Operational and financial planning of the SPES Project

G. Bisoffi, G. Fiorentini, G. La Rana, E. Nappi, L. Piazza, G. Prete, M. Taiuti

Abstract

A plan for the realization of SPES and the requested financial resources are presented in this report with the following conclusions:

1) The funding allocated up to now amounts to 20.5 million euros and is enough to complete the alpha stage (cyclotron).
2) A five-year plan for the beta phase (radioactive ion beam production) seems realistic on the basis of the available resources of the laboratory, adequate from the point of view of the international competition and achievable with regard to the yearly financial effort requested.
3) 27.9 million euros are necessary for the achievement of a reduced version (CORE_SPES), without high resolution mass selection, while further 2.7 million euros are necessary to acquire the high resolution mass selector (FULL_SPES).
4) The 12.8 million euros now available derive from a) "progetto premiale 2011" (5.6 Meuro); b) in kind contribution from LNL focused on the construction of the RFQ (3.2 Meuro); c) spared money from the reduced operation of ALPI during the five year period (4 Meuro).
5) To allocate the remaining 15.1 Meuro in 5 years a special contribution from INFN and/or Ministry (progetto premiale? Extraordinary intervention?) and/or other institutes and international agencies is due.
6) At present 50 people corresponding to 25 FTE are involved in SPES.
7) For the completion of SPES the following further 20 FTE are necessary: 5 FTE coming from a larger involvement of the permanent staff of the laboratory; 7 new student positions; 3 new art. 23 contracts and 5 new art. 15 contracts for technicians.
8) The additional costs for the temporary staff and the student positions amount to 2.45 Meuro in the five year period: 2 Meuro can be covered by means of the synergy with other laboratory projects (MIUR, UE funds...); further 450 keuro are therefore due for the five year period.

CONTENTS

1. THE SPES PROJECT: AIM, COMPETITION AND EUROPEAN COLLABORATION

1.1 Aim

The main goal of the SPES project is the realization of a second generation ISOL (Isotope Separation On Line) system able to deliver neutron rich beams for the study of nuclei far from stability. The research on these nuclei, both from the point of view of structure and of reaction mechanisms, represents a current frontier of the nuclear physics and astrophysics.

The second aim of the SPES project is the construction of a facility for interdisciplinary research; of particular significance is the possible use of the second beam line of the cyclotron for the production of new radioisotopes used in medicine.

The latter application will not be investigated in this report, which is instead devoted to the operational and financial planning of the facility for the production of radioactive ion beams.

1.2 Main technical characteristics

The second generation ISOL facilities distinguish themselves from the current ones by 3 main features:

- increase in the intensity of the delivered radioactive beams;
- increase in the energy of the reaccelerated species;
- improvement of the degree of purity of the beams.

SPES aims at reaching 10^{13} fissions per second in the target and is conceived to deliver of 1-to-2 orders of magnitude more intense beams than current facilities. The use of the superconducting ALPI Linac enables to achieve reacceleration energies above 10 A MeV, thus giving the possibility to perform experiments for multi-nucleon transfer reactions not achievable with the present facilities, like REX ISOLDE.

The realization of a mass separator (R ~ 1/20000 - 1/40000) will moreover allow to reach a degree of purity of the beam nowadays not available. Data-taking is expected to achieve 10^7–10^9 particles per second in a wide range of nuclear masses, namely $60 < A < 160$.

In conclusion, the expected beam features are not currently available in the international context.

1.3 International Competition

The SPES Project is well connected to the European background of the second generation ISOL facilities, where two other projects are in progress: SPIRAL2 and HIE-ISOLDE, see Table I.

These three facilities are all included in the NuPECC Road Map, which recommends them as an intermediate important and necessary stage towards the realization of the future third generation facility (EURISOL).

	Primary beam	Power on target	UCx target	Fission s-1	Reaccelerator	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

Table I – Performance comparison among the expected characteristics of the SPES, Spiral2 and HIE-Isolde Projects

SPES proves competitive for beam intensity and energy. It must be underlined moreover that the completion of SPES, foreseen in 2017, makes it competitive with respect to the other projects. In particular, the SPIRAL2 Project, aiming especially at high intensity stable beams, plans to start only in 2015 the construction of the part regarding radioactive beams (including the production target, the beam lines junction and the related infrastructures). As regards the HIE-ISOLDE project, the upgrade to 10 A MeV requires the construction of the new superconducting LINAC for re-acceleration, which is not expected to be completed before 2016.

Owing to the peculiar timing of the facility duty cycle and taking into account the necessary time needed for the development and optimization of the beam for a specific radioactive species, which can require up to one year, the above mentioned facilities have to be considered to be complementary in order to fulfill the requirements of the international end users.

To this purpose, a strict collaboration among the different laboratories is desirable and has been prompted on several occasions by the international committees supervising the aforementioned projects. In addition, the development of new radioactive beams has been and still is a technological challenge which must be faced with a common approach among laboratories.

1.4 National and International Collaborations

The SPES project has developed a wide network of national and international collaborations (see Fig. 1) on several issues, such as: the scientific programs, the experimental techniques, the source and the ISOL target, the selection and manipulation of beams, the superconducting LINACs and safety.

Among the most important actions, one has to mention the MoU with GANIL (LEA) and ISOLDE and the participation in the European Projects ENSAR, NUPNET, as well as the ““preparatory ***phase***” of SPIRAL2. In the framework of the cooperation with other European Laboratories the formation of an ERIC is under study.

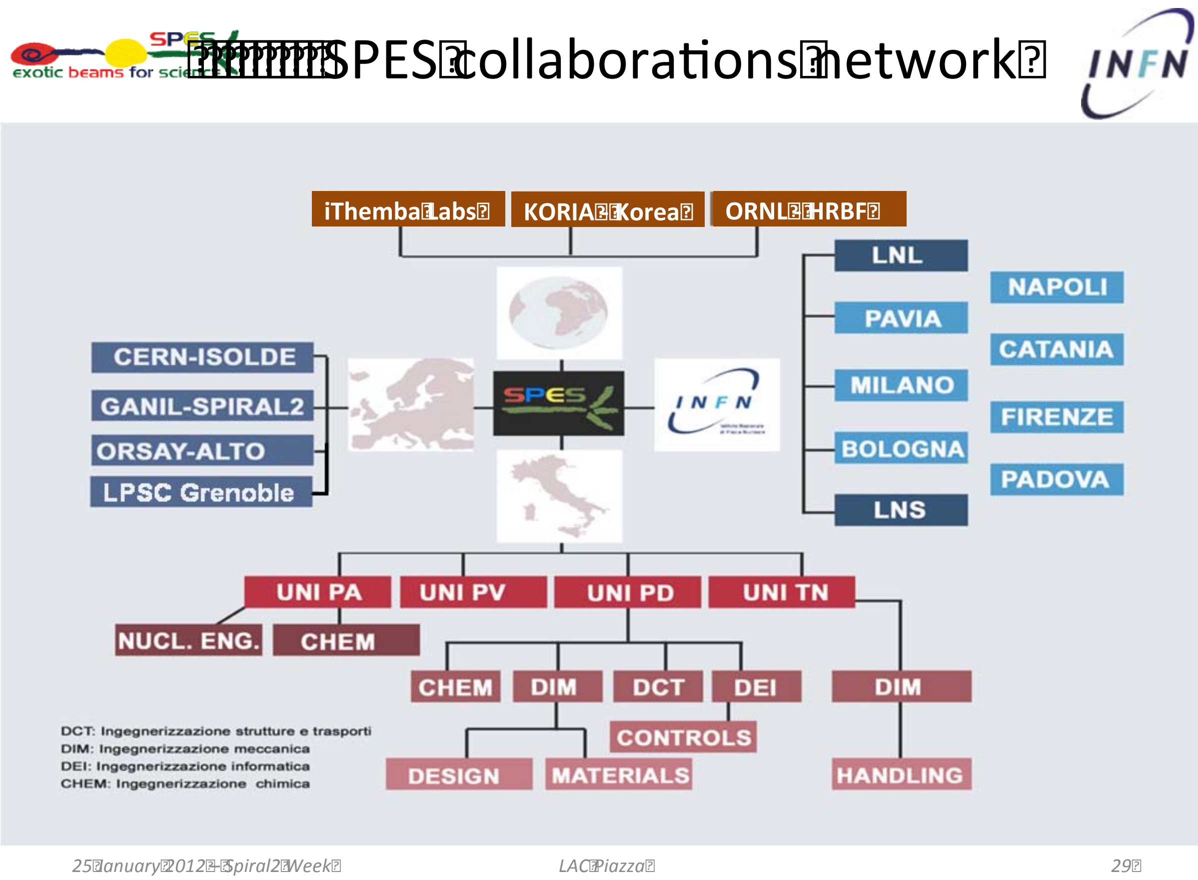


Fig. 1 – Outline of the collaboration network for the realization of SPES.

2. STATUS OF THE PROJECT

The SPES project is in progress since 2007: the proposal consists in the construction of a second generation ISOL facility based on a direct UCx target irradiated by protons delivered by a compact cyclotron (70 MeV of energy, 750 μA of current divided into two extraction lines). The facility layout is shown in Fig. 2.

After a two-year study of the target, the construction stage has begun with the development of the target-source system and of the first part of the exotic beam transport line. The system has been recently completed with the Wien filter for the beam selection and is working for laboratory tests on the ionization sources. This experimental activity is included in the European programs for the development of ISOL systems (ENSAR-ActiLab) and has produced over 40 degree theses, 3 PhD theses and 30 publications.

The purchase order for the cyclotron has been issued in 2010. The tender has been awarded to the Canadian firm BEST Theratronics Ltd. The construction of the cyclotron is under way with frequent and positive contacts between the firm and the INFN working group.

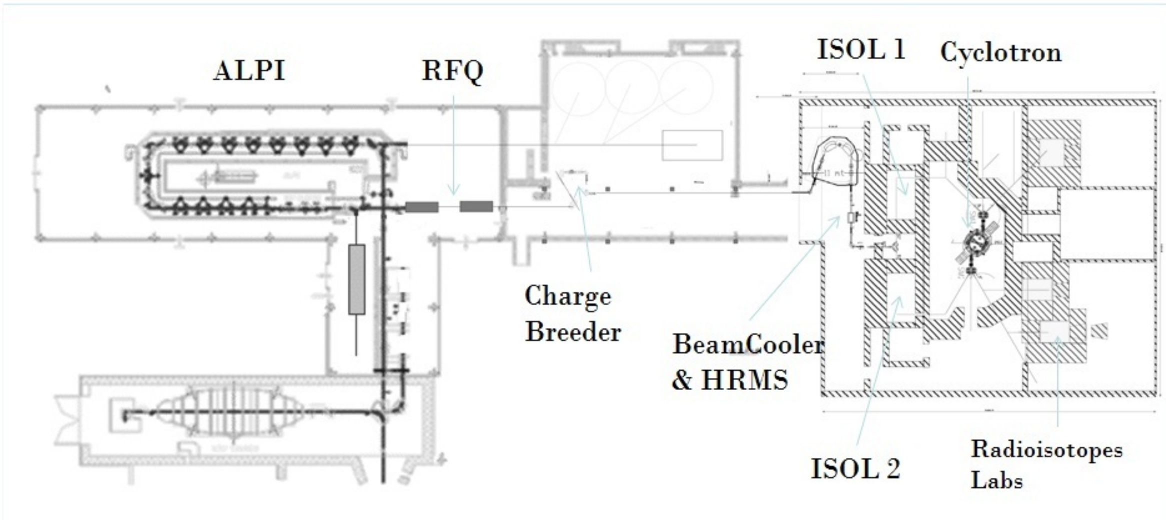


Fig. 2 – SPES layout.

The building layout has been defined. It includes the building that will lodge the cyclotron, the target areas and the beam selection system, as well as an area for applied research and the support laboratories for the cyclotron and the target. The executive project has been completed in 2012 and the tender has been awarded to the firm nBI (Bologna) belonging to the Astaldi Group. Construction works will begin on January 2013.

The re-acceleration through ALPI represents a topic of excellence for radioactive beams, since it will enable the delivery of heavy beams (A=130) at energies of 10 MeV/n, giving rise to multi-nucleon transfer reactions: a new research topic for radioactive beams. To this purpose, a technological progress has begun. In particular, the low beta section has been improved in order to allow a more effective acceleration of the heavy beams that will be produced by SPES.

The operating license has been granted by the competent authorities. It deals with the operation on UCx targets with currents up to 5 microA and on other targets up to the maximum current obtainable by the single line (500 microA). This enables the production of exotic beams rich in protons (targets made of SiC, B_4C, LaC, TaC, ...) and the performance of production tests with UCx targets. In order to perform experiments with Ucx targets at high energy (200 microA) the obtained license will have to be amended.

In order to improve the safety measures during SPES operation, the definition of a quality and safety system including risk analysis, operation procedures and document editing is in progress.

In connection with the activity carried out up to now, 20.5 Meuro have been spent or invested as described in Table II.

Item	Status	Investment (Meuro)
Building and Plants	Tender finished. Contract to be signed. Expected date for work beginning: January 2013.	6,5
Cyclotron	Under construction at BEST	10,5
ISOL System	Prototype completely developed and in operation with ionizing sources.	1
Charge breeder	Within the LEA framework, 500 Keuro have been invested in order to construct the plasma camera of the charge breeder.	0.5
ALPI	Low beta section upgrade	1
Other	Supply material and travels since 2007	1
TOTAL		**20.5**

Table II –Sums already invested for the SPES project.

Finally as regards the personnel, during 2012, 25 FTE corresponding to 50 full-time people have been involved in SPES (see Table A1 in the Annex). With regard to the contract type, we obtain the following distribution:

1) 11 FTE corresponding to 32 employees from permanent staff
2) 4FTE corresponding to 5 people from temporary staff, almost completely devoted to SPES.
3) The remaining 10 FTE are training staff (Ph.D. students, grant holders, etc.), completely devoted to SPES.

With reference to the permanent staff, Table II b shows the involvement and the distribution of the workload, distinguishing between SPES activities and non-SPES ones (the last two columns show the increase of SPES activities expected in the next years, see paragraph 7).

With regard to the Accelerator Division, the involvement is analyzed in the Annex, Table A7. The table shows the FTE assigned to SPES and to the other non-SPES activities, among which of particular importance are the activities connected to the operation of the accelerators and to the IFMIF project.

As one can deduce from table II b, with operating machines the laboratory can devote to SPES about the 10% of the available FTE.

Subunit	Current status			Estimate for the period 2013-2017	
	Permanent Staff units	**non-SPES activity (FTE)**	**SPES activity (FTE)**	**Increase**	**SPES activity (FTE)**
Research Division	**37**	34.7	2.3	1	**3.3**
Accelerator Division	**38**	33.8	4.2	3	**7.2**
Technical Division	**17**	15	2	0	**2**
Other Services (Radioprotection, Administration, etc.)	**16**	13.5	2.5	1	**3.5**
TOTAL	**108**	**97**	**11**	**5**	**16**

Table II b: Allocation of LNL permanent staff (administrative, technical, technological and research staff), workload for SPES activities and other activities (laboratory running, other projects, etc.). The last columns show the increase in SPES activities expected during the construction and commissioning of the facility (2013-2017).

3. CONSTRUCTION PLANNING

The work that has to be done yet for the completion of SPES **(FULL_SPES)** can be divided into 9 areas:

- **ISOL Target with Laser Source**
- **UCx Laboratory Building**
- **Radioactive Ion Beam Transport**
- **High resolution mass selection (HRMS and Beam Cooler)**
- **Charge Breeder**
- **RFQ for pre-acceleration**
- **Superconducting ALPI accelerator upgrade**
- **Safety and control systems**

A few comments on these areas are necessary:

i) The core of the facility is represented by the ISOL target, i.e. the system including the target-beam source with charge 1+, to which most of the R&D activity carried out up to now has been devoted. Among the different available sources, the high selectivity laser source is deemed to be the most promising in terms of performance and therefore it has been given a priority development line.

ii) Downstream the ISOL target a transport and analysis system (even at low resolution $R=M/\Delta M\approx 300$) will carry the beam to the charge breeder. This will increase the charge state of the exotic particles, making the energy rise in ALPI more effective. ALPI will be used as re-accelerator, namely as re-accelerator of the exotic species.

iii) The charge breeder is followed by a mass separator at medium resolution (R=M/ΔM≈2000) and from the RFQ pre-accelerator, that will be designed and realized in synergy with the IFMIF project.

iv) After the RFQ, the beam is transported to ALPI for re-acceleration. In order to fit SPES requirements and to work properly for a fair number of years, ALPI needs to be improved and refurbished, especially in the cryogenic, vacuum and beam detection systems.

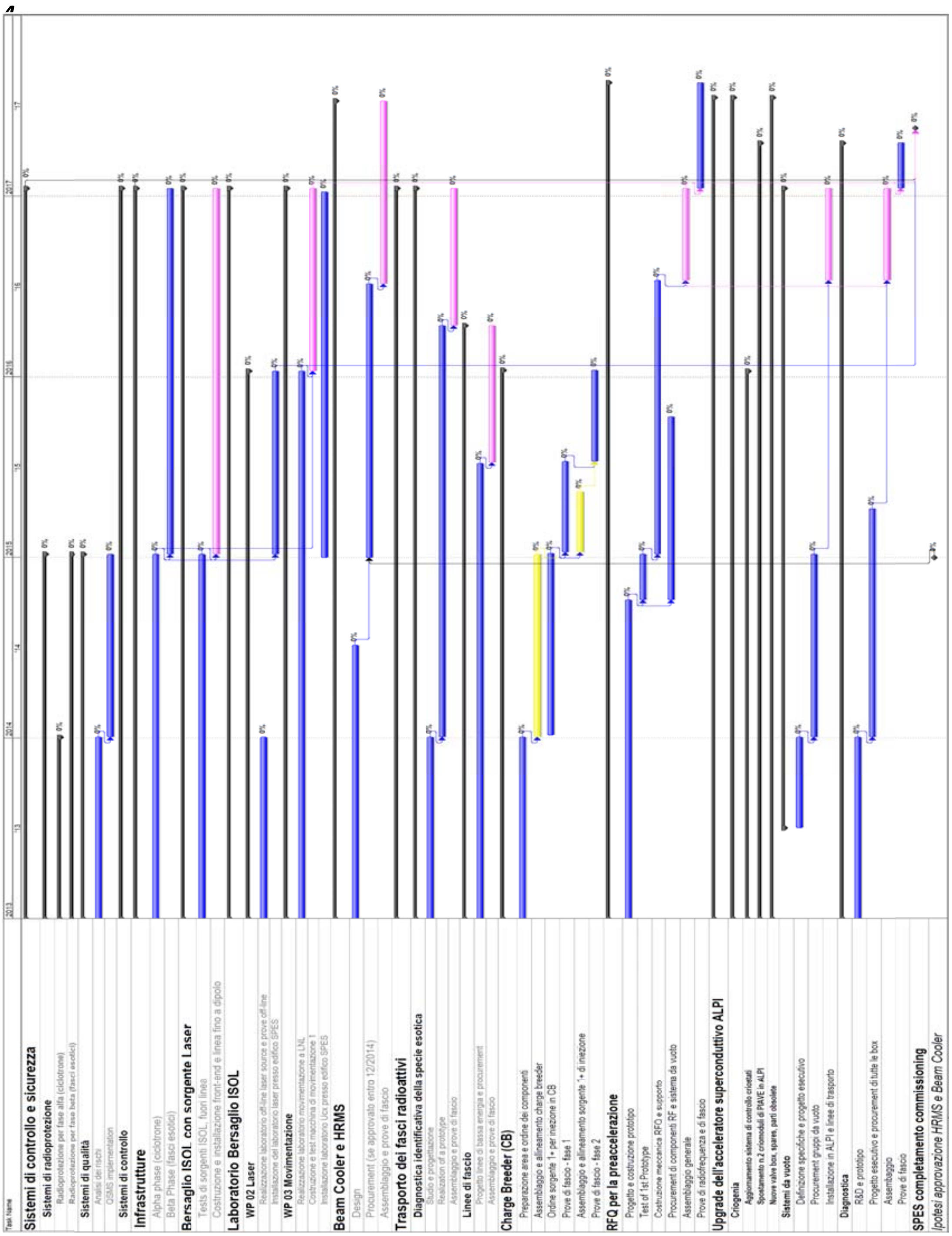
The above described tasks regard the realization of the so-called **FULL_SPES**. However, in order to operate the system within competitive time limits with respect to the other facilities under construction, the first experiments are expected to be performed without the high resolution selection system (HRMS and Beam Cooler). This reduced version of the SPES project will be hereafter referred to as **CORE_SPES**.

The construction planning for the accomplishment of CORE_SPES has been conceived in the space of 5 years, in order to be realistic on the basis of the available resources of the laboratory, adequate from the point of view of the international competition and achievable with regard to the yearly financial effort requested.

The construction planning is analyzed in Table III below (and more in detail in table A4 in the Annex). One can infer that:

1) The construction of CORE_SPES can be finished by 2016.
2) 2017 will be devoted to commissioning.
3) The construction of HRMS requires 3 years. If the resources will be granted in 2015, FULL_SPES will be available in 2018.

Table III – Outline of the time-plan of the SPES project over 5 years, the fourth year for the general assembly and the fifth for the commissioning.



4. USE OF THE EXISTING ACCELERATORS DURING SPES CONSTRUCTION

It is important to ensure the operation of the accelerators during SPES construction, so as to make them available to the users and to permit the continuous connection with the scientific community that will one day use SPES.

Nevertheless SPES construction will certainly interfere with the operation of the accelerators, as shown in Table III. In particular in 2014 and at the beginning of 2015 the installation of the charge breeder in the third experimental hall will restrict the use of the accelerators. From the second half of 2016 to the first half of 2017, period devoted to the installation of the other SPES elements, the accelerators will not be available.

In any case, for the rest of the time, the TANDEM-LINAC system will be available for about 6 months per year, while the TANDEM will be available regularly on both semesters of the year.

It is worth mentioning that the reduced use of ALPI will permit significant savings on electricity, since the operation of this machine usually requires 200.000 euro per month for the cryogenic systems and magnets power supplies.

5. COSTS FOR THE COMPLETION OF SPES

The material costs for the completion of SPES amount to 27.9 Meuro for CORE_SPES, to which 2.7 Meuro must be added to achieve FULL_SPES, according to Table IV here below (and more in detail in Table A5 in the Annex).

No.	Item	Meuro
1	ISOL target with laser source	3.2
2	UCx Laboratory Building	2.6
3	Radioactive ion beam transport	7.7
4	Mass selection at high resolution (HRMS and Beam Cooler) (*only for FULL_SPES*)	*(2.7)*
5	Charge Breeder	1.5
6	RFQ for the pre-acceleration	3.7
7	ALPI accelerator upgrade	5.6
8	Safety and control systems	3.6
	TOTAL	**27.9 (*30.6*)**

Table IV –Material costs for the completion of SPES. In brackets the costs necessary to achieve FULL_SPES.

The schedule of the investments is reported in Fig. 3.

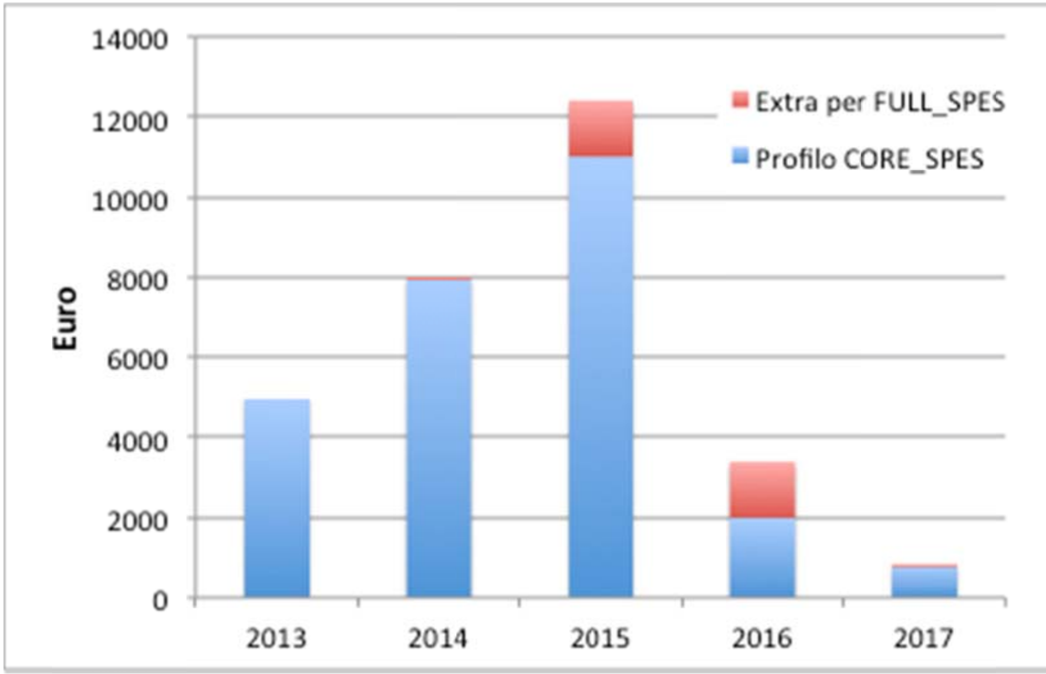


Fig. 3 – The financial schedule for CORE_SPES in blue; the additions to achieve FULL_SPES in red.

6. BUDGETARY SOURCES FOR THE CONSTRUCTION

According to the foregoing statements, the budgetary requirement to realize CORE_SPES is then of 27.9 Meuro, to be made available in the period 2013-2017.

The following contributions, amounting to 12.8 Meuro, are at present available:

1) Funds from “progetto Premiale” 2011, 5.6 Meuro.
2) In kind contribution from LNL, coming from synergies with other projects of the labs and focused on the construction of the RFQ, 3.2 Meuro.
3) Spared money from the reduced operation of ALPI during the five year period (200.000 Euro/month x 20 months), 4 Meuro.

To allocate the remaining 15.1 Meuro in 5 years a special contribution from INFN and/or Ministry (progetto premiale? Extraordinary intervention?) and/or other institutes and international agencies is due.

7. PERSONNEL NEEDED FOR THE COMPLETION OF SPES

As aforementioned, during 2012, 25 FTE corresponding to 50 full-time people have been involved in SPES. With regard to the contract type, we obtain the following distribution:

1) 11 FTE from permanent staff.
2) 4FTE from temporary staff, almost completely devoted to SPES.
3) 5/10 FTE are training staff (Ph.D. students, grant holders, etc.), completely devoted to SPES.

A PERT analysis has been carried out to estimate the activities and the personnel needed to complete the project in accordance with the schedule; see Table A4 in the Annex. One can deduce that about 45 FTE are needed in the period 2013-1017 (Fig. 4). With respect to the current situation, **20 more FTE are therefore necessary.**

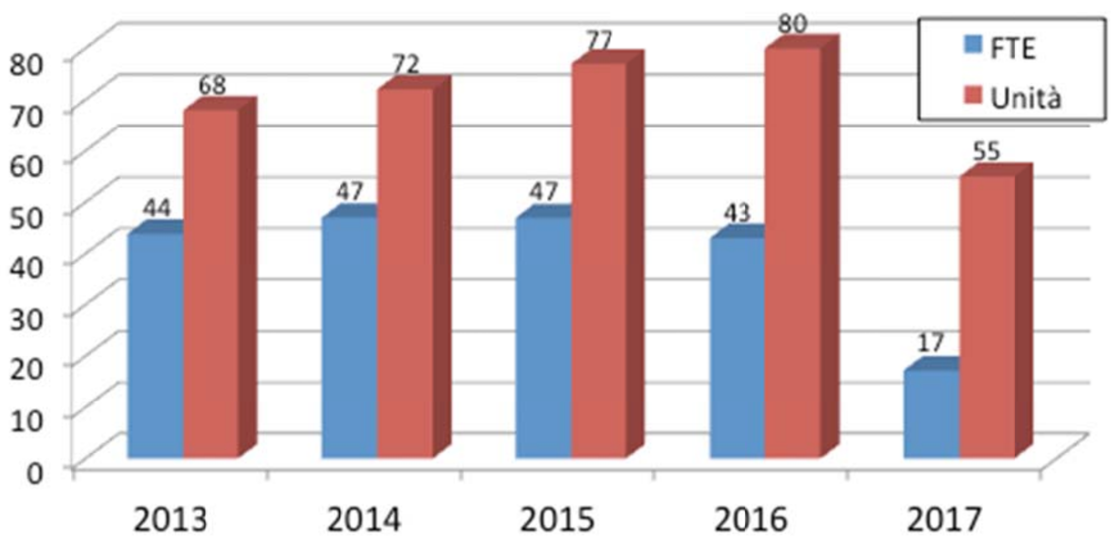


Figure 4 – Time chart of the FTE and corresponding staff positions necessary to complete SPES.

It may be inferred that **5FTE** can derive from the permanent staff's higher involvement in SPES activities.

To this purpose, one can observe that the reduction of the PIAVE-ALPI operation in the period 2013-1017 (see section 4) implies that human resources become available for SPES in the Accelerator Division. An increase of the SPES activities in the Research Division will be represented by the involvement of the Informatics and Electronic Technology Service for safety and controls. Moreover the study at LNS for the production of radioactive beams with the ISOL technique will require a greater commitment of the LNL researchers.

However, taking into account that the laboratory staff consists of only 108 people, too few with respect to the operation and working necessities of the laboratory, the increase from 11 to 16 FTE (equivalent to about 50%) is deemed to be a boundary goal.

In Table II b the last columns (and more in detail the ones of table A7 in the Annex) show the LNL subunits where the human resources for the foreseen activity increase may be singled out.

As regards the further **15 FTE units** (necessary to reach the goal of 45 FTE), Table A6 shows the list of the professional figures to be acquired and the related expected workload in the period 2013-2017. In brief, the 15 FTE are characterized as follows:

i) The training staff should increase by 7 units; supposing an average cost of 20 Keuro/year, it means that the total cost in the five-year period is 20x 7x5 =700 Keuro.
ii) Temporary contracts (art. 23) should increase up to 8 units (+3 FTE), engaging a person devoted to the ISOL source, one to the laser system and another to the detection system. On the basis of a yearly cost of 50 Keuro per person, the expense for the five-year period should be 50 x 3 x5 = 750 Keuro.
iii) 5 technicians (art. 15) **(+5 FTE**) are as well necessary (vacuum, mechanics, laser, charge breeder, control electronics). On the basis of a yearly cost of 40 Keuro per person, the expense for the five-year period should be 40 x 5 x5 = 1000 Keuro.

The most delicate questions regard the costs of the temporary contracts; according to items ii) and iii) above, 1.75 Meuro are necessary in the five-year period. If added to the costs of the training staff, the result amounts to 2.45 Meuro. We believe that about 2 Meuro can be covered even today through the synergy with other projects funded by MIUR, UE, etc. Therefore 450 Keuro remain to be granted in the five-year period.

8. "FIRST DAY" EXPERIMENTS WITH SPES

This section reports some remarks on the beams and on the scientific value of "first day" experiments, namely the ones that will be possible with CORE_SPES.

While the construction of FULL_SPES includes a HRMS 1/20000 - 1/40000 mass separator, that will allow to reach a degree of beam purity nowadays not available, the CORE_SPES version, without HRMS, will have only two features that characterize SPES as a second generation ISOL facility:

- increase in the intensity of the delivered radioactive beams;
- increase in the energy of the reaccelerated species.

With CORE_SPES we will be able to make experiments with beams of the same pureness already available for example at HRIBF (ORNL-Oak Ridge) and REX-ISOLDE (CERN), where most experiments have been carried out without a high resolution selector owing to troubles with such instrumentation (lack of the expected resolution at ORNL, lack of the beam cooler in ISOLDE).

In comparison with these two laboratories, CORE_SPES offers relevant advantages both because of the higher intensity of the delivered exotic beams and because of the greater final beam energy. These features give rise to studies in more exotic mass regions and to several investigations, such as the study of multi-nucleon transfer reactions, deep inelastic reactions and the dependence of the isospin degree of freedom in particle emission (evaporation or pre-equilibrium). During the first experimental phase, priority will be given to cases with low isobaric contaminations. Preference will be devoted to the use of the laser selective ionization system (RILIS source) with isotopic selection (in some cases even isomeric states are selected).

The use of the selective ionization allows the first separator to restrict the resolution to values between 1/100-1/400; this is made possible by a proper design of the beam transport line (the pollutants come from contaminating ionizations due to the temperature of the TIS system). Beams with adequate purity may be produced even with a surface ionization source (selective enough for Cs and Rb), as well as with direct reactions (not fission ones), in the latter case with proton-rich reactions.

The main reasons why a facility for the production of exotic species like SPES is being realized have been described many times both in the TDRs and in the number of workshops and conferences in which the project has been presented. The neutron rich nuclei that will be studied with SPES play an important role both in the structure and in the reaction mechanisms, since the neutron excess is expected to produce completely new phenomena. These nuclei take part in the rapid neutron capture process in stars (r-process), making the investigation of their properties fundamental for the study of the stellar evolution phenomena.

CORE_SPES will make possible to begin studies on nuclear structure focused on the evolution of the single particle states around shell closures. As we know, these are subjects of particular interest, studied worldwide in many nuclear physics laboratories. The aim is both to verify the several theories on nuclear models and to distinguish the different scenarios of stellar evolution. To this purpose, a number of experimental proposals have been submitted in the Letter of Intents discussed in the first international SPES Workshop, LNL 15-17 November 2010,
http://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=2660.

Other proposals are now arising out of the new results and the related questions in the field of exotic ions, as outlined in the scientific one-day meetings held in Naples and Florence, meetings that will be organized in the future with known deadlines.
SPES one-day Workshop: Transfer reactions with RIBs (Naples);
SPES one-day Workshop: Coulomb excitation with RIBs (Florence).

As an example, some physics cases, discussed in the above mentioned workshops for the first day physics, are hereafter reported:

a) The use of RILIS allows to select Zn beams in the mass range 72-80 amu. The reaccelerated beam intensities are expected to be in the order of 10^5 - 10^3 pps. Other selected beams are possible for Ga isotopes in the mass range 79-83 amu with intensities of 10^6 - 10^4 pps. These beams allow to perform direct reactions in inverse kinematics in the N=50 region (^{81}Ga+d $\rightarrow$ ^{80}Zn+ p; ^{79}Zn+d $\rightarrow$ ^{80}Ga + He). The study of this region is very interesting as it correspond to a neutron shell closure. On the other hand these studies are of particular interest in the astrophysics framework as allow to characterize the excited levels of nuclei participating in the r-process.
b) Another interesting case is the use of ^{75}Cu beam (also produced by RILIS). With this beam it is possible to study the excited states of ^{75}Cu itself by Coulomb excitation, to disentangle the role of tensorial forces in the nuclear interaction. This nucleus has 4 neutrons less and 1 proton more than the double magic nucleus ^{78}Ni. The study of the region around ^{78}Ni is of fundamental importance for the r-process, as ^{78}Ni is the only double magic nucleus in the region and represent an important

waiting point. With the same approach other interesting cases can be studied as ^{98}Sr and $^{97,99}Rb$, which are contained in a highly deformed nuclear region where protons are in f p shells whereas neutrons are in g d s shells.

c) The regions of Sr and Rb in the neutron-poor side are also interesting. These exotic beams can be obtained by proton reaction on ZrC targets and can be used to study multi-nucleon transfer reactions with the PRISMA spectrometer.

d) Other scientific cases that may be studied without ~~a~~ highly selected beam are related to the capability of tagging the reaction with the selection of entrance and exit channel. Some experimental methods, as the use of Ionization Chambers in the downstream direction, can be operated at relatively low rates ($<10^4$ - 10^5pps), in this case a selection of reactions and beams must be adopted to satisfy the experimental constraints.

The complete selection of exotic beams available in the first period of operation of SPES will be confirmed by experimental cross check on the targets produced. Several methods will be used:

a) Experiments at the in-beam ISOL facility under installation at LNS. The test-bench is equipped with tape-station, gamma and beta detectors to measure realistic production yields expected at SPES and to study the contaminations expected for each beam.
b) Chemical treatment in the target-ion source to create molecular beams (as SnS, adding Sulfur in the target) to change the mass range of the element of interest (in this case Sn) in a region where the isobaric contamination can be more easily managed.

The experiments currently proposed for SPES involve international collaborations. The user community may be estimated on the basis of the letter of intents received up to now and the attendance to the several scientific meetings and workshops, as well as on the basis of the present users of the Italian and European physics laboratories. We estimate that the Italian users will be in the order of more than 100 researchers, while at a European level the expected users amount to 700 researchers in the framework of European (12 countries) and extra-European collaborations (China, India, Canada, USA).

9. SPES AND THE INFN CVI (INTERNATIONAL EVALUATION COMMITTEE) REPORT

CVI has given the following opinion on the requirements and perspectives of the SPES project:

The CVI is concerned about how and where INFN will find the investments in times of financial difficulties to make SPES a machine for science. Significant resources are still needed to achieve that and a clear plan is needed to ensure those resources are in place on an appropriate time scale. Nevertheless, we encourage the LNL director to set with his staff appropriate priorities for realizing the infrastructure to allow for scientific programs to start in a phased approach. Being resourceful in such difficult times may help in solving part of the problem as, e.g., through trying to find surplus equipment at other laboratories or forging collaborations that would be willing to contribute to building of the equipment. It should be emphasized here that a delay of a year or even two in the realization of the full project would not impact badly on the scientific program, since other radioactive beam facilities are not able to provide even a small fraction of the requested beam time for research in this field.

A large part of these suggestions have been included in the sections above, in particular:

a) With reference to the timetable, this report describes the possibility to realize SPES in 5 years (instead of 3, as formerly reported to CVI). This term appears to be realistic on the basis of the available resources of the laboratory, adequate from the point of view of the international competition and achievable with regard to the yearly financial effort requested, see section 3.

b) As regards the financial questions, the analysis reported in the above sections demonstrates the necessity to find 15.1 Meuro in the next 5 years. A large part of this sum may derive from funds of the future “progetti premiali”.

c) As regards the synergies with other projects, it can be observed that:

   i) For the construction of the Charge Breeder SPES maintains a collaboration with GANIL, consisting of a technical and partly economical support from the French collaborators (the Charge Breeder is under realization at LPSC-Grenoble).
   ii) A collaboration, regarding the exchange of know-how on the different parts of the machine, is active with ISOLDE. To be more precise, SPES has benefited from a technical contribution in the design of the ISOL target-source system and the collaboration will continue in the future on the design and engineering of the vacuum system and cryogenic control.
   iii) A particularly significant system is represented by the selective ionization source via laser. For this activity SPES receives a support from Pavia University and CNR-Padova, from which has borrowed 2 lasers in order to begin the R&D on the source. Collaboration with ISOLDE and Jyvaskyla University is under way in order to identify technical and scientific expertise focused on the realization of an innovative system for laser ionization, also with the collaboration of Italian firms active in this field. In the framework of the next ENSAR2 European Program, SPES will take part in the project for the development of laser selective sources.
   iv) The collaboration with iThemba-Labs in South Africa, interested in the development of an ISOL system like SPES, is under formalization. Within this collaboration SPES will receive an economical support for the development of the target and the possibility to perform, without expenses, power tests at the iThemba-Labs’ high energy cyclotron. It will also be possible to acquire know-how and instrumentation for the management of proton beams with currents and energies typical of the SPES cyclotron.
   v) *Last but not least*, thanks to the synergies with the IFMIF project, SPES will obtain an in kind contribution for the RFQ construction, required for the re-acceleration, and will have the possibility to borrow part of the infrastructures necessary for the RFQ tests.

10. CONCLUSIONS

This report describes a plan for the realization of SPES and the related budgetary requirements, taking into account the suggestions contained in the CVI 2012 report. The following conclusions have been reached:

1) The investments allotted up to now amount to 20.5 Meuro and are enough for the realization of the alpha stage (cyclotron).
2) As regards the beta stage (radioactive ion beam production), a period of five years appears to be realistic on the basis of the available resources of the laboratory, adequate from the point of

view of the international competition and achievable with regard to the yearly financial effort requested.

3) In order to achieve a reduced version (CORE_SPES), without high resolution mass selection, 27.9 Meuro are necessary. Further 2.7 Meuro are necessary to add the high resolution mass selector (FULL_SPES).
4) At present, 12.8 Meuro are available and come from: a) “progetto premiale 2011” (5.6 Meuro); b) in kind contribution from LNL focused on the construction of the RFQ (3.2 Meuro); c) spared money from the reduced operation of ALPI during the five year period (4 Meuro).
5) To allocate the remaining 15.1 Meuro in 5 years a special contribution from INFN and/or Ministry (progetto premiale? Extraordinary intervention?) and/or other institutes and international agencies is due.
6) At present 50 people corresponding to 25 FTE are working at SPES.
7) For the completion of SPES the following further 20 FTE are necessary: 5 FTE coming from a larger involvement of the permanent staff of the laboratory; 7 new student positions; 3 new art. 23 contracts and 5 new art. 15 contracts for technicians.
8) The additional costs for the temporary staff and the student positions amount to 2.45 Meuro in the five year period: 2 Meuro can be covered by means of the synergy with other laboratory projects (MIUR, UE funds...); further 450 keuro are therefore due for the five year period.

It has been assessed moreover that there are interesting perspectives for the first-day physics, namely the physics that can be done even without the high resolution mass selector.

APPENDIX

Nome	Cognome	Settore	Attività	Percentuale	
Mario	Maggiore	5 Driver protoni	commissioning ciclotrone e trasporto fascio protoni gr5 40% Beam Cooler	100	Art. 23 - Contratto Tempo Determinato
Leandro A.C.	Piazza	5 Driver protoni	project management - commissioning ciclotrone - infrastrutture	100	Art. 23 - Contratto Tempo Determinato
Alessio	Galata'	7 Riacceleratore	Sottotask 7A Charge Breeder (UE 40%, gr5 20%)	40	Art. 23 - Contratto Tempo Determinato
Damiano	Bortolato	1 Sicurezze Radioprotezione e Controllo	controllo RF ALPI	100	Art. 23 - Contratto Tempo Determinato
Judilka Ivanna	Bermudez Flores	8 Supporto Scientifico		100	Ass. Scientifica - Assegno ricerca INFN
Luca	Morelli	8 Supporto Scientifico		50	Ass. Scientifica - Assegno ricerca Università
Mattia	Manzolaro	3 Bersaglio diretto	sviluppo sorgenti e analisi termo-strutturale (gr5 20%)	100	Ass. Tecnologica - Assegno ricerca INFN
Lucia	Sarchiapone	1 Sicurezze Radioprotezione e Controllo	calcoli radioprotezione (gr5 70%)	100	(passa Art23) Ass. Tecnologica - Assegno ricerca INFN
Stefano	Corradetti	3 Bersaglio diretto	materiali	100	Ass. Tecnologica - Assegno ricerca INFN
Daniele	Scarpa	3 Bersaglio diretto	sviluppo sorgenti laser (gr5 20%)	100	Ass. Tecnologica - Assegno ricerca INFN
Alberto	Monetti	3 Bersaglio diretto		100	Ass. Tecnologica - Borsa INFN laureandi
Daniela	Benini	1 Sicurezze Radioprotezione e Controllo	Sviluppo sistema di qualità e sicurezza	100	Ass. Tecnologica - Borsa INFN tecnologi
Massimo	Rossignoli	3 Bersaglio diretto	Progettazione sorgenti e front-end (gr5 20%)	100	Ass. Tecnologica - Borsa INFN tecnologi
Giuseppe	Morana	1 Sicurezze Radioprotezione e Controllo	analisi rischi	100	Ass. Tecnologica - Dottorando con borsa INFN
Jesus Alejandro	Vasquez Stanescu	3 Bersaglio diretto	controllo e sviluppo PLC	100	Ass. Tecnologica - Dottorando con borsa INFN
Cesare	Pegoraro	0 Project Management	controllo ordini e ricerche di mercato	20	Staff
Gianfranco	Prete	0 Project Management	Project Leader - Task 1 Sicurezze Radioprotezione e Controllo - Management Board	100	Staff
Giorgio	Bassato	1 Sicurezze Radioprotezione e Controllo	Sottotask 1C Controllo	50	Staff
Mauro	Giacchini	1 Sicurezze Radioprotezione e Controllo	Sottotask EPICS e supervisione di controllo e sicurezza	70	Staff
Silvia	Zanella	0 Project Management	segreteria	50	Staff
Marco	Poggi	7 Riacceleratore	Sottotask 7B Diagnostica	10	Staff
Demetre	Zafiropoulos	1 Sicurezze Radioprotezione e Controllo	Procedure Radioprotezione - Sottotask 1B Radioprotezione - Management Board	10	Staff
Fabiana	Gramegna	8 Supporto Scientifico	Task 8 Supporto Scientifico - Management Board	20	Staff
Mauro	De Lazzari	1 Sicurezze Radioprotezione e Controllo	gestione impianti vuoto	30	Staff
Luciano	Costa	1 Sicurezze Radioprotezione e Controllo	controlli e sistemi di sicurezza nucleare	30	Staff
Paolo	Favaron	2 Infrastrutture	Task 2 Infrastrutture - Management Board	20	Staff
Roberto	Pegoraro	2 Infrastrutture	Sottotask 2B Impianti	10	Staff
Alberto	Andrighetto	3 Bersaglio diretto	Task 3 Bersaglio Diretto - Sottotask 3A Front End - Management Board	100	Staff
Michele	Comunian	4 Trasporto fascio secondario	Sottotask 4A Trasporto fascio	20	Staff
Antonio	Dainelli	4 Trasporto fascio secondario	Sottotask 4C Selezione di massa		Staff
Marco	Guerzoni	3 Bersaglio diretto	Sottotask 3C Movimentazione - realizzazione sistema movimentazione bersaglio	20	Staff
Michele	Lollo	3 Bersaglio diretto	progetto e realizzazione sistemi lab. bersaglio	100	Staff
Marco	Cinausero	8 Supporto Scientifico	Sottotask 8A SPES Beam Characterization	10	Staff
Pier Luigi	Zanonato	3 Bersaglio diretto	sviluppo bersaglio UCx	30	Staff
Augusto	Lombardi	5 Driver protoni	Task 5 Driver Protoni - Management Board	70	Staff
Andrea	Pisent	7 Riacceleratore	RFQ riaccelerazione	20	Staff
Giovanni	Bisoffi	7 Riacceleratore	Task 7 Riacceleratore - Sottotask 7C PIAVE - Management Board	20	Staff
Luciano	Calabretta	4 Trasporto fascio secondario	Task 4 Trasporto Fascio Secondario - Management Board	20	Staff
Stefania	Canella	1 Sicurezze Radioprotezione e Controllo	Sottotask PLC di controllo e sicurezza	20	Staff
	OffBologna2	3 Bersaglio diretto	realizzazione sistema movimentazione bersaglio	30	Staff
Daniel Ricardo	Napoli	8 Supporto Scientifico		10	Staff
Denis	Maniero	2 Infrastrutture	Sottotask 2A Edilizia	20	Staff
Paolo	Modanese	7 Riacceleratore		30	Staff
Andrea	Calore	7 Riacceleratore		30	Staff
Damiano	Grassi	3 Bersaglio diretto	tecnico laser - sorgente RIB sviluppo sorgente laser priorità alta	20	Staff Ass. Tecnica
Alessandra	Tomaselli	3 Bersaglio diretto	Sottotask 3B Sorgente Laser	30	staff Ass. Tecnologica - Ricercatori/Professori Università
				24.1	**FTE complessivi**

Table A1 – Detailed list of the personnel involved in SPES at present.

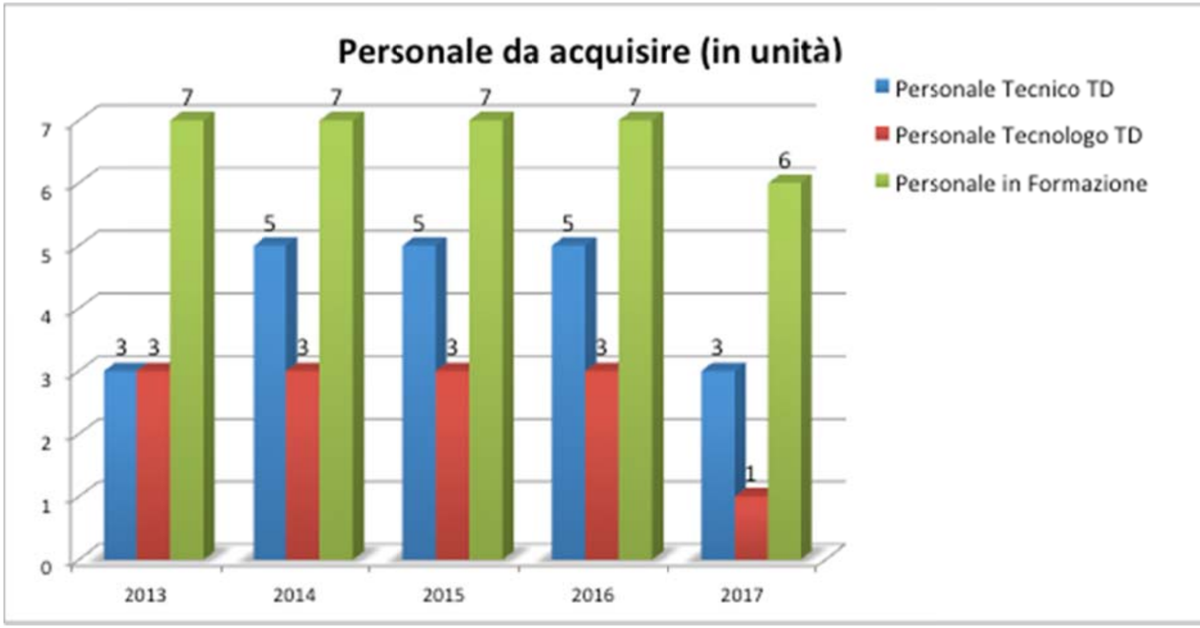


*Figure A2: the figure shows the **units** of personnel to be acquired divided in **Technicians**, **Technical Researchers** and **Training personnel***

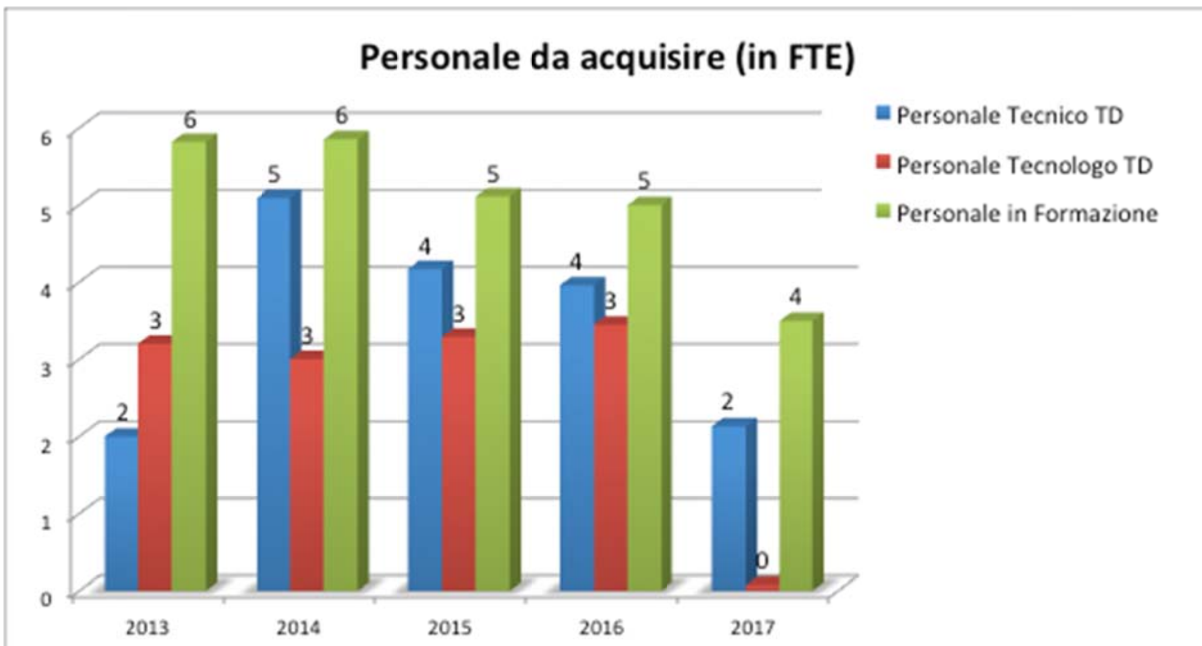


*Figure A3: the figure shows the **FTE** of personnel to be acquired divided in **Technicians**, **Technical Researchers** and **Training personnel***

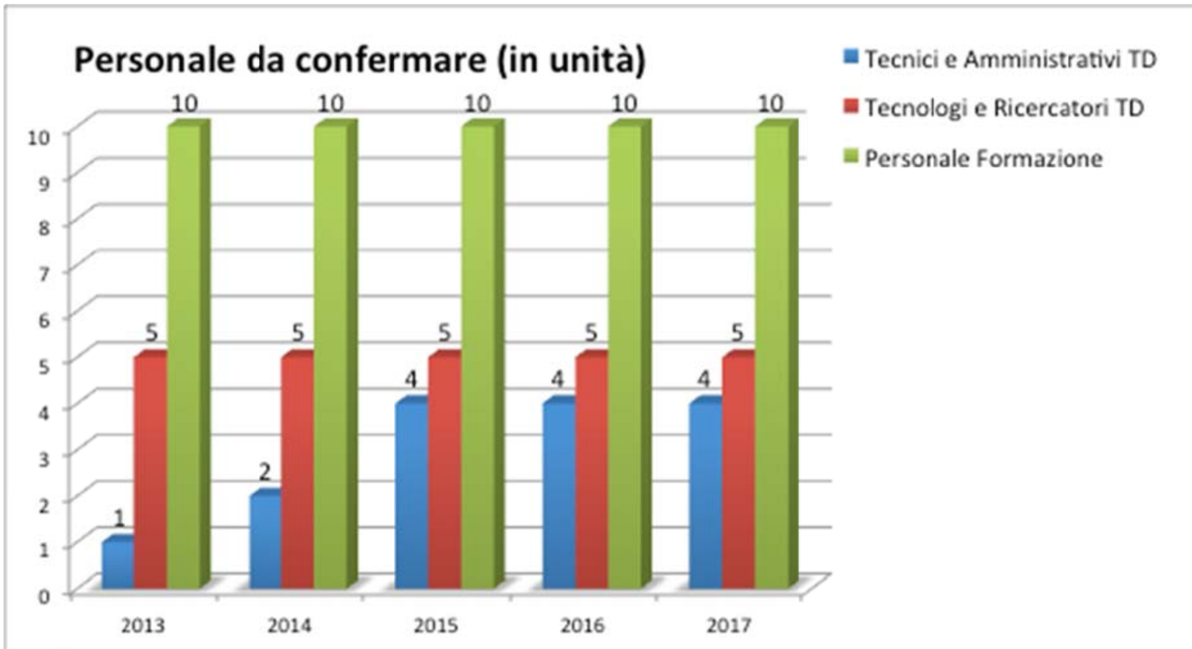
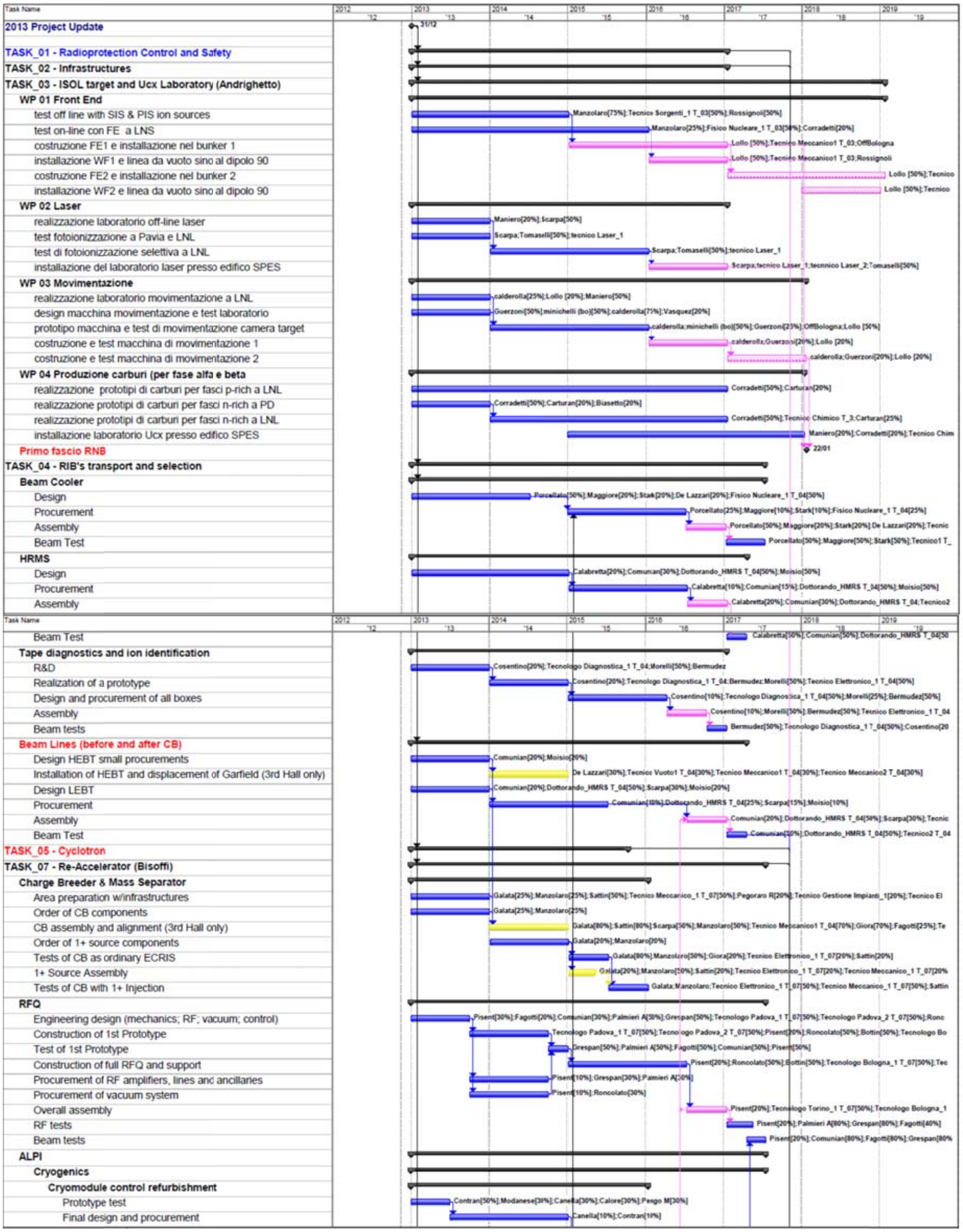
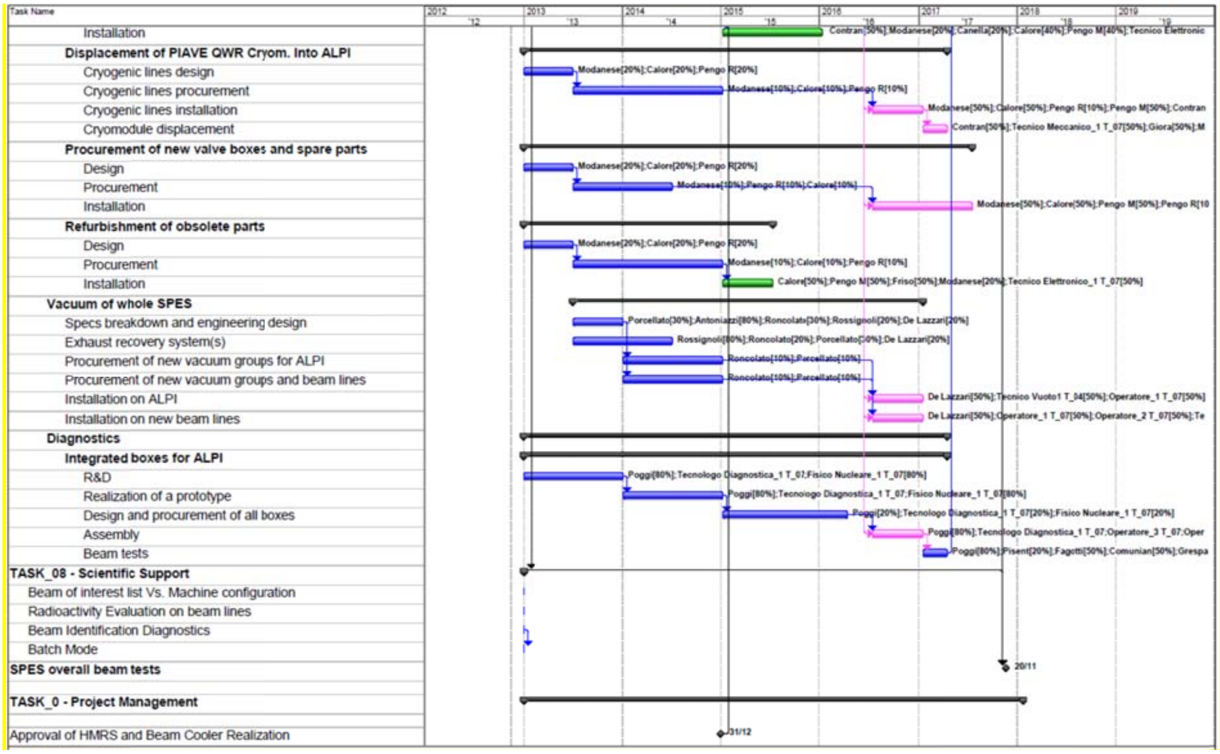


Figure A4: the figure shows ***the units*** *to be confirmed divided in* ***Technicians, Technical Researchers*** *and* ***Training personnel***


Task Name
2012 2013 2014 2015 2016 2017 2018 2019
2013 Project Update
TASK_01 - Radioprotection Control and Safety
TASK_02 - Infrastructures
TASK_03 - ISOL target and Ucx Laboratory (Andrighetto)
WP 01 Front End
test off line with SIS & PIS ion sources
test on-line con FE a LNS
costruzione FE1 e installazione nel bunker 1
installazione WF1 e linea da vuoto sino al dipolo 90
costruzione FE2 e installazione nel bunker 2
installazione WF2 e linea da vuoto sino al dipolo 90
WP 02 Laser
realizzazione laboratorio off-line laser
test fotoionizzazione a Pavia e LNL
test di fotoionizzazione selettiva a LNL
installazione del laboratorio laser presso edifico SPES
WP 03 Movimentazione
realizzazione laboratorio movimentazione a LNL
design macchina movimentazione e test laboratorio
prototipo macchina e test di movimentazione camera target
costruzione e test macchina di movimentazione 1
costruzione e test macchina di movimentazione 2
WP 04 Produzione carburi (per fase alfa e beta
realizzazione prototipi di carburi per fasci p-rich a LNL
realizzazione prototipi di carburi per fasci n-rich a PD
realizzazione prototipi di carburi per fasci n-rich a LNL
installazione laboratorio Ucx presso edifico SPES
Primo fascio RNB
TASK_04 - RIB's transport and selection
Beam Cooler
Design
Procurement
Assembly
Beam Test
HRMS
Design
Procurement
Assembly
Beam Test
Tape diagnostics and ion identification
R&D
Realization of a prototype
Design and procurement of all boxes
Assembly
Beam tests
Beam Lines (before and after CB)
Design HEBT small procurements
Installation of HEBT and displacement of Garfield (3rd Hall only)
Design LEBT
Procurement
Assembly
Beam Test
TASK_05 - Cyclotron
TASK_07 - Re-Accelerator (Bisoffi)
Charge Breeder & Mass Separator
Area preparation w/infrastructures
Order of CB components
CB assembly and alignment (3rd Hall only)
Order of 1+ source components
Tests of CB as ordinary ECRIS
1+ Source Assembly
Tests of CB with 1+ Injection
RFQ
Engineering design (mechanics; RF; vacuum; control)
Construction of 1st Prototype
Test of 1st Prototype
Construction of full RFQ and support
Procurement of RF amplifiers, lines and ancillaries
Procurement of vacuum system
Overall assembly
RF tests
Beam tests
ALPI
Cryogenics
Cryomodule control refurbishment
Prototype test
Final design and procurement



Tab A4 – More detailed temporal planning of the project. (Global planning is shown in Tab.2 in the document)

	MEuro	MEuro
1) ISOL Target with Laser Source		
- Front End	0,2	
- Laser system	1,0	
- Controls	0,3	
- Target handling	0,5	
- Primary beam separator	0,3	
- Beam monitoring	0,1	
- UCx laboratory (hot cell)	0,8	
TOTAL for ISOL Target with Laser Source		**3,2**
2) Ucx Laboratory Building		
- Building and infrastructures completion for ISOL lab	1,1	
- UCx Laboratory, premises, water distribution, electric power	0,8	
- Upgrade of the technological plants for SPES refrigeration	0,2	
- Entry doors (only one ISOL bunker)	0,6	
TOTALfor Ucx Laboratory Building		**2,6**
3) Radioactive Ion Beam Transport		
- From production platform to beam cooler and from beam cooler to HRMS:	1,7	
- MRMS with 1/400 resolution	0,5	
- Beam line from HRMS to charge breeder	1,7	
- Analysis line after the charge breeder and beam line towards LINAC	3,0	
- Study and design of the Beam Cooler	0,2	
- Control system of the transport of radioactive ions	0,7	
TOTAL for Radioactive Ion Beam Transport		**7,7**
4) High resolution mass selection (HRMS and Beam Cooler) (*only for FULL_SPES*)		
- Platform construction and commissioning (250 kV)	0,5	
- Current generator 250 kV, insulation transformer (100 kW)	0,2	
- Dipoles for beam selection (2), incl. Power supply, Steerers	0,9	
- Electrostatic quadrupole and multipole lens and power supply	0,2	
- Diagnostics items	0,1	
- Pumping systems, instrumentations, channels, mountings e infrastructures	0,2	
- Beam Cooler	0,6	
TOTAL for High resolution mass selection		**(2,7)**
5) Charge breeder		
- Source body (LEA contribution excepted)	0,3	
- Source 1+	0,1	
- Deflection and focusing systems and with related power supply	0,3	
- Diagnostics and control system	0,1	
- Pumping systems for beam lines and vacuum chambers	0,1	

- Medium resolution selector	0,6	
TOTAL for Charge breeder		**1,5**
6) RFQ for pre-acceleration		
- Mechanical structure: materials	0,6	
- Mechanical structure: manufacturing	0,6	
- Vacuum system and injector control	0,3	
- RF system	0,7	
- 3 cavities for pulsed beam	1,7	
TOTAL for RFQ for pre-acceleration		**3,7**
7) ALPI Upgrade		
- Completion of the upgrade of the low energy line	0,2	
- Cryogenics plants and cryogenic modules	0,9	
- Beam diagnostics instrumentation	0,8	
- Vacuum system	1,4	
- Upgrade of the radiofrequency control system	0,4	
- New magnetic lenses and modification of ALPI injection	1,8	
- Control System	0,2	
TOTAL for ALPI Upgrade		**5,6**
8) Safety and Control Systems		
- Access control system	0,3	
- Neutron and gamma radiation counters	0,5	
- Hand/foot dosimeter units, detectors for neutrons, beta, tritium, low background laboratory and detector laboratory	0,8	
- 1Bq/g detectors	0,2	
- Portable instrumentation	0,3	
- Calibration systems and sources	0,4	
- Control room, wire and cables	0,2	
- Radioprotection devices for low energy beam line and related control system	0,5	
- Radioprotection devices for cyclotron and related control system	0,5	
TOTAL for Safety and Control Systems		**3,6**
TOTAL CORE_SPES		**27,9**
TOTAL FULL _SPES		**(30,6)**

Tab A5 – Details of costs. General costs are reported in Tab. IV in the document.

List of Professional Figures to be acquired	2013	2014	2015	2016	2017
Technical Staff (art. 15)					
Mechanical Technician T_04-07	50%	129%	50%	50%	13%
Electronic TechnicianT_04-07	50%	130%	117%	50%	0%
Technician T_05	0%	100%	100%	100%	100%
Vacuum Technician T_04	0%	50%	50%	50%	0%
Electronic control Technician LL/HL T_01	100%	100%	100%	146%	100%
Technological Staff - Engineers(art.23)					
Diagnostics Technologist _1 T_07	100%	100%	100%	100%	0%
ISOL Technologist T_03	100%	100%	117%	117%	0%
Laser Technologist T_03	120%	100%	112%	128%	7%
Training Staff					
Ph.D. Student_HRMS T_04	100%	100%	100%	100%	100%
Ph.D. Student _ISOL/CB T_03-07	50%	70%	50%	50%	50%
Ph.D. Student _Laser T_03	110%	65%	50%	50%	50%
Ph.D. Student _Materials T_03	50%	50%	50%	50%	50%
Ph.D. Student _Controls 1 T_01	122%	100%	100%	100%	50%
Ph.D. Student _ RFQ Controls 2 T_07	50%	100%	61%	50%	50%
Ph.D. Student _ Diagnostics T_04	100%	100%	100%	100%	0%

Tab A6 – Professional figures to be acquired and workload in the period 2013-2017.

		Situazione attuale			Previsione per il 2013-2017	
Sotto-struttura	**Unità di personale a tempo indet.**	**Descrizione delle attività non-SPES**	**FTE (non-SPES)**	**FTE-SPES (attuali)**	**Incremento FTE-SPES**	**Totale FTE SPES**
DIVISIONE ACCELERATORI						
Servizio Sorgenti e Iniettori	4	1. Coordinamento e conduzione sorgenti Tandem e PIAVE; 2. contributo LNL all'iniettore di fasci neutri (progetto ITER)	4	0	0,6	0,6
Servizio Radiofrequenza e Vuoto	3	1. Gestione e manutenzione di n.84 cavità superconduttive di ALPI e PIAVE; 2. gestione di tutti i sistemi da vuoto degli acceleratori dei LNL	2,7	0,3	0,6	0,9
Servizio Operazione Macchine Acceleratrici	13	1. Coordinamento e gestione dei turni utenti (H24x7GG); 2. manutenzione su Tandem e magneti; 3. coordinamento interventi sui magneti e sugli impianti asserviti agli acceleratori	13	0	(2)*	(2)*
Servizio Fisica dei Fasci	5	1. Progettazione e realizzazione dell'RFQ del progetto IFMIF; 2. attvità progettuale e sperimentale relativa al progetto MUNES; 3. calcoli di dinamica dei fasci sugli acceleratori Tandem, ALPI e PIAVE; 4. supporto al coordinamento dei turni utenti	4,7	0,3	0,7	1
Servizio Fasci Esotici	3	1. Supporto agli utenti nelle sale sperimentali; 2. supporto al coordinamento dei turni utenti	2	1	0,3	1,3
Servizio Controllo Acceleratori	6	1. Progettazione e gestione dei sistemi di controllo di PIAVE ed ALPI quanto a radiofrequenza, diagnostica del fascio, magneti, controllo degli accessi; 2. supporto di elettronica sugli acceleratori	4,3	1,7	0,6	2,3
Servizio Acceleratori per la Fisica Interdisciplinare	2	1. Coordinamento e gestione dei turni utenti sugli acceleratori elettrostatici CN ed AN2000; 2. attività di manutenzione sugli stessi acceleratori	1,3	0,7	0	0,7
Responsabile di divisione	1	1. Coordinamento: della Divisione Acceleratori quanto agli acceleratori Tandem, ALPI, PIAVE, CN e AN2000, inclusi sicurezza ed affidabuilità operativa; dell' attività di conduzione, ricerca e sviluppo. 2. Pianificazione strategica, gestione del budget, promozione di collaborazioni e incontri anche internazionali.	0,8	0,2	0,3	0,5
Segreteria	1	Attività con contratto part-time: 1. segreteria conferenze e workshops dei LNL; 2. redazione annual report dei LNL; 3. segreteria della divisione acceleratori	0,5	0	0	0
TOTALE	**38**		**33,3**	**4,2**	**3,1**	**7,3**

Tab. A7 – Workload for SPES and others activities fort the Accelerator Division personnel; in the last two columns expected involvement in the period 2013-2017.

* Note: the Accelerators Operation Service is involved for a mean workload of 2 FTE (not accounted in the total FTE) corresponding to the 12 months stop of the accelerators (2016-2017) due to the involvment of the service into the SPES setup.