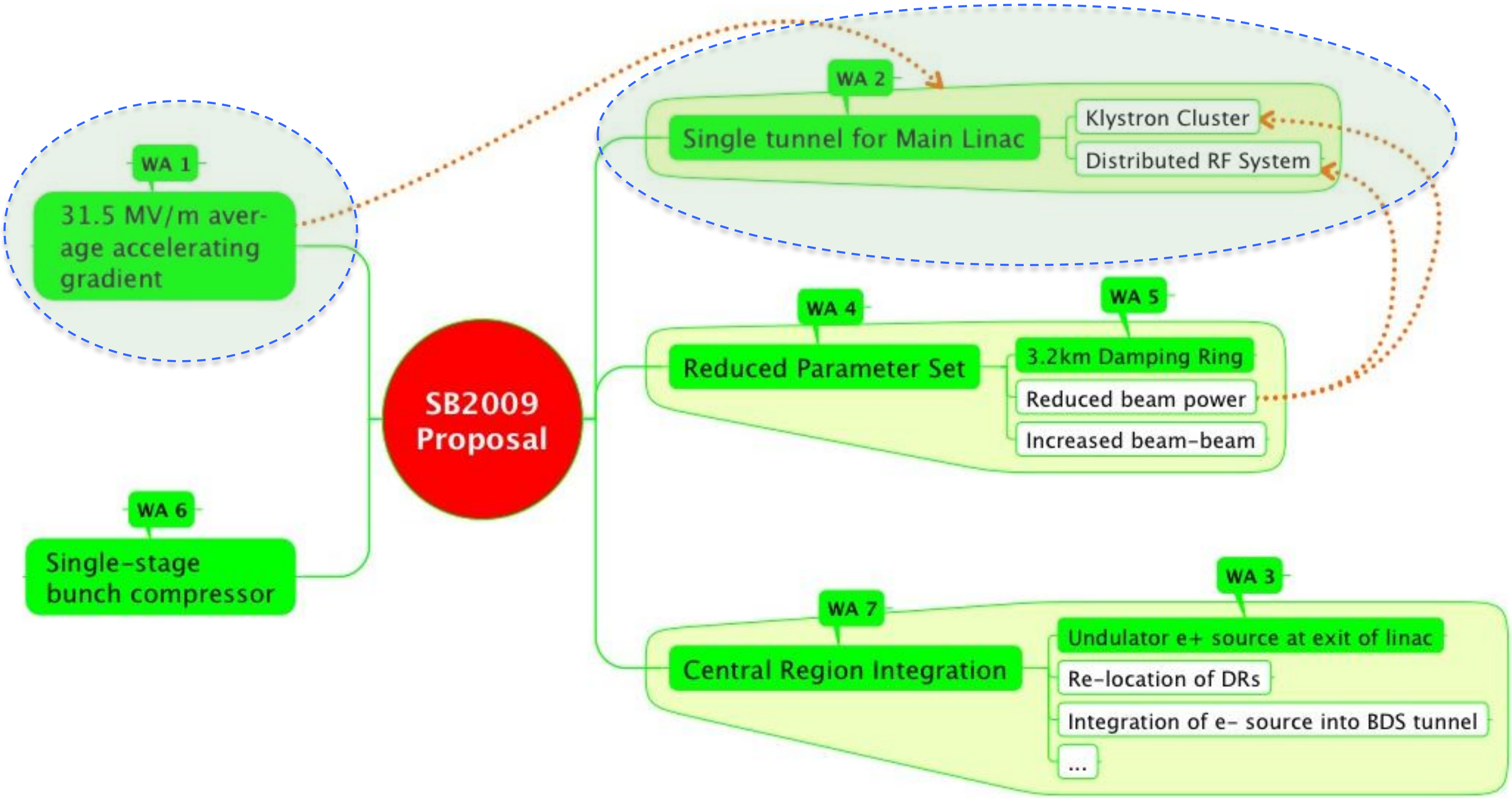
ILC-BAW1
Summary and Recommendations

Akira Yamamoto, Marc Ross and
Nick Walker
GDE Project Managers

Reported at BAW1, held at KEK, Sept. 10, 2010

SB2009 Themes



N Walker

Baseline Assessment WorkShops

Baseline Assessment Workshops

- Face to face meetings
- Open to all stakeholders
- Plenary

	When	Where	What
WAB 1	Sept. 7-10, 2010	KEK	1. Accelerating Gradient 2. Single Tunnel (HLRF)
WAB 2	Jan 18-21, 2011	SLAC	3. Reduced RF power 4. e+ source location

BAW1 Objectives and Goals

- Assess technical proposal in SB2009
- Confirm R&D Plan required and Goal in TDP-2
- Discuss Impact across system interfaces, cost, and schedule,
- Discuss toward consensus in GDE and Physics/Detector groups to prepare for TLCC.

Subjects discussed in Sessions

Date	Main Theme	Tasks
Sept. 7	Introduction HLRF-KCS: Design and R&D RDR: Technical	Make the workshop tasks clear Process for the reality including cost Feasibility as a backup solution
Sept. 8	DRFS: Design and R&D LLRF/Control Discussions	Process for the reality including cost R&F operation margin for cavity/accelerator Recommendation
Sept. 9	Cavity Gradient: R&D Discussions	Strategy for cavity gradient improvement Short-term and long-term strategy to be clear
Sept. 10	ML Accelerator Gradient Discussions	Accelerator gradient including spread, Appropriate balance of gradient in cavity/cryomodule/accelerator, and Adequate margin in accelerator operation Recommendation

Time-Table / Agenda (Sept. 7)

updated: August 27

Day	Am/pm	Subject	Chair/presenter
9/7		Single Tunnel ML Design and HLRF -1	S. Fukuda / C. Nantista
	9:0 0 90 min	Opening and Introduction - Opening address - Report from AAP - BAW1 objectives and goals	Chair: S. Yamaguchi - A. Suzuki (KEK-DG) - E. Elsen - A. Yamamoto (GDE-PM)
	10:45 90 min	Single tunnel CF design and HLRF design - Single tunnel CF design status (1 hour) - General HLRF design in SB2009 (30 min)	Chair: T. Shidara - A. Enomoto - S. Fukuda
	13:30 120 min	HLRF KCS -KCS design and R&D status (45 min) -Demonstration of feasibility (45 min)	Chair: S. Fukuda - C. Nantista - C. Adolphsen
	15:45 105 min	HLRF – EU XFEL and RDR - Introduction (20 min) - Experience from XFEL (1 hour) - RDR configuration (as backup) (10 min) - Discussion (15 min)	Chair: N. Walker -M. Ross -W. Bialowons - S. Fukuda - ALL

Time-Table / Agenda (Sept. 8)

Day	Am/pm	Subject	Convener/presenter
9/8		Single Tunnel ML Design and HLRF -2	S. Fukuda / C. Nantista
	9:00	DRFS -DRFS design and R&D status -Installation strategy -(1 hour total)	Chair: C. Nantista - S. Fukuda - S. Fukuda
	10:45	HLRF and LLRF -LLRF requirements/issues for KCS 30 -LLRF requirements/issues for DRFS 30 -Requirements from Beam Dynamics 30	Chair: T. Shidara - C. Adolphsen - S. Michizono - K. Kubo
	13:30	Operational consideration - Sorting cavities in relation with HLRF 30 - Gradient and RF Power Overhead 30	Chair: C. Adolphsen - S. Noguchi - J. Cawardine
	15:45	Discussions and Recommendations - General discussions and questions - Summary and recommendations	Chair: A. Yamamoto - TBD - ALL

Single Tunnel Proposal: intro 1

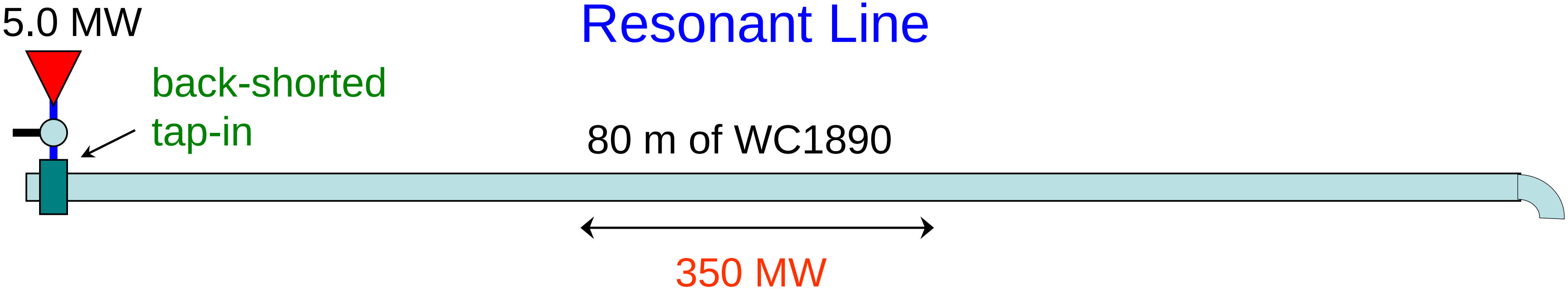
- The proposal to go to a single tunnel solution for the Main Linac technical systems remains essential that outlined in the SB2009 report.
- The primary motivation was and remains a reduction in project cost due to the removal of the service tunnel for the Main Linac.

- The original proposal was based on the adoption of two novel schemes for the HLRF:
  - KCS
  - DRFS
- KCS has been identified as a preferred solutions for 'flat land' sites where surface access (buildings) is not restricted
- DRFS has been identified as being preferred solutions for mountainous region where surface access (buildings) is severely limited.

- Having both R&D programmes in parallel can be considered as risk-mitigation against one or other of them failiing.
- It is acknowledged that both these schemes require R&D
  - Programmes are detailed in the R&D Plan Release 5
- At the time of submission in December 2009, the two primary obstacles to adoption of a single tunnel were identified as
  - Safety egress
  - Operations & Availability

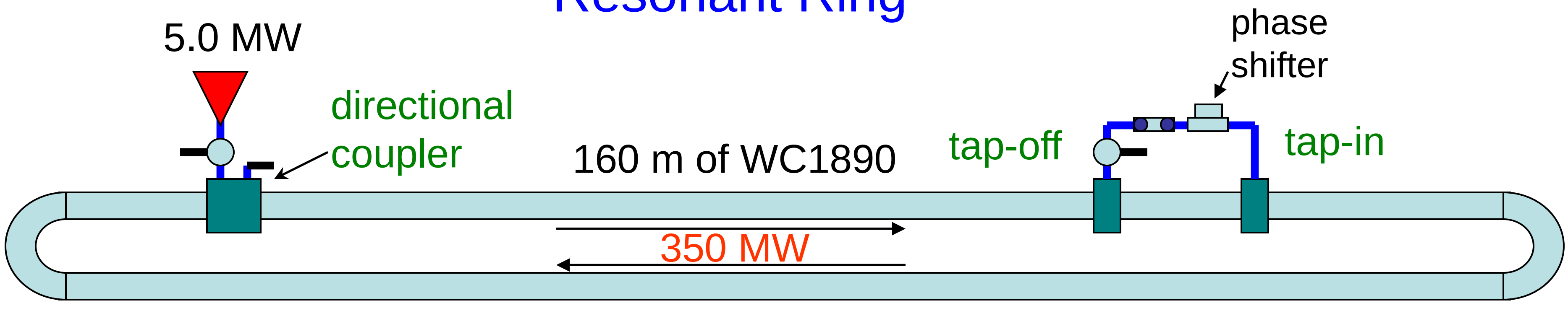
In FY11: Also extend pipe system to 80 m and add bend prototype

Resonant Line



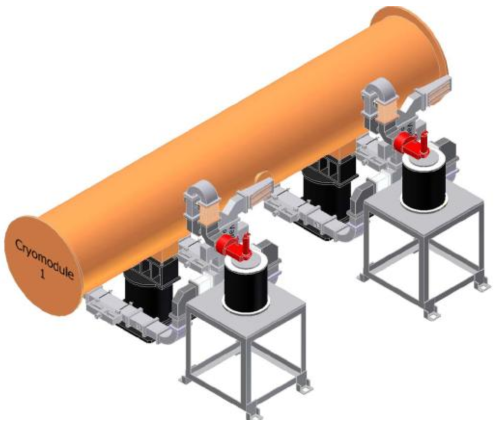
In FY12: Use resonant ring to test 'final design' bends and tap-in/off

Resonant Ring



Task and R & D schedule of DRFS in KEK

- R&D study is easy since the DRFS system is not large.
- Task force team of DRFS starts and try to solve the problems of DRFS.
- Prototype RF unit is manufactured in FY09
- Further R&D required for the DRFS RF system is continued from FY09. Three year R&D budget was approved.
- Permanent magnet, high voltage SW and IGBT will be studied intensively.
- Prototype will be evaluated in the S1 global test (2 Klystron DRFS)
- And then installed in the buncher section of STF-II aiming for the realistic operation.
- More large scale of DRFS (4~5 Klystron DRFS) is planed for STF-II in KEK.



S1-Global Plan

RDR HLRF Tech. Solution 1

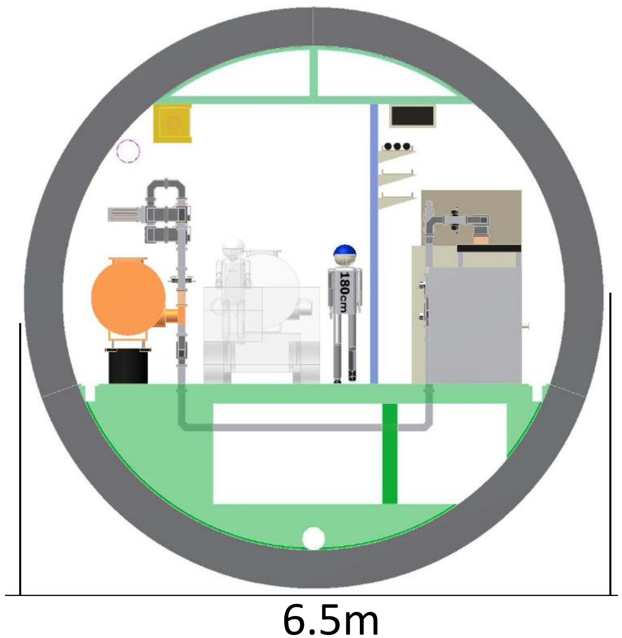
- Two scenarios have been cursorily studied for support of an RDR-like HLRF solution in a single-tunnel
  1. 10MW MBK + (Marx) Modulator in the tunnel
  2. XFEL-like solution with modulators (low-voltage) accessible in cryo refrigeration builds/caverns, with long pulsed cables feeding 10MW MBKs (via a pulse transformer) in the tunnel.
- Both are considered technically feasible.

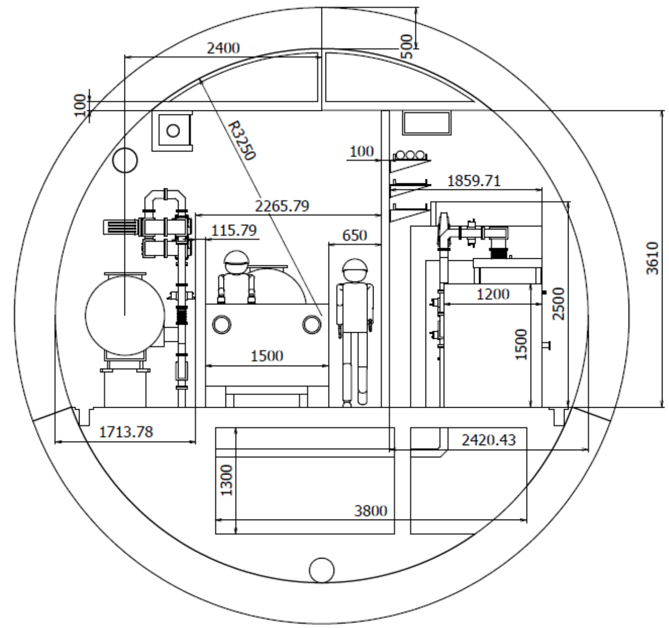
- For 1, early investigations show the tunnel diameter would need to increase to 6.5m
  - This represents an estimated 10% increase in cost/unit tunnel length (~0.5% TPC) considered acceptable.
  - Current availability* simulations (cf SB2009 proposal) suggest an additional ~5% linac overhead (~2.5% TPC)
- For 2:
  - additional space for modulators in halls/caverns is required.
  - Cost of 3000 km of pulsed cable will be required.
  - Re-design of tunnel cross-section needed to accommodate cables.
  - Current availability* simulations (cf SB2009 proposal) suggest an additional ~2.5% linac overhead (~1.3% TPC)

* see later comments on availability

3D of RDR single tunnel plan (Bouncer Modulator)-(1)

Cross Sectional View





Cryomodule is installed on the floor to avoid the vibration problem which possibly affects to the beam instability.

RF Power distribution system are under the passage in the middle of the tunnel.

RDR HLRF Tech. Solution 2

- It is proposed that these RDR-like single-tunnel solutions be carried forward in parallel, to enough detail to support a cost estimate (incremental)
- This estimate – together with the scope of the necessary re-design work to adopt one of the scenarios, will be factored into the TDR Risk Assessment
- The main R&D and AD&I effort will continue to pursue the preferred baseline solutions for KCS and DRFS.
- In order to reduce the number of scenarios to be developed, we propose to phase out one of these RDR-like options within the next six-months

* see later comments on availability

Time-Table / Agenda (Sept. 9)

Day	Am/pm	Subject	Convener/presenter
9/9		Cavity: Gradient R&D and ML Cavity Gradient	R. Geng/A. Yamamoto
	9:00	Introduction and Current Status - Technical address for the 2nd part of WS - Overview from RDR to R&D Plan 5 - Progress of cavity gradient data-base/yield	Chair: M. Ross - A. Yamamoto - R. Geng - C. Ginsburg
	10:45	R&D Status and further R&D specification - Fabrication, testing, & acceptance for XFEL/HG - R&D expected in cooperation w/ vendors - R&D w/ a pilot plant w/ vendor participation	Chair: K. Yokoya - E. Elsen - M. Champion - H. Hayano
	13:30	Short-tem R&D and Specification - Field emission and R&D strategy - Gradient, Spread, Q0, Radiation: R&D specification, standardization	Chair: C. Pagani - H. Hayano - R. Geng
	15:45	Long-term R&D ACD subjects and goals - Seamless/hydro-forming, Large Grain, Cavity shape variation, VEP, Thin Film, - Further R&D toward TEV/ML - Discussions for Cavity R&D and Recommendations	Chair: A. Yamamoto - R. Rongli to lead discussions

Time-Table / Agenda (Sept. 10)

Day	Am/pm	Subject	Convener/presenter
9/10		ILC accelerator gradient and operational margin	A. Yamamoto and J. Kerby
	9:00	Gradients from VTS to Operation - Introduction: Overview on ILC gradient specification at each testing / operation step - Terminology definition - Operational results from VT/HTS/CM tests in data base - Operational results from STF VT/CM tests at KEK	Chair: H. Hayano - A. Yamamoto - M. Ross - C. Ginsburg - E. Kako
	10:30	Operational margin - Lorentz Force Detuning and Effects on op. margin - Comments from LLRF and Beam Dynamics - Comments onAcceerator Operation gradient margin	Chair: N. Toge - E. Kako - (K. Kubo/C. Michizono) - N. Walker
	13:30	Cost Impacts - Reminder on cost effects - List of systems / technical components affected by gradient specification change - A plan to prepare for communication w/ industries	Chair: N. Walker - P. Garbincius - J. Kerby - A. Yamamoto
	15:15	General Discussion and recommendation - General discussions - Summary and recommendations	Chair: A. Yamamoto - All
	17:00	- End	

Cavity Gradient Progress

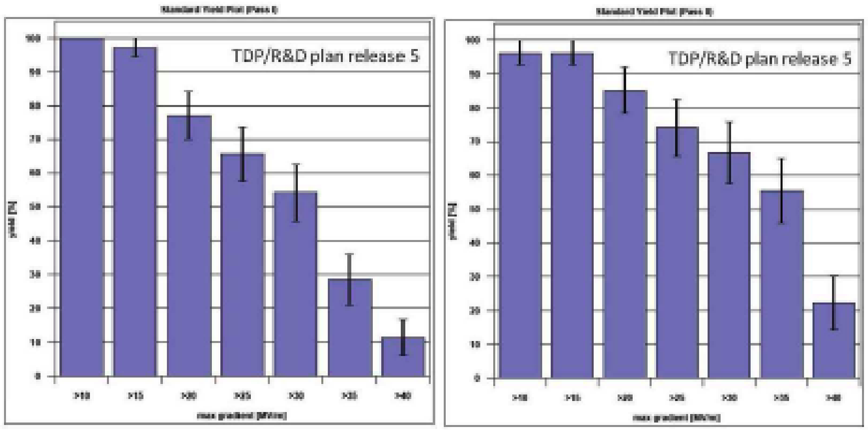


Figure 4.1: First-pass (left) and second-pass (right) yields as a function of maximum gradient. [updated data by June 30.]

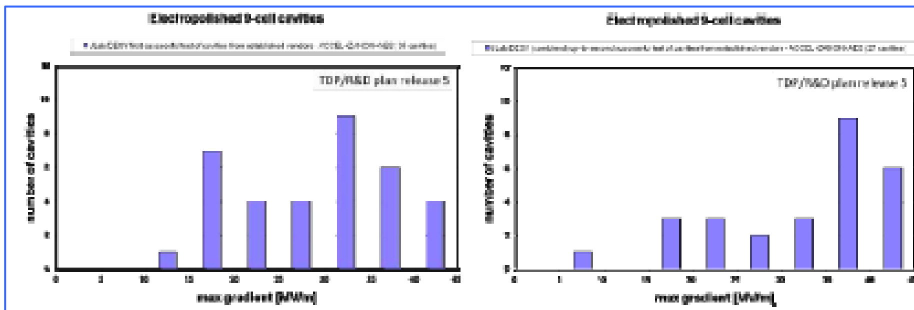
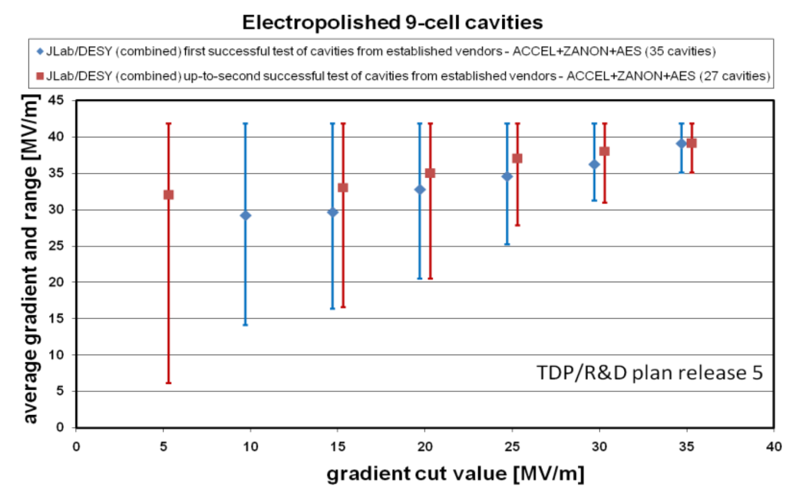


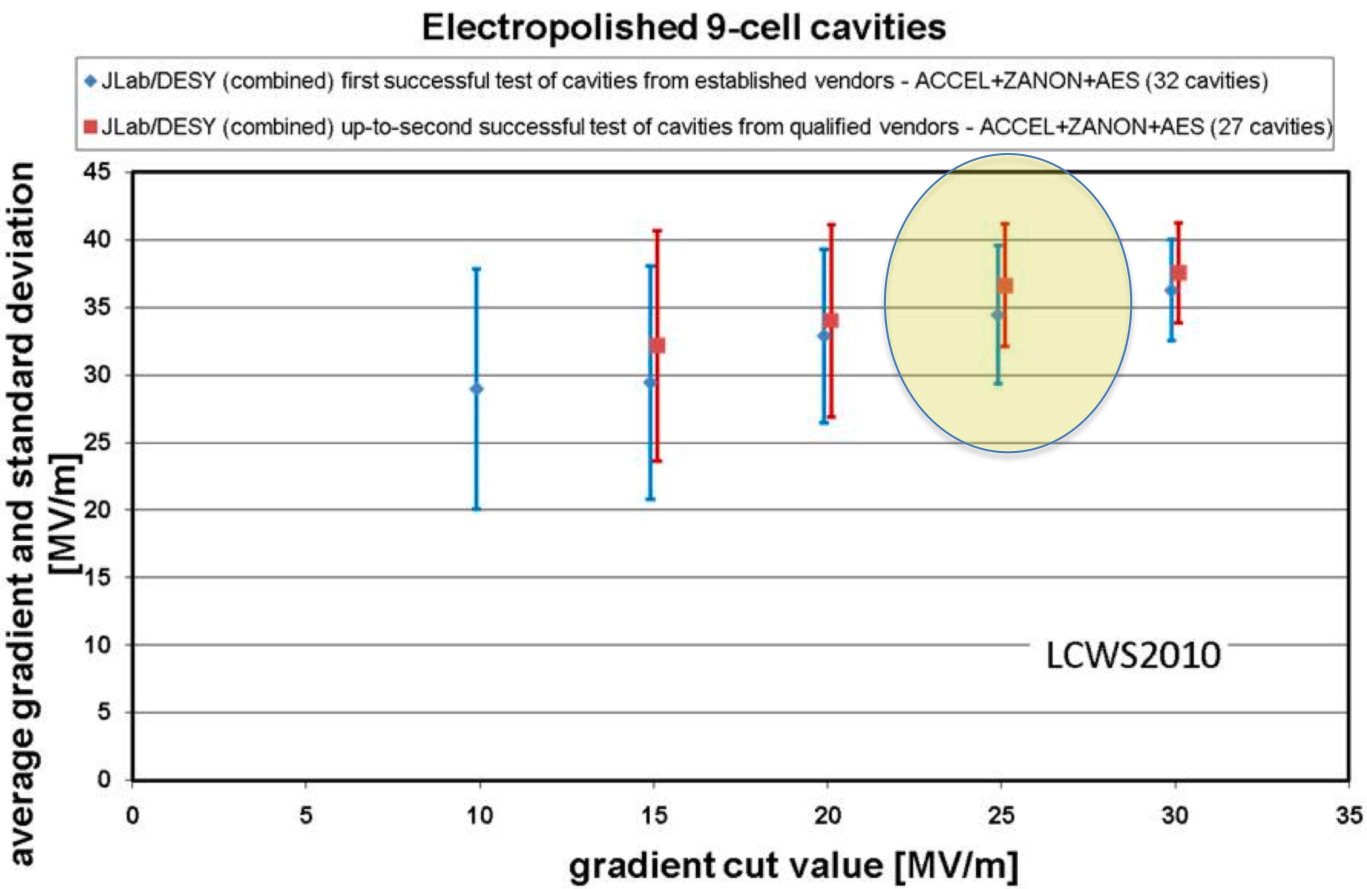
Figure 4.2: Number of cavities as a function of maximum gradient, for first-pass (left) and second-pass (right) data samples. [updated data by June 30.]

- ILC-GDE Cavity Database Team Progress report
  - C. Ginsburg et al.
  - as of June 30, 2010



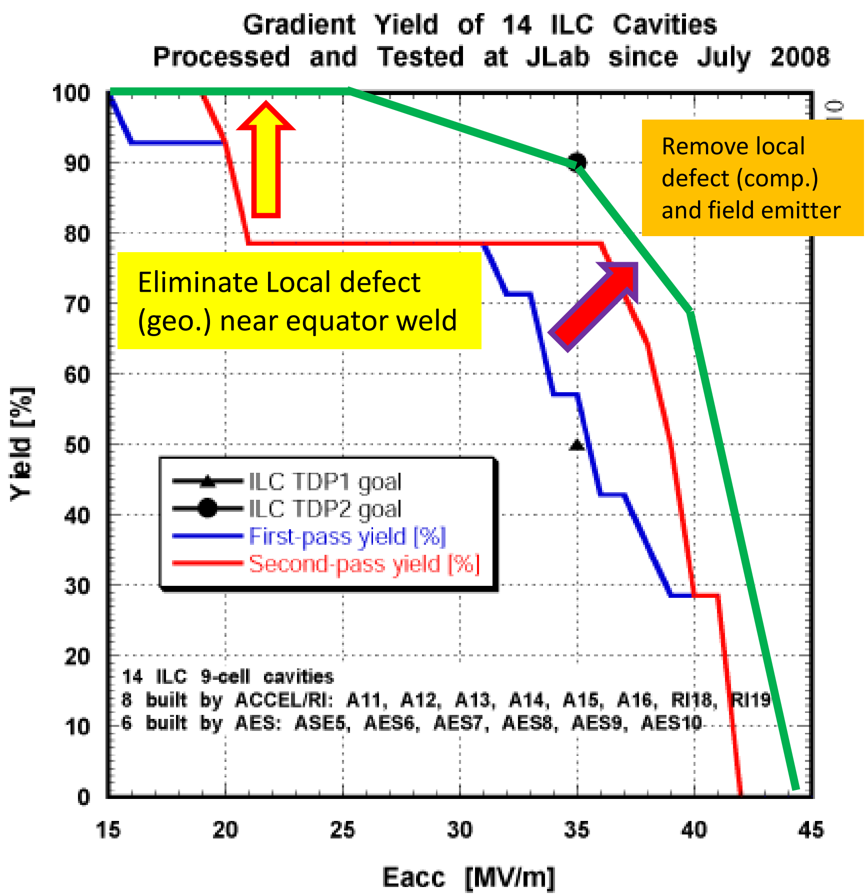
Gradient Spread and Standard Deviation

- As of June 30, 2010
- Average: ~ 36 MV/m at gradient cut at 25 MV/m
- Standard deviation: ~ 5 MV/m gradient cut at 25 MV/m



Gradient Improvement Plan

Based on Recent Understanding due to Globally Coordinated S0 Program



- Highest priority is to push yield up near 20 MV/m – the yield drop due to local (geometrical) defects near equator weld.
  - **Fab. QA/QC**
  - **Mechanical polish prior to heavy EP**
  - **Post-VT local targeted repair**
  - Seamless cavity
  - Large-grain mat. From ingot slicing
  - Fine grain mat. Optimization
- Also high priority is to suppress field emission at high gradient (up to 42 MV/m) – and quantify its effect on cryogenic loss and dark current.

R. Geng

Cavity Gradient R&D Evolution

	RDR	TDP R&D release 5
Vertical test gradient	35 MV/m	35 MV/m
Vertical test Q0	8E9	8E9
Vertical test radiation	Not specified	To be specified
Gradient yield goal	80% at 35 MV/m	90% at 35 MV/m
Gradient yield curve	Not available	Established incl. gradient spread
S0 program theme	Tight loop	Feedback loop
R&D priority	Process optimization and QA/AC	Fabrication & material optimization and QA/QC
ACD topics	ACD shapes, large grain material	Seamless cavity, ACD shapes, large grain material, thin film cavity
9-cell cavity processing/test facility	DESY (total 1)	DESY,FNAL/ANL,KEK,JLAB Cornell (total 5)
9-cell cavity fabrication facility	ACCEL, Zanon, DESY (total 3)	ACCEL/RI, Zanon, AES (qualified vendor) DESY, JLAB, MHI, PKU, Niowave (full cavity) Hitachi, Toshiba, IHEP (cavity w/o HOM) PAVAC, KEK (planed) (total 13)

R&D Milestone
Technical R&D Plan (revised: Rel-5)

Stage	Subjects	Milestones to be achieved	Year
S0	9-cell cavity	35 MV/m, max., at Q0 ≥ 8E9, with a production yield of 50% in TDP1, and 90% in TDP2 [1), 2)]	2010/ 2012
S1	Cavity-string	31.5 MV/m, in average, at Q0 ≥ 1E10, in one cryomodule, including a global effort	2010
S2	Cryomodule-string	31.5 MV/m, in average, with full-beam loading and acceleration	2012

ILC Accelerator, Operational Gradient

- Strategy for Average Accelerating Gradient in the ILC operation:
  - Overview and scope of 'production yield' progress and expectations for TDP,
    - including acceptable spread of the gradient needed to achieve the specified average gradient,
  - Cavity
    - Gradient, Q0, and Emitted Radiation in *vertical test*, including the spread and yield,
  - Cryomodule
    - Gradient, Cryogenic-load and Radiation, including the gradient spread and operational margin with nominal controls,
  - ILC Accelerator
    - Gradient, Cryogenic-load and Radiation, including the gradient spread and the operational margin with nominal controls
  - Strategy for tuning and control,
    - including feedback, control of ‘Lorentz force detuning’, tolerances and availability margin,
  - Impact on other accelerator systems: CFS, HLRF, LLRF, Cryogenics, and overall costs.

A possible balance in ILC ML Accelerator Cavity Specification

A new guideline in TD Phase 2 may be proposed as follows (summarized in Table 3-4):

- R&D goal for the 9-cell gradient to be kept at 35 MV/m at a production yield of 90 % or more
- ILC project accelerating gradient specification specifying average gradient and spread of low-power test cavity gradients and a subsequent spread in cryomodule operational cavity gradient limits.

Table 3-4: A possible balance of gradients in various stages in the ILC ML cavity production stage (to be studied and established)

Single 9-cell cavity gradient	String Cavity gradient in cryomodule w/o beam	String cryomodule gradient in accelerator with beam
35 MV/m, on average w/ spread above a threshold	34 MV/m, on average (or to be further optimized)	31.5 MV/m, on average (or to be further optimized)

Summary

- HLRF/LLRF design with Single Tunnel layout
- ML Accelerator Gradient

HLRF/LLRF Design with Single Tunnel

- The main proposal is to go to a single tunnel solution for the Main Linac technical systems remains essential that outlined in the SB2009 report, and is based on the adoption of two novel schemes, requiring RD, for the HLRF in the single tunnel:
  - KCS: preferred solutions for ‘flat land’ sites
  - DRFS: preferred solutions for mountainous region

- Two backup scenarios are proposed for supporting RDR-like HLRF solutions in a single-tunnel
  1. 10MW MBK + (Marx) Modulator in the tunnel
  2. XFEL-like solution with modulators (low-voltage) accessible in cryo refrigeration builds/caverns, with long pulsed cables feeding 10MW MBKs, via a pulse transformer, in the tunnel.
- Both are considered technically feasible, and no R&D program is proposed.
- We propose to phase out one of these RDR-like options within the next six-months, in order to reduce the number of scenarios to be developed.

- *There are comments on the Original RDR HLRF solution with two tunnel to be a fall-back solution, although PM proposal to seek for the RDR-likeHLRF solution in the single tunnel to keep effective design work*

ILC-ML SCRF Cavity Gradient Specifications proposed, based on R&D Effort and Milestone/Goals

Cost-relevant design parameter(s) for TDR	ML cavity gradient Specification	R&D Milestone	Relevant R&D Programme
Mass production distribution (models)			S0
9-cell Cavity Gradient in vertical test	35 MV/m, average - Spread: 28 – 42 MV/m (+/- 20 % or less)	35 MV/m at 90 % yield including 2nd pass, (eq. > 38 MV/m, average)	S0
Cryomodule Operational Gradient	34 MV/m, average	34 MV/m, average CM Obs. G. Limit = 3 % + **	S1
ML Operational Gradient	**31.5 MV/m avg** - Spread: 25 – 38 MV/m (+/- 20 % or less: TBD)	31.5 MV/m, average Op. G lim = 1.5 MV/m** Cntrl margin = 3 %**	S2 (S1*)
Required RF power overhead for control	10% (TBD)		S2 (S1*)

** as milestone for R&D

Accelerator Gradient
Common understanding and Recommendation

- Observation
  - Challenging operational margin in accelerator operation to be reliable enough for sufficient availability for physics run.

- Our Strategy Proposed
  - Provide two major guidelines
    - R&D milestone: 35 MV/m with 90 % yield (eq. > 38 MV/m on average) , including 2nd pass,
    - ILC ML Cavity specification: 35 MV/m on average with spread,
  - Make our best effort with forward looking position to realize the accelerator operational gradient to be 31.5 MV/m, on average with reasonable gradient spread (< ~ +/-20 %). We require an additional HLRF power of 10 %.
  - Keep cost containment concept, and prepare for the industrialization including cost and quality control.
  - Ask physics/detector groups to share our observation and forward looking strategy

Acknowledgment

on behalf of ILC-GDE Project Managers

- Many thanks for all participants at KEK and through webex.

- We would thank the LOC led by Seiya Yamaguchi and organized by Tetsuo Shidara, Tomiko Shirakata, Kazuko Toyomura, Nobuko Kobayashi, Kazuko Nagai, Emiko Kotaki, H. Hayano, Takayuki Saeki, and Araki Sake, for their much effort to bring the BAW1 successfully carried out.

backup

Higher Gradient Operation with
Better Electric Power Efficiency
Small Tuning Range
& Less DLD Effect

↓

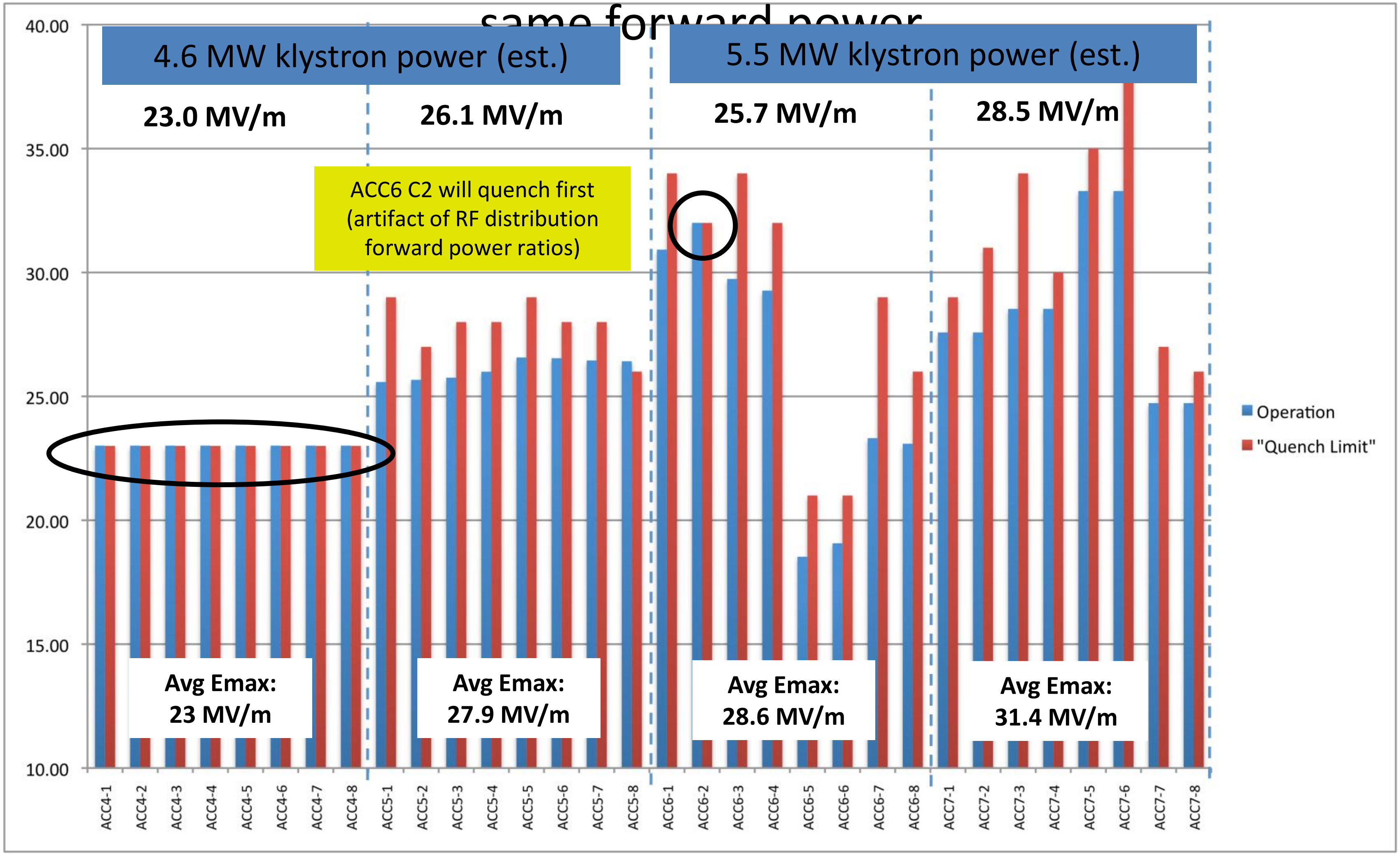
Cavity Grouping
with Over-Coupling

How should we do for Degraded Cavity ?

↓

To Save other Good Cavities,
We should have
Tunability for RF Power & Coupling.

Ideally, all cavities reach their respective quench limits at the same forward power



Reality: errors in power ratios due to manufacturing tolerances of rf attenuators
(In this case: tolerances are of the order +/-0.1dB)

Summary from S. Michizono

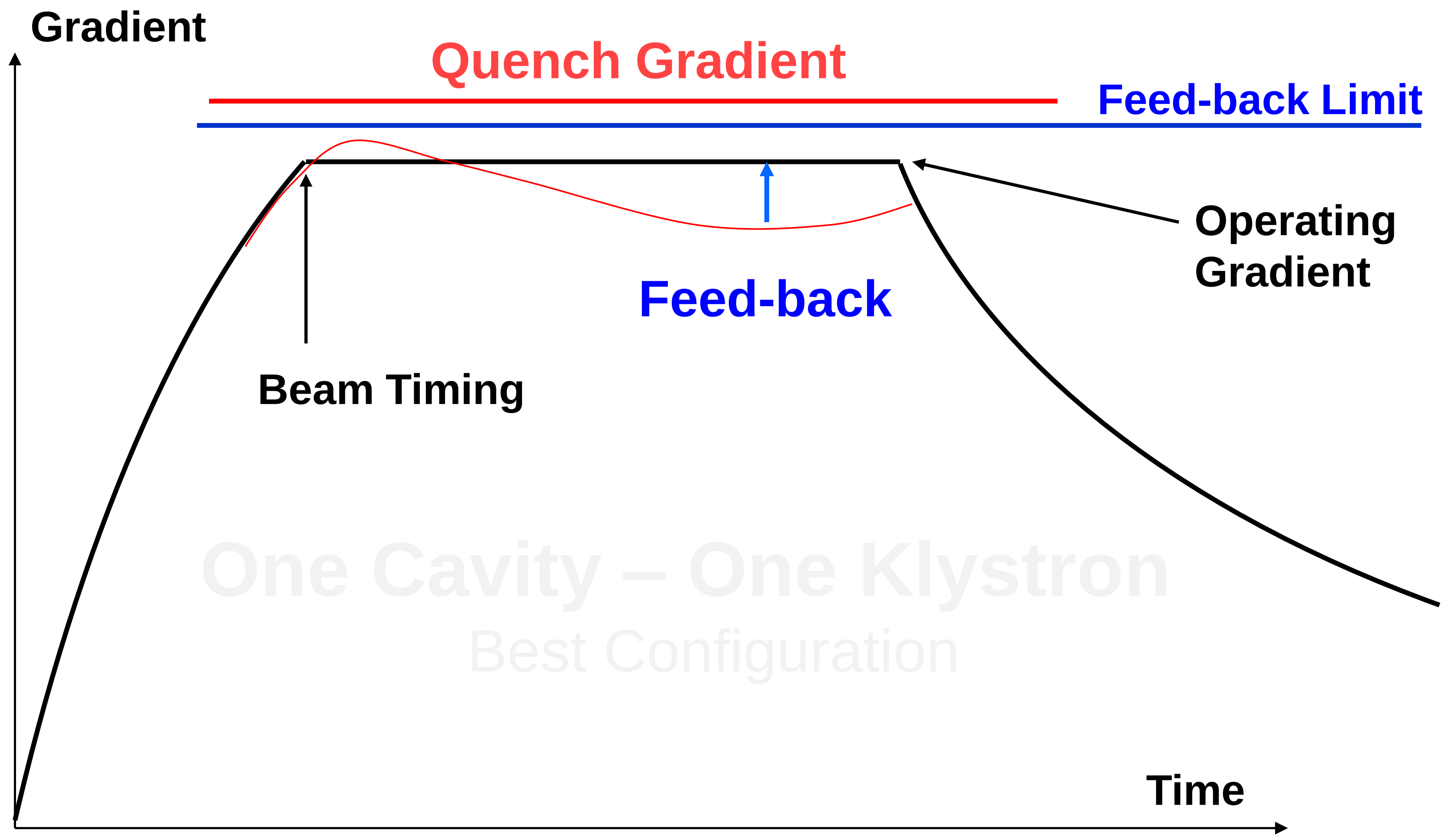
		RDR	DRFS (PkQl)	DRFS(Cavity grouping)
RF power	Operation gradient	Max. 33 MV/m	Average 31.5 MV/m	Max. 38 MV/m
	RF source	10 MW		800 kW
	Waveguide loss	8% power	2% power	2% power
	Static loss (Ql, Pk)	2% power	2% power	2% power
	Kly Hv ripple	2.5% power	2.5% power	2.5% power
	Microphonics	2% power	2% 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.

Highest Gradient Operation

From S. Nogichi



Subjects to be further studied in TDP-2

- Further Studied in TDP-2
  - How wide cavity gradient spread may be acceptable in balance of HLRF power source capacity and efficiency?
  - How large operational margin required and adequate in cryomodule and accelerator operation?