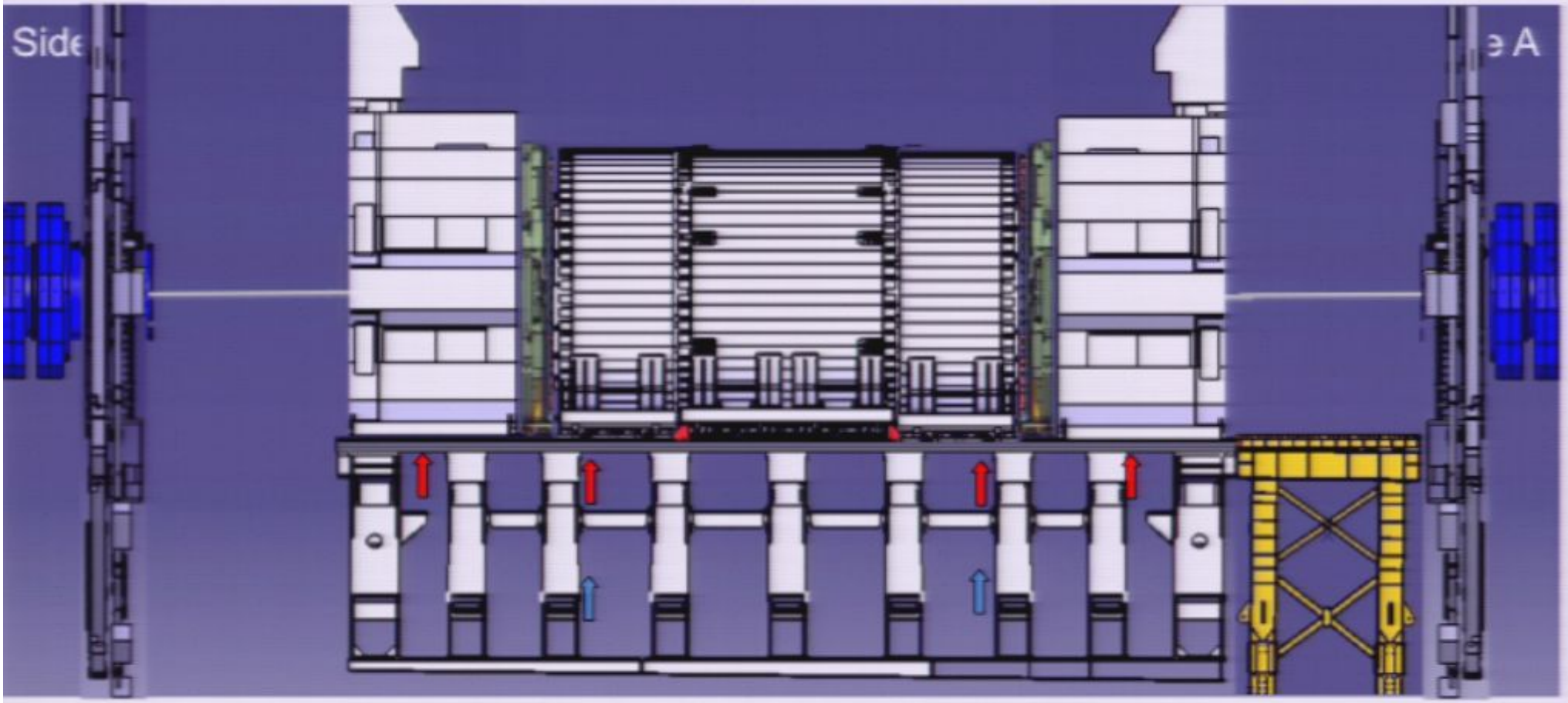

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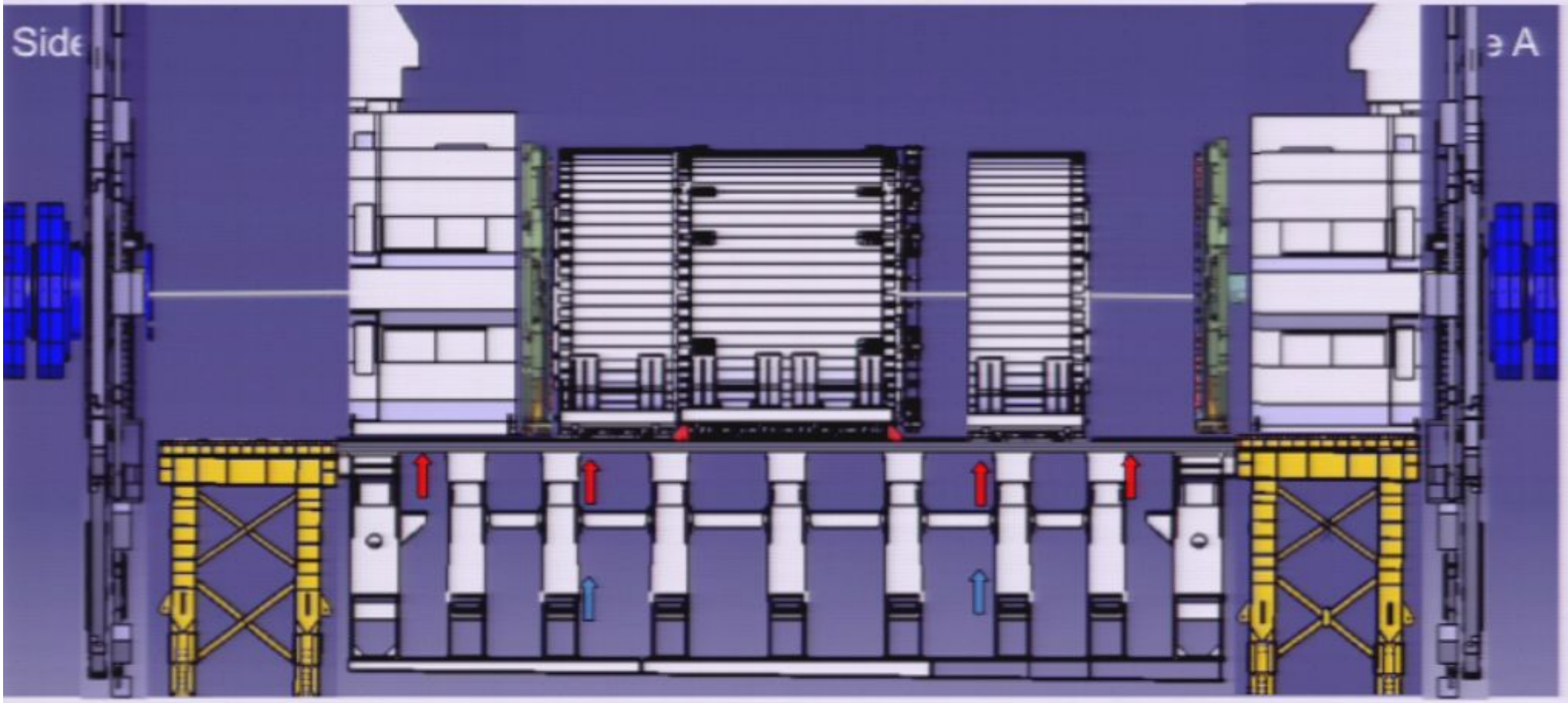

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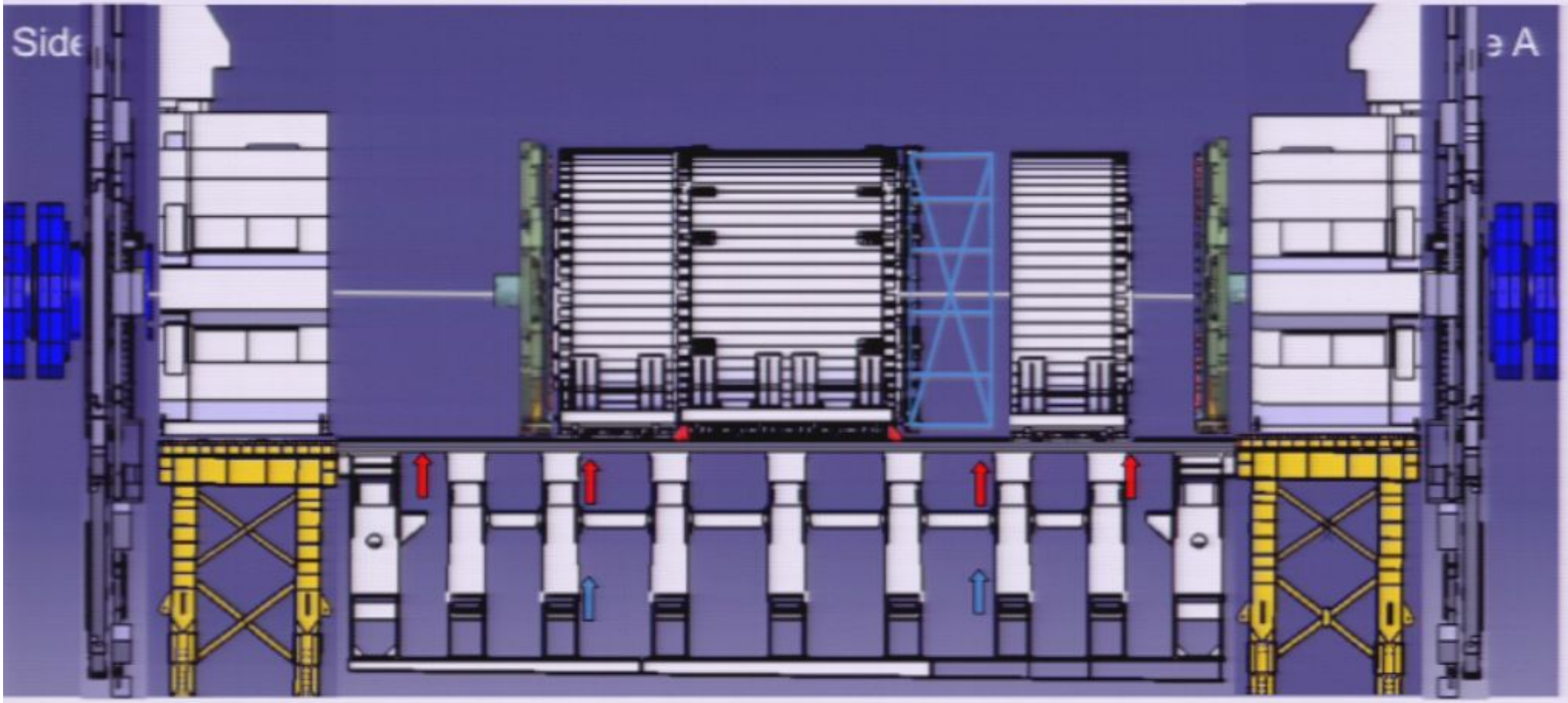

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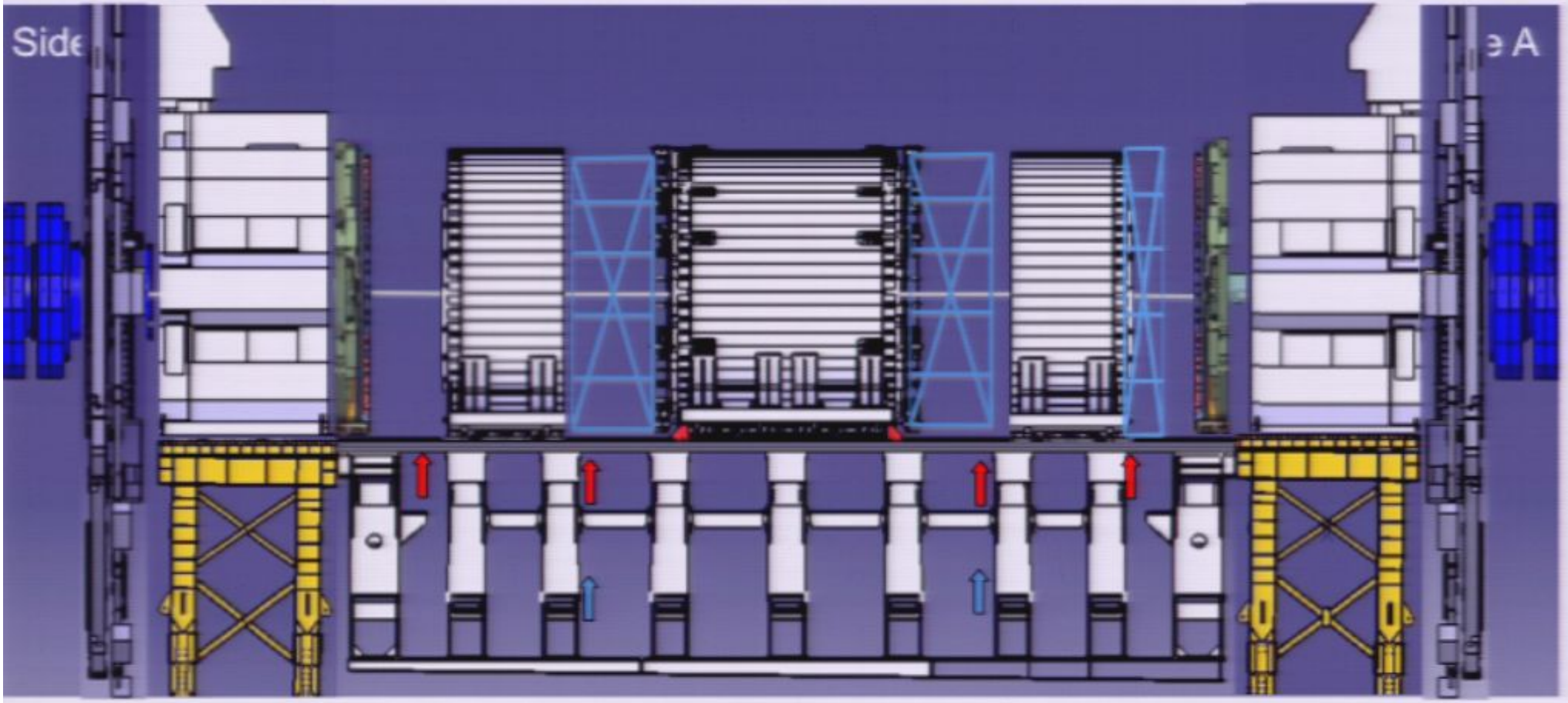

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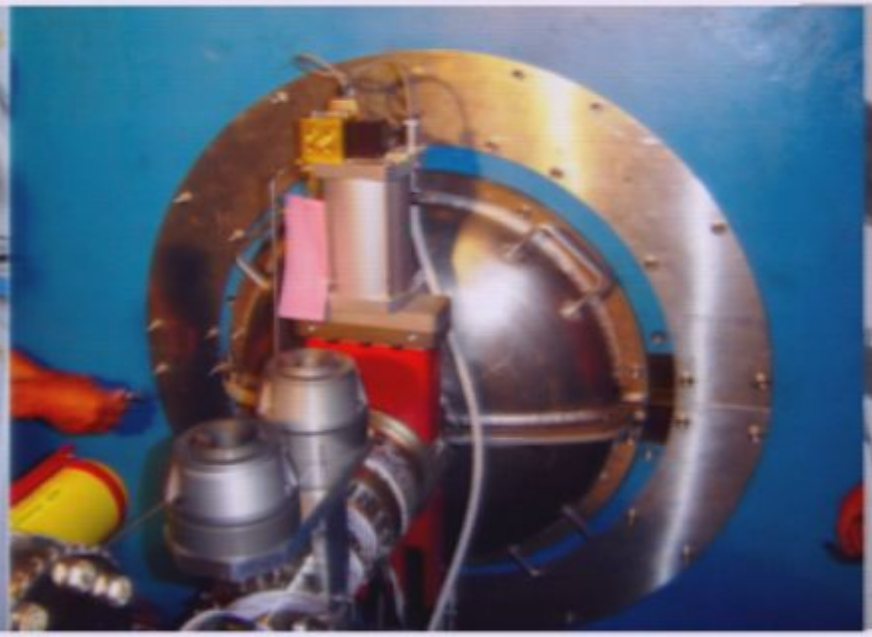
ATLAS caverns protection campaign

ATLAS cavern protected against accidental He release in the LHC tunnel.

All interfaces between the caverns and the tunnel have been redesigned and sealed according to the recommendations of the CERN task force on safety of Personnel in the LHC underground areas, following the 19th Sept. 2008 accident.

urvey gallery doors and
all



TAS region

Survey gallery services

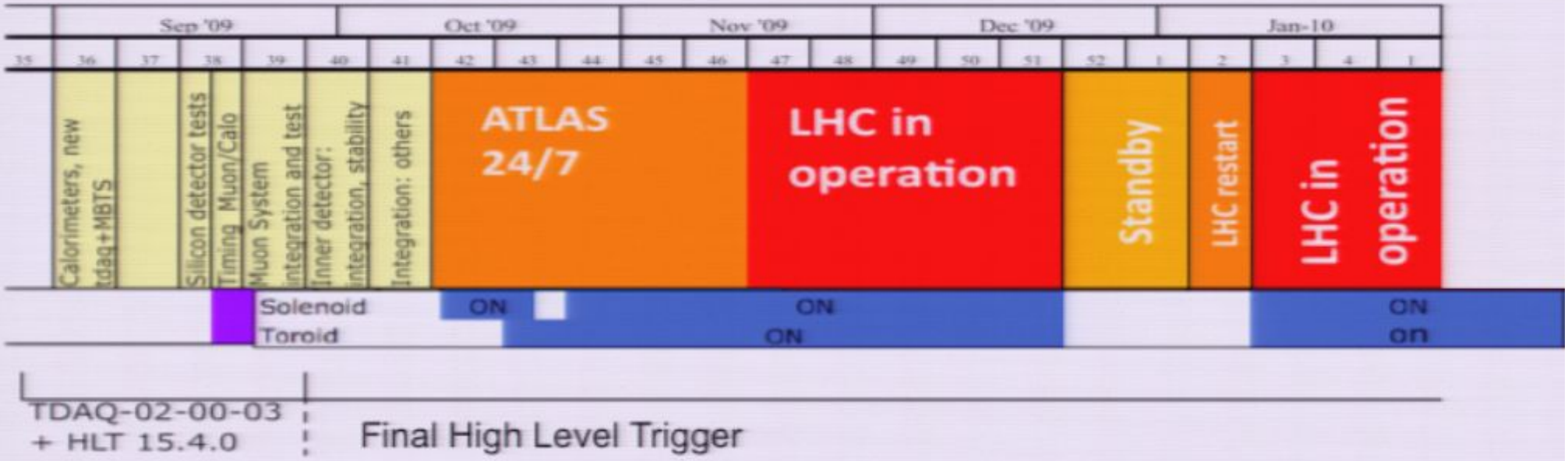
ATLAS Detector Status

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	98.0%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	98.2%
LAr EM Calorimeter	170 k	98.8%
Tile calorimeter	9800	99.5%
Hadronic endcap LAr calorimeter	5600	99.9%
Forward LAr calorimeter	3500	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	98.4%
RPC Barrel Muon Trigger	370 k	>97%
TGC Endcap Muon Trigger	320 k	99.8%
LVL1 Calo trigger	7160	99.8%

Notes:

- Muons do not include the EE chambers

ATLAS Run Schedule (next 3 months)



No Beam

* 50kHz run with all sub-systems
* High PT muon trigger
* Inclusive barrel / endcap muon trigger
* First beam trigger menu
* Alignment studies (with different B field configs)
* Trigger timing
* Express stream
* Data quality, physics monitoring
* LHC dry run, beam protection
* Stopless recovery & stability
* Access management
* ...

First Beams / Collisions

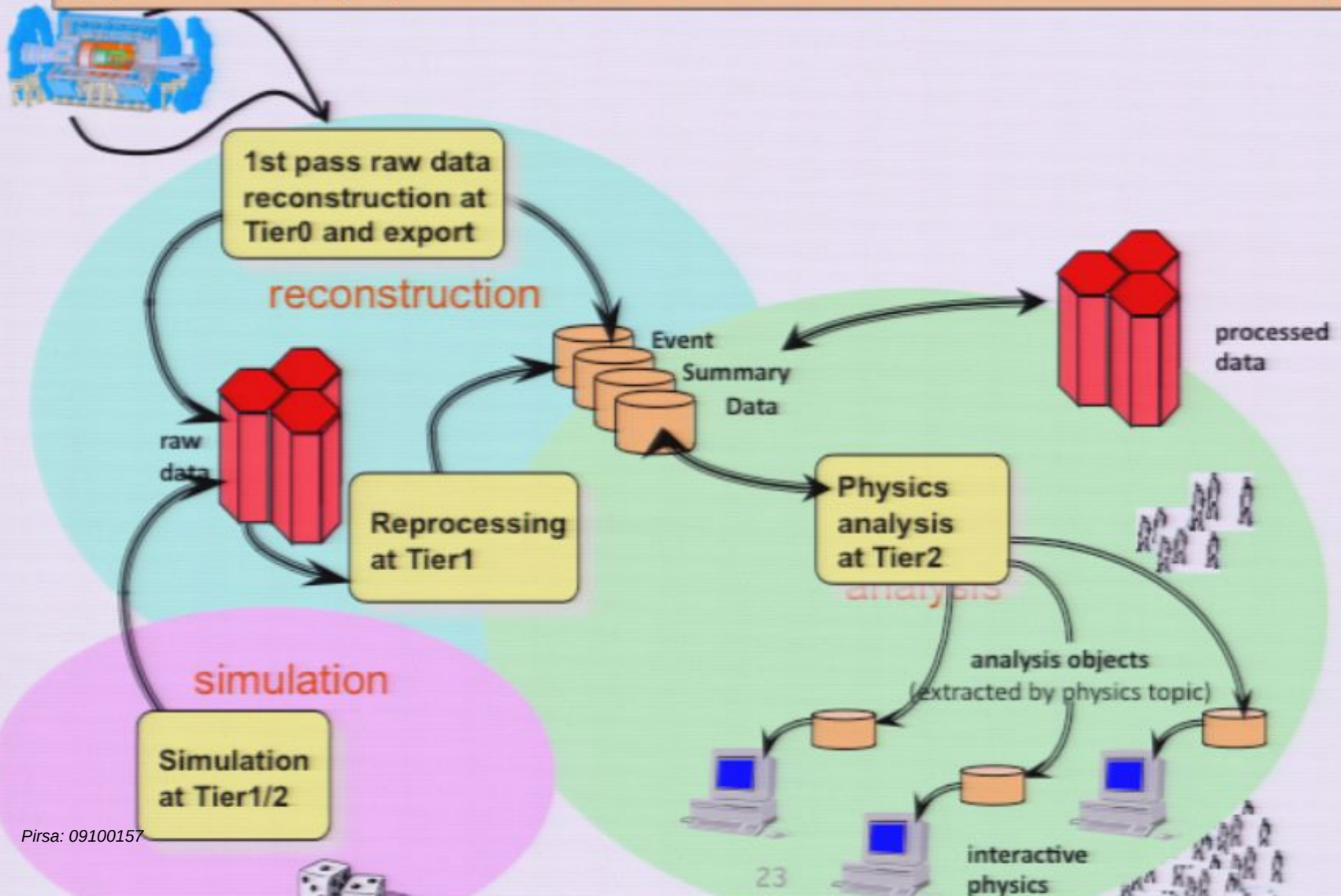
* Timing with single beam and splashes
* Timing with collisions
* First beam menu
* Phase in of HLT, physics streaming
* Validation of beam protection
* Beam conditions, collision point monitoring
* Luminosity monitoring
* Luminosity scans
* Data quality: physics objects
* Reduce dead time, readout windows

ATLAS Computing Infrastructure

ATLAS world-wide computing: ~ 70 sites
(including CERN Tier0, ten Tier-1s, forty Tier-2 federations)

4 main operations in the ATLAS Computing Model:

- First-pass reconstruction of detector data at Tier0
- Data re-processing at Tier-1s using updated calibrations
- Simulation of Monte Carlo samples at Tier-1s and Tier-2s
- (Distributed) physics analysis at Tier-2s and at more local facilities (Tier-3s)



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1st pass raw data reconstruction at Tier0 and export

reconstruction

Event Summary Data

processed data

raw data

Physics

The challenging operations (e.g. ~ 50 PB of data to be moved around the world every year, 10^9 events to be processed and reprocessed, …) Computing system stress-tested and refined through functional tests of increasing functionality, size and realism.

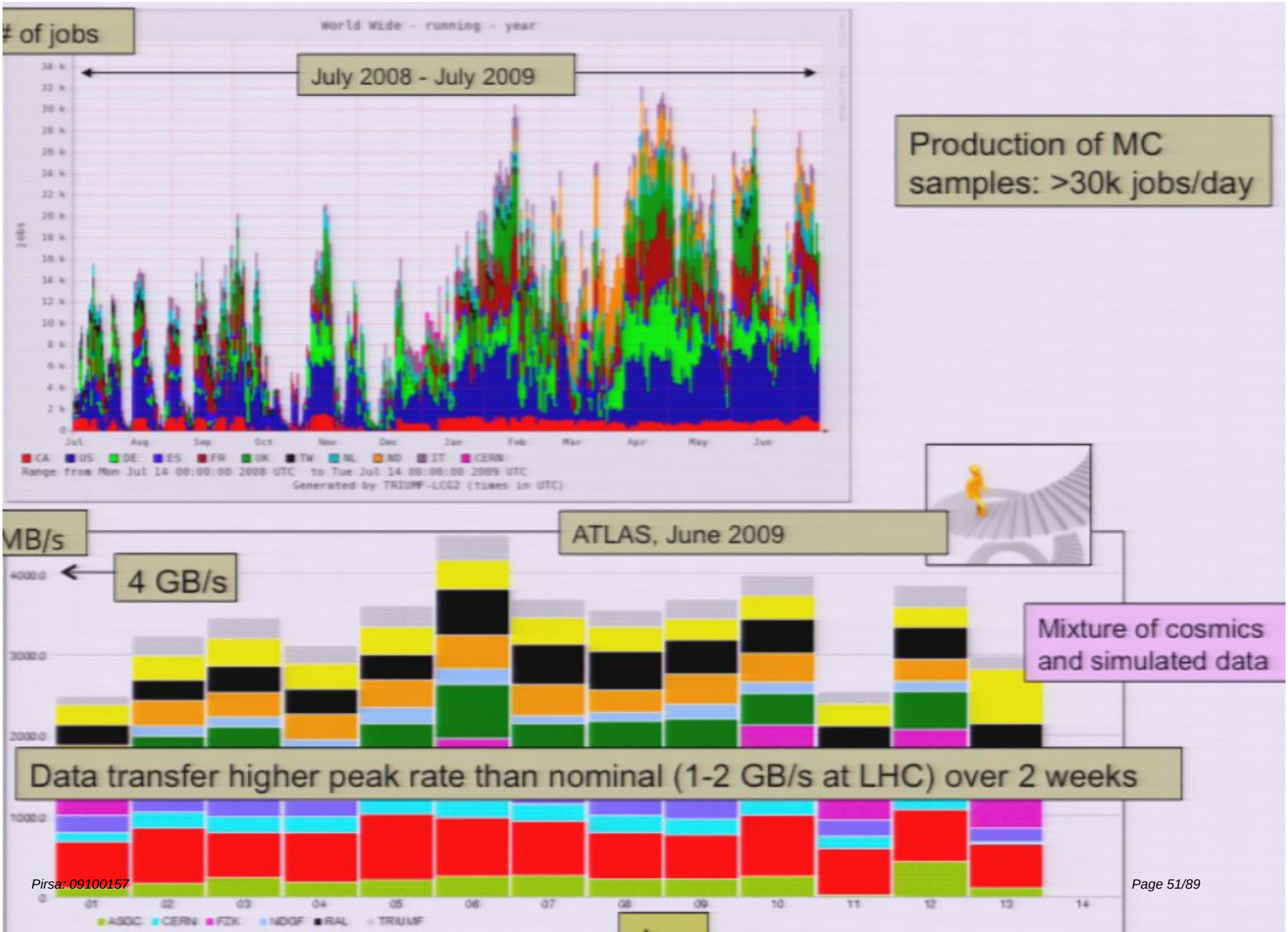
simulation

Simulation at Tier1/2

(extracted by physics topic)

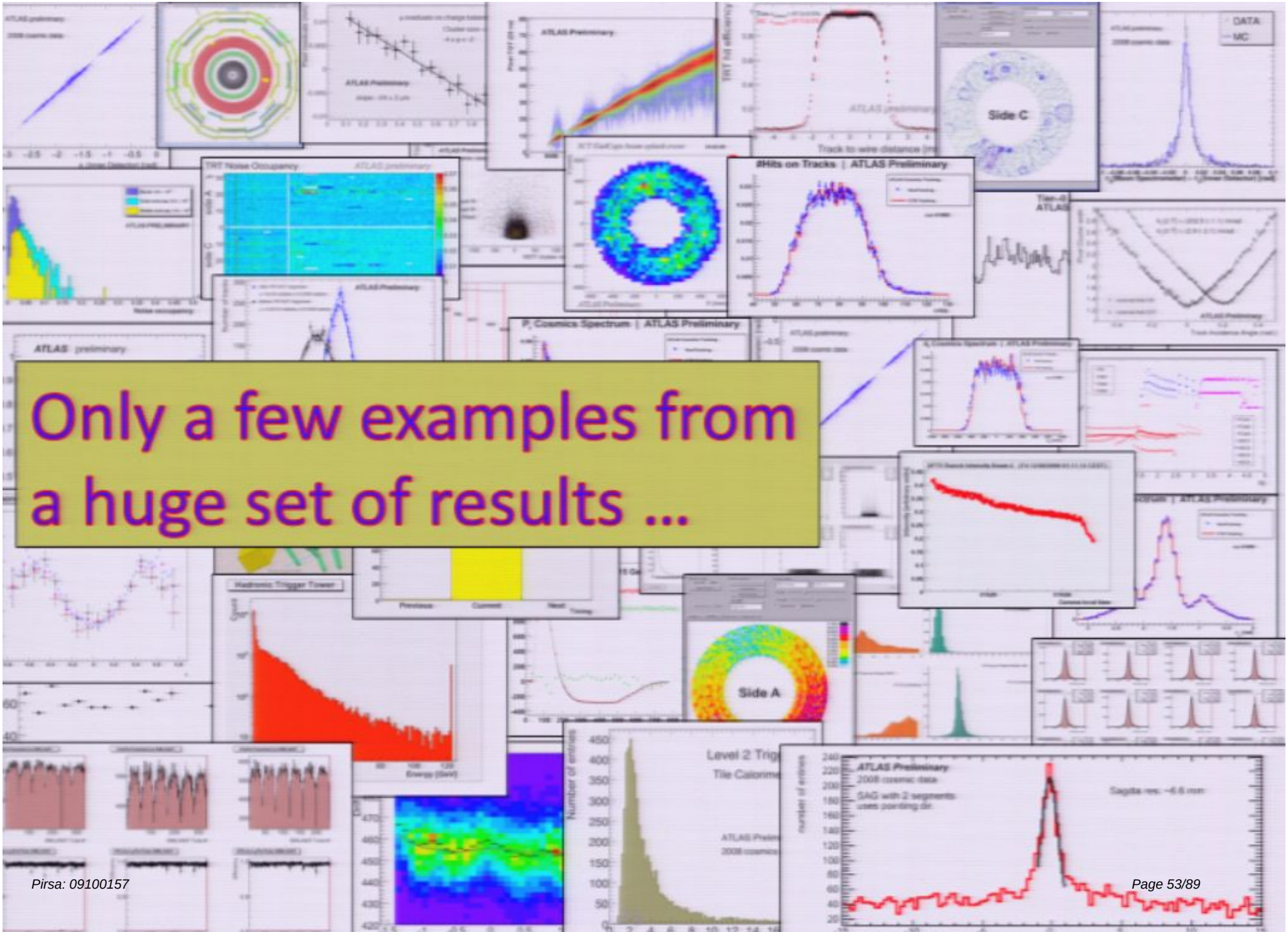
interactive physics

23

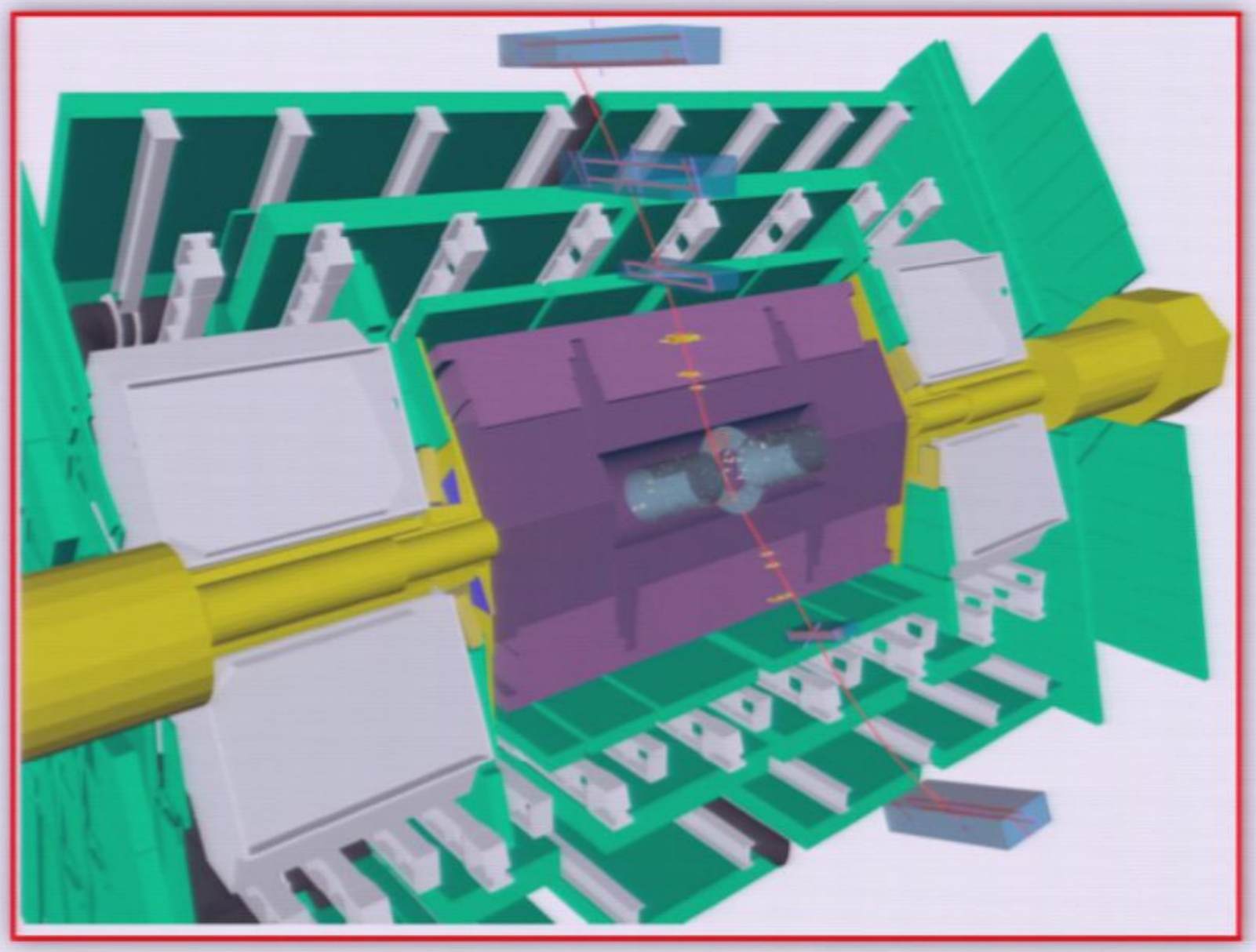

# of jobs
World Wide - running - year
July 2008 - July 2009
Production of MC samples: >30k jobs/day
MB/s
ATLAS, June 2009
4 GB/s
Mixture of cosmics and simulated data
Data transfer higher peak rate than nominal (1-2 GB/s at LHC) over 2 weeks

Detector Commissioning with Cosmic Rays

- Cosmic ray data samples with full experiment in operation
  - ~300M events in Sept/Oct 2008
  - ~100M events in June/July 2009
- O(300) plots approved for conferences this year
- Plan to publish ~8 papers before the end of the year
- Detector understanding (performance, alignment calibration) is far better than any previous experiment at this stage

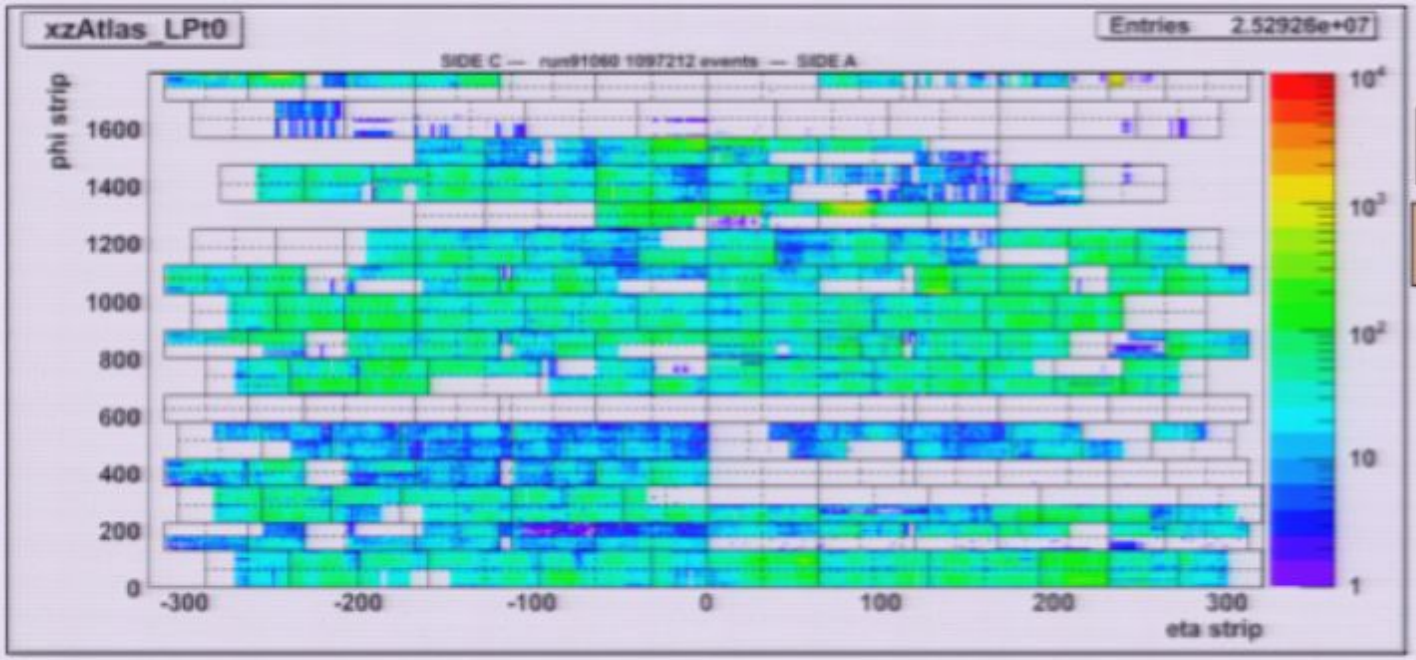

Only a few examples from a huge set of results …
ATLAS Preliminary
Side C
Side A
#Hits on Tracks | ATLAS Preliminary
TRT Noise Occupancy
Hadronic Trigger Tower
DATA
MC

Cosmic Ray through all of ATLAS (October 2008)



- Cosmic ray rate in ATLAS: 1-700 Hz depends on detector size

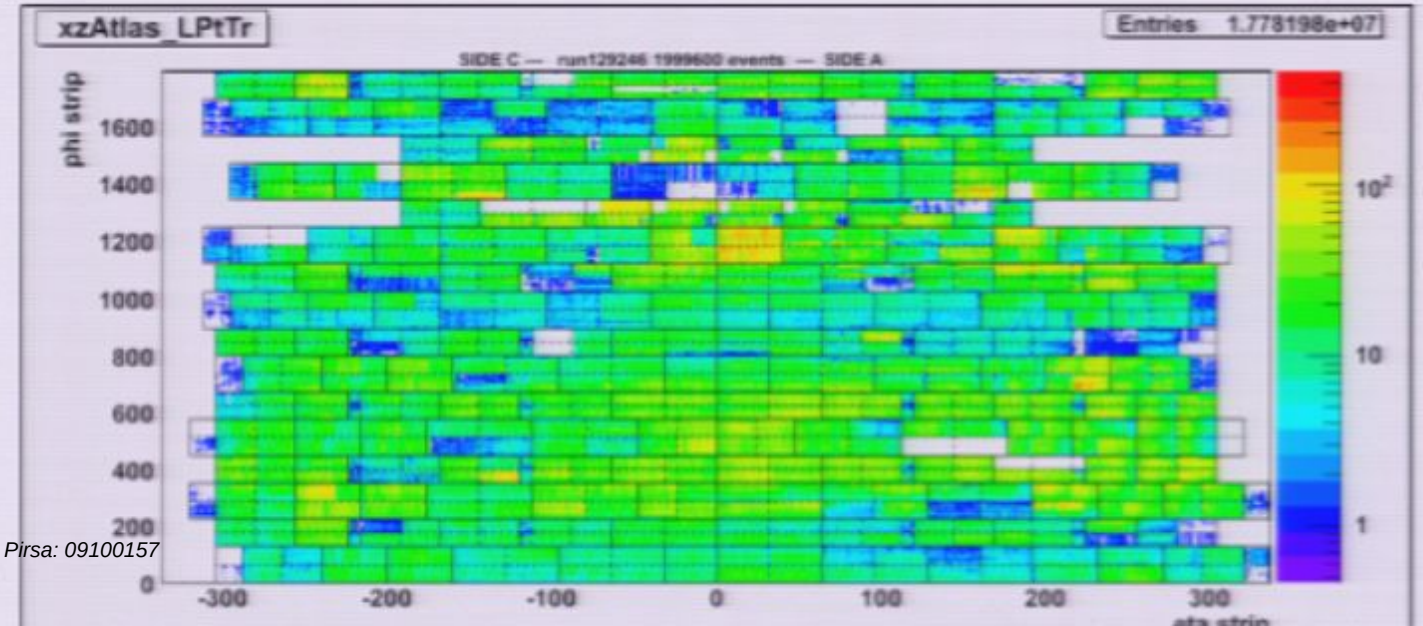
Muon Trigger Chamber hit rates



8/10/2008

Coverage ~ 70%

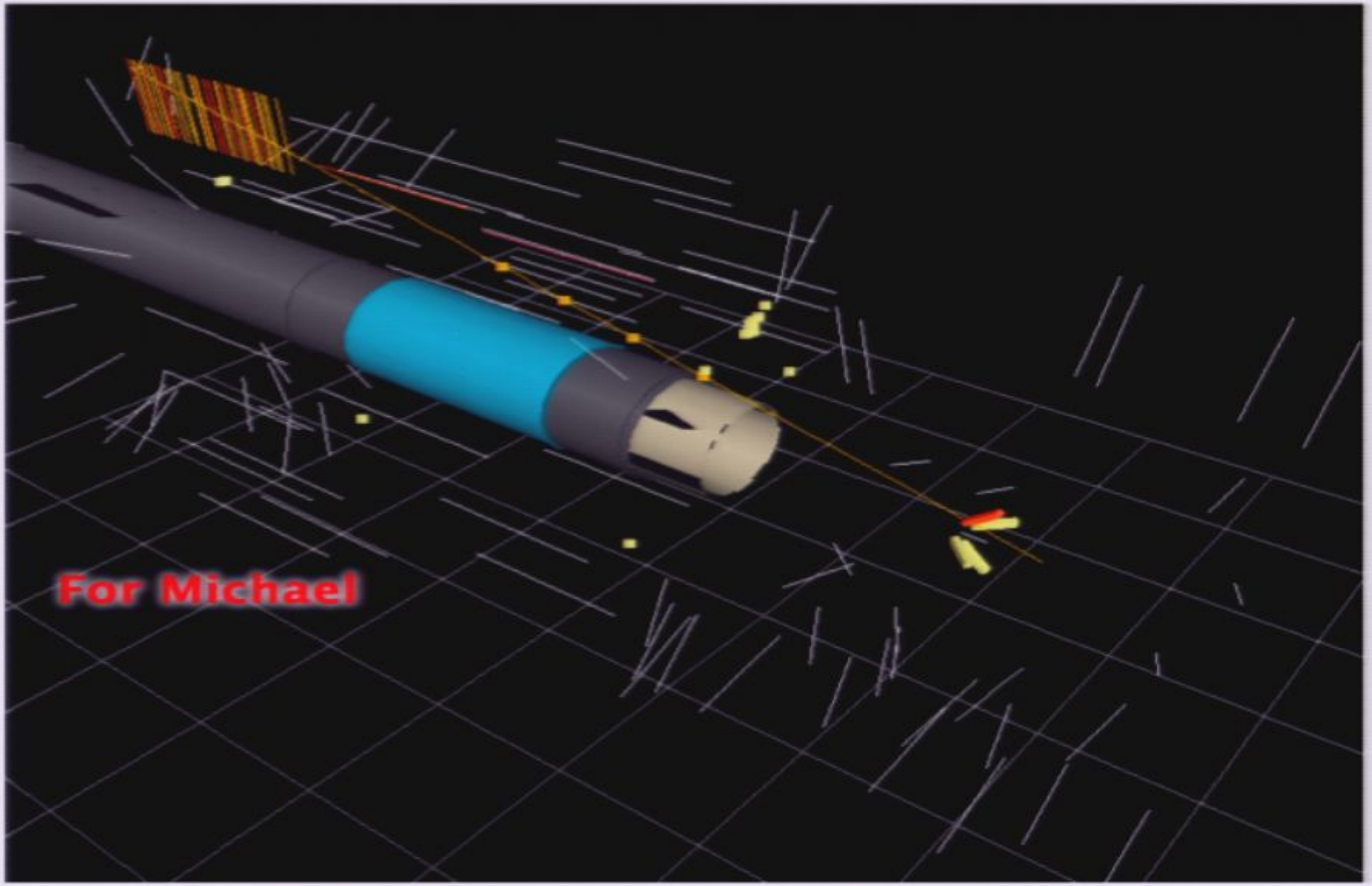
Consolidation and repair work



12/09/2009

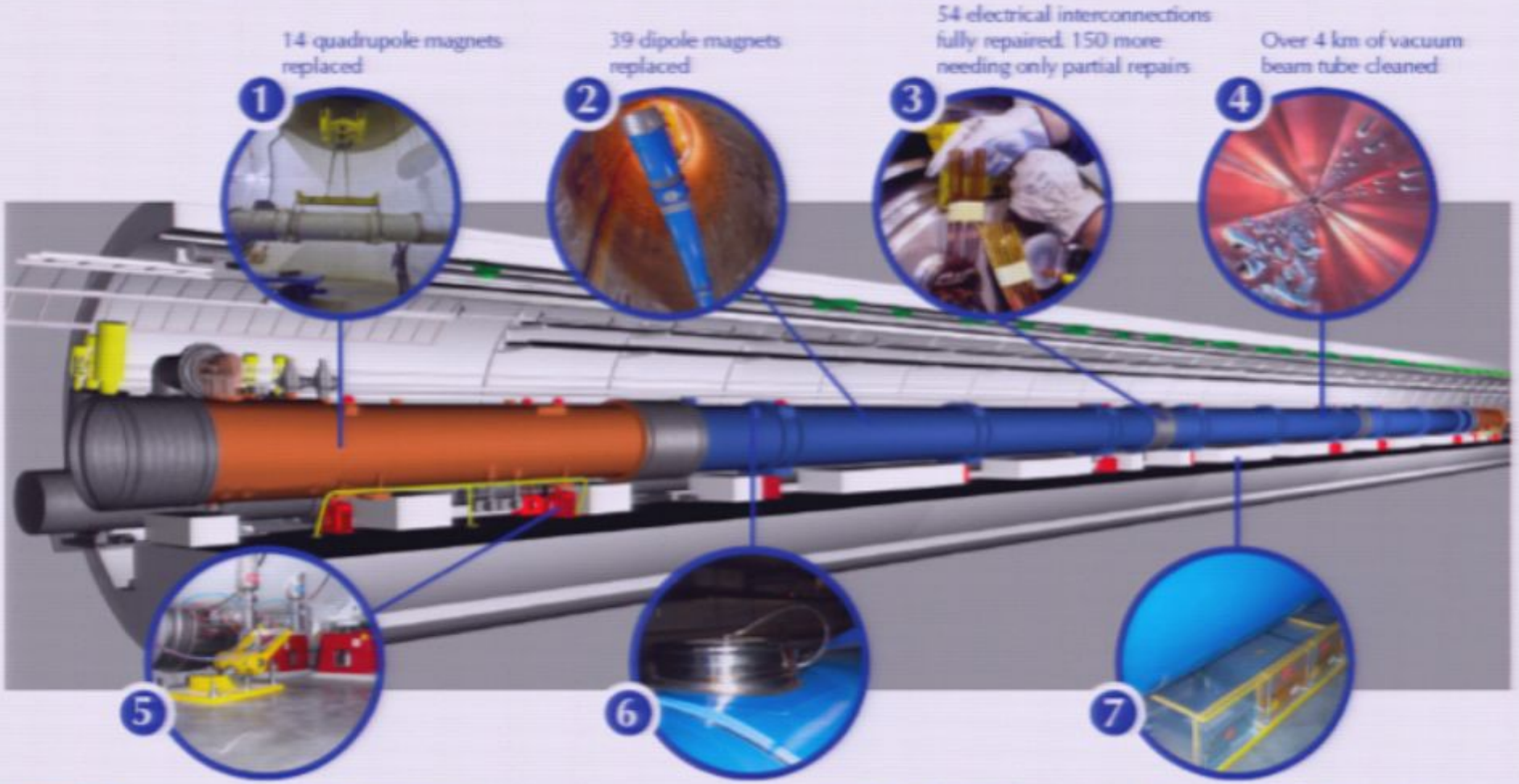
Coverage > 97%

Cosmic Ray in Smallest ATLAS Detector

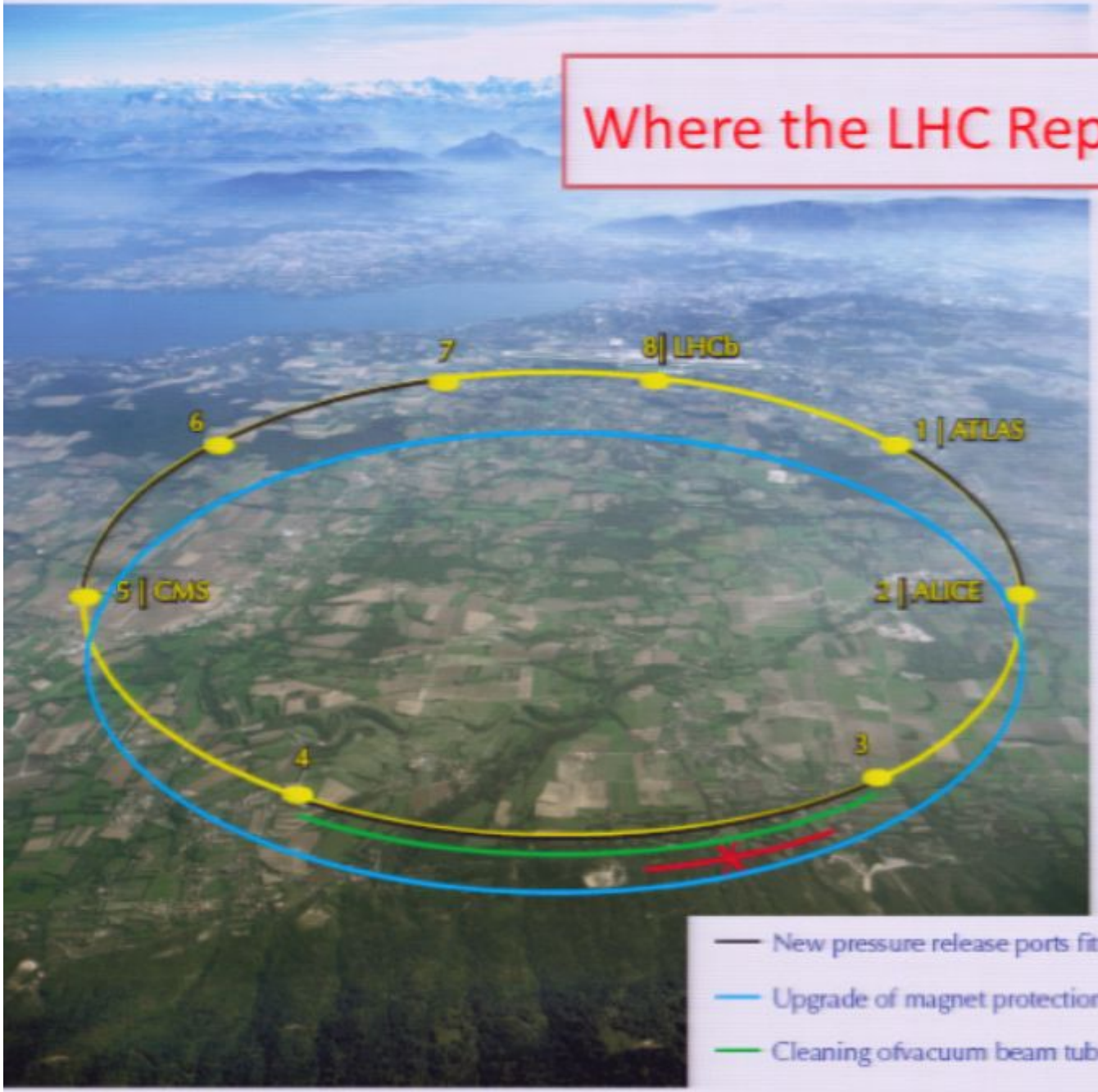


- Beam Conditions Monitor ($1cm^2$) sits in very forward acceptance

The LHC repairs in detail



Where the LHC Repairs are Happening



- New pressure release ports fitted
- Upgrade of magnet protection system
- Cleaning ofvacuum beam tube
- Dipole and quadrupole magnets replaced and electrical interconnections
- LHC ring

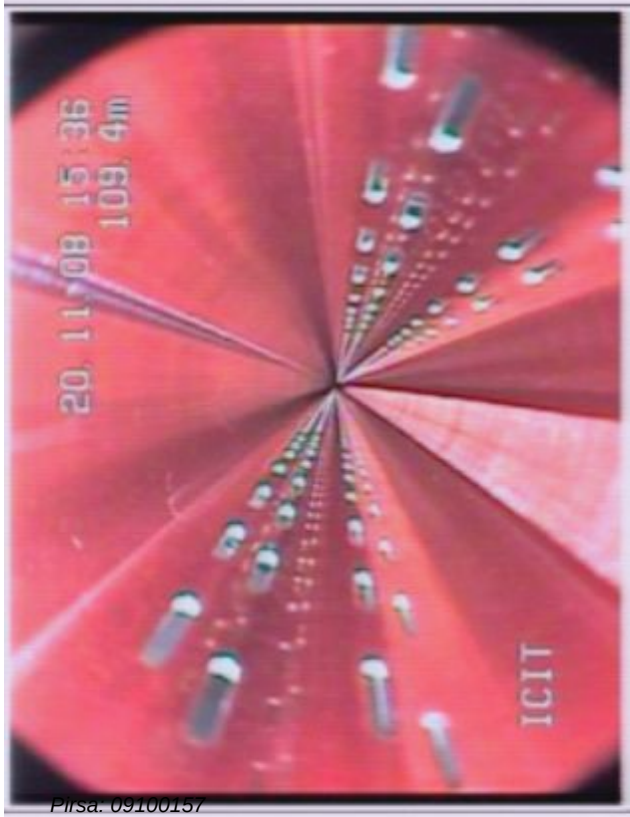
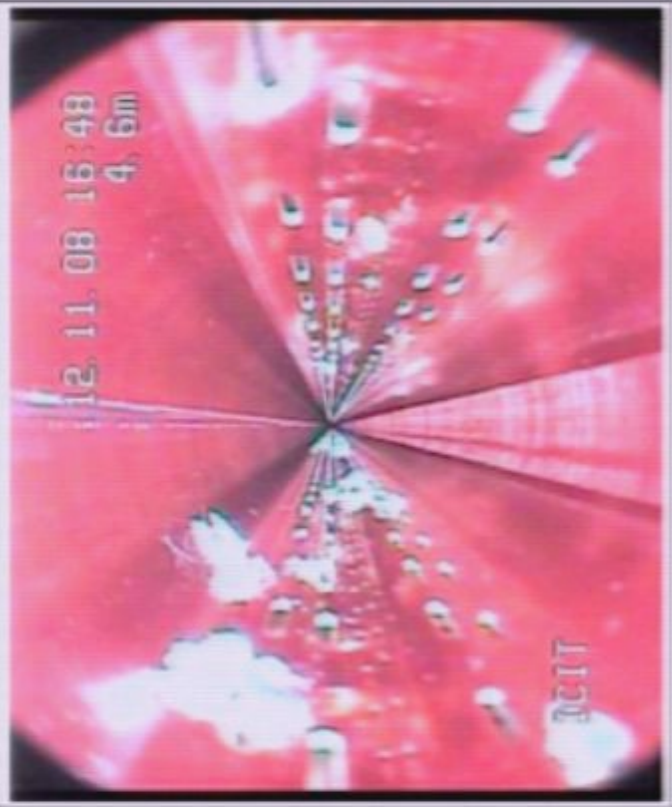
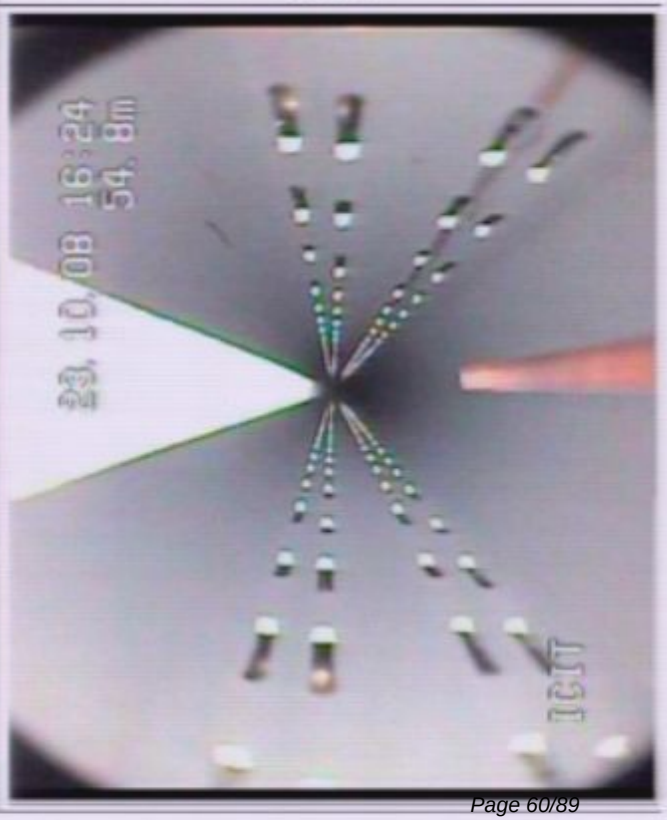
Repair of Cyrogenic Service Module in Sector 34

Before repair

After repair

Q27

Beam Screen/Vacuum Chamber Cleaning

Beam Screen (BS) : The red color is characteristi c of a clean copper surface	BS with some contaminati on by super-isolati on (MLI multi layer insulati on)	BS with soot contaminati on. The grey color varies depending on the thickness of the soot, from grey to dark.
		

Enhanced LHC machine Quench Protection

- To protect against incidents like the one that happened in 2008
  - Implement new current monitoring circuitry
  - Careful inspection of all inter-magnet splices (80K, 300K)
- Quench Protection system allows
  - Monitoring of joint resistance (nΩ) at operating temperature
  - Automated monitoring of bus-bars when magnets warm
- Also added 30 mm diameter relief valves to magnet cryostats

Quench Protection Upgrade

For installation in Phase 2

QQTE board for ground voltage tection

tal 1308 boards, 3 units/crate)

DQAMG-type S controller board

1 unit / crate, total 436 units

DQLPUS Power Packs

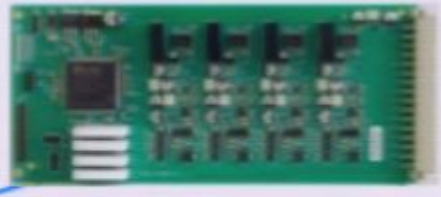
2 units / rack (total 872 units)

DQQBS board for busbar splice detection

5 such boards / crate, total 2180 units

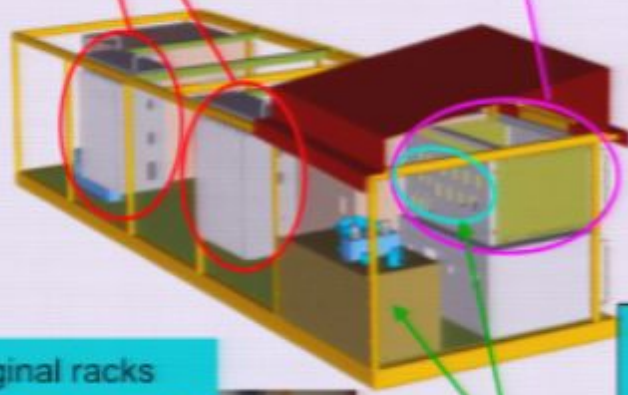
DQLPU-type S crate

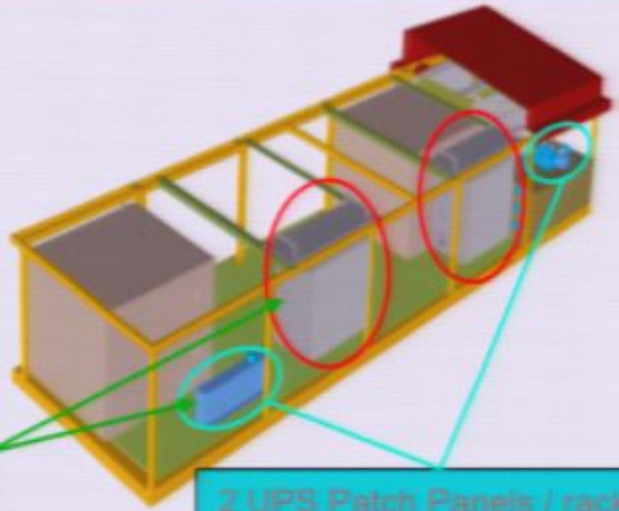
total 436 units



DQQDS board for SymQ detection

4 boards / crate, total 1744





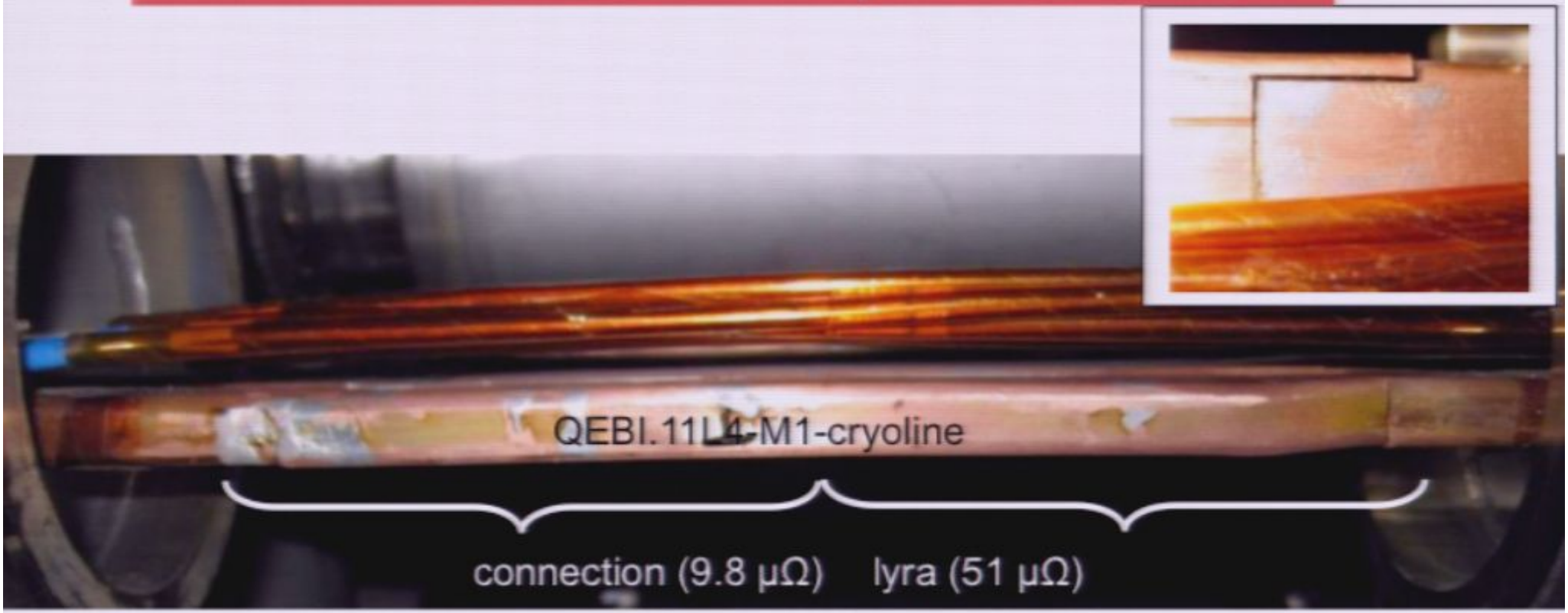
Original racks

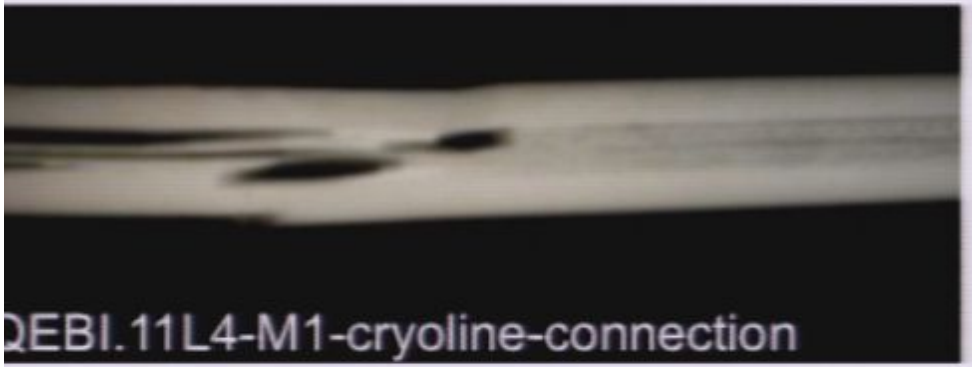
'Internal' and 'external' **cables** for sensing, trigger, interlock, UPS power, uFIP (10'400 + 4'400)

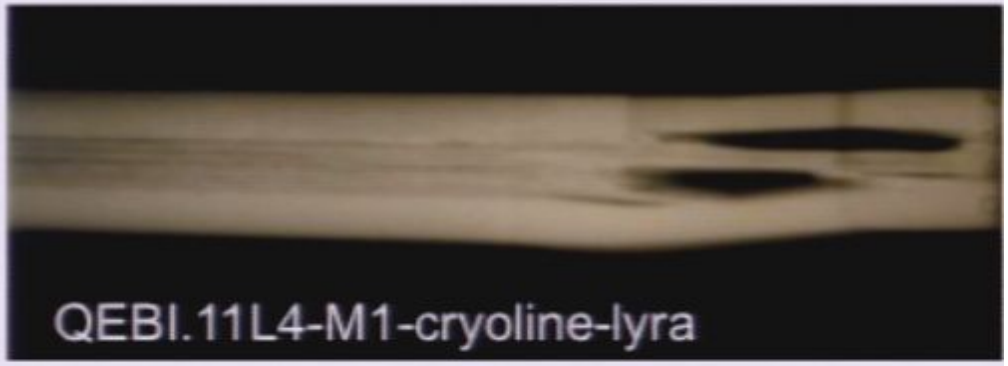
2 UPS Patch Panels / rack & 1 Trigger Patch Panel / rack

total 3456 panel

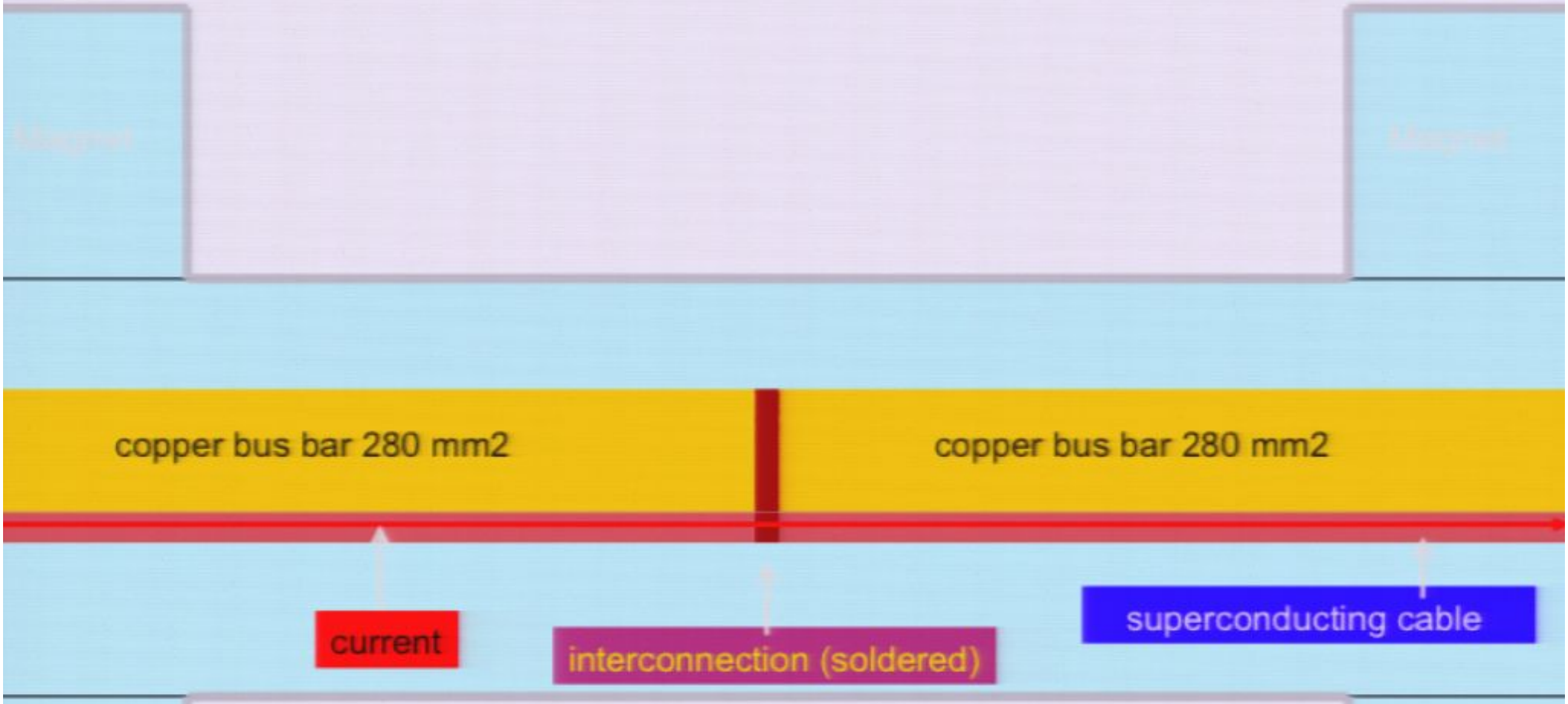
Sector 3-4 : QEBI.11L4-M1-cryoline before repair





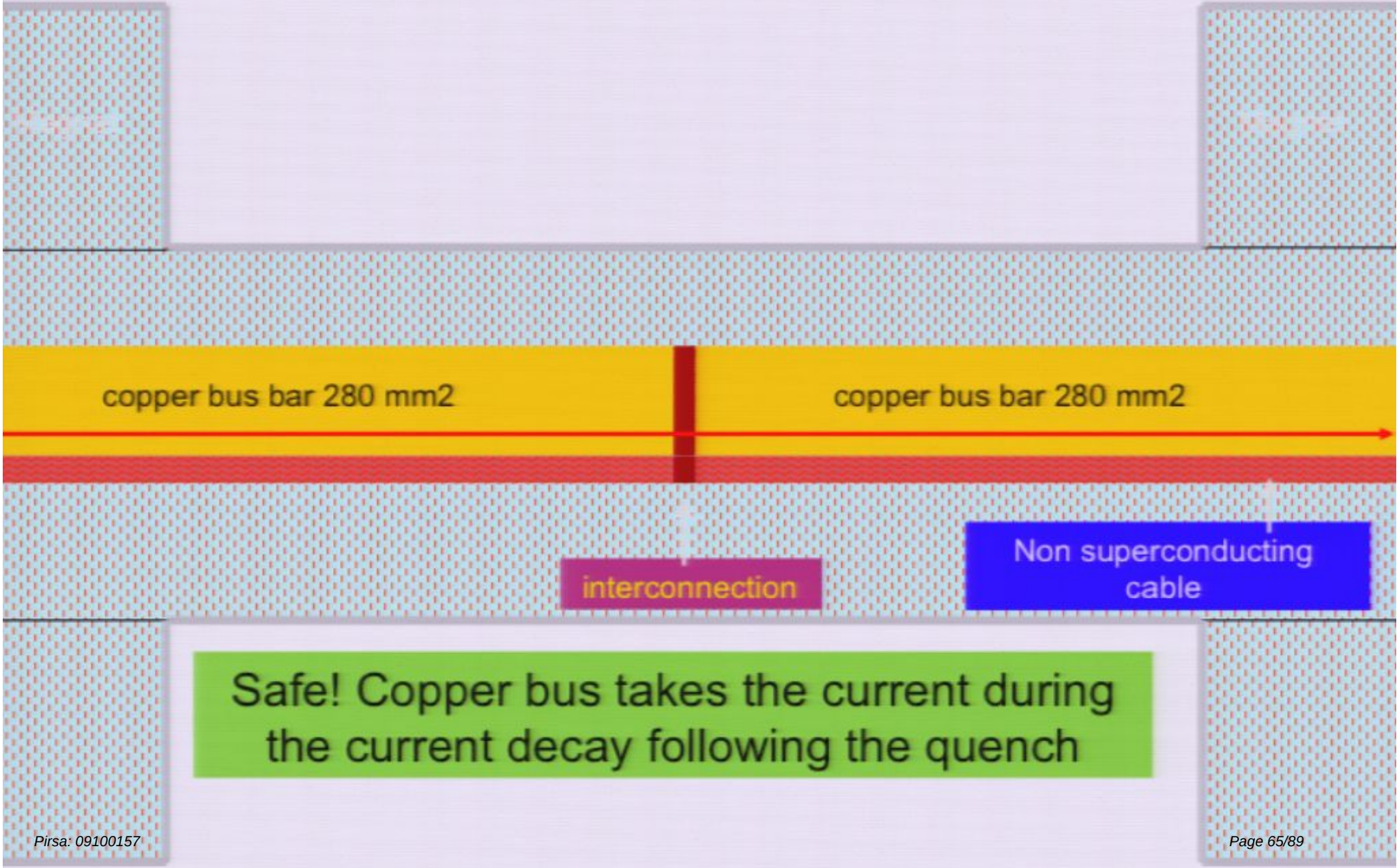


Good interconnect normal operation (1.9K)



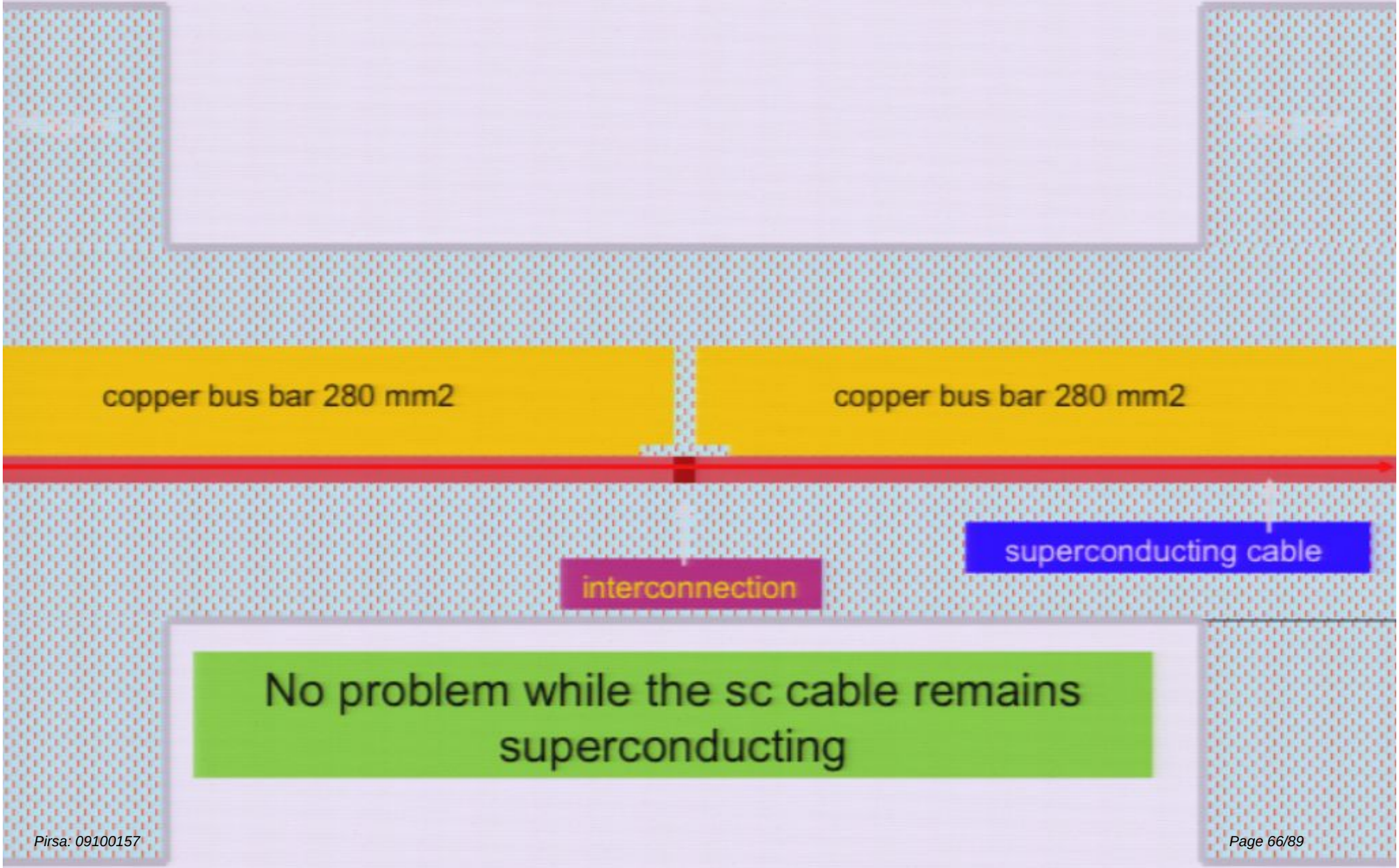
Must be sure the joint between the sc cables is good.
Measurements of nΩ at 1.9K

Good interconnect, after quench (>10K)



Safe! Copper bus takes the current during the current decay following the quench

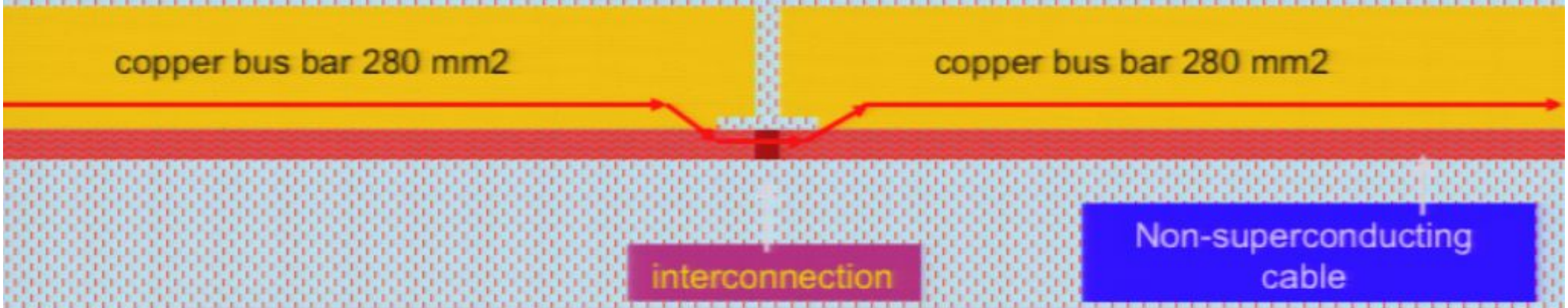
Bad interconnect, normal operation 1.9K



No problem while the sc cable remains superconducting

Bad interconnect, after quench

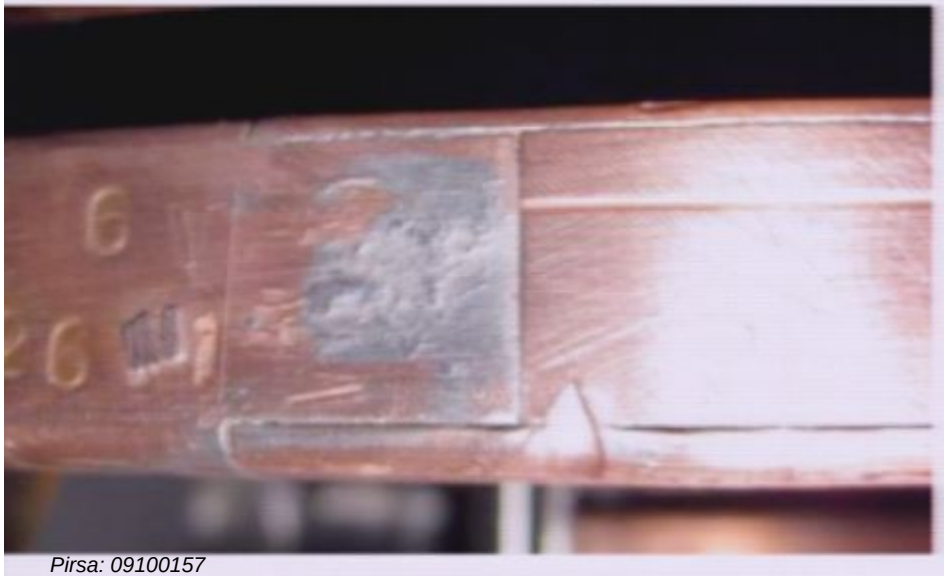
Current path is deviated through the sc cable (which is no longer sc). Depending on the current and length of this path, the cable can suffer thermal runaway

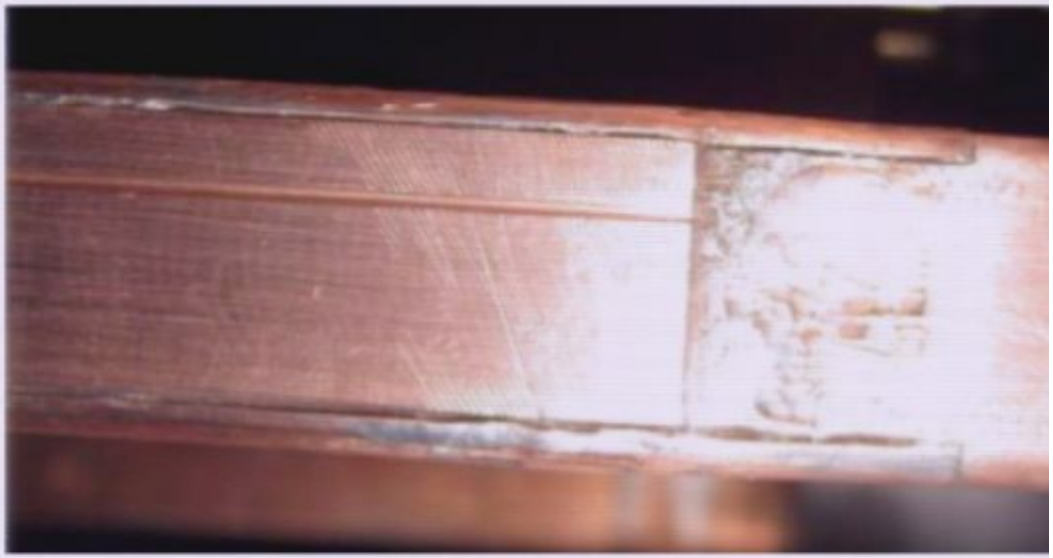


Danger of melting the sc cable then electrical arc

Must be ensure that copper stabiliser is continuous
Measure μΩ at room temperature (10's nΩ cold)

Sector 3-4 : QEBI.11L4-M1-cryoline repaired





Splice Counts in Dipoles (RB) and Quadrupoles (RQ)

circuit	splice type	splices per magnet	number of units	total splices
RB	inter pole	2	1232	2464
RB	inter aperture	1	1232	1232
RB	interlayer	4	1232	4928
RB	internal bus	1	1232	1232
RB	interconnect	2	1686	3372
RQ	Inter pole	6	394	2364
RQ	internal bus	4	394	1576
RQ	interconnect	4	1686	6744
total				23912

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Summary of Splice Resistance Measurements

- Summary of measurements performed on RB and RQ circuits

Circuit	Sector 12	Sector 23	Sector 34	Sector 45	Sector 56	Sector 67	Sector 78	Sector 81
RB	300		300, 300	300, 300	300	300, 300		
RB		80		80			80	80
RQ	300		300	300	300	300, 300		
RQ		80		80			80	80, 80

- Huge effort of dedicated measurement teams
  - About 35000 manual measurements
  - Over 400 kilometers walked in the tunnel

LHC Energy Operating Point for 2009/2010

- Worst magnet measured at 300K: 53 μΩ
  - At 7 TeV (50/10s energy extraction) shown safe to 120 μΩ
    (Conservative simulation assumptions)
  - At 10 TeV (70/15s energy extraction) safe to 70 μΩ
    (Slightly less conservative simulation assumptions)
- Decision: Operate initially at 7 TeV
  - Factor of two safety margin for worst bus-bars
  - Gather more data, operating experience, quenches
  - Use this to validate simulations
- Run at (about) 10 TeV later in 2010

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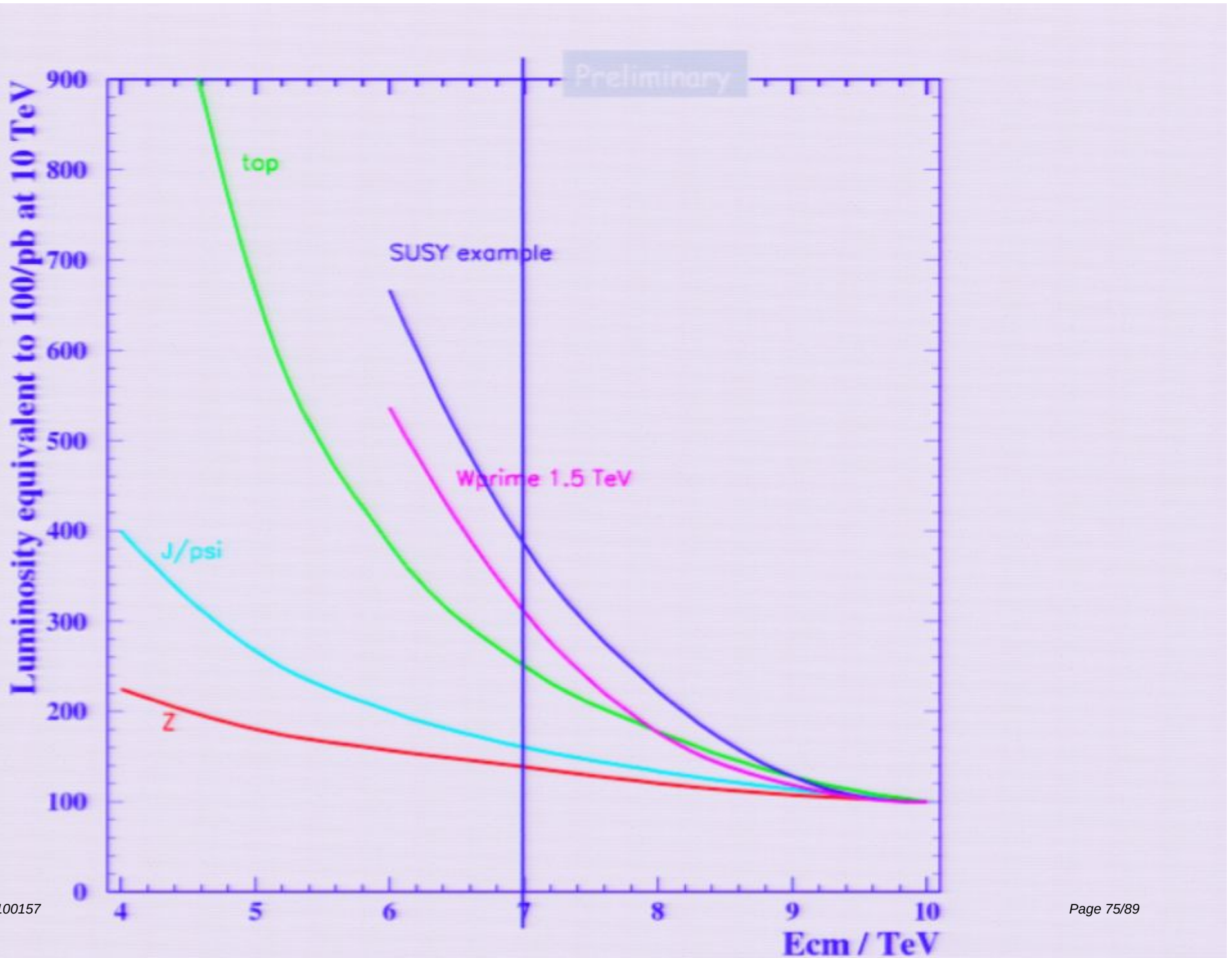

Preliminary
Luminosity equivalent to 100/pb at 10 TeV
900
800
700
600
500
400
300
200
100
0
top
SUSY example
Wprime 1.5 TeV
J/psi
Z
4
5
6
7
8
9
10
Ecm / TeV

Where is the LHC now ?

- Machine is cold
- Commissioning electrical circuits to 2000 A
- Establish circulating beams at injection energy
- Produce first collisions 900 GeV
- Establish ramp to 1.1 TeV
- Highest energy proton collisions (before end of the year)
- Commission circuits to 10,000 A
- Collisions at 7 TeV (spring of 2010?)

News: 26 October 2009

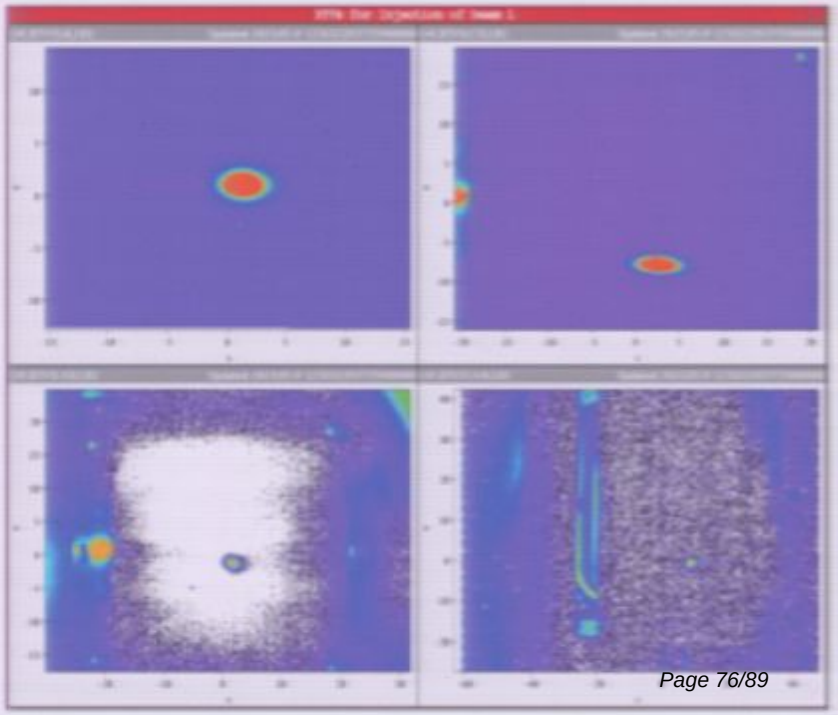
Particles are back in the LHC!

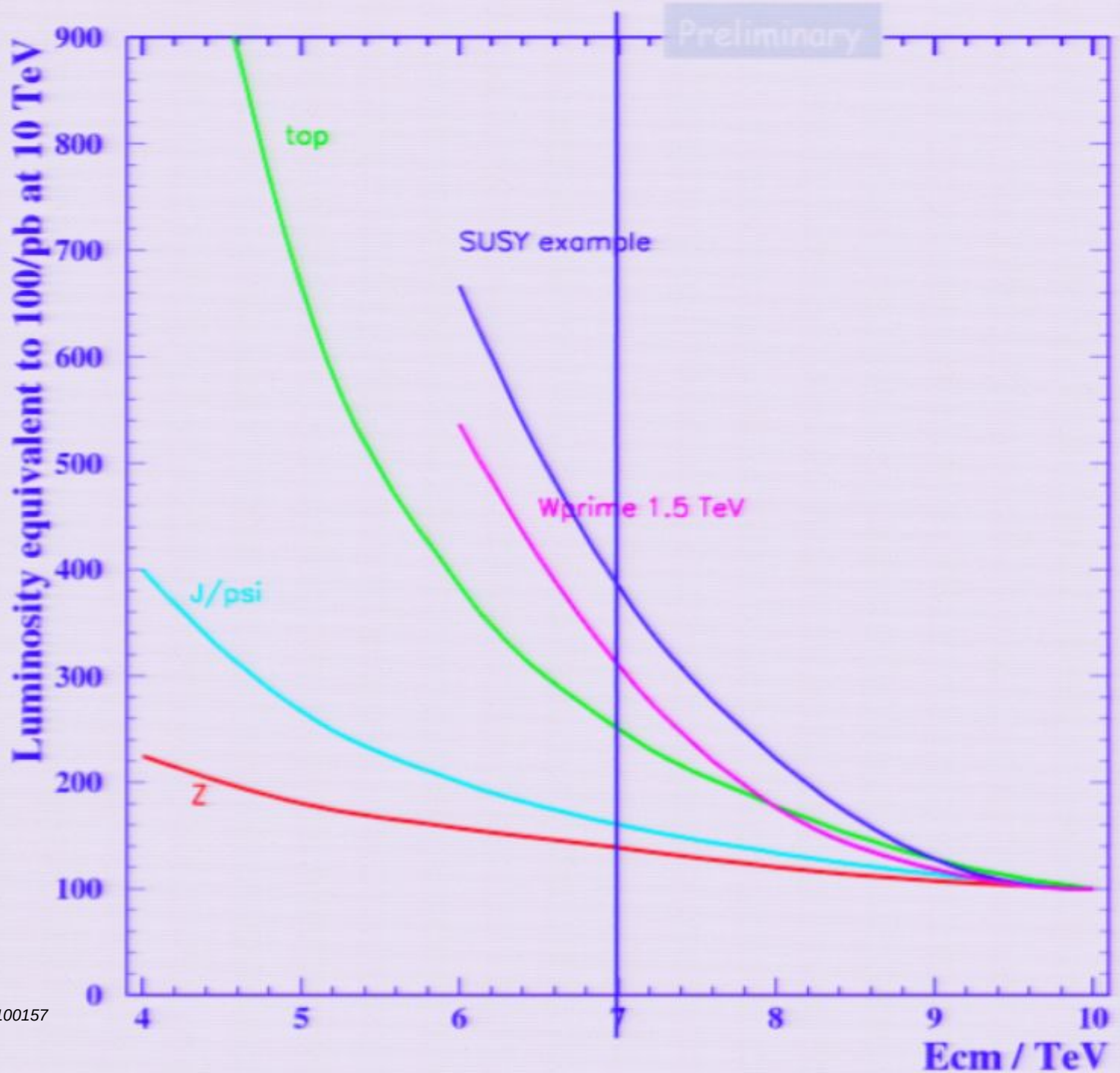
During the last weekend (23-25 October) particles have once again entered the LHC after the one-year break that followed the incident of September 2008.

Friday afternoon a first beam of ions entered the LHC clockwise beam pipe through the TI2 transfer line. The beam was successfully guided through the ALICE detector until point 3 where it was dumped.

During the late evening on Friday, the first beam of protons also entered the LHC clockwise ring and travelled until point 3. In the afternoon of Saturday, protons travelled from the SPS through the TI8 transfer line and the LHCb experiment, until point 7 where they were dumped.

All settings and parameters showed a perfect functioning of the machine, which is preparing for its first circulating beam in the coming weeks.

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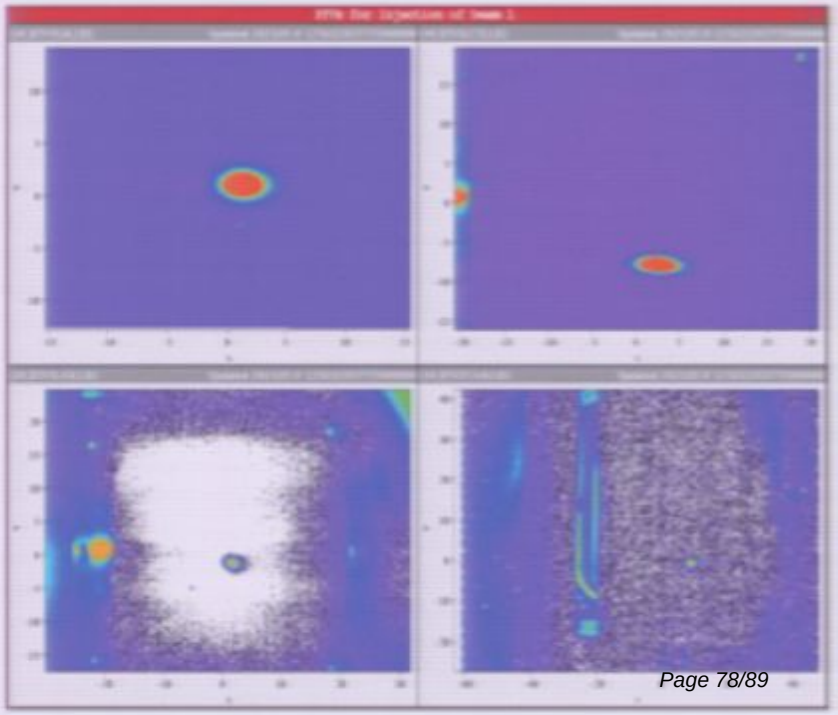
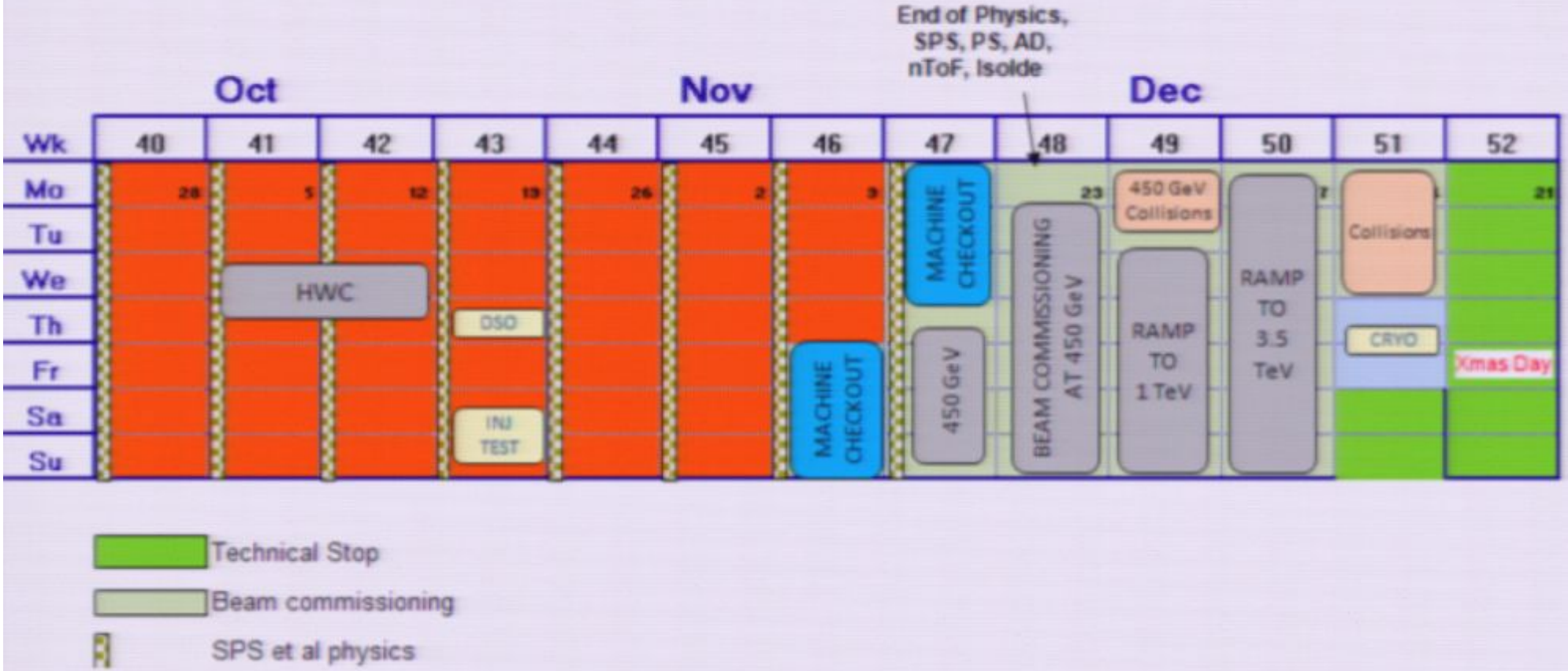


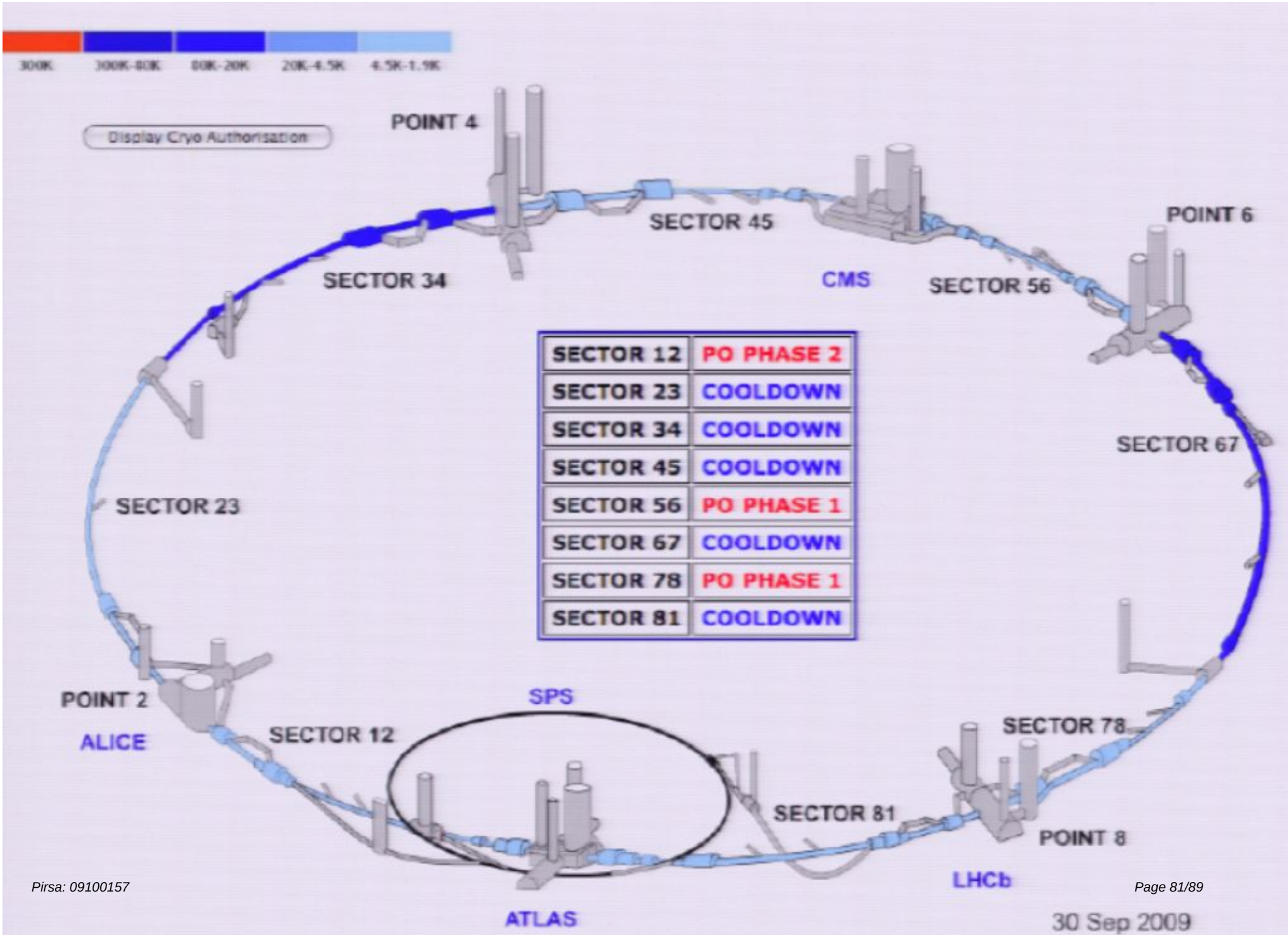
Commissioning the LHC

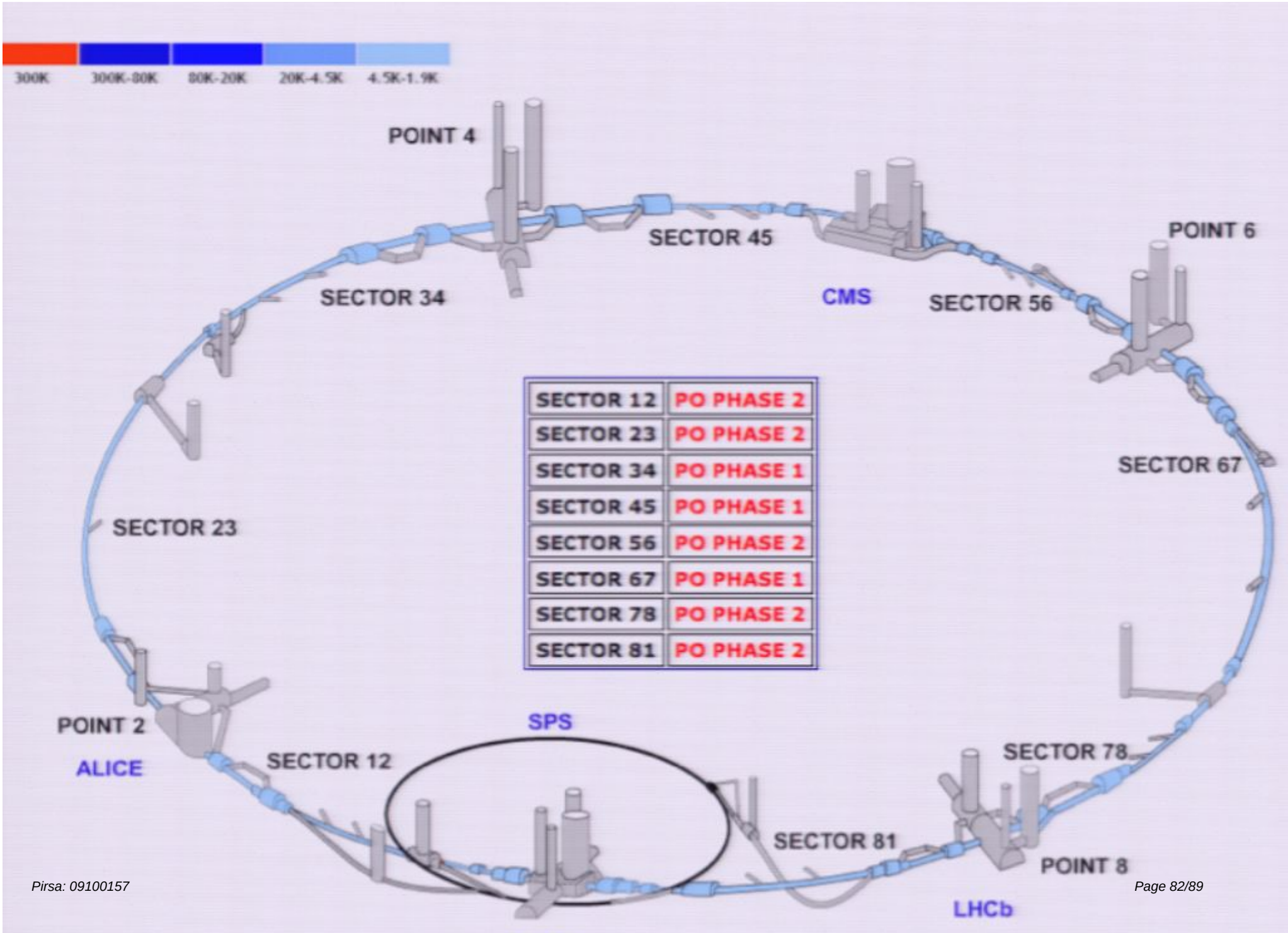
- Once the machine is cold and electrical circuits commissioned:

		Ring factor	Total Time [days] both rings
1	Injection and first turn	2	4
2	Circulating beam	2	3
3	450 GeV - initial	2	4
4	450 GeV - detailed	2	5
5	450 GeV - two beams	1	1
6	Snapback - single beam	2	3
7	Ramp - single beam	2	6
8	Ramp - both beams	1	2
9	7 TeV - setup for physics	1	2
10	Physics un-squeezed	1	-
	TOTAL to first collisions		**30**
11	Commission squeeze	2	6
12	Increase Intensity	2	6
13	Set-up physics - partially squeezed.	1	2
14	Pilot physics run		

The Current Schedule




300K
300K-80K
80K-20K
20K-4.5K
4.5K-1.9K
Display Cryo Authorisation
POINT 4
SECTOR 45
CMS
SECTOR 56
POINT 6
SECTOR 34
SECTOR 67
SECTOR 23
SECTOR 12 PO PHASE 2
SECTOR 23 COOLDOWN
SECTOR 34 COOLDOWN
SECTOR 45 COOLDOWN
SECTOR 56 PO PHASE 1
SECTOR 67 COOLDOWN
SECTOR 78 PO PHASE 1
SECTOR 81 COOLDOWN
POINT 2
ALICE
SPS
SECTOR 12
SECTOR 78
SECTOR 81
POINT 8
LHCb
ATLAS
30 Sep 2009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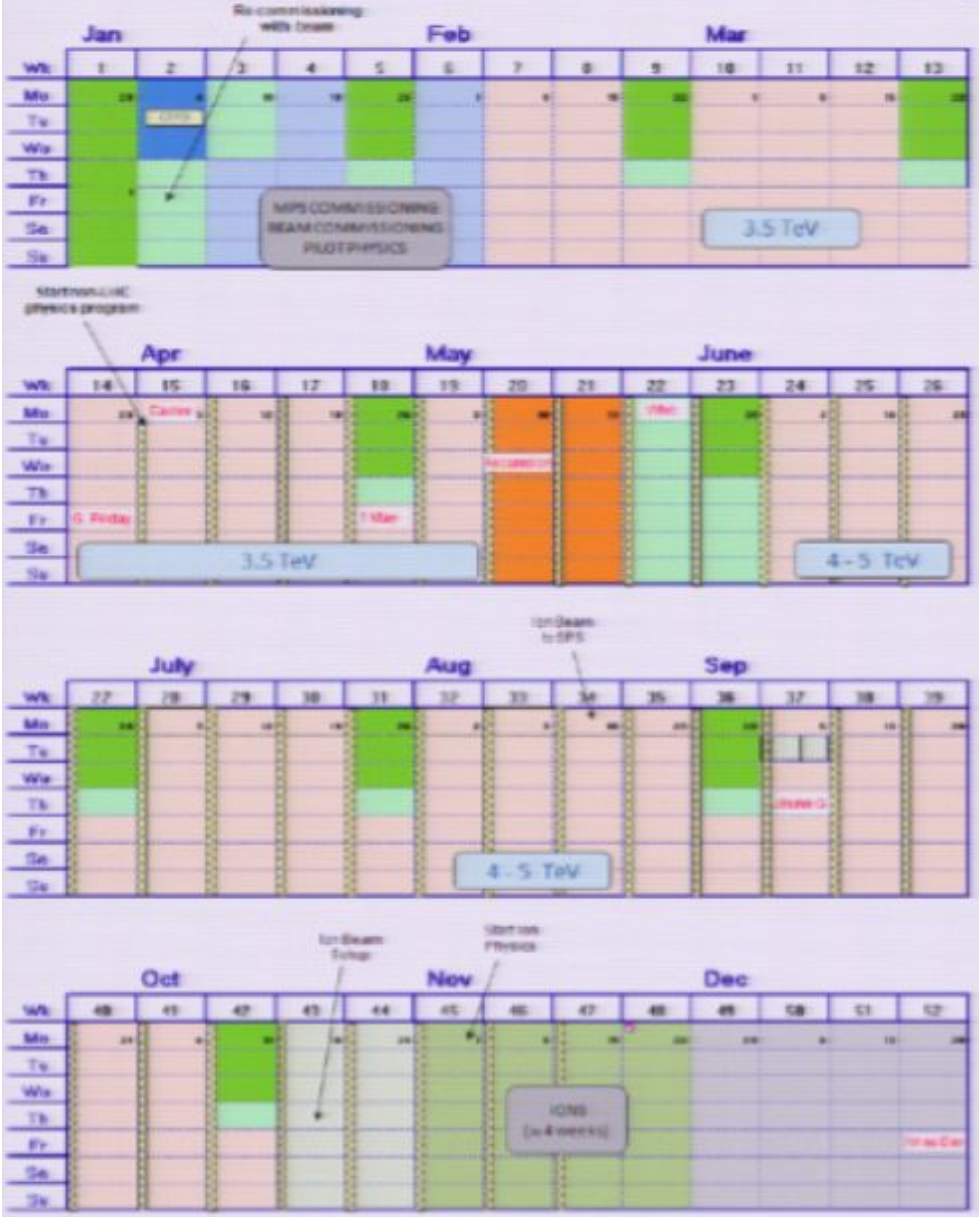
LHCb

LHC 2010 – very draft



- **2009**:
  - 1 month commissioning
- **2010**:
  - 1 month pilot & commissioning
  - 3 month 3.5 TeV
  - 1 month step-up
  - 5 month 4 - 5 TeV
  - 1 month ions

Have You Found the Higgs Yet?

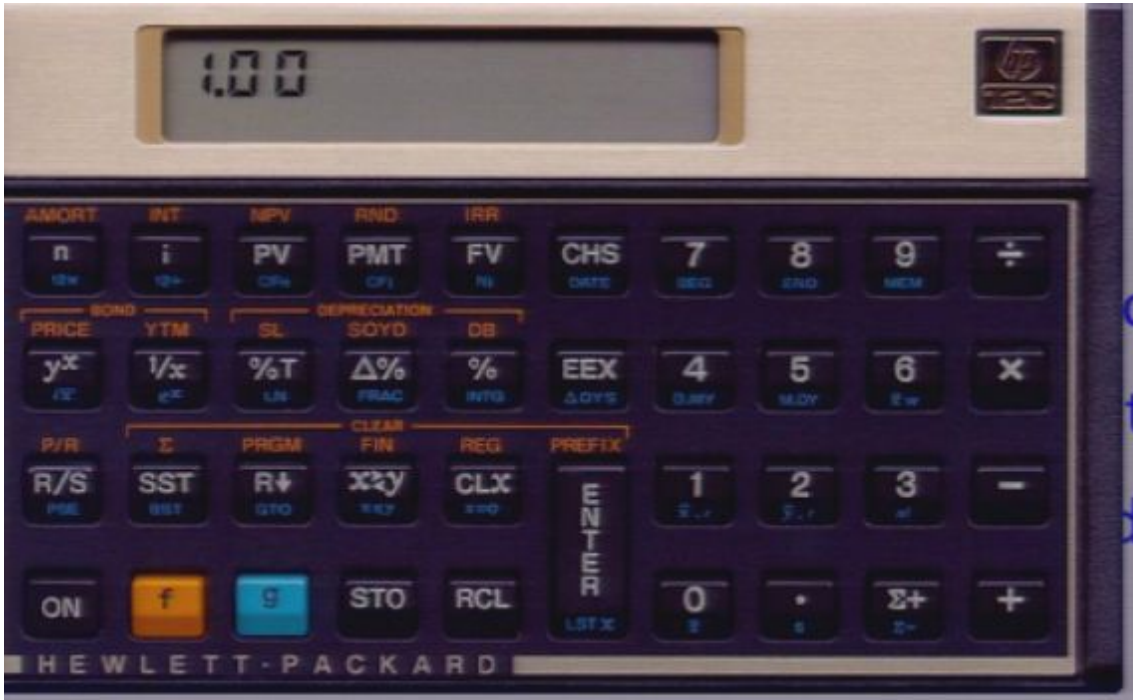
- ATLAS and CMS detectors extraordinarily well understood
- Still need tracks and jets from beam collision point
  - Even 900 GeV collisions allow us to push to next level
- Need to walk before we can run
  - Minimum bias QCD studies
  - Jets up to (and beyond Tevatron) energies
  - Top quarks (produced in Europe!)
  - Obvious physics signatures (Z', SUSY, black holes, …)
  - Higgs (esp. low mass) is among most challenging signature
- Even when we have few 100 pb^{-1} it will take time
  - Collect, analyse and understand control samples/known physics
  - Convince 2000 of our closest friends to publish …

LHC Physics Timeline? (Peskin Sept 2009)

	July	LHC	
8 TeV	2010	3 pb^{-1}	min bias, QCD
	2011	300 pb^{-1}	$\tilde{q}$ at 600 GeV, MET at 2σ, l+l+ at 3σ Z' at 1.5 TeV stable $\tilde{l}$- at 200 GeV
14 TeV	2012	1 fb^{-1}	$\tilde{q}$,$\tilde{g}$ at 1 TeV, MET, ll, lll at 5σ Higgs at 300 GeV in ZZ
	2013	10 fb^{-1}	Higgs at 140 GeV in ZZ*
	2014	30 fb^{-1}	Higgs at 120 GeV in γγ $t\bar{t}$ resonance at 3 TeV
	2015	100 fb^{-1}	strong WW scattering unexpected Q at 2 TeV
	2016	200 fb^{-1}	strong ZZ scattering unexpected Q at 3 TeV

Summary

- The LHC is most complicated scientific instrument ever constructed
- The ATLAS experiment is more ready than ever for first collisions
- Expect some collisions before the end of the year
  - Will proceed cautiously in energy
  - Expect significant 7-10 TeV dataset before end of 2010
- LHC Safety systems will be completed for 2011 running
- Canadians are fully integrated in these efforts
  - 40 faculty, 20 Postdocs, 60+ graduate students
  - Tier-1 Centre at TRIUMF + analysis resources across the country
  - Leading first phase analysis efforts



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