FROM RESEARCH TO INDUSTRY

cea

Irfu

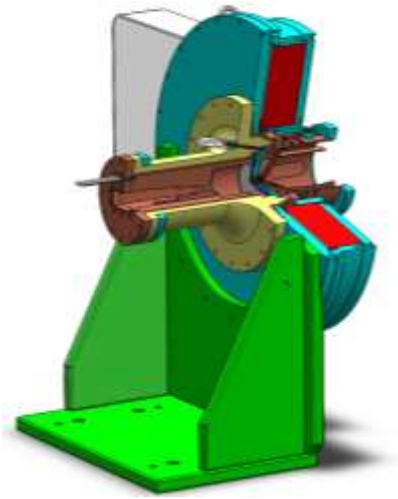
CEA - Saclay

www.cea.fr

HIGH INTENSITY LIGHT ION SOURCES

O.Tuske
Irfu / SACM

Sources for research



Research for sources

CSI, January 14-15, 2015

SUMMARY

Principle of an ECR ion source

- SILHI source for IPHI project

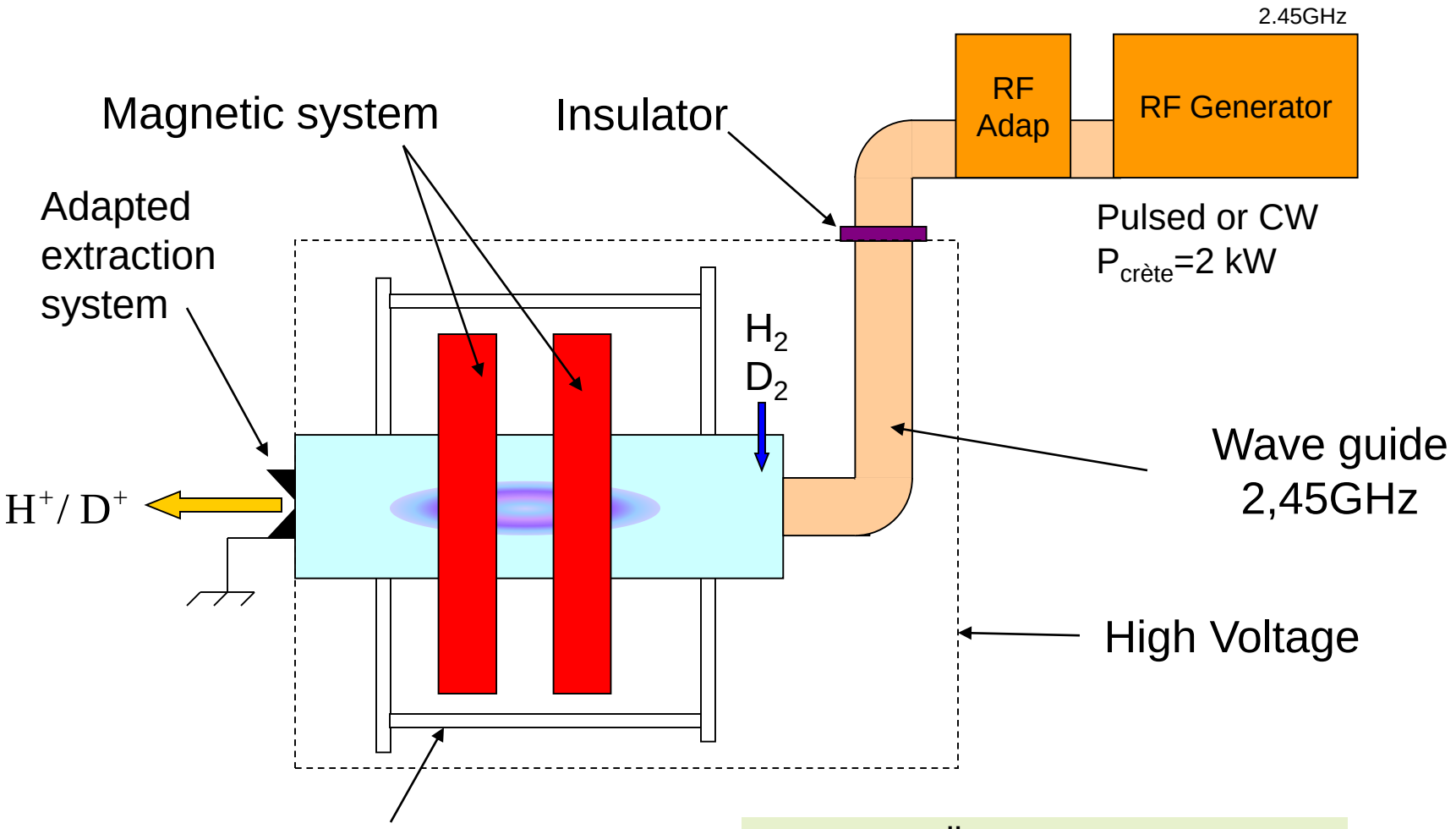
Results in recent years

- IFMIF : in Japan
- SPIRAL2 : in Caen
- FAIR : Installation of a new ion source in 2015

R&D

- Simulations with WARP code
- ALISES ion source

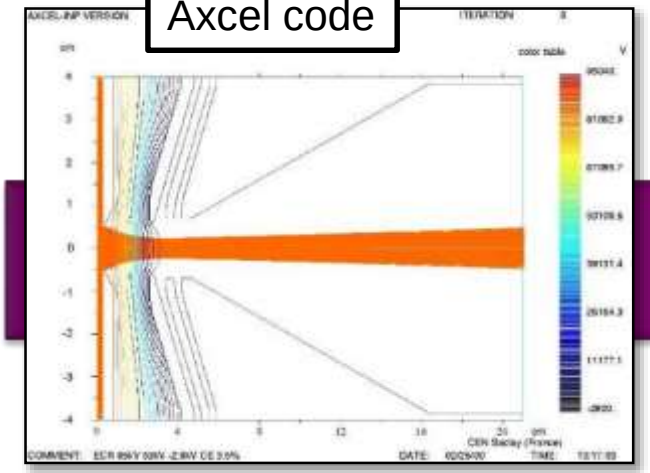
ECR PRINCIPLE

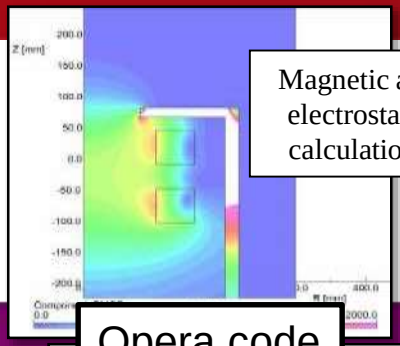


$$\left.\begin{array}{l} w_{cyclo} = \dfrac{eB}{m} \\ w_{HF} \end{array}\right\} \quad w_{cyclo} = w_{HF} \quad \text{for } B = 875 \text{ Gauss}$$

SILHI SOURCE

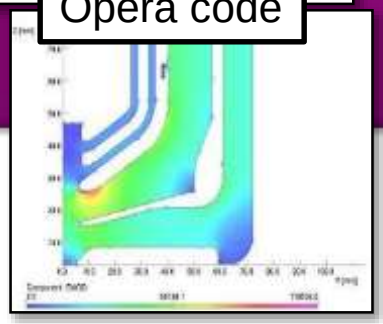
Axcel code



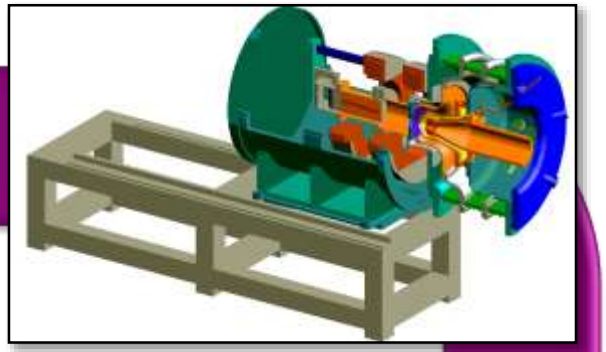


Magnetic and electrostatic calculations

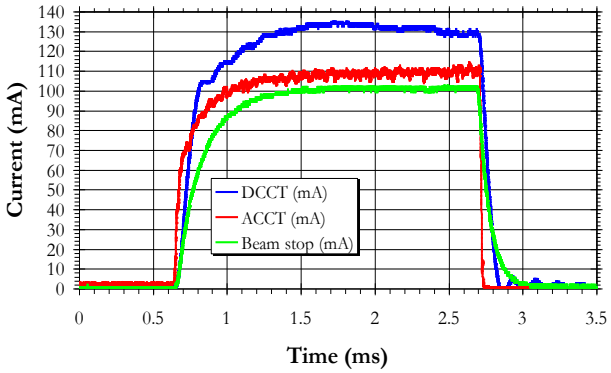
Opera code

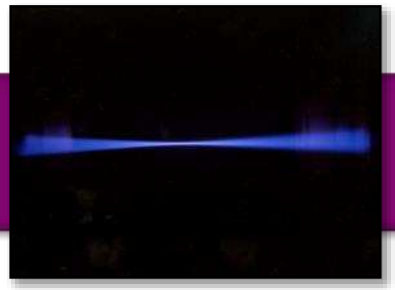


H^+/D^+
100mA @ 100kV
Pulsed or CW



H^+ ou D^+ beam



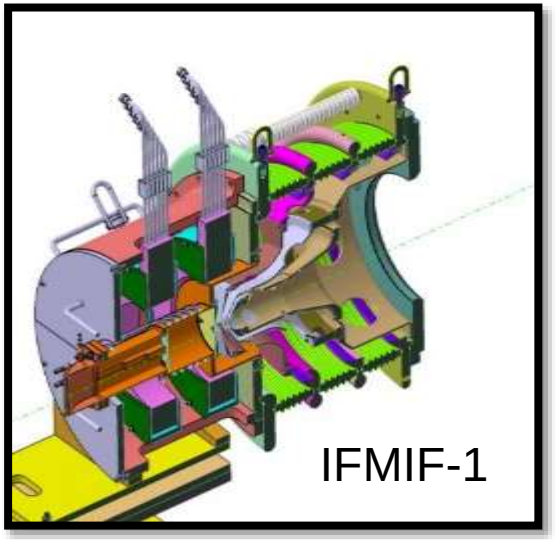


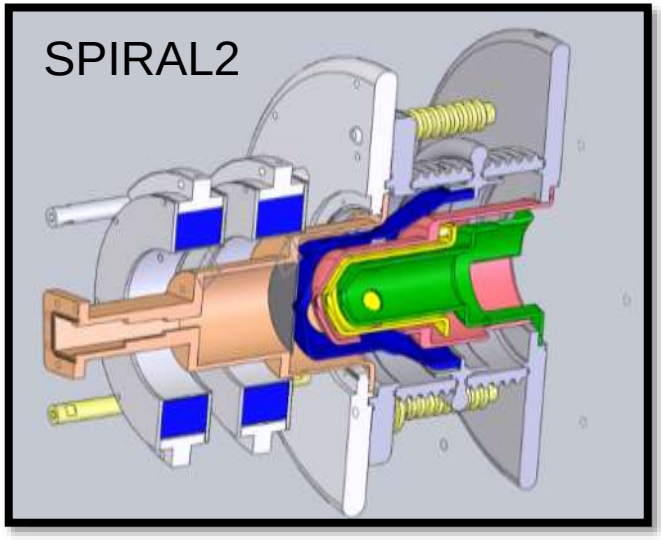
First beam in 1996, still in operation

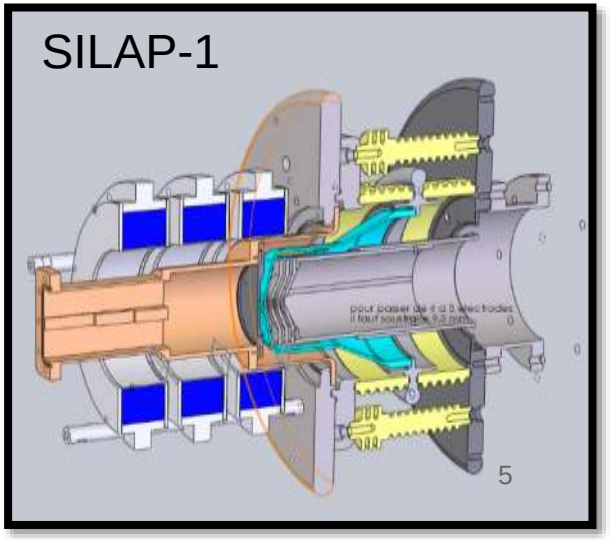
2015 GOAL :
H+ beam injection into the IPHI RFQ

ION SOURCES DEVELOPPED AT CEA SACLAY

Projet /Source	High Voltage	Exctracted intensities	Operation mode	Magnetic Configuration
SILHI ➔ IPHI	100kV	100mA H^+	CW / Pulsed	Coils
SPIRAL2	20kV 40kV	5mA H^+ 5mA D^+	CW / Pulsed	Permanent Magnets
SILAP-1	40kV	40mA H^+	Pulsed 50% DC	Permanent Magnets
IFMIF EVEDA	100kV	140mA D^+	CW / Pulsed	Coils
ALISES	30kV 100kV	18mA H^+ Not yet tested	Pusled 20% DC	Coils
SILHI2	50kV	40mA H^+	CW / Pulsed	Permanent Magnets
FAIR	95kV	Not yet tested	Pulsed 4% DC	Coils







RECENT RESULTS

IFMIF

SPIRAL2

FAIR

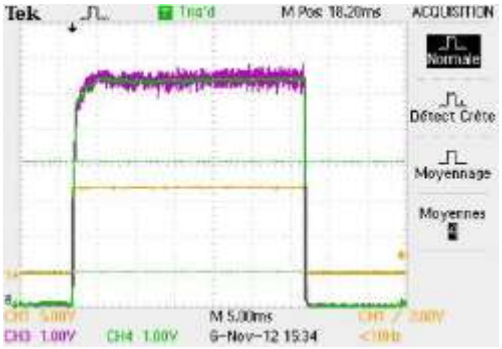
IFMIF : ION SOURCE AND LEBT COMMISSIONING AT SACLAY 2012

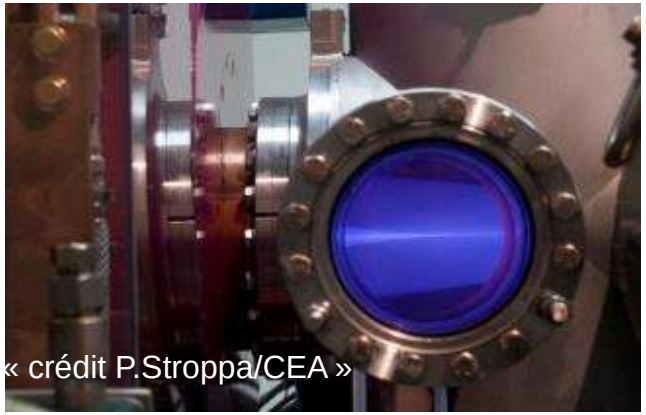
The Acceptance tests have been performed in November 2012:

- Beam characterization was made with D+ beam in both pulsed and continuous modes.
- Species fraction has been measured after 1st solenoid
- Emittance scanner was measured at end of the LEBT (after cone)

D^+ beam,
100 keV
30 % DC
160 mA total
125 mA after cone

Orange: trigger
Green: current from HVPS
Pink: current on Beam Stop

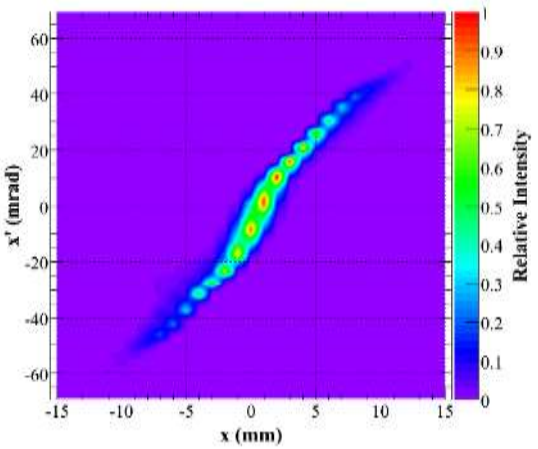



« crédit P.Stroppa/CEA »

Particles: D^+ – Extraction Voltage: 100 kV
Pulse Length: 30 ms – Repetition rate: 10 Hz.

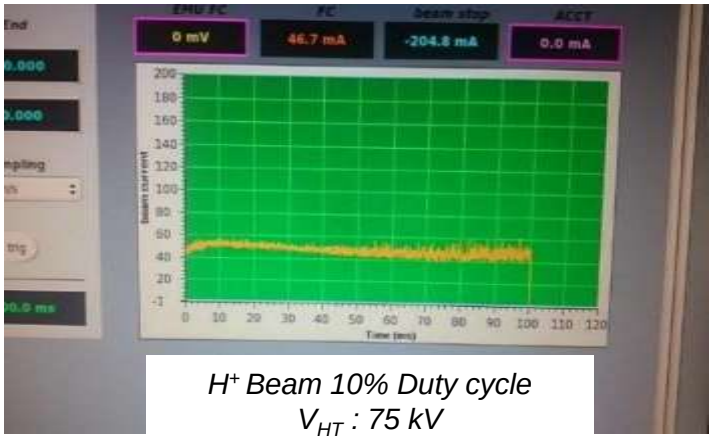
I_{BS} (mA)	I_{Tot} (mA)	D^+ proportion (%)	U_{IE} (kV)	ϵ (π.mm.mrad)
100	134	75	40	0.14
120	151	80	40	0.19
140	170	82	40	0.39
140	170	82	43	0.32

Examples of emittance measurements with 140 mA of D^+ on beam stopper

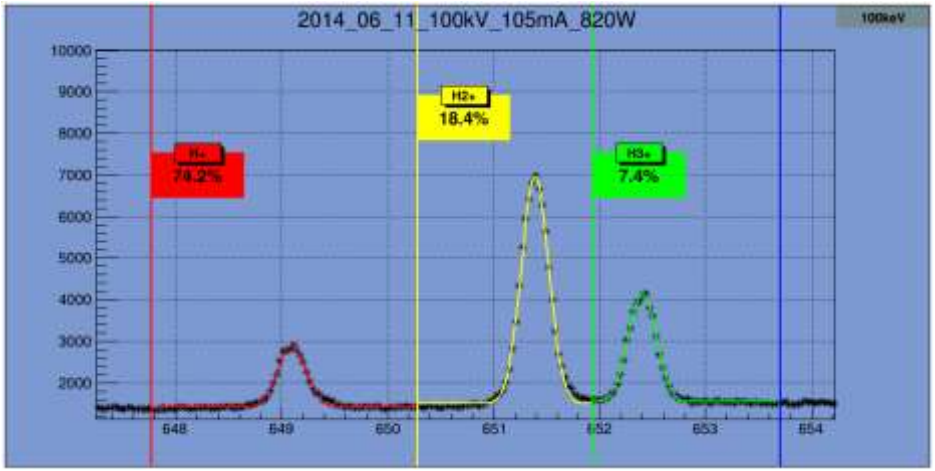


IFMIF : ION SOURCE AND LEBT INSTALLATION AND START AT ROKKASHO (JAPAN) 2014

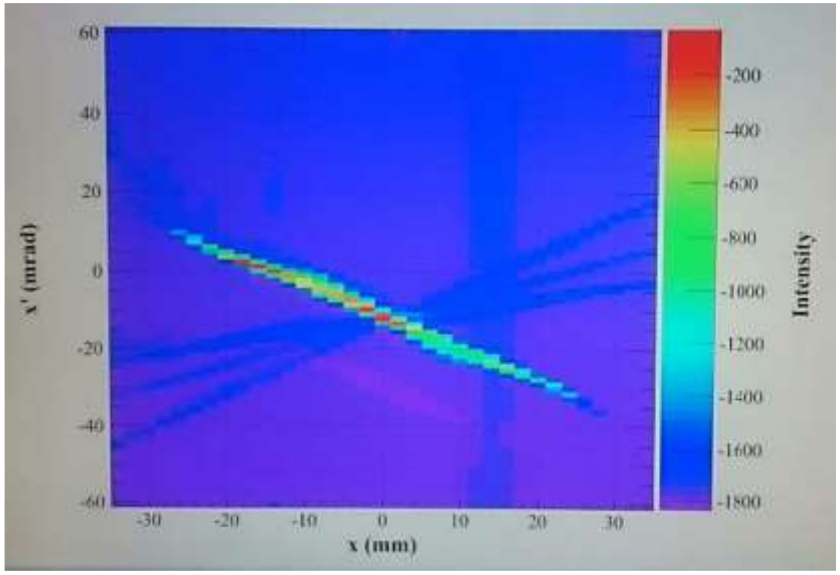
- May 2013 : Delivery of ion source and LEBT to Rokkasho
- 24 Oct 2014 : First plasma
- 04 Nov 2014 : First H^+ Beam extracted
- 05 Nov 2014 : 100keV/105mA 1Hz 50% Duty cycle



H^+ Beam 10% Duty cycle
V_{HT} : 75 kV
I_{CF} : 40 mA



H^+ Proportion measurement with Doppler shift analysis



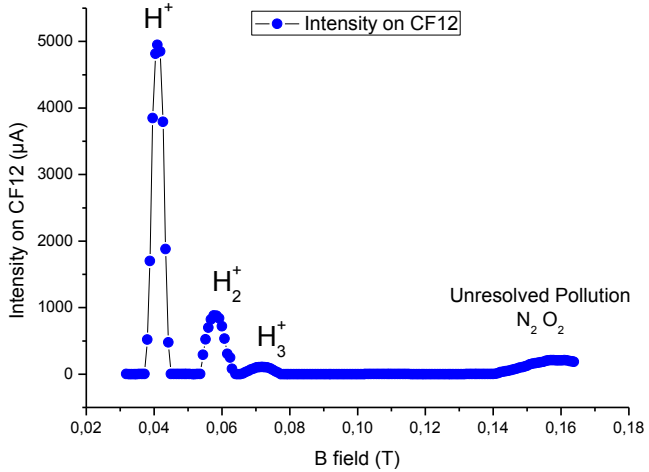
Emittance measurements after 1st solenoid

2015 GOAL : commissioning proton and deuteron beams in the first semester

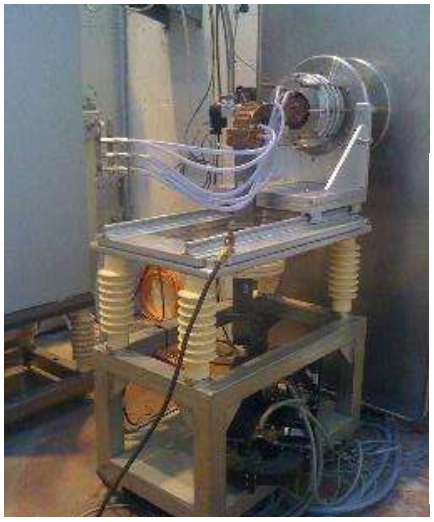
SPIRAL2: SET UP AND START OF THE DEUTERON ION SOURCE AT SACLAY 2012

- 2009 : First beam with the ion source on BETSI
- 2010-2012 : Installation of the Source inside the vault at Saclay

H⁺ / D⁺ beams
20 / 40 keV
10 mA total
5 mA end LEBT

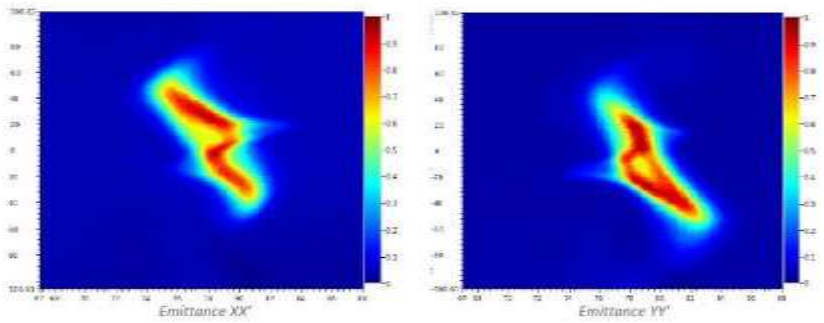


ION	%
Ions	100%
H^+ / D^+	81% / 83%
H_2^+ / D_2^+	14% / 12,3 %
H_3^+ / D_3^+	1,7% / 1,2%
Heavy	3,4% / 3,5%



Spiral2 deuteron source

5mA D^+ at RFQ injection point



ε=0,231π.mm.mrad

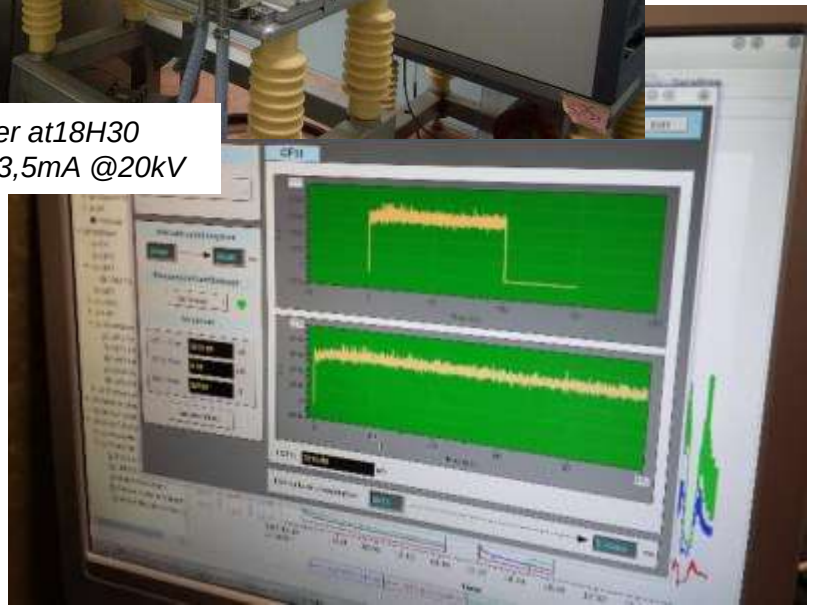
LEB2 and LBEC installed at Saclay

SPIRAL2: SET UP AND START OF THE DEUTERON SOURCE AT GANIL (FRANCE)

- 2013 : Installation of the source and all component inside the vault n°3 in Caen
- **19 December 2014 at 18h30** : First H^+ beam produced for Spiral2

March: installation of the ion source in the Vault n°3 in Spiral2

19 December at18H30
First H^+ Beam 3,5mA @20kV

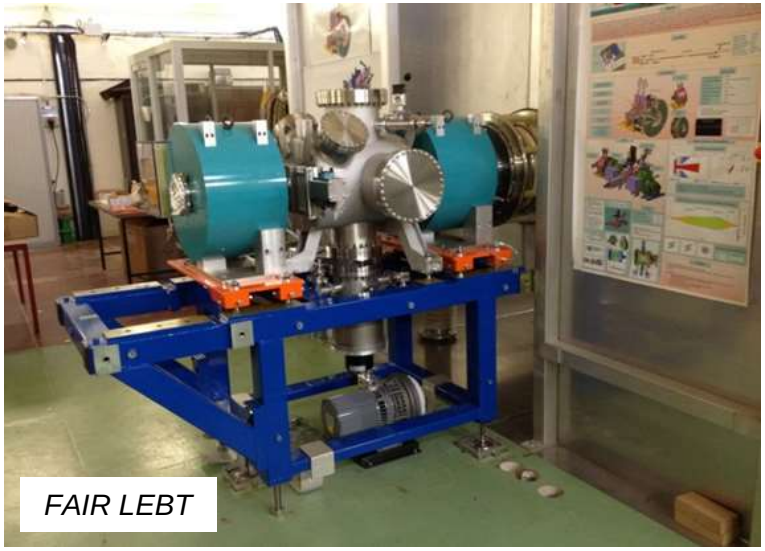


2015 GOAL :
commissioning of H^+ and D^+ beam before RFQ commissioning

FAIR : INJECTOR INSTALLED AT SACLAY

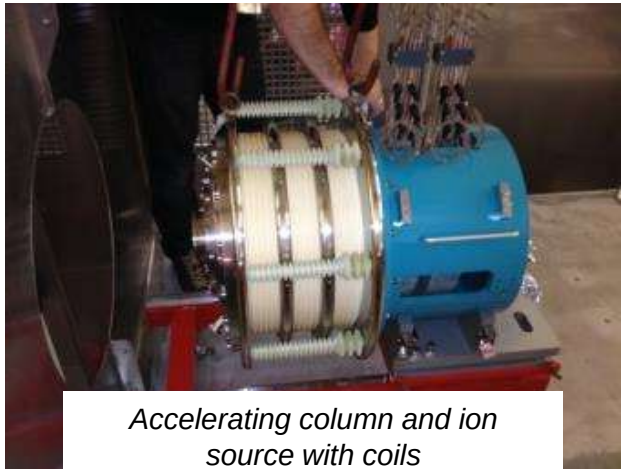
- Ions source, RF chain and accelerating column installed on HV platform
- LEBT positioned and aligned

H^+ beam,
100 keV
100 mA total
70 mA after cone
PULSED ONLY



FAIR LEBT

Accelerating column



Accelerating column and ion source with coils

Source and RF chain on plateform

2015 GOAL : Start and commissioning proton beams in the first semester

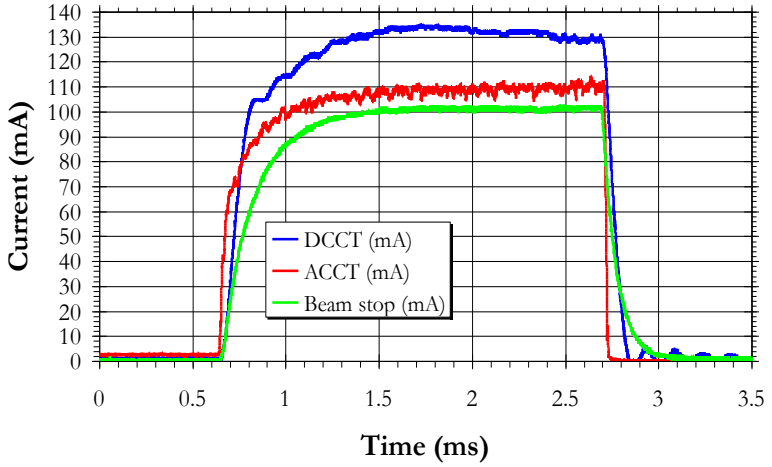
R&D PROGRAM IN CEA FOR ION SOURCE DEVELOPMENT

R&D PROGRAM

Design better ion sources with :

- Higher extracted intensities > 150 mA
- Lower Emittance < 0,2 π mm.mrad
- Shorter rise time < 100-200 µs
- Better stability < 1%
- Higher availability > 98%
- Easy maintenance
- Low cost

…



To achieve these improvements we need :

- New models for simulations,
- A polyvalent ion source « at home » that can be used to test new ideas and parameters : ALISES ion source

PLASMA SIMULATIONS

WARP
« Open source » code

Code 3D –PIC
Time dependant

Physics involved
Dissociation / Ionisation,
Secondary electrons
RF Heating
Plasma thermalization
Bias influence on plasma
Plasma chemistery

First studies in 2012 (PhD S.Nyckees)

This program restarted last October in collaboration with external company Pantechnik (co-financed post doc : R. De Guiran)

Funding for region Ile de France for a computer cluster for massive parallel calculations : ISIPIC

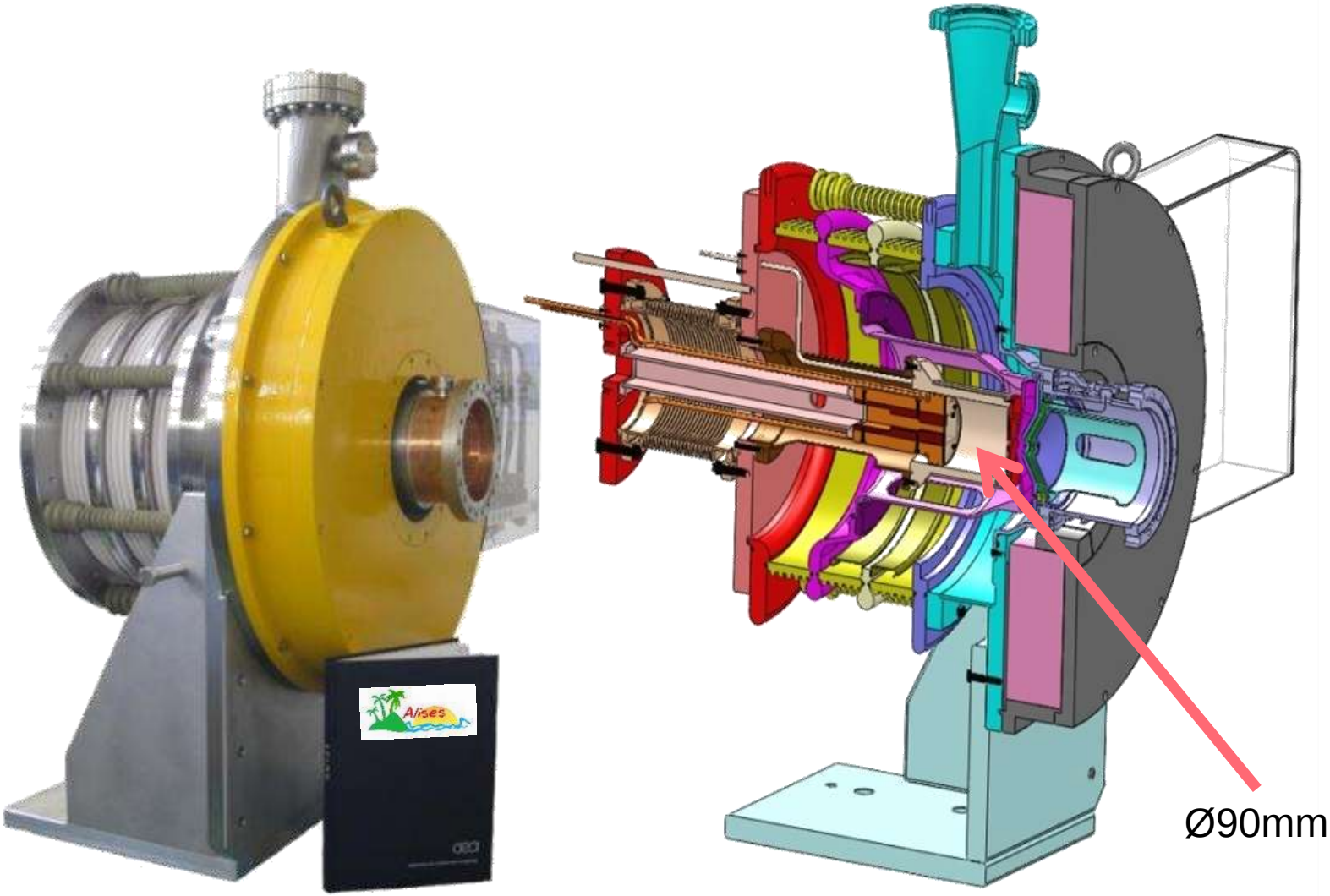
SYNERGIUM
Intensité
Plateforme de recherche sur les accélérateurs à haute intensité

îledeFrance

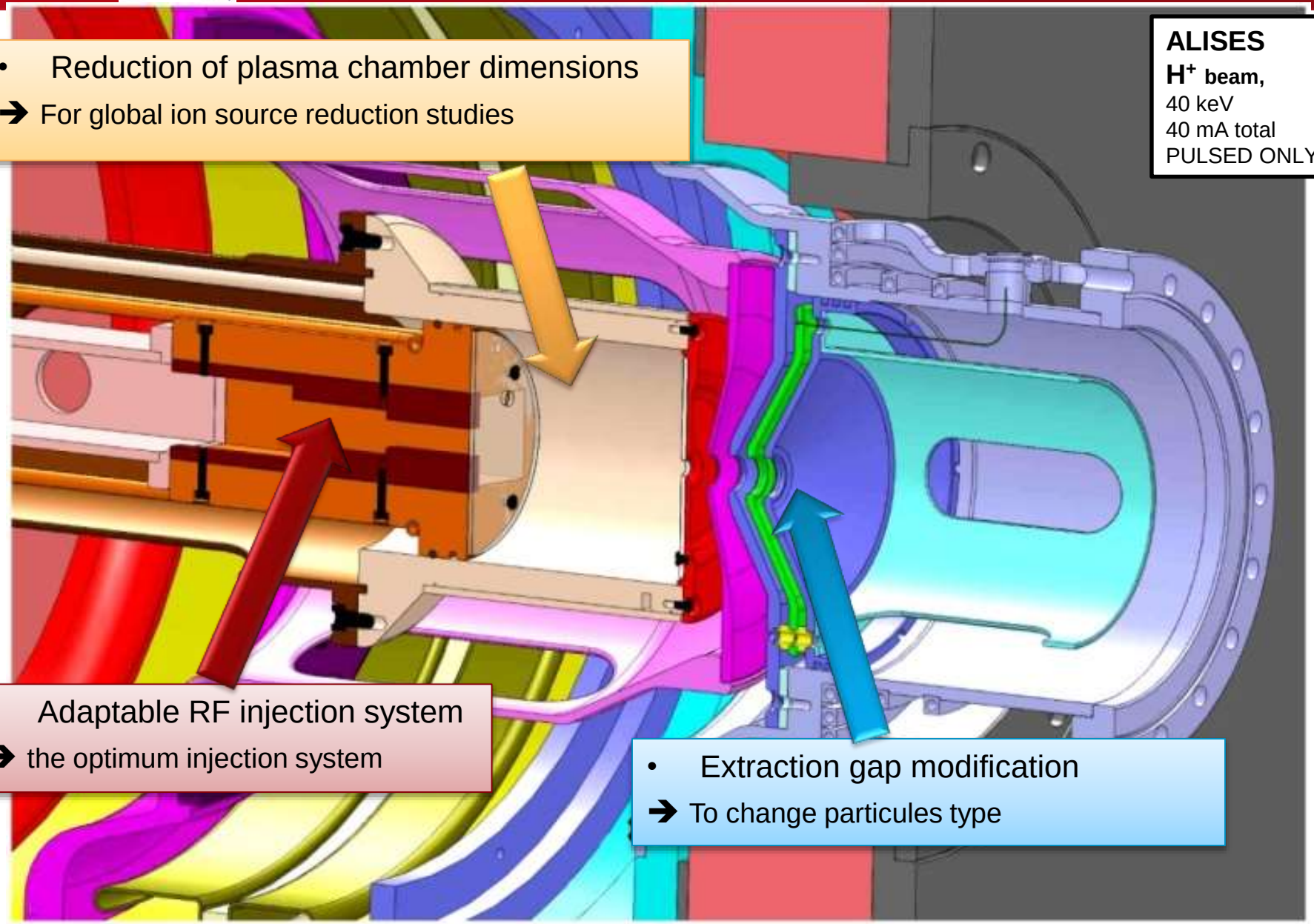
2015 GOAL :
Implement physics process in WARP
Confront simulations and measurements on ALISES ion source

ALISES : ION SOURCE FOR R&D

ALISES ion source



ALISES : ION SOURCE DETAILS



- Reduction of plasma chamber dimensions

➔ For global ion source reduction studies

ALISES
H^+ beam,
40 keV
40 mA total
PULSED ONLY

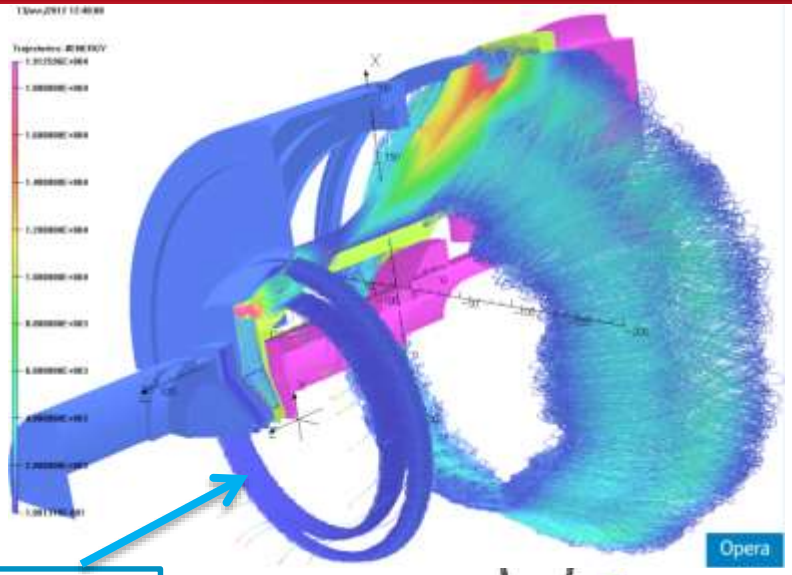
- Adaptable RF injection system

➔ the optimum injection system

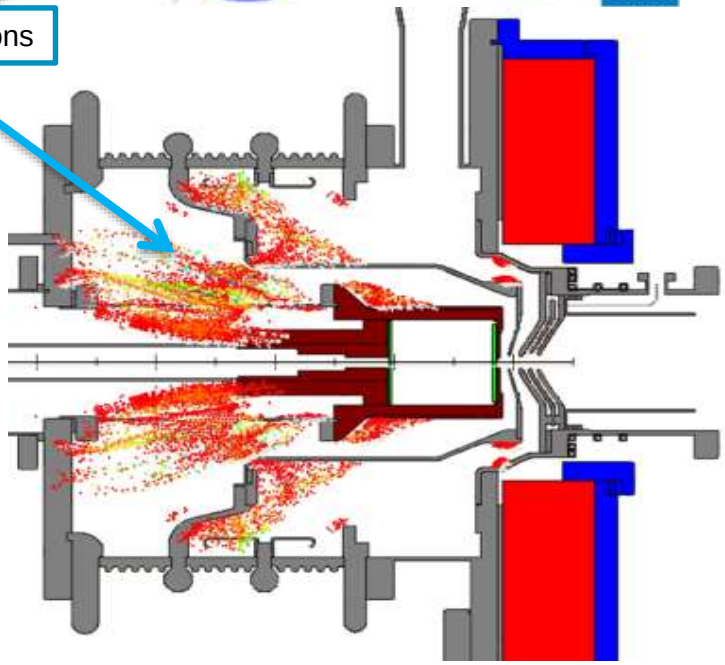
- Extraction gap modification

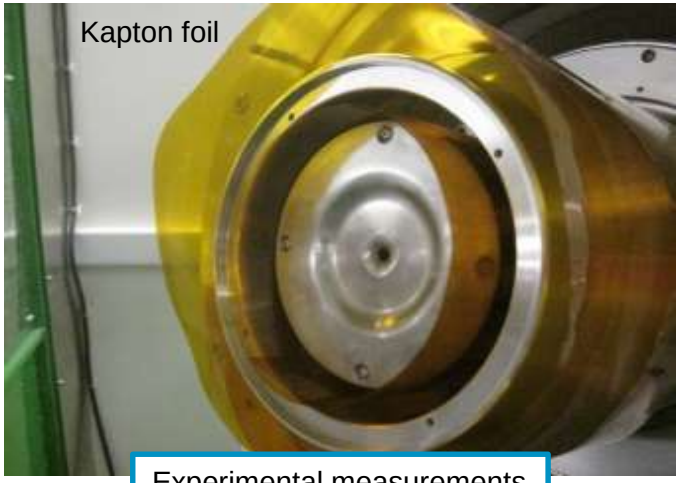
➔ To change particules type

ALISES : PENNING DISCHARGES ANALYSIS



Trapped electrons





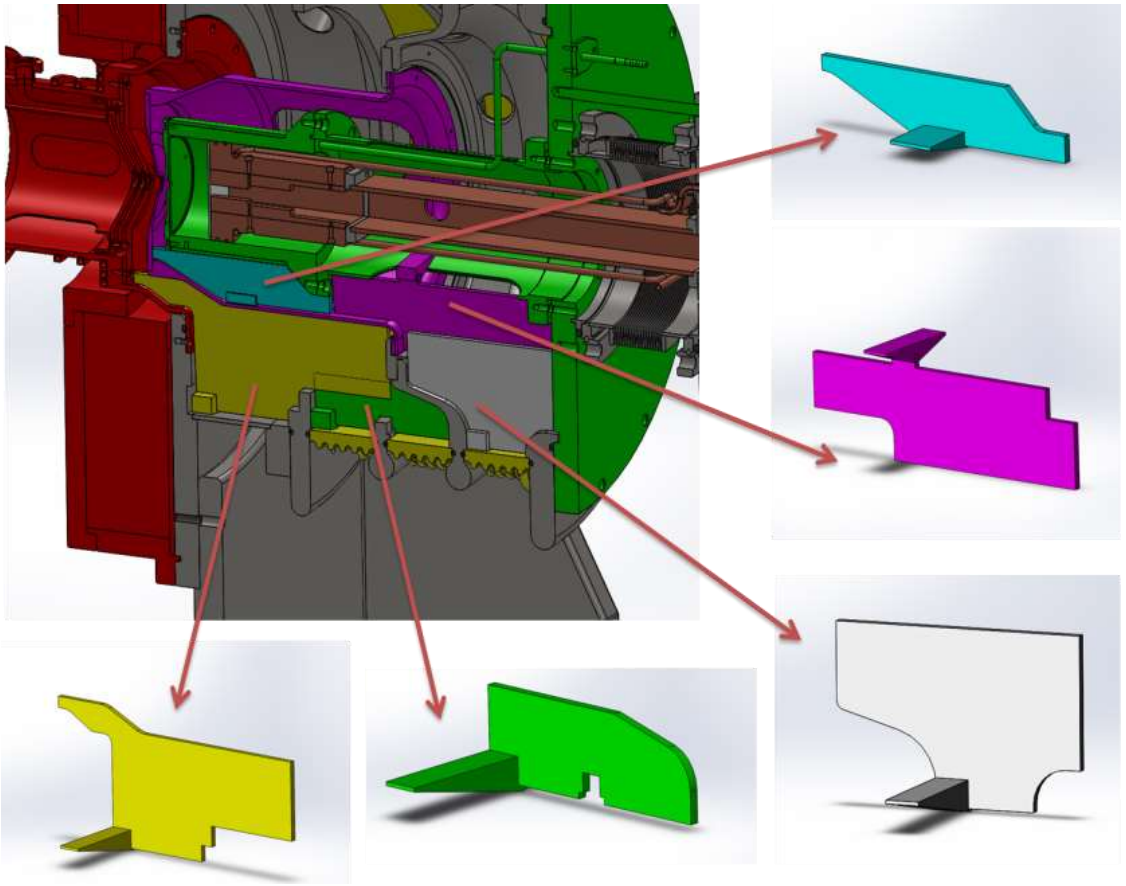
Experimental measurements

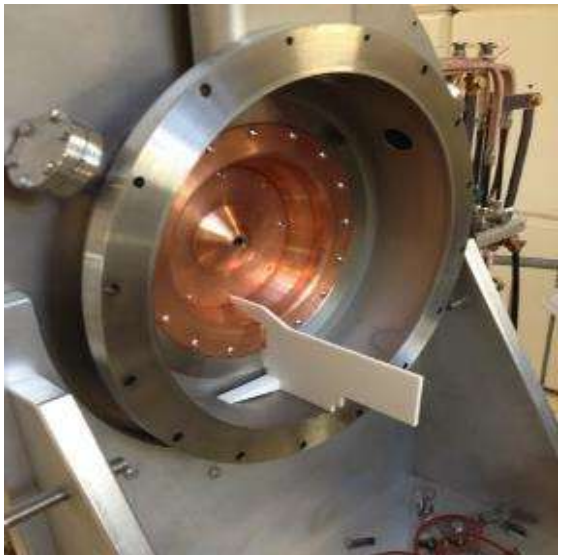
Validation of simulation

PhD S. Nyckees, 2012-12

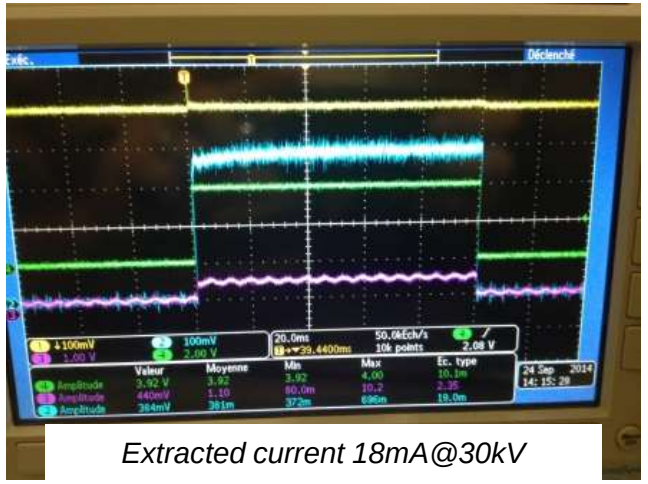
ALISES : FIRST UPGRADE

- R&D financed by SACM internal Funding in 2013
- Macor inserts were placed where electrons are trapped
  - Succeed in higher bias voltage 30kV
  - Extracted current = 18 mA



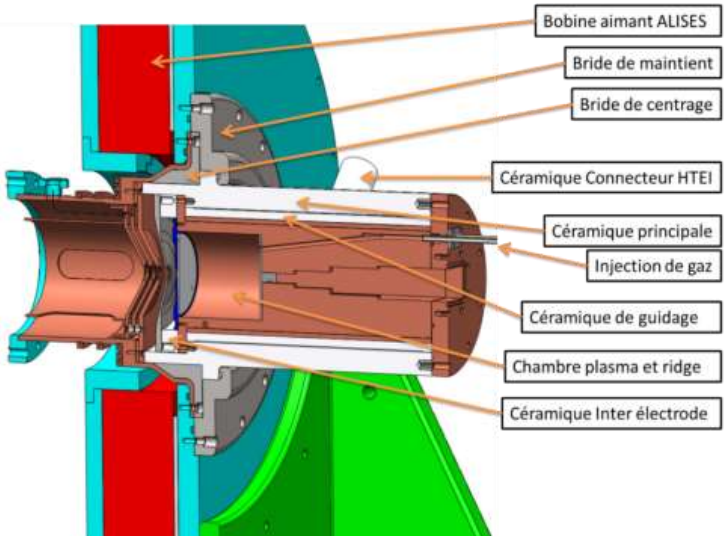


MACOR inserts inside ALISES source



Extracted current 18mA@30kV

ALISES : NEXT STEP



ALISES V2 already designed and built but not yet assembled

Yesterday 2015-01-14

2015 GOAL :

- Finish Assembling and test ALISES v2
- Confrontation of measurements with plasma simulations

CONCLUSIONS

We have R&D ideas about all aspects of ion sources :

- Develop plasma simulations and measurements
- Investigate alternative RF sources and injection systems
- Simulate and test different magnetic configurations
- Optimize the geometry of the extraction system
- Think of mechanical and electrical improvements

This R&D requires:

- A local test bench : upgrade of BETSI in progress
- Plasma and beam diagnostics : benefit from our work and experience on other projects (IFMIF, FAIR, ESS…)
- Money, manpower (scientific and **technical**) with dedicated time

THANK
YOU
FOR
YOUR
ATTENTION