Session 3
Performance Improving Consolidation and Upgrade scenario 1

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Thanks to all speakers and contributors

Setting the scene

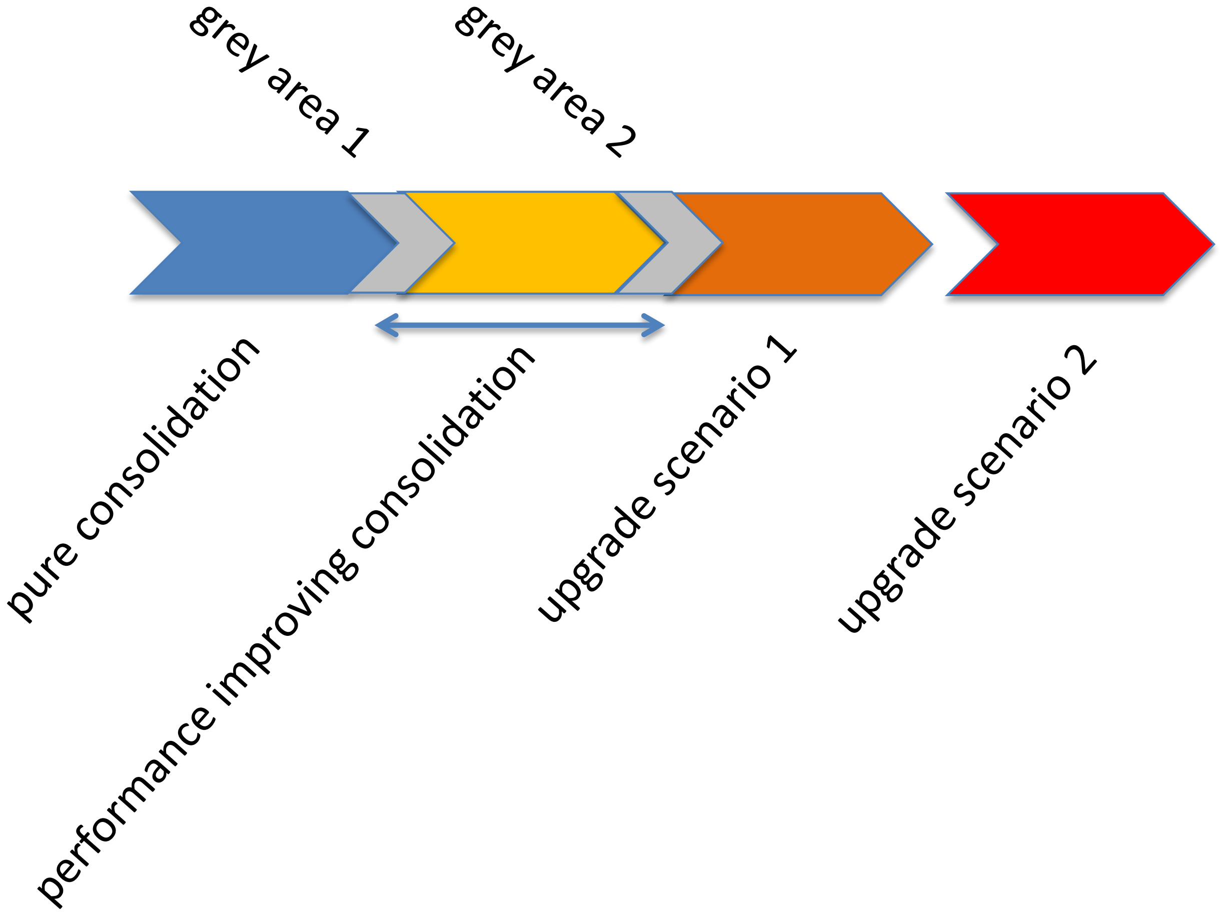
PIC: PERFORMANCE IMPROVING CONSOLIDATION:
Replacement or upgrade of a system justified by consolidation but with the goal of improving performance

	PIC	Upgrade scenario 1	Upgrade scenario 2
Initial integrated luminosity (fb^{-1})	300	300	300
Integrated luminosity after 10 years of operation (fb^{-1})	1000	2000	3000
Yearly luminosity target (fb^{-1})	70	170	270

Which beam parameters can reach these targets?
What are the related actions on the equipment?

PICs in the injectors: What are we talking about? - K. Hanke

Clear PIC definition but some overlaps and grey zone with pure consolidation and US 1 and 2.



LIU PICs in short

- **Time drivers and minimum single block**

  LIU-PSB: minimum single block **12 m**

  LIU-PS: minimum single block **3 m**

  LIU-SPS: minimum single block **6 m**

  => all time estimates depend strongly on available resources (manpower)

  => consequent amount of work to be done in parallel for all machine

  => to be considered with the Cons, maintenance, upgrade preparatory work

- **Cost of PICs**

  LIU-PSB: 50 MCHF (essentially LIU-PSB budget ~61MCHF)

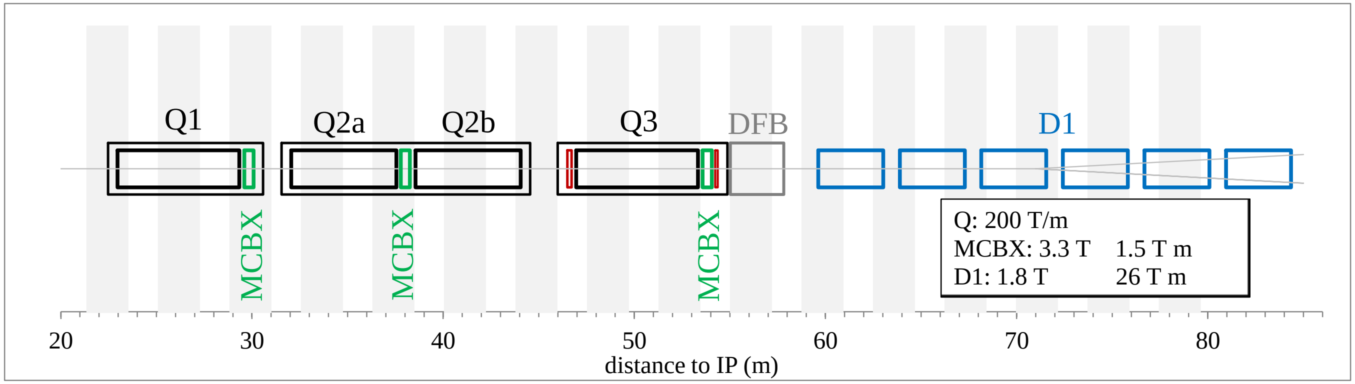
  LIU-PS: 16 MCHF (80% of total budget 20 MCHF)

  LIU-SPS: 23 MCHF (30% of total budget 77 MCF)

PICs are mandatory and must be fully implemented in LS2 in the injectors regardless of which upgrade scenario is chosen

PICs in the LHC: What are we talking about? - P. Fessia

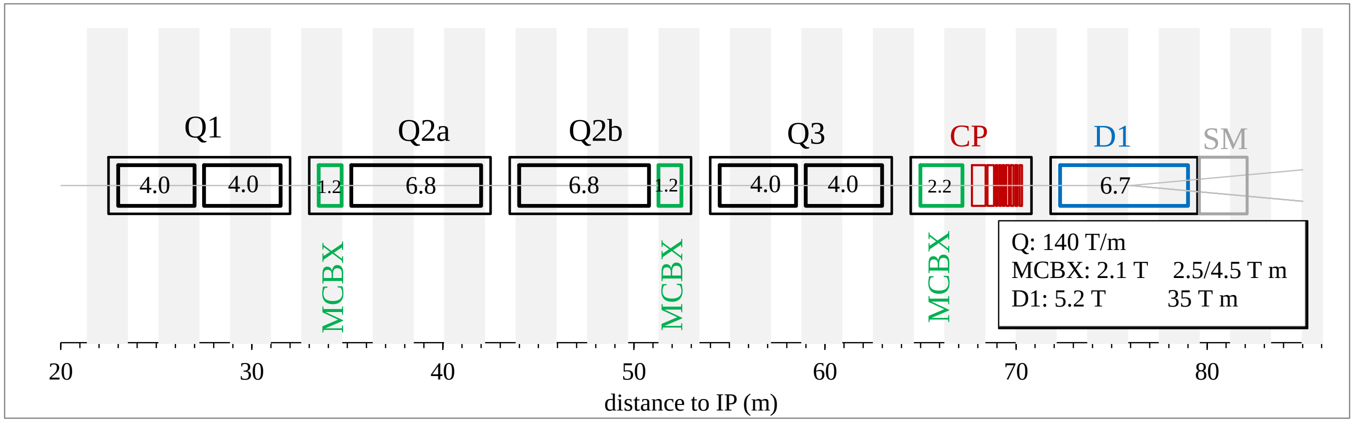
Interaction region layouts



LHC

Aperture ~twice the LHC baseline (70 mm to 150 mm),

but more compact triplet layout thanks to Nb_3Sn and superconductive D1



HL LHC

LHC PICs in short

- PIC actions
  - Concern practically all the sectors of the machine
  - They are spread between the 1st long technical stop after LS1 and LS3
- Interaction region interventions in IP 1 and 5 provide safe operation for 2025->2035 years and the required luminosity capacity
- Collimation interventions push down the whole machine impedance providing more robust collimators and ensure safe ion run in IP2.
- Beam diagnostic interventions provide the necessary diagnostic capacity, with hardware compatible with the higher radiation dose
- Sc links provide a solution to radiation electronic issues for the Power converters, but also contribute in reducing collective dose and interventions time
- Cryoplant at point 4 provides flexibility in the management of the RF interventions and eliminate the 1st machine bottleneck in term of cooling capacity. All cryo installation have to be performed with a long term view in the installation/integration perspective (foresee for future needs)
- High radiation dose call for radiation management and possible reconfiguration to provide the best possible reliability and access conditions. Radiation tolerant electronic development (including R&D and testing) will affect several equipment groups (costs, resources)

PICs: what do we gain in beam performance? – G. Arduini

PIC @ 6.5 TeV (Pile-up limit at 140)

	$\varepsilon^*_{n\ coll}$ [μm]	Opt. Fill length 2012 6h	η_{6h}/η_{opt} [%] Goal <50%	ϕ_{6h}/ϕ_{opt} [%] 2012 36%	Int. Lumi for η=50% for 6h /opt. fill length Goal > 70 fb^{-1}	Max. Mean Pile-up density/Pile-up [ev./mm]/[ev./xing] <1.3/<140
BCMS – 40/20	1.85	6.5	37/37	25/26	93/94	0.97/84
Standard - 40/20	2.25	7.3	40/40	27/28	87/88	0.79/69
BCMS – 50/25	1.85	6.8	39/39	26/27	89/89	0.77/78
Standard – 50/25	2.25	7.6	43/42	28/30	82/83	0.63/64

- I/b= 1.38e11/b in collision
- The luminosity target can be reached with 40/20 optics
- BCMS (Batch Compression Merging and Splitting): slightly higher performance but more sensitive than standard scheme to additive sources of emittance blow-up
- 50/25 optics provides margin in aperture and offers a reduction of the pile-up density below 0.7 events/mm
- Key questions and studies required in Run 2 have been sketched - Understanding and Control of the sources of blow-up; Confirmation of the feasibility of β*-levelling as a possible solution for IP8; Confirmation of the feasibility of scrubbing the dipoles down to SEY=1.3-1.4 possibly with dedicated beams; Full understanding of the stability limits for single and two-beams

Which beams in the injectors fulfil HL-LHC Upgrade Scenario 1 goals? S. Gilardoni

	LHC collision		SPS extraction	
Standard Scheme	**Int/b**	**Emitt* (µrad)**	**Int/b**	**Emitt* (µrad)**
~~US1 Baseline~~	~~1.50E+11~~	~~1.5~~	~~1.58E+11~~	~~1.25~~
~~US1 low emit.~~	~~1.20E+11~~	~~1~~	~~1.26E+11~~	~~0.83~~
US1 LIU SPS LLRF 200 MHz upgrade	1.38E+11	1.64	1.45E+11	1.37
US1 LIU SPS 200 MHz full upgrade	1.90E+11	2.26	2.00E+11	1.88
BCMS				
~~US1 Baseline with BCMS~~	~~1.50E+11~~	~~1.5~~	~~1.58E+11~~	~~1.25~~
~~US1 low emittance with BCMS~~	~~1.20E+11~~	~~1~~	~~1.26E+11~~	~~0.83~~
US1 LIU SPS LLRF 200 MHz upgrade	1.38E+11	1.09	1.45E+11	0.91
US1 LIU SPS 200 MHz full upgrade	1.90E+11	1.64	2.00E+11	1.37

Large bunch intensity in LHC more important than low emittances

200 MHz RF Upgrade necessary to match the preferred requirements of LHC-US1 with unchanged longitudinal parameters at LHC injection.

LIU US1 ≣ LIU US2

→Oliver analysis based on evaluation of non-crossed out cases and with variations of the beam emittance

HL-LHC for US1? – O. Bruening

- US1 flat beams; SPS with new LLRF system and with the RF power upgrade
- N at collisions = 1.9 10^{11}ppb
- n = 2508 colliding pairs in IR1 and IR5 (revised BCMS filling scheme)
- normalized emittance = 2.65 micrometer (> 70% blow-up wrt SPS extraction)
- flat beams with beta* = 0.4m / 0.1m
- beam separation of 10 sigma -> crossing angle of 310 microrad
- IBS growth rates of ca. 22h horizontally and 25h longitudinally (scaled)
- Peak Luminosity = 8 10^{34} cm^{-2} s^{-1}
- Leveling time = 2.9 h; Lumi decay time = 4 h; Turnaround time = 3 hours
- Total fill length (leveling + decay + turnaround) = 9.9h
- Integrated Lumi per fill =1.06 fb^{-1}; Lumi per year for perfect operation = 413fb^{-1}
- Required efficiency for achieving 170fb^{-1} per year = 41%

==> this case could reach the US1 goals and is OK from the IBS point of view, requiring essentially TAS and TAN upgrades

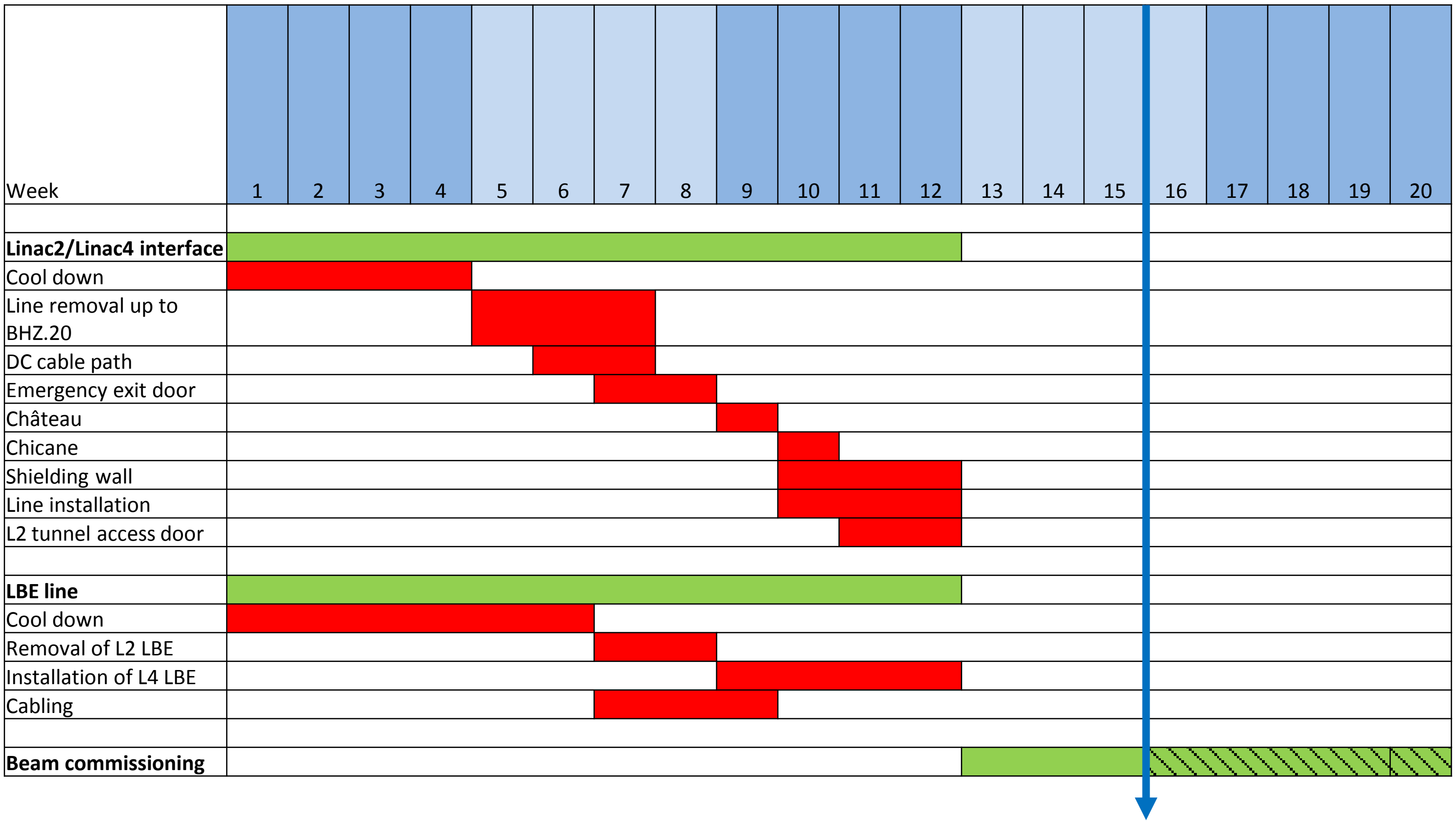
HL-LHC for US1 – O. Bruening

- Beam-Beam Wire compensator is very important for US1. Optimum position at 10σ → integration aspects with Collimation System!
- Small emittance beams from LIU upgrade can not really be utilized in the LHC for US1 due to IBS limitations .
- US1 goals compatible with full SPS upgrade and HL-LHC PIC when operating with flat beams (40cm/20cm). Smaller β^* (e.g. 40cm/10cm) can provide more performance (>20%) but requires some Matching Section upgrades

Work effort in the LHC accelerator for US1 – E. Todesco

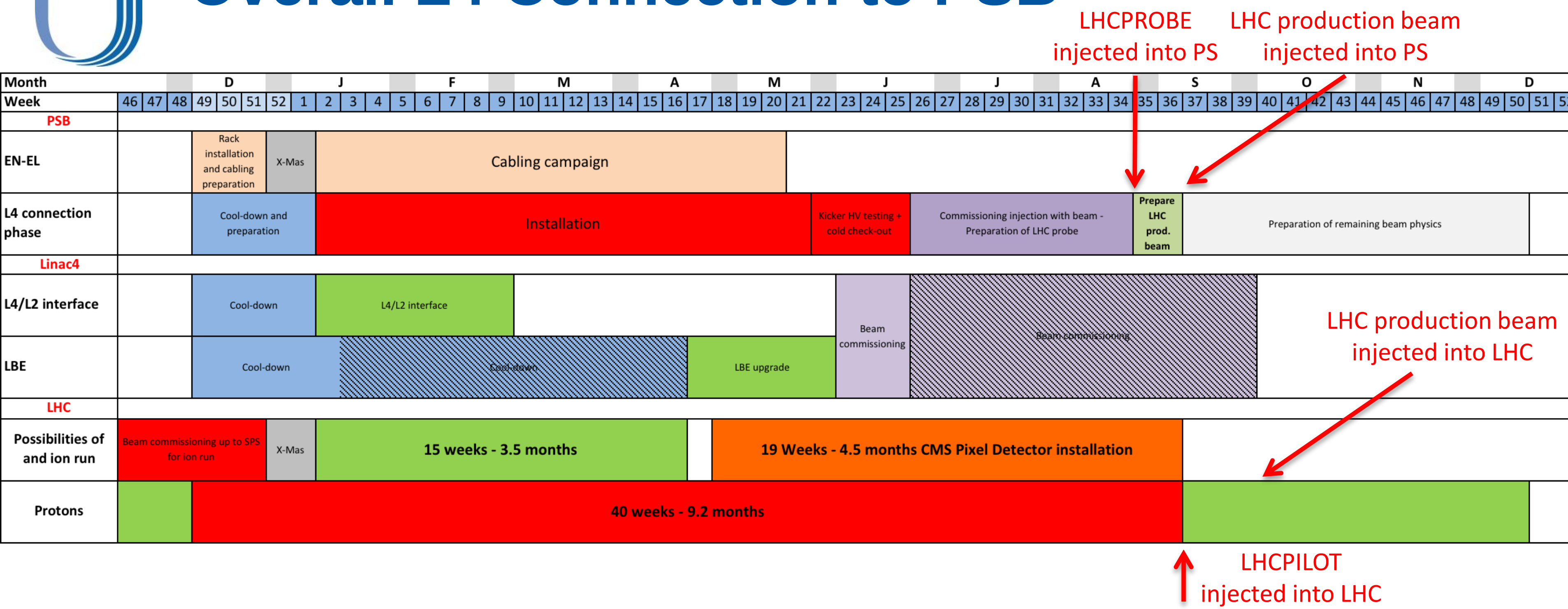
- Upgrade scenario 1 work effort
  - Same peak lumi as US2 (heat loads), and 2/3 of data (radiation damage) – many unknowns to be seen with 7 TeV operation
  - New triplet/D1 as defined for PIC allows to swallow larger heat loads, and radiation damage
  - Matching section becomes a bottelneck for β^* (not lower than 30 cm), but can swallow heat load and radiation damage
  - Scenario relies on ability to increase beam intensity
- Work effort
  - Collimators in IR7, IR1, IR5
  - Superconductive link for matching sections in IR1 and IR5
  - Beam-beam long range wire compensator needed
    - New piece of hardware, not yet proved for LHC
    - Proof of principle for the LHC in ~2017

Work Effort in the LHC Injector Complex, Including Linac4 Connection, for the Upgrade Scenarios – Jean-Baptiste Lallement, Bettina Mikulec



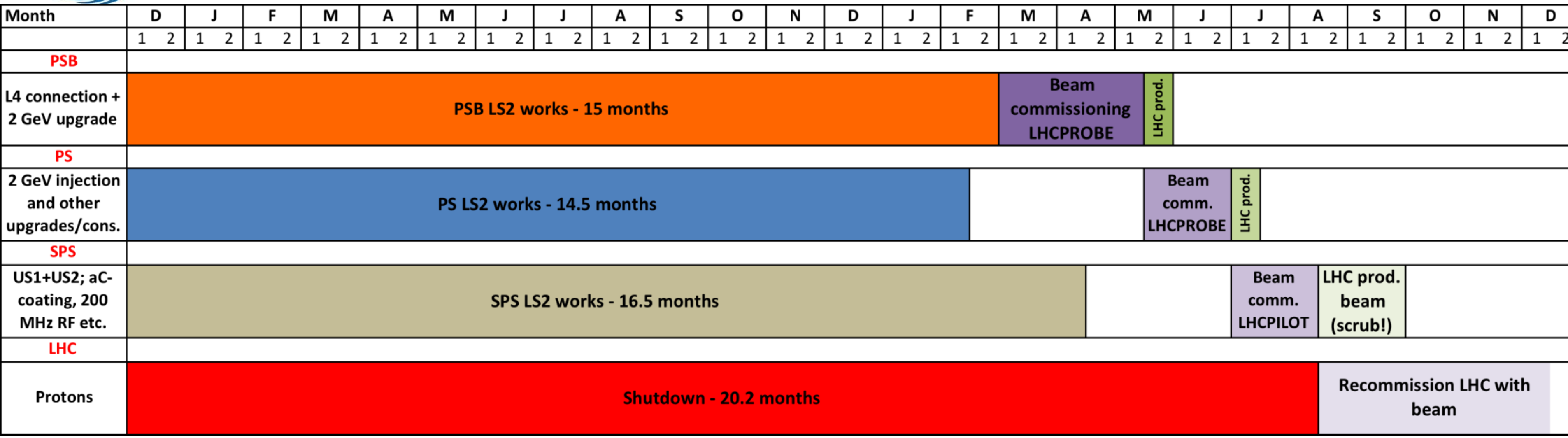
Linac4 : 15 weeks to deliver a beam to the PSB

Overall L4 Connection to PSB



- Duration for the Linac4 connection to the PSB: 9.2 months
  - Deliverable: LHC production beam injected into PS; coincides with injection of LHCPILOT beam into the LHC
  - Other physics beams to follow at an estimated rate of ~2/week
- First beam to the PS after 9 months
- Ion run and CMS pixel detector installation in parallel?
  - Ion beam commissioning in LHC ion injector chain end of 2016 in parallel to p run
  - LHC ion run of up to 3.5 month after X-mas
  - CMS pixel detector installation: 4.5 months
  - Could other activities profit? (NA61/SHINE etc.)

LIU LS2 Planning



LS2:

- Time line driven by PSB activities (impressive cabling work to be performed -> coherent scheduling in progress taking into account the overall requests needed for other projects)
  - ➢ PSB first beam (LHCPROBE) to the PS: **after 17.5 months**
  - ➢ PS ready for beam from PSB already **after 14.5 months** **-> need to gain 3 m in PSB**
  - ➢ SPS ready for beam from PS: **after 16.5 months**

→ **First injection of LHCPILOT into the LHC: after ~20.5 months**

→ **Minimum time for injection of LHC production beam into the LHC: after ~22 months** (scrubbing!)

Summary of session 3 (1/2)

- PICs
  - Need to be fully implemented in the LIU regardless of the chosen Upgrade Scenario.
  - PICs (new triplet+collimation upgrade+ Cryo…) are mandatory for future HL-LHC operation
  - PICs provide at least 70 fb^{-1} / year and fulfil the 1000 fb^{-1} target sets for the PICs only scenario until 10 y operation to 2035
- Upgrade scenario 1
  - Means Full Upgrade of the injectors (identical upgrade to scenario 2)
  - Allows reaching the set target of 2000 fb^{-1} (170 fb^{-1}/y) using 'smaller' emittance beams

Summary of session 3 (2/2)

- Schedule
  - Coordinated effort to plan all the upgrade implementation is to be started, taking into account all needed resources for LIU, HL-LHC but also CONS and other requests
  - Should cover a longer time span (few LS)
  - LS2: LIU implementation to be ready for post-LS3 operation
  - LS2 should be at least 18 months