EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments
2007-2013

Project co-financed by the European Regional Development Fund

Sectoral Operational Programme
„Increase of Economic Competitiveness"
"Investments for Your Future"

Extreme Light Infrastructure – Nuclear Physics (ELI-NP)

Quest for laser driven experiments at ELI-NP

Daniel Ursescu

19.06.2014, DFT Seminar, IFIN-HH

Content

- *Project outline*
- *Main tools*
- *Laser driven experiments*
  - *TDR1: Laser driven nuclear physics*
  - *TDR2: Strong field QED*
  - *TDR3: combined laser gamma experiments*
  - *TDR4: material science and applications*

Content

- *Project outline*
- *Main tools*
- *Laser driven experiments*
  - *TDR1: Laser driven nuclear physics*
  - *TDR2: Strong field QED*
  - *TDR3: combined laser gamma experiments*
  - *TDR4: material science and applications*

Extreme Light Infrastructure

2006 – ELI on ESFRI Roadmap

ELI-PP 2007-2010 (FP7)

ELI-Beamlines (Czech Republic)

ELI-Attoseconds (Hungary)

ELI-Nuclear Physics (Romania)

ELI-DC (Delivery Consortium): 2010

Legal entity: April 2013

Czech Republic, Hungary, Romania, Italy, Germany, UK

ELI-NP Main Equipment

- *High power laser system, 2 x 10PW maximum power*

  Thales Optronique SA and SC Thales System Romania

- *Gamma beam, high intensity, up to 20MeV,*
  produced by Compton scattering of a laser beam
  on a 700 MeV electron beam produced by a warm LINAC

EuroGammaS Association:
Instituto Nazionale di Fisica Nucleare (Italy)
Università degli Studi di Roma ”La Sapienza” (Italy),
Centre National de la Recherche Scientifique (France),
ALSYOM S.A.S. (France), ACP Systems S.A.S.U. (France),
COMEB Srl (Italy) ScandiNova Systems (Sweden), etc.

ELI–NP Nuclear Physics Research

- Nuclear Physics experiments

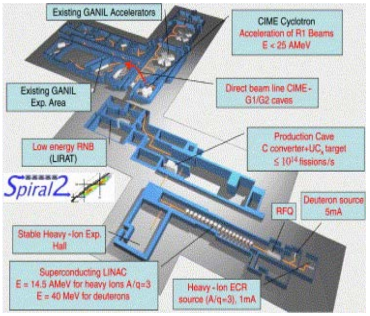
  Photo–fission & Exotic Nuclei

  Nuclear Photonics (NRF)

  Photo–nuclear reactions and structure

  Nuclear Astrophysics

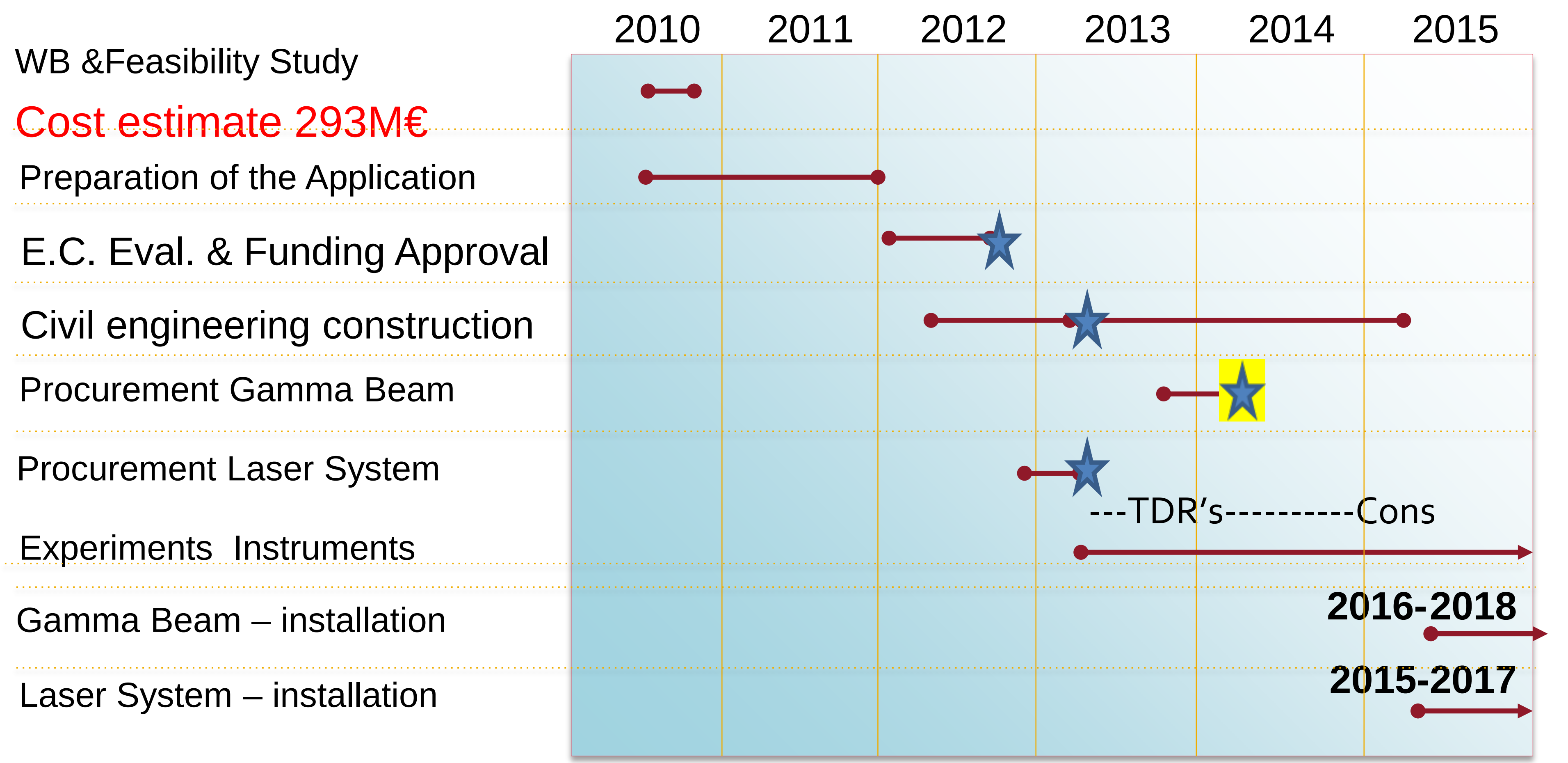
  complementary to other ESFRI Large Scale Physics Facilities (FAIR, SPIRAL2)



- **Laser–Target interaction characteristics: NP diagnostics**
- **Laser Ion driven nuclear physics experiments**
- **Strong fields QED. Towards High field (Laser + Gamma) and Plasma**
- **Applications based on HPLS and High intensity laser and very brilliant γ beams complementary to the other ELI pillars**

ELI–NP in Romania selected by the most important science committees in Europe – ESFRI and NuPECC, in the ***'Nuclear Physics Long Range Plan in Europe'*** *as a major facility*

ELI–NP Project Timeline



S.Gales for the ELI-NP team

June 14th, 2013

eli Nuclear Physics

Building progress

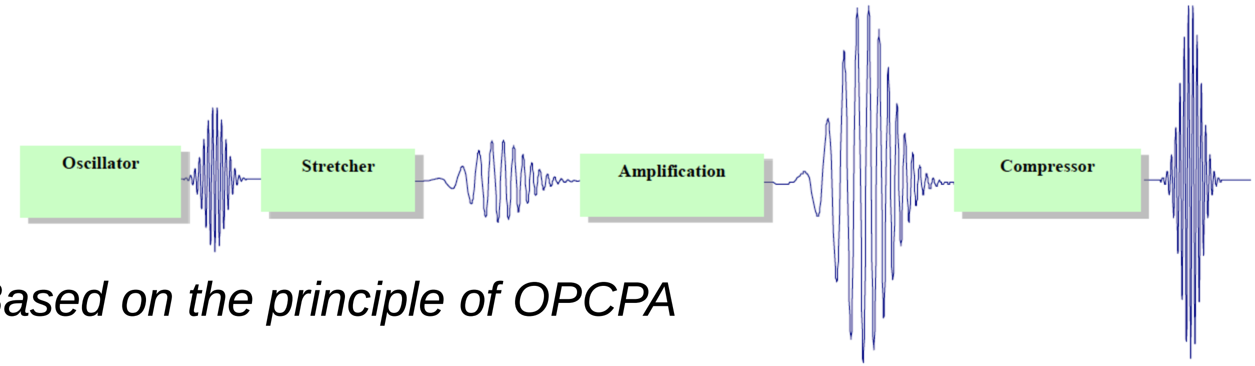

June 14, 2013


August 23, 2013 August 23, 2013


October 31, 2013


March 13, 2014

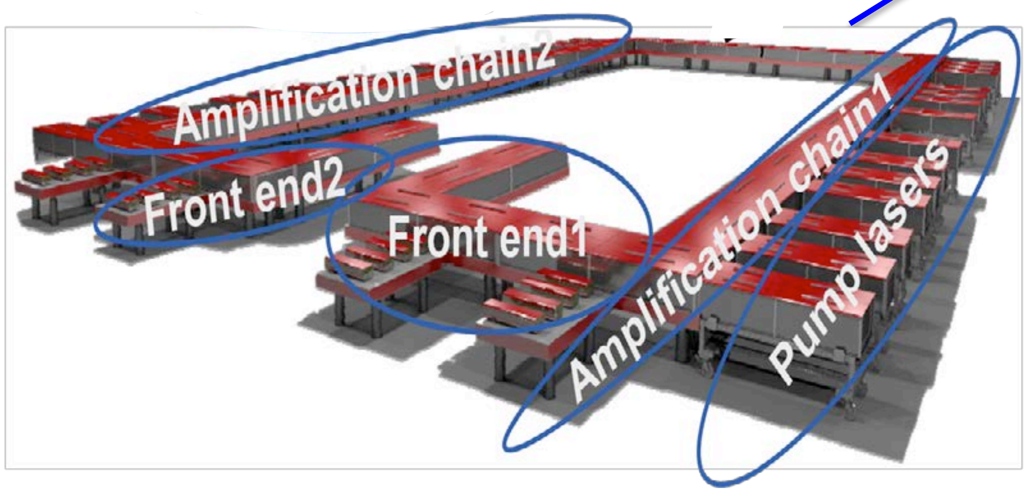
Provided by THALES - France



Based on the principle of OPCPA

2 x 0.1 PW
2 x 1 PW
2 x 10 PW

to compressors

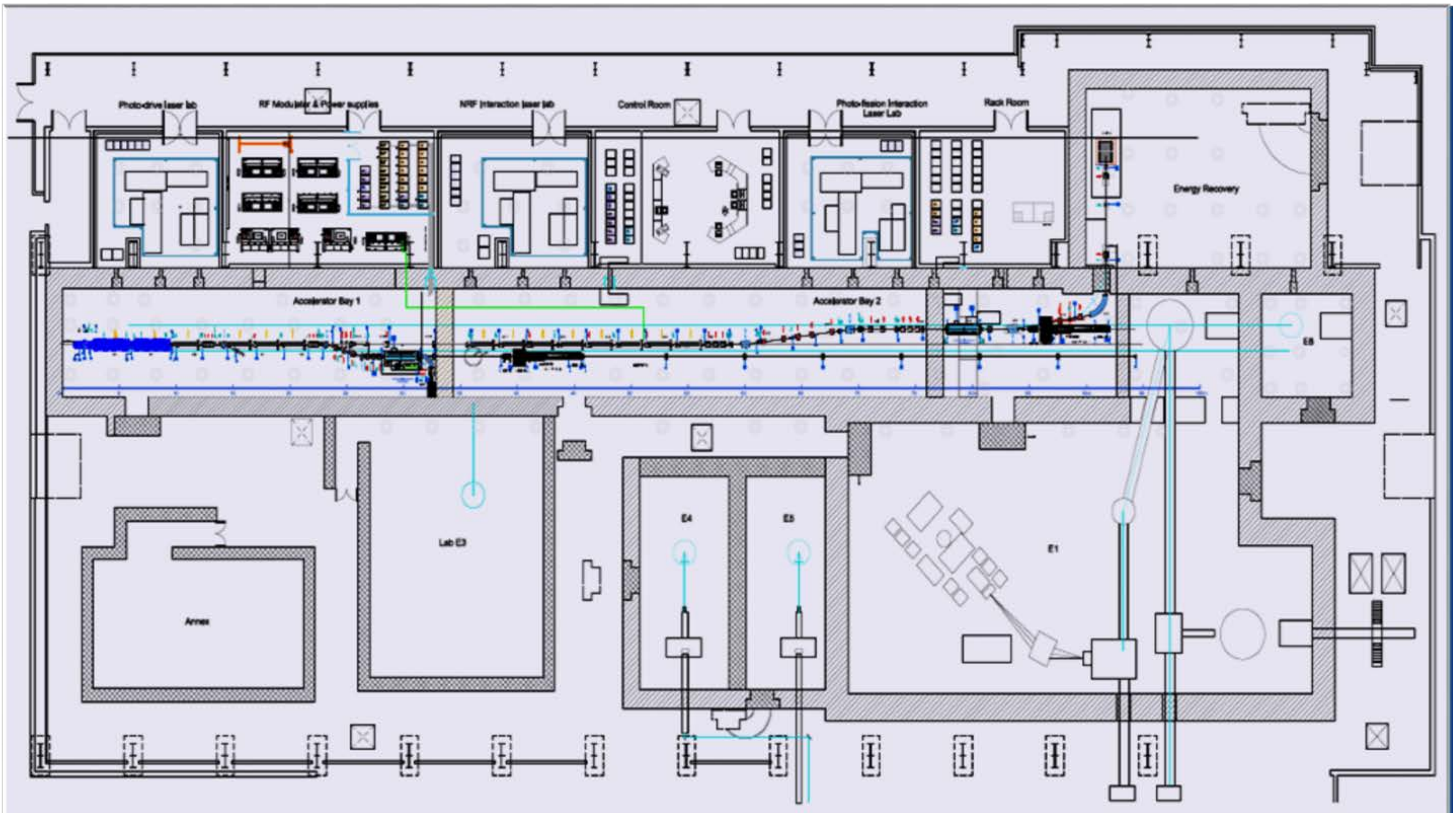


2x10PW Laser System

Thales Optronique SAS and S.C. Thales System Romania SRL

July 12^{th}, 2013

Lay –out of the Laser –Gamma Beam and experimental halls at ELI-NP



Gamma Beam System

EuroGammaS Association: Instituto Nazionale di Fisica Nucleare (Italy) and Research Institutions and Companies from

Italy, France,

Sweden, UK,

Germany, Denmark,

Slovenia, Spain

ELI–NP Scientific Coordination

Scientific Director

International Workgroups for TDR's

Gamma Beams System

1. Gamma Beam Delivery & Diagnostics
2. NRF Experiments and applications
3. Photo–fission experiments
4. (γ,n) experiments
5. (γ,p) experiments
6. Applications, including (γ,e+)

Convener ⟷ local liaison

High–Power Laser System

1. Laser delivery and beam lines
2. Laser Driven NP experiments
3. Strong field QED
4. Laser + Gamma interaction
5. Applications

Convener ⟷ local liaison

Engineering bureau : Building Interface&Transversal Technical proposals
Safety RP Dosimetry, Vacuum, Control system
Alignments, Laboratories, Utilities

Content

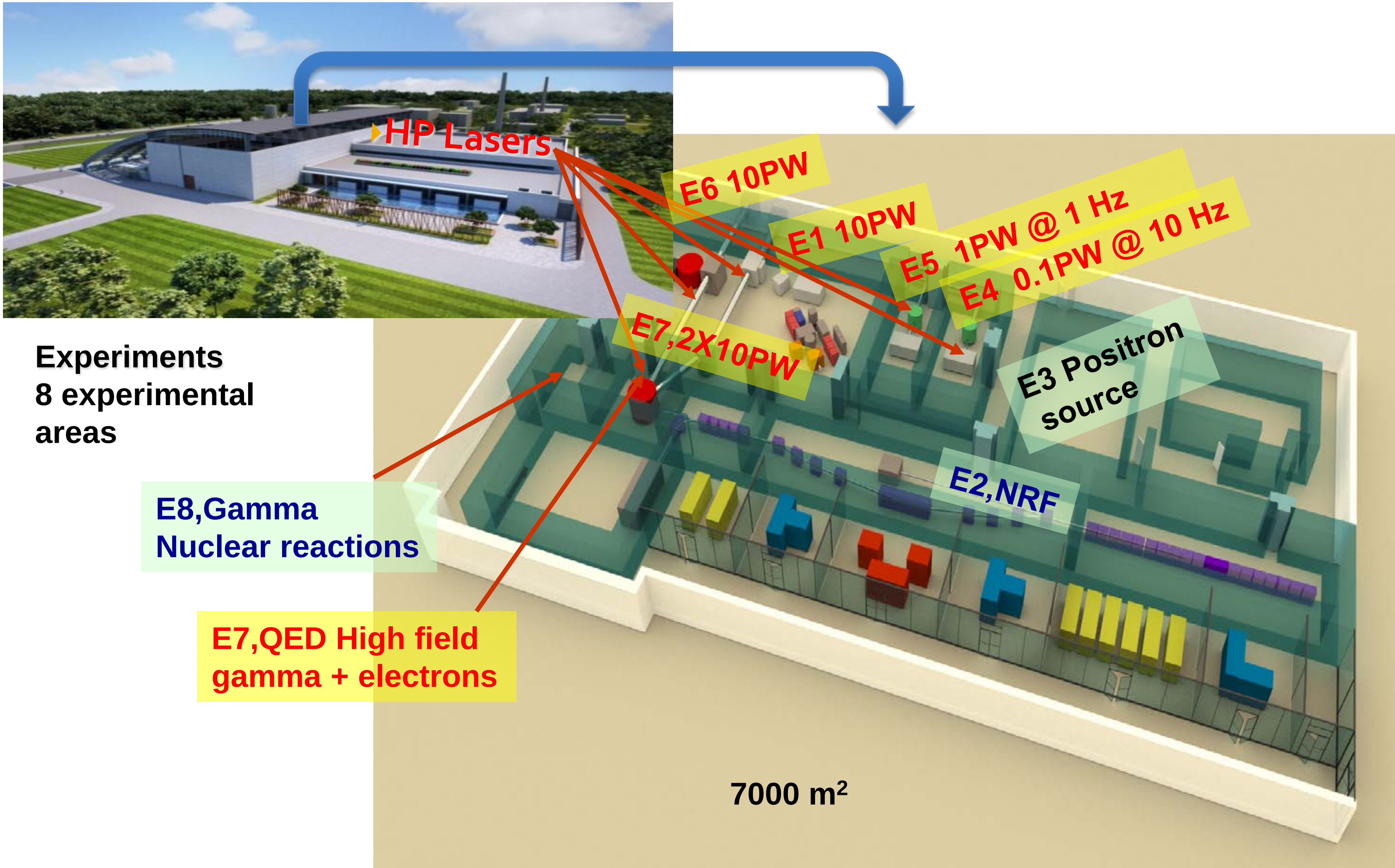
- *Project outline*
- *Main tools*
- *Laser driven experiments*
  - *TDR1: Laser driven nuclear physics*
  - *TDR2: Strong field QED*
  - *TDR3: combined laser gamma experiments*
  - *TDR4: material science and applications*

Main working groups

- **TDR Laser Beams Delivery: convener Gilles Cheriaux (LOA, France)**
- **TDR1: Laser Driven Nuclear Physics – convener Markus Roth (TU Darmstadt, Germany)**
- **TDR2: Strong Field QED – convener Paul McKenna, (SUPA, UK)**
- **TDR3: Combined Laser-Gamma experiments – convener Kensuke Homma (Hiroshima University, Japan)**
- **TDR4: Irradiated Materials Science – convener Marilena Tomut (GSI, Germany)**

- **Vacuum related issues – M Toma, ELI-NP**
- **Alignment related issues – Cristian Petcu, ELI-NP**
- **Radioprotection related issues – Sorin Bercea, ELI-NP**
- **EMP related issues – Marius Gugiu, ELI-NP**
- **Control systems related issues – Mihail Cernaianu, ELI-NP**

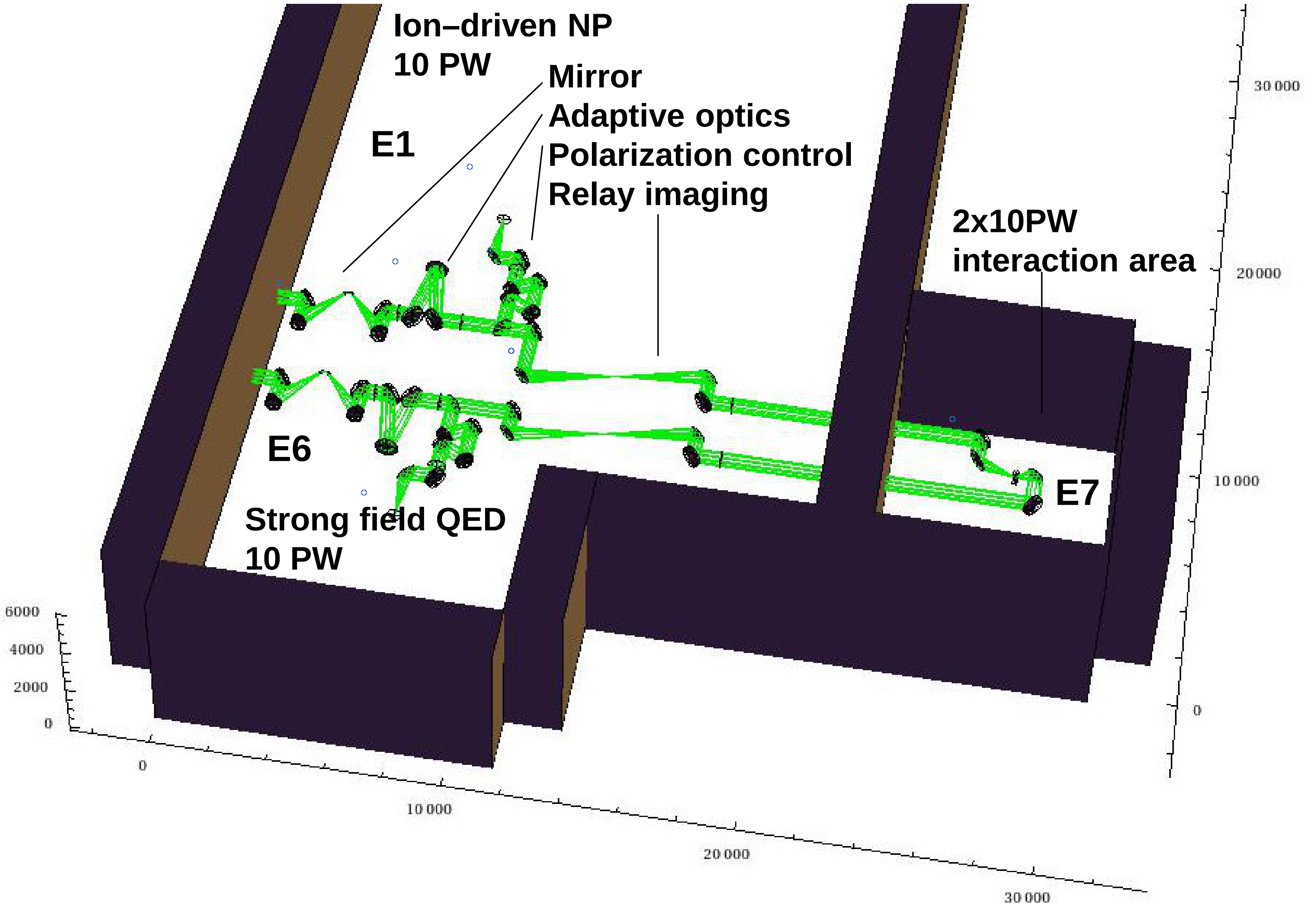
ELI–NP Experiment Building



Preliminary , first step lay out of High Power Laser Experiments in E1,E6,E5,E7 TDR1,TDR2, TDR3,TDR4

First generation of experiments to be implemented
Goals: Precise technical description , Target interaction chamber, Target technologies , vacuum, diagnostics and laboratories

HPLS Delivery



Content

- *Project outline*
- *Main tools*
- *Laser driven experiments*
  - *TDR1: Laser driven nuclear physics*
  - *TDR2: Strong field QED*
  - *TDR3: combined laser gamma experiments*
  - *TDR4: material science and applications*

Laser driven Nuclear Physics Experiments TDR1

Convener :M. Roth ELI-NP F. Negoita +WG members

- **2.1 Nuclear fusion reactions from laser-accelerated fissile ion beams**
  - ***2.1.1 RPA for heavy ions***
  - ***2.1.2 Stopping power of very dense ion bunches***
  - ***2.1.3 Fission-Fusion reaction mechanism***

- **2.2 Nuclear (de)excitation induced by lasers**
  - **26Al case**

- **2.3 Nuclear Astrophysics in Laser plasmas**
  - **2.3.1 13C(4He,n)16O and 7Li(d,n)4He-4He**

The experiments for Laser Driven Nuclear Physics for E1 area at ELI-NP

- *Nuclear fusion reactions from laser-accelerated fissile ions*, to understand the nucleosynthesis of heavy elements. The neutron rich nuclei (with N=126) produced in the laser induced fission and fusion reactions in a Thorium target, will make possible the study the production mechanism of heavy elements (through the r-process) . There is an experimental group to study:

a) Radiation Pressure Acceleration of heavy ions;

b) The Stopping Power for Intense Ion Bunches and

c) The fission – fusion reaction mechanism.

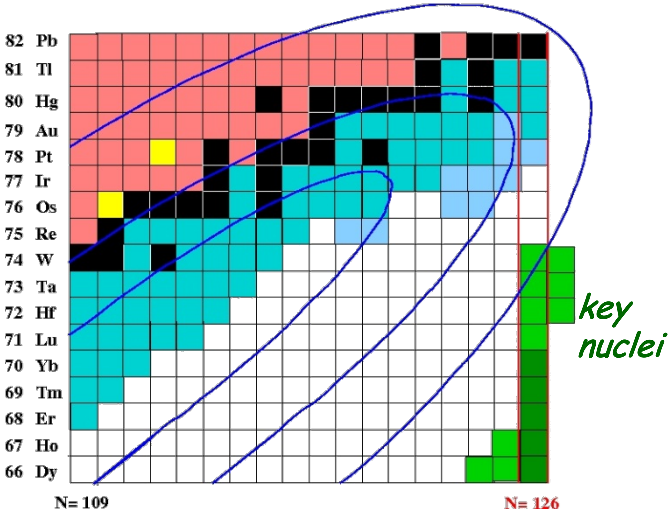
The Bethe –Bloch equation for the stopping power for the ion (eq. 1) has two terms: the binary collision term (T1) and the long range collective interaction term (T2). This allows the study of potential reduction of atomic stopping power or ultra dense ion bunches.

- Laser Induced Nuclear (De)excitation, to study the excitation levels and lifetime of ^{26}Al.

- Nuclear astrophysics in laser induced plasma, to study the nuclear reactions relevant in nucleosynthesis: ^{13}C (^{4}He, n) 16O ; ^{7}Li (d, n) ^{4}He ;

$$-\frac{dE}{dx} = 4\pi n_e \frac{Z_{eff}^2 e^4}{m_e v^2}\left[\ln\left(\frac{m_e v^2}{e^2 k_D}\right) + \ln\left(\frac{k_D v}{w_p}\right)\right] = T_1 + T_2$$

Laser Driven NP at ELI–NP

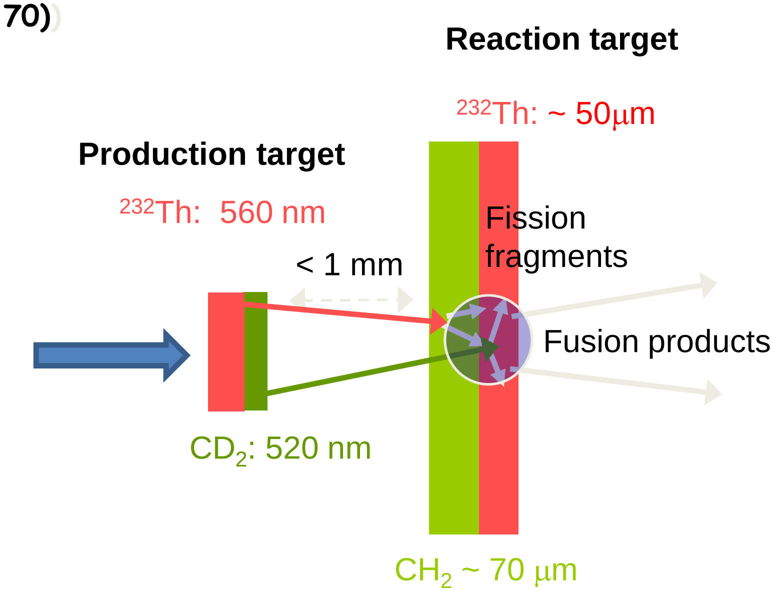


15 neutrons away
from r process path (Z≈ 70)

- Study of exotic nuclei of astrophysical interest produced using high density ion bunches :
  fission–fusion reactions.
  n–rich nuclei around N = 126 waiting point

high-power, high-contrast laser:

- **300 J, ~30 fs (10 PW)**
- **~10^{23} W/cm^2**
- **focal diam. ~ 3 μm**

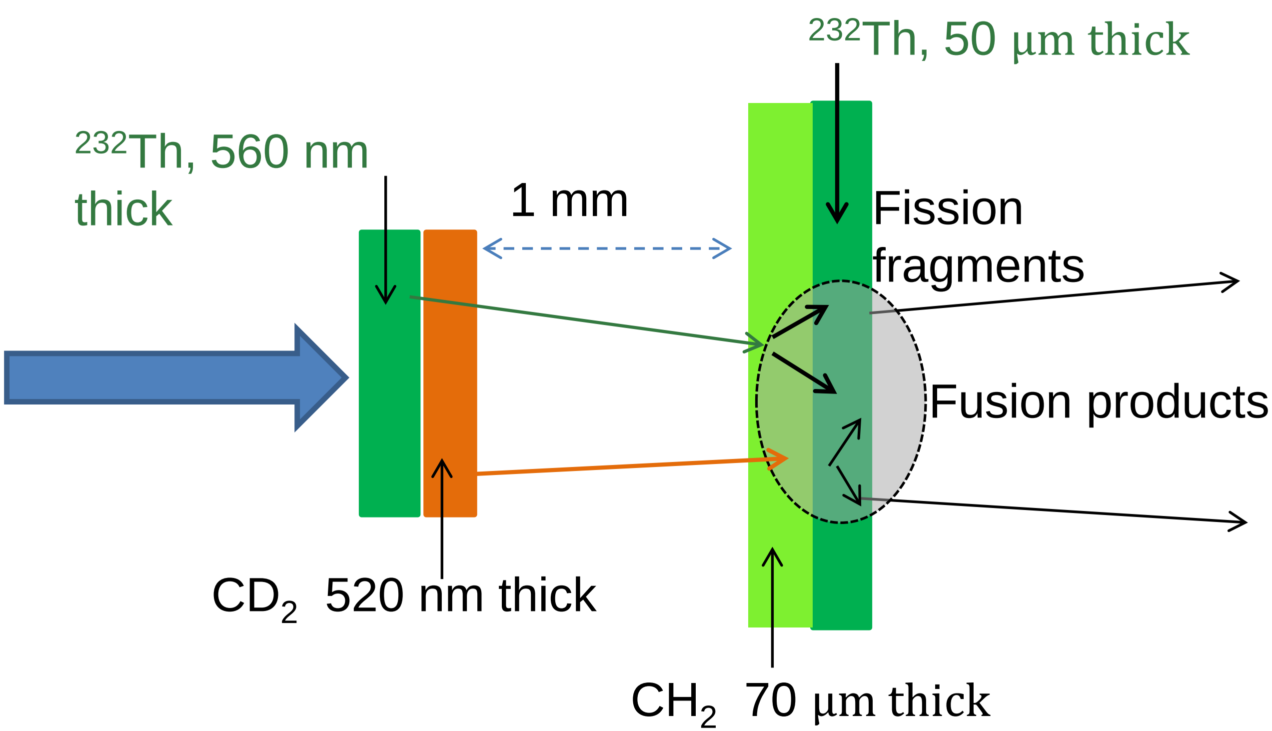


D.Habs, P.Thirolf et al., Appl. Phys. B 103, 471 (2011)

- ***Study of heavy ions acceleration mechanism at laser intensities > 10^{23} W/cm^2***
- ***Deceleration of very dense electron and ion beams***
- ***Understanding influence of screening effect on stellar reaction rates using laser plasma***
- ***Nuclear techniques for characterization of laser–induced radiations***

The scheme for fission-fusion experiments

The experiment proposed with 8.5 -17 PW laser beam (150-300 J), ultra-short pulses (32 femto-seconds). For a focal diameter of 3 micrometers, the Laser power was 1.2 $\cdot 10^{23}$ W/cm^2.



Fission:
Beam: H, C, ^{232}Th
Target: C, ^{232}Th

Target like fission fragments:

$$H,C+{}^{232}Th \rightarrow F_L + F_H$$

Beam like fission fragments:

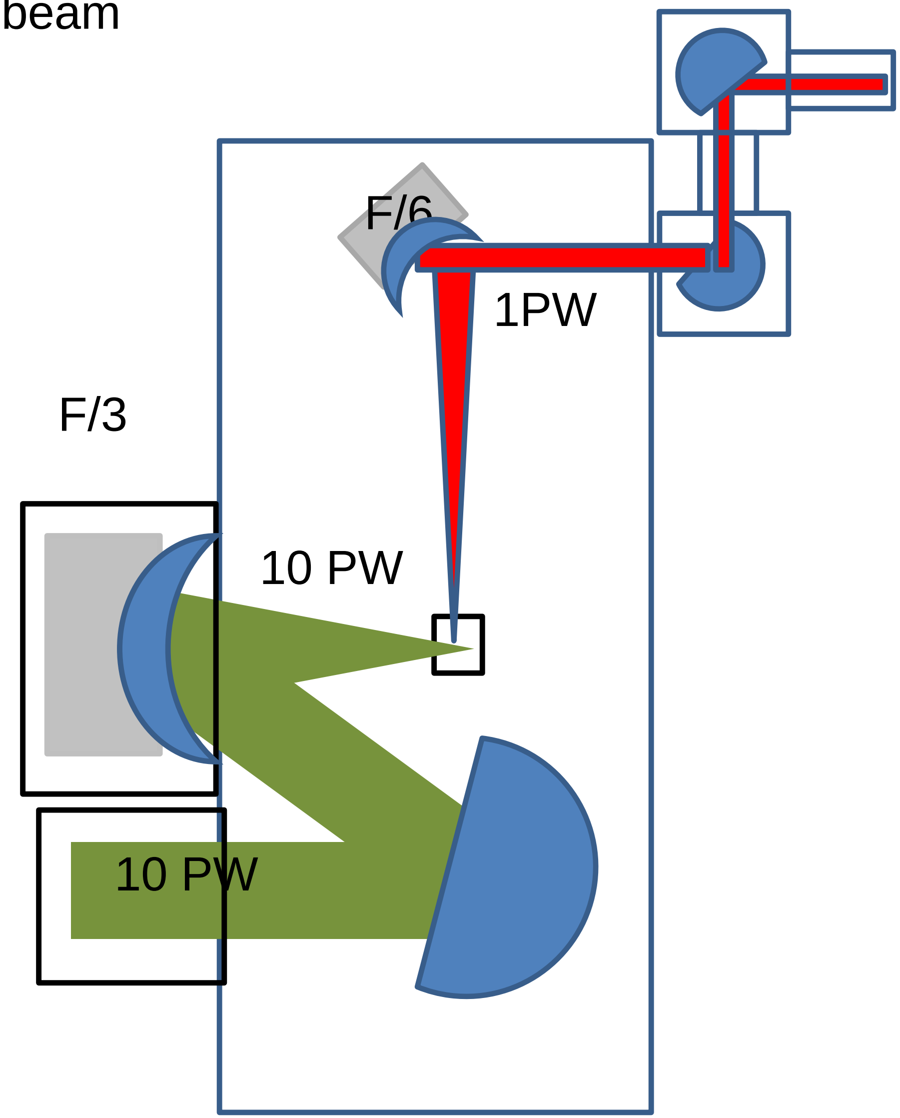
$$^{232}Th + C \rightarrow F_L^* + F_H^*$$

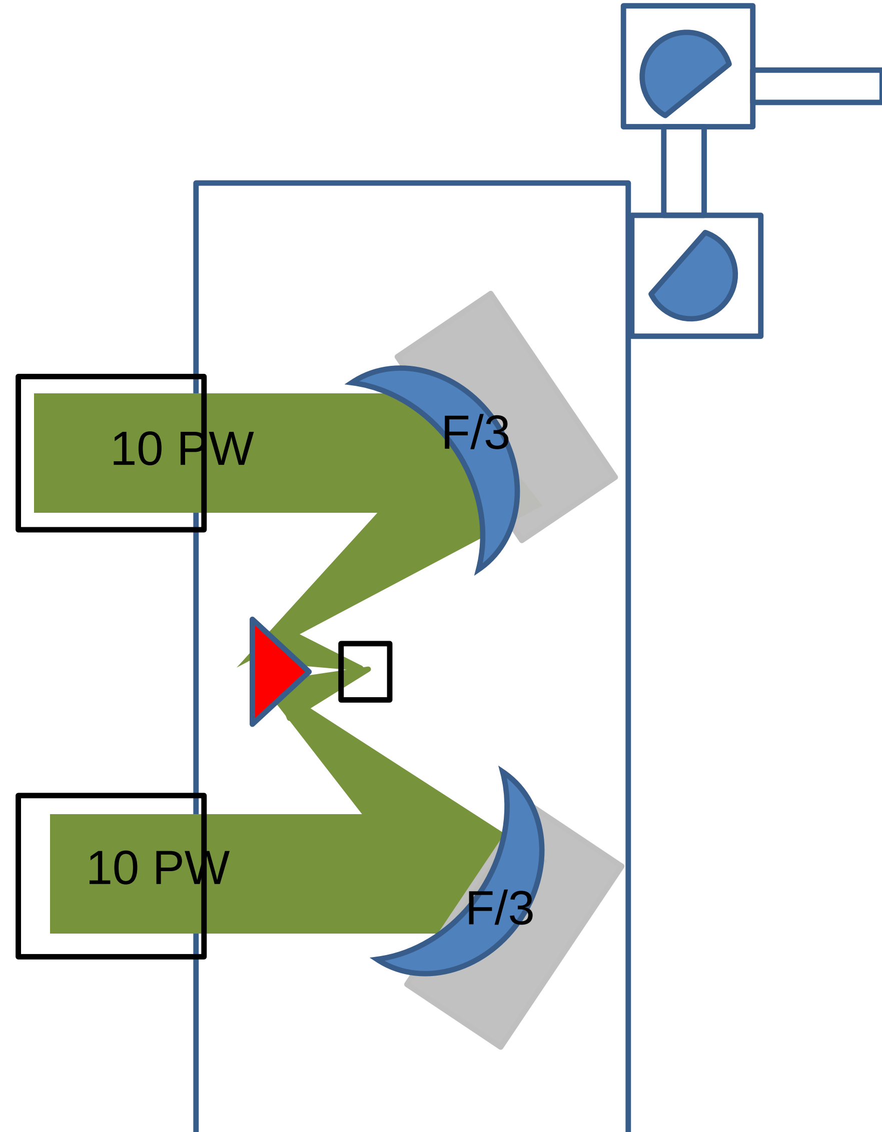
Fusion from two light fission(target-like and beam –like) fragments

D.Habs, P.Thirolf et al., Appl. Phys. B 103, 471 (2011)

Configurations possible with a 1PW and 10 PW laser beams (left fig) or two 10 PW laser beams.

1 PW of up to 250 J of compressed Laser beam





The required equipment in E1 area and the experimental challenges

- Characterization of reaction products (decay spectroscopy)
- Precision mass spectroscopy (Penning Trap or MR-TOF)

- Challenges: Laser Acceleration of Heavy Species (RPA), the Optimization of target structure and shape, the repetition rate capability, the characterization of stopping range for Laser (with investigation of potential collective effects).
- The development of the identification technique of the reaction products. : setup for precision mass measurements, wide acceptance separator for fission products, decay spectroscopy for short lived species.
- The novel laser-ion acceleration (RPA) of the new species, allows the generation of ultra-dense ion pulses and the fission-fusion reaction mechanism.

The ELI-NP Laser will have 2 X 150 Joules/pulse, 30 femto-seconds /per pulse to get and intensity of $I=10^{23}$ W/cm^2

Nuclear excitations with Ultra Intense lasers

M.M.Aléonard,
F.Hannachi, F.Gobet, M.Gerbaux, C.Plaisir, M.Tarisien, J.N.Scheurer

Some orders of magnitude

1- Time scales

Laser wave period for 1 eV ($\lambda \sim 1\mu m$) photons: $T = 4.10^{-15}$ s = **4 fs**

Pulse duration (LOA) ΔT = **30 fs** i.e. 80 % of the energy in 8 periods

Bohr orbital electron period $\tau = 4\ 10^{-17}\ Z^{-2}$ s (Al: **0.02 fs**; Ca:**0.01fs**)

2 - Electric field scales

Intra-nuclear electric field: $F_n = 10^{19}$ V/cm

Binding electric field in hydrogenoid atom $F_e = (Z^3/n^2)\ 2.7\ 10^9$ V/cm

$_{13}Al$ $F_e \sim 6\ 10^{12}$ V/cm $_{20}Ca$ $F_e \sim 2\ 10^{13}$ V/cm

laser wave electric field as a function of the intensity: $F_l = 13.7\ I^{0.5}$

I(W/cm²)	10^{14}	**10^{20}**	10^{22}	**10^{24}**	10^{26}
F_1(V/cm)	10^{8}	**10^{11}**	10^{12}	**10^{13}**	10^{14}

What kind of nuclear physics with plasma created with high-power lasers?

Warm and dense plasma

High electromagnetic fields: 10^{11} V/cm, 1000 T

Free electrons

Bound electrons

Electrons, γ, protons with high energy (keV – MeV)

Modification of bound energy and nucleus – electron couplings

Nuclear excitation and reaction yields in plasmas?

Nuclear Excitation by Electronic Capture (NEEC) in plasmas?

Modification of nuclear deexcitation processes in plasma? (Internal Conversion)

Nuclear Reactions in Plasmas
Nuclear Astrophysics

ELI-NP Meeting Darmstadt March 24, 2014
S. Tudisco

Collaboration

Università degli Studi di Catania

INFN-LNS Istituto Nazionale di Fisica Nucleare

IFIN-HH

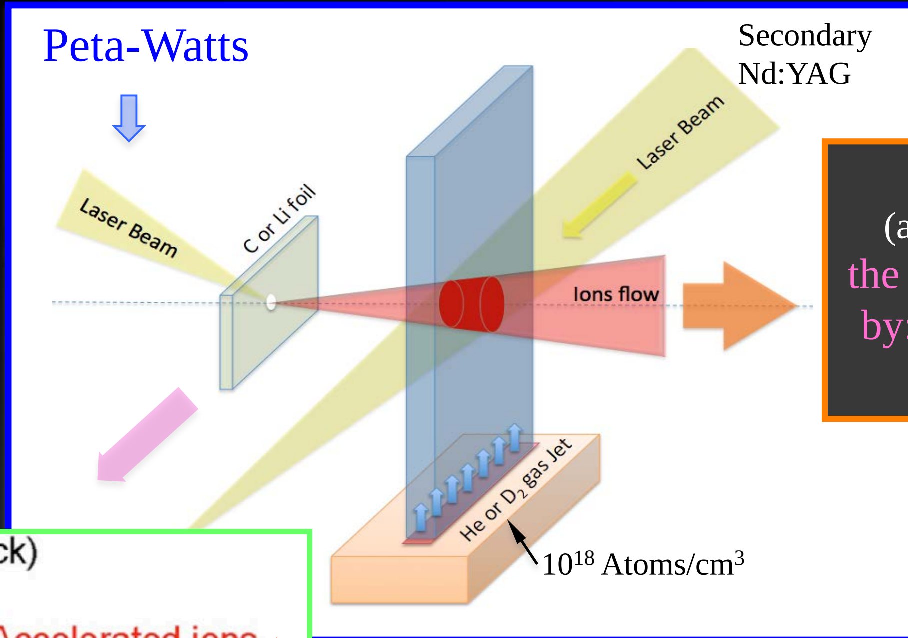
Universitatea din Bucuresti

INO Istituto Nazionale di Ottica

Consiglio Nazionale delle Ricerche – Istituto per la Microelettronica e Microsistemi

Methodology

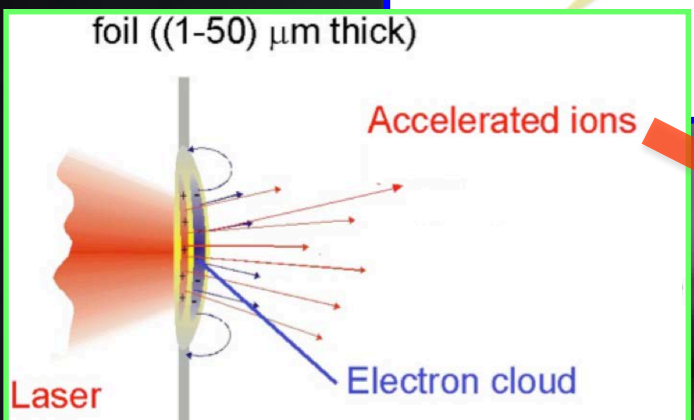
Two laser beams generating two colliding plasmas



Fixing TNSA regime

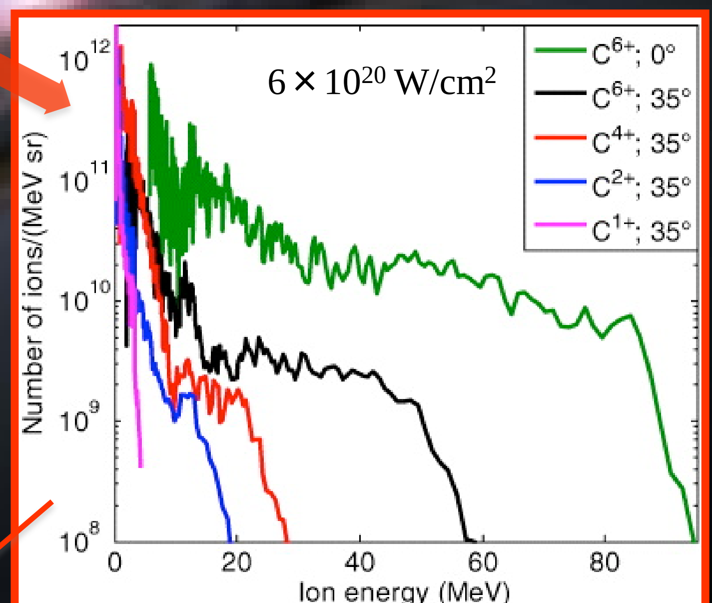
(an than the maximum ions energy)

the total ions number is determined by: Laser intensity, focal spot and target thickness



TNSA - **Target Normal Sheath Acceleration**

10^{18} - 10^{20} W/cm^2



A. Macchi et el. Rev of Mod. Phys, 85 (2013) 751

D.C. Carrol et al., New J. of Phys. 12 (2010) 045020

Content

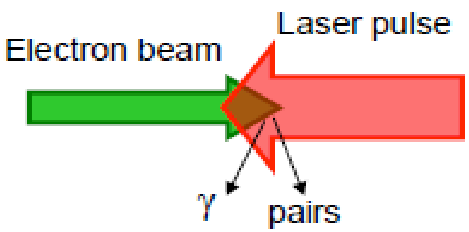
- *Project outline*
- *Main tools*
- *Laser driven experiments*
  - *TDR1: Laser driven nuclear physics*
  - *TDR2: Strong field QED*
  - *TDR3: combined laser gamma experiments*
  - *TDR4: material science and applications*

Strong Field QED

ELI–NP delivering pulse at > 10^{23} W/cm^2 will enable this exciting new regime to be investigated

Require electrons with a large Lorentz factor (γ) interacting with strong electromagnetic fields.
Ultra-intense lasers should be able to provide both the Lorentz factor and the fields

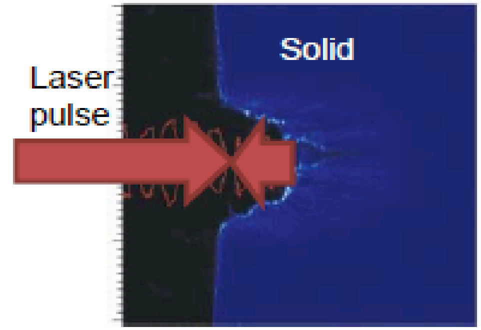
(1) Interaction of GeV electron beam (Wakefield) with TW-PW laser



(2) >10PW laser pulse interactions with dense plasma

Reaction rates are high due to high electron density

$10\text{PW} = 10^{23}\ \text{Wcm}^{-2} \rightarrow \gamma = 300 \rightarrow \eta \approx 0.2$



A.R. Bell & J.G. Kirk, Phys Rev Lett, 101, 200403 (2008)

High Field QED Experiments at ELI–NP

High Field Physics in Beam-Beam Interactions

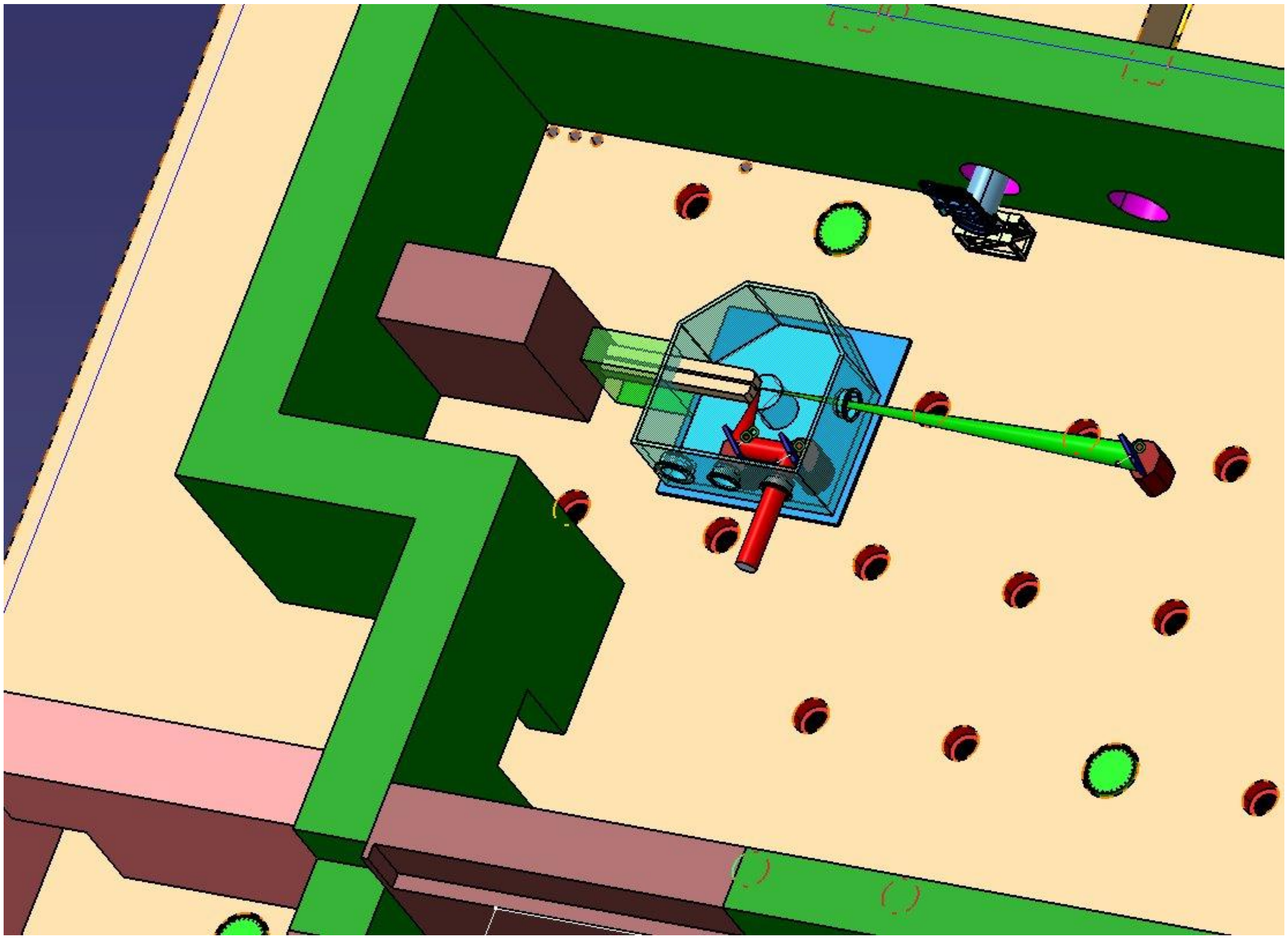
- Producing suitable secondary electron beams, gamma beams and controlling the laser pulses
- Nonlinear Compton Scattering
- Classical and Quantum kinetic radiation reaction effects

High Field Physics in Dense Plasma (Solid) Interactions

- Intense synchrotron gamma-ray generation
- Radiation reaction
- Electron-positron pair production

Nuclear Physics

High Intensity Laser Fields and QED experiments at E6 area



High Field Physics with Beam-Beam interactions (E6

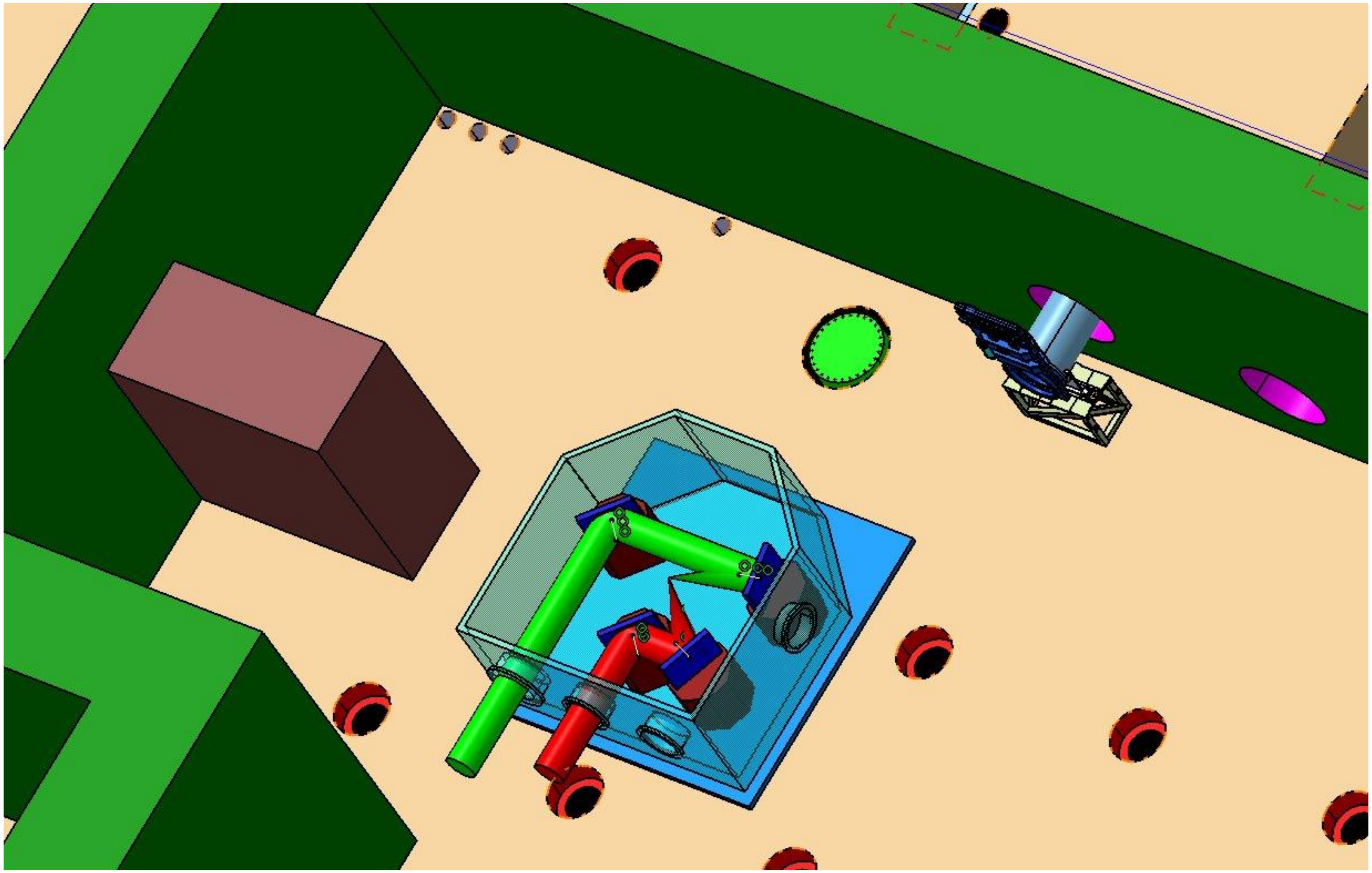
Laser beam with intensity >10^{21} W/cm^2 produces relativistic electrons in a gas plasma. The electrons are accelerated in the laser field. The work done by the Laser field a_0=eA/(mc^2). Electrons gain a longitudinal momentum a_0^2. If a laser beam can be scattered off a counter propagating electron beam with γ>>1, to produce a gamma beam with shifted frequency by a factor $4 \cdot \gamma^2$. The phenomena that can be studied are:

1. *Classical Radiation Reaction*, to understand how charged particles interact with their own radiation field. If a_0>>1 significant momentum is taken up by the electron oscillating in Laser Field and the radiation force is large. The Radiation Reaction can be treated as perturbation [1] or with a non-perturbative approach [2].
2. *Nonlinear Compton Scattering* is seen in low intensity laser beam 1< a0 < 10 and not-focused laser beam pulses to extend the interaction time and treat the laser as plane waves. Electron bunches (10 MeV) interacting head on with such laser beam, emit radiation with an intensity that depends on the mass shift of the electrons.
3. *Classical and quantum kinetic radiation effects.* Radiation Reaction tends to reduce the energy spread of the electrons when 50 MeV electron bunch collides head-on with the laser pulse of a0 =10. Quantum effects become important for 1 GeV electrons collide with a laser with a0=70, such that the Radiation Reaction increases the spread of electrons. Both effects could be studied at ELI-NP.

High Field Physics with Beam-Beam Interaction

1. *Non-linear optics in relativistic plasma*. At high laser intensity the bounce frequency of electrons trapped in trapped ponderomotive force is bigger than plasma forces. Coherent scattering in plasma, can compress laser pulses and enhance the beam intensity, allows the control of the pulse duration, the focusing and the contrast enhancement.
2. *Electron beam generation* using Laser Plasma Wake Field Acceleration. In the first stage, at ELI-NP, an electron beam will be accelerated to 5-10 GeV in the 10 PW Laser field focused in a 1 meter long plasma cell (with density $10^{16} – 10^{17}$ cm^{-3}). The electron beam will be suitable for radiation reaction studies.
3. *Betatron gamma rays generation*: The LWFA electrons can be used as a source of gamma radiation. Hard X rays emitted from femto-second laser-produced plasma and betatron X rays from LWFA electrons, were reported [1].

High Intensity Laser Fields and QED experiments at E6 area



High Field Physics with solid-laser interaction (for E6 area)

- Two main QED processes are important in laser-solid interaction: a) Thomson scattering ($e^- + \gamma_L \rightarrow e^- + \gamma_R$) in which 40% of electron energy is damped in the Laser field, via synchrotron radiation emission. b) Pair production $\gamma_L + \gamma_R \rightarrow e^- + e^+$. The two processes are important when the parameter η= γ/E (E_p +v x B), is almost unity. Here E_p is the perpendicular component of the electric field. The Lorentz factor γ >300 and η >0.2 and $I=10^{24}$ W/cm^2
- Intense synchrotron gamma rays produced from electrons accelerated by Laser's electric field, when the damping force exceed the Lorentz force on electron. The ELI-NP laser beams with 10PW and 10^{23} W/cm2 should enable the onset of radiation damping, when >35% of the Laser energy is converted to intense synchrotron radiation.
- Electron –Positron pair production : a) an electrons with E>1.022 MeV produces electron-positron pair (the single stage Trident process) and b) electron emits a synchrotron radiation E>1.022 MeV that generates the electron – positron pair (the two stage Bethe Heitler process). A cascade of gamma rays and e-e pairs is predicted at laser intensities $>10^{24}$ W/cm^2.

Requirements for laser beam control and the characterization (at E6 area)

- Highest possible intensity $>10^{23}$ W/cm^2
- Shot focal length F3 (or shorter) off-axis parabola mirrors.
- Two 10 PW beams combined on target with coherent addition of the pulses, phase front tilt control
- Polarization control needed, to switch from circular to linear polarization.
- Ultra high intensity 10^{13}:1 contrast is needed for nano-seconds pulses and 10^{14}:1 at pico-seconds pulses.
- Temporal shaping and control of rising edge of the laser pulse
- Spatial shaping and control of focal spot distribution with adaptive optics.
- Debris mitigation using suitable pellicles (with minimum front distortion) to cover the surface of the mirrors. Inter-changable optics required to minimize the downtime.

Laser diagnostics required for E6 area

- Laser dignostics
- Intensity temporal contrast measurements;
- FROG Frequency Resolved Optical Gating Diagnostics.
- Measurement of the laser focal spot energy distribution
- The degree of the temporal overlap measurement
- Synchronized optical probe to characterize the density gradient at target front surface
- Near and far field monitoring of the laser beams
- Electron beam diagnostics:
- energy spectrometer,
- beam profile,
- charge (Faraday cup, ICT and calibrated),
- emittance measurement,
- beam transport system.
- Plasma diagnostics for beam-beam experiments:
- Thomson scattering
- interferometer

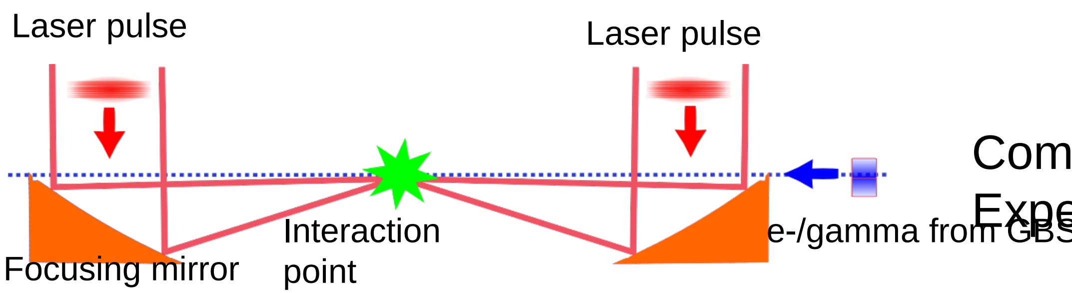
Content

- *Project outline*
- *Main tools*
- *Laser driven experiments*
  - *TDR1: Laser driven nuclear physics*
  - *TDR2: Strong field QED*
  - *TDR3: combined laser gamma experiments*
  - *TDR4: material science and applications*

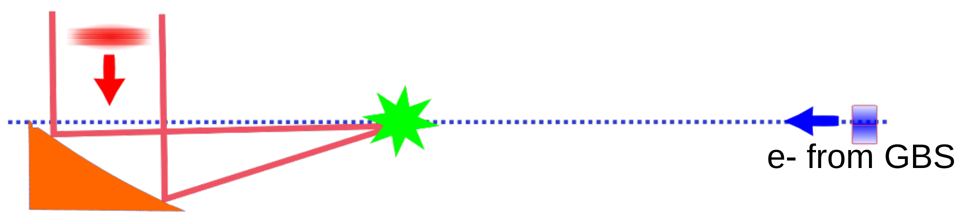
TDR3 Combined laser - gamma experiments

1. Dark field search (Four-wave mixing in the vacuum)
2. QED birefringence studies
3. Electron induced nuclear processes investigated with gamma beams
4. Gamma-gamma scattering
5. Gamma assisted electron-positron pair production in vacuum; requires:
   - Nonlinear Thomson scattering or
   - X-ray laser / high order harmonics driven Backscattering gamma source
   - Bremsstrahlung source driven by laser produced ultrarelativistic electron bunches

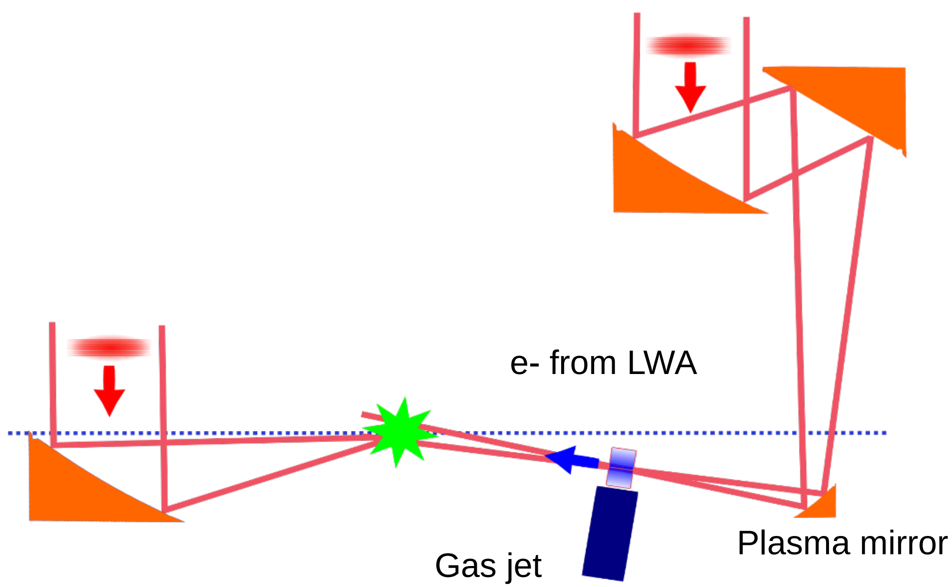
Experiments at E7



Combined laser-gamma
Experiments standard set-up



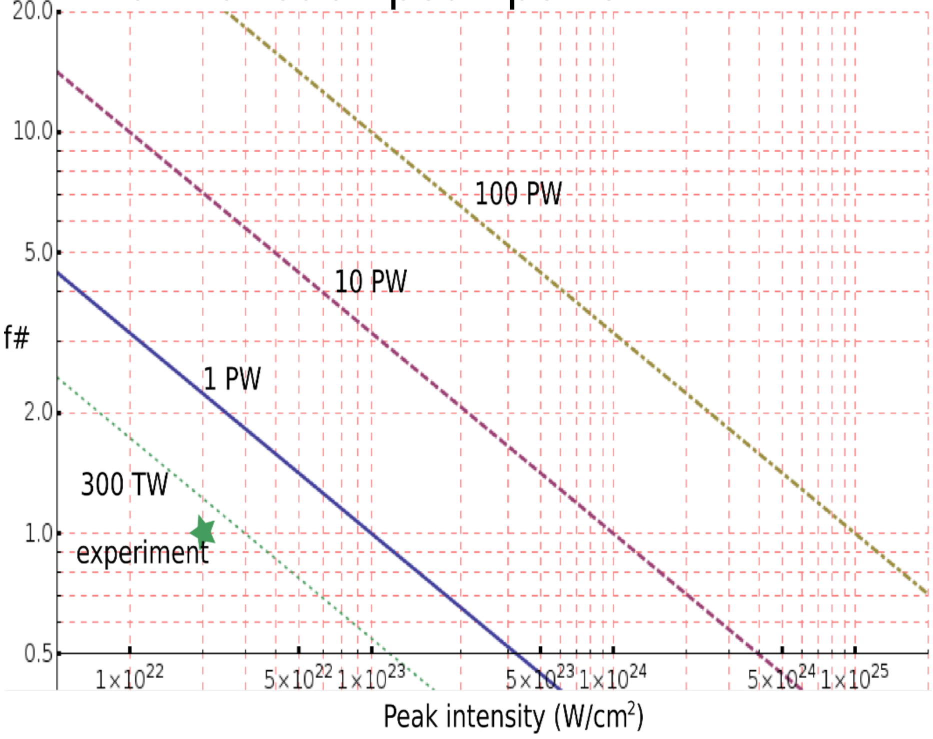
Combined laser-gamma
Nonlinear backscattering set-up



Laser-only
Nonlinear backscattering set-up

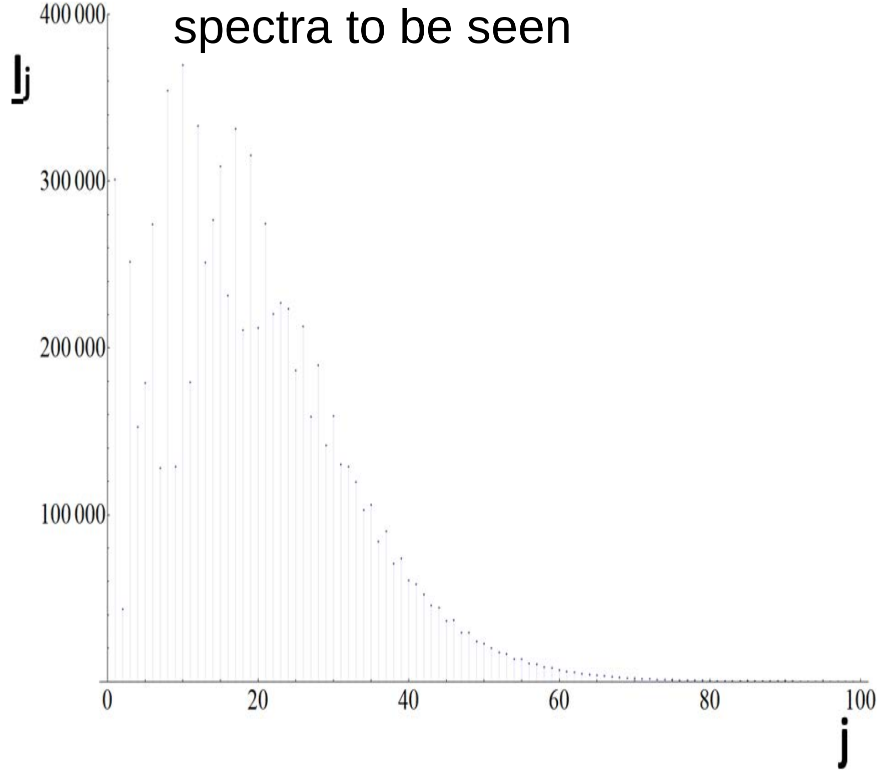
Experiments at E7: Nonlinear Scattering as extension method for the gamma range at ELI-NP

How to reach peak power



Focal distance correlation with the peak power in focus

Harmonics in the gamma spectra to be seen

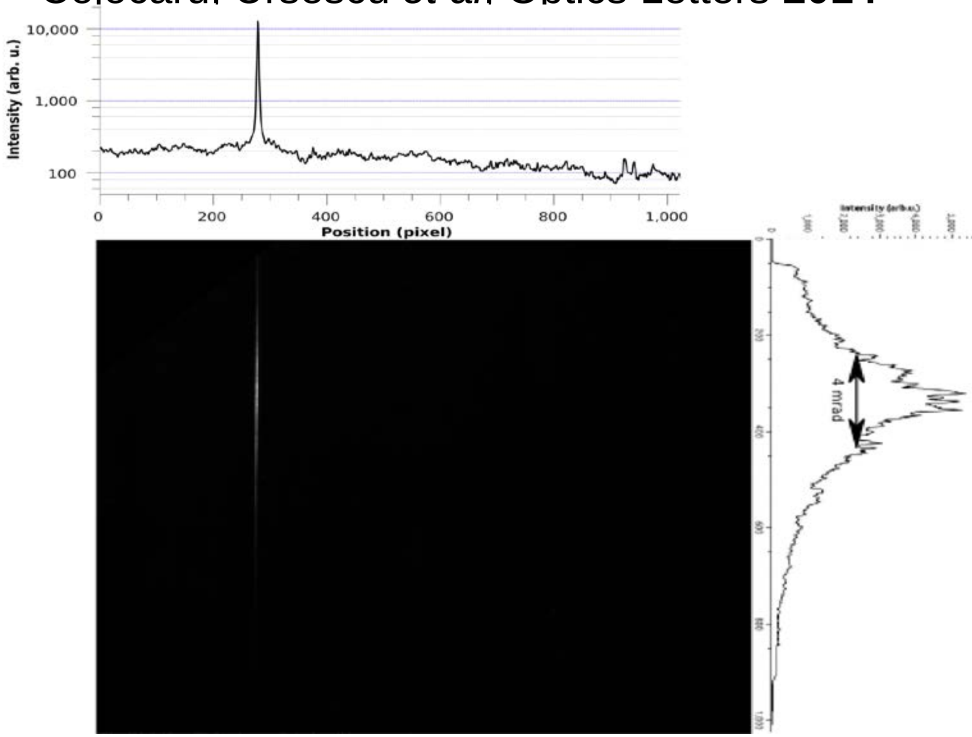


The spectrum of the normalized total scattered radiation for a=65.9. (I_j is the intensity of the j^{th} harmonic radiation).

Ionel, Ursescu, LPB2014

X-ray laser driven gamma source experiments proposal at ELI-NP

Banici,Ursescu *et al*, Optics Letters **2012**:
X-ray laser driven with 200mJ pump energy @13.9 nm and 10Hz
Cojocaru, Ursescu *et al*, Optics Letters **2014**



On-going Laserlab3 experiment for 200mJ pumped 100Hz X-ray laser @ MBI, Germany (D. Ursescu)

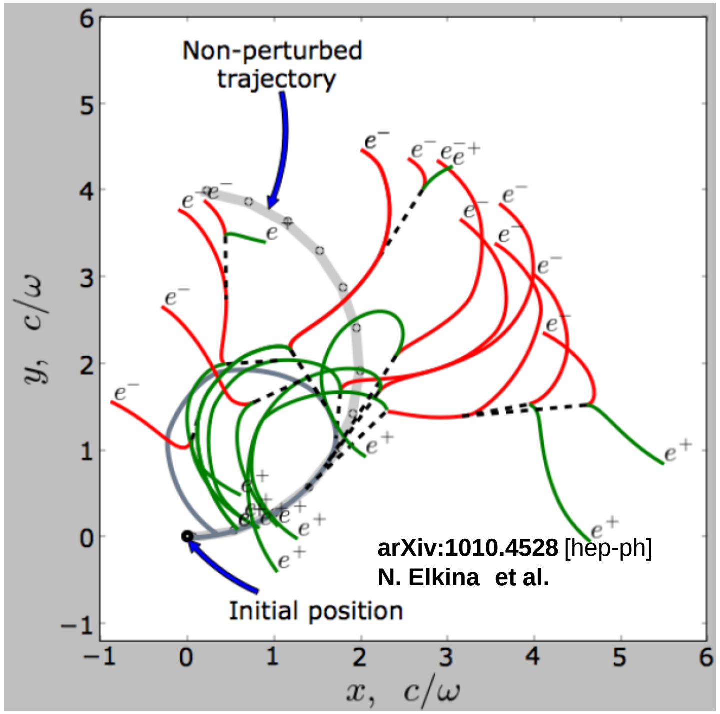
Available 100Hz laser for ELI-NP gamma facility with at least 200mJ energy/pulse

J. Rocca group, Optics Letters **2012**:
Demonstrated 100Hz operation of an XRL driven with 1000mJ pump energy @13.9 nm and 10Hz

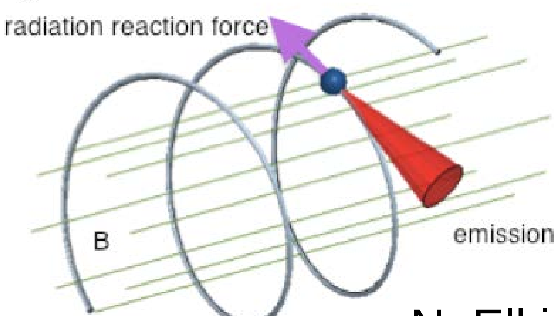
Specific technologies

- Target manipulation (gas target, solid target for bremsstrahlung generation)
- Beam manipulation (plasma mirrors, mirror shifting)
- Vacuum pipes
- Vacuum pumping
- Diagnostics of the beams at experimental areas (LBD?)
- Detection and data processing
- Beam dumps
- Logistics

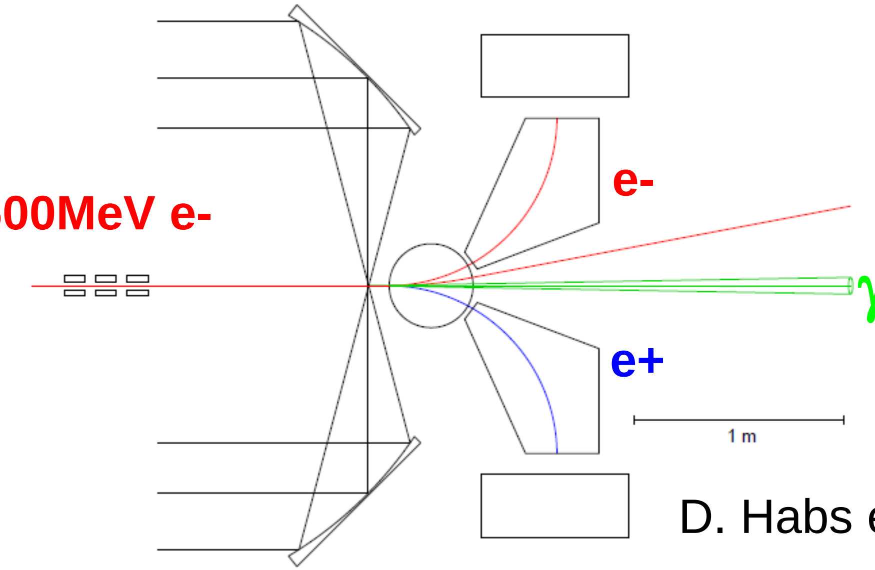
Laser-electron interaction



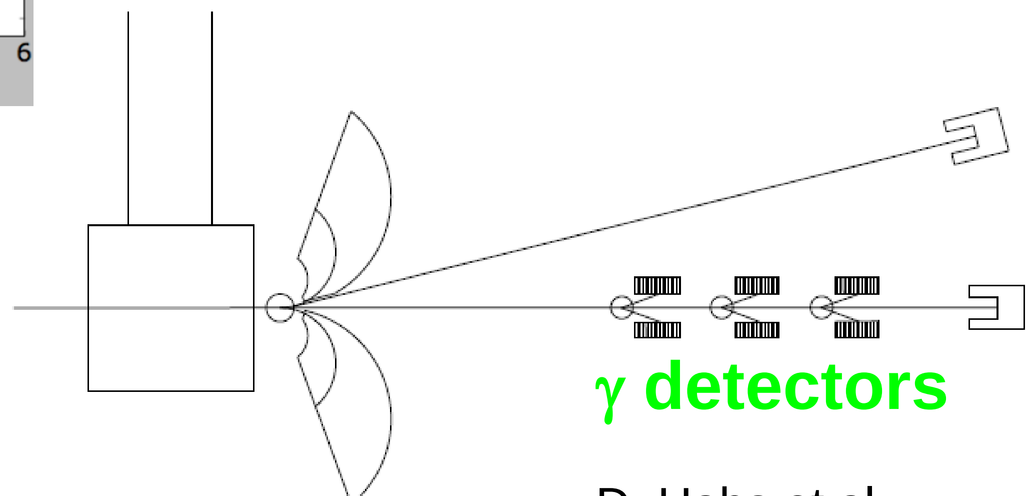
Syncrotron motion



N. Elkina



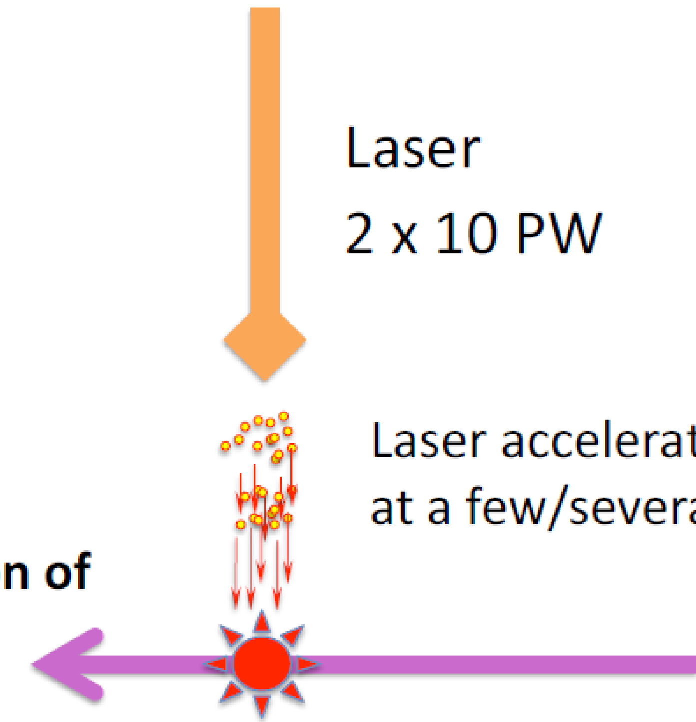
D. Habs et al.



D. Habs et al.

TDR3: Electron induced nuclear processes investigated with gamma beams

Hiroaki Utsunomiya



Photoexcitation of isomers may be induced by a simultaneous irradiation with a monochromatic γ-ray beam.

Content

- *Project outline*
- *Main tools*
- *Laser driven experiments*
  - *TDR1: Laser driven nuclear physics*
  - *TDR2: Strong field QED*
  - *TDR3: combined laser gamma experiments*
  - *TDR4: material science and applications*

TDR4: Applications of Material Science

- testing new materials for fusion and fission energy application
- testing of new materials for accelerator components
- testing materials for space science (electronics components, hypervelocity impacts)

- surface and volume modification; micro- and nano-technology)
- biological science research (effects on bio-molecules, cells)
- testing radiation hardness and developments of detectors
- irradiated optical components testing

Potential partners: *GSI, CERN, GANIL, Politecnico di Torino, ESA, Fraunhofer-Institut für Kurzzeitdynamik Ernst-Mach-Institut EMI*

Materials for Fusion Energy Systems

Extreme operating conditions on materials surrounding the plasma:

- high heat fluxes
- sputtering/redeposition
- T_2 retention

Key strategies for the coming decade:

- exploratory testing in prototypic fusion radiation environments (combined with modeling) to foster the development of candidate materials

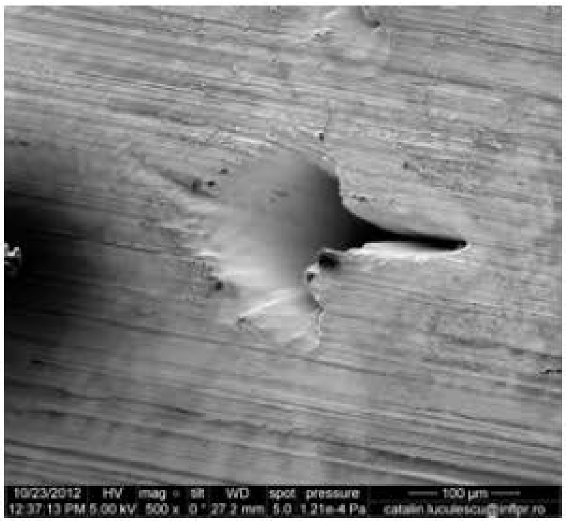
Key issues in fusion materials degradation

- Structural materials: dimensional stability and mechanical properties
- Diagnostic materials: strong changes in electrical and optical properties

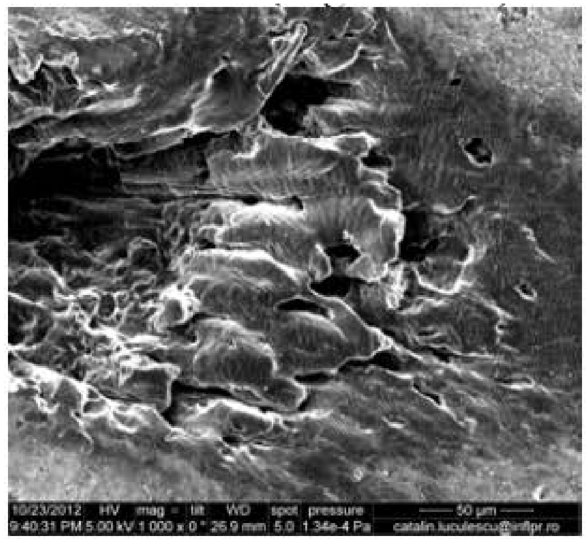
Key strategies for the coming decade :

- new high density structural materials with nanoscale features conferring improved mechanical strength and radiation resistance

Laser irradiation studies for fusion reactor materials



SEM W probe

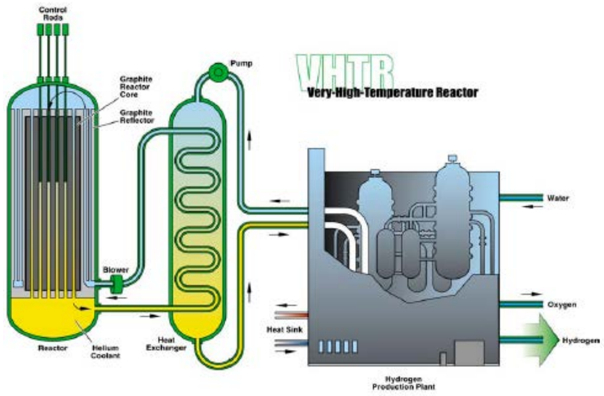


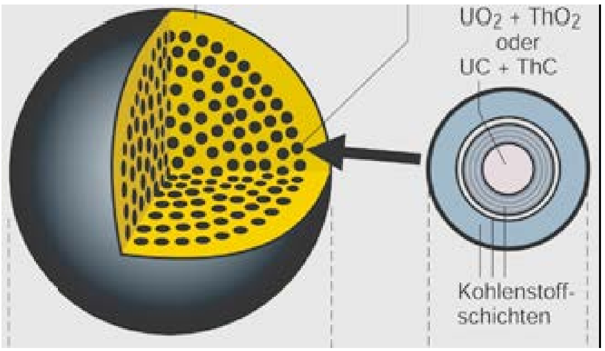
SEM C probe

SEM Be probe

Lungu, Ursescu et al, APL2014

Materials for Fission Energy Systems





Very High Temperature Reactor Purpose:

- More Efficient Power production
- Inherent passive safety features

Breakthroughs needed

- materials for extreme environments, high temperature, high radiation flux, high corrosivity

Testing of new materials for accelerator components

High power targets: production targets for radioactive beams, neutrinos, spallation targets

- Potential collaborations: RADIATE, PASI

Secondary collimators for HL-LHC

-innovative materials are needed for accelerator collimator jaws for the upgrade of the LHC

-aims of collimator material experiments at ELI-NP: testing of novel materials under extreme conditions (accidental beam impact), quantifying of material damage for LHC operating scenarios

Radiation-hard Space Electronics

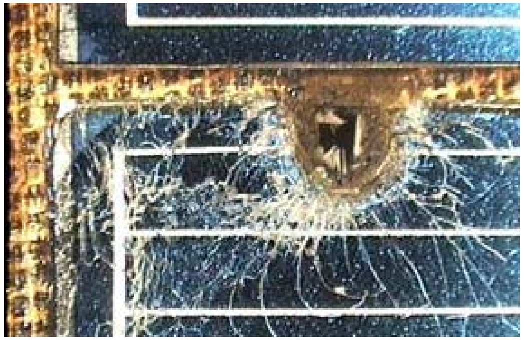
- Due to its use on low-Earth orbits, most consumer electronics is less tolerant to radiation effects, as communication (commercial) satellites are exposed to far less radiation than those placed on Geostationary orbits
- Sensors with increased ability used to gather satellite data
- Increased data traffic between satellites or back to Earth →need for more powerful algorithms and more logic in a smaller space, as satellite costs have to be “redimensioned “
- Power issues (solar cells), thermal issues and payload issues (processing large amounts of data and making decisions or send data to the ground)
- Processing power has to be “adjusted” to data traffic while using as little power as possible →shrinking of transistor size : 90 nm technology → worsening SNR
- Survival of 90 nm technology to aggressive space environment conditions
- Low voltages susceptible to radiation interference
- New technologies on the consumer market : wide-bandgap technologies
- Radiation effects: total dose, constant bombardment of radiation and low dose rate effects

Dynamic Response of Structural and Functional Space Materials to Micro-Meteoroid Impacts

Space environments are very hostile to many spacecraft materials and components due to the combined action of radiation, extreme temperature, and vacuum conditions, as well as impacting hypervelocity micro-particles:

- Can be investigated using shock waves induced with flyers launched in high-power laser impacts on specially designed targets. These experiments can be performed both on pristine materials and on samples that have been exposed to increasing cocktail doses of particles, simulating the natural radiation exposure in space.

19 mm crater in the High-Gain Antenna of the Hubble Space Telescope



Thousends of impacts on solar panels

Ground testing of space materials in extreme conditions

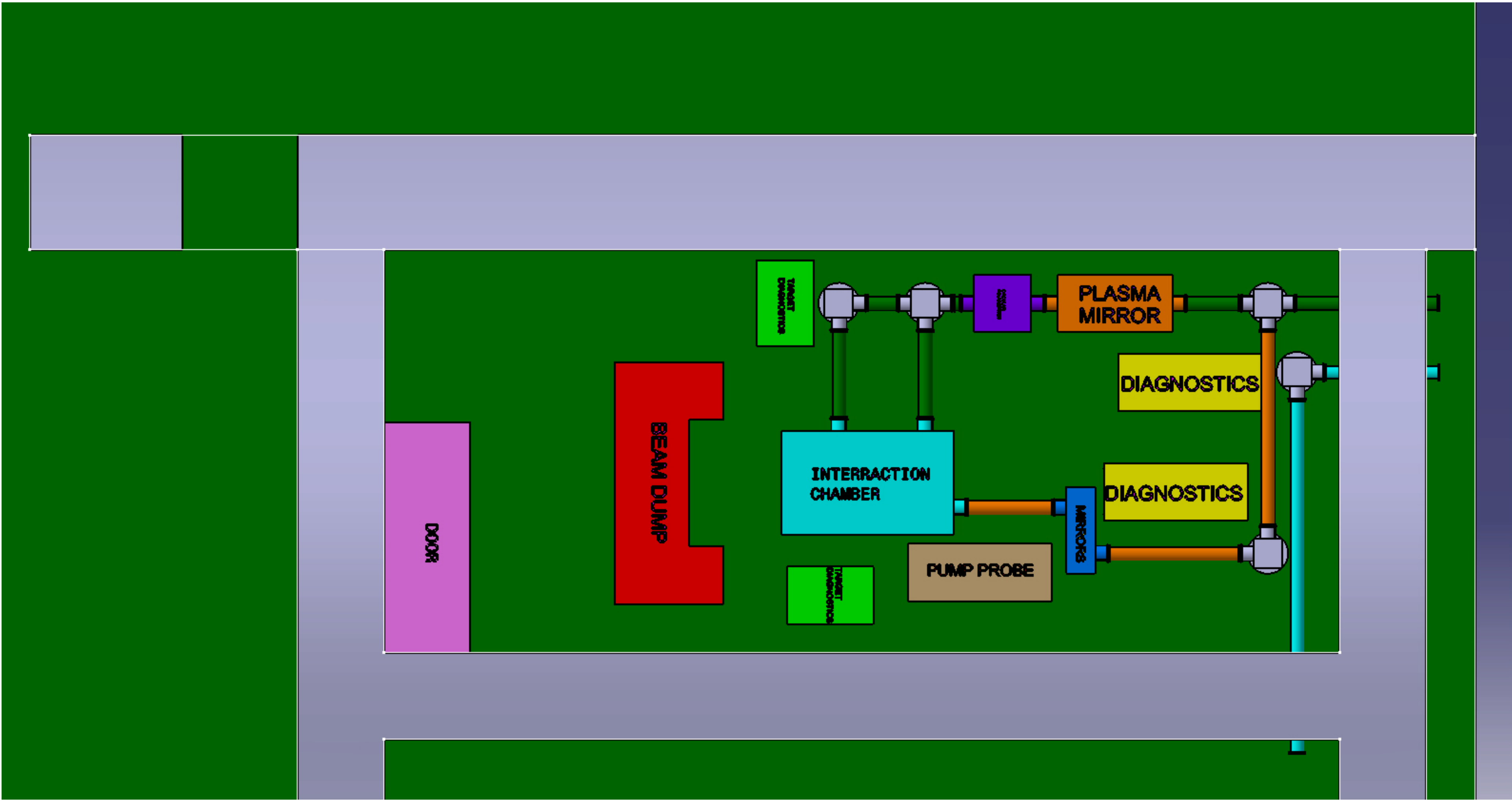
- The radiation environment used for ground testing should ideally be similar to the natural environment probed by the satellite
- This condition is difficult to achieve by traditional accelerator facilities
- Cosmic radiation includes protons, helium and heavier ions, and also electrons, neutrons, and ultraviolet radiation. In this complex radiation environment many materials are damaged and deteriorate in a complex manner
- The energy spectrum of laser accelerated particles is quite similar to the natural one (exponential energy distribution), unlike the quasi mono-energetic spectrum of accelerated particle beams in classical accelerators → develop rad hard testing procedures and standards
- Vacuum and extreme temperatures as well as thermal cycling alter physical properties and lead to material fatigue.
- Impacts of micro-meteoroids and orbiting man-made debris can damage spacecrafts and components.

Irradiated optical components testing

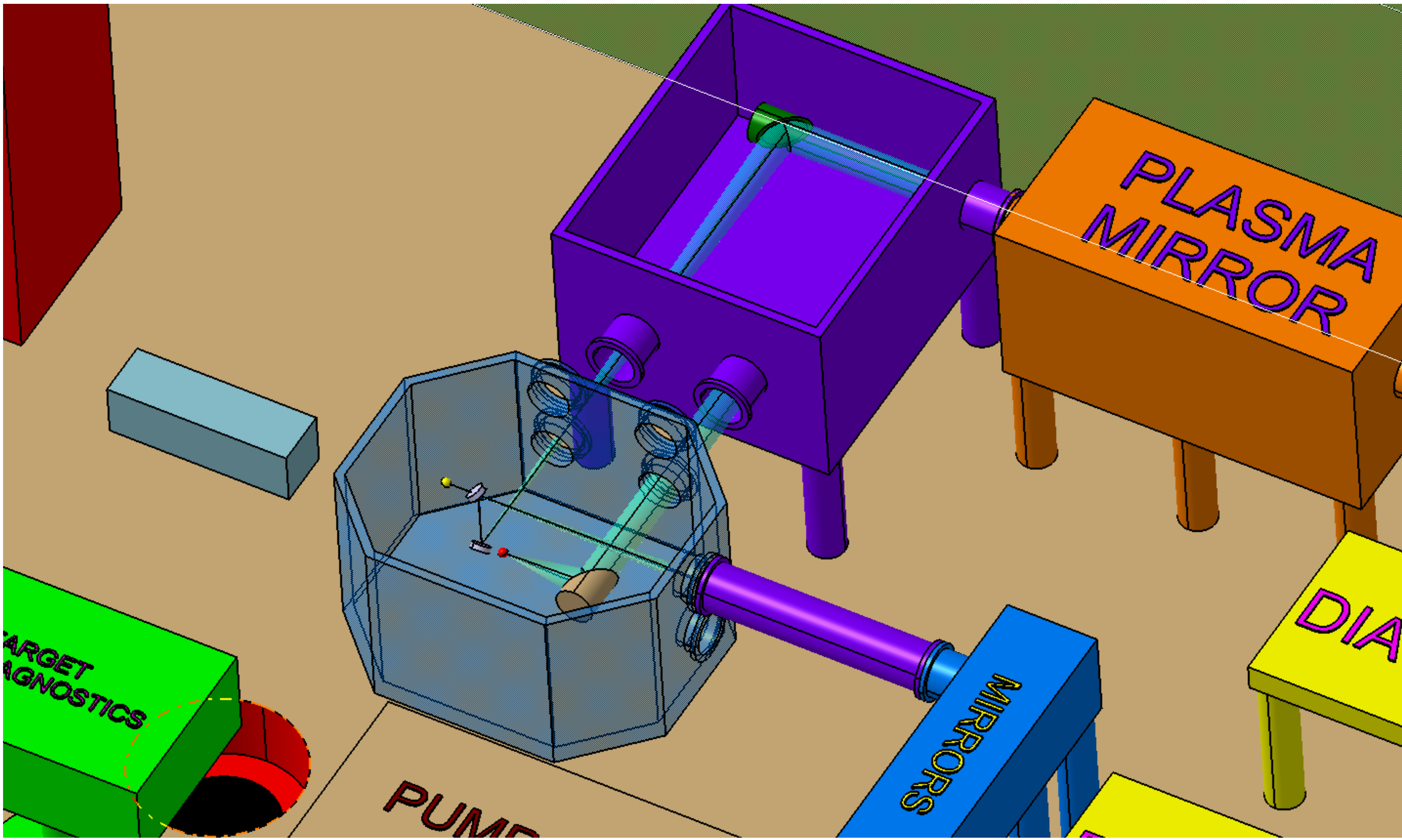
-characterization of optical components placed in the vicinity of laser driven secondary radiation sources

-measuring the damage threshold modification at ISOTEST (INFLPR)

E5 experimental area (2x1PW@1Hz)



Layout E5



Following steps

- TDRs to be completed between

  Fall 2014 and Winter 2015
- General workshop: Oct-Nov 2014
- TDRs evaluated by independent reviewers March-May 2015
- International Scientific Advisory Committee final endorsement of experiments in June 2015

EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2007-2013

Sectoral Operational Programme "Increase of Economic Competitiveness"

"Investments for Your Future!"

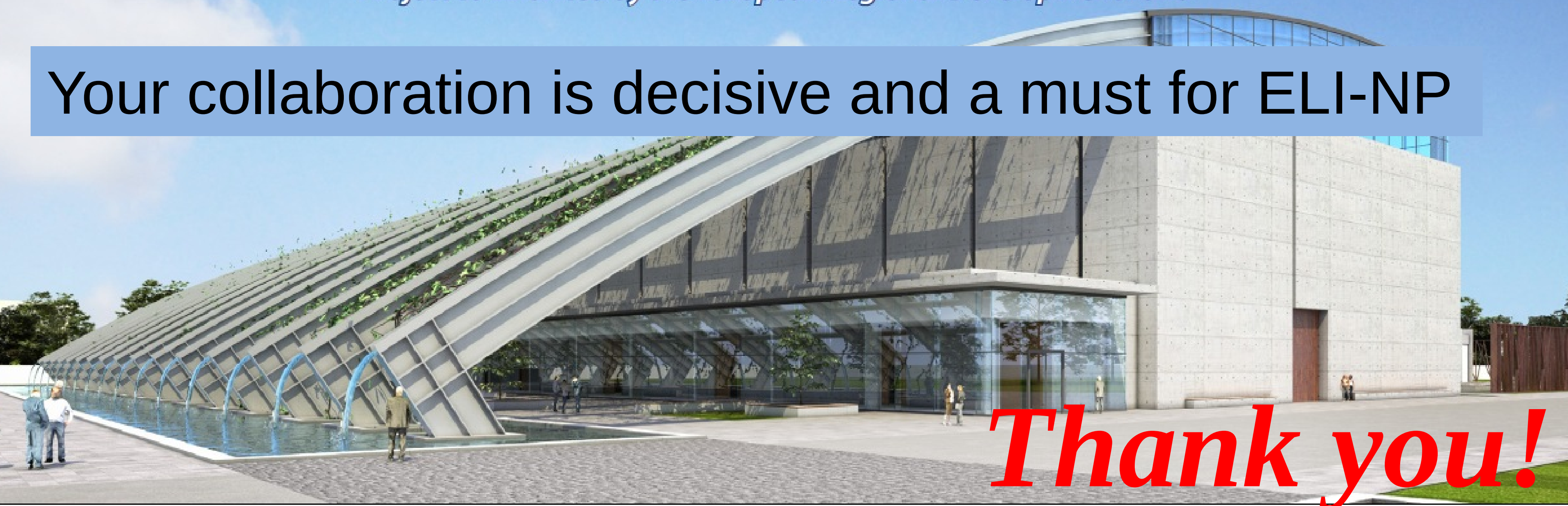
IFIN-HH

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

eli Nuclear Physics

www.eli-np.ro

Project co-financed by the European Regional Development Fund



Your collaboration is decisive and a must for ELI-NP

Thank you!