Two Approaches for H- Ion Production with 2.45 GHz ECR Ion Sources

M. Bacal, A.A. Jr. Ivanov, P. Svarnas,
Laboratoire de Physique et Technologie des Plasmas,
Ecole Polytechnique, 91 128 Palaiseau, France

and

R. Gobin, O. Delferrière, F. Harrault, O. Tuske,
Commissariat à l'Energie Atomique,
DSM/DAPNIA/SACM, CEA/Saclay, 91 191 Gif sur Yvette, France

European Network

Developments carried out at Ecole Polytechnique and CEA/Saclay in the framework of the HP-NIS European network
(supported by EU under contract HPRI-CT-2001-50021).

1) Aim of this network:

Improved Production of high intensity H- ion beams for specific HPPAs (Spallation Sources or Neutrino Factory) using compressor rings.

2) Different Researches

study and upgrade existing sources in terms of extracted current, reliability and pulse length as far as possible

new developments of ECR sources

3) Network Partners:

Frankfurt University, Rutherford Laboratory, FZ Jullich, DESY, CERN, Dublin University

4) End of the network: December 2005

5) More information: www.hpnis.dcu.ie

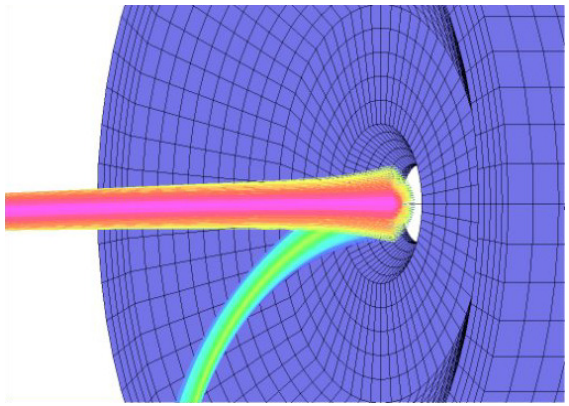
Initial CEA source design

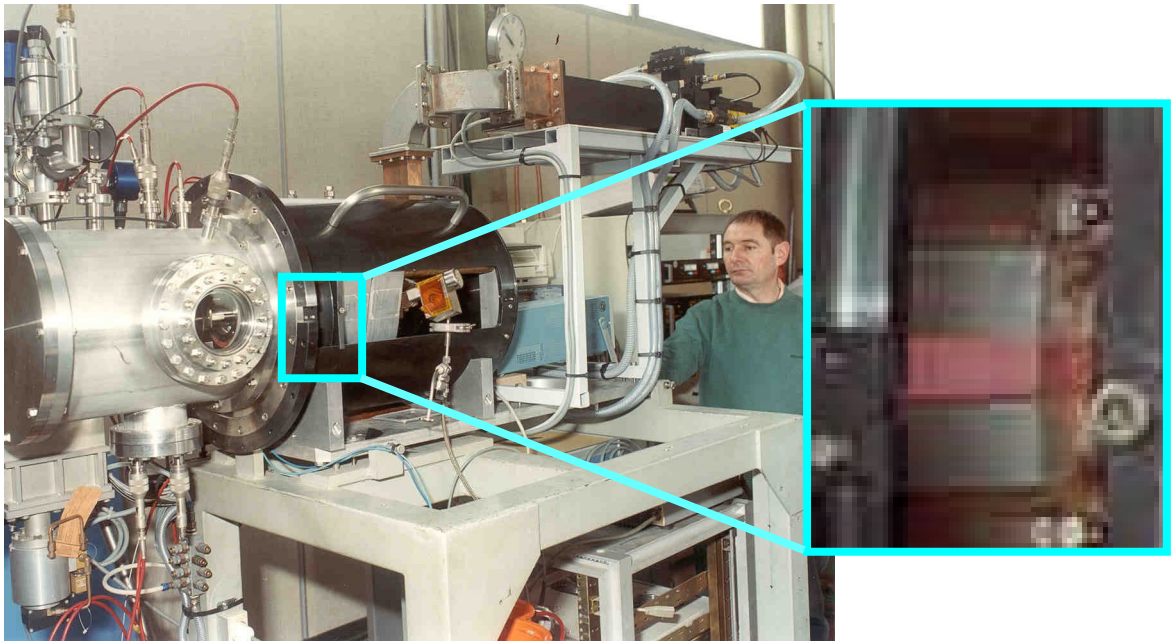
Expected currents: 20 mA of H- ions and 100 mA of electrons

Energy ; 10 keV

Pulsed mode

Preliminary calculations with Axcel and Opera 2D codes

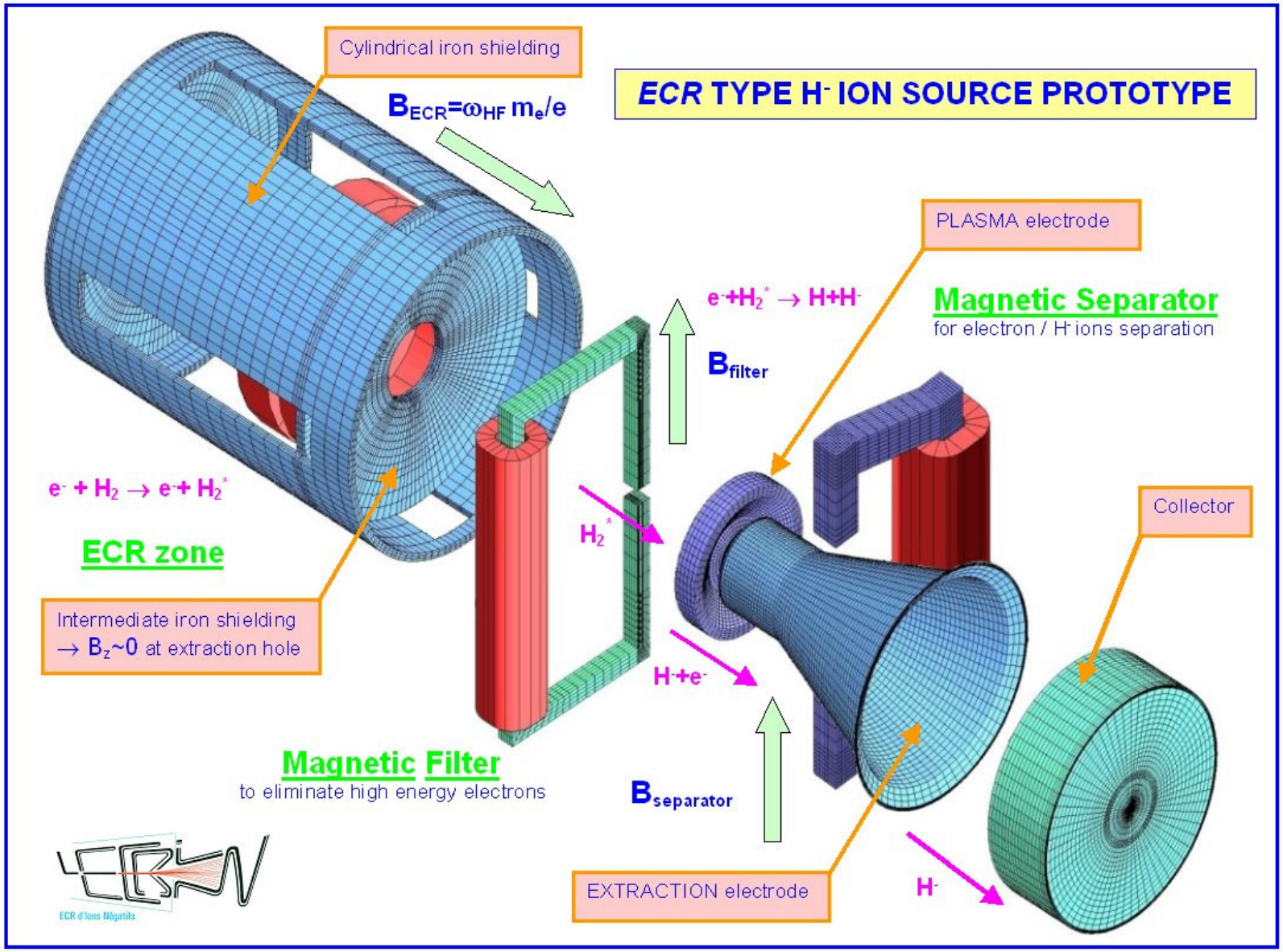




Technical options

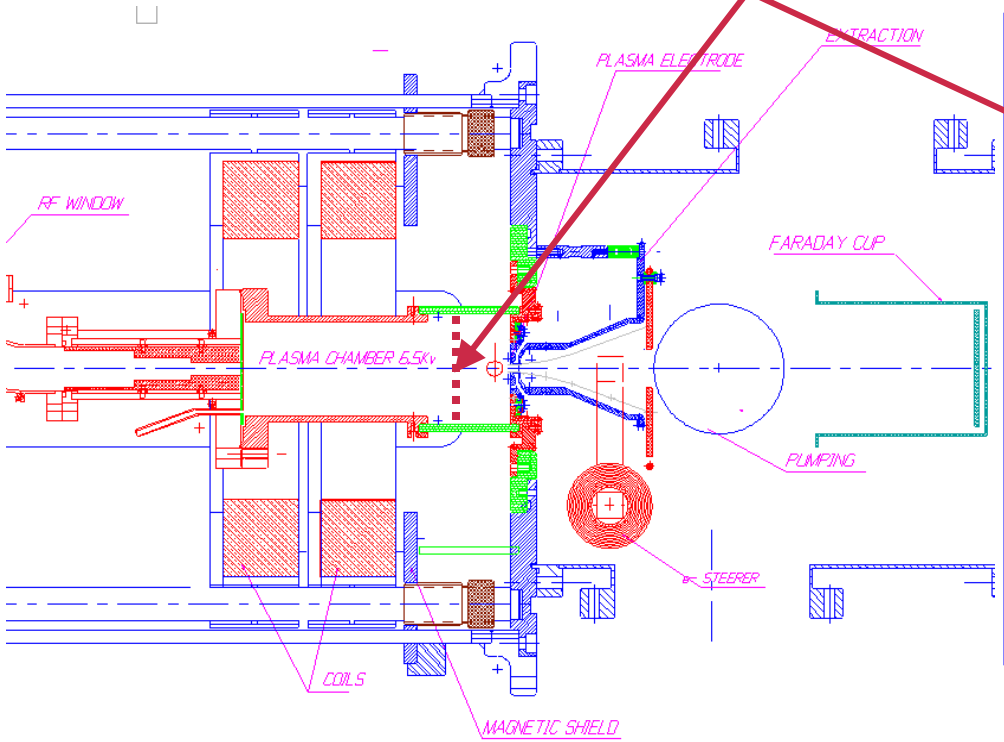
Rectangular plasma chamber
5 mm extraction aperture
Source working at 2.45 GHz
Protected window
ECR zone at RF entrance
Available plasma diagnostics

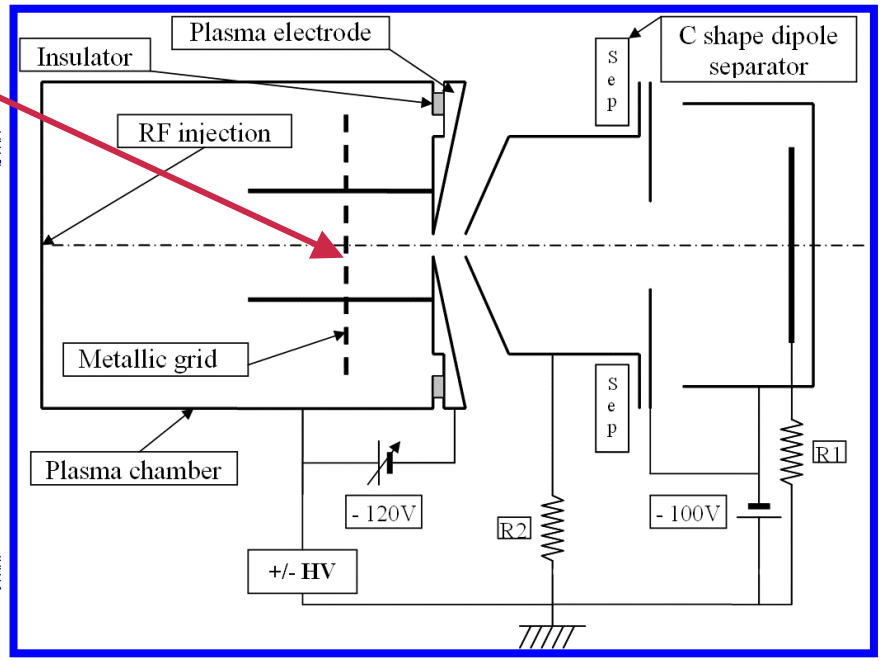
Initial magnetic configuration



Electric filter

Installation of a stainless steel grid in the rectangular plasma chamber





Gain of a factor of 2 (10 μA)

By varying the grid location (with pressure, RF power and magnetic field optimization)

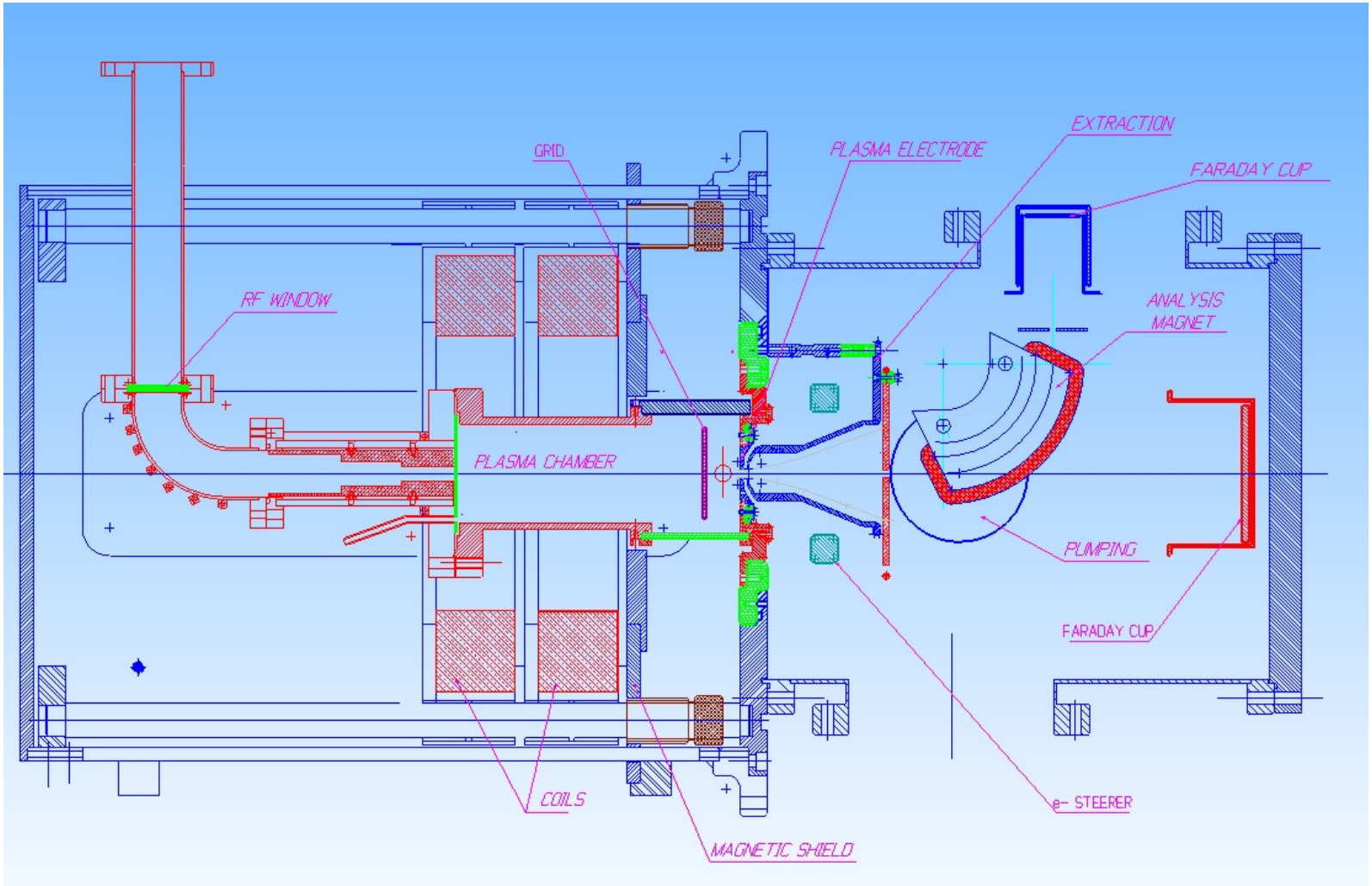
H- reaches 84 μA at 30mm

By polarizing the grid (and plasma electrode) with negative voltage

I H^- increases up to > 850 μA

Beam Diagnostic

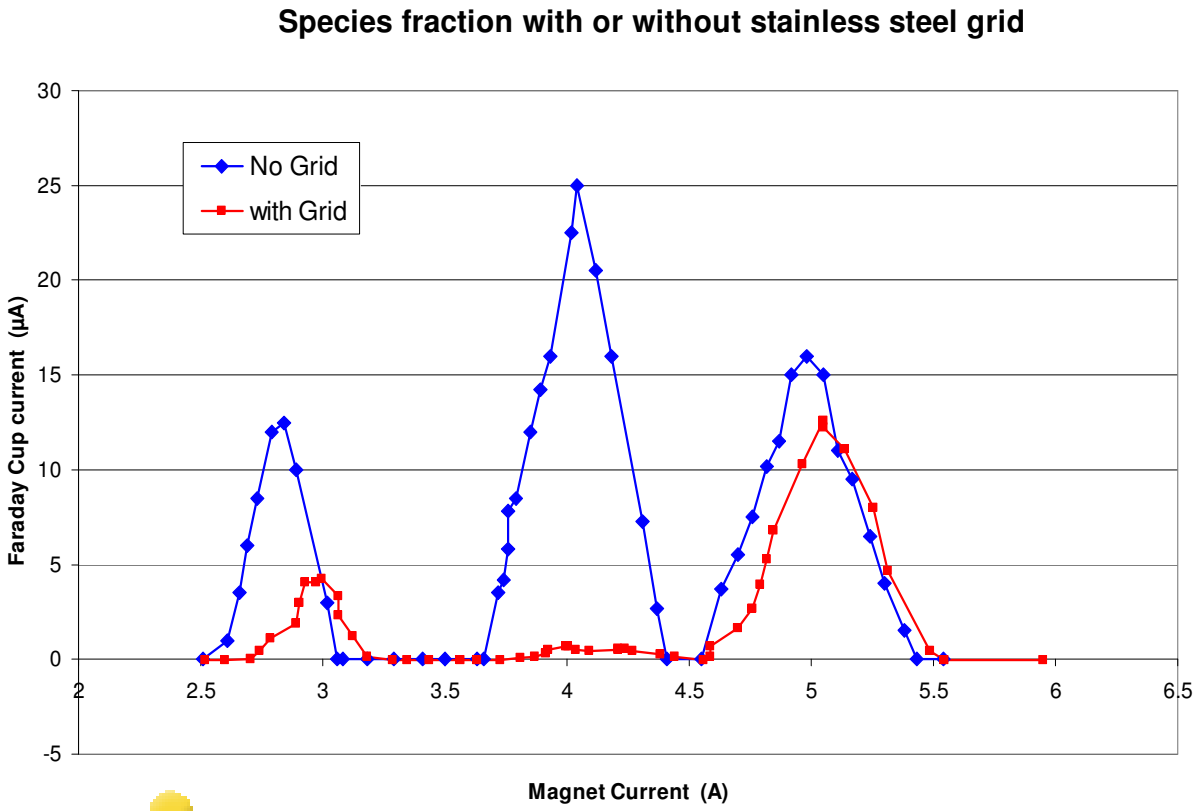
- Qualitative measurements



Positive ions analysis

Strong effect of the grid on positive ion fraction

The positives charge analysis indicates the H_2^+ ions peak decreases with the grid. The H_3^+ peak becomes the highest probably due to the reaction $H_2 + H_2^+ \rightarrow H_3^+ + H + 1.71eV$. which takes place in cold plasma.



Blue:

beginning of 2002 without grid

H^+ 23 %, H_2^+ 47 %, H_3^+ 30 %

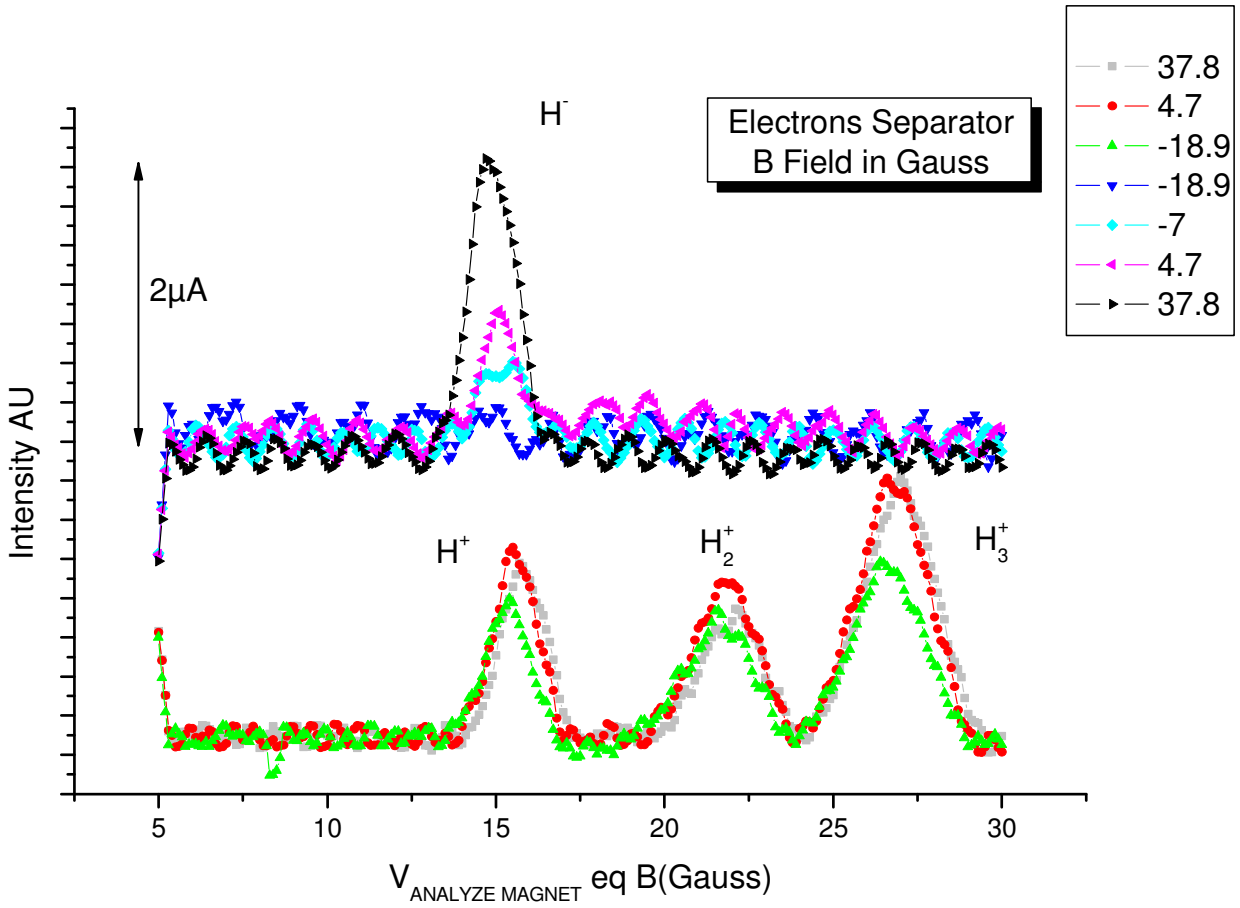
Red:

2003 with metallic grid (electric filter)

H^+ 24 %, H_2^+ 5 %, H_3^+ 71 %

Analyze magnet calibration

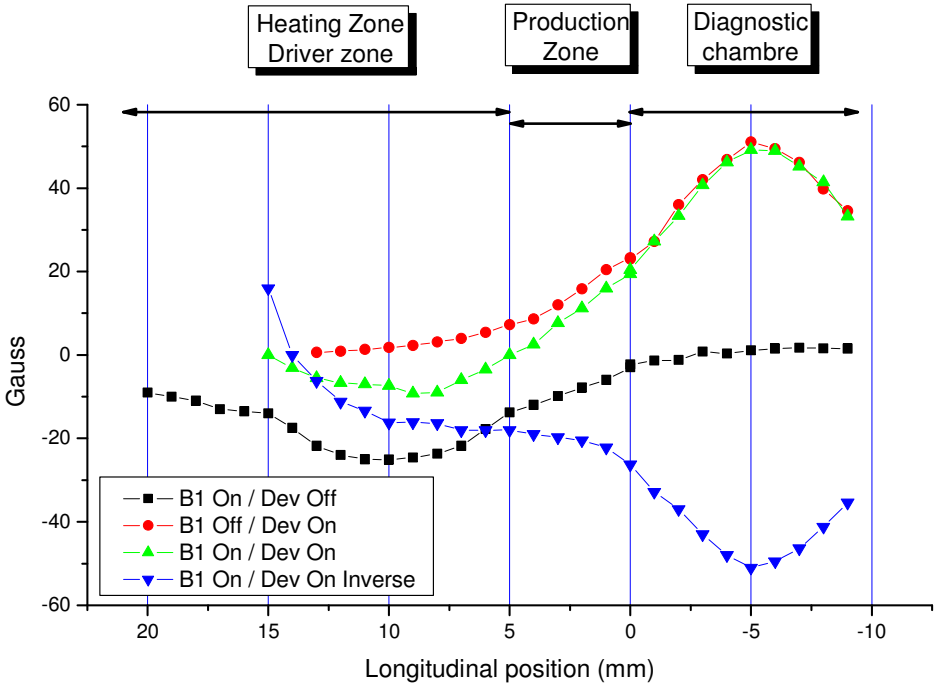
Analysis of Pos/Neg charges downstream a 5 mm sampler located at the entrance of the magnet allows us spectrometer calibration.

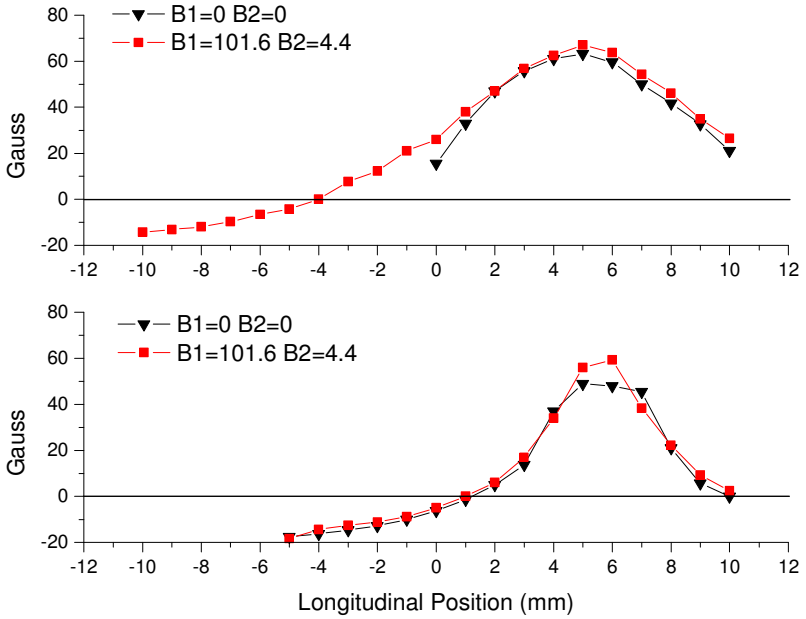


e⁻ separator and H- production

- Magnetic field from the e-separator penetrates inside production zone and influence greatly the production of negative species !

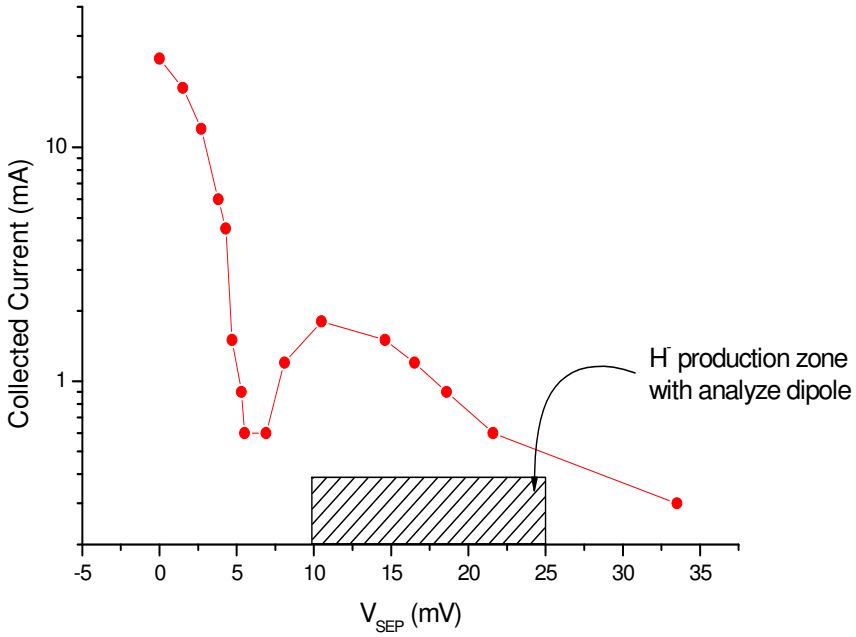
- Gap reduction of the e-steerer
  - ➔ increase the intensity of magnetic field between the gap
  - ➔ decrease the field intensity in the production zone



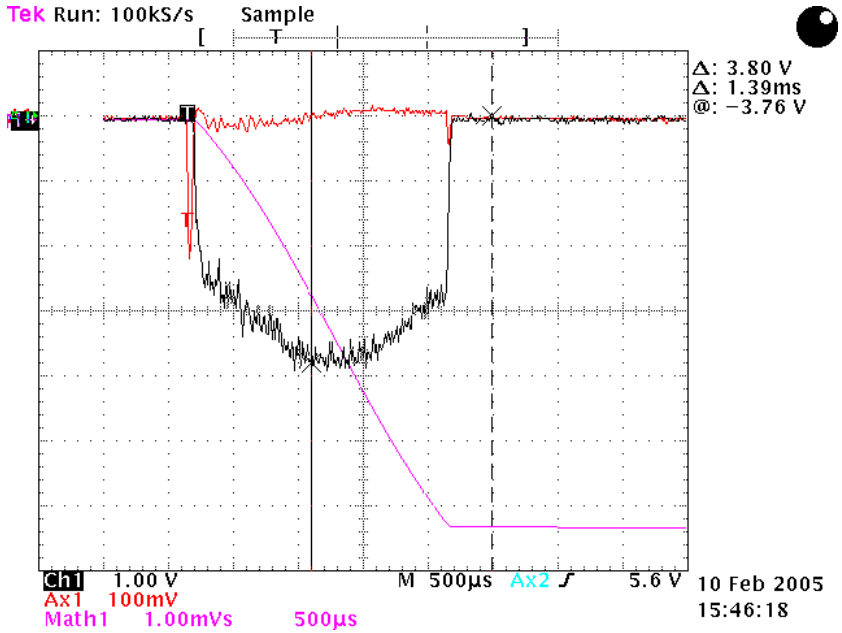


Faraday cup

- Measurement of the total extracted current.



$P=10^{-5}$ Torr
Downstream extraction aperture

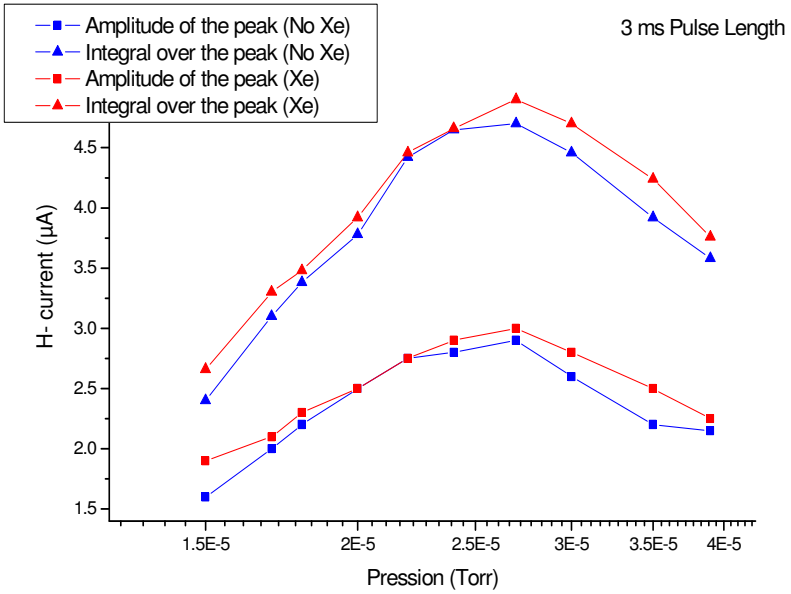


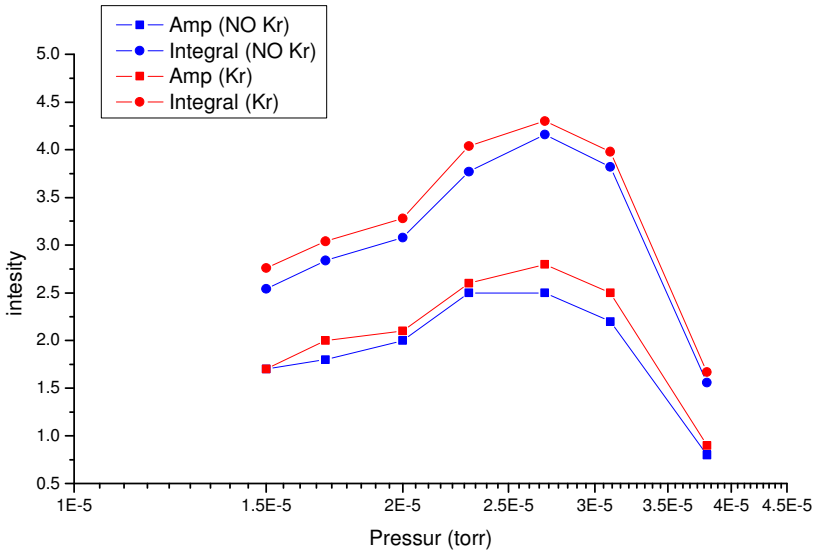
$P=10^{-6}$ Torr
Downstream extraction aperture

Gas mixing

With **Xenon** and **Krypton** we have noticed a slight increase of the H- production

(measurements performed downstream the analyzer magnet to be confirmed by global measurements)



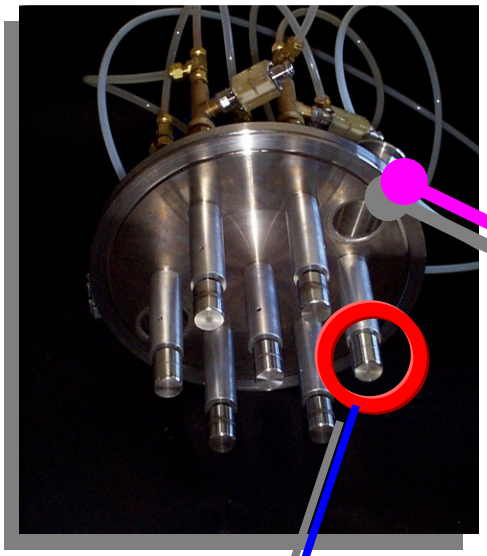


No improvement with **Ar** !!!

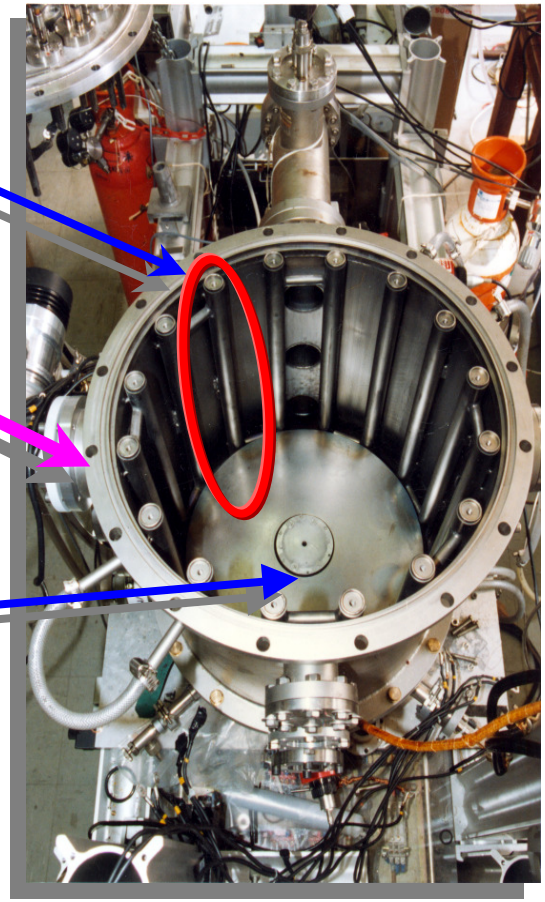
Measurements made with Thomas Steiner from CERN, thesis under way

Camembert III source at Ecole Polytechnique

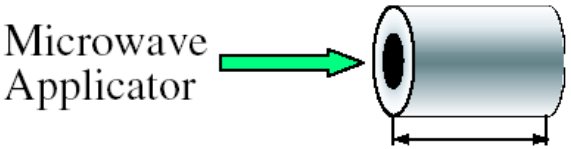
Upper flange with 7 ECR sources



Camembert III chamber with multicusp, top view



Magnetic dipole (Sm_2Co_{17})



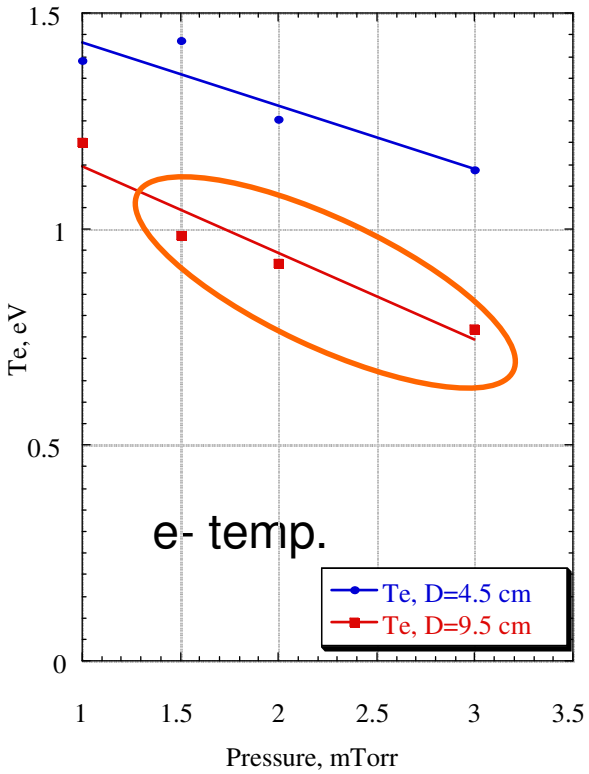
Schematic design of an elementary dipolar plasma source.

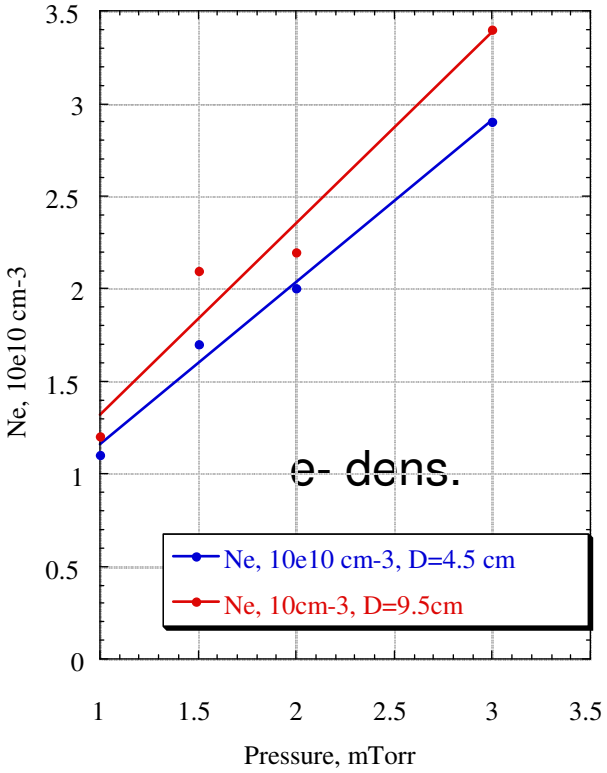
Plasma analysis

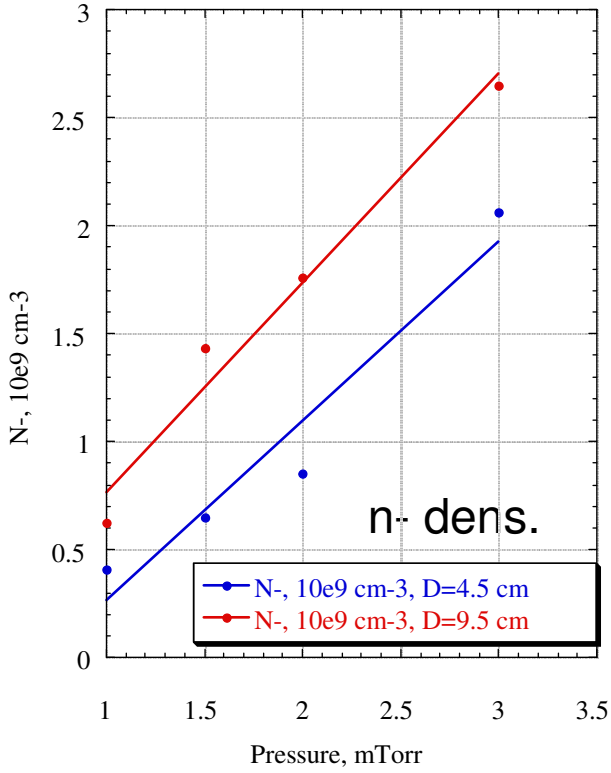
vs pressure for two distances (D) from ECR sources to the probe.
(D = 4.5 and 9.5 cm).

cw mode operation

Note that:
for the larger D: *N^- is higher *Te is lower
for higher pressure, N^- is also higher



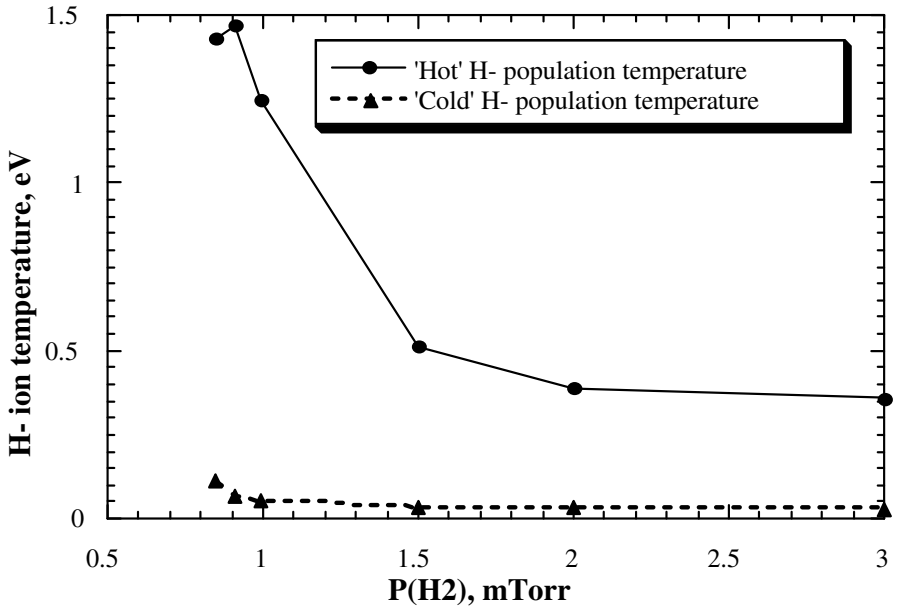




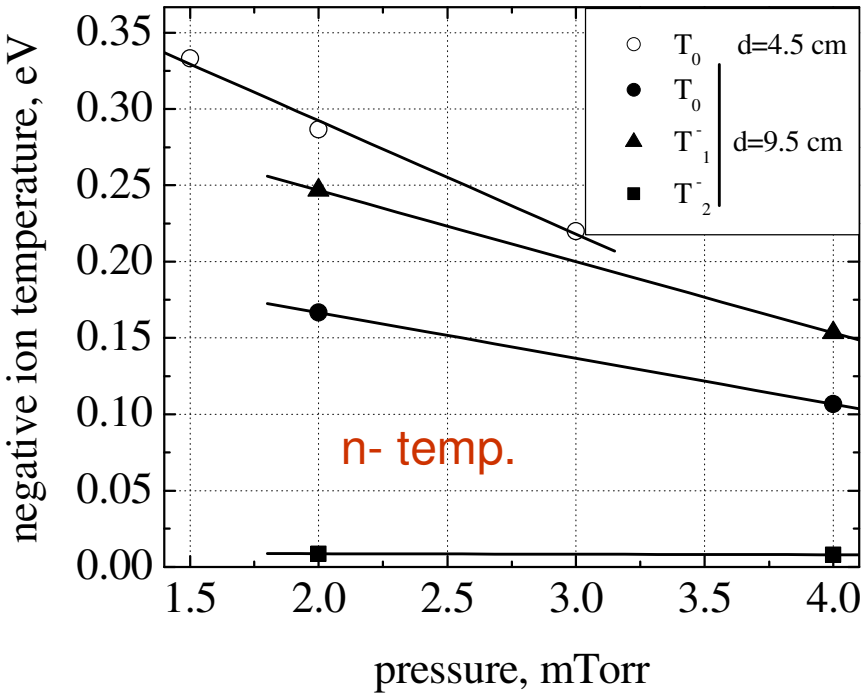
Red correspond to D = 24.5 cm and Blue correspond to D = 19.5 cm from extraction.

H^- ion temperature

Filament discharge



ECR discharge
(with 1 kW µwave power)



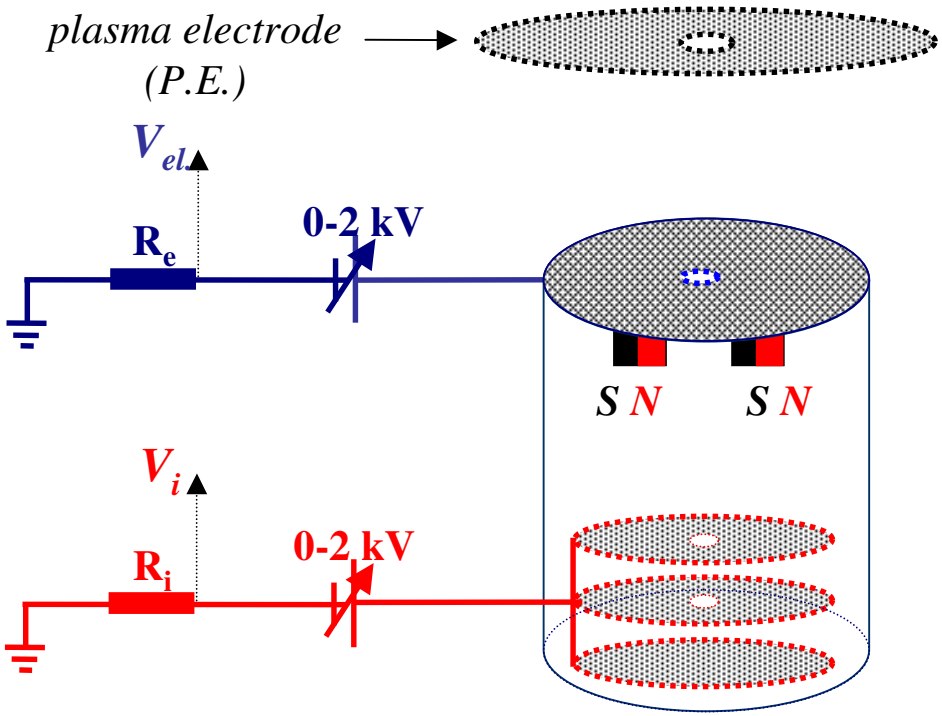
Note that n- temp. in ECR driven source are much lower than in the filament Camembert III source (whatever the distance 4.5 or 9.5 cm)

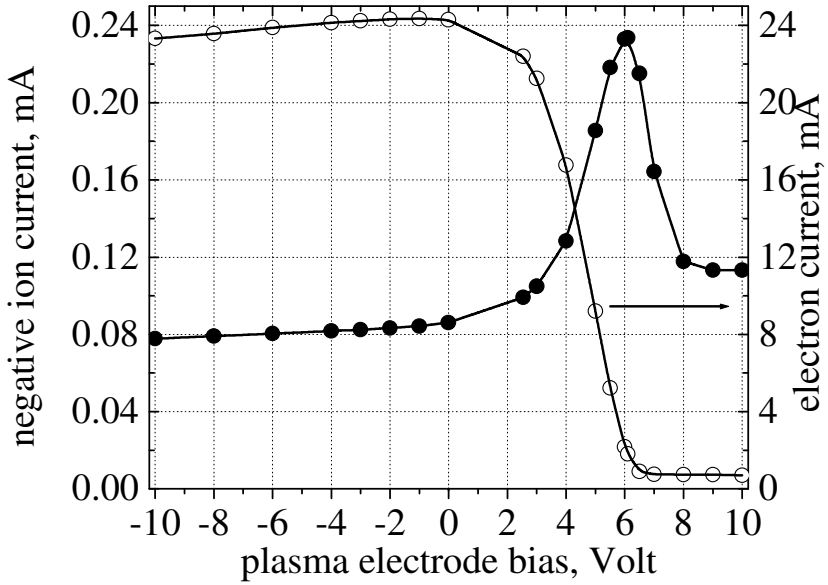
Extractor configuration

Extracted cw currents were studied in a wide range of PE potential.

The n- current goes through a maximum for PE positive bias and the e- current decreases considerably for this bias.

Note that the n- current is not negligeable for PE negative bias.

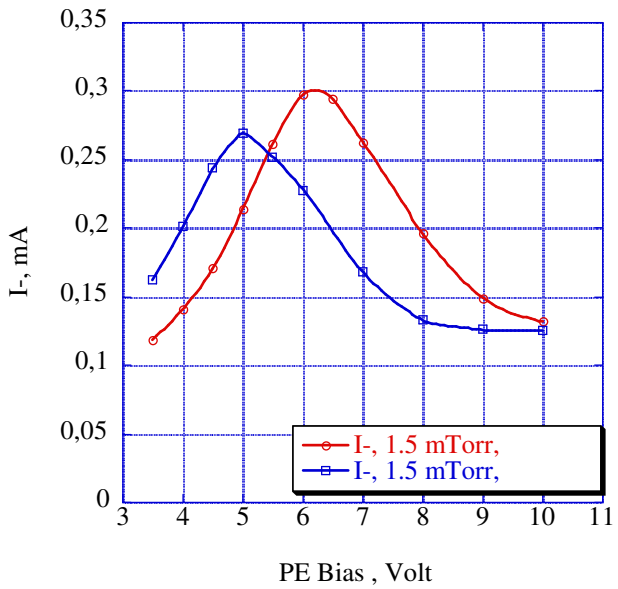




Extracted currents vs ECR sources location

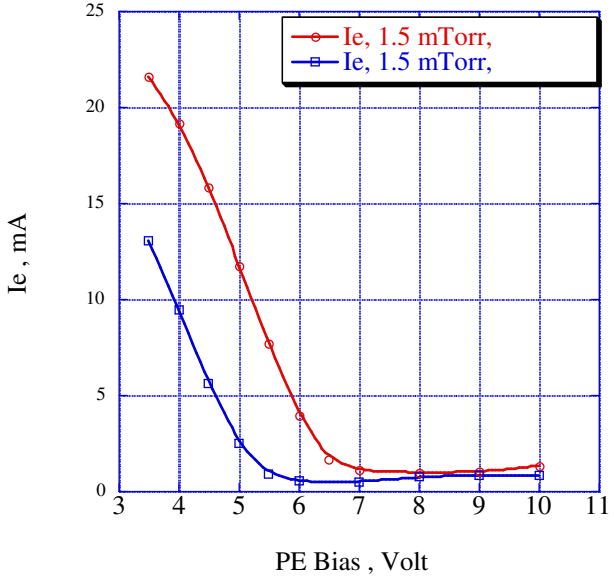
Two distances (from extraction) are compared: 19.5 cm and 24.5 cm.
Experiment effected under pressure conditions: 1.5 mTorr.

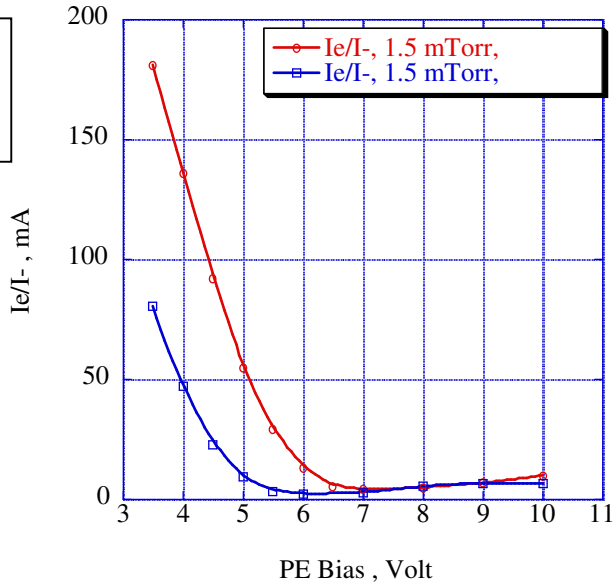
Red curves correspond to D = 19.5 cm
and
Blue curves correspond to D = 24.5 cm



Negative ions

Electrons



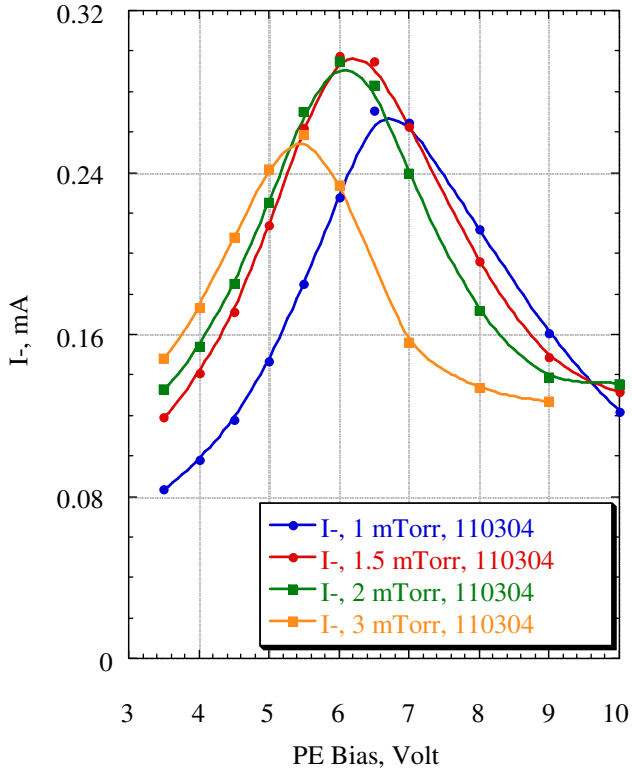


Ie/I-

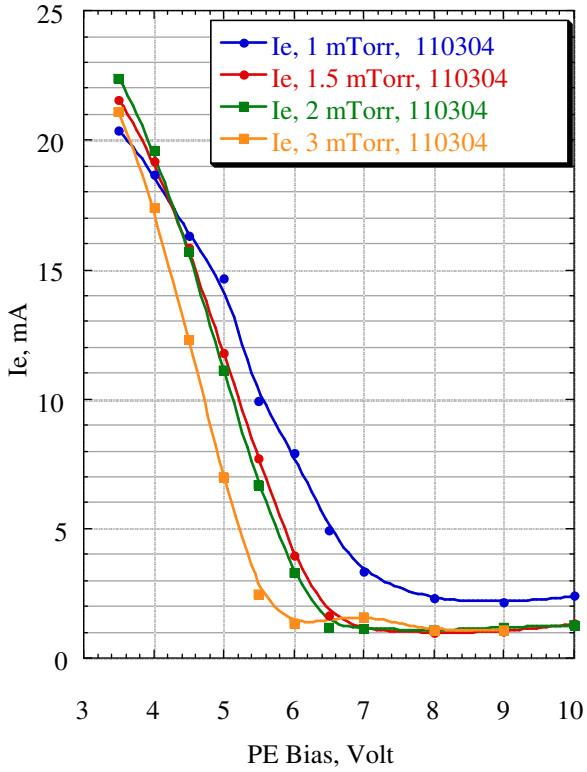
Extracted currents vs PE bias

effect of H2 pressure
MINIMUM distance from ECR sources to plasma electrode : 19.5 cm

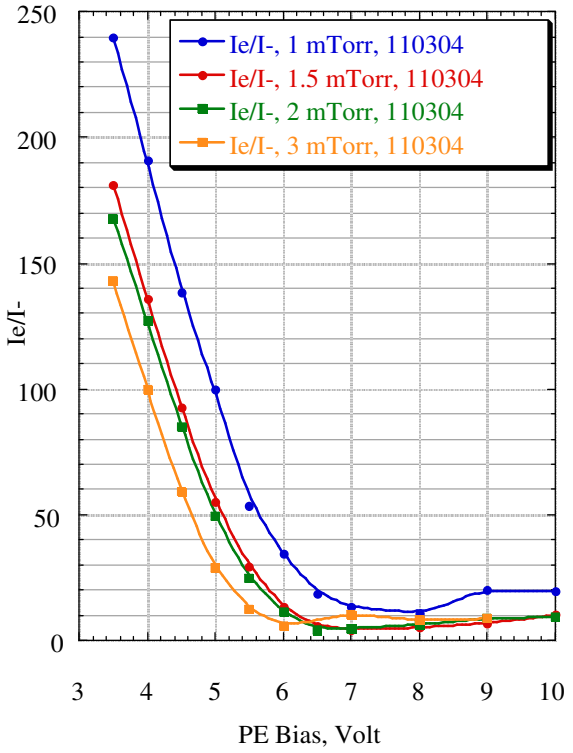
Negative ions



Electrons



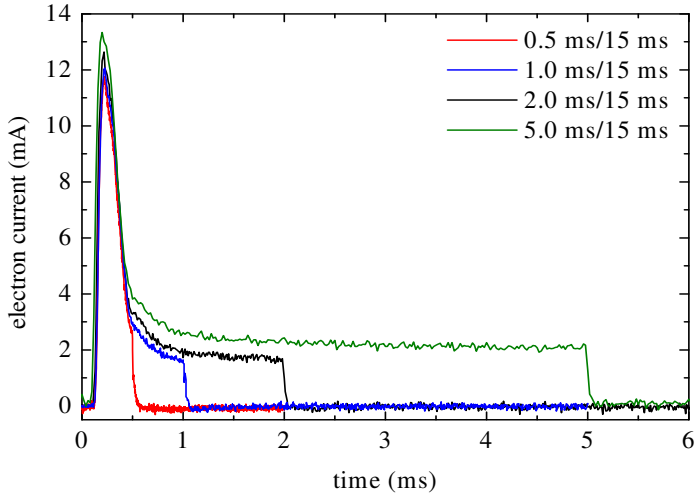
Ie/I-

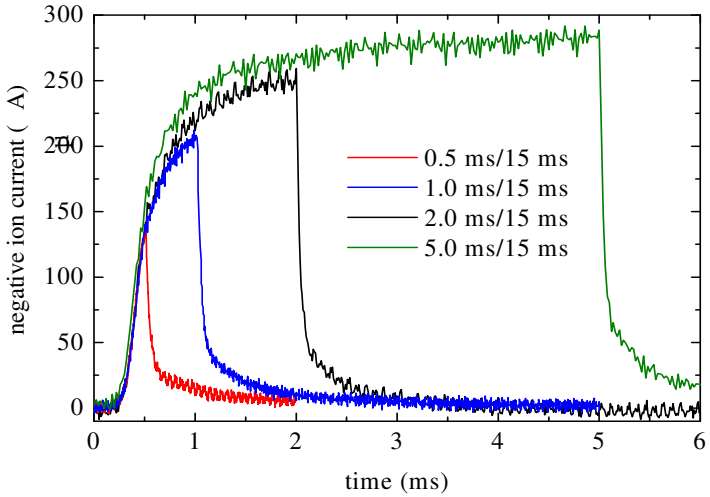


Pulsed extracted beam:

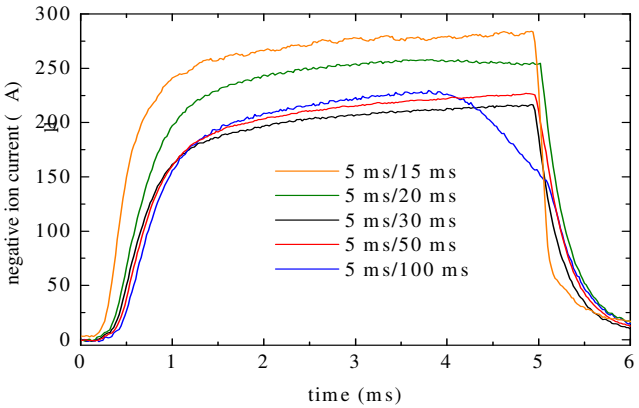
vs pulse duration and repetition rate

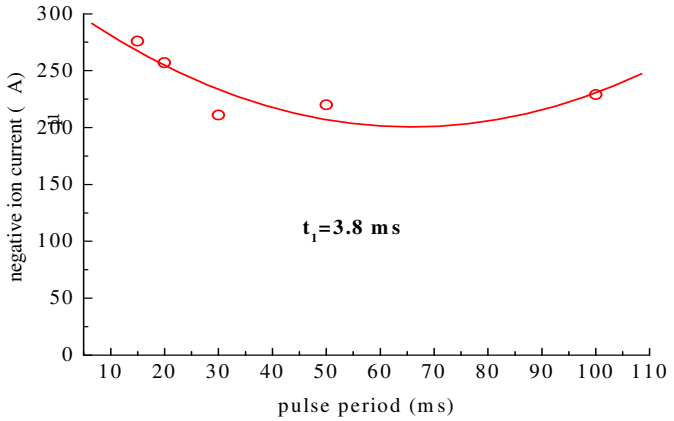
with PE bias optimised to minimise e-/H- ratio





H- currents comparable with cw extracted current when pulse ≥ 2 ms





Pressure: 1.5 mTorr,

Power: 1.2 kW,

V_{EP} = +6 V,

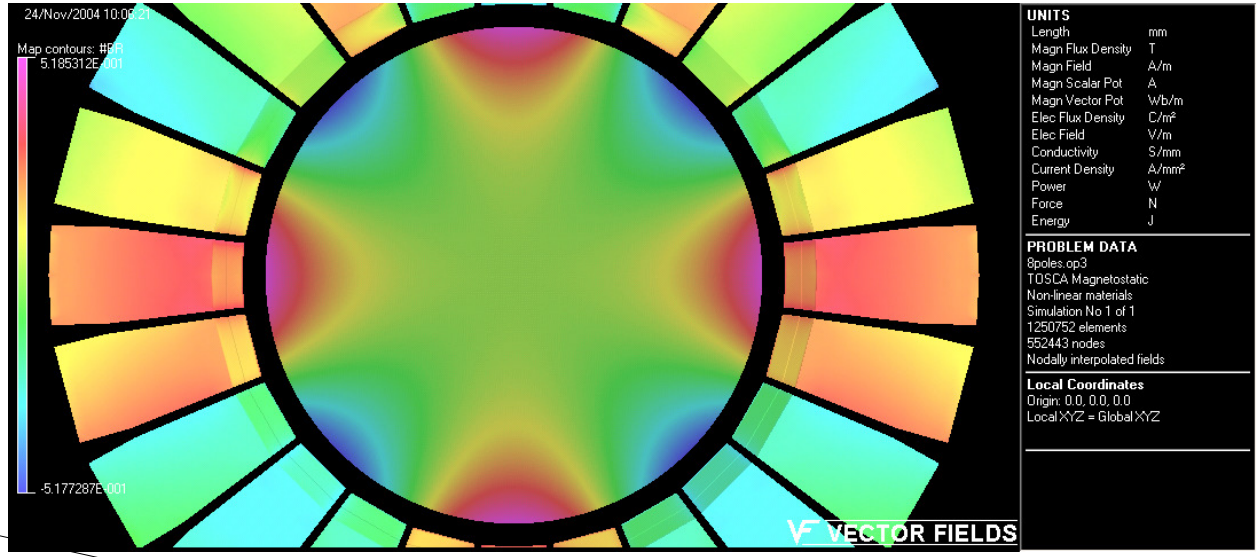
V_{ext} = 2 kV

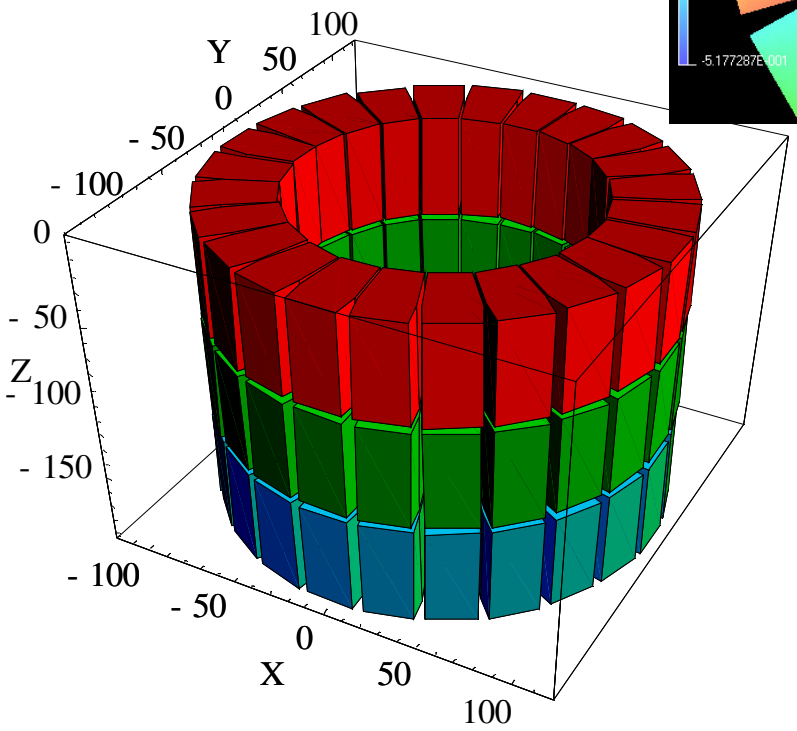
Future work

- **Study of 1 kW pulsed discharge: extracted currents, plasma parameters**
- **Study of 0.6 to 6 kW pulsed discharge (in collaboration with Saclay)**
- **Photodetachment measurements: choice of laser intensity and diameter suitable for ECR driven discharge (in collaboration with DCU)**
- **Study of a more powerful ECR mini-source**
- **Study of EEDF in collaboration with DCU**

Future work

- Multi-poles





- Octopole configuration : enough for a large heating R=32mm
- No magnetic field on the axis nor at extraction

Conclusion

Both groups observed H- ion production with two different types of 2.45 GHz ECR sources. The results are still far from the HPPA(s) requests.

Nevertheless, further improvements are expected by a better understanding of each source behavior and with several modifications.

At Ecole Polytechnique,

- Why hydrogen pressure affects differently extracted current and plasma characteristics ?
- Why the wall state degradation affects stronger the extracted currents than the plasma characteristics ?
- Investigating the different regimes while the ECR source location changes
- Increasing microwave power in pulsed mode
- Using only one ECR source (more powerful)

At Saclay,

- Some interpretations problems with
  - the behavior of H- production vs the Separator Magnetic Field
  - Increase of H- with gas mixing
- Magnetic field at extraction is too high with coils
  ➔ need to change to a multipole configuration