Status of the Proton Power (PPU) Upgrade Project

Spallation Neutron Source

29th Linear Accelerator Conference-LINAC18

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Spallation Neutron Source machine layout

Front-End: Produces a 1-msec long, chopped, H-beam at 60 Hz

Linac; 1 GeV acceleration

<table>
<thead>
<tr>
<th>DTL</th>
<th>CCL</th>
<th>SRF, ( \beta = 0.61 )</th>
<th>SRF, ( \beta = 0.81 )</th>
<th>upgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>86.8</td>
<td>186</td>
<td>387</td>
<td>1000 MeV</td>
</tr>
</tbody>
</table>

259 m

157 m

71 m

Accumulator Ring: Compress 1 msec long pulse to 700 nsec

Liquid Hg Target

Current

945 ns makes gaps

mini-pulse

1 ms macro-pulse

Average macro-pulse beam current: 26 mA

Current

1 ms
SNS is operating at its design power: 1.4 MW
SNS upgrade plans

Today

First Target Station
- 24 instrument positions
- 19 instruments built

Accelerator today

Future

First Target Station
- 24 instrument positions
- 21 instruments built

After PPU Upgrade

2 MW
0.8 MW

Second Target Station
- 22 instrument positions
- 8 initial instruments

After STS Upgrade
### Upgrade parameters: power increase with energy and current

- PPU delivers 2.8 MW capable accelerator
- Prior to STS, accelerator will run at 2 MW to First Target Station (FTS)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SNS 1.4 MW</th>
<th>PPU full upgrade capability</th>
<th>PPU FTS 60 Hz operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton beam power capability (MW)</td>
<td>1.4</td>
<td>2.8</td>
<td>2.0</td>
</tr>
<tr>
<td>Beam energy (GeV)</td>
<td>1.0</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>RFQ output peak beam current (mA)</td>
<td>33</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>Average linac chopping fraction (%)</td>
<td>22</td>
<td>18</td>
<td>41</td>
</tr>
<tr>
<td>Average macropulse beam current (mA)</td>
<td>25</td>
<td>38</td>
<td>27</td>
</tr>
<tr>
<td>Energy per pulse (kJ)</td>
<td>23</td>
<td>47</td>
<td>33</td>
</tr>
<tr>
<td>Pulse repetition rate (Hz)</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Macro-pulse length (ms)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>FTS decoupled moderator brightness/pulse (AU)</td>
<td>1</td>
<td>2.04</td>
<td>1.43</td>
</tr>
<tr>
<td>FTS coupled moderator brightness/pulse (AU)</td>
<td>1</td>
<td>2.16</td>
<td>1.51</td>
</tr>
</tbody>
</table>

- 30% energy increase
- 50% current increase
- No change
Accelerator front-end is “STS ready”

**Ion source output**

Operation production source has demonstrated required output

**RFQ output**

Measured beam at RFQ output

<table>
<thead>
<tr>
<th>RFQ Input Current (mA)</th>
<th>7/2/13</th>
<th>7/2/14</th>
<th>7/2/15</th>
<th>7/1/16</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFQ Current (mA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STS Requirement</td>
<td></td>
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</table>

STS requirement: 46 mA
Accelerator Built with Upgrade Provisions

**Tunnel:** 9 empty drift sections: fill 7 with cryomodules

**Klystron gallery:** empty area for new SRF

**Ring + transport lines:** 96% magnets and power supplies are 1.3 GeV ready
Superconducting Linac Systems

- 7 cryomodules, 28 cavities,
  - 16 MV/m gradient
  - 700 kW couplers

- SNS is responsible for cavity procurement
  - Most cavity features same as original design
  - Modifications: higher quality Nb end groups, no HOMs, no piezo tuners

- Cryomodules will be fabricated by partner lab: JLab
  - JLab built the original SNS cryomodules

- SNS built a spare cryomodule in 2012, with PPU required gradients
Will install some of the new cryomodules during normal maintenance outages

SNS has experience swapping cryomodules during maintenance outages
RF Systems

• Existing RF needs to support higher beam loading
  – Drift Tube Linac klystrons require upgrade from 2.5 to 3 MW
  – Couple Cavity Linac and existing Superconducting linac systems are OK

• New Superconducting linac RF systems
  – 28 new 700 kW klystrons: same as presently being purchased/used
  – 3 new high voltage convertor modulators

• New LLRF system to support “dual mode” beam to 2 target stations
Ring systems

• Injection region upgrades
  – New chicane magnets
    • Working with FNAL
  – Adding a view screen diagnostic in the injection dump

• Extraction region
  – Baseline plan: add additional kickers in provided space
Target Vessel Design

• 2 MW target design developed
  – Simplified flow deployment in corners (tapered shape)
  – Eliminate unneeded features from operational design
  – Includes a gas-wall “curtain” in the nose region
Target design: gas injection helps PPU design includes large increase in gas flow

- Measured operational vessel strain reduced with gas injection
  - Even with small amounts of gas injection, 10-70% reduction in strain

- Core samples from target nose indicate cavitation erosion mitigation with gas injection
Conventional Facilities

• Klystron gallery building build out
  – Finish the high energy end of the building
  – "BIM" approach for 3-D model integration of cooling, RF and other technical equipment
Conventional Facilities: transport line stub

- Tunnel “stub” in the line from the ring to target
  - Facilitate future tie in to STS without interrupting operations
Project Cost

- Present baseline cost estimate is ~ $240 M

<table>
<thead>
<tr>
<th>WBS</th>
<th>Totals</th>
</tr>
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<tbody>
<tr>
<td>P Proton Power Upgrade (PPU) Project</td>
<td>173,281,533</td>
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<tr>
<td>P.01  PPU Project Management</td>
<td>18,102,585</td>
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<tr>
<td>P.02  SCL Systems</td>
<td>35,975,950</td>
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<tr>
<td>P.03  RF Systems</td>
<td>57,601,780</td>
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<tr>
<td>P.04  Ring Systems</td>
<td>11,130,342</td>
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<tr>
<td>P.05  First Target Station Systems</td>
<td>26,175,718</td>
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<tr>
<td>P.06  Conventional Facilities</td>
<td>13,433,287</td>
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<tr>
<td>P.07  R&amp;D</td>
<td>3,279,767</td>
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<tr>
<td>P.08  Pre-Ops</td>
<td>637,480</td>
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<tr>
<td>P.09  Pre-CD1 Activities</td>
<td>6,944,625</td>
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<tr>
<td>Contingency (40%)</td>
<td>65,462,548</td>
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<tr>
<td></td>
<td>238,744,081</td>
</tr>
</tbody>
</table>
**PPU proposed schedule**

<table>
<thead>
<tr>
<th>FY17</th>
<th>FY18</th>
<th>FY19</th>
<th>FY20</th>
<th>FY21</th>
<th>FY22</th>
<th>FY23</th>
<th>FY24</th>
<th>FY25</th>
<th>FY26</th>
<th>FY27</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD 1</td>
<td>CD 3a</td>
<td>CD 2/3b</td>
<td>CD 3</td>
<td>CD 2/3b</td>
<td>CD 2/3b</td>
<td>CD 2/3b</td>
<td>CD 2/3b</td>
<td>CD 2/3b</td>
<td>CD 2/3b</td>
<td>CD 2/3b</td>
</tr>
</tbody>
</table>

- **No interruption of operations through 2023**
  - Use regular maintenance outages for tunnel activities
- **One long 6-month outage in 2023**
  - Upgrade ring injection, target systems, and tunnel stub
- **Transition to operations at high power in 2024**
Summary

• Proton Power Upgrade (PPU) project is aimed at doubling the SNS accelerator power capability

• Leveraging built in upgrade provisions

• Partnering with JLab for cryomodules and FNAL for Ring upgrades