Introduction
LIU summary

- LIU Highlights in 2013
- Outcome of the «Review of LHC and Injectors Upgrade Plans» (Oct. 2013)
- «New» schedule for LHC and injectors
- The Challenges of 2014...
**LIU Project Definition**

**Mandate (December 2010)**

“The LHC Injectors Upgrade should plan for delivering reliably to the LHC the beams required for reaching the goals of the HL-LHC. This includes LINAC4, the PS booster, the PS, the SPS, as well as the heavy ion chain.”
Basic Principles

To increase performance

Brightness ↗

⇒ Increase injection energy in the PSB from 50 to 160 MeV, Linac4 (160 MeV H⁻) to replace Linac2 (50 MeV H⁺)

⇒ Increase injection energy in the PS from 1.4 to 2 GeV, increasing the field in the PSB magnets, replacing power supply and changing transfer equipment

⇒ Upgrade the PSB, PS and SPS to make them capable to accelerate and manipulate a higher brightness beam (feedbacks, cures against electron clouds, hardware modifications to reduce impedance…)

To increase reliability and lifetime (until ~2030!)
(tightly interleaved with consolidation)

⇒ Upgrade/replace ageing equipment (power supplies, magnets, RF…)
⇒ Procure spares
⇒ Improve radioprotection measures (shielding, ventilation…)

R.G. – 11/04/2014
# Overall baseline (as of April 2014) planning

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Deliverables</th>
<th>Proton beam characteristics at LHC injection</th>
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</table>
| **2013 – mid 2014** (Long Shutdown 1 for injectors) | • TDR, CtC and planning  
• Start of commissioning of Linac4  
• Exploitation of MDs and simulations  
• Modifications and installation of prototypes in PSB, PS and SPS  
• Design $§$ construction of equipment |  

| **Mid 2014 – mid 2018** (Run 2) | • Regular operation with BCMS  
• Test/validation of installed prototypes  
• Full commissioning & reliability run of Linac4  
• Equipment design $§$ construction for PSB, PS and SPS  
• Beam studies $§$ simulation | Potential for exceeding LHC nominal luminosity (~2x) with 25 ns bunch spacing...  

| **Mid 2018 – 2020** (Long Shutdown 2) | • Connection of Linac4 to the PSB  
• Extensive installations in PSB, PS and SPS  
• Hardware commissioning  
• Beam commissioning: recovery of previous beam characteristics for LHC restart |  

| **2020 – 2022** | • Beam commissioning : MDs and studies for improving beam characteristics  
• Installation of last upgrades for protons and ions during the first winter shutdown. | Before LS3: LIU «baseline» beam characteristics attained |
LIU total: Status in April 2014 (as included in MTP2014)

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LIU summary

LIU Highlights in 2013

- Outcome of the «Review of LHC and Injectors Upgrade Plans» (Oct. 2013)
- «New» schedule for LHC and injectors
- The Challenges of 2014...
Linac4: a memorable year 2013!

A cheering crowd celebrating the first beam accelerated by the RFQ on the Test Stand (13.3.13)

Open Days 2013: 2'500 visitors!

Klystrons and modulators installed in the Linac4 Hall

The RFQ installed in its final location in the tunnel, 25.6.13

7.11.2013: ready for 3 MeV beam tests in the tunnel!

R.G. – 11/04/2014
### Linac4 in LIU 2014

**Today**

- **Start high-energy commissioning (12 MeV)**
- **Transfer 3 MeV to Linac4 tunnel**
- **Ready for 50 MeV protons as backup to Linac2**
- **Reliability run**

#### Commissioning Linac4

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<td>13</td>
<td>Linac4 ready for 50 MeV protons</td>
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<td>Reliability run</td>
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</table>

**Linac4 in LIU 2014**

- **Linac4 Drift Tube Linac**
- **H- ion source development programme**
- **Linac4 commissioning overview**

**Today's Schedule**

- **09:50** Linac4 commissioning overview 10’+10’ 20’
  Speaker: Alessandra Lombardi (CERN)
- **10:10 - 10:30** Coffee Break
- **10:30** H- ion source development programme 10’+10’ 20’
  Speaker: Jacques Lettry (CERN)
- **10:50** Linac4 Drift Tube Linac 10’+10’ 20’
  Speaker: Suitbert Ramberger (CERN)
LIU-PSB: LS1 work

Digital LLRF:
- H/w series production & validation
- Cabling done
- S/w (all levels, also application programs) to be completed by mid April 2014
- H/w installed by mid-April 2014, ready for h/w tests.
- PSB will restart with DLLRF as the operational system on 4 rings.

RF cavities:
- Addition of 5 Finemet cavity cells in ring 4 (cabling ready, cells to be installed before start-up)
LIU-PSB: LS1 work

Change of PSB front-end computers

New Beam Instrumentation:
- Orbit measurement system (in // with old one)
- BLMs and cables (in // with old ones)
- BPMs in the Linac to PSB transfer line

PSB Beam dump exchange

Stack of PUs in BI line

04/10/2013
Progress in the definition of the H⁻ injection systems (optics, apertures, vacuum sectorisation, magnets...):
  - Review of H⁻/H0 dump on 18 April, 2013
    (http://indico.cern.ch/conferenceDisplay.py?confId=244116)

Progress in the definition of the beam transfer equipment at 2 GeV:
  - Review of PSB ejection lines at 2 GeV on 10 October, 2013
    (http://indico.cern.ch/conferenceDisplay.py?confId=274495)

Active involvement in the coordination of the PSB dump replacement:
  - ALARA procedure meetings
    (http://indico.cern.ch/categoryDisplay.py?categId=4284)

Space management/cables identification in preparation for installation of future equipment

Specifications for new MPS and its building (to be shared with CV)
**LIU-PS: LS1 work**

**Resonances compensation:**
Installation of 4 skew quads for 3rd order resonance compensation and 2 more octupoles to investigate $4q_V=1$ resonance compensation.

**Transverse damper:** new power amplifiers and cables.

**One-turn delay feedback on ferrite cavities:**
- New digital electronics card being installed (derived from LHC) and cables.
- Operational immediately after LS1.

**Longitudinal coupled-bunch feedback:**
- 6 cells cavity assembled. Installation before start-up.
- Operational immediately after LS1.

**New e-cloud detectors in modified MU98 vacuum chamber**
LIU-PS: LS1 work

Injection region shielding increase (Route Goward’s hill)

Extraction region shielding increase (above SS16)
Space-charge:
• Vertical growth vs. Tune-spread and beam loss →
• Extensive simulation

Proposal for generation of very bright beam:
Pure Batch Compression (with splitting at 26 GeV) →
32 bunches per PS batch

Proposal for 8b+4e bunch train (25 ns) in case of excessive e-cloud effects in LHC with full train:
• 4 bunches missing every 8 bunches → less e-cloud in LHC
• 33 % less bunches in LHC, but with significantly higher intensity
• To be tested with beam after LS1
LIU-SPS: LS1 work

**aC coating of dipole magnets:**
- 12 additional magnets equipped with aC coated vacuum chambers (→ 16 in total after LS1)

**200 MHz high power RF:**
- Tests up to 750 kW CW and 1.05 MW pulsed (43 kHz & 172 kHz)
- Modification of all Siemens amplifiers DC circuitry

**800 MHz Low Level RF:**
- LLRF replaced with digital version

**800 MHz high power RF:**
- All klystron transmitters dismantled
- 4 IOT-based amplifiers installed

### TWC 200 MHz Power tests

- **P_{cav} kW**
  - 1050 pulsed
  - 750 CW

New 800 MHz IOT transmitters
**Dumping of LHC beam with Q20 optics**

**Longitudinal impedance of open C core extraction kicker (beam in gap)**

**Slotted coaxial kicker for High bandwidth feedback**

**SPS: instabilities and impedance model in longitudinal and transverse planes 2x10' + 15' 35’**

Speakers: Carlo Zannini (CERN), Jose Enrique Varela Campelo (CERN)

**15:00 SPS to LHC transfer line collimation 15' + 10' 25’**

Speaker: Verena Kain (CERN)

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**Major effort defining baseline**

**LIU-SPS reviews held in 2013**

- [LIU SPS Orbit Correction Review](#) 16 January 2013
- [LIU-SPS Beam Scraping System Review](#) 22 January 2013
- [LIU-SPS Internal Beam Dump Review](#) 30 January 2013
- [LIU-SPS ZS Electrostatic Septum Upgrade Review](#) 20 February 2013
- [LIU-SPS Open 'C' Core MKE Extraction Kicker Review](#) 20 March 2013
- [LIU-SPS High Bandwidth Damper Review](#) 30 July 2013
- [LIU-SPS Beam Instrumentation Review](#) 3rd October 2013
- [LIU-SPS 50 ns Injection System for Pb Ions Review](#) 4 October 2013
- [LIU-SPS/LAGUNA Collimation System Review](#) 21 November 2013
New BAFS building progress

Building BAF3

- Integration studies completed
- Enquiry 'Etude Genie Civil' sent out
- Construction to start January 2014
- Building ready by mid-2015 all inclusive (CV + EL)

Detailed planning for SPS aC coating (all main magnets)

Comprehensive ecloud studies report (50 pages)

Electron Cloud and Scrubbing Studies for the SPS in 2012


Keywords: SPS, electron cloud, scrubbing, amorphous carbon coating, 25 ns

Summary

It is important to collect all the relevant information to qualify the present status of the electron cloud in the SPS before the Long Shutdown (LS1). Therefore several electron cloud studies have taken place in the SPS during the 2012 run. At the beginning of the running period, five days were fully dedicated to electron cloud activities and scrubbing studies. After that, a few more MD sessions were devoted to following up the studies started in the scrubbing week. These results, in combination with detailed simulation studies, will provide the basis for defining strategies of electron cloud mitigation as required for the production of future high intensity and high brightness beams within the LHC Injectors Upgrade (LIU) project.

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Definition of baseline scheme with 100 ns bunch spacing

Potential scheme (with “bunch splitting” in the PS and “slip stacking” in the SPS) for a bunch spacing of 50 ns in LHC

\[ L_{LHC} \approx 4 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1} \]

\[ L_{LHC} \approx 6 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1} \]

(T.Argyropoulos, T.Bohl, E.Shaposhnikova)
LIU summary

LIU Highlights in 2013

Outcome of the «Review of LHC and Injectors Upgrade Plans» (Oct. 2013)

«New» schedule for LHC and injectors

The Challenges of 2014...
Review of LHC and Injectors Upgrade Plans

https://indico.cern.ch/event/260492/overview

29-31 October, 2013

Objectives:

✓ Review of the parameters of the LIU and HL-LHC projects following the experience and changes in the beam parameters experienced in the past two years.

✓ Produce a staged plan (beam parameters, technical work, all machines) of how we proceed from the performance at the end of 2012 to the required performance for the HL-LHC. In order to do this we need to know at what level of integrated luminosity will necessitate replacement of the inner detectors and the insertions. Also to see the importance of 3000fb⁻¹ and what level of minimum integrated luminosity would be tolerated.

Impact:

✓ Intense activity preparing the event with the study of multiple scenarios and the analysis of implementation plannings in tight connection with HL-LHC (subject of 8 dedicated LIU Technical Meetings*). Very worthwhile investment resulting in the confirmation of the LIU baseline choices, and improved coordination with HL-LHC and providing to the management the necessary information to update the LHC schedule.

* http://indico.cern.ch/category/4985/
Maximise LHC Performance (Useful integrated luminosity)

**Peak Luminosity**
- Pile-Up in the detectors
- Accelerators performance

**Useful Integrated Luminosity (4 detectors)**
- Time available for physics (iterative with shutdowns)
  - Play-off between upgrades and time lost for physics
- Timing of Upgrades (sooner the better)

**Beam Energy??**
- During discussion with CMAC possibility of energy increase came up.
Structure of the Review

• 5 different scenarios for comparison of performance and cost
• Each scenario encompasses all accelerators in the LHC chain
• For each scenario:
  • Identify the technical requirements (work needed and shutdowns)
  • evaluate the peak and integrated yearly luminosities (time available for physics)

Note: In the preparation for the review, these scenarios were meant for comparison. Later, it became apparent that they could be better used for the evaluation of the evolution of the performance with time over the long time scale examined.
Strategy

• LHC has been constructed, operated and will continue to be operated on a CONSTANT BUDGET
• We have a beautiful scientific facility, unique in the world.
• The community has invested (and are investing) a huge amount of their resources in this unique facility both for construction and for operation.

The goal of 3000 fb\(^{-1}\) by \~2035 is challenging but attainable

• Both Upgrades, LIU and HL-LHC, should aim for the maximum useful integrated luminosity possible
• LS3 should come as soon as possible in order to maximize the integrated luminosity (every delay by one year of LS3 “costs” 200 fb\(^{-1}\))
• LS2 should not delay LS3.
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«New» schedule for LHC and injectors

The Challenges of 2014...
LHC Schedule beyond LS1

Only EYETS (19 weeks) (no Linac4 connection during Run2)
LS2 starting in 2018 (July) 18 months + 3 months BC (Beam Commissioning)
LS3 LHC: starting in 2023 => 30 months + 3 BC
injectors: in 2024 => 13 months + 3 BC

LHC schedule approved by CERN management and LHC experiments spokespersons and technical coordinators Monday 2nd December 2013
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«New» schedule for LHC and injectors

The challenges of 2014...
The Challenges of 2014…

• Restart the accelerators. Absorb impact of «Controls renovation» (300 new FECs, new OS version, new hardware…) + upgrades (Digital LLRF, New cavity feedback loops…) + maintenance/repair interventions…
  ⇒ Recover 2012 beam characteristics for all users

• Progress with commissioning of Linac4. Start testing the upgrades (PSB Finemet cavity, PS longitudinal damper, SPS wide band transverse damper, new Beam Instrumentation, aC coating in SPS magnets…)
  ⇒ Prepare decision on options.

• Pursue MDs and studies for understanding sources of limitations and finding solutions for improvement
  ⇒ Progress in beam performance.

• Continue designing/building well-defined equipment.
  ⇒ Prepare for installation as scheduled.
I AM CONFIDENT YOU WILL SUCCEED, AS IN 2013!

LET’S LISTEN TO YOU...
AND CELEBRATE!

[16h45 – cafeteria bdg.30/7th floor]