EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2014-2020

eli nuclear physics

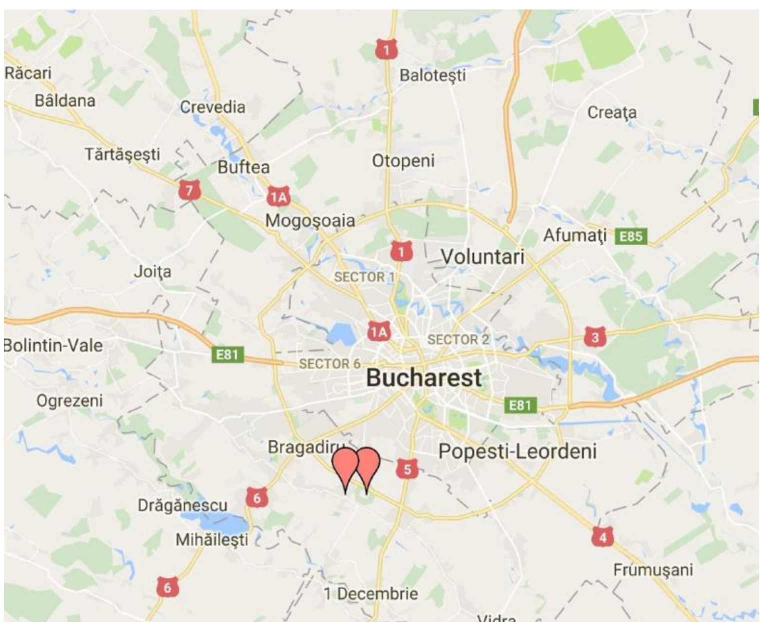
ELI-NP
Status and Perspectives

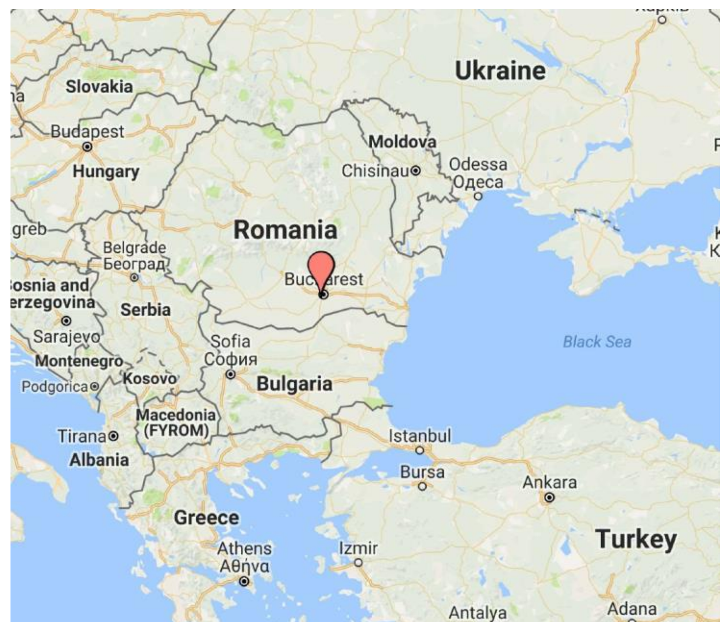
ELI Consultation of UK User Community
London, 11 June 2018

Kazuo A. Tanaka, ELI-NP, Scientific Director

ELI-NP Located at the South of Bucharest.

We are located in Bucharest.





Summary

- ELI-NP is under active implementation.
- PW laser beam will be available in 4th quarter in 2018.
  10 PW laser beam will be available in 1st quarter in 2020.
  Gamma beams will be available in 4th quarter in 2018.
- 3PW performance was confirmed in May 2018.

- Laser gamma conversion, non linear QED, plasma physics, dark matter physics, and bio and medical applications
- Nuclear resonance fluorescence, Giant/Pigmy resonances, photo disintegration, photo fission and medical applications

  will be planned with Expert User Collaboration.

- Further experimental research program will be called for via. ELI-ERIC and user workshops.

Two major systems are planned for ELI-NP User Facility

Laser System with Highest Focused Intensity

The wavelength, pulse width, energy, and beam diameter are 820 nm, 25 fsec, 250 J, and 50 cm.
Focused laser intensity may reach 10^{23} W/cm^2.
The laser light will accelerate electrons up to the speed of light.

Gamma Beam System with Highest Photon Number

The Gamma Beam photon energy is 19.5 MeV with 2 psec pulse width.
The number of photons may reach 10^9 photons/sec.
The gamma light will interact directly with nuclei for excitation and fission.

Laser system can be operated as stand alone or combined with Gamma beam system.

- Experiments under extreme conditions, so far not possible, can be conducted.

For example, we will perform

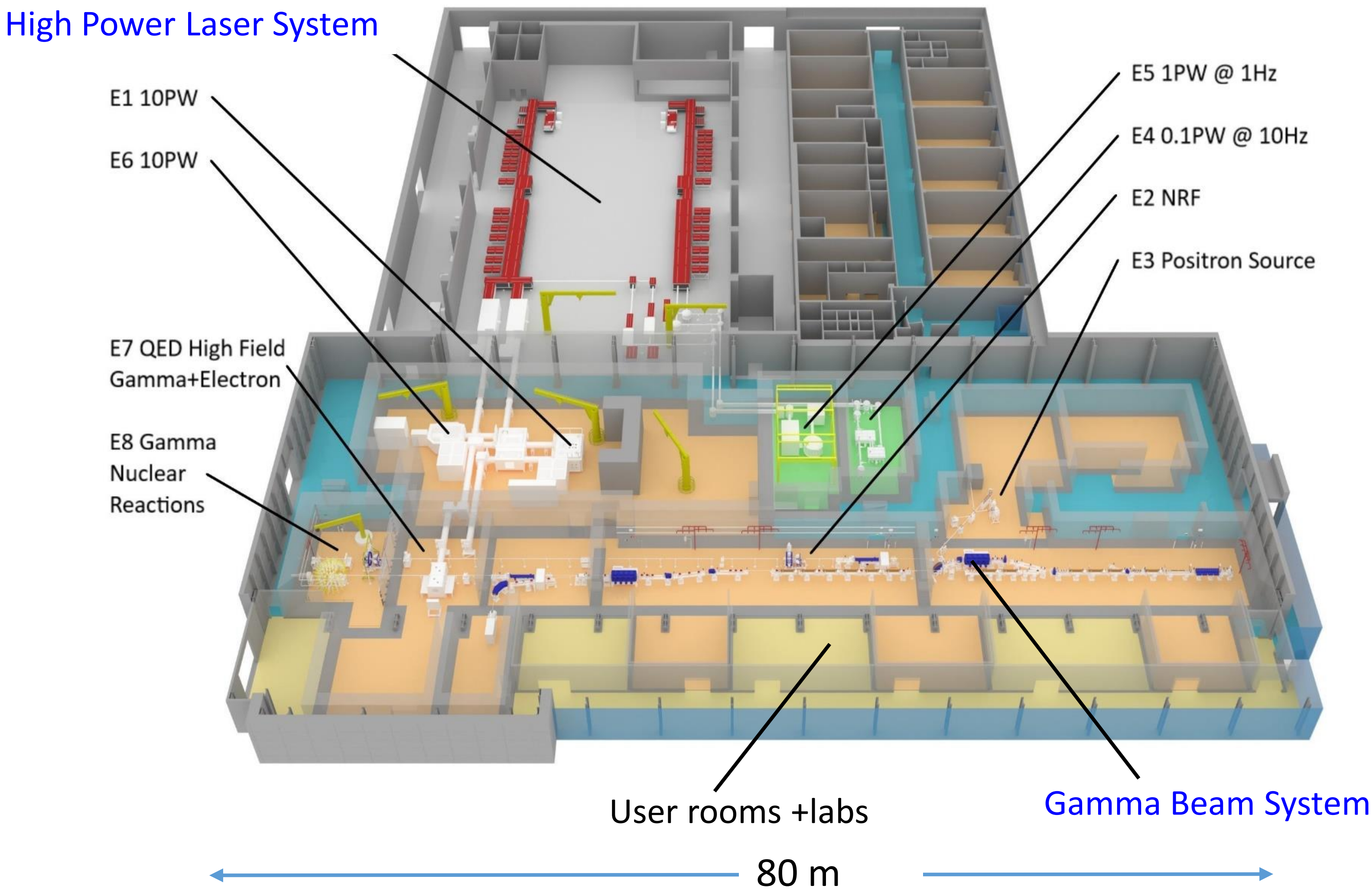
- Electron acceleration more than 10 GeV
- Nuclear fission and fusion
- Head-on collision of the laser and relativistic electron beam

Then these experiments will clarify

- History of the Universe
- Important Issues on nonlinear QED
- Isotope production for medical use

These achievements may lead to the Nobel prize and/or realistic societal impact.

HPLS, GBS, and Experimental Areas E1-E8



Special building and all infrastructures fully operational

Team Structure

General Director of IFIN/HH & Project Director

Prof Dr Nicolai Victor Zamfir

Scientific Director

Prof Dr Kazuo A Tanaka (US-Japan)

Technical Director

Dr Dan Gabriel Ghita (Rom)

Quality Assurance Director

Dr Ionel Andrei (Rom)

Departmen of Laser System	Dr Ioan Dancus(Rom)
Department Gamma Beam System	Dr Calin Ur (Italy Rom)
Department Laser Plasma Nuclear Physics	Dr Dan Stutman (US Rom)
Department Gamma Beam nuclear Physics	Dr Dimiter Balabanski (Bulgaria)
Department Combined Laser and Gamma Beam Grp.	Dr Ovidiu Tesileanu (Italy Rom)

Currently 130 members (20 Senior Sci., 60 Junior Sci. Rest Eng.)

Will boost up to 250 members.

High intensity laser system has started from these two brilliant scientisits.

When they were at Laboratory for Laser Energetics, Univ. of Rochester in early 80’s.

Gerard Mourou

IZEST France

Dana Strickland

University of Waterloo in Ontario, Canada

Laser System Installation on Time.

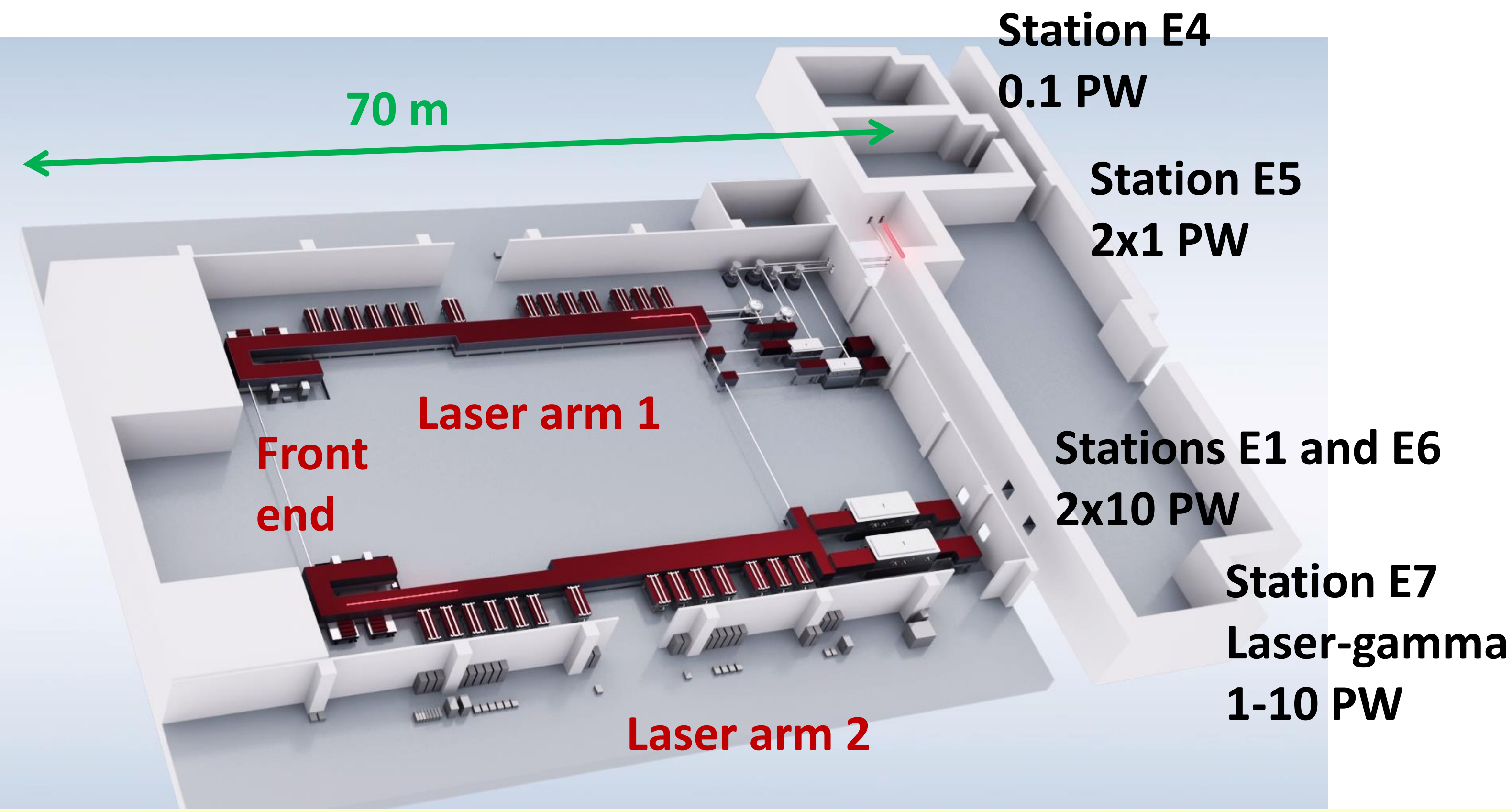
Installation in progress.

Thales Laser France and Romania

High Power Laser System

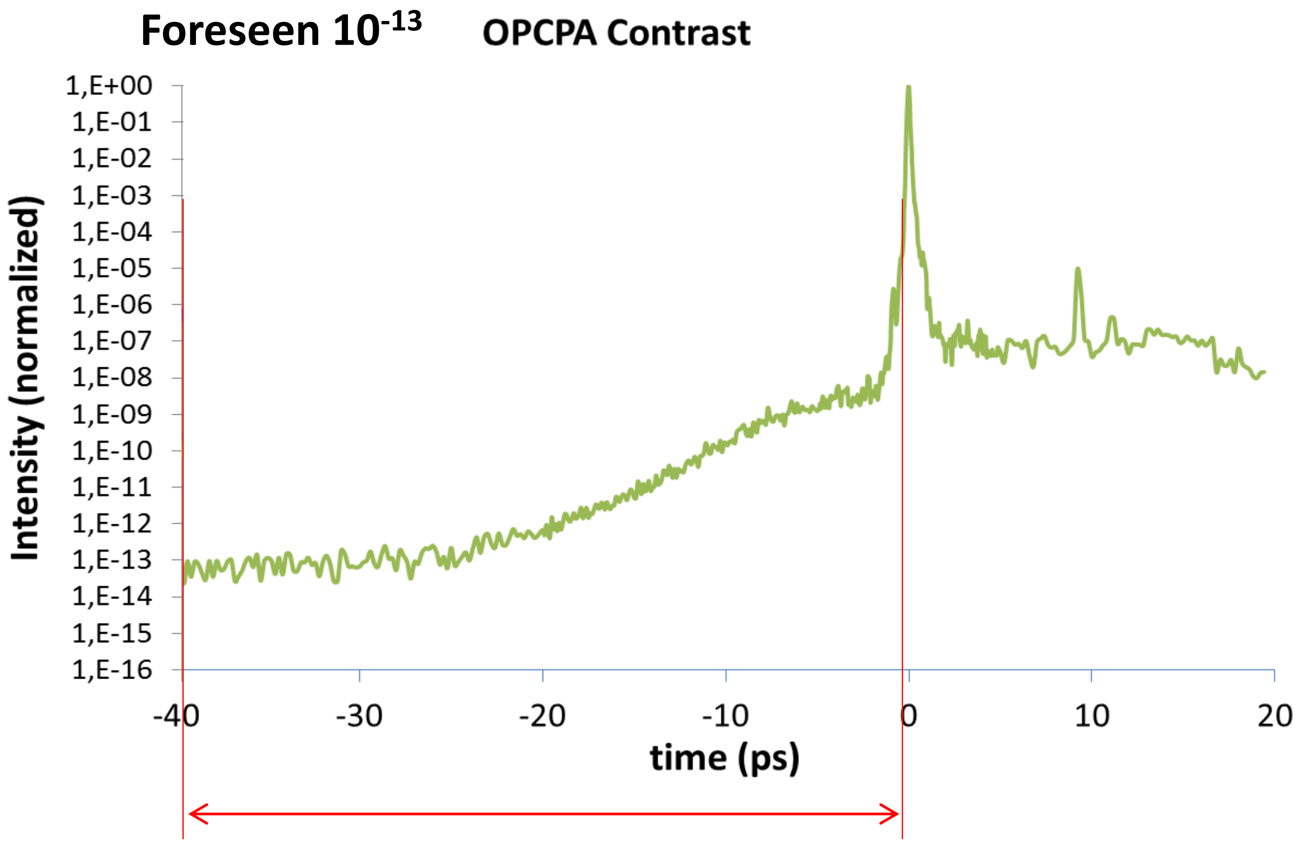
	min	max	unit
Energy/pulse	150	225	J
Central wavelength	814	825	nm
Spectral bandwidth (FWHM)	55	65	nm
Spectral bandwidth (at nearly zero level of intensity)	120	130	nm
Pulse duration (FWHM)	15	22.5	fs
FWHM beam diameter/Full aperture beam diameter	450/550		mm
Repetition rate	1		pulse /min
Strehl ratio	0.8	0.95	
Pointing stability	2	5	µrad
Beam height to the floor	1500	1510	mm

10 PW Laser System Layout



- **High performance parameters :** 250 J in 25fs, 0.9 Strehl ratio, $<10^{-13}$ contrast
- **Outputs:** 2x 10 PW/min
  2x 1 PW/1 Hz
  2 x 0.1 PW/10 Hz

We expect to have 10^{13} contrast ratio.



$E_{-40ps:-0.4ps} = 30mJ$

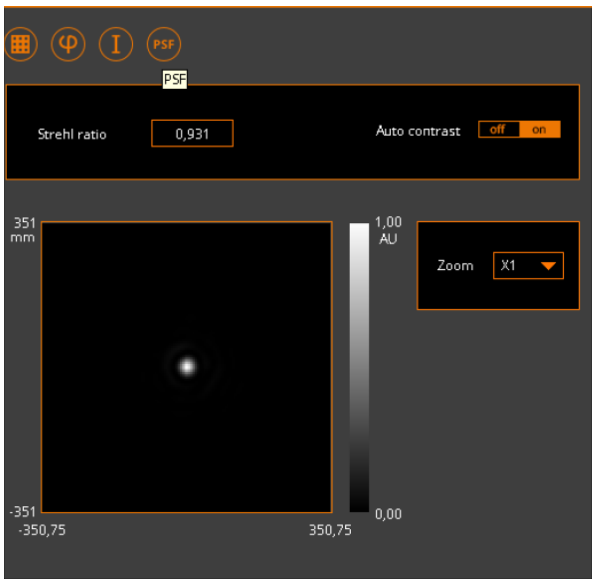
We have confirmed 3PW performance.

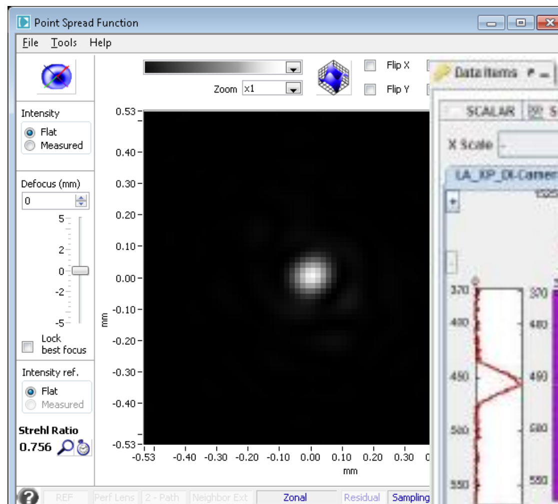
100 TW

- Output energy ~ 2.13 J
- Pulse duration 21.1fs
- Strehl ratio 0.9

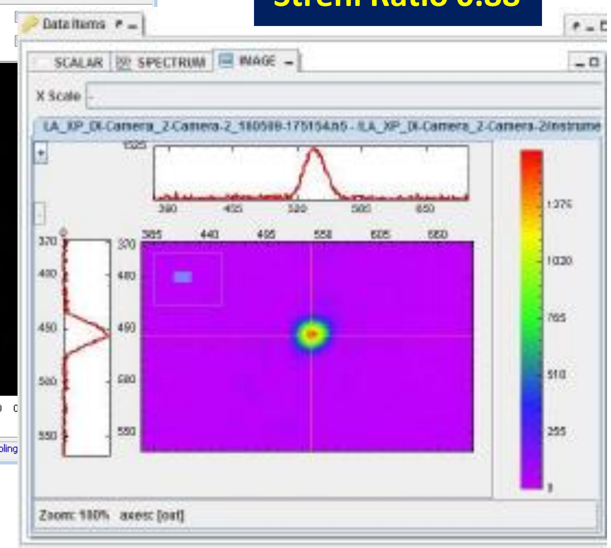
3 PW

- Injected energy (attenuated before compressor) ~ 92.3 J
- Compressor efficiency 74%
- Pulse duration 22.7 fs
- Strehl ratio 0.72



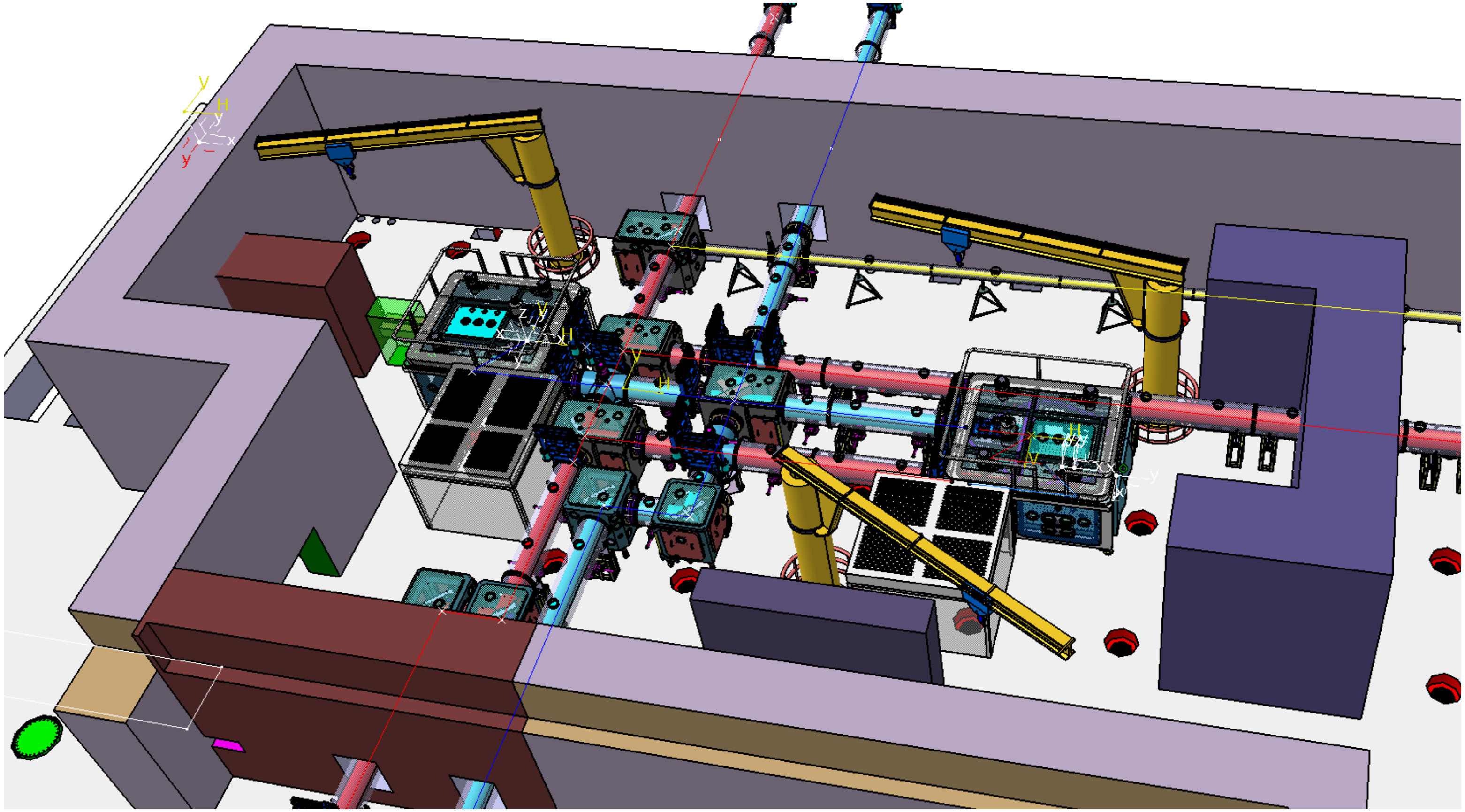


After tuning, Strehl Ratio 0.88



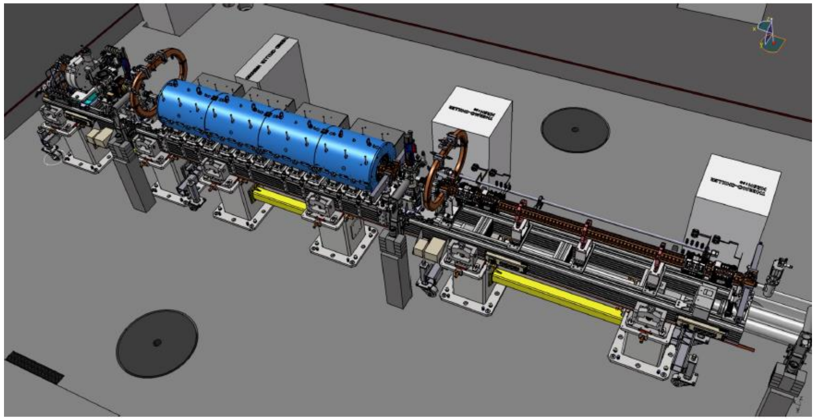
2x10 PW Laser Beam Transport System

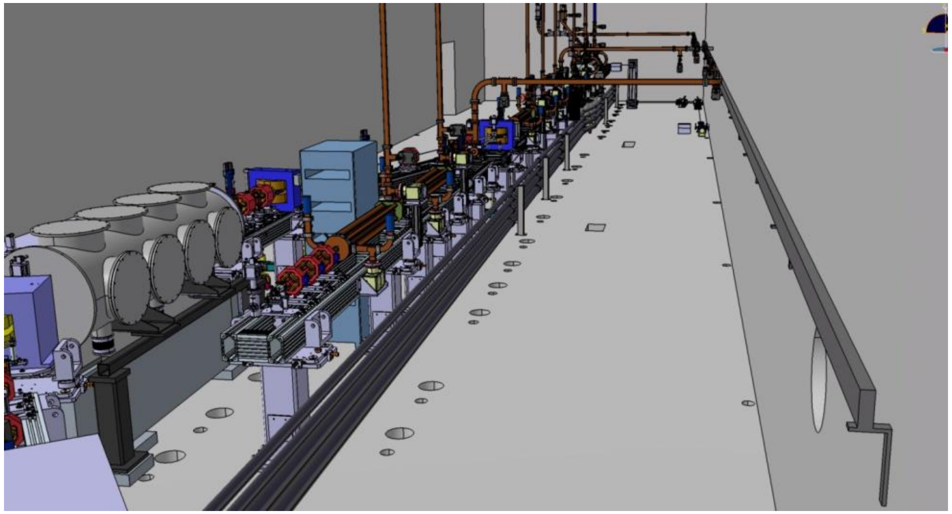
- 2x10 PW beams + 1 PW auxiliary beam to any of 3 experimental areas
- f=30 m focal length mirror for electron LWFA at 10 PW
- Under construction by Thales led consortium



Gamma Beam System

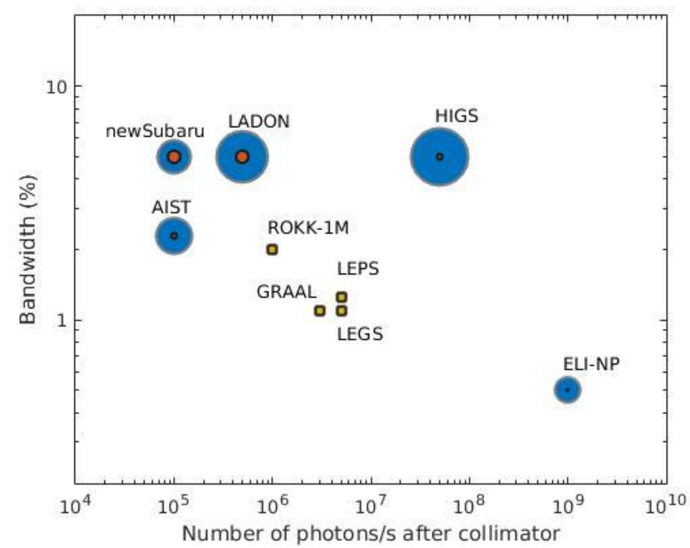
RF Photoinjector

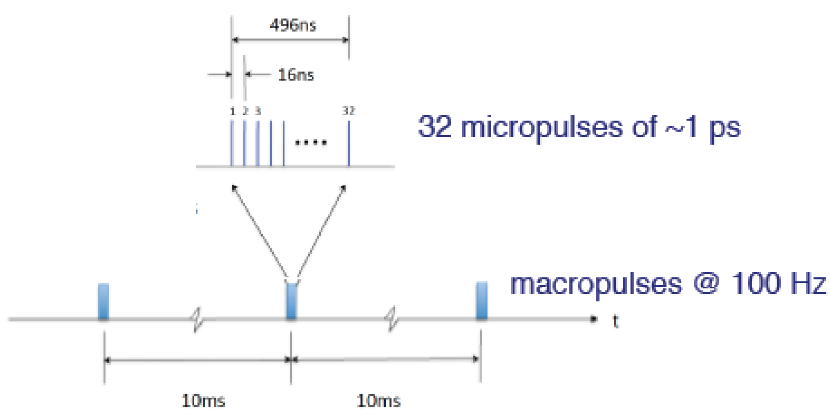




GBS Specification

Parameter [units]	Value
Photon energy [MeV]	0.2 – 19.5
Spectral density [ph/s/eV]	> 0.5 x 10^4
Bandwidth	< 0.5 %
# photons / shot FWHM bdw.	1.0 – 4.0·10^5
# photons/sec FWHM bdw.	2.0 – 8.0·10^8
Source rms size [µm]	10 – 30
Source rms divergence [µrad]	25 – 250
Peak brill. [N_{ph}/sec·mm^{2}mrad^2·0.1%]	10^{22}– 10^{24}
Radiation pulse length [ps]	0.7 – 1.5
Linear polarization	> 95 %
Macro repetition rate [Hz]	100
# of pulses per macropulse	>31
Pulse–to–pulse separation [ns]	16





Commissioning Phase in 2019.

- We will focus on the characterization of each machines: 10PW laser and 19 MeV Gamma beam systems.

10 PW Laser System

- Laser intensity: 10^{22} W/cm^2
- Electron acceleration > GeV
- Proton acceleration > 200 MeV

Gamma Beam System

- Gamma photon energy calibration-Nuclear excitation 3.5 or 19.5 MeV
- Polarization > 95%

Day 1 Experiments with 10 PW

- Radiation Reaction: Classical to QED
- Photo Nuclear Reaction
- Ion Stopping & Excitation in Plasmas
- Fission Fusion Mechanism: r process ^{232}Th
- Dark Matter Physics
- Vacuum Birefringence
- Photo-excitation of isomers

Etc.

Romanian Report in Physics 68 Supplement 2016

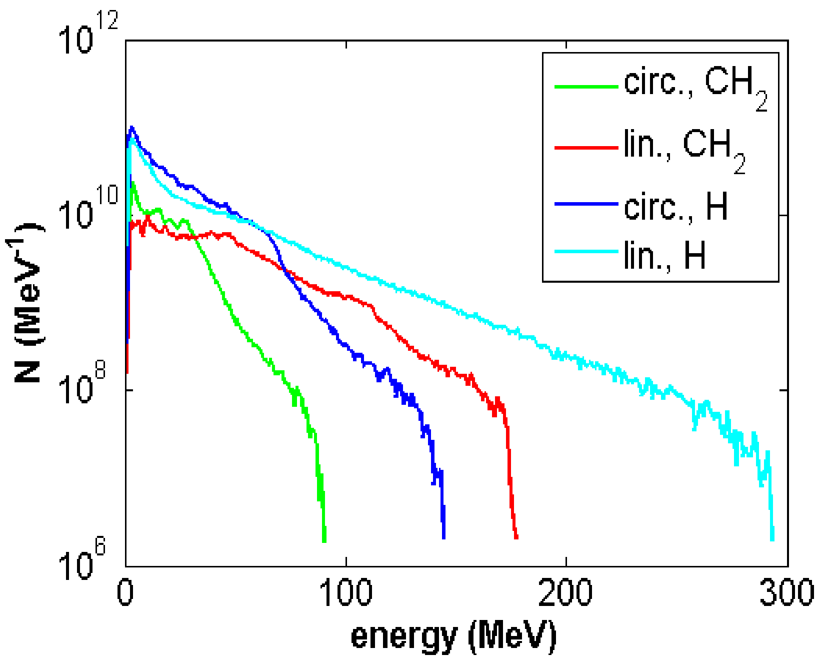
Toward New Horizons

Fission-fusion	**Astrophysics**
Dark matter	**Astrophysics**
Radiation effect	**Biology**
Nuclear Resonance	**Nuclear Physics**
Gamma Imaging	**Nuclear Security**
Material Science	**Fusion Reactor Eng.**
Medical Isotopes	**Cancer Therapy**

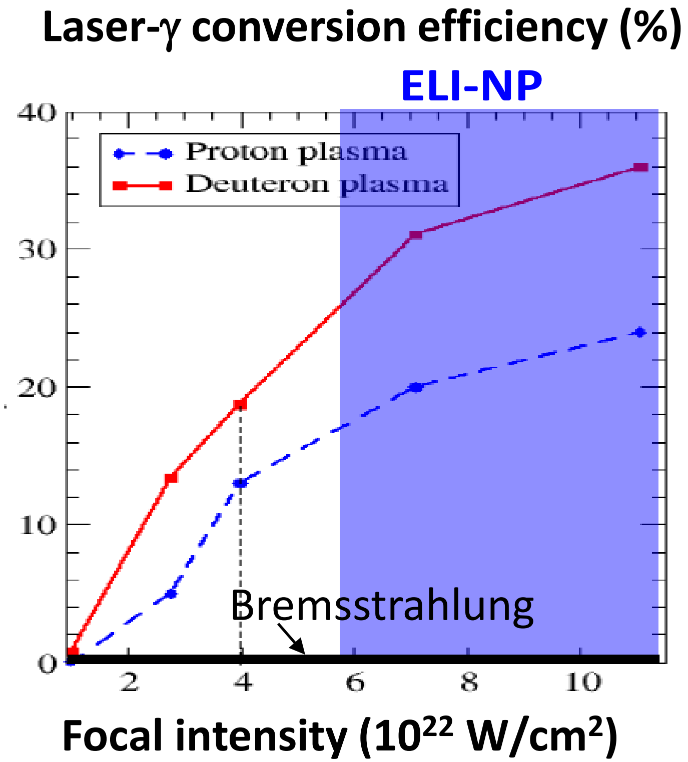
Proton >200 MeV is possible.

Predicted proton energy for LP and CP I=10^{22} W/cm2, 0.2 µm CH_2 target

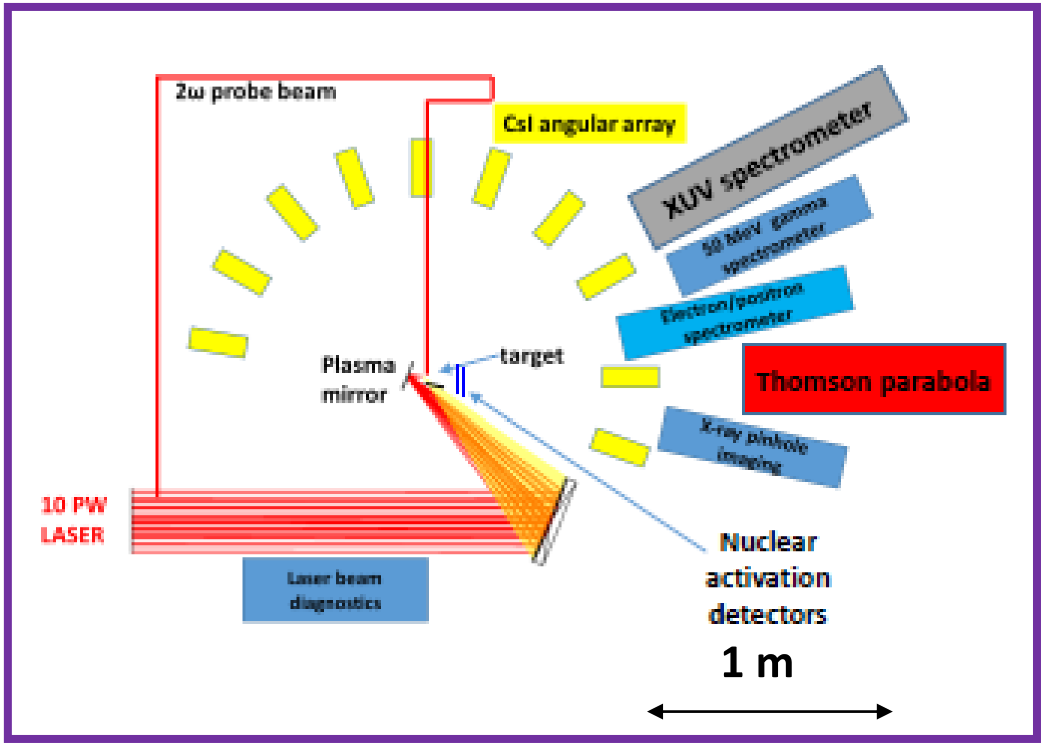
(Psikal et al J Phys Conf 2016)



Commissioning experiment: Demonstration of extreme laser intensity through efficient laser-γ conversion

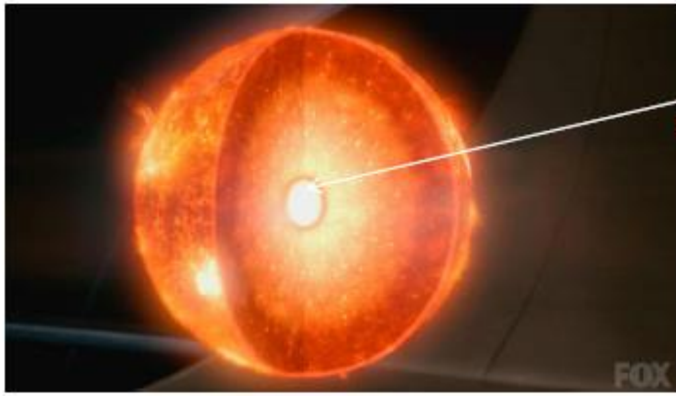


Capdessus et al RRP 2016



- ❑ Tens of % gamma conversion efficiency in μm-thick plastic or dense gas targets
- ❑ GeV dense ion bunch acceleration using same setup with thinner targets
- ❑ Plasma mirror + baffle for protection against laser back-reflection, debris
- ❑ We consider also membrane protection for the parabola

Path to Extreme pressures by irradiation of aligned nanowire arrays



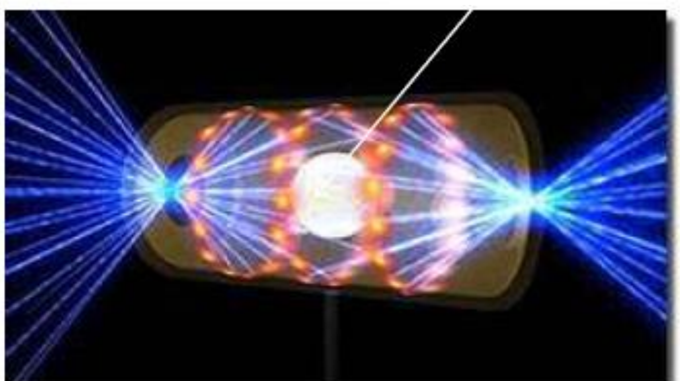
Sun Core
240 Gbar

Nanowire array plasma

$I = 1 \times 10^{22}$ W cm^{-2}

NIF Implosion

350 Gbar

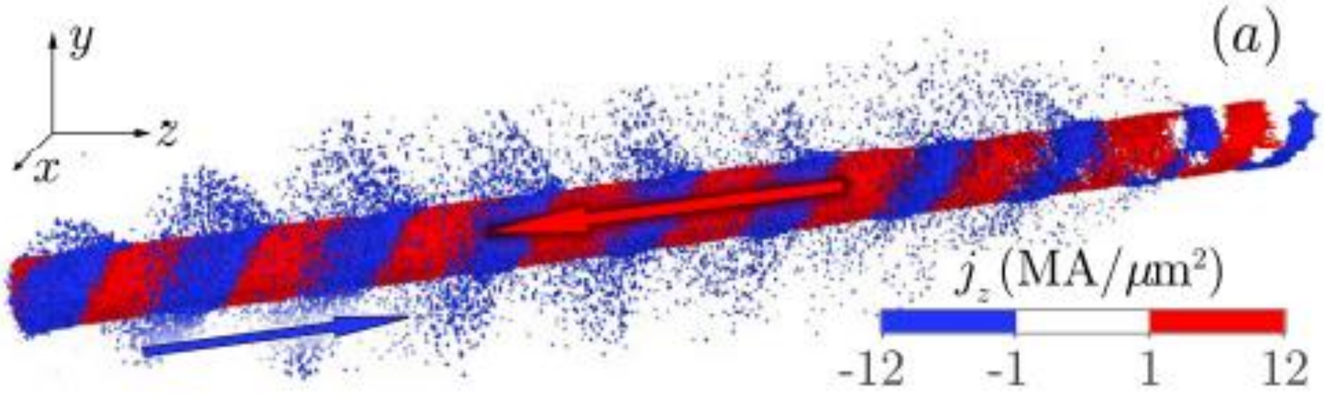


A Pukhov Heinrich Heine Univ., Germany

Kaymak et al, PRL **117**, 035004 (2016)

Nanoscale Ultradense Z -Pinch

Longitudinal current distribution



A Pukhov Heinrich Heine Univ., Germany

Nuclear Physics with High Power Lasers

- **Ultradense ion beams (10^{18} x conventional accelerator) for exotic nuclear physics**
- **Nuclear physics tools to better understand laser-target interaction**
- **Applications (industrial, medical)**
- **Novel instrumentation**

Extreme light intensity (10^{23} W/cm^2)

↓

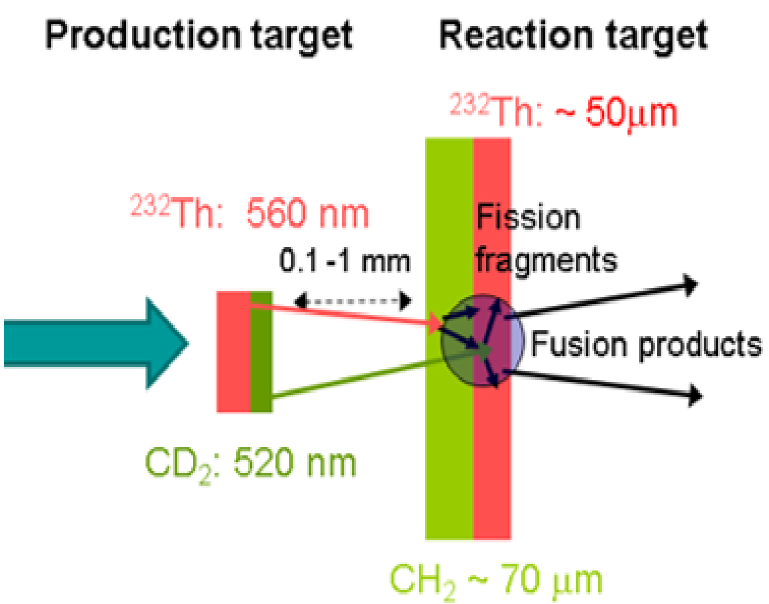
Extreme light pressure (Tbar)

↓

Radiation Pressure Acceleration of solid density 10 MeV/A ion beams

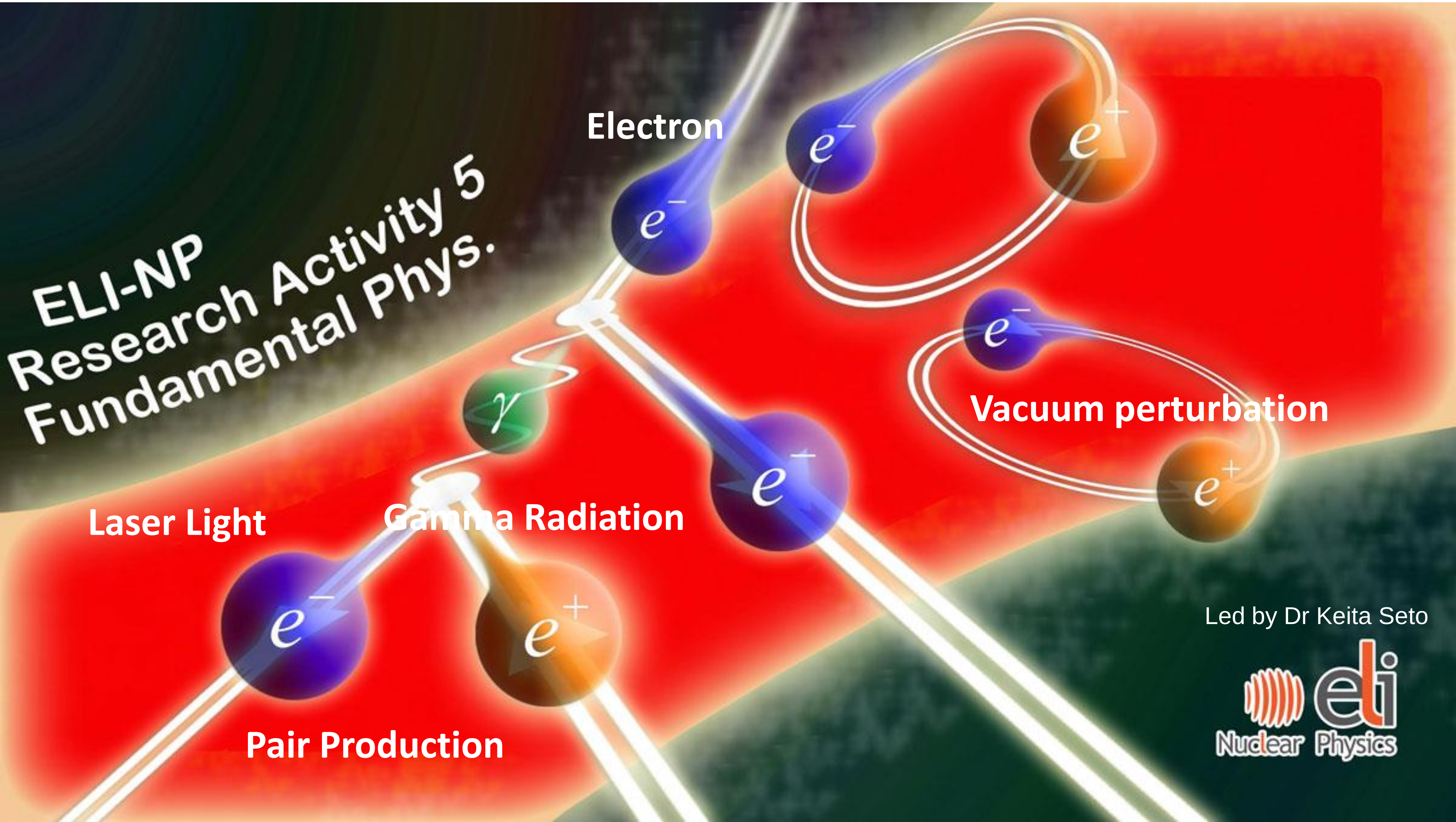
Neutron-rich nuclei production	**Ultra-intense neutron sources**	**Nuclear reactions in plasmas**

Fission-fusion scheme for producing neutron-rich nuclei

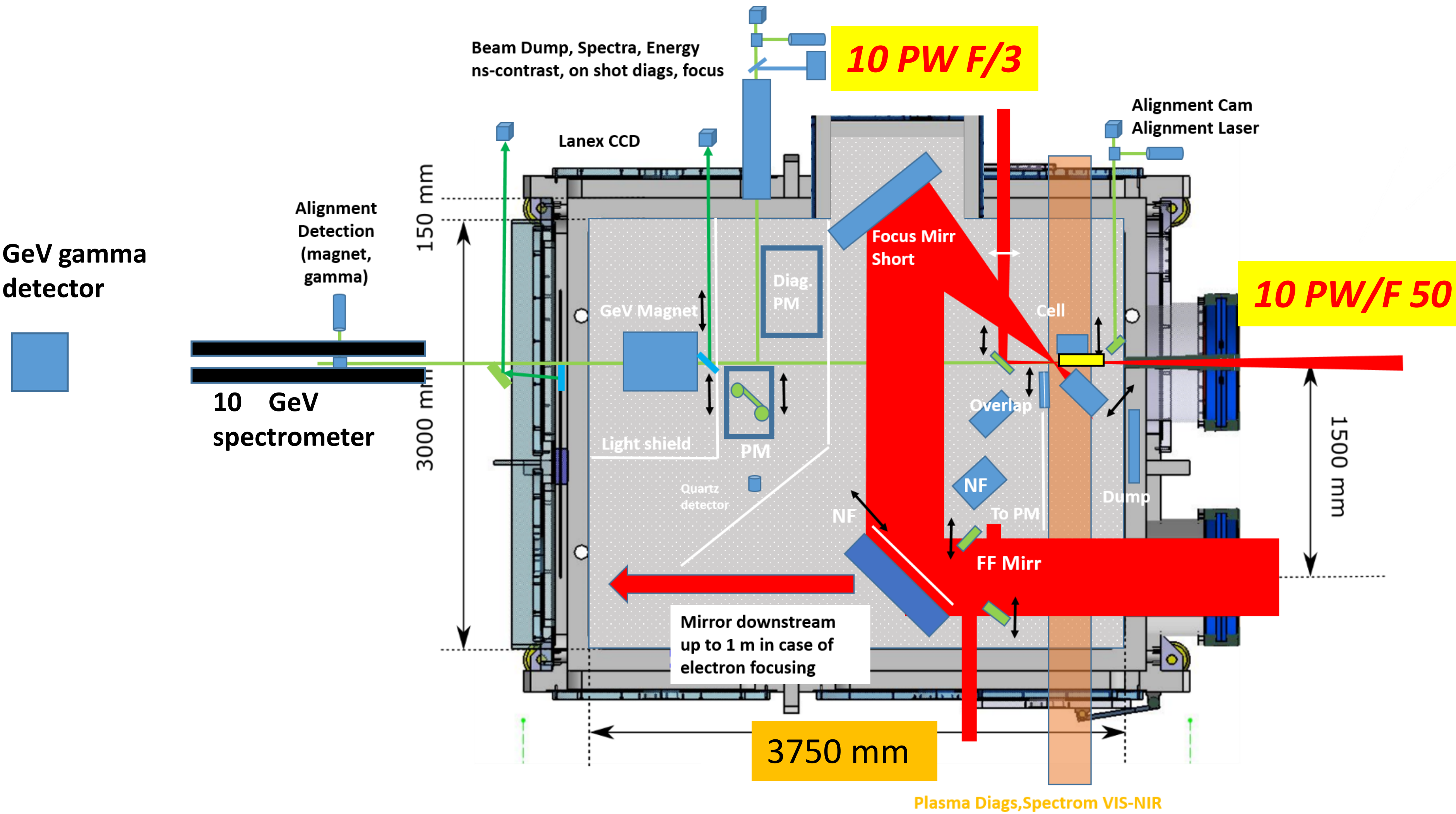


Thirolf et al AIP Conf. Proc. 2011

Nonlinear QED may be confirmed.

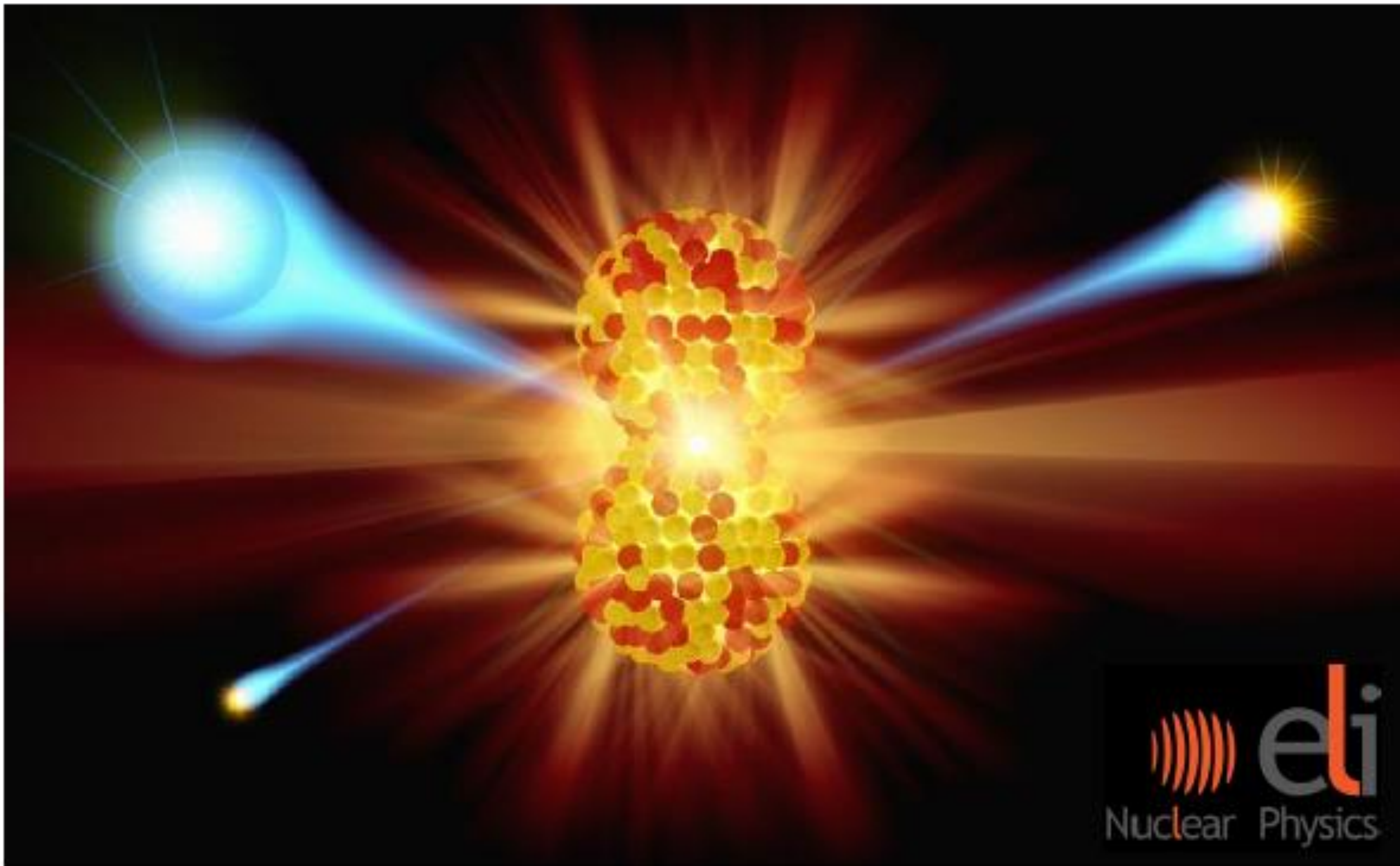


GeV electron - 10 PW laser collision experiment

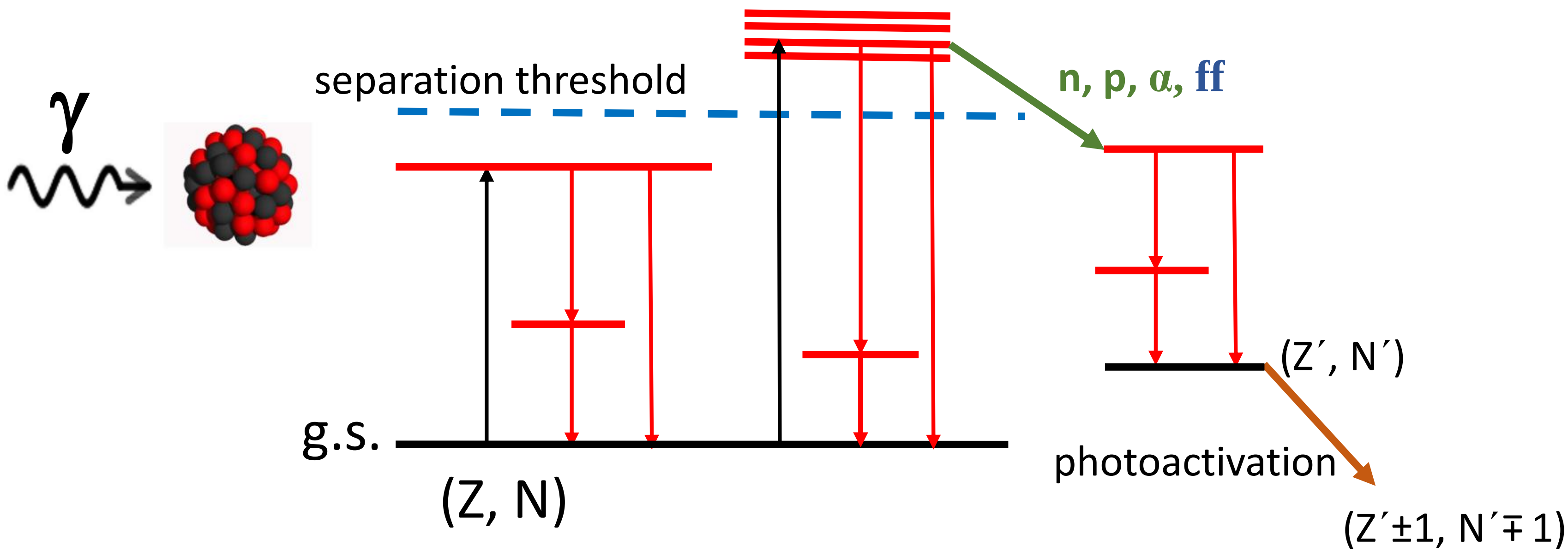


Complex setups, with meter-size mirrors and heavy instruments

Gamma Beam System Experiments

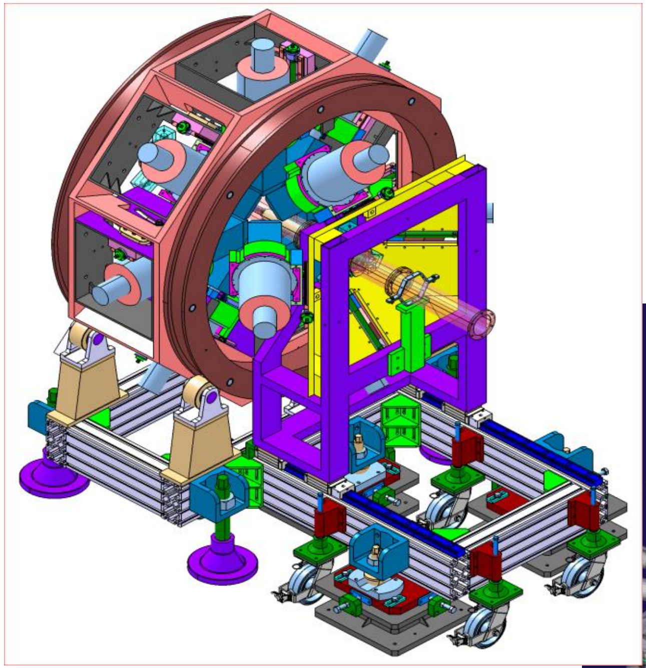


Photonuclear physics with Gamma Beam System

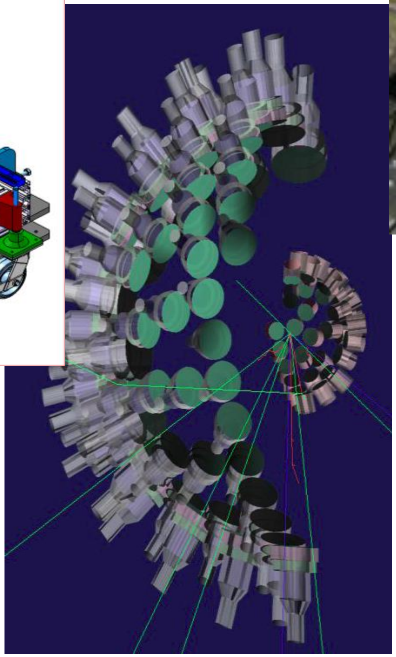


- **Nuclear Resonance Fluorescence (NRF)**
- **Giant/Pigmy Resonances (GANT)**
- **Photodisintegration (γ,n), (γ,p), (γ,α)**
- **Photofission (γ,ff)**

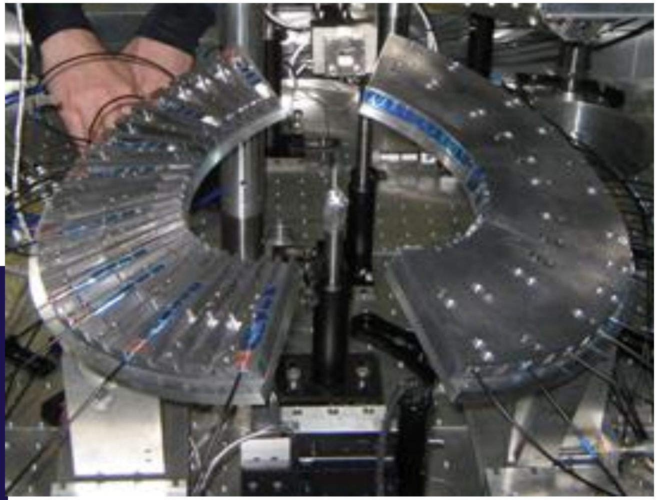
Instrumentation for Physics



ELIADE array: 8 segmented HPGe Clover detectors with anti-Compton shields + 4 LaBr3 detectors



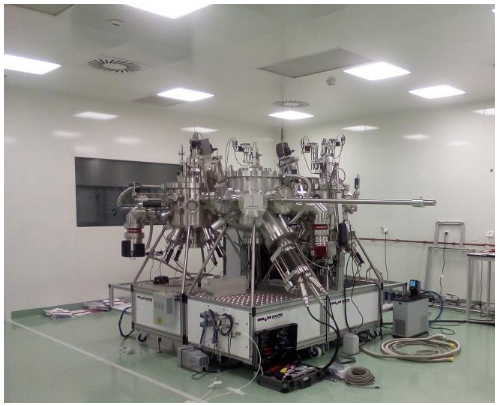
Gamma above neutron threshold (GANT)



CsI array for angle resolved calorimetry

ELI-NP Target Laboratory

Deposition techniques
- UHV RF/DC sputtering
- UHV e-beam evaporation
- spin coating

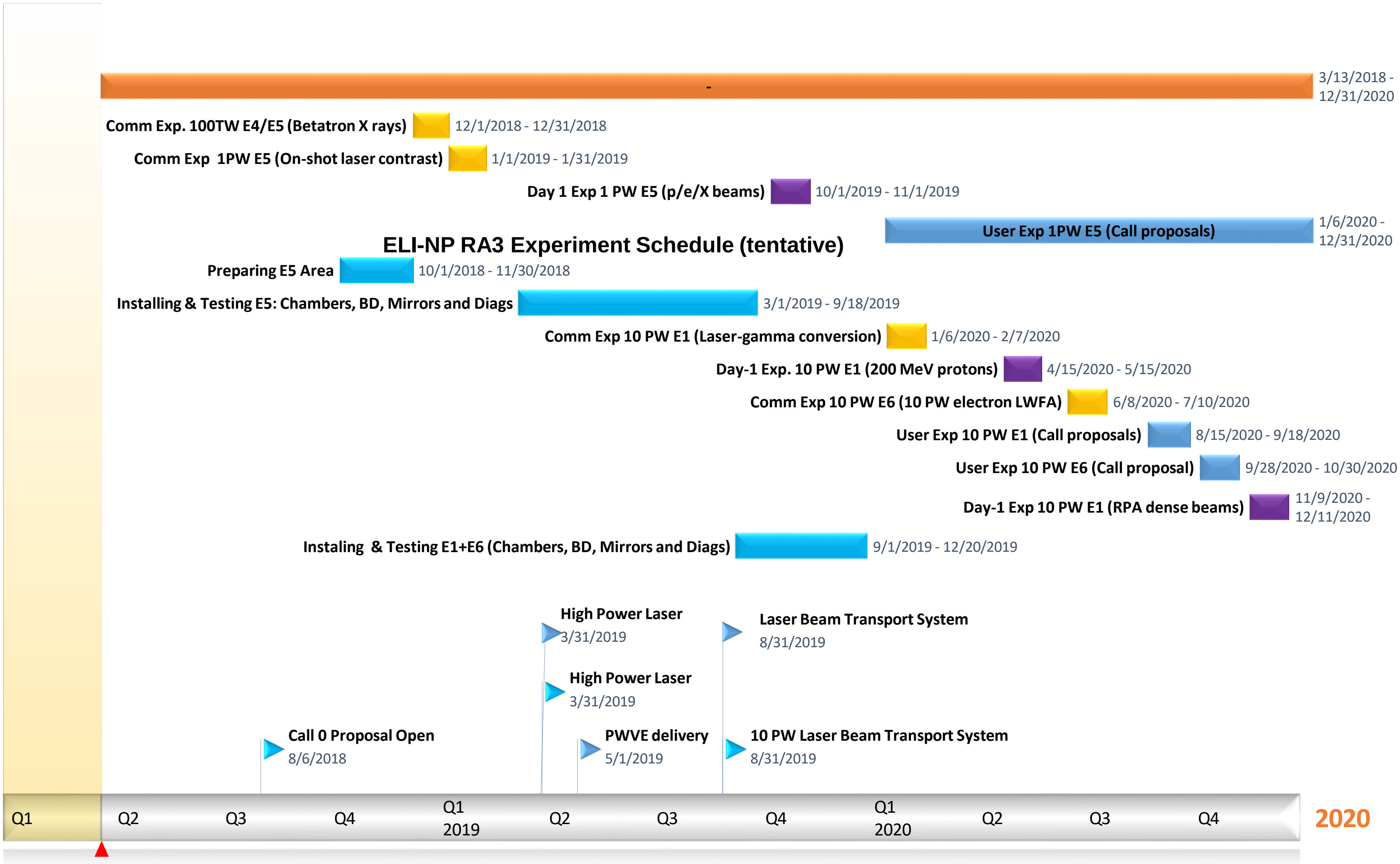


Characterization
- SEM (EDS / EBSD / EBL)
- optical profilometer
- AFM
- XRD
- optical microscope

Structuring /patterning techniques
- reactive ion etching
- optical lithography
- Ar ion milling

Cleaning methods
- Plasma (O_2, Ar, SF_6)
- Ion beam (Ar)
- thermal treatments

Time Plan of ELI-NP (tentative)



We will see you in Brasov in Romania in June.

Summary

- ELI-NP is under active implementation.
  We start test shooting as early as in Dec. 2018.
  10 PW laser beam will be available in June 2019.
  3 MeV and 19.5 MeV gamma beams in June 2019.
- 3PW performance was confirmed in May 2018.

- Fission-fusion, Non linear QED, Plasma Physics, Dark Matter Physics, and Applications to Bio and Medical fields are to be tested.

- This experimental platforms can offer excellent opportunities to young scientists to test their original ideas.

- Your proposal is welcome. Talk us please.

Acknowledgement

- Thales Laser Co.
- Scientists and Engineers at ELI-NP.
- Scientists and professors who contributed to Technical Design Report in Romanian Report in Physics. UK has contributed a lot to this RRP technical design, Thank you.

EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2007-2013

Extreme Light Infrastructure - Nuclear Physics (ELI-NP) - Phase II

Project co-financed by the European Regional Development Fund

Thank You for Your Listening

Document edited by
Horia Hulubei National Institute for Research and Development in Physics and Nuclear Engineering
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