# HINS Status and Strategy/Plans with Respect to Project X

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AAC Meeting

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# Project X AAC Charge Vis-à-vis HINS

- Review and offer comments and recommendations relative to:
  - the current status of the HINS program
  - the strategy for achieving alignment of the HINS and Project X
- More specifically:
  - Are the technical goals of the HINS program well aligned with the needs of Project X?
  - What are the primary technical risks within Project X that can and should be addressed within the HINS program?
  - Does the execution strategy of HINS mesh with the requirements of Project X?
  - What modifications to the HINS program would be effective in aligning with either ICD-1 or ICD-2?
  - Are there other approaches, beyond those being explored in the HINS program, that should be investigated as the front end of the Project X facility?

# Outline

- HINS traditional technical objectives
- Current status of the HINS program
- Re-evaluation of the traditional objectives in Project X world
- Current strategy for achieving alignment of the HINS and Project X
- The Big Questions
- What HINS can do
- What HINS is not well positioned to do
- Conclusions

# HINS Program
# Traditional Goals

- Stated Mission - To address accelerator physics and technology questions for a new concept, low-energy, high intensity, long-pulse H- superconducting Linac; in particular, to demonstrate:
  - beam acceleration using superconducting spoke-type cavity structures starting at a beam energy of 10 MeV
  - multiple high power RF vector modulators controlling RF cavities driven by a single high power klystron for acceleration of a non-relativistic beam
  - beam halo and emittance growth control by the use of solenoid focusing optics
  - a fast, 325 MHz bunch-by-bunch, beam chopper
- **Remember that HINS has been the bridge to Project X for the past nearly four years and that it brings unique and important assets even as it loses its identity within the project**

# Current Scope of HINS

- The current scope of effort to achieve the traditional HINS program goals comprises design, development, fabrication, assembly and operation of a 'first-of-a-kind' pulsed superconducting H- linac
- The components include:
  - 50 keV ion source
  - 2.5 MeV RFQ
  - MEBT with fast beam chopper system
  - 10 MeV "room temperature (RT)" linac composed of copper CH-type spoke accelerating cavities and superconducting (SC) solenoid magnets
  - One or two 9-cavity modules of 325 MHz, $\beta = 0.2$ SC spoke resonator (SSR1) cavities and SC solenoids for final 20 or 30 MeV beam energy
  - Two pulsed 2.5 MW klystrons to power the entire machine
  - A suite of beam diagnostics to characterize machine performance
- SSR2 $\beta = 0.4$ has been dropped from the program

Project X

# Current Status

- Proton ion source is operational; H- source has been prototyped
- RFQ is RF conditioned to nominal peak operating field
- Mating of ion source to RFQ begins today
- Warm cavities are being RF conditioned to nominal power
- Warm section SC solenoid cryostats are being assembled
- First SSR1 cavity is welded into helium jacket
- Order for 10 SSR1 niobium cavities is in final bid evaluation stage
- Test cryostat for full pulsed-power spoke resonator testing is being installed
- SSR1 cryomodule design is just in its infancy
- Concrete block shielding enclosure for the linac is under construction

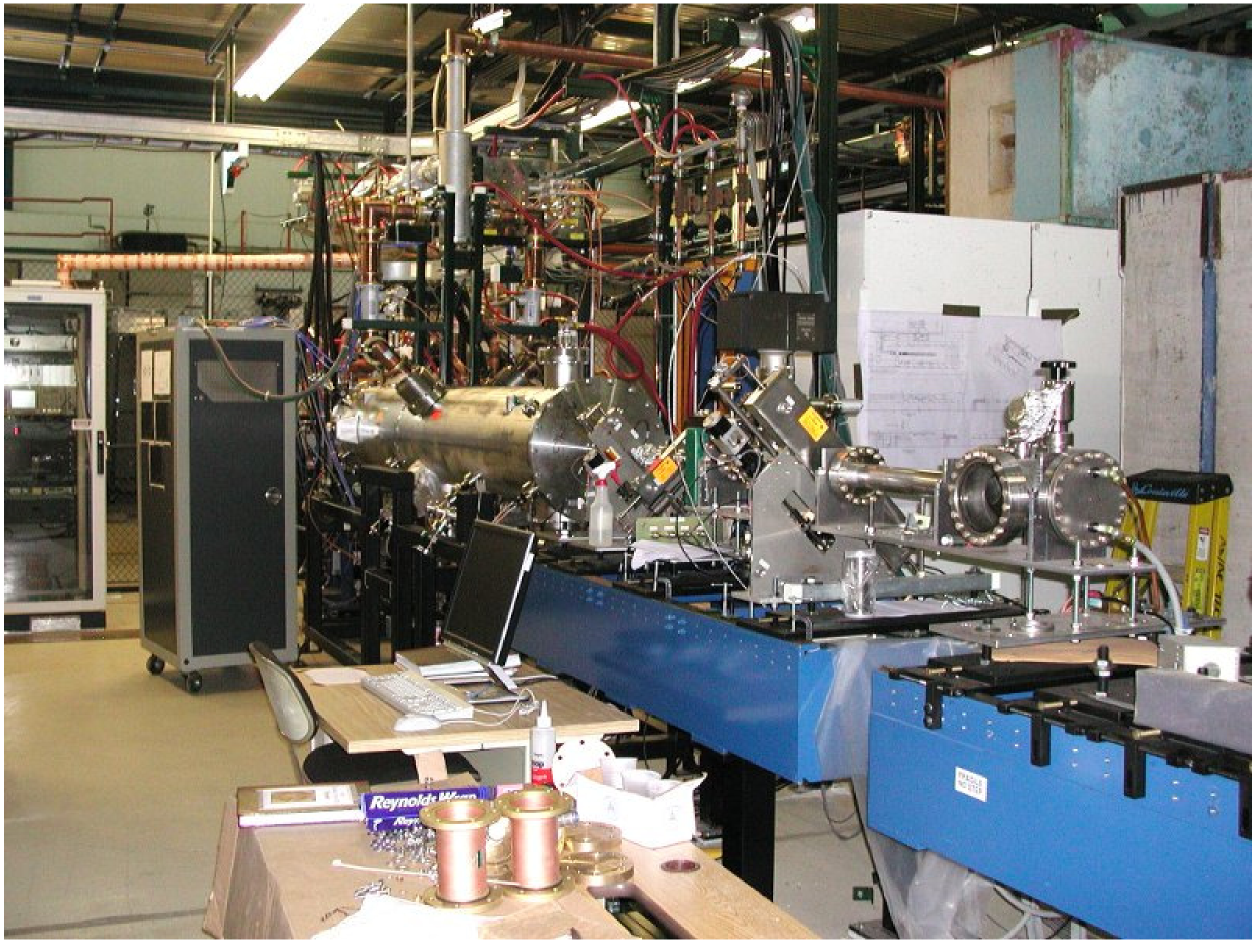
# HINS Progress in 2009

- RFQ problem:
  - Discovered Feb 19
  - At ACCSYS for repair June thru Sept
  - Now conditioned to nominal peak, but low average, power
- Received and conditioned to nominal RF power two buncher cavities manufactured with LBL effort
- Measured proton ion source beam parameters
- Studied beam transport characteristics of the solenoid focusing LEBT
- Tested prototype H- ion source (20 mA, 1 msec, 2.5 Hz) successfully
- Tested second SSR1 spoke cavity in VTS with outstanding results
- Completed fabrication of test cryostat for high pulsed power testing SSR1 cavities

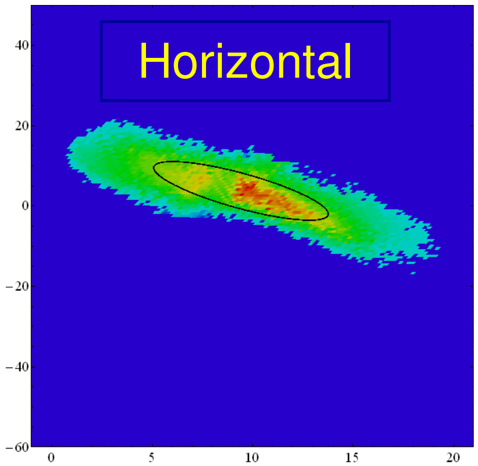
# HINS Progress in 2009

- Completed preliminary measurements of prototype SSR solenoid stray fields
- Integrated BPMs into RT-CH solenoid cryostat design
- Tested RT-CH cavities #1-5 and 9 to design RF power; fabrication problem left vacuum leaks in others (found in factory vacuum tests)
- Ran LLRF system with feedback for RFQ and RT-CH cavity
- Received and tested four wide-bandwidth, programmable vector modulator bias supplies
- Tested several SSR cavity input power couplers to HINS peak pulsed power level and to equivalent Project X IC-2 average power level

# RFQ and 2.5 MeV Beamline

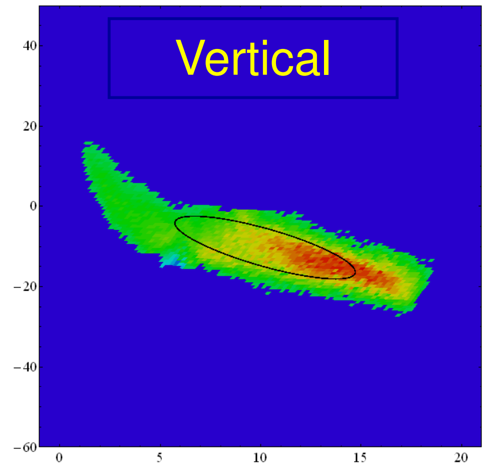


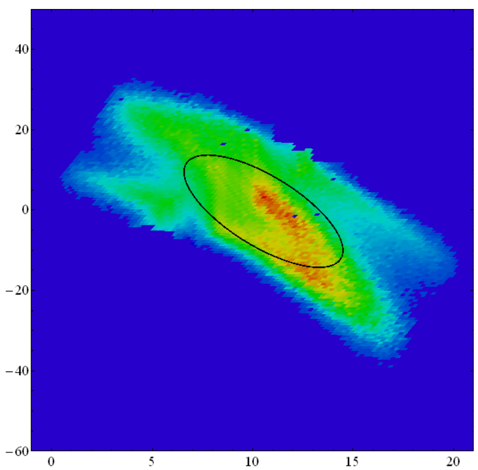
# Typical Emittance Scan Data




50 keV beam from HINS proton ion source

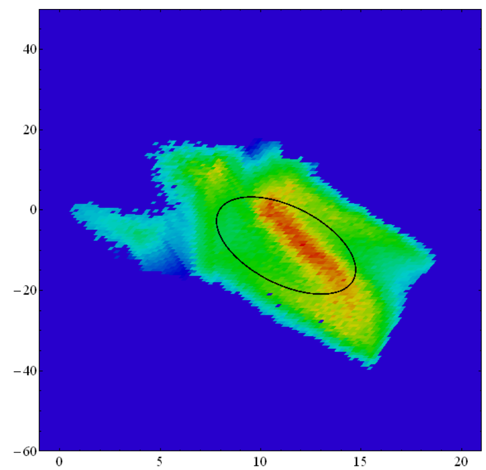
$I_b$ = 4 mA



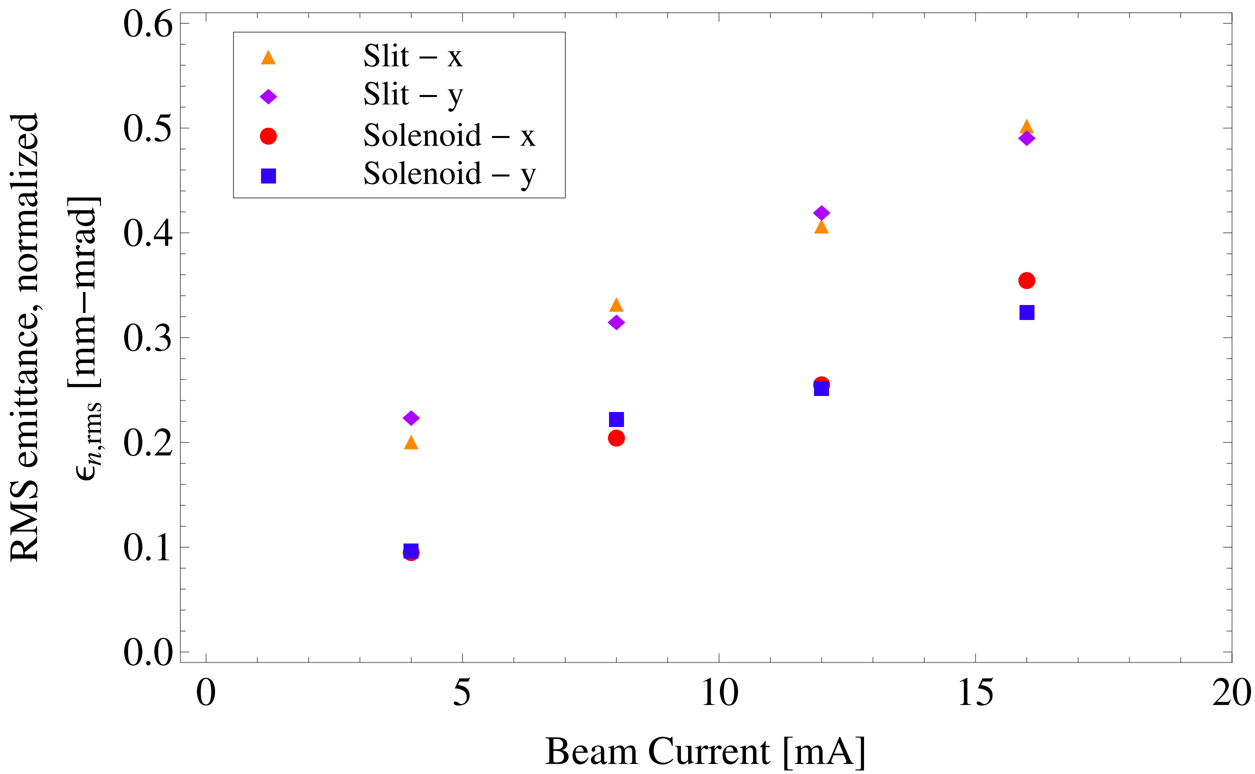



$I_b$ = 12 mA

Plots by Wai-Ming Tam



# 50 keV Proton Beam Emittance Measurement Results




Plot by
Wai-Ming Tam

Results from two methods:

Profile measurements while scanning solenoid strengths

Slit-wire method

Beam current is total current including H2+

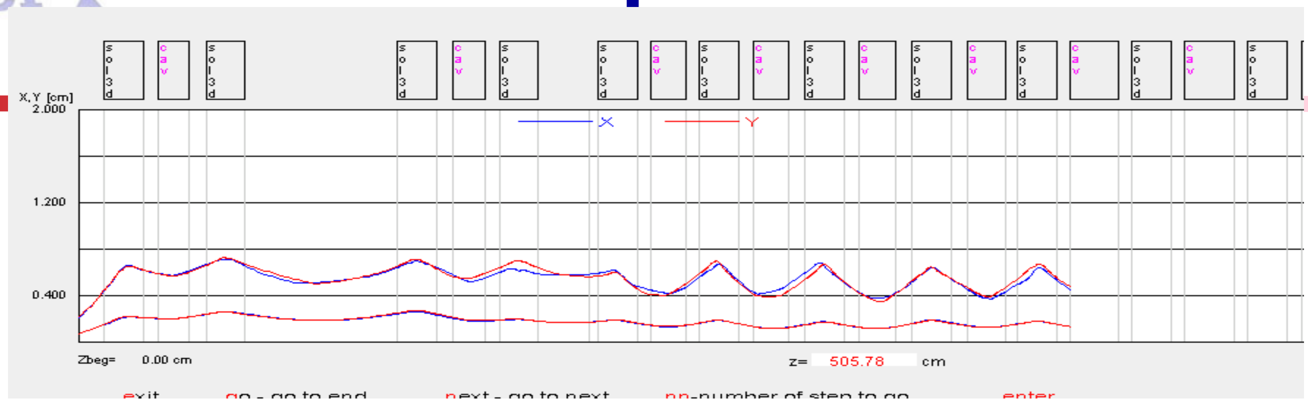
Profile method is subject to beam model assumptions

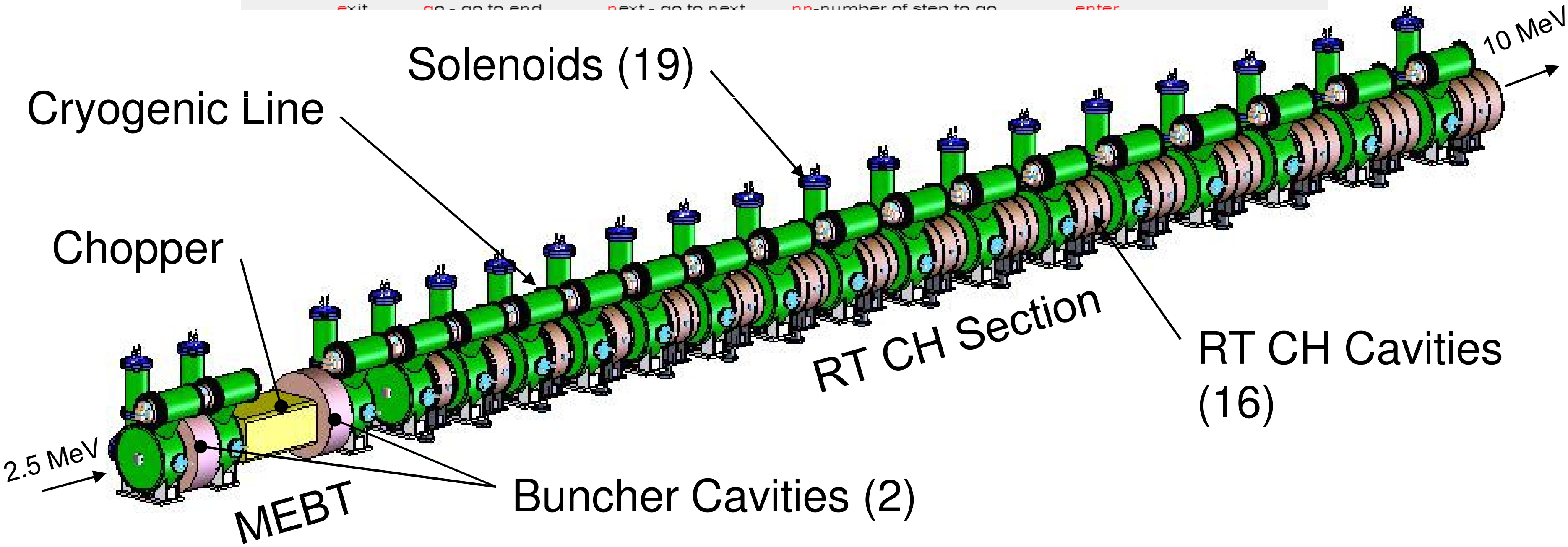
Slit-wire method is subject to a geometric factor

We have yet to reconcile systematic difference between results from the two methods

Project X

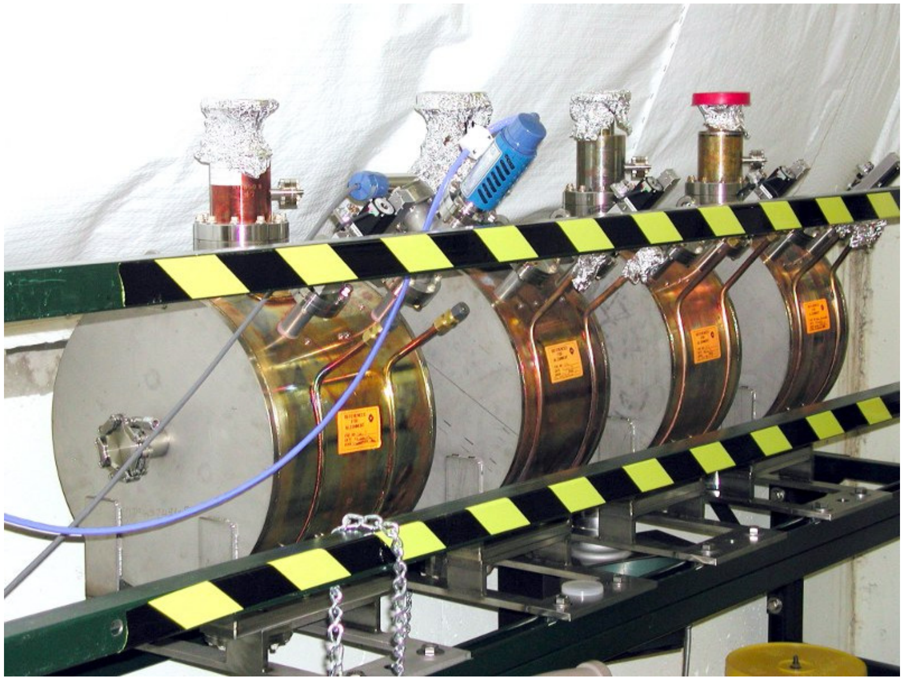
# Room Temp Linac Section



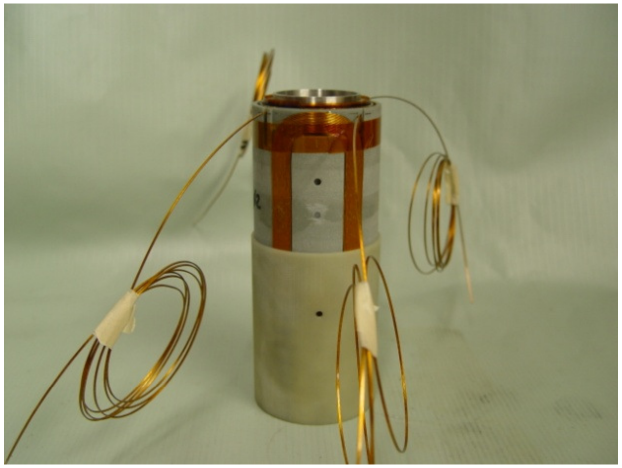



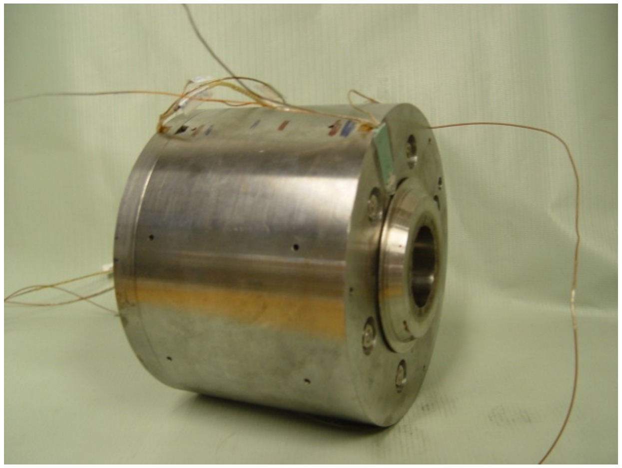
# Linac Enclosure Under Construction Around Room Temp Section Girder

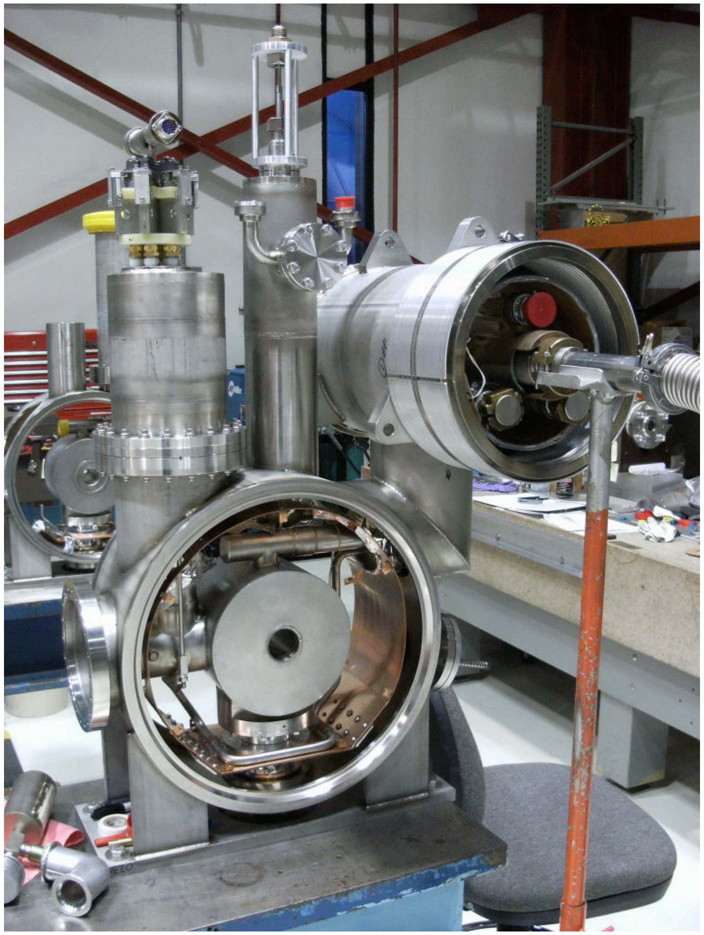
# Tested RT-CH and Buncher Cavities



# Room Temp Section Solenoid & Cryostat







Project X

# SSR1 Cavity – Bare and with Helium Vessel and Tuner

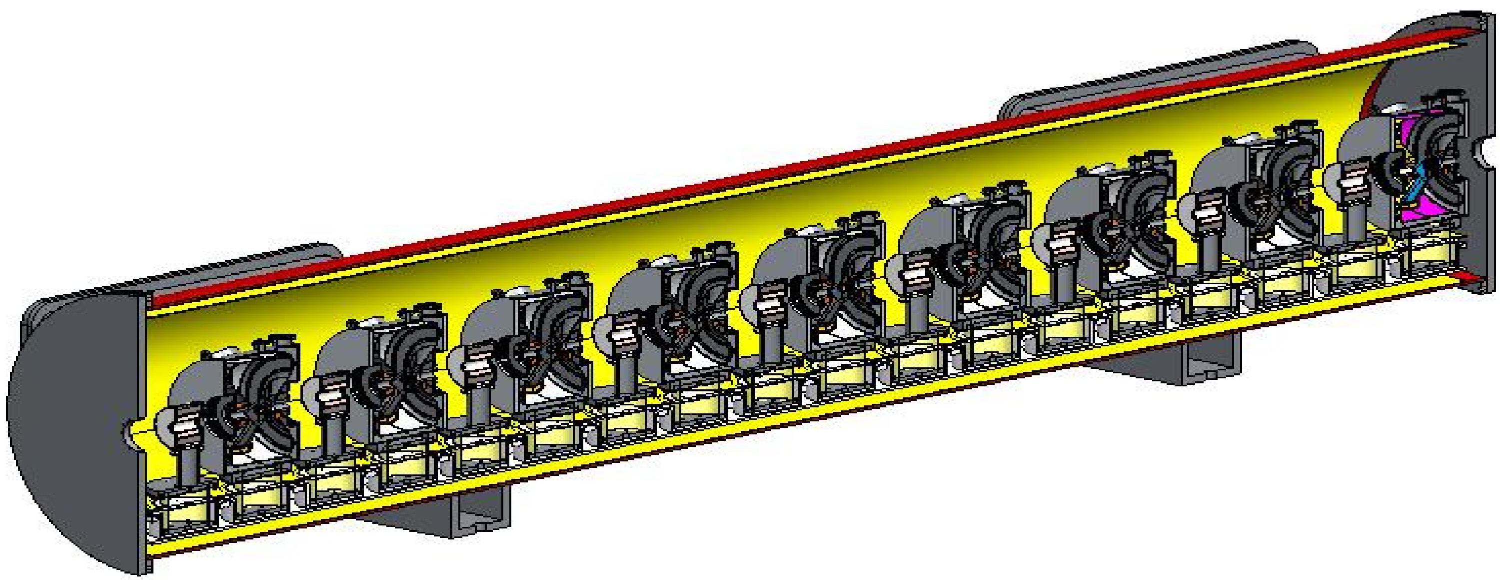

# Project X Spoke Cavity Test Cryostat

In MDB awaiting installation into test cavity cave

Project X

# SSR1 Cryomodule Model

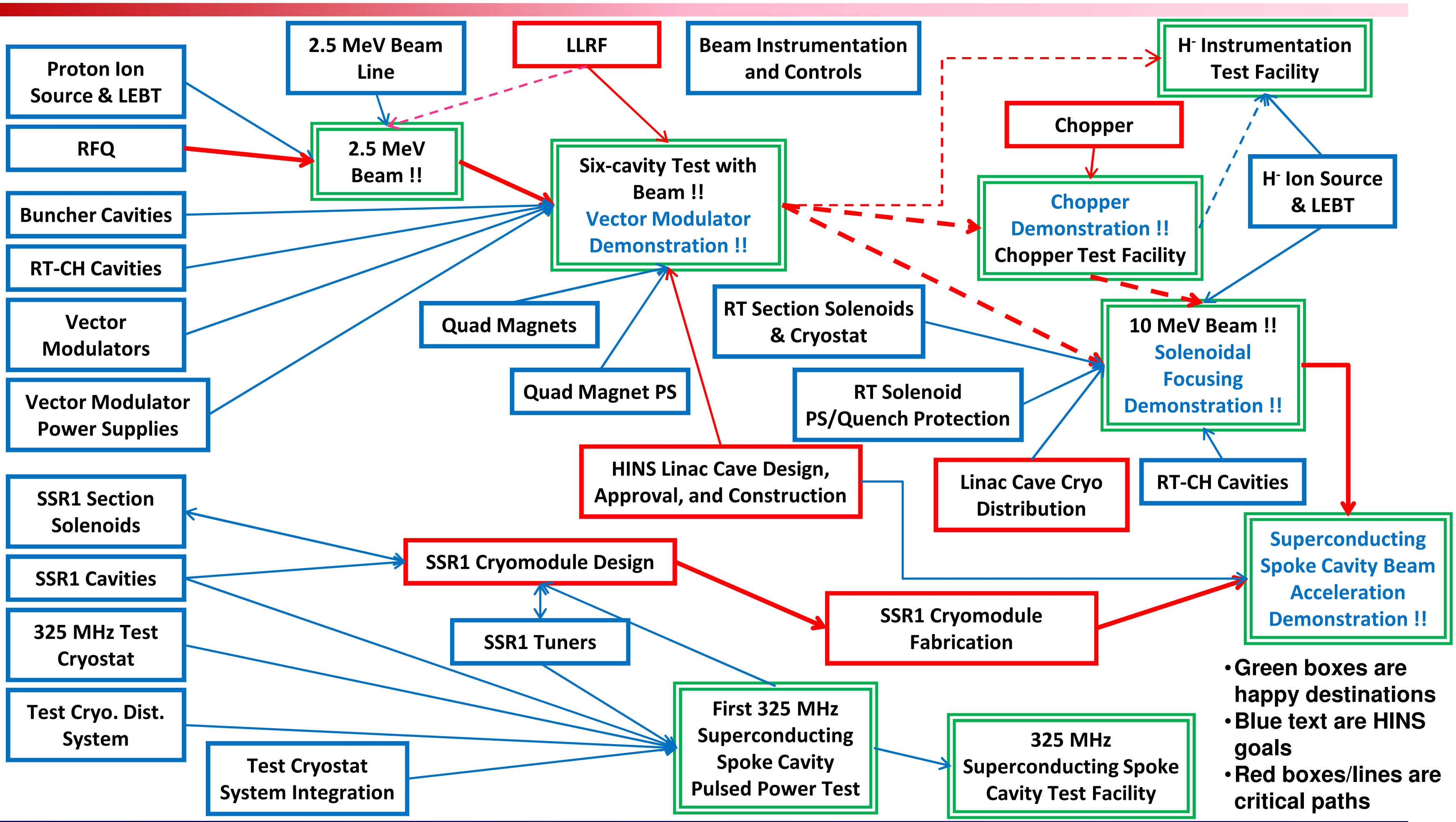
- Present conception of SSR1 Cryomodules
  - Contain 9 SSR1 cavities and 9 solenoids
  - Project X expects that these designs could be extended to SSR0 and SSR2 requirements



# Current Look at HINS Goals from Project X Perspective

- Beam acceleration with superconducting spoke-type cavity structures
  - **Development of 325 MHz SC spoke cavities and associated infrastructure must be preserved and expanded for either C-1 and IC-2**
    - **Fabrication and processing procedures**
    - **Cavity test cryostat**
    - **325 MHz RF power**
  - How important is the beam demonstration?
- 325 MHz high power RF vector modulators
  - Of the initial HINS goals, this is the earliest achievable (six-cavity test)
  - Critical to IC-1 if one klystron/many cavity option is followed
  - Not applicable to CW IC-2 where each cavity will have its own amplifier
  - **Associated 325 MHz LLRF developments are directly applicable to Project X**
- Solenoid focusing optics
  - Importance to Project X to be determined
  - Project X linac beam focusing design is not final
- Fast, 325 MHz bunch-by-bunch, beam chopper
  - **Development of chopper and beam preparation is crucial to Project X**
  - IC-2 chopper requirements are far beyond current HINS scope

# HINS Strategy Roadmap




- Green boxes are happy destinations
- Blue text are HINS goals
- Red boxes/lines are critical paths

# HINS Strategy

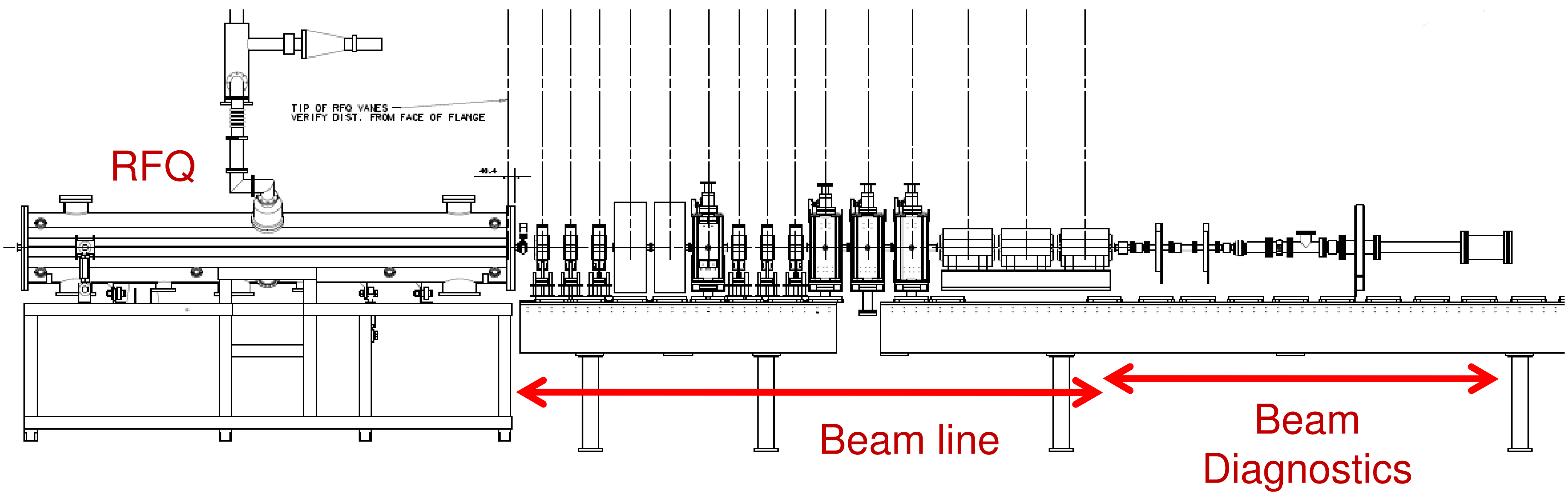
- Construct $H^-$ linac to at least 10 MeV in pursuit of original HINS goals that remain relevant
- Build a beam facility for chopper testing and beam instrumentation development
- Continue SSR1 spoke cavity and cryomodule development activities with design considerations taken for CW and 2° K operation in direct support of Project X
- Achieve world-first beam acceleration through at least one SSR1 cryomodule operating at 4° K
- Continue SC solenoid design work in support of above objectives

# The Plan – Near Term

- Achieve beam from RFQ
- Install spoke cavity test cryostat and test cavity at full pulsed power
- Continue RT section SC solenoid and cryostat assembly work
- Procure an additional ten SSR1 niobium cavities
- Complete HINS Linac shielding enclosure
  - Initially sized to contain 10 MeV Linac, beam diagnostics line and absorber
  - Designed for easy extension to house up to two SSR1 cryomodules
- Complete full safety documentation
- Complete the “Six-cavity Test” for first vector modulator demonstration with beam
- Specify and design cryogenics distribution system for HINS linac

# The Six-Cavity Test

- Purpose: early demonstration of beam acceleration with vector modulator control (before availability of cryogenics distribution system)
- Warm quadrupole magnets substituting for SC solenoids
- ~3.0 MeV protons
- Diagnostic line for beam evaluation



# Project X A Word on SSR Cryomodules

- SSR cryomodule design efforts are not yet begun in earnest
- The present concept is a cryomodule with nine cavities and nine solenoid magnets
  - It's not clear that solenoids are the focusing element of choice for a low current CW Linac
  - Grouping cavities by nine might not be optimal
  - Numerous uncertainties, including tuner design, magnetic shielding, beam instrumentation and alignment considerations, suggest that constructing a prototype cryostat with fewer elements and maybe for first spoke cavity beam tests is advisable
- Considerations are already being given to incorporating 2°K operation into the initial cryomodule design
- At either 4°K or 2°K, cryomodule design will be a major task
- HINS is currently steward of all the technologies and developments necessary to lead to a realizable 325 MHz cryomodule design

# Possibility to Modify 325 MHz Test Cryostat for 2K Operation

- Estimated cryostat modification costs
  - New internal piping assembly: $17,000 (based on original system)
  - 4K to 2K heat exchanger: $15,000 (based on a similar exchanger purchased in the LHC program)
  - Control valve to heat exchanger: $6,000 (based on a similar valve purchased in the LHC program)
  - Misc: $2,000
  - Total: $40,000
  - EDIA: 6 FTE-months (combined engineering and drafting)
- There would also need to be a major modification/addition to the cryogenics supply system, feedbox, and transfer line.
  - No cost estimate yet for that but likely several times the cryostat modification costs
- Cryogenics plant, shared with elliptical cavity HTS, might also be strained to support large additional heat load for CW elliptical cavity testing

Project X

# The Big Questions

- At what point in Project X development and/or at what HINS beam energy does it make no sense to further pursue 325 MHz pulsed Linac construction, especially if CW Project X option is taken?
- How important is beam demonstration of spoke cavities?
- How valuable to Project X or other is a flexible low energy beam facility?
- At what manpower cost? Will people be available?
- At what financial cost? Will funding remain available?
- What technical risks can be tolerated in the program?
  - 325 MHz klystron failure w/o spare?; it is required for any beam from the HINS warm front-end
  - RFQ failure to accelerate beam?; we should have answer to this in a few months
- What are we missing?

# The Unique Position of HINS for Project X - Pulsed or CW

- The Project X requirement for 325 MHz infrastructure is not negotiable unless it should opt for an unforeseen frequency change
- HINS comprises the 325 MHz spoke cavity design and development experience
- HINS provides a 325 MHz spoke cavity test cryostat
  - VTS in IB1 will not fit a jacketed spoke cavity
  - Cryostat is upgradeable for 2° K operation
- Albeit pulsed, HINS offers the only source of high power 325 MHz RF
- HINS drives 325 MHz LLRF and beam diagnostics development
- HINS can offer beam for
  - Chopper development and performance testing
  - $H^-$ beam instrumentation development and testing
- Even pulsed beam through a cryomodule powered by CW RF would be an important demonstration that might be possible at Meson Detector Building

Project X

# What is Clearly Beyond Current HINS Scope

- Spoke cavity or cryomodule development beyond SSR1
  - There is reason to believe that SSR1 is fast track to SSR0 and SSR2, but not necessarily to TSR
- CW ion source development
- CW RFQ development
- CW RF power system development
- SSR cryomodule operation at 2° K – the MDB cryogenics facility cannot support this

Project X

# The Other HINS Talks

- Two talks report in details on status of important HINS technology development work
  - Terechkine – superconducting solenoid magnets
  - Wagner – superconducting spoke cavities

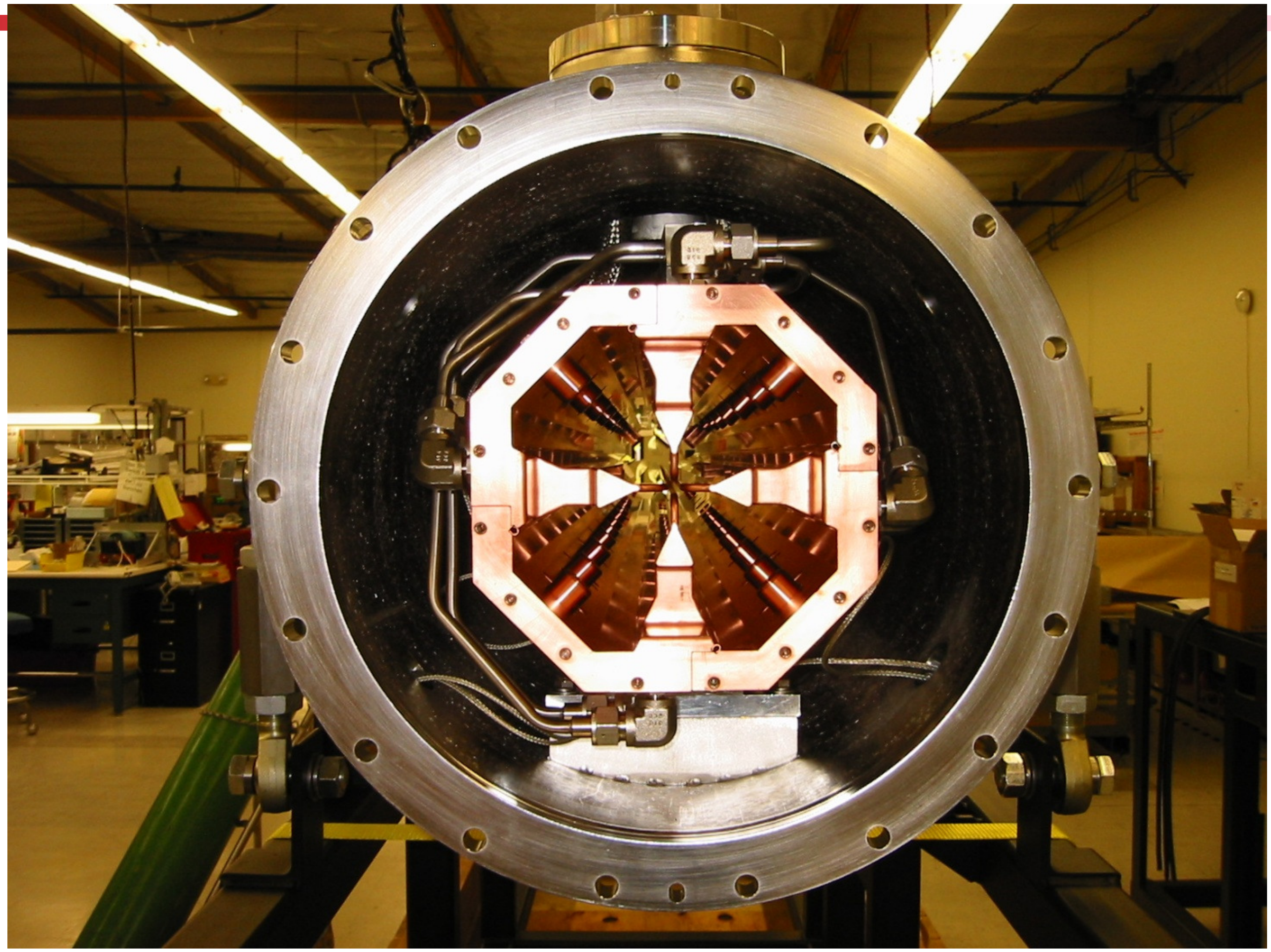
- Two talks suggest how an operating HINS beam could serve as an important and unique Project X technology development facility
  - Madrak – beam chopper performance testing
  - Scarpine – H- beam instrumentation testing

Project X

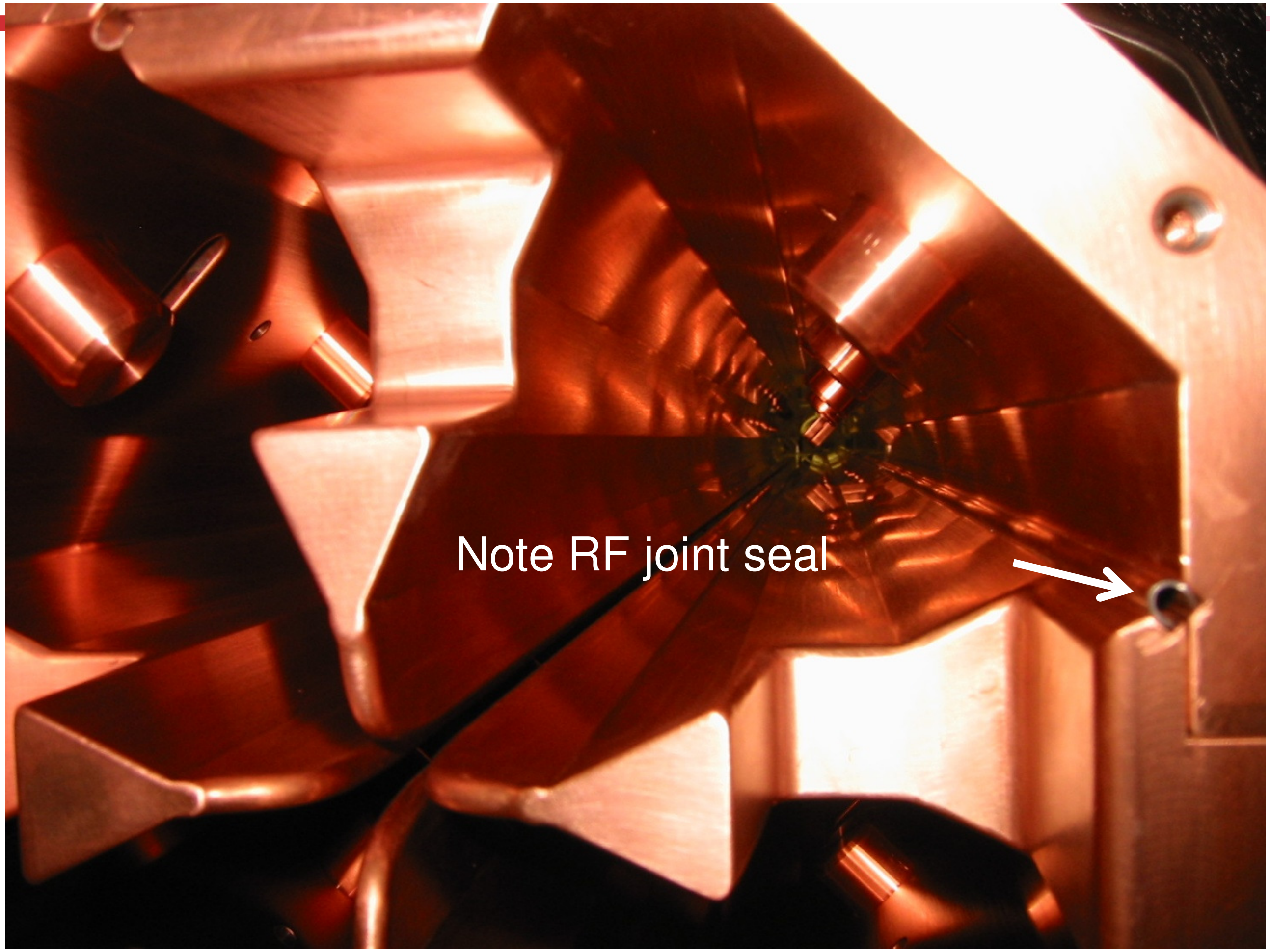
# Conclusions

- Great progress has been made and there currently is excellent momentum towards constructing and commissioning the HINS Linac
- Some years of work and considerable expense remain to achieve traditional goals
- Certain aspects of HINS, especially 325 MHz SC spoke cavity development, are mainstream and vital to Project X IC-1 and IC-2
- There are issues accompanying a CW machine HINS is not well positioned to address in it present scope
- Achieving beam, even pulsed and well below the 30 MeV goal, HINS will offer a unique beam facility for studying multiple issues of great importance to Project X including chopper performance and $H^-$ beam instrumentation
- There will be difficult decisions and new opportunities that determine the future of the traditional HINS program as it melds into Project X

# RFQ in Vacuum Tank



# RFQ Close-up



# RFQ RF Joint Failure