ATLAS

IPP AGM
17th June 2007

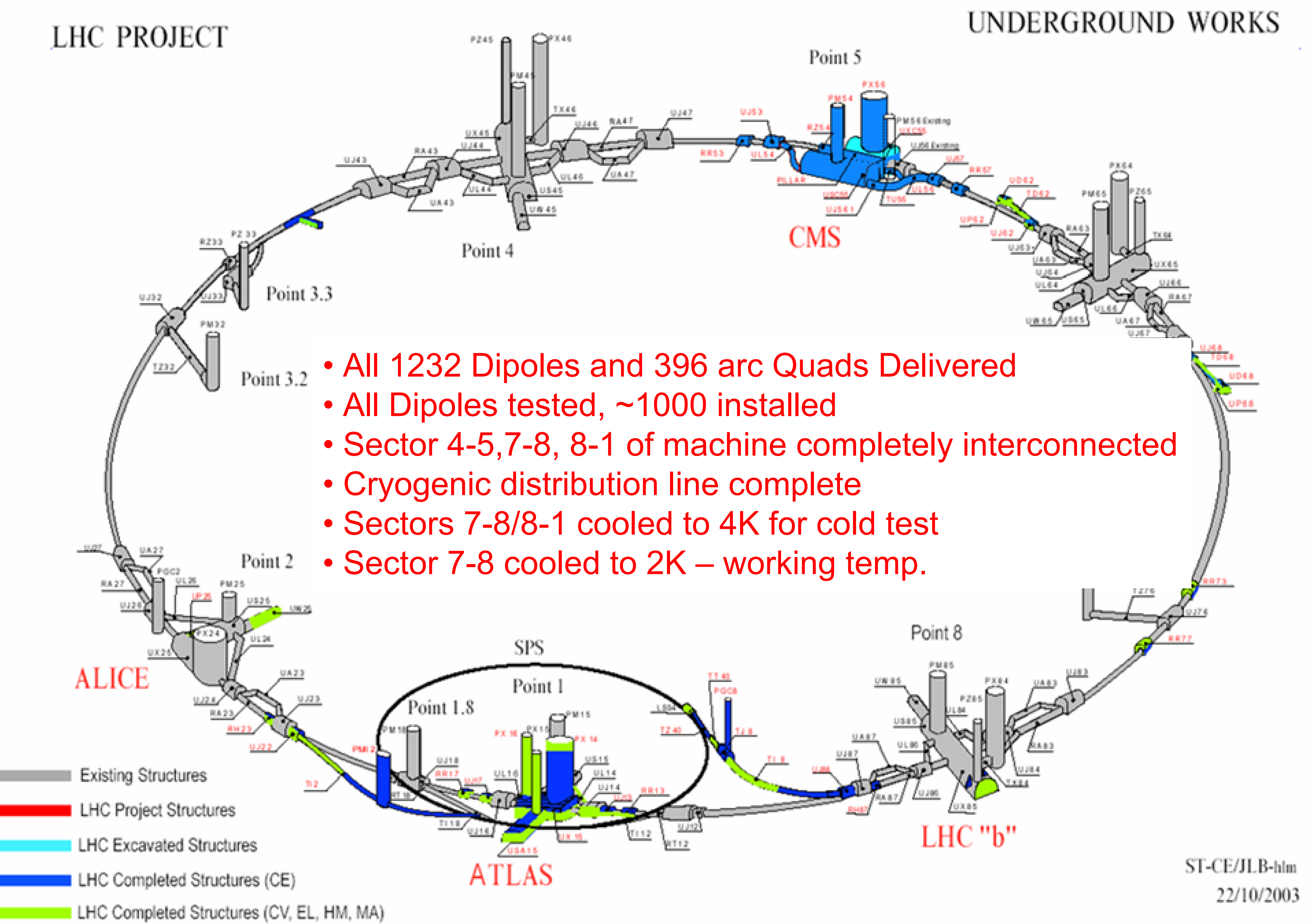
Status: LHC, ATLAS

Next Two Years

Next Five - Ten Years

Next Ten - Twenty Years

R. S. Orr

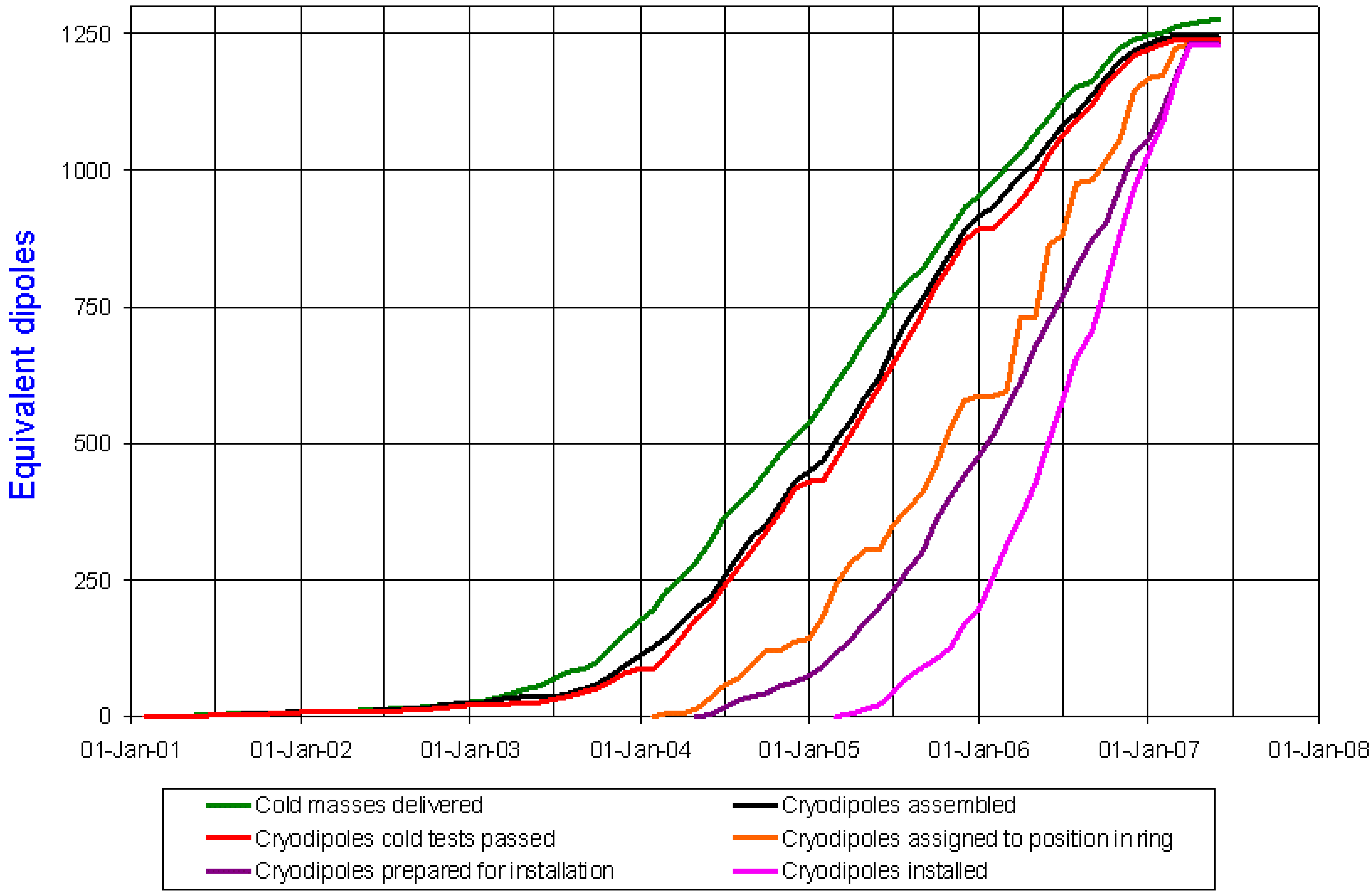


- All 1232 Dipoles and 396 arc Quads Delivered
- All Dipoles tested, ~1000 installed
- Sector 4-5,7-8, 8-1 of machine completely interconnected
- Cryogenic distribution line complete
- Sectors 7-8/8-1 cooled to 4K for cold test
- Sector 7-8 cooled to 2K – working temp.

LHC Progress Dashboard

Accelerator Technology Department

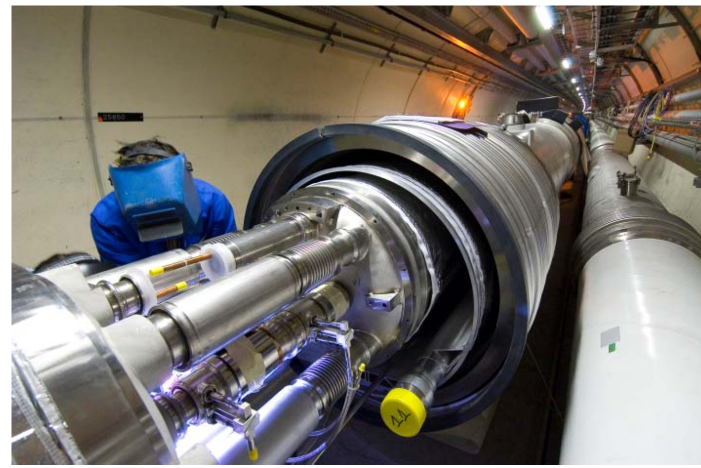
Cryodipole overview



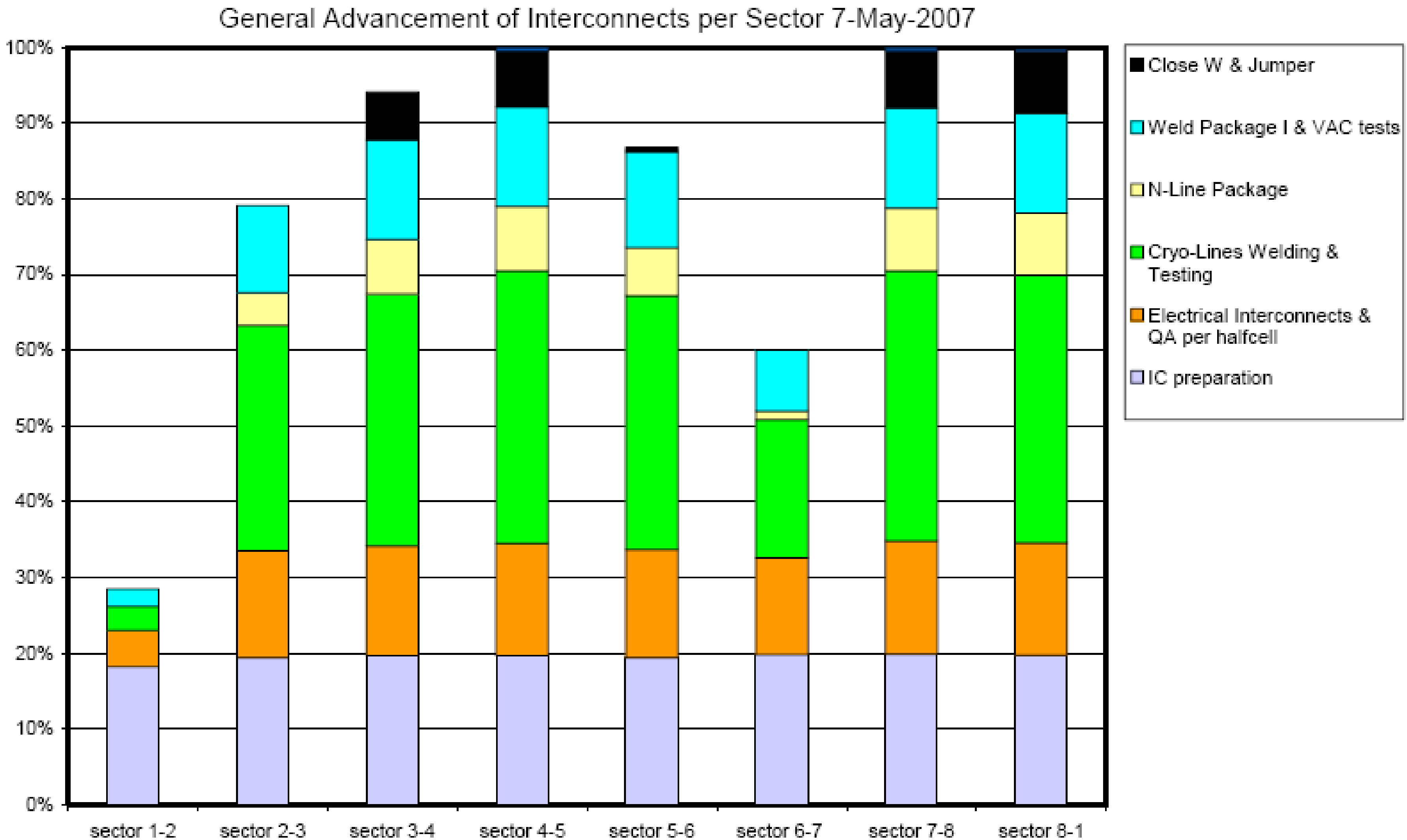
Updated 31 May 2007

Data provided by D. Tommasini AT-MCS, L. Bottura AT-MTM

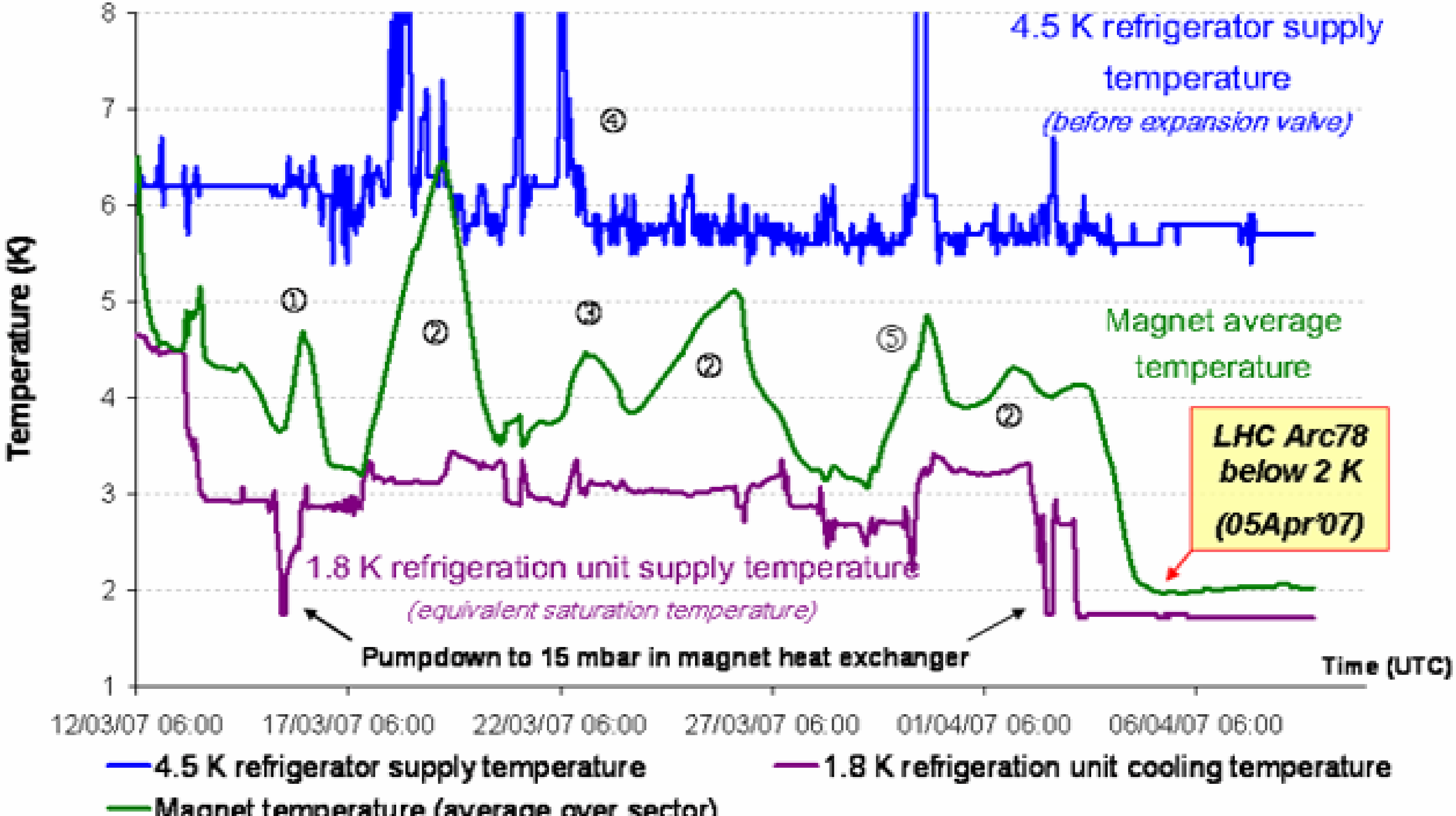
Underground
Last Dipole April 2007



Magnet Interconnections



LHC sector 78 - First cooldown - Phase 4.5 K to 1.9 K



① Tuning of cold compressors & turbines with temporary stop of magnet cooling

② Stop of active cooling in weekend with only on call activity limited to secure hardware

③ Stop of magnet cooling for logic improvement in 1.8K refrigeration unit

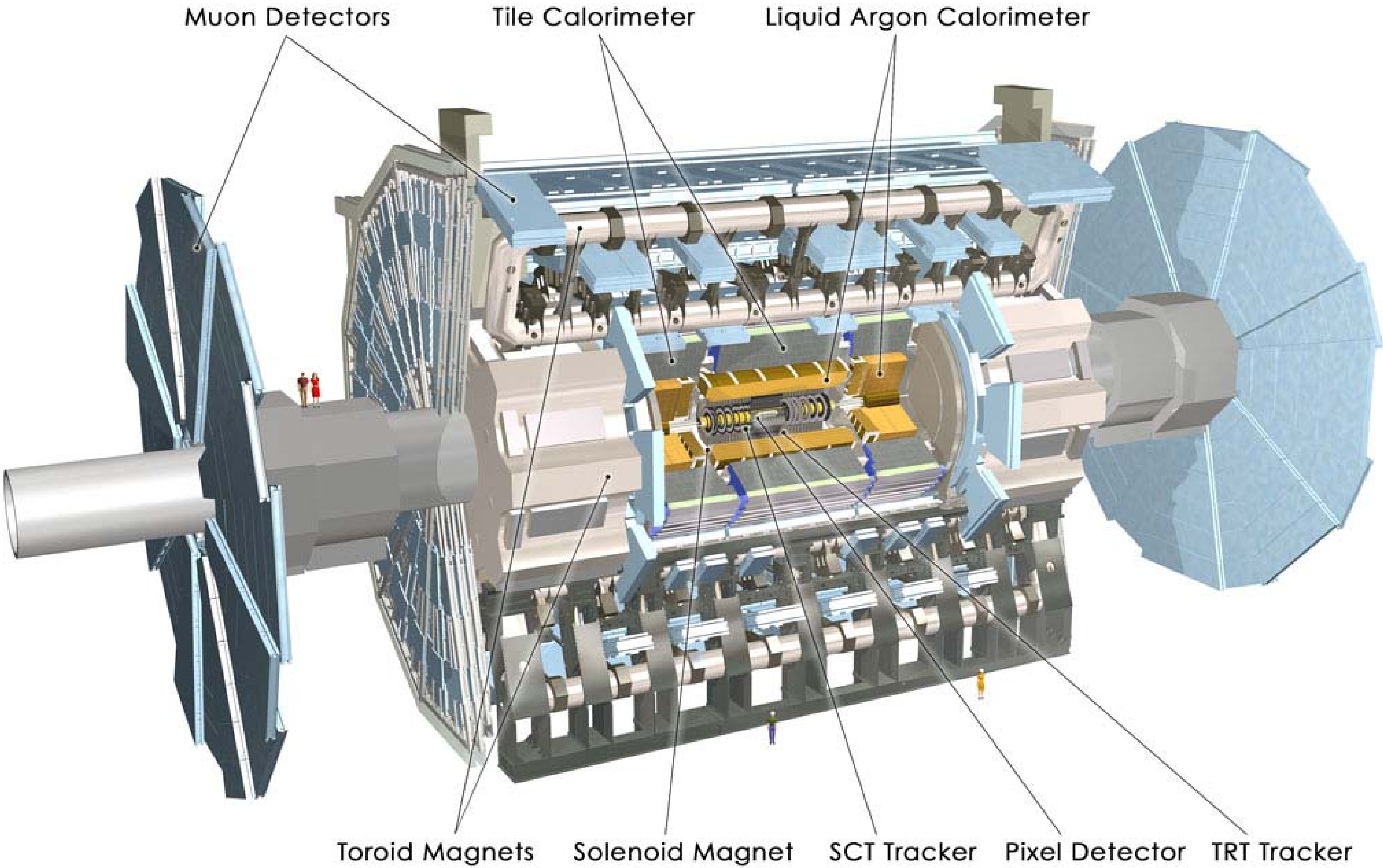
④ Random emergency stop in cryogenic surface building with stop of sector 78 cooling

⑤ micro-electrical stop followed by utility stops

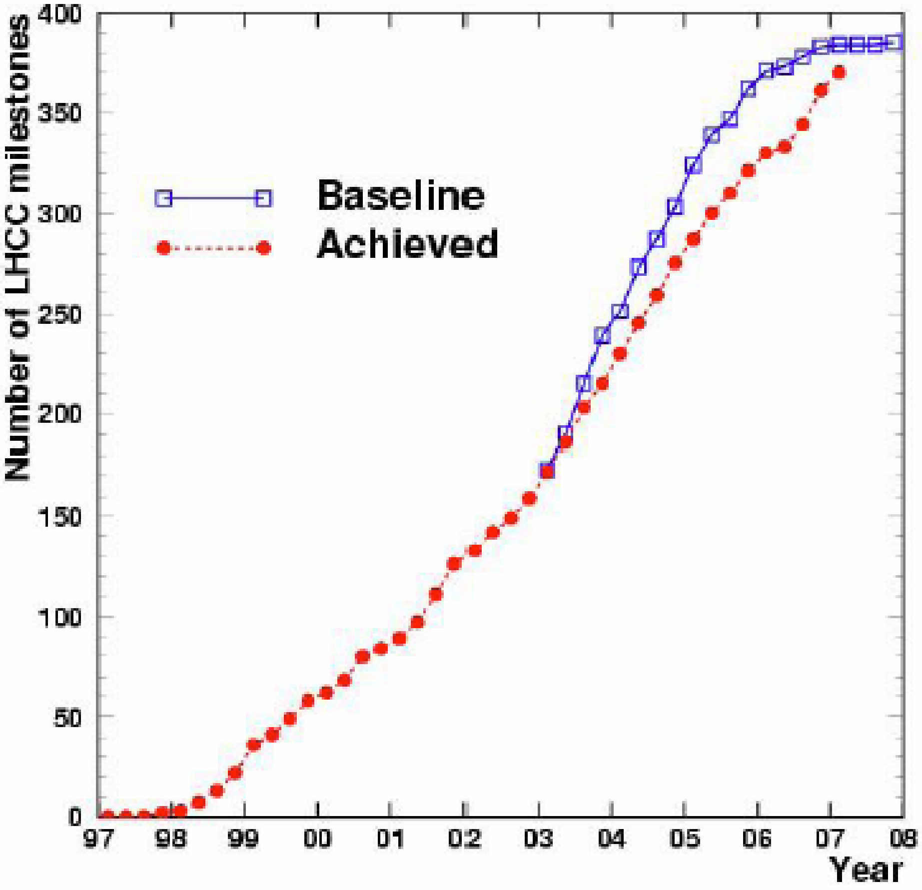
General Schedule

- Dec 2007 engineering run not possible - delays in installation and equipment commissioning.
- Schedule being reassessed, accounting for inner triplet repairs and their impact on sector commissioning
  - All technical systems commissioned to 7 TeV operation, and machine closed April 2008
  - Beam commissioning starts May 2008
  - First collisions at 14 TeV c.m. July 2008
  - Pilot run pushed to 156 bunches for reaching 10^{32} $cm^{-2}.s^{-1}$ by end 2008
  - winter 2008-09 shutdown to complete collimation system and dilution kickers, thus allowing high intensity operation
- No provision in schedule for major mishaps, e.g. additional warm-up/cooldown of sector

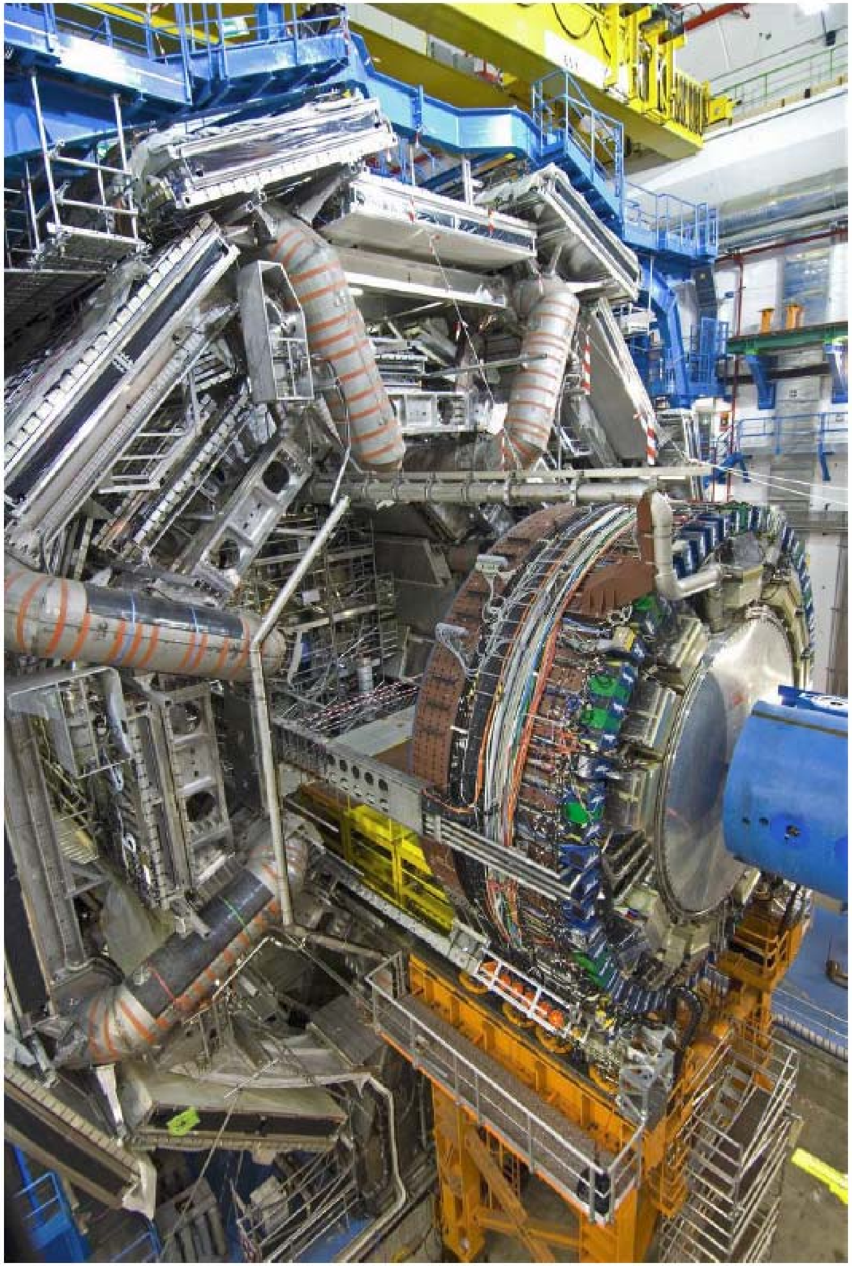
Construction Status of the Main ATLAS Detector Systems



Barrel toroid length	***26 m***
Endcap end-wall chamber span	***46 m***
Overall weight	***7000 Tons***



Integrated LHCC milestones
LHCC April 2007



LHC Prospects

- Date for first beams/collisions: ⇒ **July 2008**
- Initial physics run starts in summer/fall 2008

  ⇒ collect ~10 fb^{-1} /exp ($2.10^{33} cm^{-2} s^{-1}$) by end of 2009
- Depending on the evolution of the machine…

  ⇒ collect 200-300 fb^{-1} /exp ($3.4\text{-}10.10^{33} cm^{-2} s^{-1}$) in 5-6 years time

Already time to think of upgrading the machine

Two options presently discussed/studied

- Higher luminosity ~$10^{35} cm^{-2} s^{-1}$ (SLHC)
  - Needs changes in machine and and particularly in the detectors

  ⇒ Start change to SLHC mode some time 2012-2014

  ⇒ Collect ~3000 fb^{-1}/experiment in 3-4 years data taking.
- Higher energy?
  - LHC can reach $\sqrt{s}$ = 15 TeV with present magnets (9T field)
  - $\sqrt{s}$ of 28 (25) TeV needs ~17 (15) T magnets ⇒ R&D + MCHf needed

Machine Upgrade in Stages

- push LHC performance *without* new hardware

  luminosity →2.3x10^{34} $cm^{-2}s^{-1}$, E_b=7→7.54 TeV

- LHC IR upgrade

  replace low-β quadrupoles after ~7 years
  peak luminosity →4.6x10^{34} $cm^{-2}s^{-1}$

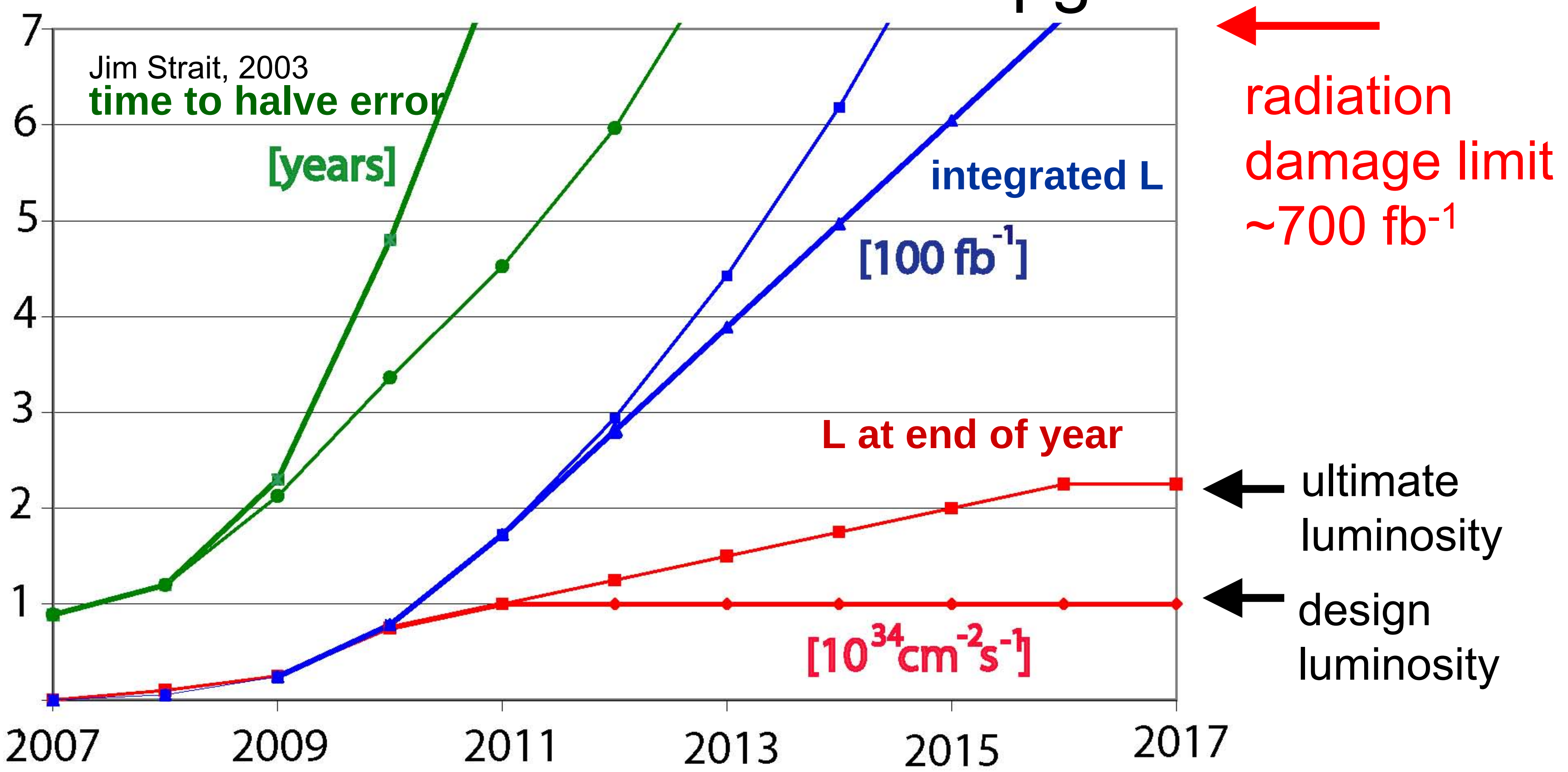
- LHC injector upgrade

  peak luminosity →9.2x10^{34} $cm^{-2}s^{-1}$

- LHC energy upgrade

  E_b→13 – 21 TeV (15 → 24 T dipole magnets)

Time Scale of an LHC upgrade



- Life expectancy of LHC IR quadrupole magnets is estimated to be <10 years due to high radiation doses
- Statistical error halving time exceeds 5 years by 2011-2012 → it is reasonable to plan a *machine luminosity upgrade based on new low-β IR magnets around ~2014-2015*

Beam-Beam Limit Luminosity Equation

injector upgrade

$$L \approx \pi \gamma n_b \frac{(\gamma \varepsilon) f_{rev}}{r_p^2 \beta^*} \Delta Q_{bb}^2 \sqrt{1+\phi^2} F_{profile}$$

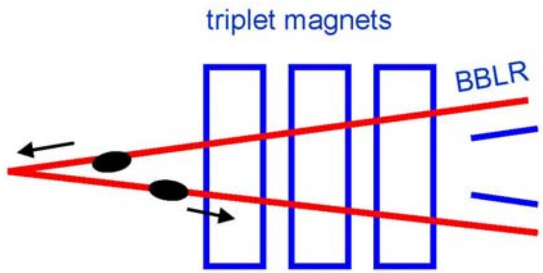
LHC + injector changes

IR upgrade

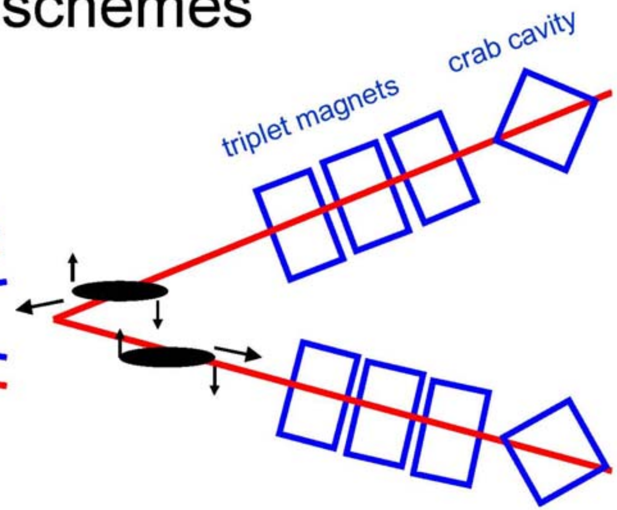
LHC+ injector changes

I R U P G R A D E

IR ‘baseline’ schemes



short bunches &
minimum crossing angle &
BBLR



crab cavities &
large crossing angle

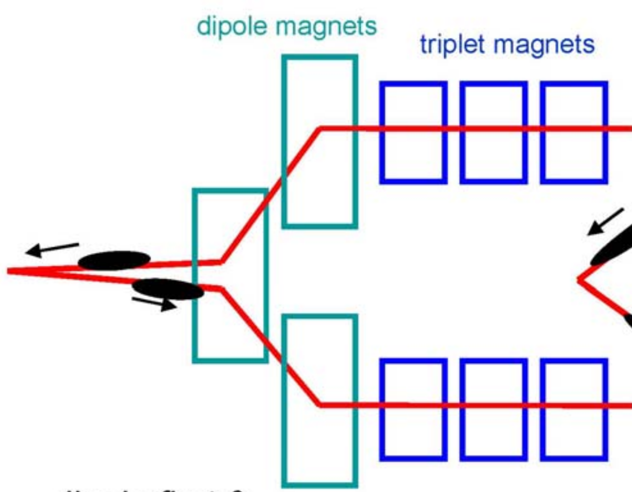
“quadrupoles first” → minimum chromaticity

alternative IR schemes → “dipole first”

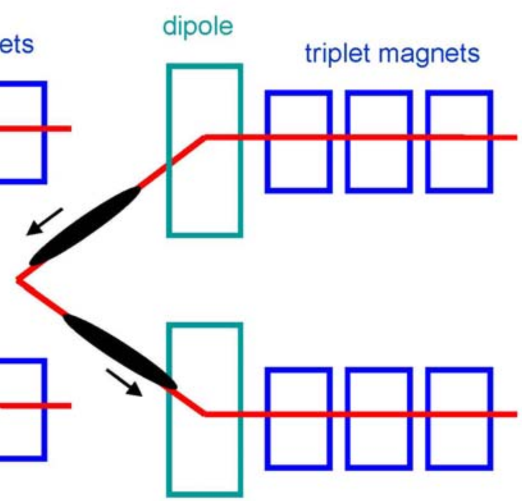
reduced # LR collisions;
collision debris hits first dipole

N. Mokhov et al., PAC2003

“open midplane s.c. dipole”
(studied by US LARP)



dipole first &
small crossing angle



dipole first &
large crossing angle &
long bunches or crab cavities

Summary of Luminosity Upgrade

Scenarios for $L \sim 10^{35} cm^{-2} s^{-1}$ with acceptable heat load and events/crossing

25-ns: push β^* to limit

Slim magnets inside detector
Crab Cavities
High Gradient, Large Aperture Nb_3Sn Quads

50-ns: Fewer bunches, higher charge

Realizable with $NbTi$
Beam-Beam tune shift due to large Piwinski angle?
Luminosity leveling via bunch length and β^* tuning

LHC Energy Doubler 14*14 TeV

Dipoles: B_{nom}=16.8T, B_{design}=19T

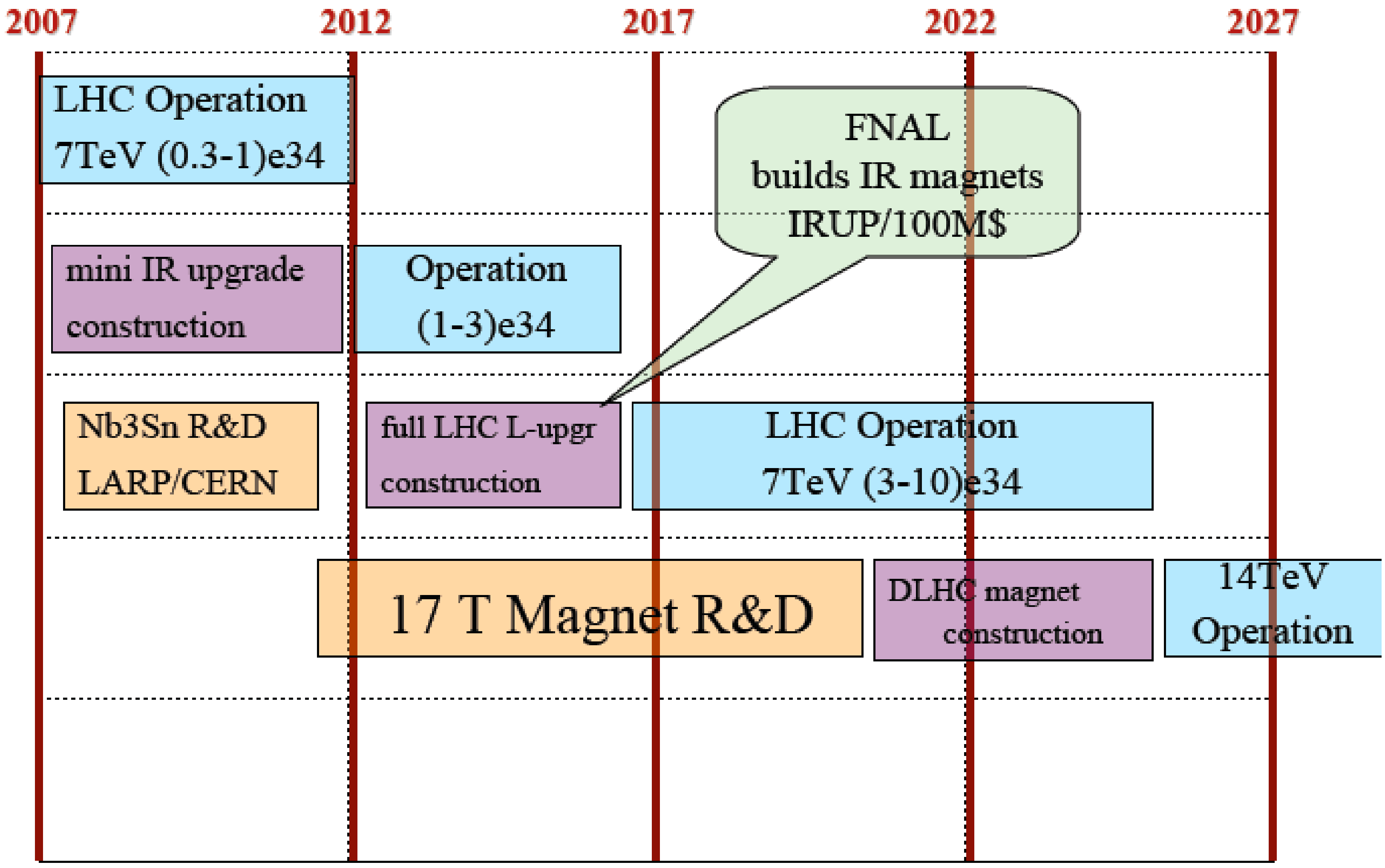
- Superconductor Nb_3Sn
- 16T demonstrated at 4K
- 10 years for R&D, 10 years production
- 3G$

LHC Energy Tripler 21*21 TeV

Dipoles: B_{nom}=25T, B_{design}=29T

- Superconductor HTS-BSCCO or Nb_3Sn
- Well above demonstrated Nb_3Sn
- 20++ years for R&D, ? years production
- ?G$

LHC, sLHC, DLHC perspective



Physics Case for the SLHC

The use/need for for the SLHC will obviously depend on how EWSB and/or the new physics will manifest itself

This will only be answered by LHC itself

What will the HEP landscape look like in 2012??

Rough expectation for the SLHC versus LHC

- Improvement of SM/Higgs parameter determination
- Improvement of New Physics parameter determinations, if discovered
- Extension of the discovery reach in the high mass region
- Extension of the sensitivity of rare processes

Indicative Physics Reach

Ellis, Gianotti, ADR
hep-ex/0112004+ updates

Units are TeV (except $W_L W_L$ reach)

☞Ldt correspond to 1 year of running at nominal luminosity for 1 experiment

PROCESS	LHC 14TeV 100 fb^{-1}	SLHC 14TeV 1000 fb^{-1}	SLHC 28TeV 100 fb^{-1}	LinCol 0.8 TeV 500 fb^{-1}	LinCol 5 TeV 100 fb^{-1}
Squarks	2.5	3	4	0.4	2.5
$W_L W_L$	2σ	4σ	4.5σ		
Z'	5	6	8	8†	8†
Extra Dim (δ=2)	9	12	15	5 - 8.5†	30 - 55†
q^*	6.5	7.5	9.5	0.8	5
Λ_{comp}	30	40	40	100	400
TGC (λ_γ)	0.0014	0.0006	0.0008	0.0004	0.00008

† indirect reach
(from precision measurements)

Approximate mass reach machines:

$\sqrt{s}$ = 14 TeV, L=10^{34} (LHC) : up to ≈ 6.5 TeV
$\sqrt{s}$ = 14 TeV, L=10^{35} (SLHC) : up to ≈ 8 TeV
$\sqrt{s}$ = 28 TeV, L=10^{34} : up to ≈ 10 TeV

Detectors: General Considerations

	LHC	SLHC
$\sqrt{s}$	14 TeV	14 TeV
L	10^{34}	10^{35}
Bunch spacing Δt	25 ns	25/50 ns
σ_{pp} (inelastic)	~ 80 mb	~ 80 mb
N. interactions/x-ing ($N=L\ \sigma_{pp}\ \Delta t$)	~ 20	~ 280/350
$dN_{ch}/d\eta$ per x-ing	~ 150	~ 2000/2500
$<E_T>$ charg. particles	~ 450 MeV	~ 450 MeV
Tracker occupancy	1	10/20
Pile-up noise in calo	1	~3
Dose central region	1	10

Normalised to LHC values.

10^4 Gy/year R=25 cm

In a cone of radius = 0.5 there is E_T ~ 200GeV.

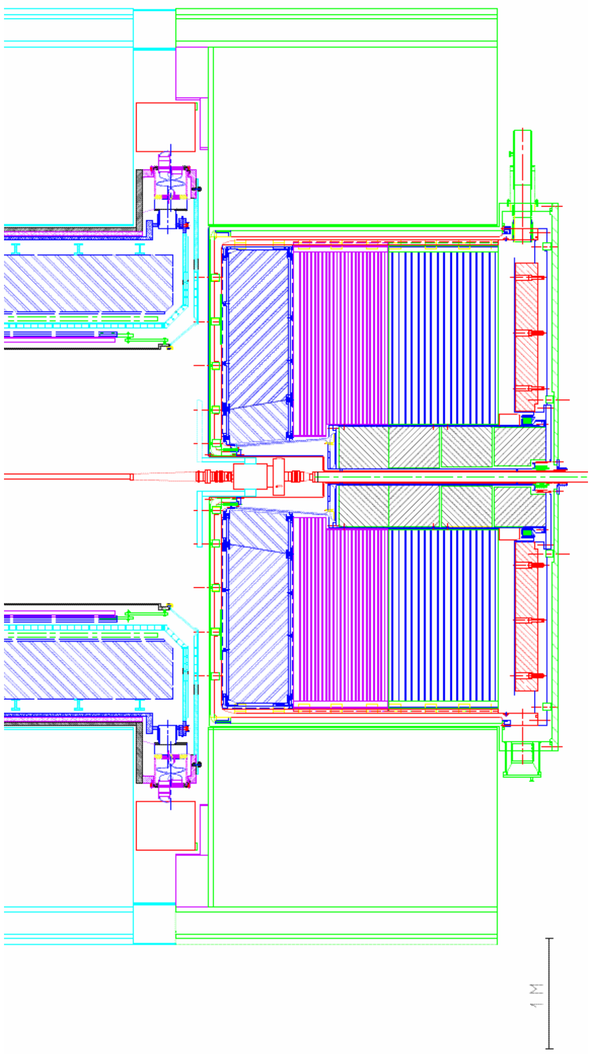
This will make low E_t jet triggering and reconstruction difficult.

Upgrade

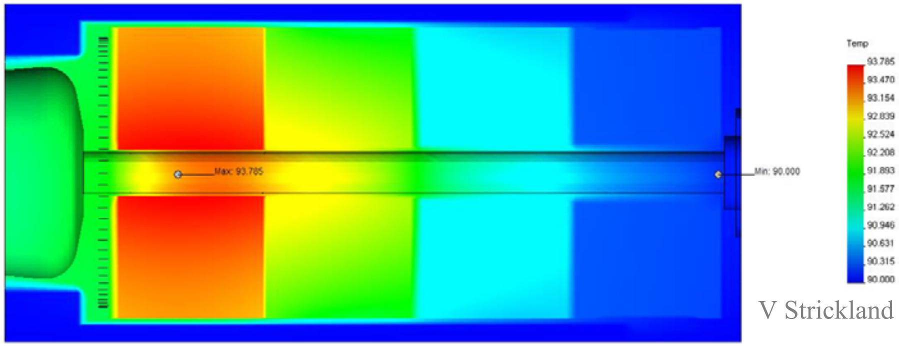
- ATLAS has begun studying what needs to be upgraded for $10^{35}cm^{-2}s^{-1}$ instantaneous luminosity
  - ~10× harsher pileup, radiation environment
  - Also constrained by existing detector: what can be moved/stored where/when
- Major ID overhaul foreseen
  - TRT replaced by Si Strips
  - Pixels move to larger radius
  - New technology for innermost layers
- Calorimeters
  - New FE electronics for HEC
  - New cold or warm FCAL
  - Opening endcap cryostat implies a long installation schedule (~2-3 years)
- Schedule to fit 2016 timescale
  - Aim for upgrade TDR in 2010 to allow adequate procurement/construction
- *Also Trigger, FE in general, etc.. etc.. etc…*

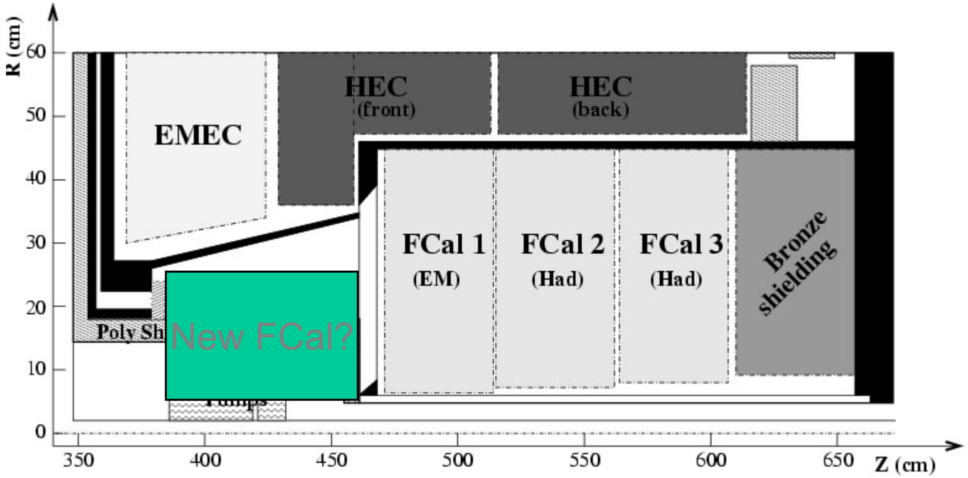
LAr Calorimeters at sLHC - Overview

- Critical issues
  - ion build up and heat load
- The HiLum ATLAS Endcap Project
- Radiation hardness:
  - R&D for HEC cold electronics;



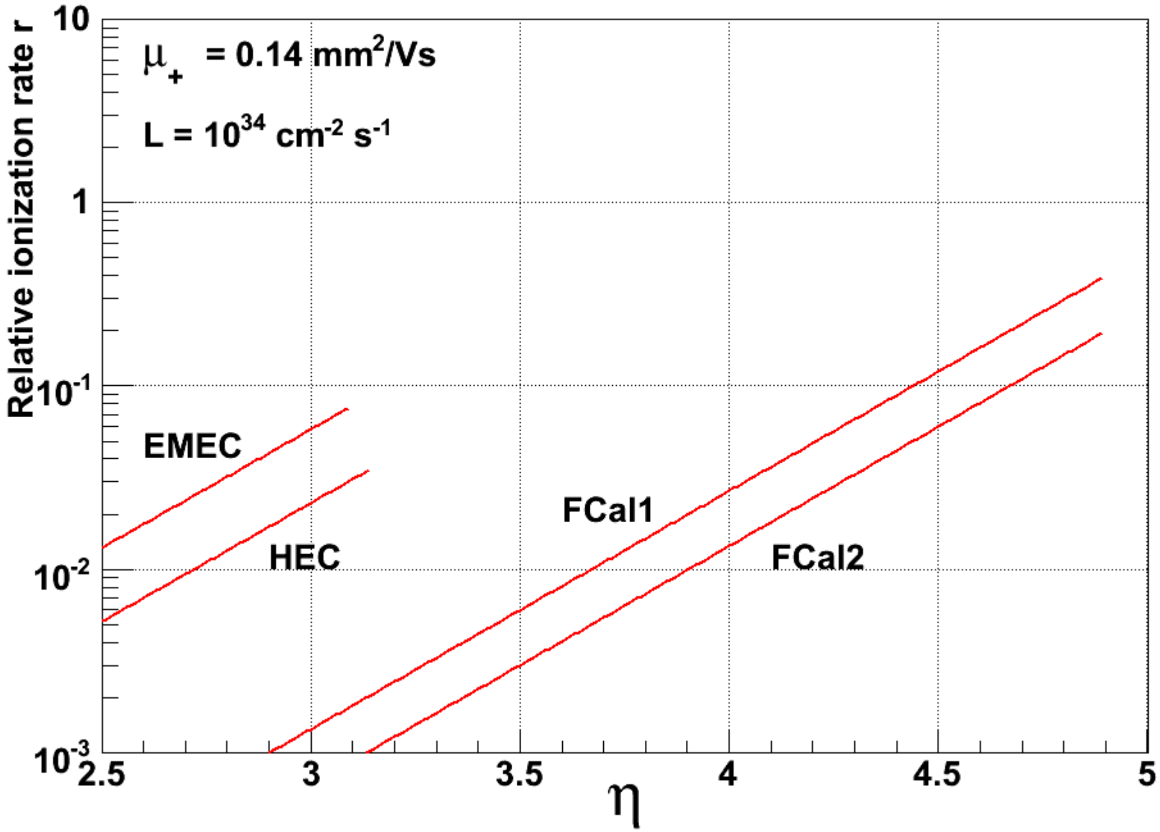
FCal - Heatload





- Simulation of LAr FCAL beam heating
  - Maximum temperature 93.8K – enough to boil LAr
- Uncertainties - convection could make things better or worse; other endcap calorimeters also implicated
- Improve FCAL cooling (open endcap cryostat)
  - ~*2-3 year round-trip – big timing challenge*
- New “warm” FCAL plug?

+ve Ion Buildup – Distorts Electric Field



limit r=1

- EMEC and HEC OK
- FCAL: reduce gap from 250 μ to 100 μ

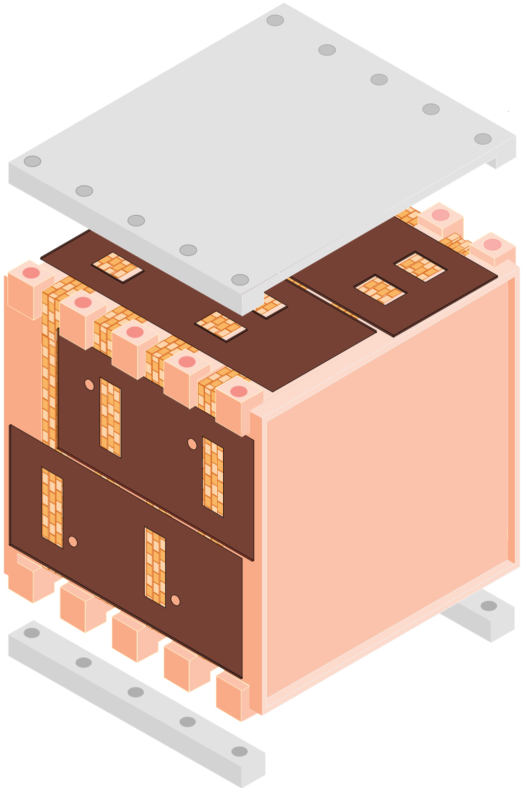
  → all endcap calorimeters stay in region $r < 1$

sLHC

HiLum ATLAS Endcap Project

- Goal: establish limitations on the operation of the endcap calorimeters (FCAL, EMEC, HEC) at highest LHC luminosities.
- R&D: 'mini modules' of FCAL, EMEC and HEC type, each in one separate cryostat;
- IHEP Protvino: beam line # 23: from 10^7 up to 10^{12} p/spill; E= 60/70 GeV;

FCAL module



- 4 'standard' HEC gaps (HEC1)
- 4 read-out channels
- 4 HV lines (one per subgap)

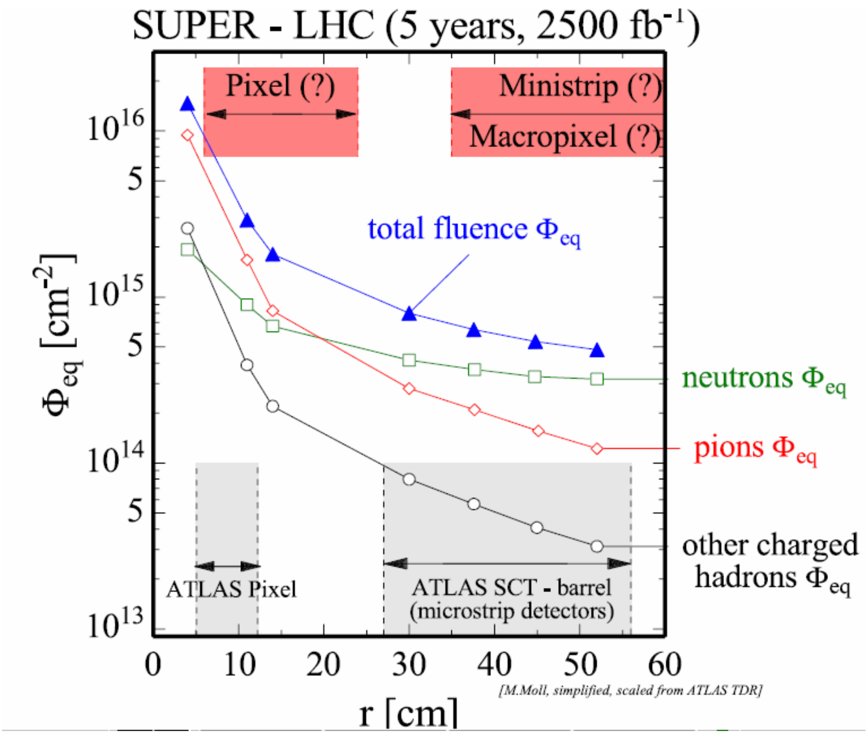
HEC Electronics Upgrade

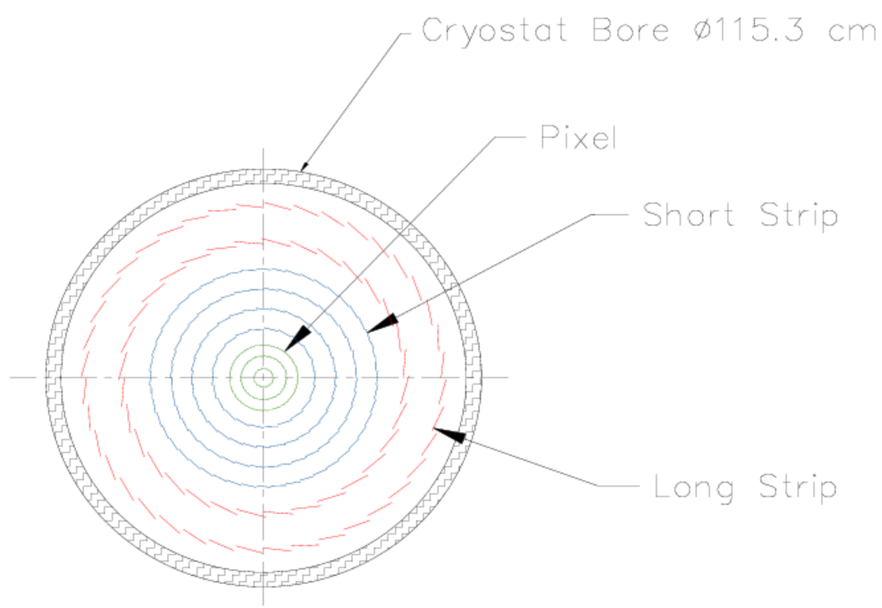
- HEC is equipped with cold electronics based on GaAs ASICs.
  - LHC - expect in 10 years neutron fluence of 0.2×10^{14} n/cm^2
  - Degradation of performance sets in at typically 3×10^{14} n/cm^2
  - Aim for factor of 10 improvement

- Electronics upgrade R&D (MPI, Kosice, TRIUMF) four options.
  - 1. Existing chips for sLHC conditions.
  - 2. Re-design ASIC with present GaAs technology
  - 3. Investigate SiGe HBT (Heterojunction Bipolar Transistor)
  - 4. Study warm electronics options: Si (or SiGe) warm preamps

- TRIUMF is contributing to options 2,3,4
  - Schematics development and simulation
  - Validation tests
  - System tests
  - Technical manpower

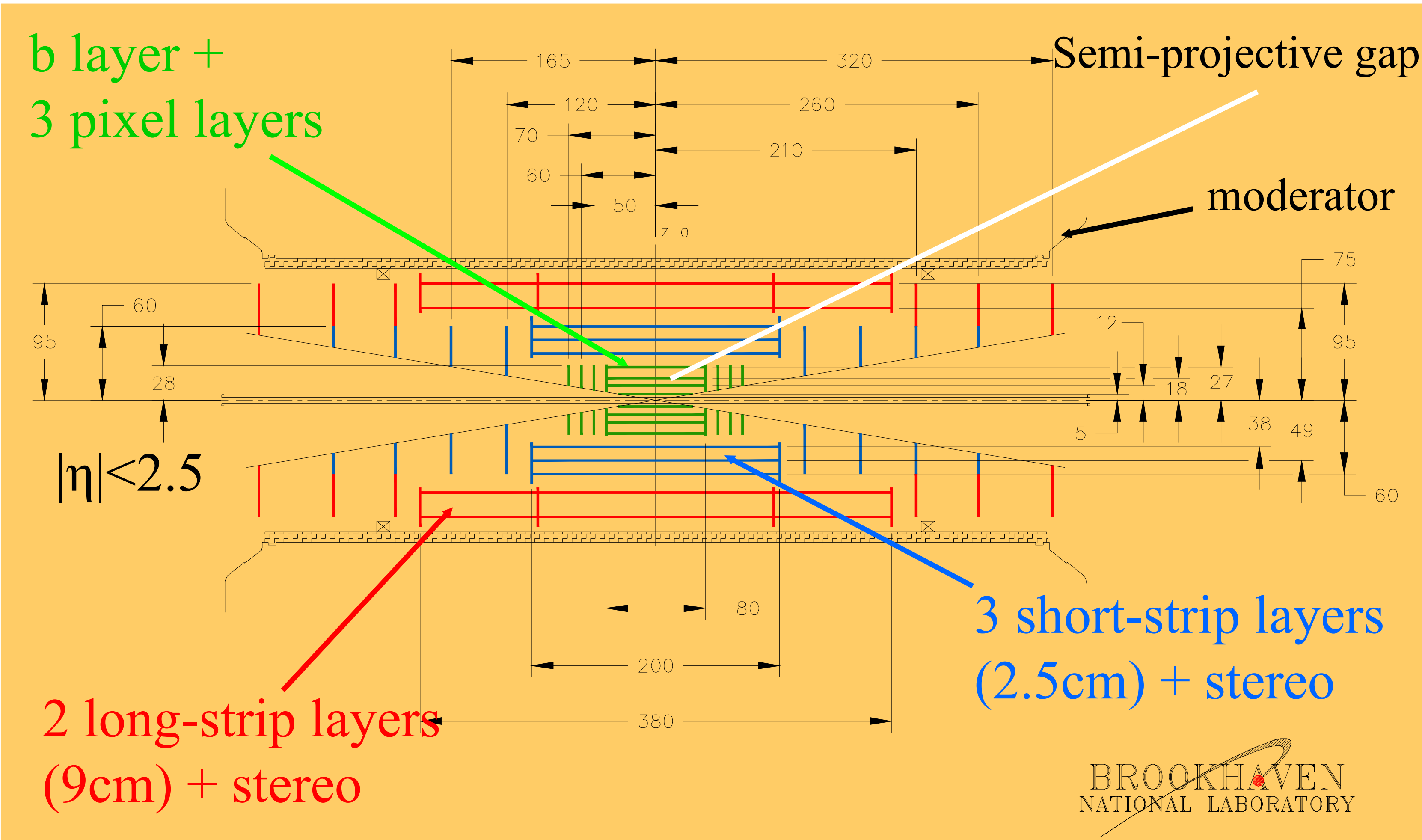
Inner Detector Replacement



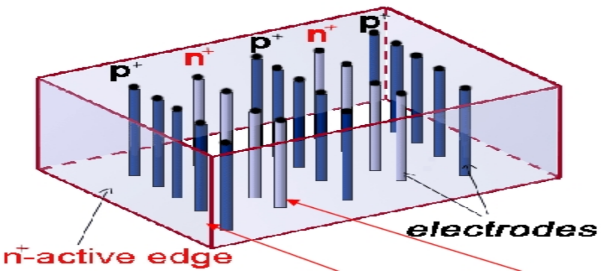


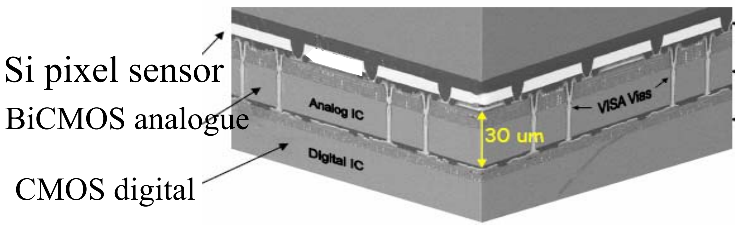
- Order of magnitude increase in Data rates, Occupancy, Irradiation
- No TRT – Si strips
- Pixels moved to larger radius
- New technology for inner layers
- R&D required on sensors, readout, and mechanical engineering

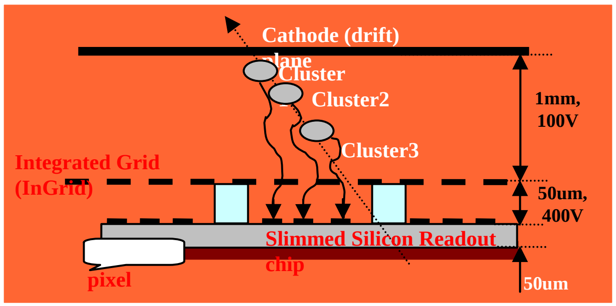
Strawman Layout of Tracker



Pixel-layer technologies







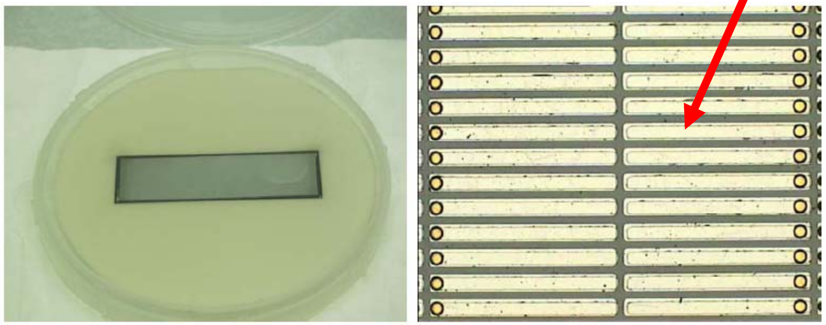


Figure 5: (a) Photograph of the ATLAS pixel diamond mounted in the carrier ready for bump bonding. (b) Zoom view of the pixel pattern after the under-bump metal is deposited.

- Harshest radiation environment (R~4cm)
  - investigate new technologies
- 3D Si
- Thin silicon + 3D interconnects
- Gas over thin pixel (GOSSIP)
- *Diamond pixels*
- May test in pre-SLHC b-layer replacement (~2012)

Schedule

Strawman & options fixed	Dec 2006
ID R&D, conceptual design	2007-2009
TDR	Feb 2010
ID cooling PRR	April 2010
Silicon sensor PRR	July 2010
ID FE electronics PRR	Oct 2010
b-layer replacement	Ready 2012
Procure parts, component assembly	2010-2012
Start surface assembly	March 2012
Stop data taking	Sep 2014
Remove old detectors, install new	2014-2015
Data	April 2016

Tracker Upgrade work in Canada

Diamond Sensors – Toronto+…..

- Prove radiation tolerance of pCVD diamond pixel prototypes
- Industrialize bump-bonding
- FE electronics
- Mechanical structure
- Test beam program 2008-2009

Electronics – Carleton, UBC, York, TRIUMF+…..

- FE ASICS – Si FE module controller
  - Initially FPGA, Move to ASIC
- Contribute to system design – develop expertise
- Backend (eg RODs) later in upgrade path
- TRIUMF Technical manpower

Diamond Pixel Sensor EOI

- Submitted early May
- Institutions:
  - Bonn
  - Carleton
  - CERN
  - Ljubljana
  - Ohio State
  - Toronto
- Review/approval in summer/fall

ATLAS project	Diamond Pixel Modules for the High Luminosity ATLAS Inner Detector Upgrade		
ATLAS Upgrade Document No:	*Institute Document No.*	*Created:* **11/05/2007**	*Page:* **1 of 12**
		Modified:	*Rev. No.:* **1.0**

Abstract

The goal of this proposal is the development of diamond pixel modules as an option for the ATLAS pixel detector upgrade. This proposal is made possible by progress in three areas: the recent reproducible production of high quality diamond material in wafers, the successful completion and test of the first diamond ATLAS pixel module, and the operation of a diamond after irradiation to $1.8x10^{15}$ p/cm^2. In this proposal we outline the results in these three areas and propose a plan to build and characterize a number of diamond ATLAS pixel modules, test their radiation hardness, explore the cooling advantages made available by the high thermal conductivity of diamond and demonstrate industrial viability of bump-bonding of diamond pixel modules .

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