High Intensity Neutrino Source R&D Overview

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Fermilab SCRF Infrastructure Review
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Outline

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- Introduction
- HINS Plans (2007-2010 and beyond)
  - Key Issues
  - Facilities Scope
  - Infrastructure Adequacy
  - Collaborations with other laboratories/Universities
  - Collaboration & development of US Industry
  - Funding
- Conclusions

FNAL Strategic Plan

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http://fra-hq.org/pdfs/Science_Strategy.pdf

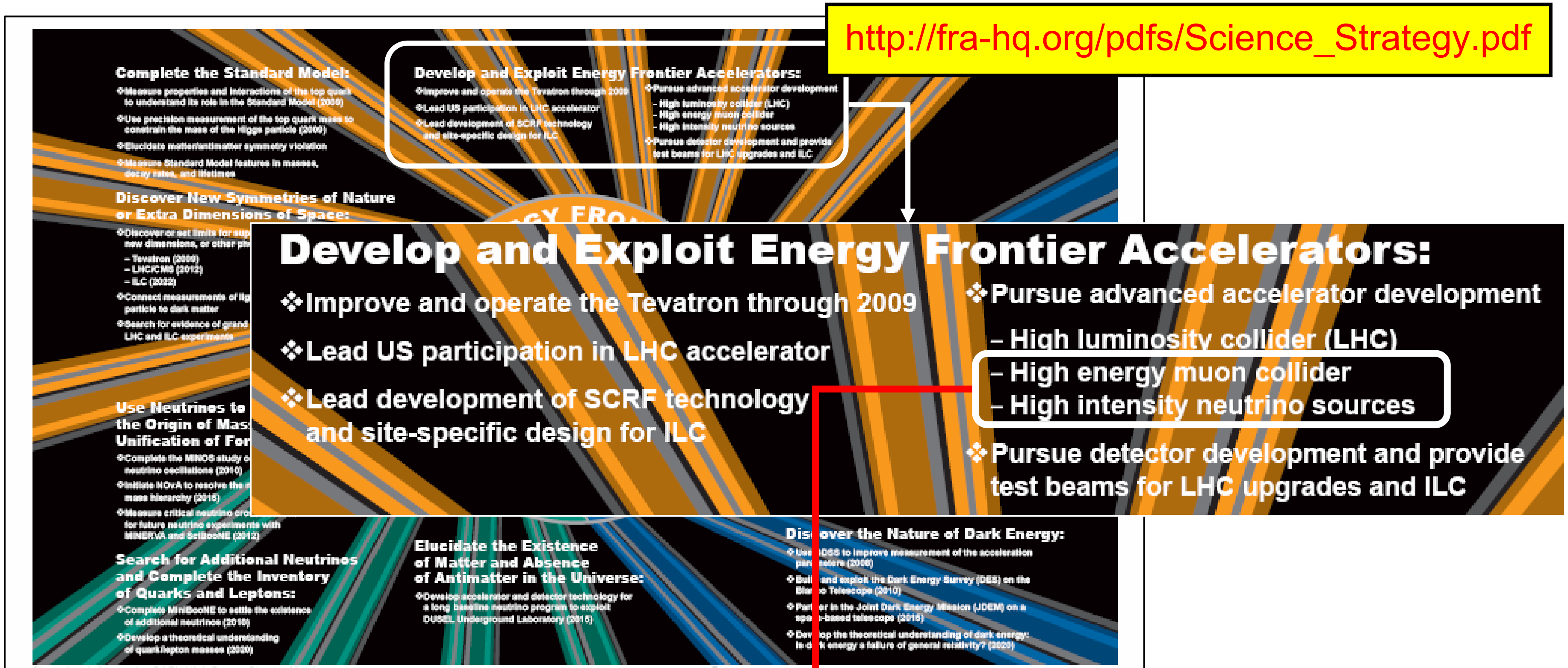


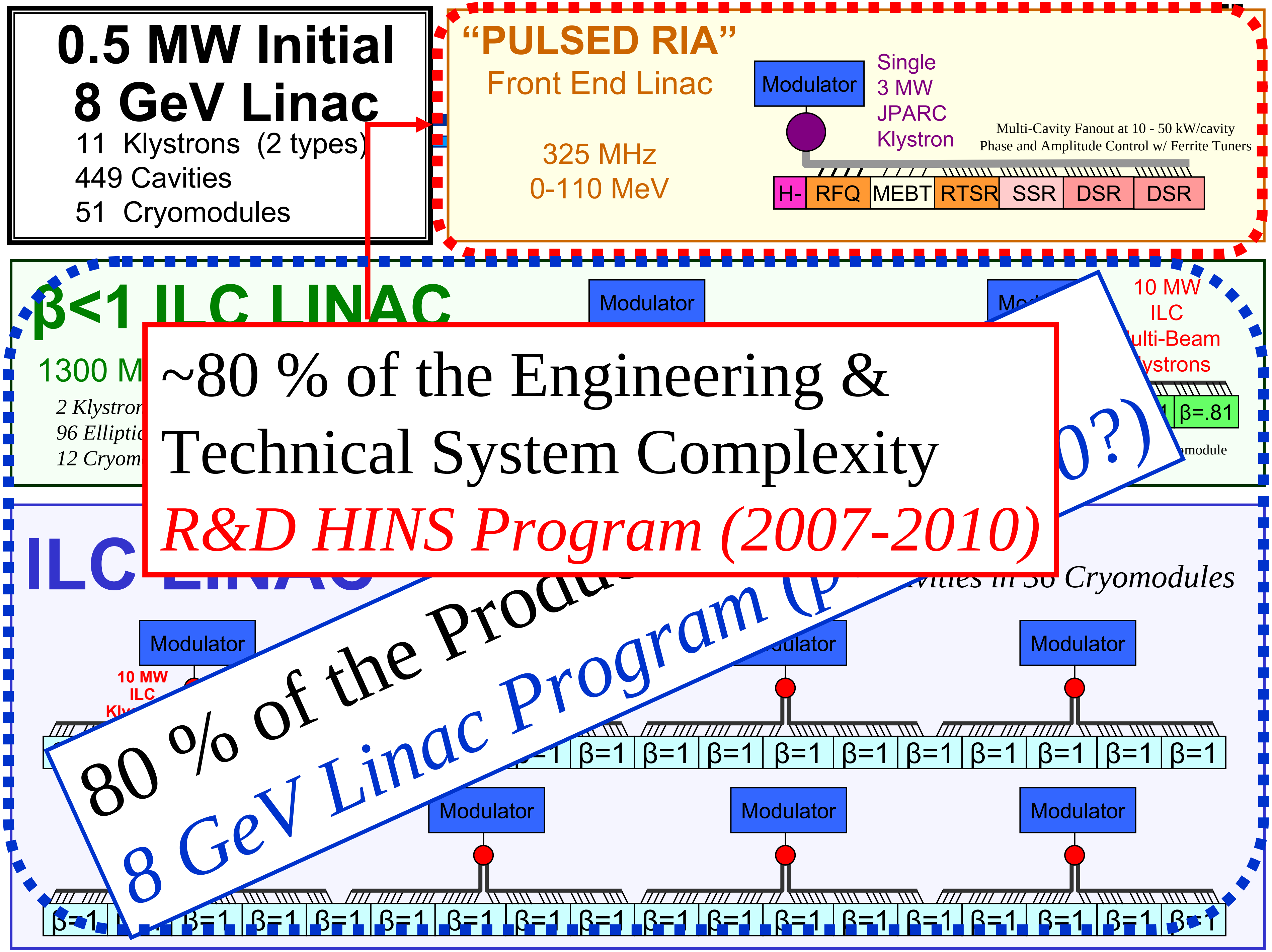
Figure 3.a-1. Supporting DOE's High-Energy Physics Mission. FRA's approach emphasizes research and discovery in three areas critical to the DOE mission: the energy frontier, the study of properties of neutrinos, and the connections between particle physics and astrophysics.

- **Intense Proton Source for neutrino and muon production**
  - **HINS R&D Program**

Role of HINS

- **Multi-MW proton source is required for full exploration of the neutrino sector**
  - **NoVA will operate at 700 kW**
  - **SuperNuMI could operate in the 1 MW range**
- **An 8 GeV Linac coupled with an upgraded Main Injector is required to get above 2 MW**
- **The 8 GeV Linac idea* incorporates concepts from the ILC, the Spallation Neutron Source, RIA and APT.**
  - **Copy SNS, RIA, and JPARC Linac design up to 1.3 GeV**
  - **Use ILC Cryomodules from 1.3 - 8 GeV**
  - **H^- Injection at 8 GeV in Main Injector**

* *The 8 GeV Linac concept actually originated with Vinod Bharadwaj and Bob Noble in 1994,when it was realized that the MI would benefit from a Linac injector. Gradients of 4-5 Mev/m did not make the proposal cost effective at the time. Idea revived and expanded by GWF in 2004 with the advent of 20-25 MeV/m gradients.*


0.5 MW Initial
8 GeV Linac
11 Klystrons (2 types)
449 Cavities
51 Cryomodules
"PULSED RIA"
Front End Linac
325 MHz
0-110 MeV
Modulator
Single
3 MW
JPARC
Klystron
Multi-Cavity Fanout at 10 - 50 kW/cavity
Phase and Amplitude Control w/ Ferrite Tuners
H-
RFQ
MEBT
RTSR
SSR
DSR
DSR
β<1 ILC LINAC
1300 M
2 Klystron
96 Ellipti
12 Cryom
Modulator
10 MW
ILC
β=.81
~80 % of the Engineering &
Technical System Complexity
R&D HINS Program (2007-2010)
ILC
Cryomodules
Modulator
10 MW
ILC
β=1
80 % of the Produ
8 GeV Linac Program (

HINS Program Goals

- **HINS R&D Phase: Proof of innovative approach to high intensity beam acceleration !**
  - 2007-2010 R&D period
  - Prove, Develop & Build Front-End in Meson Bldg. at 325 MHz (0-60 MeV) since much of the technical complexity is in the FE Mechanical/RF Systems
    - Demonstrate for the first time Amplitude/Phase Modulator (FVM) Technology and RF Power Scheme with H^-
    - Demonstrate for the first time RT-SC Transition at 10 MeV
    - Acquire capability to test/operate SC Spoke Cavities at FNAL
    - Demonstrate for the first time beam loading and pulsed operation of Spoke Cavities
    - Demonstrate Axis-Symmetric focusing and Beam Chopping
    - Demonstrate for the first time the ability to drive RT and SC Sections with a single klystron
  - Retain conceptual design compatibility between HINS and ILC
    - β=1 R&D is necessary in the event of an 8 GeV Linac phase
- **8 GeV Linac Phase**
  - "Post-2010"period
  - Timing contingent on ILC development and/or results from the international neutrino program
  - Construction of ~400 *ILC-like* cavities and ~50 *ILC-like* cryomodules at 1.3 GHz

Front End - Beam Line Layout

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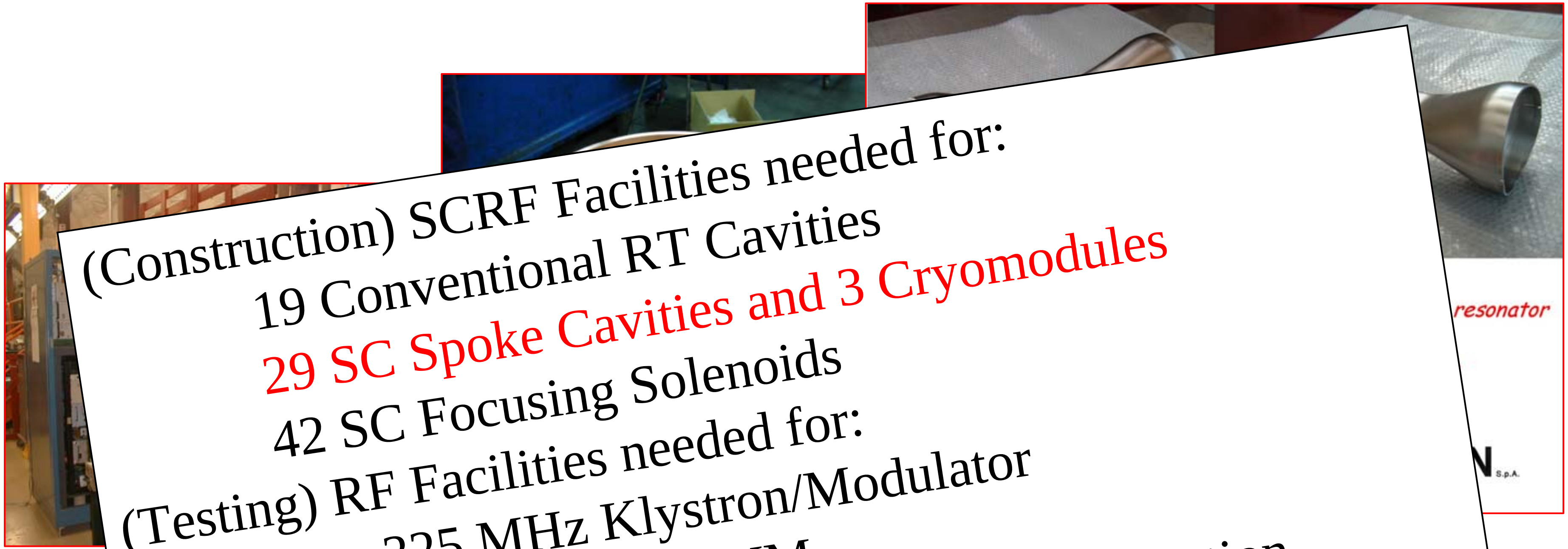
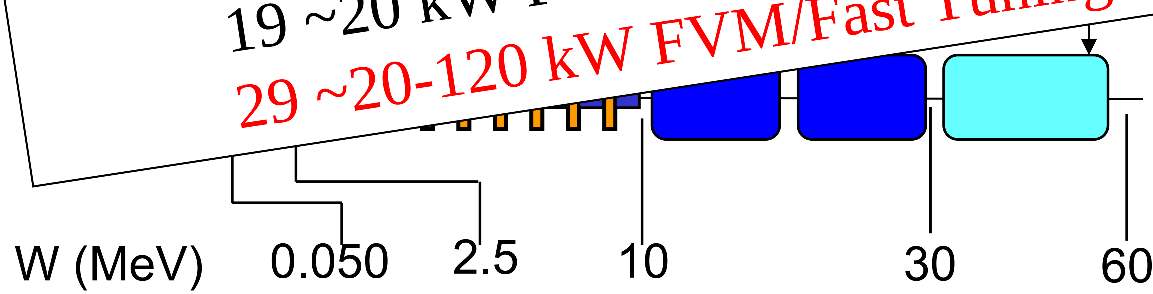
(Construction) SCRF Facilities needed for:

- 19 Conventional RT Cavities
- 29 SC Spoke Cavities and 3 Cryomodules
- 42 SC Focusing Solenoids

(Testing) RF Facilities needed for:

- one 325 MHz Klystron/Modulator
- one 400 kW RFQ FVM
- 19 ~20 kW FVM/Fast Tuning for RT Section
- 29 ~20-120 kW FVM/Fast Tuning for SC Section





Frequency 325 MHz
Total length ~ 55 m

1. What are the key R&D issues faced by the U.S. accelerator community in the area of SCRF?

- At "beam element" level:
  - Demonstrate capability for quality production of spoke cavities (RIA, HINS, India Subcritical Reactor (Th),..)
  - Study Spoke Resonator high power pulsed mode operation, including control of Lorentz detuning, experience with microphonics, etc.. (HINS)
- At "accelerator integration" level:
  - Demonstrate capability to bring SC technology to low energies (10 MeV) and accelerate high intensity non relativistic H-beams with spoke cavities.
  - Operate/Control Phase and Amplitude in power distribution
  - Solenoidal Focusing of high intensity low energy beams (RIA, HINS)

All these R&D aspects of the HINS program are innovative and have *never been tested before*. Success of the HINS R&D program will pave the way for a revolutionary improvement in the design of Front End for future machines

2. What is the scope of facilities required at FNAL to address these key issues including those questions key to the success of the ILC?

Superconducting RF R&D at Fermilab

Revised 1/30/07

Introduction

Superconducting Radio Frequency technology (SRF) cavities represent a key "enabling" accelerator technology that provides high accelerating gradient structures for future accelerators. The International Linear Collider (ILC), a new energy frontier High Energy Physics machine is being designed using this technology. The technology also is useful for electron linacs to drive Free Electron Lasers (FEL) and for intense proton sources needed for long baseline neutrino physics, neutrino factories or muon colliders. SRF cavities have additional applications in heavy ion accelerators and for energy recovery linacs for electron cooling of beams. The reduction in length in superconducting linacs is expected to generate new applications to medical accelerators for proton and neutron therapy, and for creating radio-nuclides for medical diagnostics.

The ability to consistently master the production and processing of high-gradient SRF cavities and to achieve this at a reasonable price is crucial in the future construction of these large scientific devices. Fermilab is heavily engaged and making strong technical contributions to the ILC R&D program. Regardless of where the ILC is built, the U.S. will get an opportunity to contribute to the construction of high tech components such as the SRF cavities. In total, the number of cavities required for the ILC is approximately 17,000, constructed over a four year period.

Currently the best process for producing high gradient SRF cavities involves electron beam welding of deep drawn high purity Nb components into cavities then producing very smooth interior surfaces with a technique called electropolishing (EP). In the U.S. SRF cavities have been fabricated and electropolished successfully at national laboratories such as TJNL and LANL and universities such as Cornell and MSU but very limited cavity fabrication experience and no processing experience exist in U.S. industry. In contrast, both Europe and Japan have developed the technology to fabricate and process cavities in industry and industrial capabilities are well advanced.

It is expected that U.S. industry must play a large role in the fabrication of the mass produced cavities and cryomodules for ILC. However, it is also likely that industry will not make the large financial investments in SRF cavity fabrication and processing facilities in advance of ILC project approval. Similarly, the technology and infrastructure to test SRF cavities is extensive and beyond that which can be expected from U.S. industry. The timescales and technical knowledge required to operate these facilities necessarily mean that they must be developed at large national laboratories working closely with U.S. SRF capable universities and with international partners. As expertise and capability grows, the technology can be transferred to U.S. industry when adequate funding is available. SRF technology in general is technically challenging and success in the U.S. will require close cooperation of the U.S. national laboratories and U.S. industry and considerable investment. The process for when and how U.S. industry will be

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Main Infrastructures

1. Cavity Fabrication
2. Cavity Processing Facility
3. Vertical Cavity Test Facility
4. Horizontal Test System
5. Cryomodule Assembly Facility
6. Cryomodule Test System
7. RF Unit Test at NML

How do the 2 HINS phases benefit from the facilities described in the "Superconducting RF R&D at Fermilab" document ?

	R&D ('07-'10)		Post-2010
	Front End	β=1 Cryo.	8 GeV Linac
Cavity Fabrication	~yes	yes	yes
Cavity Processing Facility	no	yes	yes
Vertical Cavity Test Facility	no	yes	yes
Horizontal Test System	no	yes	yes
Cryomod. Assembly Facility	yes	yes	yes
Cryomod. Test System	no	yes	yes
RF Unit Test at NML	no	yes	yes
325 MHz Test Cryomodule	yes		
325 MHz RF Test Unit	yes		

2.6 M$ in HINS core funds

HINS Facilities Coverage

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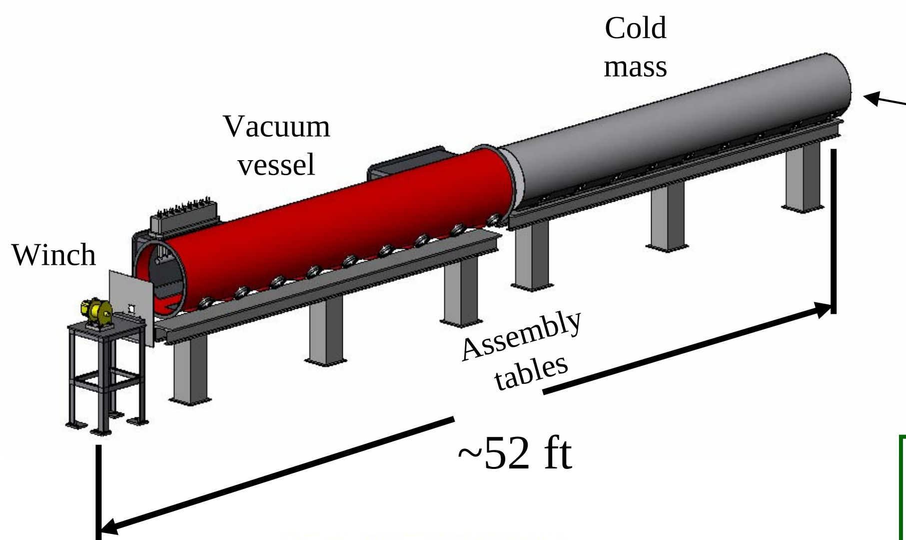
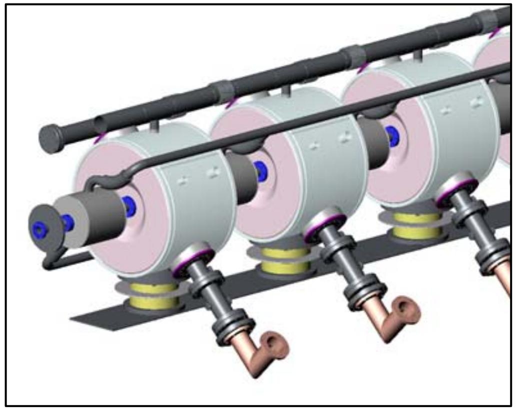
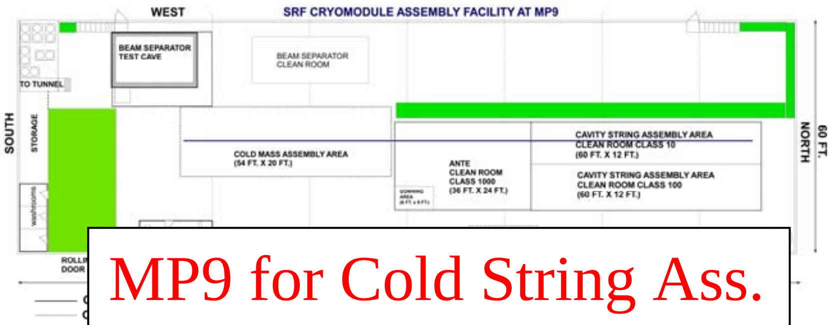
- Test cryostat, Spoke cavity Prototype and equipment for Spoke Cavities Power testing at 325 MHz
  - Webber's talk
  - Scope:
    - Provide testing facility for spoke prototypes and subset of spoke production. Using Nb scanner at FNAL.
- Clean Room for Spoke Cavity cryostat assembly
  - Arkan's talk (CAF at MP9 and ICB)
  - Scope:
    - Provide appropriate area for production of 3 HINS spoke cryostats
- Setup for 325 MHz tests and Cave for HINS F.E. Construction/Operation
  - Webber's, Chase's and Champion's talks
  - Scope:
    - Operate 325 MHz Kly and build & operate 60 MeV Accelerator
- RF Testing Lab
  - Network analyzers, bead pull meas. etc.
  - Existing in IB4 and appropriate to support ILC/HINS small-quantities testing

3. Will the laboratory SCRF infrastructure started in FY06 and planned for FY07 and beyond be adequate to address these key issues, and on what time scale. Are the proposed solutions cost effective?







MP9 for Cold String Ass.
ICB for Cryomodule Ass.

- **Production of 2 SSR1 (β=0.21) Cryostats**
  - **Cavities Production in FY08**
    - **18 SSR1s, 18 Solenoids**
  - **Cryomodule Production in FY09**
- **Production of 1 SSR2 (β=0.4) Cryostats**
  - **Cavities Production in FY09**
    - **11 SSR2s, 6 Solenoids**
  - **Cryomodule Production in FY10**

4. Does the laboratory make effective use of collaboration and existing SCRF assets at other laboratories and universities?

- **ANL**
  - **Beam Dynamics**
  - **Spoke Cavities Processing (EP & HPR - Prototypes and Production)**
- **LBL**
  - **Buncher Cavities and Electron Cloud Effects in MI**
- **BNL**
  - **Laser Beam Profiler**
- **MSU**
  - **β=0.81 Elliptical Cavities development**
- **IUAC, Delhi (India)**
  - **Spoke Cavities Prototypes (& Production)**
- **FY06 SOW: ~2.2 M$ (~4.9 M$ HINS budget)**
- ***FY07 SOW: ~0.4 M$ (~2.5 M$ HINS budget)***

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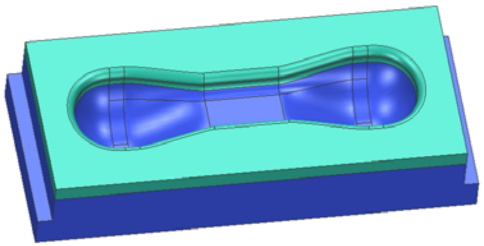
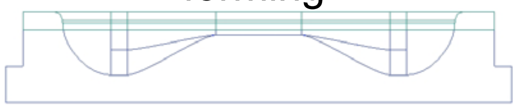
5. Does the SCRF plan for FY08 and beyond make use of and develop U.S. industry at an appropriate level?

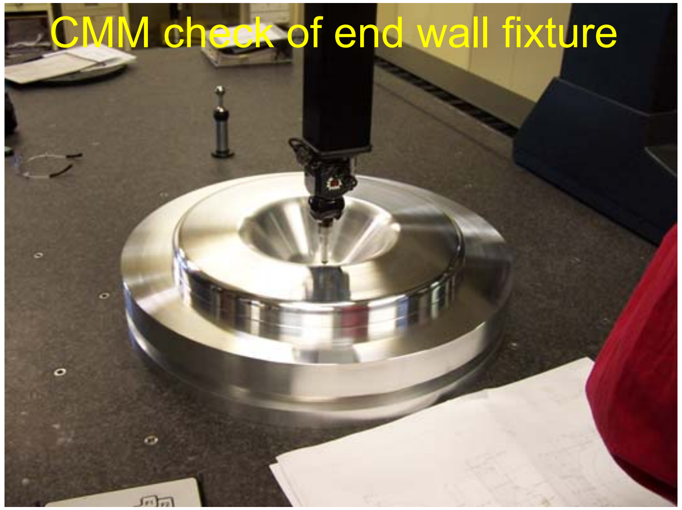
- **ROARK**
  - **One Spoke Prototype production**
  - **ANL-Roark-FNAL Collaboration**
    - **K. Shepard training Roark-FNAL**
    - **FNAL engineers learning trade**

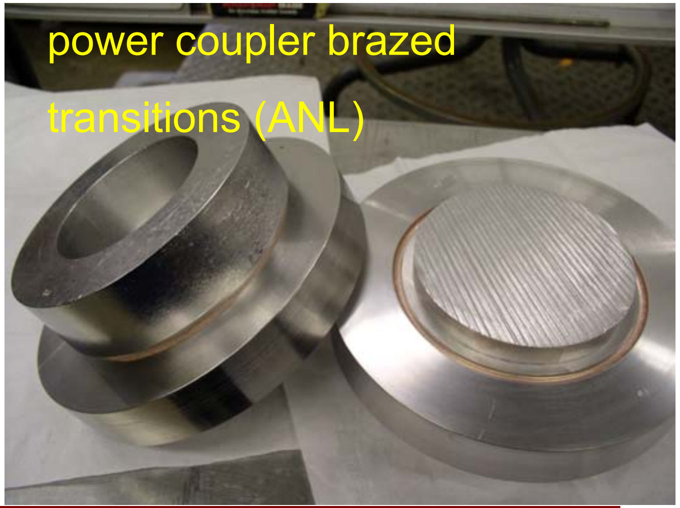


3D Model of fixture for half spoke forming



ROARK





"Post-2010" 8 GeV Linac

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- ~50 Cryomodules, ~400 cavities
  - 5 different types: SSR1 (completed in FE), SSR2, TSR, β0.81 and β1.0(ILC)
  - Too much diversity for full Industrialization -> Rely heavily on "SRF Infrastructure at FNAL"
  - Production: Cavities and Cryomodules
    - ILC SRF Infrastructure rate: ~1 cryo/month on single shift/single production line
    - 8 GeV Linac: 1.5-2 cryo/month (AAC-2005 & 2005 Director Review)
      - ~double Shift + double production line – "SRF Infrastructure" worth at least ~60-70% of 8 GeV Linac Tooling & Facilities needs
- Scale of SRF Infrastructure and Scope of facilities built for the ILC are well matched to the needs of an 8 GeV Linac production.
  - Detailed analysis may be needed for a complete match of the SRF Infrastructure to the needs of a possible 8 GeV Linac project.

6. Is the FNAL SCRF plan configured and prioritized in a such a way that it can be sensibly scaled back should all of the requested funds not be available?

- **The rate of progress on the R&D is financially limited.**
- **The Continuing Resolution scenario is forcing HINS to plan FY07 with a budget of 700 k$ forcing a slow-down of activities**
  - **"aggressive" budget request of 3.5 M$**
  - **"balanced" budget requests of 2.6-2.8 M$**
    - **Agrees with lab plans of ~2.5 M$ per year (M&S, direct costs only)**
- **HINS plans with present budget is to build and operate the front end up to RT cavity #4 (as opposed to full RT Front End of 16 cavities) in 2007**
- **Biggest Issues in CR scenario**
  - **Reduce level of Collaborations with other institutions (ANL, BNL, India, etc.)**
    - **IUAC India is interested in SCRF technology for accelerator driven power plants**
    - **HINS catalyzing India's interest in ILC technology**
  - **Timescale**
    - **Stretching out activities over longer period**

Conclusion

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- **Meson facility at 325 MHz aiming at the demonstration of the technology for the efficient acceleration of high intensity H^- beam.**
- **HINS specific infrastructure developed to test Spoke Resonators**
- **The HINS program and, in particular, the possibility of an 8 GeV Linac relies heavily on the ILC Infrastructure and R&D at FNAL.**
- **A *possible* 8 GeV Linac could become the biggest (not unique, if ILC R&D continues) customer of the "SRF Infrastructure" facilities in the post-2010 period.**