Gamma beam monitoring instruments at ELI-NP

Catalin Matei\textsuperscript{1}

J.M. Mueller\textsuperscript{2}, G. Suliman\textsuperscript{1}, C.A. Ur\textsuperscript{1}, H.R. Weller\textsuperscript{2}

\textsuperscript{1}ELI-NP, Romania

\textsuperscript{2}TUNL/ HIGS, USA
ELI-NP large equipment

- **High Power Laser System** - 2 x 10PW maximum power
  - contracted by Thales Optronique SA (~65 M€)

- **Gamma Beam System** - high intensity, tunable energy up to 20MeV
  - contracted by EuroGammaS Consortium led by INFN Rome (~65 M€)
gamma beams at ELI-NP

<table>
<thead>
<tr>
<th>Parameter [units]</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photon energy [MeV]</td>
<td>0.2 – 19.5</td>
</tr>
<tr>
<td>Spectral density [ph/s/eV]</td>
<td>&gt; $10^4$</td>
</tr>
<tr>
<td>Bandwidth (rms)</td>
<td>&lt; 0.5 %</td>
</tr>
<tr>
<td># photons / shot FWHM bdw.</td>
<td>1.0 – $4.0 \cdot 10^5$</td>
</tr>
<tr>
<td># photons/sec FWHM bdw.</td>
<td>2.0 – $8.0 \cdot 10^8$</td>
</tr>
<tr>
<td>Source rms size [µm]</td>
<td>10 – 30</td>
</tr>
<tr>
<td>Source rms divergence [µrad]</td>
<td>25 – 250</td>
</tr>
<tr>
<td>Peak brill. [$N_{ph}$/sec.mm².mrad².0.1%]</td>
<td>$10^{22} – 10^{24}$</td>
</tr>
<tr>
<td>Radiation pulse length [ps]</td>
<td>0.7 – 1.5</td>
</tr>
<tr>
<td>Linear polarization</td>
<td>&gt; 99 %</td>
</tr>
<tr>
<td>Macro repetition rate [Hz]</td>
<td>100</td>
</tr>
<tr>
<td># of pulses per macropulse</td>
<td>&gt; 31</td>
</tr>
<tr>
<td>Pulse–to–pulse separation [ns]</td>
<td>16</td>
</tr>
</tbody>
</table>

Low–energy stage: $E_\gamma < 3.5$ MeV
→ Q1 2017

High–energy stage: $E_\gamma < 19.5$ MeV
→ Q4 2018
ELI-NP experimental areas

- **E6 10PW**
- **E1 10PW**
- **E5 1PW @ 1 Hz**
- **E4 0.1PW @ 10 Hz**
- **E3 positron source**
- **E7 2X10PW**
- **E7 QED high field gamma + electrons**
- **E8 nuclear reactions**
- **E2 NRF applications**
overview – gamma beam diagnostics

- **Intensity monitoring**
  - deuteron photodisintegration
  - photo-fission

- **Energy monitoring**
  - HPGe + anti-Compton shield
  - LaBr3 + anti-Compton shield

- **Time structure monitoring**
  - small LaBr3

- **Spatial structure monitoring**
  - CCD camera
flux monitor / polarization – $d(\gamma,n)p$
d(γ,n)p – test at HIγS

- recent experiments at HIGS
- BC-501 detectors for $E_γ = 5, 6.1, 7, 15, 20$ MeV
- Li-glass detectors for $E_γ = 2.5, 2.75, 3$ MeV
- exp. asymmetry = 0.93±0.02
d(γ,n)p – proposal at ELI-NP

- d(γ,n)p systems used at HIGS
- D₂O cell – 4 cm long
- threshold reaction 3 MeV
- well known cross sections ~3%
- 3-4 neutron detectors
- Li-glass below 4 MeV
- NE213-type above 4 MeV
- beam fluence accurate to 5%

- 200 Hz rate
- DAQ: 14-bit, 500 MHz
flux monitor – fission chamber

- simple design
- almost 100% efficiency
- U-235, U-238, Pu-239
- areal density determined to 1%
- photofission cross sections to 1%
- usable above 6 MeV
- P-10 gas at max 1.2 bar
- beam fluence accurate to 2%

- 10-100 Hz rate
- DAQ: 12-bit, 250 MHz
simple design
- almost 100% efficiency
- U-235, U-238, Pu-239
- areal density determined to 1%
- photofission cross sections to 1%
- usable above 6 MeV
- P-10 gas at max 1.2 bar
- beam fluence accurate to 2%

- 10-100 Hz rate
- DAQ: 12-bit, 250 MHz

Estimated fission rates for 200 $\mu$g target
energy spread - detectors

- attenuated beam
- HPGe (150%)
- LaBr$_3$ (3” x 4”)
- anti-Compton shield
- 10 Hz rate
- # channels: 7
- DAQ: 14-bit, 500 MHz

- main use for energy spread w/ HPGe
- possible use for intensity and time structure w/ LaBr$_3$
- NaI annulus – 15 cm diameter, 25 cm long, segmented
- 60 cm Cu for HPGe
- 50 cm Cu for LaBr$_3$
- factor of 10 attenuation in 8 cm Cu cylinder
- 1×1.5 cm, 1×2.5 cm, 1×5 cm, 6×10 cm
energy spread - proposed design
beam monitor would be placed near one of the major beam-matter interaction points: collimators, attenuator, beam dump
- use a small 2”x2” LaBr₃ – may be able to count microbunches
spatial monitoring

• fast alignment of the collimators to maximize flux and reduce energy spread
• fast alignment of the experimental setup to minimize scattering
• possible polarization, intensity monitor

from HIGS
spatial monitoring

- CCD camera detector system, scintillator converter, mirror
- possible image collection at microbunch level with fast CCD
- design requirements: sub-mm resolution and high contrast
ELI-NP next steps

• Summer 2015: TDRs approved by ISAB

• Fall 2015: Start construction of instruments

• Q1 2017: Gamma Beam – end of Phase 1

• Q4 2018: Gamma Beam – begin operation