Main Linac-HLRF
DRFS (Distributed RF System)

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Introduction
From AAP Review about DRFS

- Pros:

  With more flexibility in the RF control and less CFS cost

- Cons:
  - **The large increase in the number of klystrons is critical since the lifetime of the smaller klystrons is not expected to be dramatically longer.**
  - **Since maintenance will also be more demanding, the proposal still lacks a serious study of availability implications.**
  - **The heat load in the tunnel is increased.**
  - **The cost needs to be evaluated**

- **The AAP recognizes the merits of the proposals and suggests continuing the value engineering of these options. The value engineering must include a risk assessment , i. e. availability studies and maintenance ability in addition to the cost comparison.**

Task: Preparatory information for the DESY AD&I meeting 28-29.05.09

- WA
  - Single-tunnel housing
  - Two variants for HLRF:
    - Klystron Cluster
    - DRFS
- Questions:

- What is the best (projected) choice of the average accelerating gradient, given the current status of the R&D (see comment below).
- What are the primary impact / difference with respect to the RDR of the two proposed WA for the HLRF. Specifically for the main linac tunnel, shaft and support CFS.
- What are the implications for availability and operability.
- What are the implications (CFS) of the two currently proposed tunnel layouts (specifically location of cryomodules – see also 4b below).
- What are the set of common baseline assumptions that can be agreed upon (simplification)
  - **Tunnel diameter**
  - **Location of the cryomodules (beamline components) in the tunnel**
  - **Location and number of main utility shafts / caverns (e.g. cryogenic plants)**
  - **…**

Task: Mail from Marc to Convener

- The conveners for each session are expected to take on the responsibility for producing the case in support of the new baseline proposal. The case in support should include:

1. Pros and cons compared to the current RDR baseline.
2. Estimated cost impact
3. Impact on the risk register
4. The R&D programme(s) ;
   what can and can't be directly tested by 2012,
   Extrapolation to ILC specifications (remaining risks)
5. Estimated impact on. CFS; construction schedule (installation); operations & availability
6. Plan for 2009.
   An update of section 3
   ('Detailed Scope and Plans for Minimum Machine Studies'), including what will be presented and discussed at ALCPG09 in late September.

Pros and cons compared to the current RDR baseline.

- **Pros:**
  - **Cost reduction due to the single tunnel layout is expected**
  - **Almost maximum gradient of the manufactured cavity is available since a klystron feeds power only to two cavities and optimize LLRF control for two cavities.**
  - ***Advantage of power overhead is larger than RDR due to the simple PDS***
  - **Easy operability, high capability for the beam commissioning**
  - **Smaller effects for the klystron failure than RDR**
- **Cons:**
  - **Heat load is comparable with RDR, and larger than other single tunnel layout**
  - **Higher or comparable for the HLRF costs with RDR—need to study**
- **Need to study**
  - **Is maintenance more demanding?**

Q1
What is the best (projected) choice of the average accelerating gradient, given the current status of the R&D

Since the cryomodule and cavity installation scheme is the same in RDR, DRFS and Klystron cluster scheme, **difference on average accelerating gradient is depend on the PDS and LLRF control scheme.**

DRFS has a very simple PDS **without circulator**, and **power overhead is larger than RDR. Low loss due to the short PDS**

Since each unit is available to dedicate power feed with 2 cavities, **high efficient cavity operation is realized (in next slide)**
It is possible to match to the higher field cavity, the lower field cavity and quenched cavity individually.

High efficient cavity operation in DRFS

- In SCRF, most expensive and important components are superconducting cavities. Power in the cavities are fed by vector-sum control of LLRF. Due to the different Ql and the available maximum field, average field gradient is limited by the cavity of the lowest quality. In the RDR, one MBK feed the power to 26 cavities and average field is estimated to be lower of 10% (?) from the available cavity field.
- In DRFS, one klystron feeds the power to only 2 cavities. If 2 cavities are chosen to have the same quality, possible maximum available field is attainable. So **high efficient cavity operation is possible in DRFS than in RDR.**
- During the operation if there happens the deterioration in the cavities, operation parameters are easily matched to the situation. If cavity is quenched, immediately operation is quit in minimum interruption.

Q2

What are the primary impact / difference with respect to the RDR of the two proposed WA for the HLRF. Specifically for the main linac tunnel, shaft and support CFS.

- DRFS is a complete single tunnel layout and there is no large facilities in the surface.
- Shaft and support CFS, DRFS requires the same structures or less.
- Heat load problems remains in DRFS same as the RDR. Other proposal of single tunnel plan, some fraction of heat load is dissipated in the surface.

Q3
What are the implications for availability and operability

- Since DRFS uses the large number of klystrons and it is necessary to check the implications for availability and operability.
  - **Consideration for the klystron failure**
  - **Maintenance**
  - **Operability for commissioning and normal operation**

Is the large increase in the number of klystrons critical?

- Life of the tube;
  - life of the smaller klystron is generally longer than larger klystron (though not very long)
  - Cathode life of the MBK is not clear (one MBK contains 6 separated cathodes): equivalent or shorter life than single beam klystron
  - High power klystron has the life time risk due to the arcing or other high-power failure.
- Influence of the klystron failure;
  - If the tube life is 100khr, and operation of 5khr/year, 28 tubes are failed (5/100x560): 28x26=728 cavities are not operated (in RDR)
  - If the life is the same with a smaller tube, 364 tubes are failed and 728 cavities are not operated (in DRFS) but 728 cavities are scattered in the whole linac section. This results in easy beam operation.
  - Actually, it is expected that life of smaller tube is longer than one of MBK, influence of the klystron failure in DRFS is smaller than the that in MBK.

Is the large increase in the number of klystrons critical?(2)

- Number of replaced klystrons of DRFS in the shut down period is larger comparing with the RDR case, but this is normal maintenance activities.
- So the large increase in the number of klystrons is not critical at all.

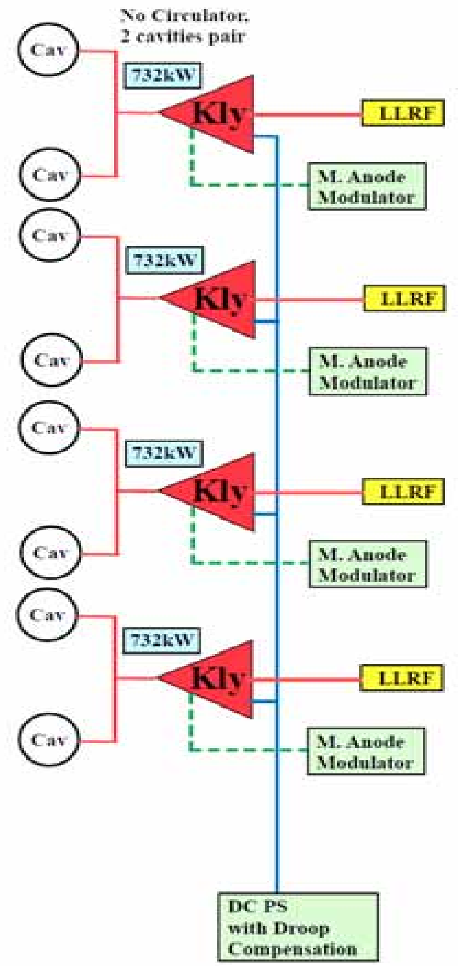
- It is necessary to investigate the failure mode of the DC power supply and Modulating anode modulator.

Q5:The R&D programs ; what can and can't be directly tested by 2012,

- Since one unit of DRFS is very small, it is easy to demonstrate the operation of minimum unit.
  - **Manufacturing of one unit (DC power supply, MA modulator, MA klystron and PDS) in FY2009.**
  - **Demonstrative operation of one unit in S1-global in 2010**
  - **Further developed model is demonstrated in FY2010-2011**
- During the demonstration phase, R&D for the industrialization (mass production model) is included.
- Also Included higher efficiency klystron R&D and sophisticated MA modulator operation model
- More reliable system design is considered including simple reliable disconnection switch.

General Cost Consideration(2): Most Likely Plan for DRFS

- Circulator elimination by power feeding to 2 cavities from one klystron. Output power is 732kW.
- Modulated Anode Klystron (MAK) is adopted.
- Anode modulation pulser does not need the high power and cost efficient pulser is manufactured.
- DC Power Supply is common for 26 cavities and voltage drop during the pulse is compensated with appropriate circuits at the level that LLRF can feed back.
- It is easy to suppress the collector power dissipation without rf in MAK by adjusting the modulated anode voltage.
- Total Number of MA-Klystron=8000
- Total Number of M. Anode Modulator=8000
- Total Number of DC PS =650



Q6: Cost Estimation

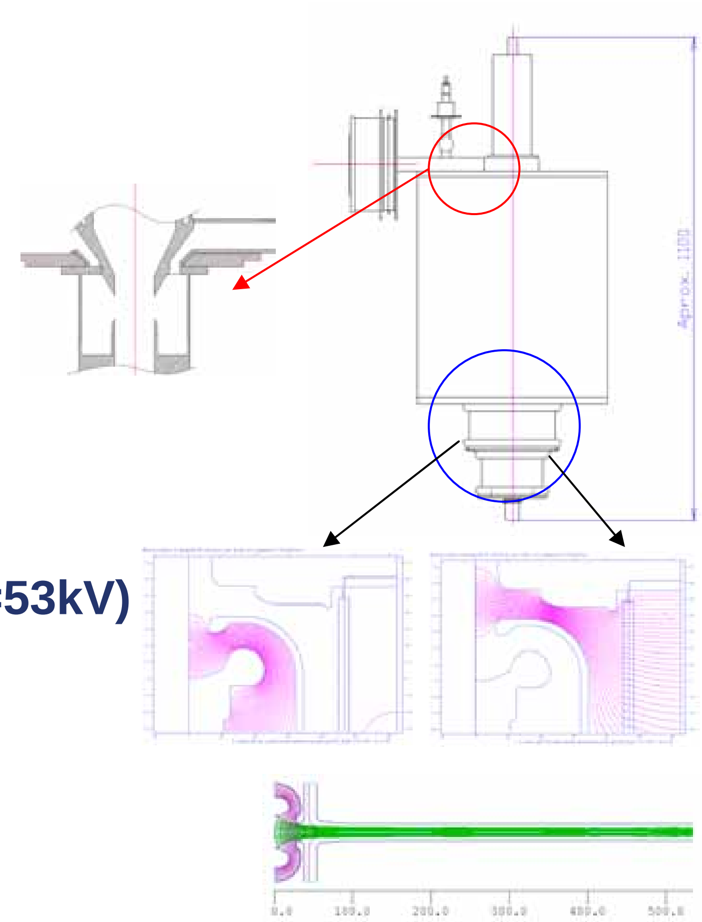
We are studying as follows;

- Klystron Design: Almost finished
- Effort of cost-reduction-oriented manufacturing
- Modulator possible configuration
- Tentative cost study for cost-reduction-oriented manufacturing
- Power Distribution System
- Estimated Cost Impact (HLRF only)
- DRFS Cost for CFS

Klystron Design for DRFS

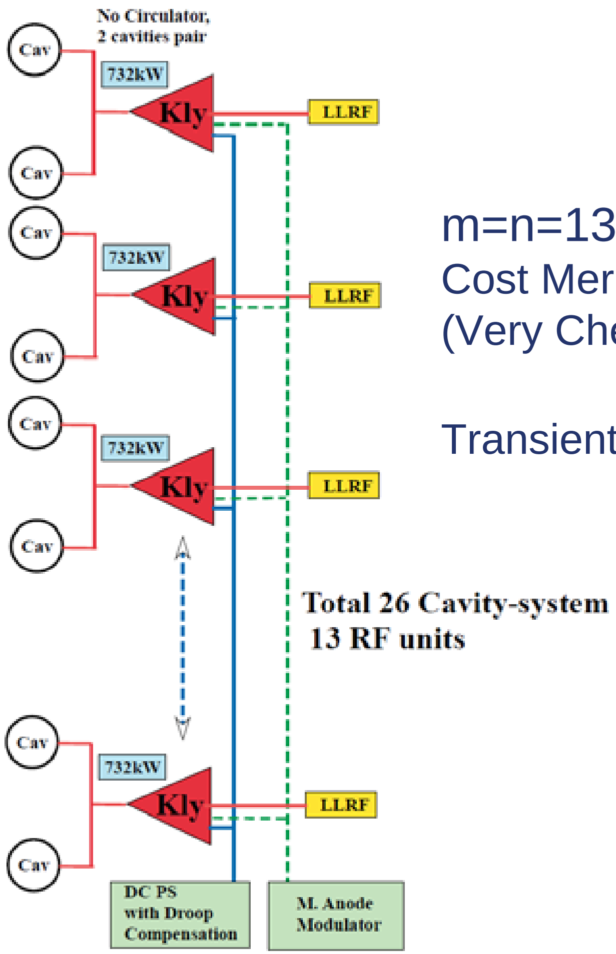
Design Parameters

- 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 1.36mP(@62kV)
- Gun Perveance 1.735mP (@Ea-k=53kV)
- DC Gun Voltage(A-B) >64kV
- Tetrode MA-type
- Electromagnetic Focusing
- Water cooling
- Total length 1.1m
- Weight 70kg



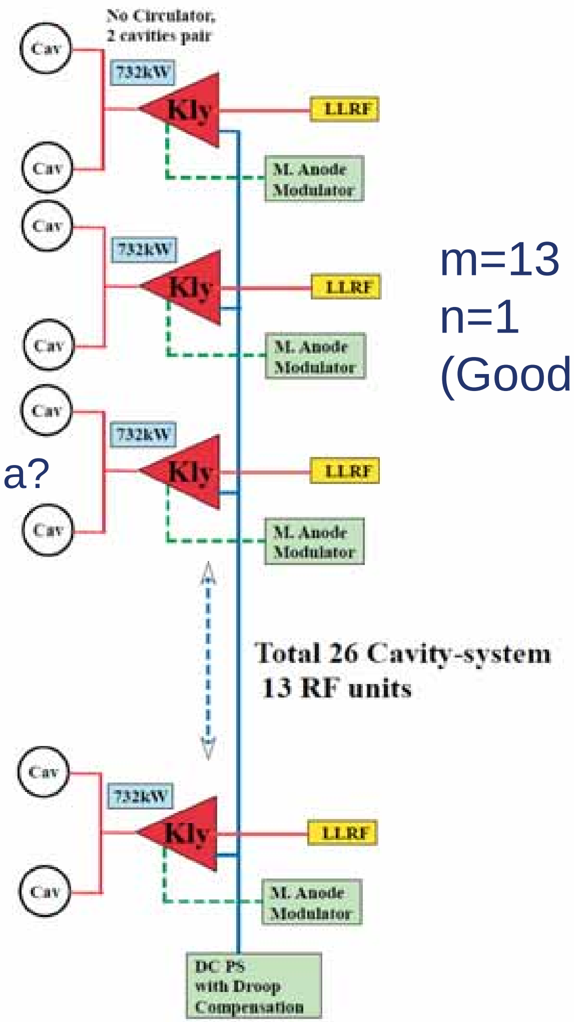
In order to manufacture cheaply, cost cut-down efforts as follows are required.

- 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 look for the cheapest manufacturer in the world. Since it is completely axial –symmetric, lathe machine and auto winder in the simple manufacturing way is expected.
- (R&D) Cooling Cost Saving by Utilizing Potential Depressed Collector
- **RF Source cost =<1.96> VA@RF unit cf. <1>VA (RF source target price=1)**



m=n=13
Cost Merit
(Very Cheep)

Transient Phenomena?

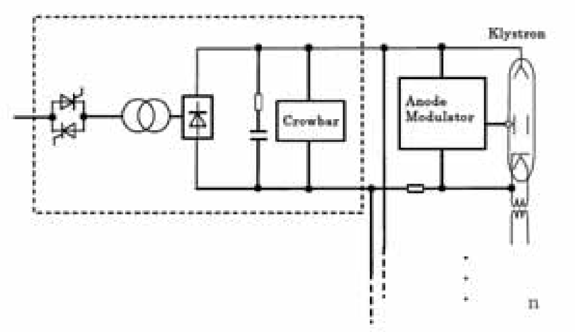


m=13
n=1
(Good operability)

Tentative Cost Study of Modulator

- Case of m=13, n=1

  DC Power supply comprises of delta-star, step-up transformer, rectifier diodes, capacitors and crowbar circuit. *(Is it possible to eliminate the crowbar?)*



- Each unit needs a disconnection switch, an M anode pulser, a filament power supply, a focusing magnet P/S and an IP P/S.
- Key point is how cheap the M anode pulser is designed and manufactured.
- 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.
- Very simple filament power supplies specially designed for this purpose.
- Very simple coil power supplies specially designed for this purpose
- 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 =<2.65>VA@1 RF unit cf. <1.73>VA (RF source target price)**

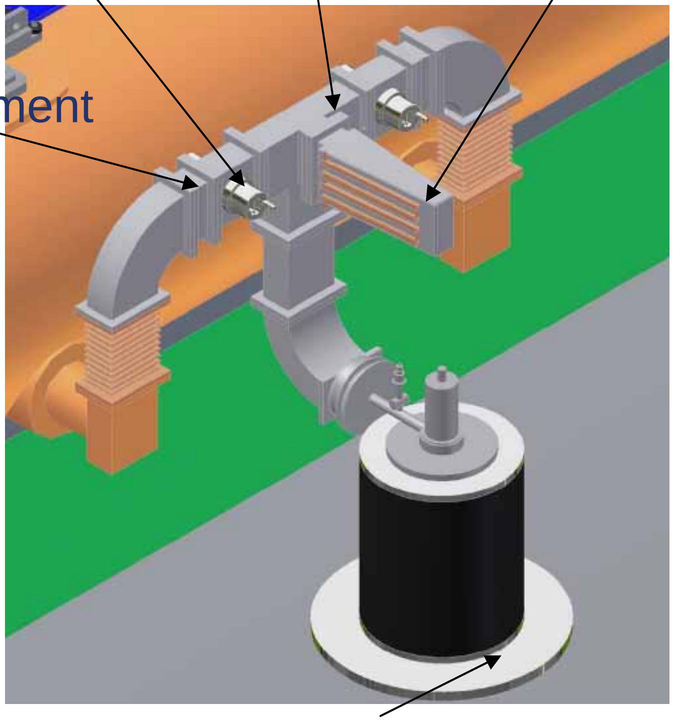
Power Distribution System

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 =<0.30>1 RF unit cf. <1.13> (RF source target price)**



Estimated cost impact (Tentative)

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

  (HLRF) (DRFS vs. RDR/13)

  - **Klystron: 1.96 vs. 1**
  - **Modulator*: 2.65 vs. 1.73**

    *** depend on the scheme, possible to be cheaper**
  - **PDS: 0.30 vs. 1.13**

  - **Total ....4.91 vs. 3.86**

Impacts on Main Linac civil engineering

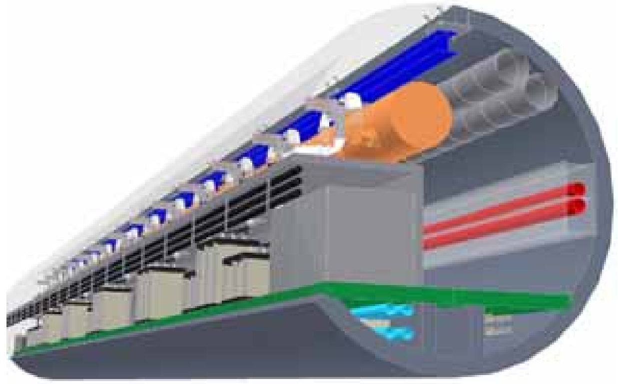
Main Linac CF	RDR	RF Cluster	Distributed RF
Tunnel Penetration Safety path Refuge area	ϕ4.5m, 22.3 km X2 (double) (ϕ0.43m, ϕ0.3m X2) X10m X560 1.2m X2.2m X20m X48 None	ϕ4.5m, 22.3 km X 1 (single) None None ?	ϕ4.5m, 22.3 km X 1 (single) None None None
Access shaft/tunnel (Size and quantity)	X6 7m X6.5m X~1,270m X6	X10 7m X6.5m X~1,270m X6 3.5m X3.5m X~1,270m X4	X 7m X6.5m X~1,270m X6
Shaft-base cavern	X6 16m X18m X100m	X6 ~ half	X6 16m X18m X100m
Surface building	X6 4,300m2 X6	X10 ~7,000m2 X10	X6 4,300m2 X6
Remarks			

Preliminary cost estimates

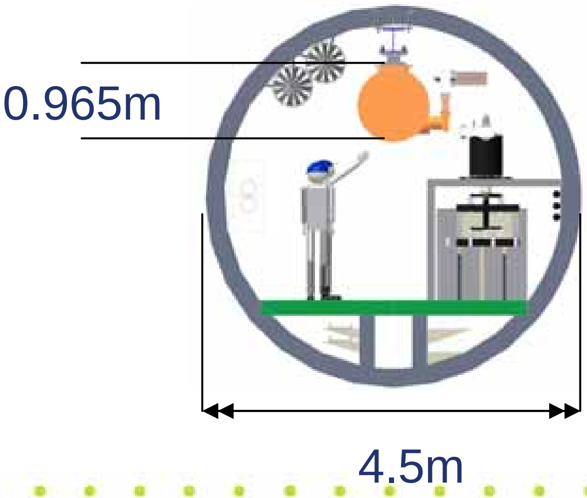
Main Linac CF	RDR	RF Cluster	Distributed RF
1711 Engineering		-1.9	-2.8
1712 Underground		-26.8	-27.0
1713 Surface		+14.6	0
1714 Site development		+2.3	-2.1
Total	100.0	88.2	68.1
Remarks			

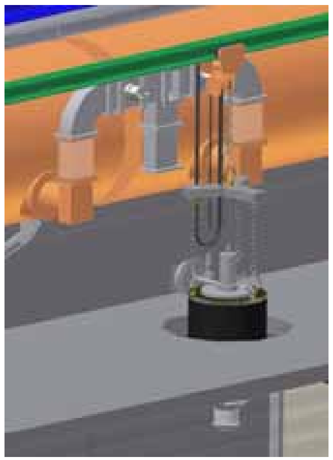
Rough Sketch for DRFS(I)

- 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.

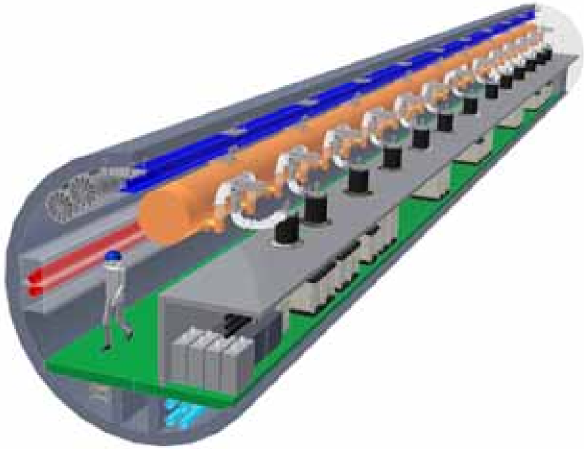


Birds-eye View

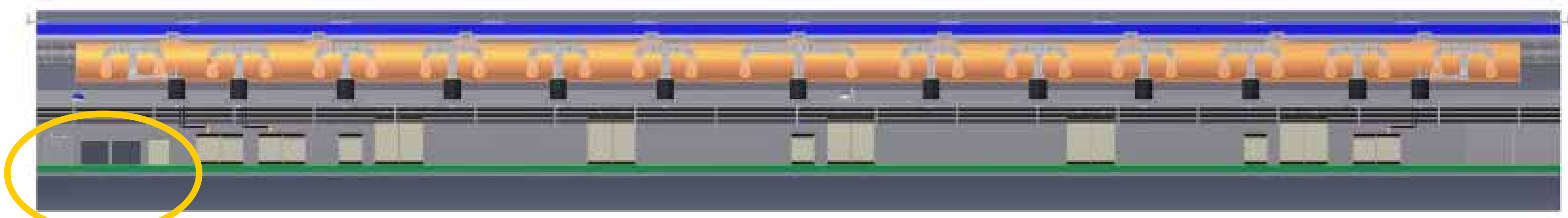




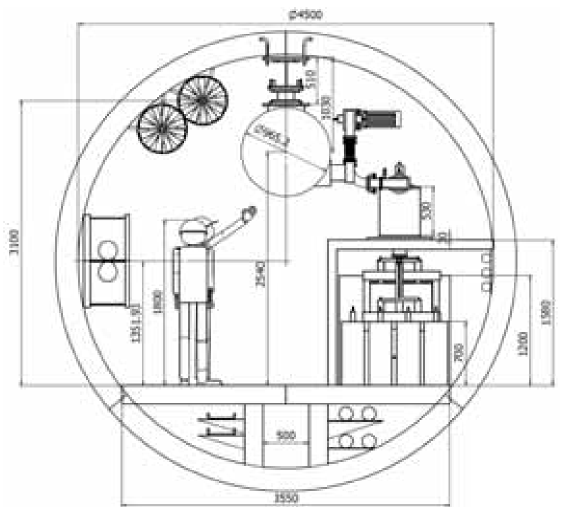
Klystron Install



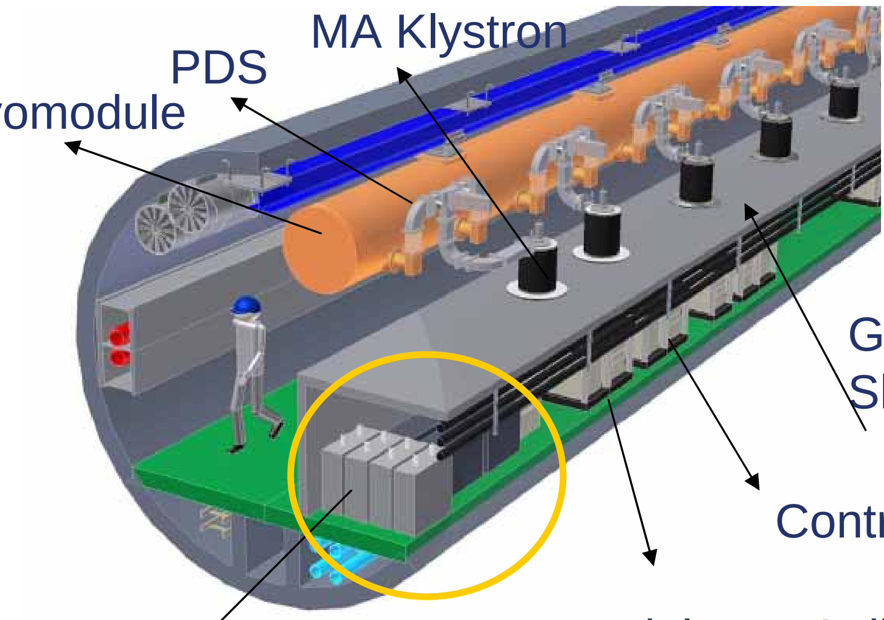
Sketch of 3-Cryo-module unit



6.6kV In & Rectifier Transformer
Capacitor Bank, Bouncer

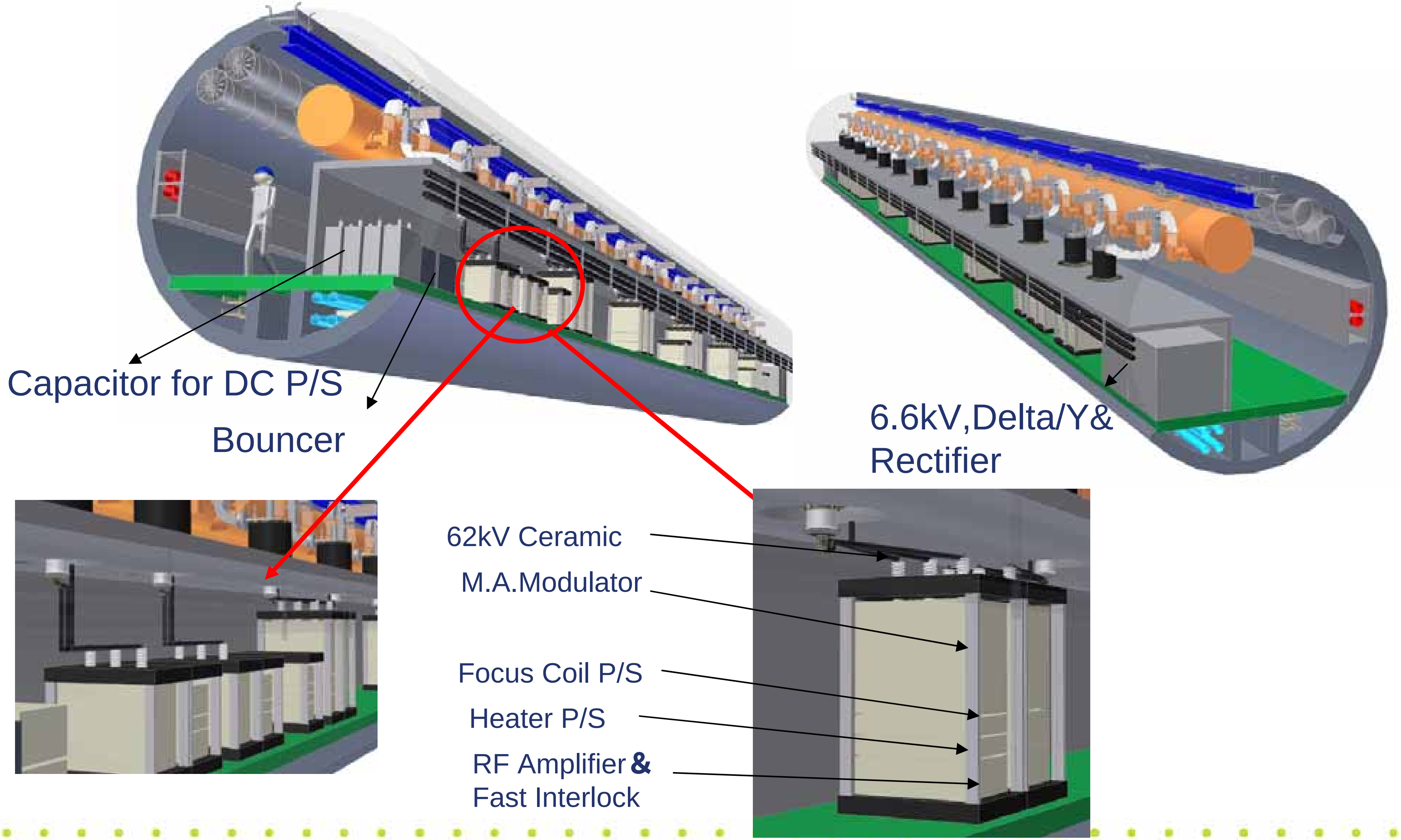


Cross Section



Configuration

Rough Sketch for DRFS(III)



Summary

- DRFS scheme are summarized in the design and integration meeting.
- Pros and Cons for the DRFS comparing with the RDR are presented.
- DRFS can utilize the cavity maximum gradient.
- DRFS is a complete single tunnel plan and there is a big cost reduction for the CFS.
- DRFS has a higher availability and operability than RDR.
- KEK has a plan to manufacture one unit DRFS unit and it will be used in S1-global test to show the feasibility.
- Tentative cost estimation for HLRF of DRFS is 25% higher than RDR, but total cost including CFS is cheaper than RDR. More cost down is expected by more refining study.
- More studied layouts are shown in this presentation.