Operational Programme Competitiveness

Extreme Light Infrastructure – Nuclear Physics (ELI-NP) – Phase II
Project co-financed by the European Regional Development Fund

EXTREME LIGHT INFRASTRUCTURE

NUCLEAR PHYSICS

CĂLIN A. UR
ELI-NP / IFIN-HH
June 2018
ELI–NP – Magurele Physics Platform

NUCLEAR
Tandem accelerators
Cyclotrons
$\gamma$ – Irradiator
Advanced Detectors
Biophysics
Environmental Phys.
Radioisotopes

ELI-NP

Lasers
Plasma
Optoelectronics
Material Physics
Theoretical Physics
Particle Physics
ELI–NP – Experimental Building

Ready since September 2016!
ELI–NP 3D Model Experimental Building

- High Power Laser System
  - E1 10PW
  - E6 10PW

- Gamma Beam System
  - E7 QED High Field Gamma+Electron
  - E8 Gamma Nuclear Reactions

- User Room Laboratories Workshops
  - E5 1PW @ 1Hz
  - E4 0.1PW @ 10Hz
  - E2 NRF
  - E3 Positron Source
The HPLS system

Unique features worldwide: 250 J in 25 fs, Strehl ratio 0.9, contrast ratio < $10^{-13}$

Outputs: 2 x 10 PW / 1 min
2 x 1 PW @ 1 Hz  2 x 100 TW @ 10 Hz

Thales Optronique, France
Thales Romania
Compressors ready to go ...

Both front-ends operational

Thales Optronique, France  &  Thales Romania
HPLS Characterization – Contrast ratio

Foreseen $10^{-13}$ OCPA Contrast

Intensity (normalized)

$E_{-40\text{ps}:0.4\text{ps}} = 30\text{mJ}$
Confirmed performance up to 3 PW

100 TW
Output energy  \( \sim 2.13 \text{ J} \)
Pulse duration  21.1 fs
Strehl ratio  0.9

3 PW
Injected energy  \( \sim 92.3 \text{ J} \)
(attenuated before compressor)
Compressor efficiency  74%
Pulse duration  22.7 fs
Strehl ratio  0.72

1 PW
Injected energy  \( \sim 35.97 \text{ J} \)
(attenuated before compressor)
Compressor efficiency  \( \sim 70\% \)
Pulse duration  23.2 fs
Strehl ratio  0.8

After tuning
Strehl ratio  0.88
- 2x10 PW beams + 1 PW auxiliary beam to any of 3 experimental areas
- 30 m focal length mirror for electron LWFA at 10 PW
Two identical chambers of 4.2 x 3.5 meters
Floor supported Al optical tables for vibration insulation
Wide range of 2x10 PW optical setups possible
Experimental area E5 for materials irradiation experiments with mixed radiation
Developing a State-of-the-Art Target Laboratory

Surface 268 m²
ISO 7, ISO 6 cleanrooms
(10,000, 1,000 cleanliness)

Capability to produce thousands of targets/day needed for high rep rate lasers
Target Laboratory

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

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

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

**Cleaning methods**
- Plasma (O₂, Ar, SF₆)
- Ion beam (Ar)
- thermal treatments
Design of 10 PW solid target commissioning setup in E1

- Experiment: demonstrate intensity $I > 10^{22} \text{ W/cm}^2$ through laser-\(\gamma\) ray conversion
- Plasma mirror protects laser optics from target back-reflection
• Experiment: collision of multi-GeV electron beam with $I>10^{22} \text{ W/cm}^2$ laser
• Electron spectrometers measure radiation reaction QED effects
Time Plan of ELI-NP (tentative)

ELI-NP RA3 Experiment Schedule (tentative)

- Comm Exp. 100TW E4/E5 (Betatron X rays) 12/1/2018 - 12/31/2018
- Comm Exp 1PW E5 (On-shot laser contrast) 1/1/2019 - 1/31/2019
  - Day 1 Exp 1 PW E5 (p/e/X beams) 10/1/2019 - 11/1/2019
  - User Exp 1PW E5 (Call proposals) 1/6/2020 - 12/31/2020
- Preparing E5 Area 10/1/2018 - 11/30/2018
- Installing & Testing E5: Chambers, BD, Mirrors and Diags 3/1/2019 - 9/18/2019
  - Comm Exp 10 PW E1 (Laser-gamma conversion) 1/6/2020 - 2/7/2020
  - Day-1 Exp. 10 PW E1 (200 MeV protons) 4/15/2020 - 5/15/2020
  - Comm Exp 10 PW E6 (10 PW electron LWFA) 8/8/2020 - 7/10/2020
  - User Exp 10 PW E1 (Call proposals) 8/15/2020 - 9/12/2020
  - User Exp 10 PW E6 (Call proposals) 9/28/2020 - 10/30/2020
  - Day-1 Exp 10 PW E1 (RPA dense beams) 11/9/2020 - 12/11/2020
- Installing & Testing E1+E6 (Chambers, BD, Mirrors and Diags) 9/1/2019 - 12/20/2019

- High Power Laser 3/31/2019
- Laser Beam Transport System 8/31/2019
- Call 0 Proposal Open 8/6/2018
- PWVE delivery 5/1/2019
- 10 PW Laser Beam Transport System 8/31/2019

Q1 2019 Q2 Q3 Q4 Q1 2019 Q2 Q3 Q4 2020
Gamma Beam System
ELI–NP Gamma Beam Diagnostics

Needs
• precise measurement of beam parameters is essential
• instruments need to be very well characterized
• multiple monitoring devices (the more, the better)
• it doesn’t stop here. more devices to be proposed
• experiments have dedicated floor space
• beam transport is versatile / changes are possible

Challenges
• beam size: 1 mm at 10 m away from collimator
• energy spread: 50 keV at $E_\gamma=10$ MeV
• time structure: micropulses at 16 ns
• photons/pulse: $10^5$
• photons/macro-pulse: $32\times10^5=3\times10^6$
• photons/s: $3\times10^8$
ELI–NP Gamma Beam Diagnostics

- Intensity/Polarization monitoring
  - deuteron photodisintegration
- Intensity monitoring
  - photo-fission of $^{238}$U
- Energy monitoring
  - HPGe + anti-Compton shield
  - LaBr3 + anti-Compton shield
- Time structure monitoring
  - small plastic/LaBr3
- Spatial structure monitoring
  - CCD camera
GBS – Polarization and intensity

- photo-dissociation of the deuteron in the d(γ,n)p reaction
- significant theoretical and experimental work over the last 40 years to understand the differential cross section and polarization asymmetry
dgn @ HIGS – circular polarized beam

- $E_\gamma = 3$ MeV
- $E_n = 384$ keV (ideal beam & target)
- Li-glass at 15 cm
- D$_2$O target ($L=4$ cm, $\Phi=3$ cm)
dgn @ HIGS – linear polarized beam

- $E_y = 3$ MeV
- $E_n = 384$ keV (ideal beam & target)
- Li-glass at 15 cm
- D$_2$O target ($L=4$ cm, $\Phi=3$ cm)
**GBS – Polarization and intensity**

\[ B_{pol} = \frac{A_{measured}}{A_{expected}} \]

\[ B_{pol} = \frac{0.89}{0.9} = 98.9\% \]

Linear polarization, in-plane vs. out-of-plane

\[ A_{pol} = \frac{\sum_{\text{in-plane}} \frac{Y_L}{Y_C} - \sum_{\text{out-plane}} \frac{Y_L}{Y_C}}{\sum_{\text{in-plane}} \frac{Y_L}{Y_C} + \sum_{\text{out-plane}} \frac{Y_L}{Y_C}} = \frac{\frac{2650-330}{430} - \frac{710-420}{892}}{\frac{2320}{430} + \frac{290}{892}} = 0.89 \]
GBS – Spatial Characterization

Proposed setup at ELI-NP:
- CCD camera detector system, possible
- design requirements: sub-mm resolution and high contrast

Advanced design:
- screen at 45° to the beam axis
- LSO, BGO or CsI(Tl) scintillator
GBS – Spatial Characterization

Images acquired with CCD camera
(StarLight express).

- Screen → BGO 2mm thick
- Source → $^{152}$Eu
- Acquisition time → 10 minutes
- 57 $\mu$m/pixel

Horizontal profile of the spot
GBS – Spatial Characterization

Image acquired with CCD + CsI(Tl) and gamma source

- CCD binning → 4 x 4
- Acquisition time → 10 min
- Image processing → ImageJ

Copper frame
GBS – Day–1 Experiments

ELIADE array
in collaboration with U. Koeln and TU Darmstadt

• detector and electronics tests are ongoing
• array implementation is at a final stage
• day-one experiments are under discussion

angular distributions
polarization measurements

Ready for first in-beam tests:
Dec. 2018
GBS – Day–1 Experiments

ELIGANT-TN array
30 $^3$He counters
40% detector efficiency
In collaboration with U. Konan

Ready for first in-beam tests: today
GBS – Day–1 Experiments

ELIGANT-GN array
30 LaBr₃ or CeBr₃
20 ⁷Li glasses
30 Lq. Scint.

In collaboration with U. Milano
Gamma Beam System – Status of Implementation

Accelerator Bay 1: LE GBS

Accelerator Bay 2: HE GBS

Gamma Source Room: HE GBS diagnostics

Same as in March 15th, 2018!

EuroGammaS Association
(INFN, Univ. Sapienza, CNRS, Scandinavian Systems, COMEB, ACP, ALSYOM)
Concluding Remarks
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/cm²
- Electron acceleration > GeV
- Proton acceleration > 200 MeV

Gamma Beam System
- Gamma photon energy calibration-Nuclear excitation 3.5 or 19.5 MeV
- Polarization > 95%
Thank you!