



LHC Injectors Upgrade

Final results from the HST

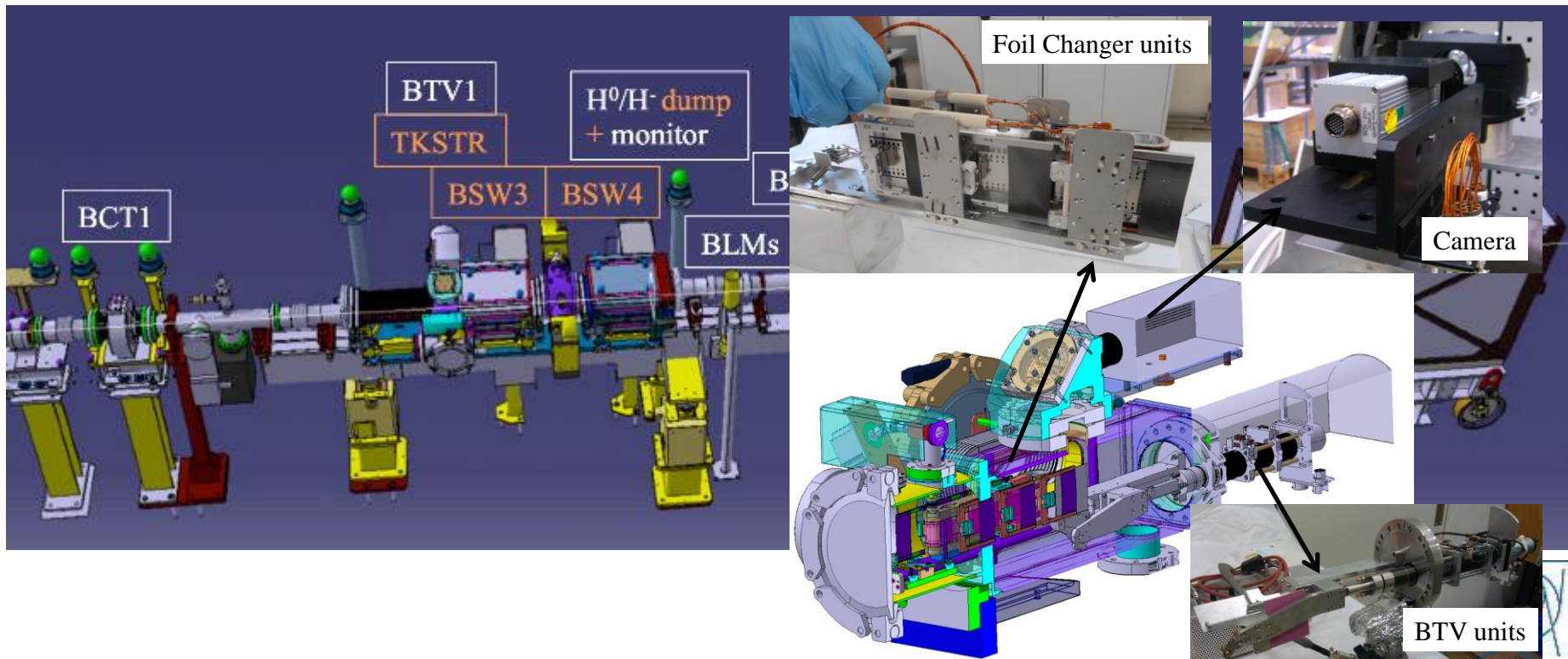
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THE HALF SECTOR TEST

Install half of the PSB injection chicane of one PSB ring in the Linac4 transfer line:

- Reduce the risks of installation problems;
- Avoid commissioning delays;
- Assure that the new equipment works according to specification.

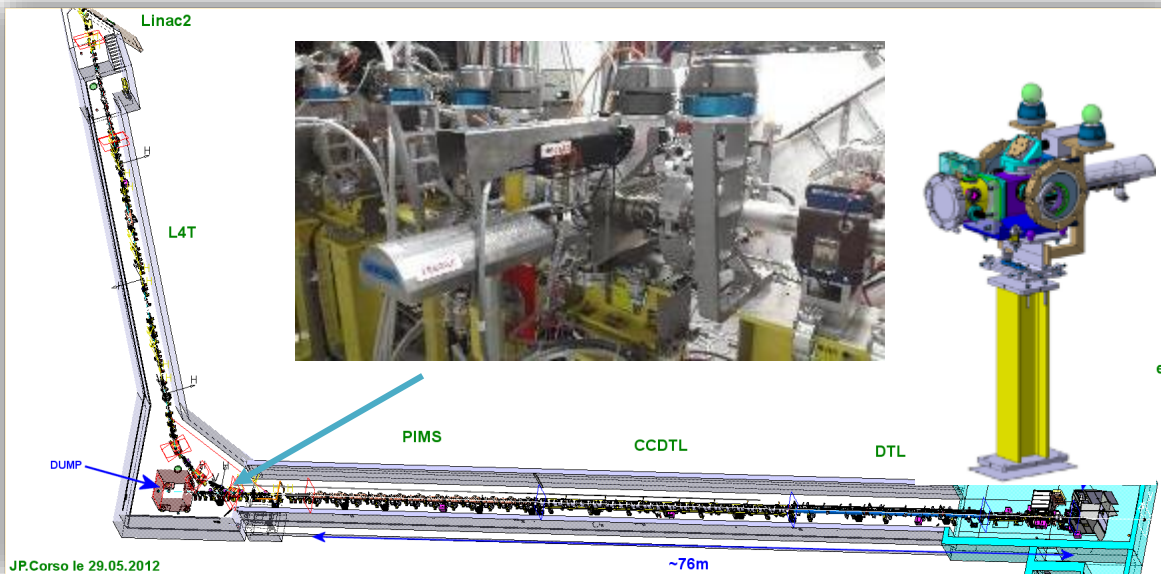




STRIPPING FOIL TEST STAND

A stripping foil test stand is installed in the Linac4 transfer line allowing tests with a 160 MeV H^- Linac4 beam:

- Testing of foil changing mechanism and interlocking functions;
- Gain experience with these very fragile foils;
- Test different foil materials and thicknesses;
- Evaluate the lifetime of the foils and foil holders;

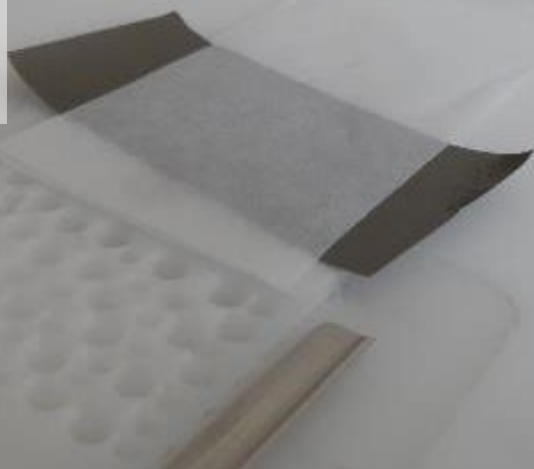


At present, stripping efficiency measurable only by means of cross-calibrated BCTs!

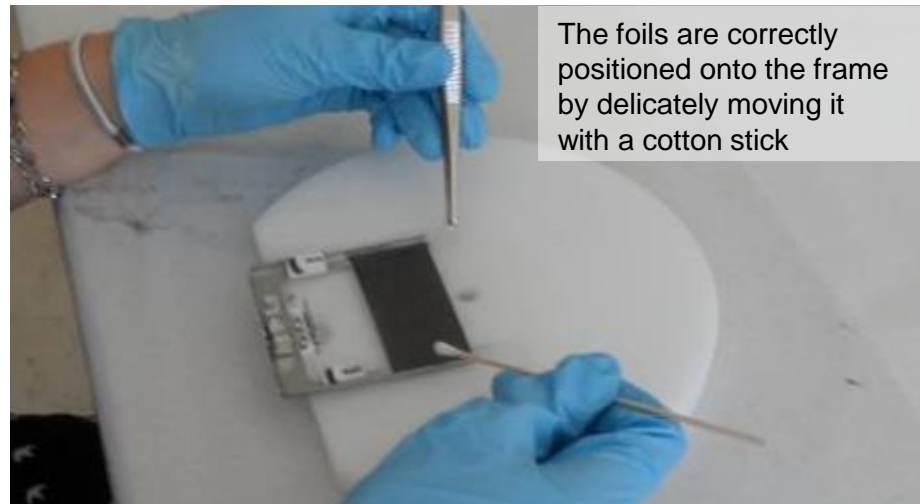


FOIL HANDLING

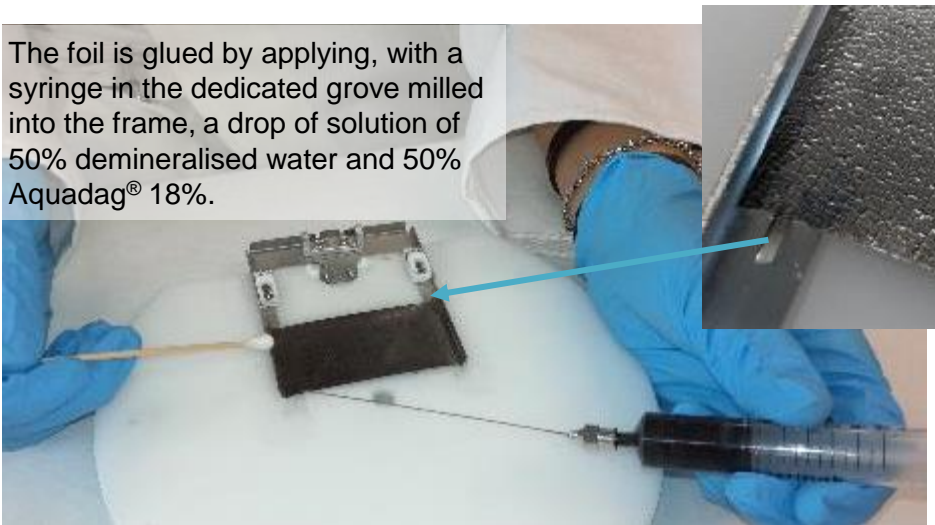
The foils are carefully manipulated between protective paper to avoid them curling.



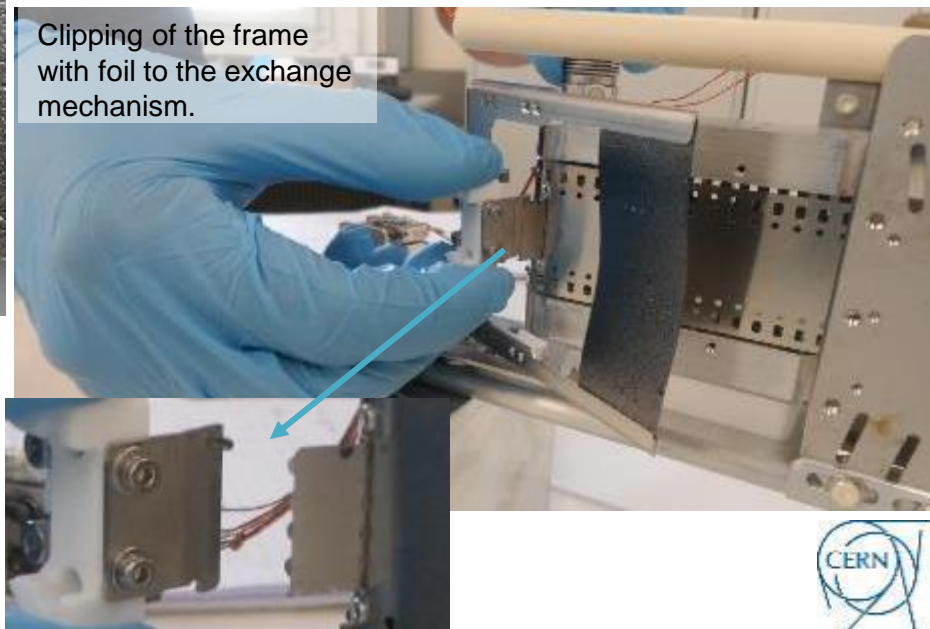
The foils are correctly positioned onto the frame by delicately moving it with a cotton stick.



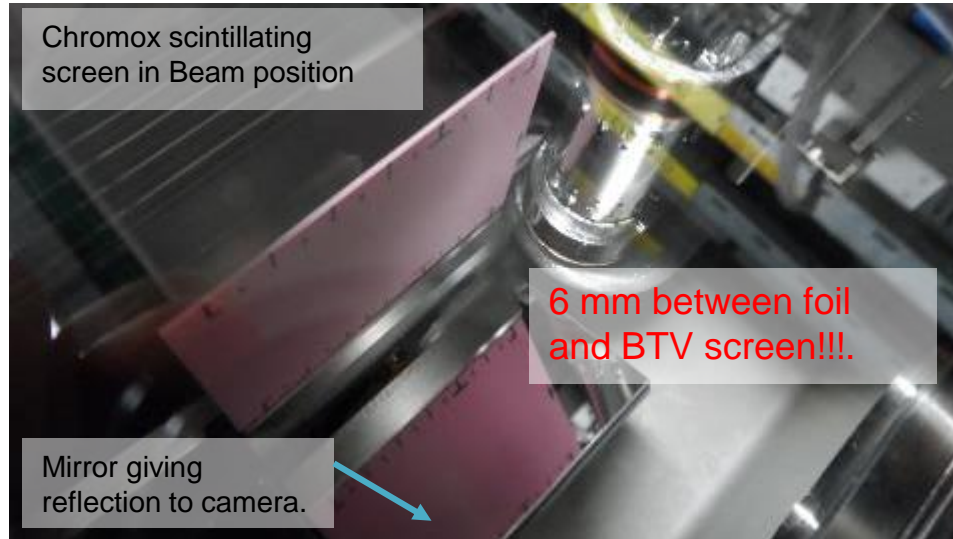
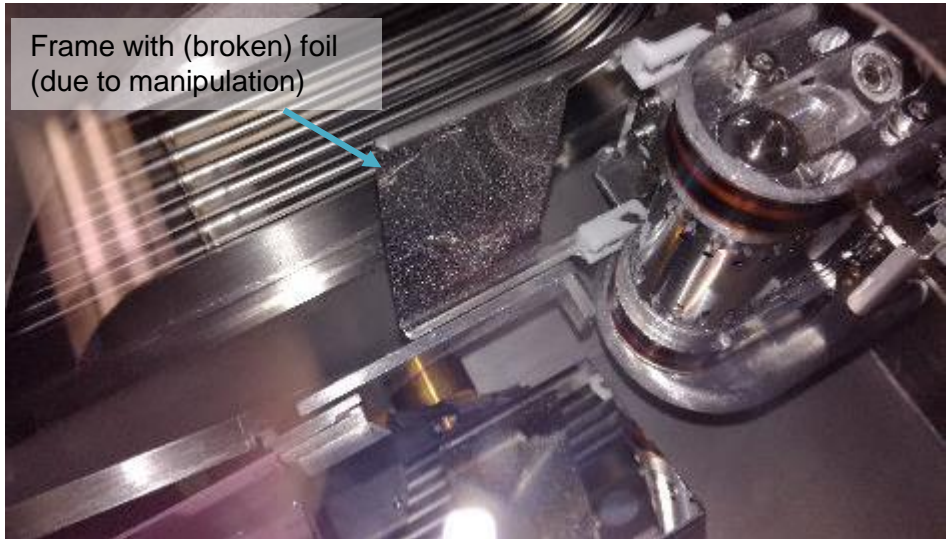
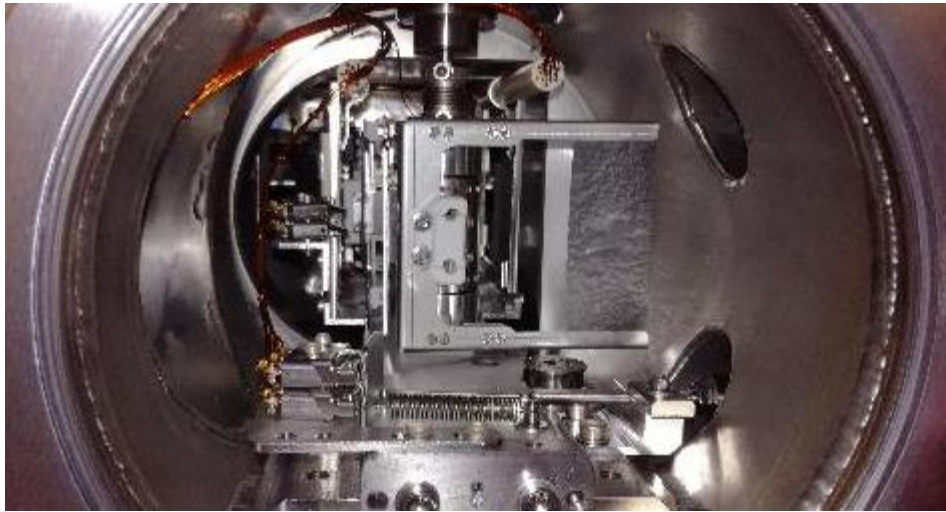
The foil is glued by applying, with a syringe in the dedicated groove milled into the frame, a drop of solution of 50% demineralised water and 50% Aquadag® 18%.



Clipping of the frame with foil to the exchange mechanism.



U FOIL HANDLING





OPERATIONAL EXPERIENCE

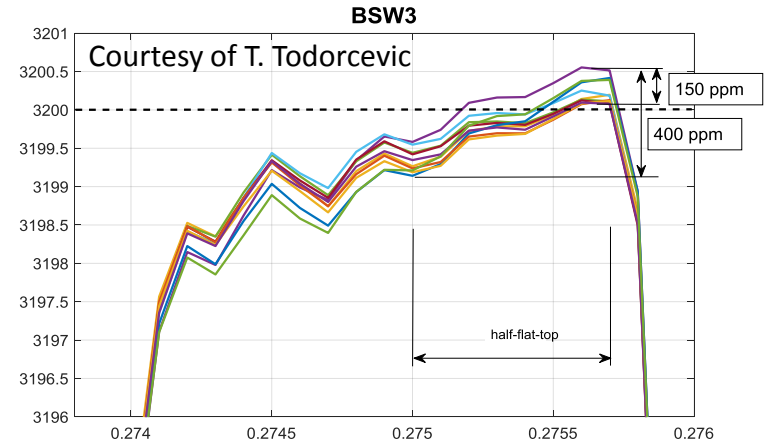
- Foil temperature measurement was not possible (always below 170°C);
- The requested ± 0.1 mm reproducibility achieved after calibration;
- Interlock logic (foil / BTV) was validated;
- BTV fully commissioned and camera inspection proved to be very useful;
- Mechanism was improved for test stand (got stuck in intermediate position).
- Interlock was added to stop the beam in case of screen movement;
- Foil breakage occurred sometimes when beam on BTV in front of foil, reason not fully understood. (Test Stand now has conductive, Ag coated, screen);
- In one occasion a foil frame got stuck behind a micro-switch. The system could be unblocked by reversing the movement of the band but this maneuver caused the rupture of the foil.
- Foil current measurement proved to be useless, stripped electrons not stopped by 1 μ m thin foils;



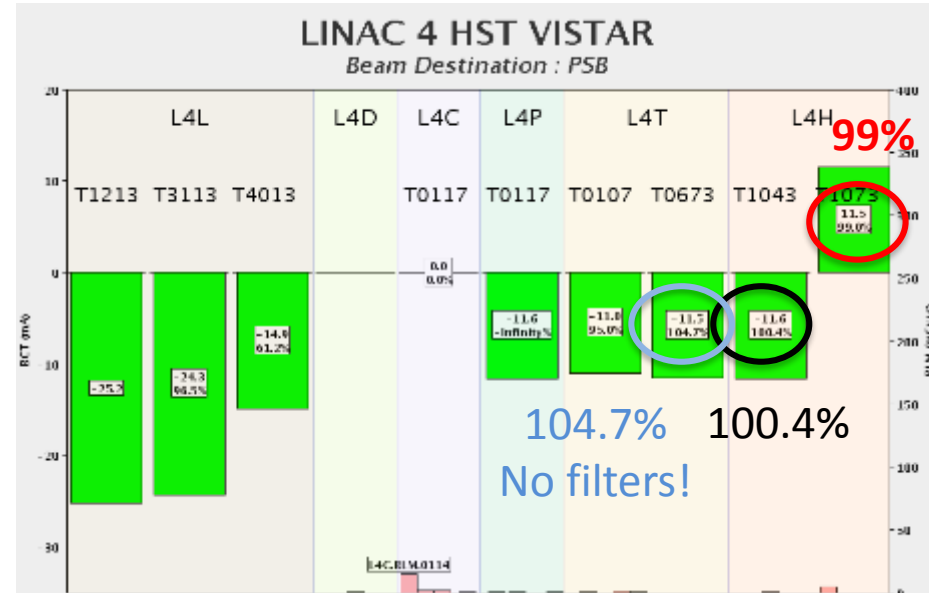
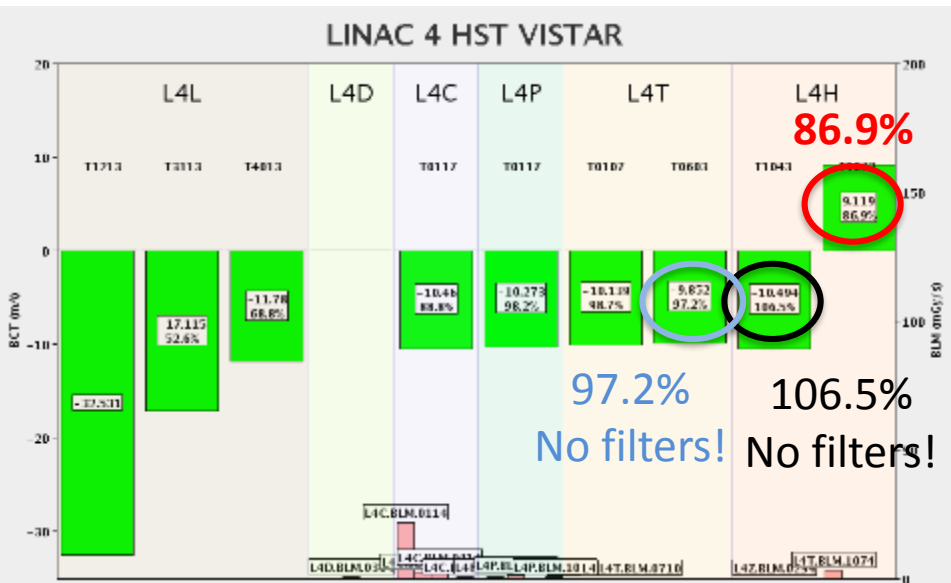


HST OPERATION OVERVIEW

- Operation with chicane magnets and power converters was flawless, BSW flat top precision still needs to be improved;
- Redesign of H⁰H⁻ dump electronics card was necessary to suppress noise for required interlocking functionality;
- Diamond BLMs: noise needs to be reduced for final installation
- New filters in BCT amplifiers to suppress high-frequency beam signals;

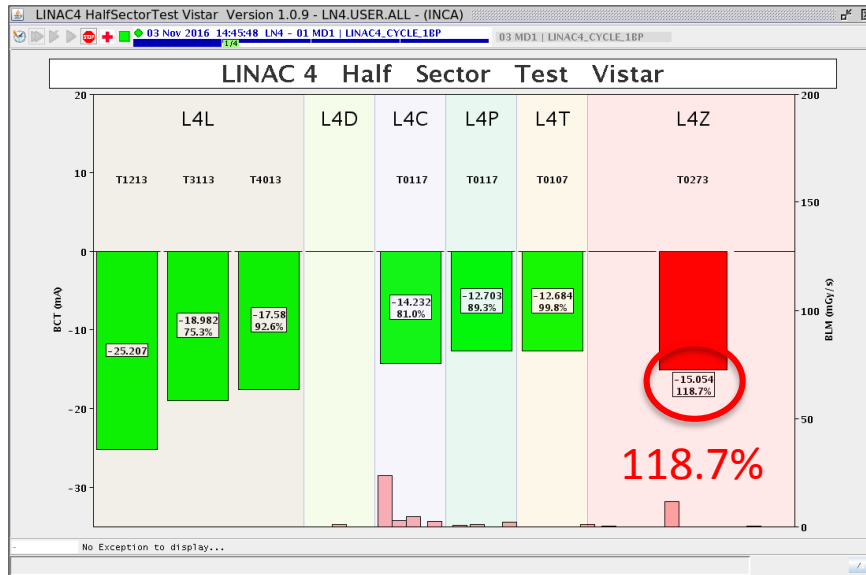


Specs: 50 ppm @ flattop, planned to implement current regulation + new switching technique (if needed)

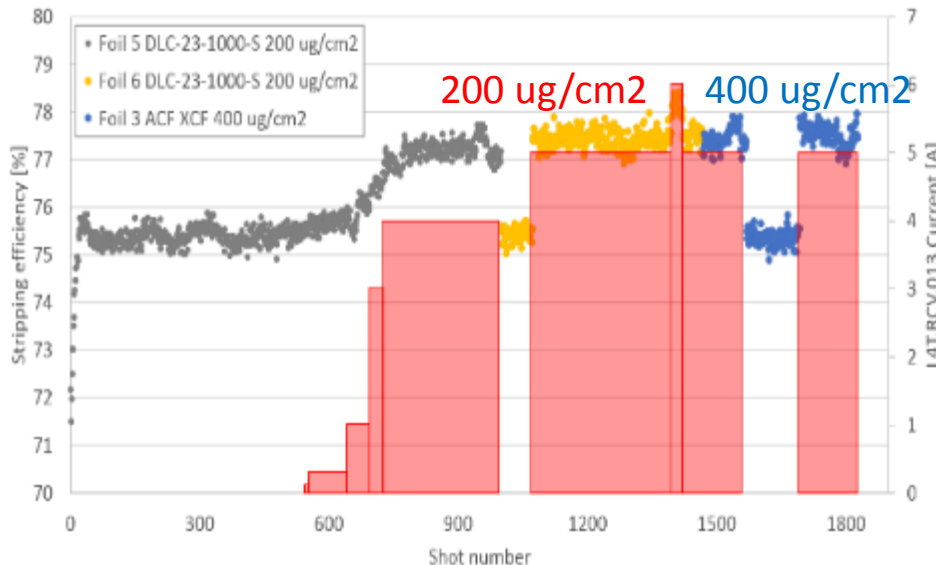




STRIPPING EFFICIENCY MEASUREMENTS @ TEST STAND



- The stripping efficiency at the test stand evaluated only by comparing the signals of two cross-calibrated Beam Current Transformers (BCT) located at each side of the unit.
- An unrealistic 120% transmission was measured without foil preventing reliable measurements.
- The same transmission was calculated for all the foils including the 400 mg/cm² thick one → stripping efficiency close to 100%.
- Influence of the stripped electrons escaping the foil on the current at the downstream BCT
- Investigate possibility to collect and measure the stripped electrons for future operation.



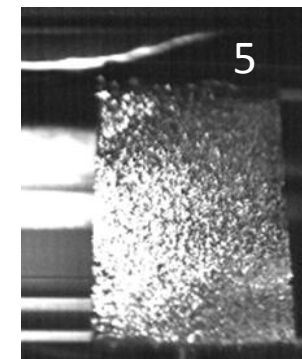
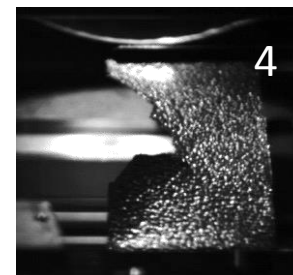
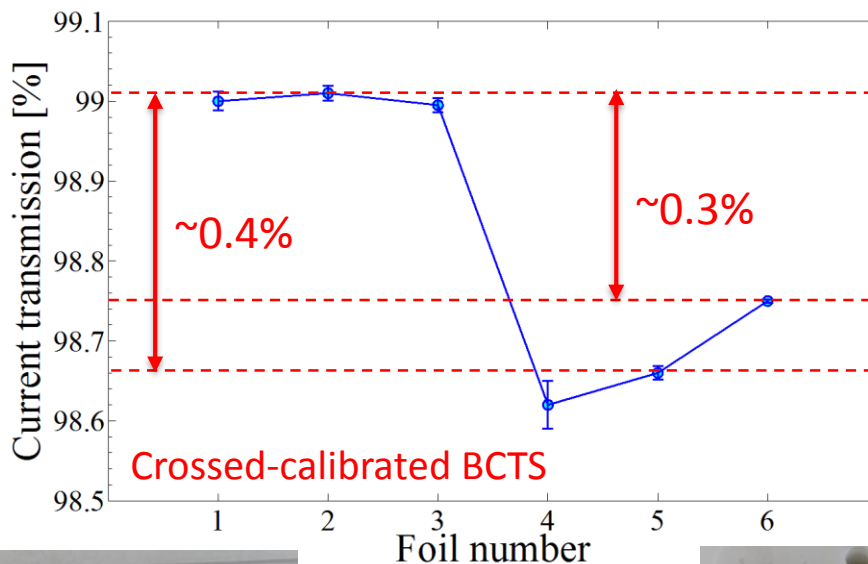
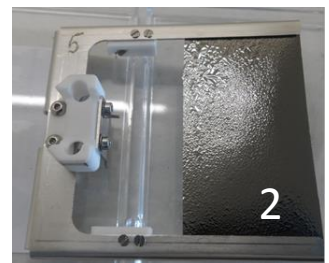
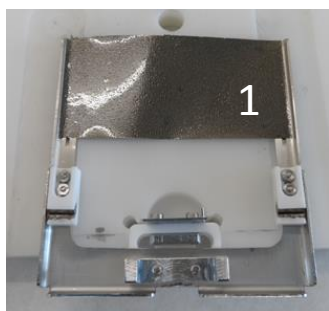


STRIPPING EFFICIENCY MEASUREMENTS @ HST

Table 1: Stripping foil characteristics. The identification number of the foils used for the stripping efficiency measurements presented in Fig. 3 is also shown. Foil 3* was broken and replaced in January 2017

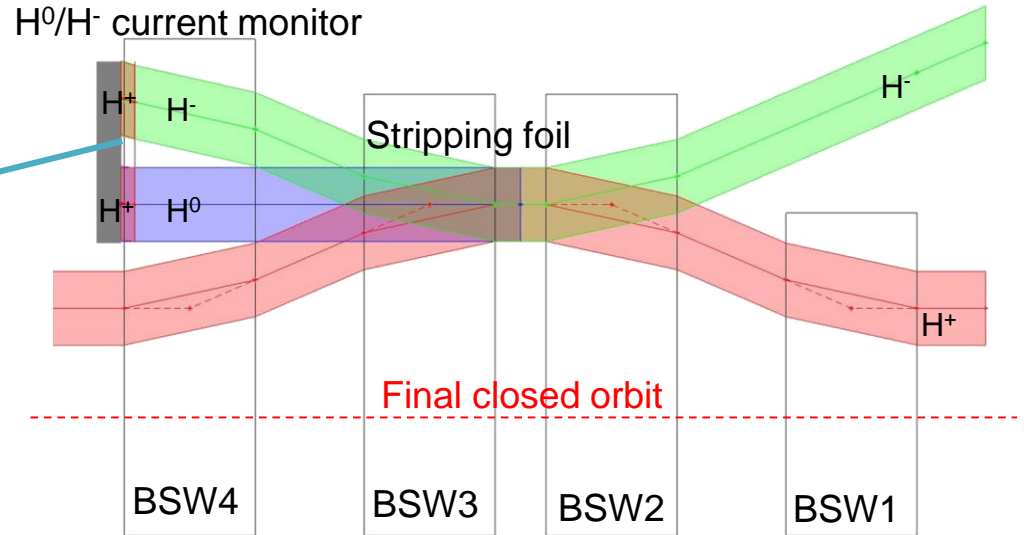
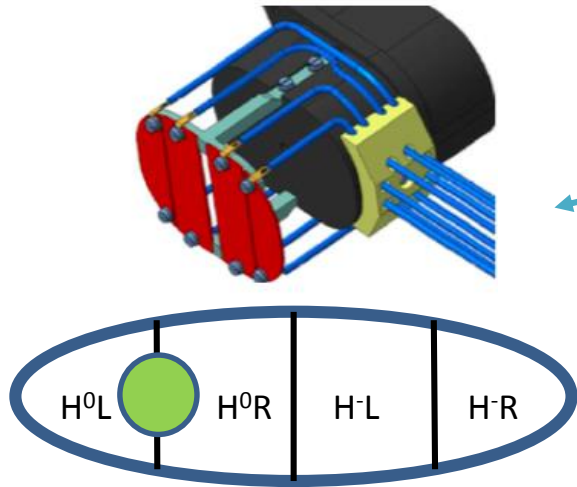
Description	Thickness [$\mu\text{g}/\text{cm}^2$]	Size [mm]	Foil number
XCF-200, arc evaporated amorphous Carbon, collodion coated [11]	200	32×68	1-4
XCF-400, arc evaporated amorphous Carbon [11]	400	32×68	3*
DLC-23-1000-S, diamond-like Carbon, boron doped 10% [12]	200	32×68	2-3
HBC, hybrid type Boron mixed Carbon [13]	200	21×68	5-6

Current transmission (BCTs)
Foil 1, 2 and 3: ~99%
Foil 4, 5 and 6: ~98.6%

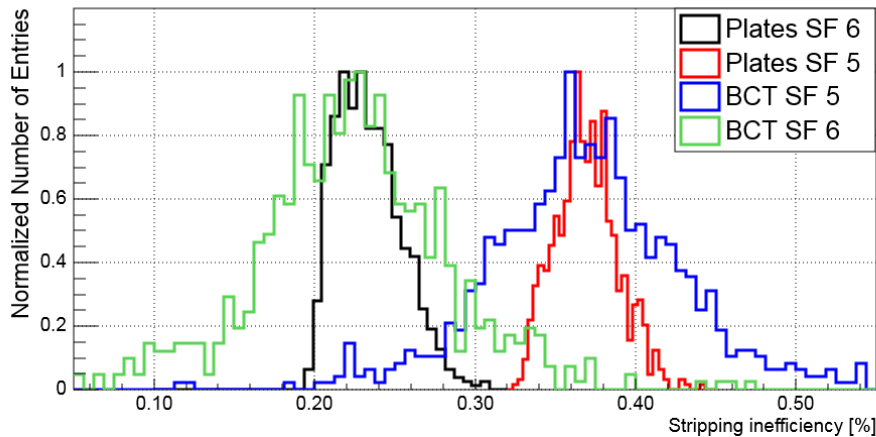




STRIPPING EFFICIENCY MEASUREMENTS @ HST



Calibration factor calculated by normalizing the plate signal to the number of H⁺ charges measured by upstream BCT.



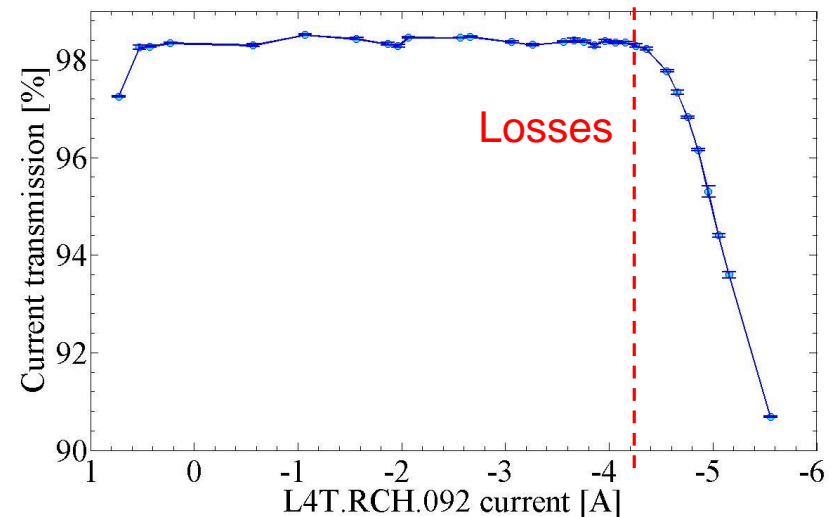
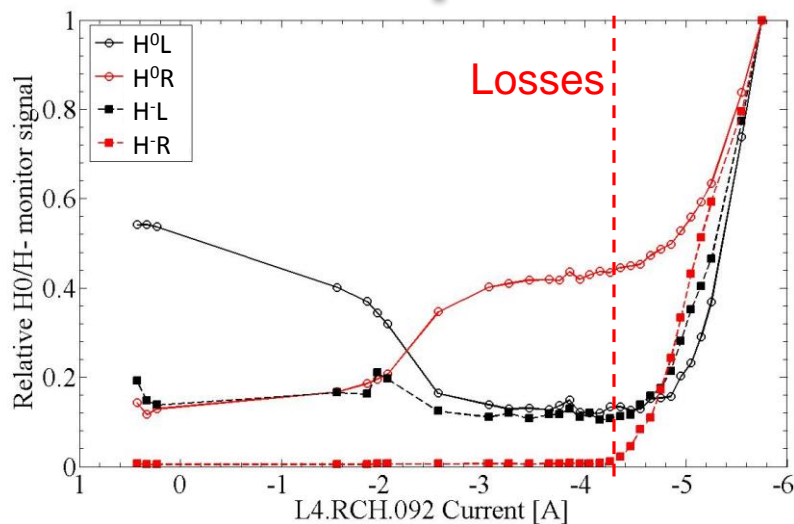
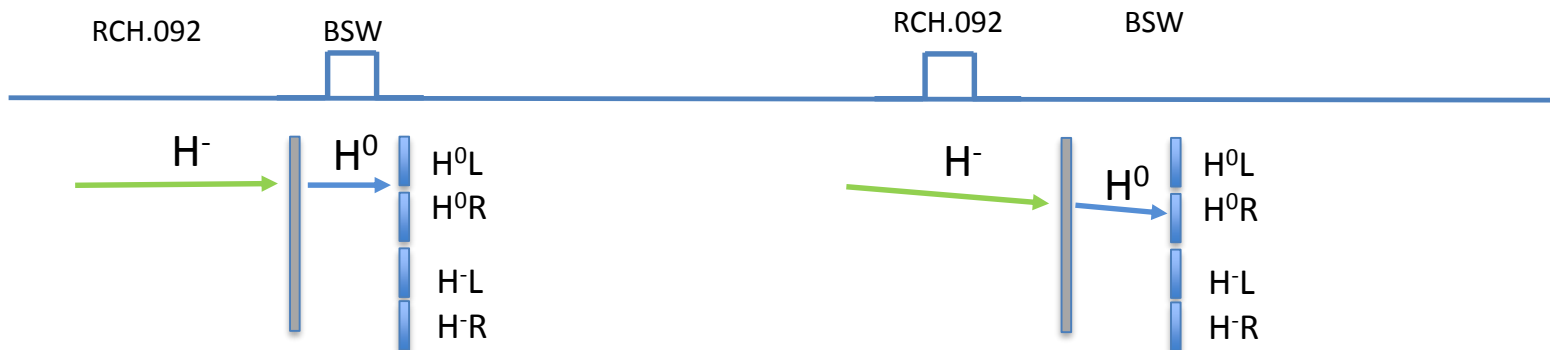
Stripping efficiency:
 Foils 1,2 and 3: ~100%
 Foils 4,5 and 6: ~99.6%
 1% stripped beam lost
 between two BCTs

Stripping Foils 1 to 4	
H0H- Plates	With BCTs
No signal	~ 1 %

Stripping Foil 5		Stripping Foil 6	
H0H- Plates	With BCTs	H0H- Plates	With BCTs
0.369%	0.389 %	0.234 %	0.243 %

STRIPPING EFFICIENCY MEASUREMENTS @ HST

- Only for the Boron mixed carbon foils a current above noise level could be measured by the H^0 monitor pointing to partially stripped beam.
- This hypothesis was validated by steering the beam to the right:
 - With BSW \rightarrow no change at H^0/H^- current monitor (neutral beam after stripping foil)
 - With a horizontal corrector located upstream of the foil \rightarrow signal on the monitor moved from the H^{0L} Left to H^{0R} .





SUMMARY

- The operational experience gained with the stripping foil units and the related diagnostics represent a fundamental step in view of the future commissioning of the new PSB injection system.
- All the main functionalities were checked and validated.
- A few weaknesses could be found; some were fixed and further improvements are being developed.
- First stripping efficiency measurements could be performed, after having solved some diagnostics issue, and confirmed the expected $>99\%$ for 200 $\mu\text{g}/\text{cm}^2$ thick Carbon based foils fulfilling the design specifications.



REFERENCES

- B. Mikulec et al., “Commissioning and Results of the Half Sector Test Installation with 160 MeV H⁻ Beam from Linac4”, in Proc. IPAC’17, Copenhagen, Denmark, May 2017, MOPIK047.
- C. Bracco et al., “Commissioning of the Stripping Foil Units for the Upgrade of the PSB H⁻ Injection System”, in Proc. IPAC’17, Copenhagen, Denmark, May 2017, MOPIK041
- F. Roncarolo et al., “Beam Instrumentation for the CERN Linac4 and PSB Half Sector Test”, in Proc. IPAC’17, Copenhagen, Denmark, May 2017, MOPAB120.
- W. Weterings et al., “First Experience with Carbon Stripping Foils for the 160 MeV H⁻ Injection into the CERN PSB”, in Proc. INTDS16, Physics Procedia (2017), Cape Town, South Africa, November 2016





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THANK YOU FOR YOUR ATTENTION!

