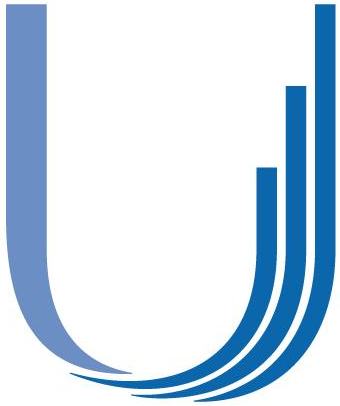
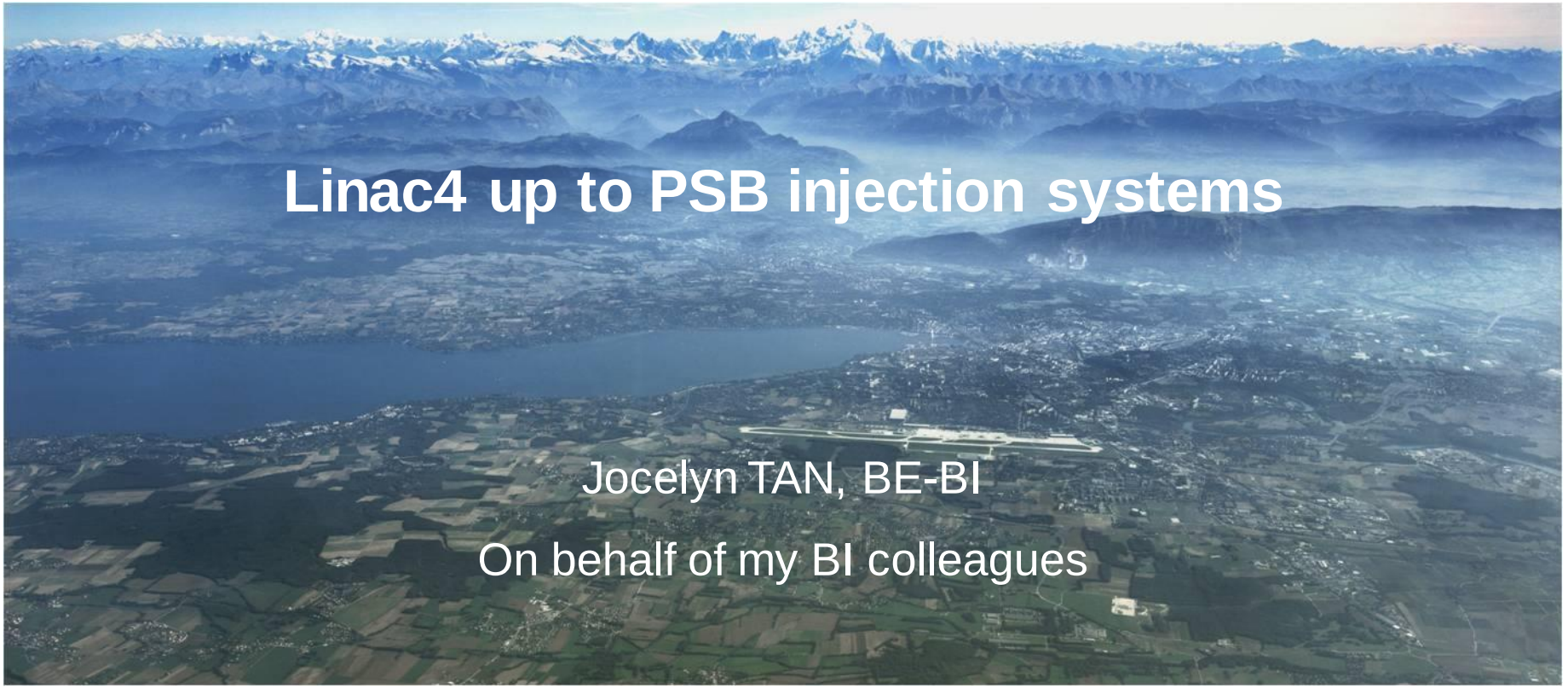


LHC Injectors Upgrade

LHC Injectors Upgrade



Linac4 up to PSB injection systems

Jocelyn TAN, BE-BI

On behalf of my BI colleagues

CERN

Outline

- Linac2 to PSB transfer lines
  - Fast BCTs
  - BPMs
- H^- INJECTION SYSTEM IN THE PSB
  - BLMs
  - H^0/H^- measurement at injection dump
  - BTV screens at stripping foil
  - SEM-Turn by turn profiles for injection matching
- New requests
- Conclusion

Fast BCTs - Consolidation

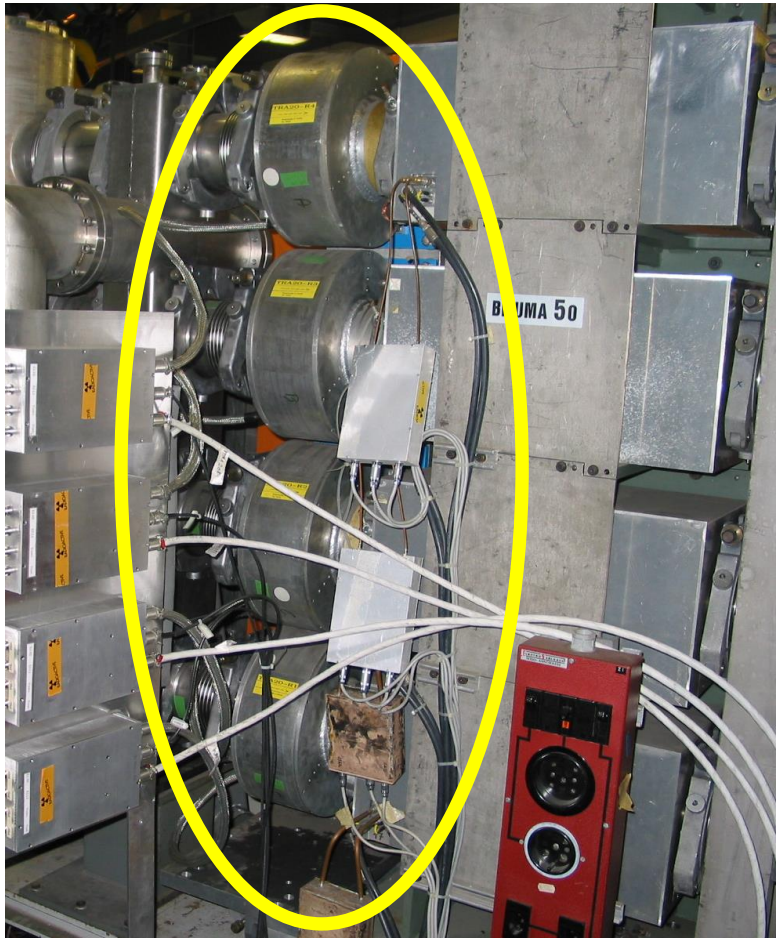
- Acquisition chain
  - Upgraded to TRIC
  - Acquisition moved to BOR: All monitors dowstream LT.BHZ20:
  - Planning: completed for LS1

- FBCT Proposed consolidation
  - Motivation: LT, LTB, LBE and LBS monitors are 35-40 years old
  - Budget: 280 kCHF for 7 BCTs
  - Planning: completed for Linac4 connection
  - WP responsible: BI-PI

Courtesy: L. Søby

Fast BCTs

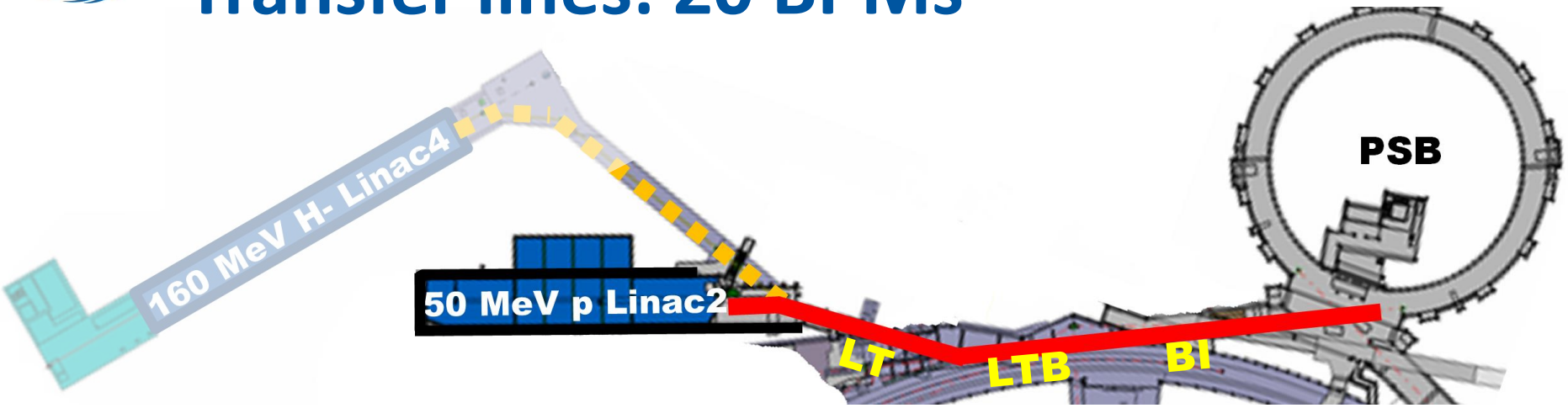
- BI.BCT10: Dose rate 10μS/h
- BI.BCT20: Dose rate **200μS/h**
- Present number of windings N=10
- For ultra short Linac4 pulses ⇒ N=20
- No spares
- Plan A:
  - LS1: Dismantle the BCTs for new windings
  - One hour per monitor
  - Collective dose: **~1000μS**
- Plan B:
  - New WP request
  - WP responsible: BI-PI
  - 2015 Build four new monitors (mechanics)
  - 2016 Ready for Linac4 connection to PSB
  - Collective dose: **~200μS**
  - Estimated cost 160 kCHF, on LIU budget



BI.BCT20: Four rings
Dose rate **200μS/h**

Courtesy: F. Lenardon

New BPMs in the Linac to Booster Transfer lines: 20 BPMs



- Motivation
  - Upgrade the LT, LTB and BI trajectory system with the Linac4 standards
- Specifications
  - Measure beam position with resolution /accuracy of 0.1/0.3 mm
  - Relative beam intensity between two BPMs (1% wrt peak current)
  - Beam phase wrt to RF reference (0.5º)
  - Energy via TOF between two BPMs (1 ‰)

Status of Development

- Commissioning
  - Sept.2012 - end of run
  - 1BPM tested with Linac2 beams
- MSWG endorsed the new system on 15/03/2013
- Cabling campain: completed
- Planning LS1
  - Analogue board: teething issues pending
  - Monitor production: on schedule
  - Nov. 2013-Jan.2014: Machine installation
- Concerns
  - Helicoflex seal – not specific to this device
  - All devices must pass new outgasing test
  - TE-VSC has limited manpower
- This system has top priority for post-LS1 start-up

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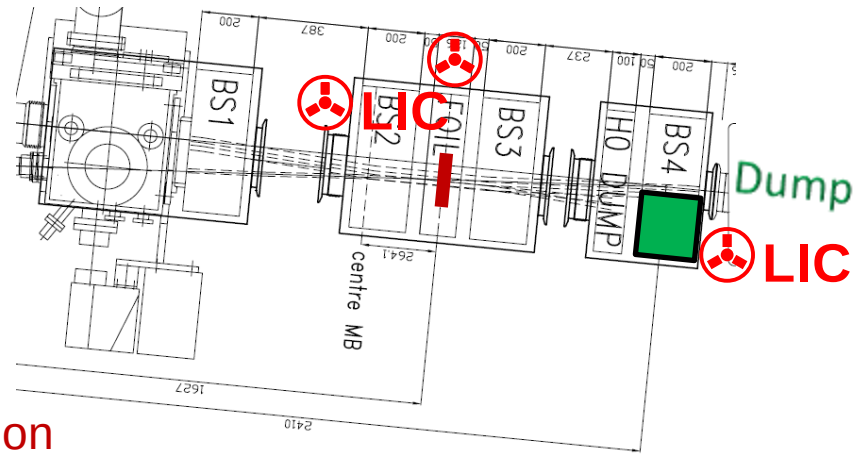
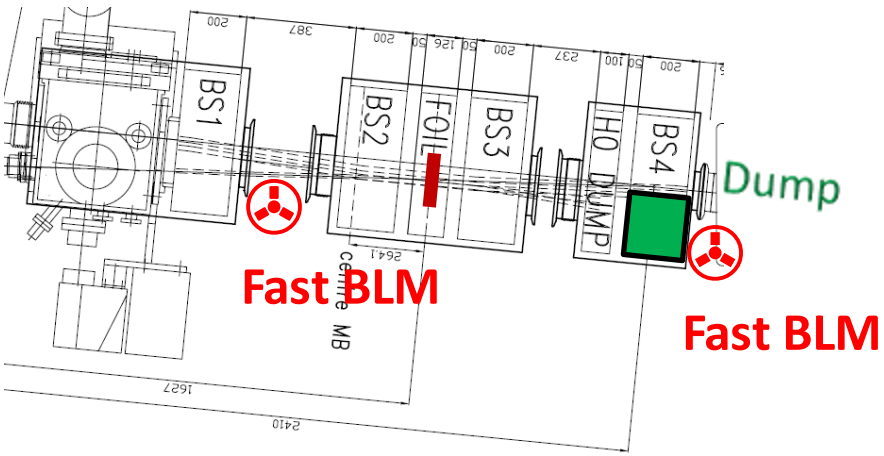
Beam Loss *Monitoring* in the H⁻ system



- Specifications
  - Monitor foil degradation
  - Machine protection : H0/H- dumps designed for 1bad pulse only: 2.5×10^{13} charges, 500 J
  - **Beam Interlock System** : Integration and High reliability
  - Resolution time : 2μs
  - Low loss threshold : PPM with FESA
  - High loss threshold : non-PPM, fully HW-based
  - PPM: enable/disable
- Proposed technology: Little Ionization Chambers (LIC)
  - Electronics: Ready
  - BLM support design and integration: Following the new vacuum sectorization, the final design from TE-ABT is needed
- Budget: 100 kCHF

Courtesy: C. Zamantzas

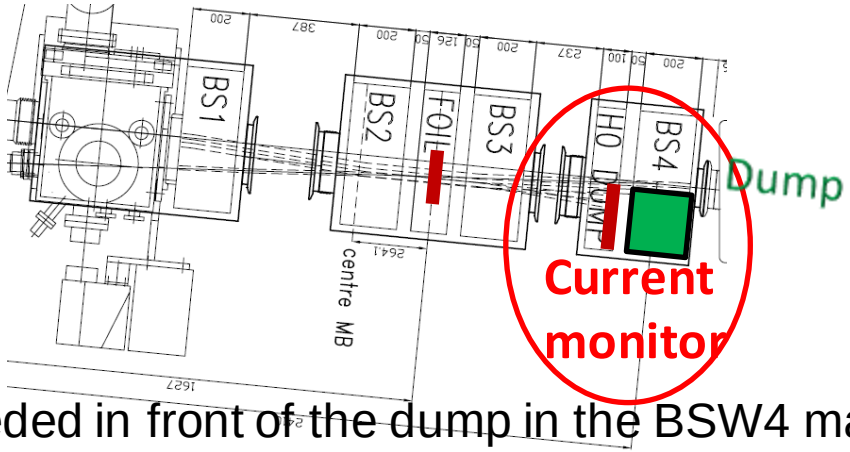
Beam Loss *Observation* in the H- system



- Specifications
  - Monitor fast losses and foil degradation
  - Optimize stripping efficiency over the injection duration (100μs)
  - Resolution time : 100 ns
  - Min/Max loss: $2x10^{10}$ / $2.5x10^{13}$
  - PPM acquisition
  - Read out under discussion: OASIS, or CIVIDEC, or VFC (BI standard carrier)
- Proposed technology: Diamond detector
- Budget : 150 kCHF

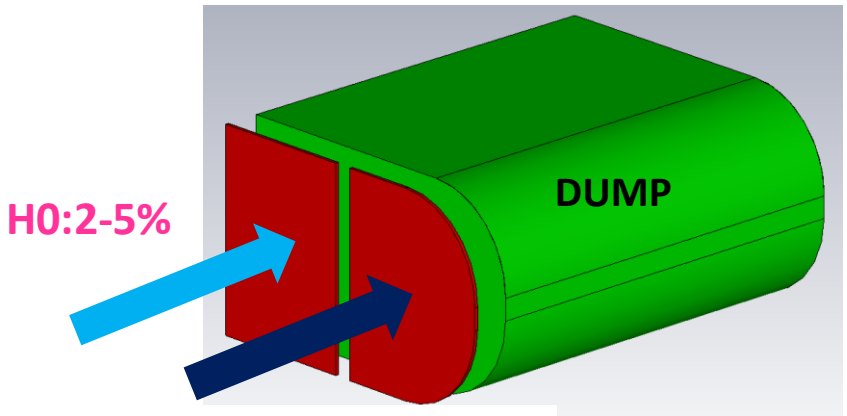
Courtesy: C. Zamantzas

H0/H- current monitor



H^0/ H^- current monitor needed in front of the dump in the BSW4 magnet

- to monitor the efficiency of the stripping foil (detect degradation and failure)
- to allow efficient setting up of the injection
- to protect the dump by providing an interlock signal in case of 10% detected beam load



Ratio $H^-/H^0 = 10^{-4}$

CONCEPT: plates intercepting the H^0 and H^- ions and acting as a Faraday cup for the stripped electrons (stripping & collection)

Courtesy: F. Zocca

Specifications

LINAC4 Project Document No.
L4-T-EP-0003 rev 1.0
CERN Div./Group or Supplier/Contractor Document No.
TE/ABT
EDMS Document No.
1069244

- Robust and simple (lifetime ≈ 20 years, no maintenance)
- Radiation dose of 0.1-1.0 MGy per year
- Vacuum level 10^{-9} mbar without beam (10^{-8} mbar with beam)
- Withstand the BSW4 pulsed magnetic field of 0.4T and at the same time do not perturb the field by more than ≈ 0.1 %
- Placed as close to the dump as possible (to minimize uncontrolled losses)
- Sensitive areas maximized to cover as much as beam halo as possible
- Withstand the heat load in normal operation condition and a full Linac4 pulse load (2.5×10^{13} H- ions), in case of failure of the stripping foil, on a one-off basis, several times per year
- Dynamic range: 5×10^{7} – 5×10^{12} ions (for H- and H0 alike)
- Absolute accuracy ± 20 %, relative accuracy ± 10 %
- Time resolution: integral over the full injection time (however better time resolution would be potential advantage for operational diagnostics)

Courtesy: F. Zocca

Proposed Technology

Titanium plates 1 mm thick:

- best compromise between the "high" conductivity needed for the current read-out and the "low" conductivity required by the presence of the magnetic field
- 1mm thickness suited to stop all the stripped electrons and tolerated in the presence of the vertical B-field (to avoid current loop in the horizontal plane)
- Acceptable thermal load (150 mW with 2% beam load)
- Low activation (low-Z material)

Comparison study with other materials:

Material	Conductivity (1/Ωm) (for signal read-out)	Thermal load (ΔT) for a full Linac4 pulse	Melting point	Neutron yield (w.r.t. n° of protons)	Signal Q (e/H^-) with NO external fields*	Signal Q (e/H^0) with NO external fields*	Compatibility with BS4 field
Graphite	6.1×10^4	67 K	3773 K	0.41 %	- 1.83	- 0.90	YES
Aluminum	3.77×10^7	50 K	933 K	0.57 %	- 1.63	- 0.80	NO
Titanium	2.34×10^6	80 K	1933 K	0.99 %	- 1.42	- 0.70	YES
Copper	5.96×10^7	98 K	1356 K	1.0 %	- 1.22	- 0.60	NO
Tungsten	1.89×10^7	229 K	3683 K	6.4 %	- 0.68	- 0.33	NO

Fully acceptable
Acceptable (not ideal)
Not acceptable

* taking into account losses due to electron backscattering and secondary emission

Courtesy: F. Zocca

Development and commissioning

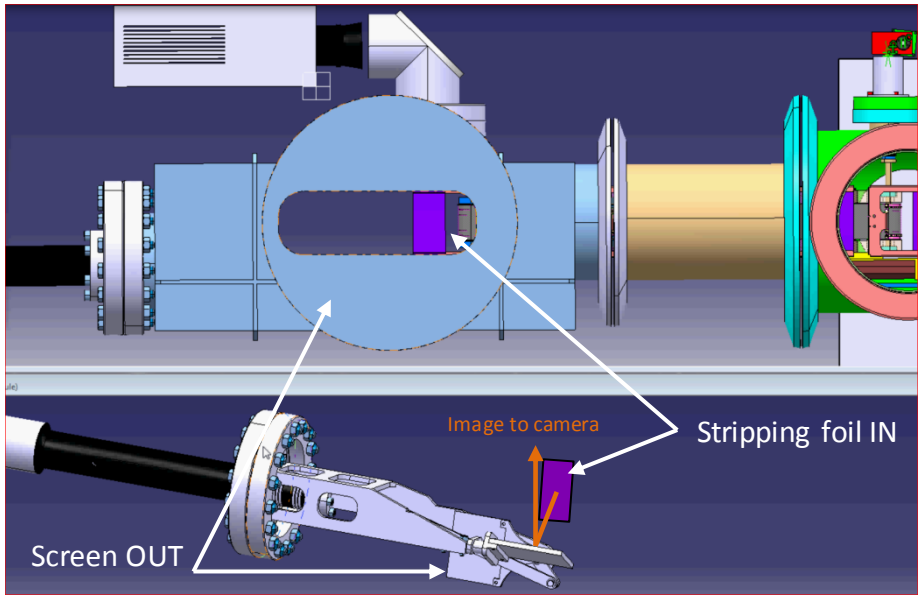
- Still on-going developments
  - Mechanical integration in the BSW4 magnet (plates support and cabling)
  - Not much flexibility for integration
  - Read-out electronics
  - Interlock circuitry: based on SEM interlock system
  - Feasibility study to add beam horizontal position information (NOT included in the specifications but potential advantage for operation diagnostics)
- Budget: 57 kCHF

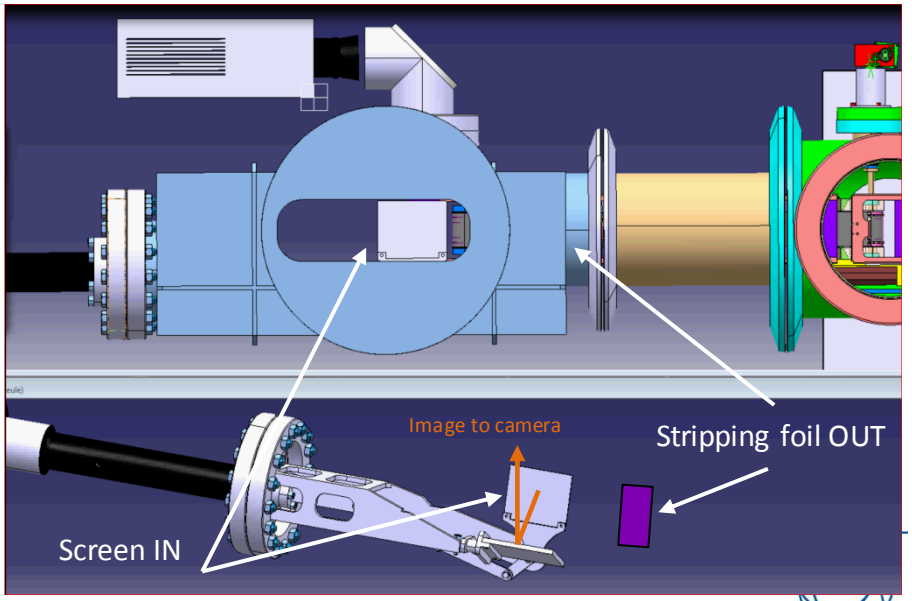
- 2014 : Finalize the integration design by Q2
- 2015 : Finalize electronics and interlock by Q4

Courtesy: F. Zocca

BTV screen at injection foil

- Foil inspection
- Measure injected beam position and size to steer the beam onto the foil after 1 turn
- Position / size accuracy : 0.2mm / 10%





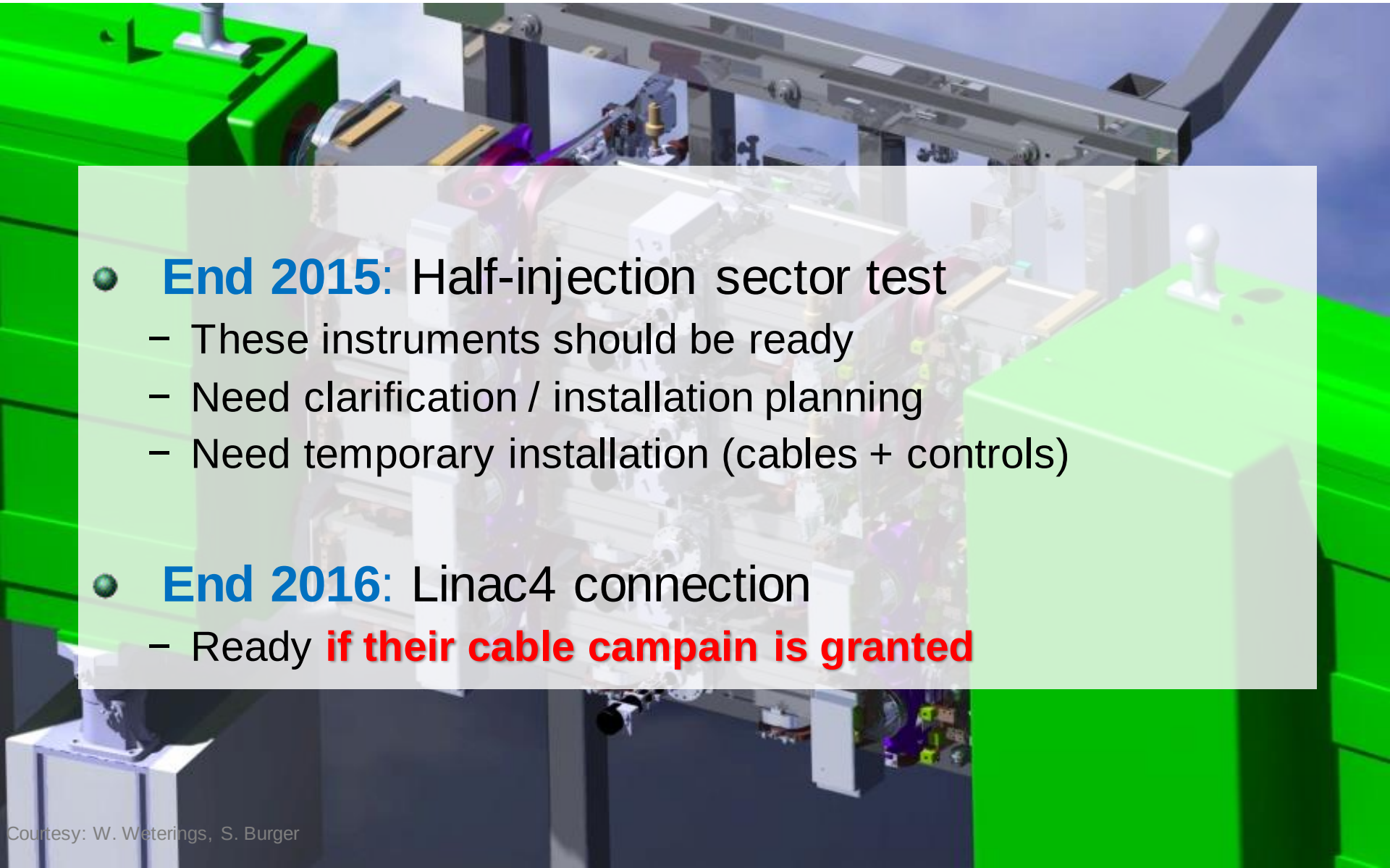
Courtesy: S. Burger

Development and commissioning

- Collaboration TE-ABT between and BE-BI
  - Mechanism integration
  - Interlock logic between screen and foil: to be defined
- Vidicon tube based camera
- Prototype: 80% to completion
- Budget: 120 kCHF
- 2014: Vacuum test of the prototype / validation
- 2015: Production of 4 BTVs + 2 spares

Courtesy: S. Burger

Planning for BTVs and H0/H- meas, and BLMs (LICs + Diamond)



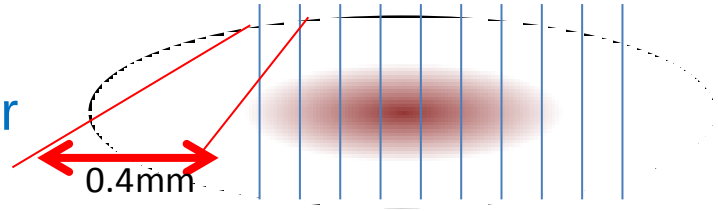
- **End 2015**: Half-injection sector test
  - These instruments should be ready
  - Need clarification / installation planning
  - Need temporary installation (cables + controls)
- **End 2016**: Linac4 connection
  - Ready **if their cable campain is granted**

Courtesy: W. Weterings, S. Burger

SEM grids for matching and emittance measurements at injection

- Specifications: based on 3 slides from C. Carli (26th October 2011)
  - injection of half a PSB turn (i.e. 0.5 μs, 2x10^{11} protons) to well separate turn-by-turn profiles
  - acquisition of – **say up to 20** – consecutive profiles
  - to avoid burning the wires : Implement an **interlock on the pre-chopper** to shorten the Linac4 pulse.
  - a pair of monitors (H+V) in one ring is sufficient
  - PPM In/Out (like the sieve) : **NOT OK**
  - *Permament implementation for MDs and operation:* **VERY DEMANDING**

- Mechanical specifications: compact monitor
  - grid size : 20mm
  - 48 graphite wires (∅= 33 μm)
  - Thick frame for stopping scattered protons



ε_{rms} of incoming beam 0.5 μm
beam size w/ β mismatch x2 1.1 -2.2 mm rms
PSB straight sections β_T = 5 m

Courtesy: C. Carli

Status

- Status
  - new monitor to be built,
  - WP responsible: section BI-PM
  - Few free straight sections: possible in 4L1
  - Simulations: 5mV Max. over 50 Ω on a wire
  - Study possibility to transport this weak signal through special coaxial lines (25m long) to the amplifiers.
- Budget : 135 KCHF
- Planning
  - 2015 Start electronics development
  - A few cables to be pulled
  - End 2016: Ready for Linac4 connection if signal/noise ratio is good enough

Courtesy: C. Carli, G.J Focker

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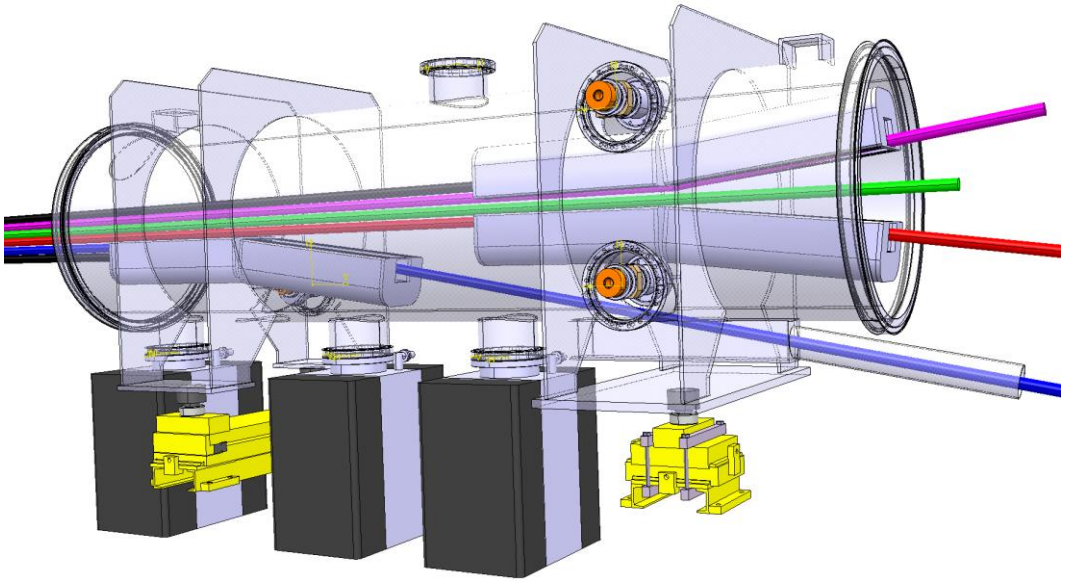
BI.SMV position plates



- Recent request, no specification, no WP
- Based on existing system: ensure the sliced beams are centered in their respective apertures.
- Metal plates, thickness to be defined for stopping electrons
- No interlock
- Direct signals on OASIS
- WP responsible: BI-PM, in collaboration with TE-ABT
- Planning: Septum design nearly completed ⇒ BI should propose a design ASAP

Courtesy: B. Mikulec, M. Hourican,

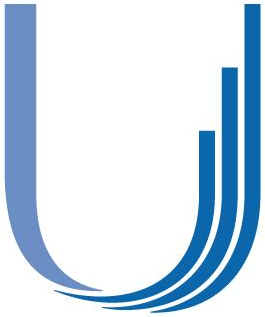
Schottky signals for energy spread measurements at injection

- Motivation:
  - Limited resolution from the Feshenko monitor in the LBS line
  - For BCMS beams: the PS needs very well defined energy spread
  - Compensate for longitudinal painting
- A schottky monitor in the PSB for $\Delta E/E$ at injection, using existing pick-ups.
- Recent request
- No specification, no WP, no planning
- WP responsible: BI-PI

Courtesy: B. Mikulec,

Conclusion

- New baseline for Linac4 to PSB connection: End 2016
- Commissioning in Half-injection sector test: OK if clear planning and temporary installation (cables + controls)
- Time and budget wise, the LIU-PSB WPs presented here can make it, provided the requested cables be pulled
- Some concerns:
  - BI.BCT20: high dose rate, no spare (CONS)
  - SEMs: S/N ratio, development in 2015
  - New WP requests: find resources



LHC Injectors Upgrade

THANK YOU FOR YOUR ATTENTION!