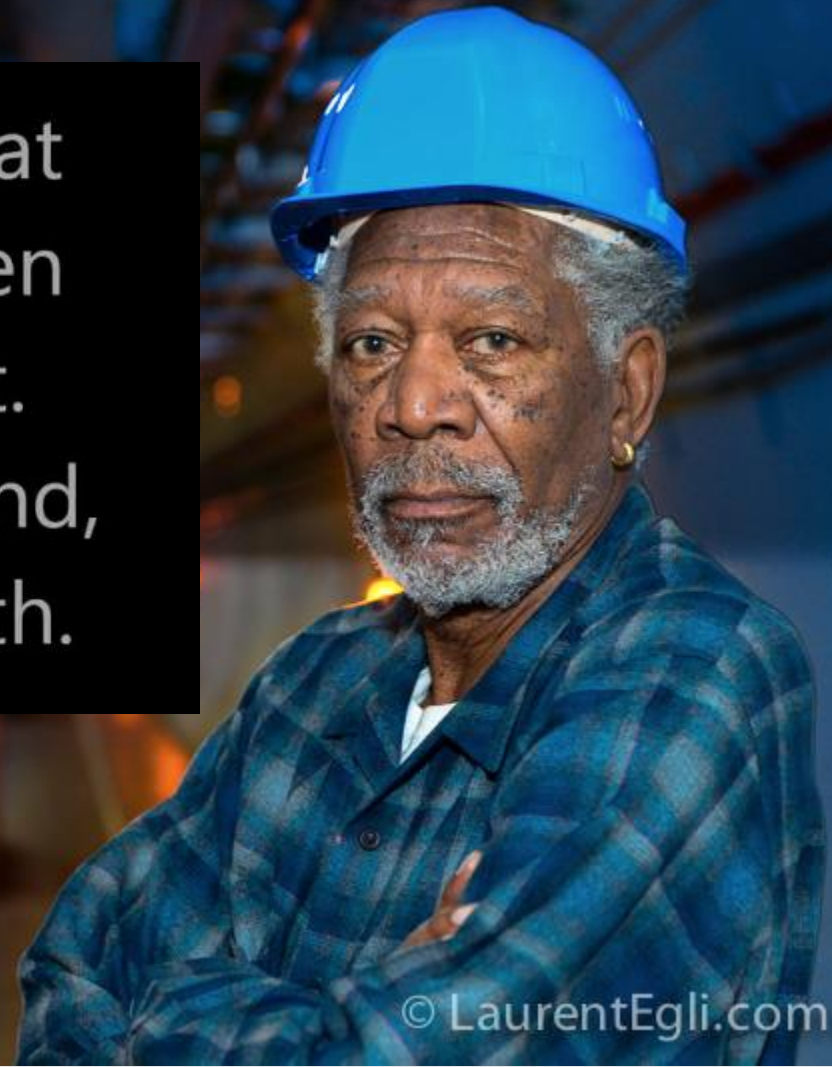


And some things that
should not have been
forgotten were lost.
History became legend,
legend became myth.



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Myth

A traditional story, esp. one that involves gods and heroes and explains a cultural practice or natural phenomenon.

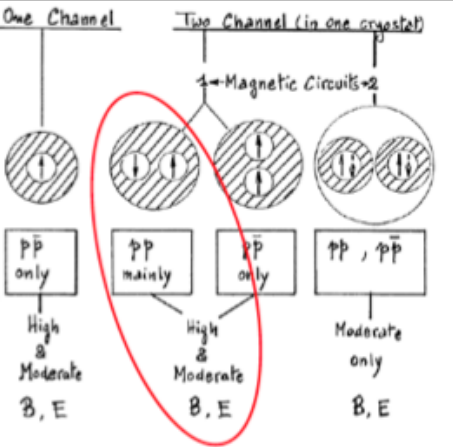
- Conception
- Birth
- Initiation
- Descent into the underworld
- Trial and Quest with the possibility of Hubris followed by Nemesis
- Withdrawal from community for meditation and preparation
- Resurrection and rebirth (and a rival)
- Ascension, apotheosis, and atonement



Repeat as
required

And they usually involve rings

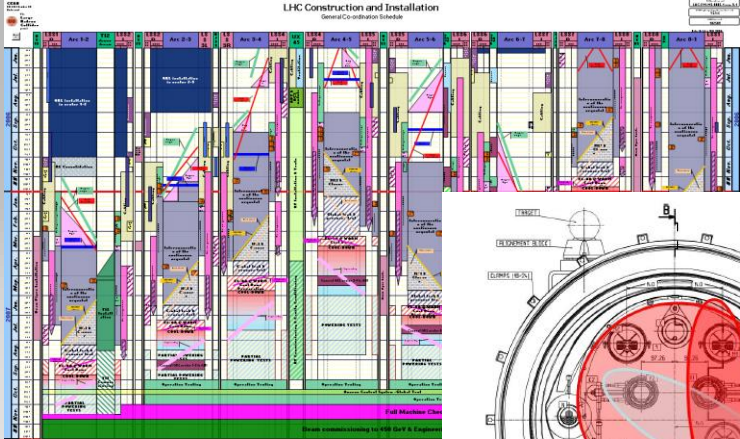
Conception



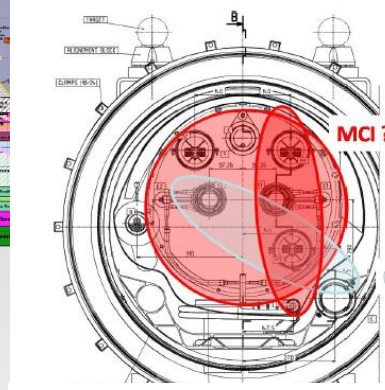
Initiation



LHC approved by the Elders



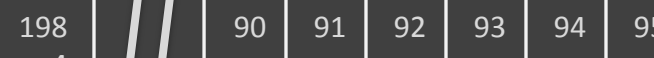
Birth – overdue



Withdrawal from community for mediation and preparation

Rival stumbles

SSC cancelled



Hubris (?) September 10, 2008

37 10:23 IDI moved to +-15mm.

38 10:25 IR1 collimators out. LHC aperture is clear of collimators...

39 10:26 First turn! [Screenshots of beam position monitors and data plots]

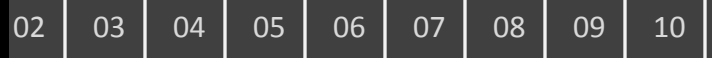
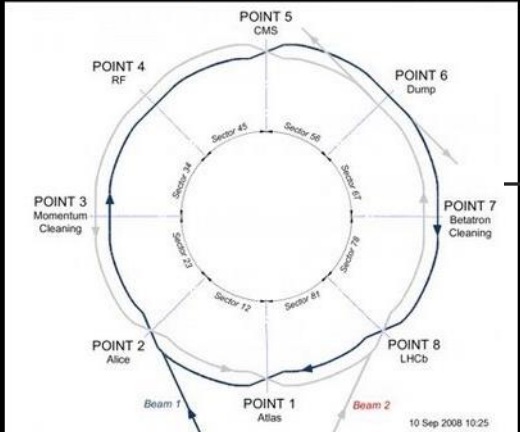
2 turns...!

CONGRATULATIONS CERN!

Sept 10, 2008
1:23 AM PDT

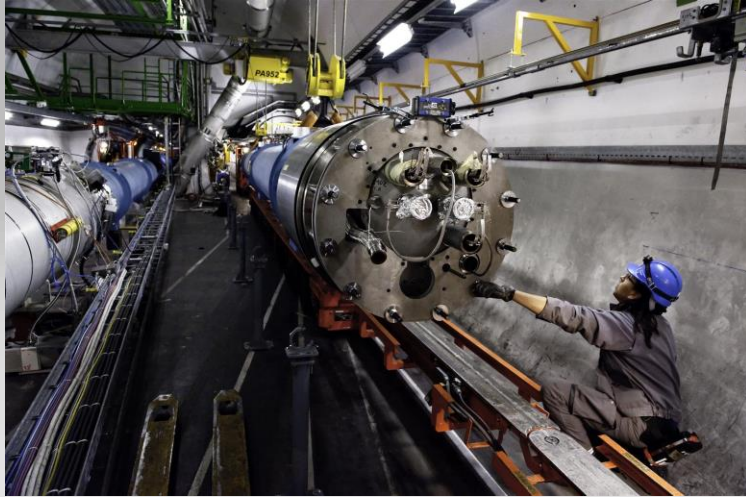
It's a proton, Lots of them.
450 GeV

"And then did all the Muses sing
Of sending protons round the ring."



Nemesis September 19, 2008





Apotheosis and atonement



Trial

4 July, 2012



November 29, 2009

Resurrection and rebirth

2009

2010

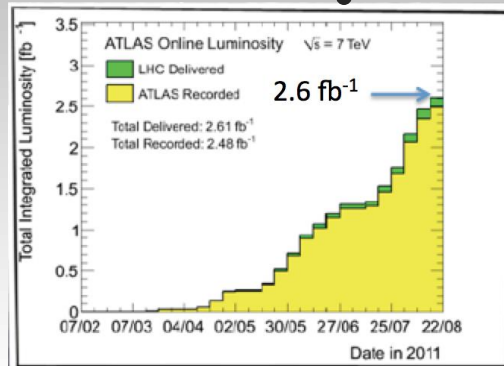
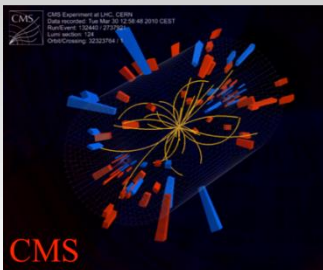
2011

2012

2013

Ascension

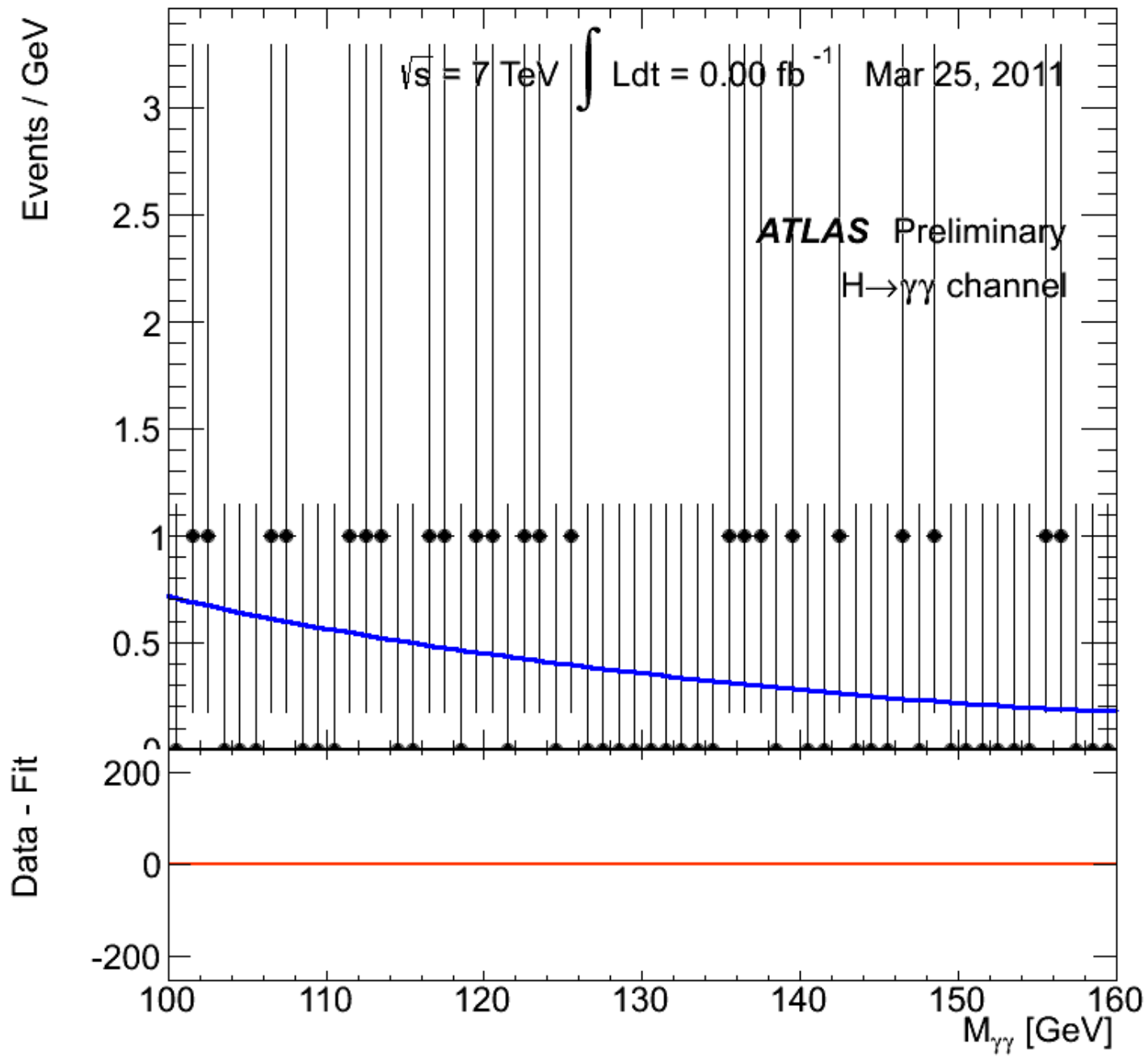
March 30, 2010
First collisions at 3.5 TeV



And let us not forget Fortuna

- Late
- Over budget
- Blew it up after 9 days
- Costly, lengthy repair
- Rival coming up fast on the outside
- Had to run at half energy
- And yet...

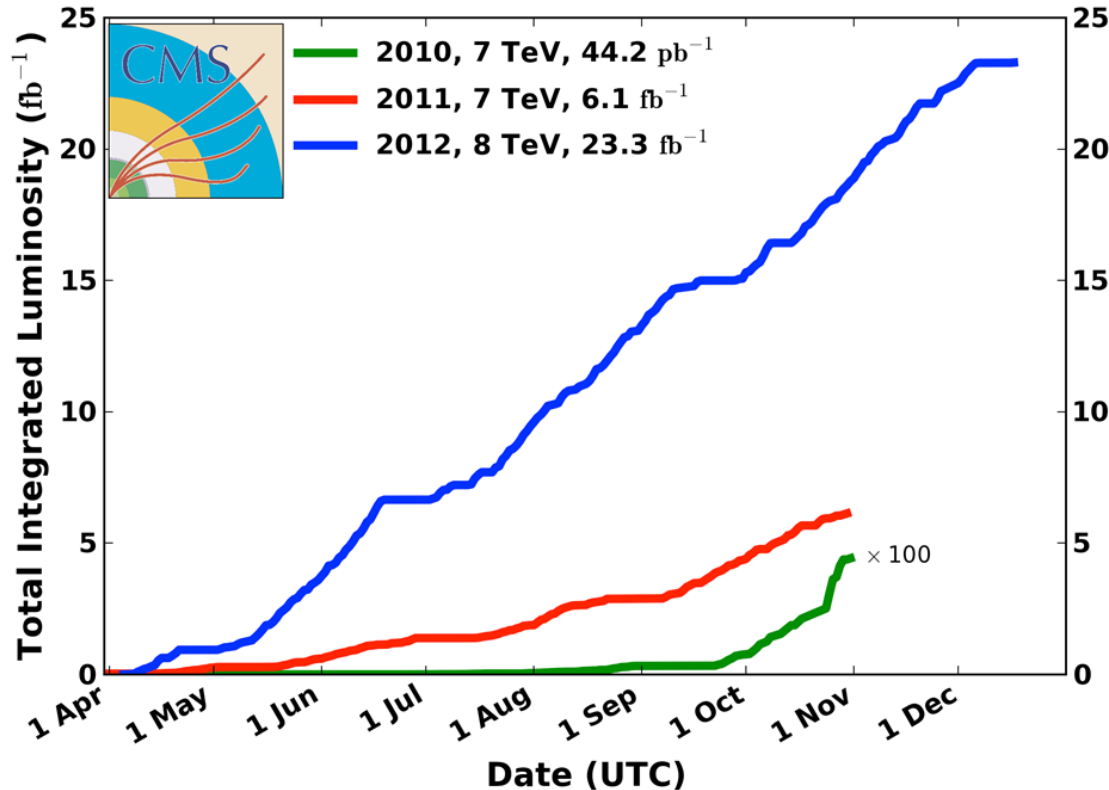




Integrated luminosity 2010-2012

CMS Integrated Luminosity, pp

Data included from 2010-03-30 11:21 to 2012-12-16 20:49 UTC



- 2010: **0.04 fb^{-1}**
 - 7 TeV CoM
 - Commissioning
- 2011: **6.1 fb^{-1}**
 - 7 TeV CoM
 - Exploring the limits
- 2012: **23.3 fb^{-1}**
 - 8 TeV CoM
 - Production

This was not luck.



It was important.



It was important.

Peak performance through the years

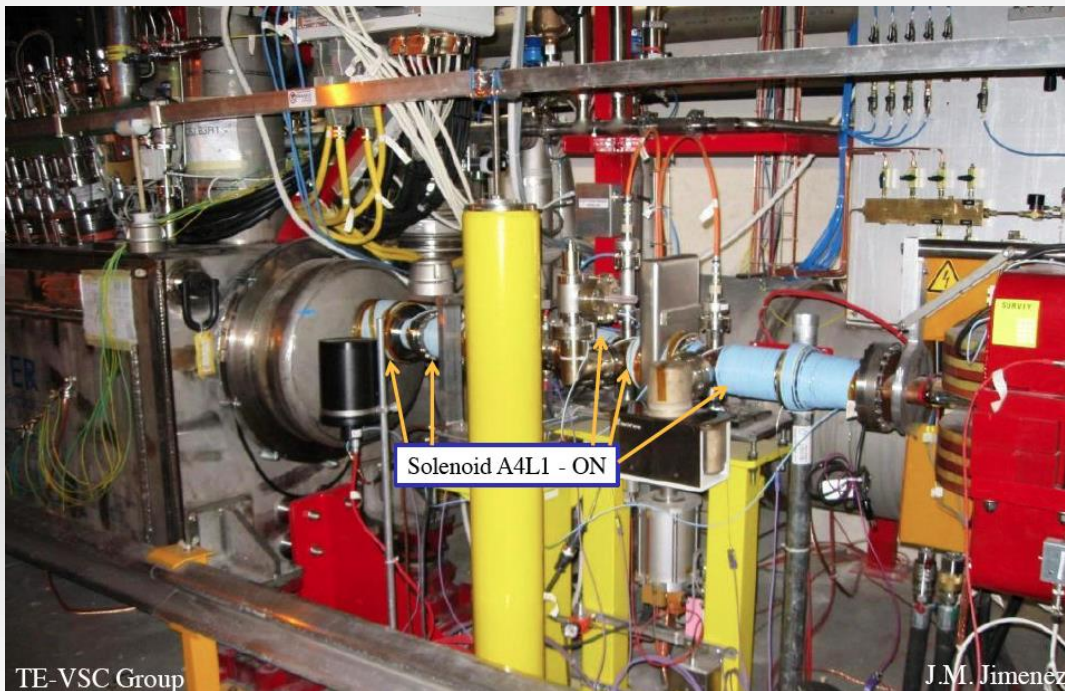
	2010	2011	2012	Nominal
Bunch spacing [ns]	150	50	50	25
No. of bunches	368	1380	1380	2808
beta* [m] ATLAS and CMS	3.5	1.0	0.6	0.55
Max bunch intensity [protons/bunch]	1.2×10^{11}	1.45×10^{11}	1.7×10^{11}	1.15×10^{11}
Normalized emittance [mm.mrad]	~2.0	~2.4	~2.5	3.75
Peak luminosity [cm ⁻² s ⁻¹]	2.1×10^{32}	3.7×10^{33}	7.7×10^{33}	1.0×10^{34}

Operational efficiency and availability was, at least occasionally, not so bad

	2010	2011	2012
Max. luminosity in one fill [pb^{-1}]	6	122	237
Max. luminosity delivered in 7 days [pb^{-1}]	25	584	1350
Longest time in stable beams for 7 days	69.9 hours (41.6%)	107.1 hours (63.7%)	91.8 hours (54.6%)

System performance

- RF, power converters, collimators, beam dumps, injection, magnets, vacuum, transverse feedback, machine protection
- Magnets, magnet protection & associated systems
- Beam instrumentation and beam based feedbacks
- Controls, databases, high level software
- Cryogenics, survey, technical infrastructure, access, radiation protection



Impossible to do justice to the commitment and effort that's gone in to getting, and keeping, the LHC operational

Run 1 – the eight fold way

- Beam from the injectors
- Beam in LHC
 - Good: lifetime, low noise, losses through the cycle, beam-beam tolerance, reproducibility...
 - Somewhat problematic: UFOs, instabilities, beam induced heating, e-cloud, emittance blow-up
- Exploitation
 - Cycle: transfer and injection, ramp, squeeze... parameter control, feedbacks (Q, orbit, ADT...)
 - Bunch spacing, beta*, collimation...
- Machine protection
 - Backbone
 - Beam related (collimation hierarchy, abort gap cleaning, BLM thresholds...)



Run 1 – the eight fold way

- System performance
 - RF, power converters, collimators, beam dumps, injection, magnets, vacuum, transverse feedback, machine protection
 - Magnets, magnet protection & associated systems
 - Beam instrumentation and beam based feedbacks
 - Controls, databases, high level software
 - Cryogenics, survey, technical infrastructure, access, radiation protection
- System availability
- Mitigation
 - R2E, non-conformities (vacuum, RF, STI, ABT...)



Descent into the underworld



LE 27.05.2014



LE TRAIN LMF
ENTRE EN GARE TERMINUS

Frédéric Savary

The Quest

The only stop
seen at LHC so far



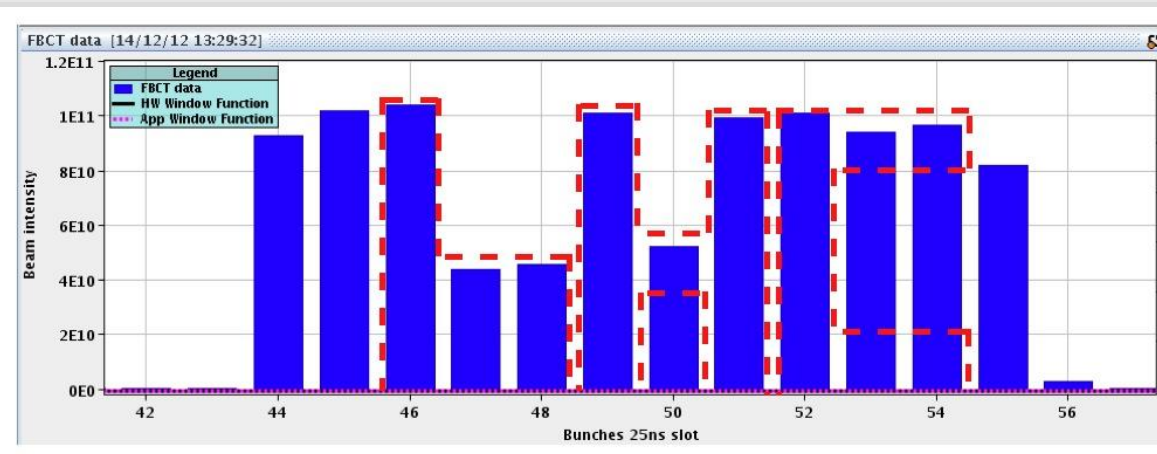
Run 2 – the re-trial (1/2)

Lot of experience but before we get too serious...

- Re-establish robust operational cycle
 - Transfer and injection, ramp...
 - Feedback, orbit references, optics
 - Magnetic cycle – decay, snapback, Q' control
 - Operational procedures (abort gap, scans, levelling)
- Characterize beam and beam related phenomena
 - Lifetime and losses through the cycle
 - UFOs, instabilities, emittance growth...
- Validate parameter choice and ensure maximally safe operating conditions
 - Aperture, collimator hierarchy...

Run 2 – the re-trial

- Fully qualify machine protection system with beam and through the ramp-up
- Commission and bed in instrumentation
- Commission and bed in beam related hardware system through the cycle
- Bed in other hardware systems (controls, QPS...) after major upgrades
- Wrestle with e-cloud, heat-load, vacuum, emittance blow-up...



The Myth of Sisyphus



...The struggle itself toward the heights is enough to fill a man's heart. One must imagine Sisyphus happy.

Albert Camus