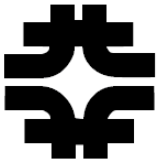
OVERVIEW OF THE HIGH INTENSITY NEUTRINO SOURCE LINAC R&D PROGRAM AT FERMILAB

Dave Wildman for HINS Team

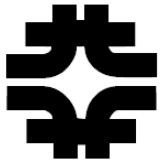
LINAC08

Introduction and History



- The High Intensity Neutrino Source (HINS) R&D Program is an effort that began in late 2005 to demonstrate the application of technologies that are innovative for a low-energy, high-intensity hadron beam linear accelerator
- HINS is a moderate R&D effort at ~7-8M$/year
- HINS technology is the likely candidate for the front-end of the proposed 8 GeV Project X Linac
- Project X expects the HINS program to deliver:
  - A prototype 66 MeV Linac operating at 325 MHz providing a 27mA beam with a 1 msec pulse length

Specific HINS R&D Objectives



- Develop and apply high power RF vector modulators to control amplitude and phase of multiple cavities powered by a single klystron to accelerate beam from 2.5 MeV
- Produce, accelerate to 60 MeV, and measure an axially-symmetric beam focused by superconducting solenoids
- Accelerate beam from 2.5 to 10 MeV with room-temperature crossbar spoke cavities
- Accelerate beam from 10 to 60 MeV using superconducting (SC) single spoke resonator (SSR) RF structures
- Demonstrate high-speed (nanosec) beam chopping at 2.5 MeV

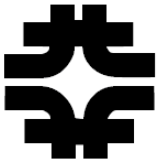
This makes HINS a first-of-a-kind superconducting 60 MeV H- linac

HINS Operating Parameters

Particle	H+ then H-	
Nominal Bunch Frequency/Spacing	325 3.1	MHz nsec
Particles per Pulse	37.5 *	E13
Pulse Length	3/1	msec
Average Pulse Current	~20	mA
Pulse Rep. Rate	2.5/10	Hz
Chopping -6% @ 89KHz and 33% @ 53MHz	0 - 37.5%	
Bunch Current	32	mA
Bunch Intensity	6.1 98	E8 pCoul

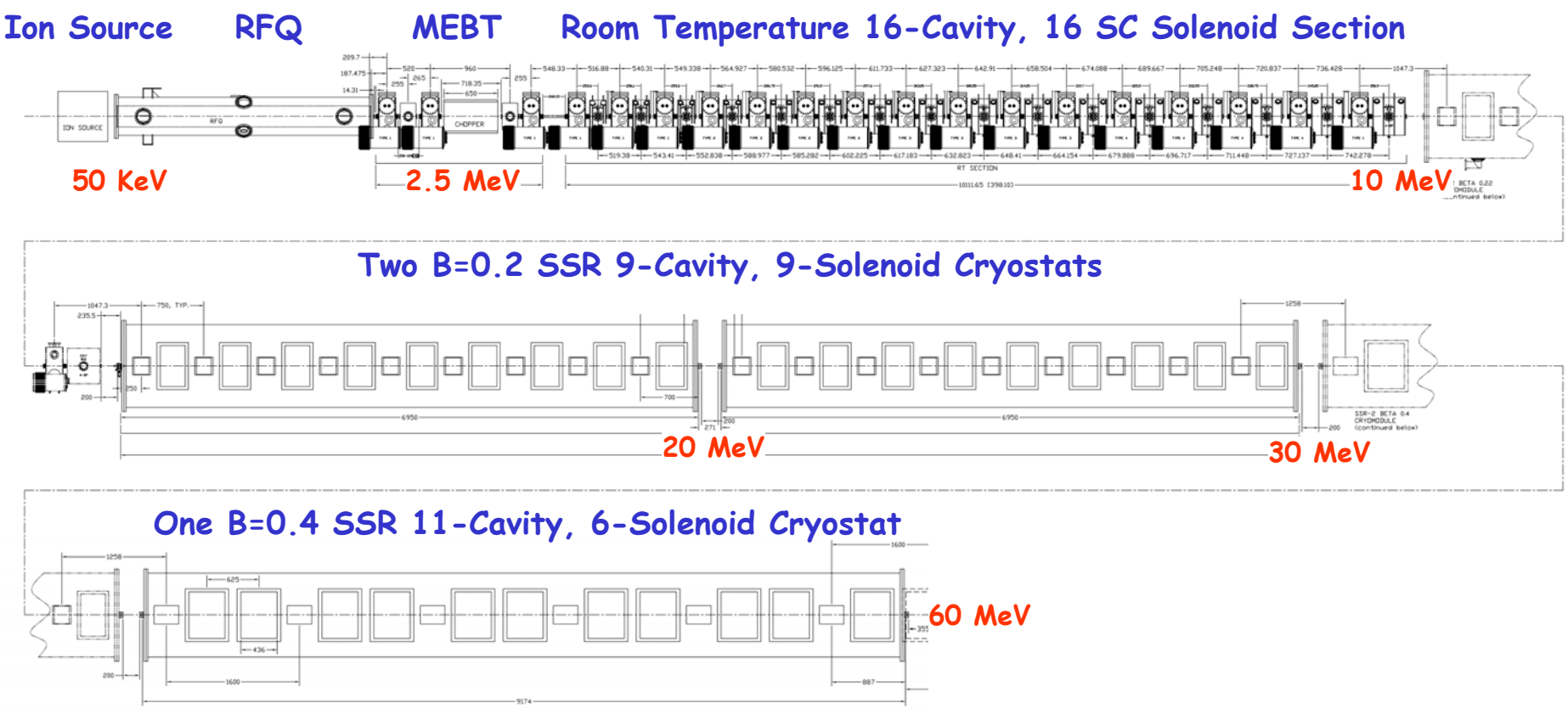
* full un-chopped 3 msec pulse at klystron-limited 20 mA

HINS Linac Sections

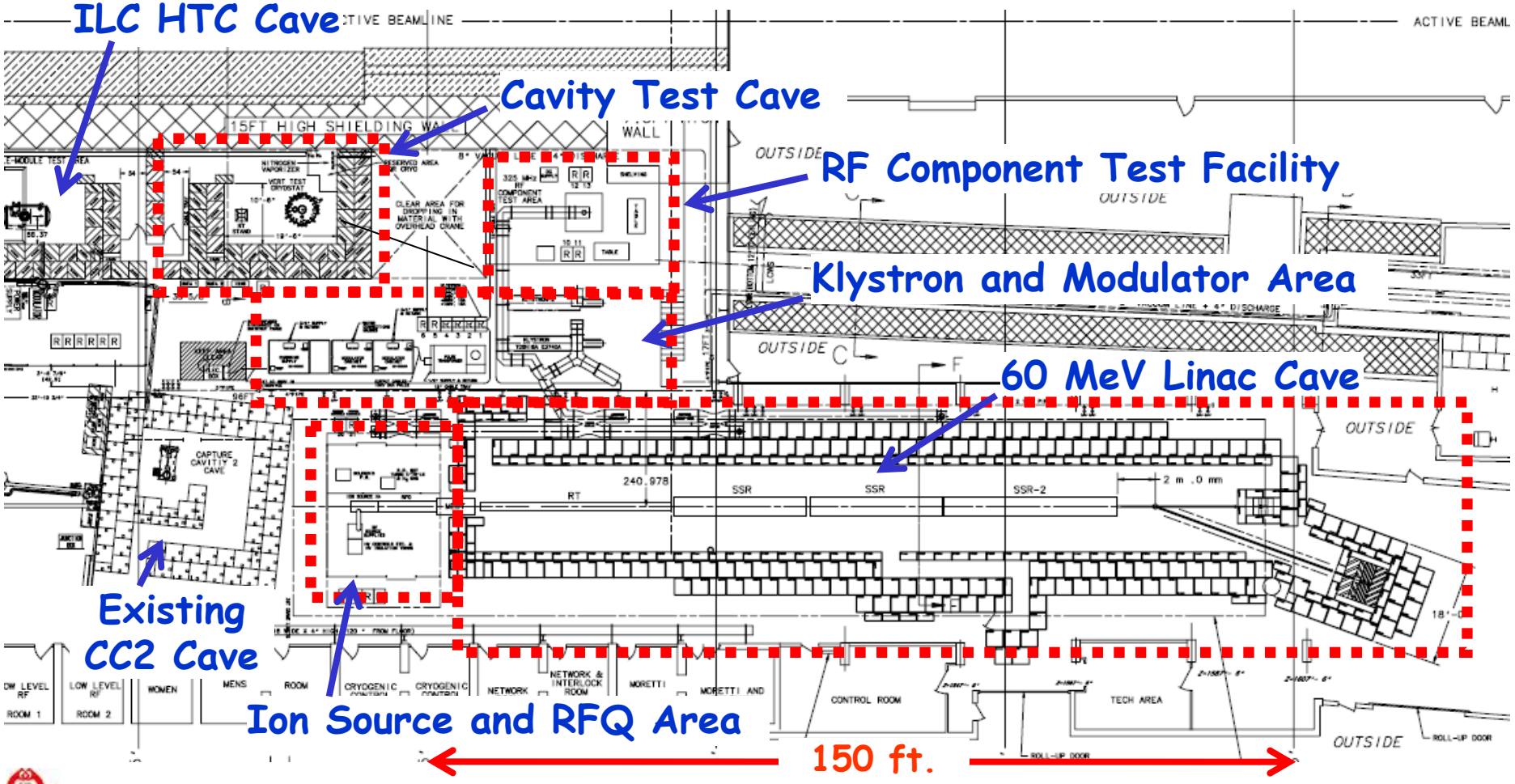


- 50 keV ion source (initially protons, ultimately H-)
- 2.5 MeV 325 MHz vane-type RFQ
- Medium Energy Beam Transport (MEBT)
  - Three superconducting solenoid magnets
  - Two 325 MHz buncher cavities
  - Fast beam chopper
- 2.5 – 10 MeV Room Temperature (RT) Cavity Section
  - Sixteen 325 MHz room-temperature crossbar-H spoke cavities
  - Sixteen superconducting solenoids
- 10 – 60 MeV SSR1 and SSR2 Cavity Section
  - Two cryomodules each with nine SSR1 β=0.2 325 MHz superconducting spoke cavities and nine superconducting solenoids
  - One cryomodule with eleven SSR2 β=0.4 325 MHz superconducting spoke cavities and six superconducting solenoids

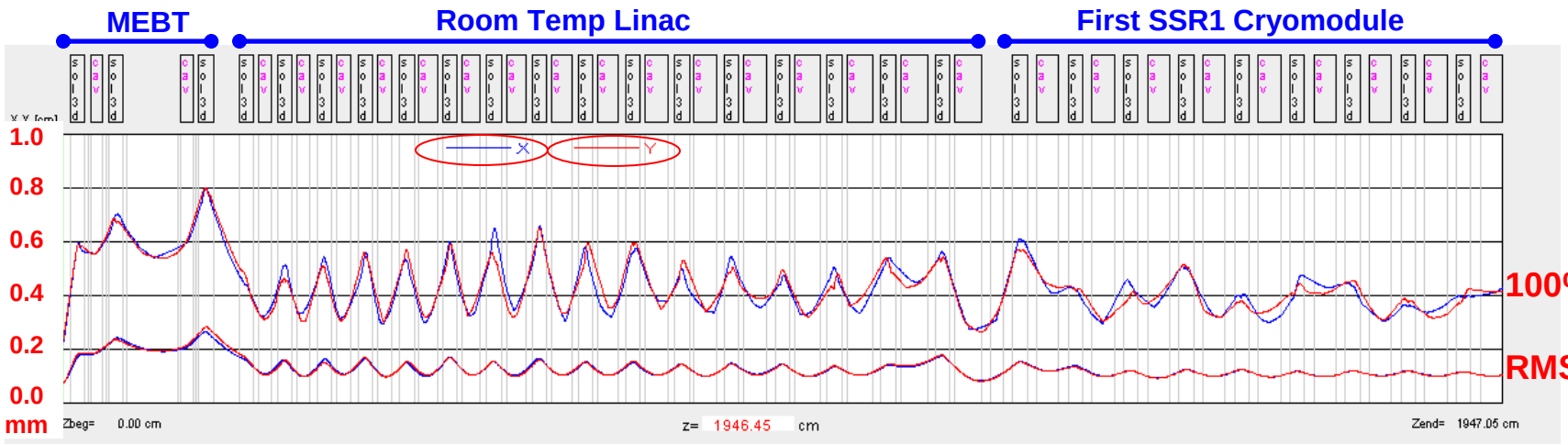
HINS Layout


Ion Source
RFQ
MEBT
Room Temperature 16-Cavity, 16 SC Solenoid Section
50 KeV
2.5 MeV
10 MeV
Two B=0.2 SSR 9-Cavity, 9-Solenoid Cryostats
20 MeV
30 MeV
One B=0.4 SSR 11-Cavity, 6-Solenoid Cryostat
60 MeV
~14 meters

HINS Floor Plan in Meson Building

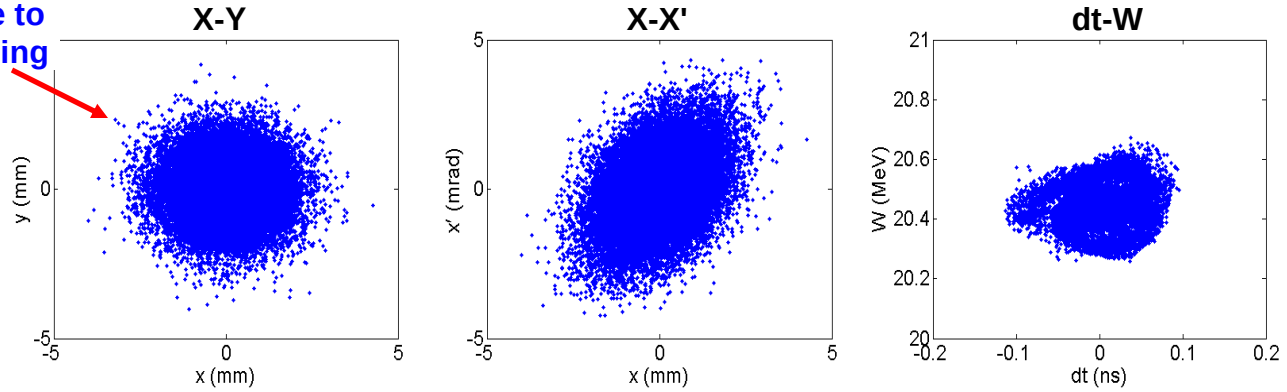


TRACK Simulation at 15 mA - RFQ to 20 MeV



Transverse Beam Size from RFQ to 20 MeV at End First SSR1 Cryomodule

Round Beam Due to Solenoidal Focusing



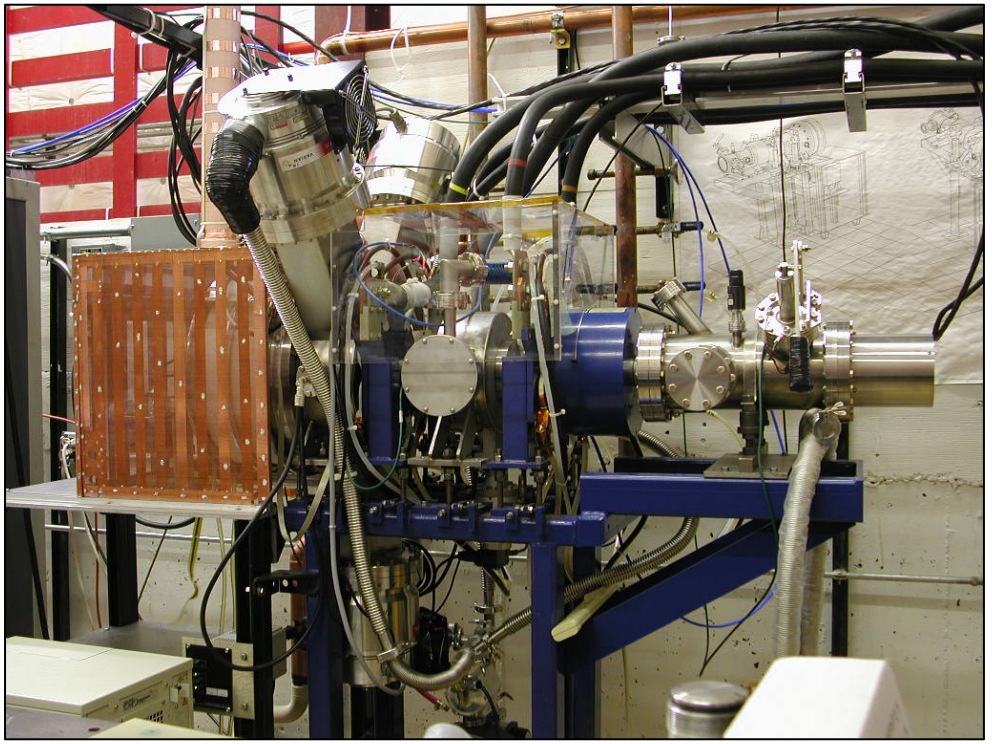
Transverse Distribution and Phase Space at 20 MeV (End First SSR1 Cryomodule)

HINS Status

- 2.5 MW, 325 MHz klystron RF power source is operational
- HINS RF Component Test Facility is operational
- Room temperature cavity RF conditioning is in progress; four cavities are on hand, the remaining 12 now being fabricated
- First SC spoke cavity tested in Vertical Test Stand (VTS) in March '08; three more cavities and first helium vessel are in production
- Proton ion source is operational in the Ion Source/RFQ Area
- RFQ was received in early September and RF conditioning is expected to begin within 2-3 weeks
- Superconducting solenoid magnets for RT section are being fabricated and cryostat procurement has begun
- Cavity test cryostat necessary for full pulsed-power testing of individual SC spoke cavities is being assembled and will be complete this year

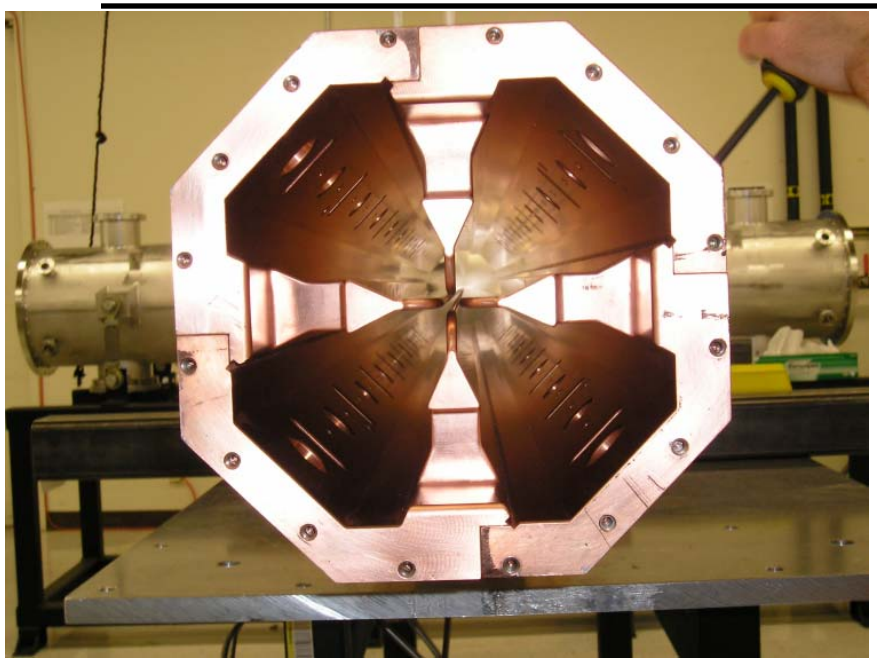
HINS Proton Ion Source and LEBT

Ion Source Control and High Voltage Racks



Ion Source and LEBT

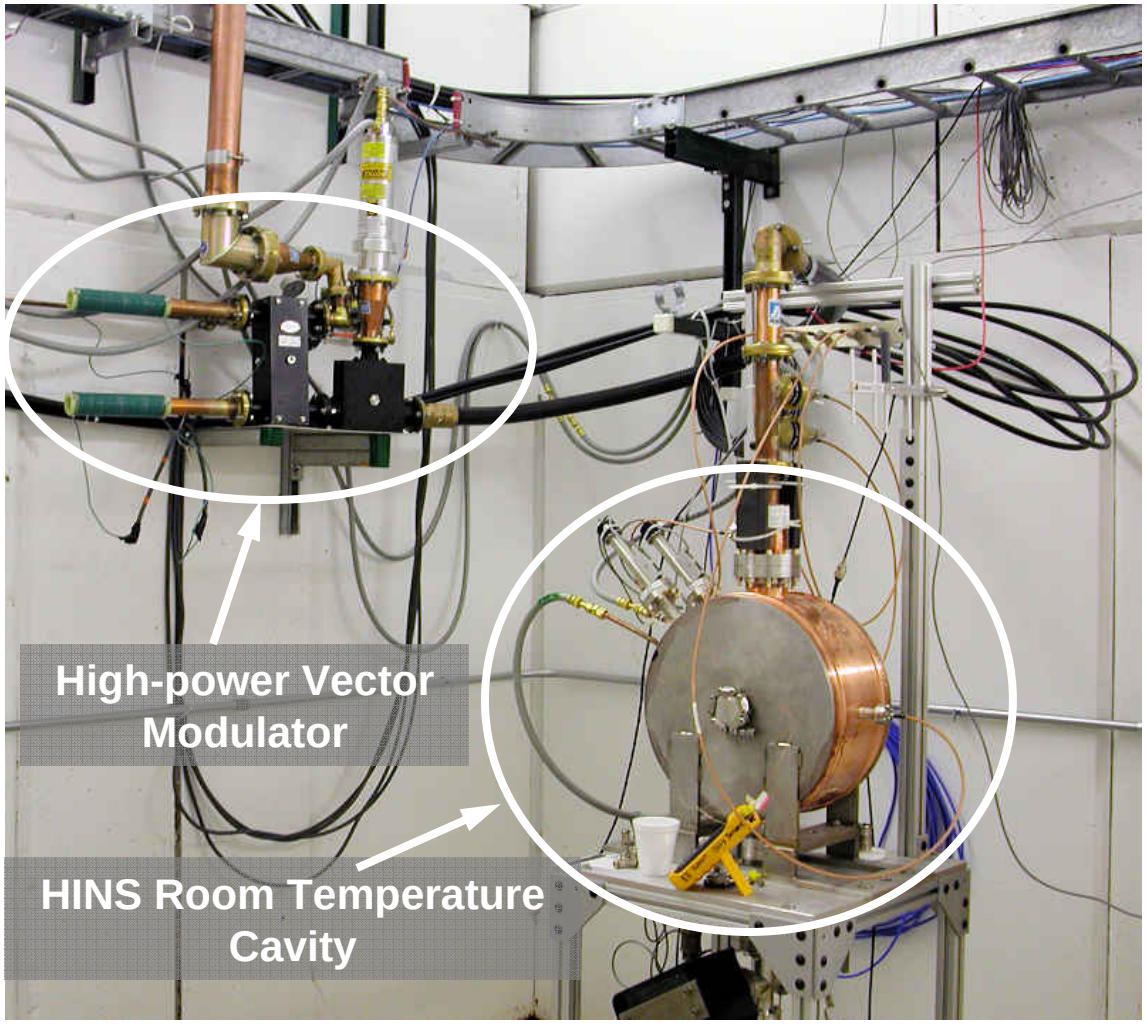
HINS 325 MHz RFQ



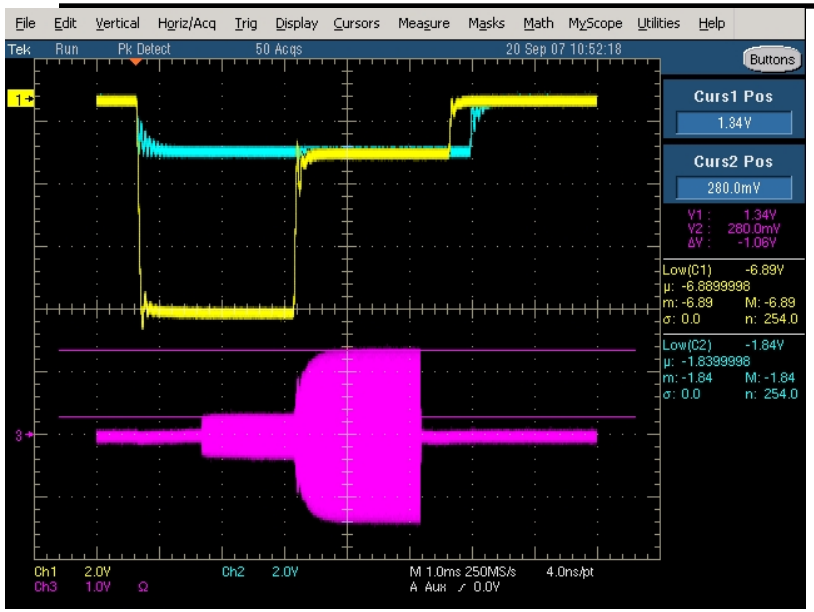
Successful field measurement bead-pull test was done on 6/17.

RFQ is now assembled and final cold tests prior to RF conditioning are nearly complete.

HINS RT Cavity & Vector Modulator

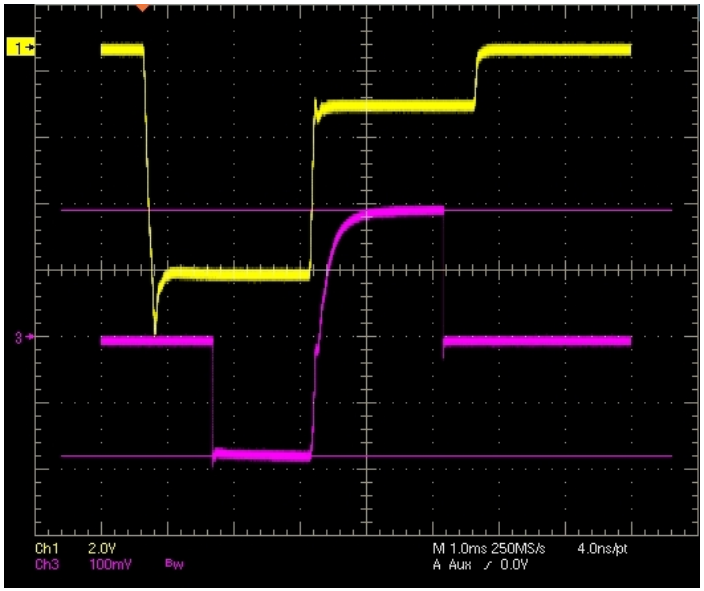


Vector Modulator Performance with Cavity at High Power



13 dB Amplitude Control with Vector Modulator for 6 kW 3.5 msec RF Pulse

Red trace is cavity RF amplitude; blue and yellow are vector modulator bias currents

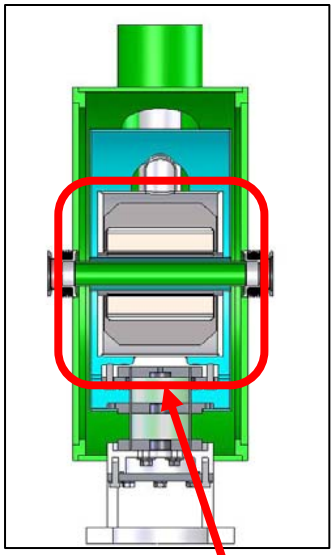


155 Degree Phase Control with Vector Modulator for 6 kW 3.5 msec RF Pulse

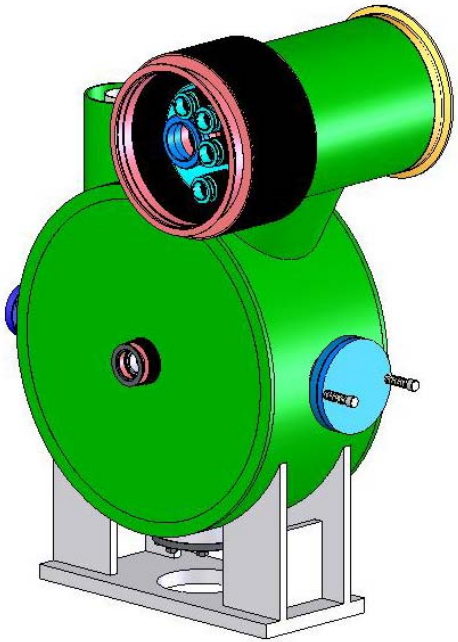
Red trace is cavity RF phase signal; blue and yellow are vector modulator bias currents

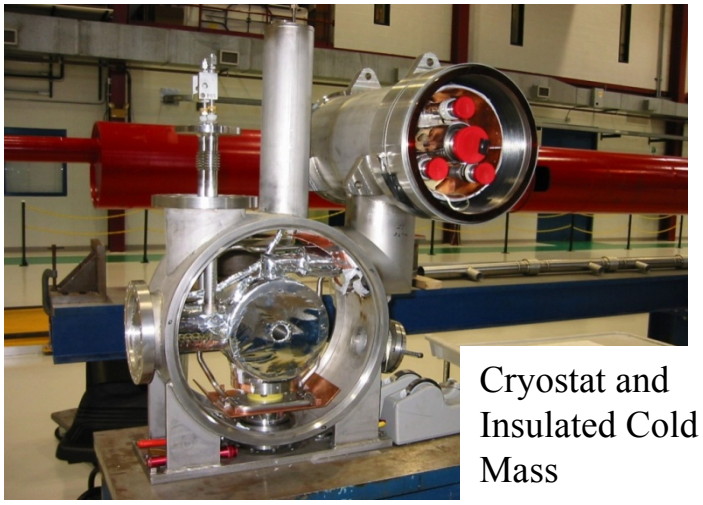
RT Section Solenoid & Cryostat

- Prototype RT superconducting solenoid and cryostat are complete
- Testing is underway
- Production solenoids and cryostats are being manufactured



Solenoid Magnet



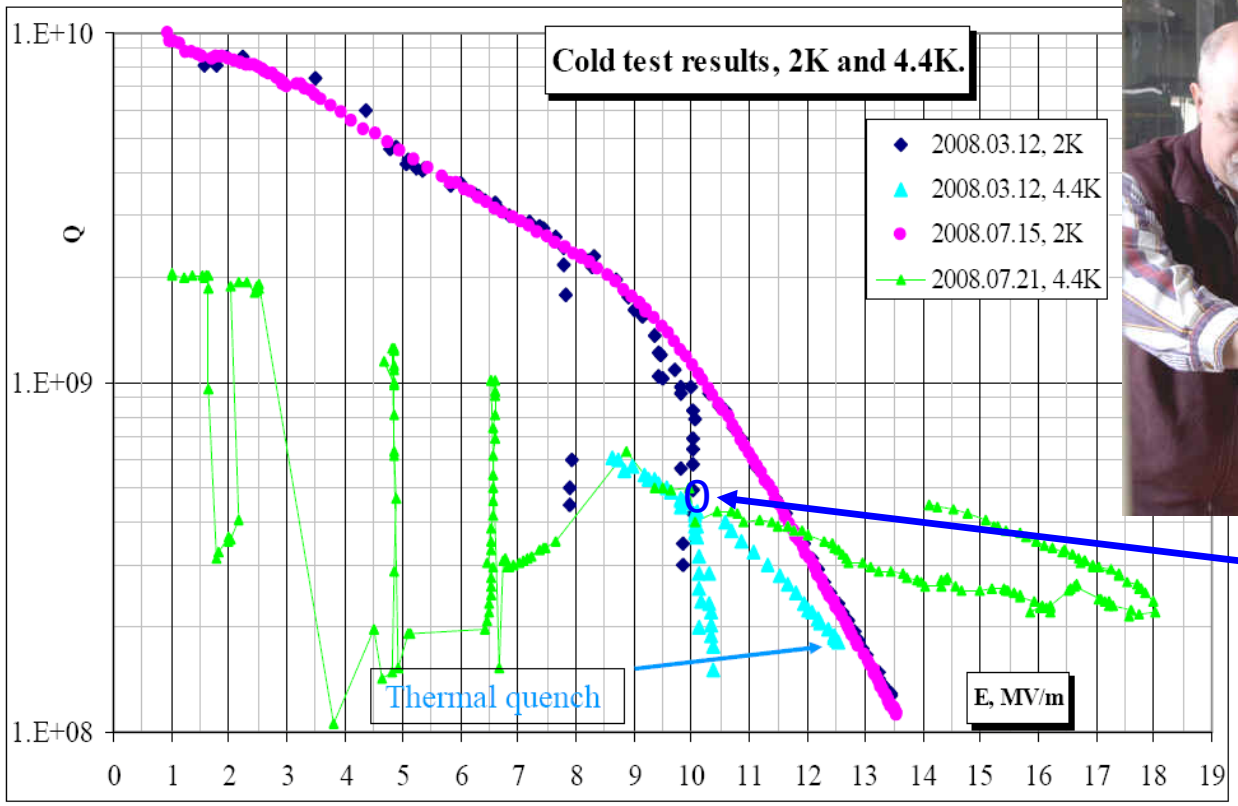


Cryostat and Insulated Cold Mass

"Last" weld

HINS SC Spoke Cavity at VTS

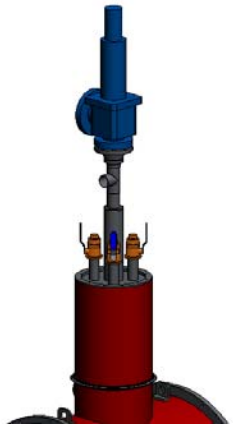
SSR1-01 Vertical Test



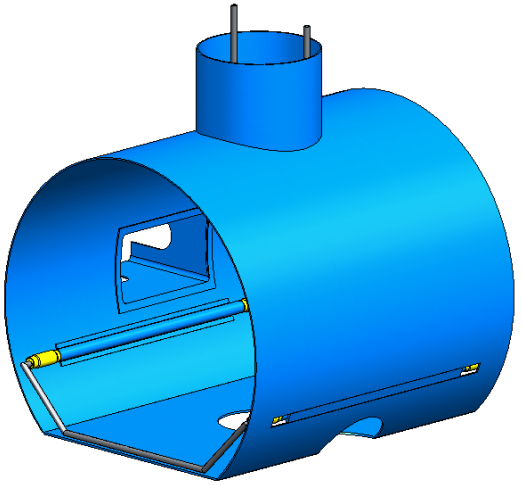
Dressed Cavity
Operating Goal @ 4K

Cavity Test Cryostat

Vacuum Vessel



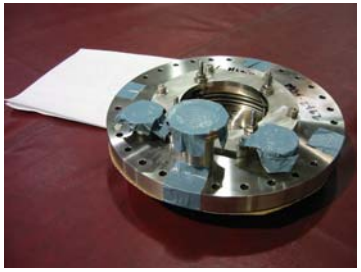
Piping Design



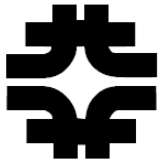
Thermal Shield

Cavity Support Post

RF Power Coupler Flange and Design

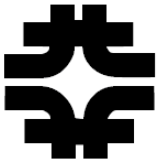


Component Fabrication and Testing Plans



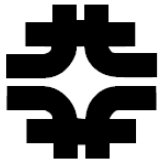
- Oct 08 – Test second superconducting spoke cavity in VTS
- Oct 08 – Complete assembly of cavity test cryostat
- Nov 08 – Receive remainder of room temperature cavities now in fabrication
- Dec 08 – Join first SSR1 SC spoke cavity to helium vessel
- Jan 09 – Assemble and demonstrate control of a two-cavity/vector modulator system at high power (w/o beam)
- Feb 09 – Install cryogenics for cavity test cryostat
- Mar 09 – Test first SSR1 cavity to full pulsed power
- Summer 09 – Complete assembly and testing of SC solenoids and cryostats for the room-temperature cavity section
- FY09 and early FY10 – Procure remaining complement of SSR1 cavities
- 2010 – Complete first SSR1 cryomodule

HINS Beam Staging



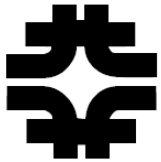
- 2.5 MeV operation
  - Temporary diagnostic/transport line and dump after RFQ
  - Diagnostic line components including beam absorber are on-hand
  - RFQ delivery, RFQ conditioning, and safety paperwork are critical path
  - Present goal for 2.5 MeV beam is Fall of this year
- Intermediate commissioning stage at >2.5 MeV and <10 MeV??
  - MEBT plus first four? RT cavities
    - Quadrupoles in lieu of SC solenoids due to cryo distribution system schedule
  - First test of RF distribution and vector modulator control with beam
  - Enclosure construction, MEBT buncher cavities and LLRF are critical path
- Full 10 MeV Room Temperature section operation
  - Early 2010
  - Solenoid production and cryogenics system are critical path
- 20 MeV operation with first SSR1 cryomodule
  - Early 2011 SSR1 cavities, cryomodule and solenoids are needed
- Full 60 MeV operation
  - Late 2011 is very optimistic

Other HINS Papers in LINAC08



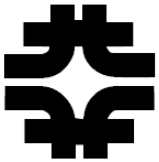
- **MONDAY POSTER SESSION**
- MOP111 - Controls Systems for Linac Test Facilities at Fermilab
  - Presenter Sharon Lackey
- MOP043 - Simulation of Multipacting in HINS Accelerating Structures with CST Particle Studio
  - Presenter Gennady Romanov
- MOP042 - Complete RF Design of the HINS RFQ with CST MWS and HFSS
  - Presenter Gennady Romanov
- MOP041 - The Fabrication and Initial Testing of the HINS RFQ
  - Presenter Gennady Romanov
- MOP013 - Focusing Solenoids for the HINS Linac Front End
  - Presenter Iouri Terechkine
- MOP012 - High Power Test of HINS RT CH Cavities
  - Presenter Wai-Ming Tam
  -
- MOP010 - A Fast Chopper for the Fermilab High Intensity Neutrino Source (HINS)
  - Presenter Robyn Leigh Madrak

Other HINS Papers in LINAC08



- **Wednesday Plenary Session**
- WE203 - Fermilab's Project X
  - Speaker Sergei Nagaitsev
- **Thursday Plenary Session**
- TH301 Beam Dynamics Studies of the 8 GeV Linac at FNAL
  - Speaker Peter Ostroumov
- **Thursday Poster Session**
- THP088 - High Power 325 MHz Vector Modulators for the Fermilab High Intensity Neutrino Source (HINS)
  - Presenter Robyn Leigh Madrak
- THP068 - High Power Test of HINS RT CH Cavities
  - Presenter Wai-Ming Tam
- THP030 - High Gradient Test Results of 325 MHz Single Spoke Cavities at Fermilab
  - Presenter Giorgio Apollinari

Conclusion



- HINS promises to demonstrate the application of technologies that are innovative for a low-energy, high-intensity proton or H- linac
- HINS will demonstrate:
  - The performance and cost savings possible by powering many accelerating cavities from a single klystron
  - The performance of axially-symmetric focusing for improved beam halo and beam loss control
  - The acceleration of beam using superconducting spoke cavity structures from 10 MeV
- The program is actively building and testing components and integrating those into a novel 60 MeV linac