Linac4 ▶ PSB ▶ PS : Schedule and expected performance

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Chamonix 2010

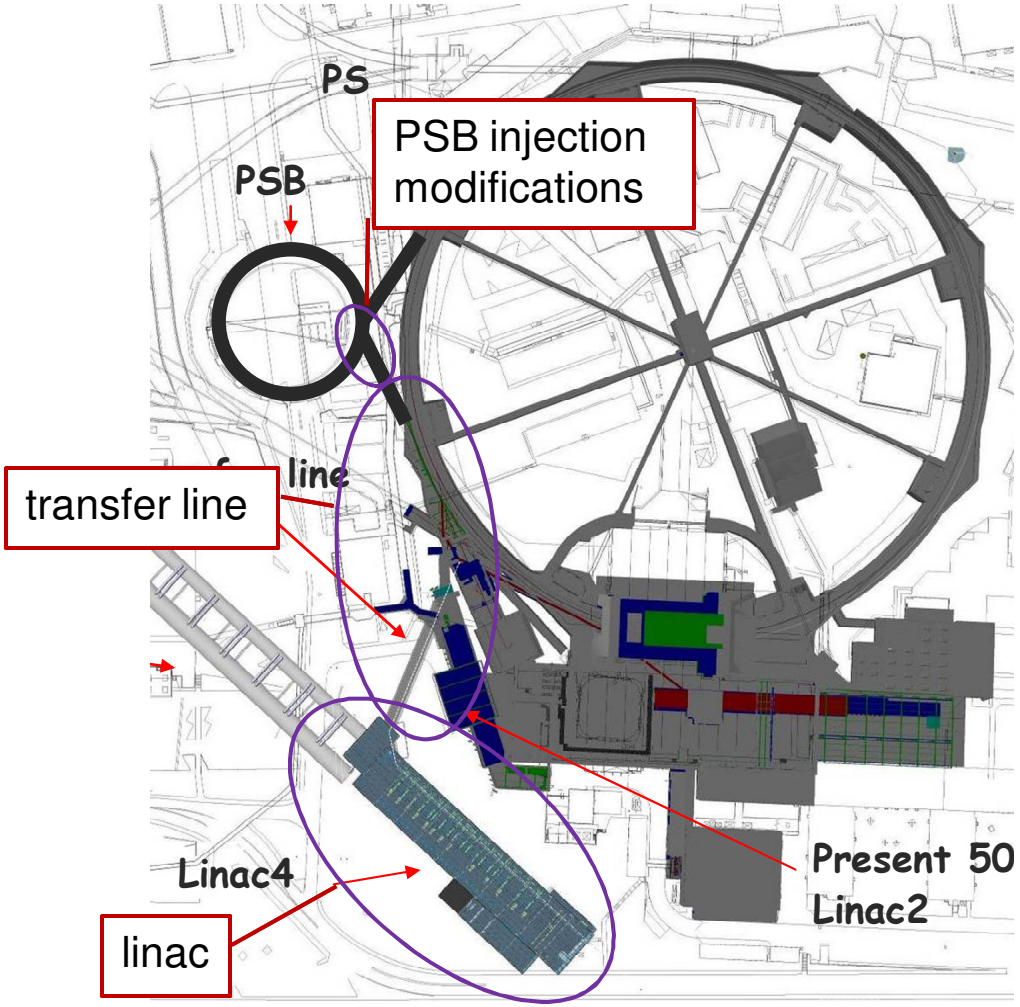
Contents

- Linac4 sub-systems and commissioning plans.
- Linac4 schedule “flexibility”.
- Linac4 shut-down duration and constraints.
- Performance of PS complex with Linac4.
- Overall schedule (construction + performance).

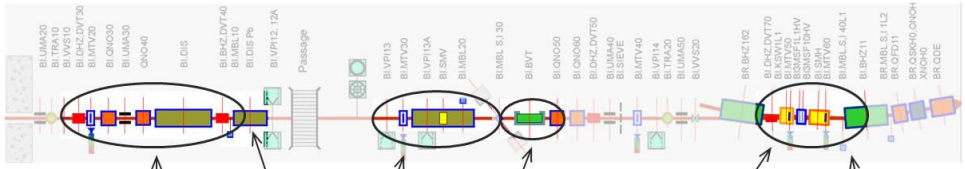
Extension of the Linac4 Project

The “Linac4 Project” is composed of 3 parts:

1. Construction and commissioning of Linac4 *(up to Linac4 dump).*
2. Construction of the transfer line, connection to Linac2 line, upgrade of the measurement lines *(up to PSB wall, LBE dump)*.
3. Modification of PSB injection region for H^-, 160 MeV *(commissioning of PSB with Linac4).*



The three project parts



Remove obsolete BI.DIS Pb

Modify BI.DIS for 4.3 mrad @ 160 MeV

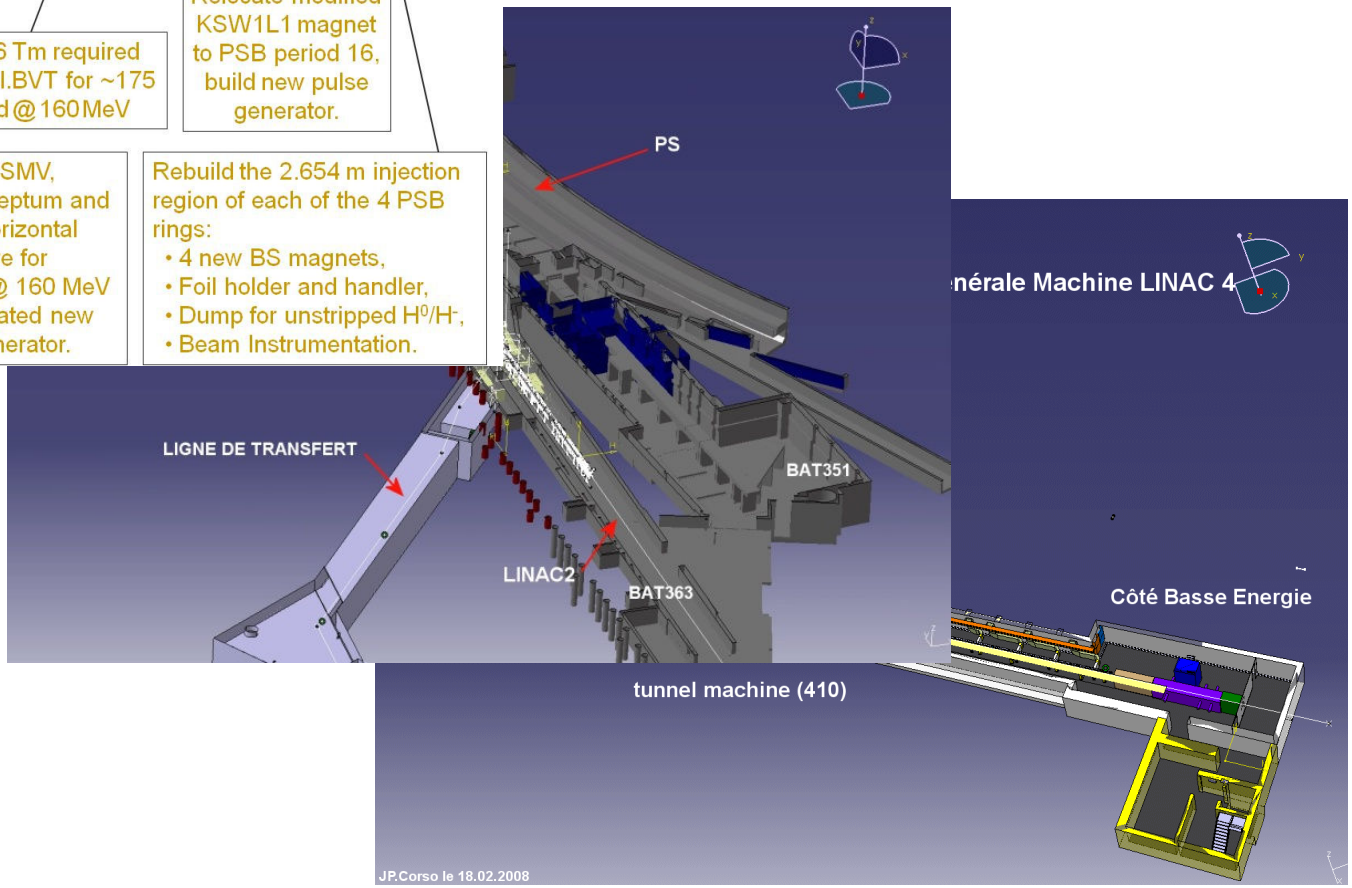
Performance increase of 1.9 in ∫B•dl of BI.DVT30, BI.QNO30, BI.QNO40, BI.DVT40.

~0.36 Tm required from BI.BVT for ~175 mrad @ 160 MeV

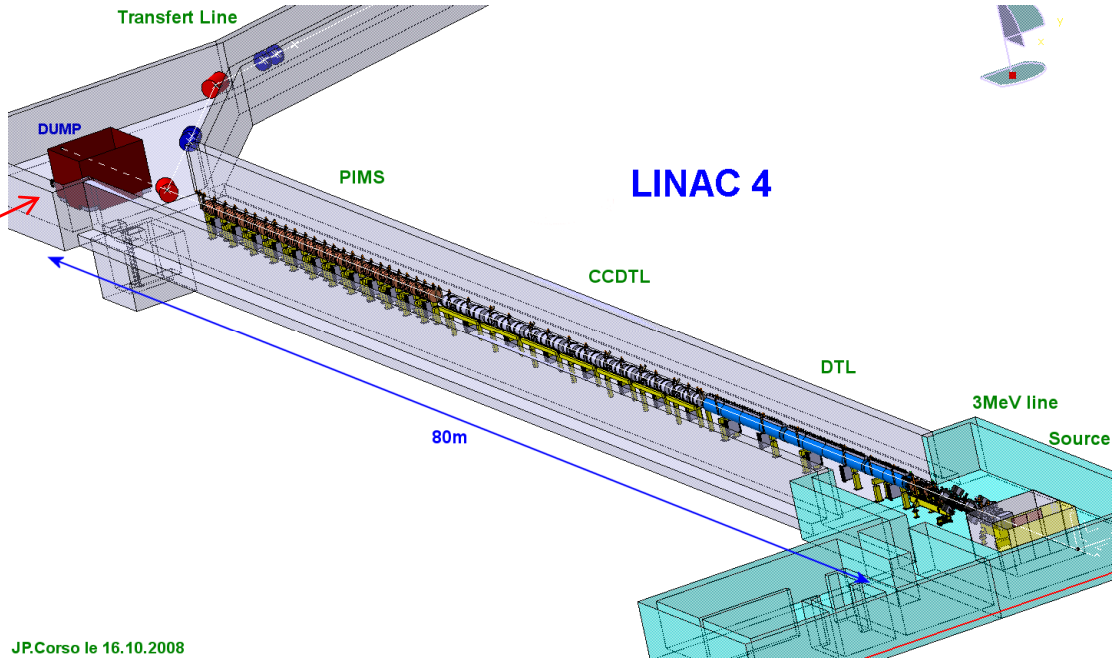
New BI.SMV, 4 mm thick septum and 70 mm horizontal aperture for ~165 mrad @ 160 MeV with associated new pulse generator.

Relocate modified KSW1L1 magnet to PSB period 16, build new pulse generator.

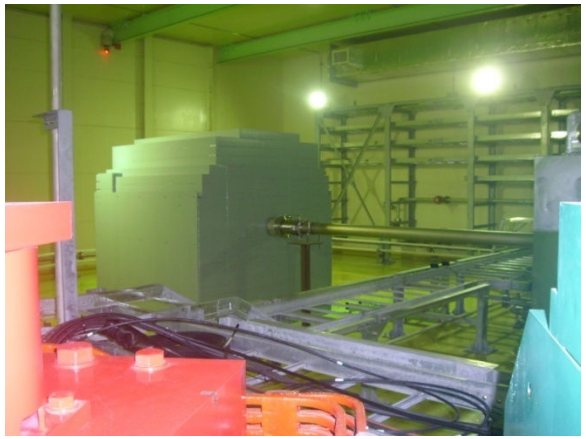
Rebuild the 2.654 m injection region of each of the 4 PSB rings:
- 4 new BS magnets,
- Foil holder and handler,
- Dump for unstripped H^0/H^-,
- Beam Instrumentation.



Linac4 Commissioning Plan



Dump at the end of Linac4



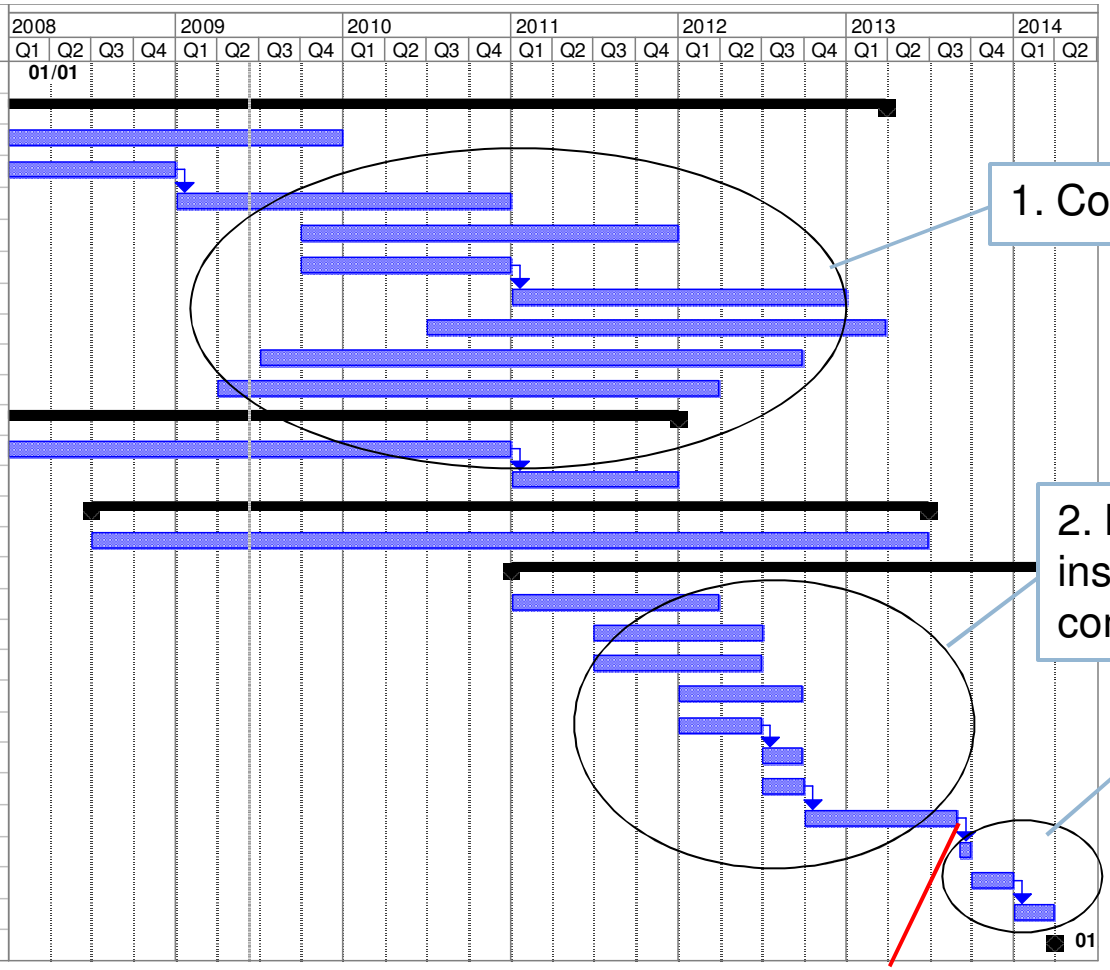
Will be similar to the JPARC linac dump shown here

1. Commissioning of 3 MeV injector.
2. Commissioning of DTL1 (12 MeV).
3. Commissioning of DTL2 (50 MeV).
4. Commissioning of CCDTL (100 MeV)
5. Commissioning of PIMS (160 MeV, to linac dump)
6. Commissioning of transfer line (to PSB or additional dump)

Linac4 schedule

Present Master Plan, approved in April 2009

ID	Task Name
1	**Linac4 project start**
2	**Linac systems**
3	Source and LEBT construction, test
4	Drawings, material procurement
5	RFQ construction and commissioning
6	Accelerating structures construction
7	Klystron prototypying
8	Klystrons production
9	Transfer line construction and installation
10	Magnets construction
11	Power converters construction
12	**Building and infrastructure**
13	Building design and construction
14	Infrastructure installation
15	**PS Booster systems**
16	PSB injection elements construction
17	**Installation and commissioning**
18	Test stand operation (3 + 10 MeV)
19	Cavities testing, conditioning
20	Cabling, waveguides installation
21	Accelerator installation
22	Klystrons, modulators installation
23	Hardware tests
24	Front-end commissioning
25	Linac accelerator commissioning
26	Transfer line commissioning
27	PSB modifications
28	PSB commissioning with Linac4
29	**PSB beam ready for PS**



1. Construction

2. Linac installation, commissioning

3. Connection and PSB commissio ning

MILESTONE: Linac4 ready for connection to PSB, *end 2013*

Flexibility in Linac4 schedule

- In the schedule we can easily separate 2 parts: a) linac construction and commissioning; b) transfer line connection, PSB modification and PSB commissioning. The commissioning of the linac has no interference with the present machines.
- When can Linac4 be ready? The project has been delayed by 1 year in 2009, the new schedule approved in April 2009 foresees end of commissioning in September 2013. So far some minor delays, but project is more or less on schedule.
- However, the recent risk analysis has underlined the risk of delays of the order of few months (mainly due to missing manpower resources) and of initial reliability issues.
- Conclusion: the connection to PSB can be delayed by 1 year (to 2014/15) if required by general planning, however it would be wise to keep the present linac schedule, and foresee the additional year as spare time, in order to: a) absorb delays, b) sort out potential reliability issues, c) improve performance.
- Consequences: 1) the shielding of the linac dump has to be improved, to stand 1 year of testing beams (limits to be checked) and an additional commissioning dump at the end of transfer line can be considered; 2) more manpower will be needed to run in parallel Linac4 and Linac2 in 2014.
- In general terms, we can (probably) continue to run test beams in Linac4 until we get the green light for the connection to the PSB.

Duration of "Linac4" shut-down

Shut-down required for the connection of Linac4 to PSB:

- 1 month for radiation cool-down in PSB injection area.
- 3 months for PSB hardware modifications.
- 3 months for PSB commissioning with the new hardware (goal: prepare all the standard beams as before the connection).
- 1 month (2+2 weeks) for commissioning PS and SPS (standard duration after long shut-down).

Note: there is no interference between the ion complex and the connection of Linac4
→ **the LHC can run with ions during the "Linac4" shut-down**.

Total time required:

- 8 months of LHC (proton) shut-down, or
- 6 months of LHC shut-down if a run is terminated with a 2-month ion run (≈ duration of a standard LHC long shut-down)

Schedule for Linac4 connection

COMPOSITION LINAC4 SHUT-DOWN	1	2	3	4	5	6	7	8	month
Cool-down radiation in PSB area									
Connection transfer line (+beam tests?)									
Modification PSB hardware									
Commissioning PSB with new hardware									
Start-up PS-SPS									

Goal: at start-up, reproduce the same beams as with Linac2

Performance with Linac4

BOTTOM LINE:

- Linac4 current 40 mA during 400 μs (in ε=0.45 π mm mrad) = 10^{14} ppp → plenty of margin in intensity.
- 160 MeV energy chosen in order to double $\beta\gamma^2$ and therefore intensity in PSB for same ΔQ ($I/\Delta Q \sim \beta\gamma^2$) → same performance as now with single batch injection from PSB into PS, increased performance in double batch.

Performance Tables

Limitations are highlighted in yellow; values to be demonstrated are in italic.

LHC INJECTORS WITH LINAC2		Nominal LHC Double Batch	Expected Maximum Double Batch	Original proposal, 1997 Nominal	Original proposal, 1997 Ultimate
PSB out *($\varepsilon^* \leq 2.5\ \mu m$)*	ppr	1.62 x10^{12} *(1bunch/ring)* ↓ *(6 bunches, h=7)*	1.8 x10^{12} *(1bunch/ring)* ↓ *(6 bunches, h=7)*	1.05 x10^{12} *(1bunch/ring)* ↓ *(8 bunches, h=8)*	1.8 x10^{12} *(1bunch/ring)* ↓ *(8 bunches, h=8)*
PS out, per pulse	ppp	9.72 x10^{12}	10.8 x10^{12}	8.4 x10^{12}	14.4 x10^{12}
PS out, per bunch *($\varepsilon^* \leq 3\ \mu m$)*	ppb	1.35 x10^{11} *(72 bunches)* ↓ *15% loss*	1.5 x10^{11} *(72 bunches)* ↓ *15% loss*	1.0 x10^{11} *(84 bunches)* ↓ *no loss*	1.7 x10^{11} *(84 bunches)* ↓ *no loss*
SPS out	ppb	1.15 x10^{11}	*1.27 x10^{11}*	1.0 x10^{11}	1.7 x10^{11}

LHC INJECTORS WITH LINAC4		Nominal LHC Single batch	Maximum Single batch	Maximum Double batch	Single batch + PS h=14, 12 bunches scheme
PSB out *($\varepsilon^* \leq 2.5\ \mu m$)*	ppr	3.25 x10^{12} *(2bunch/ring)* ↓ *(6 bunches, h=7)*	3.6 x10^{12} *(2bunch/ring)* ↓ *(6 bunches, h=7)*	1.8 x10^{12} *(1bunch/ring)* ↓ *(6 bunches, h=7)*	*3.6 x10^{12} (3bunch/ring)* ↓ *(12 bunches, h=14)*
PS out, per pulse	ppp	9.72 x10^{12}	*10.8 x10^{12}*	*12.3 x10^{12} (scaled 1998 limit, 206ns bunches)*	*14.4 x10^{12} (lower ΔQ in single batch)*
PS out, per bunch *($\varepsilon^* \leq 3\ \mu m$)*	ppb	1.35 x10^{11} *(72 bunches)* ↓ *15% loss*	*1.5 x10^{11} (72 bunches)* ↓ *<15% loss*	*1.7 x10^{11} (72 bunches)* ↓ *20% loss*	*2.0 x10^{11} (72 bunches)* ↓ *20% loss*
SPS out	ppb	1.15 x10^{11}	*>1.3 x10^{11}*	*1.37 x10^{11}*	*1.6 x10^{11}*

Goal:

Nominal intensity in single batch: shorter filling time, lower losses and emittance growth.

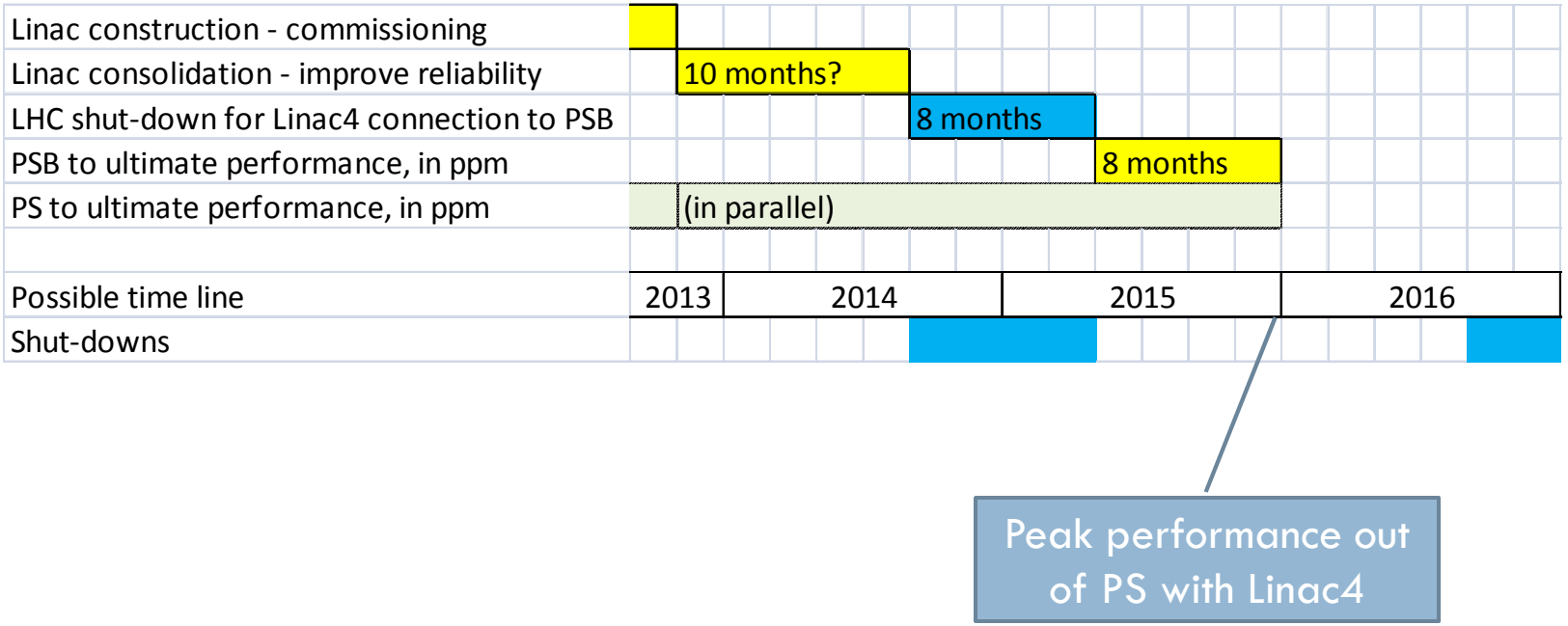
Potential for ultimate intensity out of PS in double batch.

Potential for > ultimate with a new PS scheme (in PSB: new recombination kicker, new RF gymnastics).

After the Linac4 connection

- at start-up, nominal performance (on all beams) as before the connection of Linac4.
- during 1st year of operation (or first 8 months for a 2-year run): increase PSB performance from "standard" to "ultimate with Linac4". Can be done in ppm.
- PS: the preparation for "ultimate" performance with Linac4 must be done before the connection of Linac4 to the PSB. The PSB can produce already now the density required to explore the PS limitations (longer bunches, for examples) and there is sufficient time to test possible solutions. This can be done in dedicated MDs and in ppm, and can require only minor improvements to PS diagnostics.
- If the preparation of the PS is done in advance, the setting up for peak intensity with Linac4 can be done in the "shadow" of the PSB improvements.

Tentative time line



Conclusions

- The Linac4 schedule provides enough flexibility to allow the connection to the PSB to take place any time after September 2013.
- The LHC shut-down for Linac4 connection must have a duration of 8 months (if no ion run) or of (8 months – duration of the ion run).
- It is foreseen that Linac4 will allow reaching the nominal LHC intensity in PS single batch mode and the ultimate intensity out of PS in double batch mode.
- The ultimate intensity will be reached ~ 1 year after the connection of Linac4.
- But: the limitations of the PS have to be analyzed in a series of MDs well before Linac4 is connected.
- Further improvement could come with modifications to the injectors: *change of the PS injection scheme* or *increasing the PSB energy*.