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ELI-ERIC

TECHNICAL-SCIENTIFIC

DOCUMENT

To be SUBMITTED TO THE EU

FOR THE STEP1 TOWARDS SETTING-UP

THE EXTREME LIGHT INFRASTRUCTURE

PROJECT

AS AN EUROPEAN RESEARCH INFRASTRUCTURE

CONSORTIUM

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Preamble

This Technical and Scientific Description of the ELI Research Infrastructure is part of the official proposal to the European Commission to set-up ELI-ERIC as a European Research Infrastructure Consortium. Its purpose is to provide, in a compact form, the main relevant Technical and Scientific elements to allow an informed decision, as well as references to more detailed documents.

The scope of ELI-ERIC is to develop and operate an international Research Infrastructure of Pan-European interest for experiments on extreme light-matter interactions at the highest intensities, shortest time scales and broadest spectral range. ELI will make available unprecedented peak power (>10PW, $>10^{22}W/cm^2$) and atto-second (10^{-18} s) resolution of coherent radiation and laser-accelerated particles for fundamental studies in atomic, molecular, plasma and nuclear physics to serve a large variety of scientific applications, ranging from materials science, biology, chemistry and medicine to laboratory astrophysics. ELI-ERIC is based initially on three sites (“Pillars”), now in an advanced phase of construction in the Czech Republic, Hungary and Romania with complementary scientific profiles. The overall project includes a possible future implementation of a fourth pillar with even more advanced specifications allowing going into and beyond the ultra-relativistic interaction regime.

The Extreme Light Infrastructure (ELI) project has been developed over a decade, starting from its first conception and entry in the ESFRI Roadmap in 2006. The Preparatory Phase (PP), developed after this entry, has proposed to realize ELI as an integrated project based in three Countries[1] (Host-Countries in the following). The Czech Republic made the first step forward in this direction, soon followed by Romania and Hungary and these three Countries decided to invest in this research infrastructure (and not in traditional infrastructures as, e.g. highways) a sizeable part of the European Structural & Investment Funds (ESIF)

[1] The resolutions of the Steering Committee of the Extreme-Light-Infrastructure Preparatory Phase Consortium have given the mandate to Czech Republic, Hungary and Romania to establish the Extreme-Light-Infrastructure (ELI) as a single and integrated pan-European research infrastructure based initially on three complementary research centres to be located in these three countries. The same resolutions have given the responsibility to the three host nations to establish an “ELI Delivery Consortium” leading to the future pan-European consortium (ELI-ERIC) in charge of the joint operation of the ELI research centres.

funding available to each one of them, to implement the ESFRI proposal. This has involved the approval of three executive projects funded by the ESIF implementing Authorities in the Host-Countries and has enabled the construction of the first three "Pillars " which are now well underway and nearing completion. Following the indications of the Preparatory Phase, the three Host-Countries as well as Germany, Italy and the UK, have set-up the ELI-Delivery Consortium (ELI-DC) with the mandate to ensure the setting-up of the ELI-ERIC and its sustainable development as a pan-European research infrastructure dedicated to multidisciplinary scientific applications of ultra-intense and ultra-short laser pulses[2]. This has enabled the coordination and the ongoing integration of the three projects into one single European Research Infrastructure.

ELI-DC has prepared the present proposal to the EU, including this Technical/Scientific Document and a draft Statute, and is now also involved in organizing and bringing forward the negotiations for an extended membership to the ELI-ERIC. The Members of ELI-DC participate through Representing Entities delegated by their Governments (The Institute of Physics of the Czech Academy of Science for the Czech Republic, the Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH) for Romania, the ELI-HU Kft. for Hungary, DESY for Germany, Elettra Sincrotrone for Italy and STFC for the UK) with delegations composed both by scientists and Ministry representatives, in a way which anticipates the possible composition of the General Assembly of the ELI-ERIC.

The ELI project has, therefore, evolved from the initial 2006 proposal in the ESFRI Roadmap, of a single-site facility reaching specifications well beyond the existing cutting edge technologies, to a more gradual approach, which allows already to push by one order of magnitude the limits of the present technological state-of-the-art in ultra-intense and ultra-short pulse laser technologies while offering a wider diversity, both in the service to the scientific users and in the development of the technologies needed to reach the most ambitious goal, which will be the definition and construction of the fourth, higher-intensity, pillar of ELI, allowing another order of magnitude increase in specifications. As such, the ELI project has recently been recognized as a successful project, now part of the European "landscape", in the last edition of the ESFRI Roadmap (2016).

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[2] - A Memorandum of Understanding has been signed on 16 April 2010 and amended on 18 April 2011 whereby the plenipotentiaries for ELI in the Czech Republic, Hungary and Romania confirm the intention of the three host nations to coordinate their activities of implementation of the ELI research centres within the ELI Delivery Consortium and to cooperate with all interested parties on the establishment of the future pan-European consortium in charge of the operation of ELI. The signatories of the Memorandum of Understanding recognise the necessity to preserve and promote the pan-European character of ELI, while respecting the legitimate interests of the countries hosting the ELI research centres.

The ELI Beamlines building in Dolni Brezany near Prague

The overall complex of ELI-ALPS in Szeged

The Main Laser Building of ELI-ALPS in Szeged

ELI-NP Building in Magurele

The construction of the three pillars in Central-Eastern Europe has additional beneficial effects, such as closing the gap between East and West Europe by shifting the center of investments in large research Infrastructures in favour of a more balanced distribution not only stopping but even reversing the “brain drain" and generating incoming flows of researchers and highly qualified technicians. Each Pillar project has been accompanied by specific investments in Technology Transfer to Industry and the construction of Industry-related areas, which, in some cases, are already active. Another important general effect is that of allowing the build-up of a stronger technical and scientific base in a cluster of technologies which will allow Europe to maintain and consolidate its position at the forefront worldwide in the photonics sector, which has a growing industrial base and generates a significant socio-economic impact.

The construction of the three pillars has been supported by the ESIF funding through a "phased" approach allowing to cover two succeeding funding periods, and the proposal to set-up the ELI-ERIC is made during the second (2016-2018) funding period to allow a more effective and coordinated use of the available regional resources for this final construction phase and extending to the first operation phase. This will allow a stronger integration avoiding duplication of efforts.

The proposed ELI-ERIC structure and why an ERIC now

The proposal to set-up the ELI-ERIC is planned to be submitted to the EU Commission before the end of this year 2016, the submittal being through two steps, an informal one now expected in September 2016 before the formal application which may be within the end of 2016 or the first months of 2017. The construction of the Pillars will be completed over one year, from the end of 2017 (for ELI-BL) to mid-2018 (ELI-ALPS) and end of 2018 (ELI-NP). The operation will start, in a phased approach, from the beginning of 2018 and be complete by the beginning of 2019. Therefore the integration of the three Pillars, and the support to operation as one integrated initiative, must be ready by the beginning of 2018. If the EC Decision to set-up the ERIC is taken within the first months of 2017, the past experience shows that the real operation of the new ERIC will be ready by the second-half of 2017, in time to support the operation (a new and complex initiative as ELI-ERIC requires the development of processes and procedures, as well as the hiring of the needed personnel, or the support of the Pillars in setting up the needed resources).

The process of setting-up the ERIC, if started now, has several advantages both in allowing a smoother transition between the construction and the operation phase, but will also allow the start of integrated activities already in this pre-operation phase, ensuring both the development of the best scientific offer to the users and the best cost/benefit ratio in developing the management and operation of the facilities, providing the best value for the contributions required to the Members in the operation phase. The perspective members will be able to assess, already now and in a more complete and direct way, how the distributed infrastructure is effectively set-up and integrated.

To allow a timely start of the ERIC operation, ELI-DC has set-up and tested the operation and the appropriate rules of procedure of the main bodies envisaged in the ERIC Statute, ensuring a transition to an effective governance in the final construction and (from its beginning) operation phases. These Bodies are the International Scientific and Technical Advisory Committee (ISTAC) and the Board of the Directors of the Facilities (Management Board in the Association's terminology) as well as the General Assembly referred to above. The setting-up of an Administrative and Finance Committee will also be implemented before the formal start of the ERIC, to allow a transparent assessment of the costs and financial requirements.

The draft Statute allows the non-Host Members to propose also the integration, in the Infrastructure, of Partner Facilities operating in their Countries and having capabilities, complementary to those of the pillars, in terms of offer to scientific users and/or of available technological capabilities. These Facilities will have a more specific scientific and technical scope and a more regional impact, but, within the distributed approach of ELI-ERIC, will allow building a wider and effective European integrated capability and involve more readily the Members and their scientific, technical and industrial communities in a common effort to achieve internationally competitive results. Having the possibility to involve Partner Facilities in the start-up of the operation may help to attract and train perspective users, and also the co-development of the most advanced experimental capabilities.

ELI-ERIC is the first distributed large RI which is being built in Europe by three different Institutions as such. Most other distributed ERICs or international infrastructures are set-up by integrating existing infrastructures or by one single ownership. A specific character of ELI is that of being built by using ESIF funding under the control of three different national (or also Regional) authorities, and by three different owners, while keeping an overall coordination according to the project approved within the ESFRI approach. This has required coordinating the development of three different executive projects, with some differences in the way the funding and the assessment rules have been applied.

This has been a first experience of the kind, and the successful development of the three sites as a single project has been mainly driven by the agreement and collaboration between the three different institutions in charge of the detailed design and construction of each pillar. The Project leaders have been able to effectively develop the complementary pillars within the original common scope thanks to the collaboration and exchange of expertise, which is customary in the scientific field. The coherent approach during the design and construction phases allows now the ongoing integration into a single large-scale distributed facility.

The activities of the Pillars, those through the contributions of the members of ELI-DC and those through ELITRANS (and other projects funded by the EU and the Members) have allowed already to converge on several issues, e.g. a common understanding of the access policies, the joint development and perspective preparation of common technical specifications and development of technical aspects (as, e.g. the safety approach or the control systems, the ICT and the open data approach etc.). These joint activities have been developed by working groups set-up in agreement between ELI-DC and the three Institutions managing the Pillars, and the participants integrate people from perspective Members and users whenever needed.

All these activities and the perspectives of ELI-ERIC have been presented and discussed with the perspective Partners (representatives of the perspective Members and/or Observers of ELI-ERIC, users, Partner Facilities, and Industries) in a Workshop organized in Dolní Břežany on May 31st and June 1st 2016. This exchange of ideas and suggestions has allowed assessing whether the timing to set-up the ERIC and the direction taken in several aspects of the integrated activities are the correct ones. The response has been strongly positive and this Document reflects some of the outcomes of the discussion. A direct exchange with potential users and other Members and Partners will be an ongoing process allowing collaborating with all perspective stakeholders in the next steps to complete and operate ELI-ERIC as an open and inclusive European Research Infrastructure. Another meeting with the Partners and Stakeholders is planned in the fall of this year 2016, in time to collect further suggestions and ideas before the completion of the Step 2 of the ERIC application to the EU Commission.

As anticipated above, the activity of ELI-DC has allowed to set-up, test and start, the activities of the Bodies planned for the ELI-ERIC: a General Assembly of the Members, a Board of Directors of the Facilities and the senior staff of ELI-ERIC, and an International Scientific and Technical Advisory Committee (ISTAC). Based on the experience of ELI-DC and of several large infrastructures in Europe a specific Administrative and Finance Committee has been planned in the Statute, to ensure the correct use of the resources contributed, in cash and/or in-kind, by the Members. This Committee shall also ensure the correct application of any fiscal exemption which may be granted and used within the scope of the ERIC as allowed by the ERIC Regulation.

The governance and the institutional structure of the ELI-ERIC, as designed in the Statute, leave enough flexibility, through the internal rules of procedure, to ensure the capability, for the General Assembly and the Executive and Advisory bodies, to adapt in response to the needs. The Board of Directors, within its rules of procedure and with the approval of the General Assembly, may involve the Directors of the Partner Facilities of non-Host Members in developing joint scientific and technical activities, therefore extending the capabilities of ELI-ERIC and its impact on a wider number of Countries.

The interplay between the General Assembly and the Board of Directors, as well as the scientific and technical advice of the ISTAC, have been tested within ELI-DC and has well defined references in a well consolidated approach in several other ERICs, as well as in other international initiatives.

The proposed ERIC structure also takes into account the different legal and institutional frame of the three projects and allows to design an integration process which, starting from three different ownerships and contractual frames, can allow an ever deeper integration without interrupting the present activities focused to the construction but with a smooth integration of resources and the transition towards the joint operation for users. Due consideration has been taken of the need to allow to use in a coherent way both national (and ESIF) and international (Members and/or international) funding for operation and for the future upgrades which may take place over several years.

One aspect, which is often the topic of long and difficult negotiations, is the definition of the Country hosting the Statutory Seat. The three Host Countries have expressed interest and have equal merit in having taken upon themselves the realization of ELI as an integrated Research infrastructure. The three Pillars have equal capabilities to support and coordinate the basic functions of a Statutory Seat. It has therefore been agreed that these functions and their coordination will also be distributed equally between the three Pillars and that the Statutory Seat will formally rotate between the three Host Countries with a three years period, based on a decision of the General Assembly of the ELI-ERIC.

The rotation of the formal siting of the legal seat will not require transfer of staff and/or materials. It will, however, require that the three Hosting Countries fulfil the obligations required by the EU Regulation 723/2009. As a first challenge in the speeding-up of the possible bureaucratic hurdles, it has been mutually agreed that the first Host Country which fulfils the internal procedure for the recognition of the ELI-ERIC as an International Body and an International Organization granting the tax exemptions as indicated by the EU Regulation, will also be the first Country Hosting the Statutory Seat in the first foundation cycle.

The Statutory functions of the Seat, as e.g. the support to the operation of the Bodies, the operation of the single entry User's access System, the coordination of Technology Transfer, the Administration in its various functions as, e.g., human resources, legal, procurement etc.) of the ELI-ERIC will be distributed in the three pillars and linked by a common operative ICT support (compatible hardware and common software and procedures) which will also allow the remote interaction and coordination of the activities, so that the need to move people will be minimal. Within the present working groups there are other activities and technical support structures, (e.g. optical components maintenance, software engineering etc.) may be allocated in one of the pillars but managed as a common asset, and used jointly. Some special technical capabilities could even be localized outside the pillars, in some of the Partner Facilities, who have already specialized capabilities which would be expensive and not effective to duplicate. The distributed approach shall ensure also both a cost-containment of these "central" functions as well as avoiding the build-up of a possible antagonism between a "central bureaucracy" and the operation of the research infrastructures.

A shorter timing of the transition between three institutionally independent Pillars and one institutionally integrated structure, as stimulated and allowed by setting-up the ELI-ERIC, responds also to other strategic needs related, e.g. to human resources. The development of the projects and the funding now supporting the construction of the three pillars are due to end completely in 2018, having now crossed a divide between the funding period ending in 2015 and a second phase covering 2016 to 2018. This transition has already had some consequences on the attraction and retention of some critically needed staff, and the uncertainty over the future developments would cause a lower attraction and/or retention of the personnel which is critically needed for the successful start of the full operation.

The setting-up of the ERIC will allow to ensure a stronger continuity in the attraction and retention of the critically needed staff as well as to consolidate the integration of those activities which will make the difference between a cluster of facilities and a unique integrated facility. The transition to an ERIC will also help to use in a more effective way the available and the future resources required, preparing a better defined negotiation ground and a more attractive offer for all interested perspective Members.

To ensure the most effective employment of the capabilities while containing the costs, the needs in Human Resources should be fully defined in the start-up period of the ELI-ERIC, also taking into account the comparison between the stipends in the three Host Countries and how the ELI-ERIC could help to develop a common policy, on one side attractive to international researchers and technicians, and, on the other side, allowing a strong mobility between the Pillars. In this respect, ELI-DC has been collaborating with the EU initiative to set-up an integrated Pension scheme (RESAVER[3]) which is allowing to build an additional pension scheme adapted for research staff (including technicians and managers) moving between different employments in Europe.

The integration of the resources and a phased approach to full operation

The activities towards full integration, as detailed above, are on-going. However this process has still to overcome some barriers due to the different traditions and different legal frames, in particular those connected to the contractual and fiscal environments for the staff employed and the constraints connected to the ESIF projects and applied nationally in going into the operation phase of the facilities. The setting-up of the ERIC will help to understand better the difficulties and to further develop the existing common basis to develop a more synergic approach. The present ELI-Delivery Consortium (an International Association under Belgian Law) has helped to settle some of the first steps, but its legal form (and the legal seat outside the interested Countries) is not sufficiently effective to support the direct exchanges, the coordination and the co-investments which are now needed to ensure the best use of resources.

A strong support in the project and now in preparing the transition has been given by the EU, as a prime mover both in the preparatory phase and now through the funding of specific projects. The major project (ELITRANS) is managed directly by ELI-DC and is allowing a strong action to develop the ELI-ERIC activities and structures as a coordinated effort of the three pillars, involving also other Partners.

The integration of the three Pillars is very different from the “merging” processes which take place in the industrial environment when one firm takes control of another. In the scientific enterprise we need to ensure a common vision and an equal base of understanding and participation by the staff of the three pillars as well as by the external scientific, social and political stakeholders. There must be a common vision

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3 *www.**resaver**.eu*

and a common effort, within a very specific and uncommon mandate: that of a service-oriented International Research Infrastructure.

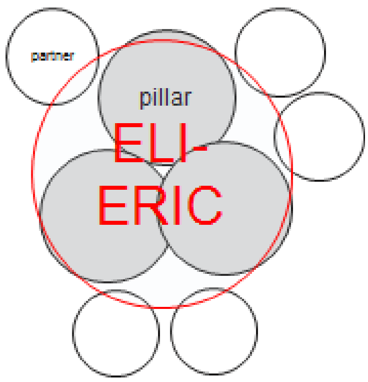
The integration and its effective implementation, as well as the common scope and understanding built with the perspective Members, must also ensure and strengthen the longer term sustainability within the specific challenge faced by competitive RIs: that of ensuring open access to the users, solely based on the scientific quality of their projects. This approach, which is well known as the one allowing the optimal growth in the quality of the infrastructure and ensuring the best returns on the investments, requires a common understanding and effort, shared between national (and/or regional) funding authorities, international institutions and Country's governments. Overall sustainability can be reached only by ensuring a durable support of the operation and of future new investments in the facilities, allowing maintaining technical and scientific competitiveness.

The ERIC is a Consortium, i.e. it allows respecting the present ownership of the infrastructures of the three pillars, while opening them to international management and use, within the scope and the outreach of the ERIC. No transfer of ownership, or change of contractual employment of the staff is necessary in the start-up period. As allowed by the Consortium approach, the Members will confer the "availability" of the infrastructures: the scope and detailed rules of the conferment will be regulated by Framework and Specific Agreements, within a well-tested approach already in use in several consortia.

One open issue which will need to be addressed in developing the agreements with perspective Members is the amount of access (and resources) dedicated to the international users accessing through the ELI-ERIC. In a first round of discussions, and based on some of the constraints of the executive ESIF projects, the Host-Countries and/or some of the owner Institutions of the three Pillars have indicated that about 80% of the available operation and capability of the pillars will be dedicated to the activities planned and developed by the ERIC (mainly the access to be offered to international users). The remaining 20% would be mainly used within a national scope, but still benchmarking it to the quality introduced by the competitive use in the international context. This discussion is ongoing, and the perspective of setting-up the ERIC has allowed a more dynamic process involving both the Hosts and the other future Members.

Within this discussion, the possible agreements with other Members about the availability of the "Partner Facilities" will be developed on a case-by-case basis.

The following figure shows a schematic of the overlapping "area of operation" between the ERIC and the Pillars, as well as between the Partner Facilities and the ERIC. The area outside the red "ERIC" circle would be the part connected mainly to a national reserve (and this would be higher in the case of the Partner Facilities).



The availability of the infrastructures of Pillars and Partner Facilities and of their capabilities, as conferred to the ERIC, would be the "in-kind contribution" of the Host and Member Countries. The opening and support for the international operation of these infrastructures will be the scope of the ERIC and shall be based on the contributions by all the Members, according to the specific agreements which will be developed by the ELI-ERIC with each Member. A different approach may become applicable in the future, after the period of about five years in which the ESIF funding requires a direct involvement of the local environment in the management and the ownership of these facilities.

The construction phase in the three pillars will be complete by the end of 2018, and, if (as assumed) the ELI-ERIC will have been set-up from the beginning of 2017, there will be two years of the ERIC operation overlapping the on-going funded implementation phase, integrated, as it is now, by contributions already acquired from EU projects and, if agreed, by the Members. This period will allow the testing and implementation of several experimental set-ups and subsystems of the overall infrastructure. If the proposal to connect the Pillars to Partner Facilities will be implemented in this earlier period, this may even allow to perform earlier demonstration activities involving external users in the Partner Facilities. A main scope of the testing and first experimental activities will be that of demonstrating the excellence of the overall infrastructure, also to satisfy the requirements of both the Host and non-Host Governments who will need to be supported in the decisions for their participation.

The period between 2019 and 2020 will be, from the technical point of view, the real start-up of the users-oriented operations, which can be designed (starting already in 2018 for some equipment) as a phased approach within the experimental demonstration and testing steps of the various primary and secondary sources installed, as well as of the use of the various experimental set-ups, many of which are now already in advanced construction phase.

The Host Members are now discussing how to support the start-up and the beginning of the operation as well as the involvement of the national communities, and how to contribute, together with the other Members, to the international operation. New investments in upgrades and to acquire possible instrumental resources are being negotiated with some of the Host Countries' managing authorities within the new funding period of the ESIF. Negotiations including the EU Commission aim also at having some support to the first operation phase. The present executive projects, as approved by the ESIF Managing Authorities and the EU, have considered a period of five years in which the operation of the three pillars planned for sustainability and to be monitored for the effective outcomes.

This set of activities shall ensure a phased transition from construction, through a start-up phase, to a full operation which can be expected from 2021 onwards.

The Infrastructures: the "Pillars" and the Partner Facilities

In a summary way the Scientific and Technical Mission of ELI-ERIC can be synthesized as follows: "Bring the European Research Area at the forefront of ultra-intense and ultra-short laser physics and technology".

Detailing better the scientific and the technical parts, the primary scientific mission aims at offering to the international users today's state-of-the-art facilities in ultra-intense and ultra-short pulse laser science and its applications, the primary technological mission of ELI is to contribute to the technological developments towards and beyond the 100 PW regime for high-field science, which is the ultimate goal of the original ELI project. In this context, other parts of the overall mission of this excellent Research Infrastructure are as important as the primary ones, as perceived by the many Stakeholders who will be involved, directly or indirectly, in defining the investments and the resources needed to support the Infrastructure. Stakeholders interested in Education and Training are strongly related to the scientific environment and appreciate how the scientific and technical success supports the quality of education, other important stakeholders may be interested in different socioeconomic aspects, and this requires that the infrastructure is capable to dedicate resources e.g. to develop the collaboration with industries, the attraction and localization of economic activities, the general strengthening of the scientific and technical culture, etc.

ELI is planned and will be implemented as a synergic pool of three complementary pillars, each one including technical and scientific aspects and capabilities at the frontier of laser technologies, as well as developing the local and national interaction with the various stakeholders. These three research centers have been designed in a coordinated way to offer to the international scientific community of academic and industrial users, worldwide, unique research opportunities, in a very broad range of fundamental and applied scientific fields, based on the use of ultra-intense and ultra-short laser pulses, integrated into a single and unique access mode. Therefore, even though some of the very hot research topics are going to be explored in a competitive way at the international level in more than one pillar, the scientific profiles of the three pillars of ELI are essentially complementary.

An optimized integration of the access to the research facilities and their support services will allow ELI-ERIC to efficiently guide users towards the best suited research facility and experimental set-up, also when the proposed scientific project can be technically undertaken in more than one center. The same coordination and possible synergies will be explored and developed in various other aspects, from the collaboration with industry to the impacts on education, technical training and overall cultural and economic returns.

As a possible access and services to users, the complementary capabilities of Partner Facilities offered by other member Countries of the ERIC, integrated in the overall infrastructure and allowing experimental activities with different and possibly incremental laser specifications, will extend the outreach to potential users. This model has a successful precursor in the Laser-Lab Europe[4] which offers combined access to most laser facilities in Europe, and the collaboration with this institutional network will ensure the full use of its demonstrated expertise.

We give herewith a short introduction of the technical and scientific contributions of each Pillar Facility to the integrated capabilities of ELI-ERIC. A more detailed presentation of each Pillar is given in the last sections, and further detail is found in the reference technical documents available and referred to in the text. In any case the common access and the selection of the proposals will be supported and allowed through a common entry point and peer review process with the approach detailed later in this document.

The projects of the three Pillars have followed the indications of the ELI “White Book” [5] which has been developed as an overall conceptual project-design during the Preparatory Phase, and then has been the basis of the executive designs of each Pillar. The projects have been developed while attracting a very international staff which has contributed by bringing in place a high level of qualifications.

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[4] http://www.laserlab-europe.net

[5] http://www.eli-beams.eu/wp-content/uploads/2011/08/ELI-Book_neues_Logo-edited-web.pdf

In the following we give first a short presentation of the specific "mission" and summary definition of each Pillar within the overall ELI remit. Their interconnection and the possible integration with other Partner Facilities can contribute to an overall Europe-wide Research Infrastructure.

The table below shows an overview of all ELI high peak-power short pulse laser sources as they are built for the whole project. As seen from the table the ELI is offering a wide range of newly developed laser sources which are leading edge technology approaches with a wide parameter space not realized so far concerning peak-power, pulse width and repetition rates.

		Peak power	Energy in pulse	Pulse duration	Repetition rate
ELI-Beamlines	**L1**	>5 TW	100 mJ	< 20 fs	kHz
	L2	1 PW	20 J	≤ 20 fs	10 - 20 Hz
	L3	≥ PW	≥ 30 J	≤ 30 fs	10 Hz
	L4	10 PW	≥ 1.5 kJ	≤ 150 fs	1 shot per min
ELI-ALPS	**HR**	> 1 TW	5 mJ	5 fs	100 kHz
	SILOS	> 20 TW	100 mJ	< 5 fs	1 kHz
	HF	> 2 PW	34 J	17 fs	10 Hz
	MIR	> 25 GW	0.16 mJ	< 4 cycles	100 kHz
ELI-NP	**HPLS output 1 (2x)**	0.1 PW	> 5 J	< 50 fs	10 Hz
	HPLS output 3 (2x)	1 PW	> 50 J	< 50 fs	1 Hz
	HPLS output 3 (2x)	10 PW	> 200 J	< 50 fs	1 shot per min

Table 1: Parameters of laser sources available in ELI

The **ELI-Beamlines** Pillar is nearing completion in Dolní Břežany, near Prague (CZ). Its name underlines its capability to support several types of different experiments for different users, offering the availability of different Laser lines. It is designed to offer, to the ELI-ERIC users, the high-energy and high repetition-rate part of the overall capabilities. The specific goal of ELI Beamlines as endorsed in the ELI White Book, is to develop a "*High-Energy Beam Facility, responsible for development and use of ultra-short pulses of high-energy particles and radiation stemming from relativistic and ultra-relativistic interactions*", as well as to address one of the "Grand Challenges" listed in it, specifically in the generation of "*Ultra-short pulses of energetic particles (>10 GeV) and radiation (up to few MeV) beams produced from compact laser plasma accelerators*". In particular, it is expected to support the "*Ultra-high field Science, i.e. access to the ultra-relativistic regime*". With its scientific research and technological concepts ELI Beamlines contributes to the high-field science approach which is the content of the 4th pillar. Furthermore there is a very strong emphasis on possible societal applications in different fields like for instance medicine. ELI-Beamlines already serves as an incubator and attractor for companies and spin-offs in different fields which settle in the so called STAR (Science and Technology Advanced Region) which is surrounding ELI Beamlines facility.

The **ELI - Attosecond Light Pulse Source** (**ELI-ALPS**) Pillar, in advanced stage of construction in Szeged (HU) will make available within ELI-ERIC a wide range of radiation and particle sources emitting, in a stable-in-specifications and robust-in-operation manner, energetic pulses of ultrashort duration and coherent radiation in the atto-second (10^{-18} s) time-resolution range. They will serve basic and applied research goals in physical, chemical, material and biomedical sciences. A parallel mission is to contribute, with the other two pillars, to the technological development towards the 100 PW class for high-field science, which is the technological main future goal of the ELI project. The ELI-ALPS Pillar has a specific focus towards the stimulation, through spill-over effects, of industrial applications, taking into account also the possible strong impact on its surrounding territory.

The ELI-NP Pillar under construction in Magurele (RO) presents a singular opportunity for opening an exciting and new window in scientific research at the frontier of knowledge involving two domains. The first one is laser-driven experiments related to nuclear physics, strong-field quantum electrodynamics and associated vacuum effects using two 10 PW lasers. The second is based on a back Compton–scattering high-brilliance and intense low-energy gamma beam (<20 MeV), a combination of laser and accelerator technology which will allow to investigate nuclear structure and reactions, as well as nuclear astrophysics with unpreceded precision and accuracy. ELI-NP will bring together two very important scientific communities, that of laser and that of nuclear and astrophysics, which had never had such a close encounter till now, to realize an integration of the two disciplines to create nuclear photonics.

As already detailed above, ELI-ERIC makes it possible to extend the capabilities of the three Pillars by building a pan-European eco-system of Partner Facilities which can be proposed by the member Countries and integrated after their evaluation by the ISTAC, thus providing a broader portfolio of research opportunities to the international users than what the three ELI Pillars alone could provide. These Partner Facilities are also expected to strengthen the regional outreach and returns. They shall help ELI to fulfil its mission as a world-leading user facility while, in return, gain increased scientific and socio-economic impact within their own region. When making part of their facilities available for access under the ELI-RPF program their owner Institutions shall fully commit to ELI's standards for the quality of access, services and management, which will be evaluated on a regular basis by the ELI-ERIC ISTAC.

The Open Access Policy and the Access procedure and its support

The access to the ELI-ERIC infrastructures can be listed by types of activities and users as follows:

- Basic and applied scientific research, and research data (non-proprietary)
- Technological development (e.g. testing and commissioning of new instruments and components for institutional and/or industrial development activities)
- Industrial/commercial use of the facilities (proprietary)
- Training for technical and scientific education

As it has been proven by most, if not all, large infrastructures, the users and the type of uses/experiments planned in the conceptual design and in the development phases will be only a part of the effective users who will show-up in the operation phase, with new, and sometimes revolutionary, ideas. The design of the three facilities has taken this into account and a wide flexibility is inbuilt in the way the infrastructures are designed and can be interconnected.

The proposed Statutes of ELI-ERIC clearly indicate open access as the basic policy. This will be implemented as far as possible for all types of users and activities.

The general reference of the "Open Access" policy is the EU Charter for Access to Research Infrastructures[6]. The policies developed by the GA will contain specific aspects taking into account that, differently from most other RIs, ELI is the only laser RI designed and built explicitly for the purpose of serving the international user community in an open access mode. Most, if not all, laser facilities, and in particular the high-power laser facilities, have been originally built for a definite national and/or institutional set of users, or even for a single specific use.

While the access for basic research and to the research data will need to have a strong orientation toward open competition between the best researchers at world level, the other types of access may be more biased, or reserved, within the ELI-ERIC membership, to allow a stronger connection between investments and returns. The single pillars may require an average of up to 20% of the access time for nationally managed access, part of which will be for industrial/commercial use. The aim is that of benchmarking also the national scientific activities to the same excellence-quality levels reached for the international access through the common peer-review evaluation and selection process.

The applications for access by international Researchers for non-proprietary research will be managed through a single entry point, including a virtual users' office (VUO) and the related scientific proposals will be selected solely on the basis of their quality by a peer-review evaluation system set-up and operated by the ELI-ERIC.

The overall access policy and selection process for the (non-proprietary) external users will include all facilities available, and is planned to include also the offer of complementary access to the Partner Facilities in agreement with the Members offering them (e.g. for the purpose of preparing specific experiments on smaller scale set-ups and to be further performed at the larger facilities of the Pillars or developing some common technologies)). If the RPFs are already part of Laser-Lab-Europe, this access will be developed in close collaboration with this network.

The overall offer of access to users is planned to start from 2018 in parallel to the commissioning of the beamlines and experimental setups. The access time and the capabilities will be gradually ramped-up to reach a full exploitation of the facilities over the first two years from the start of operation. The possibility to offer an earlier access in view of developing new ideas to be further implemented at the ELI-pillars could even be allowed before the start of the Pillars by the offer available in the Partner Facilities.

The Partner Facilities and the Pillars are expected to collaborate in the development of the user basis and for the outreach towards the national user communities, acting as possible entry points and as training sites through technical and scientific training, e.g. in collaboration with the local Technical Schools and Universities.

The scientific Management of the ELI-ERIC and of the Pillars will be finally empowered in the detailed decision-making on accepting proposals for access and in allocating the time as a function of the scientific and technical requirements. The main guideline for the Management will be that the scientific and institutional access will be selected solely on the basis of quality as evaluated by international peer review, the only filter being the technical feasibility and the limitation in the access time available. The General Assembly will give general guidelines which may indicate possible limitations and ceilings to specific types of access, connected to the overall sustainability, and linked to the available contributions by Members and

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[6] *https://**ec**.europa.**eu/research/infrastructures/**pdf/2015_**charter**foraccessto-ris.pdf*

their expected returns, as well as on the possible availability of international funding (in particular from the EU).

A very important aspect to be taken into account in managing the scientific and institutional access to any RI is that any direct relationship between payment and access will lead to a limitation of the open competition based on quality and to a decrease of the scientific values generated by the use of the facility. Therefore, the discussions at the level of the present proposers of ELI-ERIC have always accepted that there must be a quota of open access effectively open and based only on the quality, allowing the benchmark of all users to the best research proposals at world level. The scientific management will use this to ensure a continuous drive towards excellence of the users, of the staff and of the technologies available towards the international cutting edge quality of the facilities involved. The users accepted on this basis will be contributing to the scientific success of the overall facility, by acknowledging the contribution given by the facility to their successful projects and their scientific and technical achievements.

The access for industrial/commercial activities shall also be open in the sense that will be non-discriminatory, apply ethical principles, and based on a costing of the access unit which includes all real costs plus a reasonable margin. As anticipated above, the commercial access will be possible directly within the national time or through the ELI-ERIC access time. The specific rules and obligations will be defined between the ELI-ERIC and the single Pillars, taking into account also the framework in which the national funding for construction and operation has been defined. The industrial access will be managed either nationally (for the part of operation managed by the three pillars) or internationally within the activities of the Technology Transfer structures which are being set-up in coordination between the three Pillars and in view of ELI-ERIC (now involving ELI-DC). The prices charged will avoid discrimination but also state-aid issues. The Technology Transfer structure will also manage the intellectual property (IP) aspects related to external users and to the various technological developments, and develop a framework to define the property and shares among the Pillars, Members and ELI-ERIC.

The facilities and services offered to the users could be composed by several components: beam time, specialized laboratory (targets, metrology, characterization etc.) access, equipment storage space, access to utilities, test instruments and scientific (data analysis, data interpretation) and technical support through specialized workshops (mechanical, vacuum, etc.), engineers and technicians, computing and sample preparation capabilities, etc. Support for travel (visa, transfer) and logistics, housing and subsistence (guest house, canteen) could be also proposed to the users to ensure the highest standards of user service and support.

The access procedure, which will be submitted for assessment to the ISTAC, will be fully supported by web-based instruments and instructions allowing the clear understanding of the services offered, of the application requirements, as well as of the project evaluation (technical feasibility, scientific quality) and selection procedure. The access system will also allow obtaining remote technical support and advice prior to the experiments, in particular for new users and/or new instruments/experiments.

In case of refusal of access based on a negative evaluation, a feedback to the applicants will give them the possibility to improve and re-submit their application in a future call, or, in specific cases, allow a redress procedure. A user satisfaction questionnaire will be systematically employed to allow the management to continuously monitor and improve the service to the users. Key performance indicators will be defined and the yearly results of both ELI-ERIC and the ELI-RPFs will be submitted for assessment to the ISTAC and reported to the General Assembly.

The Costs estimates for operation and upgrades (and hints for a business model)

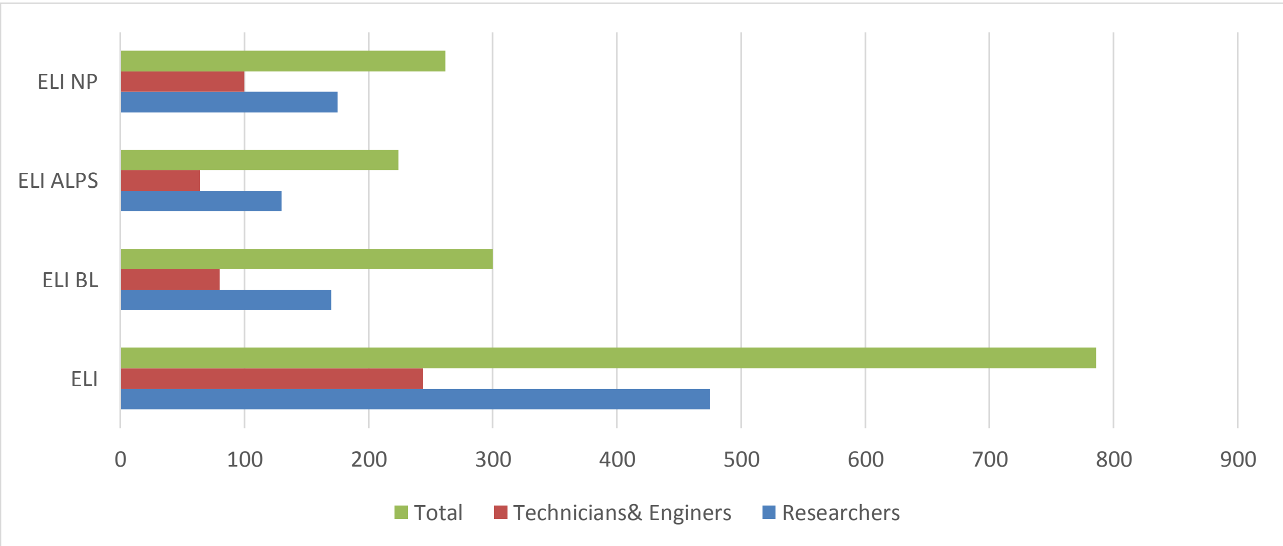
The total investment (construction costs) of the three Pillars, together, will be, over the whole construction period ending in 2018, of around 820 million euro (310 M€ for ELI-NP, 278 M€ for ELI-BL, 231 for ELI-ALPS, as detailed in Table 2) These costs are completely covered by funding contributed by the Host Countries, both on ESIF and on national funding. This funding has been based on the three executive projects as submitted, approved and funded by the national Managing Authorities. It is interesting to note, and relevant for the estimate of the operation costs, that the investments have been of about 30% in buildings, 60% in technology and 10%in personnel and services.

Table 2: the costs and cost items in the construction of the three Pillars

Item	ELI BL	ELI ALPS	ELI NP	ELI
Building + Land	84 913 000	88 705 128	79 710 986	**253 329 114**
Technology	161 876 341	105 435 077	188 627 929	**455 939 347**
Services	7 601 481	9 788 212	10 748 919	**28 138 612**
Personnel Costs	23 518 519	27 483 498	31 858 856	**82 860 873**
TOTAL	**277 909 341**	**231 411 915**	**310 946 690**	**820 267 946**

The overall staff which is planned to operate in the three Pillars when the Operational phase will be in full swing is of a total of 790 (300 in ELI-Beamlines of which 170 researchers and 80 technicians and engineers, 262 in ELI-NP of which 170 researchers and 100 technicians and engineers, 224 in ELI-ALPS of which 130 researchers, 64 engineers and technicians). The staff already working in the three Pillars is highly international and already now originates from more than 20 different Countries.

Fig. 1 the planned staff in the operational phase



A preliminary estimation of the operation costs, in the hypothesis that both the the direct expenditure by the ELI-ERIC and the expenditure through the Pillars are exempted from taxation is of about 75 million euro, these costs, if tax exemptions will be limited only to expenditure by the ERIC, will be approximately 9,5% higher (personnel costs not being affected), raising the total operation cost to about 81,5 million euro. This approximate estimate (updated in August 2016) will be subjected to a more detailed definition, on the basis of the technical specifications of the equipment and technological plants (which, in some cases, are still evolving in this implementation phase) and with reference both to the start-up period and of possible different operation intensities.

This detailed definition, to be developed within a Committee with the representatives of all interested Members (preliminary of the Administrative and Finance Committee planned in ELI-ERIC) will also take into account the possible cost-containment measures which can be designed in the integration and start-up processes. In taking into account the recurrent and non-recurrent costs during operation, there will be the estimate of possible cost-control and cost-reduction approaches both on the recurrent costs (e.g. estimating different hypothesis on energy costs, on procurement in the next ten years, the possible ceiling in the numbers of personnel - on one side- but also possible increase of wages in the ongoing alignment with the average European levels -on the other side-, ageing, etc.).

The final structure of the funding of ELI-ERIC and the balance between costs and income must take into consideration also the costs of the continuous upgrades which, given the cutting edge technologies involved and the fast progress in the laser technologies, will be needed to ensure the preservation of ELI-ERIC's competitiveness at world level. A specific advantage in the present arrangement is that a sizeable part of these costs may be covered by the ESIF funding, presumably also in the future funding period after 2020. Also in this case, the possible references to other infrastructures are limited, some aspects being similar to fast-renewing infrastructures (as, e.g. computing centers or Structural Biology laboratories with 3-5 years life-cycles) others to longer lifetime instruments (as, e.g. accelerators or astronomical observatories with life cycles often well above 10 years). The estimated difference between the possibility of the Pillars to apply tax exemptions or not gives a difference of about 20% in costs for the procurement of upgrades in equipment (personnel costs being marginal in this case).

A detailed evaluation of the maintenance and upgrade costs required to keep the facilities at the top level in terms of competitiveness will require to accumulate data related to the peculiar user-oriented aspect of these infrastructures which, differently from most existing ones, may need to have higher duty cycles and be subjected to higher technical wear. This analysis and various options will be discussed with the perspective members (and at the appropriate levels) who shall deliberate on the contributions needed to ensure the operation, the maintenance and the possible upgrades.

The structure of the various facilities and instruments available will also allow a phased approach to full operation, as well as the choice of different operation cycles (e.g. 24/7 for some instruments or only 8hr daily cycles for others, accounting for safety constraints and for users' requirements for instance). This will, but only partly, be reflected on the overall operation costs. A part of the costs and of their definition will also be connected to the requirements by the Members and their scientific and technological communities, to be further specified following negotiations.

A specific issue will be whether to implement, or not, the full opportunity given by the EU Regulation which allows Tax exemptions both for the ERIC and for its Members, and, if this is agreed by the single Member, the transfer of these exemptions to the national Representing Entity in charge of the operation and upgrade of the Pillar and/or Partner Facility, for the specific and sole purpose of the ERIC. The Statute of

ELI-ERIC allows this possibility which, in terms of operation costs, allows to save the VAT on procurements for the infrastructure and the Excise duties on the cost of utilities (in particular electricity and gas, for power, heating, and temperature control of the equipment halls). Most of the expenditure for upgrades, and, in the first years, also the operation expenditure, will be made through the Pillars and will be subject to the taxation, if the extension is not granted. Also the costs related to the 20% access time planned to be reserved for national decision could be tax deductible if the scope of the national share will be considered within the ERIC institutional remit, and open to international competition.

The overall structure and size of funding, and the ensuing operational capabilities, will be completely defined in the years 2017 and 2018 during and after the negotiations with the Members, as well as on the basis of possible funding from international sources, in particular the EU (both from the Structural and Social Funding available to the Central EU area and from the Research and Innovation Frameworks on the central EU budget).

In this frame, the role of the EU in allowing an effective start-up of this specific Research Infrastructure will be a very important factor, and a negotiation is ongoing on the possibility to have a significant support, albeit limited in time and in size. An overall target of about 20% contribution to support the first start-up period will be inserted in the business model. This, and the possible initial funding from the Host Members, could allow covering a sizeable part of the start-up operation costs already from the start in 2018.

As customary, the negotiations with the contributing Members will take into account (including for the Host Members) the expected returns and involvements. The perspective Members (in particular those who are already participating in ELI-DC) will be directly involved in the development and definition of the best practices and approaches to ensure the best scientific and socioeconomic returns.

The contributions required, and to be negotiated with each Member, may be both in cash and in kind, taking into account the need to ensure the cash-flow needed and the opportunity to acquire the resources in an equilibrated way. By comparing with the experience gained in negotiations in other distributed infrastructures, the most effective base for the definition of the contributions will need to take into account a “baseline operation” cost, and additional variable involvements (which may include in-kind contributions) related to the specific, and different, needs and requirements of each Member and Partner, some being more interested in the support to their scientific users, other in the possible (proprietary) technology transfer and industry involvement through procurement and/or access. It is assumed that ELI-ERIC will develop, with the Pillars strong training activities to support the large expected number of new users both in basic and in applied, and possibly industrial, R&D.

The financial channels will necessarily be both national, mainly from the Members through the Representing Entities (or directly through the Ministries), and international (International organizations, third Countries, and the EU). The availability of nationally managed European Structural Investment Funds (ESIF) in the three Host Countries is a specific asset which has been a strong component in the decision of siting the ELI Pillars. This funding will be subjected to national decisions and will be available mainly through the Institutions owning the Pillars.

The overall funding will, therefore, require to combine ESIF and national funding from the host Countries, directly or through their Representing Entities (in a way similar to the present construction phase), contributions to the pillars through the ERIC by Members and/or national and internationally funded projects (as, e.g. the EU framework programs funding). Equipment and personnel supported or acquired by the local institutions or by the Members may be integrated with equipment and personnel acquired by the

ERIC. Some contributions by the members could be in-kind, either through the transfer of national equipment or by the integration of some of the capabilities of the Partner Facilities operating (in a more Regional frame) in the Member Countries.

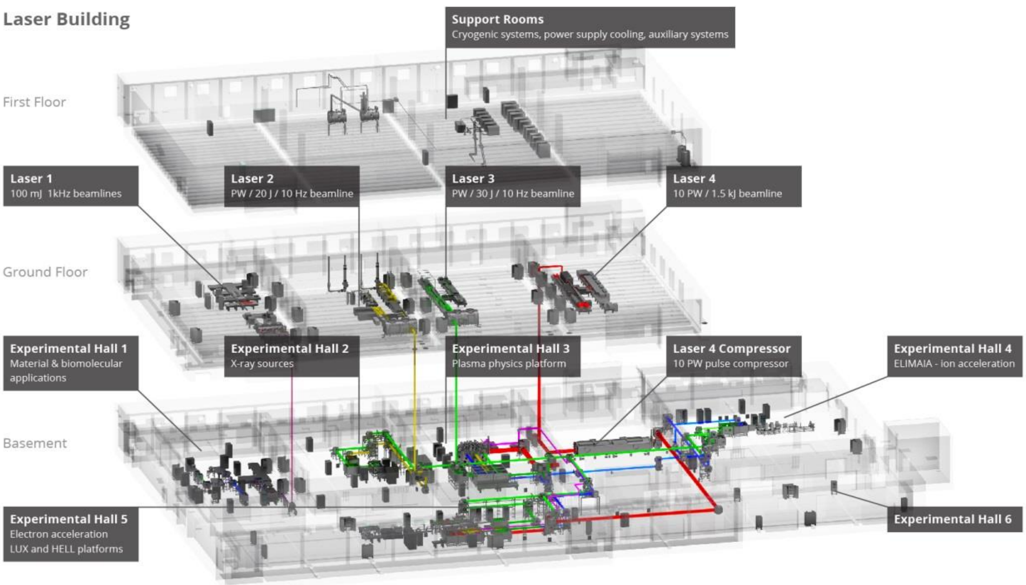
The contributions required from the Members, which will be negotiated individually, may consider a mix of in-cash and in-kind contributions. The total amount of cash will be set at a level ensuring an effective operation capability of the main infrastructures. However, several upgrades and additional scientific instruments could be an in-kind part of the contribution, based on previous agreement and upon approval by the General Assembly supported by an assessment of the ISTAC. The in-kind contributions may be connected to the scientific, technological and design capabilities of the Regional Partner Facilities.

The diversity of funding sources and methodologies requires a well-developed administrative and accounting system capable to trace and give a clear understanding of all values involved, including the values exchanged with the users, to allow the contributing Members to assess correctly their "Returns on Investment". Also this aspect is now in a development phase, making use of the more advanced developments in a number of other ERICs.

The detailed description of the three ELI-ERIC Pillars:

ELI-Beamlines

The laser resources that will be available within ELI-ERIC at the ELI-Beamlines facility are listed in its Technical Design Report document[7]. These laser resources are designed to address specific scientific challenges as identified by the international consortium within the ELI Preparatory Phase[8,9], namely in the fields of particle acceleration by lasers, generation of high-brightness XUV and X-ray pulses, and high-field physics. The ultra-short and ultra-intense pulses of light and the particles generated from interaction with solid state and gas target materials will allow a broad spectrum of projects in fundamental and applied research in chemistry, biology, medical technologies, development of new materials, and others.



The laser systems are designed to provide the following main features:

[7] TDR…………

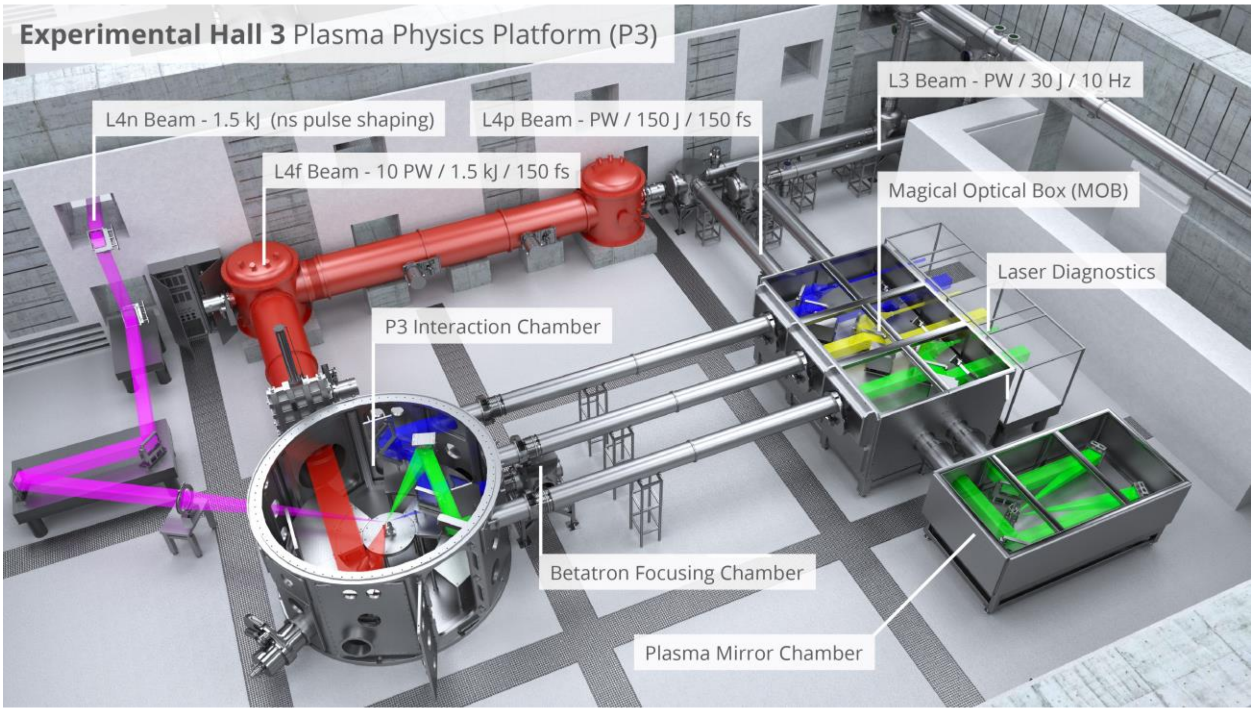
[8] Extreme Light Infrastructure: Report on the Grand Challenges Meeting 2009, edited by G. Korn and P. Antici (2009)

[9] Report on the ELI Science: Scientific Advisory Committee of Extreme Light Infrastructure, edited by T. Tajima (2009)

a) High repetition rate laser pulses delivering multi-10-TW to PW peak power with high user versatility, for projects featuring fundamental applied research;
b) Ultra-high peak power of 10 PW, providing focused intensities above 10^{22} Wcm^{-2} at increased shot rates, for fundamental science research projects.

The lasers sources L1- L4 are located in the ground floor and the beams are brought to the experimental area in the shielded basement via a sophisticated vacuum beam distribution system. The experimental halls E1-E6 host the secondary sources of x-rays and particles (beamlines) and the end-stations as well as the experimental platforms for plasma Physics and ion and electron acceleration. The short pulse x-ray beamlines cover the energy range from soft x-rays (10s of eV) to hard gamma range continuously. The ELI-Beamlines building comprises over 21000 m^2 of experimental area and extra laboratory space. Due to its monolithic structure and its location the vibrational level of the ground floor is in the range of 1-10 nm even for low frequencies below 10 Hz.

As an example the plasma Physics platform P3 design is shown in more detail below.



The Plasma Physics Platform (P3) in hall 3. The MOB combines different laser sources for experiments. The 10 PW beam in its vacuum transport (red) and the ns kJ laser beam are depicted. The diameter of the vacuum chamber is 4.5 m.

The development, research and engineering activities within the ELI-Beamlines project are structured into the following:

Major scientific directions

The ultra-short and ultra-intense pulses of light and the particles generated from interaction with solid state and gas target materials will allow a broad spectrum of projects in fundamental and applied research in chemistry, biology, medical technologies, development of new materials, and others.

1. Lasers generating rep-rate ultrashort pulses and multi-petawatt peak power

The objective of this direction is to deliver the laser system as the principal instrument and the backbone of the designed ELI-Beamlines facility. The main elements of the laser system design follow the principles described in the ELI White Book[10] and are summarized in the Technical Design Report I[11]. Upon commissioning of the laser systems this research direction will evolve by ramping up parameters of the individual beamlines as required and/or will continue development of specific technologies.

2. X-ray sources driven by rep-rate ultrashort laser pulses

The goal is to develop and routinely operate for applications, X-ray sources based on the interaction of ultrashort laser pulses with matter. These include most notably plasma-based X-ray lasers, plasma betatron, advanced K-alpha (in the text also in a more general way mentioned as incoherent plasma) sources, high-order harmonic generation in the keV region, and in the future a compact laser driven FEL which will originate from the laser undulator source LUX. Amongst competitive features of the X-ray sources developed and operated at ELI-Beamlines will be photon energy, very high spectral brightness, ultrashort pulse duration, and inherent synchronization capability of the X-ray pulses with the IR/VIS laser pulses and/or with electron bunches for advanced pump-probe experiments. Applications of the femtosecond X-ray flashes generated at ELI-Beamlines include e.g. X-ray phase-contrast and X-ray and x-ray scattering based imaging of mesoscopic, XUV and X-ray holography of complex cells and proteins, study of the very first steps of biochemical reactions, and many others.

3. Particle acceleration by lasers

The goal of this research program is development of compact laser-accelerated, versatile sources of electrons with energies achieving several 10s of GeV and of protons/ions with energies entering the GeV range. A particular goal is development of repetition rate proton/ion quasi-monochromatic sources with energy typically between 60 and 250 MeV. The research will be focused on improvement of the stability and quality of the generated beams, in terms of luminosity, emittance, and energy profile. These advanced, high-energy particle beams with the concomitant environment (diagnostics, radiation protection, etc.) will allow accomplishing multidisciplinary applications such as development of high-quality and low-cost proton sources namely for medicine (proton therapy), physics and material science (electron and photon diffraction), and for accelerator science. This activity is strongly linked with that described in the previous direction 2 (development of LUX and later FEL consisting of laser-wakefield accelerator as a source of relativistic electrons which are then injected into an undulator), and to the research listed in 5 below (high energy particle beams for applications in dense plasma probing).

4. Applications in molecular, biomedical, and material sciences

The goal is to build and operate user stations designed to enable research into challenging applications in molecular, biomedical, and material (MBM) sciences, using ultra-short XUV/X-ray and particle secondary sources, as well as the primary IR laser pulses. A major feature of ELI-Beamlines will be the fact that it will provide a unique combination of near-perfect spatial overlap and temporal synchronization of various secondary sources and the laser pulses. This will allow realization of advanced pump-probe experiments, mostly inaccessible with current techniques, to study mechanisms of physical and chemical processes at the atomic scale, to probe and control electronic processes in matter, to study complex systems in the natural state, to study living cell at very high resolution, and others. The techniques that will be used involve most notably X-ray coherent imaging , X-ray holography, time-resolved X-ray diffraction and absorption spectroscopy, sub-picosecond pulse radiolysis, probing of diluted systems, as well as X-ray and γ-ray phase and scatter sensitive imaging of materials and bio-medical objects.

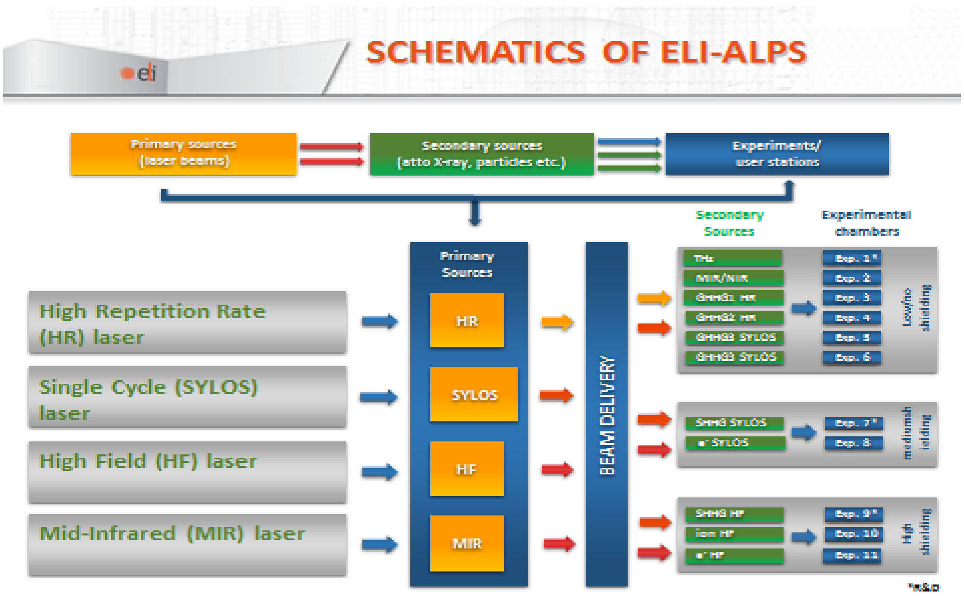
5. Laser plasma and high-energy-density physics

[10] http://www.eli-beams.eu/wp-content/uploads/2011/08/ELI-Book_neues_Logo-edited-web.pdf
[11] TDR

The goal is development of experimental projects in the field of dense plasmas and in high energy density physics (HEDP). The topics may involve nonlinear optics of plasmas and laser interactions with underdense plasmas, relativistic plasmas, laser interaction with solids/clusters/mass-limited targets, generation of warm dense matter (WDM), and physics of advanced fusion schemes, especially of fast ignition. Amongst topics related to the latter theme belong studies of transport of high-current electron beams in dense plasmas for fast ignition, stopping of a proton beam in a pre-formed dense plasma, propagation and collisions in dense plasmas for shock ignition, etc. Active plasma probing techniques will be developed and prepared for fielding in selected experiments. These will notably include 2D/3D time resolved proton radiography, optical and X-ray diagnostics using shadowgraphy, interferometry and Thomson scattering. With the prospect of jitter-free synchronization of pulses delivered by different beamlines, it will be possible to perform various interaction experiments with pre-formed plasmas and sophisticated pump-probe experiments.

6. High-field physics

The principal goal is to explore specific themes of the ultra-relativistic regime of laser-matter and laser vacuum interaction, with focused intensities exceeding 10^{24} Wcm^{-2}, sometimes also called exotic physics. This intensity territory, which is experimentally inaccessible at present, will provide an unprecedented tool for testing fundamental predictions of quantum electrodynamics in external strong electromagnetic (laser) fields, and will involve several fields such as atomic physics, plasma physics, particle physics, nuclear physics, quantum field theory, ultrahigh-pressure physics, astrophysics and cosmology, and possibly others. The "exotic" candidate experiments to be developed within the Research Program 6 include for instance electron-positron plasmas, vacuum four-wave mixing, vacuum polarization and vacuum birefringence, QED cascades. This kind of experiments will require a further increase of intensity to the ultra-relativistic regime above 10^{24}W/cm^2 and will need additional efforts in laser technology and laser plasma interaction which are topics of the 4th pillar. The high-field physics and plasma physics science together with laser technology developments will pave the way to achieve this goal. It is important to mention that using the primary high peak-power laser sources as depicted in the laser table a number of secondary short pulse sources of x-rays, particles and their corresponding user beamlines experimental stations and experimental areas are built within this project. As an example the overview is given for ELI-ALPS. We should note that this same scheme is valid for the other pillars. Users are provided with advanced beamlines within ALPS and ELI-Beamlines and new combined areas of high power lasers with a completely new high brilliance 19 MeV gamma beam source (see below)

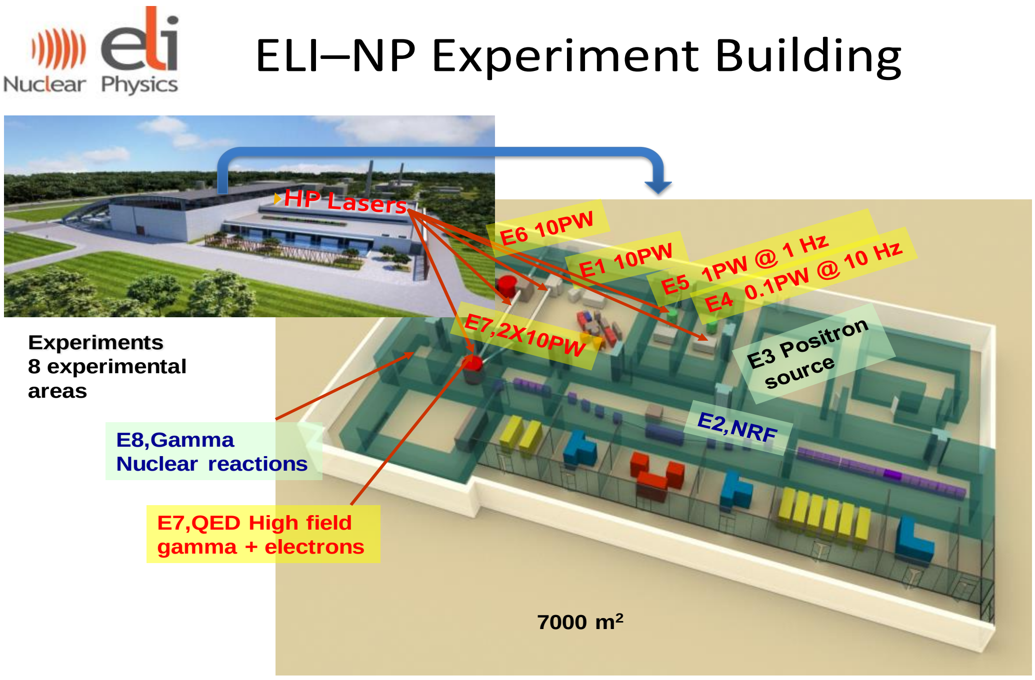


The general scheme shows how all facilities work using the example of ELI-ALPS. The primary short pulse high intensity laser sources are distributed via sophisticated beam delivery systems generate via different mechanisms the secondary sources of x-rays and particles. The secondary sources together with some short pulse pump sources drive the end-stations for different applications typically in a pump-probe mode where samples are excited and probed on extremely short up to Attosecond time-scales to reveal their dynamical behavior.

ELI-NP

The development of high power lasers and the combination of such novel devices with accelerator technology has enlarged the science reach of many research fields, in particular Particle and Nuclear Physics, Astrophysics, as well as societal applications in Material Science, Nuclear Energy and Applications for Medicine. As anticipated above, the Romanian pillar of ELI-ERIC, ELI-Nuclear Physics (ELI-NP), covers scientific research at the frontier of knowledge involving two domains[12]. The first one is laser-driven experiments related to nuclear physics, strong-field quantum electrodynamics and associated vacuum effects. The second is based on a Compton-backscattering high-brilliance and intense low-energy gamma beam (<20 MeV), a combination of laser and accelerator technology which will allow one to investigate nuclear structure and reactions, as well as nuclear astrophysics with unpreceded resolution and accuracy. In addition to fundamental themes, a large number of applications with significant societal impact are being developed. These applications extend from the nuclear power plant waste management to new radio-isotopes for medicine and cancer therapy and from space science to material and nanoscience using for example new powerful probes like a brilliant positron beam.

The main laboratory building covers an area of more than 12000 m^2. Its lay-out is displayed below. The high-power laser system (HPLS) and the gamma beam system (GBS) are placed in the laboratory building, adjacent to the corresponding experimental areas. They will be mounted on an anti-vibration slab, damping vibrations to frequencies ≤ 10 Hz with amplitudes down to ±1 µm.



12 The ELI-NP working groups 2010 The White Book of ELI Nuclear Physics Bucharest-Magurele, Romania. www.eli-np.ro/documents/ELI-NP-WhiteBook.pdf

Eight experimental areas will be available for performing experiments, among which one experimental area will allow combined experiments.

The high-power laser system (HPLS) of ELI-NP consists of a chirped pulse amplification system at about 820 nm central wavelength, with a dual front-end architecture, in order to minimize down-time for the laser facility. Each of the two parallel chains includes Ti: Sapphire amplifiers to bring the final output energy to the few hundreds of Joule level. Subsequently, the pulses are compressed to around a 22 fs pulse duration that implies a peak power of 10 PW at a repetition rate of 1 shot per min for each of the two arms. Along the two amplification chains, additional outputs with corresponding optical compressors will be installed. Their corresponding power levels are 0.1 PW and 1 PW at repetition rates of 10 Hz and 1 Hz, respectively. The intensity in reach is 10^{23} W/cm^2, thus securing a properly defined laser pulse in both space and time for interaction with thin targets.

From the experiments involving HPLS as a source, the main requests for the experimental areas are the following:

- **For Laser-driven Nuclear Physics** experiments will use accelerated heavy ions such as Th. As a consequence, the intended intensities in the focus are of the order of $10^{\mathbf{23}}$ W/cm^2, adaptive optics and short focal distances will be implemented.
- **For Strong-Field QED:** Electron behavior in ultra-intense laser fields will be studied. On one side, the tightly focused beams on solid targets will be used for electron-positron pair creation studies. In this case, the requested specifications are similar to the ones for laser-driven Nuclear Physics experiments.
- **For combined laser-gamma experiments** the synchronization of the laser beam with the laser that drives the Compton backscattering process is a must.
- **For Irradiated materials science experiments** laser pulses combined with various radiation types are requested, involving electrons, gamma, protons, neutrons and positrons. The technologies required for the 0.1 PW and for the 1 PW outputs are polarization elipticity control, plasma mirror for temporal contrast enhancement, and adaptive optics.

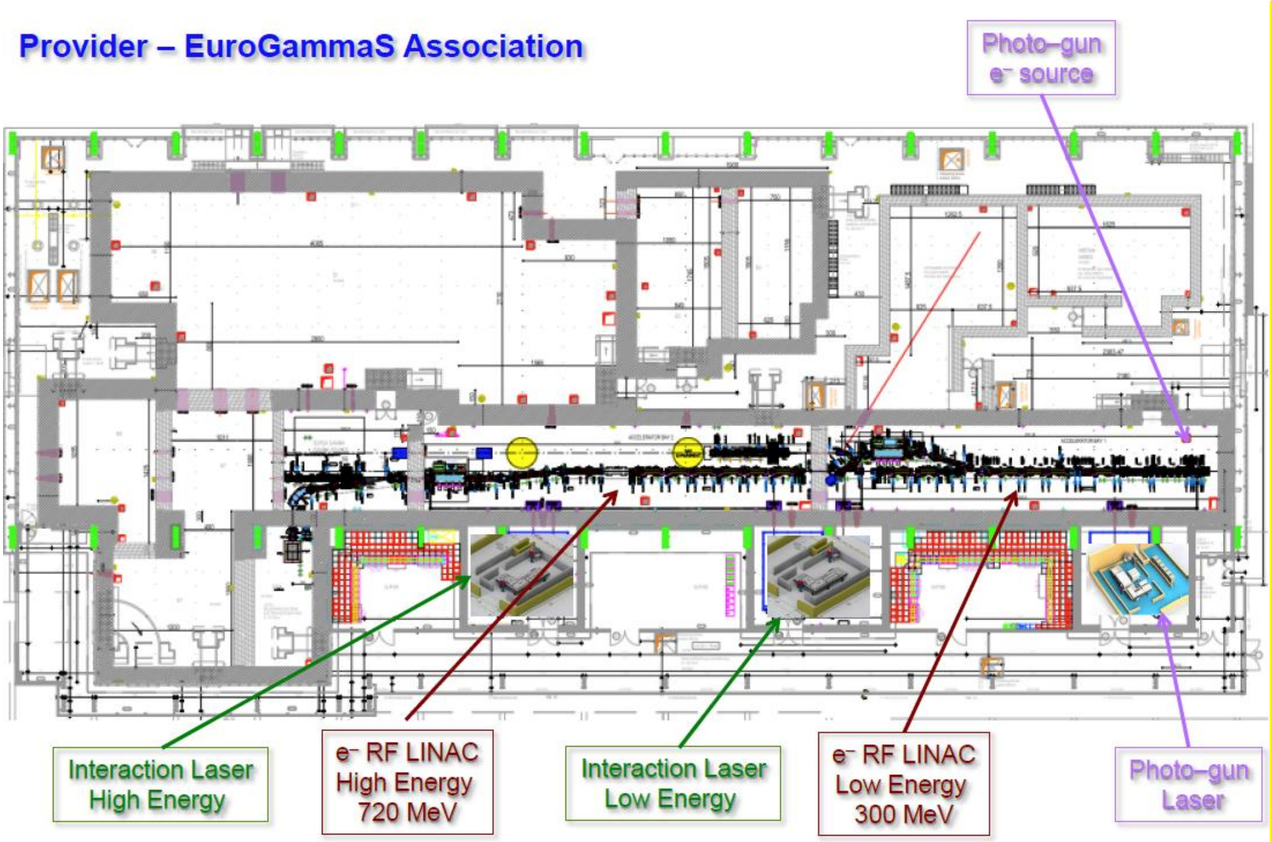
The production of the two arms 10 PW HPLS system is well on its way and on Nov 2015 a complete 1PW HPLS was operated successfully at the supplier premises as part of the contractual conditions of the final delivery.

The high brilliance Gamma Beam System at ELI-NP is based on the Inverse Compton Scattering of laser light on relativistic electron bunches (up to 720 MeV) provided by a warm radio-frequency linear accelerator.

The system will deliver quasi-monochromatic gamma ray beams (bandwidth 0.5%) with a high spectral density (10,000 photons/s/eV) and high degree of linear polarization (99%).

The ELI-NP –gamma beam experimental program will allow one to explore new territories in the field of Nuclear Resonance Fluorescence (NRF) and experiments above the particle separation threshold, such as studies of giant resonances and their role in the determination of equation of state, nuclear astrophysics reactions, and photo-fission experiments.

During the last three years, a significant fraction of the international scientific community contributed to the shaping of the ELI-NP facility science program through a series of international workshops. As a result, these scientific meetings lead to the definition of about ten new development directions for the experiments to be carried out at the future facility. For each of them, writing of Technical Design Reports (TDRs) by specialized working groups of international scientists and coordinated by ELI-NP physics team, was triggered and further developed during the workshops. These TDRs have been published in a dedicated review paper[13].



ELI-ALPS

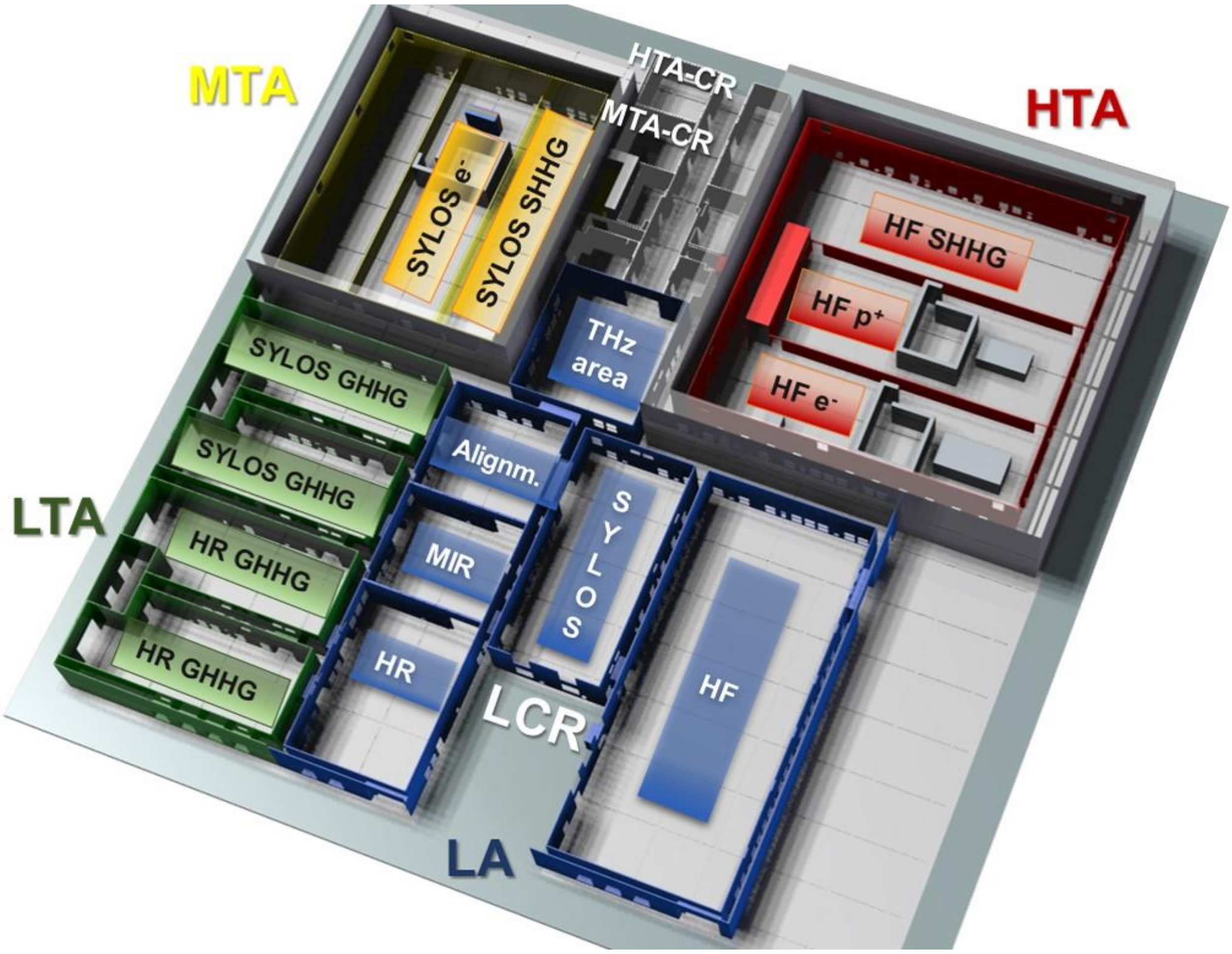
The frontiers of modern photonics are mainly defined by the characteristics of available photon sources. Synchrotrons and X-ray free-electron lasers offer angstrom wavelengths combined with high flux and brilliance, providing unique opportunities to explore the structure of matter with sub-atomic resolution all the way from crystalline solids, through nanoparticles to individual molecules. Laser-driven high-order harmonic sources, on the other hand, deliver flashes of extreme ultraviolet and soft-x-ray light with durations below hundred attoseconds, allowing direct time-domain insight into both structural and electronic motions. ELI–ALPS will combine these cutting-edge characteristics of modern photon sources: the short-wavelength and high flux of third-generation synchrotron sources with the incomparable pulse duration of laser-driven harmonic sources. Thanks to this combination of parameters never achieved before, ALPS' energetic attosecond X-ray pulses will have the dream of atomic, molecular and condensed-matter scientists come true: recording freeze-frame images of the dynamical electronic-structural behavior of complex systems, with attosecond-angstrom resolution. Furthermore, ALPS attosecond XUV/X-ray pulses will come in synchronism with the controlled few-cycle to sub-cycle fields of intense laser light all the way from terahertz (far infrared) to petahertz (ultraviolet) frequencies. These ultrashort-pulsed, ultrastrong fields – locked to attosecond probes – open the prospect for unprecedented control of microscopic processes and provide a real-time look into an unsurpassed range of non-equilibrium states of matter.

The construction of the building complex of ELI-ALPS will be completed by the end of 2016. The building complex is located in the area of the Science and Technology Park of Szeged and it consists of halls of the laser and secondary sources technology and experimental areas; scientific-technical rooms (labs, preparation workshops, offices of the researchers, and the machinery rooms serving building „A"); offices

[13] ELI-NP Technical Design Reports, Romanian Reports in Physics, Vol. 68, Supplement, P. S1, 2016

and research functions of the science center (reception, conference hall, library, seminar rooms, management offices, cafeteria);multifunctional building for storage, servicing and maintenance of the complex; and Entrance building.

This Pillar will operate four main laser sources driving six Gas target High Harmonic Generation (GHHG) secondary sources, two Surface target High Harmonic Generation (SHHG) secondary sources, two electron acceleration and one ion acceleration secondary source as schematically shown below.



The primary and secondary beams are subsequently delivered to the experimental end stations. Experiments and secondary sources are located in three main areas of building A having different degree of radiation shielding (low/no, medium and high).

The SYLOS, HF and Mid IR laser systems are developed by companies. The HF system and all the secondary sources as well as end stations are developed in the framework of R&D projects with expert research/academic institutions and companies from a variety of countries. At the same time part of the research personnel of ELI-ALPS receives training through collaborative research in these institutions and several others in the framework of collaboration MoUs that ELI-ALPS has signed with numerous academic and research institutions around the world.

The Scientific Case of ELI-ALPS includes distinct but complementary research areas addressing fundamental and applied research each of them representing completely novel research directions on their own. Two research activities encompass a broad range of research topics relevant to the development of primary and secondary photon and particle sources. Equipped with the described primary and secondary sources, ELI-ALPS will be able to tackle grand challenges in atomic, molecular and optical (AMO) physics by providing atto-second-duration excitation (pump) and probe pulses with unmatched fluxes. The high repetition rate of the sources together with the sophisticated end-stations provide a unique environment for dynamical and structural studies in surface and condensed matter science, including collective excitation dynamics in solids and strongly correlated systems. The route towards and the project objectives in atto-second 4D imaging is at the core of ELI-ALPS's Science and Technology planning. In addition, the parallel existence of atto-second pulses and PW-class lasers within the same facility offer the time-resolved investigation possibility of ultra-relativistic light-matter interaction processes. New research paradigms are also offered by the Mid IR pulses (primary source) and THz fields (as unique secondary sources) sources of the facility. These additional activities complete the facility profile with synergic relationship to the main atto-science research lines.