Beam Diagnostics & Beam Studies at HINS / MDB

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Project X Collaboration Meeting
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Outline

- Motivation
- HINS Parameters
- HINS Measurements to Date
- Beam Diagnostic Projects
- Collaborations
- Goals and Timelines
- Conclusions
The Meson Detector Building (MDB) Test Facility (formerly known as HINS – High Intensity Neutrino Source) ultimately comprises:

- A shielded beam line enclosure with first proton, then H⁻, pulsed 1% duty factor, 3 millisecond beam up to 10MeV
  - For Project X 325 MHz superconducting spoke cavity beam tests
  - For Project X chopper tests
  - For Project X H⁻ beam instrumentation development
- Shielded enclosures and RF power systems for testing individual, jacketed 1.3 GHz, 650 MHz, and 325 MHz superconducting RF cavities (no beam)
  - For ILC
  - For Project X
MDB Test Facility Layout

1.3 GHz HTS

325 MHz Spoke Cavity Test Facility

1300 CW RF

325 CAGE

Source of cryogenics

HTS-2

650 CW RF

Ion Source and RFQ

MDB Linac enclosure for 10 MEV

Scale: Square blocks are 3ft x 3ft
## HINS Beam Parameters

<table>
<thead>
<tr>
<th>Particle</th>
<th>H+ then H-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Bunch Frequency/Spacing</td>
<td>325 MHz, 3.1 nsec</td>
</tr>
<tr>
<td>Particles per Pulse</td>
<td>37.5 * E13</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>3/1 msec</td>
</tr>
<tr>
<td>Average Pulse Current</td>
<td>~ 20 mA</td>
</tr>
<tr>
<td>Pulse Rep. Rate</td>
<td>2.5/10 Hz</td>
</tr>
<tr>
<td>Bunch Current</td>
<td>32 mA</td>
</tr>
<tr>
<td>Bunch Intensity</td>
<td>6.1 * 98 E8 pCoul</td>
</tr>
</tbody>
</table>

* full un-chopped 3 msec pulse at klystron-limited 20 mA
Initial Proton Source and RFQ Beam Measurements
HINS Initial Beam Results

• First proton beam through RFQ in Spring 2010

• Beam parameters:
  – Ion source (protons): 500 usec @ 1 Hz
  – RF: 50 usec @ 0.5 Hz
    • RFQ operated without cooling

• Ion Source Toriod ~ 15-20 ma
  – <50%?? protons; >50%?? other (H2+, H3+)
  – Ion source species are being measured

• RFQ Output Toriod Current ~ 3-4 ma
  – Possible beam loss after RFQ but before toroid

• Basic diagnostics line to make transverse profiles and energy measurements
Proton Source Test Setup

LEBT Toroid

East Faraday Cup

Optimize Upstream solenoid to transmit Max protons to east Faraday cup
• spectrometer set for protons
• Up solenoid → 470 A
Horz scales aligned

Green – Source Extractor Voltage
Yellow – LEBT Toroid Current
Red – West Faraday Cup (straight ahead)
Blue – East Faraday Cup (bend)

- Downstream solenoid optimized for each species
- Upstream solenoid fixed at 470 A
Proton Source Slit-WS Emittance Measurement

Other particle species fill the beam pipe.

Background signal outweighs proton signal.

Proton

Slit motion
Signal Cleaning
Initial RFQ Measurements

Initial Diagnostics Line

Initial Beam Currents

Project X Collab Meeting
The HINS linac was equipped with a reconfigurable, movable diagnostics station at the end of the linac.
Signals from toroid and two BPM buttons, all downstream of the RFQ

Upper display: 2 μsec/div
Lower display: 20 nsec/div

Lower display shows the 44nsec delay expected for transit of 2.5 MeV beam between the BPM two buttons separated by 0.96 meters

Beam current is about 3 mA
Early 2.5 MeV Beam Profiles – Horizontal at 4 mA

Note: Beam loss after first wire scanner
Relative RFQ Output Beam vs. RF Power

RFQ Output vs RFQ Power

- BPM 325 MHz Component
- RFQ Output Toroid

Relative Signals to Peak Power

RFQ Power (KW)
Next Iteration of RFQ Beam Measurements

• Initial measurements suffered from RFQ water leak problems
  – RFQ limited to 50 μsec pulses
  – RFQ has been repaired and reinstalled at the Meson test facility

• Initial RFQ measurements suffered many issues
  – No longitudinal measurements → FFC and BSM
  – No transverse emittance measurements → Quad-Wire, Slit-Wire
  – Energy measurement was not precise → spectrometer magnet
  – RFQ transmission efficiency not measured
    • Toroid not close enough to RFQ output

• New diagnostics line has been install
  – Reconfigurable
  – Space for R&D projects
Advanced HINS Diagnostics Line

T: Toroid
GV: Gate Value
Q: Quadrupole
LW: Laser Wire
SEM: Secondary Emission Monitor
BPM: Beam Position Monitor
WS: Wire Scanner
S: Horz and Vert Slits
BSM: Bunch Shape Monitor (Longitudinal)
FFC: Fast Faraday Cup
HM: Halo Monitor
FD: Faraday Cup/Dump
SM: Spectrometer Magnet

End of beamline

H⁻ Beam
H⁺ Beam or H⁻ Beam
Current Measurements

Beam Current

End of beamline

[Diagram of beam current flow with various components labeled]
Transverse Emittance

End of beamline

Transverse Emittance

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Longitudinal Bunch Shape Monitor

- Electron
- Proton Beam
- Beam Pipe
- Bunch Length Monitor
- RF Field
- RF Deflector
  Frequency = $h \times f_0$
- Signal Pickup
- Pass at zero-phase
Beam Diagnostic Projects for Project X

- **Transverse Diagnostics**
  - Laser Transverse Profile Monitor*
  - Ionization Profile Monitors
  - Electron Wire Transverse Profile Monitor

- **Longitudinal Diagnostics**
  - Wire Longitudinal Profile Monitor*
  - Laser Longitudinal Profile Monitor*
  - Broadband Faraday-cup*

- Halo Monitoring – transverse and longitudinal
  - Vibrating wire* - *from Bergoz Instrumentation
  - Laser wire*

- **MEBT Emittance station**
  - Slit-collector*
  - Laser Slit*

*Project X related instrumentation to be tested at HINS
Project X Beam Diagnostics Collaborations

• Project X Collaboration Initiative (November 2008):
  – Present beam instrumentation collaboration projects with SNS, LBNL, and SLAC

• SNS
  – Various advanced diagnostics systems (broadband Faraday-cup, e-beam scanner, MEBT beam instrumentation, laser wires, etc.)
  – Support, information exchange, R&D help, visits, reviews, etc.,

• LBNL
  – Development of a mode-locked fiber laser system for longitudinal bunch profile measurements (also bunch tails), distribution of laser light with fiber optics
    • Byrd & Wilcox – see Wilcox talk this meeting
    • Critical to use HINS at testing facility
Laser Wire Diagnostic Test Station

Transverse Beam Profiles using Laser Wire and electron detector

Transverse Emittance using Laser Wire, electron detector and H⁰ profile monitor
• Demonstrate use of high power RF vector modulators to control multiple RF cavities driven by a single high power klystron
  – Summer 2011
Partial Installation of Six-Cavity Test

RF distribution system in background and one RF cavity in foreground inside HINS beam enclosure
Vector Modulator Setup

- Ferrite Phase Shifters
- Circulators
- Hybrid
- Trumbone
Plan – Six-Cavity Test

- **FY11**
  - Complete Linac enclosure electrical, water, and safety interlock system infrastructure installations
  - Re-commission RFQ with beam
  - Begin Six-Cavity Test beam line installation
  - Install H- source

- **FY12**
  - Complete beam line installation
  - Install and commission beam line controls, LLRF, and RF interlocks
  - Commission beam line and commence test plan

- **FY13**
  - Successfully complete Six-Cavity vector modulator/beam tests
  - Decommission test set-ups as required
  - Complete final technical papers and reports
HINS beamline will evolve – diagnostics section will adapt to changes
MDB Long Term Plan
Chopper and 4-Cavity CM

With cryomodule need additional 3+ meters cave length pending spectrometer line optics design.
Conclusion

- MDB Test Facility (HINS) has taken initial proton source and RFQ beam measurements
- RFQ has been repaired and reinstalled at MDB
- New diagnostics line has been installed
- RFQ Beam measurements to start shortly
- Six cavity (and H⁻ source?) to be installed this year
  - Laser diagnostic projects need H⁻
- Success with HINS measurements will allow for future Project X front-end testing and characterization at Meson
End