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

Fission Studies at the New ELI-NP Facility

Dimiter L. Balabanski

Extreme Light Infrastructure (ELI)

Gerard Mourou 1985: Chirped Pulse Amplification (CPA)

Bucharest-Magurele
National Physics Institutes

Nuclear Physics

BUCHAREST

ring rail/road

NUCLEAR
Tandem accelerators
Cyclotrons
γ – Irradiator
Advanced Detectors
Biophysics
Environmental Physics
Radioisotopes

ELI-NP

Lasers
Plasma
Optoelectronics
Material Physics
Theoretical Physics
Particle Physics
2005: The ELI project was initiated
2007: Identified by the ESFRI Council as top priority research infrastructure
EC supported a 36-month Preparatory Phase Project

May 2009: Four main research topics were identified, among them ELI-NP
December 2009: Approval of the Competitiveness Council

January 2012: Project submitted to the EC
July 2012: Romanian Government Decision
   Construction of the New Research Infrastructure ELI-NP: 293 M€

September 2012: EC Project Approval
   European Regional Development Fund
   Operational Programme Increase of Economic Competitiveness
   “Investments in your Future”
   Financial Support (83%) of the First phase (2012-2015) 180 M€
- Two 10 PW lasers
- Brilliant up to 20 MeV γ beam of $10^{-3}$ BW
ELI-NP Status

December 2012: *Tenders for civil construction and major instrumentation*

May 2013: *Earth breaking*


July 2013: *Laser-Beam System (LBS) contract signed*


March 2014: *Gamma-Beam System (GBS) contract signed*


April 2013: *Science Division of ELI-NP was established*

  Definition and preparation of experimental TDRs (due in early 2015)

2015: *Tenders for experimental instrumentation*

2017: *Commissioning experiments*
2x10PW Laser Contract

July 12th, 2013
Thales Optronique SAS and S.C. Thales System Romania SRL

2013-2017

61.5 Meuro
White Book (Scientific Case)
Feasibility Study
Preparation of the Application
E.C. Evaluation & Approval
Building - Preparation
Building - Construction
Major Eqp. - Tender
Major Eqp. – Constr, Install
Experimental set-ups
Recruitment

Project implementation

2010 2011 2012 2013 2014 2015

2017
Buildings – one contractor, 33000 m² total

- Experimental area building
- Office building
- Guest house
- Canteen
# High-power laser source

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available outputs power and repetition rate</td>
<td>Two outputs with 0.1PW at 10Hz</td>
</tr>
<tr>
<td></td>
<td>two outputs with 1PW at 1 Hz</td>
</tr>
<tr>
<td></td>
<td>two outputs with 10PW at 1 shot/min</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>&lt;50 fs</td>
</tr>
<tr>
<td>Strehl Ratio</td>
<td>&gt;0.7</td>
</tr>
<tr>
<td>Pointing stability</td>
<td>&lt;0.2 microrad</td>
</tr>
<tr>
<td>Temporal contrast in the nanosecond range</td>
<td>10^{11}:1 for the 0.1PW outputs</td>
</tr>
<tr>
<td></td>
<td>10^{12}:1 extrapolated for the 10PW outputs</td>
</tr>
<tr>
<td>Temporal contrast in the picosecond range</td>
<td>10^{11}:1 for the 0.1PW outputs</td>
</tr>
<tr>
<td></td>
<td>10^{12}:1 extrapolated for the 10PW outputs</td>
</tr>
<tr>
<td>External clock synchronization jitter</td>
<td>&lt;200fs</td>
</tr>
</tbody>
</table>
Experimental areas

10 PW

1 PW 0.1 PW

laser beams
Laser-induced nuclear studies

\[ F_L + F_L \to \langle A \rangle \approx 192^{\text{Re}} \]

Introducing the fis: a laser-accelerated towards the \( N = 1 \):

D. Habs · P.G. Thirolf · M. Gr A. Henig · D. Kiefer · W. Ma ·
Experimental set-up @ ELI-NP
**Parameters of the gamma-beam**

<table>
<thead>
<tr>
<th>Type</th>
<th>Units</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photon energy</td>
<td>MeV</td>
<td>0.2 – 19.5</td>
</tr>
<tr>
<td>Divergence</td>
<td>Rad</td>
<td>( \leq 2.0 \times 10^{-4} )</td>
</tr>
<tr>
<td>Average Relative Bandwidth of Gamma-Ray Beam</td>
<td></td>
<td>( \leq 5.0 \times 10^{-3} )</td>
</tr>
<tr>
<td>Time-Average Spectral Density at Peak Energy</td>
<td>1/(s eV)</td>
<td>( \geq 5.0 \times 10^{3} )</td>
</tr>
<tr>
<td>Time-Average Brilliance at Peak Energy</td>
<td>1/(s mm² mrad² 0.1% ( \eta_{\gamma} ))</td>
<td>( \geq 1.0 \times 10^{11} )</td>
</tr>
<tr>
<td>Minimum Frequency of Gamma-Ray Macropulses</td>
<td>Hz</td>
<td>( \geq 100 )</td>
</tr>
</tbody>
</table>
ELI-NP: the *F-I-UK* European proposal

**European Collaboration for the proposal of the gamma-ray source:**

- **Italy:** INFN, Sapienza
- **France:** IN2P3, Univ. Paris Sud
- **UK:** ASTeC/STFC

~ 80 collaborators elaborating the CDR/TDR
ELI-NP requirements:

State of the art + Compact = S-band Photoinjector + C-band linac
Thomson/Compton Sources are electron-photon Colliders, based on the concept of Spectral Luminosity, i.e. Luminosity per unit bandwidth

- Scattered flux
  \[ N_\gamma = L \sigma_T \]
  \[ \sigma_T = \frac{8 \pi}{3} r_e^2 \]

- Luminosity as in HEP collisions
  - Many photons, electrons
  - Focus tightly
  \[ L = \frac{N_L N_e}{4 \pi \sigma_x^2} f \]
  - ELI-NP

\[ L = \frac{1.3 \cdot 10^{18} \cdot 1.6 \cdot 10^9}{4 \pi (0.0015 \text{cm})^2} \cdot 3200(\text{sec}^{-1}) = 2.5 \cdot 10^{35} \text{ cm}^{-2} \text{ sec}^{-1} \]

\( \sigma_T = 0.67 \cdot 10^{-24} \text{ cm}^2 = 0.67 \text{ barn} \)

cfr LHC $10^{34}$ SuperB-fac $10^{36}$
A r.t. RF linac vs pulsed laser source

<table>
<thead>
<tr>
<th>Electron beam parameter at IP</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (MeV)</td>
<td>180-750</td>
<td></td>
</tr>
<tr>
<td>Bunch charge (pC)</td>
<td>25-400</td>
<td></td>
</tr>
<tr>
<td>Bunch length (µm)</td>
<td>100-400</td>
<td>0.2-0.6</td>
</tr>
<tr>
<td>$\varepsilon_{n-x,y}$ (mm-mrad)</td>
<td>0.04-0.6</td>
<td></td>
</tr>
<tr>
<td>Bunch Energy spread (%)</td>
<td>0.04-0.1</td>
<td></td>
</tr>
<tr>
<td>Focal spot size (µm)</td>
<td>15-30</td>
<td></td>
</tr>
<tr>
<td># bunches in the train</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Bunch separation (nsec)</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>energy variation along the train</td>
<td>0.1 %</td>
<td></td>
</tr>
<tr>
<td>Energy jitter shot-to-shot</td>
<td>0.1 %</td>
<td></td>
</tr>
<tr>
<td>Emittance dilution due to beam breakup</td>
<td>&lt; 10%</td>
<td></td>
</tr>
<tr>
<td>Time arrival jitter (psec)</td>
<td>&lt; 0.5</td>
<td></td>
</tr>
<tr>
<td>Pointing jitter (µm)</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulse energy (J)</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Wavelength (eV)</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>FWHM pulse length (ps)</td>
<td>2-4</td>
<td>2-4</td>
</tr>
<tr>
<td>Repetition Rate (Hz)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>$M^2$</td>
<td>$1.2$</td>
<td>$1.2$</td>
</tr>
<tr>
<td>Focal spot size $w_0$ (µm)</td>
<td>$&gt; 25$</td>
<td>$&gt; 25$</td>
</tr>
<tr>
<td>Bandwidth (rms)</td>
<td>0.05 %</td>
<td>0.05 %</td>
</tr>
<tr>
<td>Pointing Stability (µrad)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Synchronization to an ext. clock</td>
<td>&lt; 1 psec</td>
<td>&lt; 1 psec</td>
</tr>
<tr>
<td>Pulse energy stability</td>
<td>1 %</td>
<td>1 %</td>
</tr>
</tbody>
</table>
Accelerator and Equipments in ELI-NP Building
ELI-NP-GS

Fig. 197. Isometric 3D view of Building Layout of the Accelerator Hall & Experimental Areas
ELI–NP Gamma Beam System

Comparison with other LCB systems

ELI–NP Gamma Beam System

• high intensity / small emittance e\(^-\) beam from a warm LINAC
• very brilliant high rep. rate int. laser
• small collision volume
Table 1. Comparison of performance properties of existing and upcoming \( \gamma \)-beam facilities.

<table>
<thead>
<tr>
<th></th>
<th>HI( \gamma )S</th>
<th>HI( \gamma )S2</th>
<th>MEGa-Ray</th>
<th>ELI-NP</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_\gamma [MeV] )</td>
<td>2-100</td>
<td>2-100</td>
<td>&lt; 8</td>
<td>&lt; 19</td>
</tr>
<tr>
<td>total flux ([\gamma/s])</td>
<td>( \sim 10^9 )</td>
<td>( 5 \cdot 10^{12} )</td>
<td>( 10^{13} )</td>
<td>( 10^{13} )</td>
</tr>
<tr>
<td>( \Delta E/E )</td>
<td>2-5 \cdot 10^{-2}</td>
<td>( \leq 10^{-3} )</td>
<td>( \leq 10^{-3} )</td>
<td>( \leq 10^{-3} )</td>
</tr>
<tr>
<td>spectral density</td>
<td>( 10^2 )</td>
<td>( 10^4-10^6 )</td>
<td>( 10^4-10^6 )</td>
<td>( 10^4-10^6 )</td>
</tr>
</tbody>
</table>
Photonuclear Reactions

Absorption

\( A_X \)

\( A_Y \)

\( \gamma \)

\( \gamma' \)

\( \gamma' \)

\( \beta \)

\( \beta \)

Nuclear Resonance Fluorescence (NRF)

Photoactivation

Photodesintegration (-activation)

Photofission

\( \sim 8 \text{ MeV} \)
Photo-fission @ ELI-NP

Attila Krasznahorkay (ATOMKI)
Fadi Ibrahim (IPN – Orsay)
Dimiter L. Balabanski (ELI-NP)
Resonant tunneling through the triple humped fission barrier
$^{232}\text{Th}(\gamma,f)$ (Dickey 1975)

$^{232}\text{Th}(\gamma,f)$ (Knowles 1982)

PLB 116B (1982) 315
Ternary fission studies with ELI-NP

The two heavy fragments are sometimes accompanied by a Light Charged Particle: Ternary fission

(roughly 2 to 4 times every thousand events depending on the mass of the fissioning nucleus)
Let’s see what else we can squeeze from photo-fission?

In fission fragments share about 200 MeV and have angular momentum of $20\hbar$. The nuclear spin ensemble has oblate orientation with respect to the beam axis. The ions are emitted in a charge state around $20^+$. 

**Designed experiments**

- IGISOL studies of exotic nuclei
- $\gamma$-spectroscopy of exotic nuclei
What about the refractory elements?

Boiling point & Melting point

A unique opportunity for

Taken from PIAFE project Report based on Studsvik measurements
ALTO, ARIEL, etc.

ELI-NP

γ–beam spectrum at the IP (without collimator)
Production of fission fragments by photo-fission at ELI

\[ \Phi = 1.4 \cdot 10^{12} \text{ \gamma/s} \]

Will there be enough yield of fission fragments? Back-of-envelope calculation says that the yield is \( \approx 10^{10} \text{ f/s} \).

\[ \Phi \text{. s. } N = \Phi 6,4 \cdot 10^{-3} \text{ f/s} \]
Yield estimates

Yield: $6.2 \times 10^8$ f/s with a stack of targets:

$\approx 10^{10}$ f/s

Al window 19.17 mg/sm$^2$

$^{238}$U targets of 19.1 mg/sm$^2$
The IGISOL project

Input needed:
- Accelerator (gammas)
- Infrastructure radioprotection

IGISOL:
- CARIBU-like
- Leuven-like
Phase 1

high-energy Interaction point
ELIADÉ – detector array

- **ELIADÉ – ELI–NP Array of Detectors**
- Clover detector: 4 x crystals 60x90 cm (40% intrinsic efficiency)
  - EXOGAM type
  - AC shield 2 configurations
ELIADE – detector array

- **EXOGAM – like Configuration**
  - Most compact
  - Highest photopeak efficiency ~ 10%
  - 4 Clovers @ 90 deg. @ 11 cm
  - 4 Clovers @ 135 deg. @ 11 cm
  - + 4 3”x3” LaBr$_3$ det. @ 90 deg.

**Coupling to ancillary detectors:**
- fast timing with LaBr$_3$ det.
- selectivity with Bragg det.
- g-factors
External magnetic fields – how?

- Well known and controlled values
- Lower fields – suitable for longer-lived (>
- Homogeneity – what do we need?
  ~1 % should be OK

- Permanent NdFeB magnets;
- Homogeneity better than 1%;
- Field ~0.1 T with possibility of reaching > 0.5 T
Hyperfine fields in Fe

$g$-factors of deformed nuclei in the mass $A = 140$ region

- onset of deformation beyond the $N = 82$ shell
- single-particle states in odd-mass nuclei - reliable configuration assignments
- rotational bands built on nanosecond isomeric states

<table>
<thead>
<tr>
<th>isotope</th>
<th>$N$</th>
<th>$I^\pi$</th>
<th>$E_i$(keV)</th>
<th>$\tau_{1/2}$ (ns)</th>
<th>yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{136}$Xe</td>
<td>84</td>
<td>$2^+$</td>
<td>588.8</td>
<td>$2.1 \cdot 10^{-2}$</td>
<td>5.0</td>
</tr>
<tr>
<td>$^{139}$Cs</td>
<td>84</td>
<td>$2^+$</td>
<td>595.4</td>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>$^{140}$Ba</td>
<td>84</td>
<td>$2^+$</td>
<td>602.4</td>
<td>$9.7 \cdot 10^{-3}$</td>
<td>0.3</td>
</tr>
<tr>
<td>$^{139}$Xe</td>
<td>85</td>
<td>$(9/2^-)$</td>
<td>559.7</td>
<td>$\leq 10$</td>
<td>4.6</td>
</tr>
<tr>
<td>$^{140}$Cs</td>
<td>85</td>
<td>$1^-,0^-$</td>
<td>80.1</td>
<td>$&lt; 2.7$</td>
<td>2.1</td>
</tr>
<tr>
<td>$^{141}$Ba</td>
<td>85</td>
<td>$(11/2^-)$</td>
<td>643.8</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>$^{141}$Cs</td>
<td>86</td>
<td></td>
<td>105.9</td>
<td>8.7</td>
<td>3.3</td>
</tr>
<tr>
<td>$^{141}$Xe</td>
<td>87</td>
<td>$(9/2^-)$</td>
<td>111.9</td>
<td>206.7 $&lt; 2.1$</td>
<td>1.6</td>
</tr>
<tr>
<td>$^{142}$Cs</td>
<td>87</td>
<td>$l + 3(\dagger)$</td>
<td>$x + 123$</td>
<td>11</td>
<td>2.4</td>
</tr>
<tr>
<td>$^{143}$Cs</td>
<td>88</td>
<td>$9/2^-$</td>
<td>816.6</td>
<td></td>
<td>1.6</td>
</tr>
<tr>
<td>$^{145}$La</td>
<td>88</td>
<td>$(11/2^-)$</td>
<td>572.4</td>
<td></td>
<td>1.6</td>
</tr>
<tr>
<td>$^{144}$Cs</td>
<td>89</td>
<td>$(l + 1, l + 2)$</td>
<td>$x + 108$</td>
<td>$\leq 8$</td>
<td>0.2</td>
</tr>
<tr>
<td>$^{146}$La</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
<td>0.9</td>
</tr>
<tr>
<td>$^{147}$Ce</td>
<td>89</td>
<td>$(9/2^+)$</td>
<td>483.6</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>$^{147}$La</td>
<td>90</td>
<td>$(9/2^-)$</td>
<td>229.7</td>
<td>167.4</td>
<td>3.4</td>
</tr>
<tr>
<td>$^{149}$Ce</td>
<td>91</td>
<td>$(3/2^+)$</td>
<td>133.5</td>
<td>0.6</td>
<td>0.7</td>
</tr>
</tbody>
</table>

$^\dagger$decay angles $\theta$ for $(l + 1, l + 2)$ states.
### g-factors around $^{132}$Sn using the IPAC technique

<table>
<thead>
<tr>
<th>Fission rate ($^{233}$U)/s</th>
<th>Isotope</th>
<th>spin/parity</th>
<th>E-level [keV]</th>
<th>E-trans [keV]</th>
<th>M(λ)</th>
<th>$T_{1/2}$ [ns]</th>
<th>Possible configuration</th>
<th>$B_{hyp}$ Fe [T]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3E-03</td>
<td>$^{126}$Sn</td>
<td>5$^-$</td>
<td>2161.5</td>
<td>111.8</td>
<td>E1</td>
<td>10.8</td>
<td>$\nu s_{1/2} h_{11/2}$</td>
<td>8.8</td>
</tr>
<tr>
<td>1.7E-03</td>
<td>$^{128}$Sn</td>
<td>5$^-$</td>
<td>2120.9</td>
<td>120.5</td>
<td>E1</td>
<td>8.6</td>
<td>$\nu s_{1/2} h_{11/2}$</td>
<td>8.8</td>
</tr>
<tr>
<td>2.4E-03</td>
<td>$^{130}$Sn</td>
<td>4$^-$</td>
<td>2214.6</td>
<td>129.8</td>
<td>M1</td>
<td>0.5</td>
<td>$\nu d_{5/2} h_{11/2}$</td>
<td>8.8</td>
</tr>
<tr>
<td>1.1E-03</td>
<td>$^{132}$Sn</td>
<td>7$^+$</td>
<td>4919.0</td>
<td>203.1</td>
<td>M1</td>
<td>0.062</td>
<td>$\nu f_{7/2} h_{11/2}$</td>
<td>8.8</td>
</tr>
<tr>
<td>1.1E-03</td>
<td>$^{132}$Sn</td>
<td>4$^-$</td>
<td>4830.9</td>
<td>479.1</td>
<td>M1</td>
<td>0.026</td>
<td>$\nu f_{7/2} d_{3/2}$</td>
<td>8.8</td>
</tr>
<tr>
<td>1.2E-02</td>
<td>$^{132}$Sb</td>
<td>2$^+$</td>
<td>426.1</td>
<td>340.5</td>
<td>M1(+)</td>
<td>0.015</td>
<td>$\pi g_{7/2} d_{3/2}$</td>
<td>23</td>
</tr>
<tr>
<td>1.2E-02</td>
<td>$^{132}$Sb</td>
<td>2$^+_2$</td>
<td>1078.3</td>
<td>992.7</td>
<td>M1+E2</td>
<td>0.026</td>
<td>$\pi d_{5/2} d_{3/2}$</td>
<td>23</td>
</tr>
<tr>
<td>2.3E-02</td>
<td>$^{133}$Sb</td>
<td>11/2$^-$</td>
<td>2791.3</td>
<td>2791.3</td>
<td>M2</td>
<td>0.0114</td>
<td>$\pi h_{11/2}$</td>
<td>23</td>
</tr>
<tr>
<td>1.6E-02</td>
<td>$^{132}$Te</td>
<td>2$^+$</td>
<td>974.2</td>
<td>974.2</td>
<td>E2</td>
<td>0.0018</td>
<td>$\pi g_{7/2}^2$</td>
<td>68</td>
</tr>
<tr>
<td>6.0E-02</td>
<td>$^{134}$Te</td>
<td>2$^+$</td>
<td>1279.1</td>
<td>1279.1</td>
<td>E2</td>
<td>6.40E-04</td>
<td>$\pi g_{7/2}^2$</td>
<td>68</td>
</tr>
<tr>
<td>6.0E-02</td>
<td>$^{134}$Te</td>
<td>6$^+_2$</td>
<td>2397.7</td>
<td>706.3</td>
<td>M1,E2</td>
<td>0.016</td>
<td>$\pi g_{7/2} d_{9/2}$</td>
<td>68</td>
</tr>
<tr>
<td>6.0E-02</td>
<td>$^{134}$Te</td>
<td>5$^+_2$</td>
<td>2727.1</td>
<td>1150.8; 329.3</td>
<td>(M1)</td>
<td>0.02</td>
<td>$\pi g_{7/2} d_{9/2}$</td>
<td>68</td>
</tr>
<tr>
<td>3.7E-02</td>
<td>$^{135}$Te</td>
<td>11/2$^-$</td>
<td>1179.9</td>
<td>1179.9</td>
<td>E2</td>
<td>0.3</td>
<td>$\nu h_{9/2}$</td>
<td>68</td>
</tr>
<tr>
<td>2.0E-02</td>
<td>$^{136}$Te</td>
<td>2$^+$</td>
<td>606.6</td>
<td>606.5</td>
<td>E2</td>
<td>4.16E-02</td>
<td>$\pi f_{7/2}^2$</td>
<td>68</td>
</tr>
<tr>
<td>5.0E-02</td>
<td>$^{138}$Xe</td>
<td>2$^+$</td>
<td>588.8</td>
<td>588.8</td>
<td>E2</td>
<td>2.10E-02</td>
<td>$\nu g_{7/2}^2 \pi f_{7/2}^2$</td>
<td>155</td>
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</table>
g factors around neutron-rich N=60 using TDPAC

- shed light on the interplay of the proton-neutron interaction responsible for the sudden onset of deformation in the region

<table>
<thead>
<tr>
<th>Fission rate (235U)/s</th>
<th>Isotope</th>
<th>spin/parity</th>
<th>E_x[keV]</th>
<th>T1/2[ns]</th>
<th>Possible configuration</th>
<th>Expected g factor</th>
<th>Bhyp [T]</th>
<th>Osc. per 3xt&lt;sub&gt;1/2&lt;/sub&gt;</th>
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<tr>
<td>2.2E-02</td>
<td>&lt;sup&gt;91&lt;/sup&gt;Rb</td>
<td>9/2&lt;sup&gt;+&lt;/sup&gt;</td>
<td>1134</td>
<td>17</td>
<td>πg&lt;sub&gt;9/2&lt;/sub&gt;</td>
<td>1.3</td>
<td>5.4</td>
<td>5</td>
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<tr>
<td>3.1E-02</td>
<td>&lt;sup&gt;92&lt;/sup&gt;Rb</td>
<td>7&lt;sup&gt;+&lt;/sup&gt;</td>
<td>1958</td>
<td>7</td>
<td>πg&lt;sub&gt;9/2&lt;/sub&gt;xvd&lt;sub&gt;5/2&lt;/sub&gt;</td>
<td>0.66</td>
<td>5.4</td>
<td>5</td>
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<tr>
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<td>3&lt;sup&gt;−&lt;/sup&gt;</td>
<td>284</td>
<td>54</td>
<td>πp&lt;sub&gt;3/2&lt;/sub&gt;xvd&lt;sub&gt;5/2&lt;/sub&gt;</td>
<td>0.2</td>
<td>5.4</td>
<td>3</td>
</tr>
<tr>
<td>3.0E-02</td>
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<td>27/2&lt;sup&gt;−&lt;/sup&gt;</td>
<td>4423</td>
<td>111</td>
<td>πg&lt;sub&gt;9/2&lt;/sub&gt;xvg&lt;sub&gt;7/2&lt;/sub&gt;h&lt;sub&gt;11/2&lt;/sub&gt;</td>
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<td>8&lt;sup&gt;+&lt;/sup&gt;</td>
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<tr>
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<td>17/2&lt;sup&gt;−&lt;/sup&gt;</td>
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<td>7</td>
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<td></td>
<td>&lt;sup&gt;95&lt;/sup&gt;Y</td>
<td>21/2&lt;sup&gt;−&lt;/sup&gt;</td>
<td>5022</td>
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<td>0.45</td>
<td>22.6</td>
<td>27</td>
</tr>
</tbody>
</table>
Phase 2

beam dump

y-beam exp. area

ISOL exp. area

laser huts – 1st floor

Research Reactor
(end of decommissioning 2017)

ELI –NP (commissioning 2017)
**Instrumentation (gamma beams)**

**NRF set-up (the ELIADE array)**
- rings of segmented HPGe detectors (8-12 Ge Clovers)
- good timing detectors

**Nuclear structure set-up: **modular and very flexible**
- high resolution neutron detection
- gamma-ray detection with medium resolution (20 LaBr$_3$ det.)
- high-resolution $\gamma$-ray detection (in some cases)

**THGEM + DSSD detector set-up for cross section measurements**

**Gas-filled Bragg spectrometers**

**4$\pi$ DSSSD detector set-up**

**Gas-filled TPC**

**Bubble chamber**

**Production of RIB with IGISOL-type technique**
- Tape station and Ge array for decay studies
- Multi-reflection trap
- Collinear laser spectroscopy beam line
Extreme Light Infrastructure – Nuclear Physics
Finally

1. There are many scientific and technical challenges ahead of us. However, time is short and we need to find solutions now.

2. ELI-NP is open for collaborations. We are building a user community. Formal collaborations to be established through MoUs.

3. Cooperation between nuclear and laser physicists needs to be established, e.g. first unify the language (!)


**Job opportunities**

The ELI-NP research teams will consist in **218 researchers, engineers and technicians** (5 heads of research and 20 senior researchers, 107 junior researchers, 50 research assistants (PhD students), 36 engineers and technicians) from 2018 on. 31 MSc and PhD students are also expected to receive some trainings with the equipment at ELI-NP every year.

http://www.eli-np.ro/jobs.php
Thank you!