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WIEN FILTER UPGRADE AND MEASUREMENT FOR BETSI TEST BENCH*

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Abstract

During first operation of SILHI in 1995 at CEA Saclay, a velocity filter diagnostic (Wien Filter) was installed on the LEBT (Low Energy Beam Transport), analysing the 100 mA of protons at 95 keV. The device was used many years providing beam proportion measurements on the beam axis. Unfortunately, it was damaged while handling and was no longer working as intended. This paper describes the maintenance and upgrade of the diagnostic as well as the first beam proportion figures with ALISES v2 ion source.

INTRODUCTION

A velocity filter or also called a Wien Filter combines a constant dipole with a varying electric field, perpendicular to the magnetic forces. When a sample of the beam enters the dipole, the particles are naturally deviated thanks to the magnetic field. By applying an electrostatic force, these particles are brought back on the beam axis and can be collected on an isolated wire. Depending on the mass of the species, there is a specific value of bias to counter act the dipole effect. For the same energy, the lighter the particle, the stronger the electric field is required. So with the Wien Filter it is possible to estimate the proton fraction of the beam of an ion source. This value is an important value for ion source characterization. The second question that was never discussed before: does this proton fraction uniform all over the transverse plane?

This Wien Filter was developed in the 90s for SILHI ion source [1, 2], to analyse the proportion of H^+, $H_2{}^+$ and $H_3{}^+$ as well as measuring the total beam intensity. It was later installed on BETSI test bench [3] to characterize the new sources developed at Saclay, especially the ALISES ion source family [4, 5]. However, the clearance between the diagnostic and the vacuum chamber is very tight and it got stuck during the removal of the Wien Filter from BETSI test bench, damaging the actuator and the measurement system.

DESCRIPTION

This Wien Filter (see Fig.1) is composed of a water cooled beam-stopper (A) that can handle 10 kW beam power. It is equipped with a removable tantalum diaphragm (B) drilled with a ø 250 µm diameter hole and 0.2 mm in length to let a very small part of the beam through.

Right behind this diaphragm, the measurement unit is composed of a Permanent Magnet structure (C), two electrodes (D), a charge collecting wire (E) and a negative polarized electron repeller (F). All these elements are enclosed in a box constructed of 4 mm thick ARMCO plates (G) bolted together to create a magnetic shield. The side panels of this box are hollowed with an array of holes to allow the pumping of the inside.

The (C) dipole is formed by six permanent magnets, distributed equally over and under the beam, originally designed to create a 0.19 T magnetic field on the beam axis. During the reassembly of the measurement unit, it was measured at 0.183 T with a Hall probe, which remains acceptable to separate Proton from molecular $H_2{}^+$ and $H_3{}^+$ at 95 keV energy.

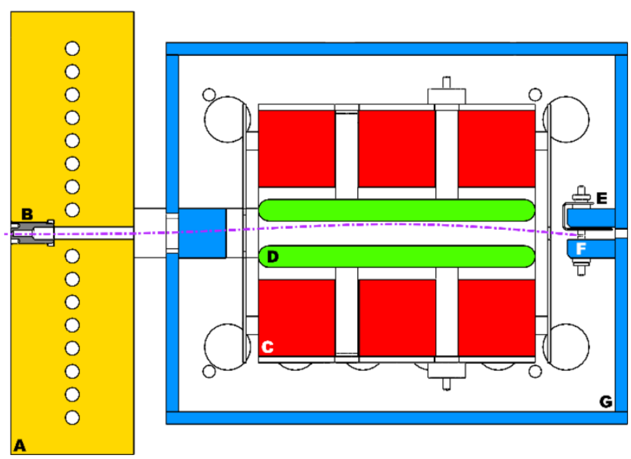

Figure 1: SILHI Wien Filter cross section.

The two stainless steel electrodes (D) are placed inside the magnetic system with the following dimensions, 90 mm along the beam axis, 36 mm in width, 7 mm thick and spaced 8 mm apart. Both of them are connected to SHV 10 kV feedthrough with Kapton insulated wire.

Coming after the deviation structure, an isolated ø 0.25 mm Tungsten wire (E) collects the particles, measuring their intensity. A thin stainless steel (F) sheet connected to another SHV feedthrough sits over the Tungsten wire to act as an electron repeller electrode.

In order to measure the beam intensity on the beam stopper (A), it must be isolated from the measurement unit and the actuator. Moreover, the measuring unit has to be mechanically mounted on the beam-stopper to ensure a good alignment of the sampling pinhole (B) and the collecting wire (E). The size of the measuring unit (see Fig. 2) left very little space to design a stiff assembly. Therefore, the mechanical attachment of the iron box to the shield was not sturdy

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enough to withstand the bound, creating a great misalignment of the wire with the sampling pinhole. To repair the Wien filter, it was compulsory to change the actuator and the system supporting the measurement unit to the diaphragm.

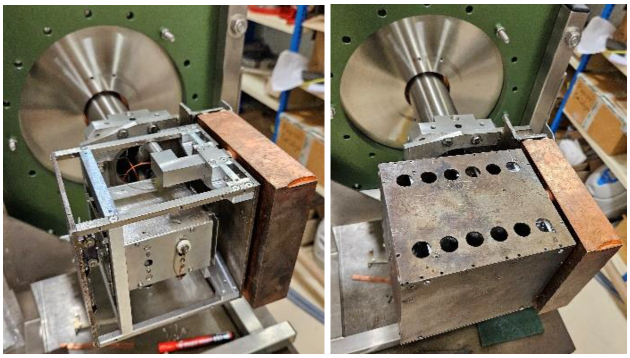

Figure 2: Measuring unit assembly.

MODIFICATIONS

The LEDA (*Laboratory of Study and Development for Accelerators*) developed its own motorized actuator, which was designed to accept the heavy-duty diagnostics such as Emittancemeter [6] or Faraday Cup or in this case a Wien Filter. With this device, the bellow is now outside of the vacuum chamber and the mounting interface of the diagnostic is close to the CF250 actuator flange. In parking position, and thanks to the improved stroke, from 150 mm to 250 mm, the distance between the permanent magnets and the beam is increased by 100 mm, reducing the perturbation induced by the permanent magnets on the beam.

The Stögra stepper motor SM56 used on the first actuator was upgraded with a Neugart PL40 planetary gearbox, compatible with the LEDA actuator motor interface.

The ability of measuring the total beam intensity with the collimator is not required any more, enabling the design of a new frame to hold the measurement unit. In the previous design, the ARMCO plates were bolted together with small screws and were attracted by the magnet during assembly. Each maintenance tasks were quite tedious with a risk of damaging a part or a cable inside of the measurement system. The new frame follows the exact internal dimensions of the box, each plate are independently positioned and bolted on the new structure. This support is made out of aluminum for its amagnetic properties and lightweightness.

MEASUREMENTS SETTINGS

The measurement campaign was performed with the ALISES v2 source biased at different voltage, from 35 kV to 50 kV [7]. The extracted intensity is around 30 mA reduced to 18 mA on the beam dump after going through two solenoids and a diaphragm. The beam pulse is set up at 10 ms and 7 Hz. The first measure is done in the center of the beam, then the diagnostic is moved up 5 mm for each 9 other positions. The diagnostic is 850 mm away from the extraction point of the ion source because the diagnostic chamber is located after the first solenoid. This magnet stayed off not to alter the trajectories of the measured species extracted from the ion source.

As for the deviation plates, one is connected to the Trek amplifier (Trek 10/10B-HS) for ±10 kV and the other one grounded with a special connector plugged on the feedthrough.

SIGNAL TREATMENT AND DATA ANALYSIS

A Labview program developed specifically for this diagnostics operates the Wien Filter. It communicates with the servomotor and the Trek amplifier to respectively move the diagnostic in the beam in the transverse plane and variate the HV voltage ie the electric field between the deflecting plates to make the mass selection. The collecting wire current is amplified by a front-end electronic and is acquired and synchronized with the beam timing trigger. The sampling frequency is set 100 kHz for a 11 ms windows, giving a list of 110 points to describe the pulse behaviour over time. This list of points are saved for each HV voltage value within the range of the HV ramp at each position of the Wien filter position inside the beam. Then they are averaged and subtracted to each pulse to remove the measure noise and obtain "filtered data".

In order to reconstruct the mass spectrum (see Fig. 3) at a set transverse position, all these filtered data are averaged and the raw spectrum obtained is corrected with a second degree polynomial baseline fit. From the 10 ms initially measured, 3 ms are cropped at the beginning of the pulse to remove the beam formation phenomenon. In the following graph, the beam current on the wire is plotted over the HV value of the biased plates. The negative signal seen after each peak is always present even with a -1kV bias voltage on the electron repeller.

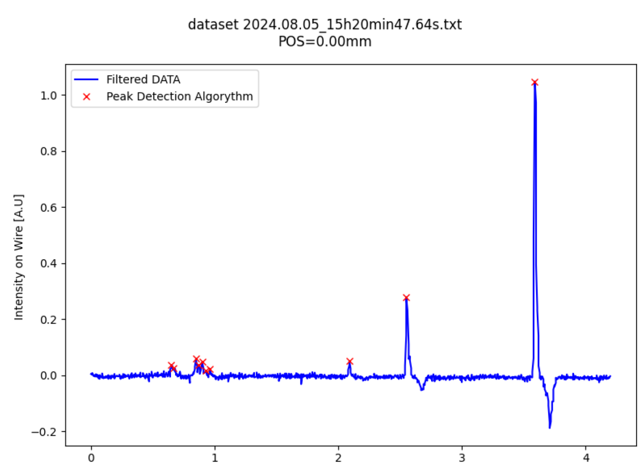

Figure 3: Mass spectrum of ALISES v2 at 35 keV.

A simple algorithm was used to detect the peak position of 10 different masses extended from one to 32 amu. The list of detected mass was determined by the position of the peak with respect to most intense proton peak and the squareroot

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of the mass ratio when the Wien filter stands on the beam axis (Eq. (1)).

$$V(ion) = V(H^+) * \sqrt{\frac{m_{H^+}}{m_{\text{ion}}}} . \qquad (1)$$

Table 1 shows all the detected peak associated to their mass. Most of them are related to oxygen and nitrogen molecules, presuming a leak in the ion source. As for the peak number 15, it could be either CH_3 or NH, but it is assumed to be NH since there is no C(amu = 12) peak detected. A measure with a RGA (Residual Gas Analyzer) on the LEBT is planned to confirm this hypothesis.

Table 1: Mass of Elements

Element	H	H_2	H_3	N	NH	O	OH	H_2O	N_2	NO
AMU	1	2	3	14	15	16	17	18	28	30

RESULTS

The intensity of all peak allows calculating the fraction of all element and more particularly the proton fraction of the ion source.

At different extraction energy (35, 40, 45 and 50 kV) on beam axis, the proton fraction is found to be around 65 and 70 %, 18 % for H_2^+, 3 % for H_3^+ and 9 % for the remaining heavier elements (Fig. 4). The proton fraction value is very close to what is expected: when adjusting the LEBT solenoids to transport the proton species, the normalized transmitted intensity collected on the LEBT beam Stopper over the power supply drain current at the same moment, respectively 20 and 30 mA gives around a 66 % proton fraction. It is possible to assume that the bias of the source does not affect the plasma formation and the type of particles created.

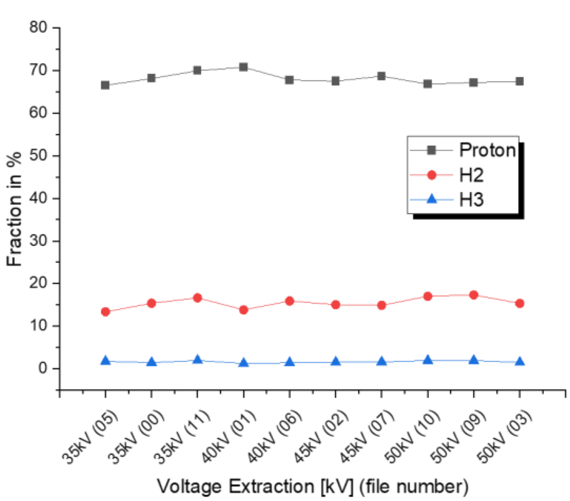

Figure 4: Evolution of the proton proportion with respect to the beam energy.

The next series of measures were done at different height in the beam transverse plane within the same range of beam energy as previously done. The following Fig. 5 only represents the interesting value, the proton fraction. At 35 kV and 40 kV, this fraction stays constant over the transverse plane. However, at higher beam energy, the value is decreasing after a certain radius, 25 mm for 45 kV and 15 mm for 50 kV. This phenomenon is directly related to the extraction conditions of the ion source. Since the bias is higher, the particles extracted are less divergent and the beam transversal size is therefore smaller at the diagnostic position. When the measurement is done far from the beam center, the wire collects less particles, and so the signal over noise ratio is decreasing making the result difficult to analyze in term of ratio.

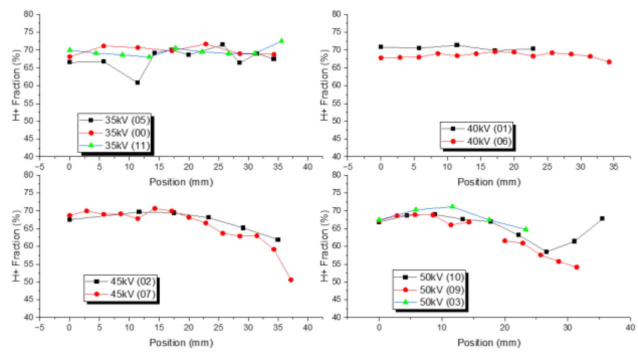

Figure 5: Evolution of the proton proportion along the beam transversal plane at different source bias.

CONCLUSION

The upgrade of the Wien Filter allowed us to measure the proton fraction at the exit of ALISES v2 ion source. At first, the proton fraction obtained on the axis is coherent with measured transmission in the LEBT with a 65 % value for both cases. Secondly, thanks to the motorized actuator, the proton fraction along transverse plane seems to be uniform, as long as beam exists. This Wien Filter is operational and ready to be compared to a Doppler shift measure, and a RGA to confirm the species detected.

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