PSB H0H- Monitor Calibration and Commissioning

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IBIC 2021

ABSTRACT

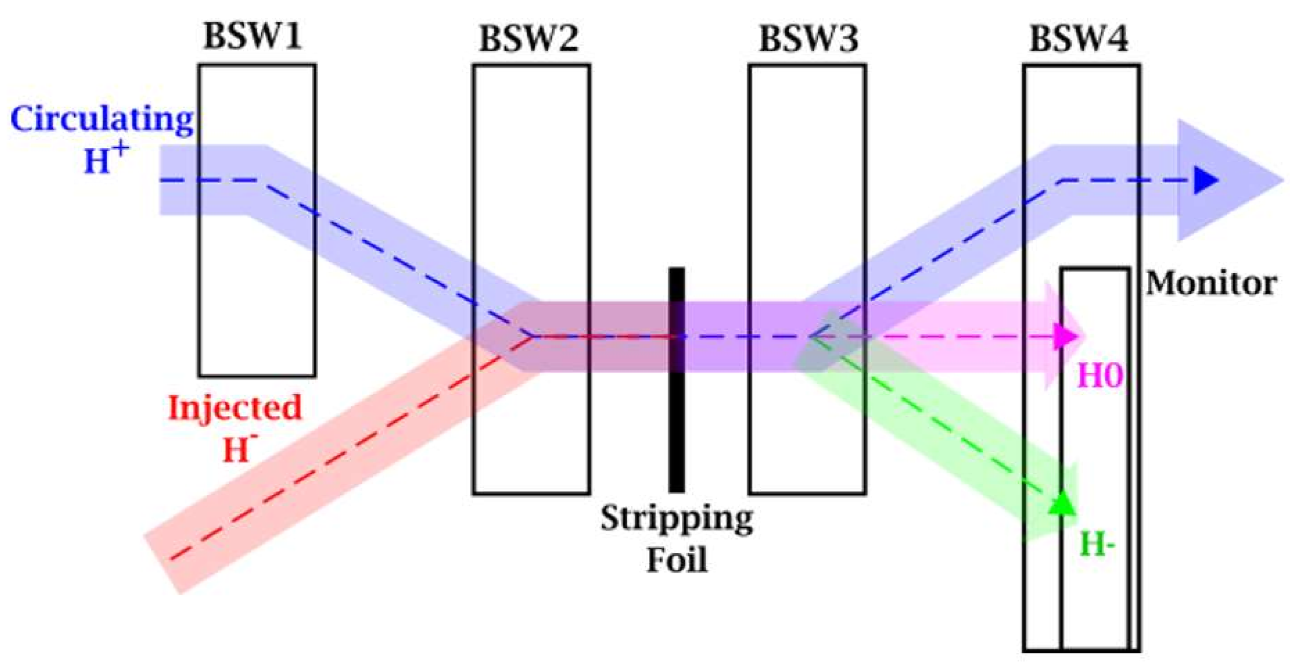
During the LHC Long Shutdown 2 (LS2), the H^- LINAC4 replaced the proton LINAC2 as Proton Synchrotron Booster (PSB) injector. In each of the four PSB rings, the injection region was upgraded to accommodate the necessary elements for a proper H^- charge exchange injection systems. Four internal beam dumps (one per ring), installed downstream the stripping foil, block the unstripped H^- particles not injected in the ring. The H^0H^- monitors consists in 4 titanium plates placed few centimetres upstream of the dump, intercepting partially stripped H^0 or not stripped H^- ions. They allow a continuous monitoring of the stripping efficiency and, connected to an interlock system, block the injection process in case of heavy degradation or breakage of the foil, which would heavily damage the dumps.

The contribution will focus on the commissioning and operation these new systems. This will include the calibration campaigns, performed by comparison to beam current transformers during special periods with low intensity beams and no stripping foils. During normal operation it was already possible to monitor stripping inefficiencies below 1% and compare different beams and stripping foil types.

Charge Exchange at PSB

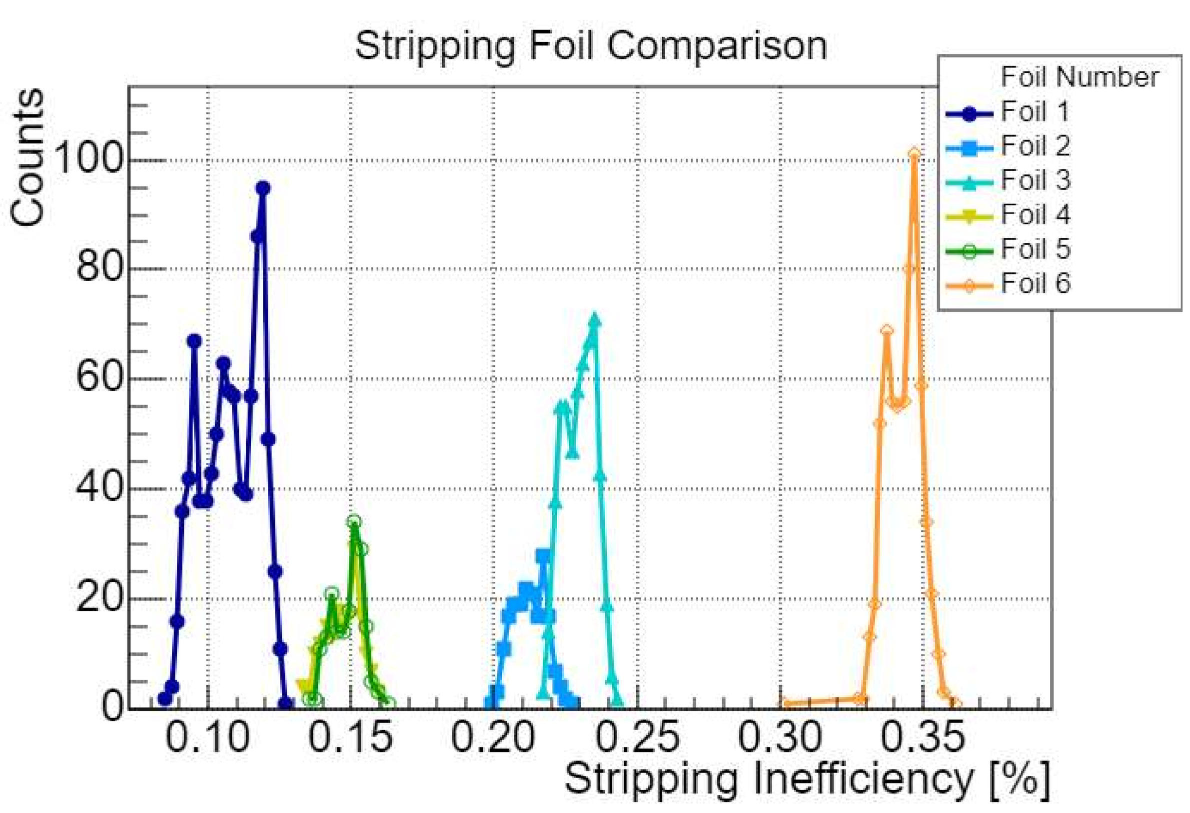
To inject the H^- beam in the PSB, a charge exchange injection system is used. This system comprises a stripping foil, a set of four pulsed dipole magnets (BSW) and four horizontal kickers (KSW). The first magnet (BSW1) acts as a septum, dividing the high field region of the circulating beam and the field-free region of the injected H^- beam. It is followed by 3 bumper magnets (BSW2-4), that help merging the injected beam to the circulating beam.

The stripping foil (about 20 mm wide and 20 mm high) is a carbon foil around 200 μgcm^{-2} . This foil, is in charge of stripping the electrons from the incident H^- particles. After the stripping foil, the completely stripped protons are injected into the circulating beam and the partially stripped, and unstripped ions are collected by the dedicated dump. The geometry of the dump provides an unobstructed passage for the circulating beam during injection as well as the injected proton beam, whilst providing optimum protection of the downstream elements by absorbing the few percent of unstripped beam during regular operation, and also by absorbing the full beam in the event of a foil failure.



Stripping Efficiency Calculations

After the calibration phase, the $H\,0H-$ monitors were used to measure the stripping efficiency from a set of six different stripping foils. This monitors are now fully commissioned and in continuous operation. They are able to measure inefficiencies smaller than 1%.

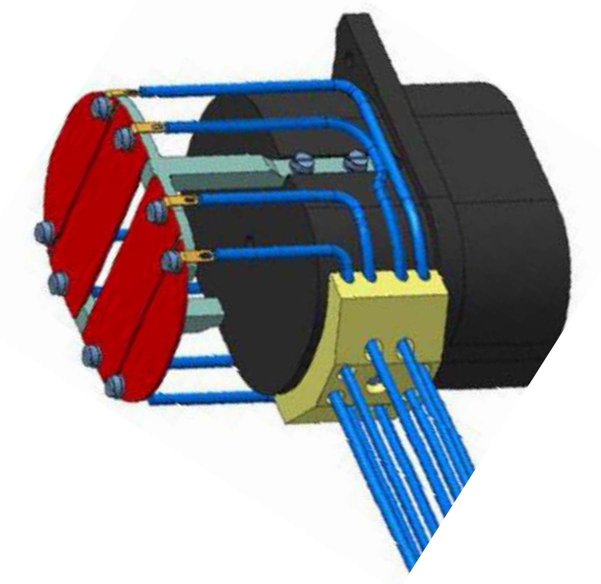


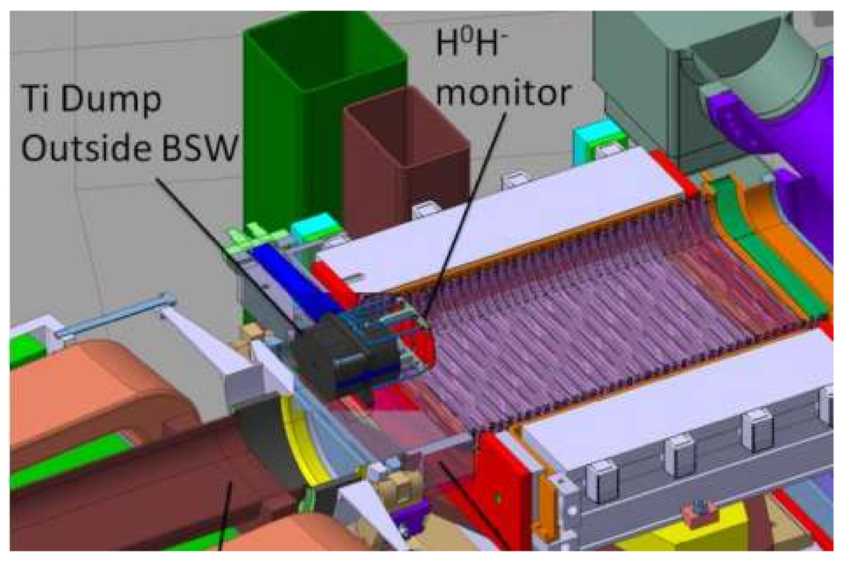
H0H- Monitors

The H^0H^- monitors are installed at a distance of 4 cm from the face of the dump. The H^0H^- monitors consist in four titanium plates, with a separation between them of 1 mm. The two more external plates are expected to measure H^- particles while the two most internal plates are expected to measure the partially stripped H^0 particles. The electrical signal generated in the plates allows determining the number of H^0 and H^- particles reaching the dump, and thus the stripping inefficiency.

$$Q\left(\frac{e}{Proj}\right) = Q_{dep} + Q_{SE} \qquad Q_{dep} = N_p \cdot \eta - N_e \cdot \mu$$

The expected number of H^0 particles should be 2% of the total Linac4 pulse. The total number of H^- particles is expected ≈ 10^{-4} %. Currents larger than10%of Linac4 beam pulse generates an interlock signal that stops the particle beam.





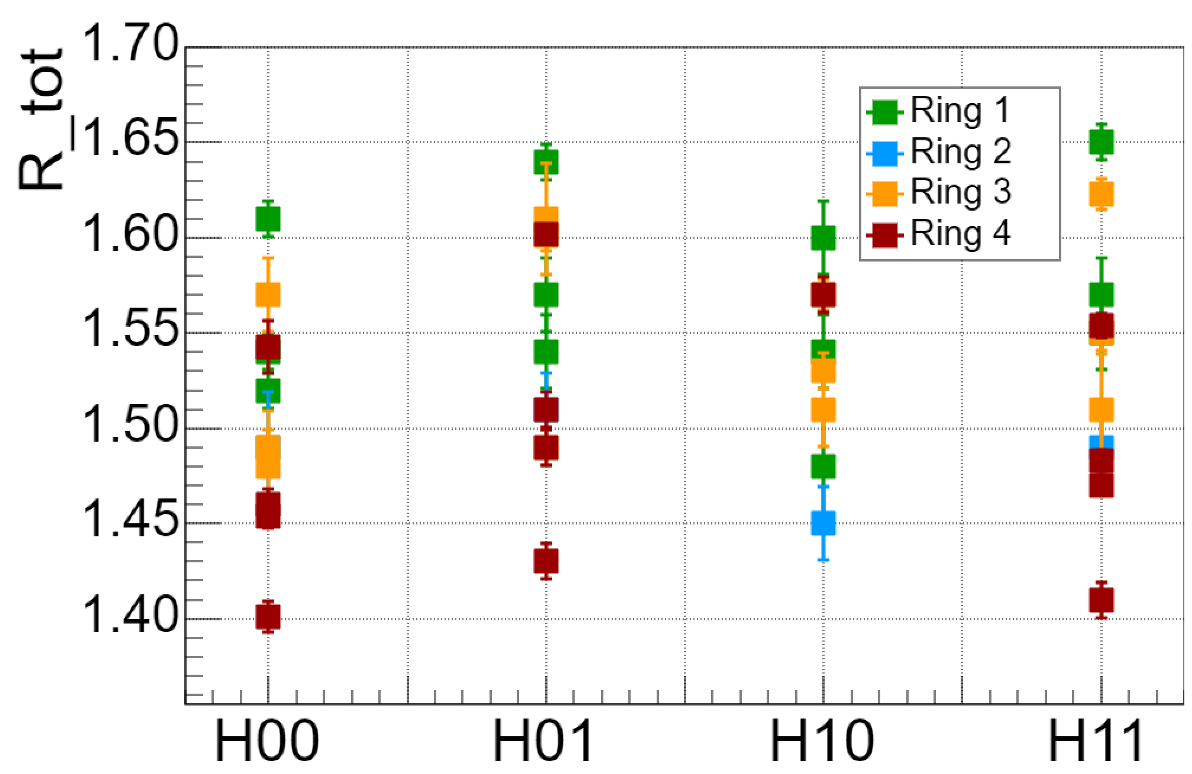
H0H- Calibration Procedure and Results

The main goal of these measurements was to obtain a calibration factor ($Rtot$) which, independently of the intensity or type of beam, relates the signal in the plates with the total number of particles reaching the dump. The tests were performed with an H- beam of particles, and a reduced beam intensity $I_{beam} < 4$mA. . A calibration factor was calculated for each one of the plates in each one of the rings, by comparing the signal measured in the plates with the signal measured by the BCTs.

$$R_i\left[\frac{Charge}{ADCcounts}\right] = \frac{SignalBCT}{SignalPlate}$$

All the measurements seem to agree to a calibration factor of R = 1.53·10−8 [Charges/ADC counts]. This calibration factor seems to remain stable within a 1.5 % for all the plates over different beam conditions. From this calibration factor, the total number of particles reaching the dump can be calculated as follows:

$$N_{Part} = R_{TOT} \cdot (2 \cdot H_{00} + 2 \cdot H_{01} + H_{M0} + H_{M1})$$



Outlook

During the long Shutdown 2, LINAC4 Replaced LINAC2 as PSB injector. The newly installed H0H- intensity monitors are indispensable for insuring a proper charge exchange injection. Due to the complexity of the electronics, a calibration factor was necessary to correlate the ADC signals with the number of particles reaching the dump. This monitors are now fully commissioned and in continuous operation. They are able to measure inefficiencies smaller than 1%.