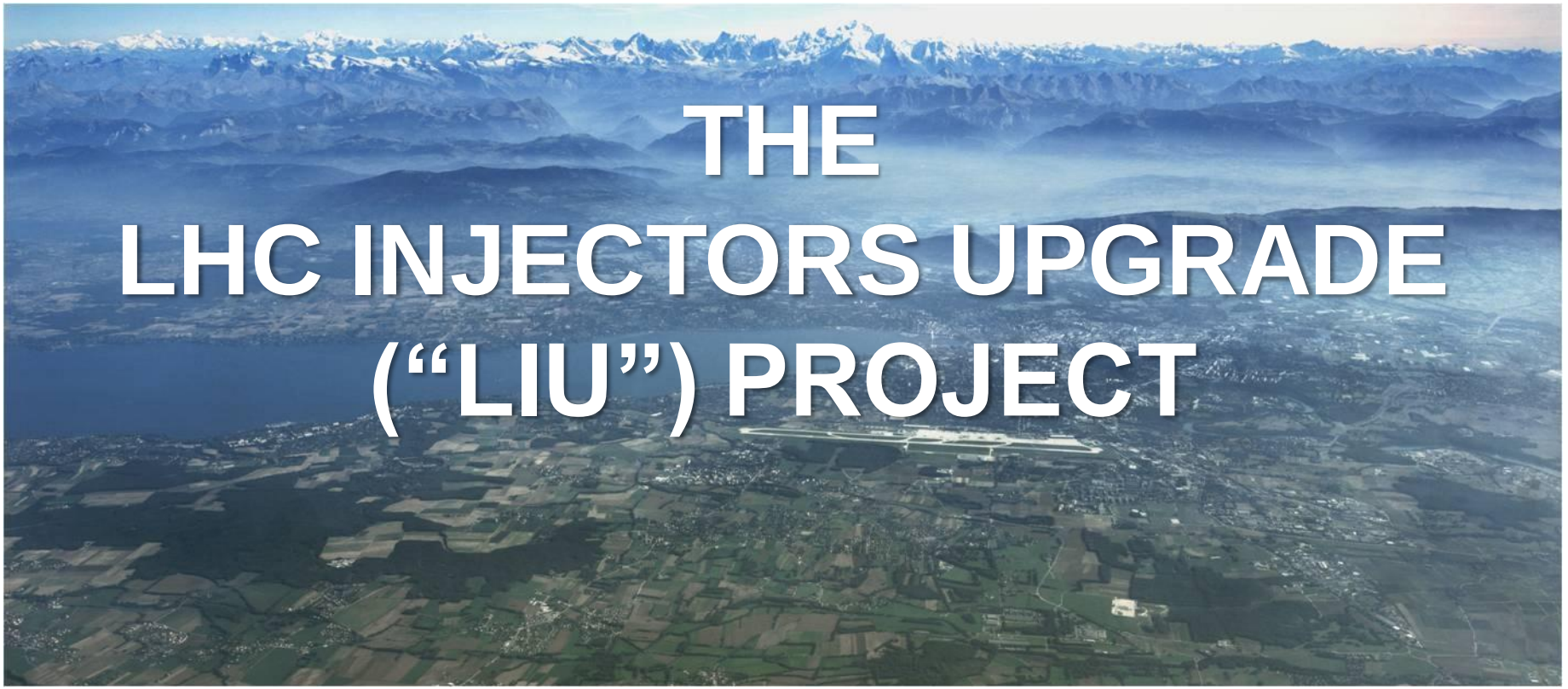
LHC Injectors Upgrade



THE LHC INJECTORS UPGRADE ("LIU") PROJECT

R. Garoby for the LIU Project Team

LIU-2011 November 25, 2011 CERN

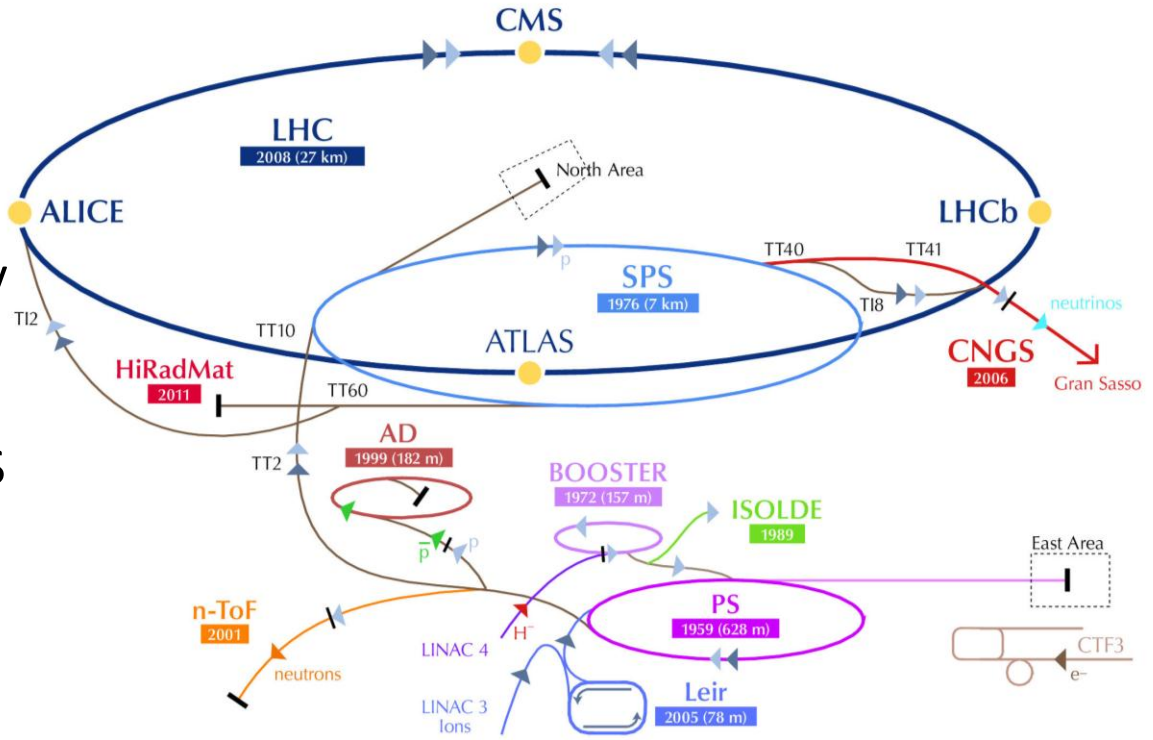
- **Introduction**
- Project Management
- Anticipated Performance Goals
- Planning
- Summary

CERN

Goals & Means

Mandate

"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…"



Implementation

The LIU Project will:

- Analyze the status of the injectors and the HL-LHC requirements,
- Propose an upgrade path for the injectors, exploiting the work done by the Task Forces on the „PSB energy upgrade" and „SPS upgrade" and by the Working Group on the SPS upgrade,
- Organize the upgrades (WBS with resources and planning) and take care of their implementation,
- Take care of hardware and beam commissioning.

Basic Principles

To increase performance (soon extended for heavy ions)

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**

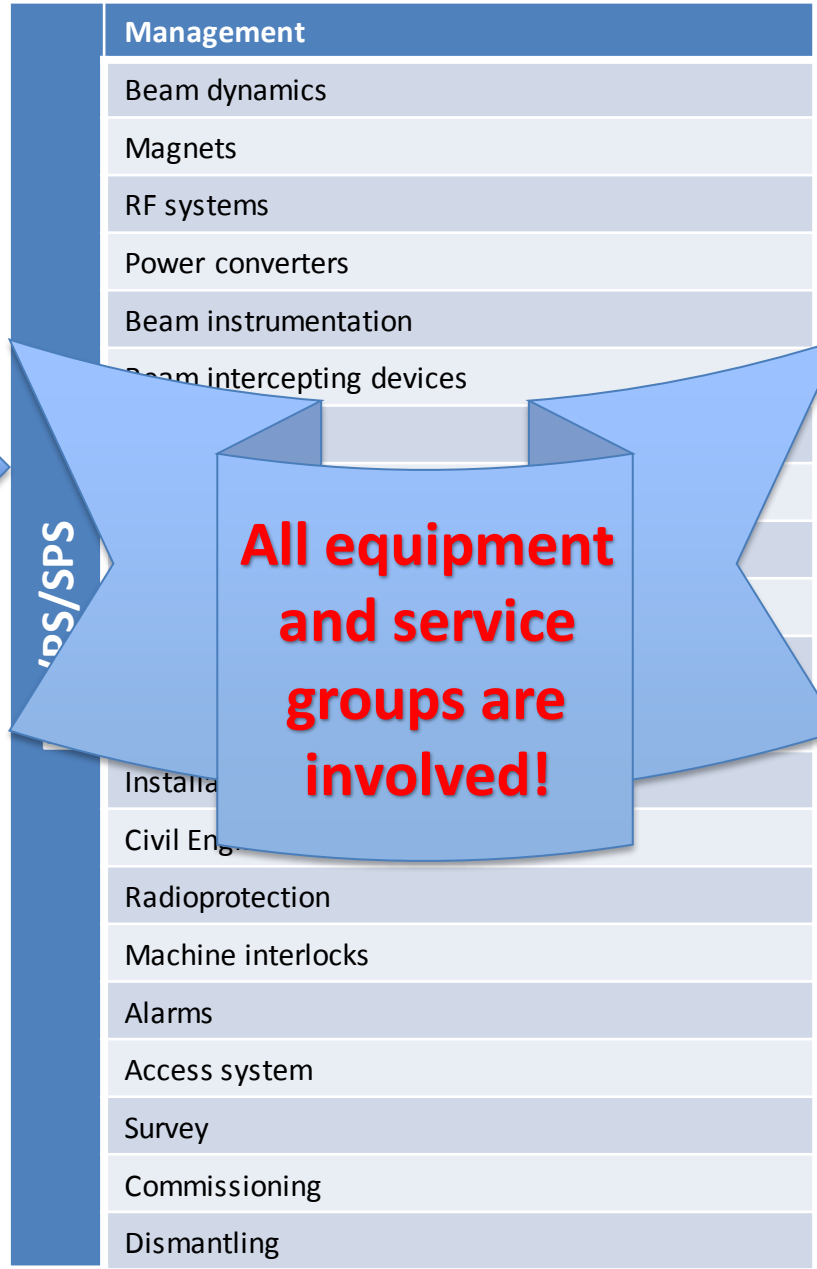
⇒ **Improve radioprotection measures (shielding, ventilation…)**

Baseline Upgrade Actions

- **Construction of LINAC4**
- **Upgrades of PSB, PS and SPS**

«Typical» list of Work Units

+ Consolidation…



- Introduction
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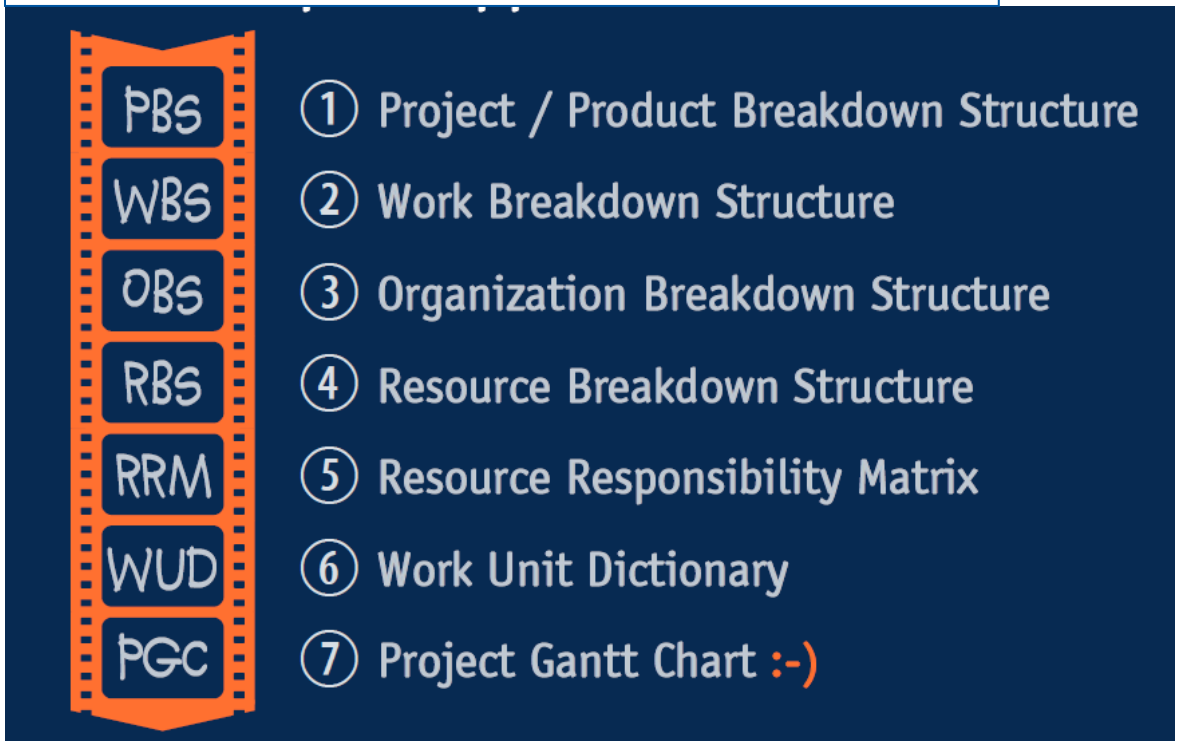
LIU Project Mandate (continued)

…

The project co-ordinator will have the responsibility for the project management (WBS, technical co-ordination and integration, manpower and budget agreement with the departments as well as budget and timescale control). They will report on a regular basis to the Director of Accelerators and Technology. The executive role for manpower and budget for the projects/studies remains with the technical groups in the departments.

LIU Project Planning and Costing



Source: Project Management case study – P. Bonnal, M. Meddahi

Project Organization Breakdown Structure

Director of Accelerators and technology - Steve Myers

LIU Project team

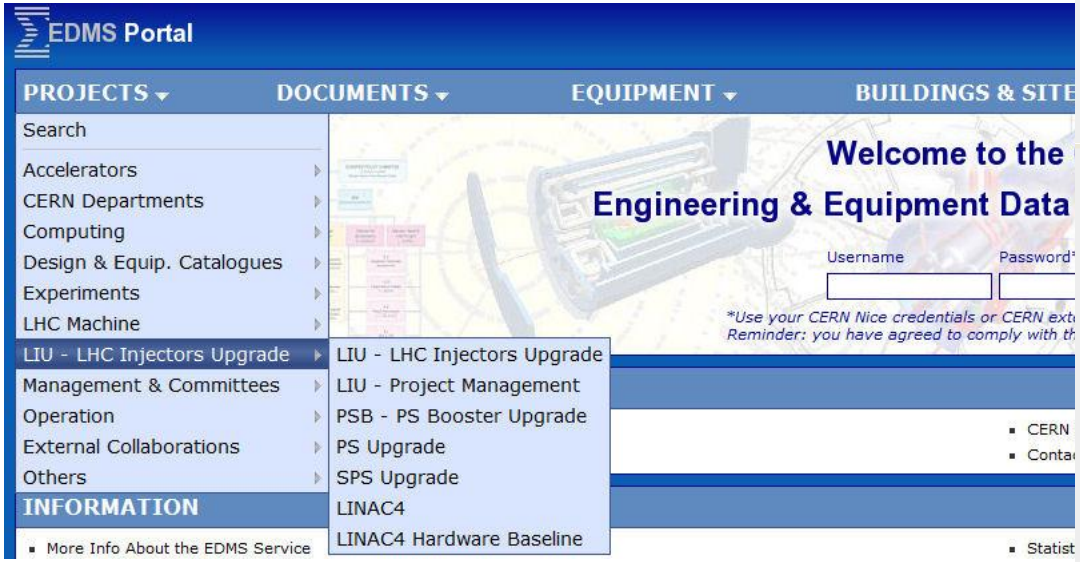
Roland Garoby (Project Leader) - Malika Meddahi (Deputy) - Brennan Goddard (LIU-SPS machine coordinator) - Simone Gilardoni (LIU-PS machine coordinator) - Klaus Hanke (LIU-PSB machine coordinator) - Maurizio Vretenar (Linac4 Project Leader)- Laurette Ponce (Project Safety Officer)-Django Manglunki (LIU-Ion chain coordinator)

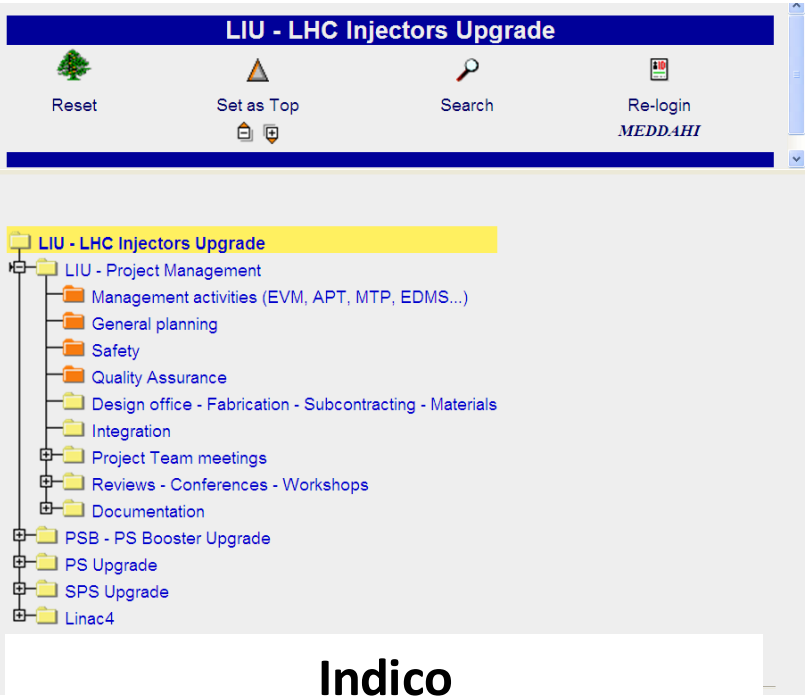
LIU-PSB coordination team	LIU- PS coordination team	LIU-SPS coordination team	LIU-Project Safety coordination	Linac4 Project
K.Hanke – Activity leader B.Mikulec – Deputy V.Raginel – Scientific secretary https://espace.cern.ch/liu-project/liu-psb/	S.Gilardoni – Activity Leader H. Damerau– Deputy and Scientific secretary https://espace.cern.ch/liu-project/liu-ps/	B.Goddard E.Shaposhnikova – Deputy G.Rumulo – Scientific secretary https://espace.cern.ch/liu-project/liu-sps/default.aspx	L. Ponce	M.Vretenar http://linac4-project.web.cern.ch/linac4-project/

LIU Administrative Support: Cécile Noels, Nadine Audrey. Project Support: Pierre Bonnal, Sylvain Weisz, Tadeusz Kurtyka - EVM coordinators: De Jonghe, Benoît Daudin

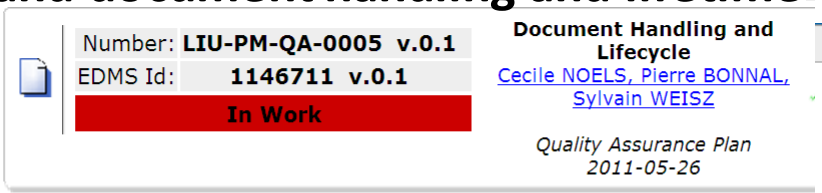
Quality Control

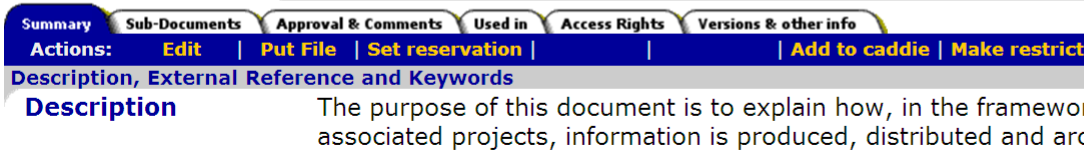
https://edms.cern.ch/ - by EDMS team and Project Support Office



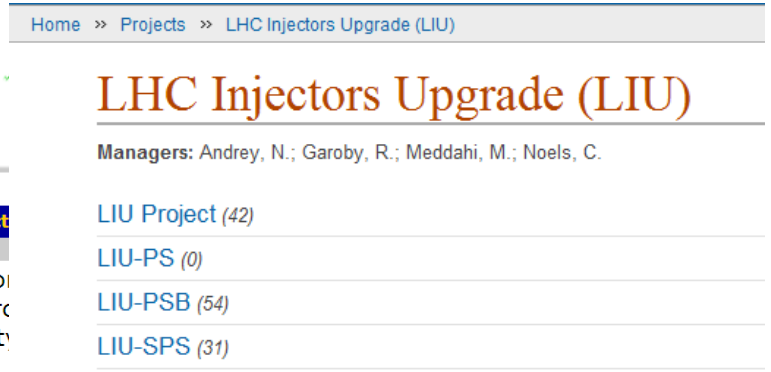


Templates and document handling and lifetime





Indico



Work Breakdown Structure

20111003 - EMDS ID 1146814					
LIU Work Breakdown Structure					
1	**LIU project**				**Roland Garoby**
	LIU 1	**62011**	Management activities (EVM, APT, MTP, EDMS…)		Roland Garoby - Malika Meddahi
	LIU 2		General planning		Roland Garoby - Malika Meddahi
	LIU 3		Safety		Laurette Ponce
	LIU 4		Quality assurance		Roland Garoby - Malika Meddahi
	LIU 5		Design office-Fabrication-Subcontracting-Materials (EN-MME)		Serge Mathot
	LIU 6		Integration		Yvon Muttoni
	LIU 7		Project team meetings		Cecile Noels
	LIU 8	**62011**	Reviews - Conferences		Cecile Noels
2	**LIU-PSB**				**Klaus Hanke**
	LIU-PSB 1	Management			Klaus Hanke
	LIU-PSB 2	PSB Beam dynamics			Christian Carli
	LIU-PSB 3	Magnets			Antony Newborough
	LIU-PSB 4	RF systems			Alan Findlay
	LIU-PSB 5	Power Convertors			David Nisbet - Serge Pittet
	LIU-PSB 6	Beam instrumentation			Jocelyn Tan
	LIU-PSB 7	Beam Intercepting Devices			Oliver Aberle - Alternate Alessandro Masi
	LIU-PSB 8	Vacuum System			Jan Hansen
	LIU-PSB 9	LINAC4 to PSB transfer line and PSB injection systems			Christian Carli - Wim Weterings
	LIU-PSB 10	PSB Extraction system and PSB-PS transfer line			Wolfgang Bartmann - Jan Borburgh
	LIU-PSB 11	Controls			Steen Jensen
	LIU-PSB 12	Electrical Systems			Davide Bozzini, Slawomir Olek
	LIU-PSB 13	Cooling and Ventilation			Mauro Nonis
	LIU-PSB 14	Installation, Transport and handling			Ingo Rühl
	LIU-PSB 15	Civil Engineering			Luz Anastasia Lopez-Hernandez
	LIU-PSB 16	Radiation Protection			Joachim Vollaire
	LIU-PSB 17	Machine Interlocks			Bruno Puccio
	LIU-PSB 18	Alarms			
	LIU-PSB 19	Access Systems - Doors			
	LIU-PSB 20	Survey			Tobias Dobers
	LIU-PSB 21	Commissioning and Operation			Bettina Mikulec
	LIU-PSB 22	Dismantling			
3	**LIU-PS**				**Simone Gilardoni**
4	**LIU-SPS**				**Brennan Goddard**

Budget Control – (APT by J. De Jonghe, B. Daudin)

WUs dictionary defined for all LIU machines - resources, schedule and deliverables

		PPA	Project	BC	Group	WBS
LIU Management	Fellows, visitors, associates, travel etc.	PBU-PRJ	LIU	62011	BE-HDO	1.1; 1.8
PSB	Management (M resources)	PBU-PRJ	LIU-PSB	67020	BE-OP	LIU-PSB 1
	Beam Dynamics	PBU-PRJ	LIU-PSB	61020	BE-ABP	LIU-PSB 2
	Magnets	PBU-PRJ	LIU-PSB	99281	TE-MSC	LIU-PSB 3
	Magnetic Measurements	PBU-PRJ	LIU-PSB			LIU-PSB 3
	RF	PBU-PRJ	LIU-PSB	69020	BE-RF	LIU-PSB 4
	L4 on LBE/LBS and shielding	PBU-PRJ	LIU-PSB	Existing 55152	EN-STI	LIU-PSB 7
	head and tail dump and the H0/H- dump	PBU-PRJ	LIU-PSB	63125	EN-STI	LIU-PSB 7
	Power Converters (PSB) - New MPS building	PBU-PRJ	LIU-PSB	99237	TE-EPC	LIU-PSB 5.2
	Power Converters (PSB) -MPS and MPS	PBU-PRJ	LIU-PSB	99238	TE-EPC	LIU-PSB 5.2
	Power Converters (PSB) - ALG1&2 upgrade	PBU-PRJ	LIU-PSB	99239	TE-EPC	LIU-PSB 5.2
	Power Converters (PSB) - Transfer bendings	PBU-PRJ	LIU-PSB	99240	TE-EPC	LIU-PSB 5.2
	Power Converters (Injection)	PBU-PRJ	LIU-PSB	Existing*	TE-EPC	LIU-PSB 5.1
	Vacuum System	PBU-PRJ	LIU-PSB	99271	TE-VSC	LIU-PSB 8
	Beam Instrumentation	PBU-PRJ	LIU-PSB	64020	BE-BI	LIU-PSB 6
	Commissioning	PBU-PRJ	LIU-PSB	67021	BE-OP	LIU-PSB 21
	Injection	PBU-PRJ	LIU-PSB	Existing*	TE-ABT	LIU-PSB 9
	Extraction, Transfer	PBU-PRJ	LIU-PSB	99236	TE-ABT	LIU-PSB 10
	Controls	PBU-PRJ	LIU-PSB	66020	BE-CO	LIU-PSB 11
	Electrical Systems	PBU-PRJ	LIU-PSB	54247	EN-EL	LIU-PSB 12
	Cooling & Ventilation	PBU-PRJ	LIU-PSB	53661	EN-CV	LIU-PSB 13
	RP and Safety	PBU-PRJ	LIU-PSB		DGS-RP	LIU-PSB 16
	Transport and Handling	PBU-PRJ	LIU-PSB	54360	EN-HE	LIU-PSB 14
	Survey	PBU-PRJ	LIU-PSB	61021	BE-ABP	LIU-PSB 20
	Machine Interlocks (added to first budget	PBU-PRJ	LIU-PSB	99290	TE-MPE	LIU-PSB 17
	Integration studies (added to first budget	PBU-PRJ	LIU-PSB	89122	EN-MEF	LIU-PSB 1.5
	PSB Total					

- **LHCINJUPG: LHC injectors upgrade**
  - **LIU:** LHC injectors upgrade parent project
    - **LIU-PRJ:** LIU project management
  - **PBU:** PS Booster upgrade
    - **PBU-PRJ:** PSB Upgrade project
      - **LIU-PSB:** LIU-PSB
    - **PBU-L2B:** Linac to booster
  - **PSU:** PS upgrade
    - **PSU-PRJ:** PS upgrade
      - **LIU-PS:** LIU-PS
  - **SPU:** SPS upgrade
    - **SPU-PRJ:** SPS Upgrade
      - **LIU-SPS:** LIU-SPS
  - **RFS:** RF improved capturing system
  - **IUM:** Injectors upgrade management
    - **IUM-PRJ:** Injectors upgrade management
      - **LIU (Common):** LIU (Common)

LIU-PSB 6: Beam instrumentation

Short — Workunits: 1- 3 of 3. Page size: 30

Workunits for year : *2011*, for WBS *LIU-PSB 6: Beam instrumentation*

ID	Description	WBS	Holder	Start Date	Finish Date
91546	Fast BLMs at injection DUMP	LIU-PSB 6	C. Zamantzas (BE-BI)	01-May-2011	01-Jan-2014
91547	Screens at extraction BT.MTV10+30	LIU-PSB 6	D. Gerard (BE-BI)	01-Jun-2011	01-Sep-2013
91542	Watchdog BR8 TMD (4 monitors)	LIU-PSB 6	P. Odier (BE-BI)	01-Nov-2011	01-Jan-2014

WORK IN PROGRESS

91546		Fast BLMs at injection DUMP	LIU-PSB 6	C. Zamantzas (BE-BI)		01-May-2011	01-Jan-2014
MSP		Monitors and Acq system	64020		60,000 CHF		
MSP		Installation	64020		10,000 CHF		
DE		Ten Monitors and acq system		30	0 / 10 U	01-May-2011	01-Jan-2014
DE		Cables		30	0 / 100 %	01-Oct-2013	01-Jan-2014
DE		Installation		10	0 / 100 %	01-Oct-2013	01-Jan-2014

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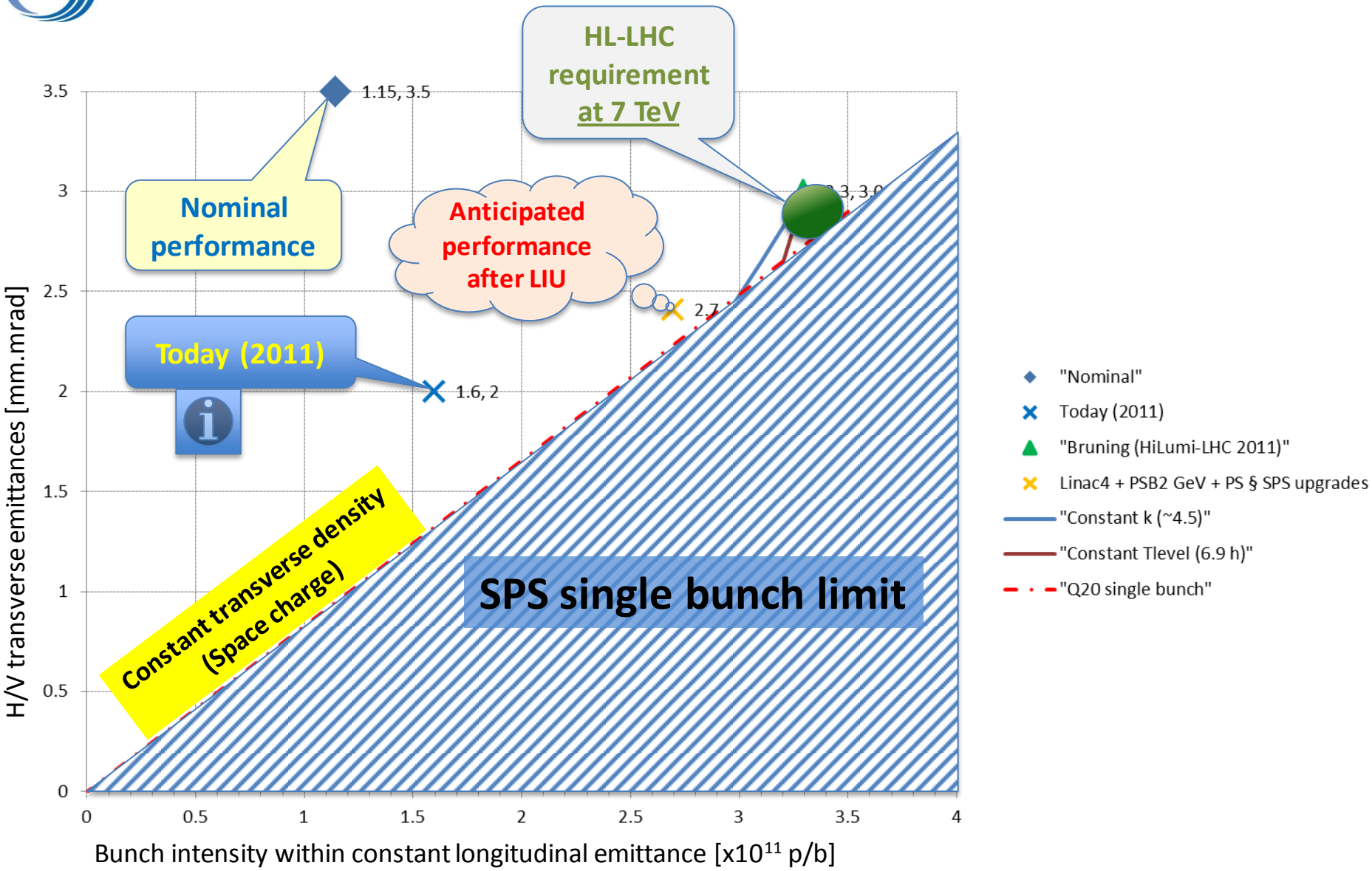
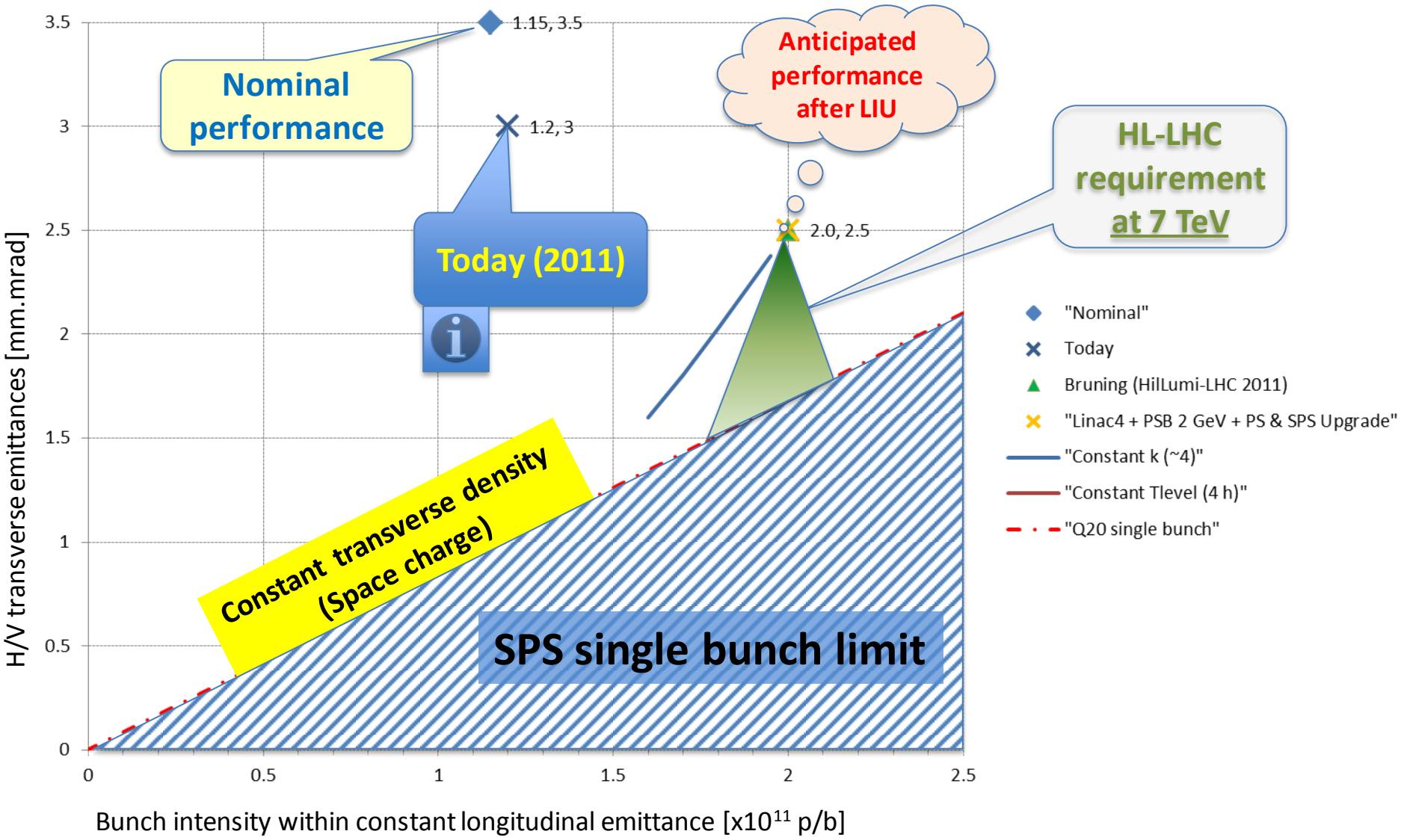
Basic assumptions

- Beam parameters are given at injection in LHC: beam loss and blow-up inside the LHC are not accounted for.
- All necessary improvements are implemented in the injectors (Linac4, PSB to PS transfer at 2 GeV, coupled bunch instabilities suppressed, e-cloud suppressed, hardware upgraded…)
- Estimated beam degradation in the accelerator chain (based on observations in 2010):
  - ✓ PS: 5 % beam loss, 5 % transverse blow-up
  - ✓ SPS: 10 % beam loss, 5 % transverse blow-up.
- RF gymnastics being kept, imperfections are unchanged:
  - ✓ +-10 % fluctuation of all bunch parameters within a given PS bunch train.
  - ✓ Traces of ghost/satellite bunches.

Beam parameters at LHC injection [50 ns]



Beam parameters at LHC injection [25 ns]



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Comments

- LIU performance goals in terms of beam characteristics at injection in the LHC have to meet the needs of HL-LHC and to be feasible... Subject of active interactions between HL-LHC and LIU teams (2nd joint «Brainstorming» session on January 24, 2012).
- MDs until the end of 2012 will help refine the knowledge and understanding of the injectors and check the potential of upgrades.
- End 2012/beginning 2013, the performance goals of the LIU project will be specified and the precise list of hardware modifications with their specifications will be issued.

Planning

	Linac4	PS injector, PS and SPS	Beam characteristics at LHC injection
2011 - 2012	Continuation of construction…	• Beam studies § simulations • Investigation of RCS option • Hardware prototyping • Test of new beam gymnastics • Design § construction of equipment • TDR	25 ns, 1.2 10^{11}p/b, **~3 mm.mrad** 50 ns, 1.7 10^{11}p/b, **~2 mm.mrad**
2013 – 2014 (Long Shutdown 1)	• Linac4 beam commissioning	• Modifications and installation of some prototypes in PSB, PS and SPS • Design § construction of equipment	
2015 - 2017	• Progressive increase of Linac4 beam current	• Implementation of new PS beam gymnastics… • PSB modification and connection to Linac4 during extentended winter shutdown • If/when Linac4 connected: progressive increase of PSB brightness with benefits for PS and SPS. • Equipment design § construction for PSB, PS and SPS • Beam studies	• Possibly smaller emittance (25 ns) with new PS beam gymnastics… • Limited gain from Linac4 proper (pending PSB, PS and SPS hardware upgrades)
2018 (Long Shutdown 2)		• Extensive installations in PSB, PS and SPS • Hardware commissioning	
2019 –2021		• Beam commissioning	After ~1 year of operation: beam characteristics for HL-LHC…

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Summary

- The goal of the LIU project is to make the LHC injector complex capable to reliably deliver the higher performance proton and ion beams required for High Luminosity in LHC until later than 2030.
- Performance for other users will at least be preserved and generally benefit (e.g. high intensity).
- More MDs will take place in 2012 to finalize the hardware modifications and their precise specifications.
- The implementation of hardware modifications will finish during LS2.

All equipment and service groups are concerned!

THANK YOU FOR YOUR ATTENTION!

Reference

Why is today's beam better than nominal?

Simple! No more blow-up along the accelerators cascade…

- PSB:
  - Improved (achromatic) optics in the Linac2 to PSB transfer line since 2005 [http://khanke.home.cern.ch/khanke/papers/2006/ab_note_2006_001.pdf]
- PS:
  - Injection trajectories
  - Working point along the whole cycle
  - Transition
- PS to SPS:
  - Transverse matching with better optics in TT2-TT10

WARNING: NO MARGIN LEFT!