ELI-NP AN EUROPEAN FACILITY AT THE FRONTIER BETWEEN PW LASERS AND NUCLEAR PHYSICS

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This paper intends to give a short overview of the ELI-NP facility in the context of the ELI Project and to provide to date information about its status. More detailed information can be found on the sites: www.extreme-light-infrastructure for the ELI Project in general and www.eli-np.ro for ELI-NP.

ELI is the acronym of Extreme Light Infrastructure. The idea of such a facility appeared about a decade ago as a result of spectacular technical and theoretical developments in the field of laser physics. Soon the idea took more concrete shapes and materialized itself into a true European project, ELI-Preparatory Phase. The detailed Scientific Case has been elaborated in which the research strategy and the accompanied necessary technical developments were laid out. Almost from the very beginning it was acknowledged that in view of the really vast field of research activities to cover, the foreseen facility must be split in a number of smaller facilities with specific tasks, under a common administrative umbrella. These facilities got the name of *pillars* and four have been designated. ELI will be a multididciplinary European and International Centre for high-level research on ultra-high intensity laser, laser-matter interaction and secondary sources and benefits of the collaboration of 13 European countries.

A first pillar, **High Energy Beam Science** will be devoted to the development and usage of dedicated beam lines with ultra short pulses of high energy radiation and particles reaching almost the speed of light. This ELI Beam Lines pillar will be built near Prague (Czech Republic).

A second pillar, **Attosecond Light Pulse Source** is designed to conduct temporal investigation of electron dynamics in atoms, molecules, plasmas and solids at attosecond scale (10^{-18} sec.). This ELI-ALPS pillar will be built at Szeged (Hungary).

The third pillar, ELI-NP is dedicated to **Laser-based Nuclear Physics**. While atomic processes are well suited to the visible or near visible laser radiation, as a third pillar, ELI-NP will generate radiation and particle beams with much higher energies and brilliances suited to studies of nuclear and fundamental processes. It will be built at Magurele near Bucharest (Romania) with IFIN-HH and INFLR, two research institutes located on the same platform.

The forth pillar and the most challenging from the point of view of physics program and technological solutions for its accomplishment is ELI-UHFS or **Ultra High Field Science** that will explore relativistic laser-matter interaction in an energy range where totally new phenomena when radiation dominated interaction becomes dominant. The decision on the location of the technologically most challenging pillar will be taken in 2013 or later after validation of the technology.

A **Delivery Consortium** has been established and positions have been opened for specialzed personel. The three host countries, Czech Republic, Hungary and Romania signed a **Memorandum of Understanding** concerning the construction of the three mentioned pillars.

The ELI-NP project will have **to basic inter-correlated installations**:

- A very high intensity laser, where two 10 PW Apollon type lasers are coherently added to rich an intensity of 10^{23}-10^{24}W/cm^2 or electrical fields of 10^{15}V/m.

- A very intense ($10^{13}\gamma$/s), brilliant γ beam, 0.1 % bandwidth, with E_γ = 19 MeV, which is obtained by incoherent Compton back scattering of a laser light off a very brilliant, intense, classical electron beam (E_e = 600 MeV). The brilliant bunched electron beam will be produced by a warm linac using the X-band technology.

The project realization will follow **two important principles**: a staged realization of ELI-NP (a sequential improvement both in laser system and gamma source) and a flexible design of the ELI-NP facility to allow for further extentions and developments. It should be said that ELI-NP field of research is *complementary* to the ones of new European facilities like FAIR, SPIRAL2, etc. Synergies are expected and finding and exploiting them is one of the aims of CRISP FP7 project.

The project has already important achievements like the establishment of an **International Scientific Advisory Board** composed of prominent physicists from many research centers all over the world.

A **White Book** has been elaborated (see on www.eli-np.ro) that describe both the possible technical solutions giving reference figures for various parameters and the large number of proposed experiments. Besides, many workshops gathering top specialists in their field took place helping defining the possible technical solutions for the laser system and gamma beam but also the necessary for the main type of experiments that will be conducted at both facilities.

In the following, the technical solutions of the White book and also some representative physics cases will be presented. The choice of the cases is personal and for a complete description the reader is directed to the ELI-NP web site where the White Book is available.

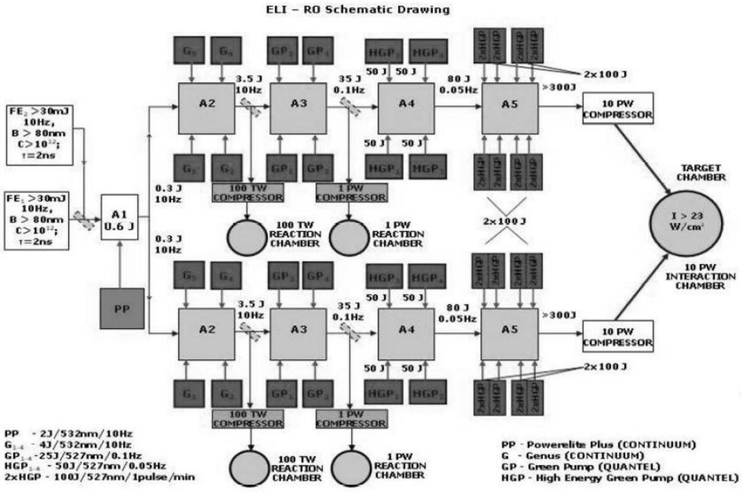
For the **laser system**, the *required specifications* are:

- Peak pulse power: 10 PW per one amplifier chain
- Pulse-width of the re-compressed amplified pulse: 30 fs
- Rep-rate: 1/10 - 1/60 Hz
- Contrast: $>10^{12}$
- Focused laser intensity: 10^{23} W/cm^2 (laser beam focused near the diffraction limit)

The The ELI-NP laser facility will use OPCPA technology at the front-end and Ti:Sapphire high-energy amplification stages, similar to the ones developed at the APOLLON laser system. The technological task is impressive: the Ti:Sapphire crystals will have a diameter close to 30cm!

The laser system conceptual design is depicted in the figure below.

For the **Gamma Beam**, the solution is to use Compton backscattering of a 532nm laser beam onto the electron beam provided by a Warm linac in X-band (11.424GHz) RF , similar to LLNL project. This approach is based on the interaction of short laser pulses with relativistic electrons (600MeV) generated by the warm linac to create ultra bright Mono-Energetic Gamma-ray (MEGa-ray) beams. The scattered radiation is Doppler upshifted by more than 1,000,000 times and is forwardly-directed in a narrow, polarized, tunable, laser-like beam. A table with the main specification for the Gamma Beam of the ELI-NP is given in the following figure.



GAMMA BEAM

The main specifications of the ELI-NP machine

Quantity	Value	Units
Peak gamma brilliance	1.5×10^{21}	Photons/sec/mm^2/mrad^2/0.1% BW
Effective Beam repetition	12,000	Hz (100 micro-bunches at 120 Hz rep rate)
Gammas per pulse	8×10^{8}	Photons
Spectral beam flux	10^{6}	Photons/sec/eV
Gamma pulse duration	2	Picoseconds
Gamma collimation	1	mrad
Gamma bandwidth	10^{-3}	Δ E/E
Gamma source size	10	Microns
Electron beam energy	600	MeV
Laser pulse energy	1.5	Joules
Gamma-ray energy	0.5–13.2 (with 532nm laser interaction) or 19.5 (with 355 nm laser interaction)	MeV

The *main directions* of the **Scientific case** of the White Book can be defined as:

- Specific phenomena at very high laser intensities (typically nonperturbative QED effects: Schwinger pair creation, vacuum birefringence)
- Laser as a tool for obtaining accelerated beams of particles, nuclear tools used to characterize the laser induced radiation
- physics around the gamma beam
- applications of lasers and gamma beams

For the **second point**, I would like to mention some key phenomena recently discovered/discussed that will be the object of detailed study at ELI-NP and with a high potential for applications:

- radiation pressure acceleration (RPA) induced by circularly polarized laser beams, a step towards particle beams with solid state density
- decrease of stopping power of solids for very dense beams (10^{-2})
- increased stopping of plasmas for intense laser driven beams (collective wakefield effect, increase by a factor 10^{6})
- possibility to obtain compact electron and ion bunches (laser piston) and their use as relativistic mirrors to produce coherent gamma beam

In what concerns **the physics with the Gamma Beam**, from the wealth of proposals I would mention few representative directions:

- Detailed studies of Giant Dipole Resonances (GDR), Pigmy Dipole Resonances and M1 scissors modes excited by the high resolution gamma beam (fine structure studies for the dissolving of these collective modes into surrounding levels also possible due to high resolution)
- Measurements of level densities and level widths in a wide range of energies and at high excitation
- Measurements of (γ,n), (γ,p), (γ,α) cross section of interest for astrophysics
- Check for non exponential decay of short lived states near and above the particle threshold predicted by the Random Matrix Theory

Some possible applications for which experiments have been proposed are:

- Nuclear Fluorescence Resonance studies for *detailed component determination* (90º detection or transmission)
- *Medical isotope production* via (γ,n) reaction (e.g. ^{195m}Pt, ^{117m}Sn,^{100}Mo) (exploratory studies for providing a possible emerging industrial solution)
- Prospecting production of brilliant sources of controlled (low) energy neutrons
- Production of brilliant sources of positrons

Finlay, I would like to present the to date status of the ELI-NP project.
It was decided to spit ELI-NP in two Phases:

Phase 1 : from Autumn 2012 => end 2015
~180 Meuro from 2007-2013 Programming Period

Phase 2 : from 2014 => 2017

~120 Meuro from 2014-2020 Programming Period

The full project is approved at National level (Romanian Government) end 2011 and the contract with the National Agency for Research is expected to be signed end 2012.

Phase 1 of the Project has been submitted to EC in February 2012 and the positive decision was received on September 2012.

Construction Permit is already obtained and the tendering for construction is due by end of 2012

Ground breaking expected in spring 2013.

Tendering for laser system and gamma source will be launched by end 2012. A call for Letters of Intent was launched aiming to:

- enlarge and prioritise the Physics Cases List
- nucleate collaborations for experimental equipment development
- define and organize the experimental halls structure according to the requirements of ELI-NP community.

As an interesting detail of the building construction, the whole heating will be ensured by heat pumps embedded in the ground, an ecological solution that will be the largest of this type in Europe.

The Technical Design for ELI-NP Buildings has been completed in December 2011and is illustrated in the figure below.

I thank the organizers for inviting me to present the status of this new European facility and to Prof. N.V. Zamfir, Director of the Project for providing me with most recent and relevant data about the project.