DRFS Equipment

KEK S. Fukuda

- Introduction: presentation in Beijing / Status
- Basic Concept of DRFS
- DRFS Tunnel Layout
- AC Power Supply
- Heat Dissipation
- Radiation Shield
- Maintenance
- Summary

Talks concerning with DRFS in LCWS10 in Beijing

- S. Fukuda DRFS Equipment Joint CFS March 27 am
  CFS matter: Layout, Cooling etc.
  Components, Equipment Detail

- S. Fukuda DRFS Development HLRF March 27 pm
  This presentation
  M. Akemoto(Webex) Power supply for DRFS March 27 pm
  Power Supply System R&D of DRFS
  S. Michizono DRFS LLRF system configuration March 27 pm
- S. Fukuda S1-Global RF Preparation March 29 am

  S. Michizono S1-Global study plan March 29 pm

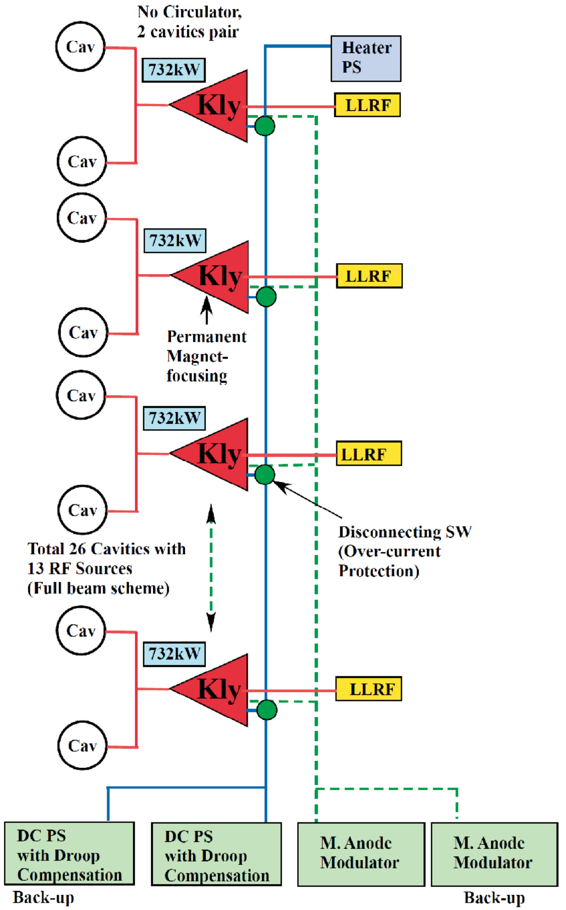
Status of CFS Related Issues for DRFS

- Due to the insufficient budget for the CFS design, drastic progress is not obtained.
- For DRFS layout in the single tunnel, unknown factor is the realistic power supply size. We are now designing the proto-type DRFS system comprised of two klystron system for S1 global plan, while this is tentative specification due to the short of period and human resource, and the size is not optimized yet.
- AC power feed line from 6.6kV line is also not yet optimized.
- Cooling issue are checked by prototype model.
- We hope to have a clear design up to GDE meeting in CERN in fall in 2010.

Concept of DRFS

- 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

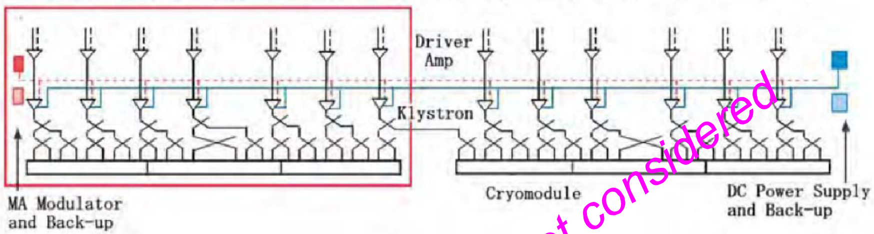
In the RDR scheme, three units of ILC cryomodules, containing 26 cavities in total, are driven by the RF power from one unit of 10MW L-band klystron.

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

Base line DRFS and upgrade pass

Base Line Scheme @ 26-Cavities (1 klystron feeds 4 cavities)



System configuration of DRFS in the baseline case.

Half Current Option is not considered

Base Line Scheme (@ 3 Cryomodules)

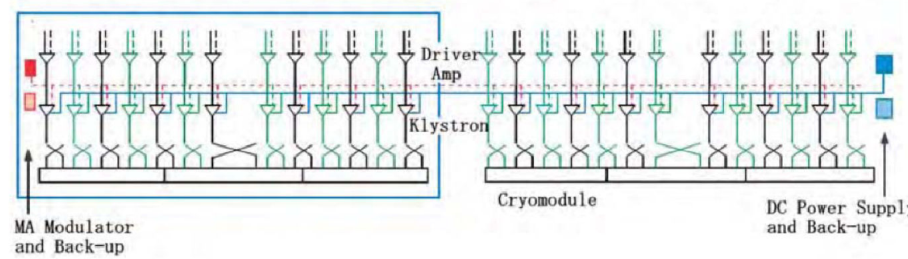
Cavity	26	
DC	26	
Magic T	19.5	
750kW Kly.	6.5	
PM Focusing	6.5	
Coil PS	0	PM focusing
Heater PS	0.5	(0.5 back-up)
Preamp	6.5	
MA Pulser	0.5	(0.5 back-up)
LLRF & Intlk	6.5	
DC P/S	0.5	(0.5 back-up)

The component count for the DRFS in the baseline case. For comparison with the RDR. The numbers are quoted for a group of three cryomodules.

Base Line Configuration

= High Current Scheme

High Current Scheme @ 26-Cavities (1 klystron feeds 2 cavities)



High Current Scheme (@ 3 Cryomodules)

Cavity	26	
DC	26	
Magic T	13	
750kW Kly.	13	
PM Focusing	13	
Coil PS	0	PM focusing
Heater PS	1	common (1 back-up)
Preamp	13	
MA Pulser	1	(1 back-up)
LLRF & Intlk	13	
DC P/S	1	(1 back-up)

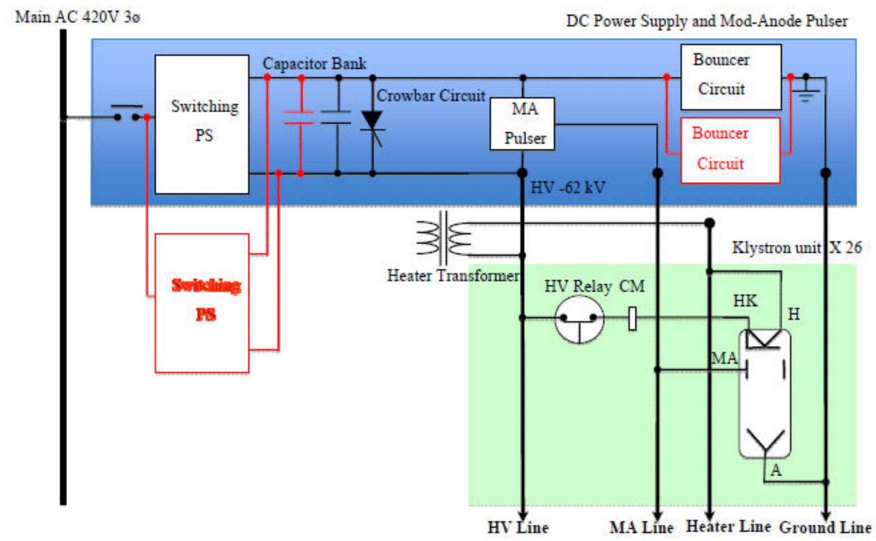
The component count for the DRFS in the high-current case. For comparison with the RDR, the numbers are quoted for a group of three cryomodules.

Modulator Scheme/Base Line DRFS

• 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 **a high-voltage SW**, 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.

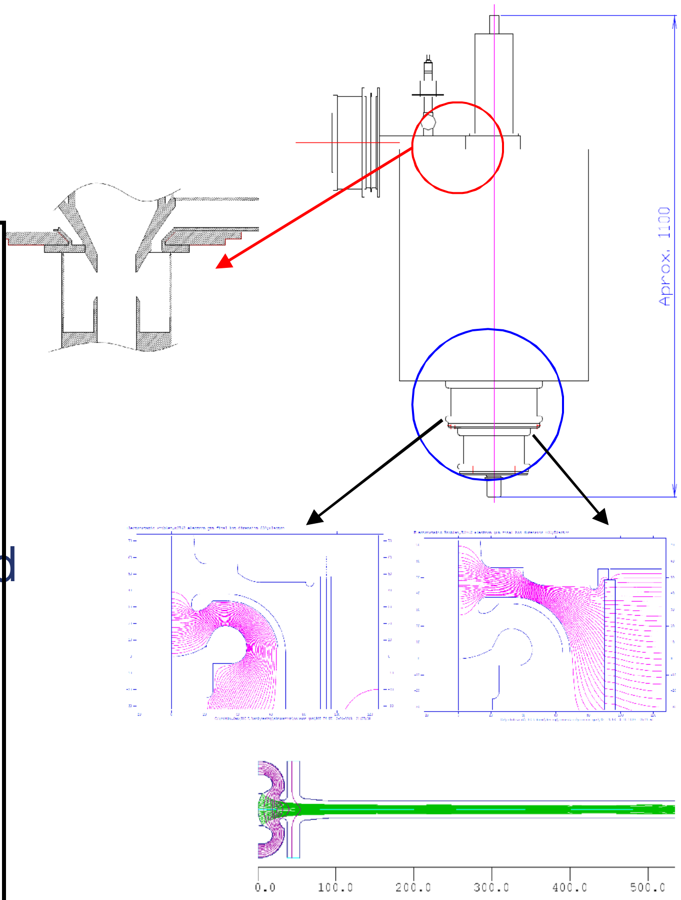
Klystron for DRFS

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



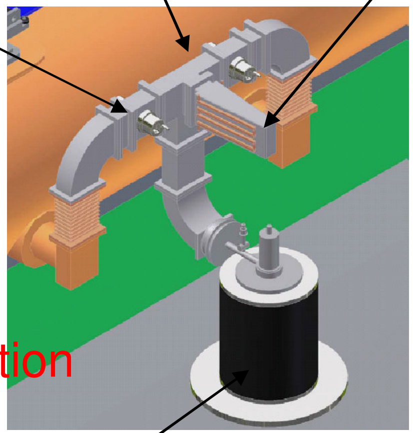
Power Distribution System (PDS) in Base line DRFS

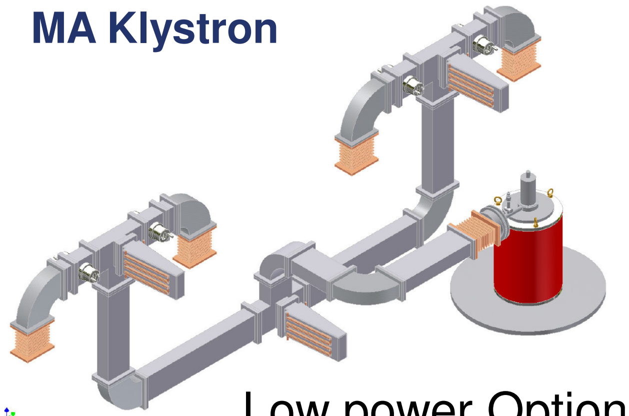
Very simple power distribution system
- No circulator
- Power divider employs magic tee with high isolation for space saving.
- One Phase-shifter with symmetric PDS between couplers or asymmetric PDS with a phase-fixed waveguide for cost saving

•Design of eliminating flange as possible

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

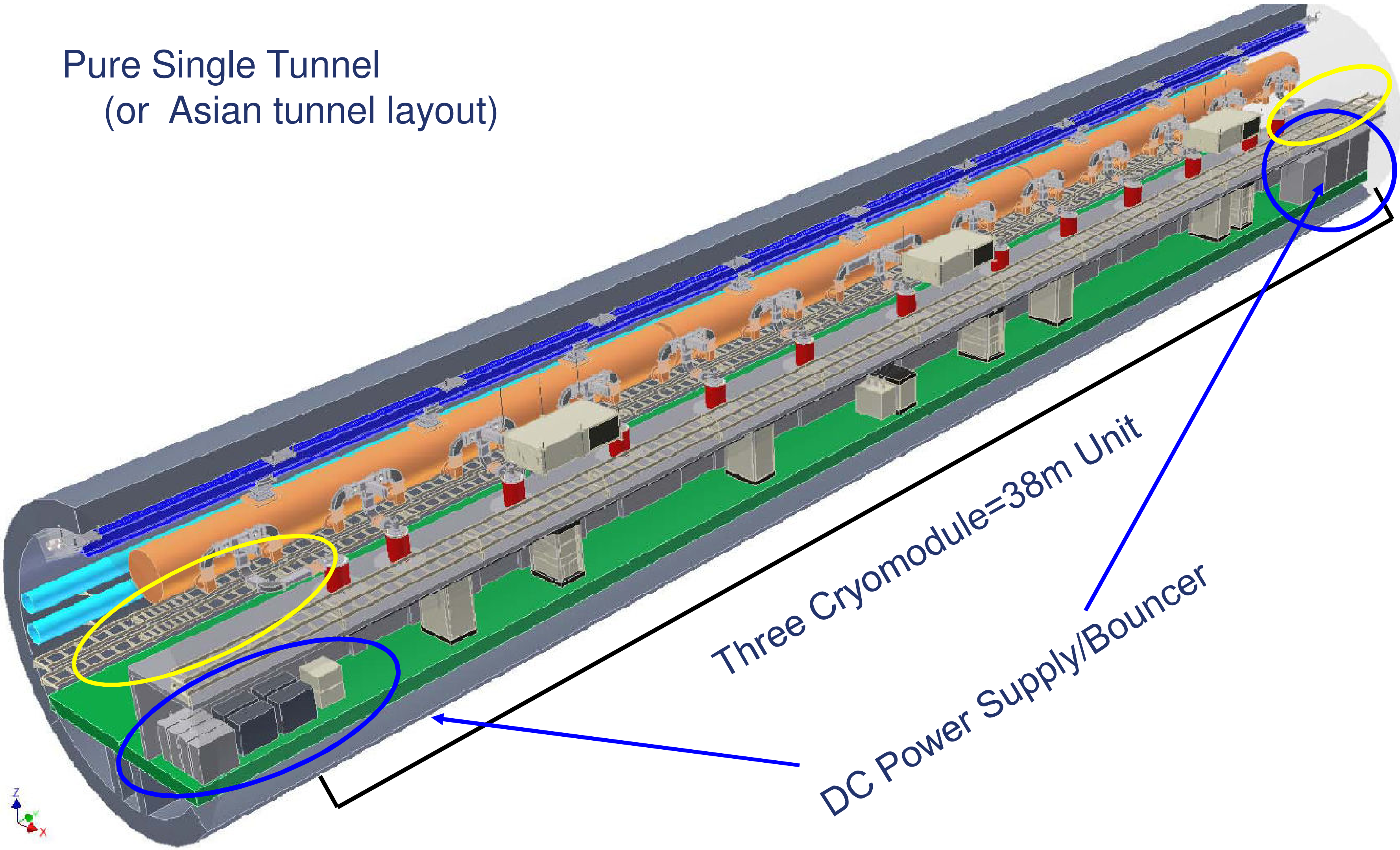
- In low power option, an MA klystron feeds power to 4 cavities and additional PDS is required.





DRFS Tunnel Layout (1)

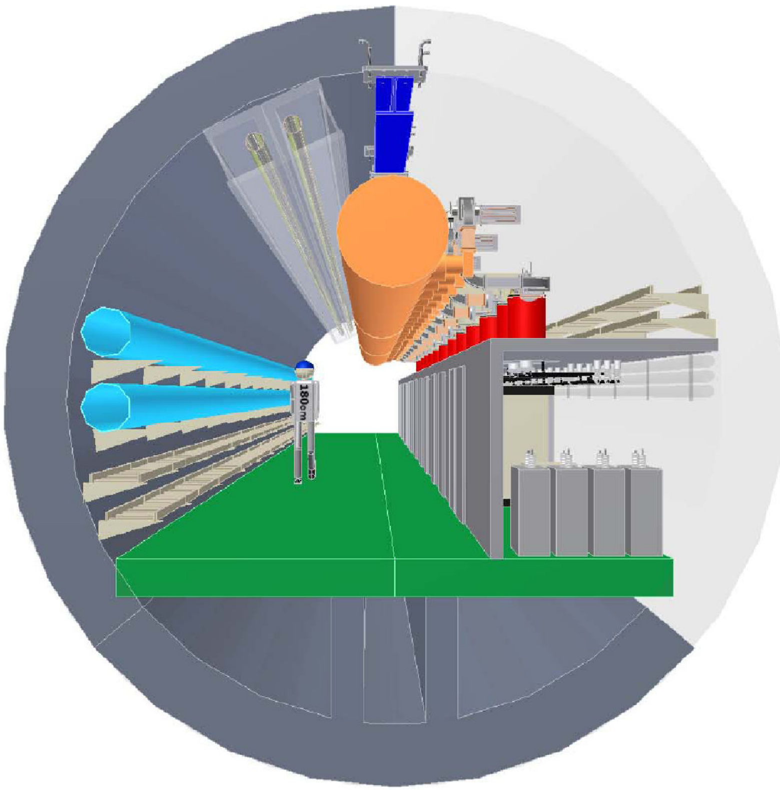
Pure Single Tunnel
(or Asian tunnel layout)

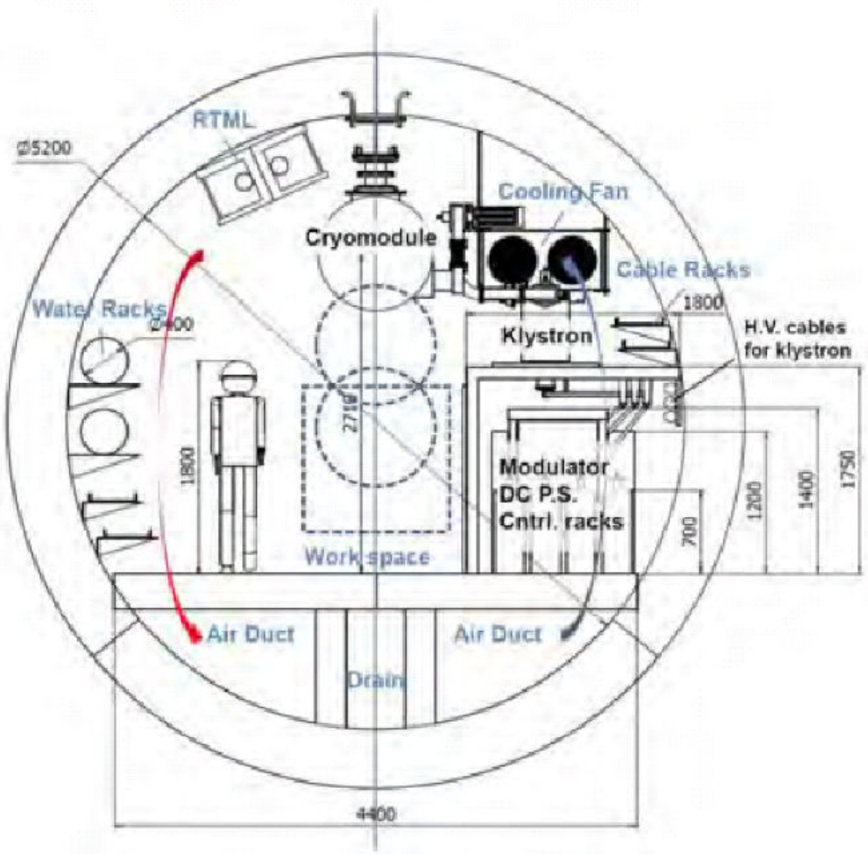


Tunnel layout (2) Cross Section

Tunnel Diameter F5.2m
Cryomodule is hanged from Ceiling

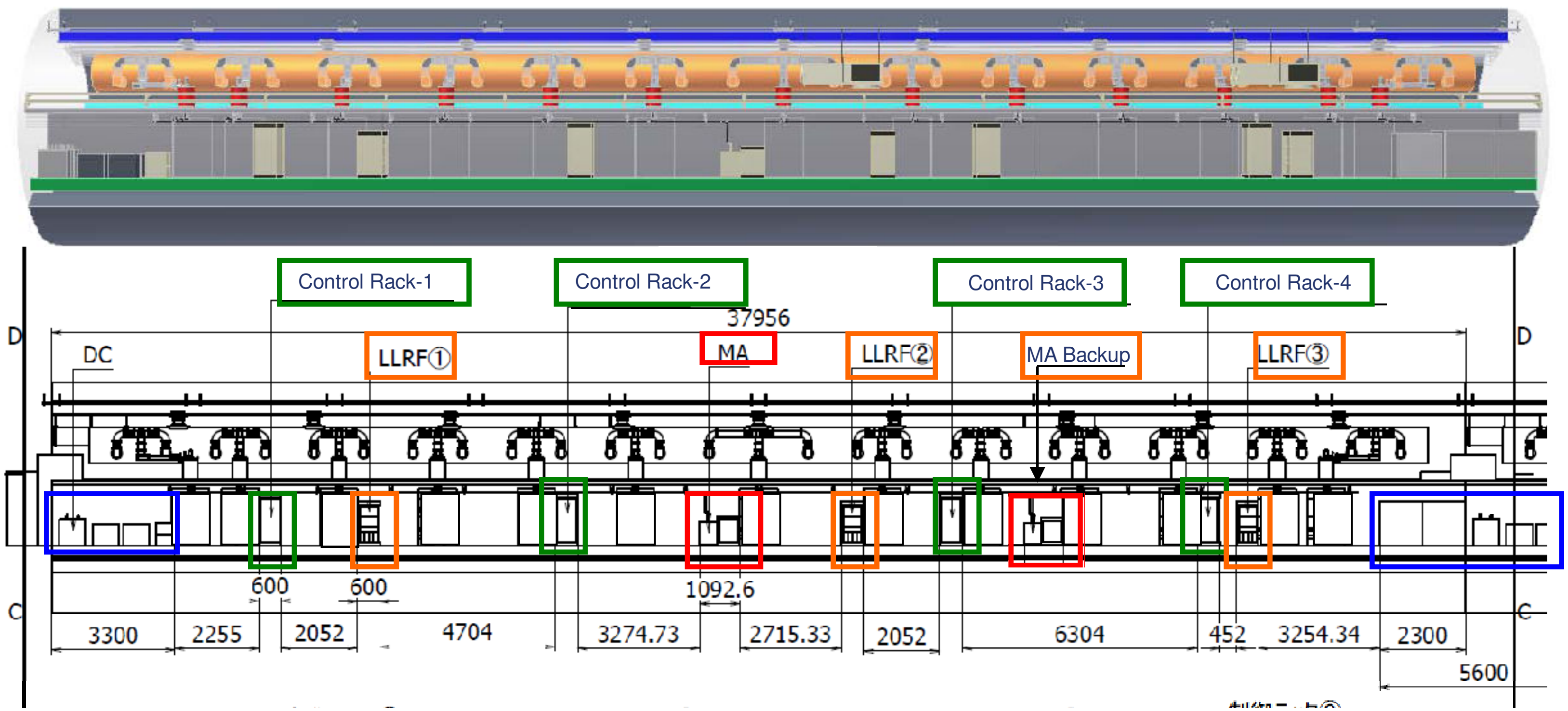
Electronics and Racks are installed in the radiation shield.

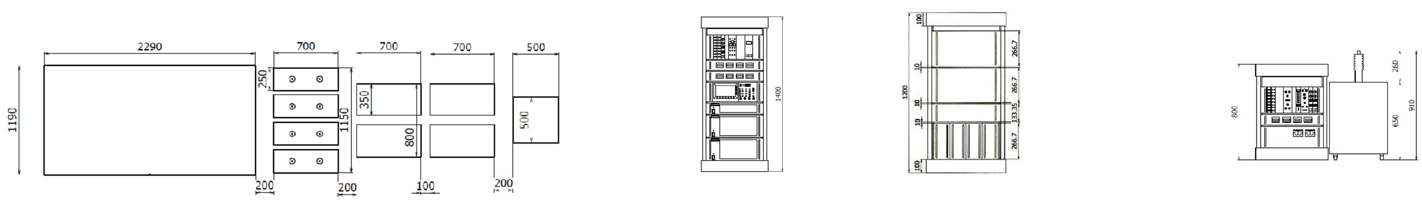




Tunnel Layout (3) Side View

Three Cryomodule Unit (~38m)





DC P/S & Bouncer

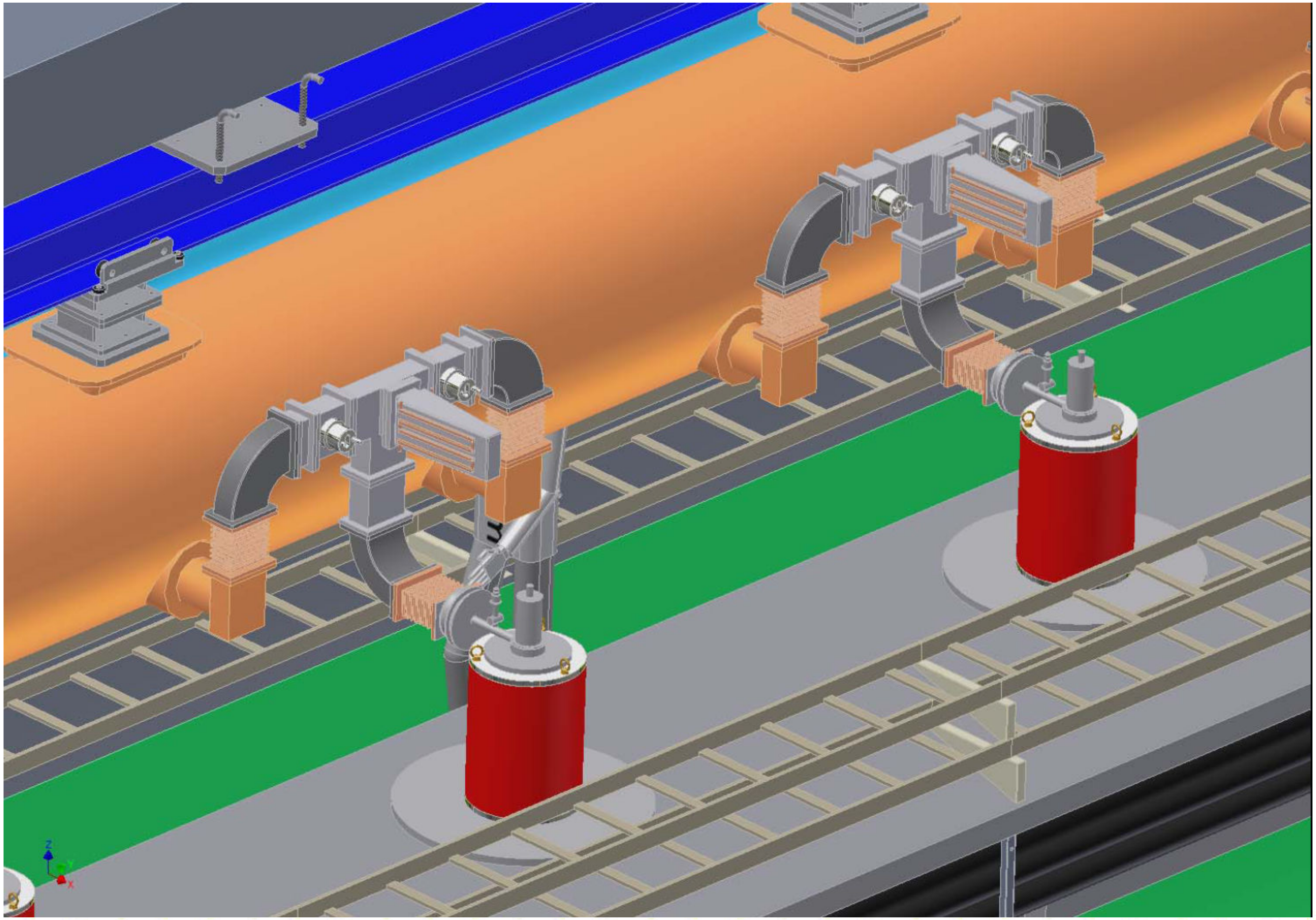
Control Rack

LLRF Rack

MA Modulator

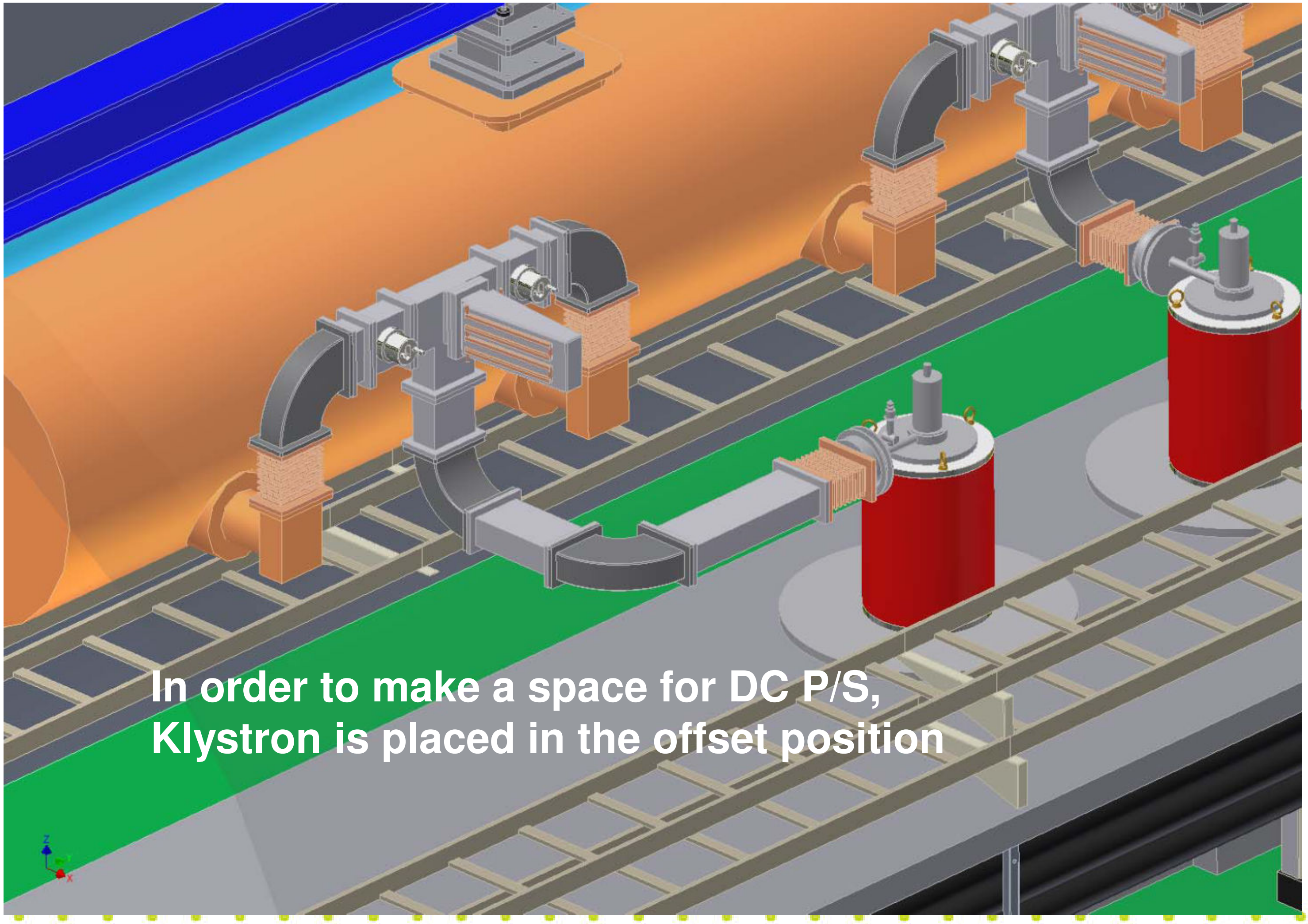
Power Distribution System 1

Regular Section

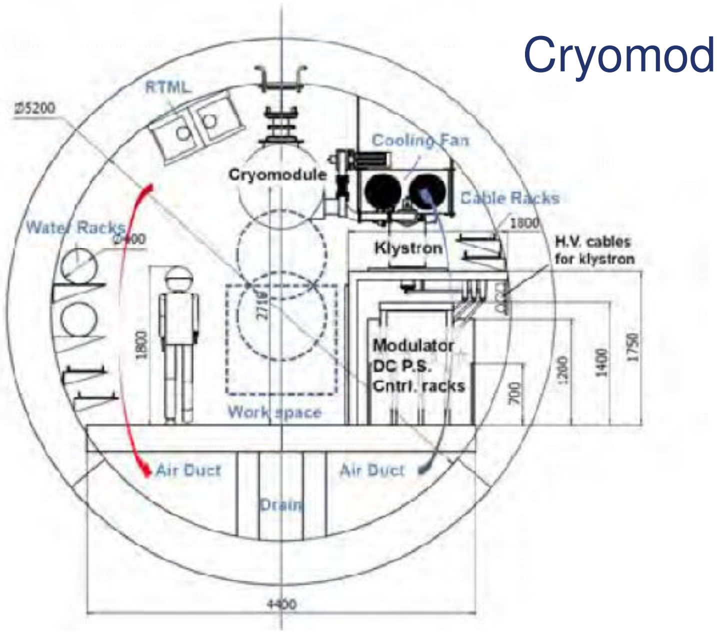


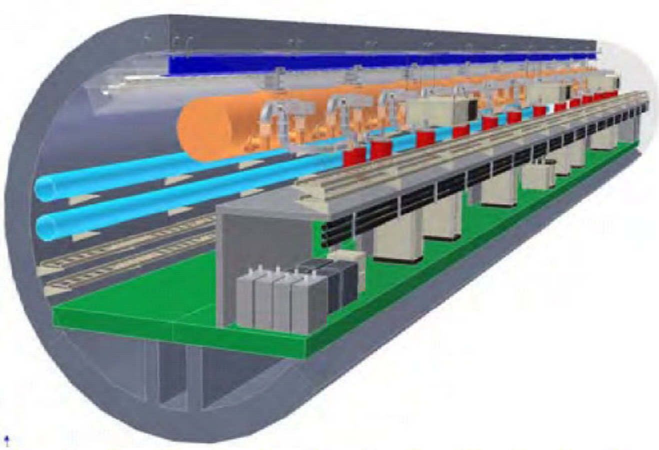
Power Distribution System 2

Boundary Section of 3-Cryomodule Unit



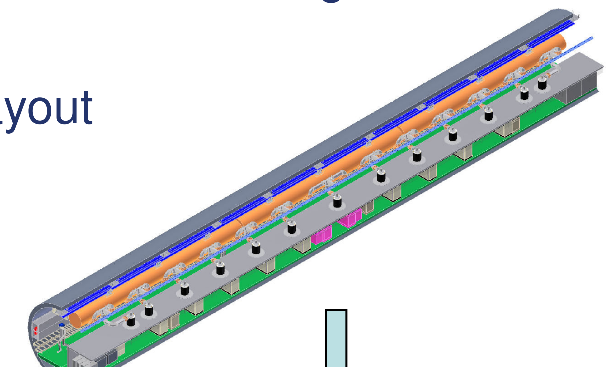
DRFS Tunnel Layout in the case of Low Current Option



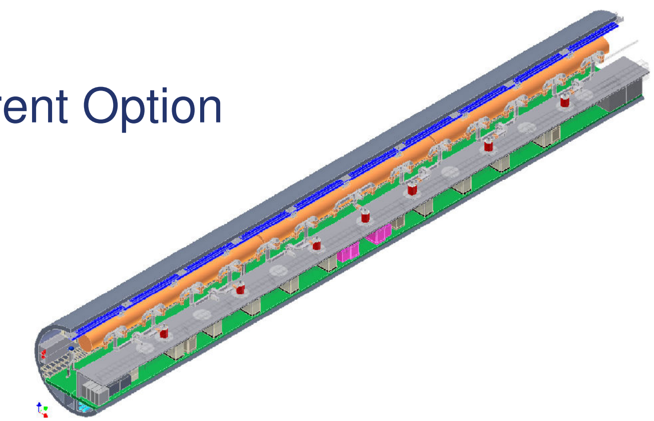


Cryomodule is hanged down from ceiling

Base line layout

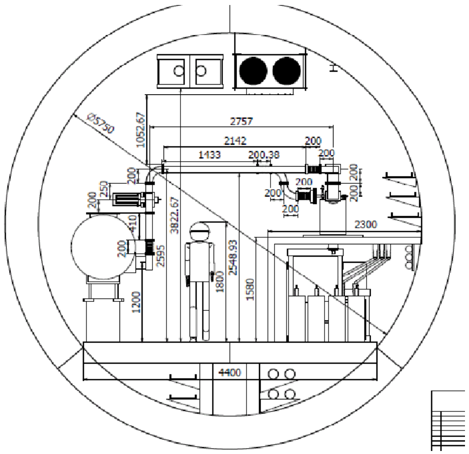


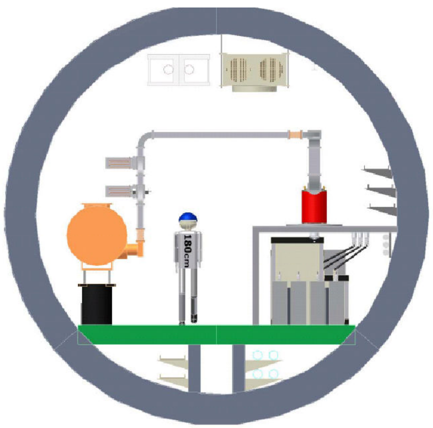
Low Current Option

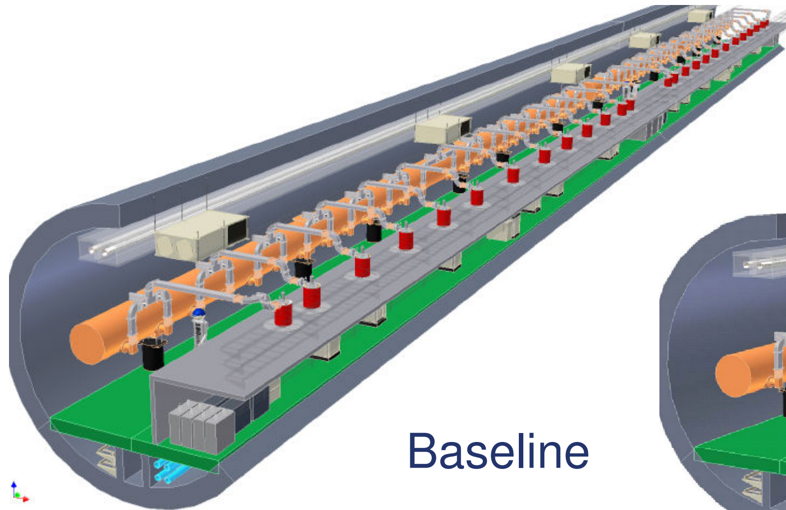


Example of LowP
PDS Layout

Another Layout of DRFS
Cryomodule on the ground

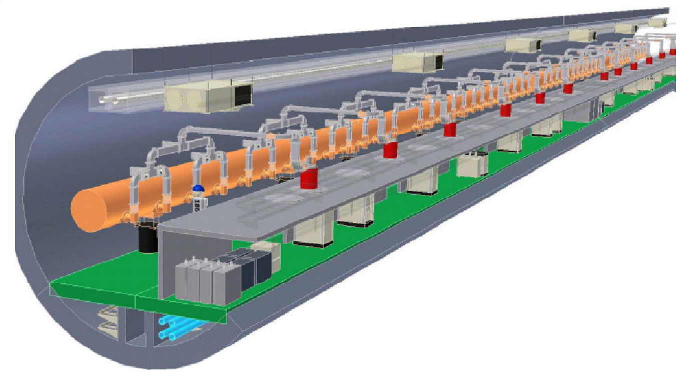


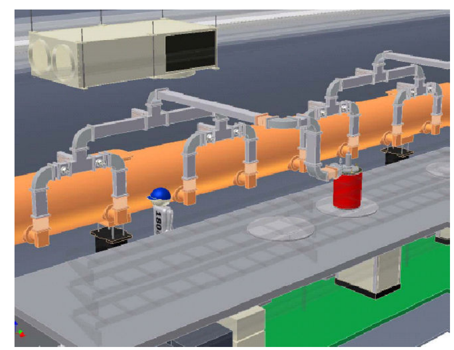




Baseline

High Current Scheme





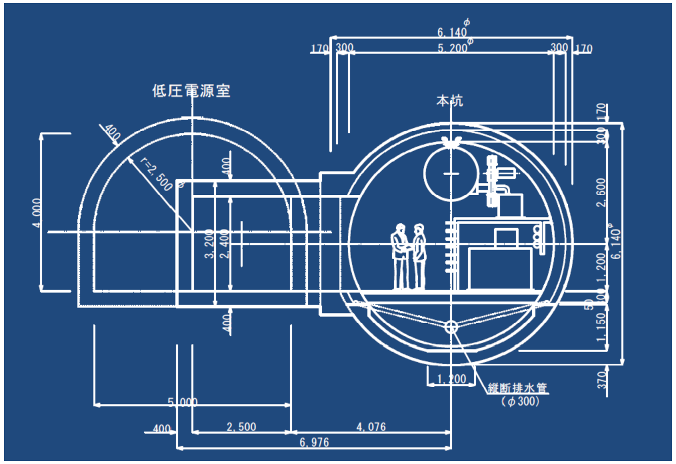
If tunnel diameter is chosen to be 5.75m, it is possible to have an enough maintenance/installing space in the center.

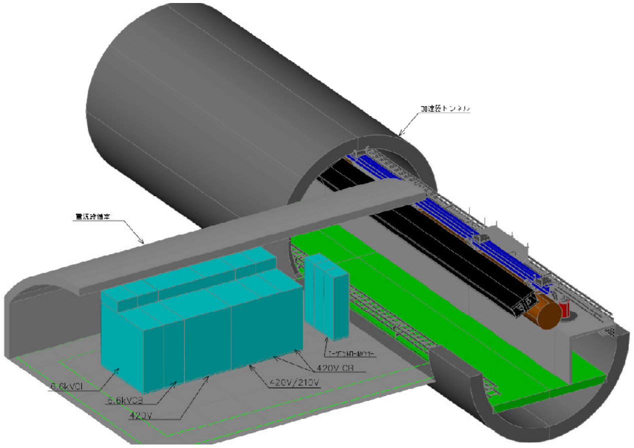
AC Power Supply Line

- For Power Supply Line, we didn't finish the final design and so far there are two possibilities :
  - **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 to each DRFS station (3-cryomodule unit) and reduced to 420V and power is fed via disconnect switch.**

    If 6.6kV VCB is compact, we employ 6.6kV VCB.
    - We didn't finish design and concern equipment size.

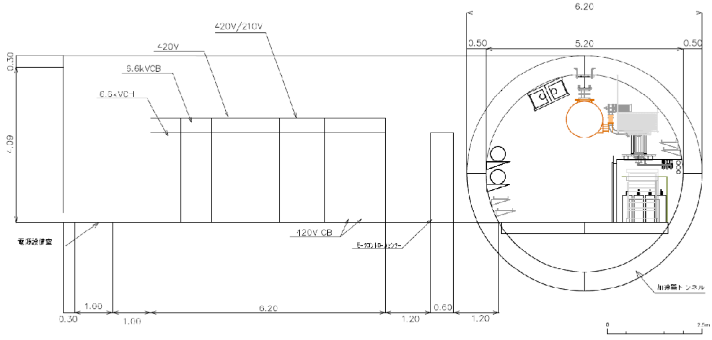
Plan-1:Low Voltage Power Facility



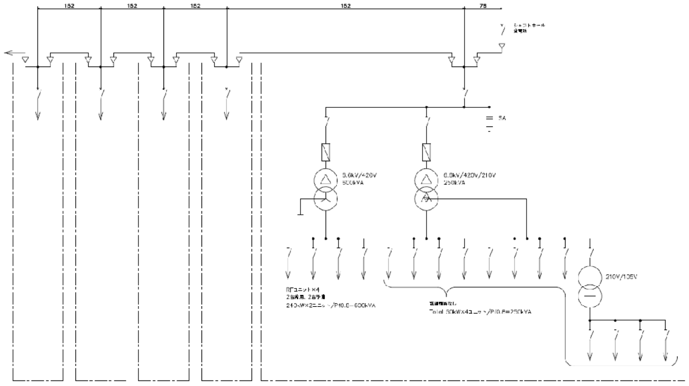


In each 152m, low voltage power facility (LVPF) is introduced and 6.6kV power is reduced to 420 V to deliver power to 4 stations.

3D drawing of low voltage power facility

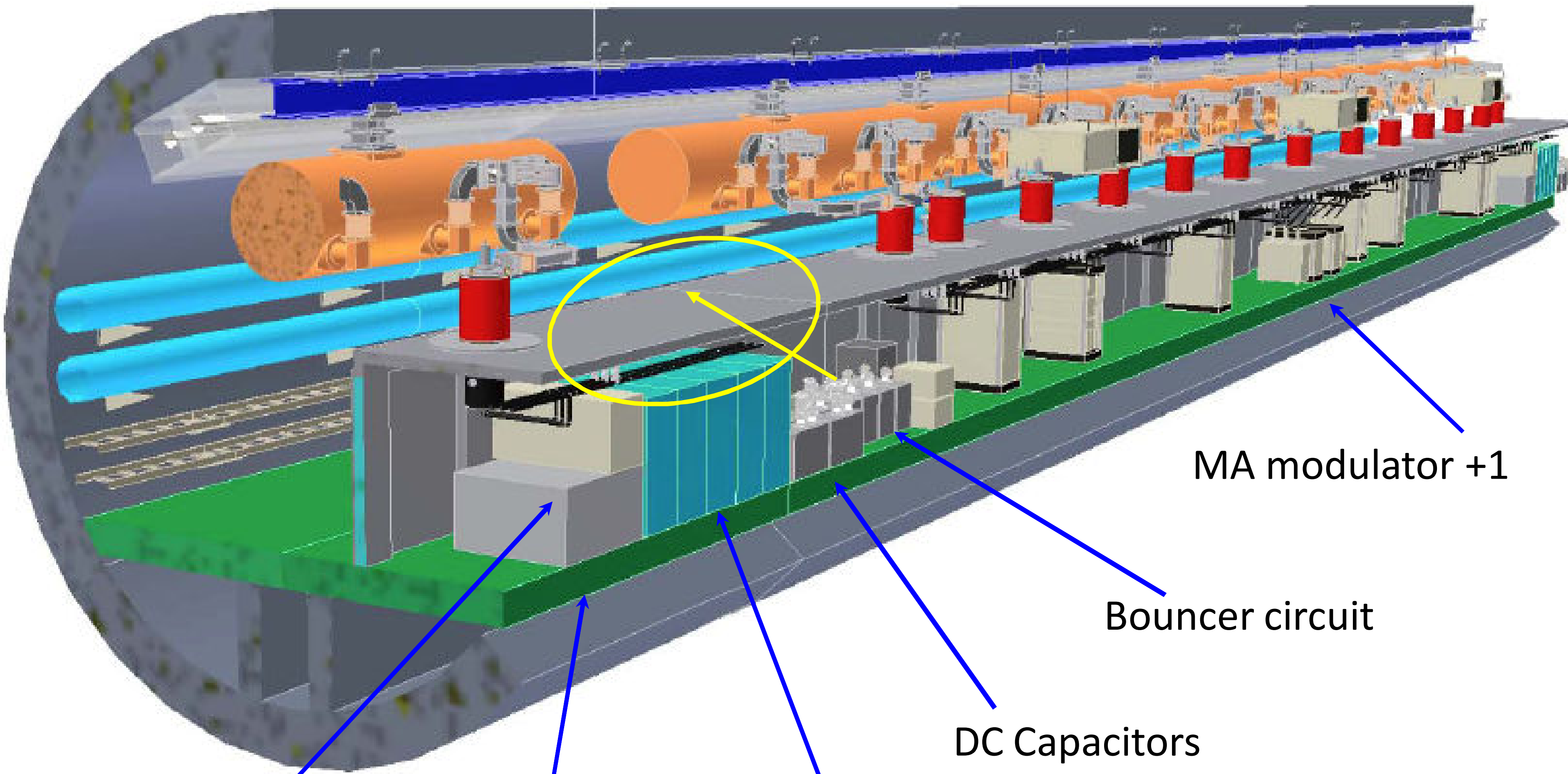


Side view of LVPF and size of transformer and VCB



Circuit Diagram

Plan-2 Each Unit Having 6.6kV/420V Transformer



Water Cooling Comparison Full Scheme DRFS

Oct 31 2007

WATER AND AIR HEAT LOAD (all LCW) and 9-8-9 ML

MAIN LINAC - ELECTRON & POSITRON

Components	Quantity Per 36m	Location	Total Heat Load (KW)		
Non-RF Components					
LCW Skid Pump 1 per 4 rf - Motor/Feeder Loss	0.25	Service Tunnel	0.60	0.60	0.60
I^2R Loss and Motor Loss (misc)	1	Service Tunnel	10.92	10.81	10.39
Fancoils (5 ton Chilled Water) 1.5 Hp	2	Service Tunnel	2.91	2.91	2.91
Rack Water Skid	0.25	Service Tunnel	0.20	0.20	0.20
Lighting Heat Dissipation ~1.3W/sf		Service Tunnel	1.65	1.65	1.65
AC Pwr Transformer 34.5-.48 kV	0.25	Service Tunnel	2.00	2.00	2.00
Emerg. AC Pwr Transformer 34.5-.48 kV		Service Tunnel	1.00	1.00	1.00
RF Components					
RF Charging Supply 34.5 Kv AC-8KV DC	1/36 m	Service Tunnel	4.0	4.00	14.0
Switching power supply 4kV 50kW	1/36 m	Service Tunnel	7.5	7.50	
Modulator	1/36 m	Service Tunnel	7.5	7.50	
Pulse Transformer	1/36 m	Service Tunnel	1.0	0.00	0.0
Klystron Socket Tank / Gun	1/36 m	Service Tunnel	1.0	6.5	6.5
Klystron Focusing Coil (Solenoid)	1/36 m	Service Tunnel	5.5	20.0	0.0
Klystron Collector	1/36 m	Service Tunnel	59.8	59.80	59.8
Klystron Body & Windows	1/36 m	Service Tunnel			
Relay Racks (Instrument Racks)	1/36 m	Service Tunnel	10.0	10.00	10.0
Attenuators	2/36 m	Service Tunnel	1.0	0.00	0.0
Waveguide (in service tunnel)	1/36 m	Service Tunnel			
Waveguide (in penetration)	1/36 m	Penetration	0.6	0.00	0.0
Waveguide (in beam tunnel)	1/36 m	Beam Tunnel	4.0		0.8
Circulators With loads (isolator)	26/36 m	Beam Tunnel		0.00	0.0
Loads	24/36 m	Beam Tunnel	22.8	22.80	22.8
Subtotal RF unit Only			109	108	104
Total RF			144	157	133

RDR

DRFS Full Scheme

Assume the same efficiency with J-Parc DC PS. If backup operates, It is doubly high.

No Pulse Transformer

Increase Socket Number from 1 to 13

Permanent Magnet Focusing

Cancel with decrease of PDS loss and Increase klystron collector loss due to The lower efficiency

Slight increase including the 2 MA modulators

Some amount of increases including the13 MA modulators

No circulator

Water Cooling Comparison LowP DRFS

Oct 31 2007

WATER AND AIR HEAT LOAD (all LCW) and 9-8-9 ML

MAIN LINAC - ELECTRON & POSITRON					
Components	Quantity Per 36m	Location	Total Heat Load (KW)		
Non-RF Components					
LCW Skid Pump 1 per 4 rf - Motor/Feeder Loss	0.25	Service Tunnel	0.60	0.60	0.60
I^2R Loss and Motor Loss (misc)	1	Service Tunnel	10.92	10.39	5.36
Fancoils (5 ton Chilled Water) 1.5 Hp	2	Service Tunnel	2.91	2.91	2.91
Rack Water Skid	0.25	Service Tunnel	0.20	0.20	0.20
Lighting Heat Dissipation ~1.3W/sf		Service Tunnel	1.65	1.65	1.65
AC Pwr Transformer 34.5-.48 kV	0.25	Service Tunnel	2.00	2.00	2.00
Emerg. AC Pwr Transformer 34.5-.48 kV		Service Tunnel	1.00	1.00	1.00
RF Components					
RF Charging Supply 34.5 Kv AC-8KV DC	1/36 m	Service Tunnel	4.0	14.0	7.0
Switching power supply 4kV 50kW	1/36 m	Service Tunnel	7.5		
Modulator	1/36 m	Service Tunnel	7.5		
Pulse Transformer	1/36 m	Service Tunnel	1.0	0.0	0.0
Klystron Socket Tank / Gun	1/36 m	Service Tunnel	1.0	6.5	3.3
Klystron Focusing Coil (Solenoid)	1/36 m	Service Tunnel	5.5	0.0	0.0
Klystron Collector	1/36 m	Service Tunnel	59.8	59.8	29.9
Klystron Body & Windows	1/36 m	Service Tunnel			
Relay Racks (Instrument Racks)	1/36 m	Service Tunnel	10.0	10.0	10.0
Attenuators	2/36 m	Service Tunnel	1.0	0.0	0.0
Waveguide (in service tunnel)	1/36 m	Service Tunnel			
Waveguide (in penetration)	1/36 m	Penetration	0.6	0.0	0.0
Waveguide (in beam tunnel)	1/36 m	Beam Tunnel	4.0	0.8	1.6
Circulators With loads (isolator)	26/36 m	Beam Tunnel		0.0	0.0
Loads	24/36 m	Beam Tunnel	22.8	22.8	11.8
Subtotal RF unit Only			109	104	54
Total RF			144	133	77

RDR
DRFS Full
DRFS LowP

Assume the same efficiency with J-Parc DC PS. If backup operates, It is doubly high.

No Pulse Transformer

Increase Socket Number from 1 to 13

Permanent Magnet Focusing

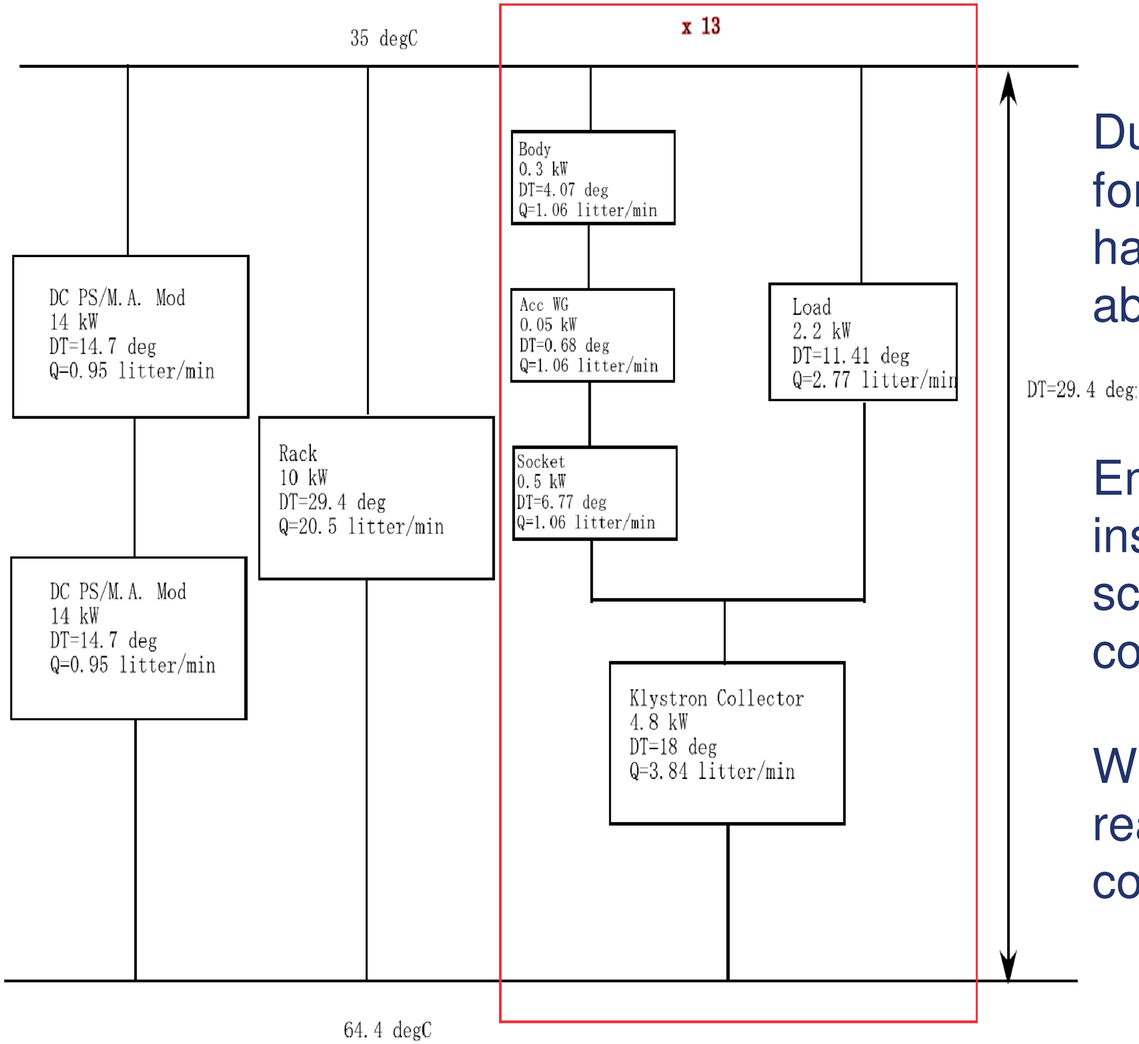
Cancel with decrease of PDS loss and Increase klystron collector loss due to The lower efficiency

Slight increase including the 2 MA modulators

Some amount of increases including the13 MA modulators

No circulator

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.

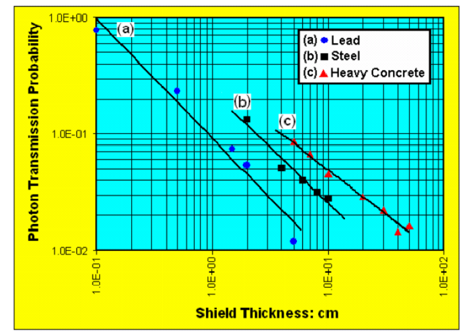
We may need the rearrangement of unit configuration.

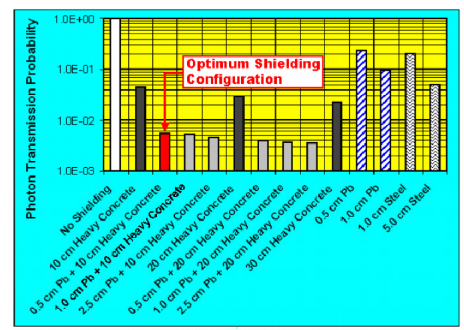
Concerns about the radiation effects against the electrical component in the tunnel

- **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.**

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

TESLA-FEL 2008-06



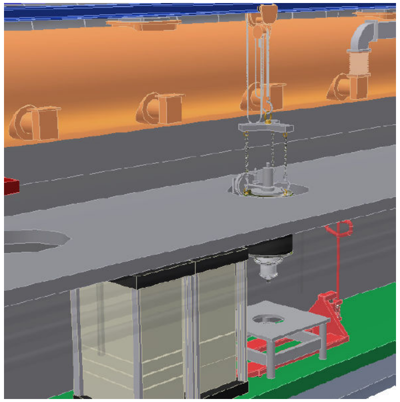


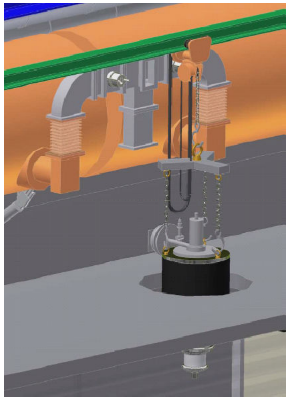
In SB2009 document, we assume the shied of 10 cm heavy concrete and 1cm lead.

DRFS Exchanging Working In Scheduled Shut down (in Baseline)

- **Maintenance model: 24 hours maintenance in every 2-weeks of continuous operation (312hrs)**
- **Numbers of replacement required**

Component	# of units requiring replacement or repair	MTBF assumed	Total # of units deployed at the ILC
DC power supply	2	50,000 hours	325
MA modulator	1.5	70,000 hours	325
MA klystron	12	110,000 hours	4225





- **Estimated times of the repair work of DRFS**

Action	Time for unit piece of work	Rationale
Transportation of klystron	0.5 person-hours / tube	2 persons in 2 hours could bring 8 tubes on one carrier.
Removal of a failed klystron and installation of a replacement klystron	4 person-hours / tube	2 hours with 2 persons
Time for personnel to move from one point of repair to another	2/3 person-hours / tube	20 minutes with 2 persons
Replacement of a MA modulator	6.67 person-hours / modulator	
Replacement of a DC power supply	27 person-hours / DC power supply	

•Then 62 person-hour for 12 MA klystron replacement.
•10 person-h for 1.5 MA Mod.
•54 person-h for 2 DC PS.
•→16 person-days
•→43 person for 9 hours/shift

•Backup for Mod. and DC PS enables us to employ less person.

This is likely to be manageable!

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.
- In this presentation, tunnel layout and equipments are shown.
- 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.