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DRFS HLRF System

KEK S. Fukuda

- Introduction:
- Basic Concept of DRFS
- Progress of Recent DRFS Scheme
- Tunnel Layout
- AC Power Supply
- Heat Dissipation
- Radiation Shield
- Maintenance
- Summary

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Introduction (1)

- DRFS, the Distributed RF Scheme (DRFS), was proposed in GDE of LCWS08. It was the complete single tunnel plan and then refinement of this scheme has been discussed and progressed.
- Since the tunnel layout of Asian site is developed in the mountain region, the complete single tunnel plan was supported in Asian region.
- Cost study, AD & I study and CFS have been intensively performed in GDE from 2009 to 2010.
- In order to progress the more refine plan, task force team of DRFS was made and discussed the design of DRFS including CFS specialties.

Introduction (2)

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- Original DRFS plan proposed was that the cryomodule was hung from the ceiling of the tunnel similar as the DESY's XFEL plan. US and Europe regions had an objection against the plan of hanging the cryomodule from ceiling.
- Recently we developed the alternative layout that the cryomodule is on the floor of the tunnel. Though it is the prototype design of the DRFS of the cryomodule on the floor, we think it is worth value to develop this idea for not only the Asian plan but also the world wide acceptable plan.
- HLRF refinement with the realistic equipment size are also developed.
- Redundancy scheme of the key power supply is also important and developed more from the Beijing meeting.
- Electricity plant scheme was also modified.
- Cooling issue are now under the survey.
- We hope to show the upgraded design in 2010 LCWS in CERN.

Concept of DRFS

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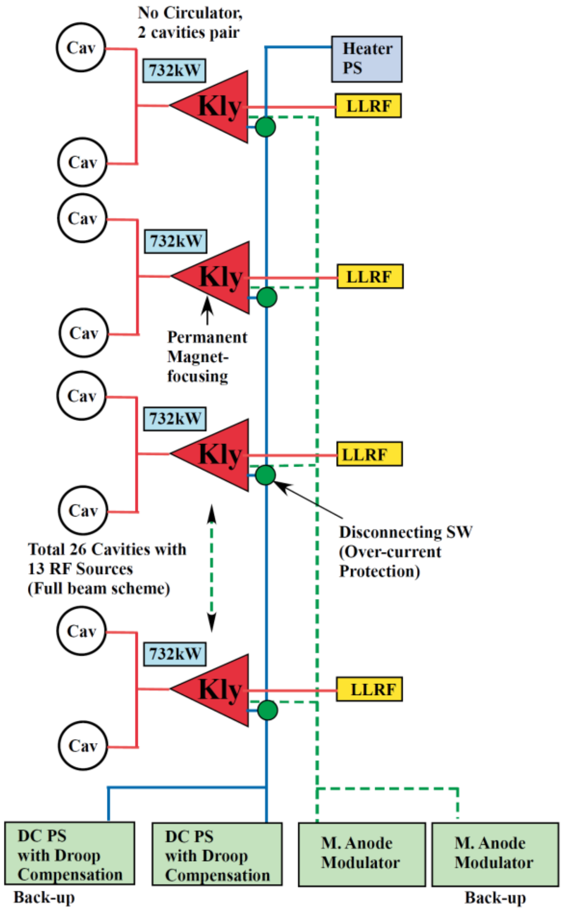
- The Distributed RF System (DRFS) is another possibility for a cost-effective solution in support of a single Main Linac tunnel design.

- Base line of proposed DRFS
  - **one unit of 750kW Modulating Anode (MA) klystron would drive two cavities (in basic configuration scheme –BCS/HCS).**
  - **totally about 8000 MA klystrons would be used.**
  - **It is based on much simpler and more compact HLRF and LLRF units than the RDR baseline or KCS.**
  - **It offers a good operational flexibility in coupling with performance variations of individual cavities.**
  - **By employing suitable back-up modules for key component, high availability would be expected.**
  - **Complete single tunnel model, no facility in the surface**



Parameters in DRFS

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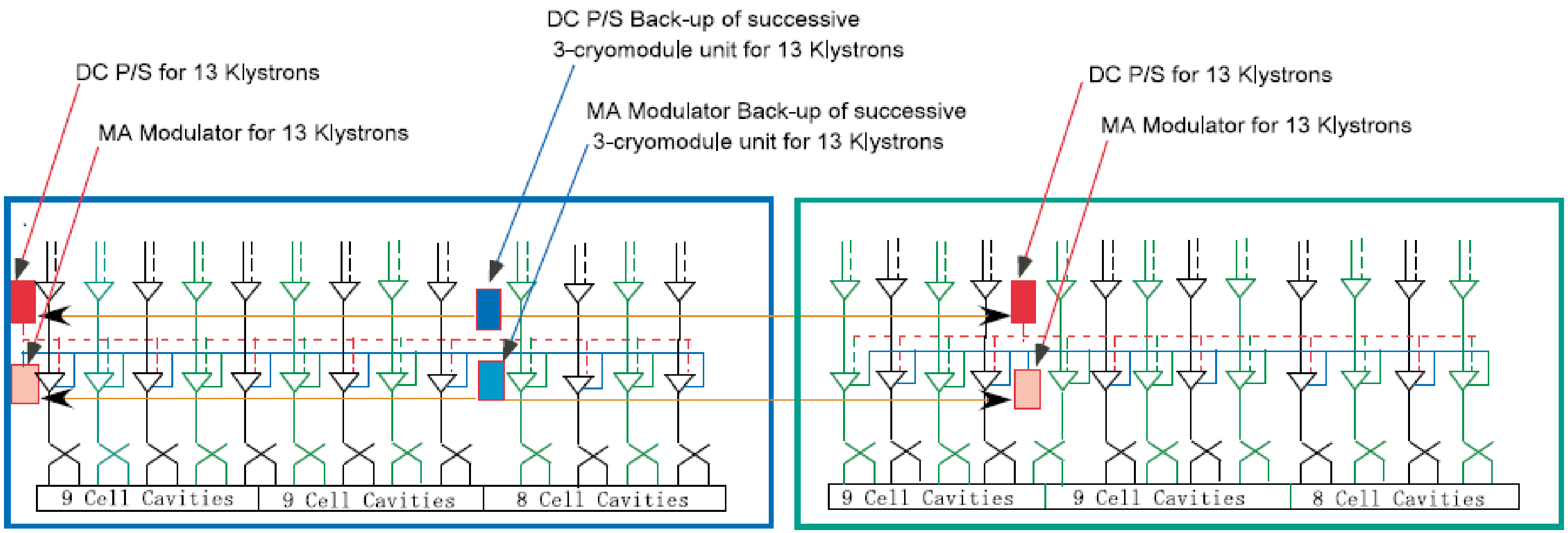
In the RDR scheme, three units of ILC cryomodules, containing 26 cavities in total, are driven by the RF power from one unit of 10MW L-band klystron.

In the proposed new scheme of DRFS, 2 cavities are driven by one unit of 750kW L-band MA klystron. Therefore, one would see that three cryomodules with 26 cavities will be driven by thirteen units of MA klystrons.

Klystron	Frequency	1.3	GHz
	Peak Power	750	kW
	Average Power Output	7.50	kW
	RF pulse width	1.5	ms
	Repitition Rate	5	Hz
	Efficiency	60	%
	Saturated Gain		
	Cathode voltage	64.1	kV
	Cathode current	19.5	A
	Perveance(Beam@64.1kV)	1.2	mPerv
	(Gun@53kV)	1.56	mPerv
	Life Time	120,000	hours
	# in 3 cryomodule	13	
	Focusing	Permanent magnet	
	Type of Klystron	Modulated Anode Type	
DC Power supply per 3 cryomodules			
	# of klystron (3 cryomodul	13	
	Max Voltage	71.5	kV
	Peak Pulse Current	244	A
	Average Current	2.47	A
	Output Power	177	kW
	Pulse width	2.2	ms
	Repitition Rate	5	Hz
	Voltage Sag	<1	%
	Capacitor	26	mF
Bouncer Circuit			
	Capacitance	260	mF
	Inductance	4.9	mH
M. Anode Modulator			
	Anode Voltage	53	kV
	Anode Bias Voltage	-2	kV

Redundancy Scheme

Availability Consideration Revised



Full Power Option@ 26-Cavities
(1 klystron feeds 2 cavities)
= 1 DC P/S +0.5 Back-up
1 MA Pulser +0.5 Back-up
13 Klystrons
26 Cavities
13 Magic-tee(Hybrid)

Full Power Option@ 26-Cavities
(1 klystron feeds 2 cavities)
= 1 DC P/S +0.5 Back-up
1 MA Pulser +0.5 Back-up
13 Klystrons
26 Cavities
13 Magic-tee(Hybrid)

Modulator Scheme/Base Line DRFS

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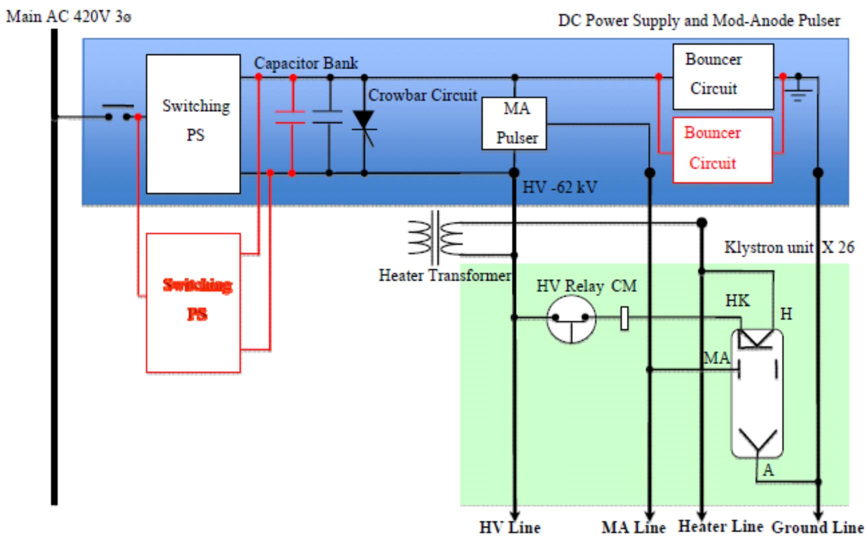
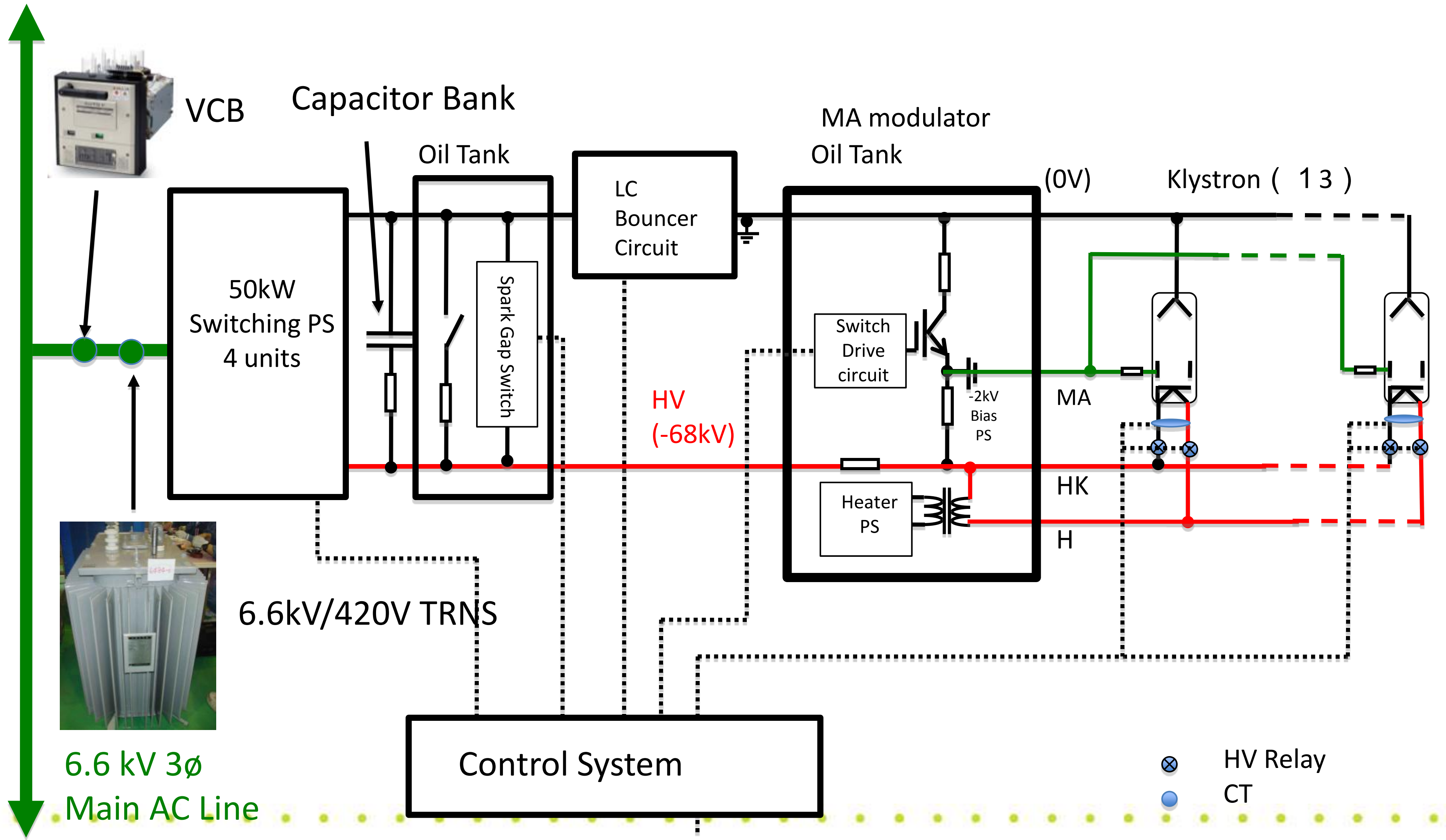


- The DC power and anode modulation for a group of 13 units of klystrons are provided by **one common DC power supply and one common anode modulator** (MA modulator).
- In order to realize high reliability, each of the DC power supplies and MA modulators is associated with **one backup** units, which will be designed and implemented to be “hot-swappable”.
- Each of the power and voltage distribution circuits will have **high-voltage SWs**, which switches off the line when over current failures are detected.
- A DC power supplies has a **bouncer circuit for compensation of the pulse flat droop**.
  (This leads to a relatively small condenser bank)
- The charger of a DC power supply comprises of a bundle of several units of identical switching PS. This allows us to increase its electrical power with ease, simply by adding more switching PS.
- Common heater power supply and permanent magnet focusing to eliminating magnet power supply.

PS system for DRFS (one unit)



Klystron for DRFS

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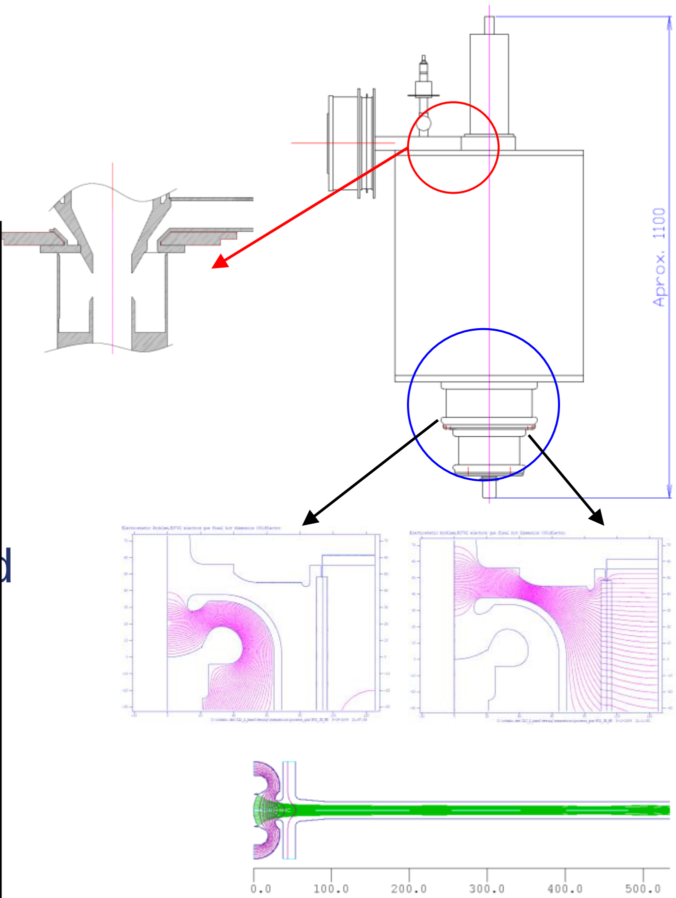
Parameters of MA klystron is summarized
In the previous table.

Features of DRFS klystron

Applied voltage of less than 65kV
60% efficiency with 1.2 microperveance
Low field gradient in klystron gun —few arcing
Low cathode loading--- long cathode life
Low output power--- free from output window failure
→ Long life of klystron would be expected

Permanent magnet focusing--- free from magnet and power supply failure
Common heater power supply with back-up --- contribute to high availability



DRFS Tunnel Layout
Cryomodule from Ceiling

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- Progress
  - **Electric Power Plant Line is changed:**
    - 6.6kV is directly introduced to each section thru VCB.
  - **Realistic size of equipments of the DC power supply.**
  - **Stand-by P/S and MA modulator are introduced in each 2 BCD units. Therefore P/S locates in every two-cryomodule unit.**
  - **Klystrons are located condensely to make a room for the water-cooled control racks.**
  - **Almost all required components are installed in the single tunnel. LCW skids are located in the alcove of the tunnel in every 4th units:152m.**

AC Power Supply Line

- For Power Supply Line,
  - **In each 152m position, low voltage power facility (LVPF) is introduced and 6.6kV line is reduced to 420V and then power of 420V is delivered to four sections (3-cryomodule unit).**
    - 420 V cable line is large and long: Special room of LVPF results in more cost.

↓

  - **6.6 kV is delivered directly to each DRFS station (3-cryomodule unit) and reduced to 420V and power is fed via VCB.**

Plan-1:Low Voltage Power Facility

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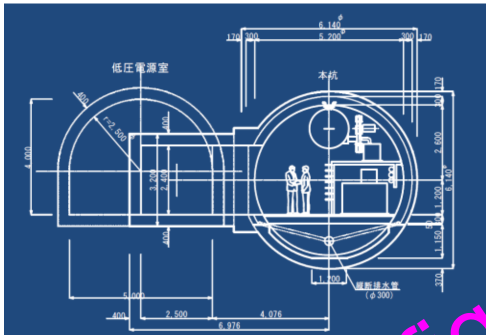
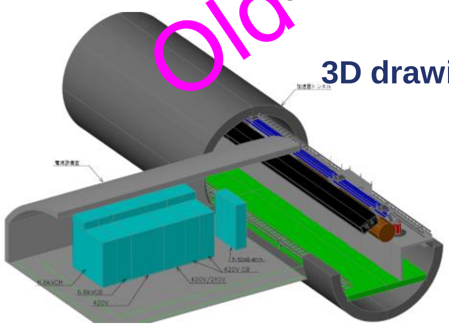
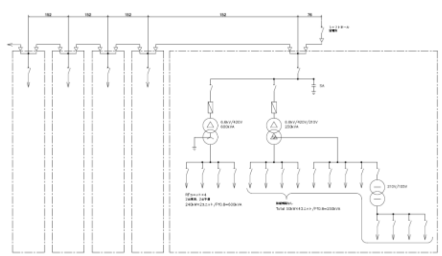


Old Configuration

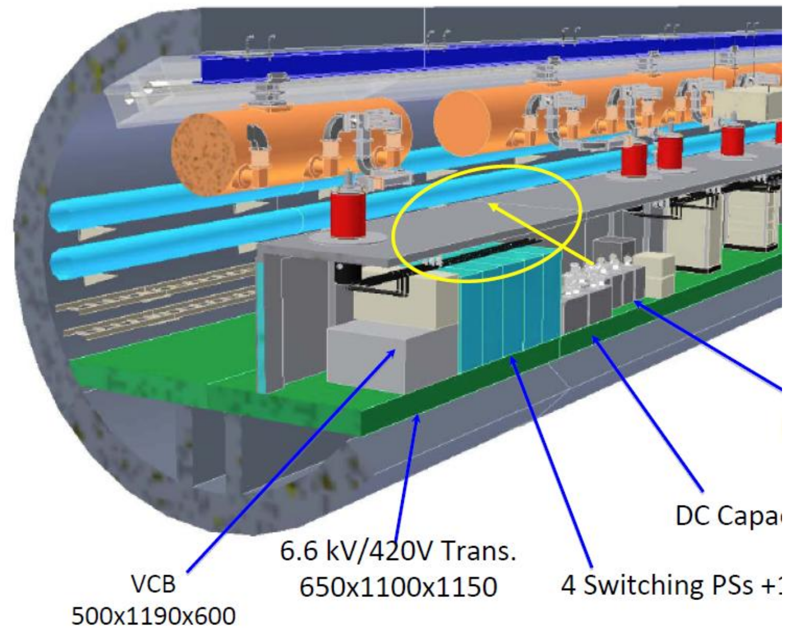
In each 152m, low voltage power facility (LVPF) is introduced and 6.6kV power is reduced to 420 V to deliver power to 4 stations.



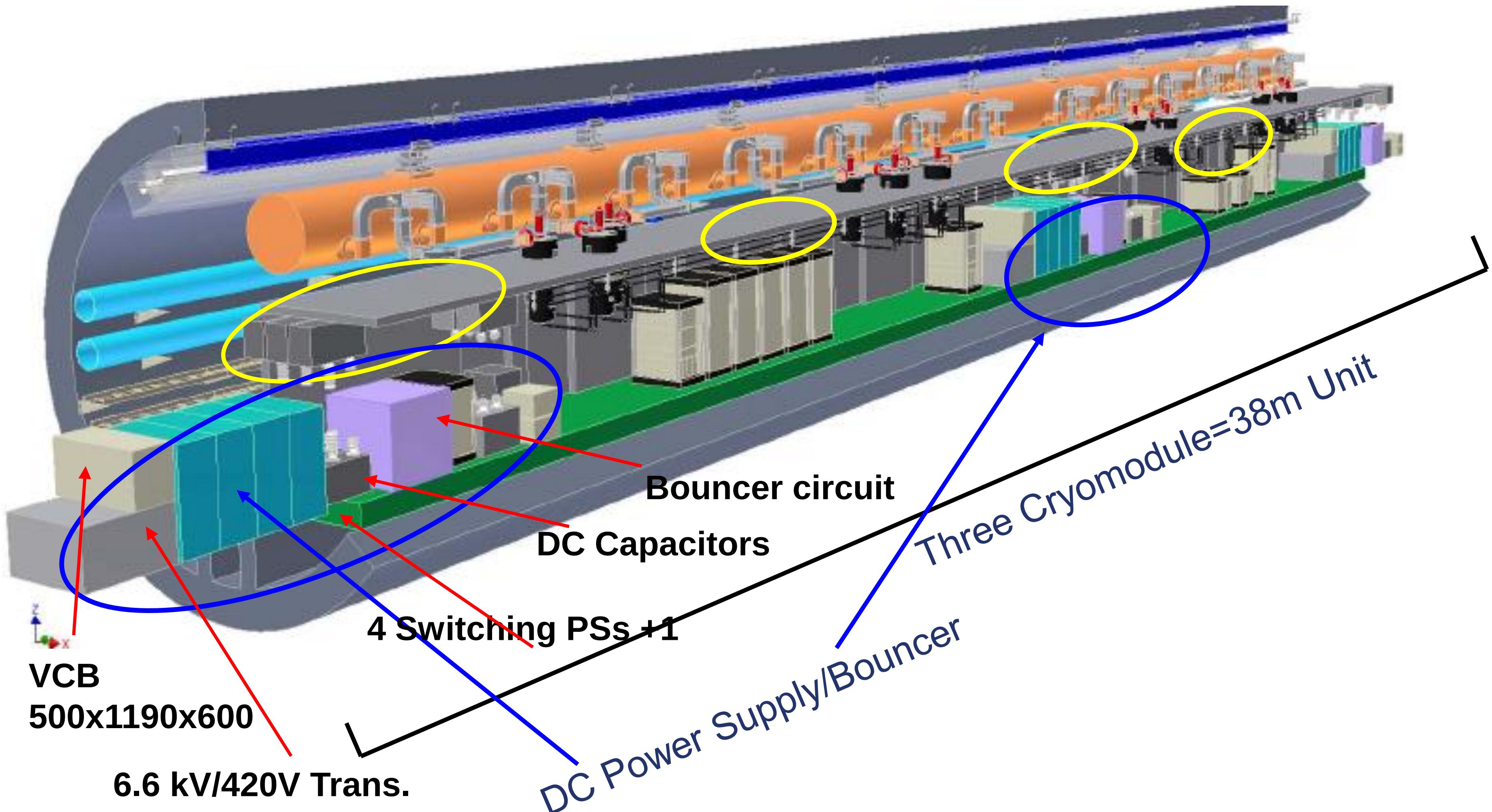
3D drawing of low voltage power facility



Circuit Diagram



DRFS Tunnel Layout
Cryomodule from Ceiling



Tunnel layout of Cryo from Ceiling (2) Cross Section

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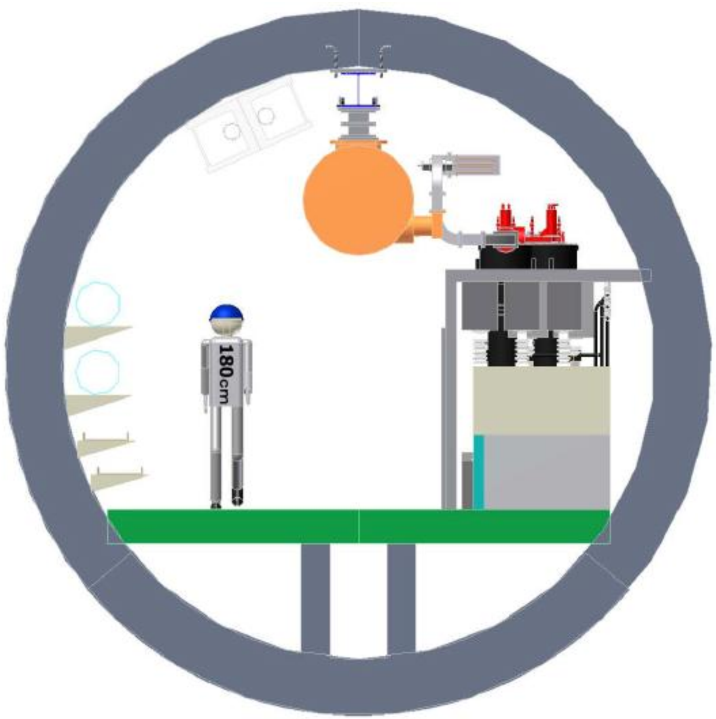
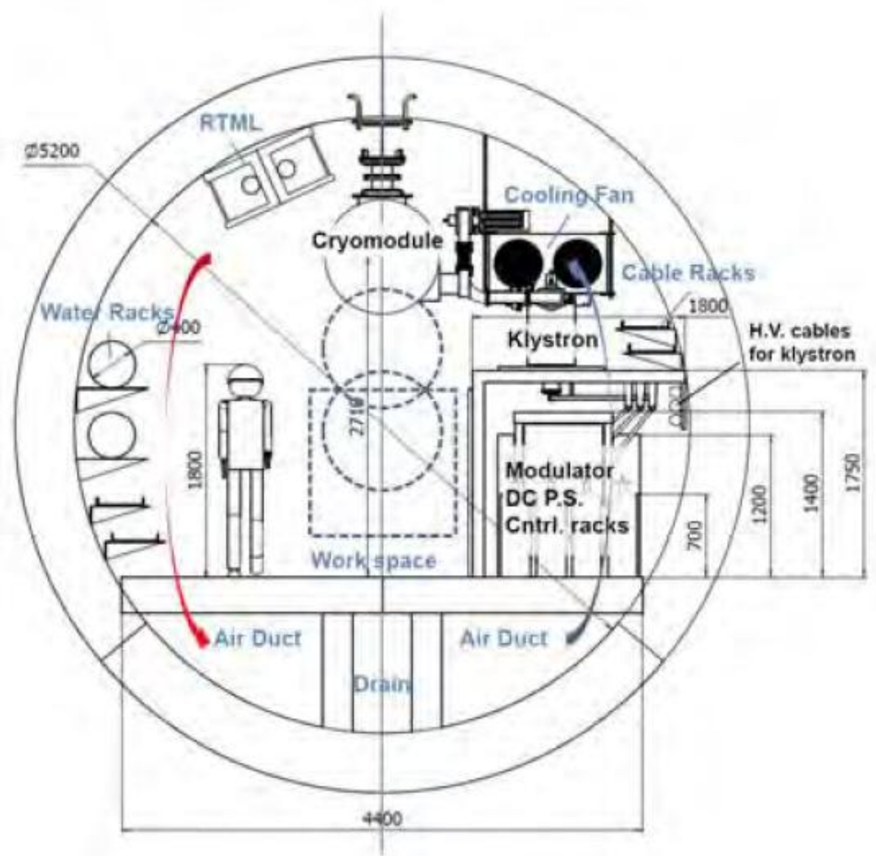
Tunnel Diameter ϕ5.2m
Cryomodule is hanged from Ceiling

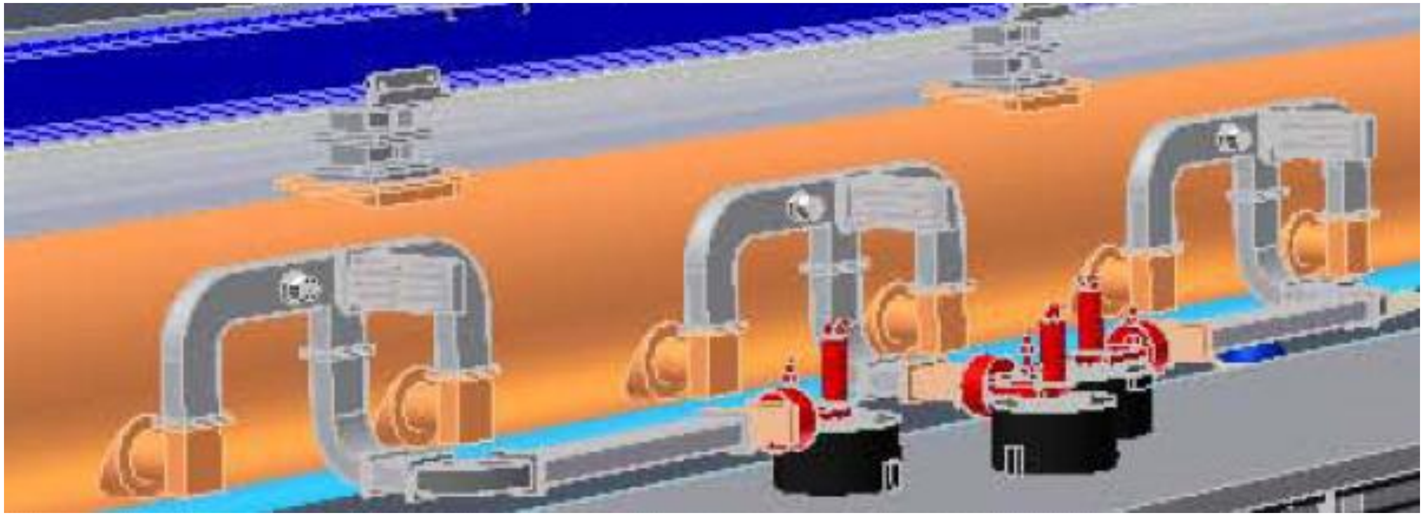


Electronics and Racks are installed in the radiation shield.



PDS in DRFS Cryomodule from Ceiling

Waveguide system eliminating WR650 flanges as possible as we can to achieve cost down.
PDSs are supported by the stems attached to cryomodule and LLRF
Adjustments are performed before installation.



DRFS Tunnel Layout Cryomodule on the floor

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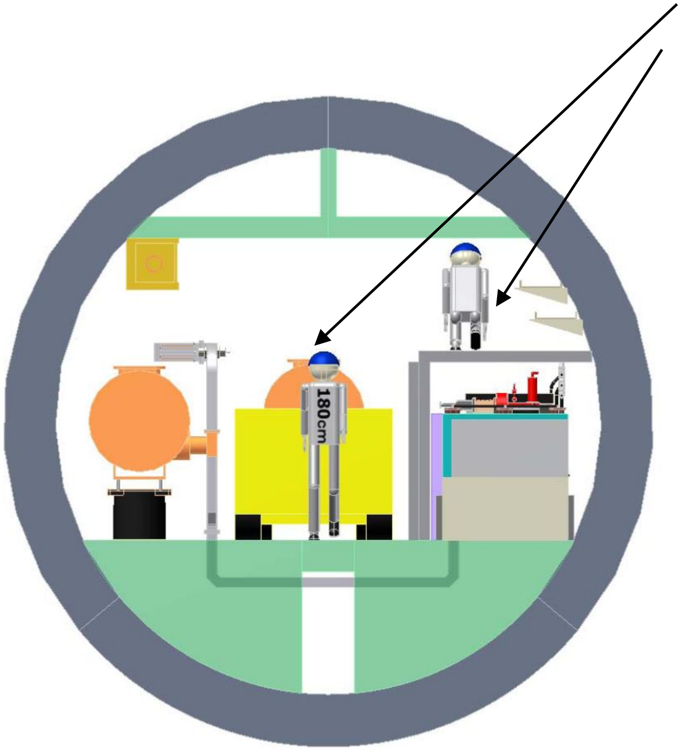
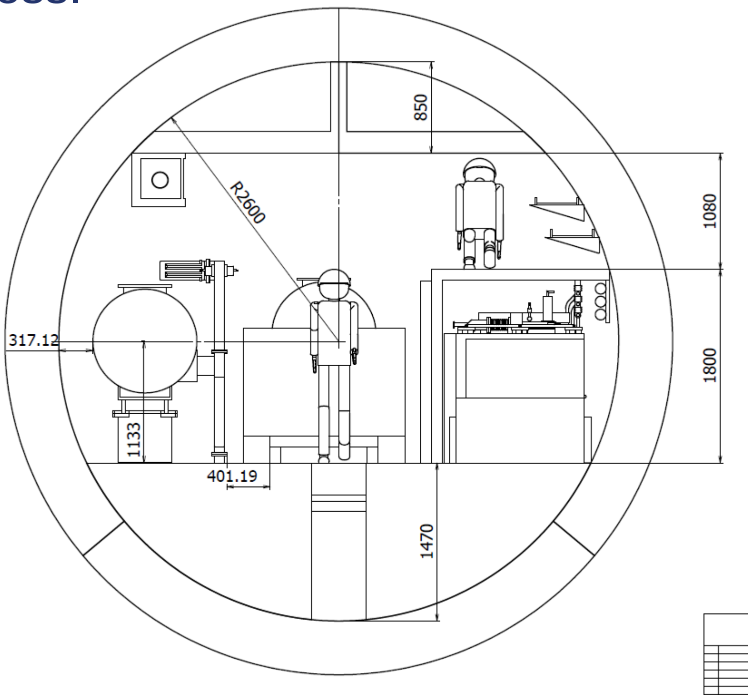
- Progress
  - Longer power distribution systems from the klystron to cryomodule are introduced. They are buried in the floor.
  - Except for PDS, basic configuration for z-direcrion is the same as the configuration of cryomodule from ceiling.
  - Ventilation and He exhausting duct are moved to the ceiling.
  - All components including klystrons are placed on the floor.
  - Still emergency egress when the cryomodule are installed, there are two plans;
    - If cryomodule installation is performed by a special carrier, part of the emergency egress is on the shield.
    - Or if cryomodule is installed from the carrier on the floor, it is necessary to increase the tunnel diameter from 5.2m to 5.75 m.

Tunnel layout of Cryo on the Floor (2) Cross Section

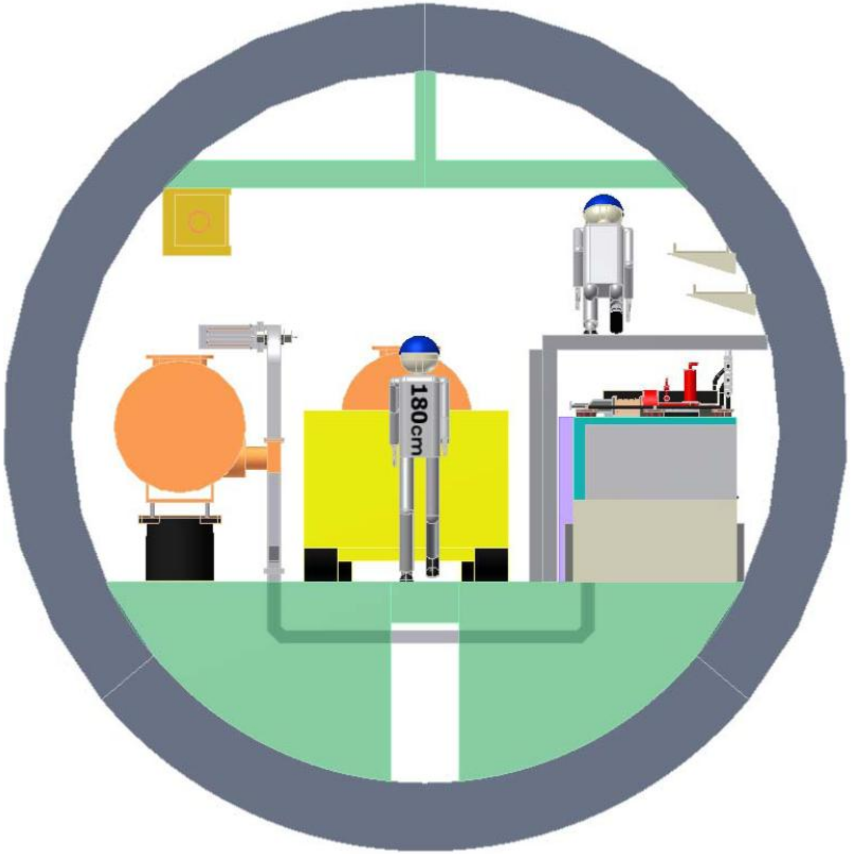
Tunnel Diameter F5.2m
Cryomodule is set on the floor

One can use the central corridor as the emergency egress where carrier is not there, while where carrier has cryomodule, one has to pass on the shield as the egress.





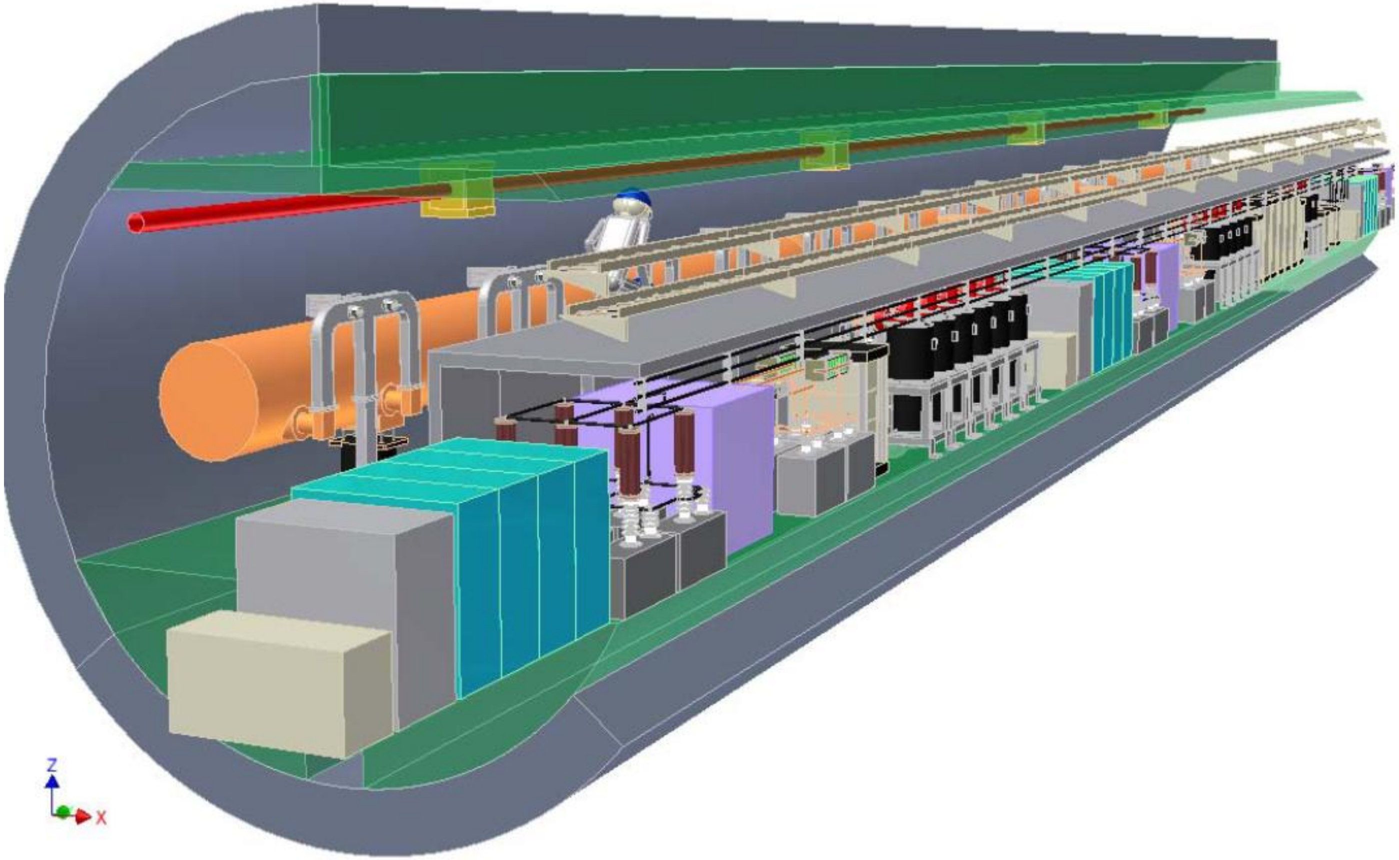
Comment for the plan of Cryomodule on the floor



- Common design for DRFS is available among the three regions.
- Almost required components are possible to install in a pure single tunnel.
- PDS cost increased comparing with the DRFS of cryomodule from ceiling.
- Heat dissipation problem is the disadvantageous points for DRFS comparing with other alternatives and needs more studies.
- Radiation shield evaluation for the electrical components are also required.

LLRF modules are set near the cryomodule in all possible plans and further data or simulation are desirable.

DRFS Tunnel Layout
Cryomodule on the floor



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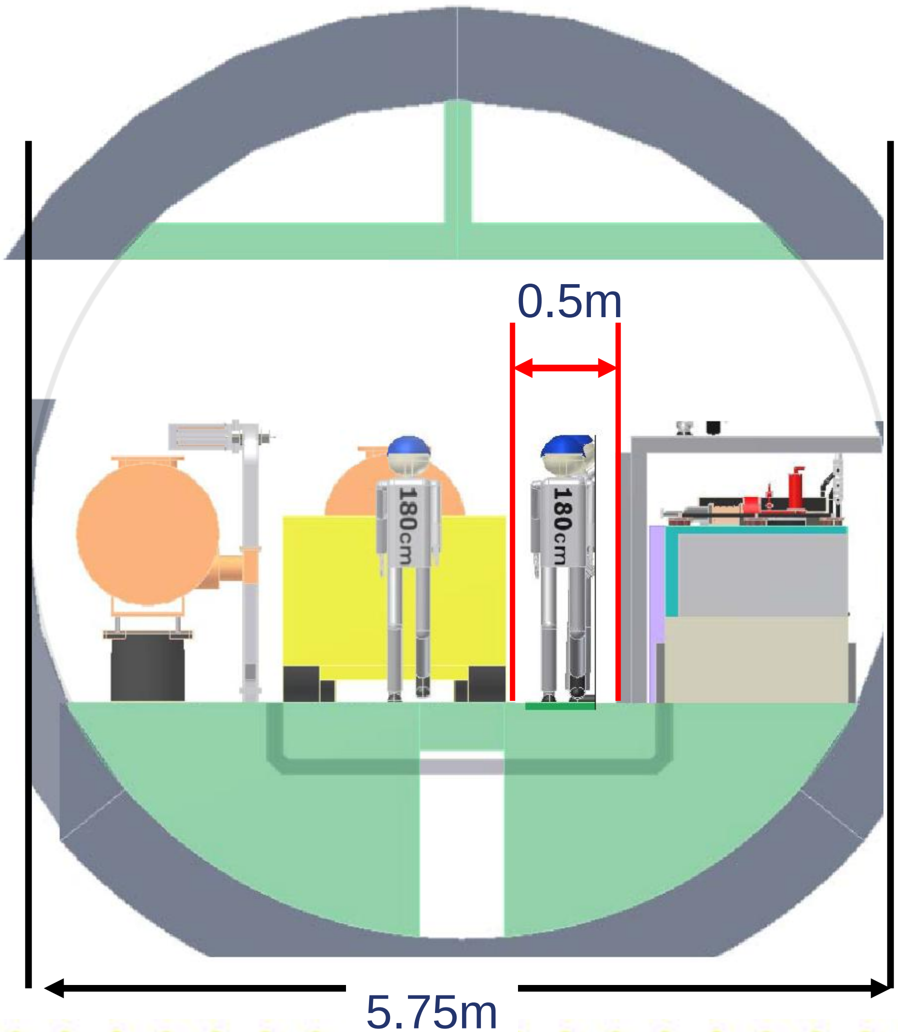
DRFS for 5.75 Diameter Tunnel



Another alternative plan is to increase the tunnel diameter from 5.2m to 5.75m.

It is easy to keep the emergency egress

(13+13)/38 m		1.79	0.00			0.00		
(1+1)/38 m			0.63			0.63		
			161.25	133.61	11.26	4.31		

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Heat Dissipation Revised

May 20 2010

WATER AND AIR HEAT LOAD for Revised DRFS

MAIN LINAC - ELECTRON & POSITRON							To Low Conductivity	to Chilled Water	To Fan Coil Chilled Water		OIL(k litter)
Components		Quantity Per 38m	Location	Total Heat Load (KW)	Average Heat Load (KW)		Heat Load to LCWater (KW)	Heat Load to Rack Chilled Water (KW)	Heat Load to Fan Coil Chilled Water (KW)	Max Space Temp (C)	
Non-RF Components											
LCW Skid Pump 1 per 4 rf - Motor/Feeder Loss		0.25	Service Tunnel	0.60	0.60		0	0	0.60		
I^2R Loss and Motor Loss (misc)		1	Service Tunnel	0.00	16.12		0	0	12.00		
Fancoils (5 ton Chilled Water) 1.5 Hp		2	Service Tunnel	2.91	2.91		0	0	2.91		
Rack Water Skid		0.25	Service Tunnel	0.20	0.20		0	0	0.20		
Lighting Heat Dissipation -1.3W/sf			Service Tunnel	1.65	1.65		0	0	1.65		
AC Pwr Transformer 34.5-.48 kV		0.25	Service Tunnel	2.00	2.00		1.50	0	2.00		
Emerg. AC Pwr Transformer 34.5-.48 kV			Service Tunnel	1.00	1.00		0	0	1.00		
RF Components											
--- High Voltage Circuit Breaker: VCB (6.6 kV) ---	Rack	1/38 m	Single Tunnel								
--- High Voltage Circuit Breaker: VCB (6.6 kV) --- Spare	Rack	1/76 m	Single Tunnel								
Step Down Transformer from 6.6kV to 420V/98% 4kW	Tank	1/38 m	Single Tunnel		4.00		3.20				0.4
Step Down Transformer from 6.6kV to 420V/Spare 5%	Tank	1/76 m	Single Tunnel		5.00		4.00				0.2
Switching Regulator Power Supply 420V/ 80% 40kW	Rack	1/38 m	Single Tunnel		40.00		32.00				0.06
Switching Regulator Power Supply 420V/ Spare 10%	Rack	1/76 m	Single Tunnel		2.00		1.60				0.03
Capacitor Limitter Registor 3.8kW		1/38 m	Single Tunnel		3.80		3.04				0.36
Capacitor Limitter Registor Spare		1/76 m	Single Tunnel		0.00		0.00				0.18
Bouncer Coil 0.5kW		1/38 m	Single Tunnel		0.50		0.40				0.17
Bouncer Coil 0.5kW Spare		1/76 m	Single Tunnel		0.00		0.00				0.085
Modulating Anode Modulator, 6.6 kV (Shunt 1.0 A, then 6 kW heat load)	Rack 3	1/38 m	Single Tunnel		6.00		4.80	0.00	0.00		0.2
Modulating Anode Modulator, 6.6 kV (Shunt 1.0 A, then 6 kW heat load), (Back-up)	Rack 4	1/76 m	Single Tunnel								0.1
Crawbar 1.2mx1.2mx1.2m		1/38 m									1.7
Crawbar 1.2mx1.2mx1.2m Spare		1/76 m									0.85
--- AC Transformer to Low Voltage (400/200/100 V) ---		1/152 m									
Heater P/S, 200V,11A, 2.2kW 90%	Rack 3	1/38 m	Single Tunnel		0.24		0.19	0.24	0.00		
Same as above (Back-up)	Rack 4	1/76 m	Single Tunnel							85 F	
Pulse Transformer		None									
Klystron Socket Tank / Gun 0.17 kW X 13=2.2kW		13/38 m	Single Tunnel		2.20		1.76	0.00	0.44		
Klystron Focusing x 26 (Permanent Magnet)		13/38 m	Single Tunnel		0.00						
Klystron Collector 4.5 kW X 13=59kW		13/38 m	Single Tunnel		58.50		56.75	0.00	1.76		
Klystron Body & Windows		13/38 m	Single Tunnel		3.76		3.76	0			
--- LLRF Racks ---											
LLRF+Amp +Int, 200V,2.5A /5 modules	Rack 5	1/38 m	Single Tunnel		0.35			0.35	0.00		
LLRF+Amp +Int, 200V,1.5A /3 modules	Rack 7	1/38 m	Single Tunnel		0.21			0.21	0.00		
LLRF+Amp +Int, 200V,2.5A /5 modules, for full power op.	Rack 8	1/38 m	Single Tunnel		0.35			0.35	0.00		
LLRF+Amp +Int, 200V,2.5A /5 modules Spare		1/76 m	Single Tunnel		0.18			0.18	0.00		
LLRF+Amp +Int, 200V,1.5A /3 modules Spare		1/76 m	Single Tunnel		0.11			0.11	0.00		
LLRF+Amp +Int, 200V,2.5A /5 modules, Spare		1/76 m	Single Tunnel		0.18			0.18	0.00		
--- Other Racks ---											
Timing , 200V,0.5kW	Rack 10	1/38 m	Single Tunnel		0.50			0.50	0.00		
Cavity , 200V,3 kW	Rack 12	1/38 m	Single Tunnel	2.95	2.05			2.05	0.00		
Cryogenics, 200V, 2.1 kW	Rack 14	1/38 m	Single Tunnel		2.10			2.10	0.00		
BPM & Mag, 200V, 5 kW	Rack 16	1/38 m	Single Tunnel		5.00			5.00	0.00		
--- RF Loads ---											
Attenuator		None									
Waveguides in service tunnel		None									
Waveguides in penetration		None									
Waveguides in beam tunnel		13/38 m	Single Tunnel		0.80		0.00	0.00	0.80		
Circulator with load		None									
RF Loads		13/38 m	Single Tunnel		22.80		22.12		0.68		
--- Other Loads ---											
Pulse motor for input coupler/tuner		(13+13)/38 m		1.79	0.00				0.00		
Vacuum Pumps		(1+1)/38 m			0.63				0.63		
Subtotal RF unit Only					161.25		133.61	11.26	4.31		
Total RF											

Evaluation of Total Heat Dissipation is Increased comparing with the RDR.

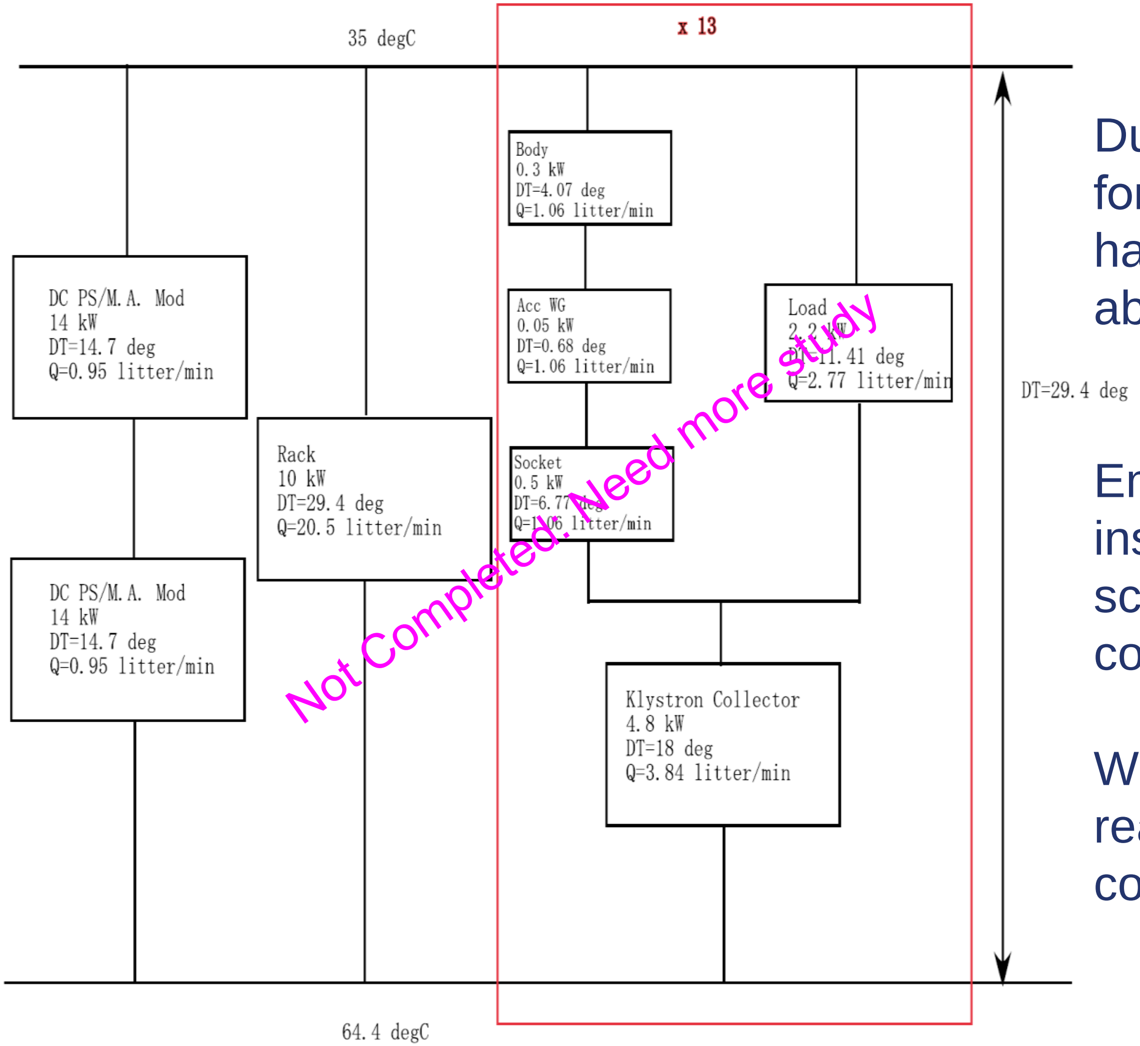
Except for the power dissipation for the redundant spare, increase owes to an pessimistic estimation of efficiency for the switching regulator P/S etc.

It is necessary to establish the basic data for the realistic efficiency.

Nominal value is strongly depend on the cavity's operation scheme. DRFS has an advantage for this point.

Insulation Oil Estimation used in the tunnel is performed.

Example of Cooling Scheme



Due to not enough budget for CFS in KEK, we didn't have a final and clear design about cooling scheme.

Emile hope to an unified instrument racks from scattered rack to achieve cost efficient cooling system.

We may need the rearrangement of unit configuration.

Concerns about the radiation effects against the electrical component in the tunnel

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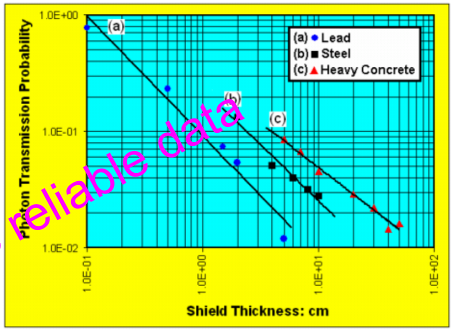
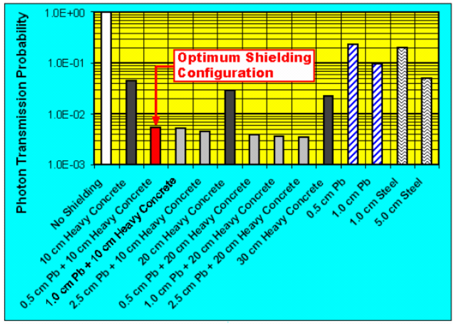
- **Since DRFS is a complete single tunnel plan, great concern of the radiation effect against the electrical components in the tunnel.**
- **Front ends of LLRF are required to be near to the cavities, RDR base line and KCS would face to the same problems.**
- **DRFS has a shielding structure which is assumed to be similar with FLASH and XFEL. All electronics would be installed in this shield.**
- **First study for the radiation effect is studied by FLASH facility in advance to construct XFEL. DRFS first insight for this problems is come from their study.**

Watch the X-FEL data or Need more reliable data

Efficacy testing of shielding materials for XFEL using the radiation fields produced at FLASH

TESLA-FEL 2008-06





In SB2009 document, we assume the shied of 10 cm heavy concrete and 1cm lead.

Summary

- CFS related of Distributed RF Scheme (DRFS) is presented.
- This is one of the possible HLRF system for a cost-effective solution in support of a single Main tunnel design.
- Realistic components are installed in the single tunnel.
- In this presentation, three possible tunnel layout plans and are shown;(1) Cryomodule from the ceiling with 5.2m dia. Tunnel, (2) Cryomodule on the floor with 5.2m dia. And (3) Cryomodule on the floor with 5.75m dai.
- We need to refine the configuration of AC power line and cooling issues.
- Some of unknown issues will be solved thru the manufacturing of prototype for S1-global in 2010.
- Complete design will be hopefully presented in GDE10 in CERN.