Developing a program for 9mA studies shifts in Sept 2012

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- **It would be natural to develop a program that builds on what was achieved in February**
  - Klystron saturation studies
  - Operation close to quench

- **Need to consider that the Sept studies will be the last chance to collect results for the ILC TDR**
  - Are there things missing from our accomplishments?

9mA studies (Feb 2012)

- **Study topics**
  - How well can we flatten the individual cavity gradients
  - How close to quench can we run the cavities with beam
  - How close to saturation can we run the klystron
  - How to ramp up to the maximum current, pulse length, and gradient without quenching

- **Machine conditions used**
  - 800us bunch-trains (2400 bunches)
  - Average current over 800us: ~4.5mA (1.5nC/3MHz)
  - Beam energy: 1GeV
  - Energy gain on ACC67: 380MeV with 13 cavities
  - Operating gradients on ACC67: 29MV/m average, four cavities running above 31MV/m

Key Results

- **Beam operation with 800us/4.5mA bunch trains, and…**
  - Gradients of all cavities in vector sum flat within +/-0.3%,
  - All cavities in vector sum operating within 5-10% of quench

- **First experience of ‘high gradient operations management’**
  - Quench detection / exception handling
  - Gradient ‘soft limiter’ to dynamically prevent quenching
  - Data-point of running machine into quench with 800us/4.5mA

- **Beam operation with 800us/4.5mA bunch trains, and..**
  - RF forward power within ~7% of klystron saturation

- **Ramp-up from ~zero to 800us/4.5mA pulses without quenching**
- **Rapid recovery to 800us/4.5mA after trip (‘crash test’)**

TD Phase R&D results (updated mid 2012): System Tests with Beam at FLASH

High beam power and long bunch-trains *(Sept 2009)*

Metric	ILC Goal	Achieved
Macro-pulse current	9mA (5.8mA)	9mA
Bunches per pulse	2400 x 3nC (3MHz)	1800 x 3nC 2400 x 2nC
Cavities operating at high gradients, close to quench	31.5MV/m +/-20%	4 cavities > 30MV/m

Gradient operating margins *(updated following Feb 2012 studies)*

Metric	ILC Goal	Achieved
Cavity gradient flatness (all cavities in vector sum)	2% ΔV/V (800μs, 5.8mA) (800μs, 9mA)	<0.3% ΔV/V (800μs, 4.5mA) *First tests of automation for Pk/Ql control*
Gradient operating margin	All cavities operating within 3% of quench limits	Some cavities within ~5% of quench (800us, 4.5mA) *First tests of operations strategies for gradients close to quench*
Energy Stability	0.1% rms at 250GeV	<0.15% p-p (0.4ms) <0.02% rms (5Hz)

Check-list of TD Phase accomplishments

- **Long bunch trains, heavy beam loading demonstration**
  - 6mA / 800us demonstrated (TDR Baseline)
  - 9mA / 800us marginally achieved (luminosity upgrade)
- **Vector Sum control of RF unit**
  - Operation of RF units comprising 16 and 24 cavities
  - Intra- and inter-pulse stability better than 0.02%
- **Operating gradients**
  - Operation up to average of 29MV/m (24MV/m to 33MV/m)
  - Lorentz-force detuning compensation on all cavities simultaneously
- **Pk/Ql control for optimizing gradient profile**
  - Demonstrated flat gradient solutions to +/-0.3%
  - ILC baseline has more knobs (power ratios), so easier

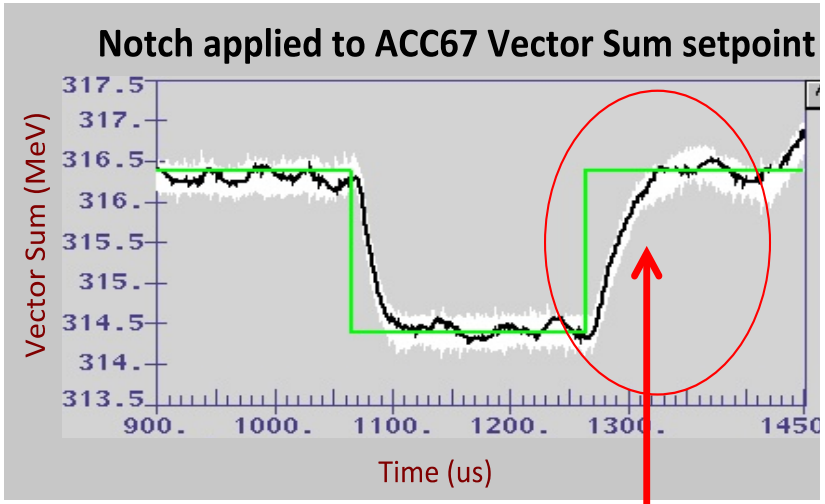
Check-list of TD Phase accomplishments

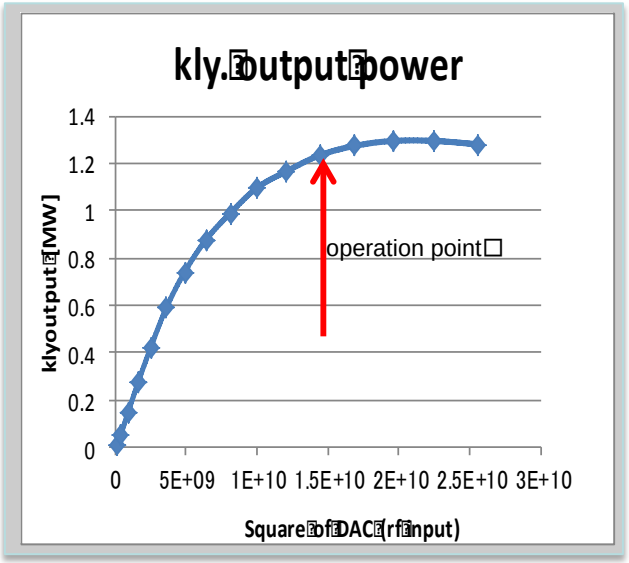
Strengthen these results

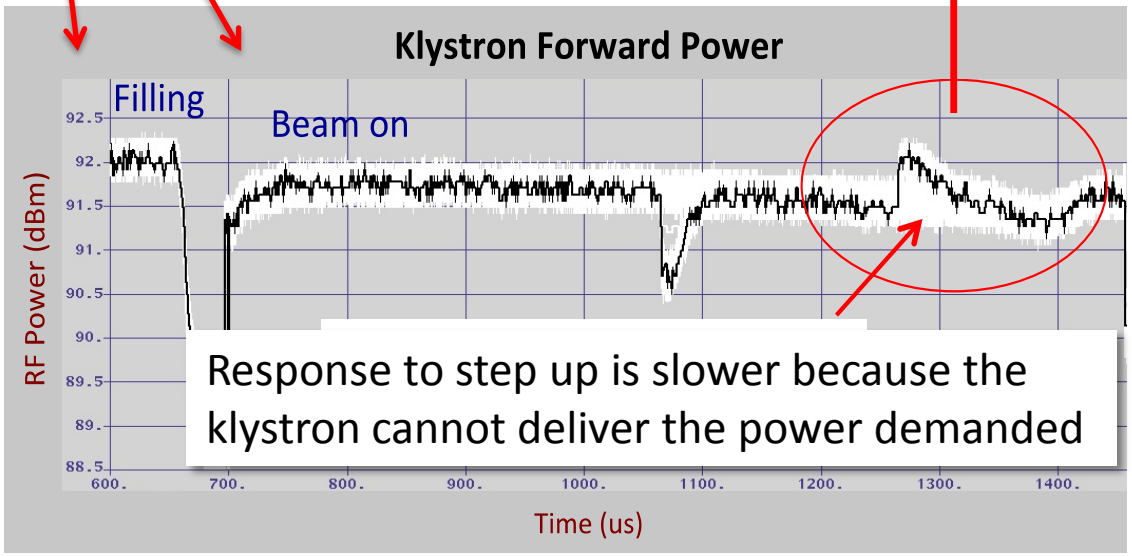
- **Klystron overhead**
  - First results: beam operation within 7% of saturation
  - (Need to evaluate effect on energy stability)
- **Operation close to quench**
  - Several cavities within 5-10% of quench at 4.5mA, 800us
- **Operation close to quench (operability)**
  - Ramp-up to 4.5mA, 800us within 10% of quench demonstrated without quenching
  - Rapid recovery after quench
  - Quench detection / prevention with beam loading
- **HOM coupler**
  - Beam tests during high power 9mA/800us tests in 2009
  - Excellent agreement between model and measured data

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







Klystron saturation studies at TDR low-power baseline parameters

- **Klystron saturation studies**
  - In Feb, we didn't have enough beam current to run in saturation during beam-on period

- **In Sept, should perform klystron saturation studies at the new TDR 'low power' baseline parameters. Parameters relative to RDR…**
  - Average current goes from 9mA to **6mA**
  - Ql goes from 3e6 to **5e6**
  - Fill time goes from 600us to **900us**
  - Pulse length goes from 1ms to **700us**

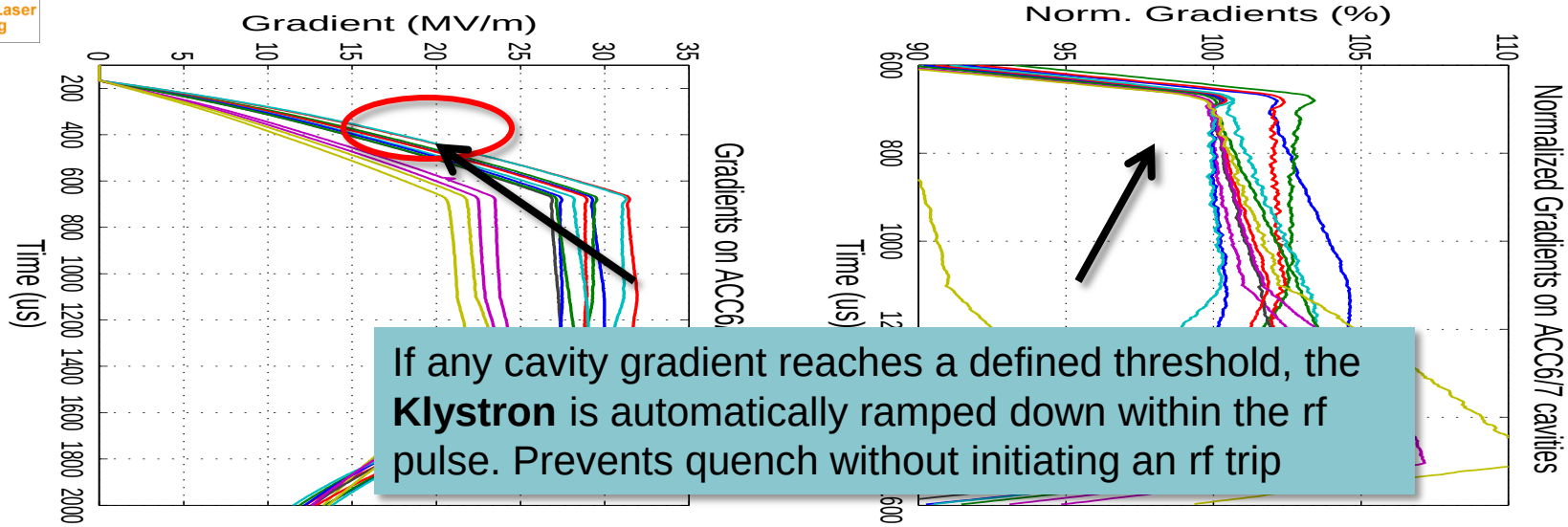
Pushing closer to quench

- **In Feb, we didn't go as far up in gradients as we could have done – we have further to go**

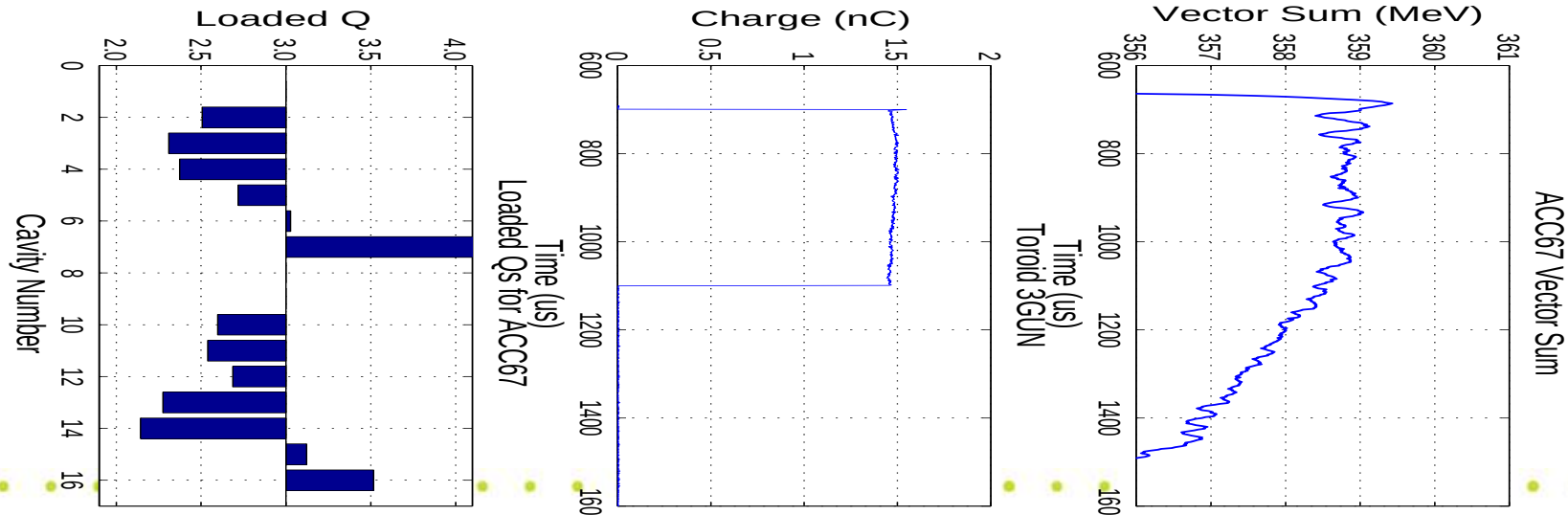
- **Gradient 'pre-limiter' was working only on ACC6 cavities, and we only barely got started on learning how to set up and use the pre-limiters**
  - In Sept, we need pre-limiters on all the ACC6/7 cavities
  - Work on setting up the limiter and pre-limiter thresholds

- **Another possible gradient related study (FEL not ILC)**
  - Pushing for higher total linac energies at lower charge
  - Would need pre-limiters on ACC4/5 as well as ACC6/7
  - Wouldn't be able to detune cavities as we do for ILC study
  - How significant would this study be?

Gradient operations management: ‘Soft-limiter’ dynamically prevents quenches



If any cavity gradient reaches a defined threshold, the **Klystron** is automatically ramped down within the rf pulse. Prevents quench without initiating an rf trip



- **Main study items**
  - Klystron saturation studies at ILC/TDR low-power baseline
  - Push more cavities closer to quench
  - *Other high priority items…?*

- **It would also be good to work on the exception handling, eg**
  - Implement ‘operations-quality’ gradient flattening algorithm
  - Cross-linkages between automation tools – **integration**
  - Need better exception handling, better uniformity

Preparation tasks – see Julien’s slide from earlier