A1

RF Distribution for S1-global

S. Fukuda

KEK

Slide 1

A1 Administrator, 9/27/2007

SCRF and STF Plan at KEK

by K. Yokoya

STF0.5 for TESLA-like (done Nov.2007)

STF0.5 for ICHIRO (to finish Mar.2008)

(red color indicates different cryostat)

STF1: for TESLA-like (to finish by summer 2008)

Full STF1 : (TESLA-like + ICHIRO)

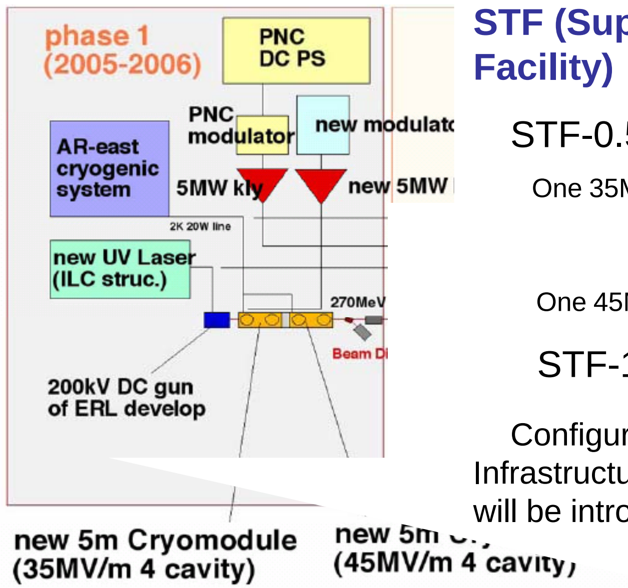
- Not yet decided
- To finish within CY2008 if to be done

>>> possible extention to **S1**, in CY2009 or later (proposed by PMs)

STF2 : design in JFY2008, construction in JFY2009-2010

(from scratch, not extension of STF1)

STF(KEK Superconducting RF Test Facility)



STF (Superconducting RF Test Facility)

STF-0.5(Under progress)

One 35MV/m-cavity in a 5m-long Cryomodule

+

One 45MV/m-cavity in a 5m-long Cryomodule

STF-1.0 (2007-2008:Delaying)

Configuration See left figure Necessary Infrastructures for STF (including EP, CP …) will be introduced.

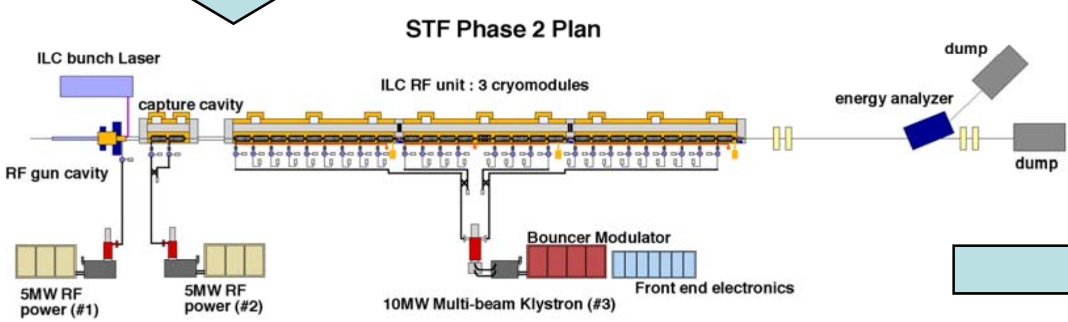
Required RF Components

STF-1.0 (1.3GHz,L-band)

- 5MW Klystron x 2
- Pulse Modulators
  - for 5-MW Klystron & for 10-MW Klystron
- Power Distribution System (PDS)
  - for 8-Cavity System
- LLRF (Analogue control, Digital control)

STF-2.0

- 10MW MBK
- Pulse Modulator
- PDS for 26-cavity system
- LLRF



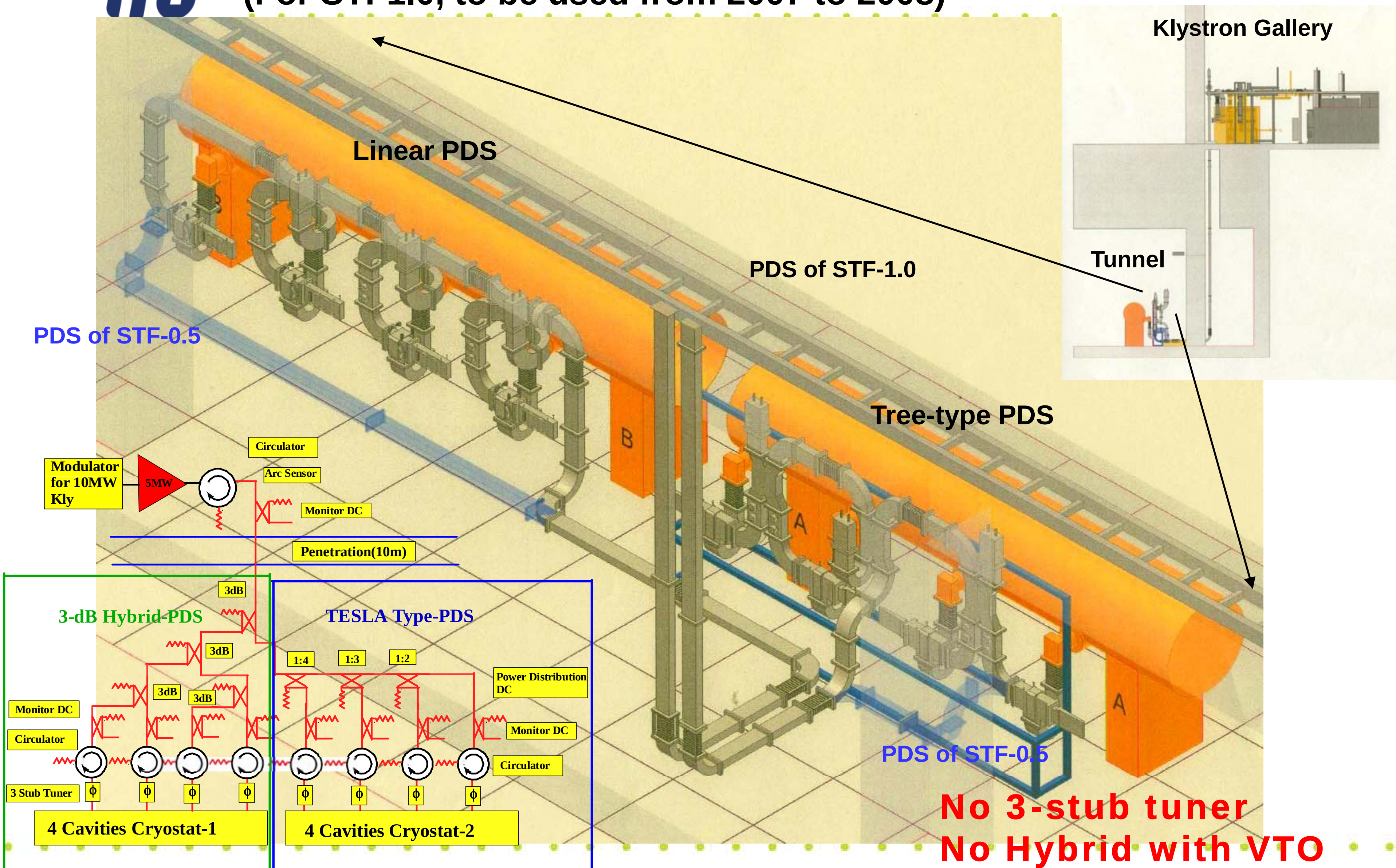
STF-Phase 3.0

Global Plan proposed

		CY08		CY10		CY12
EDR	TDP1				TDP-II	
S0: Cavity Gradient (MV/m)	30					35 (>90%)
KEK-STF-0.5a: 1 Tesla-like						
KEK-STF-0.5b: 1 LL						
KEK-STF1: 4 cavities						
S1-Global (AS-US-EU) 1 CM (4+2+2 cavities)			CM ($4_{AS}+2_{US}+2_{EU}$) <31.5 MV/m>			
S2 & STF2: One RF unit & 3 CM with beam		design	Fabrication in industries		Assembled and test at STF	
S1-Fermilab/US ILC-CM-3 or -4		CM1	CM2	CM3(Type-IV)		CM4

Current Power Distribution System in KEK

(For STF1.0, to be used from 2007 to 2008)



No 3-stub tuner
No Hybrid with VTO

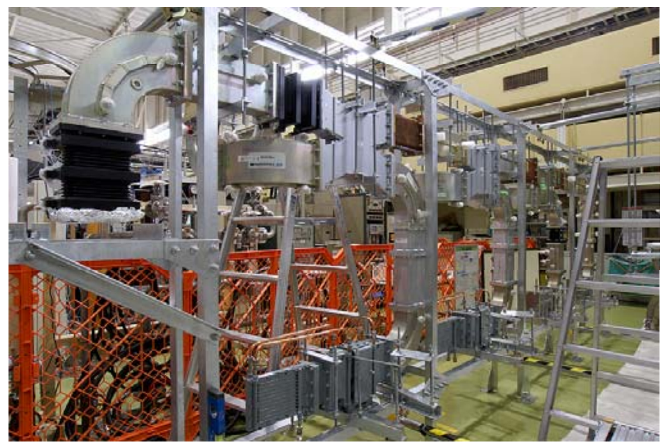
Current status of PDS for STF-0.5 and STF-1.0

STF-0.5 45MV/m Cavity side

STF-0.5 35MV/m cavity side

Installed couple to Cryomodule for the test of

Tree-like PDS (Front)



Linear PDS

Assembled PDSs in KG and waiting for the evaluation test

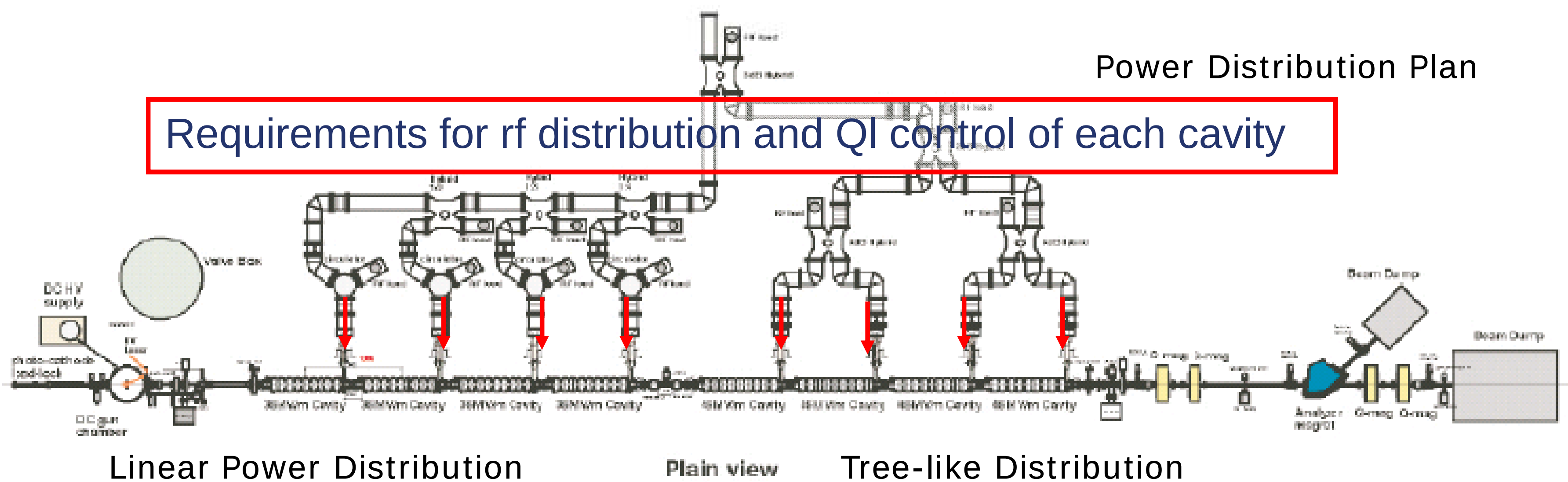
Consideration of S1-global at STF

- **Eight** cavities will be installed.
- Since we have 2 rf sources, 4 cavities (at least) may be driven by each rf source.

(Assumption)

- *Average gradient should be 31.5 MV/m.*
- *Cavities are operated without beam (no beam loading).*
- *Cavity operating gradient can be dependent the performance of each cavity and it ranges from 28.5 MV/m to 34.5 MV/m.*
- *Loaded Q of each cavity varies +/-15%. RF distribution ratio can be controlled by fine tuning (to some extent).*

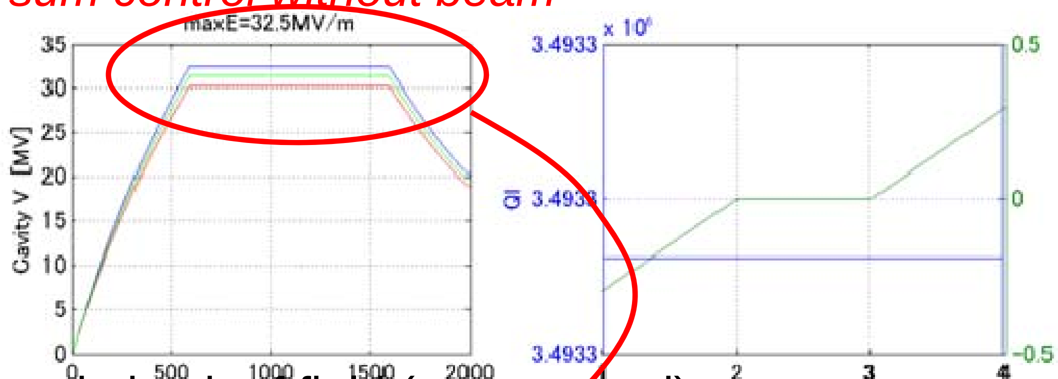
Requirements for rf distribution and Ql control of each cavity



Rf distribution and cavity field gradient

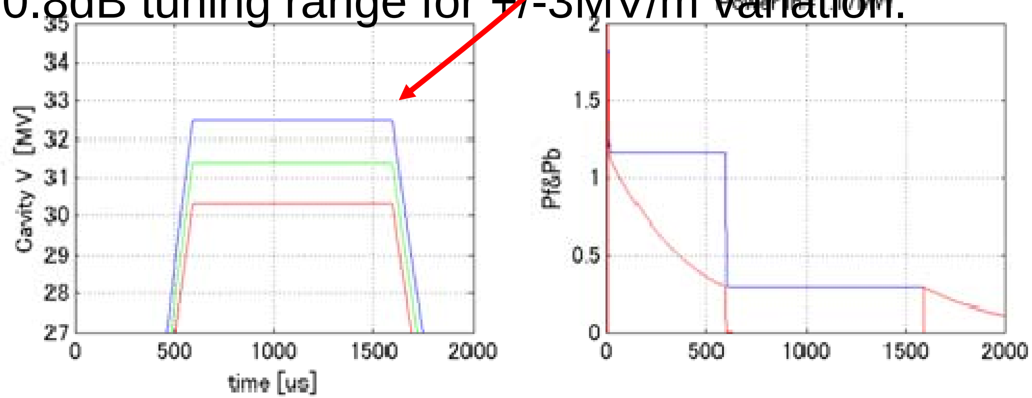
(simulation assumption)

- *4 cavities are driven.*
- *All cavities have same loaded Q (no variation).*
- *Rf distribution to cavities are -6.3dB, -6dB, -6dB, -5.7dB.* (+-0.3dB)
- *Vector sum control without beam*



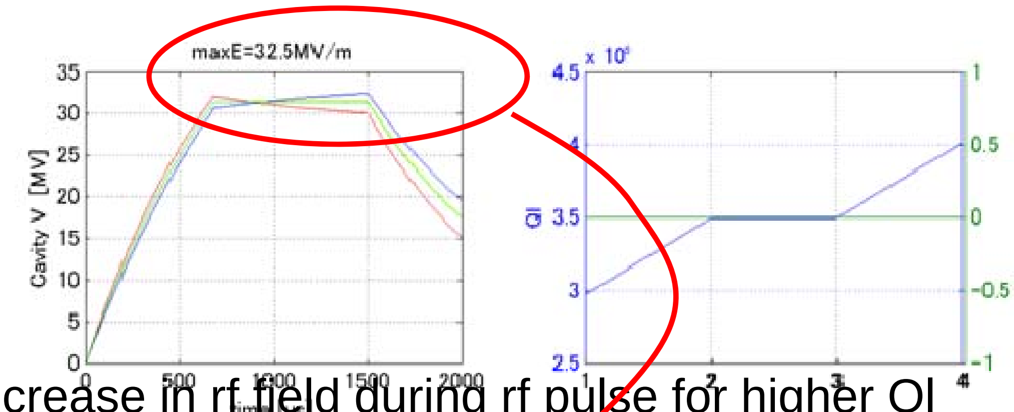
- +/-0.3dB variation in rf field (as expected).

-> need +/-0.8dB tuning range for +/-3MV/m variation.

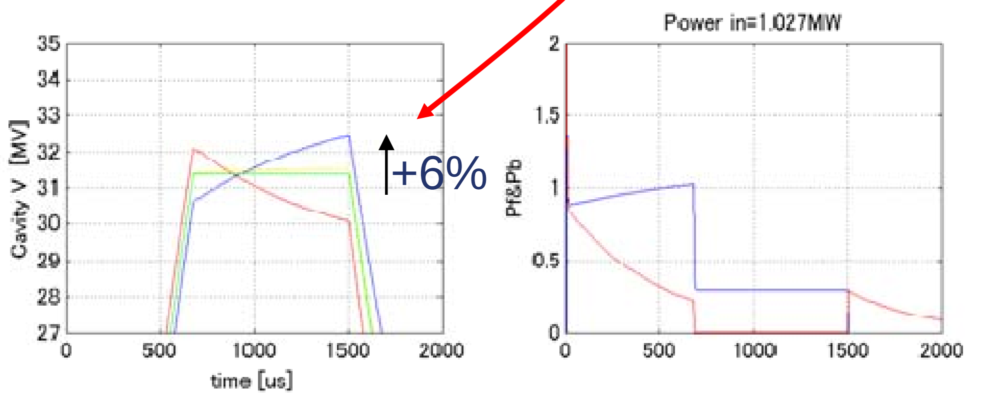


Ql variation and cavity field gradient

- *All cavities have* *same rf distribution (-6dB).*
- *Loaded Q variation of the cavities are -15%,0%,0% and 15%.* (+-15%)
- *Nominal loaded Q is 3.49e6.*
- *Vector sum control without beam*



- +6% increase in rf field during rf pulse for higher Ql



Cavities for S1-global in KEK

- Expecting Cavities for S1-global

- 2 Cryomodules with 8 Cavities

    4 from Asia including Ichiro Cavity(?)

    2 from EU

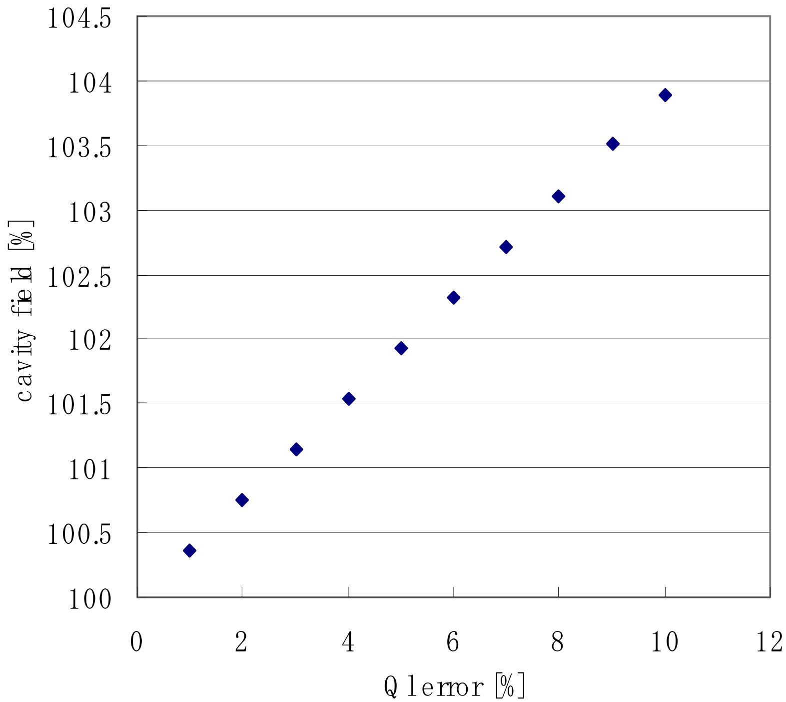
    2 from US

  Cavities with/without coupler tuners

    with different dimension

    with different gradient

Ql variation and cavity field gradient (2)



■ If the 6% field increase (+2MV/m) will not acceptable, external Ql control system by such as 3-stub should be installed.

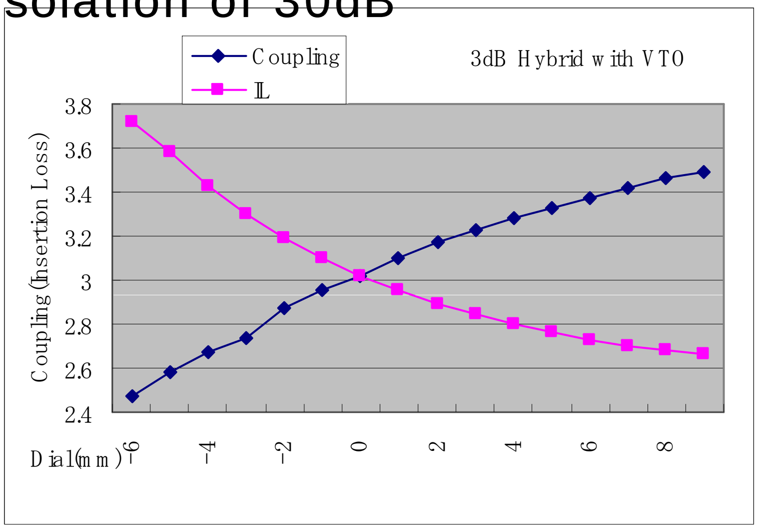
(summary)

■ **need rf input control of +/-0.8 dB and Ql control by 3-stub.**

Components for Power Regulation and Ql adjustment

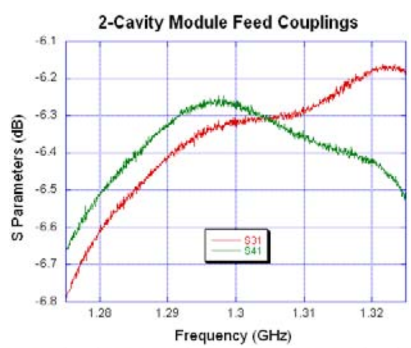
3dB Hybrid with VTO (KEK) :cheep & simple

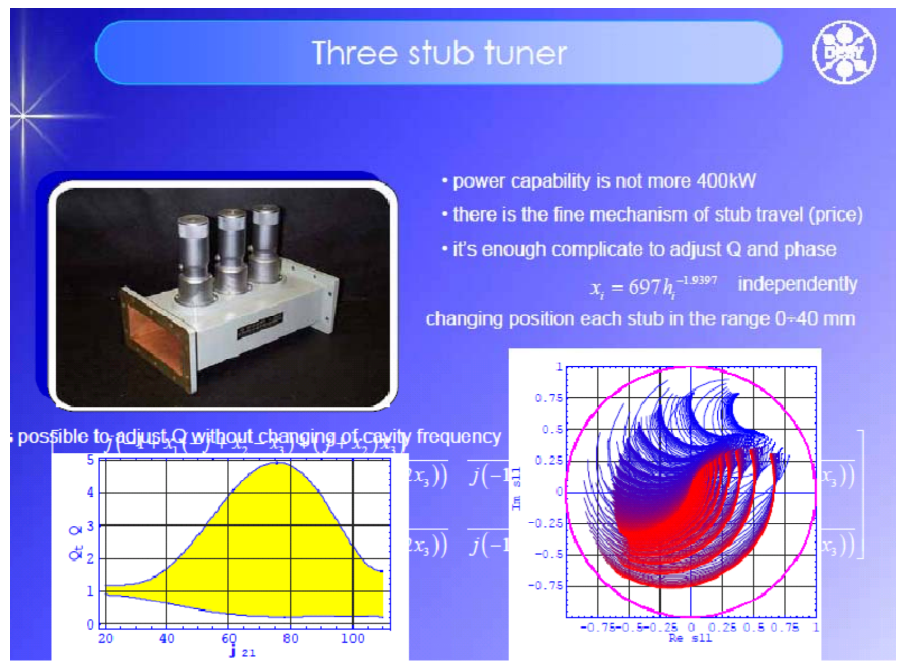
Isolation of 30dB



KEK should prepare
3 stub tuners as
Q-tuner
(Below from Kataliev)

VTO (SLAC):Isolation of 40dB





Field regulation at STF2.0 and ILC

Regulation Mechanism in RF Distribution /Coupler Tuner

- Cavities with variation of maximum operation field
- Operation with and without beam (or low beam current/ short beam pulse)

- It is impossible to obtain the flat rf field of each cavity by vector sum.
  (both with/without beam at unique rf distribution ratio and Ql)

- Alternative solutions
  - Satisfy only beam condition (by rf distribution/Ql control)
  - Dynamic detuning control (but no-saving for rf power)

Perturbations

Remarks from LLRF

• In order to evaluate LLRF stability (and satisfy llrf requirements), we need further information

- electron beam stability : <+/-1% (?)   Frequency distribution?
- positron beam stability : <+/-1% (?)

-> 1% increase caused 1% more rf power.

- damping ring rf stability : <0.3%, 0.3deg.rms (?)
- preciseness of beam current monitor at damping ring : <+/- 0.5% (This will be used for FF table at ML)

-> This precise beam current information is necessary for beam loading compensation.

- accuracy of Ql and RF distribution at HLRF : <1% (?)

-> We will benefit from measured distribution losses and setting accuracy of Ql and power splitters.

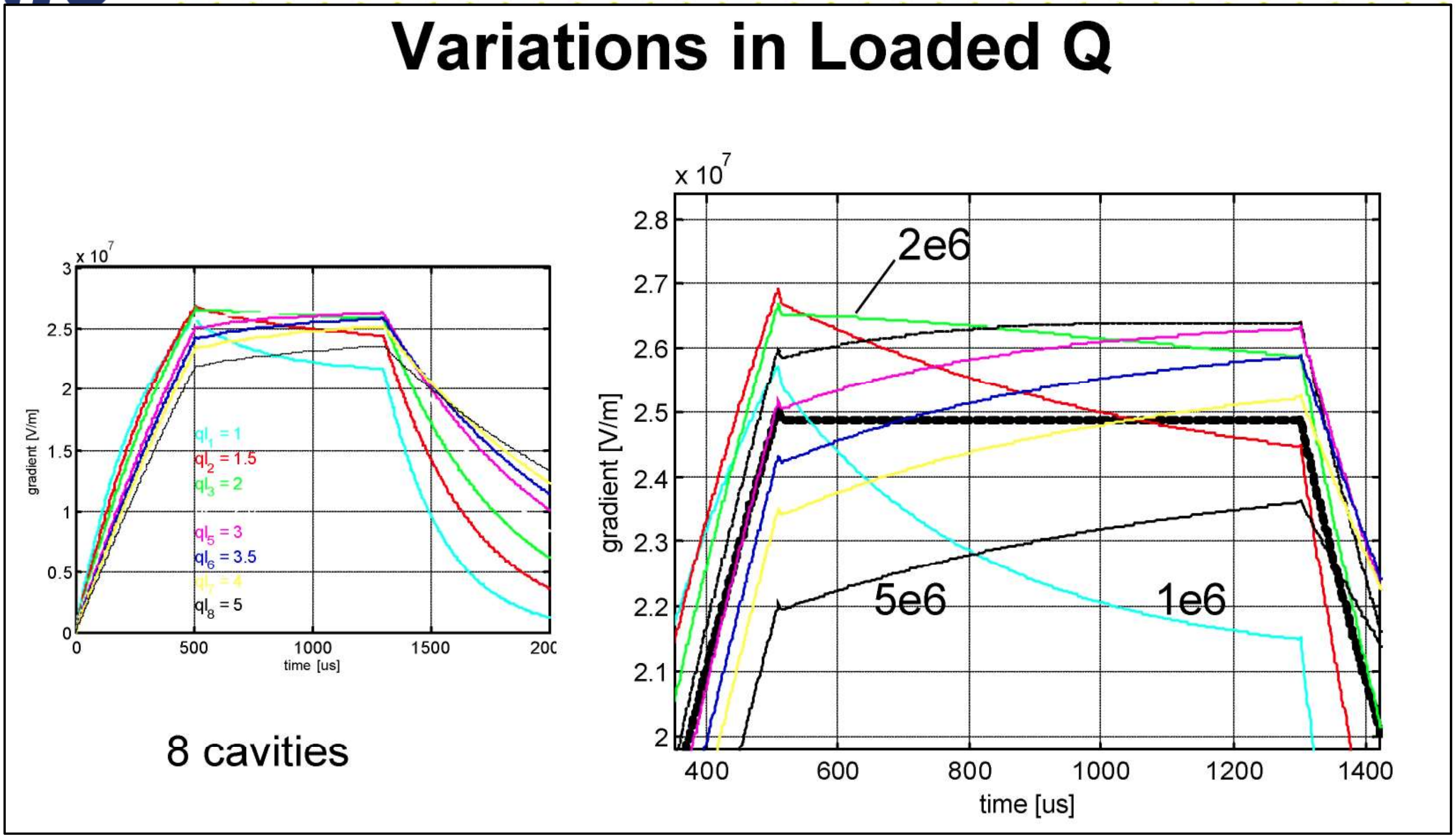
- microphonics level at cavities : <10 Hz (?)
- Lorentz force detuning with correction : <+/-50 Hz (?) (including microphonics)

-> +/-50 Hz detuning causes +/-2% additional rf power.

- Cavity gradient spread in an RF Unit

-> As much as 4% additional RF power.

Operation at Different Gradients



Variety of Ql results in the increase of rf field during rf pulse.

Strategy for lower gradient cavity

- Each cavity has ***a minimum performance of 35 MV/m*** during cavity mass-production acceptance testing. (RDR p. III-3)

-> ***At the beginning, we can operate at same rf field gradient (in principle).***

- If some cavities can not operate at 31.5~33 MV/m after long time operation, these cavities should be controlled in some strategy.

  Example: one cavity operation limit is 28 MV/m other 25 cavity-limit is 33 MV/m

(1) Conventional vector sum control:

Operation point decreases to 28 MV/m (average 28 MV/m) or one cavity detuned (average 33*25/26= 31.7 MV/m)

Advantage: simple

Disadvantage: we can not make use of the lower threshold cavity.

(2) Bane, Adolphsen, Nantista (PAC07): Ql and rf distribution control

Operation point can be 28 MV/m and 33 MV/m (average 32.8 MV/m)

Advantage: maximum usage of all the cavities with flat rf field during beam pulse

Disadvantage: complicated (motorized variable power tap-offs (VTO) and Ql are necessary), optimal Ql and VTO depend on beam current. -> When there is no beam (or short pulse beam), RF field increase with time at lower gradient cavity.

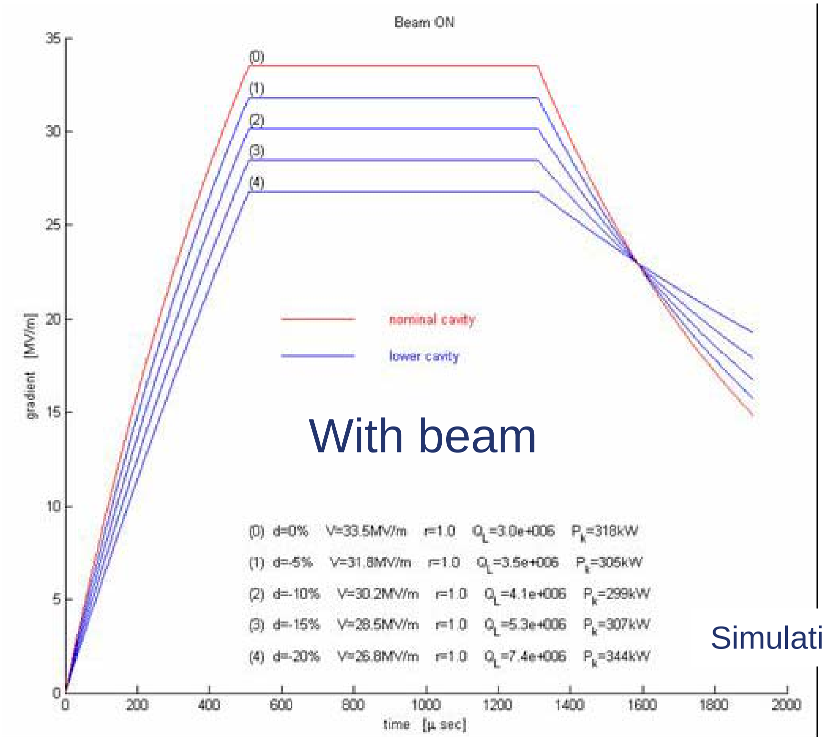
(3) Bane, Adolphsen, Nantista (PAC07): Ql control

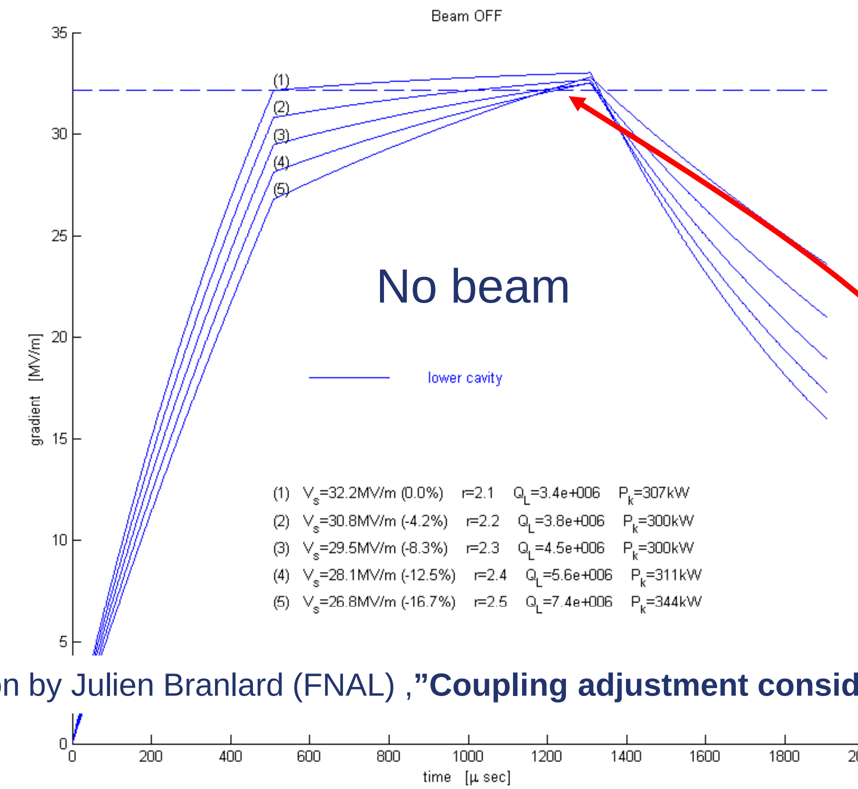
Operation point can be 28 MV/m and 33 MV/m (average 32.8 MV/m)

Advantage: more simple compared with (2)

Operation with Cavities at Different Gradients

Loaded Q and VTO control





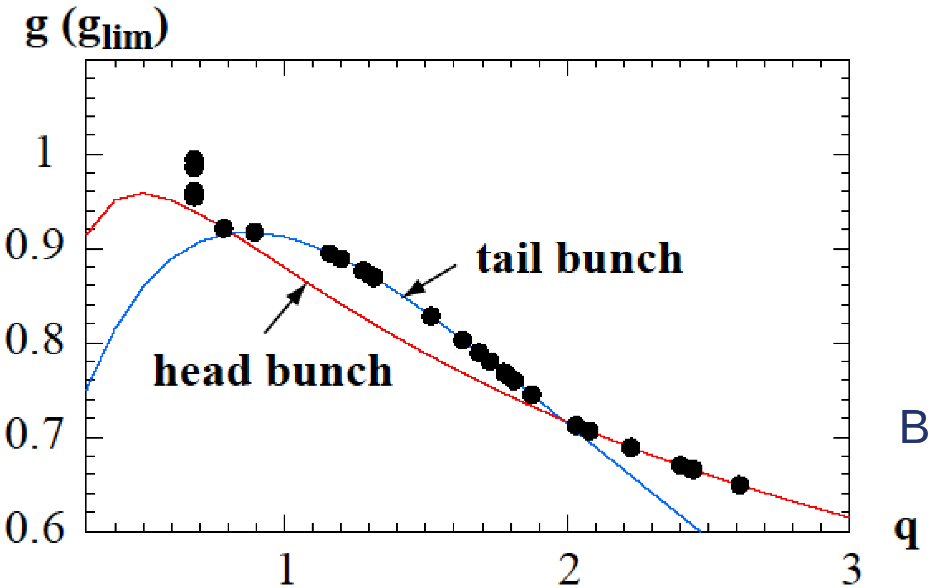
Simulation by Julien Branlard (FNAL) ,**"Coupling adjustment considerations"**

- RF field profile depends on beam condition (on/off/long/short …).
- Especially, lower gradient cavity's field increase in case of no-beam.
- Prepare two (or more) FB modes and switch them depending on beam.

…But when unexpected beam-loss takes place (by MPS,PPS), lower gradient cavity will be quenched.

Only loaded Q control

The RF unit voltage gain will not be completely flat along the bunch train (it will also, in general, not be monotonic).



Bane, Adolphsen, Nantista (PAC07)

Figure 3: 1-p, individual q's: For one seed, where optimized $p = 0.92$ and $\tau_b = 0.885$: gradient g *vs.* q for the head (red) and tail (blue) bunch in the train. Also plotted are $(g_{lim})_i$ *vs.* optimized q_i for the 26 cavities (plotting symbols). For this seed $\delta_{loss} = 2.8\%$.

Gradient Optimization with VTOs and Circulators

Consider uniform distribution of gradient limits $(G_{lim})_i$ from 22 to 34 MV/m in a 26 cavity rf unit - adjust cavity Q's and/not cavity power (P) to maximize overall gradient while keeping gradient uniform (< 1e-3 rms) during bunch train

Optimized $1-\langle G\rangle/\langle G_{lim}\rangle$; results for 100 seeds

Case	Not Sorted [%]	Sorted [%]
Individual P's and Q's (VTO and Circ)	0.0	0.0
1 *P*, individual *Q*'s (Circ but no VTO)	2.7 ± 0.4	2.7 ± 0.4
P's in pairs, *Q*'s in pairs (VTO but no Circ)	7.2 ± 1.4	0.8 ± 0.2
1 *P*, *Q*'s in pairs (no VTO, no Circ)	8.8 + 1.3	3.3 + 0.5
G_i set to lowest G_{lim} (no VTO, no Circ)	19.8 ± 2.0	19.8 ± 2.0

Bane, Adolphsen, Nantista (PAC07)

System Optimization

- From the HLRF strategy, cost reduction through the ACD is the main theme.
- No circulator, No motor-driven phase-shifter (Q-tuner) and inexpensive VTO are potential source of cost reduction.
- No circulator<-Hybrid with 40dB Isolation
- Gradient optimization

  -> Q tuning in couplers or in PDS?

  ->How frequently VTO should operate?

  semi-fixed (pre-tuned) or motor driven?

These items are optimized in the total system of HLRF, LLRF and cavity group. These are also required from the total cost optimization among the related technical group.

Summary

- For S1-global, since there are no beam, and we can demonstrate expected gradient(31MV/m) by optimizing power and Ql.

- For ILC, optimizing the cavity gradient involves more complicated features, especially for compromising the cost reduction of HLRF (no circulator, no motor drive module device).
- Sorting cavities may have some solution to eliminating circulators and no serous scarifying of the cavity gradient.
- Still for lower gradient cavity, we should pay attention to the beam conditions. Field increases at the pulse tail when there are no beam. Sophisticated LLRF may help this, partly. More complicated beam condition such as the narrower beam pulse required at the case of beam commissioning or beam study.
- Further discussion and study are required.