History of SRF at FNAL, collaboration, & 3.9GHz cavity program

H Edwards

Outline

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- Some history of FNAL SRF interest and Tesla Test Facility collaboration
- The A0 Photoinjector
- Development of 3.9GHz, operation of 1.3GHz,
- Status and issues in the development of 3.9GHz and its association with other developments
- Issues that make timely progress very hard

History- Tesla collaboration

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- 1st Tesla Workshop, Proceedings, 1990 Cornell
- Harrison & Rosenzweig proposed SRF linear accelerator
- Tesla Report 93-01, Proposal to Construct and Test Prototype SRF Structures for Linear Collider (April 92)
- Tesla Report 95-01, TTF Linac – Conceptual Deign Report
- First 250 keV beam April 96
- TTF Cap cavity installed Oct 96
- TTF Module 1 installed March 97
- First TTF Beam June 97
- TTF INJ 2 Installed Beam to bunch compressor 2 Jan-Feb 99
- 1st lasing, beam energy, laser 88 nm Febr. 2000
- PITZ Photoinjector at DESY Zeuthen 2002
- TTF2 operation start Aug 04, first Lasing Jan 2005 (32 nm)
- TTF2 present energy 760 MeV, SASE wavelength 13 nm
- Modules assembled to date 12
- Cavities produced to date 132 + 30 under fabrication (summer 07)

  including 2 prototype, 111 standard Tesla, 3 large grain, 6 Rossendorf, 4 Schwettman, 4 ACCEL, 2 BESSY
- Cavities treated & tested in 06 (22 complete treatment, i.e. BCP/EP + vert. test, add. 8 re-treatment + vert. test, 18 prep. & tested in CHECHIA)

DESY TTF Module Installation

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	installation	Cold time / months
CryoCap	**Oct 96**	**50**
M1	**Mar 97**	**5**
M1 rep.	**Jan 98**	**12**
M2	**Sep 98**	**44**
M3	**Jun 99**	**35**
M1* MSS	**Jun 02**	**14 8**
M3* M4 M5	**Apr 03**	**3 3 3**
M2* M6 M7	**Feb 04 ass. Jul 06 ass. Dec 06**	

FNAL involvement in Tesla collaboration

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- Initial phase TTF
  - 94 Modulator "bouncer", Pfeffer, Kerns, et al
  - Hi gradient 5 cell cavity tests at Cornell, Pfeffer, Crawford
  - Fermi Input couplers, Champion
  - Photoinjector design, Colby. Rosenzweig
  - Controls timing & IRM, Shea, Goodwin, Kucera
  - RF Gun
  - Injector beamline components
  - Cryo components, Vertical Test dewars & inserts, Valve box, heater, Peterson, Nicol, Walker et al
- More recent
  - Development of 3.9GHz accelerating mode cavity
  - 3.9GHz, 4 cavity module for Flash bunch compression & SASE improvement, prototype for XFEL
  - Collaboration on HOM position measurements

A0 injector, SRF, collaboration (1)

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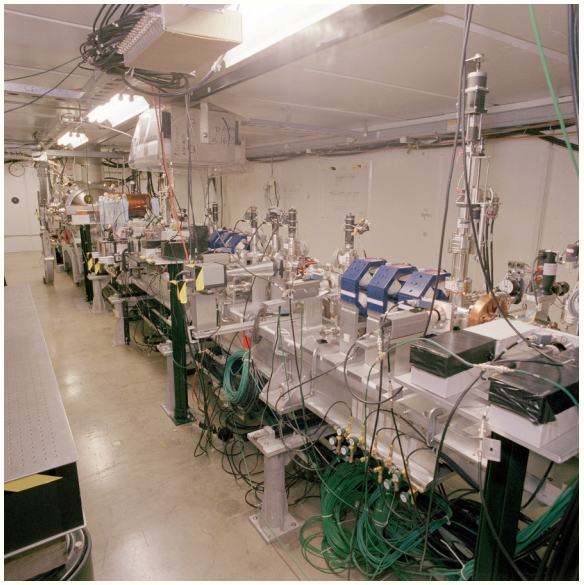
The Photoinjector- We could not have done it without collaboration!

- 4MW Klystron- Cornell
- 300 KW Klystrons (4)- DESY
- Cathode prep chamber- INFN Milano
- Laser and laser operation- Univ Rochester
- CaptureCavity1-Tesla cavity- DESY
- LLRF & BPM's- DESY
- CC1 cryostat design, tuner- Saclay, Orsay
- Injector design & components- UCLA
- Advice- DESY, Cornell, JLab, Milano
- Operational support and Diagnostics- NIU
- Students- UCLA, Rochester, Paris, Rutgers, U Chicago
- Helium vac pumps- JLab
- Experience with:
  - SRF Tesla cavity operation (since about 97),
  - CR procedures,
  - Laser operation,
  - RF gun & cathode



A0 injector, SRF, collaboration (2)

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- **More recent (& ILC follow on of collaboration activities)**
  - **CC2 hi grad cavity, 5 practice cavities, DESY/FNAL module - DESY**
    - **We actually have ~9 Tesla cavities of various ages from DESY,Saclay,Orsay**
  - **LLRF, diagnostics & controls- DESY**
  - **1.3 & 3.9 Cavity fab and processing - JLab**
  - **Cavity processing, chemistry- ANL, Cornell**
  - **Cathode prep fab, blade tuners & module design- INFN Milano**
  - **LLRF & tuners- Univ Penn**
  - **ILC kicker exp at A0- Cornell, Univ IL**

History A0 Photoinjector and SRF infrastructure & development

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- 96- Laser for Photoinjector- **Fry thesis**
- 97- Photo Inj- design/construct/test **-Colby thesis**
- 99- Fermi Photo inj 1st results- **Carneiro, et al**
- 99- Tesla cavity CC1 cryo and beam tests- **Hartung, Fuerst, et al**
- 98,99,01- 3.9 GHz Deflecting mode cavity design (CKM)- **Koeth, Bellantoni, Wanzenberg, Edwards, et al**
- 2000- Flat beam measurements- **Edwards, et al**
- 01- Plasma Beam Deceleration & acceleration, **Barov, Rosenzweig, et al**
- 03- Higher Order Modes in 3rd Harmomic Cavity- **Khabibouline, Wanzenberg et al**
- 03- 3rd Harmonic SRF cavity development- **Solyak, Mitchell et al**
- 03- BCP processing Facility- **Tereshkin, Boffo et al**
- 05- Angular Momentum & flat beams- **Yin E Sun thesis**
- 04-05 Superconducting Module & Test Facility (SMTF)- **Mishra et al**
- 05- Upgrade of Fermi/Nicadd photoinjector laboratory- **Piot et al**

Charge 4

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Does the laboratory make effective use of collaboration and existing SRF assets?

- Yes in the past- But it should be clear that effort, progress and results at FNAL has been much weaker and less well supported than at DESY with the remarkable success of TTF/Flash
- Don't mess it up- Both the lab and DOE must assure that collaborators can participate (funds, and willingness to collaborate and pool abilities and expertise)
  - Grow and increase the collaborations to the benefit of all
  - But DOE should help
- Not just ILC, but accelerator R&D for other end uses and interests, materials R&D, Tesla Technology collaboration
- Ie, There must be give and take, not just take
- Pay attention to and benefit from XFEL project
  - (and don't drive DESY nuts with too many different questions)
- But FNAL must acquire expertise by doing in all aspects of the technology from cavity building to beam operation and accelerator R&D experiments

Two 3.9 GHz cavity developments

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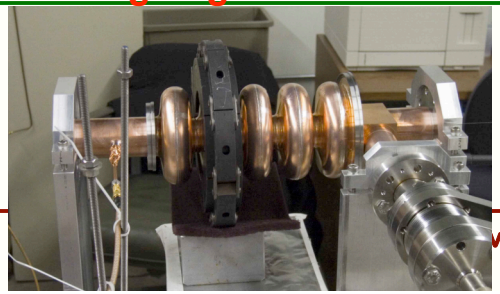
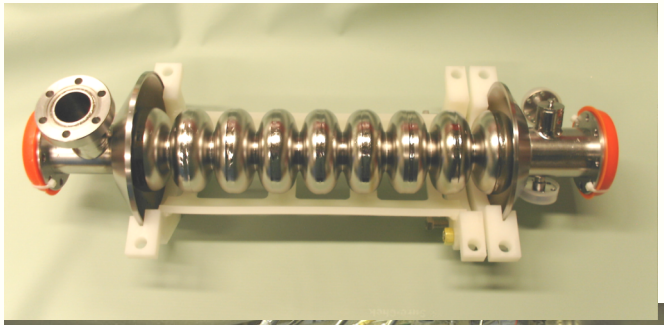
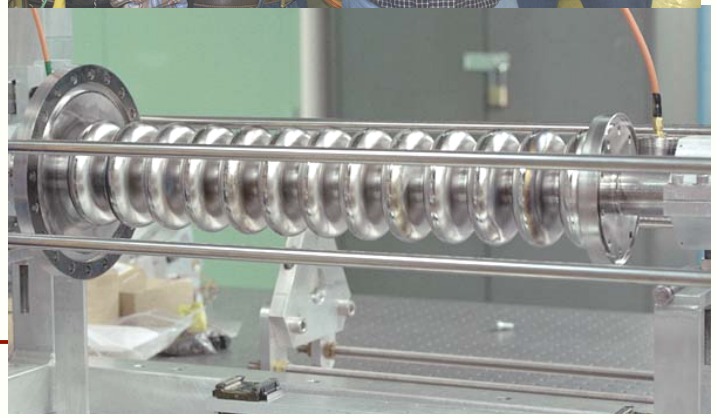
- 3rd Harmonic acc mode cavity
  - bunch compression- linearizes the 1.3 accelerating gradient over the bunch length.
  - To be used at TTF-II (4 cavity module), Photoinj Upgrade (single cavity) , Prototype for XFEL
  - We are behind in schedule Must install Spring 08 (Missed spring 07) Critical for DESY FLASH short wavelength SASE
- 3.9 GHz deflecting mode cavity
  - bunch slice diagnostics, momentum or emittance as function of position in the bunch at PhotoInj Upgrade
  - ILC crab cavity development for final focus
  - (Originally proposed for a pure Kaon beam experiment, CKM at FNAL)
  - Development on back burner till 3rd Har cavity under control. Analysis of "other" modes and design of HOM, LOM on going

Emittance exchange
Thesis project (Koeth)







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

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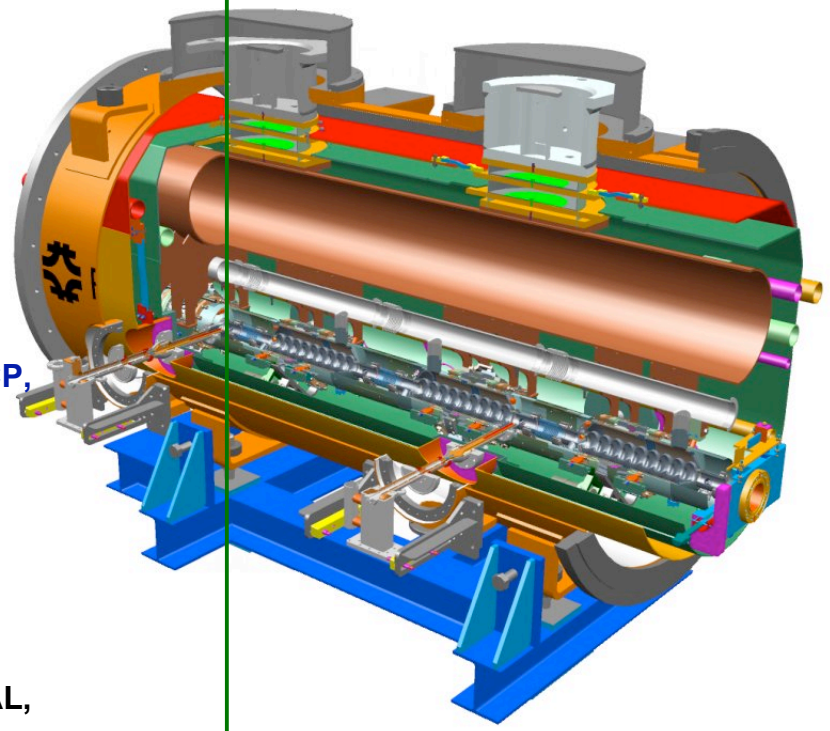
- Cavity design & HOM design
- Cavity fab & welding
- Cavity processing, bake, prep
- Vertical & horiz cavity tests
- Input coupler design and test
- Tuner
- Helium vessel, mag shielding
- Module cryostat cold mass & supports
- Help- welding at JLab and
  - from Kneisel (JLab) and Kelly (ANL) on processing BCP, 600C bake, HPR
  - BCP- JLab, ANL(existing facility), FNAL
  - Oven bake- JLab, FNAL
  - HPR- JLab, FNAL
  - Vert Test - FNAL
  - Posts INFN
- Goal: BCP-ANLnew, Oven bake-FNAL, HPR-FNAL, Test-FNAL, reasonable time turn around



Why? Why A0 injector, RF gun, Laser, SRF cavity?
Why 3.9 SRF development?

Grow competence in important future tech
Experience in all SRF aspects
Acc R&D and training

3.9 GHz "3rdHar" Acc mode cavity

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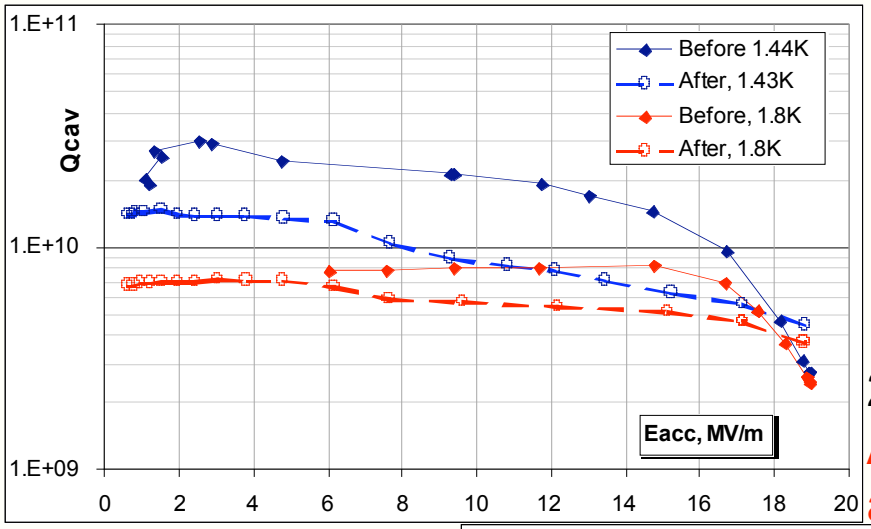
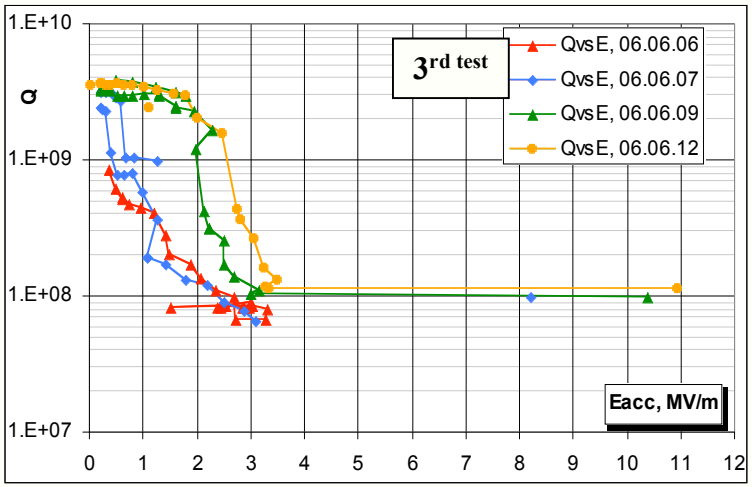
3 cell w/o HOM
~19 MV/m

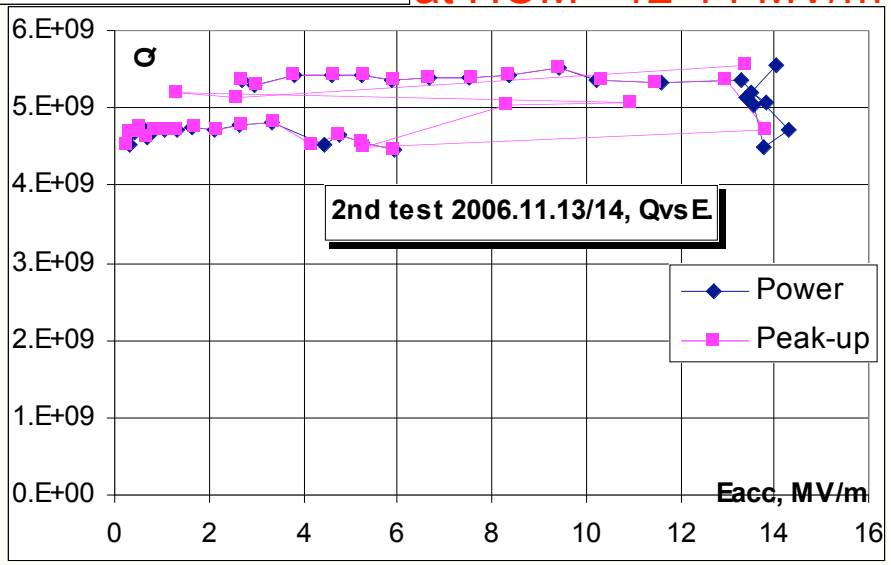


Design spec
14-15 MV/m

1st 9 cell w HOMs
Strong heating and breakdown at HOMs



2nd 9 cell w HOMs
Almost but quench at HOM ~12-14 MV/m



Investigations of broken HOM

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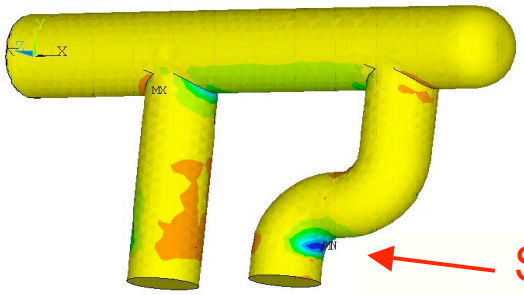
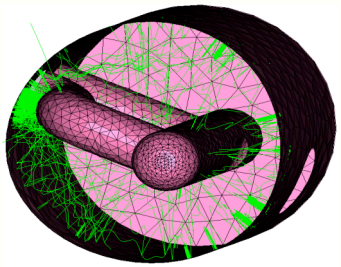
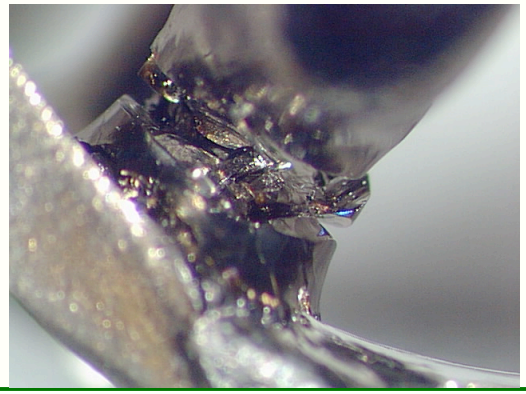
Failure Possibilities:
- Weld crack with acid in it
- Multipacting





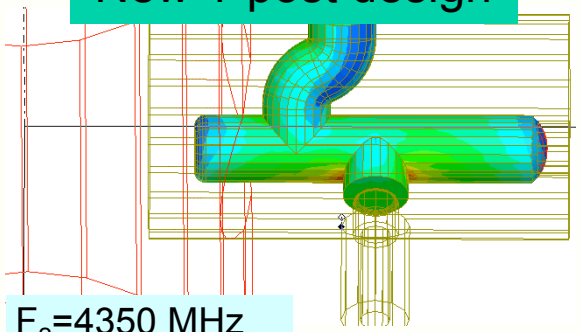
Multipacting Simulation
Omega 3P

Stress from heating

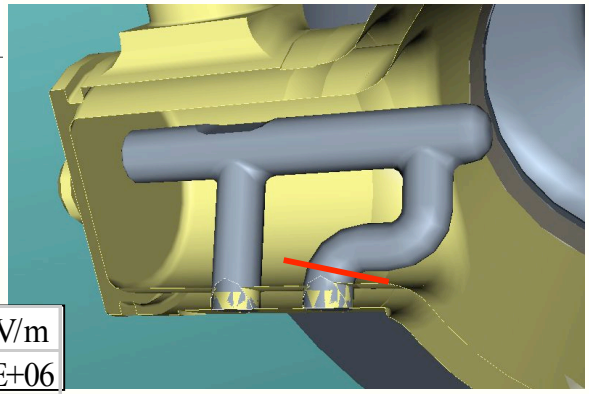


- **Cross section (DESY) through a fractured antenna leg on the can**
  - **cracks also in the welding area**
  - **large grains up to 2-3 mm**
  - **etching marks ????**

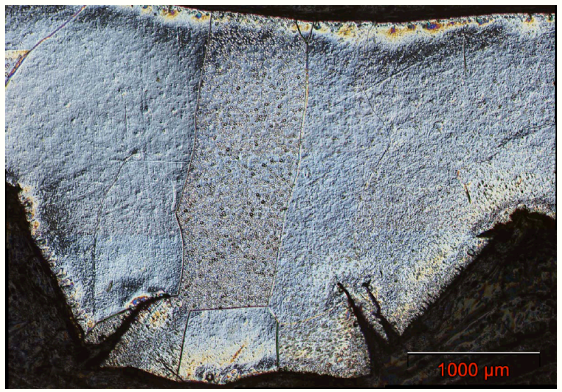
New 1-post design



F_2=4350 MHz



Surface	∫ H2dS	S, m2	Hp, A/m	Ep, V/m
Formtile	1.2E+04	0.0008	5910.1	4.6E+06



HOM issues around the world

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Be careful when you select "key issues" today's may not be tomorrow's

- SNS cavities show abnormalities
  - Abnormal Fundamental freq from HOM
  - HOM attenuators damaged
  - Beam seems to generate large HOM power bursts
- KEK ICHIRO
  - Multipacting in beam tube taper suspected
  - E beam weld of HOM suspected
- KEK "Tesla like"
  - Does not have Tesla like HOM design
  - Believe they observe heating due to multipacting
  - Can be processed away
  - They believe they observe multipacting changing the filter tune and resulting in hom power extraction
- CW applications concerned about heating of HOMs & antennas
- Need to work/commumicate together to better understand overall design issues

Infrastructure at A0

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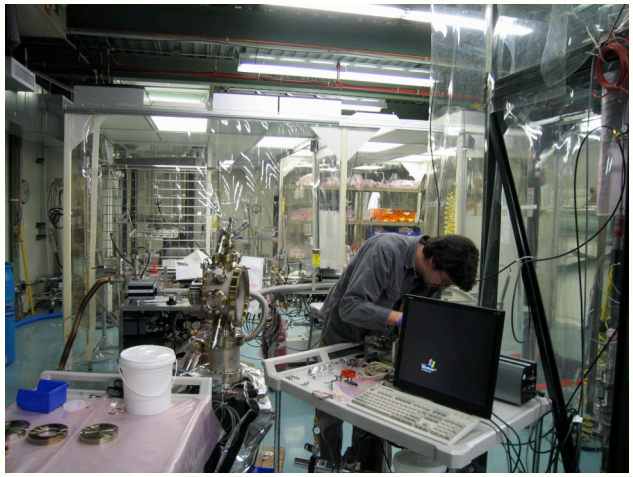
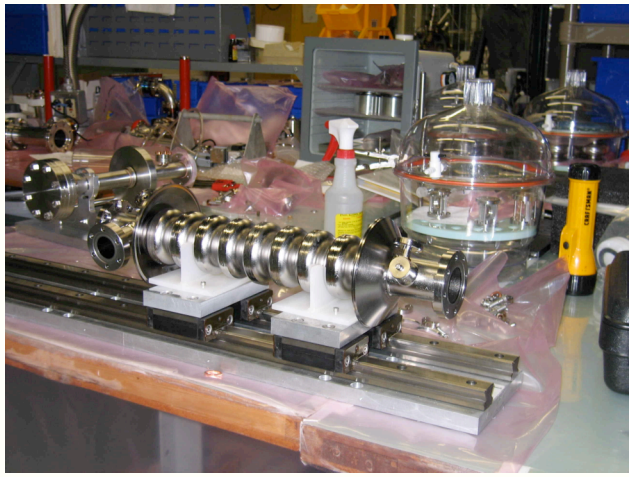


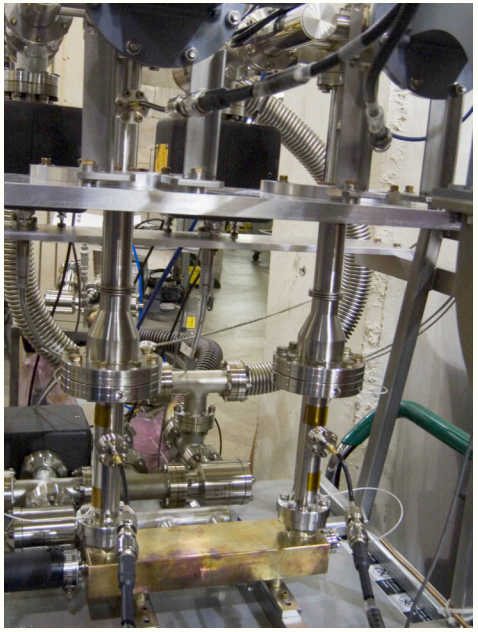

SRF infrastructure & Issues

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- We have struggled to build up modest infrastructure over the years
- It is only adequate for small efforts and is very time inefficient
  - Welding- we are at the mercy of the welding company
  - Chemistry- implementation of chemistry (BCP) has been very slow
  - Cryo- we are making use of 25 year old small capacity systems. We need a modern larger capacity system designed for 2K. Up front investment.
- If FNAL is to have a position of SRF leadership it must have the infrastructure to carry out an effective & efficient R&D program and US industrial training. One must be careful that ambitions, plans, and schedules are realistic
- And Yes the other SRF labs need support so that they do not wither and die.
- And Yes we need to build, commission, operate systems, operate with beam, and revise and improve systems designs, if we are to develop people with the expertise and the systems that work together

Future of 3.9SRF, A0 R&D & photoinjector

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- Photo injector will move to NML (Nagaitsev)
- It will allow for a continuation of Acc R&D & AARD experiments
- The A0 SRF activities will continue at the research level with processing & testing of small cavities- 3.9GHz & one cell 1.3 GHz
- The A0 injector group will be a core group at NML

END

End