



## LHC Injectors Upgrade



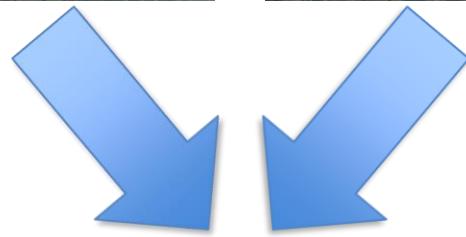
**Work Effort in the LHC Injector Complex,  
Including Linac4 Connection,  
for the Upgrade Scenarios**

J-B. Lallement, B. Mikulec

Thanks for the invaluable input from the LIU project leaders and LIU work-package holders and many other colleagues  
+ precious planning help from D. Hay, S. Mataguez and D. Mcfarlane

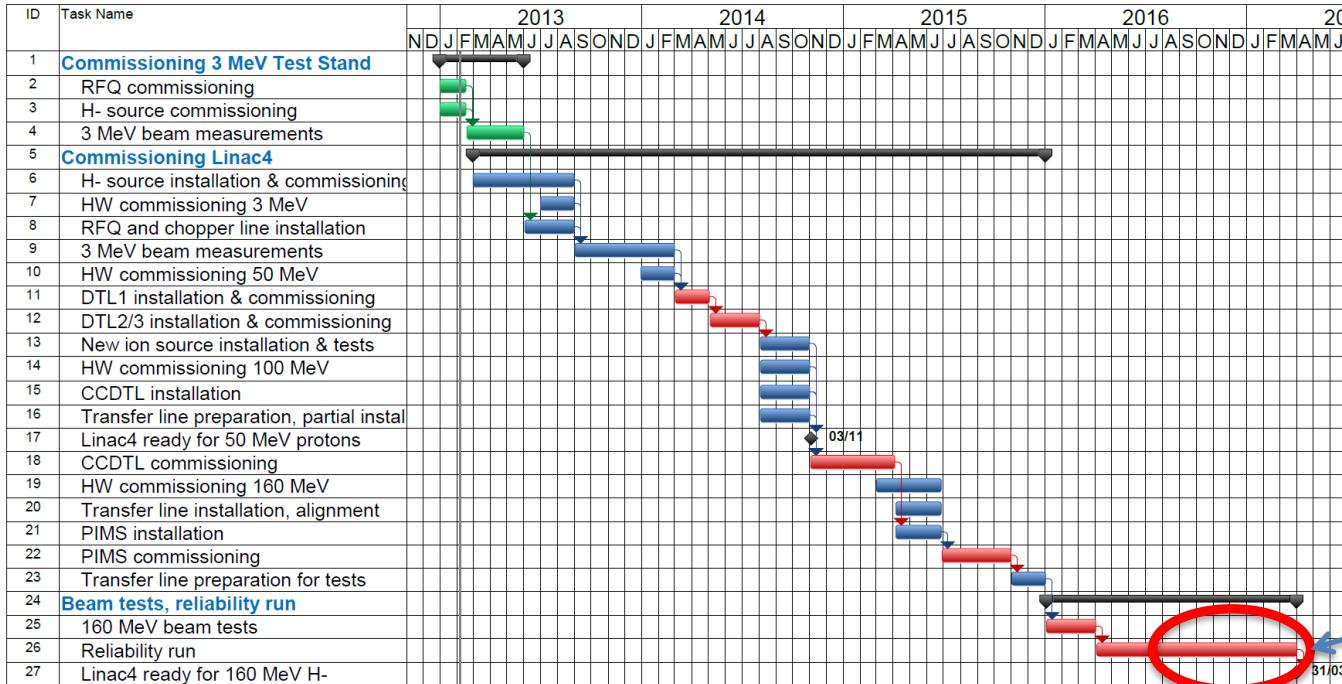
# U 2 talks in 1

For coherency and clarity:





# Linac4 ready for connection by end 2016



Flexibility to adapt  
to any connection  
schedule

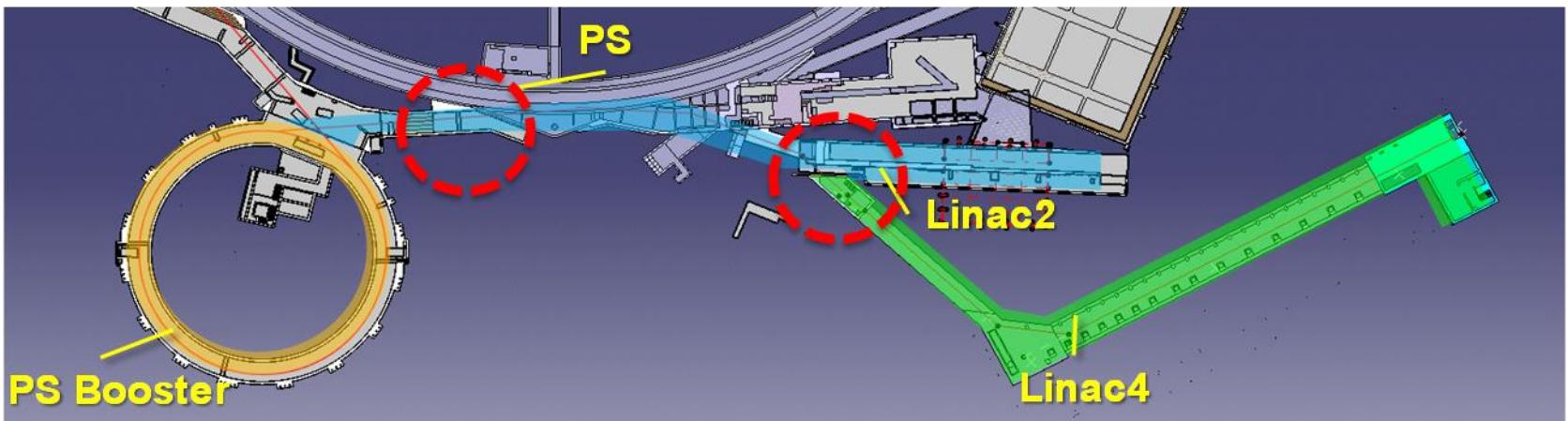
If connection in LS2:

- Risk of Linac2 breakdown – Emergency connection at 50 MeV with reduced performance.
- Linac4 in standby 2-3 years after the reliability run (1 week of beam every 2 months).
- Key experts will leave the project before LS2 (retirements, LDs, Fellows) .
- Keep the motivation to follow a planning.





# Linac4 : Working on two fronts



## 1. Linac2-Linac4 interface :

Where the connection takes place



## 2. Measurement line(s) at PSB injection :

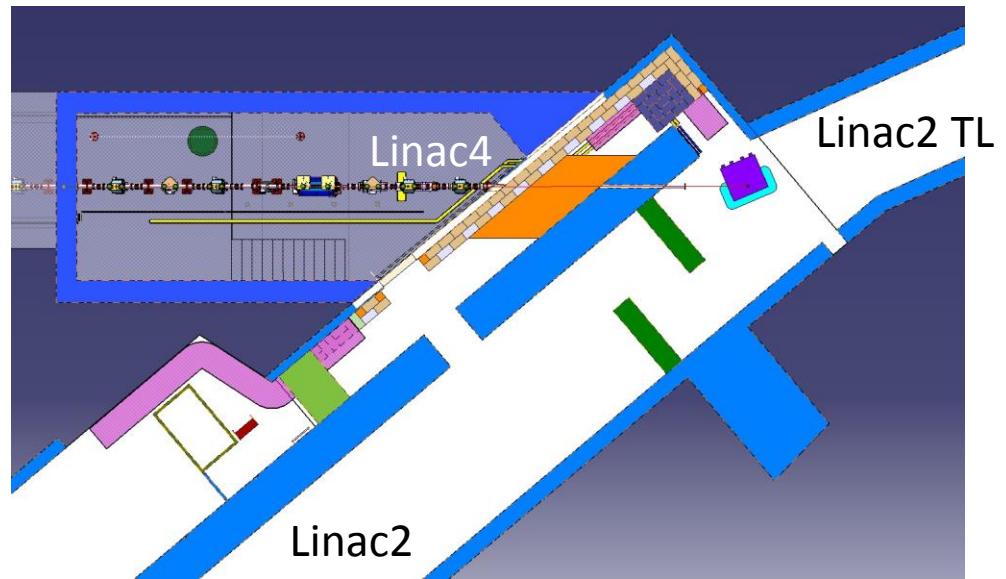
Upgrade needed from 50 to 160 MeV





# L2/L4 interface : 12 weeks

1. New path for DC cables.
2. Shielding wall.
3. Emergency exit.
4. “Chateau”.
5. Chicane.



12 weeks (4 weeks cool down)

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Linac2/Linac4 interface														
Cool down														
Line removal up to BHZ.20														
DC cable path														
Emergency exit door														
Château														
Chicane														
Shielding wall														
Line installation														
L2 tunnel access door														



# Measurement line(s) : 12 weeks

2 measurement lines : LBE and LBS.

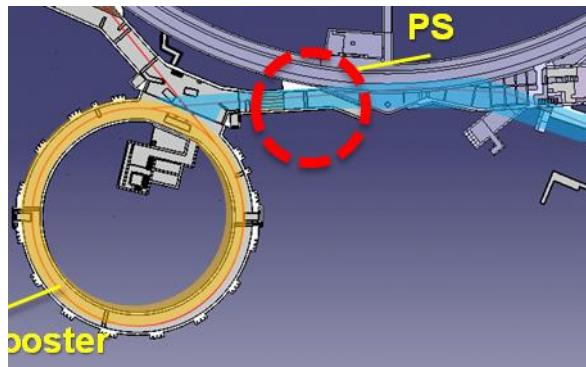
- LBE upgraded for 160 MeV.
- LBS replaced by a diagnostic in the L4 TL.

Connection time and work considerably reduced:

4-5 months less, 1 M CHF saved, better resolution.

Decoupling L4 planning from PSB and PS.

Can be kept for ions (or similar solution in L3).

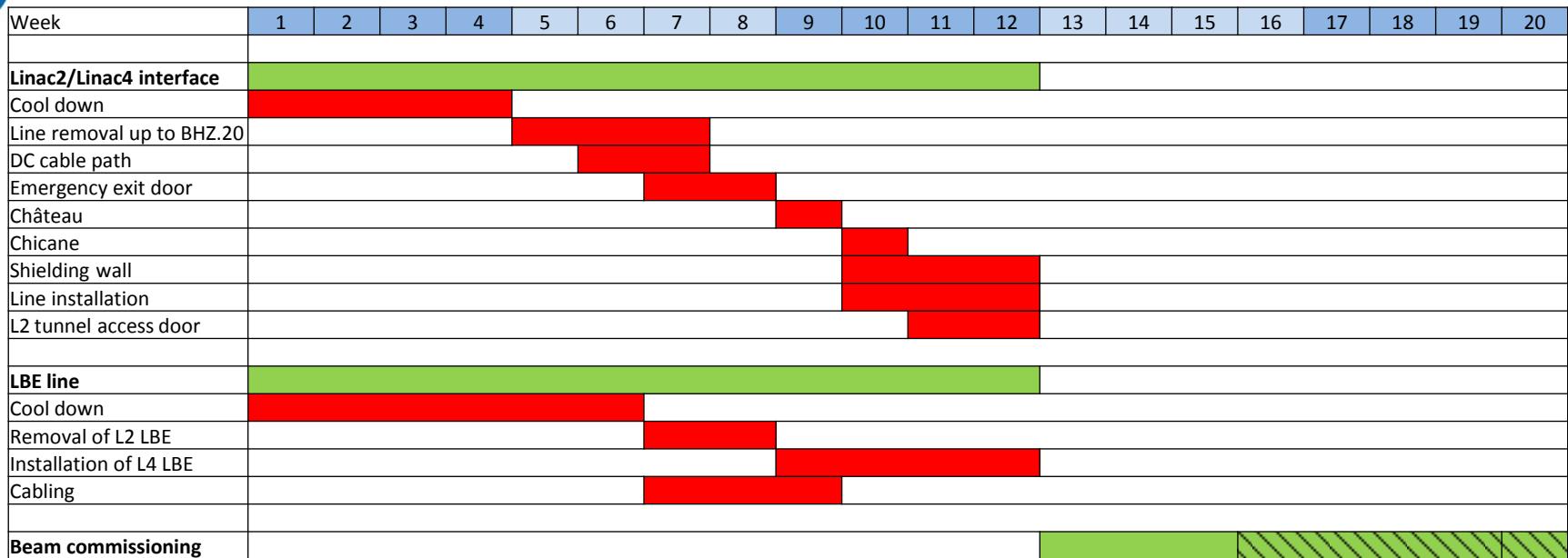


12 weeks (6 weeks cool down)

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
<b>LBE line</b>														
Cool down														
Removal of L2 LBE														
Installation of L4 LBE														
Cabling														



# Linac4 : 15 weeks to deliver a beam to the PSB



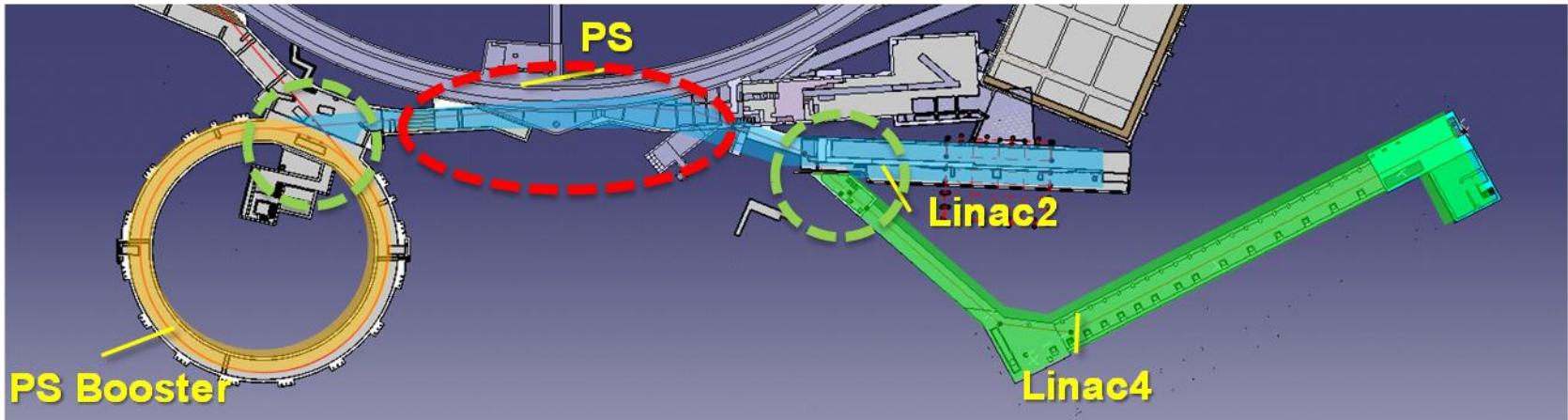
3 weeks of beam commissioning : Produce different types of beam and full characterization (transverse and longitudinal parameters).

Commissioning will be extended until validation from PSB.

Linac4 is in the shadow of PSB.



# No ions in the PS during cabling and LBE work



While ions in the PS, possible work at L4/L2 interface and PSB.

Beam stopper in the BI line for ions in PS.

Magnet consignation (LT.BHZ30).

Time required for Linac4 with no beam in the PS : 6 weeks (after 6 weeks of cool down).



# U Outline

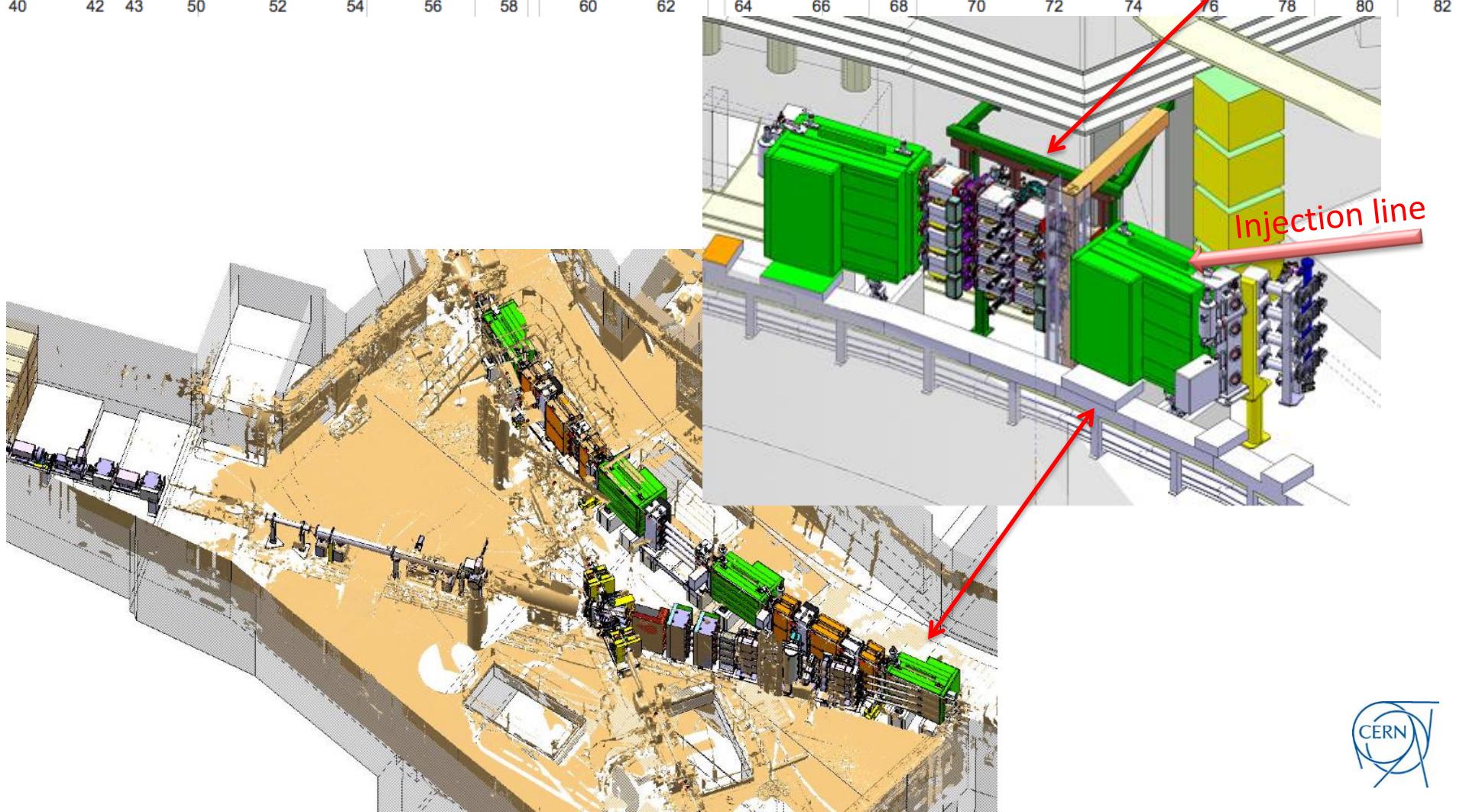
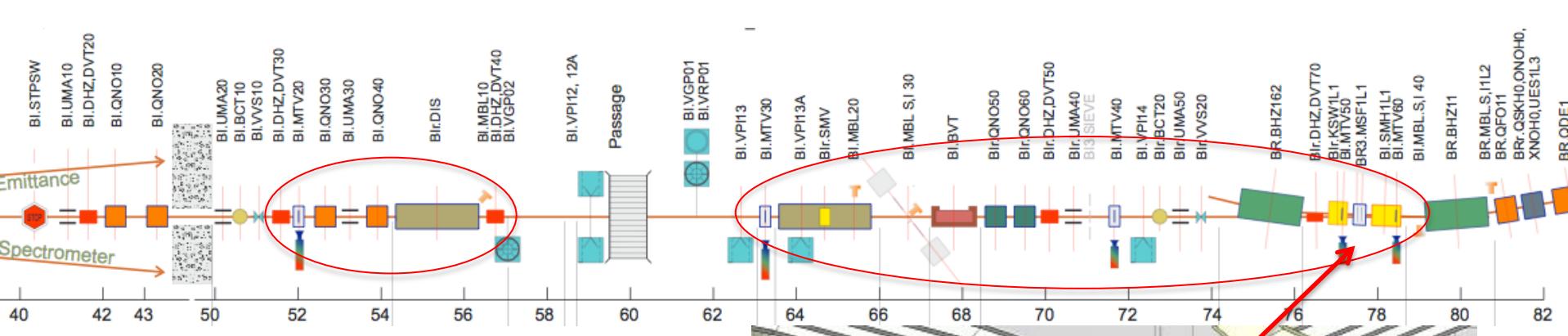
- ① Linac4 connection to the PSB – an option in case of an intermediate shutdown?
- ② PSB LS2 planning estimate
- ③ PS LS2 planning estimate
- ④ SPS LS2 planning estimate
- ⑤ Summary





# Linac4 Connection to the PSB in an Intermediate Shutdown

- Linac4 reliability run will be concluded end 2016
- PSB equipment for Linac4 connection ready end 2016
- Current baseline: Linac4 to be connected during LS2 (2018?), but:
  - Risk of Linac2 breakdown increases → emergency connection of Linac4 (50 MeV protons), but risk stop of ~2 months and reduced performance for many physics beams and spoil Linac4 commissioning
  - Linac4 would be in standby during 2-3 years
    - Difficult to maintain motivation for current commissioning progress
    - Maintenance cost
    - Several experts will leave project; problem with recommissioning?
  - Linac4 connection to PSB, 2 GeV PSB upgrade and upgrades of all other machines would be in parallel
    - Considerable risk in terms of post-LS2 beam quality/reliability
    - LS2 duration determined by work in the PSB (see next slides)

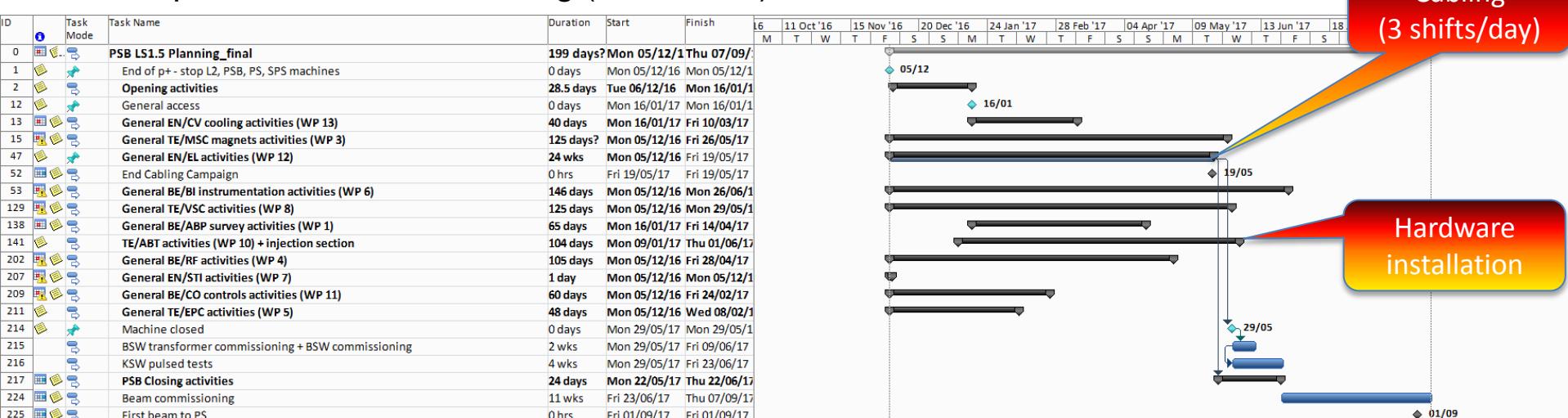


# PSB Planning Overview for L4 connection to PSB

Consider purely Linac4 connection to PSB; >200 activities

## Main activities:

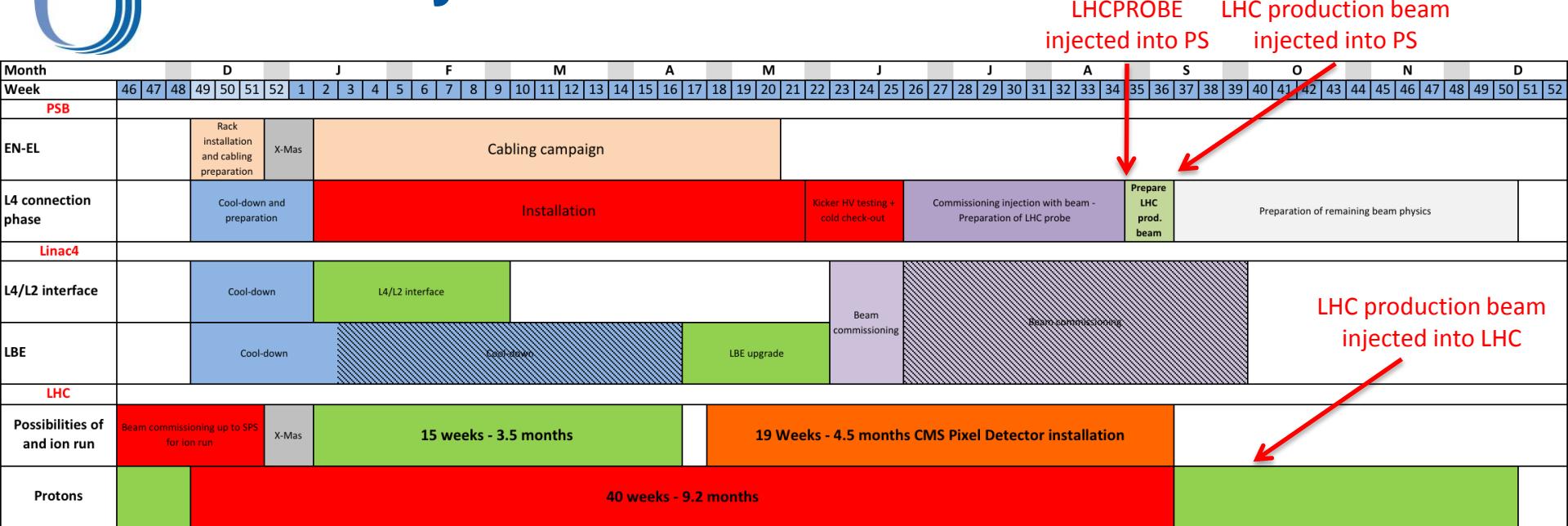
- Cabling campaign (5 months)**, magnet exchange (BI line), vertical beam distribution, injection kickers (horizontal painting), injection section (injection chicane + charge-exchange foil), beam instrumentation etc.
- KSW HV conditioning (1 month) after machine closure in parallel with HW testing and cold checkout.
- Complex beam commissioning (~2 months)



- Detailed planning worked out for installation of injection section to be confident on time estimate (**4 months**).

U

# Summary L4 Connection to PSB



- Duration for the Linac4 connection to the PSB: 9.2 months | injected into LHC
    - 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.)





## LHC Injectors Upgrade

LS2





# Boundary Conditions for LS2 Planning

- Studied: PSB, PS and SPS
- Considered:
  - All tunnel activities
  - Mainly LIU activities, but also include
    - Usual machine opening/closing activities
    - Estimated radiation cool-down times
    - Estimated cabling campaign durations and
    - Consolidation items that could affect the overall LS duration.
  - Surface activities only included if they affect LS duration
  - Estimates for beam commissioning times





# Main PSB LS2 Activities

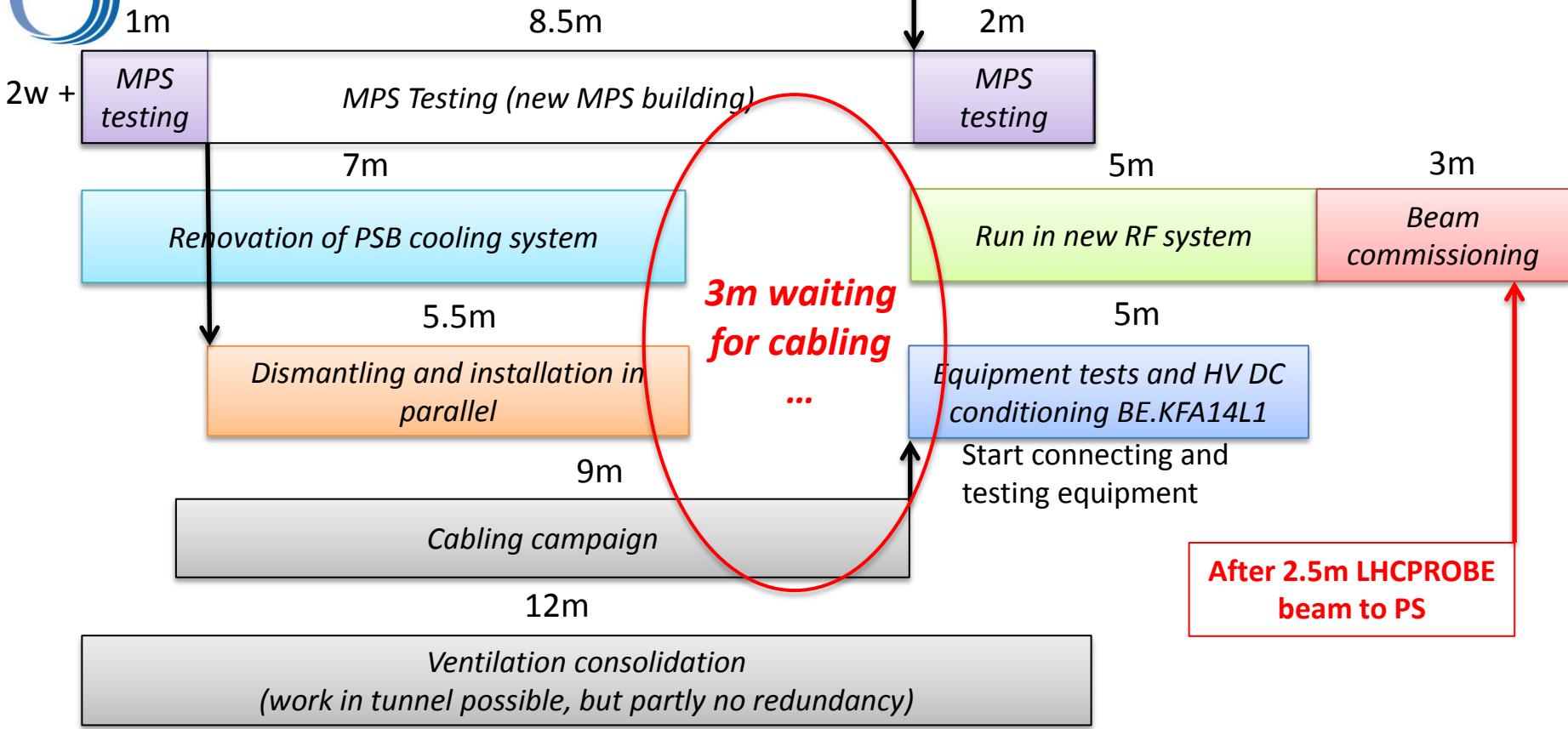
- Modification for H<sup>-</sup> injection at 160 MeV (if not done during an intermediate shutdown):
  - Renovation of PSB injection line, new vertical beam distribution system at injection, complex new injection section with charge-exchange stripping foil, related beam instrumentation, injection and painting chicanes, internal dumps, new vacuum sectorisation etc. (see Linac4 connection to PSB)
- **New MPS**
- Renovation of cooling and ventilation systems
- **RF upgrade**
- New or improved beam instrumentation
- Modifications to main magnet cooling circuits + shimming; replacement of several additional magnets
- New extraction kicker, new recombination kicker and septa
- **Impressive cabling campaign!**





# PSB LS2 Planning

1m 8.5m



- First 1.5 months: radiation cool-down (2w for standard works at end of run + 1m MPS testing)
  - **Cooling system renovation**: start dismantling transfer line cooling stations; 7 months very tight for complete renovation → study underway to construct new station in parallel to existing one in new MPS building
  - **Min. cabling campaign duration: 9 months!** (3 shifts/day)
  - **First beam to PS after 17.5 months**

→ **Delivery of LHC production beam to PS: after 18 months**



# PS LS2 Planning

#	Title	Giv. Plan. Dur.	Expected Start	Expected	Q3 / 2017			Q4 / 2017			Q1 / 2018			Q2 / 2018			Q3 / 2018			Q4 / 2018			Q1 / 2019										
					07	08	09	10	11	12	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03								
0	▼ LS2_PS_v0.2		4/12/17	25/3/19							LS2_PS_v0.2																						
1		1 day	4/12/17	4/12/17																													
2	► Pre-LS2 Injector Program		4/12/17	5/12/17							Pre-LS2 Injector Program																						
10	► Pre-LS2 Period		4/12/17	22/1/18							Pre-LS2 Period																						
37	► PS Start up program.		21/12/18	25/3/19																													
48	► PS Magnet Program		22/1/18	21/12/18							PS Magnet Program																						
55	► TE/ABT Septa and Kickers...		22/1/18	11/5/18							TE/ABT Septa and Kickers Program																						
64	► EN/STI Beam Stoppers		22/1/18	23/2/18							EN/STI Beam Stoppers																						
68	► BE/RF		22/1/18	26/11/18							BE/RF																						
88	► TE/EPC Power Supply Activ...		4/12/17	22/1/18							TE/EPC Power Supply Activities																						
93	► BE/BI Beam Instrumentation		22/1/18	16/2/18							BE/BI Beam Instrumentation																						
101	► TE/VSC Vacuum		22/1/18	28/12/18							TE/VSC Vacuum																						
108	► GS/SE PS + TT2 Tunnel ma...		22/1/18	19/2/18							S/SE PS + TT2 Tunnel maintenance program																						
112	► EN/HE Cranes.		22/1/18	22/1/18							EN/HE Cranes.																						
114	► EN/CV Cooling and Ventilation		22/1/18	22/1/18							EN/CV Cooling and Ventilation																						
116	► EN/EL PS and TT2 Cabling		22/1/18	31/8/18							EN/EL PS and TT2 Cabling																						
118	► EN/EL Electrical Services Pr...		4/12/17	6/9/18							N/EL Electrical Services Program																						
131	► BE/CO		4/12/17	4/12/17							BE/CO																						
133	► BE/ABP/SU Survey		22/6/18	22/6/18																													
135	► Tunnel Cleaning		12/12/18	19/12/18																													





# PS LS2 Planning Summary

- Radiation cool-down: 1 month
- General access: after 2 months
- **Assumed duration of cabling campaign: 8 months** (detailed cabling study still to be done)
  
- Many LIU-related activities already carried out during LS1
- Magnets: new vertical correctors and normal/skew quadrupoles (2 GeV) – 5 months; replace PFW – 1 year (consolidation)
- New injection kicker, bumper, septum – 4 months
- RF: 10 MHz upgrade etc.; duration defined by general maintenance
- BI: not time-critical (BWS, BLMs, injection SEM grid, IPM?)
- Vacuum, electrical services, ...
  
- Close PS: after 13 months
- 4 weeks of hardware test and 2 weeks of cold check-out
- Ready for beam from PSB: **after 14.5 months**





# SPS LS2 Planning

Start of shutdown works: <2 months

Restart: ~3 months

BI activities (BGI, BSRT, IMM,  
head-/tail m., BLM, MOPOS,  
wire scanners)

**200 MHz RF: ~12.5 months**

EN-STI (new external dump etc.)

TE-ABT (fast rise-time kicker for  
ions etc.)

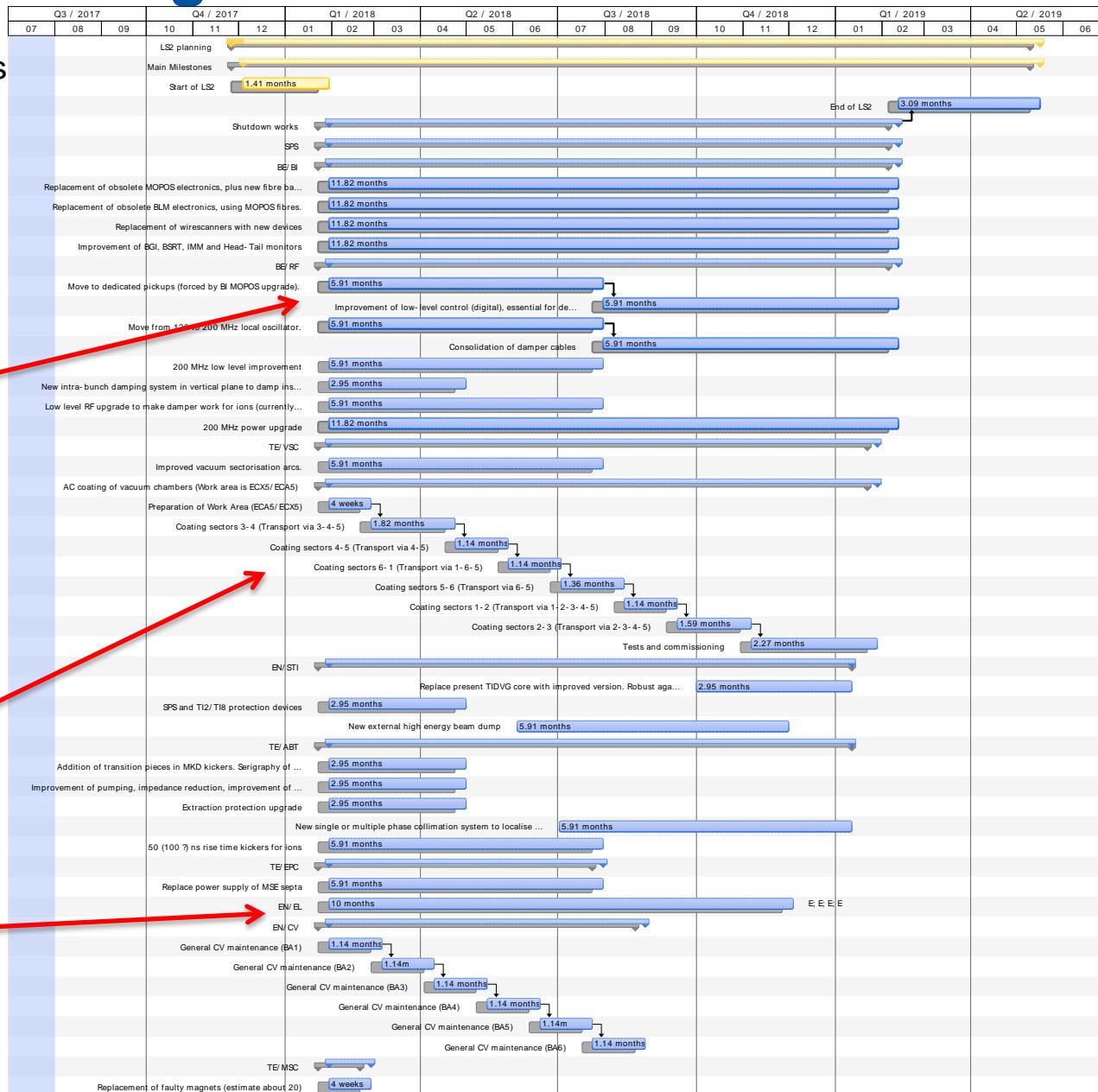
TE-EPC (MSE-septa power supply)

Replacement of faulty magnets

**aC-coating of 6 sectors:  
12 months**

**Cabling campaigns: estimated  
10 months**

CV maintenance

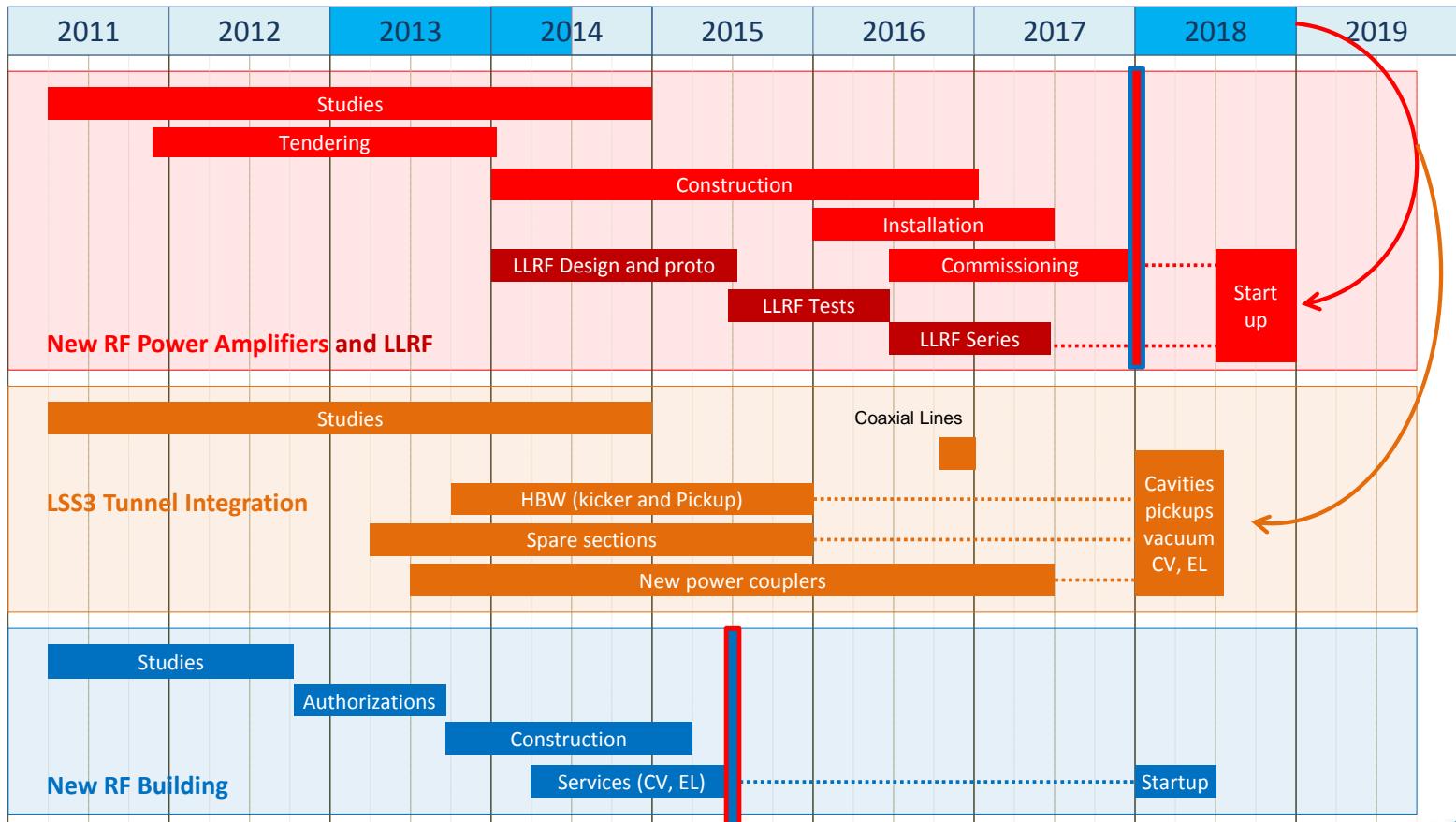




# SPS: RF 200 MHz Upgrade - Schedule

Work cannot be split and has to be done in one go...

6 months cavities re-arrangement  
2 months RF Power conditioning  
4 months LLRF commissioning





# SPS: RF 200 MHz – LS2 Details

- New building to be finished with all services by end 2015
- New amplifiers installation to start in new building beginning 2016
- First six months of LS2 for cavity rearrangement in LSS3
  - Cabling
  - Cooling system
  - Removal of all 18 existing cavity sections
  - Displacement/install new cavity supports
  - Displacement/installation new pickups
  - Re-install 18 existing cavity sections
  - Installation 2 new cavity sections
  - Installation 6 new coupler covers
  - Installation 6 new main power couplers
  - Vacuum connections and tests
  - Alignment
- Details of LSS3 interventions and schedule to be worked out
- Availability of key services (cabling, CV, VSC) to be verified
- Second six months of LS2 for system commissioning and tests





# SPS: aC Coating

- Technology now developed for treating chambers in magnets
  - Needs to be done in special workshop of 700 m<sup>2</sup> surface (not feasible in tunnel; preferably to be done in BHA5)
  - Tested for MBB and MBA chambers, and pumping ports
  - 4 SPS half-cells now equipped
  - Estimated flow: 6 magnets in / 6 magnets out per day
  - Scope of deployment: carbon thin film coating of min. 90% of the SPS
    - MBB+MBA (~5 km; >700 dipoles), QF+QD, LSS and maybe SSS (10%)
    - Including pumping port shields

**Legend**

**Preparation:** ECA5-ECX5 wall removal; concrete slab ECA5; magnet disconnection; etc....)

Coating start: ramp-up phase@ 3 magnets/day average cadency

Coating: nominal phase@ 6 magnets/day average cadency

Coating end: ramp-down phase@ 3 magnets/day average cadency

End of reinstallation; survey; vacuum reconnection; cooling circuits filling; ECAS-ECX5 wall closure; etc....



# SPS LS2 Planning Summary

- Remark: US1 + US2 involve identical hardware modifications! (e<sup>-</sup>-cloud mitigation already included in US1 changes)
- General access: after 2 months
- Critical interventions:
  - 200 MHz upgrade: 12.5 months; cannot be split
  - aC coating: 12 months
  - Cabling campaigns? – need study
- End of LS2 installations: after 14.5 months
- Patrols, DSO tests (1.5 weeks)
- 6 weeks for magnet + EPC tests
- 4 weeks cold checkout → ready to receive beam from the PS **after 16.5 months**
- 1.5 months for beam commissioning (new SPS RF beam control!)



# Summary Overall LS2 Planning

LS2 (upgrade scenarios 1 and 2 equivalent for injectors):

Limited by PSB activities (cabling)

- PSB first beam (LHCprobe) to the PS: **after 17.5 months**
  - PS ready for beam from PSB already **after 14.5 months**
    - Beam commissioning to be added: 5 weeks\*
  - SPS ready for beam from PS: **after 16.5 months**
    - Beam commissioning to be added: 1.5 months
  - **First injection of LHCPILOT into the LHC: after ~20.5 months**
  - **Depending on e-cloud situation in SPS, min. time for injection of LHC production beam into the LHC: after ~22 months (scrubbing!)**

\* Assume restarting with old beam control and have a switch-over possibility old/new beam control.





# A Few Words on Risk Management

- Minimise upgrade risks (mainly in terms of duration) through
  - Advance certain interventions if possible during short stops (not a lot to gain...)
  - Mechanical mock-ups
  - Test stands/beam tests where applicable (half-sector test in L4T)
  - Integration studies (include CV and EL equipment!)
  - Detailed planning of each modification including co-activity and personnel resources
  - Early preparation of new applications/controls
  - Detailed beam commissioning planning for restart.



# U Concluding Remarks

- Gaining 3 months in the PSB works would be necessary to align the LS2 injector schedules.
  - Detailed study of cabling and rack situation in all machines required.
- Investing an additional 3.5 months proton physics to connect Linac4 to the PSB during an intermediate shutdown (together with CMS pixel detector exchange and other potential consolidation/upgrade activities) would save 3 months in LS2, reduce the risk of coactivity during LS2 and of a very difficult beam recommissioning.
  - Would finally result in 0.5 additional months overall – useful time for ion community?

**THANKS FOR YOUR ATTENTION!**





LHC Injectors Upgrade

# Backup Slides





## Alternative Option for L4 Connection to PSB

Remark: This option is not preferred (great difficulties in commissioning of ion injector chain with ions after shutdown)!



Engineering Department

## Cabling implementation and resources for LIU project during LS1.5 and LS2

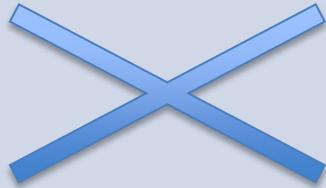
D. Ricci, JC. Guillaume on behalf of EN-EL-CF

# Working scenarios

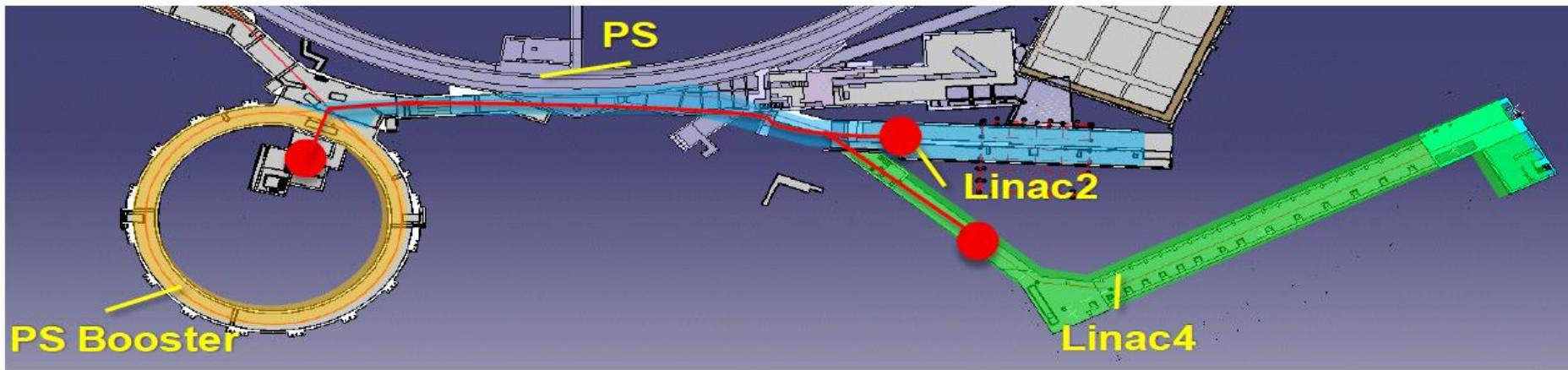
## Scenario I

LS1	LS1.5	LS2
LIU Top priorities (PSB, PS, SPS) Identification cables PSB	Transfert line PSB-LINAC4/LINAC2 - clean-up PSB - Installation PSB & LINACs	PSB upgrade PS upgrade SPS upgrade + clean-up campaigns
	Identification cables PS, SPS,LINAC2	

## Scenario II

LS1	LS1.5	LS2
LIU Top priorities (PSB, PS, SPS) Identification cables PSB		Transfert line PSB- LINAC4/LINAC2 PSB upgrade PS upgrade SPS upgrade + clean-up campaigns
	Identification cables PS, SPS,LINAC2 (T. Stops)	

# Machine layout



Equipments in PSB injection tunnel are powered/controlled from LINAC2, LINAC4 and Booster locations.

# Scenario I: LINAC4/LINAC2

LINAC4/LINAC2 cabling requests	LS1.5 (Transfert line PSB-LIN4/LIN2)	LS2
Installation de 100 câbles	23 câbles	77 câbles
Enlèvement de env. 300 câbles	0 câbles	Env. 300 câbles

**LS1.5:** Les convertisseurs existants sont laissés en place (BHZ20, 30 et 40). Seuls un tirage de nouveaux câbles est nécessaire pour les équipements de la ligne LBE: Quad, Steerers, SEM grids, BCT, Beam dump et Wire scanner.

**LS2:** Les convertisseurs (BHZ20, 30 et 40) seront remis en place définitive au bat 363; remise à jour du câblage des lignes BI, LBE, LT et LTE.

**En LS2, l'installation des nouveaux convertisseurs va nécessiter le nettoyage d'anciens câbles situés dans les faux-plancher du bat. 363.**

# Scenario I: LIU Booster

LIU-PSB cabling requests	LS1.5 (Transfert line PSB-LIN4/LIN2)	LS2 (PSB upgrade)
Installation de 1785 câbles	954 câbles	831 câbles
Enlèvement de 1210 câbles	510 câbles	700 câbles

Ce qui représente une section supplémentaire de:

- 2 échelles CTRL et 1.5 échelles Power (LS1.5)
- 0.5 échelles CTRL et 1 échelle Power (LS2)



Entrée puits Booster depuis BCER



Cheminée BCER vers machine



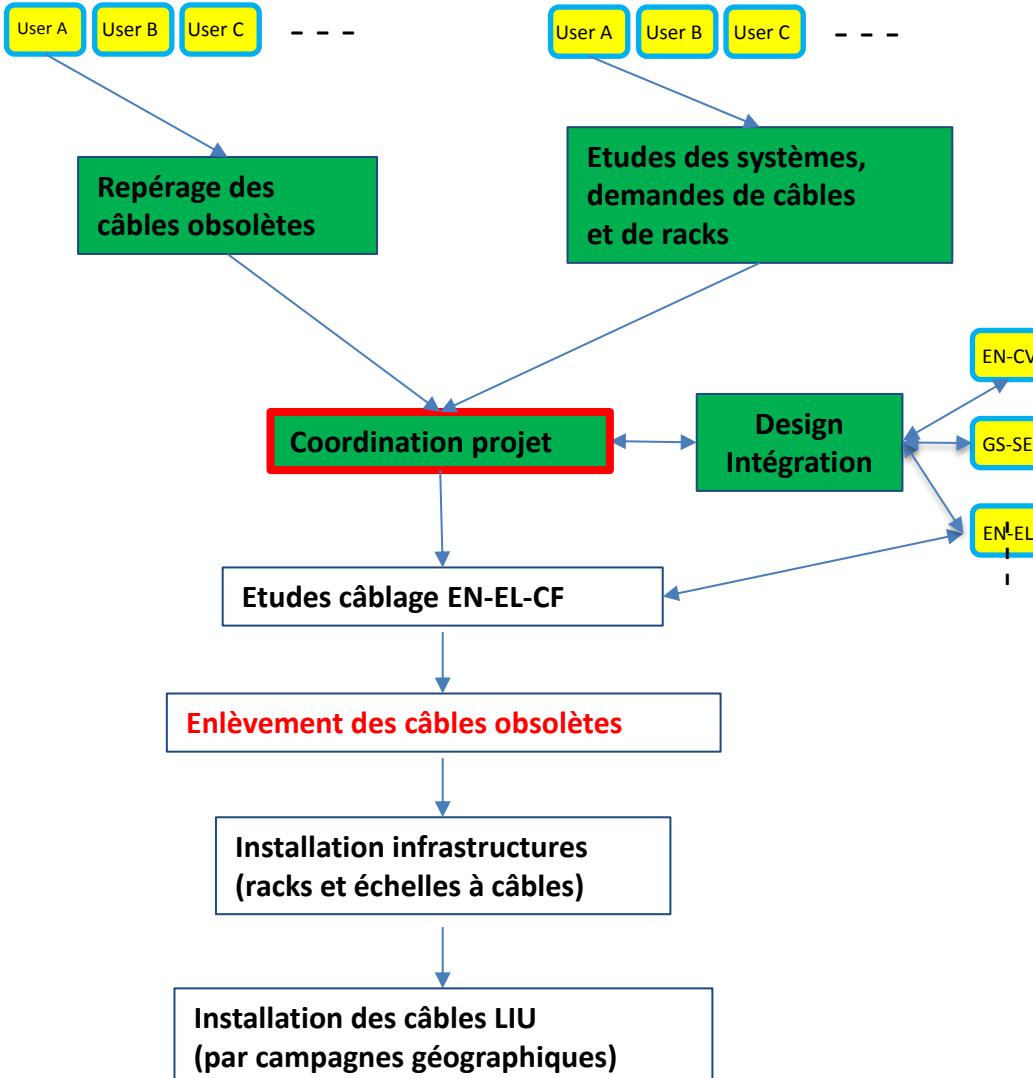
BCER vers galerie surface



Sortie BOR vers BCER

**Le retrait prévu par LIU des câbles obsolètes ne suffit pas pour LS1.5, il faut prévoir une campagne de retrait plus conséquente.**

# LIU Booster project flow



## Situation actuelle

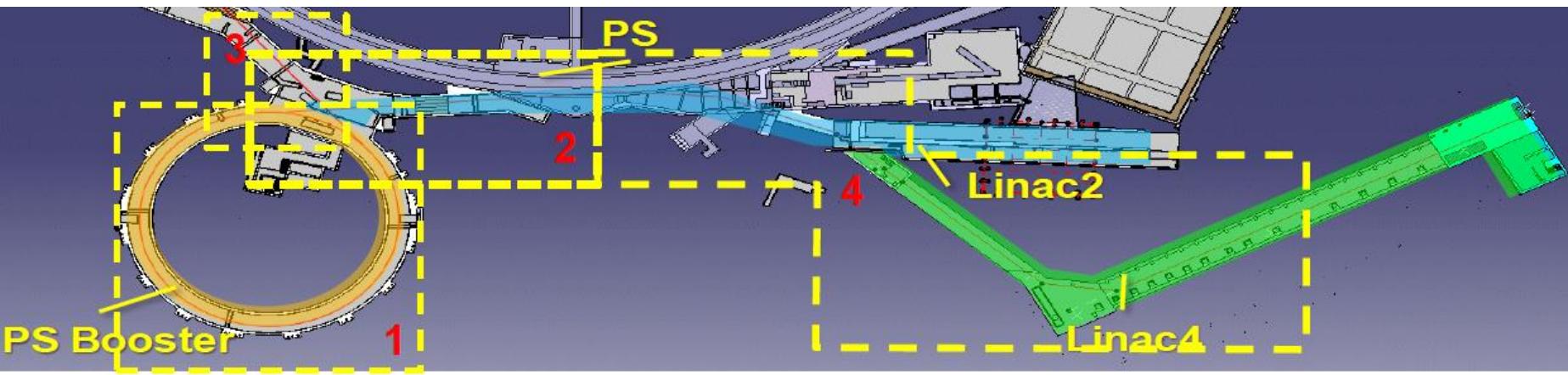
Demandes peu précises (tenants, aboutissants, type de câbles)  
Passages actuels bouchés pas pris en compte dans les demandes.

Nouvelles installations à prendre en compte.

Need actions from:

- Machine project technical coordination
- Planning coordination

# Scenario I : PSB Cabling campaigns



<u>Zones géographiques</u>	<u>Câbles enlevés LS1.5 (km)</u>	<u>Câbles ajoutés LS1.5 (km)</u>	<u>Temps estimé LS1.5 (3shifts)</u>	<u>Câbles enlevés LS2 (km)</u>	<u>Câbles ajoutés LS2 (km)</u>	<u>Temps estimé LS2 (3shifts)</u>
Travaux mécaniques dans le PSB et S. de Ctrl (inst. racks, cheminements)			2 semaines			2 semaines
Zone 1: S. de Ctrl vers Booster Ring	22	28	8 semaines	45	50	15 semaines
Zone 2 : S. de Ctrl vers ligne BI et Cellules 1 et 16	40	30	11 semaines	2	2	1 semaines
Zone 3: S. de Ctrl vers Lignes BT, BTP, BTM	2.5	3	1 semaines	2.5	3.5	1 semaines
<b>Total Zones 1, 2, et 3</b>	<b>67.5</b>	<b>62</b>	<b>22 semaines</b> (12.3 semaines dépôse)	<b>49.5</b>	<b>55.5</b>	<b>19 semaines</b> (9 semaines dépôse)
Travaux mécaniques dans le LI2. (inst. racks, cheminements)			2 semaines			
Zone 4: Linac4 vers LT Linac 2 (Travaux zone 4: Dans l'ombre des zones 1, 2 et 3.)	1	3	1 semaine	10	10	3 semaines
<u>Moyenne: 2.2 km/sem/shift.</u>						
<u>Hypothèse: 1 min / m (pose et dépôse)</u>						

Cette hypothèse doit être vérifiée avec des informations plus précises

Budget: Env 4 MCHF LS1.5 & LS2

Team work in // in the three zones not possible due to limited area and access constraints

## Scenario II (LS2)

Combination of Scenario I (LS1.5) and Scenario I (LS2)

- Transfer line PSB-LINAC4/LINAC2
- PSB, PS, SPS upgrade
- + all related clean-up campaigns

Previsional machine planning:

LS2 for injectors: DEC 2017 – JUN 2019 (???)

# Resources pour LIU

**LIU doit mettre en place une personne qui s'occupe de la coordination technique du projet pour prendre en charge:**

- 1) Mise à jour de l'intégration de tous les services existants et futurs,
- 2) Identification des câbles obsolètes par les utilisateurs,
- 3) Prise en compte des contraintes techniques de la zone,
- 4) Interface avec les utilisateurs.

## **EN-EL-CF: resources to be foreseen for projet LIU (PSB, PS, SPS).**

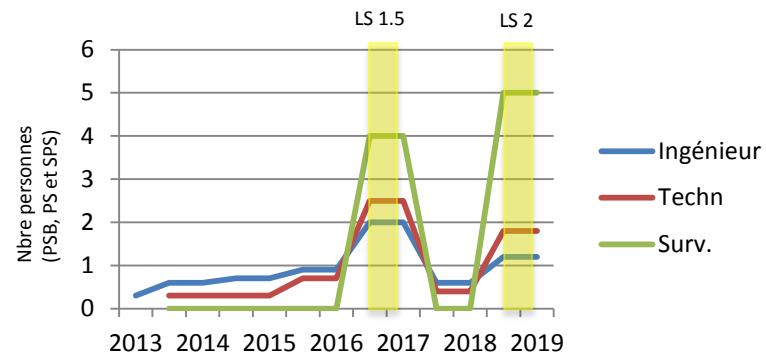
- 1 à 2 Chargés de projet (ingénieur électricité) dès le mois de novembre 2013 à fin LS2 selon graphique.
- 1 à 2 Techniciens pour le suivi du repérage des câbles obsolètes et préparation campagne de décâblage à partir de Janvier 2014 selon graphique.
- Au moment de l'installation: 1 surveillant de chantier par shift (FSU)

Given the project complexity, it is advisable to keep the already trained resources in CF (engineers and technicians) which are otherwise foreseen to leave by the end of LS1

## **+ contractor resources: 48 people for PSB only during LS1.5**

(8 people/shift + 2x turnover due to reached dose limit)

Corresponding to 50% of the total deployed for LS1 (all machines)



**EN-EL-CD:** Intégration 3D pour mise à jour:

- 1) Des échelles à câbles – existantes et nouvelles,
- 2) Racks – existants et nouveaux,
- 3) Plans d'exécution.

**EN-EL:** Mise ne place d'un ou plusieurs contrats d'exécution pour être opérationnel pour le LS1.5 et LS2 et être capable de travailler en 3 shifts sur une très longue période.

# Option: Recâblage complet du Booster

- Nombre de câbles signaux installés (selon câblo EN-EL) : 13800
- Longueur totale estimée: 600 km

Durée estimée pour le retrait total des câbles signaux: 14 semaines en 3 shifts  
(2 campagnes en //)

Travaux mécaniques (réfection des échelles à câbles) 4 semaines en 3 shifts

En admettant que 75% des câbles soient ré-installés, (= 450km),  
la durée estimée pour la ré-installation des câbles est de (connectique comprise) 50 semaines en 3 shifts

Total du recâblage: 68 semaines en 3 shifts  
(17 mois)

Hypothèse Option: Dépose: 15 s/m  
Pose: 30 s/m

Hypothèse Scénario 1 (PSB seulement) Pose & Dépose: 1 min/m soit 21.3 semaines pour la dépose sur un total de 41 (L1.5 + LS2).

Budget préliminaire: 11 MCHF

**Cette hypothèse doit être vérifiée avec des informations plus précises - l'identification par les utilisateurs des câbles inutilisés.**