Planning for the New Linear Collider Test Facility at FNAL & progress on 3.9 GHz SRF (or Do we have a plan?)

H Edwards

SRF 2005

July 13, 2005

Political statements

- "The U.S. Department of Energy has expressed its interest in the possibility of hosting a linear collider, at Fermilab, subject to the machine being affordable and scientifically validated by physics discoveries at the LHC." From DOE for inclusion in Holmes EPP2010 talk.
- "The ILC Americas regional plan is for FNAL to assume the role of lead laboratory for ILC SRF technologies, working in close partnership with other US SRF centers, including TJNAF, Argonne and Cornell." JLab-Fermilab MOU
- US ILC Linac responsibilities-FNAL and SLAC
  - FNAL- Main Linac superconducting part & RF control
  - SLAC- main Linac RF power

Outline of this talk

- Development of Infrastructure
  - Buildings
  - Cryo
- Planned Development Stages & Collaborators
  - Schedule highlights
  - Involvement of collaborators
- Technical Infrastructure & Components
  - Chemistry at ANL
  - Horizontal Test Dewar (HTD)
  - Cryo Module Assembly Facility (CAF)
  - Capture Cavity #2
  - PhotoInjector
  - 3.9GHz SRF Development Results
  - Materials Development Effort

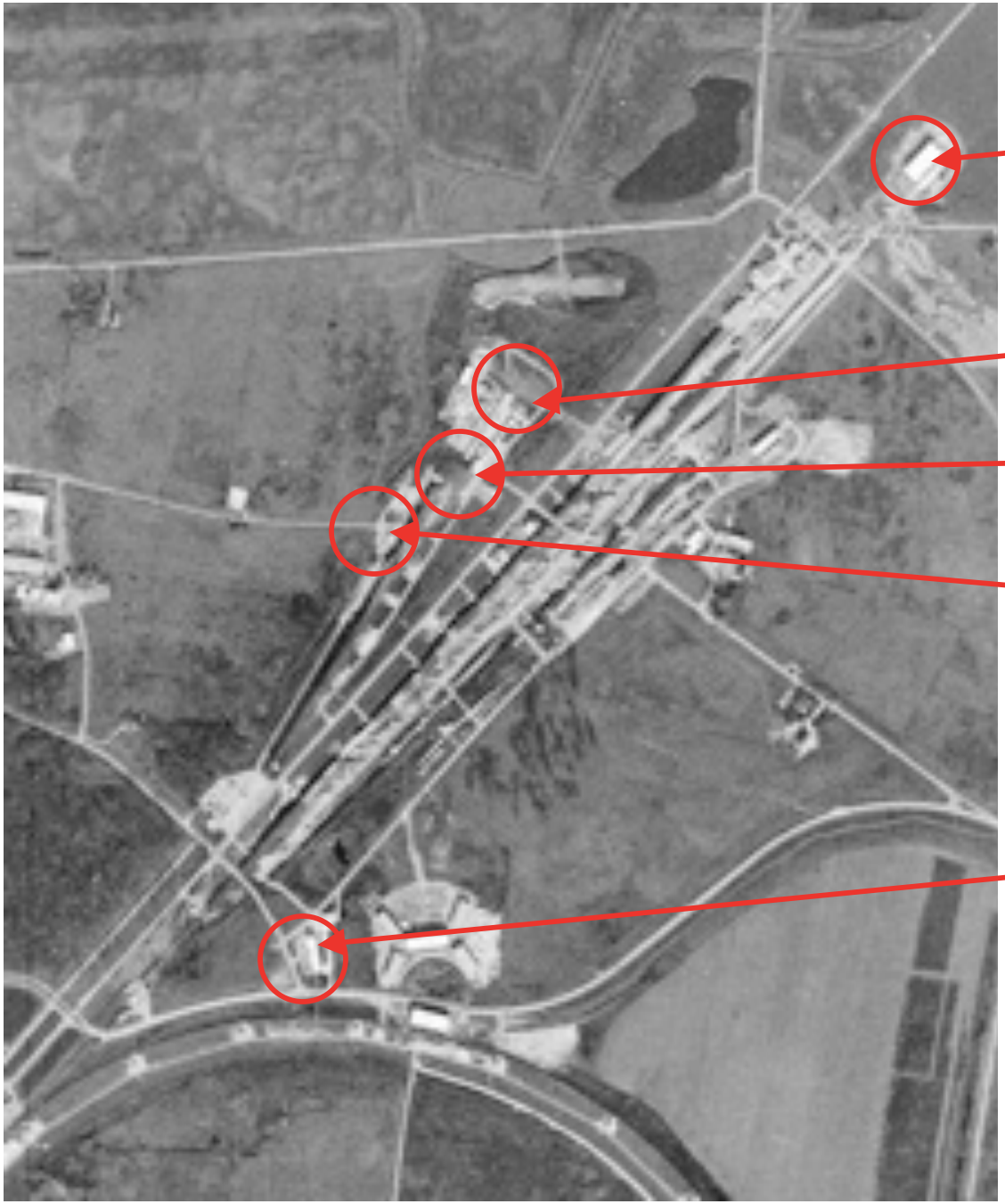
Long term R&D goals for ILC work

- Develop and test Main Linac components and subsystems
- Strengthen US & US Industry SRF capability
- Develop Fermilab expertise and capabilities
- Collaborate with other US Labs to make best use of existing capabilities
- Collaborate with International Partners

- Specific goal-
  - Module string with Beam- 4 modules & Photoinjector
  - Capability for iterative process & test of cavities & modules

- Infrastructure development planning
  - Long lead time items require looking for suitable locations for the module assembly & test

Geography



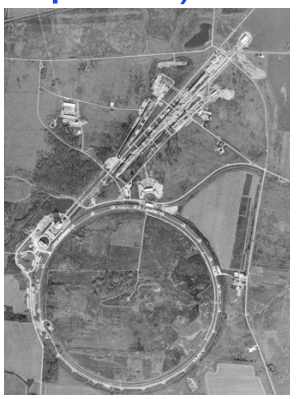
NewMuon- ILC Modules & Injector

MP9- CAF Cryo Mod Assembly

Meson Hall- PD dev

Cryo Test Facility CTF ~60W @2K

(Central Helium Liquifier)




CTF cryo test
Facility (60W@2K
Meson Hall
PD dev plus
MP9- CAF
cavity string &
module assembly

Cryo is a big deal for us

We do not have reasonable sized 2K system available at a big building

- Initially we chose Meson building because of the existence of Meson Cryo Test Facility (CTF) within few 100 ft of Meson Hall, and transfer line
  - It should be able to supply ~60Watts @2K using Vacuum pump from JLab
  - Proton Driver will be using 4K
- In going to New Muon, we will need to come up with a 2nd temporary 2K system
  - This may be either a dewar feed- gas recovery system, or a Satellite Refrig system
  - Again ~40W @2K

Cryo at NewMuon continued

- We really need ~ 300 W or greater @2K for ILC 4 modules and injector @ 5Hz
- Cryo Plant Study Group
  - Tom Peterson, Fermilab, chair
  - Rau Ganni, Jlab
  - John Weisend, SLAC
  - Joel Fuerst, ANL
  - George Mulholland, consultant
  - Should we get a new Cryo Plant a la Rossendorf?
  - Or should we make use of the SSC plant (3500 W at 4 K) that ANL has and adapt it for 2K ?
  - Report due this month
  - No matter what this will take 3 years or greater

Cryo capacity expected with temporary systems:

Cryo Test Facility (Meson)	60W@2K useful
or	1600w@4K
NewMuon	40W@2K useful

Cryo Needs:

Vertical & Horiz dewar test	Vert needs large capability ~200W?
Module string & injector	1 Hz, 5Hz see chart

Cryo needs for SMTF-ILC Inj & modules without contingency or dist loss

Typically use ~1.3*1.5=2

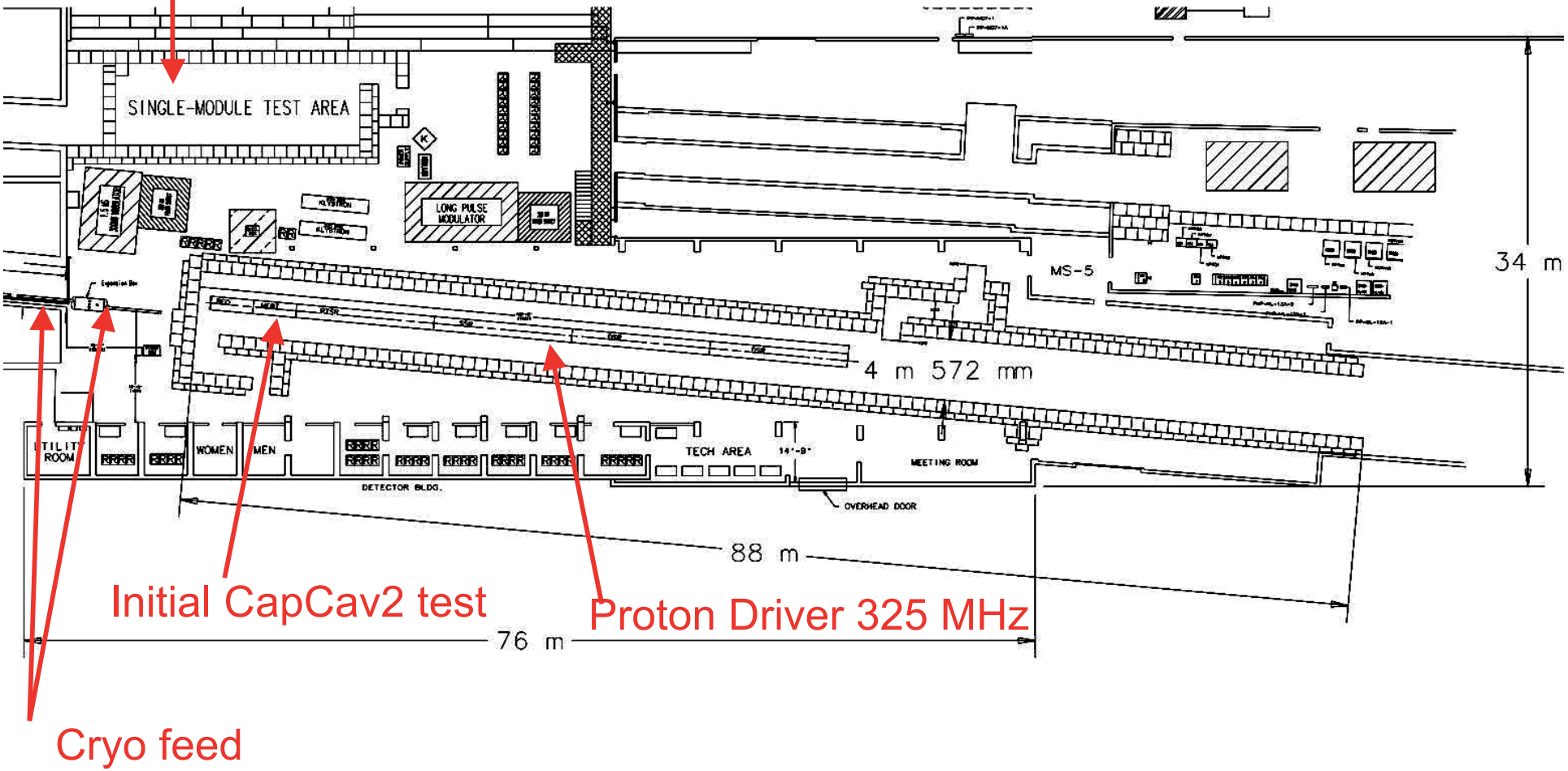
		Single Cavity Module				Multi Cavity CryoModule						Capacity Required*		
		Accelerating Gradient, [MV/m]												
	Rep rate	12.5	30	15	5	35	35	35	35	35	15	2K	5K	80K
		Cap Cav		3.9 GHz		8 Cavity Module					4 Cav			
	[Hz]	#1	#2	Acc	Tran	#1	#3	#4	#5	#6	3.9 GHz	[watts]	[watts]	[watts]
Temporary Cryogenic System	1	X	X	X								9	17	69
	1	X	X	X		X						17	33	207
	1	X	X	X		X	X					26	48	344
New Cryogenic System	5	X	X	X	X	X	X					73	79	1035
	5	X	X	X	X	X	X	X	X			129	124	1854
	5				X	X	X	X	X	X	X	153	155	2330

* - Capacity required is based on the estimated heat load for Q = 5x109

** - No extra capacity or distribution system heat leak is included

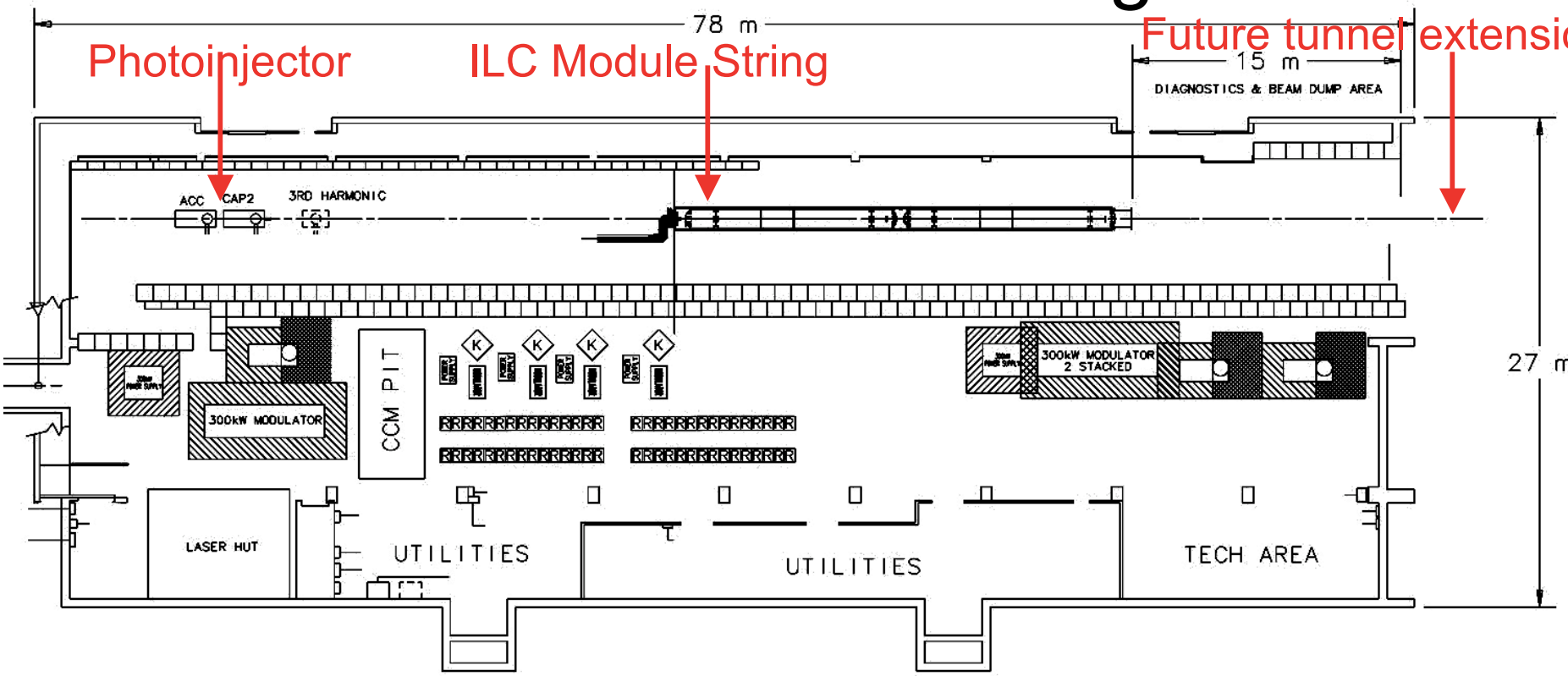
Meson Hall

Initial plan was to have both ILC & PD here. Really not long enough or enough space for both.



Meson Hall Before and After Cleanup

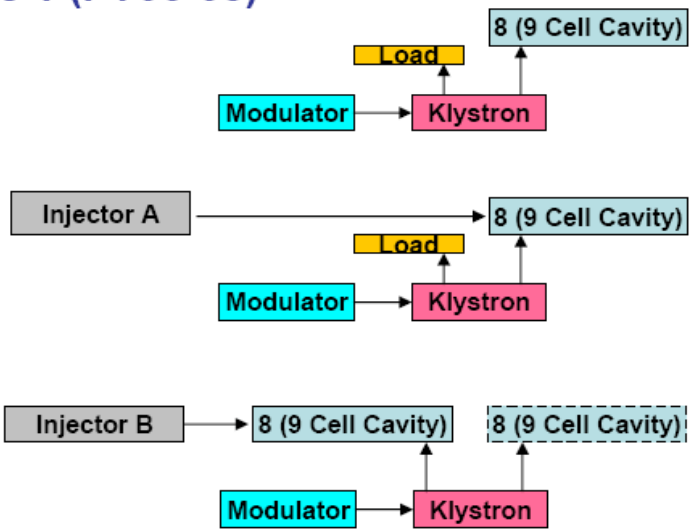
NewMuon Building



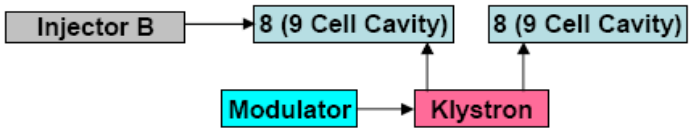
Must remove Chicago Cyclotron Magnet

Phases of ILC Test Facility

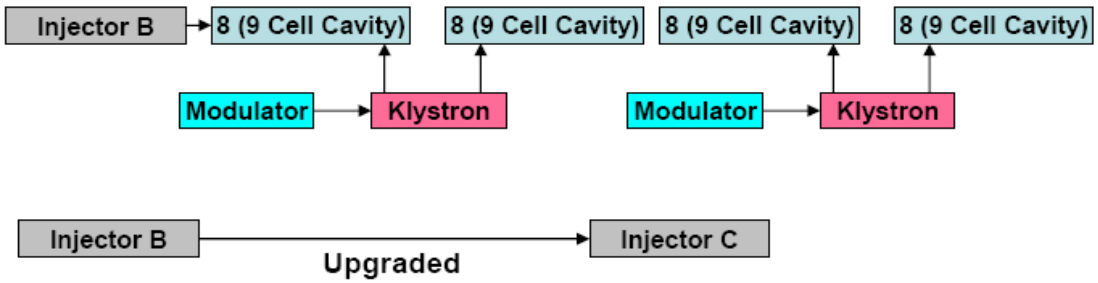
Phase 1 (FY06-08)



Phase 2 (08-09)



Phase 3 (FY09-…)



From SMTF Proposal

Phase 1 FY 06-08

06- 07

a) 1 Module
b) with Inj

08

a) Upgrade Inj
b) Prepare for 2nd module

Build ~ 3 modules, do not expect all to meet gradient

Phase 2 08-09

2 Modules & Upgraded Inj

Build ~ 2 modules

Phase 3 FY 09-….

a) Inj & 4 Modules
b) Inj with 8 cavity module (tentative) & 4 modules

Build ~ >= 1 module

First Modules- Present thoughts (agreements in process)

- "DESY/FNAL module" Type III plus
  - Parts provided by DESY
  - Cavities tested through Chechia (Horiz Test Dewar) at DESY
  - String & module assembled at FNAL
- "1st US (& international) module"
  - Cavities from Accel, AES, KEK, JLab
  - Cavities processed at JLab (EP), KEK (EP), CU (BCP),FNAL (BCP)
  - Vertical tests JLab, KEK, CU
  - Horizontal Tests FNAL
  - String & module assembly FNAL
- "4th Generation module"
  - Design evolution from TTF Type III
  - Cavity slot length, quad/BPM location, vibration issues, tuner type,..

Collaboration efforts underway or almost underway (MOUs)

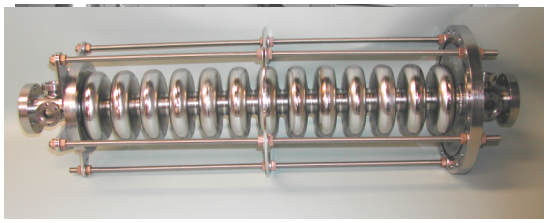
- DESY- CapCav#2, TESLA module, string assembled at FNAL
- JLab - EP Processing, Cavity VDT & dress for HDT, TESLA & 3.9GHz cavity fab, Refrigerator Study
- ANL - BCP Chemistry facility, Refrigator option
- Cornell - BCP Tesla cavities, VDT
- KEK - 4 cavities for a (2nd) module
- INFN - participate in DESY/FNAL module, 4th generation module development
- LANL?- Develop EP facility plan

Why Build a Joint Cavity Processing Facility?

Argonne & Fermilab

Beta<0.1

For two decades groups operated independently



Beta=1

ANL

Rare Isotope Accelerator
4th Generation Light Source

Fermilab

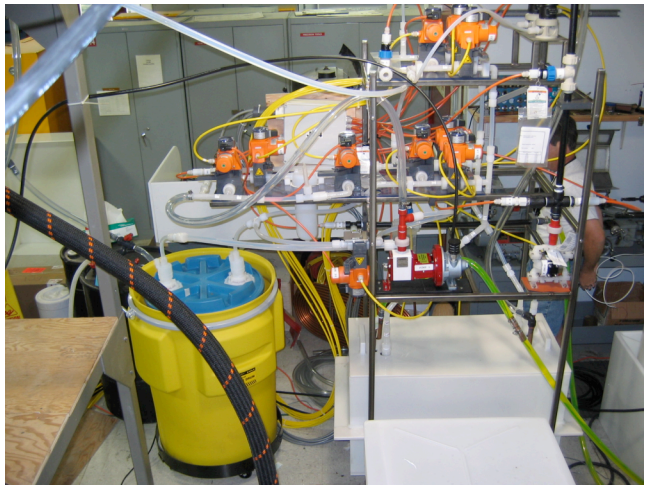
SMTF and International Linear Collider (ILC)
8 GeV Proton Injector

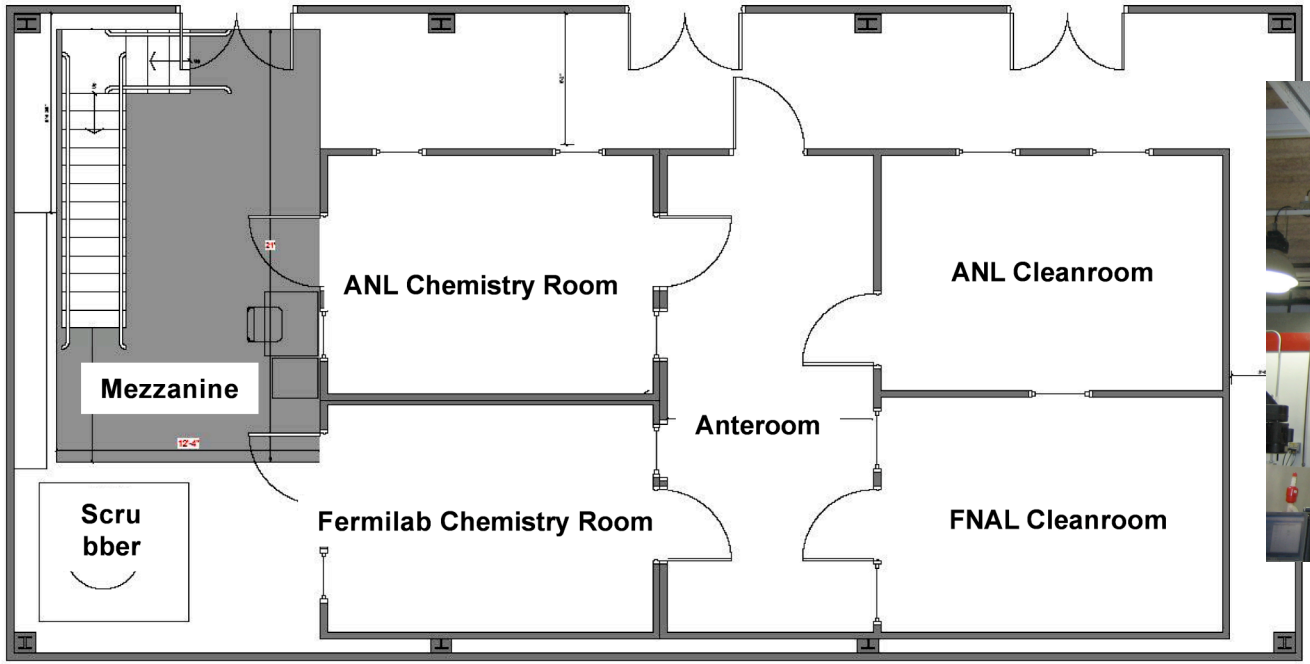
- There has been a convergence of interest in the past decade between the low- and high-beta communities
- (1) Techniques needed to achieve state-of-the-art are similar
- (2) We are filling in the region between low- and high-beta with new cavity types

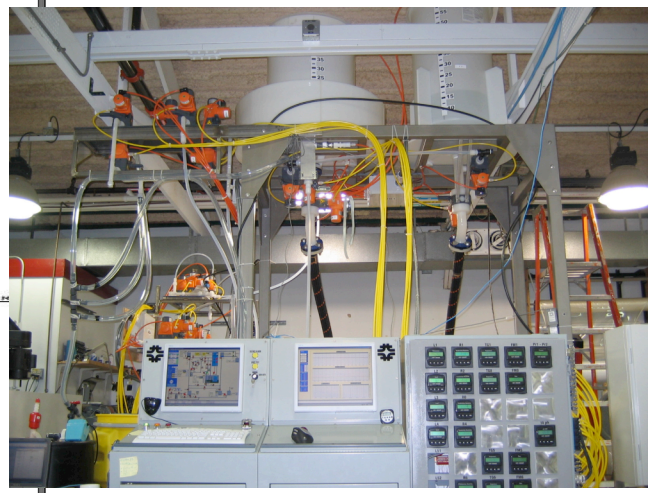
Mike Kelly

Layout: ANL/FNAL Cavity Processing Facility

Installation of Cavity Etching Hood 3/25/05







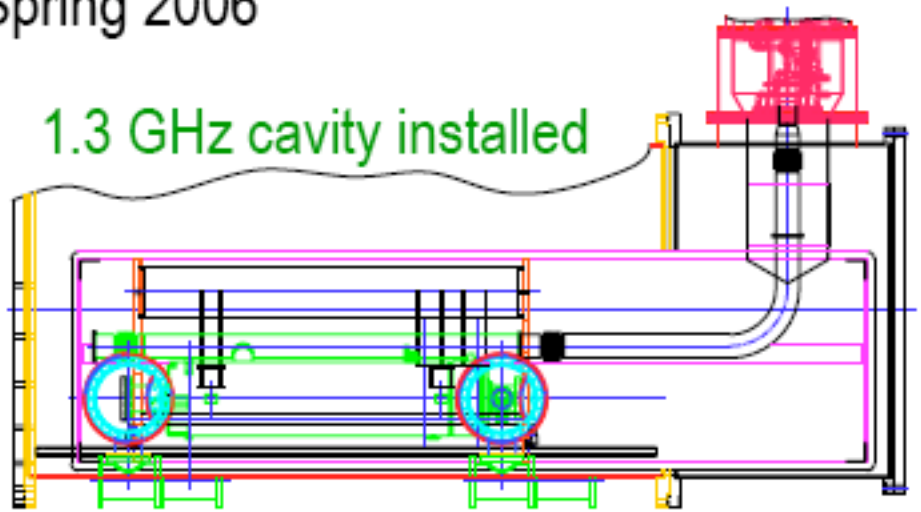
60 feet

Horizontal Test Cryostat,

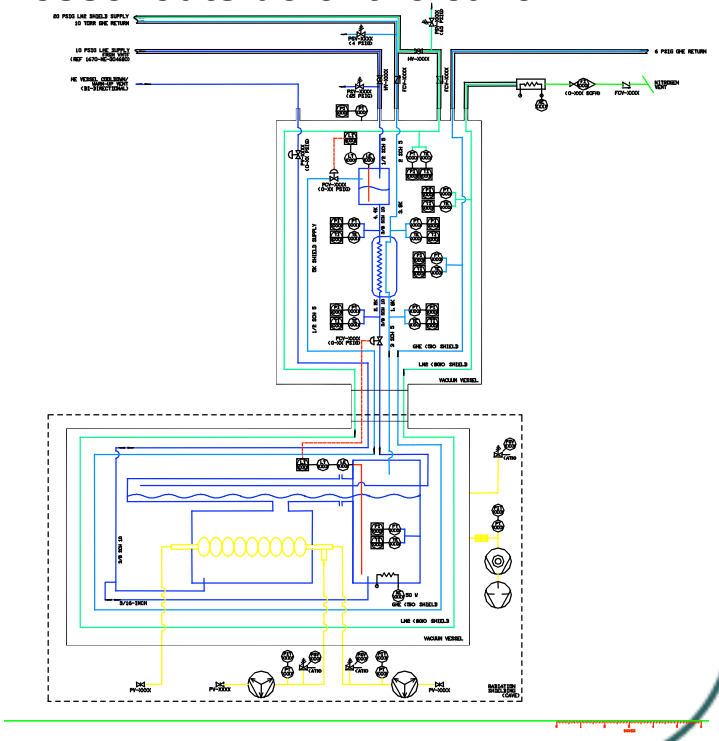
1.3 & 3.9 GHz cavity test capability

- Design work will be completed in FY05
- Major components will be ordered early in FY06
- Planned to be operational in Spring 2006

1.3 GHz cavity installed

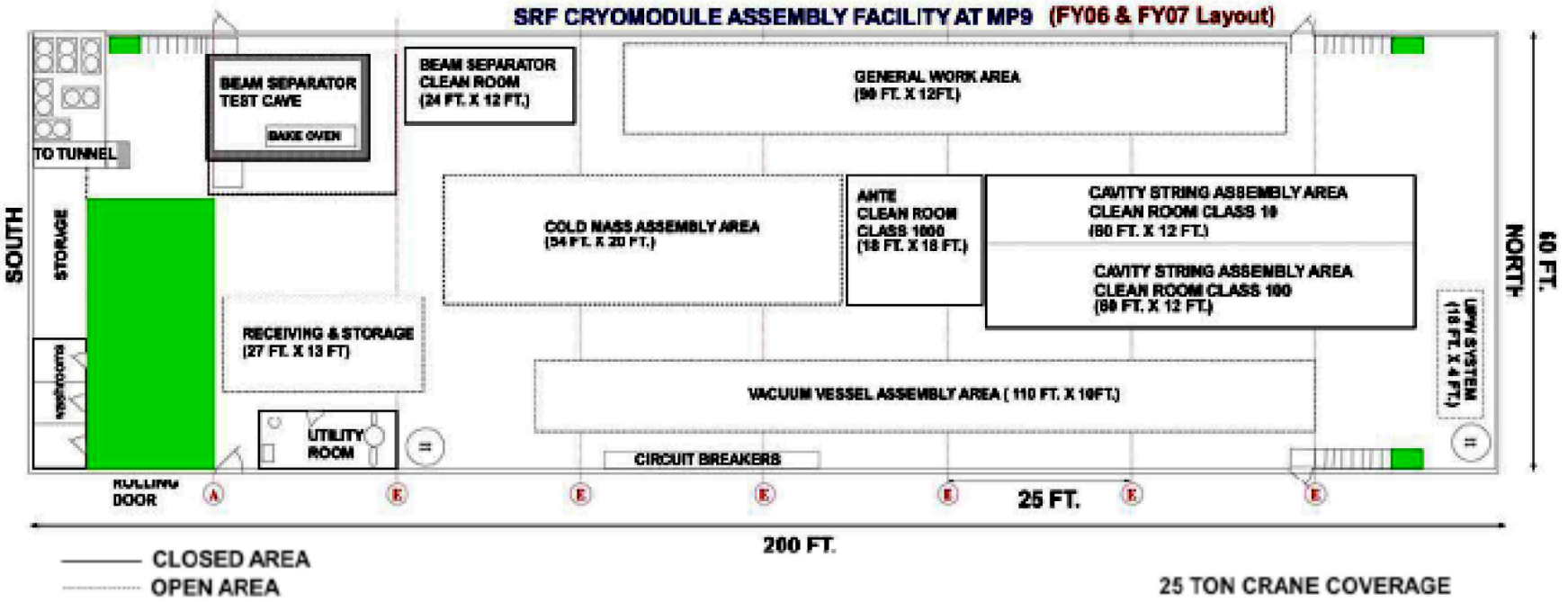


Valves, heat exchanger, and much of the cryogenic instrumentation go in a vessel outside of the cave



Support Infrastructure for 1st U.S. Built Cryomodule: MP9 Cryomodule Assembly Facility Development

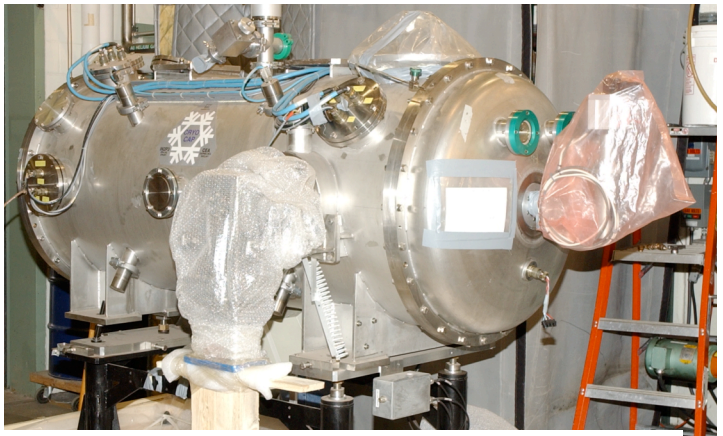
•Building is sufficiently sized for R&D production quantities (1 per month)

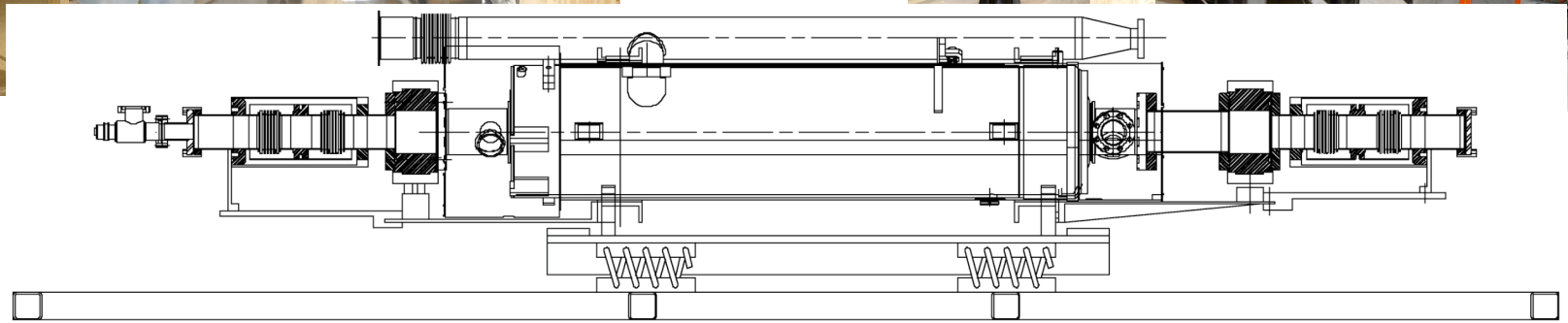


Capture Cavity2 from DESY

Student with project Koeth TuA09

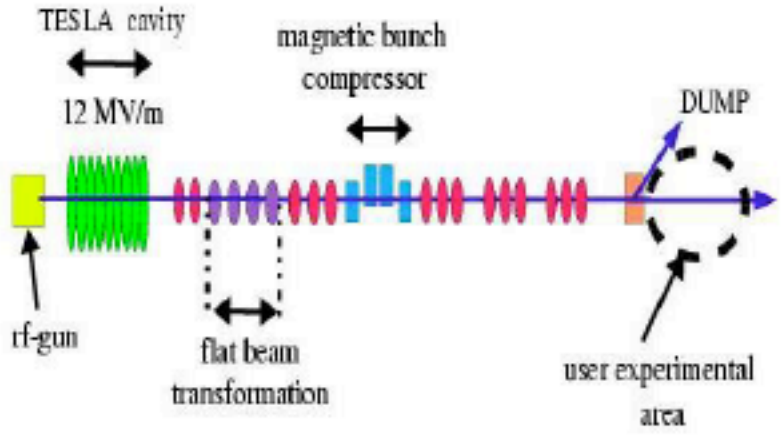
Shipping test with nothing special done - input coupler developed leak





Capture cavity module used at TTFI sent to FNAL.
Low gradient cavity is being replaced with >25MV/m cavity
New dressed cavity with beamtubes, gatevalves, etc on its way from DESY (McGee)
Ready for installation in vac vessel without opening to air.
Schedule- mount in vessel Aug, move to Meson Lab Sept and start cryo commissioning
Systems Test at Meson of: Cryo @4K, RF, LLRF, Controls, - in early 06 cryo @ 2K

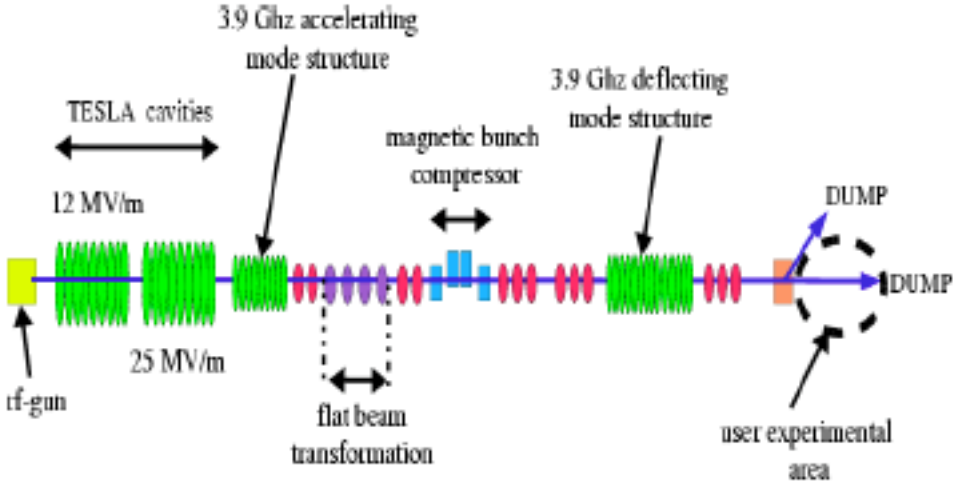
Photoinjector Upgrade for SMTF



Existing FNPL

Upgrade of existing PI includes:

- 2nd TESLA CapCavity and
- 3.9GHz acc mode “3rdHar” for bunch compression
- 3.9GHz transverse mode for bunch slice diagnostics
- Improved gun & gun modulator



FNPL Upgrades

Schedule Highlights (tentative)

- Begin CapCav#2 tests at Meson 4K — Oct 05
- Commission BCP at ANL — Jan06
- CapCav#2 operating at 2K — Feb 06
- Commission Horiz Test Dewar at Meson — April 06
- Cryo Module Assembly Fac ready for string assembly — May 06
- Move Photoinjector — Summer 06
- Temp Cryo System at NewMuon — Oct 06
- Begin tests Photoinjector — Oct 06
- Complete assembly of 1st Module — Dec 06
- Commission Module w Photoinj — early 07

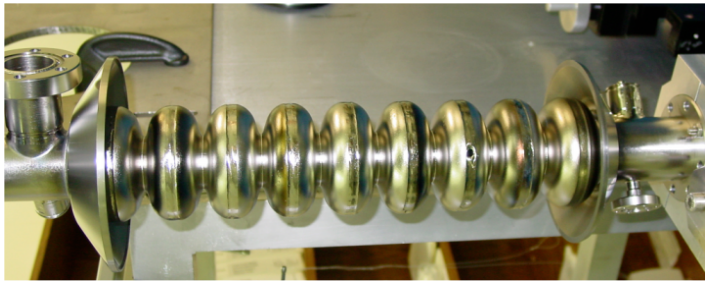
3.9GHz activities

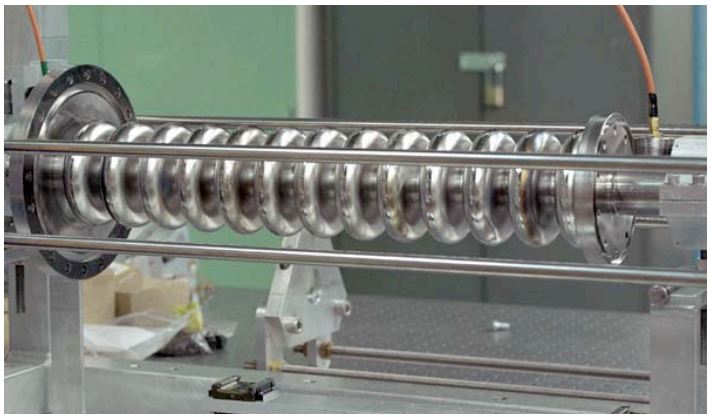
- Koeth TuA09 SC Cavities at 3.9 GHz
- Solyak TuP14 Recent results of testing 3 cell 3.9 GHz accelerating cavity
- Khabiboulline ThP50 Power coupler design for 3rd Harmonic and spoke cavities
- Mitchell ThP29 Mechanical Design and engineering of the 3.9GHz 3rd Harmonic SRF system

Two 3.9 GHz cavity developments

- 3rd Harmonic acc mode cavity for bunch compression- linearizes the 1.3 accelerating gradient over the bunch length. To be used at TTF-II (4 cavity module) and Photoinj Upgrade (single cavity)

- 3.9 GHz deflecting mode cavity for bunch slice diagnostics, momentum or emittance as function of position in the bunch at PhotoInj Upgrade (originally for a pure Kaon beam experiment at FNAL)

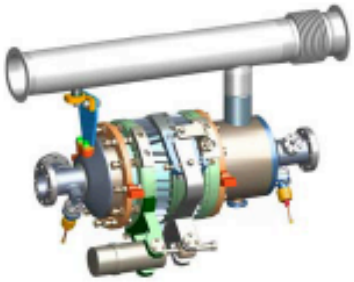


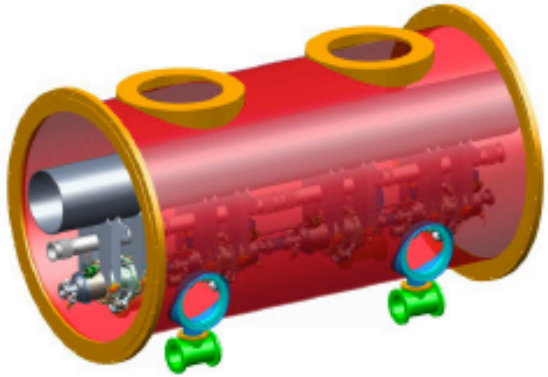


3.9 GHz acc mode 4 cavity module for TTF (all the design and fab steps by FNAL with help)

3.9 GHz Cavities & Cryostat(s): Work in Progress

- Design coldmass supports, both sliding and fixed
- Design coldmass and cryostat
- Main coupler design
- Helium vessel design complete but may need minor revision
- Helium supply pipe redesign (spacing & material)
- Heat Loads and cool-down analysis





Mitchell

3.9 GHz processing history and test results- getting our learning curve

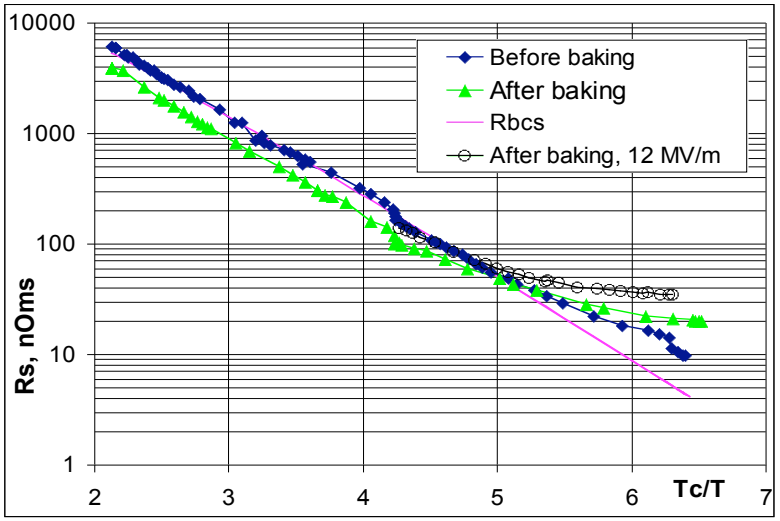
- We now have a data base of about 9 test results from each type cavity
  - Help from Kneisel (JLab) and Kelly (ANL) on processing BCP, 600C bake, HPR
  - BCP- JLab, ANL(existing facility), FNAL
  - Oven bake- JLab, FNAL
  - HPR- JLab, FNAL
  - Vert Test - FNAL
- Goal: BCP-ANLnew, Oven bake-FNAL, HPR-FNAL, Test-FNAL, reasonable time turn around
- We now have existence proof using existing ANL BCP

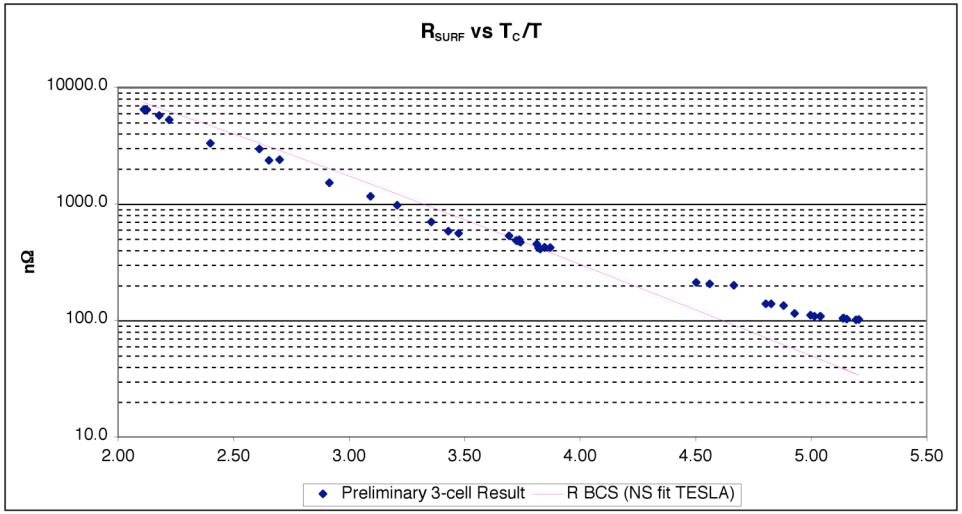
3.9 GHz Results (Rs has been the main problem)

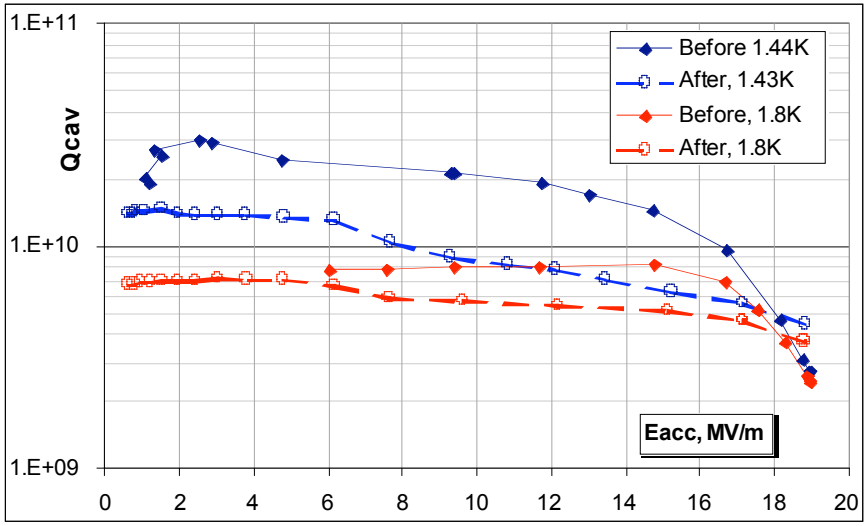
- Acc mode- Ea~19MV/m (~105mT) Rres~6-10nOhm
  - This 19MV/m would be equivalent to 21MV/m in a 9cell
  - Design requirement 14-15MV/m
  - What is Ea limit, thermal or not? It is not temp dependent

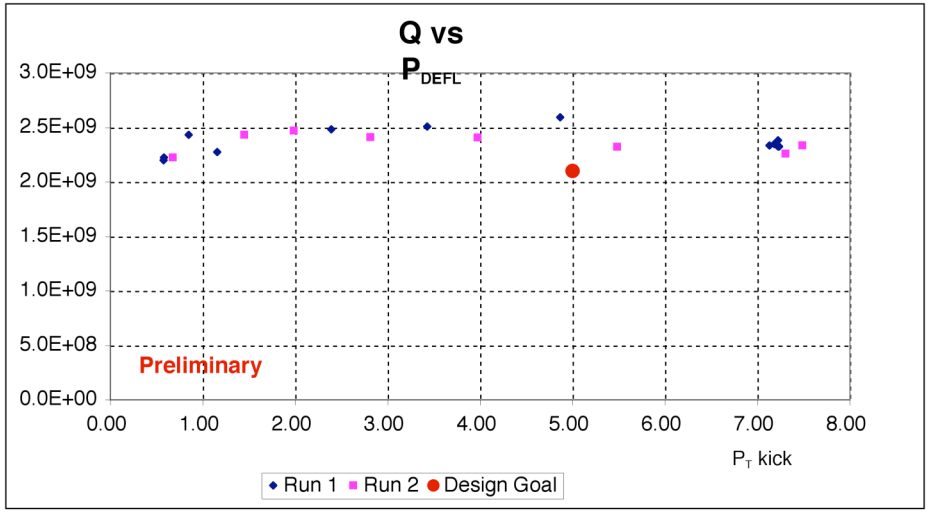
- Def mode- Etrans~7.5MV/m (~120mT) Rres~60nOhm (best to date)
  - Design requirement 5MV/m transverse
  - We still do not understand high Residual resistance

3.9GHz
Acc mode TM010 Def mode TM110









Materials research & with Universities

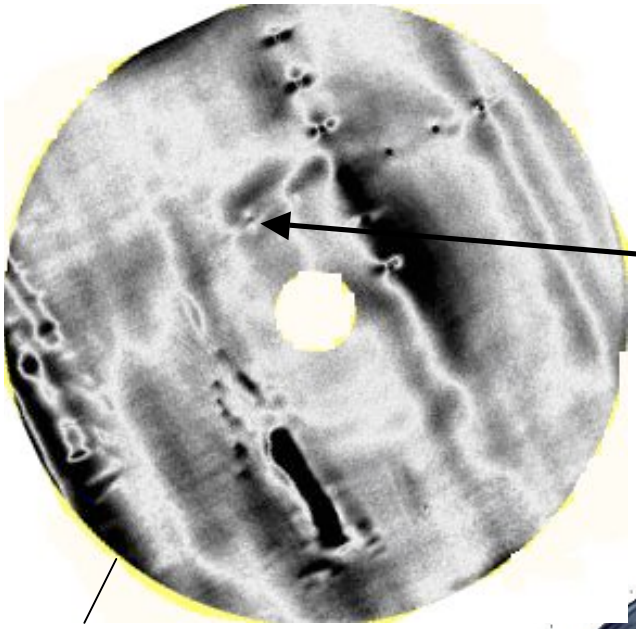
- Bauer TuP01 A comparison of Q slope models and Data in bulk Nb SRF Cavities
- Bauer TuP47 Recent RRR measurements on Nb at Fermilab
- Boffo TuP48 Eddy Current Scanning at Fermilab
- Boffo ThP01 EP on Small Samples at Fermilab

University collaborators

- Sebastian TuP06 Atom Probe Tomography
- Lee Tu54 Grain Boundry Flux Penetration & Resistivity in Large Grain Nb Sheet
- Polyanskii TuP55 Magneto Optical Study of Flux Penetration

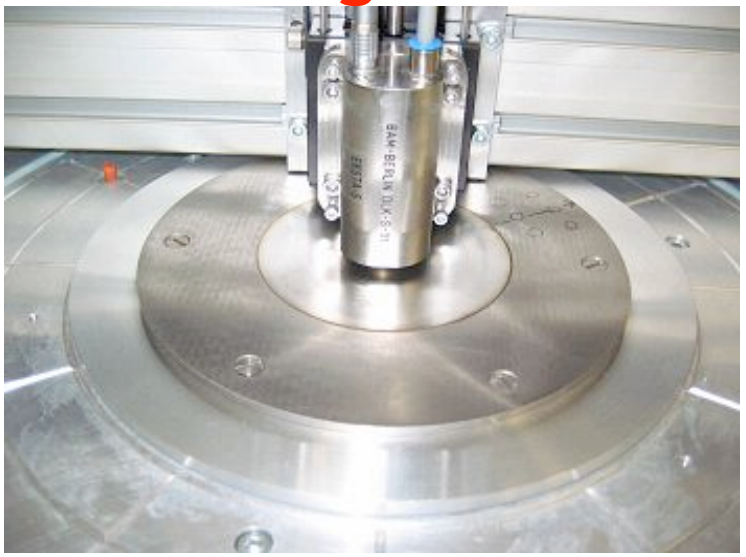
Eddy Current Scanning

DESY calibration disc scanned by A. Brinkmann/DESY

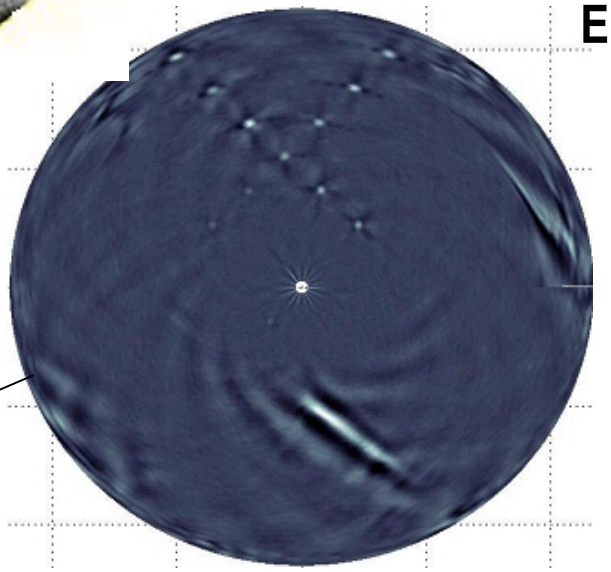


Resolution achieved:

100 μm Ta defects can be detected!

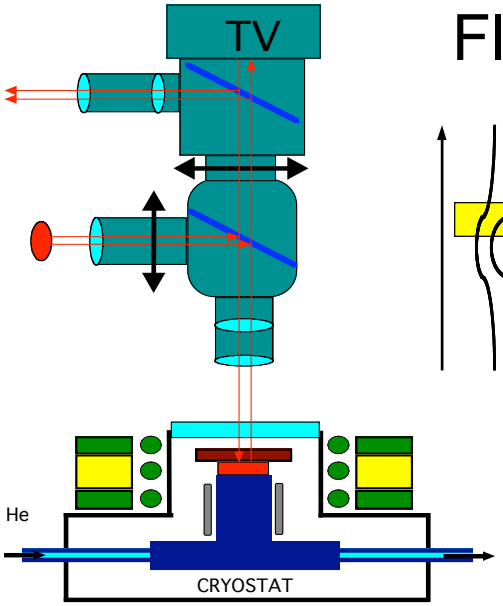


EC-Scanner – on loan from SNS

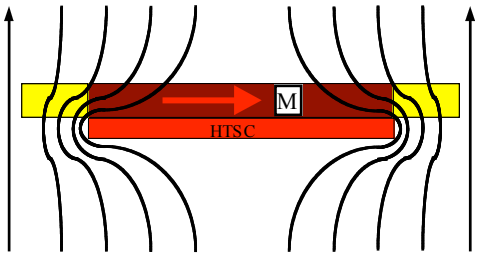


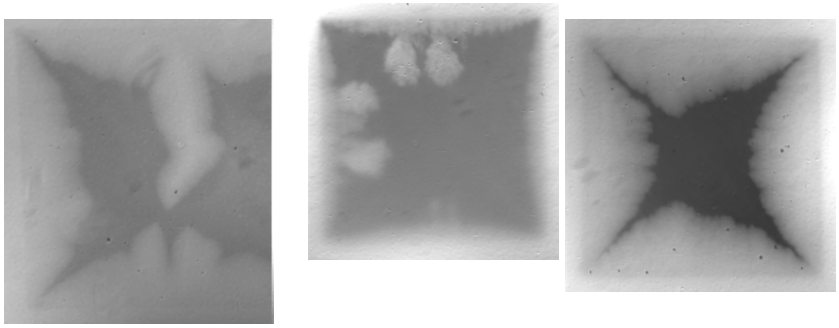
DESY calibration disc scanned at Fnal, after filtering by C. Boffo

Magneto-Optics at the University of Wisconsin



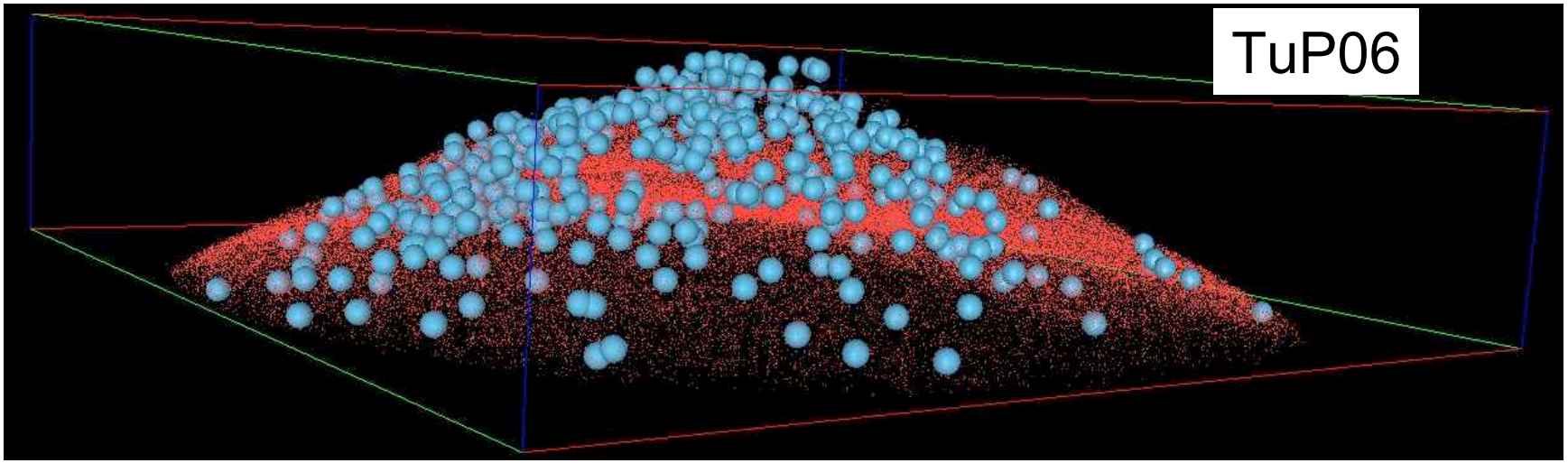
Flux penetration





TuP55

3D Atomic Probe Tomography at Northwestern



J. Sebastian / Northwestern university

3D-AP view of Nb tip with F surface contamination

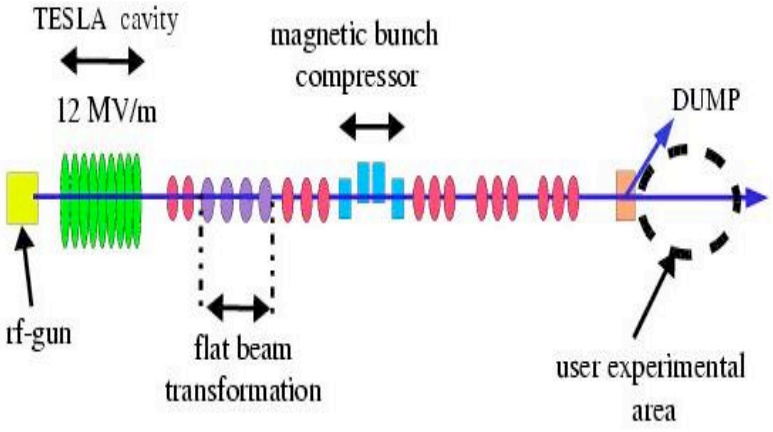
“Plans are nothing;
planning is everything.”
D Eisenhower

Results are Best

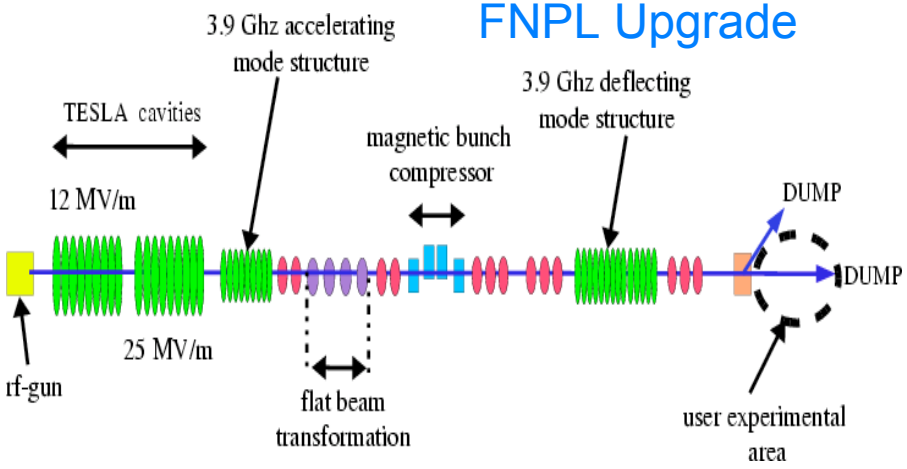
END

Thanks to all people at FNAL & other Labs
for helping us get started

FNPL as Electron Beam source for ILC Test Area



FNPL Upgrade



		SMTF proposed (up to)	Present Inj typ
RF pulse length	msec	1.5	0.03-0.6
Pulse rate	Hz	5	1
Beam pulse length	msec	1.0	10-20 micro sec
Beam current	mA	15	10
Electrons per bunch	e10	2	0.6-6.0
Bunch spacing	ns	337	1000
Beam pulse*current	ms*mA	10	0.2

History of the 3.9GHz 3-cell accelerating cavity
Eacc of 15MV/m = 75mT 9 cell, 13.6Mv/m=75mT 3 cell

Where	BCP	HT	HPWR	Test Date	Test results
FNAL	No	No	No	01/21/04	Rres = 2000nΩ Ea=5.6 MV/m; Hpk(π/0)~30/60 mT
JLAB 02/25/04	Extrn~20μm Int ~140μm	2hrs@500 C 10hrs@600C	JLAB 15'@2 loc	03/17/04 04/19/04	Rres=60nΩ → 200nΩ (after FE) Ea=11.5 MV/m; Hpk =60mT; Heavy X-ray
JLAB 06/10/04	Intern: ~30 μm	No	JLAB 30'@3 loc	07/02/04 07/19/04	Rres =70nΩ→130nΩ (after HG) E=12.5 MV/m, Hpk(pi/0)=70/110mT; X-ray
FNAL 10/10/04	No	No	~1 hrs, movable	10/14/04	R_res=60 nΩ, E=12.8 MV/m, No X-ray
JLAB 10/26/04	Intern: 20μm	No	JLAB 90'@7 loc	11/10/04 12/16/04	E= 5MV/m – vacuum leak E=15MV/m coupler problem
FNAL 01/30 /05	Internal: ~5μm	No	~2hrs movable	02/08/05 02/21/05	R_res=6 nΩ, E=19MV/m, Hpk=105mT, No X-ray
FNAL 05/25/05	No	48hrs@120C →(HPWR 3hrs after BCP)→	No	03/31/05	R_res = 16 nΩ, E=19MV/m, Hpk=105mT, No X-ray
ANL 06/01/05	1:1:2 12min(15C)	No	FNAL ~2.5hrs	06/09/05	R_res= 58 nΩ, E=12MV/m, Hpk(pi/0)=62/104mT; X-ray
FNAL 06/25/05	No	No	~6.5 hrs movable	07/05/05	R_res=10nΩ, E~19MV/m, No X-ray