Status and Plans for a Superconducting RF Accelerator Test Facility at Fermilab

Jerry Leibfritz
Fermilab
May 21, 2012
The Place with Many Names

ILC Test Accelerator
ILCTA
ILCTA_NML
STF at NML
New Muon Lab
NML
SRF Test Facility
ASTA
CMTF
PXIE
???
Outline

• Overview of ASTA Test Facility
• Project Goals and Phases
• Layout of Facility
• Current Status
• Expansion Project
• AARD Program
• Cryomodule Test Facility (CMTF)
• Future Plans
• Schedule
• **Advanced Superconducting Test Accelerator (ASTA)**
  - ASTA is a multiple purpose facility for testing 1.3 GHz cryomodules
    - International Linear Collider (ILC) R&D
    - Advanced Accelerator R&D (AARD) facility
    - Test facility for Project X pulsed linac
  - A pulsed electron Superconducting Radio Frequency (SRF) linear accelerator

• **Overall Goal**
  - Build an RF Unit Test Facility at the New Muon Lab (NML)
    - ILC RF Unit = 3 cryomodules, 10-MW RF system
    - Beam with ILC parameters (3.2 nC/bunch @3 MHz, up to 3000 bunches @ 5Hz, 300-µm rms bunch length, 1msec pulse length)
    - ~ 750 MeV beam energy
ASTA Phase–1 (FY07-FY11)

- Prepare facility for testing first cryomodule (CM1) without beam (Completed Dec. 2010)
  - Removal of Chicago Cyclotron Magnet
  - Infrastructure, RF power, cryogenics (Tevatron satellite refrigerators #1 & #2)
  - Install first cryomodule (CM1) and Capture Cavity-2 (CC2), cool down, and begin RF testing

NML During Removal of Chicago Cyclotron Magnet (CCM) (September, 2006)

NML Facility after CCM Removal and Floor Painting (February, 2007)
Phase-1 Layout of ASTA

Capture Cavity 2 (CC2)

Cryomodule-1 (CM1) (Type III+)

CC2 RF System

5 MW RF System for CM1
ASTA at NML
CM1 Installation in ASTA
Cryomodule Operations

• Cryomodule 1 (CM1) was a “kit” from DESY
  – Very successful 15 month operational plan of CM1 completed in March 2012
    • Goal was to verify our assembly techniques and learn to operate our systems
    • Overall accelerating gradient of ~ 200 MeV (avg.=23.7 MeV/m)
  – Installation of first high gradient (31.5 MV/m) CM2 in progress

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM-1 Peak Gradient</td>
<td>20.2</td>
<td>22.5</td>
<td>23.2</td>
<td>24*</td>
<td>28.2</td>
<td>24.5</td>
<td>22.3</td>
<td>25</td>
<td>23.7</td>
</tr>
<tr>
<td>Ratio compared to Chechia</td>
<td>0.86</td>
<td>1.00</td>
<td>0.758</td>
<td>0.716</td>
<td>0.773</td>
<td>0.788</td>
<td>0.782</td>
<td>0.940</td>
<td>0.827</td>
</tr>
</tbody>
</table>
ASTA Phase-2 (FY11 – FY13)

- Prepare for First Beam
  - NML Expansion construction (capability for 2 RF units)
  - Construction of new Cryomodule Test Facility
  - Install new gun, injector, test beam lines, and beam dump
  - Commission gun – generate first beam
  - Accelerate beam through single cryomodule
NML Expansion Project

- Existing NML Building
- Alcove for Cryoplant Tie-in
- Test Beamlines/AARD Area
- Beam Dump
- CM5
- CM6
- 10 meter Storage Ring
- Rack Room/Laser Lab
- Capability for 1.5 GeV beam
- ARRA Funded
- Construction Completed 4/11

May 21, 2012

IPAC12 - J. Leibfritz
NML Expansion Construction

Digging Tunnel

Finished Tunnel

Electrical Service Building
Installation of Gun & Injector
Beam Absorber/Dump

- Three High Power (75 kW) Beam Absorbers
- 1200 Tons of Steel and Concrete
Beam Absorber/Dump

WEPPD034 - C. Baffes, et al., “Mechanical Design of a High Energy Beam Absorber for the Advanced Superconducting Test Accelerator (ASTA) at Fermilab”
ASTA Summary and Future Plans

- **Phase-1 of Project is complete!**
  - CC2 and CM1 have been cooled to 2K and RF powered
  - CM1 operations complete

- **Phase-2 in progress**
  - Installation of gun, injector, beam lines, absorber/dump
  - First beam in 2012

- **Phase-3**
  - Full accelerator operation (beam through at least 3 CM’s)
  - Advanced Accelerator R&D (AARD) Program
    - Low Energy ~ (40-50 MeV)
    - High Energy ~ (150 MeV to 1.5 GeV)
## Proposals for NML (1)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Energy</th>
<th>proponent</th>
<th>Motivation/Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long. $\rightarrow$ transverse EEX</td>
<td>low</td>
<td>FNAL/ANL</td>
<td>Proof-of-principle; possible application in FELs and X-ray sources</td>
</tr>
<tr>
<td>Slit microbunching generation</td>
<td>low</td>
<td>FNAL</td>
<td>For wakefield investigations;</td>
</tr>
<tr>
<td>Ellipsoidal beam generation</td>
<td>low (egun)</td>
<td>NIU</td>
<td>Low emittance beams</td>
</tr>
<tr>
<td>Microbunching investigations</td>
<td>low, high</td>
<td>ANL</td>
<td>Beam physics; diagnostics</td>
</tr>
<tr>
<td>ODR instrumentation development</td>
<td>high</td>
<td>ANL</td>
<td>Non-invasive emittance diagnostic</td>
</tr>
<tr>
<td>Flat beam transform and image charge undulator</td>
<td>low</td>
<td>FNAL/NIU</td>
<td>Compact UV/ soft X-ray source</td>
</tr>
<tr>
<td>Flat beam transform</td>
<td>high</td>
<td>LANL</td>
<td>Proof-of-principle for MaRIE</td>
</tr>
<tr>
<td>Emittance exchange</td>
<td>high</td>
<td>LANL</td>
<td>Proof-of-principle for MaRIE</td>
</tr>
<tr>
<td>6-D muon cooling</td>
<td>high</td>
<td>IIT</td>
<td>Proof-of-principle for muon collider</td>
</tr>
<tr>
<td>Optical stochastic cooling</td>
<td>high</td>
<td>IIT</td>
<td>Proof-of-principle; muon collider</td>
</tr>
<tr>
<td>$\gamma$-ray enhancement by crystal channeling</td>
<td>high</td>
<td>ANL</td>
<td>Unpolarized e$^+$ source</td>
</tr>
<tr>
<td>High gradient wakefield acceleration with dielectric structures</td>
<td>Low?, high?</td>
<td>ANL/NIU</td>
<td>many</td>
</tr>
</tbody>
</table>
## Proposals for NML (2)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Energy</th>
<th>proponent</th>
<th>Motivation/application</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC lattice test</td>
<td>high</td>
<td>Muons Inc</td>
<td>Muon collider</td>
</tr>
<tr>
<td>Reverse emittance exchange</td>
<td>Low, high</td>
<td>Muons Inc</td>
<td>Muon collider</td>
</tr>
<tr>
<td>Dielectric Wall Accelerator section</td>
<td>Low-high</td>
<td>FNAL</td>
<td>Muon collider; induction linac</td>
</tr>
<tr>
<td>Measure plasma wakes with long bunch trains</td>
<td>high</td>
<td>USC</td>
<td>Application to 2-beam plasma acceleration</td>
</tr>
<tr>
<td>Measure plasma wakes with laser interferometry</td>
<td>high</td>
<td>USC</td>
<td>Application to 2-beam plasma acceleration</td>
</tr>
<tr>
<td>Photoproduction of muons @ 300 MeV</td>
<td>high</td>
<td>FNAL</td>
<td>Homeland security; verify production model</td>
</tr>
<tr>
<td>Test of integrable beam optics</td>
<td>high</td>
<td>FNAL</td>
<td>Proof-of-principle; future high current proton machines</td>
</tr>
<tr>
<td>Study HOM absorption</td>
<td>high</td>
<td>FNAL</td>
<td>Project-X and Muon Collider; ADS</td>
</tr>
<tr>
<td>Study coupler kicks on beams</td>
<td>low</td>
<td>FNAL</td>
<td>ILC, Pr-X, Muon collider, ADS</td>
</tr>
<tr>
<td>Study cavity BPM</td>
<td>Low-high</td>
<td>FNAL</td>
<td>ILC, Project-X, Muon Collider; ADS</td>
</tr>
<tr>
<td>High charge bunch loading</td>
<td>high</td>
<td>FNAL</td>
<td>Muon Collider (acceleration of 1e12)</td>
</tr>
<tr>
<td>MC IR optic method test</td>
<td>Low-high</td>
<td>FNAL</td>
<td>Muon collider, ADS</td>
</tr>
</tbody>
</table>
AARD Program Plan

- Selected Three “Phase-1” AARD Experiments for ASTA
  - Double Emittance Exchange (D-EEX) beam line for pulse shaping experiments (at 250-350 MeV)
  - High Brightness Compact Diamond Radiator (NIU/Vanderbilt) test experiment (at 40 MeV)
  - Integrable Optics Test Accelerator (IOTA) to demonstrate new nonlinear optics solution (at 150-300 MeV)
IOTA Storage Ring at ASTA

- **Integrable Optics Test Accelerator (IOTA)**
  - 30-meter circumference storage ring that will study non-linear accelerator optics (at 150-300 MeV)

MOYCP01 – S. Nagaitsev et al., “Design and Simulation of IOTA – A Novel Concept of Integrable Optics Test Accelerator”
• CMTF is a new set of buildings (adjacent to NML) originally designed to house two helium cryoplates and two cryomodule test stands. Now being repurposed to house PXIE.
CMTF Layout

New Cryoplant & CM Test Facility
(250 W Cryogenic Plant, Cryomodule Test Stands, RF Test Area, Vacuum Cleanroom)

Vacuum Cleanroom

Cryomodule Test Stands

RF Systems
(325 & 650 Mhz, 1.3 GHz CW and Pulsed)

Cryogenic Refrigerators

Compressor Building

Funded by ARRA

Construction Completed 12/11
Project X Injector Experiment (PXIE)

- Goal: Build a prototype of the first ~15-30 MeV of Project X
- CW H⁻ linear accelerator
- Beam through $\beta=0.1, 0.2$ CM at ~15 MeV with nearly final parameters (1 mA CW, 5 mA peak, arbitrary bunch chopping)

Several Papers on Project X and PXIE at IPAC 12
PXIE Layout in CMTF Building

CMTS1

CMTS2 replaced with PXIE
Cryogenic System

- Combined Cryogenic Systems Should Have the Following Functionality
  - Operate NML/ASTA with 2 Capture Cavities and up to 6 Cryomodules (Pulsed)
    - CW Cryomodule operation is possible, but is not in current plans
  - Operate PXIE with 1 HWR and 1 SSR1 Cryomodule (CW)
  - Operate CMTS1 capable of testing 1 Cryomodule
    - 1.3 GHz Cryomodules - Pulsed or CW
    - 325 MHz SSR or 650 MHz Cryomodules (CW)
  - Pressure stability goal 0.1 mbar (rms)

- Helium cryoplants in CMTF and NML (nominal capacities)
  - New Superfluid Refrigerator
    - 250W @ 1.8K or 500W @ 2K
  - Repurposed SLAC CTI-4000 Refrigerator - supplies LHe to NML/ASTA
    - 1500W @ 4.5K
  - Repurposed Tevatron Satellite Refrigerators (2) in NML
    - 1250W @ 4.5K
Rendition of SRF Complex
Actual SRF Complex
### Schedule/Milestones

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase-1 Cryogenic System Operational</td>
<td>(August 2007)</td>
</tr>
<tr>
<td>Delivery of First Cryomodule to NML</td>
<td>(August 2008)</td>
</tr>
<tr>
<td>Cold RF Testing of First Cryomodule</td>
<td>(Dec. 2010)</td>
</tr>
<tr>
<td>Completed Construction of NML Expansion</td>
<td>(April 2011)</td>
</tr>
<tr>
<td>Completed Construction of CMTF Building</td>
<td>(Dec. 2011)</td>
</tr>
<tr>
<td>Beam Absorbers/Dump Installed</td>
<td>(Dec. 2011)</td>
</tr>
<tr>
<td>CM1 Testing Complete</td>
<td>(March 2012)</td>
</tr>
<tr>
<td>Cold RF Testing of Second Cryomodule</td>
<td>(July 2012)</td>
</tr>
<tr>
<td>Install Injector &amp; Test Beam Lines</td>
<td>(2011-2012)</td>
</tr>
<tr>
<td>First Beam</td>
<td>(2012)</td>
</tr>
<tr>
<td>New Cryoplant Installation/Operation</td>
<td>(2013-2014)</td>
</tr>
<tr>
<td>Install 3 Cryomodule String</td>
<td>(2013-2014)</td>
</tr>
<tr>
<td>RF Unit Test with Beam (S2)</td>
<td>(2014)</td>
</tr>
</tbody>
</table>
Thanks to...

The Entire ASTA/NML Team!