ART and the Fermilab Program

Bob Kephart

FNAL ILC R&D Mission & Goals

Americas

Mission:

- **Work with the GDE Americas Regional Team (ART) to develop the ILC design & gain approval of the project**

Goals:

- Participate in the Technical Design Phase (TDP)
- Participate in Accelerator Physics, Conventional Facilities Design, and global systems work to further develop the ILC design
- Work towards GDE SRF goals
  - S0: Cavity gradient of 35 MV/m; good yield
  - S1: Cryomodules with average gradient > 31.5 MV/m
  - S2: One or more ILC RF unit with ILC beam parameters
- Perform R&D and value engineering to reduce costs
- Become a trusted international partner

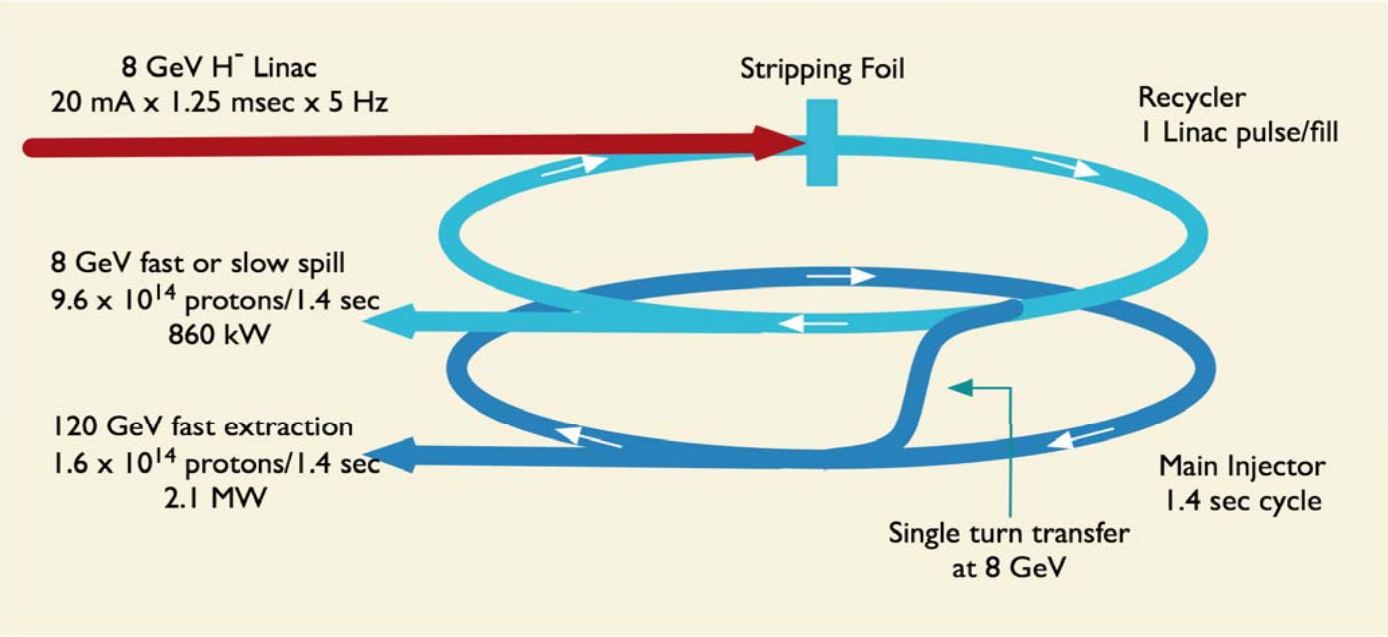
ILC: FNAL Scope of Work

- **Accelerator Physics and Beam Design**
- **Conventional Facilities Systems**
- **Global Systems – Instrumentation, LLRF, Cryogenics, Controls, etc**
- **SRF Cavity and Cryomodule development**
  - Majority of effort
- **Host the Americas GDE "office"**

Project X

New intense Proton Source at Fermilab, endorsed by HEPAP

- 2 MW of beam power over the range 60 – 120 GeV
- Simultaneous 150 kW of beam power at 8 GeV;Upgradable to 2-4 MW
- Based on 8 GeV SRF based “ILC-like” Linac (Synergy!)
- FNAL pursuing both Energy & Intensity Frontiers in parallel (ILC, Px)



FNAL SRF Program (related)

Funded under a separate B&R and not formally part of this review

Mission:

- **Develop SRF infrastructure at FNAL and perform R&D to master the technology for future accelerator projects (e.g. ILC or Project X)**

Goals:

- **Master fabrication & processing of cavities & cryomodules**
- **Build SRF infrastructure that is difficult for industry to provide**
  - Large cryogenic & RF systems, cavity & cryomodule testing systems, etc.
- **Operate facilities to acquire required expertise**
- **Transfer SRF technology to U.S. industry**
- **Participate in national & international collaborative SRF R&D**

Americas

SRF R&D Scope of Work

- Develop & Operate SRF infrastructure
  - Joint ANL/FNAL Processing Facility
  - Vertical Test Systems (VTS)
  - Cavity & Cryomodule Assembly Facility (CAF)
  - Horizontal Test Systems (HTS)
  - RF unit Beam Test Facility (ILCTA_NML)
  - Stand-alone Cryomodule Test Stand (CTS)
- Purchase cavities (ILC only provides cryomodule parts)
- Provide infrastructure for generic SRF Material R&D

- **FNAL SRF infrastructure plan reviewed by DOE in Feb 07**
  - Focused on infrastructure for ILC 1.3 GHz elliptical cavities
  - Changing scope… now support industrialization of SRF
  - Revised U.S. HEP priorities include Project X @ FNAL and ILC on a slower time line… but large overlap of Px and ILC goals
- **DOE review of FNAL SRF program scheduled for May 18-19**.

- Related SRF programs include Project X, HINS, and 3.9 GHz R&D

Americas

SRF Funding @FNAL

This review

- Synergy (by design)
  - e.g. ILC R&D supports Px since they employ similar cavities & CM
  - SRF efforts often share common personnel and infrastructure.
- SRF at Fermilab including SRF for ILC is managed as an integrated whole
  - Allows for rational cost sharing & efficiencies

~~x~~ means ILC used to fund this prior to FY08 Omnibus bill

Funding source	ILC B&R Beta=1	SRF B&R Beta=1	ARRA B&R Beta=1	Px RD&D Beta=0.8	HINS Spoke	3.9 GHz
B&R KA15 -	02 02-1	02 01-2	?		02 01-1	
Component Development						
Cavity Development	~~x~~	x	x	x	x	x
Couplers (ILC@SLAC)	x		x	x	x	x
Tuners	x		x		x	x
Cavity Dressing	x		x		x	x
Cryomodules	x		x	x	x	x
RF CM distribution(SLAC)	x		x			
Infastructure Fabrication						
Cavity Infrastructure		x	x		x	x
Vertical Test Systems	~~x~~	x	x			x
Horizontal Test System	~~x~~	x	x			
Cryomodule Assembly	~~x~~	x			x	
EP processing ANL/FNAL & JLAB	~~x~~	x	x			
RF unit Test Facility (NML)		x	x			
NML buildings and new cryoplant			x			
SRF materials infrastructure		x				
Spoke Resonator & 3.9 BCP@ANL		x			x	x
325 MHz VTS for Spokes					x	
Spoke Resonator HTS					x	
Cryomodule test stand		x				
Facilities Operations						
EP & BCP processing ANL	x			x	x	x
EP processing & VTS @ JLAB	x			x		
Industrial EP & alternate processing			x			
Bare cavity test (VTS)	x			x		x
Cavity Dressing	x			x	x	x
Dressed cavity Test (HTS)	x			x		x
Cryomodule Assembly	x			x	x	
Cryomodule test		x		x		
RF unit test		x				
SRF materials and EP Dev.		x				
Spoke Resonator Vertical Test					x	
Spoke Resonator HTS					x	

Americas

Accomplishments

- **Effort In FY08 obviously limited by FY08 Omnibus Bill**
- **Accelerator Physics and Beam Design**
  - Participated in the global effort to design the machine
  - Simulation of emittance preservation in RTML and Main Linac
  - Studies of kick due to RF coupler and effects on emittance
  - Single stage bunch compressor simulation
- **Conventional Facilities Systems**
  - Lead the U.S. and Global effort for CFS
  - Value engineering and cost reduction for the baseline design
  - Evaluated alternative tunnel configurations (single, shallow)
- **Global Systems**
  - Built/ installed 20 high resolution (<5 μ) BPM's for ATF
  - Developing new cold cavity BPM's for ILC cryomodule
  - Wire Position Monitors, BPM, Faraday cups etc for CM1 @NML
  - LLRF: 9 ma studies @ FLASH, Built HOM readout electronics
  - Contributed to global effort to design ILC cryogenic systems

Accomplishments

- Despite funding turmoil, good progress on SRF technology at FNAL with the funds supplied by the ILC & SRF B&R in 1st quarter and other KA15 B&R funds (3.9 GHz, HINS, Project X)

- FNAL has several new SRF facilities now in full operation
  - New Vertical Test Stand; tests bare cavities (35 tests in FY08-09)
  - New Horizontal Test Stand; tests dressed cavities (5 tests in FY08)
  - Cryomodule Assembly Facility; 2 CM assembled in MP9 & ICB

- Other Infrastructure was delayed substantially by Omnibus
  - Infrastructure to dress 1.3 GHz nine-cells (1st nine-cell this month)
  - ANL/FNAL Joint EP Processing; commissioning,(10 single cell tests)
  - RF unit test facility at New Muon Lab; under construction
  - 8-12 month delays due to Omnibus and FY09 CR

Accomplishments

- FNAL has built a variety of SRF components
  - Cavities: 48 ordered, 22 from U.S. industry
  - Cryomodules: Assembled 2 cryomodules with CAF
    - CM1 = Type III^{+} assembled from DESY kit of parts
    - Designed/assembled a 3.9 GHz CM for DESY
    - Parts in hand for cold mass of a 2nd type III^{+} CM… need dressed cavities
    - Type IV CM design ~ complete and ordering parts in FY09
- SRF Materials program established
  - Single-cell program for U.S. cavity vendor development
  - EP process development for ANL/FNAL joint system
  - Improved diagnostics (thermometry, optical insp)
  - Understanding reasons for poor performers (weld pits)

Americas

Accomplishments

- Industrialization (was ILC funds → SRF funds)
  - ILC cavities built by U.S. vendors (AES, Roark/Niowave)
  - Engaging several industrial vendors in cavity surface processing
  - Engaging sevral U.S. vendors to produce type IV CM parts
  - Limited by funding but ARRA funds will help this a lot

- Extensive network of collaborations (mostly SRF Technology)
  - MOU's with 18 institutions

- Host the Americas Regional office of GDE
  - FNAL personnel in key GDE positions: Ross, Kerby, Garbincius, Champion, Mitchell, Carter, Kuchler, etc
  - Offices, admin support, PM salaries, travel, etc

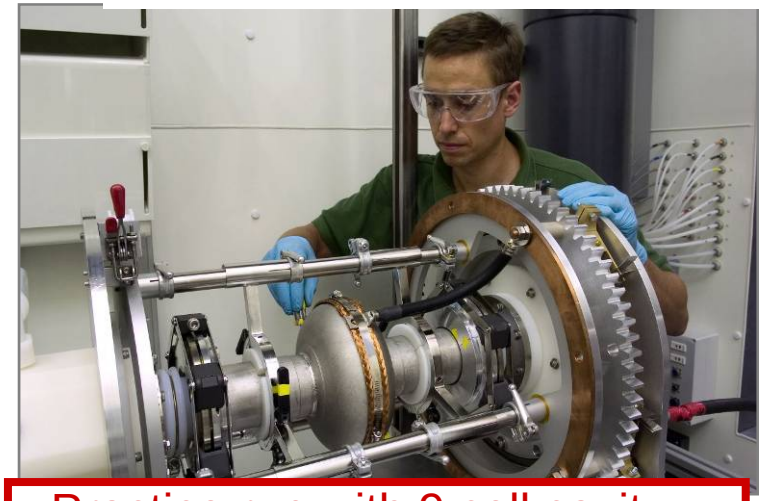
Americas

ANL/FNAL Joint EP Facility

Facility being commissioned (~ 1yr Omnibus Delay)

Provides complete processing of 1.3 GHz cavities: electro-polishing, ultrasonic cleaning, high-pressure rinse, assembly

Expect significant contribution of ANL/FNAL joint facility to ILC R&D in next yr



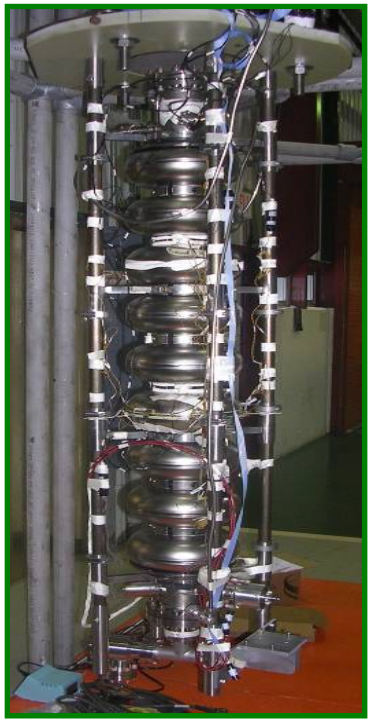
- Practice run with 9 cell cavity
- 10 single-cell EP processes complete with excellent performance >30 MV/M
- Plan 1st real attempt on 9-cell with full facility imminent

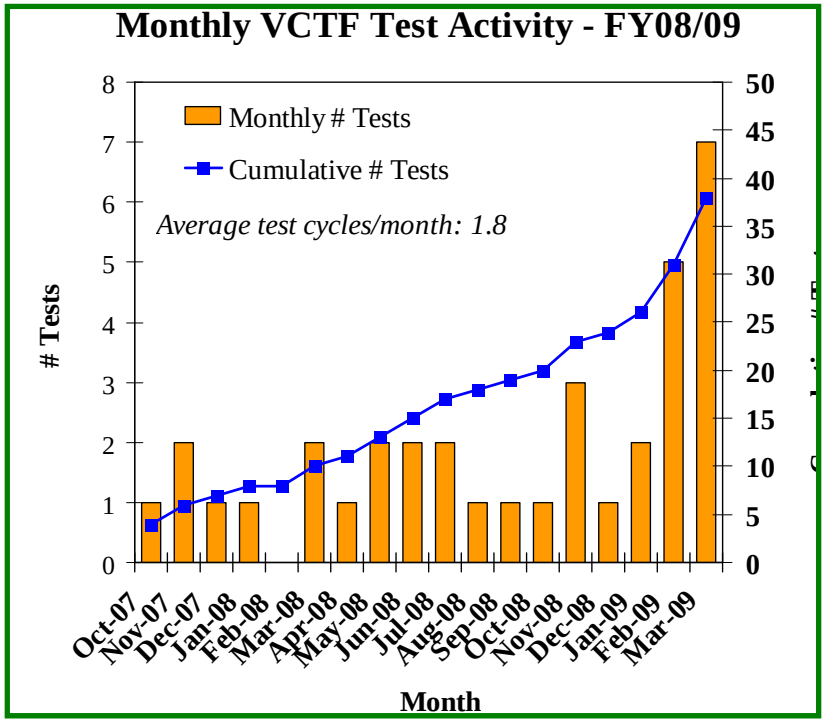
New Ultrasonic cleaning system

New High-pressure rinse system

Vertical Test System

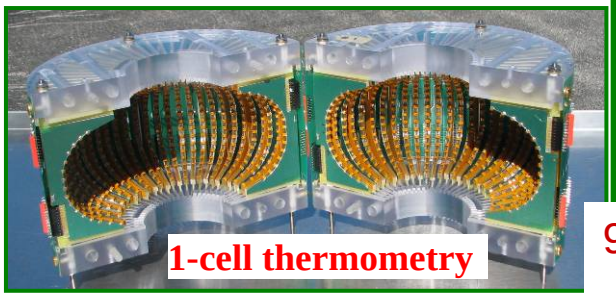
- **35 cavity tests in FY08/FY09, where "test" = cryogenic thermal cycle**
  - **9-cell & single-cell elliptical cavities, and a SSR1 HINS cavity**
  - **instrumentation development, variable coupler, thermometry, cavity vacuum pump system, cavity vendor development**
  - **Cavity tests dedicated to ANL/FNAL CPF commissioning**



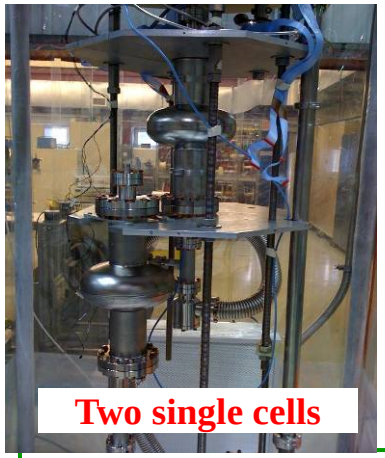


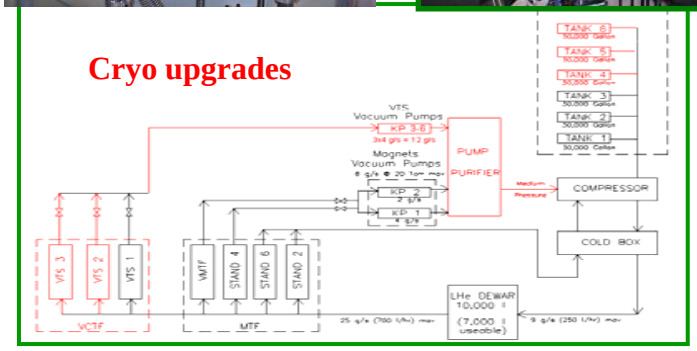
Vertical Test System

Americas

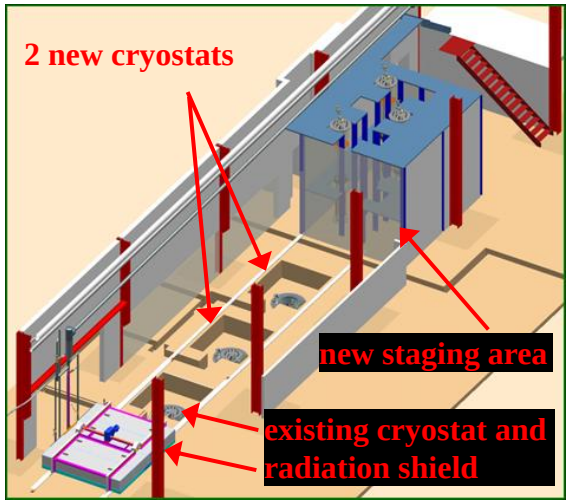


900 sensors/cell!
but multiplexed



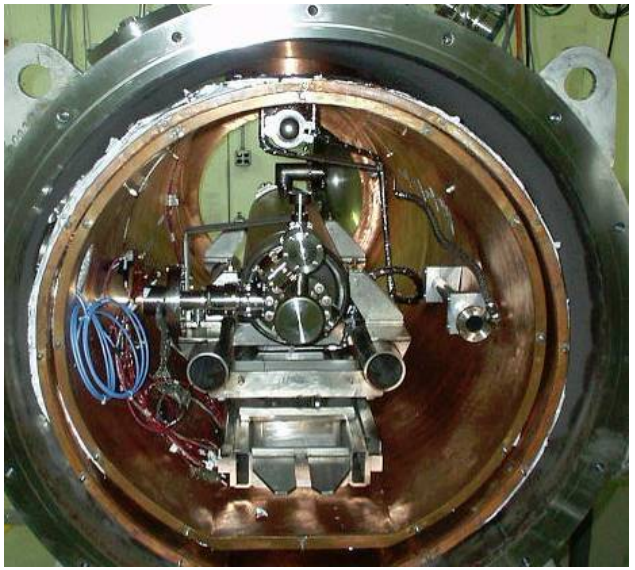


- **Upgrades in progress**
  - 9-cell thermometry
  - Two more vertical dewars
  - More top plates
  - Improved cryogenics
  - Increased throughput 15→250 tests/yr



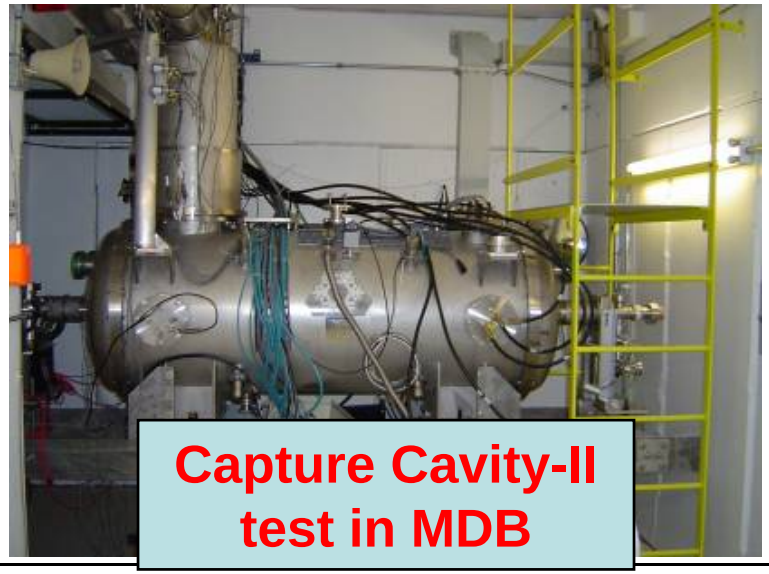
Horizontal Test Stand

- Tests Dressed Cavities with Pulsed RF Power
  - as they will see in a cryomodule
- Fully commissioned in FY08 and in operation
- In FY08-09:
  - Tested one 1.3 Ghz Cavity
  - Tested five dressed 9-cell 3.9 GHz cavities for DESY
- Will be used to qualify dressed 1.3 GHz cavities in 2009



Americas

MDB Infrastructure



Cryomodule Assembly Facility

Americas

- Goal: Assemble R&D Cryomodules
- Where: MP9 and ICB buildings
  - MP9: 2500 ft^2 clean room, Class 10/100
  - Cavity dressing and string assembly
  - ICB: final cryomodule assembly
- Infrastructure:
  - Clean Rooms, Assembly Fixtures
  - Clean Vacuum, gas, water & Leak Check
- DESY Cryomodule “kit” assembled

ICB clean: Final Assembly fixtures installed

MP9 Clean Room

String Assembly

Cavity string for 1st CM

1st FNAL built Cryomodules

3.9 GHz Cryomodule
Designed/built at FNAL for DESY

Not ILC funding but supports ILC effort

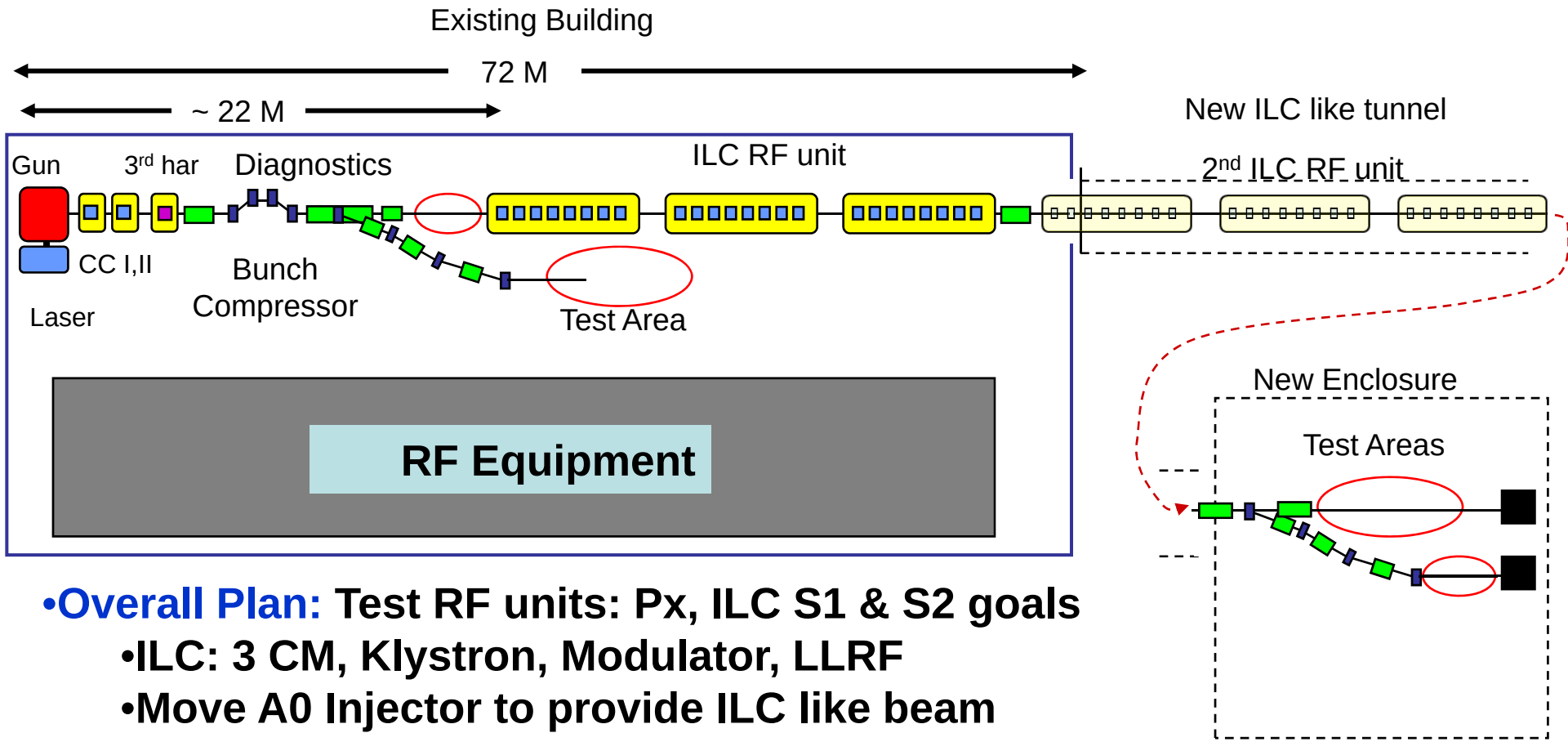
FNAL Cryomodule 2

- Goals
  - –Build a cryomodule completely equipped with cavities processed in the U.S (ILC funds)
  - –1st attempt to achieve ILC S1 goal of 31.5 MV/m average gradient in a CM
  - –Cavities equipped with INFN blade tuners
- Eight cavities are good candidates for CM 2
  - –Average gradient in VTS is 36.5 MV/m
- Final cavities used will be selected based on upcoming process & test results
- CAF(MP9) will be used to Dress cavities
- 1st dressed cavity this month
- Goal: Cryomodule 2 assembled late 2009

Vendor	Cavity #	Gradient (MV/m)
ACCEL	6	37.8
	8	31.7
	11	40.0
	12	37.0
	13	44*
	14	44*
AES	2	32.8
JLab	J2	30.0
Average		37.2

* preliminary: based on last process/test result at Jefferson Lab

RF Unit Test Facility at NML



- **Overall Plan:** Test RF units: Px, ILC S1 & S2 goals
  - ILC: 3 CM, Klystron, Modulator, LLRF
  - Move A0 Injector to provide ILC like beam
- **New Tunnel Extension:** design to allow 2nd RF unit, diagnostic beam lines, AARD facility
- **New Building:** Cryoplant, Cryomodule Test Stands

Americas

1st Cryomodule moving to NML

Note: NML is funded completely with SRF funds
Nevertheless, still an important facility for ILC R&D

RF Unit Test Facility at NML

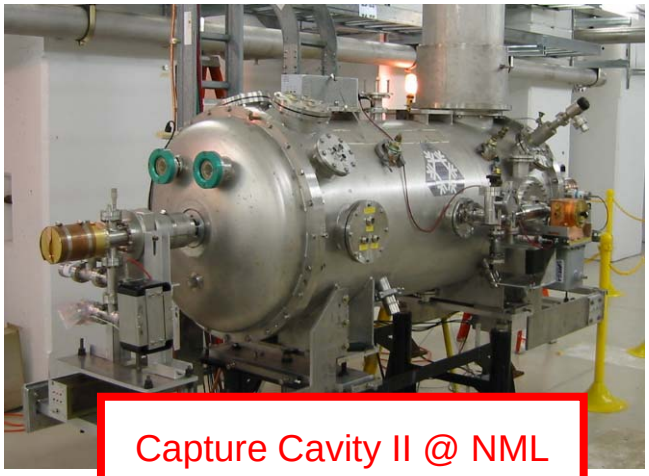
Progress at NML

1st Cryomodule Test fit

CM Feed Can

Large Vacuum Pump

Control Room



Capture Cavity II @ NML

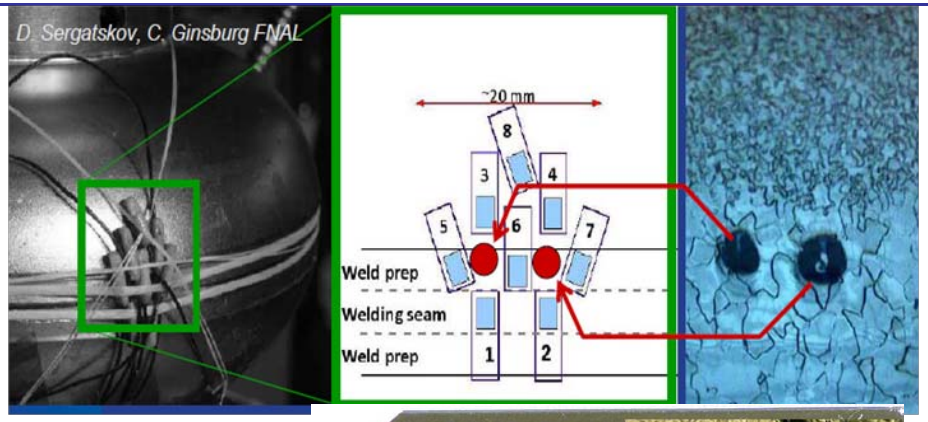
He Refrigerator

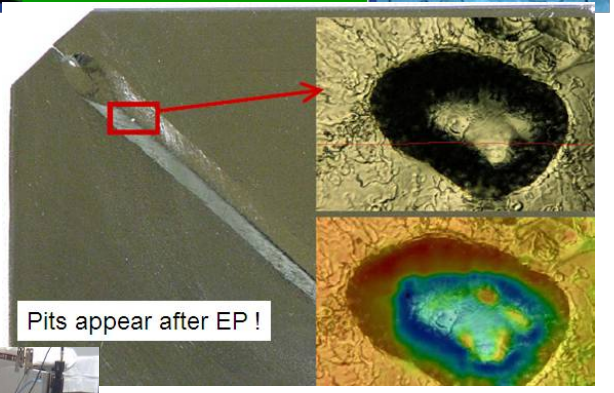
SRF Materials R&D

Americas

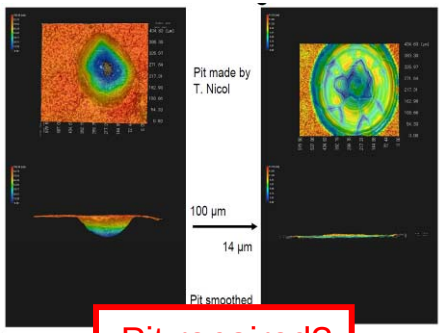
- Lots of activity !
- Understand/improve EP
- New better diagnostics
- Thermometry, optical insp
- Breakthroughs in understanding!
- Pits near EB welds ➔ cavity quench
- Can reproduce pits in small Nb samples
- Goal = Prevention!
- But… also exploring repairs
- E.g. Laser remelting of pit

Partially funded by ILC funds





Laser welding machine



Pit repaired?

Americas

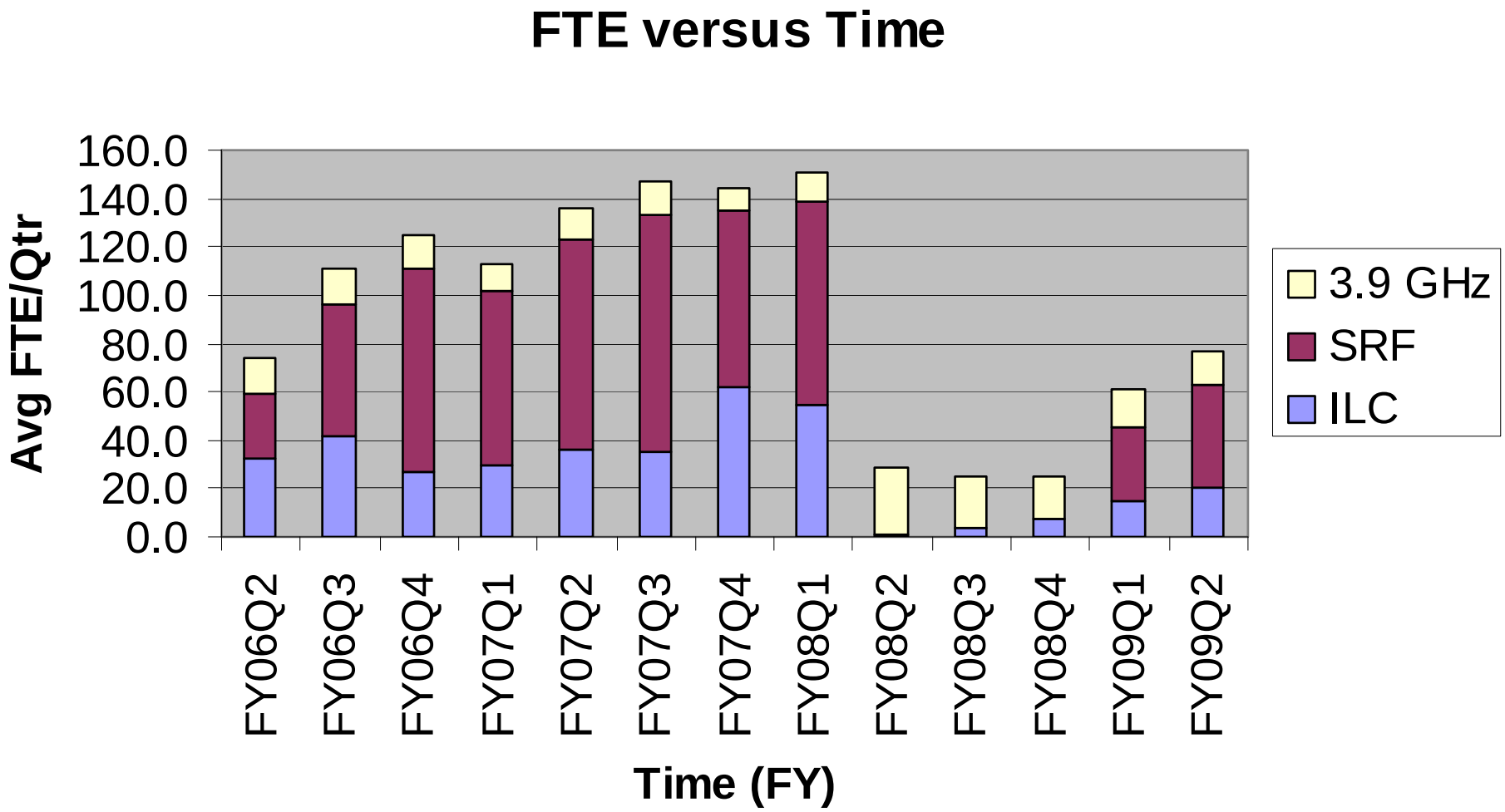
FY08-09 ILC Funding

- FY08 Omnibus Bill cut ILC funding to 25% of plan ¼ of the way through the FY
- SRF cut to 20%➔ All work infrastructure stopped Dec 07
- ILC/SRF workforce was dispersed (138 FTE)
- Work on ILC essentially stopped (2.5 FTE)
  - ~$ 1 M unspent ILC M&S funds, cavity processing at JLAB and VTS at FNAL
- SRF contingency & FY08 supplemental kept JLab, NML, & cavity vendors alive

- In FY09: $ 11.2 M of ILC funds to FNAL
  - Plus $ 1.7 M to support the GDE office
  - This allowed a restart of the ILC R&D program
  - However CR Sep 08-Mar 09 ➔ M&S limited to 60% of plan
  - Still have not received full allocation from OHEP ($ 10. 3 M as of April)
- In FY09: $ 22.8 M to build SRF infrastructure & perhaps ARRA funds
- Workforce has been restored to 75 FTE (but a struggle)
  - 23 FTE on ILC, 52 on SRF: Making up shortfalls with contract workers & guests
  - Expect 3.9 GHz effort to wind down this month (another 11 workers)
- FY08 omnibus/CR was very disruptive… cost us ~ 1 year in many places

FY08-09 ILC/SRF Labor

Americas



Has the Program Efficiently Recovered?

- No! The post-omnibus ILC program is now much smaller and envisioned to be flat vs expected large growth each yr, some delays not recoverable
- Not Yet:
  - Had a cohesive workforce in place in Dec 08—scattered to other tasks
  - FY08 funding cuts at FNAL resulted in a significant staff reduction > 100 FTE
  - Change in Focus for US HEP program ➔a number of new near term projects now exist (e.g. NOvA, LBNE, Project X, Mu2e, etc)
  - It has been difficult to get our workforce back (➔ hiring contract workers)
- Issue: Restoration of funds is not enough
  - FY08 Omnibus Bill ➔ ILC credibility damaged; some people have not reengaged
  - Areas of overlap with possible near-term projects (SRF) much easier to sell than ILC global systems, value engineering, accelerator physics, etc.
- Nevertheless FNAL is reengaged on ILC & making progress
  - 3.9 Ghz & HINS efforts were invaluable in maintaining core of SRF workers through the “dark days” of FY08

Coordination ART vs the FNAL Program

Americas

- ILC community has good mechanisms for technically coordinating the R&D effort
- A variety of mechanisms are in place
  - International GDE meetings
    - ILC EC communicates its overall strategy for TDP
    - Labs envision their possible role
    - Good forums technical exchange of information
    - Also TTC, SRF, and PAC meetings
  - International Webex meetings
    - PM meetings (e.g. Main Linac, Yamamoto)
    - S0 Meetings (cavity and gradient) etc
  - National meetings of ART (Mike Harrison)
    - Executive council (all U.S. institutions, often by WEBEX)
    - Quarterly/Annual Technical and Financial Progress reports
    - Annual budget planning (work closely with Mike)
  - DOE Reviews (like this one) + AAP, HEPAP, AAC, etc

Coordination ART vs the FNAL Program

- Coordination mechanisms (continued)
  - Face-to-face meetings
    - FNAL ILC Director (me) & ART Director (Mike)
    - FNAL ILC Director & GDE Project Managers (e.g. Mark, Akira)
    - FNAL ILC Director & OHEP Program Manager (Gerry)
    - FNAL Directorate & GDE Directorate
  - Financial Coordination
    - ART Annual Financial Planning effort
    - OHEP communications to - Fermilab budget office
    - FNAL Annual Laboratory Budget presentation to OHEP
- Technical Planning OK, Financial mechanisms less than perfect
  - Often money in FNAL Fin plan does not match ART plan
  - ART Director and OHEP maintain reserves ➔ if full ILC work force is in place, substantial M&S is not available until late in fiscal year
  - ILC funding guidance from OHEP to FNAL CFO for lab annual budget plan often does not match numbers communicated by ART Director
  - All people well intended… process is just not very smooth

Broader impacts of ILC Program

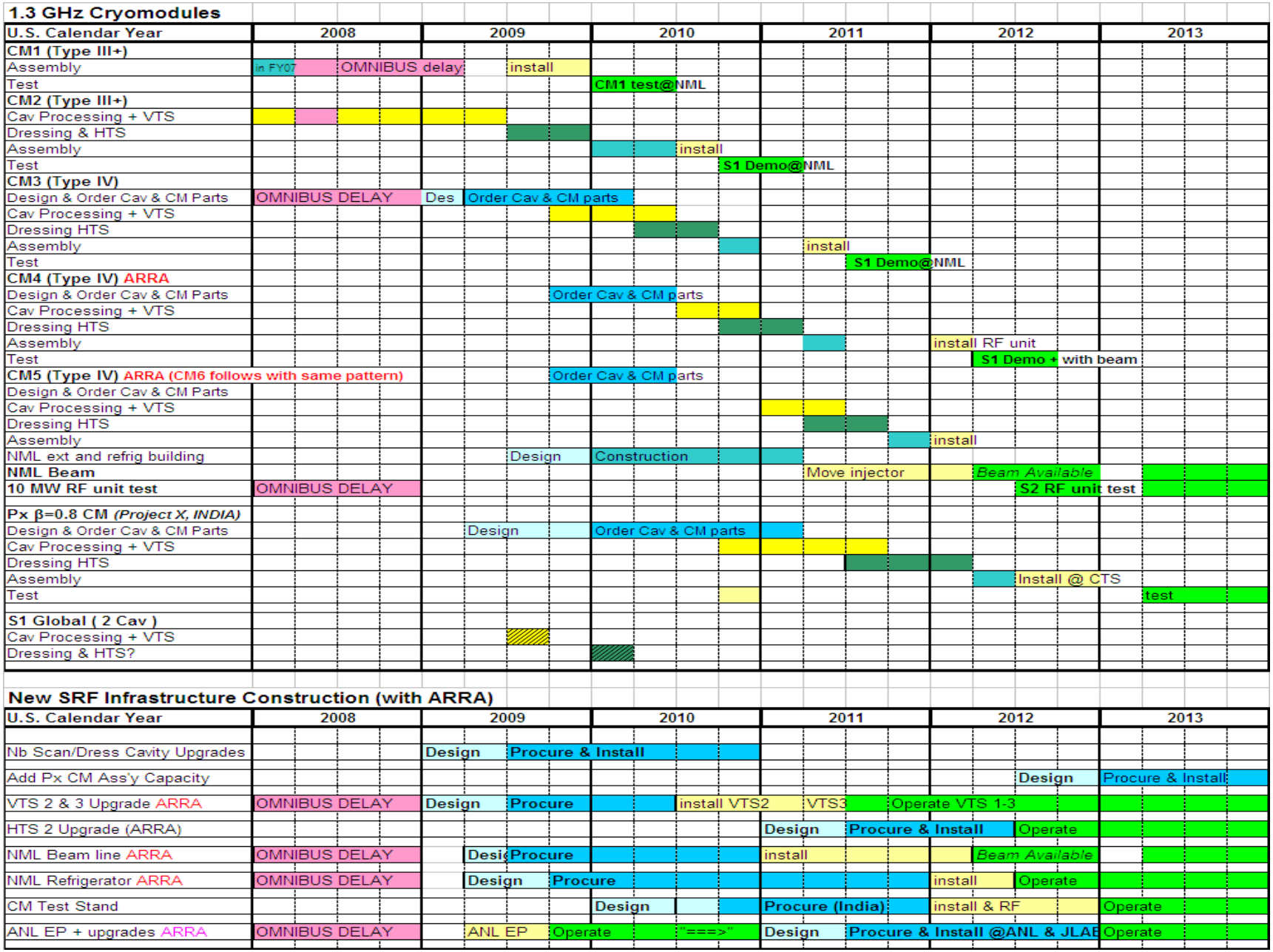
- For FNAL, the ILC R&D effort is part of a broader program of SRF development intended to allow FNAL first to capture the intensity frontier (with Project X) and later to recapture the energy frontier with ILC or a muon collider
- FNAL views SRF as an enabling technology (like SC magnets) likely to be used in all future HEP accelerators
- We have worked hard to maintain an integrated plan despite the funding turmoil of the past years
  - ARRA funds will provide the opportunity to substantially advance the program compared to our vision only a year ago
- ILC and SRF R&D provides broader benefits by developing high tech workforce at labs and in industry, and trains students via university collaborations

Americas

Collaborations (18 MOU's)

- ANL: EP development and cavity processing
- Cornell: Cavity processing & test, materials R&D
- DESY: 3.9 GHz, cryomodule kit, FLASH
- KEK: Cavity R&D, ATF II
- MSU: Cavity cost reduction, hydroform, TIG
- TJNL: EP cavity processing and test
- INFN: tuners, HTS, NML gun cathodes
- Triumf: Vendor development
- SLAC: RF power, klystrons, couplers
- CERN, DESY, KEK, INFN, etc: Type IV CM design
- India: CM design, cavities, infrastructure, etc
- China: Peking U, IHEP, cavity development
- UC,NW,NHMFL, Cornell, DESY, KEK,etc: Materials

Integrated ILC-Px SRF Plan



FY09 ILC Milestones for FNAL

Americas

	Forecast	Actual
• **1.7 Conventional Facilities**		
– Complete Water and HVAC VE	Q4	Q3
– Main Linac Tunnel Alternative	Q4	Q4
– Minimum machine CFS conceptual Design	Q4	Q4
• **1.10 Cavities and Cryomodules**		
– Complete & commission ANL/FNAL processing facility	Q2	Q2/Q3
– 1st dressed 1.3 GHz cavity tested	Q3	Q3
– Start Testing Cryomodule 1 at NML	Q3	Q4
– All Cryomodule 2 components available (except dressed cavities)	Q4	Q2
– Complete 8 dressed cavities for CM2	Q4	Q4 ?

Despite CR, doing well on milestones. Feed can for NML test of CM1 delayed, Test CCII first at NML to commission cryogenics system. 8 dressed cavities by Sept will be tough

Summary

- Fermilab has an active ILC R&D program
- FY08 omnibus cuts were disruptive, but we are recovering
- Despite Funding turmoil FNAL made considerable progress
- Significant contributions to global GDE program
  - Management, Accel Physics, machine design, global systems, cryogenic design, CFS, cost estimate, etc.
  - Major effort on SRF development
- Extensive SRF Infrastructure constructed and in operation, additional infrastructure under construction with SRF funds
  - Supports GDE S0, S1, S2 goals for ILC
  - Supports U.S. Industrialization of SRF technology
- Designing, Building, and Testing SRF components
  - Cavities, cryomodules, EP processing, SRF materials work, etc
- Integrated ILC/SRF effort at FNAL also supports Project X
- We have ambitious plans for FY09 and beyond