

SPES project at LNL: OFFLINE AND ONLINE LASER LABORATORIES UPDATE



Daniele Scarpa
INFN – Laboratori di Legnaro



SPES: The future of LNL

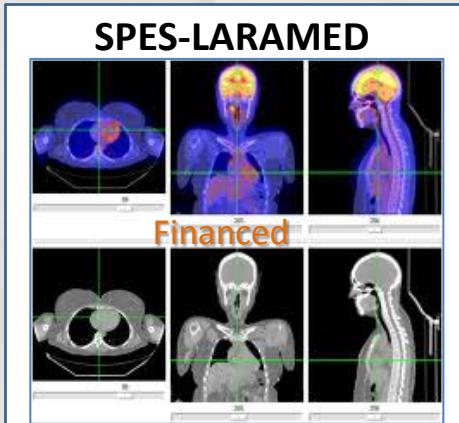
SPES is:

- 1) A second generation ISOL facility (for neutron-rich ion beams)
- 2) An interdisciplinary research center (for p,n applications)



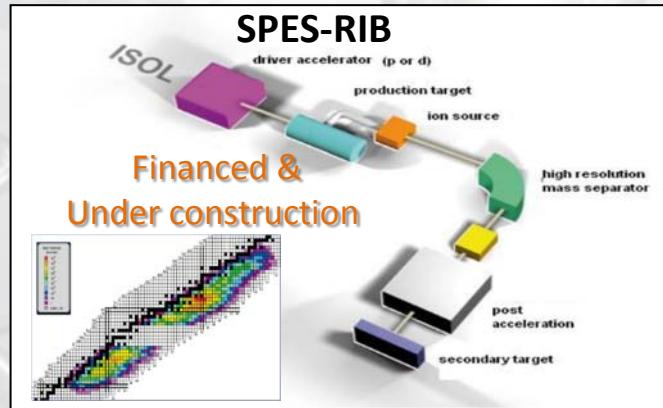
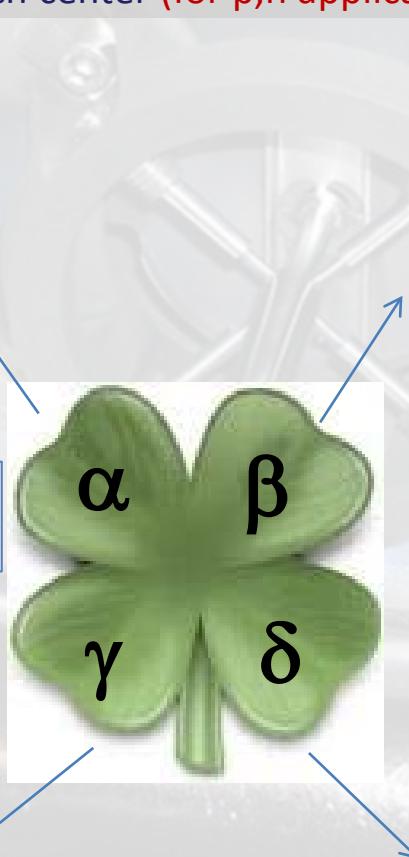
Cyclotron :

- $E=70$ MeV proton beam, $I= 750 \mu\text{A}$

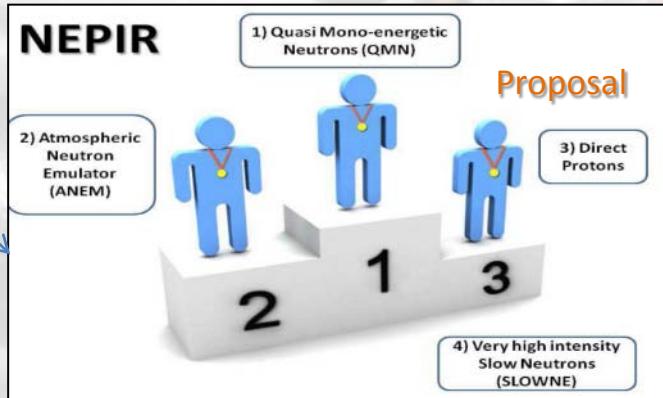


Research and Production of
Radio-Isotopes for Nuclear Medicine

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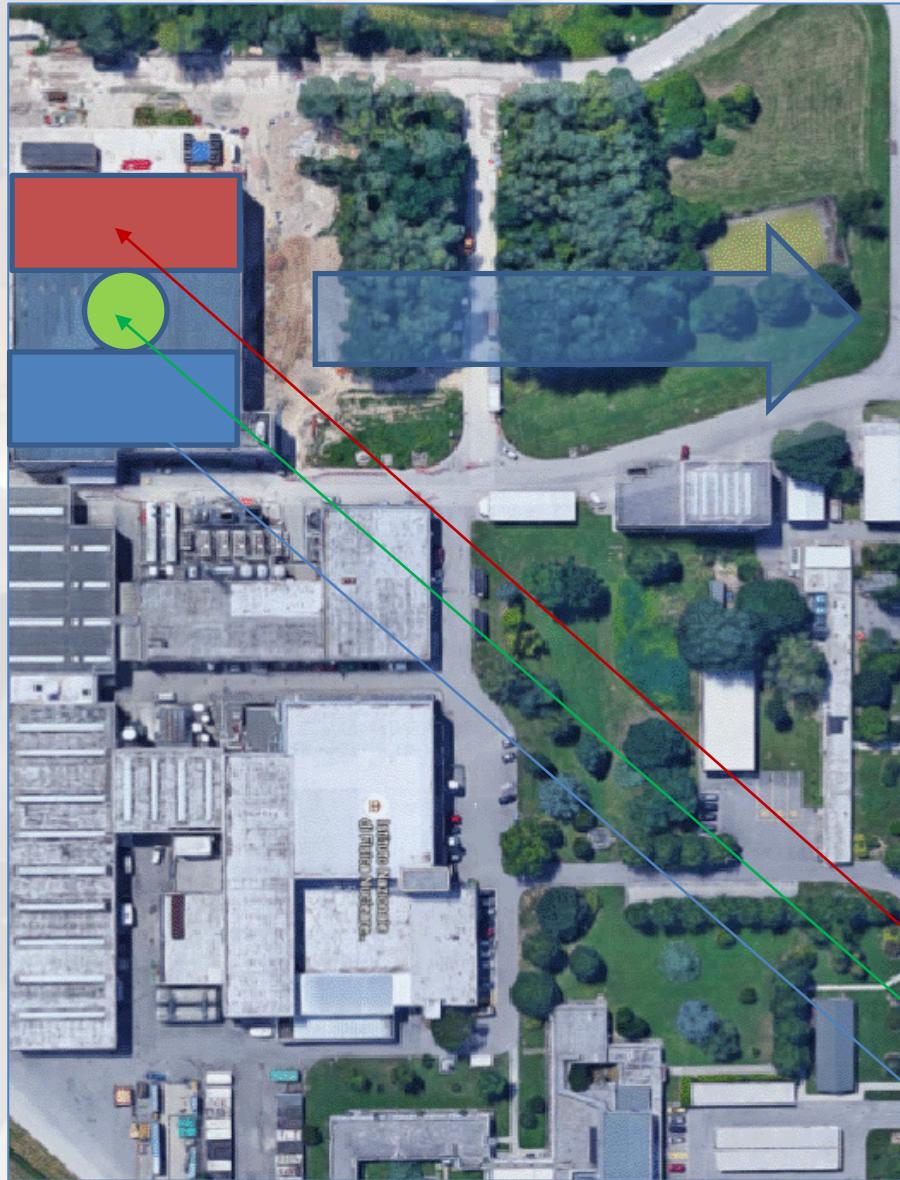


Production & re-acceleration of exotic beams,
from p-induced Fission on UCx



Accelerator based neutron source
(Proton and Neutron Facility for Applied Physics)

SPES Facility Layout

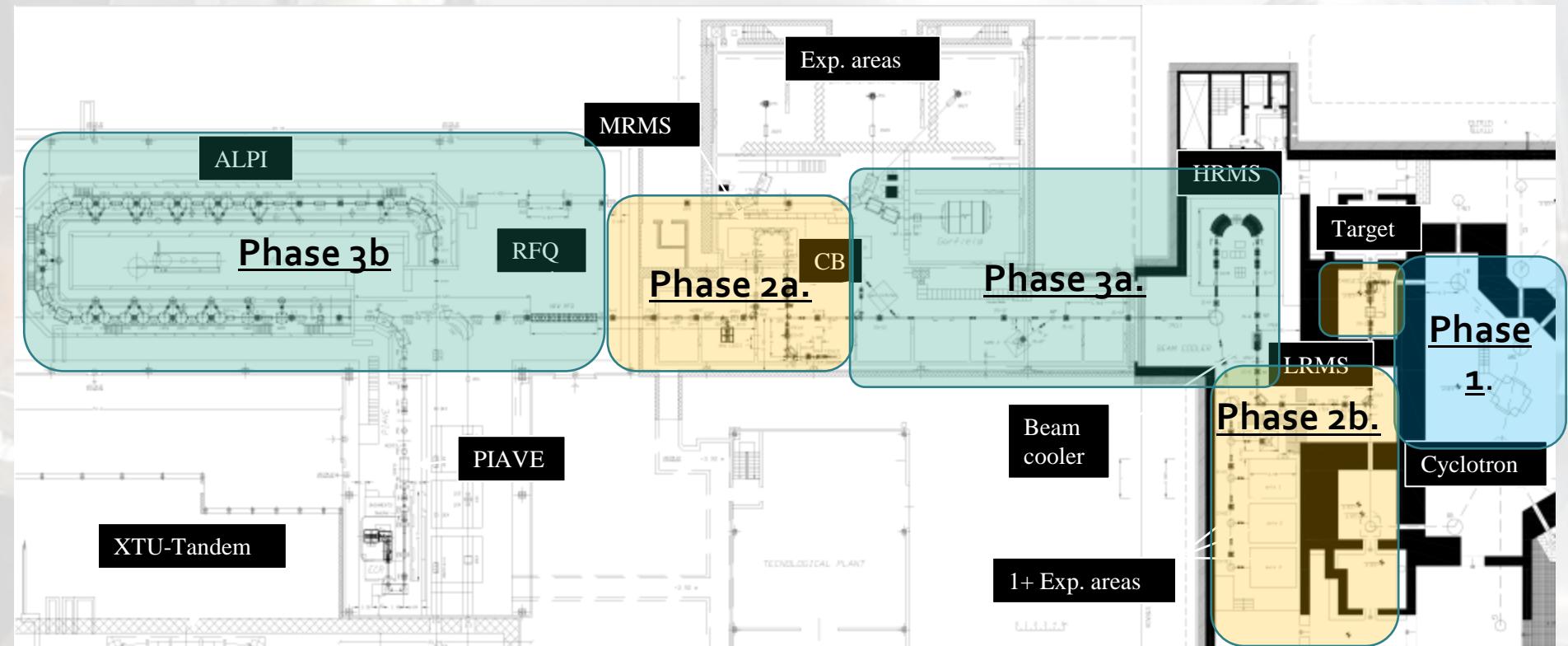


New infrastructure for:

- Application Facility
- Cyclotron
- RIB facility

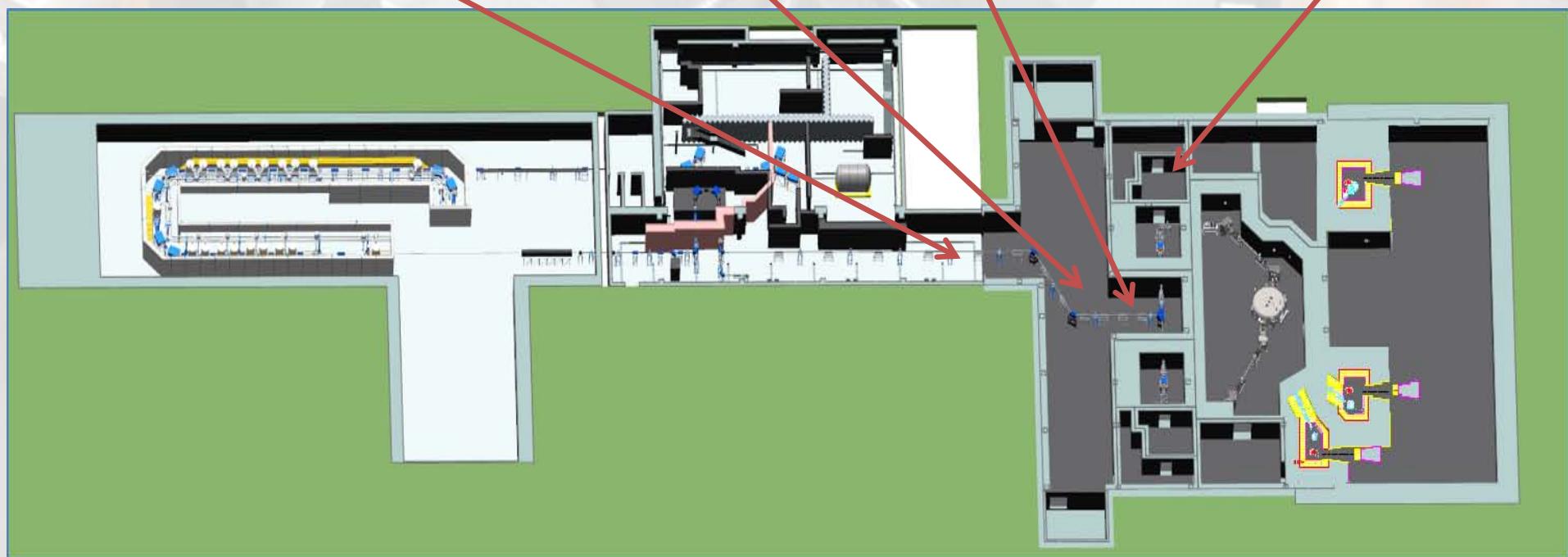


SPES Project construction Phases

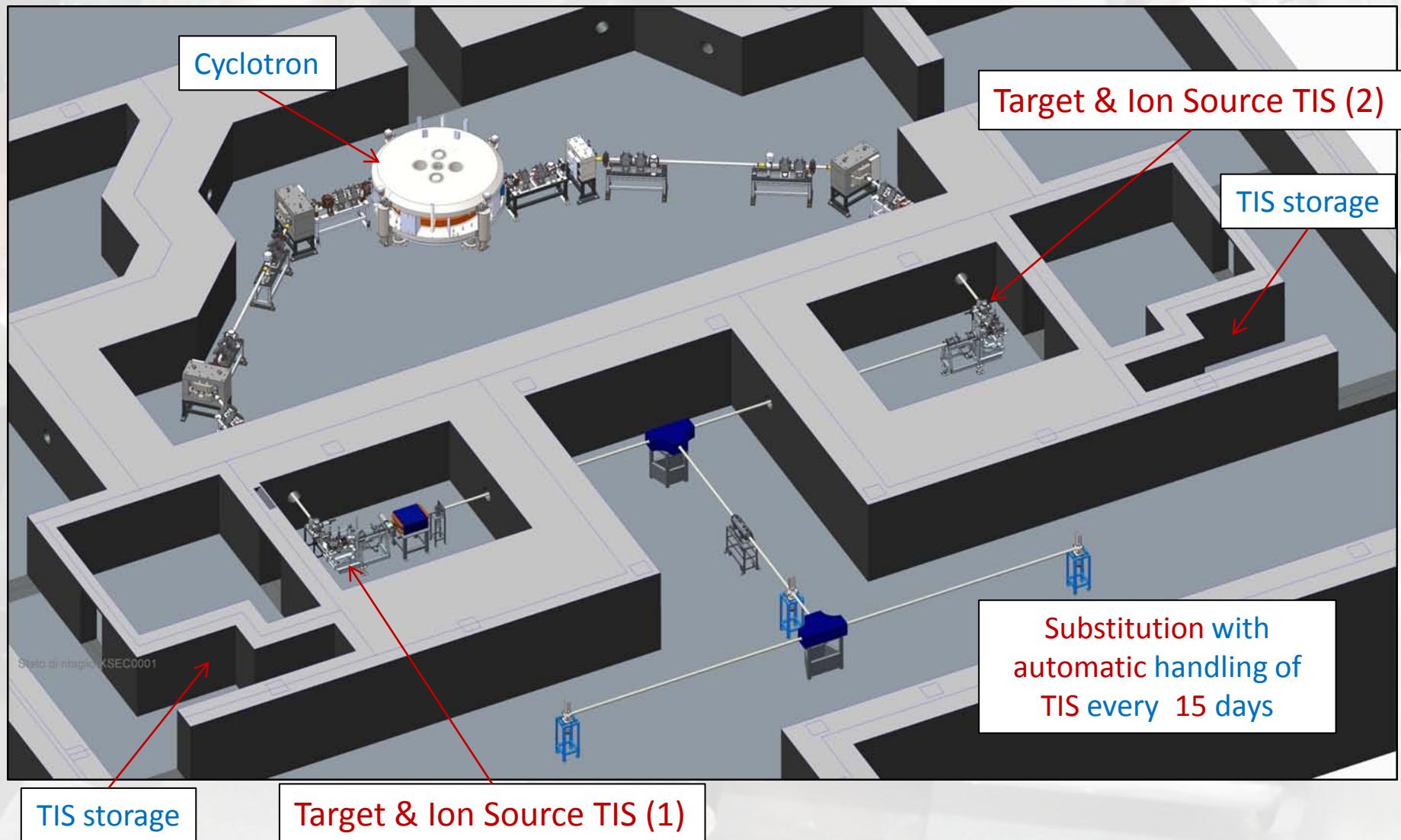


- Phase 1. 2016- Building & First Operation with the cyclotron
- Phase 2a. 2017- Charge Breeder and ALPI Injector line
- Phase 2b. 2018- SPES target, LRMS, experimental 1+ Beam Lines
- Phase 3a. 2019- From the LRMS to the CB
- Phase 3b. 2019- RFQ and ALPI

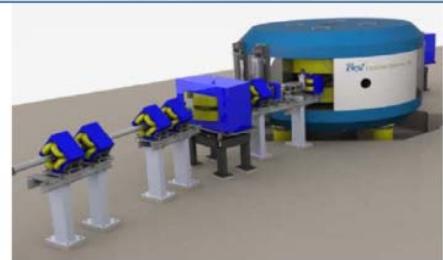
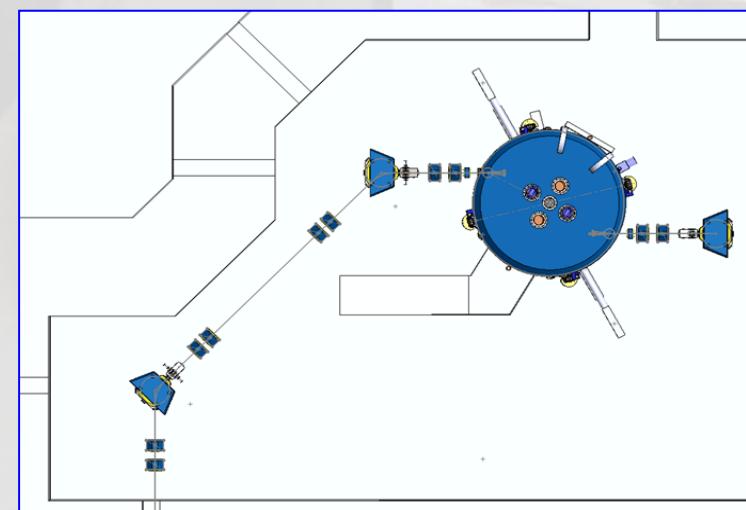
SPES building level 0



RIB production area



Cyclotron installation



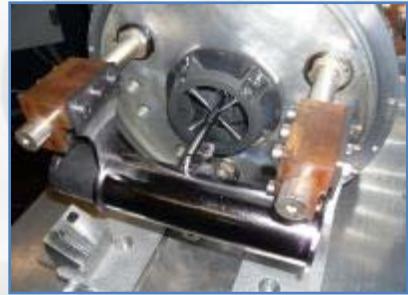
Energy	35-70 MeV (variable)
Current	> 700 uA (variable)
Extraction System	By stripping → simultaneous dual beam extraction
Injection System	Axial Injection → External Multicusp Ion Source 15-20mA DC
Main Magnet	$B_{max} = 1,6\text{ T}$ Coil current = 127 kAt Power supply = 30 kW 4 sectors, deep valley
RF System	2 resonators Frequency= 58 MHz Harmonic mode=4 Dissipated Power=15 kW per cavity DEE voltage=60-80 kV
Operational Vacuum	$2 \text{ e} - 7 \text{ mbar}$

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Laboratories & Organization



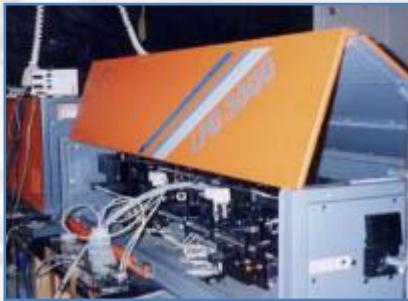
WG1:
TIS



WG2:
Materials



WG3:
Laser



WG4:
Handling



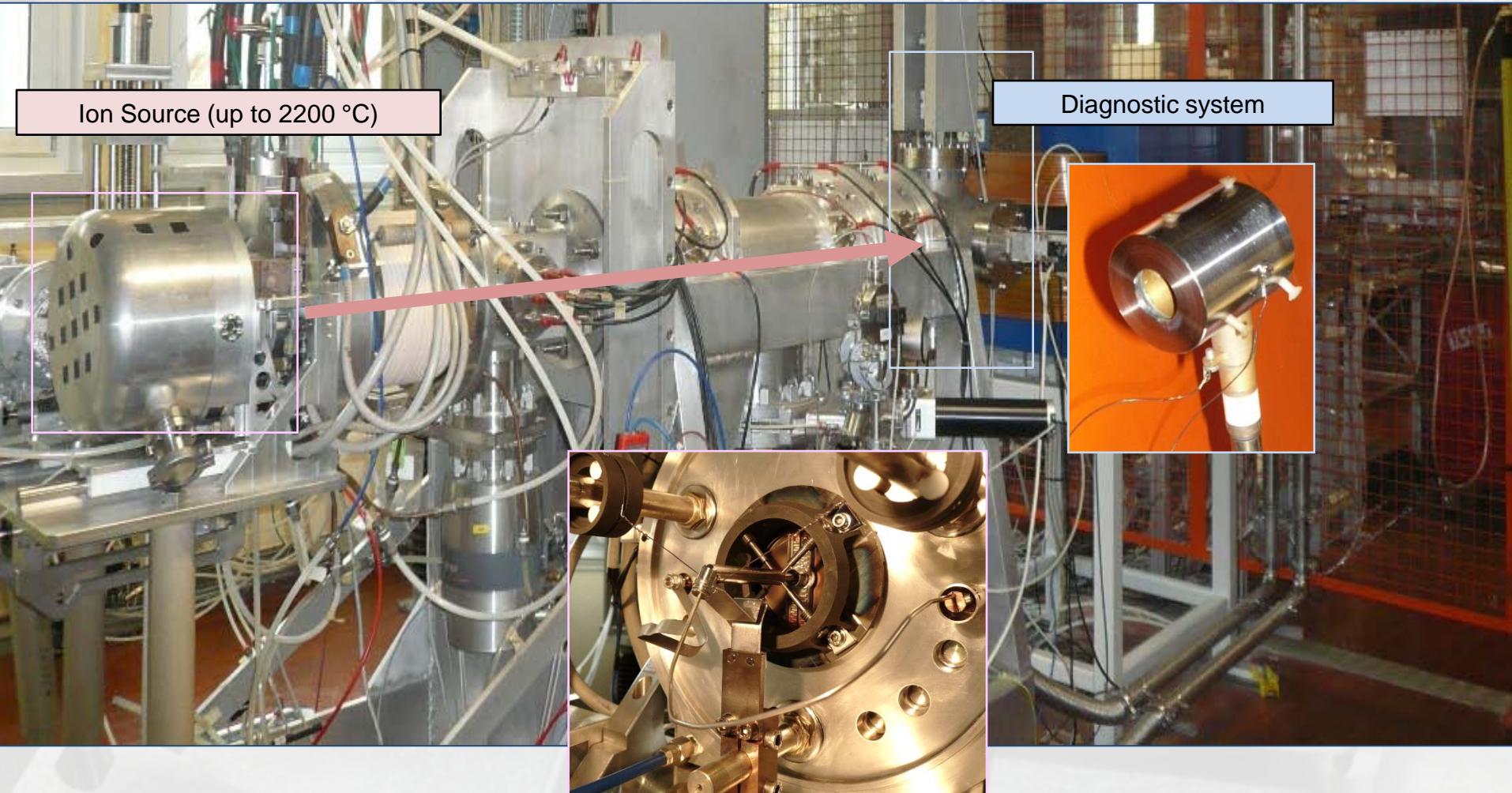
WG5:
Front End



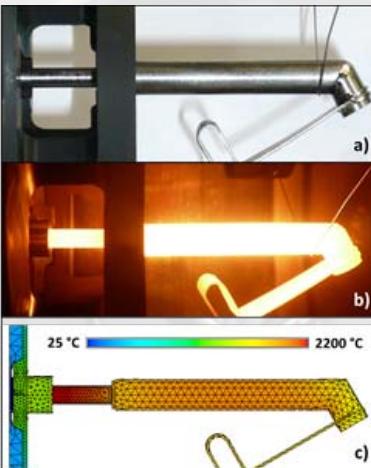
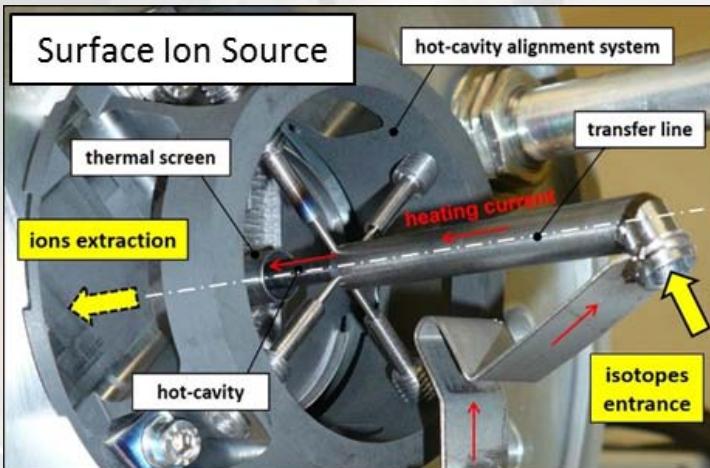
The ionization methods

Ionization Efficiency =

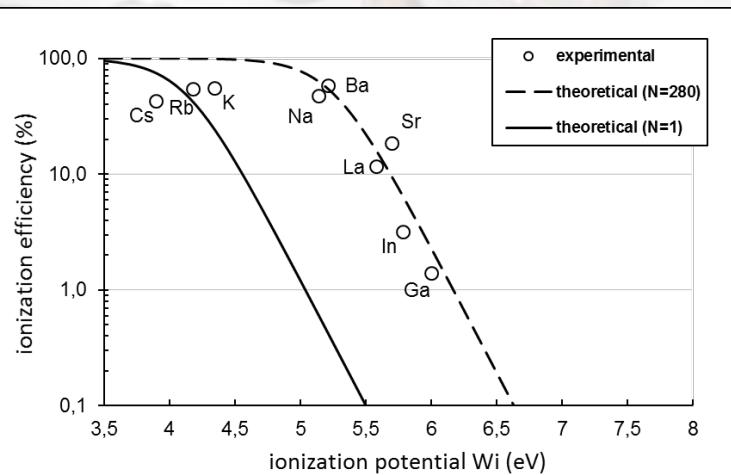
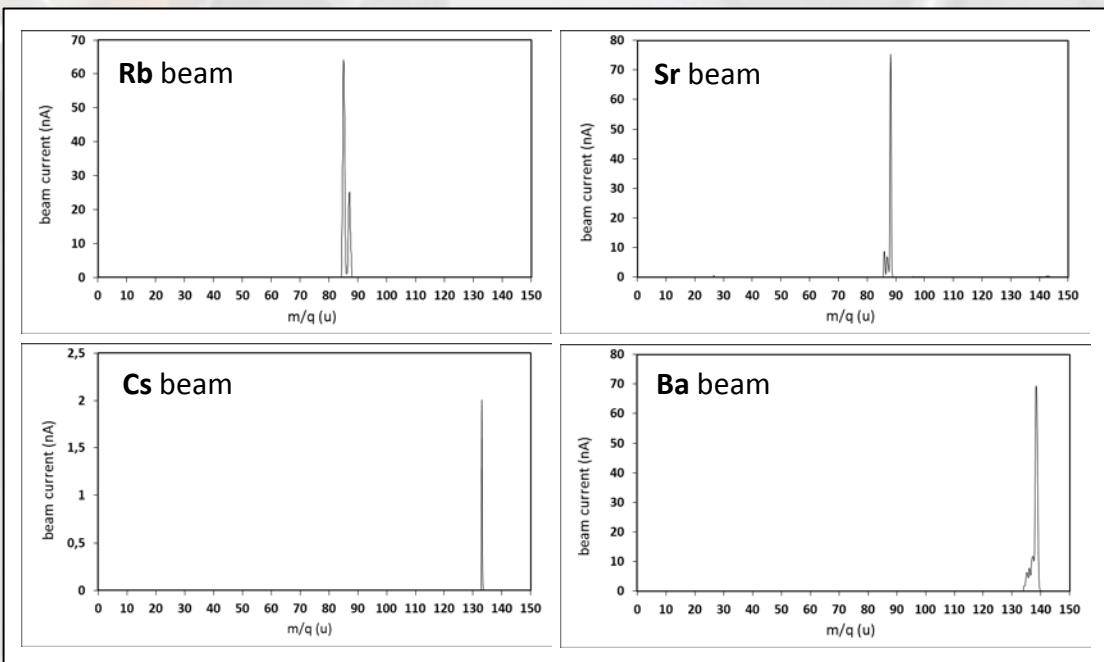
Ions collected
Atoms availables



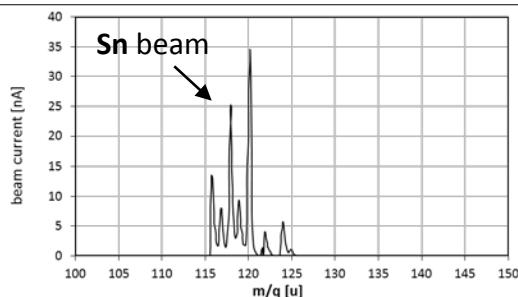
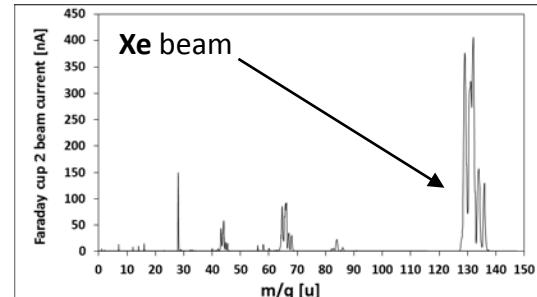
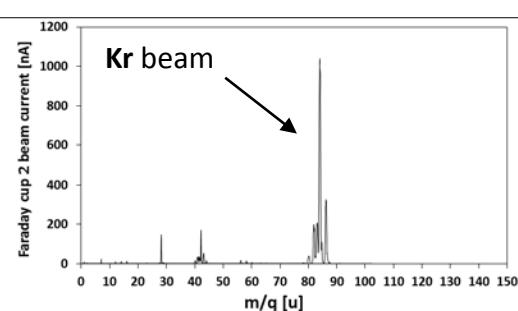
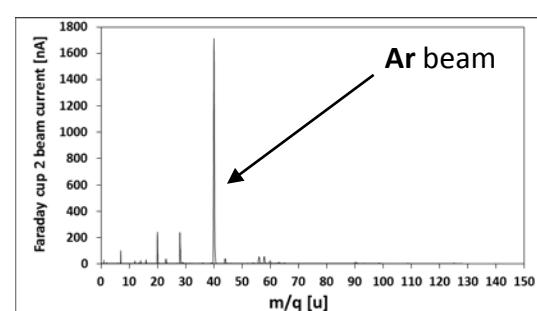
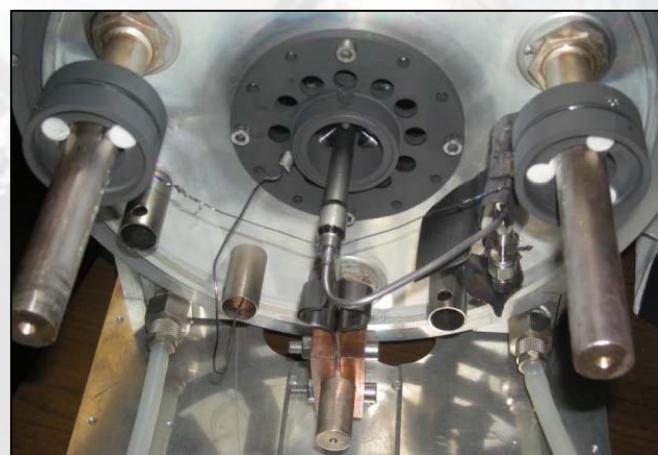
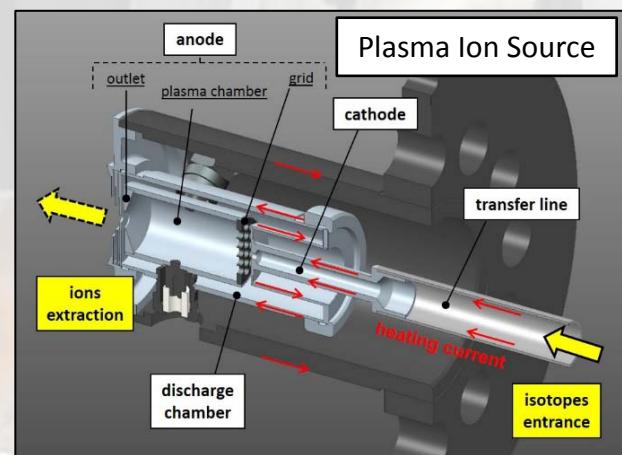
Characterization of the SPES Surface Ion Source



beam	ion. eff. (%)	hot-cavity temp. (°C)	hot-cavity material
Na	47,6	2200	Ta
K	55,4	2200	Ta
Ga	1,4	2200	Ta
Rb	54,5	2200	Ta
Sr	18,5	2200	Ta
In	3,2	2200	Ta
Cs	43,2	2200	Ta
Ba	58,8	2200	Ta
La	20,1	2200	Ta



Characterization of the SPES Plasma Ion Source



beam	ion. eff. (%)	injection mode	cathode temp. (°C)
Ar	6	gas tube	2200
Br	WIP	oven	2200
Kr	8,5	gas tube	2200
Y	very low	oven	2300
Sn	10	oven	2200
I	19	oven	2200
Xe	11	gas tube	2200

TIS unit endurance test:

Tests at high temperature with Joule heating thermal load (1300A target heater, 350A line):
heating power $\approx 12 \text{ kW}$ > primary proton beam thermal load ($\approx 10 \text{ kW}$)



- ≈ 415 testing hours at high temperature -> ≈ 220 hours at maximum power (12kW)
- 79 heating cycles sustained -> **9 with current ramps of 1 s from 0 A to 1300A (!) to 350A (!)**



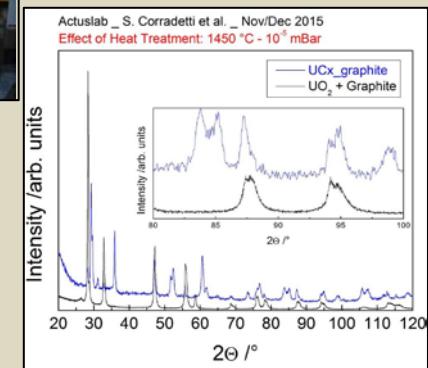
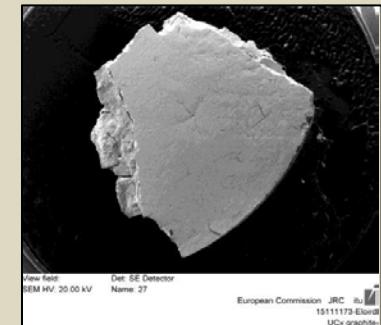
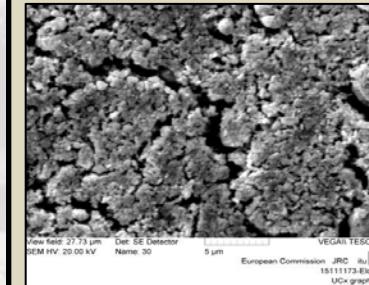
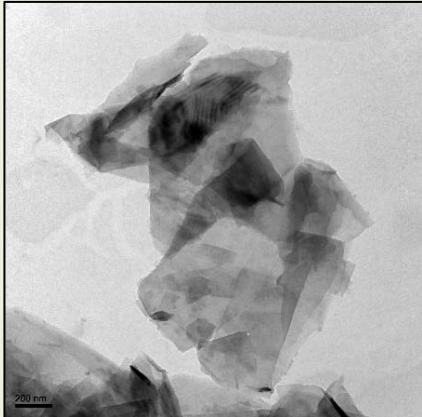
TIS UNIT STILL OPERATIVE !!

Synthesis of a novel type of UC_x using graphene

Experiment submitted & accepted at Karlsruhe: n. AUL-176 "Study of the use of Reduced Graphene Oxide as source of carbon for UC_x-Graphene nanocomposites production"

Final phase (Nov-Dec 2015, JRC-ITU
Karlsruhe, ActusLab)

Production of uranium carbide using
graphite or graphene as carbon sources



AGV test at LNL

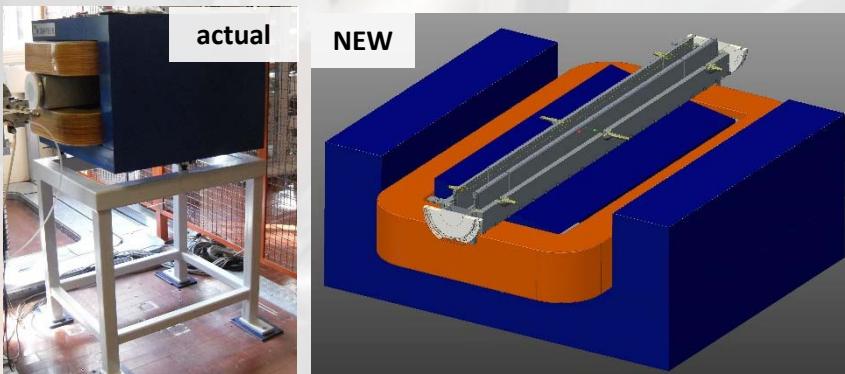


- Simulation software Siemens in Tia Portal
- Movement test in automatic mode
- Experimental tests with 3 transponder



RIB line upgrade

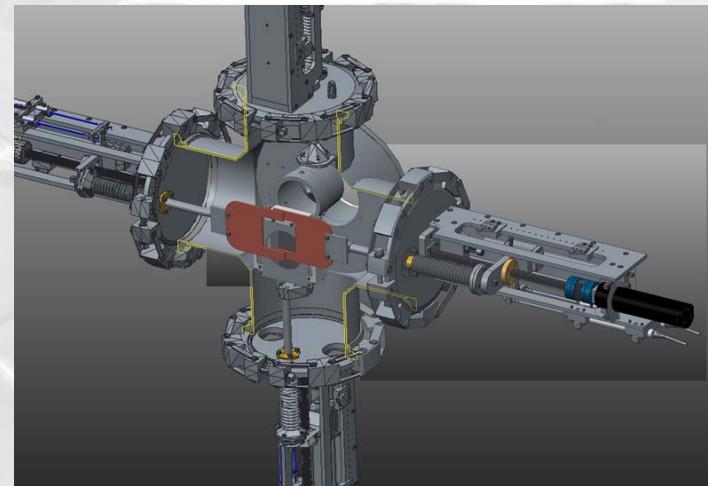
Wien Filter



Maximum magnetic field achievable with actual power supply: 0.84 T

Diagnostic boxes

Diagnostic crosses and diagnostic detector in production



Vacuum chamber (ready)



Pole prototype



INPUT

Emittance @ 25 keV = 5π mm mrad
(measured)

ΔE = 5 eV (assumed)

m = 150 uma

Energy = 42 keV

β = 0.8 T

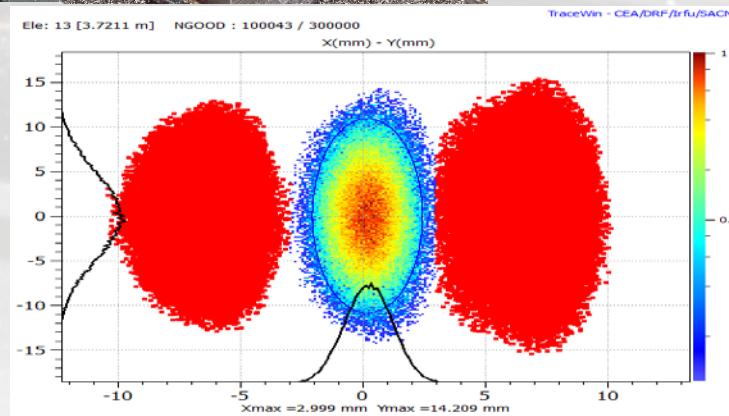
} Worst case

RESULTS

Beam size: 6 mm

M_{150} particle lost: 0.04%

"Unwanted" particles: 0.08% (M_{149})



D.Scarpa

The SPES WP3: Group

Collaborations:

Pavia University



Padua University



Siena University



PNPI



CERN



JYFL



The SPES WP3: Group

Spectroscopy:

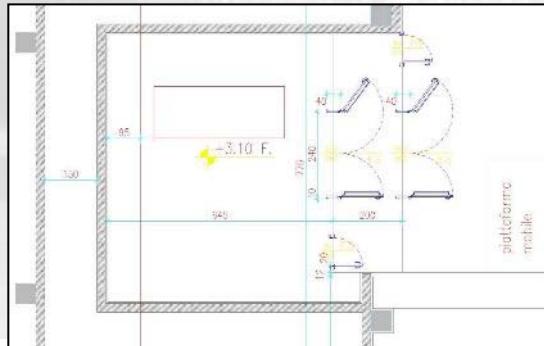
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- Offline-lab with 10Hz dye laser system
- HCL & ToF-MS



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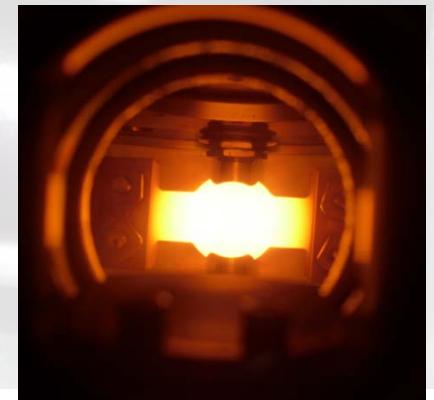
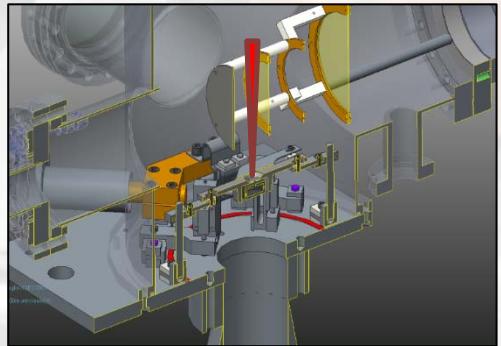
New SS laser:

- Defining RIB production laser requirements
- 10 kHz TiSa laser
- New laser lab requirements



Laser FE:

- ToF system
- Hot cavity
- Efficiency measurements



LANET⁺

The LASER Laboratories

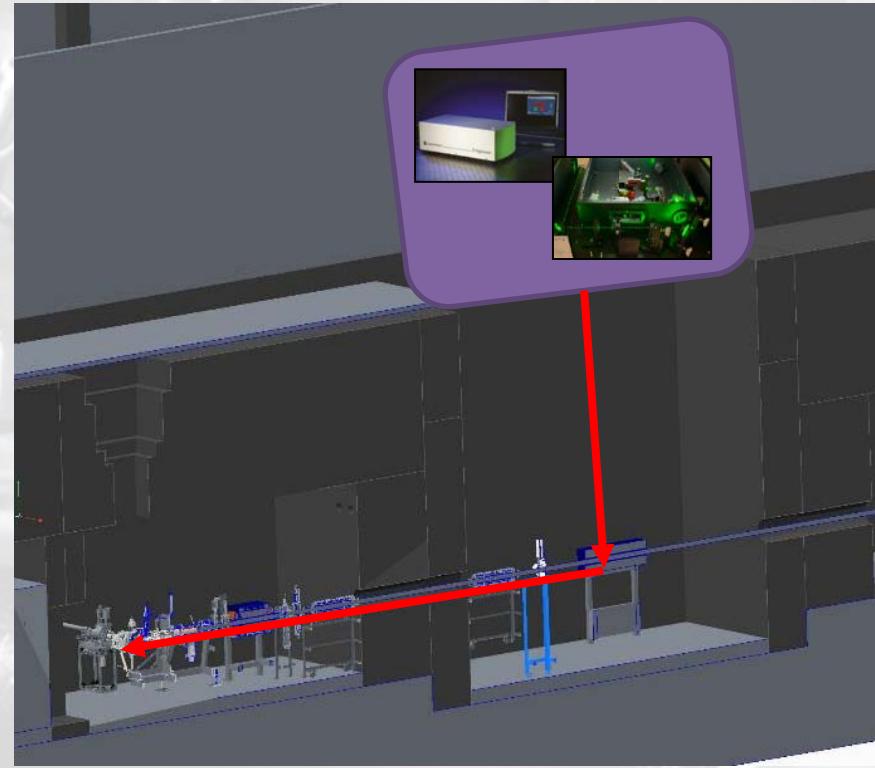
Offline: Spectroscopy

- 3 Dye Laser @ 10 Hz rep. rate



Online (SS laser): RIB prod.

- 3 TiSa Laser @ 10 kHz rep. rate



Diagnostic tools:

- Monochromator
- HCL
- ToF Mass Spectrometer

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The LASER Laboratories

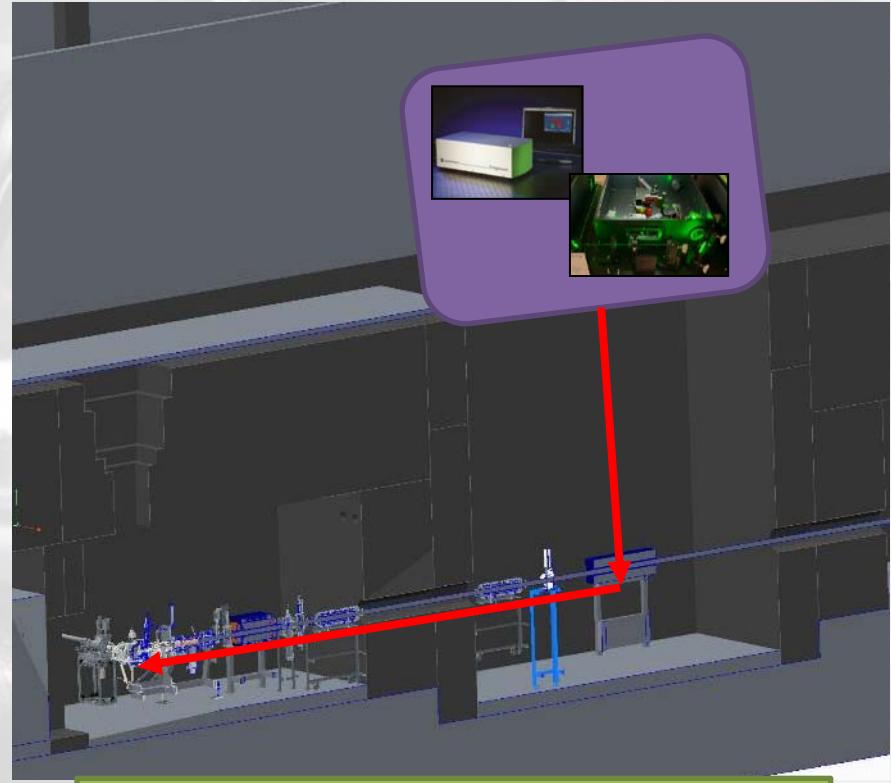
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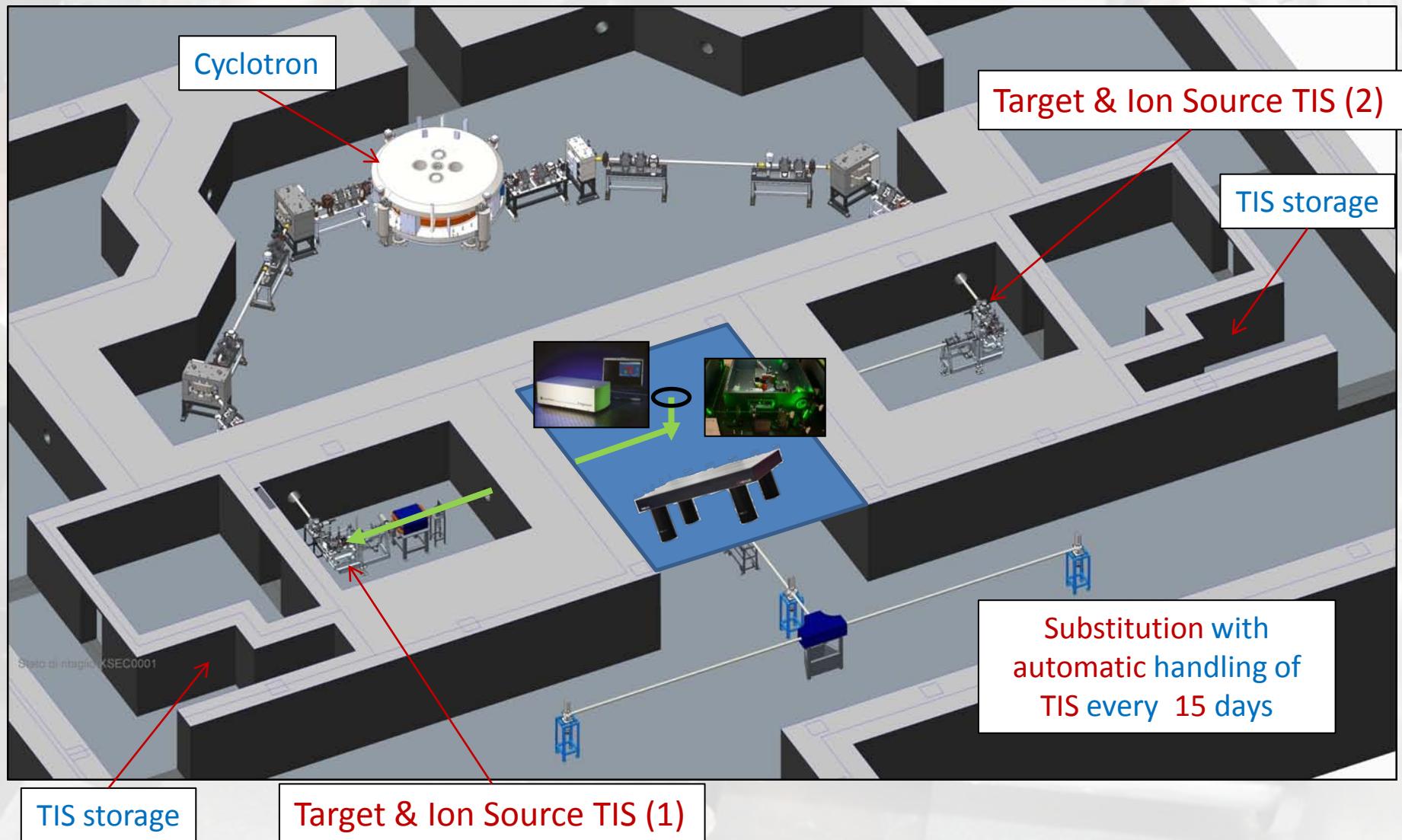
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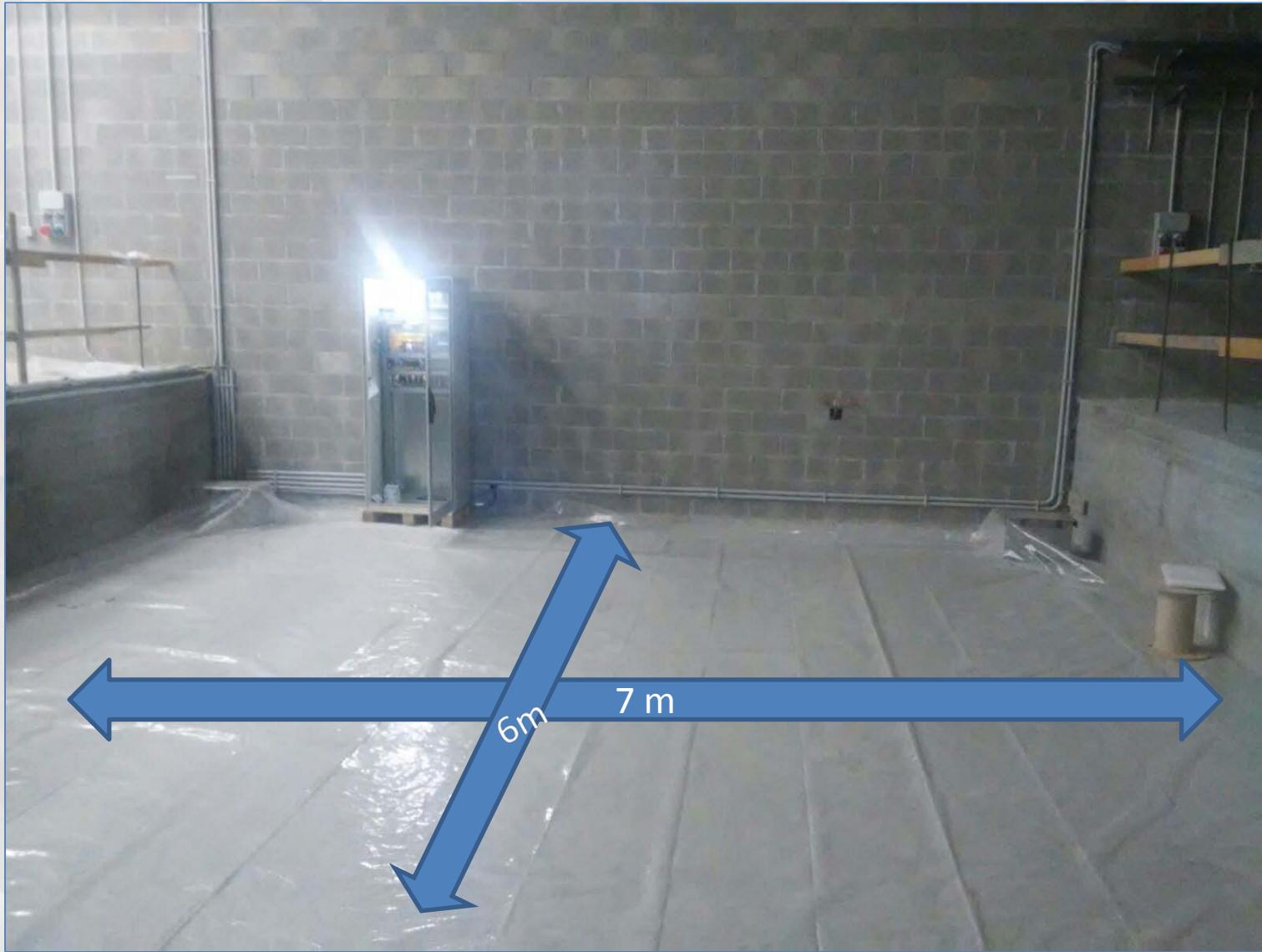
Diagnostic tools:

- Λ-meter
- Alignments System
- Ion-Beam

RIB production area

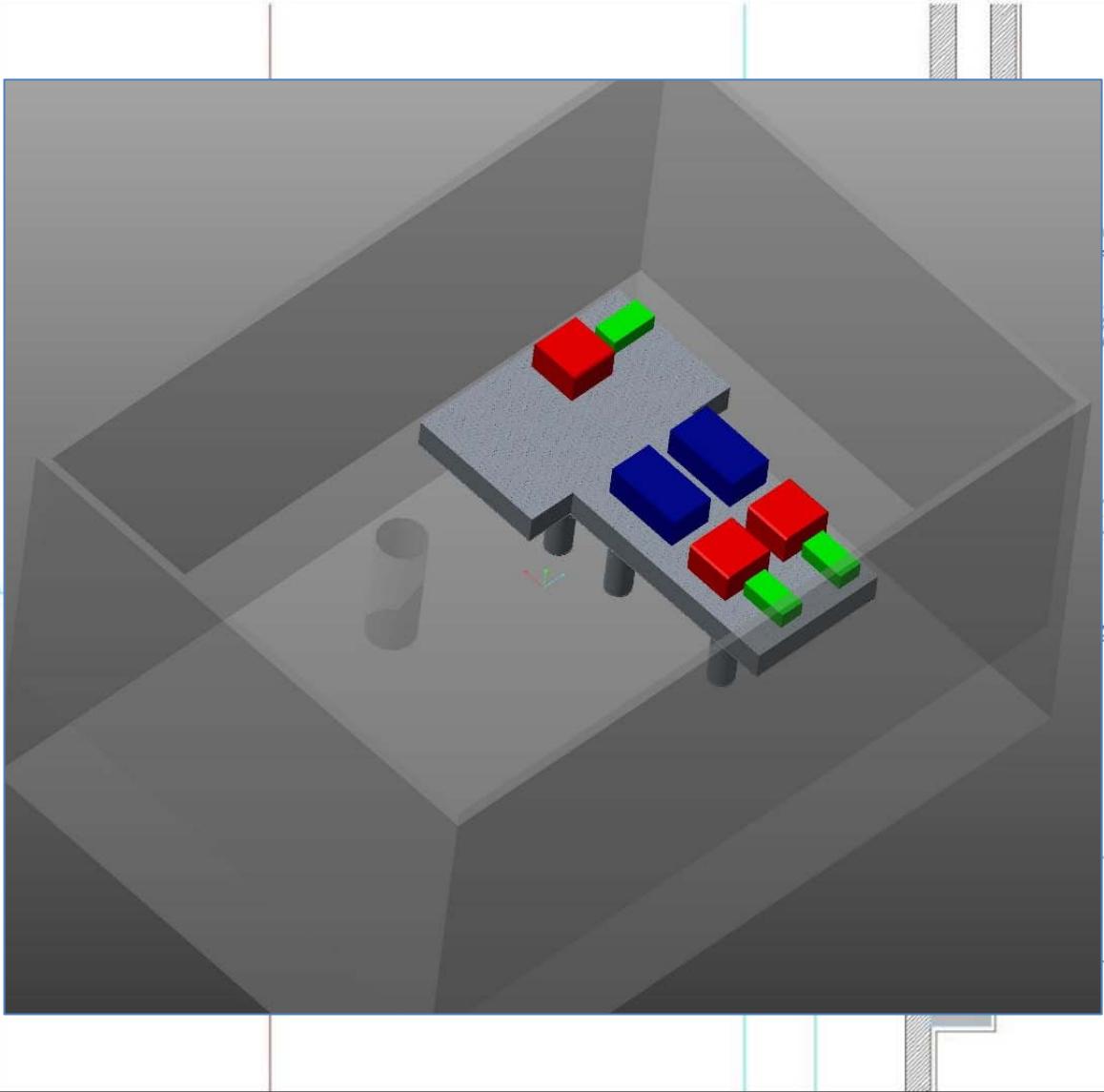


Future Online laboratory setup



Future Online laboratory setup

Proposal for layout:



L1: dressing room

- Clean env.
- Secure env.

L2: lab laser

- Temp controlled
- Overpressure
- Remote control
- Extra space for developments

piattaforma
mobile

Future Online Laser System

Laser delivery:

Phase n.	Description	Timing / Activities	Timing / Payments
1	System order date: 08/05/ 2015	T0	
2	Submitting of the technical documents to INFN-LNL for approval and definition of acceptance tests	T0+6 months	
3	Start of development and manufacturing	T0+7 months	30%
4	Start of factory tests (FAT) on first complete working line	T0+ 28 months half September 2017	35%
6	Beginning of installation Three complete lines at INFN-LNL	T0 + 32 months half January 2018	15%
7	End of installation and beginning of on-site tests (SAT)	T0+ 33 months Half February 2018	
8	Beginning of commissioning	T0+ 36 months Half May 2018	
9	End of commissioning	T0+ 39 months Half August 2018	20%

Start 2018

Half 2018



Pump lasers:

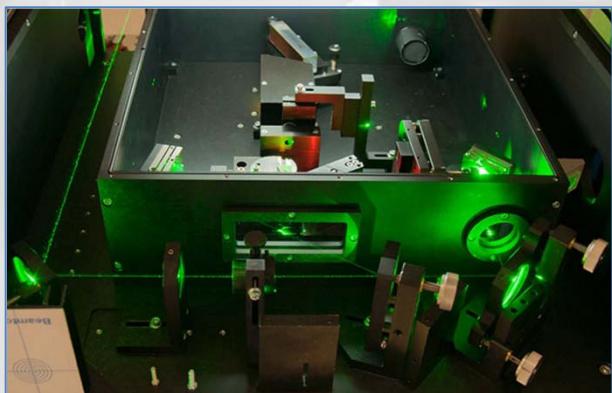
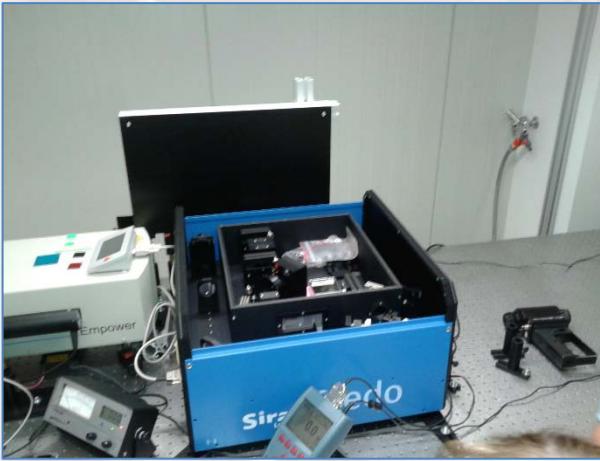
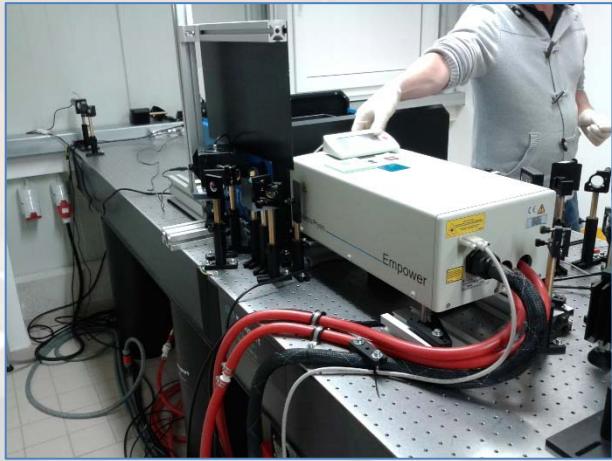
- 3 x Spectra-Physics EMPOWER
- 40 W average power
- 10 kHz rep rate

Tunable lasers:

- 3 x Credo Tisa
- 2 x High Harmonic Generator

Visit @ Sirah

Visit in October by SPES team: 1 line of 3 under development



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The SPES WP3: Group

Spectroscopy:

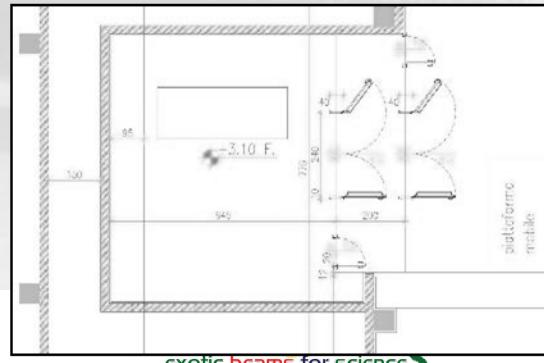
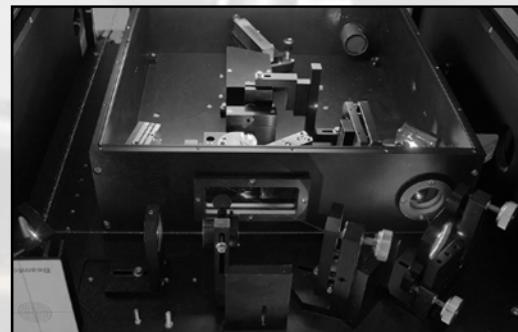
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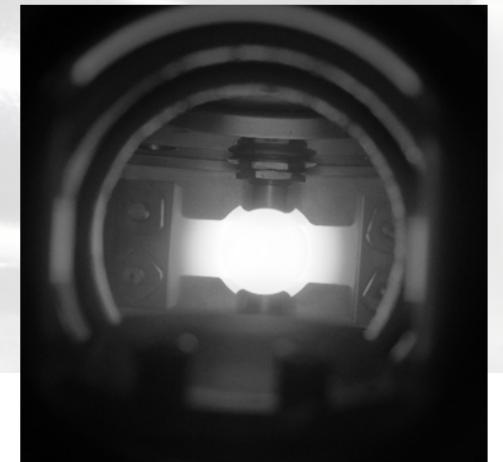
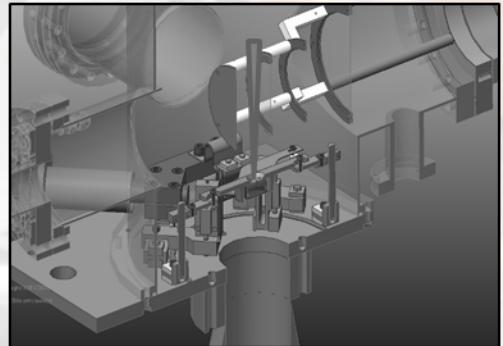
New SS laser:

- Defining RIB production laser requirements
- 10 kHz TiSa laser
- New laser lab requirements



Laser FE:

- ToF system
- Hot cavity
- Efficiency measurements



LNL-INFN SPES Offline Laser Laboratory

In 2013 a new SPES laser laboratory was build



January



March



June

2013



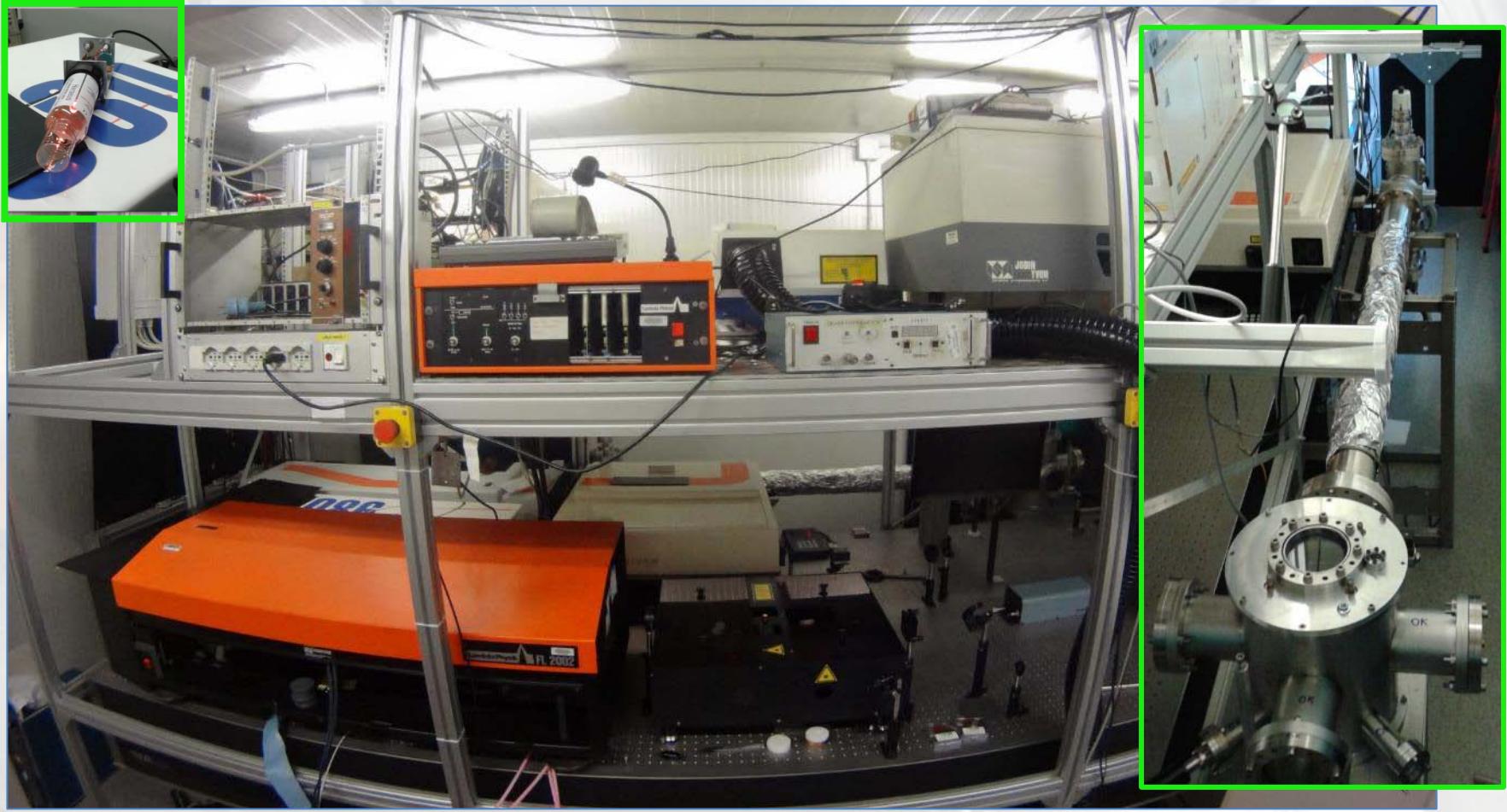
September



November



December



Lasers:

3 Dye lasers pumped by 2 Nd:YAG 10Hz rep rate lasers; Nd:YAG for ablation

Measurement systems:

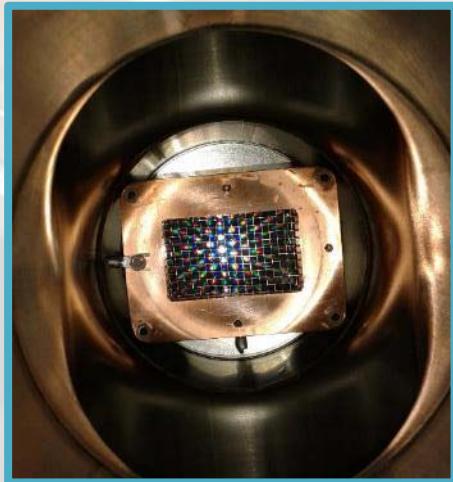
Hollow Cathode Lamps and Time of Flight Mass Spectrometer

Home-made ToF (ablation source)

Home made Time of Flight Mass Spectrometer:

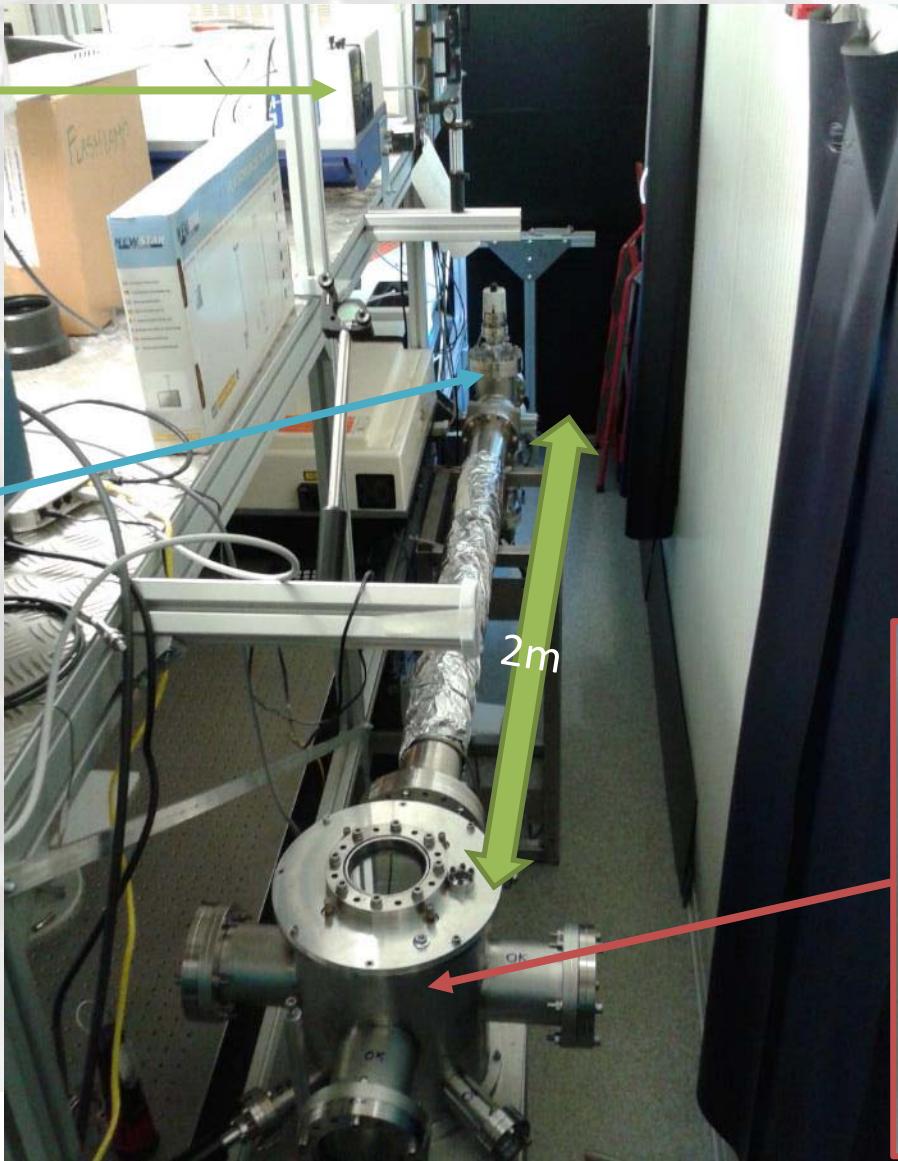
Source (1):

Quantel
1064nm for
laser ablation



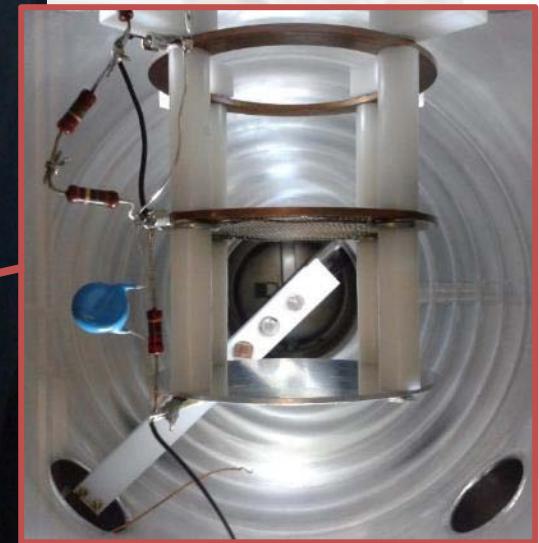
Detector:

After 1,9 m
flight, ions
impact on
40x60 cm²
MCP



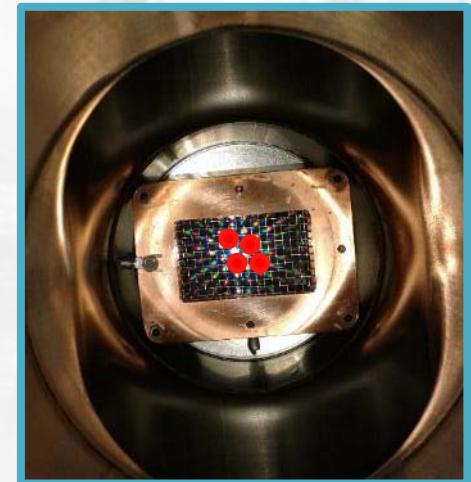
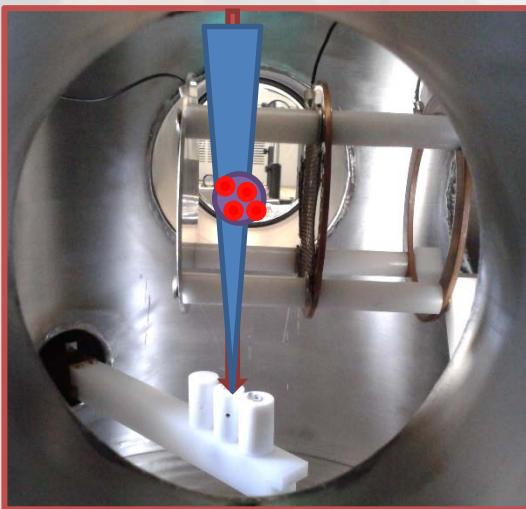
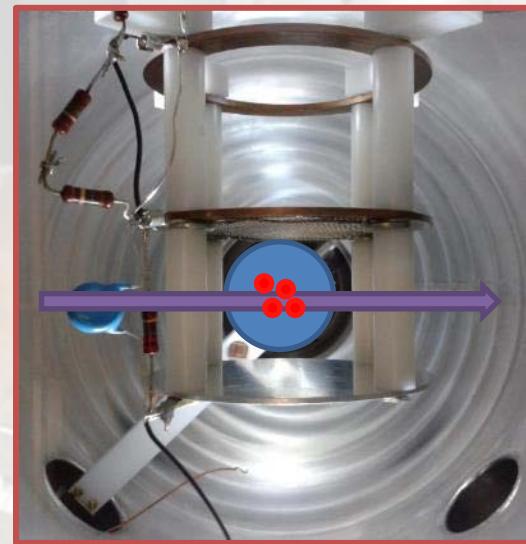
Source (2):

Multi cup with
elements of interest.
Laser ablation to
generate atoms
plume and laser
resonant ionization
as trigger for time of
flight count



Home-made ToF (ablation source)

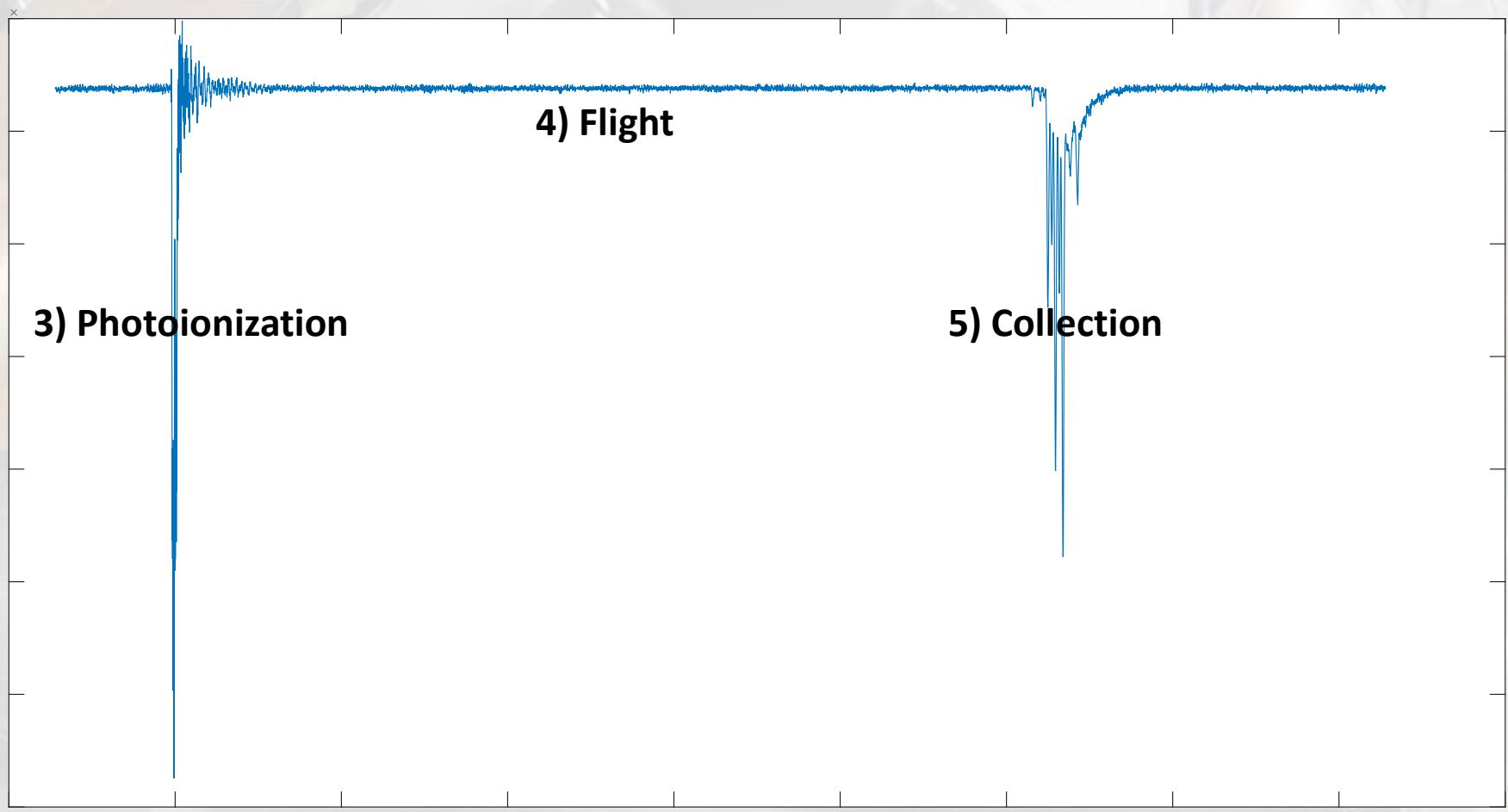
Measure Sequence:



- 1) Ablation
- 2) Plume Expansion
- 3) Photoionization
- 4) Flight
- 5) Collection

Home-made ToF (ablation source)

Typical Signal:



Actual ToF performances: Tin laser resonant ionization

Simion® simulation

VS. ToF acquisition

• ToF mass resolution



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RECEIVED: June 15, 2016

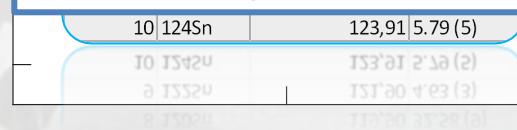
ACCEPTED: August 26, 2016

PUBLISHED: September 1, 2016

4TH INTERNATIONAL CONFERENCE FRONTIERS IN DIAGNOSTICS TECHNOLOGIES
30 MARCH 2016 TO 1 APRIL 2016
FRASCATI, ROME, ITALY

ToF diagnostic of Tin resonant laser photoionization in SPES laser offline laboratory

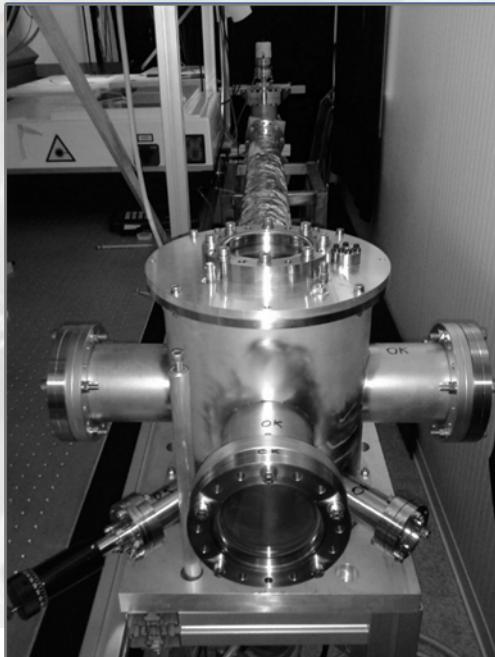
D. Scarpa,^{a,1} D. Fedorov,^b A. Andrigetto,^a E. Mariotti,^c P. Nicolosi,^d L. Sottilli,^{a,e}
A. Tomaselli,^f R. Cecchi^c and L. Stiaccini^c



The SPES WP3: Group

Spectroscopy:

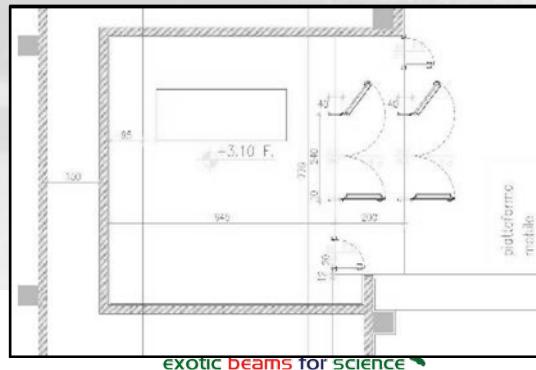
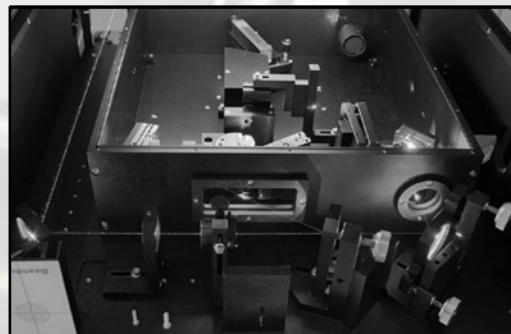
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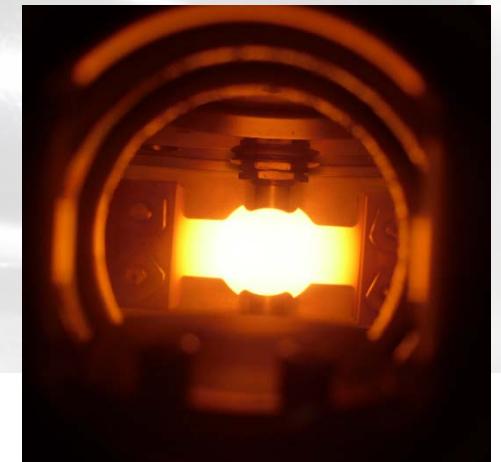
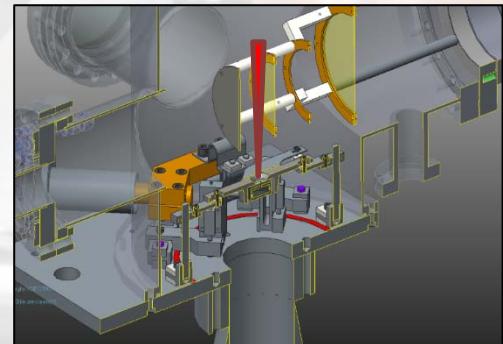
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Measuring ionization efficiency

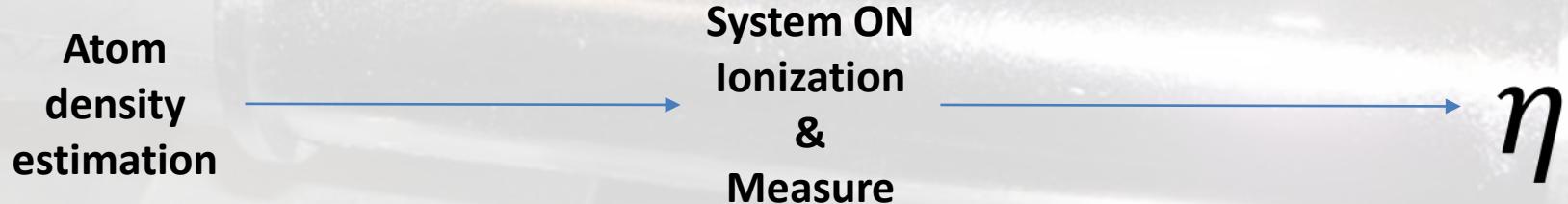
Ionization efficiency measurements:

$$\eta = \frac{\varepsilon \text{ (total charge)}}{\rho \text{ (total atom)}}$$

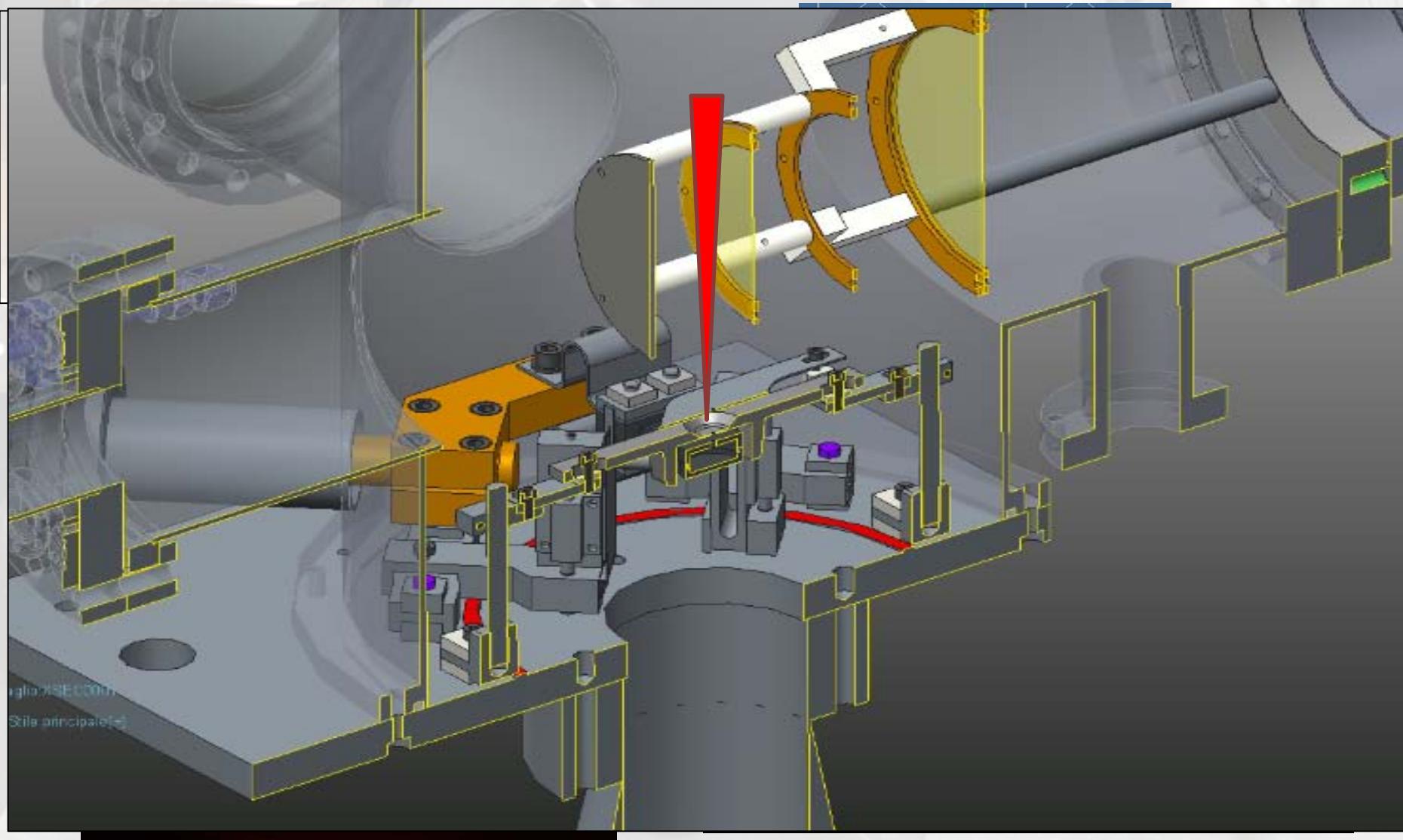
Usual method (integrated charge):



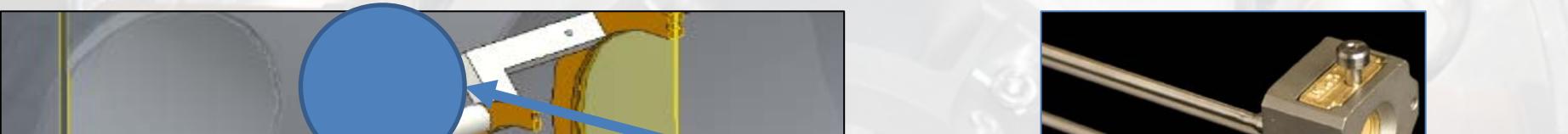
Proposed method (shot measure):



Atom density estimation



Atom density estimation => measurement check

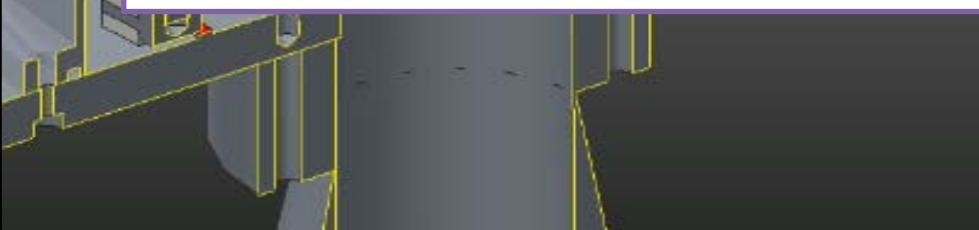


Work in progress...

- 1 PhD Thesis
- Several Master thesis
- Mechanical workshop technician

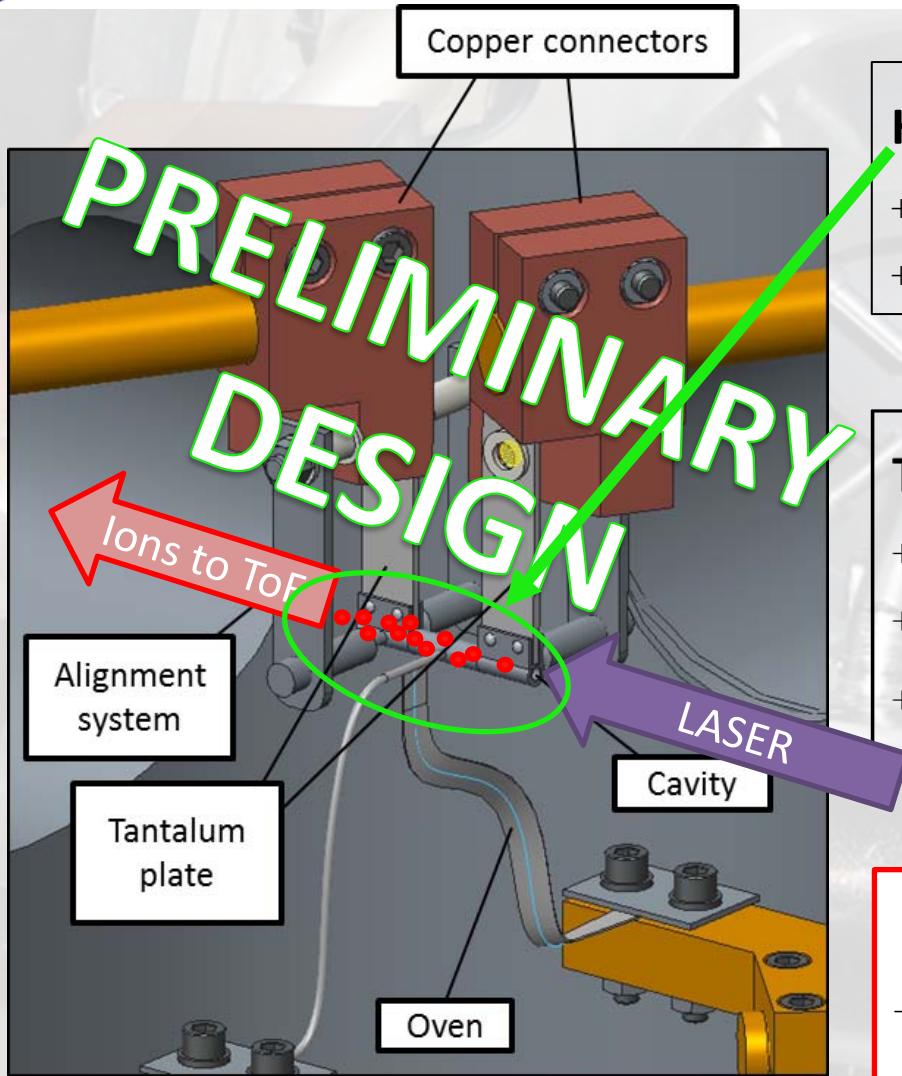
Estimated preliminary measurement in ToF chamber => 1 year

...looking ahead to the next step...



Thickness and rate resolution/measurement ¹	$\pm 0.037 \text{ \AA}$
Measurement interval	0.10 s

ToF Upgrade 2=> Laser FE



Hot Cavity Structure :

- + Reproducing online condition
- + Introducing background noise due to surface ionization



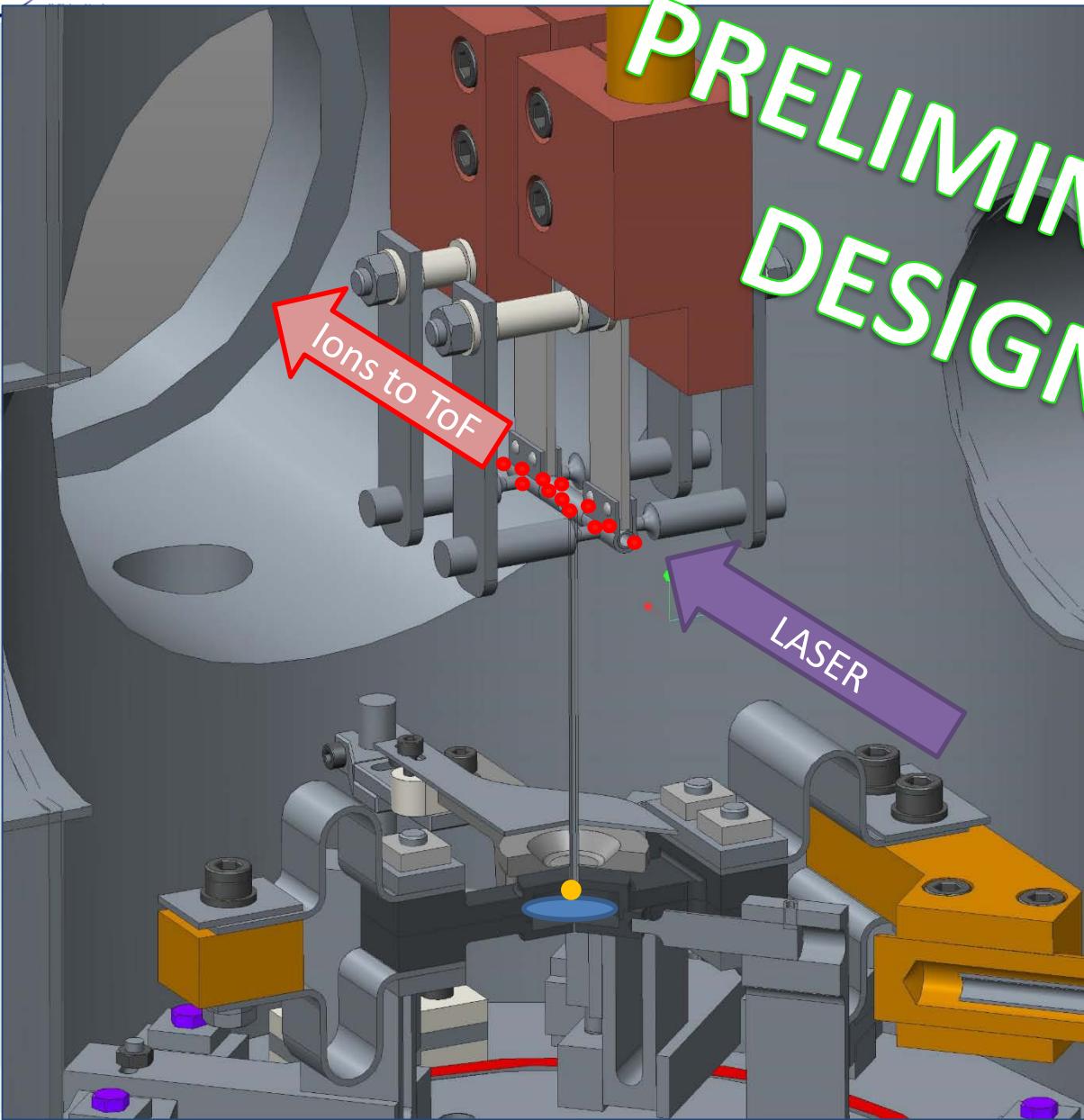
ToF System:

- + Compact system (lab space saving)
- + Simple data interpretation (just an Oscilloscope)
- + Isotopic mass separation ($\frac{m}{\Delta m} = 250$)



LASER FRONT END SYSTEM:

- + Compact system
- + Efficiency measurement capability + mass separation



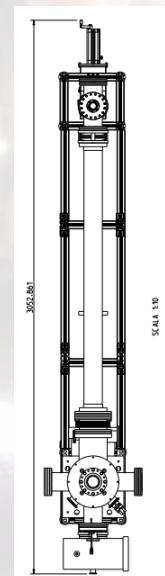
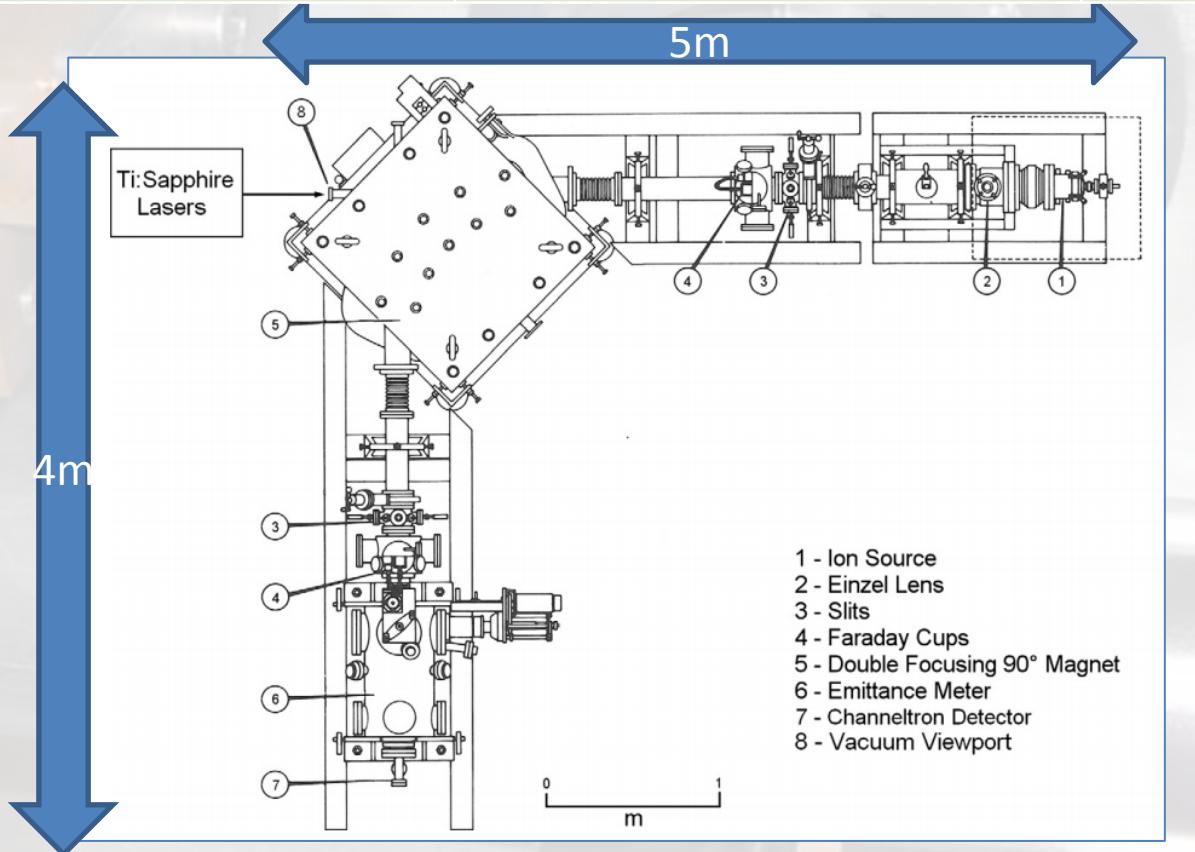
PRELIMINARY DESIGN

Best of both world:

- + Knudsen cell system
- + Controlled evaporation amount
- + Efficiency measurement capability
- + Mass separation
- + Hot cavity system
- + Laser ionization

SPES Laser Front End

	Classic	LFE
Size		✓
Cost		✓
Mass Resolution	✓ 1/1000	1/250



Y.Liu NIMB - [Volume 269, Issue 23](#), 1 December 2011, Pages 2771–2780 - Time profiles of ions produced in a hot-cavity resonant ionization laser ion source

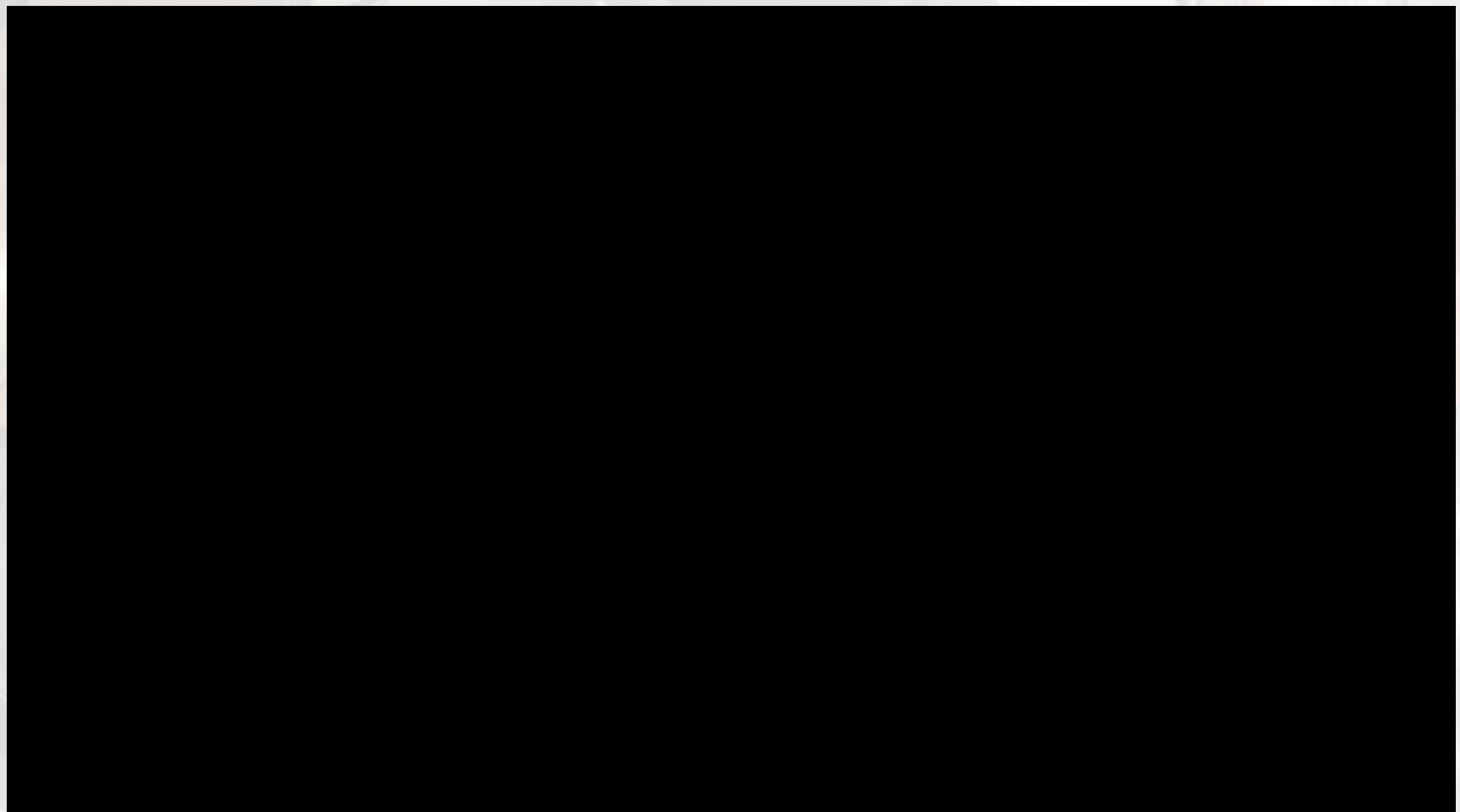
Conclusion: thanks to the team!

Few results without them...



D.Scarpa

The agv trip



Deposit