ECRIS2016
The 22nd International Workshop on ECR Ion Sources

FROM RESEARCH TO INDUSTRY

cea

DEVELOPMENT OF A COMPACT HIGH INTENSITY ION SOURCE FOR LIGHT IONS AT CEA-SACLAY

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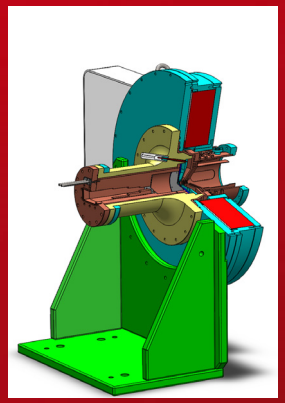
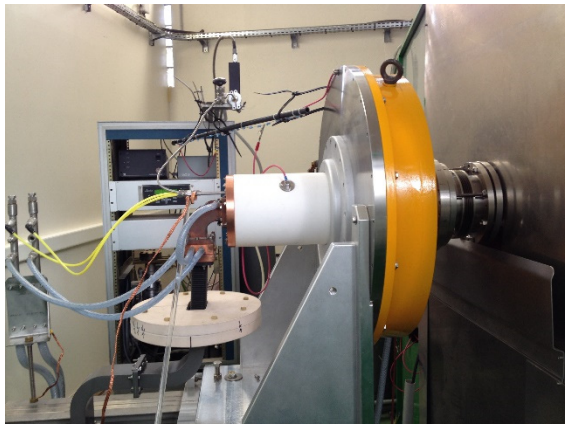
Irfu/SACM





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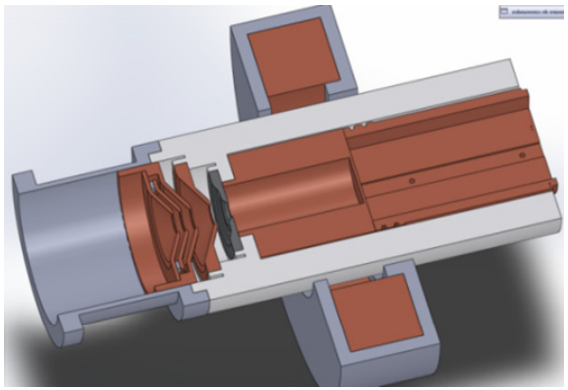
TOWARDS COMPACT HIGH INTENSITY 2.45 GHZ ECR ION SOURCES FOR LIGHT IONS

Main goal of this work : to minimize the divergence and emittance growth of intense beams extracted from ECR ion sources due to space charge effects

Outline:

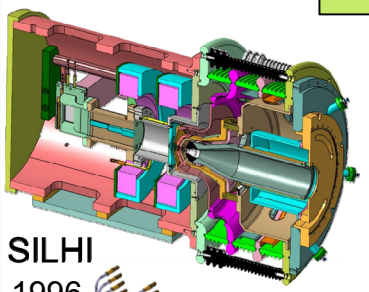
- High intensity ECR Ion sources developed at Saclay
- The ALISES concept (*Patent FR 2969371 - 2010*)
- Development of ALISES source (2009-2012)
- The Penning discharge problem
- The compact ECR ion source ALISES II (2014-2015 *Patent FR 1556871 - 2015*)
- Evolution towards ALISES III (end of 2016)



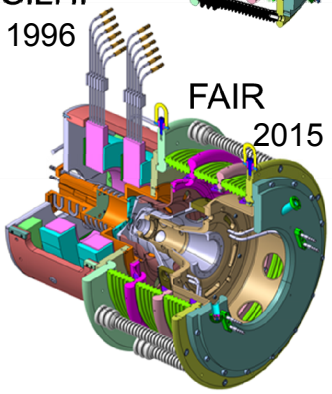
First idea of concept in 2009

ECR ION SOURCES DEVELOPED AT SACLAY
SIMULATIONS, CONCEPTION, FABRICATION

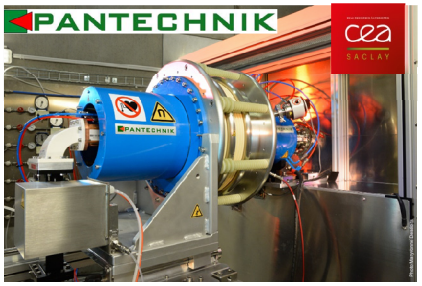
2.45GHz ECR ion sources for projects, but also sources for R&D



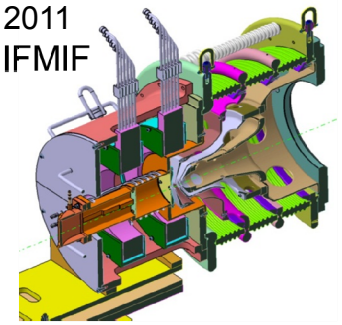
SILHI
1996



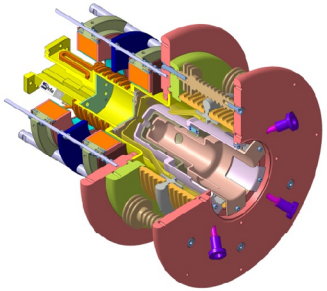
FAIR
2015



SILHI2 2014



2011
IFMIF



SPIRAL2
2009

Projects

R&D

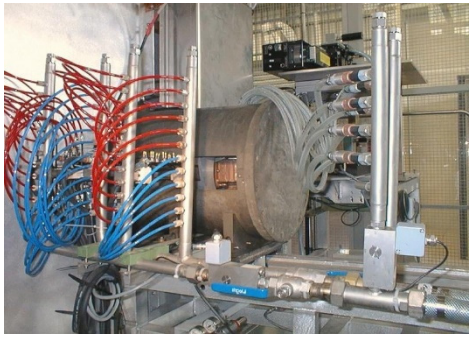
Valorization

Project /Source	High Voltage	Current	Magnetic Configuration
SILHI IPHI	100kV	100mA H^+	Coils
IFMIF EVEDA	100kV	140mA D^+	Coils
SPIRAL2	20kV 40kV	5mA H^+ 5mA D^+	Permanent Magnets
FAIR p linac	100kV	100mA H^+	coils
ALISES	23kV	18mA	Coil
ALISES II	50kV	40mA	Coil
SILAP-1	40kV	30mA / 60mA	Permanent Magnets
SILHI2	50kV	40mA H^+,D^+	Permanent Magnets

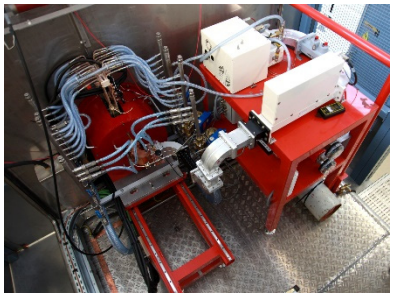
HIGH INTENSITY 2.45 GHZ ECR ION SOURCES FOR LIGHT IONS AT SACLAY

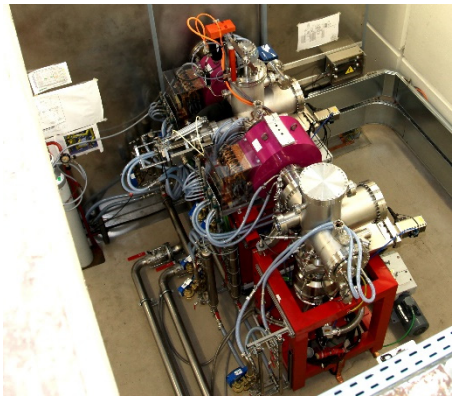
OVERVIEW

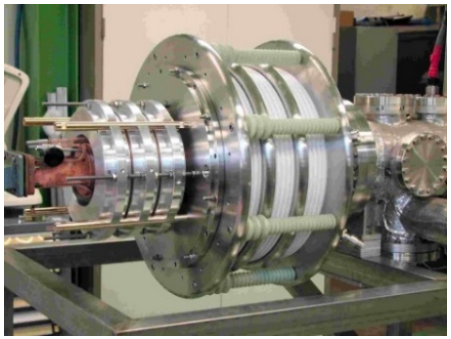
SILHI source
H^+ 100mA ,95kV CW



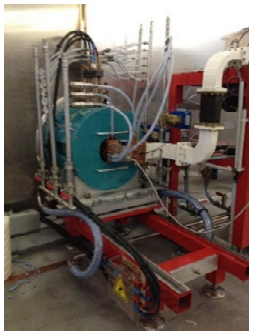
IFMIF source
D^+ 140mA ,100kV CW

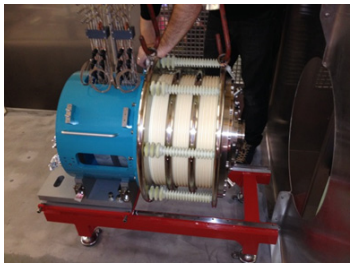






SPIRAL2 source
H^+,D^+ 5mA ,20kV/40kV



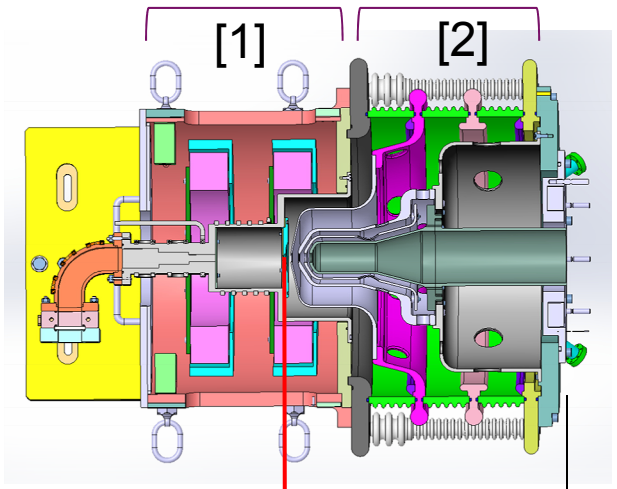


FAIR source
H^+ 100mA ,95kV
4Hz, 4% duty cycle

All these sources have the same basic structure

2 successive ensembles connected :

- [1] A source body = Magnets + plasma chamber +wave guide
- [2] An Insulating structure between HV and ground in which an extraction system is connected between plasma chamber and LEBT



High intensity beams means Space charged effects in LEBT and emittance growth

Main objective: **Reduction of LEBT length**

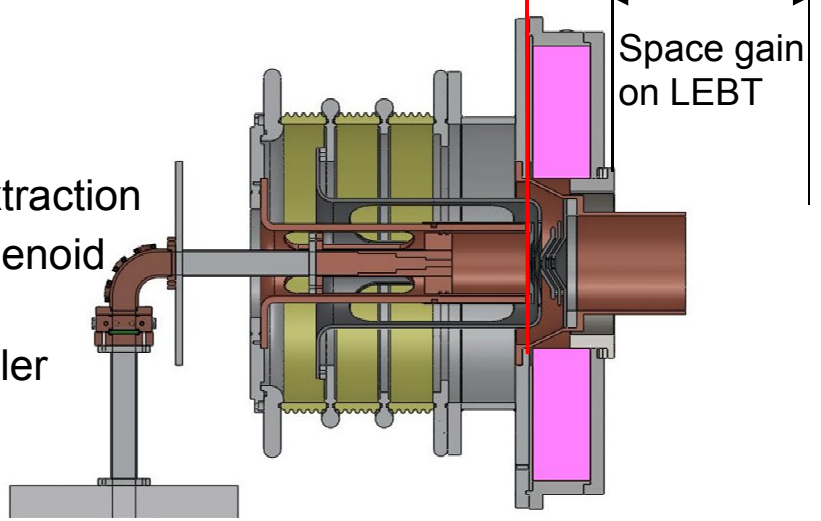
The ALISES concept

Structure reversed:

► Put the insulation structure behind the plasma extraction

► ECR resonance obtained with fringe field of a solenoid on ground potential at the beginning of LEBT

► Extraction system is simplified, except for the puller



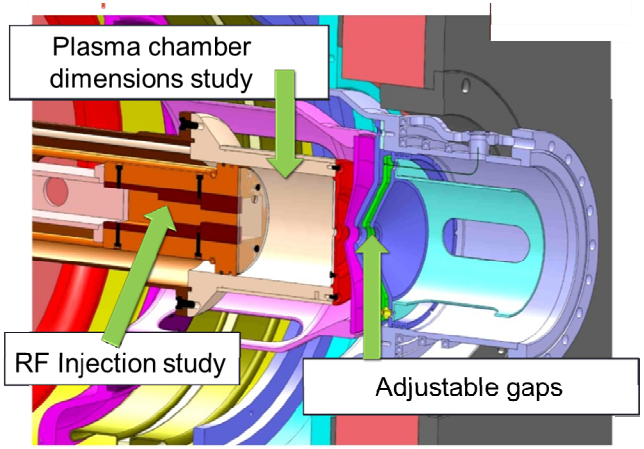
ALISES V1 source

Patent CEA FR1060578

ALISES CONCEPT

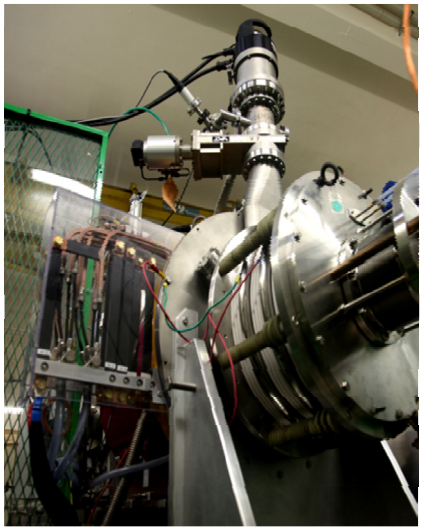
ALISES :Advanced Light Ions Source Extraction System

ALISES longitudinal cut

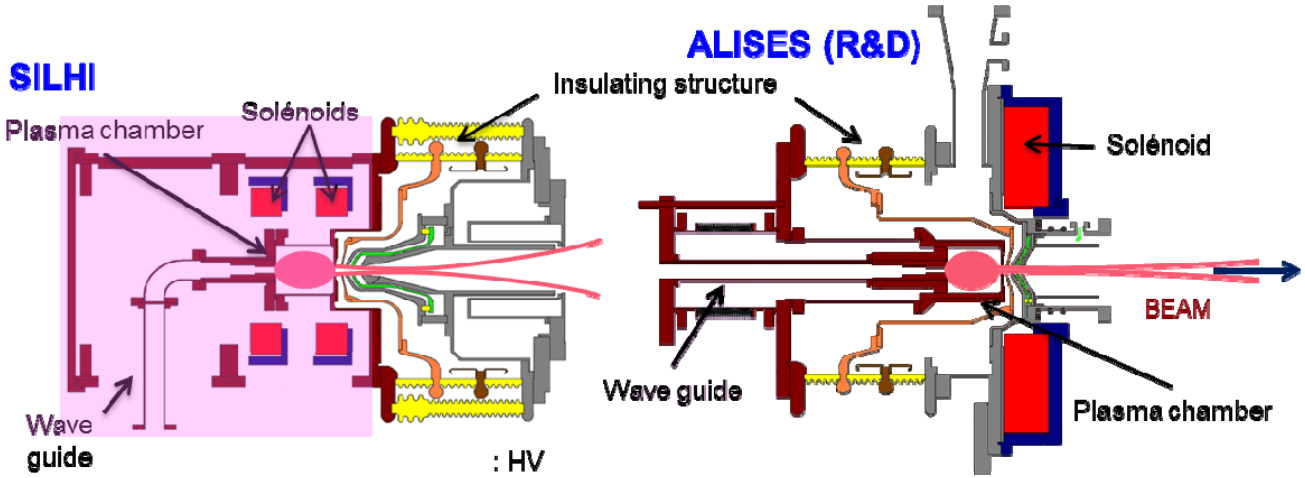


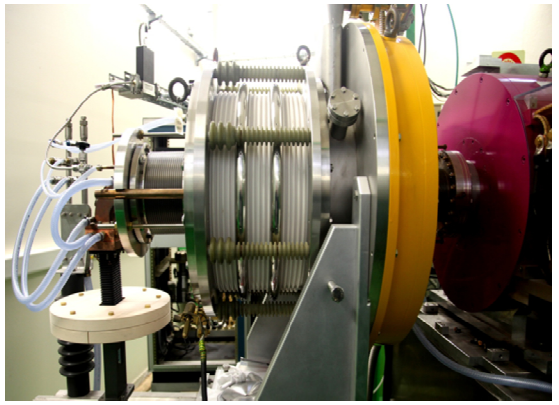
The **ALISES** source has been an innovative development of a new source geometry to simplify the source design and to reduce the length of low energy transfer lines.

ALISES for a new ECR ion source geometry at Saclay O. Delferrière et al, Rev. Sci. Instrum. 83, 02A307 (2012)

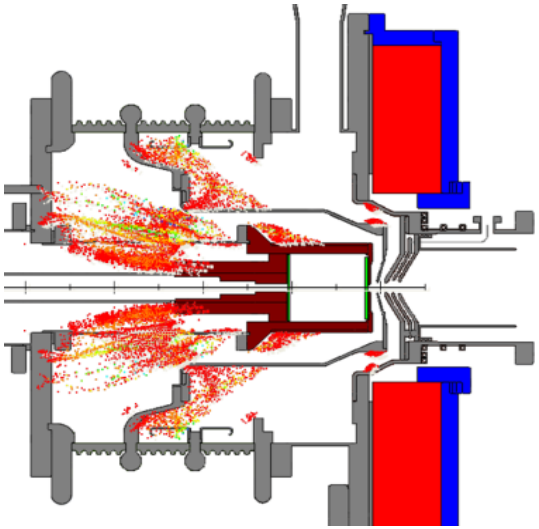


ALISES on BETSI test bench

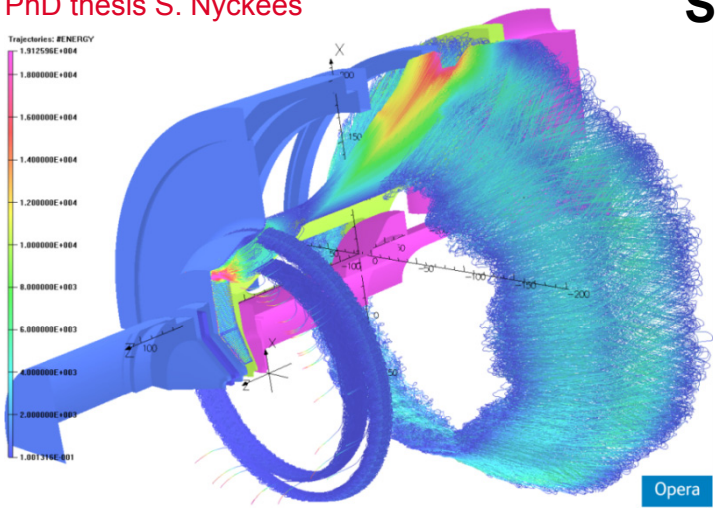




ECR ION SOURCES DEVELOPMENT AT SACLAY
LIMITATION DU TO PENNING DISCHARGES



PhD thesis S. Nyckees

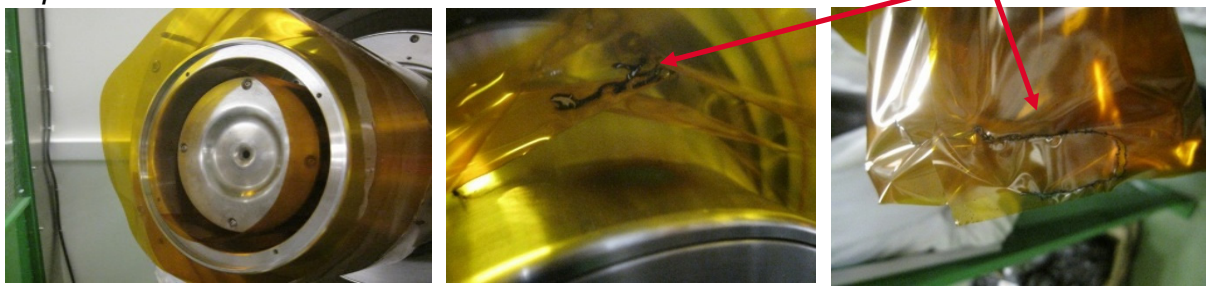


Areas where B and E field can be orthogonal:

- ► Particles accelerated and trapped, ionization
- ► Impacts on biased electrodes, limitation to 23 kV with 18mA , then shutdown of Power Supply

Kapton foils around electrodes

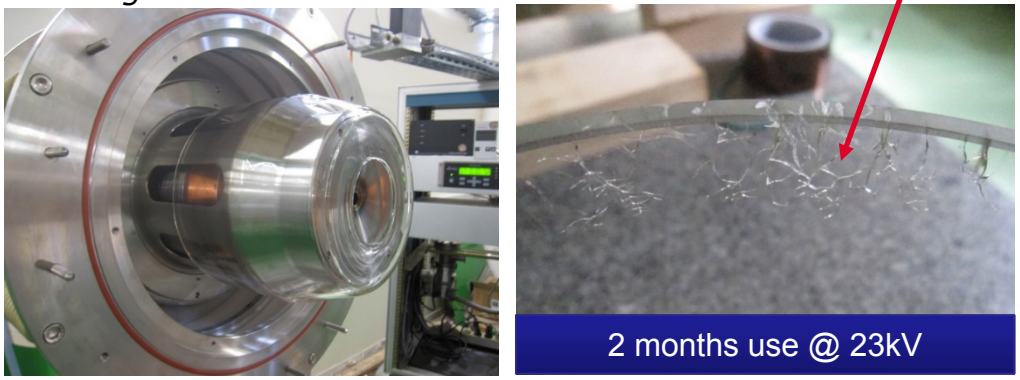
Kapton burned



Simulated with TOSCA and Verified experimentally

Use of glass tubes between electrodes

Cracks on glass



Improvement of extraction system geometry with suppression of possible Penning discharge ignition

Delferrière et al. RSI 85, 02A939 (2014)

The ALISES II concept:

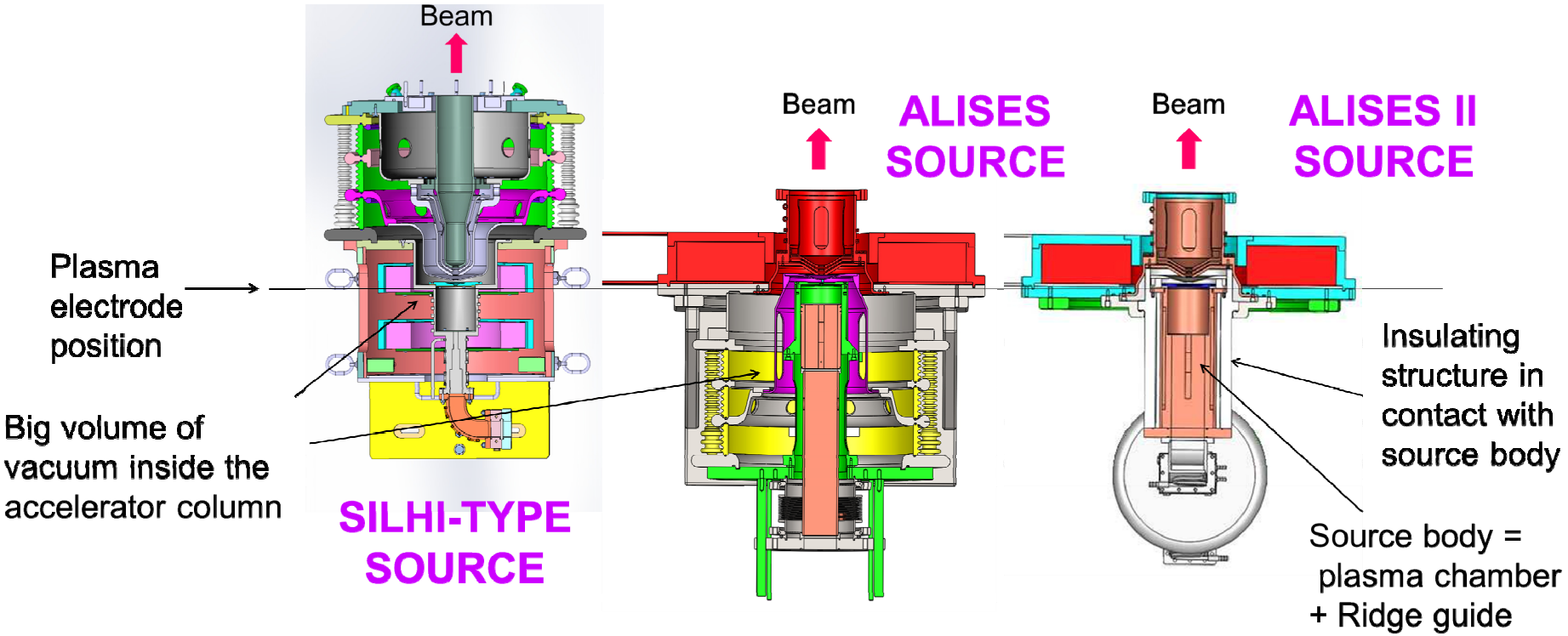
To face the Penning discharge problem:

► Eliminate all the vacuum volumes where discharge ignitions occur

► Very compact structure ALISES II

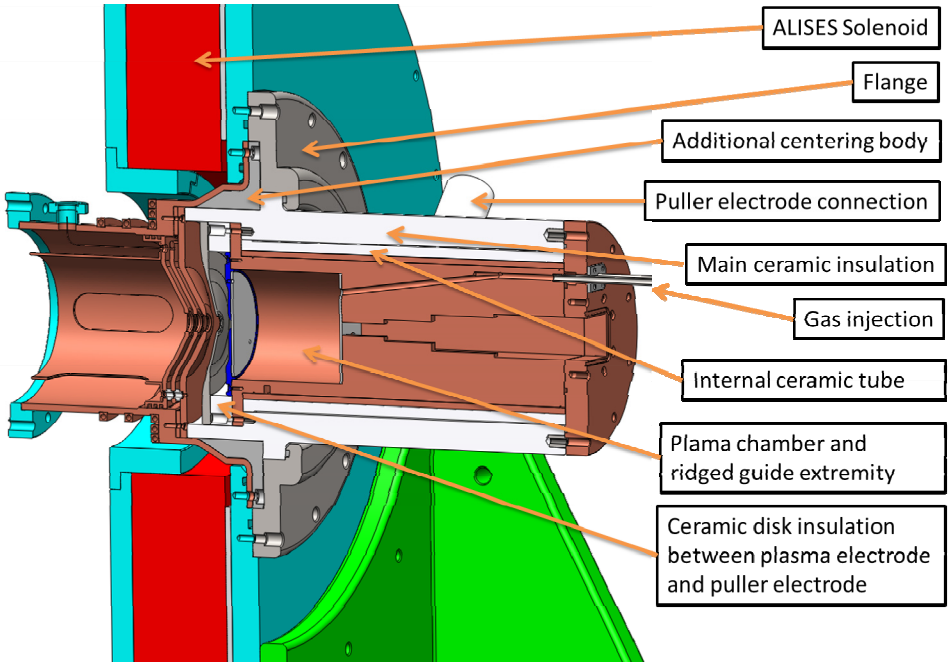
Only one compact part = Insulating structure + plasma chamber +wave guide

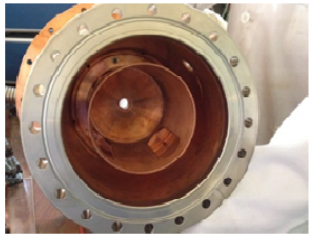
The magnet and the extraction chamber are reused from ALISES

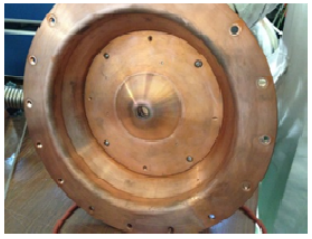


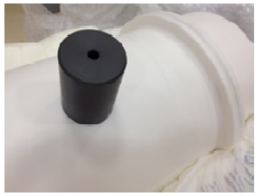
ALISES II SOURCE ASSEMBLY

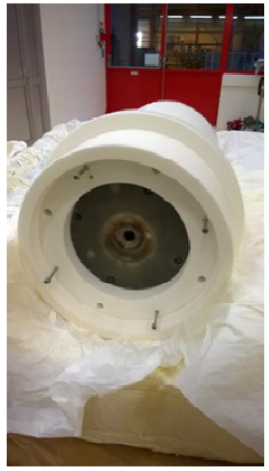
Patent CEA FR 1556871



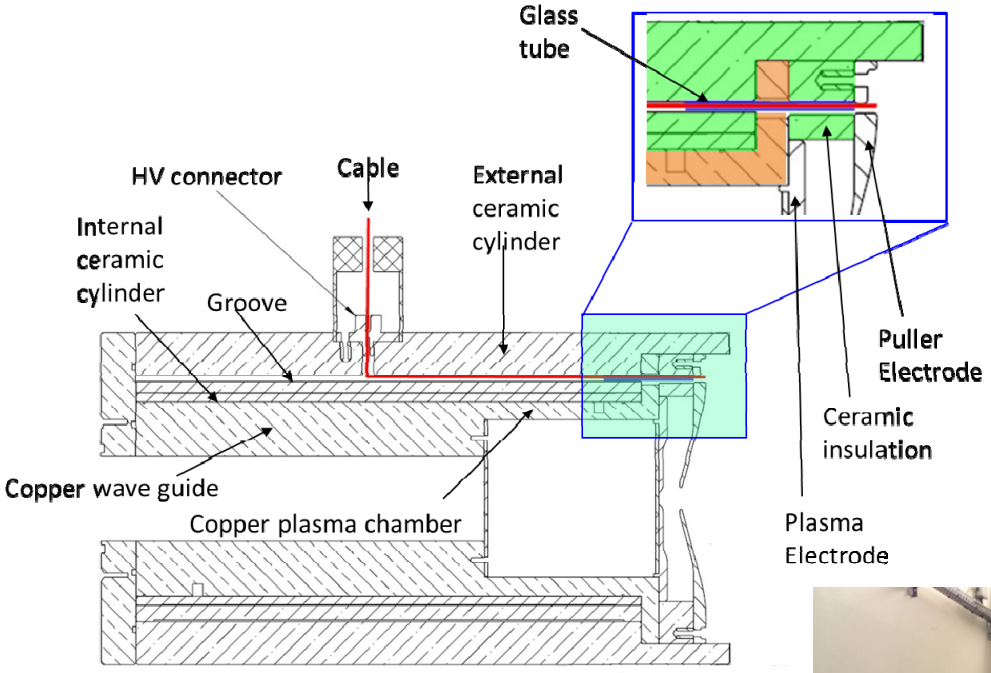


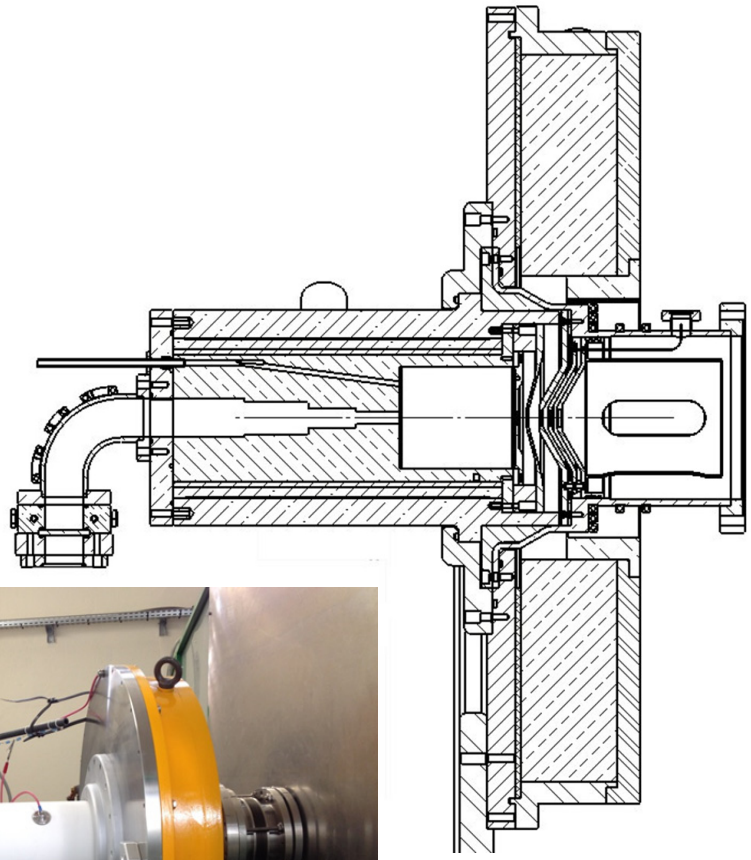




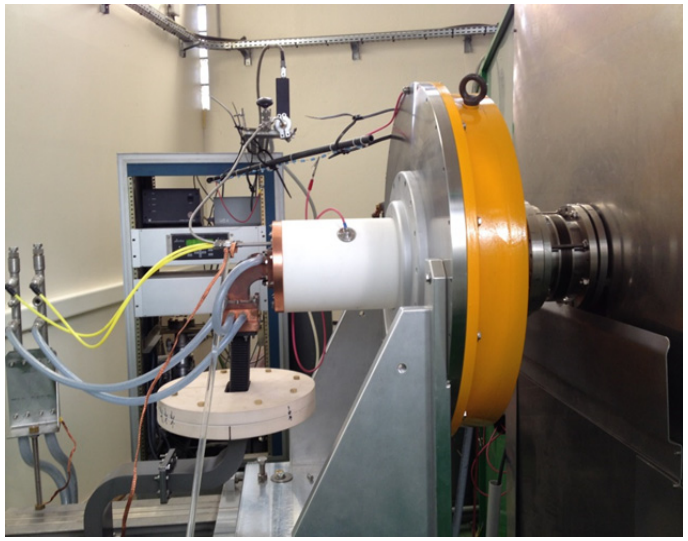


PULLER ELECTRODE HV CONNECTION

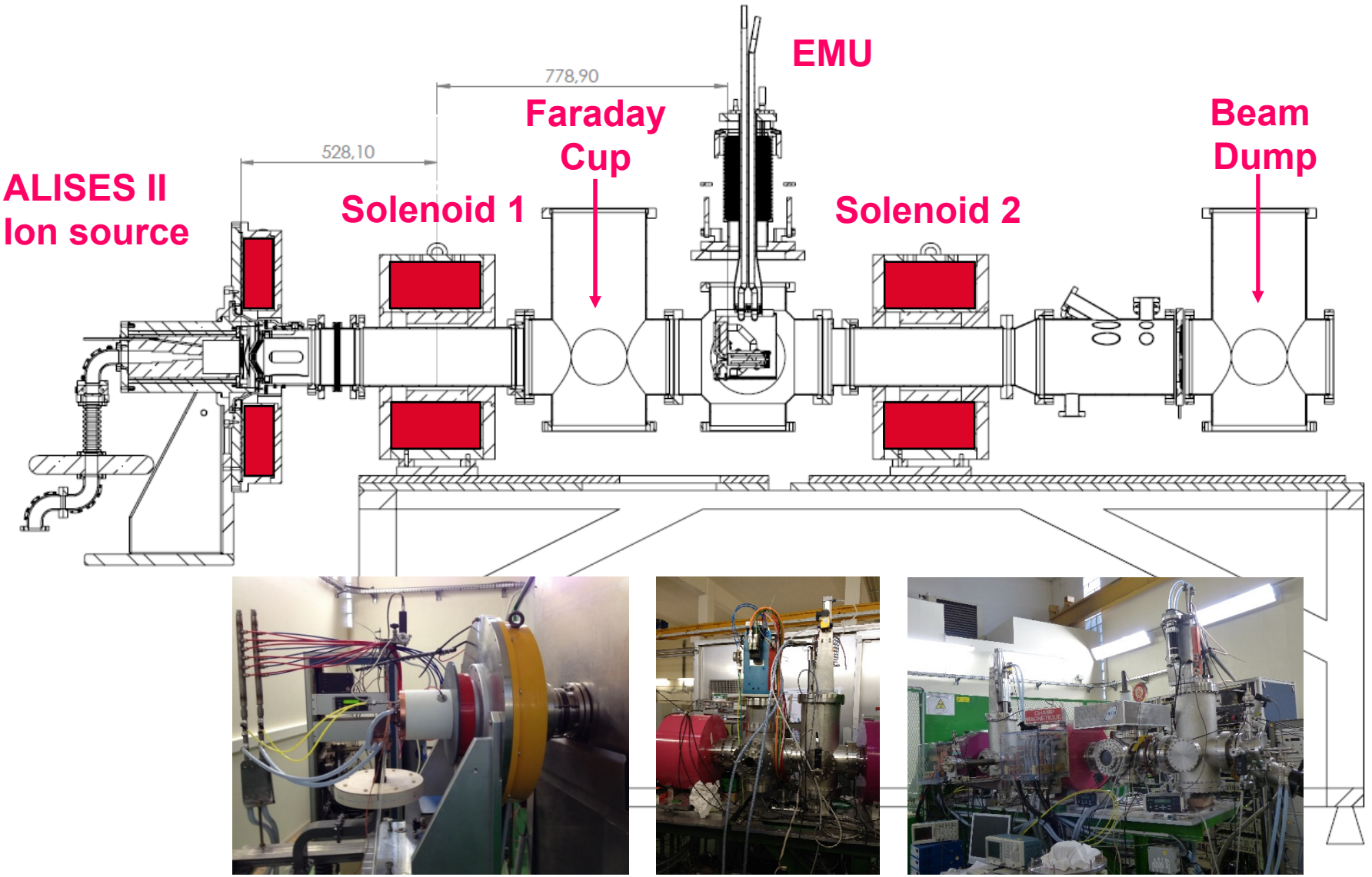




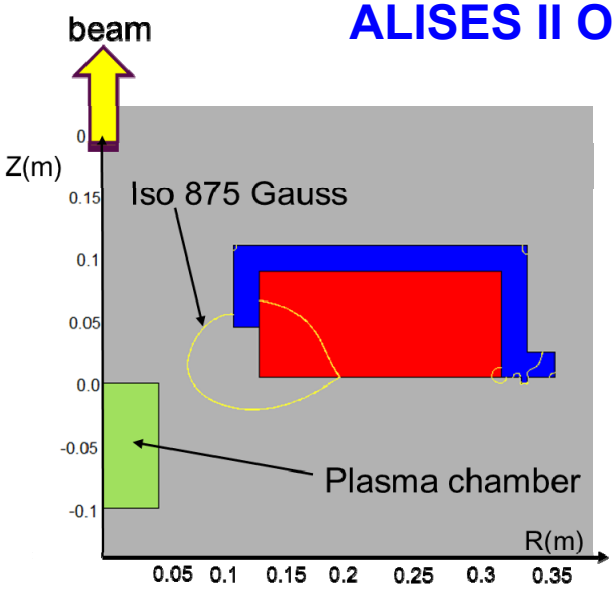
March 2015:
ALISES II installed on
BETSI test bench



BETSI EXPERIMENTAL SETUP

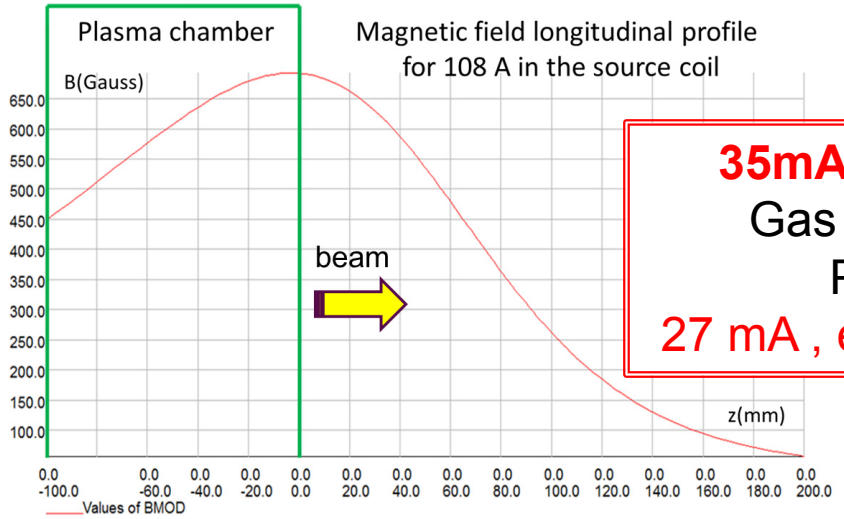


ALISES II OPTIMIZATION:

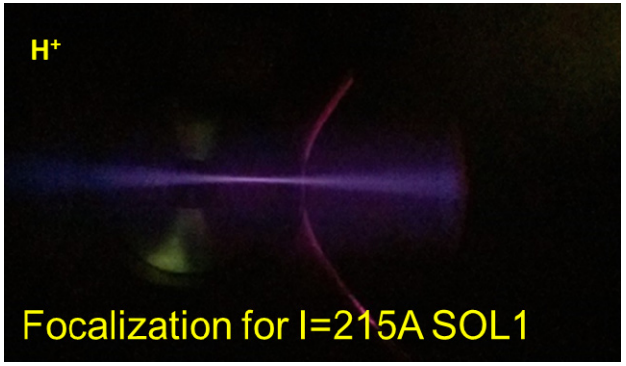


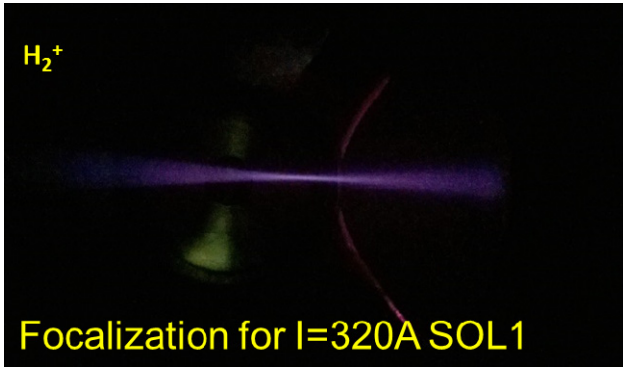
- Φ6mm plasma electrode
- Source quickly operational
- Reproducibility of the tuning
- Beam very stable

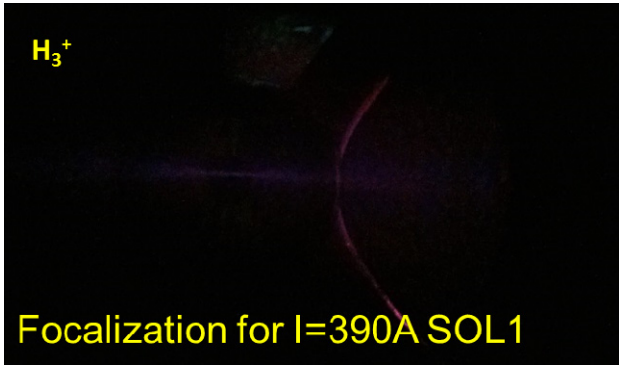
Working point I=108A in ALISES coil:
No resonance @875 Gauss inside plasma chamber
B<700 Gauss



35mA CW @ 50kV
Gas : 1.65 sccm
P=980W
27 mA , end of the LEBT

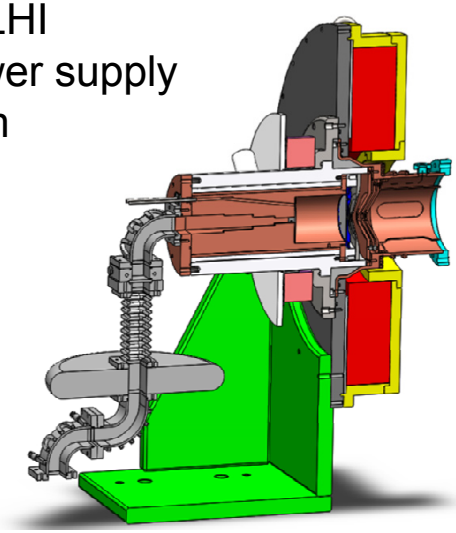


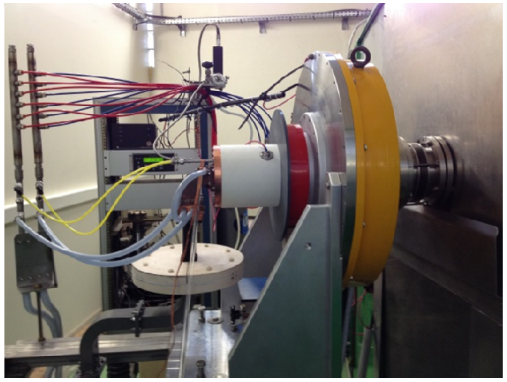


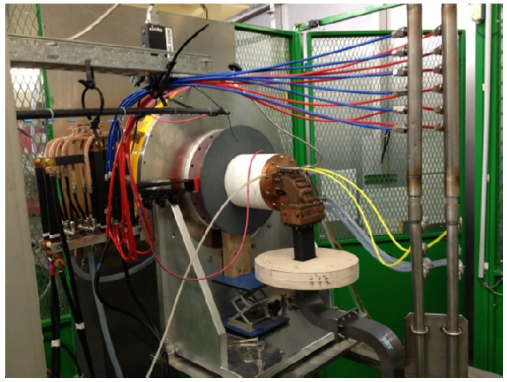


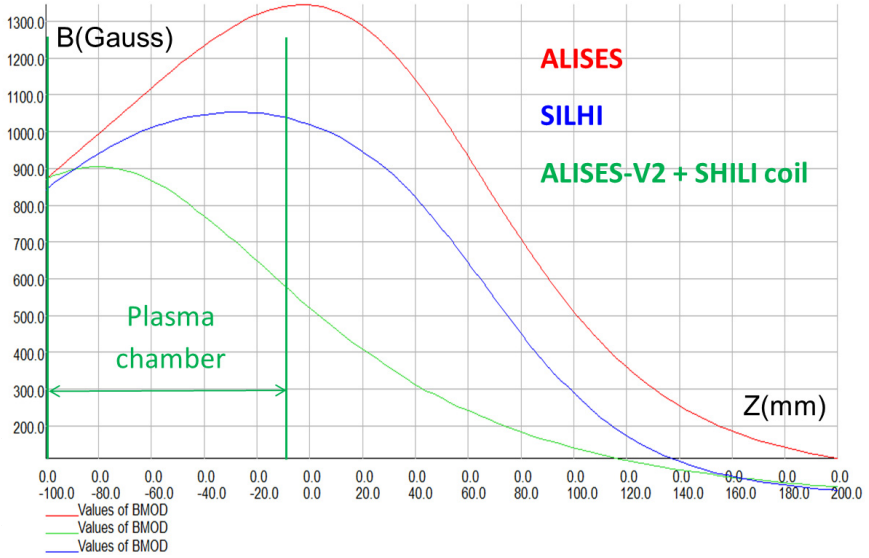
ADDITIONAL SILHI-TYPE COIL ON ALISES II

- Additional electric and magnetic shielding
- Use of a spare coil of SILHI
- Additional 125A/40V power supply
- Additional cooling system









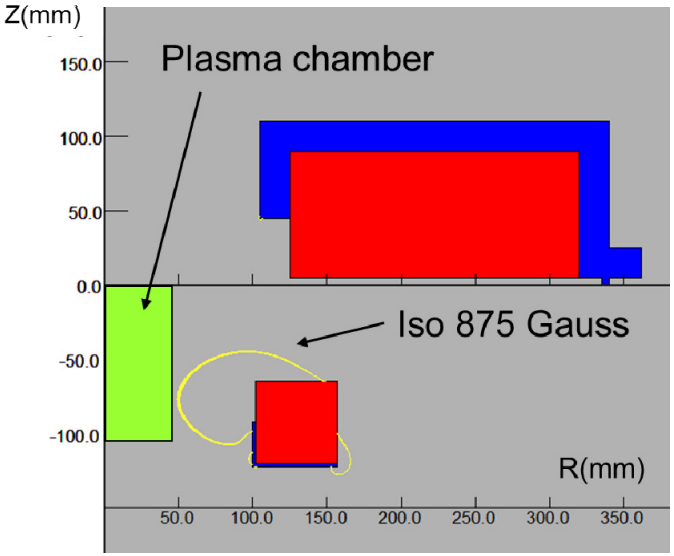
Magnetic configuration optimization

3 possible working modes :

1) Initial ALISES source coil: I=181A
2) Using only additional SILHI-type coil: I=115A
3) Tunning with both SILHI-type and ALISES source coils

ECR ION SOURCES DEVELOPMENT AT SACLAY
INVESTIGATION ON MAGNETIC FIELD PROFILE

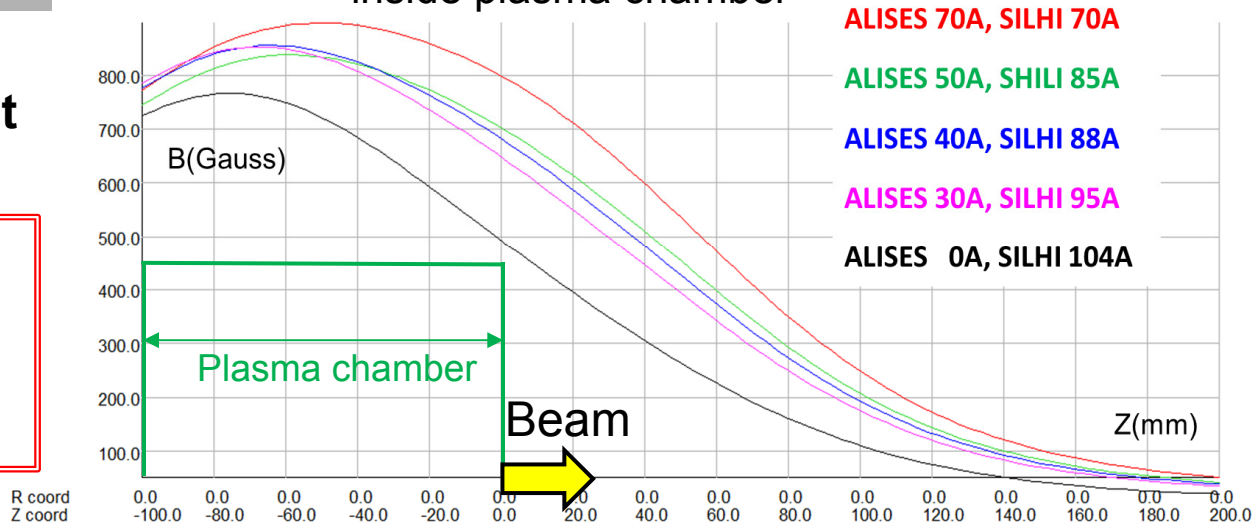
EXTRACTED CURRENT AS A FUNCTION OF MAGNETIC FIELD B PROFILE



Gas : 1.95 sccm
P=700W
Pulsed beam

ALISES coil (A)	SILHI coil (A)	$I_{extracted}$ (mA)
70	70	**35,5**
50	85	**36,6**
40	88	**37**
30	95	**37**
0	104	**40,7**

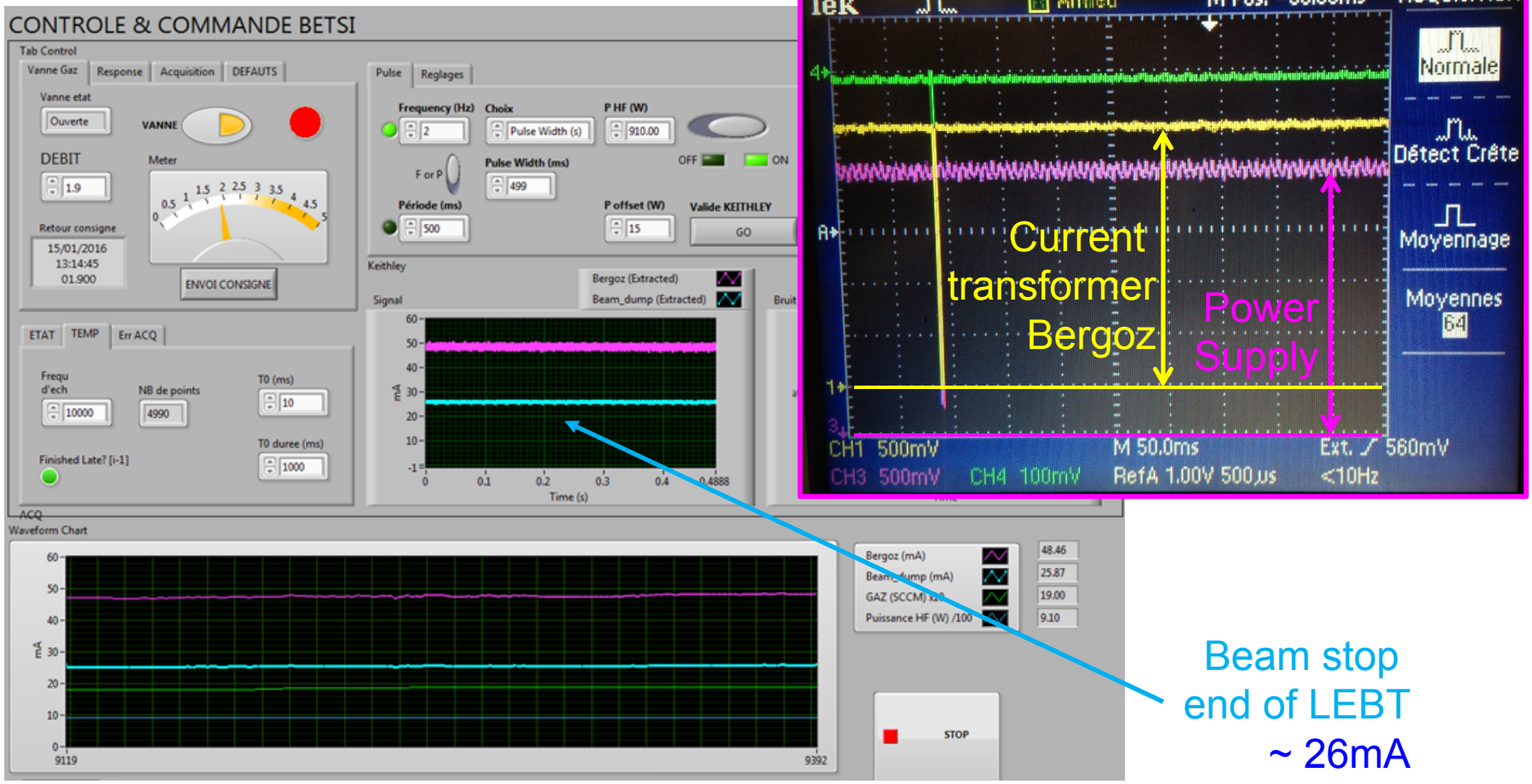
Best result in pulsed mode at I=104A in « SILHI » coil:
No resonance @875 Gauss
inside plasma chamber



Best result in CW mode at I=104A in « SILHI » coil:

48,5 mA CW @ 50kV
Gas : 2,1 sccm
P=700W
26 mA , end of the LEBT

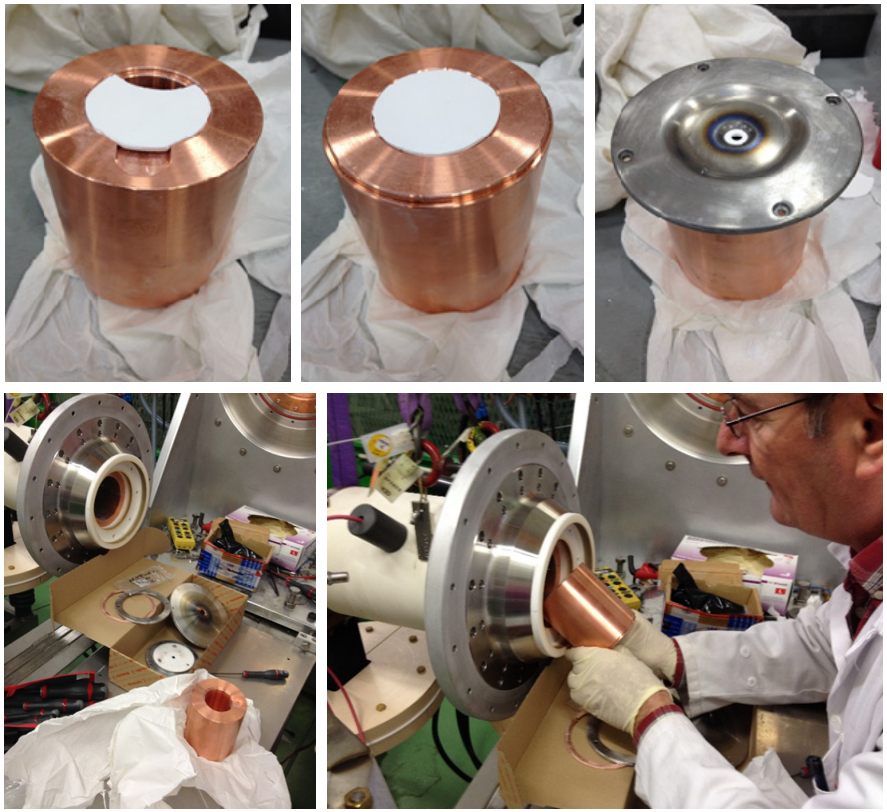
ALISES V2 extracted beam: 48,5mA@50kV
CW (499ms/500ms) Gas: 2,1 sccm
RF Power 700 W



ECR ION SOURCES DEVELOPMENT AT SACLAY
INVESTIGATION ON PLASMA CHAMBER DIAMETER

As previously shown on ALISES, reduction of plasma chamber diameter could be beneficial with higher extracted current (more efficient RF heating)

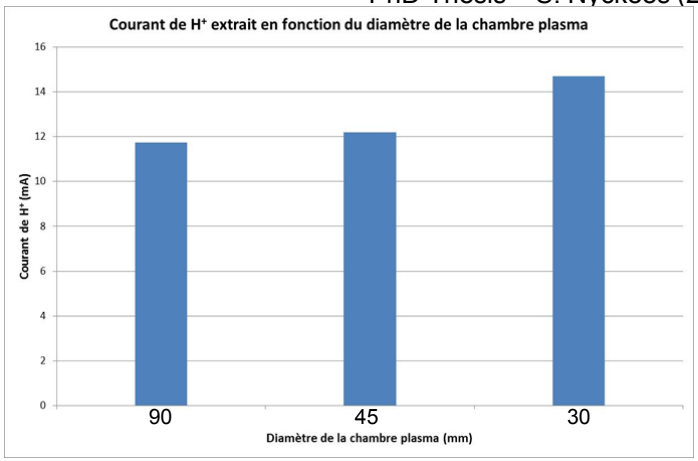
Realization of a Φ45mm copper insert



First experiments on ALISES (2009-2012)

ÉTUDE ET DÉVELOPPEMENT D'UNE NOUVELLE SOURCE ECR PRODUISANT UN FAISCEAU INTENSE D'IONS LÉGERS

PhD Thesis – S. Nyckees (2011)



Extracted current vs Plasma chamber diameter

ALISES V2 extracted beam @40kV

	Φ45mm	Φ90mm
B(A)	108	105
P(W)	750	700
Gas(sccm)	1,75	1,47
I_{ext} (mA)	40,5	36,7

ECR ION SOURCES DEVELOPMENT AT SACLAY
LAST RESULTS BEFORE SHUTDOWN OF BETSI

Performances and stability of the source:

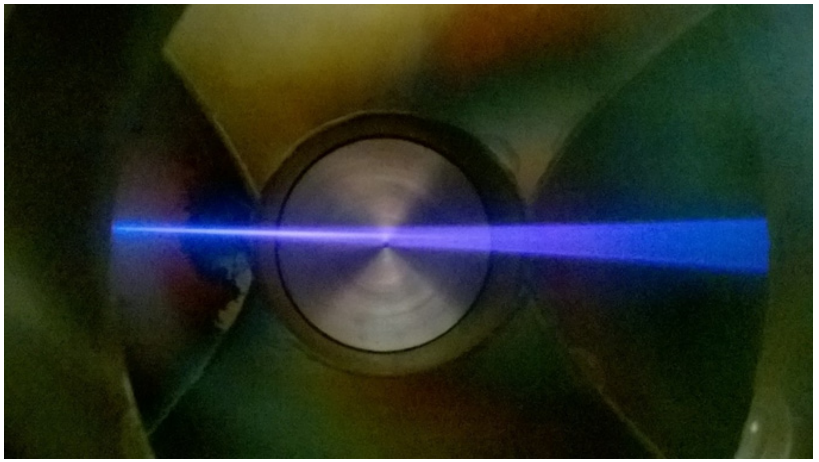
► Several experiments have been done with ALISES II on BETSI

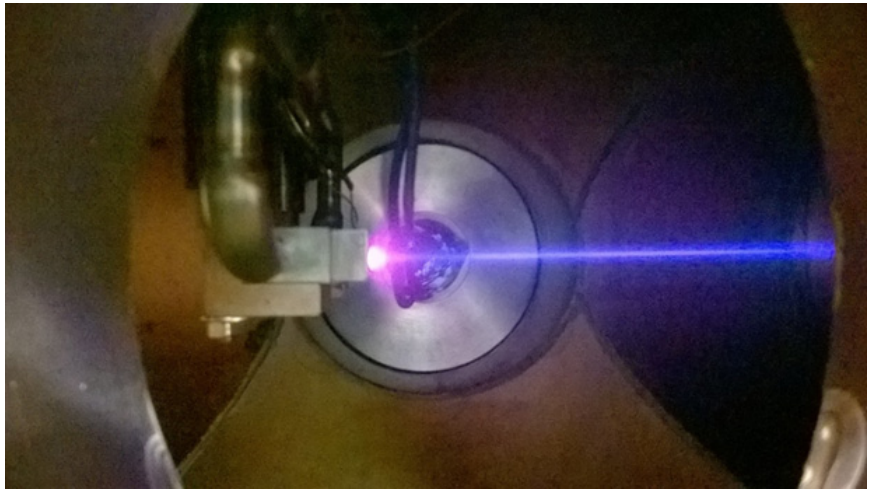
1) Irradiation of scintillators for 4D emittance meter

2) Space charge compensation measurement with 4 grid analyzer

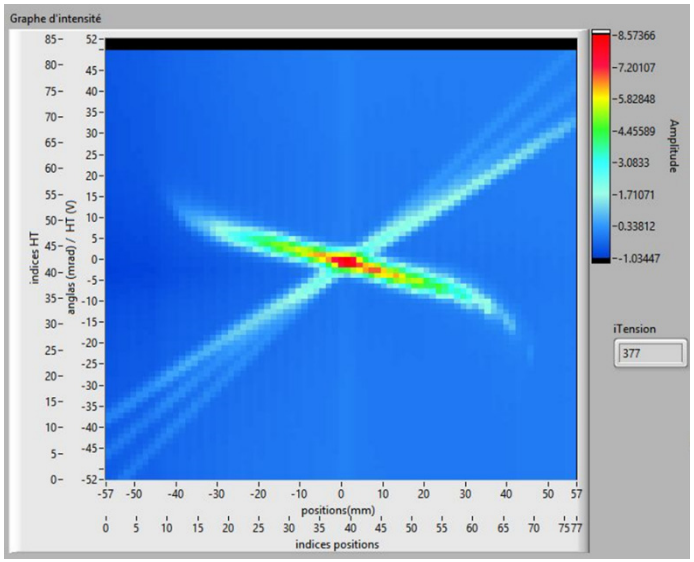
3) Bombardment of beam stop prototype for S3 spectrometer experiment (SPIRAL2 project)

4) Emittance measurements with a new Allison scanner for FAIR proton linac injector (debugging phase)





Hydrogen beam 35mA@40kV extracted from ALISES, 17mA H^+ at the end of BETSI LEBT on beam stop prototype for S3



First emittance measurement with ALISES II
Very preliminary results

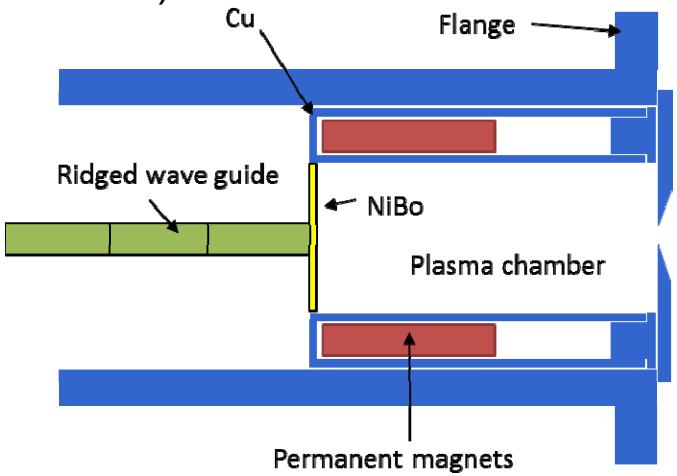
CONCLUSION AND FUTURE WORK

Performances and stability demonstrated: almost 50mA@50 kV with plasma Φ6mm

Since March 2016, BETSI has been shutdown for upgrade to 100 kV
►Q4 2016: BETSI ready @100kV

ALISES II on 100kV BETSI test bench :

- Up to now BETSI was limited to 50 kV: test up to 100 kV with plasma Φ9mm
  (ALISES II already successfully tested up to 70 kV without beam)
- Emittance measurements with Allison scanner
- Proportions to be analyzed with a Wien filter
- Permanent magnet version to be tested
  (magnets already ordered)
- Magnetic field profile investigation to continue



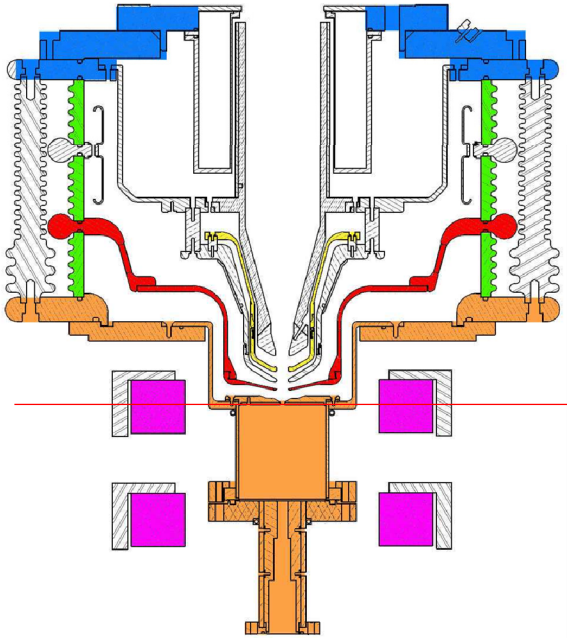
ALISES III under construction:

To be assembled and tested Q4 2016

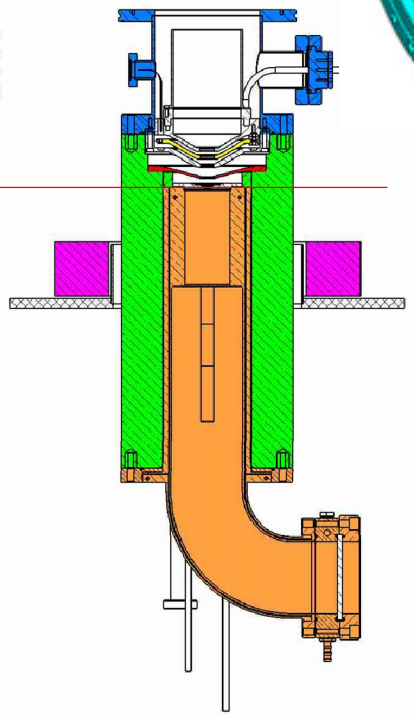
- New HV connection for puller electrode
- Magnetic field obtained with a smaller coil as SILHI coils
- Φ45mm plasma chamber
- No support, source directly connected to the LEBT

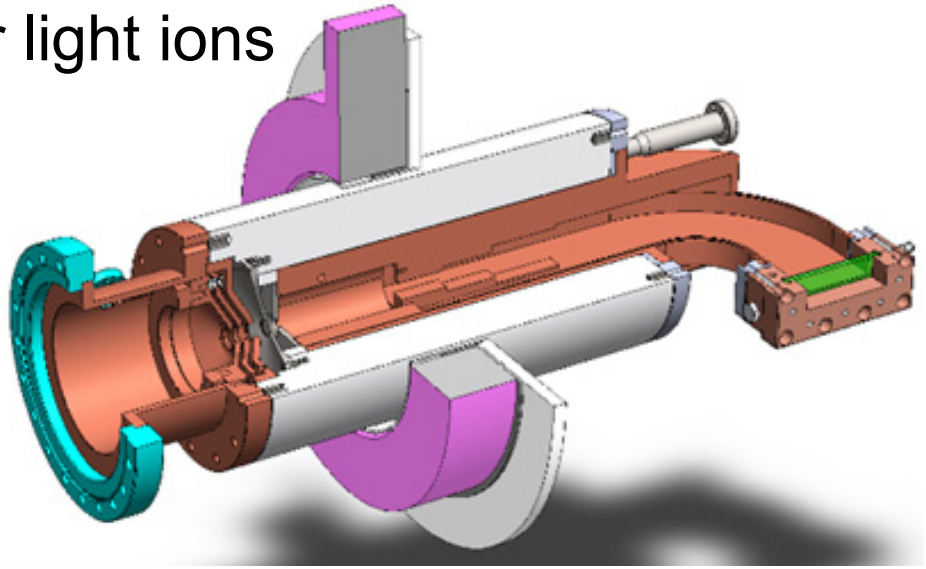
High intensity ECR ion sources for light ions

Conventional



ALISES III



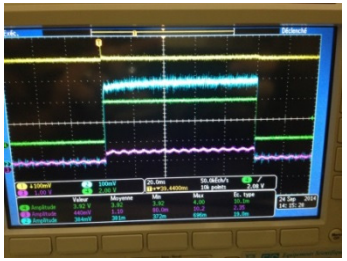


STRONG POINTS:

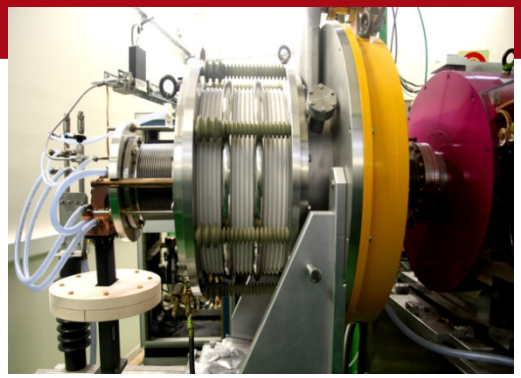
- LEBT length gain
- Geometry simplified
- Easier maintenance
- Compactness
- Only 40-50 kg
- No HV platform
- Lower price


Thank you for your attention

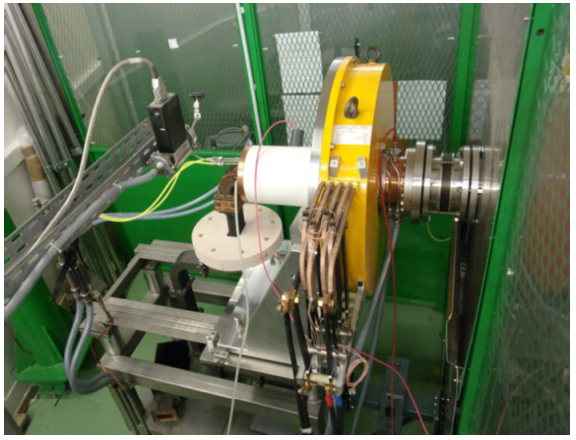
HIGH INTENSITY ECR IONS SOURCES
RESULT OF 20 YEARS OF EXPERIENCE



2012:
I_{ext}=18mA@23kV

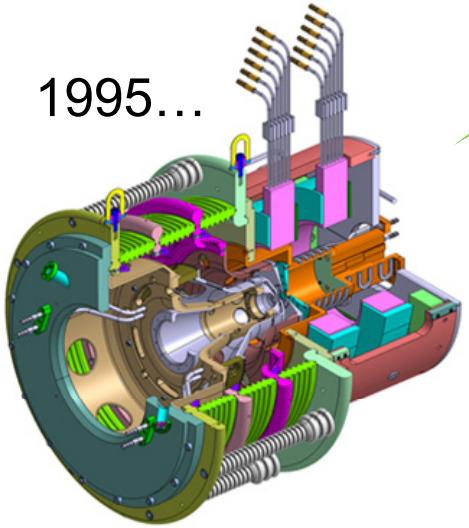


ALISES tests on BETSI

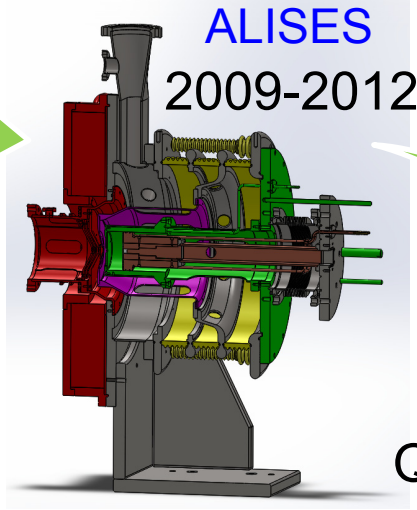


ALISES II tests on BETSI

1995…

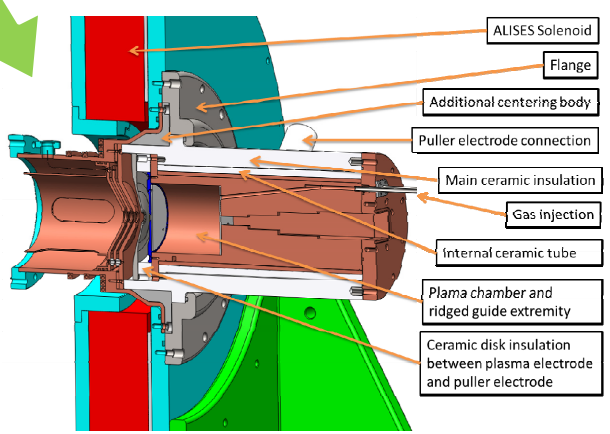


ALISES
2009-2012



2015:
I_{ext}=48,5mA@40kV

Q1-2015
ALISES II



Q4-2016
ALISES III