

# LHC Injectors Upgrade





## LHC Injectors Upgrade

# Status of the BI Work Package in the LIU-PSB frame

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Thanks to the contributions of the WU holders:

J. Belleman, P. Odier, F. Roncarolo, S. Burger, D. Gerard, C. Zamantzas, B. Dehning.



# Outline

- Foreword
- Relevant Observables
- $H^-$  injection System & Half Sector Test
- Conclusion



# LIU-PSB-BI Work Package

- Total budget: 3635 kCHF
- 5 budget codes

Machine sector	Total: 20 Work Units
BI line	2
H <sup>-</sup> Injection & Half Sector Test	6 + 3
Ring	5
Extraction lines	4

- 4 cost drivers represent 79.8 % of the WP budget
  - Wire Scanners: 970 kCHF
  - Booster TMS: 750 kCHF
  - Upgrade for L4: 648 kCHF
  - BLMs: 532 kCHF



# Outline

- Foreword
- **Relevant Observables**
  - Beam intensity
  - Beam profile
  - Beam loss
  - Beam position
- H<sup>-</sup> injection System & Half Sector Test
- Conclusion



# Relevant Observables

- **Beam Intensity**
  - Injection efficiency (Slow)
  - Acceleration efficiency (DC)
- **Beam Profile**
  - Transfer-lines: septum position plates
  - Injection matching
  - Transverse emittance
- **Beam Loss**
  - Ring and transfer lines : Monitoring
- **Beam Position**
  - Orbit and trajectory
  - Transverse instabilities between PSB and PS

# BEAM INTENSITY

## Measurement of injection efficiency with Linac4

### Summary

- **Baseline: LS2**
- Four monitors **BR.TMD in 8L1**, installed in '72, un-used since early 80s'
- Analog turn by turn acquisition, up to 100 turns
- **Watchdog** : comparison with BI.BCT20 after 100 turns

### Status after LS1

- One BCT available (without shielding) in the laboratory

### Plans for 2015-2016

- Study of the electronics, test of a prototype in the machine
- Manufacturing of a ceramic vacuum chamber. **There is no spare!**

### Plans for 2017

- Manufacturing of the Front and Back End Electronics
- Specification of the SW for the acquisition chain based on the TRIC card

### Plans for LS2 (mid 2018 and 2019)

- New cables pulling
- Reshuffle the monitors in the BI radioactive workshop
- Installation : monitors & Electronics
- Full system commissioning



Courtesy: P. Odier



# BEAM INTENSITY

## Quantify total intensity transmission during PSB cycle

### Summary

- **Baseline: End 2017**
- Four monitors BR.BCTDC in section 9 (DCCT)

### Status after LS1

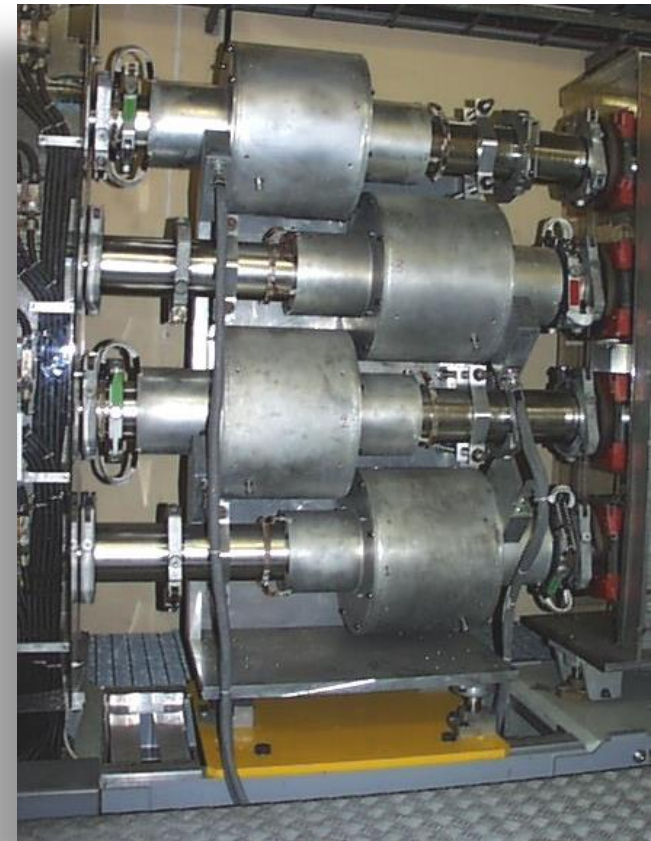
- **Acquisition chain upgraded**
  - 12 bit ADC replaced by 16 bit ADC (VD80)
  - Simplification of the HW (intervalometers for the hot spots replaced by markers acquired with the ADC)
  - Common Expert GUI for the DCCTs in the injectors 😊
- **Front End Electronics assembled** : Not installed due to higher priorities
- **Front End housing**: manufacturing launched (BI-ML)

### Plans for 2015

- **Test of the new B Train Receiver** (White Rabbit, SVEC VME card) in // with the current  $\beta$  Normalizer based on the old B Train
- **Share the firmware and the mezzanine**: contact H. Damerou (RF)
- **Installation of the new Front End Electronics** (TS 2015-2016)

### Plans for 2016-2017

- **Installation of the new B train** (White Rabbit) Receiver
- **Adaptation for Linac4 intensities**: Front and Back End for Linac 4







# BEAM PROFILE

## BI.SMV position measurement plates w/ Linac4

- 
- 
- 
- 

New WU created in 2014, baseline End 2016. Still OK?

New INJECTION SEPTUM for 160 MeV beams

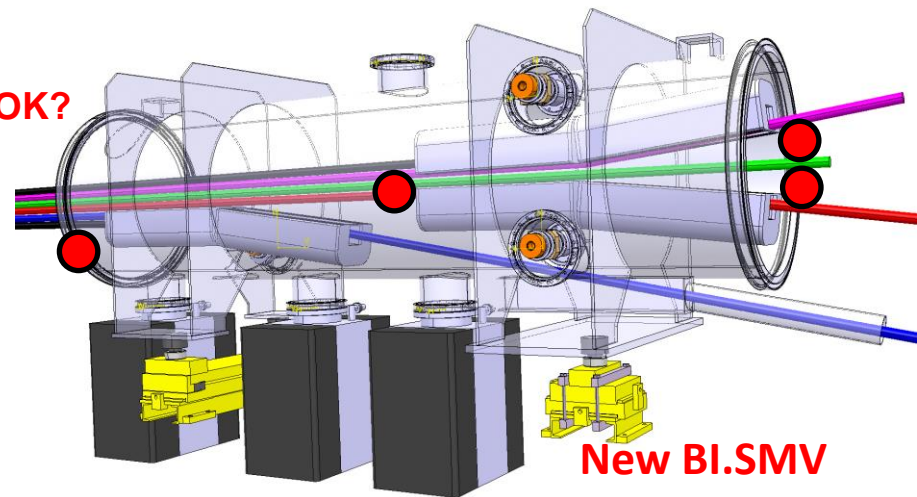
Based on existing system

Specifications under discussion w/ Bettina

- Ensure the **distributed beams** are centered in their respective apertures.
  - @ input plates: stripped electrons charge deposition
  - @ output plates: secondary emission, expected to be very weak!
- Linear,  $10^4$  dynamic range, large bandwidth (min 50ns beam pulse), Direct signals on OASIS
- No interlock, no aperture restriction

Planning for 2015 (in agreement with TE-ABT Team)

- April-June: Design
- Mid- Sept: Procurement of parts: Ti plates 1mm thick
- October: Installation in BI.SMV



Courtesy: M. Hourican



# BEAM PROFILE

EDMS NO.	REV.	VALIDITY
1415820	0.2	DRAFT

REFERENCE  
PSB-BSGMA-ES-0001

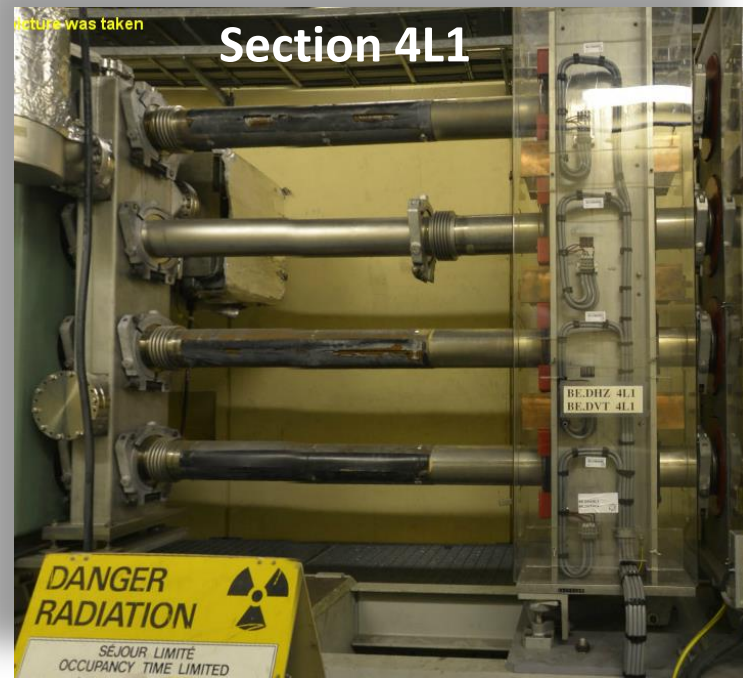
## Turn by turn meas. for injection matching w/ Linac4

### Specifications:

- **Baseline: LS2**
- injection of half a PSB turn (i.e.  $0.5 \mu\text{s}$ ,  $2 \times 10^{11}$  protons) to well separate turn-by-turn profiles.  
Only Ring 3 H+V planes
- acquisition of – **say up to 20** – consecutive profiles
- **External condition interlock** : to shorten the Linac4 pulse (max 1-turn-injection)
- NOT PPM In/Out
- Permanent implementation for commissioning, MDs and operation
- **Compact SEM grids**, grid size : 26mm, 64 graphite wires ( $\varnothing = 33 \mu\text{m}$ )
- Thick frame for stopping scattered protons

### Status

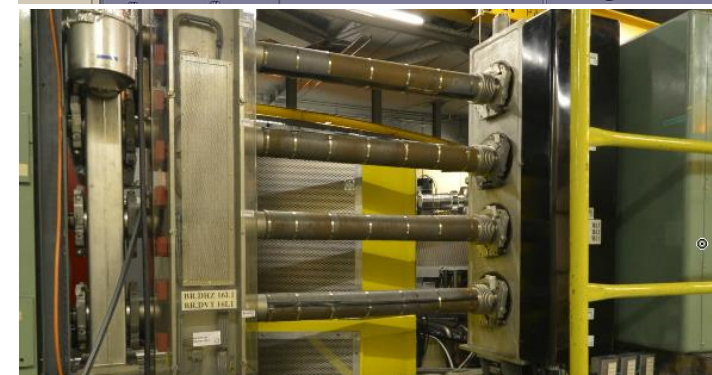
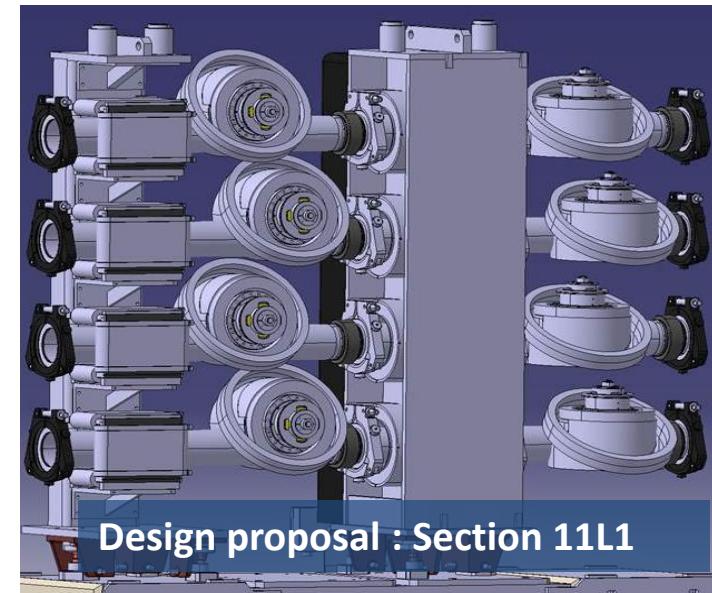
- Mechanics designs: not started
- Electronics : conceptual design started
- Proposed SEM's integration: **section 4L1**
- **To do** : Space Reservation Request for 4L1+ ECR



# BEAM PROFILE Wire Scanner

- **Baseline: LS2**
- **Aim:** adaption of the scanner design for the PS and SPS to the limited space in the PSB
- **Status**
  - Mechanical design proposals are under discussion:
  - Development of control end acquisition electronics advancing
  - Proposed BWS' integration: **section 11L1 + 16L1 ?**
  - **To do : Space Reservation Request for 11L1 and 16L1+ ECR**
- **2015**
  - Two prototypes (SPS + Lab) are used for optimisation and development of control electronics
  - If PSB study shows that integration is possible, then we can finalize the design (mechanics)
  - **Budget update**
- **2016**
  - production prototype scanner for installation YETS16-17
- **2017**
  - commissioning of prototype
- **Aim: Completion during LS2**
- **but we are on the critical path**

Courtesy: B. Dehning



BI is in favor having 2 sections: **could be 16L1**



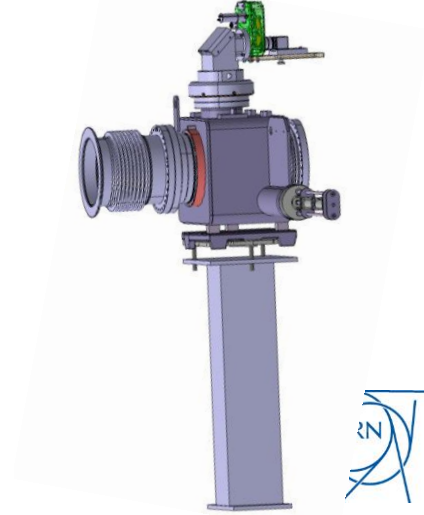
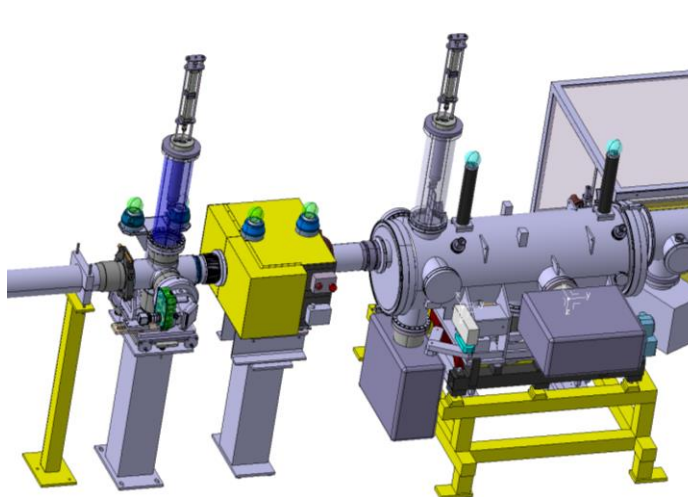
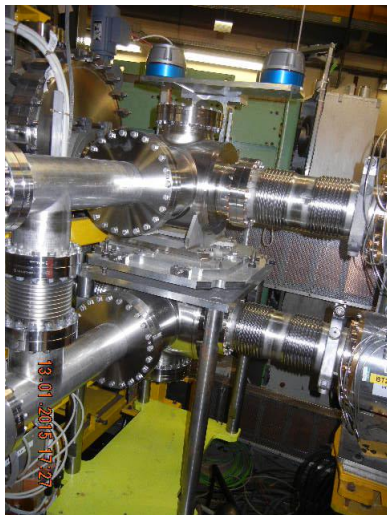
# BEAM PROFILE

## New Housings for BI.BTV30, BT.BTV10 and 30

### MOTIVATION:

The need of longer magnetic length for Septa induced by increased beam energy

Monitor	BT.BTV10	BT.BTV30	BI. BTV30
Status	Tanks installed	Design in good progress	
Plan for 2015	Production of optical mechanical part and of support		
	Production of transition pipes	Tank production	
		SSR + ECR Modification of adjacent pipes	
Baseline LS2	Monitors installation		Modification of existing tank





# BEAM LOSS

## PBS and Transfer lines BLM system

- **Baseline: End 2016**
- **Ionization Chambers (ICs): from LHC, for free**
- **Status**
  - **ICs in L2 sections**
    - WU completed during LS1: Cable pulling
  - **Flat ICs in L3 sections**
    - 2014-15: monitors' procurement
    - YETS16-17: cable pulling **ECR**
    - 2017: commissioning/operation
  - **ICs for injection and extraction lines**
    - 2014-15: Electronics procurement
    - YETS16-17: cable pulling
    - 2017: commissioning/operation
- **All systems should be ready for the 2017 start-up if cabling is granted**



# BEAM POSITION

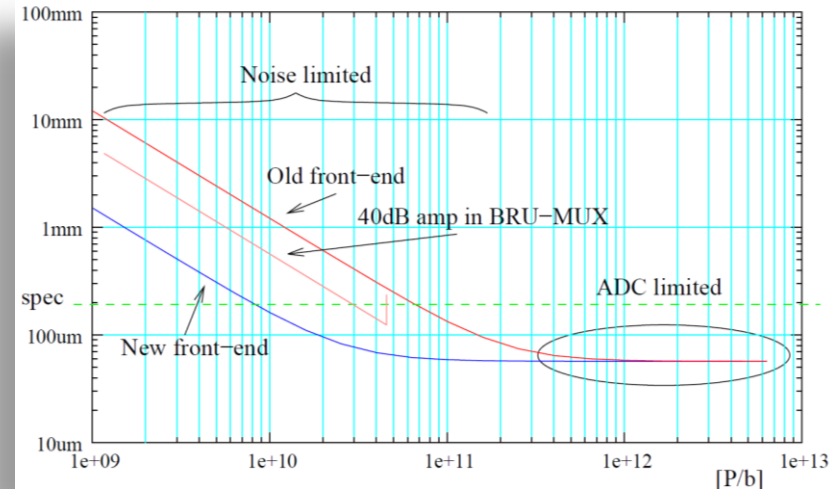
## Ring Trajectory Measurement System

### Specifications

- **Baseline: LS2**
- Bunch-by-bunch, turn-by-turn trajectories over the whole cycle
- Various derived averages (Orbits, M[RV]P)
- Position resolution 200µm
- No more multiplexing over the four rings
- New front-end electronics with settable gain

### Status

- One full ring can be acquired, multiplexed, **Design target resolution of 0.2mm**
- Software: FESA interface, with hooks for YASP and the Sampler + Expert GUI
- We're still using the old front-end electronics, without VGAs
- Interference on analogue signals is a real nuisance

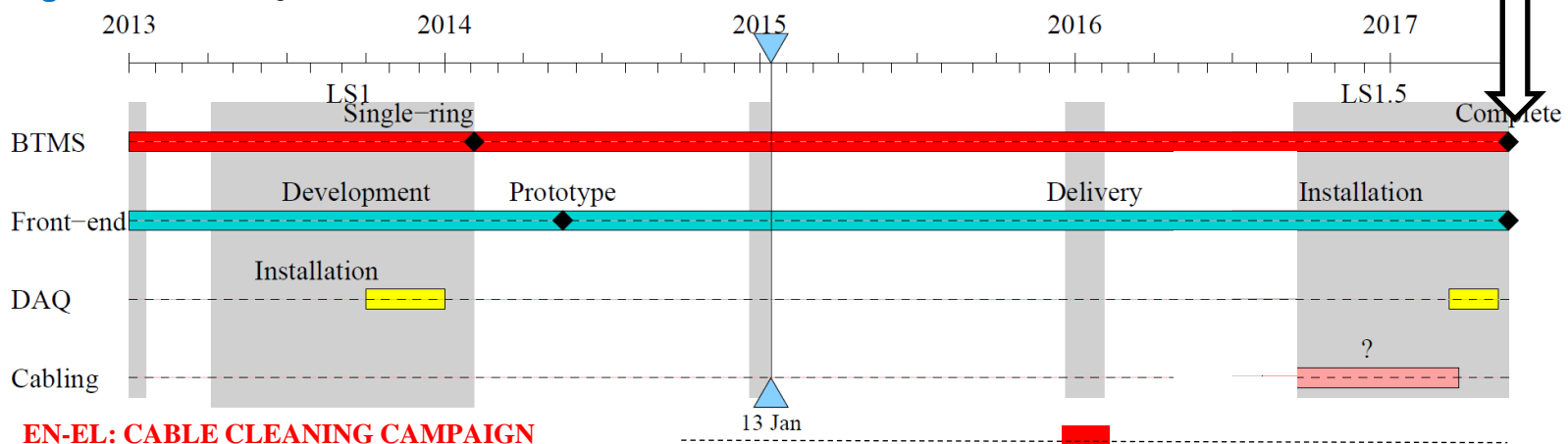


2015-16: Qualify the acquisition system

Start-up 2017: New request from OP for project COMPLETION

Budget: new re-baselining for 515 kCHF

**New baseline: FEASIBLE for 2017 if we can get cables in BOR**

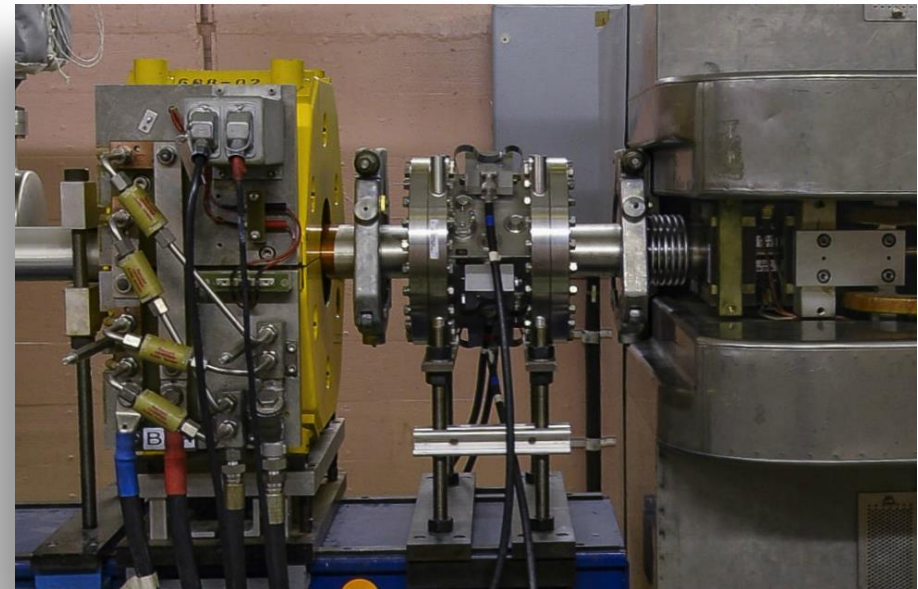


**EN-EL: CABLE CLEANING CAMPAIGN**





- **Baseline: End 2016**
- **Specifications**
  - Spot transverse instabilities during beam transfer between PSB and PS
  - Based on existing PS design (section 94)
- **Status**
  - Not started
- **Plans for 2015**
  - Design + production
  - DIC
  - Space reservation Request in BTP + ECR
- **Plans for 2016**
  - Installation and commissioning
  - Acquisition : OASIS





# BEAM POSITION

## Inductive BPMs in the extraction lines

- **Baseline: LS1**
- **Upgrade**
  - 8 monitors + 2 spares
  - New front and back end electronics for compatibility with Linac4 beams
  - New lab test bench
- **BTP and BTM lines: LIU budget**
- **Status**
  - **WU completed during LS1**
  - Some interference noise with beam being investigated





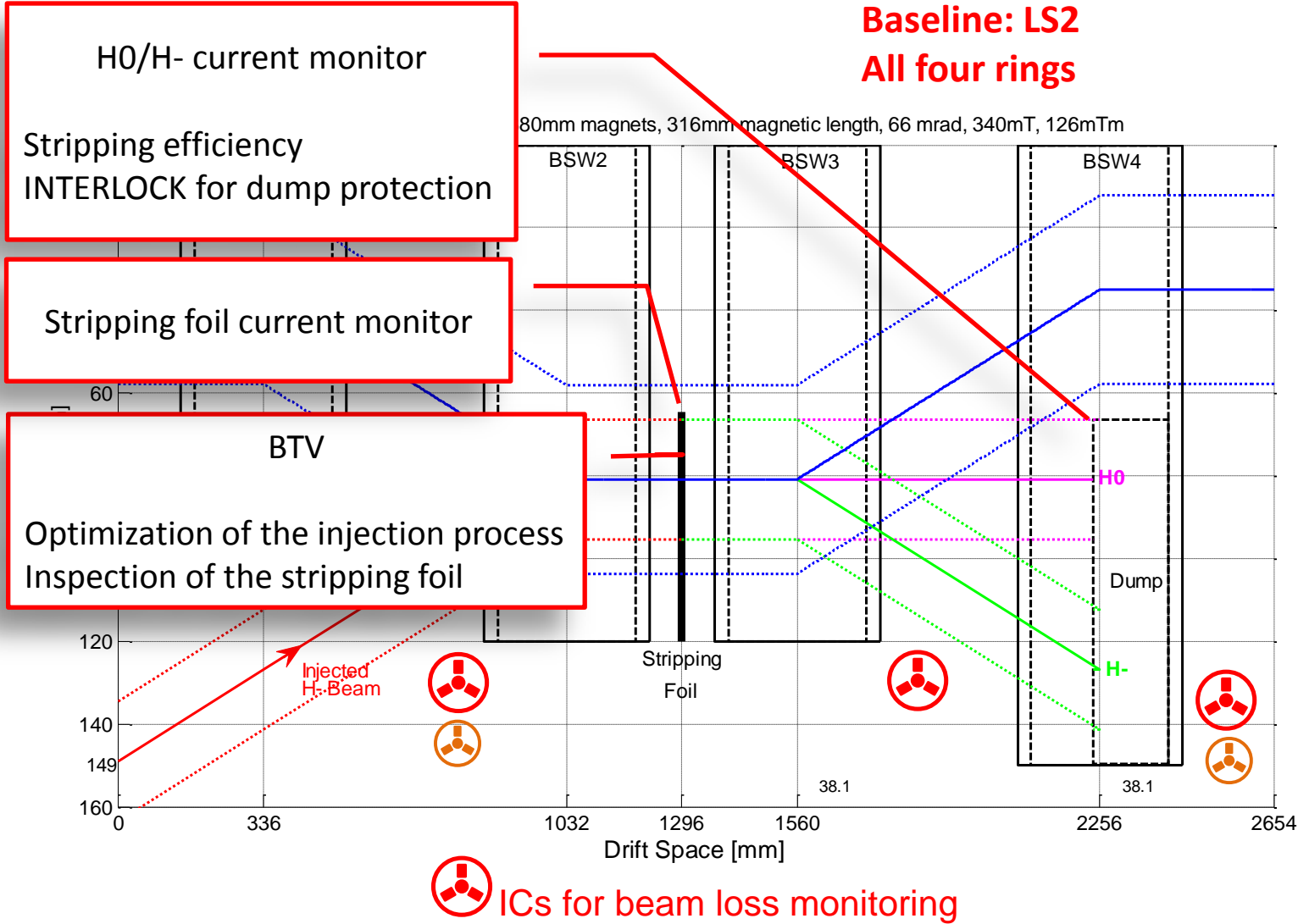


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# Beam Diagnostics for the new H<sup>-</sup> charge-exchange injection system in section 1L1



H<sup>0</sup>/H<sup>-</sup> current monitor  
Stripping efficiency  
INTERLOCK for dump protection

Stripping foil current monitor

BTV  
Optimization of the injection process  
Inspection of the stripping foil



Diamond detectors : for observation of fast losses and foil degradation

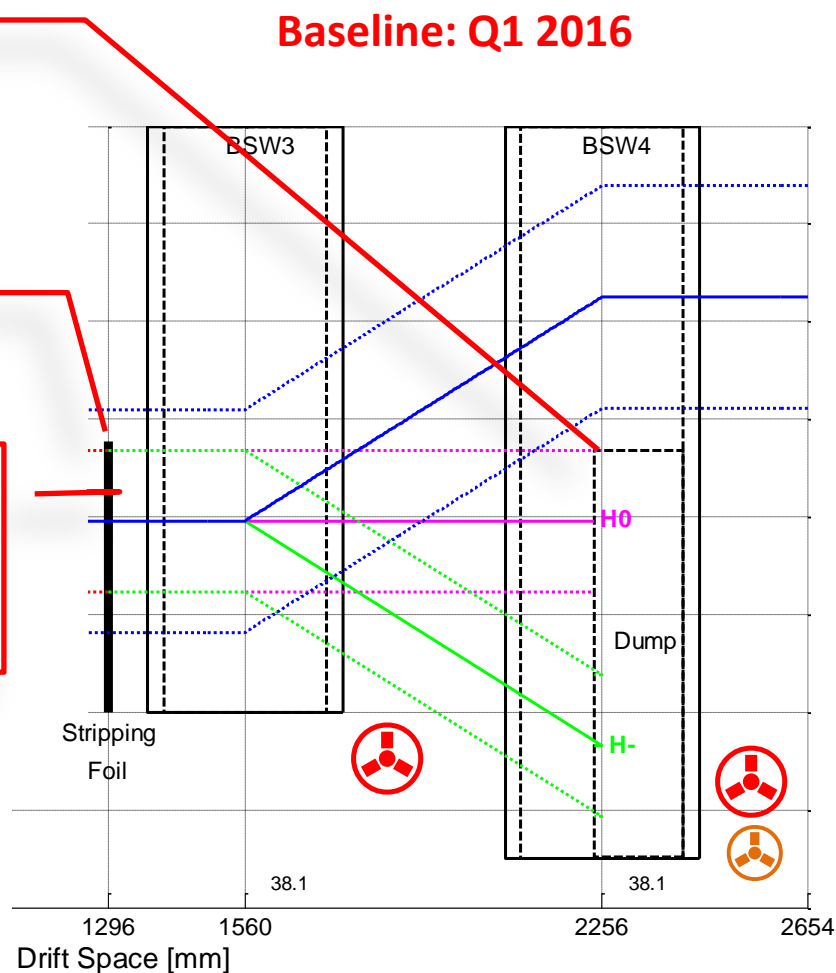



# Beam Diagnostics for the new H<sup>-</sup> charge-exchange injection system: HST in Linac4 tunnel

H<sup>0</sup>/H<sup>-</sup> current monitor  
 Stripping efficiency  
 INTERLOCK for dump protection

Stripping foil current monitor

One BTV  
 Optimization of the injection process  
 Inspection of the stripping foil



 ICs for beam loss monitoring

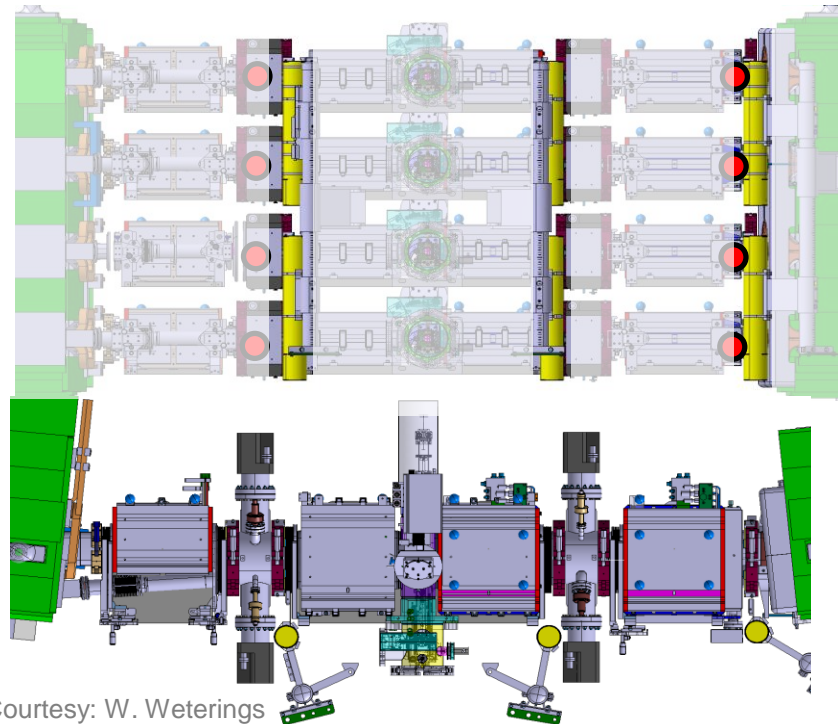
 Diamond detectors : for observation of fast losses and foil degradation





# New H<sup>-</sup> charge-exchange injection system

## Beam Loss and Interlock Systems



Courtesy: W. Weterings

### Ionization chambers : x6

- Monitoring foil degradation
- Machine protection (H<sup>0</sup>/H<sup>-</sup> dump)
- Interlock

### Diamond: x8

- Monitor fast losses & foil degradation
- Optimize stripping efficiency

Both detectors share the same support system

	Monitoring	Observation	Half Sector Test
Status	BLM support design and integration done		
2015	Acquisition chain	Acquisition chain Diamond detector	Installation + cabling
2016			Commissioning
YETS 16-17	Cabling	Cabling	





# New H<sup>-</sup> charge-exchange injection system

## H<sup>0</sup>/H<sup>-</sup> Current Monitor

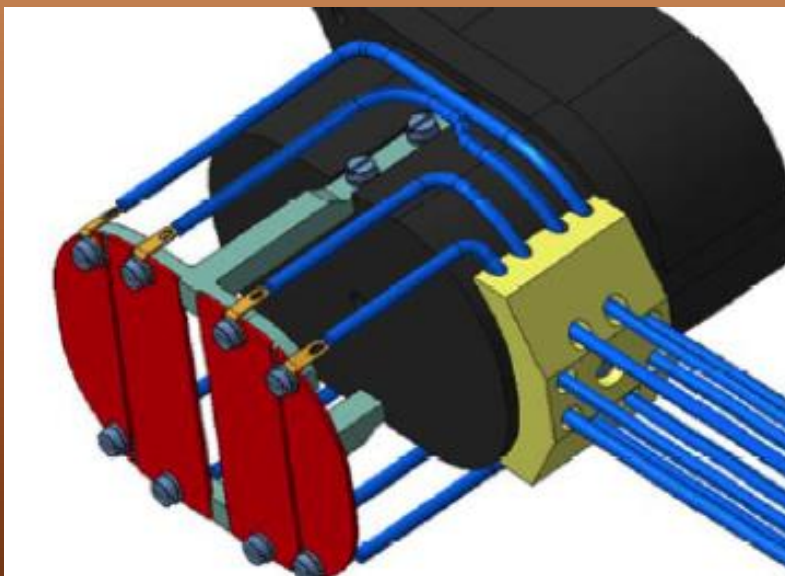
Mechanical Design Completed

Monitor to be installed in front of each H<sup>0</sup>/H<sup>-</sup> dump.

- low-Z material, low activation: Titanium plates
- medium-level conductivity (best compromise between read-out of the deposited charge and the presence of a pulsed magnetic field)

Fabrication can be launched

- **BI wants to approve the production drawings**
- B.Riffaud (MME) (via BI-ML ?)
  - 1 system will be ready for HST part 2



Electronics Design Ongoing

- 1 VME per ring, with following outputs
  - Interlock
  - 4xOasis (fast Amplifier)
  - 4xIntegrator (from 50ns to 1us)
  - 1xStripping foil current (next slide)
- 1 MHz ADC
  - Interlock
  - Sampling of integrator @ 1us  
→ time signal
- DAC for interlock reference
- Will be ready for HST
  - Part1: only stripping foil current
  - Part2: first H<sup>0</sup>-H<sup>-</sup> current system



# New H<sup>-</sup> charge-exchange injection system

## H<sup>0</sup>/H<sup>-</sup> Stripping Foil Current

- Signal cable feed through included in mechanical design
- BI is responsible from signal feedthrough
- Electronics design on going
  - Included in H<sup>0</sup>-H<sup>-</sup> VME, same readout
  - BIAS +/-10V via DAC likely envisaged (if compatible with magnetic fields)
- Will be ready for HST part 1

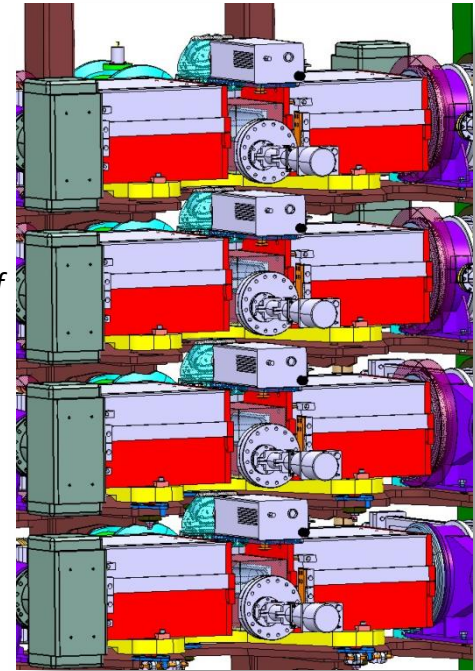


# New H<sup>-</sup> charge-exchange injection system

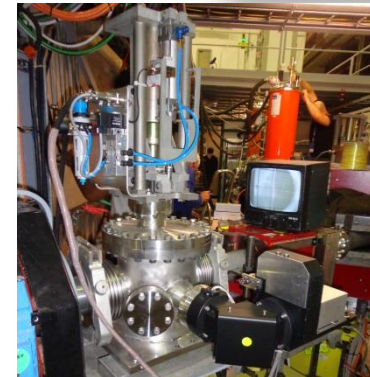
## Beam Profile and Foil Inspection

BTV Stripping Foil			
Project	Number	Permanent	Installation
L4T	1	Yes	Q3 2015
HST	1	No	Q1 2016
BOOSTER	4	Yes	2018-2019
Spare	2	-	-
Status			
Design	Done	In collaboration with EN-MME and ABP-FPS	
Integration	Done	In collaboration with EN-MME and ABP-FPS	
Production	Done	All movement and 'cloche' mechanics	
Assembly/Test	Validation of production by Q2		
Interlock	Between Screen and Foil movements to avoid collision Interface and test to be done		

BTV in front of proton dump			
Project	Number	Permanent	Installation
HST	1	No	Q1 2016
Status			
Use of available spare BTV AD/BASE type (pneumatic)			



3D view of  
BTV\_SF  
in the 4 rings of  
the BOOSTER



Pneumatic BTV  
AD/Base type  
will be used for  
the BTV dump  
of the HST



Special Rad Hard ThermoFisher cameras (CID8726DX7) and dedicated cabling have been received for the L4T and the HST installation.

# Conclusion

- Two WUs completed during LS1
- HST: on time Part 1 Q4 2015 & Part 2 Q1 2016
- BLMs & BTMS: A large cabling effort for YETS 16-17
- H<sup>-</sup> injection: on time for Linac4 connection
- BWS: on the critical path
- Other BI Work Units: No showstopper
- Can LIU provide a wishlist of monitors which might be installed before LS2 ?





# LHC Injectors Upgrade

**THANK YOU FOR YOUR ATTENTION!**





# Cost Breakdown

LIU-PSB	Budget Code	Section	Description	Type	2011	2012	2013	2014	2015	2016	2017	2018	TOTAL LIU (kCHF)			
PSB BLM System w/ IC in L2 sections	64020	BL	LIU-PSB BLM Upgrades	Ring - L2 section			127						127			
PSB BLM System w/ FIC in L3 sections				Ring - L3 section			11	30	123					164		
BLM for Extraction line w/ IC				Extraction				70	80						150	
BLMs for H- injection				BI line and H- injection				3	40	48						91
Fast BLMs at injection dump				H- injection					100	37						137
New Orbit System				64021	PI	LIU-PSB PU & BCT Upgrades	Cables in LS2		25	210	0	10	78	77	350	750
Watchdog (BR8.TMD)	4 Monitors		16				13	0	19	50	50	50		198		
DCCT Upgrade		9	15				20	50	10	10				114		
BTP Line Inductive Pus		10	131				103	20							264	
Wideband PU for BTP Line											35	40			75	
Screens at extraction BT.MTV10+30	64022	PM	LIU-PSB Profile Measurement Upgrades					9	8	11	4	45			7	84
H0/H- Meas at injection dump				H- injection				10	31	9					50	
BTV screen at stripping foil				H- injection		14	3	48	13	32					110	
New tank for BI.MTV30				H- injection			3	4	33					20	60	
T by T profile at injection				Based on fast SEM readout					10	90	20	15			135	
BI.SMV position plates				H- injection					0	40	10				50	
BWS Upgrade	64023	BL	LIU-PSB Wirescanner Upgrade					12	100	548	200	110	970			
Half Sector test	64025	BL+PM	LIU-PSB HST	H0/H- monitor				0	10				10			
				Screen + camera system				27	40	24				91		
				Stand & diamond BLMs				0	5					5		
<b>TOTAL LIU (kCHF)</b>					<b>19</b>	<b>203</b>	<b>485</b>	<b>159</b>	<b>681</b>	<b>1179</b>	<b>357</b>	<b>552</b>	<b>3635</b>			