Plans for 2016 and Run 2

Mike Lamont

An attempt at synthesis
Acknowledgements all round

After LS1

"It's going to be like after a war" Serge Claudet Evian 2012

Where are we? 1/2

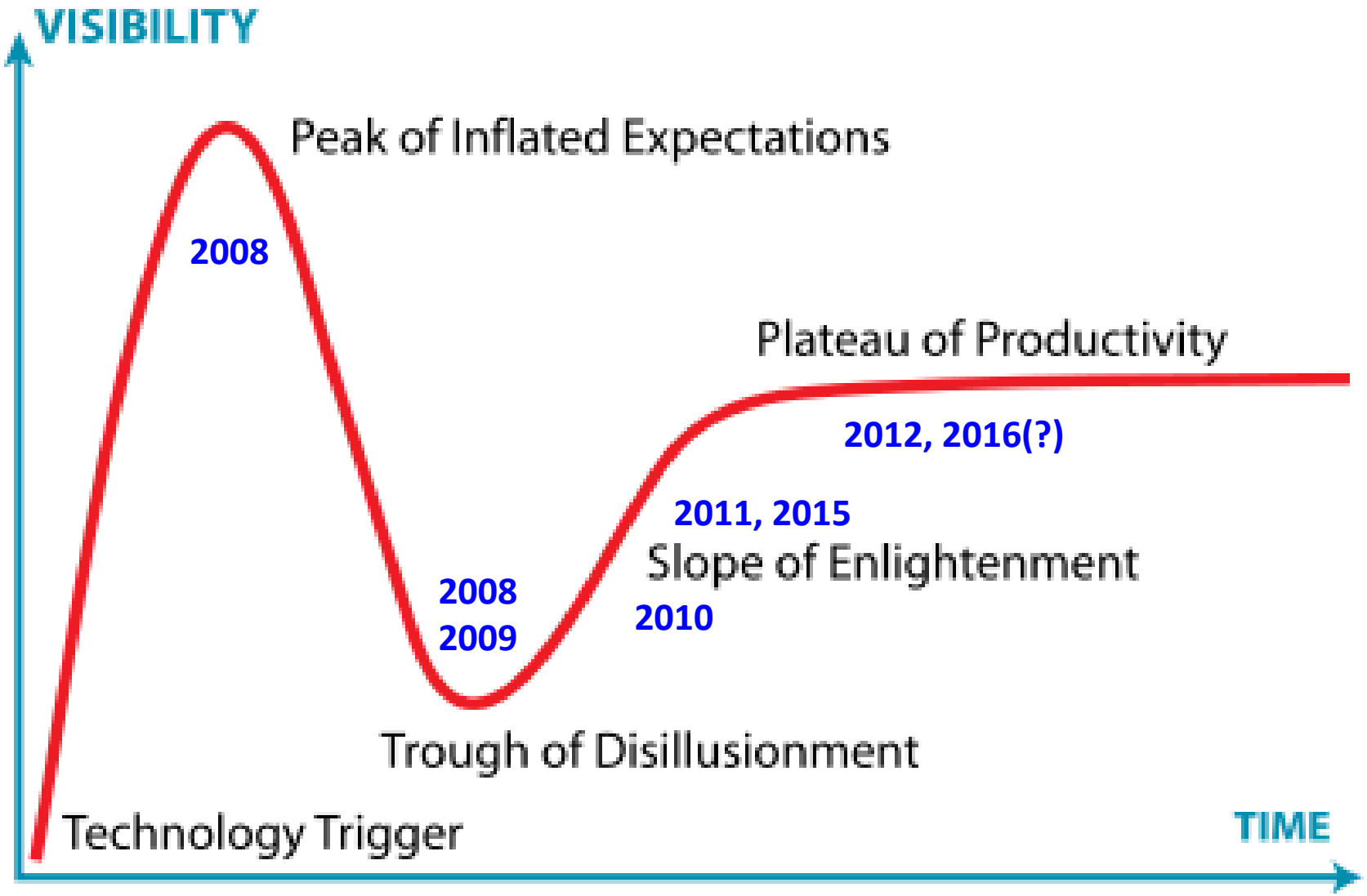
- 6.5 TeV, 2*80 cm, 2*levelled with optics well under control
- Nominal 25 ns beam, 2244 bunches
- High electron cloud
- Operating with high chromaticity, octupoles, ADT throughout the cycle to combat instabilities
- Good transmission through the cycle
- Good luminosity performance - beam-beam OK
- Acceptable emittance growth (and enjoying sync. light)
- UFO rates down

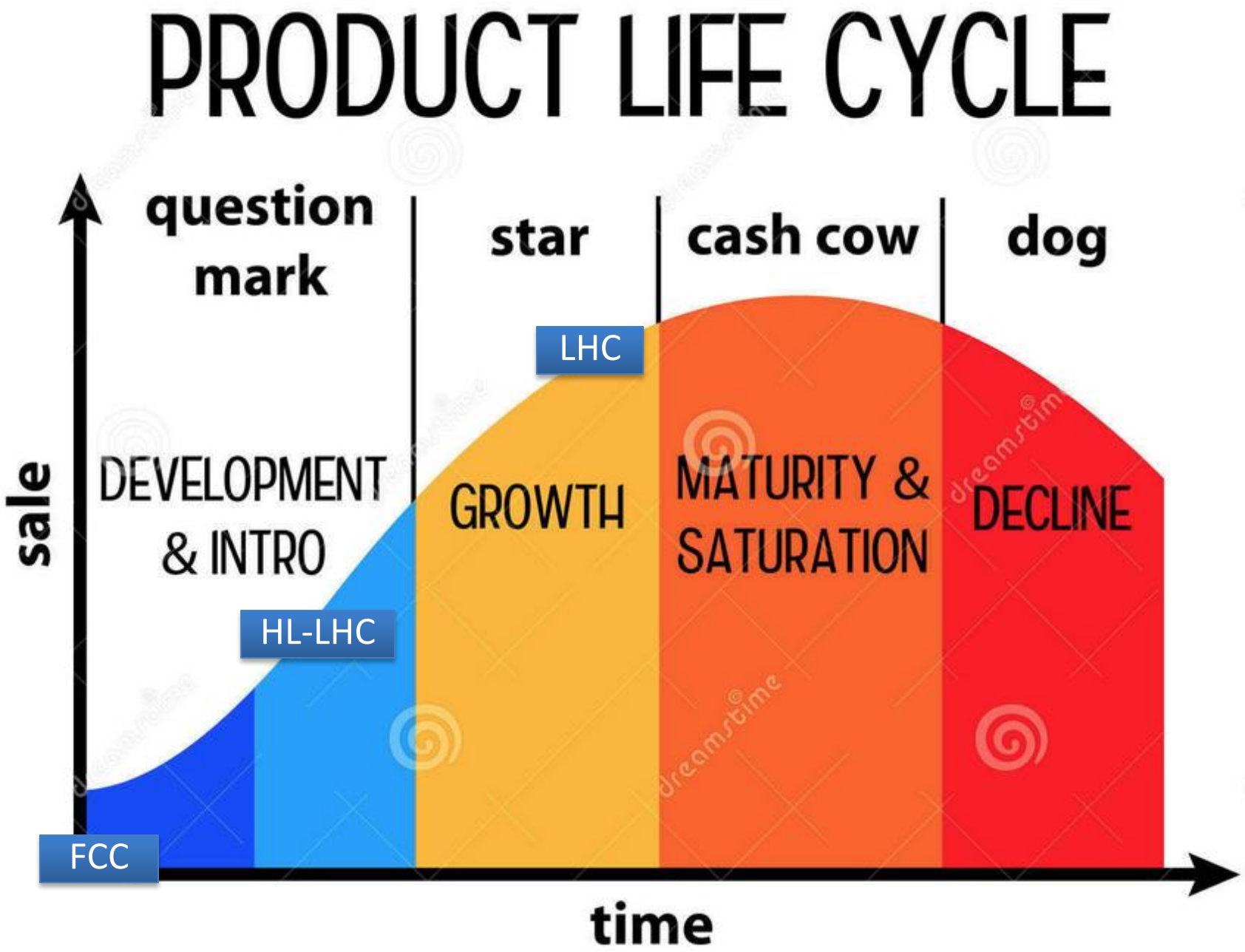
This not a bad place to start

Where are we? 2/2

- **Availability is reasonable**
- **Mature system performance**
  - QPS, RF, Cryogenics, ADT, Power converters Collimation, BI, Controls, LBDS, injection, TDI…
- **Operational efficiency is good**
  - injection, cycle, decay and snapback, feedbacks
- **Proven machine protection**
- **Challenges**
  - High e-cloud, UFOs, ULO, instabilities, (beam induced heating), R2E

Product lifecycle




PRODUCT LIFE CYCLE
question mark
star
cash cow
dog
sale
DEVELOPMENT & INTRO
GROWTH
MATURITY & SATURATION
DECLINE
LHC
HL-LHC
FCC
time

Where do we want to go?

Short term - 2016

- Stable, safe operations
- Electron cloud off
- 6.5 TeV, 40 to 50 cm
- Nominal 25 ns beam, 2748 bunches, 288 bpi
- Reasonable availability
- Excellent operational efficiency

Production operation

How are we going to get there?

- **Choose a not too challenging operating regime that will allow stable and reproducible production**
- Keep avoidable interruptions to production to a minimum (while remaining flexible)
- Don’t compromise:
  - Machine safety
  - “Remarkable cleaning stability with 6.5 TeV beam thanks to excellent machine reproducibility”

How are we going to get there?

Continued improvement: incoming for 2016

- Availability
  - Sustained effort from QDS, cryogenics, circuits, power converters, LBDS, Injection, RF, Collimation…
- System performance across the board
  - ADT performance monitoring, OBSBOX, Is the damper working?
- Operational efficiency
  - Injection, pre-cycle, combined ramp & squeeze
  - (Turn off electron cloud)
- Premature dumps
  - BLM threshold adjustment

Illustrative not encyclopedic

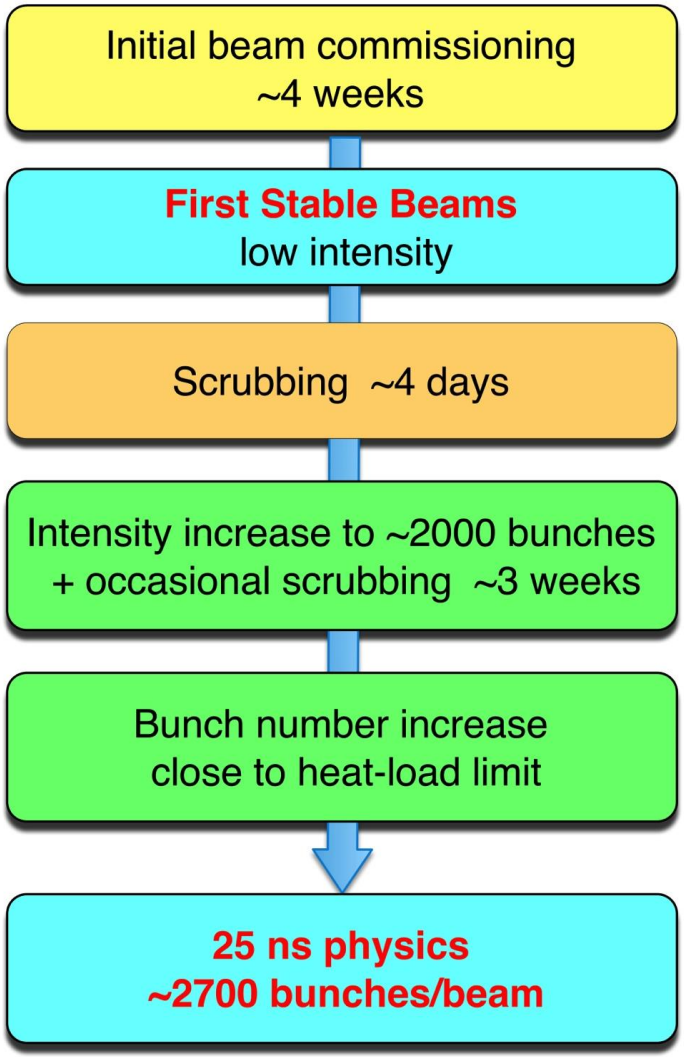
How are we going to get there?

Continued improvement: incoming for 2016

- Set-up efficiency
  - Collimation (full validation for squeeze and collide in 1 fill) and still pushing
- Machine protection
  - BCCM, Collimator BPM interlock, continued vigilance
- Beam performance
  - Emittance growth, instabilities, good control of key parameters, reduction of chromaticity and octupoles,

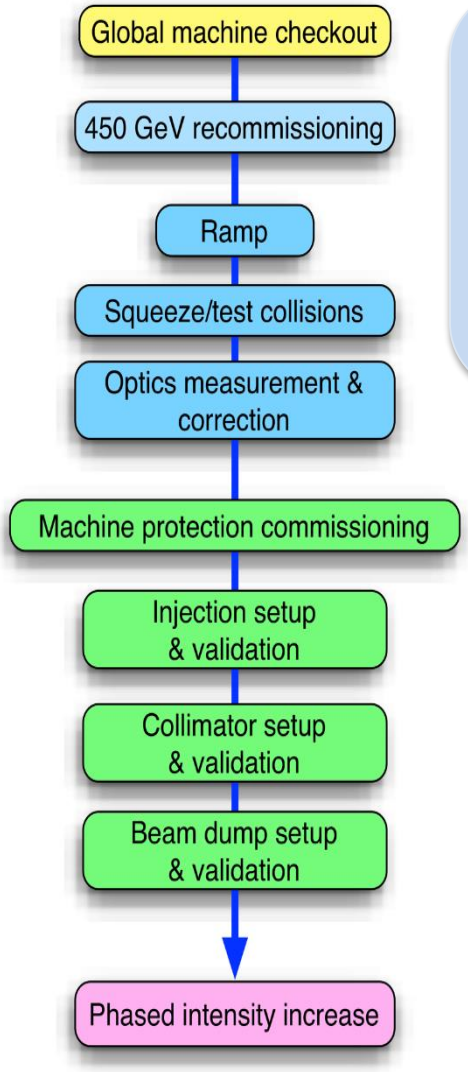
Illustrative not encyclopedic

2016



- Initial beam commissioning
- Re-establish e-cloud conditions of 2015
- Continue gentle increase in number of bunches at the heat-load limit
- Exploit

Initial commissioning



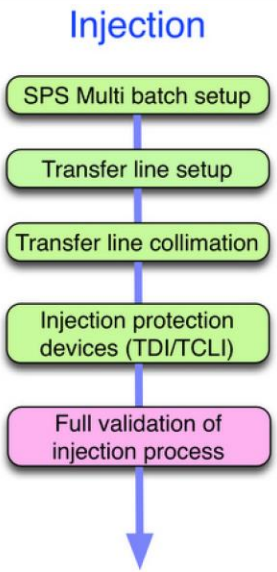
System commissioning

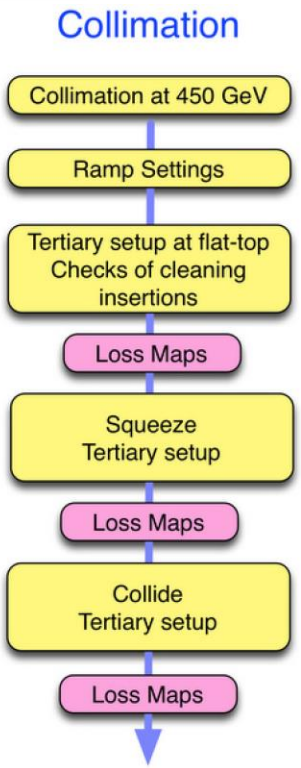
- Transverse damper
- RF
- Beam instrumentation
- Feedbacks
- Injection, beam dumps

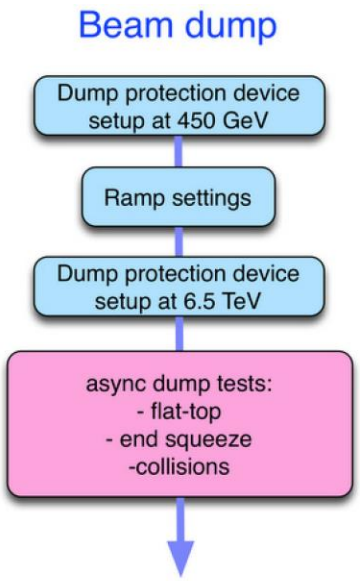
⊕

Beam based measurements

- Optics meas. & correction
- Magnet model meas. & correction
- Aperture measurements







Initial commissioning++

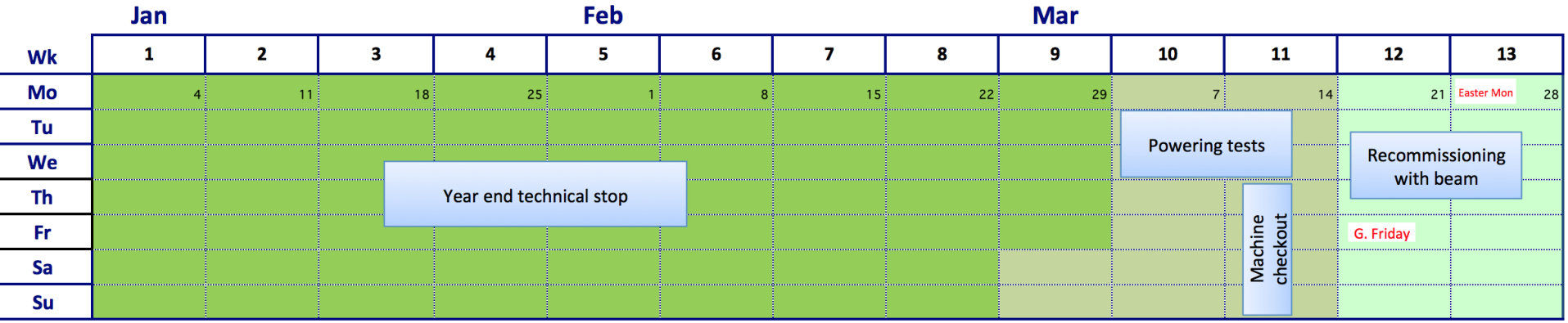
Detailed breakdown by Belen at Evian
Shouldn't hold too many mysteries – 4 weeks should be OK

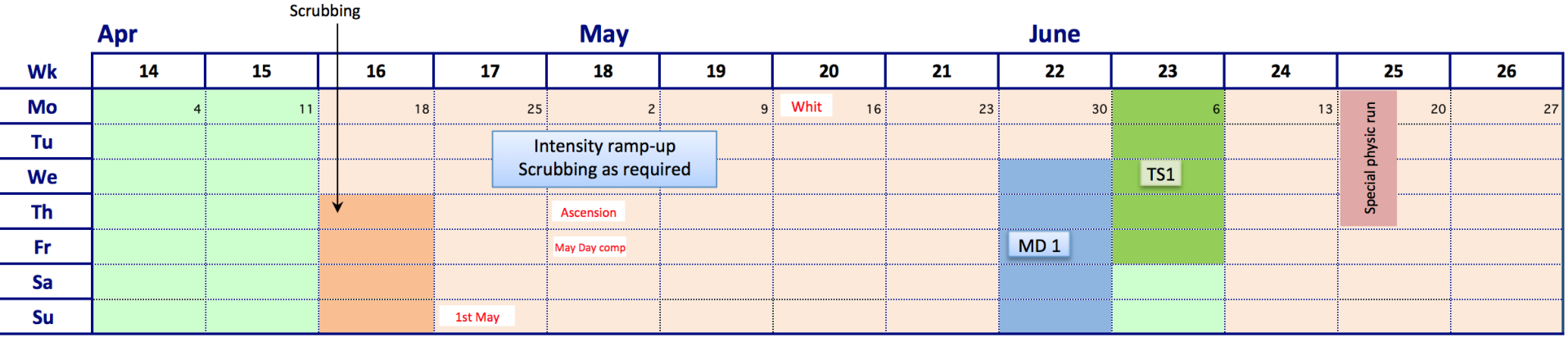
- Squeeze to 40 cm – check local aperture etc.
- Combined ramp and squeeze
- Characterize shortened pre-cycle
- Check out the ULO
- Check impedance of TDIs
- Commission additional interlocks
- Set-up TOTEM's Roman Pots
- Prep for special runs: VdM (19 m), 2.5 km

Scrubbing and intensity ramp-up

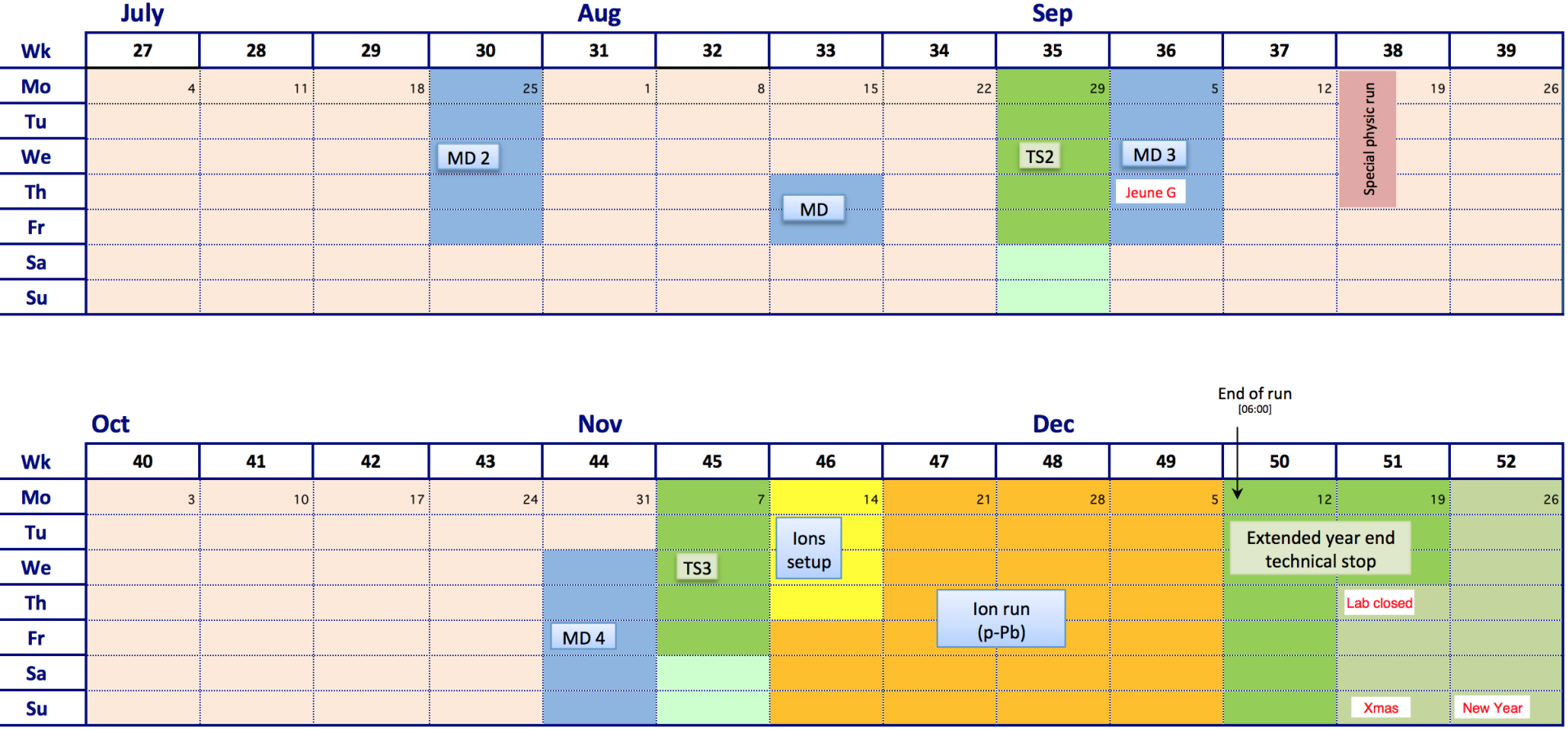
- Re-establish 2012 ~2000 bunches conditions during dedicated 4 day run (450 GeV)
- Intensity ramp-up (288b) phase 1:
  - below the heat load limit
  - remedial scrubbing as required
  - 3-12-48/72-288-570-860-1200-1700
  - ~7 steps – let's say 3 days per step – 3 weeks
- Phase 2: (maximal) scrubbing during Stable Beam
  - ~2000 to 2748
  - Small increments in number of bunches ("mini-steps") playing on batch gap
- High Q', octupoles, ADT, longer bunches, WP etc.

2016 Q1/Q2 (v1.1)





2016 Q3/Q4 (v1.1)



Timing of MD2, floating MD, special runs to be determined

2016 version 1.1

Phase	Days
Initial Commissioning	28
Scrubbing: 4 days initially and then as required during ramp-up	7
Proton physics 25 ns	**152**
Special physics runs (high beta*; VdM)	8
Machine development	22
Technical stops	15
Technical stop recovery	6
Ion setup/proton-lead run	4 + 24
Total	**266 days (38 weeks)**

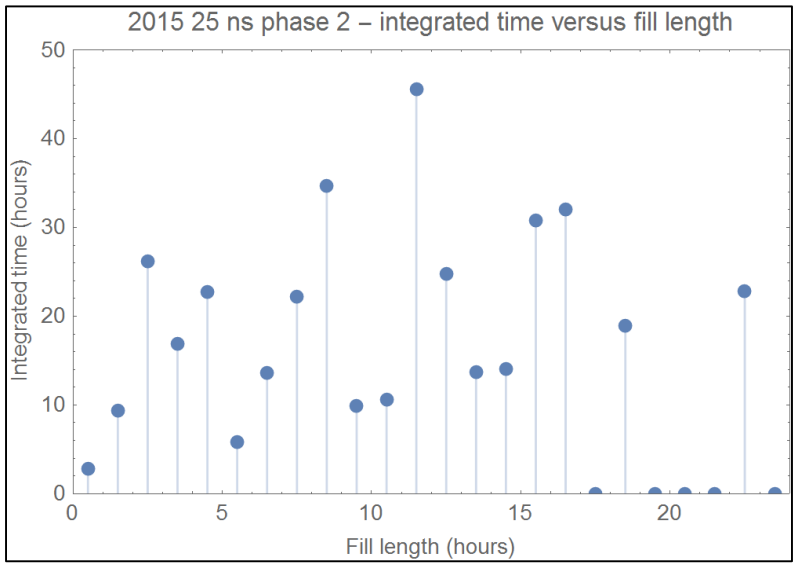
2016 beam parameters (nominal 25 ns)

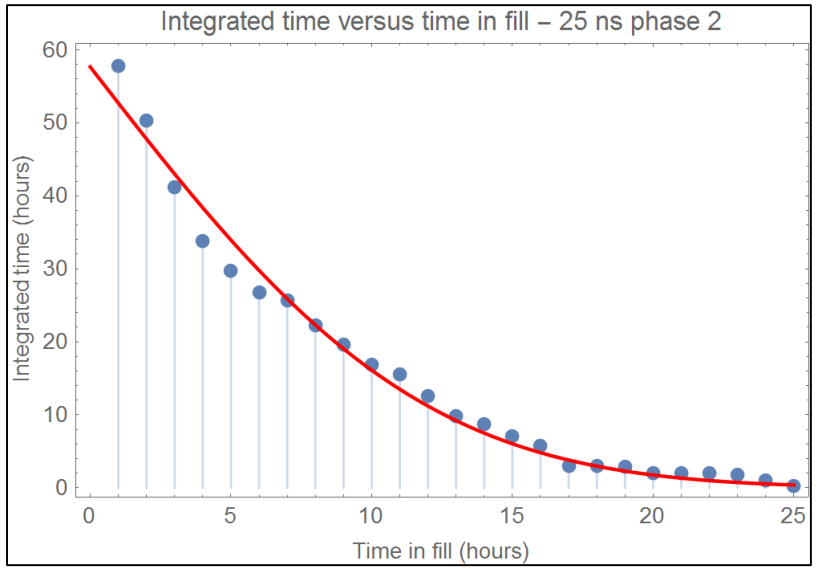
Energy	6.5 TeV
Bunch spacing	25 ns
Bunch population	~1.25e11
Max bunches/injection	288
Max. number bunches	2748
Nc GPDs	2736
Emittance exit SPS	2.7 mm.mrad
Emittance into SB	3.4 mm.mrad
Beta* GPDs	40 or 50
Crossing angle GPDs	185 or 165

Note the limit of around 1.3e11ppb from the SPS - see Verena's talk

Integrated luminosity

- Fit 2015 post-TS2 greater than 459b Stable Beam distribution
- September 8th to 3rd November
  - 52 days (90 m run taken out), 381 hours of Stable beam, ~31% physics efficiency
- * L(t) input initial luminosity, luminosity lifetime from burn
- Scale to 150 days (implies same availability, turnaround)
- Dump fill after 18 hours





40 versus 50 cm

Assume Nc = 2736, 3.5 micron, 1.2e11 ppb, 1.25 ns

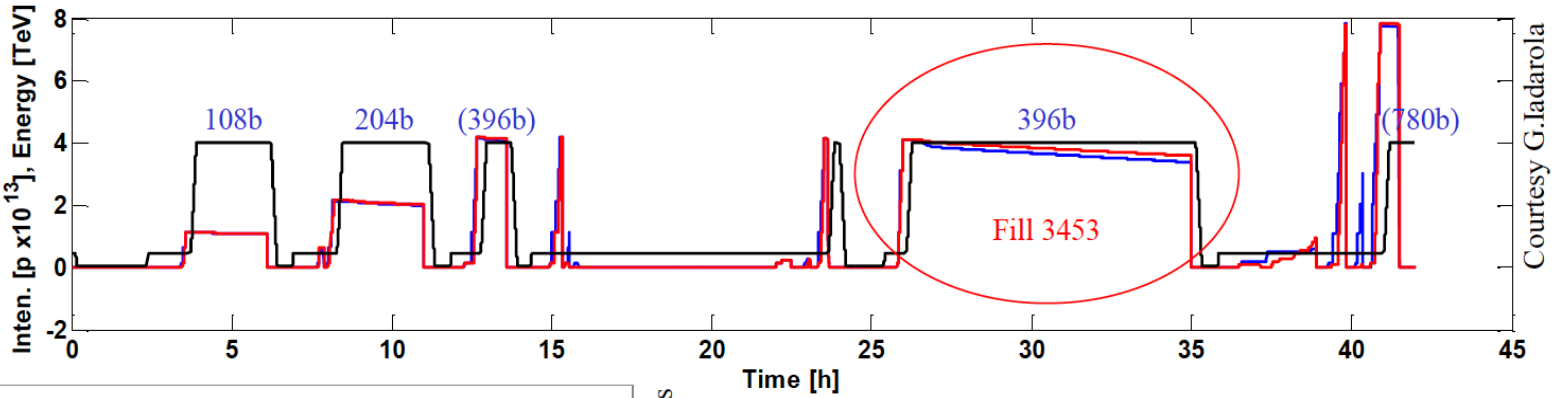
	40 cm	50 cm
Beam size at IP (um)	14.2	15.9
Crossing angle (urad)	185*2	165*2
F (bunch length: 1.25 ns)	0.63	0.72
Peak luminosity ($cm^{-2}s^{-1}$)	1.1e34	1.0e34
Burn-off lifetime (hour)	25.8	28.5
Integrated per 150 days (fb^{-1})	33.2	30.7

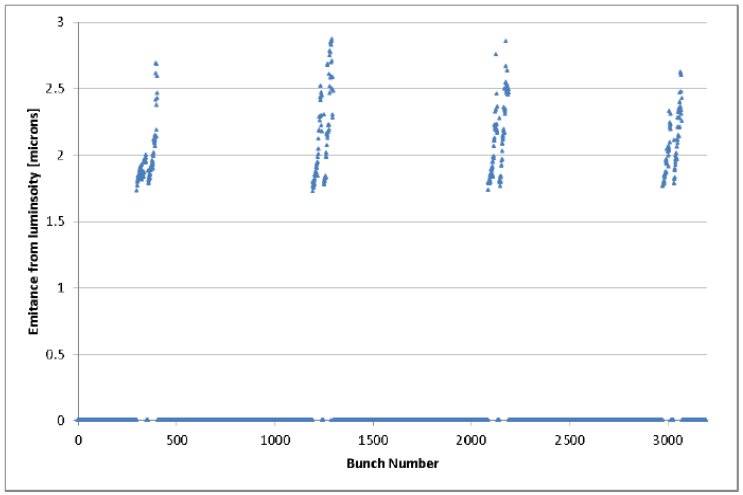
Availability? Aperture? Interlocks? Phase advance?

Courtesy Steve Hancock from 2012

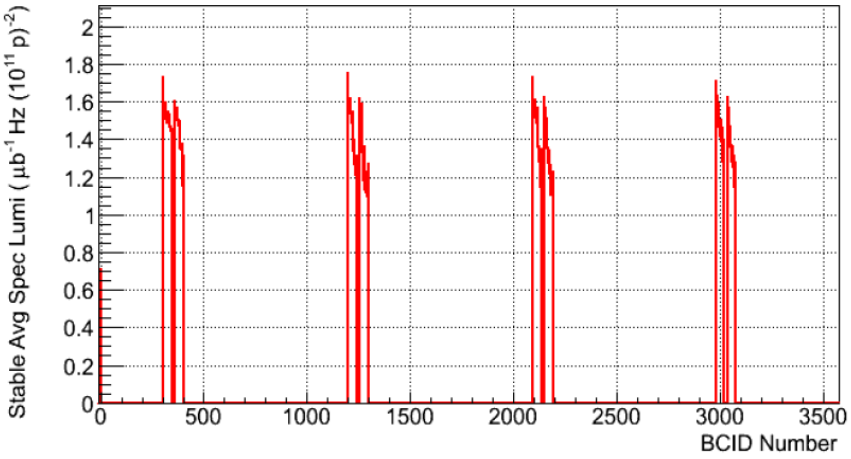
Fill 3453, BCMS 25ns

Following a 3.5 day scrubbing run with nominal 25ns beams at 450GeV, a pilot physics run took place with BCMS 25ns beams. Multiple 48-bunch batches of 1.1E11 ppb and ~1.3μm (from wirescans of the first couple of batches) were injected. Three fills made it to stable beams, with typically 1.0E11 ppb and ~1.8μm (from luminosity). The last of these showed clear indications of electron cloud.





Courtesy M.Lamont p.p. Atlas



Courtesy G.Arduini p.p. Atlas

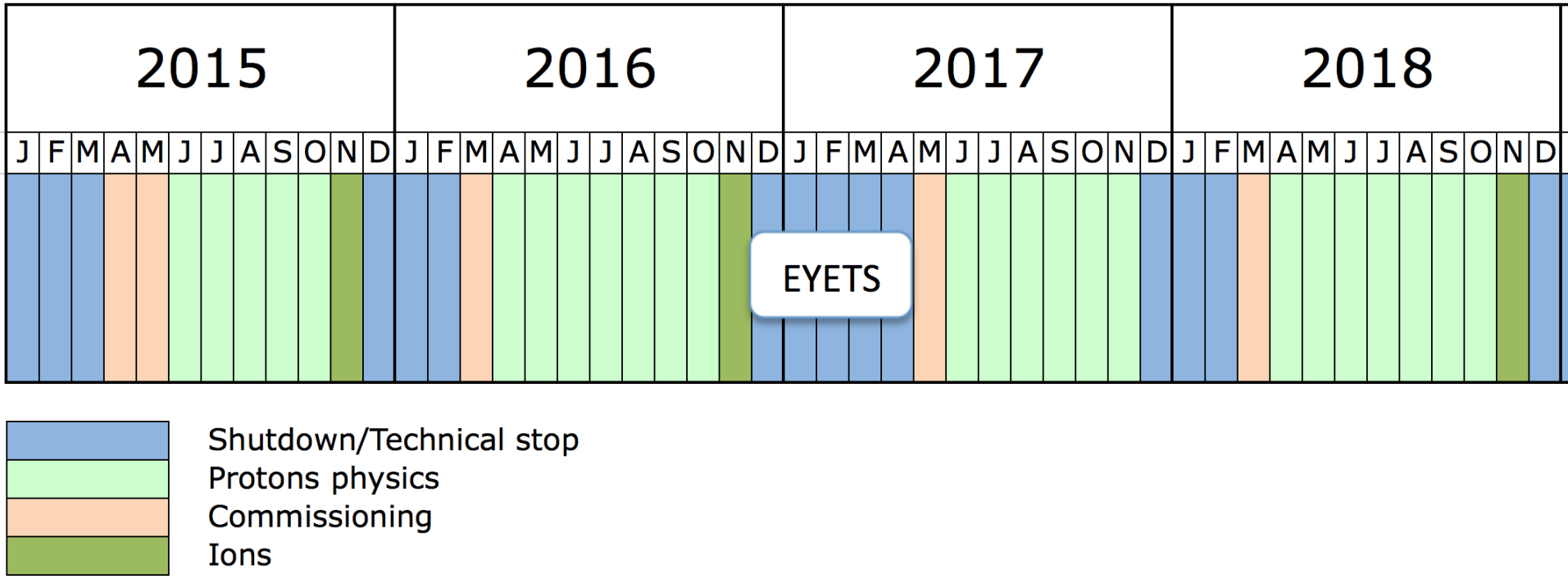
BCMS

Is clearly interesting (see Run 2 below)

- 2015: one attempt – emittance blow-up to something similar to nominal
- Possible stability issues with low emittance
- Explore possibilities with “tuned” BCMS
  - controlled emittance blow-up in injectors
- To be pursued when e-cloud settles down

Bunch population	< 1.3e11
Max bunches/injection	144
No colliding bunches GPDs	2448
Emittance exit SPS	1.9 um
Emittance into SB	2.4 um

Run 2

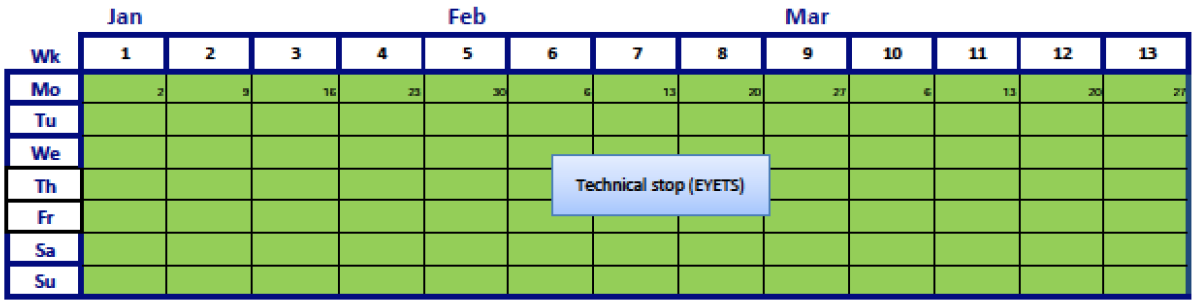


- EYETS – Extended Year End Technical Stop – 19 weeks – CMS pixel upgrade
- Assume machine stays cold during EYETS
- Assume for the moment: p-Pb end 2016, Pb-Pb end 2018 – see Jamie

Run 2 - objectives

- Deliver 100+ fb^{-1} to GPDs, keep ALICE, LHCb, TOTEM and ALFA happy
- Keep pushing performance and availability
- Now we've got the machine sorted out for Run 2 we can concentrate on the HL-LHC
- Look forward to HL-LHC without compromising present performance:
  - ATS, beta* levelling, LRBB compensation, full de-tuning…
- Look forward to the post-LS2 LIU era and how to exploit the potential
- Prepare for (or go to) 7 TeV operation

2017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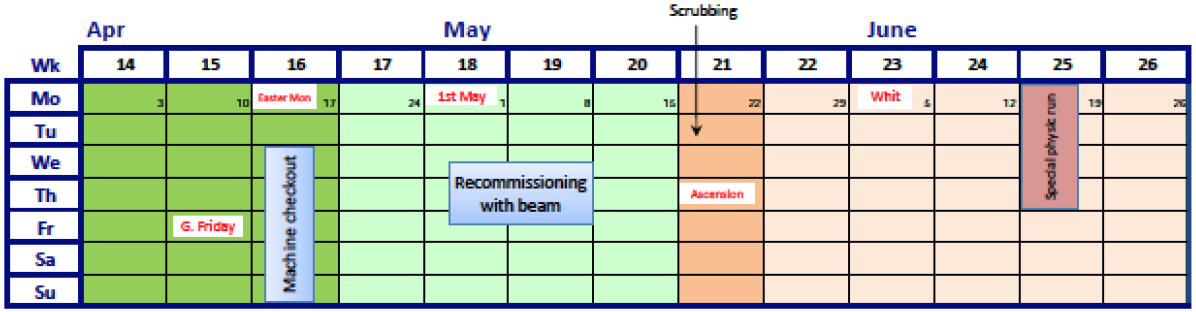
Technical stop (EYETS)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Machine checkout
Recommissioning with beam
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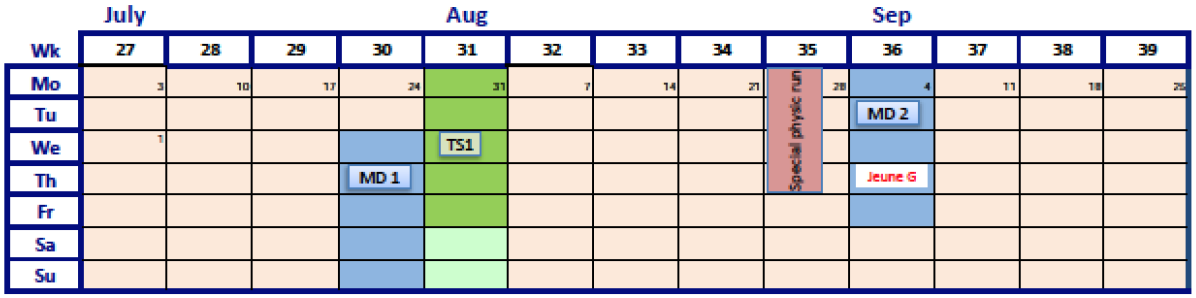
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Special physic run
MD 2
TS1
MD 1
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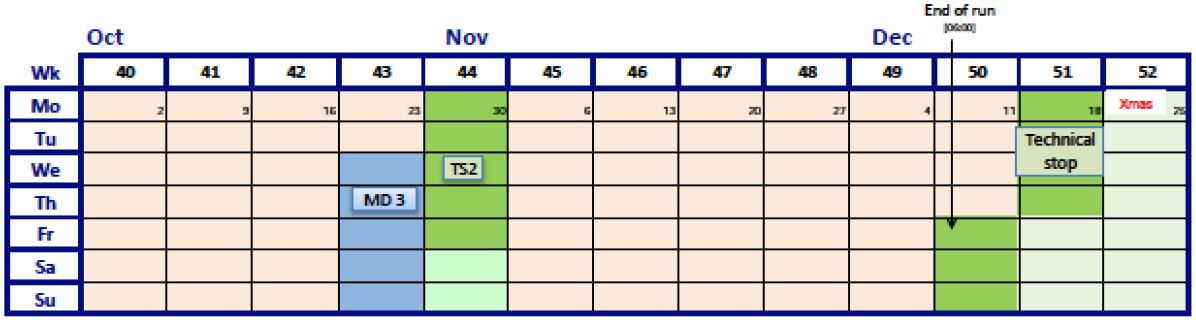
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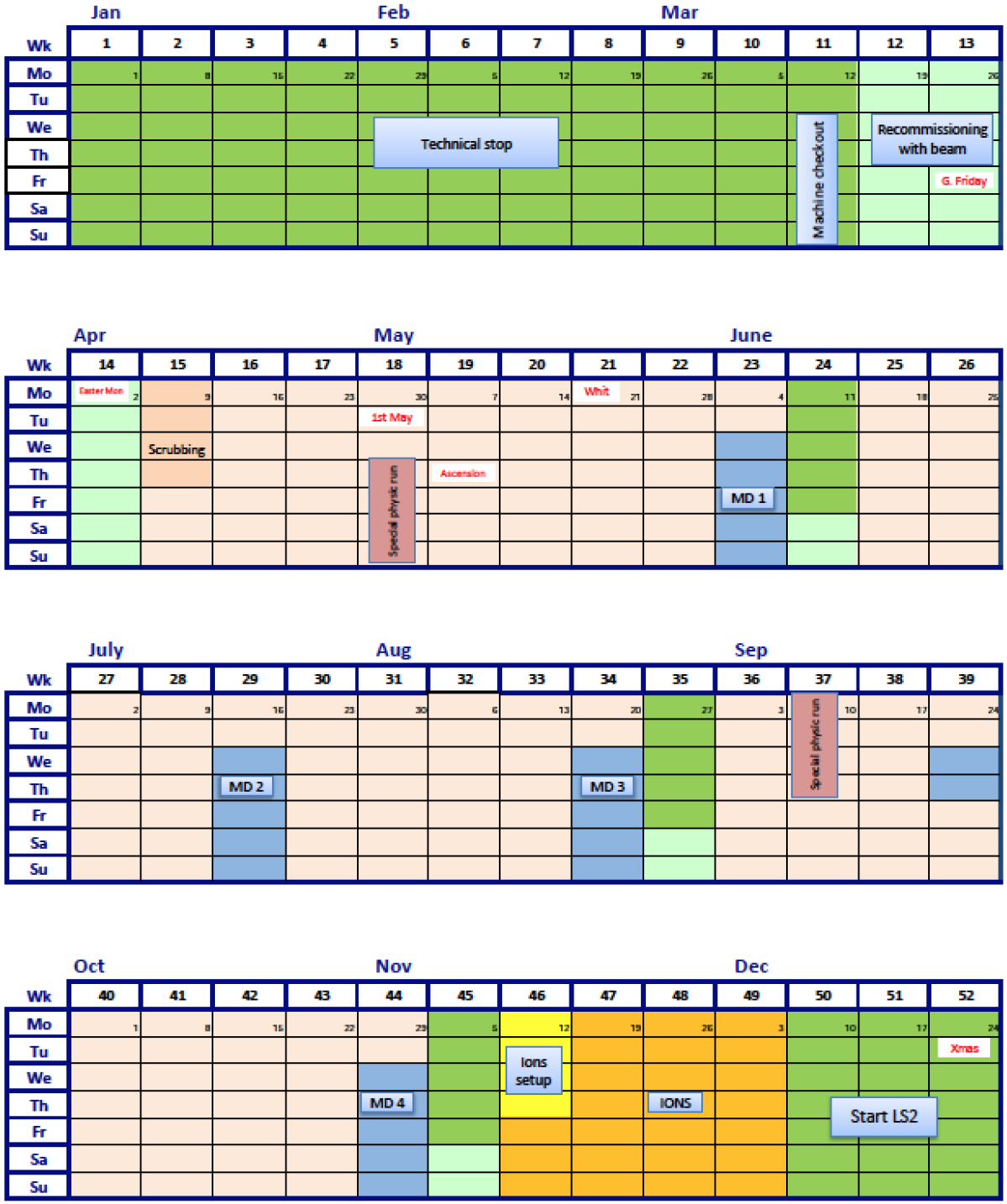
Technical stop
TS2
MD 3

2017 version v0.1

Phase	Days
Initial Commissioning post EYETS	28
Scrubbing (assuming machine stays cold)	7
Proton physics 25 ns	**163**
Special physics runs	8
Machine development	15
Technical stops	10
Technical stop recovery	4
Total	**235 days (34 weeks)**

- Machine development scaled down
- Might debate: initial commissioning; start of YETS17-18

2018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Technical stop
Machine checkout
Recommissioning with beam
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Scrubbing
Ascension
Special physic run
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MD 2
MD 3
Special physic run
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Dec
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Ions setup
MD 4
IONS
Start LS2
Xmas

2018 version 0.2

Phase	Days
Initial Commissioning	21
Scrubbing	4
Proton physics 25 ns	**162**
Special physics runs	8
Machine development	22
Technical stops	15
Technical stop recovery	6
Ion setup/ion run	4 + 24
Total	**266 days (38 weeks)**

Peak performance increase?

- Turn off electron cloud
- BCMS
- Injector optimization PSB to SPS
- Emittance conversation in LHC
- Novel optics… flat beams, squeezing further
- Reduced crossing angle (LRBB limits)
- Maximizing number of bunches
  - 12b, SPS injection, PS – 80 bunches

E-cloud should come as a matter of course, the others need to be actively pursued

Possible 2017/18 parameters

	Nominal	BCMS
Beta* (1/2/5/8)	0.4/10/0.4/3	0.4/10/0.4/3
Half crossing angle	-185/200/185/-250	-155/200/155/-250
Nc	2736	2448
Proton per bunch	1.25e11	1.25e11
Emittance into SB	3.2	2.3
Bunch length	1.25	1.25
Peak luminosity	~1.3e34	~1.6e34
Peak pile-up	~33	~47
Luminosity lifetime	~23	~17
150 days	38 fb^{-1}	43 fb^{-1}

Peak luminosity limited to ~1.7e34 by inner triplets (Laurent Tavian Evian 2012)

Illustrative! All usual caveats apply

Conclusions

- Looking good for 2016
  - On the back of experience and a huge amount of effort across the board - should be entering the exploitation domain
  - Clear priority to get e-cloud scrubbed
  - Known unknowns: ULO, earth faults…
  - Been operating the LHC for long enough not to worry about unknown unknowns
- **Enthusiasm and commitment remains high – we could do some serious stuff in 2017 & 2018**