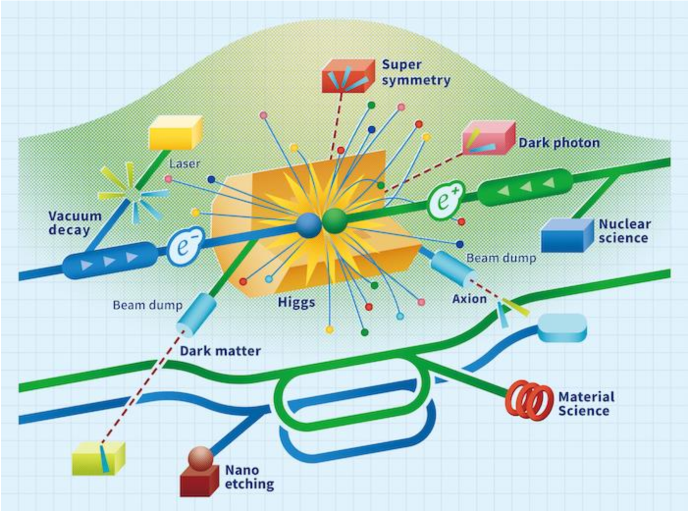
Summary of CM design session

ILCX2021 ILC Workshop on Potential Experiments

- 8 presenters
- ~25 attendee
- Reviews on TDR
- Recent progress
- Many discussion



Thu 28/10

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21:00			
	GDE and History (Akira Yamamoto and Kirk) *Room #1, Zoom Meeting ID: 869 3543 0074*	*Akira Yamamoto*	21:30 - 21:40
	Renewed CM design (Yuriy Orlov) *Room #1, Zoom Meeting ID: 869 3543 0074*	*Yuriy Orlov*	21:40 - 22:00
22:00	**SRF Tuner developed by FNAL for LCLS II Project is strong candidate for ILC (Yuriy Pischalnikov)** *Room #1, Zoom Meeting ID: 869 3543 0074*	*Yuriy Pischalnikov*	22:00 - 22:20
	High Pressure Gas Safety Regulation in Japan (Kensei Umemori) *Room #1, Zoom Meeting ID: 869 3543 0074*	*Kensei Umemori*	22:20 - 22:35
	Different material joint (Ti-SS and Al-SS) (Takeshi Dohmae) *Room #1, Zoom Meeting ID: 869 3543 0074*	*Takeshi Dohmae*	22:35 - 22:45
	Pipe standard and CAD software used for CM drawing (Taro Konomi) *Room #1, Zoom Meeting ID: 869 3543 0074*	*Taro Konomi*	22:45 - 22:50
	RF distribution system (Toshihiro Matsumoto) *Room #1, Zoom Meeting ID: 869 3543 0074*	*Toshihiro Matsumoto*	22:50 - 23:00
23:00	**Progress of auto cleaning system (Stephane Berry)** *Room #1, Zoom Meeting ID: 869 3543 0074*	*Sthephane Berry*	23:00 - 23:15
	Discussion *Room #1, Zoom Meeting ID: 869 3543 0074*		23:15 - 23:30

25:00 Finished

Memorandum will be uploaded later

Kirk

Reviews on TDR by Akira Yamamoto-san (KEK)

ILC Cryomodule Design and Development in GDE-TDR and LCC/IDT Phases

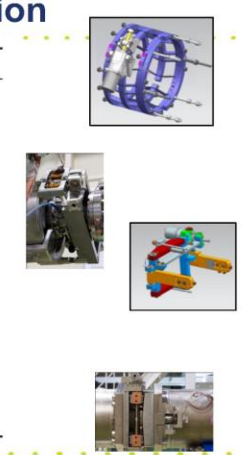
Akira Yamamoto and Yasuchika (Kirk) Yamamoto (KEK)

To be presented at ILCX-2021 (online), 2021-10-28

Tuner is one important item to be decided

Tuner Design Specification

Tuner	Parameter	Specifications
Slow tuner		
	Tuning range	> 600 kHz
	Hysteresis	$< 10\mu$m
	Motor characteristics	Step motor, power-off holding, magnetically shielded
	Motor location	Inside 5K shield, accessible from outside
	Magnetic shield	$<$ 20mG
	Heat load by motor	$<$ 50 mW at 2 K
	Motor lifetime	$> 20 \times 10^6$ steps
Fast tuner		
	Tuning range	>1KHz at 2 K
	LFD residuals	$<$ 50 Hz at 31.5 MV/m flat-top
	Actuator	Piezo actuator, located inside 5K shield, Two actuators for redundancy
	Heat load by actuator	$<$ 50 mW at 2 K
	Magnetic shield	$<$ 20mG
	Actuator lifetime	$> 10^{10}$ pulses



Each dimension boundary should be checked

ILC Type-IV CM design, in TDR, compared with Eu-XFEL CM

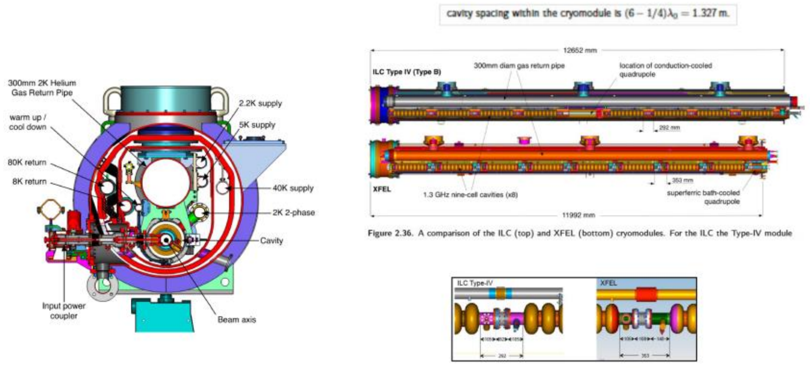


Figure 2.36. A comparison of the ILC (top) and XFEL (bottom) cryomodules. For the ILC the Type-IV module

If we want to change something, we need to submit "change request"

Overview of ILC Design Change Requests made in GDE and LCC Phase

ILC-CR-0001	Insertion of a dogleg in the electron side	D00000001082395
ILC-CR-0002	Baseline optics to provide for a single L*	D00000001082495
ILC-CR-0003	Detector hall with vertical shaft access	D00000001084745
ILC-CR-0004	Extension of the Main Linac tunnels	D00000001092915
ILC-CR-0005	Update of published ILC top-level luminosity parameters	D00000001100895
ILC-CR-0006	Adding a stripline BPM downstream of QD0	D00000001102185
ILC-CR-0007	Adoption of the Asian design as sole baseline	D00000001107065
ILC-CR-0008	Release of the ILC2015a lattice	D00000001110885
ILC-CR-0009	Cryogenic Layout	D00000001118315
ILC-CR-0010	Proposal to include Bunch Compressor sections into Main Linac AS	D00000001119175
ILC-CR-0011	The rearrangement of undulator positron source	D00000001121535
ILC-CR-0012	Reduction of width of Linac Shield Wall and Tunnel Cross-Section	D00000001127835
ILC-CR-0013	Update of the ILC beam dump specifications	D00000001145035
ILC-CR-0014	Cryogenic layout (2)	D00000001146525
ILC-CR-0015	Kamaboko shaped positron BDS tunnel	D00000001154075
ILC-CR-0016	Luminosity improvement at 250GeV CM	D00000001159725
ILC-CR-0017	Orientation of electron/positron linacs	D00000001169745
ILC-CR-0018	Updated power estimate for ILC-250	D00000001169675
ILC-CR-0019	Luminosity for operation at the Z-pole	D00000001169785
ILC-CR-0020	SRF Accelerator Cryogenics: He Inventory storage	not yet available
ILC-CR-0021	Updated power estimate for Z-pole operation of ILC-250	not yet available

Renewed CM design by Yuriy Orlov (FNAL)

Great contribution from FNAL

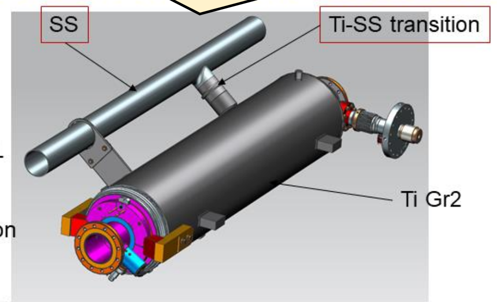
ILC 1.3 GHz CM. 2021

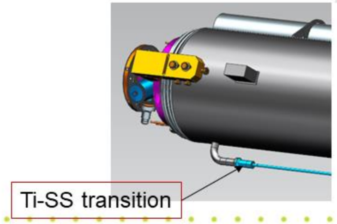
Design status on 10/28/21,
by Y. Orlov, behalf FNAL and KEK teams

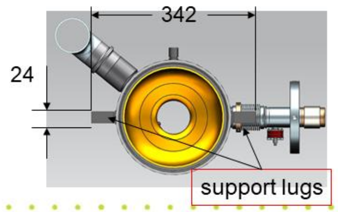
SUS pipe is used as 2-phase pipe

1.3 GHz IL

- 9-cell cavity, TESLA style
- 1247.4mm, flange to flange
- Support lugs - LCLS-II
- He vessel material: Ti Gr2
- 2-phase pipe material: SS316L
- Ti-SS transition joins used:
  - warm up nozzle
  - 2 phase pipe connection







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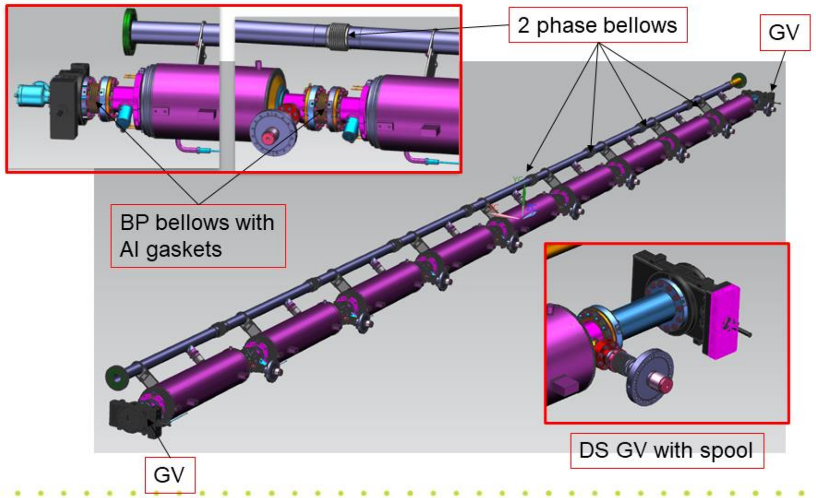
Drawing for Type-A string was also developed

1.3 GHz cavity string-A



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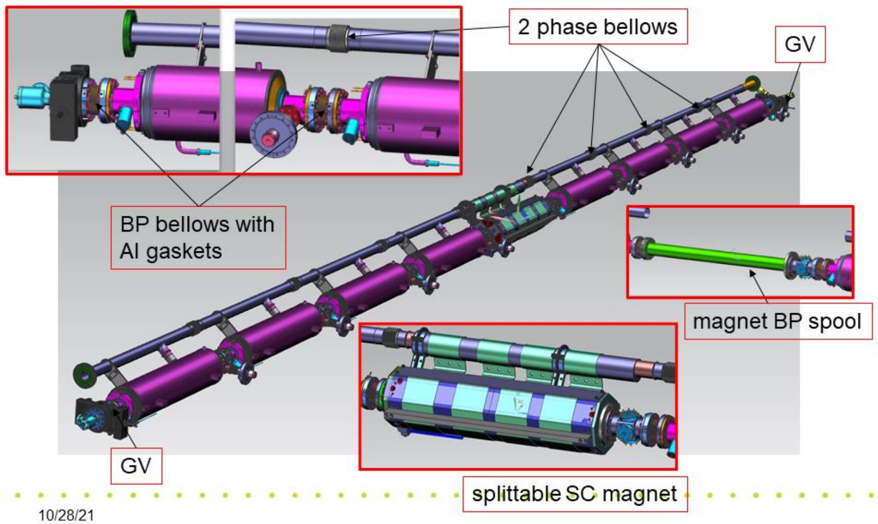
1.3 GHz cavity string-B



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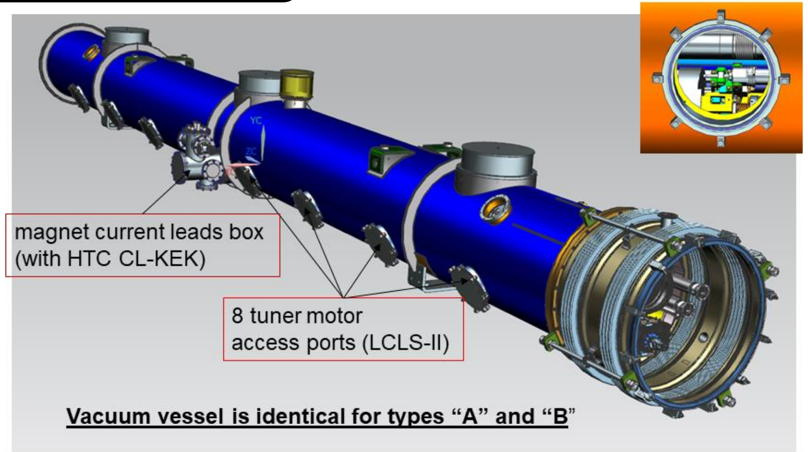
Renewed CM design by Yuriy Orlov (FNAL)

Tuner access port is added

GHz ILC CM-B



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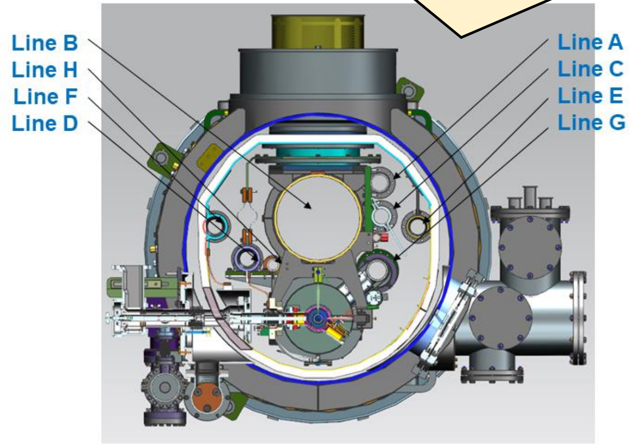
Removal of 5K thermal shield
(MLI is used for cavity/pipes)

ILC CM I



Installation of CM into 45ft container was checked

Typical 45' container

Inside Dimension

Measure	Length	Width	Height
Millimeters	13,556	2,352	2,700
Feet	44' 5 5/8"	7' 8 5/8"	8' 10 1/4"

Door Opening

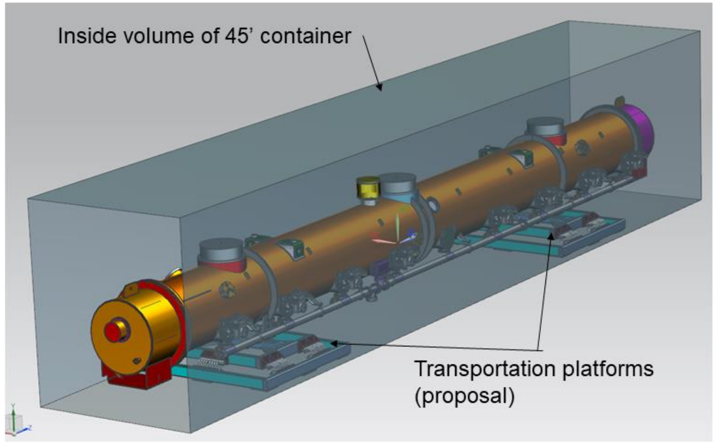
Measure	Width	Height
Millimeters	2,340	2,597
Feet	7' 8 1/8"	8' 6 1/4"

Weight

Measure	Max Gross	Tare (Weight)	Max Payload
Kilograms	32,500	4,800	27,700
Pounds	71,650	10,552	61,067

10/28/21

Transportation of 1.3 GHz CM



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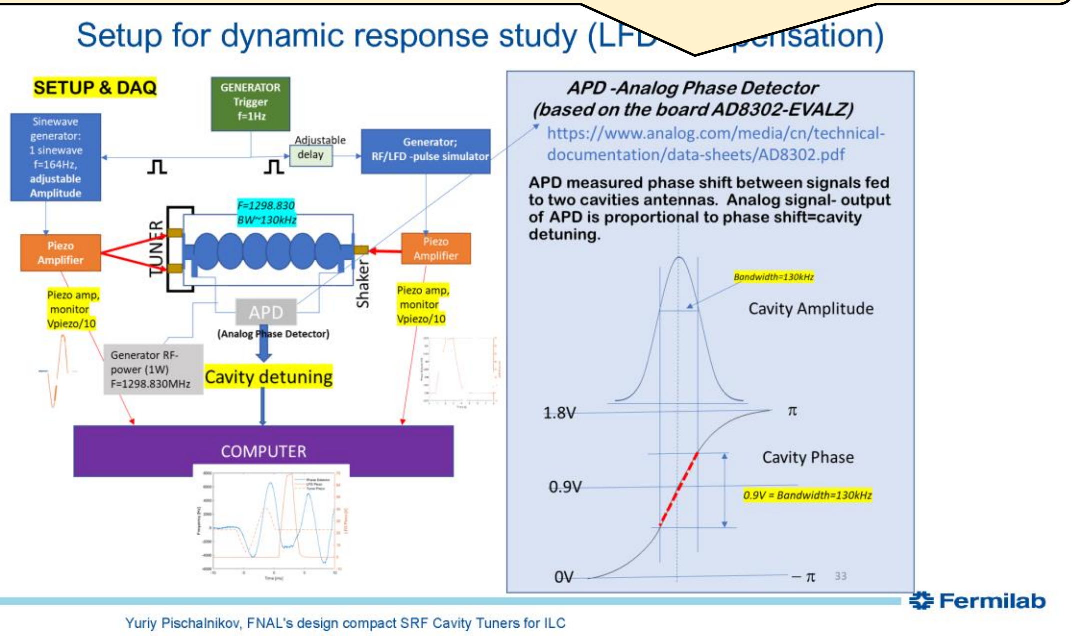
Tuner progress by Yuriy Piscalnikov (FNAL)

Great effort from FNAL

Four types of tuner

Experiment on "imitated LFD compensation" was done



LCLS-II tuner has been worked well in all cold tests for CM

Conclusion: Developed by FNAL for LCLS II SRF cavity tuner met all ILC specs

(during design of this tuner FNAL team has advantage to apply experience gained by other teams from all previously designed tuners; SACLAY I; SLIM Blade, Slide Jack, etc.)

- ✓ Compact double-lever Tuner that fit on the "short-short" cavity.
- ✓ Robust/Low-cost tuner frame design.
- ✓ High tuner stiffness for minimization of LFD
- ✓ Tuner design allow to replace actuators (stepper & piezo) through designated CM port without tuner dis-assembly
- ✓ Highly reliable actuators (stepper & piezo) designed in collaboration with industrial partners
- ✓ Slow tuner range more than 800kHz & hysteresis ~45Hz
- ✓ Encapsulated piezo actuators translated stroke directly to the cavity (piezo stroke >2,5kHz and low group delay–important for active LFD compensation)
- ✓ Simple dynamic test on the warm cavity demonstrated capability of the LCLS II tuner to mitigate LFD.
- ✓ More than 320 tuners that built and deployed at 40 LCLS II have been cold tested/qualified for LINAC operations (additional 180 tuners will be built for LCLS II HE) →total 500 units…

Fermilab

26 Yuriy Pischalnikov, FNAL's design compact SRF Cavity Tuners for ILC

Progress of HPGS by Umemori-san (KEK)

We need the certification by KHK for cavity production

High pressure gas safety regulation in Japan
~Mainly cavity fabrication~

ILCX2021
2021/10/28
KEK CASA Kensei Umemori

There are some categories in HPGS

Regulations in high pre...

Designated equipment inspection regulation

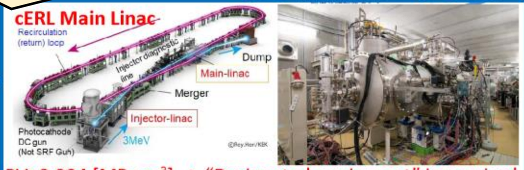
General high-pressure gas safety regulation

LPG(Liquefied petroleum gas) safety regulation

Industrial complex (kombinat) safety regulation

Refrigeration safety regulation

etc.



PV>0.004 [MPa m^3] => "Designated equipment" is required

For ILC & ILC pre-lab, we try to apply

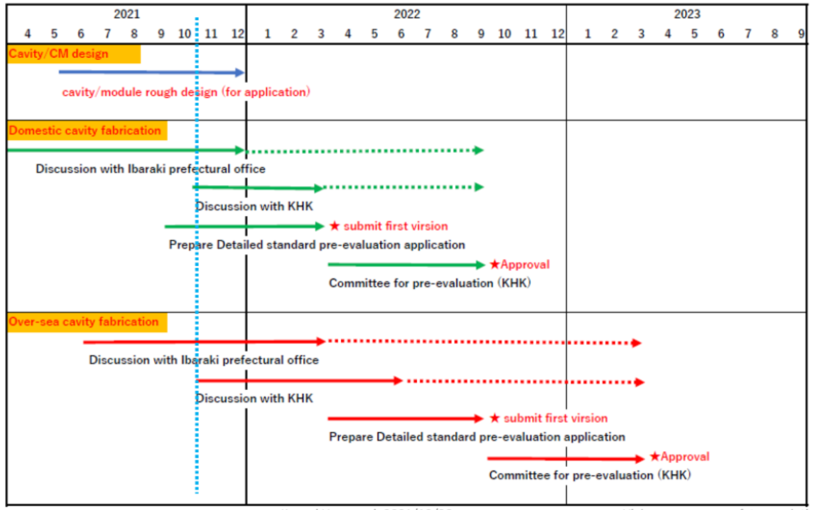
"Refrigerator safety regulation" looks preferable for ILC

Comparison between general high-pressure safety and refrigeration safety regulation

Item/Process	General high-pressure gas regulation	Refrigerator safety regulation
System	Open / closed loop	Only closed loop
Inspection of completed cavity	Inspection by KHK	Inspection by qualified person
Expiration date of inspection pass	3 years	(Basically) no limitation
Operation	Security staff (with license) must be resident	No need of security staff
Maintenance Regular inspection	Security inspection with prefectural office (once/year) + self inspection (> once/year)	Self inspection (> once/year) Unannounced inspection by prefectural office
Change category	Possible to change to refrigerator safety regulation	Impossible to change to general high-pressure gas regulation

Negotiation with local government already started

Schedule (target plan)



After approval of Detailed standard pre-evaluation, we can start cavity fabrication.

Ti-SS joint by Dohmae-san (KEK)

SUS pipe has higher reliability for welding

Different-Metal Joint for the Dressed Cavity

ILCX2021

2021/10/28

Takeshi DOHMAE

KEK

Comparison among three projects

Usage of clad joint in E-XFEL and LCLS-II

European XFEL:
- Product of Asahi-Kasei, Japan
- Used for both cool down line and two-phase He-lines at CM ends
- **Authorized by PED/TUV**

  Charpy impact strength: low at low T, and noted as "Reference test"

LCLS-II:
- Product of High Energy Metals, US
- Applied for both two-phase He-line and cool down line
- "Case of the ASME Boiler and Pressure Vessel Code is used to qualify the butt joint transition for cryogenic applications"
- Charpy impact strength is low at low T
- **Safety factor of > 11 (in 4K) demonstrated with simulation**
- Test tube using clad joint cleared leak test and radiography test after cold shock with liquid nitrogen.

	He vessel	Two-phase line	Cool down line	Two-phase line at the end of CM
E-XFEL	Ti	Ti	SS (Ti→SS)	SS (Ti→SS)
LCLS-II	Ti	SS (Ti→SS)	SS (Ti→SS)	SS
ILC (to be discussed)	Ti	SS (Ti→SS)	SS (Ti→SS)	SS

4

Charpy impact test has been done for LCLS-II

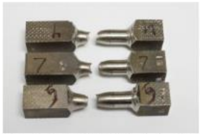
Mechanical test of clad joint

Mechanical tests of clad joint were performed by FNAL and ASAHI Kasei (DESY).

Results from FNAL

Tensile Test - Ultimate strength	
Test temperature 290 K	
Sample #4	789 MPa
Sample #5	788 MPa
Sample #7	774 MPa
Average	784 MPa
Test temperature 4 K	
Sample #12	1138 MPa
Sample #13	1259 MPa
Sample #18	1328 MPa
Average	1242 MPa

Charpy test	
Test temperature 290 K	
Sample #1	12.9 J
Sample #2	8.1 J
Sample #3	10.2 J
Average	10.4 J
Test temperature 4 K	
Sample #4	2.7 J
Sample #5	2.7 J
Sample #6	2.0 J
Average	1.8 J



(a) Samples tested at 290 K with the break on the Ti side.

(b) Typical cross section of ductile break (Titanium).

(c) Samples tested at 4 K with the break around the joint interface.

(d) Typical cross section of brittle break at joint interface.

"He Vessel Engineering note for LCLS-II", Donato Passarelli, Joshua Kaluzny
"Stainless steel to titanium bimetallic transitions", J A Kaluzny, C Grimm, and D Passarelli

✓ Enough tensile strength
✓ But too brittle

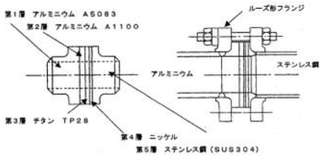
<Japanese regulation >
Average value of 3 samples >= 18 J
Minimum value of samples >= 14 J

6

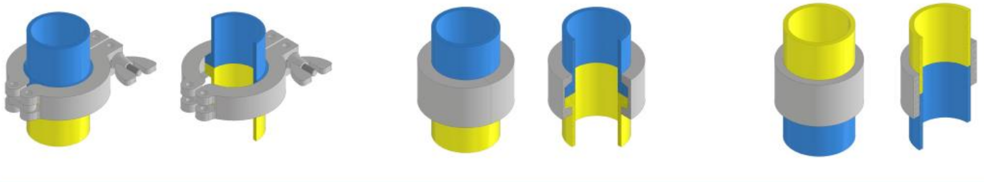
New idea may be necessary for reinforcing joint

Reinforce the joint

One of the possible solution is to reinforce the joint by clamping structure.
This procedure is also instructed by Japanese high pressure gas safety authority. (in case of SS-Al joint)



Suggested by KEK



Pipe standard and CAD by Konomi-san (KEK)

We have to take care of plug-compatibility to select all pipes used for CM

Pipe standard and CAD software used for CM drawing

2021. 10. 28

Taro Konomi

Different standard in each region/country

Type	abbreviation	Institution
International	ISO	International Organization for Standardization
Regional	EN	European standards
National	ANSI	US
	BS	UK
	DIN	Germany
	JIS	Japan
Organization	ASTM	American Society for Testing and Materials
	ASME	American Society of Mechanical Engineers
	JSME	Japan Society of Mechanical Engineers
	・・・	

Stainless steel pipes

In Japan, we usually use JIS

Japanese standard pipe

JIS G 3459: stainless steel pipes

Nominal diameter		Outer Diameter (mm)	Thickness (mm)						
A	B		5S	10S	20S	40	80	120	160
6	1/8	10.5	1		1.5	1.7	2.4		
8	1/4	13.8	1.2		2	2.2	3		
10	3/8	17.3	1.2		2	2.3	3.2		
15	1/2	21.7	1.65		2.5	2.8	3.7		4.7
20	3/4	27.2	1.65	2.1	2.5	2.9	3.9		5.5
25	1	34	1.65	2.8	3	3.4	4.5		6.4
32	1 1/4	**42.7**	**1.65**	2.8	3	3.6	4.9		6.4
40	1 1/2	**48.6**	**1.65**	2.8	3	3.7	5.1		7.1
50	2	**60.5**	**1.65**	2.8	3.5	3.9	5.5		8.7
65	2 1/2	**76.3**	**2.1**	3	3.5	5.2	7		9.5
80	3	89.1	2.1	3	4	5.5	7.6		11.1
90	3 1/2	101.6	2.1	3	4	5.7	8.1		12.7
100	4	114.3	2.1	3	4	6	8.6	11.1	13.5
125	5	139.8	2.8	3.4	5	6.6	9.5	12.7	15.9
150	6	165.2	2.8	3.4	5	7.1	11	14.3	18.2
200	8	216.3	2.8	4	6.5	8.2	12.7	18.2	23
250	10	267.4	3.4	4	6.5	9.3	15.1	21.4	28.6
300	12	318.5	4	4.5	6.5	10.3	17.4	25.4	33.3
350	14	355.6				11.1	19	27.8	35.7
⋮									

JIS G 3447:
Stainless steel sanitary tube

Nominal diameter	Outer Diameter (mm)	Thickness (mm)
8A	13.8	1.7
10A	17.3	1.7
15A	21.7	2.1
1.0S	25.4	1.2
1.25S	31.8	1.2
1.5S	38.1	1.2
2.0S	**50.8**	**1.5**
2.5S	**63.5**	**2.0**
3.0S	**76.3**	**2.0**
3.5S	89.1	2.0
4.0S	101.6	2.0
4.5S	114.3	3.0
5.5S	139.8	3.0
6.5S	165.2	3.0
⋮		

CAD software to develop drawings should be unified

CAD software

- There are many CAD software.
- KEK decided to use SIEMENS NX (NX93100 NX Mach 3) for CM design following FNAL.
- Use intermediate files (STEP, IGES, etc.) to exchange from NX to other software.

SIEMENS
Ingenuity for life

NX MACH 3 Product Design
The MACH 3 Product Design package provides a high-performance solution with NX design capabilities for advanced assembly design, advanced freeform modeling and surface analysis, design optimization and molded part validation.

	NX MACH Designer	NX Layout	NX MACH 1 Design	NX MACH 2 Product Design	NX Cool Shape Design	NX MACH 3 Product Design	NX MACH 3 Industrial Design
Design modeling							
Feature-based solid modeling	•		•	•	•	•	•
DesignLogic	•		•	•	•	•	•
User-defined features				•	•	•	•
Assembly design	•		•	•	•	•	•
Advanced assembly modeling						•	•
WAVE control							•
Basic freeform modeling	•		•	•	•	•	•
Advanced freeform modeling					•	•	•
Freeform shape design					•	•	•
NX Realize Shape					•		•
Process-specific modeling tools							
Sheet metal design	•		•	•		•	•
Basic routing				•		•	•
Flexible PCB				•		•	
Drafting and annotation							
NX Layout		•					
Drafting	•	•	•	•		•	•
GD&T, 3D annotation				•		•	•
Product validation							
HD3D Visual Report Viewing			•	•	•	•	•
HD3D Visual Report Authoring						•	•
Product and data validation				•		•	•
Molded Part Validation						•	•
Simulation							
Stress and vibration wizards	•		•	•		•	•
Design utilities							
Design optimization						•	•
Data exchange	•	•	•	•	•	•	•
XpresReview collaboration	•		•	•	•	•	•
Web publishing	•		•	•	•	•	•
Rendering				•	•	•	•
Custom program execution	•		•	•	•	•	•
Knowledge Fusion and custom wizard execution	•		•	•	•	•	•
Rapid prototyping	•		•	•	•	•	•
Engineering process management		•	•	•	•	•	•

RF system equipped with CM by Matsumoto-san (KEK)

Matumoto-san is considering to change the RF distribution system equipped with CM

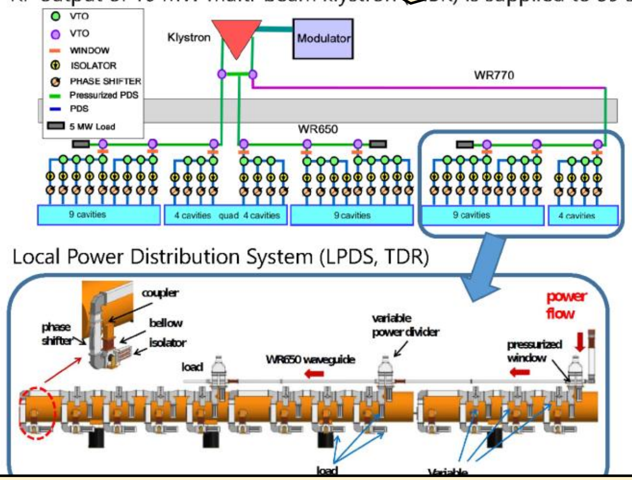
MATSUMOTO, Toshihiro (KEK, Accel. Lab.)

- Contents

1. Main Linac Configuration in the ILC
2. Local Power Distribution System (LPDS)
   - LPDS – ILC-TDR model
3. Proposal of Compact LPDS (cLPDS)
   - Several Candidates of cLPDS configuration
4. Issues to be resolved for the final design
5. Summary

In TDR, local PDS was adopted

RF output of 10 MW multi-beam klystron (MBK) is supplied to 39 superconducting cavities.



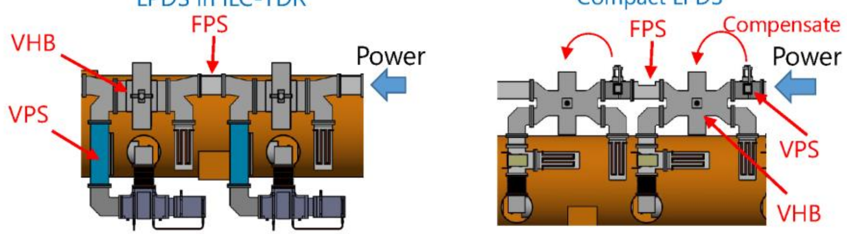
O 10 MW multi-beam klystron (MBK)

Thales TH1801 CANON E3736H

O MARX modulator

Comparison between LPDS and compact LPDS

Proposal of Compact LPDS (cLPDS)



VHB : Variable hybrid; VPS : Variable phase shifter; FPS : Fixed phase shifter

O **Disadvantage of ILC-TDR model for operation**

- The amount of phase shift changes when the coupling ratio in the VHB is changed.
- The VPS with 360 degree of change requires a length of more than 1 m.

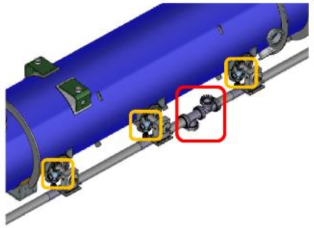
⇒ In the ILC-TDR LPDS, the amount of phase shift in the VHB upstream is accumulated to downstream.
In the proposed Compact LPDS (cLPDS),
the amount of phase shift of each VHB is compensated by the VPS upstream of the VHB.

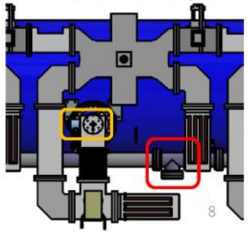
Du Baiting "Development of a compact Local Power Distribution System for the ILC"

RF experts should decide the following items before production

Issues to be resolved for the final design

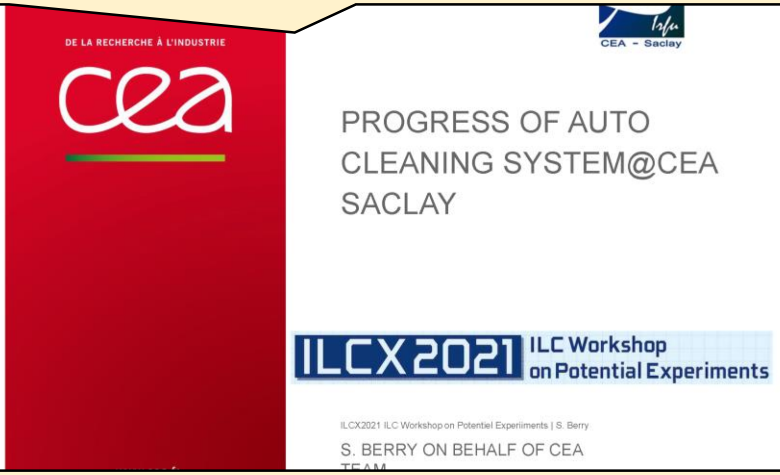
- ILC-TDR or cLPDS (or others)?
  ⇒ To be determined with rational reason finally
- The direction of Input coupler port (Upward or downward)
  ⇒ Downward direction is better for waveguide system
- The direction of the input coupler's vacuum exhaust port and the location of the vacuum pipe
  ⇒ The vacuum pipe should be located near the cryomodule than the LPDS w/o any interference.
  ⇒ In present, there is no request for the direction of the the input coupler's vacuum exhaust port (hard operability of open/close valve)
  ⇒ The location of the vacuum pump port should be reviewed. (not to interfere with the LPDS)



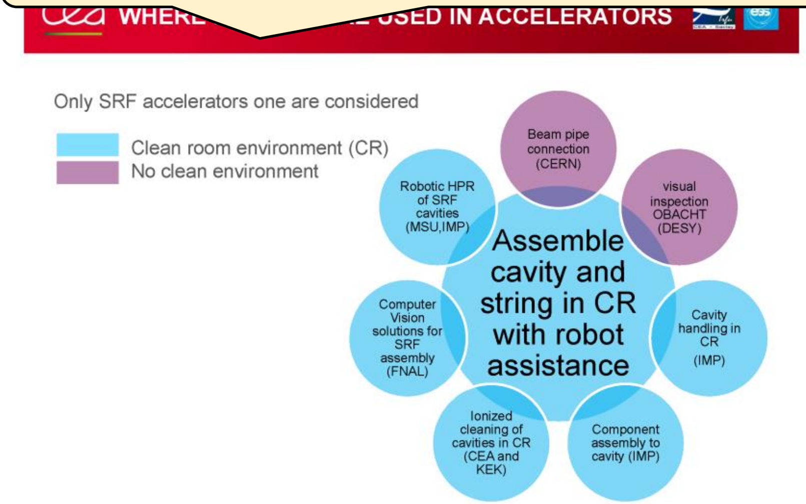


Reviews of automation technique by Stephane Berry (CEA)

Recently, many automation tools are used in SRF cavity/accelerator

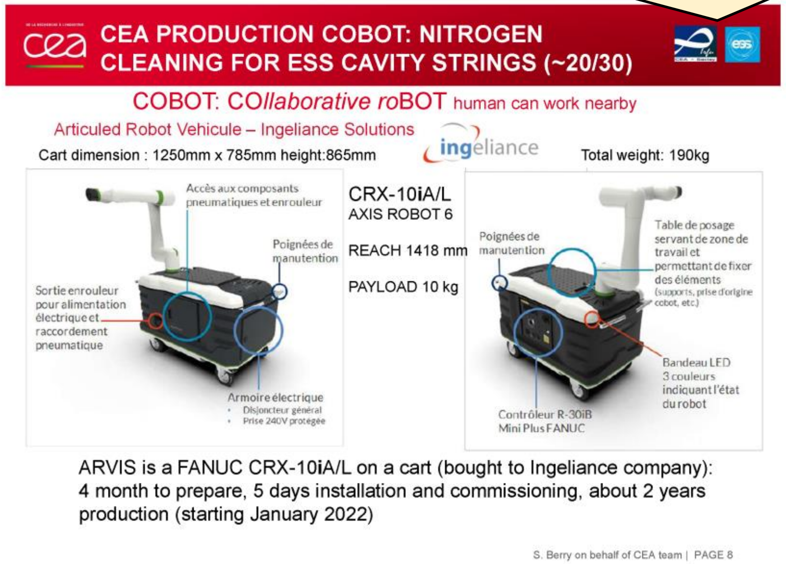


Many institutes are developing automation tools



CEA introduced auto cleaning system for ESS cavity

CEA will change the type of COBOT from next year



Items we discussed in CM design session (memorandum)

- Tuner design
  - For the negotiation with KHK, we have to decide the unique drawing of cavity with helium tank
  - For ILC, we need some reviews and what is the boundary for the design should be clear
- 5K thermal shield (removal of lower part)
  - Even after removing this part, we need to attach MLI for all cooling pipes and cavities
  - How many layers of MLI for cavity/5K/70K? → should be checked
- Magnetic shield (installed inside helium tank)
  - This depends on design of helium tank with bellows and tuner type
  - We need to consider inside (blade) or outside (double lever) according to the type of tuner
  - We need to consider the overlap of the two magnetic shields
- Ti-SS joint for 2-phase pipe including pre-cooling line
  - Ti-SS joint is the better selection for ILC than Ti-Ti joint (helium tank + chimney + 2-phase pipe)
- SS-Al joint for 2-phase pipe contacted to Al thermal straps of splittable QUAD
  - Under consideration, we need to ask KHK
- Port of current-lead for QUAD
  - Distance between outer envelope of CM and tunnel wall should be checked, some consideration is still needed
- Position of HOM absorber
  - Should be installed at transition region between CMs
- Availability in 45ft container
  - We have to keep this size as outside dimension with suspending structure, not necessary for specialized container
- RF distribution (how to equip with CM)
  - Position of vacuum port should be decided
- Access port to tuner
  - We can think about long time operation like SNS, where some tuner components were failed and replaced for 15 years
  - E-XFEL had no problem in tuner since 2017 even though all CMs have no access port
- Pipe standard
  - Plug-compatibility at transition region between CMs should be taken care
  - Pipe diameter for every cooling pipe at transition region should be decided
- 2D/3D CAD software for cavity/CM
  - NX has been used in DESY, FNAL
  - Recently, KEK and CEA are changing to NX
  - We may consider NX as a common CAD software for ILC

Thank you very much for your attention