EUROPEAN UNION

GOVERNMENT OF ROMANIA

Structural Instruments 2007-2013

Operational Programme Competitiveness

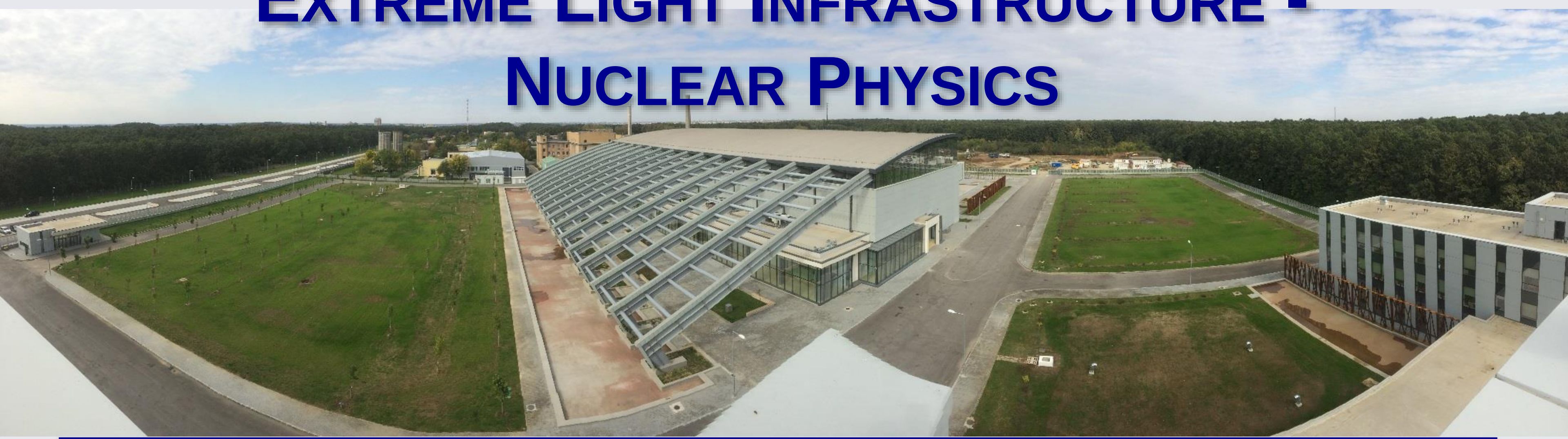
Extreme Light Infrastructure – Nuclear Physics (ELI-NP) – Phase II

Project co-financed by the European Regional Development Fund

NEW RESEARCH OPPORTUNITIES

AT

EXTREME LIGHT INFRASTRUCTURE - NUCLEAR PHYSICS



EuroNanoForum 2019

June 12-14, 2019

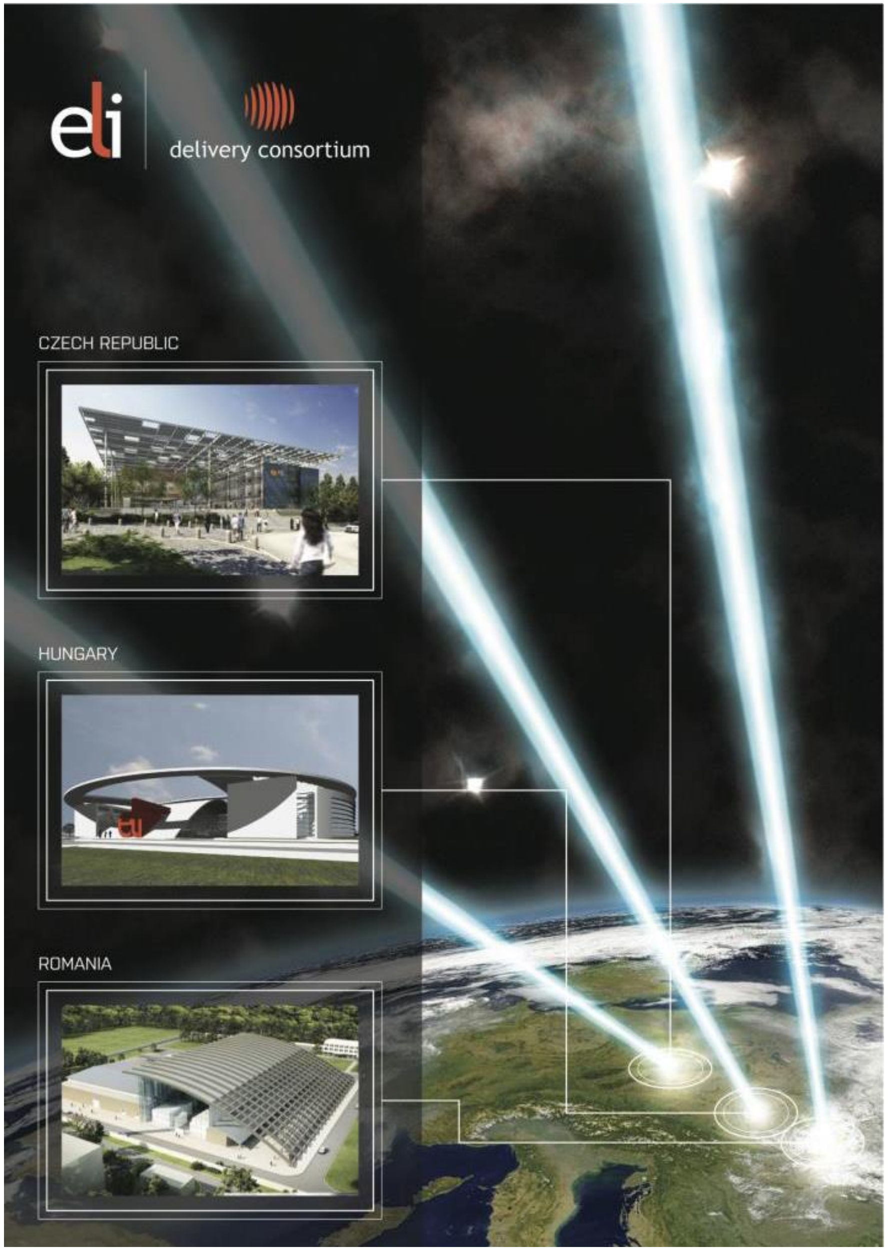
eli Nuclear Physics

IFIN-HH

CĂLIN A. UR

ELI–NP / IFIN–HH

ELI in a Nutshell



Extreme Light Infrastructure

Pan–European Research Center

Target: implement the world's largest laser research infrastructure

Infrastructure: distributed over three complementary pillars (CZ, HU, RO) – user facilities

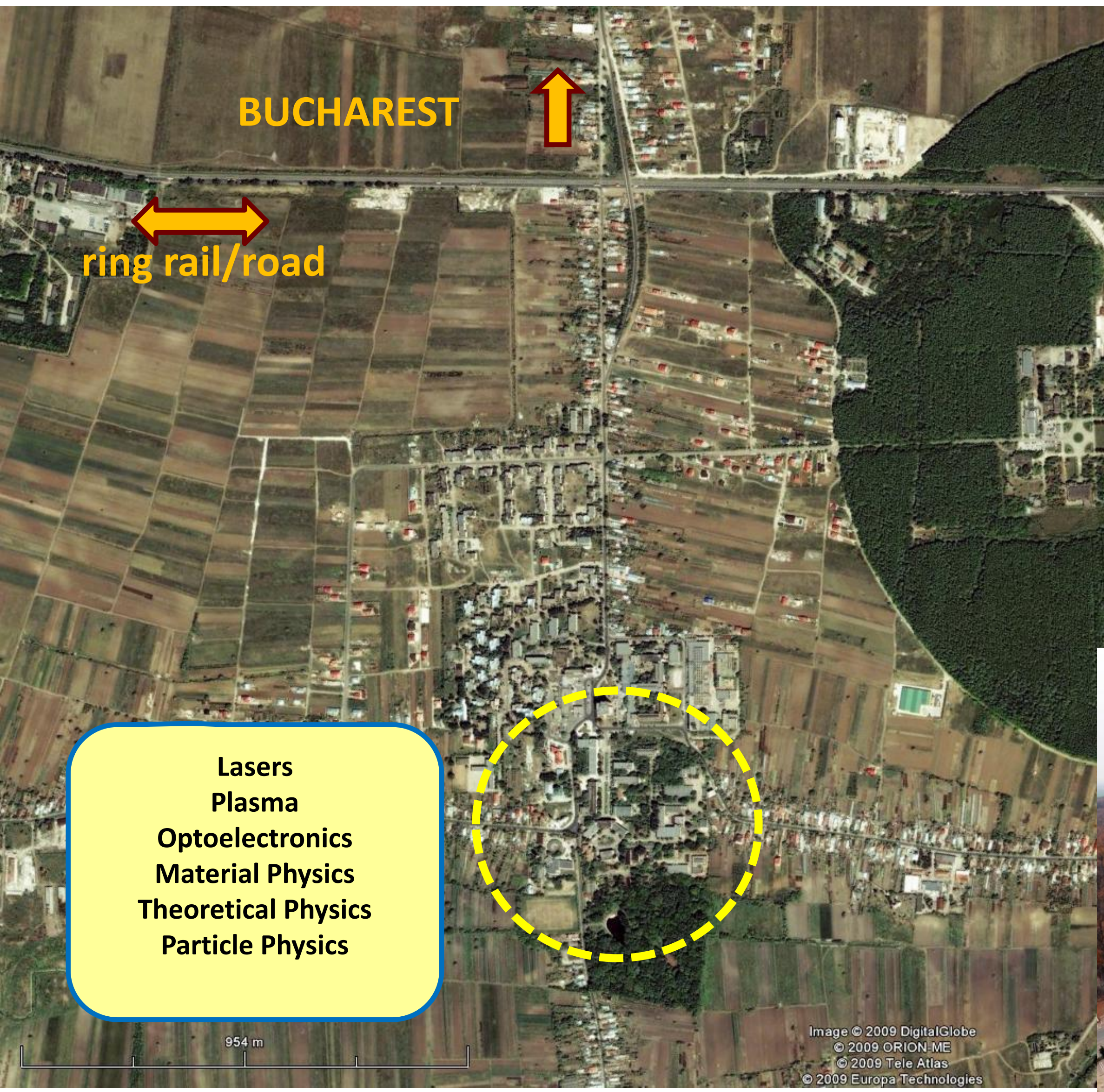
Strategy: first ESFRI project to be fully implemented in newer EU member states

Funding: novel model combining ERDF funds for the implementation and contributions to an ERIC for the operation

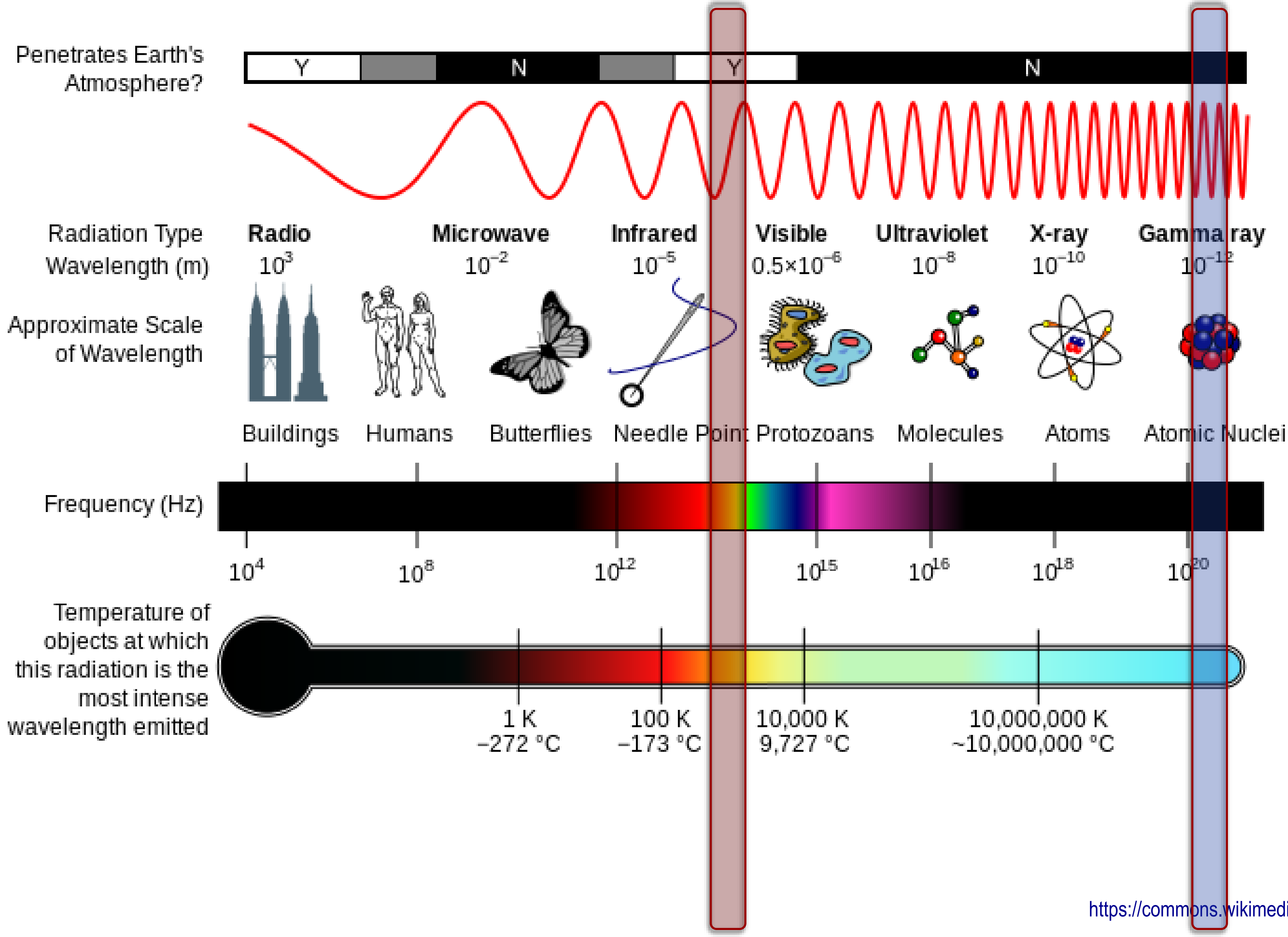
ELI–NP, Magurele, RO: Nuclear Physics Facility with ultra–intense laser and brilliant gamma beams

nuclear physics with extreme e.m. fields

ELI–NP – Magurele Physics Platform



Extreme Light to Study Matter



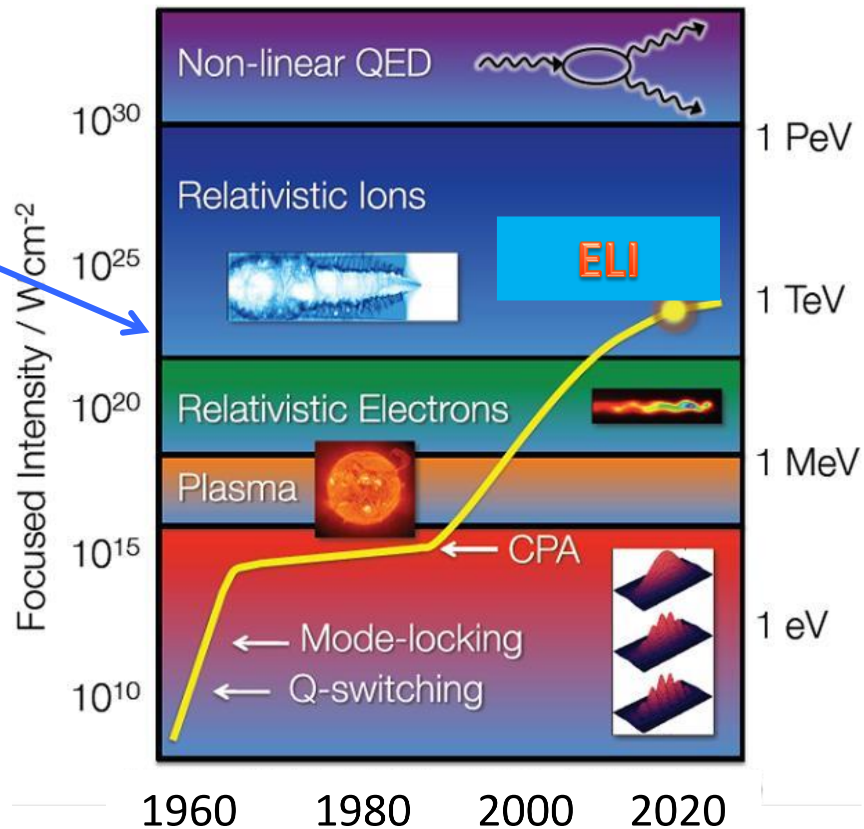
https://commons.wikimedia.org

ELI–NP The Most Powerful Laser in the World

Nuclear Physics

High Power Lasers = 2 x 10 PW

20 PW ~ 10% of the Sun power on Earth



Gerard Mourou

(The Nobel Prize in Physics 2018)

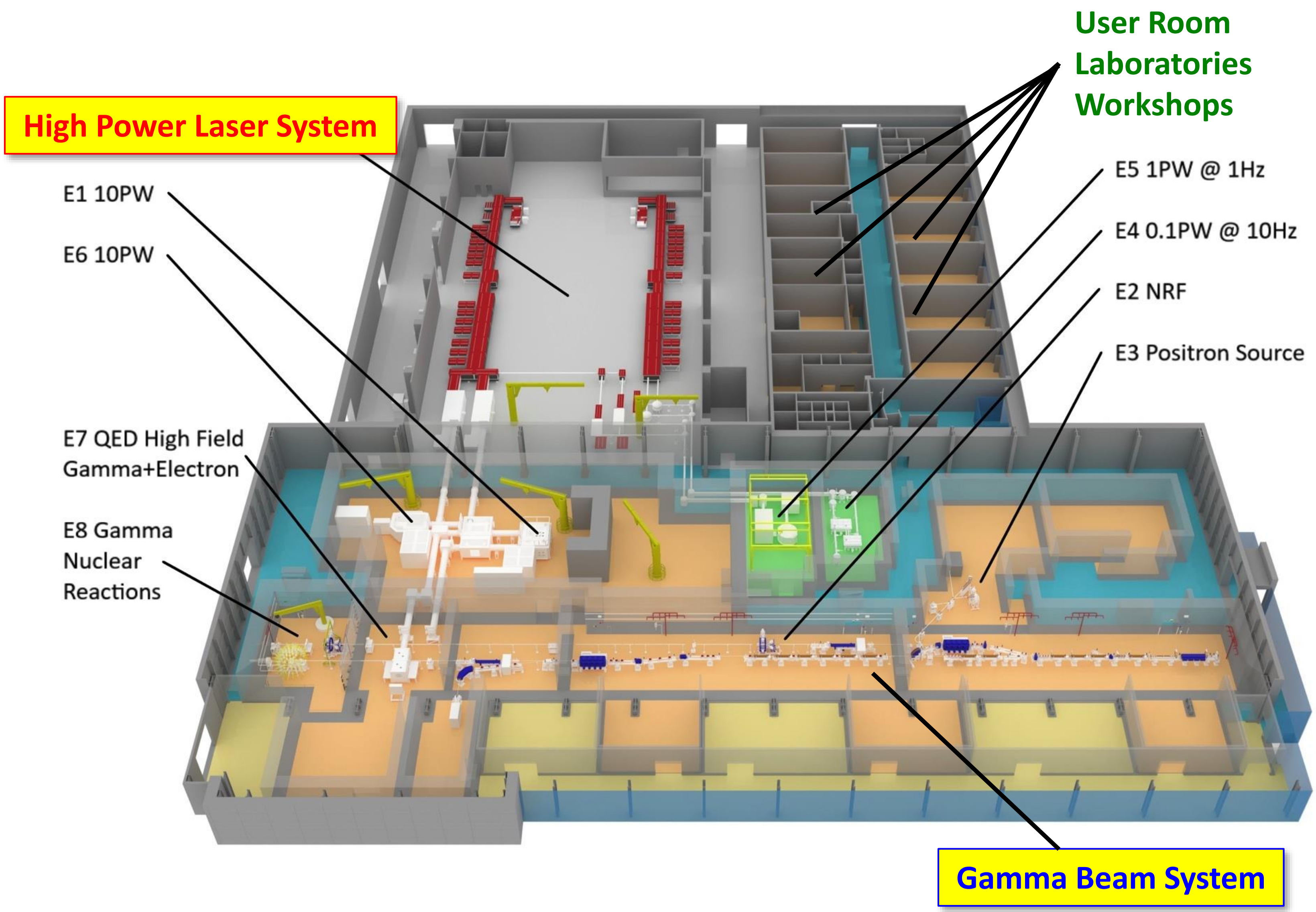
March 13, 2019

ELI-NP – has reached the highest level of power ever produced by mankind

10.88 PW

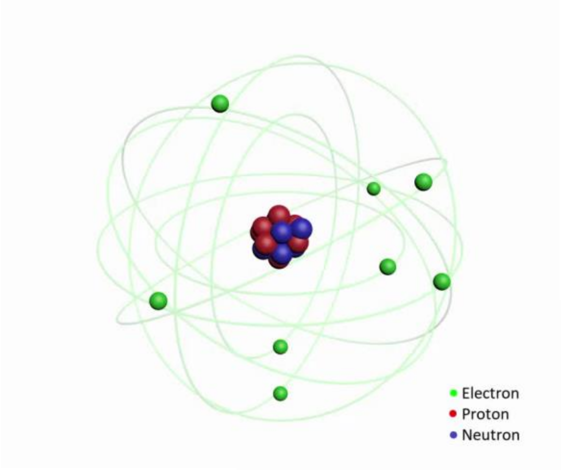
Gerard Mourou 1985: Chirped Pulse Amplification (CPA)

ELI–NP 3D Model Experimental Building



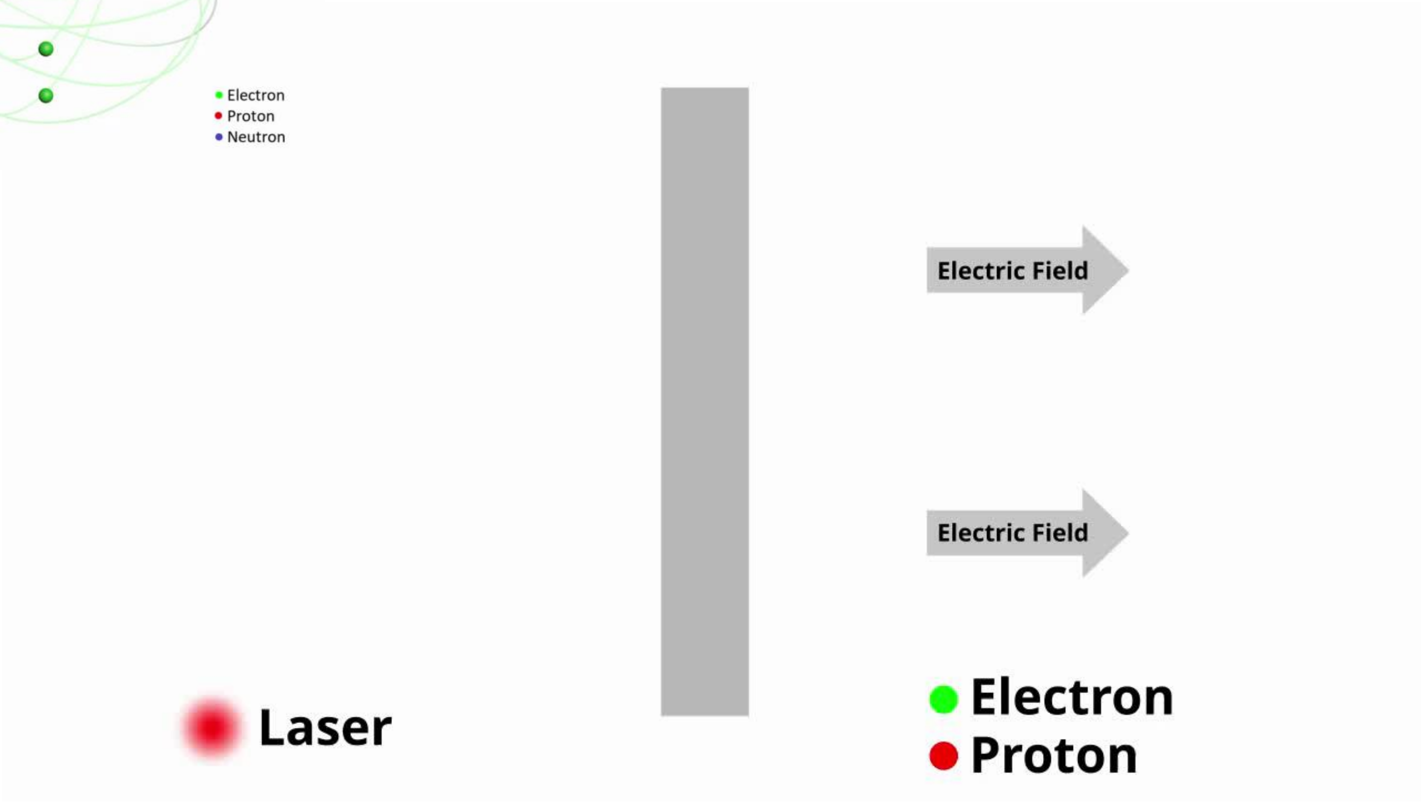
Extreme Light Interaction with Matter

Nuclear Physics

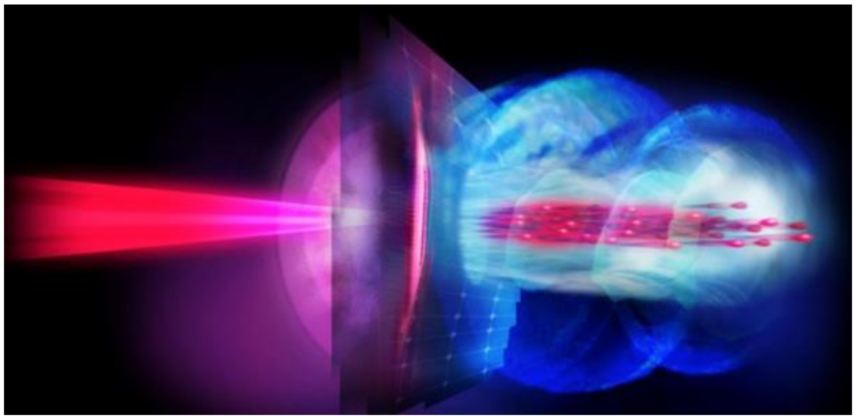


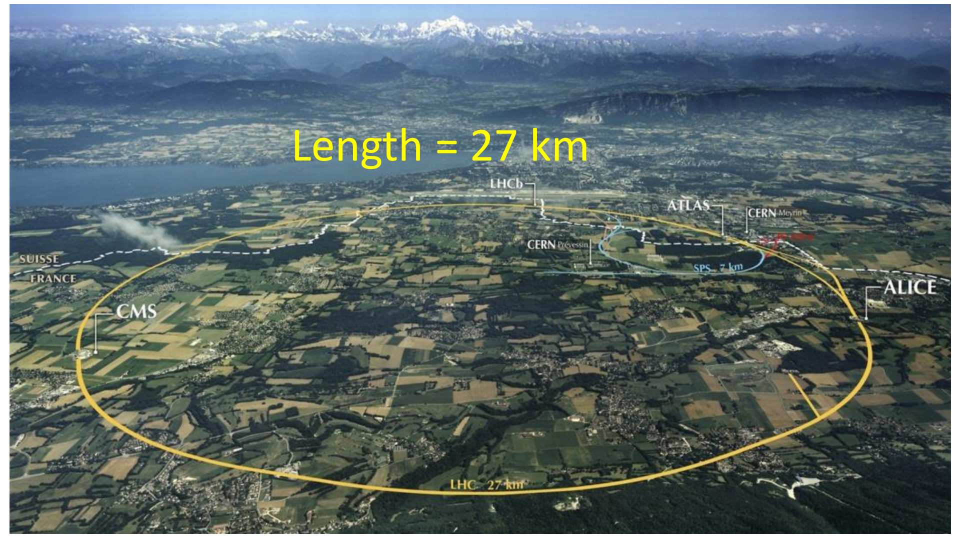
HPLS Focused Intensity ~ 10^{23} W/cm^2

Extreme Electric Fields ~ 10^{15} V/m



New Paradigm in Particle Acceleration





E~ 10^{15}V/m

CERN - Geneva

Electron and ion beams accelerated at solid state densities of 10^{24} cm^{-3}
(Classical beam densities ~ 10^{8} cm^{-3})

Acceleration on very short distances (µm-mm)

10 PW – Unique Experiments from Day – 1

Nuclear Physics

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

Extreme electric fields (10^{15} V/m)

Strong-field QED

10 PW laser + solid target

Ultra-intense PW γ-source

"Commissioning"

10 PW laser + GeV LWFA electrons

Radiation reaction, Breit-Wheeler pairs

Extreme light pressures (Tbar)

Nuclear Physics with Lasers

10 PW Radiation Pressure Acceleration of dense ion beams

Neutron-rich nuclei

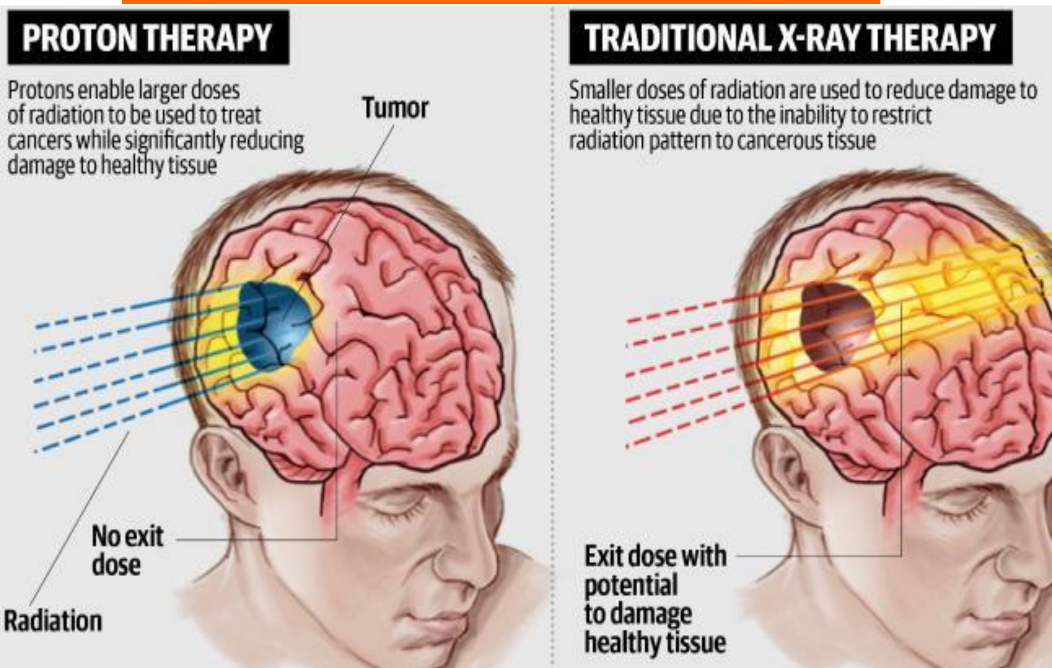
Ultra-intense neutron source

Nuclear reactions in plasmas

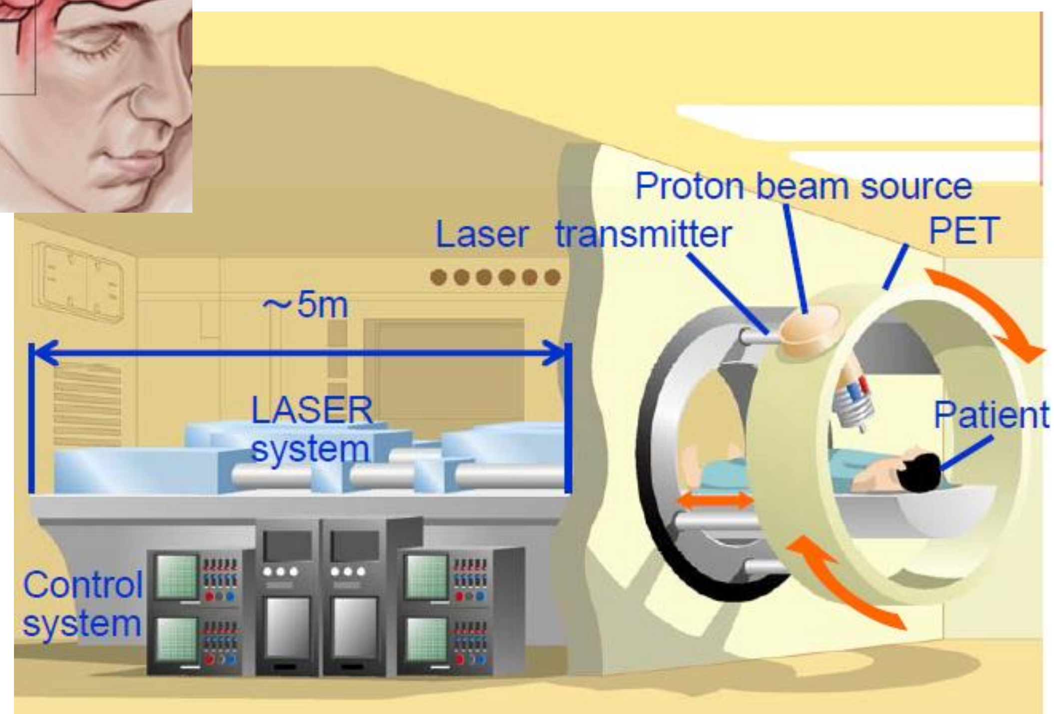
- **Goals of commissioning experiments:**
  - **physics based validation of laser system performance**
  - **develop particle beams for nuclear and QED experiments**

Medical Applications with High Power Lasers

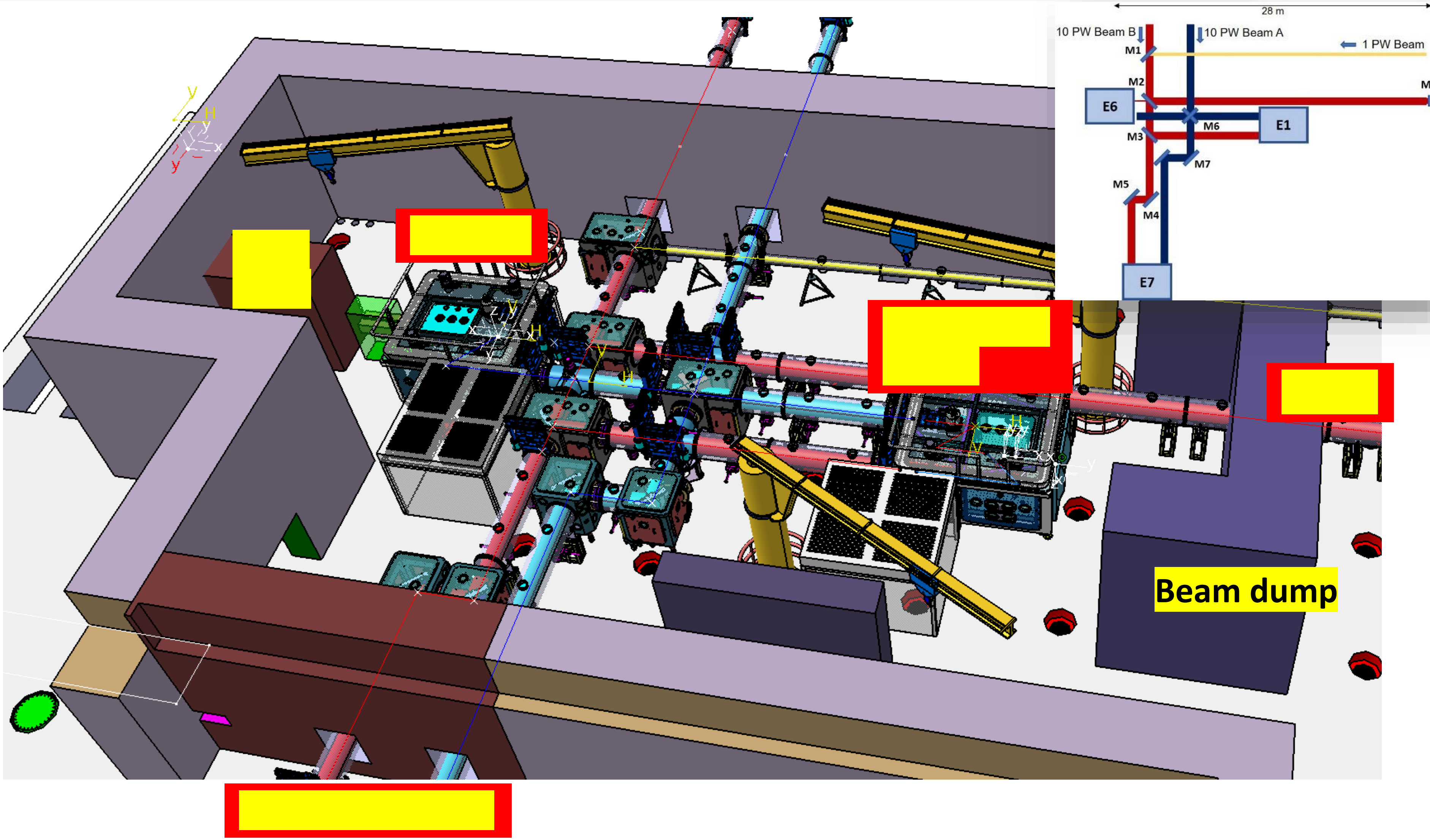
Therapy with proton beams



PW lasers can provide proton accelerators of compact sizes for hospitals



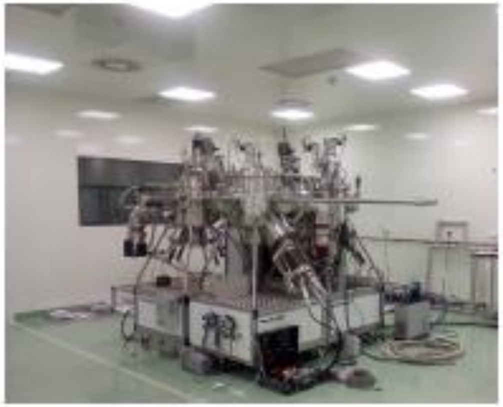
10 PW Laser Beam Transport System



- 2x10 PW beams + 1 PW auxiliary beam to any of 3 experimental areas
- 30 m focal length mirror for electron LWFA at 10 PW

Target Laboratory

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

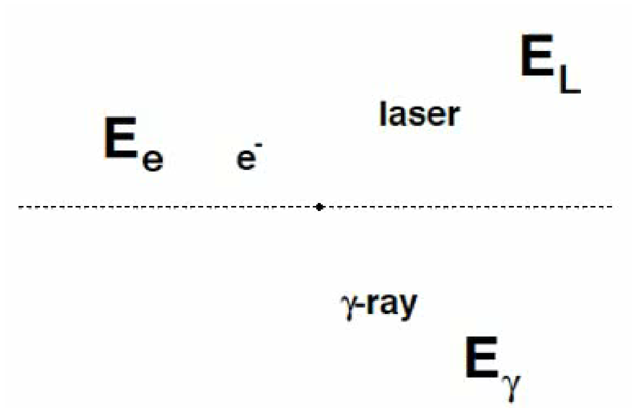


Characterization
- SEM (EDS / EBSD / EBL)
- optical profilometer
- AFM
- XRD
- optical microscope

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

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

ELI–NP Gamma Beam System Principles



Gamma–rays from Inverse Compton Scattering

photon scattering on highly relativistic electrons ($\gamma \gg 1$)

the most efficient frequency amplifier

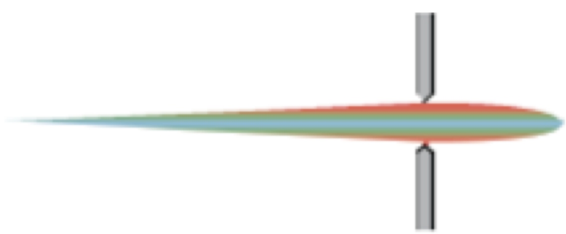
$$E_\gamma \approx 4 \cdot \gamma_e^2 \cdot E_L$$

'Photon accelerator'

Strong forward focusing of the scattered photons

$$\Delta\theta \approx \frac{1}{\gamma}$$

$\gamma = 10^3 \rightarrow \Delta\theta \sim 1$ mrad



Nuclear Photonics with Gamma Beams

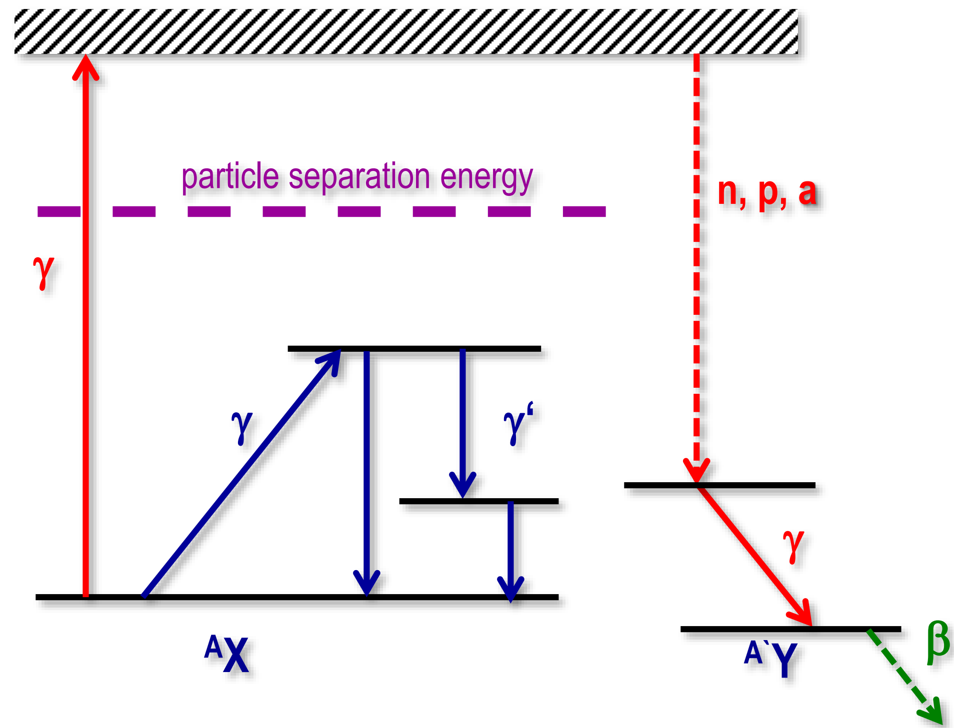
Fundamental Research

Nuclear Resonance Fluorescence

Nuclear Astrophysics (γ,p) (γ,α)

Photonuclear Reactions (γ,n)

Photofission & Studies of Exotic Nuclei



Applications

Gamma Imaging

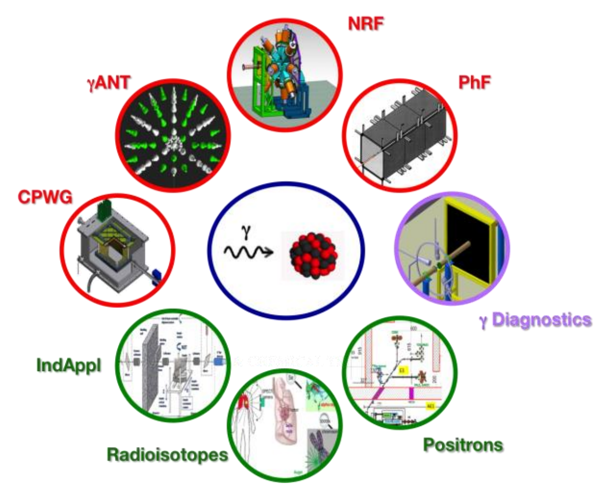
Material Science with Positrons

Medical Radioisotopes Production

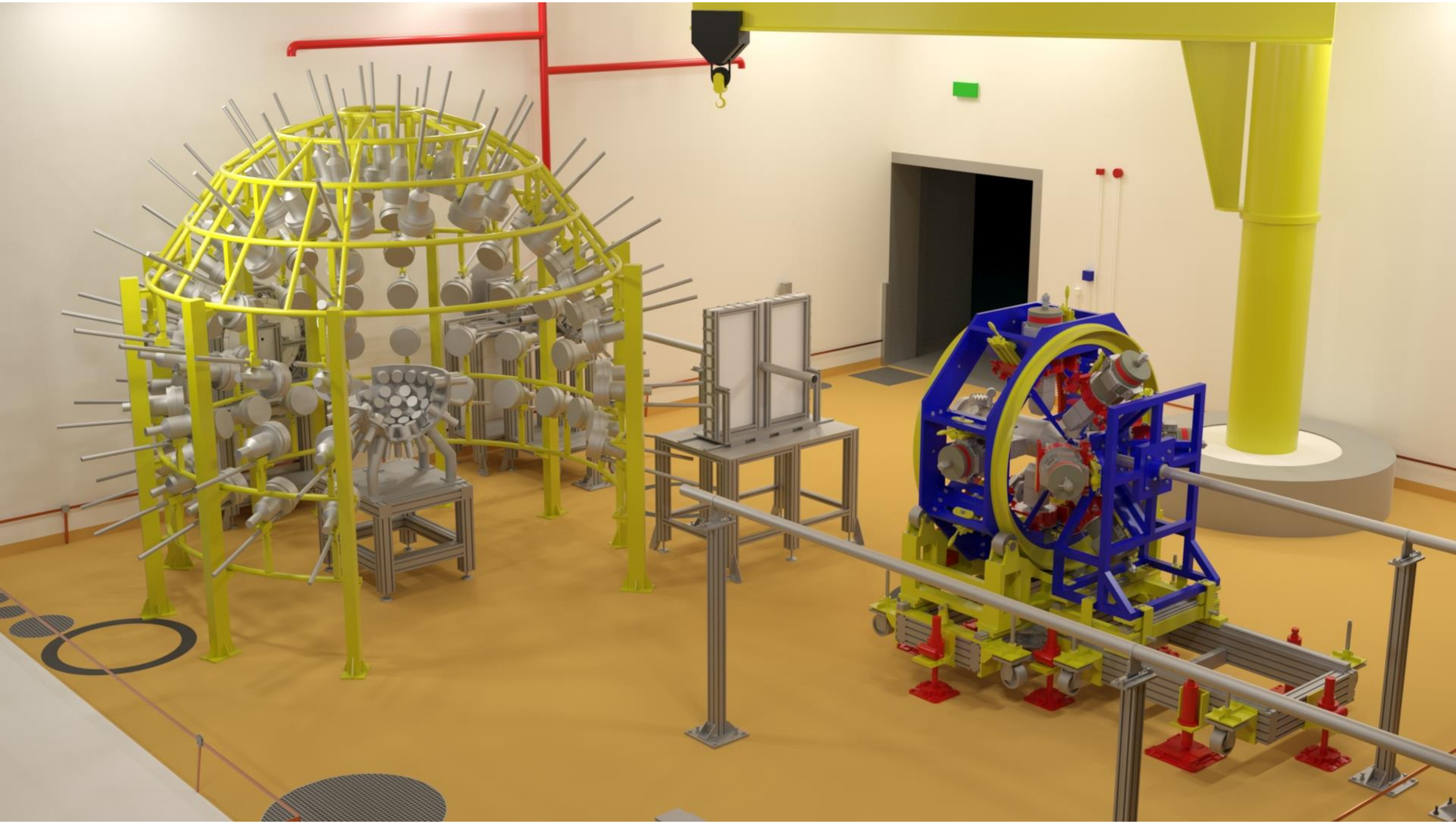
R&D Gamma Beam Diagnostics Detectors

Gamma Beam Delivery and Diagnostics

Broad International Collaboration
Germany, USA, Japan, Italy, Hungary, France,
Poland, Belgium, Vietnam, Switzerland, UK, Russia, Israel, China, …



ELIADE and ELIGANT



NRF Applications: Non–destructive investigation

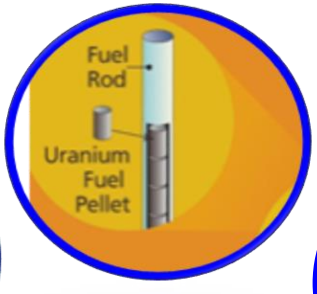
Aim: Use the gamma beam as a probe to study the structural properties and the elemental composition of industrial objects

NRF + CT: Elemental/isotopic maps

A. Active interrogation – Nuclear Resonance Fluorescence

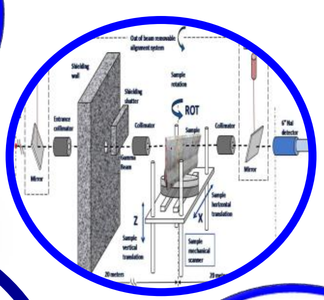
B. High resolution radiography and tomography imaging

Nuclear fuel[1]

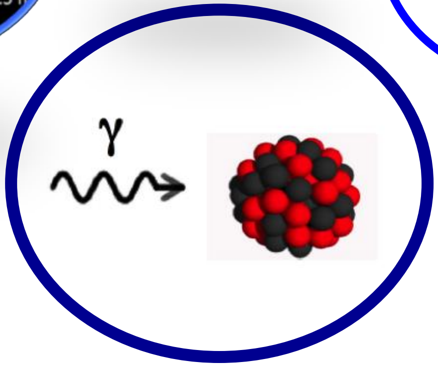


Special Nuclear Materials

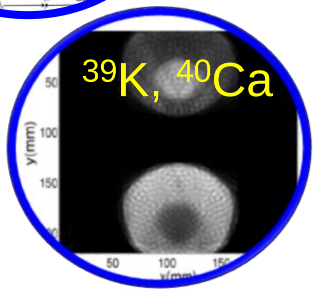
Industrial CT



Cultural Heritage



Density screening[2]



[1]nrc.gov; [2]M. N. Lakshmanan et al. Nucl. IEEE Trans. Med Imag. 33, 546 (2014)

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Thank you!

We invite you to visit our facility