Status of Project X

Keith Gollwitzer
Accelerator Division
Fermilab

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Outline

• Project X Goals
• Evolution
  – Initial Configuration
• Documentation
  – Functional Requirements
• Upgrade to Proton Driver
• Site
• Bureaucracy
  – CD Process
  – Staging
• R&D and Collaboration
**Project X Goals**

- Mainly based upon P5 report
  - A neutrino beam for long baseline neutrino oscillation experiments
  - Kaon- and muon-based precision experiments
  - A path toward a muon source for a possible neutrino factory and potentially a muon collider
- Recognized can also serve nuclear physics community
  - Test bed for accelerator and target studies related to:
    - Accelerator Driver Subcritical reactors
    - Accelerator Transmutation of Waste
Project X Evolution

• Initial design (8 GeV pulsed linac)
  – Did not support kaon/muon precision measurement program

• Second design
  – CW 3 GeV 1 mA H\(^{-}\) linac
    • Above kaon production threshold
    • Produces low energy pions for low energy muon experiments
    • Allows nuclear physics experiments
    • Low energy chopping allow supporting different experiment needs
    • Splitter/switchyard to simultaneously support the experiments
  – 3-8 GeV pulsed linac (accumulation in Recycler)
    • Satisfies long baseline neutrino 2 MW program
    • Additional 8 GeV beam power available for other experiments
Project X Layout

January 15, 2011
Gollwitzer - Status of Project X

[Diagram of Project X Layout]

- H- Source
- 3 GeV, 1.0 mA CW Linac
- 3-8 GeV Pulsed Linac
- Recycler / Main Injector 120 GeV
- Neutrinos 2 MW
- 0.75 MW Nuclear
- 1.5 MW Kaons
- 0.75 MW Muons
• Functional Requirement Specification
  – Outlines the parameters needed/desired

• Reference Design Report
  – Initial design to achieve the Functional Requirements
  – Initial cost range is based upon this report
## 3 GeV Linac Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>Delivered Beam Energy, maximum</td>
<td>3 GeV (kinetic)</td>
</tr>
<tr>
<td>L2</td>
<td>Delivered Beam Power at 3 GeV</td>
<td>3 MW</td>
</tr>
<tr>
<td>L3</td>
<td>Average Beam Current (averaged over &gt;1 μsec)</td>
<td>1 mA</td>
</tr>
<tr>
<td>L4</td>
<td>Maximum Beam Current (sustained for &lt;1 μsec)</td>
<td>5 mA</td>
</tr>
<tr>
<td>L5</td>
<td>The 3 GeV linac must be capable of delivering correctly formatted beam to a pulsed linac, for acceleration to 8 GeV</td>
<td></td>
</tr>
<tr>
<td>L6</td>
<td>Charge delivered to pulsed linac</td>
<td>26 mA-msec in &lt; 0.75 sec</td>
</tr>
<tr>
<td>L7</td>
<td>Maximum Bunch Intensity</td>
<td>$1.9 \times 10^8$</td>
</tr>
<tr>
<td>L8</td>
<td>Minimum Bunch Spacing</td>
<td>6.2 nsec (1/162.5 MHz)</td>
</tr>
<tr>
<td>L9</td>
<td>Bunch Length</td>
<td>&lt;50 psec (full-width half max)</td>
</tr>
<tr>
<td>L10</td>
<td>Bunch Pattern</td>
<td>Programmable</td>
</tr>
<tr>
<td>L11</td>
<td>RF Duty Factor</td>
<td>100% (CW)</td>
</tr>
<tr>
<td>L12</td>
<td>RF Frequency</td>
<td>162.5 MHz and harmonics thereof</td>
</tr>
<tr>
<td>L13</td>
<td>3 GeV Beam Split</td>
<td>Three-way</td>
</tr>
</tbody>
</table>
# Main Injector/Recycler Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
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</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>Delivered Beam Energy, maximum</td>
<td>120 GeV</td>
</tr>
<tr>
<td>M2</td>
<td>Delivered Beam Energy, minimum</td>
<td>60 GeV</td>
</tr>
<tr>
<td>M3</td>
<td>Minimum Injection Energy</td>
<td>6 GeV</td>
</tr>
<tr>
<td>M4</td>
<td>Beam Power (60-120 GeV)</td>
<td>&gt; 2 MW</td>
</tr>
<tr>
<td>M5</td>
<td>Beam Particles</td>
<td>Protons</td>
</tr>
<tr>
<td>M6</td>
<td>Beam Intensity</td>
<td>$1.6 \times 10^{14}$ protons per pulse</td>
</tr>
<tr>
<td>M7</td>
<td>Beam Pulse Length</td>
<td>~10 μsec</td>
</tr>
<tr>
<td>M8</td>
<td>Bunches per Pulse</td>
<td>~550</td>
</tr>
<tr>
<td>M9</td>
<td>Bunch Spacing</td>
<td>18.8 nsec (1/53.1 MHz)</td>
</tr>
<tr>
<td>M10</td>
<td>Bunch Length</td>
<td>&lt;2 nsec (fullwidth half max)</td>
</tr>
<tr>
<td>M11</td>
<td>Pulse Repetition Rate (120 GeV)</td>
<td>1.2 sec</td>
</tr>
<tr>
<td>M12</td>
<td>Pulse Repetition Rate (60 GeV)</td>
<td>0.75 sec</td>
</tr>
<tr>
<td>M13</td>
<td>Max Momentum Spread at extraction</td>
<td>$2 \times 10^{-3}$</td>
</tr>
</tbody>
</table>
# 3-8 GeV Pulsed Linac Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Maximum beam Energy</td>
<td>8 GeV</td>
</tr>
<tr>
<td>P2</td>
<td>The 3-8 GeV pulsed linac must be capable of delivering correctly formatted beam for injection into the Recycler (or Main Injector).</td>
<td></td>
</tr>
<tr>
<td>P3</td>
<td>Charge to fill Main Injector/cycle</td>
<td>26 mA-msec in &lt;0.75 sec</td>
</tr>
<tr>
<td>P4</td>
<td>Maximum beam power delivered to 8 GeV</td>
<td>300 kW</td>
</tr>
<tr>
<td>P5</td>
<td>Duty Factor (initial)</td>
<td>&lt; 4%</td>
</tr>
</tbody>
</table>
Beam Power

- Initial Pulsed Linac to deliver ~300KW
  - Duty factor of < 4%

- We want to be able to have 4MW at 8GeV
  - 1 mA average current in CW Linac would mean a duty factor of 50% for Pulsed Linac
  - Pulsed Linac duty factor of 4% would mean an average current of 12.5mA for CW Linac

- Or upgrade both Linacs
# Upgradability Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U1</strong></td>
<td>Provisions should be made to support an upgrade of the CW linac to support an average current of 5 mA.</td>
</tr>
<tr>
<td><strong>U2</strong></td>
<td>Provisions should be made to support an upgrade of the Main Injector to support a delivered beam power of ~4 MW at 120 GeV.</td>
</tr>
<tr>
<td><strong>U3</strong></td>
<td>Provisions should be made to deliver CW proton beams as low as 1 GeV.</td>
</tr>
<tr>
<td><strong>U4</strong></td>
<td>Provision should be made to support an upgrade to the CW linac such that it can accelerate Protons.</td>
</tr>
<tr>
<td><strong>U5</strong></td>
<td>Provisions should be made to support an upgrade of the pulsed linac to a duty factor of 10%.</td>
</tr>
<tr>
<td><strong>U6</strong></td>
<td>Provisions should be made to support an upgrade of the CW linac to 3.1 ns bunch spacing.</td>
</tr>
</tbody>
</table>

If requirements U1 and U5 are achieved, then will have 4 MW at 8 GeV.
Project X to Proton Driver

- **Proton Accumulation Ring**
  - Considerations
    - Space charge
    - H\(^{-}\) stripping

- **Bunch Compressor Ring**
  - Considerations
    - Forming 1-3 ns bunches
    - NF: keeping short bunch length for many turns before 2\(^{nd}\) and 3\(^{rd}\) bunch extractions
    - MC: one bunch or delivery of several bunches at once to target
Proton Driver Site

Transfer Line out of Accumulator is on wrong side
CD Process

- Will go through the DOE Critical Decision (CD) process for large projects (> $750M)
  - CD-0: Mission Need
  - CD-1: Alternative Selection and Cost Range
  - CD-2: Performance Baseline
  - CD-3: Start of Construction
  - CD-4: Start of Operations/Project Completion

- Timeline with CD-0 in Mar11 is to have Project X operational in 2020
Project X & DOE

• Fermilab has provided accelerator documentation to DOE required for CD-0
  – New DOE order 4.13.3b going into effect
    • Allows for staging
      – Fermilab providing more documentation
        » Phasing/staging
        » Experimental area/detector(s) are being added
          • Rare Kaon experiment is being added
    • Independent Cost Review prior to CD-0
      – DOE is figuring out what they want for this
R&D Program

• The primary elements of the R&D program include:
  – Development of a wide-band chopper
    • Capable of removing bunches in arbitrary patterns at a 162.5 MHz bunch rate
  – Development of an H- injection system
    • Require between 4.4 – 26 msec injection period, depending on pulsed linac operating scenario
  – Superconducting rf development
    • Includes six different cavity types at three different frequencies
    • Includes development of qualified industrial partners
Collaboration

- A multi-institutional collaboration has been established to execute the Project X RD&D Program.
  - Organized as a “national project with international participation”
    - Fermilab as lead laboratory
    - International participation via in-kind contributions, established through bi-lateral MOUs.
  - Collaboration MOUs for the RD&D phase outlines basic goals, and the means of organizing and executing the work. Signatories:

<table>
<thead>
<tr>
<th>ANL</th>
<th>ORNL/SNS</th>
<th>BARC/Mumbai</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNL</td>
<td>MSU</td>
<td>IUAC/Delhi</td>
</tr>
<tr>
<td>Cornell</td>
<td>TJNAF</td>
<td>RRCAT/Indore</td>
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<tr>
<td>Fermilab</td>
<td>SLAC</td>
<td>VECC/Kolkata</td>
</tr>
<tr>
<td>LBNL</td>
<td>ILC/ART</td>
<td></td>
</tr>
</tbody>
</table>
Summary

• Project X continues to move forward
• Fermilab is working with DOE to move along the CD process
• DOE is working to provide a “funding profile” for Project X
• Project X collaboration is moving forward with R&D
Neutrino Factory

Initial concept
Muon Collider

Initial concept