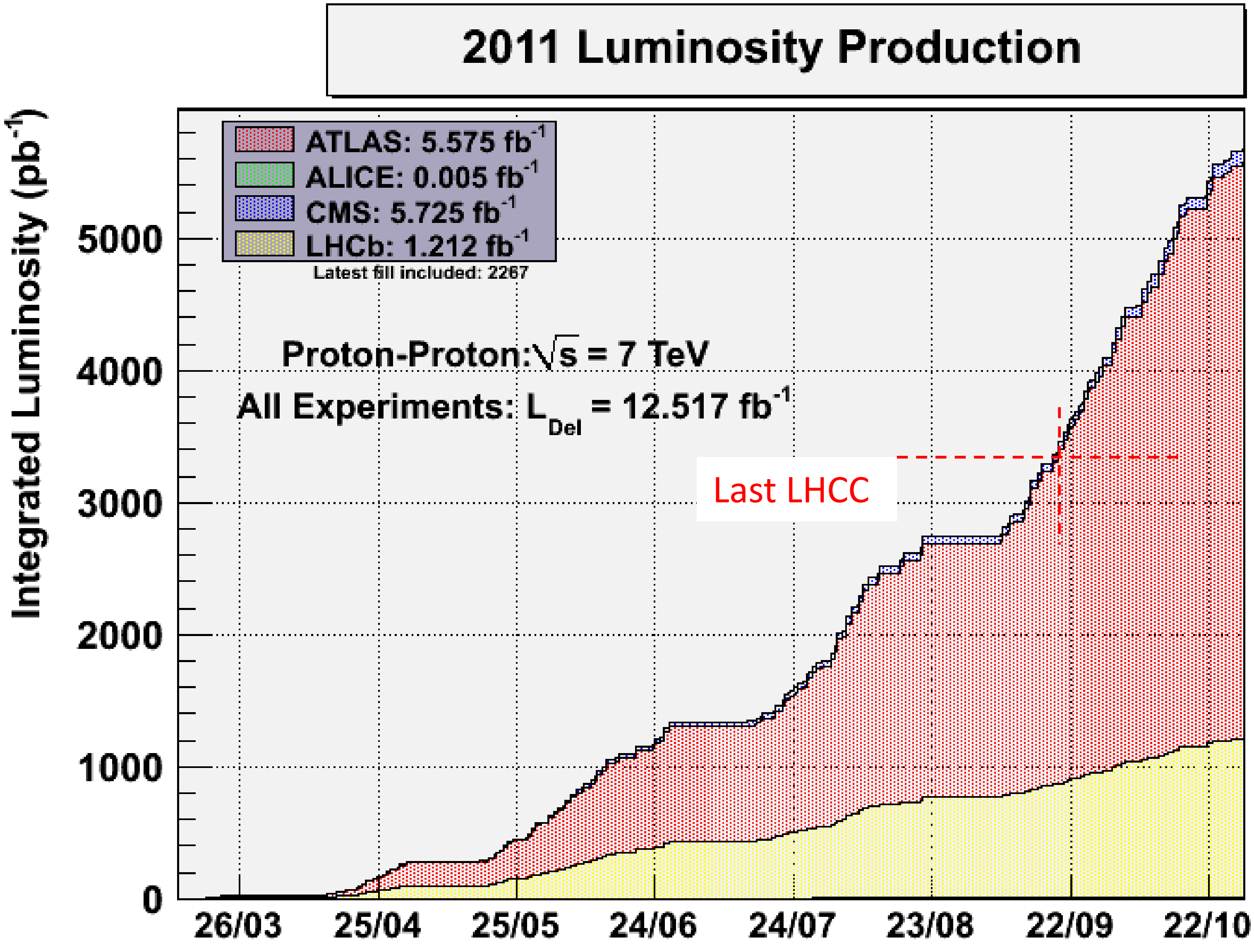
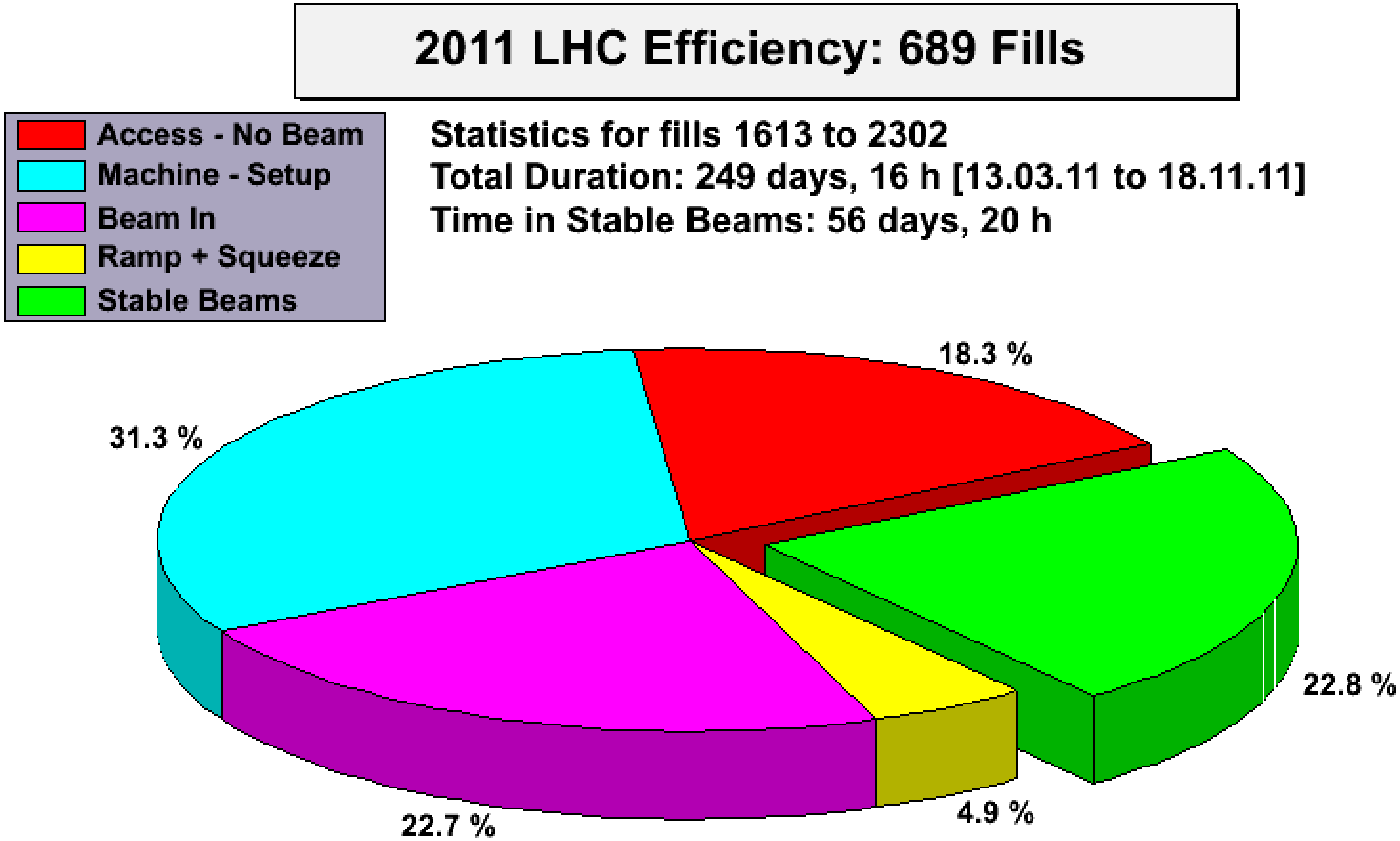
LHC 2011, 2012 and 2015

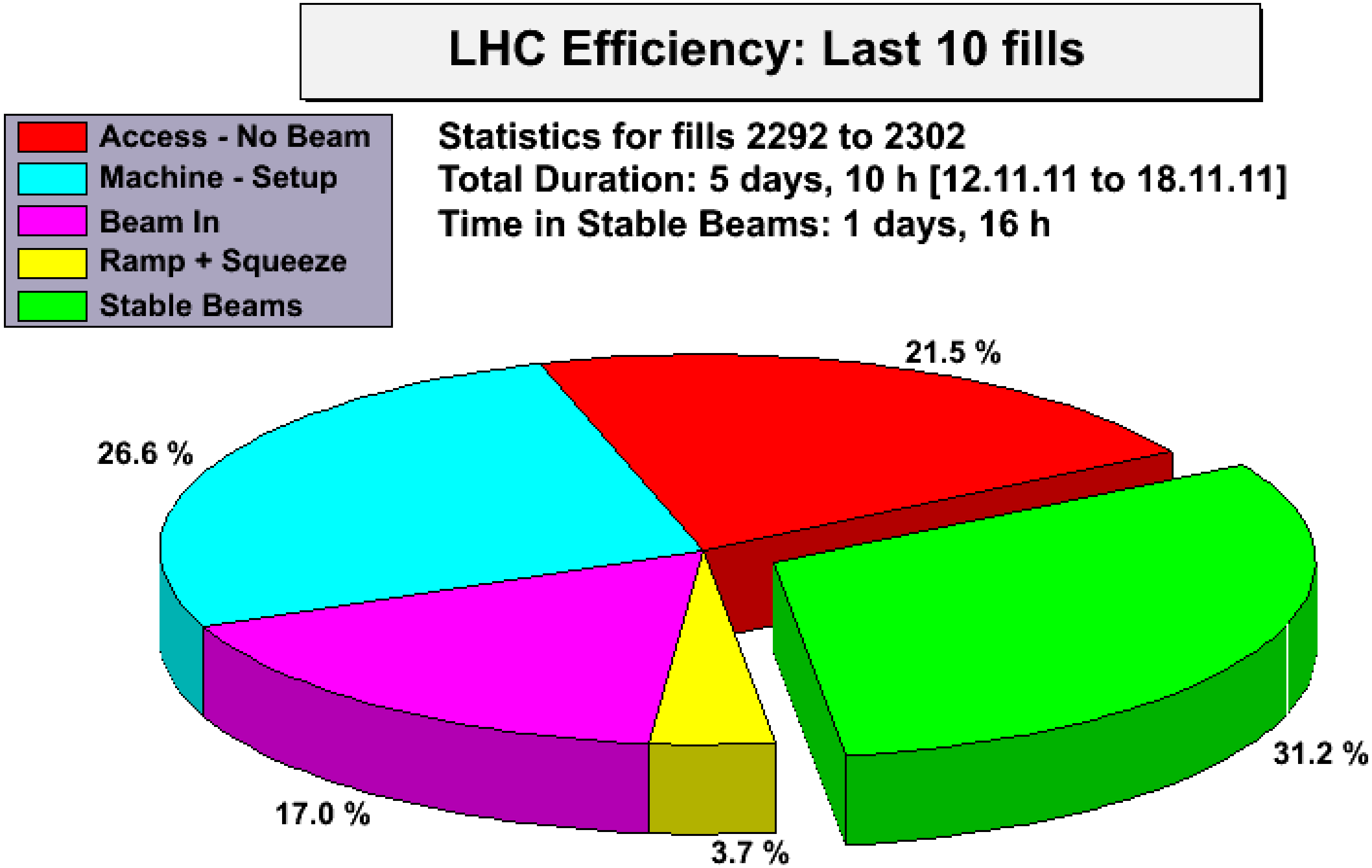
Steve Myers

2011



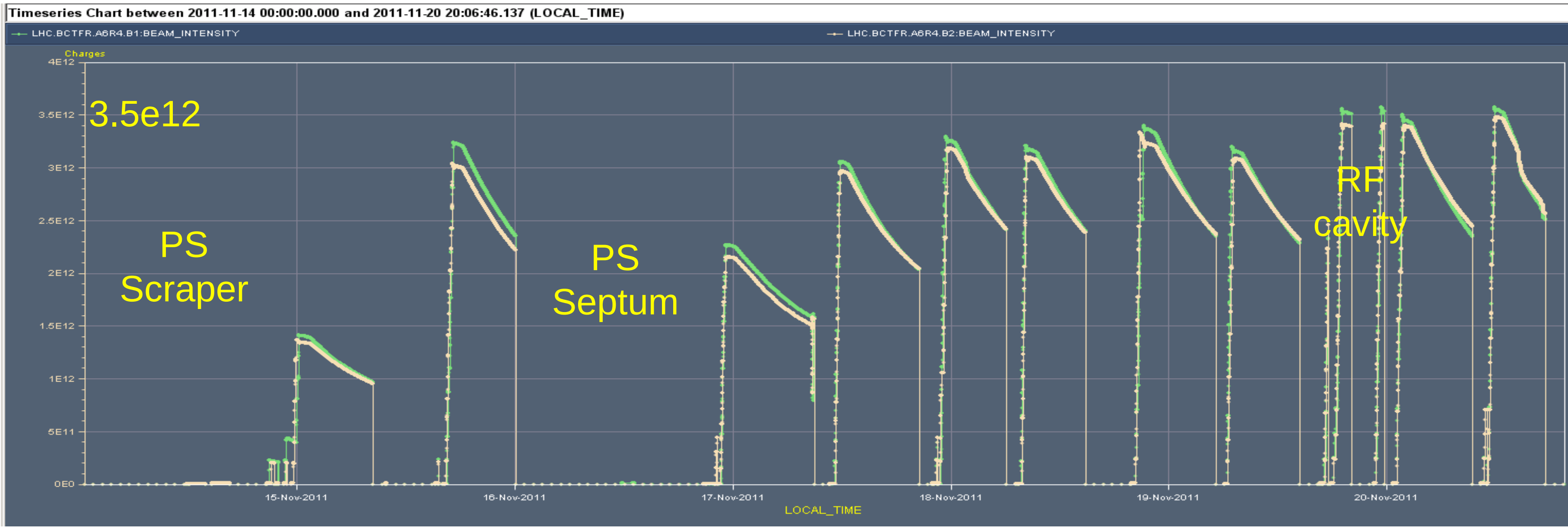
2011 Luminosity Production
ATLAS: 5.575 fb-1
ALICE: 0.005 fb-1
CMS: 5.725 fb-1
LHCb: 1.212 fb-1
Latest fill included: 2267
Proton-Proton:√s = 7 TeV
All Experiments: L_Del = 12.517 fb-1
Last LHCC
Integrated Luminosity (pb-1)
0
1000
2000
3000
4000
5000
26/03
25/04
25/05
24/06
24/07
23/08
22/09
22/10

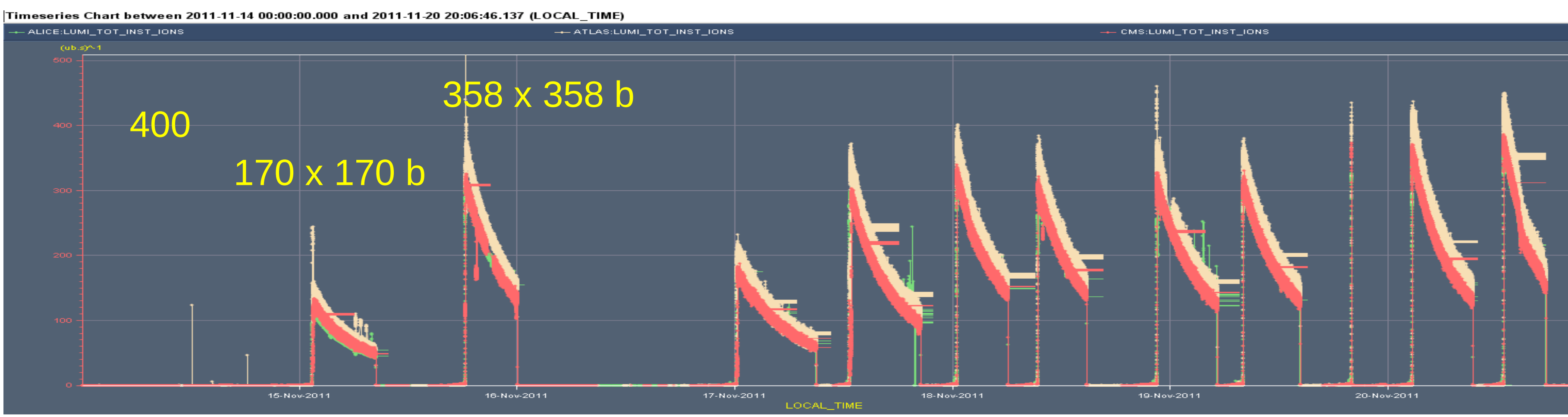

2011 LHC Efficiency: 689 Fills
Access - No Beam
Machine - Setup
Beam In
Ramp + Squeeze
Stable Beams
Statistics for fills 1613 to 2302
Total Duration: 249 days, 16 h [13.03.11 to 18.11.11]
Time in Stable Beams: 56 days, 20 h
18.3 %
31.3 %
22.8 %
22.7 %
4.9 %


LHC Efficiency: Last 10 fills
Access - No Beam
Machine - Setup
Beam In
Ramp + Squeeze
Stable Beams
Statistics for fills 2292 to 2302
Total Duration: 5 days, 10 h [12.11.11 to 18.11.11]
Time in Stable Beams: 1 days, 16 h
21.5 %
26.6 %
31.2 %
17.0 %
3.7 %

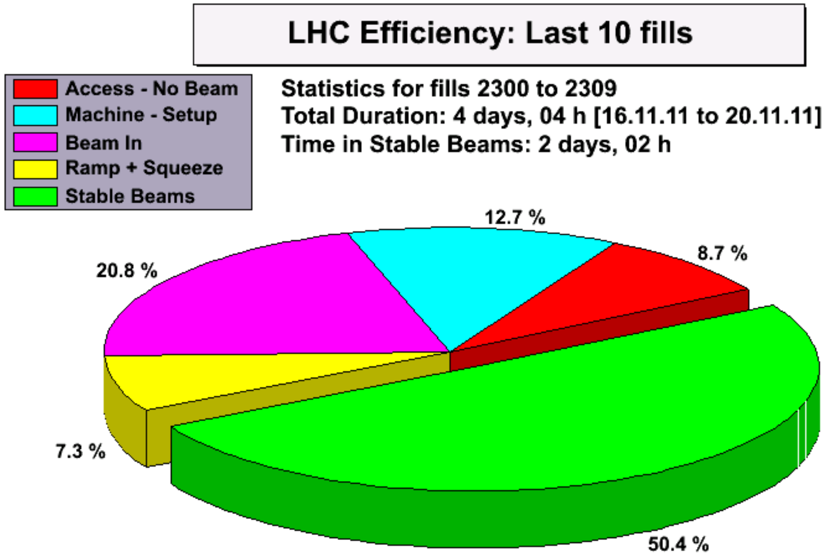
2011 Ions

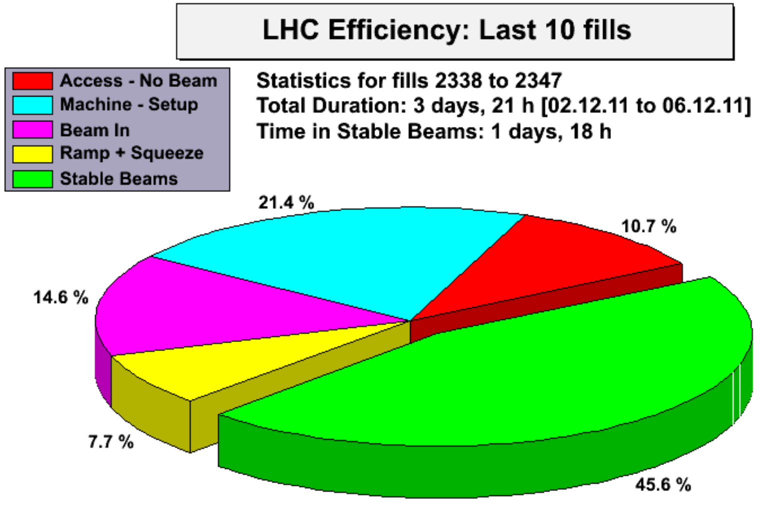
Beam Current and Lumi Plots



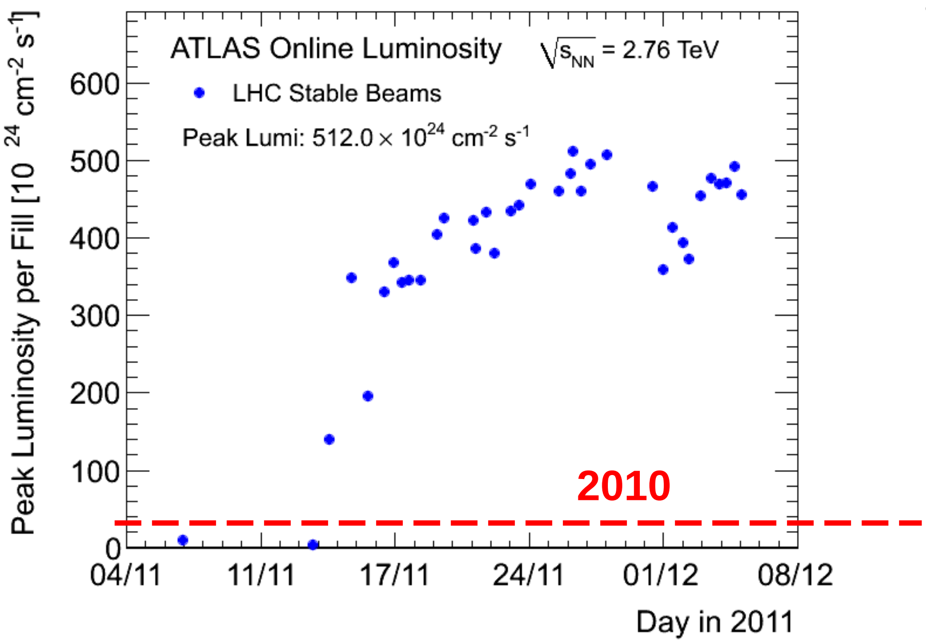


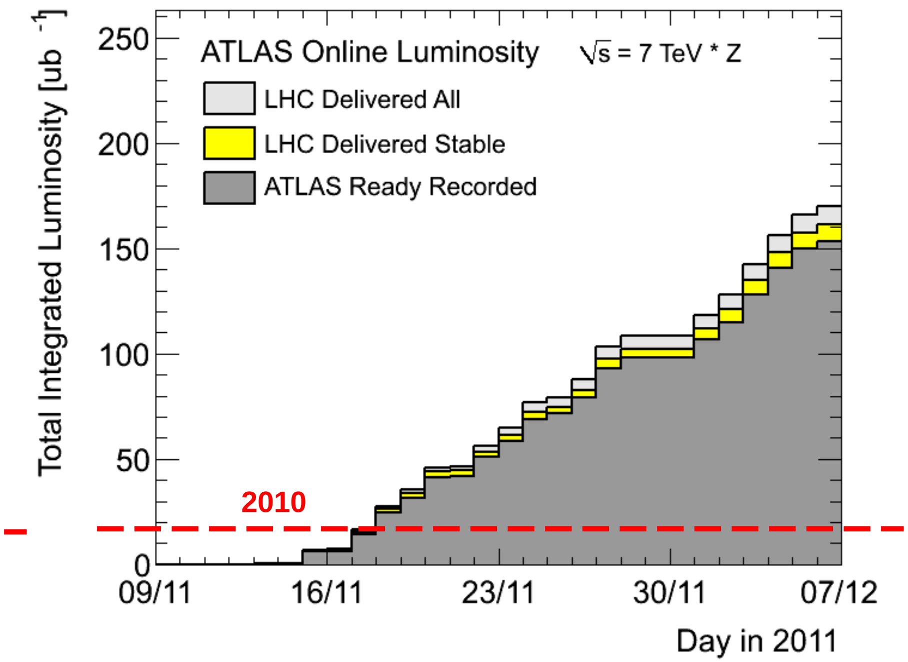
Stable Beams ~ 50 %





Peak and Integrated luminosity





356 bunches

In 2010:

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

Using 2011 Data to Predict

Peak Luminosity

$$L_{peak} = \frac{n_b \cdot N_{bunch,1} \cdot N_{bunch,2} \cdot f_{rev}}{4\pi \cdot \beta^* \cdot \varepsilon_N} \cdot R(\phi, \beta^*, \varepsilon_N, \sigma_s)$$

$$L_{peak} = K_L \cdot (N_{bunch} \cdot n_b) \cdot \left(\frac{N_{bunch}}{\varepsilon_N}\right) = K_L \cdot N_{total} \cdot B$$

$$L_{peak} = K_L \cdot N_{total} \cdot B$$

$$K_L = \frac{f_{rev} \cdot R \cdot \gamma}{4\pi \cdot \beta^*}$$

Peak Luminosity

Procedure

$$L_{peak} = K_L \cdot N_{total} \cdot B$$

$$K_L = \frac{f_{rev} \cdot R \cdot \gamma}{4\pi \cdot \beta^*}$$

From the results of 2011

- Calculate the brightness (B) from the luminosity data

For the first part of 2011 (until "mini Chamonix" at the end of July) the brightness was artificially decreased in the SPS before injection to the LHC. Only the data from the last period of 2011 is relevant

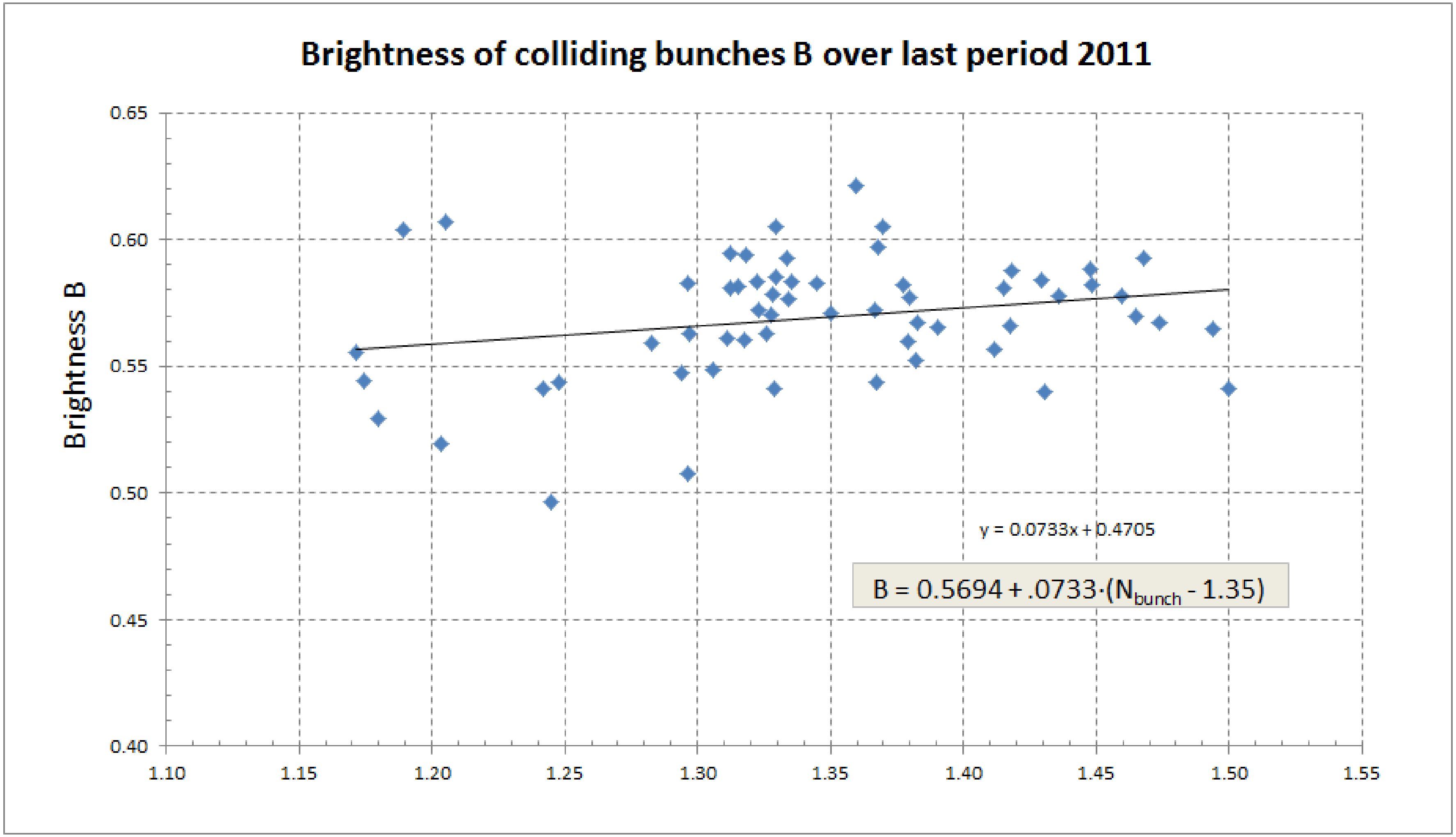
In the mini-Chamonix the presented maximum brightness parameters from the injectors were (at extraction of the SPS)

50ns: N_{bunch} = 1.55E11, with ε_N= 2.0μm; i.e. B_{max} = .775

25ns: N_{bunch} = 1.15E11, with ε_N= 3.3μm; i.e. B_{max} = .348

It was also observed that there was a reduction of the beam brightness when comparing collisions conditions with injection. The reduction was on average roughly 30%

Brightness from Peak Luminosity



From the Luminosity Data of the Last Period of 2011

The brightness in collision is fairly constant at 0.569 at intensities in the range 1.25 to 1.50E11 protons per bunch (colliding). Consequently the average measured loss of brightness from extraction at the SPS to collisions in LHC is 27%: i.e.

$$\frac{B_{inj}}{B_{LHC}} = \frac{.569}{.775} = 73\%$$

The brightness in the LHC (for 50ns bunch spacing) is given by

$$B_{LHC} = .5694 + .0733 \cdot (N_b - 1.35)$$

Or more generally (for different bunch spacings of 25 and 50ns)

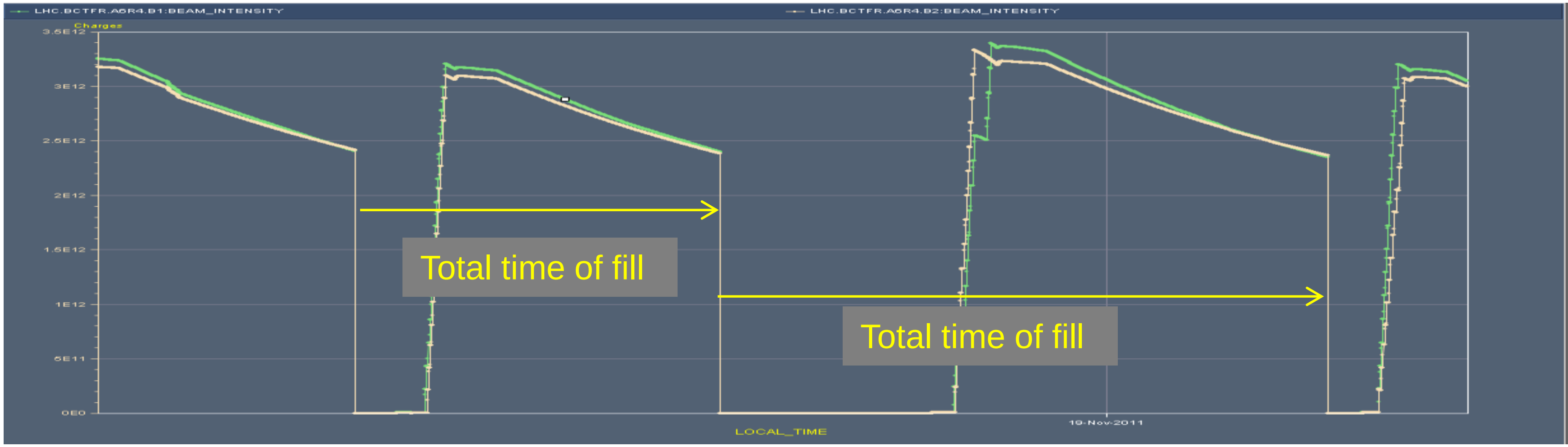
$$B_{LHC} = B_{inj} \cdot (73\%) + .0733 \cdot (N_b - 1.35)$$

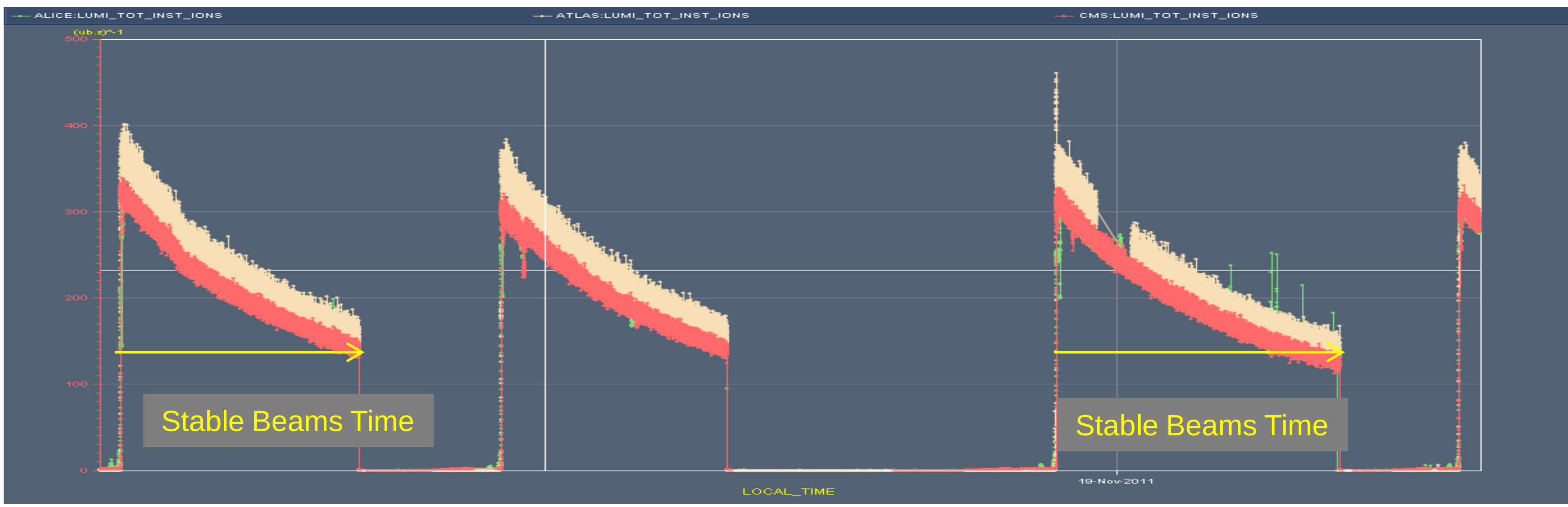
Evaluating Integrated Luminosity

- The Integrated Luminosity is influenced by
  - The peak luminosity
  - The luminosity loss rate (lifetime)
  - The lost time between fills
    - Time to prepare stable beams
    - Technical problems causing beam dumps and inability to refill
- Try to get a statistical model from 2011 fills
- Procedure
  - Calculate L_{ave}/L_{peak} from the 2011 data (time weighted) as a function of L_{peak}.

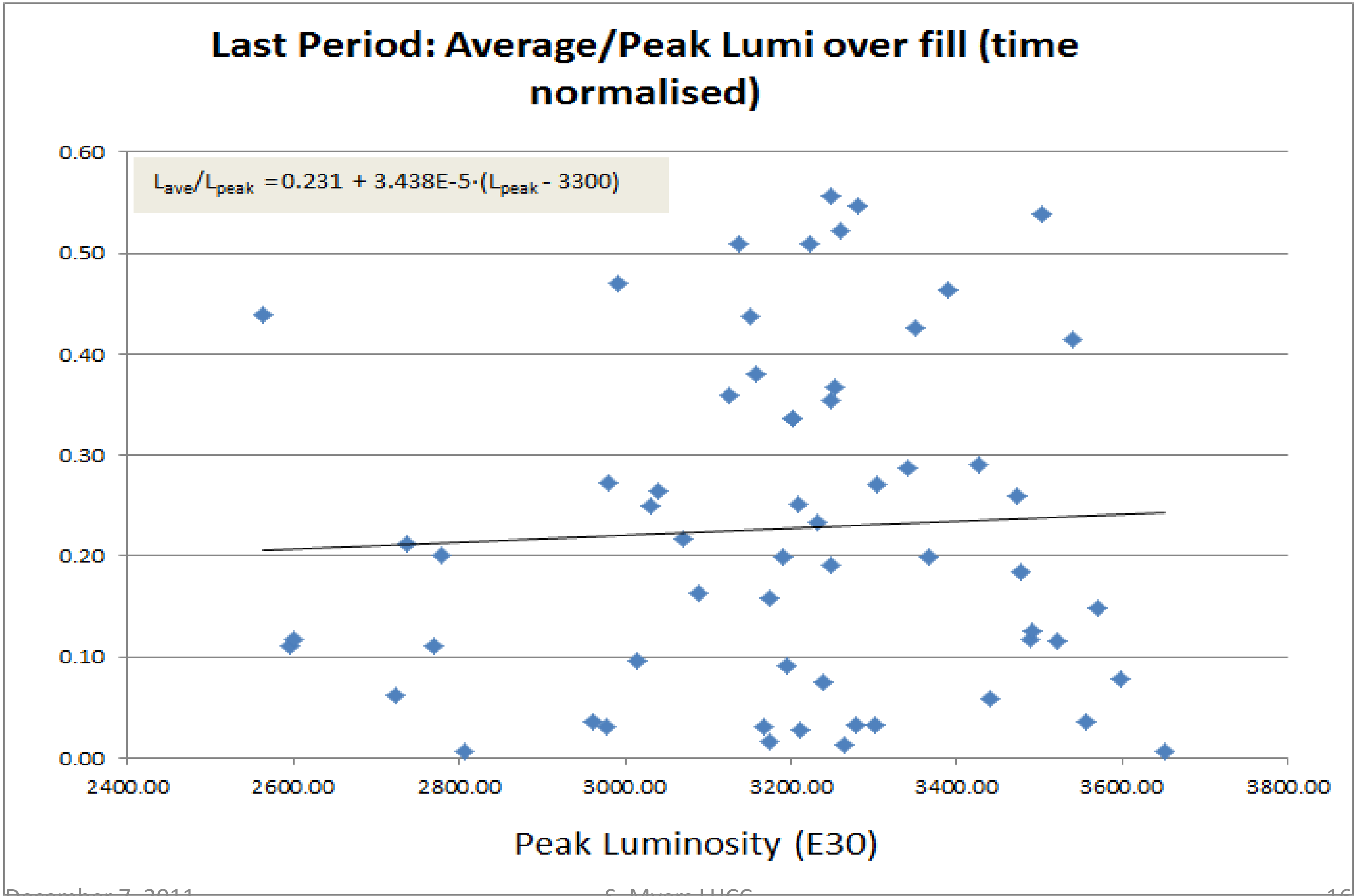
The Average Luminosity

L_{ave} = (Integrated luminosity)/(total time of fill)





L_{ave} /L_{peak} is calculated for each fill

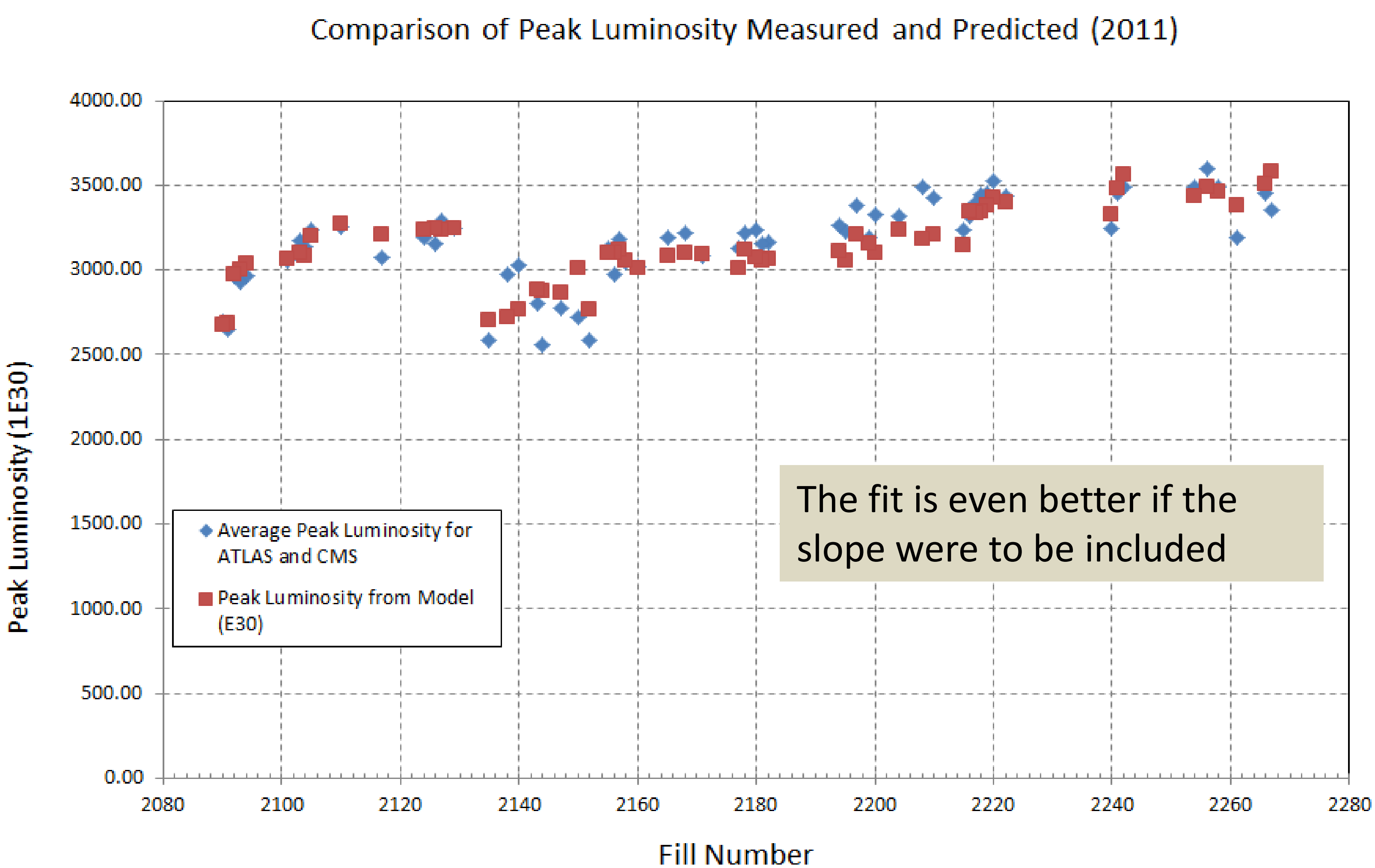


Evaluating Integrated Luminosity from Peak

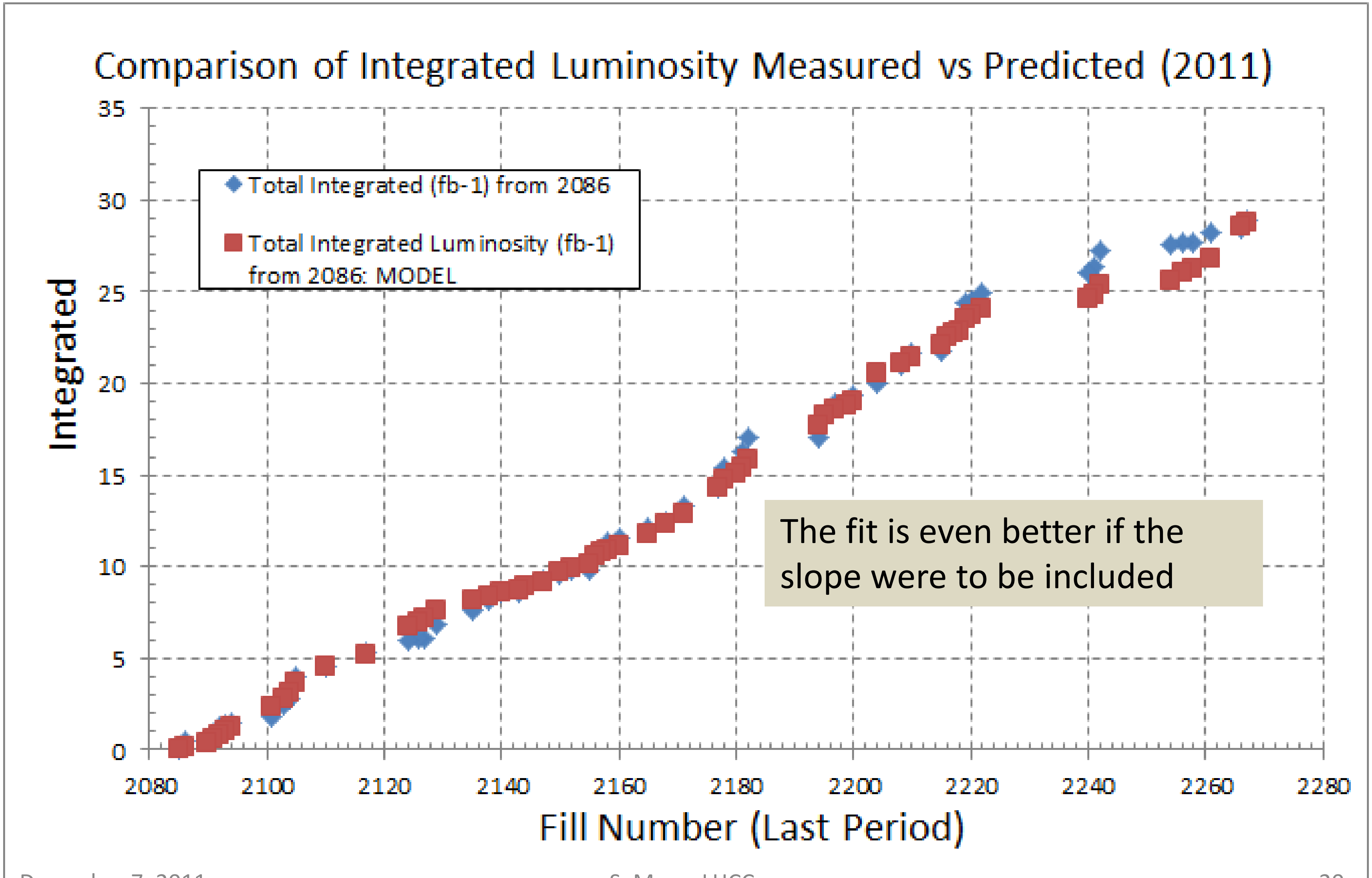
- Brightness
  - 50ns: $B = 0.5694 + 0.0 \cdot (N_{bunch} - 1.35)$
  - 25ns: $B = 0.2560 + 0.0 \cdot (N_{bunch} - 1.35)$
- Average (Integrated) Luminosity
  - $L_{ave}/L_{peak} = 0.231 + 0.0 \cdot (L_{peak} - 3300)$

Predicting 2011 Luminosities

L_{peak} 2011 Last period (50ns)



2011 Last Period (50ns)



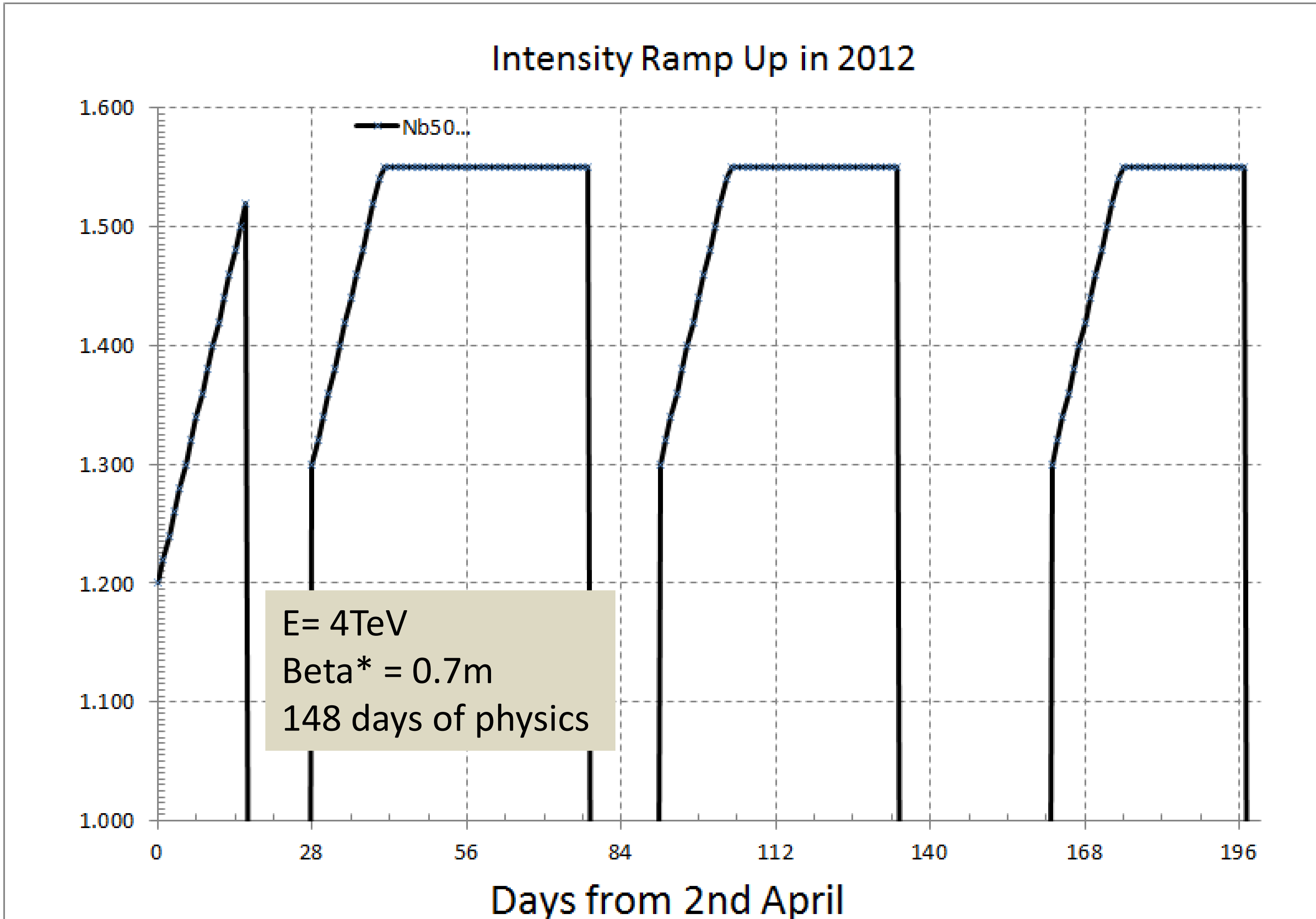
2012 (Preparing for Chamonix)

Assumptions

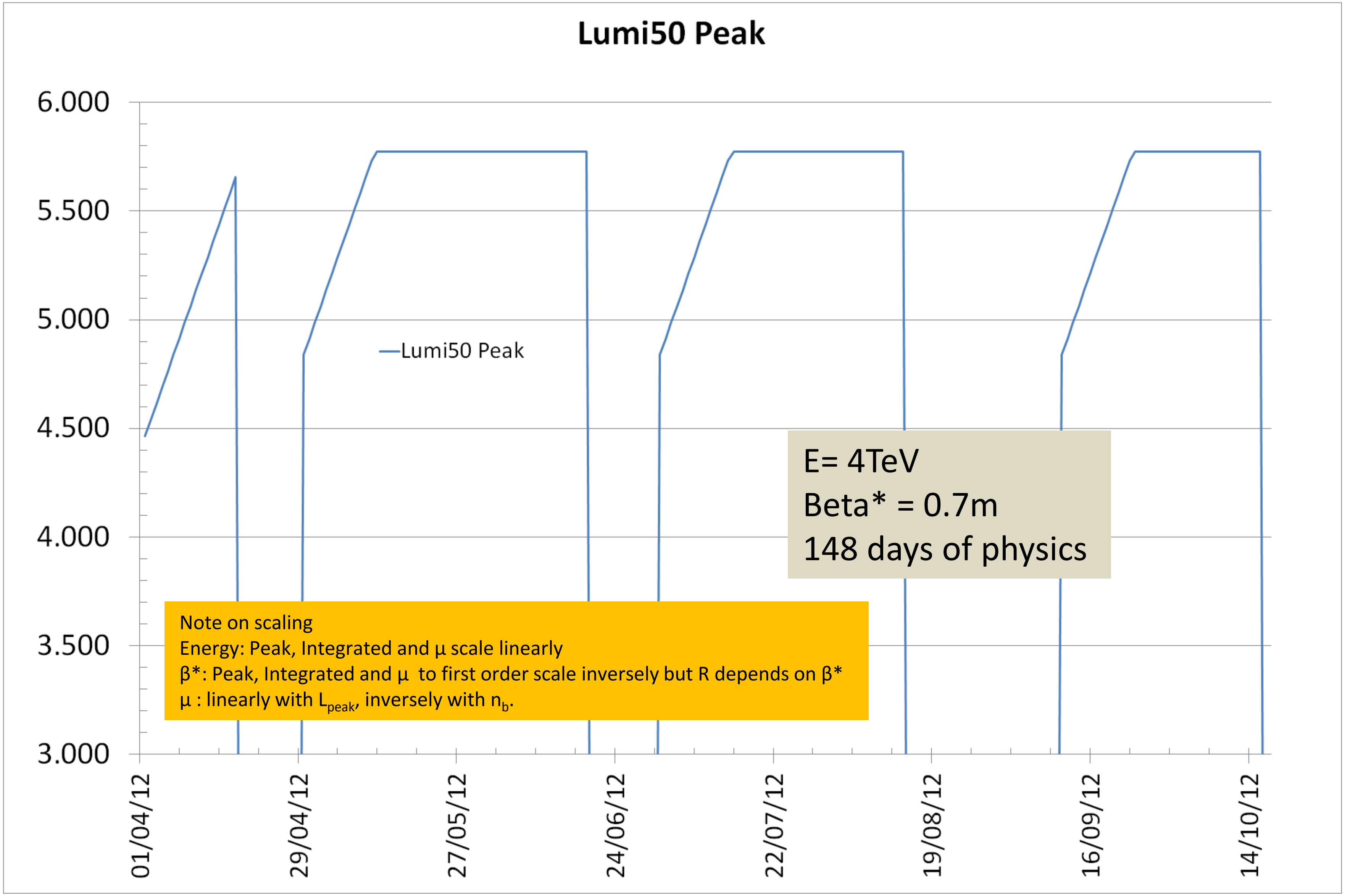
- E=4TeV
- β* = 0.7m (will be more difficult for 25ns)
- 148 days of physics (5days scrubbing and 8 days special runs. N.B. more scrubbing would be needed for 25ns)
- no intensity limit for 25ns

Note on scaling
Energy: Peak, Integrated and μ scale linearly
β*: Peak, Integrated and μ to first order scale inversely but R depends on β*, crossing angle and emittances
μ : linearly with L_{peak}, inversely with n_b.

2012 Intensity Ramp Up



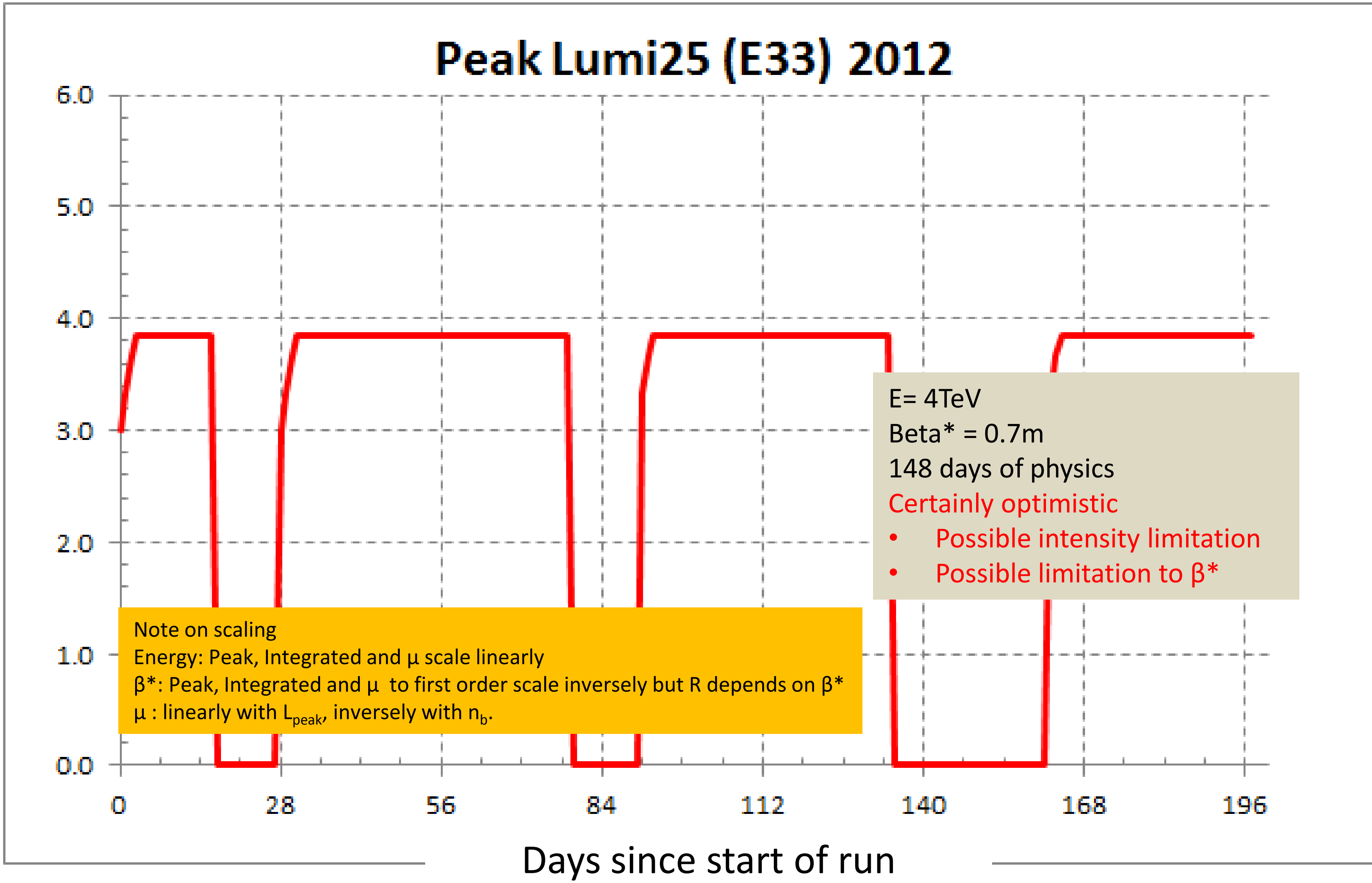
Peak Luminosity with 50ns (2012)



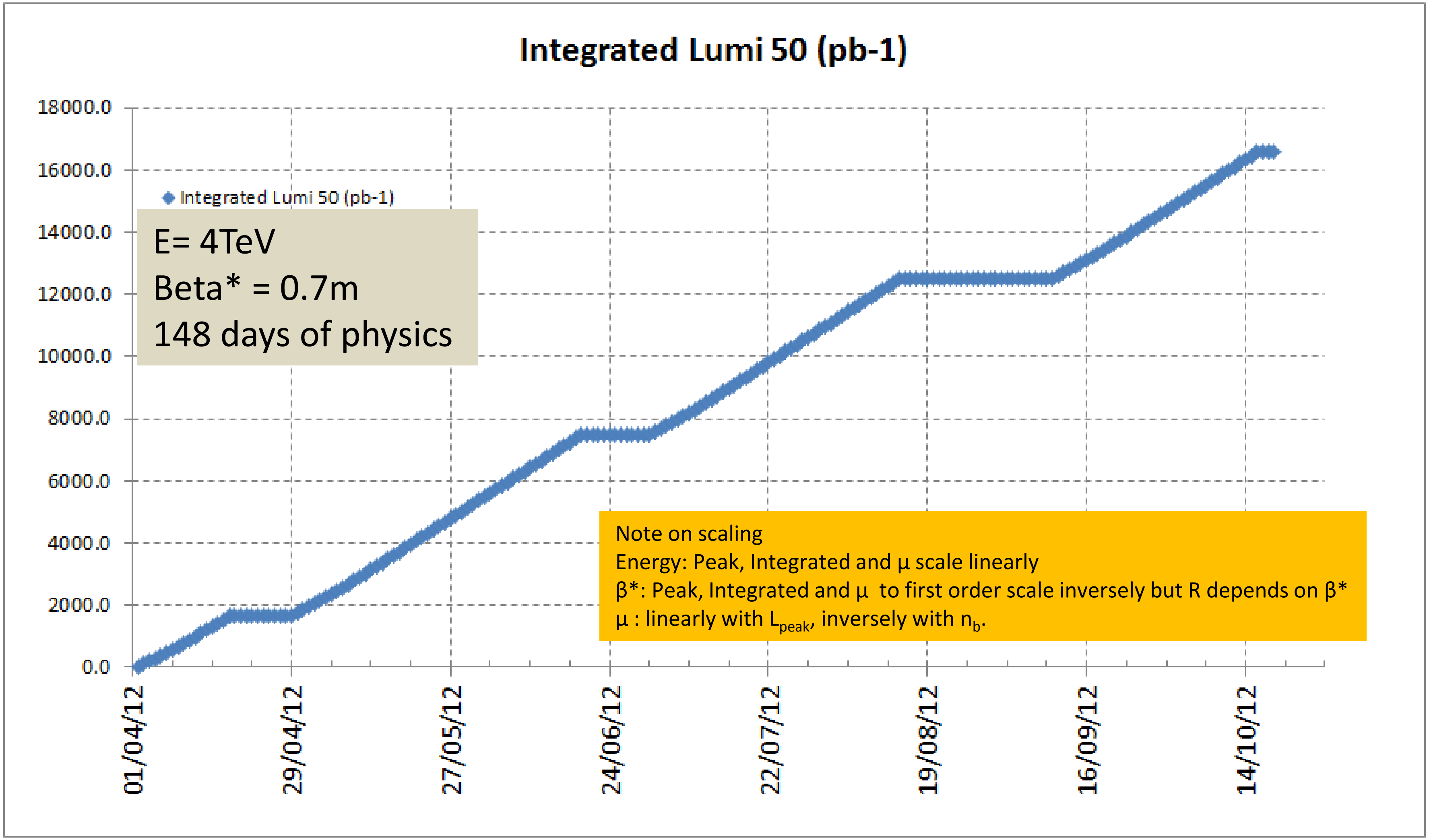
E= 4TeV
Beta* = 0.7m
148 days of physics

Note on scaling
Energy: Peak, Integrated and μ scale linearly
β*: Peak, Integrated and μ to first order scale inversely but R depends on β*
μ : linearly with L_{peak}, inversely with n_b.

Peak Luminosity with 25ns (2012)



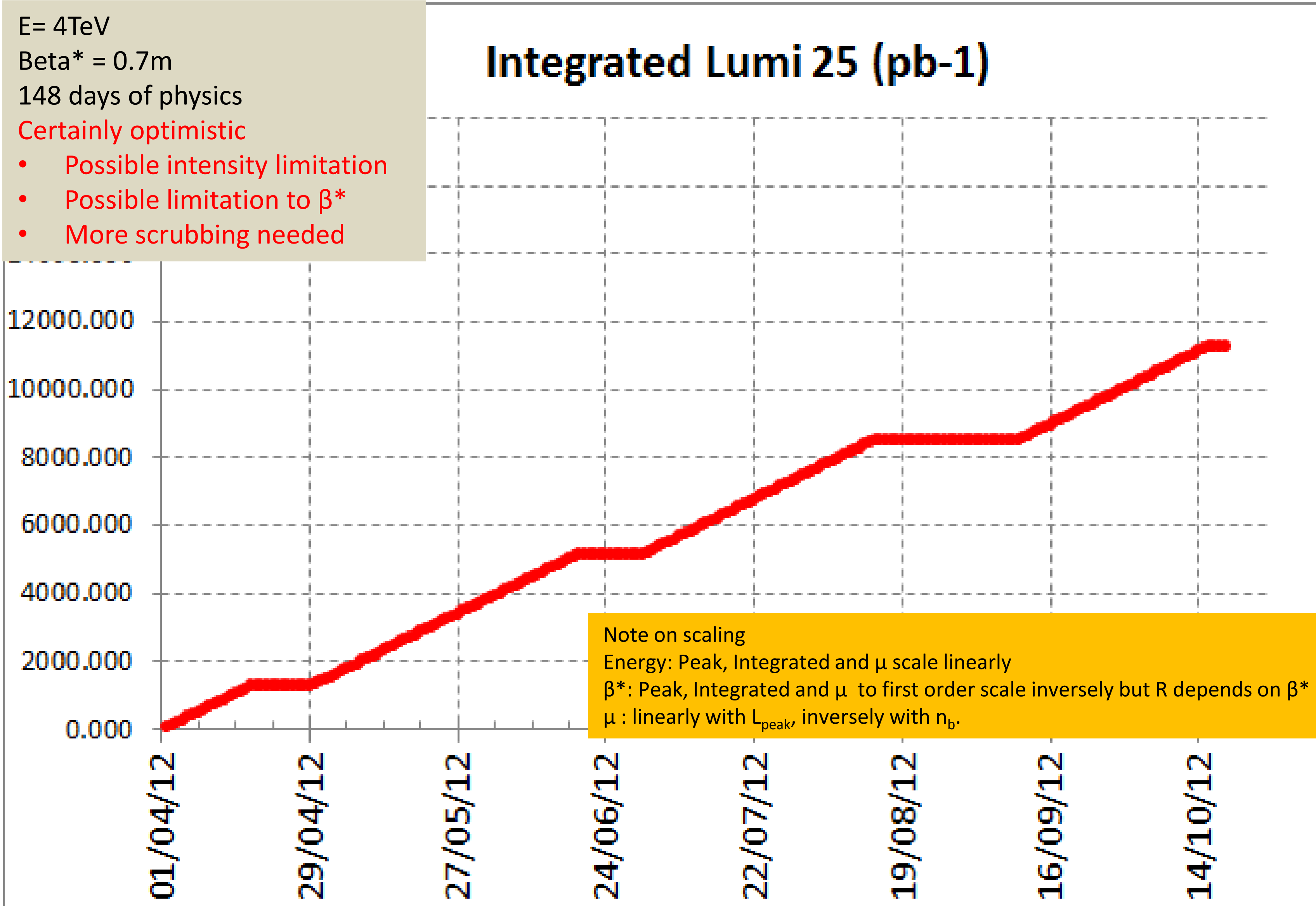
2012 Integrated with 50ns



2012 Integrated with 25ns

E= 4TeV
Beta* = 0.7m
148 days of physics
Certainly optimistic

- Possible intensity limitation
- Possible limitation to β*
- More scrubbing needed



Note on scaling
Energy: Peak, Integrated and μ scale linearly
β*: Peak, Integrated and μ to first order scale inversely but R depends on β*
μ : linearly with L_{peak}, inversely with n_b.

Summary for 2012

Assumptions

E=4TeV: beta* = 0.7m: 148 days of physics: no intensity limit for 25ns

Bunch Spacing	Peak Luminosity	Integrated Luminosity (fb-1)	Pile Up	N max
50ns	5.80E+33	~16	~27	1.55E+11
25ns	3.80E+33	~10	~9	1.15E+11

$$L_{peak} = K_L \cdot N_{total} \cdot B$$

$$K_L = \frac{f_{rev} \cdot R \cdot \gamma}{4\pi \cdot \beta^*}$$

Note on scaling

Energy: Peak, Integrated and μ scale linearly

β*: Peak, Integrated and μ to first order scale inversely but R depends on β*, crossing angle and emittances

μ : linearly with L_{peak}, inversely with n_b.

What to do if Pile up is too high?

Three Possibilities

	Scheme	Advantages	Disadvantages	Unknowns
1	25ns	lower μ	lower luminosity and inflexible, more scrubbing needed	Total intensity, minimum β* higher
2	50ns with Lumi reduced by offset	adjustable μ, Lumi, and possibility of levelling	None	feasibility, (beam-beam)
3	bunch trains with different intensities	simultaneous low and high μ		feasibility for detectors, LHC

We must keep the maximum flexibility for 2012

Using 2011 Data to Predict

Peak Luminosity

$$L_{peak} = \frac{n_b \cdot N_{bunch,1} \cdot N_{bunch,2} \cdot f_{rev}}{4\pi \cdot \beta^* \cdot \varepsilon_N} \cdot R(\phi, \beta^*, \varepsilon_N, \sigma_s)$$

$$L_{peak} = K_L \cdot (N_{bunch} \cdot n_b) \cdot \left(\frac{N_{bunch}}{\varepsilon_N}\right) = K_L \cdot N_{total} \cdot B$$

$$L_{peak} = K_L \cdot N_{total} \cdot B$$

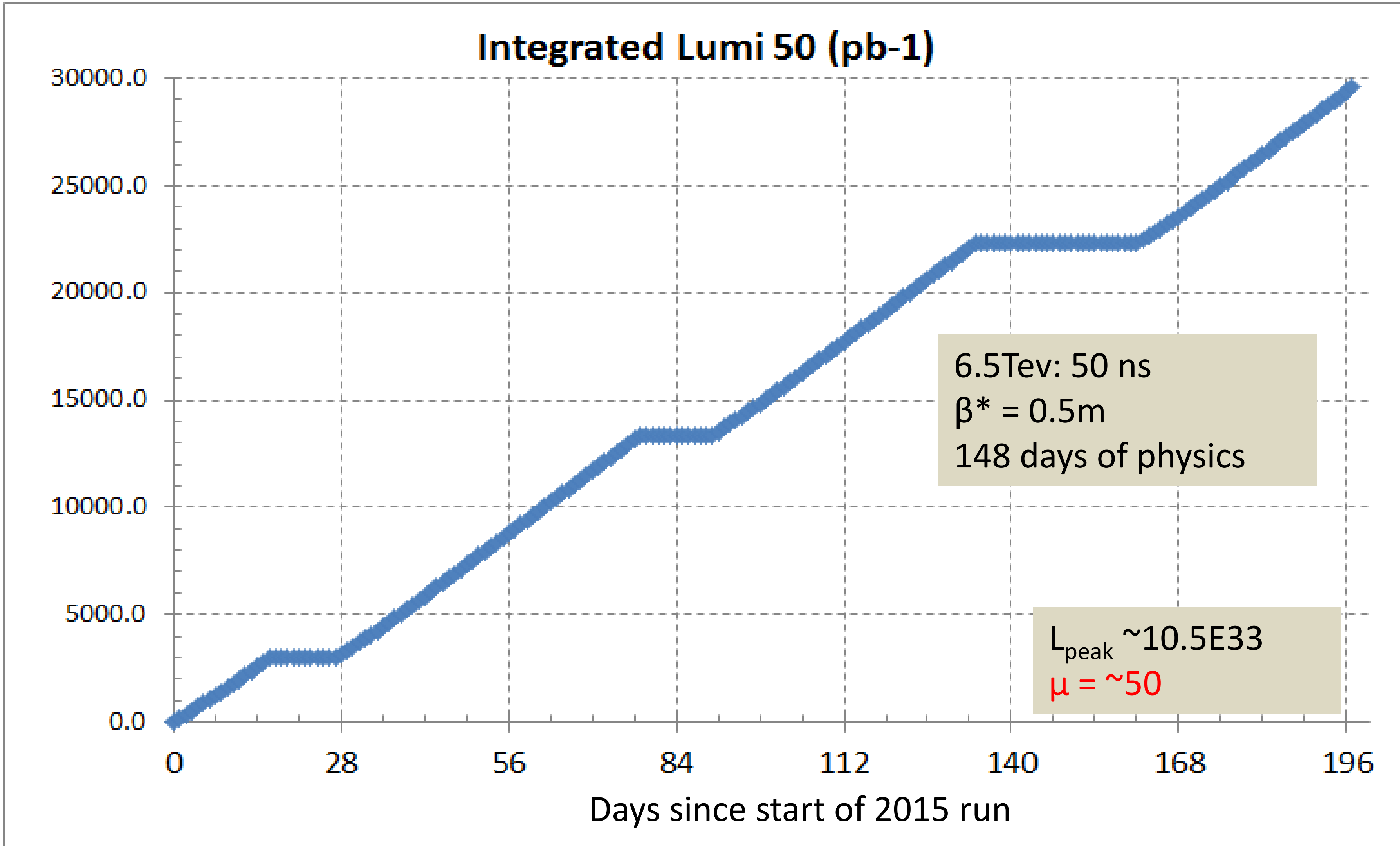
$$K_L = \frac{f_{rev} \cdot R \cdot \gamma}{4\pi \cdot \beta^*}$$

At 6.5TeV per beam

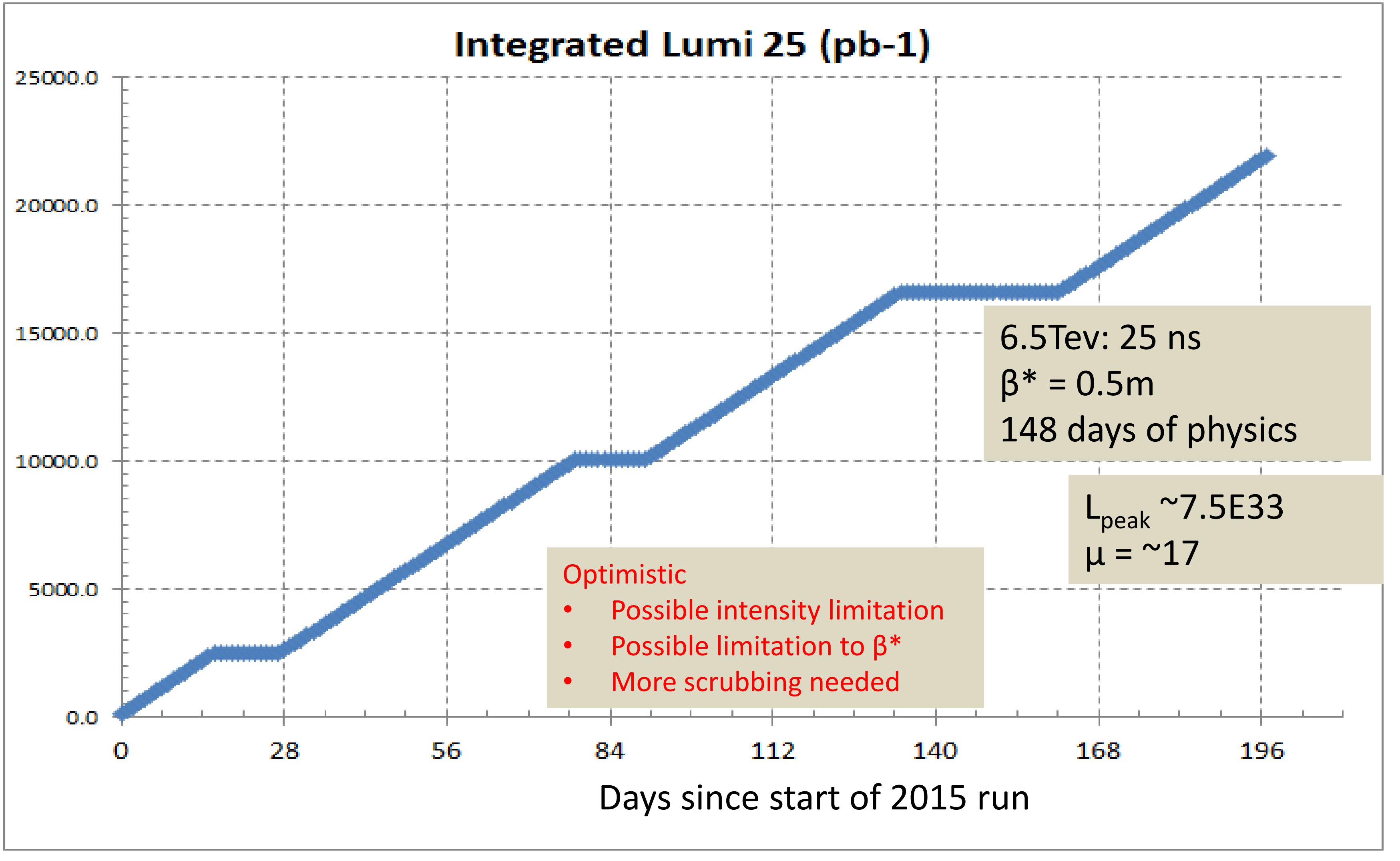
Assumptions

- 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
L peak ~7.5E33
μ = ~17
Optimistic
• Possible intensity limitation
• Possible limitation to β*
• More scrubbing needed

Thank you for your attention