-- Proposal for a Design-Update --

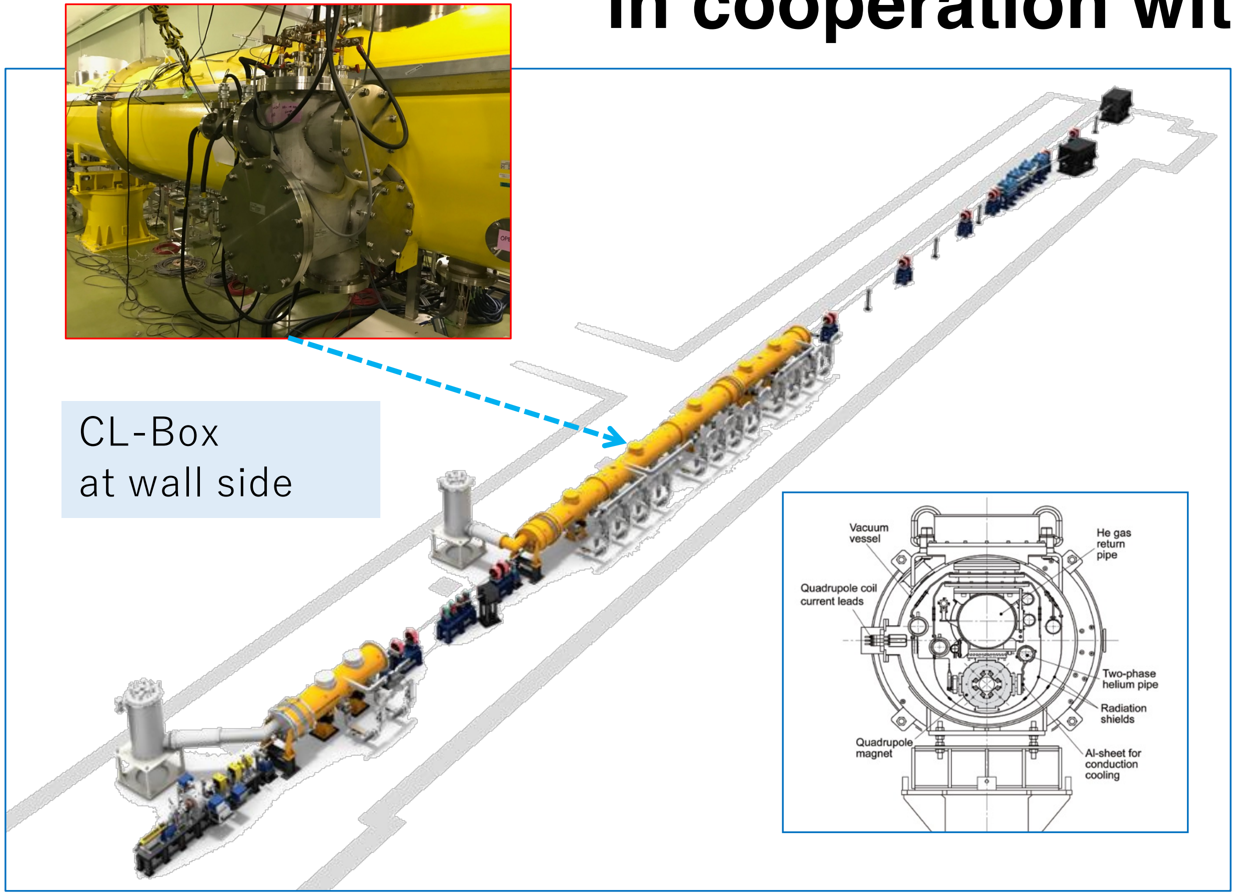
ILC-ML-SCQ Current-Lead Port Layout

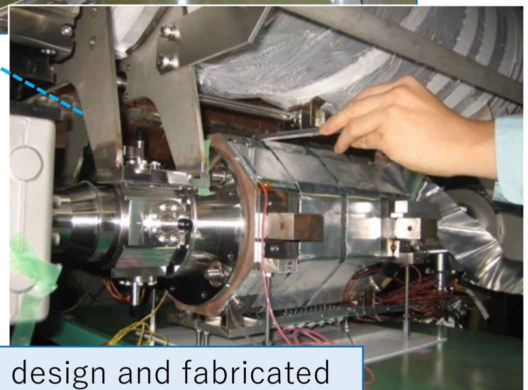
A. Yamamoto,
H. Shimizu, Z. Zong, Y. Arimoto , N. Ohuchi, and Y. Yamamoto

To be reported at ILC-IDT-WG2-SRF Meeting,
2022-6-21

A prototype Conduction-cooled SCQ

installed into KEK-STF2 beam line in cooperation with Fermilab





SCQ prototype design and fabricated
in cooperation with Fermilab

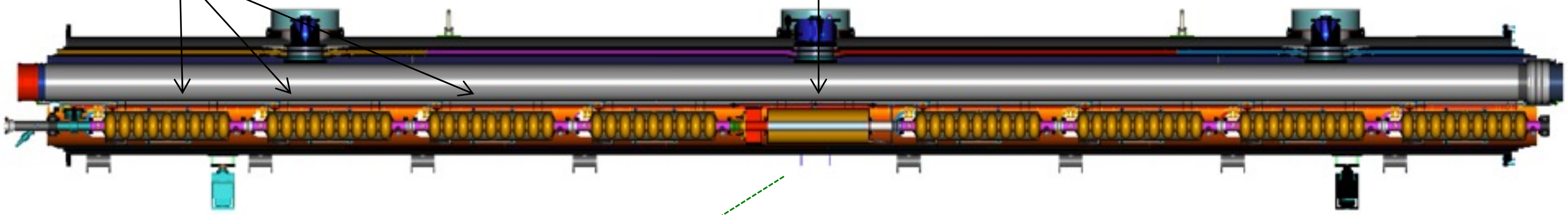
CM Assembly with SC Quadrupole (SCQ)

cavities (8)

SC quad package

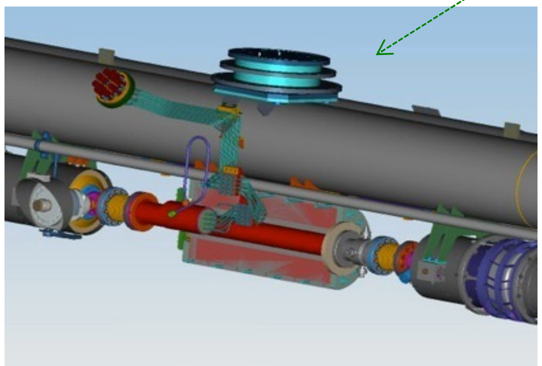
Type-B module

Type-A has 9 cavities and no quadrupole



12.652 m (slot length)

Very tight space at wall side



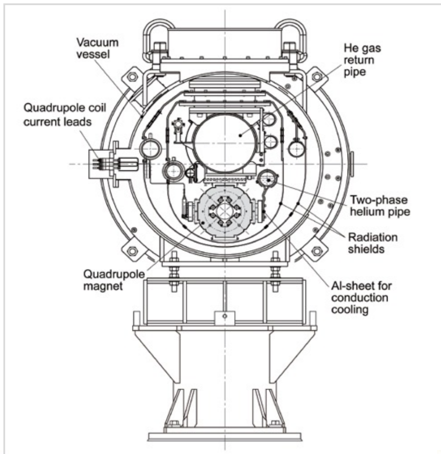
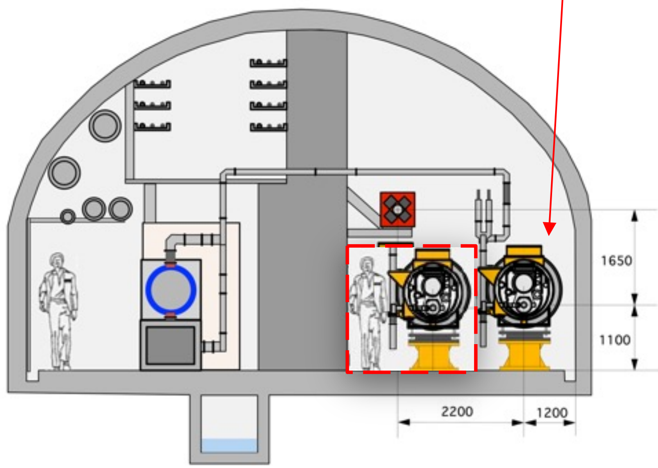
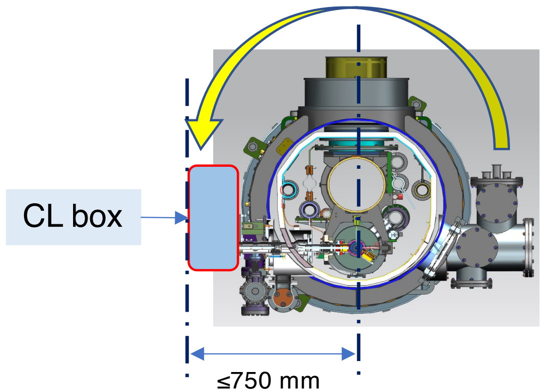


Image of ML cross-section

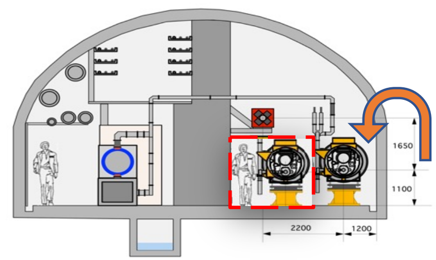


Proposal for the ILC-ML-SCQ Current-Lead Box Location to the other side of CM

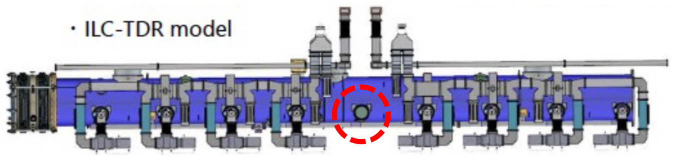
- **SCQ current-lead (CL) box location:**
  - The CL box is moved to the coupler side,
  - The box envelope in width needs to be limited to ≤ 750 mm, from the CM axis.



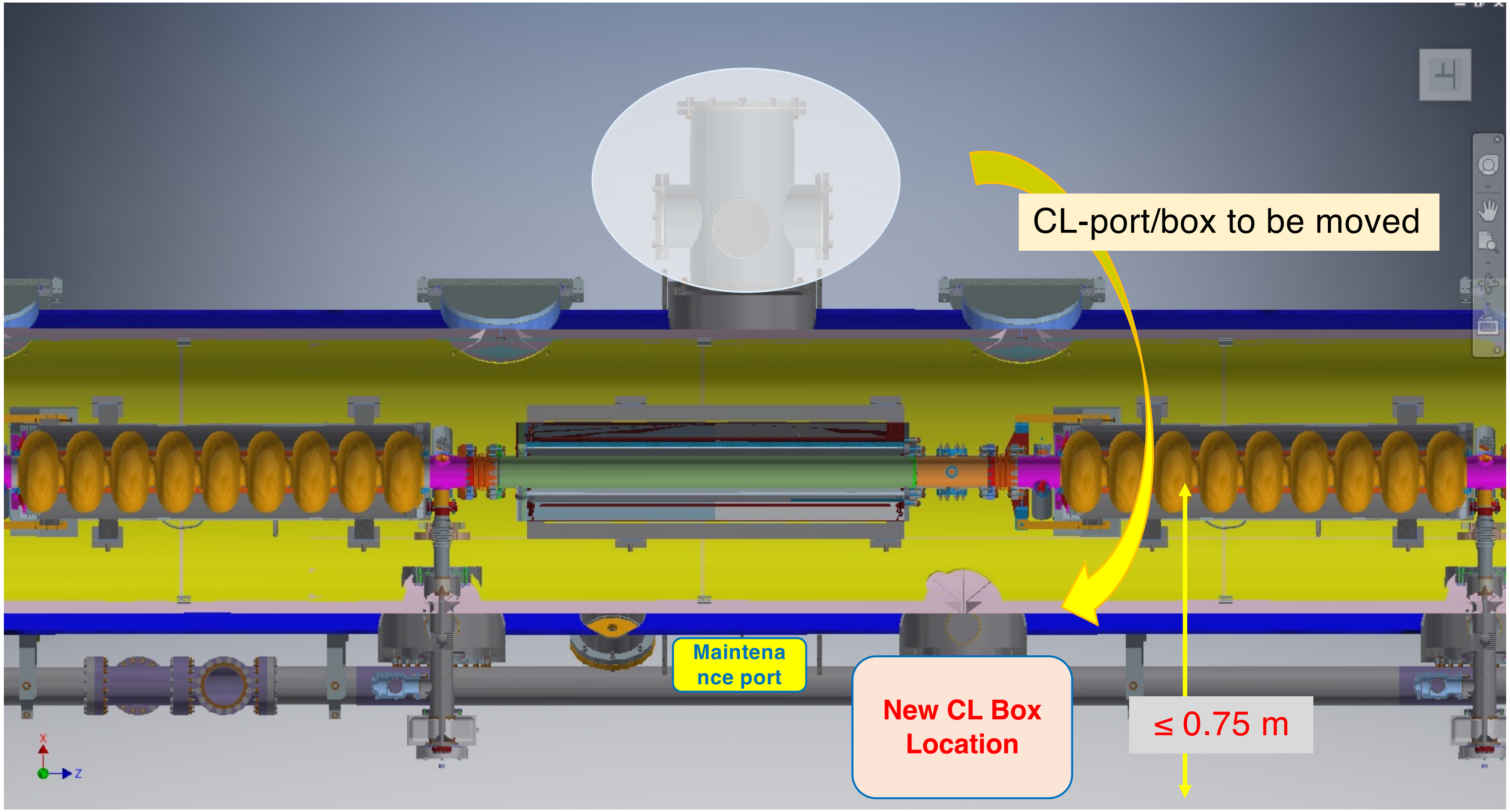
- **Reasons:**
  - Space/gap between CM and Wall is very tight,
  - Free space is required for other CM installation and for walking,



- **Recent confirmation:**
  - An empty (coupler) port is available at axial center of CM.

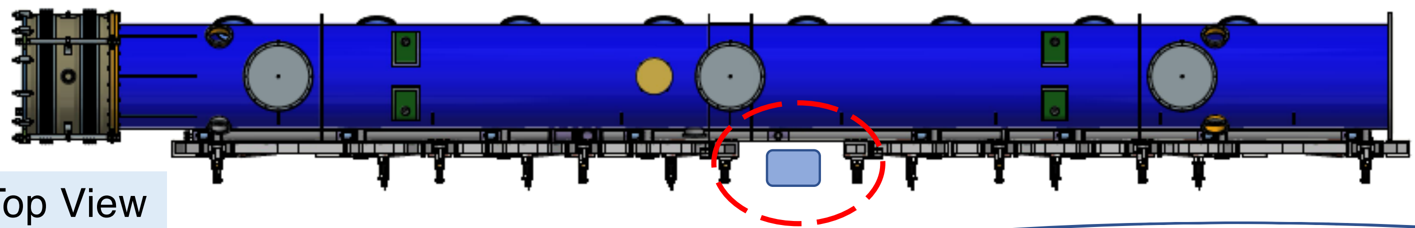


Proposal for the CL box to be moved to the Coupler Port Side

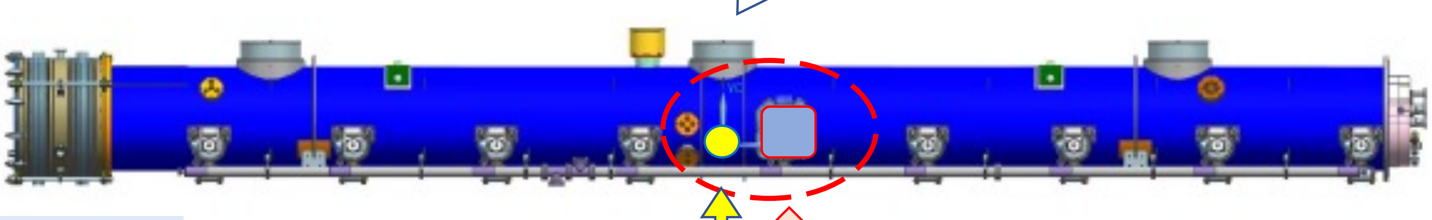


Courtesy:
T. Matsumoto (211112)

ILC-ML SCQ CL and RF Wave-Guide Layout:

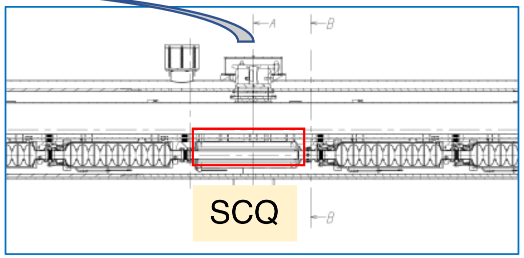


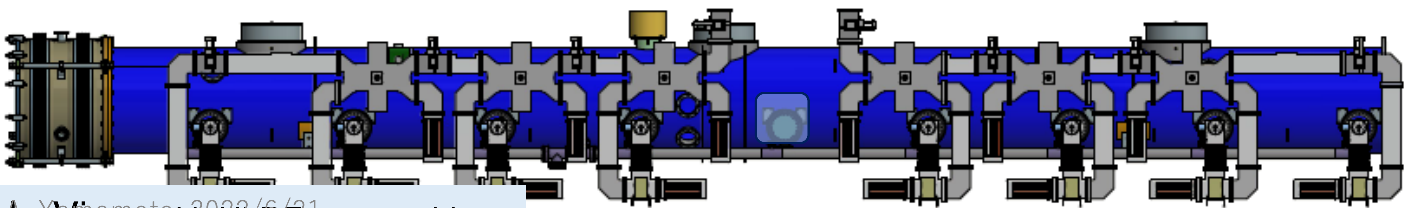
Top View



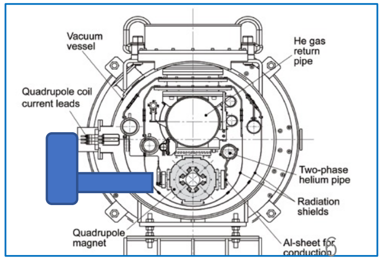
Side View

1. **CL-Box (port)**
2. Maintenance port

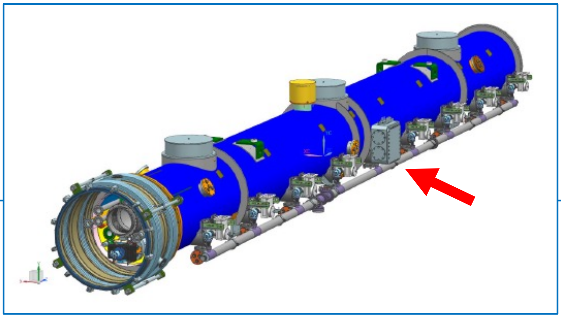


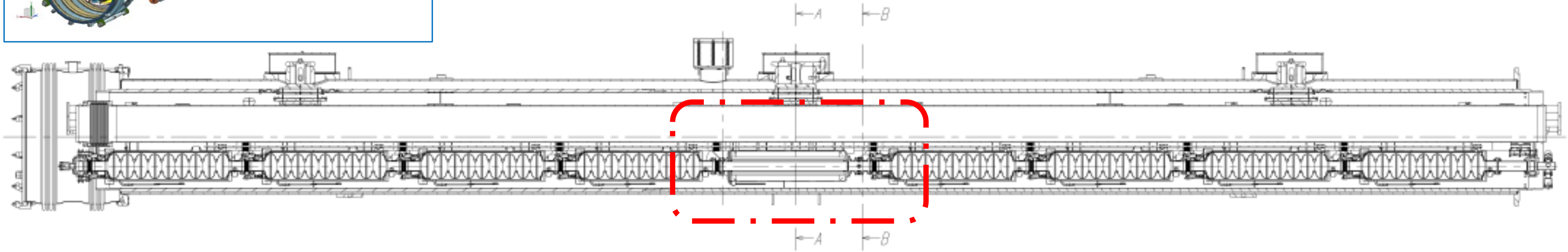


Side View with HLRF wave-guide

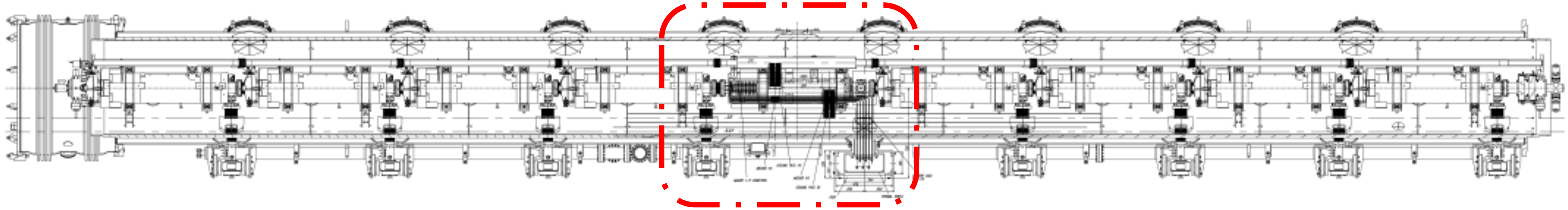


ILC-ML CM configuration with SRF cavity and SCQ



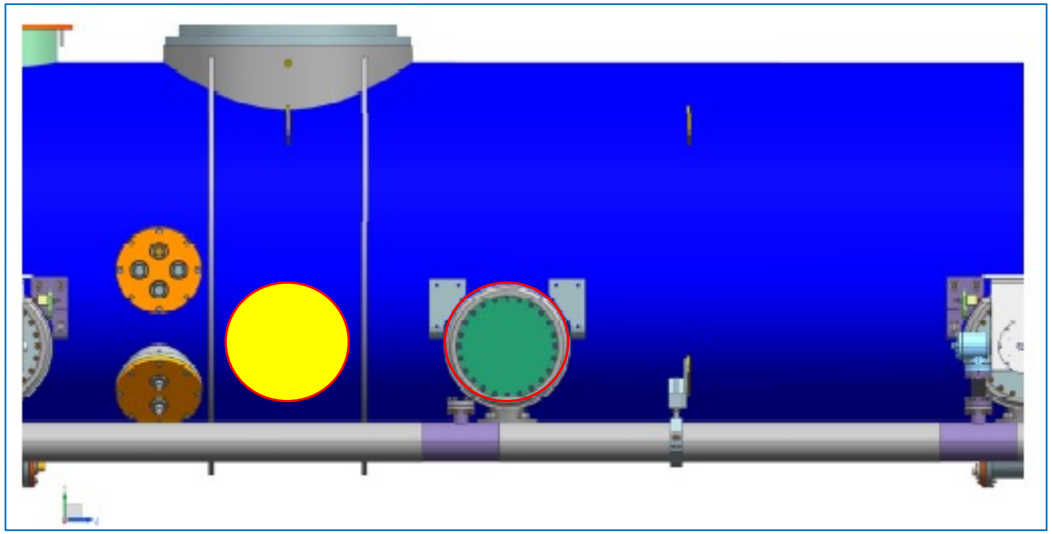


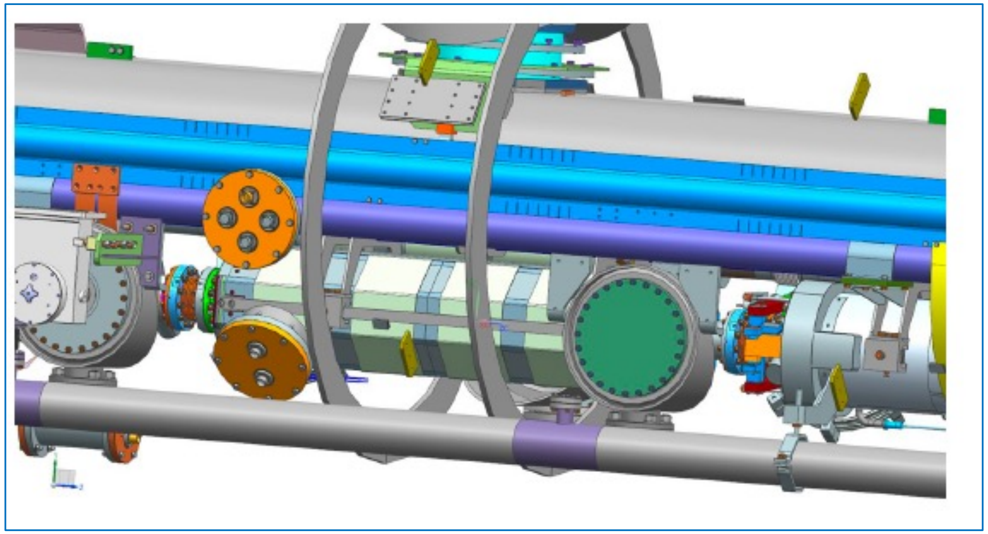
Side View



Top/plane view

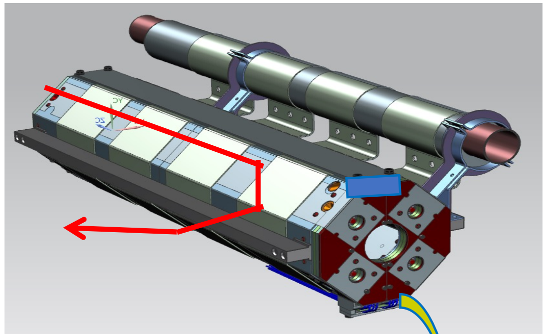
SCQ Layout with CL/Coupler Flange

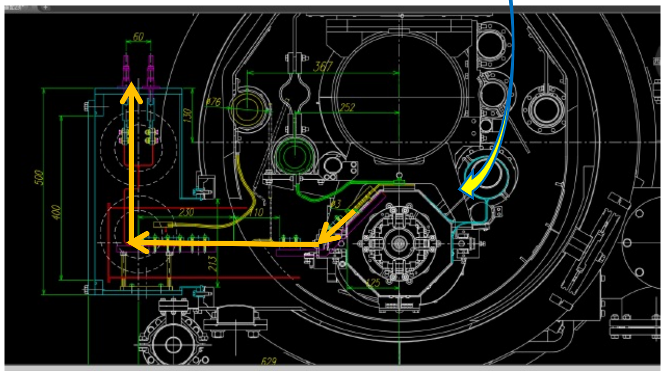


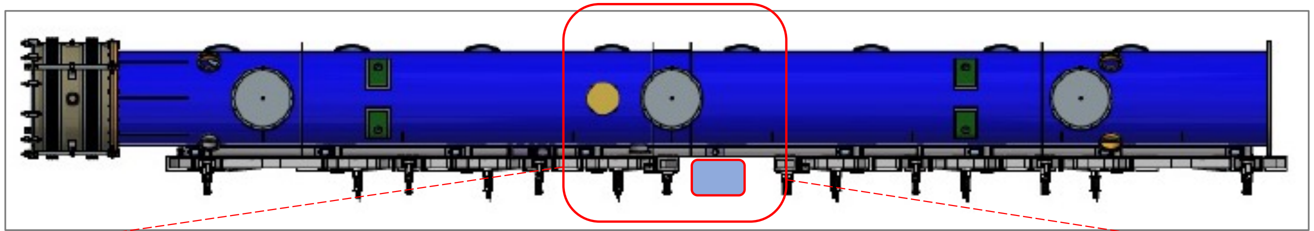


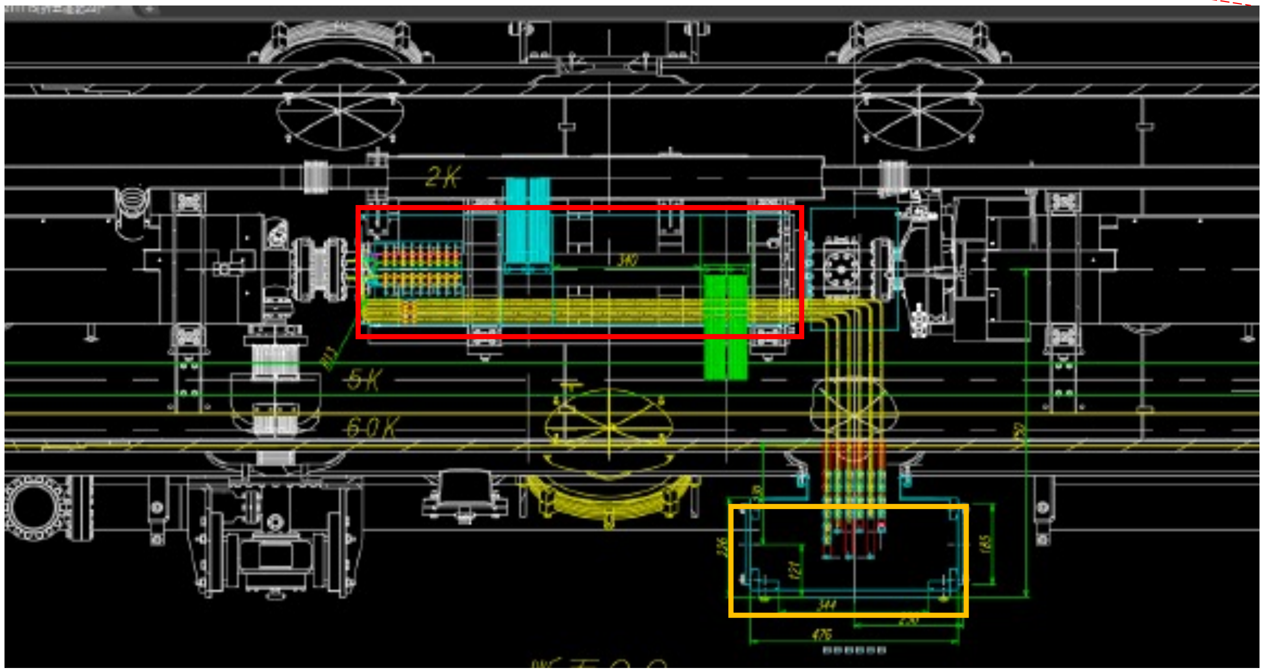
1. **CL-Box port**
2. Maintenance port
   (Same port size as Coupler's or Tuner's)

ILC-ML SCQ-CL and CL-Box

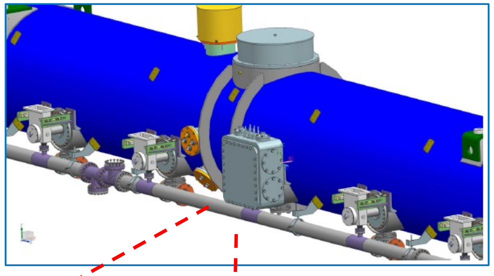


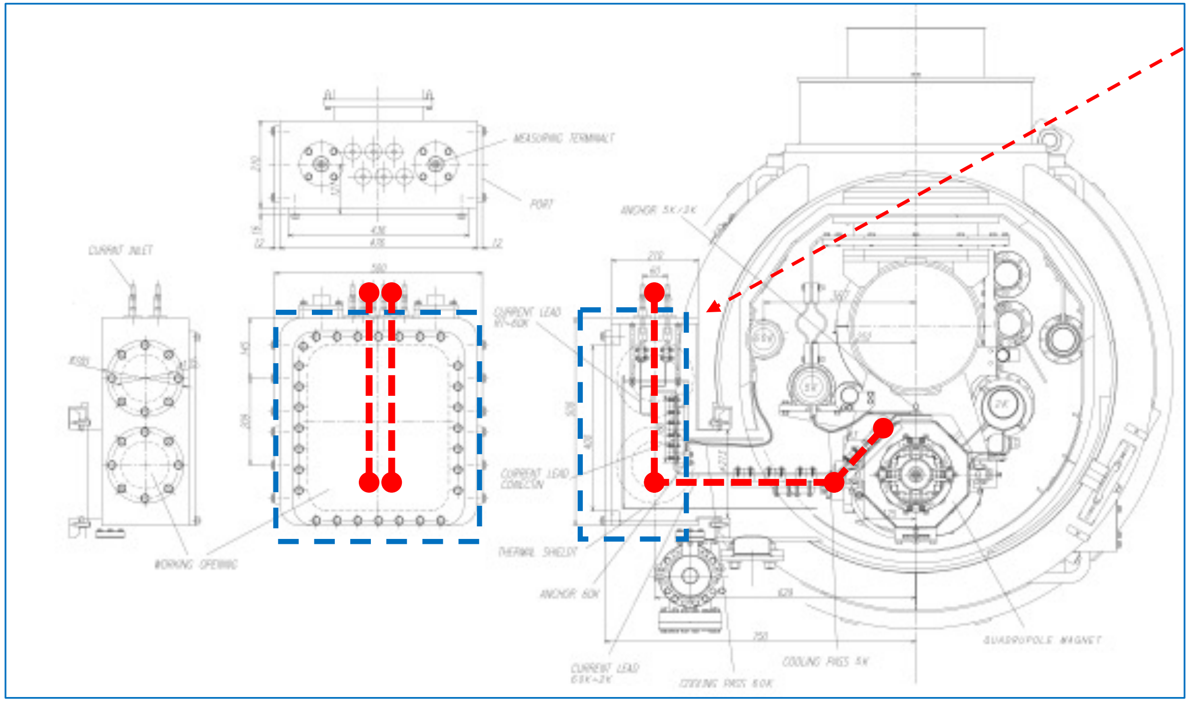


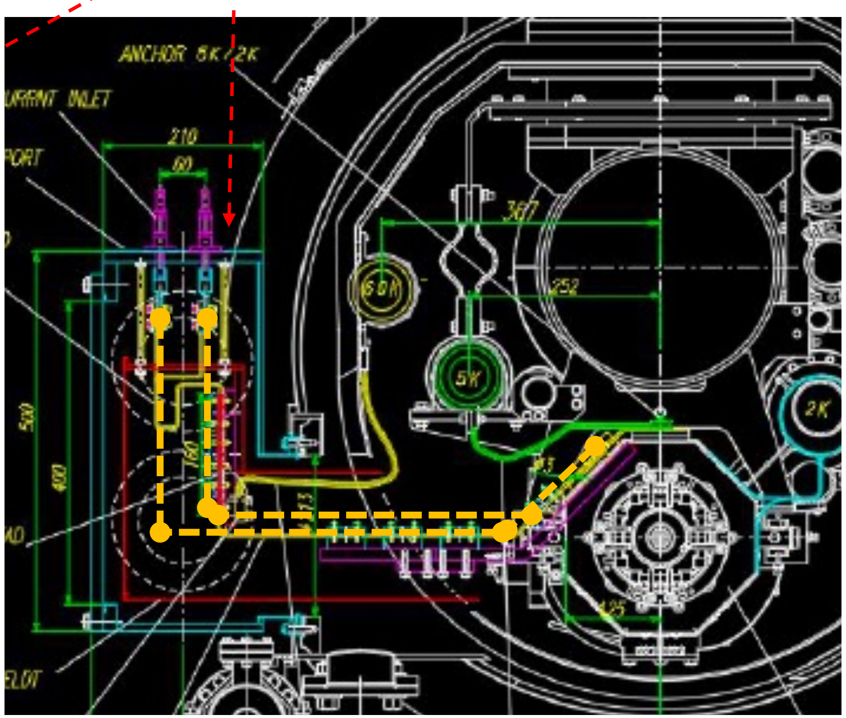




Current Lead Box







ML-CM Heat Loads averaged in ILC-TDR

Table 3.9
Average heat loads per module in a ML unit, for the baseline parameter in Table 3.1. All values are in watts [27].

	2 K		5–8 K		40–80 K	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
RF Load		8.02				
Radiation Load			1.41		32.49	
Supports	0.60		2.40		18.0	
Input coupler	0.17	0.41	1.73	3.06	16.47	41.78
HOM coupler (cables)	0.01	0.12	0.29	1.17	1.84	5.8
HOM absorber	0.14	0.01	3.13	0.36	-3.27	7.09
Beam tube bellows		0.39				
Current leads	0.28	0.28	0.47	0.47	4.13	4.13
HOM to structure		0.56				
Coax cable (4)	0.05					
Instrumentation taps	0.07					
Diagnostic cable			1.39		5.38	
Sum	1.32	9.79	10.82	5.05	75.04	58.80
Total	11.11		15.87		133.84	

Averaged heat loads for SCQ (Quad.+2 Dipoles) with 6 CLs of < 6 x 100 A,
--> 1 /3 of one SCQ package

ML-CM Heat Loads, averaged, in ILC-TDR

Table 3.9
Average heat loads per module in a ML unit, for the baseline parameter in Table 3.1. All values are in watts [27].

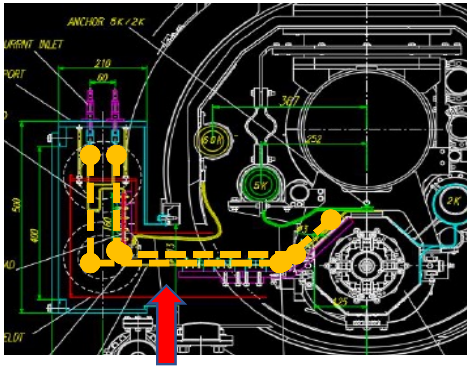
	2 K		5–8 K		40–80 K	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
RF Load		8.02				
Radiation Load			1.41		32.49	
Supports	0.60		2.40		18.0	
Input coupler	0.17	0.41	1.73	3.06	16.47	41.78
HOM coupler (cables)	0.01	0.12	0.29	1.17	1.84	5.8
HOM absorber	0.14	0.01	3.13	0.36	-3.27	7.09
Beam tube bellows		0.39				
Current leads	0.28	0.28	0.47	0.47	4.13	4.13

Averaged heat loads for SCQ (Quad.+2 Dipoles) with 6 CLs of < 6 x 100 A,
--> 1 /3 of one SCQ package

	2K	5-8K	40-80K
<T.L.> in 3 CM	0.56	0.94	8.26
T.L. / SCQ	1.68	2.82	24.78

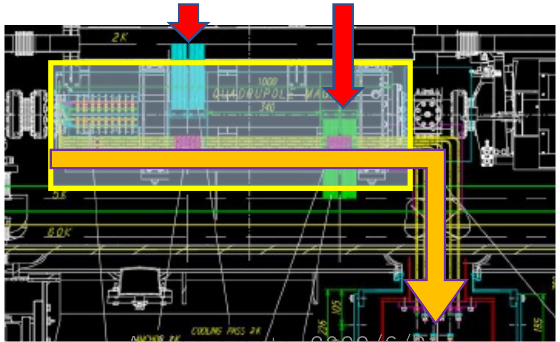
SCQ-CL New Design Optimization in Progress

Material	(ILC-TDR)		(New) Cu		Cu + NbTi		Cu + MgB_2		Cu + HTS	
Component	St,	Dyn,	Cond.	Heat.	Cond.	Heat.	Cond.	Heat	Cond.	Heat
RT → 60K (x 16.5)	3 x 4.13	3 x 4.13	15.3	9.0	15.3	9.0	15.3	9.0	15.3	9.0
	24.78 (W)		24.3		24.3		24.3		24.3	
60 → 5K (x 198)	3x 0.47	3x0.47	0.9	1.5	0.9	1.3	0.9	0.8	0.1	0
	2.82 (W)		2.4		2.1		1.7		0.1	
5 → 2 K (x 703)	3x0.28	3x0.28	0.6	0.2	0.01	0	0.01	0	0.01	0
	1.68 (W)		0.8		0.01		0.01		0.01	
Integrated to RT	2148 (W)		1439		824		745		428	

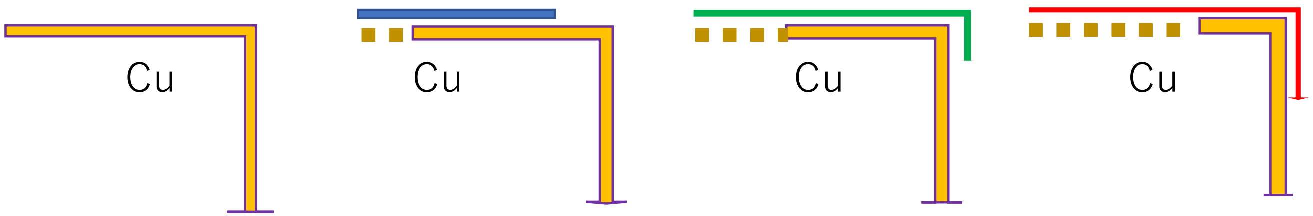


60 K anchor

2 K, 5K anchor



+ NbTI (Tc, 9K) + MgB_2 (Tc, 39K) + HTS (Tc, >70K)



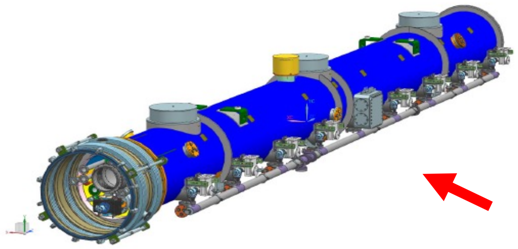
ILC ML Heat Loads estimated in TDR V3, Part II
and conversion efficiency in Watt/Watt, on page 54.

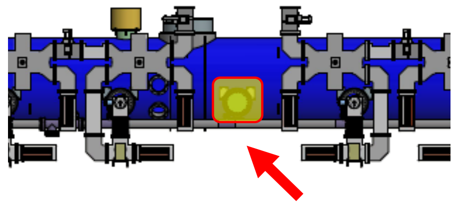
Table 3.11. Main-linac heat loads and cryogenic plant size [34]. Where there is a site dependence, the values for the flat / mountain topographies are quoted respectively. (The primary difference is in the choice the number of cryo-plants, specifically 6 and 5 plants for flat and mountainous topographies respectively.)

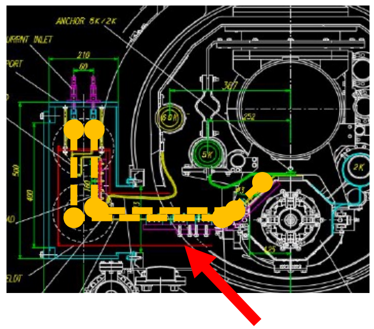
		40–80 K	5–8 K	2 K
Predicted module static heat load	(W/module)	75.04	10.82	1.32
Predicted module dynamic heat load	(W/module)	58.80	5.05	9.79
Number of cryomodules per cryogenic unit		156 / 189	156 / 189	156 / 189
Non-module heat load per cryo unit	(kW)	0.7 / 1.1	0.14 / 0.22	0.14 / 0.22
Total predicted heat per cryogenic unit	(kW)	21.58 / 26.40	2.61 / 3.22	1.87 / 2.32
Efficiency (fraction Carnot)		0.28	0.24	0.22
Efficiency in Watts/Watt	(W/W)	16.45	197.94	702.98
Overall net cryogenic capacity multiplier		1.54	1.54	1.54
Heat load per cryogenic unit including multiplier	(kW)	33.23 / 40.65	4.03 / 4.96	2.88 / 3.57
Installed power	(kW)	547/669	797/981	2028 / 2511
Installed 4.5 K equiv	(kW)	2.50 / 3.05	3.64 / 4.48	9.26 / 11.47
Percent of total power at each level		0.16	0.24	0.60
Total operating power for one cryo unit based on predicted heat (MW)			2.63 / 3.24	
Total installed power for one cryo unit (MW)			3.37 / 4.16	
Total installed 4.5 K equivalent power for one cryo unit (kW)			15.40 / 19.01	

Summary

- We **propose** a **new SCQ current lead (CL) box** to be implemented into ILC-ML CM design, **by using an empty port** for the RF Power Coupler.
- It will **benefit** to **minimize** the **CM** horizontal **width** (envelop), for **easier installation** into the ML tunnel, and **provide more flexible space** between the **CM and tunnel-wall.**
- **No major issues** have been **found** with envelopes of **HLRF wave guides** and **power coupler** system including vacuum pipe-line
- The **conceptual design** and layout of the **CL-box** has been **made**, and it is **ready to be implemented** into the ILC-ML CM design, **if** the proposal may be **agreed with the IDT-WG2-SRF group** and recognized **as a new baseline** design with the authorization for the ILC-250.
- We would thank, in advance, **Fermilab** cooperation to integrate the new CL box design envelope to be implemented into the ILC CM CAD drawings.
- The **SCQ-CLs** may be **conduction-cooled**, as same as the SCQ itself (meaning HPGS regulation free).   **Further optimization** study is in progress, to establish the best CL configuration **with a combination of Cu and LTS/HTS** to minimize the power consumption (converted to AC-plug power).







Acknowledgements

- *Special thanks for* ***Sergey Belomestnykh*** *and* ***Yuriy M. Orlov****, and* ***Vladimir Kashikhin, Fermilab****, for their kindest cooperation for the CM design drawings and for the SCQ magnet design and development.*

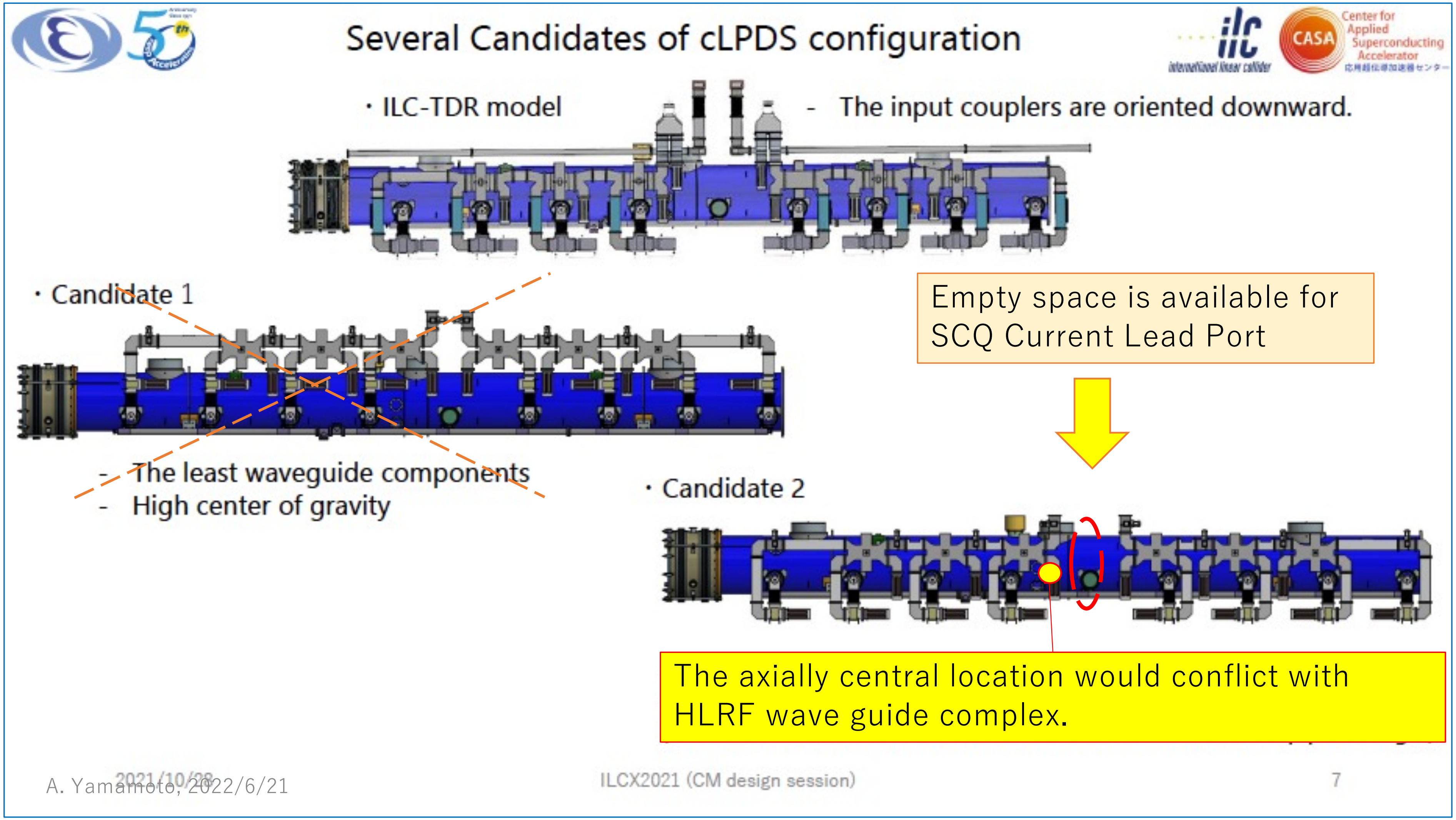
- *We would thank* ***Toshiba Corp****. for their professional cooperation for the new SCQ CL and CL-box engineering design work.*

- *We would thank* ***Marc Ross, SLAC****, for his warmest support and cooperation for our design work, based on the US-Japan cooperation program and the license agreement to refer the LCLS-II CM and SRF design work.*

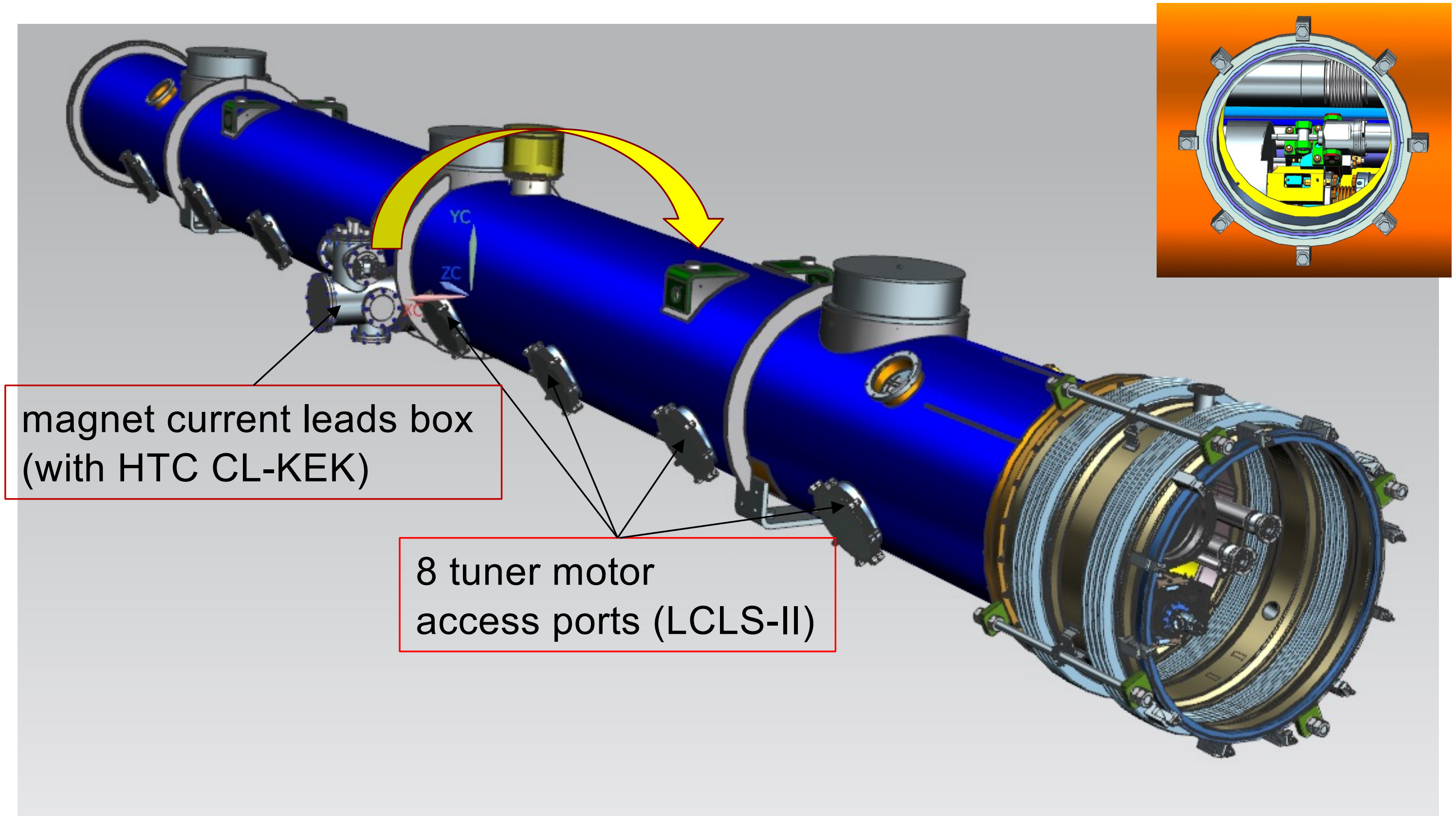
Appendix

Courtesy: T. Matsumoto

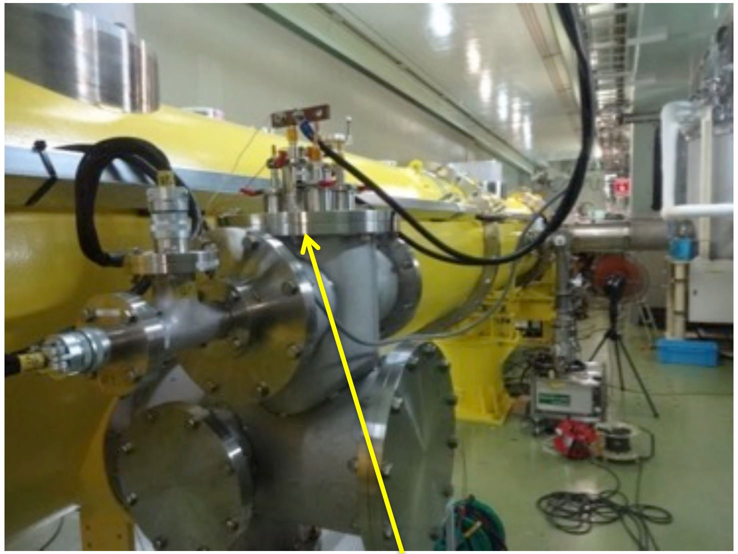
HLRF Wave Guide Layout Design in Progress

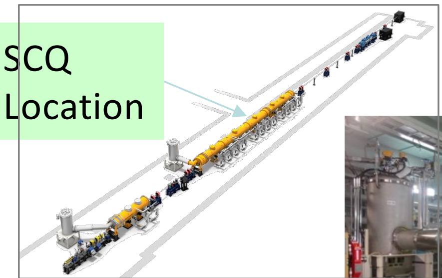


1.3 GHz ILC CM (tuner port view) : based on a Prototype SCQ installed in KEK-STF

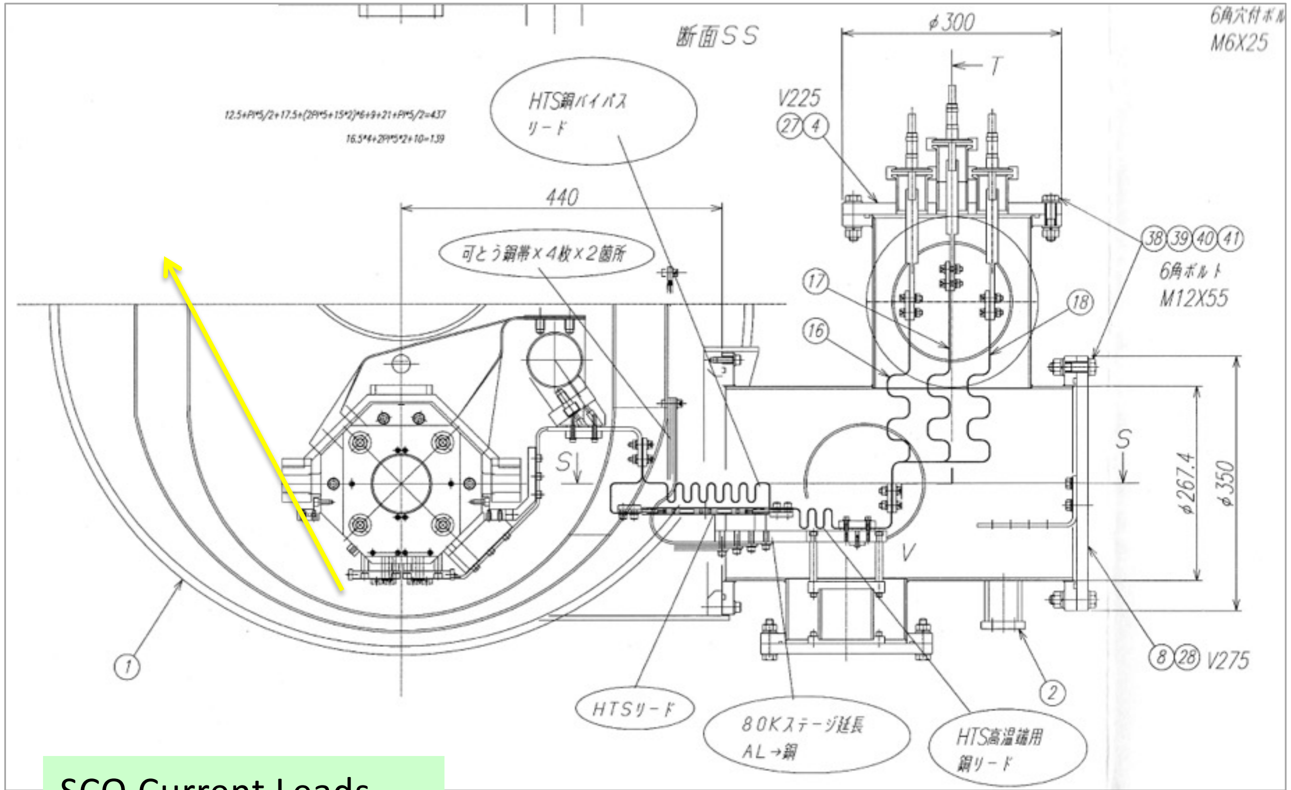


STF-CM and SCQ Test in Nov. 2016



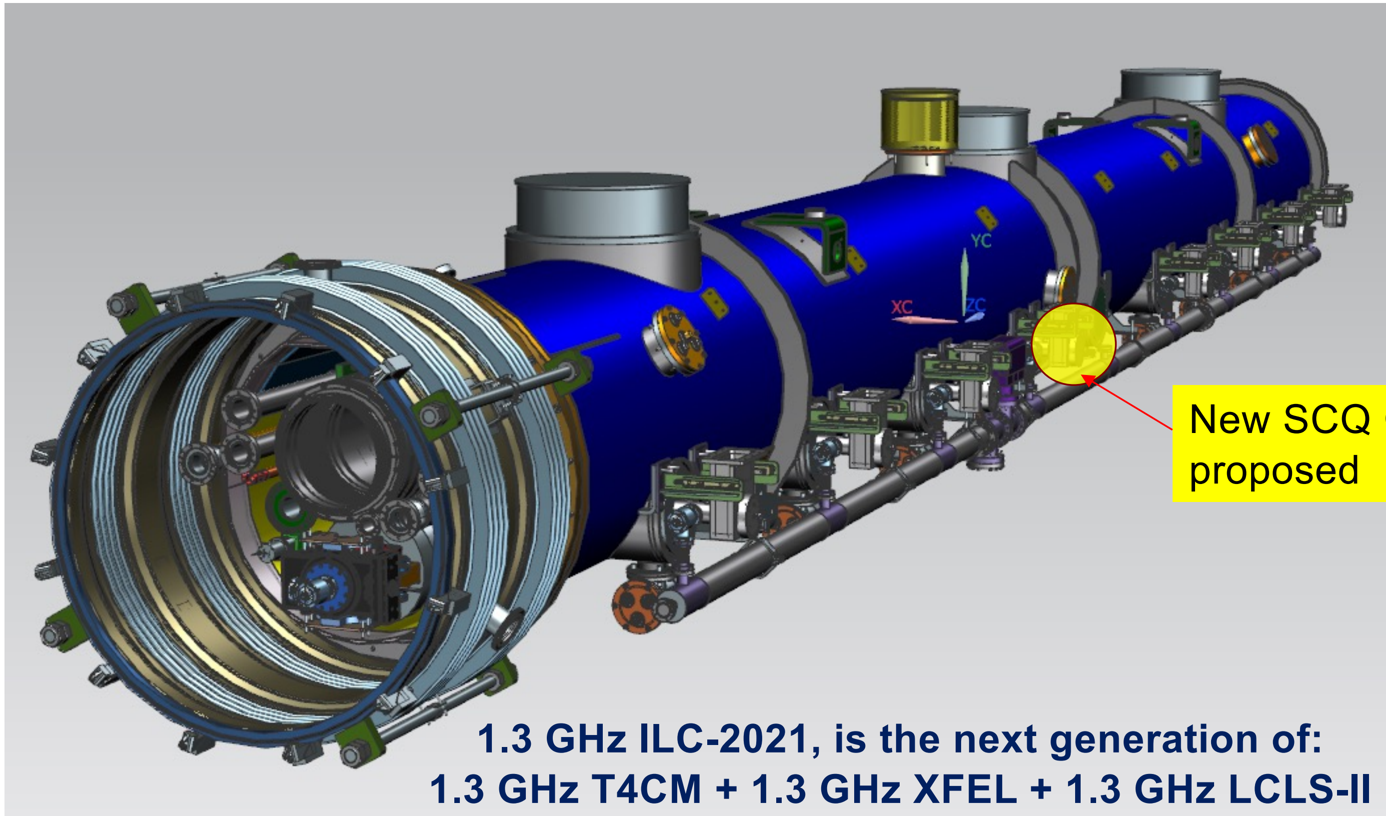


SCQ Location

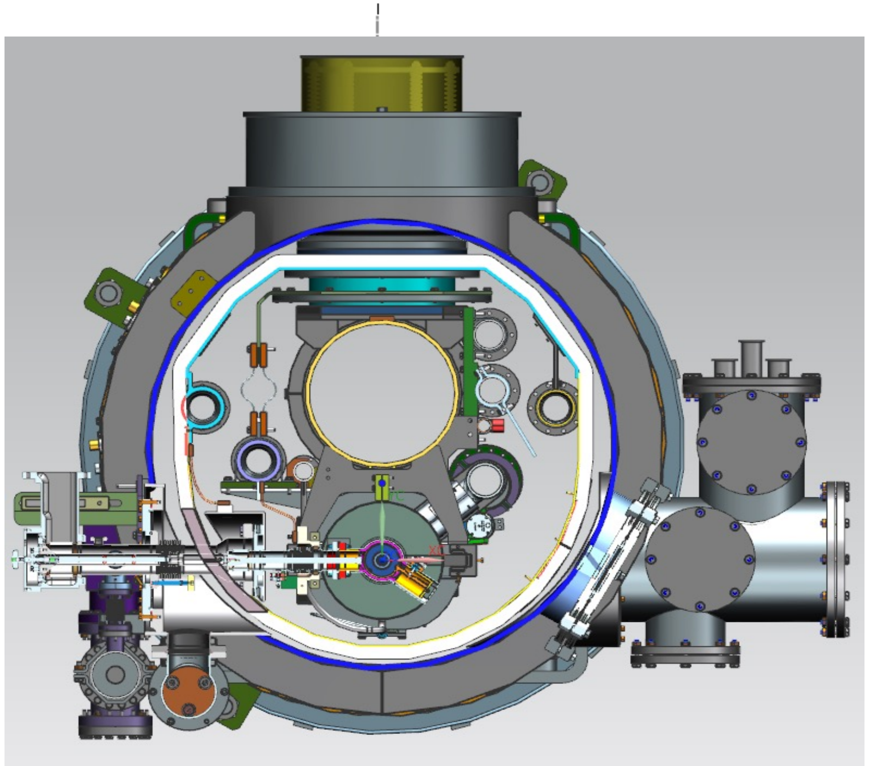


SCQ Current Leads

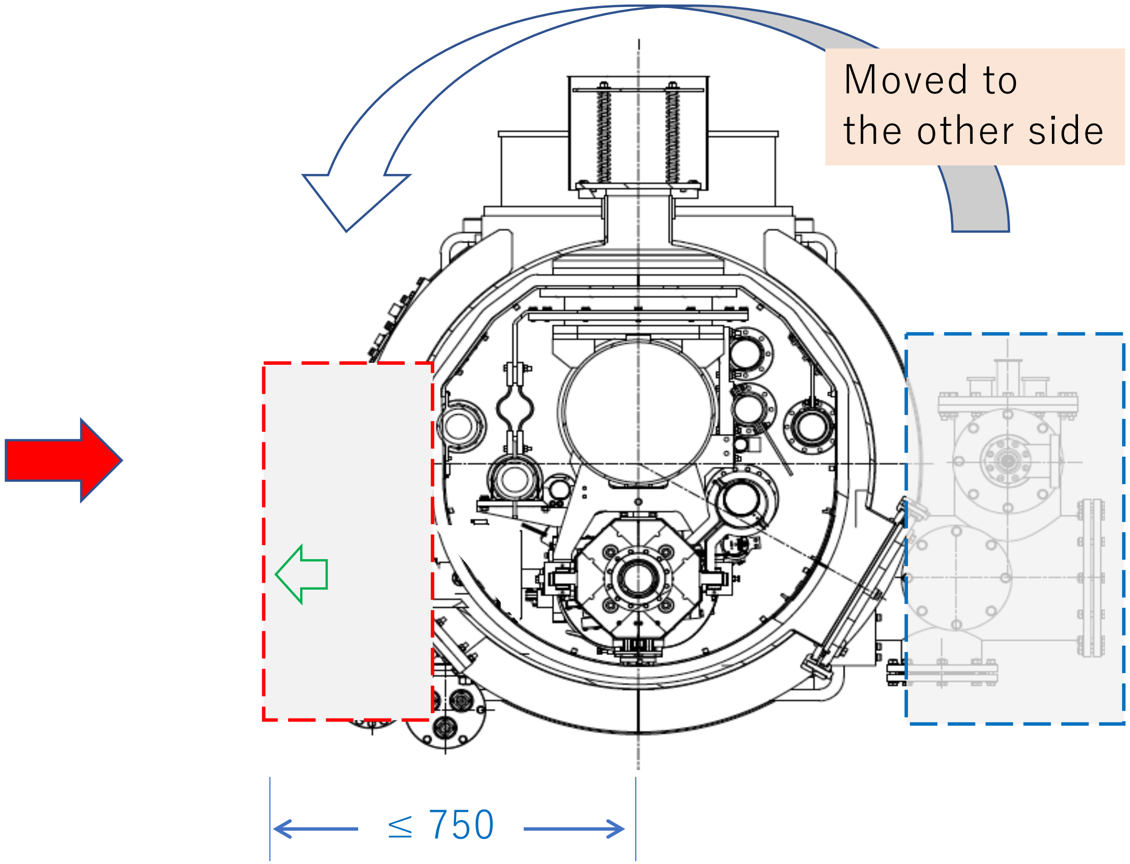
1.3 GHz ILC CM (power coupler view)



ILC-ML/CM-SCQ Current-Lead Port Layout
-- Update Proposal to be reviewed --

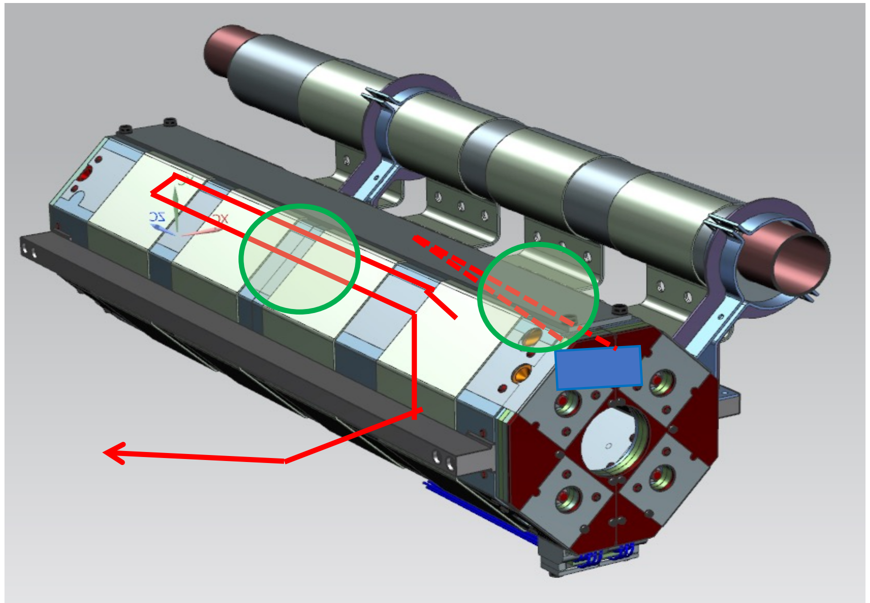


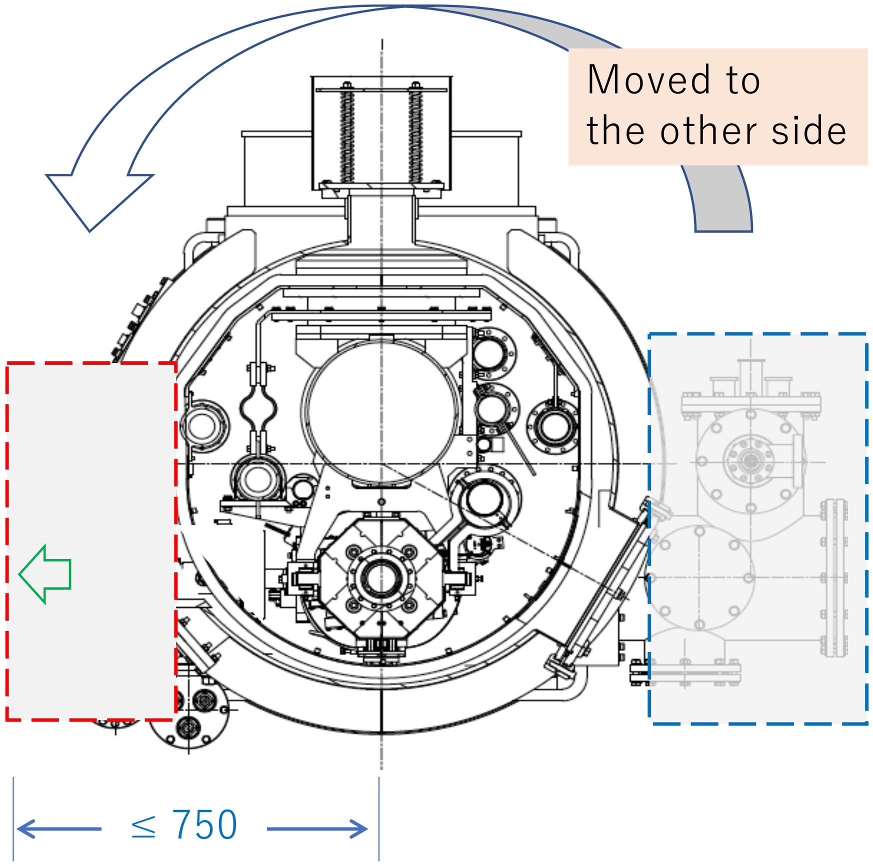
Current layout



Update Proposal to be reviewed

ILC-ML/CM-SCQ Current-Lead Port Layout
-- Update Proposal to be reviewed --



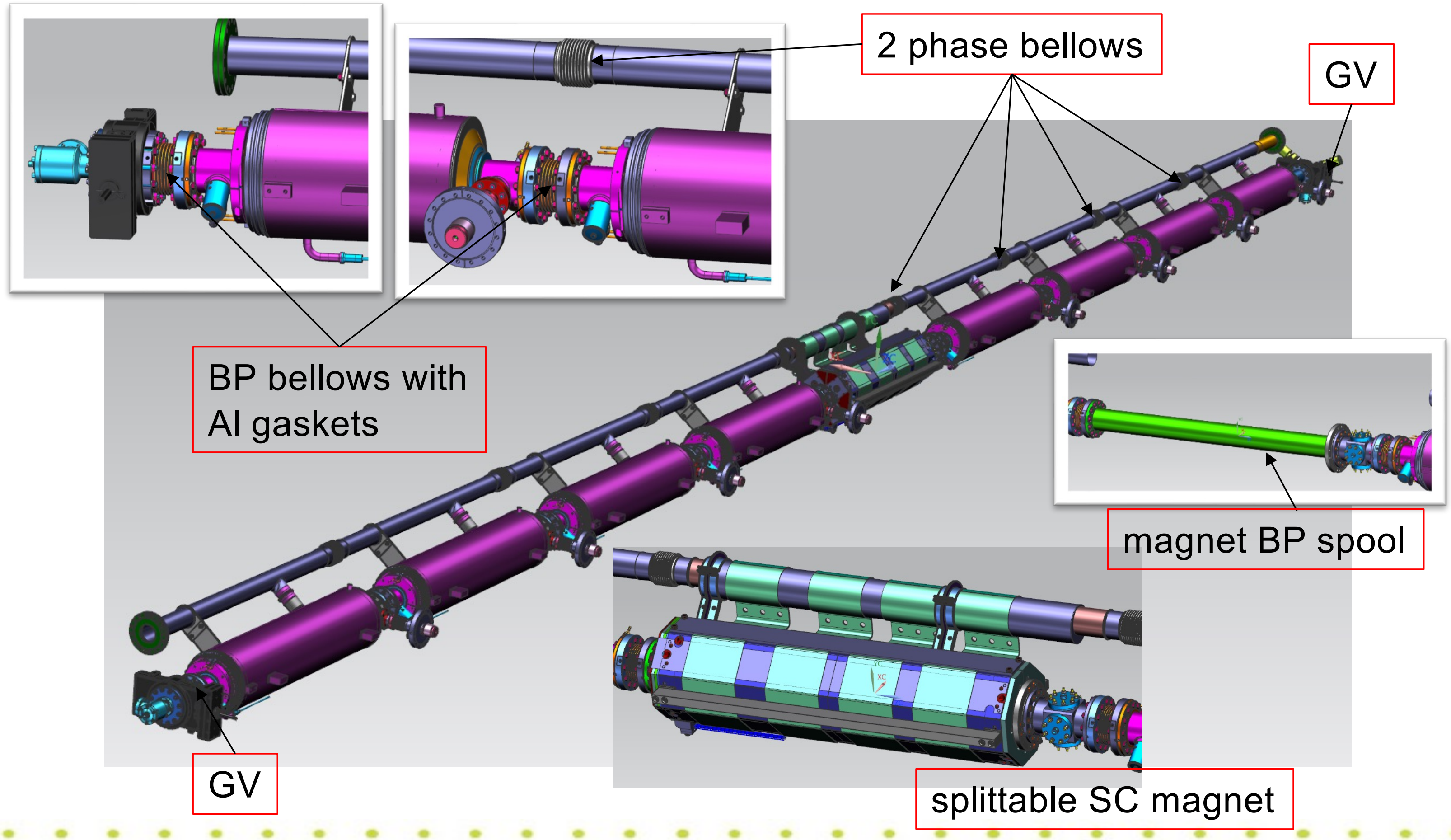


A. Yamamoto, 2022/6/21

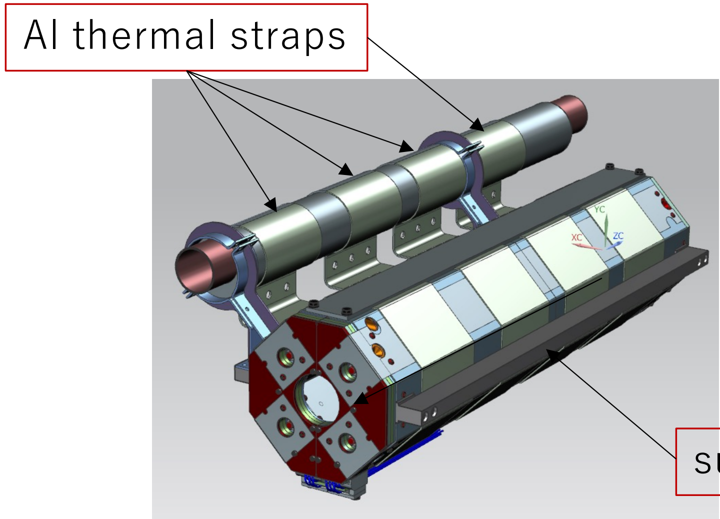
Current layout

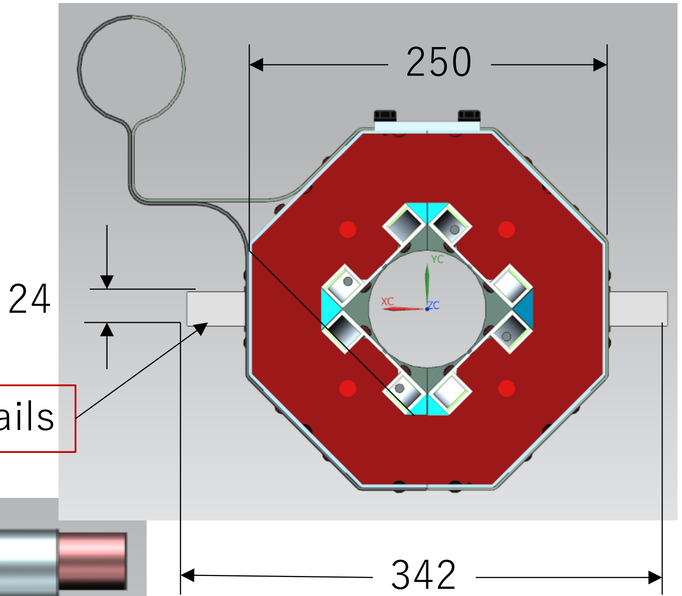
Update Proposal to be reviewed

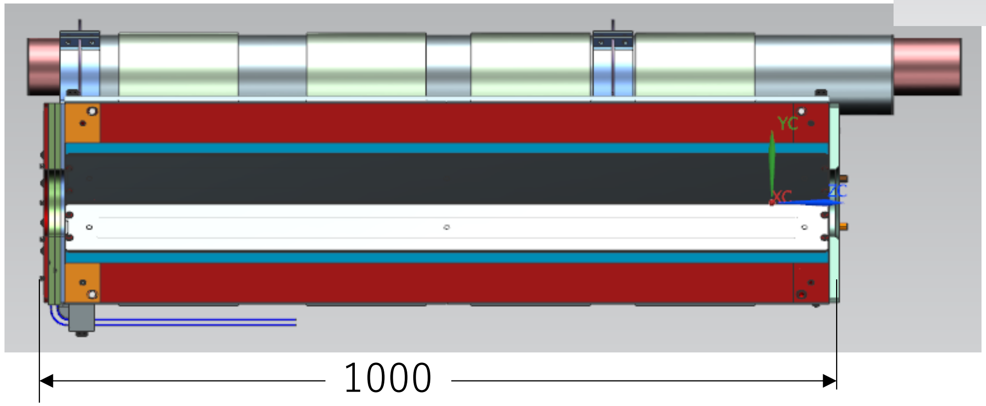
1.3 GHz cavity string



1.3 GHz ILC magnet



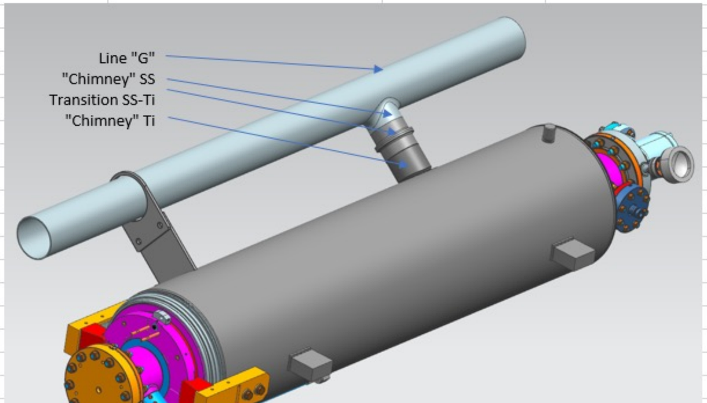




- ILC conduction cooled splittable quad, ~1 m
- Magnet 2-phase pipe have extra volume for He

ILC CM cryogenic piping sizes

2								By Tom P. Calculation
3	Cryigenic Line	OD, mm	ID,mm	Wall. mr	Material			ID,mm
4	A	63.500	60.198	1.651	316L St. Steel	Tube, 2.5"-OD, .065" Wall, 316L SS		60.2
5	B	312.000	300.000	6.000	316L St. Steel	Tube, 300mm-OD, 6mm Wall, 316L SS		300.0
6	C	63.500	57.404	3.048	316L St. Steel	Tube, 2.5"-OD, .120" Wall, 316L SS		
7	C	60.325	57.023	1.651	316L St. Steel	Pipe 2", SCH 5S		56.1
8	D	88.900	76.200	6.350	Al 6061	Tube, 3.5"-OD. .25" Wall, Al 6061		69.9
9	E	76.200	71.984	2.108	316L St. Steel	Tube, 3"-OD, .083" Wall, 316L SS		72.0
10	F	88.900	76.200	6.350	Al 6061	Extrusion		79.4
11	G, 2-phase	73.025	68.809	2.108	316L St. Steel	Pipe 2 1/2", SCH 5S		69.0
12	"Chimney"-SS	60.325	57.023	1.651	316L St. Steel	Pipe 2", SCH 5S		54.9
13	"Chimney"-Ti	60.325	57.023	1.651	Ti	Pipe 2", SCH 5S		
14	H	42.164	38.862	1.651	316L St. Steel	Pipe 1 1/4", SCH 5S		38.9
15								
16	Not Used							
17	The same OD, wall thickness- because the same Transition Joint from Al to SS							



F10157648 (Assembly, 1.3GHz ILC Cavity)