TTF/FLASH 9mA studies:
Main studies objectives for January 2011

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21st October 2010

Proposed studies from WG3

- **Machine / LLRF**
  - Coupling between longitudinal and transverse effects and with LLRF
- **LLRF**
  - Vector Sum calibration
  - Long-term energy stability
  - Performance regulations at high gradient / high current
- **Gradient overhead studies (ACC67)**
  - Optimization of Qext, prove concept for at least 3mA
  - Microphonics and LFD, can be done w/o beam
- **Klystron Overhead**
  - Need high current, at 3mA need retune Qext
- **ILC Bunch compressor stability studies**
  - 2 RF units ACC45 & ACC67
  - Demonstrate 0.25 deg phase stability
- **HOM studies**

FLASH operations schedule Nov-Feb

	40	4.Oct - 10.Oct	1	User Run	
	41	11.Oct - 17.Oct	1		
	42	18.Oct - 24.Oct	1		
	43	25.Oct - 31.Oct	1		
	44	1.Nov - 7.Nov	2	FEL studies	
	45	8.Nov - 14.Nov	2		
	46	15.Nov - 21.Nov	3		preparation user run
	47	22.Nov - 28.Nov	1	User Run	
	48	29.Nov - 5.Dec	1		
	49	6.Dec - 12.Dec	1		
	50	13.Dec - 19.Dec	1		
	51	20.Dec - 26.Dec	5	Maintenance	
January	52	27.Dec - 2.Jan	5		
2011	1	3.Jan - 9.Jan	4		preparation accelerator studies
	2	10.Jan - 16.Jan	4	Accelerator studies	
	3	17.Jan - 23.Jan	4		
	4	24.Jan - 30.Jan	2	FEL studies	
	5	31.Jan - 6.Feb	2		
	6	7.Feb - 13.Feb	3		preparation user run
	7	14.Feb - 20.Feb	1	User Run	
	8	21.Feb - 27.Feb	1		
	9	28.Feb - 6.Mar	1		
	10	7.Mar - 13.Mar	1		

Nov 18-20 (6 shifts):
FEL studies with long bunch trains at ~1.25GeV

Anticipated: ~1 week dedicated ‘9mA’ studies

Machine conditions for January

- **We will chose to do studies with less than 9mA**
  - Plan studies with 1-2nC/bunch (3nC risks long setup time)
  - At 1nC we can operate in FEL mode: machine better characterized and more reliable; standard setup files
  - Nominal maximum current: 3mA at 3MHz bunch rep rate
    - (FEL operation with >1nC will be attempted in Nov)
- **Length of bunch-train is currently limited to ~300us due to gun RF window conditioning**
  - Still can operate the modules with 800us RF pulse length
- **Drive laser rep rate currently at 1MHz – requires recommissioning for 3MHz operation**

Primary studies focus

What's the maximum usable gradient?

- **In practical terms…**
  - Get all cavity gradients on same klystron as flat as possible with 800us-long bunch trains and full beam loading
  - Find out how close we can get to the quench limits and still operate reliably

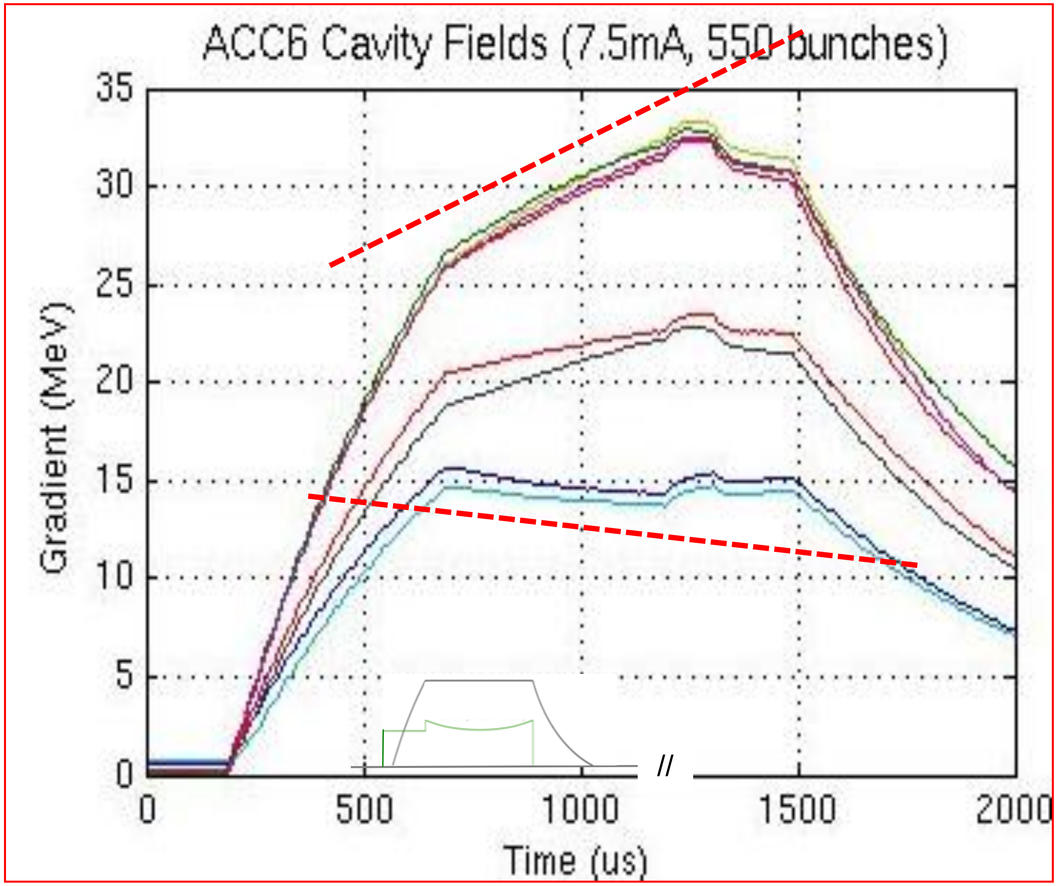
Gradient tilts from beam loading

Lorentz-force detuning

- **Also of interest for FEL user studies**

- *Many practical and operational details…*

Cavity gradient tilts from beam loading



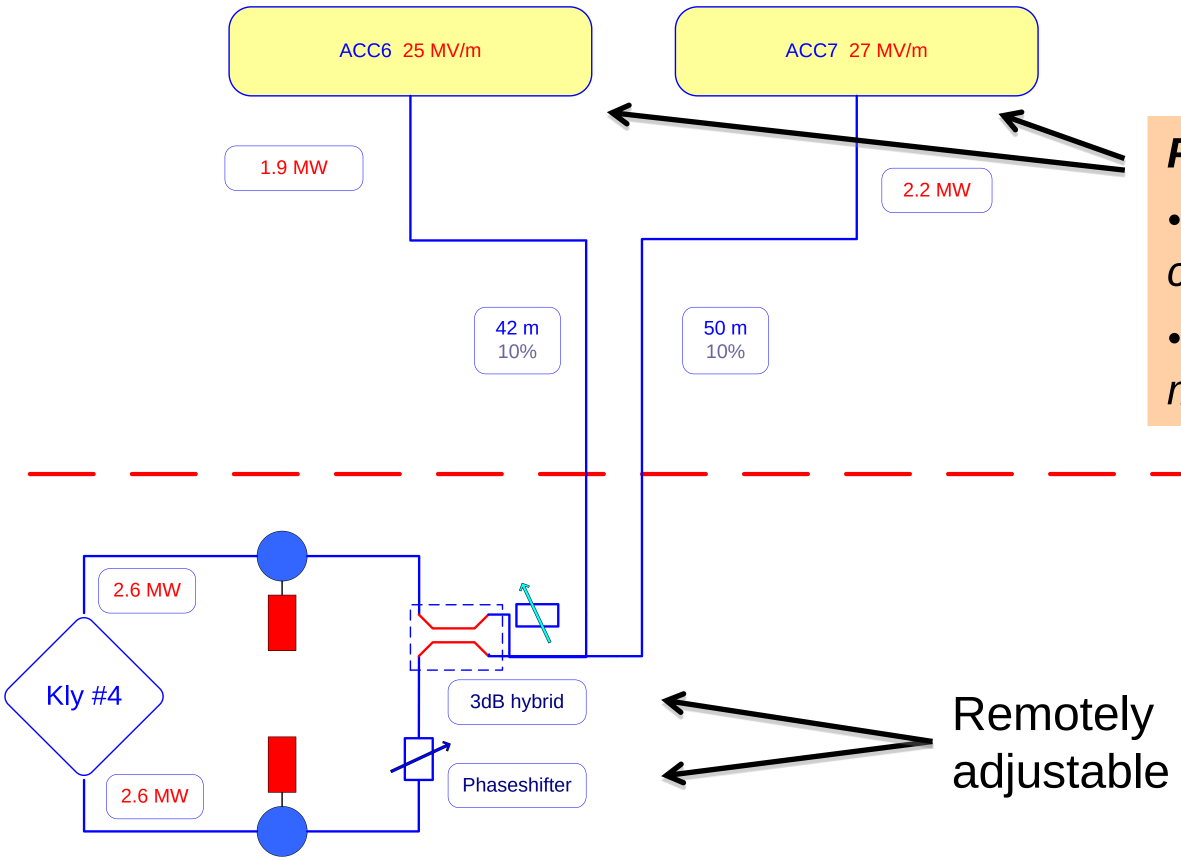
A 'feature' of running cavities with a spread of gradients from same RF source

Matched beam current with constant Pk:

$$I_{matched} = \frac{V_k}{\left(\frac{r}{Q}\right)Q_{ext}}$$

Waveguide distribution for ACC67

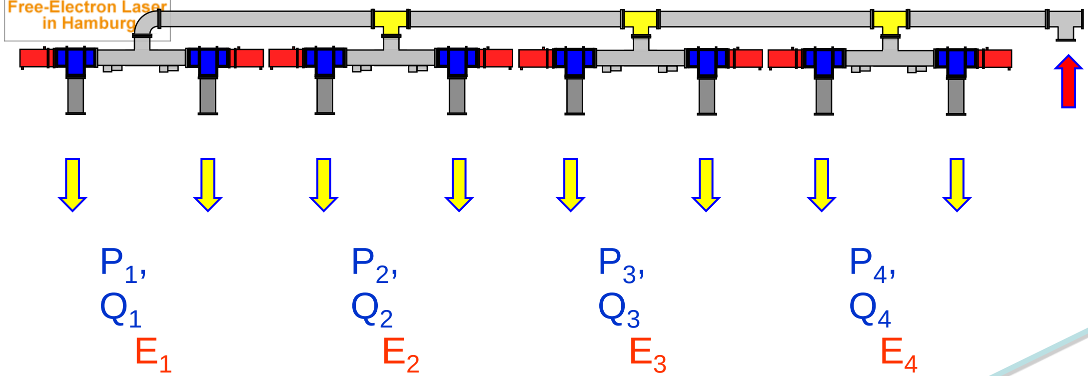
Waveguide distribution for klystron #4 *(status 05.02.2010)*

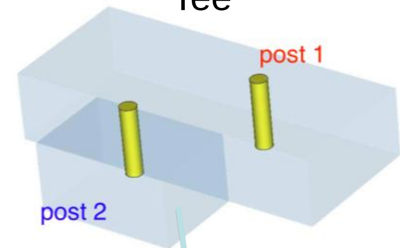


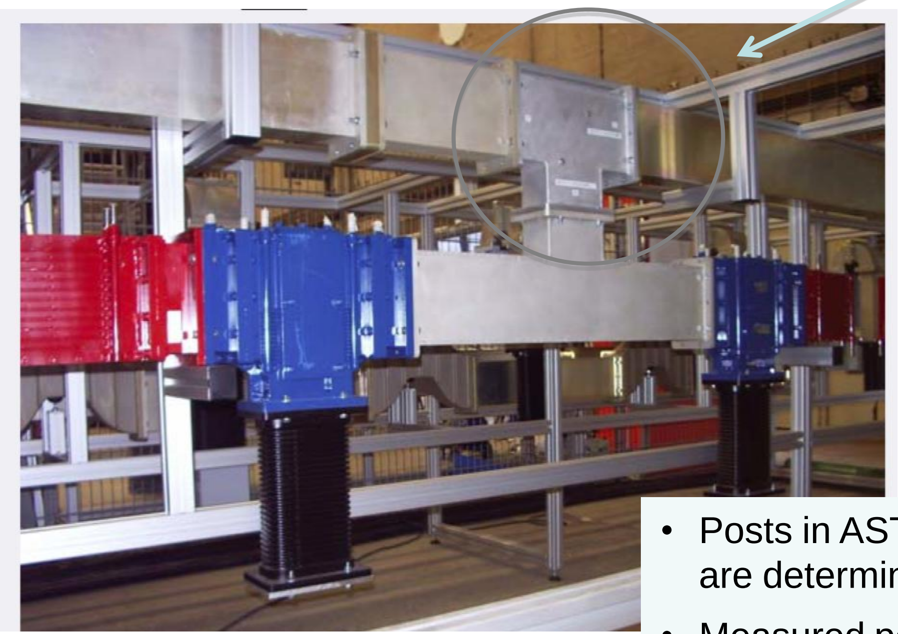
Pk/Qext knobs on ACC67

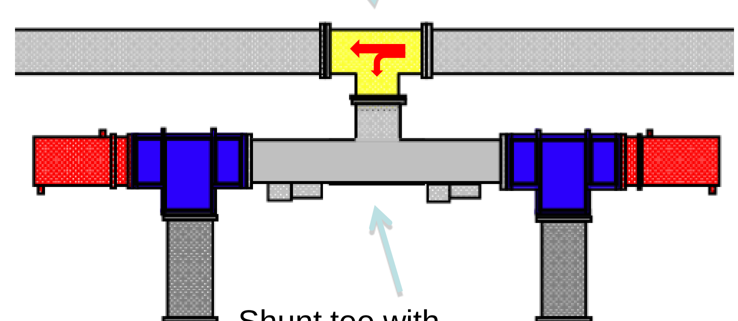
- *<u>Pfwd</u>: requires waveguide components to be changed*
- *<u>Qext</u>: remotely adjustable motorized couplers*

Waveguide distribution system for ACC6 (ACC7 similar)



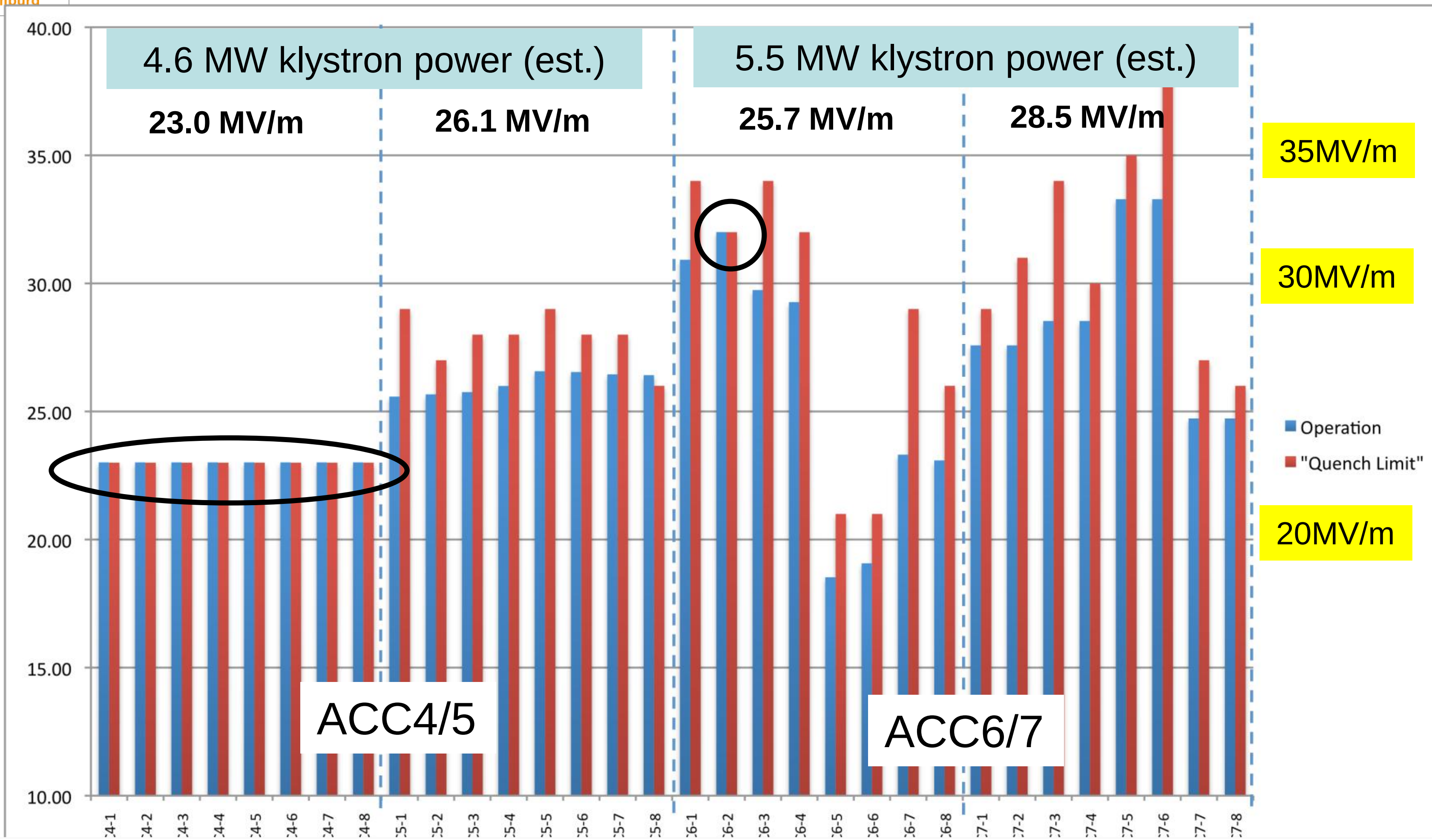






- Posts in AST are fixed in place during manufacture – locations are determined analytically from the desired power ratio.
- Measured power ratio is typically +/-0.1dB from the design value
- To change the power ratio, have swap out the ASTs

Theoretical maximum gradients at FLASH (point at which the first cavities quench)



Tolerances in the actual forward power ratios = reduction in the effective usable gradient, because not all cavities quench at the same point

ACC67 gradient tilt scenarios for different beam currents

Summary

		Optimization	Beam	Cavity tilt
1	Default Ql,Pk	---	0 mA	3.5%*
2			3 mA	6.5%
3			6 mA	9.5%
4	PkQl like	3mA	3 mA	0%
5			0 mA	6.6%
6		6mA	6 mA	0%
7			0 mA	28.3%

*due to the variation of Qls at default Ql configuration.

S. Michizono

Optimal Pk.Qext solutions exist for ACC67 cavities with ≥6mA where we only have to adjust Qexts

9mA meeting (July 6th, 2010)

A solution has not been found for all ACC67 cavities with 9mA (gradient spread too wide)

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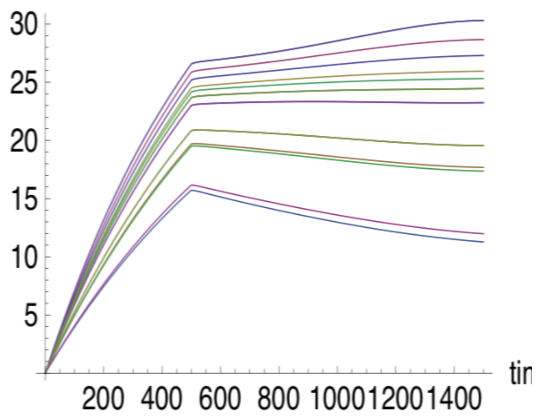
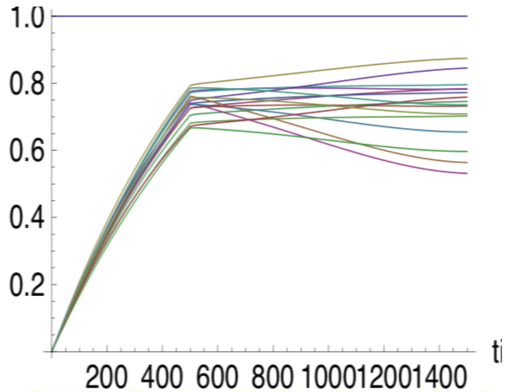
Methodology for ramping to maximum gradient and full beam loading…?

Step 1

Cavity Voltages: 6mA
Default Qexts, 3.5MW

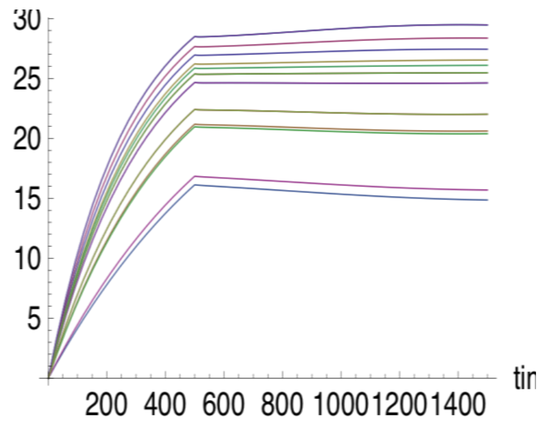


Fraction of quench limit



Step 2

Cavity Voltages: 6mA
Shin's Qexts, 3.5MW



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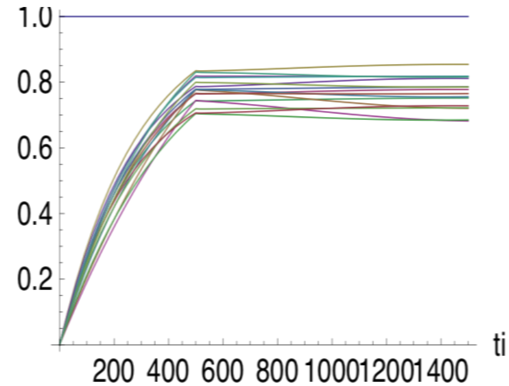
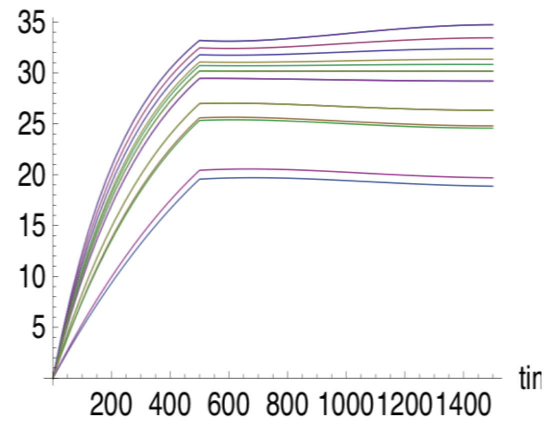


Step 3

Cavity Voltages: 6mA
Shin's Qexts, 5.1MW



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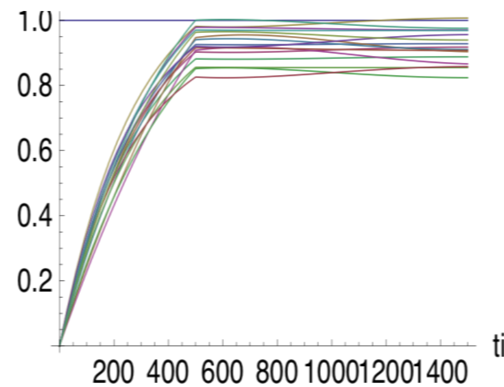
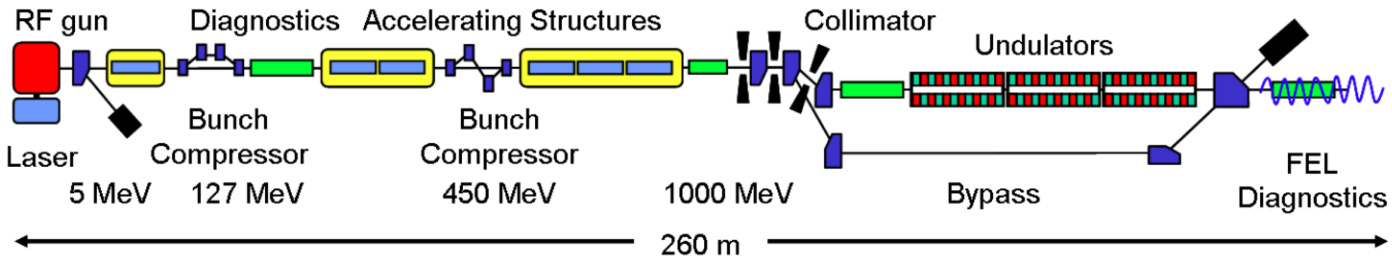
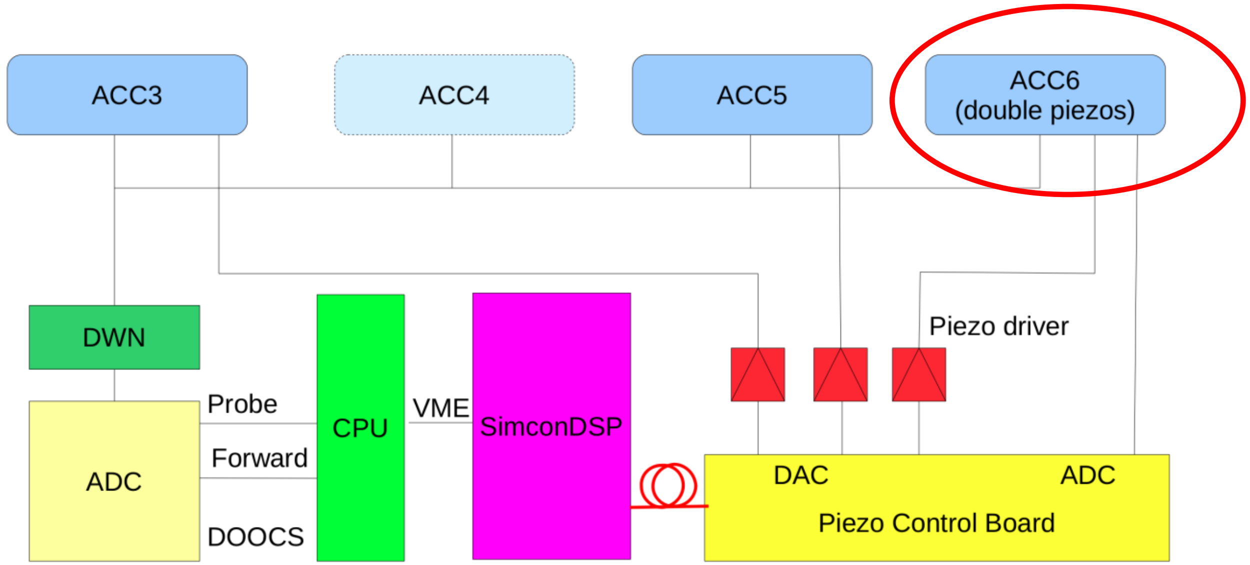


Would be possible to do initial tests of methodology in RF-only mode, eg at NML

Piezo tuners at FLASH

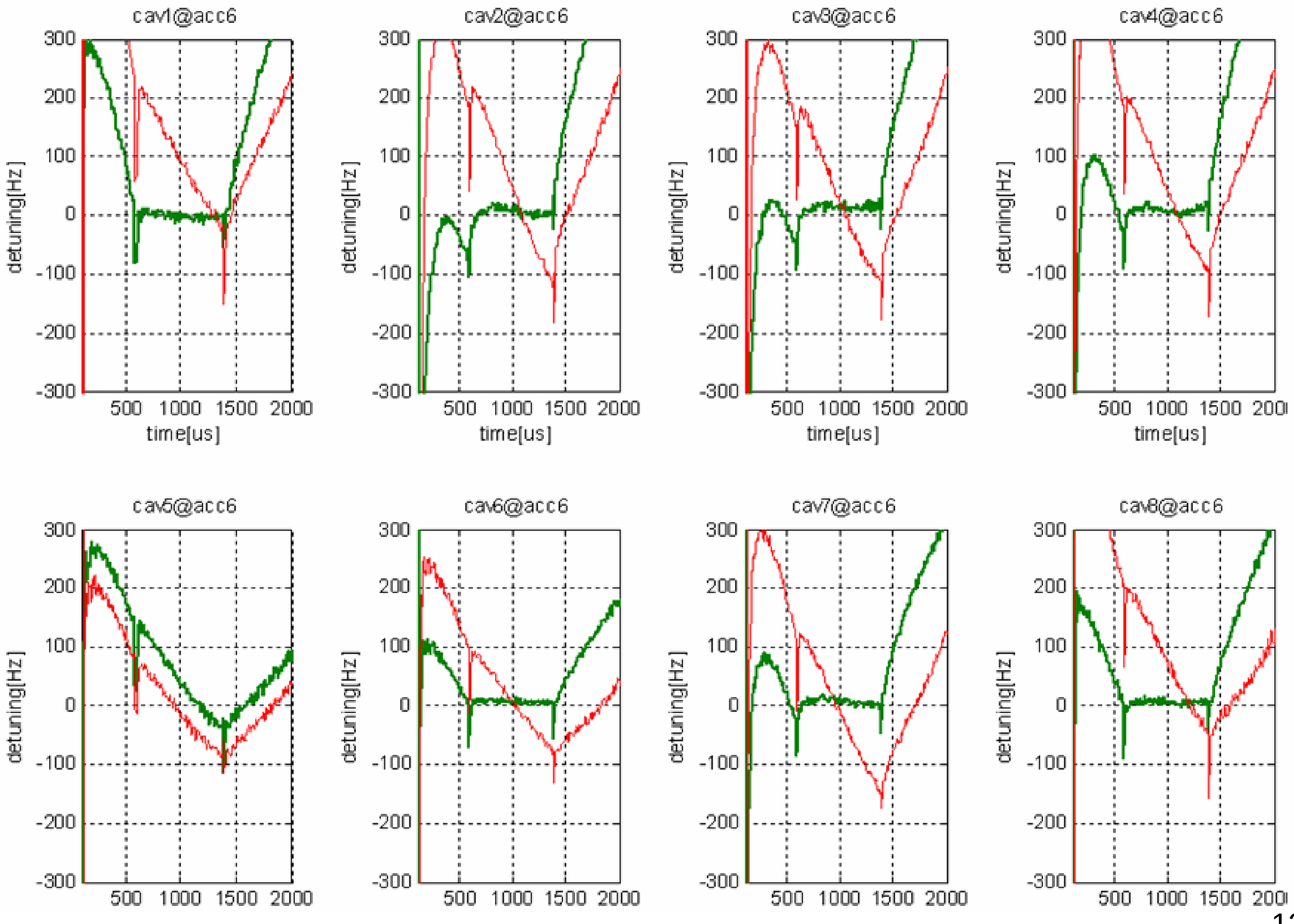




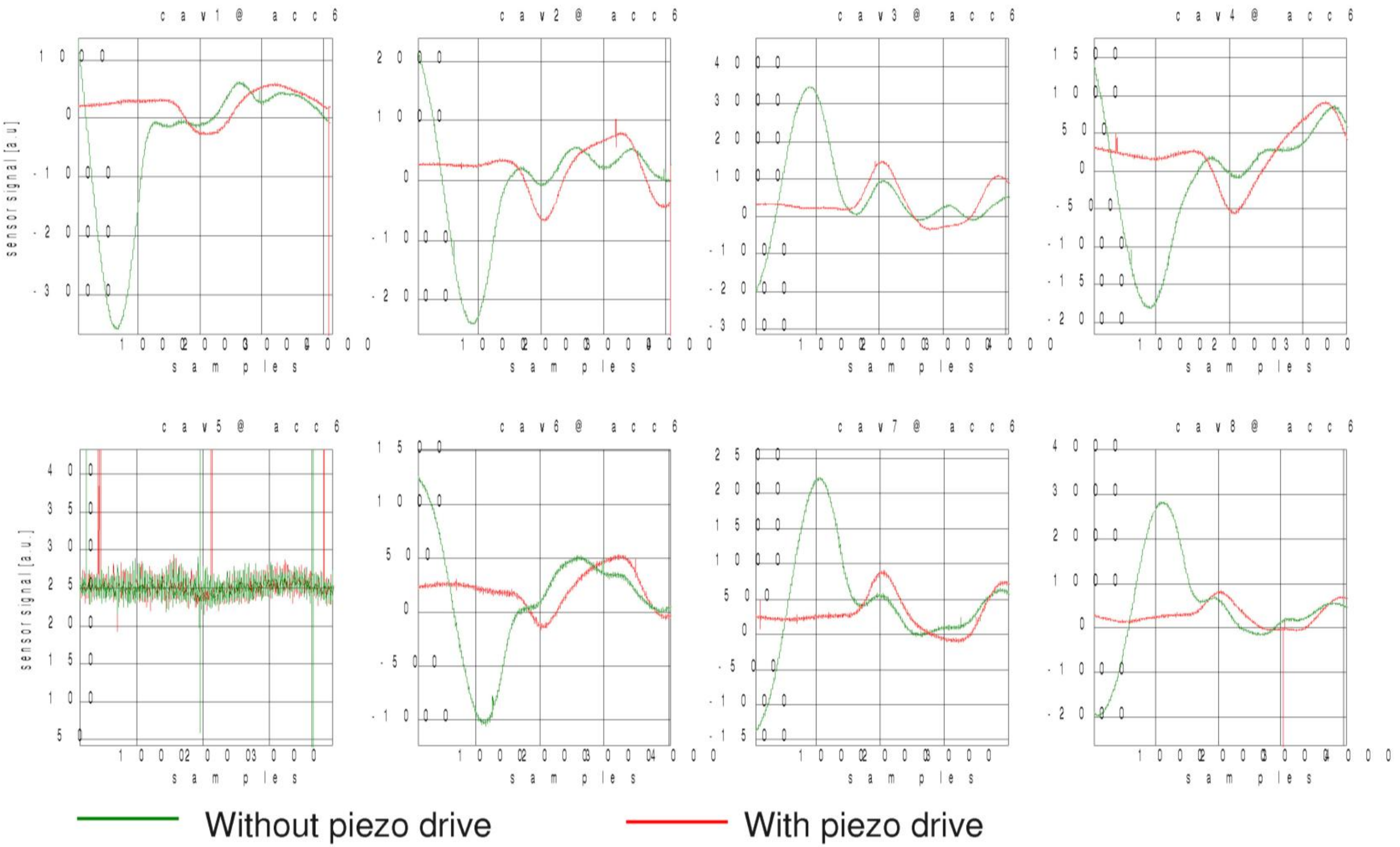
Similarly ACC7

Testing impulse response method is an option using existing hardware (need to work on software)

Piezo tuner studies at FLASH



ACC6 piezo compensation in time domain

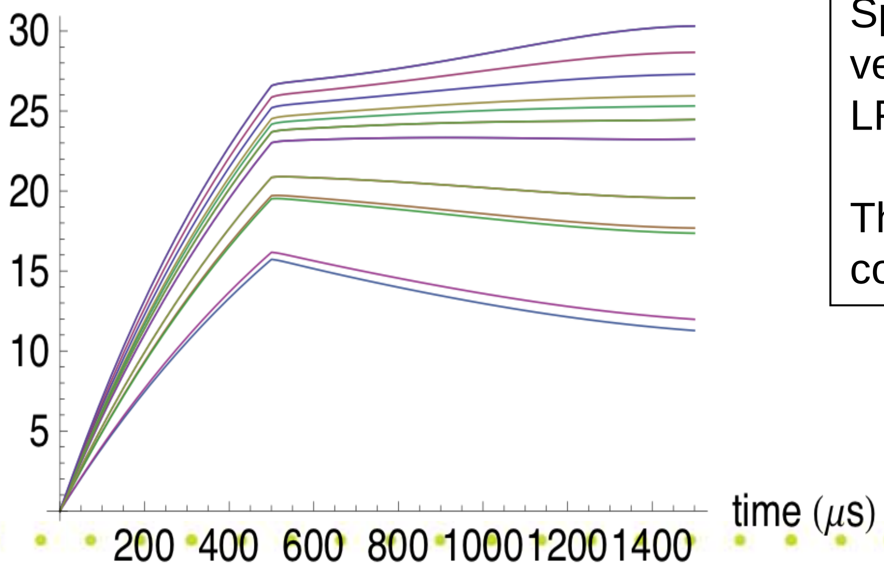


M.Grecki

Issue at 10Hz rep rate, cavity is still ringing 100ms after pulse (need to compensate)

Lorentz-force detuning compensation to support gradient studies

- **Gradient studies goal is to minimize variations in individual cavity gradients over the flat top**
  - Compensate all 16 cavities simultaneously
  - All the individual cavity gradients should all be perfectly flat when the vector sum is perfectly flat (amplitude and phase)
  - For this study, power efficiency is not the priority
  - *Does this change how we would optimize the piezo tuners?*



Spread in operating gradients in the vector sum means significantly different LFD effects on individual cavity gradients

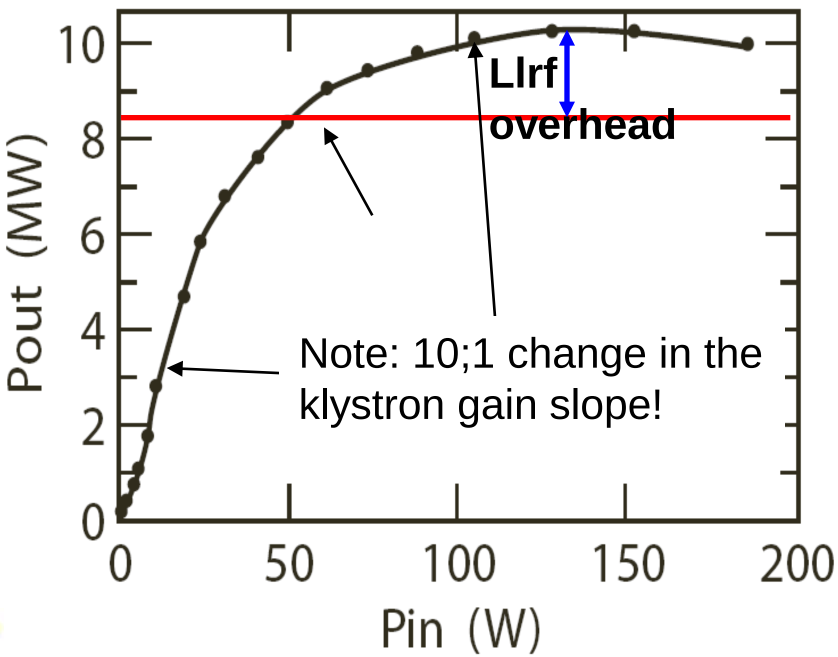
The Vector Sum reflects only the common features

Need to leverage the very good recent results from S1-Global

Understand requirements for RF power overhead

- **RF power required for regulation**
- **Maximum usable power from each klystron?**
  - ie how far into saturation can we operate without compromising performance
  - Klystron linearization helps but only so far…

Will have to 'turn down' the klystrons to see saturation (could be done in LLRF firmware or using klystron HV)



Summary

- **Priorities for January studies**
  - Maximum usable gradient
  - Maximum usable klystron power
  - *“Pseudo” Pk/Qext control*
  - *Piezo tuner studies*

- **Should be able to make good ‘incremental’ progress even with reduced bunch-train length and lower beam loading**

- **Input from S1-Global… Use of NML + STF for preparatory studies**

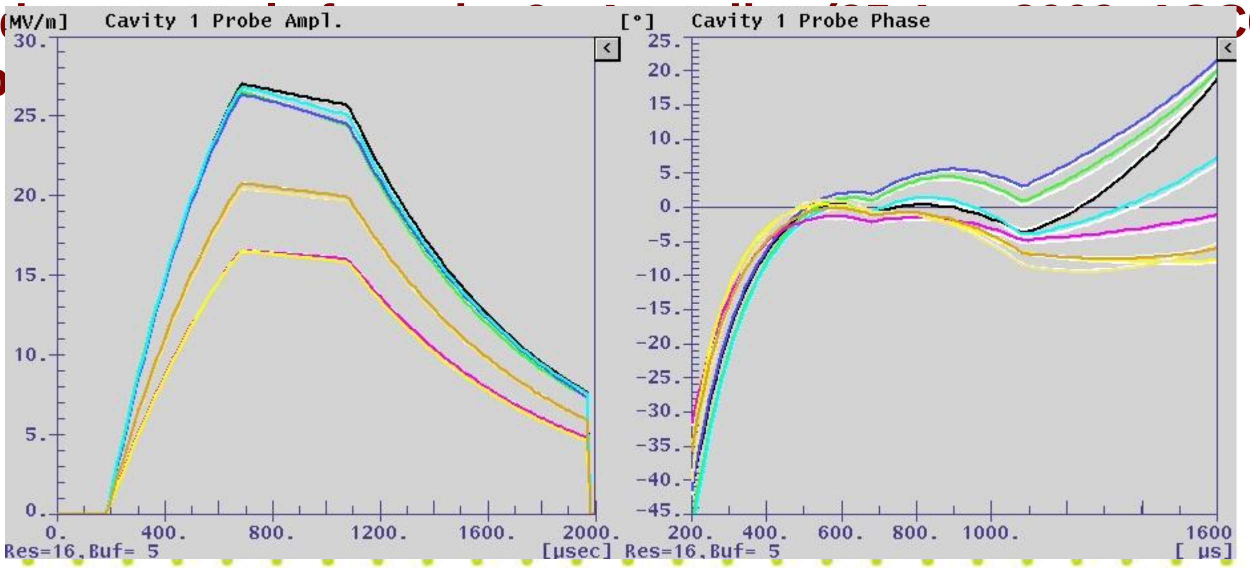
- **Will participate in November FEL studies: possible gradient focus gives chance to get preliminary data for January**

Extras

Cavity gradient tilt studies

- **Flattening cavity field amplitudes and phases without beam is not trivial**
  - Optimization of mechanical tuners, Qext, piezo feedforward,…
- **We should start with the no-beam case (already hard)**

Ran … 6 probes,
no b



From 24th August

Proposed ramp-up scheme

- **Basic objective: perform experiment at 90% of quench limits before trying to get to maximum gradient.**

- **Step 1**
  - Set up cavities for normal conditions (flat gradients at zero beam current and at gradients that do not quench with tilts from 6mA), pre-detune for resonance in the middle of the flat top
  - Tune machine for full pulse length and 6mA current
- **Step 2**
  - Keep the full pulse length and 6mA
  - One by one, ramp the Qexts to values for 90% gradient (adjust cavities with lower gradients first)
  - Set up piezos to get linear gradient slopes
- **Step 3**
  - Keeping 6mA and full pulse length, increase gradient to 90% nominal
  - Confirm gradients are nominally flat
  - Perform detailed fine tuning to get 'exactly flat' gradients and phases

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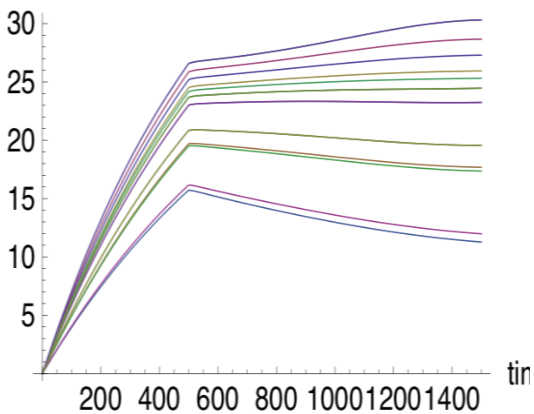
Default Qexts, 3.5MW



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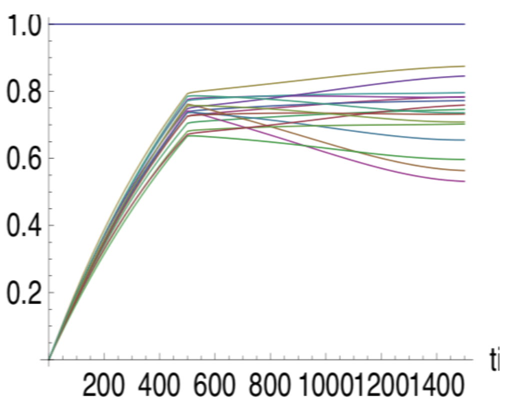

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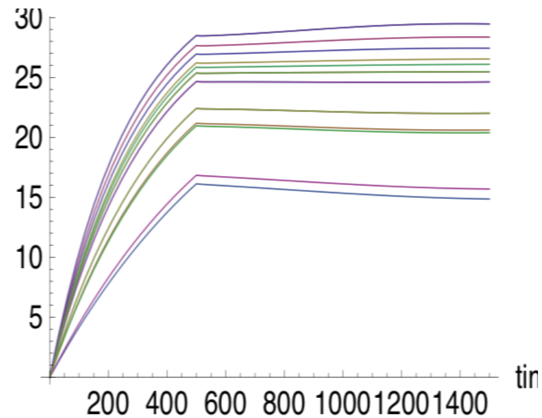

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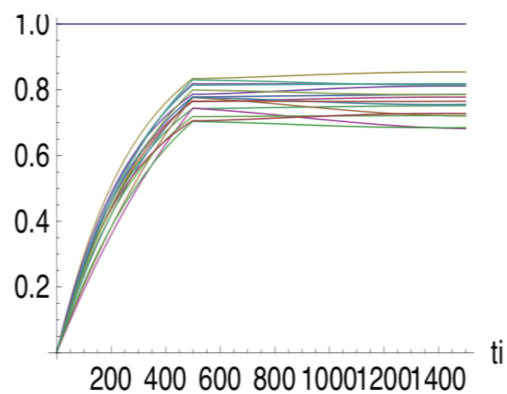

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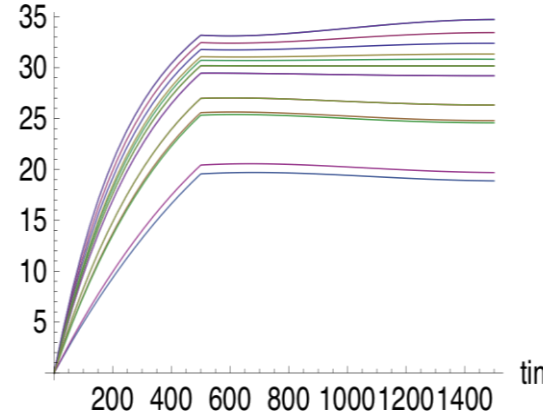
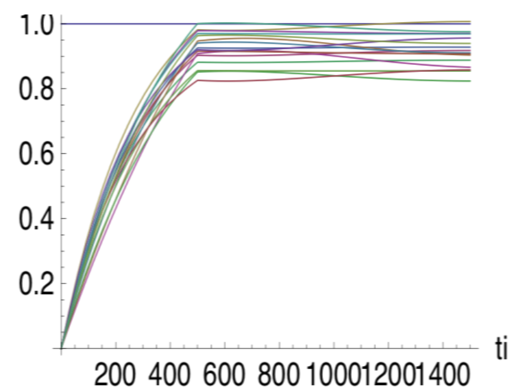


Fraction of quench limit

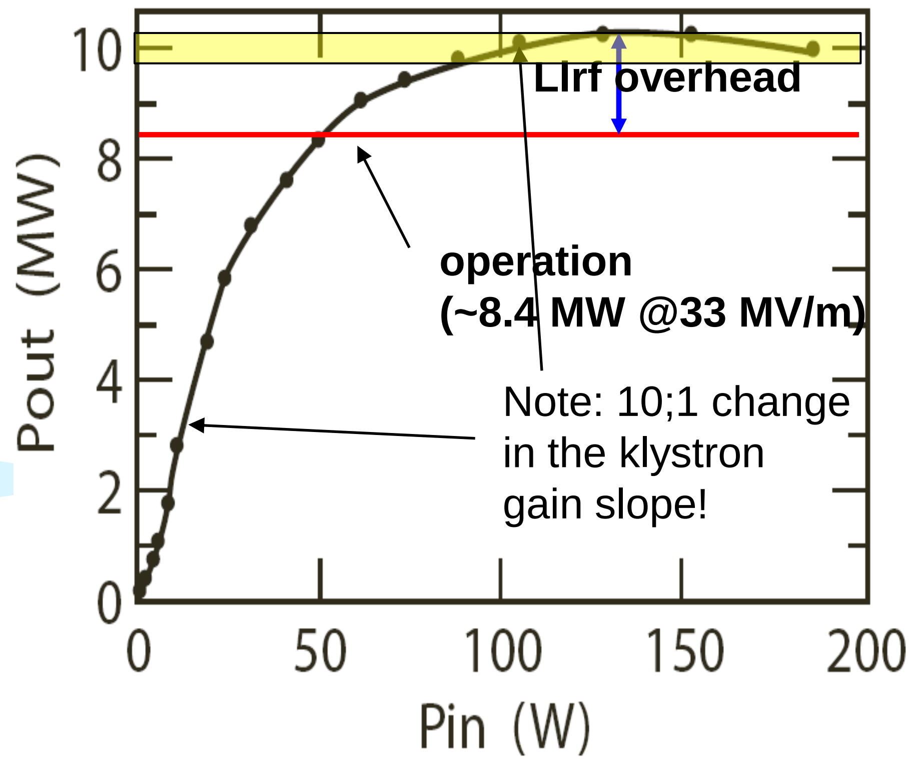


Llrf tuning overhead

- As in RDR, llrf tuning overhead is 16% in power.

LE 2.6-2
nit parameters.

Parameter	Value	Units
Modulator overall efficiency	82.8	%
Maximum klyston output power	10	MW
Klystron efficiency	65	%
RF distribution system power loss	7	%
Number of cavities	26	
Effective cavity length	1.038	m
Nominal gradient with 22% tuning overhead	31.5	MV/m
Power limited gradient with 16% tuning overhead	33.0	MV/m
RF pulse power per cavity	293.7	kW
RF pulse length	1.565	ms
Average RF power to 26 cavities	59.8	kW
Average power transferred to beam	36.9	kW



•Under optimal Ql and detuning, Pg becomes minimum.
Pg= 33 MV/m*1.038 m *9 mA *cos(5deg.)*26 cav.= 7.98 MW ~ 8 MW
RF loss (7%) -> available rf power= 9.3 MW
Llrf overhead = 9.3/7.98 -1 ~16%