Status and Plans of the LHC

Steve Myers

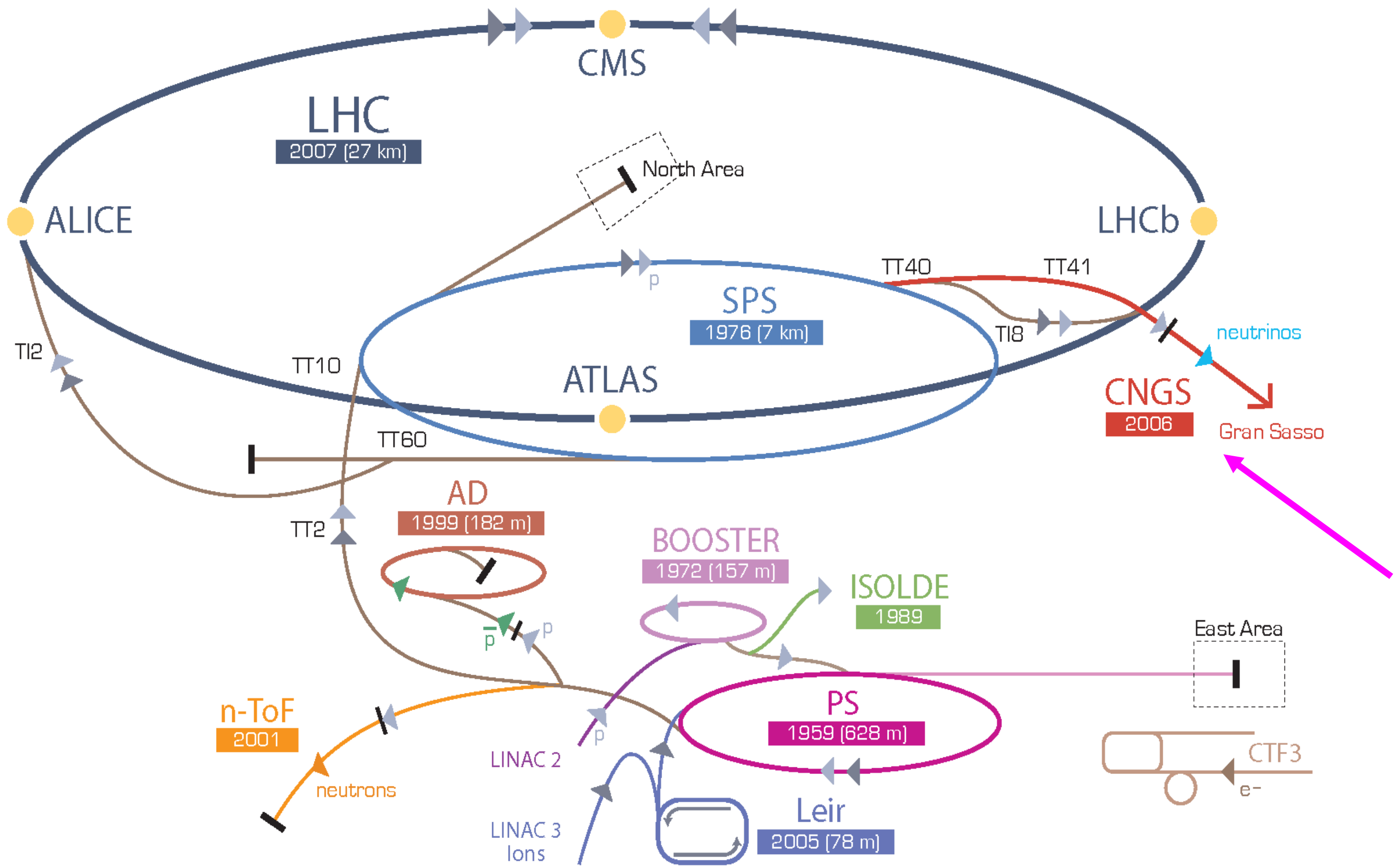
For the LHC team and

All our international collaborators and contributors

Main Topics

- Introduction
- LHC Performance in 2010/2011/2012
- Estimates of Performance in 2012
- Future
  - Long Shutdown 1 (LS1) 2013-2014
  - Estimated performance in 2015
- Upgrades
  - Luminosity Upgrade (HL-LHC)
  - Energy Upgrade (HE-LHC)
  - LHeC
  - LEP3

CERN Accelerator Complex



p (proton) ion neutrons p̄ (antiproton) proton/antiproton conversion neutrinos electron

LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

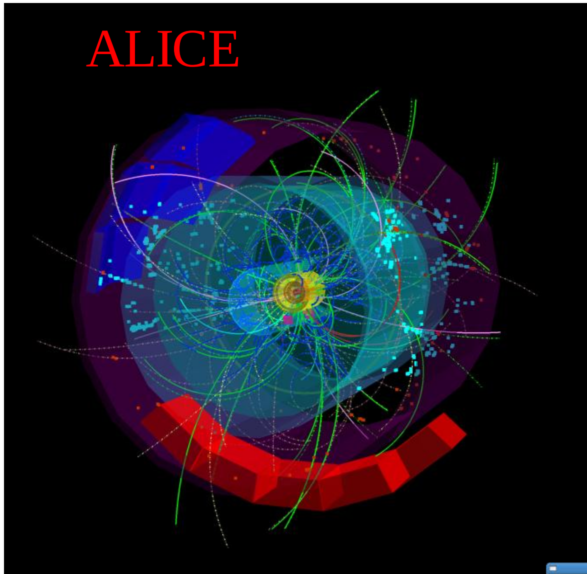
The LHC

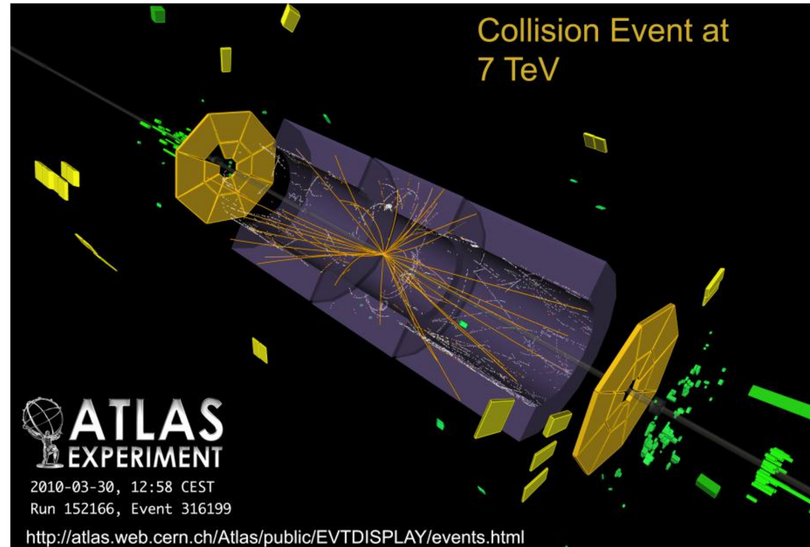
Superconducting Proton Accelerator and Collider
installed in a 27km circumference underground tunnel (tunnel cross-section diameter 4m) at CERN
Tunnel was built for LEP collider in 1985

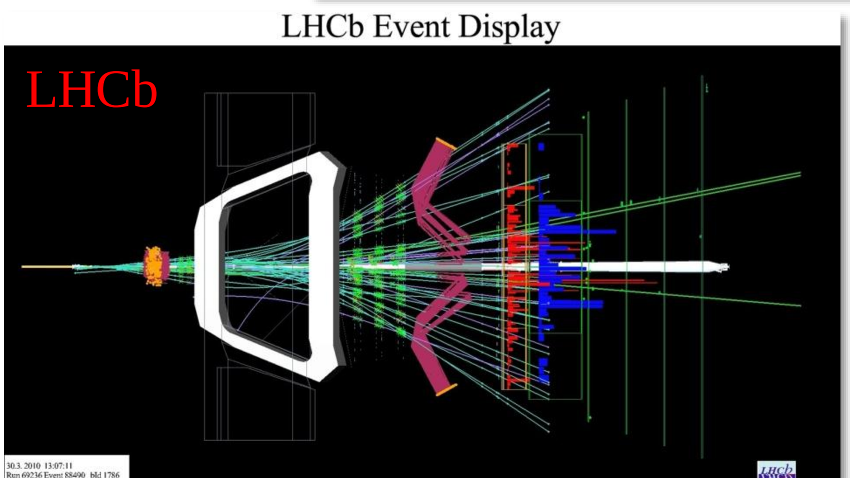
LHC: Some of the Technical Challenges

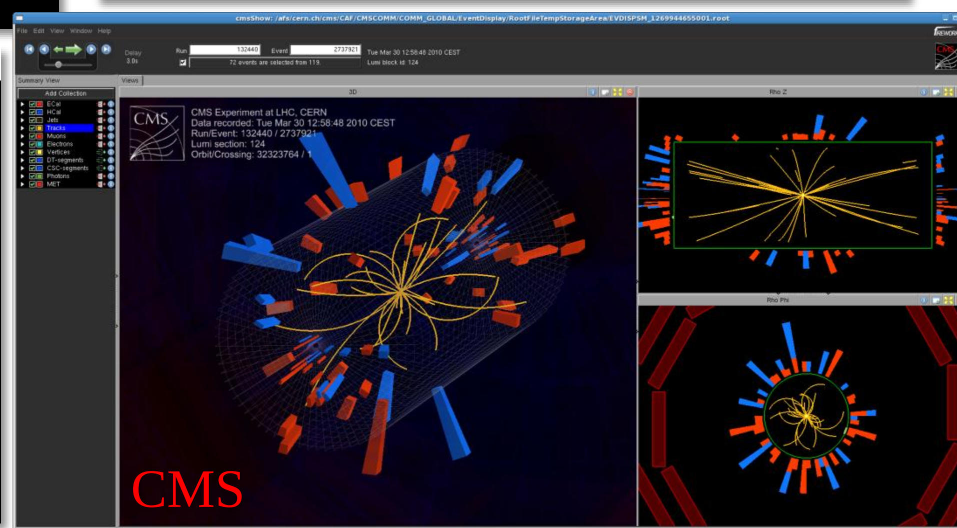
Circumference (km)	26.7	100-150m underground
Number of Dipoles	1232	Cable Nb-Ti, cold mass 37million kg
Length of Dipole (m)	14.3	
Dipole Field Strength (Tesla)	8.4	Results from the high beam energy needed
Operating Temperature (K)	1.9	Superconducting magnets needed for the high magnetic field Super-fluid helium
Current in dipole sc coils (A)	13000	Results from the high magnetic field 1ppm resolution
Beam Intensity (A)	0.5	$2.2.10^{-6}$ loss causes quench
Beam Stored Energy (MJoules)	362	Results from high beam energy and high beam current 1MJ melts 2kg Cu
Magnet Stored Energy (MJoules)/octant	1100	Results from the high magnetic field
Sector Powering Circuit	8	1612 different electrical circuits

LHC: First collisions at 7 TeV on 30 March 2010









Peak Luminosity for First Run 10^{27} cm^{-2} s^{-1}

Maximizing the Luminosity

Luminosity (round beams):

$$L = \frac{n_b \cdot N_{bunch1} \cdot N_{bunch2} \cdot f_{rev}}{4\pi \cdot \beta^* \cdot \varepsilon_n} \cdot R(\phi, \beta^*, \varepsilon_n, \sigma_s)$$

➔1) maximize bunch brightness [N_{bunch}/ε_n]
beam-beam limit and injector complex performance
➔2) minimize beam size [β^*] (constant beam power)
➔3) maximize number of bunches (beam power limit)
➔4) compensate for 'R'

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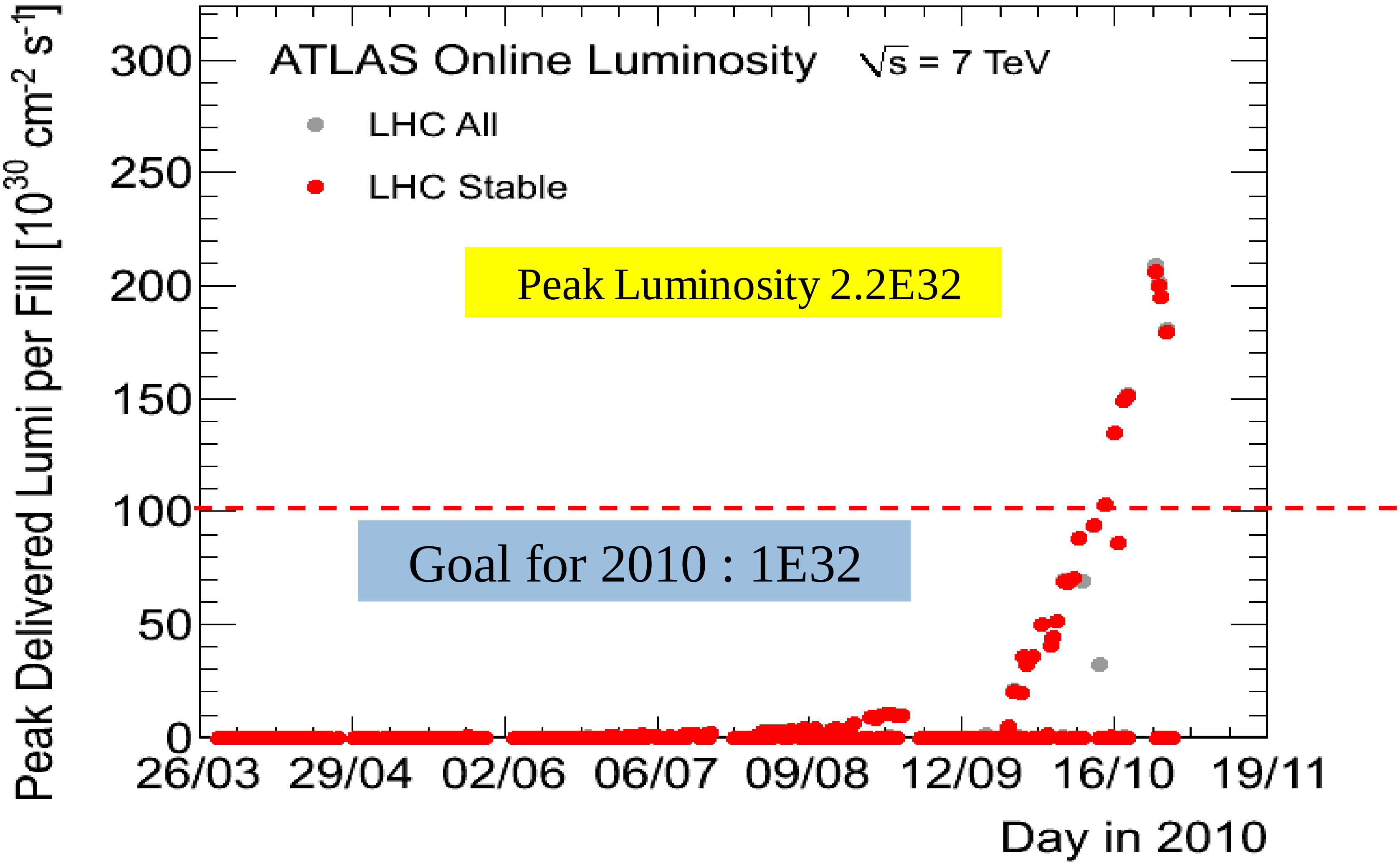
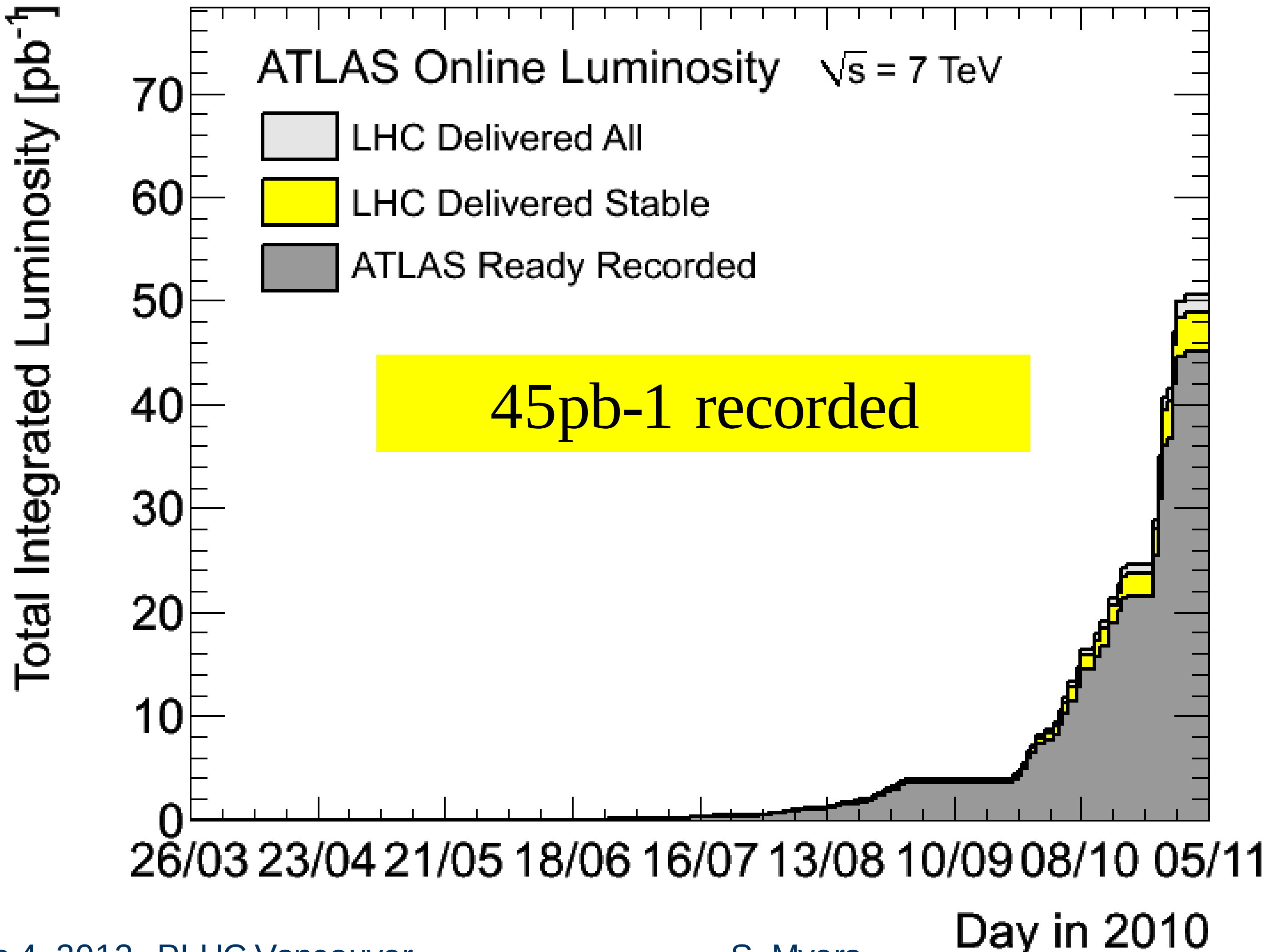
Peak Luminosity 2010



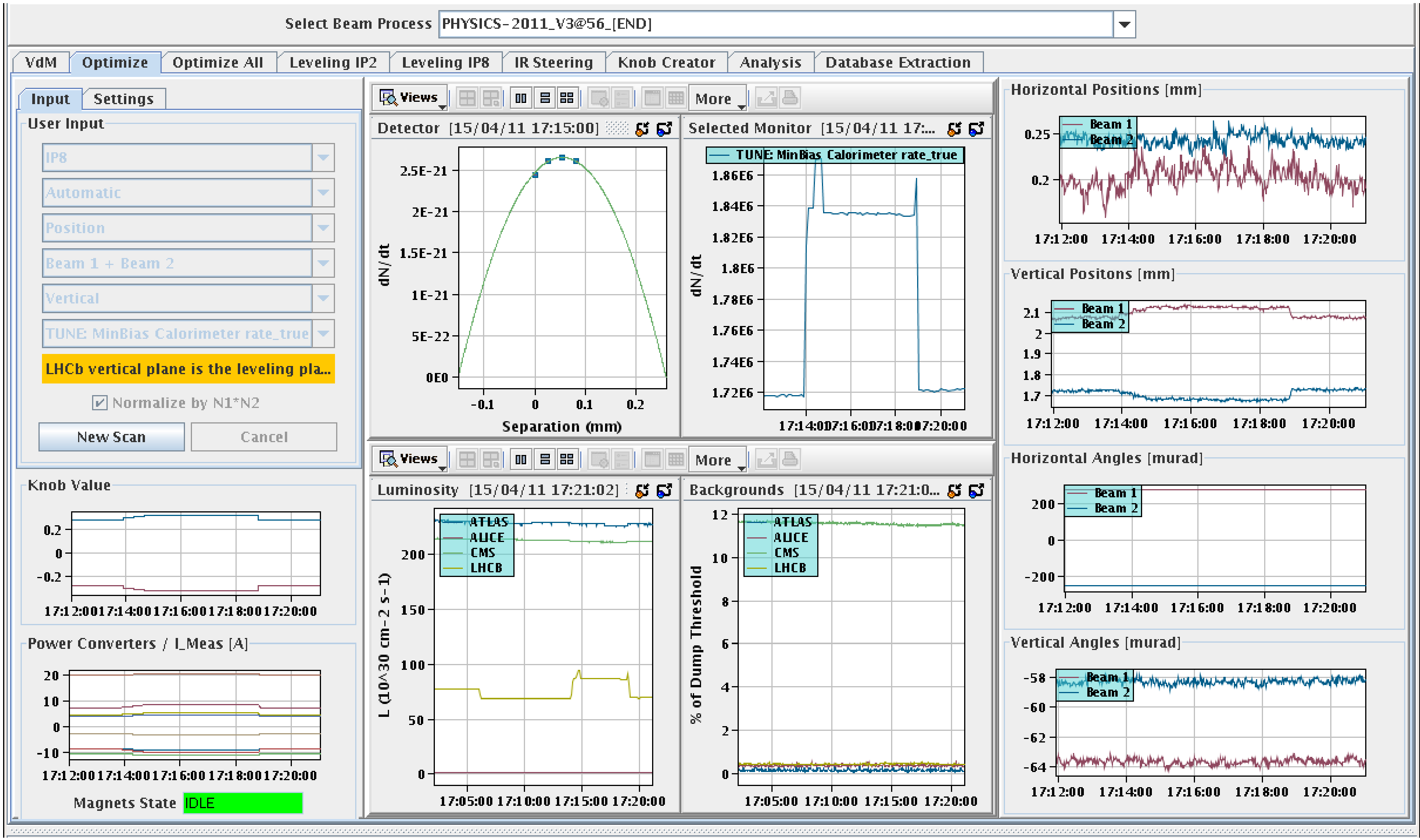
Integrated Luminosity in 2010



2011 Operation

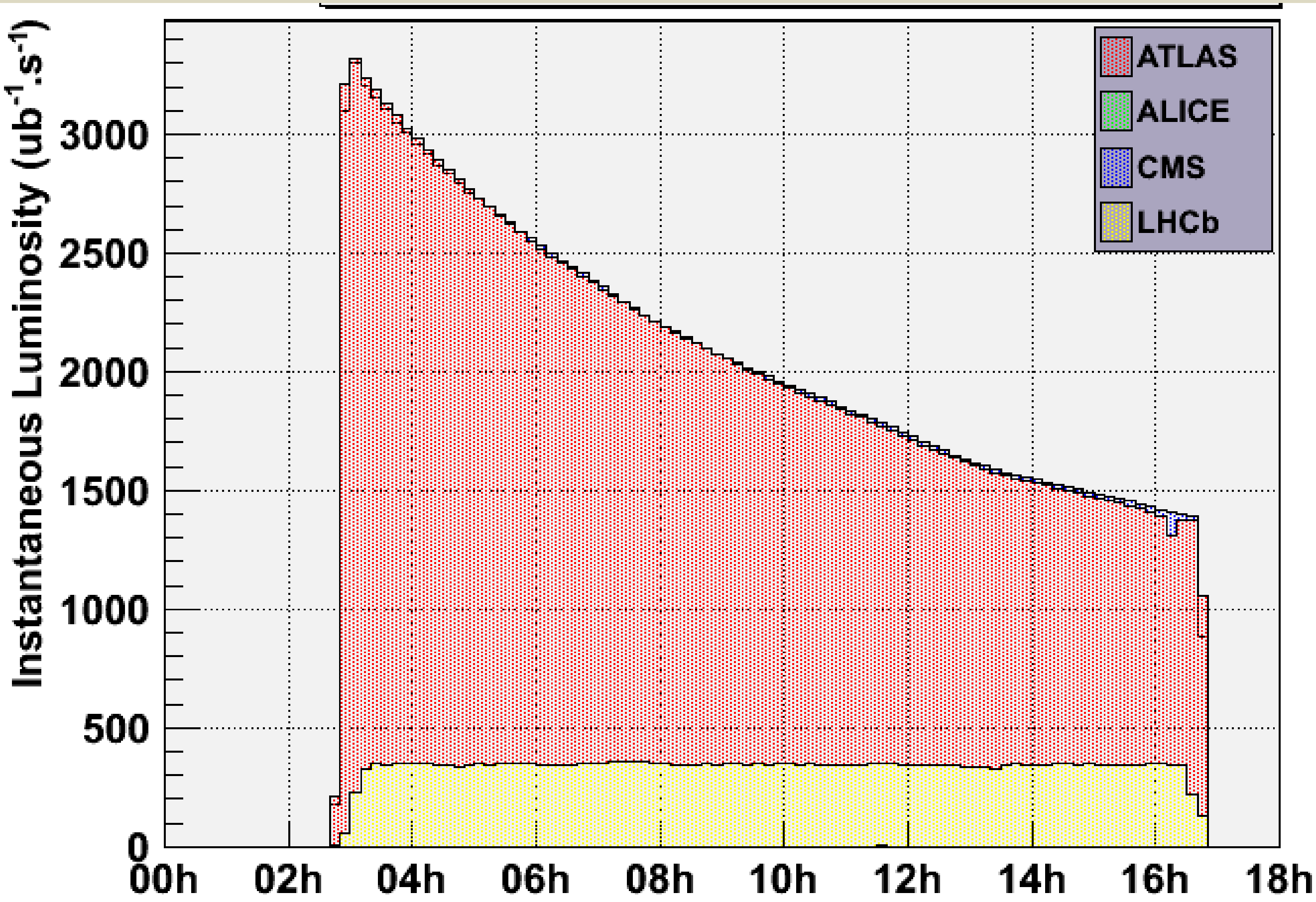
(Goal for the year was 1000pb-1
i.e 22 times more than 2010)

"Lumi leveling" first tested 15th April 2011



Luminosity Leveling via beam Separation

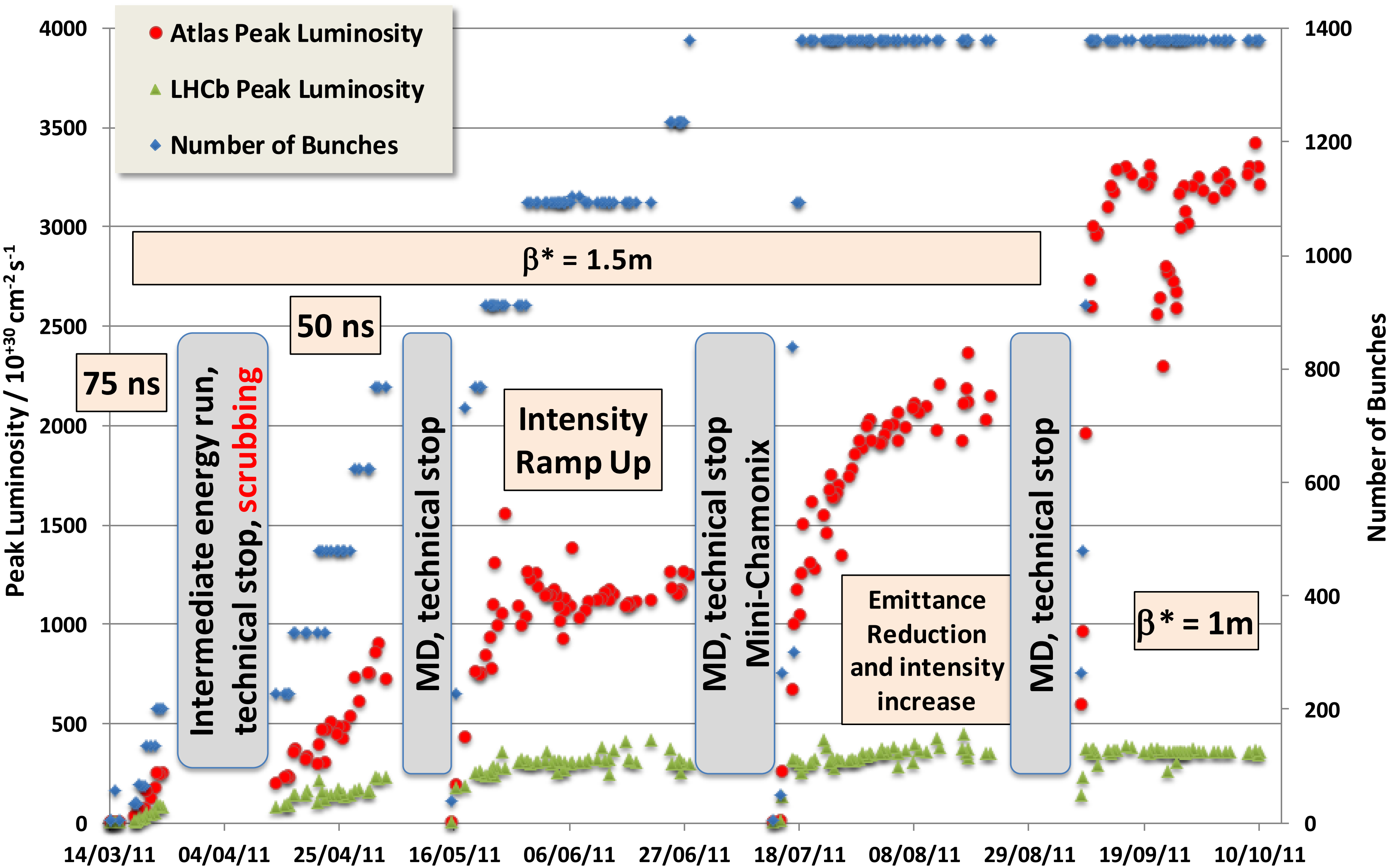
Introduced <u>luminosity leveling</u> for LHCb → can run at optimal μ and L_{max}



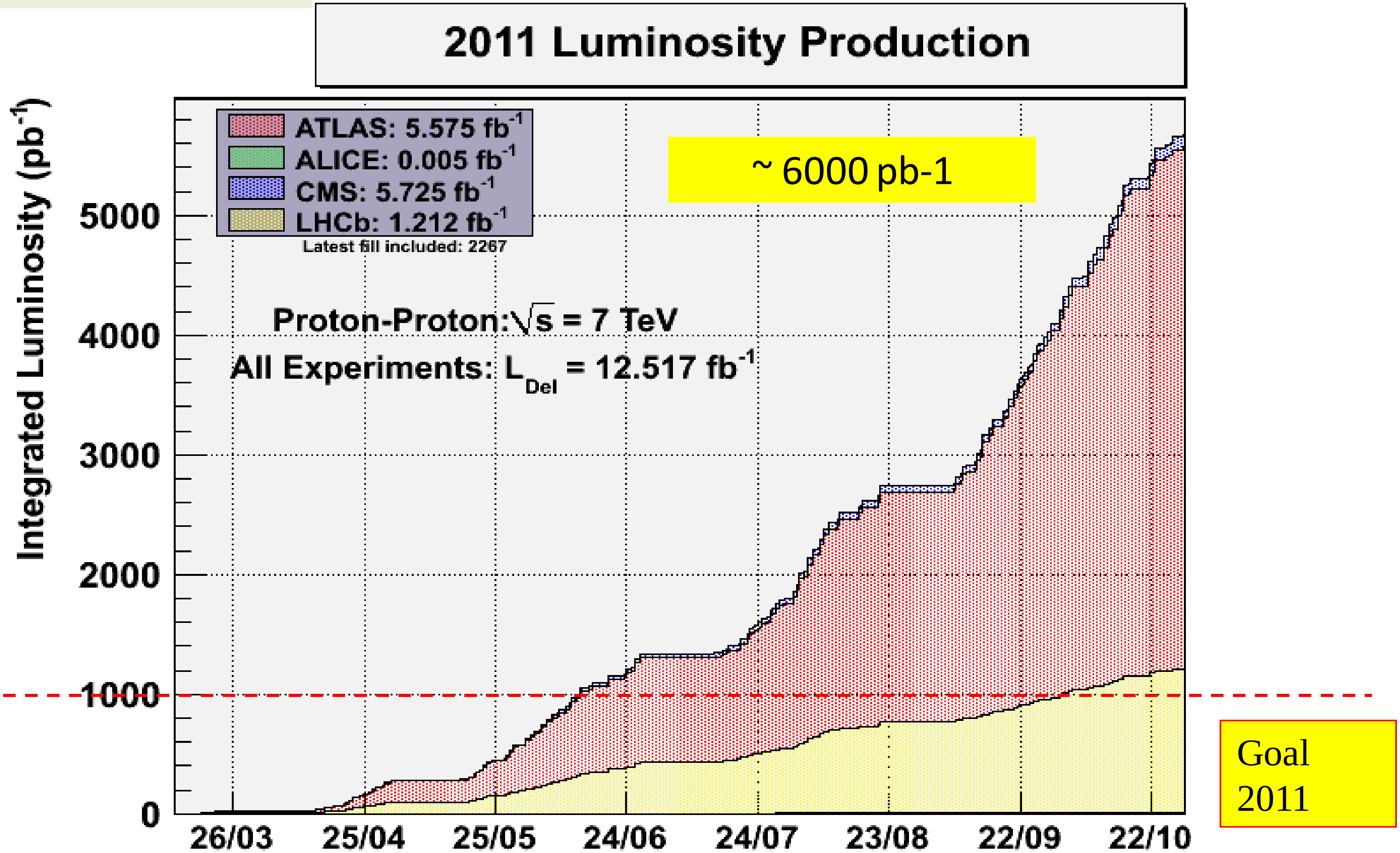
→ Since end of May running at constant $L \sim 3\text{-}3.5 \cdot 10^{32}$ cm^{-2}s^{-1} with μ ~ 1.5

→ LHCb want maximum time in physics and not an increase in peak performance

History of 2011 Peak Luminosity



Protons

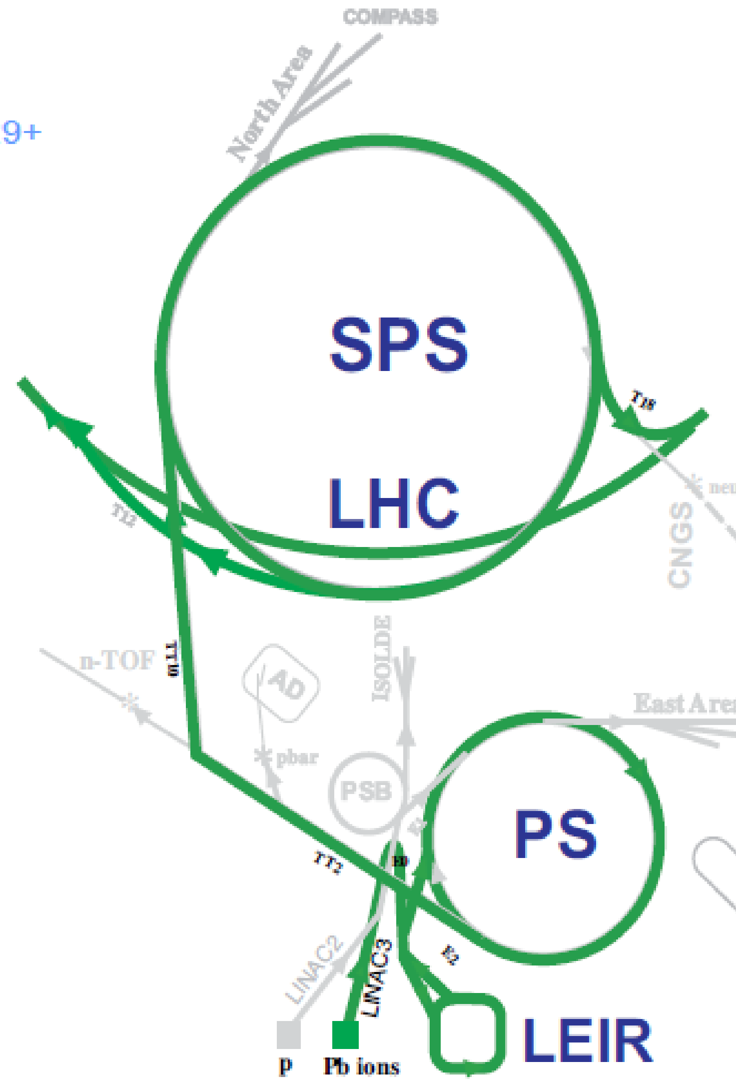


2011 Luminosity Production
ATLAS: 5.575 fb-1
ALICE: 0.005 fb-1
CMS: 5.725 fb-1
LHCb: 1.212 fb-1
Latest fill included: 2267
~ 6000 pb-1
Proton-Proton: √s = 7 TeV
All Experiments: L_Del = 12.517 fb-1
Integrated Luminosity (pb-1)
0
1000
2000
3000
4000
5000
26/03
25/04
25/05
24/06
24/07
23/08
22/09
22/10
Goal 2011

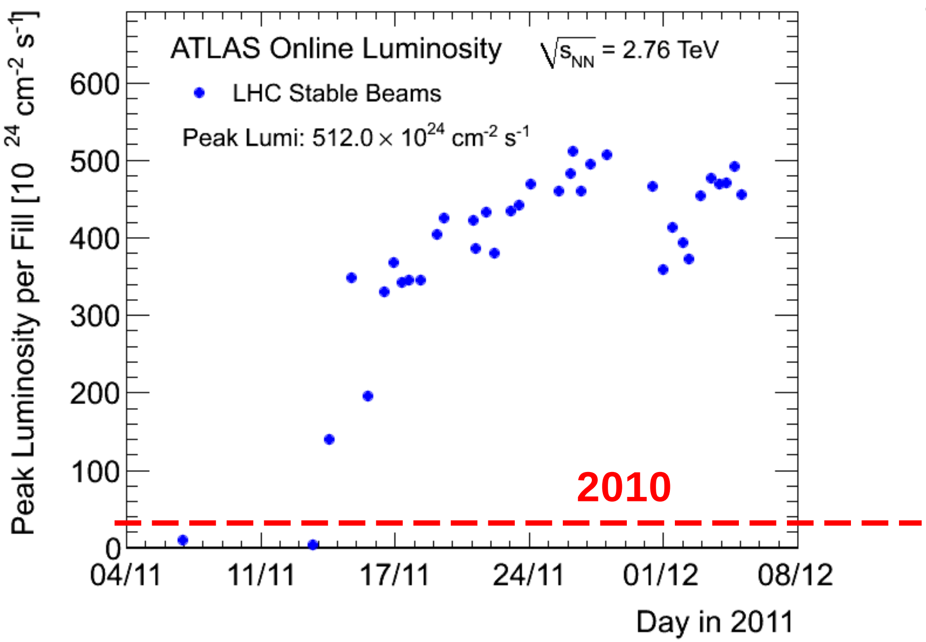
Heavy Ion Operation

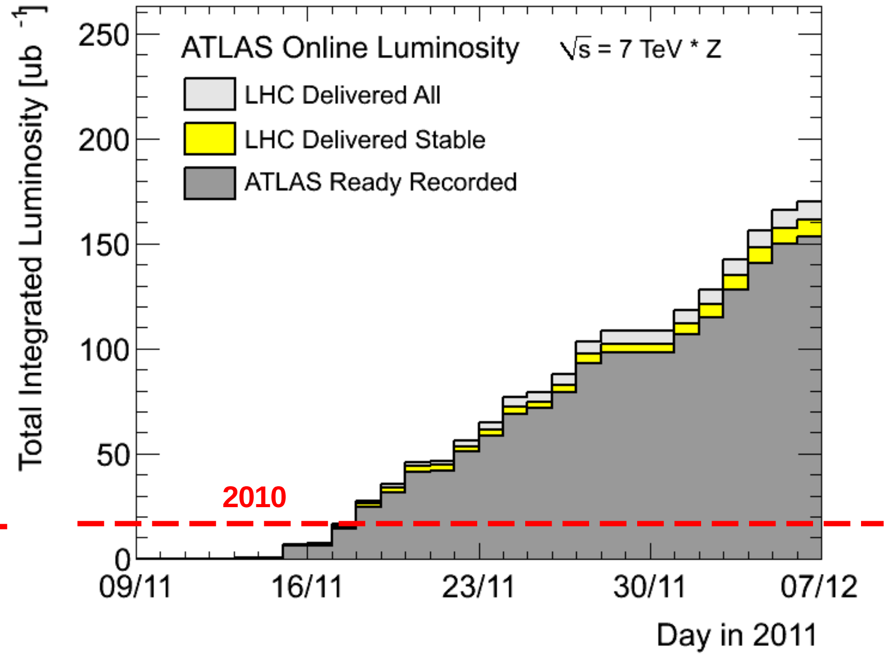
Lead ion injector chain

- ECR ion source (2005)
  - Provide highest possible intensity of Pb^{29+}
- RFQ + Linac 3
  - Adapt to LEIR injection energy
  - strip to Pb^{54+}
- LEIR (2005)
  - Accumulate and cool Linac 3 beam
  - Prepare bunch structure for PS
- PS (2006)
  - Define LHC bunch structure
  - Strip to Pb^{82+}
- SPS (2007)
  - Define filling scheme



Peak and Integrated luminosity





356 bunches

<u>In 2010:</u>

Peak ~18E24; Integrated ~18ub-1
Max 137 bunches, larger β*, smaller bunch intensities

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Reminder of 2012 Priorities

1. The LHC machine must produce enough integrated luminosity to allow ATLAS and CMS to independently discover the Higgs before the start of LS1.

2. We must also prepare for the proton-lead ion run at the end of the year.
3. We must (in 2012) do the necessary machine experiments to allow high energy, useful high luminosity running after LS1.

Pile up and 25ns

Integrated luminosity needed for Discovery of Higgs

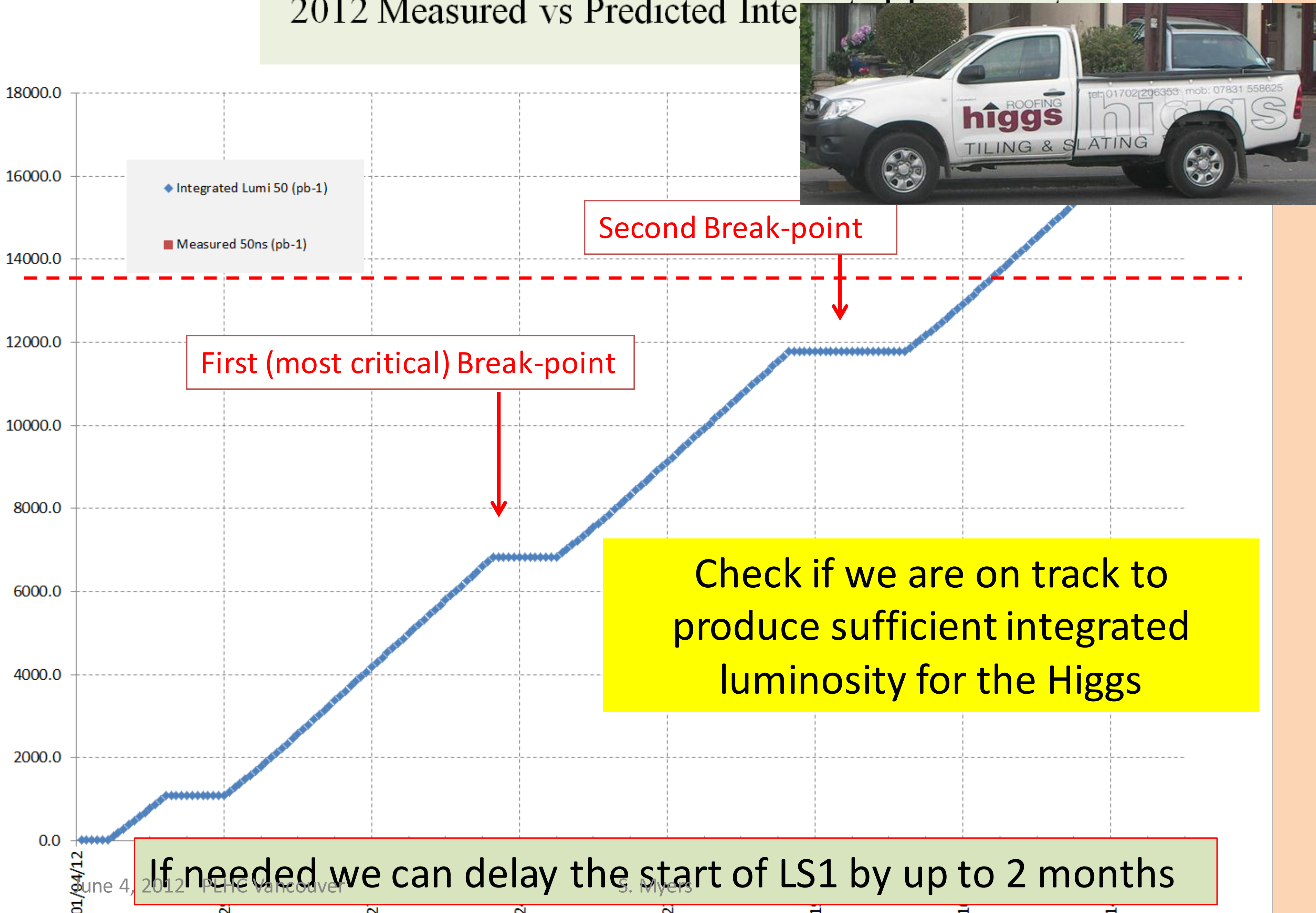
Year	fb-1	signal (in σ)	Beam Energy	
2011	5	2.5	3.5	
2012	15	5	3.5	Needed
2012	11.5	5	4.0	Needed
2012	13.3	5	4.0	addditional 15% for pile up and margin

Reminder 2012 run configuration

- Energy – 4
- Bunch spa
- Collimator settings – tight
- Atlas and CMS beta* - 60 cm
- Alice and LHCb beta* - 3 m
  - Natural satellites versus main bunches in Alice

Real Challenge
2 high luminosity experiments(ATLAS, CMS)
1 mid-luminosity (LHCb) x20 lower
1 low-luminosity (ALICE) x10,000
Non colliding bunches to monitor background
Also TOTEM and ALFA

2012 Measured vs Predicted Inte



Check if we are on track to produce sufficient integrated luminosity for the Higgs

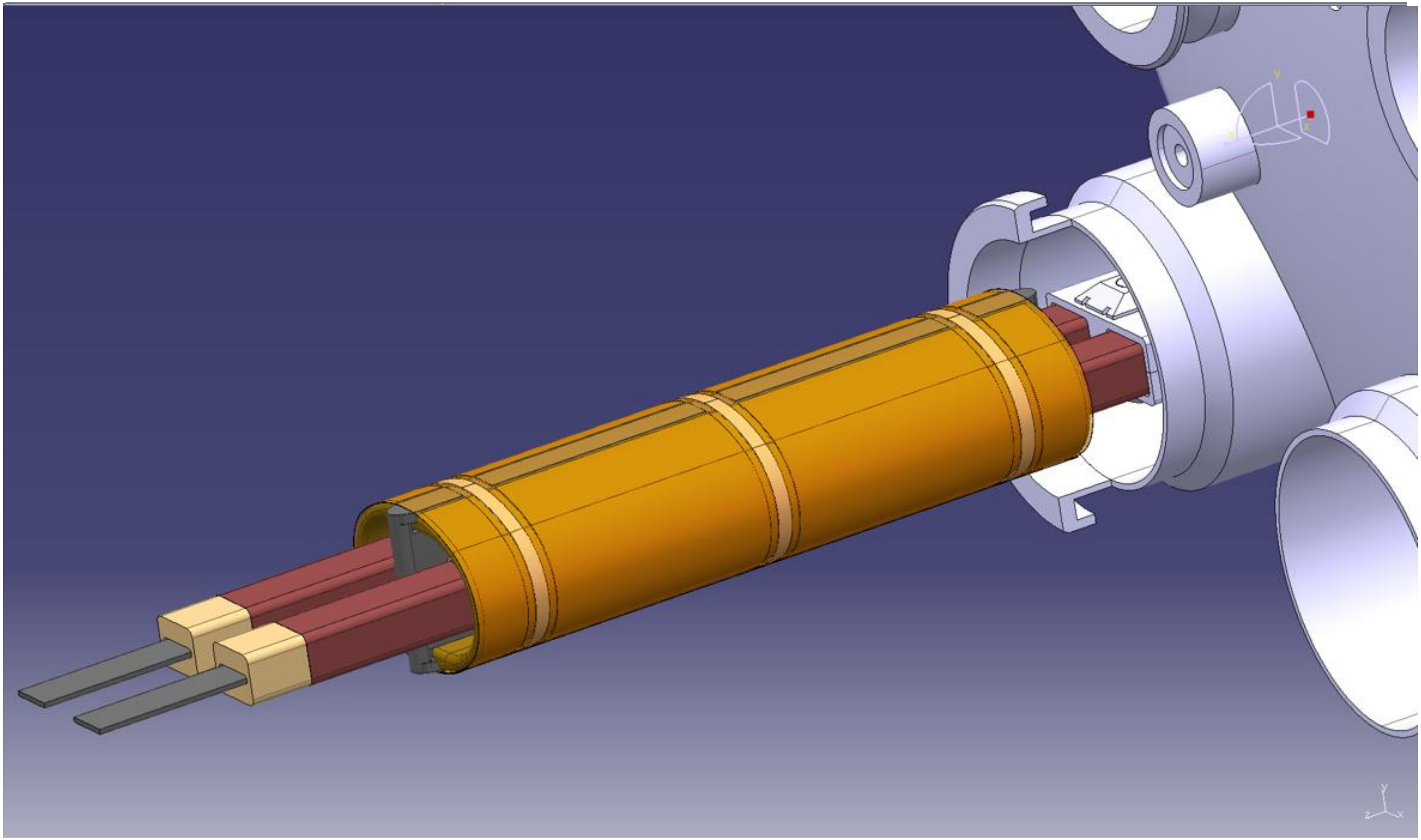
If needed we can delay the start of LS1 by up to 2 months

Draft 10 year plan (27/10/2011)

Main LS1 Work

- Repair defectuous interconnects
- Consolidate all interconnects with new design
- Finish off pressure release valves (DN200)
- Bring all necessary equipment up to the level needed for 7TeV/beam

LHC MB circuit splice consolidation proposal



Phase III

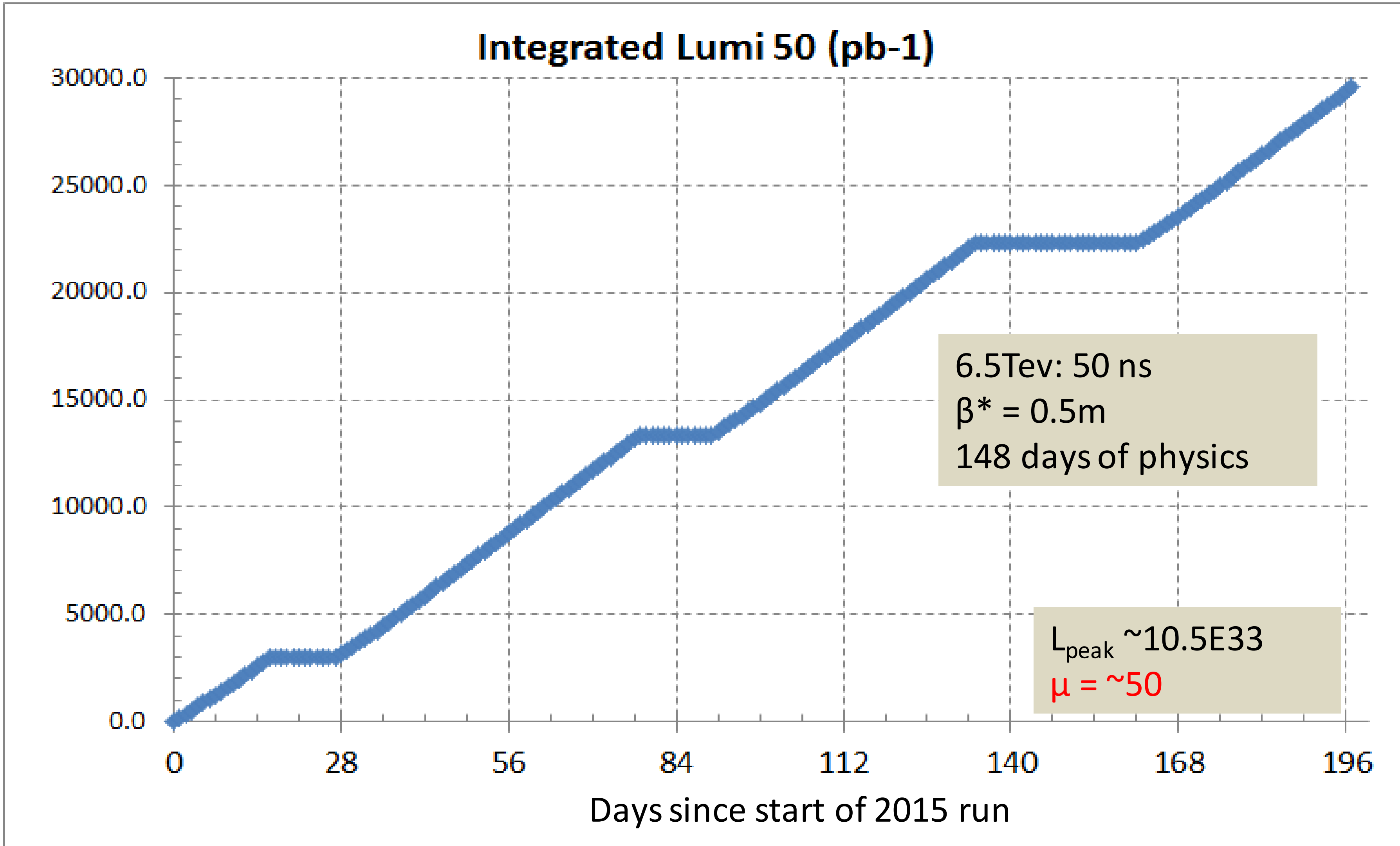
Insulation between bus bar and to ground, Lorentz force clamping

After LS1:
operation at 6.5TeV per beam

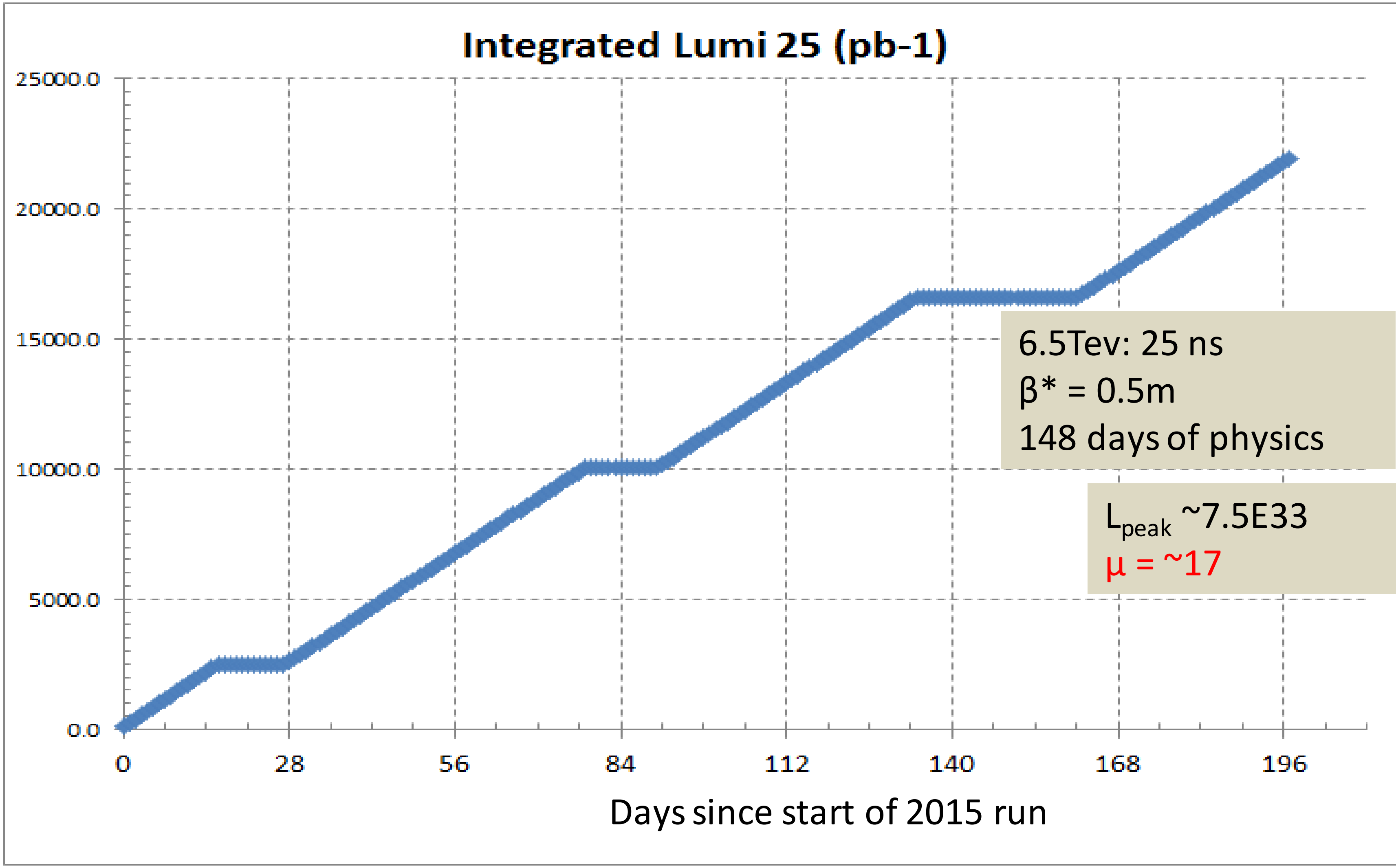
Assumptions

- E=6.5TeV
- β^* = 0.5m
- All other conditions as in 2012 i.e. no improvement (yet) in injector brightness, LHC availability same etc

6.5TeV per beam with 50ns



6.5TeV: 25ns



Integrated Lumi 25 (pb-1)
25000.0
20000.0
15000.0
10000.0
5000.0
0.0
0
28
56
84
112
140
168
196
Days since start of 2015 run
6.5Tev: 25 ns
β* = 0.5m
148 days of physics
Lpeak ~7.5E33
μ = ~17

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Draft 10 year plan (27/10/2011)

LS2 : 2018, LHC Injector Upgrades

Connect Linac4 to PS Booster, (if not already achieved)

- **New PS Booster injection channel**

Upgrade PS Booster from 1.4 to 2.0 GeV

- **New Power Supplies, RF system etc.**
- **Upgrade transfer lines, instrumentation etc.**

Upgrades to the PS

- **New Injection region for 2.0 GeV Injection**
- **New/Upgraded RF systems**
- **Upgrades to Feedbacks/Instrumentation etc.**

Upgrades to the SPS

- **Electron Cloud mitigation – strong feedback system, or coating of the vacuum system**
- **Impedance reduction, improved feedbacks**
- **Large-scale modification to the main RF system**

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HL- LHC Upgrade

Aim to produce ~3000fb^{-1} delivered to the experiments over 10 years.

With a luminosity ~5x10^{34} and leveling to limit pile-up

- Increased bunch charge, low emittance from the injectors
- Very Low β* (10-20 cm) in Atlas and CMS: new insertions
- (Crab-cavities to perform leveling)
- (Enhanced Collimation system)

Presently in the R&D Phase (magnets, RF, beam studies)

- Major R&D Effort for High-Field Magnets
- Studies of Crab-Cavity designs underway
- Collimators in the cold arcs + robust jaw material studies

Construction of technical equipment is likely to start around 2016-17

For installation during Long shutdown 3 (2022)

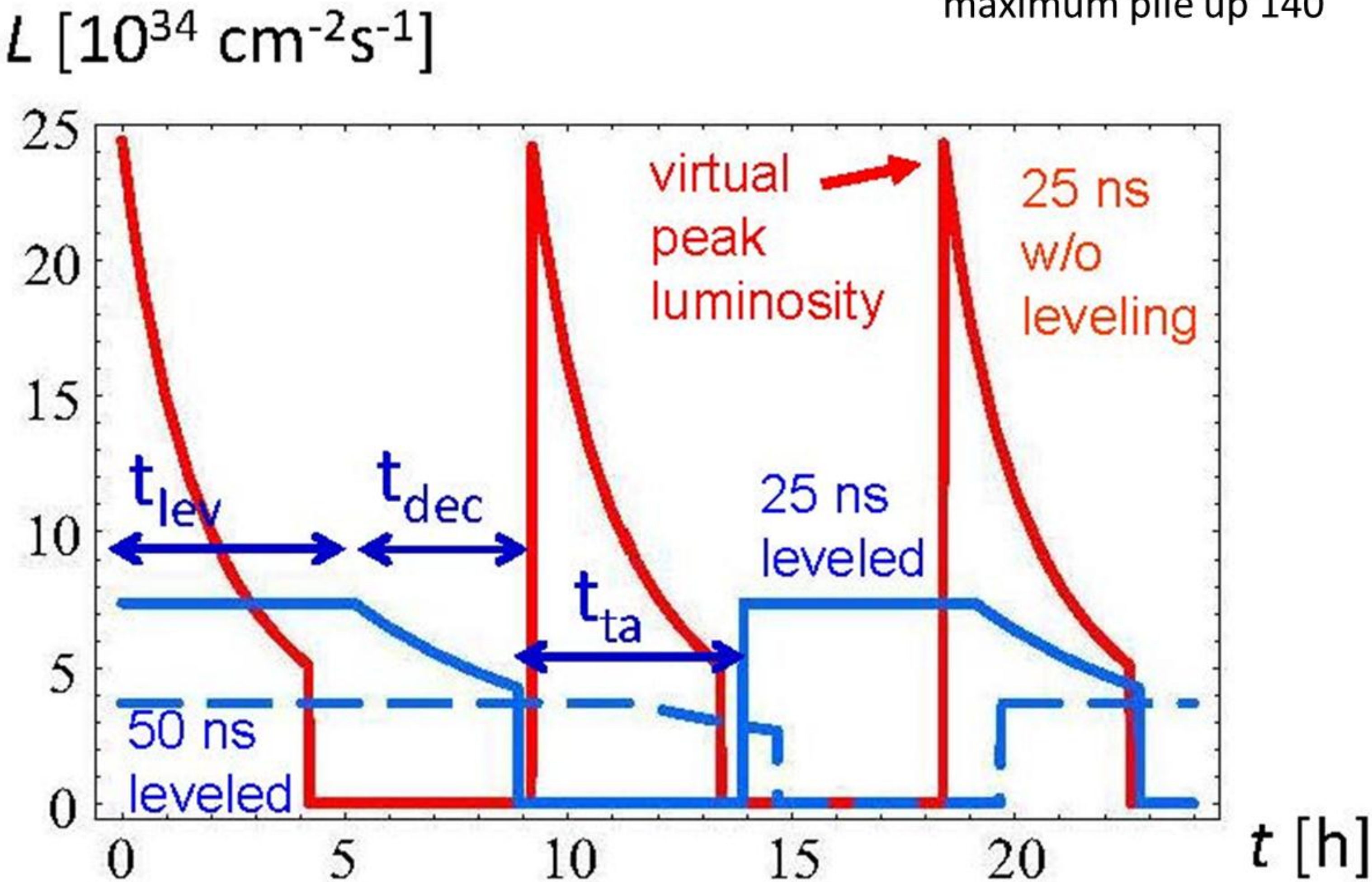
HL-LHC baseline parameters

O. Brüning,
F. Zimmermann,
IPAC'12, MOPPC005

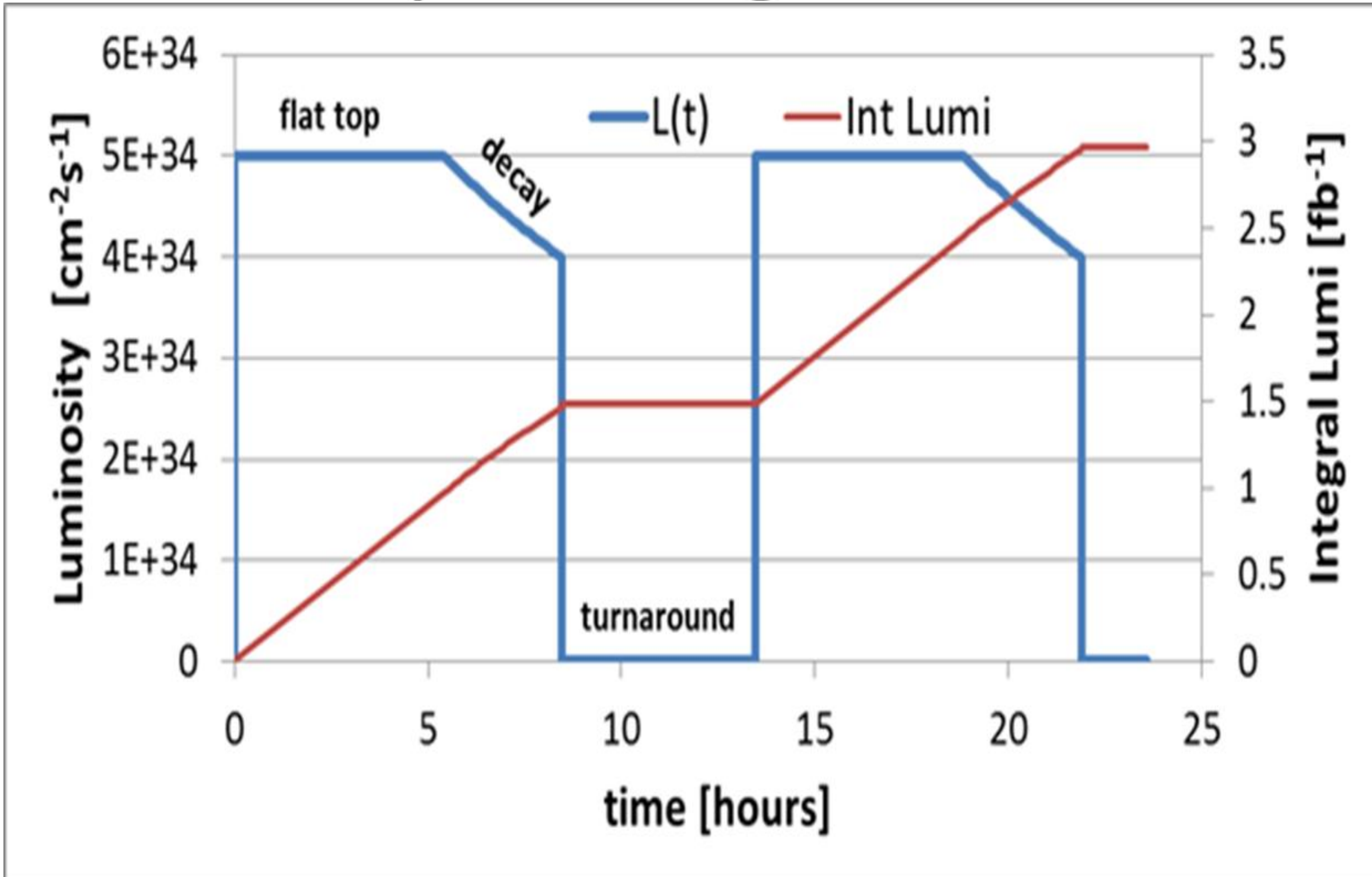
parameter	nominal	**HL-LHC (25 ns)**	**HL-LHC (50 ns)**
protons per bunch	1.15	**2.2**	**3.5**
rms bunch length [cm]	7.55	**7.55**	**7.55**
beta* at IP1&5 [m]	0.55	**0.15**	**0.15**
normalized emittance[μm]	3.75	**2.5**	**3.0**
maximum total b-b tune shift	0.011	**0.015**	**0.019**
potential peak luminosity	1	**24**	**25**
actual (levelled) peak luminosity	1	**7.4**	**3.8**
(pile up, average value)	19	**140**	**140**
needed availability	(50)	**45**	**72**
annual integrated luminosity	(37)	**250**	**250**

luminosity leveling at the HL-LHC

maximum pile up 140

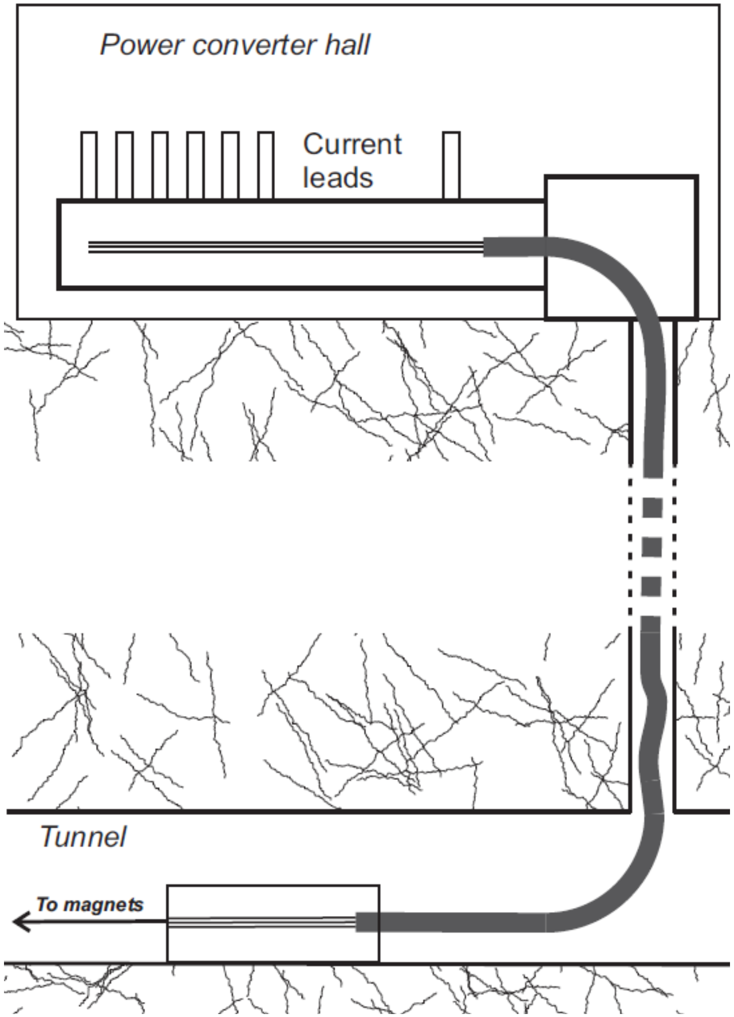


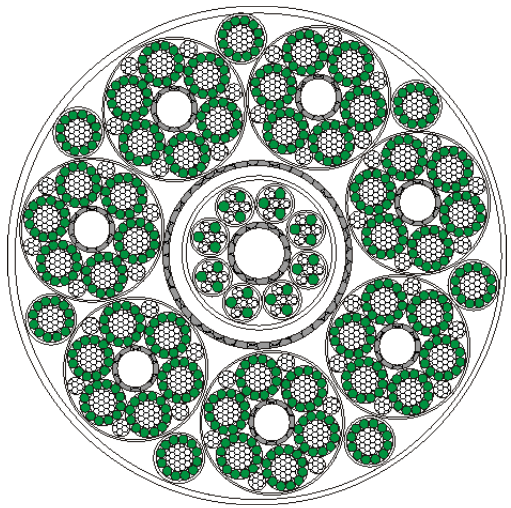
luminosity leveling at the HL-LHC



R&D Superconducting Links

Motivated by the need to remove the power converters out of the tunnel, avoiding radiation effects





Φ = 62 mm

MgB2
(or other HTS)

7 × 14 kA, 7 × 3 kA and 8 × 0.6 kA cables – Itot~120 kA @ 30 K

Also DFs with current leads removed to surface
Definitive solution to R2E problem
Make room for shielding unmovable electronics
Make much easier maintnance and application ALARA

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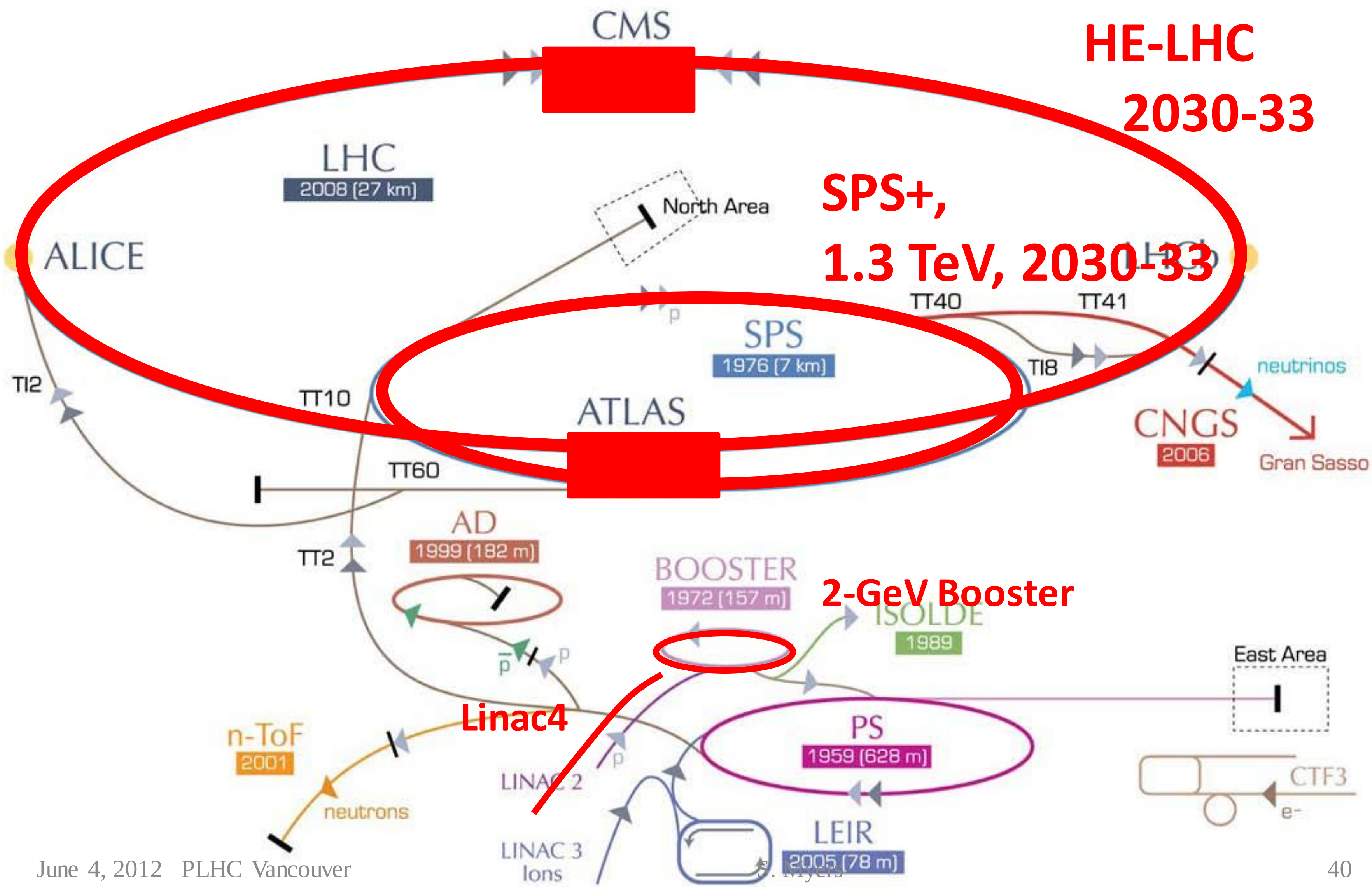
HE-LHC – LHC modifications



Very Long Term Objectives: Higher Energy LHC

Preliminary HE-LHC - parameters

	nom	HE-LHC
beam energy [TeV]		16.5
dipole field [T]		20
dipole coil aperture [mm]		40-45
#bunches / beam		1404
bunch population [10^{11}]		1.29
initial transverse normalized em [μm]		3.75 (x), 1.84 (y)
number of IPs contributi	3	2
maximum total bear	0.01	0.01
IP beta function	0.55	1.0 (x), 0.43 (y)
full crossing	285 (9.5 $\sigma_{x,y}$)	175 (12 σ_{x0})
stored b	362	479
SR pc	3.6	62.3
longitu amping time [h]	12.9	0.98
events pe	19	76
peak lumin $cm^{-2}s^{-1}$]	1.0	2.0
beam lifetime	46	13
integrated luminosity over 10 h [fb^{-1}]	0.3	0.5

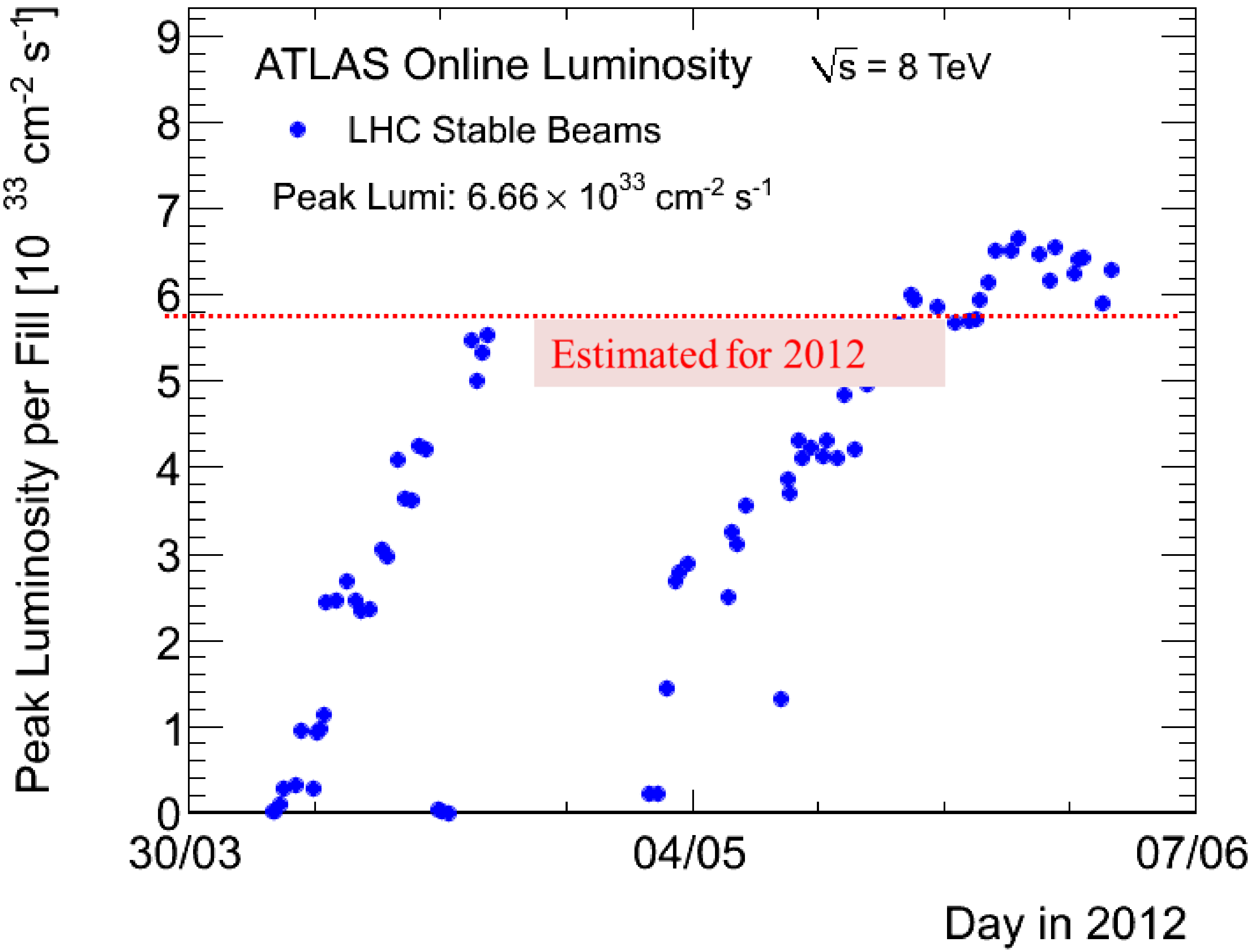
Very preliminary with large error bars

HE-LHC – main issues and R&D

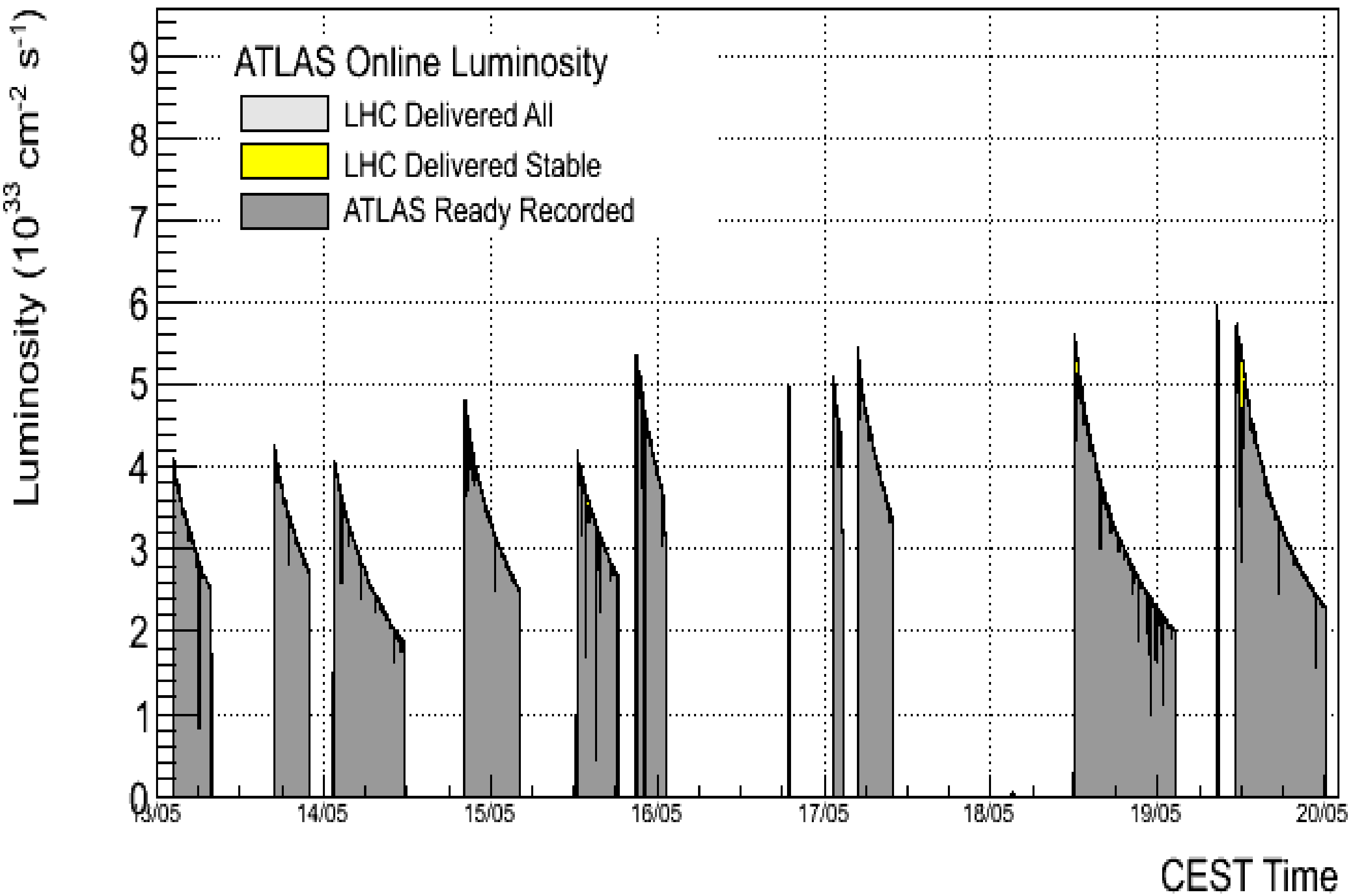
- High-field 20T dipole magnets based on Nb_3Sn, Nb_3Al, and HTS
- High-gradient quadrupole magnets for arc and IR
- Fast cycling SC magnets for ~1.3TeV injector
- Emittance control in regime of strong SR damping and IBS
- Cryogenic handling of SR heat load (first analysis; looks manageable)
- Dynamic vacuum

Stop Press: Present Performance

Peak Luminosity



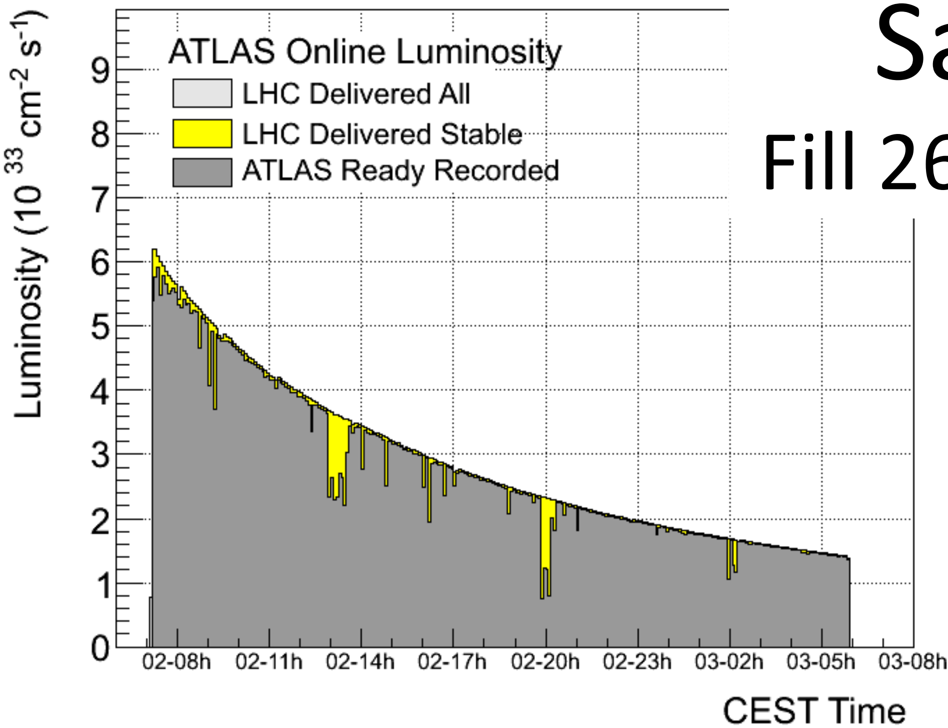
7 Days of production (~1fb^{-1})

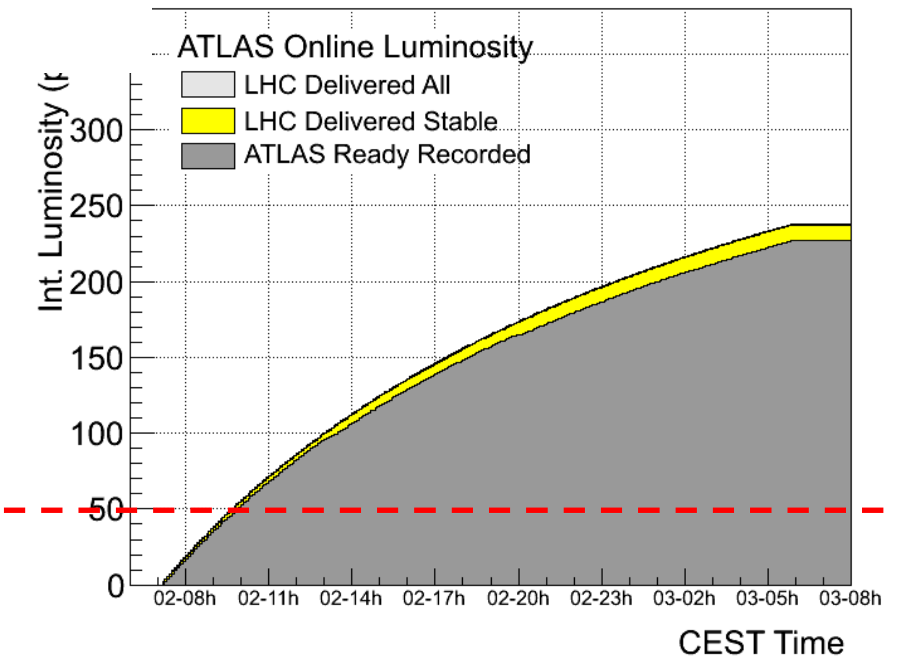


Sunday 3rd June: Last 24 hours…

Saturday 2nd June

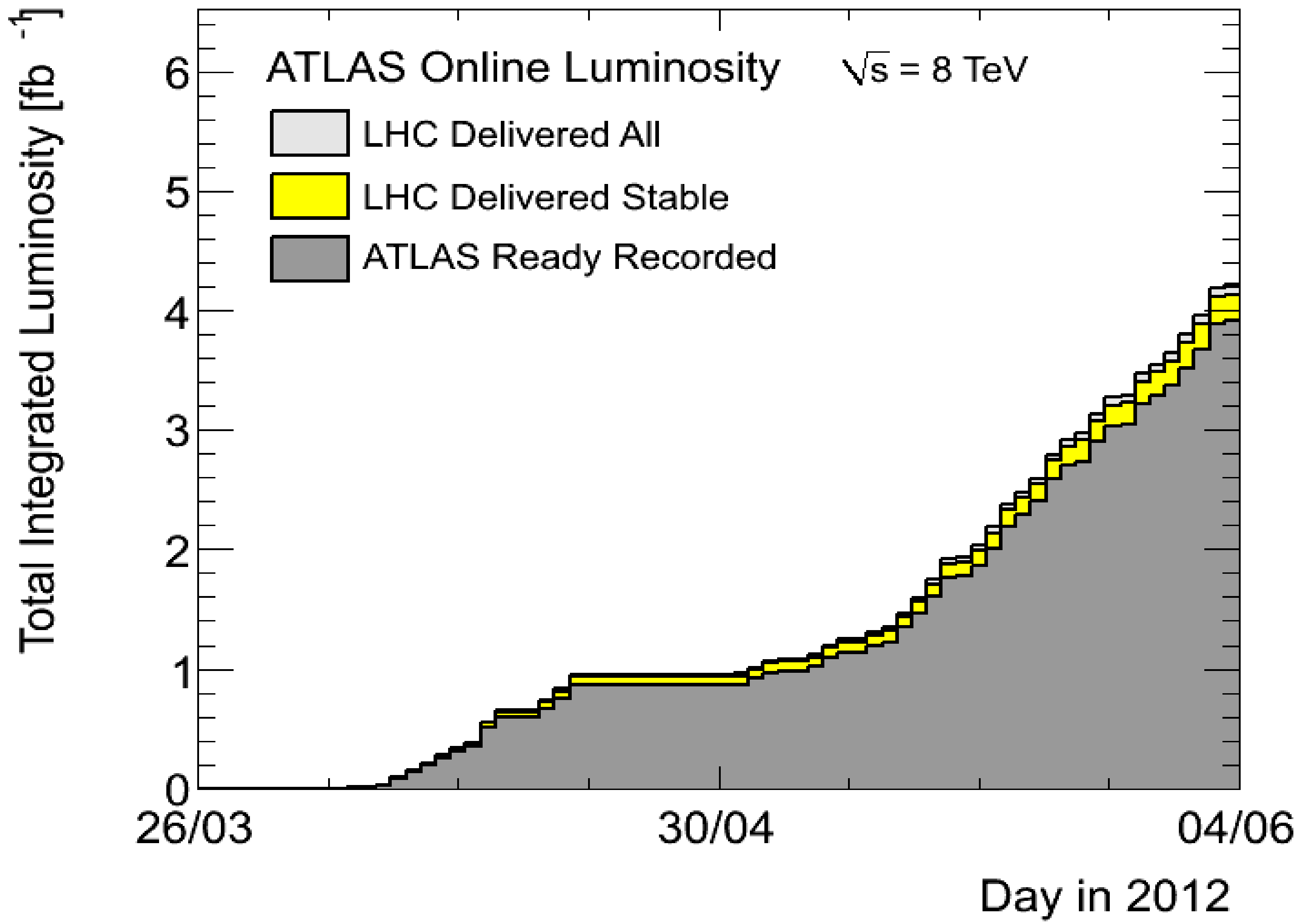
Fill 2692 (238pb-1 in 23 hours)



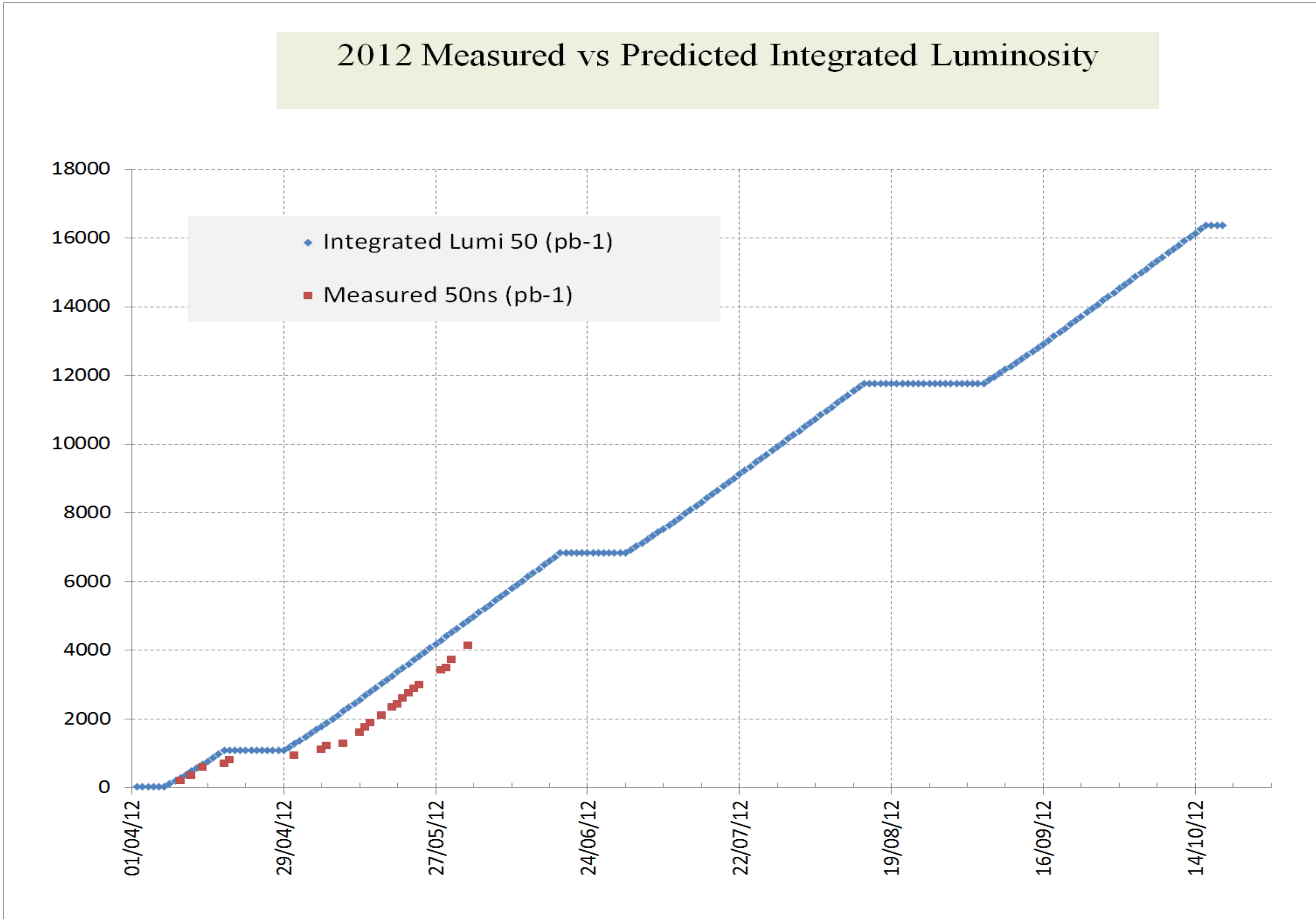


Integral of all of 2010

Total Integrated so far



With Respect to estimates (as of Saturday June 2)



Records

Peak Stable Luminosity Delivered	6.66×10^{33} $cm^{-2}s^{-1}$	Fill 2670	12/05/26, 12:42
Maximum Luminosity Delivered in one fill	237.32 pb^{-1}	Fill 2692	12/06/02, 01:55
Maximum Luminosity Delivered in one day	228.55 pb^{-1}	Saturday 02 June, 2012	
Maximum Luminosity Delivered in 7 days	973.68 pb^{-1}	Thursday 17 May, 2012 - Wednesday 23 May, 2012	
Maximum Colliding Bunches	1380	Fill 2660	12/05/24, 13:17
Maximum Peak Events per Bunch Crossing	43.81	Fill 2479	12/04/06, 10:22
Maximum Average Events per Bunch Crossing	31.34	Fill 2670	12/05/26, 12:42
Longest Time in Stable Beams for one fill	22.8 hours	Fill 2692	12/06/02, 05:10
Longest Time in Stable Beams for one day	20.5 hours (85.6%)	Saturday 02 June, 2012	
Longest Time in Stable Beams for 7 days	77.5 hours (46.1%)	Sunday 08 April, 2012 - Saturday 14 April, 2012	
Fastest Turnaround to Stable Beams	2.13 hours	Fill 2472	12/04/05, 15:46

Don’t get the idea that it’s easy!(1)

- Beam-beam
  - luminosity levelling by transverse separation,
  - crossing angle and separation schemes
  - bunches with a range of betatron tunes,
- Instabilities (TMCI, Head-tail, coherent instabilities, electron cloud) Collimators very close to beam
  - Transverse Damping
  - Landau damping octupoles,
  - Beam-beam stabilization
  - Solenoidal fields in warm regions
- Beam Induced Heating

Don’t get the idea that it’s easy!(2)

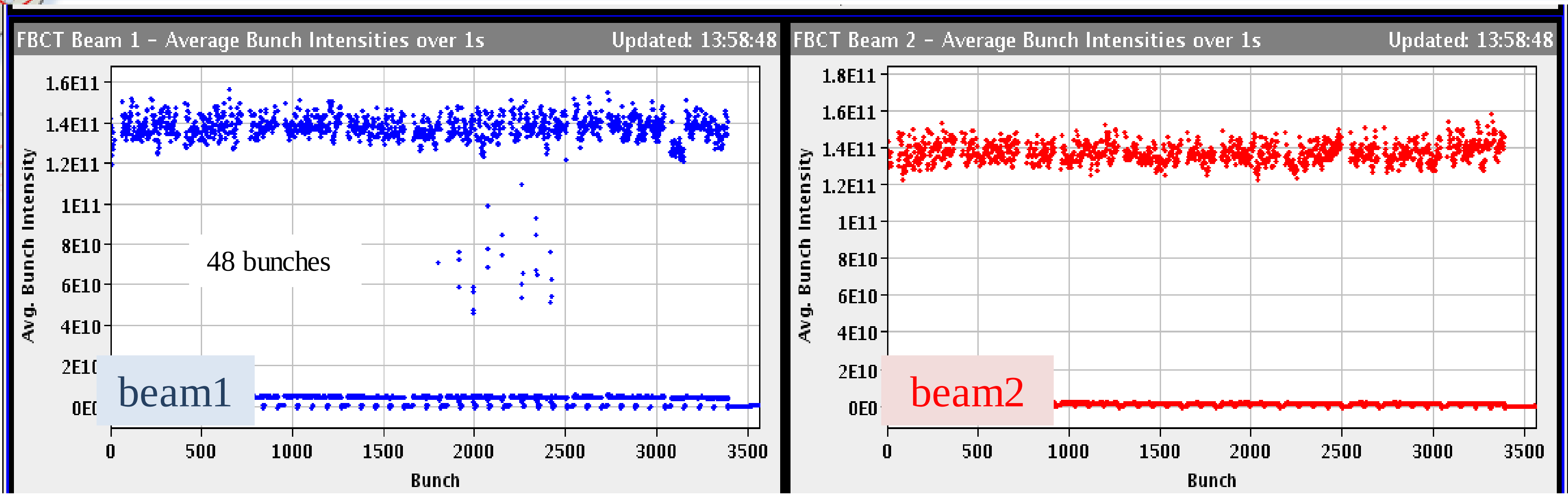
- Magnet measurement system (snapback, persistent currents..)
- Machine protection
  - Injection (protection devices, BLMS, injection interlocks..)
  - Ramp and squeeze (collimators, BLMS, orbit control…)
  - Collisions (idem, FCMM, UFOs…) electrical storms
- Emittance Control (longitudinal and transverse)
- Aperture

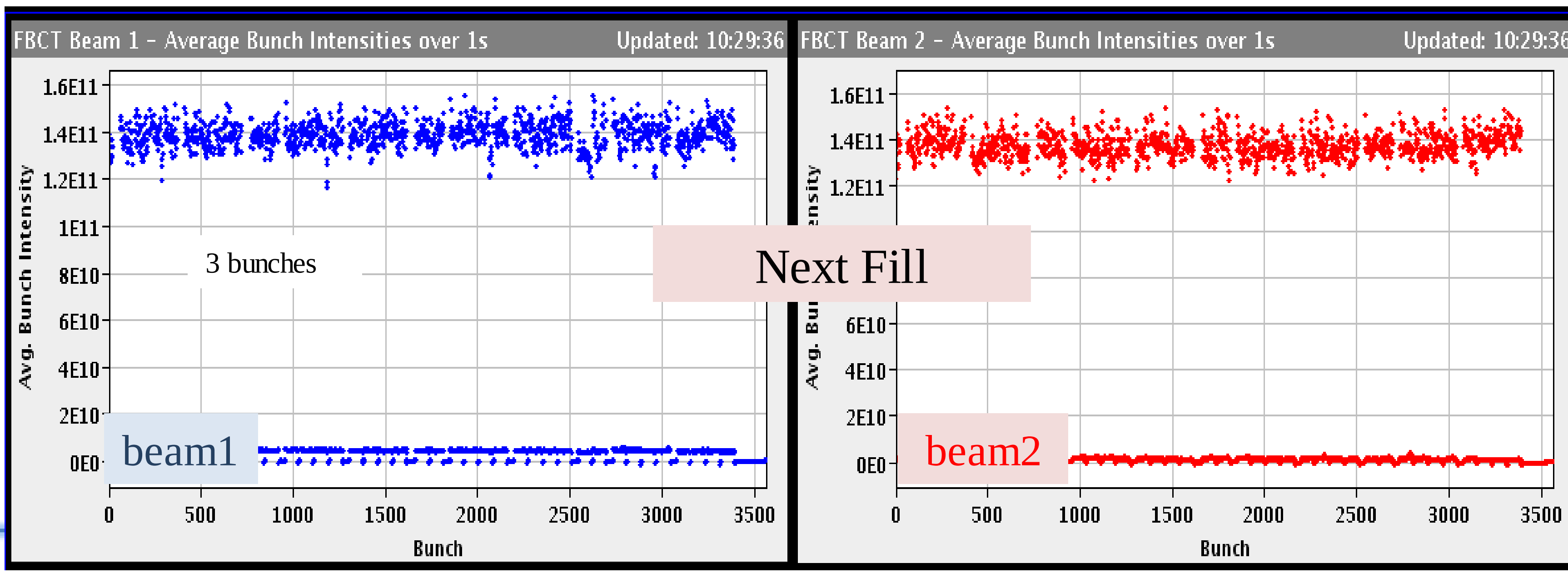
Don’t get the idea that it’s easy!(3)

- UFOs… dust particles
- R2E and Single Event Upsets(SEUs)
- Abort gap cleaning and Beam dump
- Beam feedback; orbit, tune, chromaticity
- Vacuum and electron cloud

Recent Example

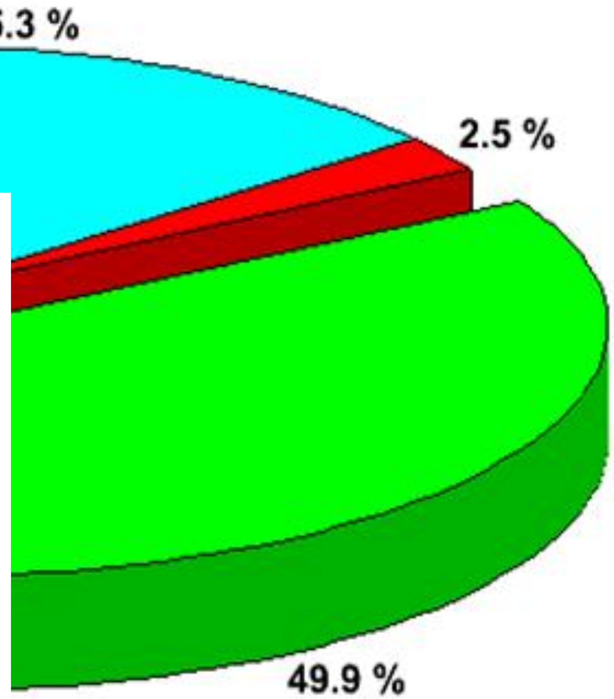
Bunches used for background monitoring (only interact in LHCb) get lost and trigger the machine protection system to dump the beam

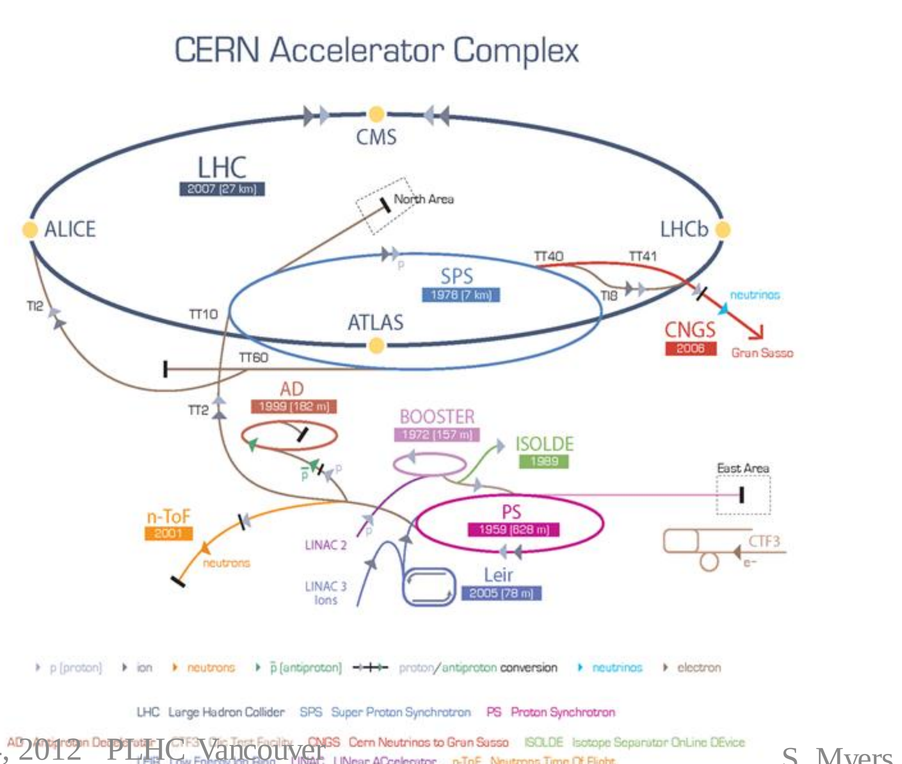




LHC Efficiency: Last 10 fills

Statistics for fills 2637 to 2646
Total Duration: 2 days, 14 h [17.05.12 to 20.05.12]
Time in Stable Beams: 1 days, 07 h





Acknowledgements

- The performance of the LHC is due to many hundreds of engineers and physicists working at CERN and our collaborating institutes
- The operation from the control room is carried out by
  - Machine coordinators (week to week)
  - Engineers-in-Charge and operators (shift to shift)
  - All under the capable leadership of the Operations group leader Mike Lamont

Summary

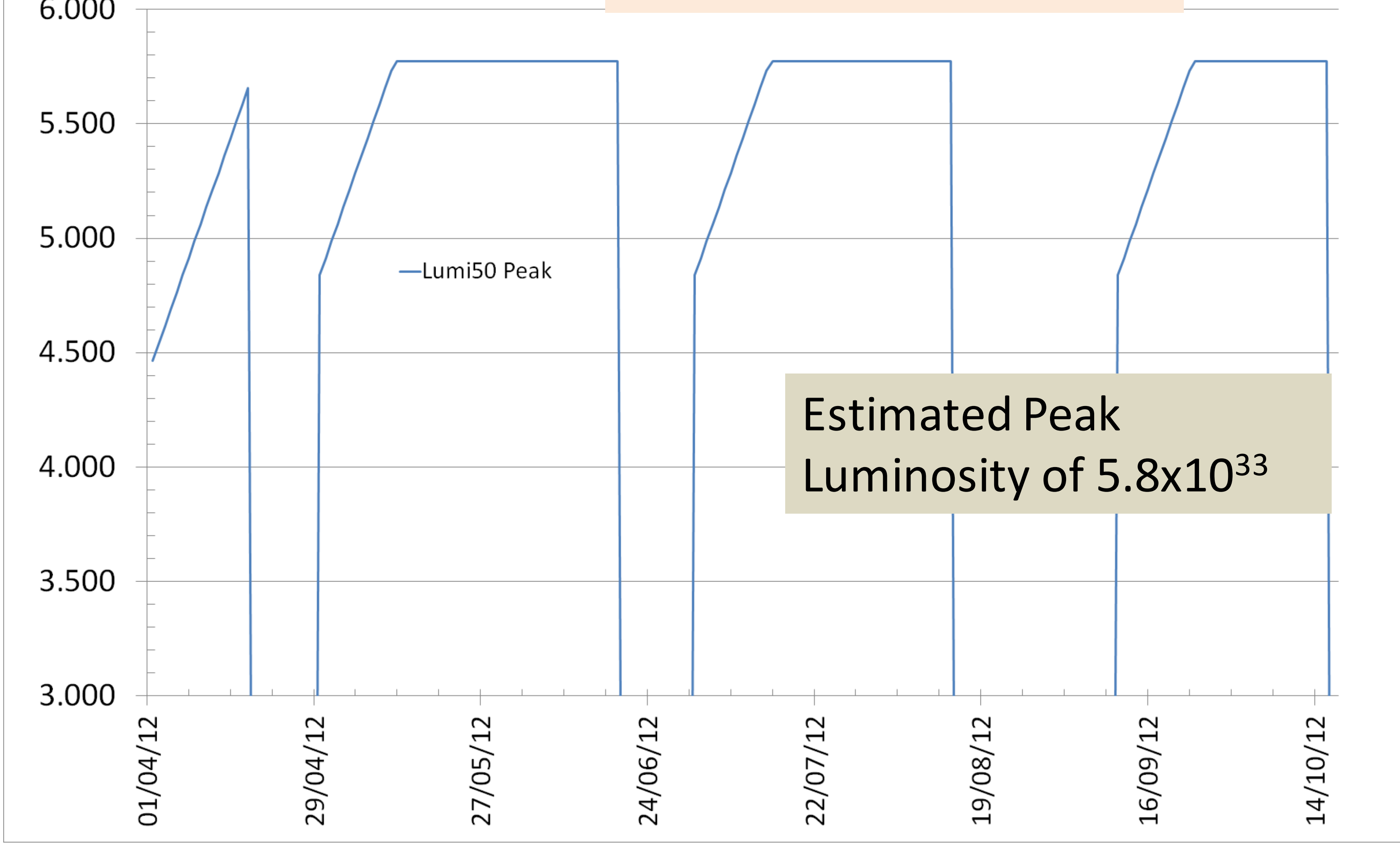
- The First two years of LHC operation hav
  performance: well beyond our wildest e
- The combination of the performance of
  detectors and the Grid have proven to b
  particle physics.
- However, we must remain extremely vig
  protection of the machine (120MJ of sto
  there are no old “unexploded bombs” ir
- In the absence of any major technical failure, the LHC machine
  WILL produce enough integrated lur
  detectors to discover or exclude the
  DISCOVERY OR EXCLUSION WILL BE
- The high energy operation after the
  another exciting era in discovery phy

Thank you for your attention

Removed 31/5/12

Estimated Peak Luminosity with 50ns (2012)

We are currently operating here!
~6.6x10 ^{33}



Estimated Peak Luminosity of 5.8×10^{33}

Target p-Pb performance in 2012 (ATLAS/CMS)

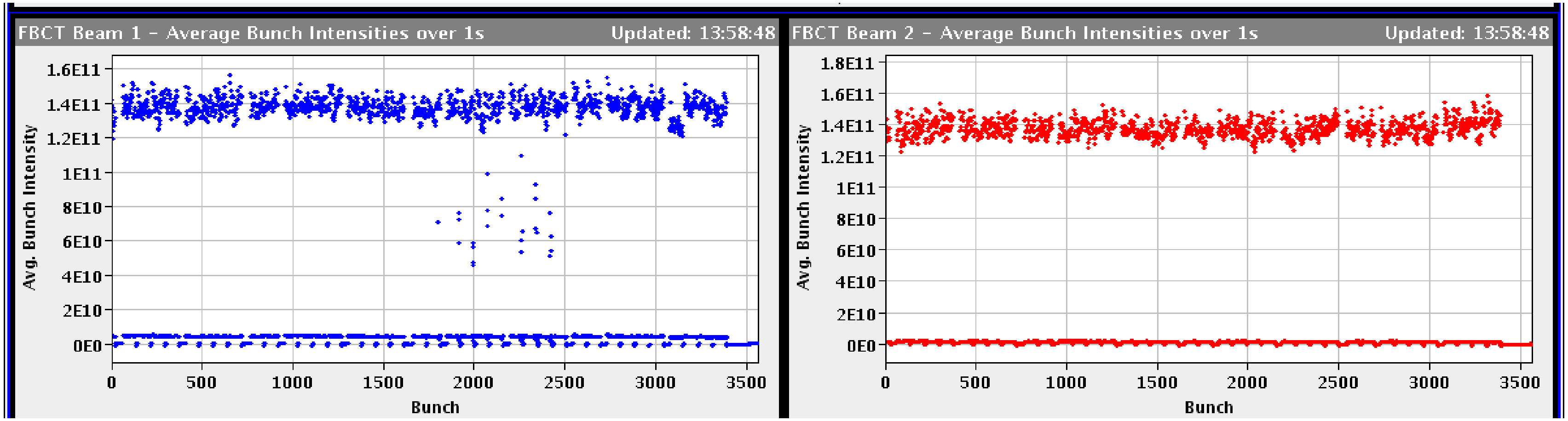
Main choice:	**Units**	**200 ns**	**200ns**	**100 ns**	**100**
Beam energy/(Z TeV)	*Z* TeV	3.5	4	3.5	4
Colliding bunches		356	356	550	550
β^*	m	0.7	0.6	0.7	0.6
Emittance protons	μm	3.75	3.75	3.75	3.75
Emittance Pb	μm	1.5	1.5	1.5	1.5
Pb/bunch	10^8	1.2	1.2	0.8	0.8
p/bunch	10^{10}	1.15	1.15	1.15	1.15
Initial Luminosity L_0	10^{28} cm^{-2} s^{-1}	**6.2**	**8.3**	**6.4**	**8.5**
Operating days		**22**	**24**	**22**	**24**
Difficulty (subjective)		**0.9**	**1**	**0.9**	**1**
Integrated luminosity	μb^{-1}	**15.4**	**22.4**	**15.9**	**23.1**

Integrate luminosity by scaling from 2011.
Average Pb bunch intensities from best 2011 experience.
Proton bunch intensities conservative, another factor 10 ????
Proton emittance conservative, another factor 1.37 ??
Untested moving encounter effects, possible reduction factor 0.1 ??

Removed 19/5/12

Fri Morning

***still:** losses of single bunch intensities in the very first part of “stable beams”*



***careful analysis of the problem:** one colleague in front of every relevant screen*

** only losses in **beam 1***

** **single bunch** losses*

... and only bunches affected that collide exclusively in IP8

** it happens **AFTER adjust**, i.e. in stable beam condition*

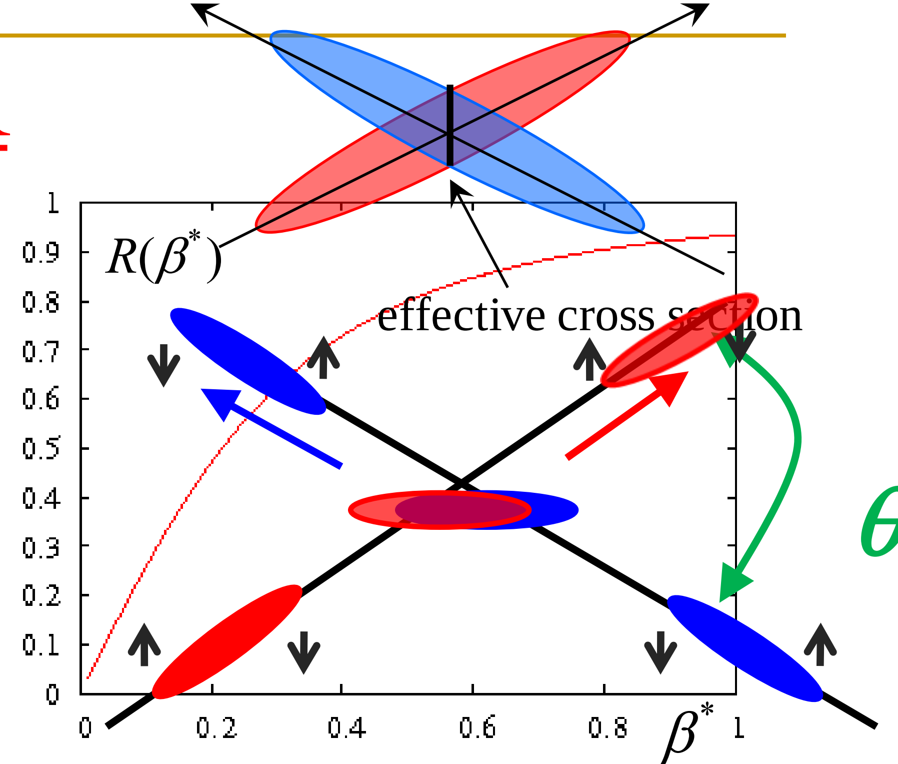
** surprising **emittance values***

LHC Challenges: R

geometric luminosity reduction factor:

Piwinski angle

$$R_\theta = \frac{1}{\sqrt{1+\Theta^2}}; \quad \Theta \equiv \frac{\theta_c \sigma_z}{2\sigma_x}$$



large crossing angle:

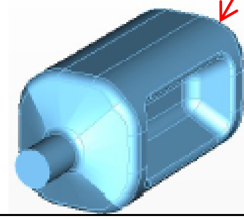
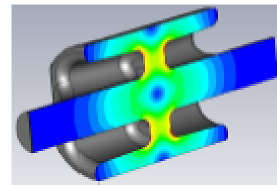
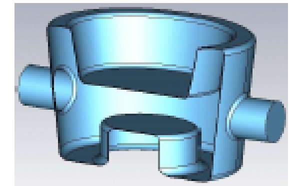
- ➔ reduction of long range beam-beam interactions
- ➔ reduction of head-on beam-beam parameter
- ➔ reduction of the mechanical aperture
- ➔ synchro-betatron resonances
- ➔ reduction of instantaneous luminosity
  - ➔ inefficient use of beam current
  - ➔ option for L leveling!

Remaining Designs*

Performance Chart

Kick Voltage: 3 MV, 400 MHz

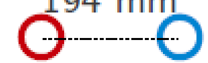
LARP

Geometrical

RF

	Double Ridge (ODU-SLAC)	4-Rod (UK)	¼ Wave (BNL)
Cavity Radius [mm]	**147.5**	**143/118**	**142/122**
Cavity length [mm]	597	500	380
Beam Pipe [mm]	84	84	84
Peak E-Field [MV/m]	33	32	47
Peak B-Field [mT]	56	60.5	71
R_T/Q [Ω]	287	915	318
Nearest Mode [MHz]	584	371-378	575



< 60 MV/m

< 100 mT

damping more complicated

The operational performance of the LHC machine both for proton and lead ion operation are reviewed for the period 2010 and up the present. The beam parameter path allowing the very high rate of collider performance is presented and discussed. The accelerator issues encountered and those somewhat surprisingly not encountered are also discussed. The short and longer term plans for the LHC are also briefly presented.

HL-LHC Performance Estimates

- nominal bunch length and minimum β^*: Chamonix'11 & 'HL-LHC Kickoff'

Parameter	nominal	minimum β^* 25ns	minimum β^* 50ns		
N	1.15E+11	**2.0E+11**	**3.[illegible]**	5.6 10^{14} and 4.6 10^{14} p/beam	
n_b	2808	2808	[illegible]		
beam current [A]	0.58	**1.02**	**[illegible]4**		
x-ing angle [μrad]	300	475	580		
beam separation [σ]	10	10	10		
β^* [m]	0.55	**0.15**	**0.15**		
ε_n [μm]	3.75	**2.[illegible]**	**3.75**		
ε_L [eVs]	2.51	[illegible]	2.5		
energy spread	1.00E-04	1.0[illegible]	1.00E-04		
bunch length [m]	7.50E-02	7.[illegible]	7.50E-02		
IBS horizontal [h]	80 -> 106	**[illegible]**	**37**		
IBS longitudinal [h]	61 -> 60	**21**	**21**		
Piwinski parameter	0.68	**2.5**	**2.5**		
geom. reduction	0.83	**0.37**	**0.37**		
beam-beam / IP	3.10E-03	**[illegible].9E-03**	**3.9E-03**		
Peak Luminosity	1 10^{34}	**7.4 10^{34}**	**6.8 10^{34}**	(Leveled to 5 10^{34} cm^{-2} s^{-1})	
Events / crossing	19	**141**	**257**	**95**	**190**

OK for HL goals, if CRAB cavities are a viable option

HL-LHC parameters

Parameter	Nom. 25 ns	Stretched 25 ns	Stretched 50 ns	Baseline 25 ns	Baseline 50 ns
N_b [10^{11}]	1.15	2.2	3.5	1.7	2.5
β^* [m]	0.55	0.15	0.15	0.15	0.15
ε_n [μm]	3.75	2.5	3.0	2.5	2.0
b-b/IP[10^{-3}]	3.1	3.9	5	3	5.6
L_{peak} (no crab)	1	9.0	9.0	5.3	7.2
Crabbing	no	yes	yes	yes	yes
$L_{peak\ virtual}$	1	25	25	14.3	19.5
Lumi level	=	5	2.5	5	2.5
Pileup $L_{lev}=5L_0$	19	95	95	95	95

UFOs

UFOs in the LHC

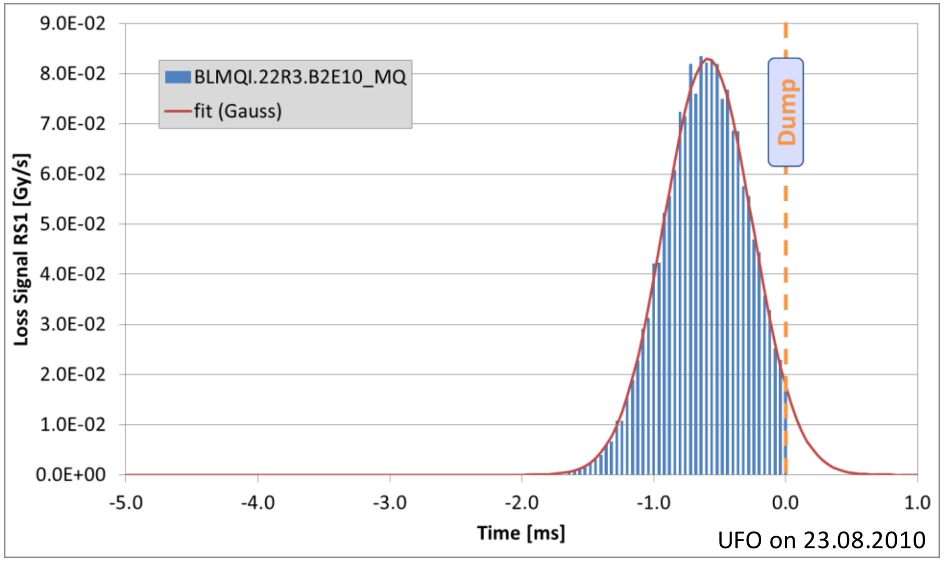
- Since July 2010, **35 beam dumps** due to (***U***n)identified ***F***alling ***O***bjects (17 in 2011).

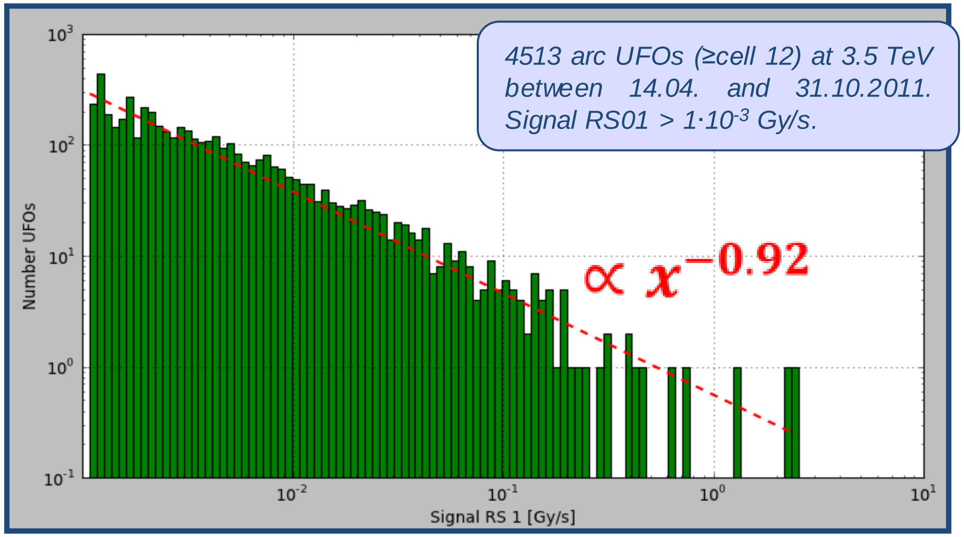
  Loss duration: about 10 turns.

  Often unconventional loss locations (e.g. in the arc).

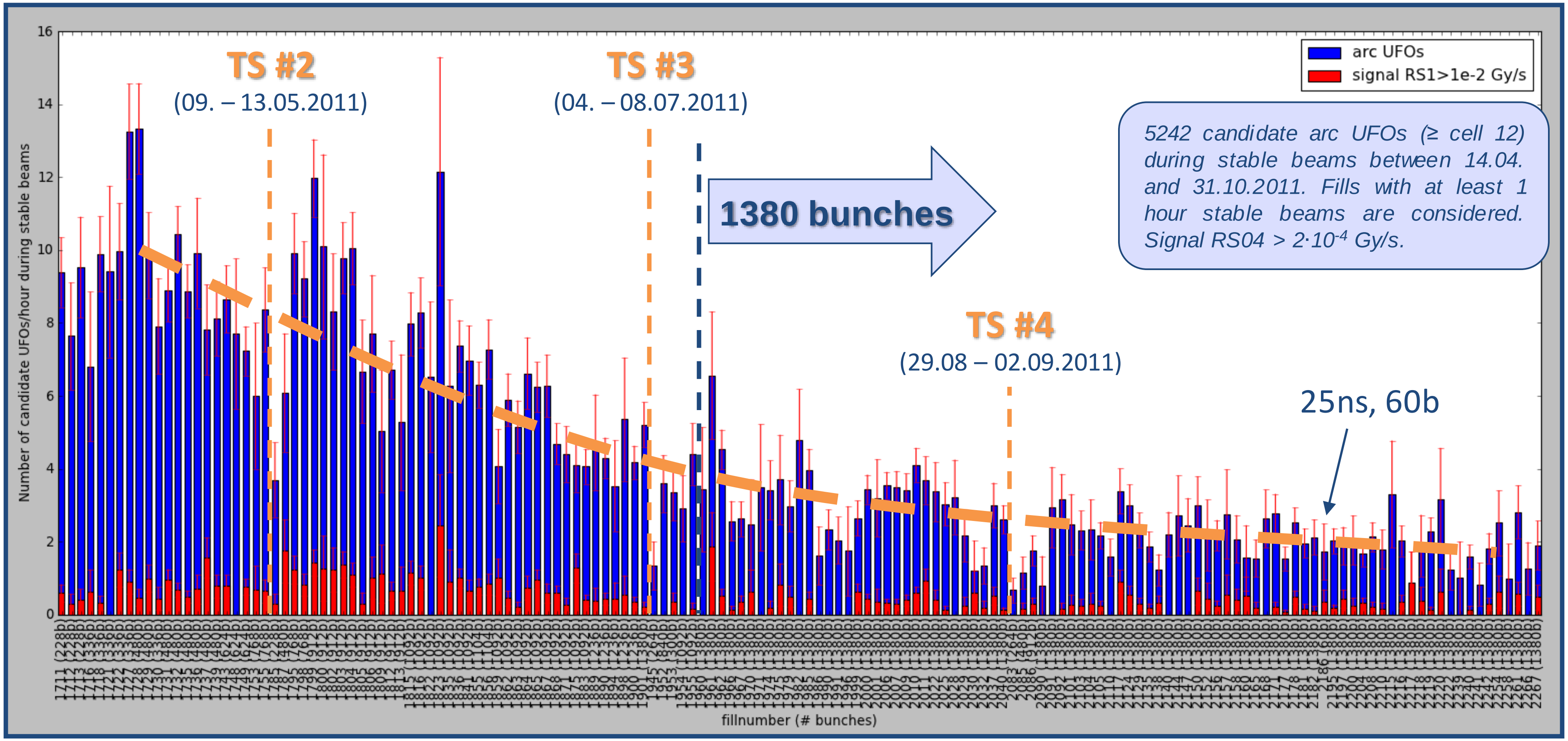
- In 2011: **16,000 candidate UFOs** below BLM dump thresholds found.

- $\frac{1}{x}$ **distribution** of BLM signal is well explained by **dust particle size distribution** measured in SM12. *(T. Baer et al., Evian Workshop 2011)*





UFO rate 2011



Decrease of UFO rate from ≈10 UFOs/hour to ≈2 UFOs/hour.

Plans for 2012 and Beyond

- Better **localization of arc UFOs** by **mobile BLMs** in cell 19R3.
- FLUKA simulations for arc UFOs (underway).
- Better **temporal resolution** of UFO events (dust particle dynamics).
  - *80μs time resolution of BLM study buffer.*
  - *Bunch-by-bunch diagnostics for UFO events by diamond detectors.*
- Study impact of **25ns operation.**
  - *25ns high intensity (> 1000 bunches) beam for several hours at flat top.*
- MKI UFO MD.
  - ***25ns**, e-cloud correlation, **UFO production mechanism**, particle dynamics.*
- Possibly installation of shaker device.
  - *Study production mechanism of UFOs.*

R2E

Radiation to electronics (R2E)

Affected Equipment Group	LHC Critical Areas	2011 #ofDumps	2011 #ofFailures	Estimated Downtime (partl. in shadow)	2011 Avoided SEE Dumps	2012 Expected Dumps No Additional Mitigation	2012 Estimated Dumps With Mitigation
QPS	Tunnel, UJs/RRs	23	140	~60 hours	150	69	~20
Cryogenics	UJs	25	48	~250 hours	~25	75	1-2
Power-Converters	Tunnel, UJs/RRs, UAs	13	15	~30 hours	few (FGC)	39	10-20
Collimation Control	UJs (P1/5)	6	8	~20 hours	-	18	7
B/P/WIC	UJs, US85	3	4	~15 hours	1-2	9	0
Access	UJs	-	~4-8	~10 hours	-	-	
EN/EL	UJ56, US85	2	3	~15 hours	-	6	~1
Totals		72	~220	~400h	~180	216	~30-50

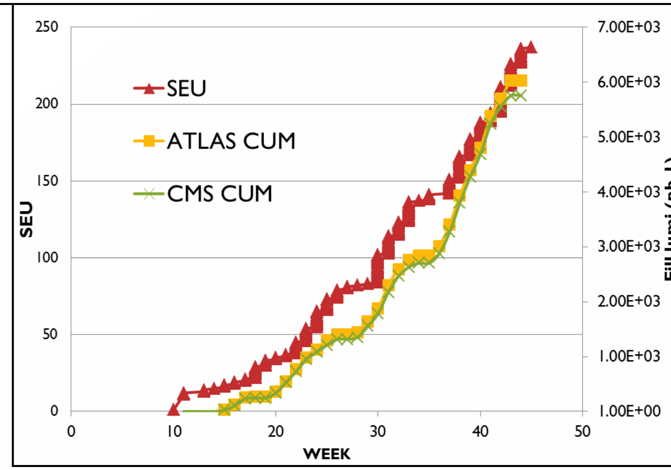
- **xMas-Mitigation crucial: patch, shielding, relocat.**
- **Patches to continue during 2012**
- **Particular emphasis (analysis) of 'new' failures**

R2E & 2011 LHC Operation

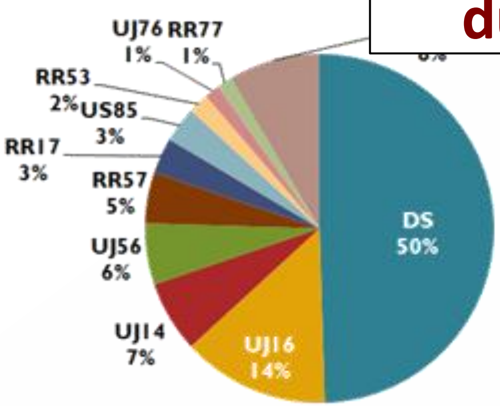
- **Very good agreement between predicted and measured radiation levels**

Area	FLUKA 2011 (HEH/cm²)	Measured 2011 (HEH/cm²)
UJ14/16	~1.5*10⁸	~2*10⁸
RR13/17	~3*10⁷	7.0*10⁶
UJ56	5*10⁷-10⁸	3.5*10⁷
RR53/57	~3*10⁷	1*10⁷
UJ76	~4*10⁶	5*10⁶
RR73/77	~2*10⁶	~8*10⁶
UX85B	~3*10⁸	2*10⁸
US85	~7*10⁷	3.5*10⁷

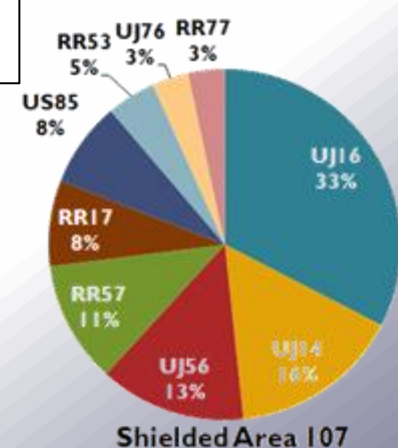
- **Clear correlation of radiation source an failures**



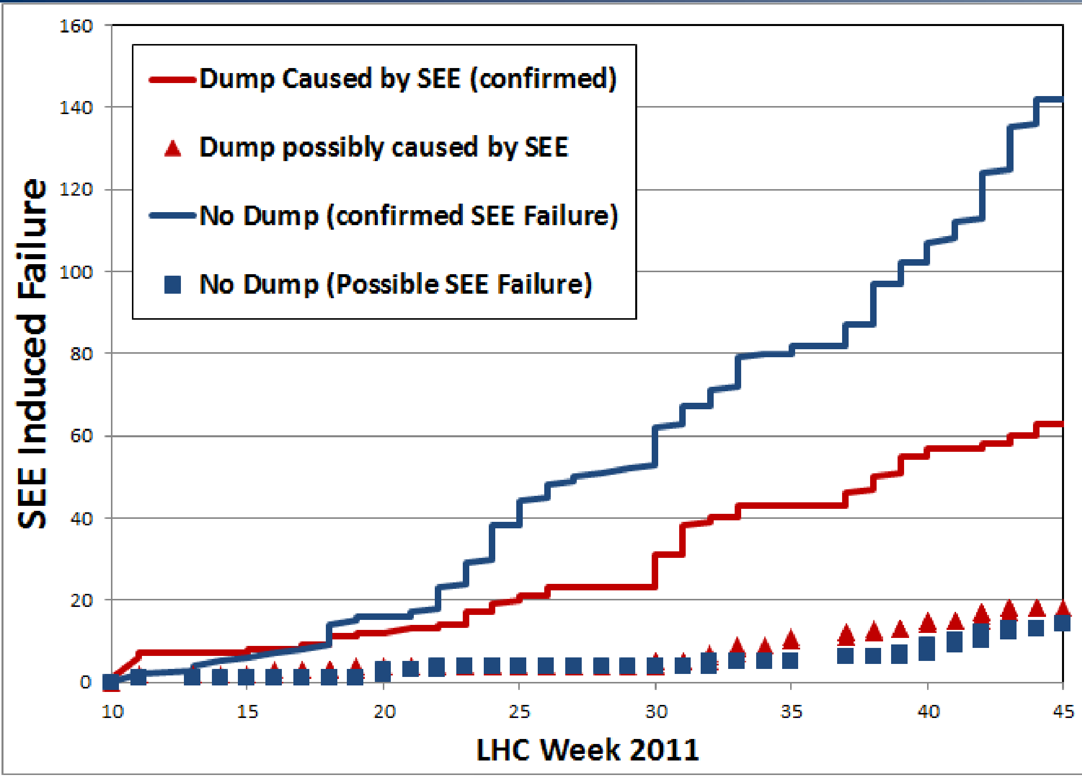
- **Total number of failures kept 'limited' due to parallel mitigation actions**

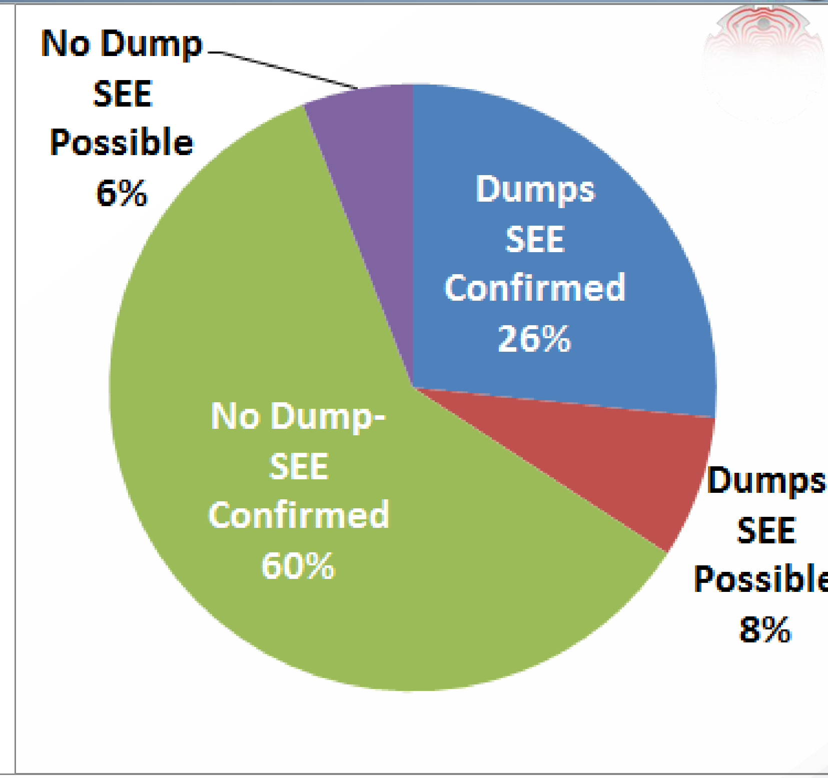


- **70 SEE related beam-dumps** (downtime ~450h)
- **Anticipated shielding/relocation** already prior 2011
- **Most sensitive units relocated in parallel** to 2012 operation



Failures during 2011 operation





- Events to be confirmed represent a relatively small fraction
- Increase of the "no dump events"
  - consequence of patch solutions (QPS + Cryo)

Mitigation Options

RELOCATION

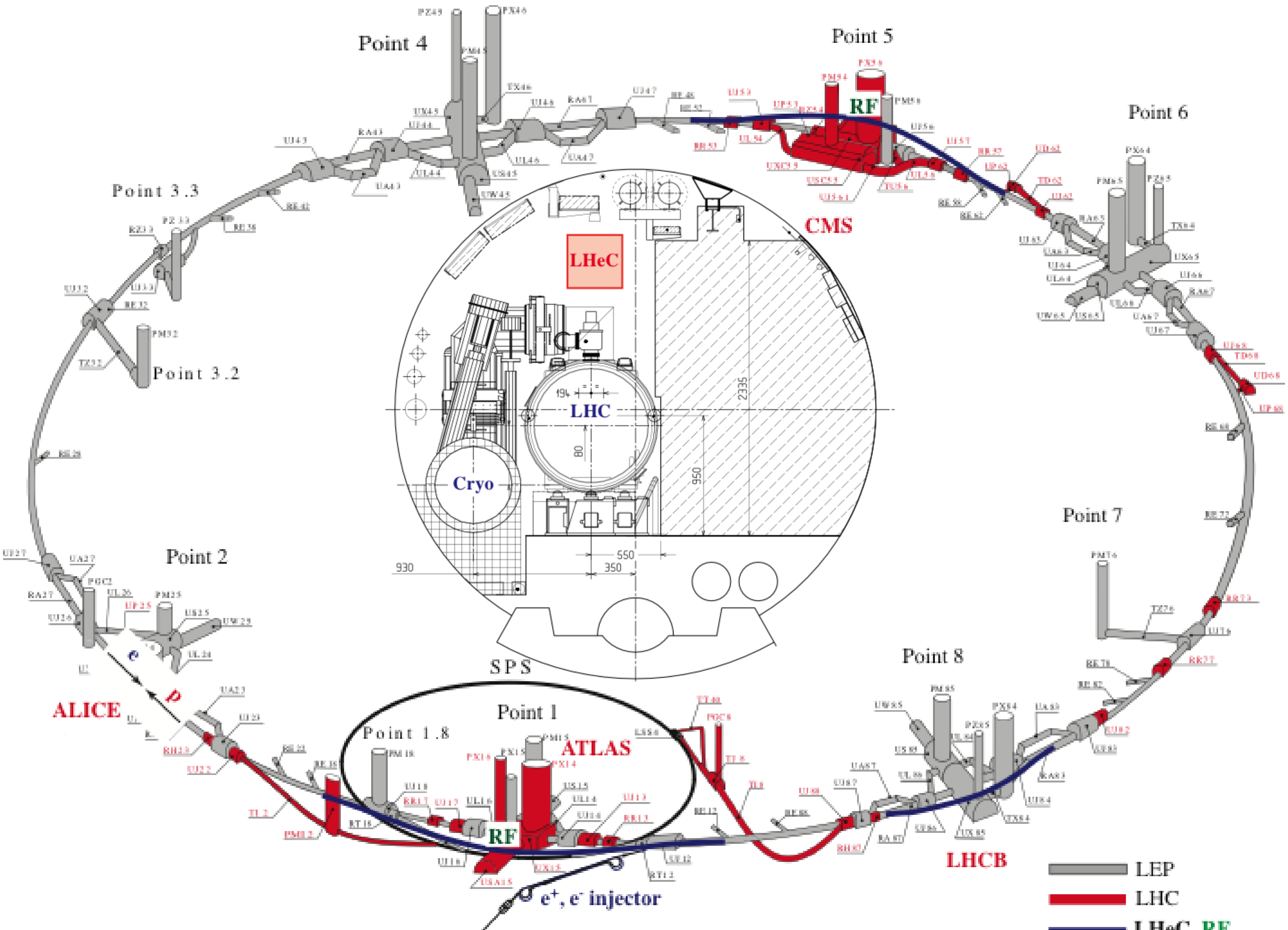
SHIELDING

RAD-TOL DESIGN

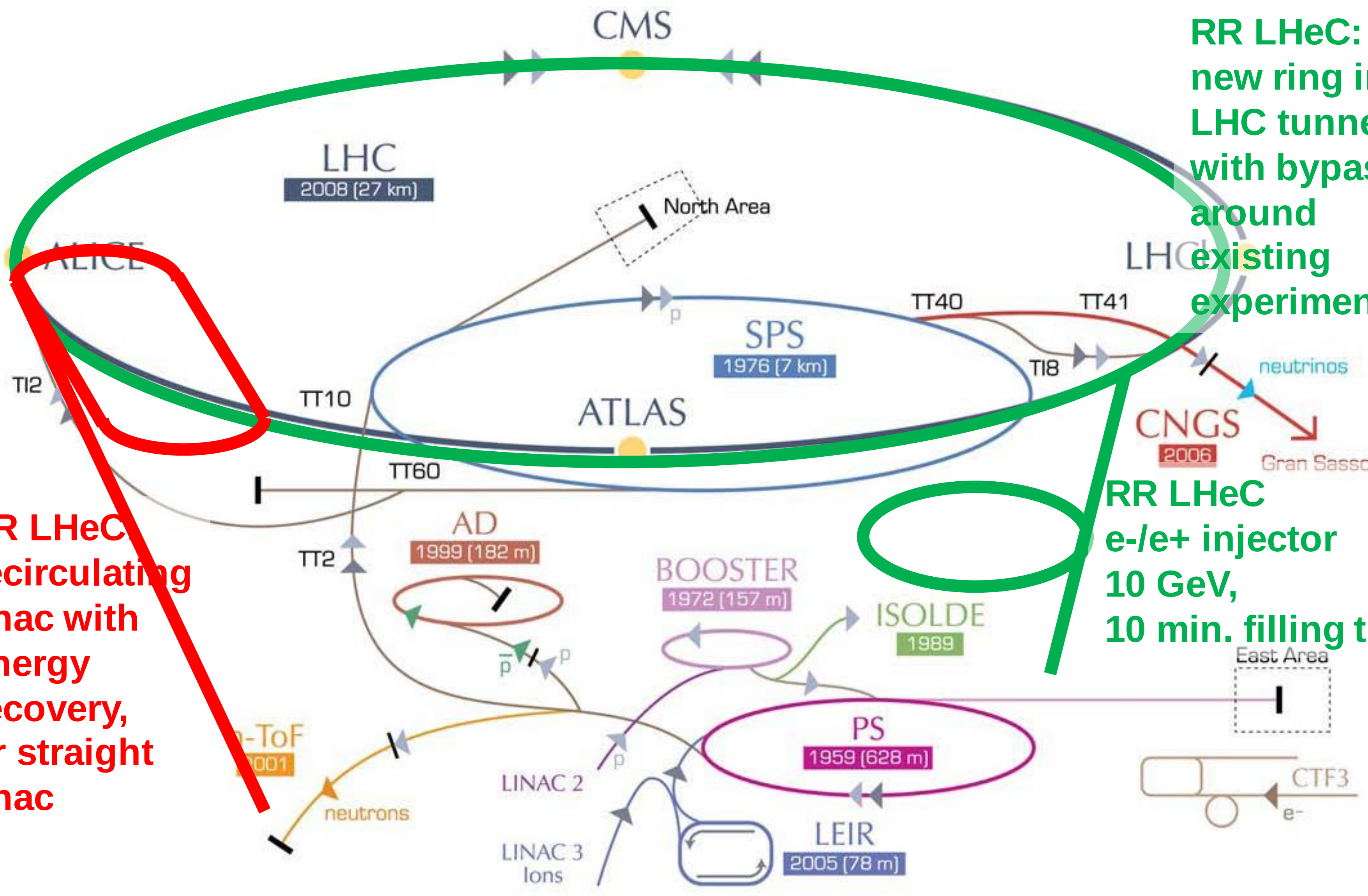
~~CIVIL ENGINEERING~~

LHeC

LHeC Ring-Ring Layout and Integration



LHeC options: RR and LR



RR LHeC: new ring in LHC tunnel, with bypasses around existing experiments

RR LHeC e-/e+ injector 10 GeV, 10 min. filling time

LR LHeC: recirculating linac with energy recovery, or straight linac

LHeC Planning and Timeline

- We assume the LHC will reach end of its lifetime with the end of the HL-LHC project:

  -Goal of integrated luminosity of 3000 fb^{-1} with 200fb^{-1} to 300fb^{-1} production per year → ca. 10 years of HL-LHC operation

  -Current planning based on HL-LHC start in 2022

  → end of LHC lifetime by 2032 to 2035

- LHeC operation:

  -Luminosity goal based on ca. 10 year exploitation time (100fb^{-1})

  -LHeC operation beyond or after HL-LHC operation will imply significant operational cost overhead for LHC consolidation

LHeC Tentative Time Schedule

-Only 2 long shutdowns planned before 2022

-Only 10 years for the LHeC from CDR to project start.

(Other smaller projects like ESS and PSI XFEL plan for 8 to 9 years [TDR to project start] and the EU XFEL plans for 5 years from construction to operation start)

HERA required ca.10 years from proposal to completion

W ...es for the project time line on the experience of other projects, such as (LEP, ... LINAC4 at CERN and the European XFEL at DESY and the PSI XFEL)

LHeC Options: Executive Summary

Ring-Ring option:

-We know we can do it: → LEP 1.5

-Challenge 1: integration in tunnel and co-existence with LHC HW

-Challenge 2: installation within LHC shutdown schedule

Linac-Ring option:

-Installation decoupled from LHC operation and shutdown planning

-Infrastructure investment with potential exploitation beyond LHeC

-Challenge 1: technology → high current, high energy SC ERL

-Challenge 2: Positron source