PS Booster Energy Upgrade
K. Hanke
for the PSB Upgrade WG
LIU Event 01/12/10
PS Booster

• upgrade of the BI line and injection region for 160 MeV H- & intensity increase (so far L4 project – now part of LIU_PSB)
• upgrade of the machine itself and the transfer line to the PS for 2 GeV

• construction 1972
• present energy range 50 MeV to 1.4 GeV
• **energy upgrades from 800 MeV to 1 GeV (1988), and from 1 GeV to 1.4 GeV (1999)**
• 7 flavors of LHC beams, 10 types of fixed target beams, intensity and emittances cover several orders of magnitude
• ppm operation (1.2 s cycle length)
PS Booster Energy Upgrade

Follow-up of the 2010 LHC performance workshop at Chamonix
http://indico.cern.ch/conferenceOtherViews.py?view=standard&conflId=67839

- remove bottlenecks in the LHC injector chain
- consolidation of the injectors is necessary anyway
- put in place Task Force for a feasibility study and first resource & time estimate

Working group web page:
https://twiki.cern.ch/twiki/bin/view/PSBUrgrade/WebHome
Mandate

The aim of the study is to evaluate the technical feasibility of an increase in beam energy of the CERN PS Booster from presently 1.4 GeV to about 2 GeV as proposed at the Chamonix 2010 workshop.

The study comprises:
• Confirm the potential gain in terms of intensity and brilliance for LHC-type beams as presented at the Chamonix 2010 workshop.

• Confirm the technical feasibility. Identify accelerator components and equipment that need to be upgraded or exchanged. Identify potential showstoppers and point out solutions. Assign the responsible groups/units. Provide first rough time estimates for the various interventions needed.

• Provide a first estimate of material and personnel resources needed to complete the upgrade. Draft a project break-down into work packages, in preparation for a project to be launched by the director of accelerators.
## Working Group Organisation

**coordinator** K. Hanke / **sc. secretary** T. Hermanns

<table>
<thead>
<tr>
<th>1. Beam Dynamics</th>
<th>G. Rumolo</th>
<th>BE/ABP</th>
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<tbody>
<tr>
<td>2. Magnets</td>
<td>D. Tommasini, A. Newborough</td>
<td>TE/MCS</td>
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<td>3. Magnetic Measurements</td>
<td>M. Buzio</td>
<td>TE/MCS</td>
</tr>
<tr>
<td>4. RF System</td>
<td>A. Findlay, M. Paoluzzi</td>
<td>BE/RF</td>
</tr>
<tr>
<td>5. Beam Intercepting Devices</td>
<td>O. Aberle</td>
<td>EN/STI</td>
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<tr>
<td>6. Power Converters</td>
<td>S. Pittet</td>
<td>TE/EPC</td>
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<tr>
<td>7. Vacuum Systems</td>
<td>E. Mahner</td>
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<td>8. Instrumentation</td>
<td>J. Tan</td>
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<td>9. Commissioning &amp; OP Issues</td>
<td>B. Mikulec (deputy coordinator)</td>
<td>BE/OP</td>
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<td>10. Extraction and Transfer</td>
<td>J. Borburgh</td>
<td>TE/ABT</td>
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<td>11. Controls</td>
<td>L. Fernandez</td>
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<td>12. Electrical Systems</td>
<td>D. Bozzini, S. Olek</td>
<td>EN/EL</td>
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<tr>
<td>13. Cooling and Ventilation</td>
<td>M. Nonis</td>
<td>EN/CV</td>
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<td>14. RP and Safety</td>
<td>M. Widorski</td>
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<td>15. Transport and Handling</td>
<td>I. Ruehl</td>
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<td>16. Survey</td>
<td>T. Dobers</td>
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**Linkperson Consolidation**

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<tr>
<th>N. Gilbert</th>
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**Linkperson Design Office**

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<th>R. Folch</th>
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**Linkperson PS**

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<th>R. Steerenberg</th>
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**US LARP**

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<tr>
<th>E. Prebys</th>
<th>FNAL</th>
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...plus other experts from various fields
## Feasibility Study

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<td>7.</td>
<td>Vacuum System</td>
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<td>10.</td>
<td>Extraction, Transfer, PS Injection</td>
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Summary (before going into the details)

• we have double checked the arguments presented at the 2010 Chamonix workshop and we confirm that an increase in beam energy will facilitate injection of high-brilliance and intensity beams into the PS

• we have done a complete survey of all PSB equipment and systems with regard to an energy increase and did not find any showstopper

• we have identified PSB equipment and systems that need to be modified or exchanged in order to operate at 2 GeV beam energy

• we propose technical solutions for these items, along with a cost estimate and schedule

• we have identified items, which were already accounted for in the consolidation program; we have disentangled these items from our budget request

• we propose a project schedule, which is in line with the long-term LHC planning
Feasibility Study

PS BOOSTER ENERGY UPGRADE
FEASIBILITY STUDY
FIRST REPORT

Abstract
This document summarises a survey of the CERN PS Booster systems with regard to a possible energy upgrade to 2 GeV. Technical solutions are proposed along with a preliminary estimate of the required resources and the time lines.

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Rhodri Jones
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Ingo Ruhl
Marc Tavlet

Approved by:
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Roland Garoby
Frederick Bordry
Paul Collier
Roberto Saban

Distribution List: R. Heuer
Findings and Recommendations

- we were asked to put in place the upgrade rapidly, even before Linac4; this turned out to be technically challenging and schedule wise unrealistic
  → energy upgrade and commissioning with L4 will coincide (in 2015/16)
- the aim is energy increase and not intensity increase; however we will operate at 2 GeV with Linac4 (increased intensity)
  → compatibility with L4 intensities
- the study aims at LHC beams only; however we found that no savings are expected by upgrading only LHC beams (presently under discussion whether kickers can be re-used)
  → consider all beams to the PS at 2 GeV (ISOLDE remains at the present 1.0/1.4 GeV) confirmed as baseline by scenario by the LIU project
- we have studied variants of the “LHC-only” scenario, where we suppress fixed-target physics cycles whenever we have LHC cycles in the injectors (LHC filling and setting up)
  → some savings (but not the cost drivers), while the loss of non-LHC physics is substantial; separate note published (https://edms.cern.ch/document/1079117/1)
- we have addressed the question of intermediate energies between 1.4 and 2.0 GeV
  → we found that the present MPS is not able to run at any higher energy than 1.4 GeV and needs to be replaced anyway; not considered an option
- we have designed a magnetic cycle where the rms current remains within 10% of the present one
  → only minor modifications to the main magnet cooling circuits required
WU 2 Magnets [A. Newborough, D. Tommasini]

**Issues:**
- Concern over life span due to mechanical stress during permanent pulsing at 2 GeV
- Saturation of outer rings will increase even more
- Main unit cooling, present system insufficient
- Auxiliary magnets: majority not affected, but study to be completed
- 15-18/59 transfer line magnets presumably require exchange; need optics studies for final confirmation
- PS injection bumpers, correctors and quads being studied; preliminary results suggest that the majority of PS low-energy magnets will need to be replaced

**Proposed Technical Solutions:**
- Main magnets: new field levels are achievable
- Stress test completed in SM18; no degradation found
- Change solid retaining plates by laminated ones to reduce/eliminate saturation
- Cycle with rms current within 10% of the present one makes only minor modifications on the cooling circuits necessary (in situ)
- Auxiliary ring magnets mainly used at low energy, no worry
- Modification/replacement of ~30% of the transfer line magnets
- Replacement of many PS low-energy magnets; study ongoing

**Budget:** 3445 kCHF − 210 (cons.) = 3235 kCHF
issues:
- if consolidation is budgeted and completed in time for the 2 GeV upgrade: everything covered by consolidation, no issues left for the upgrade project.

proposed technical solution:
- high-level rf: consolidation of C02, C04 and C15
- consolidation of ll rf, transverse damper, rf cables

important notice: it is a necessary condition for the energy upgrade that the RF consolidation is completed; in case this is not (or not completely) covered, or if consolidation is not completed within the time frame of the upgrade, then the upgrade will not work

budget: 14320 kCHF – 14320 kCHF (cons.) = 0 kCHF
**WU 5 Beam Intercepting Devices [O. Aberle]**

**issues:**
- present dump and BTP beam stopper not appropriate
- study of the PSB dump has been triggered by the question whether it can accept L4 intensities – the energy upgrade comes now as additional constraint into this ongoing study
- beam stopper BTP.STP10 has to be checked with regard to 2 GeV operation; new design might be needed, still to be confirmed.

**proposed technical solution:**
- dump: new design (in progress), production of a new dump plus spare to be launched.
- BTP stopper: if insufficient, launch new design and construction (2 units)

**budget:** 700 kCHF – 700 kCHF (cons.) = 0 kCHF
**WU 6 Power Converters [S. Pittet]**

**issues:**
- present MPS is not able to deliver a 2 GeV cycle; in addition it cannot deliver required RMS current; increasing peak power using traditional thyristor technology would have an unacceptable effect on the whole Meyrin network; the present 1.4 GeV is the limit, any higher energy than this will require a new MPS
- number of smaller power converters needs to be changed
- number of power converters in the PS to be upgraded
- ppm operation between 1.0/1.4 GeV (ISOLDE) and 2 GeV (PS) is feasible

**proposed technical solution:**
- new POPS-type MPS using capacitor bank
- some civil engineering needed
- divide machine in 2 circuits (inner and outer rings); will make 1+4 Trim power supply obsolete
- replacement of a number of smaller power supplies

**budget:** 20850 kCHF (cost driver) – 6630 kCHF (cons.) = 14220 kCHF

see S. Pittet
**WU 10 Extraction, Transfer & PS Injection [J. Borburgh]**

**issues:**
- number of septa/kickers to be re-built, notably PSB extraction kicker, recombination septa and PS injection septum
- re-design PS injection; under study; presently not yet completed to the last detail
- PS injection kicker rise time and ripple increase if used in short-circuit mode to obtain required deflection (emittance growth)

**proposed technical solution:**
- PSB extraction kicker and septa need modification
- PSB recombination kickers and septa need modification
- longer PS injection septum under study
- PS injection kickers either in short-circuit mode or supplementary PS injection kicker to be built

For injection into the PS two options being considered:
  a) injection as now in ss42: requires new septum, new bumpers, possibly supplementary new kicker in PS (53?)
  b) injection in ss41: requires enlarged vacuum chamber in main dipole, new BTP line, new septum, new bumpers and possibly supplementary new kicker in PS (53?)

Should have a conclusion beginning 2011

**budget:** 5763 kCHF – 550 kCHF (cons.) = 5213 kCHF
issues:
- present power consumption around 10 MVA
- future electrical distribution will depend on the requests (power, magnets and CV)
- TE/EPC estimates a 10% increase in their request for the MPS, and 40% for the transfer line.
- CV estimate a 15-20% increase of the power demand
- no more power available from transformer for general services; 18 kV cubicles cannot be extended; system needs consolidation

proposed technical solution:
- After topical meetings with EN/CV and TE/EPC the needs have been clarified and the re-design of the system has started; to be seen within the context of a global re-design of the electrical network on the Meyrin site

budget: 1700 kCHF
WU 13 Cooling and Ventilation [M. Nonis]

issues:
- cooling: future design of cooling and ventilation will depend on the cooling needs, mainly magnets, power and rf; survey of the cooling needs of the different work units has shown so far no increase in the cooling needs
- ventilation: no specific need communicated to CV, work will consist in the complete refurbishment of existing plant keeping the same existing working functionalities

proposed technical solution:
- refurbishment of cooling station and some distribution piping
- the work schedule has to take into account the commissioning of cooling plant and the commissioning of new equipment, delays are therefore more important; length of the shutdowns is a concern (might need ~6 months in a row)

recently RP has expressed concerns whether a general revision of the Booster ventilation might be required; discussions ongoing

budget: 5500 kCHF – 4500 kCHF (cons.) = 1000 kCHF
## Summary Resources in kCHF

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<tr>
<th>Item</th>
<th>Consolidation</th>
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<td>Total Beam Dynamics</td>
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<td>Total Magnets</td>
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<td>Total Magnetic Measurements</td>
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Behind this overview there is a detailed budget & manpower break-down for each WP.
Draft Project Schedule

assumes resources (money and manpower) are made available in due time
Summary & Next Steps

- One year of intense work
- We know what we need to do and what resources we need
- Consolidation items have been disentangled from the budget
- The budget we have estimated has been entered in the MTP
- Next steps:
  - conclusions from retreat and Chamonix
  - freeze design choices
  - prepare TDR