GDE ACCELERATOR ADVISORY PANEL REVIEW

CONVENTIONAL FACILITIES AND SITING GROUP

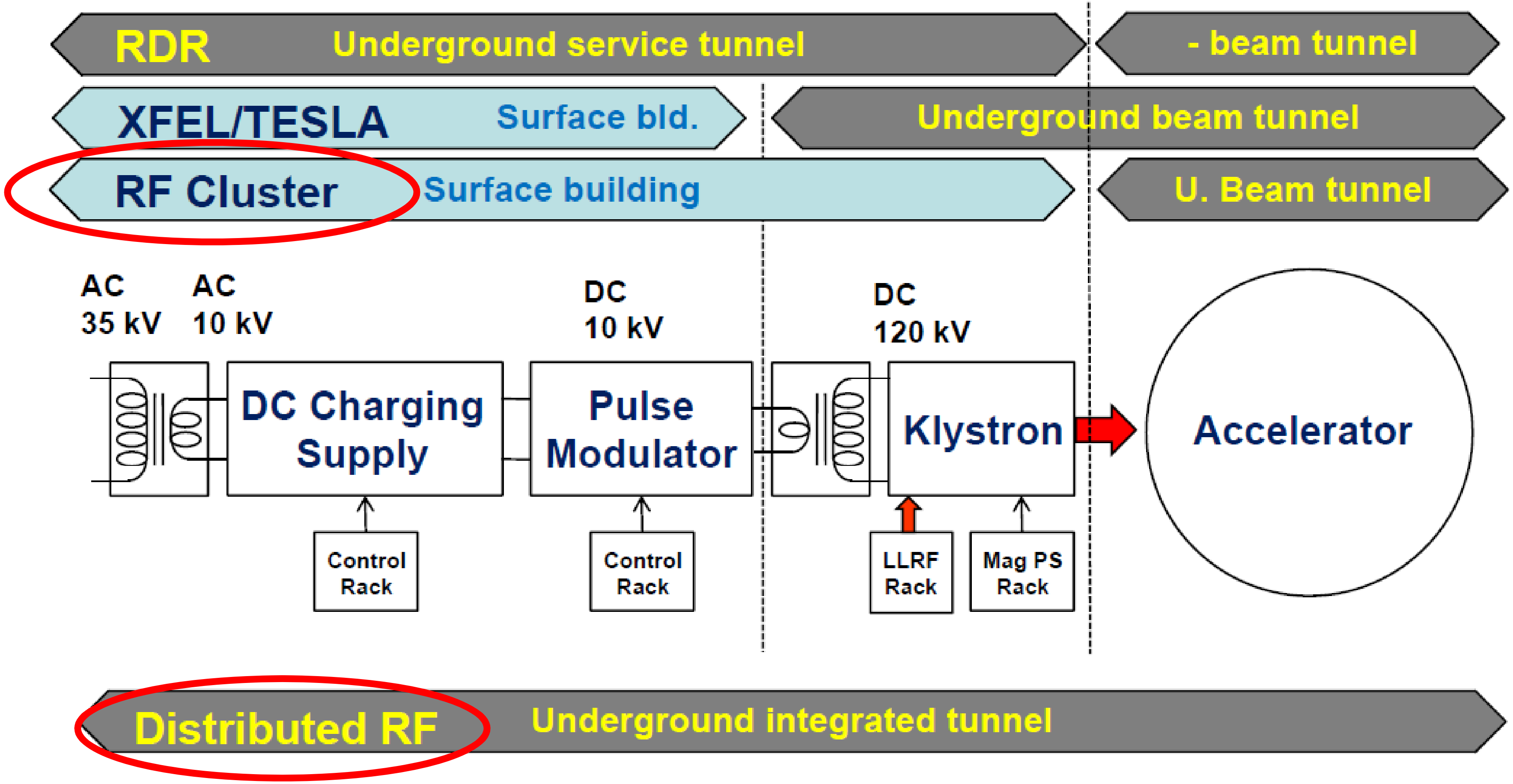
Single-tunnel scheme studies at KEK (RF Cluster and Distributed RF System)

Atsushi Enomoto

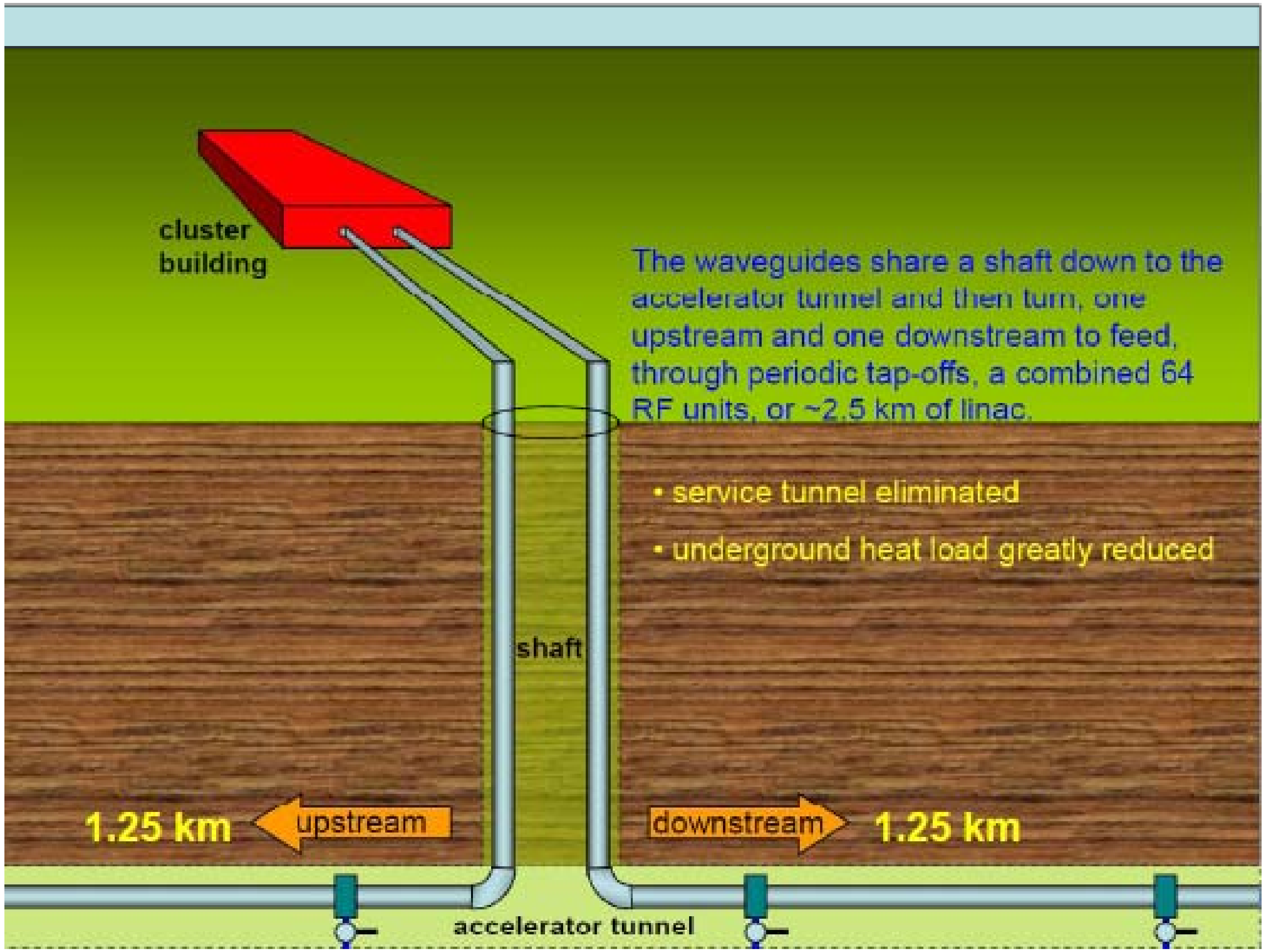
Contents of this talk

- Two kinds of single-tunnel schemes applicable for the Asian sample site (deep tunnel).
- Pros and cons of these schemes from CFS point of view.
- Understanding of degree of cost impacts for the single tunnel scheme.
- Plans of further studies.

Single-tunnel configurations and power distribution systems

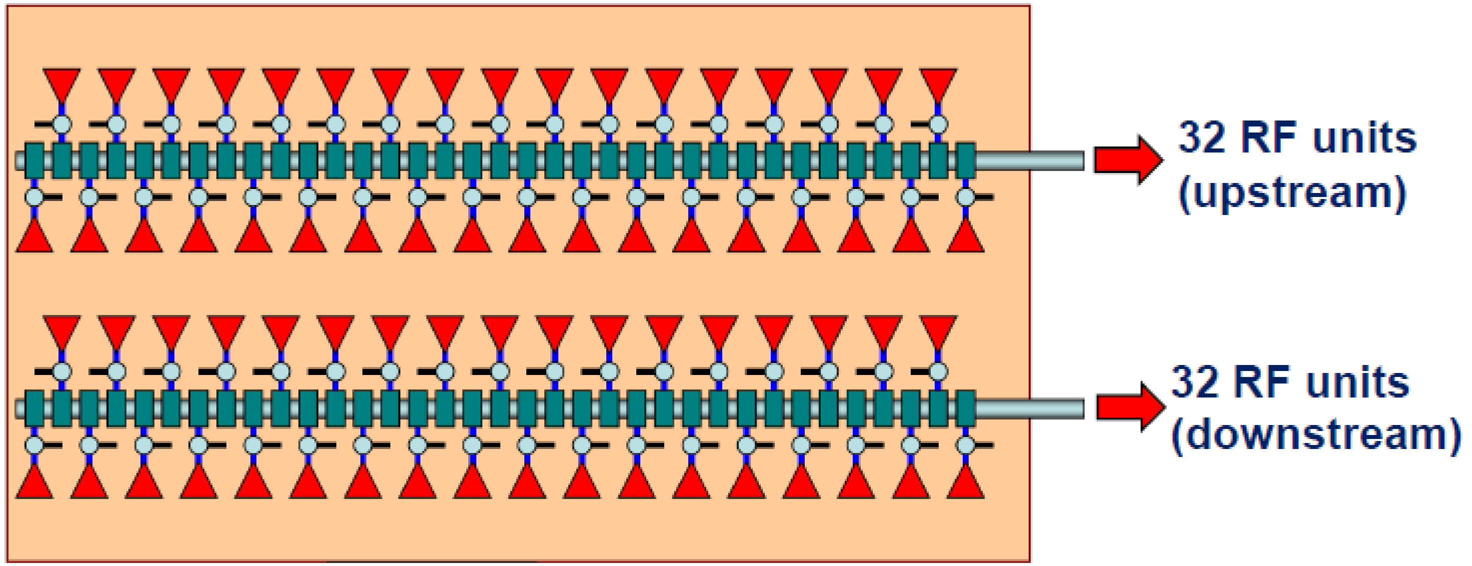


(1) RF Cluster Scheme



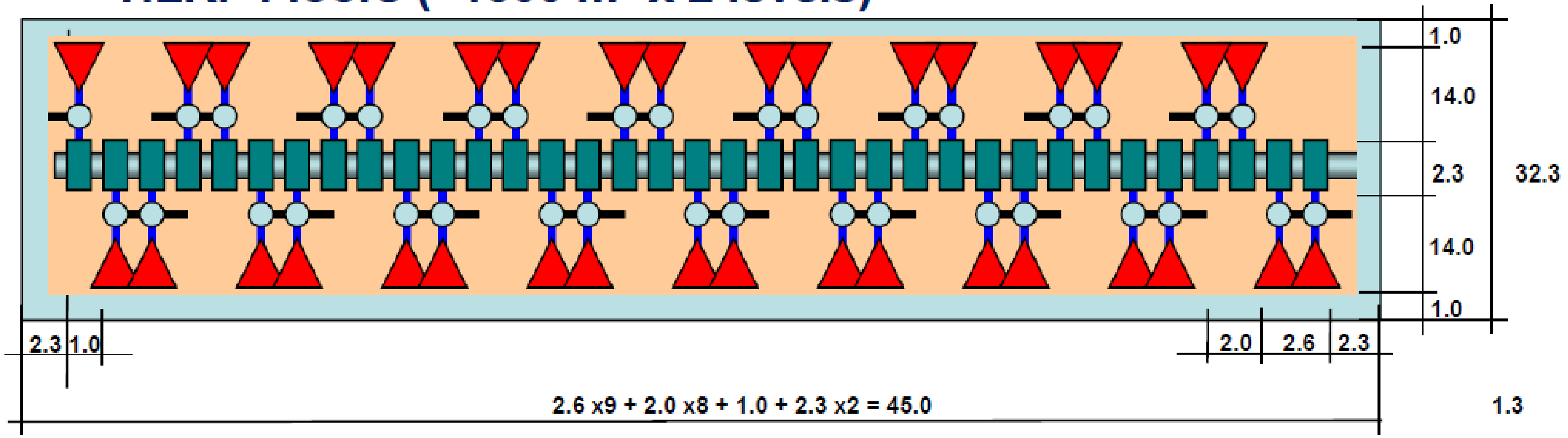
Surface Station of RF Cluster Scheme

Clusters of 70 10 MW klystrons housed, with modulators, in a single building on the surface, feed 350 MW into each of two ~0.5 m diameter evacuated circular waveguides.

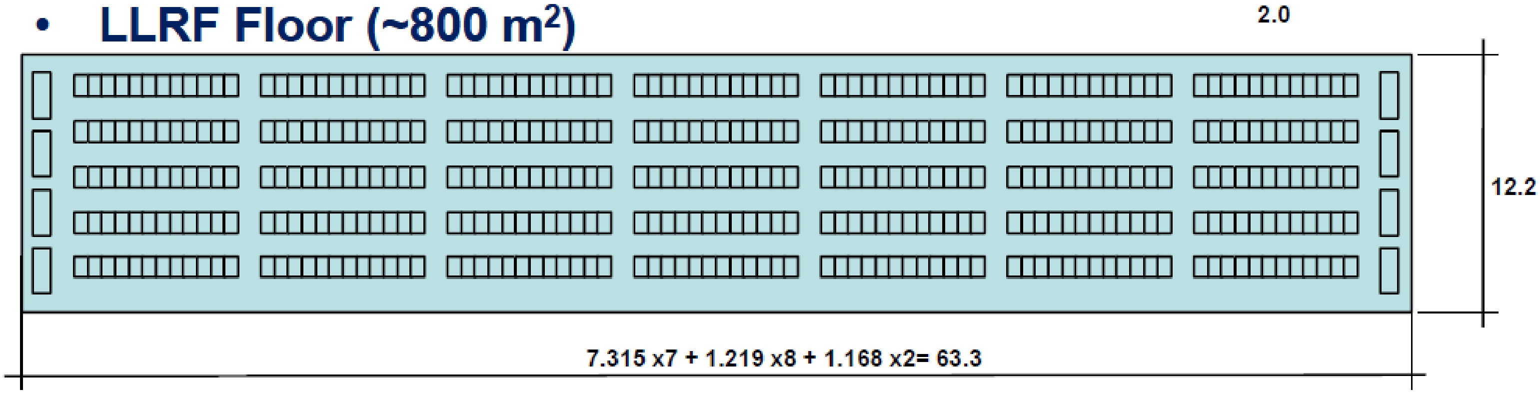


Estimation of floor size

- HLRF Floors (~1500 m^2 x 2 levels)

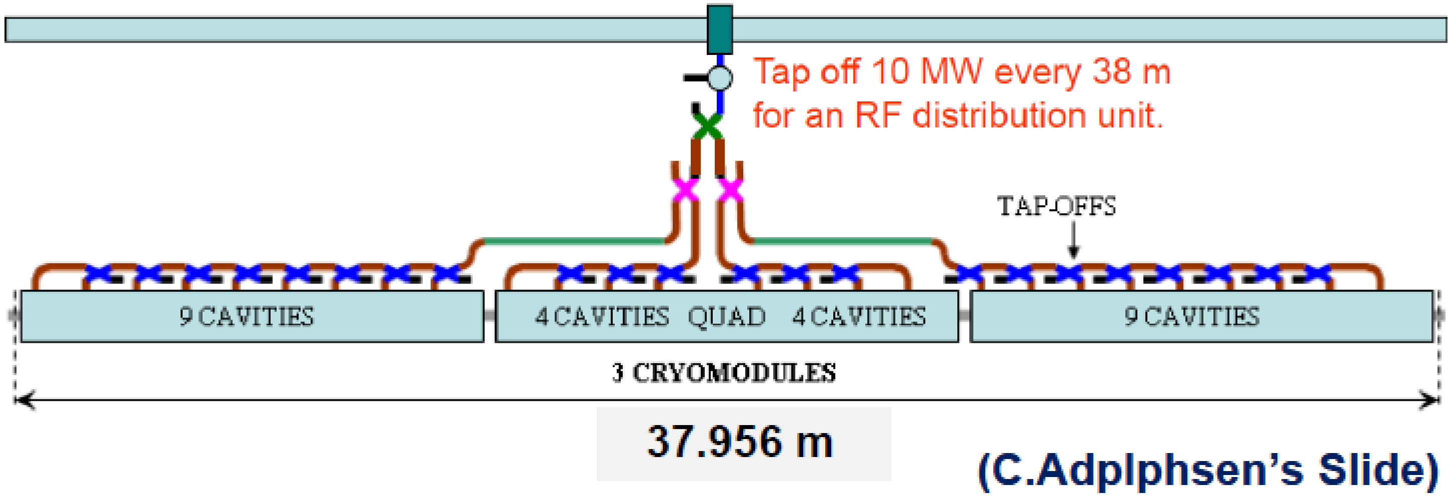


- LLRF Floor (~800 m^2)



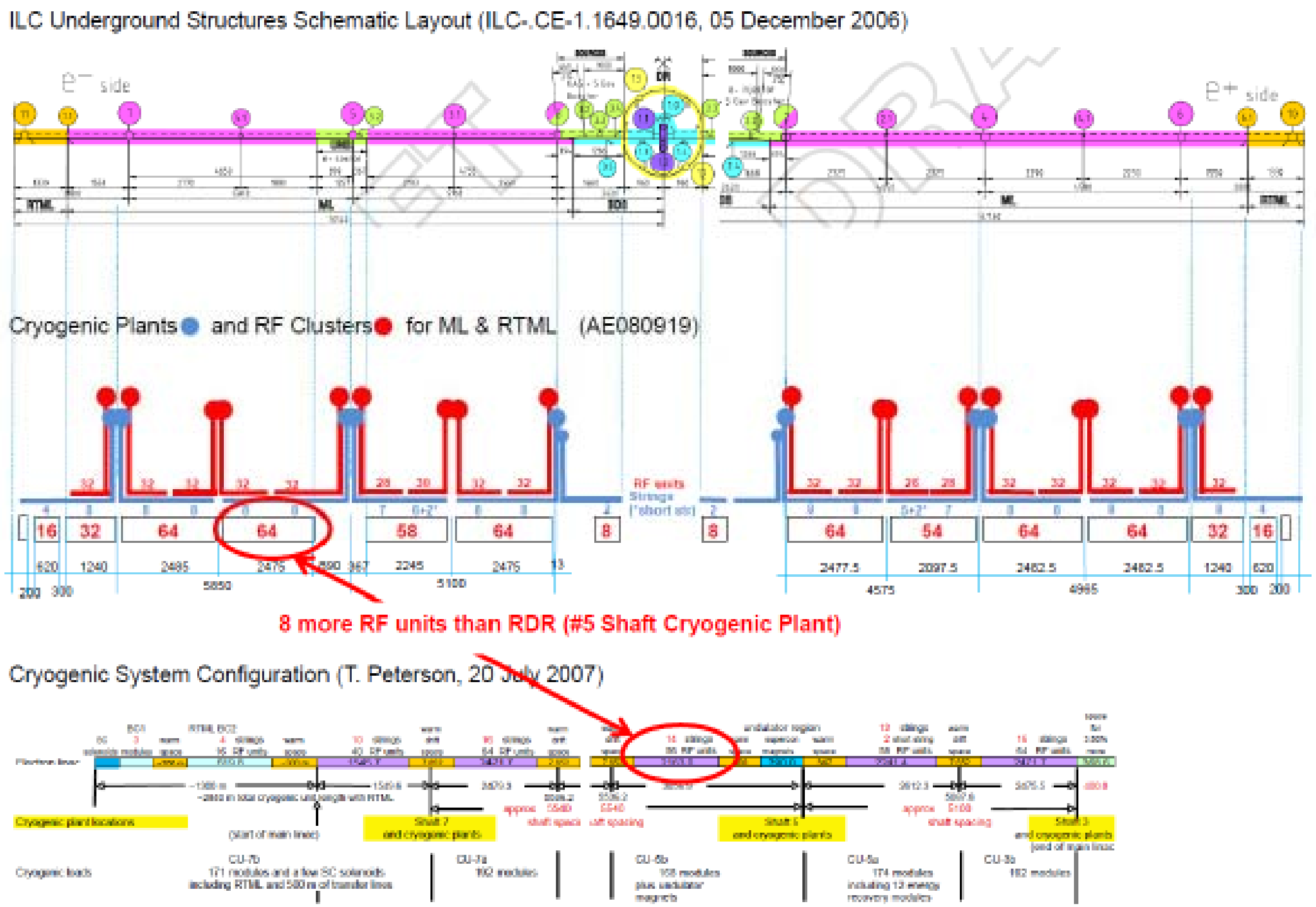
Local distribution of RF Cluster Scheme

Each tap-off from the main waveguide feeds 10 MW
through a high power window and probably a circulator or switch
to a local PDS for a 3 cryomodule, 26 cavity RF unit (as shown for baseline).

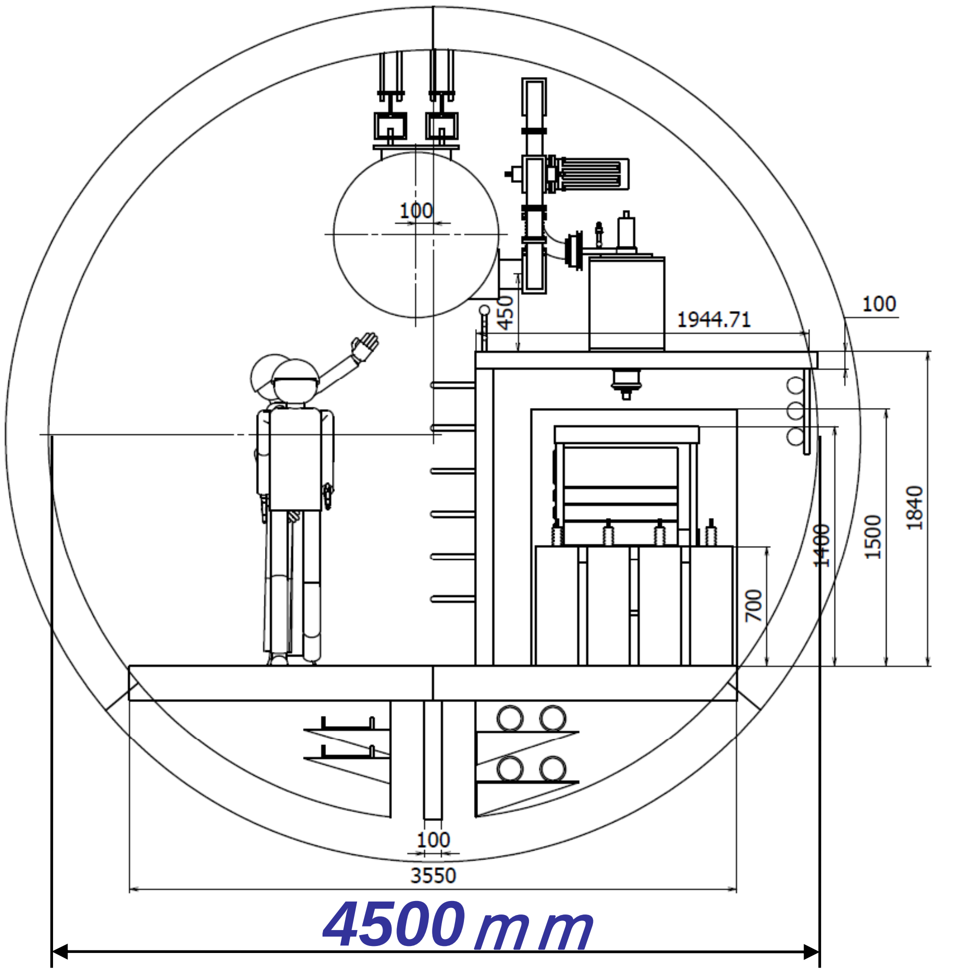


(C.Adplphsen's Slide)

Schematic layouts of conventional facilities and RF units



(2) Distributed RF System (Tunnel view)



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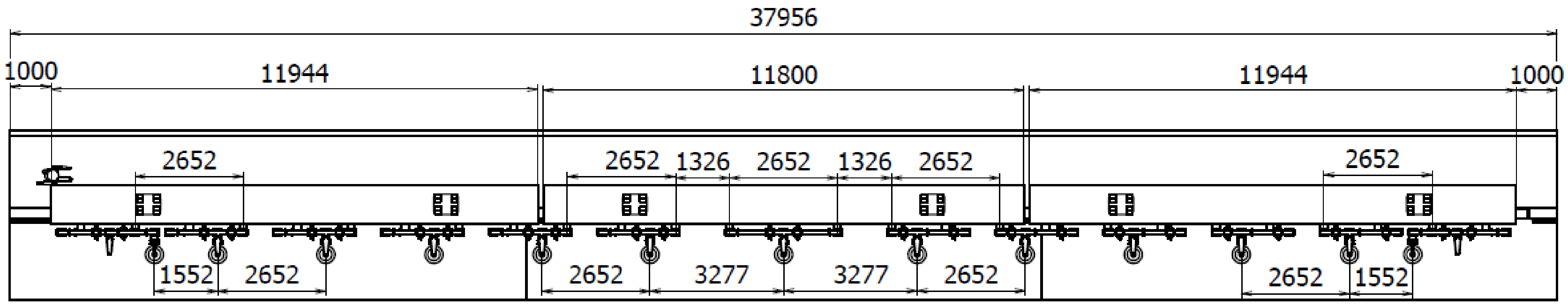

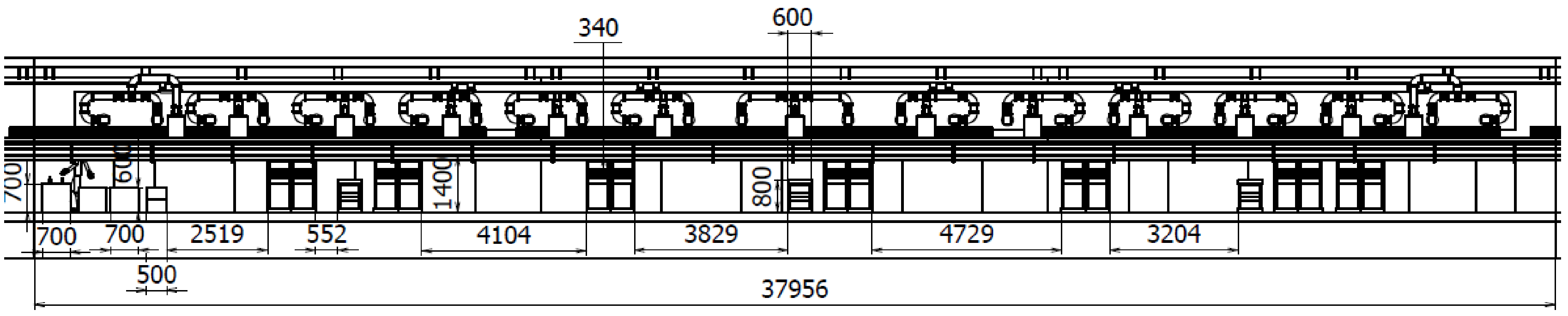

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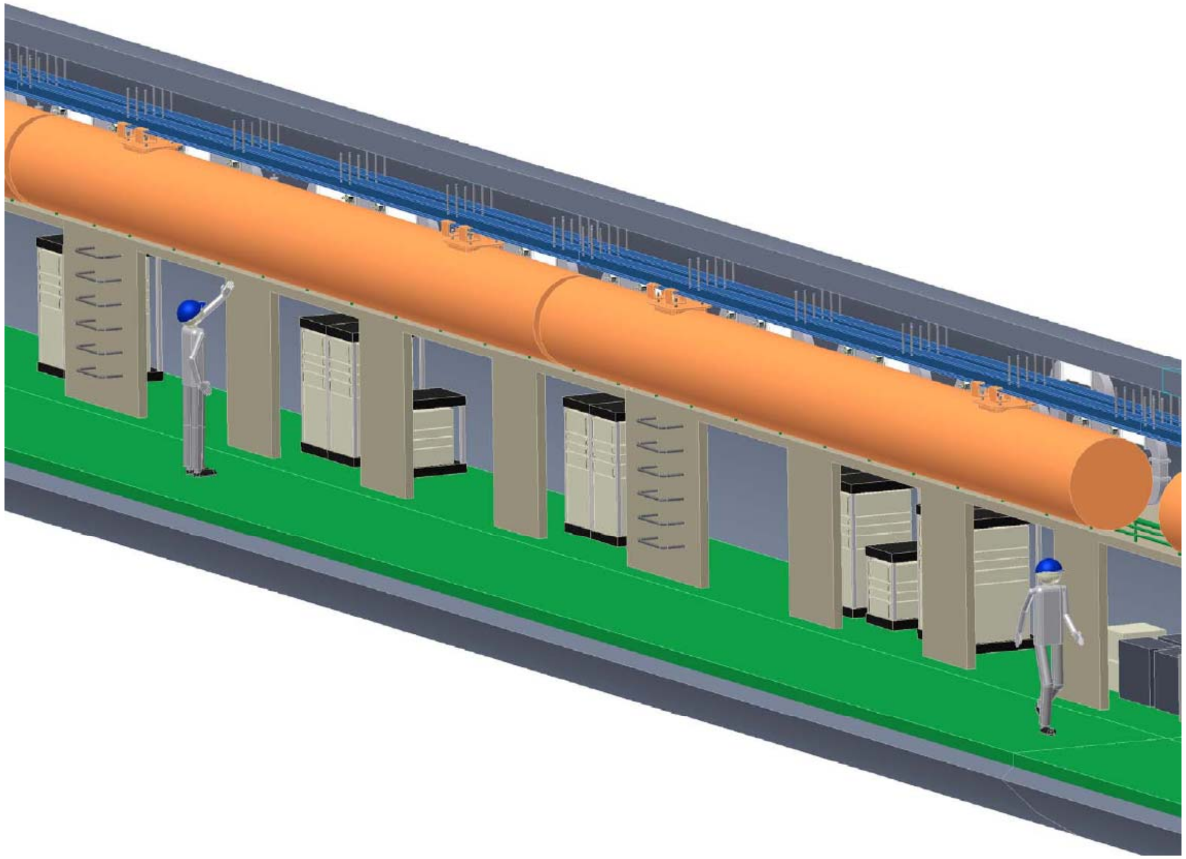
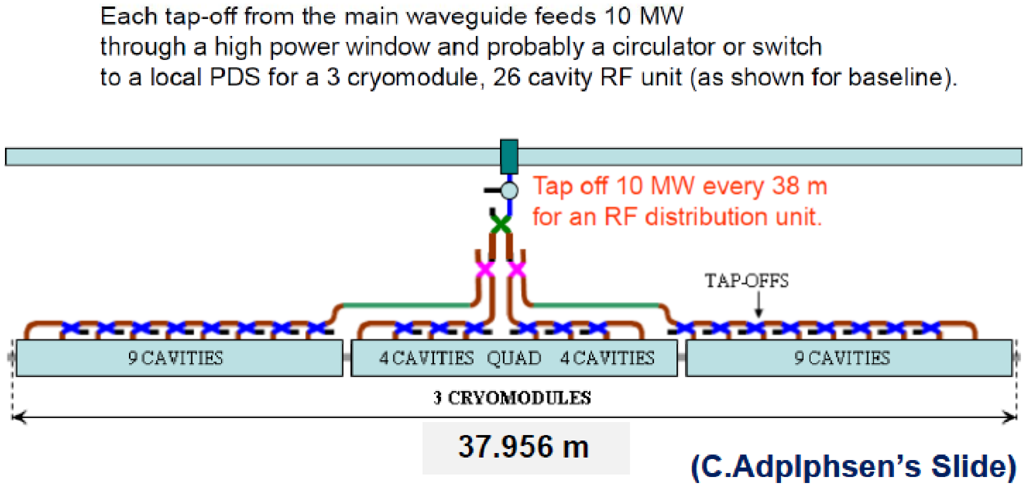
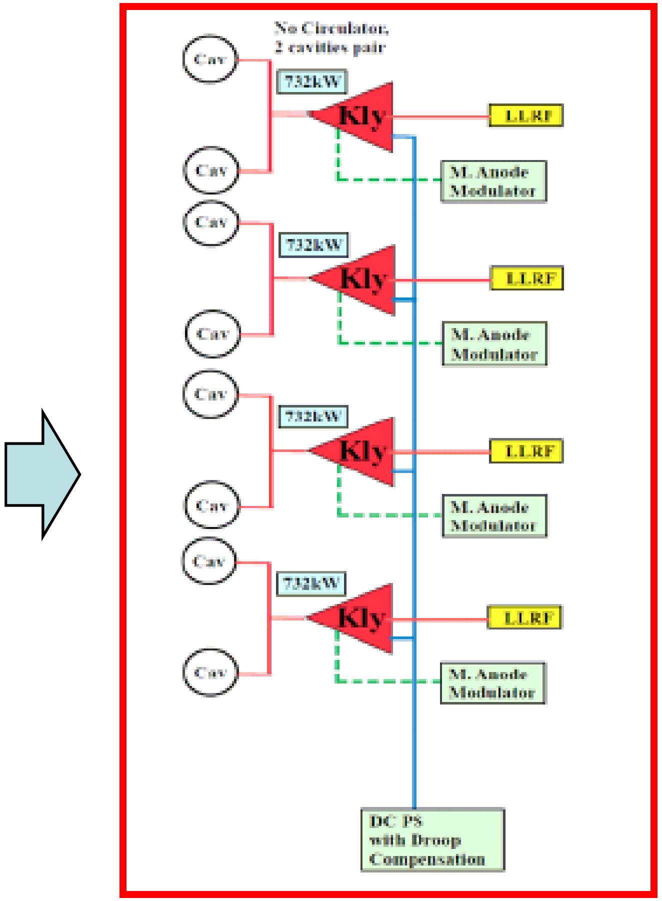


13 small-size klystrons used instead of one big klystron



(C.Adplphsen's Slide)



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			

Cost impact factor (RDR)

TABLE 6.2-2
Distribution of the ILC Value Estimate by area system and common infrastructure, in ILC Units. The estimate for the experimental detectors for particle physics is not included. (The Conventional Facilities estimates have been averaged over the three regional site estimates.)

Area - M ILC Units	Total	Components	Conventional Facilities
Main Linac	3,894	2,723	1,172
DR	630	398	231
RTML	554	320	234
e^{+} source	398	232	166
BDS	408	157	252
Common	369	229	140
Exp Hall	200	0	200
e^{-} source	165	87	78
Sum	6,618	4,146	2,472

TABLE 6.2-1
Possible division of responsibilities for the 3 sample sites (ILC Units).

	Region	Site-Specific	Shared	Total
	Asia	1.75 B	4.78 B	6.53 B
	Americas	1.89 B	4.79 B	6.68 B
	Europe	1.85 B	4.79 B	6.64 B
and	Average	1.83 B	4.79 B	6.62 B

plus 14 K person-years of explicit labor
or 24 M person-hours 1,700 hours/year

1 ILC Unit = 1 US 2007\$ (= 0.83 Euro = 117 Yen)

Total Project Cost	6.62		
CFS	2.47		
ML	1.17		
Civil (Asia)			

Total Project Cost	100		
CFS	37	100	
ML	18	47	100
Civil (Asia)			

Impacts on cooling system

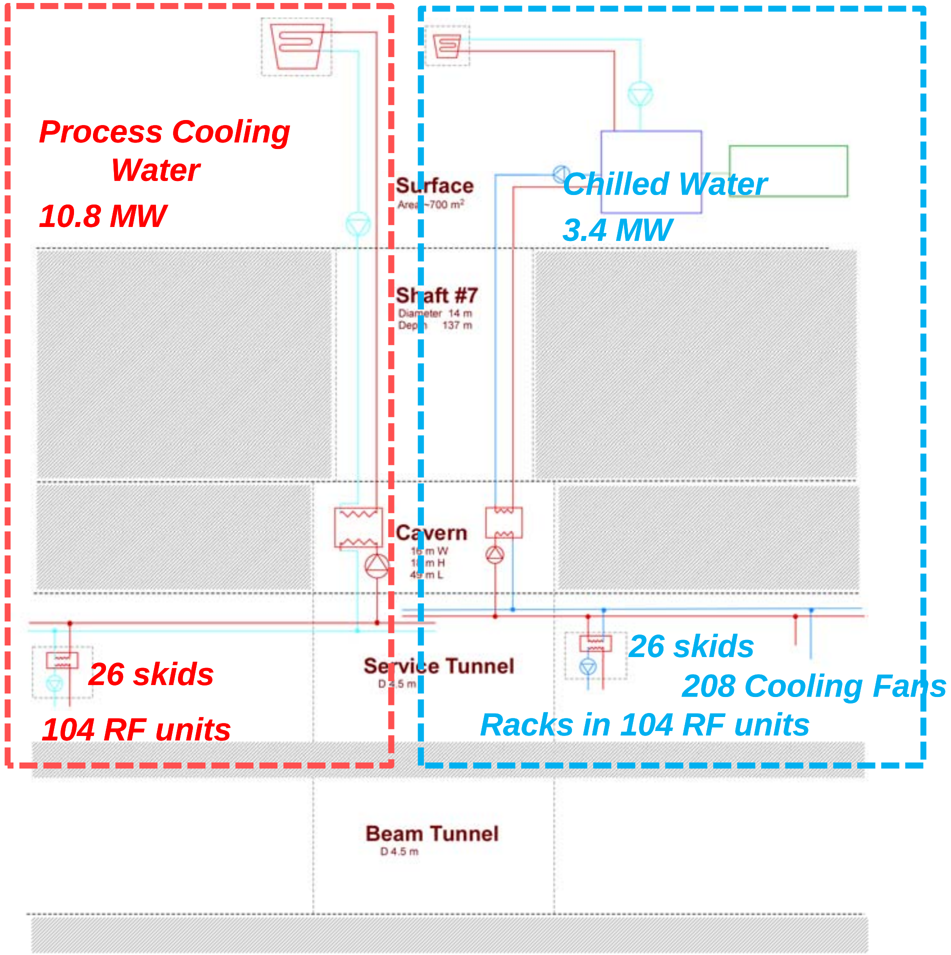
(heat loads)

Dec 14 2007

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

MAIN LINAC - ELECTRON & POSITRON					To Low Conductivity Water	to Chilled Water	keith Jobe load to Air Nov 22 06	
Components	Quantity Per 36m	Location	Total Heat Load (KW)	Average Heat Load (KW)	Heat Load to Water (KW)	Heat Load to Water (KW)	Power fraction to Tunnel Air (0-1)	Power to Tunnel Air (KW)
Non-RF Components								
LCW Skid Pump 1 per 4 rf -Motor/Feeder Loss	0.25	Service Tunnel	0.60	0.60	0	0	1.00	0.60
I^2R Loss and Motor Loss (misc)	1	Service Tunnel	8.99	8.22	0	0	1.00	8.22
Fancoils (5 ton Chilled Water) 1.5 Hp	2	Service Tunnel	2.91	2.91	0	0		
Rack Water Skid	0.25	Service Tunnel	0.20	0.20	0	0	1.00	0.20
Lighting Heat Dissipation ~1.3W/sf		Service Tunnel	1.65	1.65	0	0	1.00	1.65
AC Pwr Transformer 34.5-.48 kV	0.25	Service Tunnel	2.00	2.00	1.50	0	0.25	0.50
Emerg. AC Pwr Transformer 34.5-.48 kV		Service Tunnel	1.00	1.00	0	0	1.00	1.00
RF Components								
RF Charging Supply 34.5 Kv AC-8KV DC	1/36 m	Service Tunnel	4.0	4.0	2.8	0	0.3	1.2
Switching power supply 4kV 50kW	1/36 m	Service Tunnel	7.5	7.5	4.5	0	0.4	3.0
Modulator	1/36 m	Service Tunnel	7.5	7.5	4.5	0	0.4	3.0
Pulse Transformer	1/36 m	Service Tunnel	1.0	1.0	0.7	0	0.3	0.3
Klystron Socket Tank / Gun	1/36 m	Service Tunnel	1.0	1.0	0.8	0	0.2	0.2
Klystron Focusing Coil (Solenoid)	1/36 m	Service Tunnel		4.0	5.5	0	0.1	0.4
Klystron Collector	1/36 m	Service Tunnel	58.9	47.2	45.8	0	0.0	1.4
Klystron Body & Windows	1/36 m	Service Tunnel			4.2	0		
Relay Racks (Instrument Racks)	1/36 m	Service Tunnel	10.0	10.0	0	11.5	-0.2	-1.5
RF Distribution (Attenuators, Loads, Waveguide, Circulators all in series connection)	2/36 m	Service Tunnel			0			0.0
	1/36 m	Service Tunnel			0			[illegible]166
	1/36 m	Penetration			0.676			
	1/36 m	Beam Tunnel			0.0	0		5.9
	26/36 m	Beam Tunnel			2.49	0		0.0
	24/36 m	Beam Tunnel			30.05			0.0
Subtotal RF unit Only			90	82	102.0			
Total RF			107	99	103.5	11.5		21.4

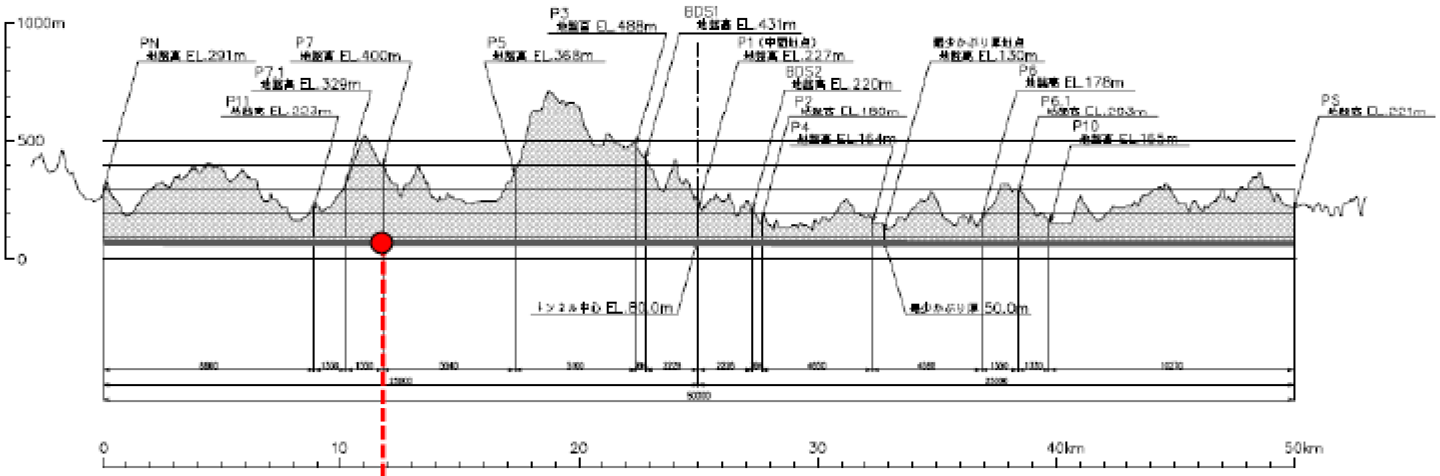
Total Heat load to Air/Chilled water in service tunnel (per RF)	32.9
Total Heat load to LCW (per RF)	103.5
Total Heat load to air in beam tunnel (ignore rock contribution for now)	5.9

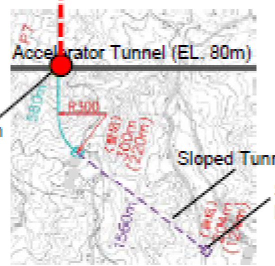


In RF cluster scheme, ~40% of the heat loads remain in the undergroud.

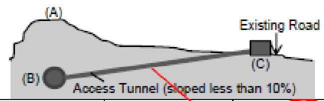
Area for substation at shaft-base cavern and RF skids will be reduced in capacity but not eliminated.

Site specific issues for Asian sample site





RDR



Point ID	Elevation		Overburden above Beam Tunnel = (A)-(B)	Elevation	Drop from Entrance to Beam Tunnel = (C)-(B)	Length from Entrance to Beam Tunnel
	(A) Surface	(B) Beam Tunnel		(C) Entrance		
7	400	80	320	204	124	1,540
5	368	80	288	226	146	1,608
3	488	80	408	238	158	1,706
2	180	80	100	156	76	1,198
4	164	80	84	117	37	652
6	178	80	98	165	85	934
Average	296	80	216	184	104	1,273

Longer transportaion of RF (RF cluster)

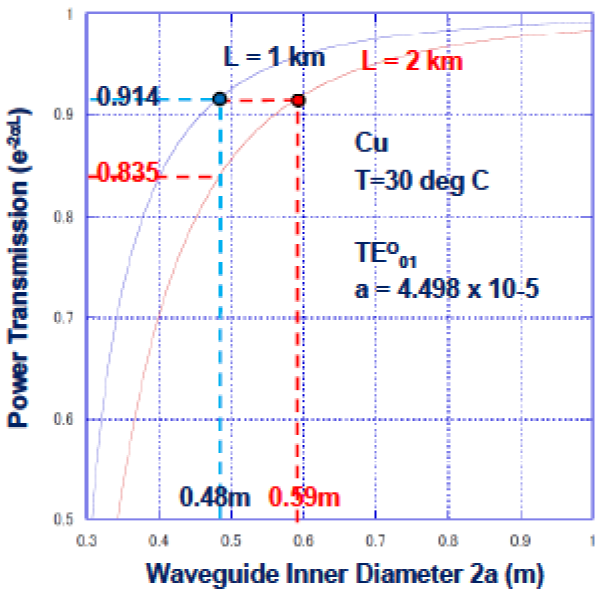
Attenuation Of RF Through Cylindrical Waveguides

$$TE^{\circ}_{01}: \alpha = \frac{R_s}{Z_0} \frac{1}{\sqrt{k_0^2 - (\chi_{01}/a)^2}} \frac{\chi_{01}^2}{k_0 a^3} \Omega$$

α: attenuation constant (neper/m)
R_s: skin resistance (Ω)
Z_0: intrinsic impedance ~377 Ω
k_0: propagation constant in free space
$k_c = X_{01}/a$: cut-off propagation constant
X_{01} = 3.832 for TE01 mode
2a: inner diameter of cylindrical waveguide

Cu
$\rho_{20} = 1.72 \times 10^{-8}\ \Omega m$
$\rho_{0\text{-}100} = 4.3 \times 10^{-3}$ /deg

TE^{o}_{01}
$\alpha = 4.498 \times 10^{-5}$ (2a = 0.48 m)
$\alpha = 2.233 \times 10^{-5}$ (2a = 0.59 m)
@T=30 deg C



Waveguides which are ~1 km longer than those in Americas site have to be used,
with two choices,
- to use 0.48-m diameter waveguides and 8% more RF sources;
- to use 0.59-m diameter waveguides.

Longer transportaion of RF (RF cluster)

Waveguide Temperature Issue - without cooling water -

$$-\frac{dP}{dx} = 2\alpha P$$

$$P = P_0 e^{-2\alpha x}$$

-dP/dx: lossed microwave power per unit length (W/m)
α: attenuation constant (neper/m)
P: transmitted power (W)
P_0: initial power generated by RF cluster (W)
x: transmitted distance (m)

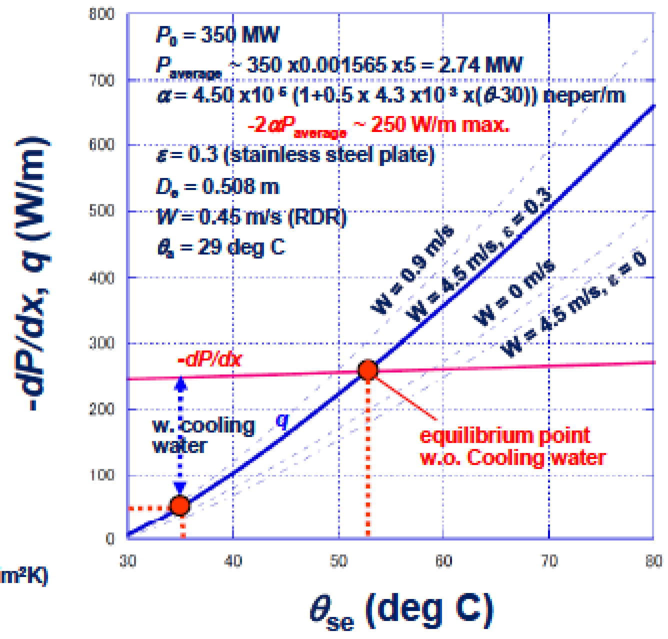
$$q = h_{se}\pi D_e \Delta\theta$$

$$h_{se} = \varepsilon\sigma(T_{se}^4 - T_a^4)/\Delta\theta + 1.19\left(\frac{\Delta\theta}{D_e}\right)^{0.25}\left(\frac{w+0.348}{0.348}\right)^{0.5}$$

$$\Delta\theta = \theta_{se} - \theta_a$$

(JIS A9501)

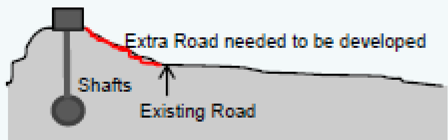
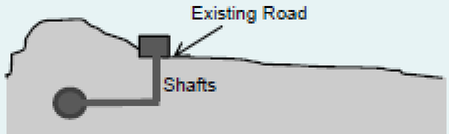
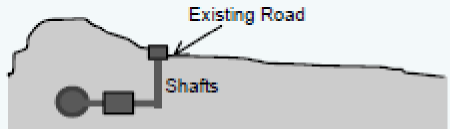
q: dissipated heat by radiation and convection per unit length (W/m)
h_{se}: heat dissipation constant from surface of horizontal beam pipe (W/m²K)
D_e: outer diameter of waveguide (m)
θ_{se}: temperature of surface on waveguide (deg C)
θ_a: temperature of ambient air around waveguide (deg C)
ε: radiation efficiency
σ: Stefan-Boltzmann constant 5.67 x10^{-8} (Wm^{-2}K^{-4})
T_{se}: temperature of surface on waveguide (deg K) $= \theta_{se}+273$
T_a: temperature of ambient air around waveguide (deg K) $= \theta_a+273$
w: wind velocity (m/s)



Waveguides radiate ~250 W/m max. or ~9 kW/RF unit max. w/o cooling water;
Expansion of SUS (copper coating inside) pipe will be 240 mm/km for $\Delta\theta$ = 20 deg C.

Plans of further studies

Possibilities of reducing distance from surface to underground tunnel
----- though it may cost higher

Case	Access way	Schematic Layout
RDR	Sloped Tunnel	
Case B	Shaft	
Case C	Shaft + Horizontal Tunnel (surface hall)	
Case D	Shaft + Horizontal Tunnel (underground hall)	

Summary of this talk

- *As a study of minimum machine, two kinds of single-tunnel schemes was investigated in order to apply them for the Asian sample site (deep tunnel).*
- *Though both of two are considered to be applicable, from a civil-engineering point of view, "Distributed RF Scheme" seems more suitable for the Asian site.*
- *Further studies should cover overall CF designs such as cooling and safety issues.*