Production of phosphorus and carbon ions with MONO 1001

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1- Phosphorus

Mission

ECR source MONO1001[1 4] has been tested for the production of different ions[2 3]. The Pantechnik company, holder of the producer of the source MONO1001, asked the Ganil's Ions Production Group to study the performances of this source for the production of phosphorus 1+ and its capacities to ionize carbon from CO_2. The objectives are 200µAp of P+ with an efficiency around 20%.

Method

A container in AL_2O_3, with an internal diameter 3.3mm and working length 22mm, is used to receive red phosphorus. To ensure the production, hydrogen support gas reacts with phosphorus to form volatile molecules[5 6 7]. This gas is ionized by the plasma of MONO1001 in a similar way to sulphur from molecules SO_2 or SF_6 for which the efficiency is 40% for S^+. we use an oven developed by Pantechnik, with an external diameter is of 8mm to control the temperature of the chemical reaction between hydrogen and phosphorus and therefore achieve a more stable beam.

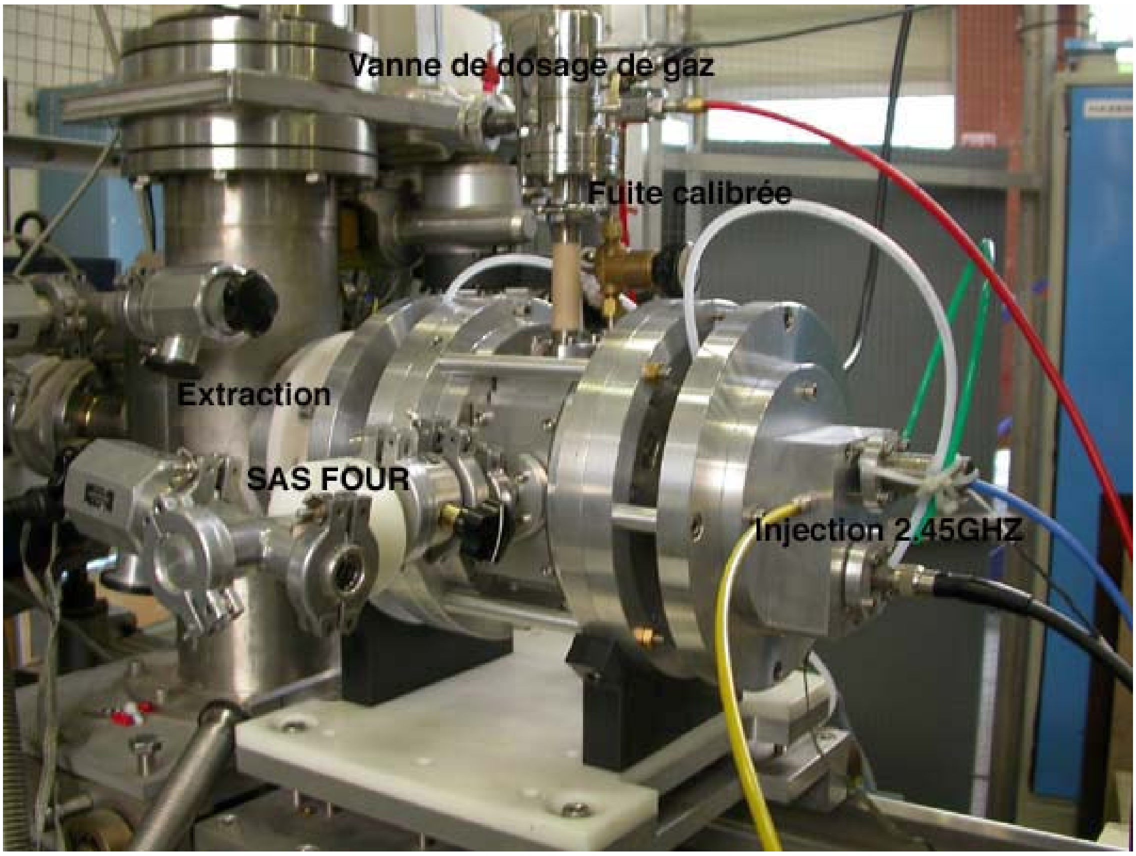
Installation of source MONO1001

A gas valve UDV 140 "Pfeiffer" is used for hydrogen injection and the source is equipped with a calibrated leak of 18µAp for Ar.

The plasma electrode, with a hole diameter of 6.5mm, is located in an axial magnetic field of 2000 gauss. The puller electrode of diameter 15mm is placed at 31mm from the plasma electrode.

The oven is positioned laterally in direct view of plasma and its extremity is situated in a surface with a magnetic field module of 2100gauss.

MONO 1001



Operation

The oven "Pantechnik" (fig.1 and 2) in the position chosen for phosphorus operation didn't effect the normal operaton of the source MONO1001.

The beam efficiency transport, for 1mA of current produce by the source, is respectively 80% and 85% with a 14kV and 18kV extraction voltage (ratio between the sum of the pics measured on the faraday cup right behind the analysing magnet and the total extracted current beam). The transmission was also measured for a lower voltage of 9kV (45%) to quantify the molecules intensities until P_4 (mass 124).

With an HF power of 35 Watts, the ionization efficiency for argon under these conditions is about 90%.

Several production tests showed the direct dependence of the intensity with the injected quantity of hydrogen. The heating of the oven also increases the P^+ beam intensity, but in a less significant way. On the other hand, it strongly contributes to stabilize the produced P^+ beam. To obtain 230µAe of P^+, measured on the Faraday, the RF power necessary ranges between 70 and 100W and the oven temperature is at 370°C. The necessary time to obtain a stable beam of 230µAe is about one hour.

For the measurement of phosphorus ionization efficiency, the output current of the source is about 2mAe, and the extraction pressure is 5.10^{-6}mbar (fig. 3 and 4). The beam transport efficiency for Ar, defined by the ratio between the sum of the Ar peeks in the spectrum and amount of Ar injected through the calibrated leak, is 69.5%. The source was operated during 32 hours with a P^+ average intensity of 200µAp what gives 14% of P^+ efficiency not corrected of transport. The total efficiency for phosphorus compounds obtained on the faraday is 22%. The corrected values by the Ar efficiency transport are 20% for P^+ and 31% for the total of ions containing of phosphorus.

The percentages of the main phosphorus compounds present in the spectrum are: P^+: 64% P_2^+: 6%, PH^+: 24%, P^{++}: 5%.

At the end of this test and when opening the ion source, we notice a deposit of phosphorus with a diameter of 11mm on the plasma electrode (fig1). A visual check didn't show any phosphorus traces on the walls of the plasma chamber.

A test was carried out by increasing the hole diameter of the plasma electrode to 13mm. The current output from the source raises up to 6.7mA and is probably polluted by secondary electrons. The P^+ intensity measured in the faraday cup is up to 360µAp (fig 5). Transport efficiency under these conditions strongly decreases, approximately 30% on the total spectrum, which increases the uncertainty on the P+ intensity at the source. If we assume that the transport efficiency is about 30%, one gets 1200µAp of P+ produced with the source.

plasma electrode

fig.1

Pantechnik oven and alumina container

fig.2

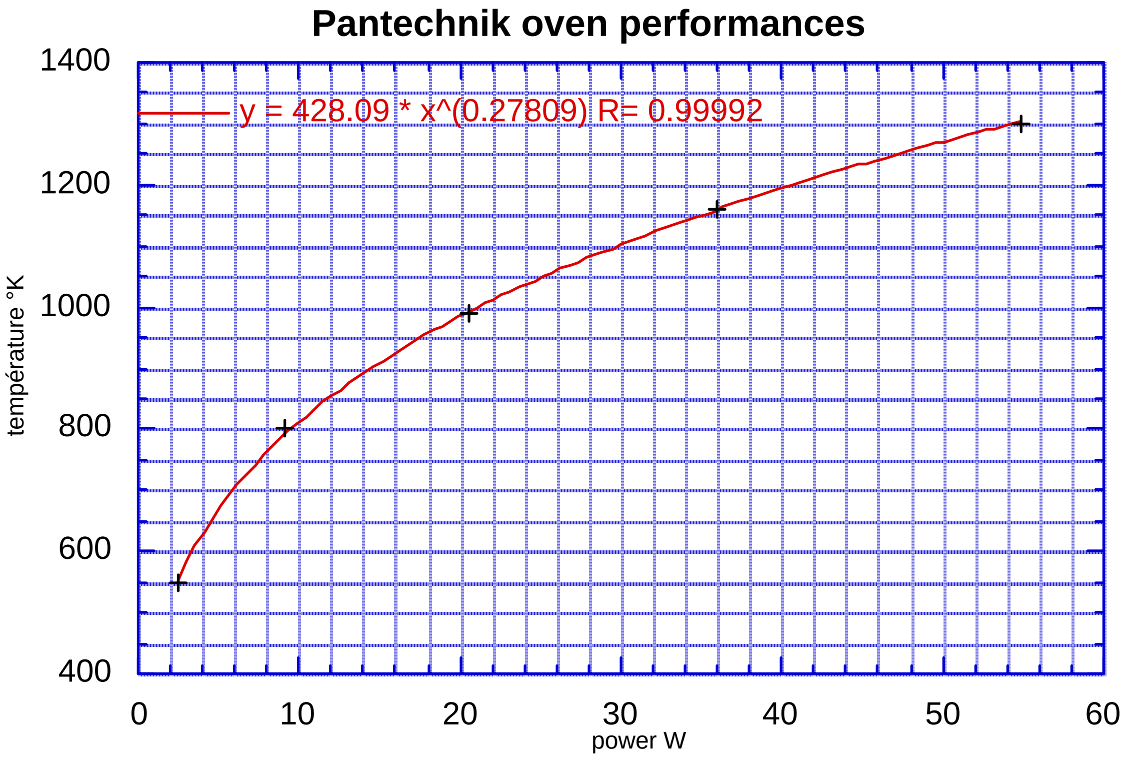
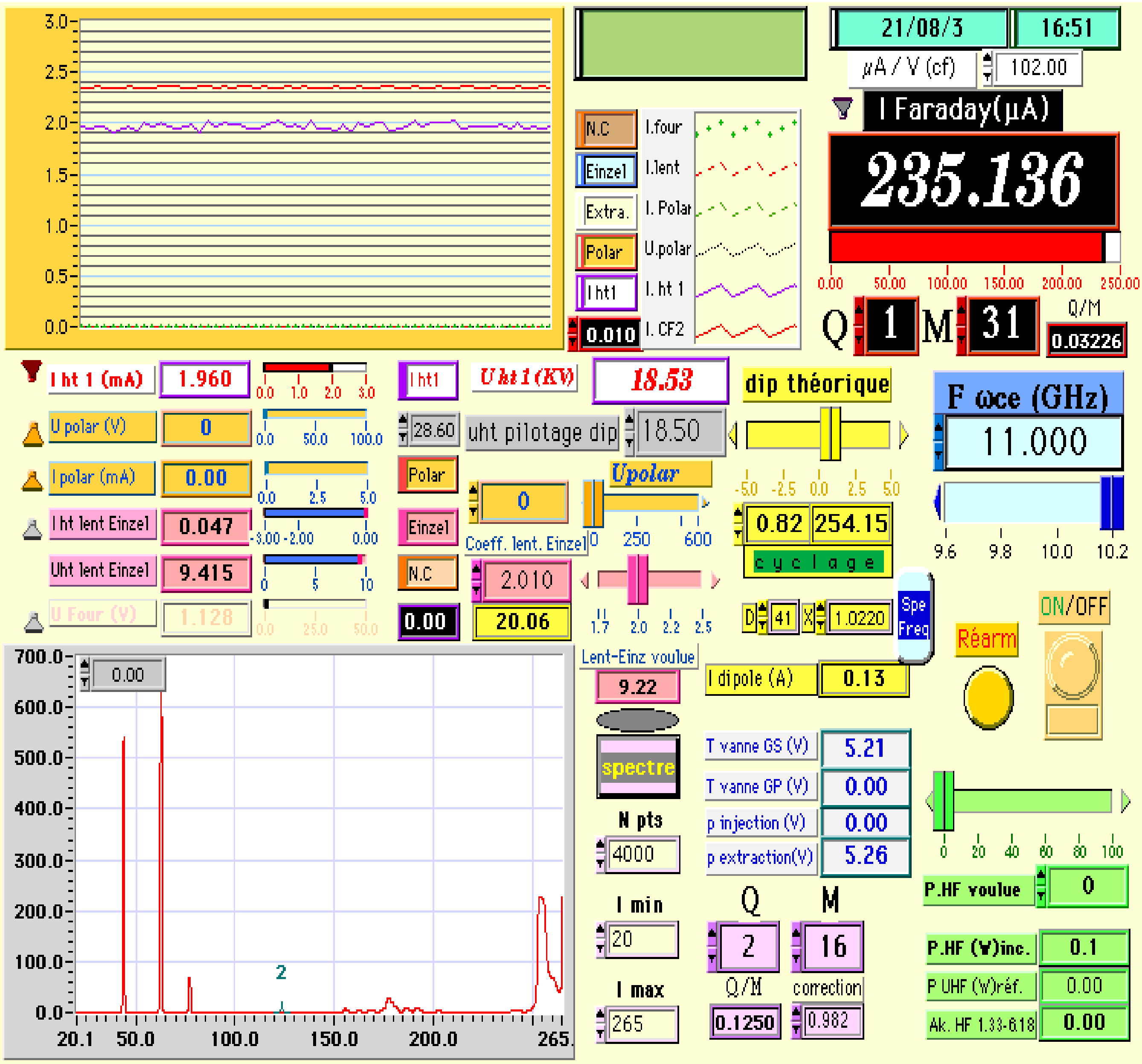


fig.3

Phosphorus acquisition



Phosphorus spectrum with hydrogen support gas
(hole in the plasma electrode of 6.5mm diameter)

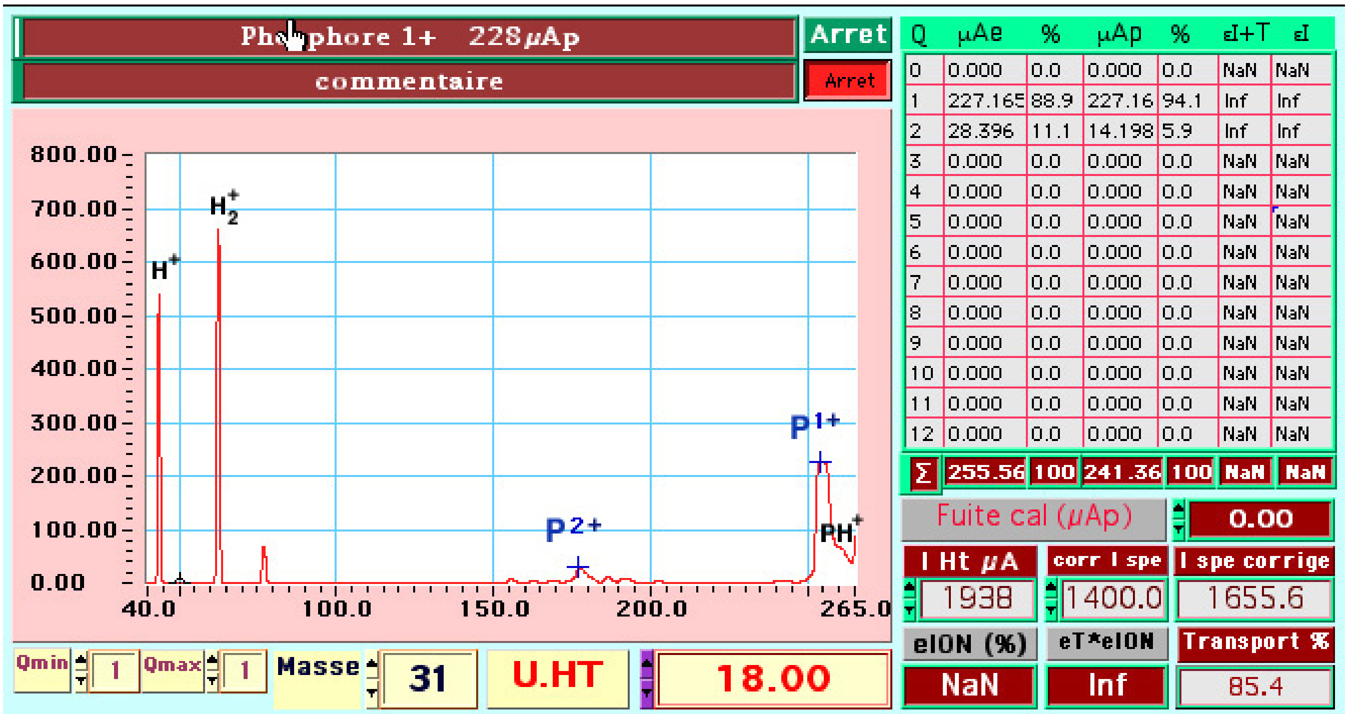


fig.4

Phosphorus spectrum with a hole in the plasma electrode of diameter 13mm

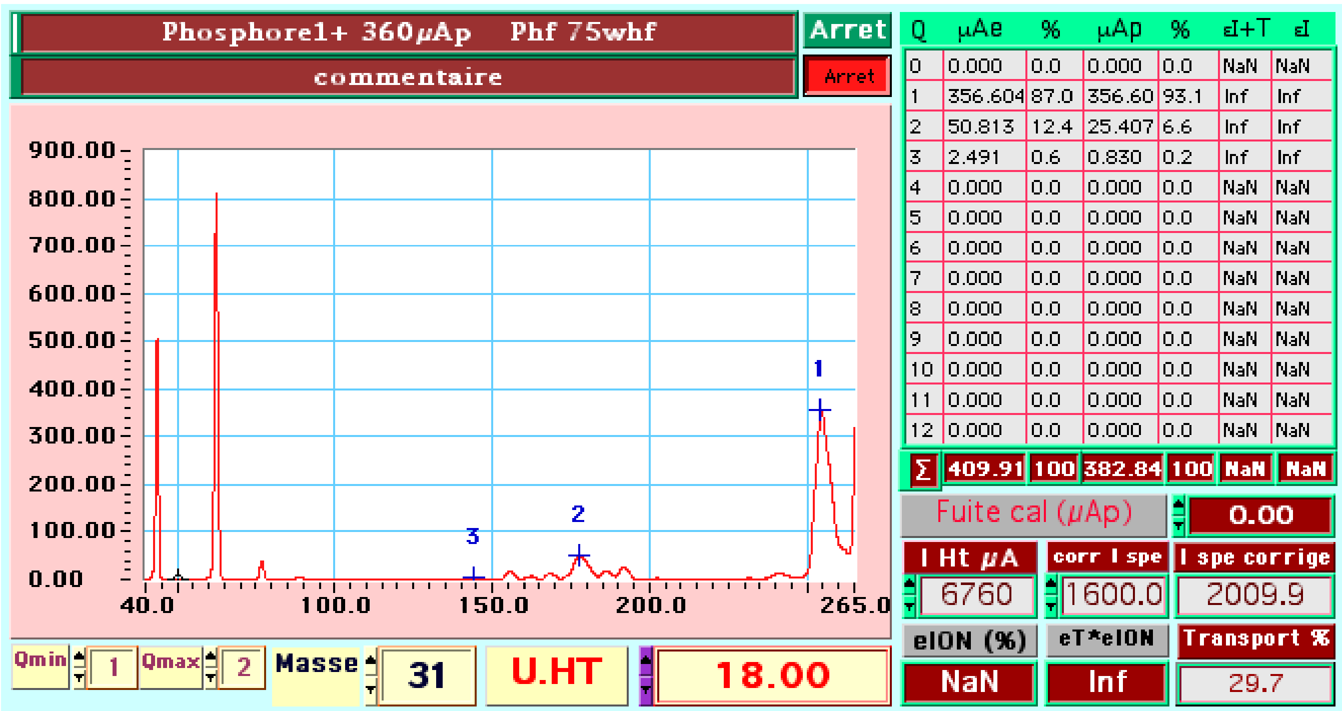


fig.5

2-Carbon

Mission

The goal of this experiment is to measure the production efficiency of the C^+ ion from CO_2 injected in MONO 1001.

Method

For this experiment, two gases have been injected in the source, CO_2 through a gas valve UDV140 and $^{13}CO_2$ through a calibrated leak. CO_2 is used for the carbon production and the $^{13}CO_2$ was devoted for mesuring the beam transport efficiency.

Operation

The plasma electrode with a hole diameter of 4.4mm is located in an axial magnetic field of 2000 gauss.
The transport efficiency, for 0.65mA of output current the source (fig 6), is roughly 89% at 18kV (beam measured on the faraday cup behind the analysing magnet). Due to the poor resolution of the analysing magnet, the ratio between the carbon compounds was difficult to otain. Therefore, the slits have been closed at the image point of the analysing magnet (fig 7).
At 140 Watts RF power, the ionization efficiency for CO_2 under the previous conditions and for C^+ current of 100µAp is about 60% for all carbon compounds and 27% for the C^+ ions.
The percentage of the main carbon compounds present in the spectrum are on average of: C^+: 46%, CO^+: 48%, CO_2^+: 6%.
To perform this test, the hole diameter of plasma electrode was 4.4mm and the previous experiments showed that the current increases with the hole surface proportionally up to a diameter of 8mm. In this situation, one can estimate C^+ currents around 300 or 400µAp.

Phosphorus and carbon with MONO1001

ion	intensity on FC µA (corrected number by transport)	% relative abundance	% total efficiency	production methode
P^+	230 (275)	64	19	oven P + H_2
P^{++}	18	5		
PH^+	86	24		
P_2^+	22	6		
C^+	86 (97)	46	27	gas CO_2
CO^+	90	48		

carbon spectrum obtained with MONO 1001 from CO_2

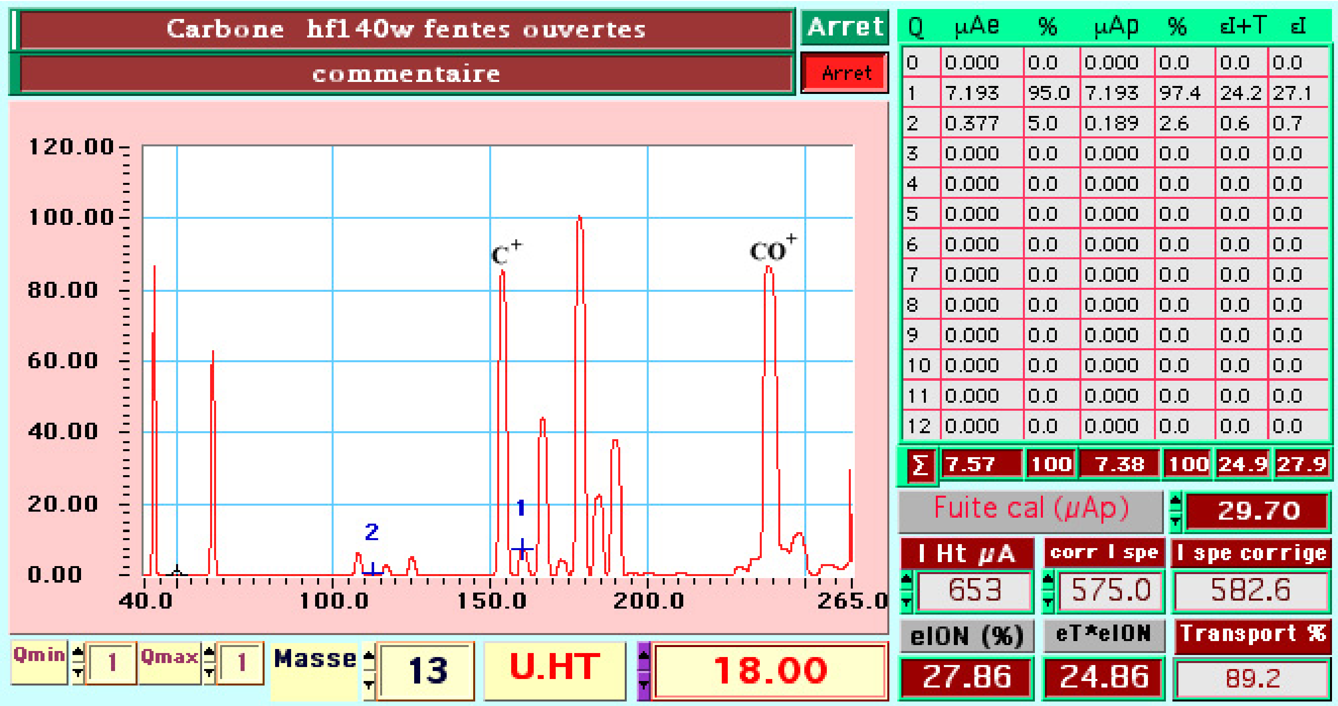


fig.6

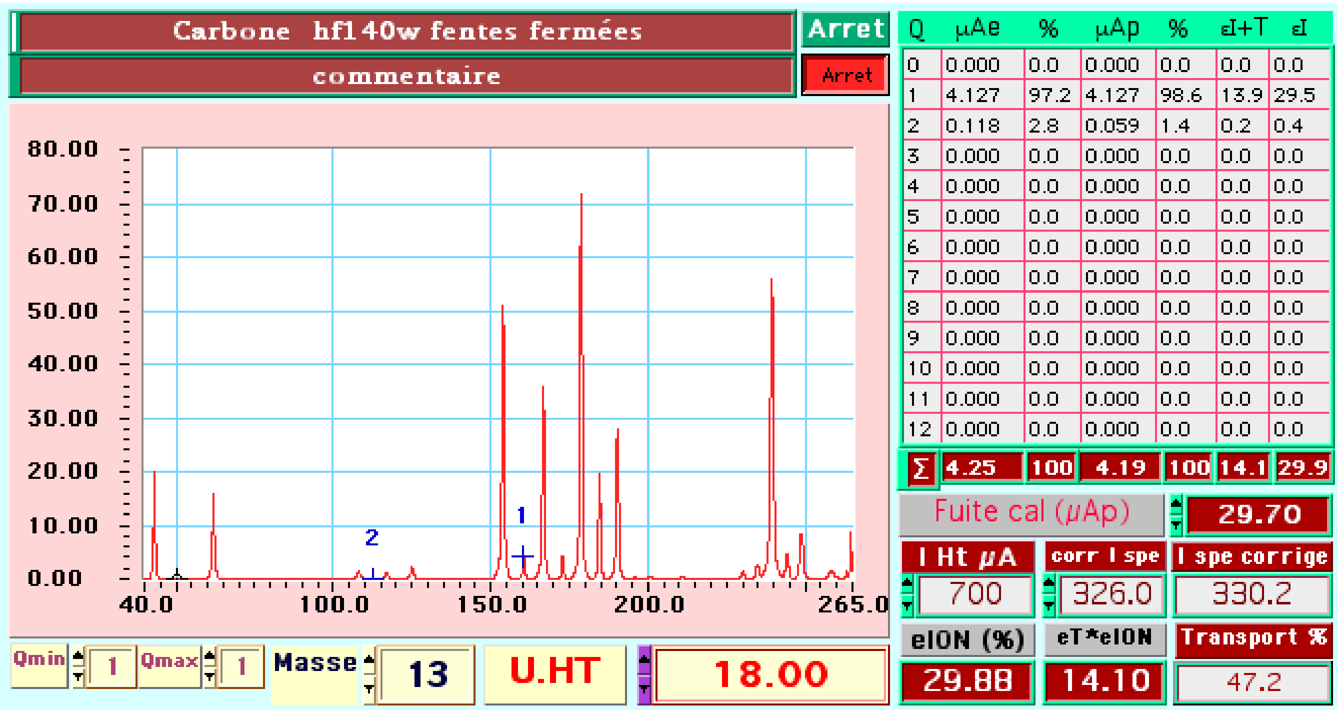


fig.7

[1] P.Jardin et al., Rev. of Sci. Inst., 73 (2), 789, (2002)

[2] J.Y. Pacquet et al., MONO 1001, internal report GANIL R 0206

[3] L Maunoury et al. MONO 1001: a source for singly charged ions applied to the production of multicharged fullerene beams, to be published in RSI (2004)

[4] J.Y. Pacquet, R Leroy, US Patent N° 6.194.836 (fev 2001)

[5] M.-A. Golombeck, S. Heise, K. Schloesser, B. Schuessler, H. Schweickert, Nucl. Inst. Meth B 206 (2003) p 495

[6] P. Fehsenfeld, M. Golombeck, A. Kleinrahm, K. Schloesser, B. Schuessler, H. Schweickert and C. Hehrlein, Semin intervent cardiol 3 (1998) 157

[7] E. Huttel, J. Kaltenbaek, K. Schloesser and H. Schweickert, Rev. of Scientific Inst. 73 (2002) 825