International Linear Collider Workshop 2010
LCWS10 and ILC10

Beijing, China March 26–31, 2010

Main Linac/SRF Working Group

Conveners: Hitoshi Hayano, Carlo Pagani, Christopher Nantista

Closing Plenary Summary, Part 1

Saturday, March 27

Morning 10:30–12:00

Tunnel Layout and Joint with CFS

Afternoon 13:30–15:30

HLRF ("High Level" RF), w/ CFS

1:30–1:50 DRFS Development – Shigeki Fukuda
1:50–2:05 Power Supply for DRFS – Mitsuo Akemoto (webex)
2:05–2:15 LLRF Considerations for DRFS – Shinichiro Michizono
2:15–2:35 KCS Development – Christopher Nantista
2:35–3:00 HOM's and Gradient Spread – Chris Adolphsen
~~3:00–3:30 discussion (with CFS)~~

Afternoon 16:00–18:00

MLI (Main Linac Integration), w/ Beam Dyamics

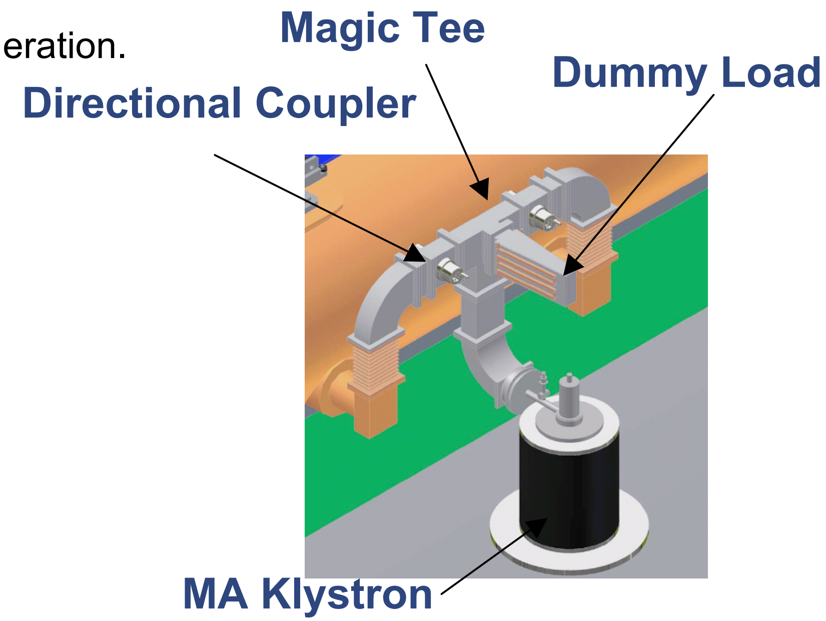
4:00–4:10 FLASH Overview – Nicholas Walker
4:10–4:30 Analysis of FLASH Beam-On Gradient Stability Data – Shilun Pei
4:30–4:50 9mA FLASH Workshop Summary – Shinichiro Michizono
4:50–5:05 Update on RTML and FNAL BPM – Nikolay Solyak
5:05–5:20 Split SC Quad – Nikolay Solyak
5:20–5:40 Lorentz Force Detuning Studies at STF – Yasuchika Yamamoto
5:40–6:00 Linac Beam Dynamics Update – Kiyoshi Kubo

DRFS Development

KEK S. Fukuda

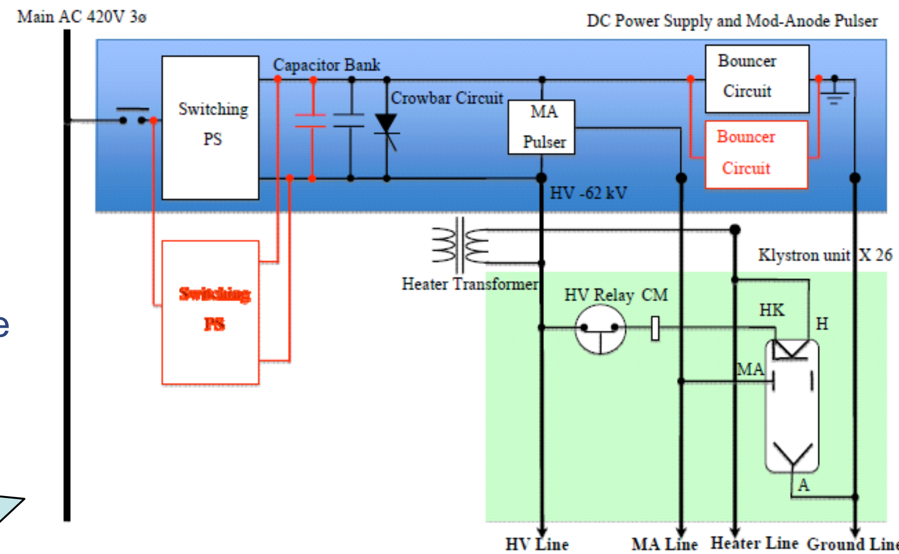
- DRFS Plan is supported in ASIAN ILC project, especially it is matched with Japan site condition.
- For S1 global in end of 2010, budget of 2-klystron DRFS system are approved or will be approved).
- For STF phase-II project in 2013, DRFS system for 1 full cryomodule, i.e., 4-5 klystron DRFS system, is strongly supported.
- For these periods, study of DRFS basic configuration are performed.
- Critical issues such as the reliability of the over-current protection HV relay or switch and crowbar protection are intensively studied.
- Cost related study of klystron are now under consideration.

Klystron	Frequency	1.3	GHz
	Peak Power	750	kW
	Average Power Output	7.50	kW
	RF pulse width	1.5	ms
	Repitition Rate	5	Hz
	Efficiency	60	%
	Saturated Gain		
	Cathode voltage	64.1	kV
	Cathode current	19.5	A
	Perveance(Beam@64.1kV)	1.2	mPerv
	(Gun@53kV)	1.56	mPerv
	Life Time	120,000	hours
	# in 3 cryomodule	13	
	Focusing	Permanent magnet	
	Type of Klystron	Modulated Anode Type	
DC Power supply per 3 cryomodules			
	# of klystron (3 cryomodul	13	
	Max Voltage	71.5	kV
	Peak Pulse Current	244	A
	Average Current	2.47	A
	Output Power	177	kW
	Pulse width	2.2	ms
	Repitition Rate	5	Hz
	Voltage Sag	<1	%
	Capacitor	26	mF
Bouncer Circuit			
	Capacitance	260	mF
	Inductance	4.9	mH
M. Anode Modulator			
	Anode Voltage	53	kV
	Anode Bias Voltage	-2	kV



In the proposed new scheme of DRFS, 2 cavities are driven by one unit of 750kW L-band MA klystron. Therefore, one would see that three cryomodules with 26 cavities will be driven by thirteen units of MA klystrons.

Features of DRFS klystron:
Applied voltage of less than 65kV
60% efficiency with 1.2 microperveance
Low field gradient in klystron gun —few arcing
Low cathode loading--- long cathode life
Low output power--- free from output window failure
Long life of klystron would be expected
Permanent magnet focusing
--- free from magnet and power supply failure
Common heater power supply with back-up
--- contribute to high availability



•13 klystrons one common DC power supply and one common anode modulator
•each DC power supplies and MA modulators is associated with one "hot-swappable" backup
• Each distribution circuits will have a high-voltage SW or relay.
• A DC power supplies has a bouncer circuit for compensation of the pulse flat droop.

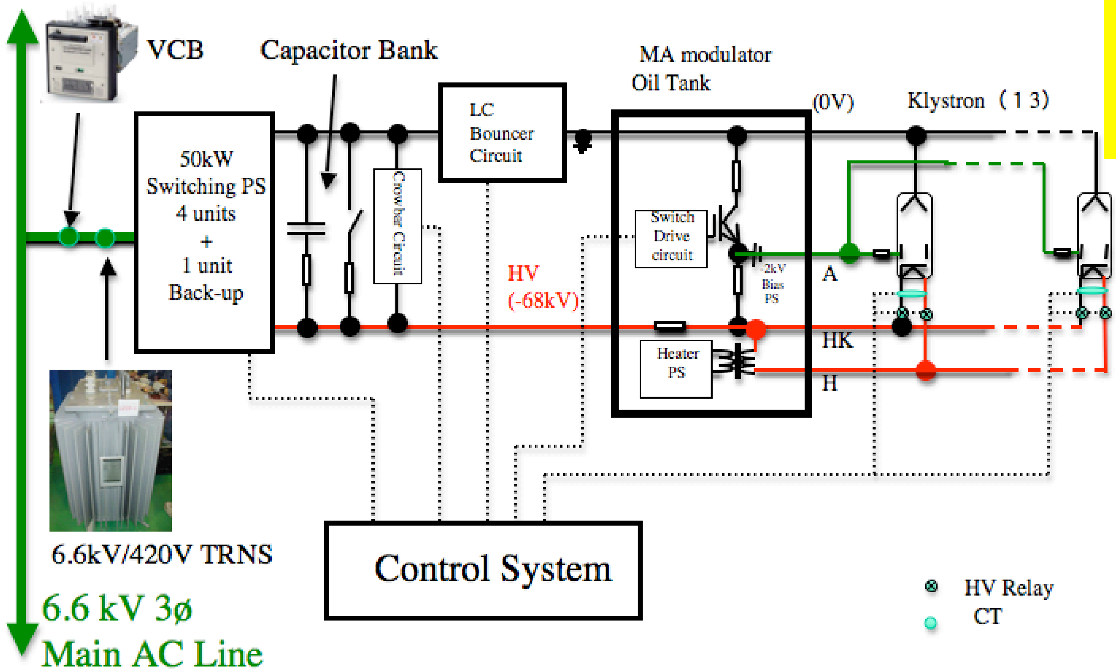
S1-Global Plan

Summary

- R&D plan of Distributed RF Scheme (DRFS) is presented.
- 2-klystron DRFS is almost approved and is demonstrated in S1- global test.
- 4 (5)- klystron DRFS is strongly supported for STF-phase II in 2013 and R&D plan is under establishing.
- A prototype DRFS klystron is now manufacturing.
- A prototype power supply is also under manufacturing.
- Several R&D key issues are described.

Power Supply System for DRFS

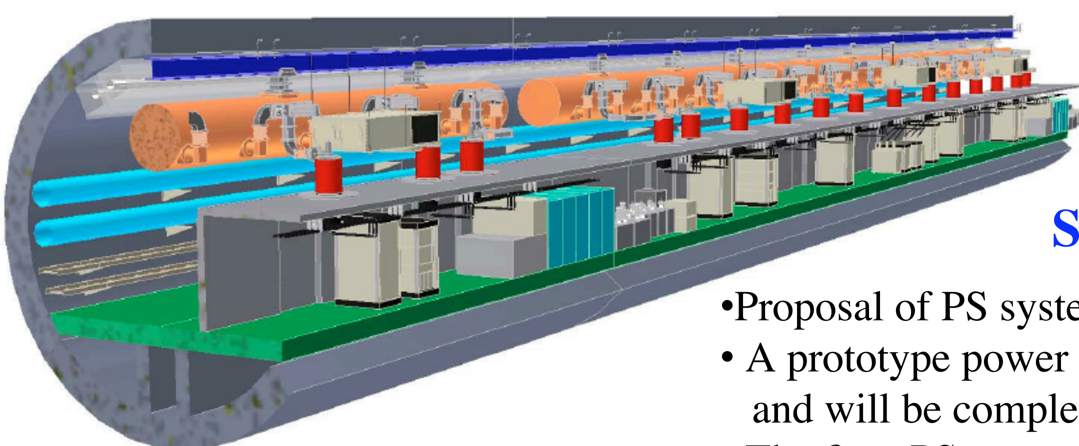
Mitsuo Akemoto(KEK)



To realize high available system capable of continuous operation, should be high-reliability and low cost

Main Features

1. Use of switching Power Supply to charge the capacitor bank
2. One common dc power supply with a bouncer circuit and one common modulation anode modulator
3. Redundancy of one unit for switching power supply and modulation anode modulator (Backup system)
4. Individual HV relay and CT monitor for all klystrons to separate the failed klystron from the system



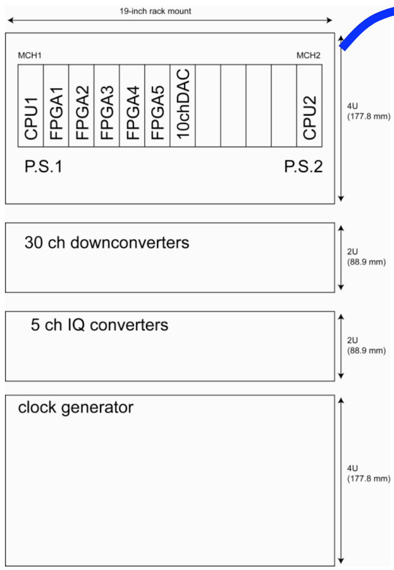
Summary

•Proposal of PS system for DRFS is presented.
• A prototype power supply for S1-Global is under construction and will be completed in October.
• The first PS system for DRFS will be evaluated in S1-Global test.

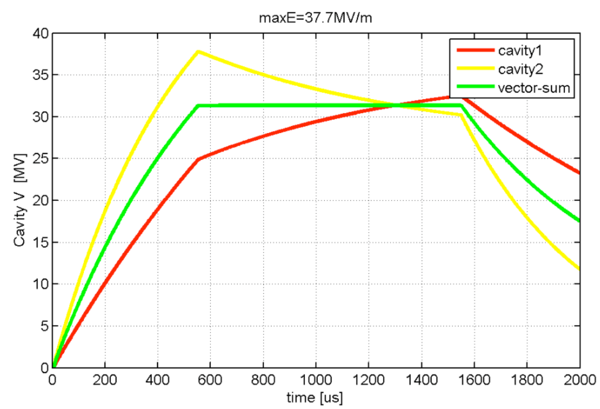
DRFS LLRF system configuration

Shin MICHIZONO, KEK

Micro-TCA



- Each FPGA board (FPGA1-5) drives a klystron.
- 10ch DACs are used for piezo drivers.
- 30 ch downconverters receive rf signals (cavity , forward and reflection power of each cavity)
- Clock generator creates clock and timing signals synchronized with master oscillator.



- If different gradient cavities are driven by a klystron, we need more power to operate them (~14% if operate 25&38MV/m cav.)
- In addition, flatness is only guaranteed when operated the certain beam current.

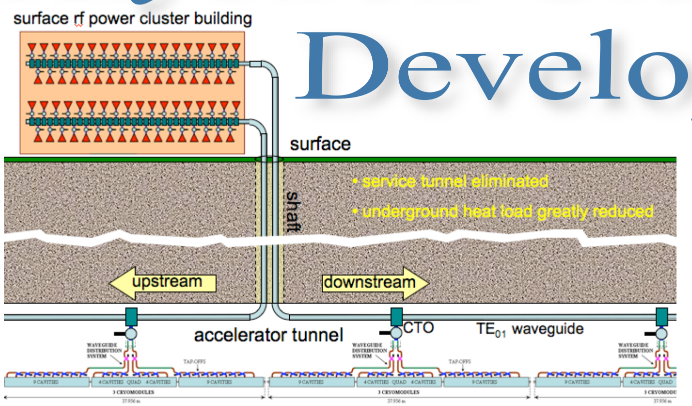
-> In DRFS, we will make cavity grouping and operate at same gradient.

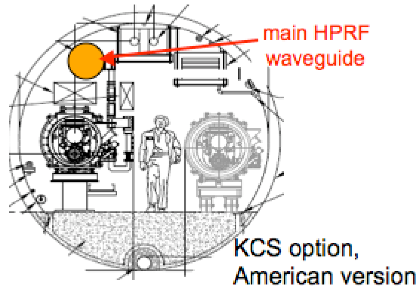
Summary

- μTCA based llrf system is planed for DRFS.
- Cavity grouping will be adopted for higher cavity efficiency.
- Nominal 770 kW klystrons can drive 35 MV/m pair and the good-performance klystrons can drive 38 MV/m pair.
- Full-power filling scheme is proposed and will be studied at S1-grobal.

Klystron Cluster System Development

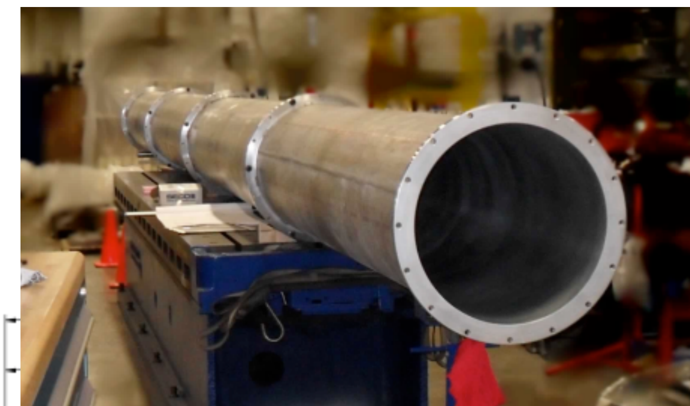
Christopher Nantista, SLAC

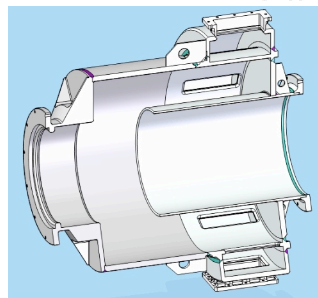


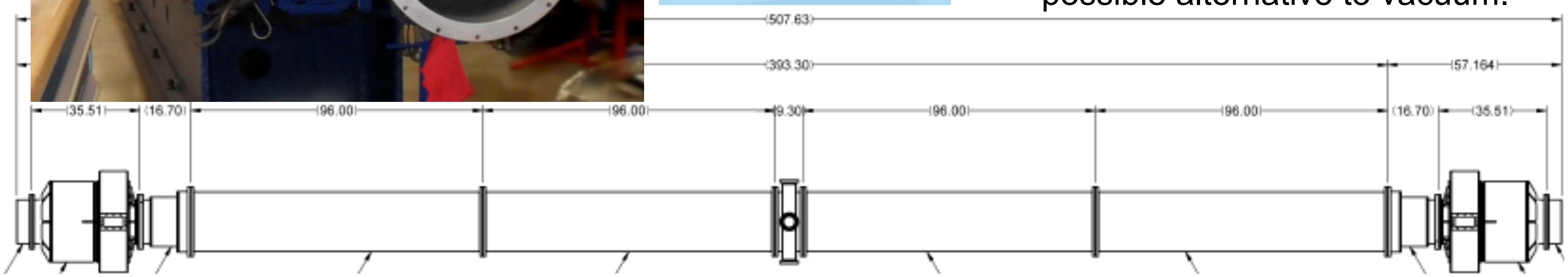


Current Test Program

- Prototype CTO and main overmoded circular waveguide.
- Cold test CTO in launching mode.
- Test waveguide under vacuum.
- Test transmission efficiency of waveguide between two CTO's
- Test CTO at ~1/2 full power level to be seen by rectangular ports (klystron limited).
- Test waveguide as a resonant line up to maximum field levels to be seen.
- Redo tests under 14.5 psig pressure, as possible alternative to vacuum.





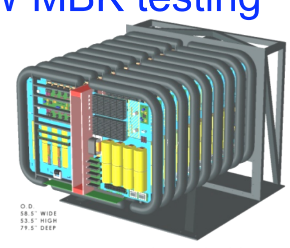


Phase shifter for Local PDS tailoring

SLAC Marx Modlator andToshiba 10MW MBK testing

Integrated uptimes, to date:

Month	Klys.	Mod.
Total Hrs	1301.1	1449.8
Total Days	54.21	60.41



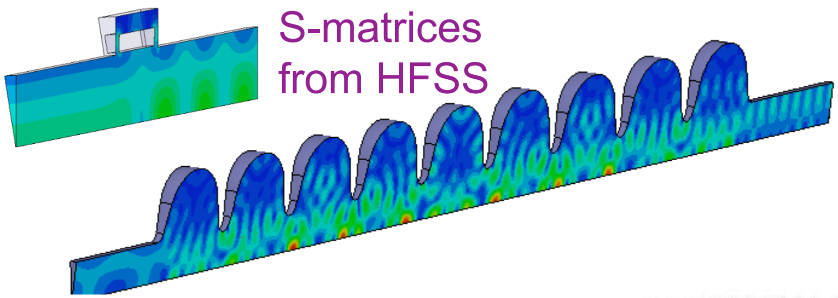
Study of Absorber Effectiveness in the ILC Main Linacs

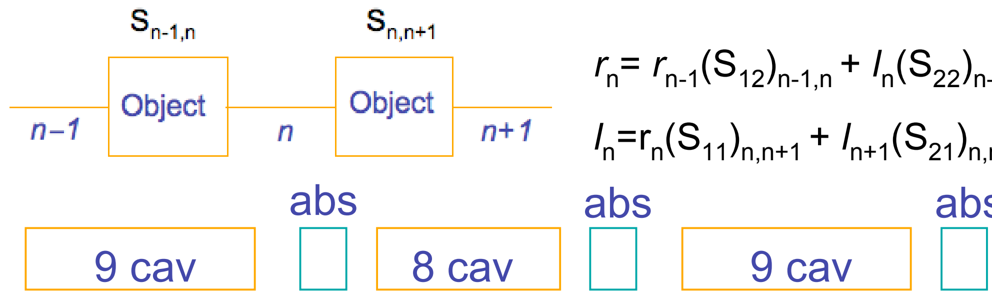
K. Bane, C. Nantista and C. Adolphsen, SLAC

Goal: Compute the HOM monopole losses in the 2K NC beam pipe relative to the losses in the 70 K beamline absorbers.

Procedure: For select frequencies, TM_{0n} modes and cavity spacings, compute relative power losses in a periodic system of cryomodules to assess probability that the beam pipe cryoload is significant due to ‘trapped’ modes. At worse, such losses would double 2K dynamic load as the HOM power above cutoff is of the order of the 1.3 GHz wall losses.

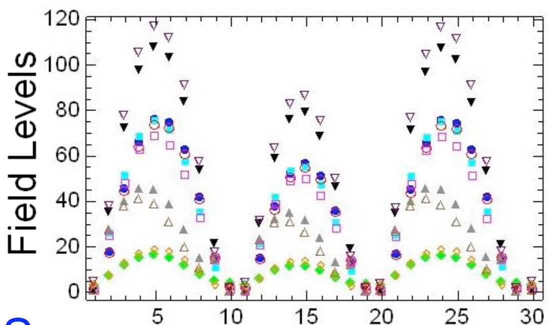
S-matrices from HFSS

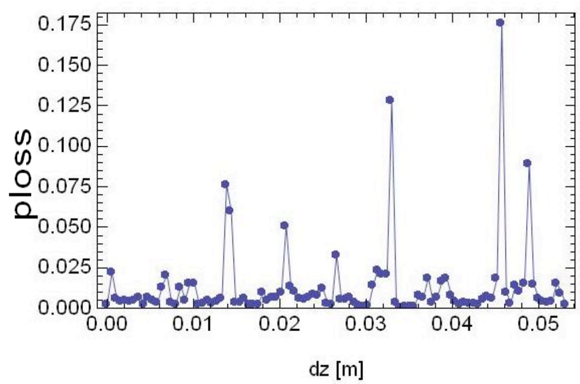




$$r_n = r_{n-1}(S_{12})_{n-1,n} + l_n(S_{22})_{n-1,n}$$

$$l_n = r_n(S_{11})_{n,n+1} + l_{n+1}(S_{21})_{n,n+1}$$





Statistics on p_{pipe}/p_{tot}

m	average	rms	.90 quant
1	.014	.030	.025
2	.012	.024	.022
3	.012	.023	.023

Summary

Method provides a quick, worst-case estimate of relative losses with different absorber configurations - cavity losses (walls, HOM ports and power couplers) are not included.

Find low probability for trapped modes that produce significant (> 10%) losses in 2K beam pipe versus absorbers. Is the average loss over dz the relevant quantity ?

Should redo with a more realistic beamline model, more frequencies and non-uniform cavity spacings.

Cryomodule String Test: TTF/FLASH 9mA Experiment

Nick Walker (DESY)
John Carwardine (ANL)

Primary objectives of 9mA program

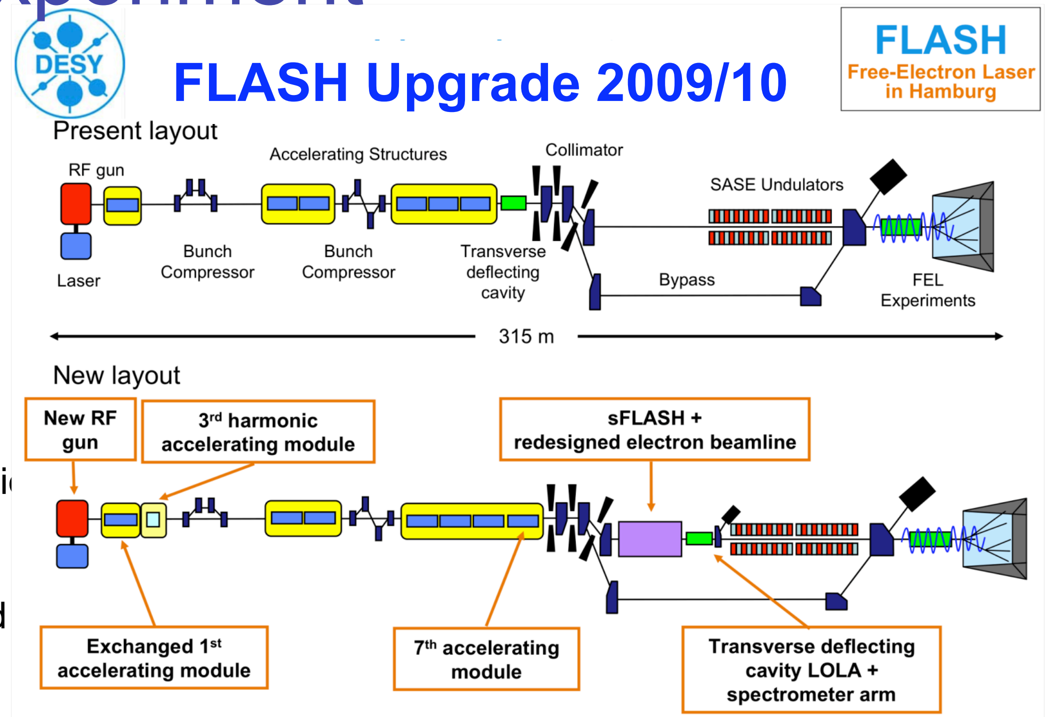
Long-pulse high beam-loading (9mA) demonstration
- 800μs pulse with 2400 bunches (3MHz)
- 3nC per bunch
- Beam energy 700 MeV ≤ E_{beam} ≤ 1 GeV

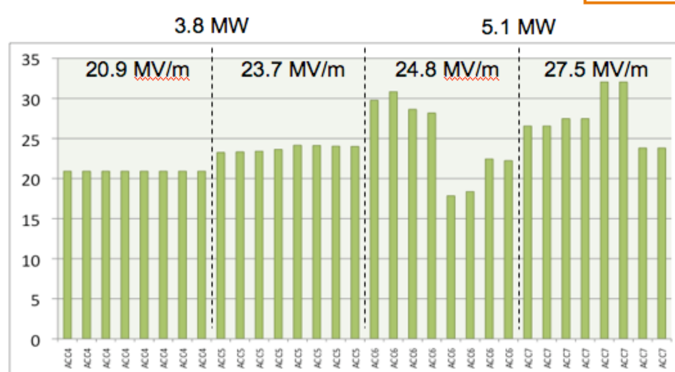
Primary goals
- Demonstration of beam energy stability
  - Over extended period
- Characterisation of energy stability limitati
  - Operations close to gradient limits
- Quantification of control overhead
  - Minimum required klystron overhead LLRF control
- HOM absorber studies (cryo-load)
- …

Major operational challenge for FLASH !
- Pushes many current operational limits

Goals partially achieved in September 09 run

Dealing with high beam-power not trivial (losses!)
'New' hardware and 'shutdown recovery' syndrome



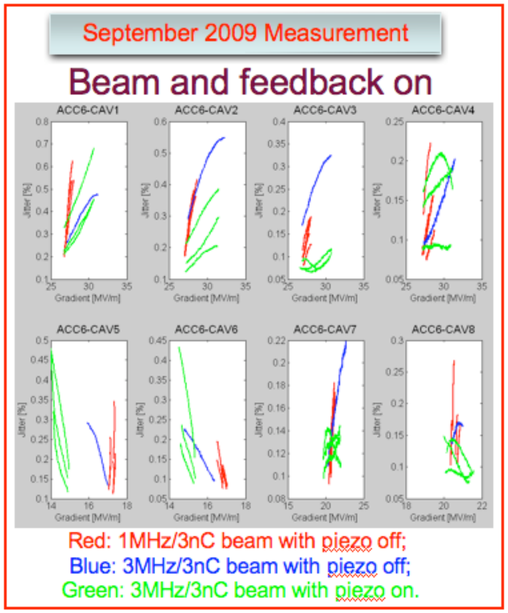


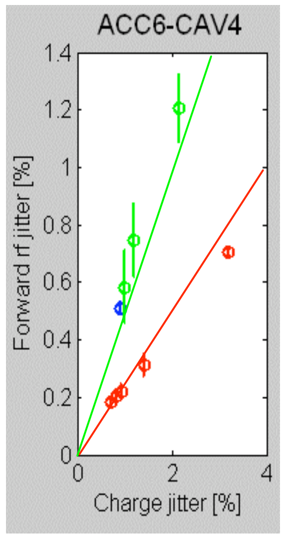
Nominal foreseen for 1.3 GeV beam energy

Next Accelerator Physics period <u>early January</u>
- Expect to have dedicated 9mA experimental time

Analysis of FLASH Beam On Cavity Gradient Stability Data

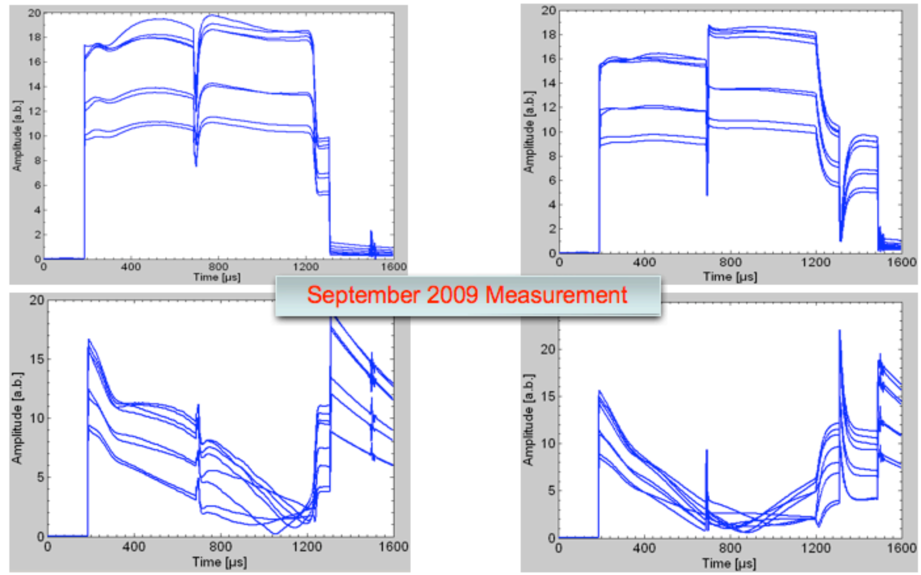
Shilun Pei, Chris Adolphsen





Cavities in ACC6 with piezo off
3MHz/3nC beam with 1600 bunches

Cavities in ACC6 with Piezo on
3MHz/3nC beam with 1500 bunches



Summary

- As with previous beam-off, feedback-off data, the input rf stability is very good with 0.10-0.15% rms variations at full power (scales as 1/amp)
- Also, in this case, the cavity gradient variations are similar with proper choice of initial detuning – else, can get up to ~ 1% cavity field variations – they are well explained by a model that includes initial detuning and a few Hz of microphonics induced cavity frequency jitter (with piezos on, cavity field jitter may increase somewhat).
- With beam and feedback on, input rf jitters up to ~ 1%.: it correlates as expected with the beam charge variations (slope of ~½ at nominal 9 mA current and slope of ~¼ with 3 mA data).
- Feedback does well with beam on despite the poor setup of the cavities where flattop gradients vary significantly (tuning likely OK however).
- Piezos reduce required overhead from LFD, but only AAC6 equipped, which makes the required residual overhead hard to estimate.

"Workshop on Linac Operation with Long Bunch Trains" Summary

Feb.22,2010-Feb.24,2010 **Shin MICHIZONO (KEK)**

Highest priority goal:

- ***to demonstrate beam phase and energy stability at nominal current***
- (including a test of beam based feedbacks),
- This can only be done at the DESY-based main linac beam test facility TTF / FLASH
  - Until late 2012
  - ~2013 → Fermilab 'NML' test facility and KEK 'STF' begin beam operation

Secondary goals:

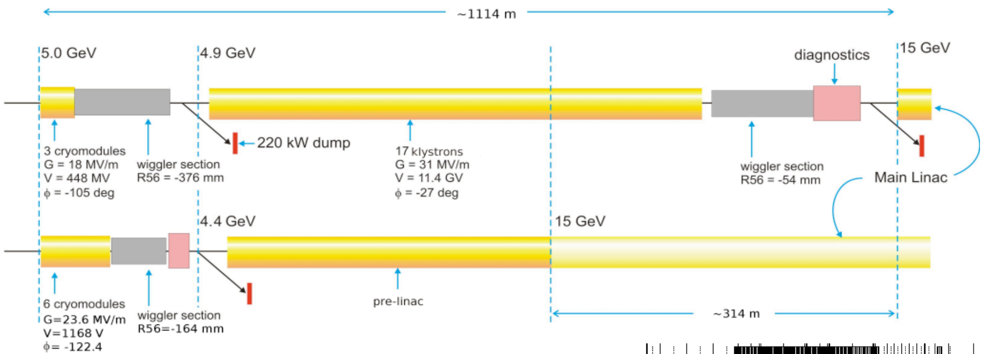
- which have impact on the cost of the ILC:

1. demonstrate ***operation of a nominal section*** or RF-unit,
2. determine the ***required power overhead*** under practical operating conditions,
3. to measure ***dark current*** and x-ray emission
   - (to be used to establish precise radiation dose-rate limit vertical test acceptance criteria),
4. and to check for heating from ***higher-order modes*** in order to determine the ***dynamic cryogenic heat load*** with full beam current operation.

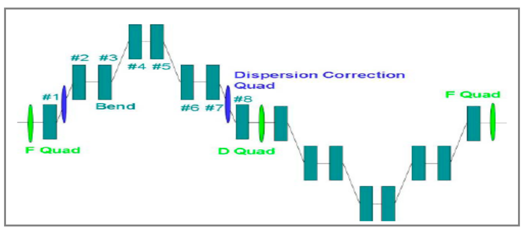
- Working Group #1:
  FLASH setup, tuning, and operation
  - **Leaders: B. Faatz, J. Carwardine**
- Working Group #2:
  FLASH feedback and control
  - **Leaders: H. Schlarb, V. Ayvazyan**
- Working Group #3:
  ILC studies at FLASH
  - **Leaders: N. Solyak, S. Michizono**
- Working Group #4:
  DAQ and data analysis
  - **Leaders: T. Wilksen, N. Arnold)**

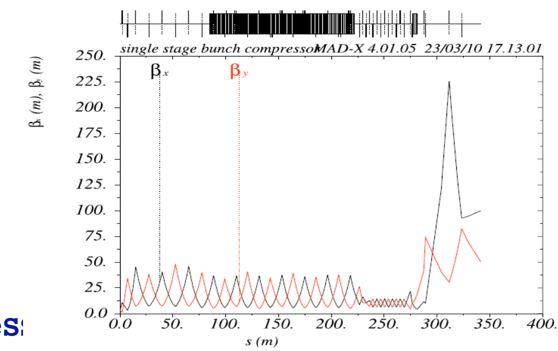
Update of RTML

Nikolay Solyak, Fermilab



	BC1+BC2	BC1S + preLinac*
Length [m]	1114	800
RF units / klystrons	16	14
Cryomodules	48	42
Cavities	414	360
Bends	148	76
Quads (warm)	71	42
BPMs	71	42
LOLA profile monitor	2	1
Bunch length monitor	2	1
Phase monitor	2	1
Laser Wires	4	4

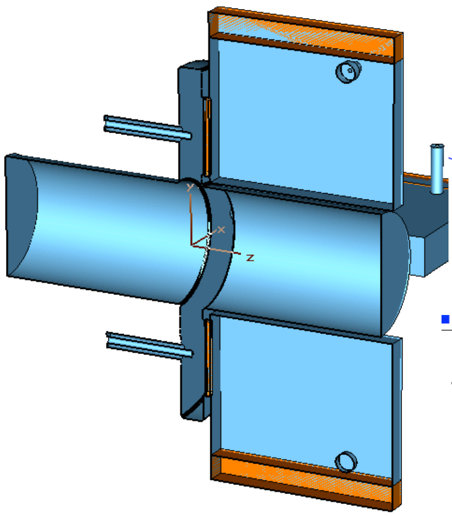
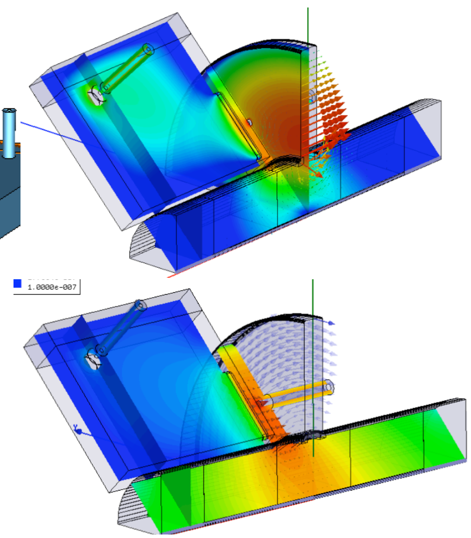
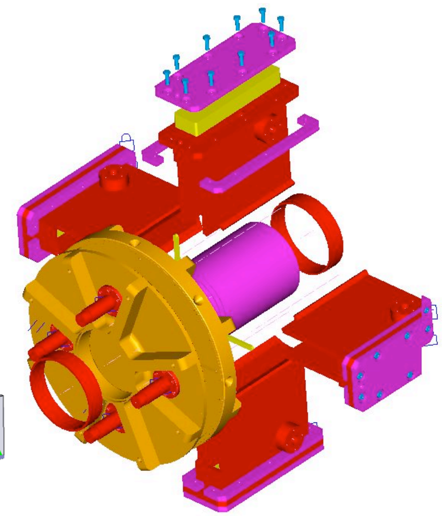
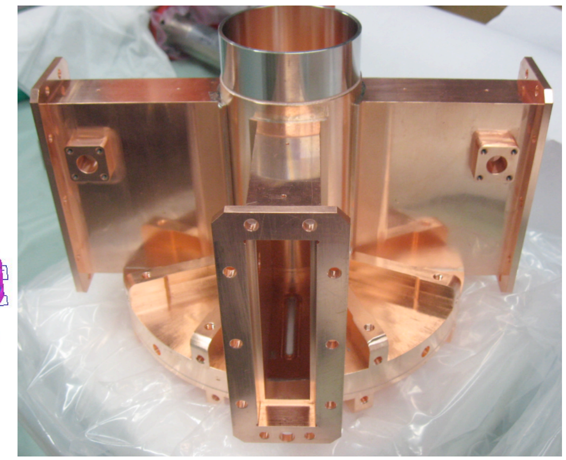




- Single-stage Bunch Compres
  - Emittance growth in 1-stage compressor can be effectively controlled (DFS, bumps and possible CM angle adjustment).
  - BC1S performance (beam parameters, emittance growth, etc.) is comparable with RDR 2-stage design for the same compr. ratio: 20
  - BC1S is able to compress bunch from 6mm to ~220 μm
- Extraction line is re-designed to accommodate bunch with a larger energy spread after single-stage compressor.
- Preliminary lattice design for RTML in central area is done. Matching and beam dynamics studies are in progress.
- Simulations of RF kick from the coupler was updated
- ILC-CLIC collaboration: BPM and spin rotator design
- Remaining issues are subject for R&D program

Fermilab BPM R&D Activities

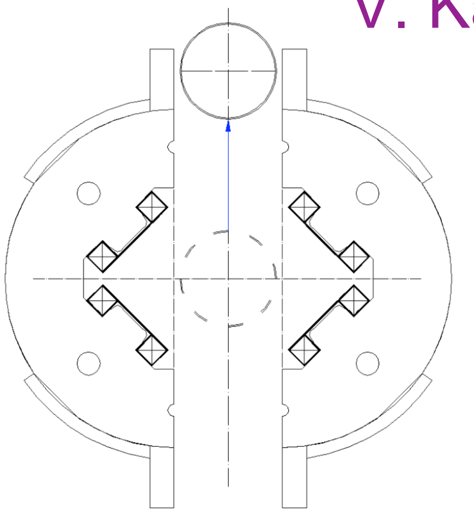
Nikolay Solyak, et al.

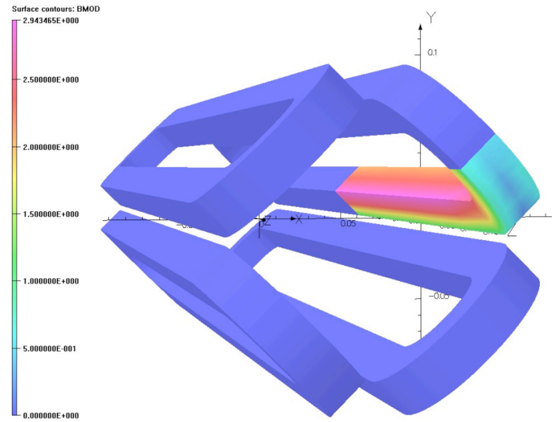





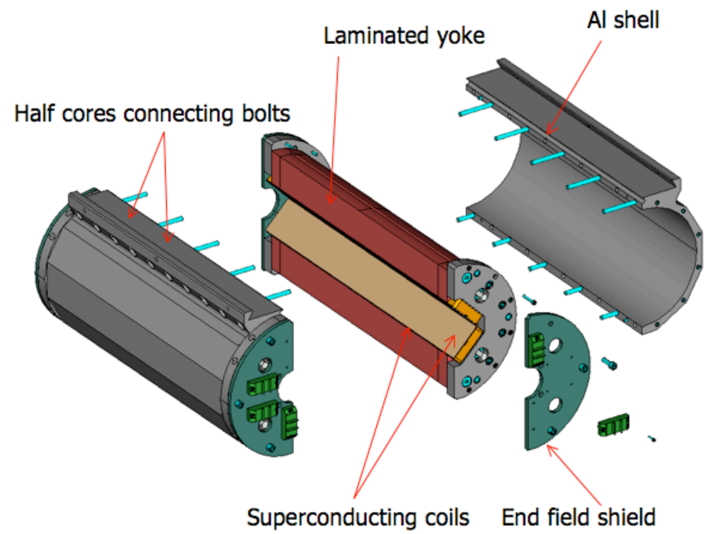
- Fermilab continues instrumentation and diagnostics R&D for the ILC and other HEP accelerator projects.
- BPM activities include detector and read-out systems.
- The cold L-Band cavity BPM progress is very slow, but still moving!
  - We still plan for a beam test of the prototype.
- A X-Band cavity BPM R&D for the CLIC Main Linac has been initiated in collaboration with CERN
  - The prototype design operates at CTF bunch frequencies.
- ILC/LC collaboration activities are focused on the
  KEK ATF damping ring BPM upgrade project.
  - With minor modifications this read-out system can be applied to other BPM detectors and systems, also for HOM signals.

ILC Main Linac Superconducting Cryogen Free Splittable Quadrupole (Technical Design)

V. Kashikhin for Superconducting Magnet Team



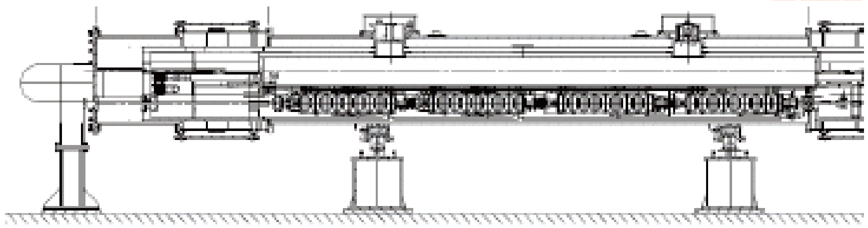


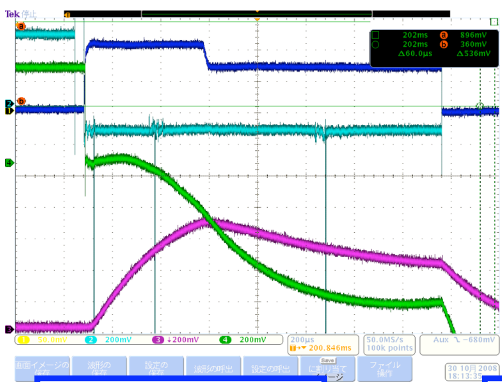


- The splittable cryogen free quadrupole could be fabricated in FY10.
- Proposed the quadrupole with a vertical split and racetrack coils.
- The quadrupole set of drawings is released.
- Quadrupole has a conduction cooling from the LHe supply pipe.
- Quadrupole mounted around the beam pipe outside of a clean room.
- BPM has tight connection with quadrupole.
- Quadrupole bolted to the strong 300 mm diameter He return pipe.
- Special attention paid on the magnet assembly and mounting tolerances.
- Magnet cooling down time ~ 38 Hours.
- The magnet in 2010 only could be tested in TD/VMTF in a bath cooling mode.

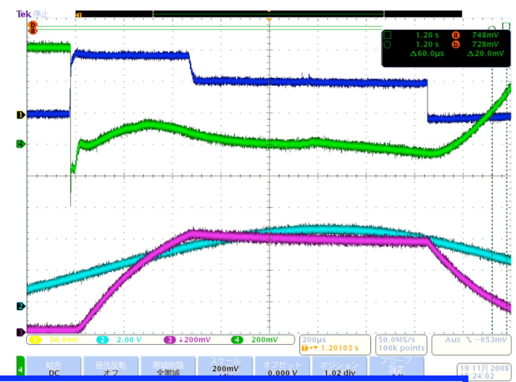
Lorentz Force Detuning Studies at STF (Phase–1.0)

Kirk (Yamamoto)

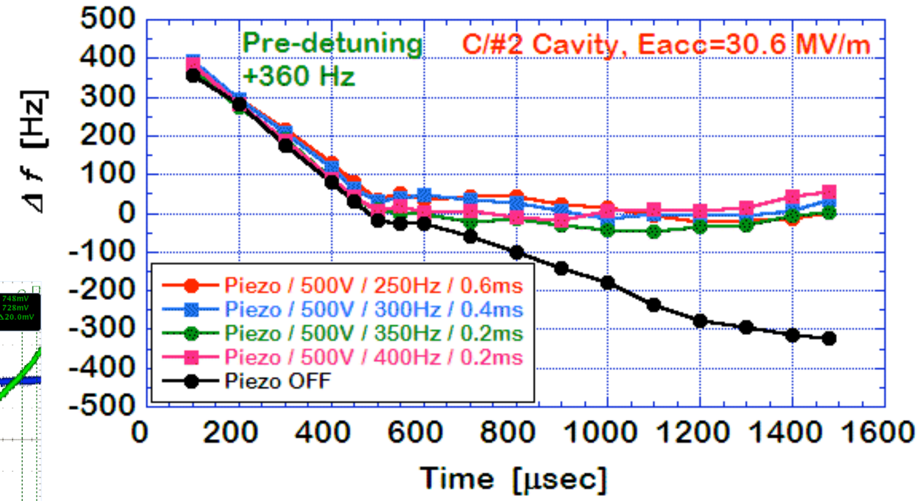


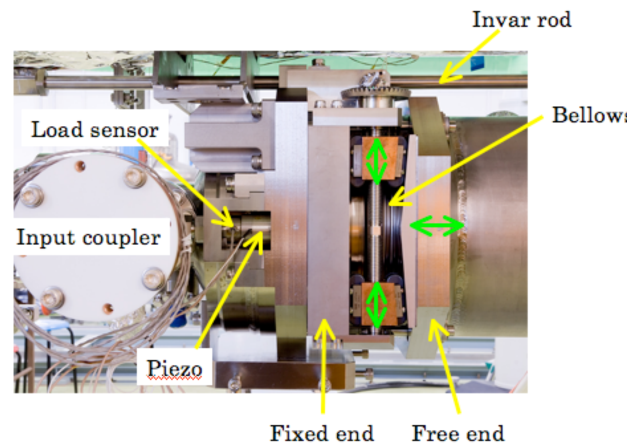


F.B. Off
Piezo Off
No pre-detuning



F.B. Off
Piezo ON(500V/300Hz/0.8msec)
Pre-detuning (~300Hz)





Summary

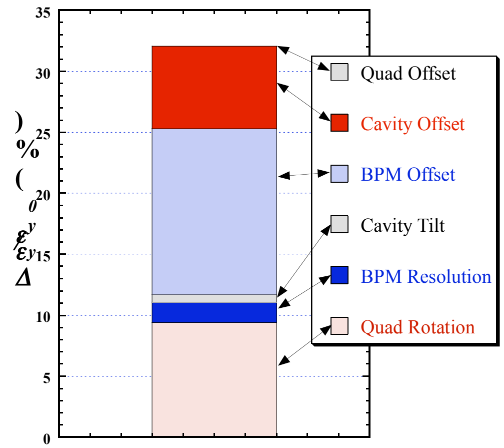
- Piezo compensation at STF Phase–1.0 was successful within ±30Hz.
- Optimum condition of Piezo operation was relatively wide.
- High power operation with Piezo compensation was stable at 30MV/m over 3 hours twice.
- DAQ system of LLRF was useful for measurement of Lorentz Detuning.

Main Linac Tolerances
What do they mean?

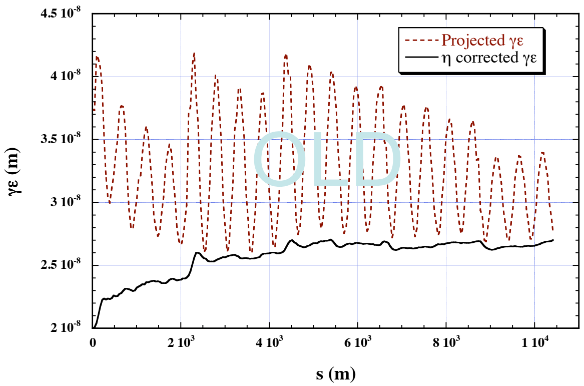
Kiyoshi Kubo

"Standard" errors

Quad offset w.r.t. Cryomodule (μm)	300
Cavity offset w.r.t. Cryomodule (μm)	300
BPM offset w.r.t. Cryomodule (μm)	300
Quad roll w.r.t. design (μrad)	300
Cavity pitch w.r.t. Cryomodule (μrad)	300
Cryomodule offset w.r.t. design (μm)	200
Cryomodule pitch w.r.t. design (μrad)	20
BPM resolution (μm)	1



Contributions to Emittance growth



Vertical Emittance along linac

- Vertical motion is concerned.
  - Horizontal tolerance is much larger than vertical, e.g. alignment tolerance should be more than 10 times larger. (proportional to sqrt. of emittance)
- We have a "Standard" error set for "static" errors.
  - They are not necessarily tolerances.
  - "Static" means not changing in time scale necessary for performing (complicated) corrections.
  - **Main purpose of this presentation is to understand what these errors can be interpreted in actual construction.**
- We use DMS (Dispersion Matching Steering, or often called DFS, dispersion free steering).

- Many Simulation Codes have given similar results. Here, I quote mostly my own results, using code SLEPT.
- Multi-bunch effect is not considered well, or supposed not to be problematic. (But it should be checked, actually.)