Cavity and Cryomodule Plug-Compatibility

To Reach Consensus

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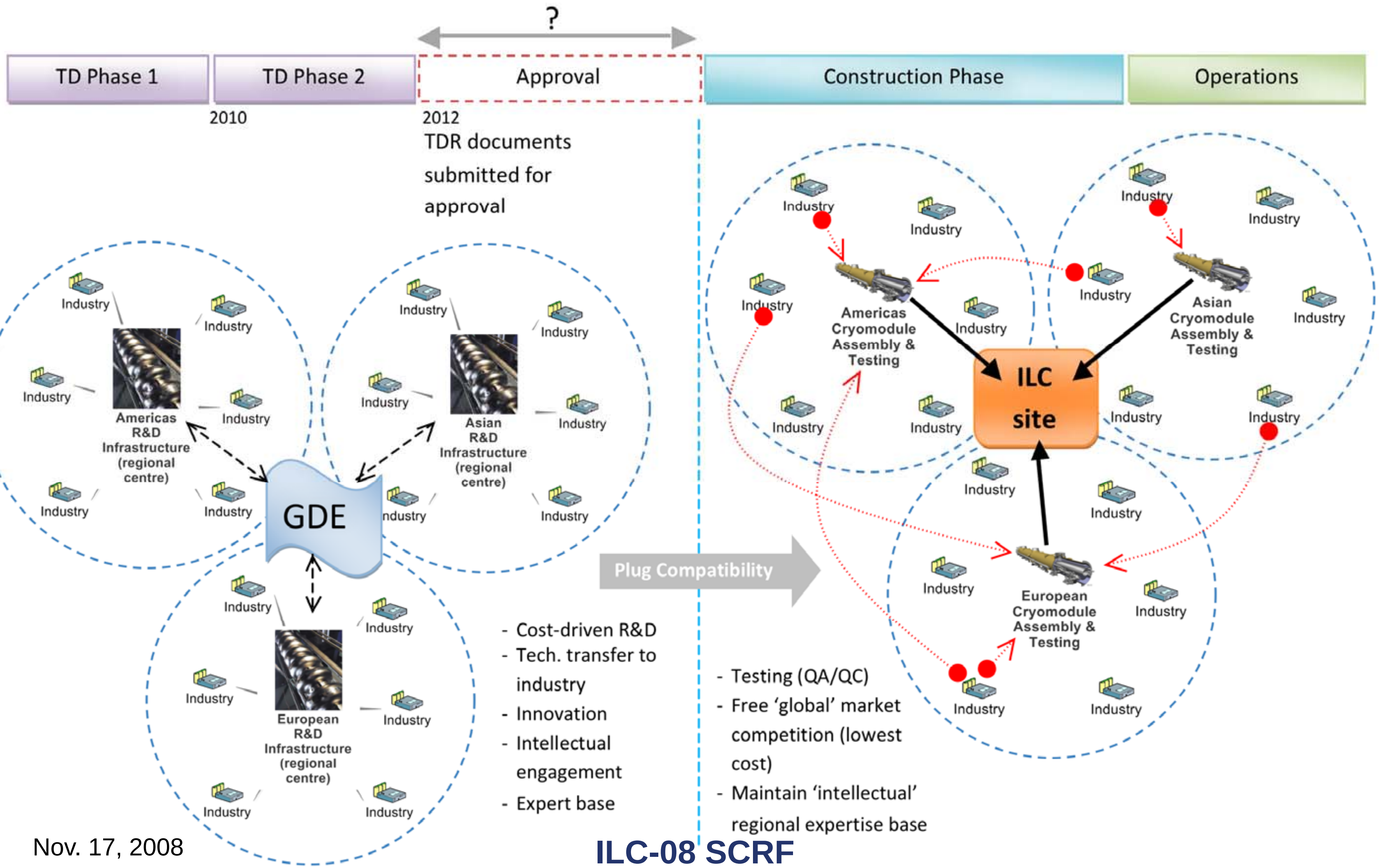
ILC-08, Chicago, Nov. 17, 2008

Why and How Plug-compatibility ?

- **Cavity**
  - Necessary "extended research" to improve field gradient,
  - Keep "room" to improve field gradient,
  - Establish common interface conditions,
- **Cryomodule**
  - Nearly ready for "system engineering"
  - Establish unified interface conditions,
  - Intend nearly unified engineering design
  - Need to adapt to each regional feature and industrial constraint

Global Cooperation with Plug-compatible Design and R&Ds



Plug-compatibility in R&D and Construction Phases

- **R&D Phase**
  - Creative work for further improvement with keeping replaceable condition,
  - Global cooperation and share for intellectual engagement
- **Construction Phase**
  - Keep competition with free market/multiple-suppliers, and effort for const-reduction, (with insurance)
  - Maintain "intellectual" regional expertise base
  - Encourage regional centers for fabrication/test facilities with accepting regional features/constraints

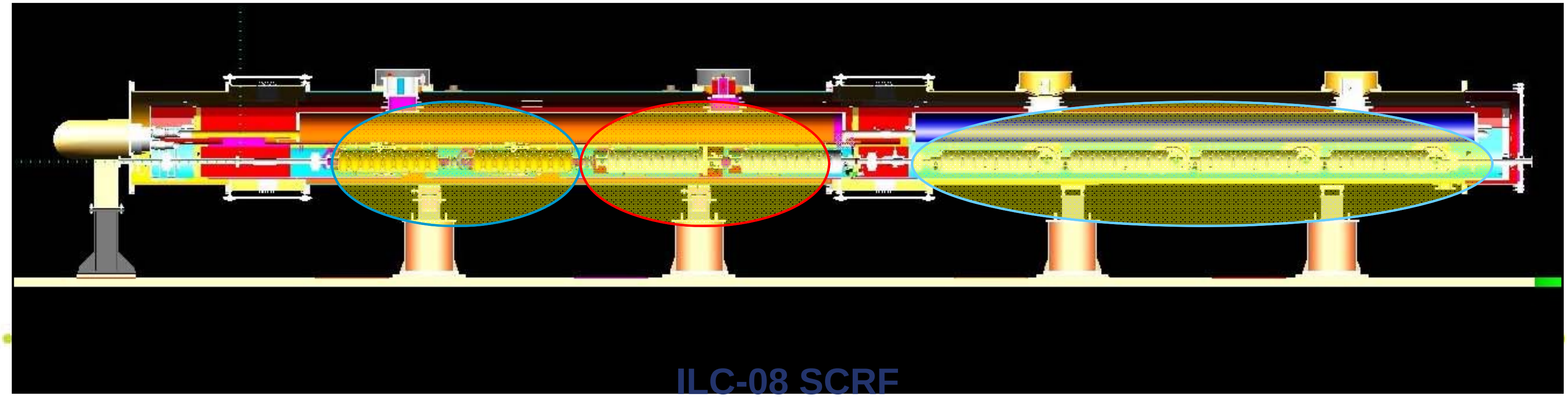
How do we discuss the Cavity Plug-compatibility ?

- Constraint in S1-Global:
  - S1-Global cryomodule design has already progressed, and in fabrication stage
  - DESY, Fermilab, KEK cavity design difference has been already absorbed in the S1-global cryomdule design,

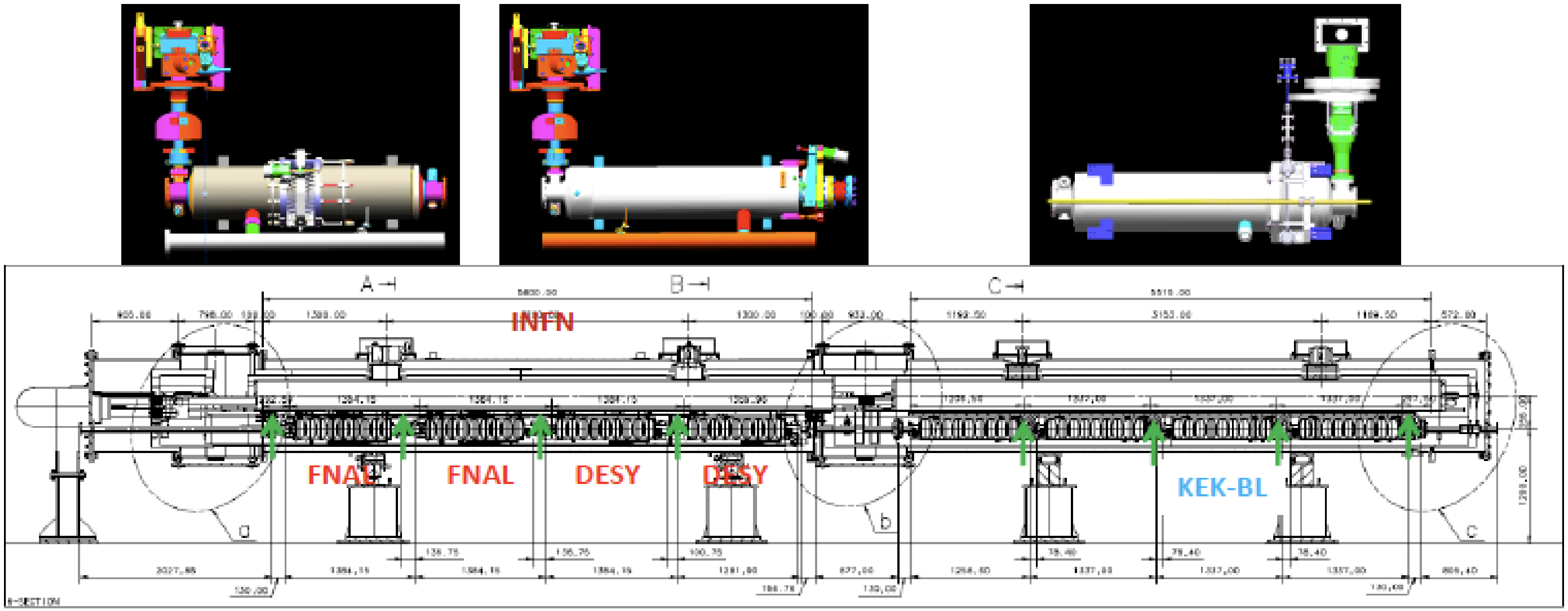
- Discuss “the plug-compatible design” in long-term scope,

Cavity and Cryomodule Test with Plug Compatibility

- Cavity integration and the String Test to be organized with:
  - 2 cavities from EU (DESY) and AMs (Fermilab)
  - 4 cavities from AS (KEK (and IHEP))
  - Each half-cryomodule from INFN and KEK



S1-Global: Cryomodule Assembly



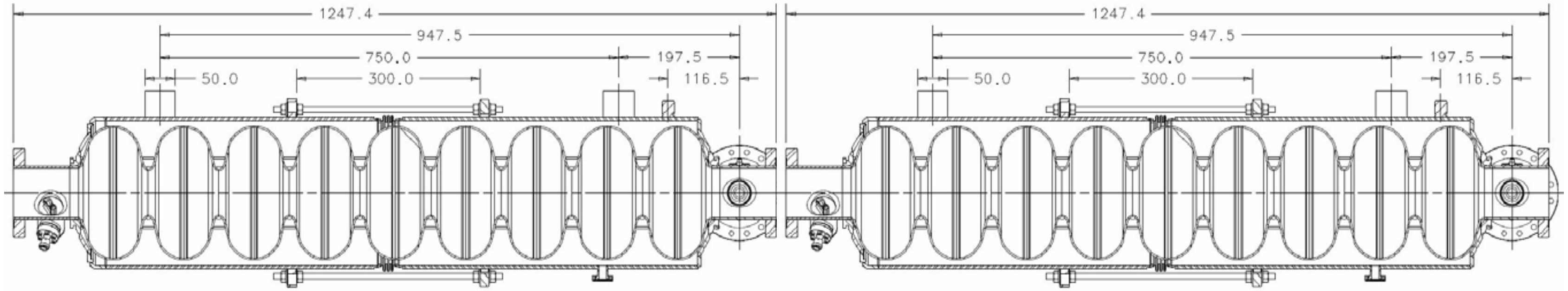
Cryogenic system | Module C | Module A

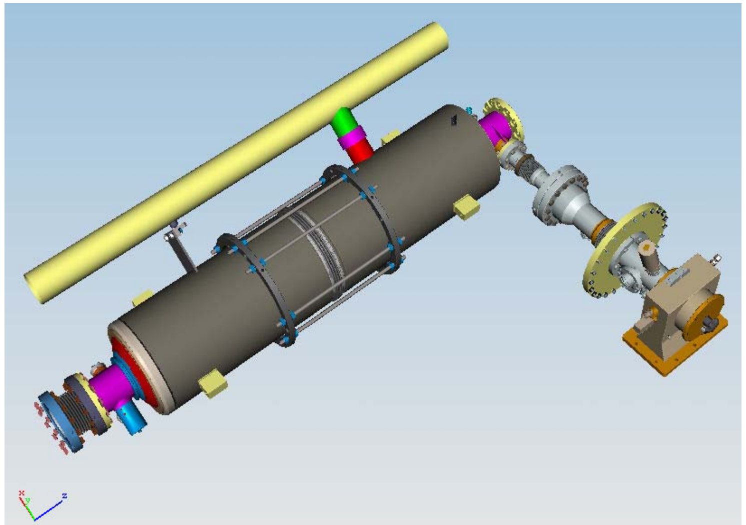
Plug-compatibility to be examined

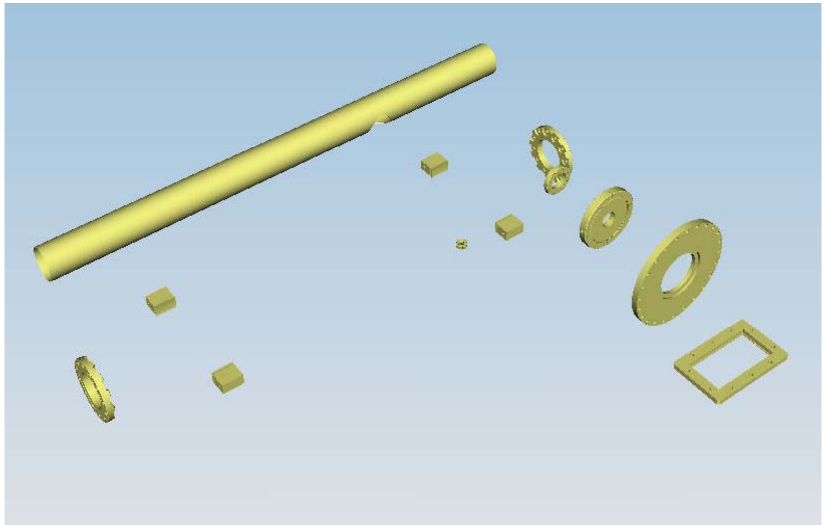
Two steps

- Nov. 17:
  - Discuss and fix general envelopes
  - Preliminary discussions on
    - Tuner and Coupler
- Nov. 18:
  - Discuss Tuner and Coupler
    - Fix the cavity suspension point/interface

Plug-compatible Development

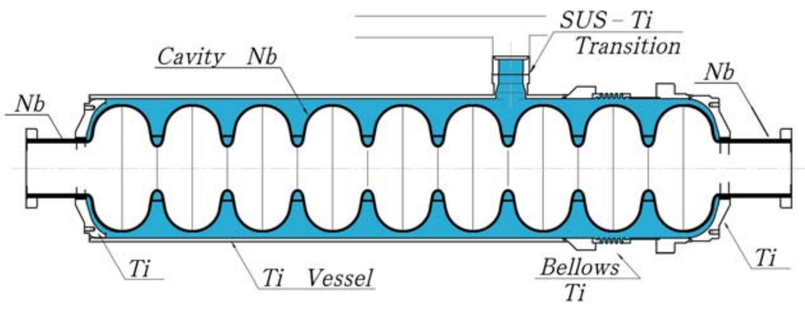


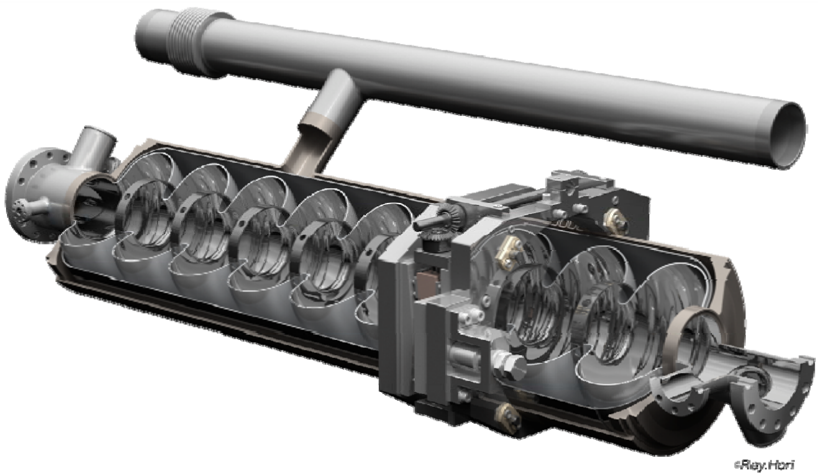




Plug-compatible interface to be established

Plug compatible conditions at Cavity package (in progress)

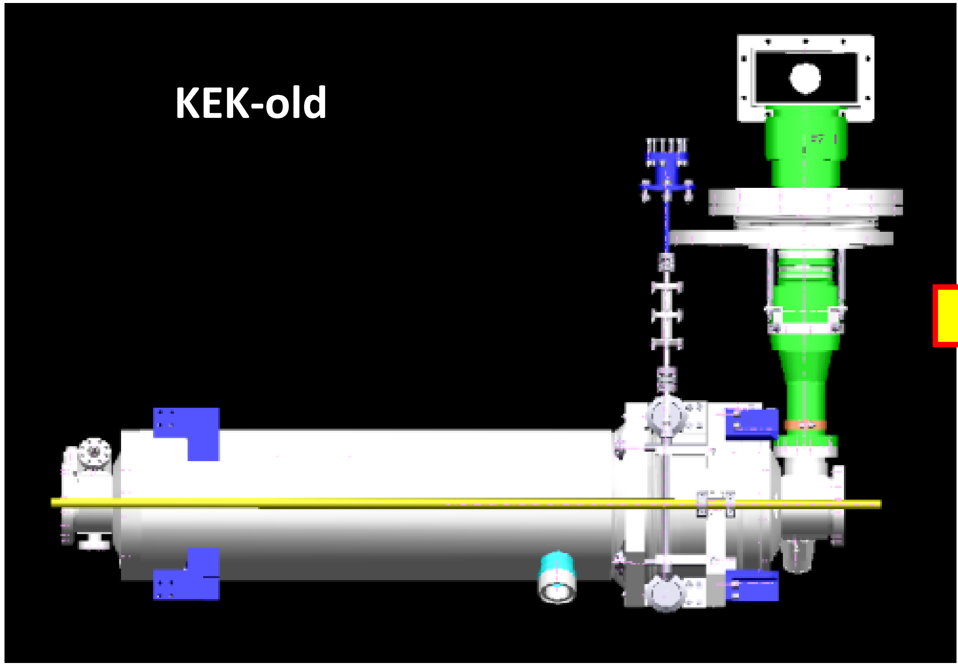


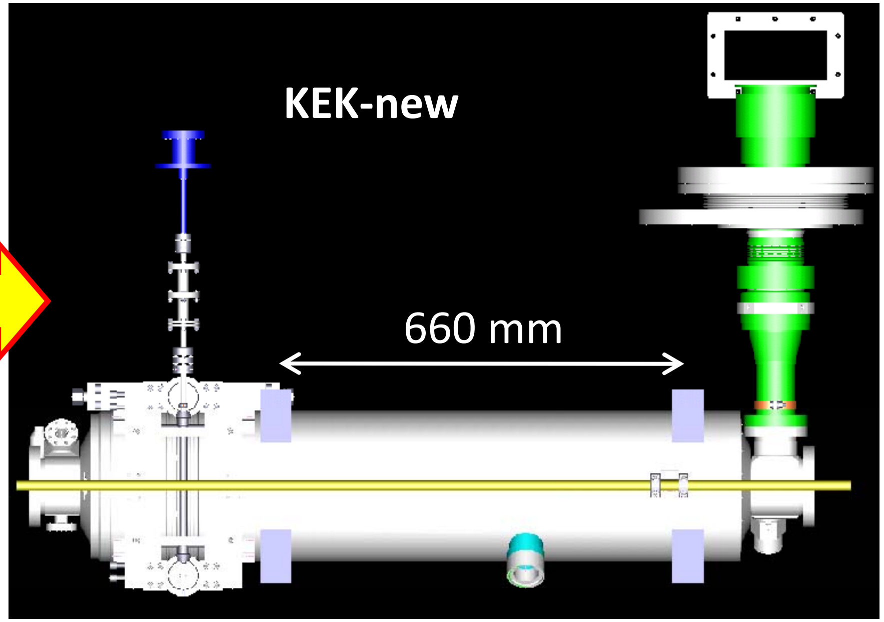


Item	Can be flexible	Plug-compatible
Cavity shape	TeSLA/LL/RE	
Length		Required
Beam pipe dia		Reuuired
Flange		Required
Tuner	TBD	
Coupler flange		Required
He –in-line joint		Required
Input coupler	TBD	TBD

Design change of KEK cavity-vessel

- Position of the slide jack tuner
  - Motor-drive-shaft moves to the opposite side of input coupler.
- Cavity length (1258.6mm → 1247.6mm)

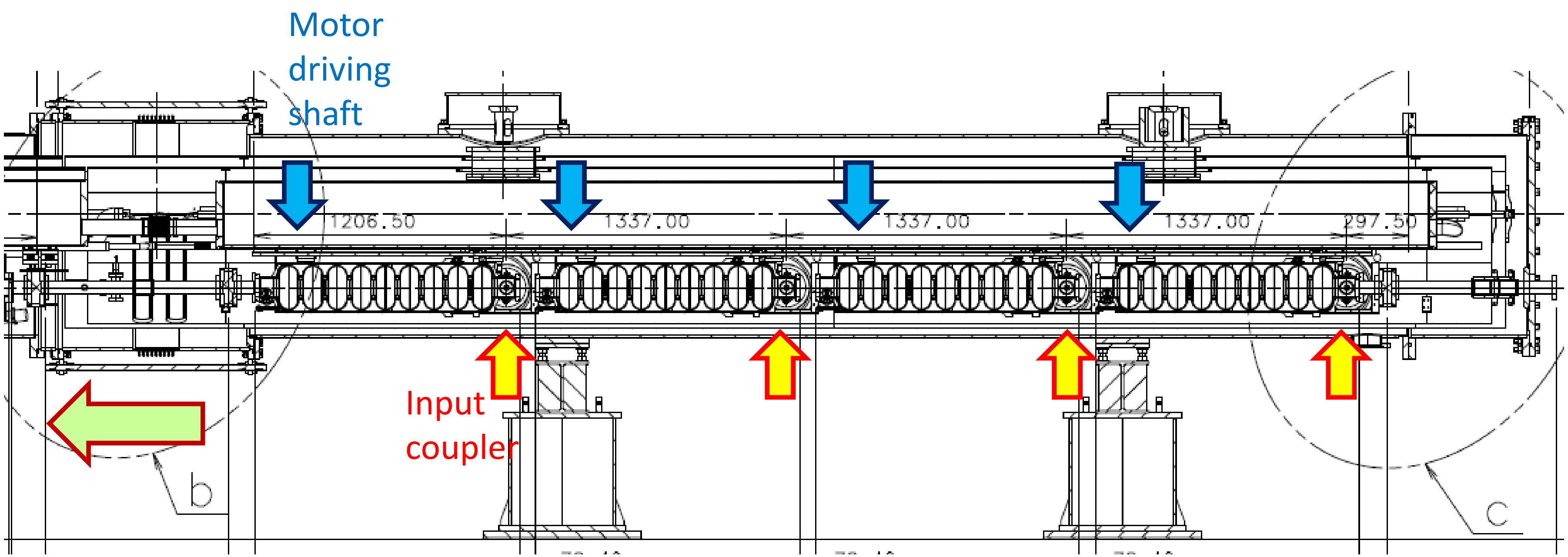




Flange to flange = 1258.6 mm

Flange to flange = 1247.6 mm

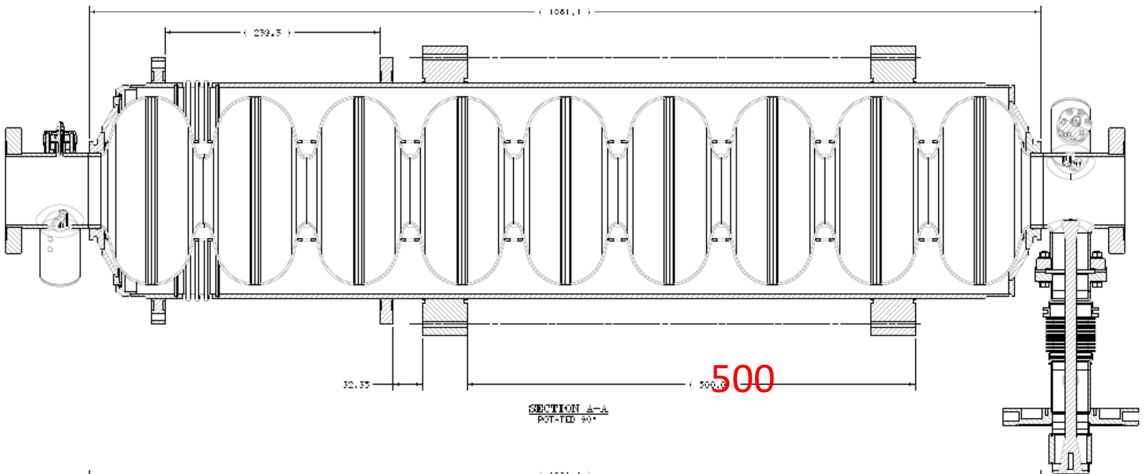
Design change of KEK cavity-vessel

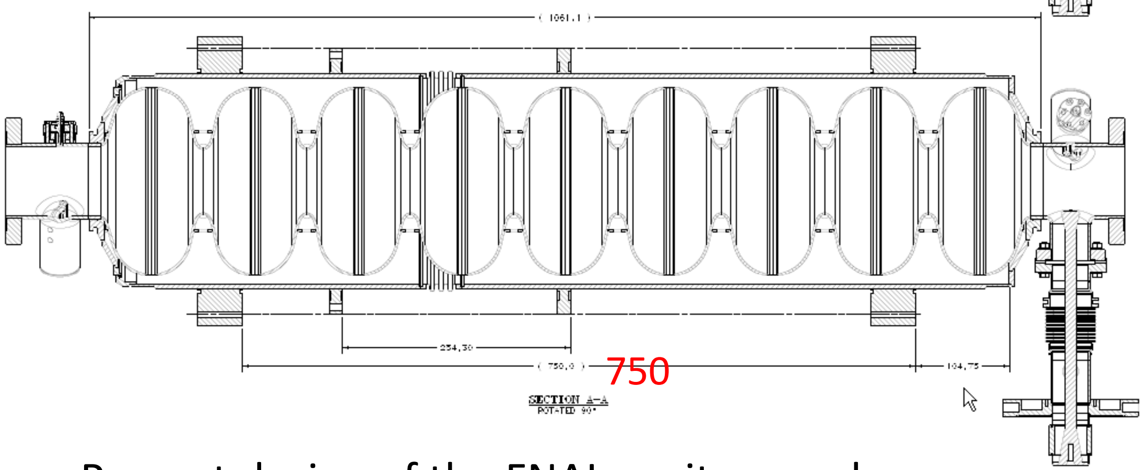


- The vacuum bellow was designed to move on the side of Module-A.
  - Interference between the vacuum bellows and the motor-drive-shaft.
  - The big vacuum bellows need to be re-designed in order to move to the side of Module-C.
- For the ILC-module design, the flange for the drive-shaft should be re-designed without interference with the big vacuum bellows.

Proposal of the design change of FNAL cavity-vessel

Modified design of the FNAL-cavity vessel

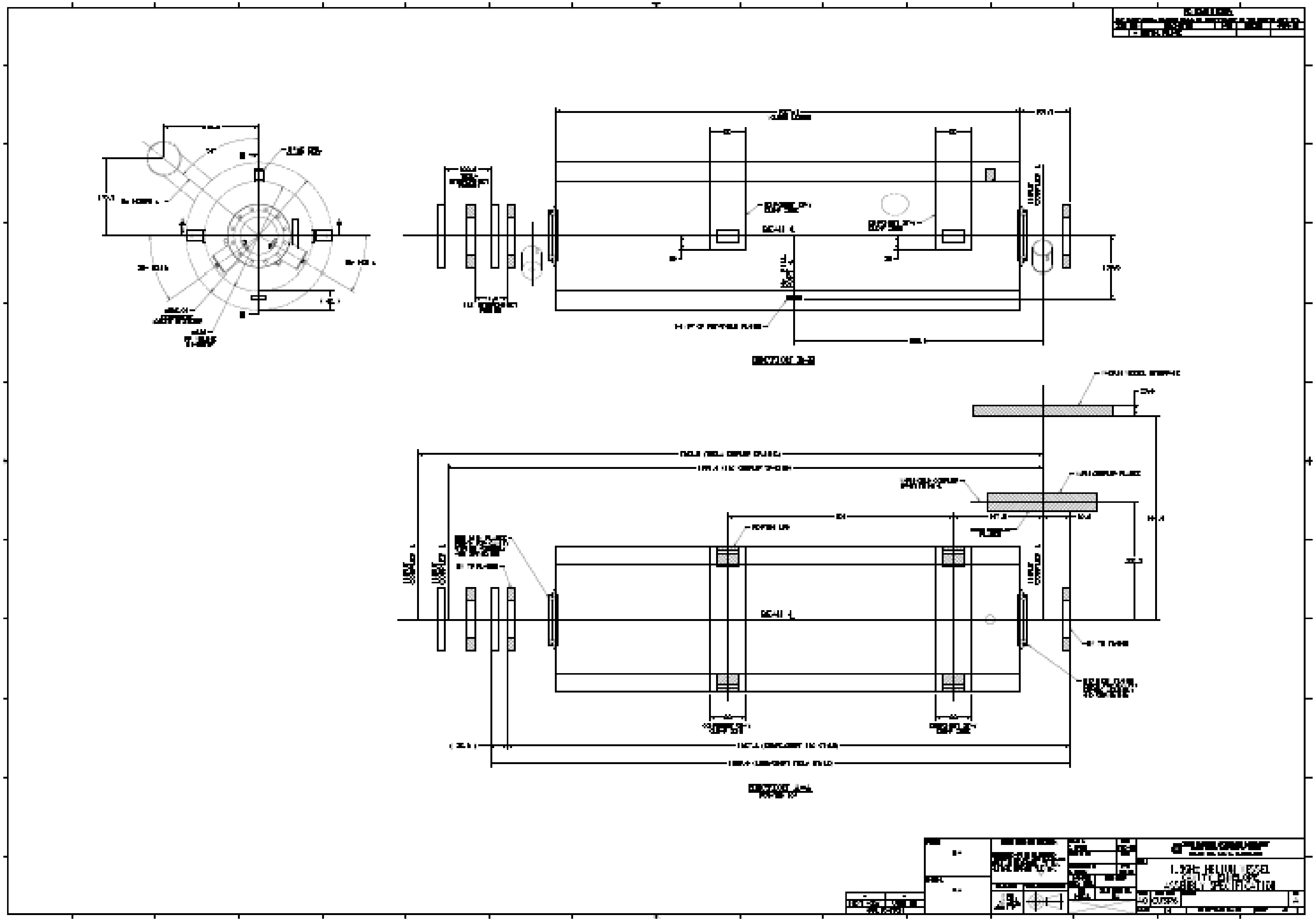




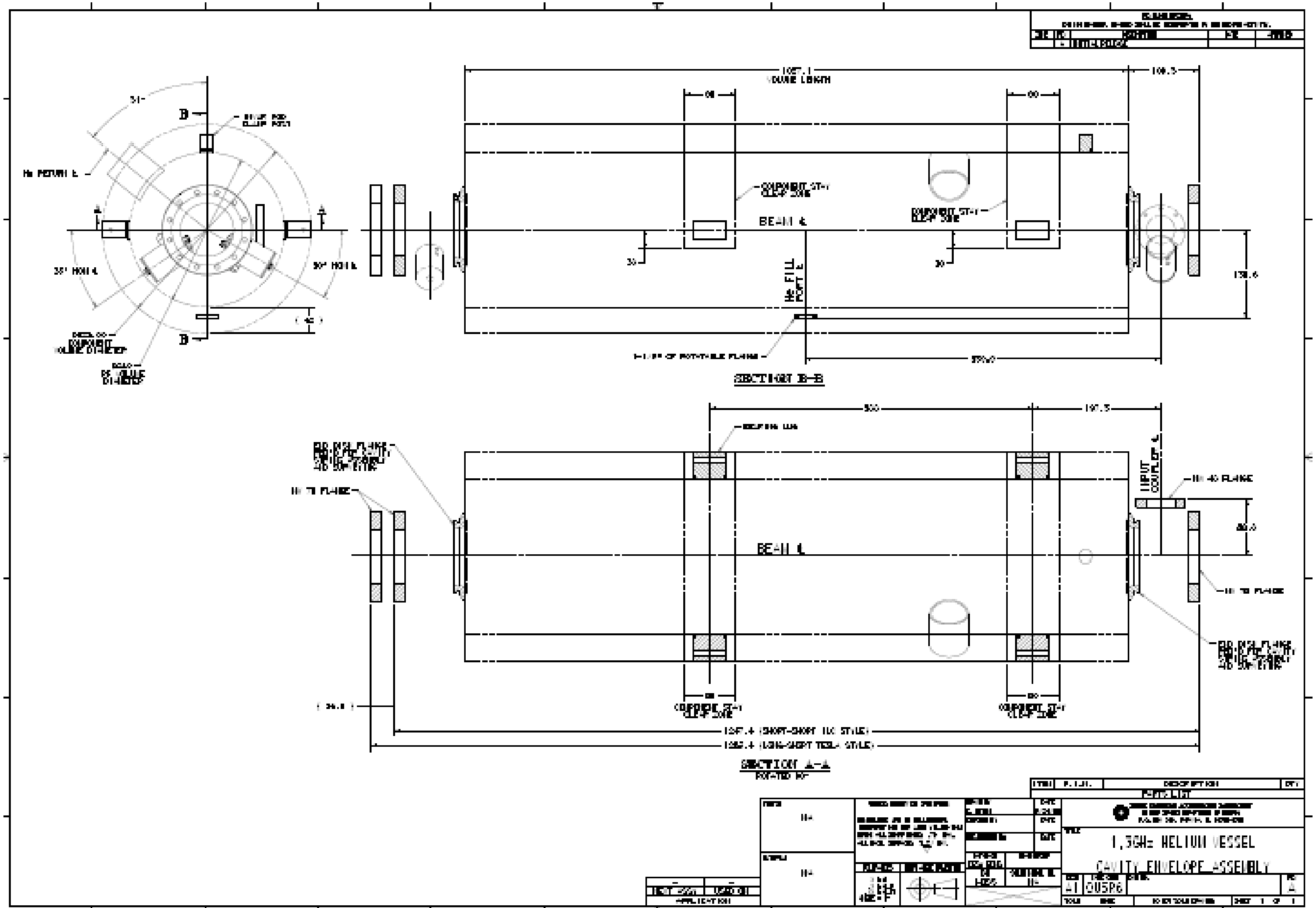
Present design of the FNAL-cavity vessel

- The positions of the support lags between the DESY and the present FNAL cavities have the compatibility.
- FNAL group proposed the change of the blade tuner position.
- By this design change, the support legs under the GRP should be re-designed in order to accommodate the FNAL cavities.

Cavity Envelope (1)



Envelope (2)



BEAM ℄
He FILL PORT
SECTION B-B
BEAM ℄
INPUT COUPLER ℄
SECTION A-A
1.3GHz HELIUM VESSEL
CAVITY ENVELOPE ASSEMBLY

Specification profile tables update

H. Hayano, 11172008

Specification Profile Tables

The purpose of table:

to understand specification of function, specification of physical dimensions, etc.
to understand what is fixed, what is not fixed, for item by item.
to facilitate 'Plug compatibility' concept.

Tables visualize the specifications for;

Cavity
Tuner
Coupler

We had the discussion

at Cavity Kick-off meeting in DESY (Sep. 2007),
at ML-SCRF meeting in DESY (Jan. 2008),
at GDE meeting in Sendai (Mar. 2008),
at ML-SCRF meeting in FNAL (Apr. 2008)

Updated tables are followings;

cavity	specification item	specification	unit and comments	further comments
RF properties	Frequency	1.30	GHz	
	Number of cells	9.00	cells	
	Gradient	31.50	MV/m	operational
		35.00	MV/m	Vertical test
	Q0	0.80	10^10	at 35
		1.00	10^10	at 31.5
	HOM damping		Q	decide later
			R/Q	decide later
	Short range wake			decide later
	Operating temperature	2.00	K	
Physical properties	Length	1247	mm	TESLA-short length
	Aperture		mm	must be compatible with beam dynamics
	Alignment accuray	300.00	um	rms
	Material	Niobium		
	Wall thickness	2.80	mm	
	Stiffness			decide later
	Flange/Seal system		Material	decide later
	Maximum overpressure allowed	2	bar	
	Lorentz force detuning over Flat-top at 35 MV/m	1.00	kHz	maximum
	Outer diameter He vessel	230.00	mm(inner diameter)	Mag shield outside, decide later for precise number
		230.00	mm(inner diameter)	KEK Mag shield inside, decide later for precise number
	Magnetic shielding		inside/outside	decide later

* yellow boxes indicate ‘not fixed’

tuner	specification item	specification	unit and comments	further comments
Slow tuner	Tuning range	>600	kHz	
	Hysteresis in Slow tuning	<10	μm	
	Motor requirement	step-motor use, Power-off Holding, magnetic shielding		
	Motor specification	ex) 5 phase, xxA/phase, …	match to driver unit, match to connector pin asignment,…	decide later
	Motor location	insdie 4K? / outside 300K? / inside 300K accessible from outside?	need availability discussion, MTBF	decide later
	Magnetic shielding	<20	mG at Cavity surface, average on equater	
	Heat Load by motor	<50	mW at 2K	
	Physical envelope	do not conflict with GRP, 2-phase line, vessel support, alignment references, Invar rod, flange connection,…		cable connection, Mag shield
	Survive Frequency Change in Lifetime of machine	~20 Mio. steps	could be total number of steps in 20 years,	

* yellow boxes indicate ‘not fixed’

Fast tuner	Tuning range	>1	kHz over flat-top at 2K	
	Lorentz detuning residuals	<50	Hz at 31.5MV/m flat-top	(LD and microphinics? or LD only?) :decide later
	Actuator specification	ex) low voltage piezo 0-1000V, …	match to driver unit, match to connector pin asignment, …	decide later
	Actuator location	insdie 4K?/inside 4K accessible/inside 100K? accesible / inside 300K accessible from outside?		decide later
	Magnetic shielding	<20	mG at Cavity surface average	
	Heat Load in operation	<50	mW	
	Physical envelope	do not conflict with GRP, 2-phase line, vessel support, alignment references, Invar rod, flange connection,…		
	Survive Frequency Change in Lifetime of machine	$>10^{10}$	number of pulses over 20 years, ($2x10^{9}$:operational number)	

* yellow boxes indicate ‘not fixed’

Coupler	condition	specification	unit and comments	further comments
Power requirements	Operation	>400	kW for 1600 us	
	Processing	>1200	kW upto 400 us	need after vac break, cool-down
		>600	kW larger than 400 us	need after vac break, cool-down
	Processing with reflection mode	>600	kW for 1600us	in Test stand
Processing time	warm	<50	hours	after installation, definition of power/pulse_width target are the same as 'Power Requirement' above.
	cold	<30	hours	after installation, definition of power/pulse_width target are the same as 'Power Requirement' above.
Heat loads /coupler	2K static	< 0.063	W	
	5K static	< 0.171	W	depend on tunability
	40 K static	< 1.79	W	
	2K dynamic	< 0.018	W	
	5K dynamic	< 0.152	W	
	40K dynamic	< 6.93	W	
Cavity vacuum integrety	# of windows	2		
	bias capablity	yes		
RF Properties	Qext	Yes/No	tunable	decide later
	Tuning range	1-10	10^6 if tunable	
Physical envelope	Position		compatible to TTF-III	decide later
	Flange		compatible to TTF-III	decide later (to cavity, to cryostat)
	waveguide		compatible to TTF-III	decide later
	support		compatible to TTF-III	decide later
Instrumentation	vacuum level	>= 1		
	spark detection	0	at window	
	electron current detection	>= 1	at coax	
	temperature	>= 1	at window	

* yellow boxes indicate ‘not fixed’

The next step

The tables are to be included into ‘Plug Compatibility Document’.

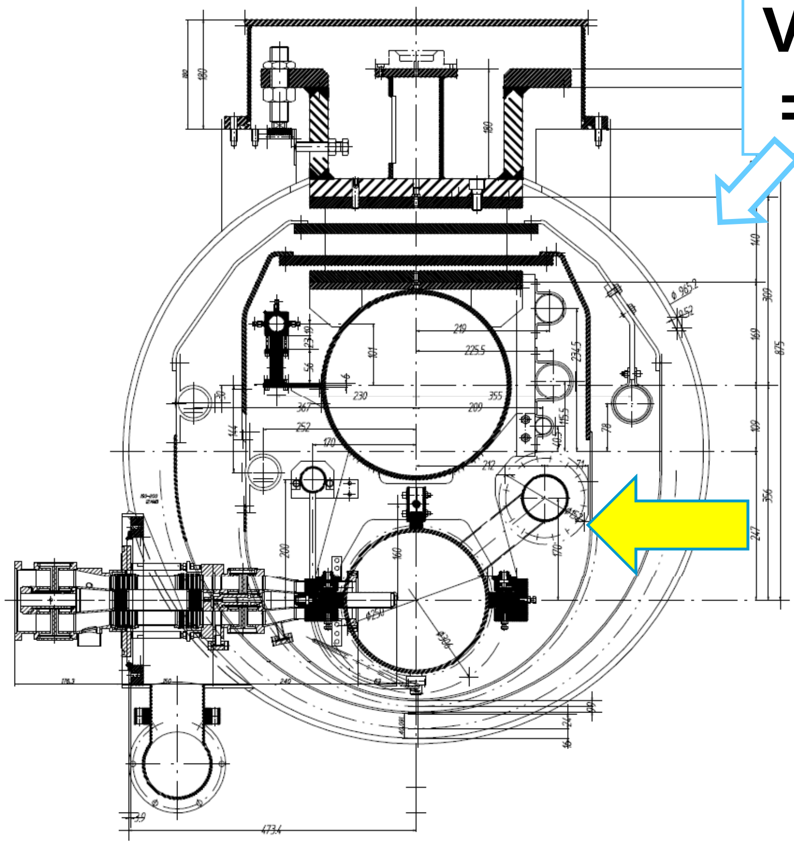
Revision of table contents is by ‘GDE meeting discussion’.

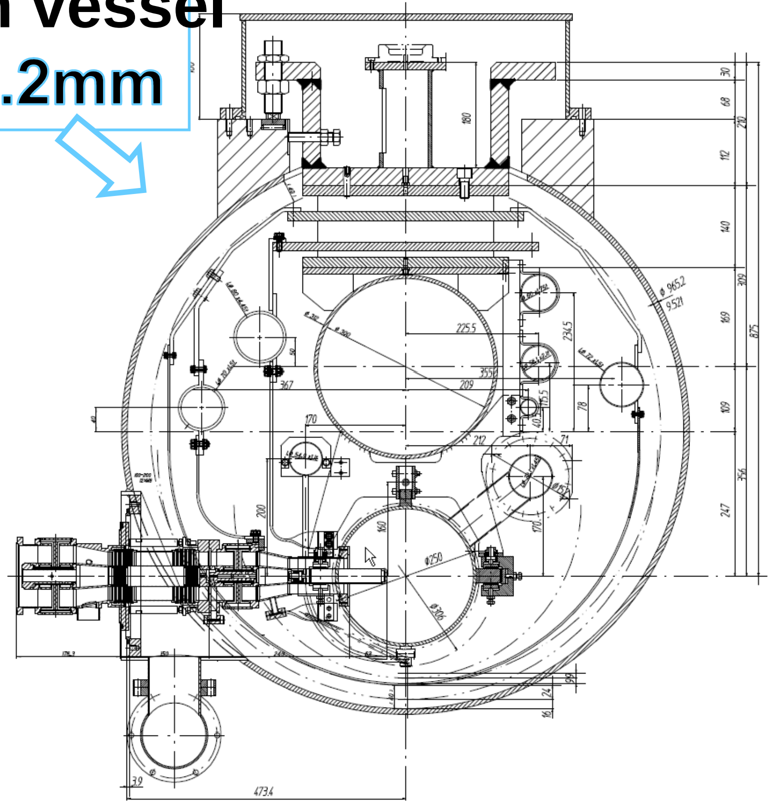
Technical Area Group Leaders maintain the contents.
(Table in EDMS will be revised.)

end.

Study of the “plug-compatible” cryomodule cross-section

Vacuum vessel
= ϕ 965.2mm





Two shields model based on TTF-III

One shield model to save fabrication cost

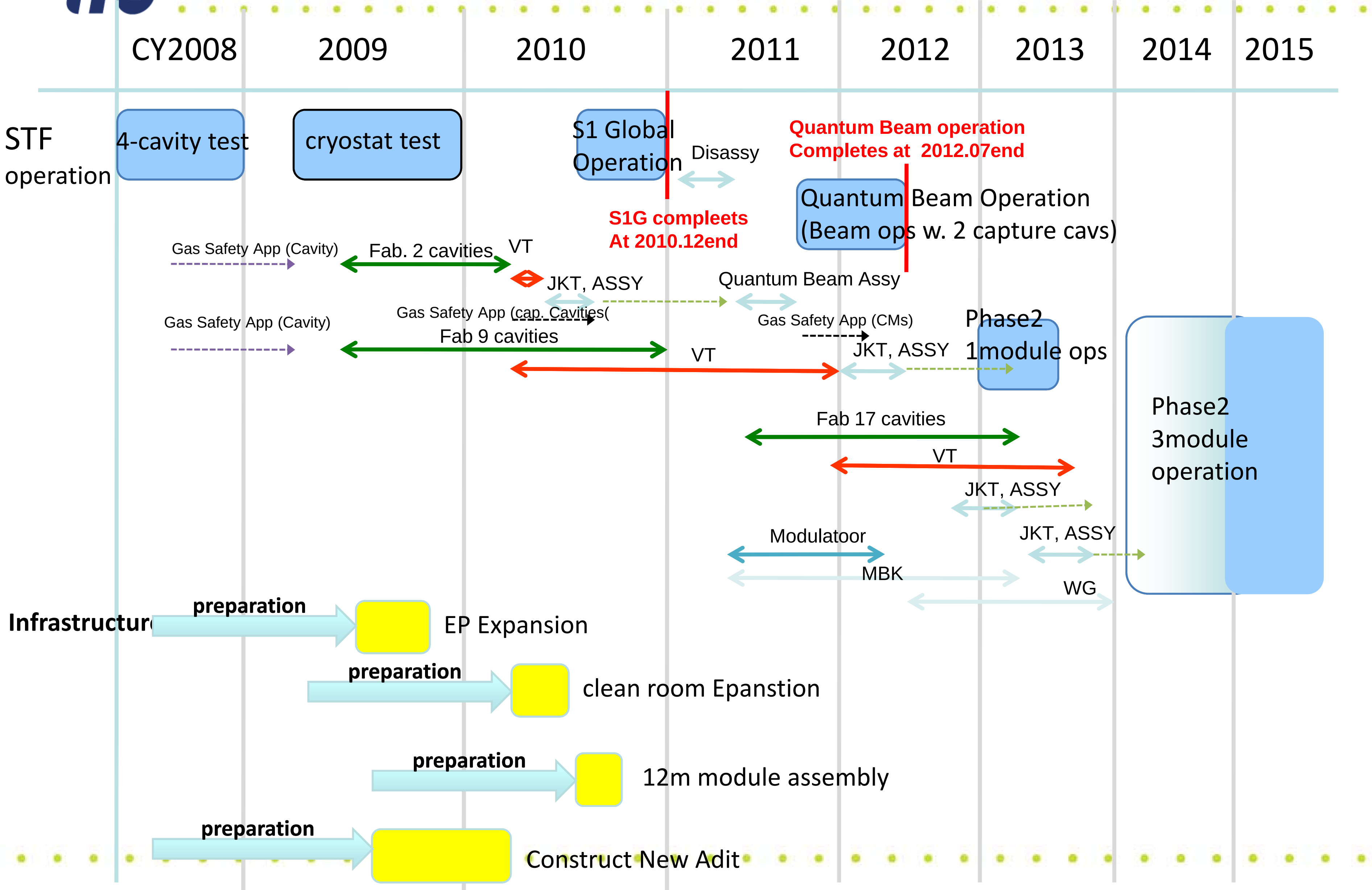
Cryomodule

V.V. material	Carbon steel		
Inn. Diameter	946.2 mm		
Slot length	12,680 mm		
Length w/o bellows	11,830 mm		
Coupler pitch	1326.7 mm		
Cav. Susp. Position	Center – 24.7 mm		
Magnetic shield		In	

		8 C + 1 Q
Number		627
Heat Load	at 2K	11.7 W
(Static + Dynamic)	at 5K	14.2 W
	at 40K	149.4 W
Alignment Tolerance [RMS]	Cavity offset w.r.t. cryomodule	0.3 mm
	Quadrupole offset w.r.t cryomodule	0.3 mm
	Quadrupole rotation w.r.t. design	0.3 mrad
	Cavity pitch w.r.t. cryomodule	0.2 mrad
	Cavity yaw w.r.t. cryomodule	1 mrad
	Cryomodule offset w.r.t. design	0.2 mm
	Cryomodule pitch w.r.t. design	0.02 mrad
	Cryomodule yaw w.r.t. design	0.1 mrad
Vacuum vessel	Cryomodule slot length	12680
	Material (demagnetized)	Carbon Steel
	Length (+ vacuum bellow length)	11830 (+850)
	tolerance of length	± 3
	Outer diameter	965.2
	Inner diameter	955.7
	Height of vessel center axis from the support base level	585
	Input coupler port	8
	Main Coupler #1 z position	-4744.1
	Main Coupler #2 z position	-3417.4
	Main Coupler #3 z position	-2090.7
	Main Coupler #4 z position	-764
	Main Coupler #5 z position	(Quadrupole PKG)
	Main Coupler #6 z position	1889.4
	Main Coupler #7 z position	3216.1
	Main Coupler #8 z position	4542.8
	Main Coupler #9 z position	**5869.5**
	(Tuner driver-shaft port)	8
	Port for current leads	1
	current lead terminals (quadrupole, 2 dipoles)	6
	Port for signal wires	2
	Port for vacuum	2
	Residual magnetic field on the beam line	< 0.1 Gauss
Cavity Helium jacket	Cavity slot length	1326.7
	Material	SUS or Ti
	Length (between connection flanges)	1247.4
	Maximum outer diameter	240
	Position of cavity center w.r.t. the vacuum vessel center (x,y)	(0., -247.)
	Support lugs (fabricated on the horizontal surface of jacket center)	
	lug1-to-Main coupler center distance	197.5
	lug2-to-Main coupler center distance	947.5
	Machining tolerance of lugs w.r.t. design , mm	0.1
	2-phase pipe cross connect, z position w.r.t. main coupler axis	755
	LHe precooling pipe location on the jacket (x,y, z)	105
	Maximum design pressure , bar	2 at warm (4 at cold)
Cooling pipes		
2.2 K subcooled supply pipe	Material	SUS

	LHe precooling pipe location on the jacket (x,y, z)	105
	Maximum design pressure , bar	2 at warm (4 at cold)
Cooling pipes		
2.2 K subcooled supply pipe	Material	SUS
	Inner diameter , mm	60
	Maximum design pressure , bar	20
	Position w.r.t. the cavity center (x,y)	(219, 481.5)
Major return header (GRP)	Material	SUS
	Inner diameter , mm	300
	Maximum design pressure , bar	2 at warm (4 at cold)
	Position w.r.t. the cavity center (x,y)	(0., 356)
5K shield and intercept (supply)	Material	Al 1050 or equivalent material
	Inner diameter , mm	56.1
	Maximum design pressure , bar	20
	Position w.r.t. the cavity center (x,y)	(225.5, 362.5)
8K shield and intercept (return)	Material	Al 1050 or equivalent material
	Inner diameter , mm	70
	Maximum design pressure , bar	20
	Position w.r.t. the cavity center (x,y)	(-252, 210)
40K-80K shield and intercept (supply)	Material	Al 1050 or equivalent material
	Inner diameter , mm	72
	Maximum design pressure , bar	20
	Position w.r.t. the cavity center (x,y)	(355, 325)
40K-80K shield and intercept (return)	Material	Al 1050 or equivalent material
	Inner diameter , mm	80
	Maximum design pressure , bar	20
	Position w.r.t. the cavity center (x,y)	(-367, 326)
2-phase pipe	Material	SUS or Ti
	Inner diameter , mm	72.1
	Maximum design pressure , bar	2 at warm (4 at cold)
	Position w.r.t. the cavity center (x,y)	(210.6, 170.6)
Cooldown and Warmup	Material	SUS
	Inner diameter , mm	38.9
	Maximum design pressure , bar	20
	Position w.r.t. the cavity center (x,y)	(-170, 200)
Helium vessel to 2-phase pipe cross-connect	Material	SUS or Ti
	Inner diameter , mm	54.9
	Maximum design pressure , bar	2 at warm (4 at cold)
GRP as the support structure	Machining tolerance of the connection flanges to the support post w.r.t. design , mm	0.1
	Machining tolerance of the support feet for cavities and quad w.r.t. design , mm	0.1
Thermal radiation shield (inner)	Material	Al 1050 or equivalent material
	Thickness (upper), mm	6
	Thickness (lower), mm	3
	Layers of SI on the shield	10
	Operation temperature , K	5 ~ 8
Thermal radiation shield (outer)	Material	Al 1050 or equivalent material
	Thickness (upper), mm	6
	Thickness (lower), mm	3
	Layers of SI on the shield	30
	Operation temperature , K	40 ~ 80
Support post (furnished with alignment target base)	Number of posts	3
	Z positions of three post centers, mm	-5697.3, 0., 6132.3
	Maximum load for one post , N	
	Distance between the beam line and target center, mm	932.6
Quadrupole package	Length , mm	< cavity slot length>
	Maximum outer diameter , mm	< cavity jacket maximum radius>
	Operation temperature , K	2
All components in Cryomodule	Max. temperature difference during the cool-down and warm-up , K	

STF Schedule under Discussion



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