Gradient Yield

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Gradient Limiting Factors – 1/4

- Field emission
  - Much reduction is seen by alcohol rinsing and ultrasonic cleaning w/ detergent (USC)
  - Still present sometimes
    - FE means reduction in Q0 (increase in cryogenic load) and/or dark current
    - Acceptable FE loading for ILC yet to be defined (DESY has example for XFEL cavities)
    - Measure should be developed for FE monitoring during cavity vertical test, that can be translated to dark current
    - Understanding expected to continue and further reduction seems possible. Recent example at JLab: first 9-cell test of a 9-cell cavity up to 40 MV/m without X-ray.
  - Re-cleaning (USC+HPR) is available as a counter-measure
    - Effectiveness found in all cases studied at JLab
    - DESY seems to have similar experience
    - Need to track and quantify effectiveness
  - FE performance in cavity string
    - This is what matters in the end
    - Need to establish relationship with respect to FE vertical test performance

Gradient Limiting Factors – 2/4

- Q-drop
  - Reliable counter measure well established
    - For the so called "high-field Q-slope"
    - Baseline procedure 120C X 48 hours "in-situ" bake
    - (despite lacking understanding of why it works)
    - Useful R&D (for example "fast baking") seems to have discontinued
  - Another class of Q-drop
    - Observed in multiple cases
    - Caused by "abnormal" EP conditions (excessive water or too much acid flow)
    - This should be preventable by EP process parameter control
    - It is also shown this class of Q-drop is treatable by re-EP
  - Long term stability
    - Q-drop seems not to be re-introduced by storage or re-assembly
    - This means vertical test qualification is all one needs

Gradient Limiting Factors – 3/4

- Q-disease
  - Reliable counter measure well established
    - o Vacuum furnace treatment after bulk EP
    - o This removes hydrogen from niobium
    - o May also entail some (beneficial) metallurgical effect
  - Process variability
    - o There are three variants (600-800CX10-2 hours)
    - o Measurements should be done to find the correct optimal (may be dependent on the starting niobium material) for hydrogen removal as well as metallurgical properties
    - o Some material properties may be of interest for pressure code conformity?

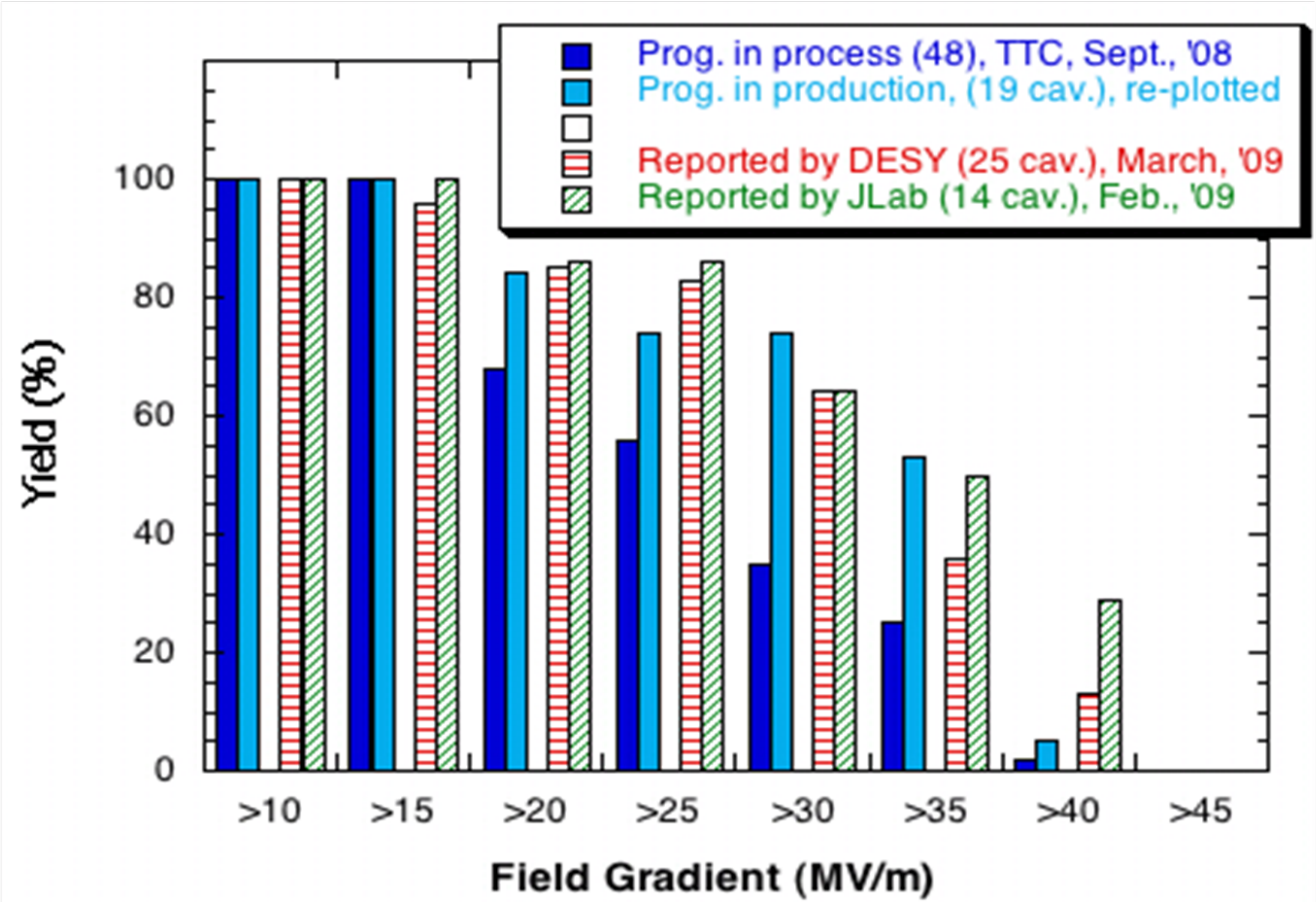
Gradient Limiting Factors – 4/4

- Quench
  - Many recent cases have to do with defect near equator
    - Responsible for "yield drop" near 20 MV/m
    - Quench/defect correlation made by T-mapping and optical inspection
    - Usually strong pre-cursor heating
    - Re-EP seems to have little effect
    - Most likely cause is material/fab
    - Intensive studies underway (particularly for new vendor cavities)
    - Understanding and solution likely to benefit any future SRF project
  - Another class of quench
    - Happens ~ 30 MV/m level; not very often but observable
    - No observable feature at quench location
    - May not have pre-cursor heating
    - Re-EP raises limiting gradient (in one case at JLab)
  - Counter measures
    - Should be developed for treating cavities failling first-pass qualification (more later)
    - One example (tumbling) already shown at Cornell
    - Other methods (local grinding, local e-beam re-melting) being explored
    - In the mean time, feed back to cavity vendor for defect prevention by QA/QC

Gradient Yield

- Processing yield vs. production yield
  - Lessons learned
    - o Yield can be pessimistically lowered by repeated EP processing of candidate cavity (example next slide)
    - o For various reasons: physical defect from mat/fab not effectively removed by EP; facility failure/human error (process complexity & many critical steps)
  - What counts is production yield
    - o Particularly the first-pass production yield
    - o It has been shown cavities from some vendor have (significant) advantage
    - o The first-pass production yield of cavities from “qualified” vendor should serve the purpose of the “best possible” yield
    - o A small (cavities processed at JLab & DESY) data set is now available; more statistics expected in view of new cavity orders (for example FNAL’s order of >=12 cavities)
  - Second-pass production yield
    - o Given the cost for cavity construction, first-pass result is a decision point
    - o Re-work or reject?
    - o Re-working may take different path (data driven): re-HPR; re-EP, repair & re-process
    - o In the current R&D phase, we may need to develop a re-work strategy

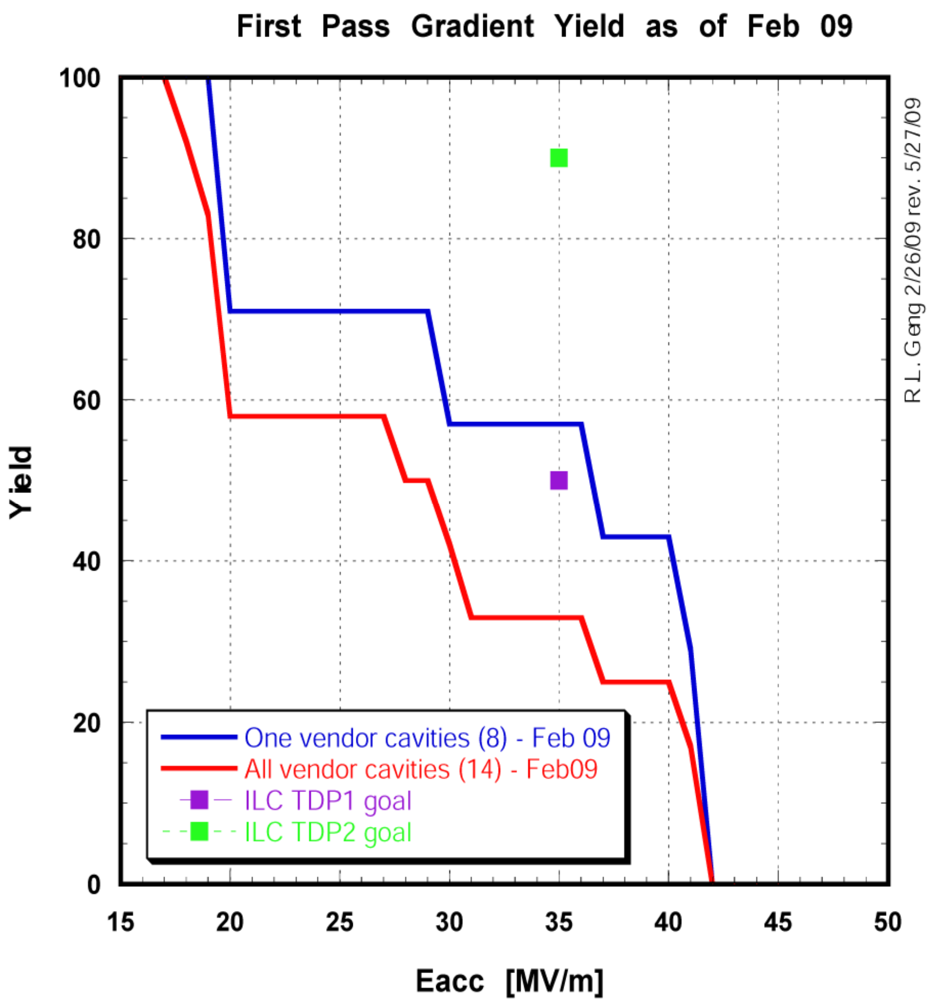
Recently Reported Gradient Yield

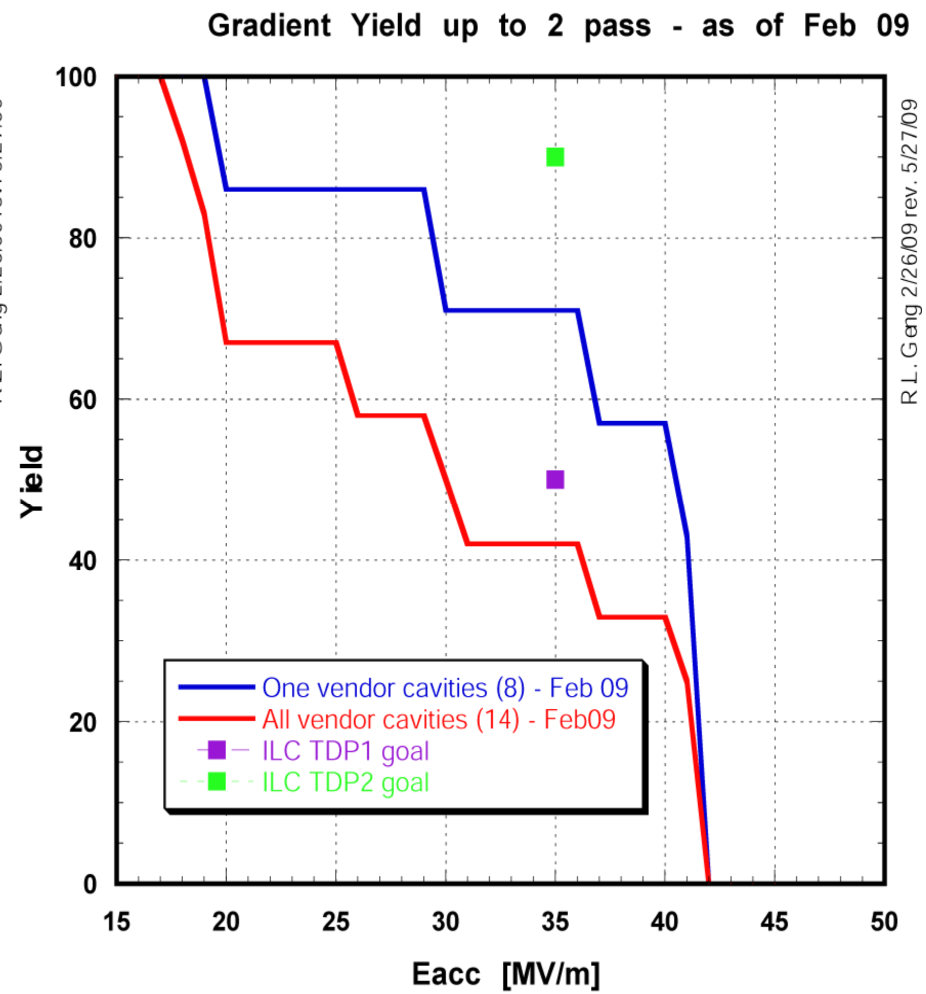


A Proposed Method for Gradient Yield

First-pass result decides path forward:
- Move on for S1 if spec met
- Re-process (Re-HPR; Re-EP; Local repair) if spec not met

Sample data from JLab





Summary

- Gradient limiting factors categorized
- Sate of understanding on limiting factors presented
- Variability in reported yield curve analyzed
- Future yield analysis requires updated definition – example is given

- Statistics expected to improve
- > 60 cavities to be ordered in next 2 years
- New players (such as new company in North America and new labs/university groups in China and India) are joining the cavity work
- Collaboration & knowledge transfer necessary for yield improvement

- The robustness of yield curve depends on robustness of the material, the fabrication and processing tools

A Global Data Base for Yield Tracking & Analysis

Cavity Information													RF Result							Database Information	
		9-cell	TESLA (EU and US)	Fine-grain	Wah Chang	EP	JLab#1	None								Quench				yes	
		1-cell	TESLA (KEK)	Large-grain	Tokyo Denkai	BCP	KEK#1	600-800								Field emission				no	
		other (please specify in remark)	LL	other (please specify in remark)	Heraeus		HPR only	1400 with getter													
			Ichiro				none									FE/quench					
			other (please specify in remark)													other (please specify in comment)					
Cavity Name	**Aliases**	**Type of cavity**	**Cell shape**	**Material**	**Material vendor**	**Bulk surface removal**	**Final surface treatment**	**High temperature heat treatment**	**Cavity Remarks**	**RF test location**	**RF test date**	**RF test #**	**Gradient [MV/m]**	**Q0 [10^10]**	**Field emission Onset field [MV/m]**	**Limitation**	**RF Result Comment**	**Additional information known about cavity limitation and source of understanding**	**Cavity Plan**	**Should this cavity test be included in data analysis?**	**if no, please explain**
																				yes	
AES001	AES1, TB9AES001	9-cell	TESLA (EU and US)	Fine-grain	Wah Chang	EP	JLab#1	600-800	600C HT; material removal 213 um	JLAB	3/6/2007	1	17.5		none	Quench	mode measurements: quench on cell 3 or 7			yes	
AES001	AES1, TB9AES001	9-cell	TESLA (EU and US)	Fine-grain	Wah Chang		JLab#1	None	material removal 236 um	JLAB	3/28/2007	2	18.0		none	Quench	mode measurements: quench on cell 3 or 7			yes	

Under development, more from Camille Ginsburg, FNAL