Proposed RF/LLRF performance measurements

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- ILC parameters
- Perturbations and overhead
- Non linearity
- Perturbations and stabilities
- Cavity field flatness
- Exception handling

ILC parameters

- *It is most important to demonstrate the operation under ilc specifications.*

- ***goal: to achieve the ilc requirements (beam current, pulse width and field gradient).***

TABLE 2.6-1
Nominal beam parameters in the ILC Main Linacs.

Parameter	Value	Units
Initial beam energy	15	GeV
Final beam energy	250	GeV
Particles per Bunch	2×10^{10}	
Beam current	9.0	mA
Bunch spacing	369	ns
Bunch train length	969	μs
Number of bunches		2625
Pulse repetition rate	5	Hz

TABLE 2.6-2
RF unit 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

- ***proposed measurements:***
Beam current (9mA), beam width (800us) and cavity gradient (>31.5MV/m?)

Perturbations and overhead

- *goal: to obtain the proper llrf overhead under the certain perturbations.*
- ***These perturbations should be monitored synchronously with llrf measurements.***
- ***For instance, the beam current (by beam monitor), HV applied to the klystron (by HV monitor) and rf field (by llrf monitor) should be monitored in the same rf pulse.***
- ***The long time operation is proposed to obtain the long time drift of the operational rf power.***

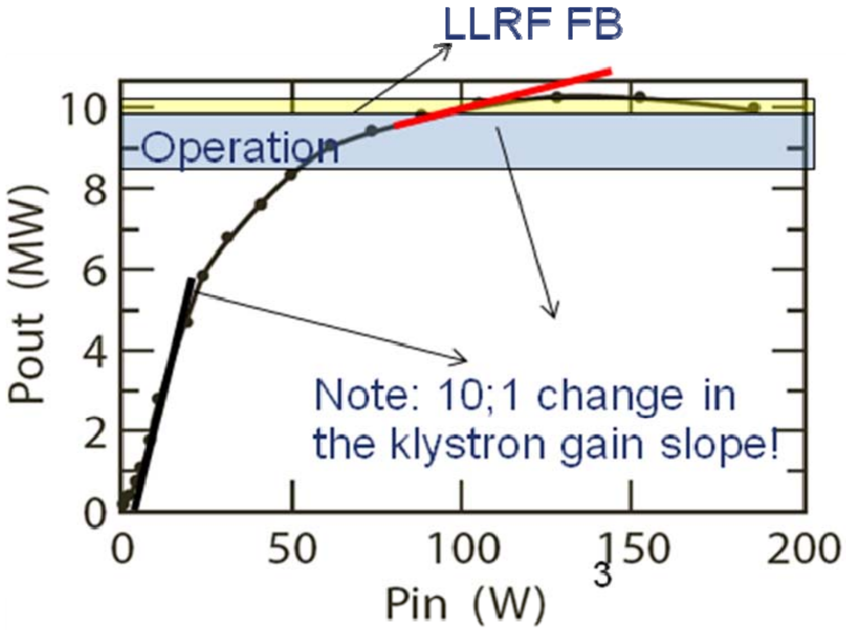
perturbation	specification	measurements
piezo compensation	+/- 40Hz	rf phase
microphonics		
beam current	+/-1%	beam current
klystron HV	+/-0.5%	HV
klystron saturation w&w/o linearlization	-5% or -10%	---

- *proposed measurements:*

Beam current, cavity detuning, HV regulation v.s. klystron output power

Non linearity

- *goal: to operate near the klystron saturation.*
- ***The present operation point of the klystron is -5% from its saturation (the worst case*).***
- ***The llrf performance should be evaluated under the circumstance and compare with the case of -10% or more.***



* RF power budget cavity input 8.02 MW (33 MV/m * 1.038 m * 26 cav. * 9 mA)
a) reflection from waveguide system 1% (VSWR~1.2)
b) non-optimal coupling 2% (if over-coupling x1.3)
(We should also consider the rf-output reduction due to the rf reflection to klystron)
c) rf loss 8.54% (should be minimized!)
d) beam fluctuation 1% (should be compensated by fast feedforward)
e) modulator ripple 2.5% (pulse-to-pulse +/- 0.5%HV ripple)
f) cavity detuning 2% (*40 Hz peak* of Lorentz force and microphonics)
Remained rf power:
10 MW – 8.02 MW*(1.01 * 1.02 * 1.01* 1.025 * 1.02)/(1-0.0854)=0.47MW
LLRF feedback overhead
8.02* (1.01 * 1.02 * 1.01 * 1.025 * 1.02* X)/(1-0.0854)=10
X=1.049 (5%) *(2.5% in amplitude)*

- ***proposed measurements:***

Field regulation under the rf operation near saturation (-5%, -10%, -20%)

Perturbations and stabilities

- *goal: to measure the rf stabilities under the certain perturbations.*
- ***In principle, noises can be 1/G (G: proportional gain).***
- ***Confirm the performance***
- ***Effects of vector sum calibration should be also evaluated.***

TABLE 3.9-1

Summary of tolerances for phase and amplitude control. These tolerances limit the average luminosity loss to <2% and limit the increase in RMS center-of-mass energy spread to <10% of the nominal energy spread.

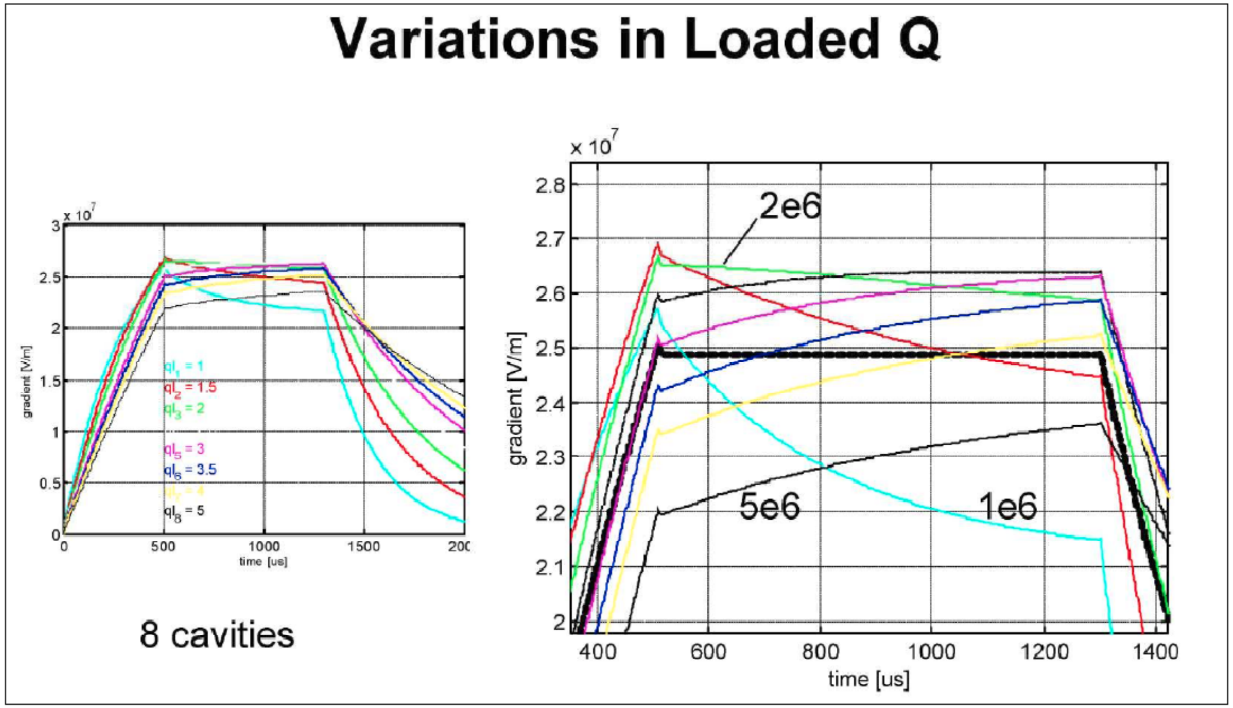
Location	Phase (degree)		Amplitude (%)		limitation
	correlated	uncorr.	correlated	uncorr.	
Bunch Compressor	0.24	0.48	0.5	1.6	timing stability at IP (luminosity)
Main Linac	0.35	5.6	0.07	1.05	energy stability $\leq 0.1\%$

- ***proposed measurements:***

Beam current, cavity detuning, HV regulation v.s. field stabilities (amplitude, phase) and beam energy under some feedback gain (50~100)

Cavity field flatness

- ***Since the mismatch of Q's introduce the additional rf power, this is also important to evaluate the rf power margin.***
- ***Goal: to evaluate the flatness of various loaded Q variation, operational gradient and beam current***

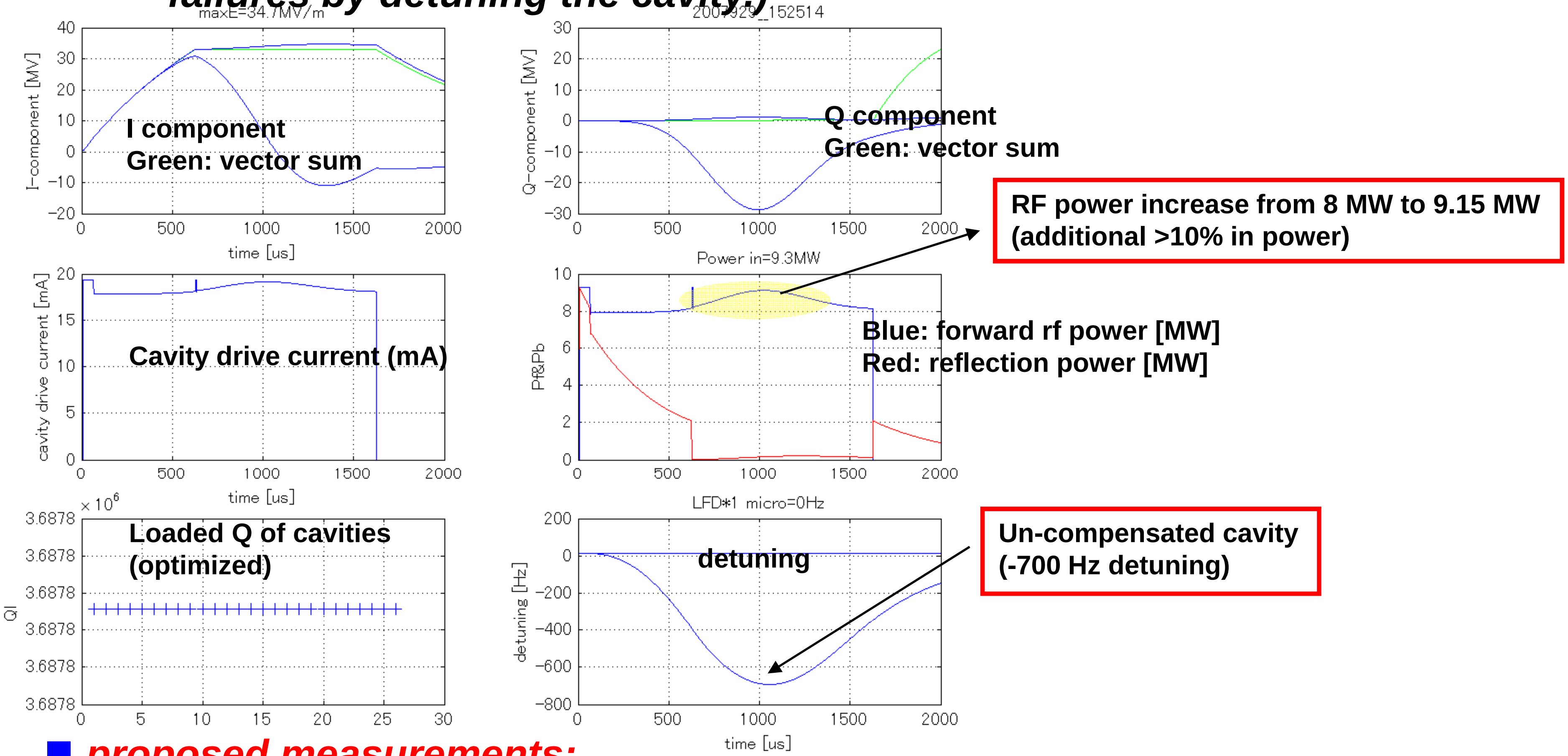


- ***proposed measurements:***

Change loaded Q (via 3 stub tuners) and evaluate the cavity performance with various beam loading.

Exception handling

- *Present llrf operation point is not considering the cavity failure. (If llrf had enough margin, we can continue rf operation in case of cavity failures by detuning the cavity.)*



- ***proposed measurements:***

LLRF performance at sudden one piezo failure

Some other preparation before study

- RF power monitor calibration

In order to compare and evaluate the overhead, fine calibration of rf power (or amplitude) is necessary. (also for evaluating rf losses at waveguide, circulators and so on.)

- Decision of operational gradient for study

Due to the quench limits of the cavities, it looks difficult to operate 31.5MV/m average. (and the operational gradients have wide variety.)
It will be desirable to make a decision about operational gradient in advance.

- Strategy for have flat fields with long bunches high current

Some proposals have been made for flattening the cavity fields under various quench limits (such as Ql, rf distribution controls).
FLASH (especially ACC6) will be operated at different rf input power and operational gradient. And maybe rf distribution will not variable.
Thus some strategy will be decided before study.

Summary

- ILC parameters

Beam current (9mA), beam width (969us) and cavity gradient (>31.5MV/m)

- Perturbations and overhead

Beam current, cavity detuning, HV regulation v.s. klystron output power

- Non linearity

Field regulation v.s. rf operation point (saturation -5%, -10%, -20%)

- Perturbations and stabilities

Beam current, cavity detuning, HV regulation v.s.
field stabilities (amplitude, phase) and beam energy under some feedback gain (50~100)

- Cavity field flatness

loaded Q variation (via 3 stub tuners) under various beam loading v.s. field flatness

- Exception handling

LLRF performance at sudden one piezo failure