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Summary
RLIUP Session 2
Post LS1 scenarios without and with LINAC4

Acknowledgements: L. Bottura, K. Foraz, G. Rumolo, J. Wenninger

Session 2

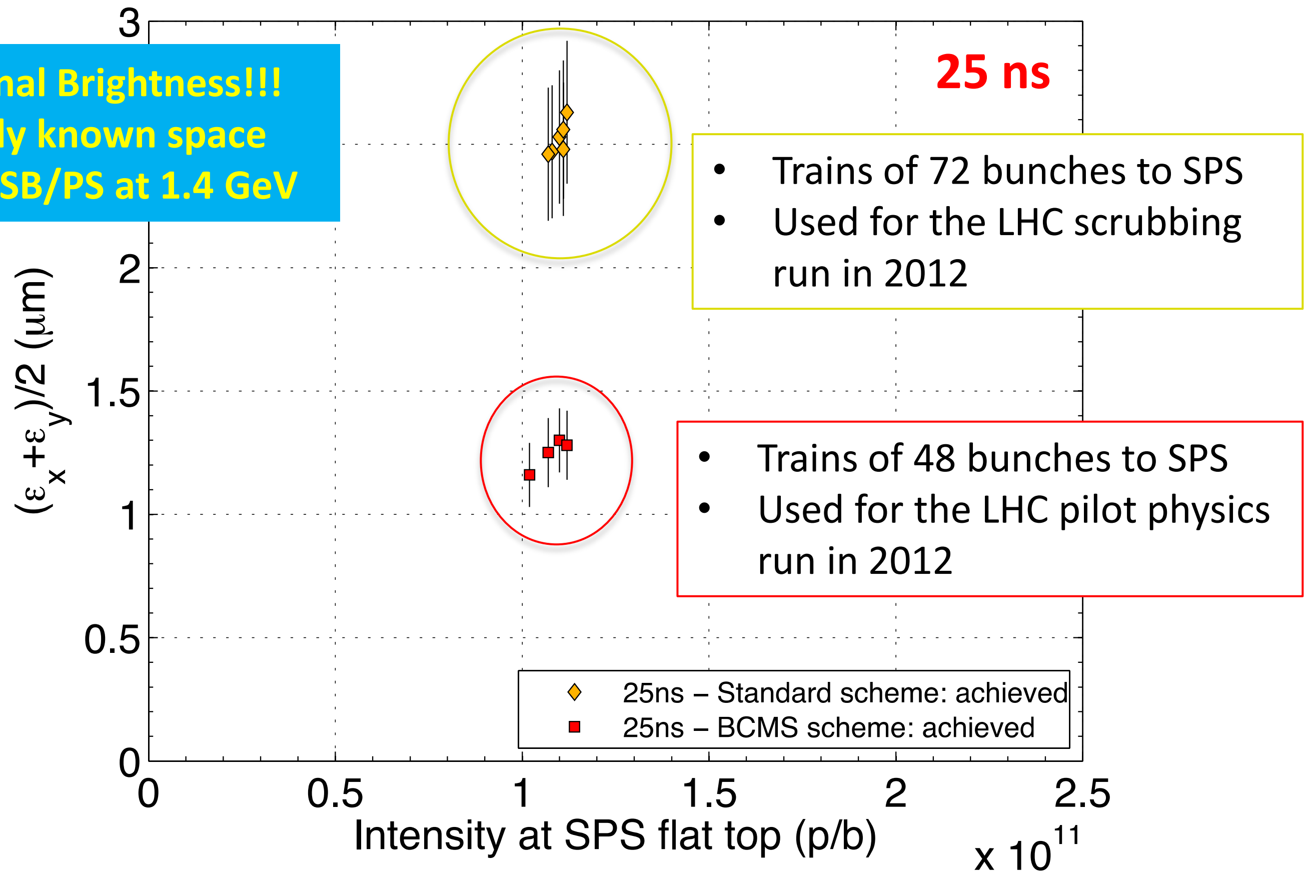
- Performance of the injectors and LHC peak and integrated luminosity if no major upgrade except the connection of LINAC4 and H- injection (G. Rumolo and J. Wenninger)

- Expected shut-down schedule (assuming only "winter stops" for regular maintenance) taking into account the lifetime of major accelerator components (K. Foraz and L. Bottura)

G. Rumolo

2012 injector performance (@SPS ext.)

Up to 3 x Nominal Brightness!!!
At the presently known space
charge limit of PSB/PS at 1.4 GeV



Measurement points

- Emittances deduced from combined wire-scans at end of SPS flat bottom (values cross-checked with LHC)
- Error bars include spread from several measurements as well as systematic uncertainty (10%)
- Intensity measured at SPS flat top after scraping

G. Rumolo

Expected Injector performance after LS1

- 25 ns beam (both standard production and BCMS) already very close to the limits in injectors

- **Higher intensity (SPS RF power limit)**
  - **max 1.3 x 10^{11} ppb**

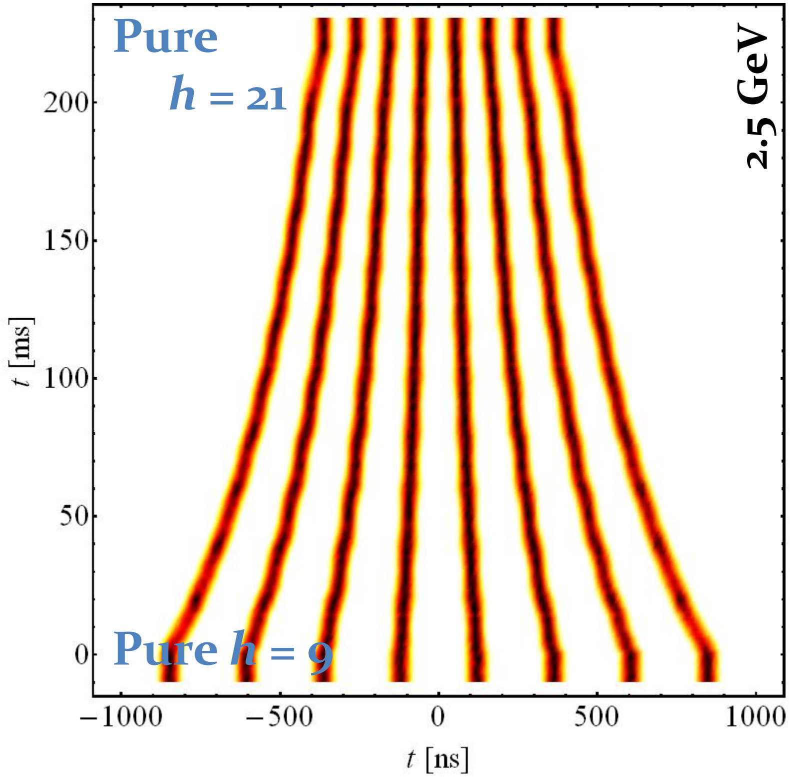
- **Higher brightness (PS space charge)**
  - RF manipulations in the PS @2.5 GeV (instead of 1.4 GeV)
  - PSB control of longitudinal parameters along the cycle

G. Rumolo

Expected Injector performance after LS1

Alternative production scheme
for 25 ns beams

- →**Pure batch compression** at 2.5 GeV (from h=9 to h=21)
- →Twice double splitting at FT
- →Trains of 32 bunches to the SPS
  - ➜ promise to produce ultra-bright 25 ns beams for the post-LS1 era with short trains (favorable against electron cloud), at the price of 13% lower number of bunches in LHC



G. Rumolo

Expected Injector performance after LS1

		PSB						
		N (10^{11} p)	$\epsilon_{x,y}$ (μm)	E (GeV)	ϵ_z (eVs)	B_l (ns)	$\delta p/p_0$	$\Delta Q_{x,y}$
Post-LS1	Standard	19.21	2.02	0.05	1.0	1100	$2.4 \cdot 10^{-3}$	(0.58, 0.67)
	BCMS	9.60	1.06	0.05	1.0	1100	$2.4 \cdot 10^{-3}$	(0.48, 0.61)
	Pure BC	6.40	0.78	0.05	1.0	1100	$2.4 \cdot 10^{-3}$	(0.40, 0.53)

		PS (double injection)						
		N (10^{11} p/b)	$\epsilon_{x,y}$ (μm)	E (GeV)	ϵ_z (eVs/b)	B_l (ns)	$\delta p/p_0$	$\Delta Q_{x,y}$
Post LS1	Standard	18.25	2.12	1.4	2.79	220	$1.8 \cdot 10^{-3}$	(0.14, 0.23)
	BCMS	9.12	1.11	1.4	1.48	150	$1.4 \cdot 10^{-3}$	(0.18, 0.31)
	Pure BC	6.08	0.72	1.4	1.0	150	$0.9 \cdot 10^{-3}$	(0.21, 0.31)

		SPS (several injections)						
					after filamentation (ϵ_z=0.35 eVs, B_l=4 ns @inj)			
		N (10^{11} p/b)	$\epsilon_{x,y}$ (μm)	p (GeV/c)	ϵ_z (eVs/b)	B_l (ns)	$\delta p/p_0$	$\Delta Q_{x,y}$
Post-LS1	Standard	1.44	2.22	26	0.42	3.0	$1.5 \cdot 10^{-3}$	(0.05, 0.08)
	BCMS	1.44	1.16	26	0.42	3.0	$1.5 \cdot 10^{-3}$	(0.08, 0.14)
	Pure BC	1.44	0.86	26	0.42	3.0	$1.5 \cdot 10^{-3}$	(0.10, 0.18)

		LHC					
		N (10^{11} p/b)	$\epsilon_{x,y}$ (μm)	p (GeV/c)	ϵ_z (eVs/b)	B_l (ns)	bunches/train
Post-LS1	Standard	1.30	2.44	450	0.47	1.63	72
	BCMS	1.30	1.28	450	0.47	1.63	48
	Pure BC	1.30	0.95	450	0.47	1.63	32

Small emittances are more difficult to handle in the LHC: IBS, additive sources of blow-up, beam stability

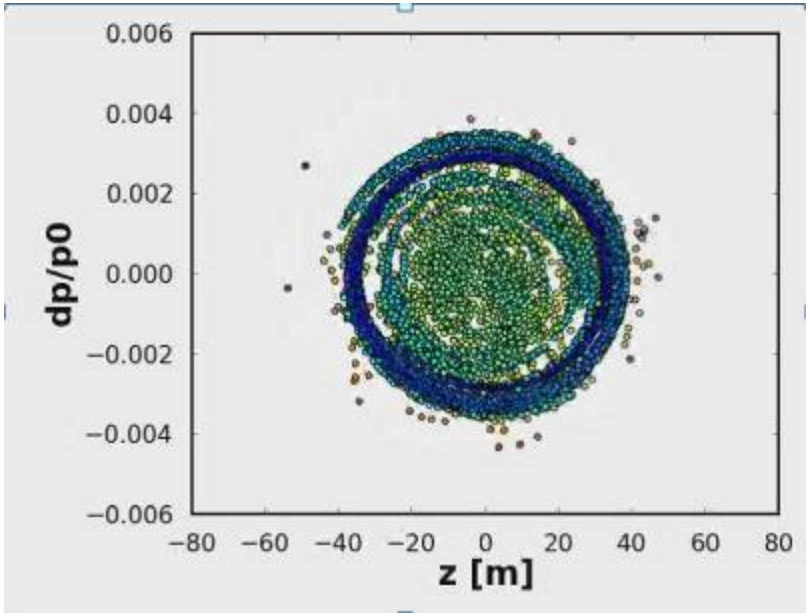
Expected Injector performance after LS1

Only Linac4

→ Standard 25 ns beams: 50% higher brightness (limited by PS space charge) **but intensity limited by the SPS**

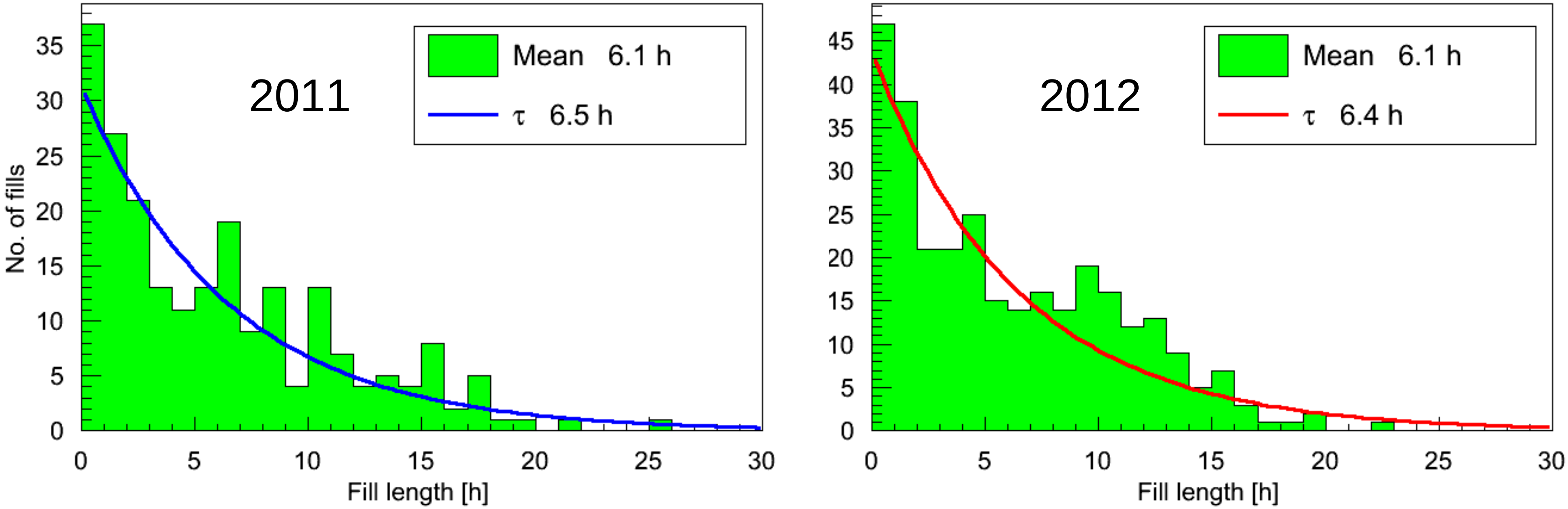
→ BCMS beams: no improvement with Linac4 (space charge in PS)

→ Possible additional gains by creating **hollow bunches** or **using alternative optics in the PS at injection** → need lots of MD time and full experimental validation!



J. Wenninger

- Fill lengths in 2011 and 2012 ≈ exponentials.
  - *~30% of the fills are dumped by OP.*



- An exponential fill length distribution is used for the performance figures quoted in the next slides.

LHC performance estimate post-LS1

J. Wenninger

- The expected integrated luminosity per year for 25 ns is in the range of 45-55 fb^{-1} for a 2012-like efficiency.
  - *For 5 ½ years of operation until LS3 → 250-300 fb^{-1}.*
  - *Unknowns on limitations, emittance, efficiency – 10% level effects – situation will be clearer end 2015.*
  - *Peak luminosity close to / above expected triplet limitation (**~1.75 ×10^{34} $cm^{-2}s^{-1}$** ±10-20%) !!!!*
  - *Pile-up limit in the experiments assumed to be ~45 events/crossing*

- With L4 the standard 25 ns beams and the BCMS beams have very similar performance.
  - *Bonus for standard 25 ns: lower pile-up (~10%).*
  - *The emittances that are eventually achieved may make the difference – easier for standard (larger ε) ?*

LHC performance estimate post-LS1

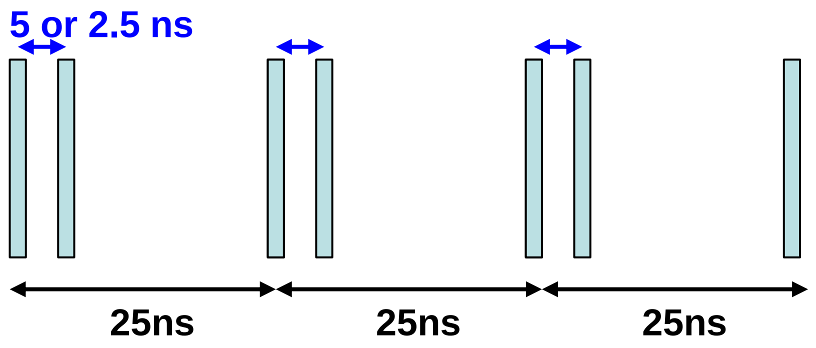
J. Wenninger

- The intensity/brightness may be limited by instabilities.
  - *E-cloud*
  - *Instabilities*
  - *heating*
  - *UFOs.*

Enhance scrubbing at 450 GeV to remove e-cloud in the dipoles "completely" with dedicated scrubbing beam is essential

Use **doublet** beam : **5 – 20 ns or 2.5 – 22.5 ns spacing**

Implications and issues (BI, RF, ADT) under investigation.



Important to test and push bunch population for doublet scheme (20+5 ns) in 2014 to allow faster scrubbing in the SPS and LHC (essential for 25 ns!!!)

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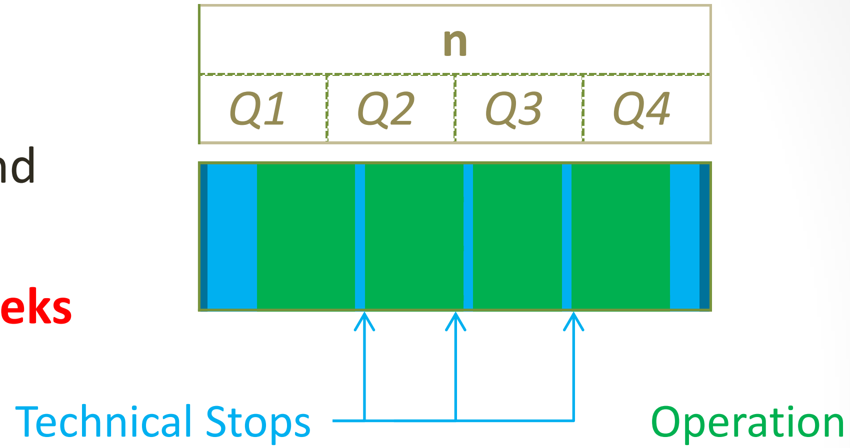
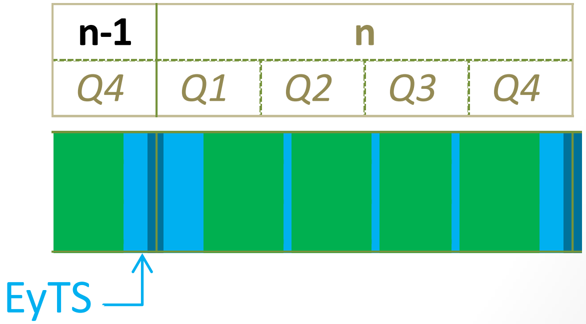
Shutdown schedule until 2035

- **Technical Stops:**
  - In order to perform preventive and corrective maintenance
  - Min. length **= 5 days every 10 weeks**



End of Year Technical Stops:

- ***Assuming ion operation in LHC with no protons in the Injectors at the end of each year (cool-down time)***
- Min. length: **10 weeks** *(incl. Xmas holidays)*

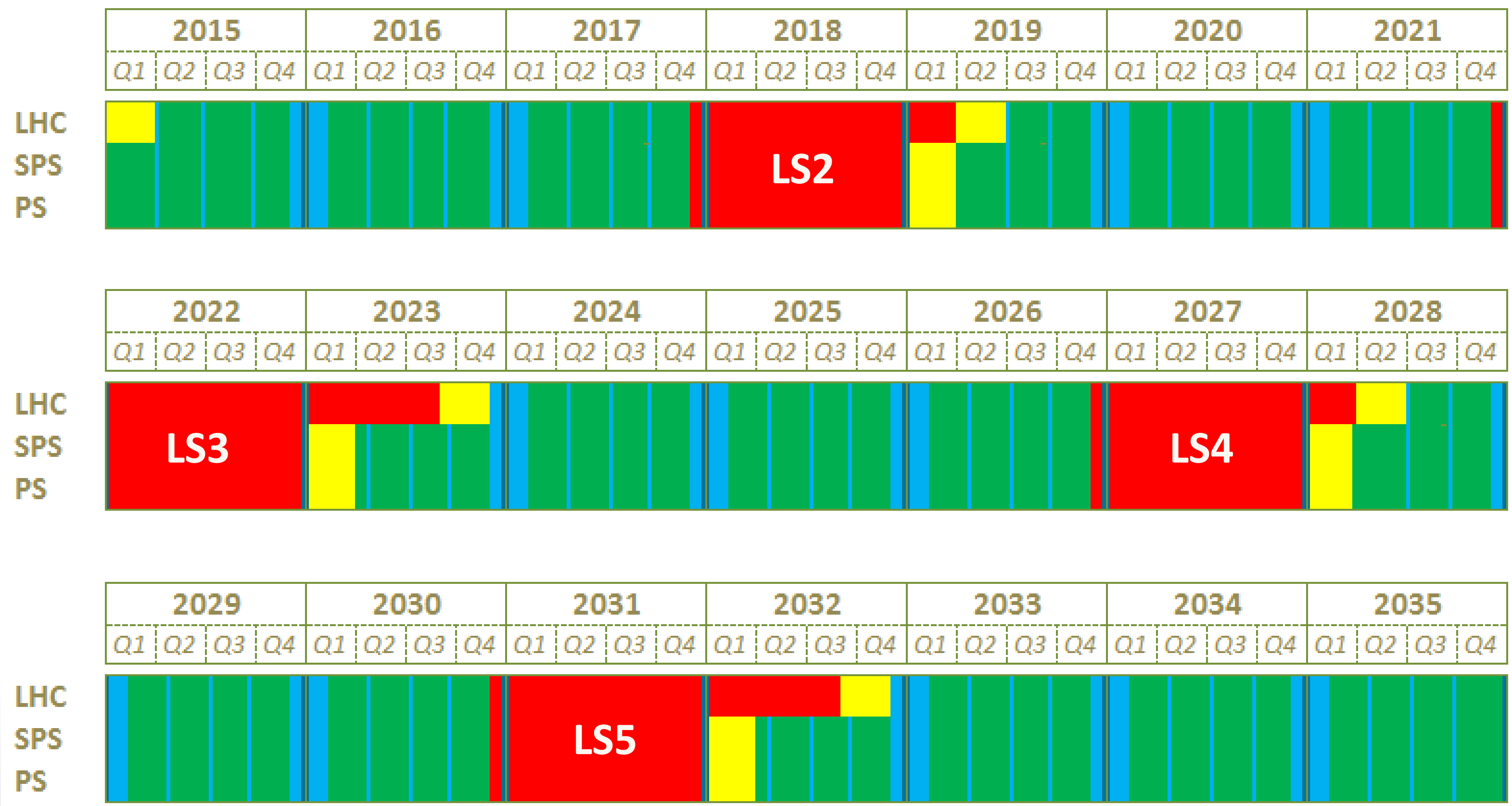


K. Foraz

Shutdown schedule until 2035

Scenario 1

from 2015 to 2035: beam = 57%

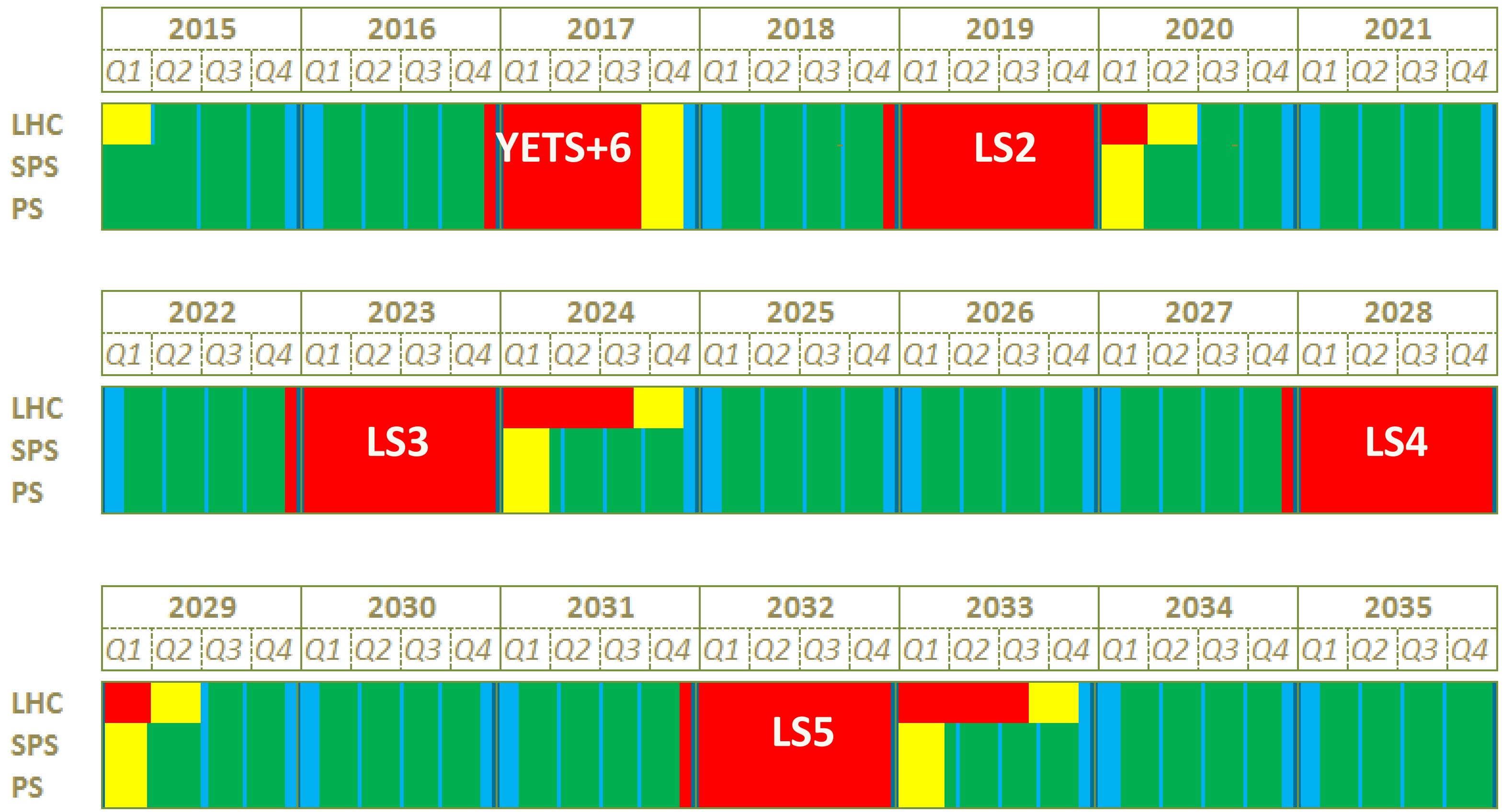


K. Foraz

Shutdown schedule until 2035

Scenario 2

from 2015 to 2035: beam = 54 % of time



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Shutdown schedule until 2035

- Minimum shutdown lengths have been given
  - Leading to beam operation **~3/5th of the time from 2015 to 2035**
  - LS2: LHC 16 months (CV and Cryo), Injectors 12 months (CV and access)
  - LS3: LHC 20 months (**triplets**) , Injectors 12 months (CV)
  - LS4: LHC 16 months (CV+Cryo), Injectors 12 months (CV)
  - LS5: LHC 20 months (**triplets**), Injectors 12 months (CV)

Significantly long stops are required even with no upgrades!

- **Preference for scenario with YETS+6 (see Session 3 – B. Mikulec)**
  - Mitigate risk of Linac2 failure
  - Linac4 is not left idle
  - Reduce LS2 workload (mainly in Injectors) EL, GS, CV….
  - Reduced physics potential (~ 4 %) can be recuperated with one year of additional running in 2036

What could stop us?

- Potential causes of mechanical failures of SC magnets
  - Mechanical fatigue on coil, structure, busses:
    - Powering cycles: 10^4 per magnet
    - Thermal cycles: a few for the LHC
  - Singular events and associated thermal and electrical stress:
    - Quenches: order of 10 per magnet
    - Heater discharges (triggers): order of 10 per magnet
  - Radiation and associated degradation of mechanical and electrical strength:
    - Magnet in the triplet region (Point 1 and Point 5)
    - Magnets in the collimators region (Point 7)

L. Bottura

What could stop us?

- Electromechanical failures:
  - An MTBF of 400…500 years has been estimated for the LHC superconducting magnets
  - This translates in approximately 3…4 magnet electrical NC's per year of operation, and at least 10…15 magnets exchanges every long shutdown ➔ need to have tools to evaluate (on-line) effect of non-conformities
  - Given the estimated MTBF, the probability of electrical failure of one of the triplet magnets within the next 10 years of operation is 3 %, i.e. 1 magnet

- Questions:
  - Ageing?
  - Impact of number of cycles?
  - Experimental magnets

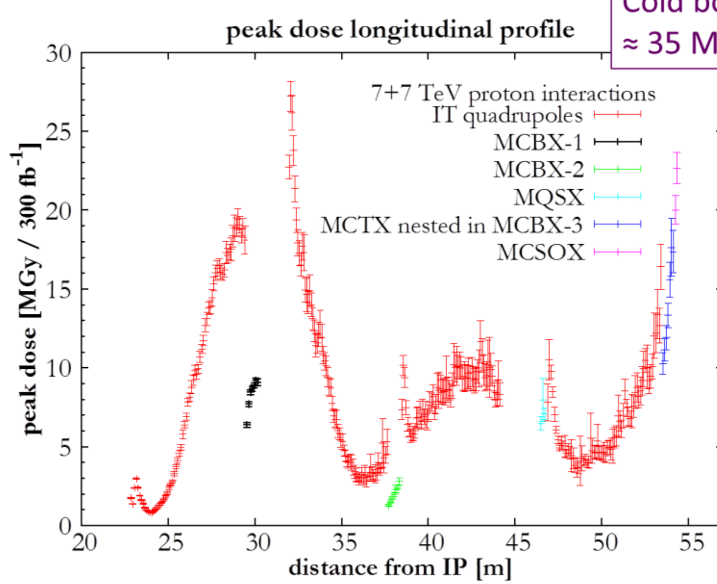
What could stop us?

- Radiation and Inner Triplets

L. Bottura

- Expected dose by LS3 (300 fb^{-1})
  - Range of 27 [18…40] MGy in the Q2
  - Range of 20 [13…30] MGy in the MCBX
- IT may experience mechanically-induced insulation failure in the range of 300 fb^{-1} (LS3 ± 1 year) **consistent with previous analyses.**
- Effects:
  - Premature quenches (cracks in end spacers)
  - Insulation degradation (monitor on line)
  - Mechanical failure (nested coils in MCBX)

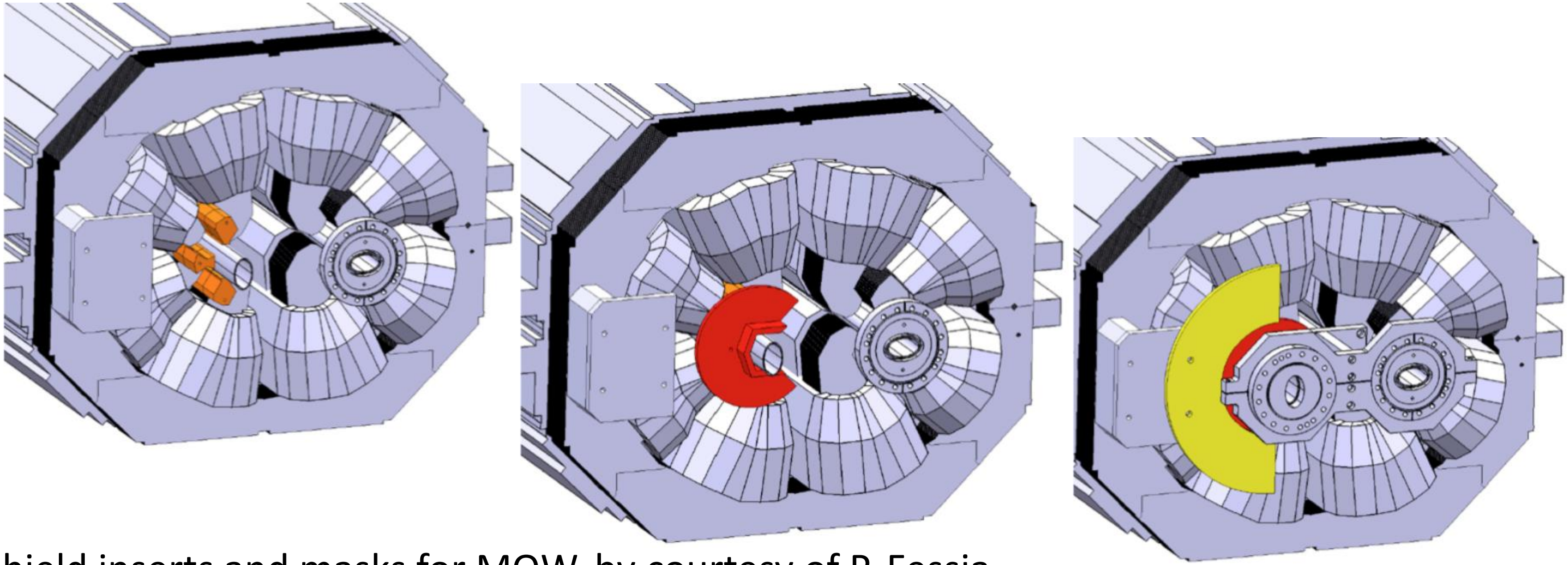
Cold bore insulation ≈ 35 MGy



What could stop us?

L. Bottura

- Radiation on the warm magnets (collimation area)
- Expected dose by LS3 (300 fb^{-1})
  - Range of 80….90 MGy in the MBW and MQW
- Actions have been proposed and approved to avoid insulation failure in the period LS2 to LS3
- Starting in LS1

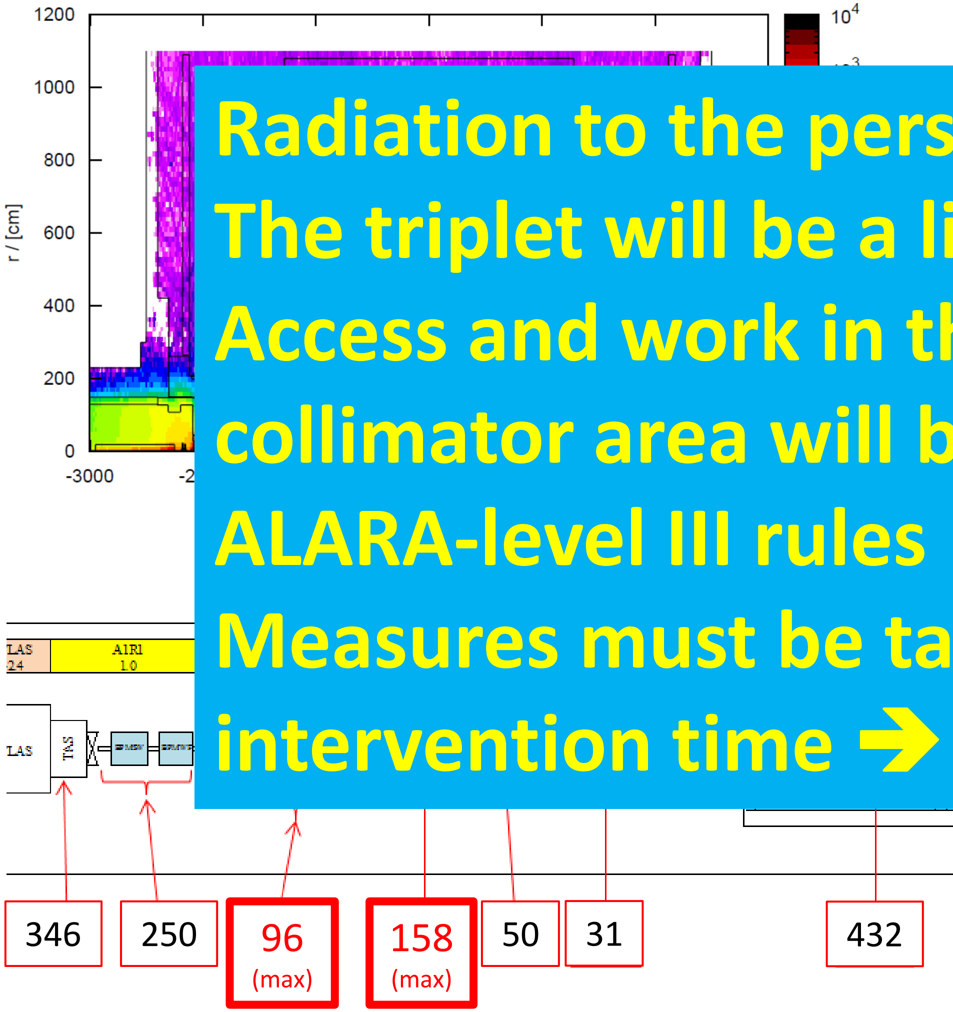


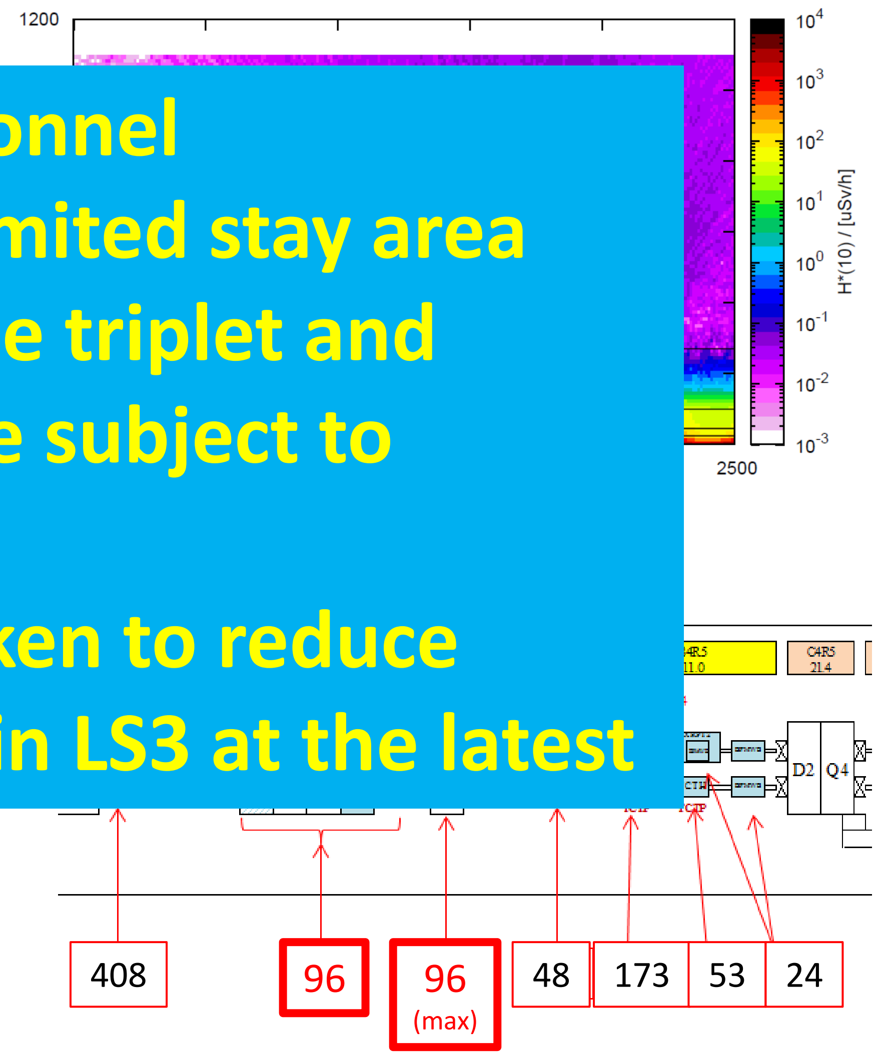
Shield inserts and masks for MQW, by courtesy of P. Fessia

L. Bottura

What could stop us?

- Point 1
- Point 5





Radiation to the personnel
The triplet will be a limited stay area
Access and work in the triplet and collimator area will be subject to ALARA-level III rules
Measures must be taken to reduce intervention time → in LS3 at the latest

S. Roesler, The Panorama of the Future Radioactive Zones from Now to 2020, May 2013
https://indico.cern.ch/conferenceDisplay.py?confId=233480