AE87: Hard X-ray ICS

(2018-19) BNL ATF user meeting
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Fund Source: DNDO, DOE

Monochromatic YAG ICS at ~ 100 keV range,

FOR ✴ Applications ( Medicine, High Z materials )
✴ Detector developments ( Betatron radiation from high energy electron etc )
✴ Strong field physics ( With multi TW CO2 laser)
Initial demonstration of Photon Activated Therapy by ICS with Gold Nano Particle in ATF (in 2019)

ICS spectrum: $h\nu > 81$ keV  
\((Au \ K\text{-}edge)\)

Enhanced does by monochromatic X-ray:

**Hard X-ray absorption by Gold K-shell**

\[\downarrow\]

\textit{Emission of Auger electron from outer shell etc,}  
\[\rightarrow \text{Dose enhancement around surface of GNP.}\]

\[\uparrow\downarrow\]

\textit{Gold Nano Particle size} \(\sim 1 \text{ nm}\)

\textit{Penetration depth of Auger electron} \(\sim 10s \text{ nm?}\)

\((\sim \text{mg/g uptake} \leftrightarrow \text{a GNP per } \mu\text{m}^3)\)

\textit{Details will be studied later.}\n
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**Requirement:**

Assuming target dimension of \((L_{I.P. \text{ to target}} \times 1/\gamma)^2 = 1 \text{ cm}^3\),  
\((1 \text{ m away from I.P. at } 1/\gamma = 10 \text{ mrad})\)

Radiation dose per kg of water per shot:  
\(1 \text{ [Gy]} = 1 \text{ J} / (10 \text{ cm})^3 \leftrightarrow 1 \text{ mJ} / (1 \text{ cm})^3.\)

Total irradiation time required:  
\(1 \text{ mJ} / 0.1 \mu\text{J} = 10,000 \text{ shot}\)

\[\leftrightarrow > 1 \text{ Hz} \times 60 \text{ min} \times 3 \text{ hour? run time.}\]
Done (2017-18):
★ Installation of Compton chamber (3rd I.P. of BL1)
★ YAG laser transport to BL1
★ 30 mJ output from YAG Amp (2 path) at BL1
★ Installation of YAG optics (OAP) in the chamber

Must be done in 2018:
❖ YAG alignment with e-beam line
❖ Cd-Te detector test by e-beam bremsstrahlung
❖ Synchronization by mJ YAG & 60 MeV e-beam
Plan in 2018-19 year

2018, Dec, 1 week:
Synchronization of e-beam (60 MeV) with mJ YAG laser
(by 100s µm Si semiconductor switch)

2019yr:
January, 1 week:
Hard X-ray generation, and characterization by Amplified YAG & 70 MeV e-beam.
   Au, Pb K-edge filtering.
   (If necessarily, Synchronization by streak camera (OTR signal))

February-March, 1 week:
Spectrum characterization of <100 keV X-ray by Bent crystal etc.

June- ?:  
Initial Photon activation study.
# Electron Beam Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nominal</th>
<th>Requested Experiment Parameters</th>
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<tbody>
<tr>
<td>Beam Energy (MeV)</td>
<td>68-70 to 75 MeV</td>
<td>Full range is ~ 15-75 MeV with highest beam quality at nominal values</td>
</tr>
<tr>
<td>Bunch Charge (nC)</td>
<td>0.3-0.5 nC</td>
<td>Bunch length &amp; emittance vary with charge</td>
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<tr>
<td>Compression</td>
<td>none</td>
<td>A magnetic bunch compressor available to compress bunch down to ~ 100 fs. Beam quality is variable depending on charge and amount of compression required.</td>
</tr>
<tr>
<td>Transverse size at IP (sigma, um)</td>
<td>&lt; 30 um at BL1 Compton chamber (10 um may be required)</td>
<td>It is possible to achieve transverse sizes below 10 um with special permanent magnet optics.</td>
</tr>
<tr>
<td>Normalized Emittance (um)</td>
<td>1 (at 0.3 nC)</td>
<td>Variable with bunch charge</td>
</tr>
<tr>
<td>Rep. Rate (Hz)</td>
<td>3 Hz is better.</td>
<td>3 Hz also available if needed</td>
</tr>
</tbody>
</table>

Special Equipment:  
Stable Nd: YAG laser & Continuous electron beam run time for > several hours. Thank you.
2019 Experiment Time Estimates
(2018: 1 week on December)

Run Hours (include setup time in hours estimate):
Number of electron beam only hours:
  ~ 40 hours (a few days X several times).

Number of YAG laser hours, + ebeam, delivered to electron beam experiment hall:
  160 hours (4 weeks.)

Overall % setup time: ~ 20 %.

Hazards & installation requirements:
Large installation (chamber, insertion device etc…): Yes
Laser use (other than CO₂): Nd: YAG laser at <100 mJ, or Multi bunch mode 10s mJ
Cryogens: Y/N
Introducing new magnetic elements: maybe No.
Introducing new materials into the beam path: Yes: GNP target, Semiconductor, OTR, YAG
Any other foreseeable beam line modifications: Maybe Yes.