DRFS High Availability

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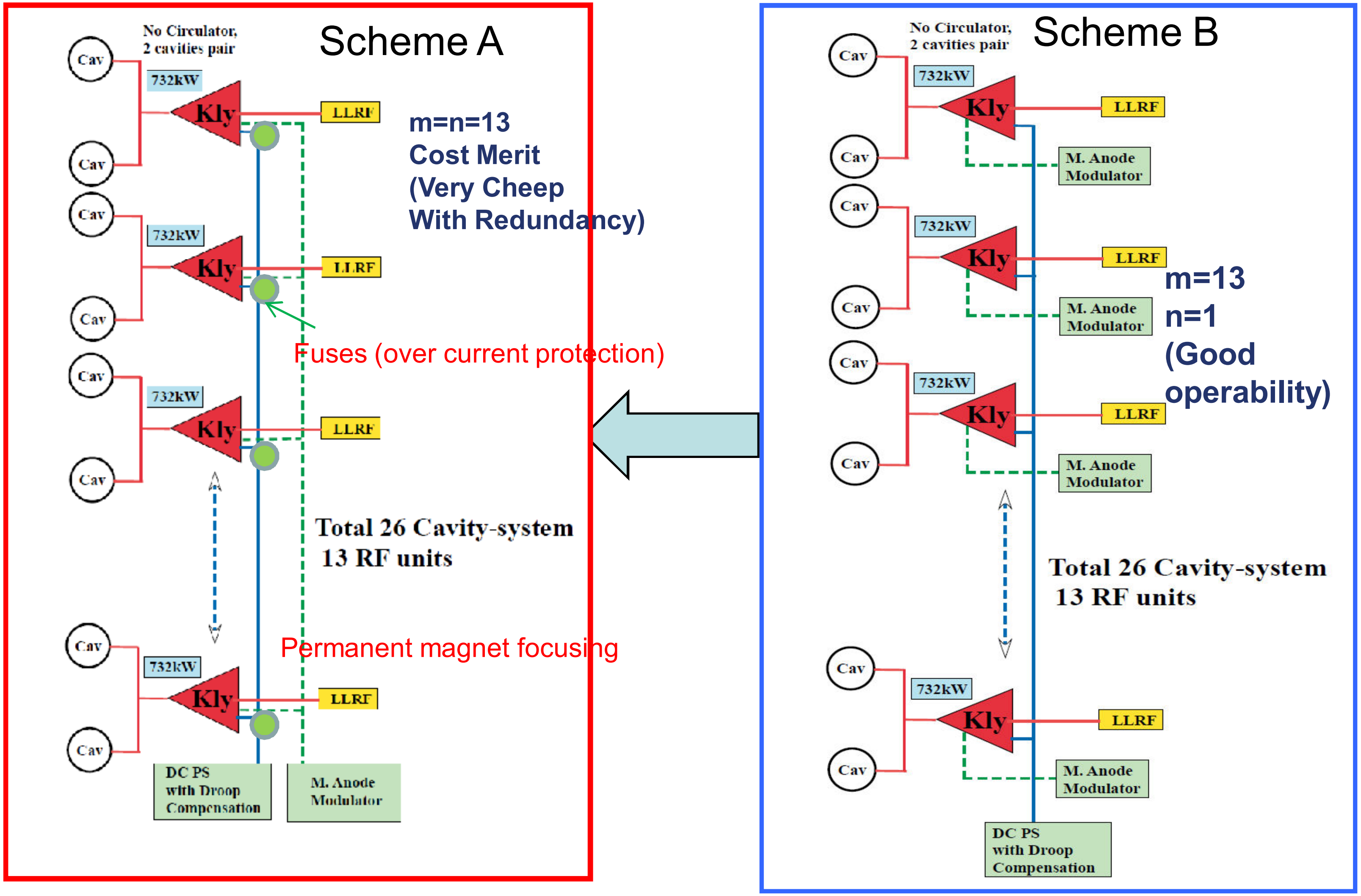
KEK

Contents

Revised DRFS Scheme

- DRFS was proposed in LCWS08 in Chicago as an alternative R&D plan mated to single tunnel configuration.
- Basic DRFS has 750kW MA klystron which feeds power to two cavities. Voltage pulse of each klystron is applied by a MA modulator. 13 klystrons are connected to a common DC power supply.
- Cost estimation, specification and layout are investigated and reported in TILC08 and DESY AT&I meeting.
- Recently DRFS scheme was re-evaluated thru the discussion for the high availability meeting in the KEK DRFS project team.
- This slide shows the presentation of new configuration of DRFS, new cost evaluation and the consideration for the high availability.

DRFS Scheme



Scheme A
No Circulator,
2 cavities pair
Cav
732kW
Kly
LLRF
m=n=13
Cost Merit
(Very Cheep
With Redundancy)
Fuses (over current protection)
Total 26 Cavity-system
13 RF units
Permanent magnet focusing
DC PS
with Droop
Compensation
M. Anode
Modulator
Scheme B
No Circulator,
2 cavities pair
M. Anode
Modulator
m=13
n=1
(Good
operability)
Total 26 Cavity-system
13 RF units
DC PS
with Droop
Compensation

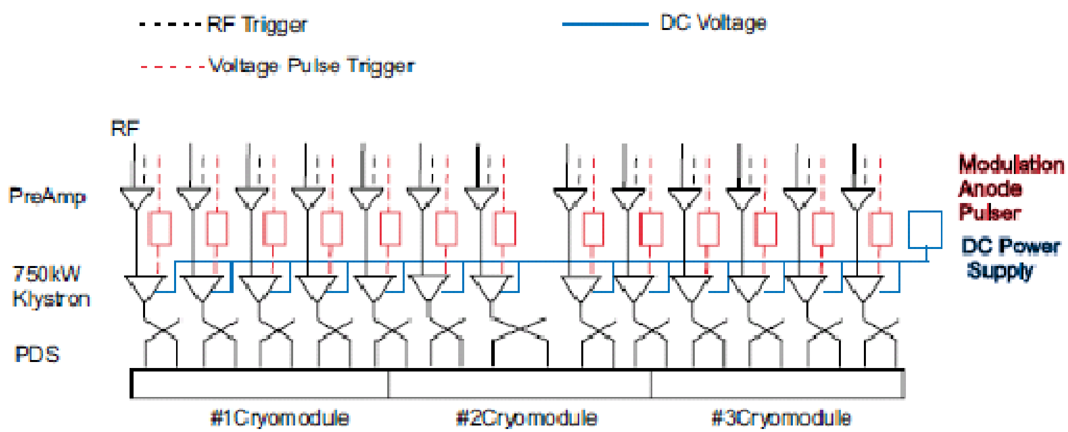
Comparison between scheme A and B

- Proposal made before based on the scheme B has a good operability. Control of both voltage pulse and rf pulse are performed, while it required 13 MA modulators, which result in higher cost, poor availability and many repairing works for modulators.
- If applied voltage pulses for MA klystrons are same, a common MA modulator for 13 klystrons are possible. Operability is not sacrified as long as keeping use of 13 klystrons.

  Scheme A has many advantages for cost saving, higher availability and reducing the repairing works.
- Attempt for further cost saving are considered.

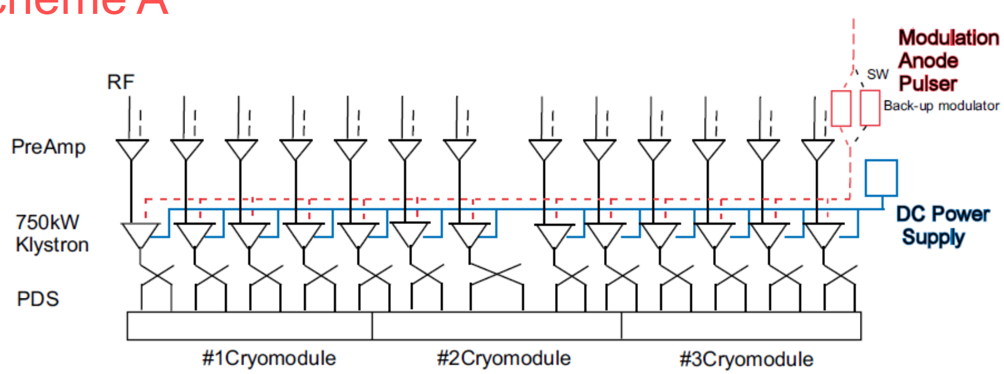
Basic Configuration of DRFS @1 BCD unit

Scheme B



Cavity	26
DC	26
Magic T	13
750kW Kly.	13
Coil	13
Coil PS	13
Heater PS	13
Preamp	13
MA Pulser	13
LLRF & Intlk	13
DC P/S	1

Scheme A

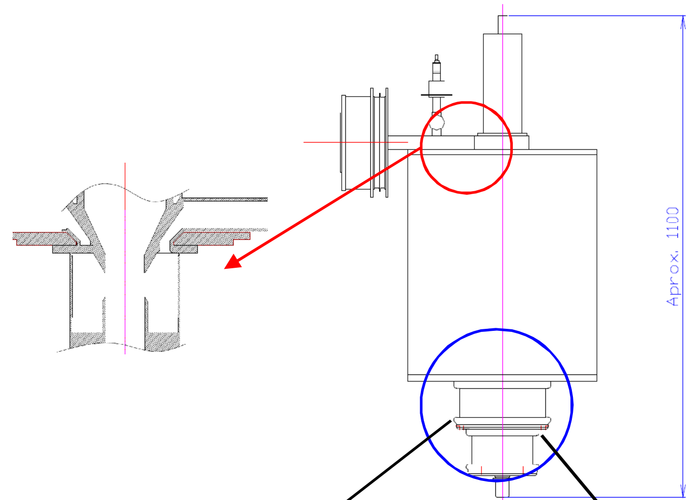


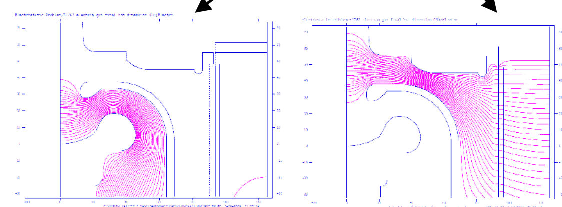
Cavity	26	
DC	26	
Magic T	13	
750kW Kly.	13	
PM Focusing	13	
Coil PS	0	PM focusing
Heater PS	2	common
Preamp	13	
MA Pulser	2	one is backup
LLRF & Intlk	13	
DC P/S	1(or2)	

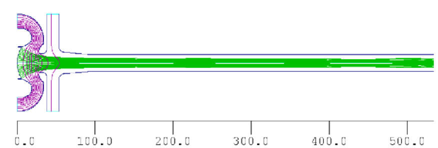
Klystron Design for DRFS

Design Parameters

- **Frequency** **1300MHz**
- **Output Power** **750kW**
- **RF pulse width** **1.565ms**
- **Beam pulse width** **1.7ms**
- **Average RF power** **6kW**
- **Peak beam voltage** **62kV**
- **Peak beam current** **21A**
- **Beam Perveance** **1.36μP(@62kV)**
- **Gun Perveance** **1.735μP (@Ea-k=53kV)**
- **DC Gun Voltage(A-B)** **>64kV**
- **Triode MA-type**
- **Electromagnetic Focusing (proto-type)**
  → **Permanent focusing**
- **Water cooling** → **Only collector**
- **Total length** **1.1m**
- **Weight** **70kg**





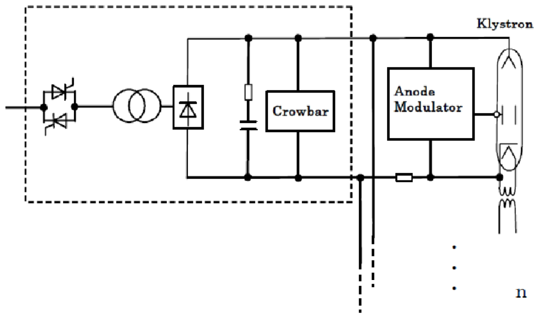


Cost Consideration for the MAK

In order to manufacture cheaply, cost cut-down efforts as follows are required.

- 9000 tubes are manufactured during the 5 years (1,800/year) and 400/year manufacturing is follows as the maintenance.
- Company proceeds up to the tube baking. (Company needs to invest the baking and brazing furnaces)
- Tube processing is performed at the ILC site utilizing the ILC modulator.
- Common parts of the tube : employing hydro-forming
- Cavity tuning: auto tuning introducing the tuning machine
- No ion pump: getter in the tube
- No lead shield in the tunnel of the ILC
- Gun insulation ceramic is operated in the air. Corrugated ceramic to make a longer insulation length is considered.
- Focusing magnet is relatively high cost, and we need to introduce permanent focusing. KEK has an experience to employ permanent focusing in S-band klystron. Elimination of PS leads to high availability.
- (R&D) Cooling Cost Saving by Utilizing Potential Depressed Collector or equivalent new idea to apply to 2nd tube.
- **RF Source cost =65k$@1 RF unit cf. 23k$ (RF source target price)**

Aggressive Cost Study of Modulator based on Scheme A



- Case of m=1, n=1 (**Scheme A**)
  DC Power supply comprises of VCB, delta-star, step-up transformer, rectifier diodes, capacitors and crowbar circuit.
- Common one modulating anode modulator supply the voltage pulse. In order to have a high reliability, there is another back-up stand-by modulator and switched in at the modulator's failure.
- Common filament power supply with back-up PS and NO focusing magnet P/S and an IP P/S.
- M anode pulser employs oil tank and insulation ceramic output connects to klystron.
- Another issue is to eliminate IP power supply by employing the getter in the tube.
- Eliminate the disconnection SW, which is related with the system redundancies. R&D of 66kV fuse-like disconnector might help the system reliability.
- Very simple control system such as a PLC in one DC P/S with EPICS control (ex).
- **Modulator cost =18.7k$@1 RF unit cf. 40k$ (RF source target price)**

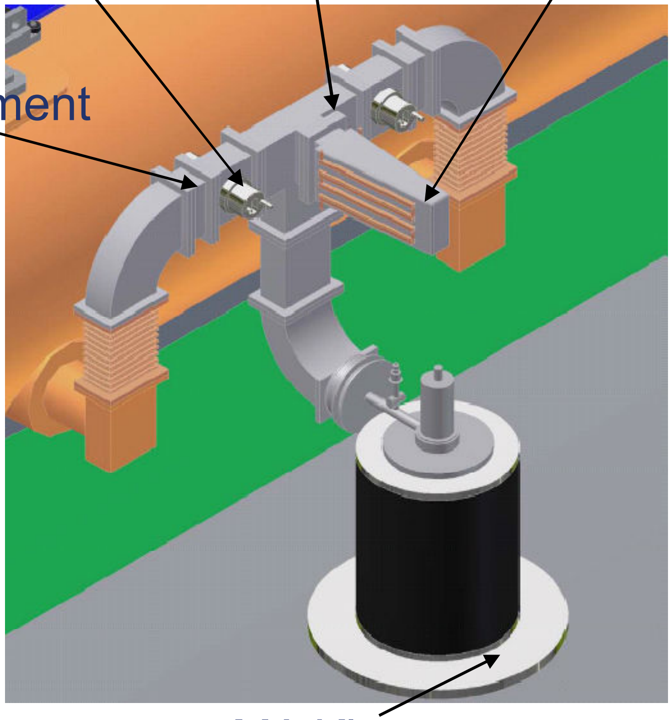
Power Distribution System

Very simple power distribution system is proposed in this scheme.

• No circulator
• Power divider employs magic tee with high isolation for space saving.
• One Phase-shifter with symmetric PDS between couplers or asymmetric PDS with a phase-fixed waveguide for cost saving

• 750kW RF is propagated in the dry air without any extra ceramic window

• PDS cost =7k$@1 RF unit cf. 26.5k$ (RF source target price)



Estimated cost impact (Tentative)

- Cost estimation is strongly depend on the technical design as following slides.

(HLRF)	(DRFS Scheme-A		DRFS Scheme-B	vs.	RDR/13)
– Klystron:	65k$	vs.	45k$	vs.	23k$
– Modulator*:	19k$	vs.	61k$	vs.	40k$
* depend on the scheme, possible to be cheaper					
– PDS:	7k$	vs.	7k$	vs.	26k$
– Total	91k$	vs.	113k$	vs.	89k$

Important components of DRFS

Items	No	MTBF
DC Power Supply	1	50,000
possibly having redundancy	+1(Back-up)	>100,000 (Failure free/y)
Modulating Anode Modulator	1	70,000
possibly having redundancy	+1(Back-up)	>100,000 (Failure free/y)
MA Klystron	13	110,000 (KEK's recent 10 years data)
Focusing Coil— **Permanent Magnet**	13	Degaussing by gamma ray???
Coil PS	0	-
Heater Power Supply	1+1(Back-up)	70,000 (Fan)
IP PS	0	-
Preamplifier	13	>100,000 (radiation?)
Interlock module	13	
Bin module/PS	13	
Rack System with cooling	2	
Water flow SW	15	

Main components which potentially produce a serious interrupt of operation (1)

- Klystron: MTBF=110,000hr, ILC Op/year=5000hr, then 325 tubes are failured. Fraction=4.5%

  If overhead is more than 4.5%, klystron failures don't affect to the ILC operation. Repair is conducted in summer shutdown. If not, unscheduled maintenance would be necessary when failured fraction exceeds overhead.
- DC Power supply: MTBF of 70000hr is assumed. Fraction=7.1%

  This fraction exceeds the allowable overhead. It is possible to introduce backup DC power supply as the redundancy as MA modulator. Cost impact is discussed later.
- MA Modulator: Assume MTBF=from 50,000 to 70,000 hr. Back-up modulator covers the another modulator's failure. Since two modulators failures at the same time are very rare, we can expect no failure in a year operation. Failured MA modulator are repaired or exchanged in the scheduled shutdown.
-

Components which potentially produce a serious interrupt of operation (2)

Components associated with klystrons are simplified.

@1 RDR unit

- No Ion pump PS
- No Klystron Focusing Coil PS by using Permanent Magnet.
- Only 1 Heater PS with an another back-up PS.
- LLRF
- Effect of strong gamma ray disposal.
  - Interlock system?,
  - LLRF control?

Interlock Structure

- Define 1Sector =13 Units=1 BCD RF Unit
- 1 Sector Interlock (Active for 13Units)
  - LV Control/Cooling/Heater
  - HV Cooling/Control/HV Abnormal/VCB
  - TRGR Vac at Beam Duct/ Overcurrent, Pulse voltage abnormal
- 1 unit Interlock (Active for 1 Klystron/2 cavities)
  - RF VSWR, Vac(Coupler), Arc(Quench), Preamp

Interlocks and operability

	interlock	Effects	Response	Faital breakdown?
Modulator	DC down	13 klystrons will stop	(back-up necessary?)	Yes
	MA down	13 klystrons will stop	backup PS will work simultaneously.	No
	Heater PS	13 klystrons will stop	backup PS will work simultaneously.	No
Klystron	Heater open	One klystron will stop	ignore	No
	Heater short	One klystron will stop	Fuse will work.	No
	Discharge	One klystron will stop	Fuse will work for fatal discharge.	No
	Ceramic discharge	One klystron will stop	Fuse will work.	No
	Emission decrease	One klystron will stop	LLRF will control phase/amplitude.	No
	Magnet	No magnet PS	No magnet PS.	No
	RF window	One klystron will stop	RF off*	No
	RF discharge	One klystron will stop	RF off*	No
	RF reflection	One klystron will stop	RF off*	No
Cavity	Input coupler	One klystron will stop	RF off*	No
	Cavity quench	One cavity will be detuned.	Cavity detune	No
	Piezo Mis-control	One cavity failure	RF off*	No
	Cavity vacuum	One cryomodule	RF off*	No

* The effects of "RF off" are limited because 2 (4) cavities driving from single klystron.

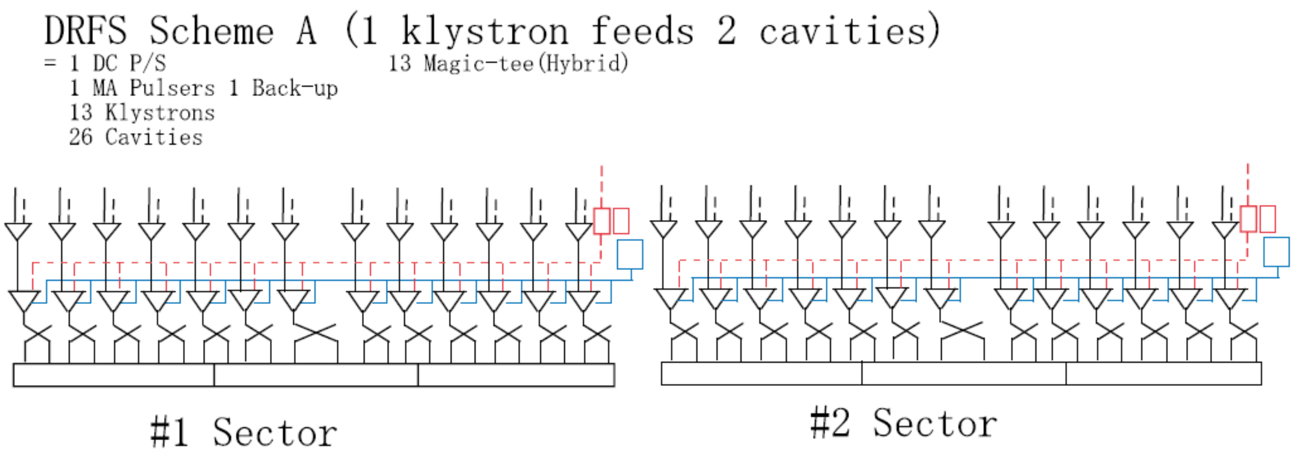
Estimated cost impact with DC PS Redundancy

- DC PS backup required increase of 144k$/13@1-DRFS unit(11k$). If 1 DC PS supplies 2 BCD unit with a back-up, then 144k$*1.4/26@1-DRFS unit(7.8k$)

(HLRF)	DRFS Scheme-A	A with Backup	1 DC feeds 26 Kly	1 DC feeds 26 Kly with Backup
– Klystron:	65k$	65k$	65k$	65k$
– Modulator*:	19k$	30k$	12k$	20k$
– PDS:	7k$	7k$	7k$	7k$
– Total	91k$	102k$	84k$	92k$

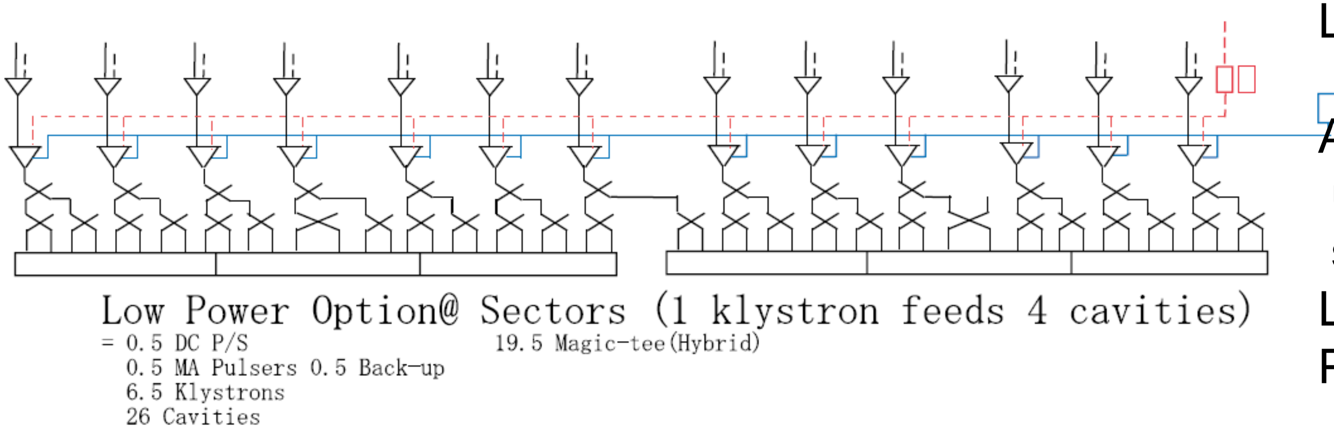
- Since RDR cost corresponds to 89k$@1-DRFS unit, in the case of DC PS supplying 2 BCD unit with a backup DC PS is almost the same as BCD cost.

LowP Scheme for DRFS



Standard Scheme

High operability
Maximum usage of SC cavity



Low Power Option

Aiming for the easy upgradeability to standard scheme
Low cost
Partial sacrifice of DRFS operability

Cost Impact for LowP DRFS

DRFS	Standard		Low P		Cost Impact
	No	Cost	No	Cost	%
DC PS w Backup	1	288	1	166	
MA Modulator	2	100	1	50	
MA Klystron	13	845	7	423	
Magic Tee	13	91	20	137	
		1324		775	58.6
BCD	Standard		Low P		
	No	Cost	No	Cost	
Mod	1	515	1	297	
Kly	1	300	1	150	
PDS	1	345	1	173	
		1160		620	53.4

Assume the PS's cost proportional to Square root of av. Power.

Maintenance in Scheduled Shut down

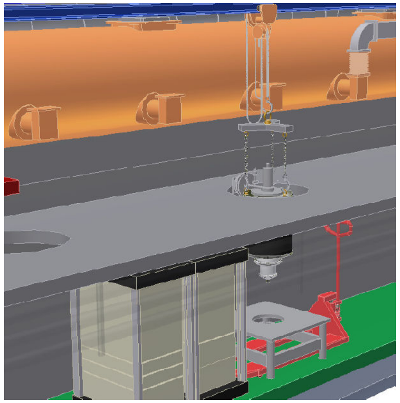
- Here let's consider the repairing work of main components of DRFS in scheduled Shut Down.
- DC PS and MA Modulator of 650, MA Klystron of 8450

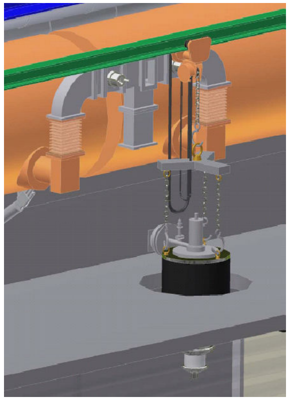
  Operation hr of a year; 5,000hrs. Scheduled shut down of 3 months
- No. of Failure components in a year
  - DC PS : 65 if MTBF of 50,000 hr (assume)
  - MA Modulator: 46 if MTBF of 70,000hr (assume)
  - MA Klystron: 384 if MTBF of 110,000hr (assume)

Klystron Exchanging Working In Scheduled Shut down

- Total 384 tubes,8 Shafts, --48 tubes@shaft, 1 carrier with 8 tubes→8 go and come then klystron delivering takes 4 hrs with 2 person
- One Klystron disassemble and install

	Klystron Exchange Work (for 2 person)	
Step	Content	time(min)
0	Move Klystron from Transfer P	10
1	Dicconnect cable	10
2	Disconnect Waveguide	15
3	Klystron Disassemble	15
4	Klystron Exchange Pullup	15
5	Klystron Installation	15
6	Waveguide Connection	15
7	Cabling work	15
	Total	120





total→ 2hrs*48=96hrs

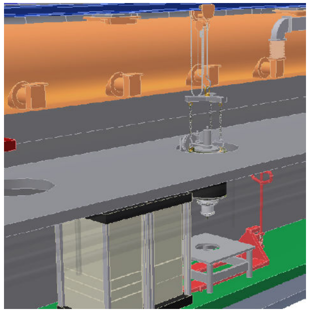
- Average moving time from point to point→20 min , then total 12 hr(20*48).
- At 1 shaft, Total112hrs(4+96+12) with 2 person =14 days with 2 person
- For 384 tubes, 112 days with 2 person (224 days/person)
- Independent supervising at each shaft, 2.8 weeks work for replacing the tube with 2 person in the every shaft.

MA modulators Exchanging Working in Scheduled Shut down

- Total 46 MA modulators, 8 Shafts, --5.75 MA modulators @shaft, 1 carrier with 2 MA modulators →3 go and come

then MA modulators delivering takes 2.6 hrs with 2 person

- One MA modulators disassemble and install
  - Exchange whole Rack of MA Modulator
  - Disconnecting the cable and remove failure set
  - Install new MA modulator
  - Cabling Work



(1 MA Modulator Exchange takes 2 hrs with 2 person)

total→ 2hrs*6=11.5hrs

- Average moving time from point to point→20 min , then total 2 hr(20*6)
- At 1 shaft, Total16 hrs(2.6+11.5+2) with 2 person =2 days with 2 person
- For 46 MA modulators, 16 days with 2 person (32 days/person)
- Independent supervising at each shaft, 0.4 weeks work for replacing the MA modulators with 2 person in the every shaft.

DC Power Supply Repairing in Scheduled Shut down

- In the case of DC power supply, it is necessary to diagnose the failure of the DC power supply by the special engineer. Assume one day (8 hrs)@failure unit to find out the source of failure.
- For the replacement, it is possible to use the same calculation of the required human resources.

- Total 65 DC Power Supply Failure, 8 Shafts, --8 DC Power Supply @shaft, then replacing parts delivering takes 4.3 hrs with 2 person
- One DC power supply disassemble and install
  - Disconnecting the cable and remove failure set
  - Replace the parts of the failure
  - Cabling Work

  (1 DC power supply Exchange takes 11 hrs including diagnosing time with 2 person)

  total→ 11hrs*6=11.5hrs

- Average moving time from point to point→20 min , then total 3 hr(20*9)
- At 1 shaft, Tota96 hrs(4.3+89+3) with 2 person =12 days with 2 person
- For 65 DC Power Supply , 12 days with 2 person (242 days/person)
- Independent supervising at each shaft, 2.4 weeks work for replacing the DC power supply with 2 person in the every shaft.

Resources required for fixing main components of DRFS

- Resources Per 1 shaft
  - Klystron replacement of 384= 5.8 weeks*person
  - MA modulator replacing of 46=0.8 weeks*person
  - DC power supply repairing of 65=4.8 weeks*person

    (including engineer work of 3.2 weeks*person

    Is this overestimate???)

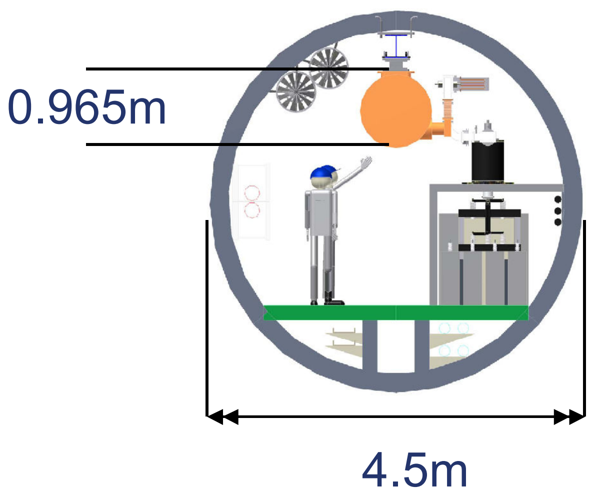
    =11.4 weeks*person per shaft
- Resources of whole LC

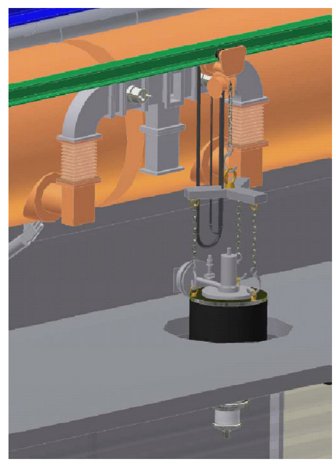
  =91.2 weeks*person

Configuration

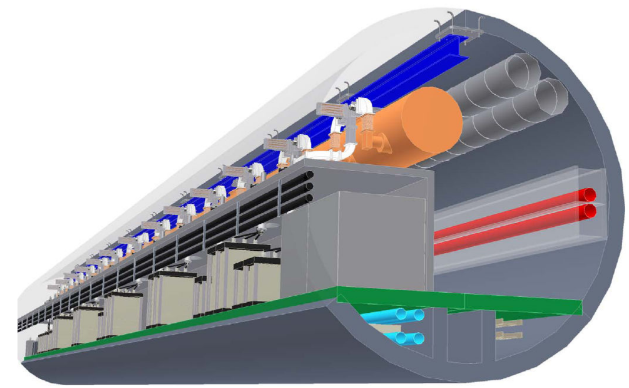
Rough Sketch for DRFS(I)

- Single tunnel layout. 4.5m diameter (like RDR beam tunnel)
- Cryomodule is hanged down from the top of the tunnel. Suppression structure for vibration are considered.
- RF sources are connected to cavities without circulator
- In this drawing, a modulator applies the voltage to two RF source. Working space and installing way of klystron are considered.
- Modulators, LLRF units and other electrical devices are installed in the shielding tunnel.
- There is a choice that the DC power supplies or chargers are concentrated for 13 units or more.

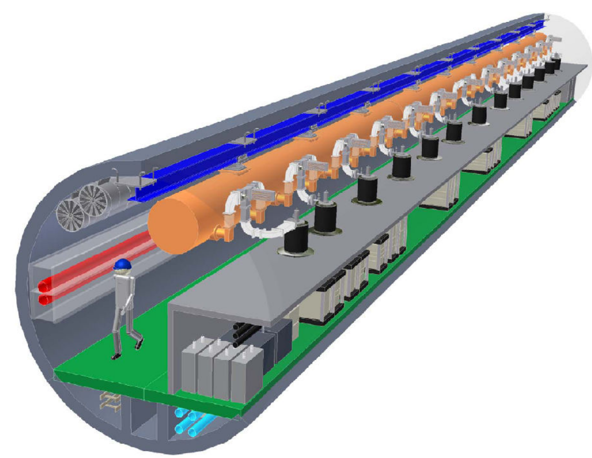




Klystron Install

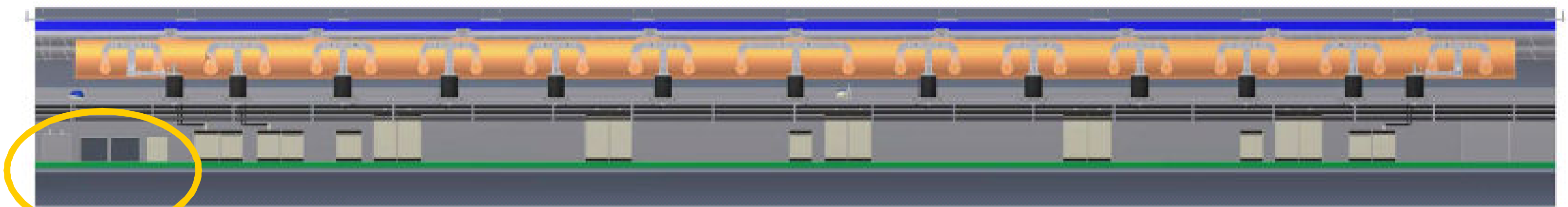


Birds-eye View

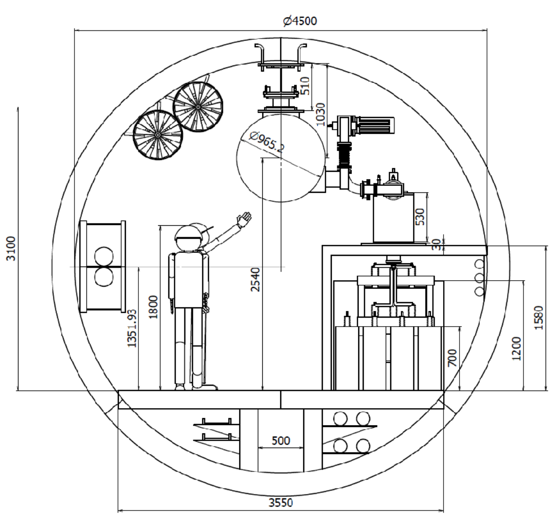


Configuration
Rough Sketch for DRFS(II)

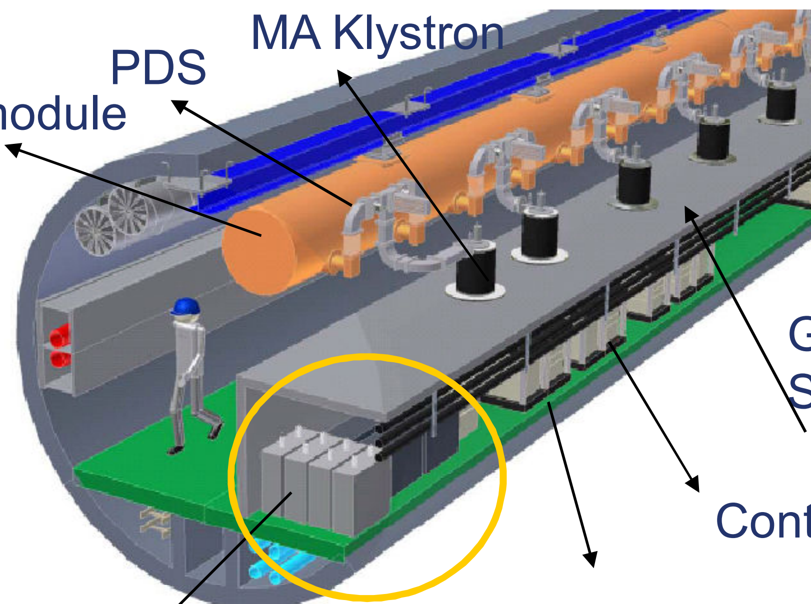
Sketch of 3-Cryo-module unit



6.6kV In & Rectifier Transformer
Capacitor Bank, Bouncer

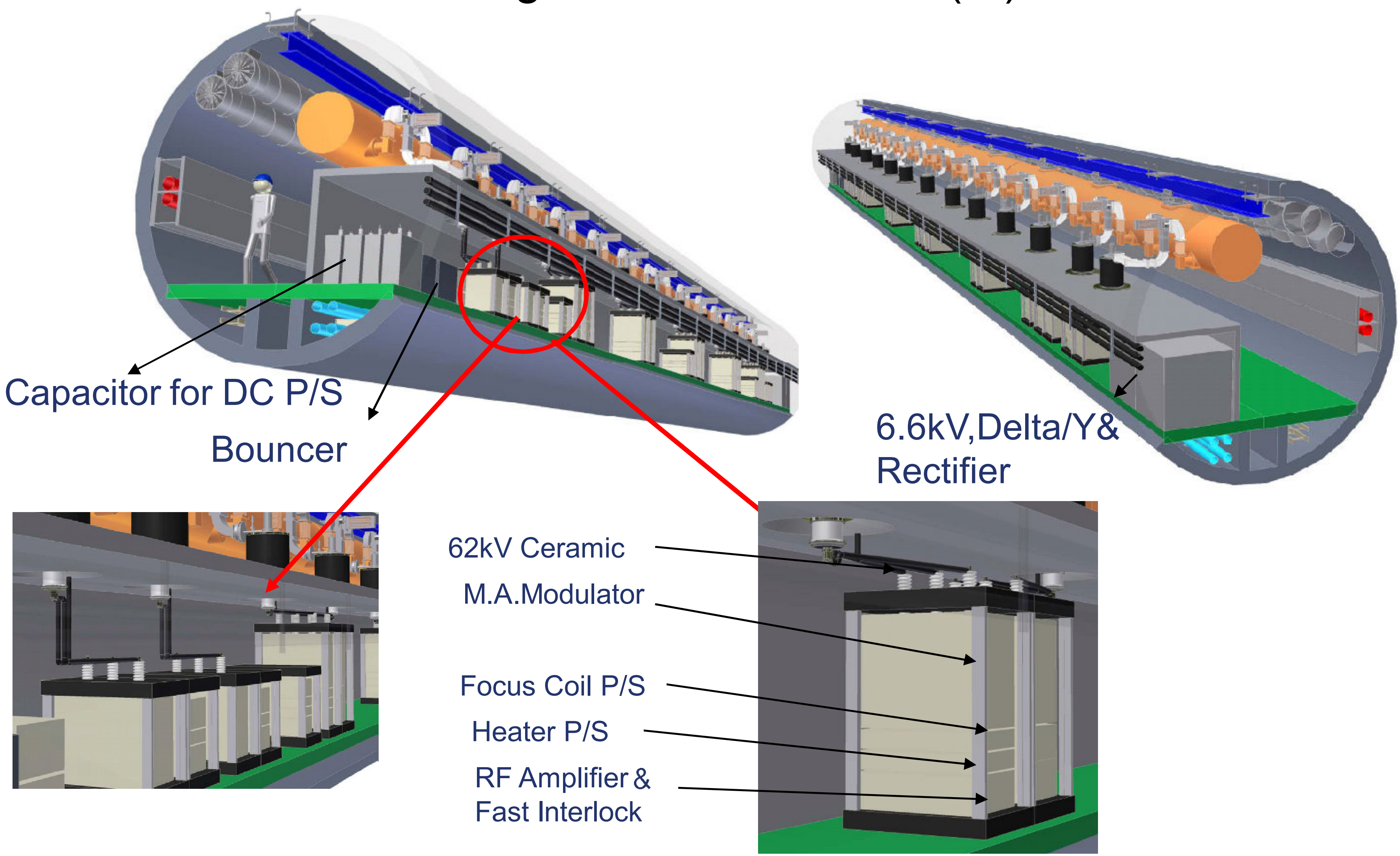


Cross Section



Configuration

Rough Sketch for DRFS(III)



Task and R & D schedule of DRFS in KEK

- Task force team of DRFS starts and try to solve the problems of DRFS.
- Prototype RF unit is manufactured in FY09
- Further R&D required for the DRFS RF system is continued in FY09
- Prototype will be evaluated in the S1 global test
- And then installed in the buncher section of STF-II aiming for the realistic operation.
- After fixing the scheme, collaborative CFS work and realistic cost estimation will be performed in FY09.
- Evaluation of Vibration of cryomodules due to the hanging-down structure from ceiling is planed/

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	FY2009				FY2010				FY2011			
	Apr-09	Jul-09	Oct-09	Jan-10	Apr-10	Jul-10	Oct-10	Jan-11	Apr-11	Jul-11	Oct-11	Jan-12
ILC Schedule												
KEK Schedule						S1 Global	DRFS Install					
MA Klystron #1	Design	#1 MA Kly Manufacturing →			Test →							
MA Modulator #1		Design	#1 Manufacture →									
DC Power supply #1		Design	#1 Manufacture →									
PDS of #1			Manufacture									
MA Klystron #2			Design →		#2 MA Kly Manufacturing →							