INFN Istituto Nazionale di Fisica Nucleare

SPES Project

SPES exotic beams for science

SPES status

1st Technical Advisory Committee

Gianfranco Prete
Project leader

LNL, January 22nd 2014

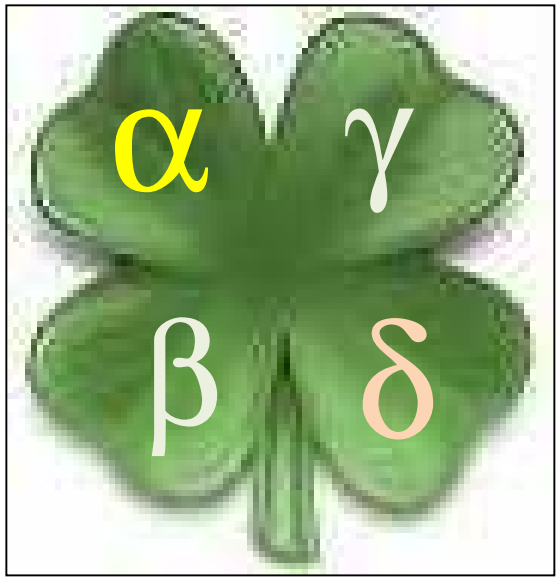
SPES project strategy

- Develop a Neutron Rich ISOL facility delivering Radioactive Ion Beams at 10A MeV using the LNL linear accelerator ALPI as re-accelerator .
- Make use of a Direct ISOL Target based on UCx and able to reach 10^{13} Fission/s (fission is the main reaction mechanism to produce n-rich isotopes).
- Develop an applied physics facility based on the technology and the components of the ISOL facility. Applications in medicine and neutron production.

Exotic nuclei

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

Reacceleration high purity beam Reacceleration up to ≥10 MeV/u



Applications

Radioisotope produduction & Medical applications (**LARAMED**, partially funded)

Proton and neutron facility for applied physics (**NEPIR**, preliminary design)

Time line of SPES project

Main goal : **10^{13} fission/s in-target production, and re-acceleration at 10*A MeV (A=132)**

2002	TDR for 2 Step Target ISOL facility (100kW berillium n-converter + UCx production target). Proton driver: high current LINAC (3mA, 100MeV). Evaluated cost: ~**100 Meuro.**
2003	Assigned dedicated funding by INFN (16.3 Meuro).
2005	Design of a High performance Direct Target for 10^{13} fission/s at 10 kW beam.
2007-08	TDR for Direct Target ISOL facility. Present dual-exit cyclotron-based facility Capability to operate two targets at the same time. Evaluated cost: ~ **50Meuro**.
2011	Start of cyclotron design/construction.,
2011	additional 3Meuro INFN funding
2012	INFN management approve the reallization plan for SPES
2012	5.6 Meuro from MIUR Premium Project for SPES beta
2013	Start building construction.
2013	7 Meuro from MIUR Premium Project for Medical Radio Isotope facility

(A.Duatti)

SPES α & β

Selective Production (and reacceleration) of Exotic Species

Nuclear Physics

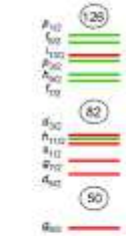
Fission process is the prefered way to produce neutron-rich beams

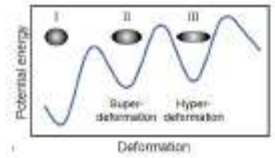
high angular momentum

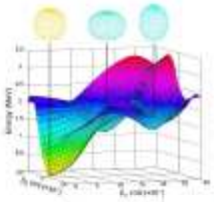
deformed nuclei

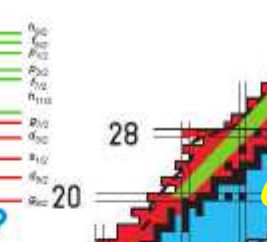
correlation (pairing)

shell evolution









π drip line

ν drip line

SPES beams

TERRA INCOGNITA

heavy elements origin
r−,p−,s−process

stellar explosion
X-ray burst and supernovae

neutron stars

Nuclear Astrophysics

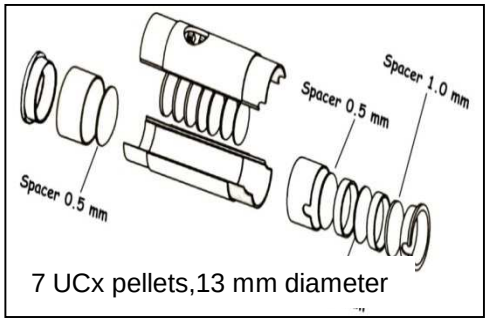
Estimated reaccelerated beams

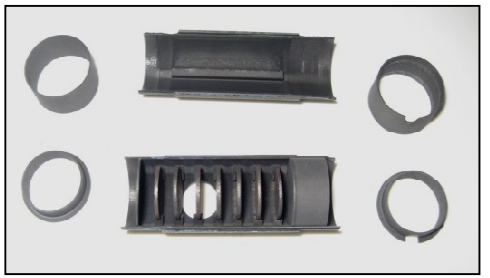
Preliminary experimental work at ORNL- HRIBF, 2010-2012

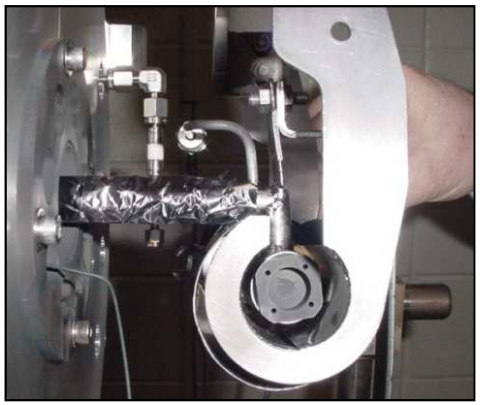
Experiments with SPES target configuration

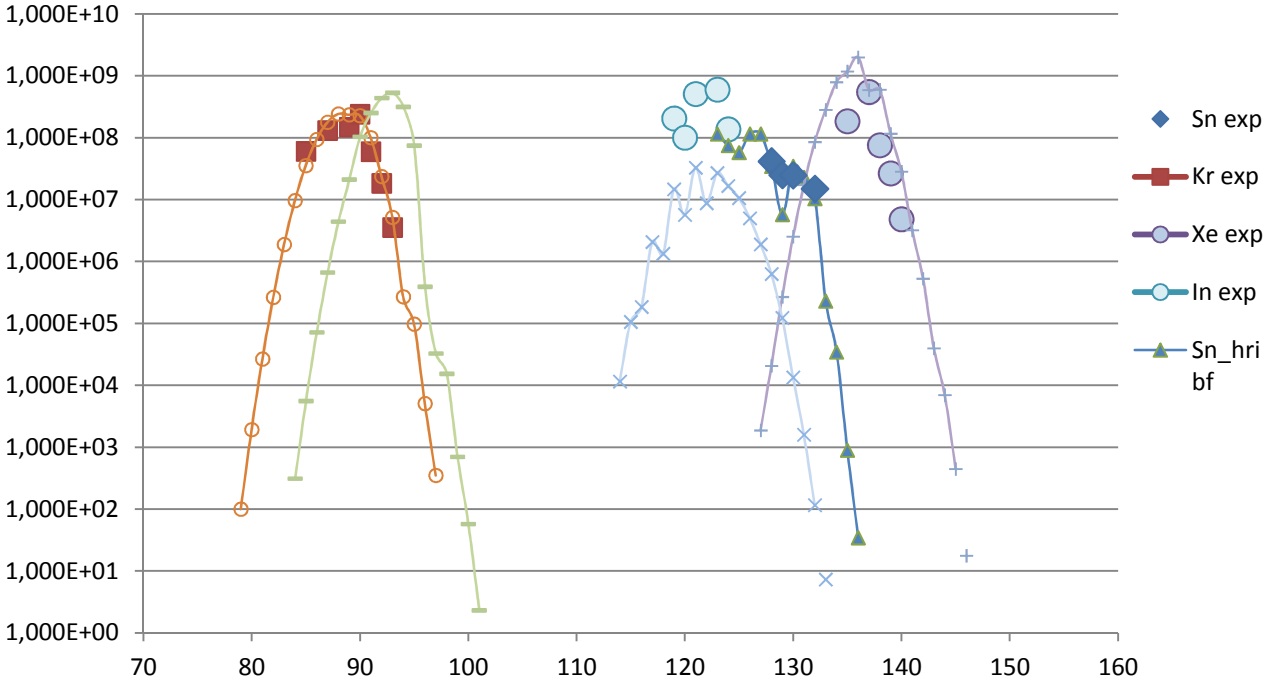
Proton beam: 40 MeV, 50 nA

Expected beam on target scaled to 200 μA,
2-5 % transport efficiency



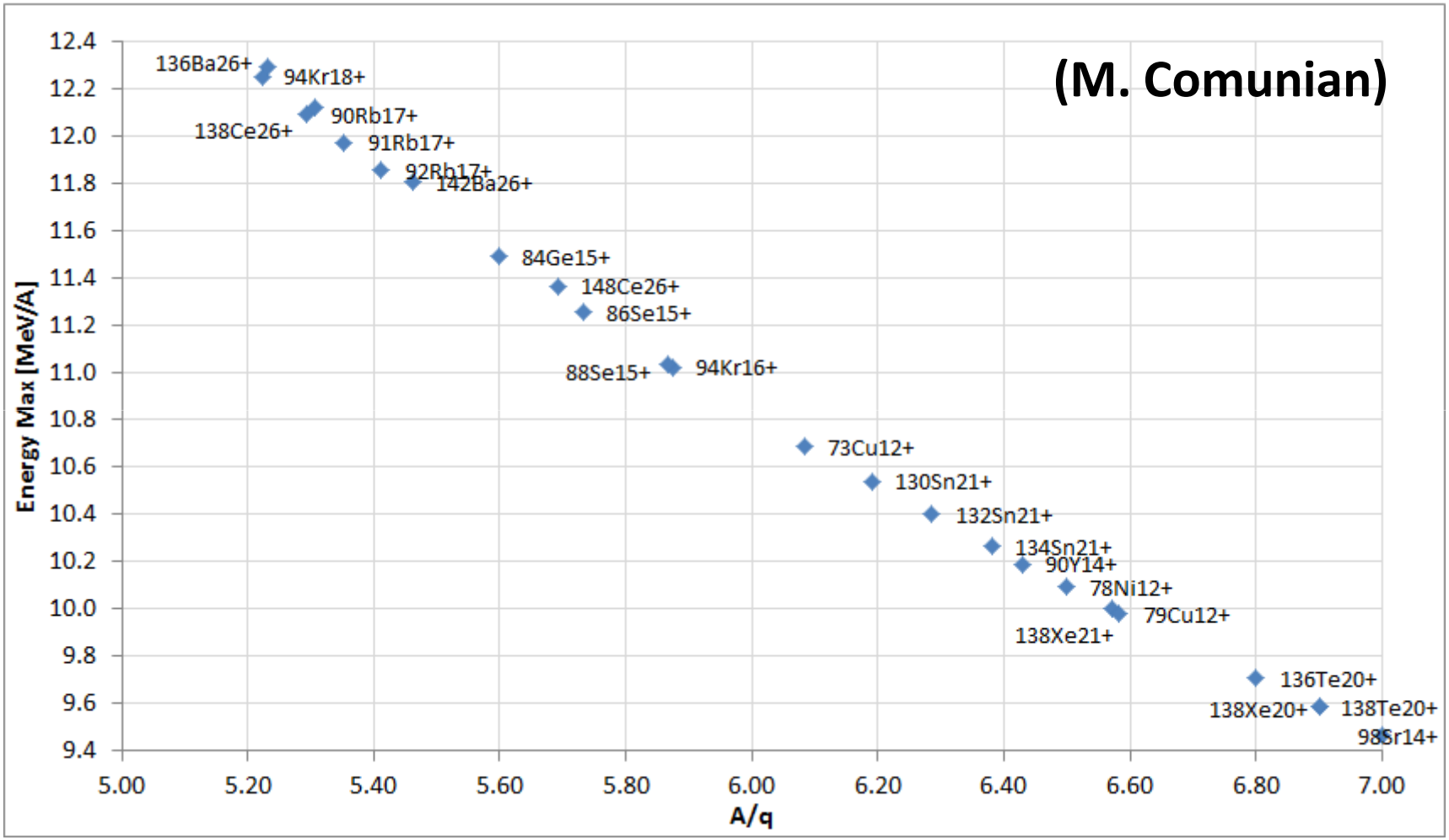






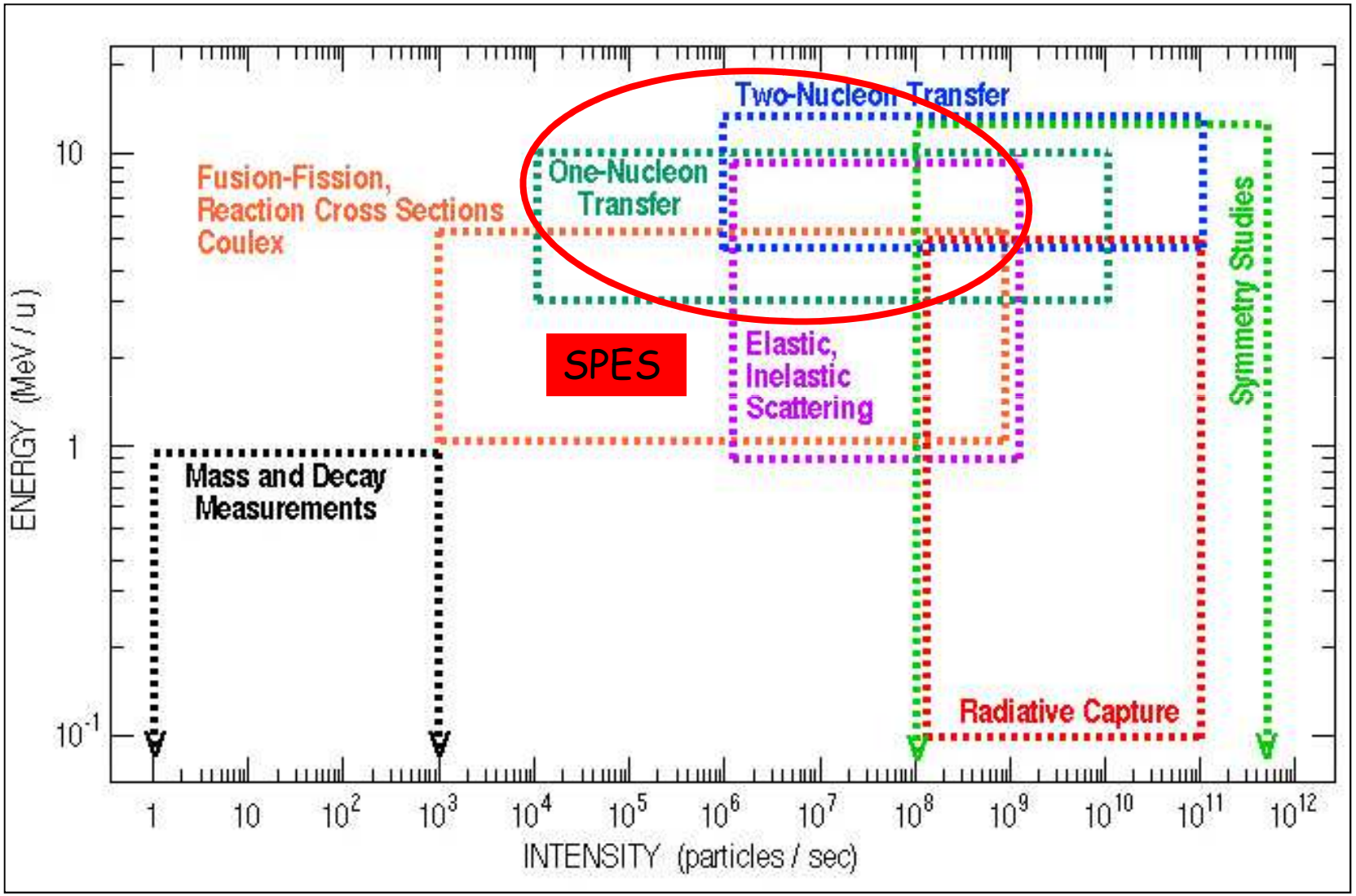
Lines: from HRIBF data base extrapolation
Solid markers: extrapolation from SPES-target experiment at ORNL

Energy from SPES Post-Accelerator as function of A/q



Preliminary results from alpi performances with 2 cavities as margin, Low Beta=5 MV/m, Medium Beta=4.3 MV/m, High Beta=5.5 MV/m

Physics Domain with RIB



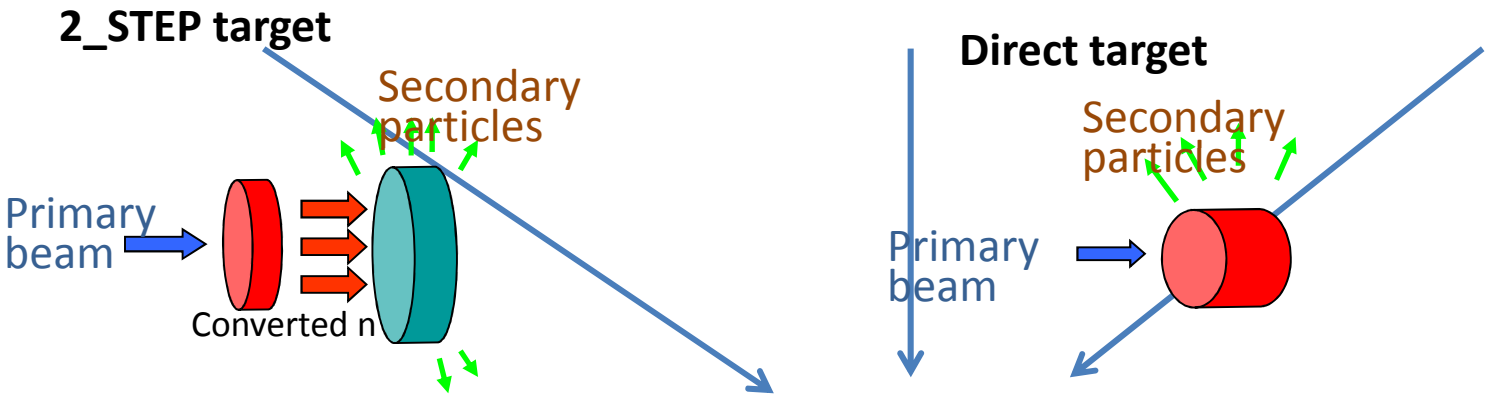
ISOL Roadmap in EUROPE

Second generation 2014-2025	10^{13-14} fission/s 10 MeV/n (A=130)	Effective Mass resolution 1/20000

GANIL laboratoire commun CEA/DSM spiral2 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)

	Primary beam	Power on target	UCx target	Fission s-1	Reaccelerator	MeV/A A=132, 21+
HIE ISOLDE upgrade	p 1-1.4 GeV - 2 μA	0.8 kW	Direct (150g)	**10^{12}** **10^{13}**	SC Linac	5-10
SPIRAL2	d 40 MeV 5mA	200 kW	Converter (4000g)	**10^{13}** 10^{14}	Cyclotron	6
SPES	p 40 MeV 200 μA	8 kW	Direct (30g)	**10^{13}**	SC Linac	10

- Coordinated efforts toward EURISOL
- Complementarities of scientific programs
- Collaboration for technical developments

SPES collaborations network

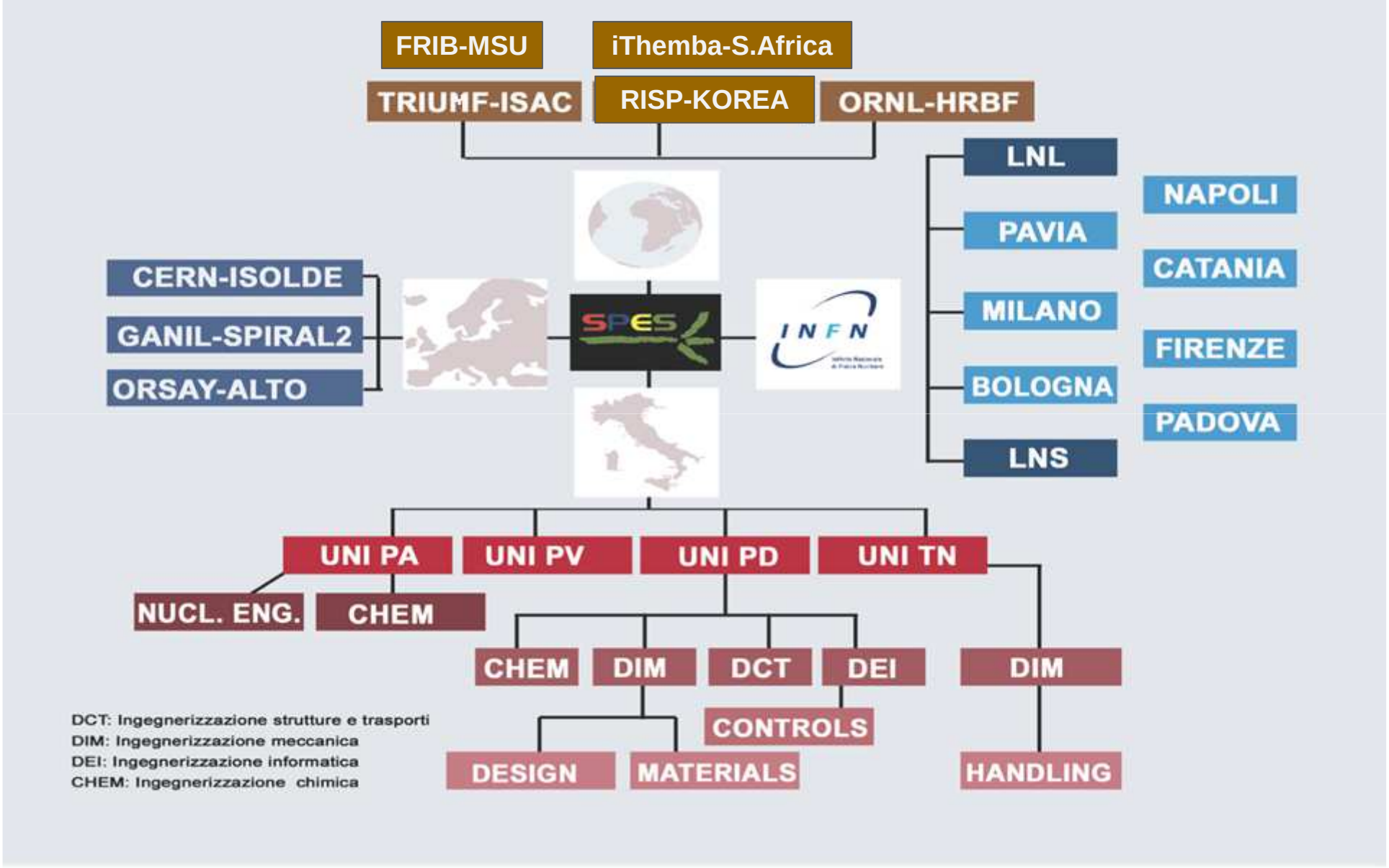
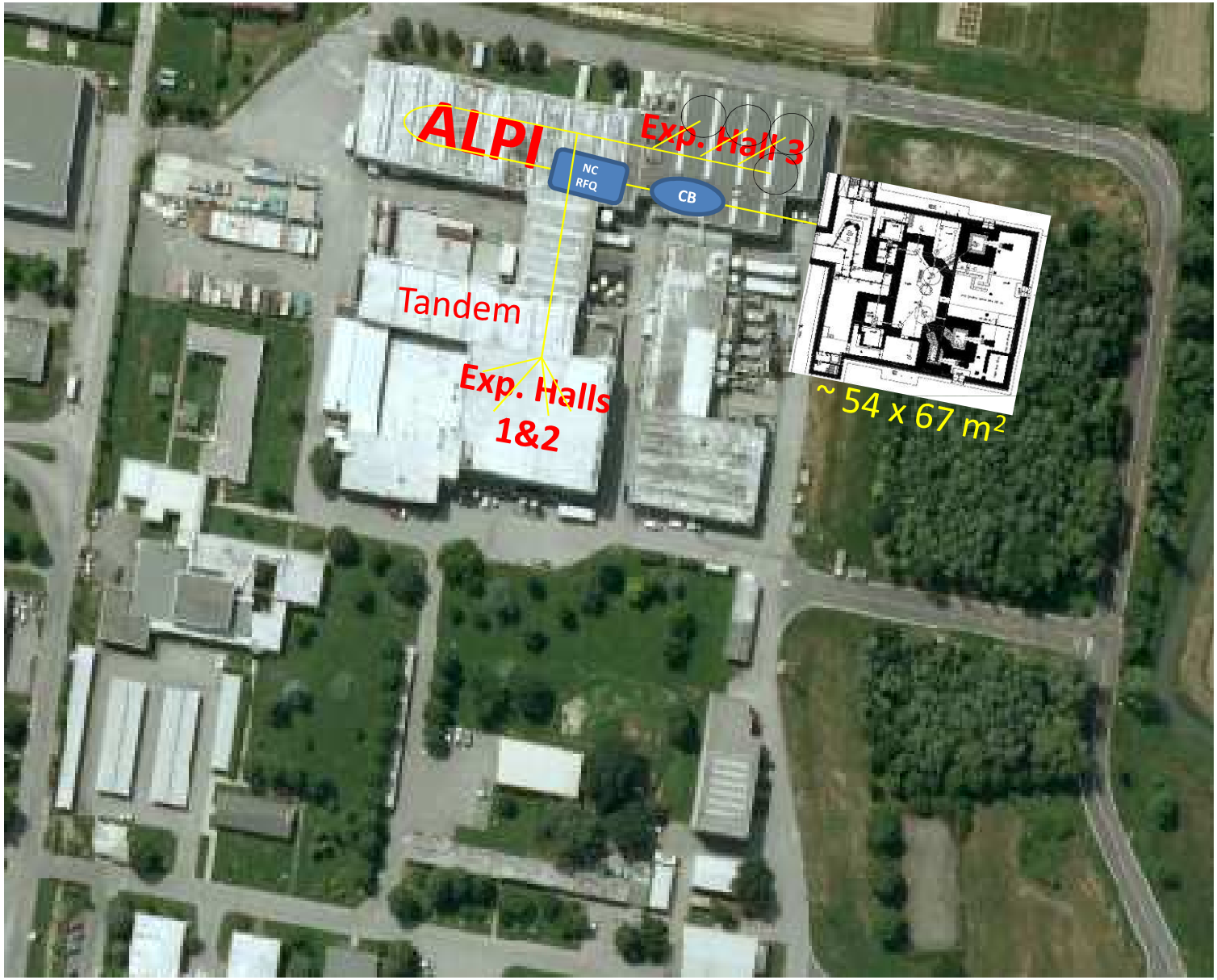
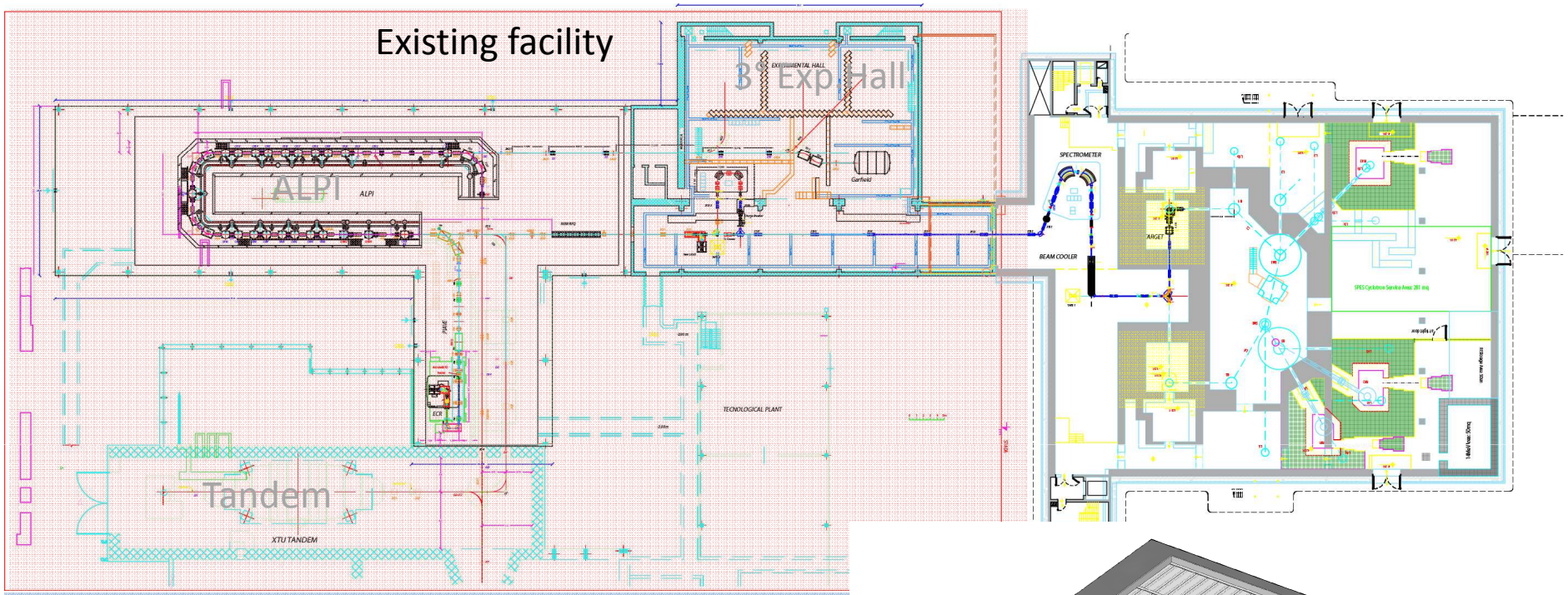


Fig. 3.25: Rete delle collaborazioni di SPES.

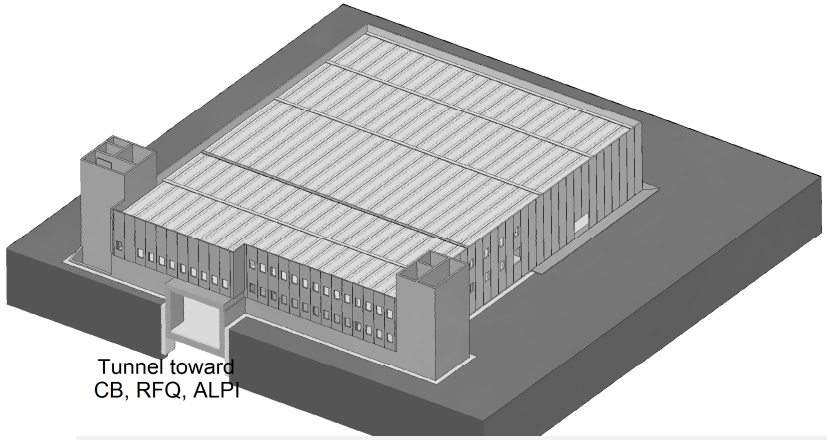
SPES Facility Layout



SPES Facility Layout



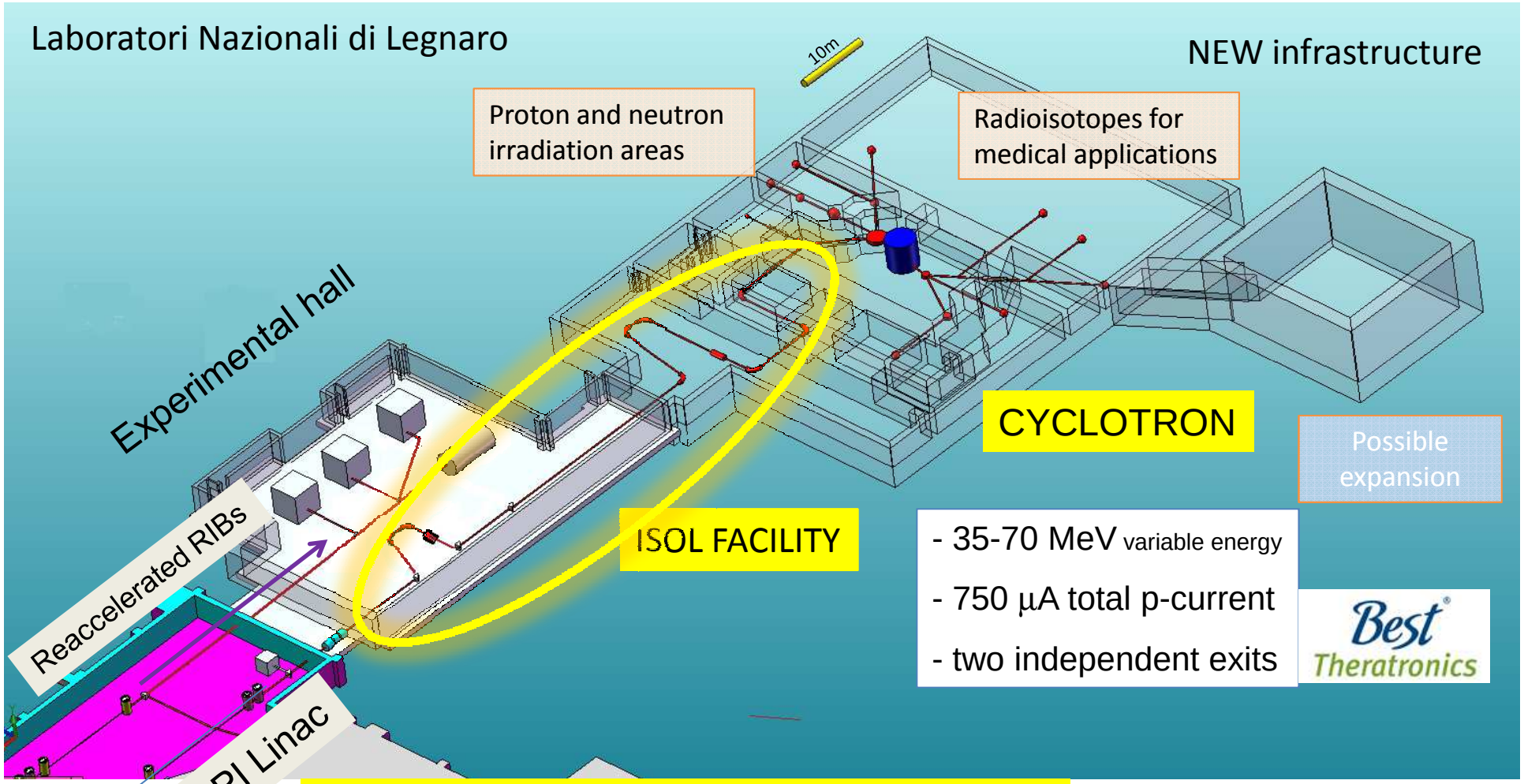
- Accelerator system at **underground level** to match existing ALPI beam line
- **2 ISOL bunkers** for redundance and optimal operation



M.Comunian
Beam transfer and reacceleration

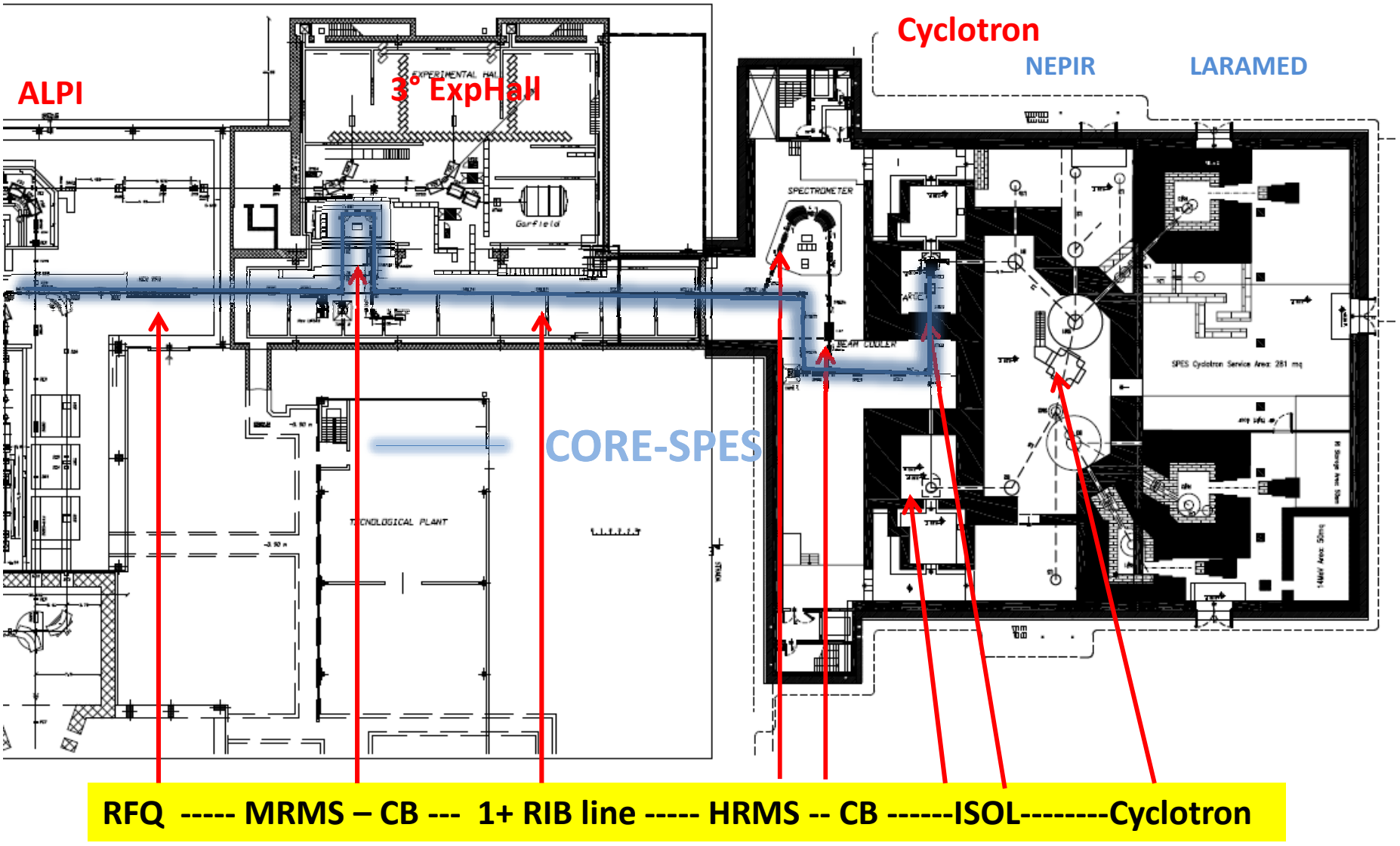
P.Favaron
Building and infrastructure

SPES layout



Radioactive Ion Beams are reaccelerated by the superconductive linac ALPI

SPES Layout

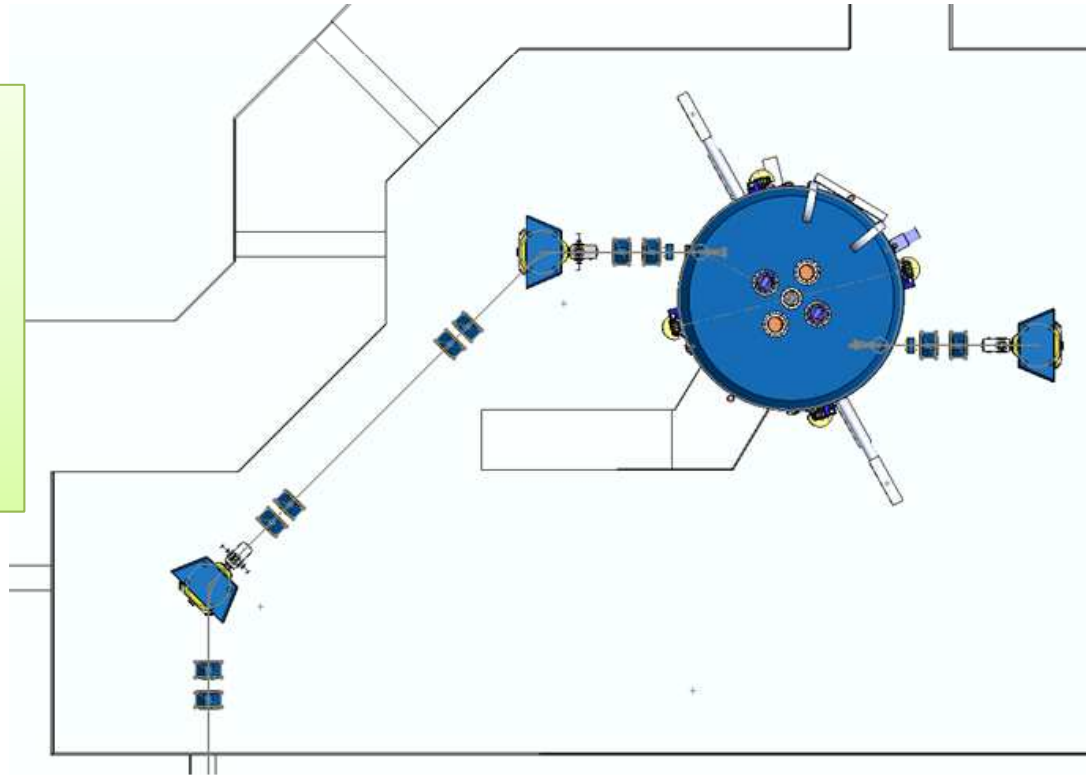

ALPI
3° ExpHall
Cyclotron
NEPIR
LARAMED
CORE-SPES
RFQ ----- MRMS – CB --- 1+ RIB line ----- HRMS -- CB ------ISOL--------Cyclotron

Cyclotron Schedule (2013-2014)

	2013		2014			2015
	II	III	I	II	III	
Final Assembly and Testing						
Factory Commissioning						
Disassembly and Shipping						
Installation at LNL						
Commissioning at LNL						

The Contract with BEST Theratronics provides for:

- Cyclotron
- Two exit channels
- High power beam transport line (up to SPES target)



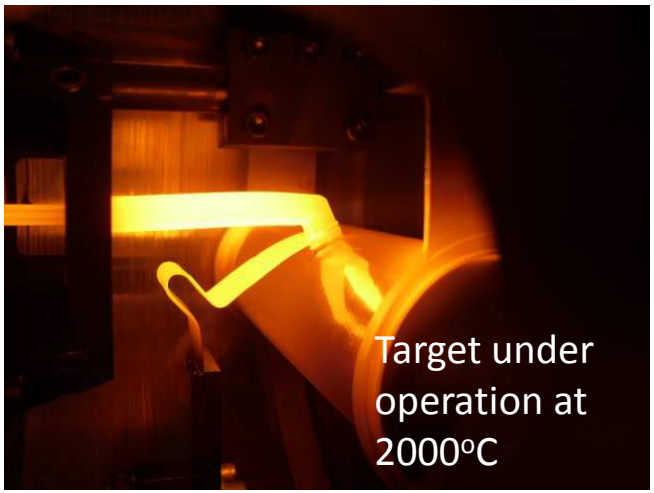
(A.Lombardi)

Technical highlights

SPES DIRECT TARGET CONCEPT to operate with 8 kW proton beam

(A.Andrighetto)

- Direct Target carefully designed to reach 10^{13} fissions/s with 8 kW proton beam. (Thermo-mechanical considerations)
- In beam test scheduled at iThemba labs.
- Prototype under operation.
- Fully developed front-end following ISOLDE design.



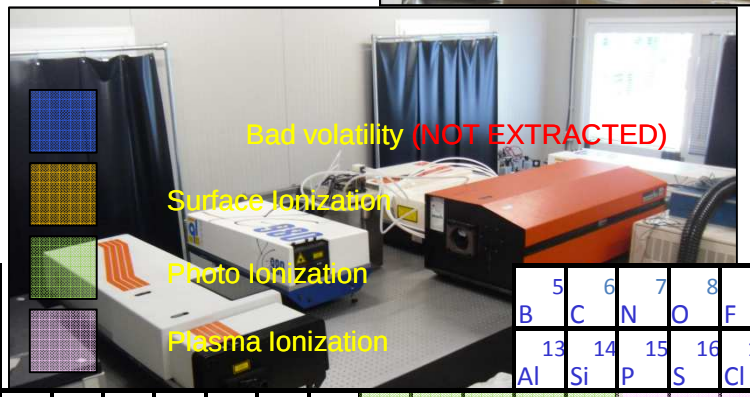
Technical highlights

Ion sources and Laser laboratory

Development of ion sources able to ionize the full set of produced isotopes. Pointing to SELECTIVE ionization.

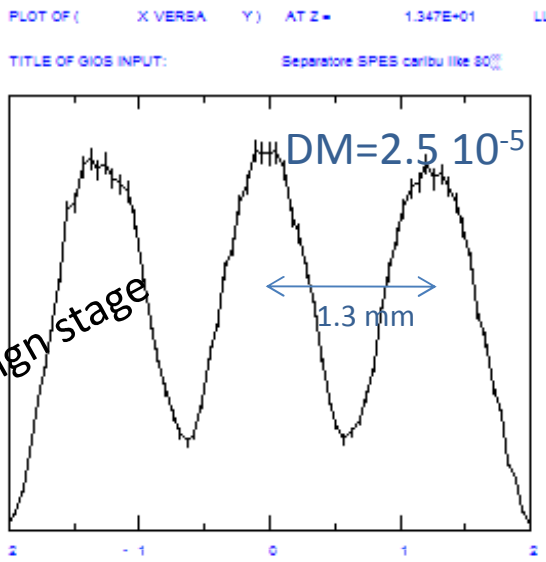
- Surface ionization and plasma ion source was developed and are under laboratory test and characterization.
- A new laser laboratory was settled at LNL to develop the resonant laser ionization ion source. Work in collaboration with Pavia University, participation to ENSAR2 JRA.

(A. Andrighetto)



High Resolution Mass Separator & Beam Cooler

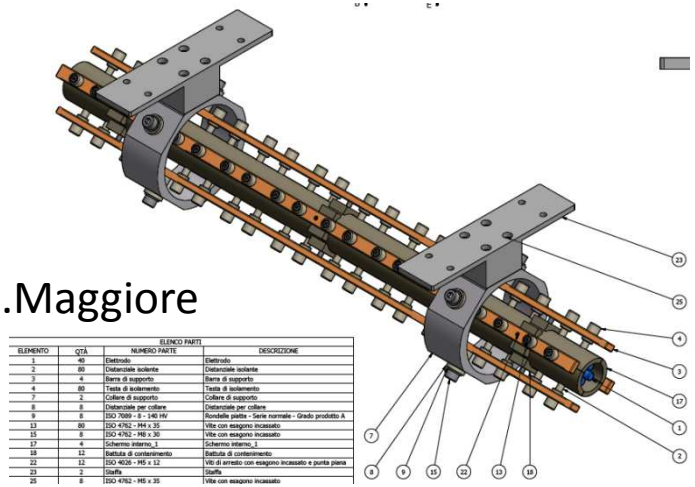
- Scaled-up version of the separator designed by Cary Davids for CARIBU, Argonne
- Mass resolution: 1/40000 (eng. design: 1/25000)



Beam Cooler to match the HRMS input requirements

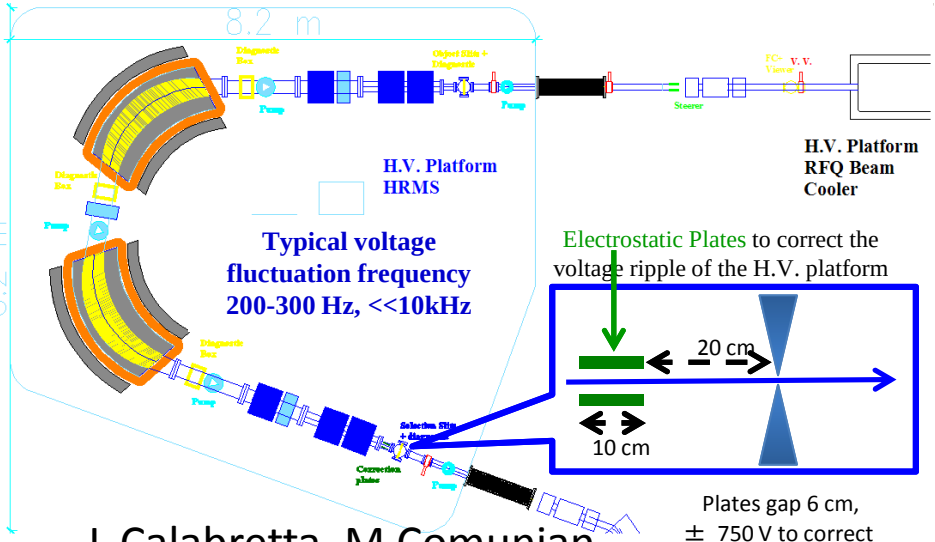
COOLBEAM experiment financed by INFN-CSN5, 2012→2015

Collaboration: LNL-LNS, Mi bicocca



M.Maggiore

High Resolution Mass Separator



L.Calabretta, M.Comunian

Collaboration with LPSC for SPES Charge Breeder

- **Development of an upgraded PHOENIX booster for SPES** is part of a MoU in the frame of the European Associated Laboratories (LEA-Colliga) with GANIL. (In exchange: development of the n-converter for SPIRAL2 by INFN)
- INFN allocated 500 k€
- Final contacts to complete the formal agreement with LPSC are on the way
- LPSC has worldwide competence in ECR and CB and will take care of the CB construction.

Schedule defined for the Charge Breeder development

- 2010 Preliminary measurements
- 2011 Conceptual design and schedule definition
- 2012 Design
- 2013 Agreement definition
- 2014 Construction
- 2015 Commissioning

Improve breeding for ISOL

Charge Breeder is a well known key point for ISOL facilities.
The European project EMILIE is settled to address this problem.

ERA-NET for Nuclear Physics Infrastructures

Enhanced Multi-Ionization of short-Lived Isotopes at EURISOL

- EMILIE project (Enhanced Multi-Ionization of short-Lived Isotopes at EURISOL)
- This project will investigate two technologies of ion sources (ECRIS and EBIS) to optimize their performance for radioactive ion beam charge breeding at future Isotope Separation On Line (ISOL) facilities. This work should benefit to SPIRAL upgrade, SPIRAL 2, HIE-ISOLDE, SPES and EURISOL projects.

CNRS : GANIL, LPSC, France

INFN, Italy

JYFL- Finland

HIL- Poland

ECRIS - large intensities (>>10^{10} pps) for moderate charge states, but low efficiency for condensable elements.
EBIS - high charge states - limited in capacity (<10^{10} pps) and are pulsed devices which complicate events detection especially for in-beams experiments.

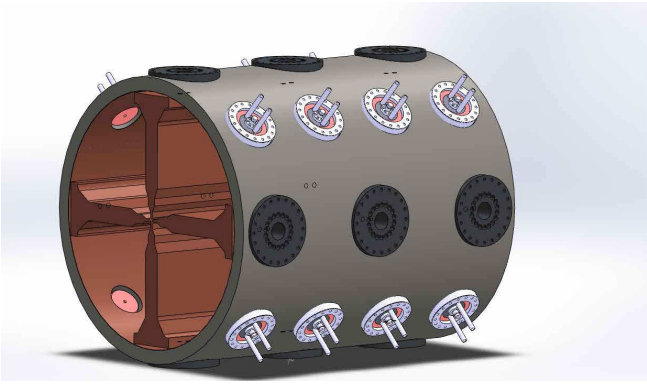
A.Galatà, G.Patti

NEW RFQ injector for ALPI

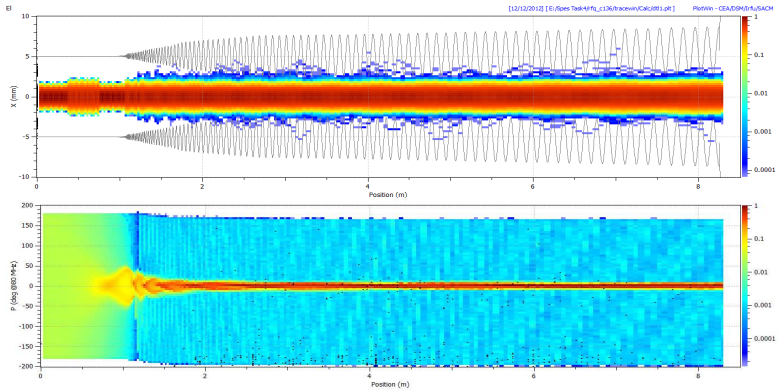
(A.Pisent)

A high transmission RFQ to match the ALPI entrance requirements

- **Beam transmission >95%,** low RMS longitudinal emittance at output: 0.15 ns*keV/u.
- Energy 5.7 –> 727.3 [β=0.0395] KeV/A (A/q=7) matching the ALPI entrance requirements
- **Mechanical design and realization, taking advantage of IFMIF experience** (LNL, INFN_Pd, Bo, To).



Mechanical layout of the RFQ tank module of about 1 meter.



Upgraded ALPI layout

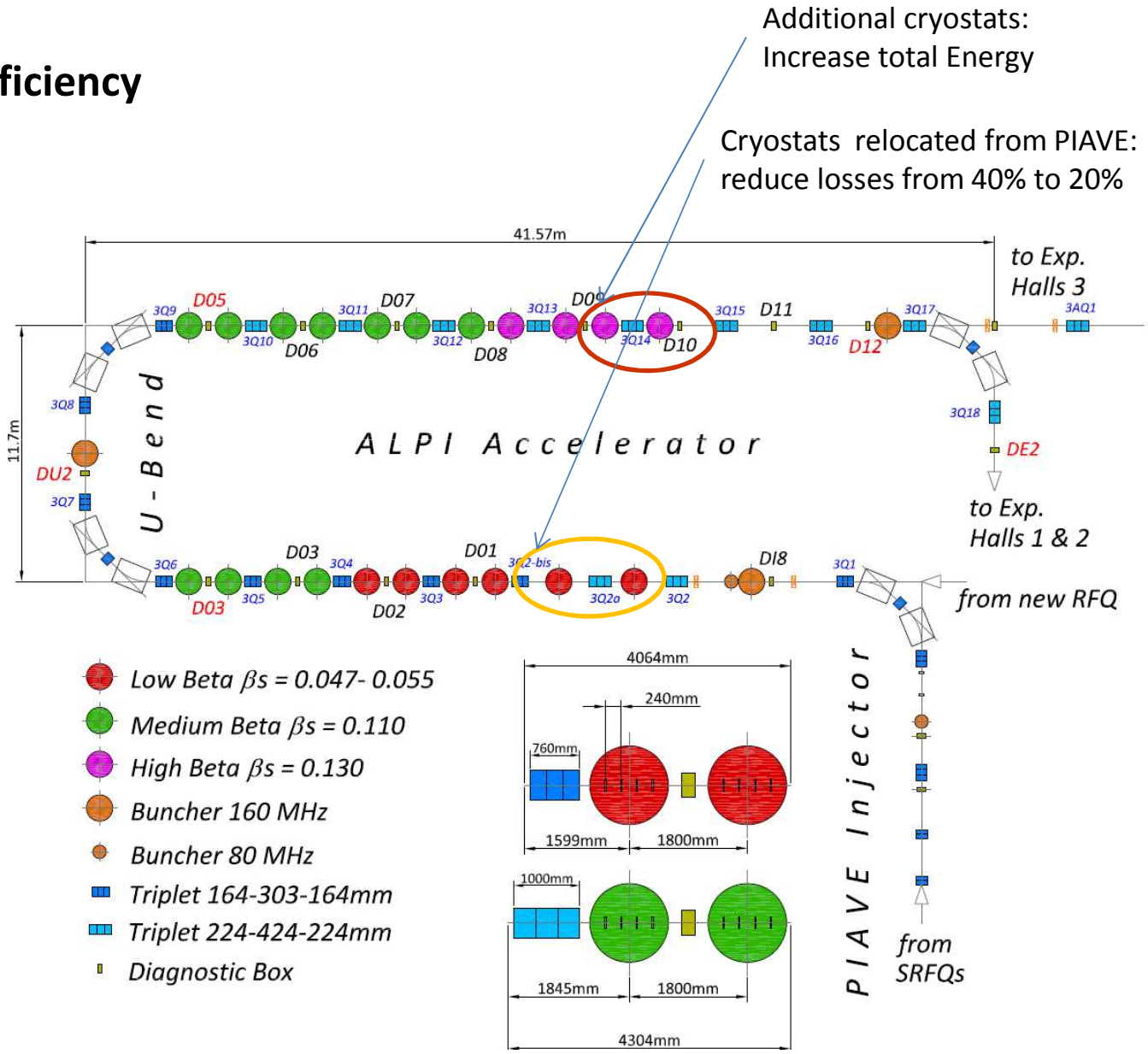
- **Increase energy**
- **Optimize transport efficiency**

- All Cavities from CR03 to CR07 at 4.5 MV/m.

- Medium beta CR07 to CR18 at 4.5 MV/m.

- High beta 6.5 MV/m for CR19-CR22.

- **Final Energy : ~ 10 MeV/A (A/q=7)**



Radiation protection Safety and Controls

RADIOPROTECTION: Evaluation of radioactivity and radiation risk
Authorization request for SPES operation:

completed

phase 1 request for cyclotron operation at 0.5 mA on standard targets and 5 microA on UCx

Phase 2 request for full power operation on UCx target (0.2 mA)

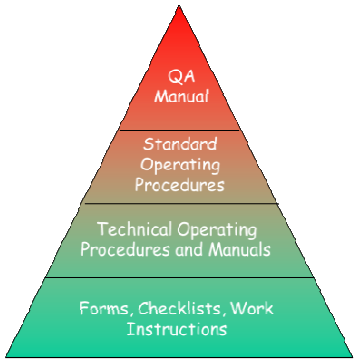
SAFETY: Development of a Quality and Safety Management System for SPES and definition of a safety system.

(D.Zafiropoulos J.Esposito)

CONTROLS: EPICS defined as a common supervisor for SPES. Migration of all controls on the same supervisor improve the quality and the safety of the system

(M.Bellato)

SPES safety system on the way

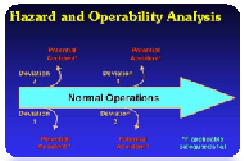


QSMS: Quality and Safety Management System

ISO 12100:2010/14121:2007 for all **Quality aspects**
OHSAS 18001:2007 for **Safety issues**

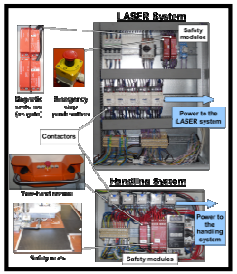
Severity level (S)	Occurrence Probability (P)												
	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3	4	5	6	7	8	9	10	11	12	13	14	15
2	6	8	10	12	14	16	18	20	22	24	26	28	30
3	9	12	15	18	21	24	27	30	33	36	39	42	45
4	12	16	20	24	28	32	36	40	44	48	52	56	60

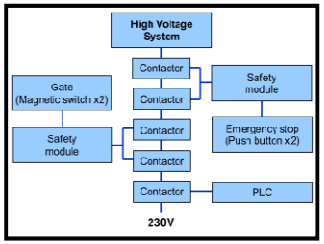
RISK analisys



- **FMEA - Failure Mode and Effects Analyses**
- **FMECA - Failure Mode Effects and Criticality Analyses**
- **HAZOP - HAZard and Operability study**

EPICS





SAFETY system

Criticality for the project: hot item for 2014

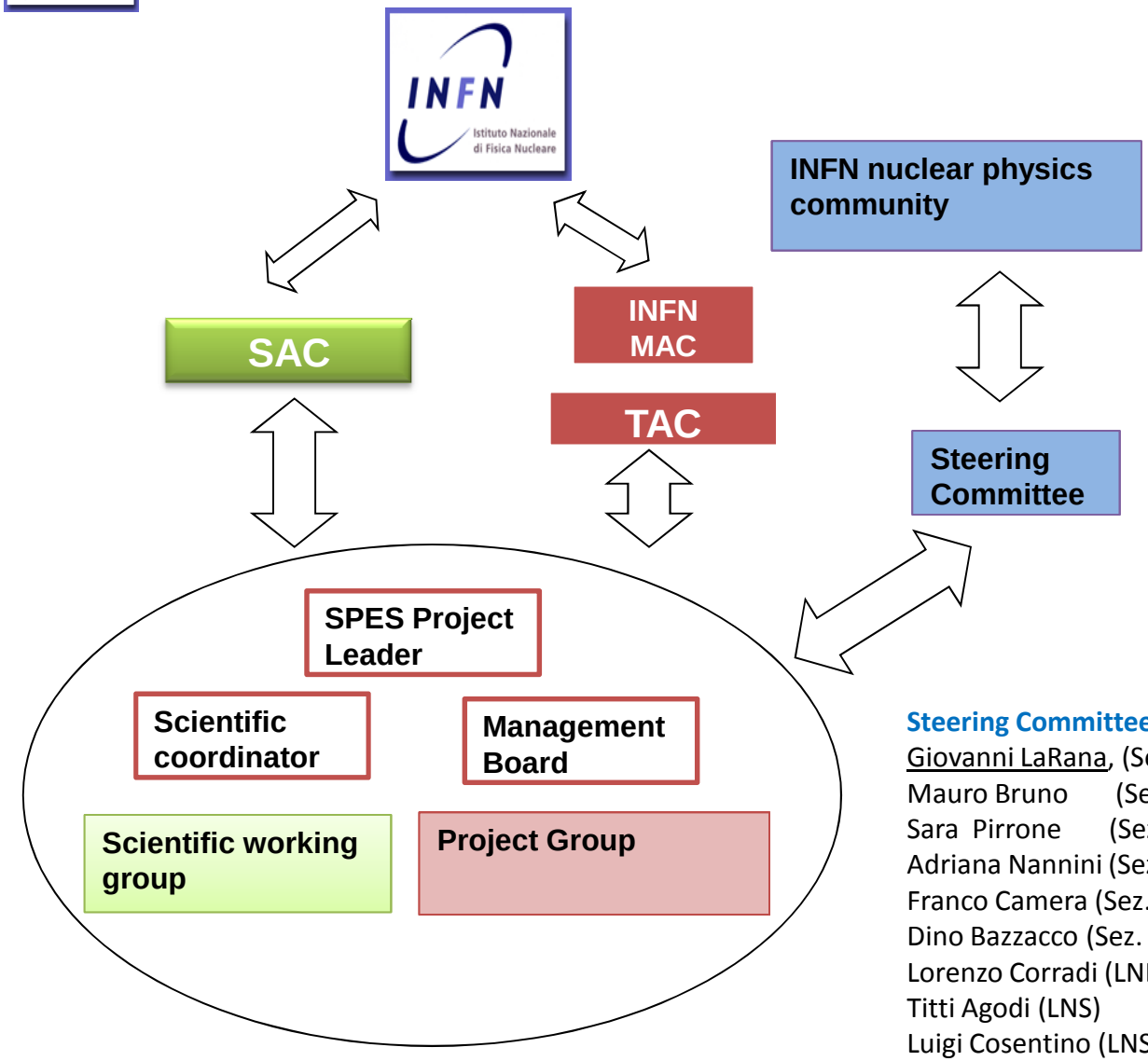
QSMS defined

On the way the risk analisys (collaboration with nuclear eng. Palermo)

Performed Safety systems (software and hardware) for ISOL lab.

Contacts with italian companies for full design (SOGIN, NUCLECO, ENEL, ..)

SPES organization



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G.Fiorentini, G.Prete

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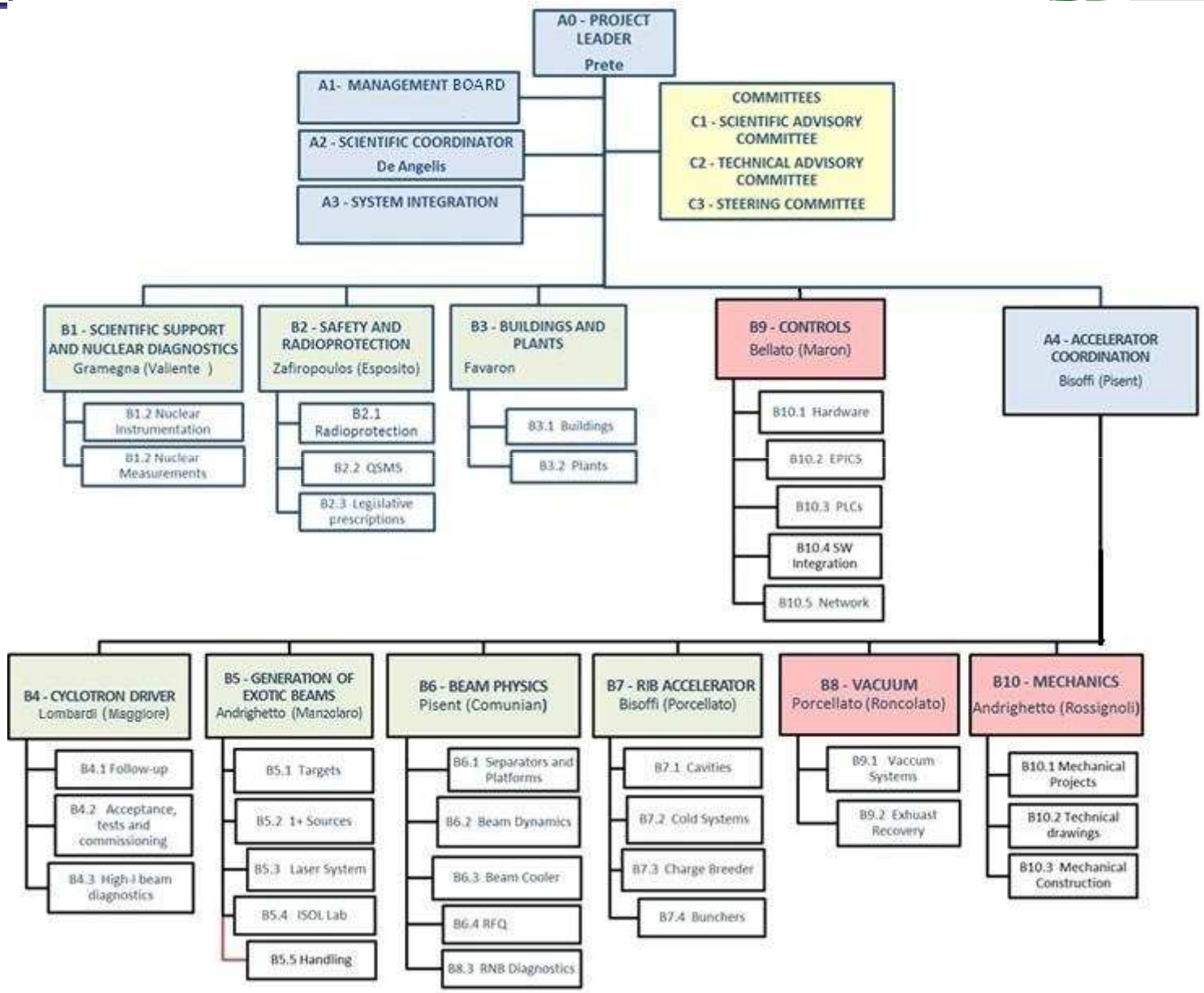
R. Catherall (ISOLDE),
M. Pelliccioni (INFN),
G.Bisoffi (LNL)

SPES organization and Work Packages



Reference document approved by INFN for SPES (3 Dec, 2012)

INFN approved the construction planning of the SPES project in Dec. 2012

Already invested 20.5 Meuro upto 2012

Building	6.5
Cyclotron	10.5
ISOL R&D and prototype	1.0
Charge breeder (funding fixed)	0.5
Low Beta ALPI upgrade	1.0
Consumable	1.0

To complete the construction about 30 Meuro are necessary

N.	Voce	Meuro
1	Bersaglio ISOL con Sorgente laser	3.2
2	Edilizia per Laboratorio UCx	2.6
3	Trasporto del fascio di ioni radioattivi	7.7
4	Selezione in massa ad alta risoluzione (HRMS e Beam Cooler) (solo per FULL_SPES)	(2.7)
5	Charge Breeder	1.5
6	RFQ per la preaccelerazione	3.7
7	Upgrade dell'acceleratore ALPI	5.6
8	Sistemi di controllo e sicurezza	3.6
	TOTALE	27.9 (30.6)

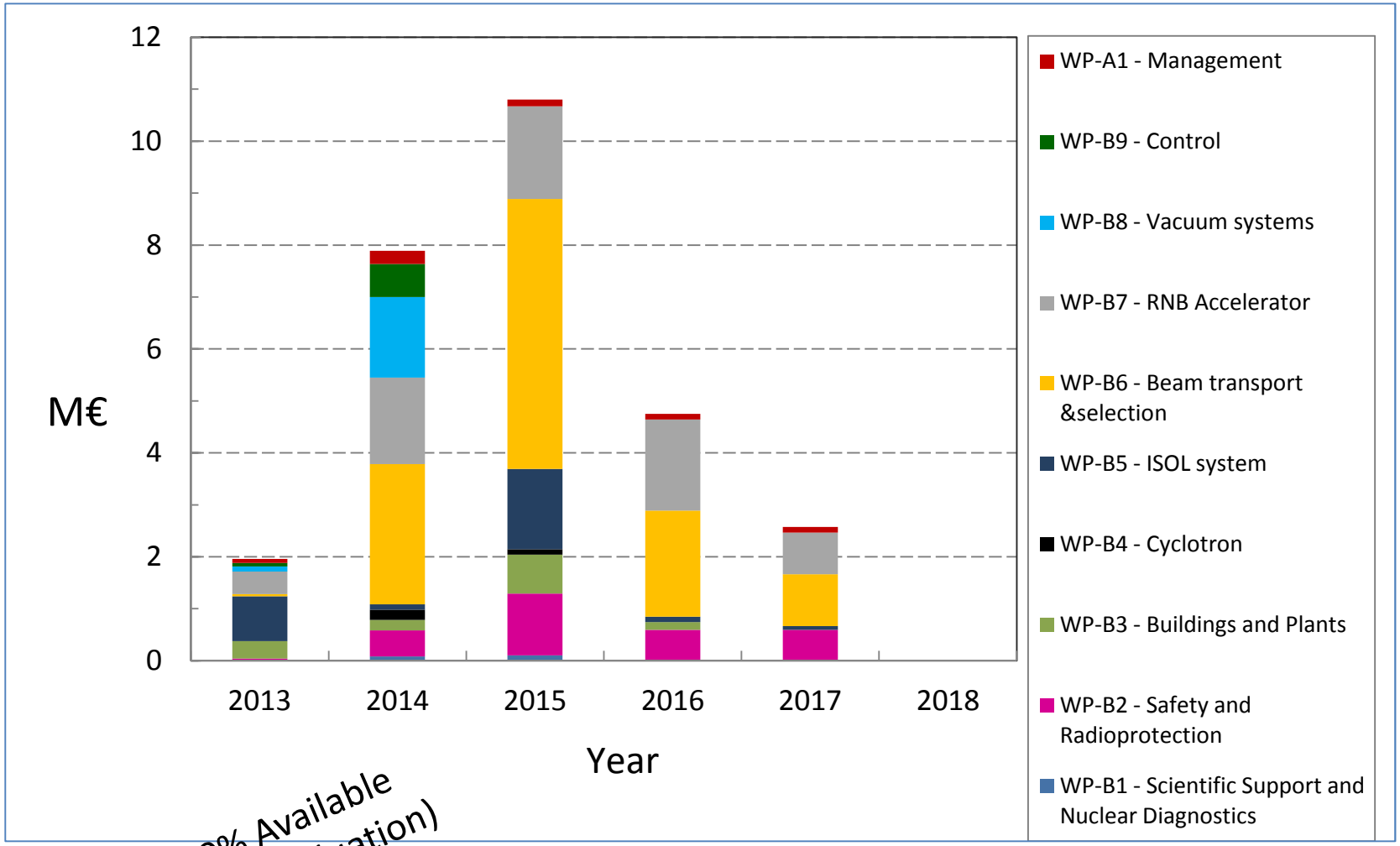
SPES funding plan for CORE SPES

SPES funding plan (k€)
without High Resolution Mass Selection system (CORE SPES)

	2013	2014	2015	2016	2017
CONSTRUCTION (28 M€ to complete **CORE_SPES**)	**1.9**	**7** **0.9***	**8.5** **2.3***	**4.7**	**2.6**
PERSONNEL (IN TRAINING)	0.5	0.6	0.4	0.3	0.3
Total	**2.4**	**8.5**	**11.2**	**5**	**2.9**

* LNL contribution to RFQ construction

CORE SPES funding plan



2014 Budget: 50% Available
(also subject to TAC evaluation)

Funding plan 2014

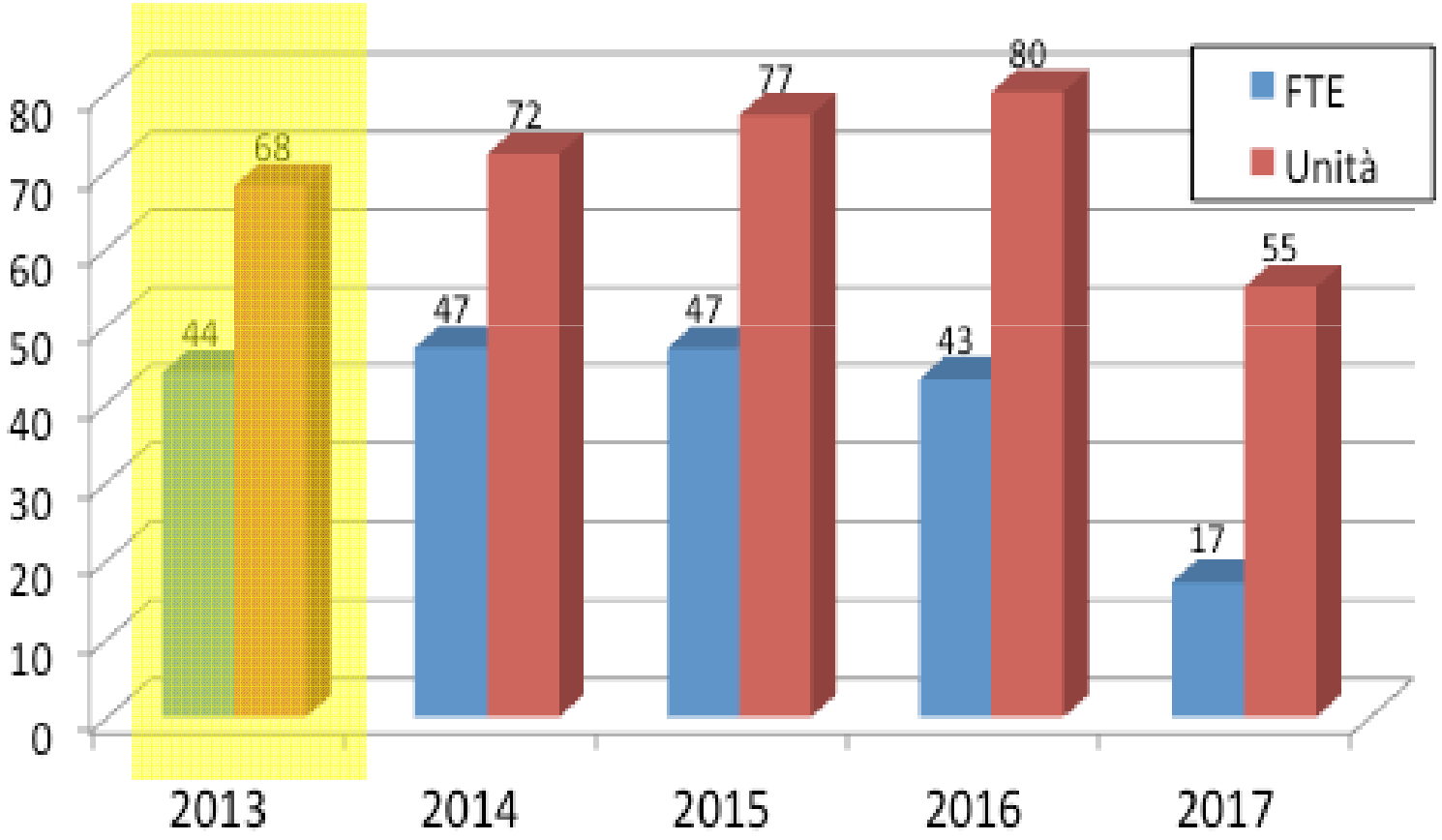
Assignement requested to INFN for year 2014

	Total 2014 (k€)	*Residues 2013 (k€)*	*First tranche 2014 (k€)*	*Second tranche 2014 (k€)*
PERSONNEL (IN TRAINING)	653	49	328	276
TRAVEL EXPENSES	80	23	37	20
SERVICES	100	0	50	50
CONSUMABLES	70	0	48	22
APPARATUSES	6405	1	2321	4083
DURABLES	133	5	66	62
BUILDINGS	200	16	150	34
Total	**7641 =**	**94 +**	**3000 +**	**4547**

Detailed Economic plan 2014

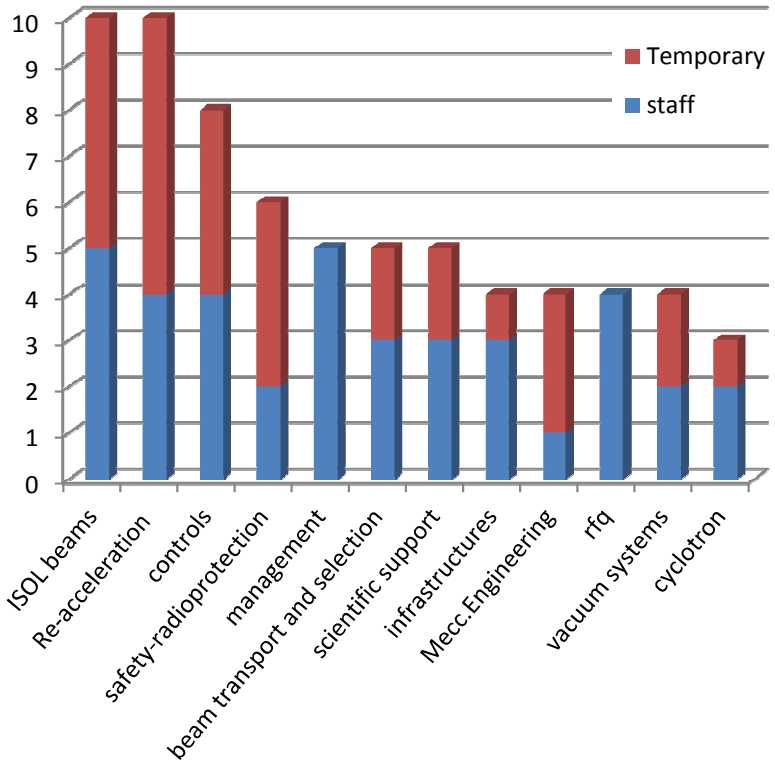
Task	Item	(k€)	notes
Scientific support	Radioactive beam identification	83	Tape system instrumented with gamma-beta detectors and ACQ
Radiation protection	Radiation monitors	500	Design of radiation monitor system for cyclotron operation
Buildings	General services and plants	200	Distribution of services in cyclotron and ISOL areas
ISOL beams	ISOL laboratory and Laser source	100	Measurements and optimization of ion sources and ISOL front-end
Beam Transport	CB-RFQ beam line	**1700**	Design and order of MRMS components and n+ CB beam line
Beam Cooler	BC test stand	100	Set-up of BC vacuum chamber and test stand
Cyclotron	Installation	200	Cyclotron connection to electric power and services
RFQ (in-kind contribution LNL)	First tranche of materials and machining for RFQ development	(900)	This item comes as in-kind synergy with others LNL projects.
ALPI	Cryogenic system	345	New valve box purification system
Diagnostic	Diagnostic Box	**670**	Order of 20 low current diagnostic boxes
Charge Breeder	Power supplies, 1+ beam transport elements	**650**	Construction of CB. Installation and test of 1+ ion source.
Vacuum	Vacuum systems for 1+ radioactive beam line	**1550**	Order of 20 vacuum systems
Controls	ALPI access control system RF and CB controls	**640**	Installation and commissioning of new Access Control system for ALPI. Design and order of controls for RF and Charge Breeder.
Training personnel		653	
Consumables		70	
Travels		80	
Other services		100	External services for installations
TOTAL		**7641 (+900)**	

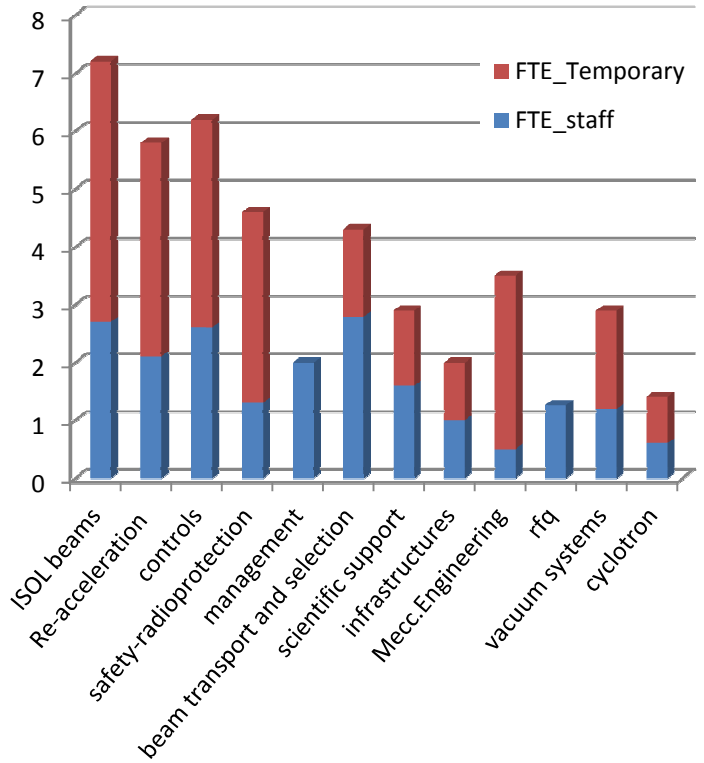
SPES personnel plan



SPES personnel plan

SPES personnel in 2013





Involved personnel in 2013: 68 persons, 44 FTE

42 staff, 13 training, 13 temporary contracts

SPES Schedule January 2014

	2012	2013	2014	2015	2016	2017
Authorization to operate and safety	UCx 5μA	Full UCx authorization				
ISOL Target-Ion Sources development						
ISOL Targets construction and installation						
Building Construction	Executive project	raw building construction				
Cyclotron Construction & commissioning						
RFQ development and Alpi up-grade						
Design of RIB transport & selection (HRMS, Charge Breeder, Beam Cooler)						
Construction and Installation of RIBs transfer lines , CB and spectrometers						
Complete commissioning and first exotic beam						

SPES in summary

Items in construction

- Building and infrastructures
- Cyclotron
- ISOL system and sources
- Charge Breeder (starting 2014)
- Linac ALPI up-grade
- Beam transport
- Control system

- Authorization to cyclotron operation (completed)

Items under final Design

- RFQ
- MRMS (n+ separator)

- LARAMED

- Safety system
- Authorization extension to UCx full power and applications

criticality

Items in Preliminary Design

- HRMS
- Beam cooler

- NEPIR neutron facility

Items on critical path in 2014

Thank you


INFN
Istituto Nazionale
di Fisica Nucleare


α β
δ γ


SPES
exotic beams for science

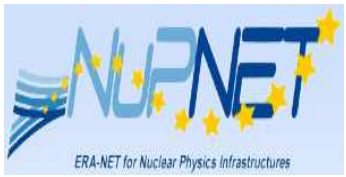
Gianfranco Prete-T0
Bisoffi-T0
Andrighetto-T3
Favaron-T2
Lombardi-T5
ex Piazza
De Martinis-T5
Maggiore-T5
Tecnico1 T_05
Tecnico2 T_05
Gulmini-T1
Bellato-T1
Toniolo-T1
Canella-T1
Bassato-T1
Gelain ND
Vasquez-T3
Antoniazzi-T7
Giacchini-T1
Bortolato-T1

Pegoraro R-T2
calderolla
Maniero-T2
Scarpa-T3
Corradetti-T3
Tomaselli-T3
Guerzoni-T3
Zanonato-T3
monetti
Manzolaro-T3
Lollo-T3
Pavan-T3
Zanella-T0
D'Este-T0
Pegoraro C-T0
Gambalonga-T2
Pasquato ND
Benini-T1

Rossignoli-T3
Visentin T_04
Grespan-T7
Palmieri A-T7
Fagotti-T7
Pisent-T7
borsa ND
borsa ND
Stark-T4
Bottin-T7
Pengo M-T7
Friso-T7
Contran-T7
Sattin-T7
Calore-T7
Modanese-T7
Galatà-T7
Zafiropoulos-T1
Sarchiapone-T1

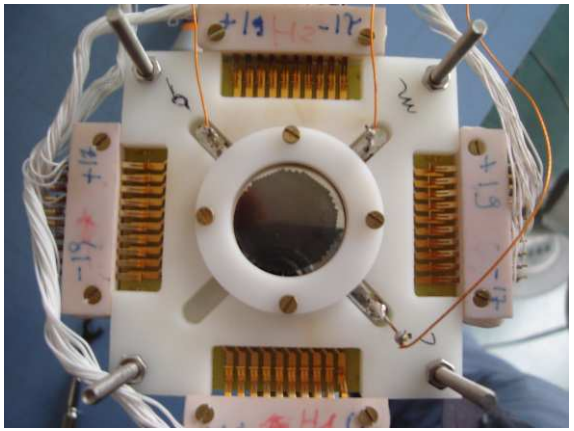
Buffa-T1
Esposito
Gramegna-T8
Valiente-T8
Napoli-T8
Bermudez-T8
Barbara Melon-T8
Antonio Russo (LNS)_04
Moisio-T4
dainelli
monetti
Comunian-T4
Poggi-T7
Roncolato-T7
Tecnico Vuoto1 T_04
Porcellato-T4
De Lazzari-T7
pedretti
dottorato laser

European actions and MoU



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

Beam Diagnostics

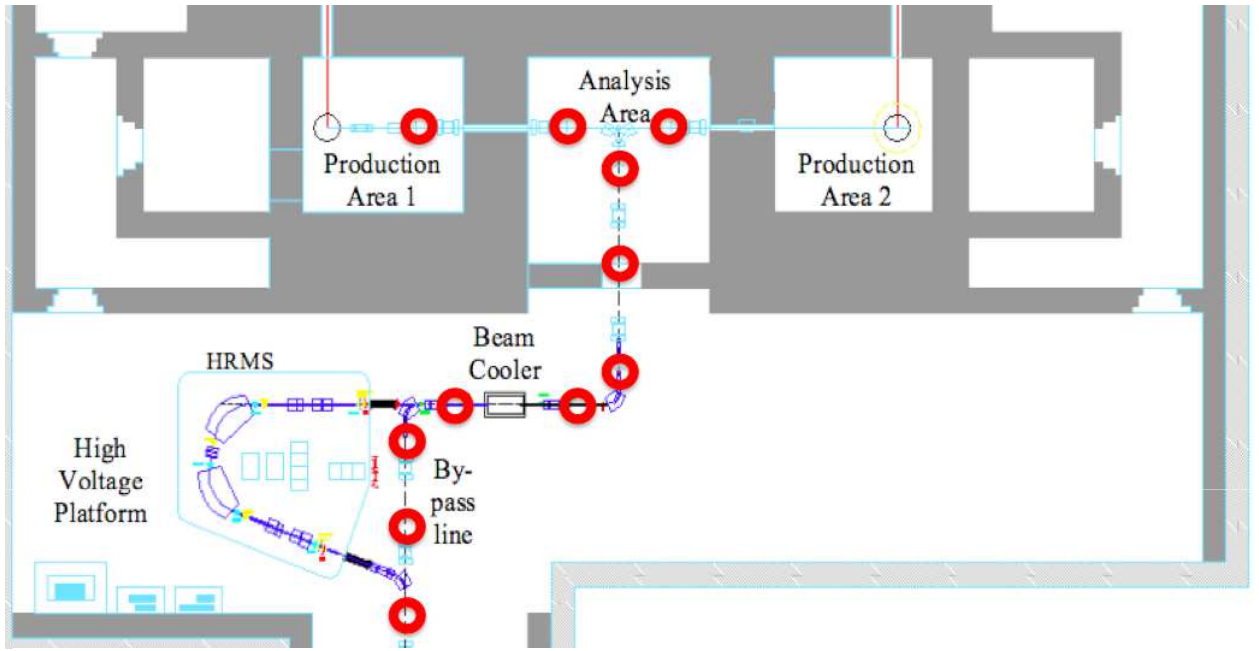


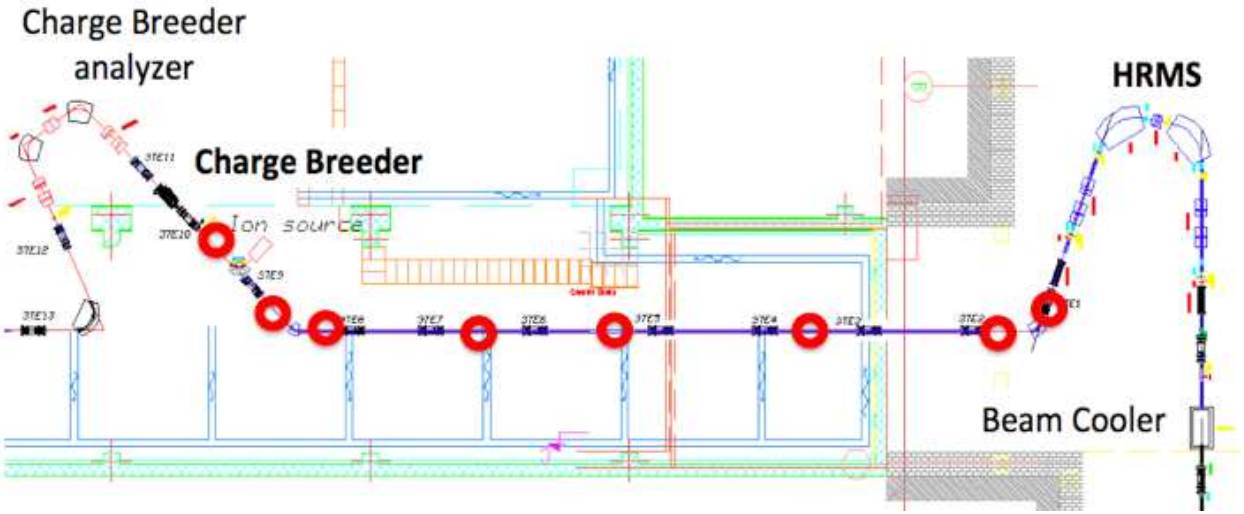
Beam position and profile monitors, based essentially on microchannel plates (MCP) as beam intensifiers. MCP is put directly on the beam line. Electrons produced on it and collected, after multiplication, on a position sensitive anode give the beam impact position. Measured 0.75 mm position resolution was mesured for a 100 fA ^{12}C beam. **FC, E, ϕ detectors** are developed too.

Tape station system: under development for SPES; moving tape system (1 cm wide mylar tape) and γ-ray counting chamber. Ge detectors, well shielded from potential background in the beam pipe, will be located at the counting chamber in a different position, a few cm far from the tape. The counting chamber will also accommodate plastic detectors for detecting positron decays.

Position of diagnostic boxes

Positions of the diagnostic box and of the main vacuum pumps along the beam transfer line





10^{13} fission/s

1-step: p 40 MeV 200μA on multi-slice direct target (30gr UCx) SPES actual version

2-step: d 40 MeV 2mA on thick ^{12}C converter + UCx target (800 gr) SPES former version

Release times considered:
1-step 2 s
2-step 40 s

Intensities evaluated considering emission, ionization and acceleration Efficiencies.

In-target production from MCNPX: 10^{13} fissions/s