ERIBS: Towards better heavy ion beam services

Paul Greenlees
On behalf of the ERIBS collaboration

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ERIBS partners

ATOMKI
CNRS-IPHC
INFN-LNL
INFN-LNS
GANIL
GSI-FAIR
JYFL
UMCG-PARTREC
CNRS-LPSC (associate partner)

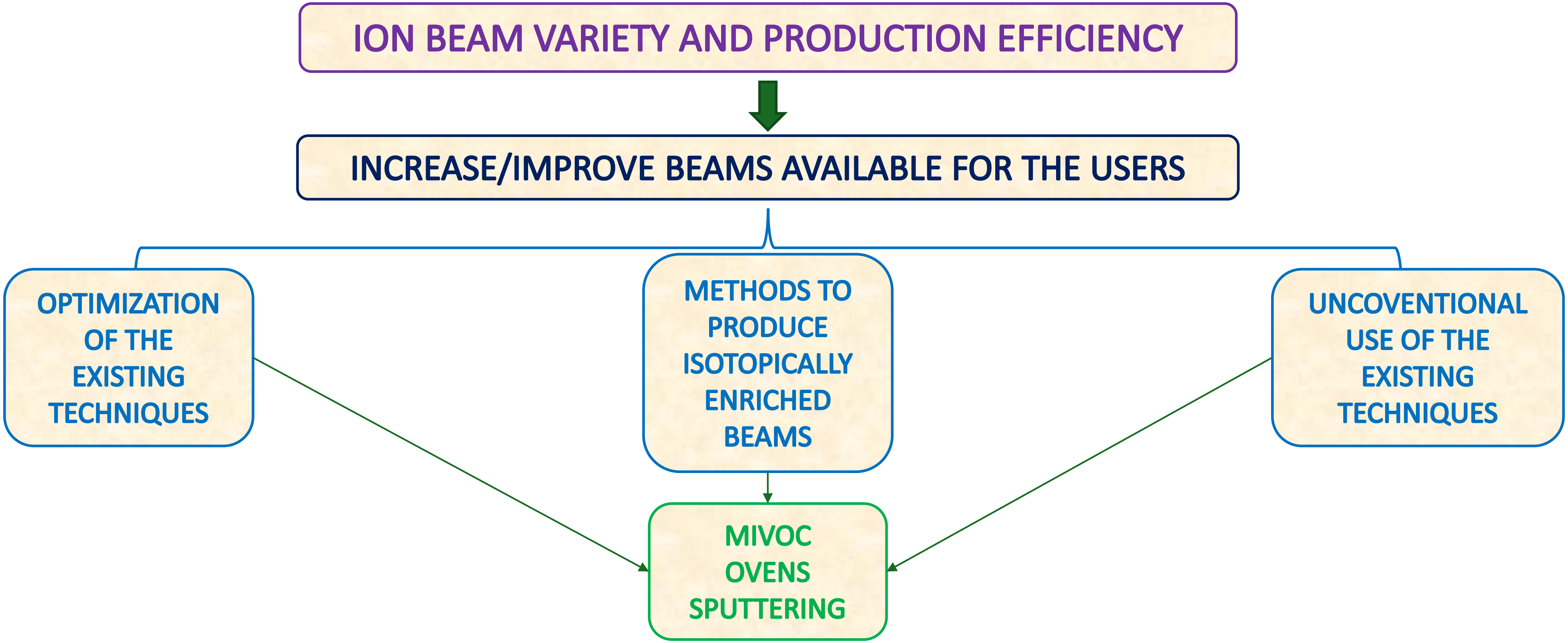
ERIBS tasks

Objectives of ERIBS are to improve:

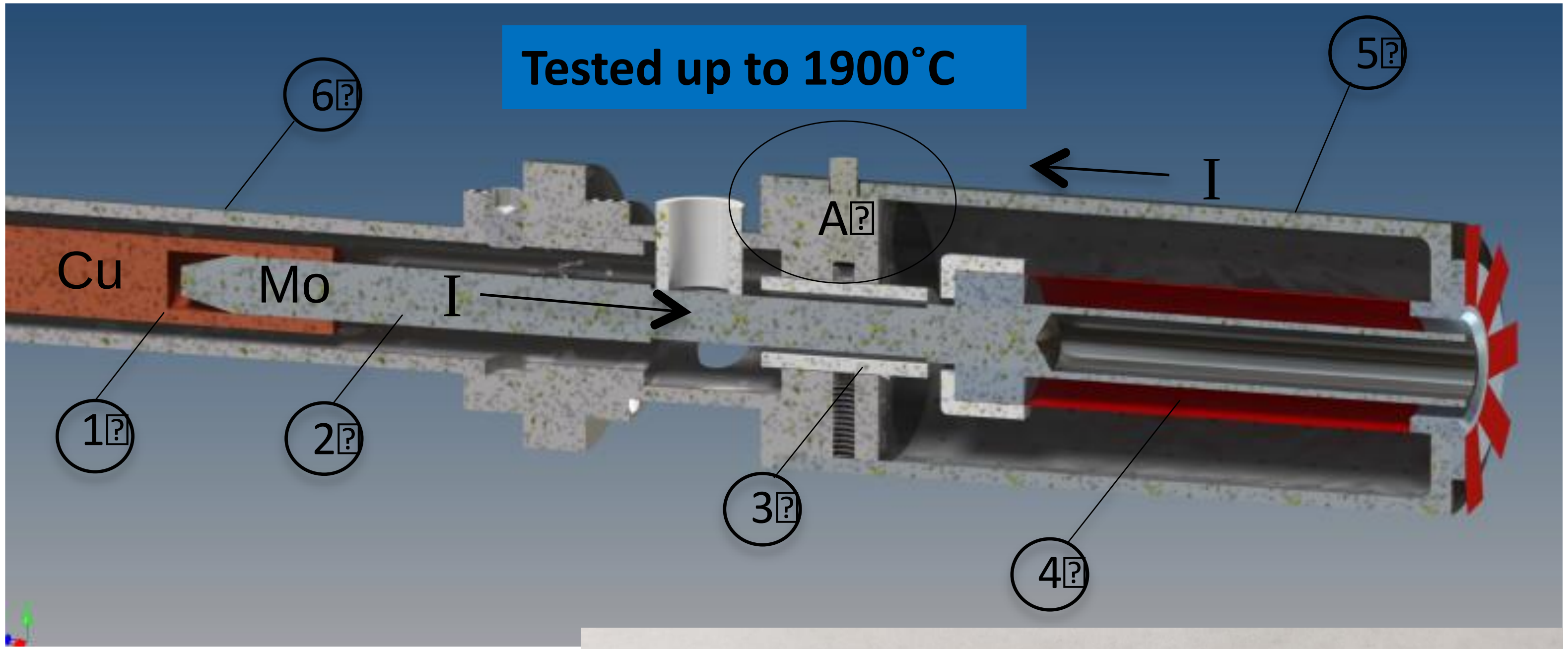
Task 1: Ion beam variety and production efficiency (Leader: Alessio Galata, INFN-LNL)

Task 2: Short and long-term beam stability (Leader: Rob Kremers, PARTREC)

Task 1


ION BEAM VARIETY AND PRODUCTION EFFICIENCY
INCREASE/IMPROVE BEAMS AVAILABLE FOR THE USERS
OPTIMIZATION OF THE EXISTING TECHNIQUES
METHODS TO PRODUCE ISOTOPICALLY ENRICHED BEAMS
UNCOVENTIONAL USE OF THE EXISTING TECHNIQUES
MIVOC
OVENS
SPUTTERING

Task1: High temperature oven



1) *copper rod,*
2) *Mo support structure,*
3) *Al_2O_3 insulator,*
4) *Ta foil (20 µm in thickness),*
5) *outer Mo oven structure for return current,*
6) *SS tube for return current.*

A) locking/connection system (bajonet)

History: The assembly of the heater foil was challenging → unrealiable solution

Due to challenges, this oven approach was abandoned at JYFL for almost 10 years

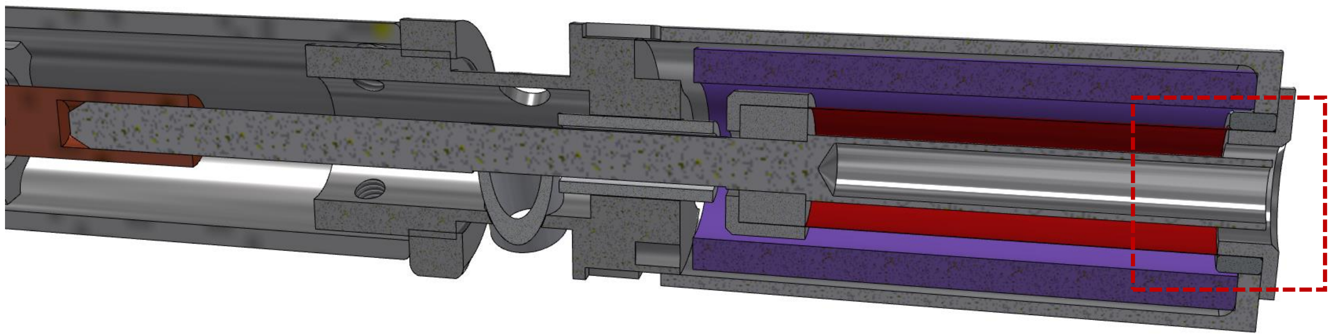
GANIL team continued the development of the foil oven concept

High temperature oven knowledge transfer between GANIL and JYFL

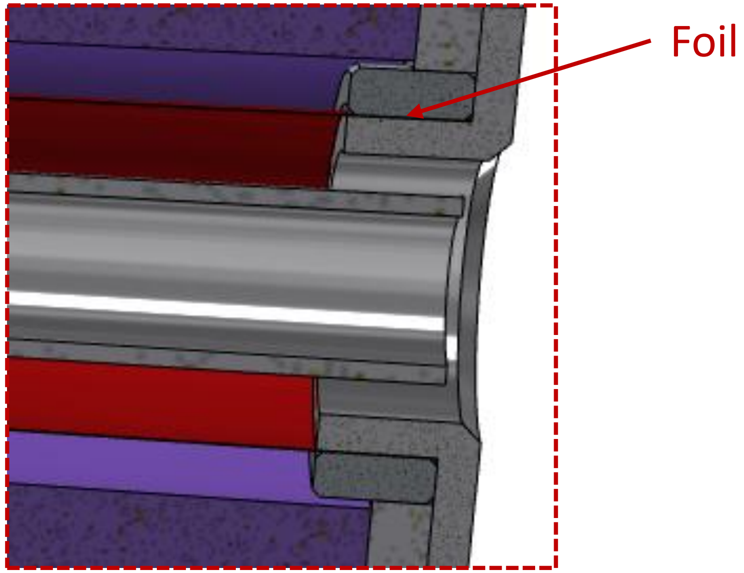
Visit of JYFL team members to GANIL in May 2024:

- The GANIL high temperature oven would require strong modifications to the JYFL foil oven and to the injection of the JYFL 14 GHz ECRIS.
- we decided to revisit the design of the JYFL foil oven → a novel new solution was found

→ New high temperature oven design for EURO-LABS laboratories



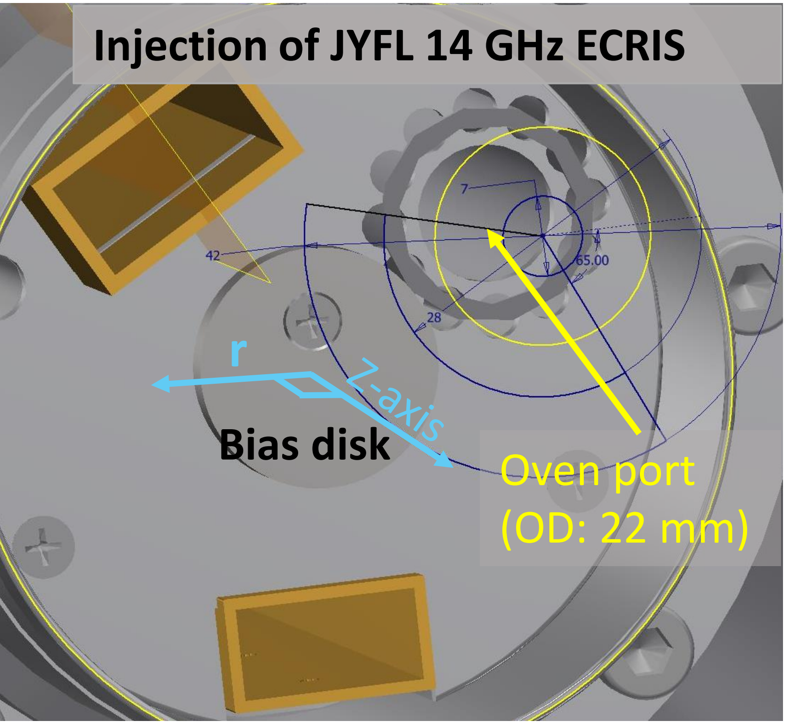
New design has been completed and construction work has been started. Modified version will be tested by the end of 2024.



Axial sputtering for metal ion beams

Axial sputtering is not available with the European ECR ion sources

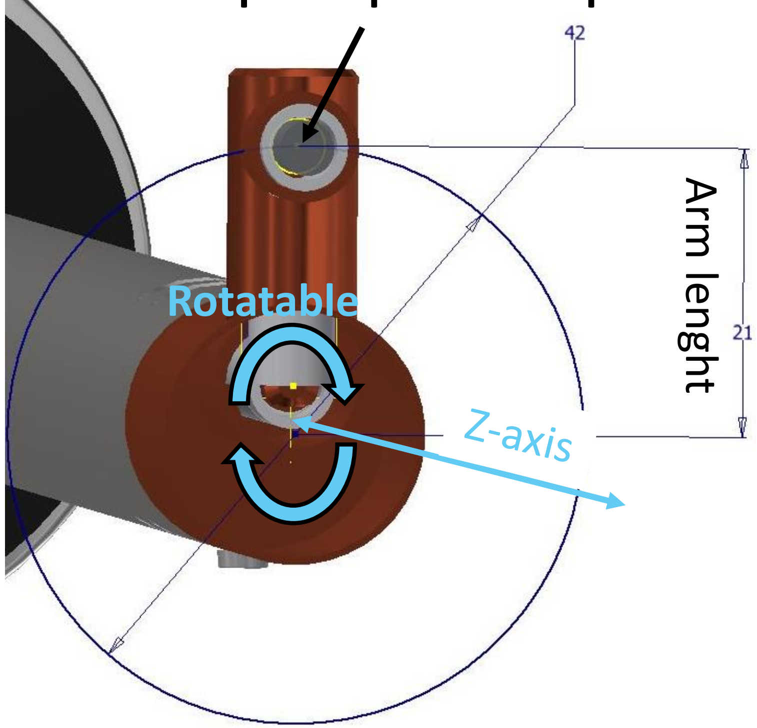
- In ERIBS: development work for ON- and OFF- axis sputtering (INFN-LNL/JYFL collaboration)
- Optimum geometry for the sputter sample will be *simulated* by the INFN-LNL team



To find an optimum sample position in 3D

- Movable sample along z-axis
- Rotatable
- Different arm lengths will be tested

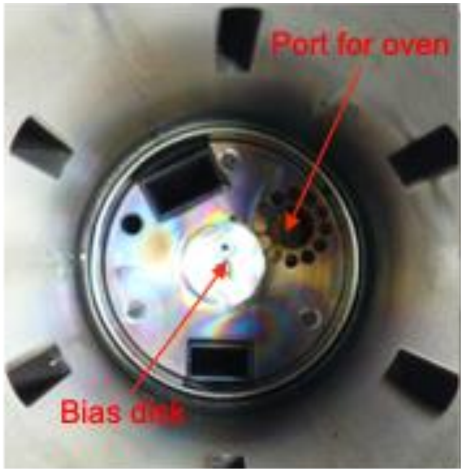
→ Determination of optimum sputtering conditions for maximum beam performance

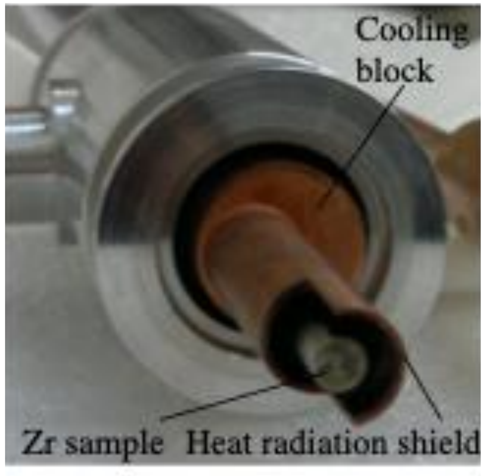


First off-axis sputter experiments

First 1D experiments along the axis of plasma chamber: (without the "3D part")

JYFL 14 GHz ECRIS



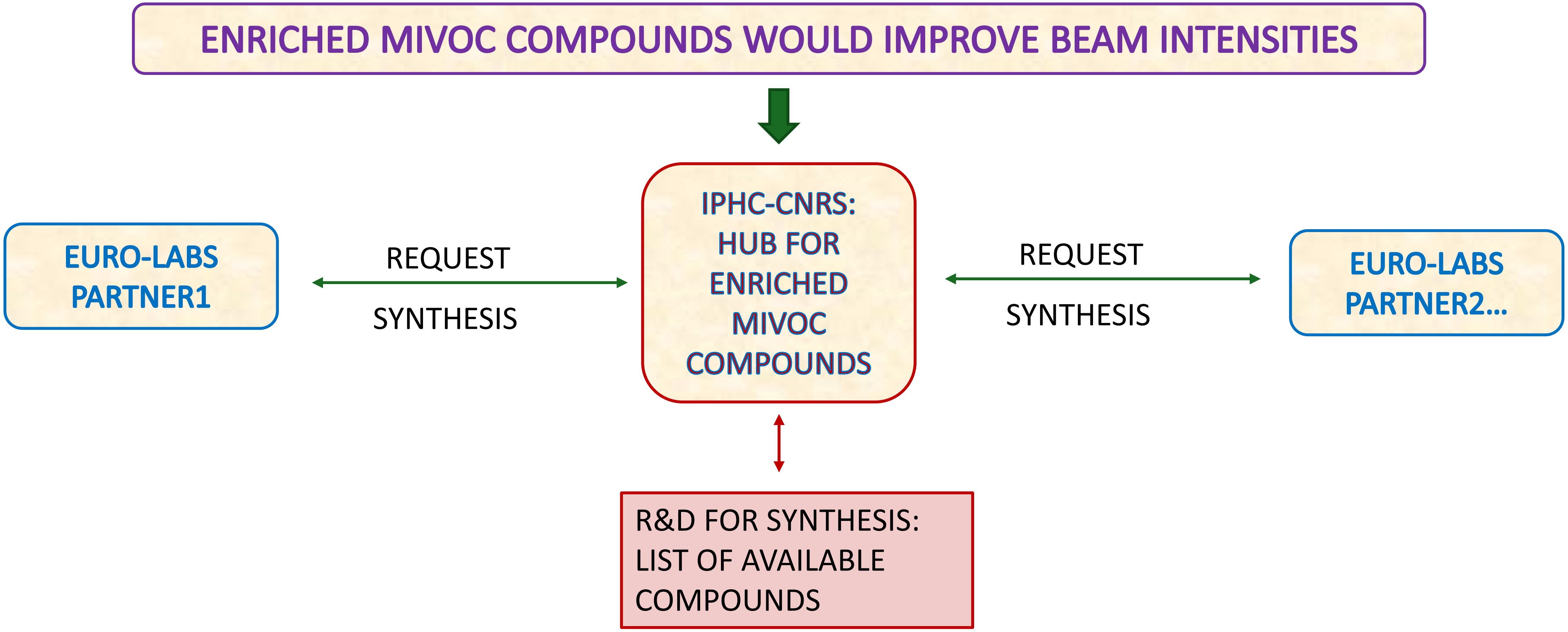


- Intensity increased vigorously when the sample was moved along the axis
- Very promising intensities for highly charged Zr (> *5 µA for Zr^{18+}*)

More makes more→ let's move sample further:

- More beam but…melting of copper holder
- New design has been completed
- Studies will be continued as soon as all parts are machined

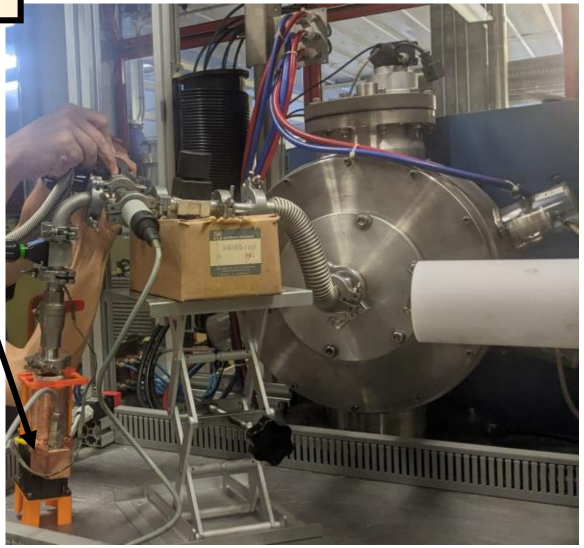
Hub for enriched MIVOC beams



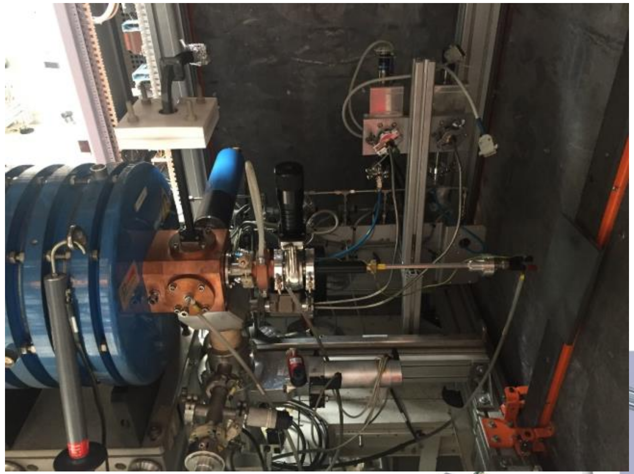
For example: compounds for ^{54}Cr, ^{64}Ni (JYFL) and ^{50}Cr (GANIL) ion beams have been synthesized by IPHC for scientific programs of EURO-LABS

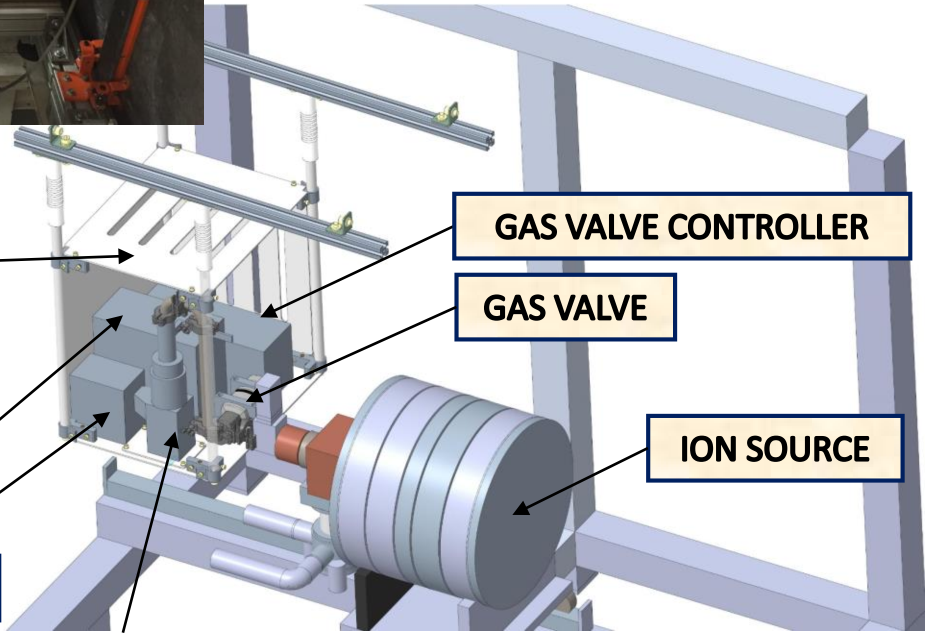
Transfer of MIVOC technology

LNL TRAINING ON MIVOC BY IPHC team



IMPLEMENTATION OF MIVOC @ LNL

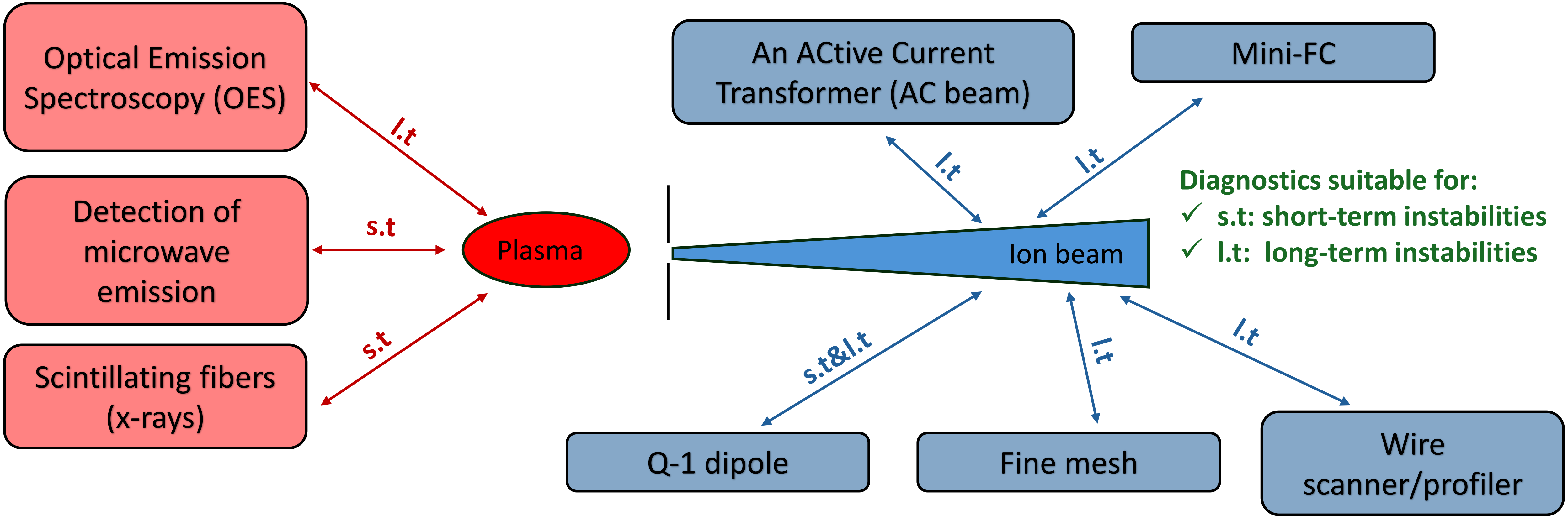




Task2

Objective: development work to improve the (low cost and robust) short- and long-term beam stability and to keep the beam intensity within preset values.

Following techniques/approaches have been included for the task:



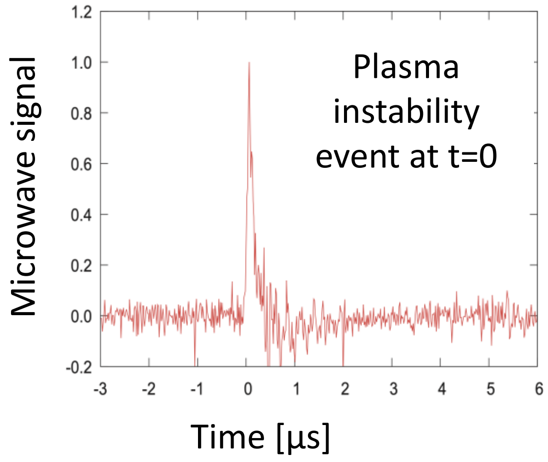
Diagnostics suitable for:

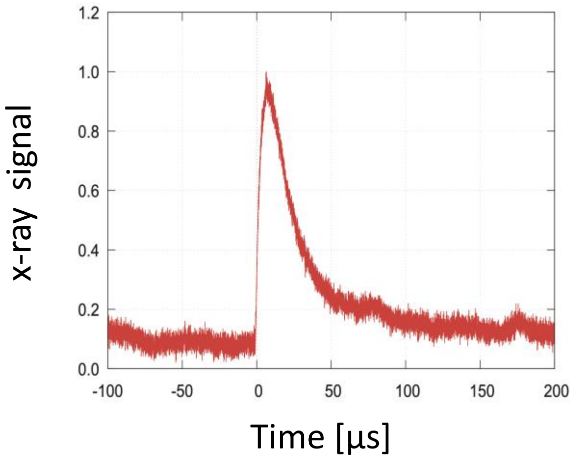
- ✓ s.t: short-term instabilities
- ✓ l.t: long-term instabilities

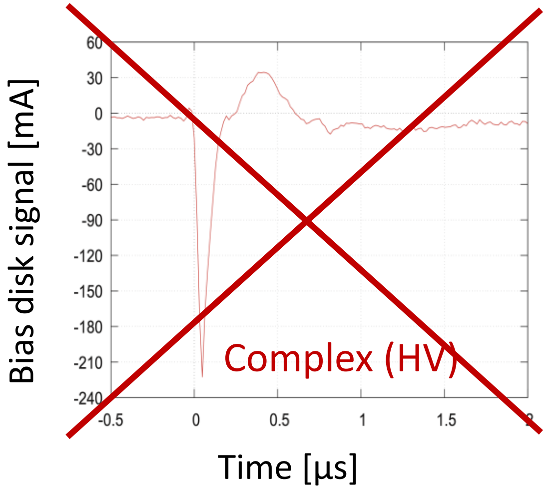
Online monitoring: short-term instabilities

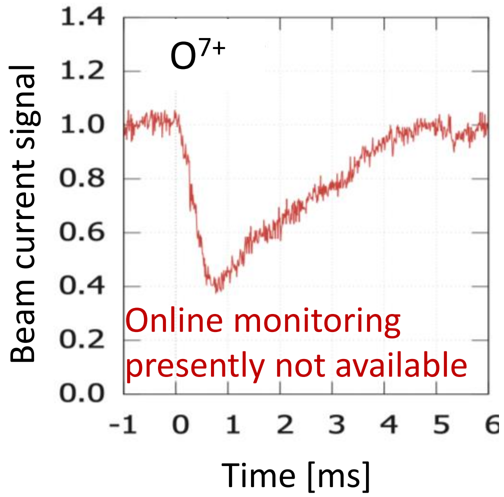
- Plasma instability decreases beam intensity. This effect increases with charge state q
- Sputters plasma chamber→ erosion of plasma chamber, beam contamination
- Ion beam inherits the plasma instabilities

Possible signals for monitoring (s.t) : microwave emission, x-rays, bias disk current, FC current









Possible diagnostics for online monitoring

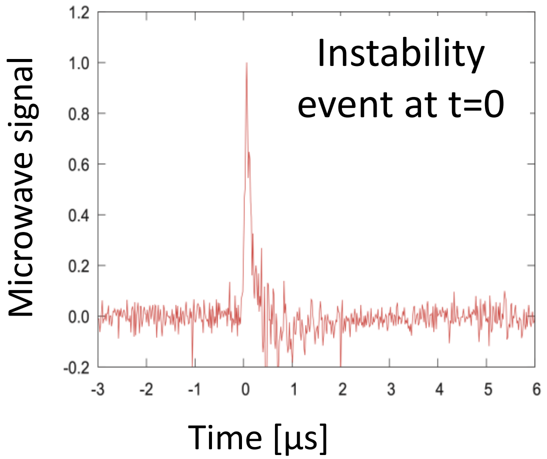
Detection of microwave emission

Scintillating fibers

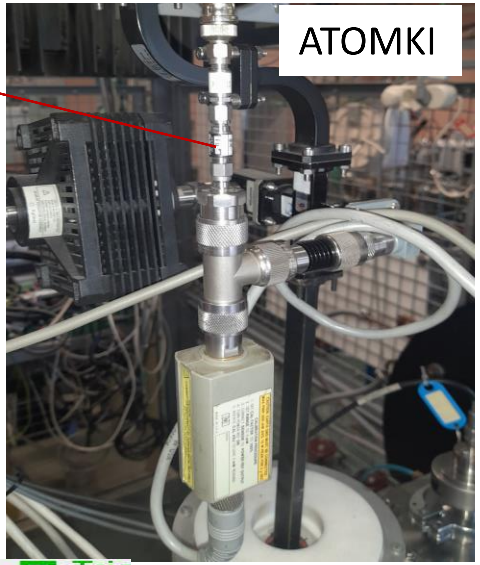
Q-1 dipole

Low cost monitoring of plasma instabilities:
ATOMKI+INFN-LNS

Microwave detection

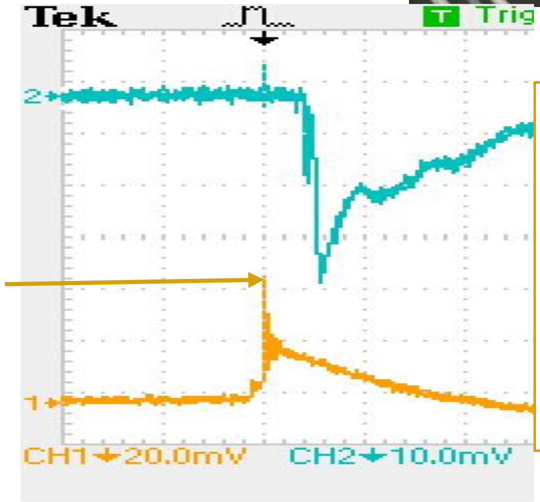


RF power diode for plasma emitted microwaves



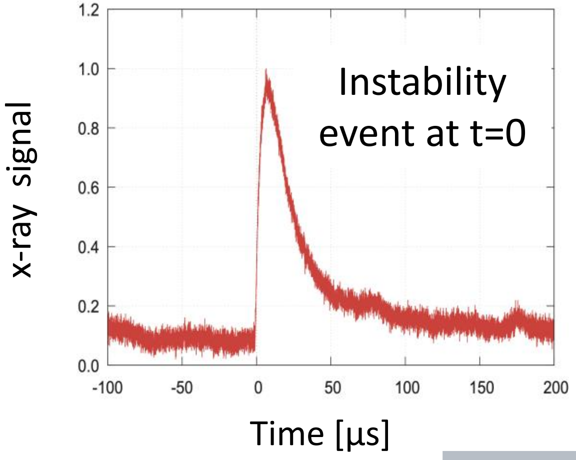
Highly charged ion beam current

RF emission peak caused by kinetic instability

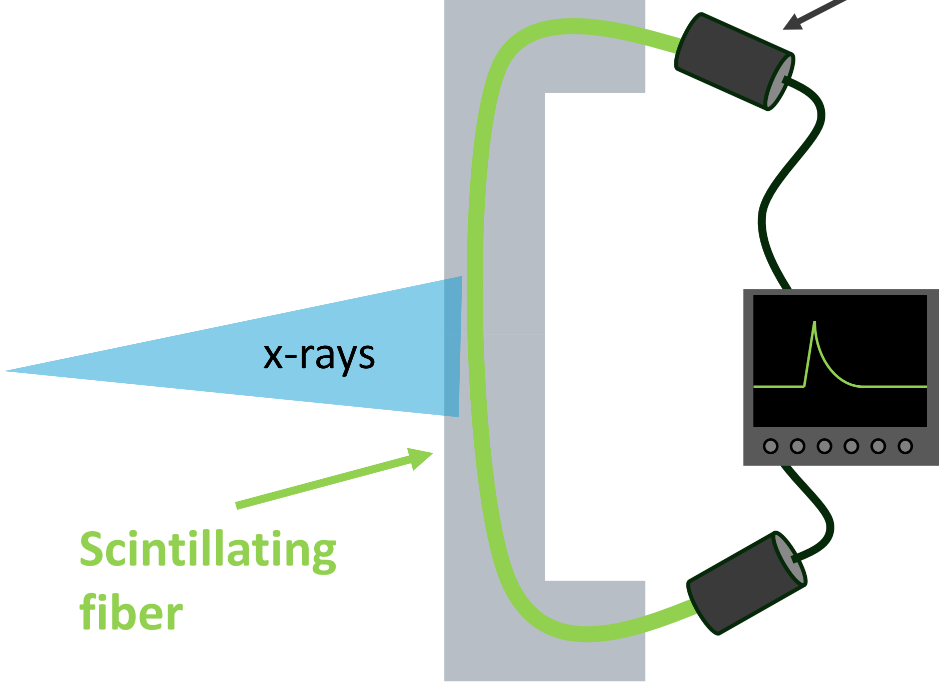


Good correlation between beam current and RF emission!

X-ray detection



Photomultiplier

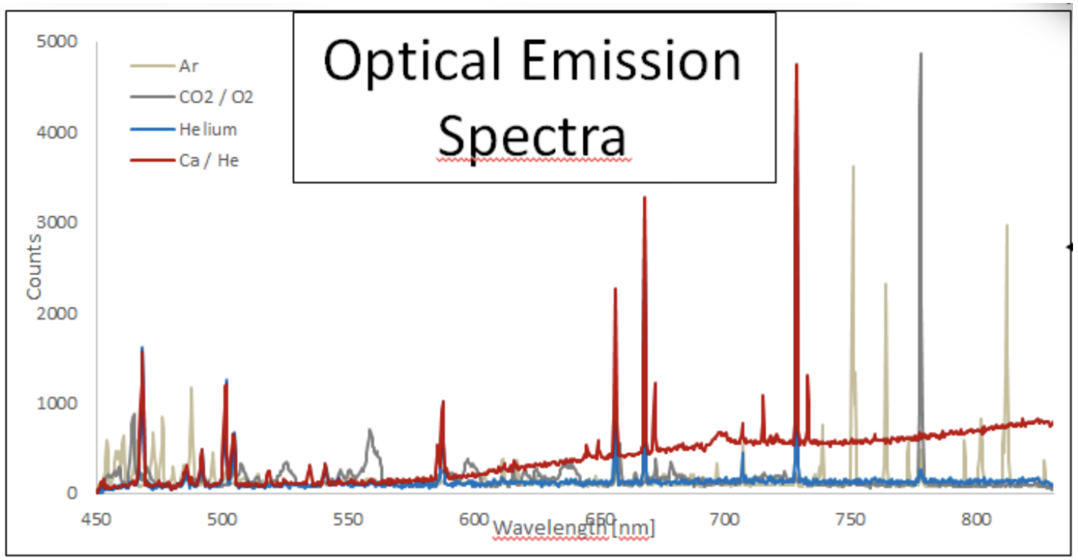


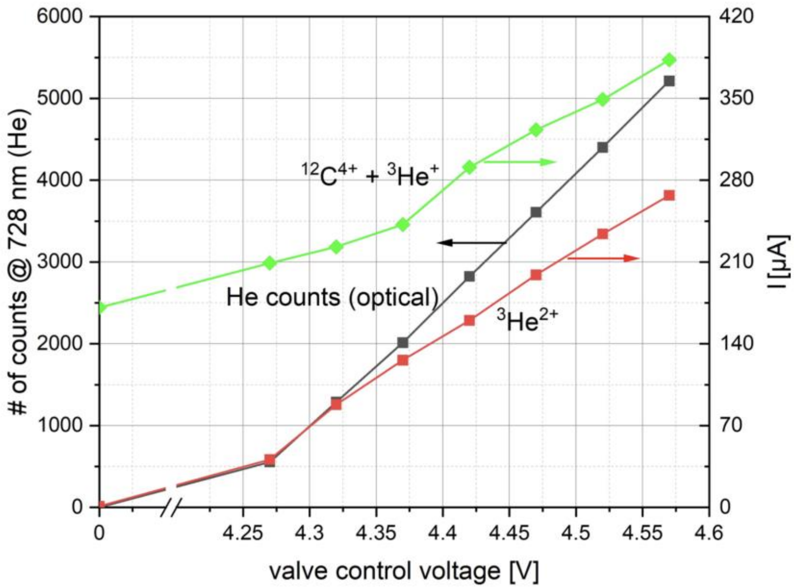
Scintillating fiber

Online monitoring: long-term stability (OES)

- **At GSI, it has been demonstrated that optical emission spectroscopy (OES) is suitable for metallic ion beam monitoring and operation**
- **Feasibility study for long-term plasma monitoring for noble gases (Ar, Kr, etc.)**

Ca with oven



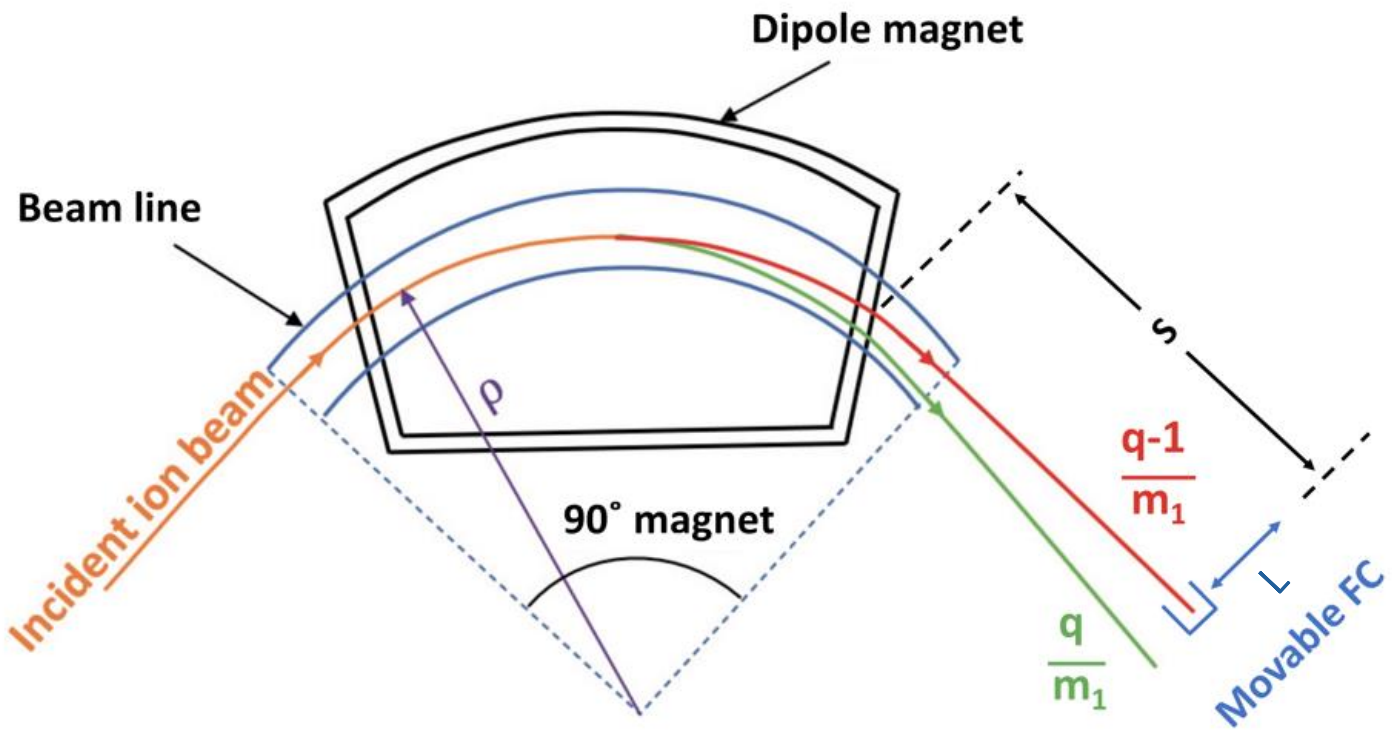


F. Maimone et al 2024 J. Phys.: Conf. Ser. 2743 012048

- Spectral peaks→ elemental identification, and monitoring of intensity
- Infrared spectrum → oven temperature

Q-1dipole: online beam monitoring

Allows online monitoring of q-1 beam while beam of interest is delivered to cyclotron (charge state q).
The diagnostic is capable of monitoring both short- and long-term beam stabilities

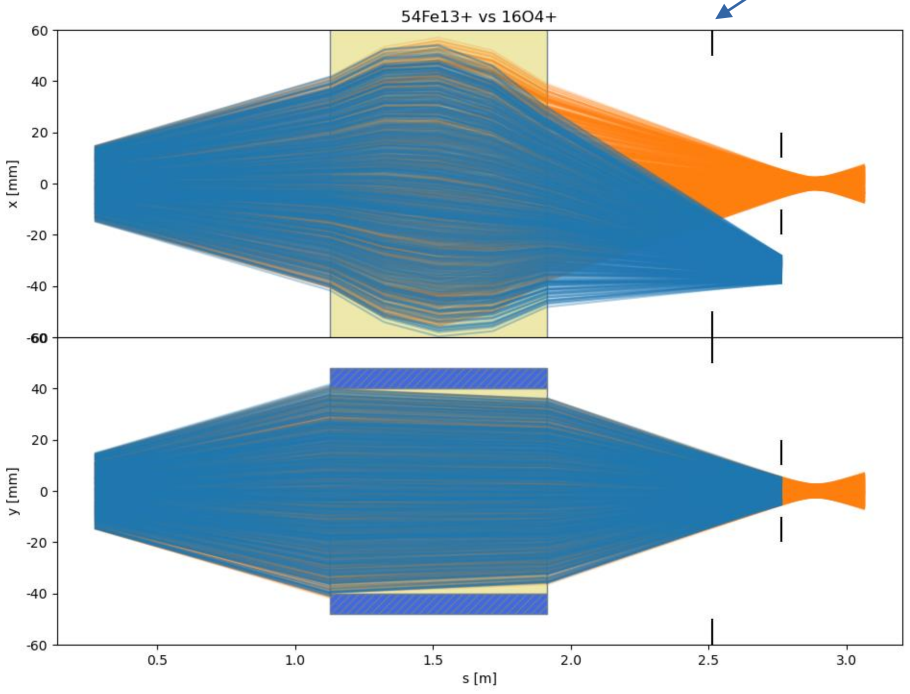


Define:

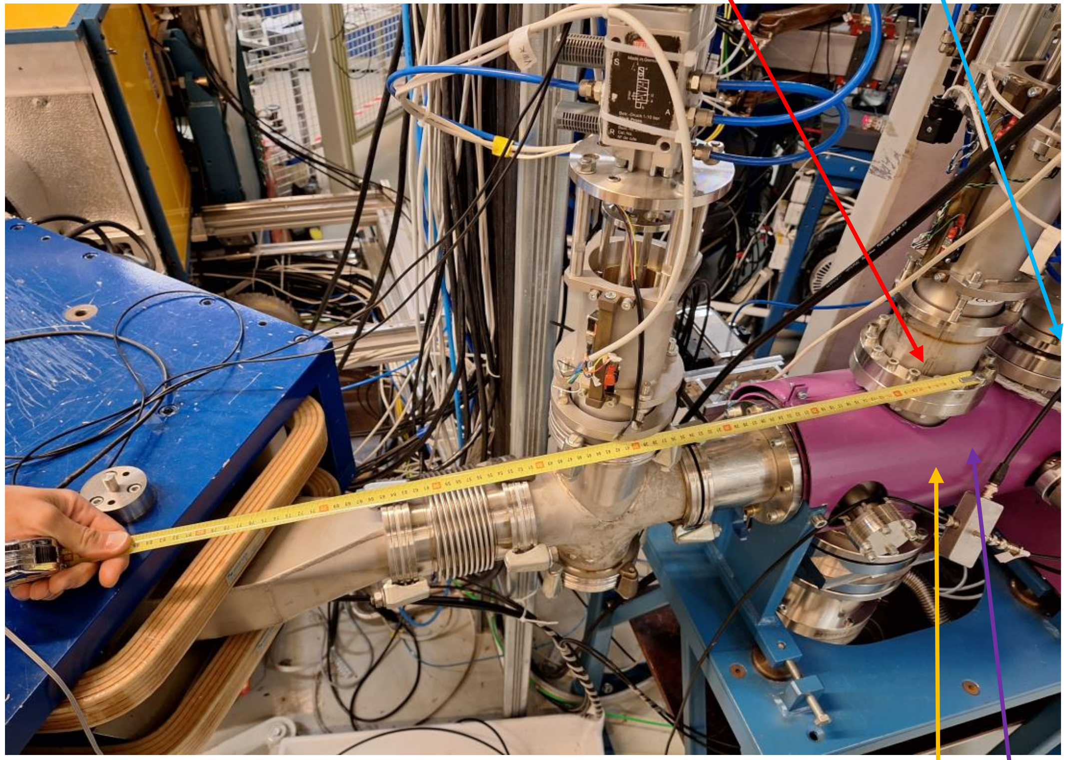
- Location (S) of movable FC along beam propagation for adequate q/m resolution
- Movement range (L) of q-1 FC

Location of q-1 diagnostics

Beam species are not separated before start of diagnostics chamber.



Same way: movement L of q-1 FC was defined



Technical design work has been started

Feedback to maintain stable conditions

Objective for the response system (leader PARTREC):

A. Alarm to the operator: unstable conditions/the preset intensity limit has been exceeded
B. System gives instructions to restore the stable conditions/requested beam intensity

In order to accomplish this:

- sample the beam current to calculate the average current and standard deviation
- define the most relevant operation parameters (multidimensional map) and track them to maintain the stable operation condition

EURO-LABS
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ERIBS

Example: Multidimensional map for response system

Power-Bmin/Beccr-Maps

6E-7 mbar

	100	300	400	500	600	700	800
0,6825		13%	13%	8%	10%	3%	
0,704		20%	22%	13%	10%	5%	
0,729		30%	28%	18%	9%	3%	
0,755		25%	55%	6%	3%	0%	
0,778		20%	15%	0%	0%	0%	
0,803		3%	0%	0%	0%	0%	
0,827		0%	0%	0%	0%	0%	
0,853		0%	0%	0%	0%	0%	
0,879		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
0,905		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
0,931		0%	0%	0%	0%	0%	

7E-7 mbar

B_{min}/B_{ECR}

	100	300	400	500	600	700	800
0,6825	0%	9%	15%	20%	43%	43%	43%
0,704	1%	16%	26%	60%	64%	63%	58%
0,729	1%	38%	73%	82%	80%	80%	66%
0,755	3%	56%	80%	100%	20%	25%	0%
0,778	5%	79%	75%	35%	0%	0%	0%
0,803	8%	15%	6%	0%	0%	0%	0%
0,827	10%	1%	0%	0%	0%	0%	0%
0,853	6%	0%	0%	0%	0%	0%	0%
0,879	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0%
0,905	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0%
0,931	0%	0%	0%	0%	0%	0%	0%

Microwave power

Instability threshold

Optimum operation point for Ar^{11+}

Pressure decreases→

New operation point

Example (@ATOMKI): Intensity map for Ar^{11+}

1E-6 mbar

	100	300	400	500	600	700	800
0,6825	0%	6%	10%	13%	17%	25%	30%
0,704	0%	7%	14%	25%	30%	33%	31%
0,729	1%	14%	25%	32%	36%	41%	33%
0,755	1%	17%	28%	33%	24%	23%	25%
0,778	2%	16%	23%	25%	18%	15%	0%
0,803	3%	10%	8%	5%	2%	1%	0%
0,827	4%	4%	2%	0%	0%	0%	0%
0,853	6%	2%	0%	0%	0%	0%	0%
0,879	1%	0%	0%	0%	0%	0%	0%
0,905	1%	0%	0%	0%	0%	0%	0%
0,931	0%	0%	0%	0%	0%	0%	0%

1.3E-6 mbar

	100	300	400	500	600	700	800
0,6825	0%	0%	1%	3%	3%	4%	6%
0,704	0%	0%	2%	4%	5%	7%	8%
0,729	0%	0%	3%	6%	8%	12%	16%
0,755	0%	0%	5%	10%	13%	18%	22%
0,778	0%	0%	11%	18%	20%	25%	30%
0,803	0%	0%	14%	25%	31%	13%	6%
0,827	0%	0%	14%	10%	6%	3%	0%
0,853	0%	0%	15%	5%	3%	3%	0%
0,879	0%	0%	10%	0%	3%	1%	0%
0,905	0%	0%	5%	0%	0%	1%	0%
0,931	0%	0%	1%	0%	0%	0%	0%

This is unstable operation point! Feedback system has to guide to restore the stable condition

Challenging and complex, multidimensional problem