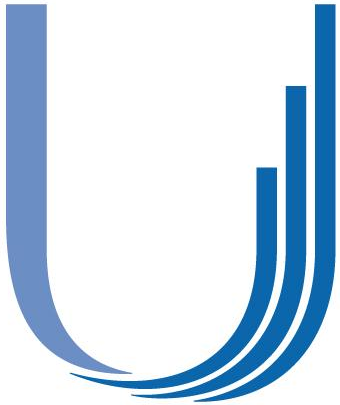


LHC Injectors Upgrade

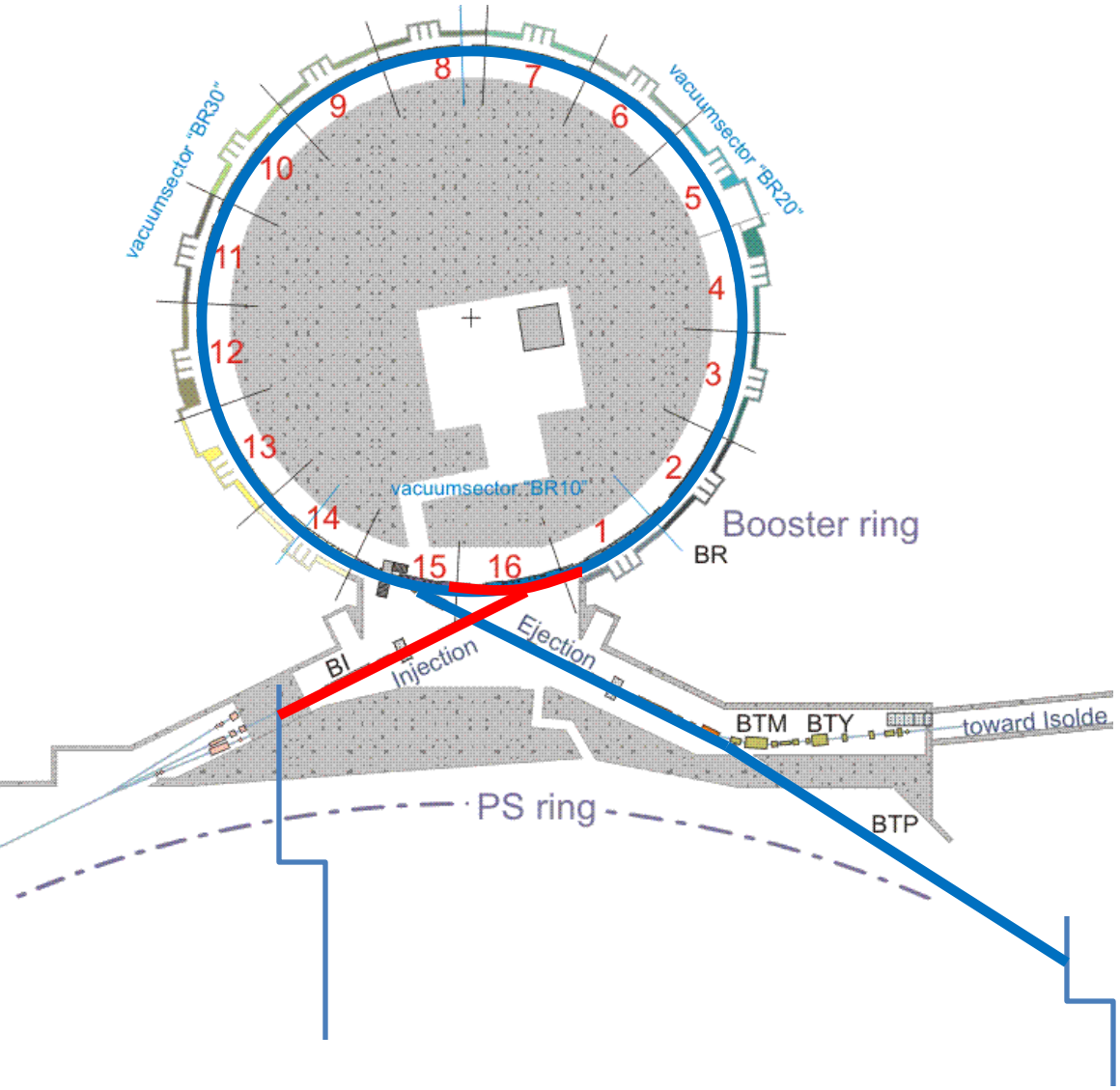
LHC Injectors Upgrade

LIU-PSB Overview

K. Hanke for the LIU-PSB Working Group

CERN

Scope of LIU-PSB



upgrade of the injection from 50 MeV protons to 160 MeV H- and increased intensity

- re-build injection line for 160 MeV
- replace injection septum by stripping foil
- injection bumps
- diagnostics
- …

upgrade of rings and extraction / transfer from 1.4 GeV to 2.0 GeV and increased intensity

- replace main power supply, number of smaller power supplies, magnets, kickers, etc.

Upgrade of the Injection for Linac4

Why re-building the injection region?

- increased energy from 50 MeV to 160 MeV with Linac4

→ reduce space-charge effects at PSB injection

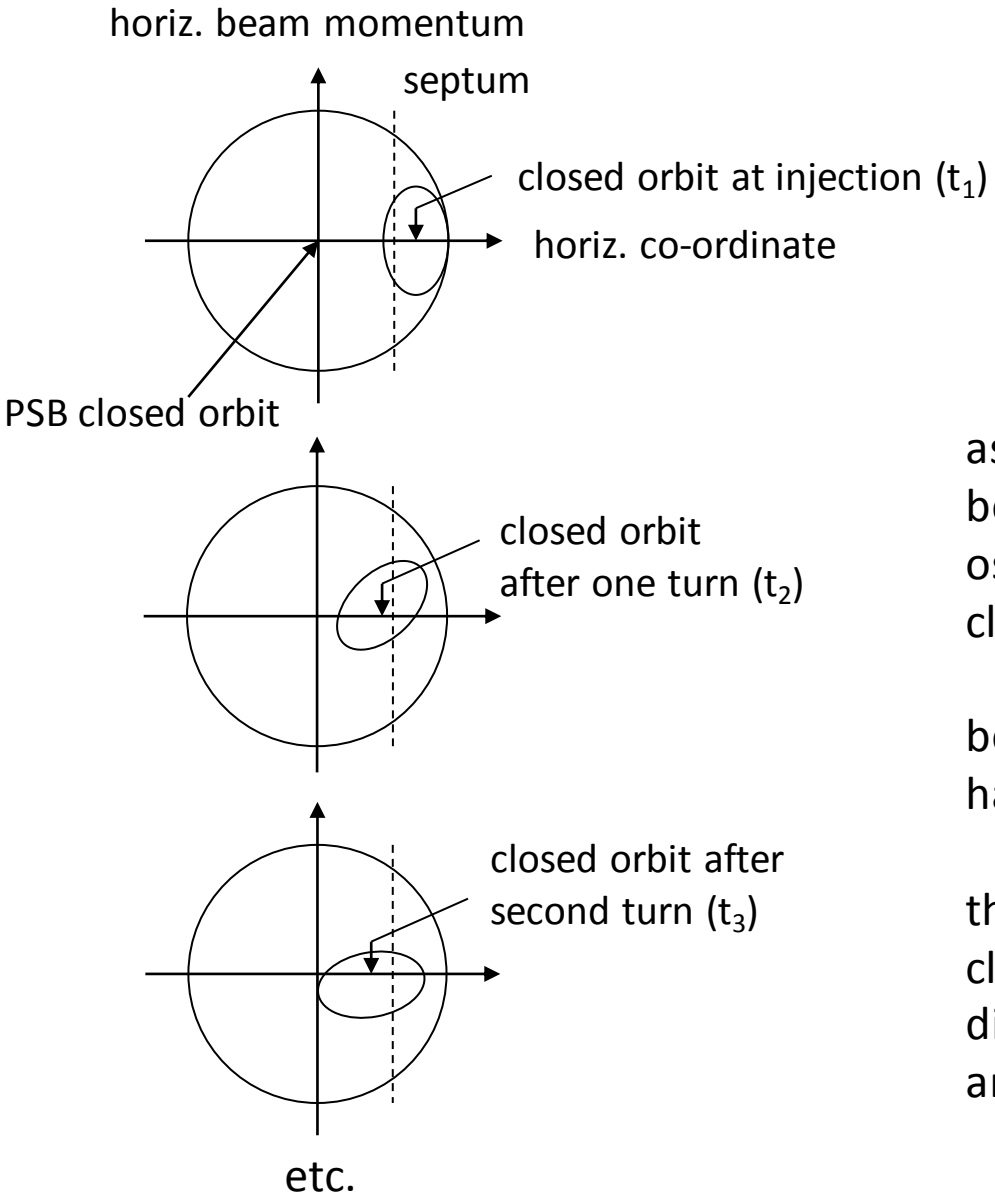
- injection of H- ions rather than protons

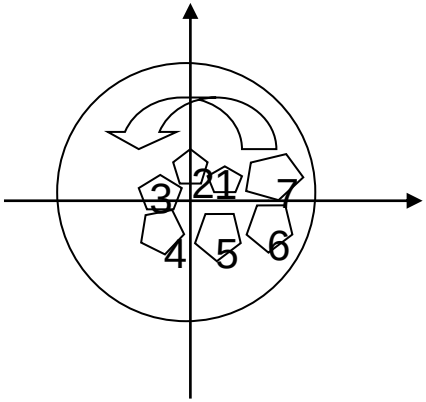
→ significantly reduce injection losses (at the moment about 50% of the beam is lost on the injection septum!)

→ more flexibility in tailoring emittances by transverse phase space painting

		Ring 1		Ring 2		Ring 3		Ring 4		Sum		
0	LTB.BCT60	1873		1826		1852		1903		7438		
1	BI.BCT10	1820	97 %	1773	97 %	1831	99 %	1884	99 %	7293	98 %	0
2	BI.BCT20	1640	90 %	1601	90 %	1604	88 %	1654	88 %	6500	89 %	1
3	Injection	1008	61 %	1075	67 %	982	61 %	915	55 %	3981	61 %	2
4	Capture	838	83 %	959	89 %	905	92 %	816	89 %	3519	88 %	3
5	Accel.	631	75 %	918	96 %	871	96 %	693	85 %	3113	88 %	4
6	BT.BCT.00									3121	100 %	5
7	BTP.BCT.00									1	0 %	6
8	BTM.BCT.00									10	0 %	6
9	BTY.BCT112									NaN	□	6
10	BTY.BCT.213									2910	□	9
11	BTY.BCT.325									4	□	9

Present Multiturn Injection



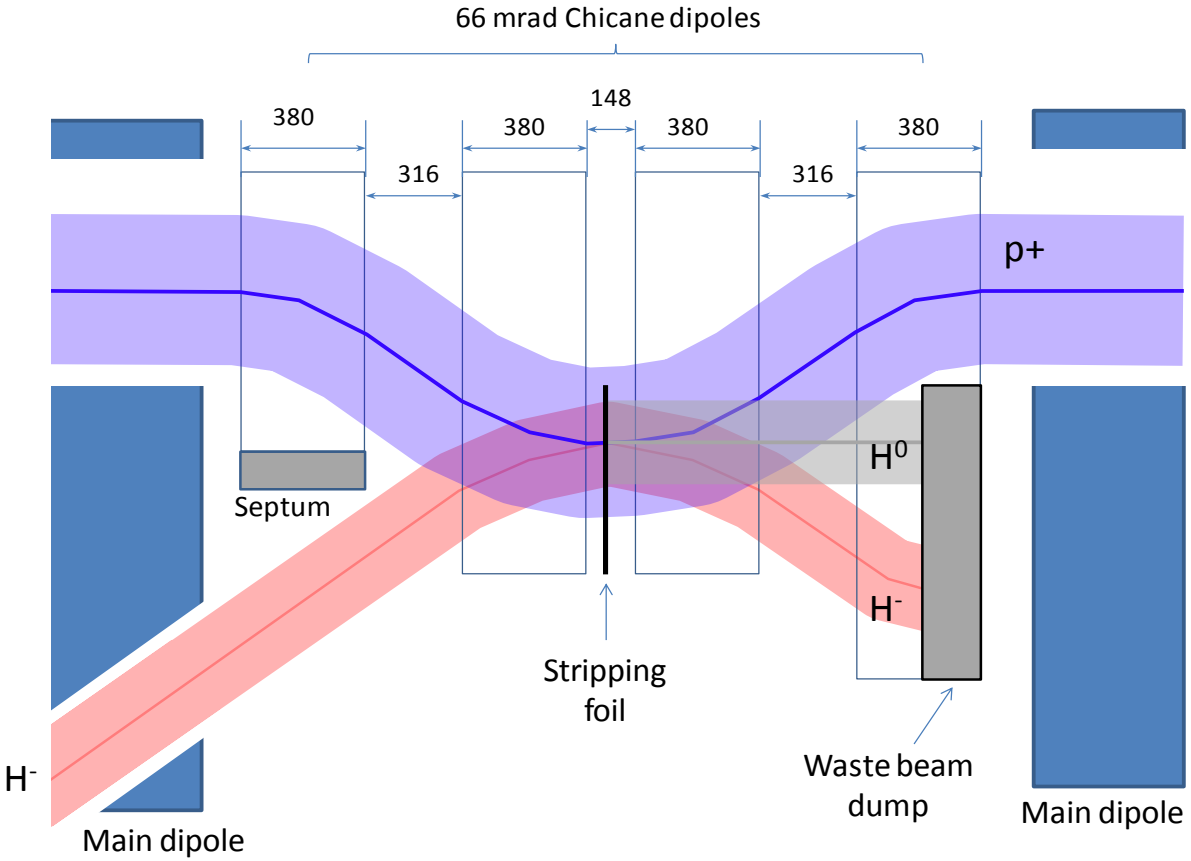


as this process takes place, subsequent linac beam "slices" are injected, with increasing oscillation amplitude around the instantaneous closed orbit ("horizontal stacking")

beamlets are now "polygons", as they have undergone several cuts

they spiral up around the (moving) closed orbit, leading to a density distribution which is dense in the core and less dense in the outer part

Charge Exchange Injection



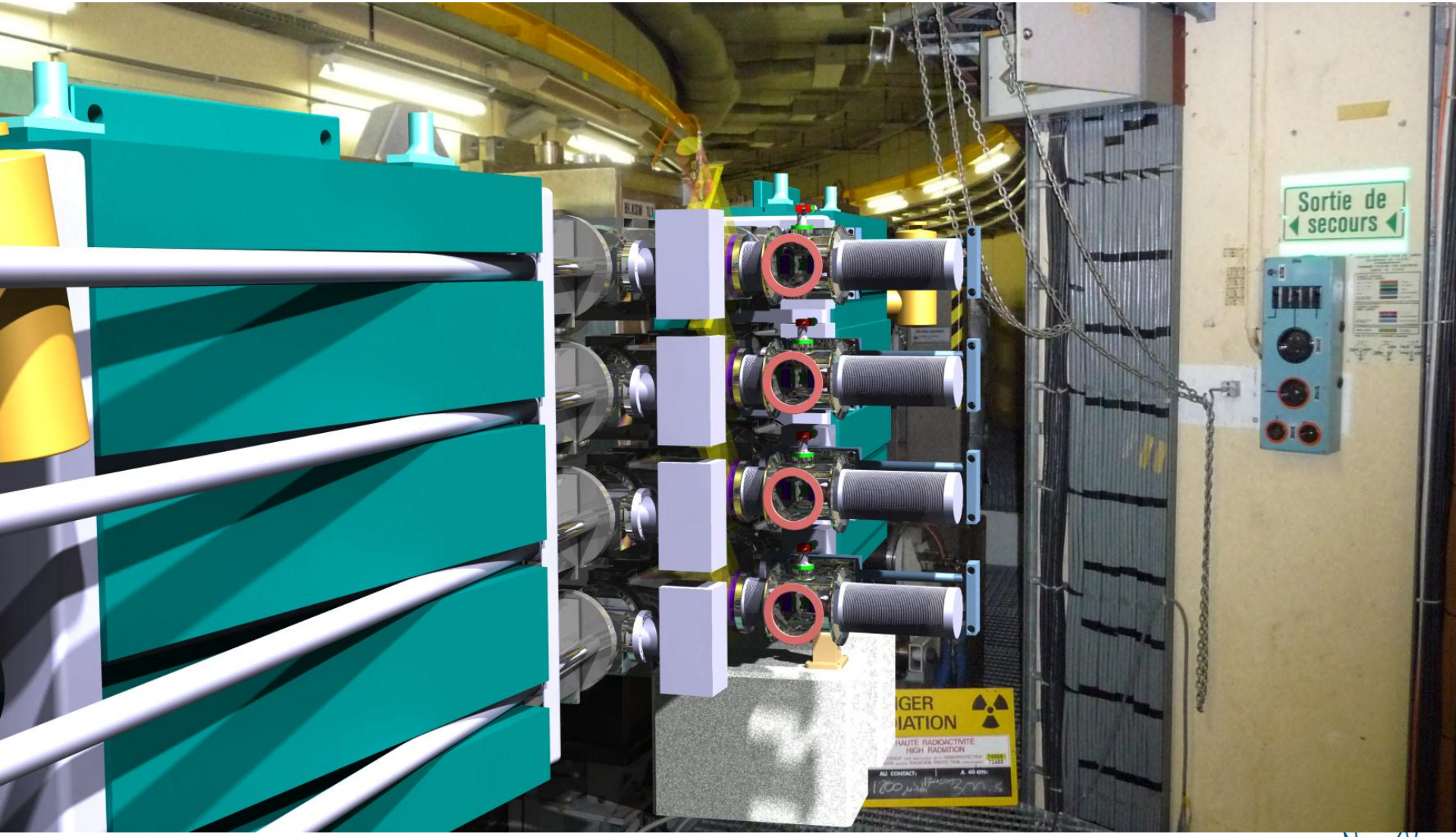
more technical details:

→ review held 9-10 November, see

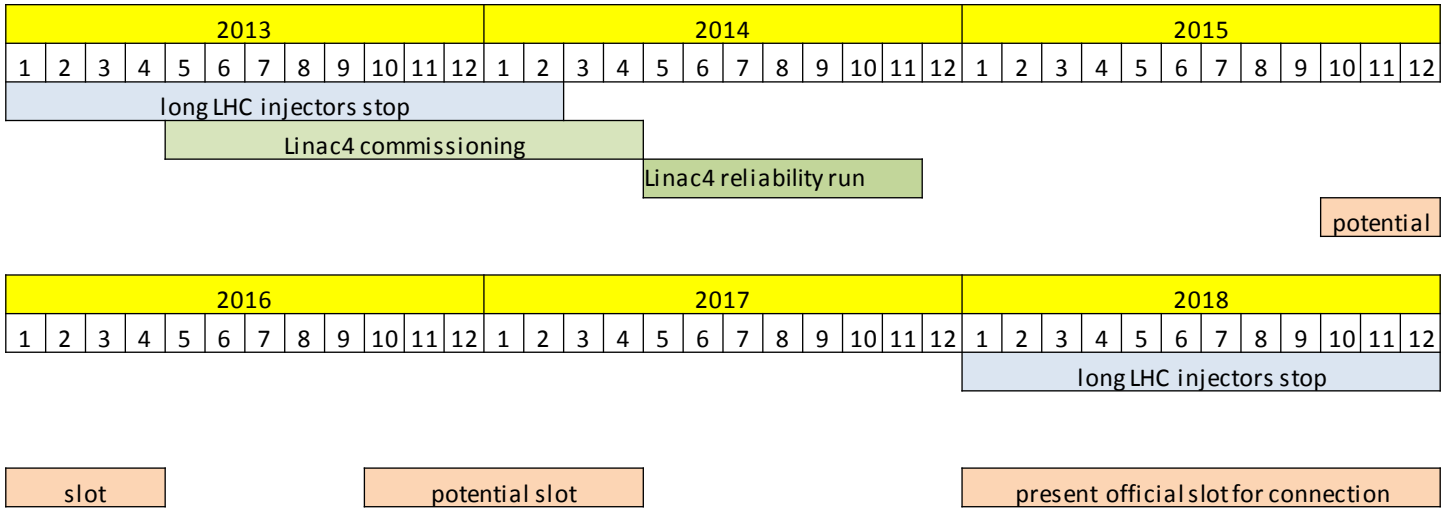
https://indico.cern.ch/conferenceTimeTable.py?confId=158153#20111109

→ talk by W. Weterings at this meeting

Present and Future Injection Region

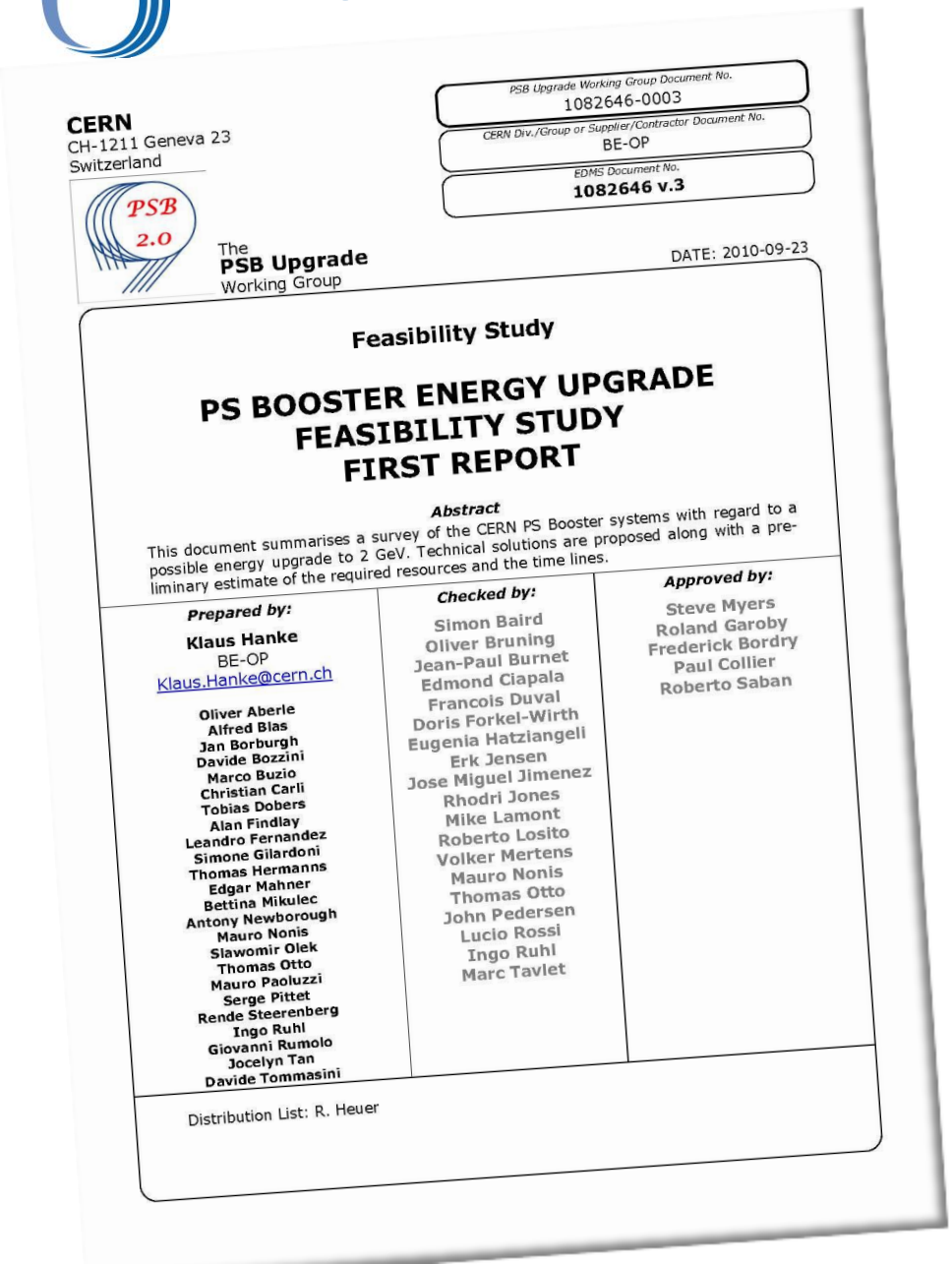


Booster Injection: Planning



1. Connection of Linac4 to the PSB during LS1 ruled out
2. Connect to the PSB during an intermediate length shut-down (2015/16 or 2016/17)
3. Connect to the PSB during LS2 (assumed 2018)
4. Depending on the physics results, there is still a (minor) possibility that LS1 could move

Upgrade of the Booster to 2 GeV



CERN
CH-1211 Geneva 23
Switzerland

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

The **PSB Upgrade** Working Group

DATE: 2010-09-23

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.

Prepared by:

Klaus Hanke
BE-OP
Klaus.Hanke@cern.ch

Oliver Aberle
Alfred Blas
Jan Borburgh
Davide Bozzini
Marco Buzio
Christian Carli
Tobias Dobers
Alan Findlay
Leandro Fernandez
Simone Gilardoni
Thomas Hermanns
Edgar Mahner
Bettina Mikulec
Antony Newborough
Mauro Nonis
Slawomir Olek
Thomas Otto
Mauro Paoluzzi
Serge Pittet
Rende Steerenberg
Ingo Ruhl
Giovanni Rumolo
Jocelyn Tan
Davide Tommasini

Checked by:

Simon Baird
Oliver Bruning
Jean-Paul Burnet
Edmond Ciapala
Francois Duval
Doris Forkel-Wirth
Eugenia Hatziangeli
Erk Jensen
Jose Miguel Jimenez
Rhodri Jones
Mike Lamont
Roberto Losito
Volker Mertens
Mauro Nonis
Thomas Otto
John Pedersen
Lucio Rossi
Ingo Ruhl
Marc Tavlet

Approved by:

Steve Myers
Roland Garoby
Frederick Bordry
Paul Collier
Roberto Saban

Distribution List: R. Heuer

study launched following Chamonix 2010
→ feasibility, cost & time lines confirmed
RCS alternative studied following Chx. 2011
→Booster option retained

3rd energy upgrade:
- from 800 MeV to 1 GeV (1988)
- from 1 GeV to 1.4 GeV (1999)
- from 1.4 GeV to 2.0 GeV (LS2)

- no technical showstoppers identified
- however a number of equipment and
- systems need to be changed or upgraded
- high-impact items: MPS, RF, kickers, septa, …

Expected Performance Gain with 2 GeV

- injection at 2GeV lowers space charge effect by a factor $(\beta\gamma^2)_{2GeV}/(\beta\gamma^2)_{1.4GeV} \approx 1.63$
  → can inject beams **~65% more** intense keeping the same space charge tune spread as now
- if we assume to conserve the longitudinal emittance (e.g., 1.3 eVs, LHC beam h=1), the bunch at 2GeV will be 33% shorter at the exit of the PSB, which would in principle limit the above gain to less than 40%; however, the PS bucket acceptance at injection also increases by 50%, which allows for injection of larger longitudinal emittances, recovering the desired gain (50% larger longitudinal emittance required)
- larger transverse emittances acceptable at the PS injection, if the final transverse emittances to the LHC are the same? Unlikely, as the previously PSB specified transverse emittances have meanwhile become the "nominal" LHC emittances!

→ at least 65% intensity increase (within constant emittance) expected

$$\Delta Q_x = \frac{R_p N_b}{(2\pi)^{3/2}\gamma^3\beta^2\sigma_z} \oint \frac{\beta_x(s)ds}{\sigma_x(s)\left[\sigma_x(s)+\sigma_y(s)\right]}$$

$$\Delta Q_y = \frac{R_p N_b}{(2\pi)^{3/2}\gamma^3\beta^2\sigma_z\sqrt{\epsilon_y}} \oint \frac{\sqrt{\beta_y(s)}ds}{\sigma_x(s)+\sigma_y(s)}$$

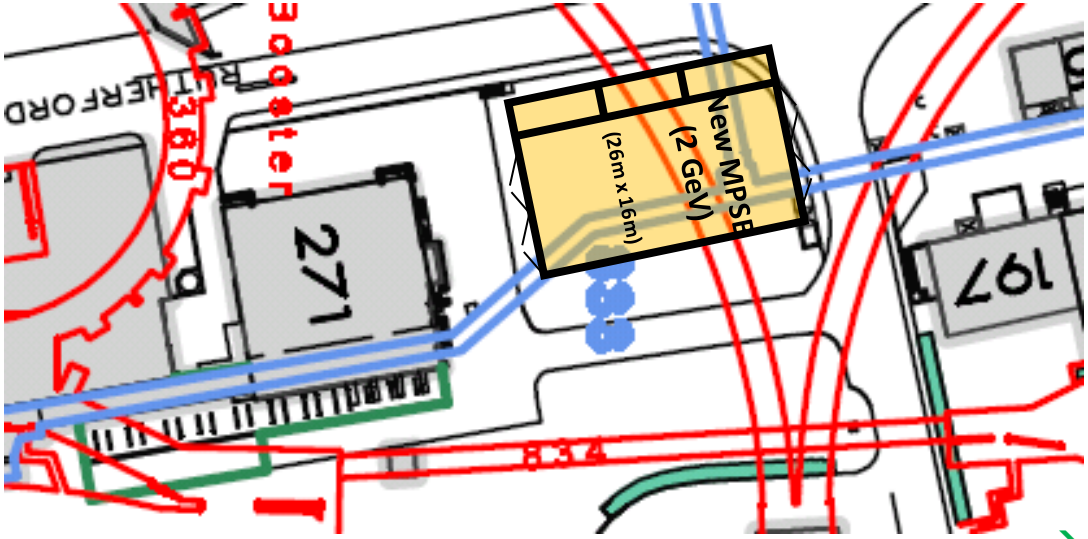
$$\begin{cases} \sigma_x(s) = \sqrt{\epsilon_x\beta_x(s) + D_x^2(s)\left(\frac{\delta p}{p_0}\right)^2} \\ \sigma_y(s) = \sqrt{\epsilon_y\beta_y(s)} \end{cases}$$

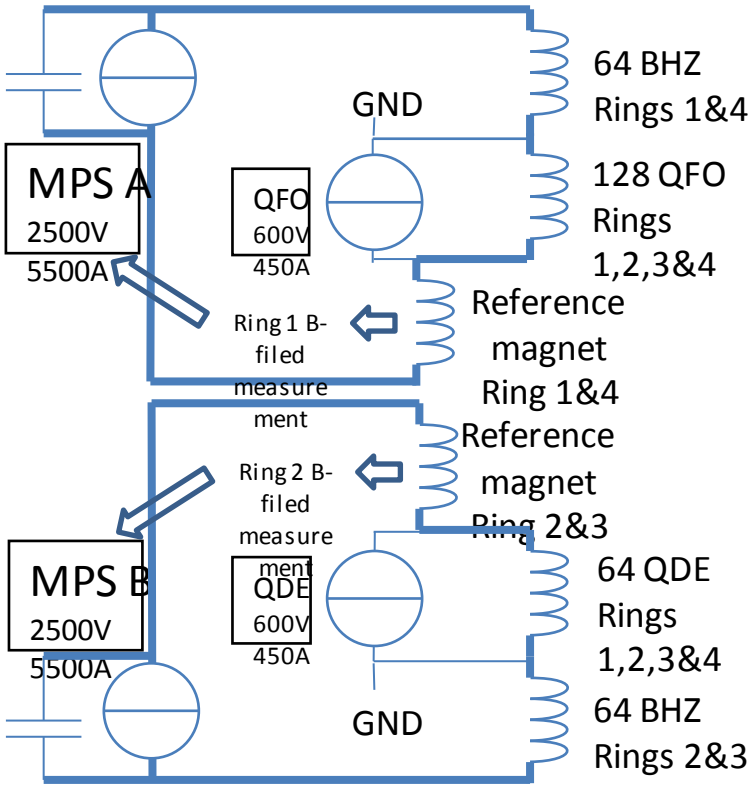
$$\epsilon_{x,y} = \frac{\epsilon_{xn,yn}}{\beta\gamma}$$

$1/\beta\gamma^2$ $1/\sigma_z$ $1/\varepsilon$

Booster 2 GeV Upgrade: Power

- **Main Power Supply**
  - present converter cannot deliver more than 1.4 GeV
  - POPS-type converter proposed (capacitor bank)
  - divide machine in 2 circuits (inner and outer rings)
  - will make R 1+4 trim power supply obsolete
  - new building needed
- **Other Power Supplies**
  - number of smaller converters to be changed





S. Pittet

→ talk by S. Pittet at this meeting

Booster 2 GeV Upgrade: Magnets, Dumps, Transfer

- **Magnets**
  - main dipoles can operate at 2 GeV with some modifications (cooling, retaining plates)
  - number of other magnets to be changed

- **Beam Intercepting Devices**
  - new dump and beam stopper being designed
  - removal of the old and installation of the new dump being studied for LS1

- **Extraction & Transfer**
  - number of septa/kickers cannot operate at 2 GeV, notably extraction kickers (BE.KFA) and recombination septa (BT.SMV)

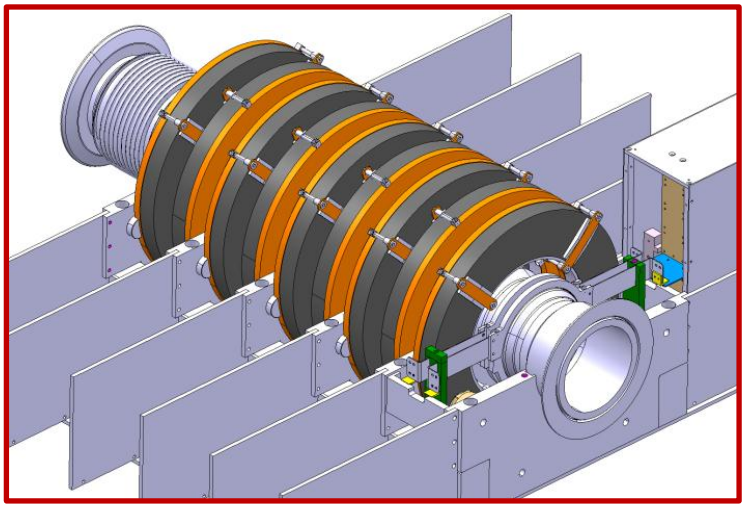
Booster main magnet undergoing tests for operation at 2 GeV

A. Newborough, M. Buzio

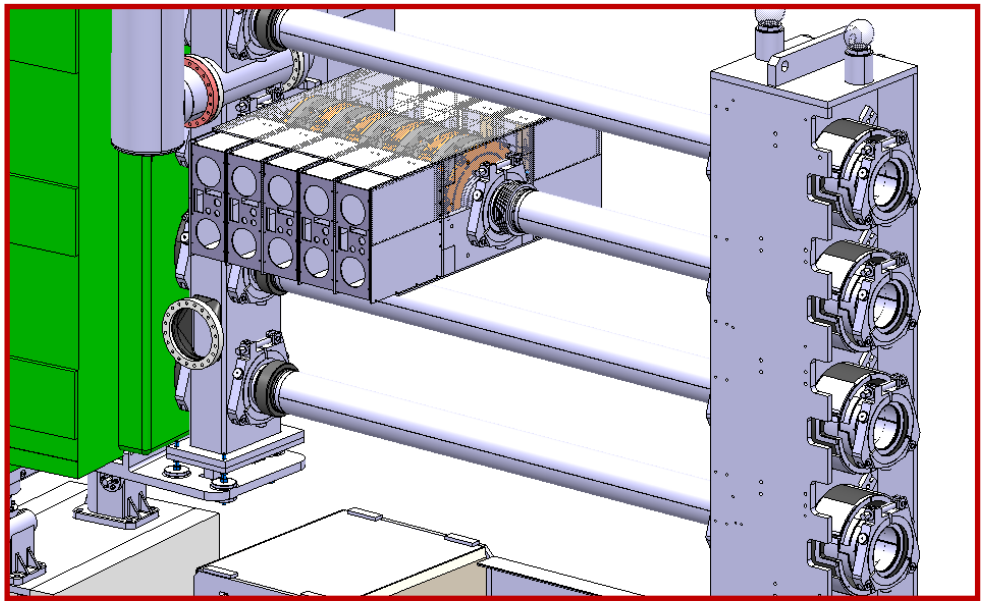
Booster 2 GeV Upgrade: RF System

- complete upgrade of the Booster high-level RF to new Finemet cavities
- development of a prototype system (collaboration with KEK-RF team)
- installation in PSB during winter stop 2011-2012 approved by IEFC on 7 Oct. 2011

→ talk by M. Paoluzzi at this meeting



- upgrade program for the LL RF



Finemet cavity test installation in the PSB

M. Paoluzzi

Other Items

- **Cooling & Ventilation**
  - refurbishment of cooling station and some distribution piping
  - complete refurbishment of existing ventilation plant keeping the same functionalities

- **Electrical Systems**
  - re-design of the system has started

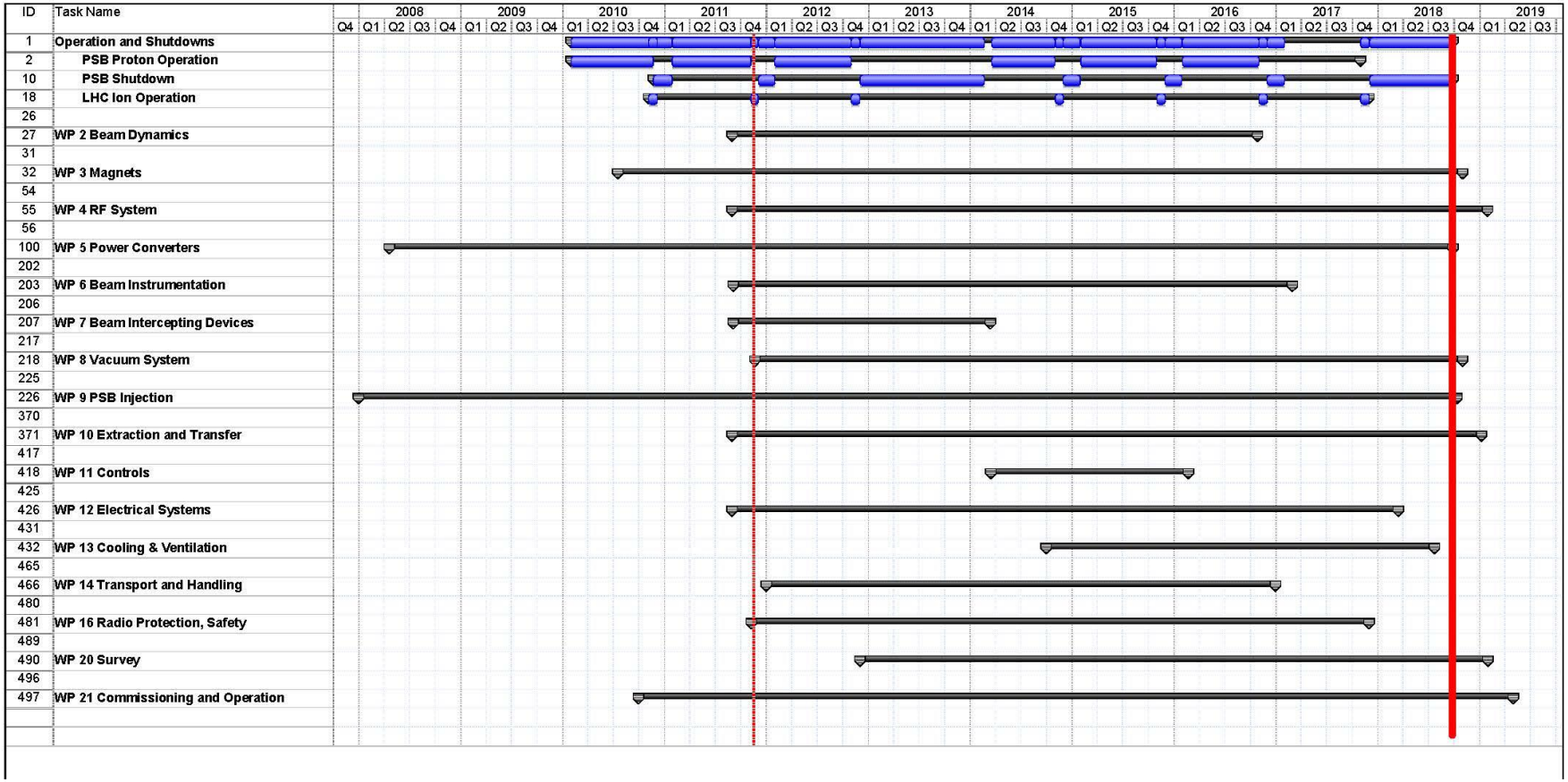
- **Other items:**
  - beam instrumentation, transport, controls, interlocks, design office, vacuum, etc. etc.

for the full picture see

https://espace.cern.ch/liu-project/liu-psb/default.aspx

Work-Package	Responsible	Unit
2.Beam Dynamics	C. Carli	BE/ABP
3.Magnets	D. Tommasini, A. Newborough	TE/MCS
4.RF Systems	A. Findlay, M. Paoluzzi, M.E. Angoletta, A. Blas, A. Butterworth	BE/RF
5.Power Converters	S. Pittet, D. Nisbet	TE/EPC
6.Instrumentation	J. Tan	BE/BI
7.Beam Intercepting Devices	O. Aberle, A. Massi	EN/STI
8.Vacuum System	J. Hansen	TE/VSC
9.L4-PSB Transfer and PSB Injection	W. Weterings, C. Carli	TE/ABT, BE/ABP
10.PSB Extraction and PSB-PS Transfer	J. Borburgh, W.Bartmann	TE/ABT
11.Controls	S. Jensen	BE/CO
12.Electrical Systems	D. Bozzini, S. Olek	EN/EL
13.Cooling and Ventilation	M. Nonis	EN/CV
14.Installation, Transport and Handling	I. Ruehl, C. Bertone	EN/HE
15.Civil Engineering	L.A. Lopez-Hernandez	GS/SE
16.Radiation Protection	J. Vollaire	DGS/RP
17.Interlock Systems	B. Puccio, P. Dahlen, B. Todd	TE/MPE
18.Alarms		--/---
19.Access Systems - Doors		--/---
20.Survey	T. Dobers	BE/ABP
21.Commissioning and Operation	B. Mikulec	BE/OP
22.Dismantling		--/---

Time Lines



- Linac4 connection possible as from end 2015, constrained by LHC stops
- full upgrade including 2 GeV to be completed during LS2

Next Steps

- TDR to be written
- Ongoing MD activity during the next years
- Some work during coming winter stops (removal ion distributor, Finemet test installation, …)
- Some work to be done during LS1: change of the Booster dump, renovation of handling equipment, …)
- Most work in LS2 (complete hardware upgrade); if Linac4 connection could be advanced, this would reduce the stress on the intervening groups and on the recommissioning, and is therefore the preferred scenario
- If Linac4 and the 2 GeV upgrade will coincide in LS2, we will have a lot to do

→ ***We will come out of LS2 with a new Booster***