The High Intensity Future of Fermilab

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July 7, 2012
The Intensity Frontier at Fermilab

The standard model is a very successful theory. But is not complete; can not answer many deep questions

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diverse (tunable) and intense beams of neutrinos unmatched in the world today
Accelerator Improvement Plan (Proton Sources)

- **Muon**
  - 8 GeV
  - 120 GeV
- **LBNE**
- **NOvA**
- **MINERvA**
- **MINOS+**
- **MicroBooNE**
- **MiniBooNE**
- **Mu2e**
- **Muon g-2**

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Accelerator Improvement Plan (Proton Sources)

- Main Injector
- Booster Neutrinos
- g-2
- mu2e
- Total

- NOvA
- LBNE
- MINERvA
- MINOS+

- MicroBooNE
- MiniBooNE
- 8 GeV ν
- 120 GeV ν
- 8 GeV μ
- Muon g-2
- Mu2e

Project X

R&D

Phase-1 Construction

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Neutrino Program (this and next decades)
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NOvA (far) under construction
online 2013
(700 kW)

MINOS (far) operating
since 2005
(350 kW)

NOvA (near) online 2013
(700 kW)

MINOS (near)

MicroBooNE under construction
(LAr TPC)

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Neutrino Program (this and next decades)

Developed a phased approach:
Stage 2 approval – expected by this Christmas

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Muon Program (this decade)

Mu2e (muon to electron conversion)

Proton delivery

Beam Transfer

Muon Campus

Muon g-2

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Illinois Acceleration Research Center (IARC)

CDF
DZero
Kaon Program
(if an opportunity arises)

$1,000 K^+ \rightarrow \pi^+ \nu \bar{\nu}$ events (SM rate $\sim 10^{-10}$)
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CDF
DZero
Project X site
Illinois Accel Research Center (IARC)
Kaon experiment (potential)
Project X site

Fermilab Accelerator Complex 2012

Protons
Neutrinos
Muons
Electrons
Target

Test-Beam
Fixed-Target Beamlines
ASTA
Advanced Superconducting Test Accelerator (under construction)
MTA
Muon Test Area
Muon Campus (under construction)
Booster Neutrino Beam
Main Injector and Recycler

MINOS - NOvA
To Minnesota

Tevatron (decommissioned)

Linac and Booster

Illinois Accel Research Center (IARC)

Tevice
DZero

under development
Project X

Powerful (> 5 MW) and flexible (162 MHz) proton source
Explore new physics in unprecedented breadth and depth
Establish a versatile technical foundation for future accelerators

- **3 MW CW @3 GeV**
  - for rare processes
  - muons, karons, nuclei

- **2.4 MW @60-120 GeV**
  - neutrinos

- **200 kW @8 GeV**
  - Neutrinos, muons

- **1 MW CW @1 GeV**
  - nuclei (EDMs, nuclear energy)

Neutrinos to LBNE

Transfer into Main Injector & Recycler

8 GeV Pulsed Proton Beam
Project X
Reference Design
3 MW @ 3 GeV
200 kW @ 8 GeV
2.4 MW @ 120 GeV

Beta = 0.11
Beta = 0.22 ~ 0.4
Beta = 0.61 ~ 0.9

Muons
Nuclei
Kaons

Beam Transport to Main Injector and Neutrino Beamlines

Scale 400 Feet
Service Buildings

1.3 GHz Cryomodule
325 MHz Cryomodule
162.5 MHz Cryomodule

Radio Frequency Quadrupole
H- Ion Source
SRF Development: 1.3 GHz (ILC)

- 90 nine-cell cavities ordered; 60 received (32 from U.S. industry: 16 from AES, 16 from Niowave-Roark)
- ~40 processed and tested, ~20 dressed
- 2 CMs built: one from a DESY kit and a second U.S. procured
SRF Development: 650 MHz

- JLab built two single-cell \( \beta = 0.61 \) cavities

- Six \( \beta = 0.9 \) single-cell cavities built by U.S. industry

- Order for six \( \beta = 0.61 \) (2 JLab, 2 FNAL design) single-cell cavities in industry

- Five-cell design complete for \( \beta_G = 0.9 \) cavities
  - four 5-cell cavities on order from AES
  - two expected in FY12
SCRF Development: 325 MHz and 162.5 MHz

- **SSR2** ($\beta_G = 0.47$) Single Spoke Resonator
  - EM design complete
  - Mechanical design in progress

SSR1 ($\beta_G = 0.22$) Single Spoke Resonator
- Initiated under HINS program → more advanced
- 8 prototype cavities to date
  - 3 tested as bare cavities at 2K
  - One dressed and tested at 4.8K

HWR ($\beta_G = 0.11$) Half Wave Resonator
- EM and mechanical design underway at ANL
- Similar to cavities & CM already manufactured by ANL
### Operating Scenario for High Power Campus

<table>
<thead>
<tr>
<th>Period</th>
<th>Frequency</th>
<th>Duration</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 μsec</td>
<td>3 GeV</td>
<td>162.5 MHz</td>
<td>80 nsec</td>
</tr>
<tr>
<td>1 μsec</td>
<td>27 MHz</td>
<td>2.1 MeV</td>
<td>1 mA</td>
</tr>
<tr>
<td>1 μsec</td>
<td>13.5 MHz</td>
<td>770 kW</td>
<td></td>
</tr>
</tbody>
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Ion source and RFQ operate at 4.4mA; 77% of bunches are chopped @2.1MeV
⇒ maintain 1 mA over 1 μsec
Project X Injector Experiment (PXIE)

- PXIE is the centerpiece of the Project X R&D program
  - Integrated systems test for Project X front end components

- Collaboration between Fermilab, ANL, LBNL, SLAC, India
Muon Beamline & Neutrino Factory

Highest-intensity muon and neutrino source in the world
The High Intensity Future of Fermilab,
Young-Kee Kim, ICHEP, July 7, 2012

Muon Collider
The first collider of this kind
Summary

- Fermilab continues to operate most of its existing accelerators with enhanced capabilities and next generation experiments (2010s)

- Project X is a staged evolution of the best assets of the Fermilab accelerator complex with the revolution in super-conducting RF technology; Each Stage of Project X will raise many boats of the Intensity Frontier in particle physics, with a program scope of more than 20 world-leading particle physics experiments and an associated robust user community.

- A path toward a muon source for possible future Neutrino Factory and/or a Muon Collider

- Project X R&D underway with very significant investment in SCRF
  - Emphasis on the CW linac/Stage 1 components, including front end development program (PXIE)

- Significant effort is being invested in defining Project X physics programs associated with all stages