Superconducting RF Module & Test Facility (SM&TF)

Goal: Develop U.S. Capabilities in high gradient and high Q superconducting accelerating structure in support of the International Linear Collider, Proton Driver, RIA, 4th Generation Light Source and other accelerator projects of interest to U.S and the world physics community.

Contacts for SMTF

Swapan Chattopadhyay, JLAB, Helen Edwards, FNAL,

Nigel Lockyer, U of Penn, & Shekhar Mishra FNAL

Talk at ANL 1/26/05

SMTF Expression Of Interest

- Expression of Interest for the Superconducting Module & Test Facility (SMTF) was submitted to Fermilab director 10/29/04

- US Institutions Involved in Discussions
  - Argonne Laboratory (ANL),
  - Brookhaven (BNL),
  - Cornell University,
  - Fermilab,
  - Jefferson Laboratory (JLAB),
  - Lawrence Berkeley National Laboratory (LBNL),
  - Los Alamos National Laboratory (LANL),
  - MIT-Bates Laboratory,
  - National Superconducting Cyclotron Laboratory (MSU-NSCL),
  - Northern Illinois University (NIU),
  - Spallation Neutron Source (SNS) at Oak Ridge,
  - University of Pennsylvania
  - Stanford Linear Accelerator Center (SLAC).

- International: TESLA Collaboration, DESY, INFN, KEK, CAT (India)

- The participating institutions visited DOE (HEP & NP) to talk about EOI.

Request to submit SMTF Proposal

Fermilab

Fermi National Accelerator Labora
P.O.Box 500 • Batavia, Il.• 60510-
630-840-3211 FAX 630-840-2

Director's Of

December 16, 2004

TO: Swapan Chattopadyhay
Helen Edwards
Nigel Lockyer
Shekhar Mishra

FROM: Michael Witherell

SUBJECT: Expression of Interest for the Superconducting Module and Test Facility

Thank you very much for the Expression of Interest for a Superconducting Module and Test Facility (SMTF) that Fermilab received on October 29, 2004. This EOI offers what we believe is a unique opportunity to develop an integrated approach to superconducting rf development in the U.S., capitalizing on the considerable assets and expertise available in the DOE and NSF laboratories and universities. Fermilab is enthusiastic about the prospects for hosting such a facility. We would like to invite the SMTF interested parties to submit a formal proposal for consideration by the laboratory.

In order to allow for the most effective consideration by Fermilab, by the funding agencies, and by potential partners we would ask that the proposal specifically include the following elements:

- goals and a proposed scope of work
- infrastructure requirements at Fermilab
- a proposed schedule for implementation, including opportunities for phasing
- resource requirements (people and materials)
- a proposed organization which can provide an umbrella for integrating the facility with the associated hardware development and testing aspects.
- a proposed division of responsibility among the participating institutions
- the relationship to international efforts.

In preparing your proposal, I would request that you work in the context of the following principles:

1. The primary motivation for SMTF should be the development of U.S. scrf capabilities in support of the International Linear Collider, Proton Driver, and other projects of interest to U.S. laboratories within the DOE Office of Science and the NSF Directorate for Mathematical and Physical Sciences (for example RIA and 4th generation light sources utilizing CW operations). The proposal needs to reflect the needs of these communities.
2. This proposal needs to be cognizant of other scrf acvities in the U.S. and abroad, and to provide an integrated program that maximizes efficiency and effectiveness. The proposal should make use of existing infrastructure in the way that best advances the R&D goals.
3. Fermilab views the test facility component of SMTF as formally distinct from the hardware to be tested. Because it is proposed to situate the test facility on the Fermilab site, Fermilab will serve as host laboratory and will assume responsibility for the overall design, implementation, and operation of the test facility with input from the SMTF collaboration.
4. Because of the strongly interconnected nature of the test facility and the hardware to be tested the proposal should encompass the plans, schedules, and resource requirements for construction of both the facility and the hardware to be tested.
5. The primary institutional interests of Fermilab and the DOE Division of High Energy Physics are the ILC and Proton Driver development activities. The proposal should assume annual funding from DOE/HEP (M&S and SWF) of \$20M, rising to \$30M, over the time frame FY06-09 in support of the test facility and the associated ILC and Proton Driver scrf activities. It is assumed that funding for the associated development programs for RIA and CW will come from the appropriate DOE Office.
6. We encourage the SMTF collaboration to work with international scrf efforts to the maximum extent possible in developing the proposal.

The goal should be to have the proposal acted upon and supported formally by the collaborating institutions and funding agencies in FY2006. In order to meet this goal it would be most useful if you could submit a proposal on or about February 1, 2005.

In preparing your proposal I would request that you work directly with the Fermilab Associate Director for Accelerators, Steve Holmes, as the representative of Fermilab's institutional interests and to assure the proposal is consistent with Fermilab's infrastructure. We look forward to receiving your proposal and embarking on this exciting endeavor.

Cc
D. Burke
J. Dorfan
G. Dugan
H. Grunder
S. Holmes
D. Kovar
C. Leemann
P. Oddone
R. Staffin
M. Tigner

International Linear Collider
ILC America @ Fermilab

SMTF Collaboration

Collaborating Institutions and their representative

- Argonne National Laboratory: *Kwang-Je Kim*
- Brookhaven National Laboratory: *Ilan Ben-Zvi*
- Center of Advanced Technology, India: *Vinod Sahni*
- Cornell University: *Hasan Padamsee*
- DESY: *Deiter Trines*
- Fermi National Accelerator Laboratory: *Robert Kephart*
- INFN, Pisa : *Giorgio Belletini*
- INFN, Frascati: *Sergio Bertolucci*
- INFN, Milano: *Carlo Pagani*
- Illinois Institute of Technology: *Chris White*
- KEK: *Nobu Toge*
- Lawrence Berkeley National Laboratory: *John Byrd*
- Los Alamos National Laboratory: J. *Patrick Kelley*
- Massachusetts Institute of Technology: *Townsend Zwart*
- Michigan State University: *Terry Grimm*
- Northern Illinois University: *Court Bohn*
- Oak Ridge National Laboratory: *Stuart Henderson*
- Stanford Linear Accelerator Center: *Chris Adolphsen*
- Thomas Jefferson National Accelerator Facility: *Swapan Chattopadhaya*
- University of Pennsylvania: *Nigel Lockyer*
- University of Rochester: Adrian Melissions

Proposal is being prepared to be submitted to Fermilab by Feb. 10th 2005.

Fermilab Perspective on SMTF

- Following the ITRP recommendation the first imperative is establishment of US-based capability in the fabrication of high gradient superconducting accelerating structures.
  - Expanding upon existing scrf expertise at: Argonne, Cornell, Fermilab Jefferson Lab, MSU
  - Provisional goal is to have three U.S. and one European 1.3 GHz ILC cryomodules under test, with beam, by the end of 2008.

⇒ **Fermilab is committed to providing the US leadership with close coordination with the ILC-Americas collaboration.**

- From Fermilab point of view SMTF is the primary mechanism for providing this leadership while allowing us to simultaneously integrate our ILC and PD R&D activities.
- Infrastructure created for this purpose will be of more general utility to a variety of scrf-based U.S. projects (RIA, 4th generation light sources, ERL's, etc)

Superconducting Module & Test Facility

SMTF is envisioned as:

- A multi-laboratory collaboration on SRF development over a broad range of applications. The synergy of expertise will benefit all SCRF areas.

- A facility where different module types and linac systems can be tested (some with beam).

- An organization that will develop inter-laboratory collaboration (including non-US participation) on cold linac technology, including module development and fabrication.

- The area specific to ILC will be carried out under ILC-Americas direction.

- Fermilab has proposed to host of SMTF at the Meson East Area.

Motivations for SM&TF

- Several ambitious SCRF accelerator projects being planned in US
  Examples: International Linear Collider & FELs, Light sources, RIA, PD

- US needs and the SM&TF will provide:
  - a facility where different module types & linac systems can be tested (beam)
  - a collaboration on cold linac technology, module development & fabrication

- SM&TF will allow US to:
  - Take advantage of advances in technology to extend science goals
  - Pursue potential of SCRF
  - Minimize cost of new projects by using most advanced SCRF methods
  - Build cooperation with industry
  - Collaborate & compete effectively with Europe and Asia

- Overlap of national experts at one facility allows exchange of ideas and thus unifies US approach to SCRF-compete better and more effective use of resources

- Build collaboration to prepare/plan to host ILC & build ~1/3 of main linac in US (under direction of ILC-Americas Organization)

Four Main Areas of Program

- ILC
  - Fabricate in US 1.3 GHz cryomodules under ILC Americas leadership
  - Initially two modules are planned
  - Establish high gradient test area
- CW (4^{th} Generation Light Source)
  - Fabricate high-Q value cryomodules
  - Establish a test area that extends US reach
- Proton Driver
  - Fabricate structures and cryomodules
  - Establish a $\beta<1$ test area
- RIA
  - Fabricate structures and cryomodules
  - Establish a $\beta<1$ test area

SMTF Program Goals

- Demonstrate for ILC 1.3 GHz cavity operation at 35 MV/m with beam currents up to 15 mA at a 1% duty factor in two cryomodules with 8 cavities each.
- Demonstrate for CW applications 20 MV/m cavity operation at Q values > 3E10.
- Demonstrate for the Proton Driver 1.3 GHz, $\beta \sim 0.5$-0.8, elliptical cavity operation at > 15 MV/m at Q > 5E9 and a 1% duty factor with multiple cavities being driven by one klystron.
- Demonstrate for the Proton Driver and related applications high gradient operation in pulsed mode of 1.3 GHz and 325 MHz, $\beta < 1$ cavities and cryomodules.
- Demonstrate individual cavity resonance control with multiple cavities driven from one klystron, using fast ferrite phase shifters, at both 1.3 GHz and 325 MHz
- Demonstration of RIA cavities and cryomodules.

Specific Goals for ILC: SMTF

- Establish a high gradient, 1.3 GHz cryomodule test area at Fermilab with a high quality pulsed electron beam using an upgraded A0 injector.

- Fabricate four 1.3 GHz high gradient cryomodules (eight cavities each) using industrial and laboratory partners in the US.

- The fabrication R&D will be carried out as a collaborative effort under the leadership of Fermilab for the ILC-Americas organization.

- Test cryomodules and other rf components as fabrication and operation experience is acquired and designs are optimized.

Existing Infrastructure Slides Few Examples From

- Jlab
- Cornell
- LANL
- MSU
- Fermilab
- Argonne
- SLAC (e-beam welder)
- AES (industrial)
  - Meyer Tool
  - Sciacky

SMTF Cryomodule Fabrication Model

Cavity, HOM, Coupler, Tuner, He Vessel etc.
Get build and tested at the
Collaborating Institutes with Industry
(Dressed and Tested Cavities)

Components of Cold Mass Get build
At Collaborating Institutes and/or
acquired from Industry

String Assembly
Cryomodule Fabrication
At Fermilab

Cryomodule Testing at SMTF

This is the model
We are working
with for ILC and PD

Model for
RIA and CW
under
discussion

International Linear Collider
ILC America @ Fermilab

Development of Cryomodule

Raw Niobium Material
Formed and Machined Components

Inspect
Machine
Etch
Clean
Test

Internal Cavity Section Welding

Half Cells
Dumbells
Multi Cells

Iris Weld

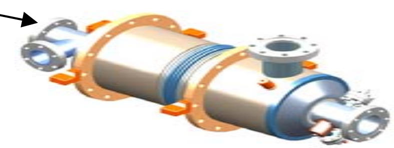
Equatorial Weld

End Section Fabrication Welding

Antenna
Formteil
HOM Coupler
Beam Tube
Input Coupler
Flanges
End Half Cells
Adapter Ring

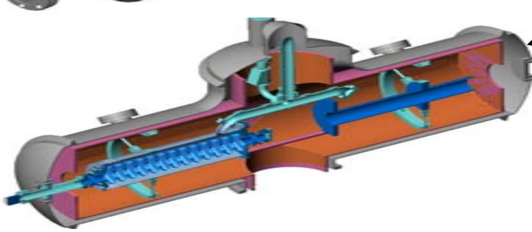
Bare Cavity Vertical Test

Install He Vessel



Completed Cavity

Completed Cavity Horizontal Test



1 or 2 Helium Vesseled Cavites
in Horizontal Test Stand

Delivery

SMTF
8 to 12 Completed Cavities
per Cryostat

Laboratories Collaboration: A Model

Cavity Fabrication & Testing

↓

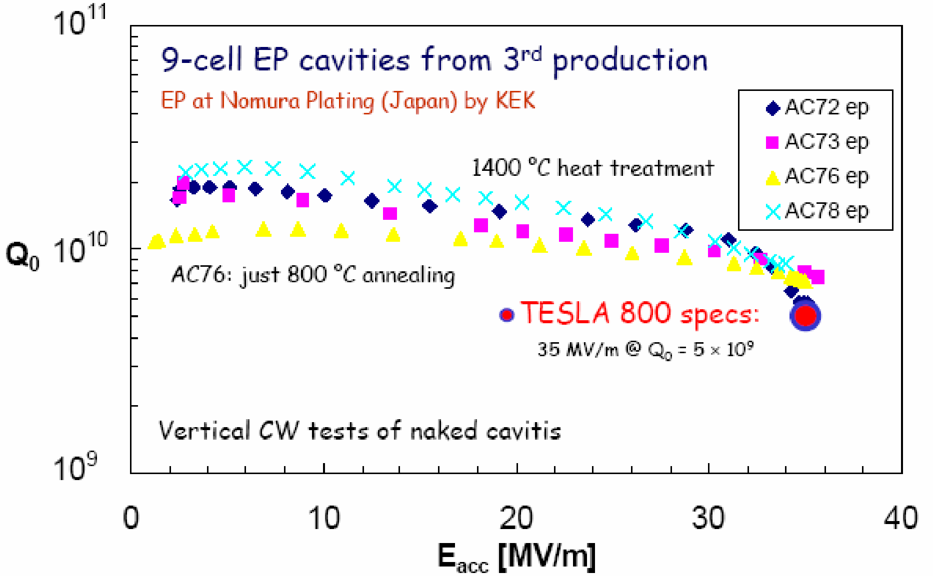
Cryomodule Assembly

↓

Testing at SMTF

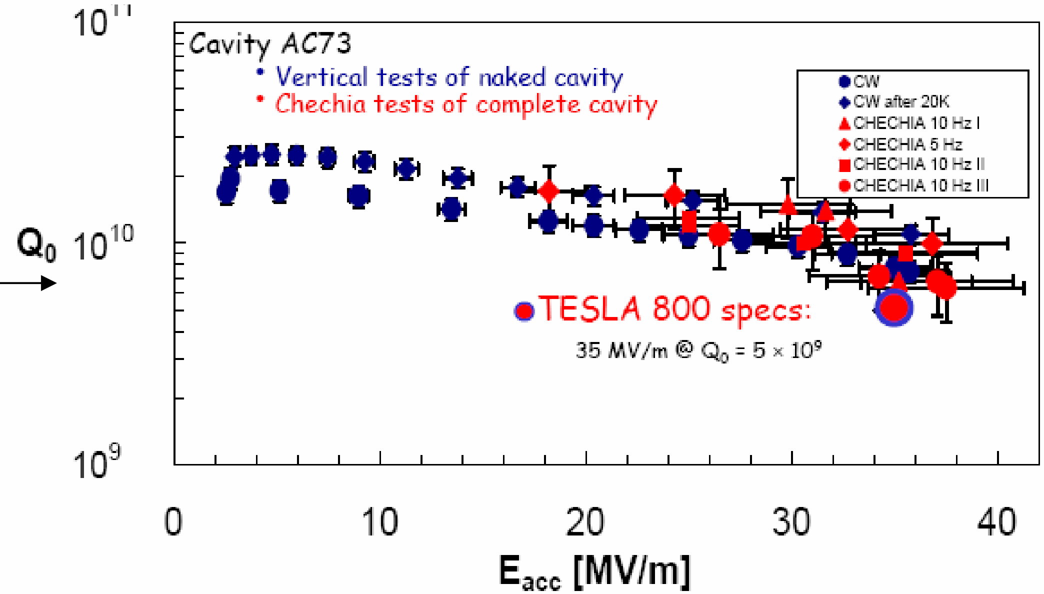
- The cryogenic elements of the Linac are developed under Fermilab leadership in collaboration with US and International laboratories and tested at SMTF.
- We expect that in US the 1.3 GHz cryomodules will be developed in collaboration with Jlab, Cornell, ANL, LANL, Fermilab, SLAC, KEK, INFN, DESY and Industry.
- Expanding present industrial, laboratory, and university capabilities to contribute significantly is essential for the success of the ILC.
- Our goal will be to work with and integrate industrial capabilities.

ILC Technology Status
Accelerating Structures



Vertical (low power test)

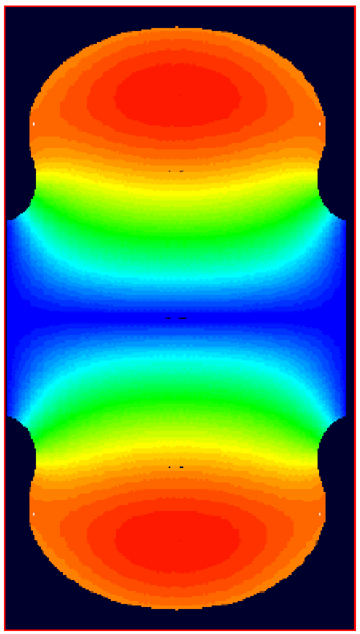
Comparison of low and high power tests (AC73)



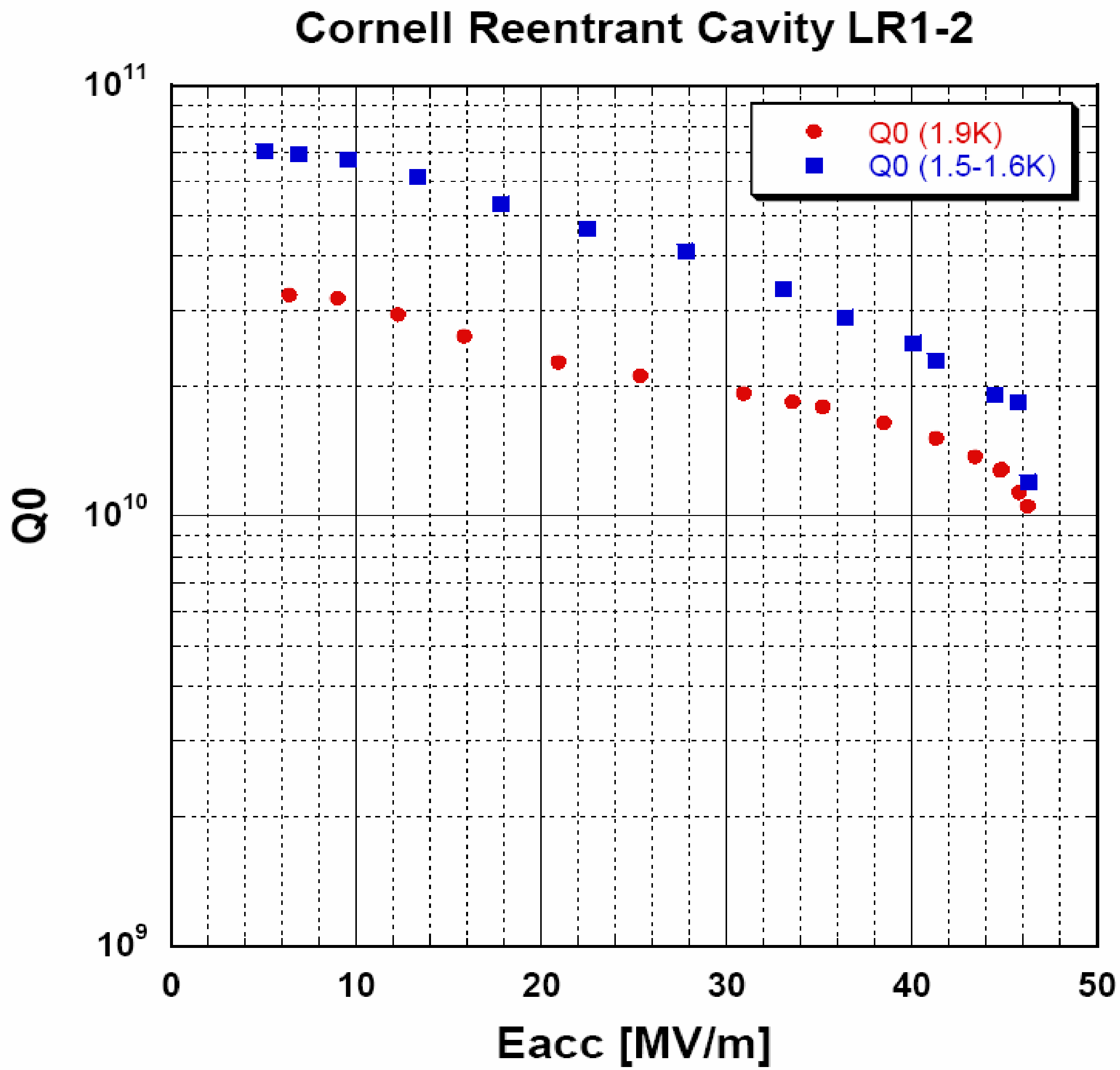
High Gradient Cavity R&D

Re-entrant

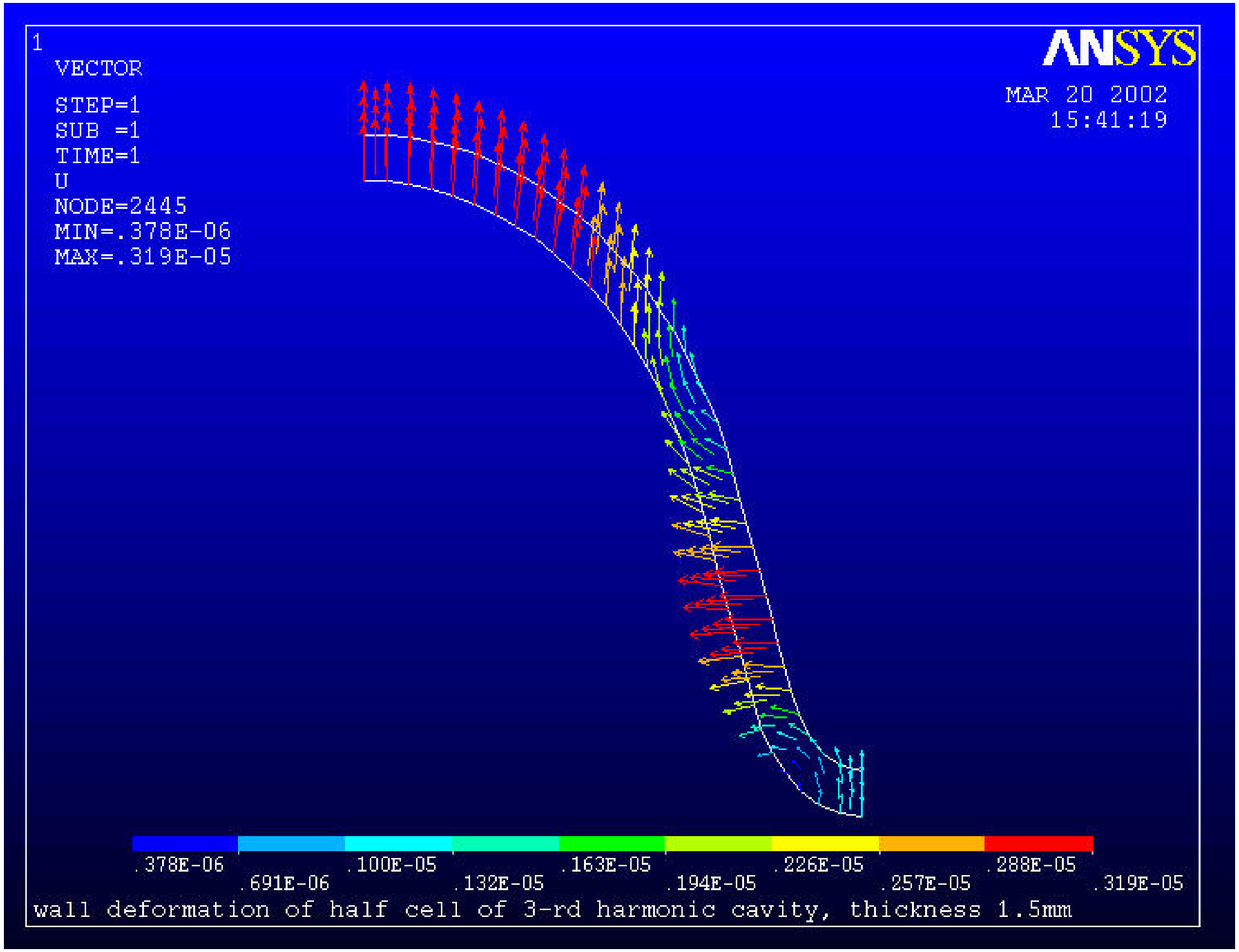
RE shape



Cornell University



Choice of NB thickness.
Frequency shift due to Lorentz forces.



- **HFSS simulation of half cell**
  - P = $(\mu_0 H^2 - \varepsilon_0 E^2)/4$
  - data exchange (HFSS-ANSYS)
- **ANSYS simulation of stresses in half cell**
  - different wall thickness
  - Yung modulus, Poisson's ratio
- **Frequency shift due to Lorentz force (Slater's Theorem)**

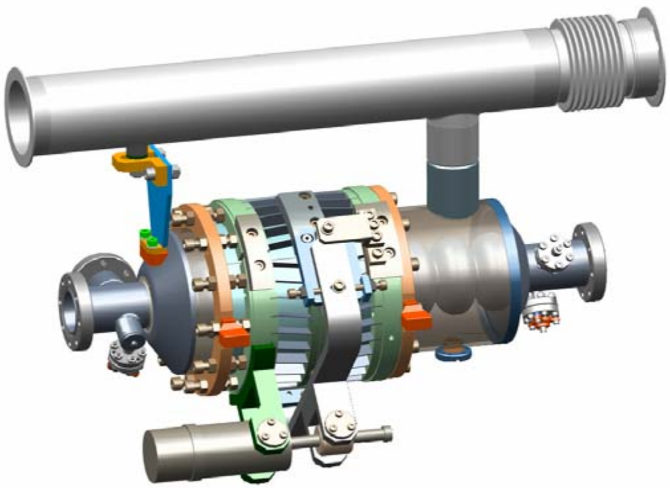
$$\Delta F = F/(4W)\int_{\Delta V}(\varepsilon_0 E^2 - \mu_0 H^2)dV$$

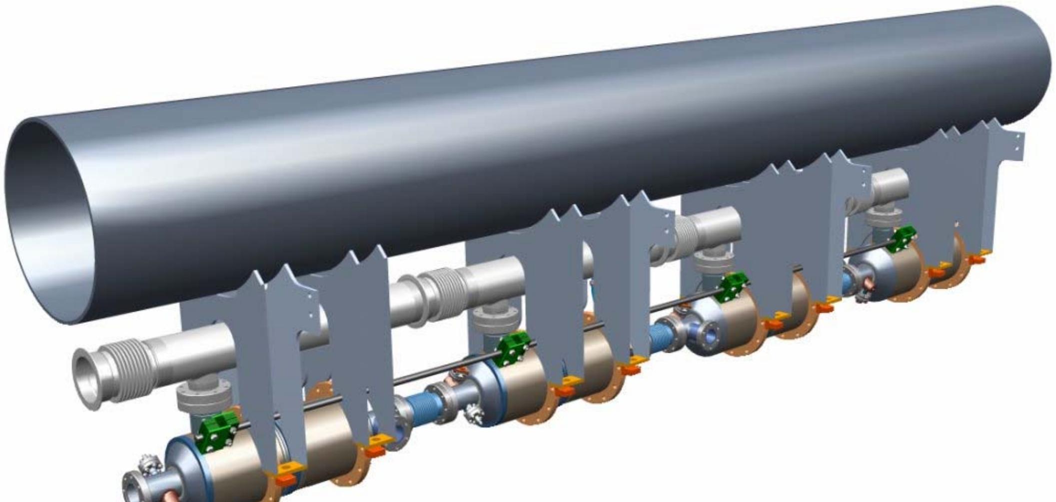
Thickness (mm)	ΔF (Hz)
1.5	200
2.8	90

Displacement of the cell wall due to Lorentz force. Wall thickness T=1.5 mm.

(Ivan Gonin)

Engineering and designing

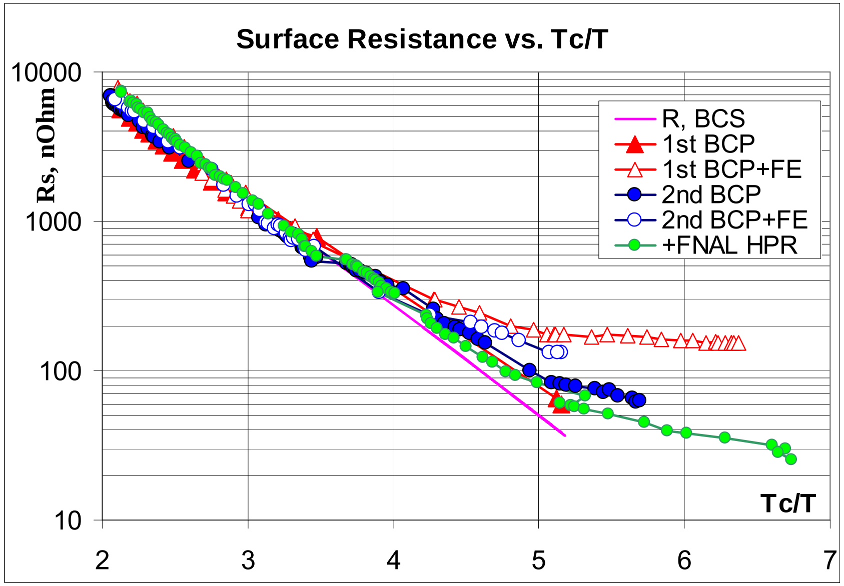


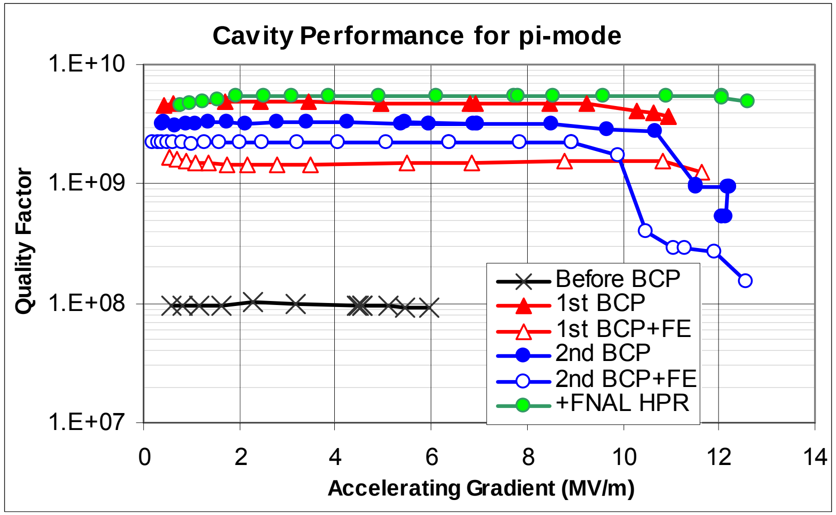


Status of the 3^{rd} harm cavity

- Cavity design is finished
- Built and tested two 9-cell copper models
- Built and tested one 3-cell Nb cavity
- First 9-cell cavity in production (by the end 2004)
- Helium vessel in production (end 2004)
- Blade-tuner in production (end 2004)
- Main coupler under design
- Cryostat for 4 cavities under design
- A0 horizontal cryomodule for single CKM/ 3^{rd} harm. cavities under design

Cold Test of the 3-cell 3.9 GHz cavity in the Vertical Dewar





Q

Gradient Mv/m

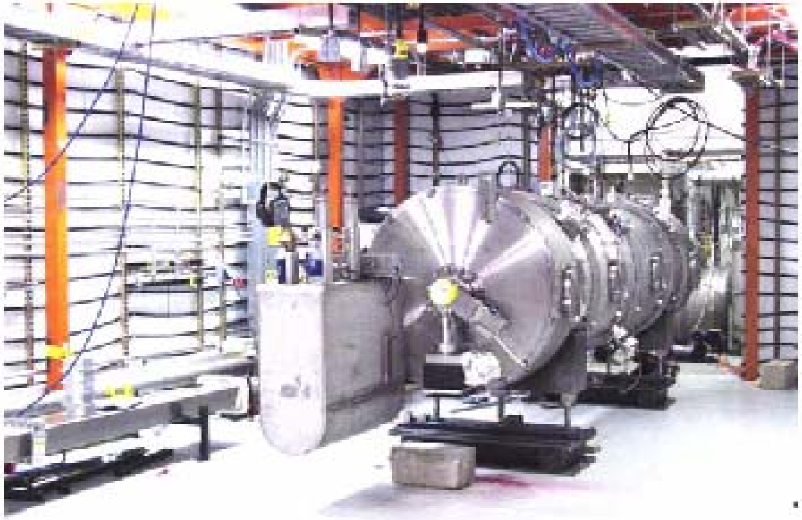
<u>Test history</u>

#1 – No BCP

#2-5 - After100 μm BCP, HT, HPR(15') -JLAB

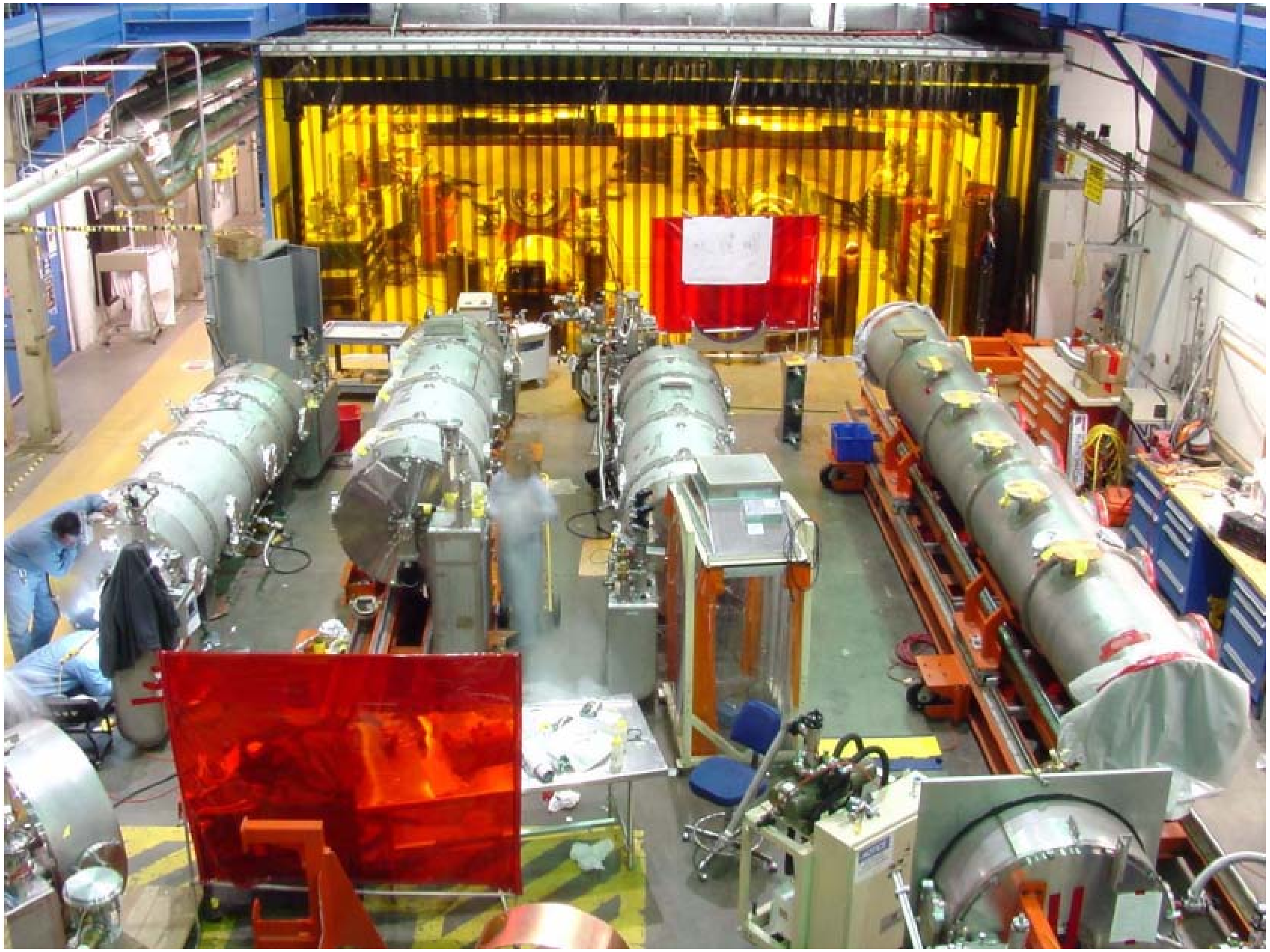
#6,7 – Additional 20 μm BCP, HPR(30')-JLAB

Jlab - Cryomodule Assembly and Test Areas



Cryomodule Test Facility (CMTF)

SNS Cryomodule Assemblies at JLAB



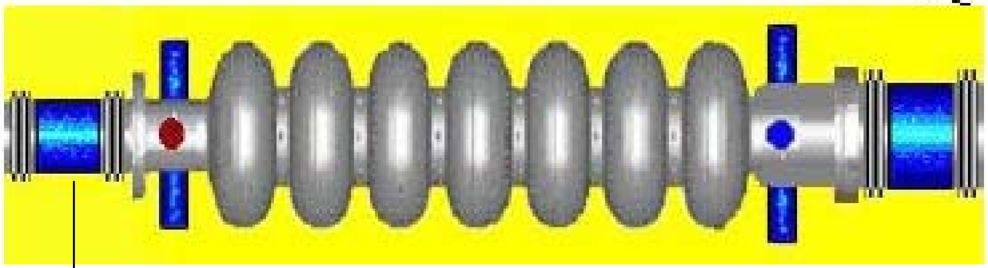
Cryomodule cold-test stations not shown. For single-cavity qualifying, RIA would require 14 stations operating continually for two-year production period.

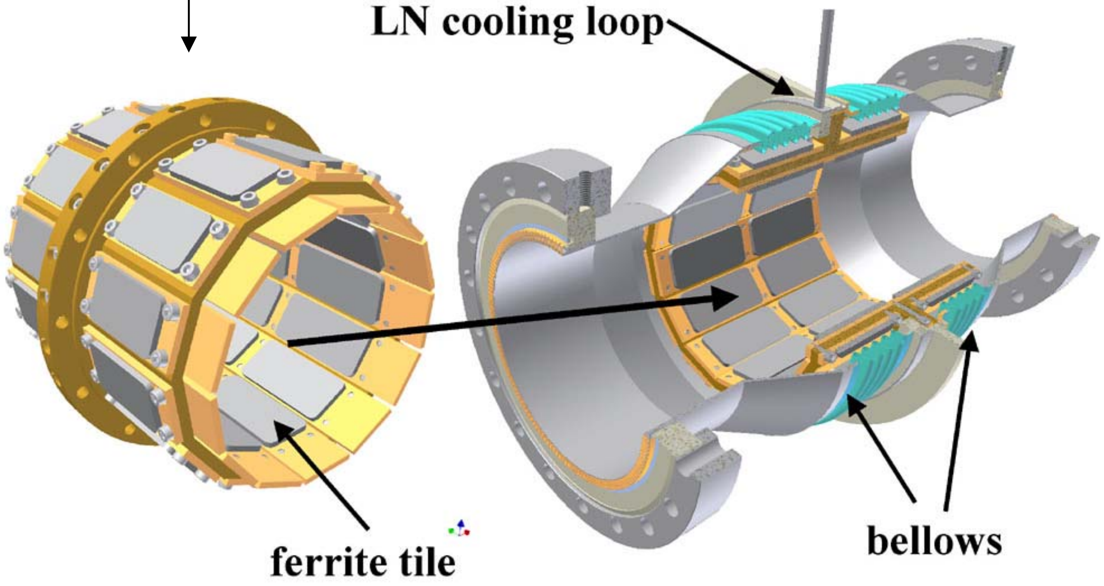
JLAB

Cavity Vertical Test Areas

Cornell

7-cell, large beam pipe, 1.3 GHz





HOM couplers inside cryomodule

200 watts

Cornell
Cavity
Test Pits

The ANL/FNAL Cavity Processing Facility

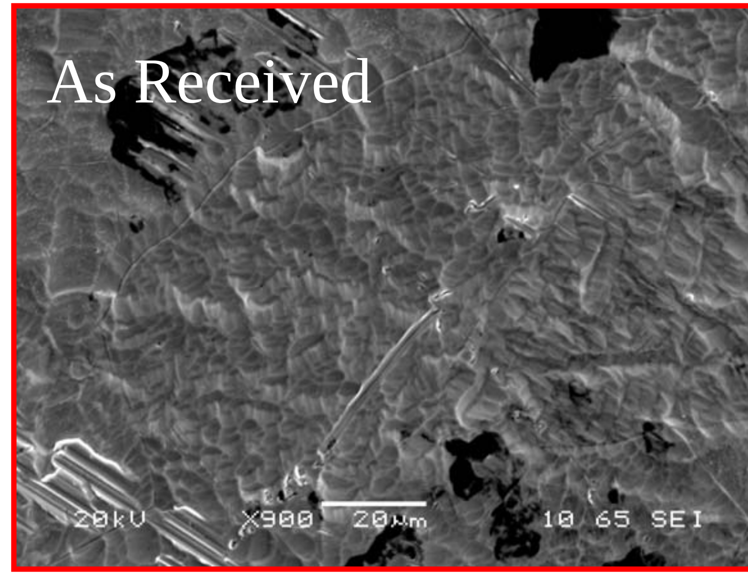
- **Can provide a valuable support facility for ILC development/cryomodule test facility (SMTF) at Fermilab**
- **Comprehensive surface processing capability for SC devices and related hardware using:**
  - **Buffered Chemical Polishing (BCP)**
  - **Electropolishing (EP)**
  - **Ultrasonic cleaning**
  - **Ultrapure high-pressure water rinsing**
  - **Cleanroom assembly of rf devices (single cavities, couplers)**
- **Layout, design and principal areas:**
  - **Two large sealed chemistry areas with a large air scrubber**
  - **Remotely controlled BCP and EP operations**
  - **A large clean anteroom (gowning & ultrasonic cleaning of hardware)**
  - **Two separate class 100 or better clean areas with a dedicated high pressure rinse capability**

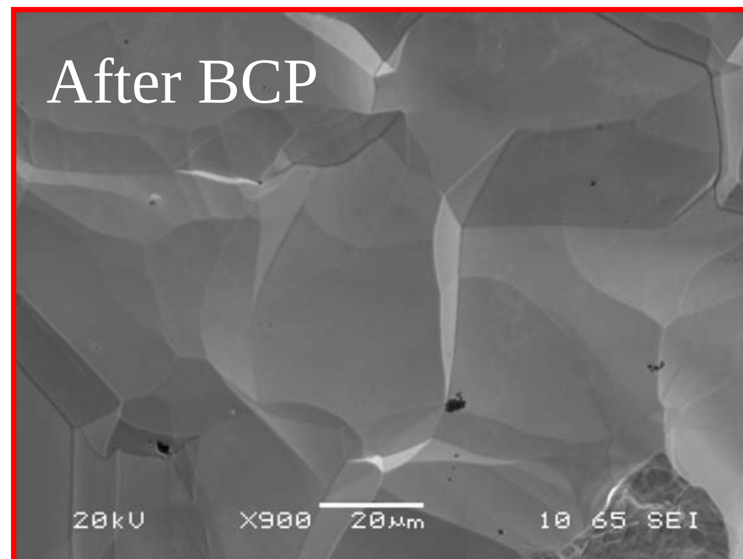
SRF Cavity Surface Chemical Treatment

1. Chemical removal of contaminated and damaged surface layer of a cavity

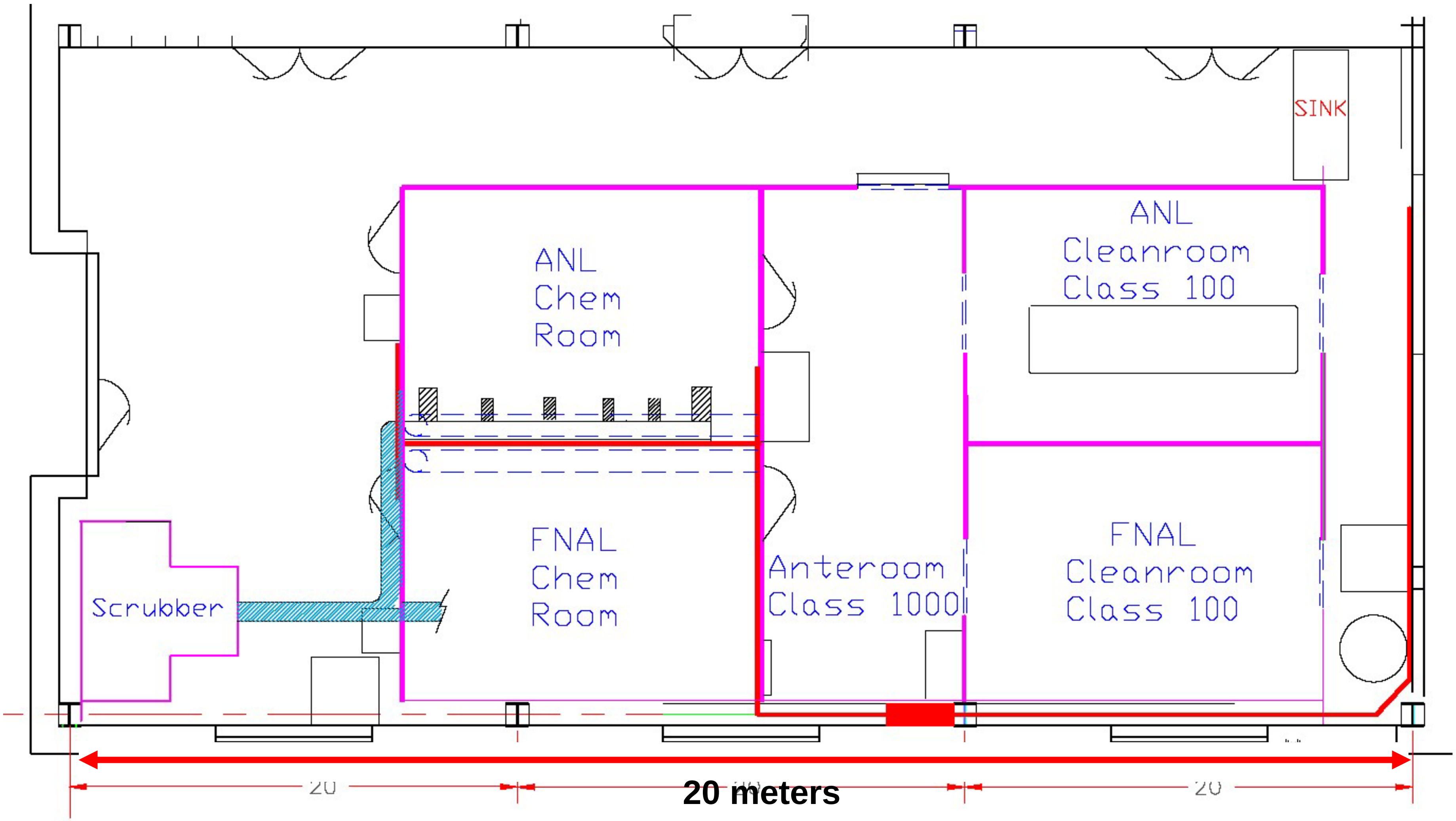
2. Polishing.

Two major types of the treatment: Buffered Chemical Polishing (BCP) and Electropolishing (EP)





The Joint ANL/FNAL SCRF Cavity Processing Facility at Argonne

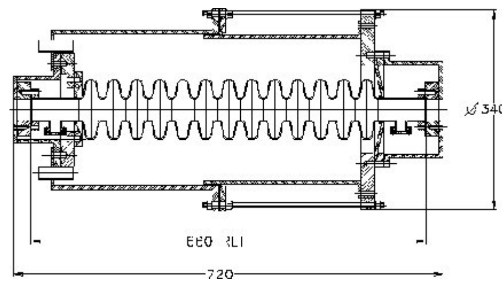


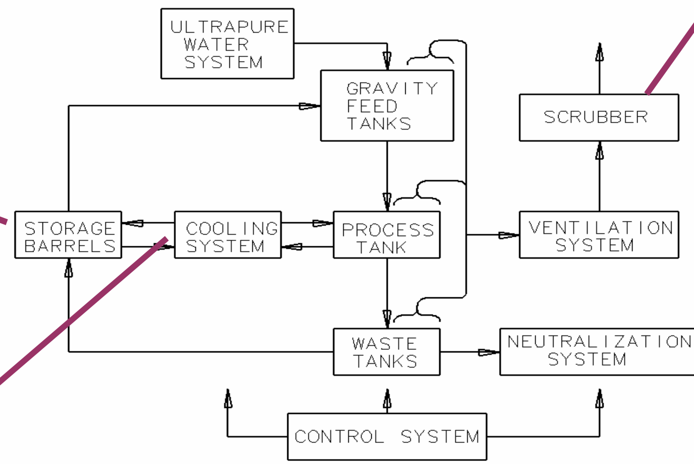
Phase I: The ANL/FNAL Chemistry Facility

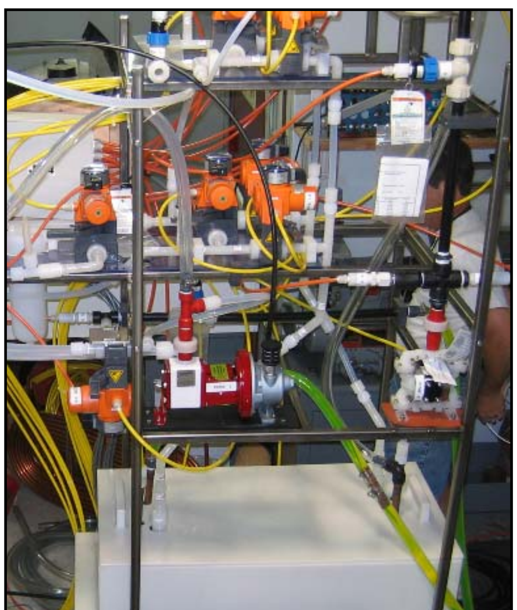
Chemical Processing Rooms

Air Scrubber

BCP Process Design





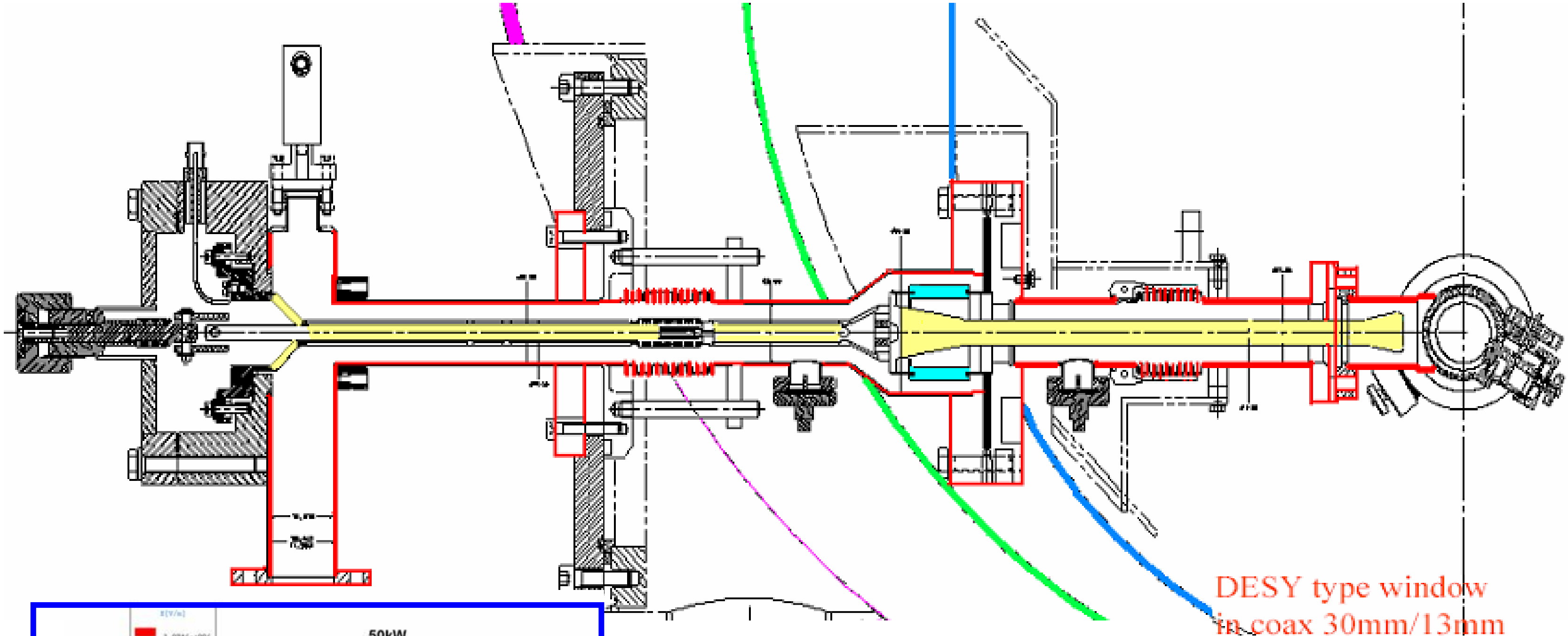


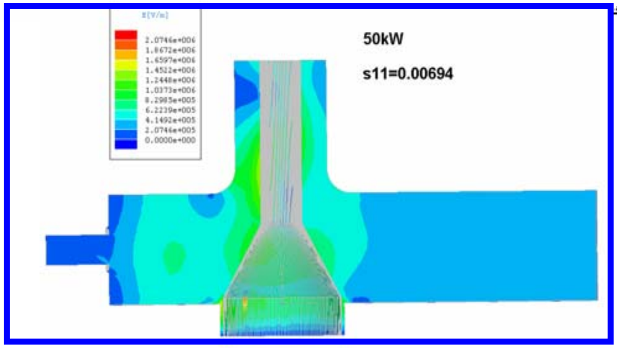
RF Power Sources

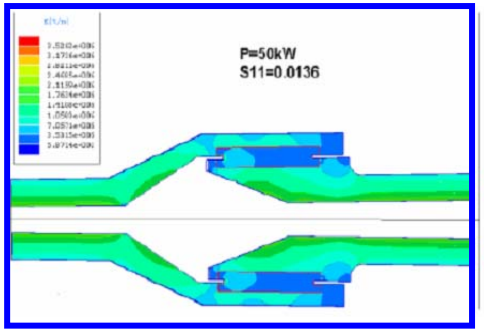
- Three Thales TH1801 Multi-beam klystrons fabricated and tested.
  - Efficiency = 65%
  - Pulse width = 1.5 msec
  - Peak power = 10 MW
  - Repetition rate = 5 Hz
  - Operational hours (at full spec) = 500 hours
  - Operational hours (<full spec) = 4500 hours

- Independent MBK R&D efforts now underway at CPI and Toshiba
- 10 Modulators have been built
  - 3 by Fermilab and 7 by industry
  - 7 modulators are in operation
  - Based on Fermilab design
  - 10 years operation experience

Fermilab Designed Coupler for 3rd harmonic cavity

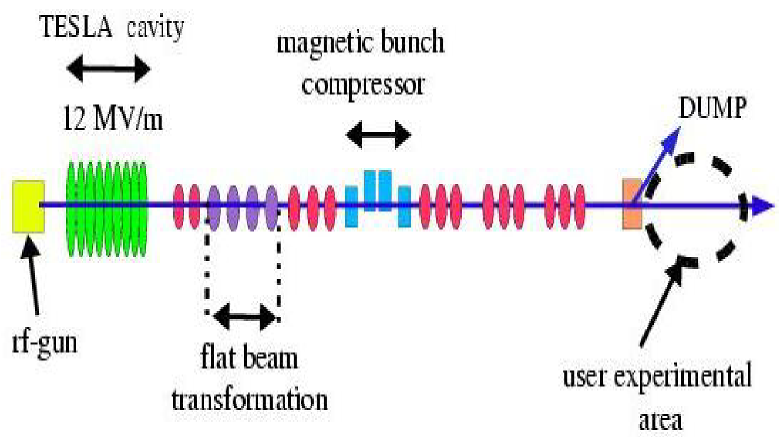




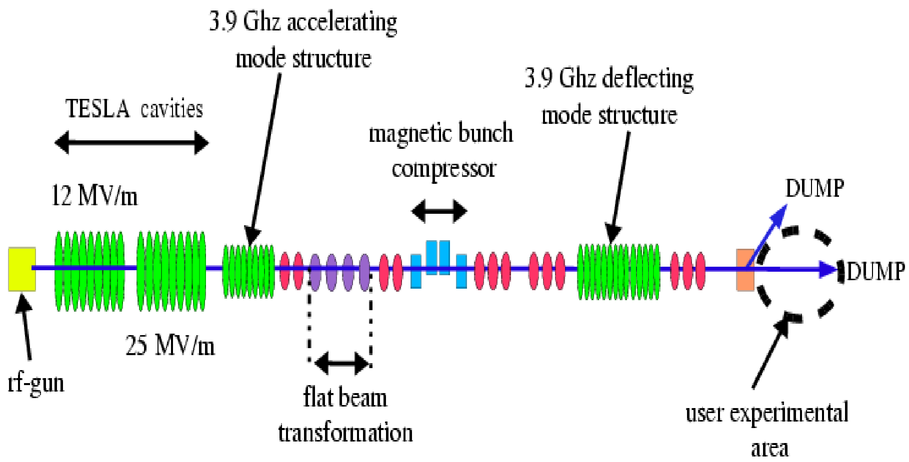


Fermilab also helped design 1.3 GHz couplers

The Fermilab NICADD Photoinjector Laboratory (FNPL)

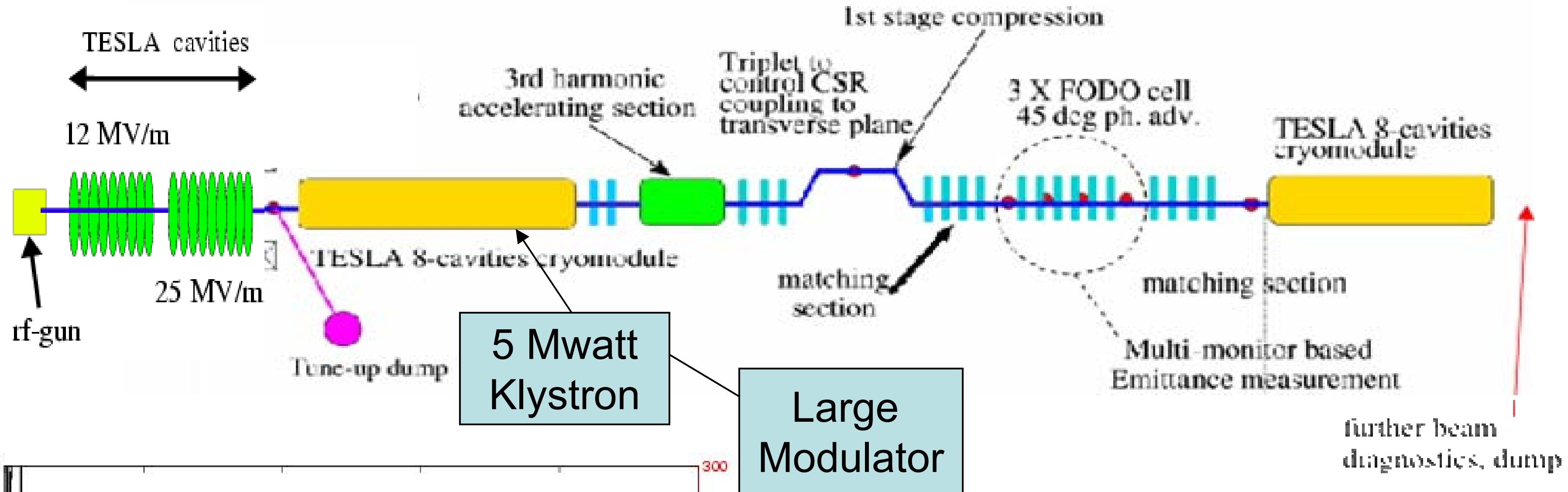


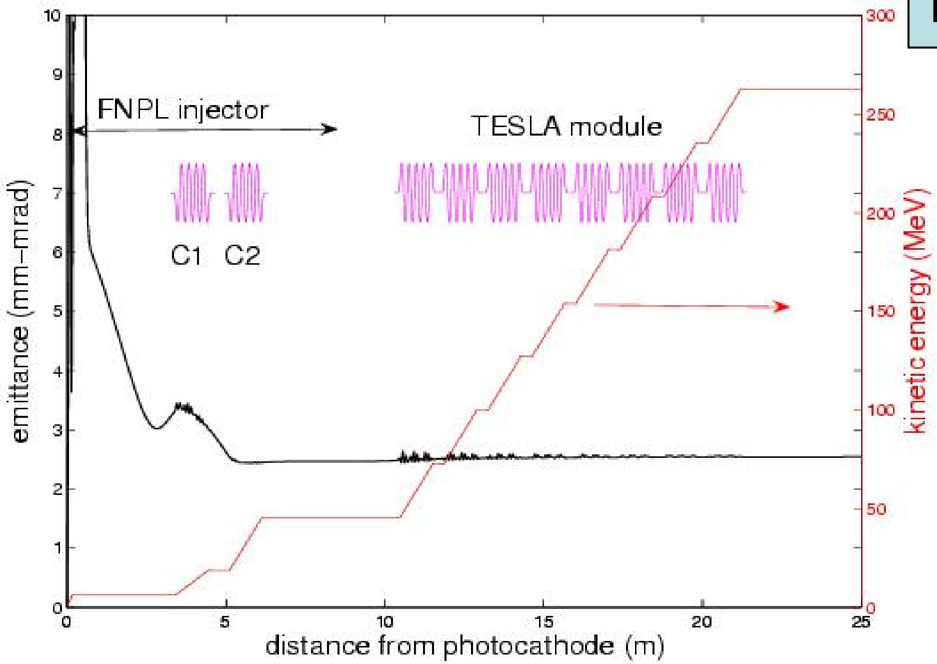
FNPL Upgrade



- 2nd incarnation of the TTF Injector II, with extended diagnostics,
- One normal conducting rf gun, one superconducting booster cavity
- Beam energy up to 16 MeV, bunch charge up to 12 nC
- Normalized emittance 3-4 π mm mrad (with 1 nC)
- Beam physics studies with high brightness beams
- Experimental area for advanced accelerator concepts
- Education of students

2nd Stage Upgrade of FNPL





Example of transverse emittance (black) and kinetic energy (red) evolution for a 3.2 nC bunch (TESLA nominal charge). C1 and C2 are the two TESLA cavities to be operated in the FNPL upgrade (here operated at 12.5 and 25 MV/m average accelerating gradient). The upgraded FNPL injector extend from z=0 to z=8 m. The beam is then injected in a TESLA accelerating module. The magenta curves stands for the longitudinal fields, i.e. the location of the TESLA cavities.

What is an RF Unit ?

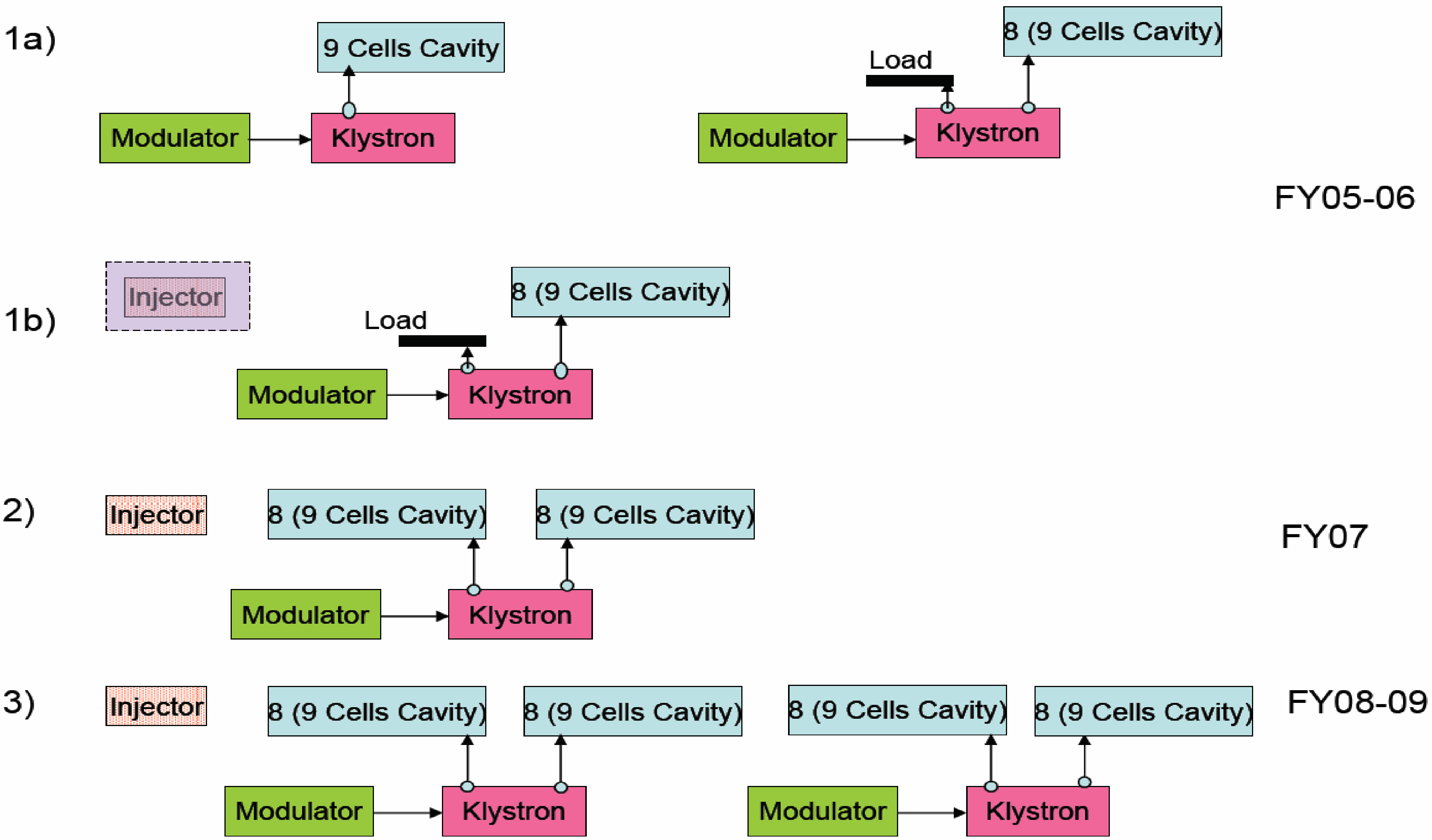
- An RF unit will eventually need to be defined for both the 500 GeV and 1 TeV ILC designs.
- In our discussions, we are moving towards an ILC with 35 MV/m, 1.3 GHz cavities for both 500 GeV and 1 TeV operation.
- The power sources currently being developed can provide 10 MW of rf power so it is natural to define an rf unit as the number of cavities powered by such a source (i.e., one modulator and one klystron).
- Given the state of cryomodule development and the desire to have some overhead in choosing the ILC beam current, we define an RF unit for test purposes as two cyromodules with eight TESLA-like (9 cell) cavities each.
- Assuming 6% transport losses, each cavity in the rf unit could be powered up to 530 kW with a 10% overhead. At 35 MV/m, a 15 mA beam could be accelerated, which is about 15% more current than in the TELSA 800 design.
- The present design of the ILC cryostat is based on the DESY design, which contains eight nine-cell cavities. It may be cost effective (needs study) for the ILC to have 12 nine-cell cavities per cryomodule.

Phases of ILC: SMTF

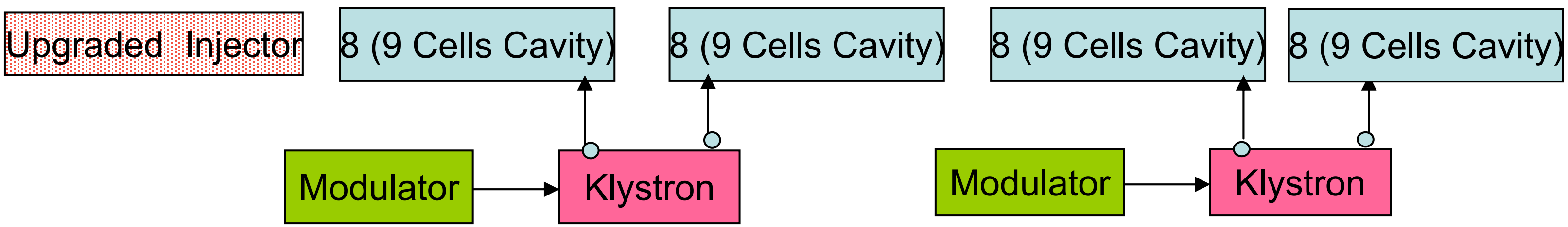
- We propose to bring into operation one cryomodule with the goal of demonstrating 35 MV/m cavity operation. It is expected that it may take more than one module iteration to achieve this gradient.
  - The A0 photo injector will be moved, installed and re-commissioned with the cryomodule (step 1) in order to perform beam measurements, which are discussed below.
  - We will initiate beam tests of a single ILC cryomodule utilizing the photo injector.
- We propose to bring into operation one SMTF-ILC rf unit, defined as two cryomodules each containing eight 9-cell cavities, one high power modulator, one 10 MW multi-beam klystron and perform beam measurements.
  - The injector will be upgraded to include the Fermilab built 3.9 GHz accelerating and deflecting cavities.
- We propose to bring into operation two SMTF-ILC rf units and associated rf power, instrumentation and controls.

SMTF: Three Phase Approach

1.3 GHz Cryomodule Test Facility



Two SMTF-ILC RF Unit Construction



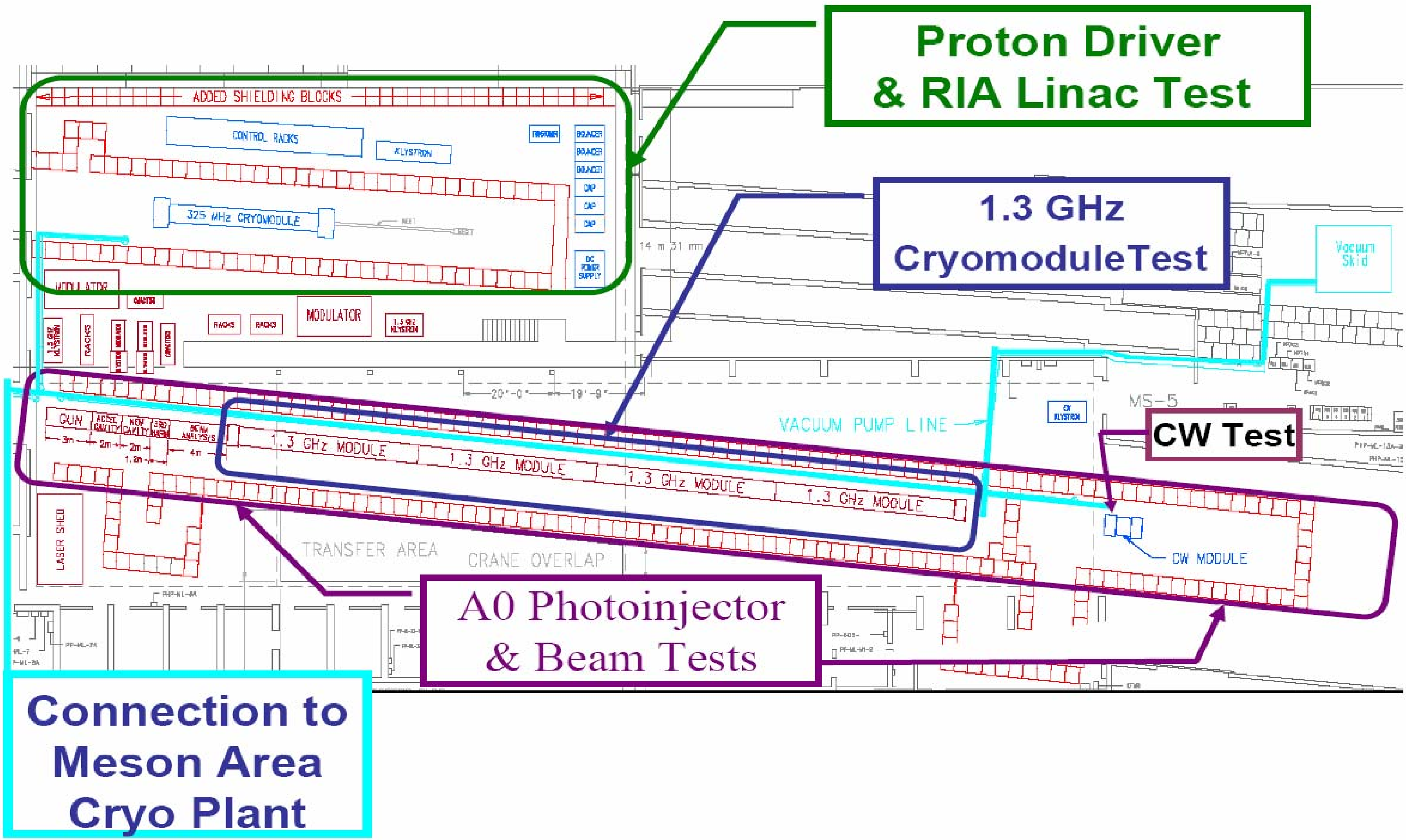
4 Cryomodule (32 cavities, HOM, blade tuners, He vessel, couplers) + 2 Klystrons + 2 Modulator + Controls

- FY05: 1 3.9 GHz cavity 3rd Harmonic
- FY05: 1 3.9 GHz cavity deflecting

} Finish the construction already in progress.

- FY05: Start fabrication of 1 cyromodule (8, 1.3 GHz cavities) (We are expecting to get 1 additional cryomodule from DESY)
- FY06-09: US Build 3-4 cyromodule (8, 1.3 GHz cavities)
- FY05-07: 2 cryomodule (4, 3.9 GHz 3rd Harmonic cavities) FY05-07

FNAL Meson Area SM&TF Layout Concept



Meson Area Fermilab

Technology Studies

- Determine the maximum operating gradient of each cavity & its limitations.
- Evaluate gradient spread and its operational implications.
- Measure dark currents, cryogenic load, dark current propagation, and radiation levels.
- Measure alignment of the quadrupole, cavities and BPM in-situ using conventional techniques (e.g. wire or optical).
- Measure vibration spectra of the cryomodule components, especially the quadrupole magnet.
- Measure system trip rates and recovery times to assess availability.
- Develop LLRF exception handling software to automate system and reduce downtime.
- Evaluate failures with long recovery times: vacuum, tuners, piezo controllers, and couplers.

Physics Measurements

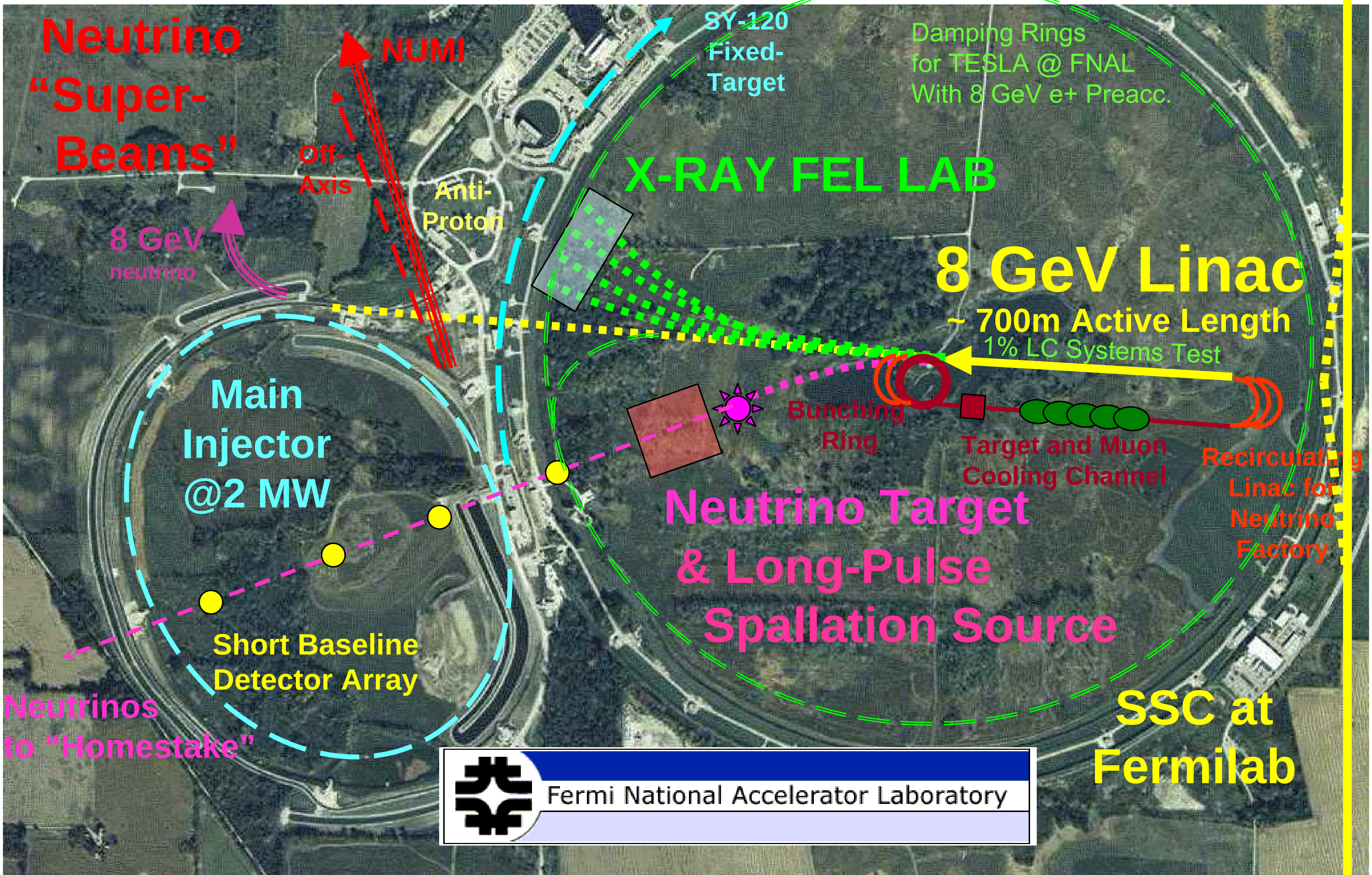
- Beam energy: a spectrometer would provide an independent and accurate measurement of the accelerating gradient (rf based techniques are not as accurate).
- Long-range wake-field characterization: Measure frequency spectra of bunch positions downstream of cryomodule to search for high Q cavity dipole modes that could cause beam break-up in the ILC. Correlate these data with HOM power measurements.
- Tests of low-level rf system: demonstrate that a < 0.1% bunch-to-bunch energy spread can be achieved in a 1 msec bunch train.
- Impact of the SCRF cavity on transverse beam dynamics: measure the beam kicks caused by the fundamental mode fields.
- Study beam centering based on HOM dipole signals.

Proton Driver

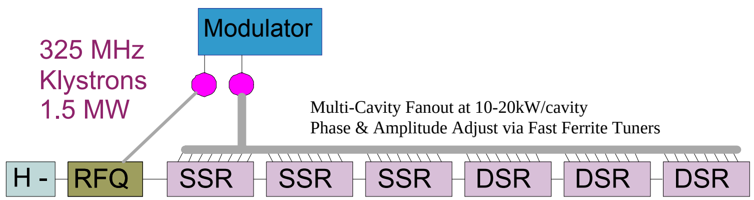
- The Proton Driver is an 8 GeV SCRF proton linac
  - For Neutrino Super-Beams & other new capabilities at FNAL
- The last 85% of the PD linac (1 GeV to 8 GeV) is *identical to the ILC.*
- Thus, R&D program for the *back end* of the Proton Driver is identical to the ILC ➔ SMTF synergy.
- The Proton Driver represents a 1.5% system test of ILC
- R&D for the *front end* of the PD extends technology of SNS, RIA, JPARC, TESLA, and other projects.

8 GeV Superconducting Linac

With X-Ray FEL, 8 GeV Neutrino & Spallation Sources, LC and Neutrino Factory



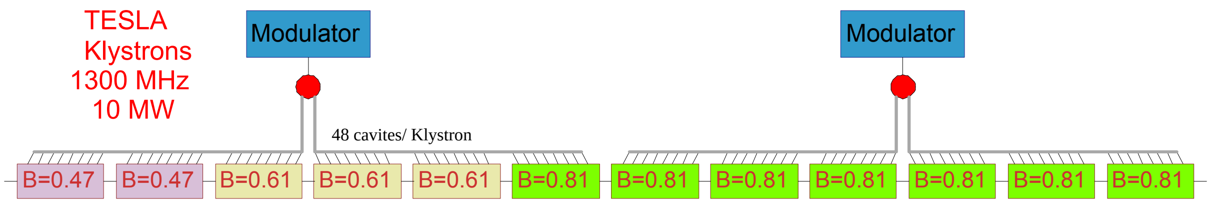
0.5 MW with TESLA Frequencies & SCRF F.E.



"Pulsed RIA"
SCRF Linac
325 MHz
0 - 120 MeV

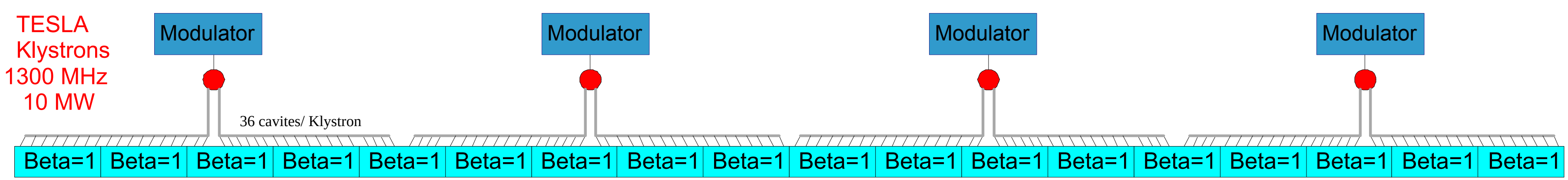
8 GeV 0.5 MW LINAC

12 Klystrons (2 types)
11 Modulators 20 MW ea.
1 Warm Linac Load
54 Cryomodules
~550 Superconducting Cavities



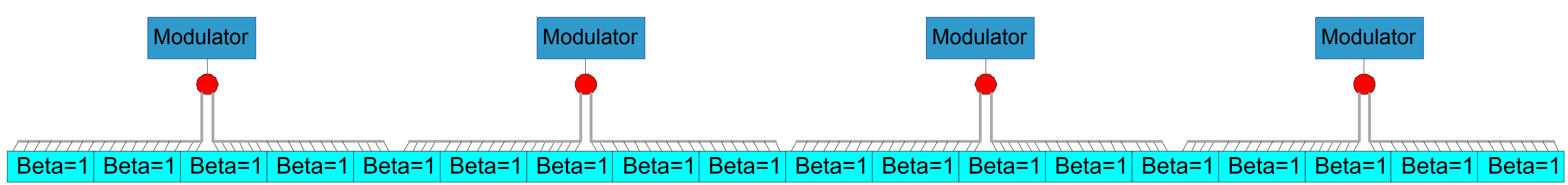
"Squeezed TESLA"
Superconducting Linac
1300 MHz 0.087 - 1.2 GeV

2 Klystrons
96 cavites in 12 Cryomodules

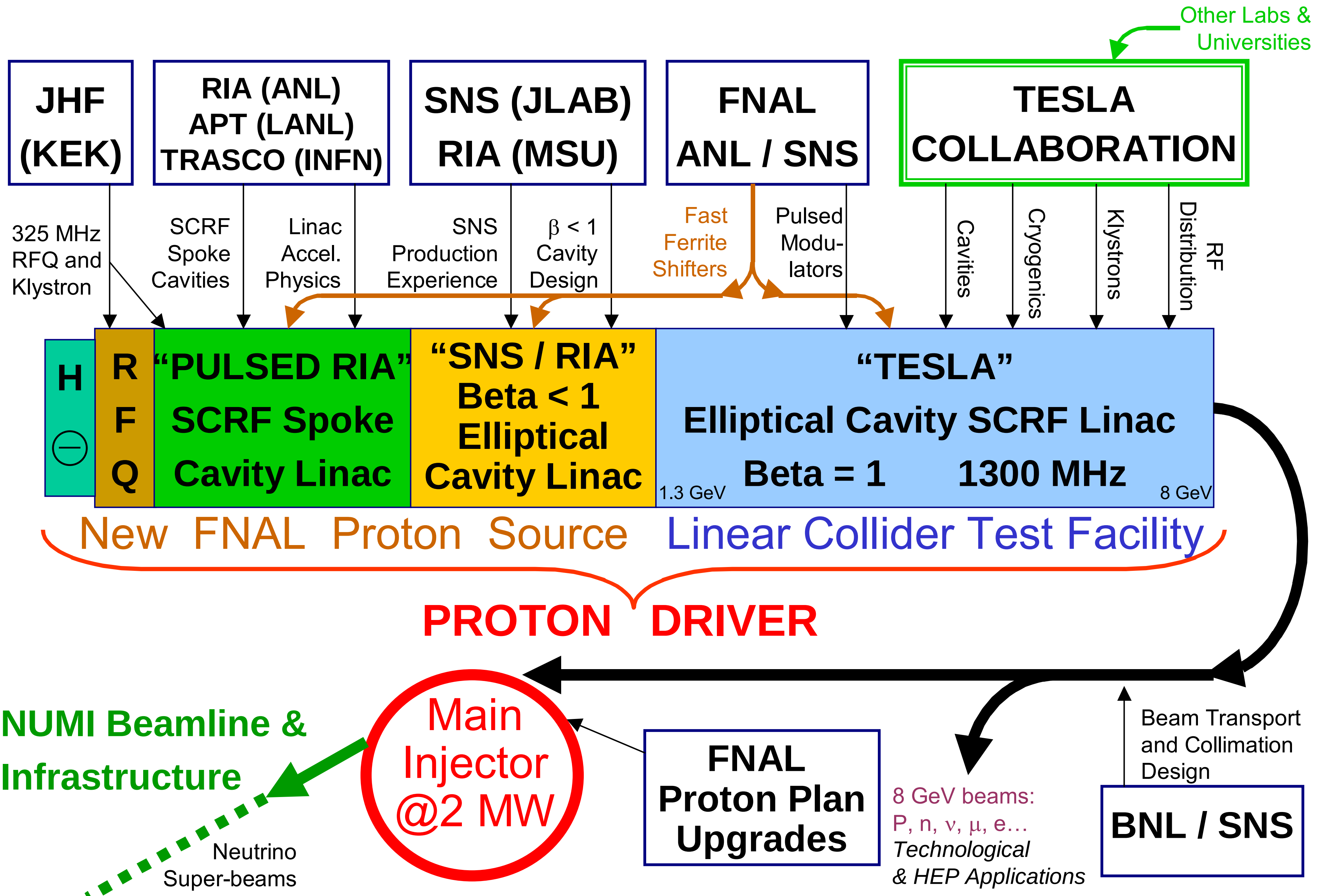


"TESLA" LINAC 1300 MHz Beta=1

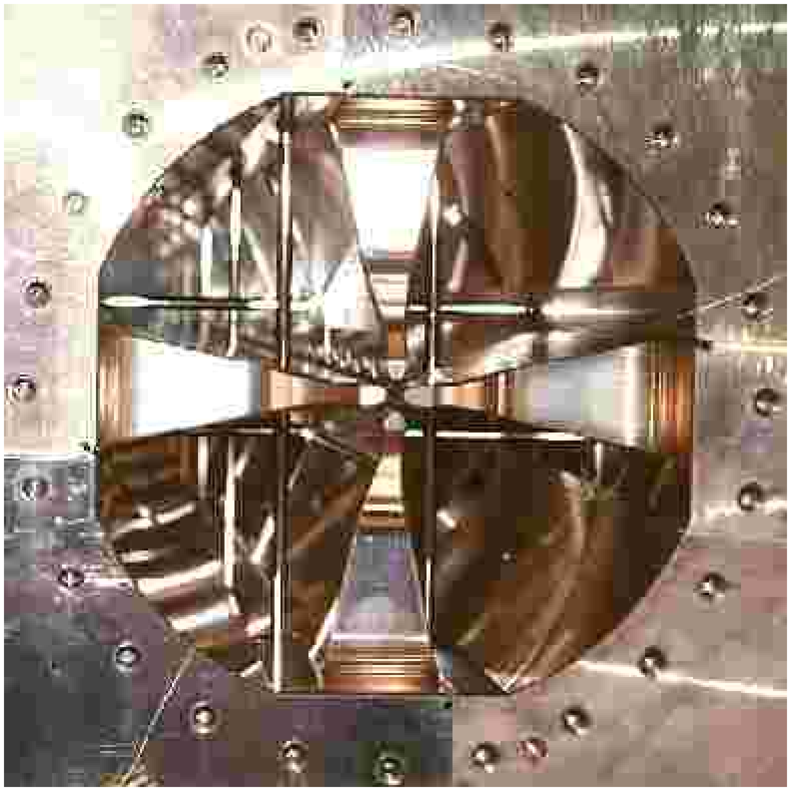
8 Klystrons
288 cavites in 36 Cryomodules



Proton Driver Linac - Technology Flow

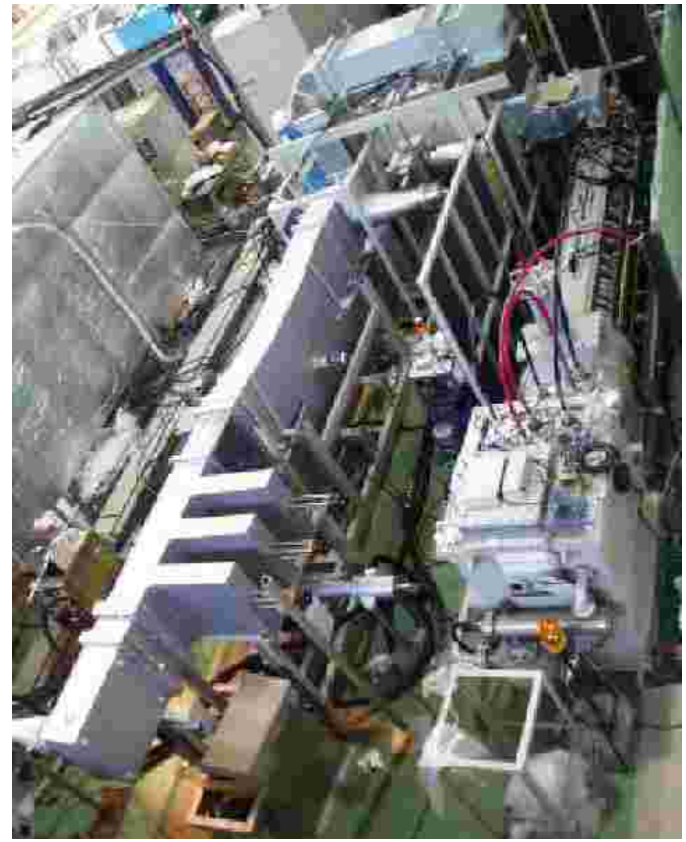


JHF 325 MHz RFQ and Klystrons for TESLA-Compatible* Front End



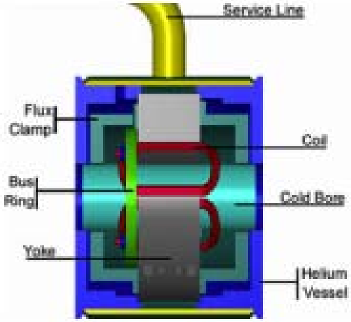
JHF 325 MHz RF Quad

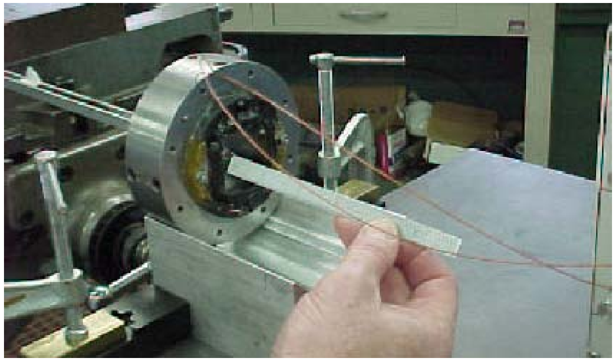
* TESLA frequency = 1300 MHz
= 4*325 MHz



JHF 325 MHz
3 MW Klystron

Beta<1 Cavities and Superconducting Quads





- INFN (Legnaro) / MSU Collaboration

Single- and double-spoke resonator

LANL (APT)

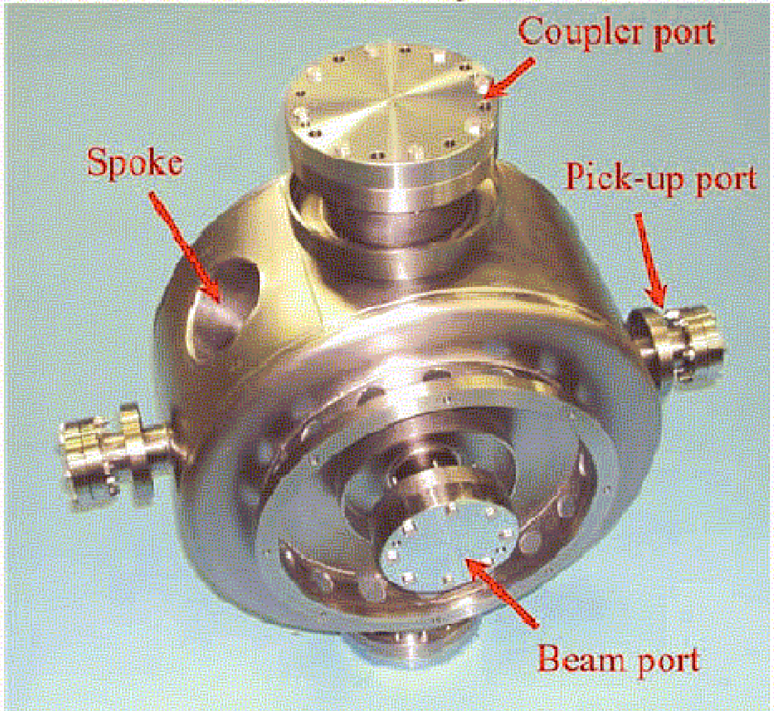


Figure 1: Los Alamos-built 350 MHz, β=0.175, single-spoke niobium cavity

ANL (RIA)

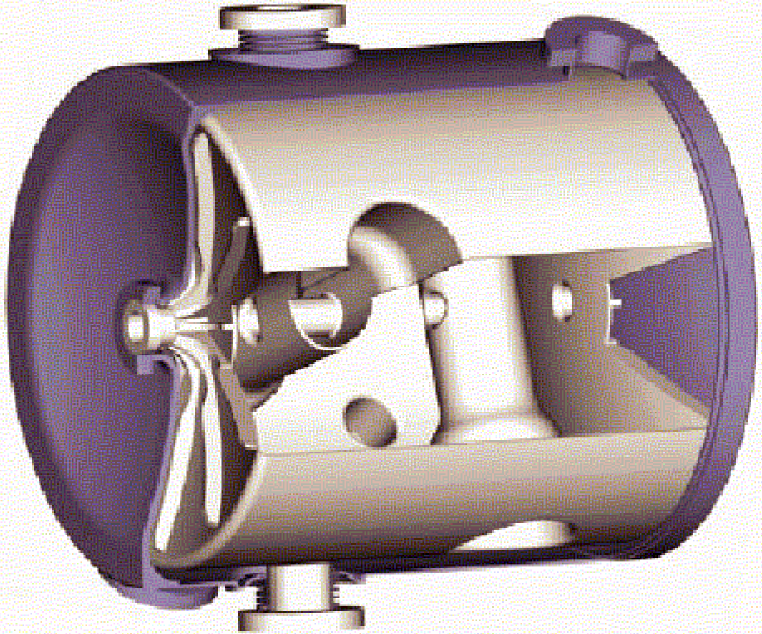
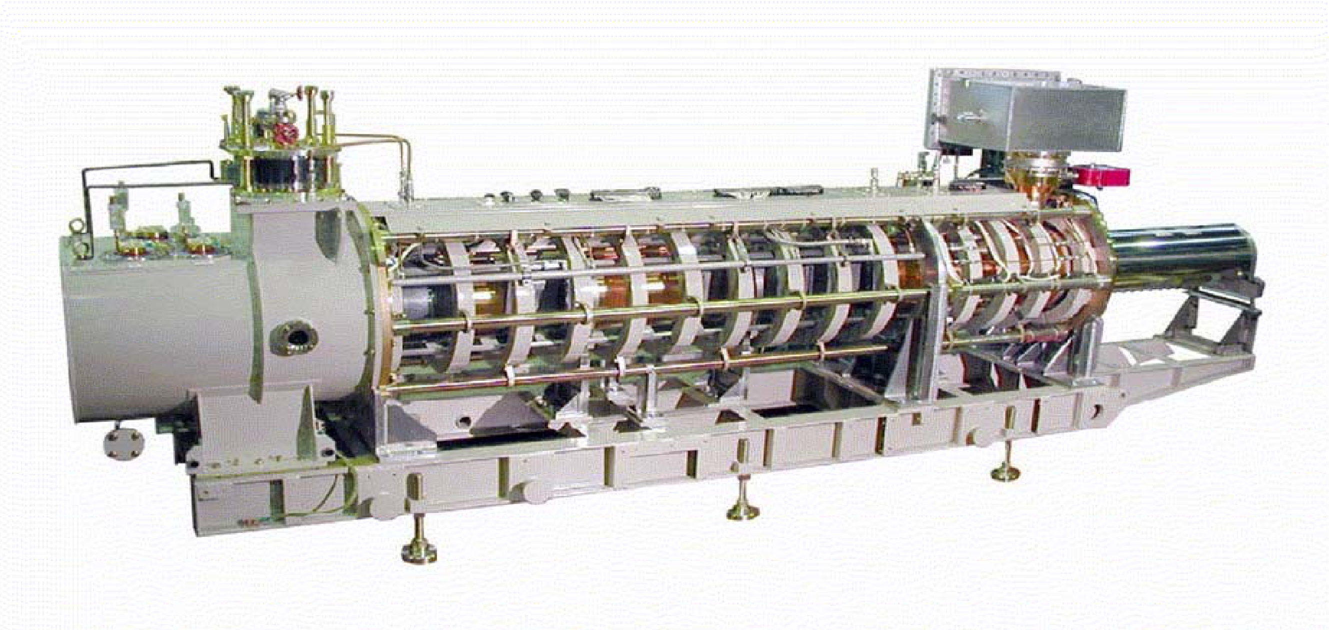


Figure 5: A 345 MHz, double-spoke, three-gap cavity for β=0.4. A niobium prototype has been built and tested at Argonne National Laboratory

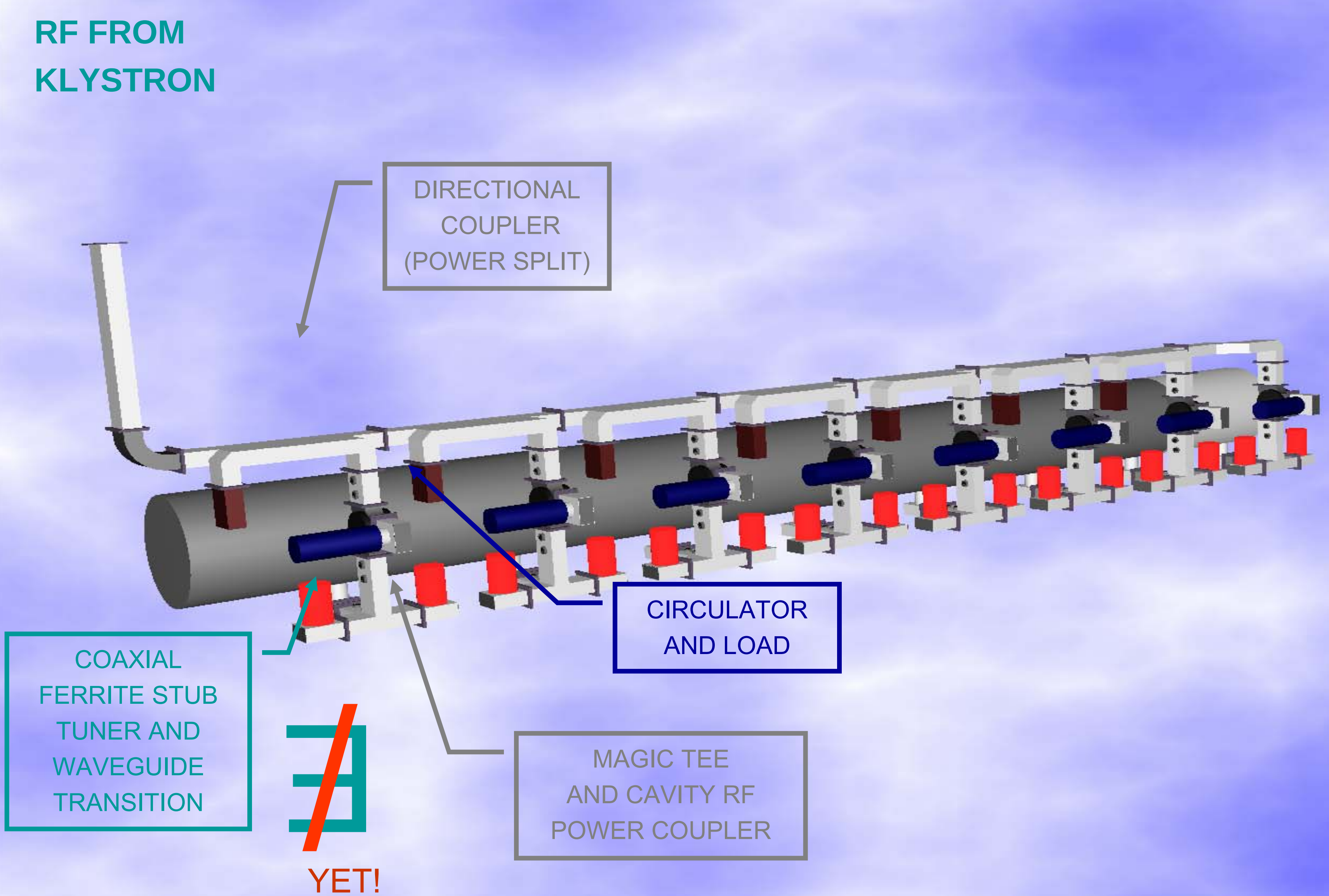
Proton Driver Klystrons

1300 MHz
10 MW
3 Manufacturers



Toshiba E3740A
325 MHz   3 MW
(In Production for JPARC)

Advanced RF Distribution



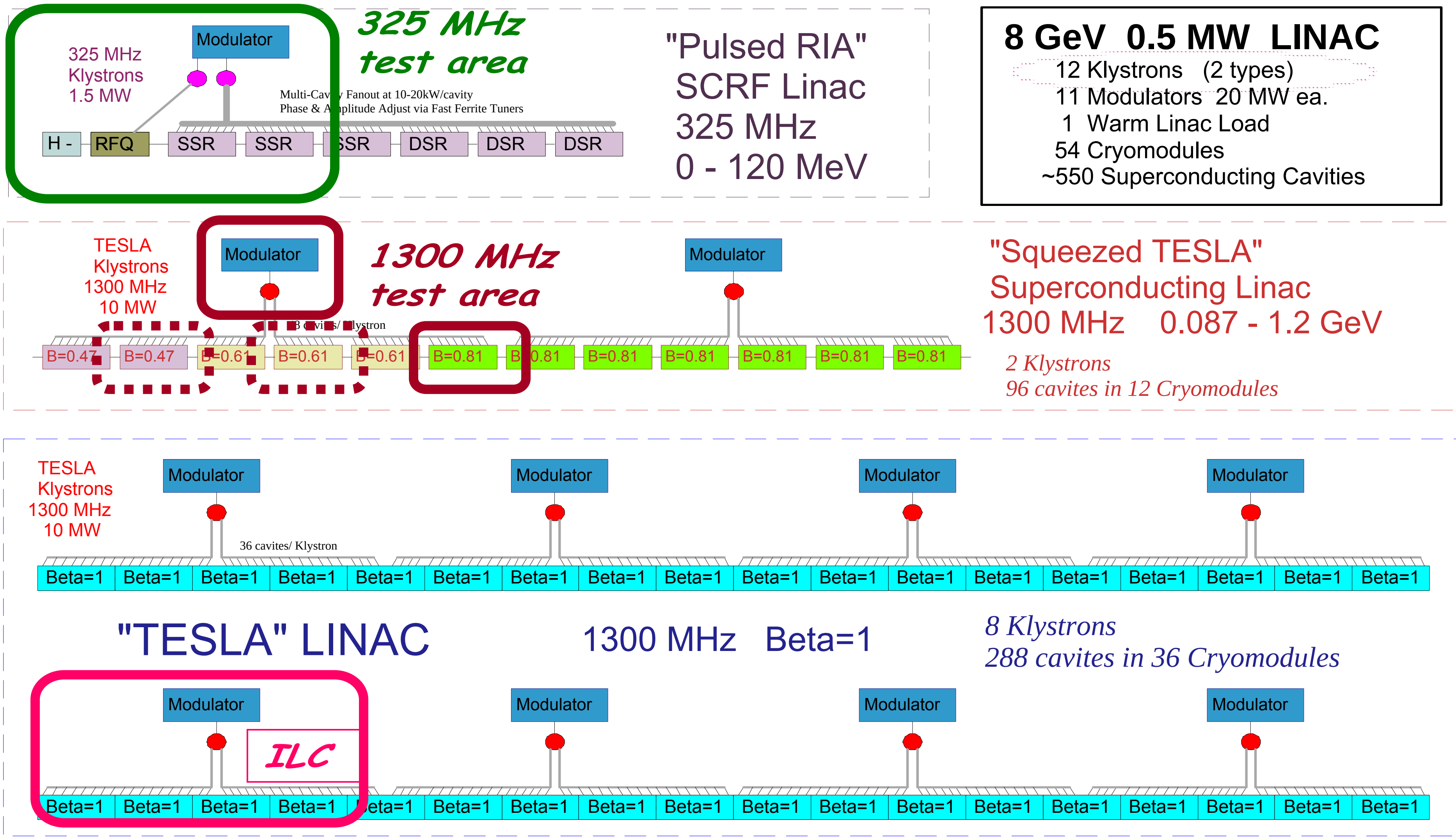
THE NEXT STEP

- There is a 100% overlap in the plans for the next step of the SCRF Proton Driver and the SCRF Linear Collider:

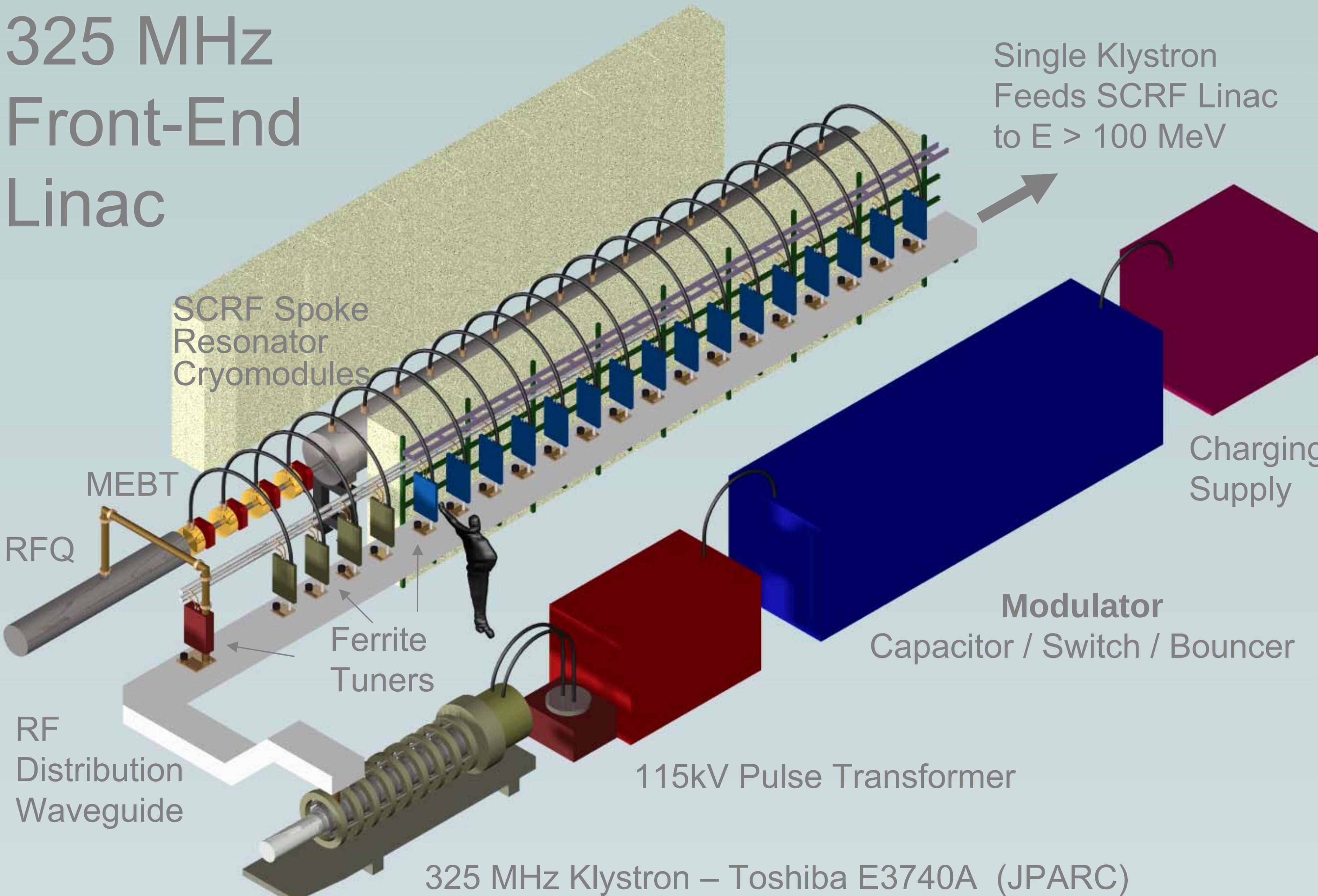
- ***Set up 1 GeV of Cold linac***
  - At Fermilab
  - With as many components from new vendors as possible

- ***Demonstrate a 325 MHz TESLA-Compatibile SCRF linac For Protons and Ions***
  - At Fermilab
  - With as many components from new collaborators and vendors as possible

Proton Driver - 0.5 MW with TESLA Frequencies & SCRF F.E.



325 MHz Front-End Linac

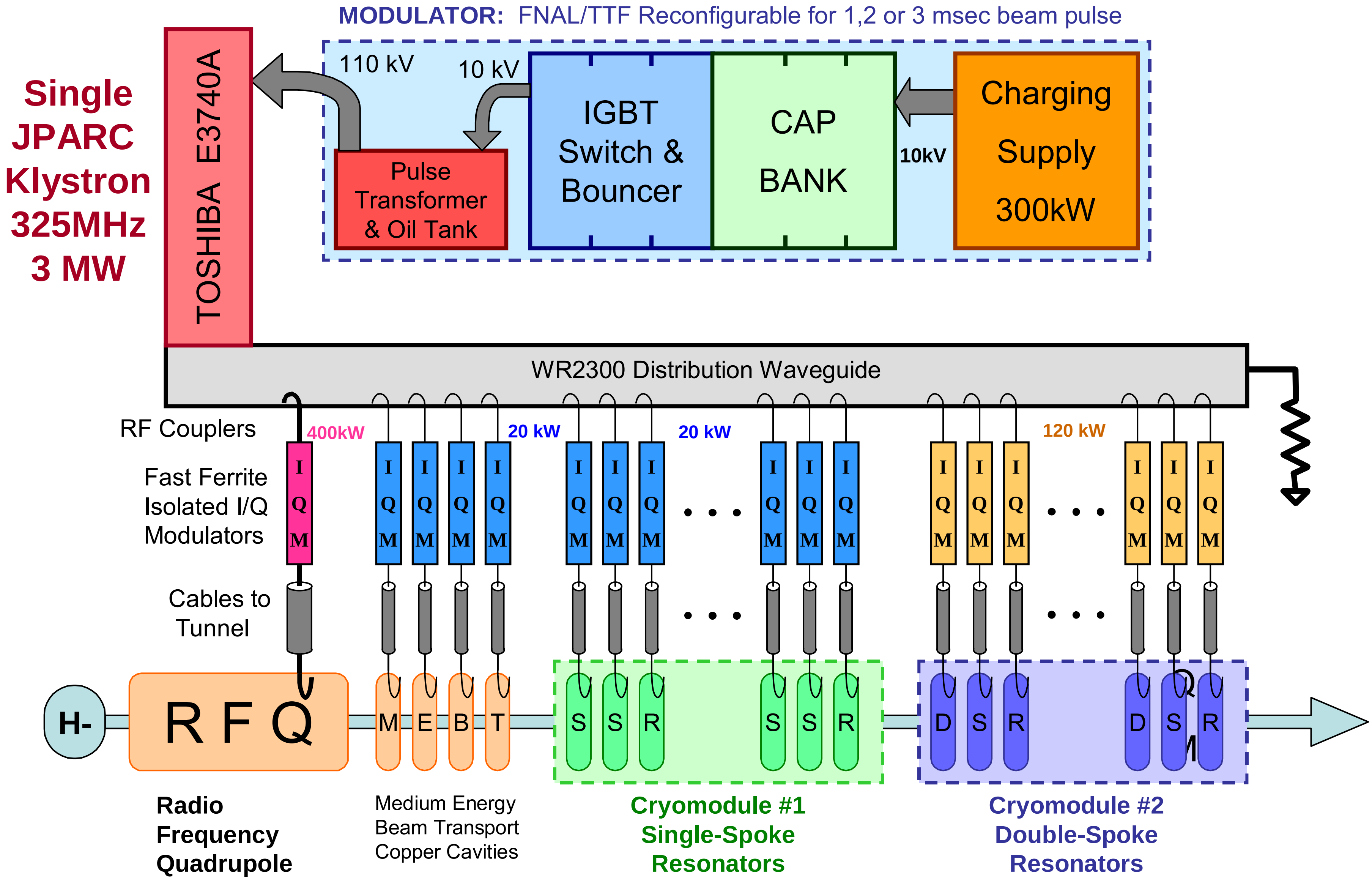


TESLA-Compatible $\beta < 1$ linac concept

1. Cost-Effective TESLA design at 1300 MHz for e- and relativistic protons
2. Modified RIA SCRF design at 325MHz for ~3 MeV < E < ~200 MeV

- *Single Klystron Drives entire linac up to 200 MeV*
- *Beta < 1 SCRF components spread across international collaboration*
- *Become "standard threads" for future designs*

325 MHz RF System



Collaborate to Develop Standard SCRF Components

- Standardization is difficult (and often unadvisable) when a technology is developing rapidly
- SCRF is now mature, and within a factor of ~1.5 of ultimate gradients
- The TESLA-XFEL project guarantees a large base of 1300 MHz SCRF.

➔ *Collaborate to Develop standard designs at TESLA-compatible frequencies, for many new projects.*

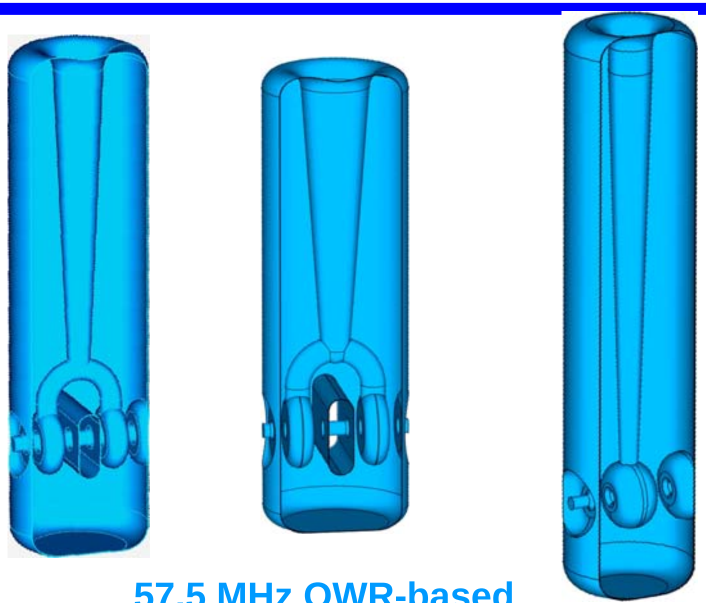
RIA

- The U.S. Rare Isotope Accelerator Project (RIA) will include the construction of nearly 500 superconducting cavities of as many as 10 different types to accelerate ions over a velocity range $0.02 < \beta < 0.85$.

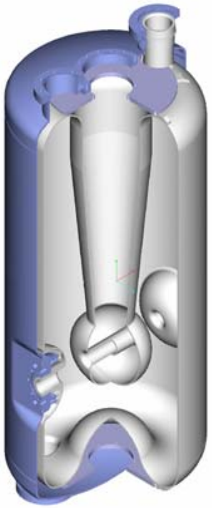
- Cavity types, cryomodules, couplers, and tuners are similar in design to PD

- Rare Isotope Accelerator (RIA) Projects:
  - Cleaning and cold-testing of individual cavities, after chemical processing
  - Clean assembly of cavities into cavity strings, forming a sealed assembly including RF couplers, beam line valves, and vacuum manifold and valves.
  - Assembly of cryomodules incorporating the cavity strings.
  - Cold test of assembled cryomodules.

RIA Driver Linac Nb SC Cavity Array



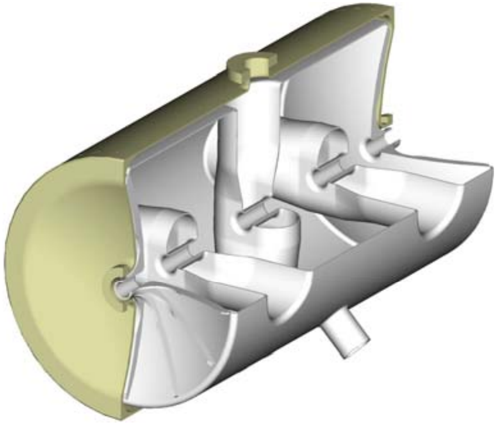
57.5 MHz QWR-based structures .02< β <0.14



115 MHz β=0.15

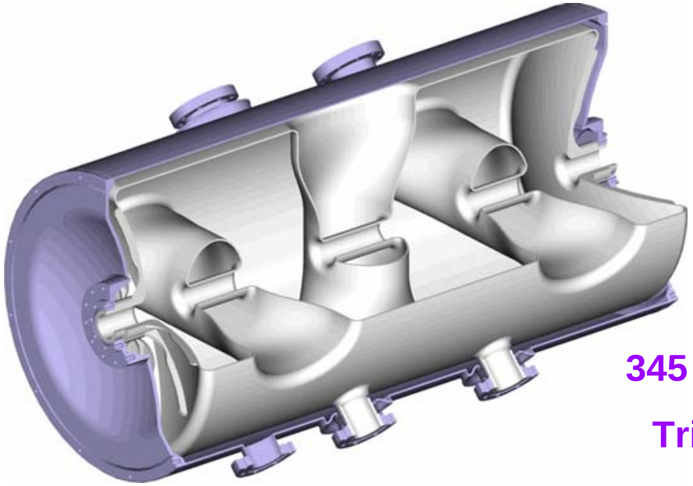
Corrected QWR

172.5 MHz β=0.28 HWR



345 MHz β=0.5

Triple-spoke

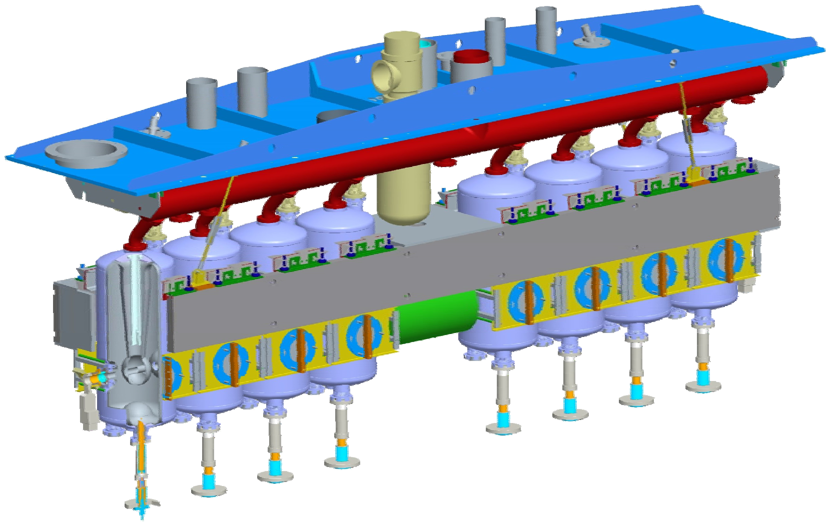


345 MHz β=0.62

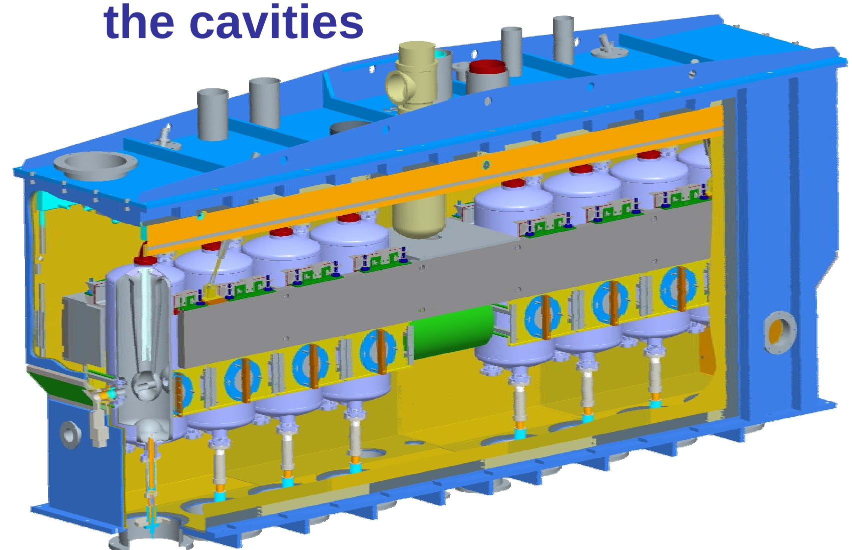
Triple-spoke

RIA: Cryomodule

Cryo-insert



The vacuum box is a 50 $k piece. *Test* with an o-ring top-seal, *final* assembly top flange is welded. Test also qualifies the cavities



At this point, virtually all systems are completely assembled and ready for test.

Cryo-module

The cryomodule test station would be two boxes with o-ring top flanges

Summary: Minimum RIA requirements

- Class 100 clean area – 2700 square feet
- Class 10,000 clean assembly area – 2300 square feet
- High-bay assembly & cold-test area – 4800 square feet
- Helium refrigeration 1000 watts at 4.3 K, possibly 300+ watts at 2K
- RF power: 5 kW at 4 or 5 frequencies, at least two of each
- Storage for incoming parts
- Office & lab space for the cryomodule assembly and test team (30 – 35 people)

CW, b=1 Test Facility and Program for Next-Generation Light Sources

- Multi-cell cavity for the ILC, at 1.3 GHz, offers an existing design suitable to application in CW mode to meet the needs of future facilities with modest beam loading (~ 10 μA).

- SMTF would provide a location and infrastructure for development of CW SCRF systems specific to these needs, and complementary to the existing facilities and R&D programs.

- Superconducting RF structures operated in CW mode have advantages in providing high accelerating gradients, extremely stable RF fields, inherently small perturbative effects on the beam, and with lower RF power requirements than normal conducting structures.

Goals:

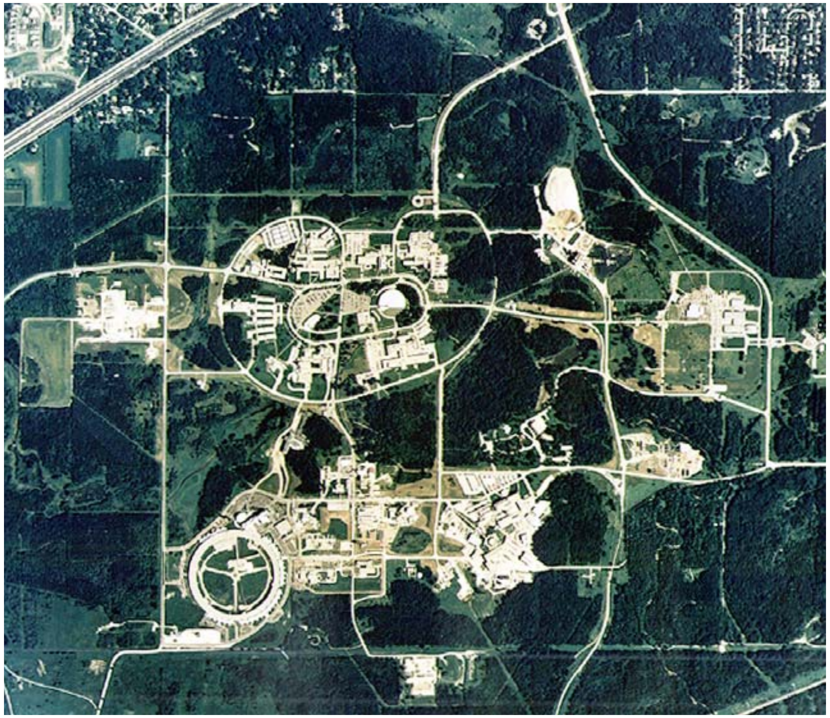
- High Q values in CW operations at 20 MV/m, goal of Qo > 3x10E10

- High stability and control of accelerating fields, goals of phase error < 0.01° and amplitude error <1E-4

- The above performance in the presence of electron beam of 1 nC charge, repetition rate ~ 10 kHz

Chicago Area is Uniquely Endowed with Two Major National Laboratories!

Argonne National Laboratory



Fermi National Acceleratory Laboratory

Only 30 minutes apart by car!

Towards Greater Coordination Beyond ANL: IAAP(Institute for Advanced Accelerator Physics)

- Goal: **A collaborative organization of the Chicago region institutions for a higher level of productivity in basic accelerator research aiming to produce a solid knowledgebase for future accelerators**

- Participation
  - ANL and FNAL: Accelerators and infrastructure, expertise in accelerator physics and operation
  - University groups: Knowledge in basic sciences to overcome the technology limits; students and other manpower
    - UC, NIU, IIT, NWU, UIUC, …

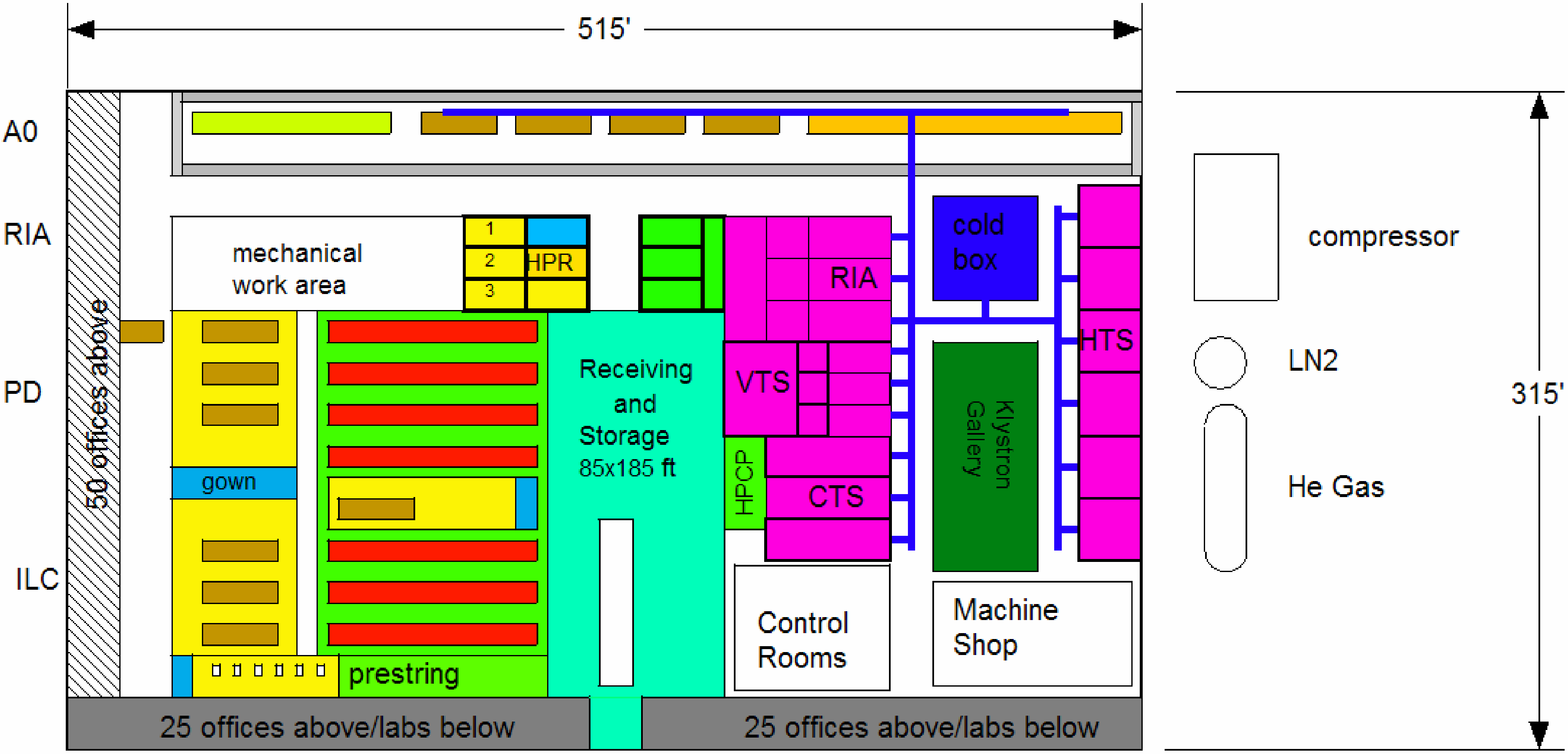
- **IAAP will enhance the probability of hosting major accelerator projects to the Chicago area:**
  - **RIA, APS II, ILC, Proton Driver, …**

- **The SRF facility at the Tech Park may be the beginning of IAAP.**

Cryomodule Development and Test Facility: FNAL View

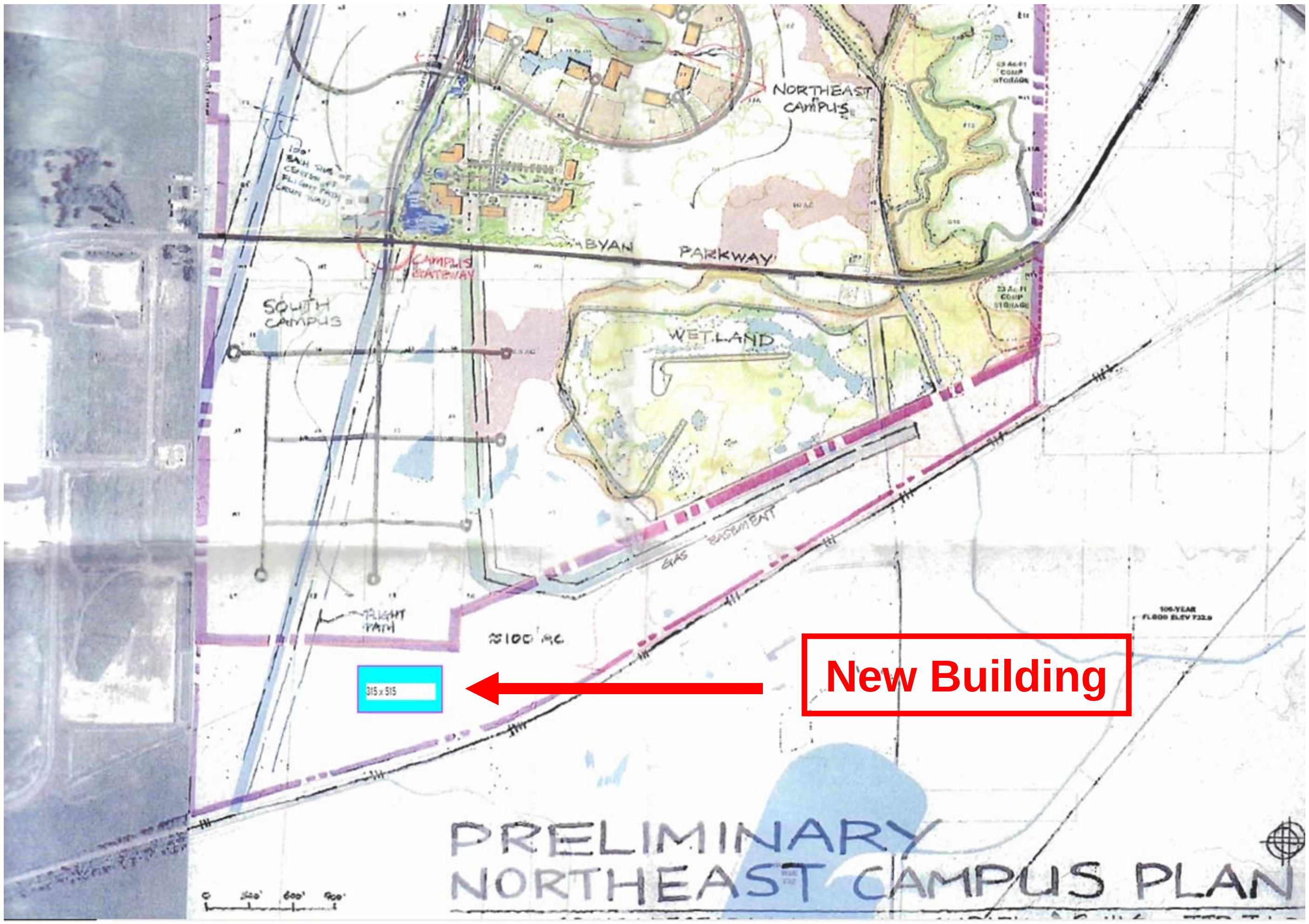
- 3 New large accelerator projects are proposed for sites in Illinois
  - RIA: Rare Isotope Accelerator (Argonne)
  - PD: Proton Driver (Fermilab)
  - ILC: International Linear Collider (West of Fermilab)
- All 3 projects propose to use SuperConducting RadioFrequency (SCRF) cavities
- R&D and significant infrastructure is required both to prepare for and execute these projects

Building Layout



~150,000 ft**2 ➔ ~ $25 M + infrastructure = $ 35 M ?

Layout near Tech Park



International Linear Collider
ILC America @ Fermilab

Summary

- SMTF is the essential first step in realizing ILC with US in a leadership role
- Broad and talented team assembled & good agreement on how to proceed with a US facility for SCRF (EOI submitted)
- International view of SMTF very positive
- Allows a fast start for ILC in US
- SMTF will be important for CW and $\beta<1$ project advancement
- We are starting to work on a formal proposal.