

TDR Writing: FLASH 9mA Experiment

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Outline (2)

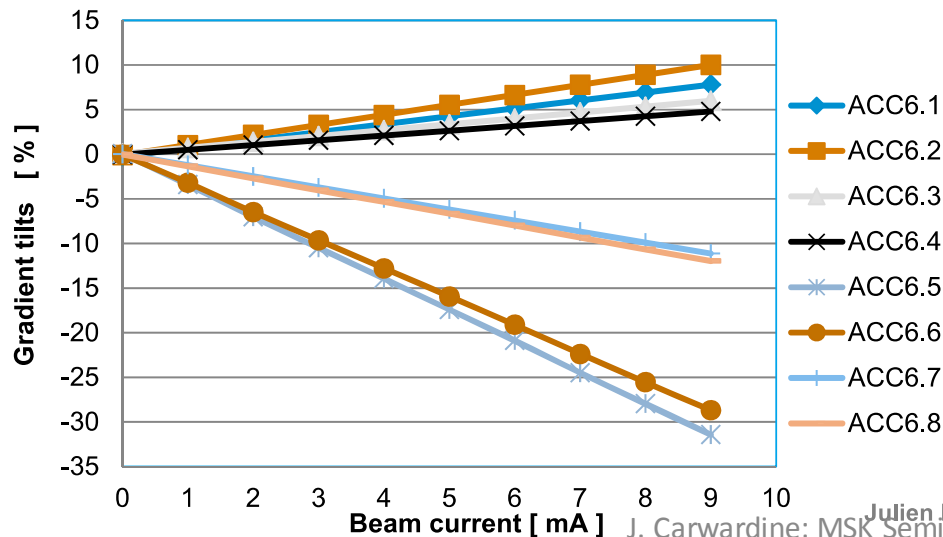
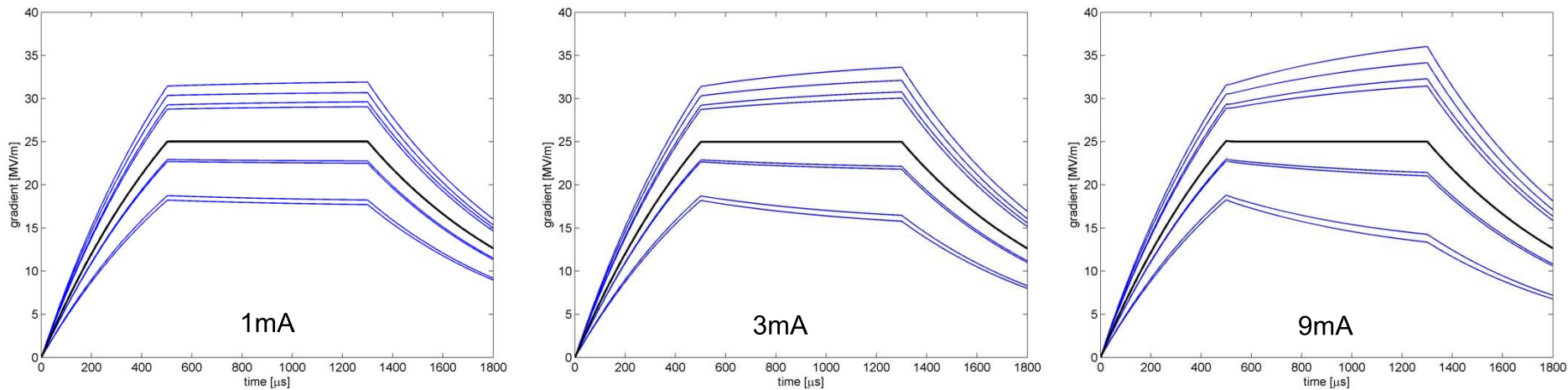
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New since Interim Report

- Pseudo-Pk / QI studies for flat gradients
- Operation close to quench with beam loading
- Klystron saturation studies with beam loading
- Include background for rf power overhead and gradient margins (cost drivers)?
- Need to explain principles of Pk/QI control

Impact of beam loading

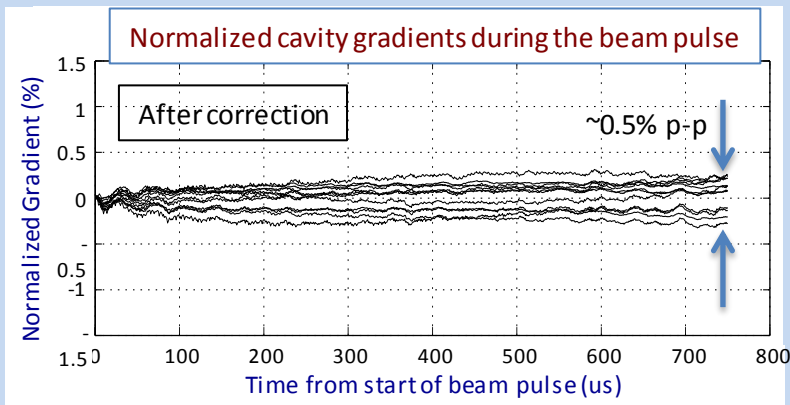
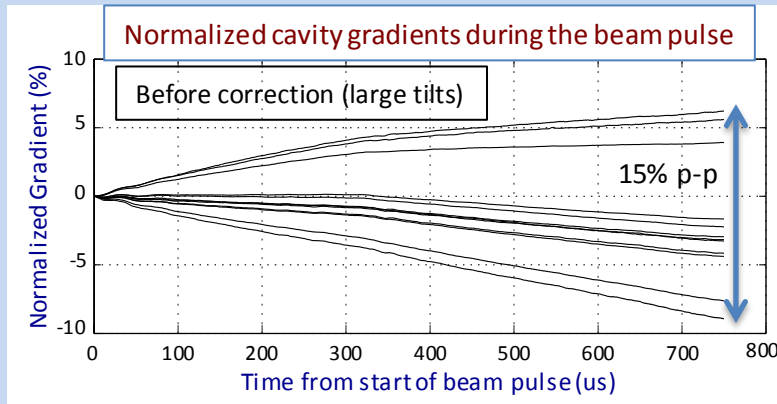
> Beam loading tilts scale linearly with beam current



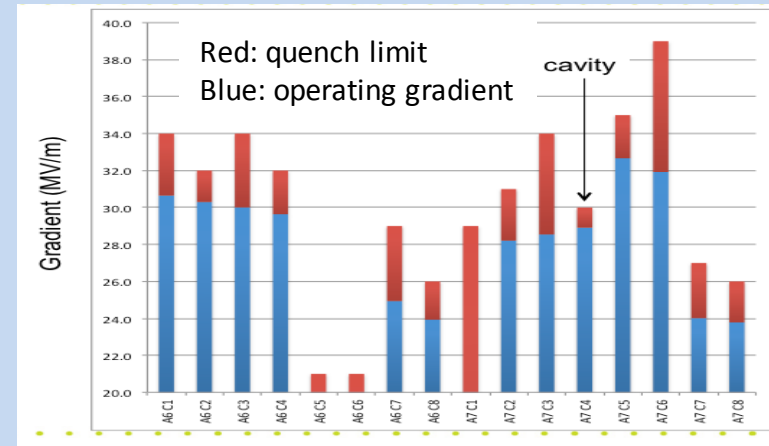
Simulated gradient tilts in ACC6,
for a 800 usec flat top
with current FLASH Q_L setup

9mA Studies: beam operation close to cavity gradient limits (4.5mA/800us bunch trains)

Tailored cavity Loaded-Qs to cancel beam-loading induced gradient tilts



Operation at 380MeV on ACC67 (13 cavities)

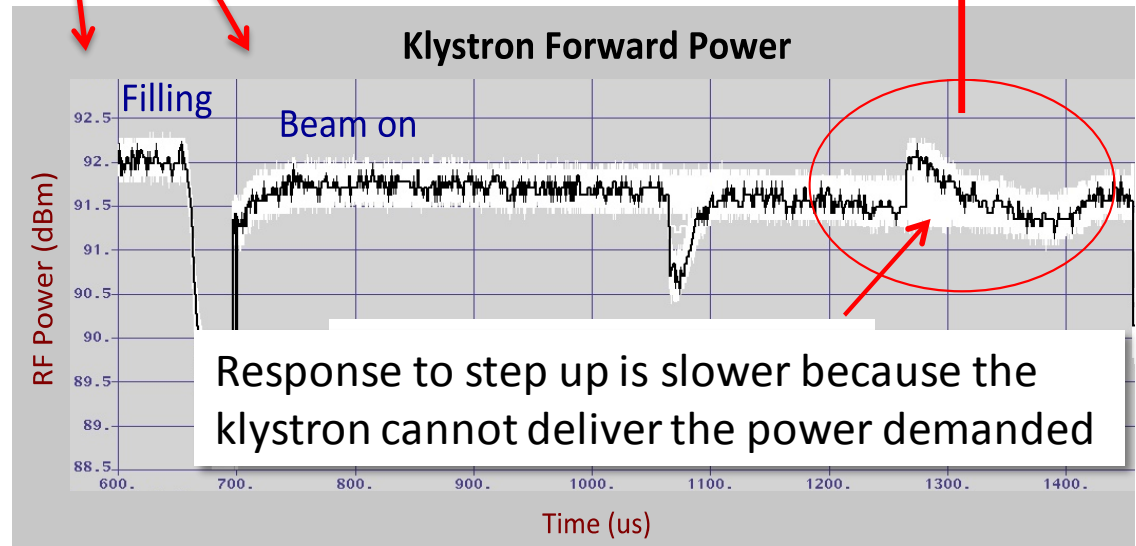
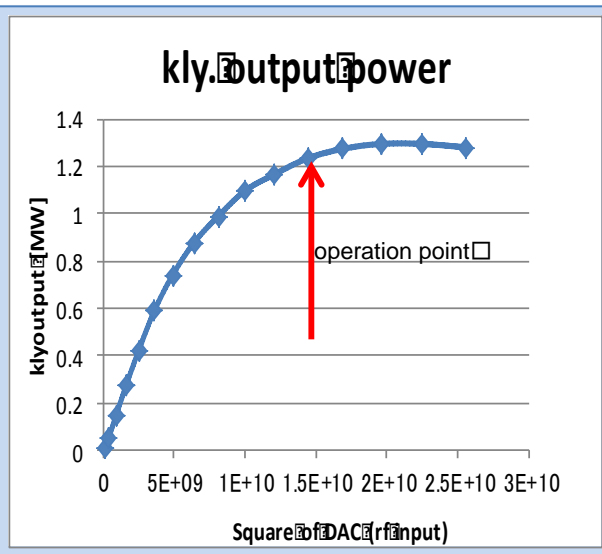
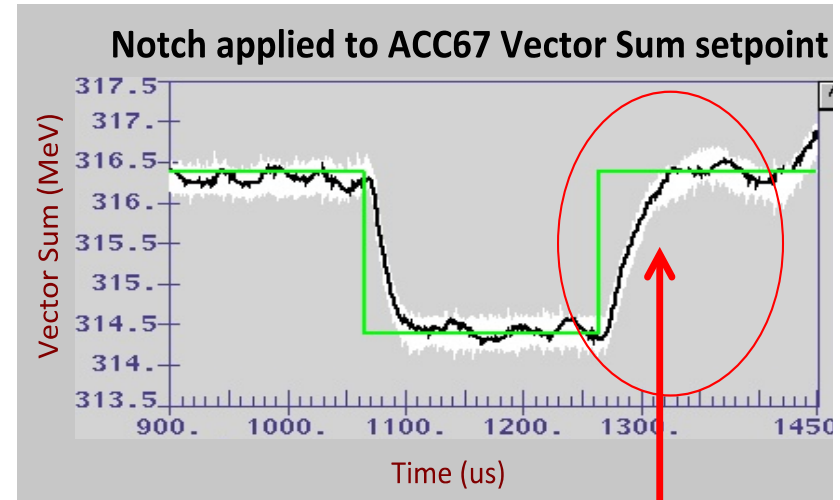


The limiting cavity is within 5% of quench

- Flattened individual gradients to $\ll 1\%$ p-p
- Several cavities within 10% of quench
- 'Crash test': very rapid recovery of 800us / 4.5mA after beam trip
- Ramped up current from \sim zero to 4.5mA with ACC67 gradients approaching quench
- 'Cavity gradient limiter' to dynamically prevent quenching without turning off the rf

9mA Studies: evaluating rf power overhead requirements (4.5mA/800us bunch trains)

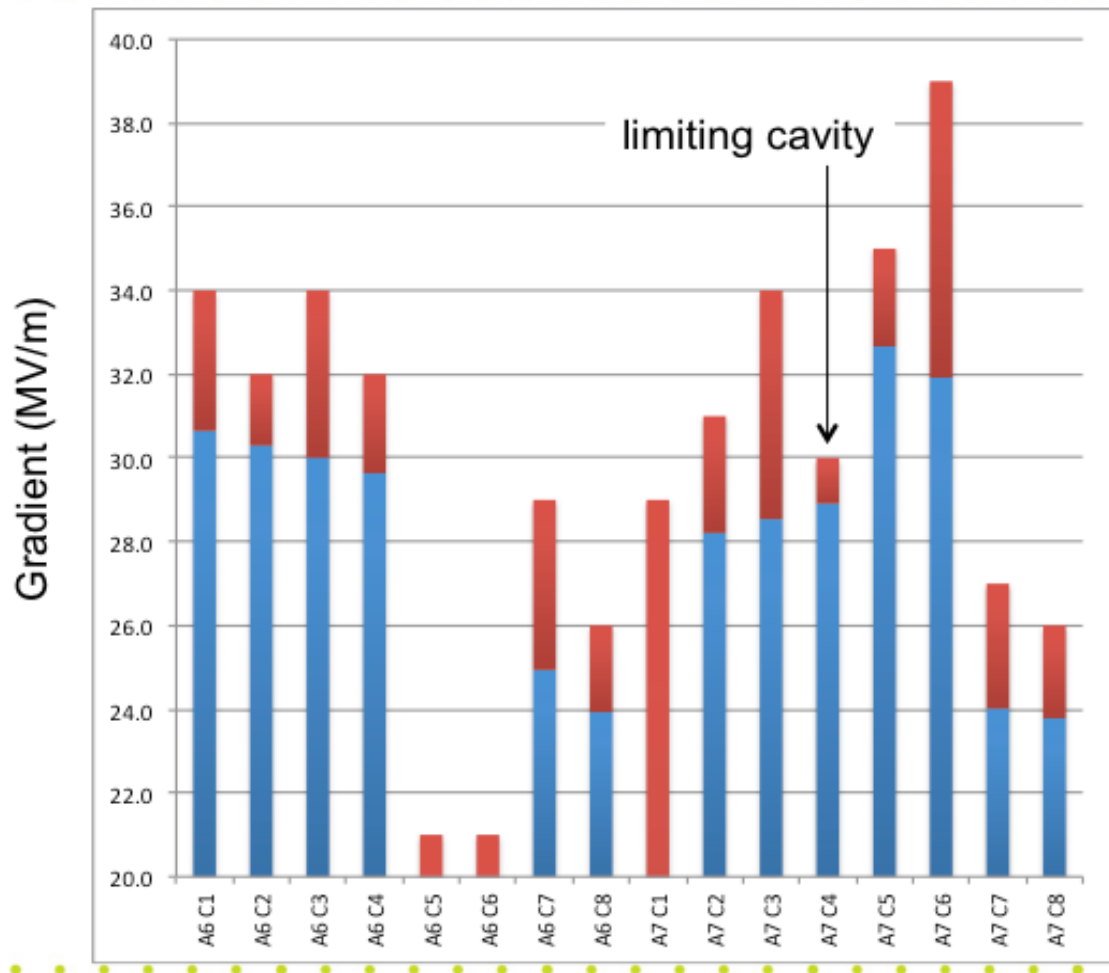
- Klystron high voltage was reduced from 108KV to 86.5KV so that the rf output just saturated during the fill
- The required beam-on power ended up being ~7% below saturation



Extrapolation to ILC baseline

- Long bunch trains, heavy beam loading
 - 6mA / 800us demonstrated (baseline)
 - 9mA / 800us marginally achieved (upgrade)
 - Energy stability demonstrated
- Vector Sum control of RF unit
 - Operation of RF unit demonstrated with 24 cavities and 16 caviities
 - Relevance to KCS control...?
- Gradient
 - FLASH: average is $\sim 28\text{MV/m}$, but cavities go to 35MV/m
 - Gradient spread is comparable
 - Lorentz-force detuning

Limits achieved (380 MV)



Extrapolation to ILC baseline

- Pk/QI control
 - Demonstrated flat gradient solutions to $\ll 1\%$ pk-pk
 - ILC baseline has more knobs, so easier
- Operation close to quench
 - Several cavities within 10% of quench at 4.5mA, 800us
 - One cavity within 5% of quench
- Klystron overhead
 - Preliminary results: operation within 7% of saturation
 - Need to evaluate effect on energy stability

Extrapolation to ILC baseline

- Operability
 - Ramp-up to 4.5mA, 800us within 10% of quench demonstrated without quenching
 - Rapid recovery after quench
 - Quench detection / prevention with beam loading
- Taking credit for FLASH FEL operations...
 - Many 1000's hours of routine operation
 - LLRF control and automation
 - Energy and arrival time stability better than RTML requirements