Coupler Tune-ability
&
Power Distribution System

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Grouping Concept for Scattered Cavity Gradient

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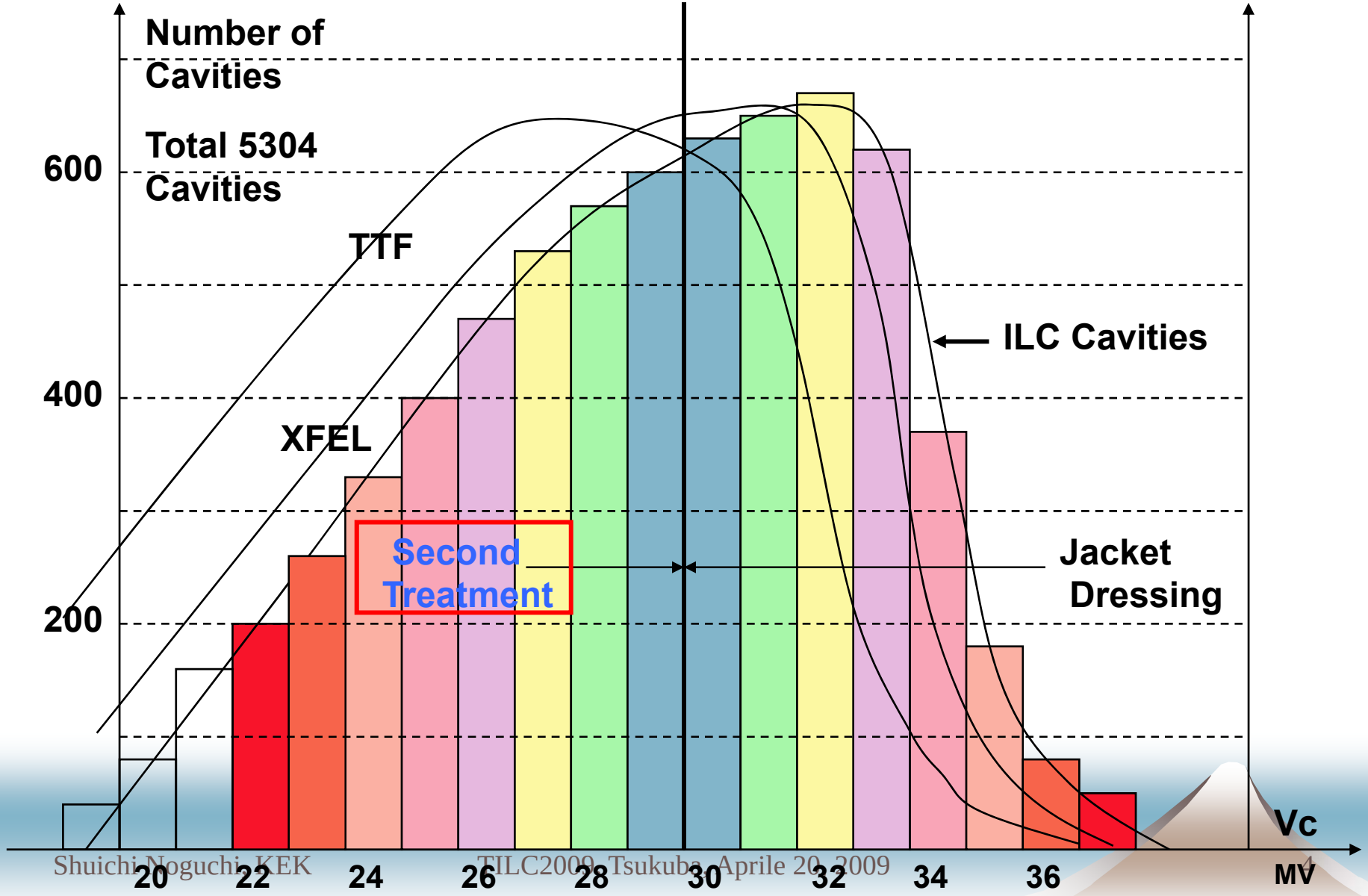
Assumption

- A Power Source Drives Multiple Cavities.
- Scatter of the Maximum Gradients.
- Maximum Use of Cavity Gradient.
- Maximum Power Efficiency.

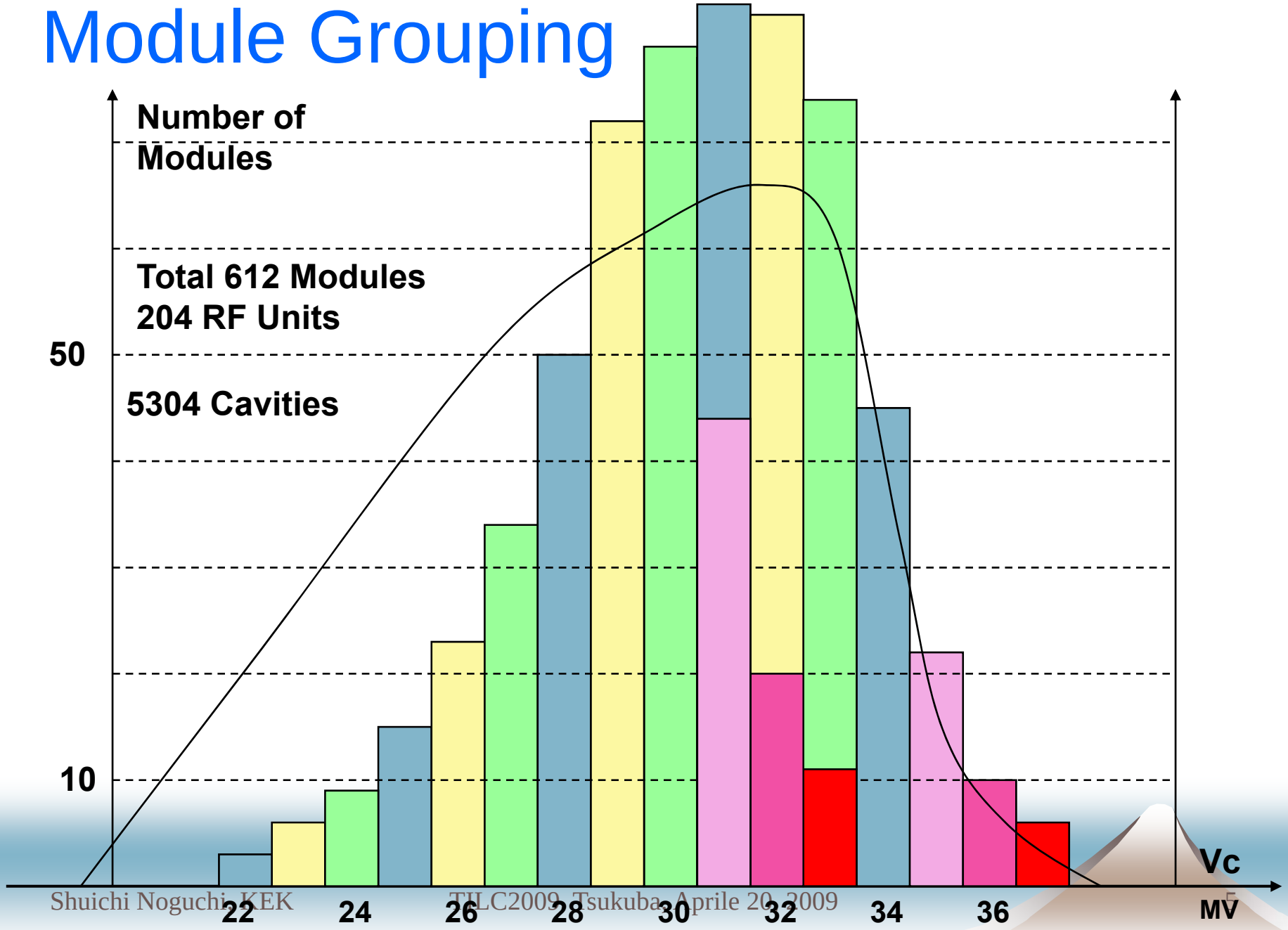
Cavity Grouping Concept

- Install the Cavities having nearly the same Maximum Gradient into the same Cryostat.
- Drive the same Gradient Cryomodules by one Klystron.
- Combine a higher Gradient module with two other lower Gradient Modules.

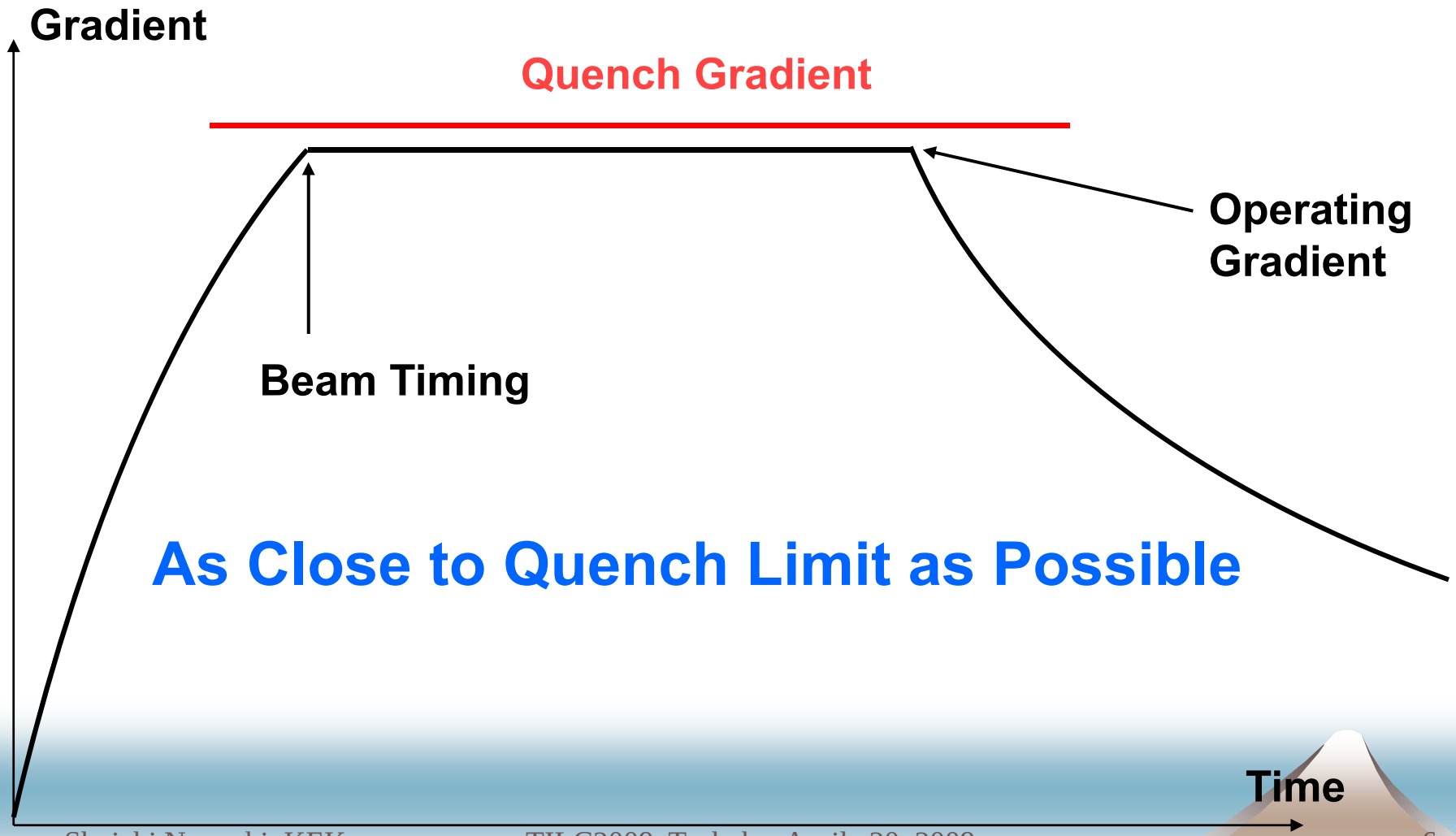
Cavity Grouping



Module Grouping



Highest Gradient Operation



As Close to Quench Limit as Possible

Parameter Setting for Flat-Top

Accelerating Voltage V_0 , Beam Current I_b

↓

Optimum $\beta = \beta_b + 1$, $\beta_b = P_{Beam} / P_0$

↓

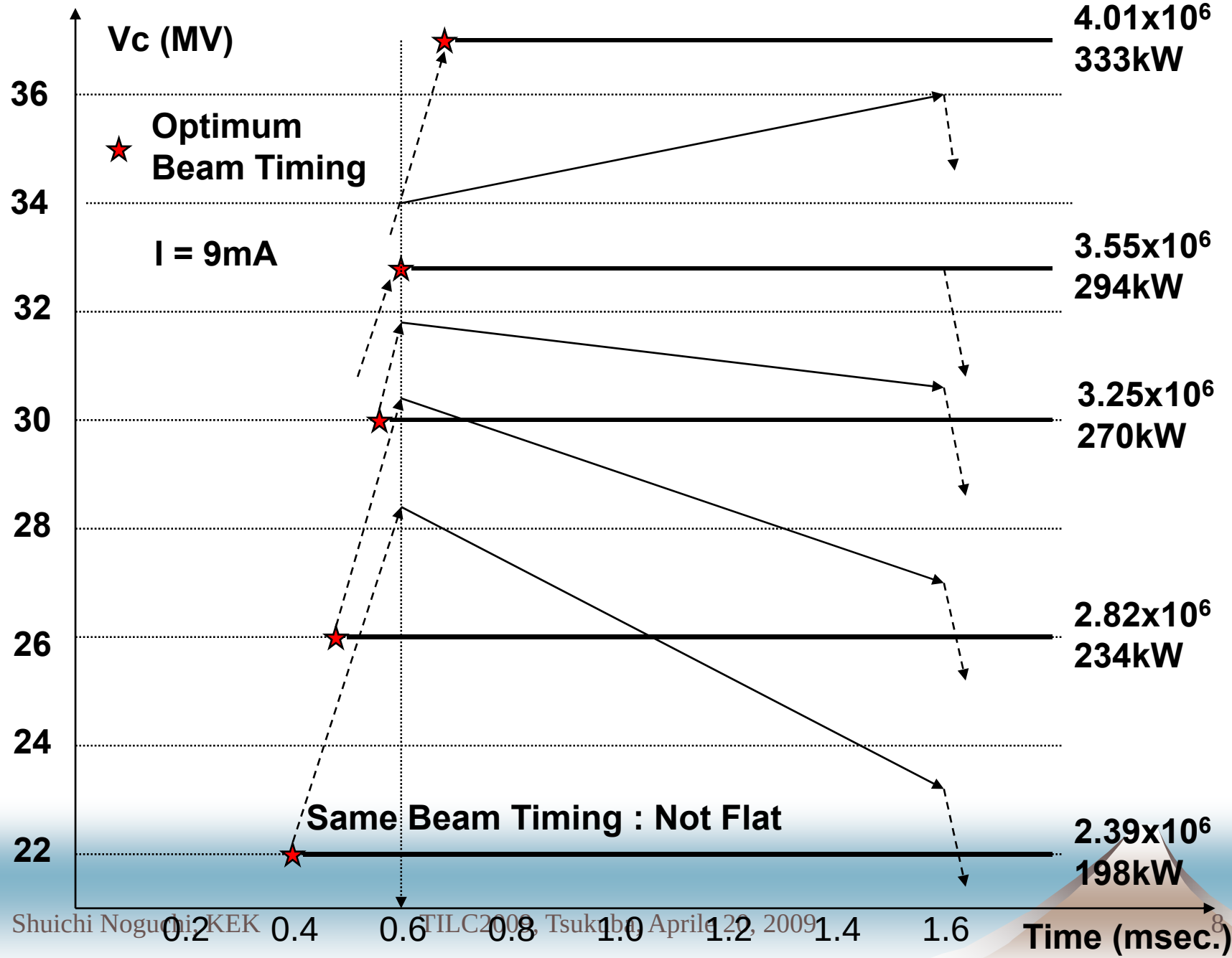
CW

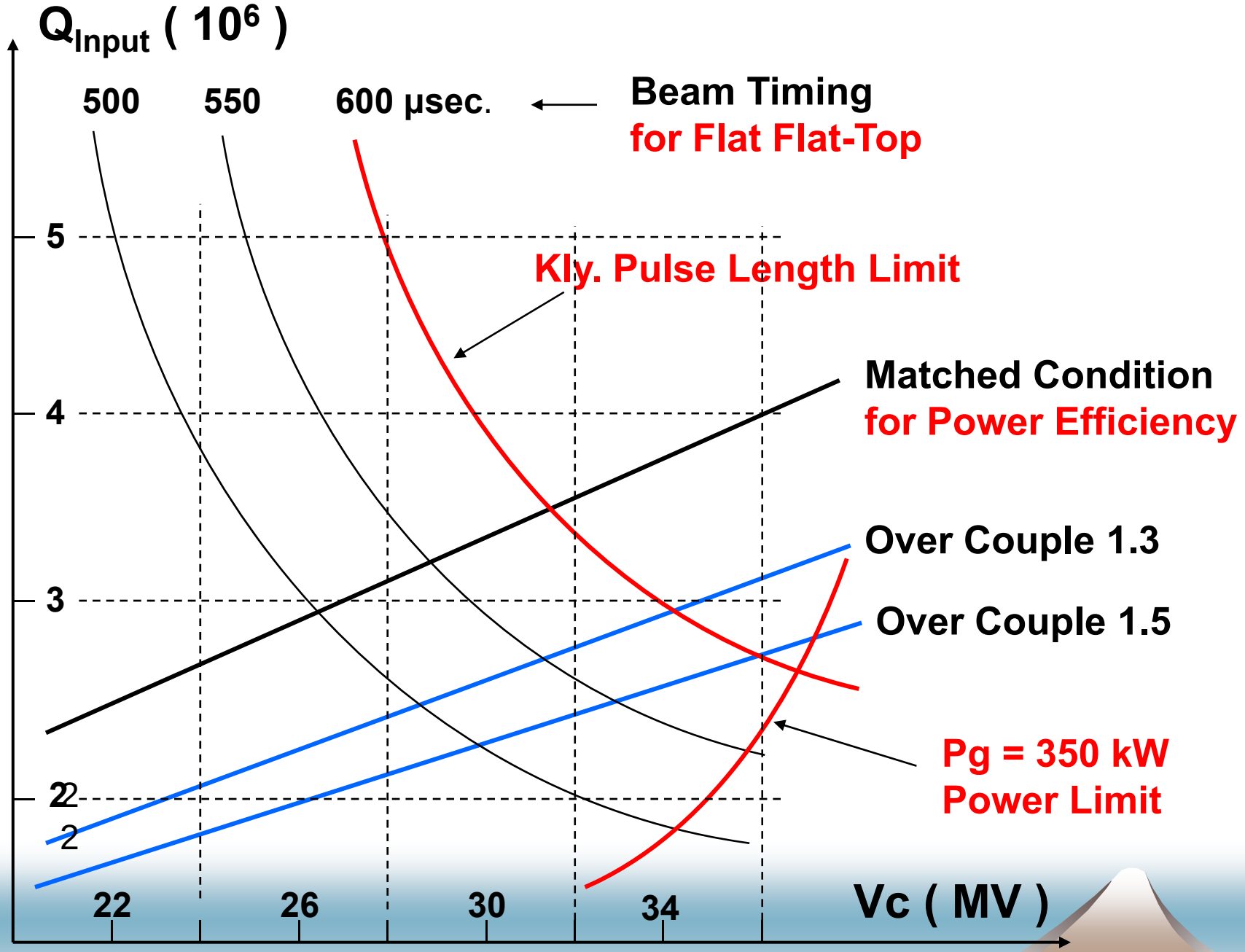
Pg

Pulse for Flat-Top

↓

Beam Timing	$T_e = T_F \ln \frac{1 + \beta + \beta_b}{\beta_b}$

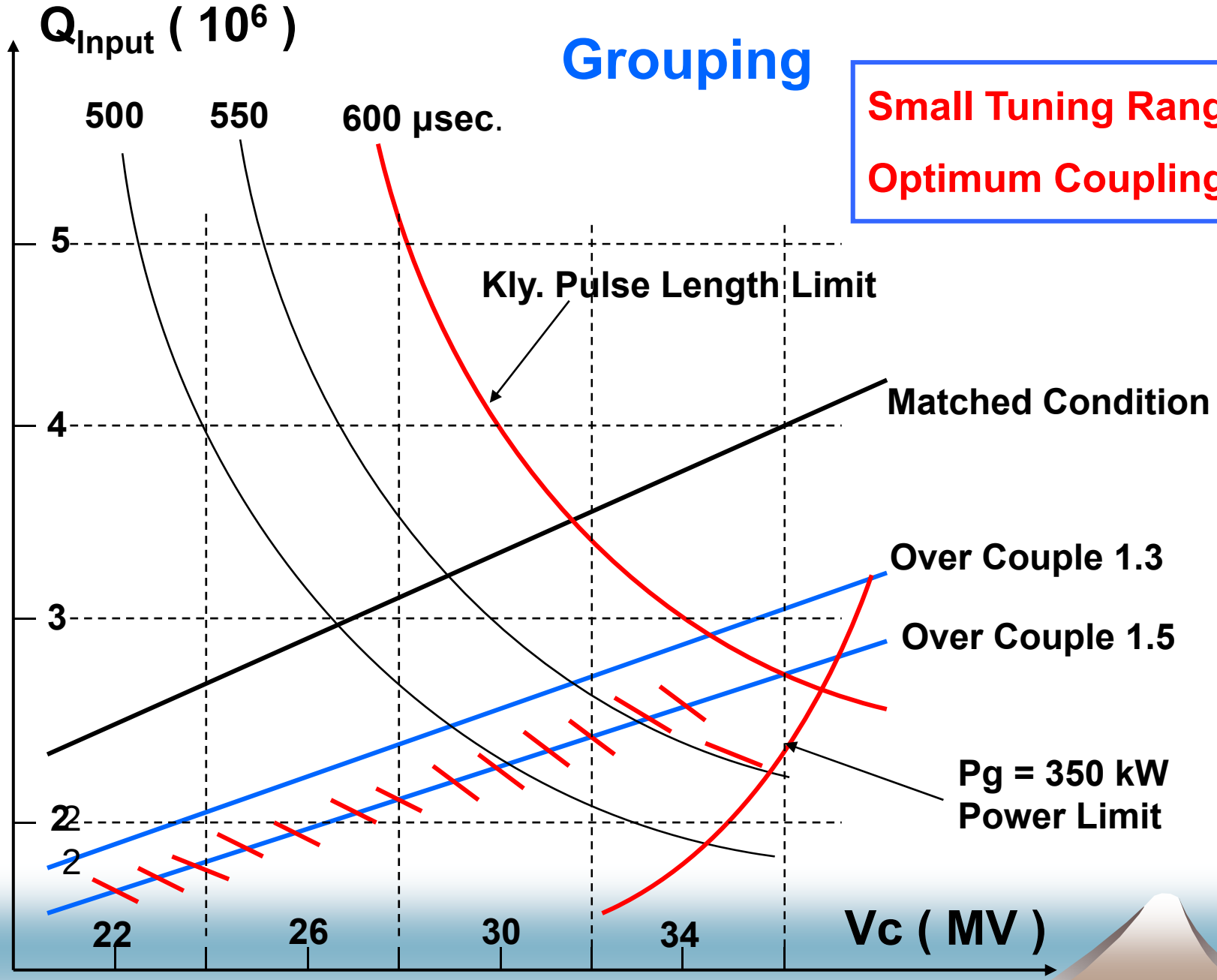

Vc (MV)
36
34
32
30
28
26
24
22
Optimum
Beam Timing
I = 9mA
4.01x10^6
333kW
3.55x10^6
294kW
3.25x10^6
270kW
2.82x10^6
234kW
2.39x10^6
198kW
Same Beam Timing : Not Flat
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Time (msec.)


Q_{Input} (10^6)
500
550
600 μsec.
Beam Timing
for Flat Flat-Top
5
4
3
2
Kly. Pulse Length Limit
Matched Condition
for Power Efficiency
Over Couple 1.3
Over Couple 1.5
Pg = 350 kW
Power Limit
22
26
30
34
Vc (MV)

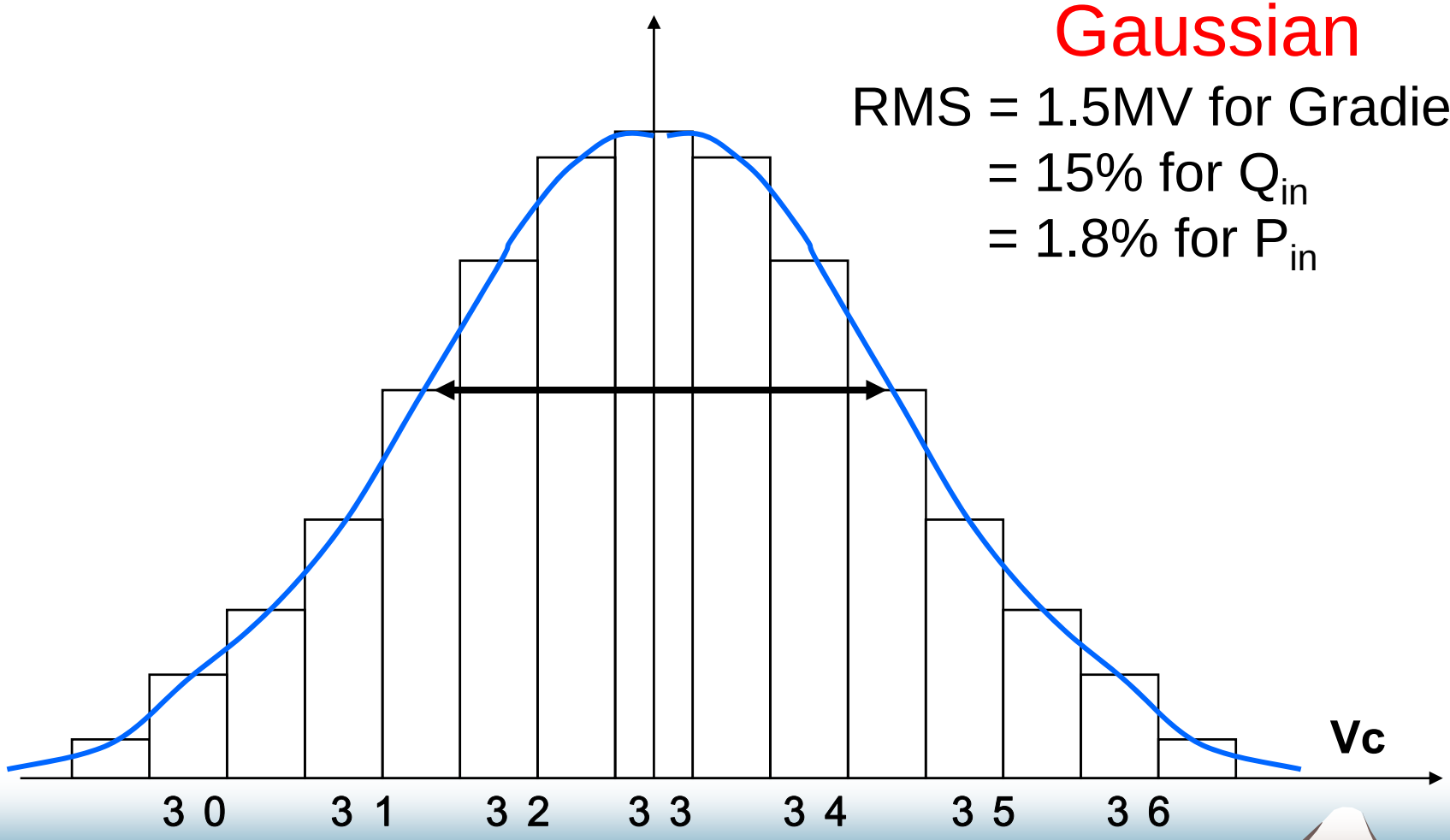
Grouping

Small Tuning Range

Optimum Coupling



Realistic Gradient Distribution



Gaussian

RMS = 1.5MV for Gradient

= 15% for Q_{in}

= 1.8% for P_{in}

Error Souses of Operating Gradient

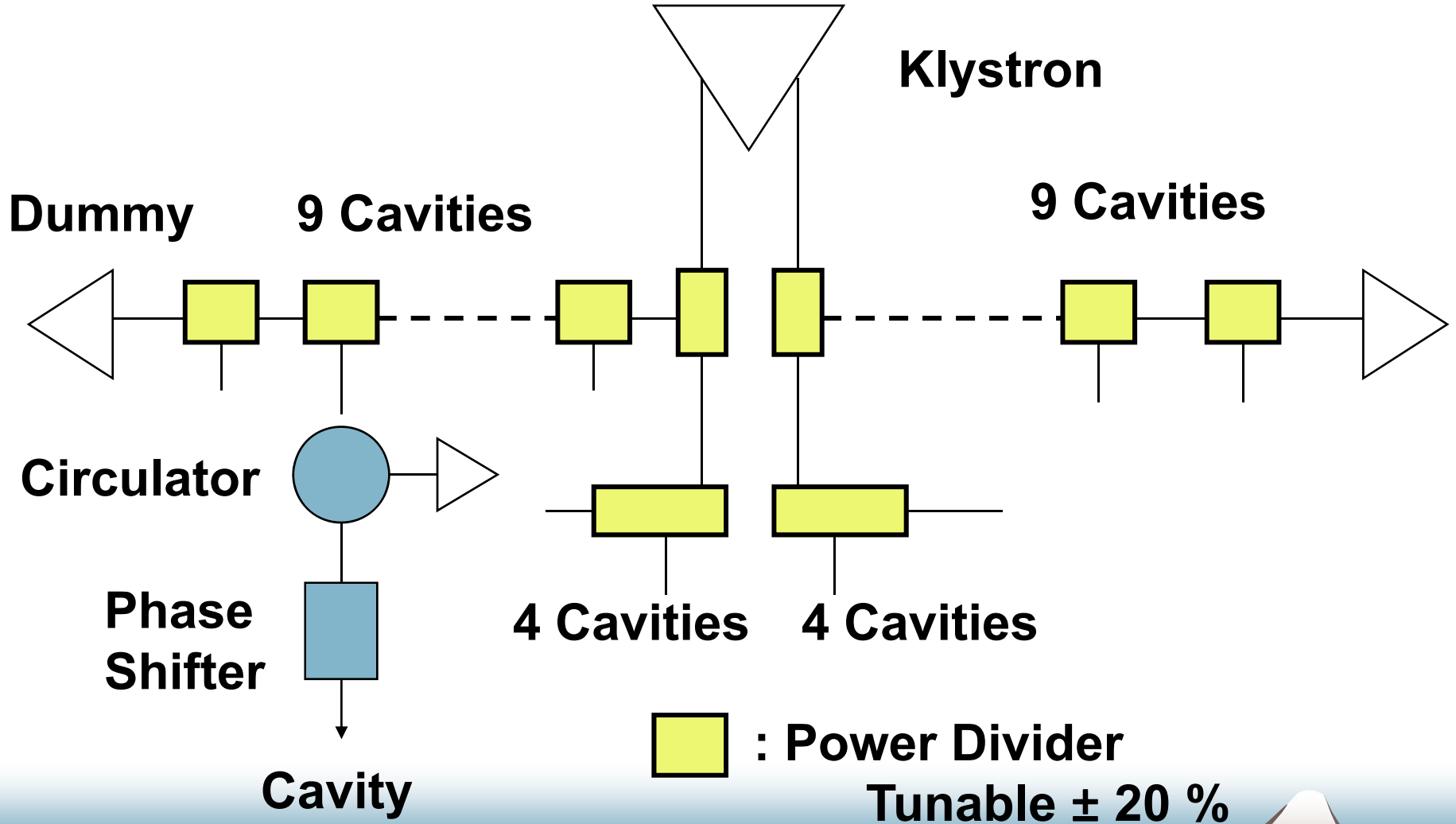
Error Souse	Error	Effect on Energy Gain	
Input Coupling Geometric + Field Flatness	15%	+1.9, -2.3%	Fixed
Input Power	1.8%	±1.4 %	Fixed
Input Power Phase	3 deg.	-0.14%	Fluctuation
Lorentz Detuning Compensation Error	50 Hz 13 deg.	-5.1%	Some Fluctuation

Cost Comparison

ML costs 4000 MILC, Assembly & Tuning Cost are not evaluated.

Tuning	Energy Reduction	Extra Cost	Devise Cost	Total Cost-Up
No Tuning	> 10 %	> 400	0	> 400
Full Tuning	0	0	60 + 60	120
Coupling $2.5 – 6.7 \times 10^6$	1.8 %	72	60	132
Power 227 – 347 kW	1.5 % 1.6 % (5mA)	60	60	120

Power Distribution



Distributed RF System

- Nearly Equal Gradient Cavities.
- Coupling Tune-ability may be not necessary.
- Tunable Power Divider may be not necessary.
- Circulators ?

  Low Current Operation

  Detuned Operation

Cluster Scheme

- Wide Range of Operating Gradient.
- Wide Range of Tune-ability are necessary, both for Coupling and Power Dividing.
- Circulator ?

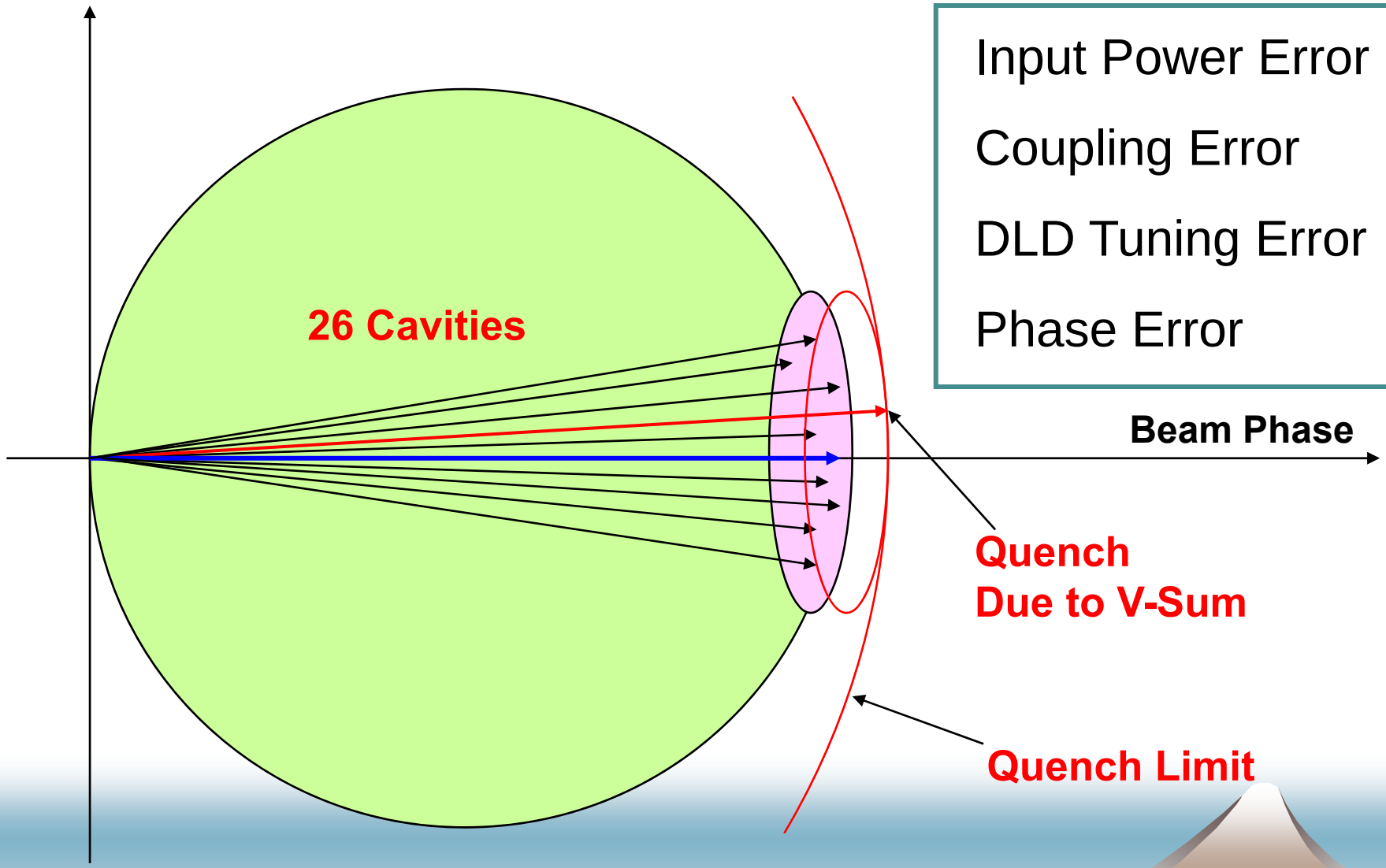
Error Souses of Operating Gradient

Error Souse	Error	Effect on Energy Gain	
Input Coupling Geometric + Field Flatness	15%	+1.9, -2.3%	Fixed
Power Dividing Ratio	2%	+1.5, -1.6%	Fixed
Input Power Phase	3 deg.	-0.14%	Fluctuation
Lorentz Detuning Compensation Error	50 Hz 13 deg.	-5.1%	Some Fluctuation

Operating Condition in ILC - ML

- 26 Cavities are Driven by One Klystron.
- Scatter of Cavity Gradient Performance.
- Design Maximum Klystron Power is 8 MW + Feed-back Margin (15 %).
- Maximum Pulse Width is 1.6 msec.
- Cavities above 150 GeV are used in Deceleration Mode, also.
- Lower Beam Current Operation.

Vector Sum Control



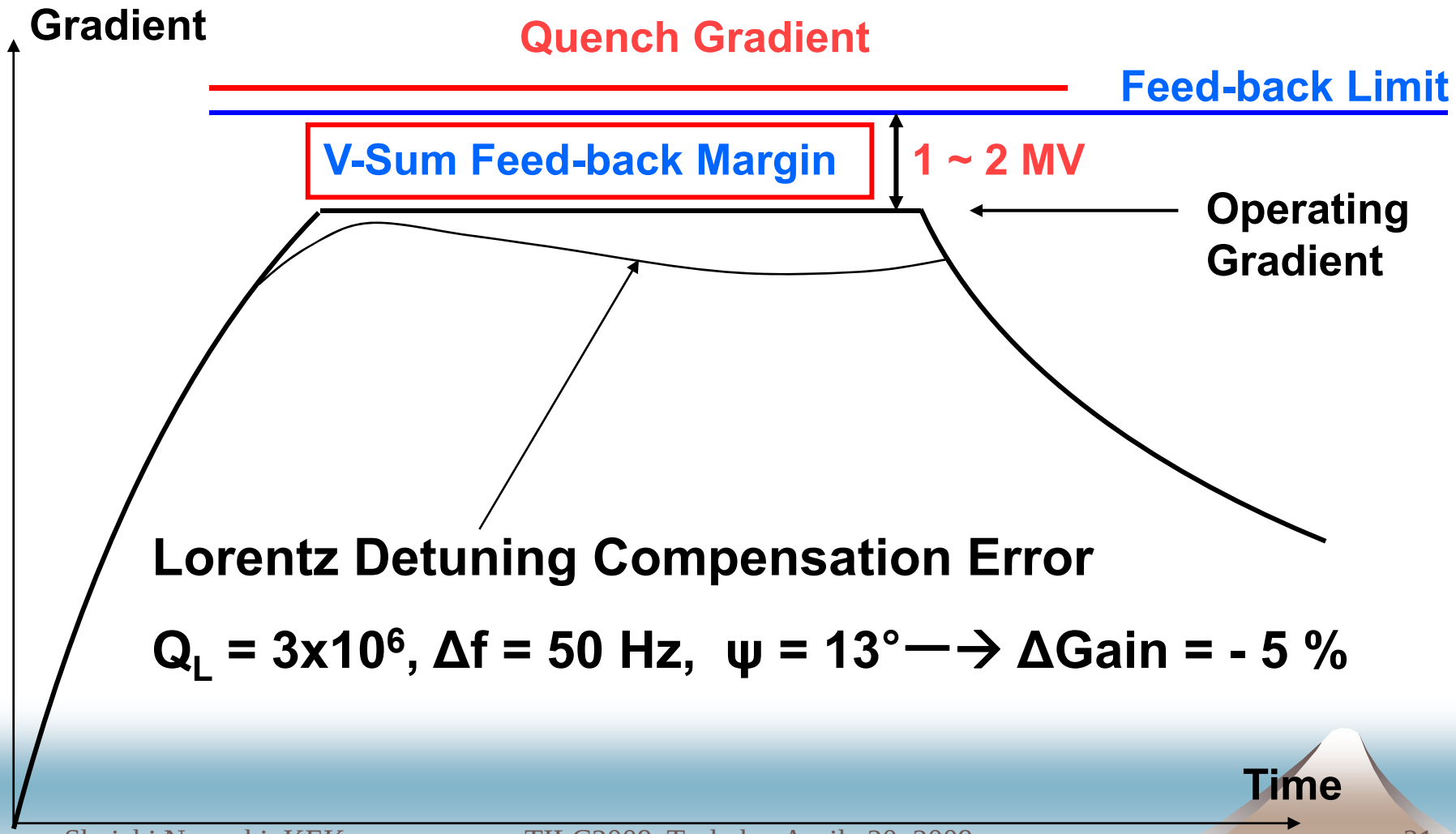
Input Power Error

Coupling Error

DLD Tuning Error

Phase Error

Highest Gradient Operation



Lorentz Detuning Compensation Error

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

Tuning & Gradient Reduction in Grouped Cavities

- No Tuning
- Power Tuning
- Coupling Tuning
- Power & Coupling Tuning
- DLD Compensation Error is not Included.(Biggest Effect)

Summary

- Cavity Grouping Scheme is Proposed.
  Power Effective, Small Tuning Range
  & Less DLD Effect.
- If we use this scheme, and assume the following number, the coupling tune-ability may be not cost effective.
  Coupling Error : 15 % RMS
  Gradient Distribution : 1.5MV RMS
- Input Coupler must have a capacity of 400 kW.
- Precise Evaluation of cost performance is necessary.

Coupler Acceptance Test Parameters

- Maximum Operating Power

  350 kW x 1.15 = 400 kW

- Test Parameter (Example)

  1.0 MW, 1.6msec.

  1.7 MW, 0.3msec.