‘Overhead and Margin’ – *an attempt to set standard terminology*

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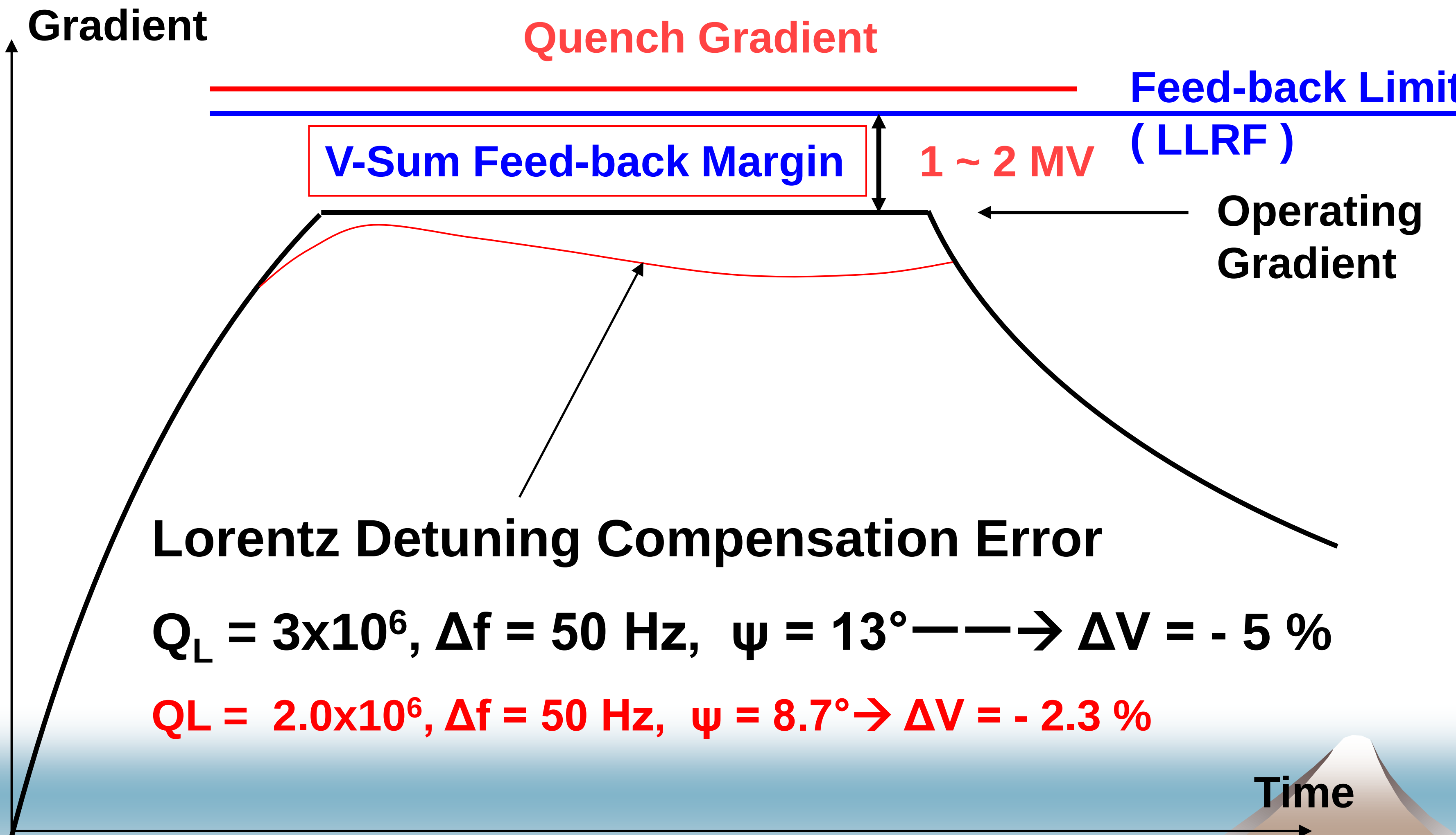
Highest Gradient Operation



Lorentz Detuning Compensation Error

$Q_L = 3x10^6$, $\Delta f = 50$ Hz, $\psi = 13°$ ——→ $\Delta V = -5$ %

QL = $2.0x10^6$, $\Delta f = 50$ Hz, $\psi = 8.7°$ → $\Delta V = -2.3$ %

Cavity Characteristics

- From its first cold power-on test through to its operation with beam we should track:
- ***gradient performance and***
- ***field emission***
  - **(also Q_0).**
- Gradient limit(s) and *perceived origin of the limit*
  - **(precision to be discussed and defined)**

Gradient Performance

- (Field emission is similar)
- In vertical dewar low power 'CW' test, a maximum gradient (and an associated Q_0) is observed and recorded:
- '*vertical test observed gradient limit*',
  - **And observed Q_0 at the limit.**
- in subsequent testing:
- '*horizontal test observed gradient limit*' and
- '*cryomodule test observed gradient limit*'
  - **(Noguchi: 'Quench Gradient')**
  - **are recorded**
  - **in general, are each different .**

Operation

- in operation,
  - **(administratively controlled):**
- '*operational gradient limit*' beyond which the cavity should not be routinely operated.
  - **(Noguchi: 'Feedback Limit')**
- Furthermore:
- '*power-limited gradient'* beyond which the capabilities of the RF power source (and power distribution system) are exceeded.
- Others:
  - **limitations due to cryogenics, controls, coupler, and etc)**
- ***This defines the maximum capability of the linac - but not how it is stably operated: CONTROLS***

Controls

- ('Feedback and Control Margin')
- Proper control of the cavity accelerating voltage includes control of:

1) the RF power source,
2) the power distribution system and coupler,
3) the cavity frequency resonance, and
4) beam current.

- In general, closed – loop feedback (or trim) with adequate control actuator range, setting precision and bandwidth is required for each.
- To know the effectiveness of the voltage control, the performance of each should be examined.

Selected terms (1):

Observed Gradient limit	The observed limit for steady superconducting operation in Vertical Low Power test, Horizontal test, cryomodule test and linac operation
Operational Gradient limit	Cavity should not be operated beyond this limiting voltage after installation in the linac; the limit may depend on duration/time
Cryomodule assembly Gradient limit change	The difference between the vertical test Observed Gradient limit and the cryomodule test Observed Gradient limit.
Matched Condition	Beam current and input power match – no reflected power
Gradient slope	Change in cavity voltage between the first bunch and the last bunch- typ P/P

Selected Terms (2):

Lorentz Force Detuning	Cavity resonant frequency shift due to 1.3 GHz RF energy 'pressure'
Pre-detuning	intentional cavity tuning offset used to achieve partial LFD compensation and minimize LFD compensation mover stroke amplitude
Pulse to pulse fluctuation/pulse to pulse stability	Distribution characteristics for a sequence of machine pulses; bunch intensity, average beam current, HLRF modulator pulse, etc RMS vs P/P
Within the pulse fluctuation	

Selected Terms (3):

Loaded Q – Q_l	(Loaded Quality factor)
External Q	(External Quality factor)
P_k	Input forward power
Pulse to pulse fluctuation/pulse to pulse stability	Distribution characteristics for a sequence of machine pulses; bunch intensity, average beam current, HLRF modulator pulse, etc
Within the pulse fluctuation	

Others:

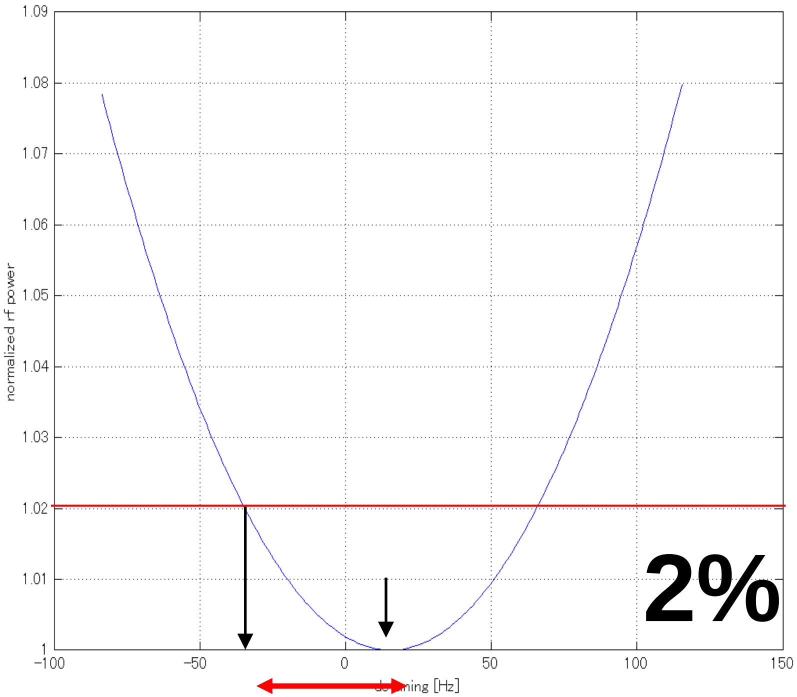
- Tuning Overhead
- Energy overhead
- Microphonics
- Residual vibration
- Vector Sum

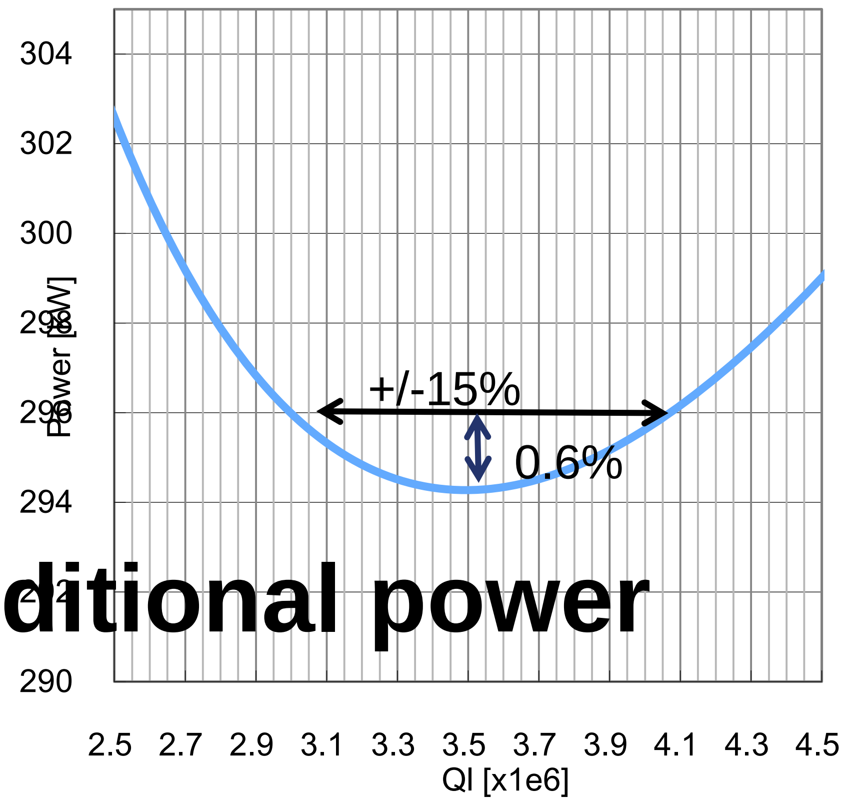
- Slow tuner
- Fast tuner
- Cavity Grouping
- Gradient spread
- Klystron saturation

Our task:

- Develop an optimized cost-conscious ILC linac design
- We know too little about optimizing high – gradient, 9 mA, CM performance
- To Note:
  - **P_k/Q_l (Michizono)**
  - **RDR DESIGN INCLUDES P_k/Q_l remote control via 3 stub tuner motors**
  - **(and Q_l control via coupler)**

Detuning , Ql tolerance





2% additional power

50 Hz

- 50 Hz detuning requires additional 2% rf power
- +/-15% Ql difference requires 0.6% additional power.

BAW1 (Sep.,2010)

Summary – Shin Michizono

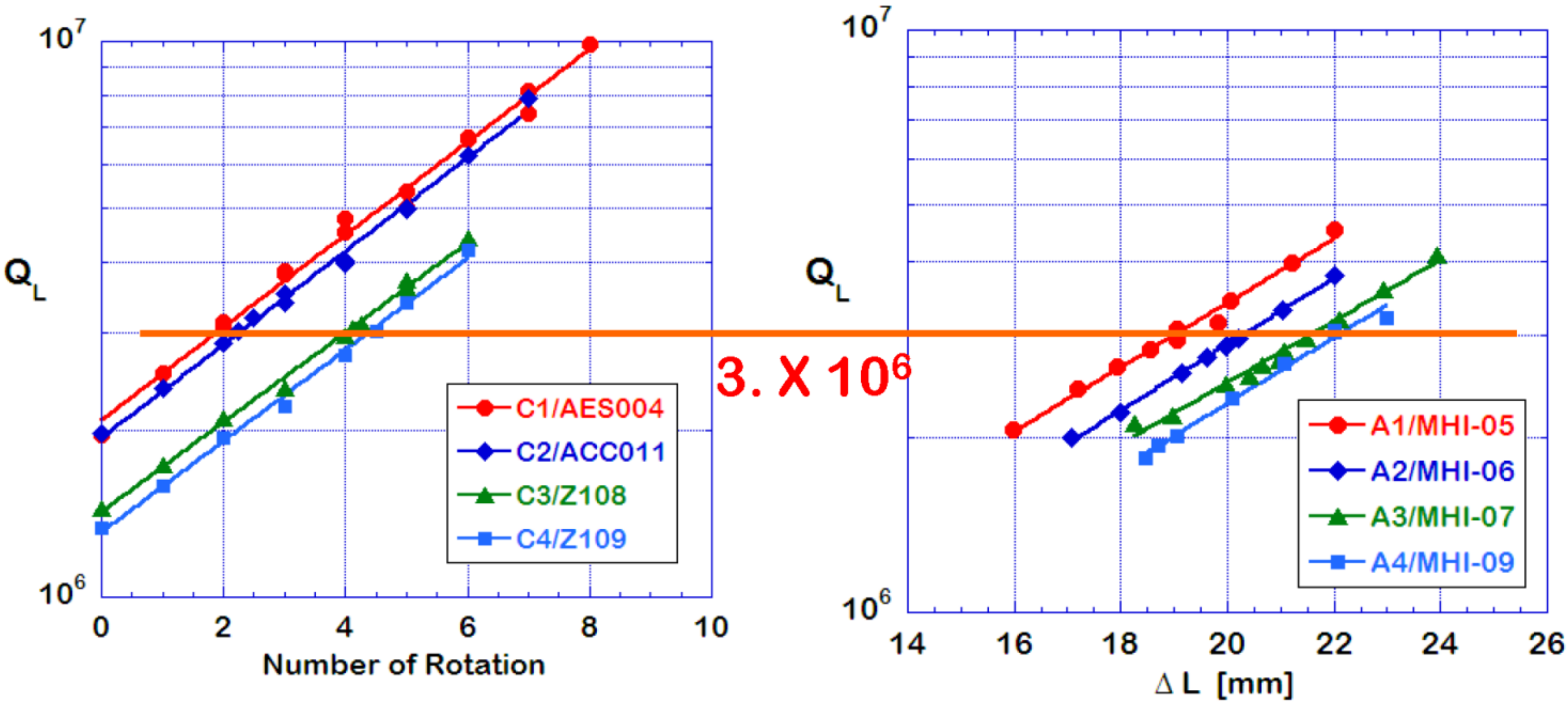
		RDR	DRFS (PkQl)	DRFS(Cavity grouping)
RF power	Operation gradient	Max. 33 MV/m	Average 31.5 MV/m	Max. 38 MV/m
	RF source	10 MW		800 kW
	Waveguide loss	8% power	2% power	2% power
	Static loss (Ql, Pk)	2% power	2% power	2% power
	Kly Hv ripple	2.5% power	2.5% power	2.5% power
	Microphonics	2% power	2% power	2% power
	Reflection	0% power	14% power	0% power
	Other LLRF margin	10% power	10% power	5%~10% power
Tolerance	Ql tolerance		3% (2)	3% (2)
	Pk tolerance		0.2dB (2)	0.2dB (2)
	Detuning tolerance		15Hz rms(3)	20Hz rms (3)
	Beam current offset		2% rms (3)	

(1) LLRF overhead ~5%
(2) Cavity gradient tilt (repetitive) ~5%
(3) Pulse-to-pulse gradient fluctuation ~1%rms

- We have to examine these numbers experimentally.
- Tolerance should be discussed with cavity and HLRF group. If the tolerance is smaller, better gradient tilt would be possible.

Q_L of Variable Input Coupler

Cryomodule - C　　Cryomodule - A

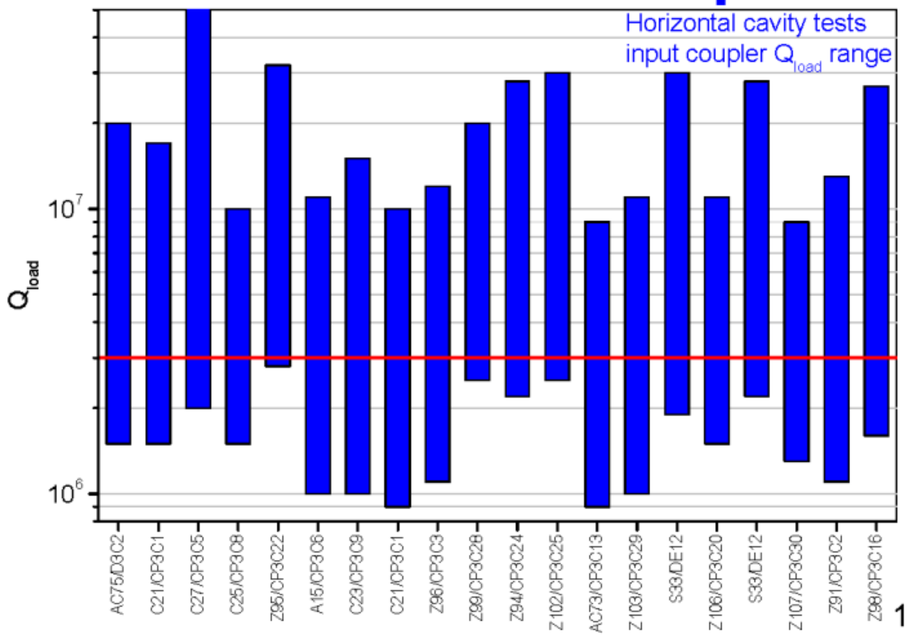


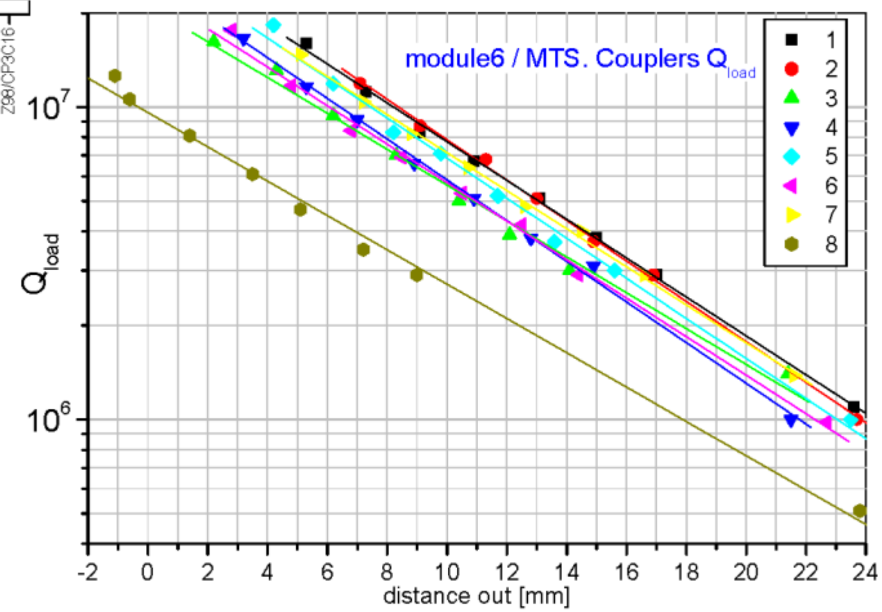
$Q_L = 2.0 \sim 8. \times 10^6$ (FNAL)

$Q_L = 1.3 \sim 4. \times 10^6$ (DESY)

$Q_L = 2.0 \sim 4. \times 10^6$ (KEK)

RF Couplers Q_{load} tests





‘LFD Compensation’

- (Noguchi: DLD compensation)
- Warren Schappert and Yuriy Pischalnikov
    - **Piezo control using Least-Square minimization**
    - **Of Finite Impulse Response Calibration Matrix**

Schappert
Pischalnikov
Fermilab TD

Detuning Response to Piezo pulse time