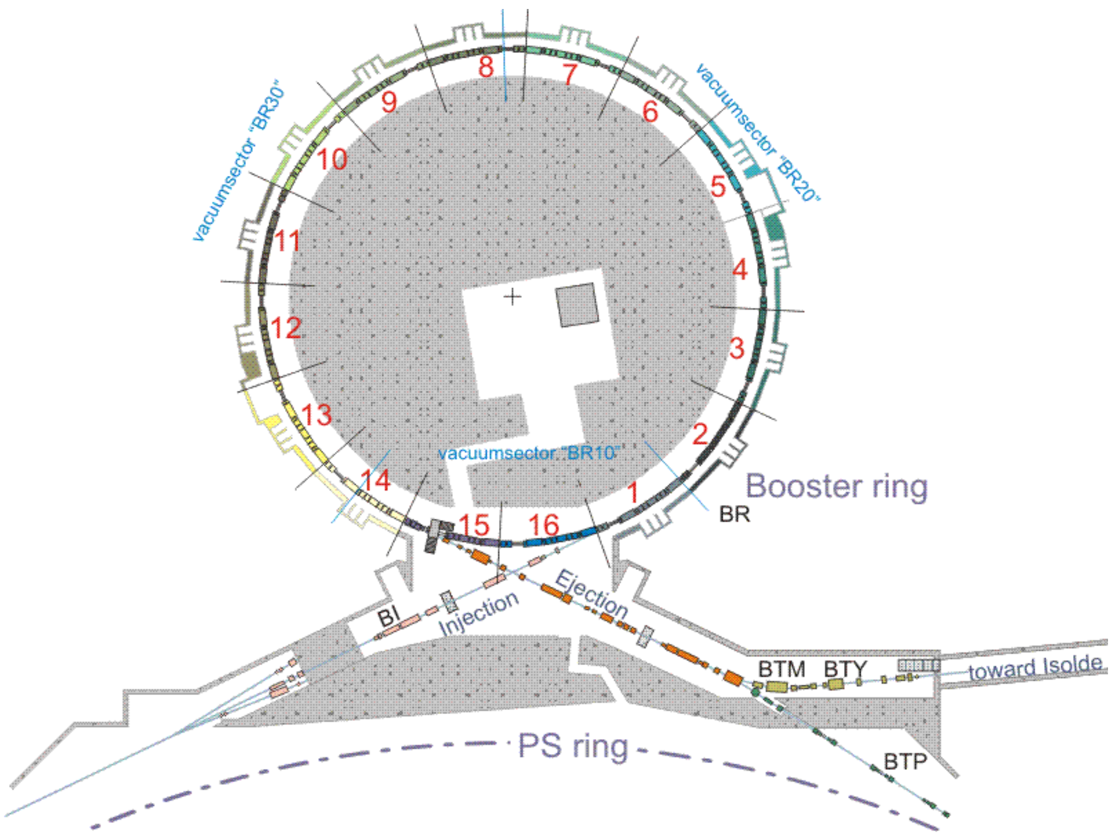
Possibility of a higher PSB to PS transfer energy

K. Hanke
for the PSB Upgrade WG

Chamonix 2011

PS Booster

- 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)



- upgrade of the Booster ring and the transfer line to the PS for 2 GeV

→ this Task Force

- upgrade of the BI line and injection region for 160 MeV H- & intensity increase

→ so far L4 project – now part of LIU_PSB

PS Booster Energy Upgrade

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

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

Linkperson Consolidation	N. Gilbert	EN/MEF
Linkperson Design Office	R. Folch	EN/MME
Linkperson PS	R. Steerenberg, S. Gilardoni	BE/OP
US LARP	E. Prebys	FNAL

recently a work unit “Booster injection” [W. Weterings] has been added

Feasibility Study

			feasible	impact
1.	Beam Dynamics	BE/ABP	**YES**	
2.	Magnets	TE/MCS	**YES**	+++
3.	Magnetic Measurements	TE/MCS	**YES**	
4.	RF System	BE/RF	**YES**	(+++)
5.	Beam Intercepting Devices	EN/STI	**YES**	(+)
6.	Power Converters	TE/EPC	**YES**	+++
7.	Vacuum System	TE/VSC	**YES**	+
8.	Instrumentation	BE/BI	**YES**	
9.	Commissioning	BE/OP	**YES**	
10.	Extraction, Transfer, PS Injection	TE/ABT	**YES**	+++
11.	Controls	BE/CO	**YES**	
12.	Electrical Systems	EN/EL	**YES**	++
13.	Cooling and Ventilation	EN/CV	**YES**	++
14.	RP and Safety	DGS/RP	**YES**	
15.	Transport and Handling	EN/HE	**YES**	
16.	Survey	BE/ABP	**YES**	

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 high 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 the budget estimate for the energy upgrade

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

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The
PSB Upgrade
Working Group

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

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.

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Main Findings and Recommendations

- the study aims at LHC beams only; however we found that the cost drivers do not change when restricting ourselves to LHC beams;
  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 appeared unacceptable to us (https://edms.cern.ch/document/1079117/1)

→ **consider all beams to the PS at 2 GeV (ISOLDE remains at the present 1.0/1.4 GeV)**
→ **enable the full machine including PS transfer for ppm operation**
→ **confirmed as baseline scenario by the LIU project**

- 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)**
→ **compatibility with L4 intensities**

- 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 energy higher than 1.4 GeV and needs to be replaced in any scenario (cost driver)**

Expected Performance Gain with 2 GeV [G. Rumolo, LIU Day, 1 Dec 2010]

- 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

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

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

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

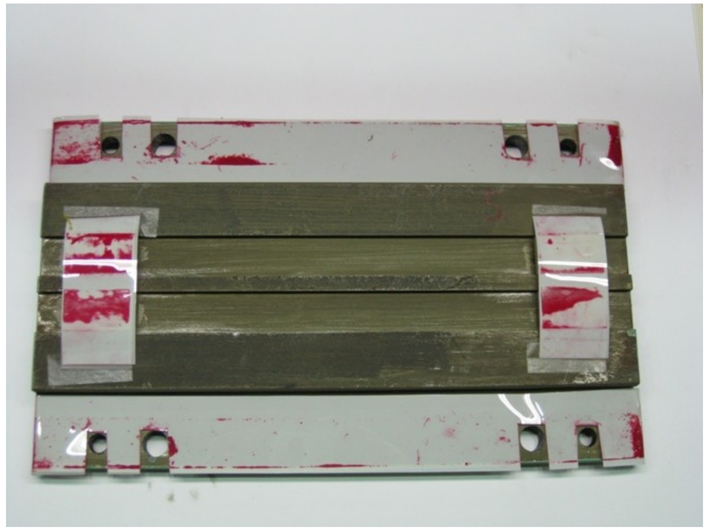
$$\epsilon_{x,y} = \frac{\epsilon_{xn,yn}}{\beta\gamma}$$

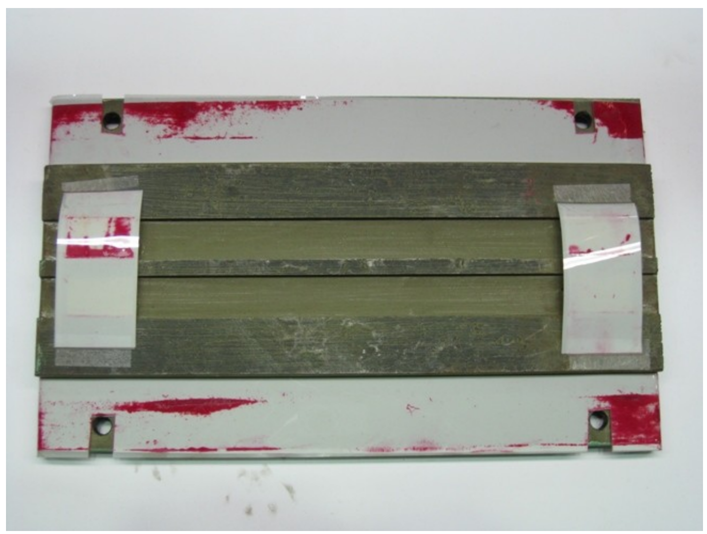
$1/\beta\gamma^2$ $1/\sigma_z$ $1/\varepsilon$

WU 2 Magnets [A. Newborough, D. Tommasini]

achievable field levels for 2 GeV	new field levels are achievable
concern over life span due to mechanical stress	stress test completed in SM18; no degradation found but modifications had to be made
saturation of outer rings will increase even more	change solid retaining plates by laminated ones to reduce/eliminate saturation
present main unit cooling system insufficient	cycle designed with rms current within 10% of the present one, only minor modifications to the cooling circuits necessary (in situ)
auxiliary magnets: majority not affected, but study to be completed	auxiliary ring magnets mainly used at low energy, no worry
15-18/59 transfer line magnets presumably require exchange; need optics studies for final confirmation	modification/replacement of ~30% of the transfer line magnets
PS injection bumpers, correctors and quads	replacement of many PS low-energy magnets; study ongoing ; now part of LIU_PS

Booster main magnet undergoing tests for operation at 2 GeV





top left – PS Booster main dipole.

bottom left – coil, coil shims and coil retaining plate.

right – the coil retaining plates with Fuji pressure sensitive film showing the un-even distribution of the force on the coil shims at the upgrade current

WU 4 RF System [A. Findlay, M. Paoluzzi]

high-level rf: consolidation of C02, C04 and C16

consolidation of low-level rf, transverse damper, rf cables

everything covered by consolidation, no issues left for the upgrade project

notice:
the consolidation of the C04 and the LL RF are mandatory to achieve 2 GeV; Consolidation of the C02 and C16 system is not mandatory for the energy increase but required for a reliable operation over the next 25 years

it is a necessary condition for the energy upgrade that the RF consolidation is completed; in case the mandatory items are not completed, or not completed within the time frame of the upgrade, then the upgrade will not work

WU 5 Beam Intercepting Devices [O. Aberle]

present dump obsolete, no spare, neither appropriate for L4 intensities nor for 2 GeV

new design in progress, production of a new dump plus spare to be launched

beam stopper BTP.STP10 has to be checked with regard to 2 GeV operation; new design might be needed, still to be confirmed.

if insufficient, launch new design and construction (2 units)

notice:
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

WU 6 Power Converters [S. Pittet]

present MPS cannot deliver 2 GeV cycle
- it can neither deliver the required rms nor peak current
- increasing peak power using traditional thyristor technology would have unacceptable effect on the whole Meyrin network
- the present 1.4 GeV is a hard limit for the existing MPS

new POPS-type MPS using capacitor bank
- divide machine in 2 circuits (inner and outer rings); will make R 1+4 trim power supply obsolete
- new building needed

number of smaller power converters needs to be changed

replacement of a number of smaller power supplies

notice:
ppm operation between 1.0/1.4 GeV (ISOLDE) and 2 GeV (PS) for some power supplies
all calculations assume fast cycle to reduce rms power

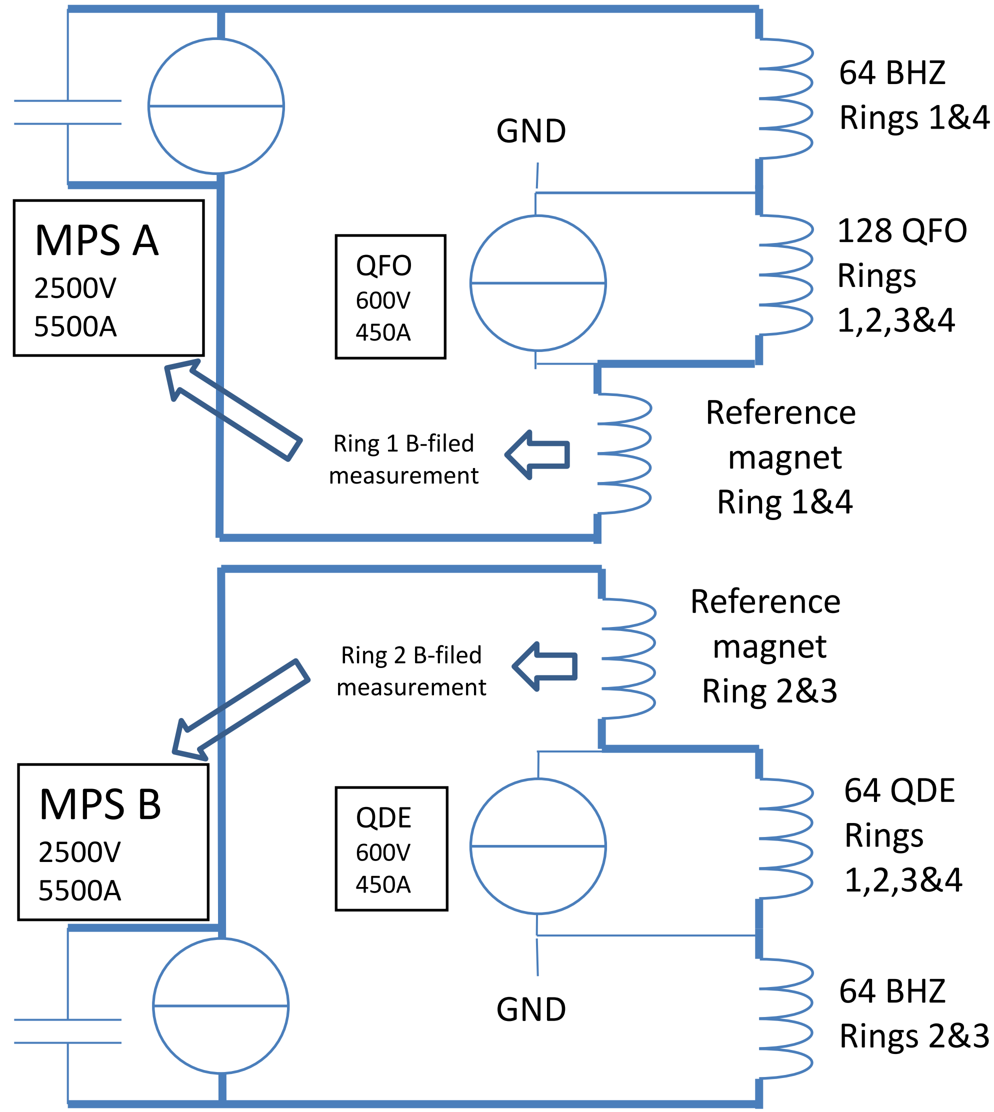
WU 6 Power Converters: POPS – Type Supply [S. Pittet]

Benefits

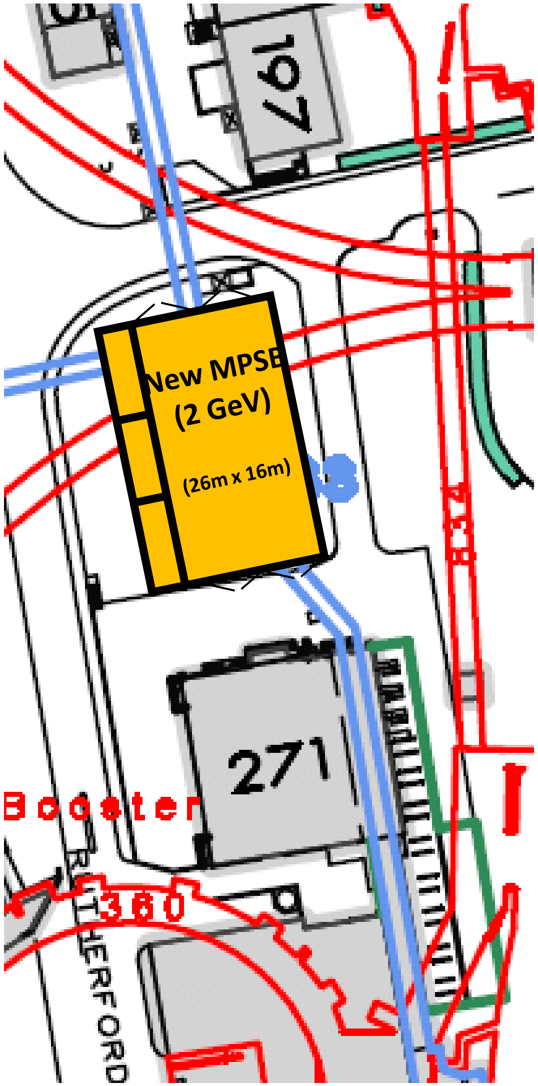
- Overall voltage available increases and would allow a reduction of the RMS current using a faster ramping.
- The capacitor bank totally absorbs the peak power on the 18kV network. Meyrin SVC would then become optional.
- Spare sharing between MPS A and B and eventually with POPS.
- Only a few new cables needed between the reference magnet (BCER) and the MPS.
- New B-field regulation to minimize eddy currents and saturation effects impact at higher current and acceleration rate.

Drawbacks

- Cost estimation 14MCHF using POPS module.
- RF acceleration has to be increased.



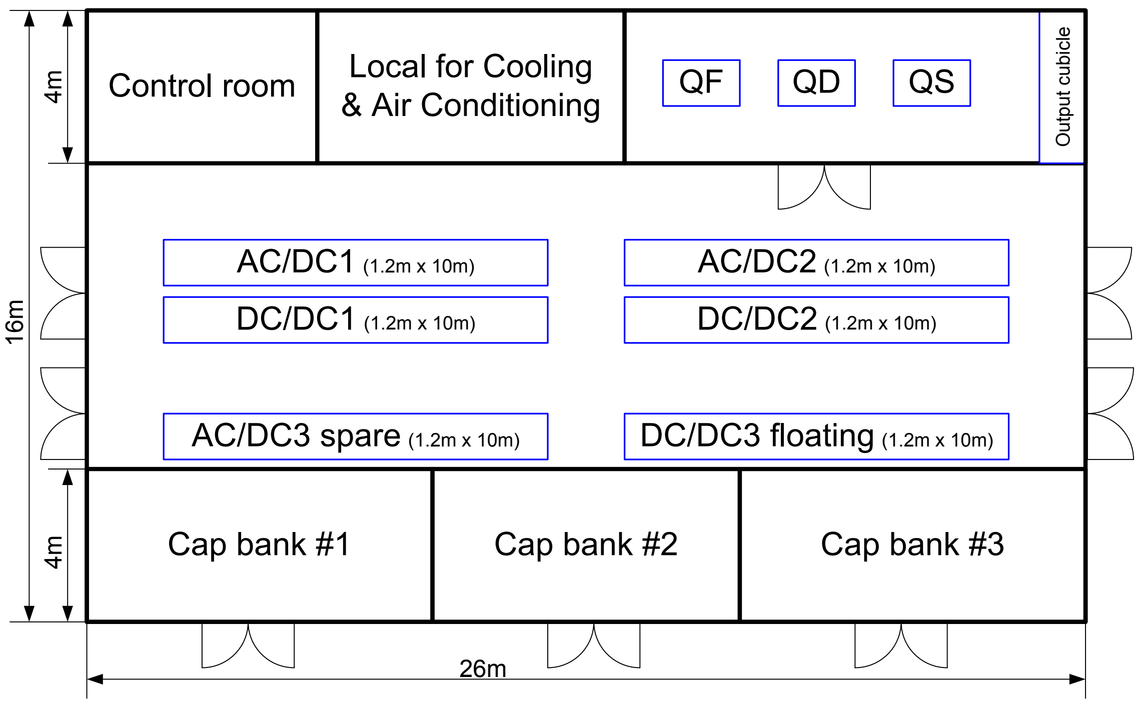
WU 6 Power Converters: POPS – Type Supply [S. Pittet]



- 420m² required, only 190m² available in bdg. 271 ground floor.
- Only 200kg/m² allowed in bdg. 271 first floor.
- No space left in bdg. 361.

With this new building:

- We can install and commission during Booster operation.
- We have a backup power supply during the first years.
- Easy connection to existing cables and cooling services.



WU 10 Extraction, Transfer & PS Injection [J. Borburgh]

number of extraction elements OK

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

PS injection kicker and injection septum do not work at 2 GeV

extraction kicker and recombination septa to be re-designed and re-built; some other elements (BE.SMH) to be modified (re-inforce cooling)

longer PS injection septum and complete injection region to be re-designed and re-built (now LIU_PS).

PS injection kicker OK if operated in short-circuit mode, otherwise additional kickers

The re-design of the PS injection region is under way; it is hoped that the injection point can stay where it is now (SS42); otherwise displace to SS41.
Work in progress; conclusion expected for early 2011.
→ see talk S. Gilardoni

WU 12 Electrical Systems [D. Bozzini, S. Olek]

present power consumption around 10 MVA; future electrical distribution will depend on the requests

after topical meetings with EN/CV and TE/EPC the needs have been clarified:
- TE/EPC estimates a 10% increase in their request for the MPS, and 100% 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

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

WU 13 Cooling and Ventilation [M. Nonis]

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	refurbishment of cooling station and some distribution piping
ventilation: no specific needs communicated to CV	complete refurbishment of existing plant keeping the same functionalities
RP aspects to be considered for the refurbishment of the ventilation system	being followed up; might have big impact

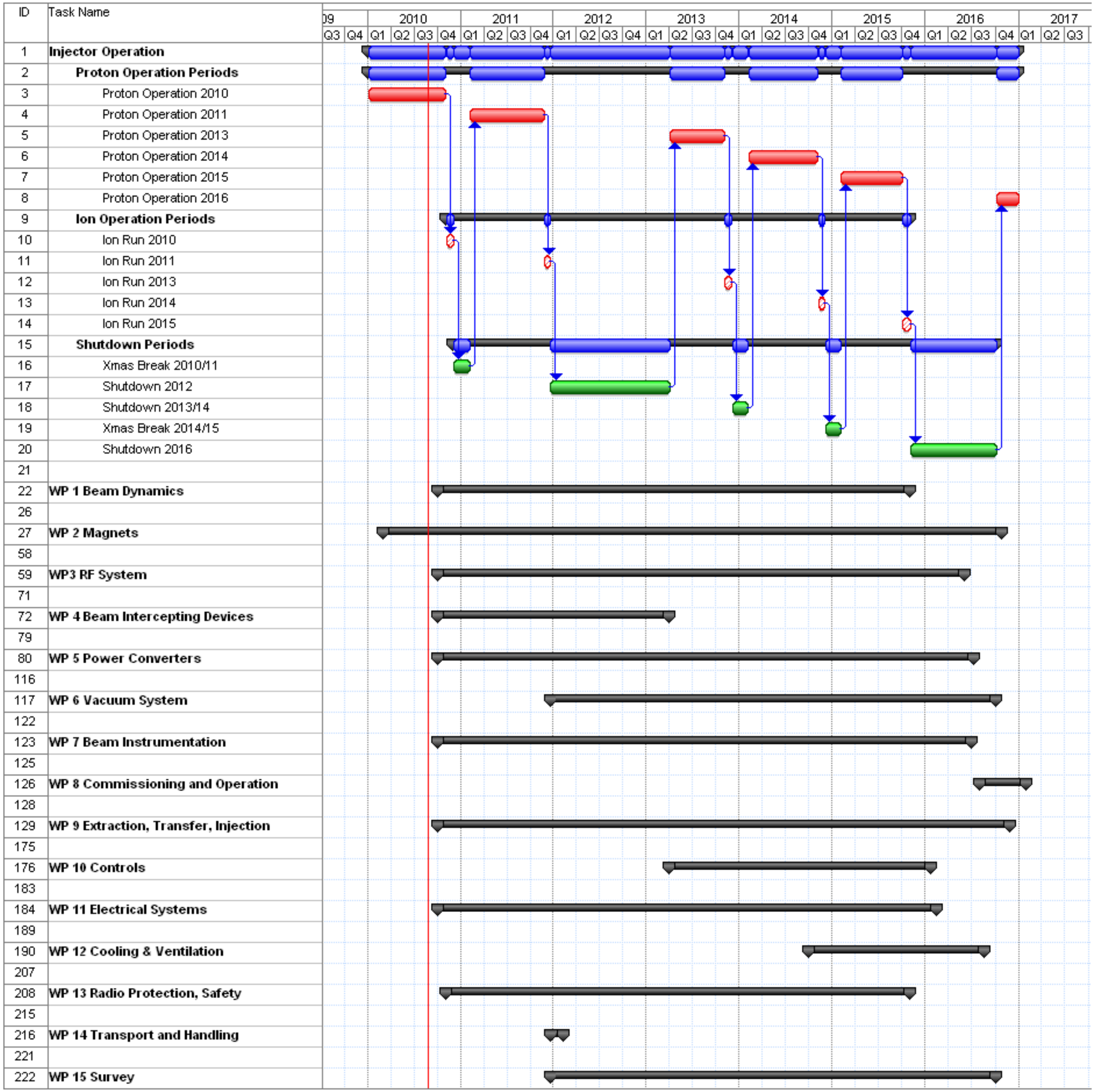
notice:
need ~6 months in a row for commissioning of cooling plant and new equipment, length of the shutdowns is therefore a concern

Summary Resources in kCHF

		Consolidation	
Total Beam Dynamics	50	0	50
Total Magnets	3445	-210	3235
Total Magnetic Measurements	111	0	111
Total RF	14320	-14320	0
Total Beam Intercepting Devices	700	-700	0
Total Power Converters	21100	-6630	14470
Total Vacuum System	100	0	100
Total Beam Instrumentation	67	-10	57
Total Commissioning	50	0	50
Total Extraction, Transfer, Injection	5763	-550	5213
Total Controls	116	0	116
Total Electrical Systems	1700	0	1700
Total Cooling & Ventilation	5500	-4500	1000
Total RP	0	0	0
Total Transport and Handling	680	-400	280
Total Survey	50	0	50
Total Project	**53752**	**-27320**	**26432**

Behind this overview there is a detailed budget & manpower break-down for each WP
- Booster injection has recently been transferred to this project, will come with budget
- some PS related items will be moved to the LIU PS upgrade project

Draft Project Schedule



Summary & Next Steps

- one year of intense work
- different options studied; baseline scenario chosen
- an upgrade of the PSB from 1.4 GeV to 2.0 GeV is technically feasible
- a realistic estimate of budget and time lines has been made; the upgrade can be completed by 2016
- consolidation items have been disentangled from the budget
- the budget has been entered in the MTP according to our estimate
- we are ready to go

next steps:

- evaluate alternative scenarios, e.g. new magnet design (potential long-term savings)
- conclusions from Chamonix and LIU project
- make decision and freeze design choices
- prepare TDR