AWG3 Summary Report

Jim Kerby for

Akira Yamamoto, Tetsuo Shidara, Chris Adolphsen, Paolo Pierini, Chris Nantista, Rongli Geng, Camille Ginsburg, Shigeki Fukuda, Fumio Furuta, John Hogan, Tom Peterson, Marc Ross, Jie Gao, Basir Sabirov, Hitoshi Hayano, Nick Walker, Eckhard Elsen, Marc Wenskat, Elvin Harms, John Carwardine, Catherine Madec, Norihito Ohuchi, Gerry Dugan, Vladimir Kashikhin, Lance Cooley, Charlie Cooper and with my sincere apologies to anyone I've missed

Charge to ML –SCRF WG

M. Ross, Monday→

Our implementation:

- **Tuesday: ongoing R&D**
- **Wednesday: TDR Parameters, Value Engr, Integration**
- **Thursday: post TDR R&D**

Workshop Goals

- **review the status** and **rate the adequacy** of scientific and technical studies toward achieving project goals.
- comprehensive discussion of R&D needs in order to **develop proposals** for future work.
- set aside discussion time to foster ILC-CLIC collaboration on topics of common interest.

3 important ILC-GDE steps:

1) Reviewing the TDR outline and **finalizing writing assignments**.

2) Developing the **agenda for the upcoming Baseline Technical Reviews** - Central Region, Main Linac and CFS.

3) Discussing the **path forward**, including work after publication of the TDR.

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Ongoing R&D

Multiple System Tests Finishing up or ongoing

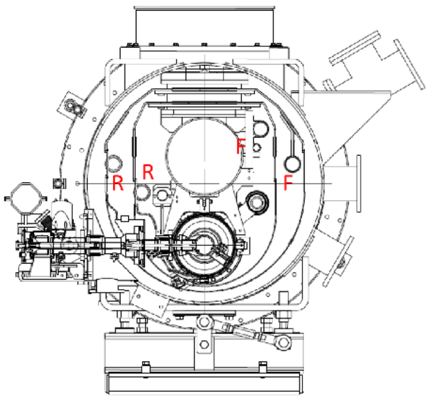
- **S1 Global**
- **FLASH**
- **CM1 @NML**
- **KCS Pipe**
- **DRFS**

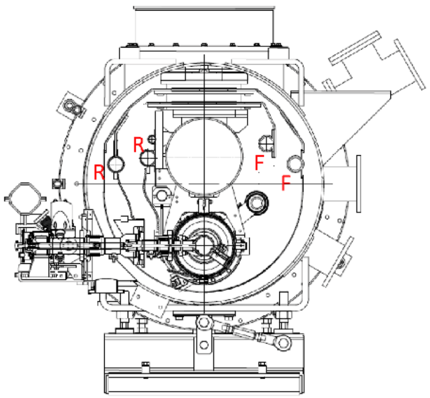
And all the subsystems associated with them!

S1 Global

Present cryomodule cross section

Cooling scheme by Tom

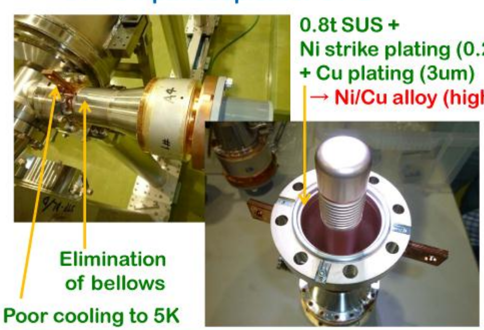




Further studies in STF-2 couplers

- ***Reduction of static loss***
- ***Reduction of dynamic loss***
- ***Efficient cooling by thermal anchor***

STF-2 input coupler for S1-G



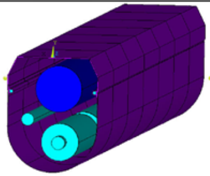
Two input couplers
for QB-Cryomodule

(Coupler-B, 10um) (Coupler-A, 5um)

→ avoiding Ni-strike plating

E. Kako (KEK) Webex Meeting in Sept. 20, 2011 22

ANSYS 3D Model



Radiation model implemented into ANSYS with the previous values from exp.

- **Removal of shield leads to 0.76 W increase**
- **well matched to measurements (0.78-0.80 W)**

	Vacuum vessel	80 K shield outer/inner	5 K shield outer/inner	GRP LHe sup.	Dummy vessel
perature, K	300	84	5	2	2
sivity	0.2	0.0035/0.06	0.02/0.06	0.03	0.2
load [with 5K shield], W	NA	27.2	0.68	0.19E-3	0.57E-3
load [w/o 5K low shield], W	NA	26.7	0.74	0.20	0.76

5/2011 Grenada, LCWS2011 13

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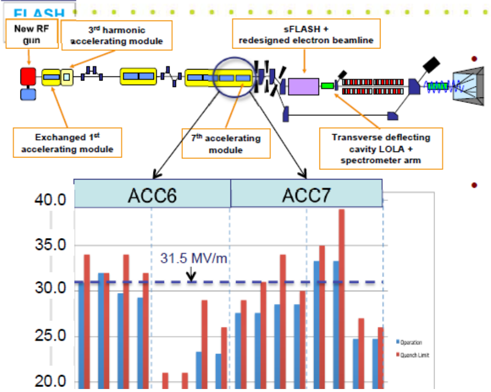
FLASH

Main TDP R&D goal driving the 9mA studies in February 2011



- **Operation with Gradient Spread**
  - From single RF source
- **Specifically: achieving constant gradients for each individual cavity during beam pulse**
  - to within few percent
  - close to gradient limits
  - 'Effective usable gradient'

If we had to write the TDR today

- **Goal of stable operation with 9mA / 800us**
  - 'Essentially done'
- **Goal of stable operation with +/-20% gradient spread and heavy beam loading**
  - 'Very good first results, concept has been proven'
- **Goal of <0.1% energy stability with beam loading**
  - 'Exceeds goal'
- **Still to be studied…**
  - Goal of operating close to quench
  - Goal of operating at limits of klystron output power

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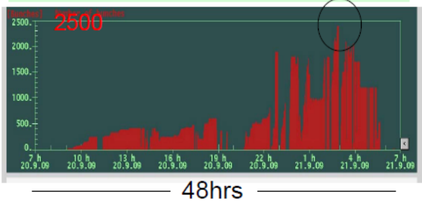
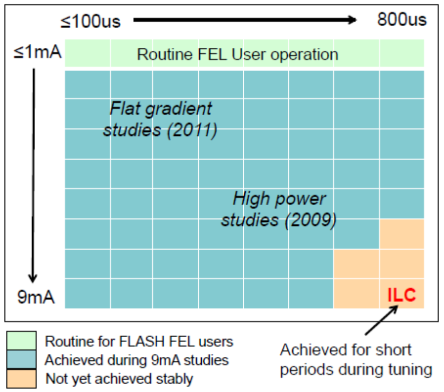
Long-pulse high current: achieved parameter space

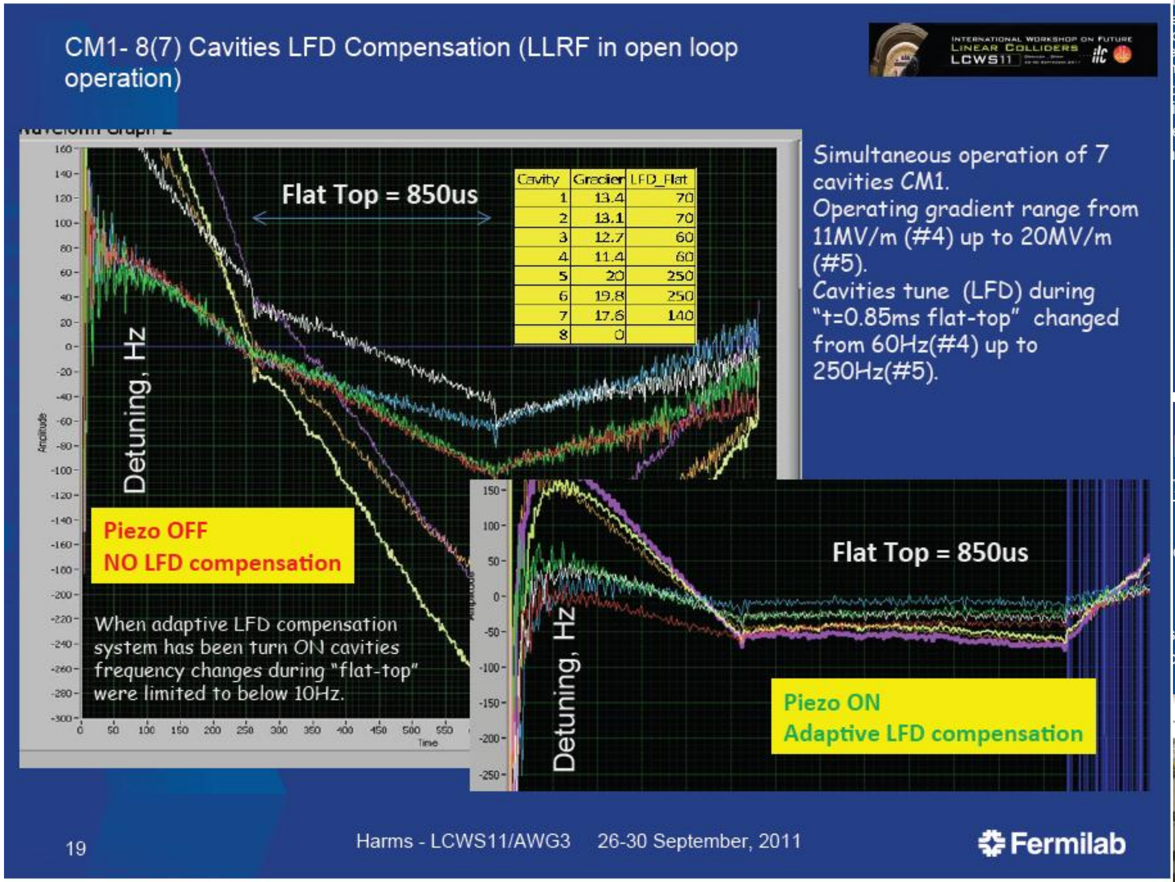
800 bunches at 3mA for 15hrs

Ramp-up in number of bunches @ 3MHz

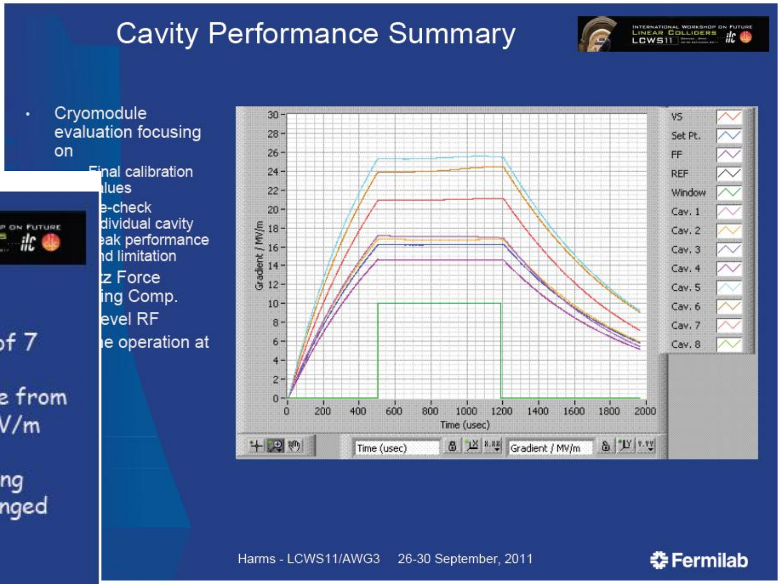




CM1



Cavity	Gradient	LFD_Flat
1	13.4	70
2	13.1	70
3	12.7	60
4	11.4	60
5	20	250
6	19.8	250
7	17.6	140
8	0	

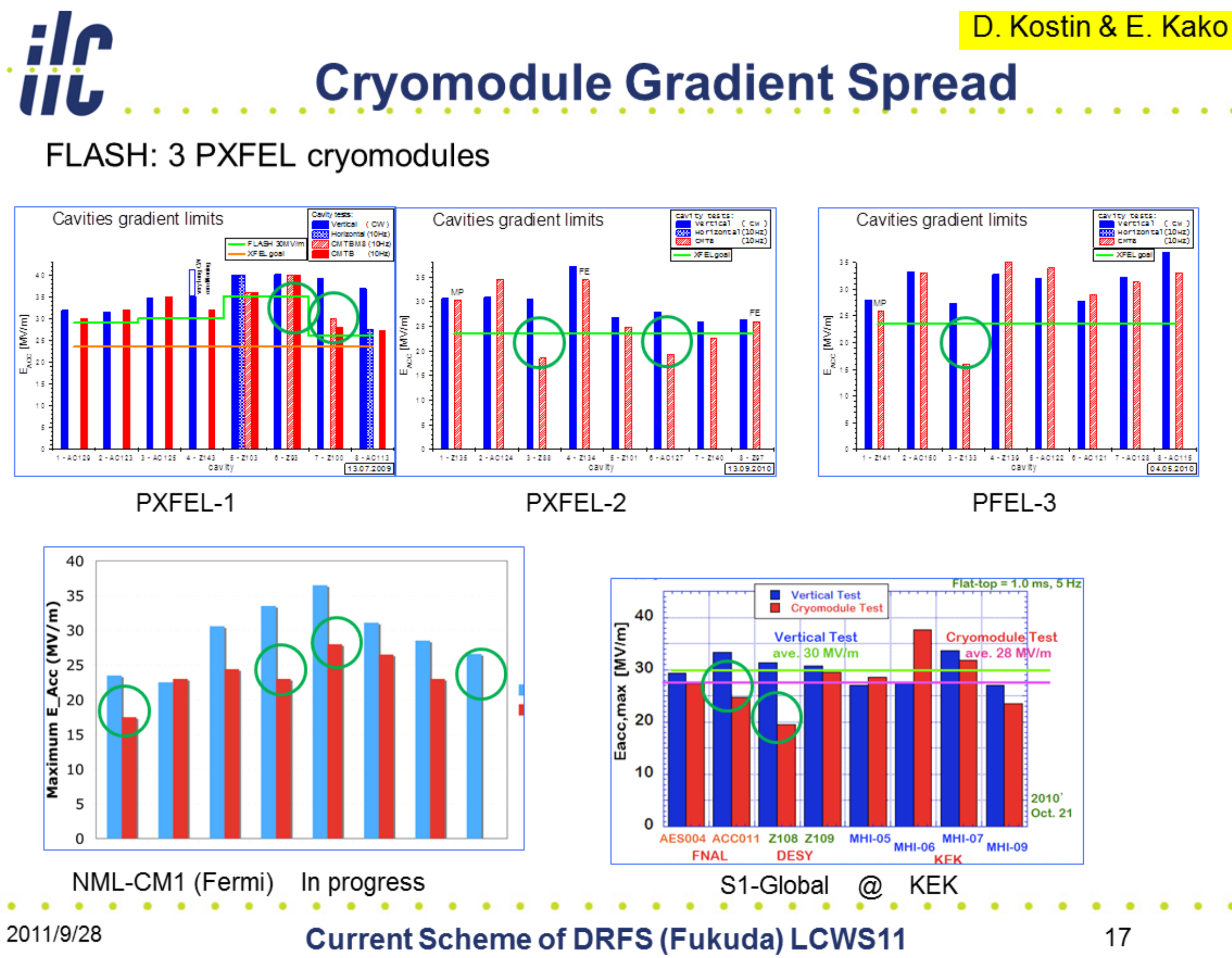


Cryomodule System Summary

The first opportunities for system tests…

Detailed investigations of limiting factors (tuners / cryo / couplers / ??) ongoing.

Further tests upcoming in all three regions…

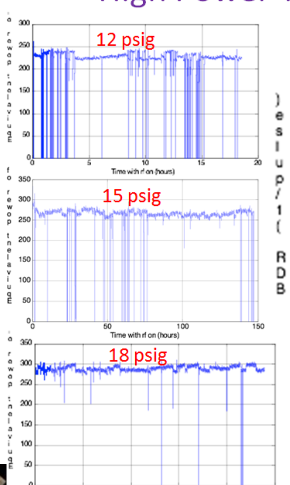


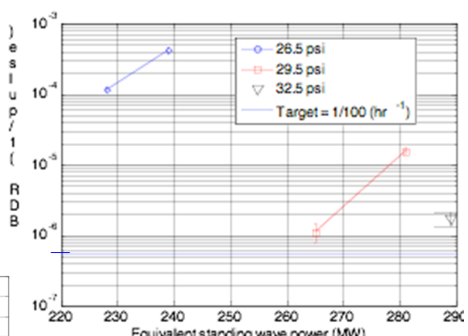
KCS

KCS "Big Pipe" Waveguide Tests

0.48 m diameter, pressurized aluminum pipe resonantly powered to ~300 MW TE_{01} mode field equivalent in 1 ms pulses @ 5 Hz.

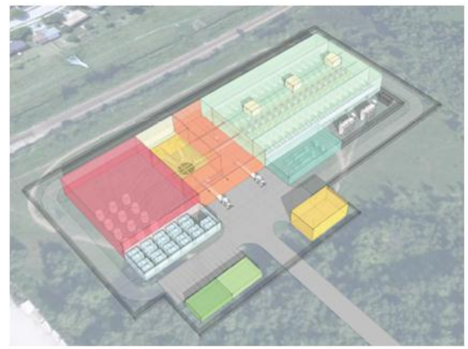
High Power Test History of "Big Pipe"





courtesy of Faya Wang

KCS Surface Buildings and Main Waveguide



Building Concepts by Holabird/Root
(from Vic)

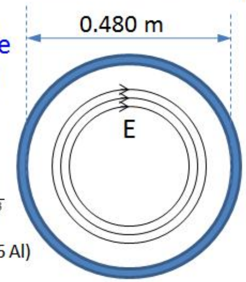
Two clusters can be housed in one building (feeding upstream and downstream).

10 MW, 1.6 ms, 1.3 GHz multi-beam klystrons (like **RDR**) powered by 120 kV (Marx?) modulators.

Main KCS Waveguide
(Aluminum WC1890)
~~evacuated~~
pressurized

$$\alpha = \frac{R_s}{Z_0}\frac{1}{\sqrt{k_0^2-(\chi_{01}/a)^2}}\frac{\chi_{01}^2}{k_0 a^3}$$

$= 6.771\times10^{-5}\ m^{-1}$ (6061-T6 Al)



TE_{01} mode:

- No surface electric field → high power handling capacity
- Attenuation falls quickly with radius → low loss achievable (~13%/km)
- Extensive experience from NLC pulse compression, power distribution R&D

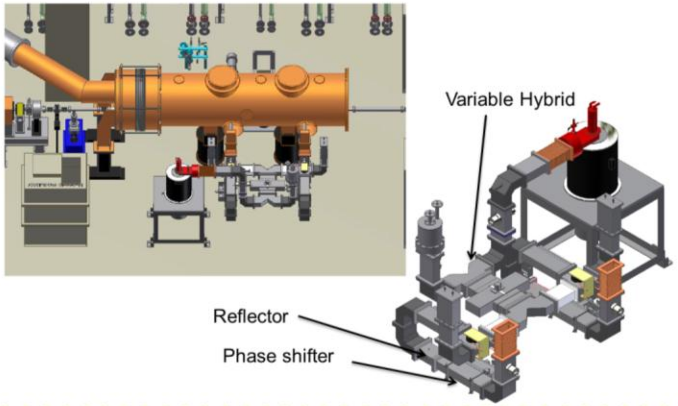
DRFS

Summary

- As recent progress and status of DRFS in KEK, 4 main topics are presented.
- DRFS Status in S1-global – HLRF are reported. Basic feasibility was successfully demonstrated. Circulator-less PDF system was also shown to be good performance. Therefore, recent design change forces to change the direction of DRFS PDS.
- DRFS Status in S1-global – LLRF are reported. LLRF components were developed and studied many items in S1-global DRFS.
- DRFS theme at quantum beam project and preparation are presented.
-

2011/9

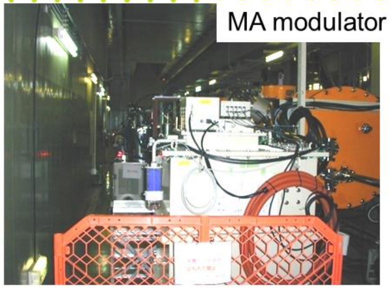
DRFS Preparation for Quantum Beam Project

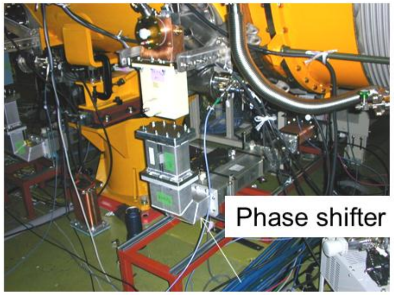


2011/9/27 LCWS11 DRFS Status (S. Fukuda) 25

Pictures of S1-global test (2)

DRFS #1





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Joint Session – Field Emission

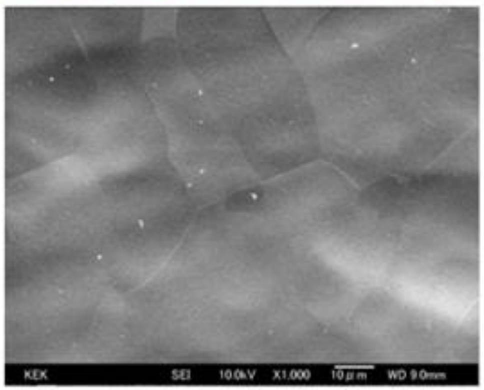
Field emission study on Nb surface

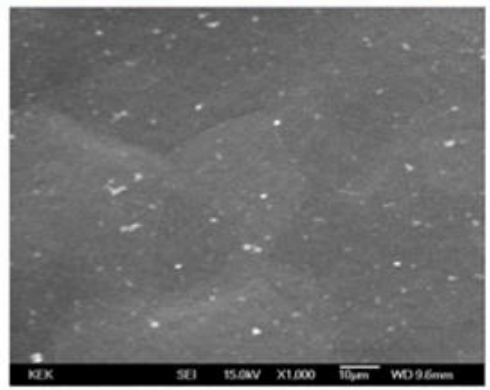
Hitoshi Hayano

SEM Observations

SEM Images of Beam Pipe Sample

EPed in Cavity EP 1 Experiment (Fresh EP Acid)	EPed in Cavity EP 2 Experiment (Aged EP Acid)





- Surfaces were covered with many particles.
- Particles size was several sub-micrometers to few micrometers.
- A high density of particles was observed on the surfaces treated with aged EP acid.

EP parameter optimization by XPS (SEM)

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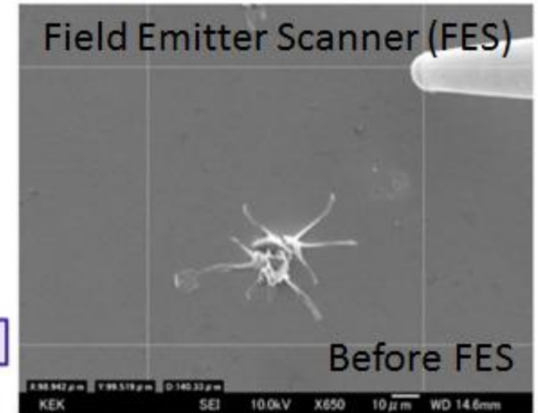
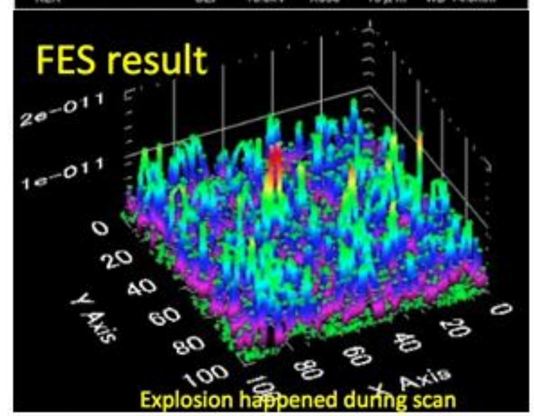
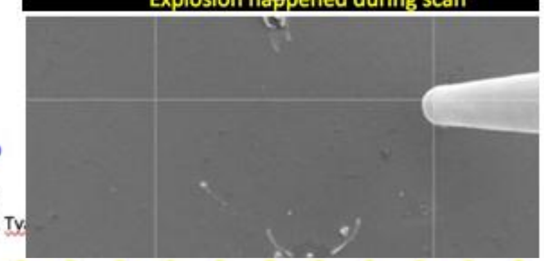
P.V. Ty







SCRF Cavities - Yield

TDR-SCRF
Report and Discussions, Sept. 28

- **Cavity Gradient**
  - Scope for the gradient improvement, and updates of recipe
  - Preparation for the production yield evaluation update
- **Cavity, Cryomodule, and Cryogenics**
  - Plug-compatibility with performance/cost constraint
    - Guideline: plug-compatibility with constraints of the lowest cost for acceptable performance
  - Cavity-string configuration (8+8+8) and split quadrupole
- **HLRF**
  - Single tunnel, gradient spread and degradation, and tunability, AC p
- **ML Integration**
  - Beam dynamics, stability, bunch spacing?, alignment, extend-ability TeV upgrade, and availability, reliability , backups.
- **Industrialization**
  - Cooperation with costing group, followed by report by G. Dug

A. Yamamoto -110928 **TDR ACC & SCRF Guidline**

How to prepare for TDR?

- **Discussion during LCWS**

⇩

- **Further technical discussion in TTC, Dec. 5 - 8**
- **ILC Specific discussion in post-TTC, Dec. 8-9,**

⇩

- **Consensus for TDR writing, BTR at KEK, Jan. 19 – 20, 2012**

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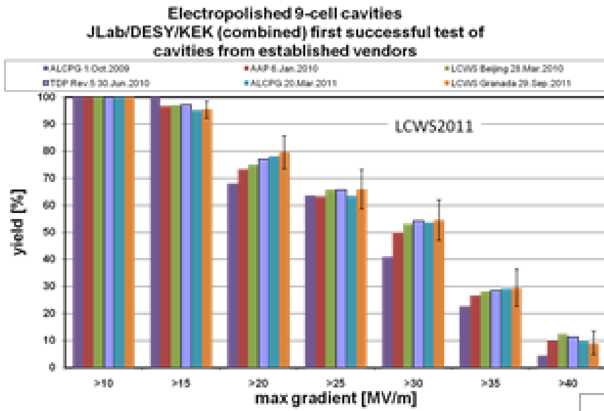
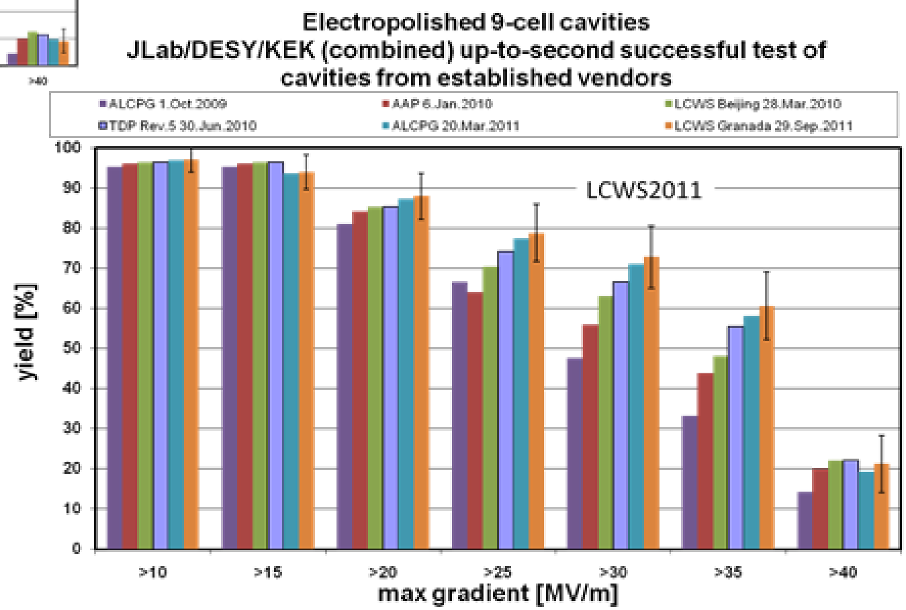
Toward the TDR

Time Progression by Workshop

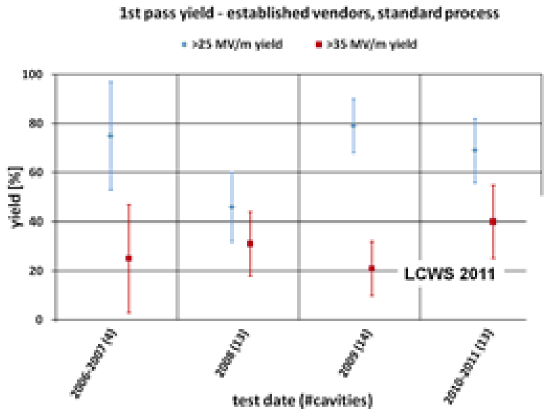


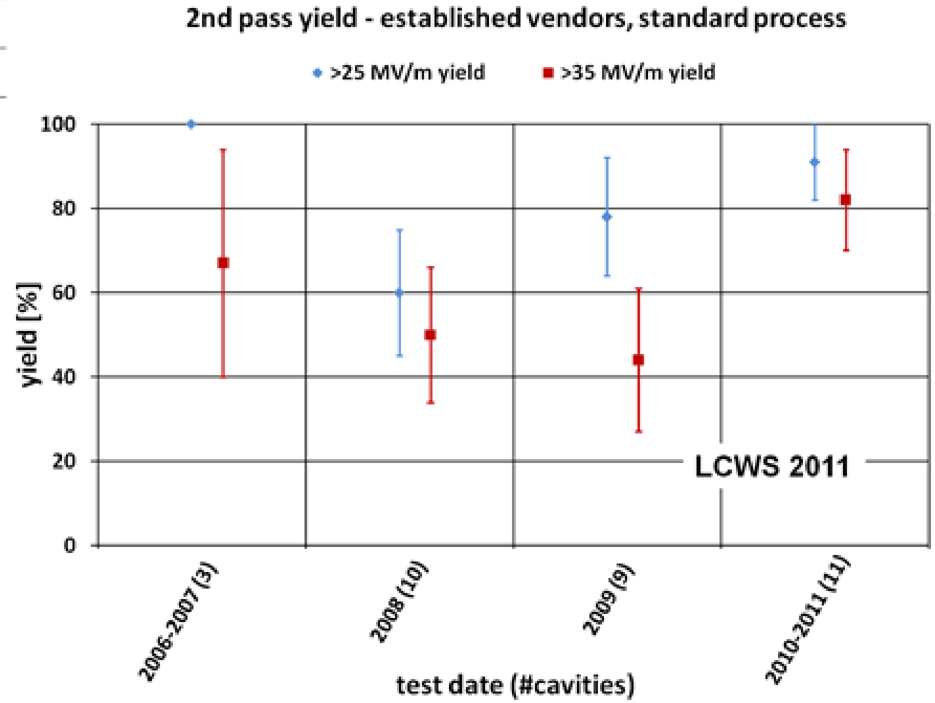


CMGinsburg (FNAL) ILC Cavity DB LCWS11 29.Sep.2011 7

SCRF Cavities - Yield

Time Progression by Year



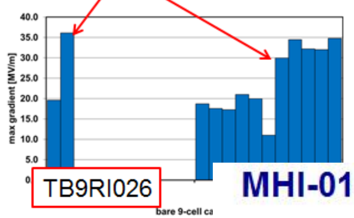


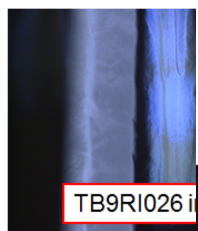
CMGinsburg (FNAL) ILC Cavity DB LCWS11 29.Sep.2011 8

SCRF Cavities - Yield

Localized Grinding (w/KEK)

- AES003 History
  - Four times tight-loop process/test at JLab, cavity consistently limited to average 19 MV/m
    - Localized quench limitation T-mapped with JLab/FNAL collaboration
  - Various commissioning activities degraded cavity
  - Cavity sent to KEK for localized grinding
    - Local grinding applied to limiting features and largest iris scratches
    - EP 50 um, degreaser rinse, UPW rinse and HPR, surface inspection, HPR, sealed, pumped and then returned to FNAL
  - Without further FNAL/ANL processing, improved performance (FE limit)
  - After several additional process/tests, improved performance was maintained
    - Struggled with field emission (probably not related to grinding), but eventually beat it
- TB9RI026 History
  - 1st test after standard FNAL/ANL EP: limited by FE
    - Initially reached 28.8 MV/m with several FE burn-off events; did not recover well from one FE event; final gradient limit 19.6 MV/m
  - Iris pit was noted in FNAL optical inspection and molded
  - Cavity sent to KEK for localized grinding
    - Local grinding of iris pit, tuning more than 98% flatness, and then 20-30um EP, followed by HPR, drying, and flanged in the clean room air
  - HPR and assembly at FNAL/ANL
  - Improved performance, field-emission free



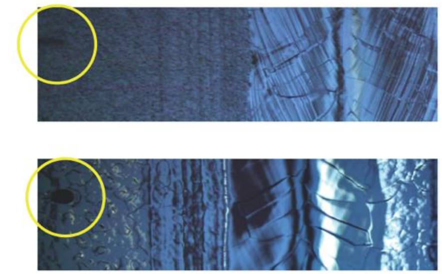


ENERGY | Argonne | Cornell University | Fermilab | Jefferson Lab | CMGins LCWS11

R. Geng, S0 Group Leader—wenow have a much better understanding of the decision tree and how to handle different types of failures

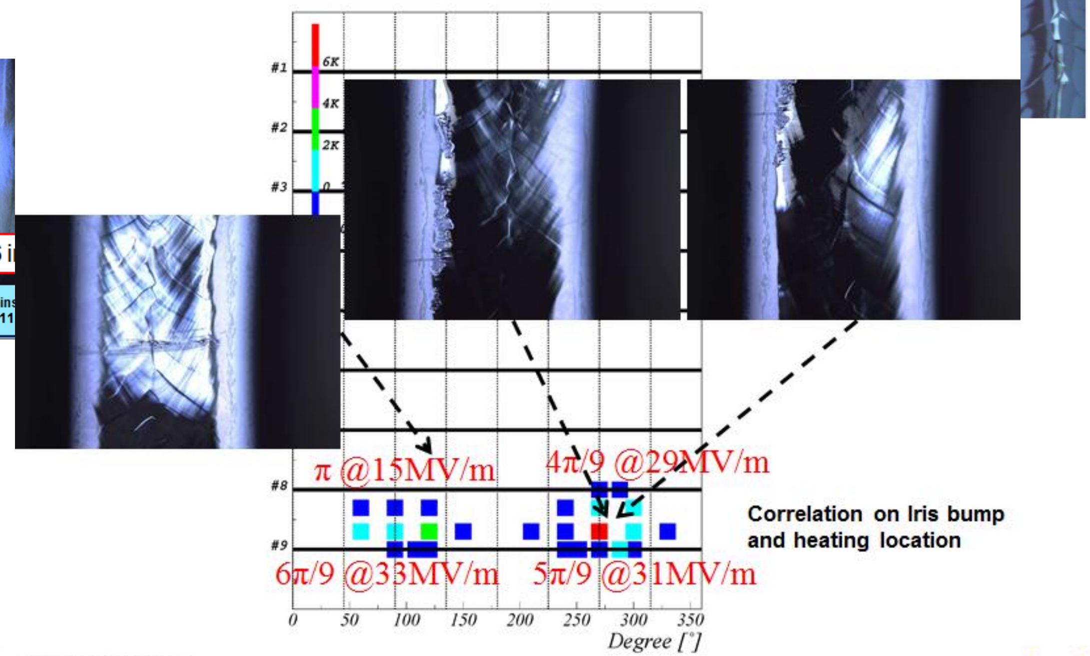
Towards automatic surface feature recognition

- Goals
  - categorize surface
    - typical feature size
    - roughness
    - shape
  - identify irregularities



MHI-014

Comparison of T-mapping and optical inspection



Correlation on Iris bump and heating location

Yasuchika Yamamoto

TDR Preparation

Our "homework"

Subjects to be prepared for SCRF in TDR - 1

- Cavity gradient :
  - Update of successful production yield definition/evaluation for production stage, including new parameters such as radiation, and ....
  - 31.5 MV/m +/-20 %, with sorting, and requirements for HLRF
  - Gradient degradation after installation into cryomodule
- Cavity Integration and Cryomodule assembly
  - Delivery condition of cavity with LHe vessel, and necessary testing sequence and monitor,
  - Plug compatibility specially on, beam-flange, couplers and tuner, magnetic shield,
  - Cost saving with 5K radiation-shield simplification, removal of 5 K shield at inter-connect
  - Acceptance criteria w/ He vessel, and test program (including high-pressure code)
- Cryomodule and HLRF configuration with single tunnel
  - 8 + (4+Q+4) + 8 cavity-string assembly
  - Split yoke, conduction-cooled quadrupoles
- Cavity-string and cryomodule Test
  - Warm conditioning of Input Coupler: before or after installation into the tunnel
  - Cold performance test: How much fraction to be cold tested? Subjects to be tested?

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Subjects to be prepared for SCRF in TDR- 2

- Cryogenics
  - Location and the options of cryogenic systems
  - Heat balance with thermal design harmonization with cryomodule
- HLRF
  - KCS/DRFS/RDR-unit HLRF system configuration including backup power supply and utilities with the single tunnel design
  - Marx generator?
  - AC power with gradient spreads,
  - Rescue/recovery plan against cavity degradation after installation into cryomodule, by using circulator and power distribution system,
  - Optimizations for low-power and high-power option.
- ML Integration
  - Beam dynamics
    - Quadrupole periodicity, locations, alignment, and beam tunability,
    - Bunch spacing limit specially on KCS (requirement of DR beam dynamics)

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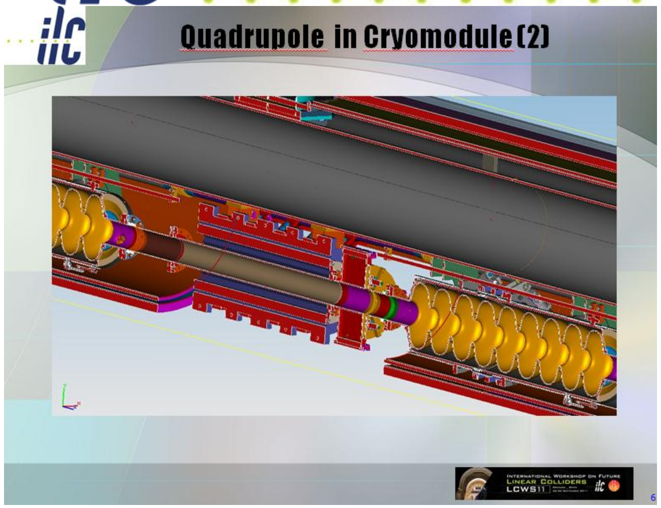
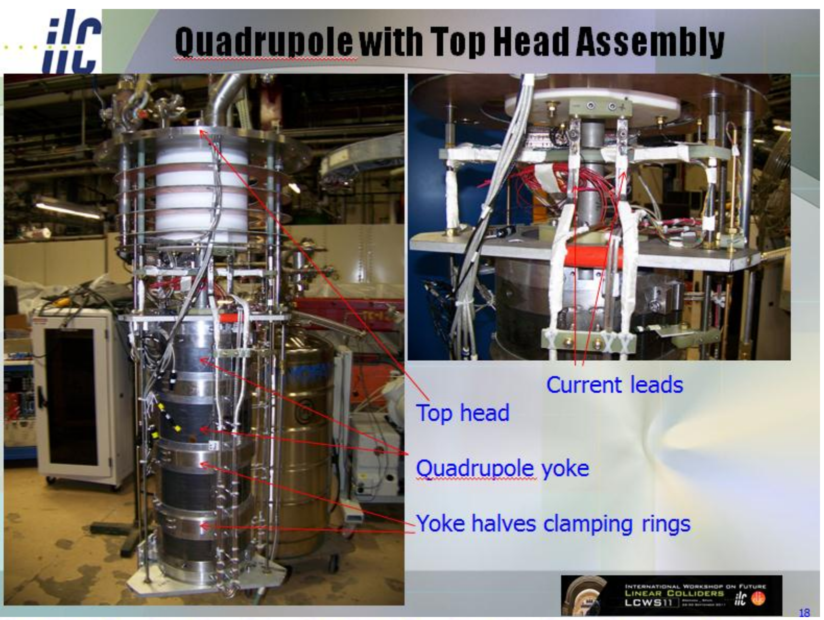
- Affecting cryomodule area
  - **Plug Compatibility**
    - with Cavity Integration
  - **Cost Savings**
    - 5K or not 5K? with Cryogenics
  - **Assembly**
    - many interfaces
    - (hear XFEL story)
  - **Configuration (1T)**
    - 8+(4+Q+4)+8, with Cryogenics
    - Conduction cooled quad
  - **Cryomodule testing scope**
    - next order correlation: S1 to S2?
  - **Thermal design harmonization**
    - with Cryogenics
  - **Quadrupole periodicity**
    - See 8 vs 12, with ML Integration and BD

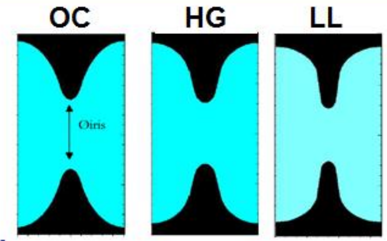
Cryomodule Value Engineering





Lessons Learned (cont'd)

Renascence: Final developmental cryomodule



- Used as testbed
  - 2 new cell shapes
    - HG: High Gradient (reduced E_{max})
    - LL: Low Loss (reduced B_{max})
  - New tuner (Internal – cold motor)
- Problem: Cavity HOM probe heating
  - Response:
    - Reduce HOM couplers from 4 to 2
    - Add thermal anchoring for HOM signal cables
    - Re-optimize probes for 12 GeV design
- Problem: Tuner reliability
  - Response: Return to original design
- Beam Break Up (BBU)
  - Response:
    - Refined specification
      - longitudinal/transverse modes
    - Revised acceptance criterion

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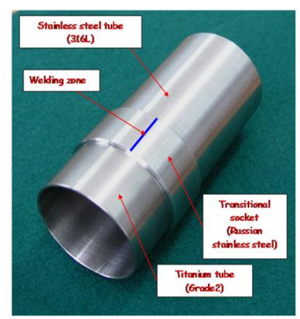


The pilot specimen was severely tested for strength and leakage. The tests were carried out in Sarov and Dubna (Russia), Pisa (Italy), and Fermilab (USA) under various shock conditions: thermal cycling in liquid nitrogen, cooling to 2K, pressure up to 6 atm inside the specimen. The leak test showed absence of leakage at the leak detector background indication ≈10^{-10} atm·cm^3·s^{-1}. To verify the results, we manufactured and tested another 24 Ti + SS transition elements. The tests for leakage and strength of the joints yielded similar results.

•A.Basti et al., *"Characterization measurements of Ti-SS Bimetallic transition joint samples"*, ILC-NOTE-2008-044, May 2008; JINR, E13-2008-111, Dubna,2008.
•W.Soyars et al., *"Superfluid Helium Testing of a Stainless Steel to Titanium Piping Transition Joint"*, «Cryogenic Engineering Conference», 2009 at Tuscon, Arizona, USA.

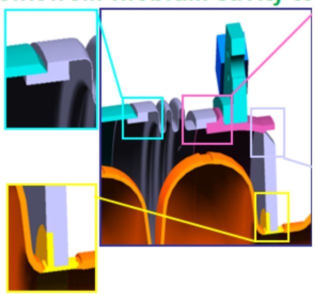
LCWS11, Granada – Sabirov B. 6

Cryomodule Value Engineering

12 GeV Final Design (cont'd)

C100 Cavity
- Low Loss (LL) shape
  - Best HOM spectrum, thermal load, and RF power
- Two optimized HOM couplers

Helium Vessel
- Stainless steel design: cost reduction
  - Utilizes a brazed joint from niobium cavity to helium vessel



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CEA preparation for XFEL cryomodules integration

Context
Pre-industrialisation studies
Prototyping
Industrialisation

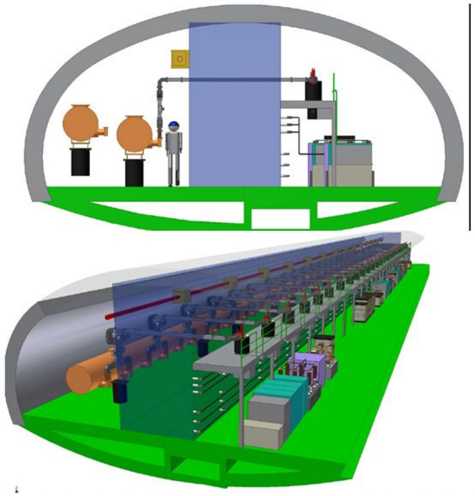


29/09/2011 LCWS'11 – C. MADEC 1

CFS Joint Session

Propose the Name of "Kamaboko" Tunnel

We (Japanese) want to name this tunnel as "Kamaboko" tunnel. Kamaboko is a Japanese traditional food, which is made from fresh fish's paste, and very delicious. Cross-section of tunnel is actually just the shape of kamaboko!



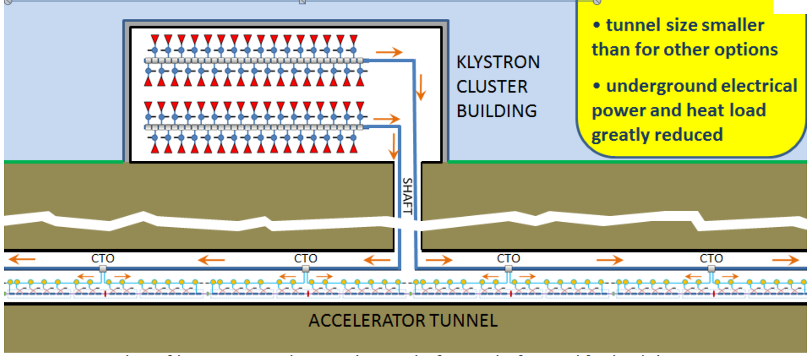
2011/9/28 Current Scheme of DRFS (Fukuda) LCWS11 10

Klystron Cluster Scheme

- Main linac rf power is produced in surface buildings and brought down to and along the tunnel in low-loss circular waveguide.
- Many modulators and klystrons are "clustered" to minimize surface presence and number of required shafts.
- Power from a cluster is combined and then tapped off in equal amounts at 3-cryomodule (RDR rf unit) intervals.

ADVANTAGES

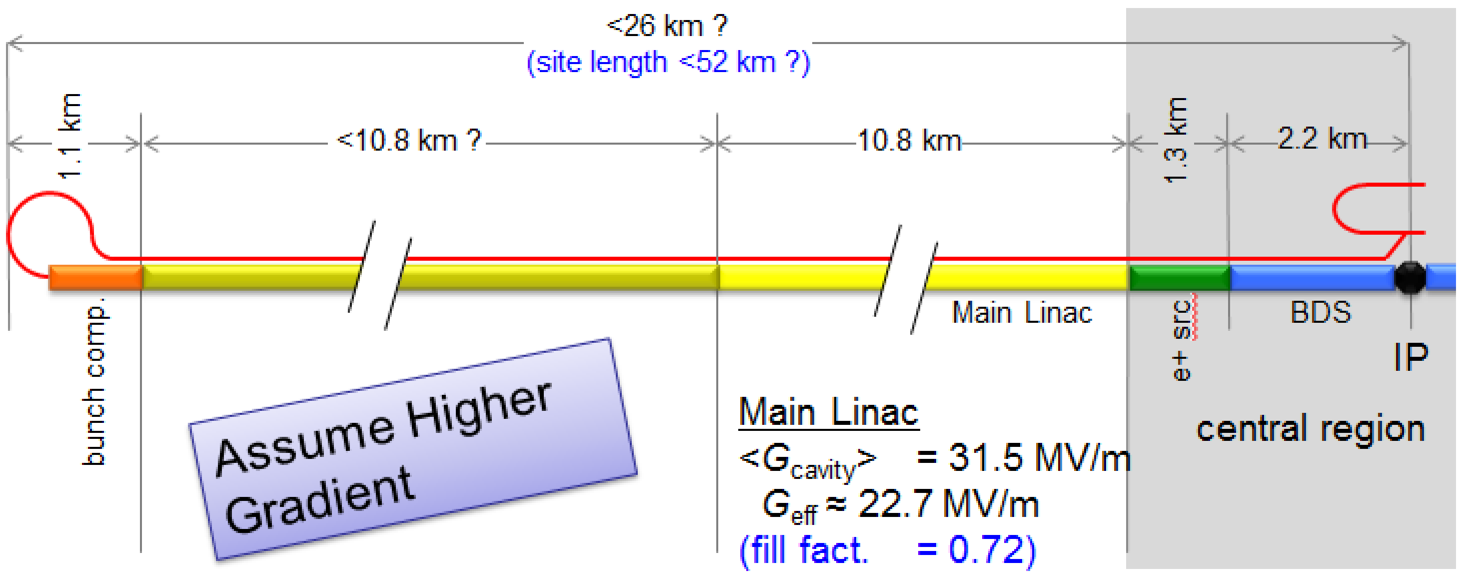
- equipment accessib for maintenance
- tunnel size smaller than for other options
- underground electrical power and heat load greatly reduced



2.05 km of linac powered per 2-cluster shaft. 12 shafts total for both linacs.

Beyond 2012

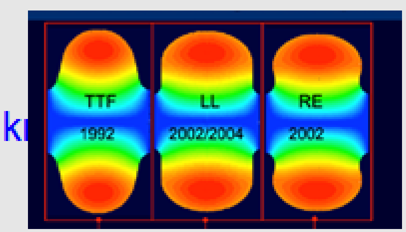
From 500 to 1000 GeV



Snowmass 2005 baseline recommendation for TeV upgrade:

G_{cavity} = 36 MV/m ⇒ 9.6 k

(VT ≥ 40 MV/m)



Based on use of low-loss or re-entrant cavity shapes

SCRF R&D post 2012

Toward 50 MV/m SRF Acceleration without Field Emission

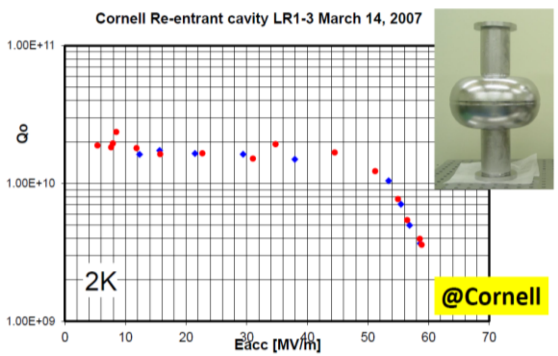
INTERNATIONAL WORKSHOP ON FUTURE LINEAR COLLIDERS LCWS11 GRANADA _ SPAIN 26-30 SEPTEMBER 2011

Rong-Li Geng
Jefferson Lab

LCWS11, Granada, Spain, September 26-30, 2011

U.S. DEPARTMENT OF ENERGY · Office of Science, U.S. DEPARTMENT OF ENERGY · Jefferson Lab

Proof of high gradient w/ single cells (2)



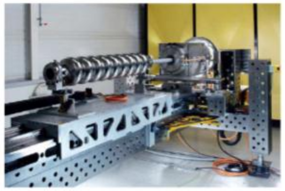
Materials R&D for Increase of Q, E_{Acc}, and Energy

Lance Cooley
Head, Superconducting Materials Department
Technical Division, Fermilab

Fermilab

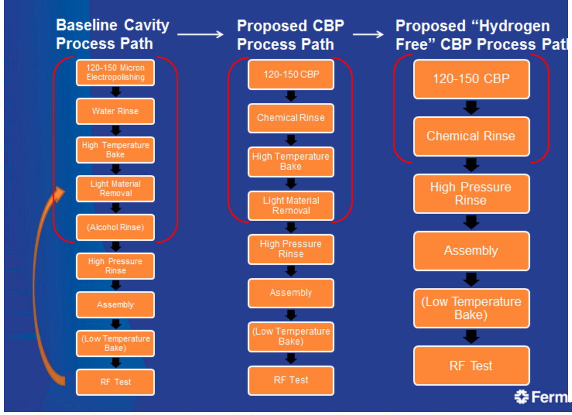
OBACHT

- Optical bench for automated cavity inspection with high resolution and short timescales



- Fully automated optical inspection: camera position, illumination, auto focus, image taking and image storing
- The timescale for a single inspection decreases from the order of day
- Image processing will run in parallel using the stored images
- Camera system based on Kyoto Camera

How Cavities Would be Processed with CBP

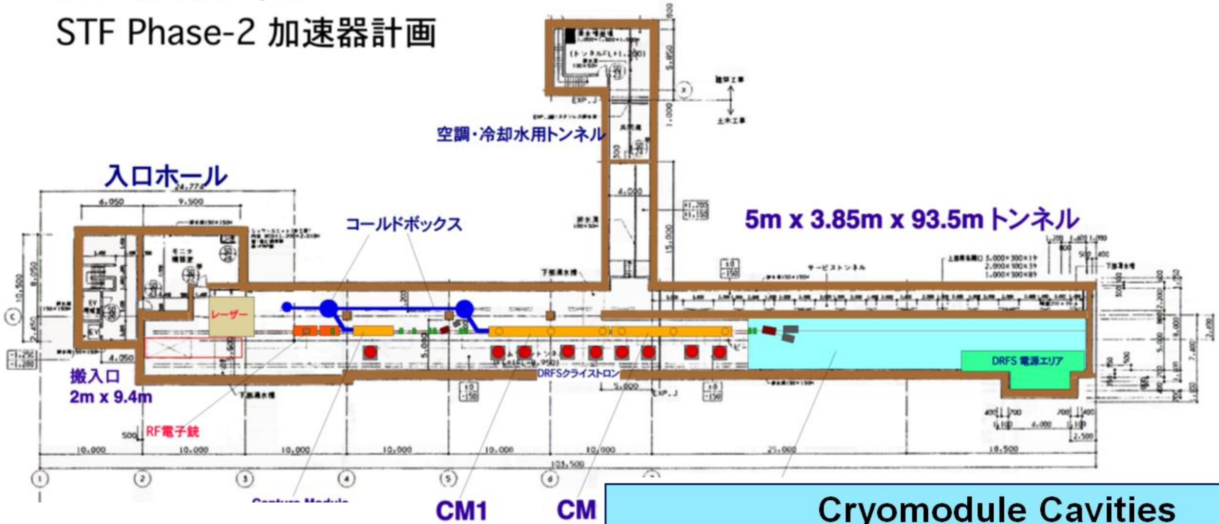


Summary

- DESY will focus on proper handling of the 800+ cavities for the European XFEL — *High statistics*
- Future laboratory interest is primarily focused on cw-operation — *Q_0*
  - single crystal cavities
  - hydroforming
- Systematic studies of gradient limitation — *Material and surface science*

Ongoing System Tests

STF 地下トンネル
STF Phase-2 加速器計画



Longer term:
Study topics

- **Effective usable gradient (gradient margins)**
  - Trade-studies: effective usable gradient vs stability vs gradient spread vs beam current vs …
- **Develop automation methodologies and strategies**
  - Operate the linac 'as if there were 16,000 cavities'
  - FLASH – 'scale-model' of EU-XFEL operations
  - EU-XFEL – scale-model of ILC operations
- **Exception handling**
  - Fault detection and recovery
- **Address 'devil in the details' practical issues, eg**
  - Measurement and calibration
  - Resolution of control of parameters (Loaded-Q, tuning,…)
  - Thermal stability, repeatability, robustness

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Cryomodule Cavities

FNAL-CM2 23.Sep.2011

CM2 string (8-cavity + magnet) assembled and leak checked at FNAL

CM2 position	cavity	latest	Eacc
2	TB9RI018	test	35 (HT)
6	TB9AES009	HPR	35 (HT)
3	TB9AES010	HPR	35 (HT)
1	TB9AES008	HPR	35 (HT)
5	TB9ACC016	HPR	36.5 (VT)
4	TB9RI019	test	35 (HT)
7	TB9RI027	test	35 (HT)
8	TB9RI028	test	33 (HT)
status 20.Sep.2011			

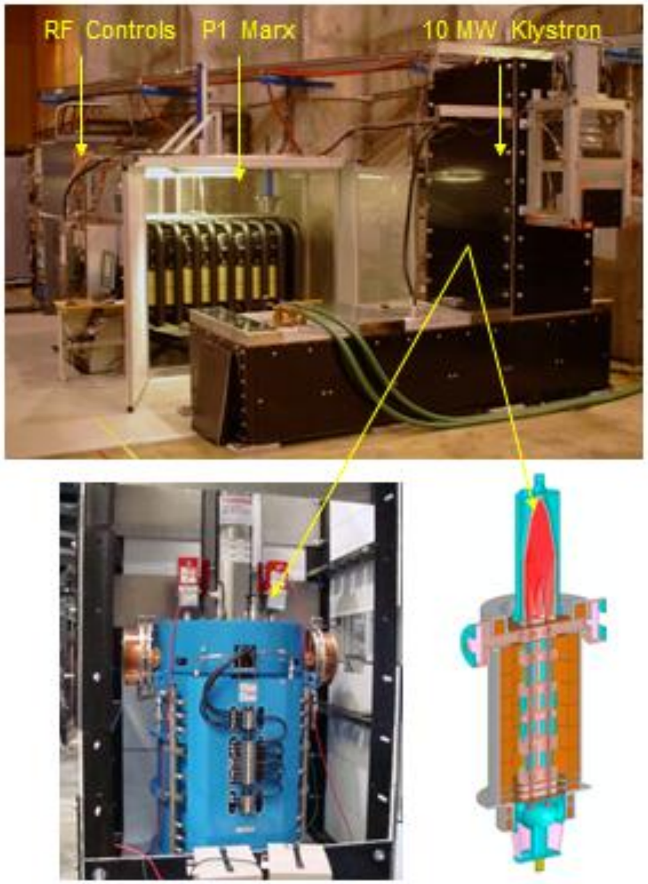
All these cavities for CM2 were processed and vertically tested at JLab dressed and horizontally tested at FNAL

CMGinsburg (FNAL) LCWS11 27.Sep.2011 12

HLRF (example…)

Marx Modulators

- P1 Marx: has operated over 5 khr although at half pulse length this year due to capacitor lifetime problem – will upgrade with zinc versions
- P2 Marx: has lower voltage cells with individual droop control – being assembled
- In FY12, no funding for new development, but
  - P1 and P2 will be long-term tested
  - A SBIR funded DTI Marx will be evaluated
  - A new 10 MW MBK will be acquired



Toshiba 10 MW Multi-Beam Klystron (MBK)

Chris Adolphsen

AWG 3 Conclusion

- **A busy, constructive, useful workshop**
- **Great progress on components and industrialization**
  - Glad the we make one of the DG's favorite plots!
- **Many exciting system tests in progress…discovering all the details**
- **A start on high level TDR parameters made…enough to keep moving forward**
- **Many opportunities for collaboration already complete..many <u>more</u> to come**