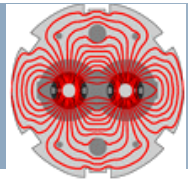




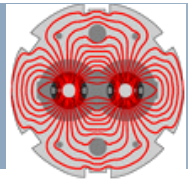
LATEST RESULTS FROM THE LHC
-LPCC and the CERN Summer Student Programme Committee
12 July 2012

LHC operations: status and prospects

Giulia Papotti for the LHC team



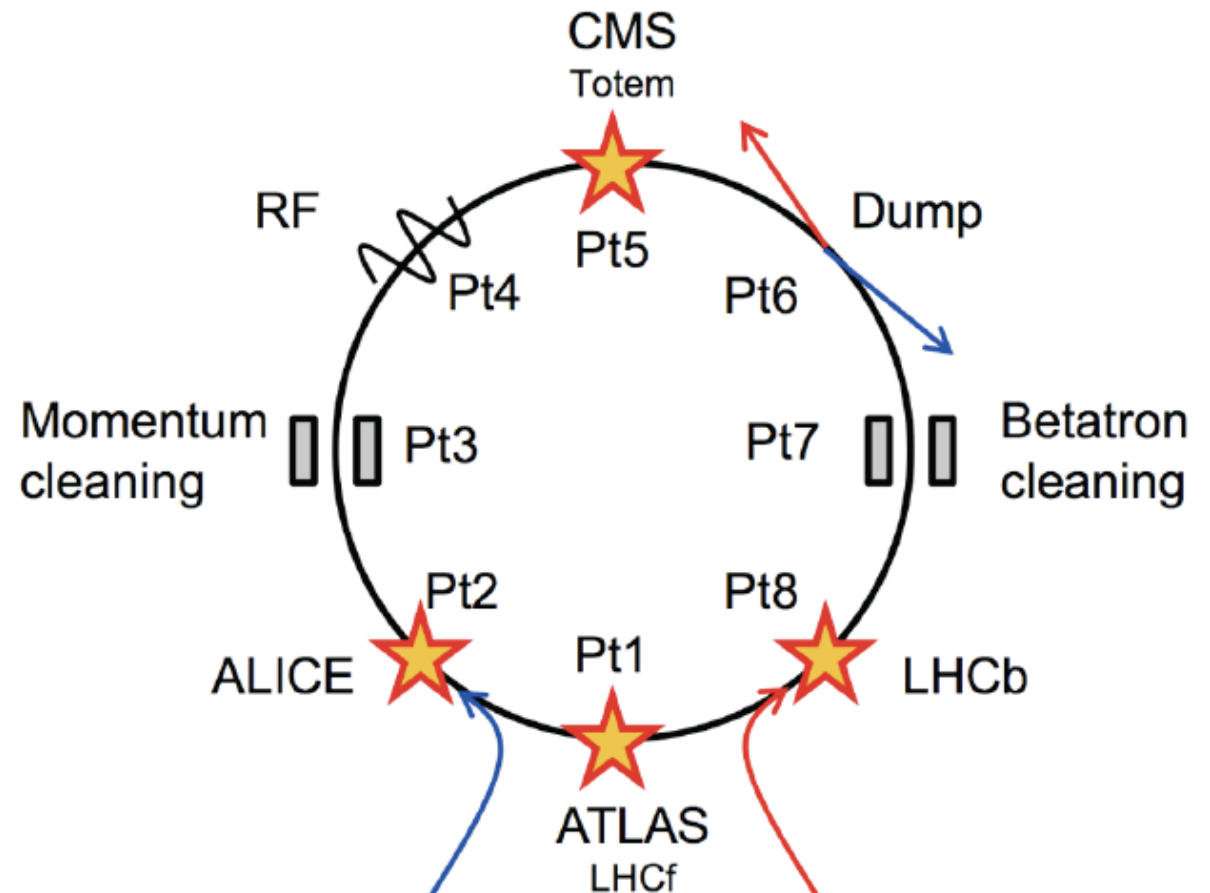
- reminders
 - LHC layout
 - luminosity
- 2012 operational parameters
- nominal cycle
- availability, turnaround and some statistics
- issues
 - e.g. beam instabilities
- outlook to the future

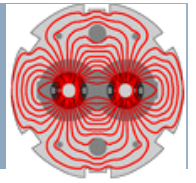


- Large Hadron Collider: very big, very cold, very high energy

- 8 arcs (~3km)
- 8 straight sections (~700m)
- two-in-one magnet design

- 4 Interaction Points (IPs)
 - IP1, 2, 5 and 8
- IP2 and 8: beam injection
- IP6: beam dump region
- IP4: RF (acceleration) and beam instrumentation
- IP3/7: beam cleaning (collimators)





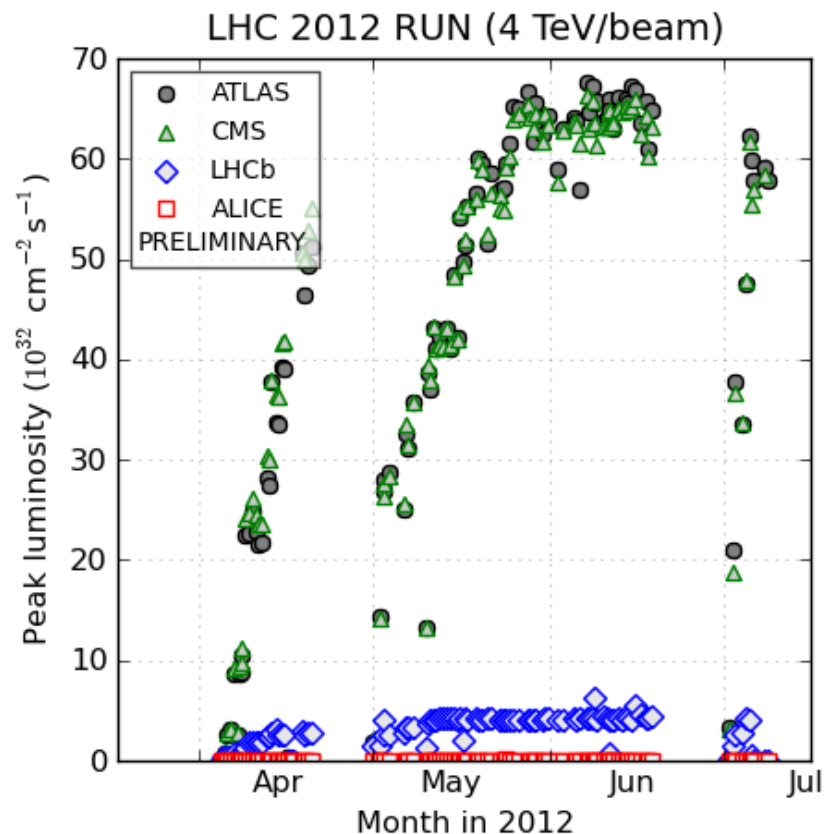
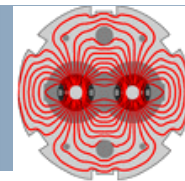
definition: $N = \sigma \int L dt$

- N: number of events (e.g. 5)
- σ : cross section (e.g. 0.5 fb, 1 fb = 10^{-39} cm²)
- L: instantaneous luminosity (e.g. integrate to 10 fb⁻¹)

from machine parameters:

$$L = \frac{kN^2 f}{4\pi\sigma_x^* \sigma_y^*} F = \frac{kN^2 f \gamma}{4\pi\beta^* \varepsilon} F \quad \text{with} \quad \sigma_x^* = \sigma_y^* = \sqrt{\frac{\beta^* \varepsilon}{\gamma}}$$

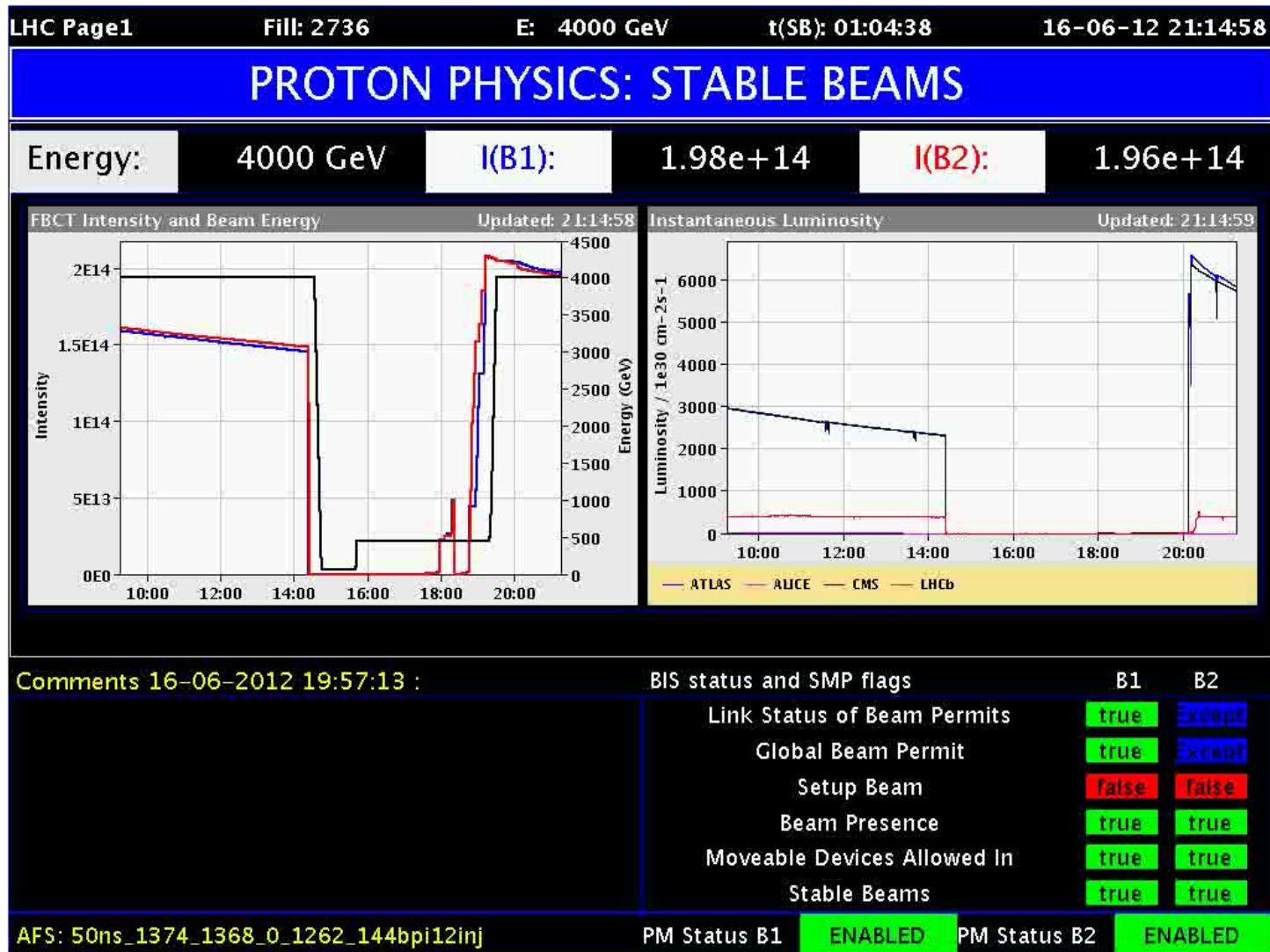
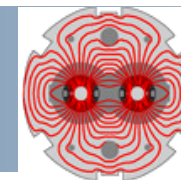
- k: number of colliding bunch pairs (e.g. 1368)
- N: bunch population (e.g. $1.5 \cdot 10^{11}$ ppb)
- f: revolution frequency (11.25 kHz)
- F: geometric factor (≤ 1 , loss) from the crossing angle (e.g. 0.8)
- σ^* : beam size at IP (e.g. $18 \cdot 10^{-6}$ m)
- $\gamma = E/m$ (e.g. 4264)
- ε : normalized emittance (e.g. 2.4 μ m rad)
- β^* : betatron (envelope) function at the IP (e.g. 0.6 m)



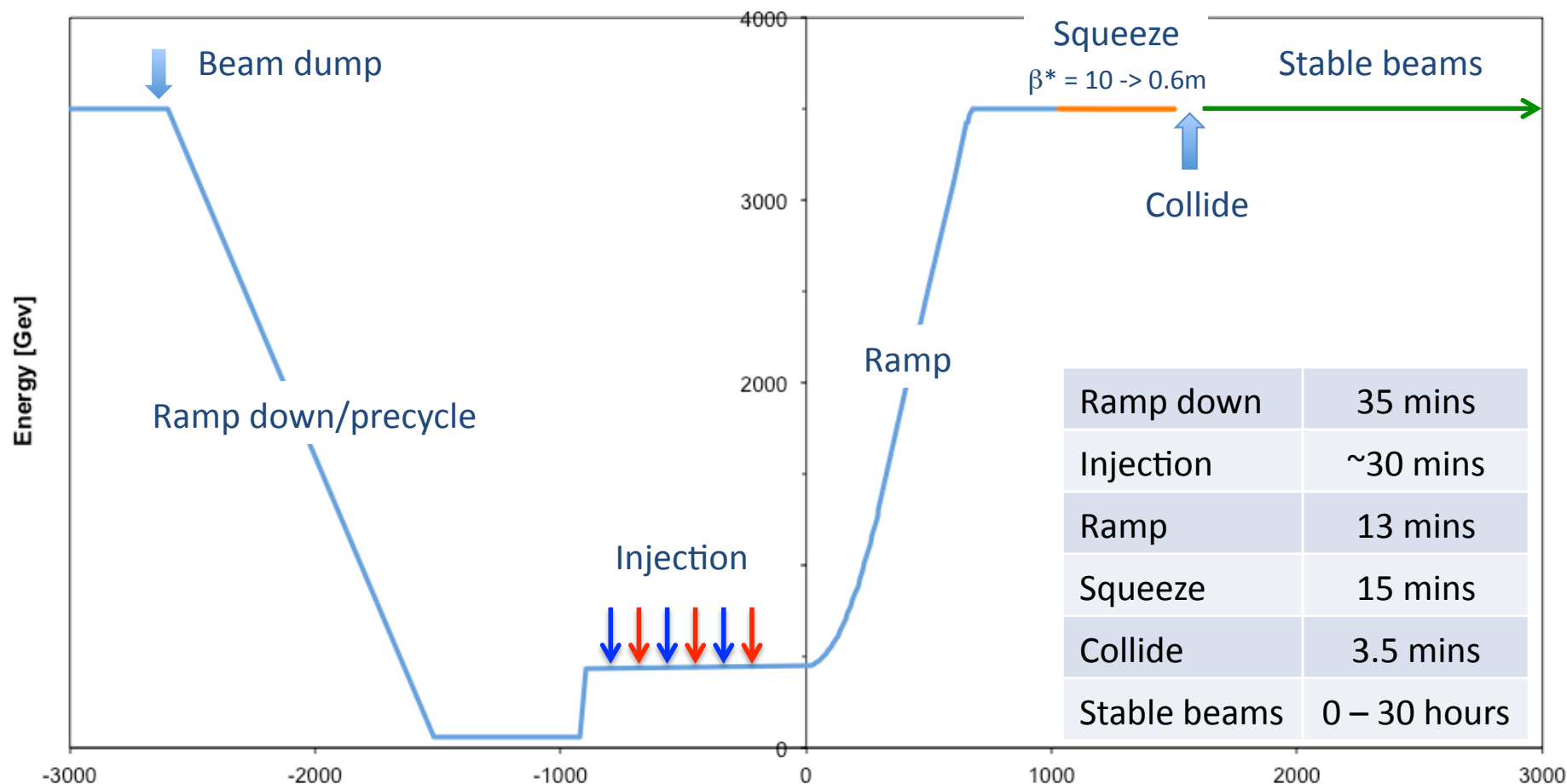
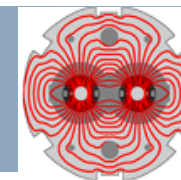
- now at ~65% of design luminosity!
 - ~nominal β^* thanks to excellent aperture and 'tight' collimators

parameter	design	now
beam injection energy (TeV)	0.45	0.45
beam energy (TeV)	7	4
number of bunches per beam	2808	1374
beam envelope at IP 1 & 5 (m)	0.55	0.6
number of particles per bunch (10^{11})	1.15	1.5
norm. transverse emittance ($\mu\text{m rad}$)	3.75	2.4
colliding beam size (μm)	16	18
stored beam energy (MJ)	362	110

- note
 - LHCb and Alice at $\beta^* = 3 \text{ m}$
 - LHCb with tilted crossing
 - Alice with satellite / main collisions
 - 100 MJ = ~21 kg of TNT



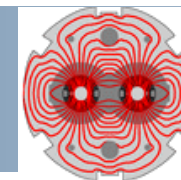
<http://op-webtools.web.cern.ch/op-webtools/vistar/vistars.php?usr=lhc1>



- ‘turn around’ has been as fast as ~2h10m in 2012



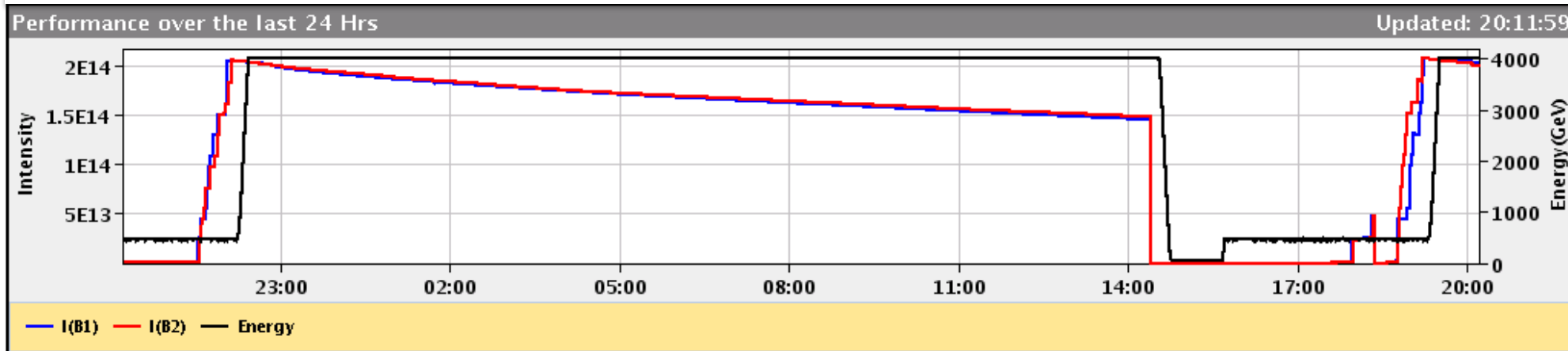
a good day (June 16)



16-Jun-2012 20:12:00 Fill #: 2736 Energy: 4000 GeV I(B1): 2.03e+14 I(B2): 1.99e+14

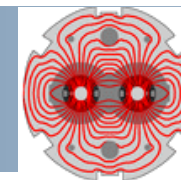
Experiment Status	ATLAS	ALICE	CMS	LHCb
	PHYSICS	STANDBY	STANDBY	PHYSICS
Instantaneous Lumi [(ub.s) ⁻¹]	6577.3	0.000	6345.4	30.4

OP dump
MKI cool down
TL steering



<http://op-webtools.web.cern.ch/op-webtools/vistar/vistars.php?usr=LHC3>

a bad day (July 5)



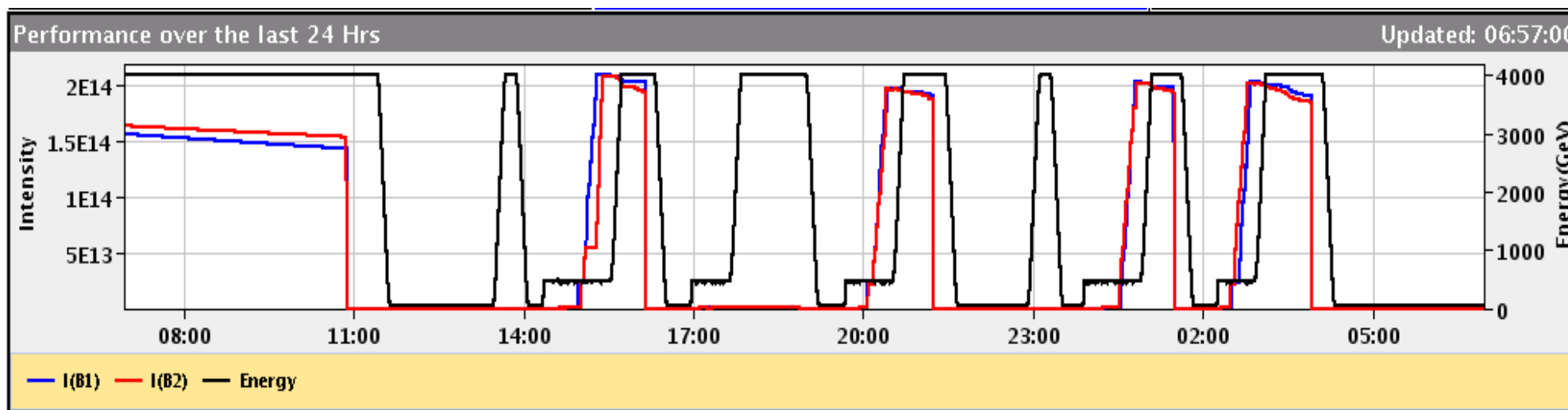
QPS RQ4/5.L1

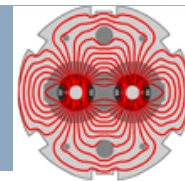
losses going
into collision
test ramp

storm

losses going
into collision

RB45 trip



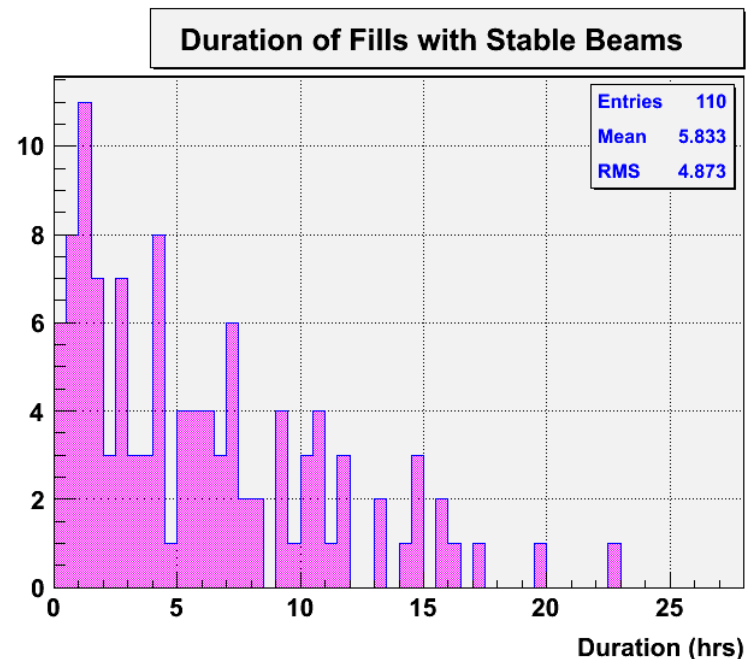


Mode: Proton Physics
Number of Fills: 261
Time in SB: 26 days 0 hrs 12 mins



Access - No beam	: 13.58%
Machine setup	: 27.23%
Beam in	: 14.67%
Ramp + squeeze	: 7.62%
Stable beams	: 36.9%

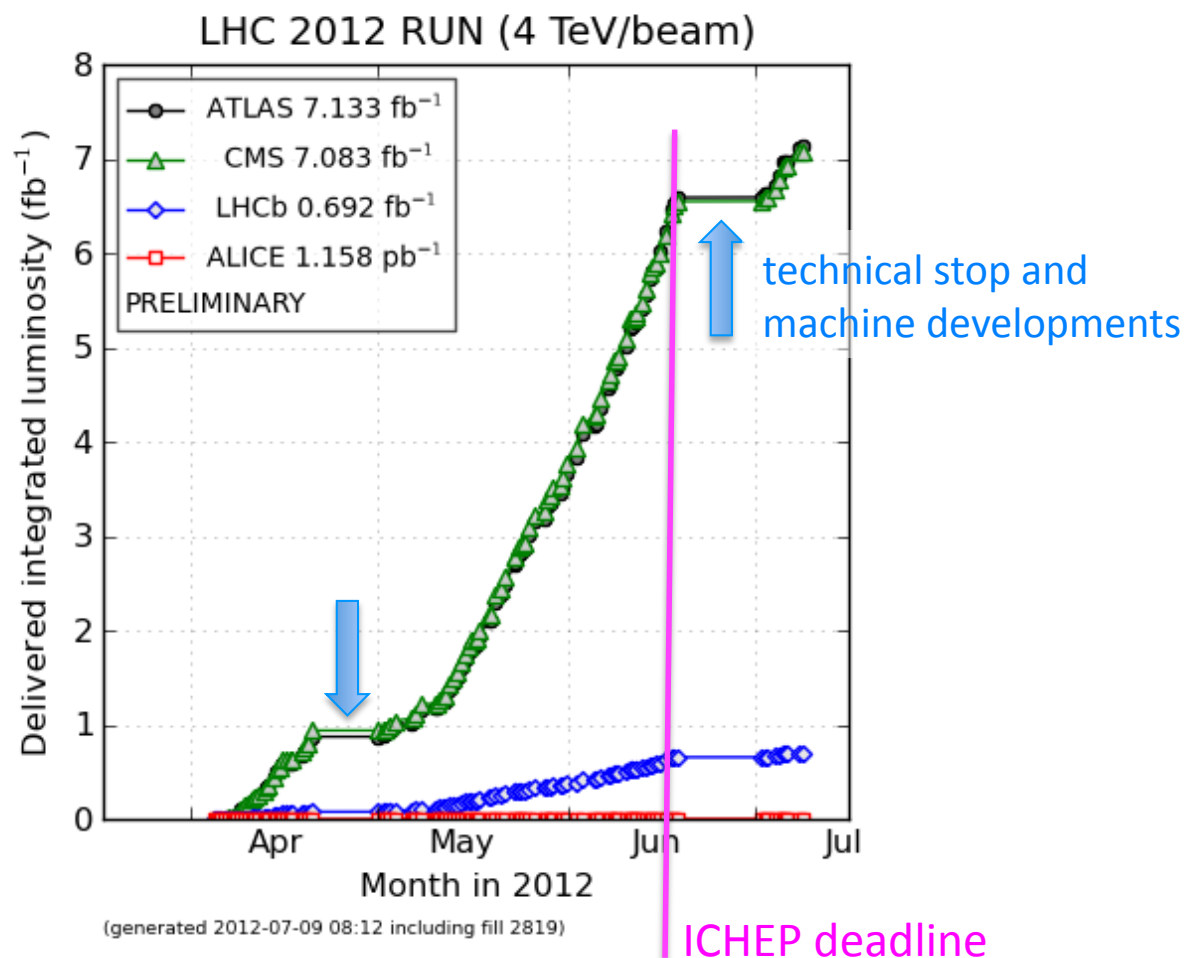
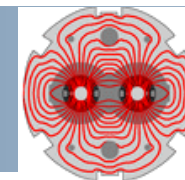
total: ~60% beam in



- luminosity lifetime ~ 20 h
- optimum fill length ~ 12-16 h
 - produce up to ~ 200 pb⁻¹/day
 - achieved: ~ 1 fb⁻¹/week
- beams frequently dumped before due to HW issues

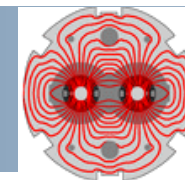
<https://lhc-statistics.web.cern.ch/LHC-Statistics/>

2012 luminosity production

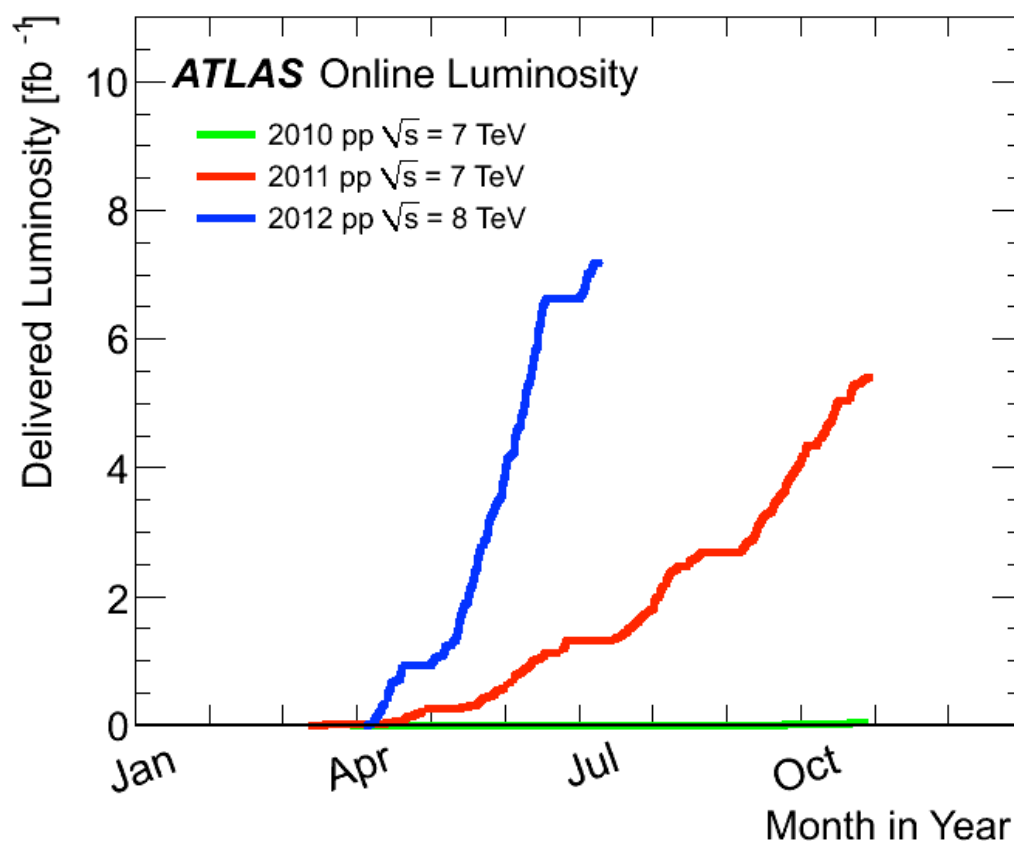


...and do not forget the experiment's efficiency!

<http://lpc.web.cern.ch/lpc/> or <https://lhc-statistics.web.cern.ch/LHC-Statistics/>

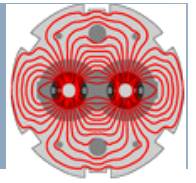


- 2010: achieve an inst. luminosity of 10^{32} Hz/ub $\rightarrow$ did 2×10^{32} Hz/ub
- 2011: integrate at least 1 fb^{-1} $\rightarrow$ did 5.5 fb^{-1}
- 2012: integrate 'enough' ($\sim 15\text{-}20 \text{ fb}^{-1}$)
 - at least 5 fb^{-1} for ICHEP $\rightarrow$ did $>6 \text{ fb}^{-1}$

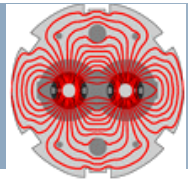




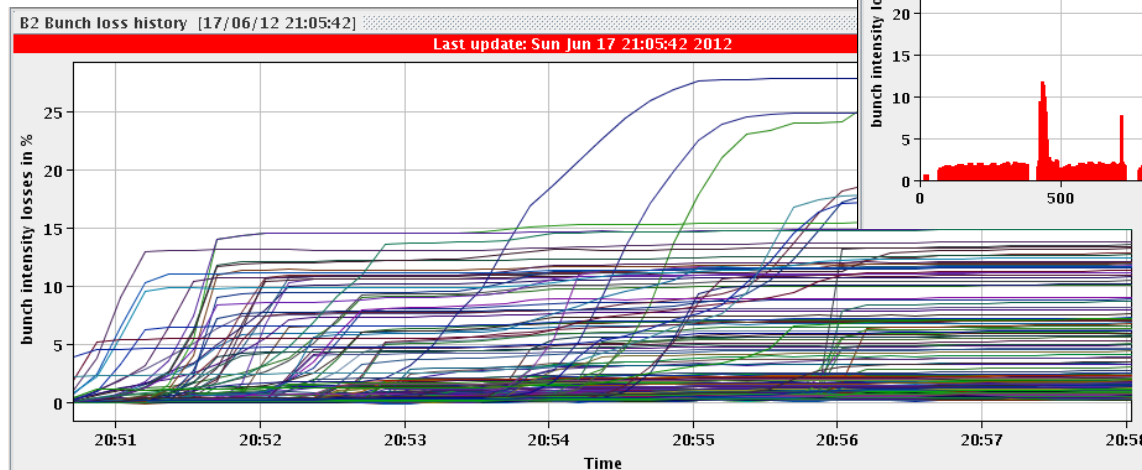
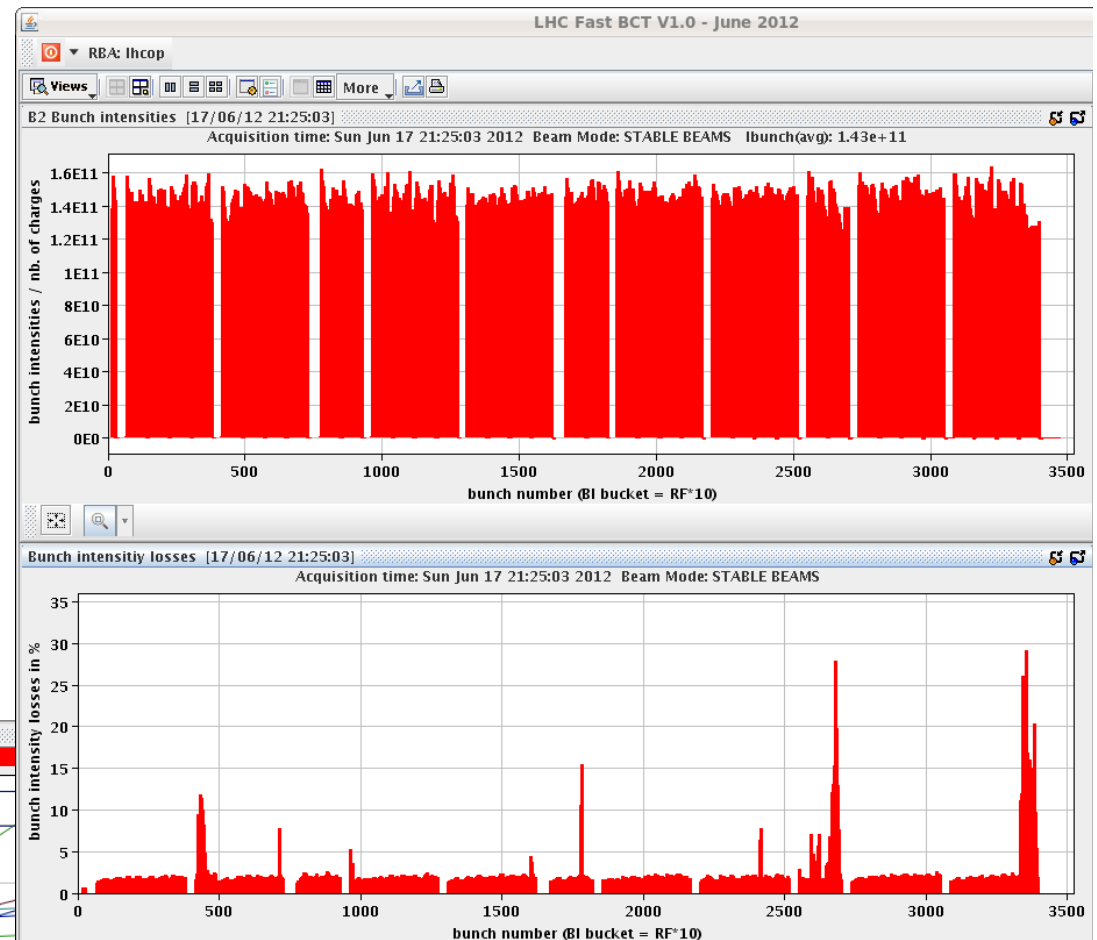
also have plenty of problems...

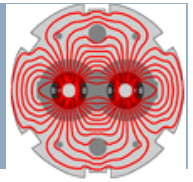


- some acronyms I have no time to detail (random order):
 - Unidentified Falling Objects (UFOs), i.e. fast loss events
 - increased loss thresholds, likely issue for higher energy
 - radiation to electronics (Single Event Effects)
 - ongoing campaign: shielding, relocation, hardware/firmware fixes...
 - electron cloud: will hit us with 25 ns
 - scrubbing run and machine developments already this year
 - beam induced heating (e.g. on injection kickers)
 - beam instabilities



- sometimes observe losses on selected bunches
 - beam stability needs interplay of tune, chromaticity, octupole current, beam-beam force, ...
 - accelerator physicists working on understanding and solutions



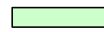


	July			Aug				Sep				Scrubbing run (date tbc)	
Wk	27	28	29	30	31	32	33	34	35	36	37	38	39
Mo	2	9	VdM scans [48 h]	23	30	6	13	20	27	3	10	17	
Tu		Floating MD [48 h]						500 m [24 h]	Floating MD [48 h]				
We		90 m [24 h]										TS3	
Th								500 m [24 h]		J. Genevois			
Fr	90 m [24 h]												MD
Sa													
Su													

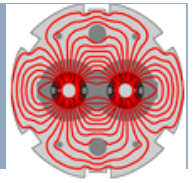
Scrubbing run
(date tbc)

	Oct			Nov					Dec					
Wk	40	41	42	43	44	45	46	47	48	49	50	51	52	
Mo	1	8	15	22	29	5	12	19	26	3	10	17		
Tu													Xmas	
We														
Th											MD		Christmas technical stop	
Fr														
Sa														
Su														

p run end
was here!

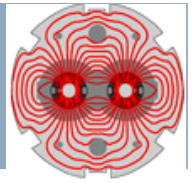
	Technical Stop
	Recommissioning with beam
	Machine development
	Special physics runs

- p run extended to provide more data
- coming up also:
 - Machine Developments
 - highlights: beam-beam and stability limits, quench tests, ATS for HL-LHC, levelling by β^* , ...
 - scrubbing run & 25 ns tests



	Jan			Feb				Mar					
Wk	1	2	3	4	5	6	7	8	9	10	11	12	13
Mo	31	7	14	21	28	4	11	18	25	4	11	18	25
Tu	Technical stop												
We													
Th								Powering tests					
Fr													G. Friday
Sa													
Su													

- then Long Shutdown 1 (LS1) will take us into late 2014
 - splice consolidation, radiation effects (SEE) reduction, finish installation of pressure release valves, install collimators with integrated button BPMs, experiments consolidation/upgrades,...
- restart at 6.5/7 TeV and likely 25 ns (for pile-up)
- LS2 in 2018 to prepare for 'ultimate LHC' parameter set
 - phase II collimation upgrade, major injectors upgrades, preparation for crab cavities...



- 2012 another stunning year: abundant production... and discovery!
 - LHC performance continues to exceed our most optimistic expectations
 - machine is reproducible, cycle is solid, machine protection works very well
 - routine collimation of 110 MJ beams without a single quench from stored beams
 - work ongoing for improving availability and parameter optimization
- run was extended to maximize data collection before LS1
 - restart in late 2014 with 25 ns bunch spacing and 6.5/7 TeV
- “the LHC is a beautiful machine and a real testament to those who conceived, built and installed it”

... enjoy the following talks and your stay at CERN!