SPES Project

Selective Production of Exotic Species

Gianfranco Prete LNL-INFN
On behalf of the SPES Collaboration

1 5 November 2010, SPES workshop

Starting points:

Introduction

1. To develop a Neutron Rich ISOL facility using the ALPI linac as reaccelerator is a step forward in the nuclear physics research.
2. The development of an ISOL facility at 10^{13} Fission/s is a challenging goal at the up to date level.
3. The structure of an ISOL facility is of interest for applications in fields as neutron production and medicine.

SPES strategy

Exotic nuclei

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

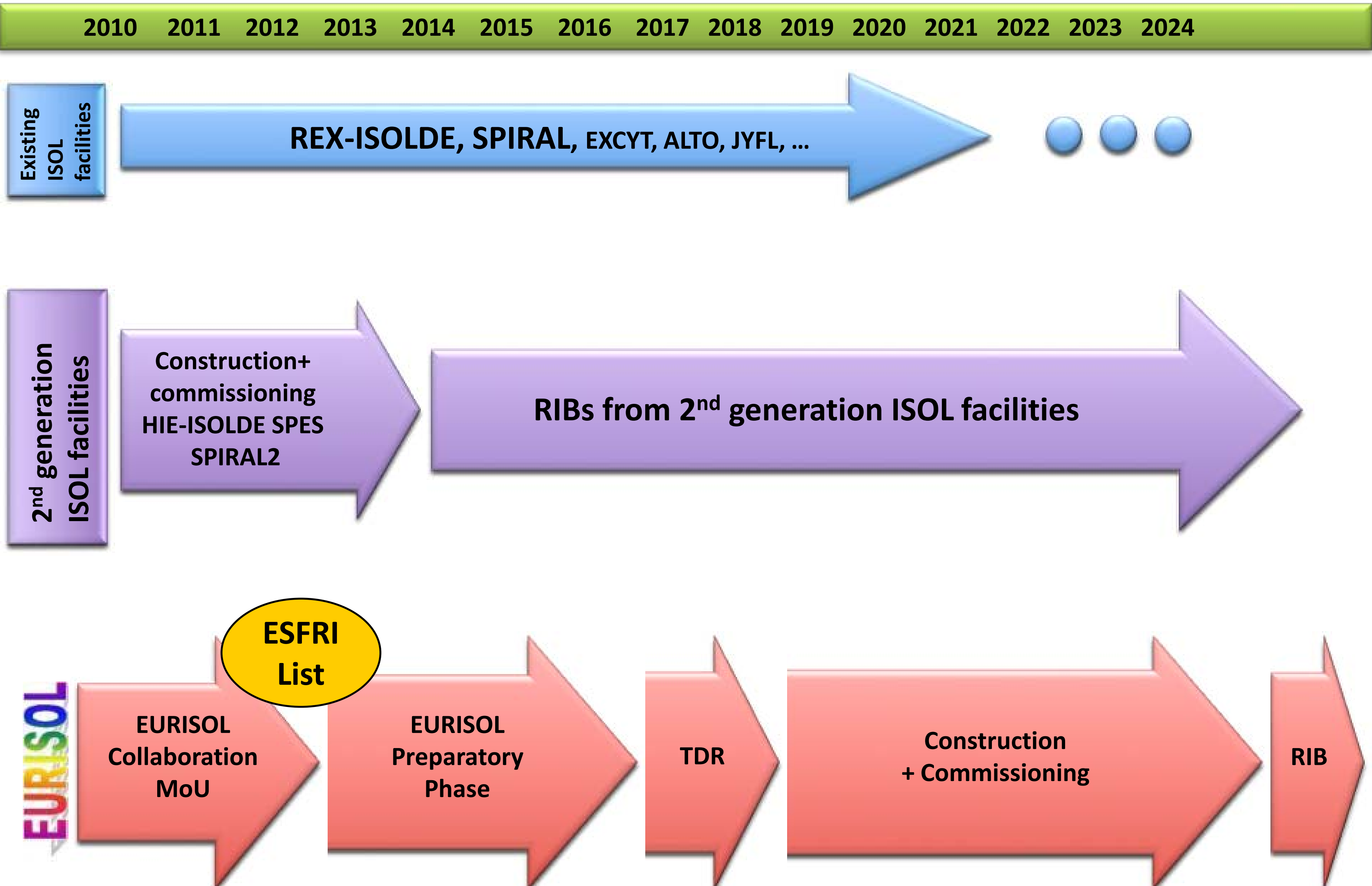
high purity beam Reacceleration up to $\geq$10 MeV/u

Applications

Proton and neutron facility for applied physiscs

Material science & Medical applications

Timeline for European ISOL RIB facilities



Adapted from M. Lewitowicz

Sinergies and Complementarities between the 2nd generation RIB facilities

Different primary beams, production methods and beam handling

Developments of a variety of new and complementary techniques which will be all essential for EURISOL

Different capabilities in providing RIBs, with limited duty cycle

Complementarity in satisfying the future beam time requests

(Importance of an european coordination)

SPES ISOL facility at LNL

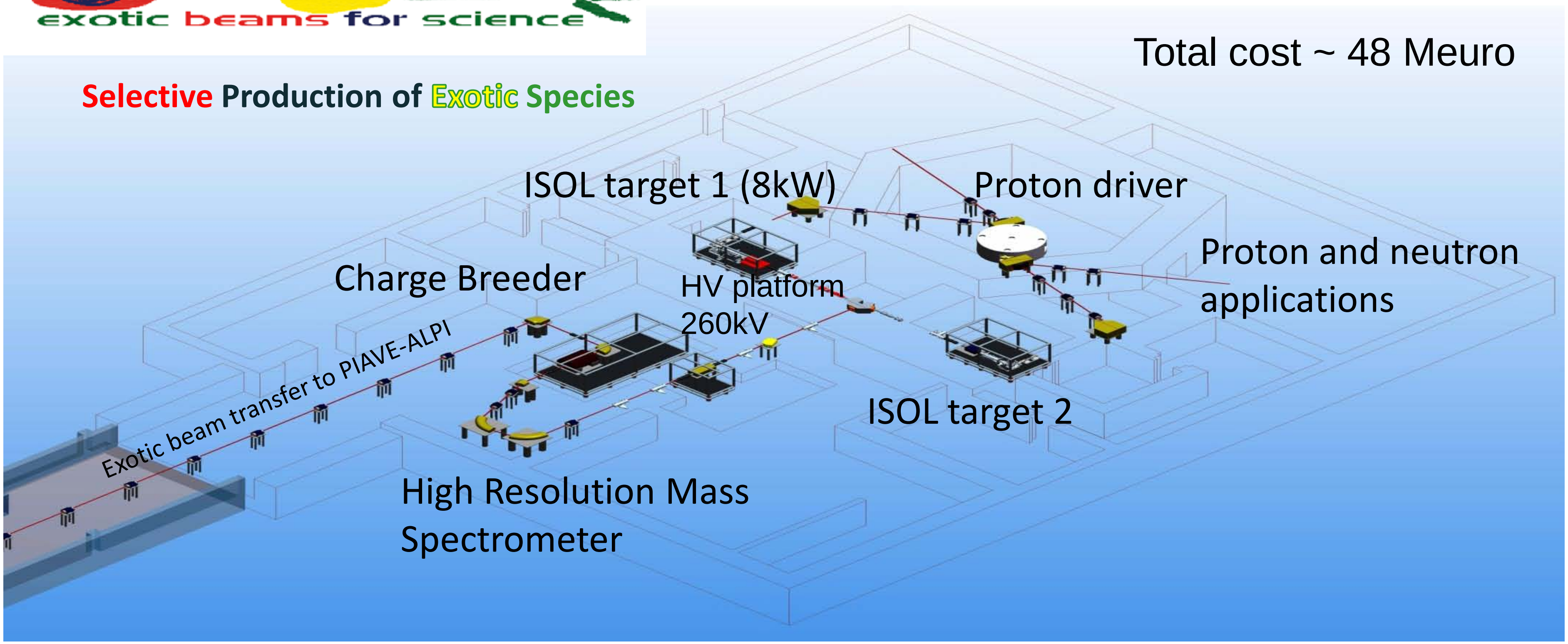
SPES ISOL facility

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



Exotic beams at SPES ISOL facility

Research with exotic nuclei
(extreme N/Z ratio)

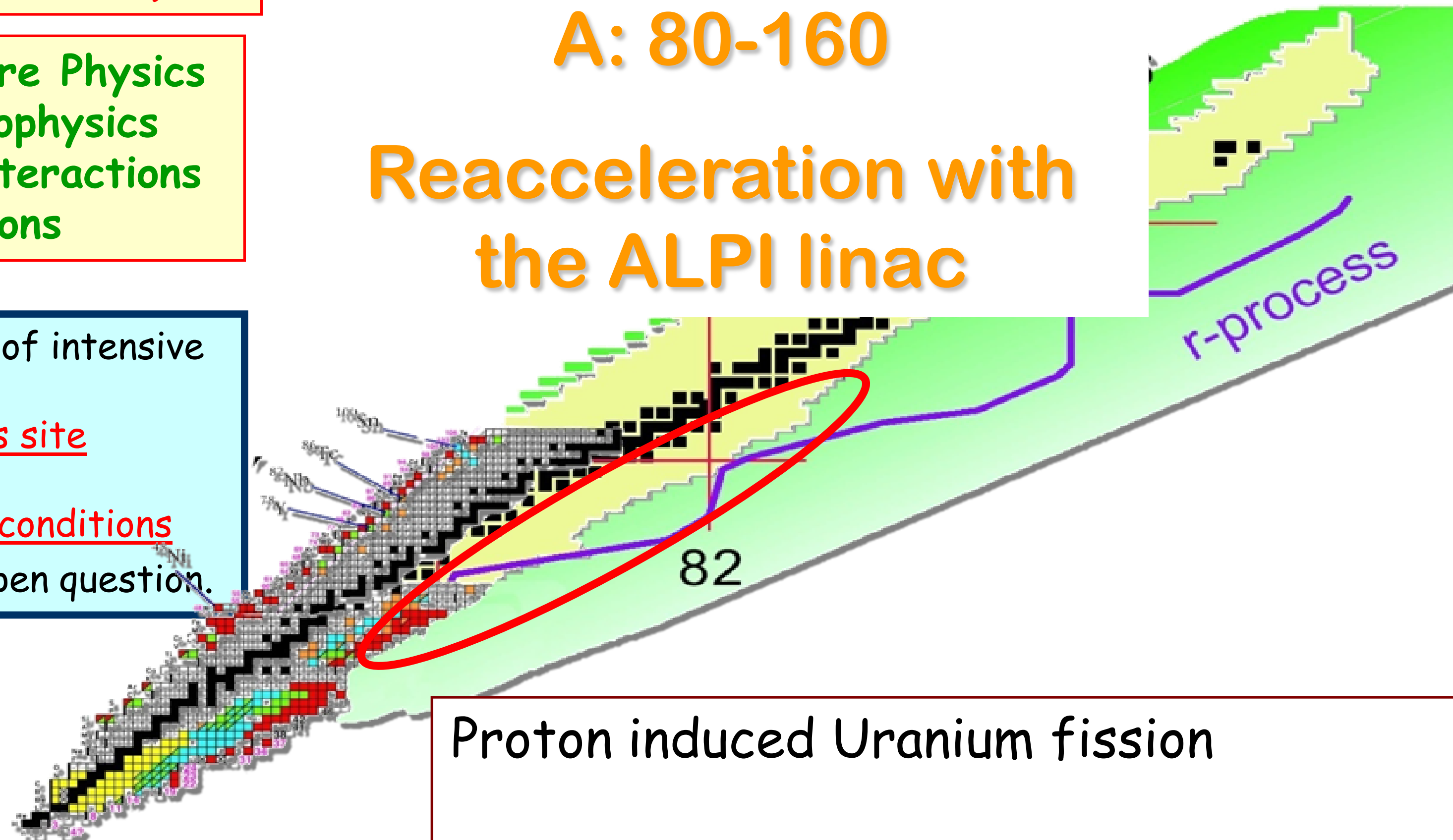
Nuclear-Structure Physics
Nuclear Astrophysics
Fundamental Interactions
Applications

Neutron Rich Isotopes

A: 80-160

Reacceleration with the ALPI linac

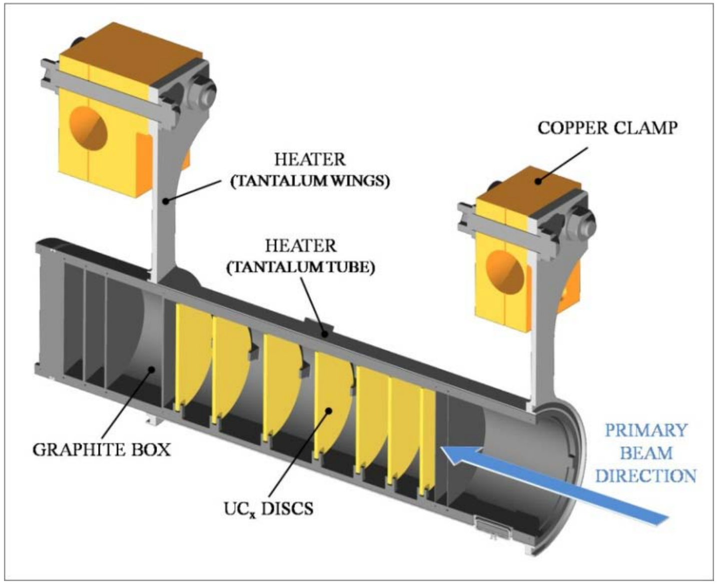
Despite many years of intensive effort,
the r-process site
and
the astrophysical conditions
continues to be an open question.



Proton induced Uranium fission

RIB INTENSITY:
10^7-10^9 rare ions/s
on the experimental target

Evaluation of SPES RIBs



Target: **7** UCx disks
4 cm diameter
1.3 mm thick
(3 g/ cm^3 UCx density).

Beam: **40 MeV/ 0.2 mA proton beam**

Evaluation of the SPES production yields are based on calculations and experimental yields measured at HRIBF at the ionization source exit **(1+).**

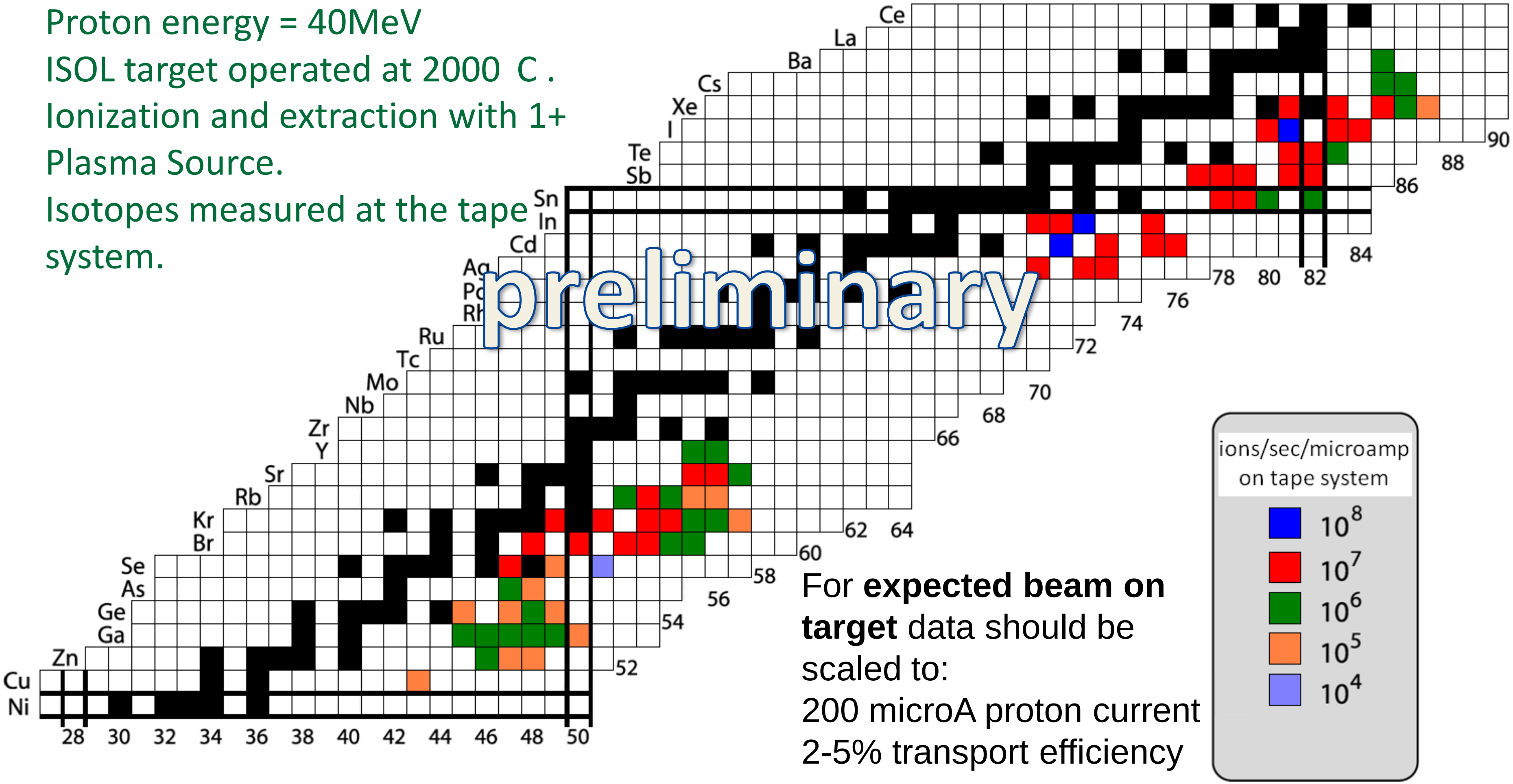
The baseline method is based firmly on existing techniques and does not utilize the full power of the Cyclotron; it leaves substantial scope for improvement as we improve our experience with the machine and the target development.

SPES Target
Preliminary data of HRIBF experiment

Experiment March 2010

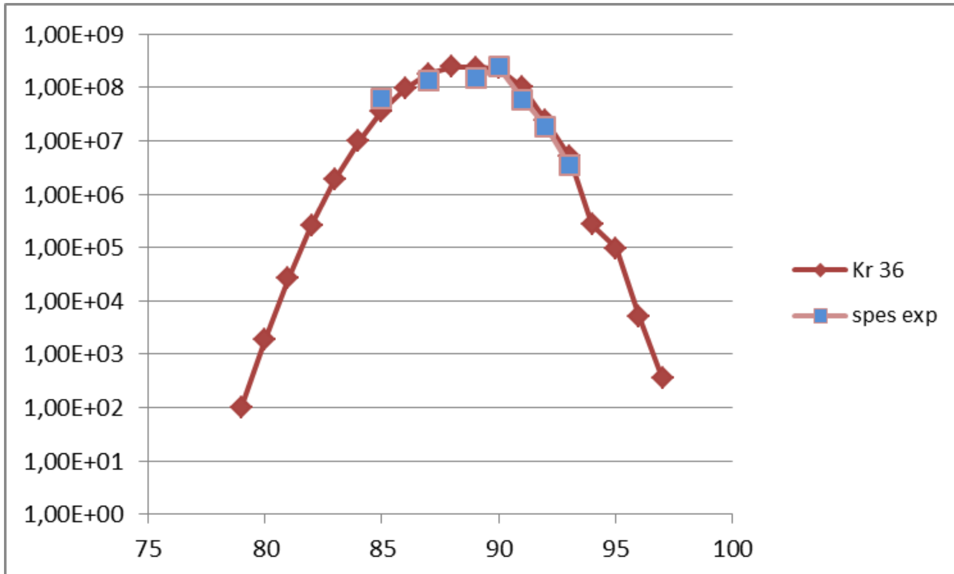
Evaluated production rate for 1 microA proton current

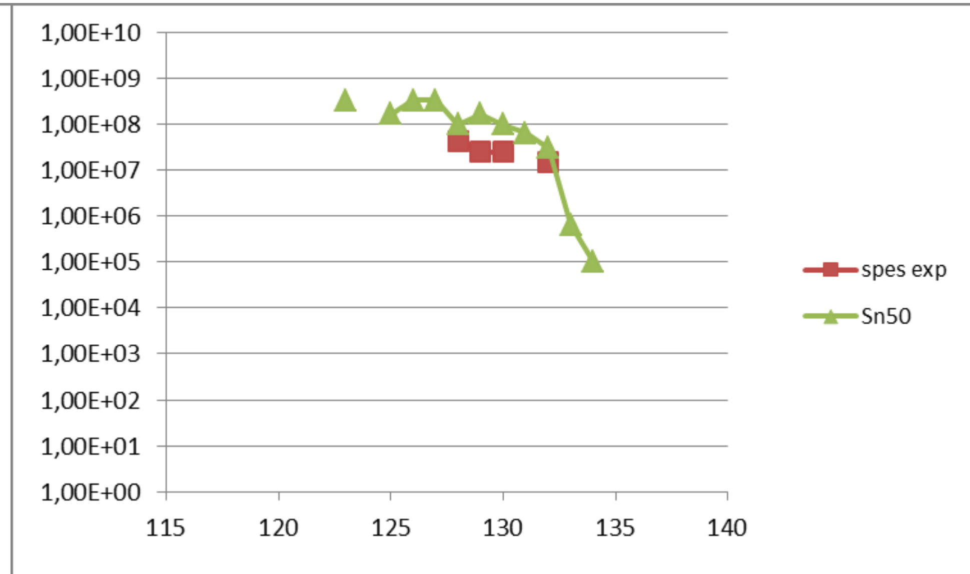
Proton energy = 40MeV
ISOL target operated at 2000 C .
Ionization and extraction with 1+ Plasma Source.
Isotopes measured at the tape system.

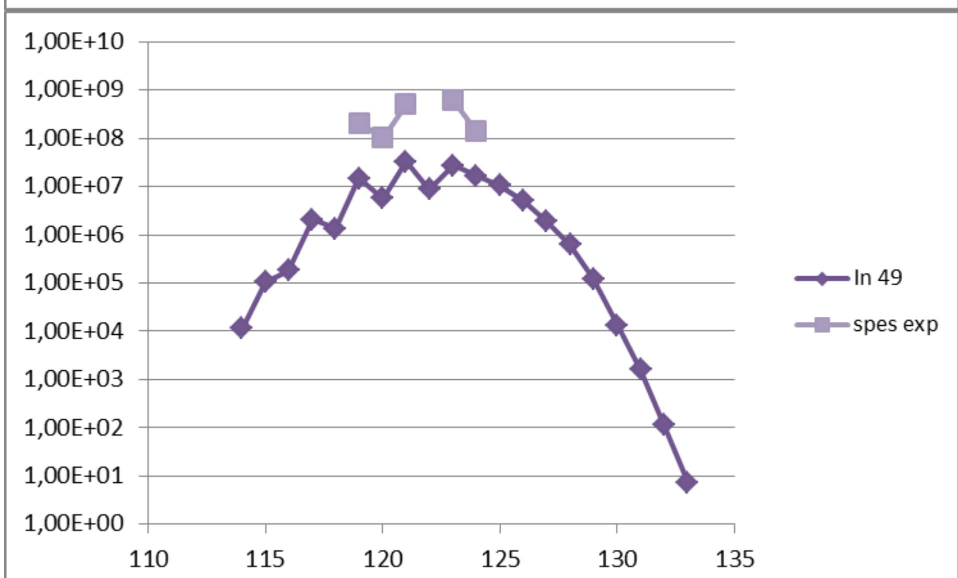


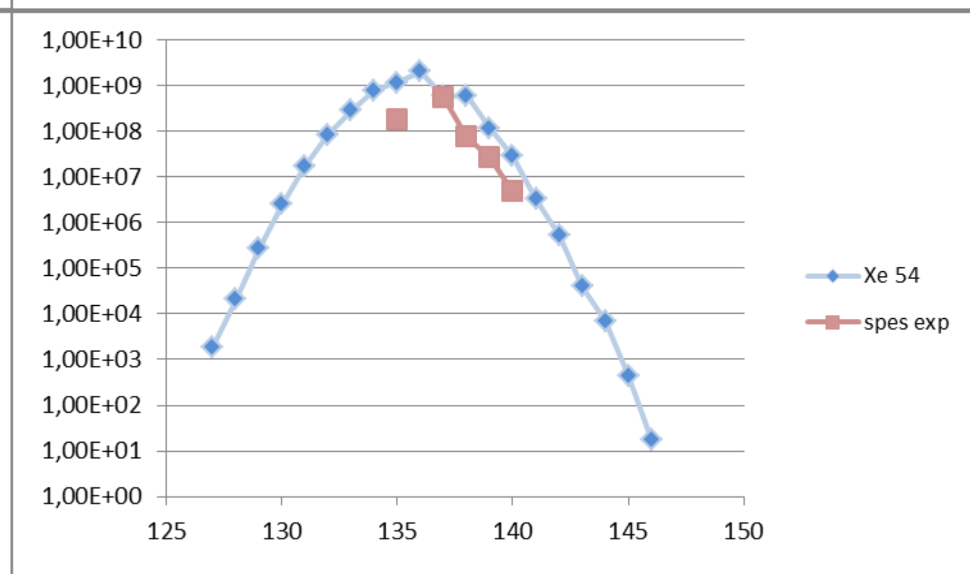
For **expected beam on target** data should be scaled to:
200 microA proton current
2-5% transport efficiency

SPES re-accelereted RIB's scaled from HRIBF data and 2010 test experiment









SPES CYCLOTRON
load work per year

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: more than 10000 hours per year

	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

Batch-mode isotopes production

Production of radioactive isotopes with long decay time (days-years) and acceleration in the Tandem-ALPI ion source.

Proton current : 10-100 μA
Irradiation time : 10 days

Target R&D needs to improve the power dissipation and production rate

Expected beam on target:
in the order of 10^8 pps

HRIBF-ORNL
Batch mode
target-source

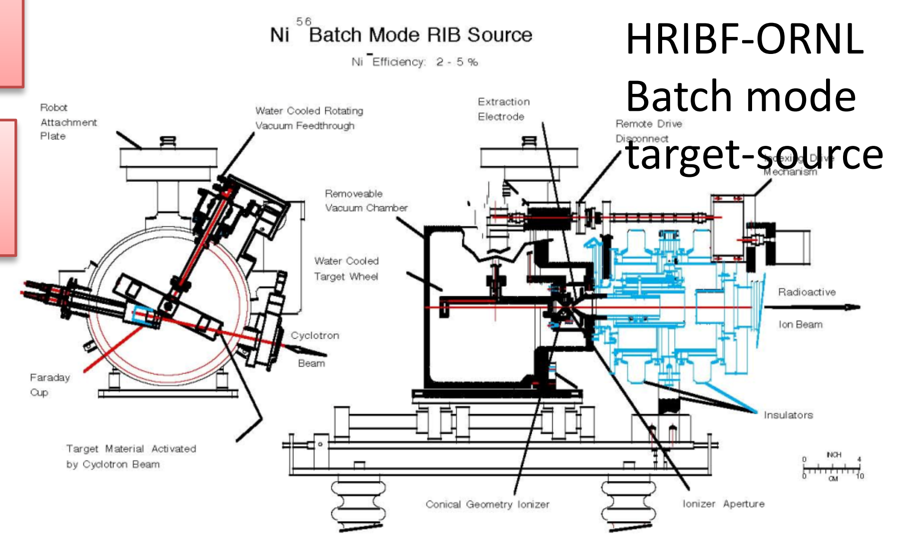


Fig. 1. Schematic drawing (side-view) of the batch mode Cs-sputter negative ion source for generation of RIBs with long half-lives.

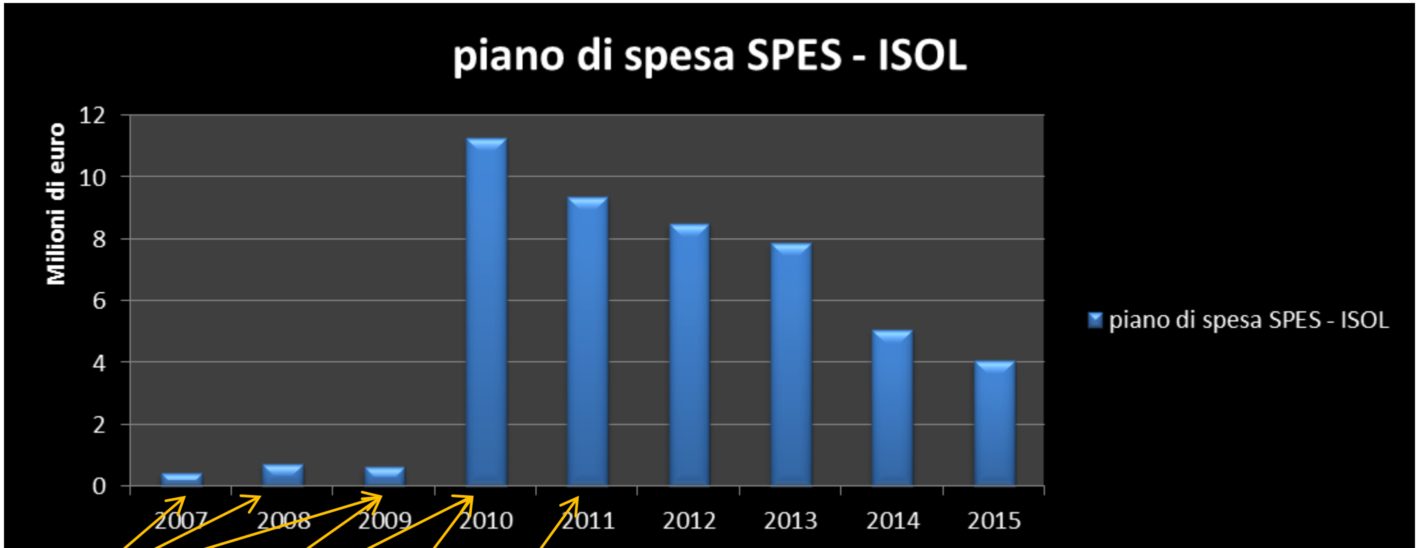
Some proton-rich isotopes can be produced in Batch Mode

	^{46}Ti(p,2n)^{44}Ti	^{58}Ni(p,2n)^{56}Ni	^{70}Ge(p,2n)^{68}Ge	^{74}Se(p,2n)^{72}Se	^{84}Sr(p,2n)^{82}Sr	^{90}Zr(p,2n)^{88}Zr
T1/2	47.3y	6.1d	288d	8.5d	25.5d	83.4d
N(t) = produced atoms	1.4 10^{16}	2.6 10^{15}	2.7 10^{17}	3.2 10^{14}	8.9 10^{17}	4.6 10^{16}
Target Massa (mg)	47	51	55	60	112	60
Number di atoms in the target	6.4 10^{20}	5.3 10^{20}	4.7 10^{20}	4 10^{20}	8 10^{20}	4 10^{20}
produced atoms/ target atoms	2.2^{-5}	4.9 10^{-6}	6 10^{-4}	1.1 10^{-4}	1 10^{-3}	1.1 10^{-4}
Extracted isotopes/sec	2.6 10^8	3.0 10^7	3.6 10^9	7 10^8	7 10^9	7 10^8
accelerated RIB (ions/sec)	**3 10^7**	**3.0 10^6**	**4 10^8**	**7 10^7**	**7 10^8**	**7 10^7**

SPES Schedule July 2010

	2010	2011	2012	2013	2014	2015
	11.3 ME	9.4 ME	8.5ME	8.0 ME	5.1 ME	4.1 ME
Facility preliminary design completion						
Prototype of ISOL Target and ion source						
ISOL Targets construction and installation						
Authorization to operate And safety	Cyclotron operation			UCx operation		
Building's Tender & Construction						
Cyclotron Tender & Construction						
Cyclotron Installation and commissioning						
Neutron facility design						
Neutron facility construction						
Alpi preparation for post acceleration						
Design of RIB transport & selection (HRMS, Charge Breeder, Beam Cooler)						
Construction and Installation of RIBs transfer lines and spectrometer						
Complete commissioning						

SPES ISOL economic plan

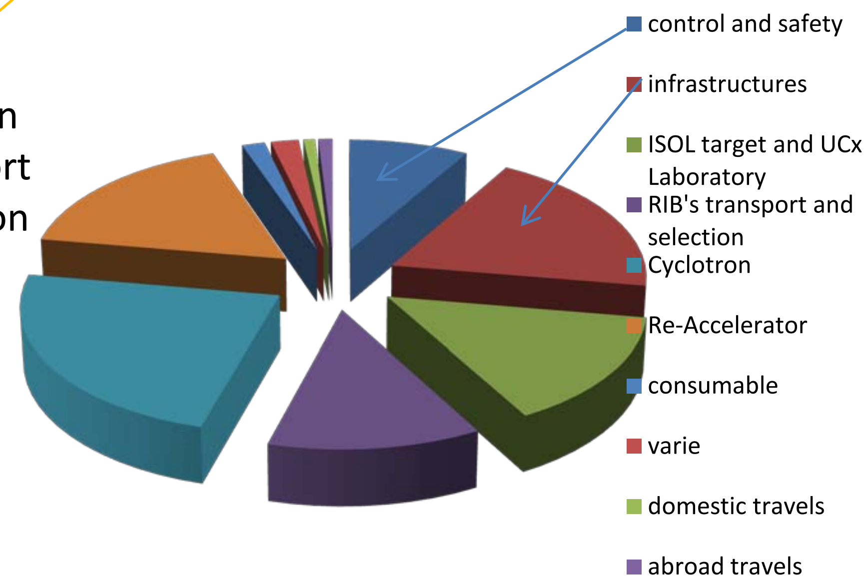


ISOL target development
ALPI Low Beta up-grade

Cyclotron

Building and infrastructures

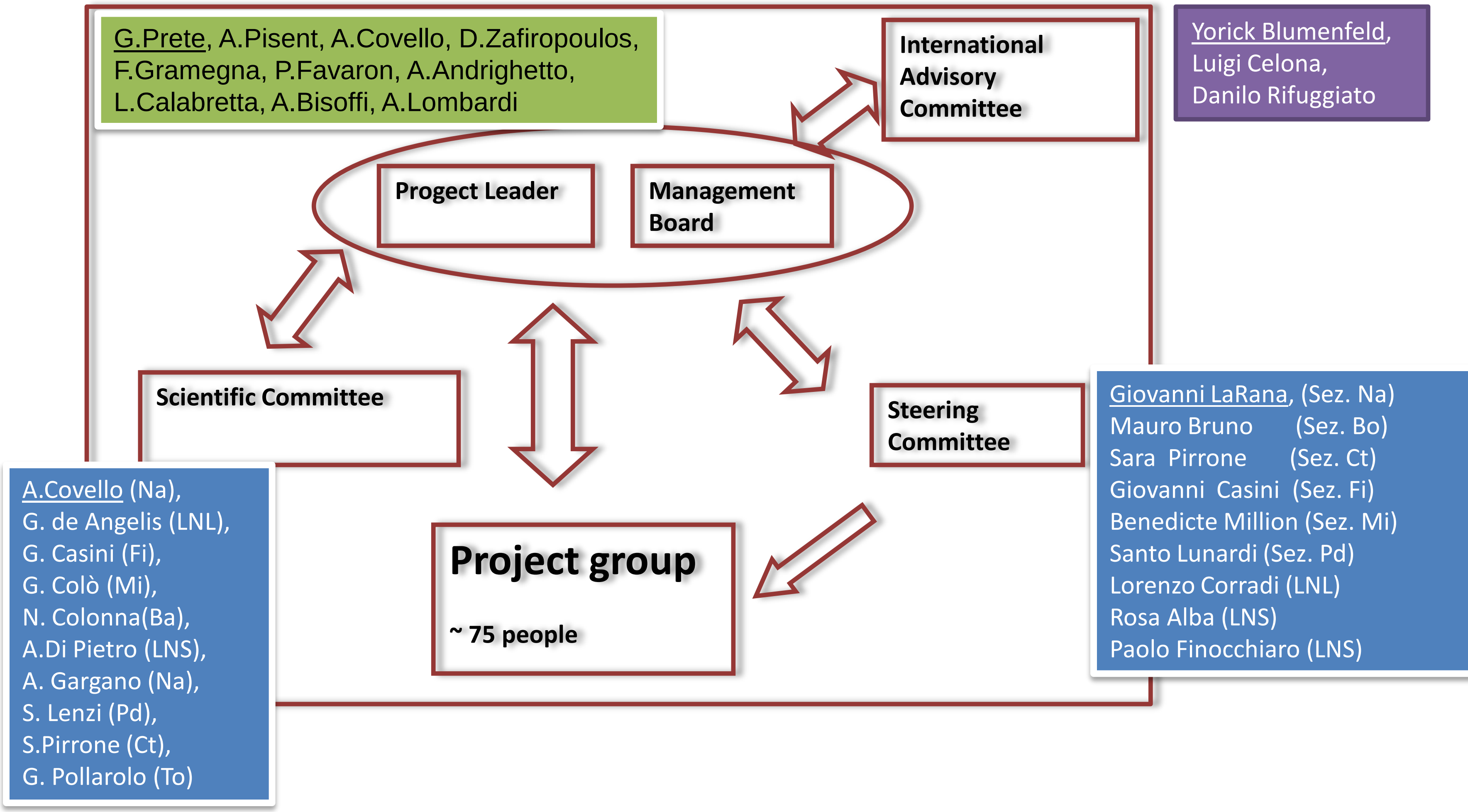
RIB production
Beam transport
Re-acceleration



Cost evaluation of the SPES ISOL facility ~ 48 M€
+ Personnel ~ 6 M€

Operation ~ 2 M€/year

SPES Organizzation



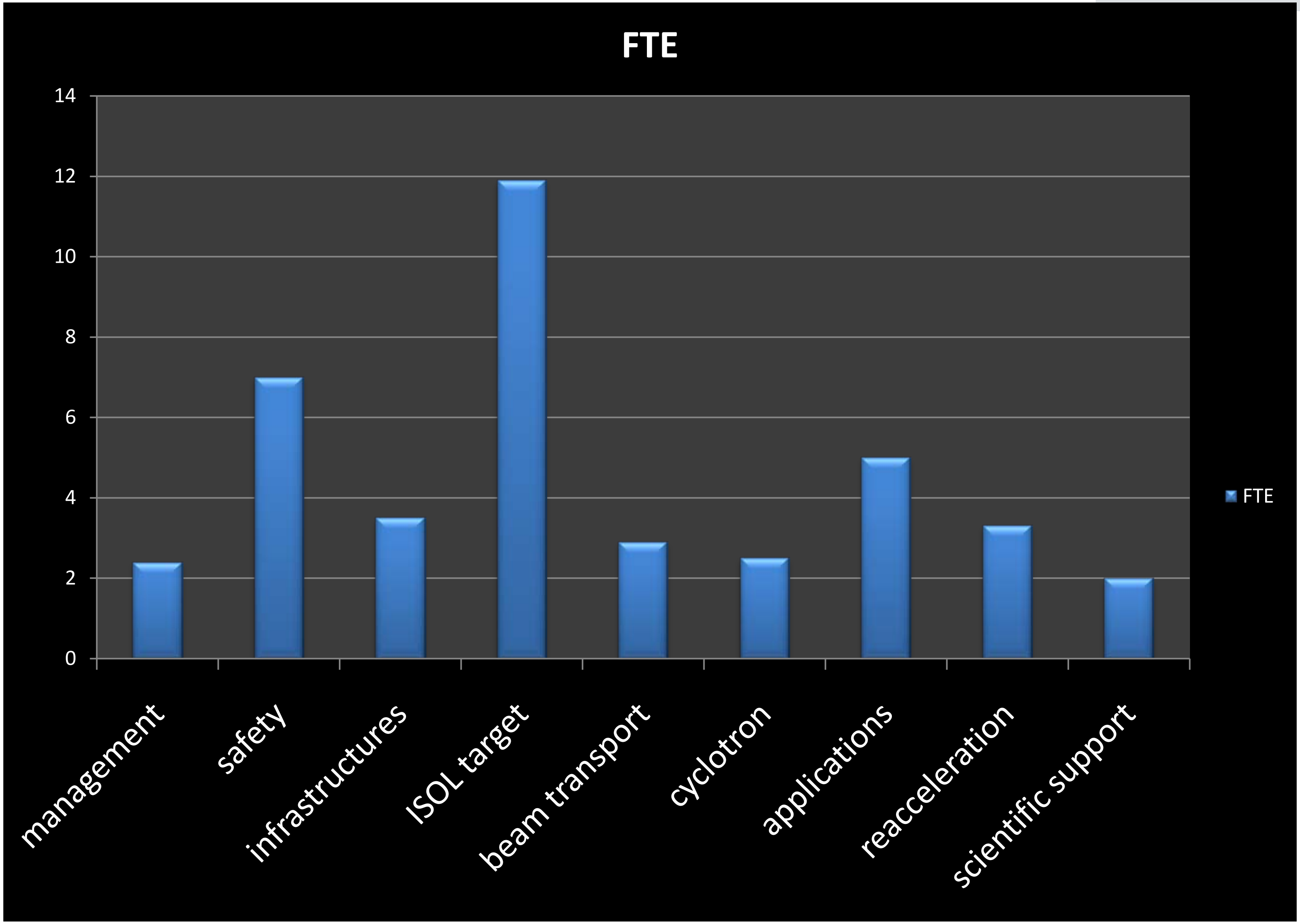
SPES ORGANIZATION

TASK	Responsible	Subtask	Responsible	
SAFETY RADIATION PROTECTION CONTROLS	G. Prete	Safety	G. Prete	See D. Zafiropoulos talk
		Radiation Protection	D. Zafiropoulos	
		Controls	G. Bassato	
INFRASTRUCTURES	P. Favaron	Buildings	E. Brezzi	Later in this talk
		Technical Plants	R. Pegoraro	
ISOL TARGET	A. Andrighetto	Front End	A. Andrighetto	See A.Andrighetto talk
		Laser Source	P. Benetti	
		Target Handling	M. Guerzoni	
BEAM TRANSPORT & MANIPULATION	L. Calabretta	RIB Transport	M. Comunian	See L. Calabretta talk
		HV Platform	F. Moisio	
		Mass Selection	A. Dainelli	
		Beam Cooler	A.M. Porcellato	

SPES ORGANIZATION

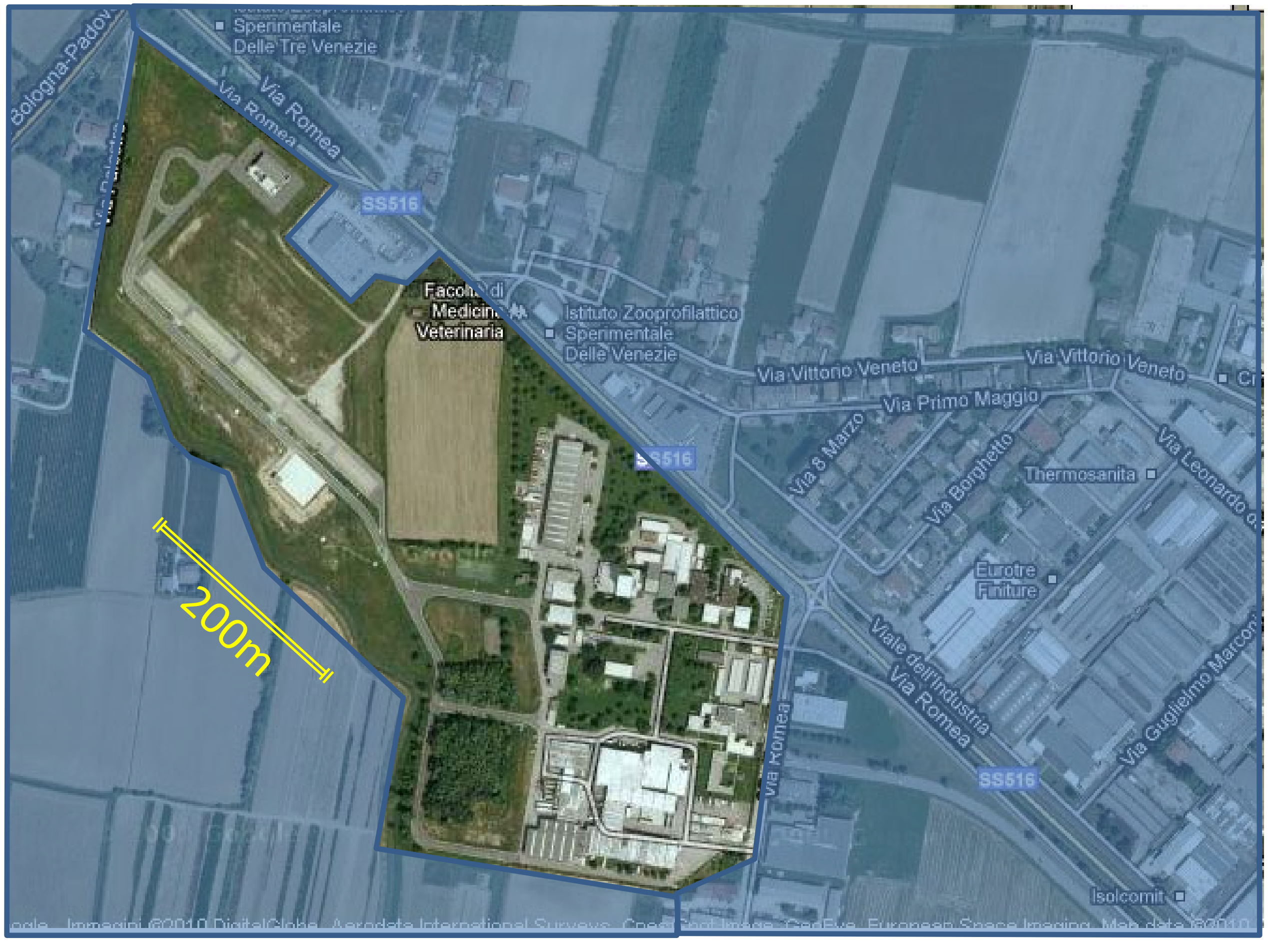
TASK	Responsible	Subtask	Responsible	TASK
HIGH INTENSITY linac (switched to IFMIF)	A. Pisent	High Intensity LINAC	E. Fagotti	See P.F. Mastinu & E. Fagotti LEA Colliga talks
		BNCT	J. Esposito	
		LENOS	P.F. Mastinu	
PROTON DRIVER	A. Lombardi	optics and beam transport	M.Maggiore	Later in this talk
		Infrustructures and RF	L.Piazza	
RE-ACCELERATON	G. Bisoffi	Charge Breeder	A. Galatà	See G. Bisoffi talk & T. Lamy LEA Colliga talk
		Diagnostic	M. Poggi	
		PIAVE	G. Bisoffi	
		ALPI low-Beta	A. Facco	
SCIENTIFIC SUPPORT	F. Gramegna	SPES beam evaluation	M. Cinausero	Later in this talk
		Batch Mode	F. Recchia	
		Nucl. Phys. Experiments	A.F. Di Pietro	
		Communication and Scientific Documentation		
PROJECT MANAGEMENT		Project management	L. Piazza	

Project group PERSONNEL



Total units: 75 persons for a total of 40 FTE

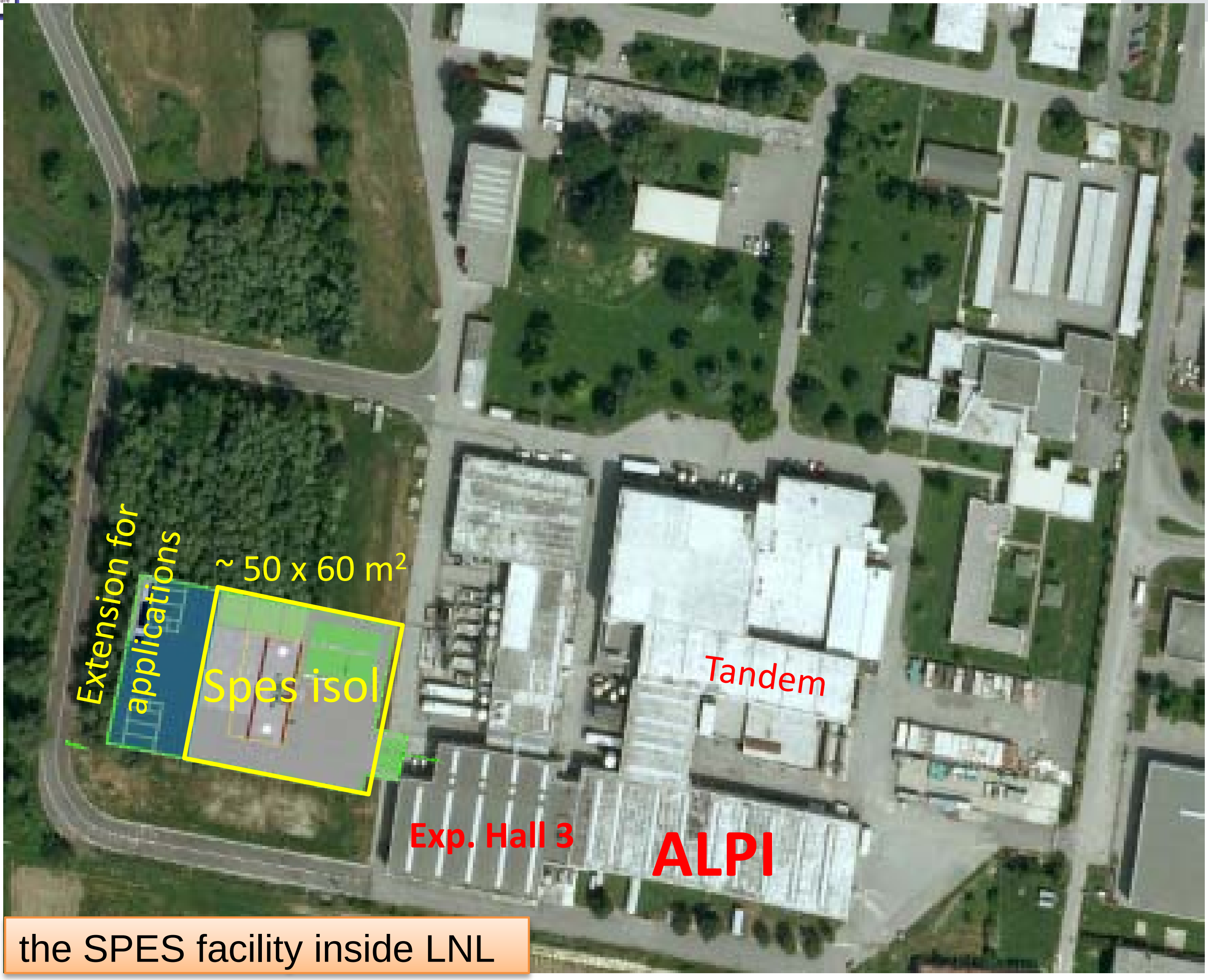
Area of Laboratori Nazionali di Legnaro



More than 200.000 m^2

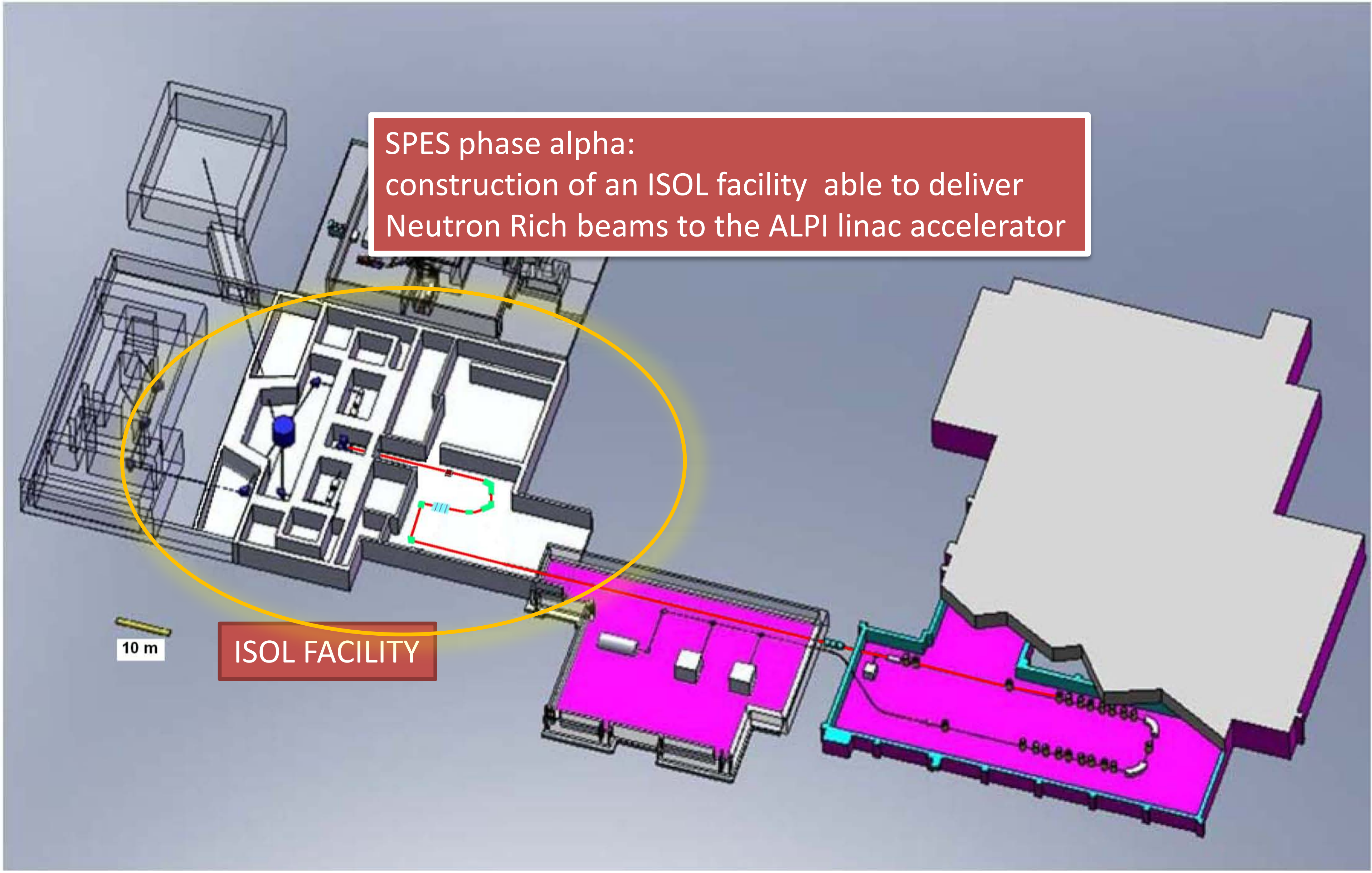
1/3 occupied, 2/3 available for expansion

SPES Facility Layout

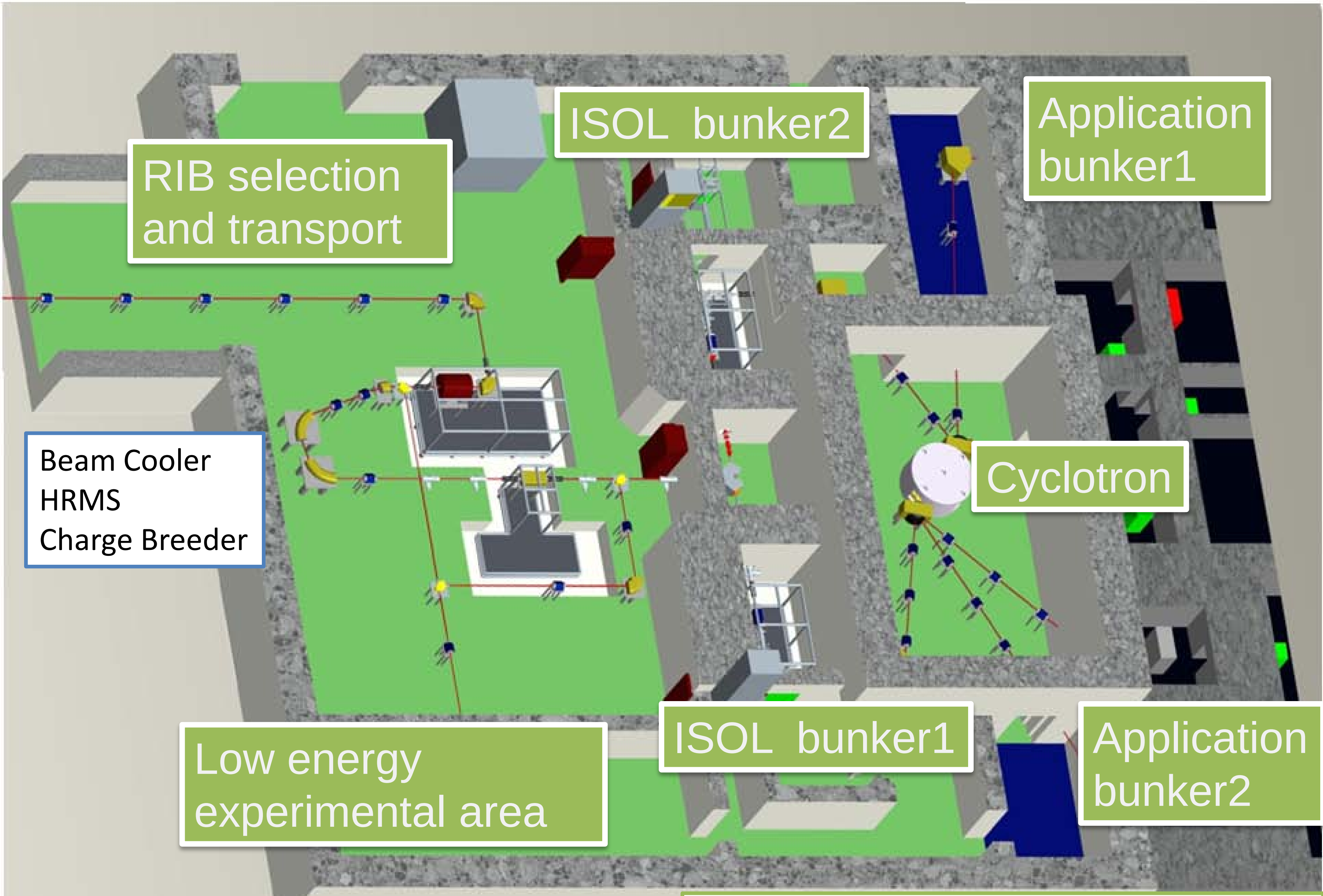


the SPES facility inside LNL

SPES layout

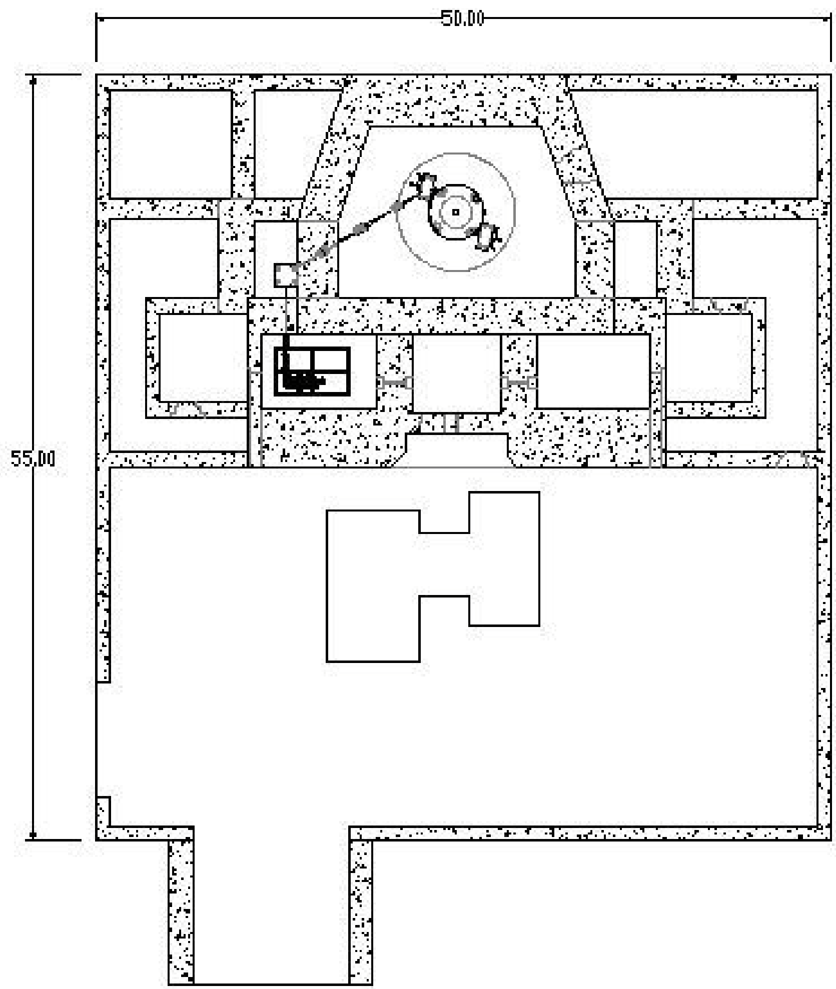

SPES phase alpha:
construction of an ISOL facility able to deliver Neutron Rich beams to the ALPI linac accelerator
10 m
ISOL FACILITY

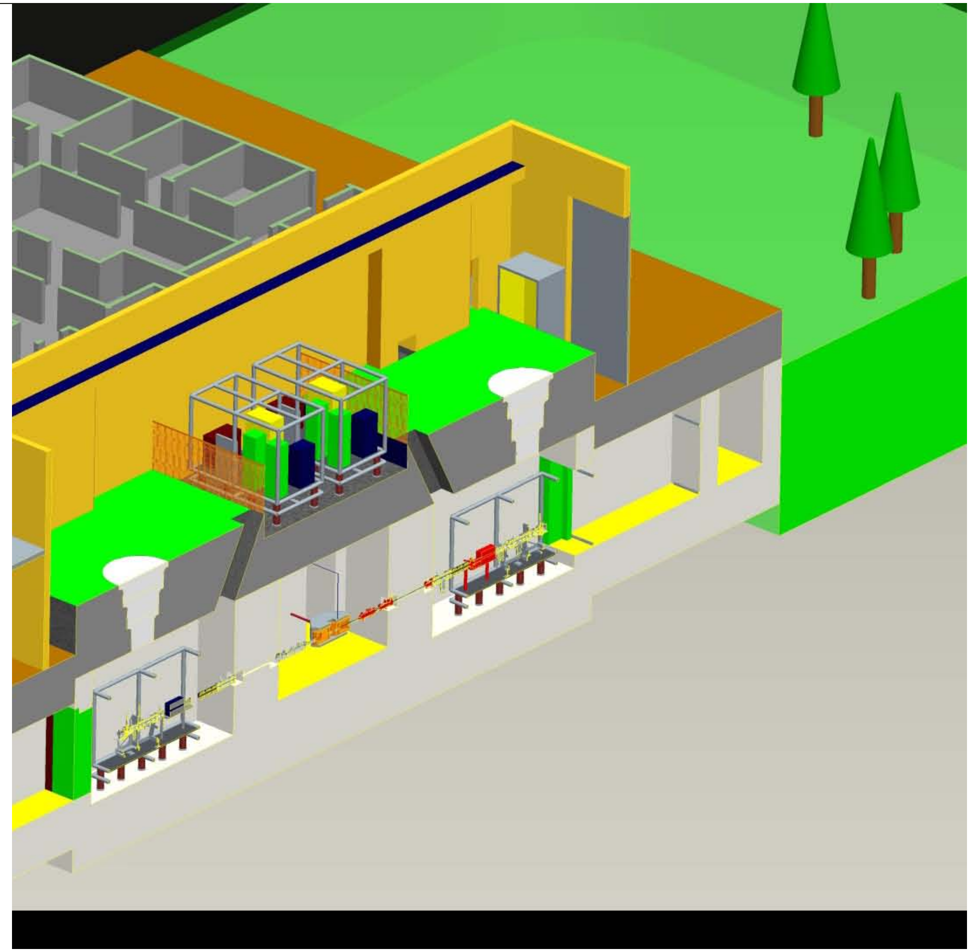
SPES - ISOL facility layout: Level -1



Artistic view of the SPES isol facility

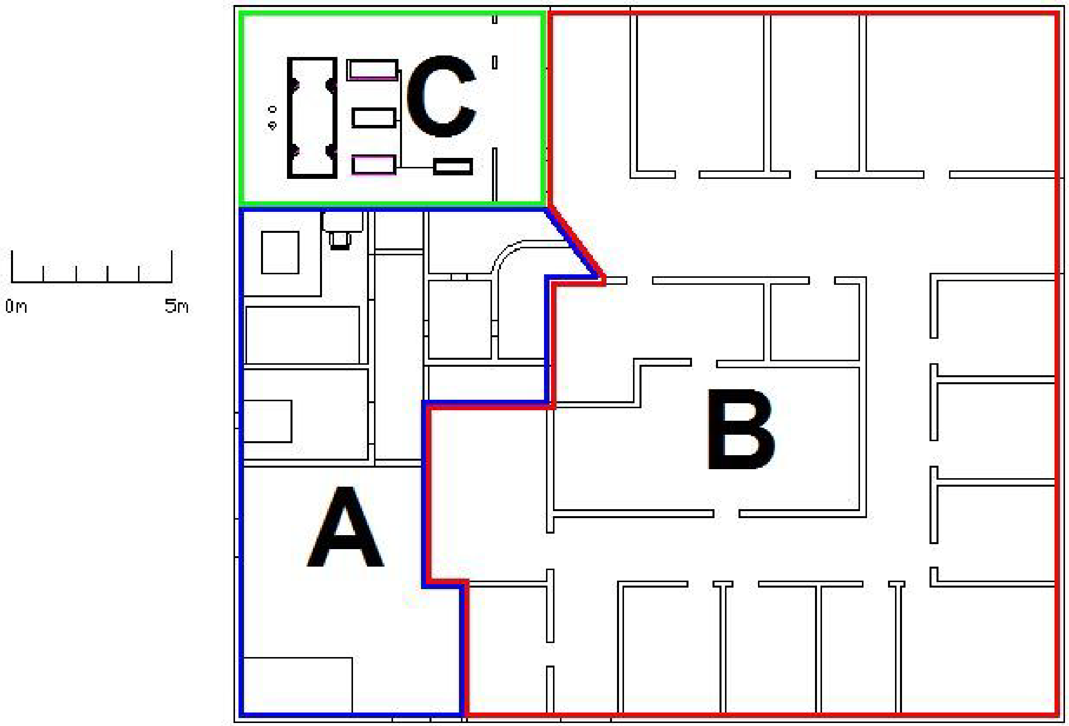
Task Infrastructures





Cyclotron and ISOL bunkers

Task Infrastructures

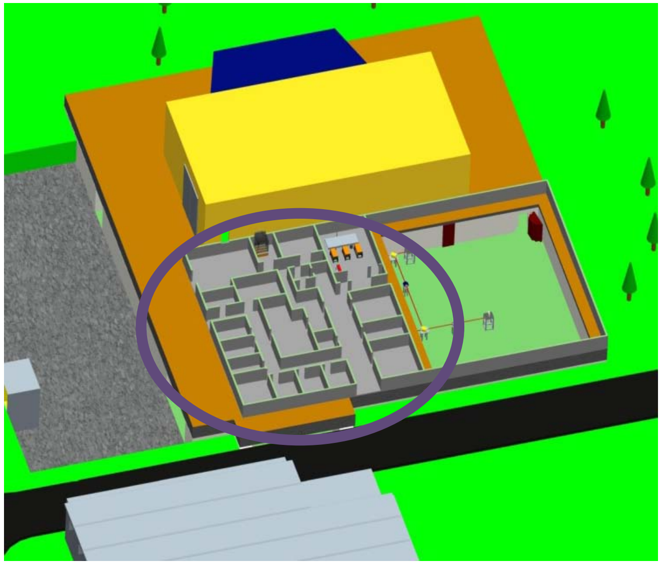


ISOL Target laboratory

A: UCx production and test.
Class A laboratory.

B: Ion suorce laboratory and
offices.

C: Laser laboratory.



Task Infrastructures

Defined the functional description of the SPES building.

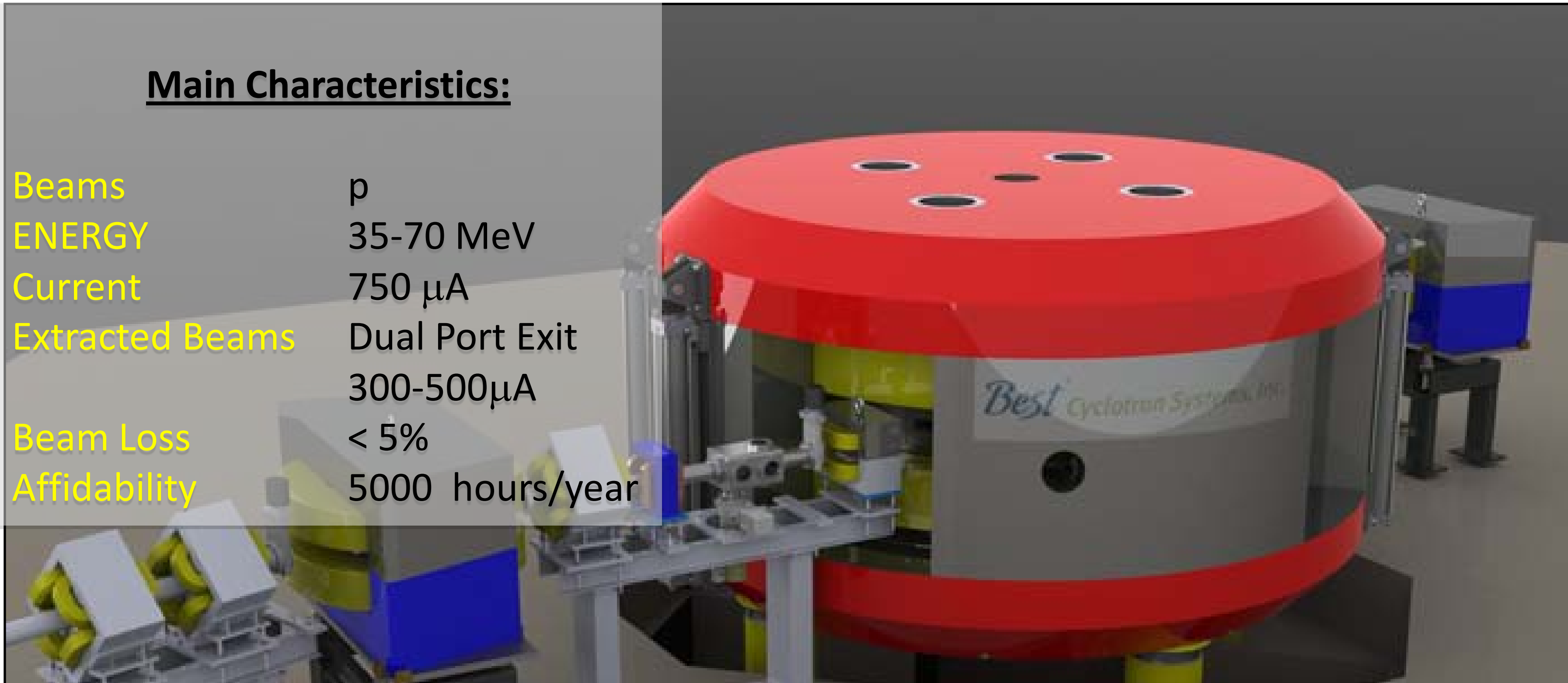
Defined the general layout, the plants needs, optimizing the space considering the people and instrumentation paths inside the facility.

A dialogue with the Infrastructures contractor is in progress to define the executive project.

Executive project expected at end of March 2011.

Building construction: 2012-2013.

SPES 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

Schedule:
Contract signed Oct 28th, 2010

Cyclotron Delivery end 2013-2014

SPES control system

EPICS

EPICS has been chosen as the general framework to develop the control system of SPES

Main challenge is the integration of different hardware technologies under a common model of data and communication protocols.

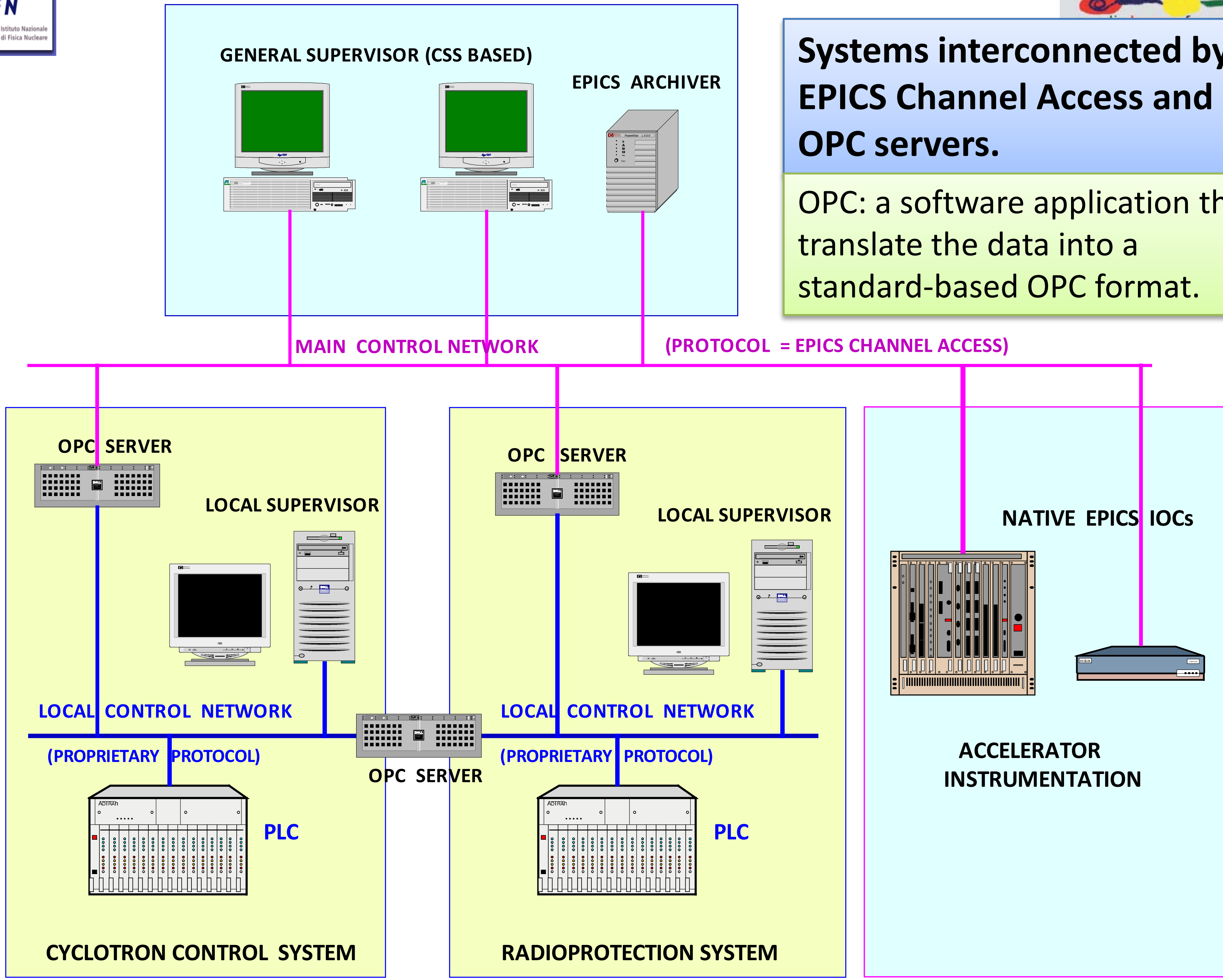
Due to security requirements, a significant part of controls will be based on industrial PLCs

The control of accelerator equipment and beam diagnostic instrumentation will be implemented on native EPICS IOCs (Input/Output Controllers).

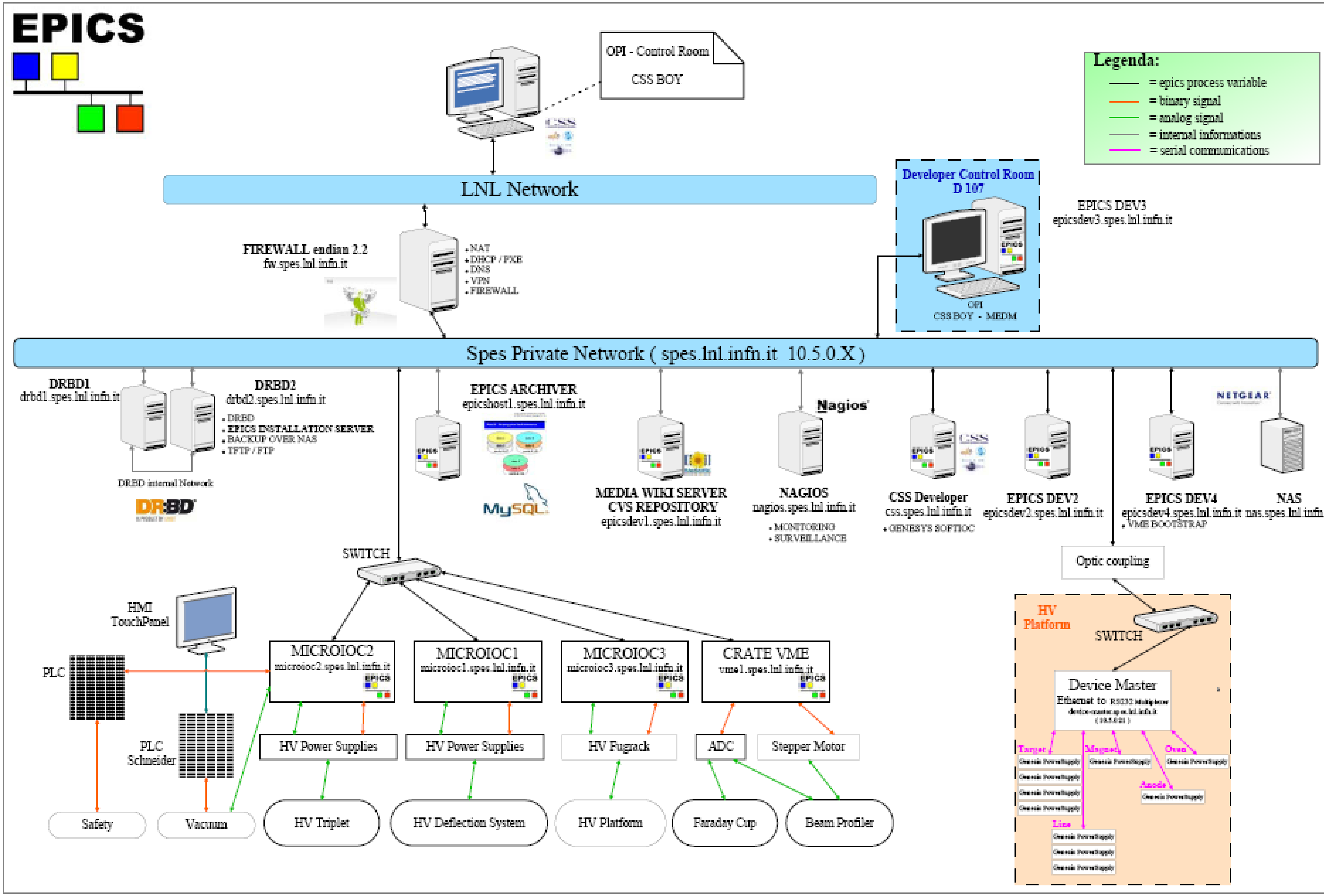
SPES control system architecture

Systems interconnected by EPICS Channel Access and OPC servers.

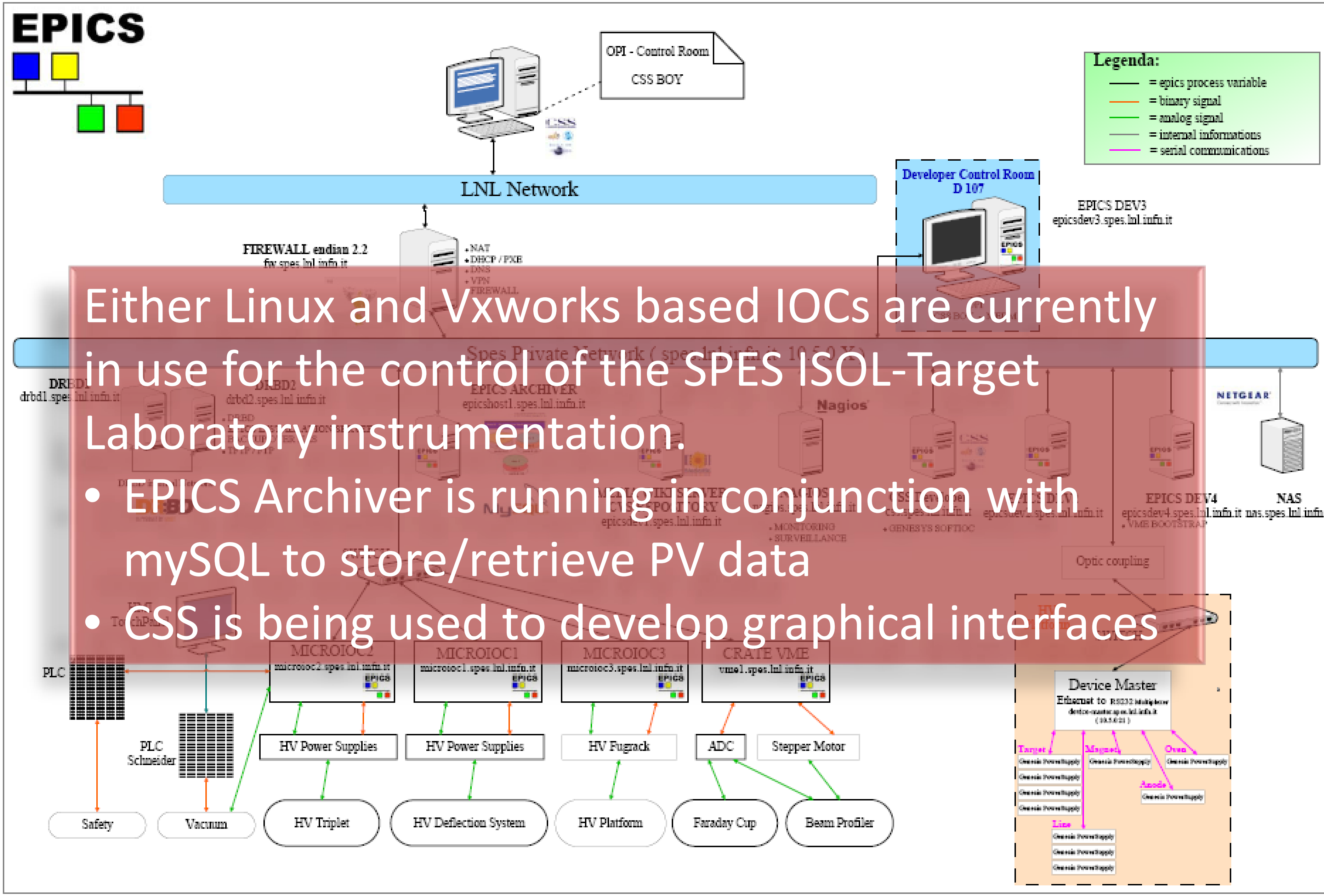
OPC: a software application that translate the data into a standard-based OPC format.



SPES control system: test &development



SPES control system: test &development



Either Linux and Vxworks based IOCs are currently in use for the control of the SPES ISOL-Target Laboratory instrumentation.

- EPICS Archiver is running in conjunction with mySQL to store/retrieve PV data
- CSS is being used to develop graphical interfaces

Radio-isotopes for medicine

Production of radionuclides of interest for medicine using the SPES cyclotron

Table 7 – List of Isotopes Produced by Proton Accelerators of Various Energies

30 MeV		45 MeV		70 MeV	
Isotope	Half-Life	Isotope	Half-Life	Isotope	Half-Life
Cu-64	12.7 h	Zn-62	9.2 h	Fe-52	8.3 h
Y-86	14.6 h	Co-55	17.5 h	Xe-122	20.1 h
Cu-67 *	2.58 d	Hg-195m	41.6 h	Mg-28	21 h
Sc-47	3.35 d	Bi-206	6.2 d	Ba-128	2.43 d
I-124	4.2 d			Cu-67 *	2.58 d
Tc-96	4.28 d			Ru-97	2.79 d
Xe-127	36.4 d			Sn-117m	13.6 d
Y-88	106.7 d			Sr-82	25.4 d
Ge-268	271 d				

New radio-isotopes of interest for medicine available at 70 MeV

ARRONAX – SPES collaboration for Isotopes production and high-power target development

Neutron facility at the SPES Cyclotron

SPES exotic beams for science

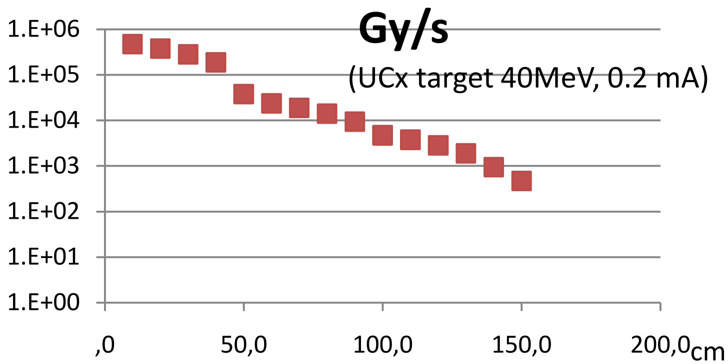
Integral neutron production at SPES Cyclotron Proton beam= 70 MeV, 500 μA Target = W 5mm			
Energy region (MeV)	Sn (n/s) $\sim 6 \cdot 10^{14}$ s^{-1}	**Φ_n @ 2.5 m ($n\ cm^{-2}\ s^{-1}$)**	**Φ_n @ 1 cm ($n\ cm^{-2}\ s^{-1}$)**
1 < E < 10	$\sim 5 \cdot 10^{14}$ s^{-1}	5×10^{8}	3×10^{13}
10 < E < 50	$\sim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

LINCE project

LIFAN: Single Event Effect and DIRECT proton irradiation facility

FARETRA: Moderated neutron facility with Neutron spectra similar to Gen IV

Dose rate in forward direction
(similar to ITER at the wall)

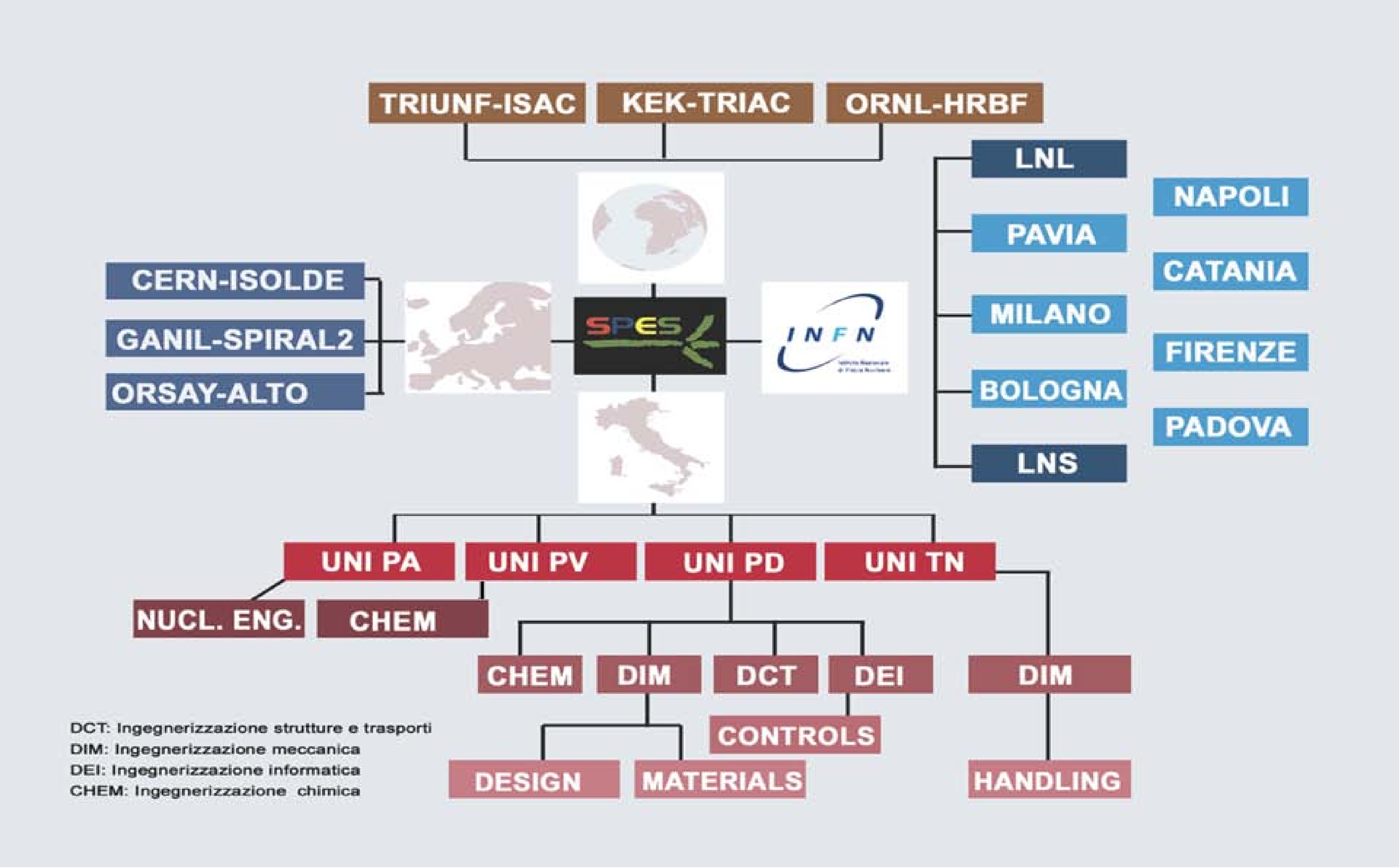


UCANS

Union for Compact Accelerator-based Neutron Sources

Evaluated Total cost: 4Meuro (additional buildings not included)

The SPES collaborations network



TASK 8 - ORGANIZATION

SPES BEAM Characterization : Marco Cinausero

a) tape system - slow control system, acquisition system, Installation LNS
Developement of Detectors for Beam Characterization and/or diagnostics

b) Production Experiments with UCx and different targets.

2. Batch Mode: Francesco Recchia

a) Study and definition nuclear systems
b) Production experiments (cross section, feasibility)
c) Technology of the target/source system (collab. with TASK3)
d) Contacts with Intern. Lab. (Oak Ridge etc.)

3. Nuclear Physics Experiment @existing RIB facilities: Alessia di Pietro

personnel training@ ORNL, ISOLDE etc., proposal presentations.

4. Production Calculations :

MCNPX e FLUKA **calculations**
diffusion-effusion calculations with RIBO or similar

5. Communication and Scientific Documentation: Daniel R. Napoli

Web Page
Conferences
Communication @ INFN
Communication@ LNL and LNS (personnel training)
Scientific Documentation

HIGHLIGHTS 2011

- Final Definition of the Executive Project to define Buildings & Infrastuctures.

- Validation of the Construction Design of the Cyclotron.

•Study of Beam Production through the Laser Source, using the SPES ISOL Front-End in the Target Laboratory and the Pavia laser laboratory.

- Design and construction of an ISOL System to be used at LNS for in-beam production measurements.

- New Proposals of Nuclear Physics Experiments @existing RIB facilities

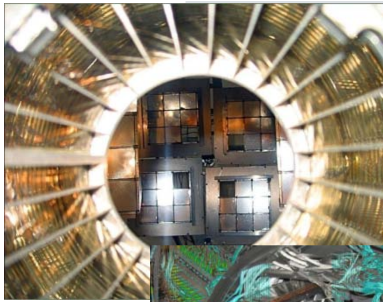
- Study of New Materials for the production of different ISOL targets
- Study of New Materials for the production of different densities UCx pills.

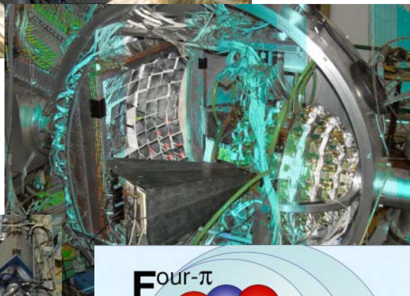
- Preparation of an upgraded TDR for the ISOL facility
- Preparation of the TDRs for the LINCE and LARAMED Applicative Projects

Letters of Intent

23 proposals

13 Nuclear Structure | **10 Nuclear Reactions**





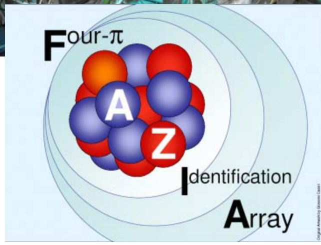
International collaborations:

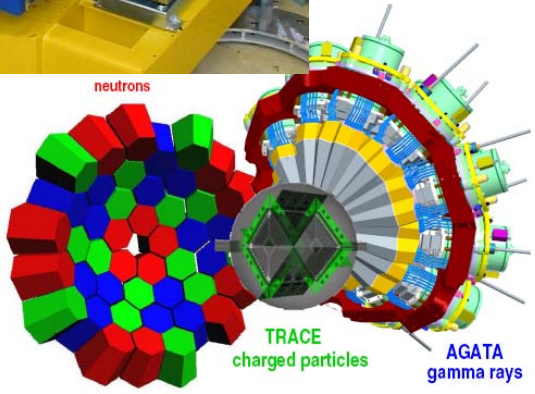
Italy
Bulgaria
Hungary
France
Poland
Spain
Great Britain
Turkey
USA
Slovakia
Romania
Croazia
Russia
India
Germany
Canada

Instrumentation:

1 GARFIELD F. Gramegna
2 PRISMA A.M. Stefanini
3 8PLP M. Cinausero
4 RIPEN M. Cinausero
5 GALILEO C. Ur
6 TRACE D. Mengoni
7 AGATA E. Farnea
8 FAZIA G. Casini
9 NEDA J.J. Valiente Dobon

collaboration between SPES&SPIRAL2





- Channel selection
- Sensitivity enhancement
- Spectroscopic information

CONCLUSIONS

The SPES project is on the construction phase.

After this meeting a selection of beams will be defined for first-day experiments.

The support of the Nuclear Physics community is essential to complete the SPES project.