# ATLAS

## Toronto Group Meeting
25th June 2007

**Status: LHC, ATLAS**

**Next Two Years**

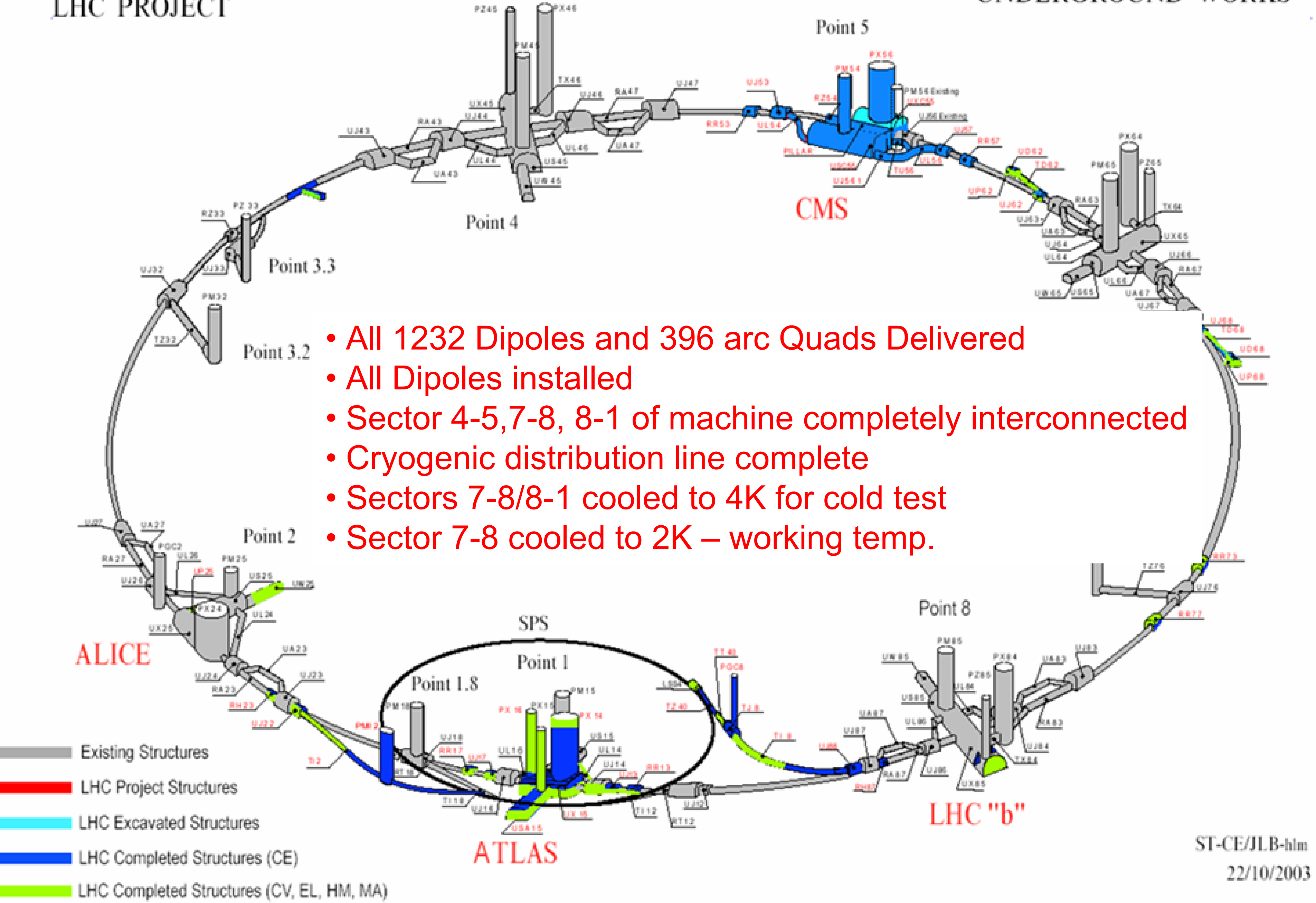
**Next Five - Ten Years**

**Next Ten - Twenty Years**

R. S. Orr

LHC PROJECT

UNDERGROUND WORKS



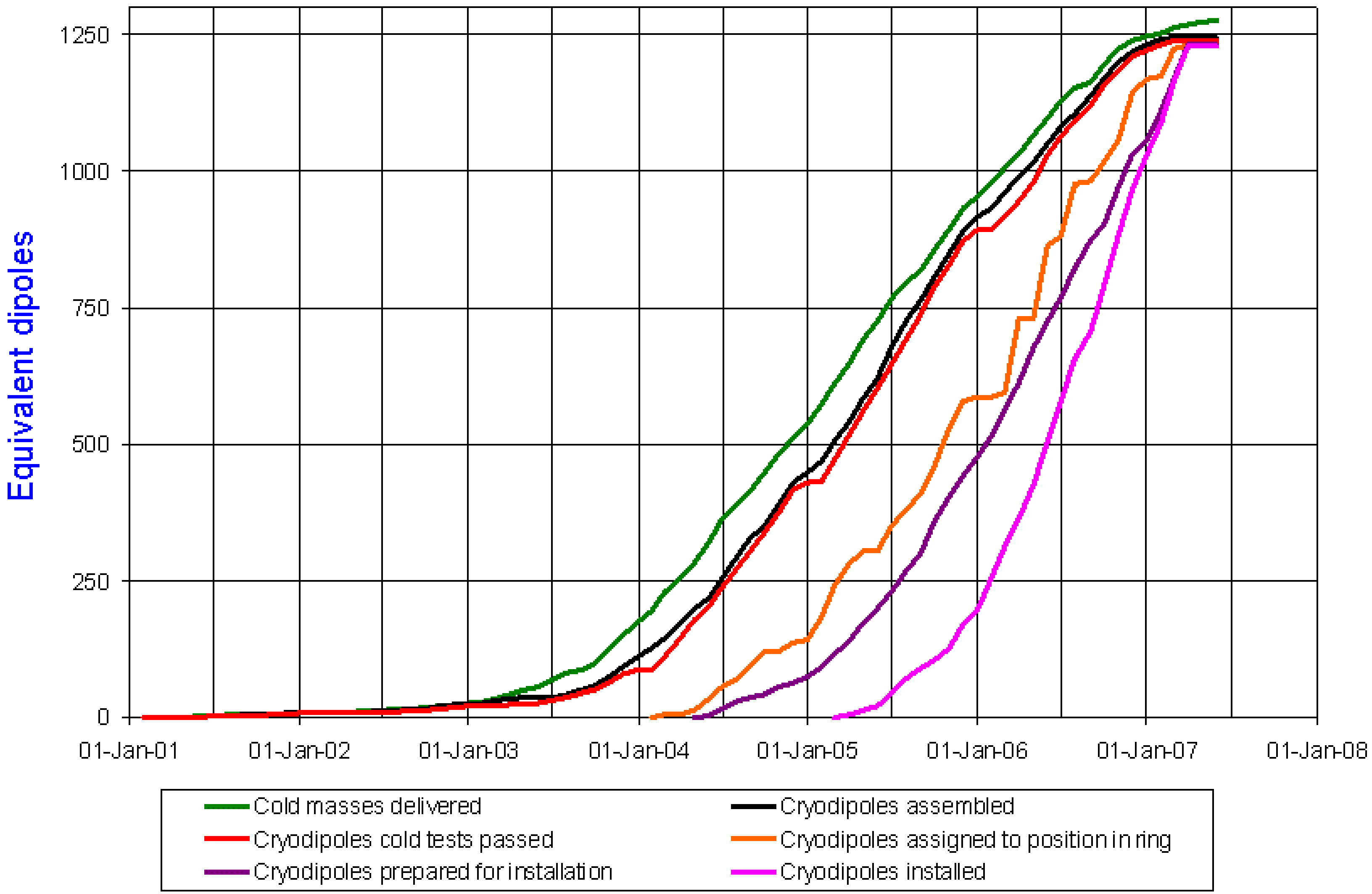
- All 1232 Dipoles and 396 arc Quads Delivered
- All Dipoles installed
- Sector 4-5,7-8, 8-1 of machine completely interconnected
- Cryogenic distribution line complete
- Sectors 7-8/8-1 cooled to 4K for cold test
- Sector 7-8 cooled to 2K – working temp.

ST-CE/JLB-hlm
22/10/2003

# LHC Progress Dashboard

Accelerator
Technology
Department

## Cryodipole overview



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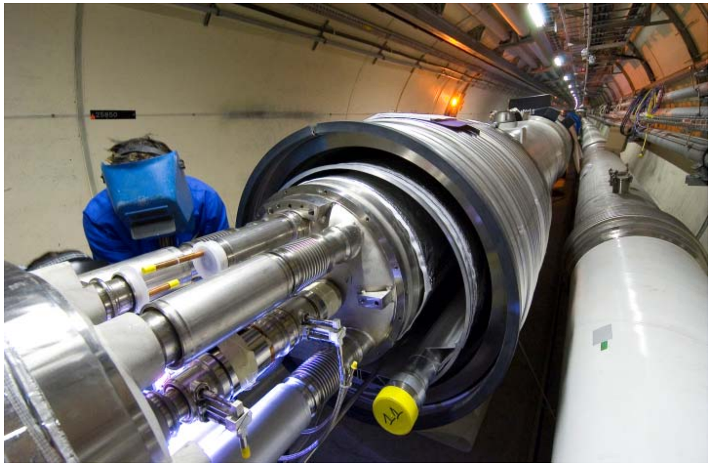
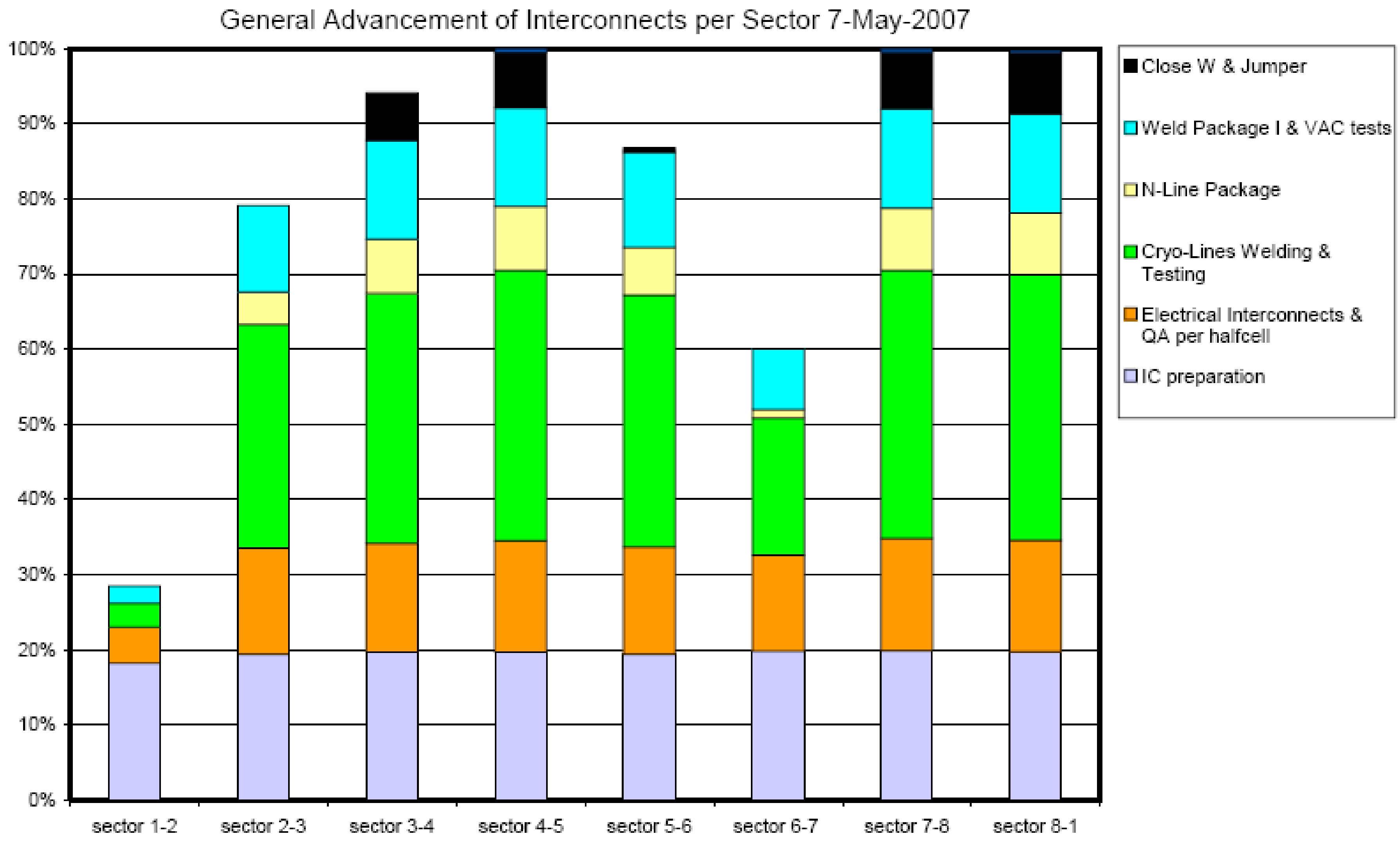
Updated 31 May 2007

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

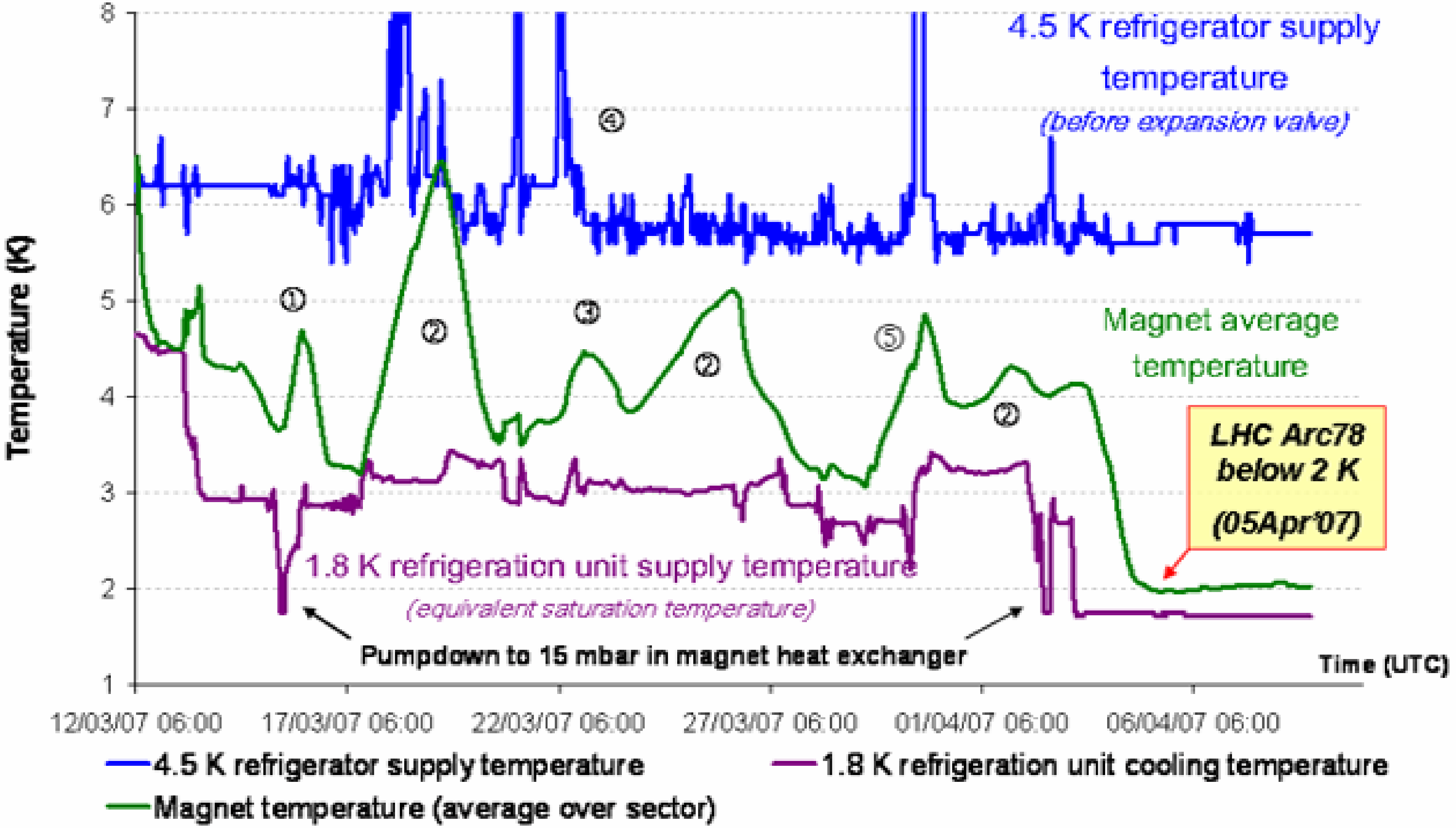
# Underground
# Last Dipole April 2007



# Magnet Interconnections



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

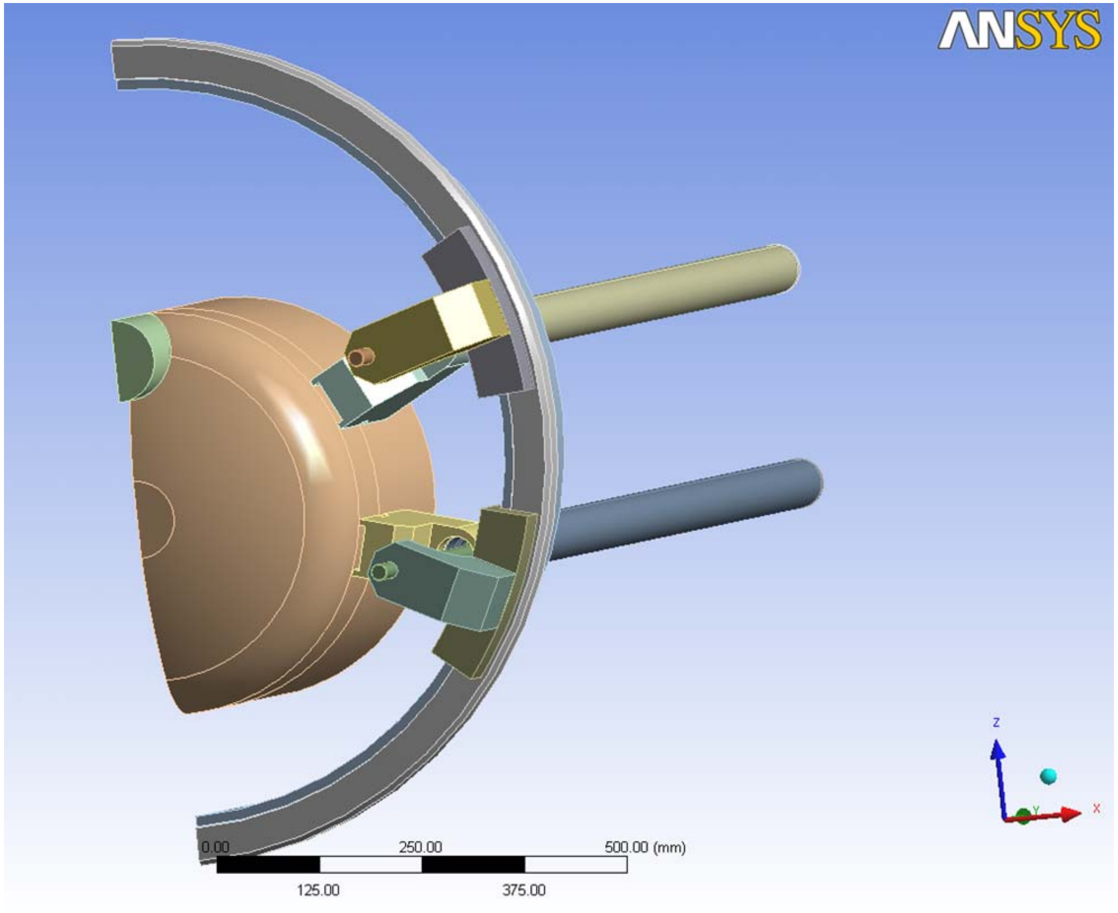


① Tuning of cold compressors & turbines with temporary stop of magnet cooling
② Stop of active cooling in weekend with only on call activity limited to secure hardware
③ Stop of magnet cooling for logic improvement in 1.8K refrigeration unit
④ Random emergency stop in cryogenic surface building with stop of sector 78 cooling
⑤ micro-electrical stop followed by utility stops

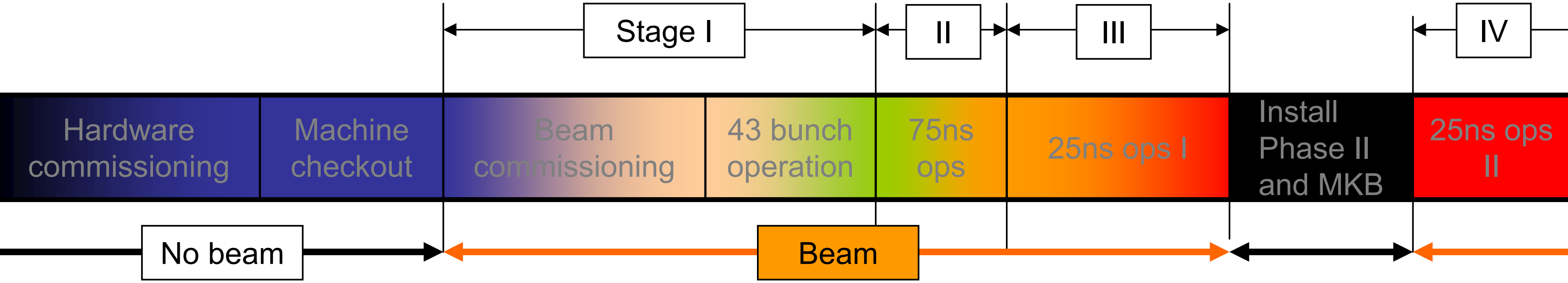
# Inner Triplet: Cold Mass

# Repair Cartridge

- Affixed at Q1 non-IP end and at Q3 IP end
- Transfer load at all temperatures
- Limits support deflections
- Compound design with Invar rod and aluminium alloy tube
- Attached with brackets to cold mass and cryostat outer vessel



# Staged Commissioning Plan for Protons (R. Bailey)



Stage I

II

III

IV

Hardware commissioning

Machine checkout

Beam commissioning

43 bunch operation

75ns ops

25ns ops I

Install Phase II and MKB

25ns ops II

No beam

Beam

**Pilot physics run**

- First collisions
- 43 bunches, no crossing angle, no squeeze, moderate intensities
- Push performance (156 bunches)
- *Performance limit $10^{32}$ cm$^{-2}$ s$^{-1}$ (event pileup)*

**75ns operation**

- Establish multi-bunch operation, moderate intensities
- Relaxed machine parameters (squeeze and crossing angle
- Push squeeze and crossing angle
- *Performance limit $10^{33}$ cm$^{-2}$ s$^{-1}$ (event pileup)*

**25ns operation I**

- Nominal crossing angle
- Push squeeze
- Increase intensity to 50% nominal
- *Performance limit 2 $10^{33}$ cm$^{-2}$ s$^{-1}$*

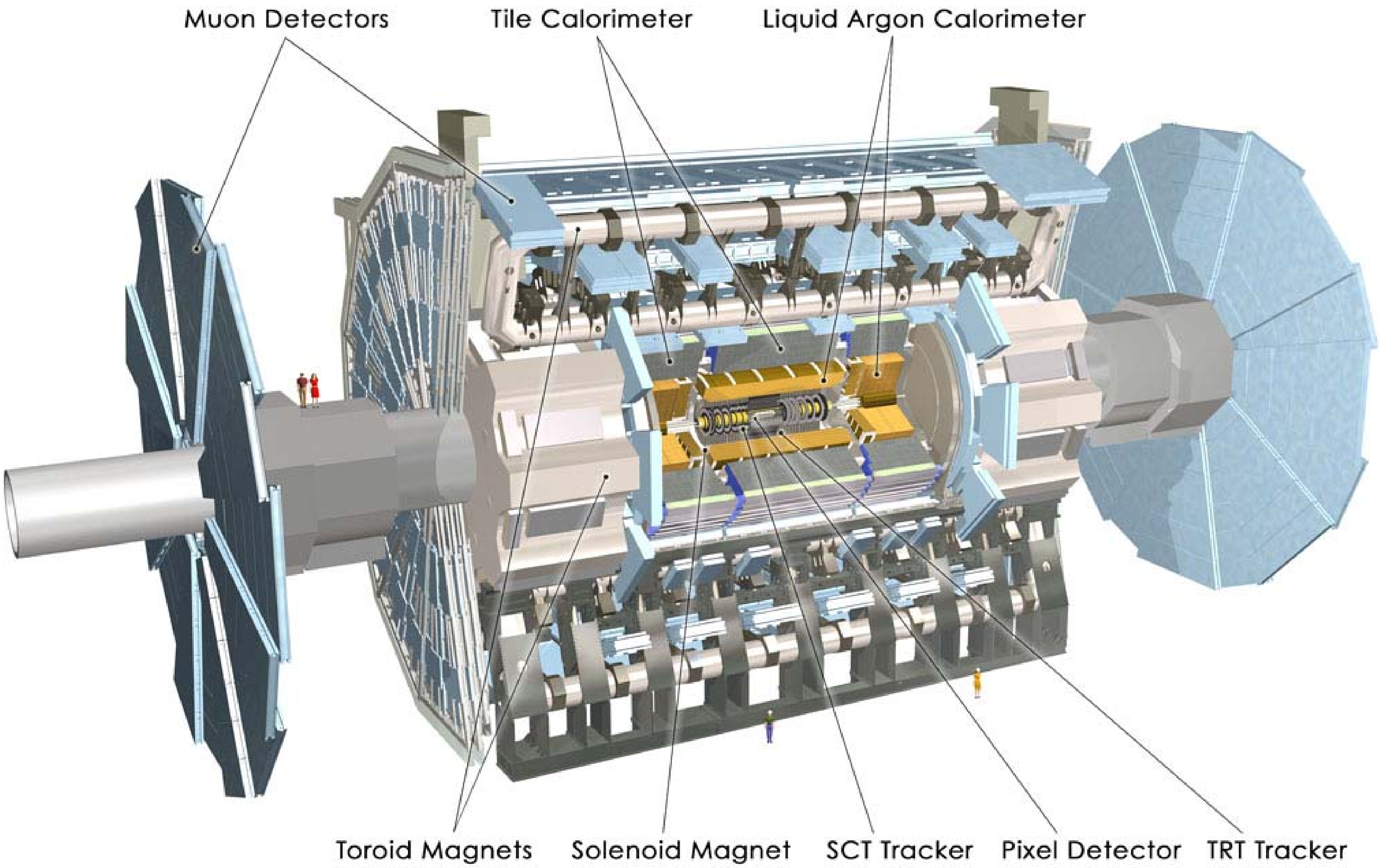
**25ns operation II**

- Push towards nominal performance

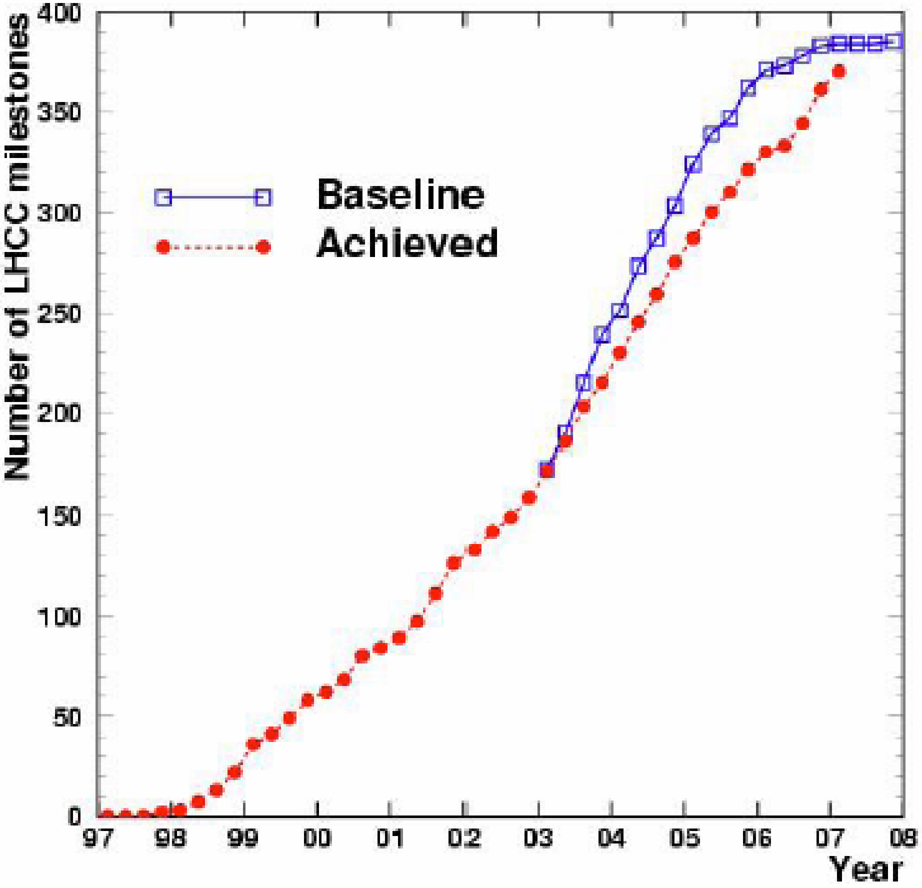
# General Schedule

- 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 mis-haps, e.g. additionnel warm-up/cool-down of sector

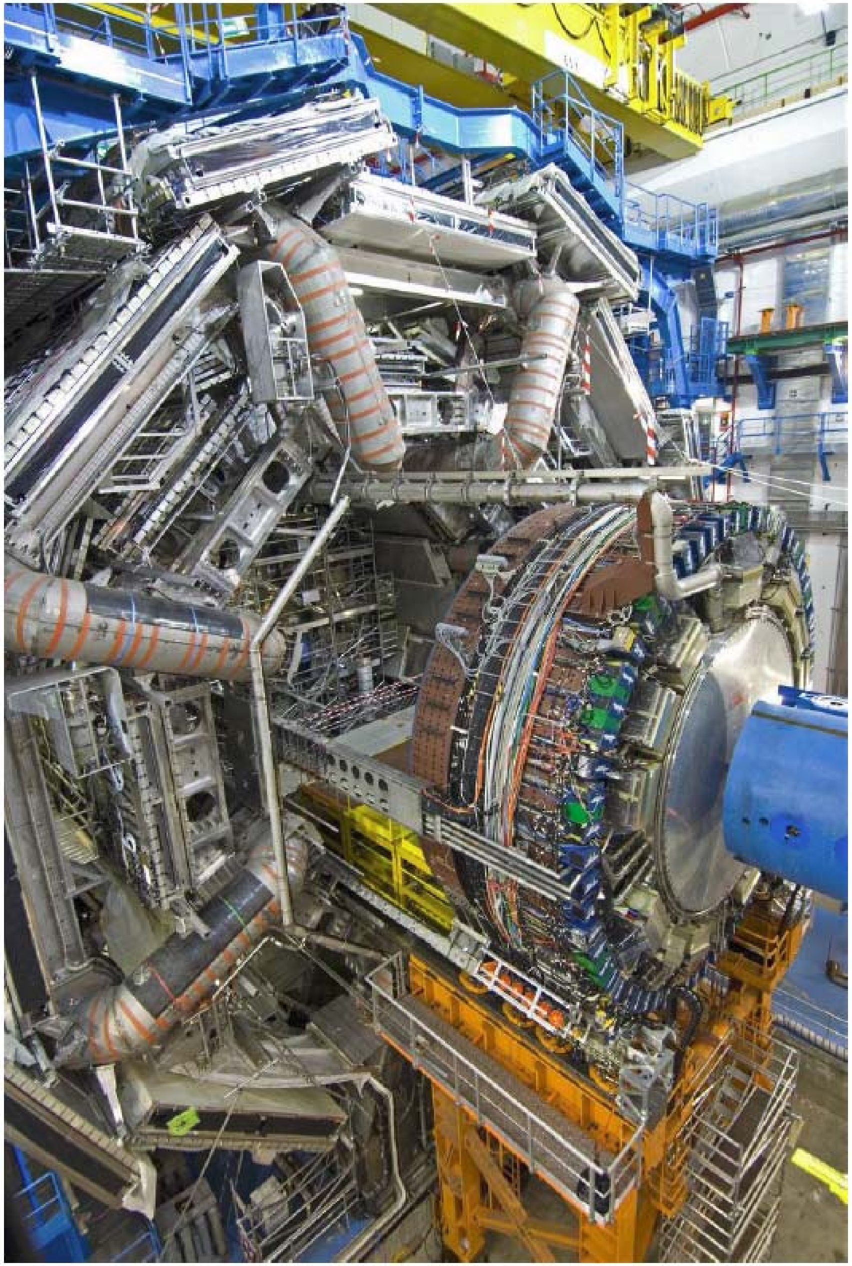
# Construction Status of ATLAS Detector Systems



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



Integrated LHCC
milestones
LHCC April 2007



# LHC Prospects

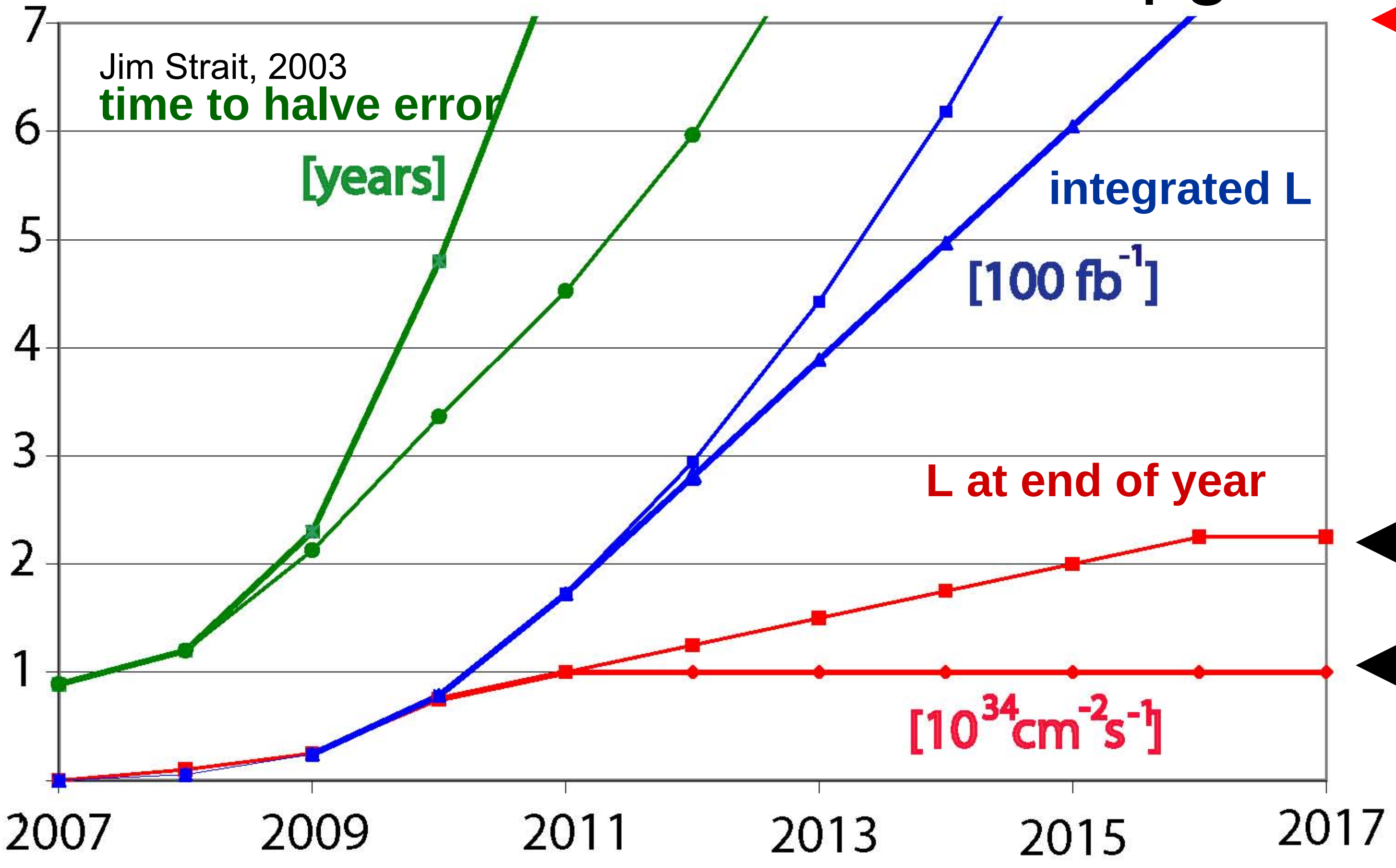
- Date for first beams/collisions: ⇒ **July 2008**
- Initial physics run starts in summer/fall 2008
  ⇒ collect ~10 $fb^{-1}$ /exp (2.$10^{33}cm^{-2}\ s^{-1}$) by end of 2009
- Depending on the evolution of the machine…
  ⇒ collect 200-300 $fb^{-1}$ /exp (3.4-10.$10^{33}cm^{-2}\ s^{-1}$ ) in 5-6 years 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 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

# Time Scale of an LHC upgrade



radiation damage limit ~700 fb$^{-1}$

ultimate luminosity

design luminosity

- 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-$\beta$ IR magnets around ~2014-2015*

# Machine Upgrade in Stages

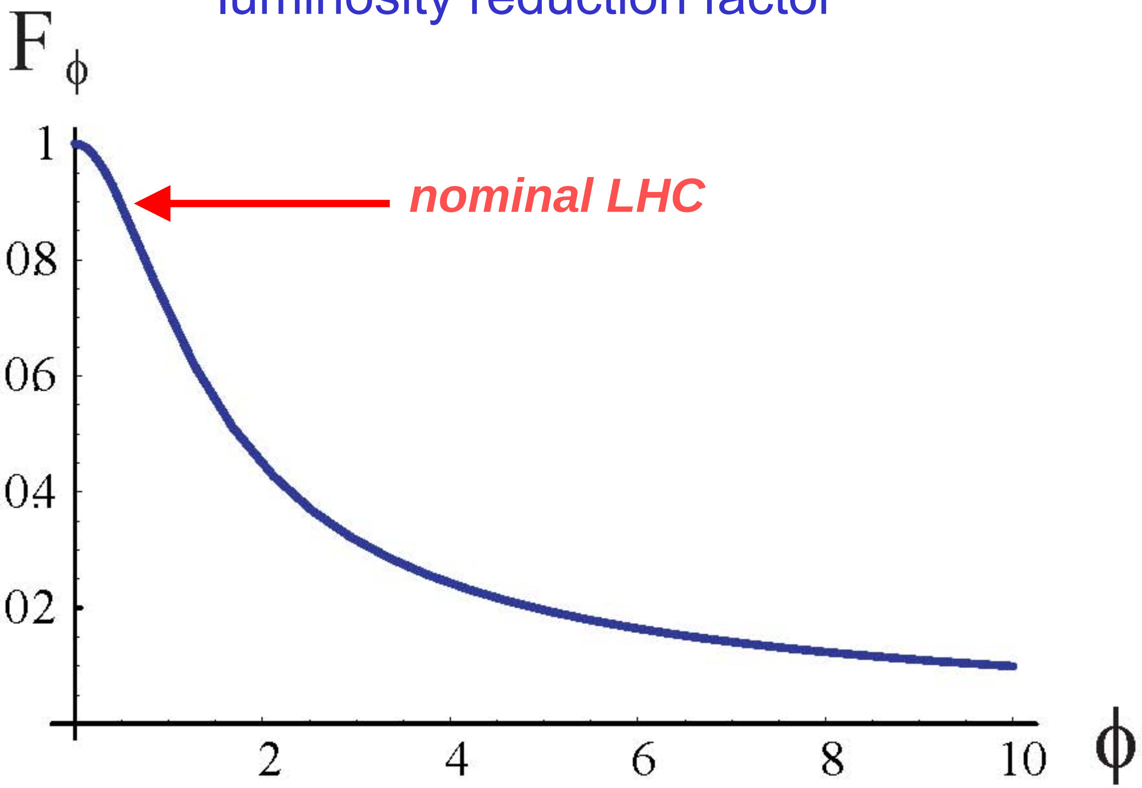
- Push LHC performance *without* new hardware
  - luminosity →$2.3 \times 10^{34}$ cm$^{-2}$s$^{-1}$, $E_b$=7→7.54 TeV
- LHC IR upgrade
  - replace low-β quadrupoles after ~7 years
    peak luminosity →$4.6 \times 10^{34}$ cm$^{-2}$s$^{-1}$
- LHC injector upgrade
  - peak luminosity →$9.2 \times 10^{34}$ cm$^{-2}$s$^{-1}$
- LHC energy upgrade
  - $E_b$→13 – 21 TeV (15 → 24 T dipole magnets)

# Nominal Crossing Angle "at the edge"

$$F_{\phi} = \frac{1}{\sqrt{1+\phi^2}}; \quad \phi \equiv \frac{\theta_c \sigma_z}{2\sigma_x}$$

Piwinski angle

luminosity reduction factor



# Beam-Beam Limit Luminosity Equation

injector upgrade

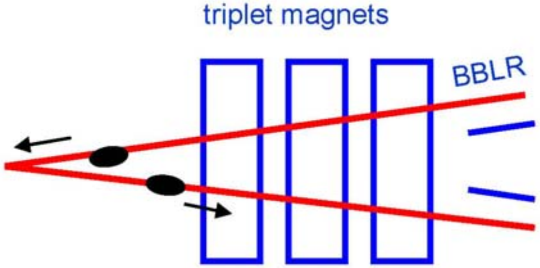
$$L \approx \pi\gamma n_b \frac{(\gamma\varepsilon) f_{rev}}{r_p^2 \beta^*} \Delta Q_{bb}^2 \sqrt{1+\phi^2} F_{profile}$$

LHC + injector changes

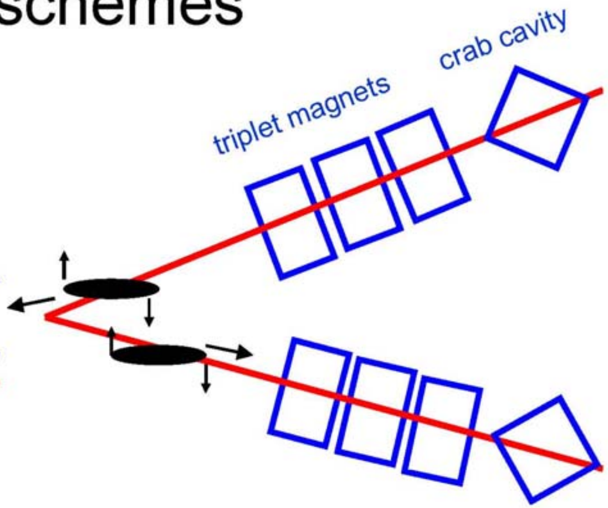
IR upgrade

LHC+ injector changes

# IR ‘baseline’ schemes



short bunches &
minimum crossing angle &
BBLR

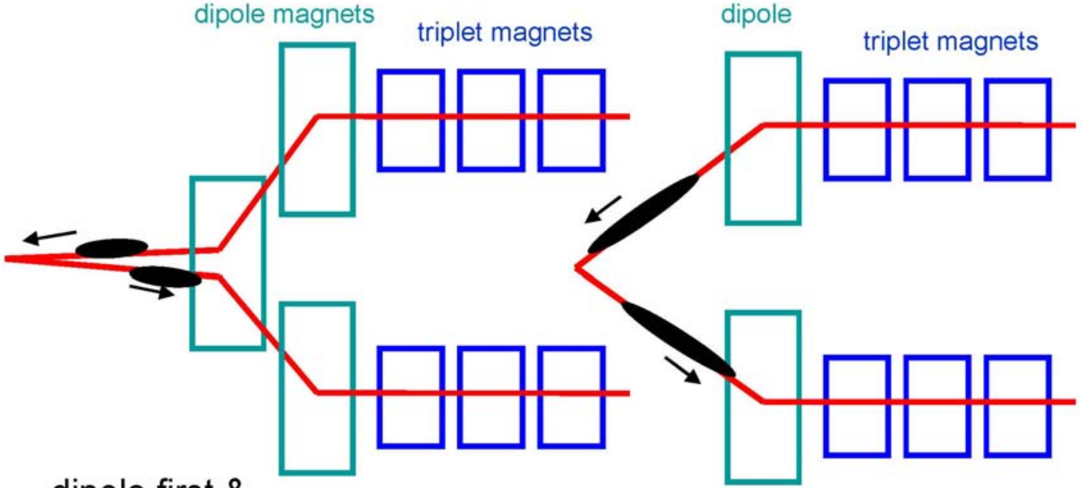


crab cavities &
large crossing angle

“quadrupoles first”

minimum chromaticity

# alternative IR schemes → “dipole first”



dipole first &
small crossing angle

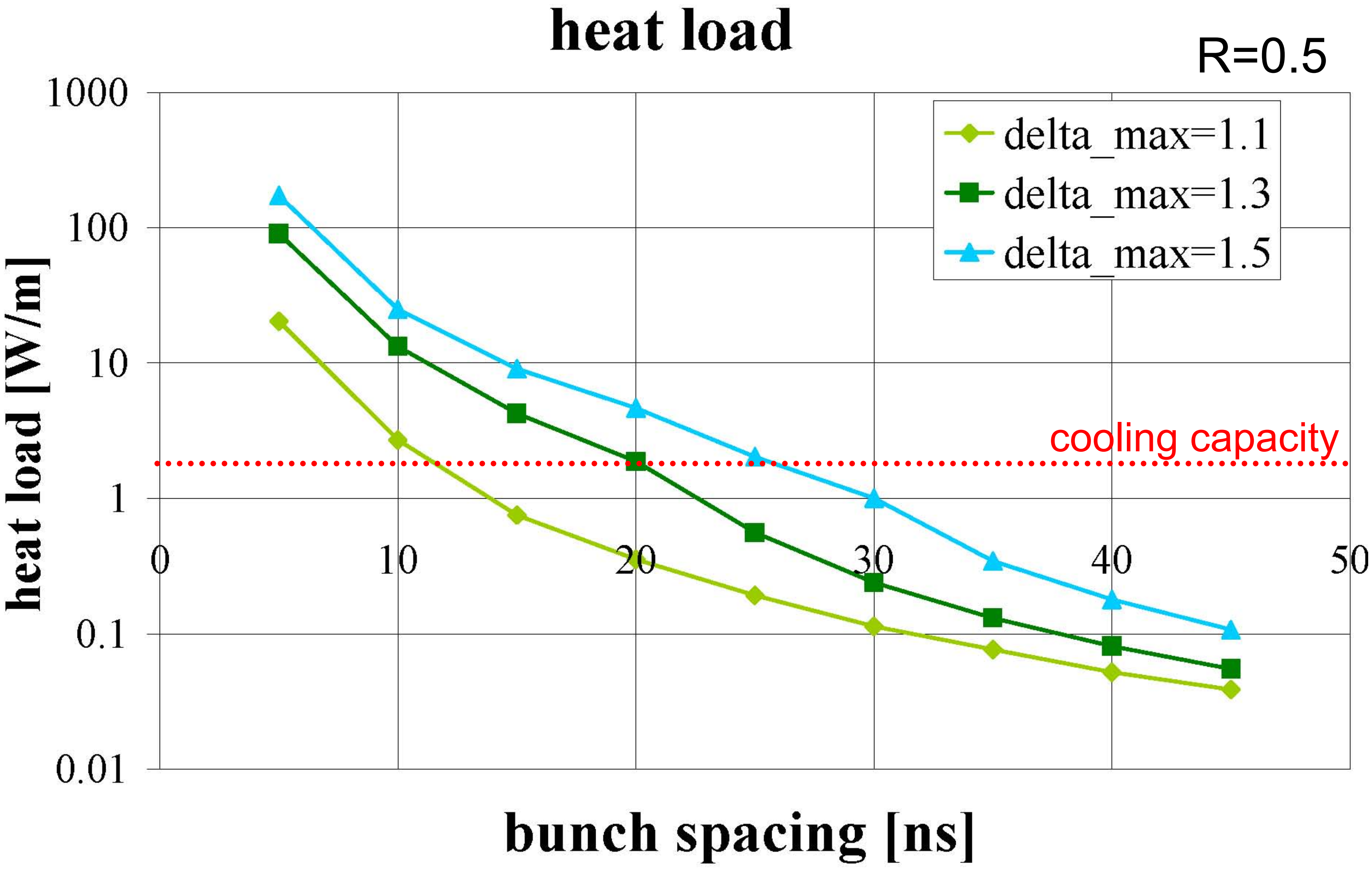
dipole first &
large crossing angle &
long bunches or crab cavities

*reduced # LR collisions;*
*collision debris hits first dipole*

N. Mokhov et al.,
PAC2003

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

# arc heat load vs. spacing, $N_b$=1.15x$10^{11}$, ‘best’ model



# Summary of Luminosity Upgrade

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

25-ns: push $\beta^*$ 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 $\beta^*$ tuning

# LHC Energy Doubler 14*14 TeV

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

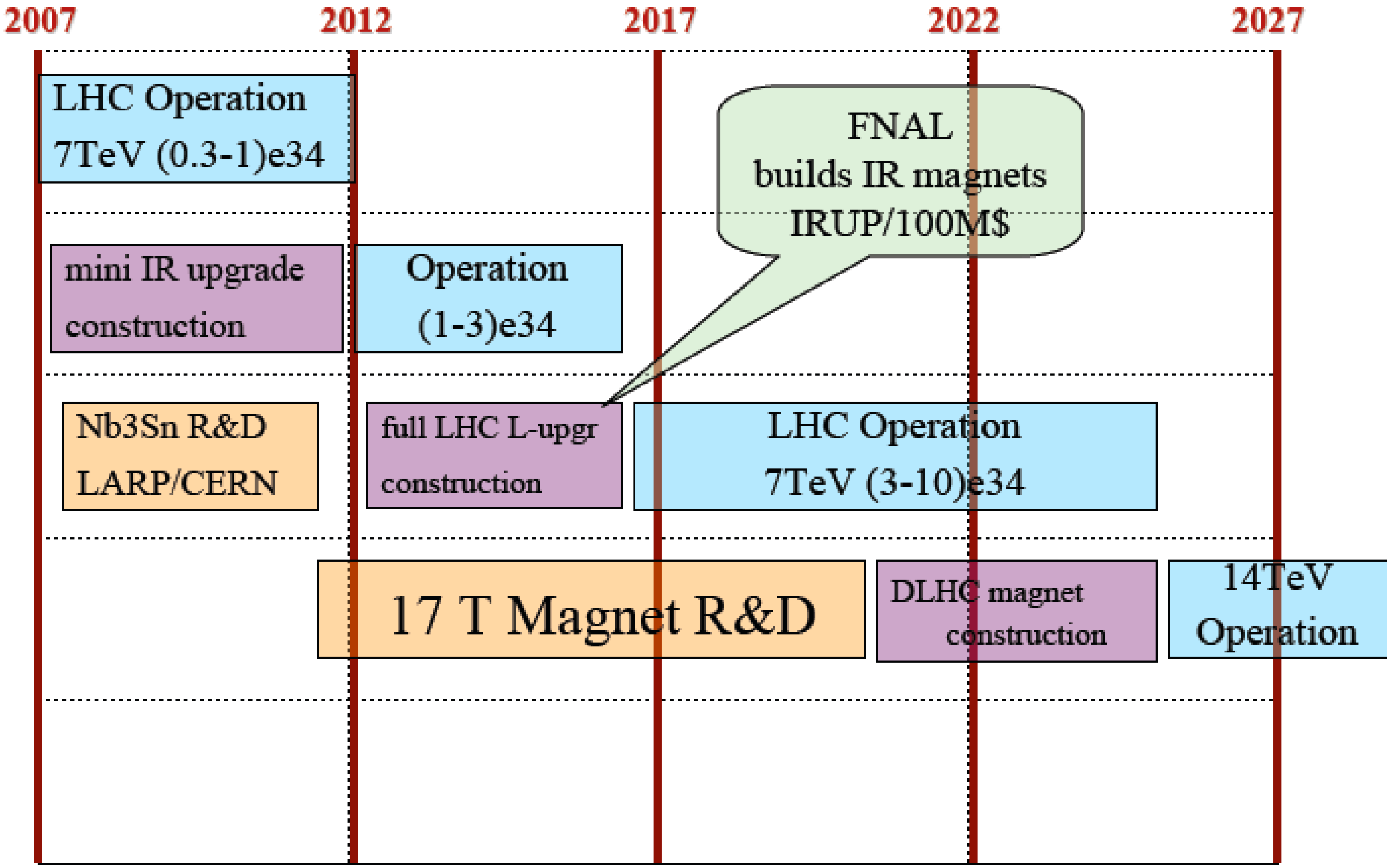
- Superconductor $Nb_3Sn$
- 16T demonstrated at 4K
- 10 years for R&D, 10 years production
- 3G$

# 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



2007 2012 2017 2022 2027

LHC Operation
7TeV (0.3-1)e34

mini IR upgrade
construction

Operation
(1-3)e34

FNAL
builds IR magnets
IRUP/100M$

Nb3Sn R&D
LARP/CERN

full LHC L-upgr
construction

LHC Operation
7TeV (3-10)e34

17 T Magnet R&D

DLHC magnet
construction

14TeV
Operation

# 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??

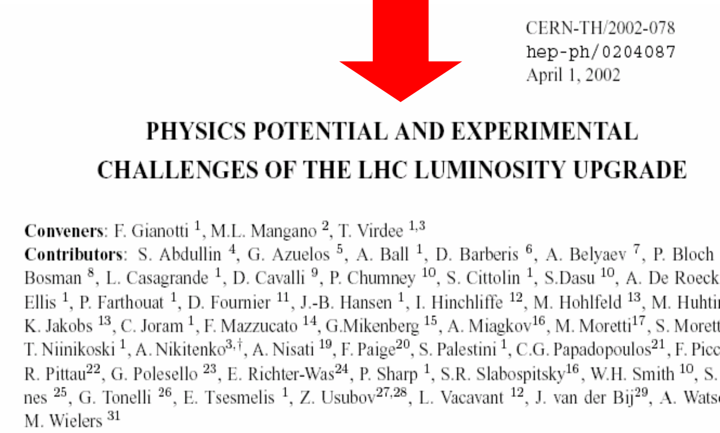
Rough expectation for the SLHC versus LHC

- 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

# Extending the Physics Potential of LHC

- **Electroweak Physics**
  - production of multiple gauge bosons ($n_V \geq 3$)
  - triple and quartic gauge boson couplings
  - top quarks/rare decays
- **Higgs physics**
  - rare decay modes
  - Higgs couplings to fermions and bosons
  - Higgs self-couplings
  - Heavy Higgs bosons of the MSSM
- **Supersymmetry**
- **Extra Dimensions**
  - Direct graviton production in ADD models
  - Resonance production in Randall-Sundrum models $\text{TeV}^{-1}$ scale models
  - Black Hole production
- **Quark substructure**
- **Strongly-coupled vector boson system**
  - $W_L Z_L$ g $W_L Z_L$ , $Z_L Z_L$ scalar resonance, $W^+_L W^+_L$
- **New Gauge Bosons**

Examples studied in some detail



CERN-TH/2002-078
hep-ph/0204087
April 1, 2002

PHYSICS POTENTIAL AND EXPERIMENTAL
CHALLENGES OF THE LHC LUMINOSITY UPGRADE

**Conveners**: F. Gianotti [1], M.L. Mangano [2], T. Virdee [1,3]
**Contributors**: S. Abdullin [4], G. Azuelos [5], A. Ball [1], D. Barberis [6], A. Belyaev [7], P. Bloch
Bosman [8], L. Casagrande [1], D. Cavalli [9], P. Chumney [10], S. Cittolin [1], S.Dasu [10], A. De Roeck
Ellis [1], P. Farthouat [1], D. Fournier [11], J.-B. Hansen [1], I. Hinchliffe [12], M. Hohlfeld [13], M. Huhti
K. Jakobs [13], C. Joram [1], F. Mazzucato [14], G.Mikenberg [15], A. Miagkov[16], M. Moretti[17], S. Morett
T. Niinikoski [1], A. Nikitenko[3,†], A. Nisati [19], F. Paige[20], S. Palestini [1], C.G. Papadopoulos[21], F. Picc
R. Pittau[22], G. Polesello [23], E. Richter-Was[24], P. Sharp [1], S.R. Slabospitsky[16], W.H. Smith [10], S.
nes [25], G. Tonelli [26], E. Tsesmelis [1], Z. Usubov[27,28], L. Vacavant [12], J. van der Bij[29], A. Wats
M. Wielers [31]

Include pile up, detector

Preliminary…

# 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<br>14TeV<br>100 $fb^{-1}$ | SLHC<br>14TeV<br>1000 $fb^{-1}$ | SLHC<br>28TeV<br>100 $fb^{-1}$ | LinCol<br>0.8 TeV<br>500 $fb^{-1}$ | LinCol<br>5 TeV<br>100 $fb^{-1}$ |
|---|---|---|---|---|---|
| Squarks | 2.5 | 3 | 4 | 0.4 | 2.5 |
| $W_L W_L$ | $2\sigma$ | $4\sigma$ | $4.5\sigma$ | | |
| $Z'$ | 5 | 6 | 8 | 8† | 8† |
| Extra Dim ($\delta$=2) | 9 | 12 | 15 | 5 - 8.5† | 30 - 55† |
| $q^*$ | 6.5 | 7.5 | 9.5 | 0.8 | 5 |
| $\Lambda_{comp}$ | 30 | 40 | 40 | 100 | 400 |
| TGC ($\lambda_\gamma$) | 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 $\Delta t$ | 25 ns | 25/50 ns |
| $\sigma_{pp}$ (inelastic) | ~ 80 mb | ~ 80 mb |
| N. interactions/x-ing | ~ 20 | ~ 280/350 |
| ($N=L\ \sigma_{pp}\ \Delta t$) | | |
| $dN_{ch}/d\eta$ 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 | ~9 |
| 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.

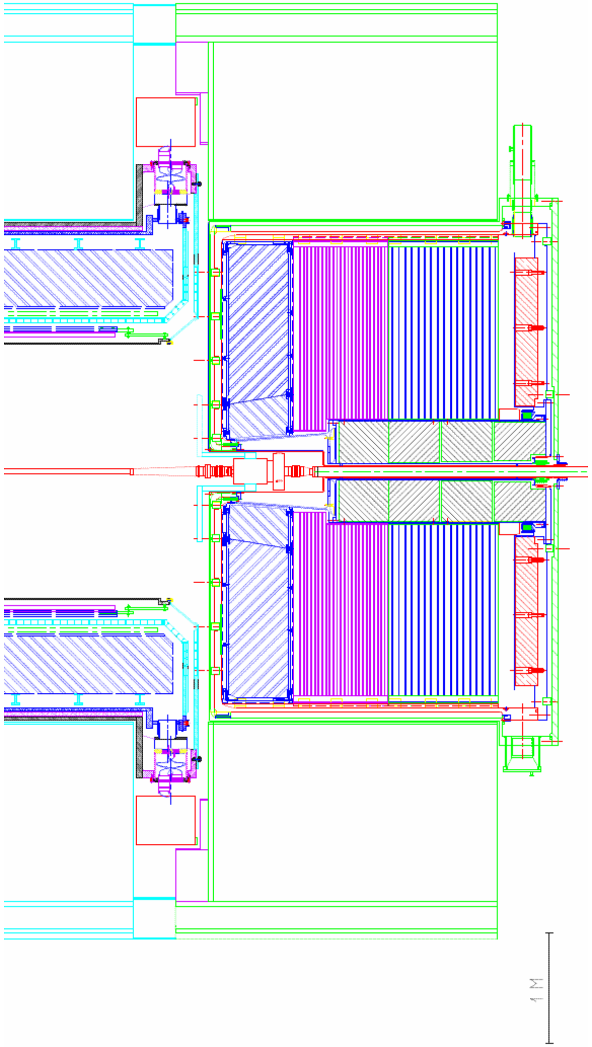
This will make low $E_t$ jet triggering and reconstruction difficult.

# Detector Upgrade

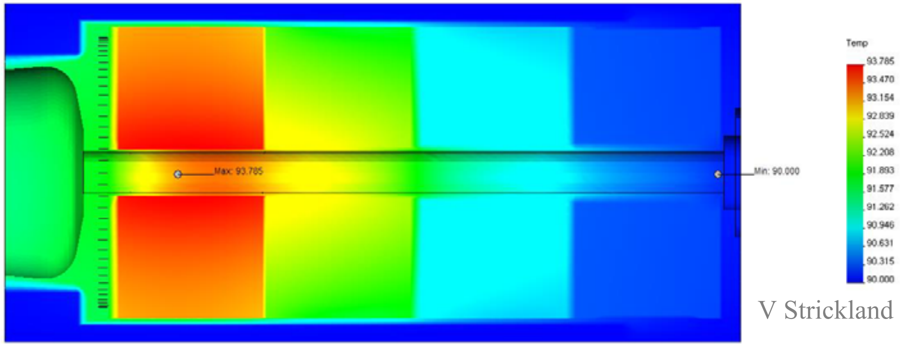
- ATLAS has begun studying what needs to be upgraded for $10^{35}cm^{-2}s^{-1}$ instantaneous luminosity
  - ~10× harsher pileup, radiation environment
  - Also constrained by existing detector: what can be moved/stored where/when
- Major ID overhaul foreseen
  - TRT replaced by Si Strips
  - Pixels 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

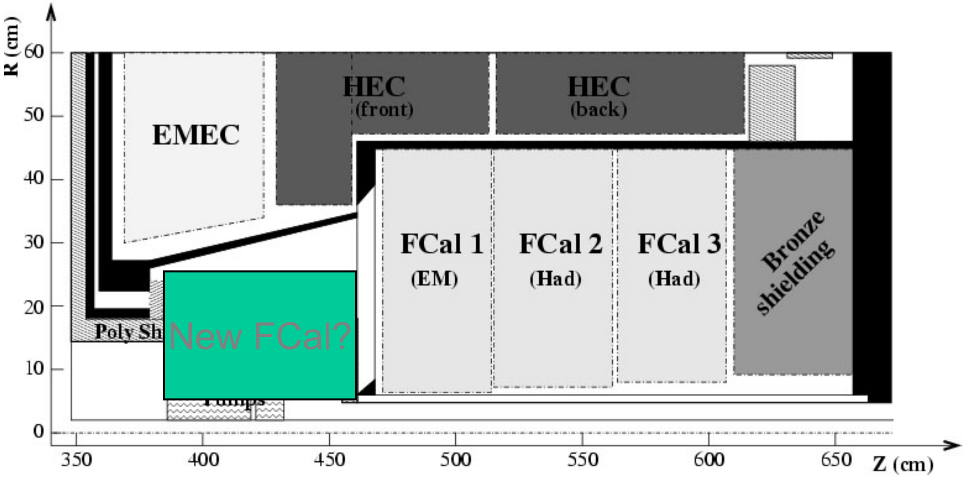
- Critical issues
  - ion build up and heat load
- The HiLum ATLAS Endcap Project
- Radiation hardness:
  - R&D for HEC cold electronics;



# FCal - Heatload

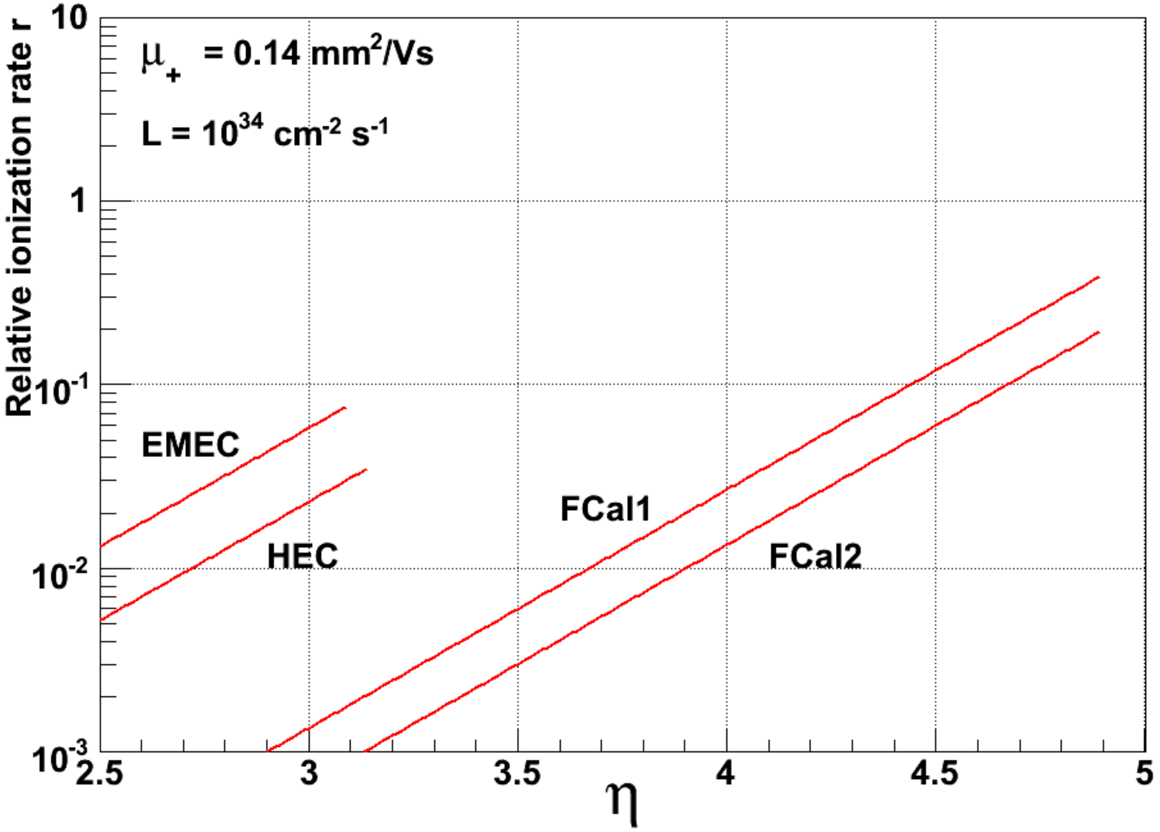


V Strickland



- 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**

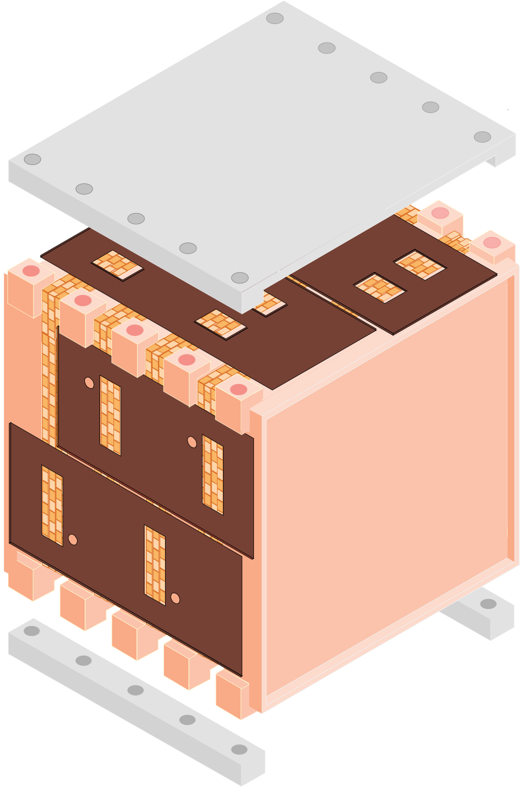
sLHC

# 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;
- Arizona, Dresden, JINR Dubna, Kosice, Mainz, LPI Moscow, MPI Munich, BINP Novosibirsk, IHEP Protvino, TRIUMF, Wuppertal.

# HiLum Test Modules

FCAL module



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

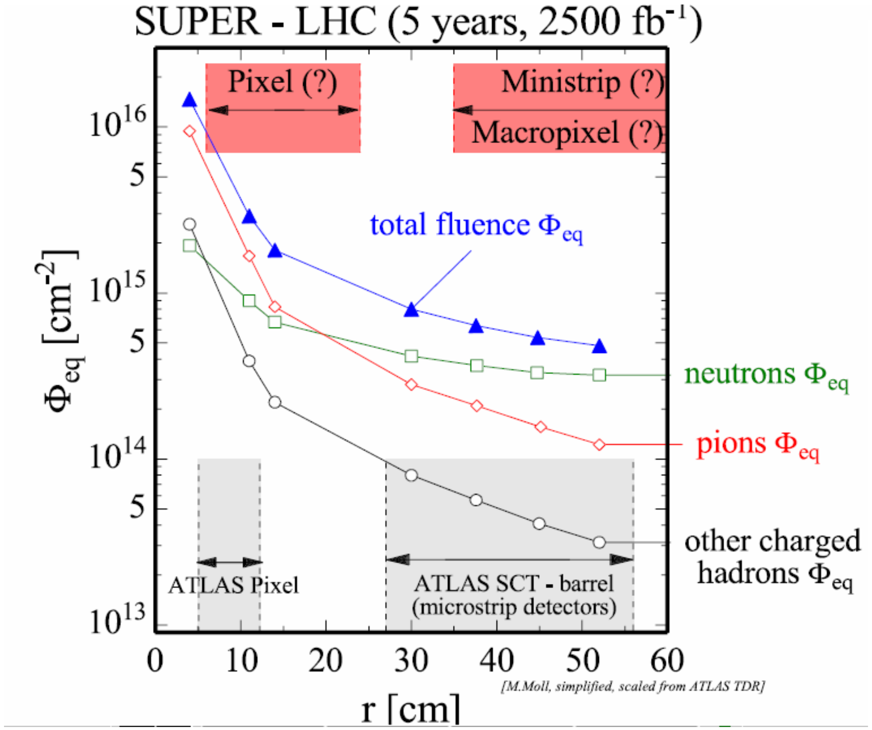
# HEC Electronics Upgrade

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

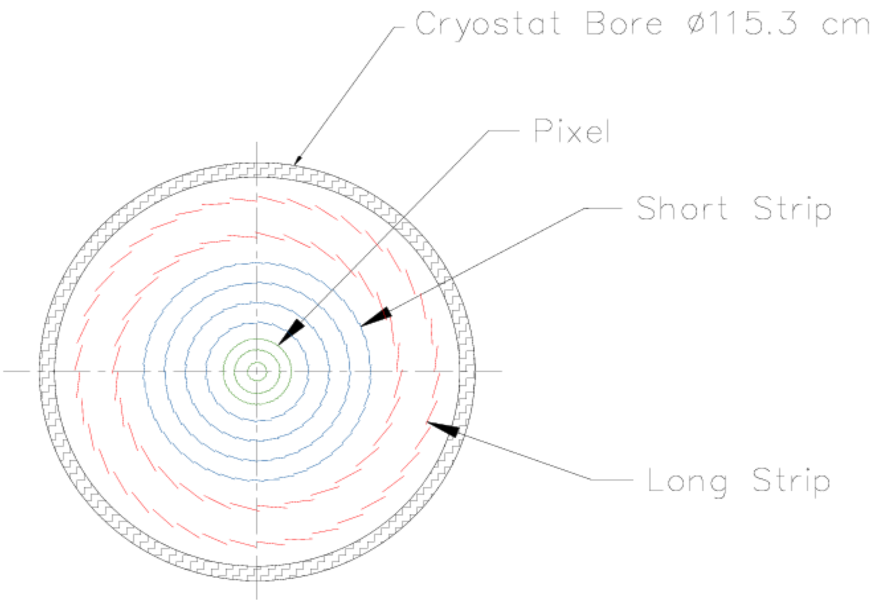
- Electronics upgrade R&D (Montréal, MPI, Kosice, TRIUMF) four options.
  - 1. Existing chips for sLHC conditions.
  - 2. Re-design ASIC with present GaAs technology
  - 3. Investigate SiGe HBT (Heterojunction Bipolar Transistor)
  - 4. Study warm electronics options: Si (or SiGe) warm preamps

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

# Inner Detector Replacement

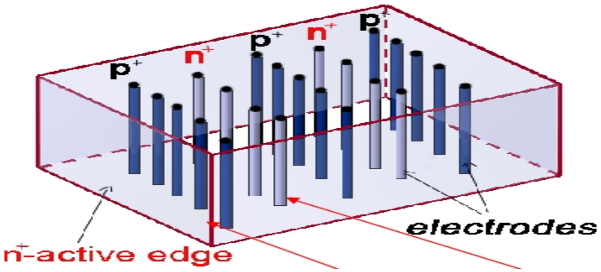


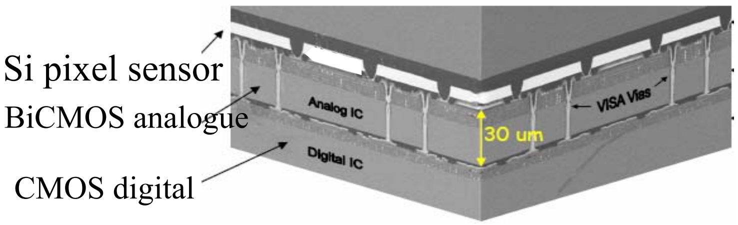
[M.Moll, simplified, scaled from ATLAS TDR]

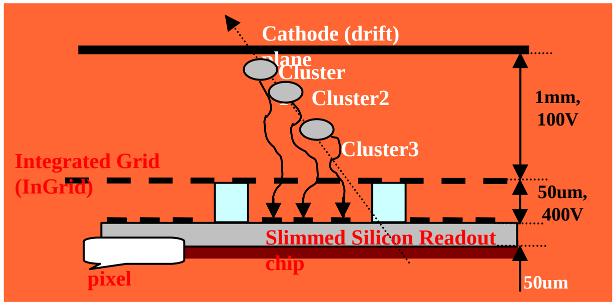


- Order of magnitude increase in Data rates, Occupancy, Irradiation
- No TRT – Si strips
- Pixels moved to larger radius
- New technology for inner layers
- R&D required on sensors, readout, and mechanical engineering

# Pixel-layer Technologies







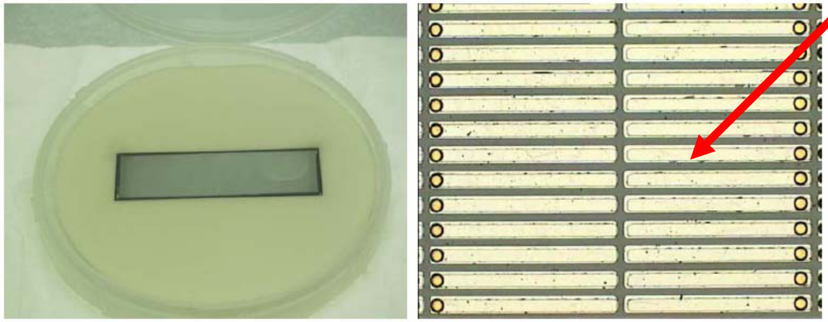
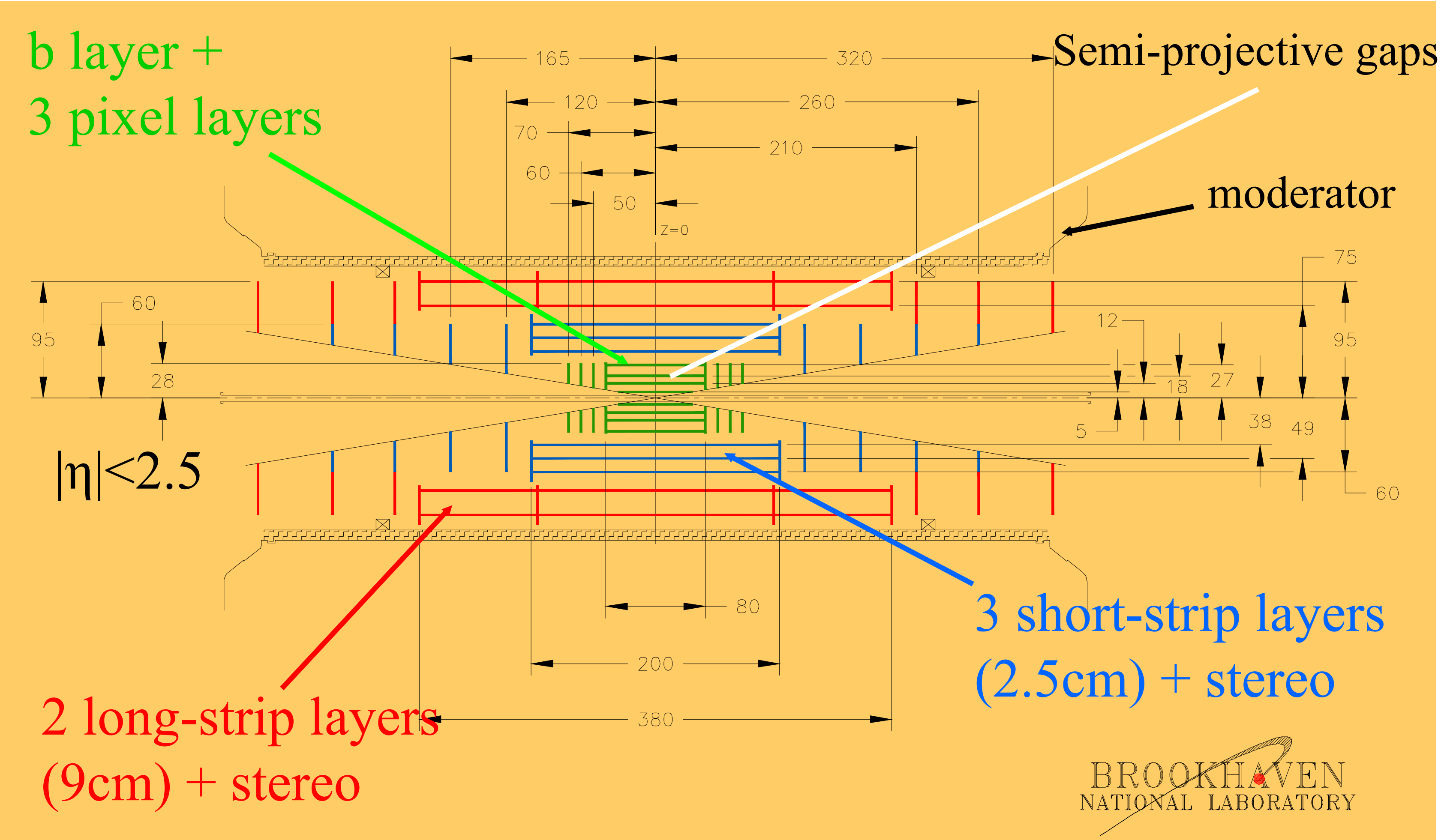


Figure 5: (a) Photograph of the ATLAS pixel diamond mounted in the carrier ready for bump bonding. (b) Zoom view of the pixel pattern after the under-bump metal is deposited.

- 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)

# Strawman Layout of Tracker



b layer +
3 pixel layers

Semi-projective gaps

moderator

|η|<2.5

3 short-strip layers
(2.5cm) + stereo

2 long-strip layers
(9cm) + stereo

# 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, Carleton, Montréal +…..

- 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

# Bottom Line

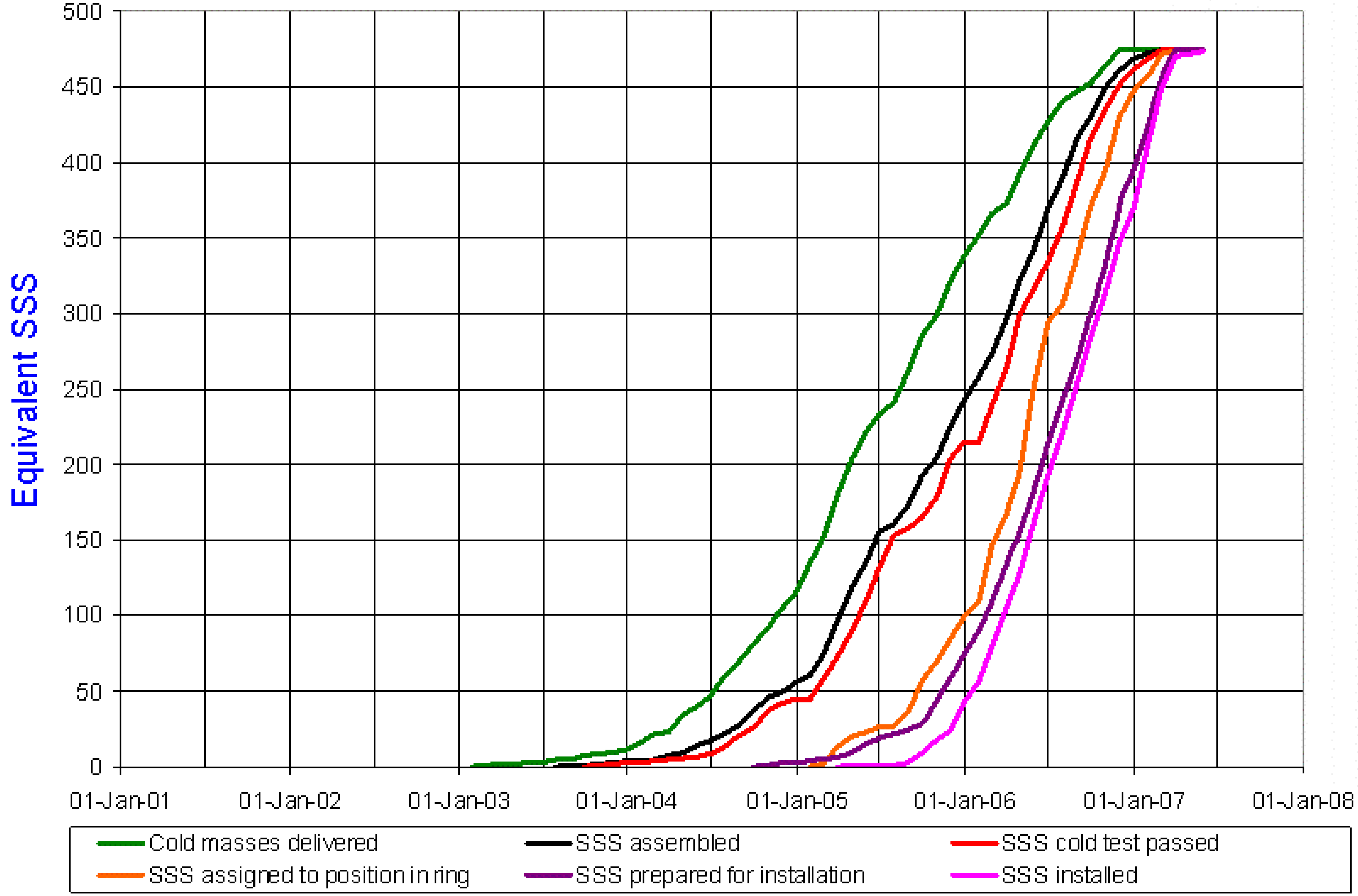
- LHC with Luminosity upgrade will likely be built.
    - Work in Canada needs to start soon
    - Scope for new people and new ideas

# MACHINE EXTRAS

# MACHINE EXTRAS

# MACHINE EXTRAS

# Short Straight Section Overview



Updated 31 May 2007

Data provided by M. Modena AT-MCS, L. Bottura AT-MTM

# Inner Triplet Problem March 2007

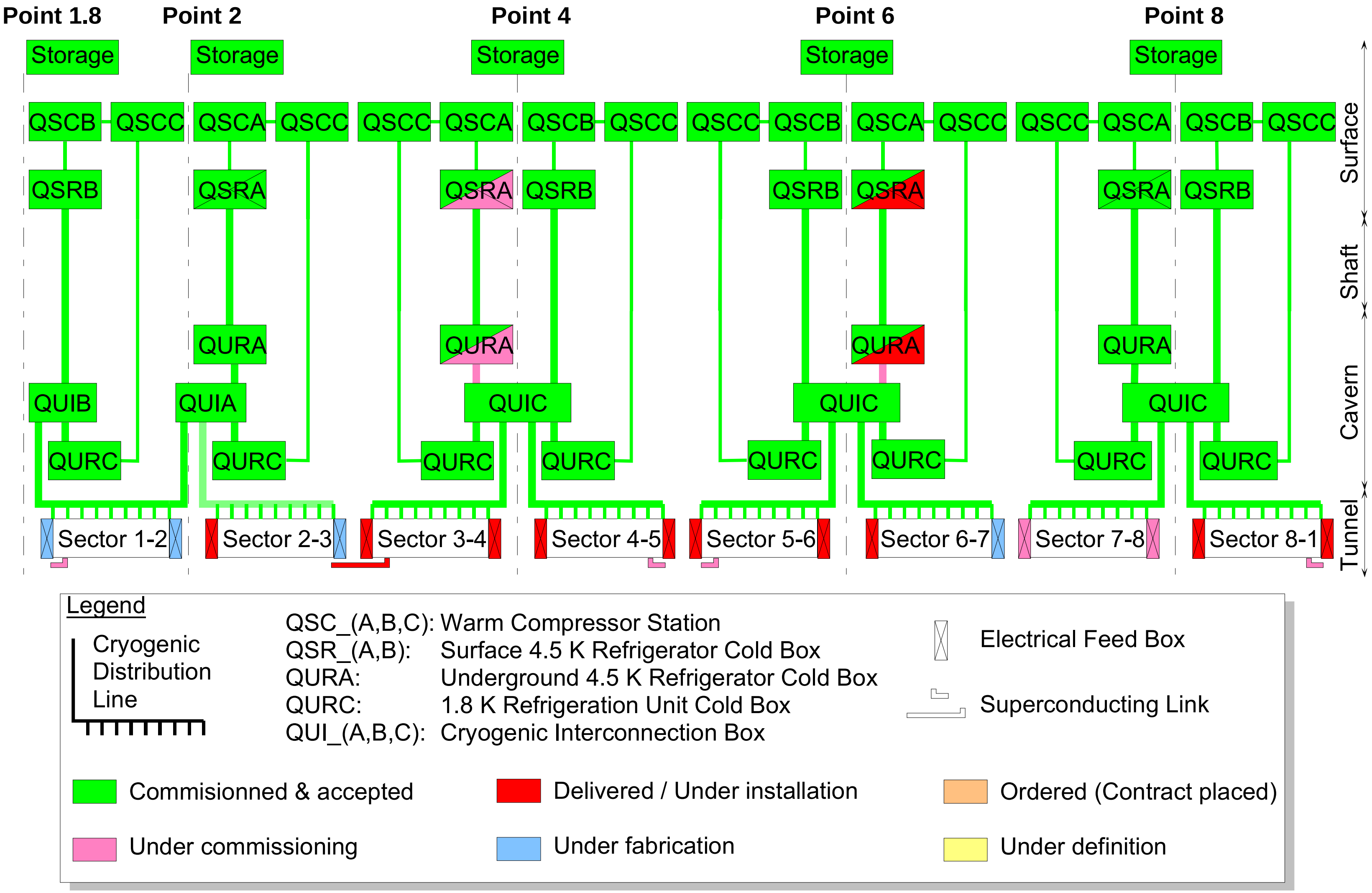
- During the pressure test of the repaired triplet in 5L (27 March 2007), longitudinal fixed points on the “spider” supports of the cold mass broke at 20 bar.

- Loading conditions resulting from such pressure forces not taken into account in the design

- A complete review of the mechanical design of the Inner Triplets was conducted at CERN (24-25 April 2007) - repair solutions based on contraction-compensated compound metallic columns transfering longitudinal pressure forces onto the cryostat outer vessels

- Detailed design and validation of this solution are under way, and an implementation schedule is being established

# Cryogenic System Overview



Legend

Cryogenic Distribution Line

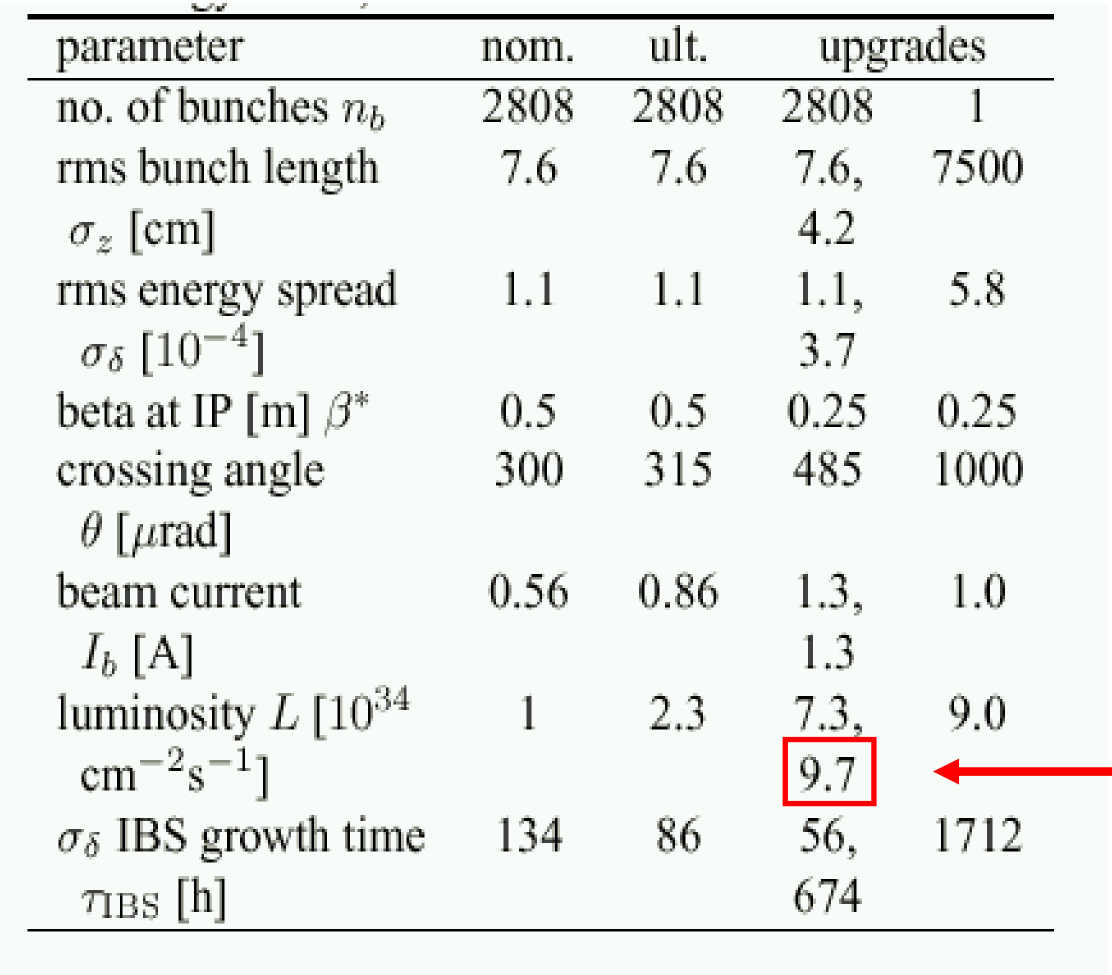
QSC_(A,B,C): Warm Compressor Station
QSR_(A,B): Surface 4.5 K Refrigerator Cold Box
QURA: Underground 4.5 K Refrigerator Cold Box
QURC: 1.8 K Refrigeration Unit Cold Box
QUI_(A,B,C): Cryogenic Interconnection Box

Electrical Feed Box

Superconducting Link

🟩 Commisionned & accepted
🟥 Delivered / Under installation
🟧 Ordered (Contract placed)
🟪 Under commissioning
🟦 Under fabrication
🟨 Under definition

# Machine upgrade



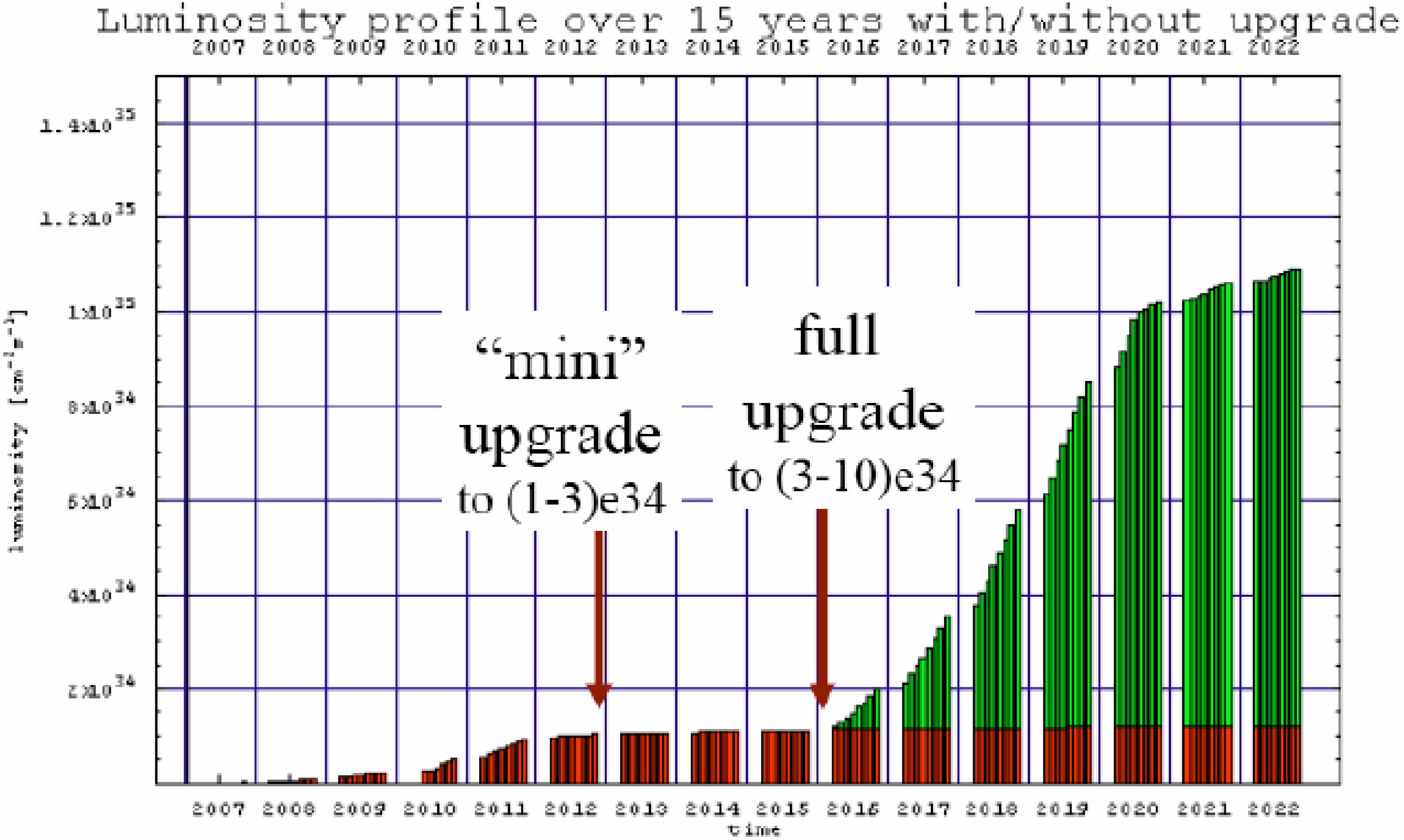
| parameter | nom. | ult. | upgrades | |
|---|---|---|---|---|
| no. of bunches $n_b$ | 2808 | 2808 | 2808 | 1 |
| rms bunch length $\sigma_z$ [cm] | 7.6 | 7.6 | 7.6, 4.2 | 7500 |
| rms energy spread $\sigma_\delta$ [$10^{-4}$] | 1.1 | 1.1 | 1.1, 3.7 | 5.8 |
| beta at IP [m] $\beta^*$ | 0.5 | 0.5 | 0.25 | 0.25 |
| crossing angle $\theta$ [$\mu$rad] | 300 | 315 | 485 | 1000 |
| beam current $I_b$ [A] | 0.56 | 0.86 | 1.3, 1.3 | 1.0 |
| luminosity $L$ [$10^{34}$ cm$^{-2}$s$^{-1}$] | 1 | 2.3 | 7.3, 9.7 | 9.0 |
| $\sigma_\delta$ IBS growth time $\tau_{\mathrm{IBS}}$ [h] | 134 | 86 | 56, 674 | 1712 |

Latest parameter set:
F. Ruggiero et al.
PAC2003 report
May 2003

A luminosity of $10^{35}$cm$^{-2}$ s$^{-1}$ seems possible

(*) Superbunch: 1 bunch of 75 m (rms) in each ring
Good for electron cloud effects/bad for experiments: 50000 events/25 ns slice

# LHC luminosity upgrade: the LARP perspective



Luminosity profile over 15 years with/without upgrade

“mini” upgrade to (1-3)e34

full upgrade to (3-10)e34

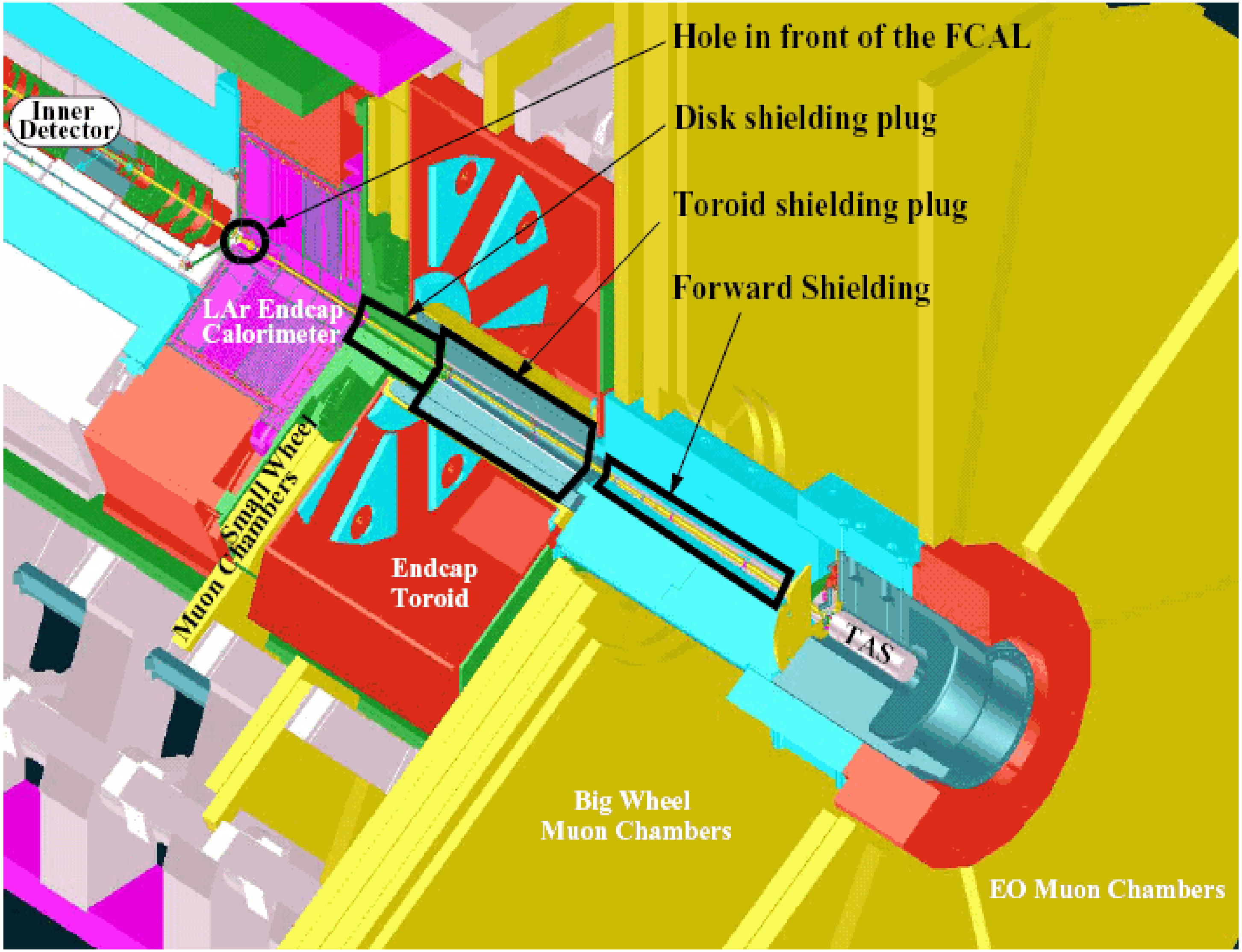
Courtesy of V. Shiltsev - FNAL

# Basic Ingredients

- Bunch spacing or bunch frequency
- Number of protons/bunch
- Bunch length, bunch profile
- Emittance
- Crossing angle
- ß* i.e ß at the IP
- L* i.e distance between IP and the starting point of the inner triplet
- Aperture,gradient and length of the inner triplet (also technology NbTi/NbSn)
- IP layout i.e dipole or quadrupole first
- Early separation schemes - D0 inside ATLAS
- Crab cavities
- Slim quadrupoles (Q0) to modify the behaviour of ß inside the experiment
- Wire compensation for long range beam-beam compensation

Some of these ingredients only works in combination with others and some are independent

# Slim magnets inside ATLAS



LUMI'06 parameters

| parameter | symbol | ultimate | 25 ns, smaller β* | 25 ns, large ε | 50 ns, long |
|---|---|---|---|---|---|
| transverse emittance | ε [μm] | 3.75 | 3.75 | 7.5 | 3.75 |
| protons per bunch | $N_b$ [$10^{11}$] | 1.7 | 1.7 | 3.4 | 4.9 |
| bunch spacing | Δt [ns] | 25 | 25 |  | 50 |
| beam current | I [A] | 0.86 | 0.86 | 1.72 | 1.22 |
| longitudinal profile |  | Gauss | Gauss | Gauss | Flat |
| rms bunch length | $\sigma_z$ [cm] | 7.55 | 7.55 | 3.78 | 14.4 |
| beta* at IP1&5 | β* [m] | 0.5 | 0.08 | 0.25 | 0.25 |
| full crossing angle | $\theta_c$ [μrad] | 315 | 100 | 539 | 381 |
| Piwinski parameter | $\theta_c\sigma_z/(2\sigma_x^*)$ | 0.75 | 0.60 | 0.64 | 2.5 |
| peak luminosity | $L$ [$10^{34}$ cm$^{-2}$s$^{-1}$] | 2.3 | 15.5 | 9.7 | 8.9 |
| events per crossing |  | 44 | 296 |  | 340 |
| initial lumi lifetime | $\tau_L$ [h] | 14 | 2.1 | 6.8 | 5.3 |
| effective luminosity ($T_{turnaround}$=10 h) | $L_{eff}$[$10^{34}$ cm$^{-2}$s$^{-1}$] | 0.91 | 2.4 | 2.7 | 2.3 |
|  | $T_{run,opt}$ [h] | 17.0 | 6.5 | 12.0 | 10.3 |
| effective luminosity ($T_{turnaround}$=5 h) | $L_{eff}$[$10^{34}$ cm$^{-2}$s$^{-1}$] | 1.15 | 3.6 | 3.6 | 3.1 |
|  | $T_{run,opt}$ [h] | 12.0 | 4.6 | 8.5 | 7.3 |
| e-c heat SEY=1.4(1.3) | P [W/m] | 1.04 (0.59) | 1.04 (0.59) | 2.56 (2.1) | 0.36 (0.1) |
| SR heat load 4.6-20 K | $P_{SR}$ [W/m] | 0.25 | 0.25 | 0.5 | 0.36 |
| image current heat | $P_{IC}$ [W/m] | 0.33 | 0.33 | 3.74 | 0.78 |
| gas-s. 100 h (10 h) $\tau_b$ | $P_{gas}$ [W/m] | 0.06 (0.56) | 0.06 (0.56) | 0.11 (1.13) | 0.09 (0.9) |
| comment |  |  | D0 + crab | wire comp. | wire comp. |

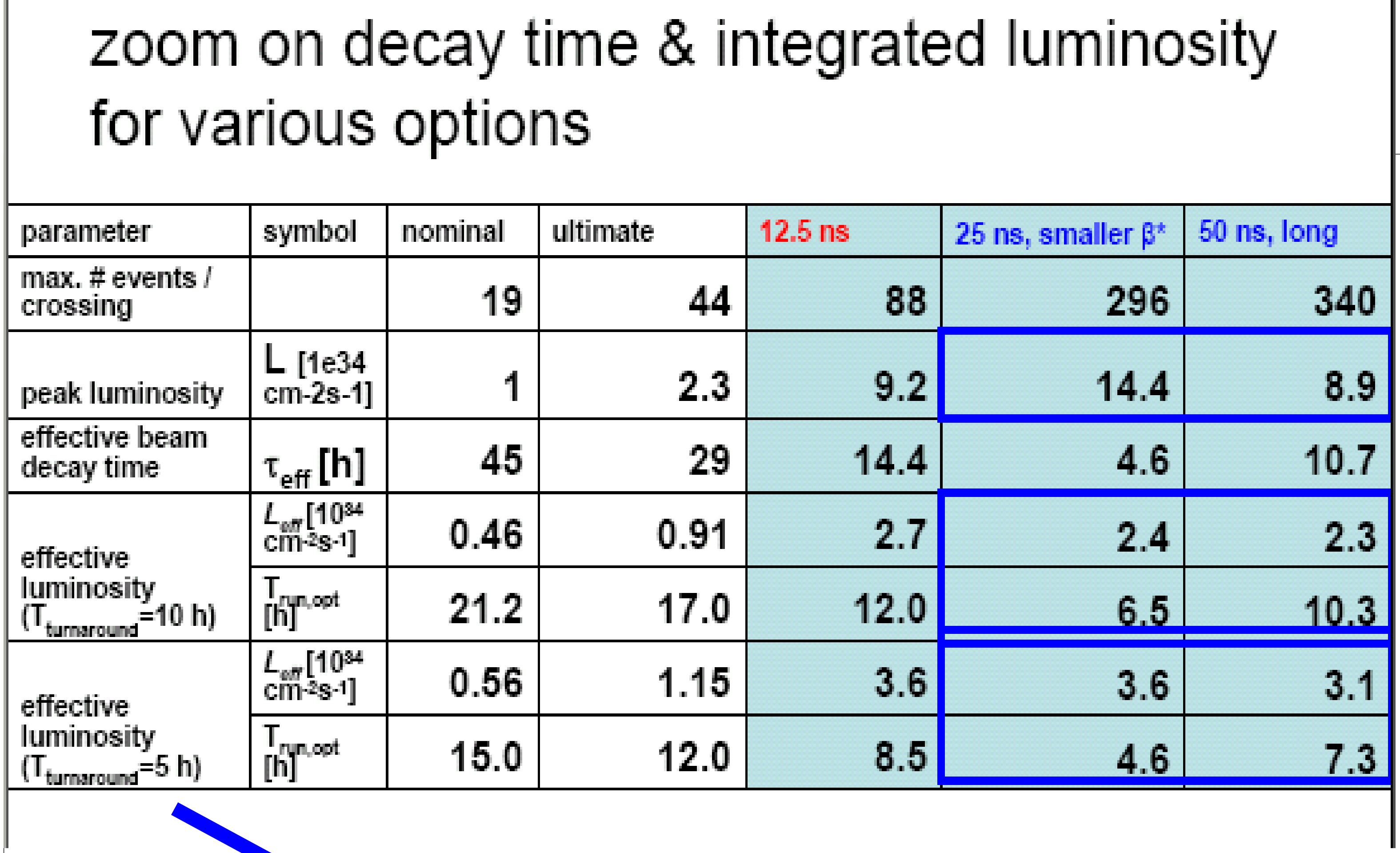
## new upgrade parameters

# Hardware needed for these two scenarios

- 25 ns small ß (8 cm)
  - New triplet with bigger aperture (L* =23m)
  - Small angle crab cavity (~100 m from IP)
  - D0 needed
  - If NbTi  technology Qo is needed
  - If $Nb_3Sn$ technology no Qo needed
- 50 ns long bunch
  - New triplet with bigger aperture (L*=23 m)
  - No D0 needed
  - Both NbTi and $Nb_3Sn$ possible without need for Qo
  - Wire compensation needed (~100 m from IP)

# Relevant parameters for two scenarios

| | 25 ns small β | 50 ns long bunc |
|---|---|---|
| – Bunch spacing: | 25 ns | 50 ns |
| – Rms bunch length: | 7.55 cm | 14.4 cm |
| – Long. Profile: | Gauss | Flat |
| – Luminous region: | 2.5 cm | 3.5 cm |
| – Peak lumi: | 15.5 $10^{34}$ | 8.9 $10^{34}$ |
| – Events crossing: | 296 | 340 |
| – Lumi. Life time: | 2.1 h | 5.3 h |
| – Effective lumi :<br>• (10 h turn around) | 2.4 $10^{34}$ | 2.3 $10^{34}$ |
| – Effective lumi: (5 h turn around) | 3.6 $10^{34}$ | 3.1 $10^{34}$ |

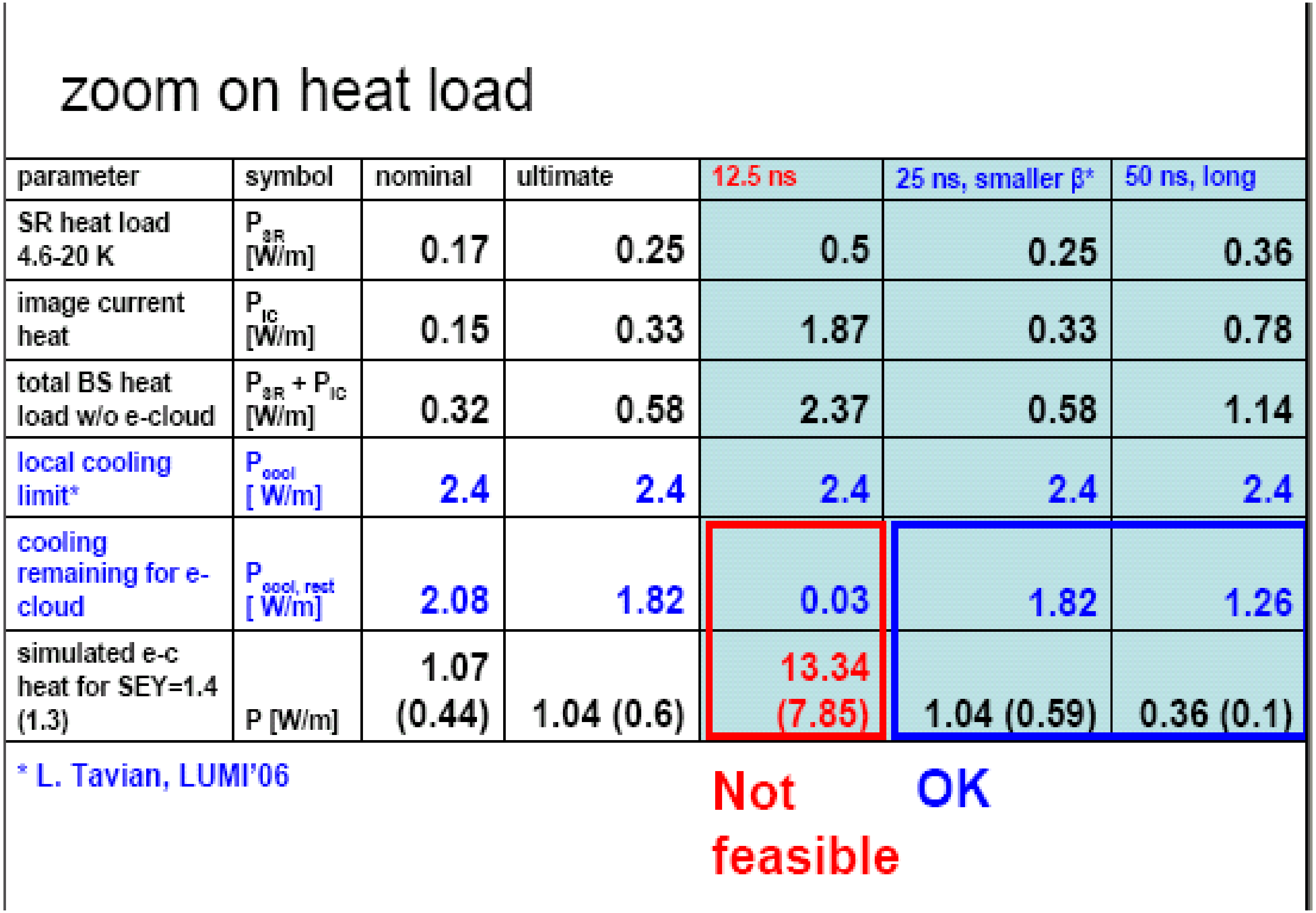


# zoom on decay time & integrated luminosity for various options

| parameter | symbol | nominal | ultimate | 12.5 ns | 25 ns, smaller β* | 50 ns, long |
|---|---|---|---|---|---|---|
| max. # events / crossing | | 19 | 44 | 88 | 296 | 340 |
| peak luminosity | L [1e34 cm-2s-1] | 1 | 2.3 | 9.2 | 14.4 | 8.9 |
| effective beam decay time | $\tau_{eff}$ [h] | 45 | 29 | 14.4 | 4.6 | 10.7 |
| effective luminosity ($T_{turnaround}$=10 h) | $L_{eff}$[$10^{34}$ cm$^{-2}$s$^{-1}$] | 0.46 | 0.91 | 2.7 | 2.4 | 2.3 |
| | $T_{run,opt}$ [h] | 21.2 | 17.0 | 12.0 | 6.5 | 10.3 |
| effective luminosity ($T_{turnaround}$=5 h) | $L_{eff}$[$10^{34}$ cm$^{-2}$s$^{-1}$] | 0.56 | 1.15 | 3.6 | 3.6 | 3.1 |
| | $T_{run,opt}$ [h] | 15.0 | 12.0 | 8.5 | 4.6 | 7.3 |

Average events/bc 150 208

# Heat load



## zoom on heat load

| parameter | symbol | nominal | ultimate | 12.5 ns | 25 ns, smaller β* | 50 ns, long |
|---|---|---|---|---|---|---|
| SR heat load 4.6-20 K | $P_{SR}$ [W/m] | 0.17 | 0.25 | 0.5 | 0.25 | 0.36 |
| image current heat | $P_{IC}$ [W/m] | 0.15 | 0.33 | 1.87 | 0.33 | 0.78 |
| total BS heat load w/o e-cloud | $P_{SR} + P_{IC}$ [W/m] | 0.32 | 0.58 | 2.37 | 0.58 | 1.14 |
| local cooling limit* | $P_{cool}$ [ W/m] | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| cooling remaining for e-cloud | $P_{cool, rest}$ [ W/m] | 2.08 | 1.82 | 0.03 | 1.82 | 1.26 |
| simulated e-c heat for SEY=1.4 (1.3) | P [W/m] | 1.07 (0.44) | 1.04 (0.6) | 13.34 (7.85) | 1.04 (0.59) | 0.36 (0.1) |

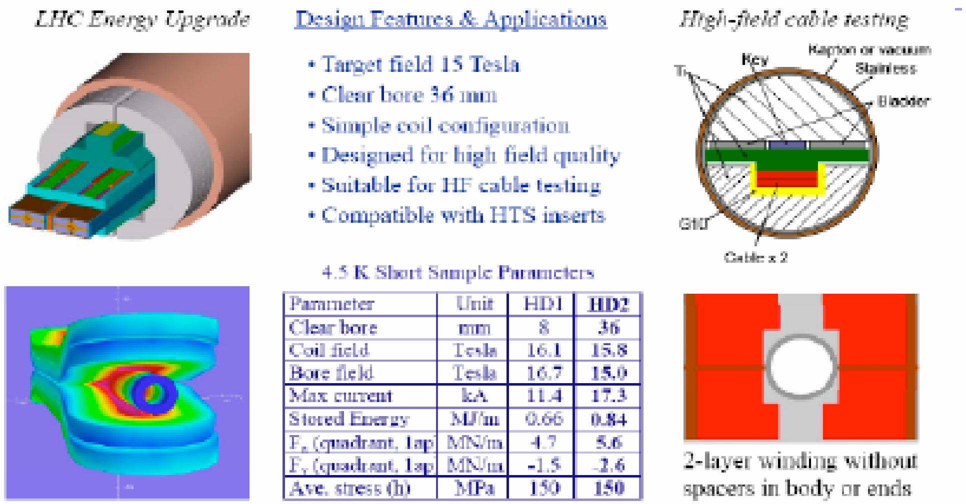
* L. Tavian, LUMI'06

**Not feasible**

**OK**

# LHC energy doubler 14*14 TeV

- dipole field $B_{nom}$ = 16.8 T, $B_{design}$ = 18.5-19.3 T (10-15% margin)
  - superconductor - $Nb_3Sn$
  - 10-13 T field demonstrated in several 1-m long Nb3Sn dipole models
  - DLHC magnet parameters well above the demonstrated Nb3Sn magnet technology
- R&D and construction time and cost estimates
  - 10+ years for magnet technology development and demonstration
  - Magnet production by industry ~ 8-10 years
  - High cost for R&D and construction (cost of dipoles > 3GCHF ?)



*LHC Energy Upgrade*

Design Features & Applications

- Target field 15 Tesla
- Clear bore 36 mm
- Simple coil configuration
- Designed for high field quality
- Suitable for HF cable testing
- Compatible with HTS inserts

*High-field cable testing*

4.5 K Short Sample Parameters

| Parameter | Unit | HD1 | **HD2** |
|---|---|---|---|
| Clear bore | mm | 8 | **36** |
| Coil field | Tesla | 16.1 | **15.8** |
| Bore field | Tesla | 16.7 | **15.0** |
| Max current | kA | 11.4 | **17.3** |
| Stored Energy | MJ/m | 0.66 | **0.84** |
| $F_x$ (quadrant, 1ap | MN/m | 4.7 | **5.6** |
| $F_y$ (quadrant, 1ap | MN/m | -1.5 | **-2.6** |
| Ave. stress (h) | MPa | 150 | **150** |

2-layer winding without spacers in body or ends

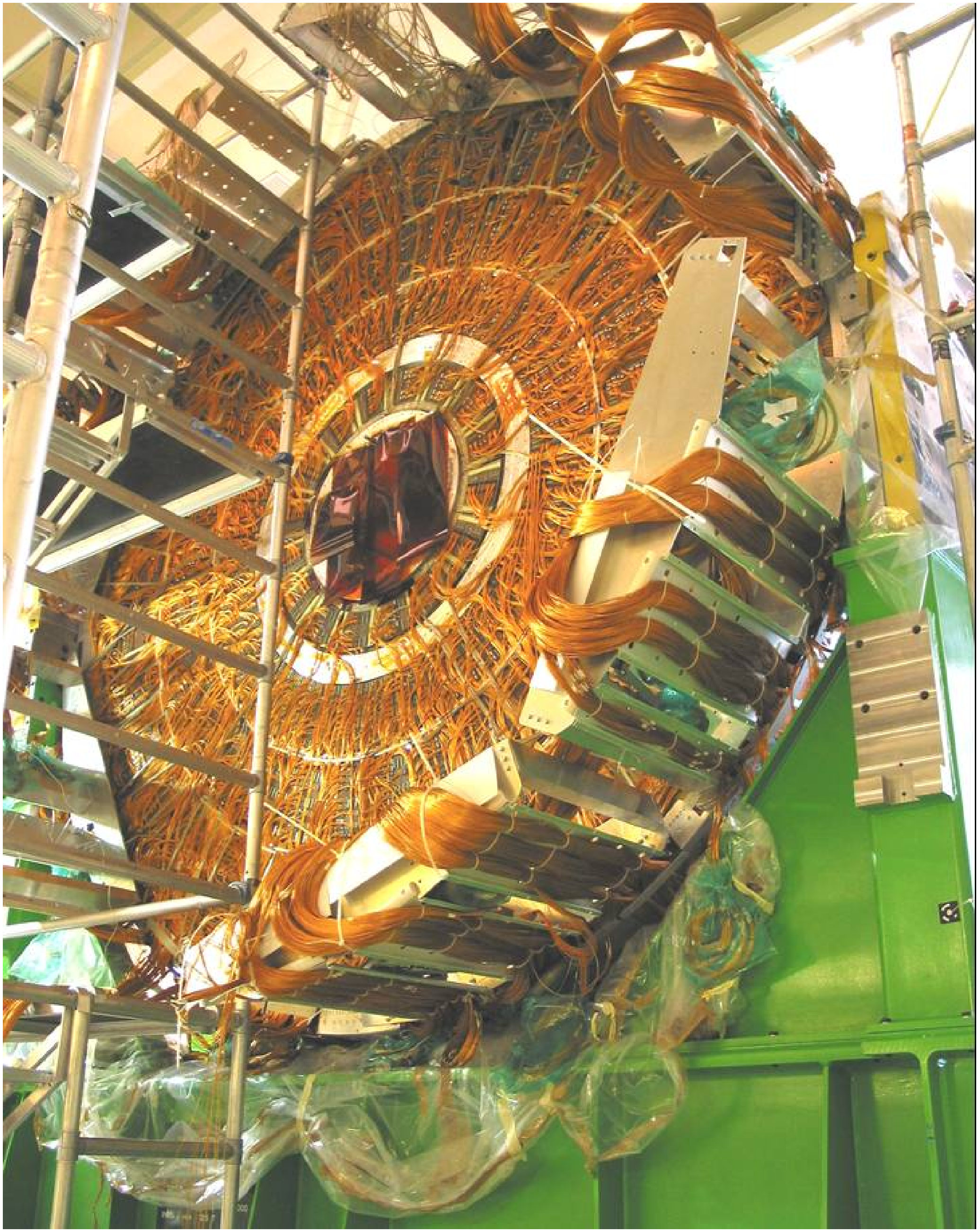
# LHC energy tripler 21*21 TeV

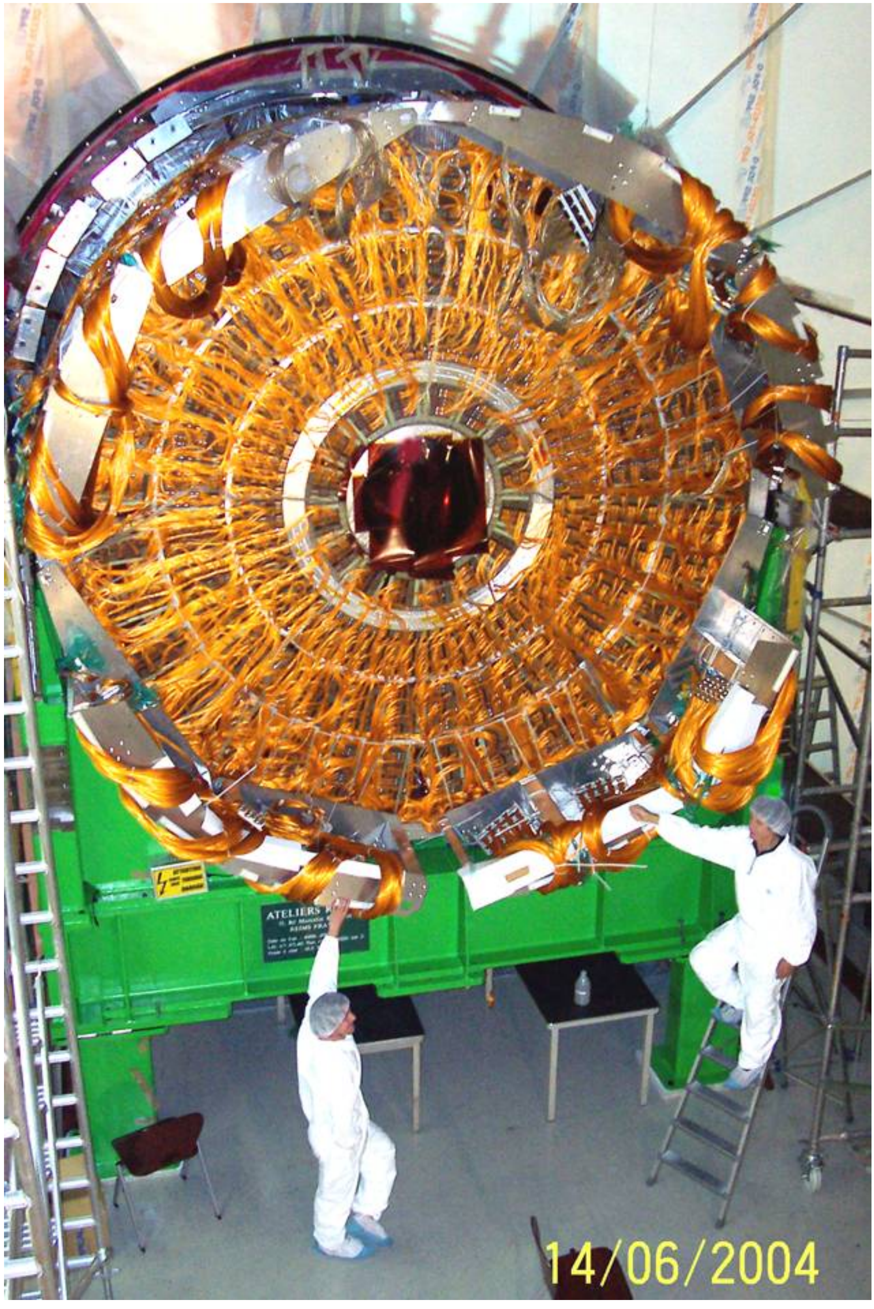
- dipole field $B_{nom}$ = 25 T, $B_{design}$ = 28-29 T (10-15% margin)
  - superconductor - HTS-BSCCO (low demand) or $Nb_3Sn$
  - Magnet technology to be fully demonstrated
  - DLHC magnet parameters well above the demonstrated Nb3Sn magnet technology
- Large aperture dipole to accommodate an efficient beam screen

- R&D and construction time and cost/risk estimates
  - 20++ years for magnet technology development and demonstration
  - Extremely high R&D and construction cost and risk
    - *SC cable to be developed,*
    - *Magnetic coil stress requires innovative dipole cross section*
  - Magnet production by industry (?) ?? years

# SLHC Physics Extras

# EM EndCap A wheel on the insertion stand, May - June 2004





# LAr Forward Calorimeters

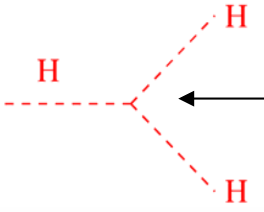
- C end in Cryostat
- A end assembled into support tube

- FCAL C assembly into tube – Fall 2003

# Higgs Self Coupling Measurements

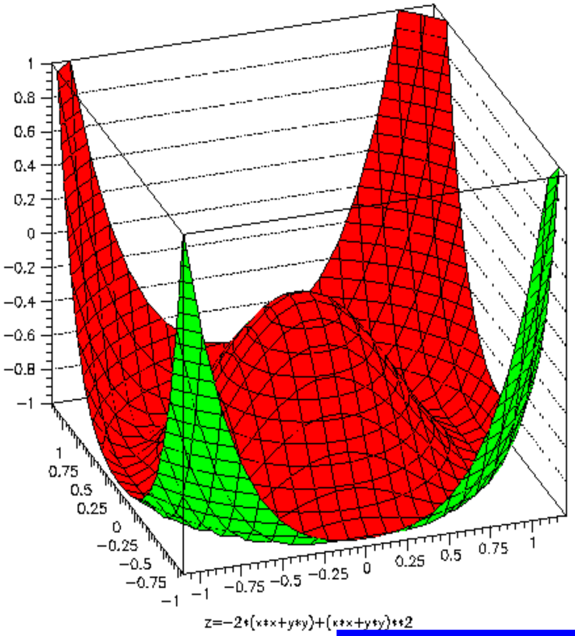
Once the Higgs particle is found, try to reconstruct the Higgs potential

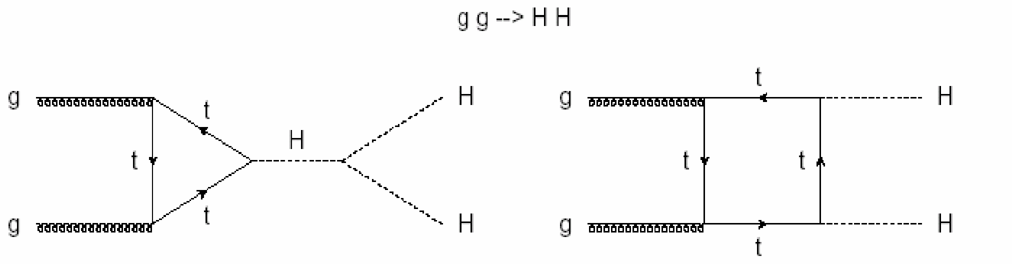
$$V(\Phi) = -\lambda v^2(\Phi^\dagger\Phi) + \lambda(\Phi^\dagger\Phi)^2$$

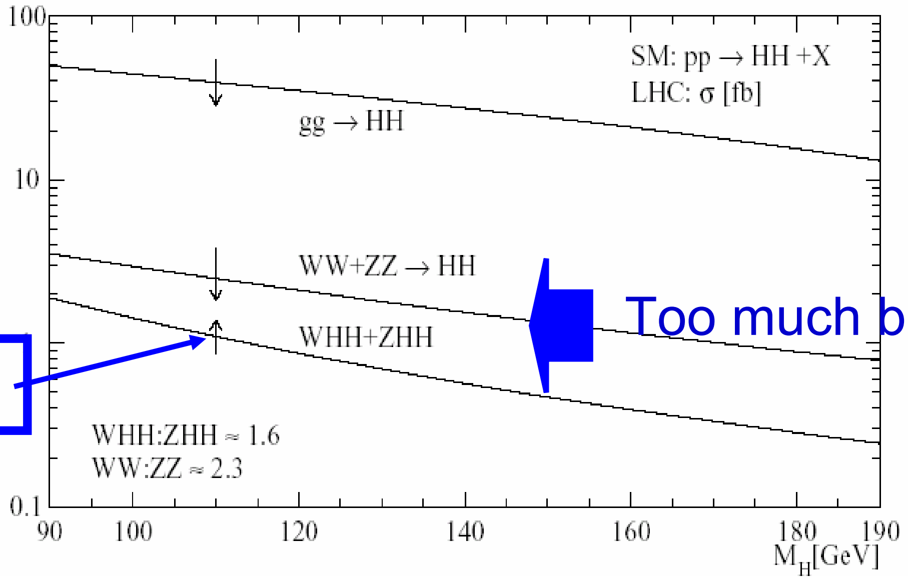


~ $\lambda v$

$m_H^2 = 2\,\lambda\,v^2$







Djouadi
et al.

$\lambda_{SM}/2 < \lambda < 3\lambda_{SM}/2$

Too much backgr.

Not possible at the LHC

# Higgs Self Couplings

**LHC :** $\sigma$ (pp $\rightarrow$ HH) < 40 fb   $m_H$ > 110 GeV
+ small BR for clean final states $\rightarrow$ **no sensitivity**

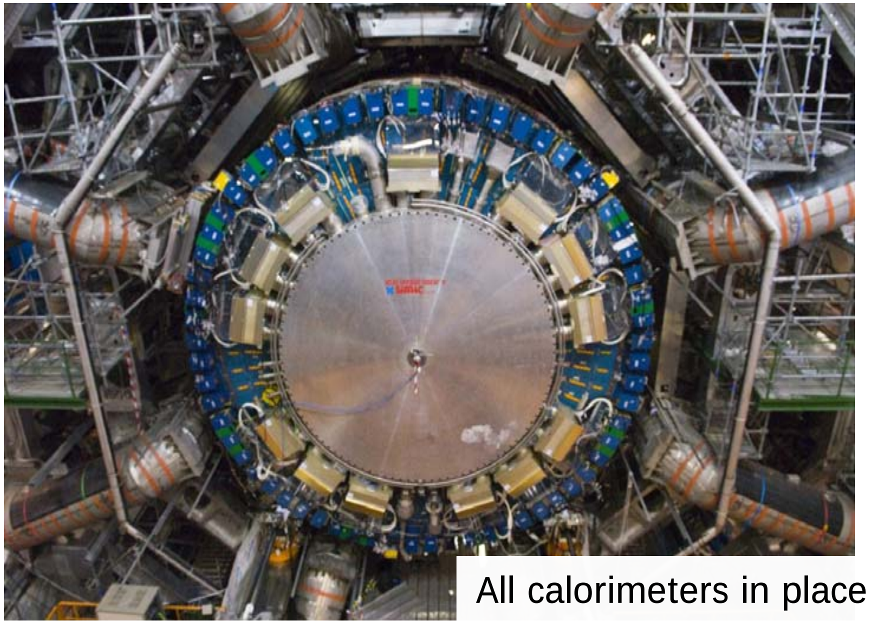
**SLHC :** HH $\rightarrow W^+ W^- W^+ W^- \rightarrow \ell^\pm \nu jj \;\; \ell^\pm \nu jj$
studied (<u>very preliminary</u>)

| 6000 $fb^{-1}$ | S | S/B | S/$\sqrt{B}$ |
|---|---|---|---|
| $m_H$ = 170 GeV | 350 | 8% | 5.4 |
| $m_H$ = 200 GeV | 220 | 7% | 3.8 |

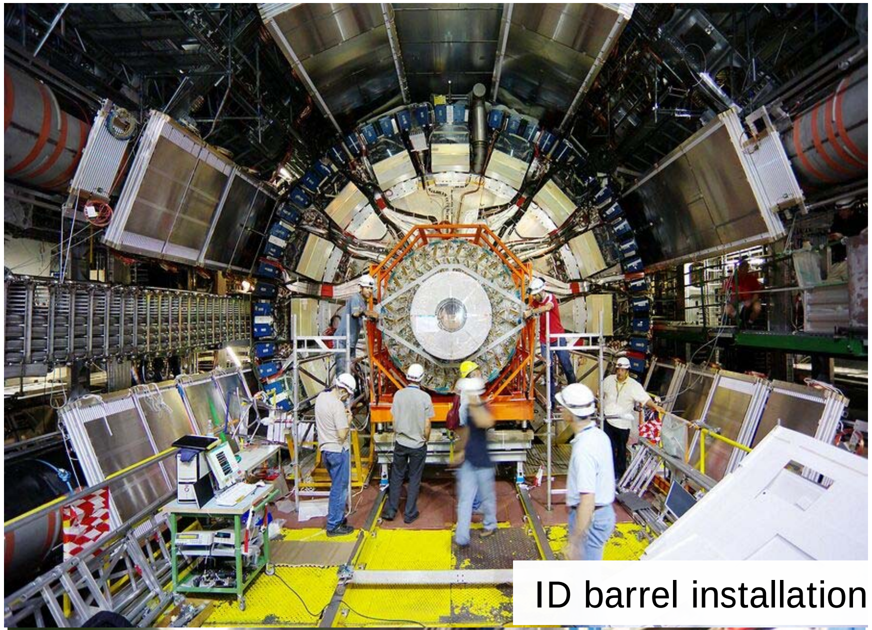
-- HH production may be observed first at SLHC: ~150 <$M_H$<200 GeV
-- $\lambda$ may be measured with statistical error ~ 20-25%

LC : precision up to 20-25% but for $M_H$ < 150 GeV ($\sqrt{s} \geq$ 500-800 GeV, 1000 $fb^{-1}$)

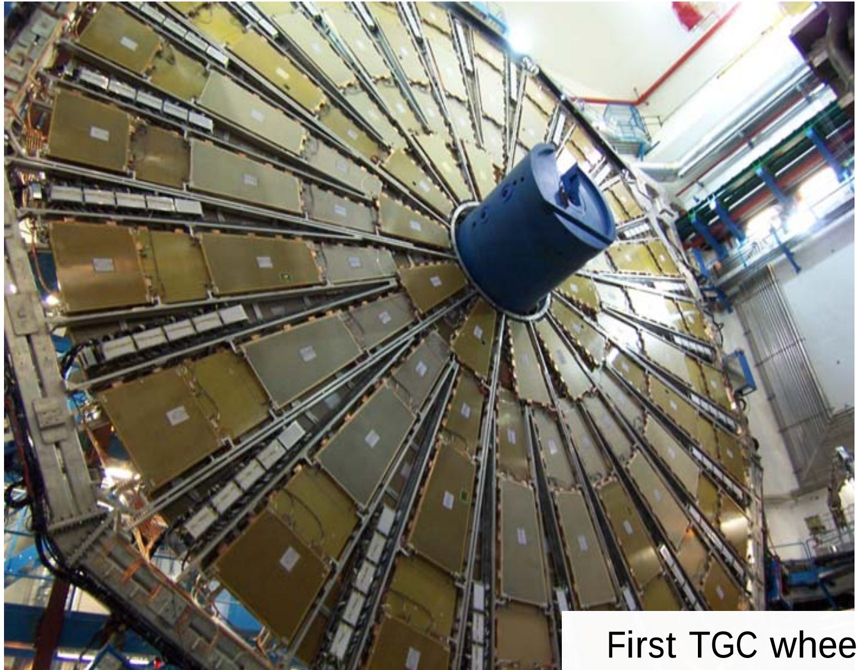
# ATLAS Detector construction in UX15



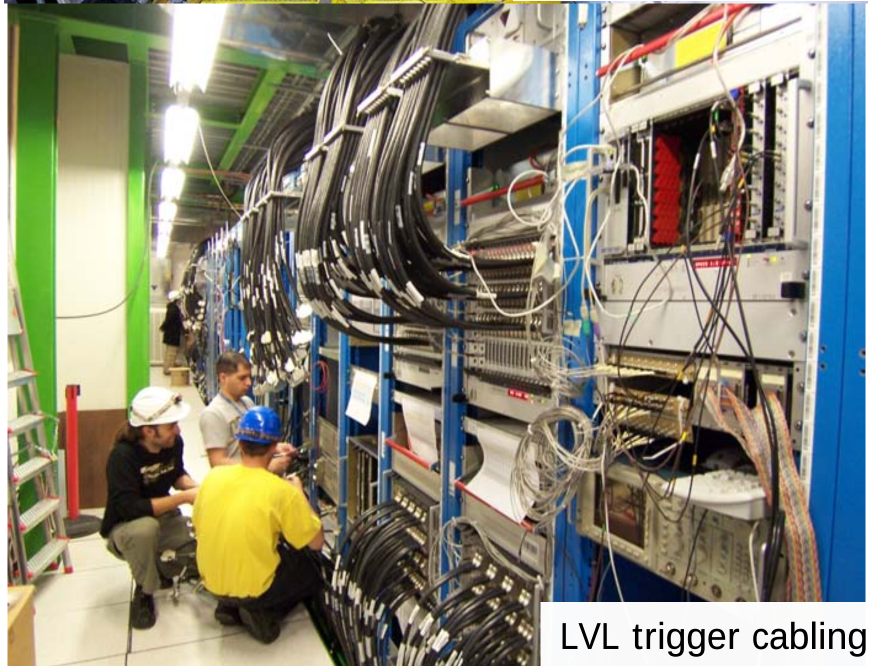
All calorimeters in place



ID barrel installation



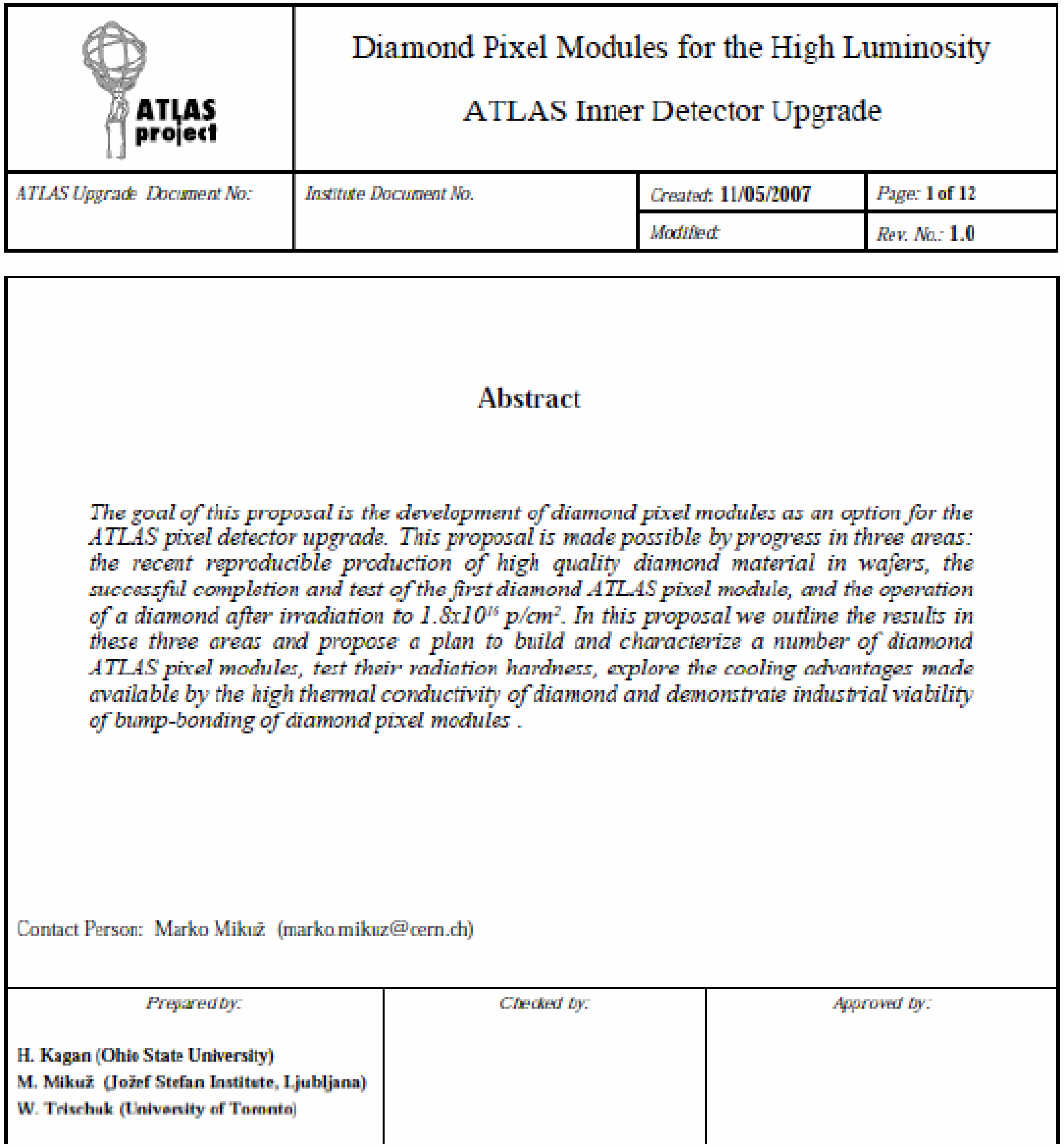
First TGC wheel



LVL trigger cabling

# Diamond Pixel Sensor EOI

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



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 $1.8x10^{16}$ 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 .*

Contact Person: Marko Mikuž (marko.mikuz@cern.ch)

| *Prepared by:* | *Checked by:* | *Approved by:* |
|---|---|---|
| **H. Kagan (Ohio State University)**<br>**M. Mikuž (Jožef Stefan Institute, Ljubljana)**<br>**W. Trischuk (University of Toronto)** | | |