MARS15 RESULTS FOR THE LBNE-BLIP IRRADIATION TEST

Nikolai Mokhov

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Outline

• Fall 2009 Conclusions in 3 slides

• New Sample Geometry and Beam in MARS15

• Power Density, DPA, Gas Production and Activation

• Summary
NuMI Target

120-GeV proton beam
\( \sigma_x = \sigma_y = 1.1 \text{ mm} \)

2e13 p/s \( \times \) 2e7 s/yr = 4e20 p/yr

Target: POCO Graphite, 1.78 gcc
47 \( \times \) (15 \( \times \) 6.4 \( \times \) 20 mm)

Peak: 0.45 DPA/yr, 123 W/g

\( y = \pm 1 \text{ mm} \)
\( z = 15 \text{ cm} \)
BLIP Target (2009)

165-MeV proton beam to get 101 MeV downstream
\[ \sigma_x = \sigma_y = 4.233 \text{ mm} \]

90\(\mu\)A: \(5.62 \times 10^{14} \text{ p/s} \times 2 \times 10^7 \text{ s/yr} = 1.124 \times 10^{22} \text{ p/yr} \)

Nine 6-mm thick samples, 3 per box

Box-1: Be + IG-43 + POCO (Water)
Box-2: IG-430 + CC + POCO (Vacuum)
Box-3: Be + Albmet + POCO (He)

Peaks in POCO graphite (3d sample in each box):
- 1.37, 1.41 and 1.55 DPA/yr, respectively,
- 0.37, 0.38 and 0.42 DPA in 9 weeks (\(\sim 1\) LBNE year at 700 kW).

Peak power density is \(\sim 400 \text{ W/g} \).
Physics process contribution (%) at beam axis: 
z=15 cm (NuMI) and Box 2 POCO graphite (BLIP)

<table>
<thead>
<tr>
<th>Target</th>
<th>Nuclear</th>
<th>EM elastic</th>
<th>L.E. neutrons</th>
<th>e ±</th>
</tr>
</thead>
<tbody>
<tr>
<td>NuMI</td>
<td>50.8</td>
<td>43.3</td>
<td>1.5</td>
<td>4.4</td>
</tr>
<tr>
<td>BLIP</td>
<td>43.5</td>
<td>53</td>
<td>3.5</td>
<td>0.02</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Target</th>
<th>E_p (GeV)</th>
<th>Beam σ (mm)</th>
<th>N_p (1/yr)</th>
<th>DPA (1/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NuMI/LBNE</td>
<td>120</td>
<td>1.1</td>
<td>4.0e20</td>
<td>0.45</td>
</tr>
<tr>
<td>BLIP</td>
<td>0.165</td>
<td>4.23</td>
<td>1.124e22</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Earlier obtained 0.2-DPA damage limit for carbon materials of interest for 0.7-MW LBNE can be achieved at BLIP over 7 weeks
Exit proton beam energy needed = 112.65 MeV,\n\[\sigma_x = 8.92\ \text{mm},\ \sigma_y = 6.79\ \text{mm}\]
94\[\mu\text{A}: 5.87e14\ \text{p/s}\]
9 weeks = 63 days = 5.44e6 s
Proton beam energy from Linac needed = 188 MeV

*Calculated:* particle fluxes, power density, DPA, hydrogen and helium gas production and residual dose two-dimensional distributions along and across the beam.

*All values are inversely proportional to the beam area, therefore *expected reduction* is*

\[
\frac{4.233^2}{(8.92\times6.79)} \sim 0.3
\]
Proton Flux

![Proton Flux Graph](image-url)
Proton Flux in 1st (POCO) and 11th (AlBeMet) Samples
DPA in 9 Weeks
DPA in 1st (POCO) and 11th (AlBeMet) Samples

In 9 weeks

Peak: 0.11–0.13 DPA in 1st to 8th graphite sample, 0.13 DPA in hBN, 0.06 DPA in Be, and 0.3 DPA in AlBeMet
Hydrogen Gas Production

![Graph showing hydrogen gas production](image)
Hydrogen in 1st (POCO) and 11th (AlBeMet) Samples

Peak: $2.5 \times 10^{12}$ cm$^{-3}$ s$^{-1}$
Helium Gas Production
Power Density

![Power Density Graph]

- Axial position (cm)
- Radial position (cm)
- Power density (mW/g)
Power Density in 1\textsuperscript{st} (POCO) and 11\textsuperscript{th} (AlBeMet) Samples

Peak: Grows from 113 to 123 W/g when one moves from 1\textsuperscript{st} to 8\textsuperscript{th} graphite sample, 118 W/g in hBN, and 112 W/g in Be & AlBeMet
Residual Dose on Contact after 63/1 days

Residual dose (mSv/hr) after 63-day irradiation and 1-day cooling

~50 Sv/hr on BLIP Drive Box
Summary

• Detailed MARS15 calculations performed in the current sample set for the latest BLIP beam parameters. Linac beam energy found for this set is 188 MeV. Calculated distributions are particle fluxes, power density, DPA, hydrogen and helium gas production and residual dose rate.

• All peak values in central samples are a factor of 3 lower compared to the previous numbers because of corresponding increase of the beam spot size.

• Peak DPA in central samples for the 9-week irradiation are 0.11-0.13 in graphite and hBN, 0.06 in Be and 0.3 in AlBeMet. They are 0.01-0.03 DPA in the outer samples, i.e. substantially lower than “desirable” 0.2 DPA value.

• Ways to increase these rates are to decrease the beam spot size to what was originally planned, increase irradiation time and/or increase intensity (?).