Fermilab/Argonne
Cavity Test Results

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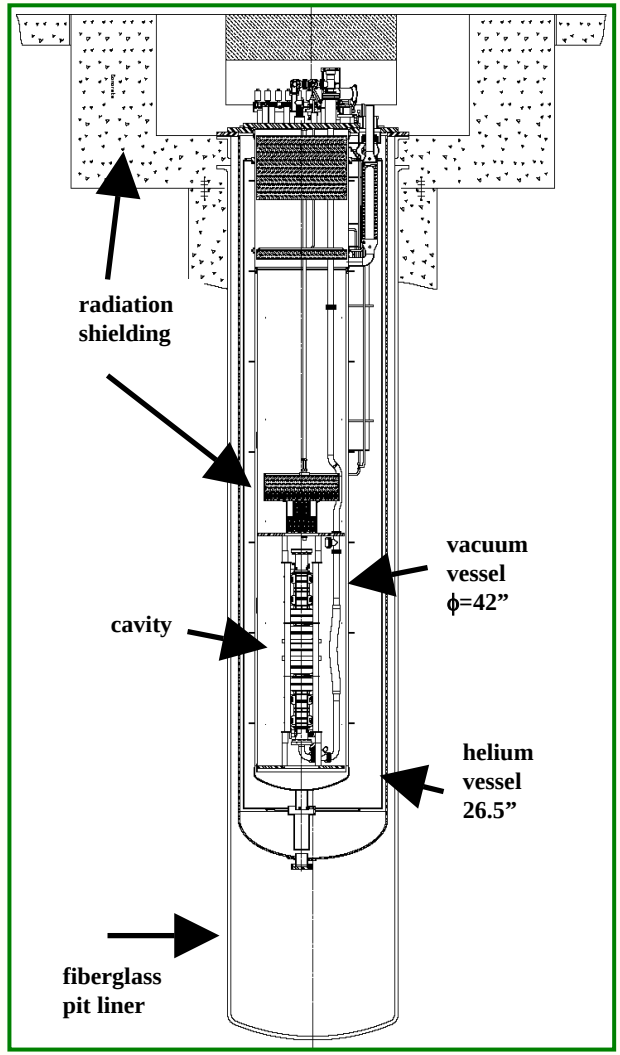
Outline

- Intro to
  - Fermilab Vertical Cavity Test Facility (VCTF)
  - Argonne/Fermilab Cavity Processing & Assembly Facility (CPF)
- Cavity test results
  - our cavity tests are tests of infrastructure or instrumentation!
    - no cavity first tests yet
  - 9-cell cavity processing was primarily done at JLab, then shipped under vacuum to Fermilab
  - 1-cell cavity first processing was done at Cornell
- Near-future plans for cavity process/tests

Fermilab VCTF

- Design
  - Existing 125W@ 2K Cryogenic plant; 1.5K minimum
  - RF system in collaboration with JLab
    - 250 W available at cavity
  - Radiation and magnetic shielding
    - < 5 mrem in an hour immediately outside the shielding <0.25 mrem/hr in normal working areas
    - <10 mG
  - Thermometry for quench location
  - Capable of testing ~50 Cavities/year
- Status
  - One Vertical Test Stand (VTS1) commissioned 7/2007
  - 17 cavity test cycles in FY08 (ILC 1- & 9-cell, SSR1)

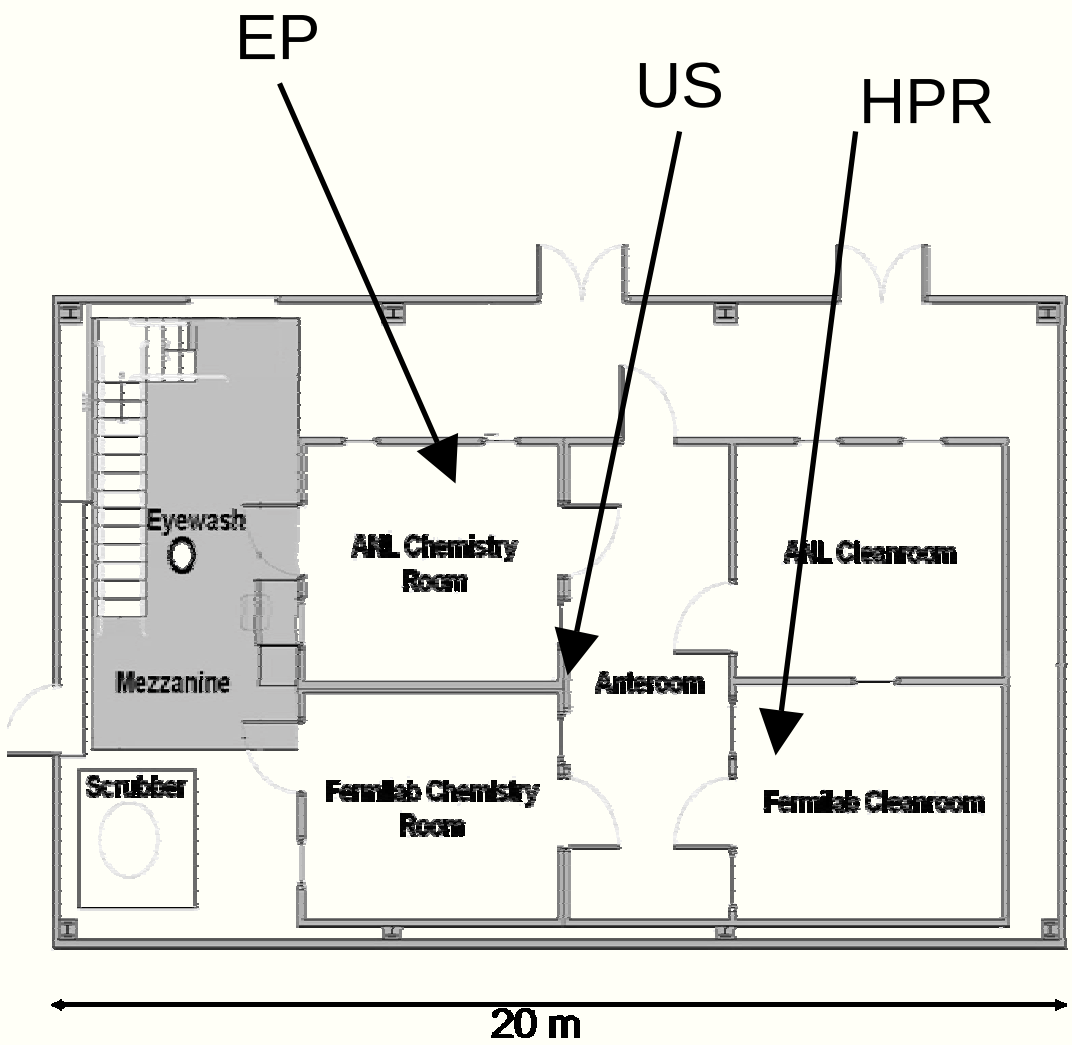
VTS Cryostat



9-cell Tesla-style cavity

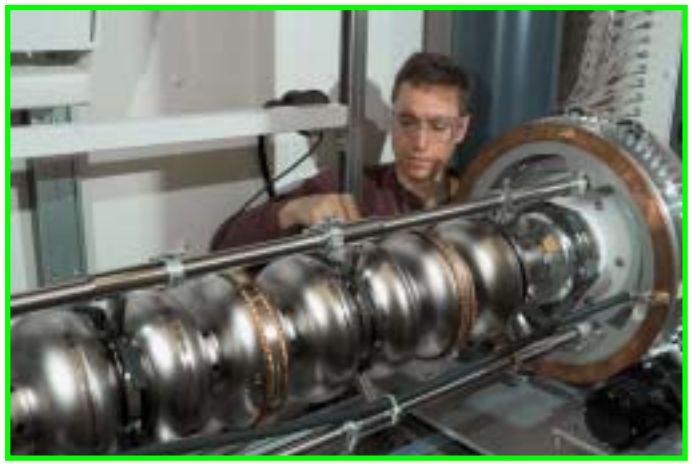
Argonne/Fermilab CPF

- Cavity processing and assembly facility
- Located at ANL; designed and built jointly
- ANL group Electropolishing (EP) of 1-cell and 9-cell ILC-style cavities
  - Accel-7 (9-cell) and two 1-cell cavities have been EP'd
- FNAL group high-pressure water rinse (HPR) tool
  - Cavity moves vertically, wand rotates
  - Instrumentation to be commissioned soon
  - Commission with a cavity Fall'08
- Cleanroom class 10, 100, 1000 in progress
- Ultrasonic (US) rinse tank for anteroom in progress
- Cavity vacuum system in progress



Argonne Electropolishing

- Accel-7 EP'd in May 2008
- Average EP material removal (ultrasound measurement)
  - equator ~ 0.866 mil (22 microns)
  - iris ~ 1.25 mil (31.9 microns)
  - beam tubes ~ 0.55 mil (14 microns)
- Sent to JLab for final cleaning/assembly/test
  - ultrasonic cleaning (Micro-90), HPR, ass'y, HPR
- ~30% E_{acc} reduction & field emission observed
- EP process of 1-cell tested at FNAL

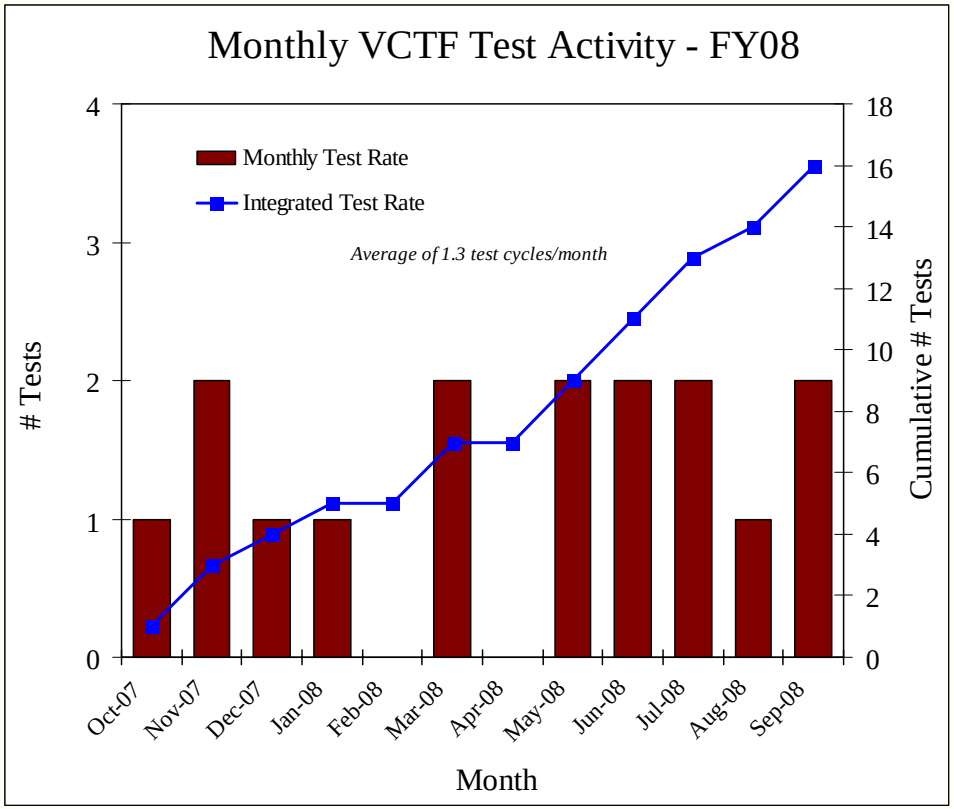


Additional infrastructure

- **Since Argonne/Fermilab CPF not fully ready, making use of Fermilab MP9 facility (cryomodule assembly) and A0 facility (3.9 GHz facility)**

FY08 VCTF Test Cycle Summary

- "test" = cryogenic thermal cycle
- Includes 9-cell cavities, single-cell cavities, and SSR1 HINS cavity
- One 1-cell test in Sep.08 is not shown



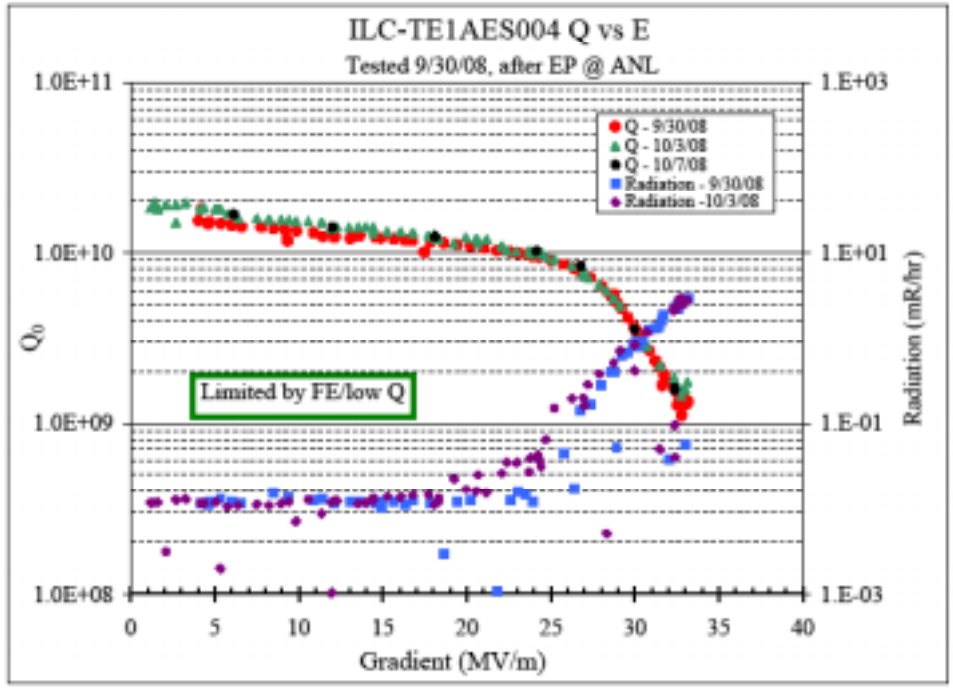
FY08: Oct 2007-Sep 2008

FY08 major infrastructure work

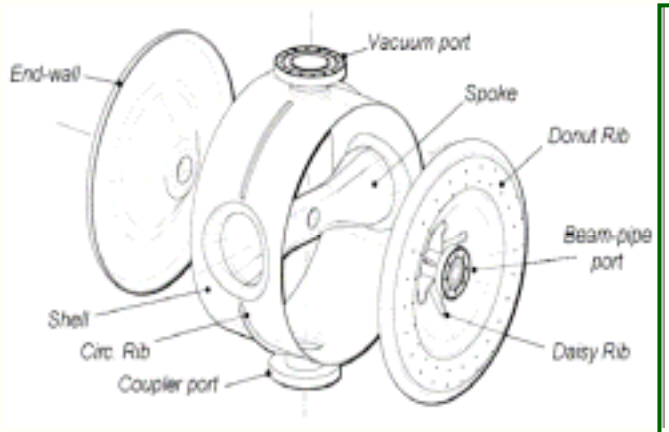
- **Inner magnetic shield installation**
- **Active cavity vacuum pumping**
- **Permanent "Fast Thermometry" system deployment at VTS1**
- **Adaptation for 325 MHz HINS SSR1 cavity test support**
- **Variable input power coupler**

Single-cell cavity tests

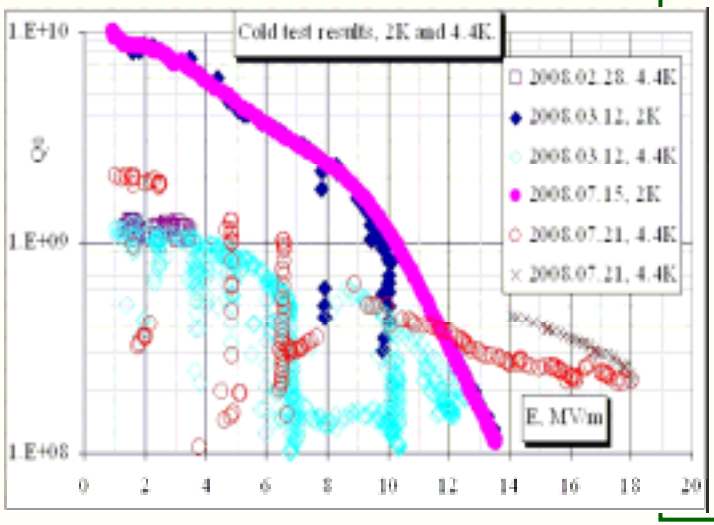
- **TE1AES004**
  - **BCP'd and tested at Cornell in Dec.2007, reaching Eacc~25 MV/m with the limitation of Q-slope**
  - **EP'd at Argonne, HPR at A0, ass'y at MP9**
  - **33 MV/m limited by field emission, after processing of multipacting barrier and field emission**
- **Also, 1-cell version of 9-cell thermometry commissioned**



Single-spoke resonator tests

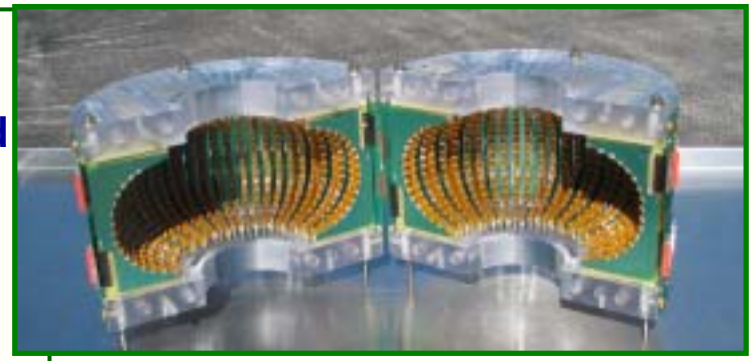


- SSR1 cavity for HINS/Project X
- Requirements/Design parameters
  - 10 MV/m with Q_0>5×10^8
  - Operating temperature is 4K
  - 325 MHz
  - manufactured by Zanon
- Process
  - BCP (120 μm) and HPR at Argonne (the not-new facility)
- Three test cycles (no BCP/HPR)
  - Initial trouble with cavity vacuum, multipacting, and probably insufficient drying
  - Final Eacc~18 MV/m with Q_0~2×10^8

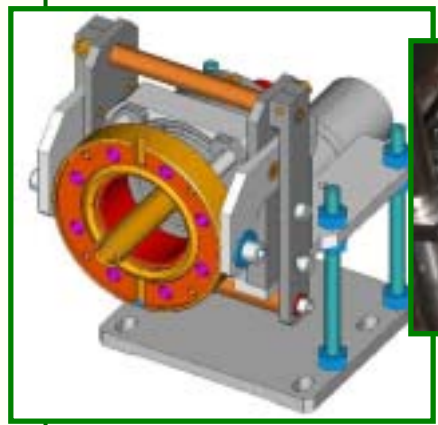


Test instrumentation

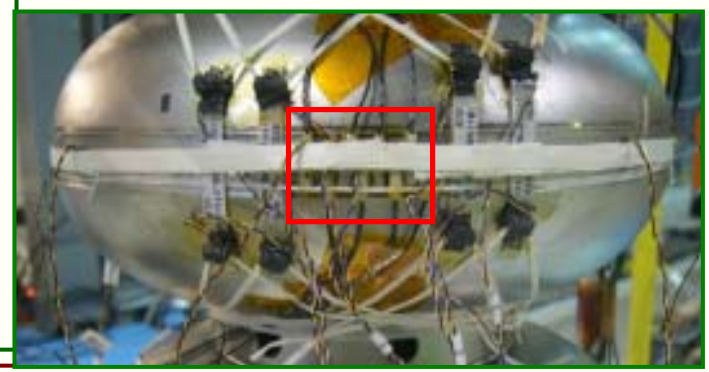
- 9-cell thermometry
  - Measure temperature rise, not absolute temperature, in a comprehensive pattern around each of the 9 cells, all 9-cells tested in a single step
  - Fast installation; use for “every” 9 cell test
  - First test of 1-cell version Sep.2008



- Variable RF input coupler
  - Keeps cavity critically coupled; facilitates mode meas.
  - Mounts to standard input coupler port; uses cryogenic motor
  - Movement range $\Delta R \sim 15$ mm (equiv. 2×10^{9} ☜ Qext ☜ 4×10^{10})
  - Tested twice; installation procedure under development



- “Fast” thermometry
  - Cernox RTD sensors flexibly placed, depending on test requirements, with G10 band/nylon thread & Apiezon grease for mounting
  - Well tested, reliable system; used in all cavity tests

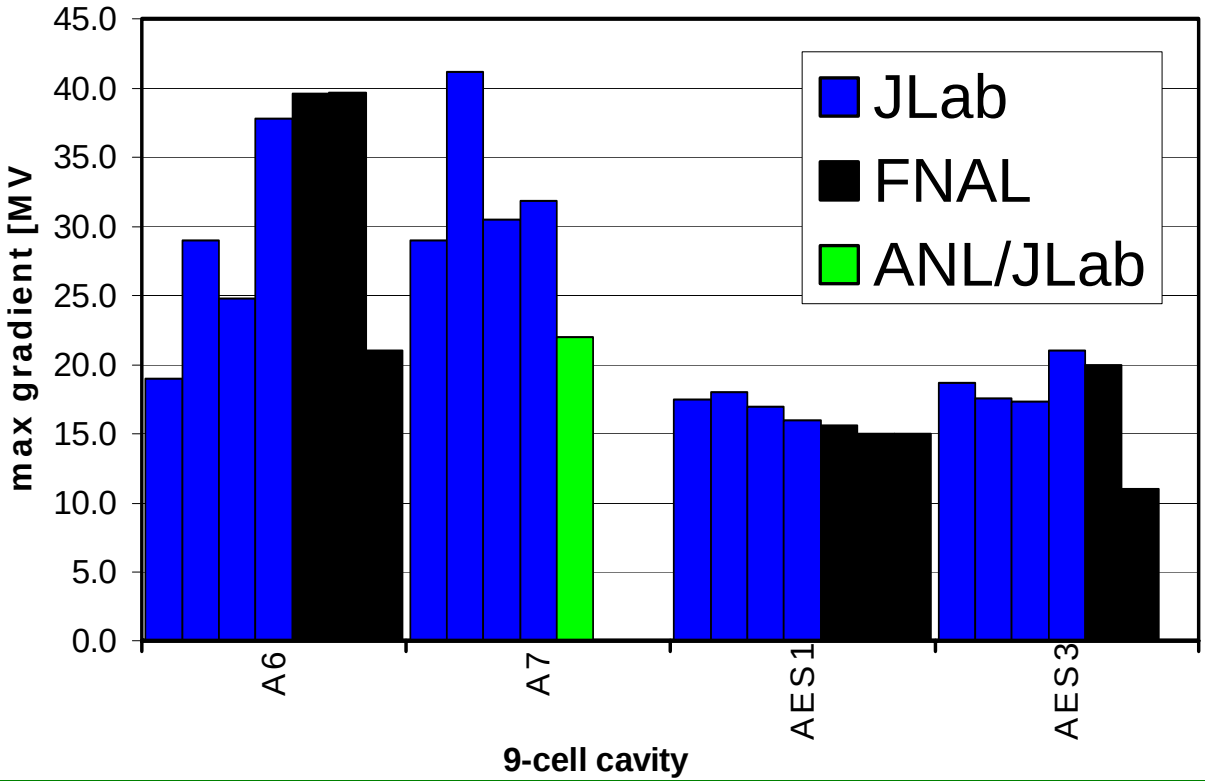


9-cell Cavity Tests at FNAL

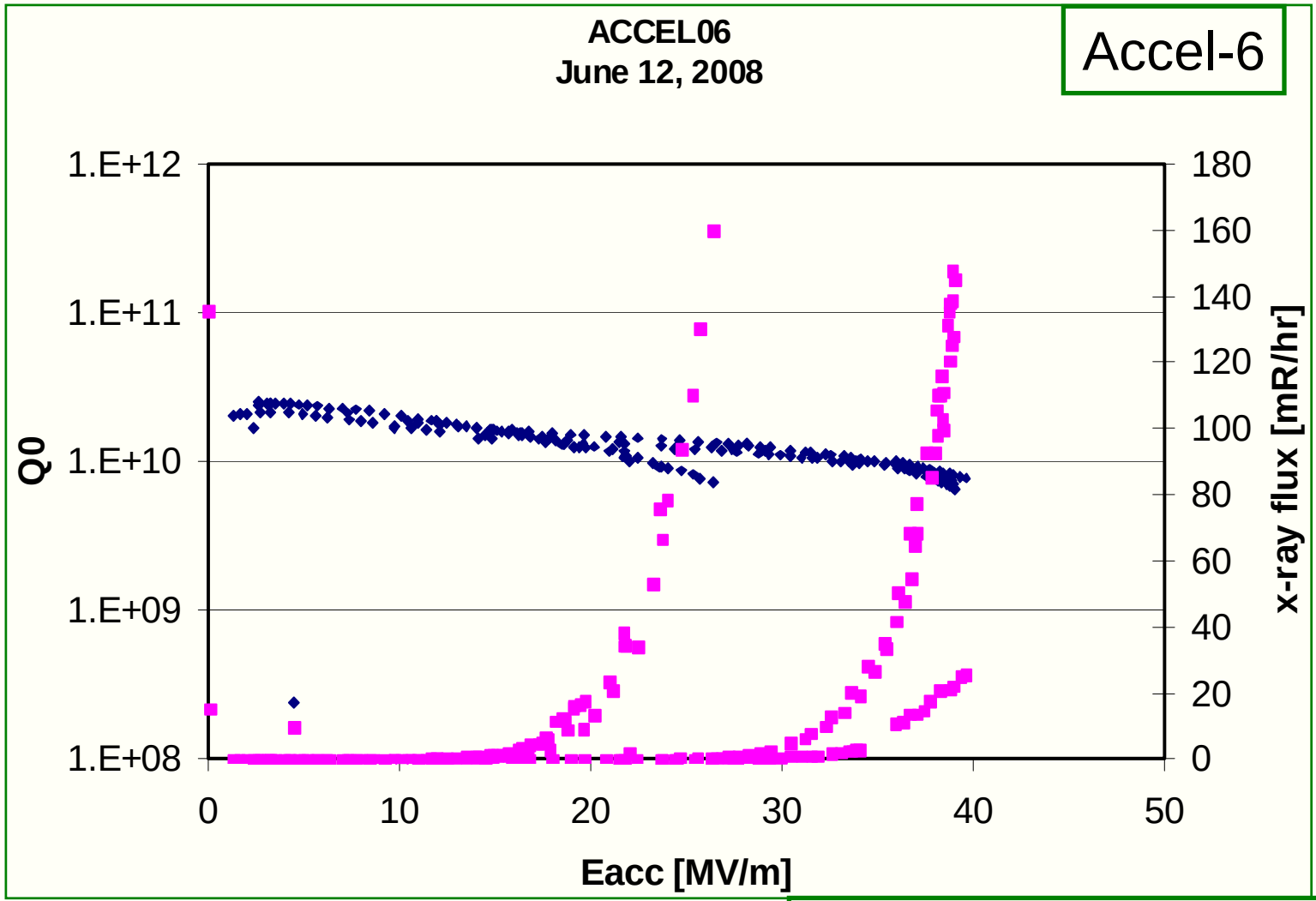
- **Accel-6**
  - Three thermal cycles
  - First test cycle: Eacc~39 MV/m
  - Second test cycle: Eacc~39 MV/m; first test of cavity vacuum active pumping
  - Third test cycle: Eacc~21 MV/m; field emission induced (variable input coupler)
- **AES1**
  - First 9-cell ILC-style cavity tested at FNAL, Sep.'07
  - Three thermal cycles: Eacc~15 MV/m
  - Fast Thermometry and mode measurements were used to find isolated and repeatable quench locations
- **AES3**
  - Two thermal cycles
  - First test cycle: Eacc~20 MV/m
  - Fast Thermometry and mode measurements were used to find isolated and repeatable quench locations
  - Second test cycle: Eacc~11 MV/m; field emission induced (variable input coupler)

9-cell Cavity Test Summary

- 7 nine-cell cavity tests at FNAL VTS (black)
  - Processing primarily done at JLab, so previous JLab tests of these cavities are included for comparison (blue) [R.L. Geng et al., SRF2007, Beijing]
- Test at JLab of ANL EP'd cavity (green)



Best-Cavity Test



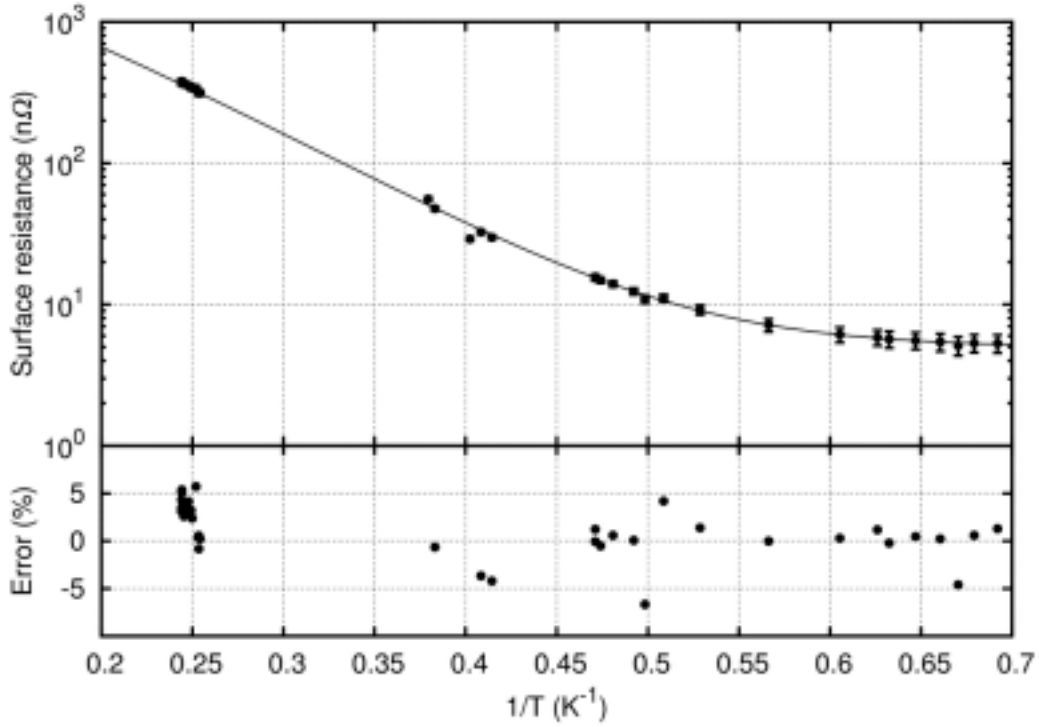
40 MV/m; quench limitation

Q vs. T Measurement

- Accel-6
  - 9-cell ILC-style cavity manufactured by Accel
  - Wah Chang niobium, measured RRR ~500
- Q_0 measured as a function of temperature from 4K down to 1.42 K, G=270Ω
- Data below T_λ fit to

$$R_s = \kappa \times \frac{1}{T} \times \exp\left(-\beta \frac{1}{T}\right) + R_{mag}$$

- R_s=4.97⊁0.16 nΩ



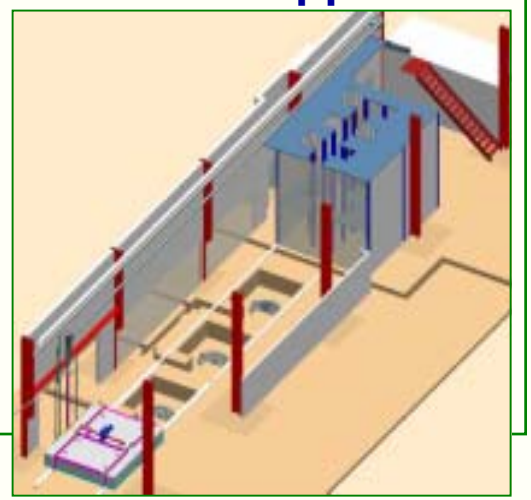
Vertical test cryostat works well as designed

VCTF upgrade plans

- Cavities to accommodate
  - ILC/SRF R&D
    - 9-cell and 1-cell elliptical ILC cavities
  - HINS/Project X
    - SSR1
    - SSR2
    - TSR

    } Do not fit in VTS1
    - 9-cell elliptical cavities
- Conclusion
  - VTS1 is sufficient to support FY09, FY10 test plans
  - VTS2 with larger diameter operational by ~Dec. 2010 to support SSR2, TSR, and increased throughput
  - VTS3 needed by ~Sep. 2011
- Planned upgrades
  - 2 cavities at a time
  - Cryogenic system & infrastructure upgrades
  - Plan for two additional VTS cryostats
    - Ultimate capacity ~ 250 cavity tests/yr

Plan 2 more VTS pits & staging area



Conclusions

- 17 cavity tests at Fermilab VCTF in the last year
  - one 1-cell, three 9-cell Tesla-shape (1.3 GHz)
  - single-spoke resonator (325 MHz)
- Commissioning of ANL/FNAL cavity processing facility and infrastructure required to prepare cavity for test
  - It works – excellent achievement by many people
  - Field emission to be overcome
- Commissioning of instrumentation
  - 9-cell thermometry: 1-cell version first full system test complete
  - variable coupler: two full system tests, installation/cleaning need work (field emission)
- Vertical test cryostat works great
- Facility upgrades underway to increase throughput and accommodate future cavities

Thanks

- The presented work is a great coordinated effort by many people
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