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ILC Cavity R&D

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ILC Program

Fermilab

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Cavity R&D: American Regional Team

- The Global Design Effort (GDE) American Regional Team for the International Linear Collider (ART-ILC) is in process of developing its R&D plan for FY07.
- These plans are a continuation of an R&D Program in progress for many years as part of the TESLA collaboration and greatly enlarged since the ILC technology choice in FY05.
- The plan for 1.3 GHz cavities and cryomodules was initially proposed by the SMTF collaboration in Nov 04.
- The approach taken attempted to maximize the benefit of existing U.S. SCRF infrastructure to make progress on the ILC as soon as possible.
- The initial infrastructure being built is distributed across the U.S. SCRF labs rather than focused at Fermilab.
- Although expedient, this approach is in contrast to what is done at DESY and KEK where all facilities are centralized.
- During the last two years significant resources have been invested in upgrading and developing infrastructure at US laboratories including Fermilab to support these R&D.
- The Main Linac: Cavity and Cryomodule R&D plan proposed by FNAL for FY07 is based on extensive discussions with ILC-GDE,SMTF, Collaboration, Tesla Technology Collaboration, and laboratories with extensive SCRF experience such as DESY, TJNL and Cornell and attempts to balance efforts between near term R&D imperatives and the long term needs of the ILC project.

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ILC Cavity and Cryomodule R&D Goals

- The US ILC R&D is focused to address the high priority ILC design and technical issues as recommended by ILC-TRC and recently by ILC-GDE R&D Board.
- We (American region Team) have organized ourselves to fully support the GDE R&D Priorities. The focus is on Baseline configuration of the ILC.
- The main thrust of the ILC Cavity and Cryomodule R&D is to establish technical capabilities in the Superconducting Radio Frequency (SRF) Cavity and Cryomodule technology. The main priorities are
  1. ILC Design Cavity fabrication and processing technology development in the US to routinely achieve 35 MV/m and Q ~0.5-1e10 with less than 10% spread. (S0)
  2. Fabrication of Cryomodule with 35 MV/m (S1)
  3. Fabrication of an RF unit(s) for system test (S2)
- Development of U.S. laboratories and industrial infrastructure for the fabrication, processing and testing of high performance SRF cavities, Coupler, Tuner, HOM and Cryomodule.

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ILC Cavity: R&D

- Material R&D: Fine Grain (with very limited R&D on Large Grain and Single Crystal)
- Fabrication (Material QC, Inspection after fabrication, RF measurement, Field Flatting etc)
  - A number of minor modifications and improvements could be implemented without impact to the basic cavity design. (i.e. Cavity length)
- Cavity Preparation
- Buffer Chemical Processing
- Cavity Processing R&D
  - Electro-polishing (EP) System
  - High Pressure Rinsing (HPR)
  - Clean Assembly Procedure

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Plans for 35 MV/m and High Yield

- Cavity Fabrication, Preparation, Surface Processing, Clean Surface and Clean environment is the key to achieving a high gradient in the ILC cavities.
- Fermilab in collaboration with SMTF is leading the US effort with collaborating laboratories.
  - Niobium is being scanned at Fermilab. (Need larger inventory. There are variation from batch to batch, vendor to vendor etc.)
  - Cavity is being fabricated at industry under the supervision of Fermilab and Cornell. Jlab will join this soon.
  - Cavity is inspected, Field Flatness measured at Fermilab. Fermilab is starting to do manual tuning.
  - Cavity is being processed (BCP, EP and HPR) and vertical tested at R&D Facilities at Cornell, Jlab and will be processed at ANL/FNAL
    - We are discussing a pre-production processing and testing facility, where ~100 cavity/year can be tested, at Fermilab by 08.
- Fermilab is fabricating 8 (FY05), 16(FY06), 24-36 (FY07) ILC cavities.
- These cavities will be systematically processed and testing. We would systematically collect data during the fabrication, processing and testing.
- These data would be analyzed for co-relations to understand the process.

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Cavity Fabrication

- Industrial production of the cavity by Fermilab (ACCEL, AES,…)
  - 8 TESLA Design Cavities ordered
  - 12-16 ILC Baseline Design Cavities in FY06
  - 24-36 ILC Baseline Design Cavities in FY07
- Cavity fabrication at Jlab (FY06)
  - 2 ILC Baseline design and Type-IV
  - 2 Low Loss Cavity
  - Several single cell for Process and Material R&D
  - Material R&D (Fine Grain, Large Grain, Single Crystal)
- Cavity fabrication at Cornell (FY06)
  - Re-Entrant Cavities (70 mm)
  - Re-Entrant Cavities (60 mm)
  - Several single cell for Process R&D
- Cavity fabrication at KEK (US-Japan)
  - Cavities of TESLA, Low Loss and ICHIRO design

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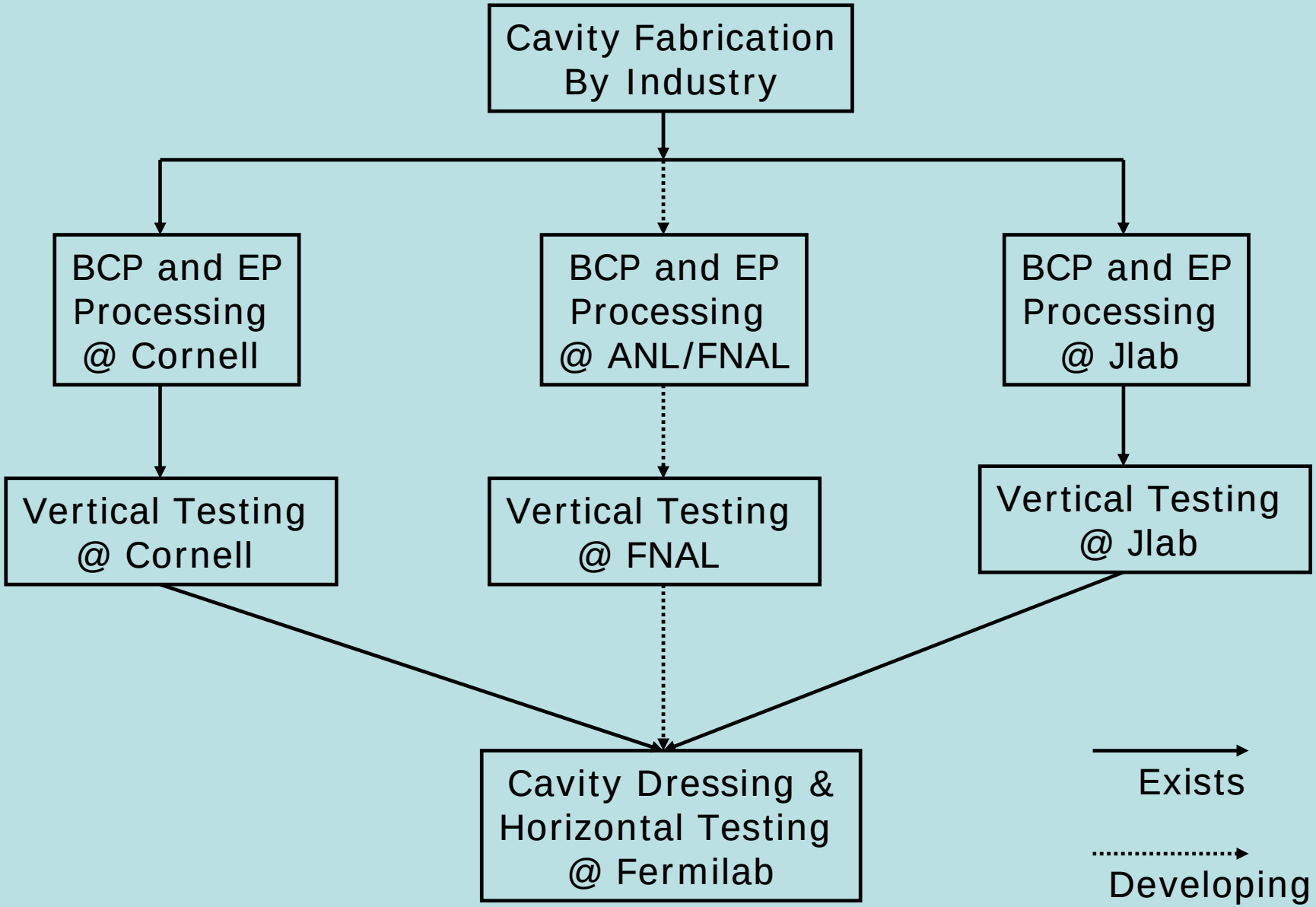
Cavity Fabrication, Processing and Testing Road Map



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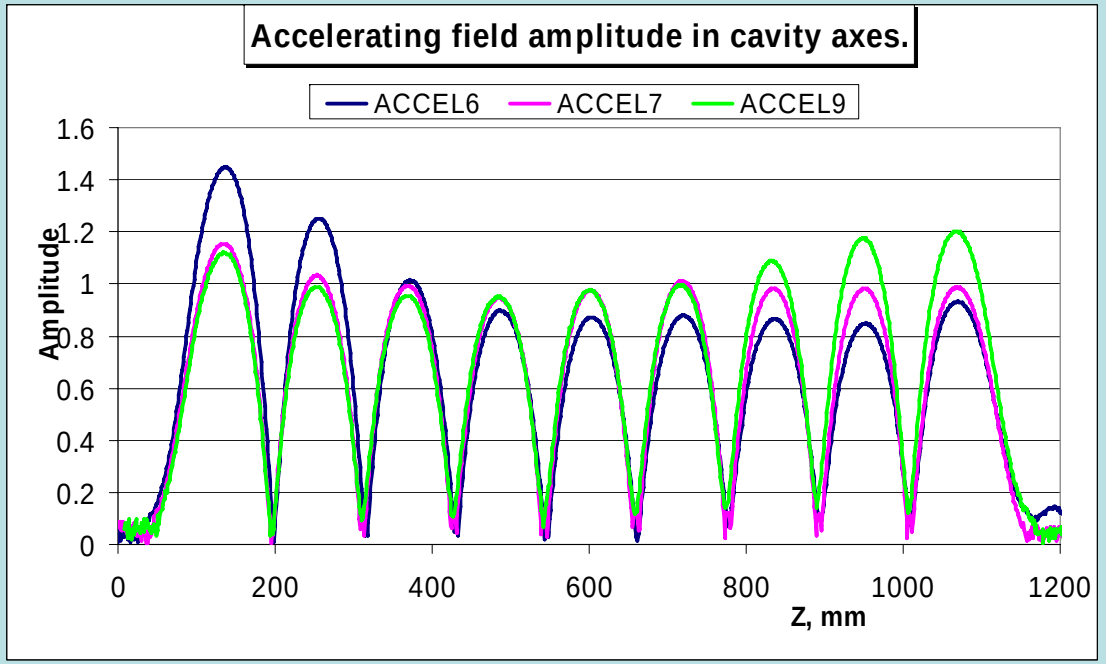
Cavity Measurements

- RF measurement of the ACCEL Cavities at Fermilab.



Fermilab has just started tuning these cavities (Manual) for field flatness.

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ILC Cavity Processing

- We are using infrastructures at the collaborating laboratories to develop the processing capabilities and parameters in USA to achieve 25 MV/m with BCP and 35 MV/m with EP.
- These R&D facilities are also being used to train people.
- Cornell:
  - BCP and HPR
  - Vertical EP (Almost Ready for 9 Cell)
- Jlab
  - EP
- Fermilab and ANL (New Facility)
  - BCP
  - EP
- We are also sending Fermilab staff to DESY for participation and training in surface processing, vertical and Horizontal testing.

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First ACCEL ILC Cavity at Cornell

BCP Complete

HPR Complete

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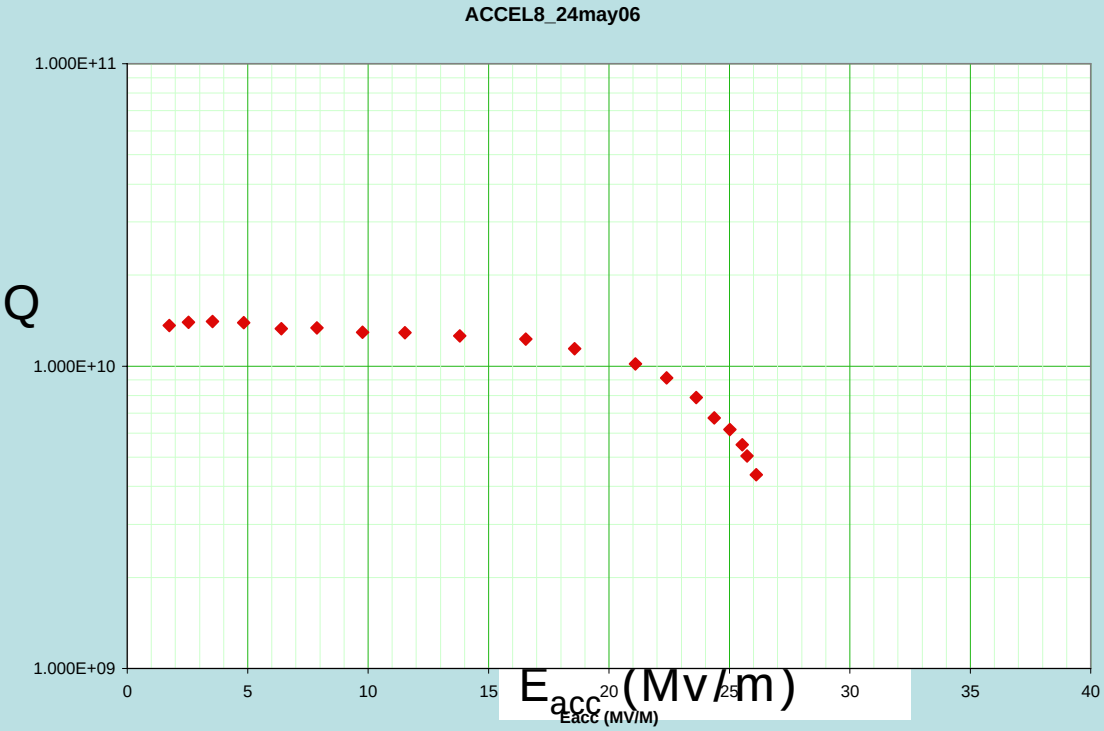
Vertical Test of ACCEL Cavity

50 + 60 μm BCP + 50 μm at ACCEL + HPR

No Field emission, Q > 0.4×10^{10}, E_{acc} = 26 MV/m, No Heat treatment at 800 Deg C.



Fermilab is planning to send engineering staff and technician to participate in the BCP/EP and vertical testing at Cornell.

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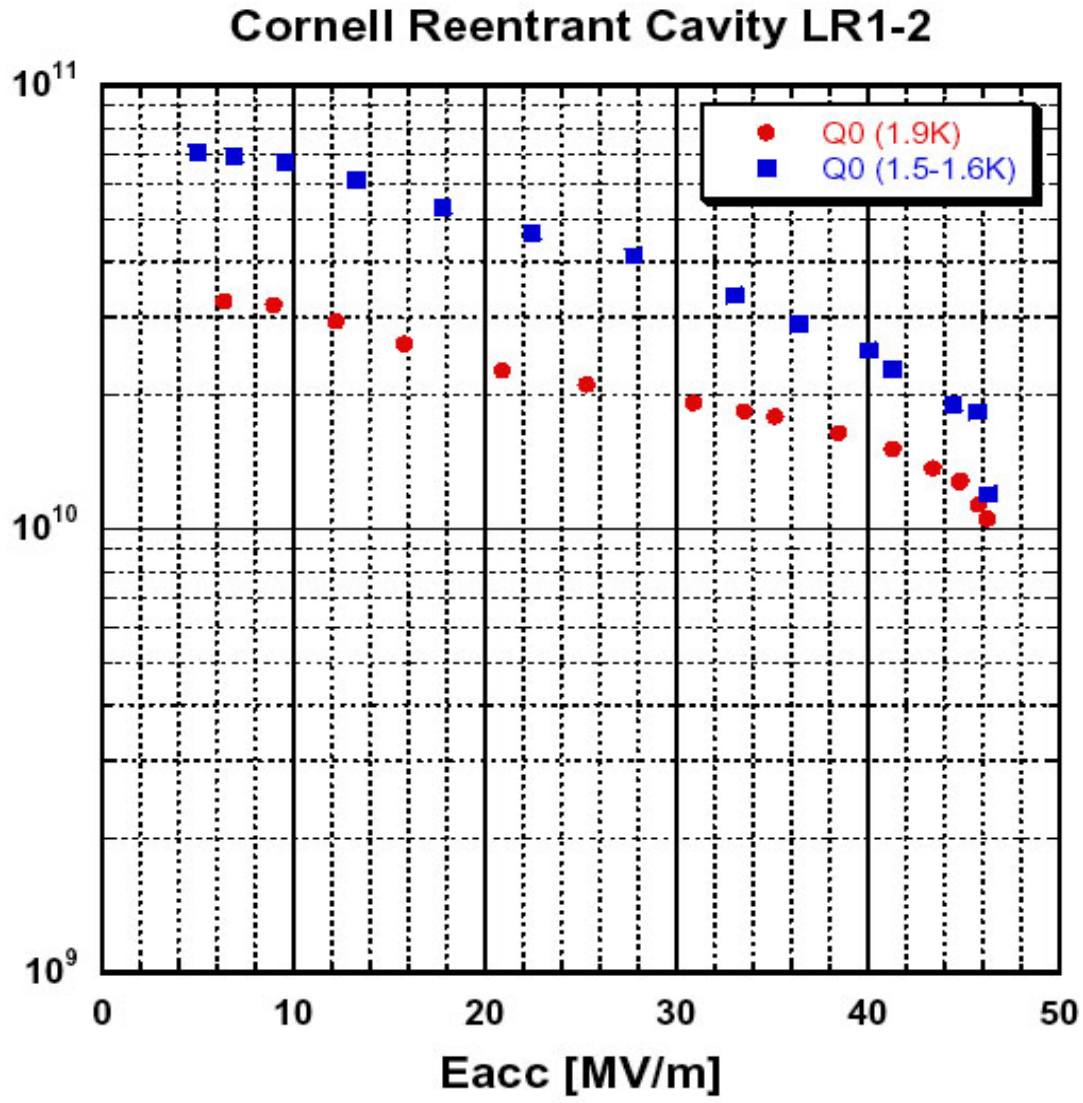
Vertical EP at Cornell

Single Cell Re-Entrant



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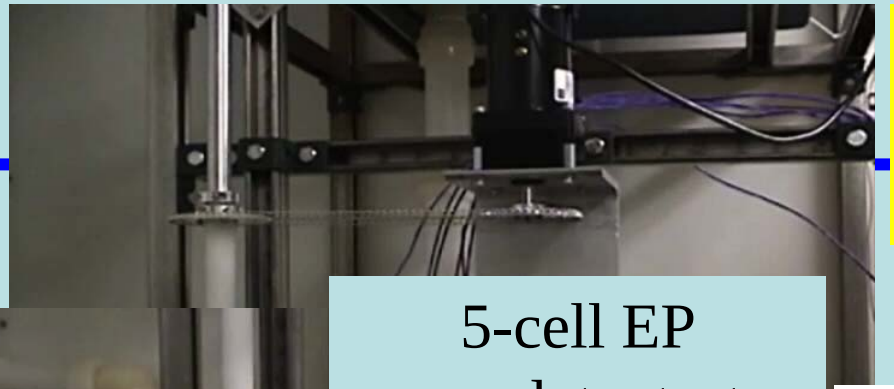
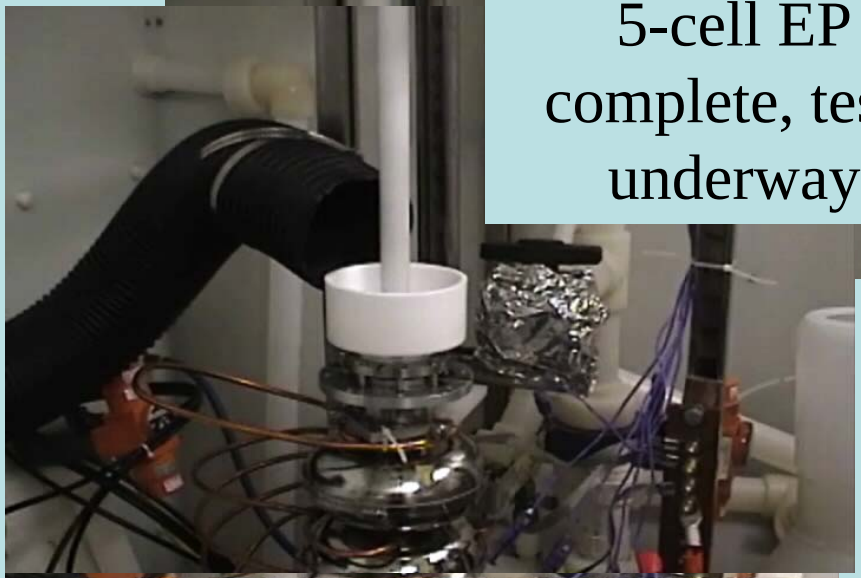
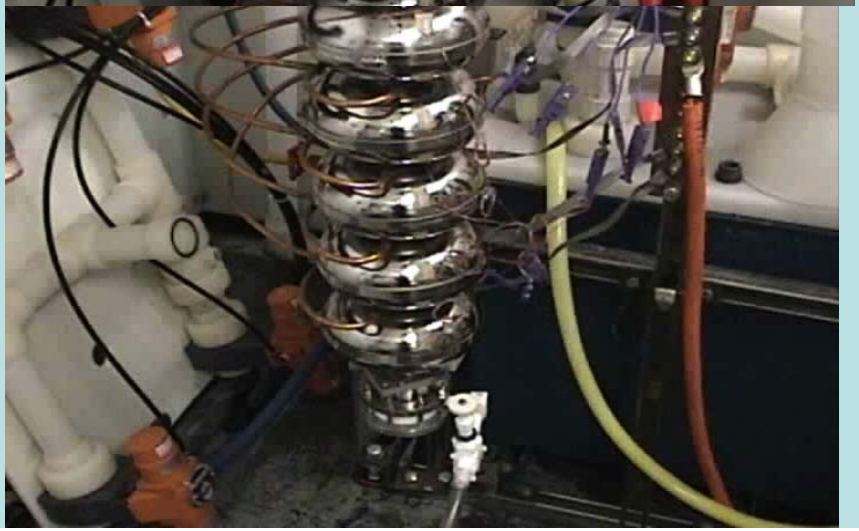
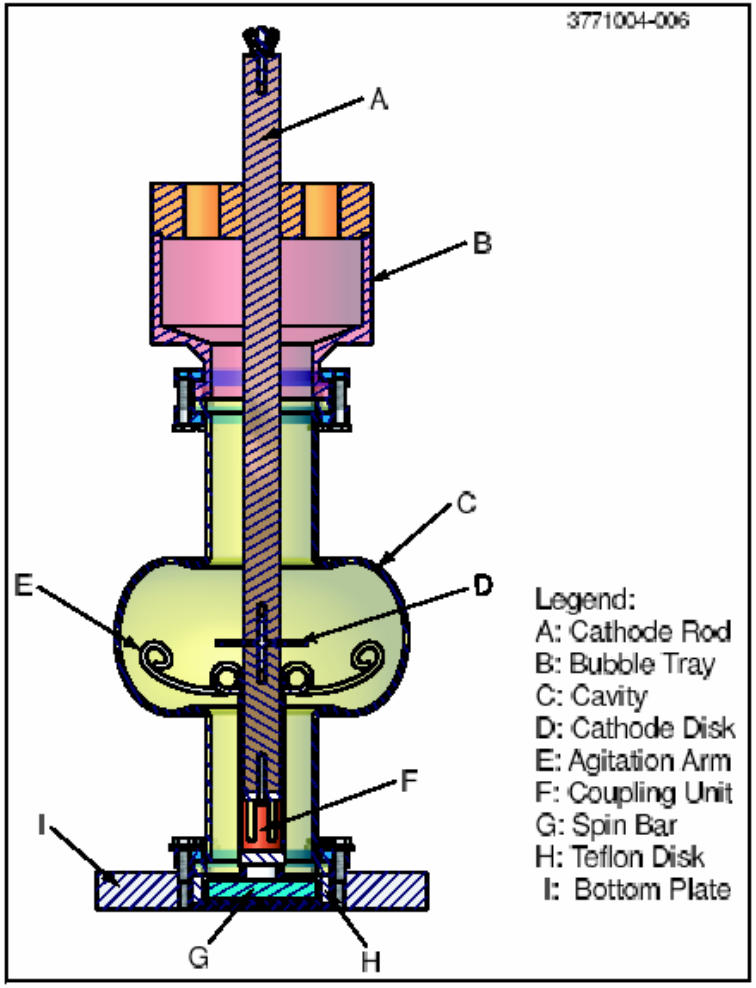
Vertical EP at Cornell





5-cell EP complete, tests underway





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Check Reproducibility of HPR

Work done in Collaboration with KEK

Reproducibility @ 2K and Error

Re-HPR, Re-evacuation

Low Loss @ 2K

Eacc,max	Qo @ Eacc,max
46.5	1.20E10
47.3	1.13E10
46.6	1.50E10
45.0	1.03E10
44.0	1.20E10

45.9±1.3 MV/m , Q0 = (1.21±0.18) E10

Reentrant@ 2k

Eacc,max	Qo @ Eacc,max
51.2	0.59E10
52.3	0.97E10
51.9	1.11E10
52.4	1.21E10
50.0	0.98E10

51.6 ±1.0 MV/m, Q0 = (0.97±0.24) E10

Cornell Re-entrant Cavity

HPR should remain a focus of our R&D.

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Goals for EP Development at Jlab

Establish EP processing for ILC 9-cell cavities at Jlab

- Commissioning EP cabinet with Spare DESY 9-cell cavity
- Perform HPR, assembly and testing with S35 cavity to analyze procedure effectiveness and reproducibility
- Investigate standard process procedures to gain a better understanding of current issues (Sulfur precipitation, HF loss during use)
  - Identify and develop relevant process metrics and QA steps
- Establish and document procedures
  - Aim is uniform reproducible etching with clean surfaces after rinsing
- EP ILC Cavity, test, qualify and prep cavities for FNAL string assembly

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Electropolish Development for ILC

HPR and Assembly Alignment Cage

Jlab EP Cabinet

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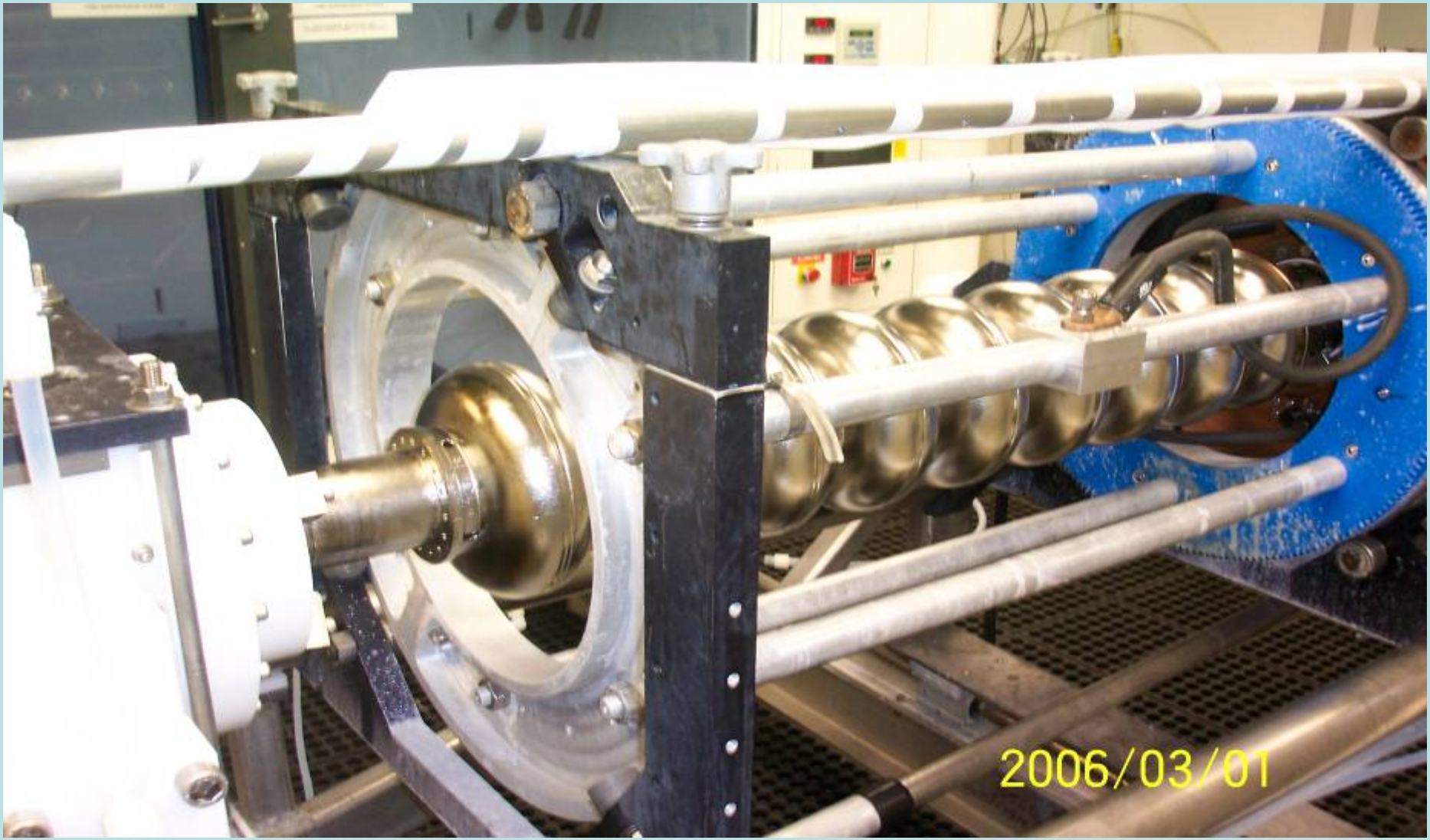
EP System Alignment Frame and Cathode with ILC Cavity



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ILC Surface Processing Facility Development at ANL/FNAL

- The Joint ANL/FNAL Superconducting Surface Processing Facility (SCSPF), located at Argonne National Laboratory, is a major chemical processing facility capable of electro-polishing and buffered chemical polishing a large quantity and variety of superconducting structures.
- This BCP part of the facility is ready and going through the safety approval. It is expected to be operational end of 06.
- An initial plans has been developed for an EP facility to be build (FY06-07) at ANL/Fermilab Surface Processing Facility at ANL.
- This facility should include the knowledge of EP from the ILC Collaboration.

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What would be the cavity preparation/testing rate with EP?

- Discuss with John Mammosser and Hasan Padamsee
- We assume one set-up each for EP, HPR, furnace, tuning system, and vertical test
- Assume one shift, and 5 working days/week
- First step: Layout a timeline for ONE cycle of operations
- Assume sufficient number of cavities in hand and
- Sufficient manpower to run an “assembly line”
- Determine the max cycle rate

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EP Steps and Durations

- Degrease (ultrasound solvent), EP 80 um (3 days)
- HPR, drying (2 days)
- H-removal, 600 – 800 C (3 days)
- Tune field flat (1 day)
- EP 10 um (1 day)
- HPR, dry (3 days)
- First stage assembly, HPR, dry (2 days)
- Final assembly, evacuation (2 days)
- 120 C bake (3 days)
- Cold test, warm up (3 days)
- Total 23 days (4 weeks)

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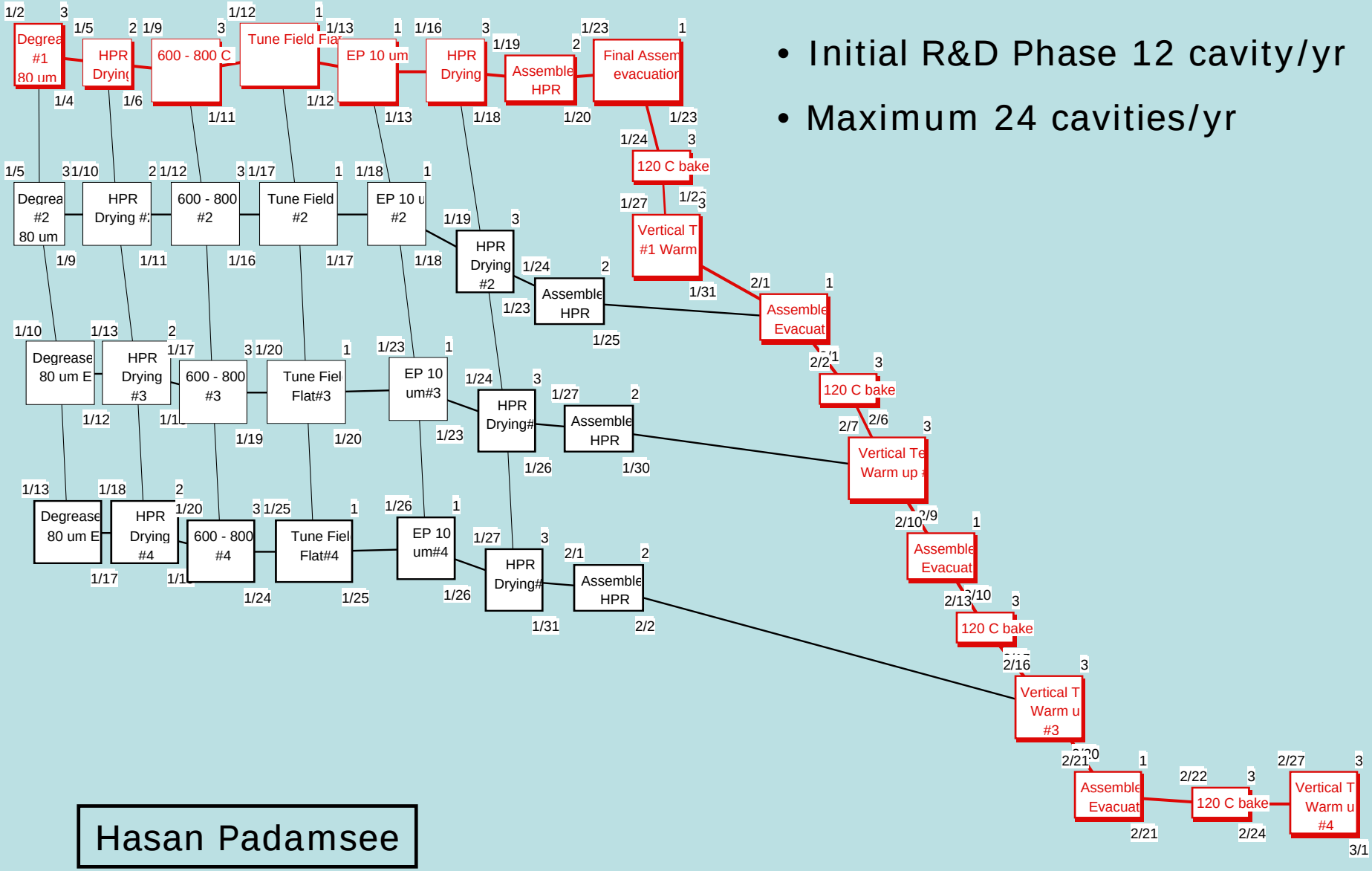
EP Timeline



- Initial R&D Phase 12 cavity/yr
- Maximum 24 cavities/yr

Hasan Padamsee

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EP Timeline: Preliminary Result

- One month to finish first cavity
- => Ramp-up rate could be one cavity/month
- Two months to finish 4 cavities
- => Assembly line rate: 2 cavities per month
- Need 6 – 7 FTEs to run the assembly line
- Cavity preparation plan should involve industry

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Model Cavity Testing

- Cavity manufacturing QC is performed at Fermilab.
- Cavity needs to be tested and tuned for field flatness and frequency. This will be done at Fermilab after initial QC and shipment to Cornell, Jlab and ANL.
- We are in process of designing and building a automated tuner based on DESY design. This will be installed at IB4 next to bead pull measurement station.
- Cavity will be vertically tested at the laboratory where it is getting processed for feed back on processing. In the case of ANL where it will get final HPR and vertical testing at Fermilab.
- Jlab can do baking. Cornell and ANL will ship the cavity to Fermilab for final bake.
- All the data from the collaborating laboratories will be collected in a common database for analysis. Fermilab is developing such a database.

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Pre-Production and Tight Loop Processing and Testing

- Fermilab is in process of developing a plan for the Pre-Production Processing and Testing Facility.
- We would be in position to discuss this plan in about two months.

- This could have several Processing (EP, HPR) facilities and capability to vertical test several cavities.

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Diagnostic: Available and Planned

- Temperature Mapping: Fermilab is in processed of developing a plan to fabricated several 9 Cell Temperature mapping device for use with Vertical Testing.
- The Vertical Testing pit has X-ray detection.
- The Fermilab Horizontal Test Facility will have Faraday Cup and all the diagnostic we have developed for the Capture Cavity 2 studies.

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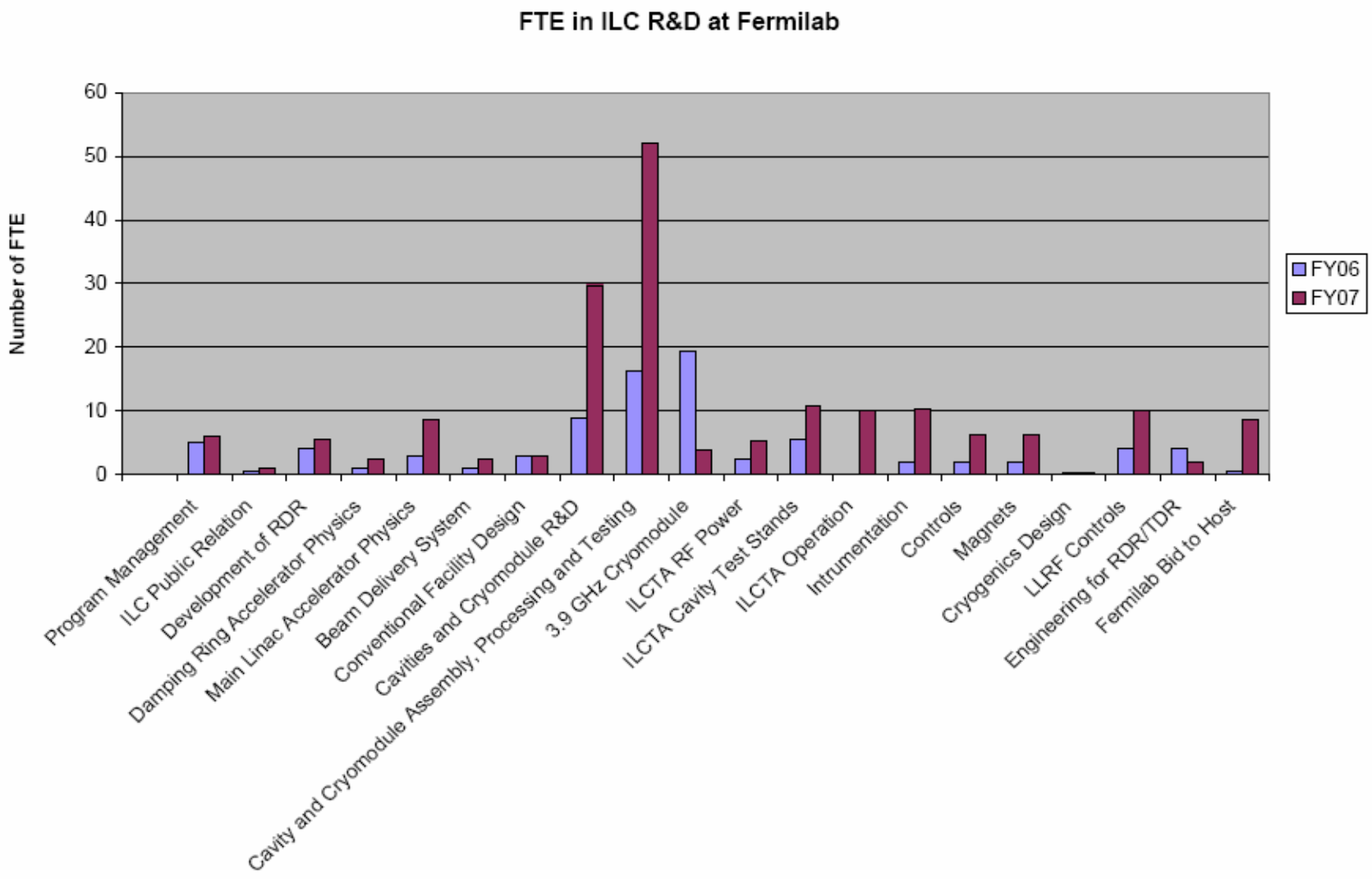
FTE in ILC R&D at Fermilab: FY06 and FY07



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More focus of Cavity R&D requires resources

- Fermilab has qualified scientists and engineers who wants to work on ILC.
- If additional resources are available we can do these in 2-3 years.
- We continue to defer investment that would be needed for more focused R&D.
  - Cavity R&D: (This is the highest R&D priority for ILC-GDE)
    - Niobium
    - More cavities fabrication at industry. We should fabricate enough to saturate the pipeline at existing and upcoming processing facilities.
    - Electron Beam Welding (This is a bottleneck in cavity fabrication)
    - Surface Processing: We need a pre-production BCP, EP and HPR system at Fermilab. This should industrial strength processing.
    - Vendor development
  - Cavity Tuning Device (A copy of DESY Design)
  - Vertical testing temperature study
  - Cryomodule Testing
  - Industrial fabrication
    - US industries could fabricate an RF unit using laboratory infrastructure.

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Summary

- US-ILC Main Linac: Cavity and Cryomodule R&D program is established to address the key technology issues.
  - Cavity Gradient
  - ILC Cryomodule design and fabrication
- R&D is focused on the Baseline design of the cavity and cryomodule.
- We are also working on alternate design for Cavity and material. But this is not the main focus of US R&D.
- We are upgrading existing infrastructure at US laboratories to cost effectively advance the R&D program on a ambitious schedule.
- We are developing infrastructure at Fermilab for cavity processing and testing and fabrication of cryomodule.