EDMS: 1109677

2011-01-21

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Outcome of the "LIU day"

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Keywords: Linac4, PSB, PS, SPS, High Luminosity LHC (HL-LHC), LHC Injectors Upgrade (LIU)

Abstract

The "LHC Injectors Upgrade day" (thereafter "LIU") [1] took place on the 1st of December 2010, as part of the analysis phase of the LHC Injectors Upgrade Project [2] in the presence of 40 invited participants (Appendix A). The present ideas and the related main technical issues (Appendix B) were presented and submitted to discussion and counter proposals. The outcome is summarised in the present document.

1. Introduction

The LHC Injectors Upgrade Project has been created at the end of September 2010 [2] with the mandate of coordinating the work on the LHC injectors in order to deliver reliably the beams required by the High Luminosity-LHC. This includes LINAC4, PS Booster, PS, SPS, as well as the heavy ion chain.

The LIU Project starts from the work accomplished by the SPS Upgrade Working Group [3] and the Task Forces on the PSB Energy Upgrade [4] and on the SPS Upgrade. It includes all members of these former teams. The LIU Project is the coordination frame for 4 accelerator-specific projects concerning Linac4, PSB Upgrade, PS Upgrade and SPS Upgrade. When the need for heavy ions will be defined, the Project will be extended to include Linac3 and LEIR.

The first goal of the LIU Project is to propose for April 2011 a baseline plan for integration within the next CERN Medium Term Plan.

2. Ideas and comments

a. General for all LIU

Subject	Comments	Action
Link with HL-LHC Project	The nature of the upgrades depends upon: • Goal for 6D brightness (intensity/bunch, emittances and distance between bunches)? • Variety of beams? • Acceptable imperfections? • Same questions for heavy ions + types of ions and speed of switch between them.	• Establish beam specifications by an iterative process optimizing the whole chain of accelerators (injectors and LHC) in close connection with HL-LHC. • Specs shall include schedule (evolution of the needs with time), tolerances for imperfections (# between bunches) and margin. • Plan roadmap to firm specs together with HL-LHC.
Link with Consolidation Project	Crucial need for synchronization with Consolidation Project.	Negotiate mode of operation with Consolidation Project (extract some subjects?) e.g. new PSB power supply, PSB RF ...
Resources (human)	Manpower not yet properly accounted / included in the departmental plans.	To be negotiated in the context of the MTP2011.
Project Planning	Modification and commissioning of the injectors may impact on the duration of the 2016-2017 shutdown	• Draft an integrated schedule including all injectors • Define planning of progress of beam characteristics
MDs	Many subjects to study in all injectors: • Need for MD time during all the duration of the project, and especially during the first years	Review short term needs in all machines and negotiate beam time
Operation	Management of “users”, fast re-start after incident...	Inform OP and CO of the needs. Request higher INCA reliability. Automatic restart of equipment.
BI	• Specification – incl. quality/reliability of beam instrumentation • Bunch-by-bunch measurements	To be provided to BI for actions
EMC	Poor EM Compatibility and Susceptibility leads to delays and dissipation of resources.	New equipment shall respect EMC norms
Energy	Reduction of the use of resources (electricity, water) is going to be more and more important.	Aspect to be used when comparing alternatives. Ref. ESS project.
Cooling and ventilation	Needs/Resource not yet evaluated by the former Task Forces and Working Groups.	Action launched. Being followed-up to be integrated in the resources and planning.
Beam loss and collimation	Need to reduce hardware activation (all machines) and guarantee emittances at LHC entrance.	Study potential solutions based on scrapers and/collimators (especially SPS)

Radiation protection issues	Transport/consolidation/maintenance/installation/storage/automated manipulation of radioactive equipments – Simulation of remnant and intervention doses – Dismantling studies of all new facilities / equipments.	To be evaluated in terms of resources / time/ planning

b. Linac4

Subject	Comments	Action
Linac4 challenges and risks	Many issues concerning beam dynamics and hardware	Items and actions documented in the published risk analysis [5]
H^- ion source	Difficulty with present status of ion source. However: • LHC beam is feasible with ½ of the nominal beam current (20 mA instead of 40 mA) • Margin for compromising with emittance • Possible compensation by increasing pulse length (cost: 150 kCHF)	• New source development launched. • Analyse consequences of longer pulse (e.g. on PSB injection) and decide within 6 months
Delayed stop of Linac2	Depending upon the LHC planning, Linac2 must continue to operate until 2015 or 2016	• Review Linac2 status • Train new staff
Linac2 as a back-up after Linac4 is on-line	Not practical because: • Reverting to protons requires replacing the PSB H- injection (4/5 months). • Staying with H- requires switching to H^- source with additional HV platform • Large performance degradation (50 MeV + reduced pulse duration)	None: already documented within Linac4 project
Linac4 as a back-up if Linac2 fails before the 2016-2017 shutdown	Large PSB performance degradation because changing PSB injection system to H^- would be too long: • Maximum pulse current in Linac4 is 25 % of normal Linac2 current (40 mA wrt 160 mA) • Beam has to pass through idle & detuned CCDTL and PIMS cavities • Shortened/cancelled Linac4 reliability run • Transfer line will require rematching and check of beam quality	To be studied and quantified.
Higher energy from Linac4	Space for additional hardware in equipment hall and tunnel (and shafts for waveguides) for reaching ~180 MeV	• None for Linac4: already documented within project • For PSB: to be studied (low priority)

c. PSB

Subject	Comments	Action
Beam loss	• Higher activation at 160 MeV => need to reduce uncontrolled beam loss at injection & capture from 60 % to less than 15 % • Need for collimation (in TL and/or PSB)?	• Refine & simulate design of injection and painting schemes • Study interest of collimators
Beam dynamics	Beam characteristics with Linac4 at extraction to the PS at 1.4 and 2 GeV (Double and single batch cases)?	• Pursue study of intensity limits (including beam instabilities) and implications of the increased extraction energy in the PSB itself. • Analyze and publish beam parameters.
Magnets	• Ring magnets: ~OK for 25 years with careful monitoring • Impact of Eddy current on the vacuum chambers? • Transfer line magnets: multiple devices to be replaced. In some cases, specifications depend upon the PS injection layout is defined	• Maintenance and systematic monitoring of ring magnets in place [6] • Study of Eddy current effects • Design PS injection layout • Design and construction of new magnets: part of LIU-PSB
RF	Need for major hardware changes: • detailed plan missing • presently supported by consolidation => risk of not being available on-time for LIU	• Publication of plan by RF group • Secure timely completion of RF upgrade (transfer from consolidation to LIU?)
Beam Instrumentation	Presently supported by consolidation => risk of not being available on-time for LIU	Secure timely completion of upgrades of Beam Instrumentation (transfer from consolidation to LIU?)
Cycling period	1.2 s minimizes the impact for acceleration to 2 GeV in the PSB.	Study PS interest for faster cycling (0.9 s)
PPM of transfer line magnets	Interest of optimizing optics for high intensity or high brightness beams	Now part of baseline
ISOLDE at 2 GeV	Baseline is to keep ISOLDE at 1.4 GeV	Checks physics needs and, if required, evaluate cost of 2 GeV option for ISOLDE
Reduced Linac4 current	Mitigation means for lower current from the ions source?	Study possibility of a longer duration of injection

Optimization of total lifetime cost (construction + electrical consumption)	• Interest of building new optimized magnets: • Saving of ~X GWh/ year (18 MCHF over 25 years at today's price of kWh • Simplification (savings?) on new power supply	• Magnets Specifications (aperture, future high power cycles...) • Magnet conceptual design / cost estimate • Study of impact on power supply
Global optimization	Comparison with a 10 Hz single ring RCS.	• Preliminary analysis of RCS • Evaluate impact on Linac4 and PS
CV modifications	RP requirements might lead to large cost.	Study RP needs and impact on CV.
Impact if 2012 shutdown is delayed to 2013	Favourable for installation and tests.	None.
Availability of nominal Linac4 beam	PSB, PS and SPS need to plan for being ready for exploiting Linac4 beam as soon as it is available	Planning...

d. PS

Subject	Comments	Action
Magnets	• Dipoles are ~OK for 25 years with careful monitoring • PFW windings and bus bars more risky • Observed detachment of some yokes laminations...	• Maintenance & systematic monitoring in place [6] • Spares ordered • Define strategy for mitigation of problem with yokes laminations. • Study/define possibility to increase Bdot as possible with POPS.
Is injection >1.4 GeV necessary?	Depends upon: • PS performance with large ΔQ • Beam specifications of HL-LHC	• Test PS performance with large ΔQ • Optimization of the PS injecton working point. • Get HL-LHC specifications.
Longitudinal instabilities	• Dominated by beam impedance of RF systems... • Operational complexity of present longitudinal feedback • Limiting intensity for distances between bunches larger than 25 ns	• Study possible improvements of RF systems • Study potential broadband instability damper • Study limitations for bunch spacings larger than 25 ns
Transverse instabilities	• Present transverse damper inactive • Potential of change of chromaticity not exploited • Possibility to cross transition faster?	• Upgrade transverse damper • Study potential of chromaticity change • Study potential of a faster

		gamma-t jump • Study limitations for bunch spacings larger than 25 ns
Improvement of longitudinal beam transfer to SPS	Options for a better bunch compression: • Larger gamma-t ? • More RF voltage at 40 and/or 80 MHz or suppression of bunch compression in the PS and transfer of long bunches to the SPS...	• Study potential of gamma-t control in the PS • Study possibility of additional low frequency RF in SPS
Variety of beams	Many adjustments are required to change beam characteristics (number of bunches, distance between bunches, intensity...)	• Need for increased controls' flexibility (more users...)
Equality between bunches	Function of RF hardware and beam characteristics.	• Get HL-LHC specifications • Study possibilities of improvement (new RF gymnastics, feedback etc.) • BI to provide bunch-bunch measurements (emittance...)
e-clouds	Disturbing only after capture with 40 MHz RF. Presently forces to use RF manipulations minimizing time with 40 MHz.	• Pursue study with beam for all bunch spacings to establish scaling with intensity and emittance. • Implement cure against e-cloud (coating?) or • Send long bunches to the SPS...
14 GeV beam for SPS FT	• Need to finalize implementation of MTE and optimize adjustment • Reduced emittance with Linac4? (reduction of loss in SPS & space for clearing electrodes...) • Can MTE help by decreasing the physical emittance of FT beams at the SPS? Can we extract from the PS at higher energies the CT/MTE?	• Solve remaining problems with MTE • Estimate future beam characteristics with Linac4 • Study the possibility to extract at higher energy

e. SPS

Subject	Comments	Action
Magnets	~OK for 25 years with careful monitoring	Maintenance & systematic monitoring in place [6]
Beam loss	TIDVG limitations	Review & investigate solutions
Low frequency RF system	• Simplification of PS operation and hardware. • Positive impact on longitudinal capture efficiency and ghost bunches	Review potential and consequences
200 MHz system	Crucial for LIU. Need to document all aspects of extensive upgrade (planning, resources, beam characteristics...)	Organize review at the beginning of 2011
800 MHz system	Crucial for LIU. Need to document all aspects of planned upgrade (planning, resources, beam characteristics...)	• Organize review • Consolidation budget for 800 MHz system upgrade already allocated.
Longitudinal instabilities	• Critically depends upon controlled blow-up and 800 MHz system.	Continue MDs
Transverse instabilities	• Large fraction of impedance not identified • Importance of measuring bunches individually • Promising results with smaller gamma-t • Present damper system needs to be upgraded in power	• Complete the impedance model and impedance localization campaign to remove the present discrepancy. • Upgrade beam instrumentation (wire scanners especially) • Continue MDs with small gamma-t • Upgrade transverse damper
Open issues	No explanation for: • Transverse blow-up (>1.8E11 p/b single bunch or nominal intensity with 25 ns spacing) • slow loss on injection porch • No improvement of TMCI with smaller transverse emittances observed so far although it is expected (theory and simulations) from higher direct space charge. • Worse PS-SPS transfer for smaller transverse emittances.	• MDs and modelling of the expected tune footprint under space charge, e-cloud and other collective effects • Optimization of working point

e-clouds	Severe limitation. Deserves action: • Scrubbing: time consuming and limited in potential • Low SEY coating of chambers: aging? • Clearing electrodes: aperture reduction? Consequence of impedance increase?	• Continue investigations of cures and their consequences • Study possibilities to reduce PS beam physical emittance (smaller normalised emittance or higher energy) for smaller SPS aperture • Define strategy (Which information is required? When? Risks? Deadline for taking decision?) • Demonstrate effectiveness of clearing electrodes in whole range of conditions relevant to the SPS for LHC. • Evaluate impact of clearing electrodes impedance.
FT beam	• Beam loss	• Study possibility to reduce below 20 GeV the SPS transition energy and avoid crossing transition with FT beams

References

[1] LIU day: http://indico.cern.ch/conferenceDisplay.py?confId=112934 – All talks can be found at that location.

[2] Memorandum about "Projects Structure in the Accelerators and Technology Sector", DG-DAT-2010-005.

[3] SPS Upgrade Study Team: https://paf-spsu.web.cern.ch/paf-spsu/

[4] PSB Upgrade Working Group: https://twiki.cern.ch/twiki/bin/view/PSBUpgrade/WebHome

[5] Linac4 risk analysis

[6] The PS Booster, PS and SPS Magnets for the next 25 years, D. Tommasini, CERN TE-Note-2010-003

EDMS no: 1057909

Appendix A: Invited participants

Present (40):

Gianluigi Arduini, Chandra Baht, Jérémie Bauche, Giulia Bellodi, Jan Borburgh, Davide Bozzini, Christian Carli, Fritz Caspers, Paolo Chiggiato, Heiko Damerau, Roland Garoby, Simone Gilardoni, Massimo Giovannozzi, Brennan Goddard, Jean-Jacques Gras, Klaus Hanke, Wolfgang Hofle, Jose Miguel Jimenez, Alessandra Lombardi, Roberto Losito, Malika Meddahi, Volker Mertens, Gabriel Metral, Bettina Mikulec, Eric Montesinos, Antony Newborough, Mauro Paoluzzi, Yannis Papaphilippou, Serge Pittet, Carlo Rossi, Giovanni Rumolo, Benoit Salvant, Elena Shaposhnikova, Rende Steerenberg, Mauro Taborelli, Davide Tommasini, Marc Vanden Eynden, Maurizio Vretenar, Sylvain Weisz, Markus Widorski

Excused (8):

Simon Baird, Dominique Bodart, Frederick Bordry, Alan Findlay, Steven Hancock, Stephan Maury, Elias Metral, Helmut Vincke

Appendix B: Timetable of the "LIU day"

Wednesday 1 December 2010 – Holiday Inn – Thoiry

9:00	Introduction of LIU Project	R. Garoby
9:20	Linac4 Project session	
	Linac4	M. Vretenar
	Discussion	
10:00	Coffee break	
10:30	PSB Upgrade session	
	Introduction	K. Hanke
	Magnet issues at 2 GeV	A. Newborough
	Power supply issues at 2 GeV	S. Pittet
	Discussion	
12:15	Lunch	
13:30	PS Upgrade session	
	Setting the scene	S. Gilardoni
	PS beam dynamics for LHC beams upgrade	G. Rumolo
	RF issues with (beyond) ultimate LHC beam in the PS with Linac4	H. Damerau
	Discussion	
15:15	SPS Upgrade session	
	SPS Upgrade: a short overview	B. Goddard
	Beam dynamics issues and present limits	E. Chapochnikova
	e-clouds: where are we?	M. Taborelli
	Discussion	
17:15	Wrapping-up	R. Garoby