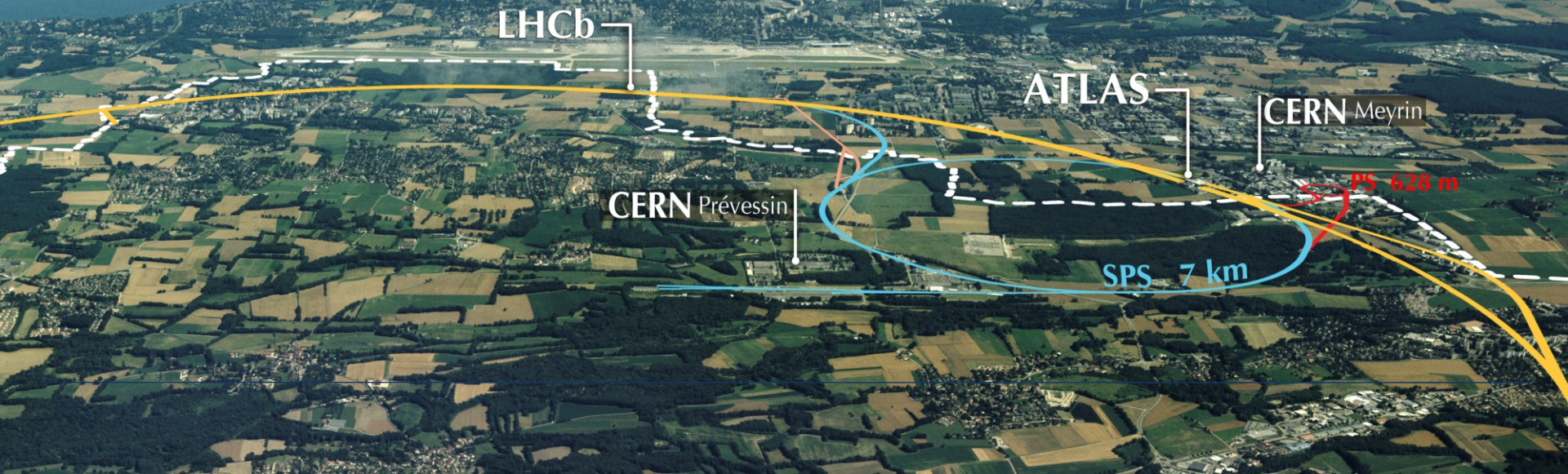


BEAM PARAMETERS AND PLANNING OF THE LHC INJECTORS UPGRADE

R. Garoby for the LIU Project Team

24/03/2011



LIU Project Team

<https://espace.cern.ch/liu-project>

Subject	Leader	Deputy
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SPS	B. Goddard	E. Shaposhnikova
PS	S. Gilardoni	H. Damerau
PS injector	K. Hanke	B. Mikulec
Linac4	M. Vretenar	A. Lombardi, S. Maury

- **Introduction**
- Plans for the injectors' upgrade
- Estimated beam characteristics after LIU
- Planning
- Summary

Organization

<https://espace.cern.ch/liu-project>

- **Two projects have been created at the end of 2010 for studying and implementing the High Luminosity Upgrade of the LHC:**

- ⇒ **“HL-LHC” for the LHC itself**

“This new study combines all work related to the provision of a peak luminosity of five times the design luminosity of the LHC (i.e. $5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$) and with an enhanced luminosity lifetime by “luminosity leveling””.

- ⇒ **“LHC Injectors Upgrade” (LIU) for the injector complex**

“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.”

Project Tools

<https://espace.cern.ch/liu-project>

- **EDMS**

EDMS Portal Help | Login - GUE

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Accelerators

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Computing

Design & Equip. Catalogues

Experiments

LHC Machine

LIU - LHC Injectors Upgrade

Management & Committees

Operation

External Collaborations

Others

INFORMATION

More Info About the EDMS Service

LIU - LHC Injectors Upgrade

LIU - Project Management

PSB - PS Booster Upgrade

PS Upgrade

SPS Upgrade

LINAC4

LINAC4 Hardware Baseline

Statistics

Welcome to the CERN Engineering & Equipment Data Management Service

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LHC Injectors Upgrade

Managers: Andrey, N.; Garoby, R.; Meddahi, M.; Noels, C.

LIU Project (16)

LIU-PS (0)

LIU-PSB (0)

LIU-SPS (22)

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Goals & Means

<https://espace.cern.ch/liu-project>

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...)

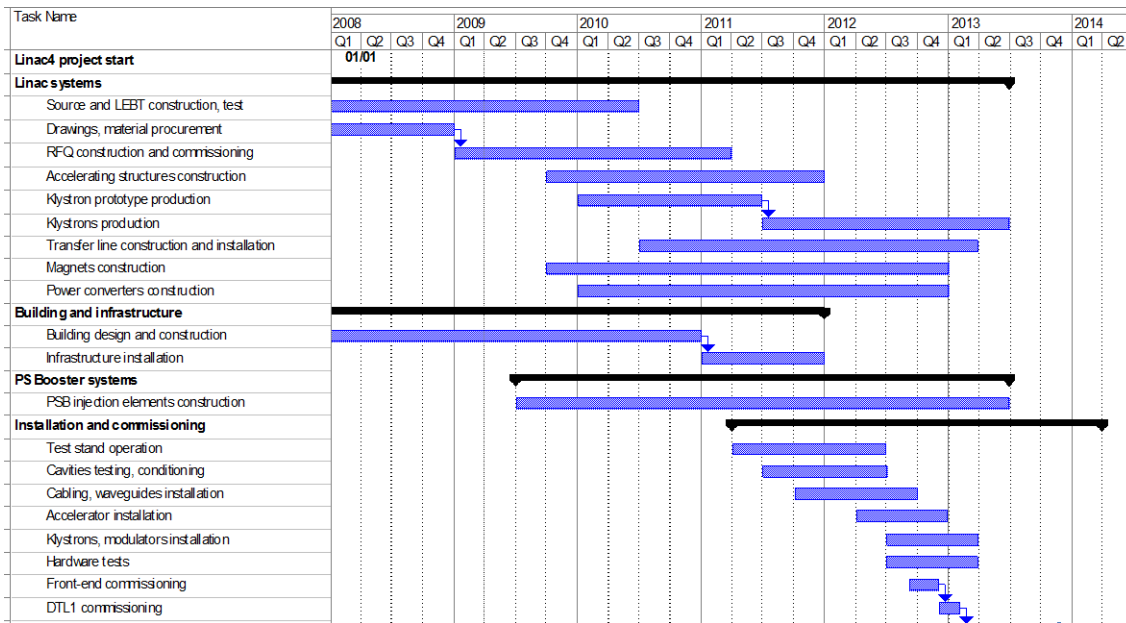
To increase reliability and lifetime (until ~2030!)

(tightly interleaved with consolidation)

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

Linac4

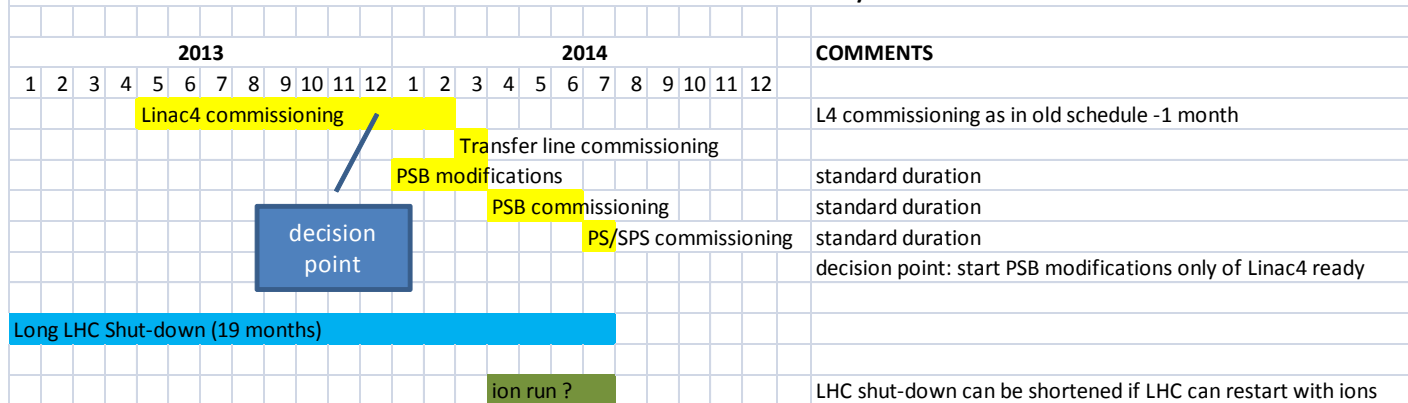
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Milestones

- End CE works: December 2010
- Infrastructure: 2011
- Installation: 2011-2012
- Commissioning: 2013 till Q1-2014
- Modifications PSB: Q1-2014
- **PSB commissioning: Q2-2014 ?**
- **Operation: Q3-2014 ?**

TENTATIVE SCHEDULE - CONNECTION LINAC4 DURING LONG SHUT-DOWN 2013/2014 - version 10.2.11



PSB Upgrade

<https://espace.cern.ch/liu-project>

K. Hanke

Geneva 23
Switzerland



The
PSB Upgrade
Working Group

DATE: 2010-09-23

PSB Upgrade Working Group Document No. 1082646-0003
CERN Div./Group or Supplier/Contractor Document No. BE-OP
EDMS Document No. 1082646 v.3

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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Task Force

Items

(material cost in kCHF)

Magnets	3445
Magnetic Measurements	111
RF (High power and Low Level)	14320
Beam Intercepting Devices	700
Power Converters	21100
Vacuum System	100
Beam Instrumentation	67
Commissioning	50
Extraction, Transfer, Injection	5763
Controls	116
Electrical Systems	1700
Cooling & Ventilation	5500
Radio-Protection	0
Transport and Handling	680
Survey	50
Total Project	53702

RCS option

C. Carli

Tentative RCS parameters

Energy range	160 MeV to 2 GeV
Circumference	$(200/7) \pi \text{ m} \approx 89.76 \text{ m}$
Repetition rate	$\sim 10 \text{ Hz}$
RF voltage	60 kV
Harmonics	h
Frequency range	
Beam parameters for (for lower energy design)	
Lat	determined by
Tunes	4 < $Q_{H,V}$ < 5
Relativistic factor	~ 4
Bending magnetic field	56 %
Maximum magnetic field	1.16 T

Benefits:

- Competitive cost wrt PSB consolidation and upgrade (?)
- Reliability (new hardware / modern design)
- Commissioning decoupled from physics operation
- Limited risk: Linac2 + PSB can remain available for a few years as back-up.

PS Upgrades

S. Gilardoni

<https://espace.cern.ch/liu-project>

Injection, magnets, power converters...

System	Elements
Injection elements	Injection septum Injection bumpers Eventual extra kicker
Low energy correctors	100 horizontal correctors 30 vertical correctors
Low energy skew quadrupoles	45 magnets
Low energy quadrupoles	40 magnets
Transverse damper	Power part of existing system
e-cloud attenuation system	Chamber coating or electrode Installation
Instrumentation	BWS, BCT, Orbit system, profile monitors.
Improved shielding on top of route Goward and on top of SMH16	Shielding elements

RF

Priority	Item	When
[1]	New coupled-bunch FB	2012
2	Dedicated kicker cavity	2015-2020
10 MHz		
[1]	1-turn delay FB	2011
1	Renovate FB amplifiers	2011-2015 (?)
1	Slow phase loops around each cavity	2013-2014
2	New power amplifier (1 tube/gap)	2014-2018 (?)
20 MHz		
1	1-turn delay FB	2012
2	Slow phase loops around each cavity	2012
40 MHz		
[1]	Automatic tuning system	2011
1	1-turn delay FB	2012
2	New feedback amplifier in grooves	2014
2	Slow phase loops around each cavity	2012
3	Study more voltage per cavity	2013
3	New power supplies	2014-
80 MHz		
1	1-turn delay FB	2012
1	Automatic tuning system - PLC, prot./ions switching	2011-2012
2	Slow phase loops around each cavity	2012
2	New feedback amplifier in grooves	2014
2	Fast ferrite tuner	2016
3	Study more voltage per cavity	2013
3	New power supplies	2014-
3	Extra 80 MHz cavity	???

Baseline for LIU-SPS

- RF 200 MHz upgrade: completed for 2018
- ecloud mitigation: aC coating, 1 sextant LS1, completed for 2018
- New high bandwidth damper: completed for 2016
- Existing damper power upgrade: completed for 2014
- Beam instrumentation upgrade : completed for 2014
- Scraper upgrade: completed for 2014
- Extraction and TL protection upgrade: completed for 2015
- MKE impedance reduction: completed for 2012
- MKDV/H impedance reduction (transitions): completed for 2014

- Beam dump design study: completed by end 2013
- New MKE design study: completed by end 2013

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Preliminary comments

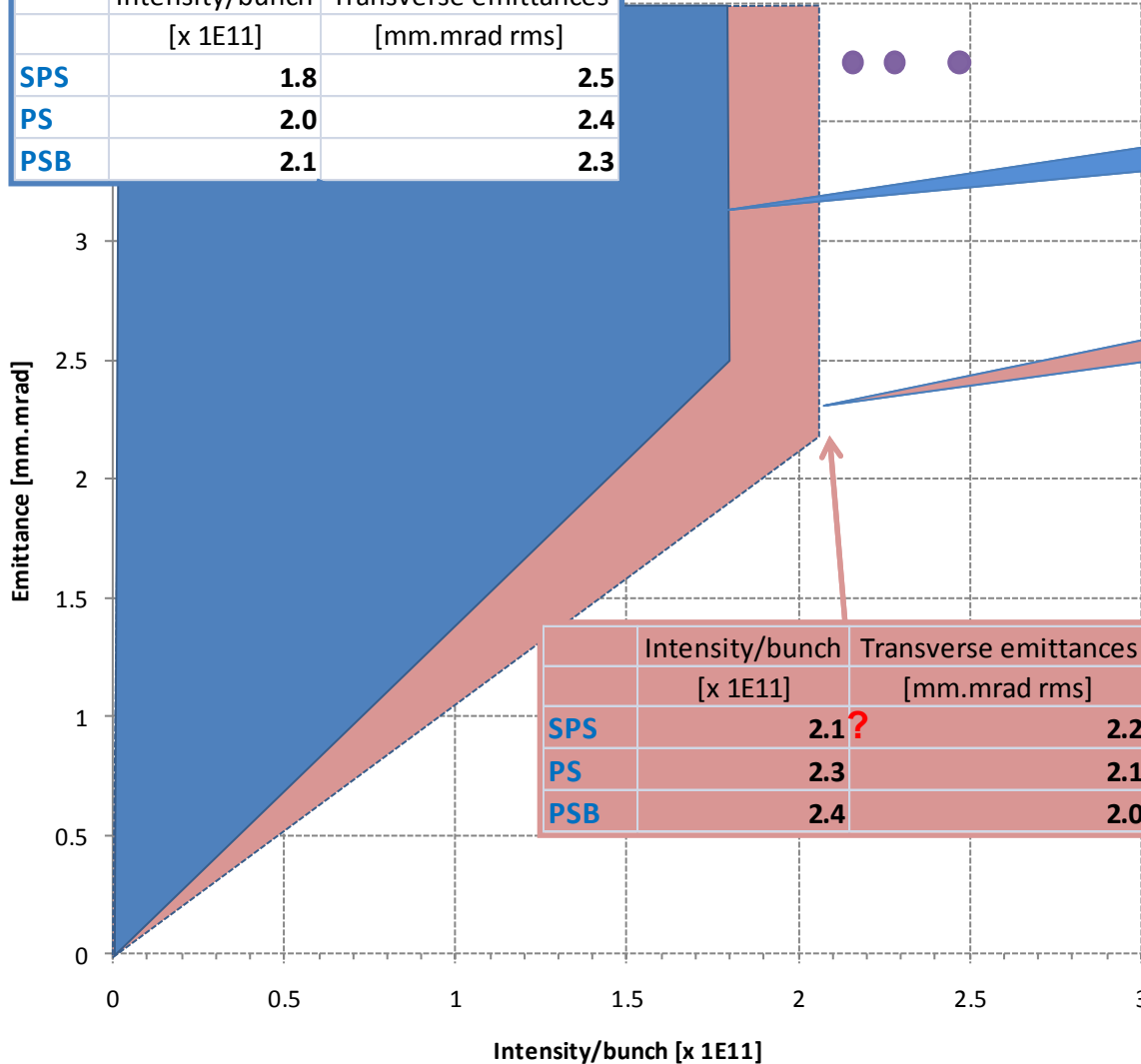
<https://espace.cern.ch/liu-project>

- Beam parameters are given at injection in LHC: beam loss and blow-up in LHC are not counted.
- All proposed improvements are implemented in the injectors
- Based on observations in 2010, the following estimates are made in the accelerator chain:
 - PS: 5 % beam loss, 5 % transverse blow-up
 - SPS: 10 % beam loss, 5 % transverse blow-up.
- RF gymnastics being kept, imperfections are unchanged: $\pm 10\%$ in all bunch parameters within a given PS bunch train. Traces of ghost bunches.

Beam parameters at LHC injection [25 ns]

<https://espace.cern.ch/liu-project>

	Intensity/bunch [x 1E11]	Transverse emittances [mm.mrad rms]
SPS	1.8	2.5
PS	2.0	2.4
PSB	2.1	2.3



LIU baseline goal

LIU stretched* goal

- Sterbini (LHC CC10)
- ◆ Fartoukh (Chamonix11)
- ▲ Bruning (Chamonix11)
- Zimmermann (Chamonix11)

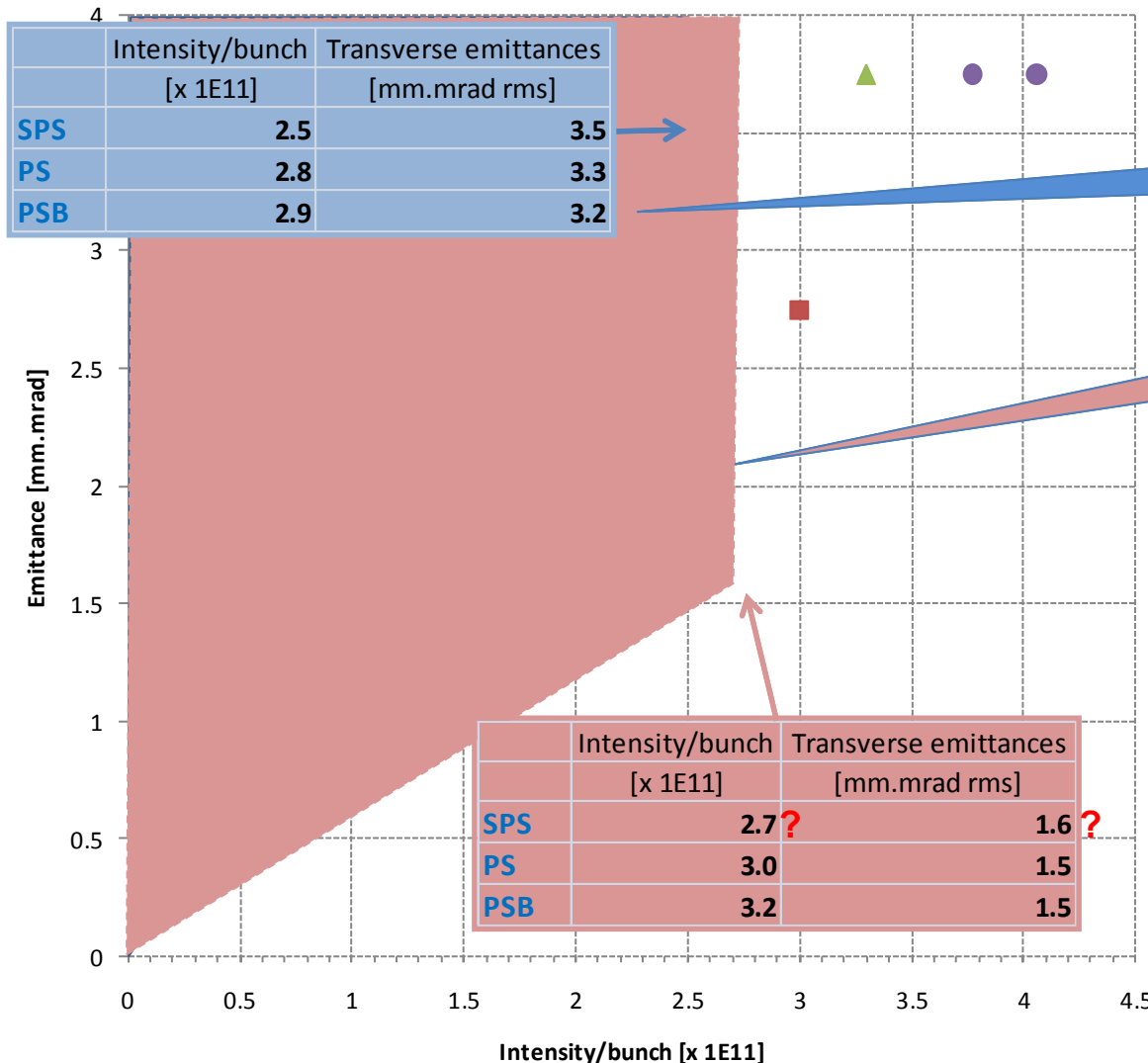
Beam Parameters at 7 TeV

	Intensity/bunch [x 1E11]	Transverse emittances [mm.mrad rms]
SPS	2.1 ?	2.2 ?
PS	2.3	2.1
PSB	2.4	2.0

* Feasible for the SPS injectors...

Beam parameters at LHC injection [50 ns]

<https://espace.cern.ch/liu-project>



LIU baseline goal

LIU stretched* goal

- ◆ Sterbini (LHC CC10)
 - Fartoukh (Chamonix11)
 - ▲ Bruning (Chamonix11)
 - Zimmermann (Chamonix11)
- Beam Parameters at 7 TeV

* Feasible for the SPS injectors...

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(Draft) Planning

<https://espace.cern.ch/liu-project>

	Linac4	PS injector, PS and SPS	Beam characteristics at LHC injection
2011 - 2012	Continuation of construction...	<ul style="list-style-type: none"> • Beam studies • Investigation • Hardware • Design & construction of some equipment • TDR 	25 ns, $1.15 \cdot 10^{11}$ p/b, 3.5 mm.mrad 50 ns, $1.7 \cdot 10^{11}$ p/b, ≤ 3.5 mm.mrad 75 ns, $1.2 \cdot 10^{11}$ p/b, ≤ 2 mm.mrad
2013 – Q2/2014 (Long Shutdown 1)	<ul style="list-style-type: none"> • Linac4 beam commissioning • Connection to PSB ? 	<ul style="list-style-type: none"> • PSB modification (H⁻ injection) ? • PSB beam commissioning ? • Modifications and installation of prototypes in PS and SPS 	
Q3/2014 - 2016	<ul style="list-style-type: none"> • Progressive increase of Linac4 beam current • Progressive increase of PSB beam brightness ? 	<ul style="list-style-type: none"> • Beam studies • Equipment design & construction 	<ul style="list-style-type: none"> • Improved beam from PSB ? • Some improvement of PS beam • Little gain for the SPS (pending SPS hardware upgrades)
2017 – Qx/2018 (Long Shutdown 2)		<ul style="list-style-type: none"> • Installation in PS and SPS • Beam commissioning 	
Qy/2018 –2020			After ~1 year: All beam characteristics expected for the HL-LHC...

SPS limitation

PS limitation

- Introduction
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Summary

<https://espace.cern.ch/liu-project>

- Experience with beam in the LHC and its injectors during 2011-2012 will help refine the needs of HL-LHC and the required upgrades.
- Well-identified improvements shall be implemented as soon as possible to allow studying the other limitations (e.g. RF upgrade in the SPS).
- Decision about connection of Linac4 to the PSB during the first long shutdown will be taken in the Summer as part of the plan for LS1.
- The feasibility study of an RCS replacing the PSB will conclude in the Summer 2011. Decision in September.

**THANK YOU
FOR YOUR ATTENTION!**