FNAL/ANL Cavity R&D Status

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On behalf of the FNAL/ANL Cavity Crew

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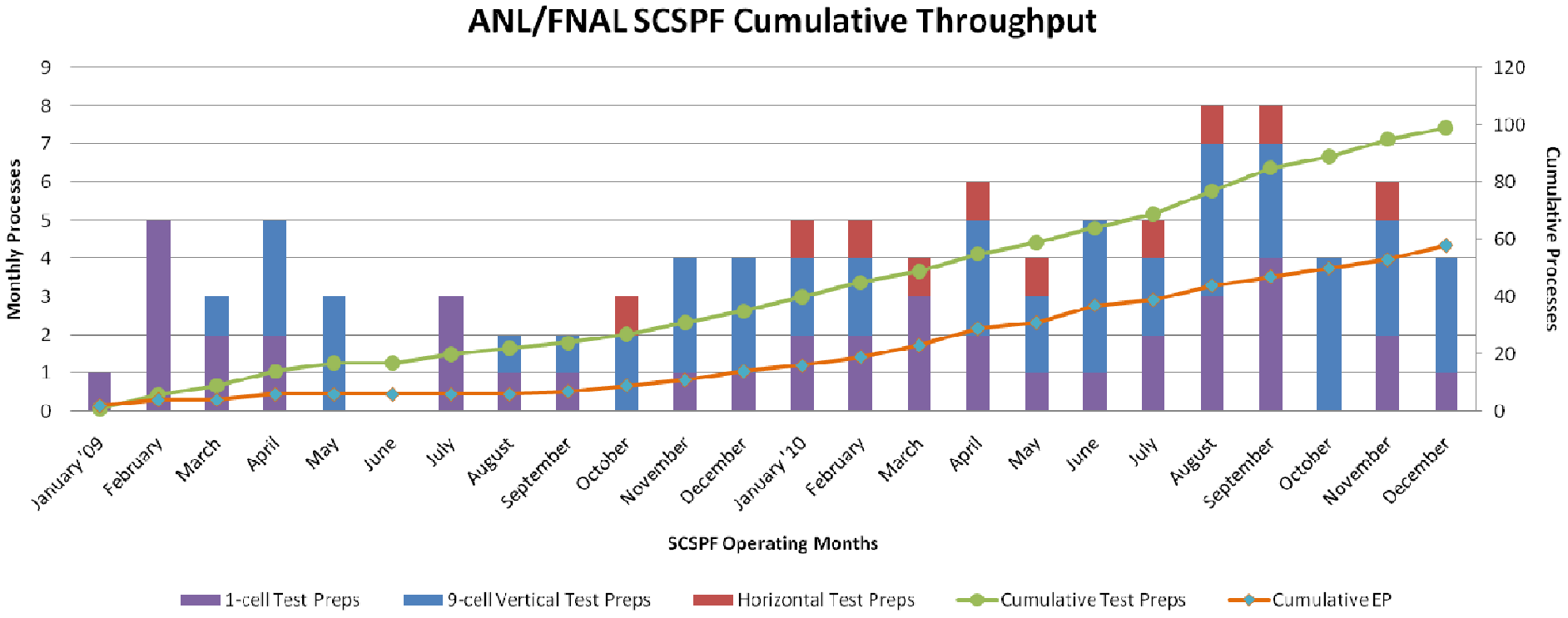
Overview

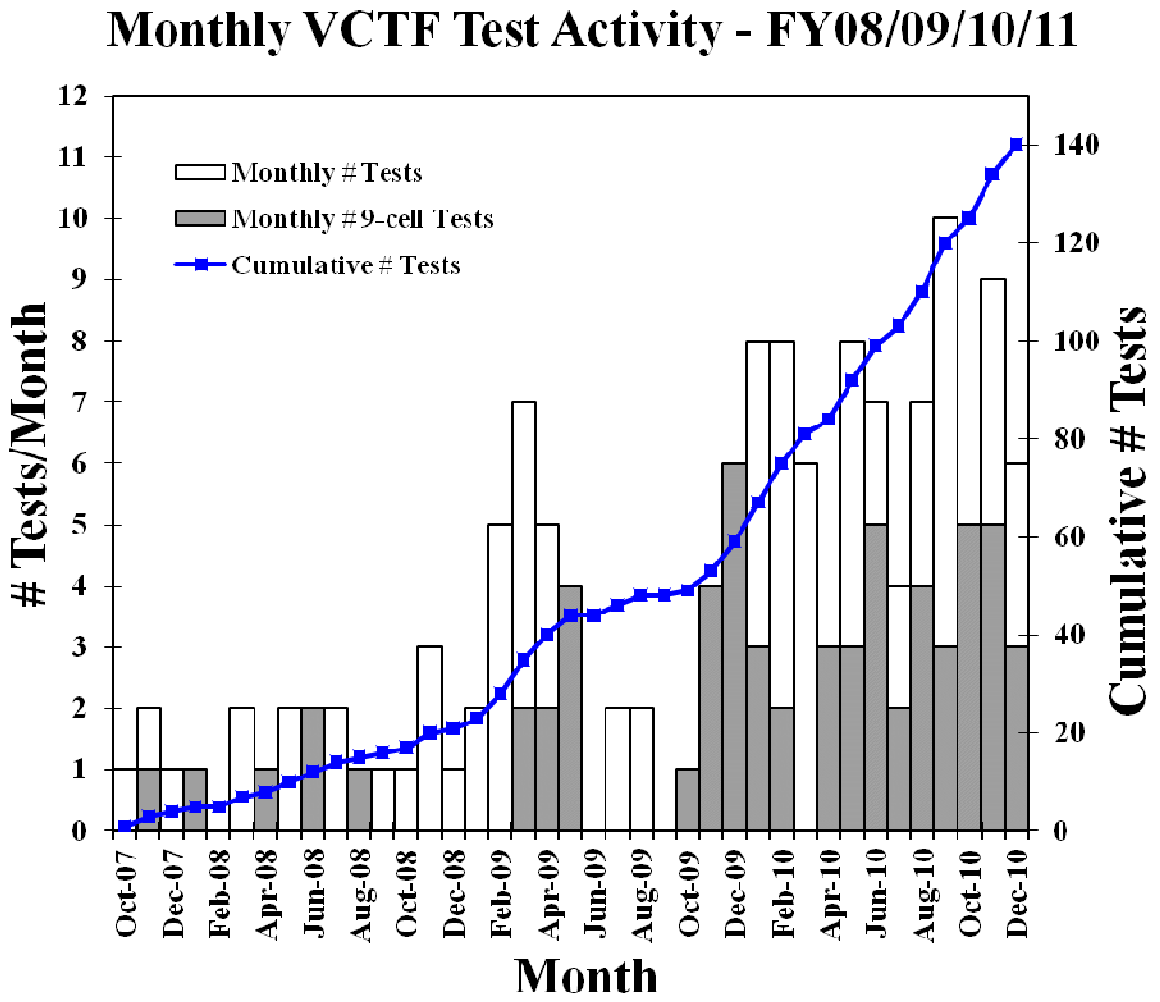
- SRF activity at FNAL/ANL is in support of ILC, Project X, or other future SRF projects, including vendor development and associated cavity R&D for improved performance
  - maximize Q0 at moderate gradient ~15-20 MV/m
  - maximize gradient
  - study differences of 1300 MHz pulsed with respect to 650 MHz CW
- 6 cryomodules shall be built in the next few years, including CM1 (DESY kit). Preparation of cavities and assembly infrastructure for CM2 is ongoing.
- Recent selected cavity performance results to be shown
- R&D topics to be briefly described

FNAL/ANL Processing Throughput



- **CY2010 :** 44 EP's, 23 1-cell vertical test preps, 32 9-cell vertical test preps, 9 (9-cell) horizontal test preps

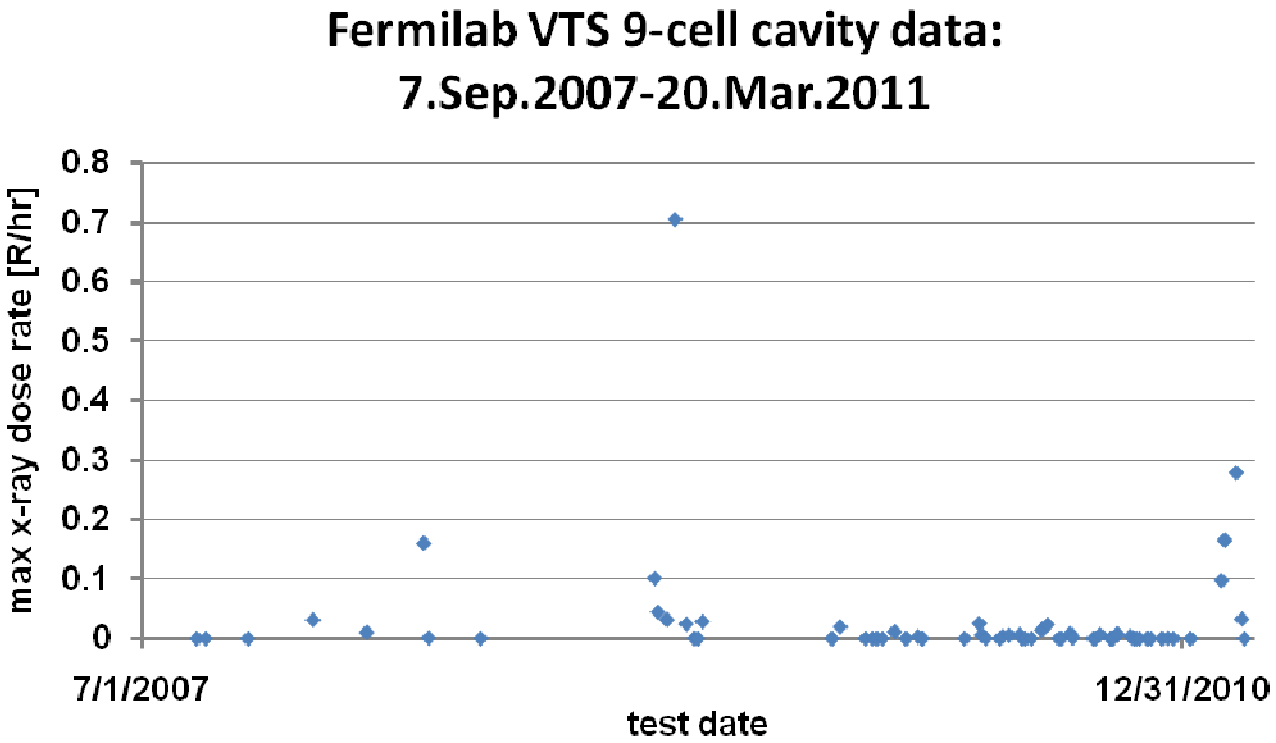
Vertical Test Throughput



- **CY2010:** 81 vertical tests
  - 38 9-cell tests, 39 1-cell tests, and 4 R&D cavity tests

FNAL/ANL Process: FE

- FE well managed on 9-cell vertical tests and 1-cell tests
- Since Nov. 2009, only few 9-cell cavities with persistent FE problematic
- Cavity performance limits generally not FE related
- HPR alone has shown FE mitigation



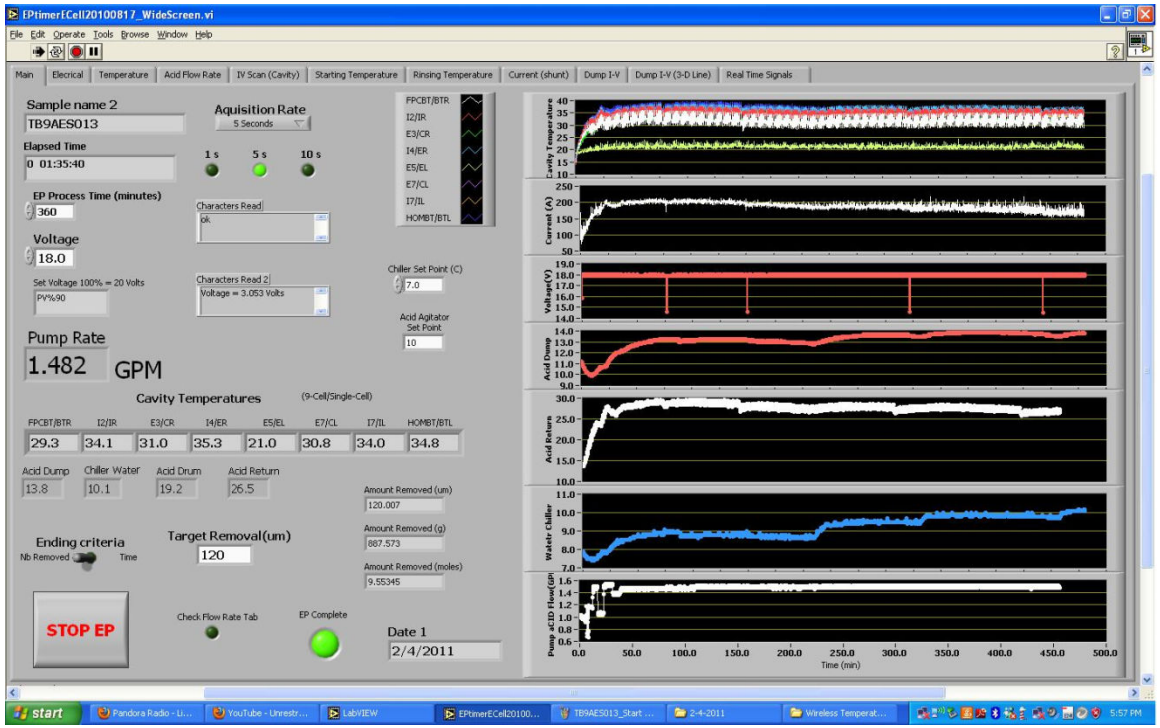
NB: contains also JLab-processed cavities

Nominal background level <~few E-5 R/hr

❑ Conclusion: HPR and assembly/post EP sequence being performed well, but problems also pop up along the way despite careful efforts

FNAL/ANL Process: EP

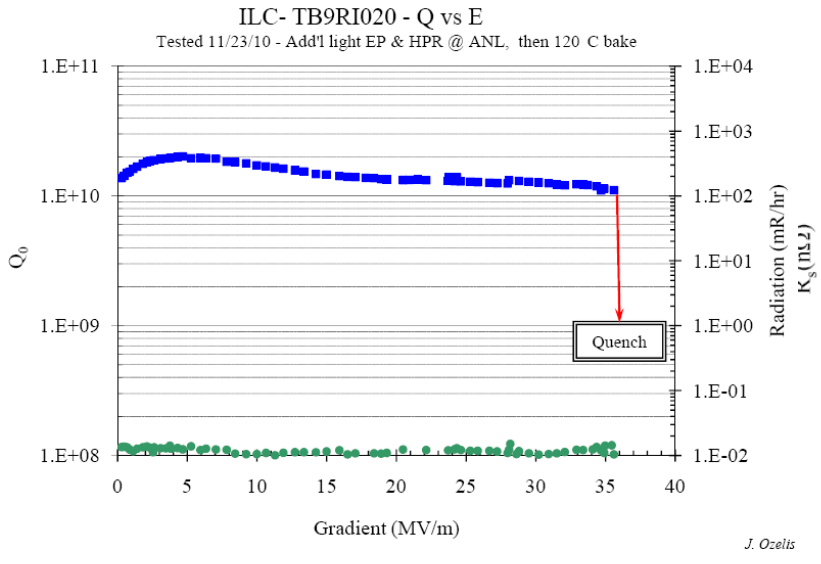
- EP parameters were varied during 2010 in response to ILC/S0 study
  - Start: high voltage, high temperature [18V, 30-35°C @equator]
  - After ILC/S0 study: low voltage, low temperature [14.5V, 25-30°C @equator]
  - Final parameters: high voltage, low temperature [18V, 25-30°C @equator]
- FNAL/ANL final EP recipe works well, with some cavities reaching ILC spec. performance
- Process is stable and reproducible, with key parameters monitored

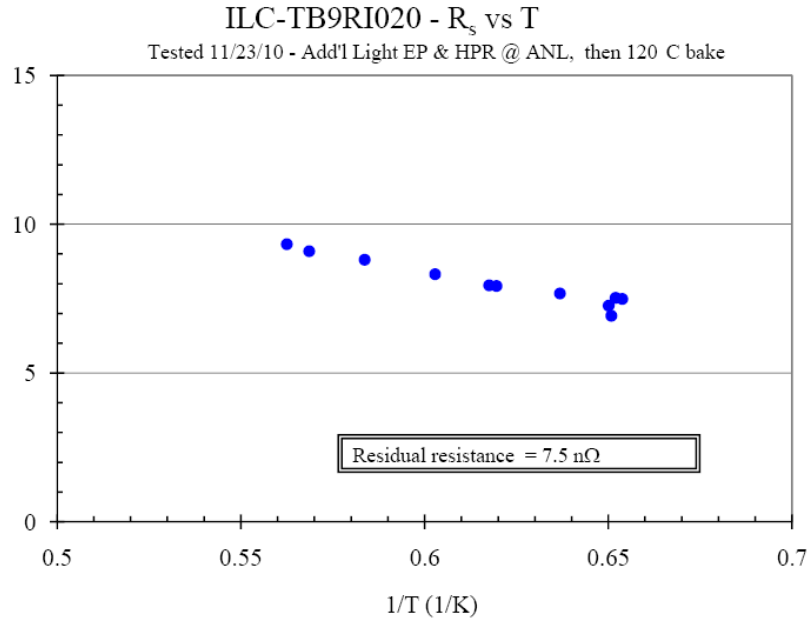


cavity temp
current
voltage
acid dump temp
acid return temp
water chiller temp
pump acid flow

FNAL/ANL Process: Performance

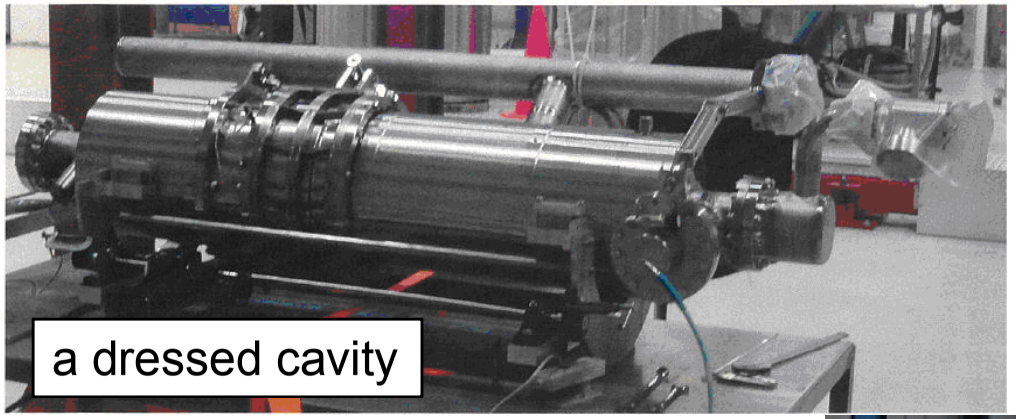
- **TB9RI020:** 1st fully qualified ILC spec cavity through FNAL/ANL facility
  - Qualified after 2nd EP process
  - Low T, high V on last light EP
  - Rs=7.5 nOhm, Eacc,max=36.1 MV/m, Q0 at max gradient=1.1E10, no FE >background
- **TB9RI029**: 1st cavity qualified with RI bulk-EP and FNAL/ANL light EP
  - Qualified after 1st EP process
  - Low T, low V on last light EP
  - Rs=5.8 nOhm, Eacc,max =34.6 MV/m, Q0 at max gradient=1.2E10, no FE >background

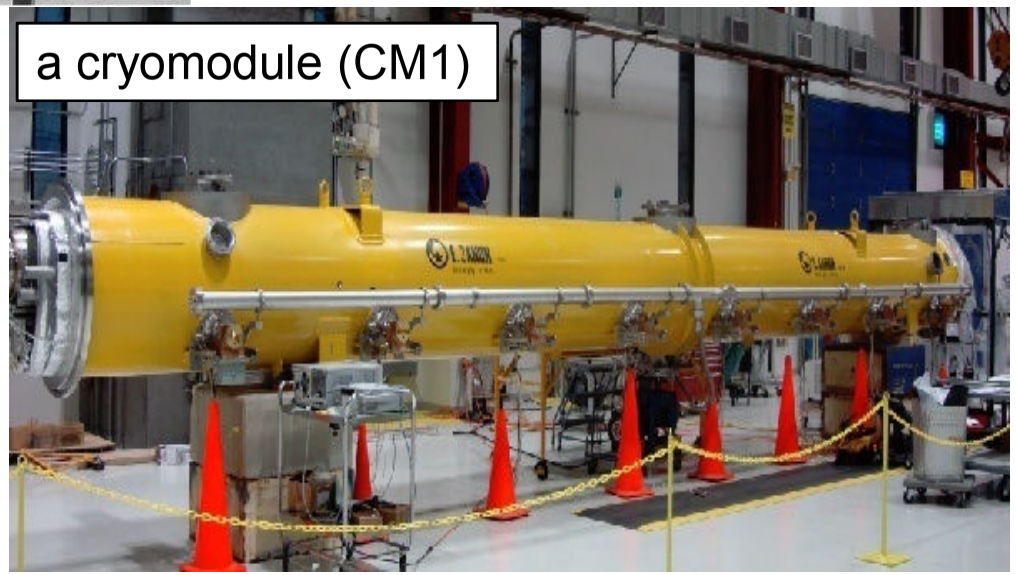




Cavity Dressing and CM Ass'y

- 17 cavities have been dressed for CM2 and subsequent CM's


a dressed cavity


a cryomodule (CM1)

Cryomodule Cavities

- **Three ILC-qualified cavities are CM ready at MP9**
  - **TB9AES009** (dressed) – **CM2#1 [VT 36 MV/m, HT 35 MV/m]**
  - **TB9AES010** (dressed) – **CM2#2 [VT 38 MV/m, HT >35 MV/m]**
  - **TB9AES008** (dressed) – **CM2#3 [VT 41 MV/m , HT >35 MV/m]**
- **Two lower performers are CM ready at MP9 and are held as backup**
  - **ACCEL8** (dressed) – **CM2-backup [VT 31 MV/m, HT 31 MV/m]**
  - **TB9AES007** (dressed) – **CM2-backup [VT 42 MV/m, HT 33 MV/m(FE)]**
    - VTS FE turn-on 20 MV/m, HTS FE turn-on at 21 MV/m
- **One was tested in HTS, with additional cavity vacuum tests**
  - **TB9RI018** (dressed) – **CM2-candidate#4 [VT 39 MV/m, HTS >35 MV/m]**
    - Limited by field emission in second test after vent/evacuation cycle
- **One cavity is dressed and ready for HTS next**
  - **TB9RI019** (dressed) – **CM2-candidate#5 [VT 38 MV/m]**
- **Four cavities are dressed & will on HTS time scale get ANL HTS prep**
  - **TB9RI028** (dressed) – **CM2-candidate#6 [VT 39 MV/m]**
  - **TB9RI020** (dressed) – **CM2-candidate#7 [VT 36 MV/m]**
  - **TB9RI027** (dressed) – **CM2-candidate#8 [VT 40 MV/m]**
  - **TB9RI024** (dressed) – **CM2-backup [VT 40 MV/m]**

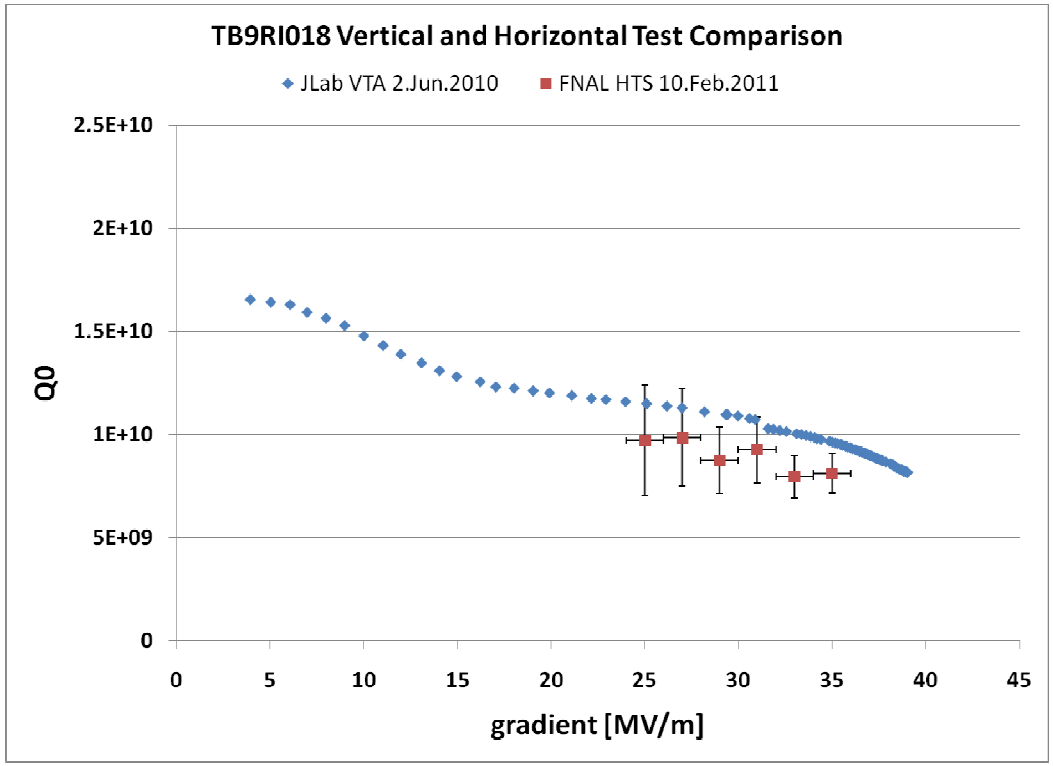
FNAL /ANL process

Most qualified cavities for CM2 received process/test at JLab

Vertical / Horizontal Test

- Have completed 9 horizontal tests of 1.3 GHz 9-cell cavities
- Some difficulty with field emission being addressed
- Procedurally limit to 35 MV/m in HTS
- Good agreement between vertical and horizontal test performance
- More studies of VT/HT performance comparison underway, in collaboration with JLab

Cavity ID	CM2 candidate	VT [MV/m]	Horizontal Test
TB9AES009	1	36	35 MV/m
TB9AES010	2	38	>35 MV/m
TB9AES008	3	41	>35 MV/m
TB9RI019	4	38	next
TB9RI024	5	36	
TB9RI028	6	39	
TB9RI020	7	36	
TB9RI027	8	40	
ACCEL8	backup	31	31 MV/m
TB9RI029	backup	35	29 MV/m
TB9AES007	backup	42	33 MV/m(FE)
TB9ACC013	repair	38	FE limit(Cu)
TB9ACC016	repair	39	FE limit(Cu)
TB9RI018	repair	39	35 ->20 MV/m (FE)



Dressed Cavity Remediation

- One cavity with simple performance degradation seen in horizontal test
  - **TB9RI029** (dressed) - **CM2-backup [VT 35 MV/m, HT 29 MV/m]**
  - Study VT/HT correlations
  - Cavity to be retained as hot spare
- Two cavities had potential copper contamination
  - **TB9ACC013** (dressed) **CM2-backup [VT 38 MV/m, heavy FE in HT]**
    - Bad FE after arc event at HTS. After HPR and re-HT, FE still a problem. FE onset 5 MV/m, 20 MV/m max. Defect seen on copper coating of inner rim of input coupler flange. Optically inspected coupler region with Questar system, saw nothing unusual.
  - **TB9ACC016** (dressed) **CM2-backup [VT 39 MV/m, heavy FE in HT]**
    - Bad FE seen in HT. FE onset 18 MV/m, 27 MV/m max. Copper flakes found on input coupler antenna tip. Std optical inspection with KEK/Kyoto system; no obvious problem observed
  - **Plan**: helium two-phase pipe removal, HPR+VT for baseline measurement, HNO3 rinse (ANL)+VT
- Dressed EP technique developed
  - **TB9AES002 (dressed) R&D cavity**
    - First demonstration of repair technique
    - Improved performance by ~50% in gradient (from 19.8 MV/m to 28.5 MV/m)

9-cell Cavity Process Development

- **FNAL/ANL process as described is baseline for ILC 9 cell cavities**
  - Continue to look at improvements in base process, alternative process techniques, and repair techniques
- **Generate infrastructure for 9-cell chemical rinse at FNAL/ANL facility**
  - May be useful as part of cavity repair (laser-remelting, etc.) or tumbling process
  - HNO3, HF are some of the options
  - Only very light rinse, e.g., <<10 um, will be possible: no process temperature control [(over-)fill with chilled low concentration acid, hold, dump]
  - Ready now
- **Tumbling**
  - One R&D cavity done, promising results
  - One R&D cavity done, field emission limited (limit likely unrelated to tumbling)
  - One repaired cavity in progress
  - One fresh cavity in progress
- **New vendor qualification (collaboration with JLab)**
  - First pass process/test of two NR cavities is complete; moderate results; will do a 2nd pass but no rush since next four cavities are on the way after lots of feedback
- **Laser re-melting**
  - One cavity in progress
- **Localized grinding (collaboration with KEK)**
  - AES003 was improved
  - Two cavities recently returned from KEK, to be VT prepped and tested at FNAL

More 9-cell Cavities in the Pipeline

- In the upcoming weeks and months we will process and test in collaboration with JLab and Cornell
  - Two remaining from an RI batch of 12, received RI bulk-EP
  - Four remaining from an AES batch of 6, received 10-15 um BCP at AES
  - Four remaining from a Niowave-Roark batch of 6, received light BCP at NR, arrived first week of March
- In the longer term 40 ARRA cavities from AES, NR, and PAVAC are due in the timeframe CY2011-2012

*=bulk-EP'd at RI

1-cell R&D topics

- Cavity repair: tumble polishing, laser re-melting
- Manufacturing/quality assurance optimization
  - Eddy current scanning investigation
    - Study effect on defect of multiple processes
    - Optimize benefits of ECS
  - X-ray tomography – with external companies
  - Cavity vendor/collaborating institution qualification: RRCAT, PAVAC, Niowave-Roark
- Cavity processing R&D
  - Tumble polishing
  - CABOT: chemical mechanical polishing
  - Faraday Technologies: pulse-pulse-reverse EP with dilute sulfuric electrolyte
  - Skipping unnecessary process steps
- Basic SRF R&D
  - Understanding medium- and high-field Q-slope, associated with process type
  - Materials science of hot and cold spots using cut-outs
  - Optimization of RF surface properties: surface morphology, contamination, coatings, ...
  - Studies of performance as a function of surface finish, using tumbling

Summary/Plans

- FNAL/ANL processing/preparation/test facilities working well
  - VTS2 delivery expected soon, VTS3 later in CY2011, HTS2 later
- Bare cavity processing throughput targets for CY2011 represent a 25-30% increase over 2010 : 75-80 test preparations and 55-60 EP cycles,
- For now, aim to get high quality cavities qualified and into cryomodules
  - Tumbling development is high priority
  - Dressed cavity improvement also high priority
  - Understand cavity performance changes between CM preparation stages
- For the future, effort increased to understand and improve medium field Q-slope to reduce power dissipation for CW operation for Project X