SPES Project

Selective Production of Exotic Species

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On behalf of the SPES Collaboration

EURORIB'12 Abano Terme (Italy), 20-25 May 2012

SPES facility goals @ LNL

Selective Production of Exotic Species

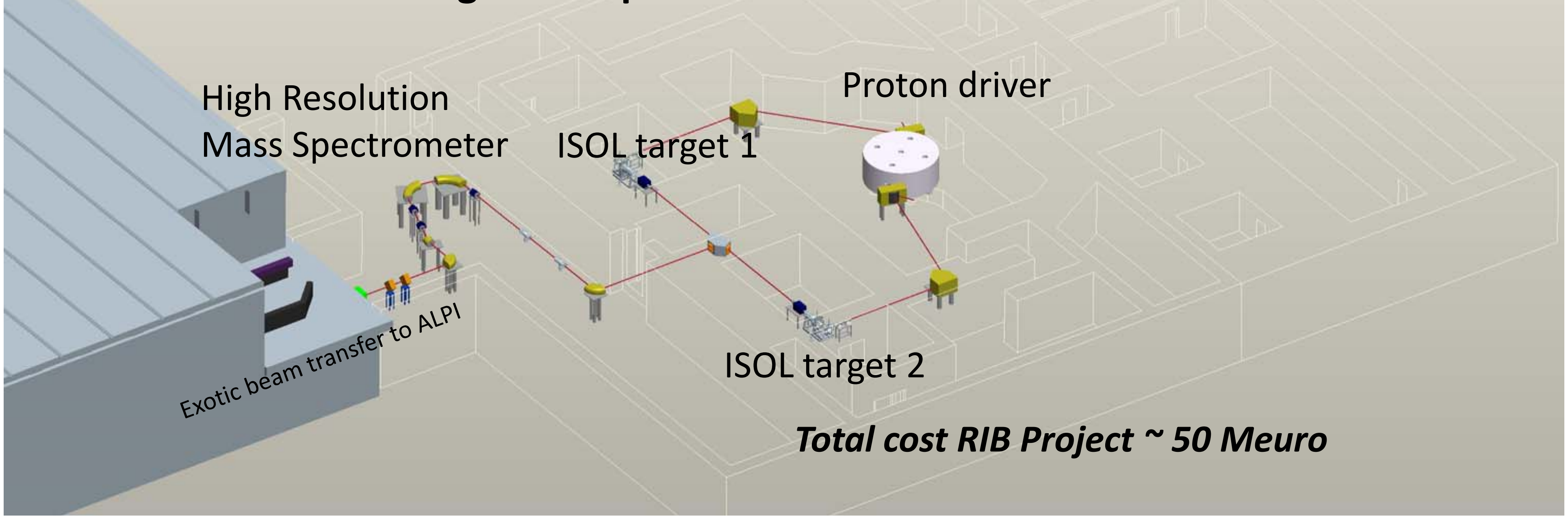
- second generation ISOL facility for re-accelerated neutron-rich ion beams
- interdisciplinary multi-user research center

ISOL BEAM FACILITY

***Primary Beam*: 750 μA, 70 MeV protons from a 2 exit ports New Cyclotron**

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

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



Total cost RIB Project ~ 50 Meuro

SPES strategy

Selective Production of Exotic Species

The project is divided in four phases providing an efficient use of the proton driver beam.

Exotic nuclei

ISOL facility for Neutron rich nuclei by U fission 10^{13} f/s

high purity beam
Reacceleration up to ≥10 MeV/u

Applications

Proton and neutron facility for applied physics

Radioisotopes produduction & Medical applications

INFN priority. Phase alpha:funded
Phase beta: applied for special funding

ISOL target 2

In collaboration with others research and commercial partners

Total cost RIB Project ~ 50 Meuro

Evaluated cost of application facility ~ 30 Meuro

NuPECC ISOL Roadmap in EUROPE

TODAY Generation 1

10^{12} fission/s ,
2 MeV/n (A=130)

Effective Mass resolution 1/4000

SPIRAL – GANIL

ISOLDE CERN

INFN LNS - EXCYT

2014-2025 Generation 2

$10^{13\text{-}14}$ fission/s
10 MeV/n (A=130)

Effective Mass resolution 1/20000

GANIL spiral2 laboratoire commun CEA/DSM CNRS/IN2P3

HIE ISOLDE

SPES exotic beams for science

EURISOL

FROM 2025

> 10^{15} fission/s
100 MeV/n (A=130)
Mass resolution 1/20000

Second generation ISOL facilities in Europe (UCx target)

Production and study of neutron-rich nuclei

	Primary beam	Power on target	UCx target	Fission s-1	Reacceler ator	Nominal energy AMeV A=130
HIE ISOLDE upgrade	p 1-1.4 GeV - 2 μA	0.8 kW	Direct (150g)	**$4\cdot10^{12}$**	SC Linac	5-10
SPIRAL2	d 40 MeV 5mA	200 kW	Converter (4000g)	**10^{13}** 10^{14}	CIME Cyclotron	5
SPES	p 40 MeV 200 μA	8 kW	Direct (30g)	**10^{13}**	ALPI SC Linac	10

Synergy & complementarity
will offer to the European nuclear physics community up-to date facilities to improve the knowledge of nuclei

European actions and MoU

ENSAR — NUPNET (ERA-NET for Nuclear Physics Infrastructures) — Spiral2 Preparatory Phase — EURISOL

Associate European Laboratory (LEA-COLLIGA)

Memorandum of Understandig with Ganil and Isolde

- Physics programs
- Experimental techniques
- ISOL technology
- Target-ion sources
- RIB selection & handling
- Superconductive LINAC
- Vacuum
- Safety

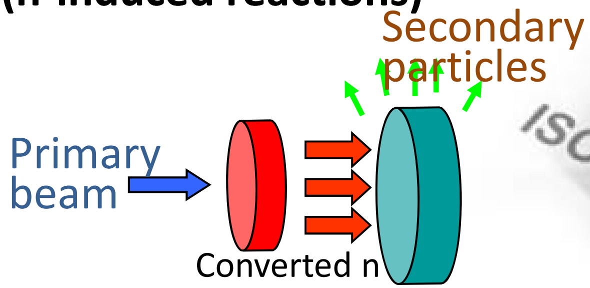
Collaboration agreement K1699/PH between INFN and CERN concerning scientific collaboration for the benefit of the SPES beam facility at INFN and the ISOLDE experiment at CERN

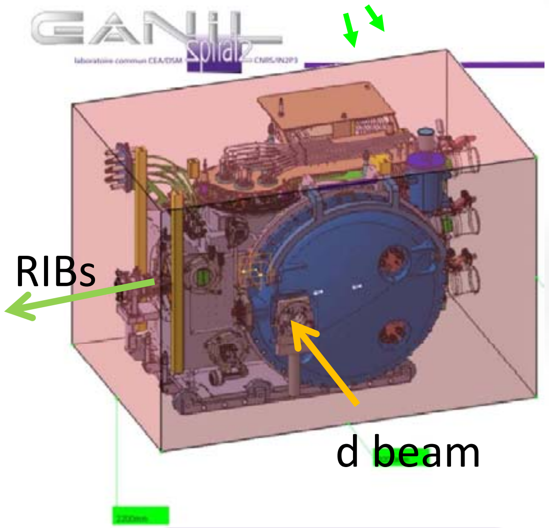
Radioactive Ion Beams: ISOL production methods

2 step

High Power target (n-induced reactions)

Decoupling the power of the driver beam from the RIB production target





Height: 2.15 m
Length: 3.20 m
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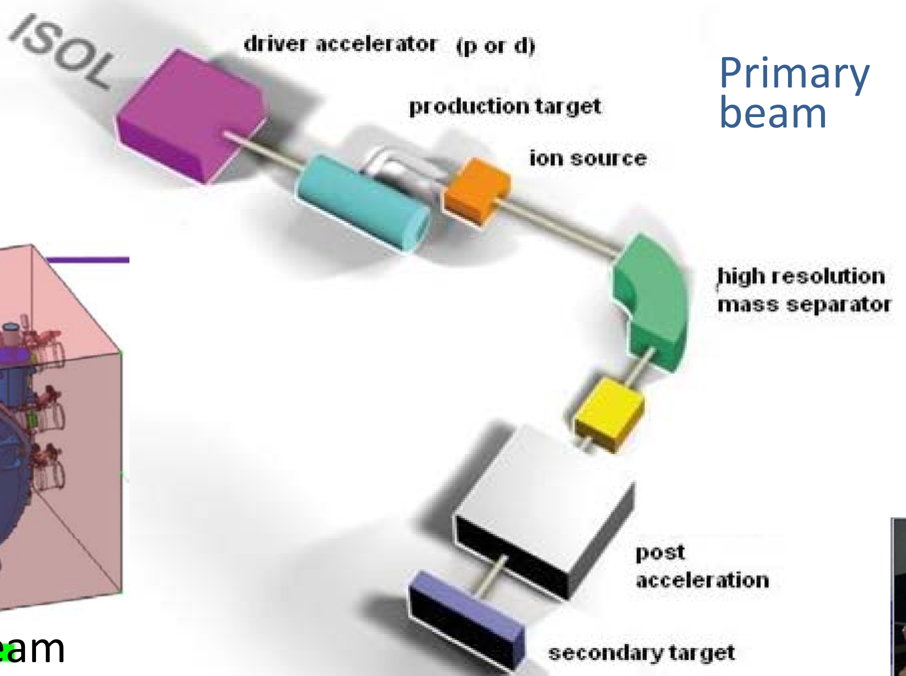
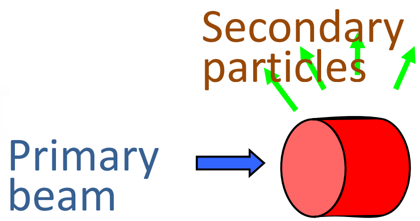
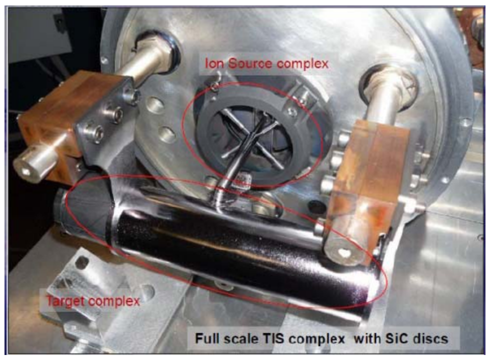
Weigth: 8 t



Direct target

Proton –induced reactions



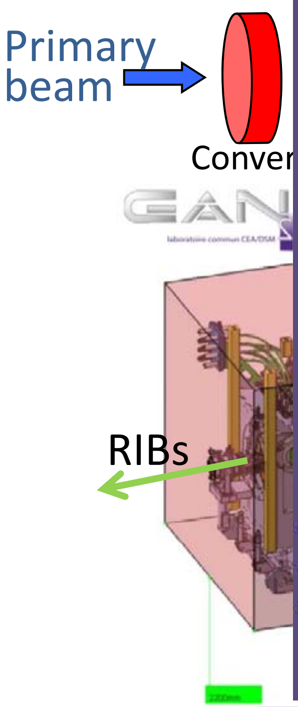


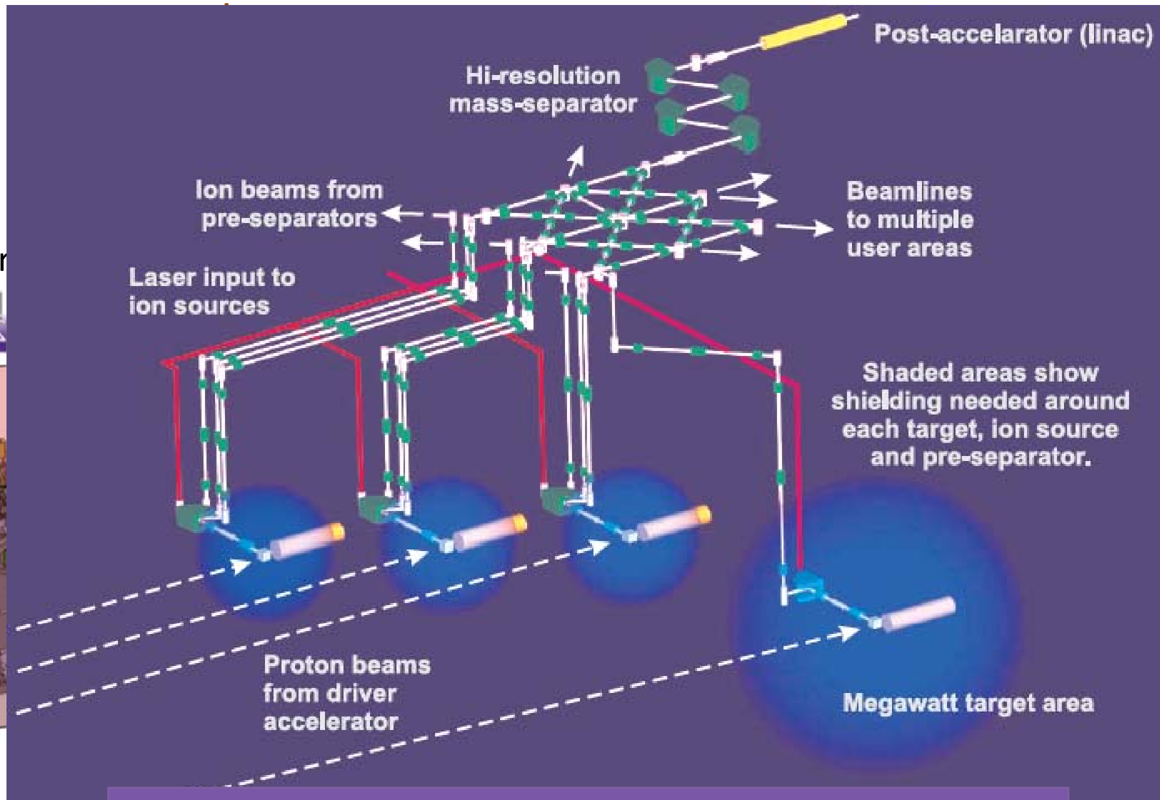
SPES direct target-ion source
50x50x50 cm3
25 kg
ISOLDE-type target

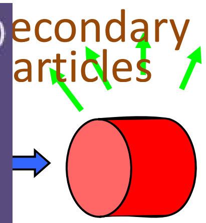
Radioactive Ion Beams: ISOL production methods

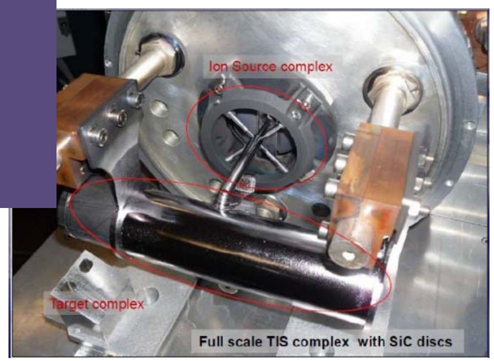
2 step target (n-induced reactions)

Direct target Proton –induced reactions









Height: 2
Length: 3
Width: 2
Weigth: 8

3x 100 kW	Direct targets
1x 5 MW	2-step target

SPES collaboration network

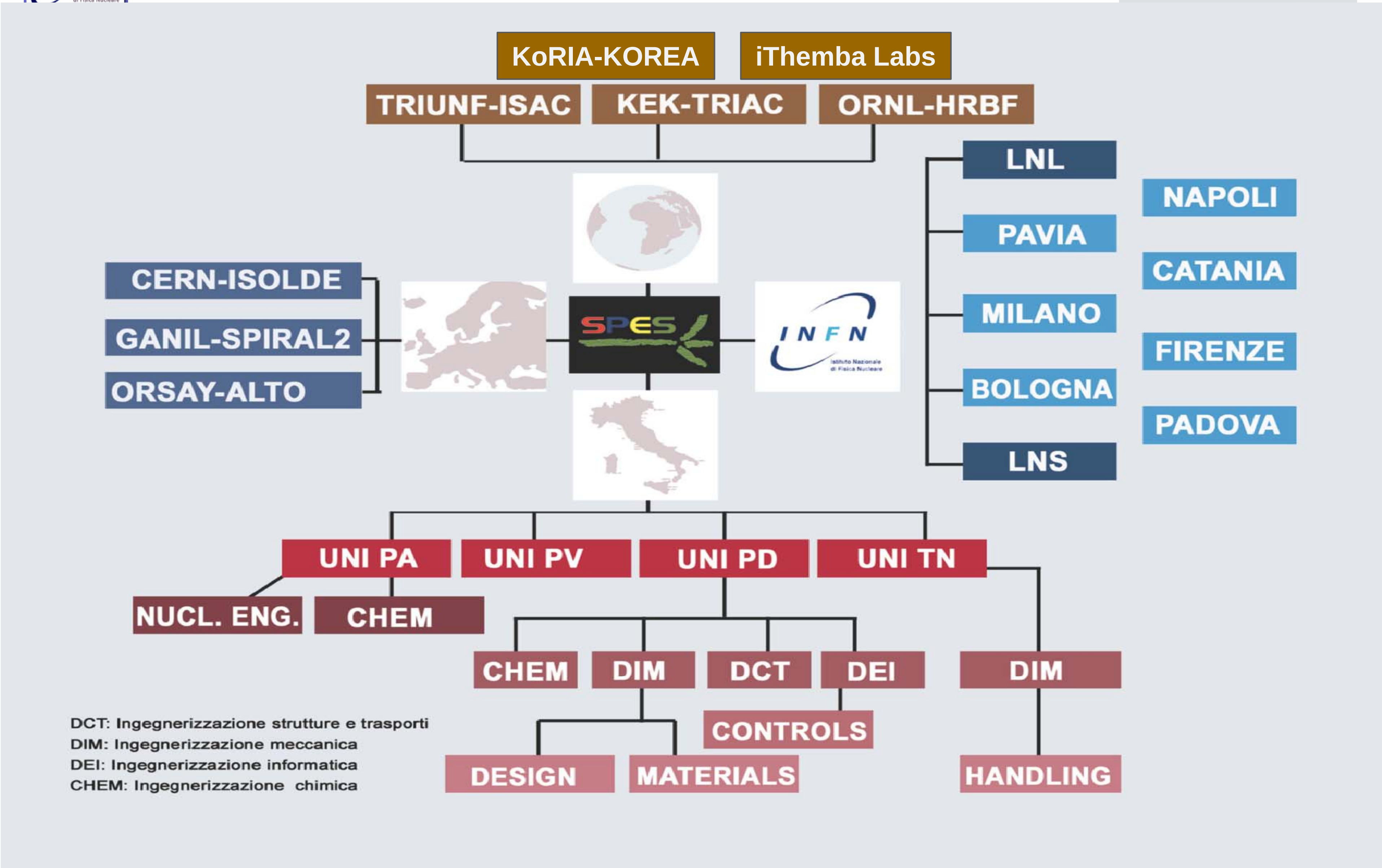


Fig. 3.25: Rete delle collaborazioni di SPES.

Letters of Intent for SPES

SPES2010 Workshop
(LNL- November 15th-17th, 2010)

24 LoI’s for reaccelerated exotic beams

Nuclear structure and reaction mechanism

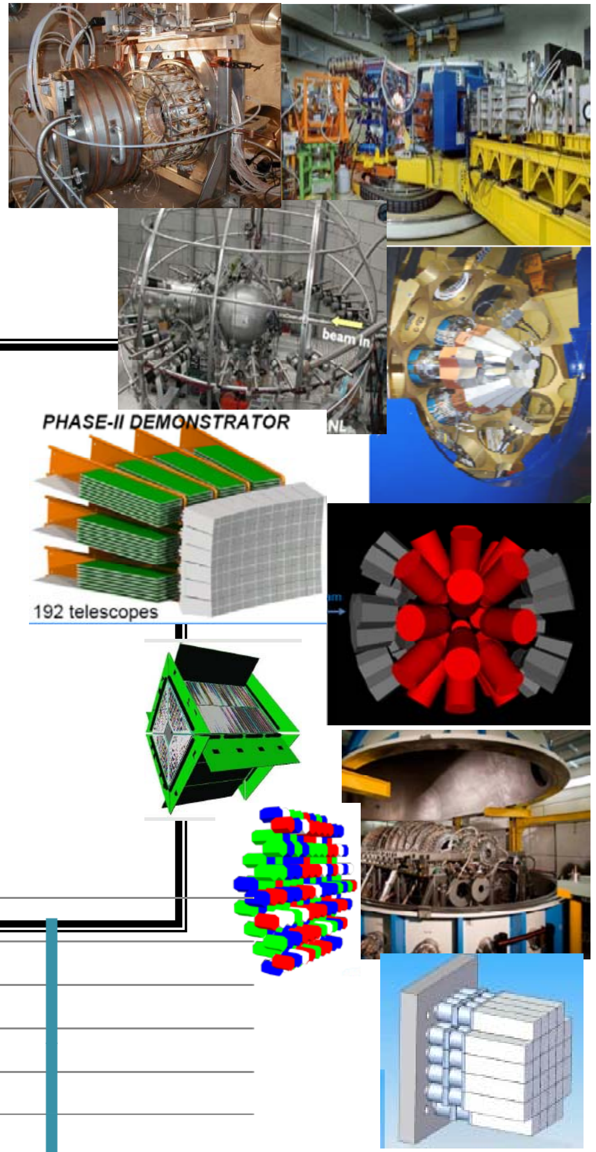
International collaborations:

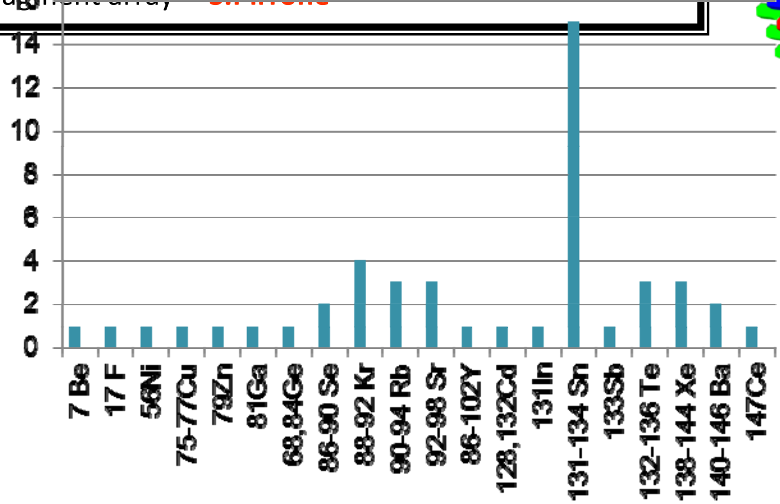
Italy
Bulgaria
Hungary
France
Poland
Spain
Great Britain
Turkey
USA
Slovakia
Romania
Croazia
Russia
India
Germany
Canada

Instrumentation:

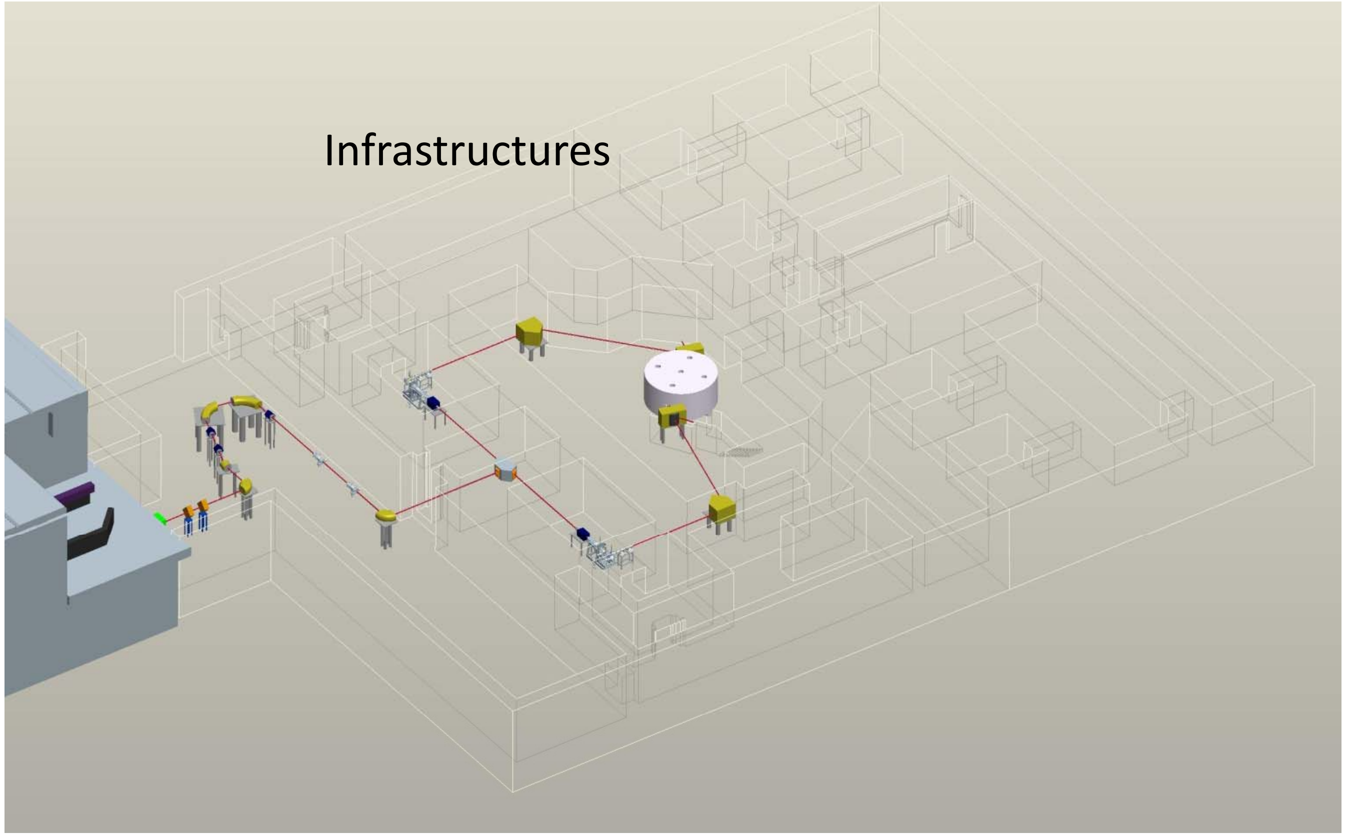
1 **GARFIELD** Low threshold 4π LCP-Fragment array - **F. Gramegna**
2 **PRISMA** Large acceptance spectrometer - **A.M. Stefanini**
3 **8PLP** 4π LCP-Fission Fragment array - **M. Cinausero**
4 **RIPEN** Neutron array - **M. Cinausero**
5 **GALILEO** γ-array - **C. Ur**
6 **TRACE** Compact LCP array - **D. Mengoni**
7* **AGATA** High performance γ-array - **E. Farnea**
8* **FAZIA** High performance LCP-Fragment array - **G. Casini**
9* **NEDA** New generation neutron array - **J.J. Valiente Dobon**
10* **PARIS** New generation high energy γ-ray array - **A. Maj**
11** **CHIMERA** Low threshold 4π LCP-Fragment array – **S.Pirrone**

* SPES&SPIRAL2 collaboration LEA-Colliga
** part of Chimera installed at SPES





Definition of First Day Experiments:
- Scientific priorities
- Instrumentation development
- RIB production



SPES Project

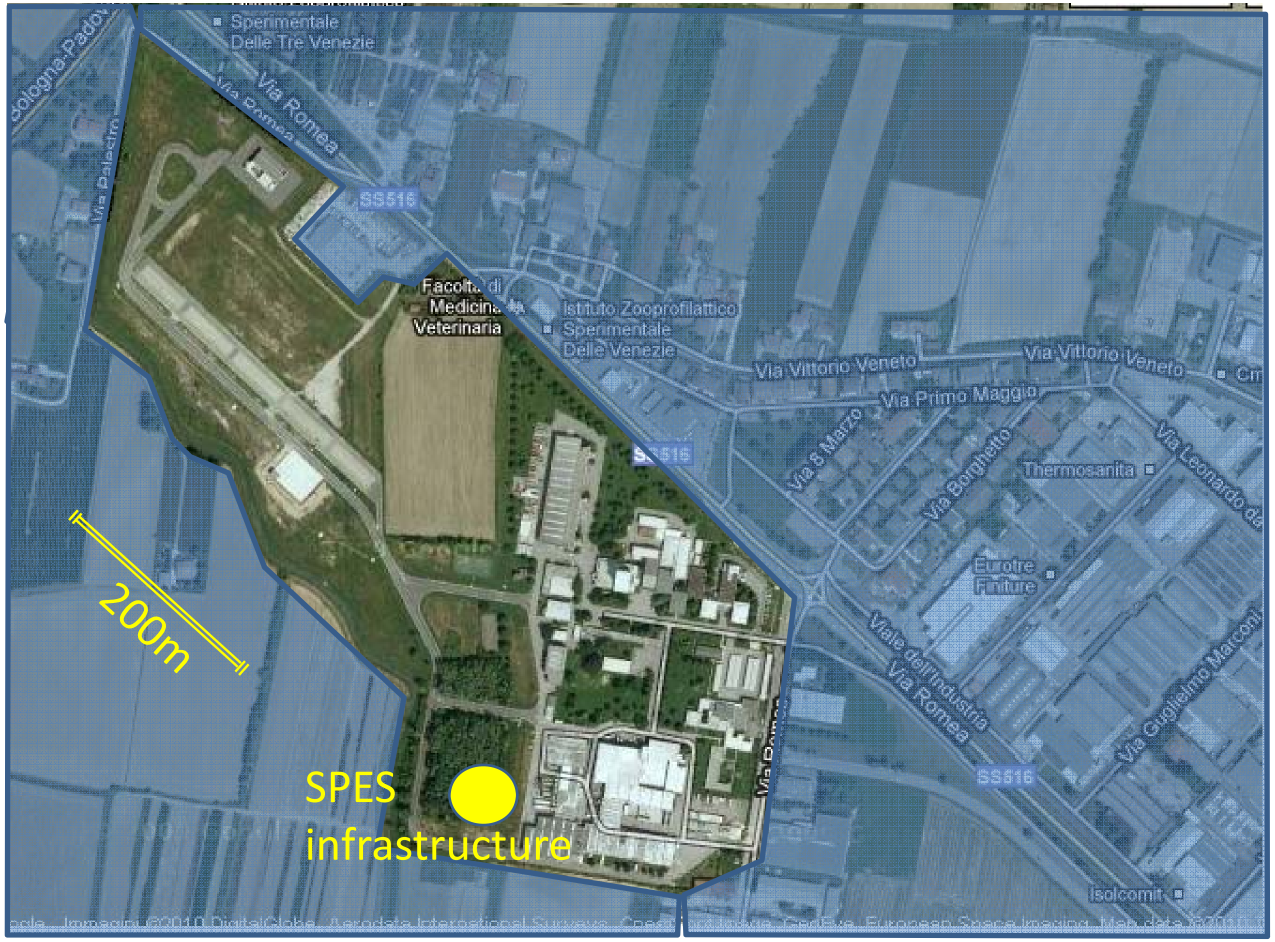
SPES FACILITY infrastructures

Bid for construction on the way
ground breaking expected in Feb 2013

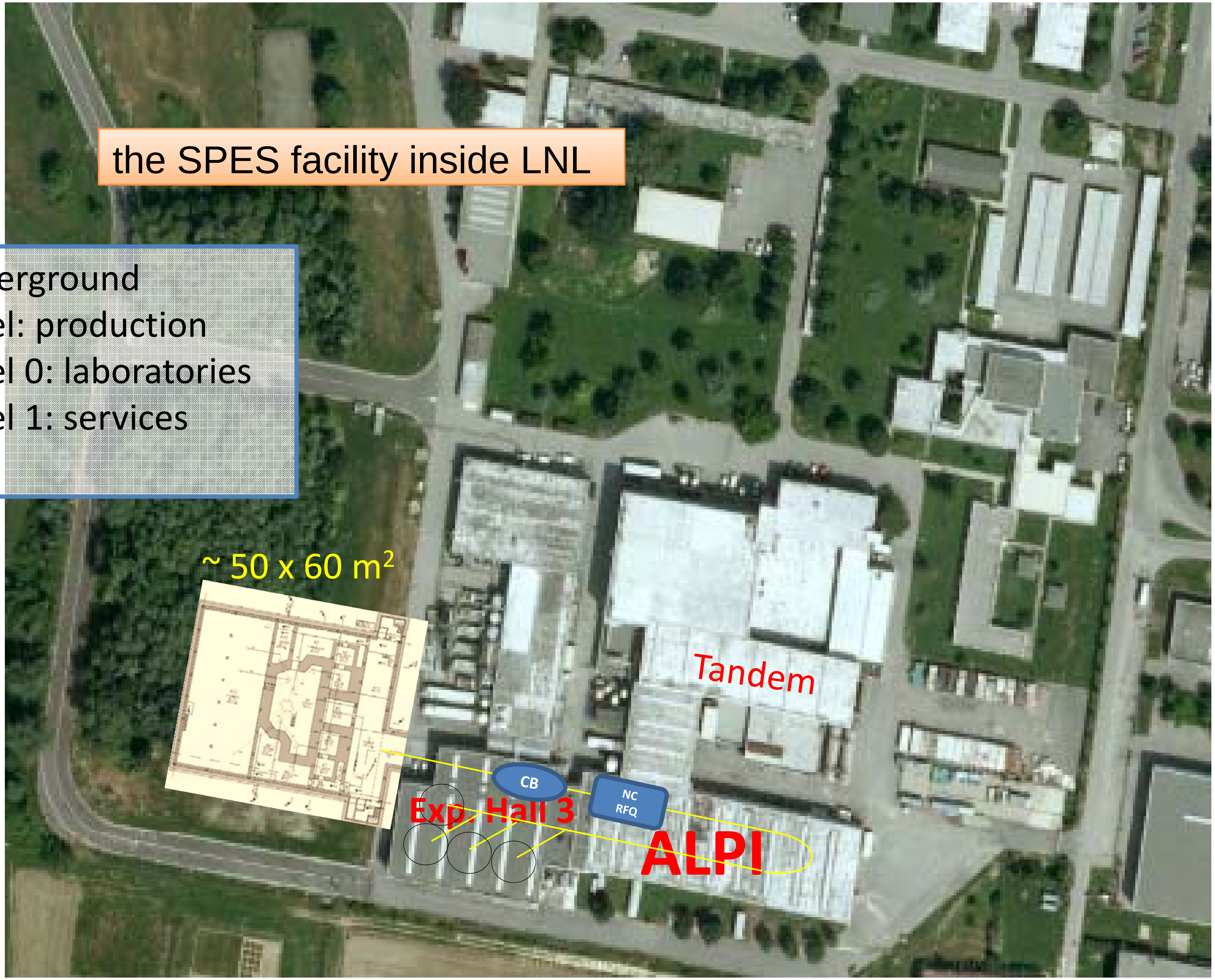
Laboratori Nazionali di Legnaro: site area

More than
200.000 m^2

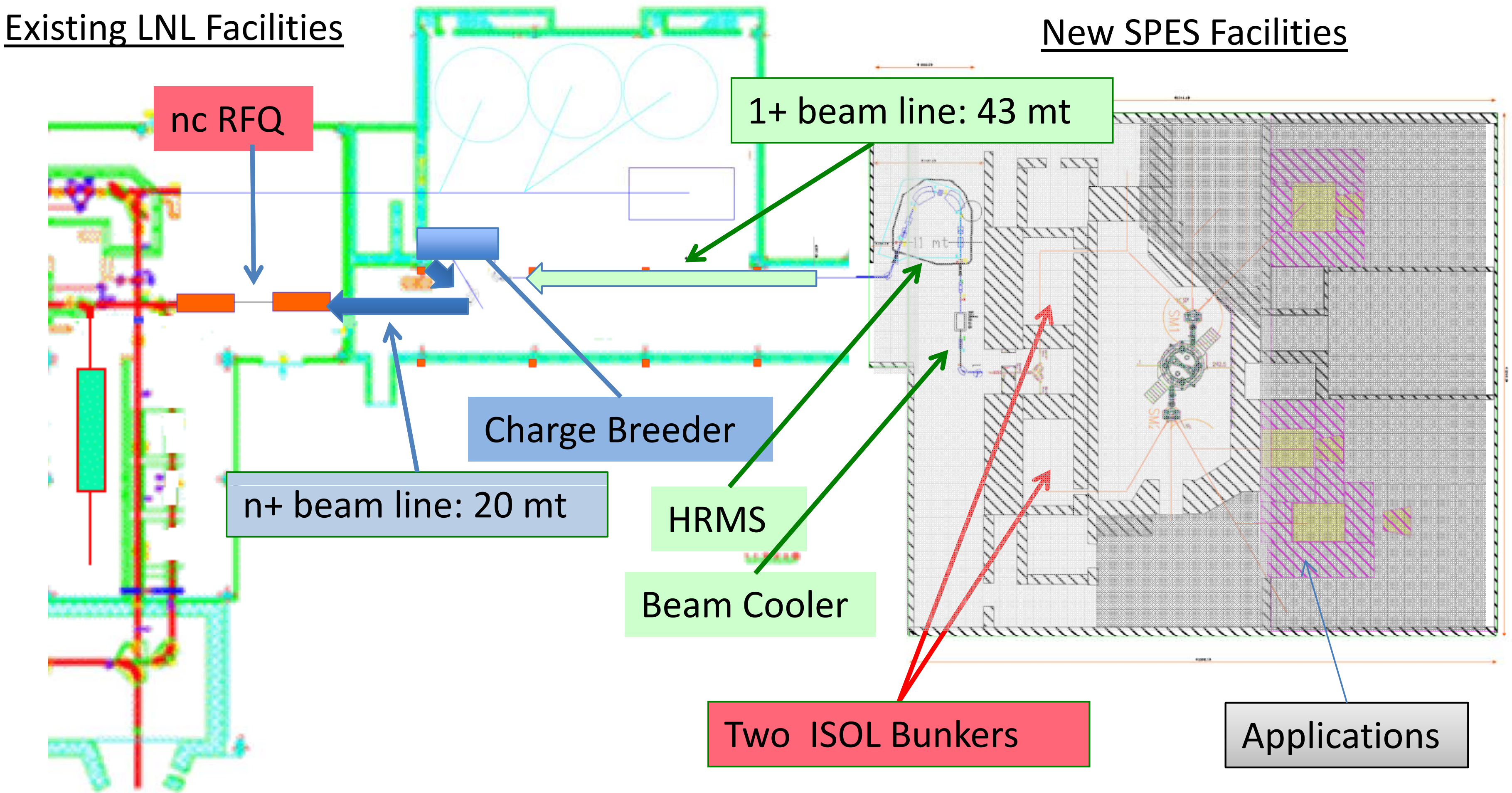
occupied 1/3
available 2/3



SPES Facility Layout



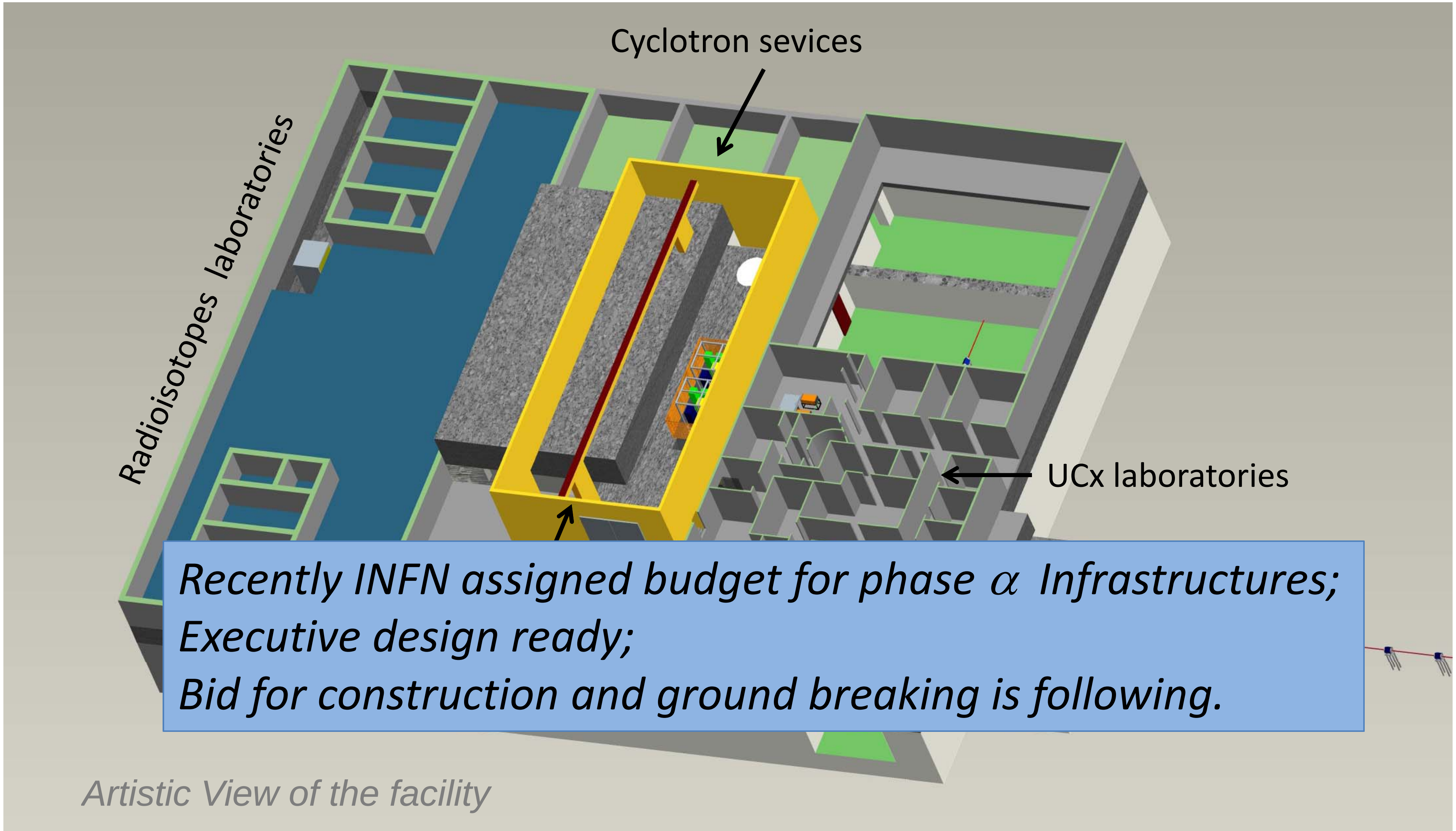
SPES Reviewed Transport Layout



1 *Cyclo&Target building close to Alpi linac; Charge Breeder placed close to nc-RFQ; Transport of 1+ beam in experimental hall3 allows to set-up RIBs experiments at low energy.*

2 *Pre-acceleration with normal conductive RFQ up to 0.7 AMeV (cover PIAVE energy), injection in ALPI*

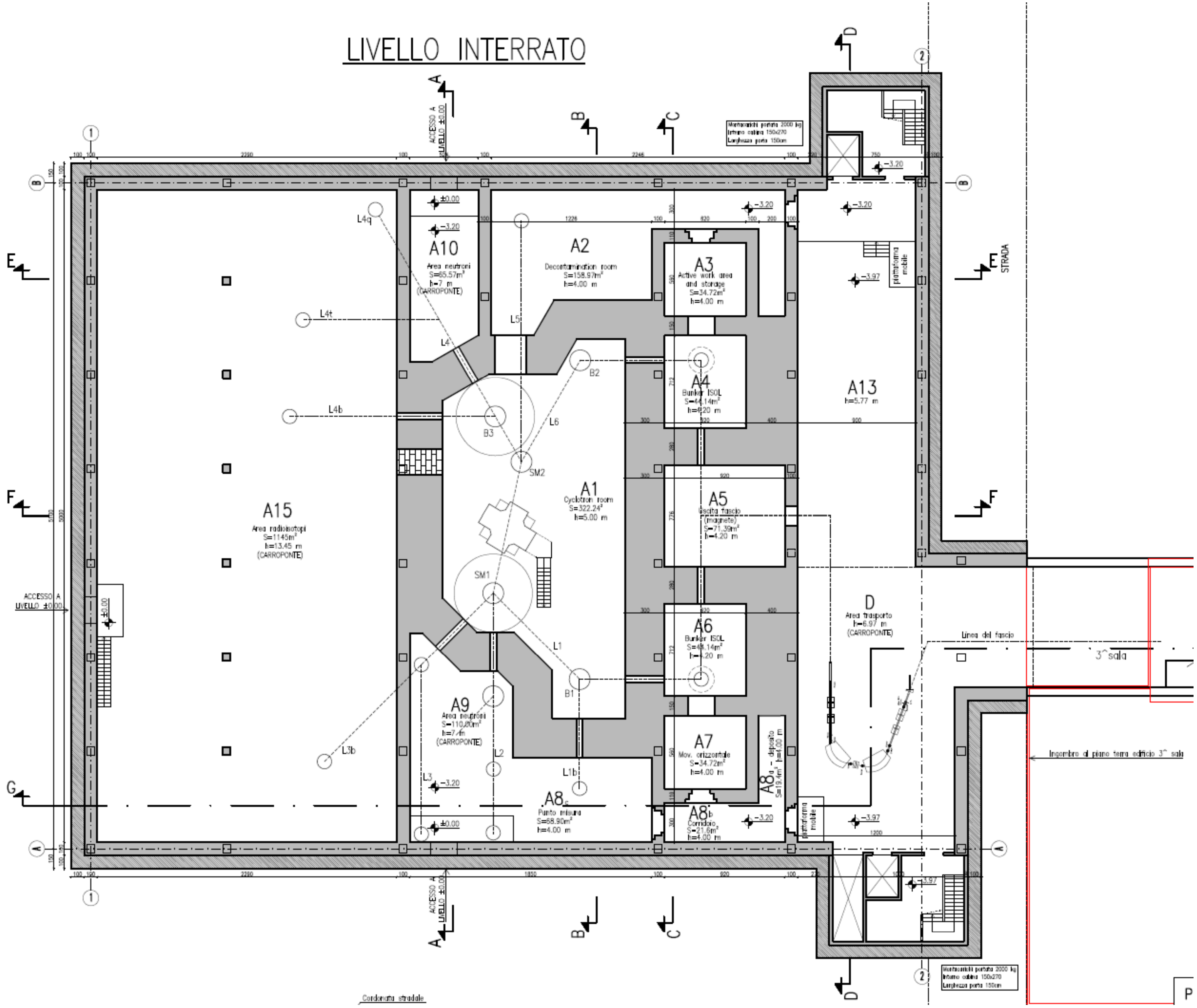
SPES Layout, Level 0



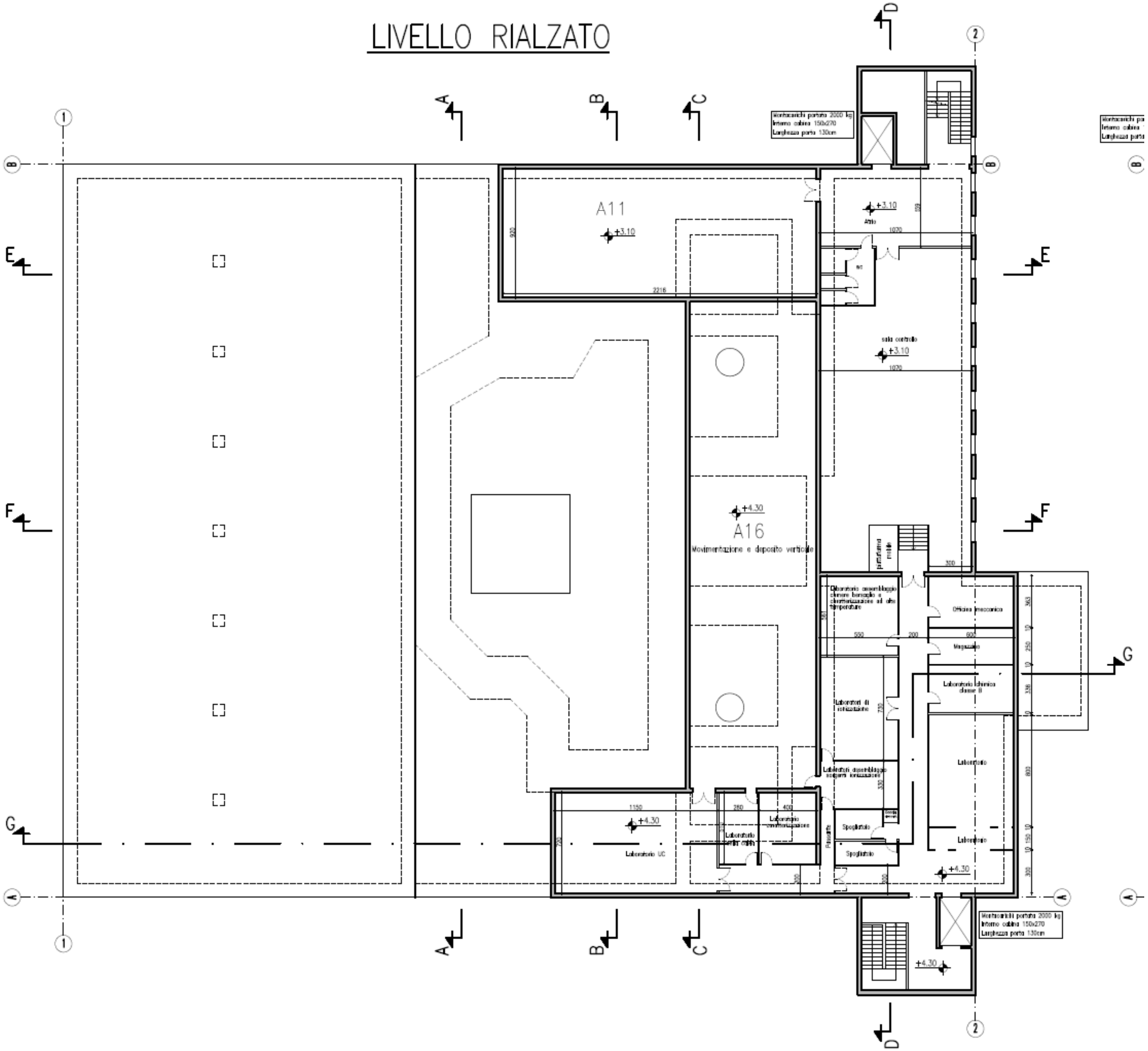
Recently INFN assigned budget for phase α Infrastructures;
Executive design ready;
Bid for construction and ground breaking is following.

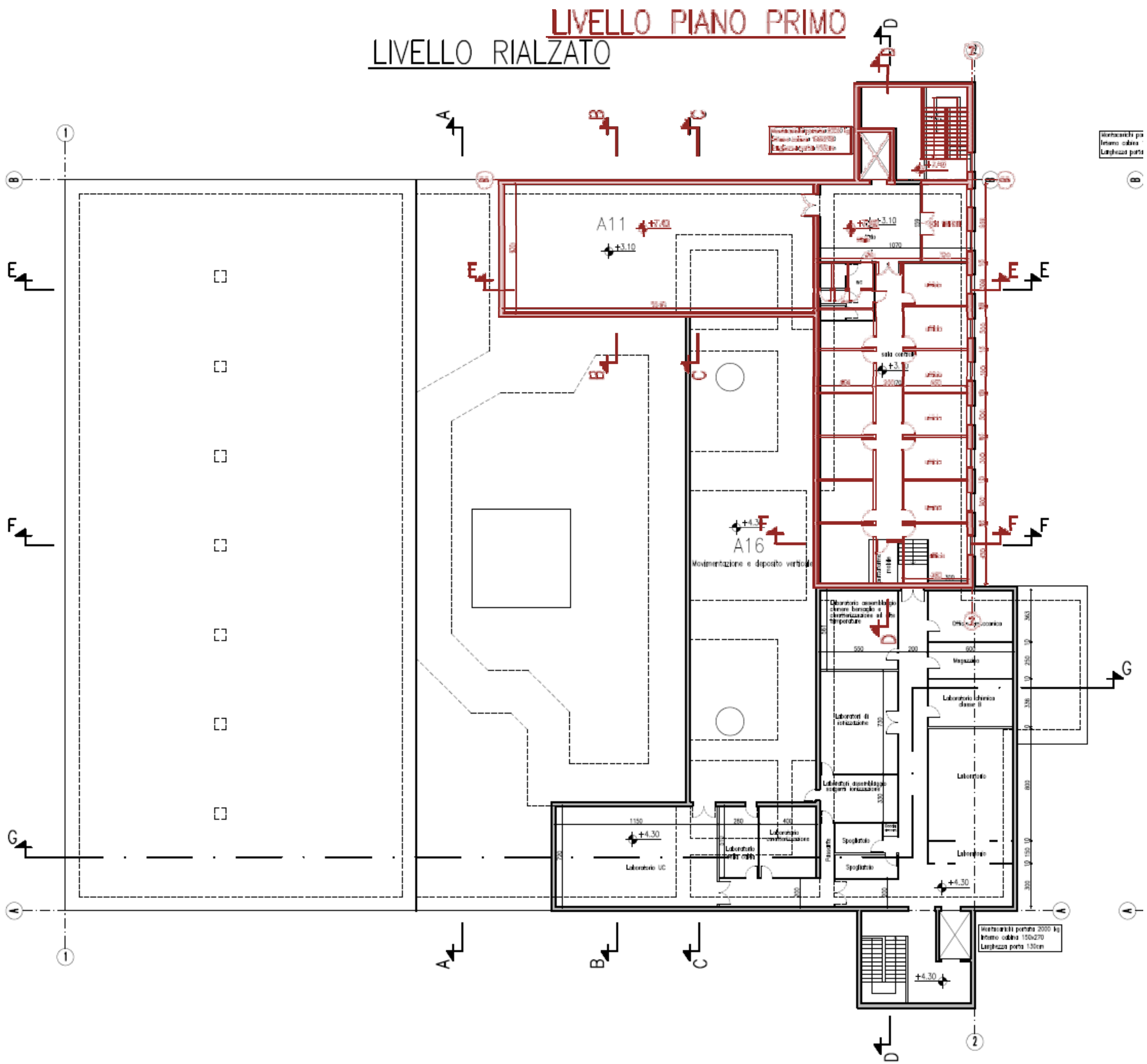
Artistic View of the facility

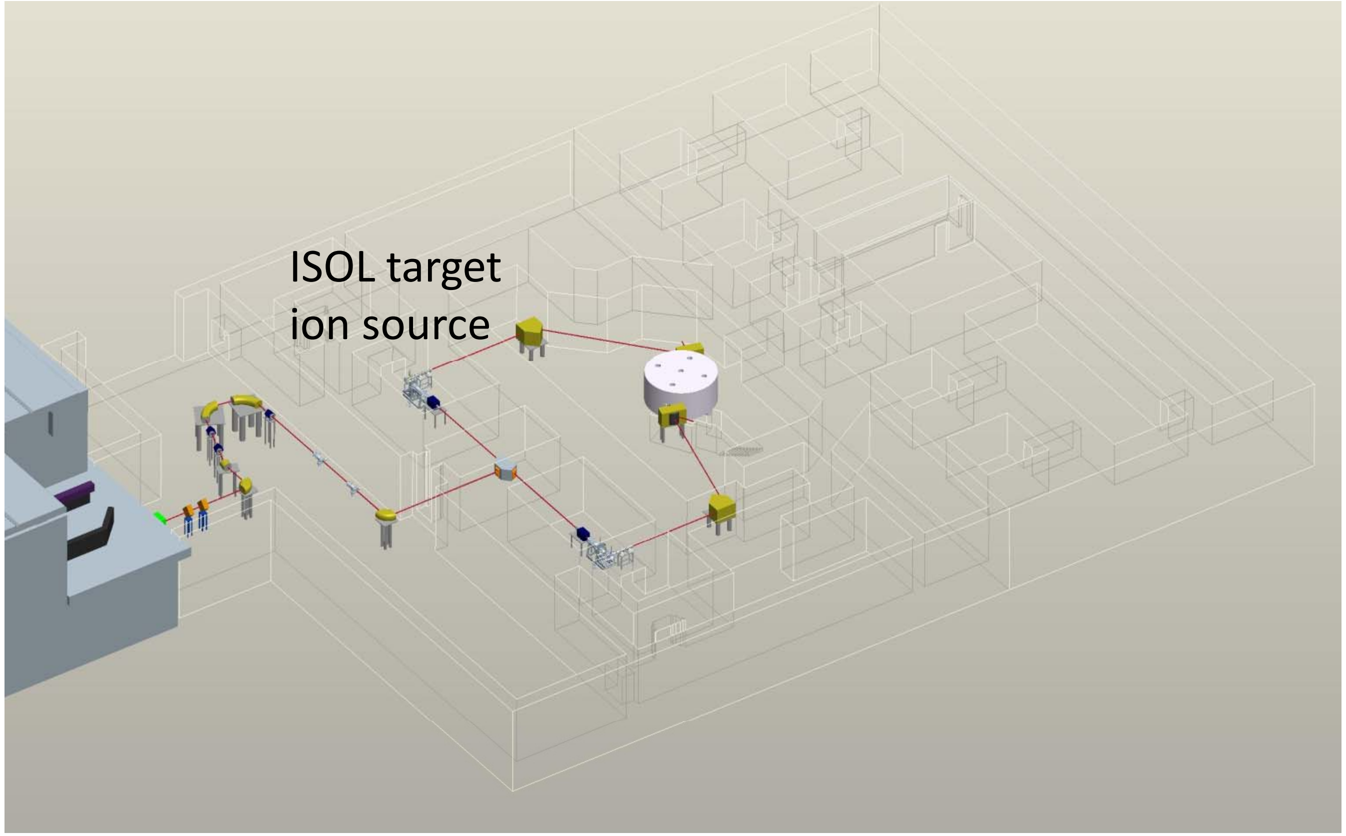
LIVELLO INTERRATO



LIVELLO RIALZATO




LIVELLO PIANO PRIMO
LIVELLO RIALZATO
A11
+7.40
+3.10
A16
+4.30
Movimentazione e deposito verticale
sala controllo
Laboratorio
Laboratorio chimico classe B
Magazzino
Laboratori di ionizzazione
Laboratori assemblaggio sorgenti ionizzazione
Spogliatoio
Passante
Laboratorio contaminazione
Laboratorio UC
Montacarichi portata 2000 kg
Interno cabina 150x270
Larghezza porta 130cm



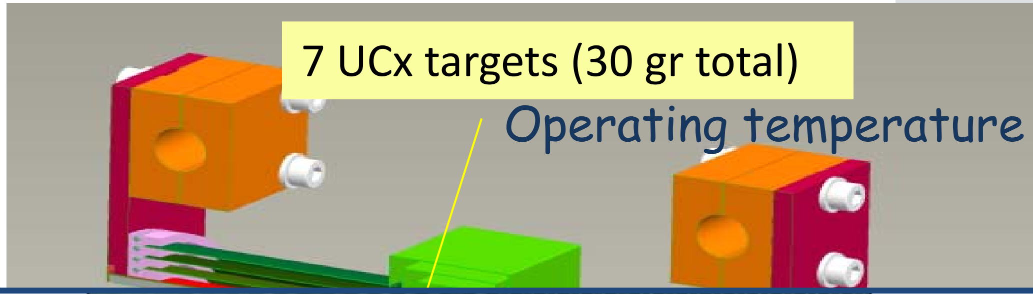
SPES Project

SPES ISOL TARGET-ION-SOURCE

Target Ion Source Complex under characterization

SPES target: operation principle

~ 200 μA → 10^{13} fissions/sec



© 7 UCx SLICES (ρ=3 g/cr

diameter 4cm

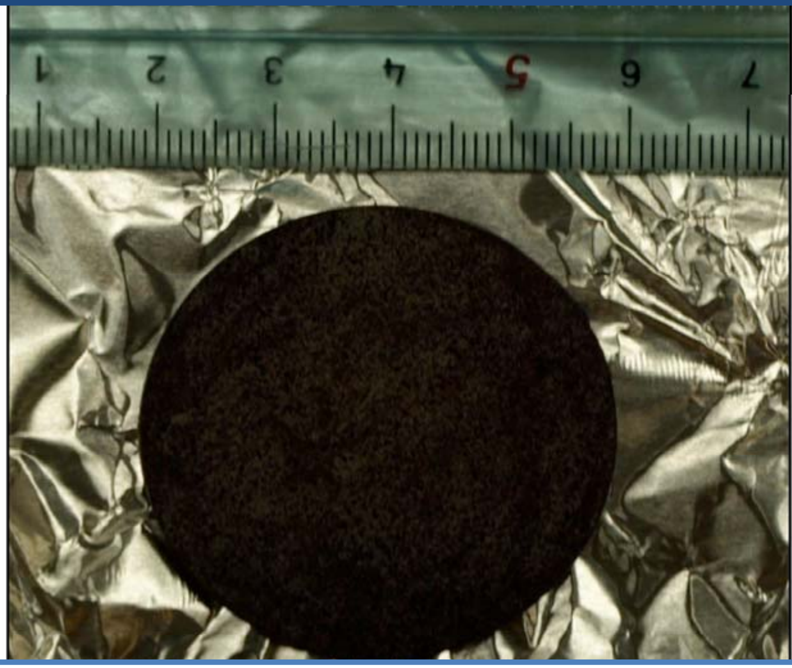
1.3 mm thick each (30gr

Power density in UCx = 14

s, 0.9mm

© 3 graphite DUMP

(slowing down protons wi
fission cross section and h
density)



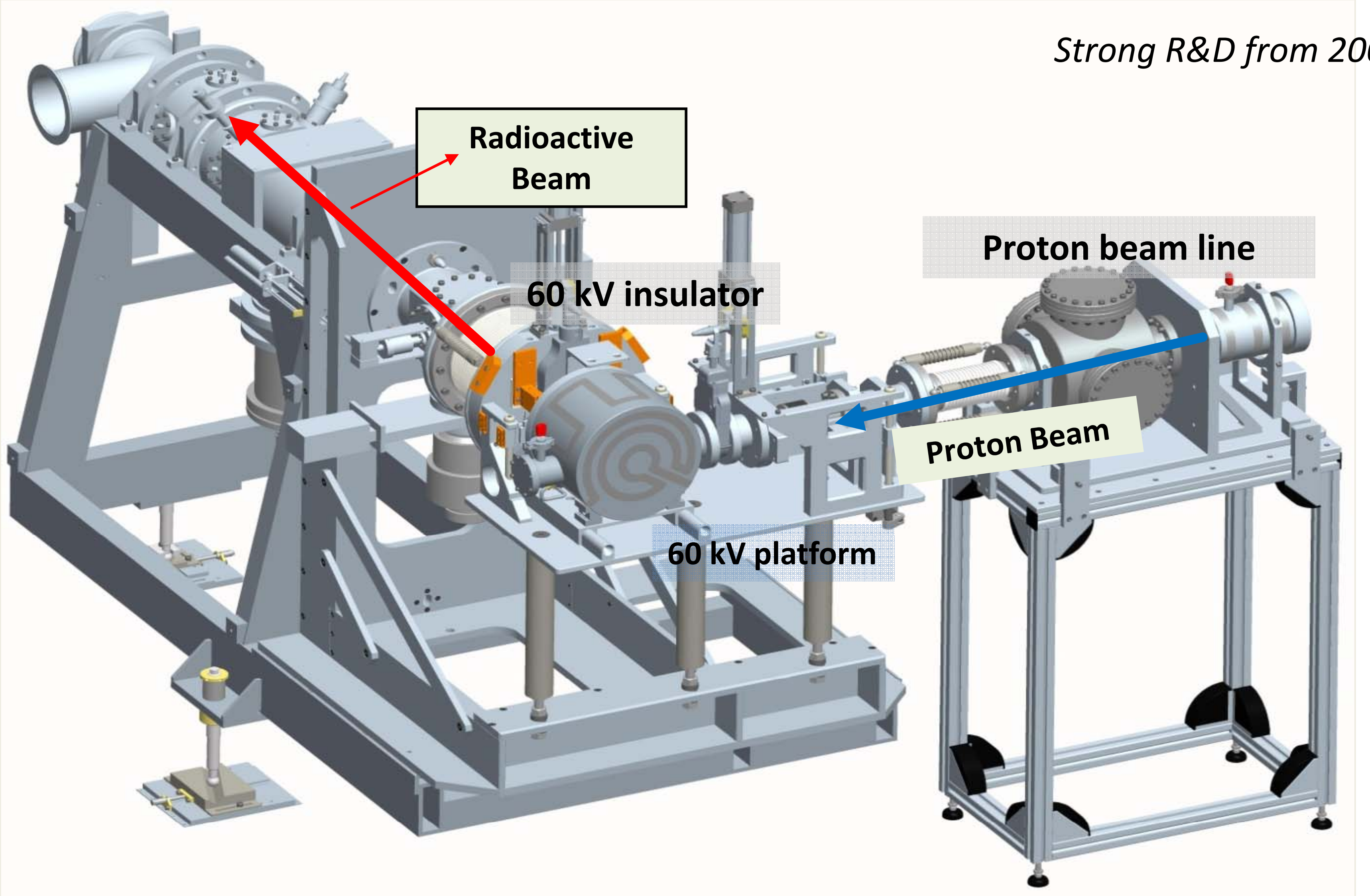
UCx pellets production: 1 mm thick, 40 mm dia

Fig. 5.22: The 40 mm UCx pellet (1 mm thick) after thermal treatment (the average bulk density is about 3 g/cm³).

Three parameters to o
1) a high number of fis
2) a careful simulation ures)
3) a fast isotope releas

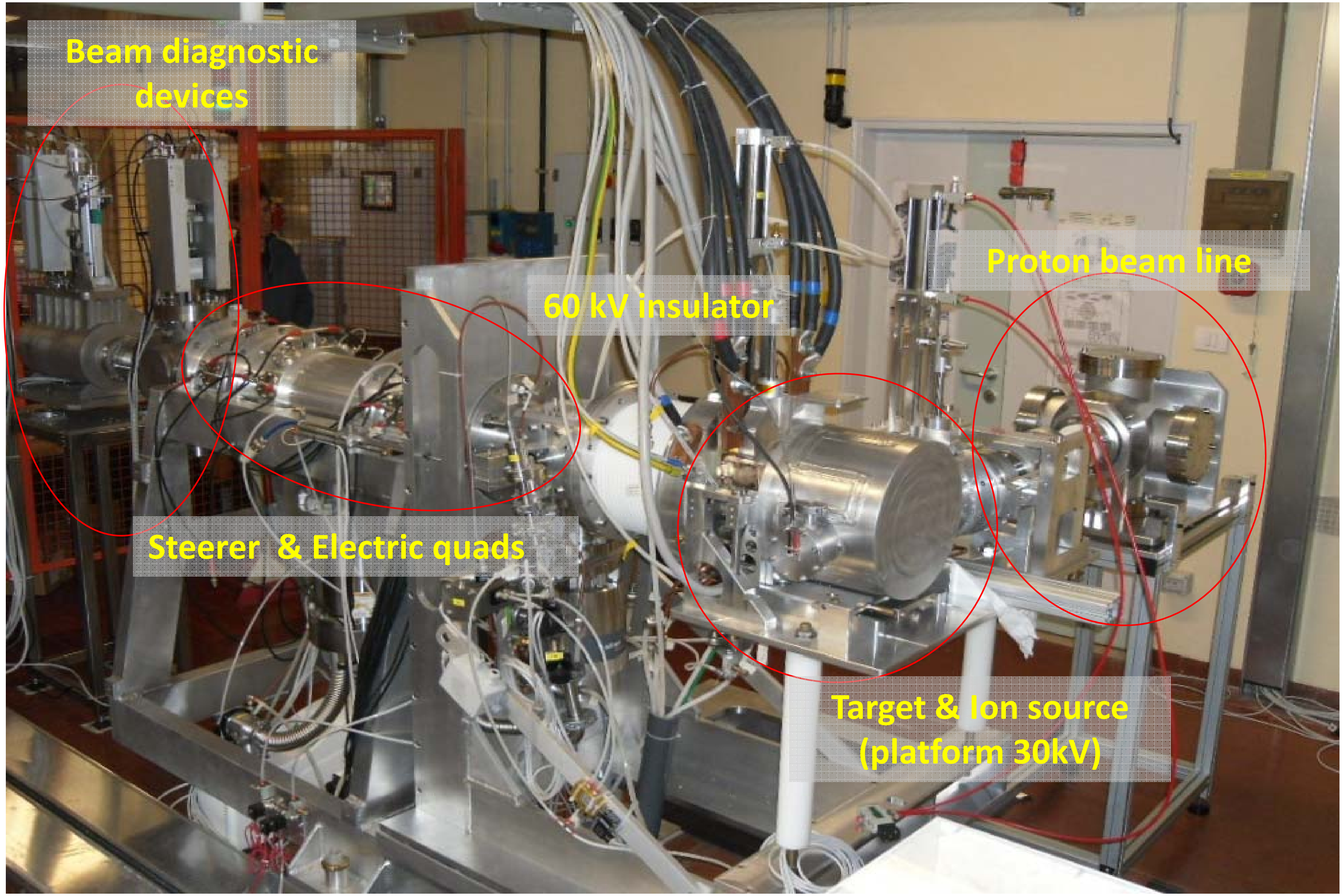
The SPES Front - End

Strong R&D from 2006

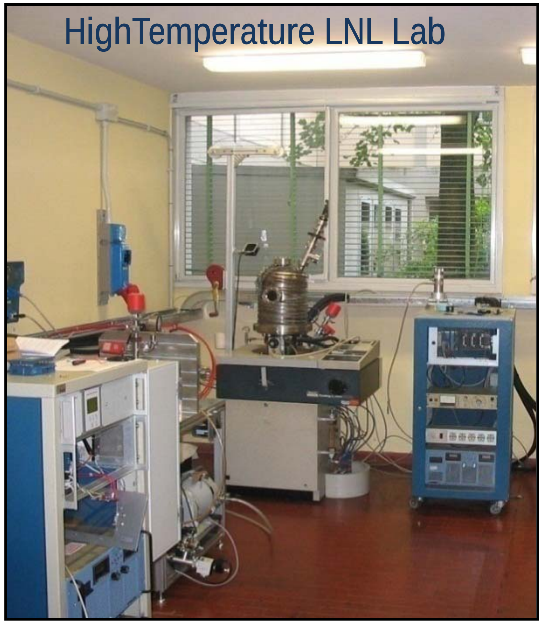


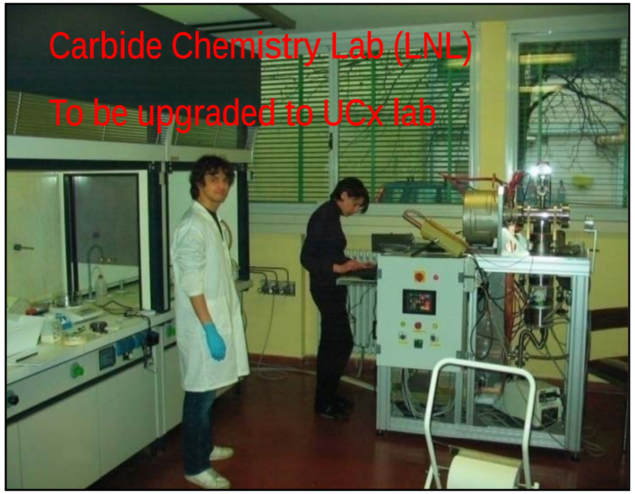
(SPES - ISOLDE collaboration)

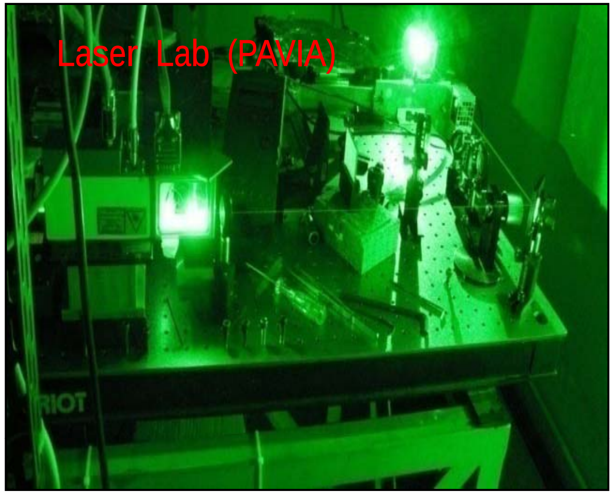
The SPES Front-End is fully operative !



The ISOL SPES Laboratories

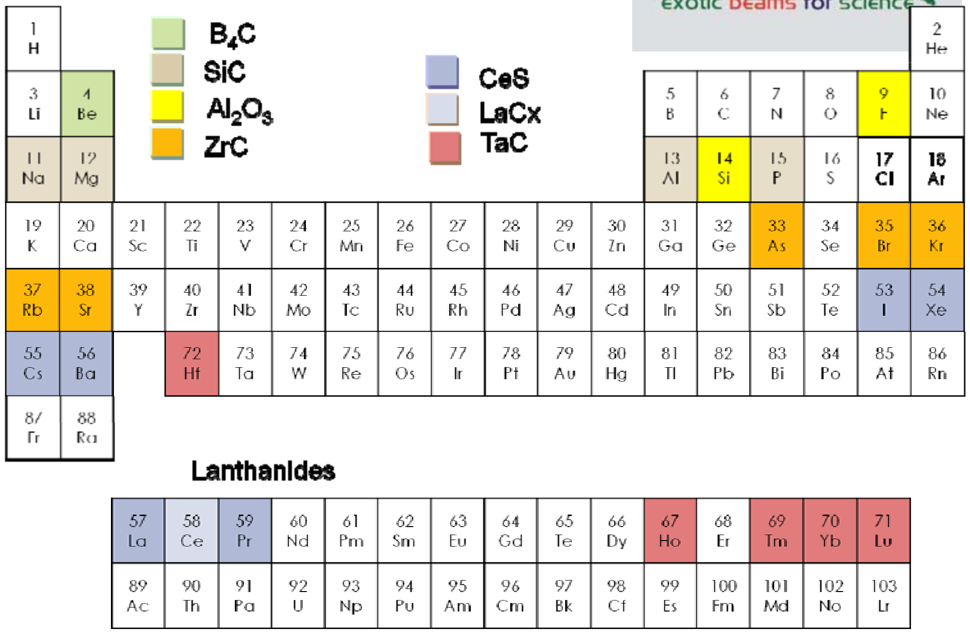




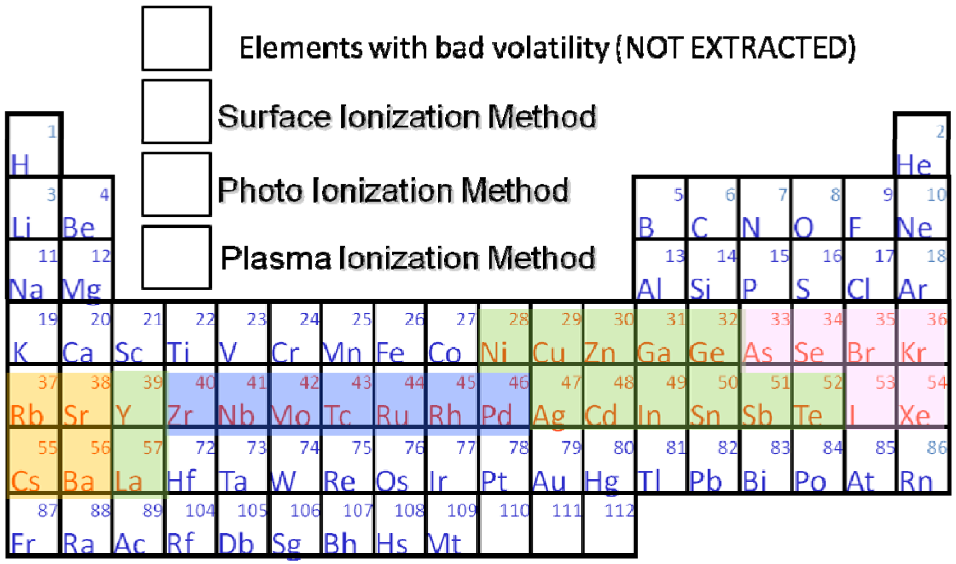


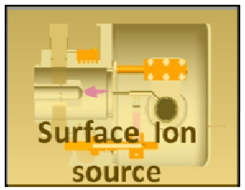
Target materials & ion source development

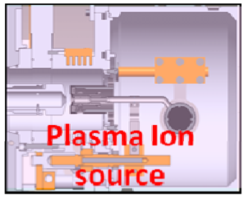
Targets developed for SPES ISOL facility allow to produce a variety of beams in the proton-rich and neutron-rich area



UCx



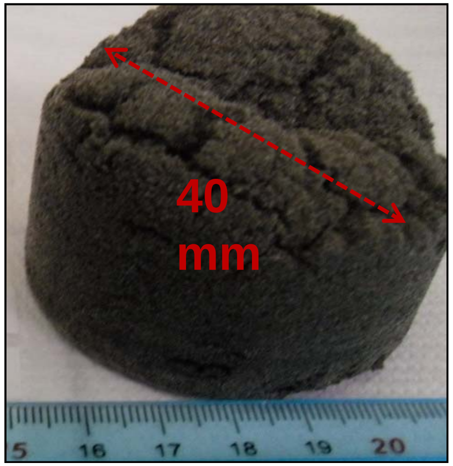




Main fission (p-> ^{238}U) fragments

The BAD VOLATILITY elements are produced and trapped in the target. These elements are highly required for nuclear medicine applications.

Target material development

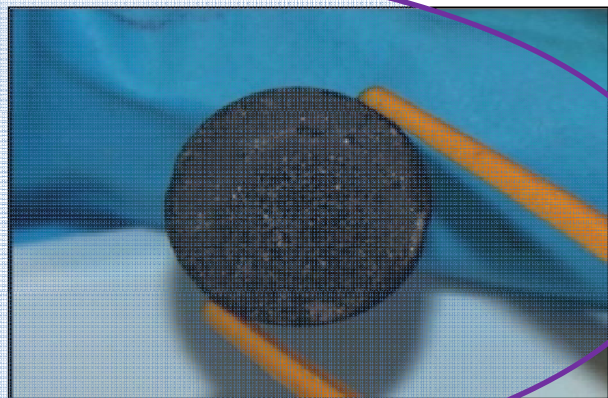


Use of expanding agents
to create porosity

Burn-out of sacrificial filler
to create porosity

**Porous graphite (for effusion tests)
Produced with two different
synthetic routes**

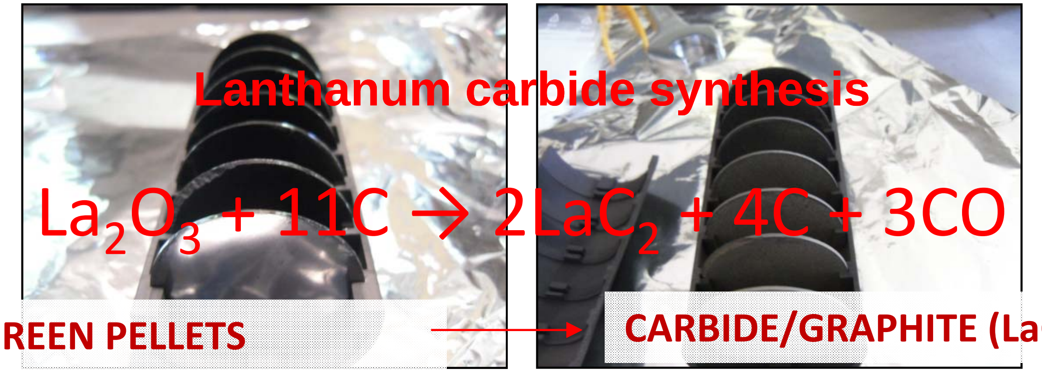
**Advanced
UCx target material**



Lanthanum carbide synthesis

LaC_2

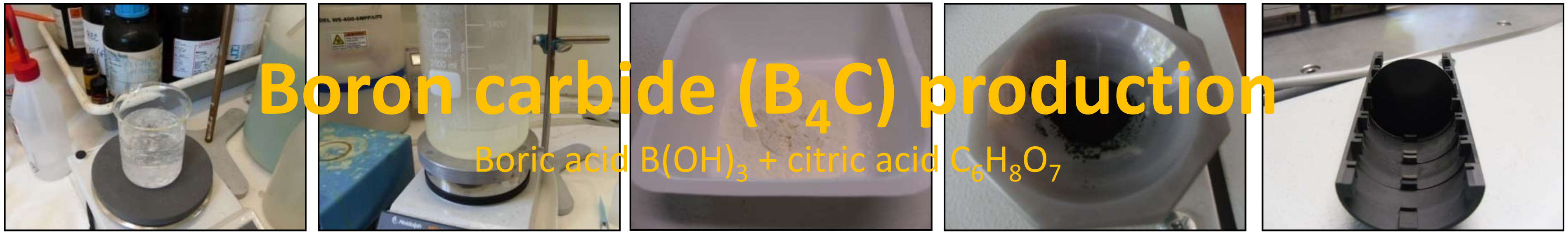
$$La_2O_3 + 11C \rightarrow 2LaC_2 + 4C + 3CO$$



OXIDE + GRAPHITE GREEN PELLETS → CARBIDE/GRAPHITE (LaCx) PELLETS

Boron carbide (B_4C) production

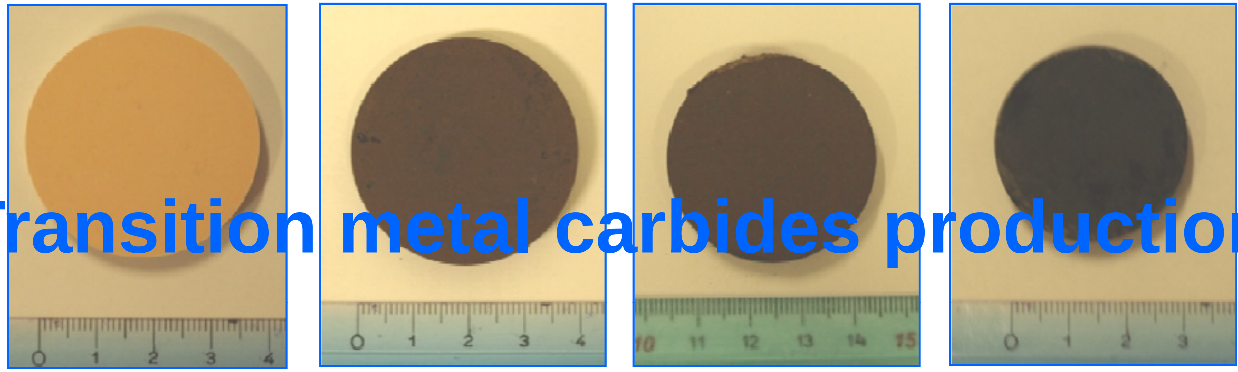
Boric acid $B(OH)_3$ + citric acid $C_6H_8O_7$



Solution of the acid | Gel formation | Grounding of the dried gel | Thermal treated powder | High temperature sintering

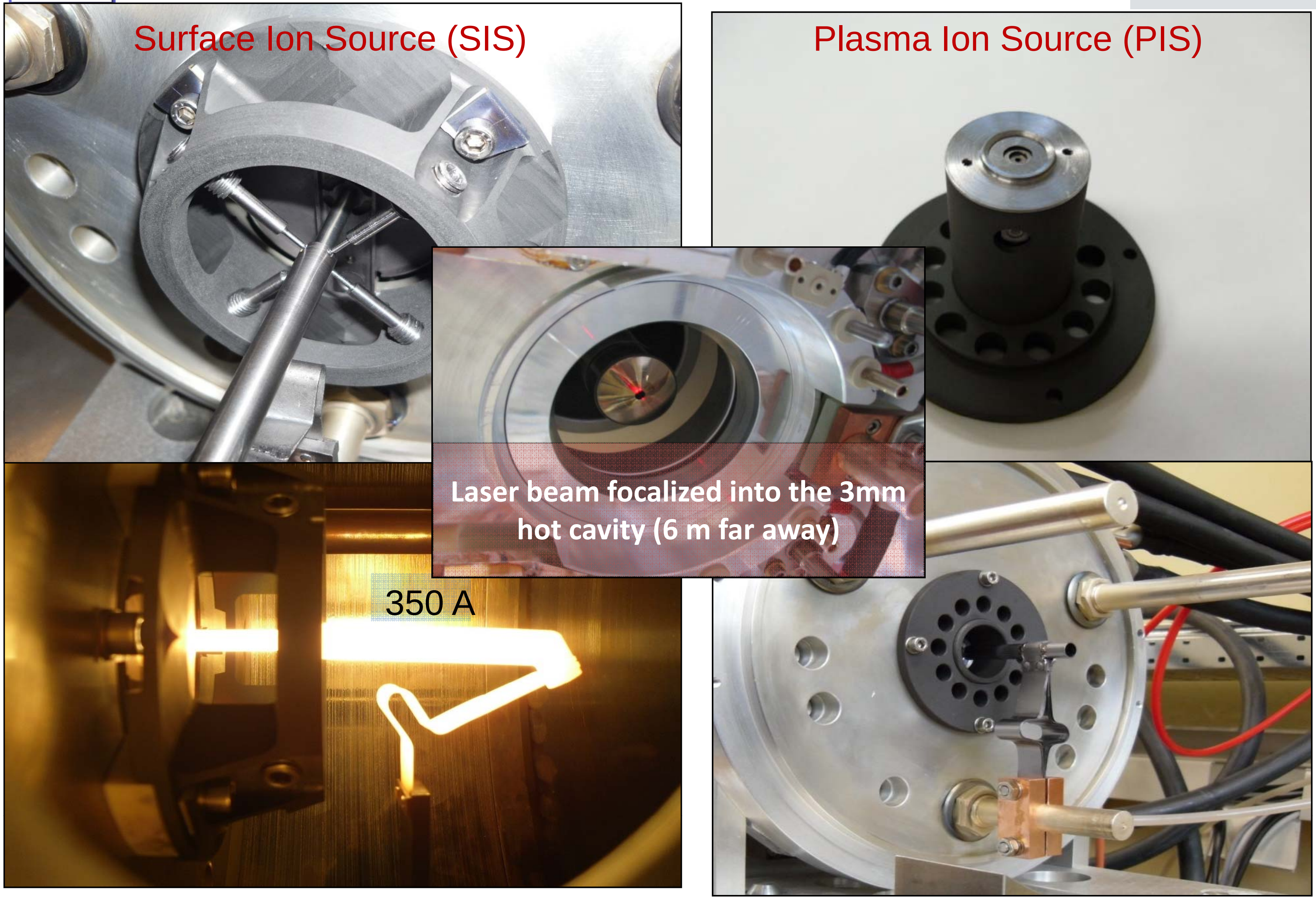
Transition metal carbides production

ZrC foams



As pressed | Post-cured | After burn-out | Final carbide

The SPES Ion Sources

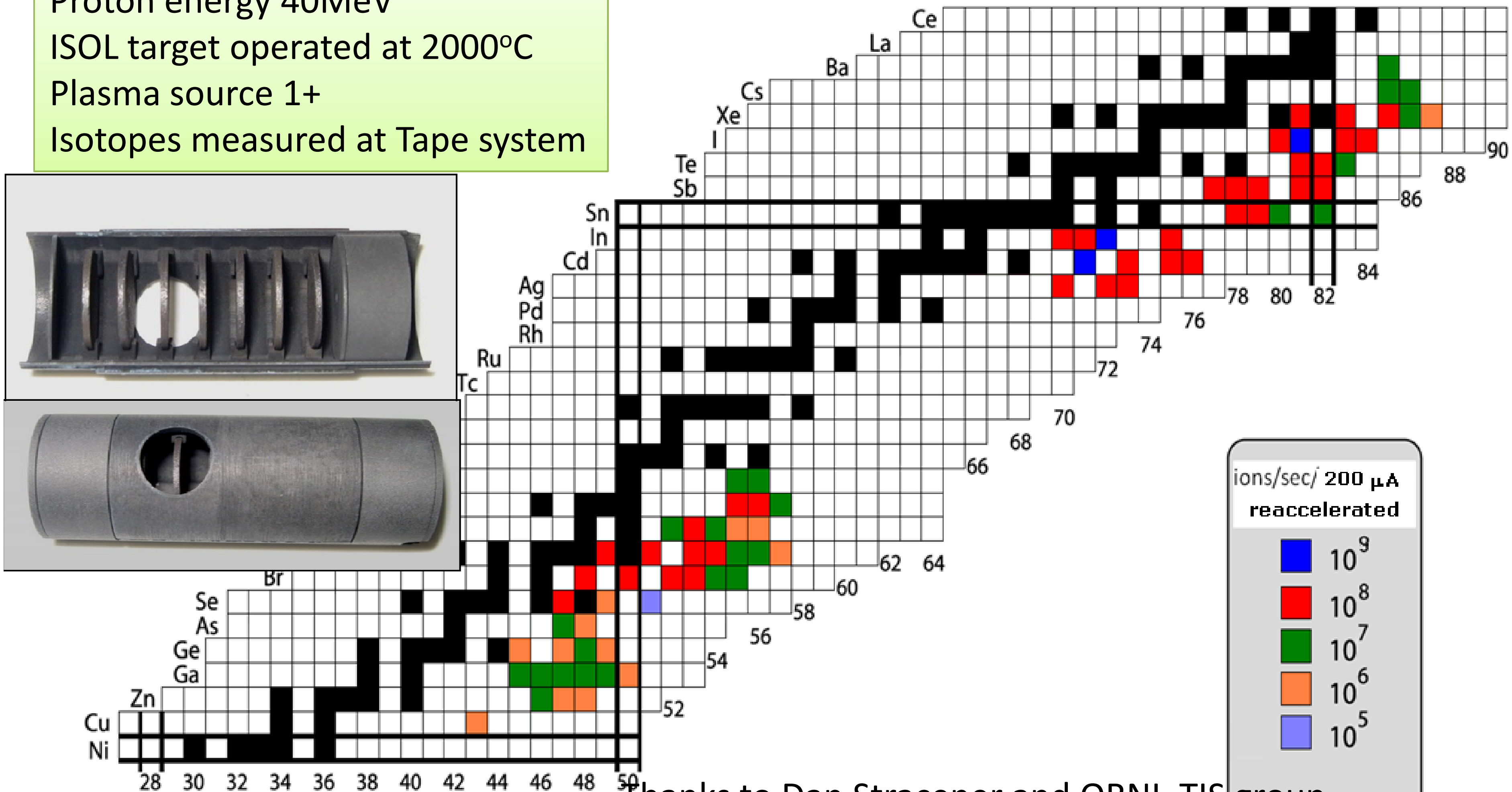


On-line SPES Target
Test experiment at ORNL

Experiment 2010-2011

Proton energy 40MeV
ISOL target operated at 2000°C
Plasma source 1+
Isotopes measured at Tape system

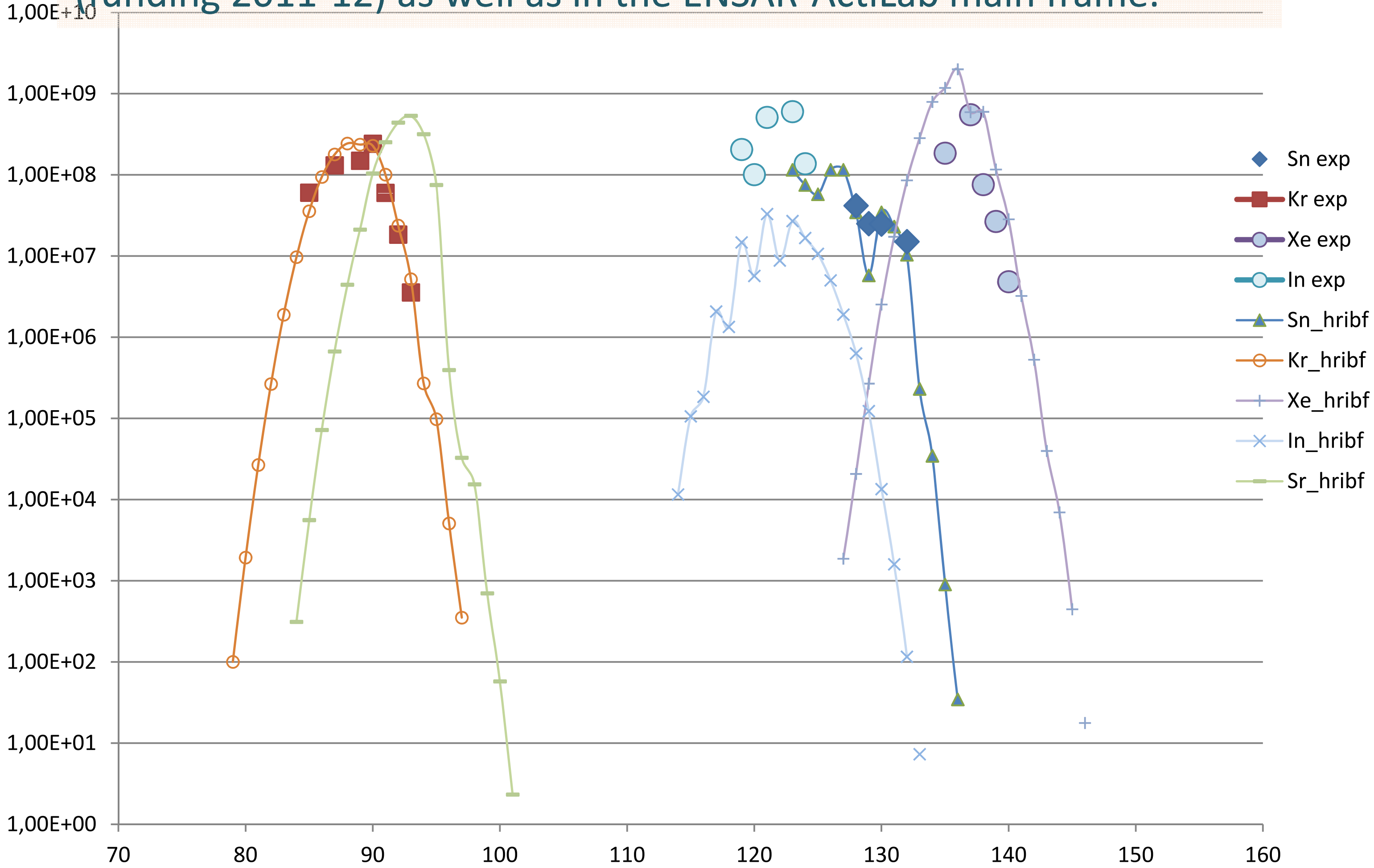
For **expected beam on target,** data are scaled to:
200 microA proton current
2-5% 1+→ N+ & RIB transport efficiency



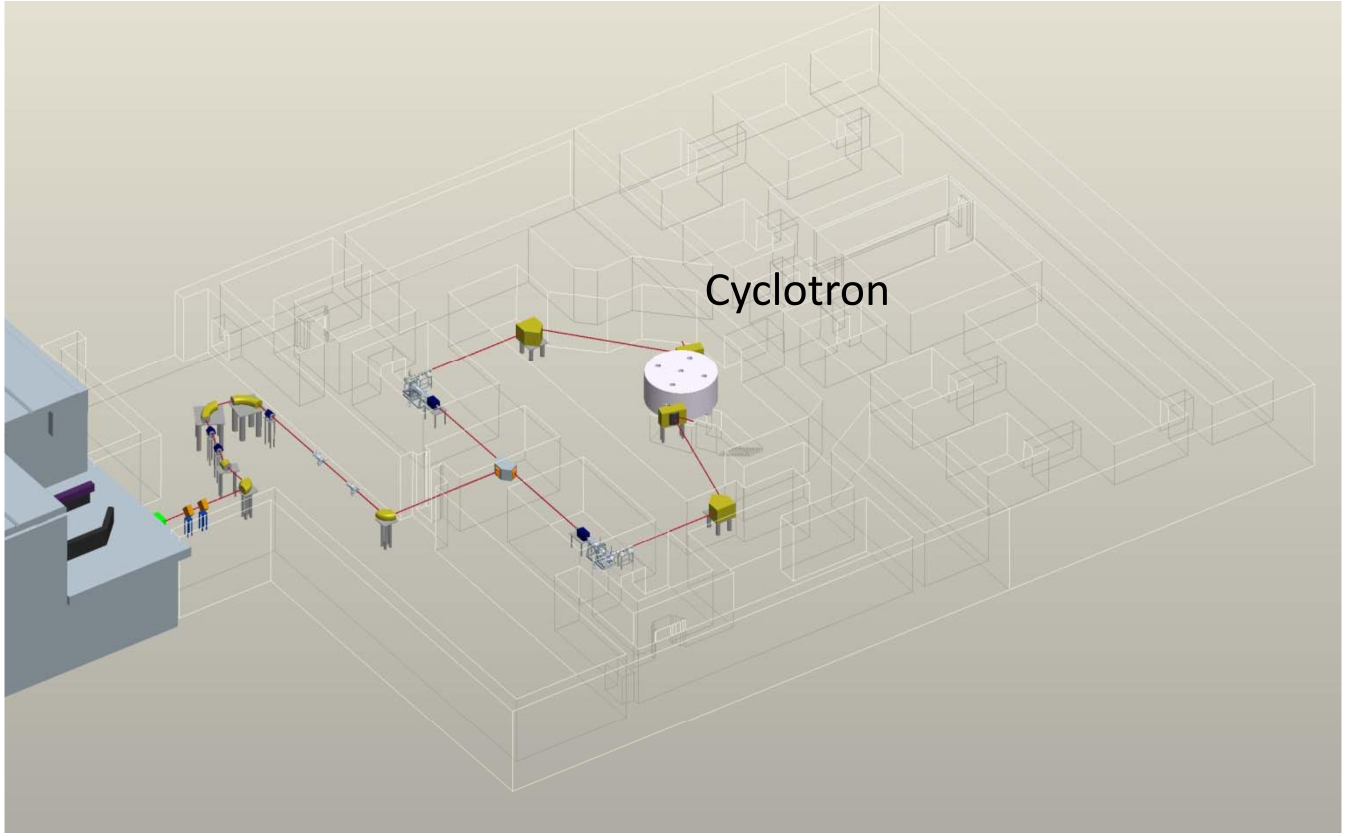
Thanks to Dan Stracener and ORNL-TIS group

Evaluated reaccelerated beams

Experimental work will continue at ORNL and LNS, using the CS proton beam, with the installation of an on-line ISOL test-bench (funding 2011-12) as well as in the ENSAR-ActiLab main frame.



Lines: from HRIBF extrapolation
Solid markers: SPES-target experiment at ORNL



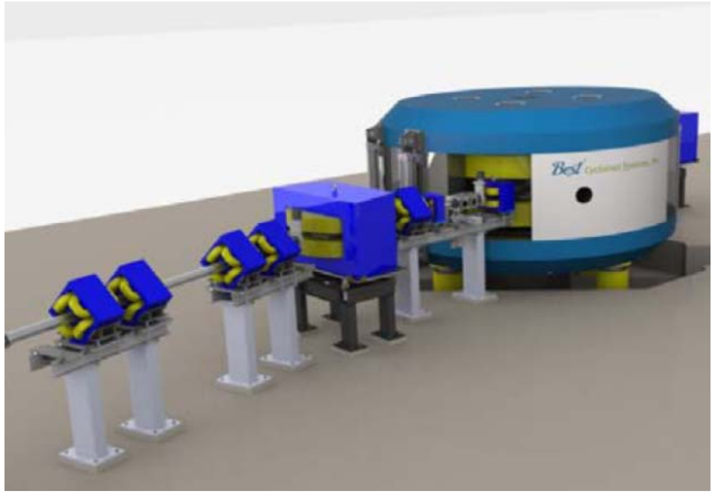
SPES Project

SPES CYCLOTRON

Cyclotron realization in progress

BEST Cyclotron parameters

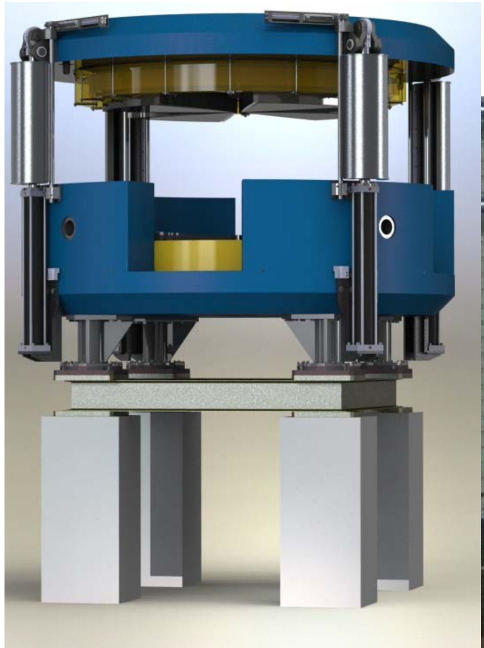
Total Costs:
cyclotron and 1 beam line 10 M€
Delivery 3-4 years (start 28 Oct '10)



Main Dimensions
Diameter = 4.5 m
Height= 1.7 m
Weight = 210 tons

BEST 70 MeV Cyclotron	
Accelerated Particle	H-
Extracted Particle	**Protons**
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 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 e -7 mbar

BEST 70p Model & Magnet



70p Model.

70p Magnet in Japan (Dec 2011)

Best 70p Magnet

70p Magnet in Baltimore.

Machining is planned to begin in Marmen, May 2012.

SPES CYCLOTRON

load work per year

Expected Beam on target: 10600 hours per year.

Over 5000 hours/year of proton beam available for RIB production and 5000 hours/year for applications.

2 weeks per shift

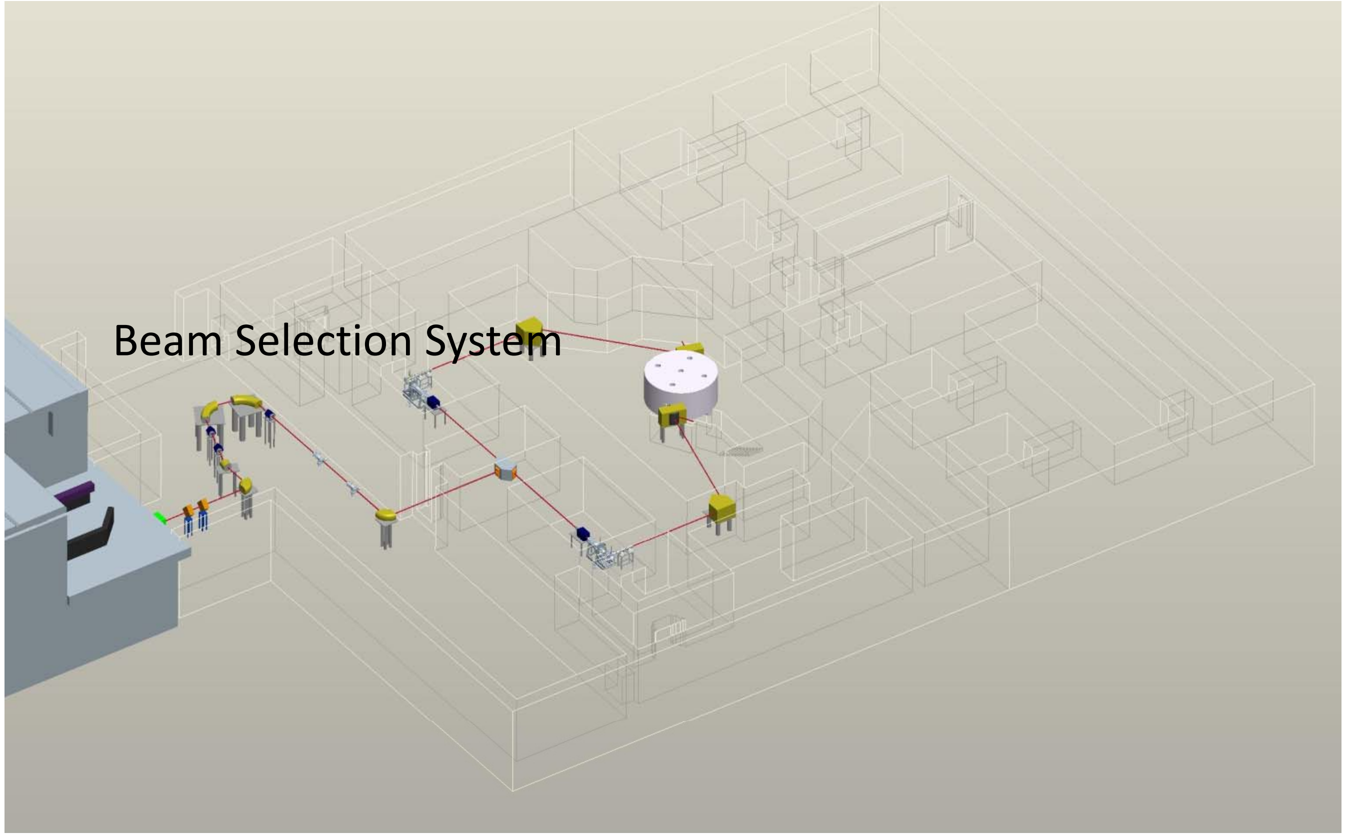
Beam preparation 2 days
Beam on target 12 days

Beam on target →280 hours per shift

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

Beam sharing skeme

	Proton beam	N.rs of SHIFTS	Beam on target: Total 10600 hours
ISOL 1	300μA 40MeV	10	2800
Irradiation 1	500 μA 70MeV	9	2500
Irradiation 2	500 μA 70MeV	10	2800
ISOL 2	300 μA 40MeV	9	2500
Maintanance		7	7x14x24= 2350
Cyclotron Operation		19	19x12x24= 5462 esperiment 19X2x24= 912 beam preparation



SPES Project

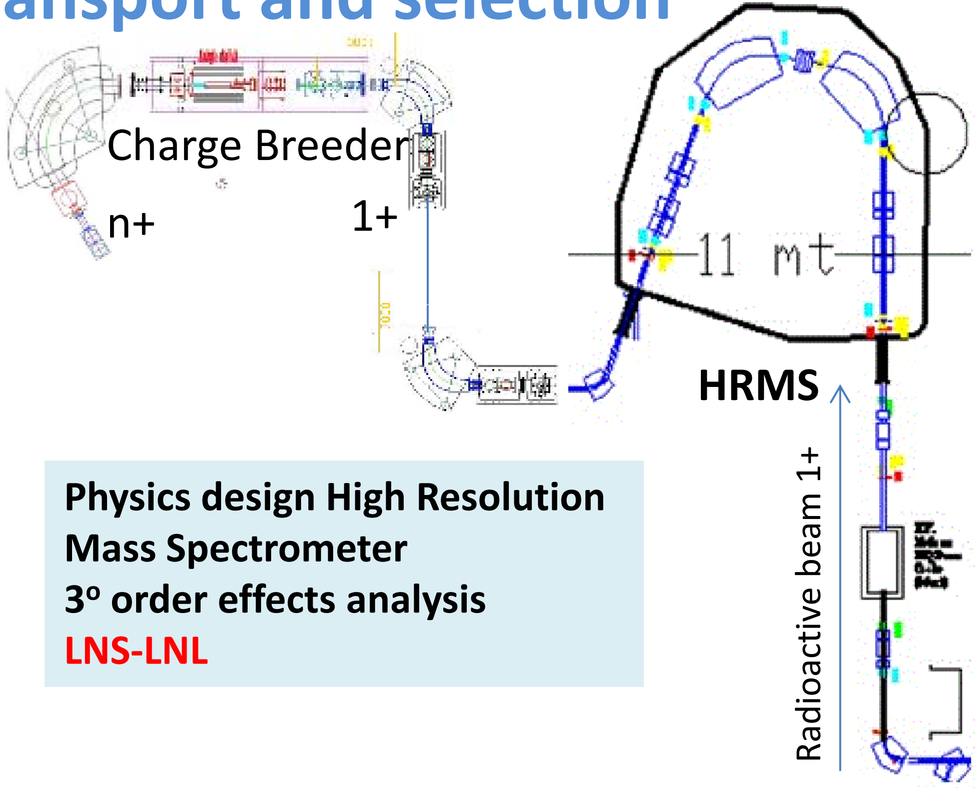
SPES BEAM SELECTION SYSTEM

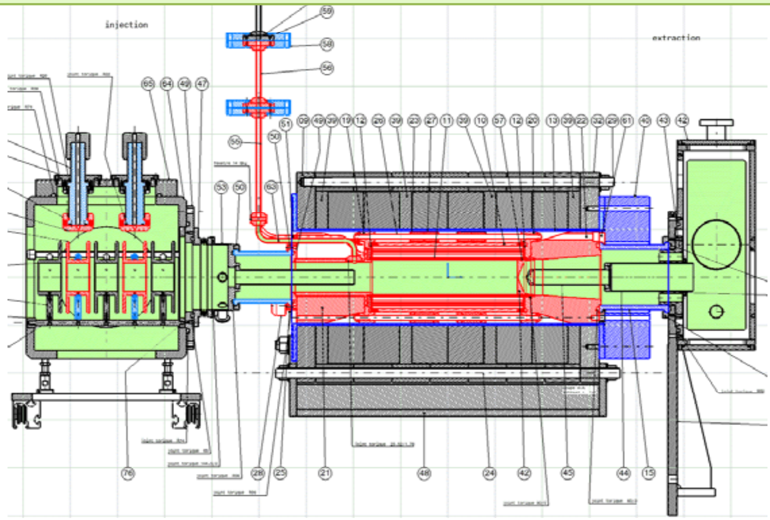
R&D Design studies in progress

Radioactive Beam transport and selection

Development of an upgraded POHENIX booster
Part of MoU GANIL_SPIRAL2 – INFN_SPES

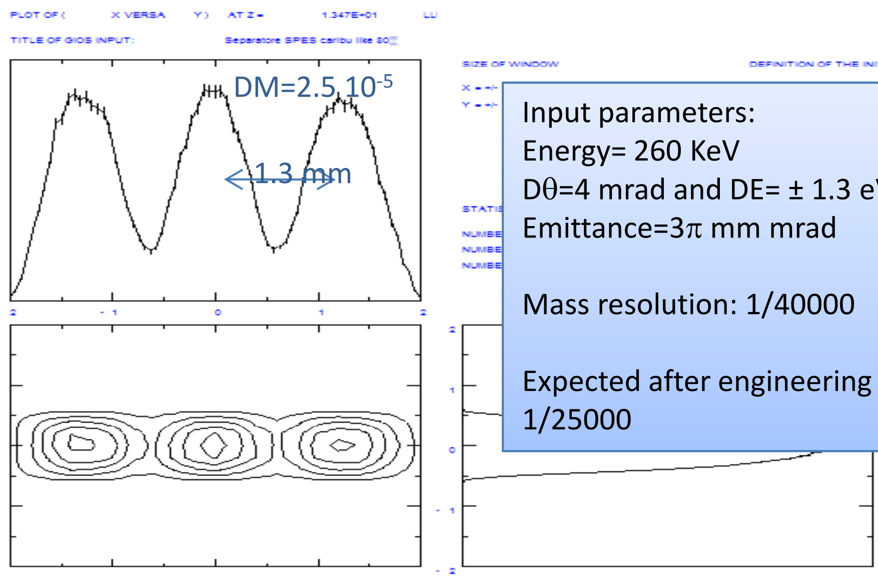
2010 Preliminary measurements
2011 Conceptual design and schedule definition
2012 Design
2013 Construction
2014 Commissioning





Physics design High Resolution Mass Spectrometer
3° order effects analysis
LNS-LNL

INFN-GANIL MoU:
INFN: neutron converter for SPIRAL2
LPCS: Charge Breeder for SPES



Input parameters:
Energy= 260 KeV
Dθ=4 mrad and DE= ± 1.3 eV
Emittance=3π mm mrad

Mass resolution: 1/40000

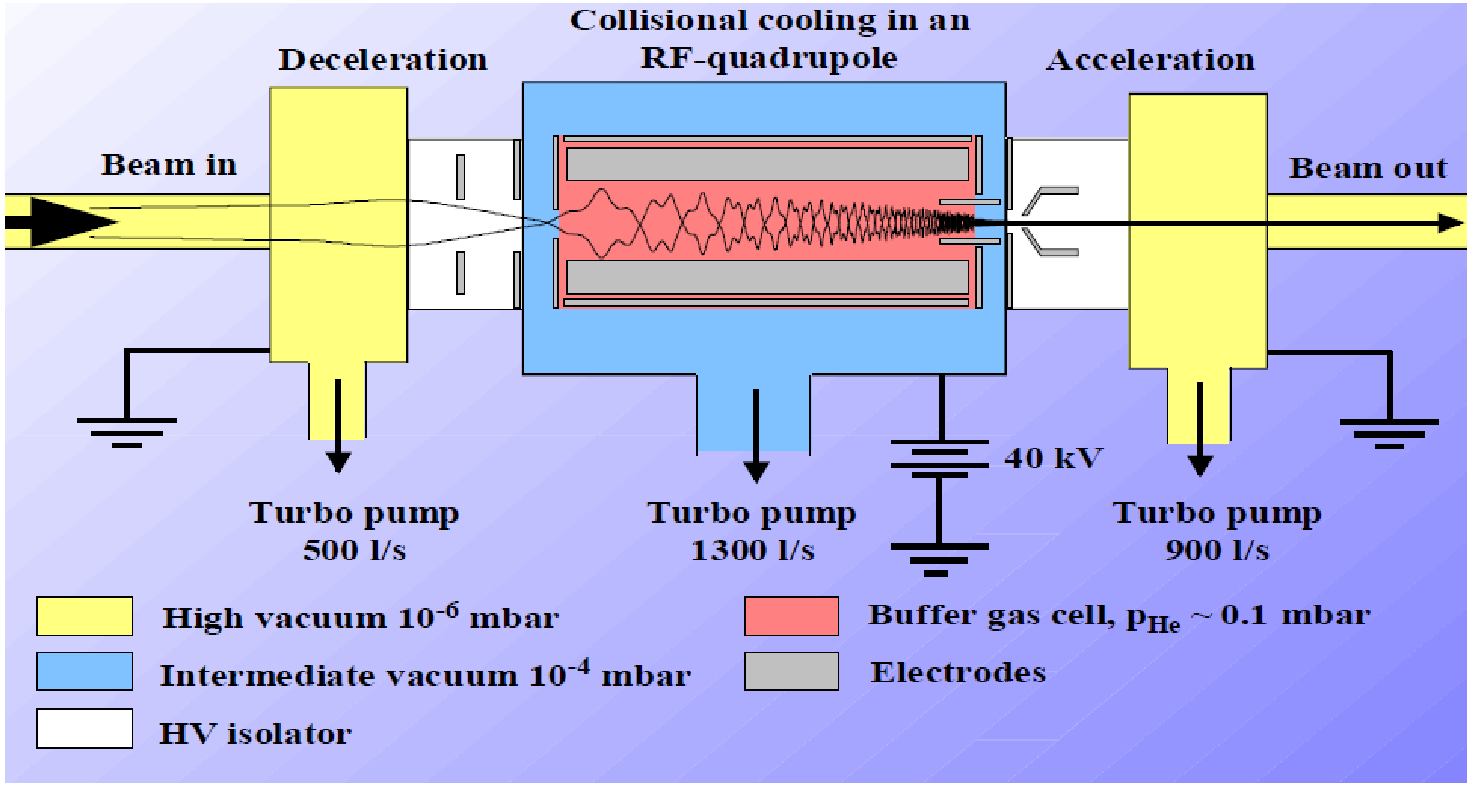
Expected after engineering design: 1/25000

RFQ Beam Cooler

Feasibility study in progress within the INFN experiment

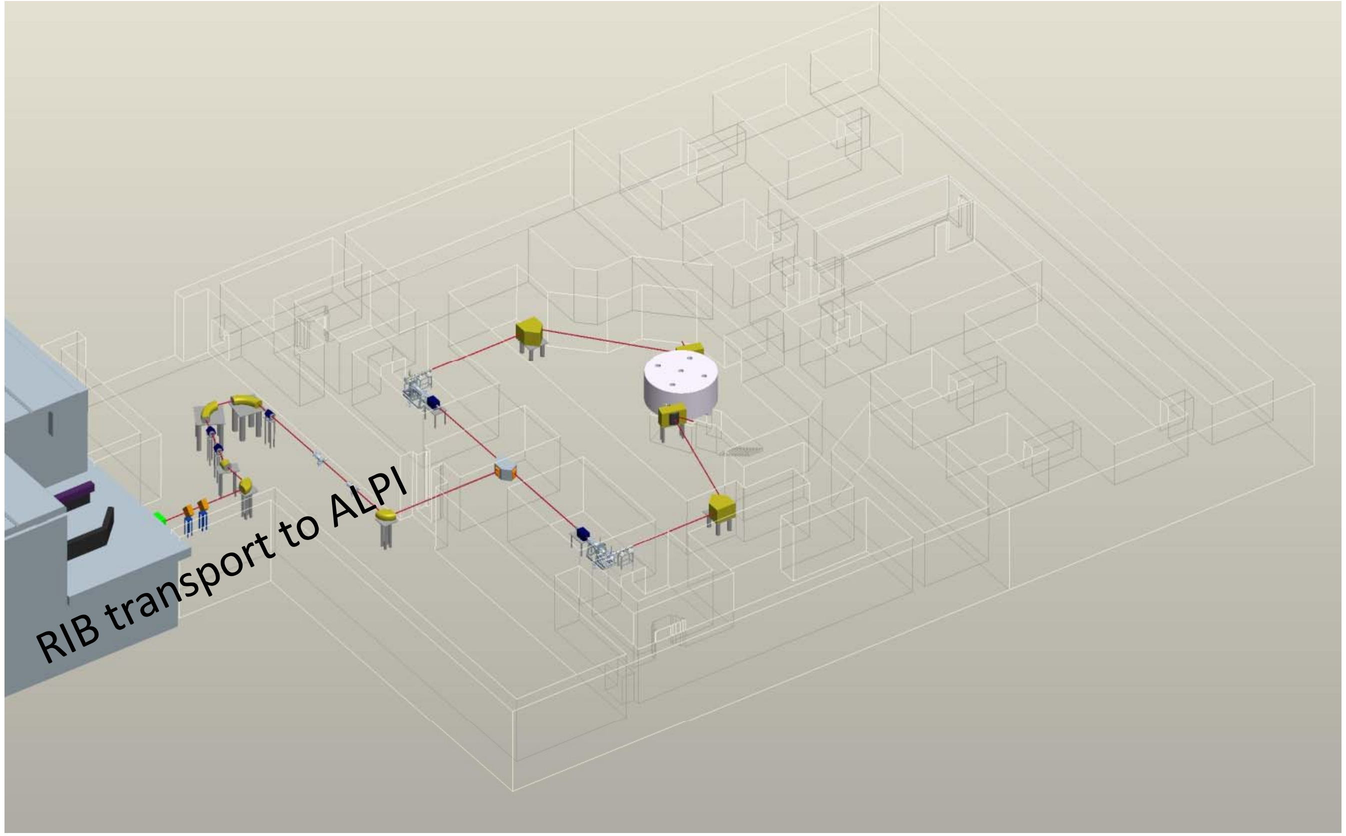
REGATA

R_iduttore di E_mittanza a GA_s TA_mpone



To reduce <u>transversal emittance</u> and <u>energy spread</u>

→ to improve resolving power of Mass separator



SPES Project

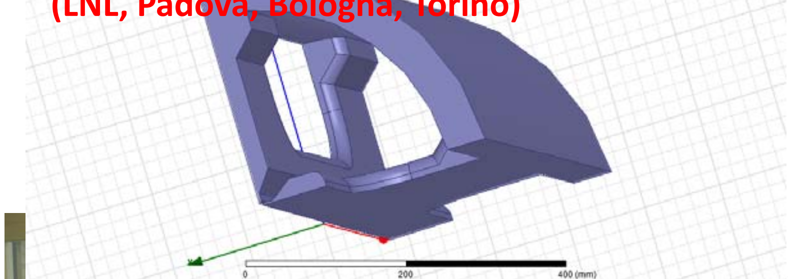
SPES POST ACCELERATION SYSTEM

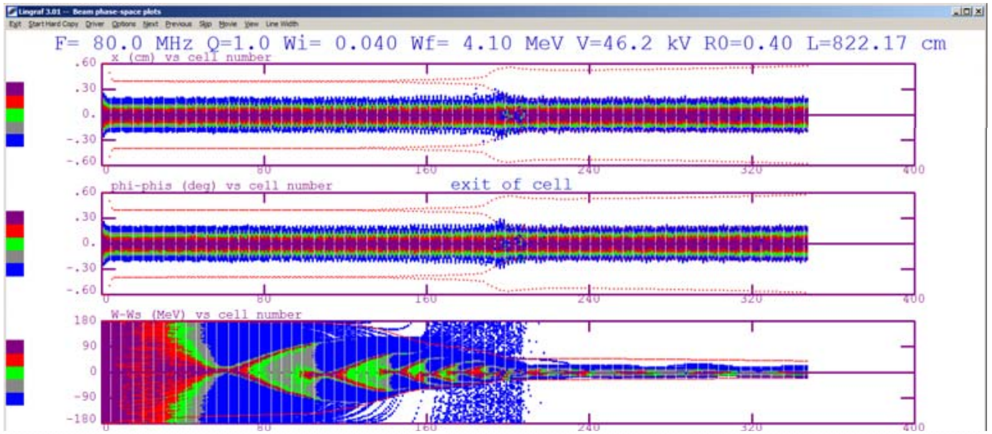
LINAC Upgrade in progress

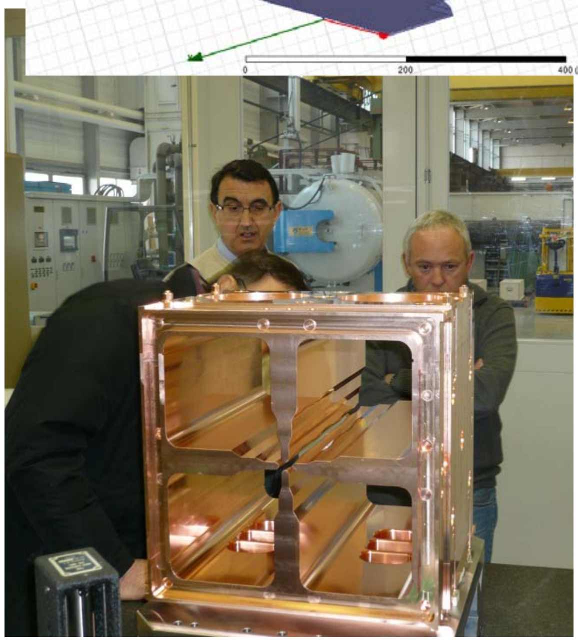
Pre-acceleration by normal conductive RFQ

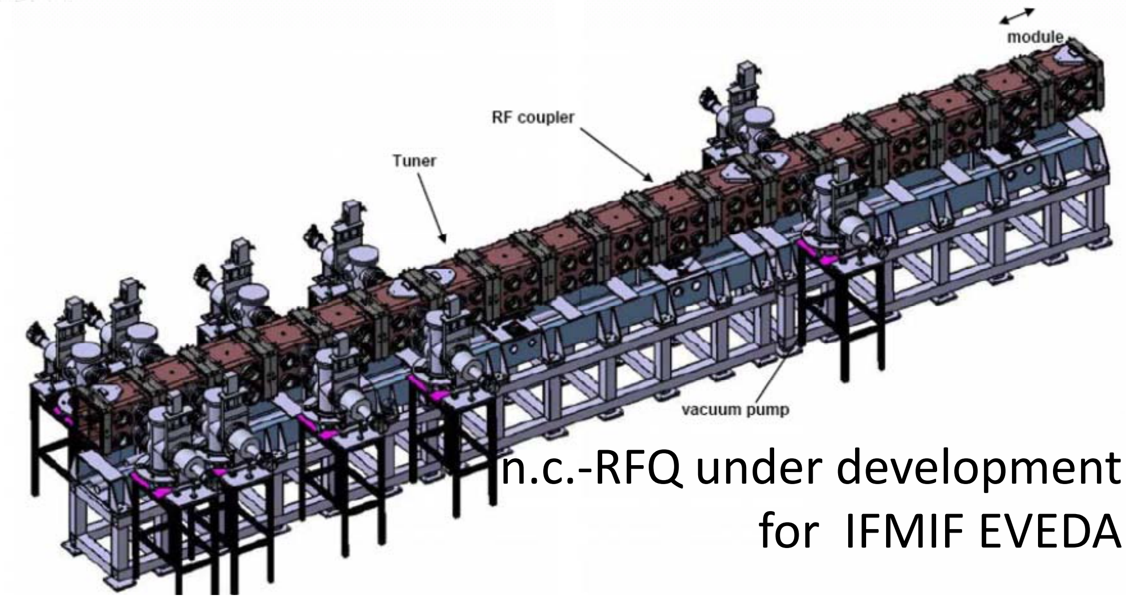
- Energy 5.7 –> 700 KeV/A (A/q=7)
- Beam transmission >95%
- Length 650 cm intervane voltage = 46kV
- RF power Ladder 100 kW Q=9000
- DB Electronics amplifier 100kW CW 80 Mhz as SPIRAL2 RFQ can be used
- Mechanical design and realization takes advantage of IFMIF experience and follows same collaboration (LNL, Padova, Bologna, Torino)

New pre-accelerator to fit ALPI acceptance: development of a 80MHz normal conductive RFQ following the IFMIF-EVEDA technology.









n.c.-RFQ under development for IFMIF EVEDA

ALPI Low-Beta Cavity Upgrade

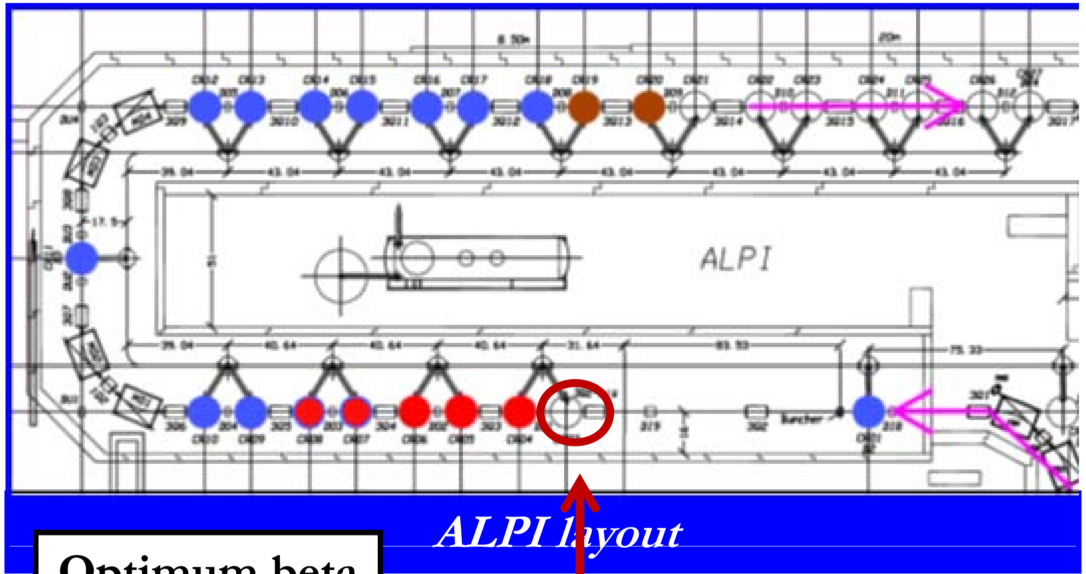
Motivation: to achieve at least **10 MeV/A up to A/q=7**
most beam species, up to the heaviest, with a more efficient linac
better beam dynamics → higher beam transmission

- **Starting situation: 20 QWRs in 5 cryostats**

  E_a ~ 3 MV/m (limited by rf system) - total accelerating voltage ~ 11 MV

- ***After upgrade: 24 QWRs (one more cryostat with 4 cavities)***

  E_a = 5 MV/m (upgraded rf system) - total accelerating voltage ~ 21 MV

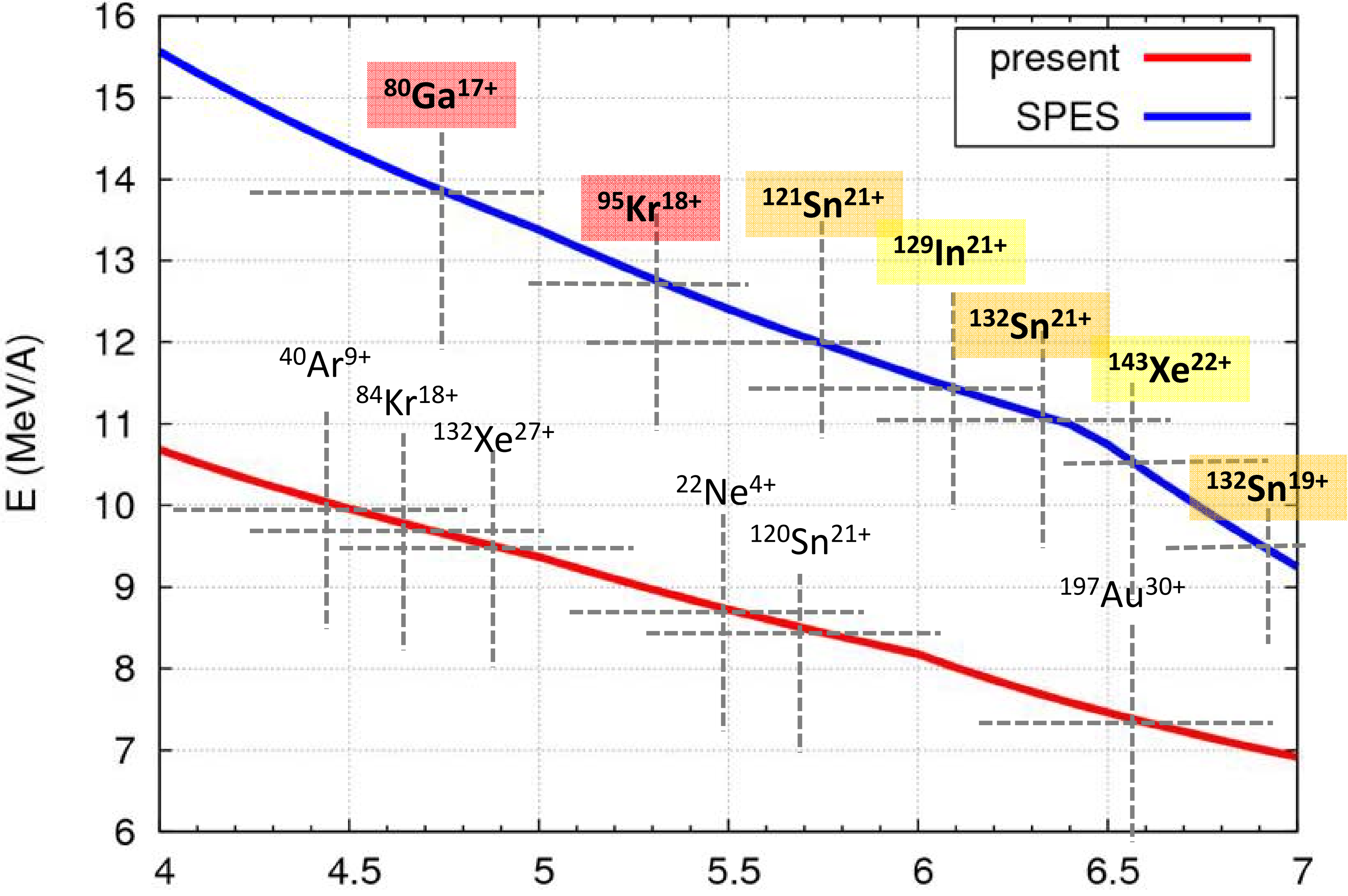


Optimum beta
βo = 0.056
βo = 0.11
βo = 0.13

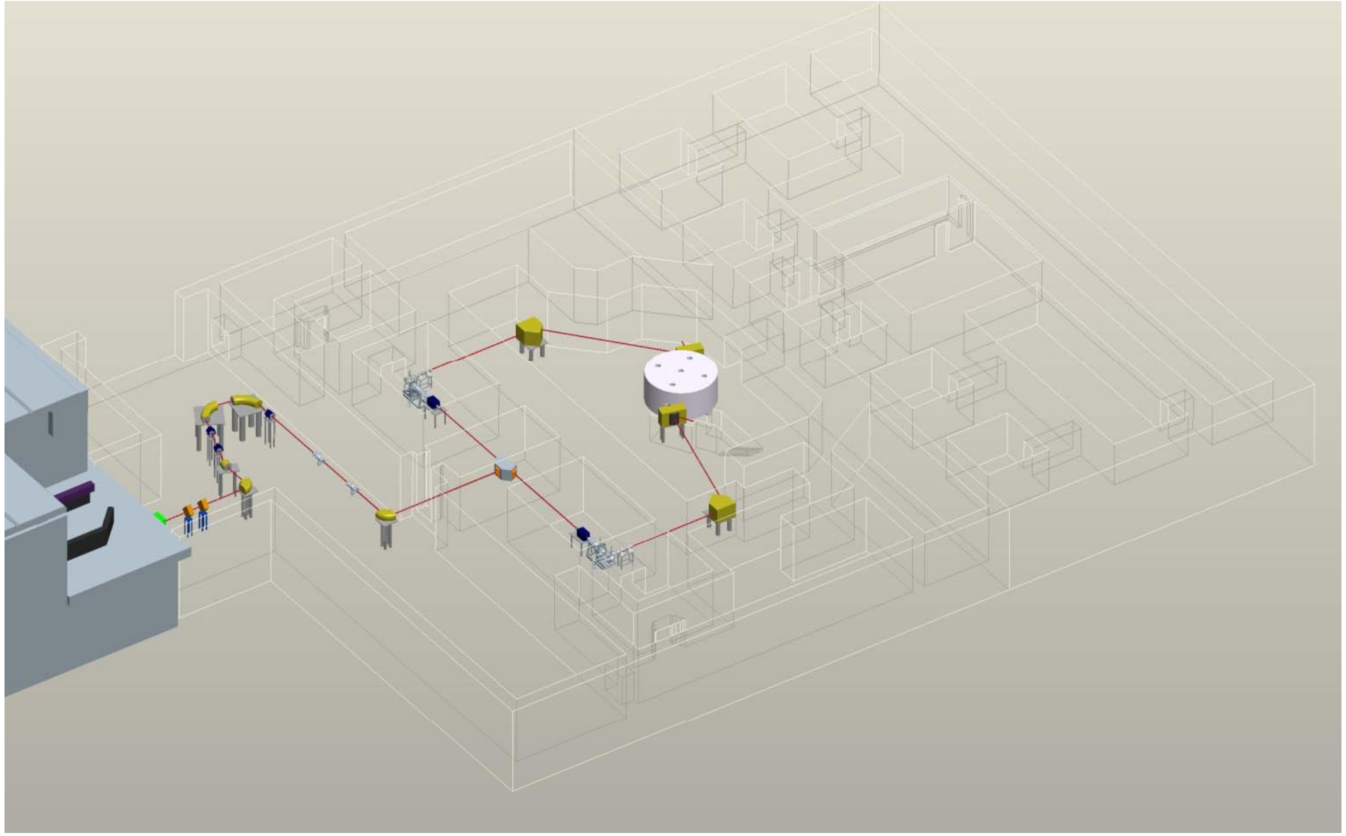
CR03 – prototype work completed

A. Facco, P. Modanese

SPES Final Performance
(Phoenix charge- bred beams)



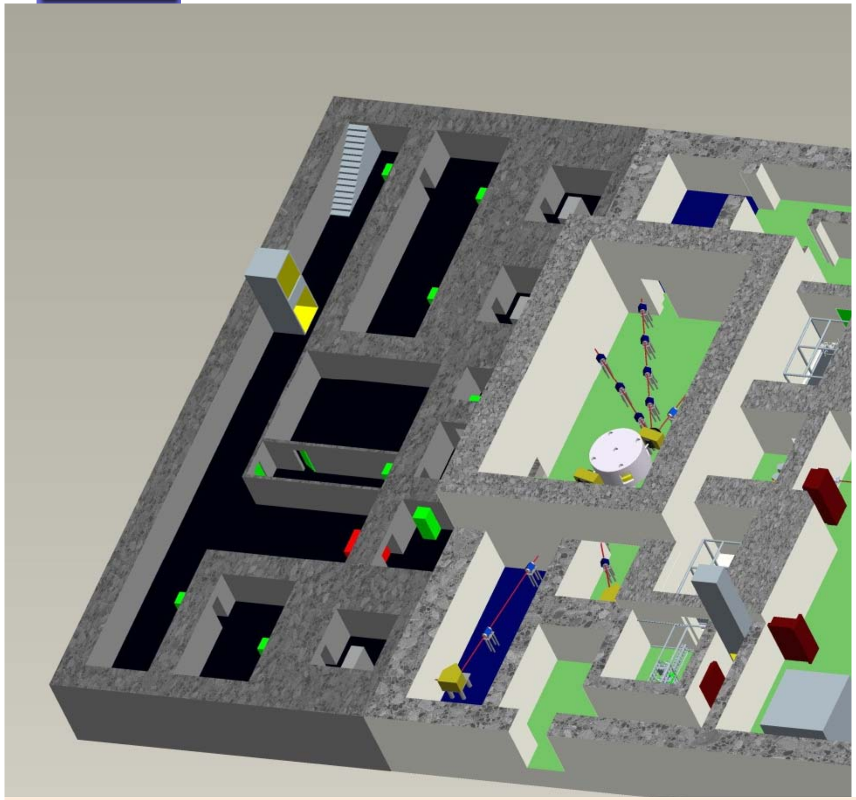
ε = 2,7÷4 | 6÷6,3 | 8÷8,3 %



SPES Project

APPLICATIONS

Radio-isotopes for medicine



LARAMED Facility:
Production of radionuclides of interest for medicine using the SPES cyclotron

IAEA- Coordinated Research Project (CRP)

Accelerator-based Alternatives to Non-HEU Production of Molybdenum-99/Technetium-99m

IAEA Consultant meeting, July 26-29, 2011
IAEA Headquarters Vienna, Austria
(HEU: high enriched Uranium)

$^{100}Mo(p,2n)^{99m}Tc$

application forms on **http://www-crp.iaea.org/**

INFN – ARRONAX:

New target technology for the production of radionuclides
Development of new radiopharmaceuticals of copper-67/64
Development of new radiopharmaceuticals of rhenium-188
Investigation of the biological effect of alpha radiation

INFN – BEST Theratronics:

Production of Mo-99/Tc-99m at clinical levels
Direct Production of Tc-99m by p+^{100}Mo
Production via UCx Target (p-induced fission)

Evaluated Total cost: 20Meuro (Lab. Extension)

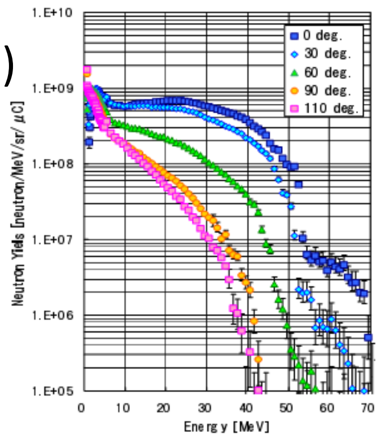
SPES Neutron facilities

LINCE: Legnaro Italian Neutron CEnter

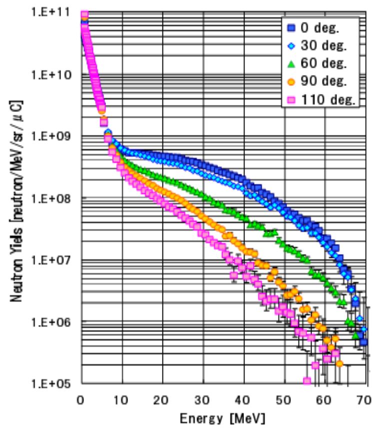
Integral neutron production at SPES Cyclotron Proton beam= 70 MeV, 500 μA Target = W 5mm			
Energy region (MeV)	Sn (n/s) $\sim 6{\cdot}10^{14}\ s^{-1}$	**Φ_n @ 2.5 m ($n\ cm^{-2}\ s^{-1}$)**	**Φ_n @ 1 cm ($n\ cm^{-2}\ s^{-1}$)**
1 < E < 10	$\sim 5{\cdot}10^{14}\ s^{-1}$	5×10^{8}	3×10^{13}
10 < E < 50	$\sim 1{\cdot}10^{14}\ s^{-1}$	1×10^{8}	$6x10^{12}$

Neutron spectra for 70 MeV protons on different targets

C(p,xn)



W(p,xn)



UCANS

Union for Compact Accelerator-based Neutron Sources

SPES Neutron facilities

LINCE: Legnaro Italian Neutron CEnter

LIFAN
(Legnaro Intense FAst Neutron facility)**:**

- SEE Single Event Effect used for electronics' irradiation
- DIRECT proton irradiation facility

scope:
The facility produces a beam similar to the **atmospheric spectrum** (limited to 70MeV) and allows to study the behavior of complex systems subjected to neutrondamage.

FARETRA
(FAst REactor simulator for TRAnsmutation studies)
Moderated neutron facility with Neutron spectra similar to Gen IV reactors

scope:
The facility reproduces a **spectrum typical of a fast neutron fission reactor** to perform measurements of integral cross sections of fission and capture of

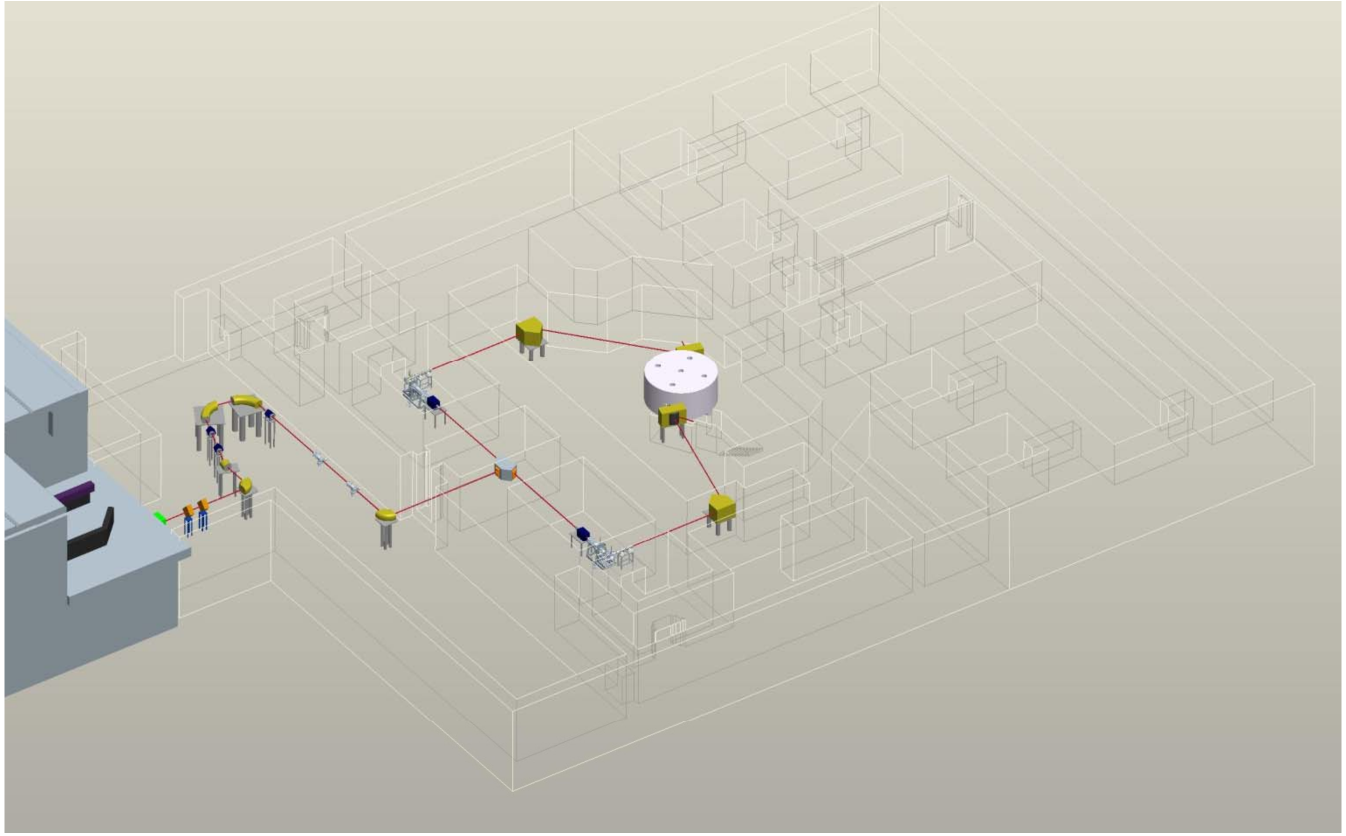
- minor actinides (MA),
- short-lived fission fragments (FF)

and activation measures of structural parts and materials for cooling for Generation IV fast reactors.

third meeting of the UCANS collaboration

UCANS

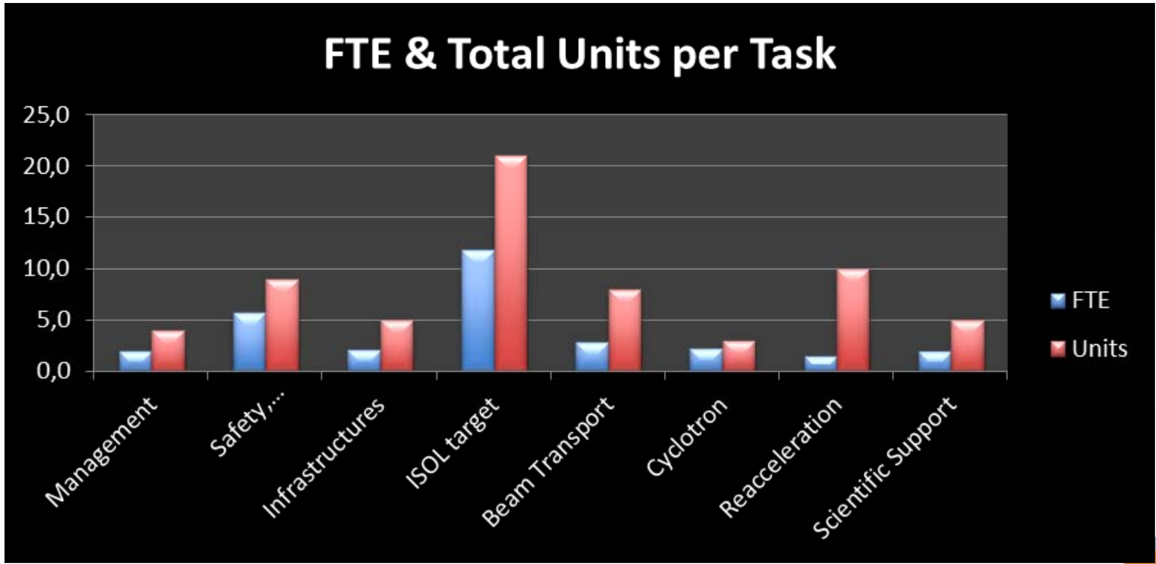
The Union for Compact Accelerator-driven Neutron Sources
July 31 st to 3rd August,
Bilbao, Spain

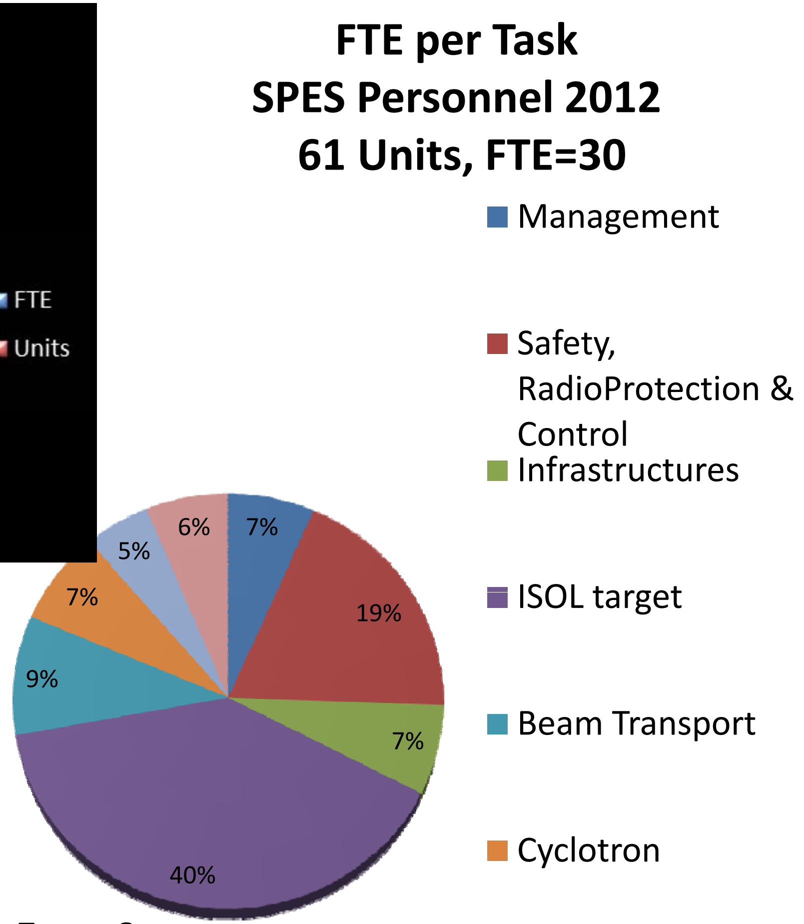


SPES Project

PERSONNEL AND STATUS

SPES – Personnel 2012





	units	FTE	task0	1	2	3	4	5	7	8
Temporary	19	15,9	0,2	3	0,3	8,8	1,4	1,3	0,4	0,5
Staff	42	14,2	1,8	2,7	1,8	3,1	1,4	0,9	1,1	1,4
total	61	30,1	2,0	5,7	2,1	11,9	2,8	2,2	1,5	1,9

INFN Fellowship for young foreign PhD

To be published on INFN jobs opportunity

INFN
Istituto Nazionale
di Fisica Nucleare

POST-DOCTORAL FELLOWSHIPS FOR NON ITALIAN CITIZENS
IN THE FOLLOWING RESEARCH AREAS

EXPERIMENTAL PHYSICS (N. 20)

Next call: December 2012.....

Please contact me for further information's

E-mail: spes-segreteria@lnl.infn.it

SPES Schedule March 2012

	2010	2011	2012	2013	2014	2015
Facility preliminary design completion						
Prototype of ISOL Target and ion source						
ISOL Targets construction and installation						
Authorization to operate and safety	Cyclotron	operation	(on shedule)	UCx ope	ration	
Building's Tender & Construction bid start	building project					
Cyclotron Tender & Construction	in	schedule				
Alpi up-grade & pre-acceleration						
Design of RIB transport & selection (HRMS, Charge Breeder, Beam Cooler)						
Construction and Installation of RIBs transfer lines and spectrometer						
Complete commissioning						

Current status

- Letters of Intent: under discussion to select first-day-experiments
- ISOL Target and Ion Source: under test with FEBIAD and Laser
- Layout for pre-acceleration: defined
- Safety report and radiation protection: ready authorization for cyclotron operation
- Contract for cyclotron: signed November ‘10, final design accepted in June ’11, iron under machining
- Final building project: ready, international bid on the way
- Expected ground breaking Feb.2013

Thank you for the attention

INFN
Istituto Nazionale di Fisica Nucleare

SPES
exotic beams for science