SPES Project

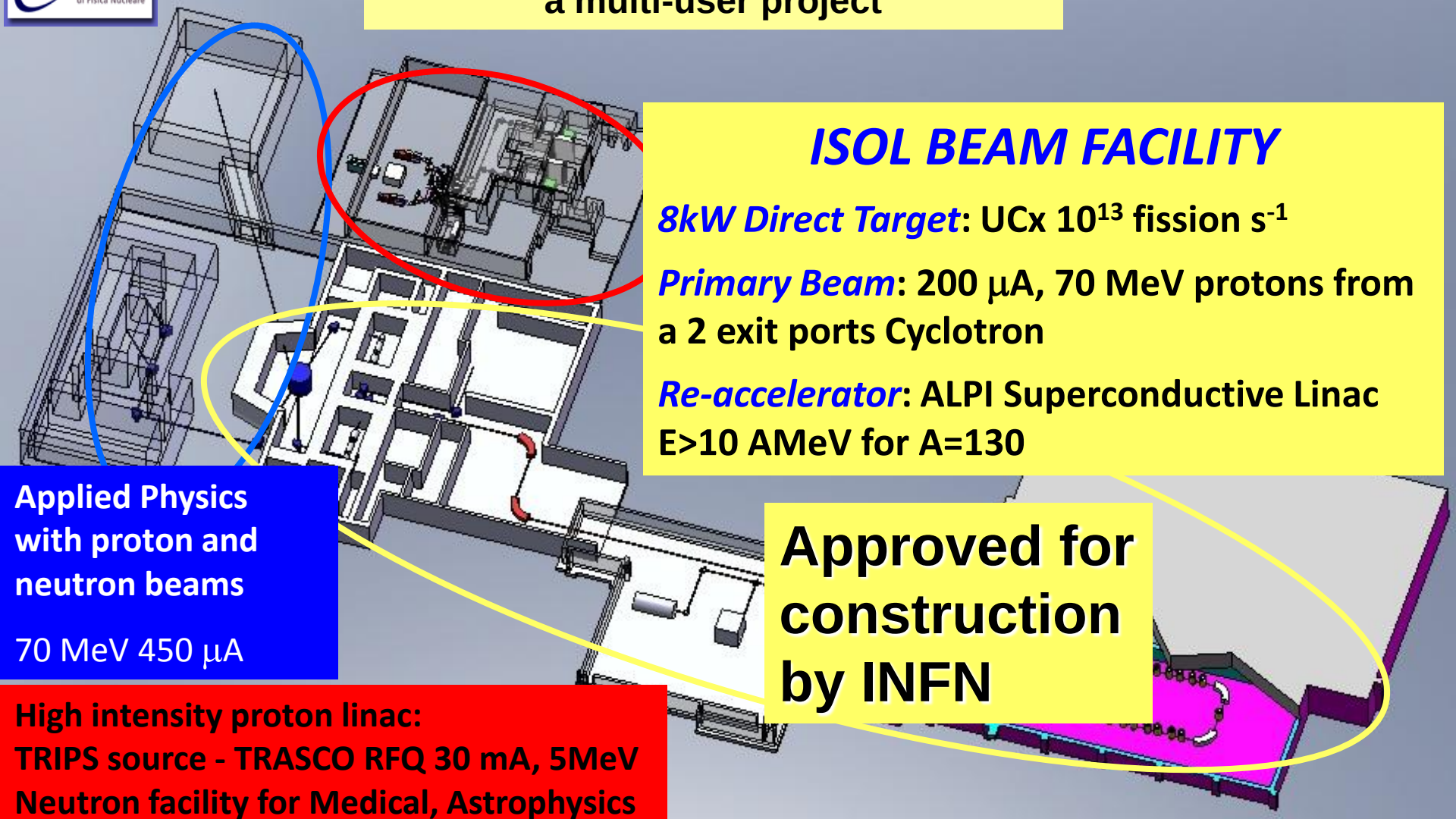
Selective Production of Exotic Species

Gianfranco Prete LNL-INFN
On behalf of the SPES Collaboration

eurorib'10 6-11 June 2010 Lamoura, France

The SPES Project @ LNL

a multi-user project



ISOL BEAM FACILITY

***8kW Direct Target*: UCx 10^{13} fission s^{-1}**

***Primary Beam*: 200 μA, 70 MeV protons from a 2 exit ports Cyclotron**

***Re-accelerator*: ALPI Superconductive Linac E>10 AMeV for A=130**

Applied Physics with proton and neutron beams

70 MeV 450 μA

Approved for construction by INFN

High intensity proton linac:
TRIPS source - TRASCO RFQ 30 mA, 5MeV
Neutron facility for Medical, Astrophysics and Material science.
Neutron source up to 10^{14} n s^{-1}
Thermal neutrons: 10^{9} n s^{-1} cm^{-2}

SPES ISOL facility at LNL

SPES ISOL facility

Proton induced fission on UCx

10^{13} fission/s

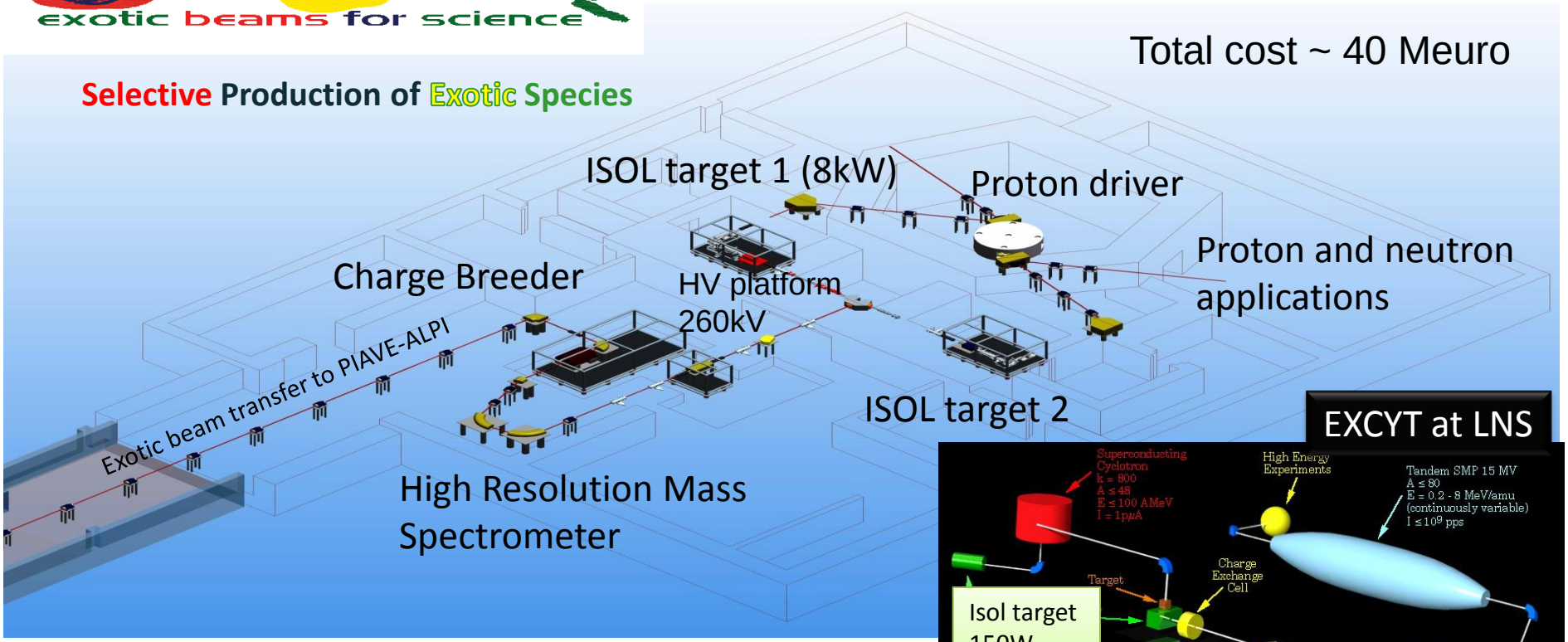
8 kW on direct target

A second generation ISOL facility for neutron-rich ion beams and an interdisciplinary research center

SPES exotic beams for science

Total cost ~ 40 Meuro

Selective Production of Exotic Species



EXCYT at LNS

8Li, 11C, 21Na, 25Al, 27Si

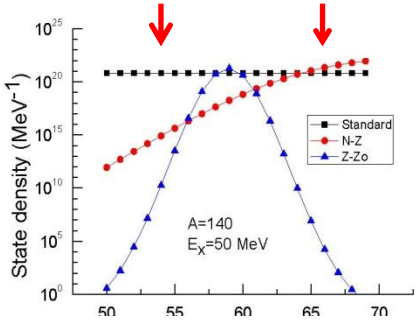
Neutron Rich Isotopes A: 80-160

SPES RIB INTENSITY:

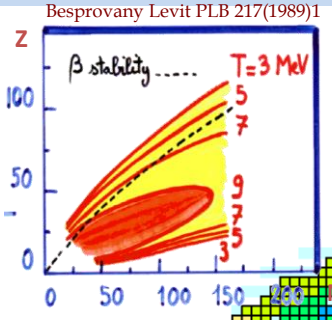
10^7-10^9 exotic ions/s 10-15 MeV/amu

on the experimental target

Understand nuclei out of the stability valley



Isospin & level density



Limiting T

Evolution of shell nuclear structure

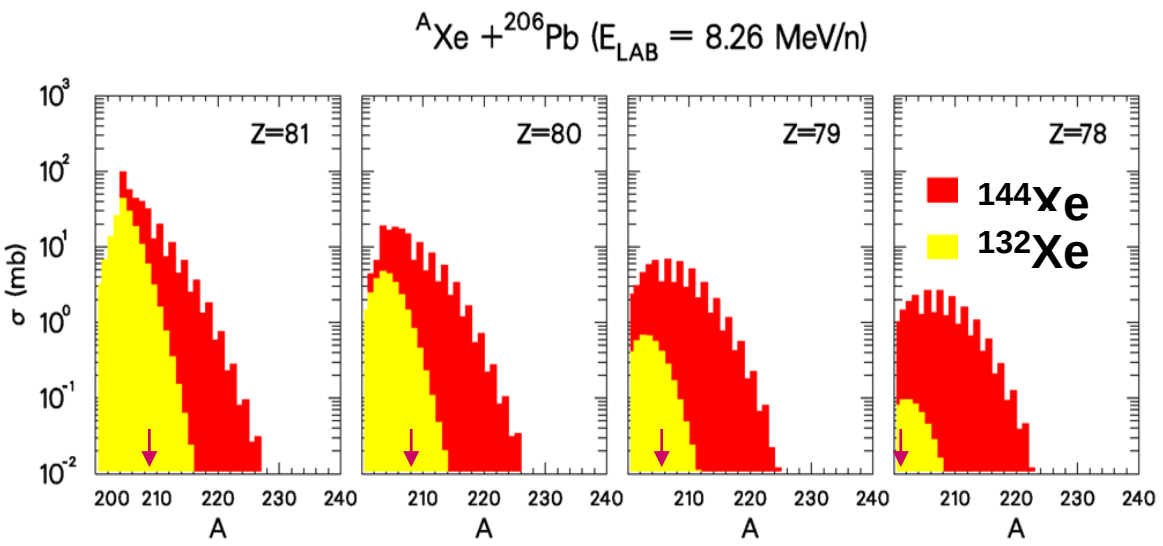
Pigmy resonance

Halo nuclei

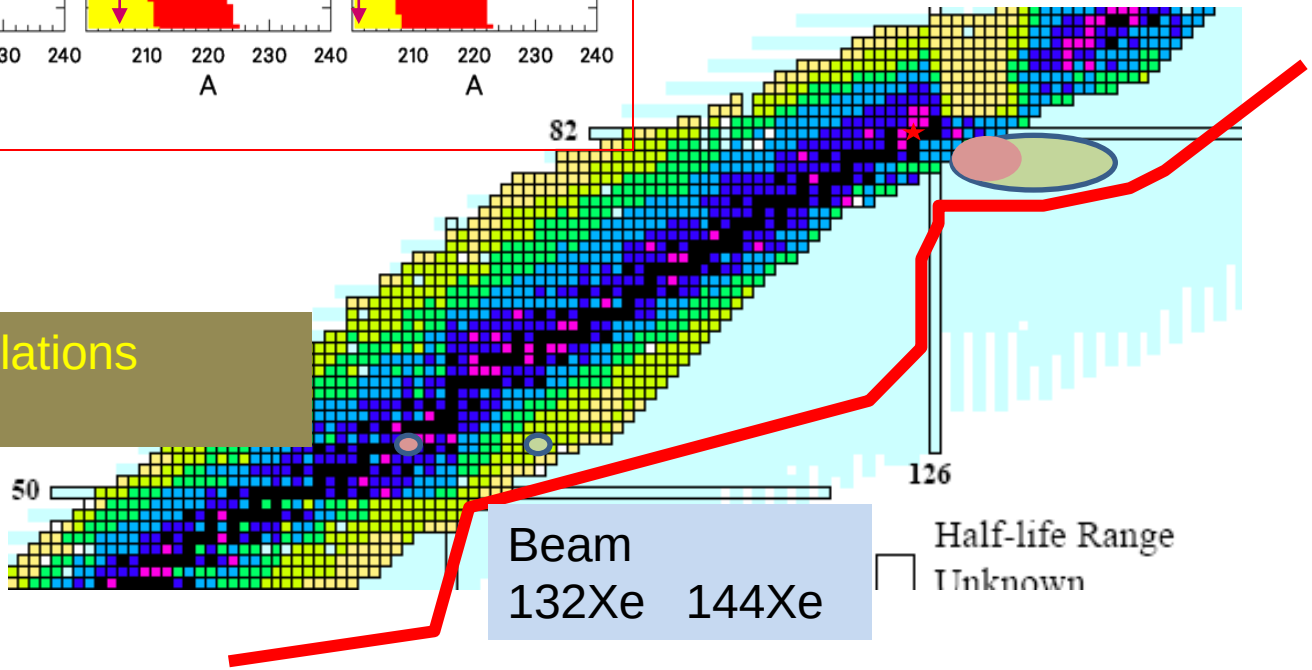
Borromean nuclei

11Li

neutron-rich radioactive beams as a tool to investigate nuclei far from stability



Target 206 Pb



Coupled channel calculations (Grazing). G. Pollarolo

Beam
132Xe 144Xe

Laboratori Nazionali di Legnaro: site for SPES facility

S P E S

(Selective production of exotic species)
ISOL facility & applied physics

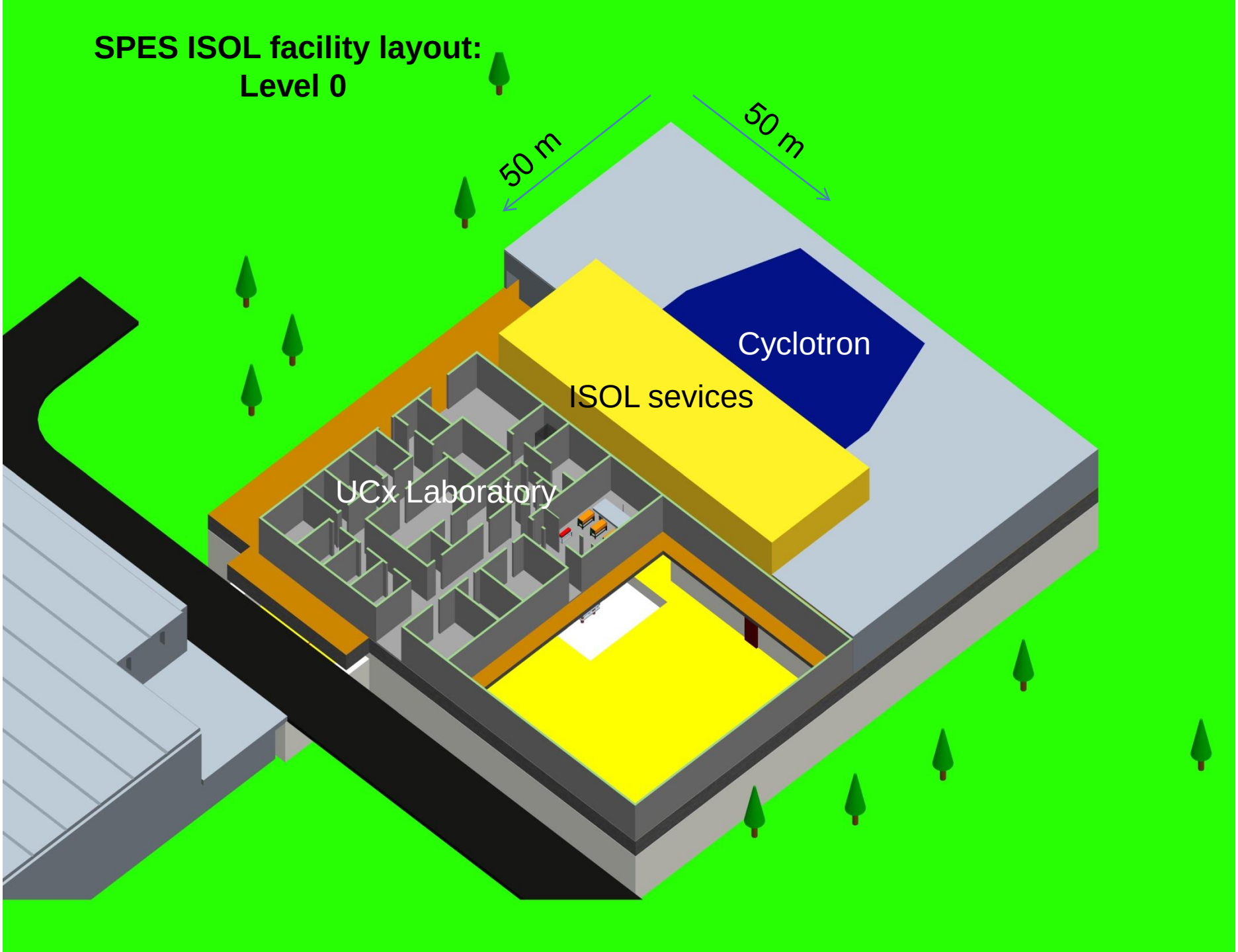
PIAVE HI Injector

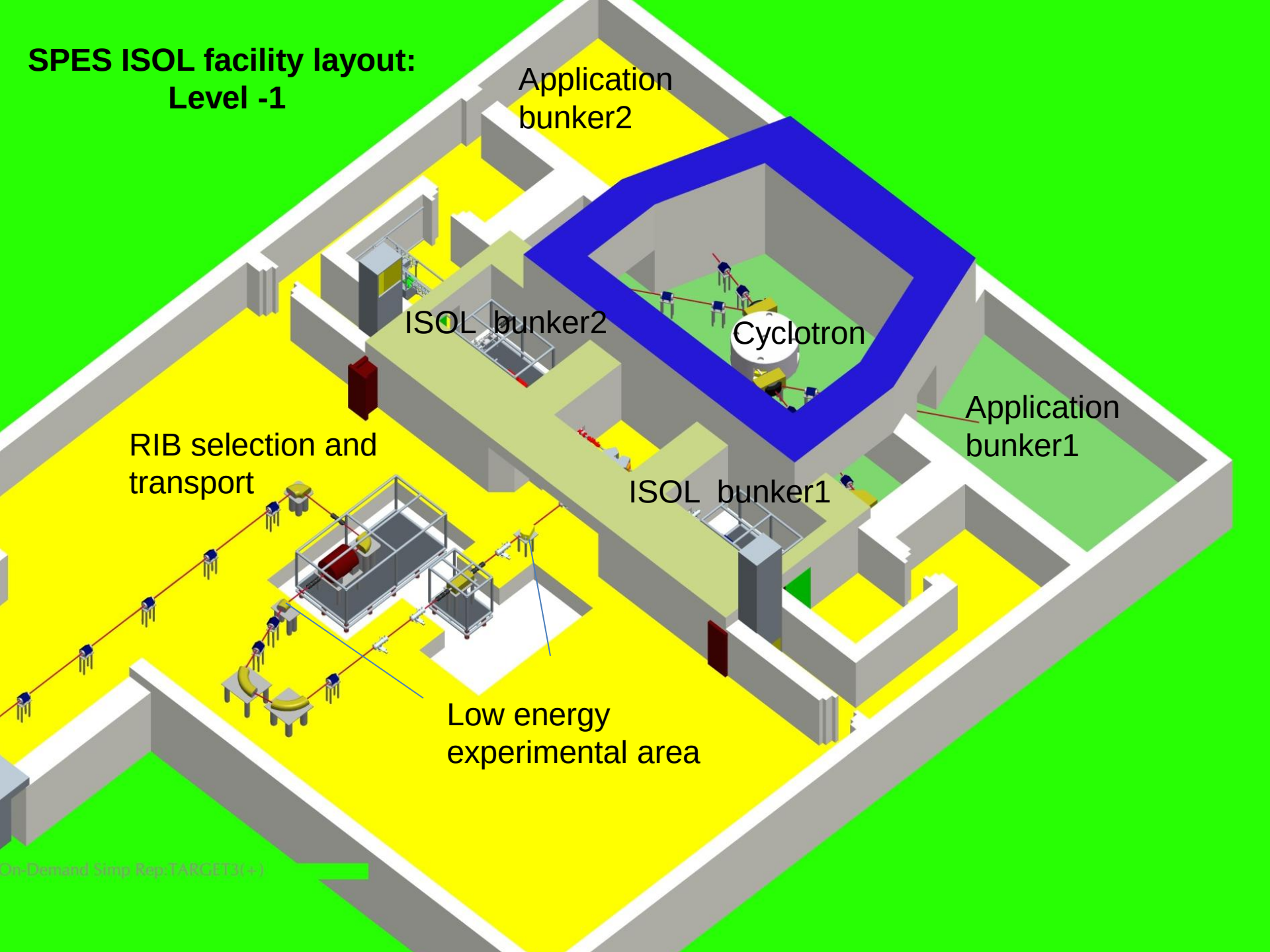
AN2000 2 MV

ALPI Linac 40 MVeq

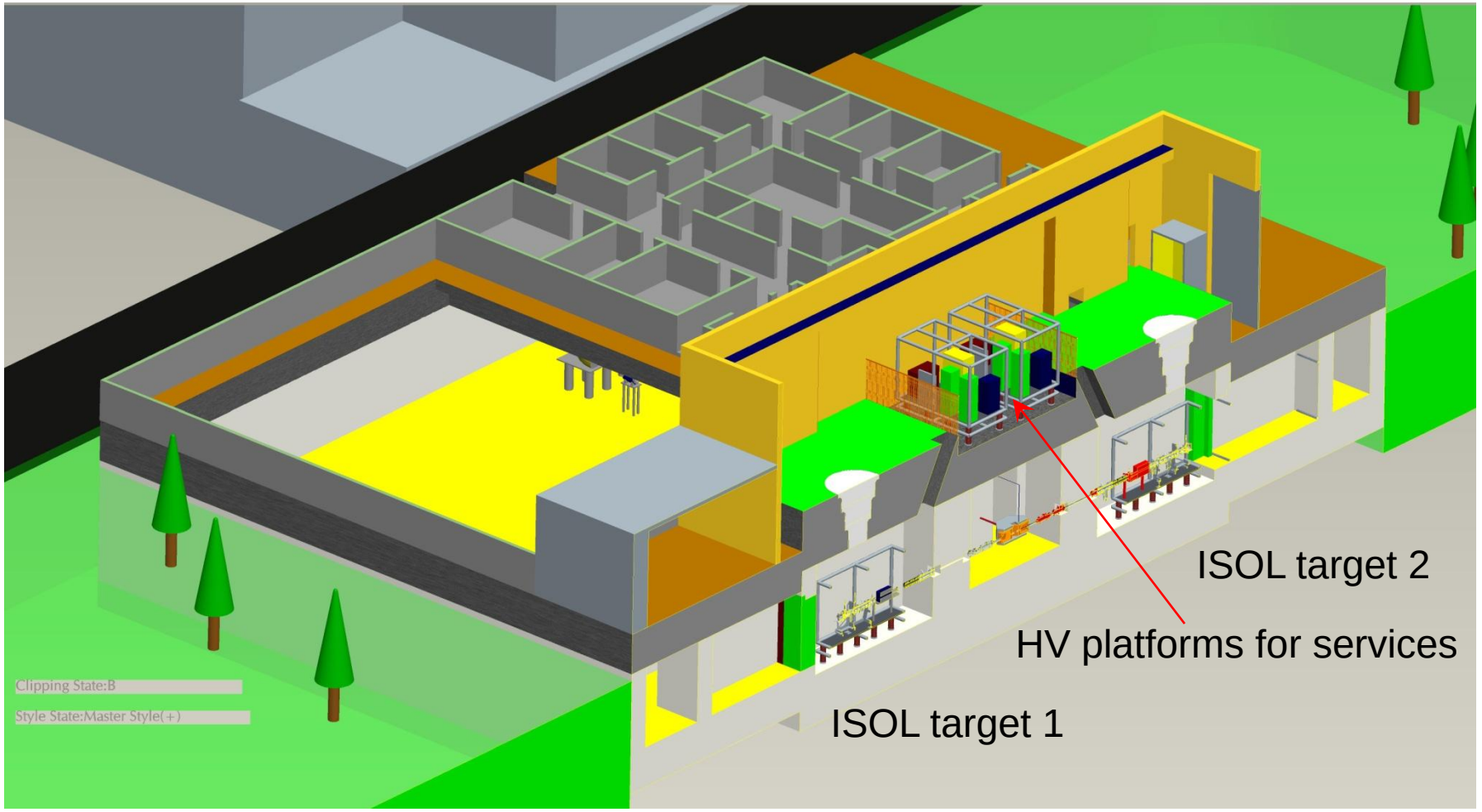
CN 7 MV

Tandem XTU 15 MV

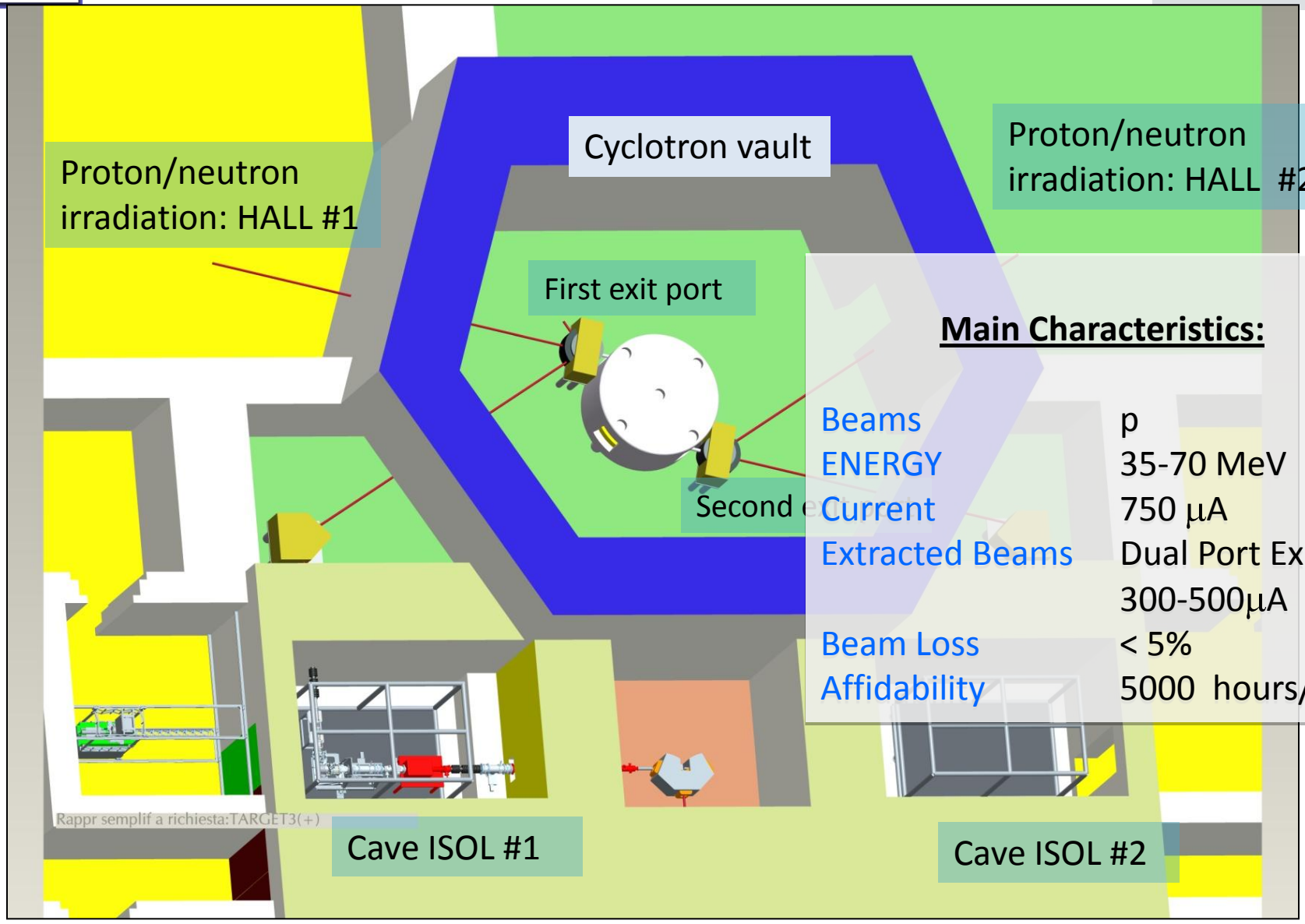

SPES ISOL facility layout:
Level 0
50 m
50 m
Cyclotron
ISOL sevices
UCx Laboratory


SPES ISOL facility layout:
Level -1
Application
bunker2
ISOL bunker2
Cyclotron
Application
bunker1
RIB selection and
transport
ISOL bunker1
Low energy
experimental area

SPES ISOL facility layout: Target areas and services



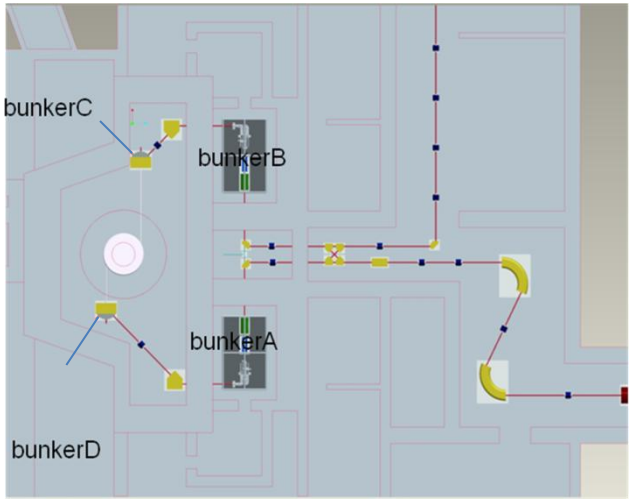
Commercial High Current Cyclotron



Main Characteristics:

Beams	p
ENERGY	35-70 MeV
Current	750 μA
Extracted Beams	Dual Port Exit
	300-500μA
Beam Loss	< 5%
Affidability	5000 hours/year

SPES CYCLOTRON load work per year



Target	secondary beam	Bunker
(UCx)	fission fragments	A - B ISOL
HfO_2, ZrO_2, CeO_2	F	A - B ISOL
B_4C	Be	A - B ISOL
SiC	Al	A - B ISOL
CeS	Cl	A - B ISOL
Li, Be, Pb, W, (UO)	neutrons	B,C,D

2 weeks per shift

Beam preparation 2 days

Beam on target 12 days

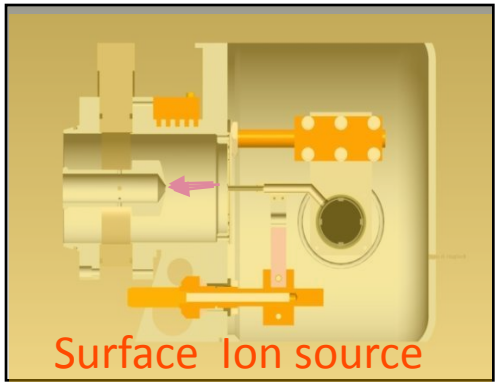
Beam on target →280 hours per shift

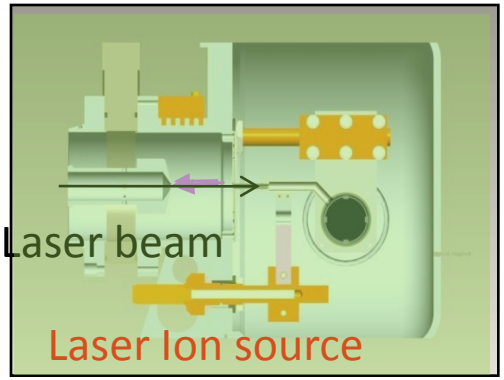
Each bunker will cool down for 14 days after target irradiation.

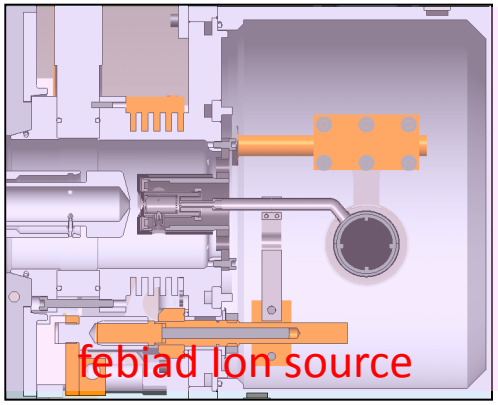
Expected Beam on target:
10600 hours per year

	Proton beam	Numers of shift	Beam on target: Total 10600 hours
Bunker A ISOL	300μA 40MeV	10	2800
Bunker B	500 μA 70MeV	9	2500
Bunker C	500 μA 70MeV	10	2800
Bunker D	500 μA 70MeV	9	2500
Maintanance		7	7x14x24= 2350
Cyclotron Operation		19	19x12x24= 5462 esperiment 19X2x24= 912 beam preparation

ION sources







Elements with bad volatility (NOT EXTRACTED)

Surface Ionization Method

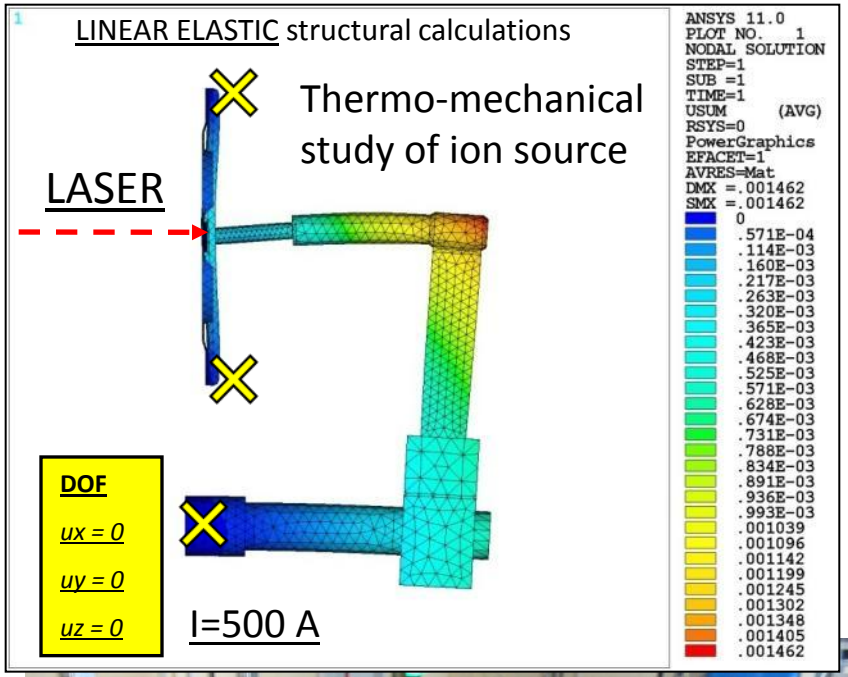
Photo Ionization Method

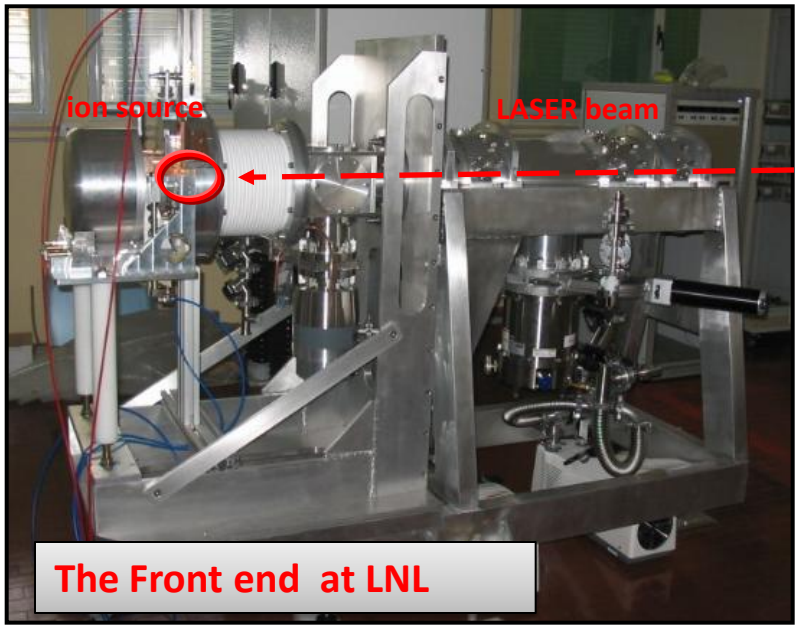
Plasma Ionization Method

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110	111	112						

Main fission 238U fragments

Ion Source:
surface ionization & laser photo-ionization





(See poster D.SCARPA)

The SPES Laser Lab

Actual instrumentation

LNL

LPX200 Lambda Physik excimer laser
Up to 200 mJ per pulse
Up to 100 Hz repetition rate

R&D work on Aluminum and Tin
(see Daniele Scarpa poster)

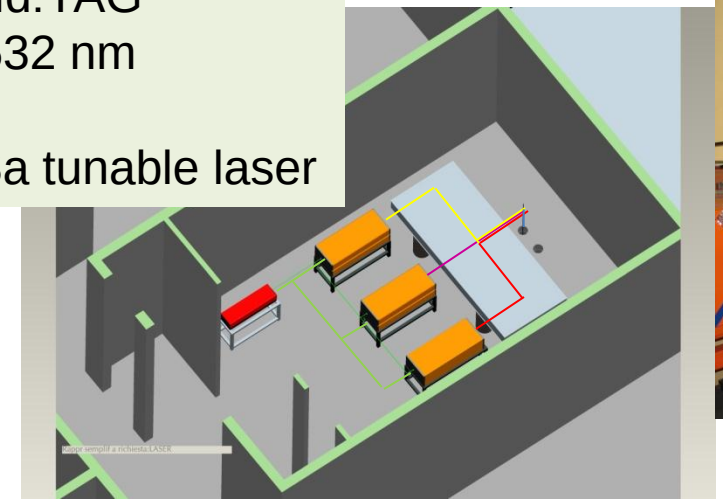
Pavia

-1 Pump laser Quanta System Nd:YAG
- 532 nm output
-10 Hz rep rate
-Up to 300 mJ per pulse

- 3 Lambda Physik dye laser
-Possibility of intracavity etalon
-Possibility of SHG

Instrumentation up-grade (new laboratory)

1) New Pum Laser Nd:YAG
10 kHz @ 532 nm
100 W
2) 3x Solid state Ti-Sa tunable laser

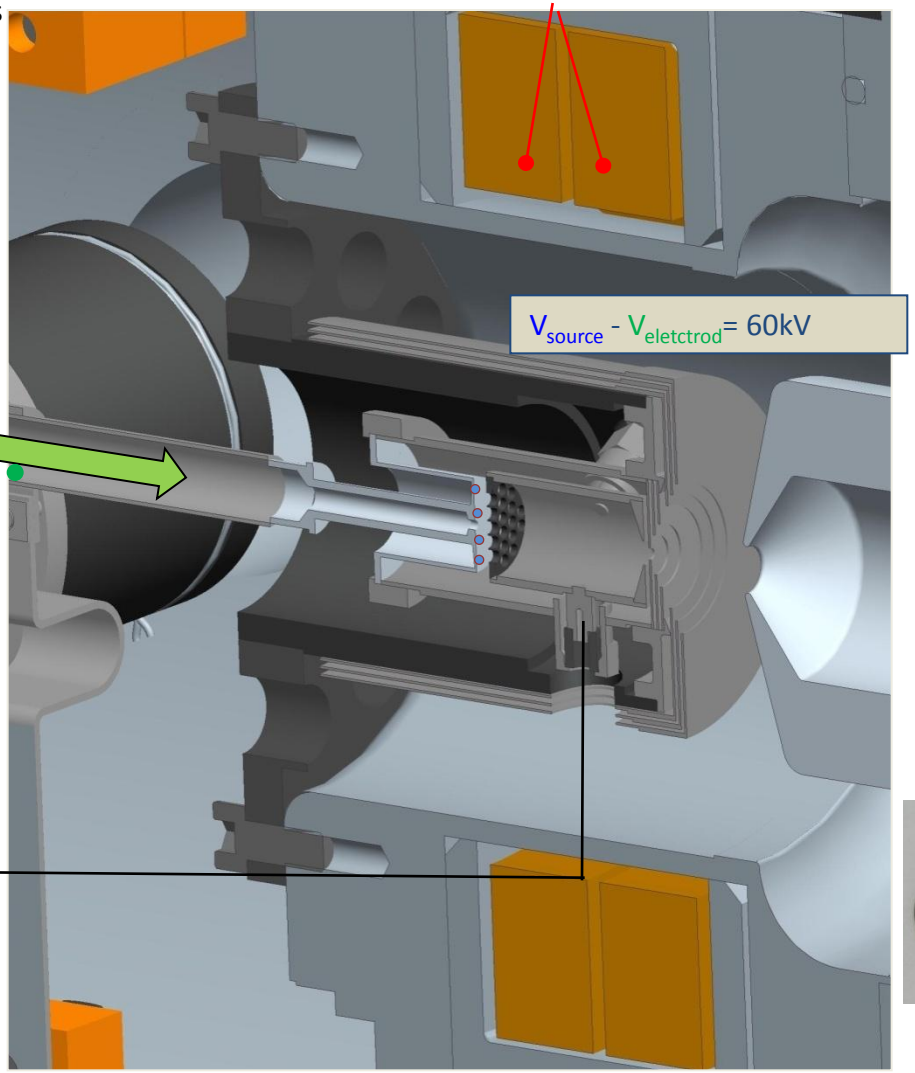


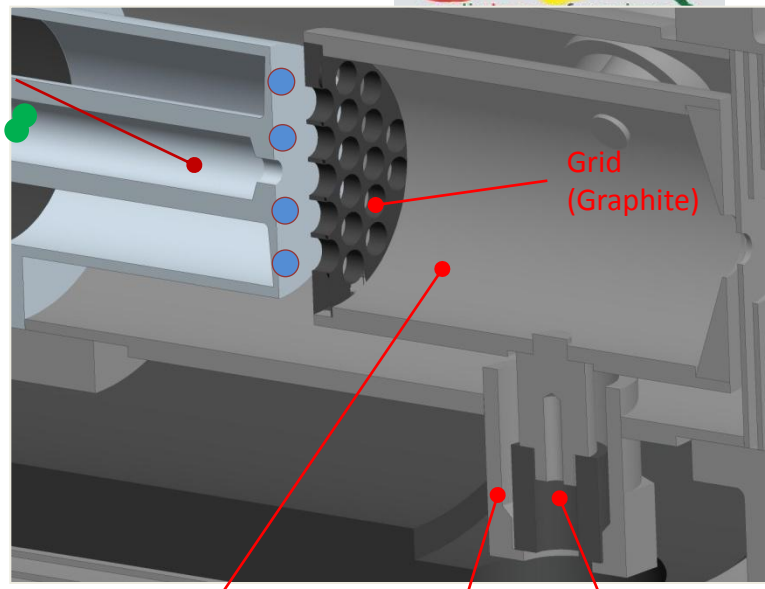
The FEBIAD ionization source

neutral atoms

electrons

Ions 1+



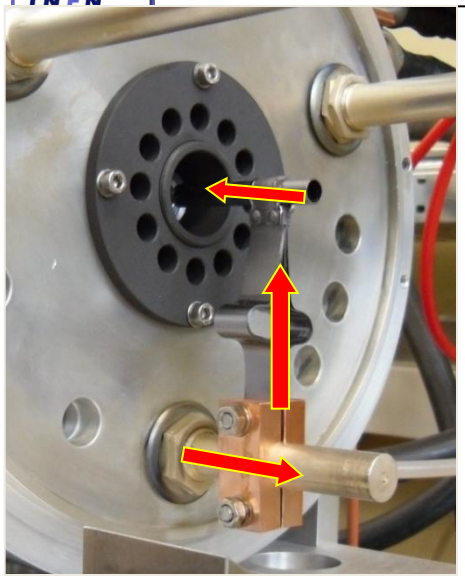


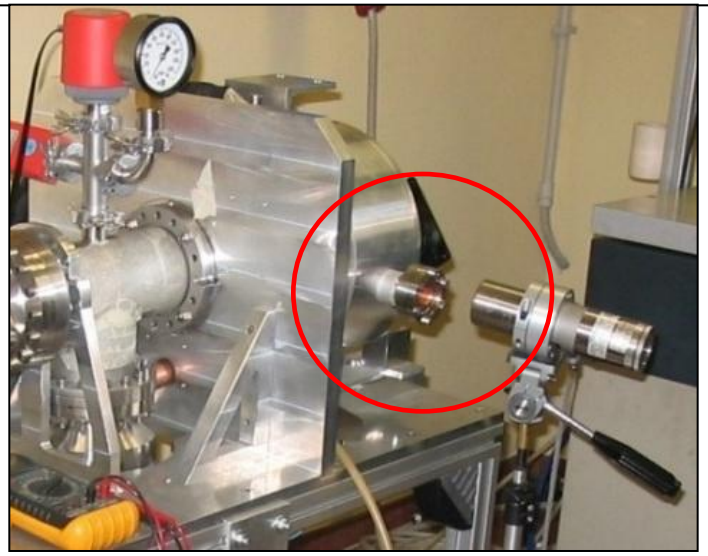
Anode

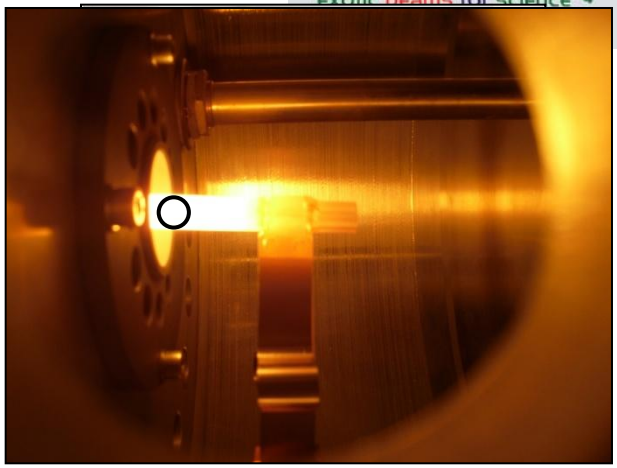
Cathode

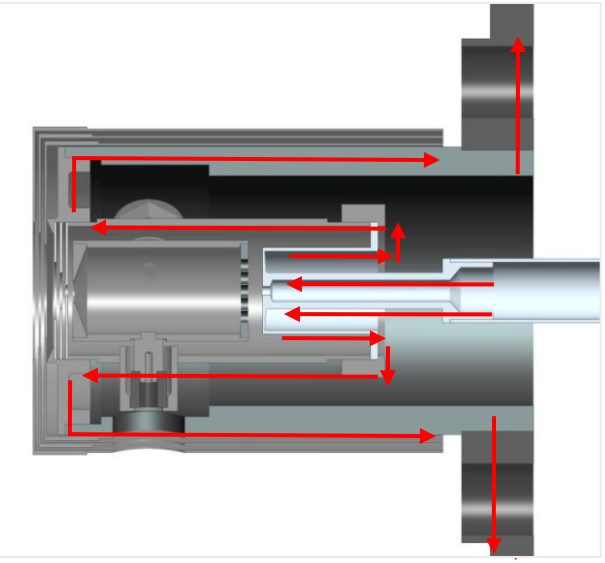
Thesi Andrea Baraldo: elettro-therml-structural study of the SPES plasma ionization source

Plasma source development

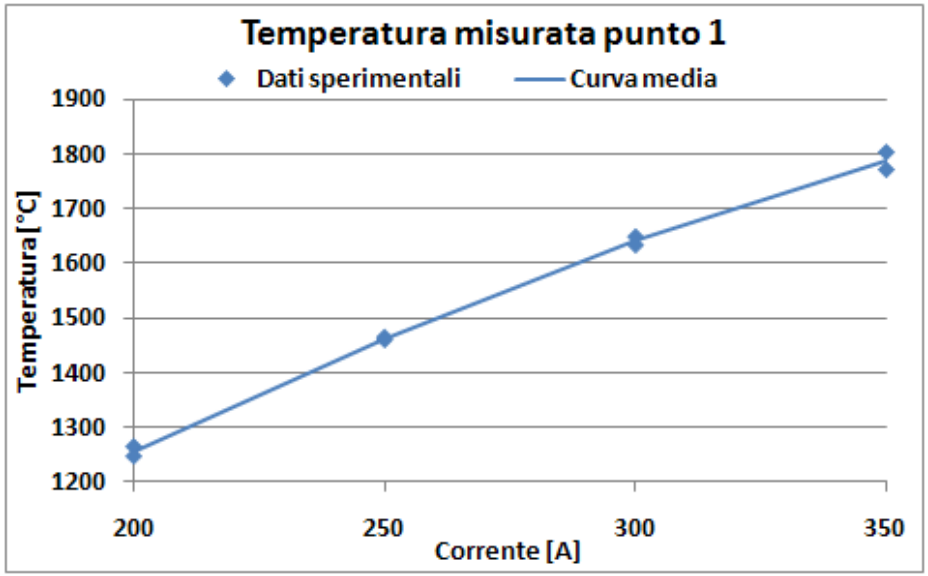






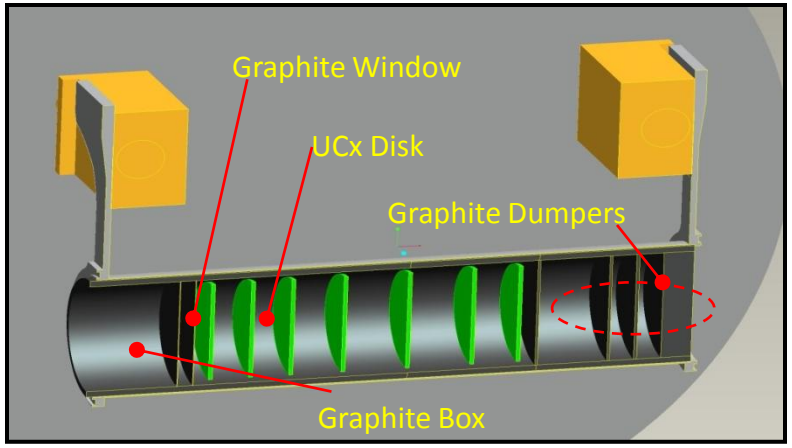


Transfer tube TEMPERATURE MEASUREMENT vs. CURRENT SUPPLIED

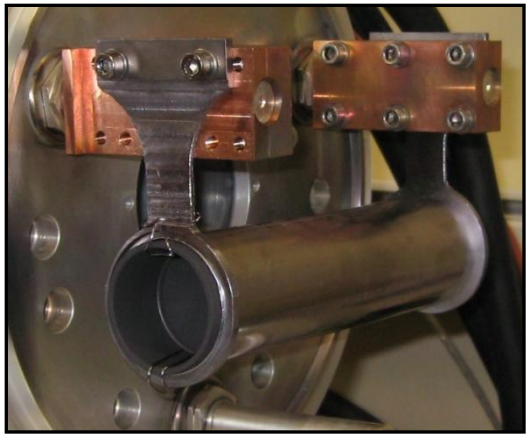


Thesi Andrea Baraldo: elettro-therml-structural study of the SPES plasma ionization source

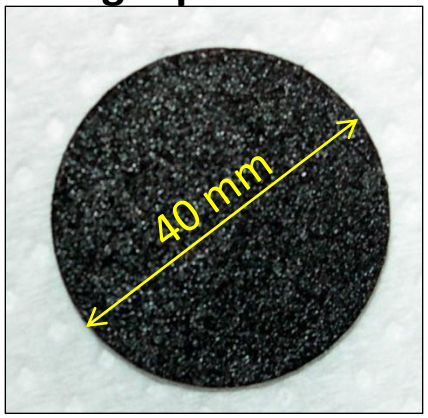
The SPES target prototype

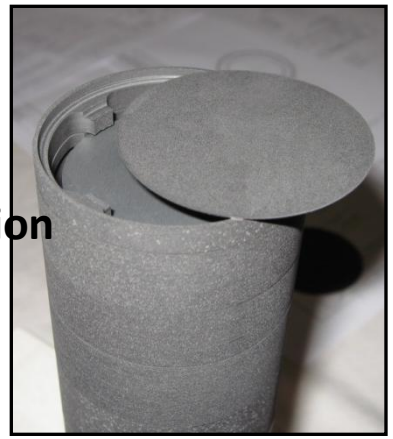


(See poster A.ANDRIGHETTO)

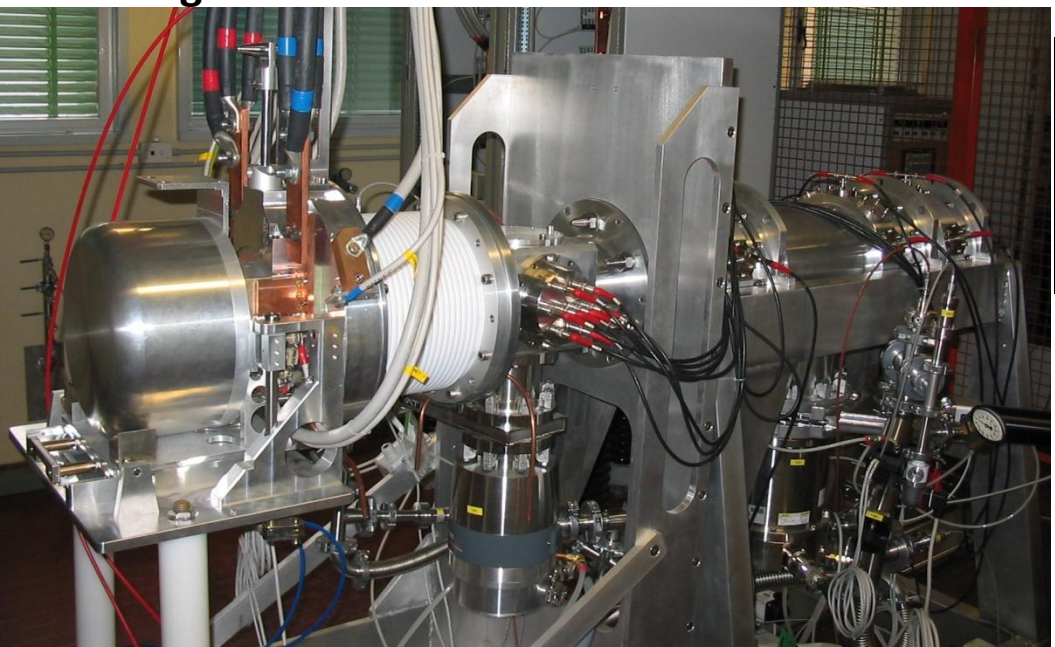


UCx target procuction

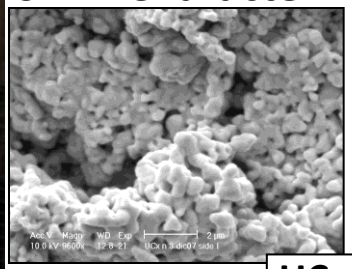




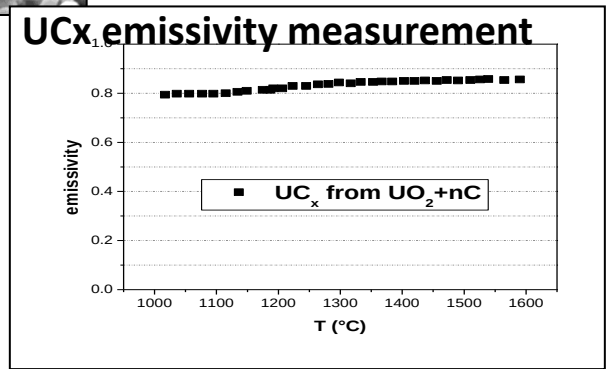
SPES target-ion-source Front End



SEM Characterization



UCx emissivity measurement



Production and Characteriztion of UC_x made with Carbon Nano Tubes (MWCNTs)

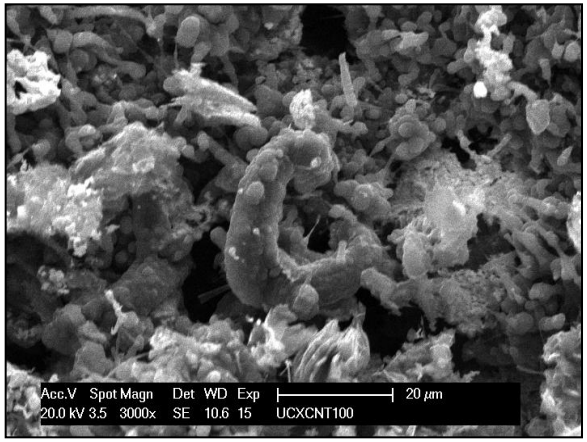
Multi-walled Carbon Nanotube

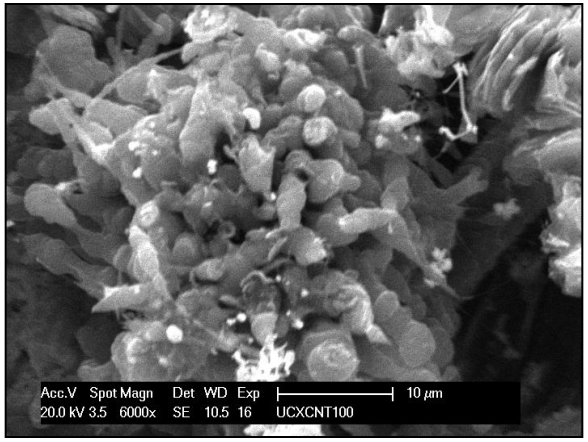
$$UO_2+6C \rightarrow UC_2+2C+2CO$$

where C is given by MWCNTs

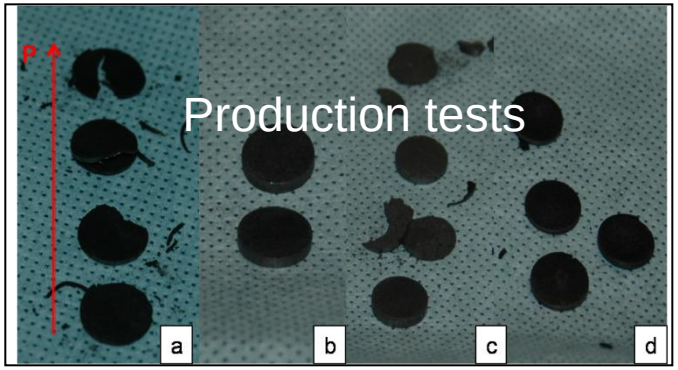
Development and characterization at LNL. Production at ISOLDE (2 targets)

SEM

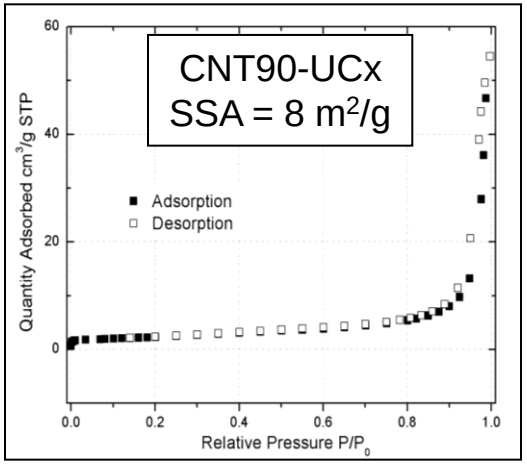


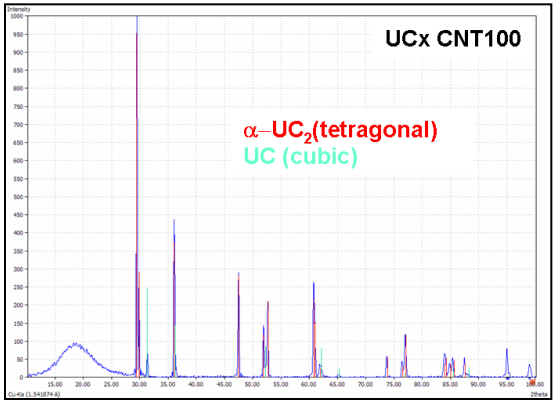


UCx MWCNTs



BET and XRD

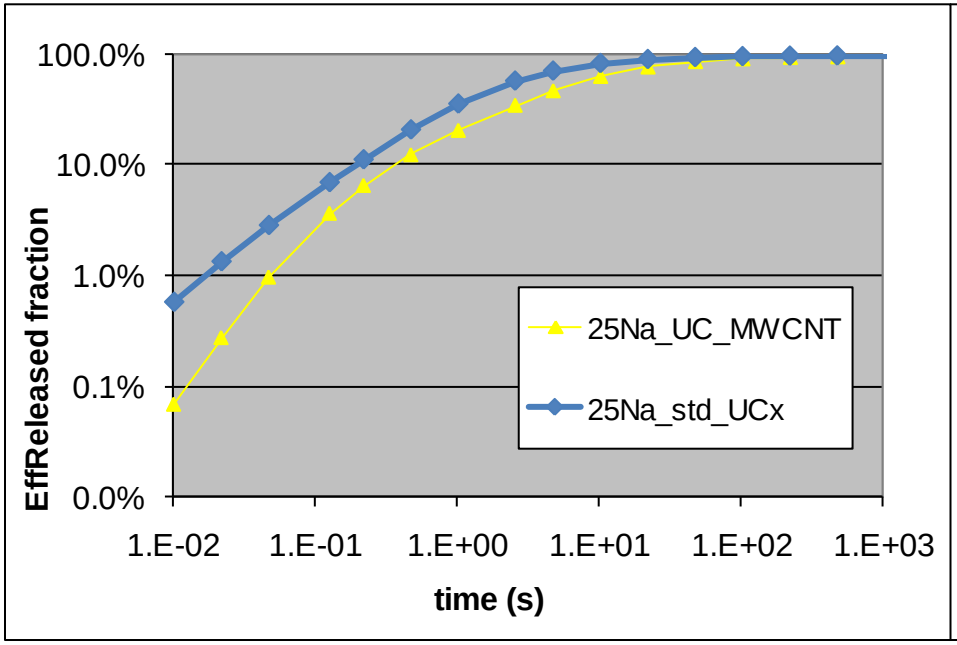


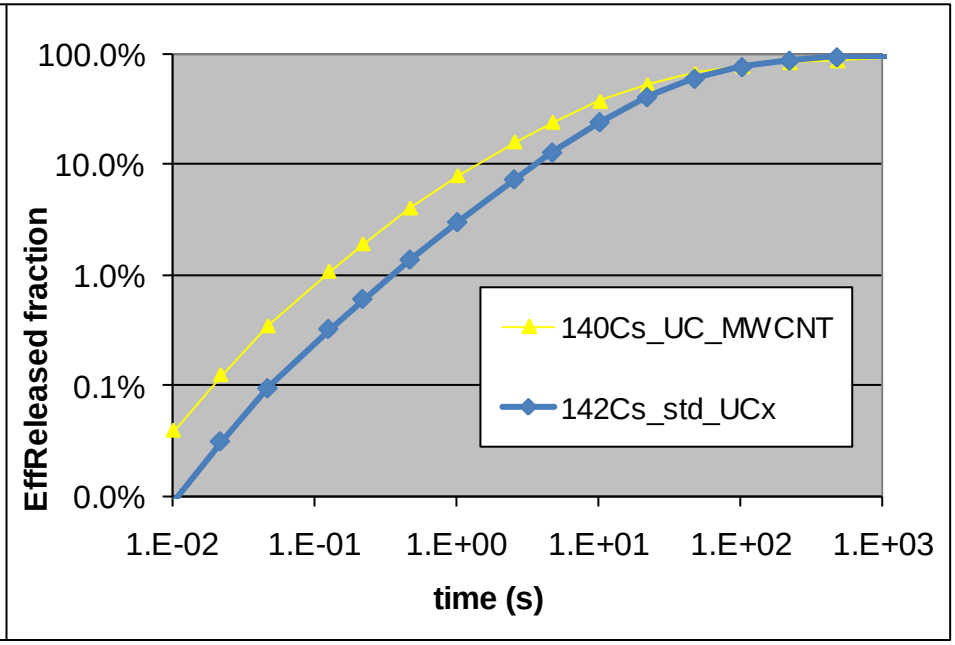


Preliminary Results on Release efficiency

ISOLDE experiment: June 2009

Comparison released fraction standard ISOLDE UC_X at 2000°C and UC-MWCNT at 1800°C





	ρ_{bulk} (g/cm^3)	^{depl}U (g)
ISOLDE Standard- UCx	3	70
ISOLDE UCx-CNTs	1.3	34

^{25}Na: $T_{1/2}$ 59 sec

^{140}Cs: $T_{1/2}$ 65 sec

^{142}Cs: $T_{1/2}$ 1.7 sec

Data Collected and Analyzed by dr T. Storà and ISOLDE group

Recent test of SPES UC_2 targets

(test performed on March '10 at HRIBF)

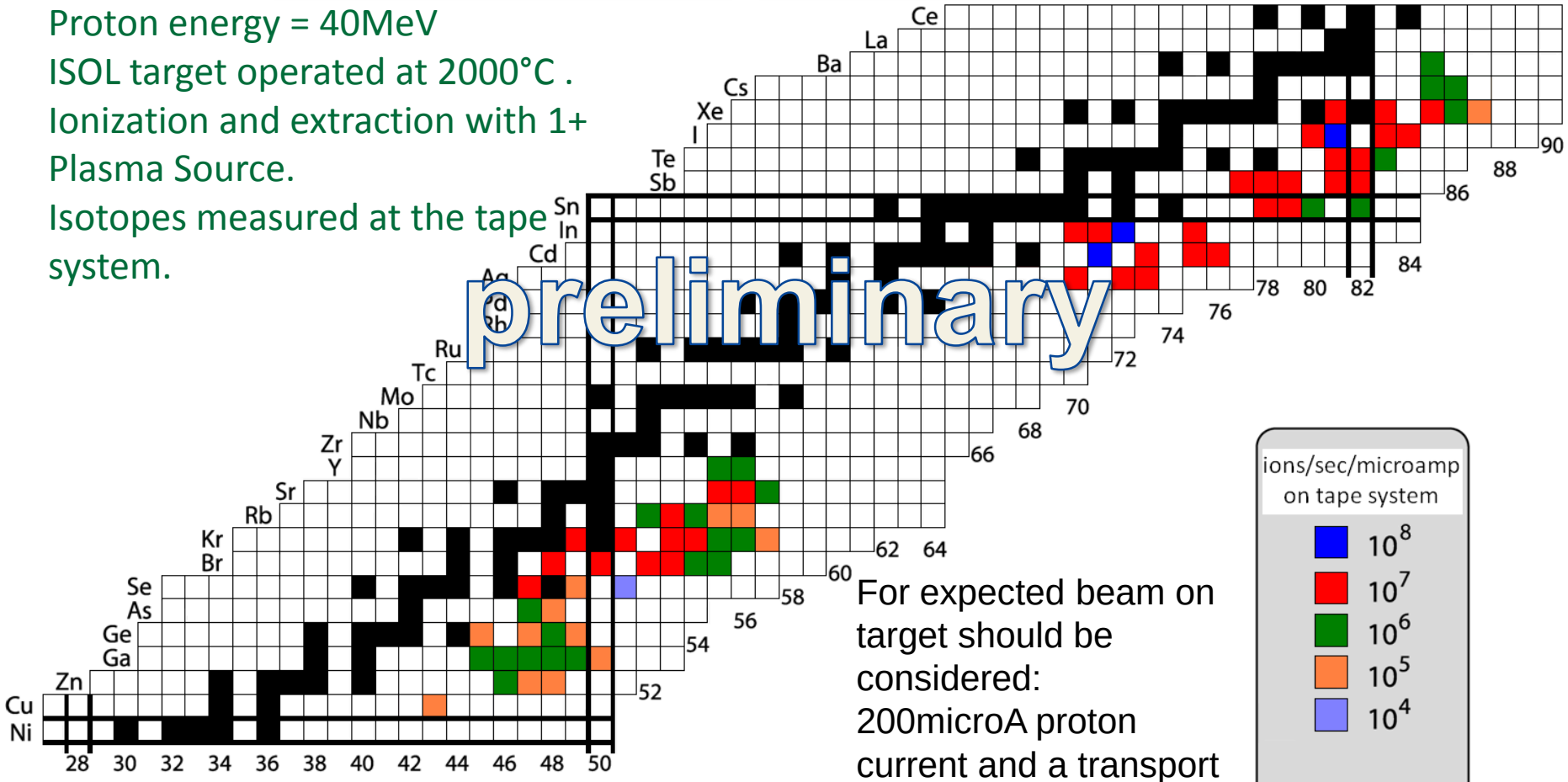
- Seven UC_2 samples prepared by the SPES Target Group
- Densities in the range of 4.2 g/cm^3
- Used the SPES design for target geometry
- Heated to 2000° C for about two weeks without any out-gassing or obvious change in structure (samples observed after the on-line test)

SPES Target
Preliminary data of HRIBF experiment

Experiment March 2010

Evaluated production rate for 1 microA proton current

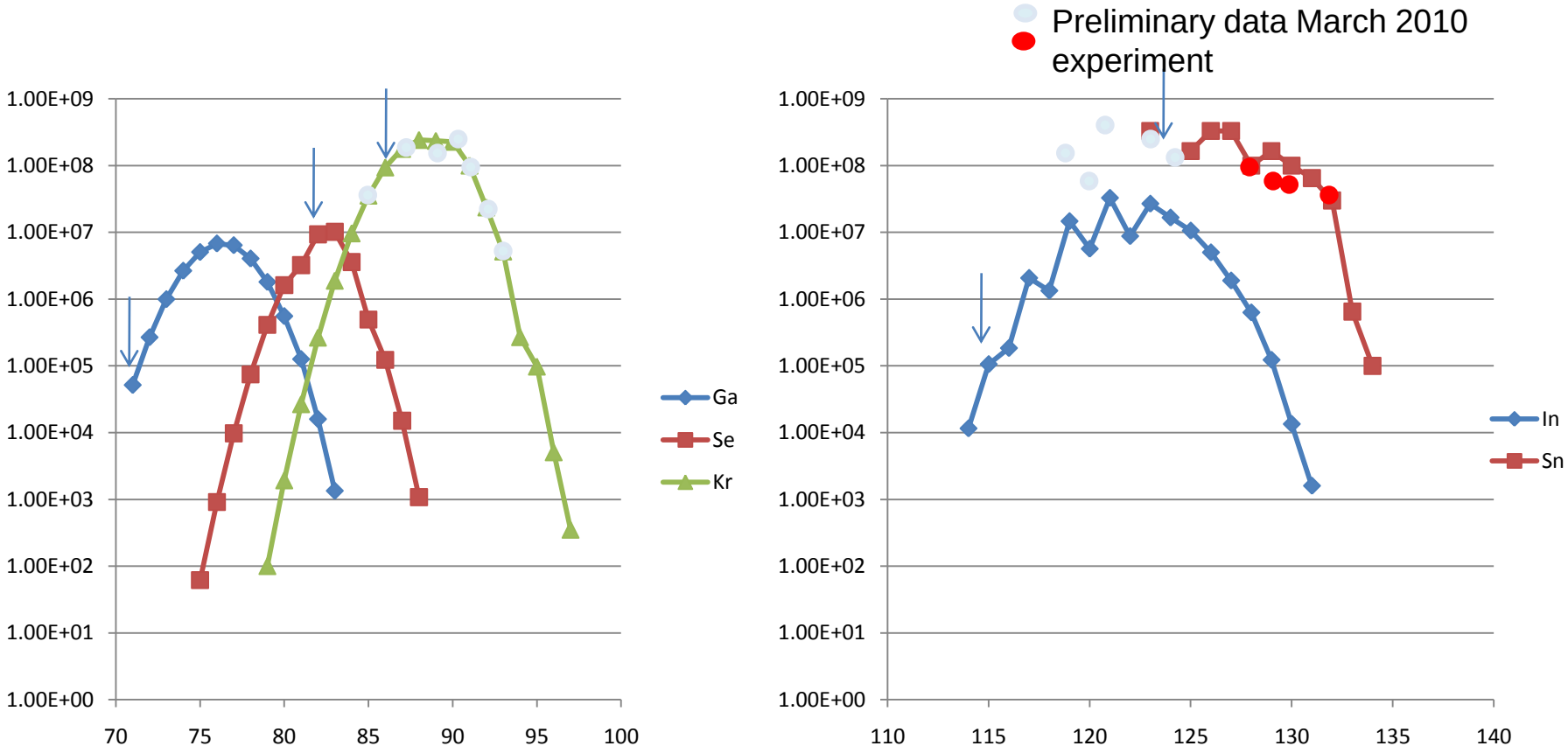
Proton energy = 40MeV
ISOL target operated at 2000°C .
Ionization and extraction with 1+ Plasma Source.
Isotopes measured at the tape system.



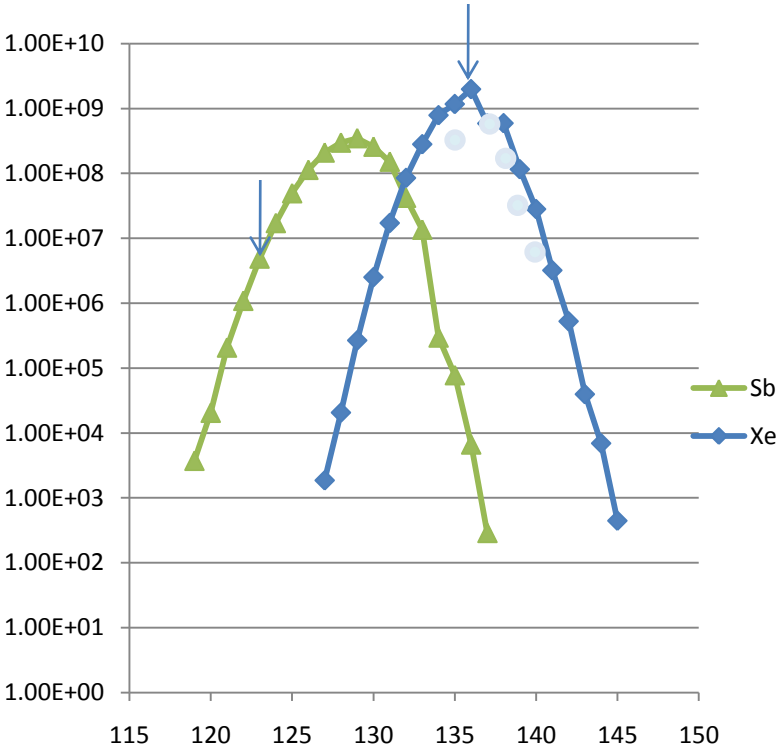
For expected beam on target should be considered:
200microA proton current and a transport efficiency of 2-5%

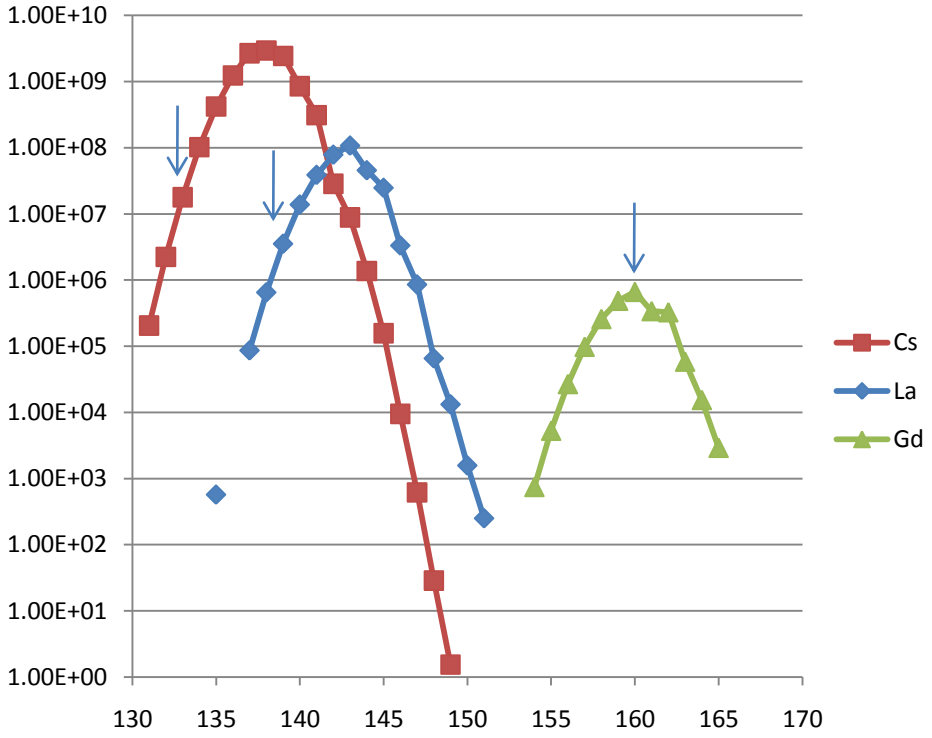
Ing. S. Corradetti PHD

SPES reaccelereted RIB's scaled from HRIBF



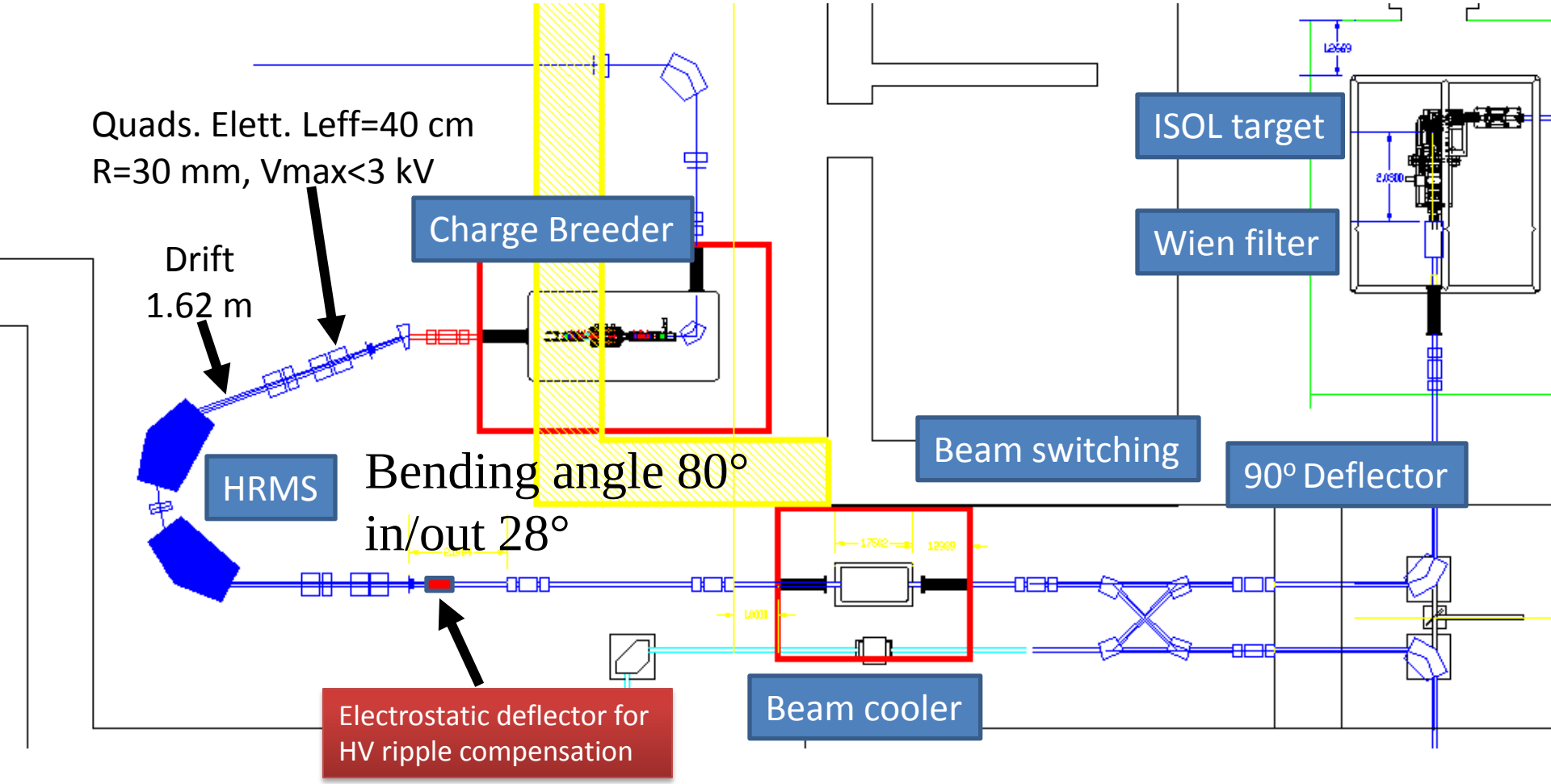
SPES reaccelereted RIB's scaled from HRIBF



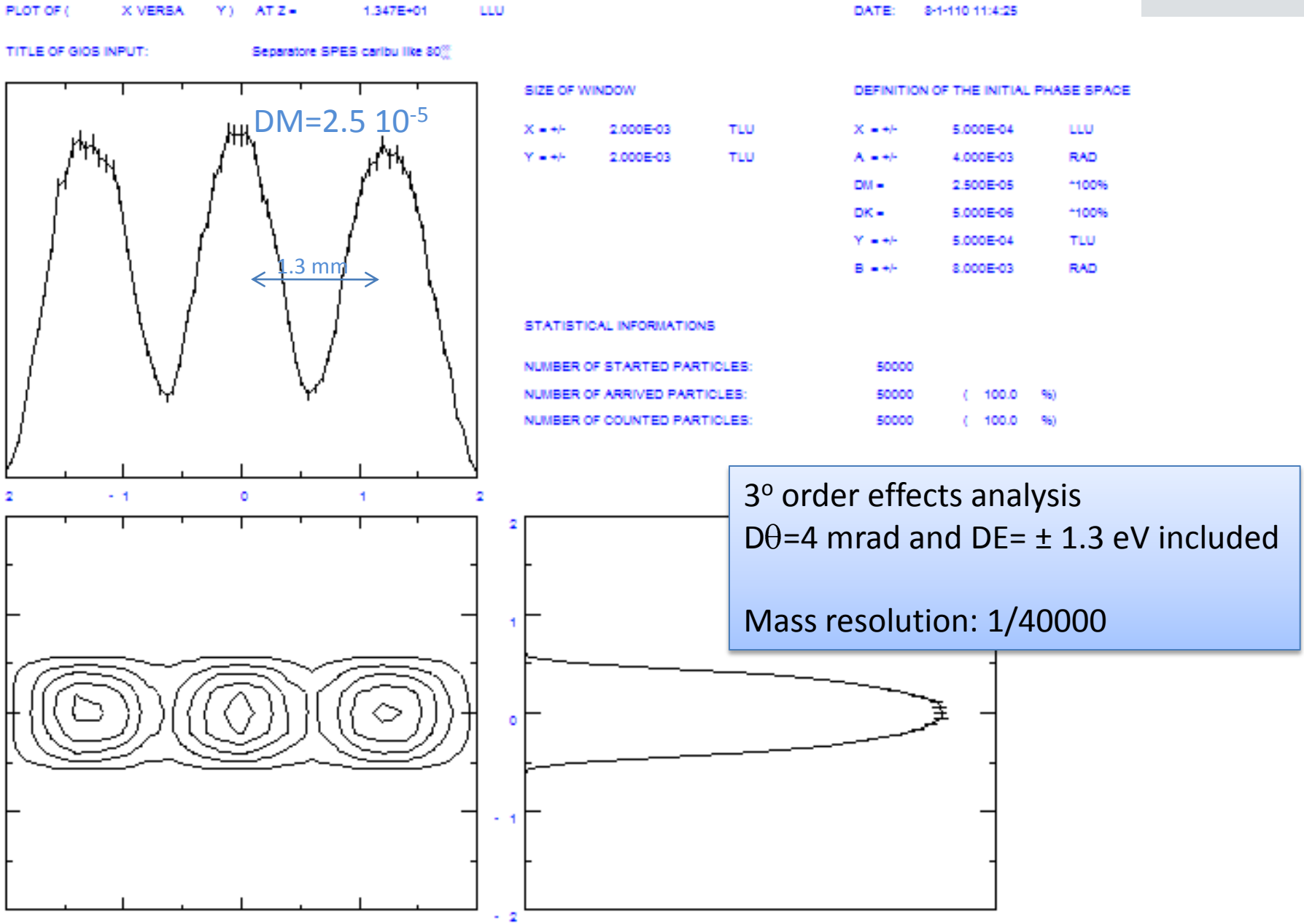


The SPES beam selection

Beam transport & Spectrometer



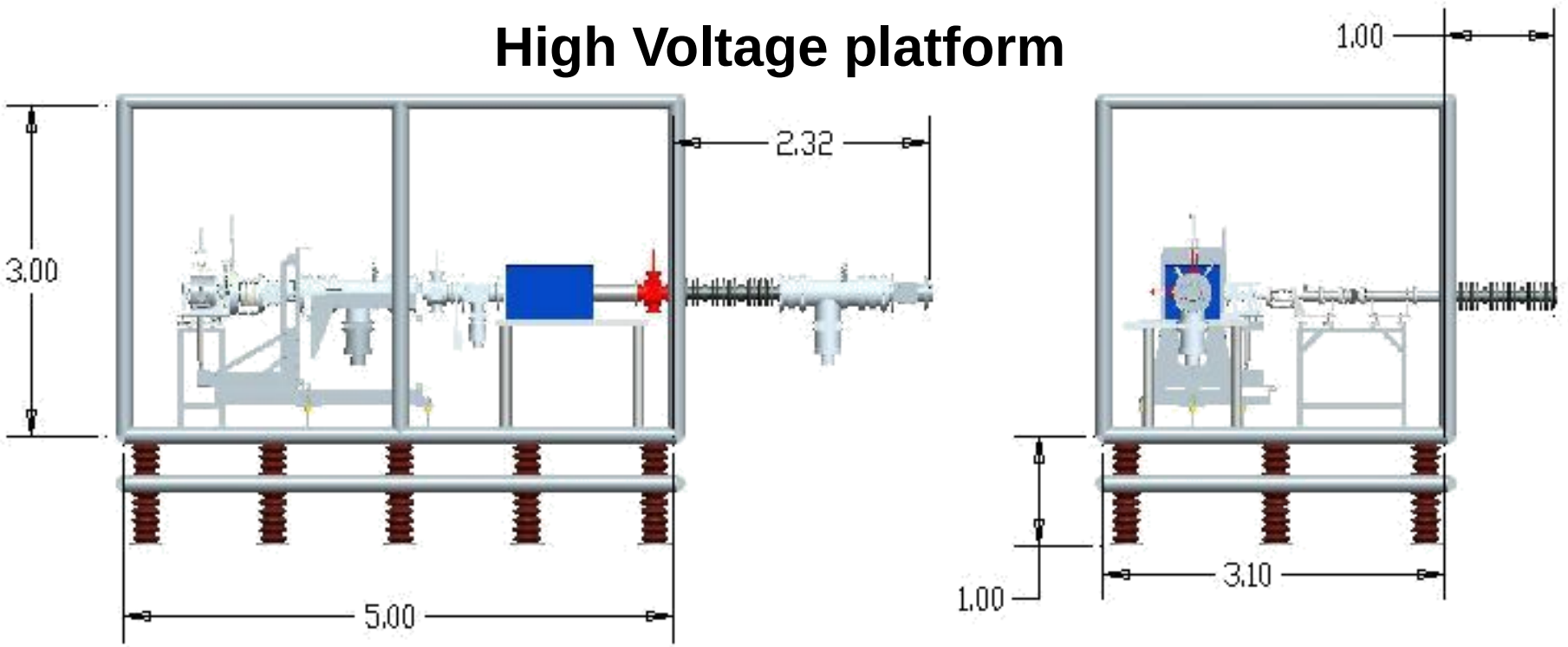
HRMS physics design

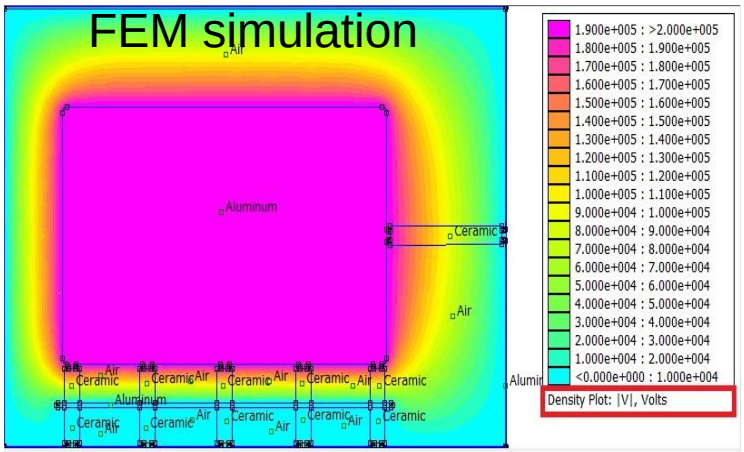


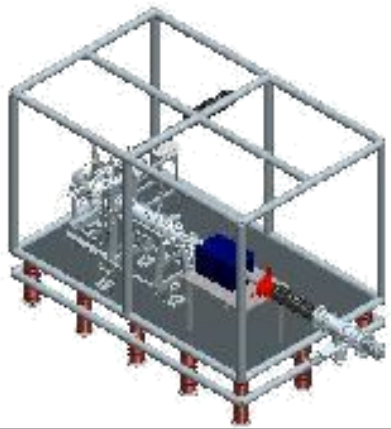
3° order effects analysis
Dθ=4 mrad and DE= ± 1.3 eV included

Mass resolution: 1/40000

ISOL front-end
High Voltage platform





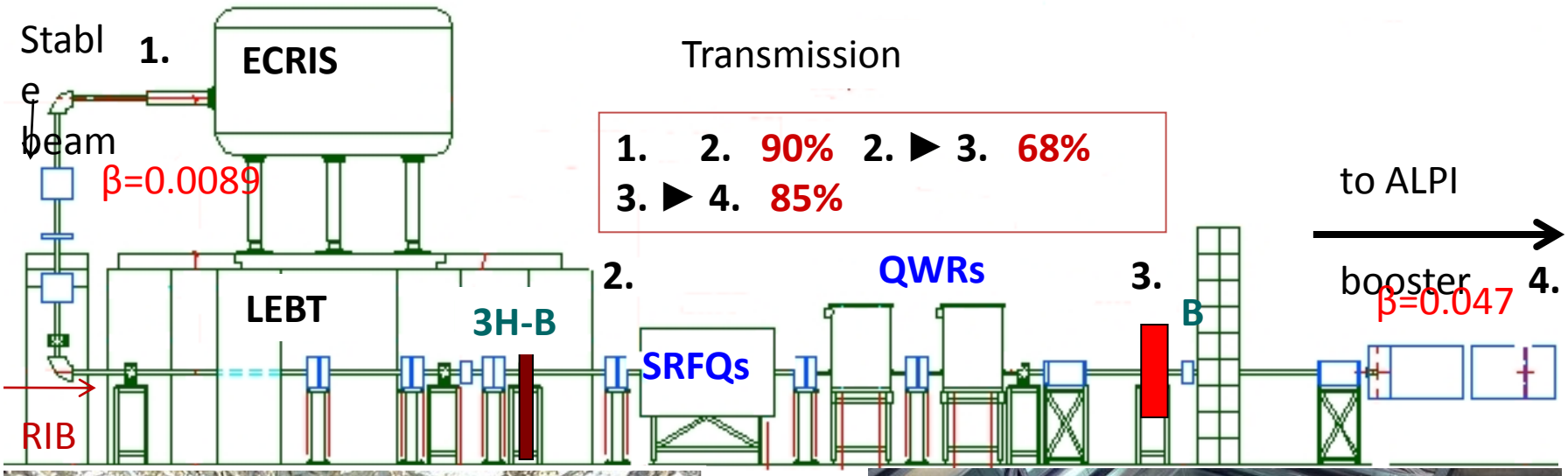


Mechanical and electrical design.

Critical point: operation in highly radioactive area

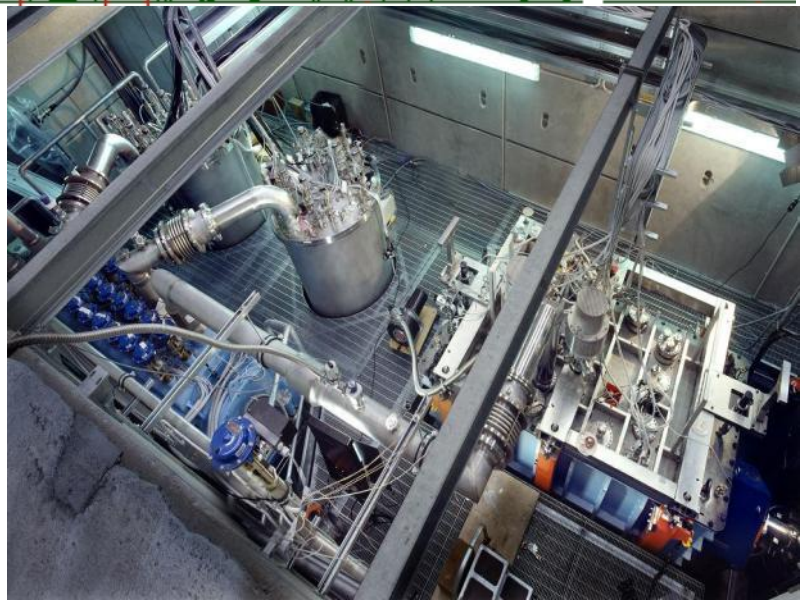
The SPES Post acceleration system

The PIAVE Superconductive RFQ

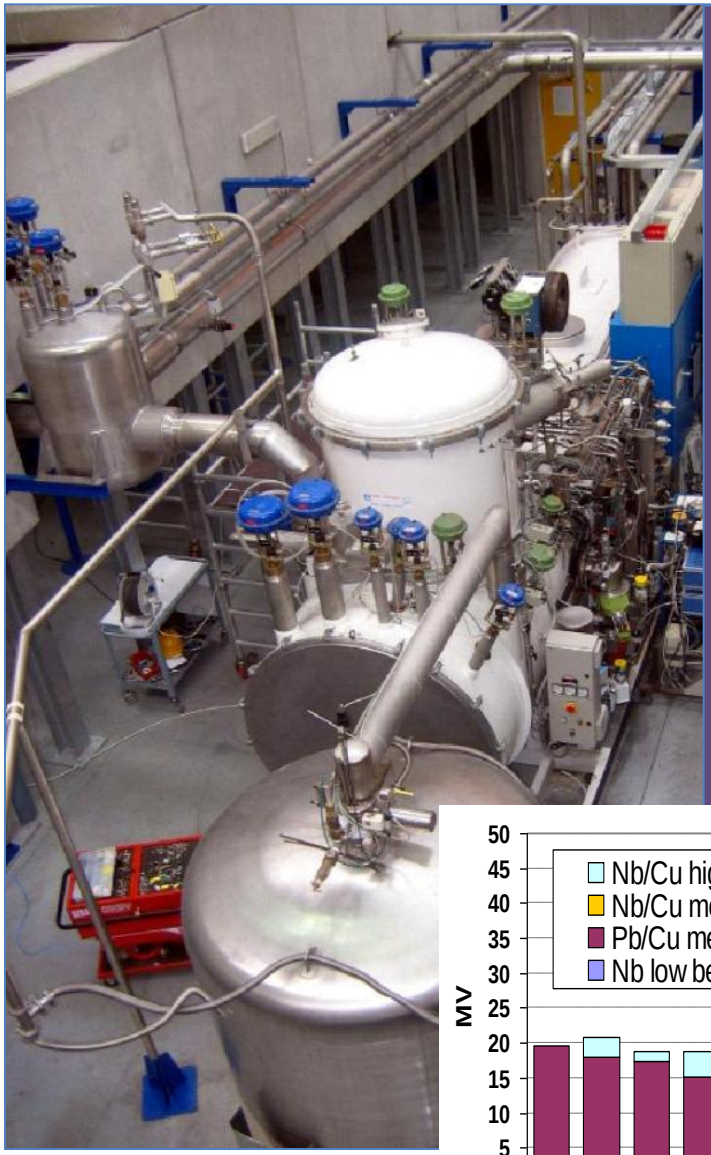


Transmission

1. 2. 90% 2. ► 3. 68%
3. ► 4. 85%



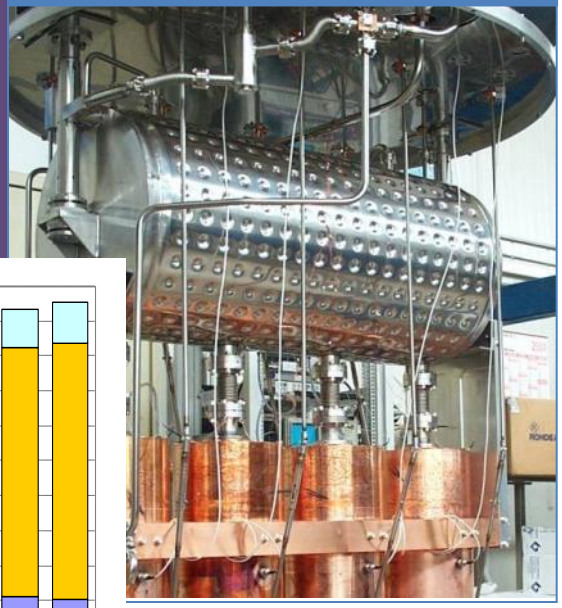
The ALPI Sc-Linac

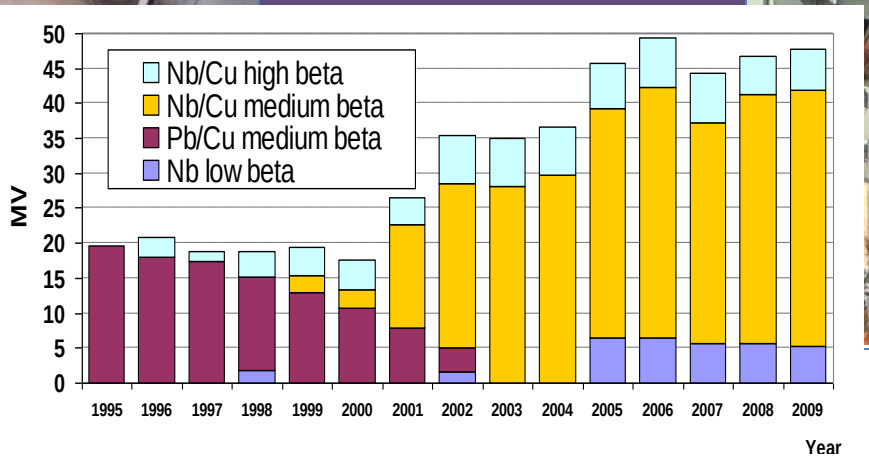


Superconductive linac based on QW resonators.

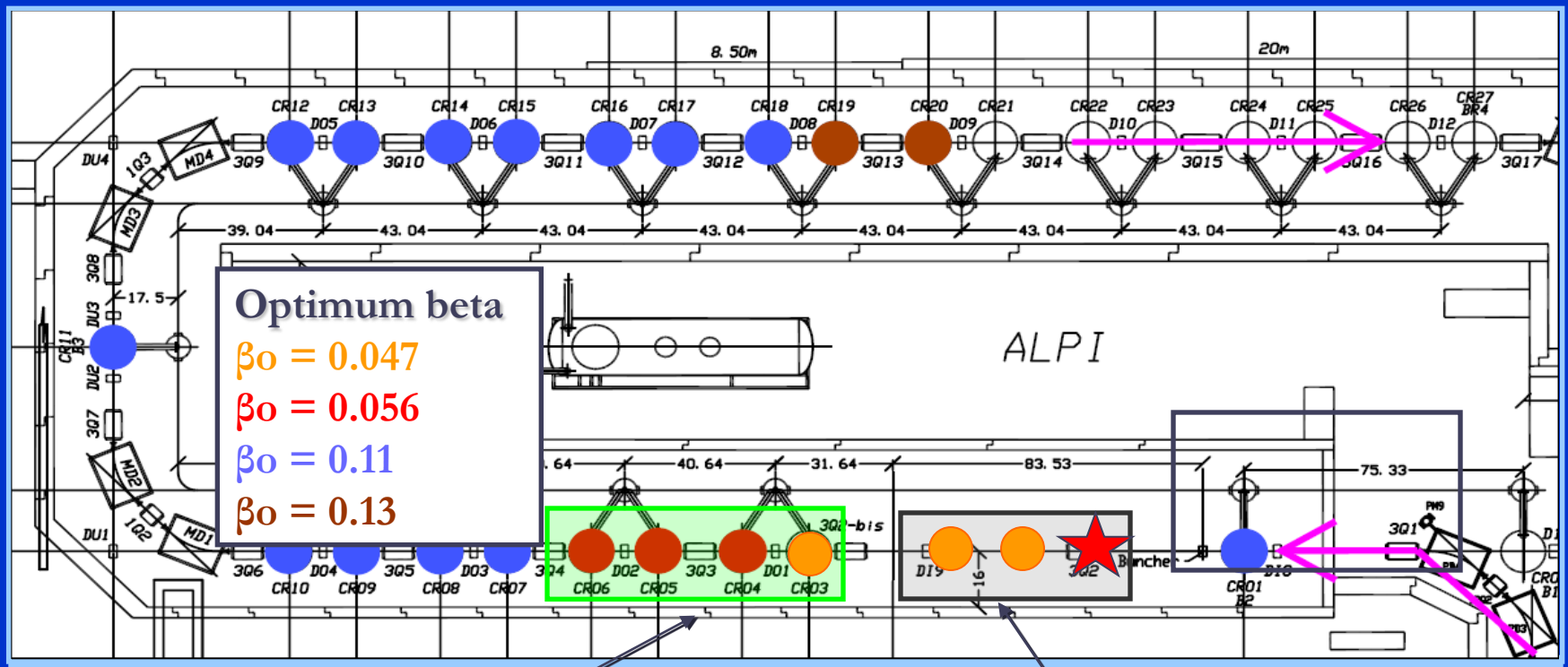
2003: Up graded to Veq ~ 40 MV

From Pb/Cu cavities to Nb/Cu spattered cavities
or bulk Nb cavities





Low beta cavities ALPI upgrade for SPES



ALPI layout

Funded upgrade (2009)
LowBeta CR3, new couplers

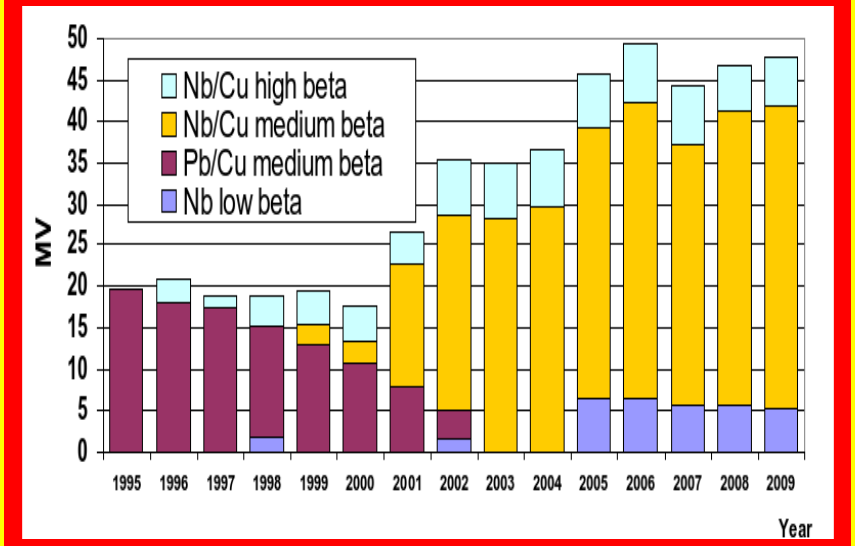
To be funded:

2 additional LowBeta Cryostats (CR1, CR2) a New buncher

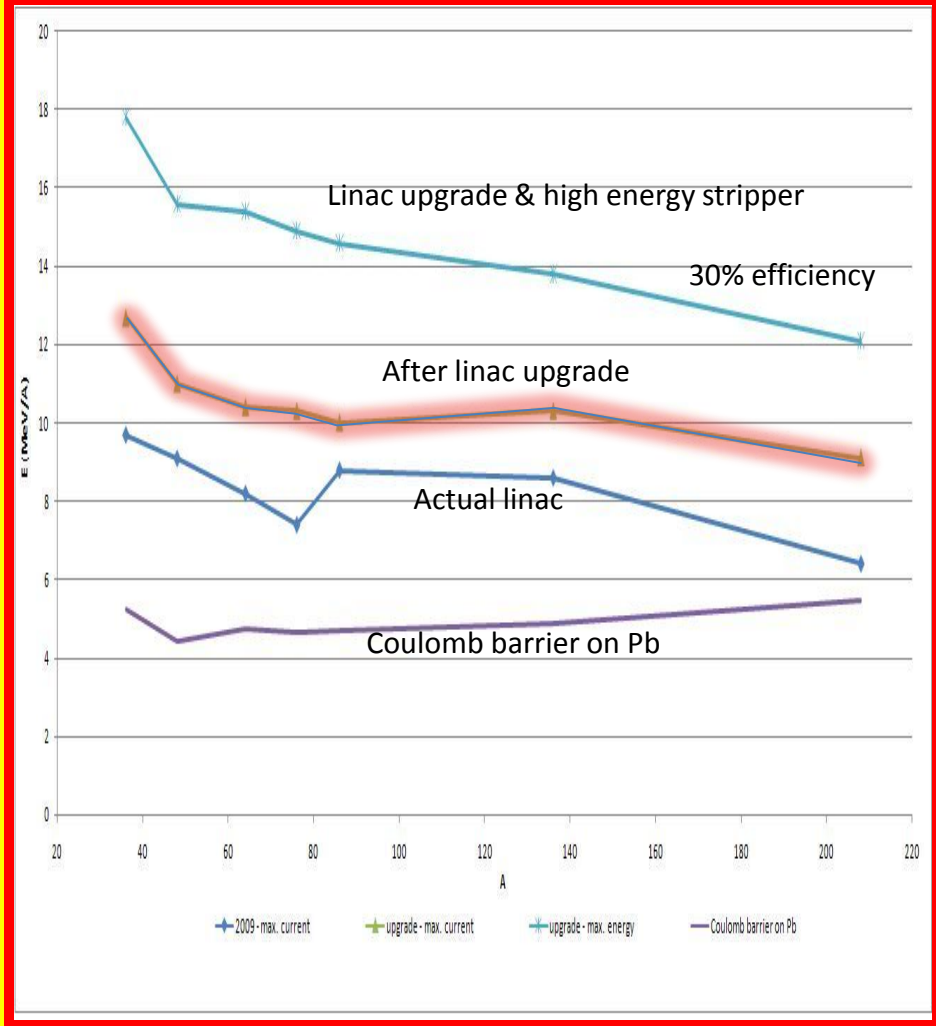
New magnetic lenses (upgrade from 20 to 30 T/m)

The ALPI post accelerator

- **Superconductinglinac based on QW Resonators**
- **2003: Up graded to Veq ~ 40 MV - Nb/Cu sputtered cavities or bulk Nb cavities; 2009: <u>48MV</u>**
- **2010: Low Beta RF upgrade to 5MV/m**
- **Energies up to 10-12 MeV/A for A=130 beams**



Expected SPES energies

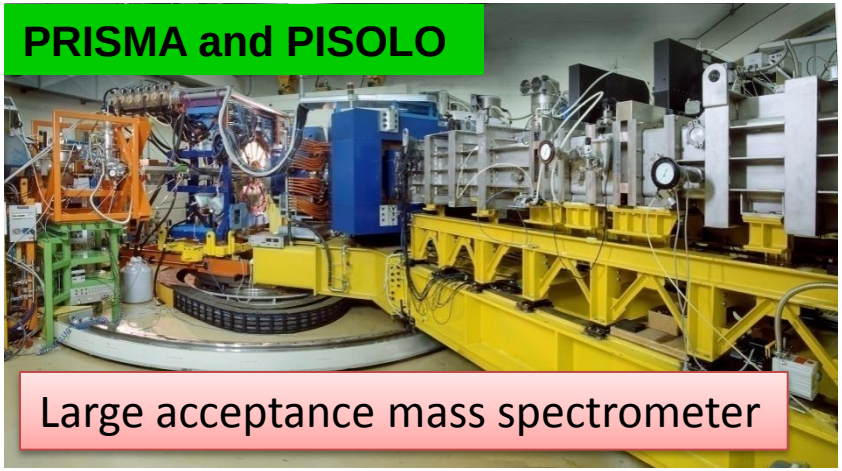


Available INSTRUMENTATION

Nuclear structure research

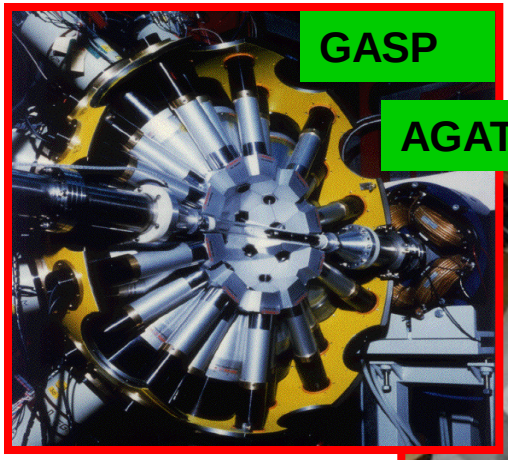
Reaction dynamics research

PRISMA and PISOLO

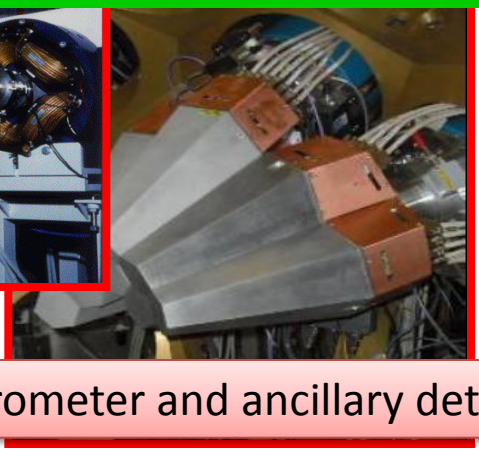


Large acceptance mass spectrometer

GASP

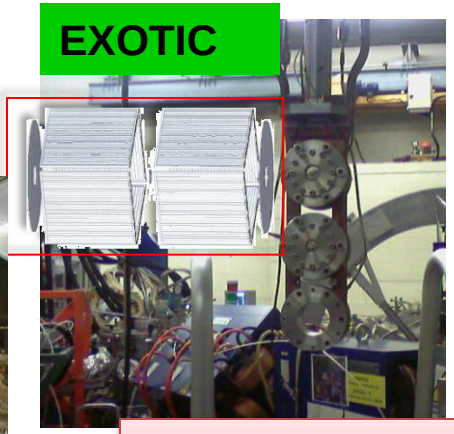


AGATA demonstrator



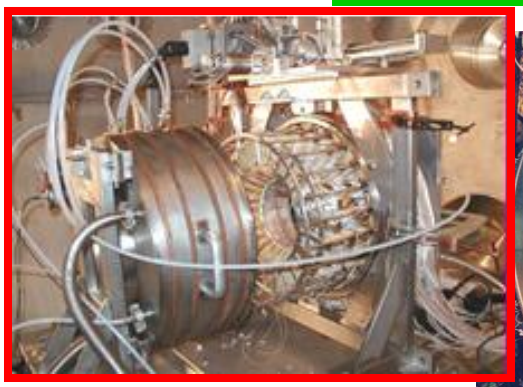
Gamma spectrometer and ancillary det.

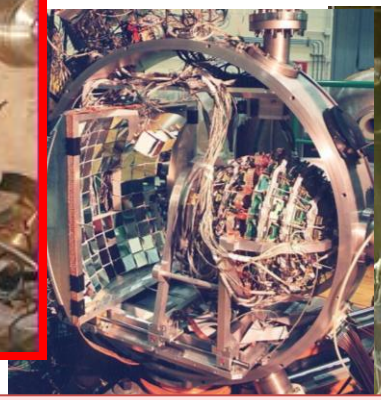
EXOTIC



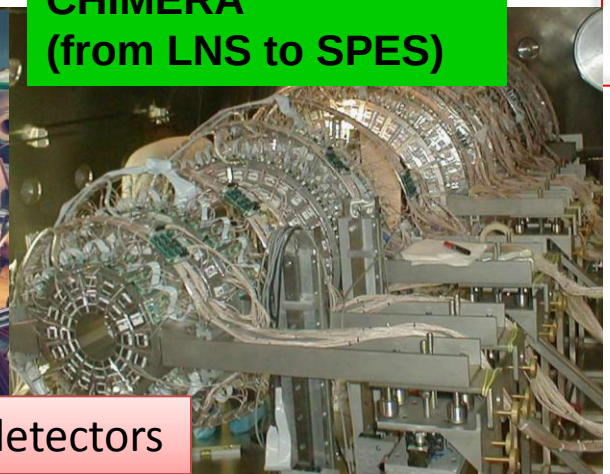
4π strip detector
Gas target

GARFIELD and 8πLP





CHIMERA (from LNS to SPES)



Large solid angle particle detectors

Available INSTRUMENTATION

Nuclear structure research

Reaction dynamics research

PRISMA and PISOLO

-Multinucleon transfer
- Nuclear superfluidity (pair transfer)
- Elastic and inelastic scattering
- Near and sub-barrier fusion

Large acceptance mass spectrometer

- High spin states
- Collectivity and shell model
- Isospin symmetries
- Isospin mixing in N=Z nuclei
- Spectroscopy at the dripline
- Shell stability and evolution in neutron rich nuclei
- Symmetries at the critical point
- Rotational damping

Gamma spectrometer and ancillary det.

EXOTIC

- Inverse kinematics
- Break up processes
- Quasi elastic scattering with light ions produced in secondary reactions

4π strip detector
Gas target

GARFIELD and 8πLP

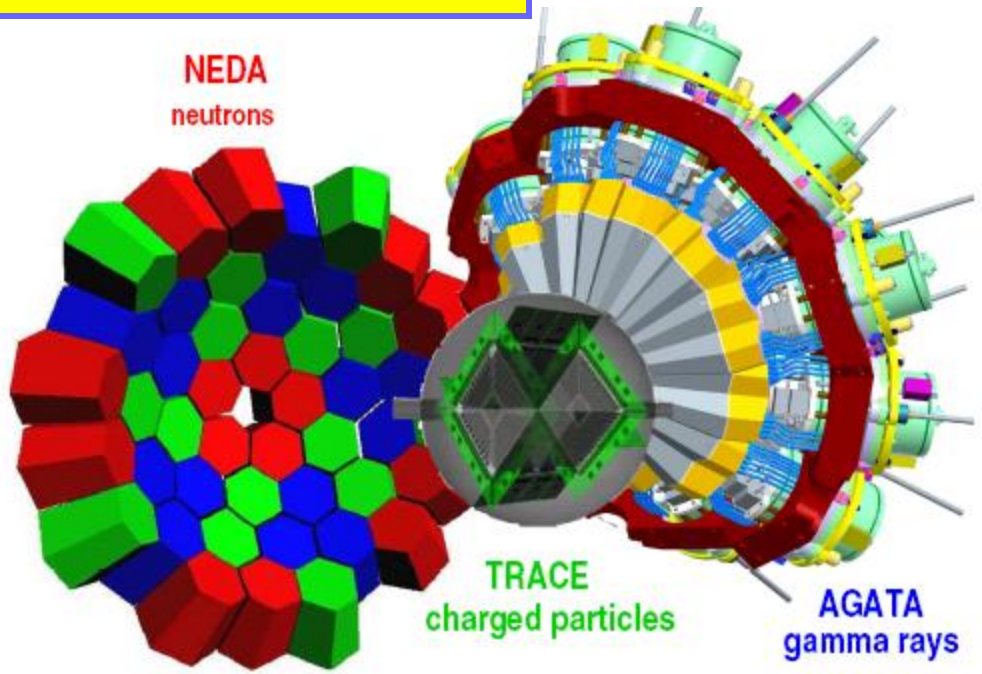
- Multifragmentation at low excitation energies
- Nuclear level density
- Collective modes of excitations

CHIMERA (from LNS to SPES)

Large solid angle particle detectors

NEW detectors: Spiral2pp - SPES

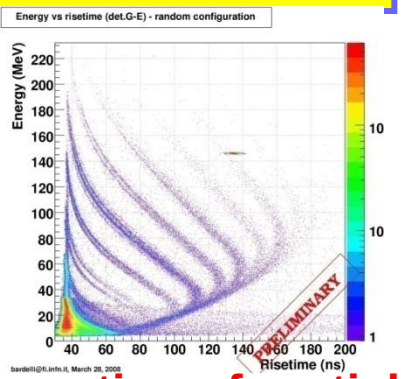
NEDA and TRACE



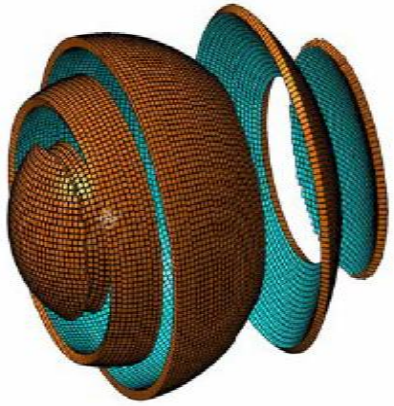
Neutrons and Light Particles AGATA ancillaries

- Channel selection
- Sensitivity enhancement
- Spectroscopic information

The FAZIA Initiative



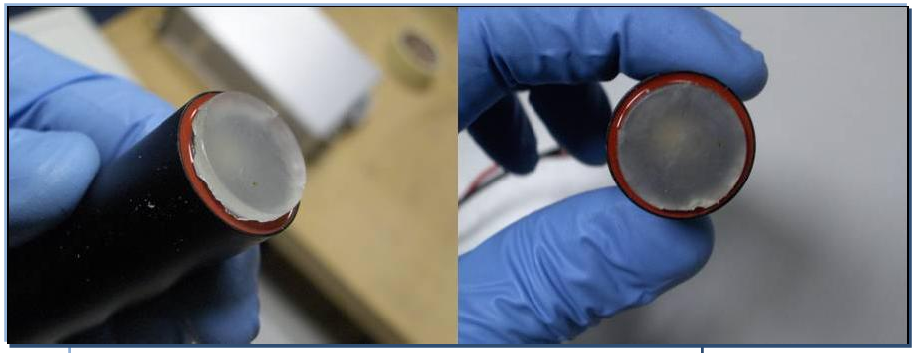
New generation of particle identification detector

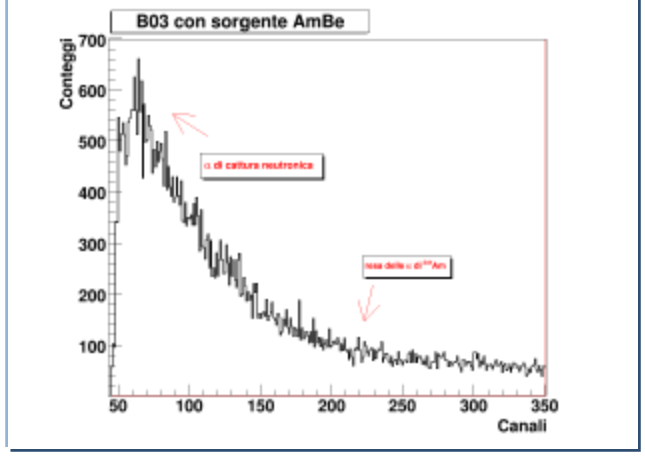


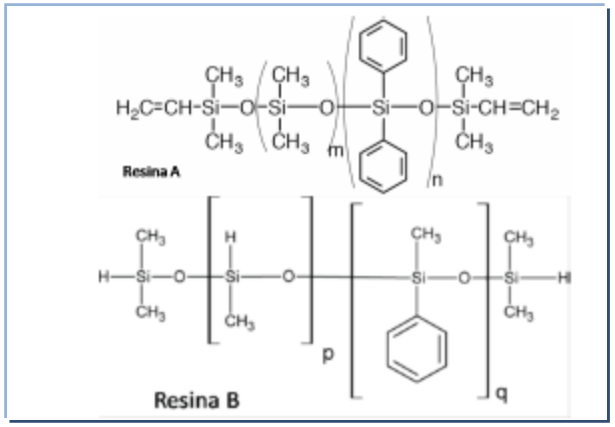
Siliconix Neutron detectors

OrIONe

Study for solid neutron detectors.
Alternative to liquid detectors:
improved safety
simple handling





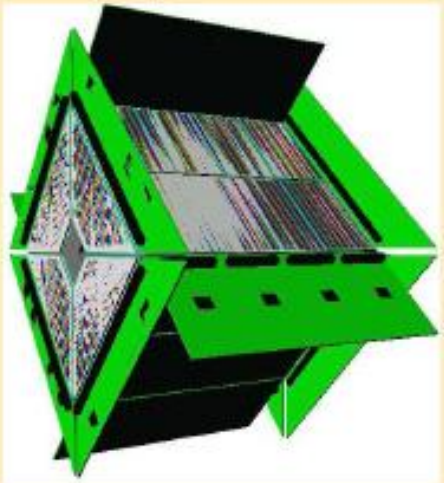


Very preliminary tests with **Boron and Gadolinium doped samples and PMT** allowed to observe a good response to thermal neutrons.

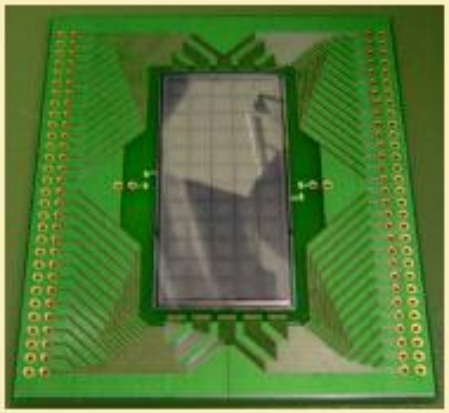
TRACE

TRacking Array for light Charged particle Ejectiles

TRACE



FBK-IRST(Trento)



High Segm.: PSA

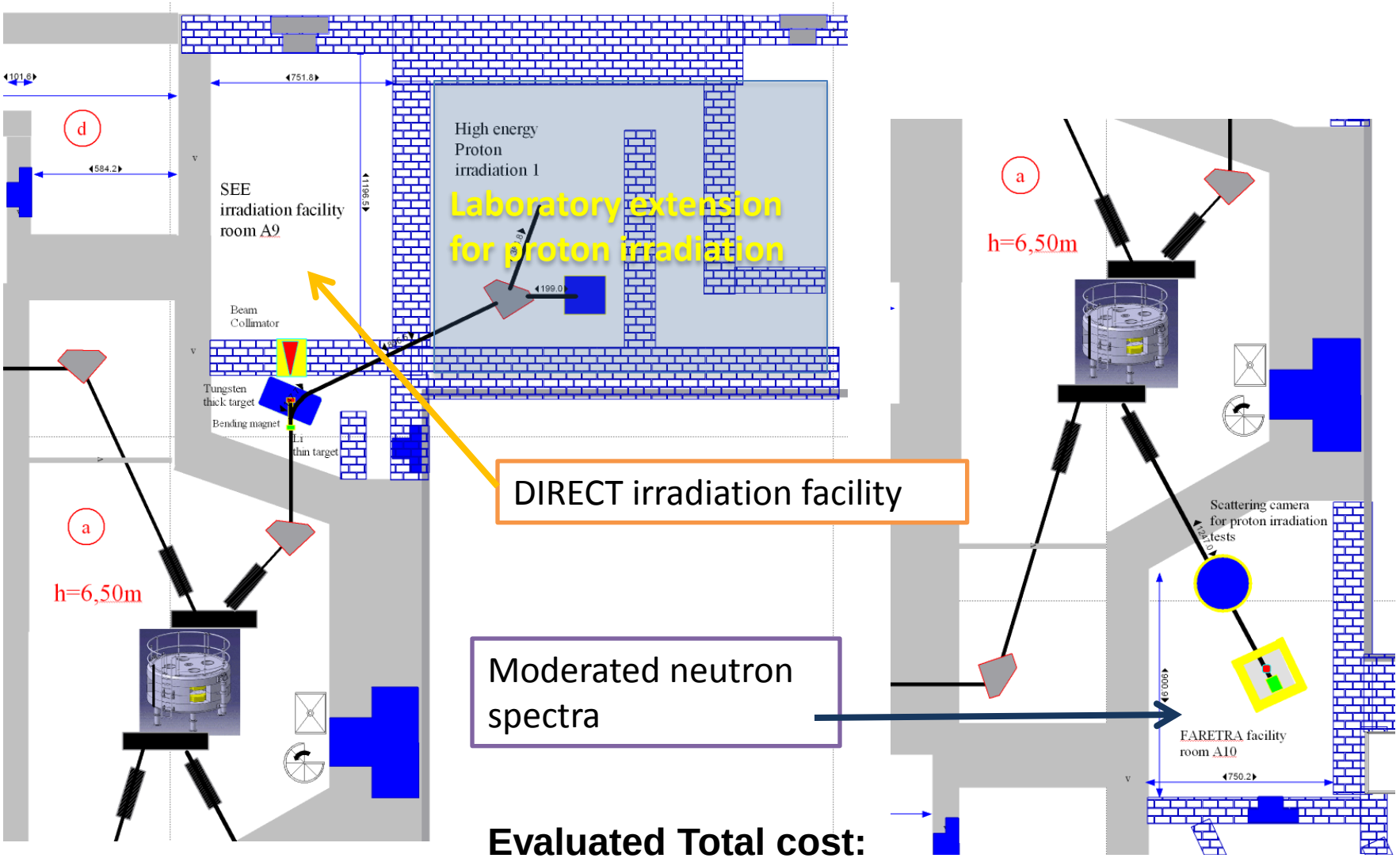
during my PhD ▸ goto

- geometry simulation
- signals simulation (PSA)
- impact on AGATA
- test with ASICs
- in-beam test
- AGATA Coupling

Technological impact

- ΔE-E telescope array: 150μm and 1.5mm;
- PSA&ToF, high sementation (~10000 ch, 1÷2°), 4x4 mm^2 at 10 cm;
- High counting rate.
- ASICs evolution

Neutron facility at the SPES Cyclotron



NEUTRON spectra at SPES CYCLOTRON

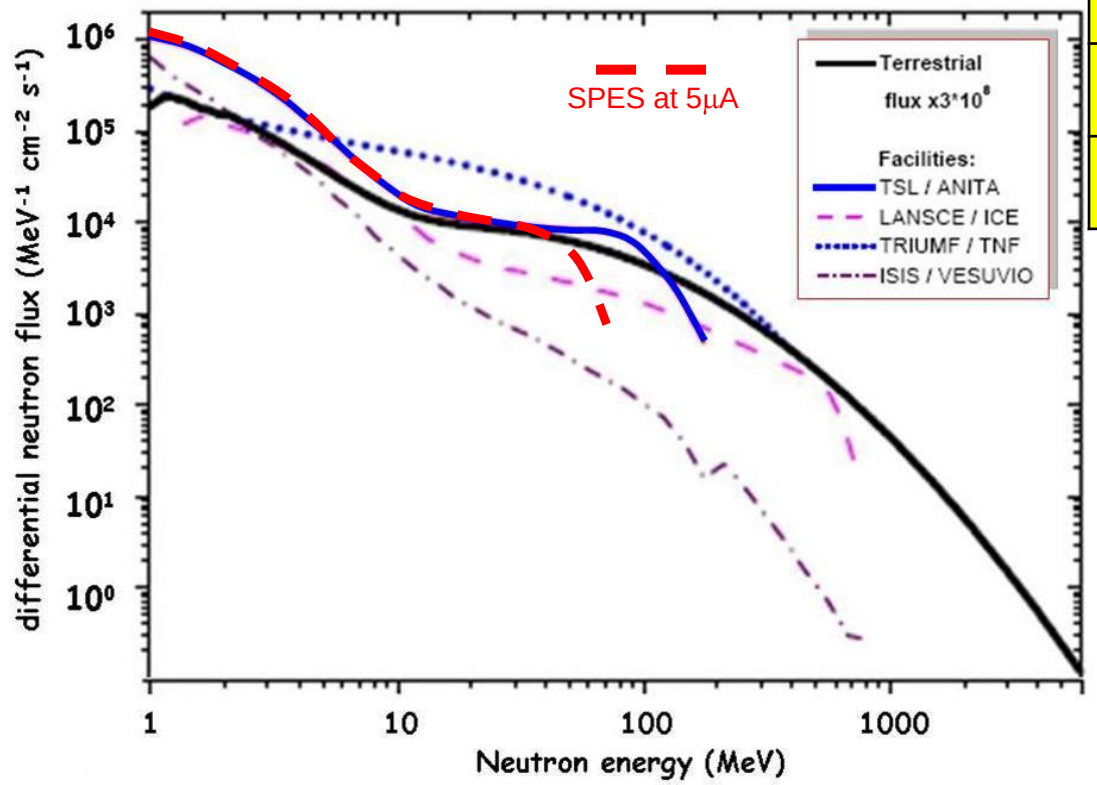
Study for a SINGLE EVENT EFFECT facility

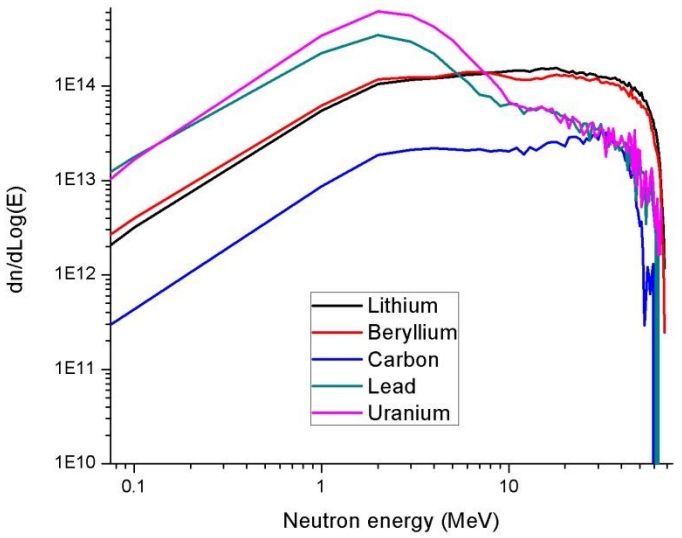
Acceleration factor 3×10^8 @ 5microA 70MeV

integral neutron production at SPES Cyclotron

Proton beam= 500 μA, Target = W 5mm

Energy region (MeV)	Sn (n/s) ~ $6 \cdot 10^{14}$ s^{-1}	Φ_n @ 2.5 m (n cm^{-2} s^{-1})
1 < E < 10	~ $5 \cdot 10^{14}$ s^{-1}	5×10^8
10 < E < 50	~ $1 \cdot 10^{14}$ s^{-1}	1×10^8



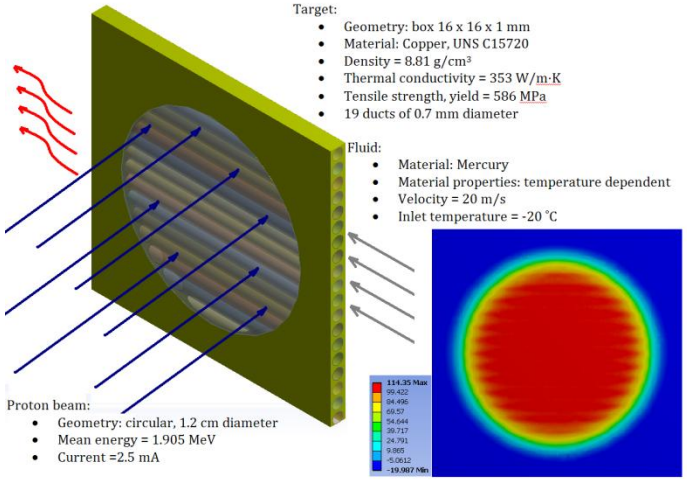


Study for Pure Lithium target

Microchannel cooling system

Copper backing has been successfully manufactured.

Preliminary power transfer test performed



Tests done depositing a thin Indium layer instead of Lithium.
Melting point of Indium 157°C.
Maximum working temperature of Li target will be 150 °C.

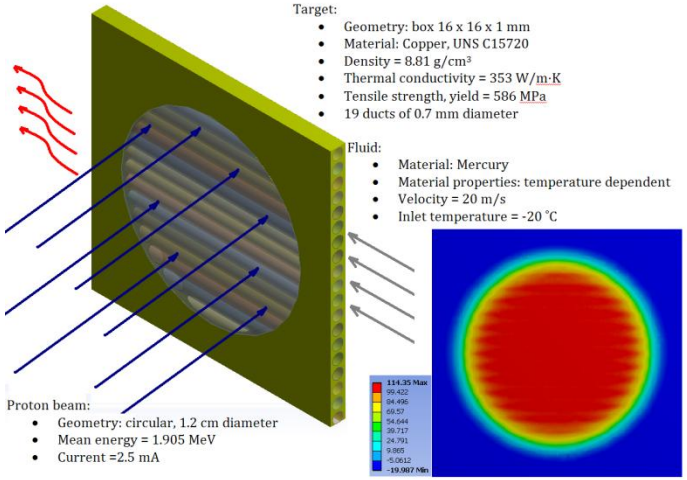
Test with a TIG soldering system and water cooling

Study for Pure Lithium target

Microchannel cooling system

Copper backing has been successfully manufactured.

Preliminary power transfer test performed

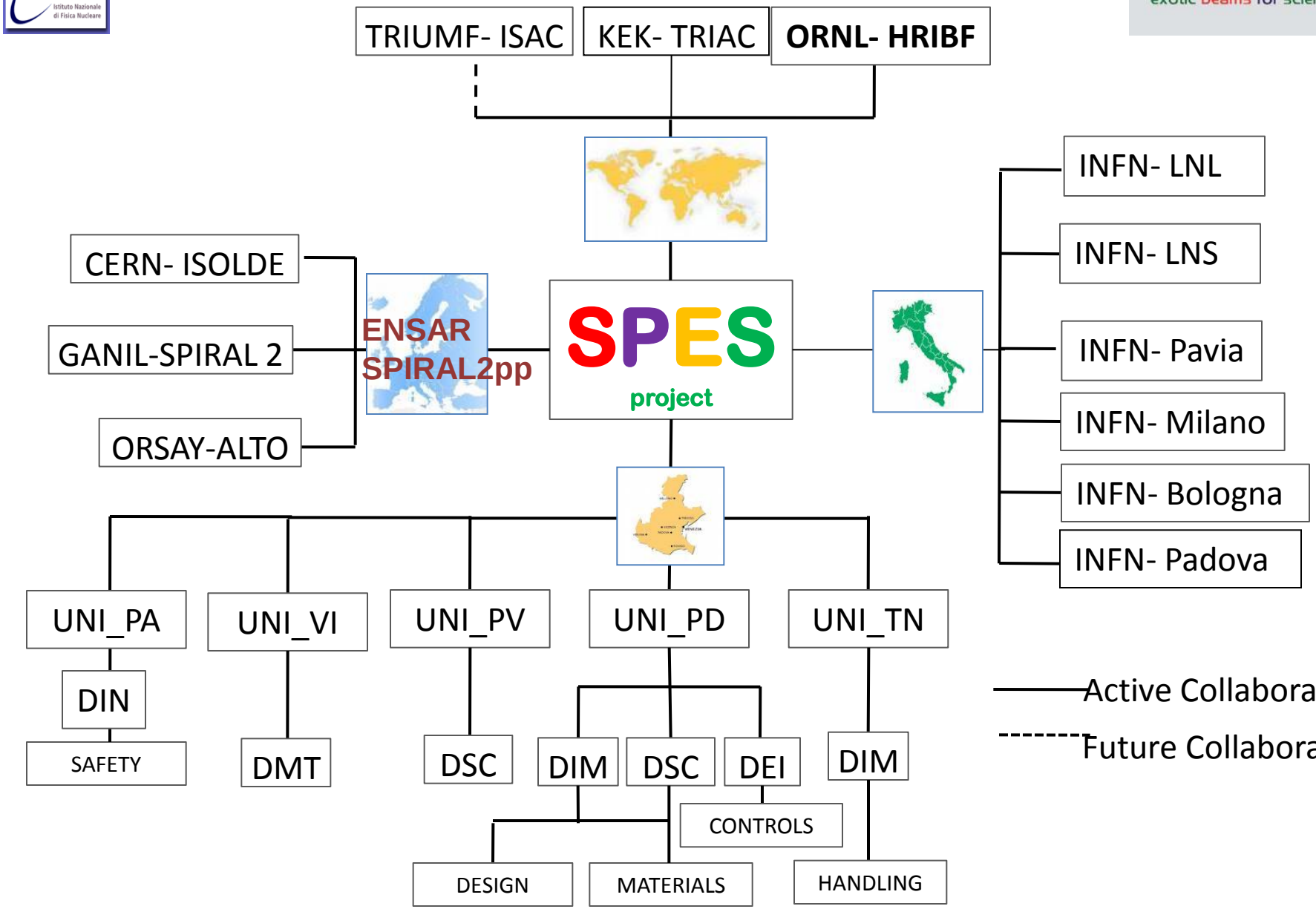


Measured power transfer: 3.4 kW/cm²
Not reached the Indium melting point

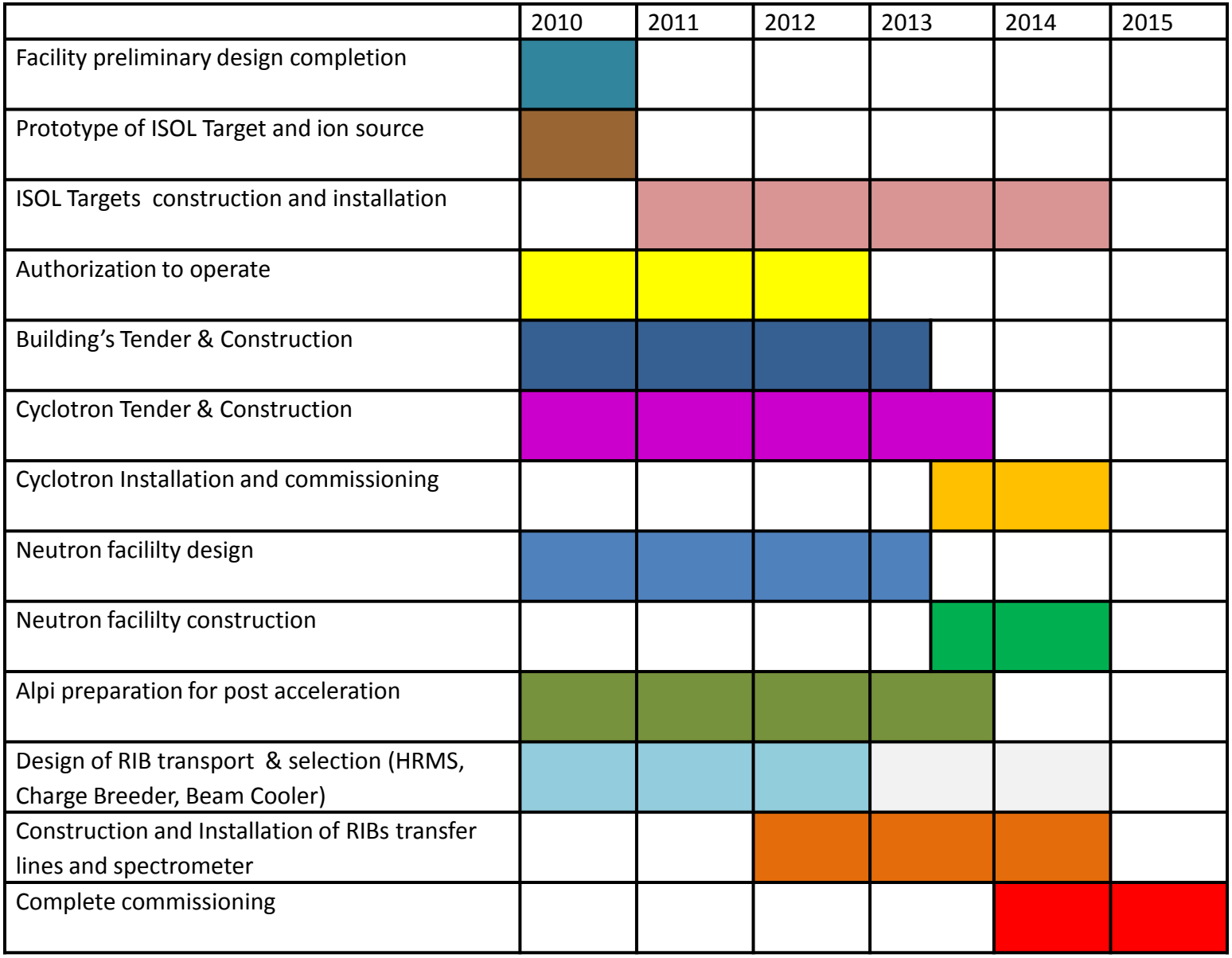
Tests done depositing a thin Indium layer instead of Lithium.
Melting point of Indium 157°C.
Maximum working temperature of Li target will be 150 °C.

Test with a TIG soldering system and water cooling

The SPES collaborations network



SPES Schedule



Call for Letters of Intent

Researchers interested in proposing experiments with the SPES facility at LNL are invited to
submit Letters of Intent to the Scientific Committee of SPES.

Information on the SPES: http://spes.lnl.infn.it/
deadline for submission is October 1st 2010
The documents can be submitted via email tothe Chair of the Scientific Committee AldoCovello
covello@na.infn.it
The submitted LoI will be presented and discussed in the forthcoming
SPES2010 Workshop (LNL- November 15th-17th, 2010)

The goal is to build scientific collaborations around the SPES facility, defining priorities in the development of exotic beams and instrumentation.

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CONCLUSIONS

- The SPES project was approved by INFN
- The ISOL Target and Ion Source was developed and are under test
- The Safety report for cyclotron operation is completed
- The bid for the cyclotron proton driver will be concluded in June
- The bid for final building design is assigned
- Expected ground breaking in 2011

Thanks for attention