KEKB Review 2009

Upgrade of RF Power Source & Cooling System

KEK; M. Ono

2009-02-10

Super KEKB RF parameters; Base Line Design

Ring	LER	HER		unit
Beam energy	3.5	8.0		GeV
Beam current	9.4	4.1		A
Energy loss /turn	0.84	3.42		MV
Radiation loss	7.91	14.02		MW
Total loss factor, assumed	40 ± 5	45 ± 10		V/pC
Parasitic loss	7.09 ± 0.89	1.52 ± 0.34		MW
Total beam power	15.0 ± 0.9	15.5 ± 0.3		MW
Cavity type	ARES (modified)	ARES	SCC	
Number of cavities (= klystrons)	22～24	18～16	8	
Voltage /cavity	0.5	0.5	1.3	MV
Beam power /cavity	650	720	460	kW
Wall loss /cavity	233	150	-	kW
Detuning frequency	44	31	75	kHz
Klystron power	940	930	490	kW
Total RF voltage	～11	～18		MV
Total AC plug power	35	33		MW

Number of RF units(=Klystron #)

For Acceleration Cavity		KEKB		SuperKEKB	
		LER	HER	LER	HER
Oho	D4		3		12
	D5		4	8/12	4/0
Fuji	D7	5		8	
	D8	5		8	
Nikko	D10		4		4
	D11		4		4
Total		25		48	
For Crab Cavity		LER	HER	LER	HER
Nikko	D10				(1)
	D11	1	1	1	1
Total		2		2(+1)	

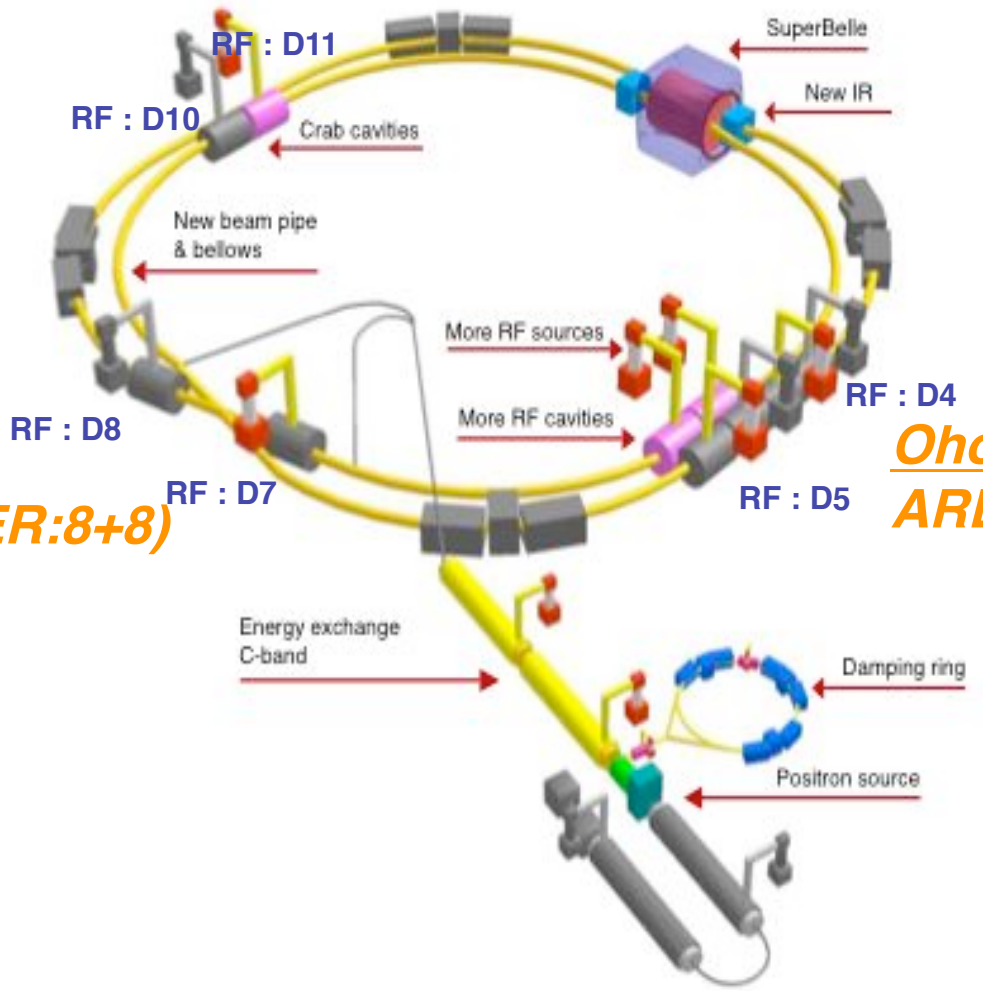
Share is not decided

If HER Crab added

50(+1) Klystrons will be used

High Power RF Source Distribution

Nikko:
SCC(HER:4+4)
& Crab(HER:1(+1) / LER:1)



Fuji:
ARES(LER:8+8)

Oho:
ARES(HER:12+4(0)
/ LER:0+8(12))

High Power RF-unit

Klystron : CW1.2 MW, 509MHz , Modulating Anode

Typical Ope. Condition for 1MW Output : >90kV, 17A

Wave Guide System : WG(WR1500), Circulator, Dummy Load

Water Cooling: Cooling of WG System and Klystron Body

Vapor Cooling: Cooling of Klystron Collector

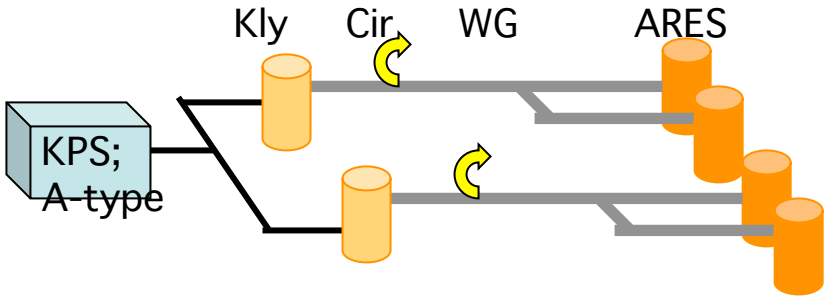
Klystron Power Supply (KPS): A-Type (for 2 Klystrons);
Cathode(90kV, 40A), [Anode(+80kV, 10mA)/Heater(30V,28A) PS] x 2, Crowbar

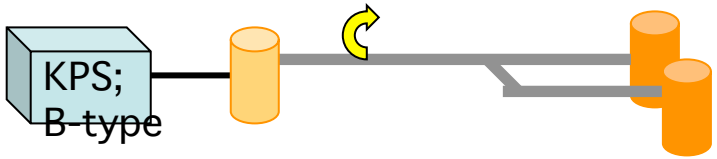
Cavity: ARES, SCC, Crab

Every Components are quite Stably and Reliably operated.

But, almost every things are Old enough!

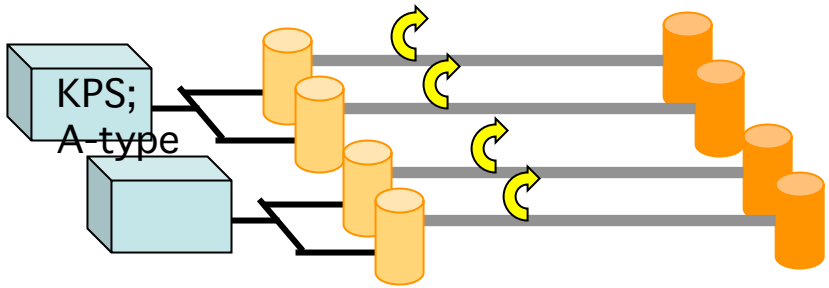
RF units: for ARES cavity(Fuji/Oho)





KEKB:

Kly Out ~ 600kW for two ARES



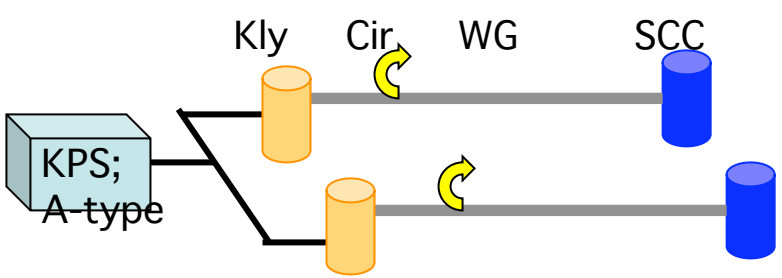
Super KEKB:

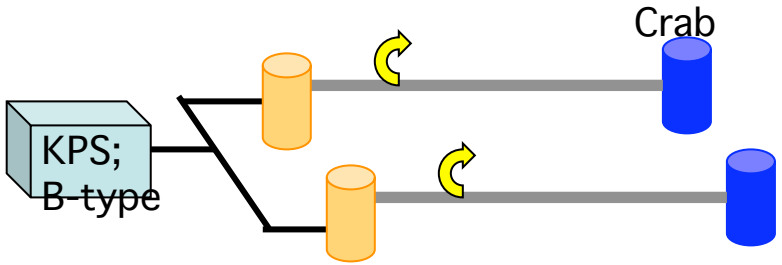
Kly Out > 900kW for one ARES

Not only increase # of Cavities, but also increase the Out put power of Klystron.

Comment on KPS; A-type is for two- & B-type is for one klystron.

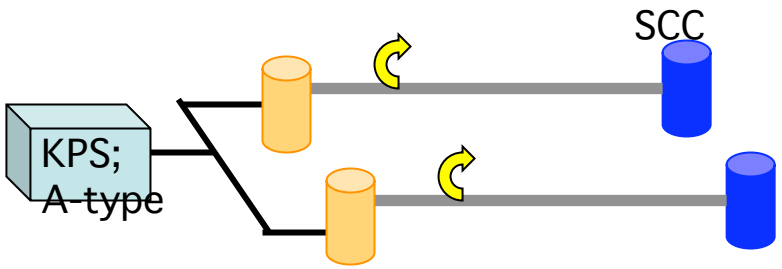
RF units: for SCC/Crab cavity(Nikko)

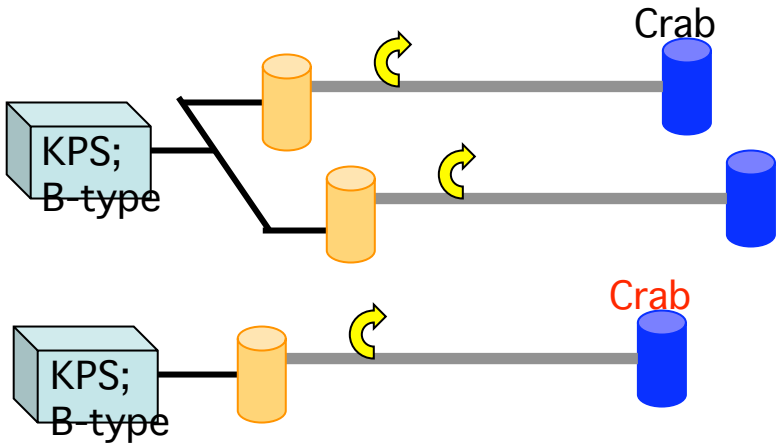




KEKB:

Kly Out ~ 300kW for one SCC





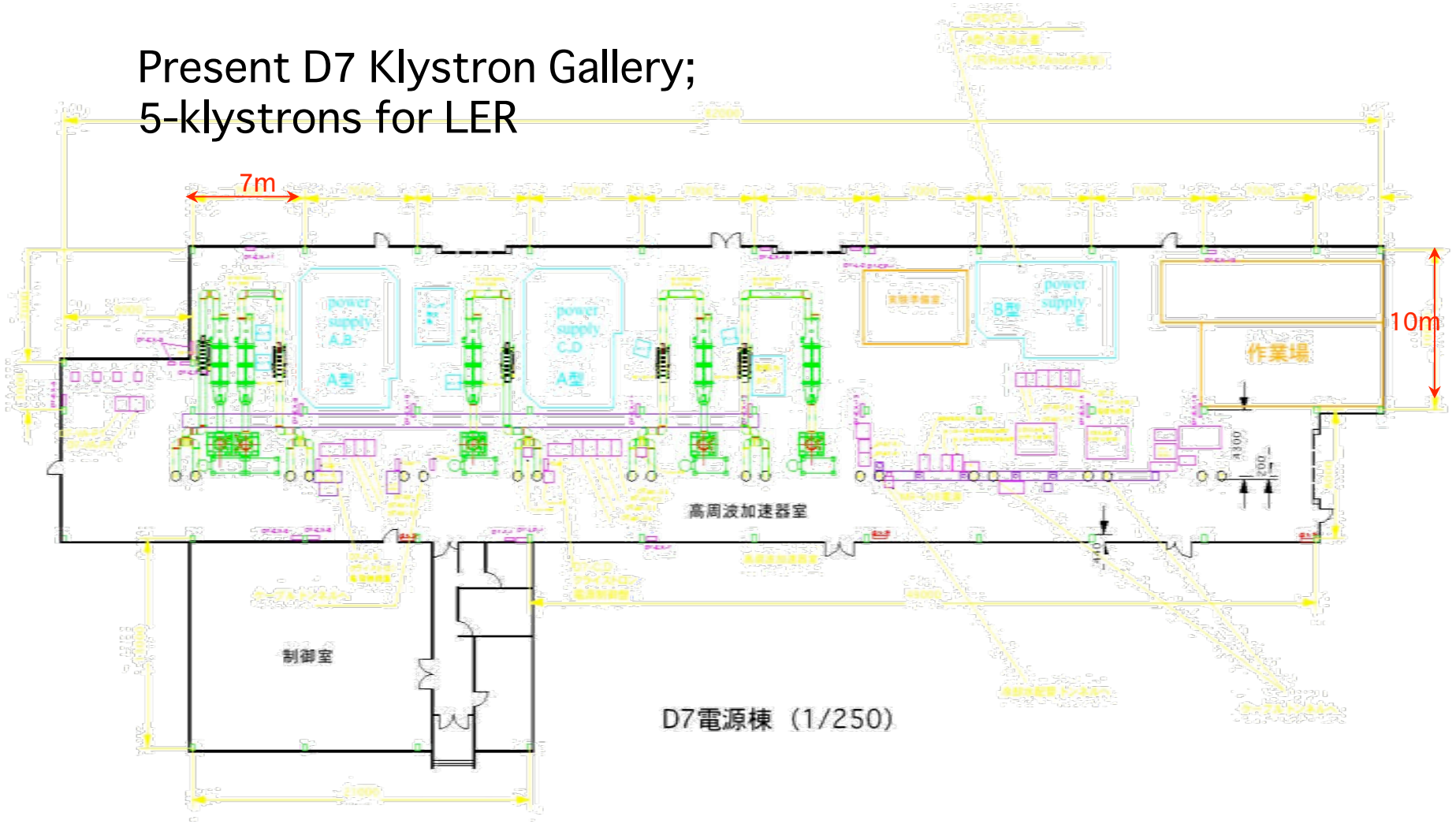
Super KEKB:

Kly Out ~ 490kW for one SCC

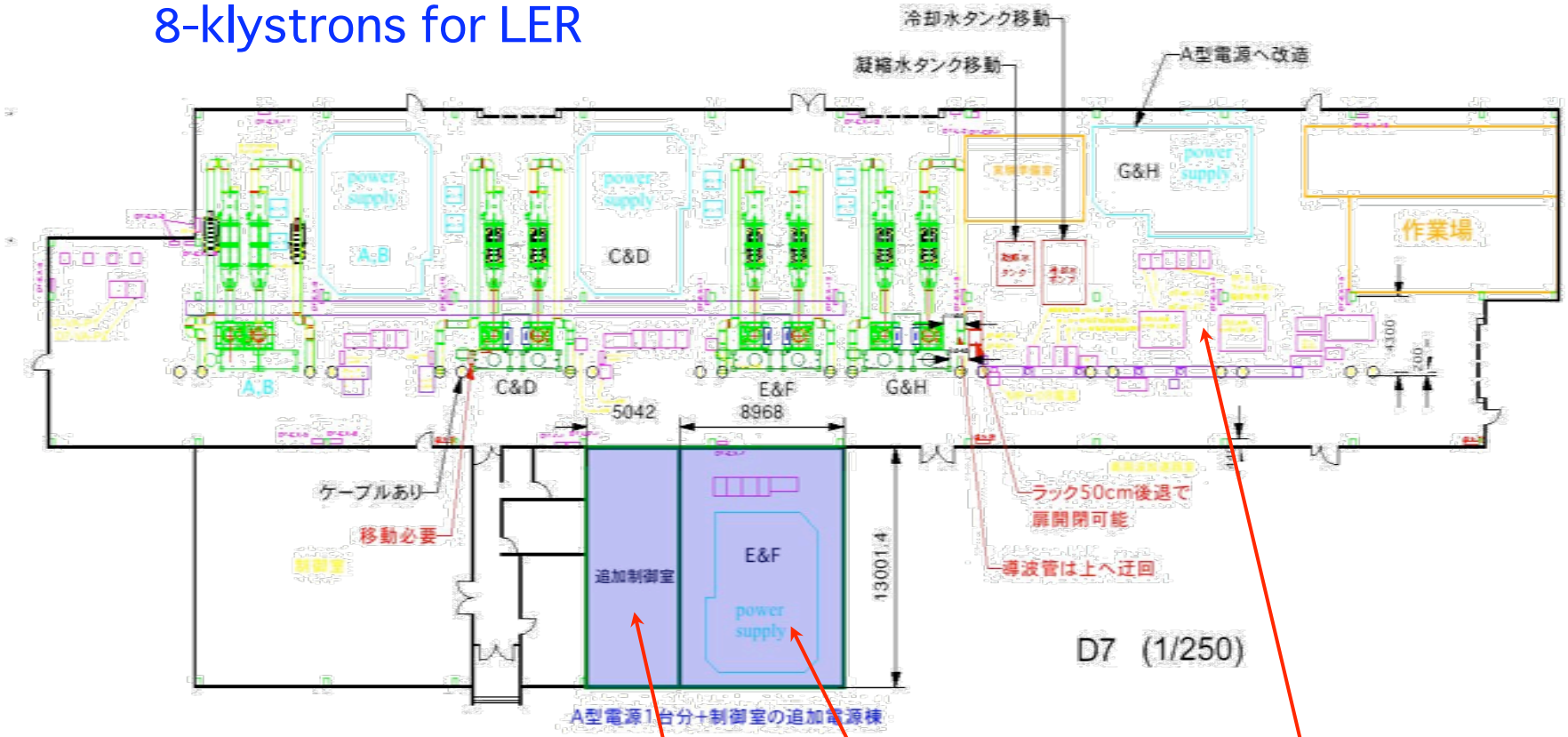
If one more Crab will be added, need one more RF unit.

Layout of RF-unit is not changed, but increase the Out put power of Klystron.

Present D7 Klystron Gallery;
5-klystrons for LER



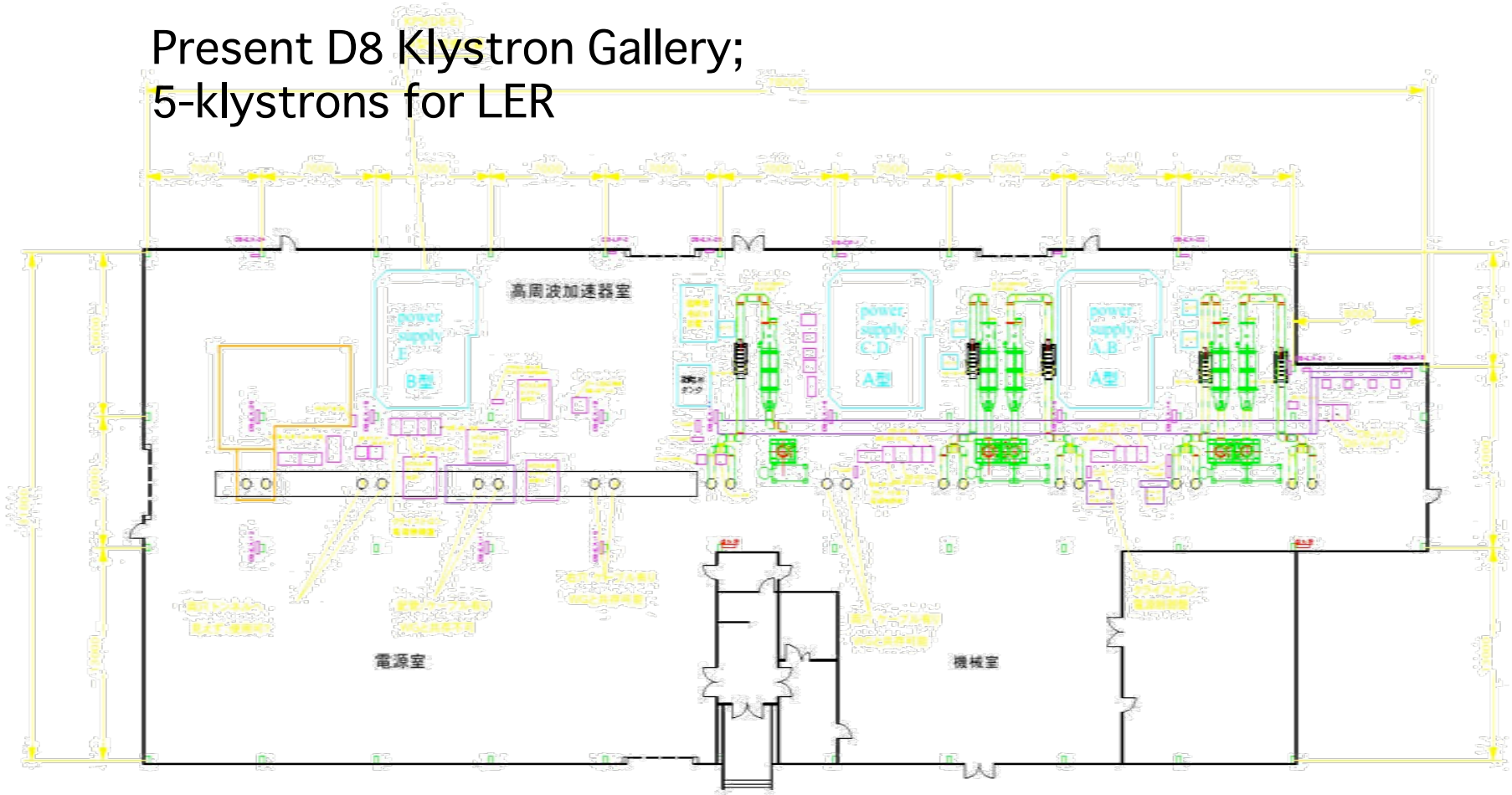
D7 Klystron Gallery;
8-klystrons for LER



Reserved for
Kicker/Septum

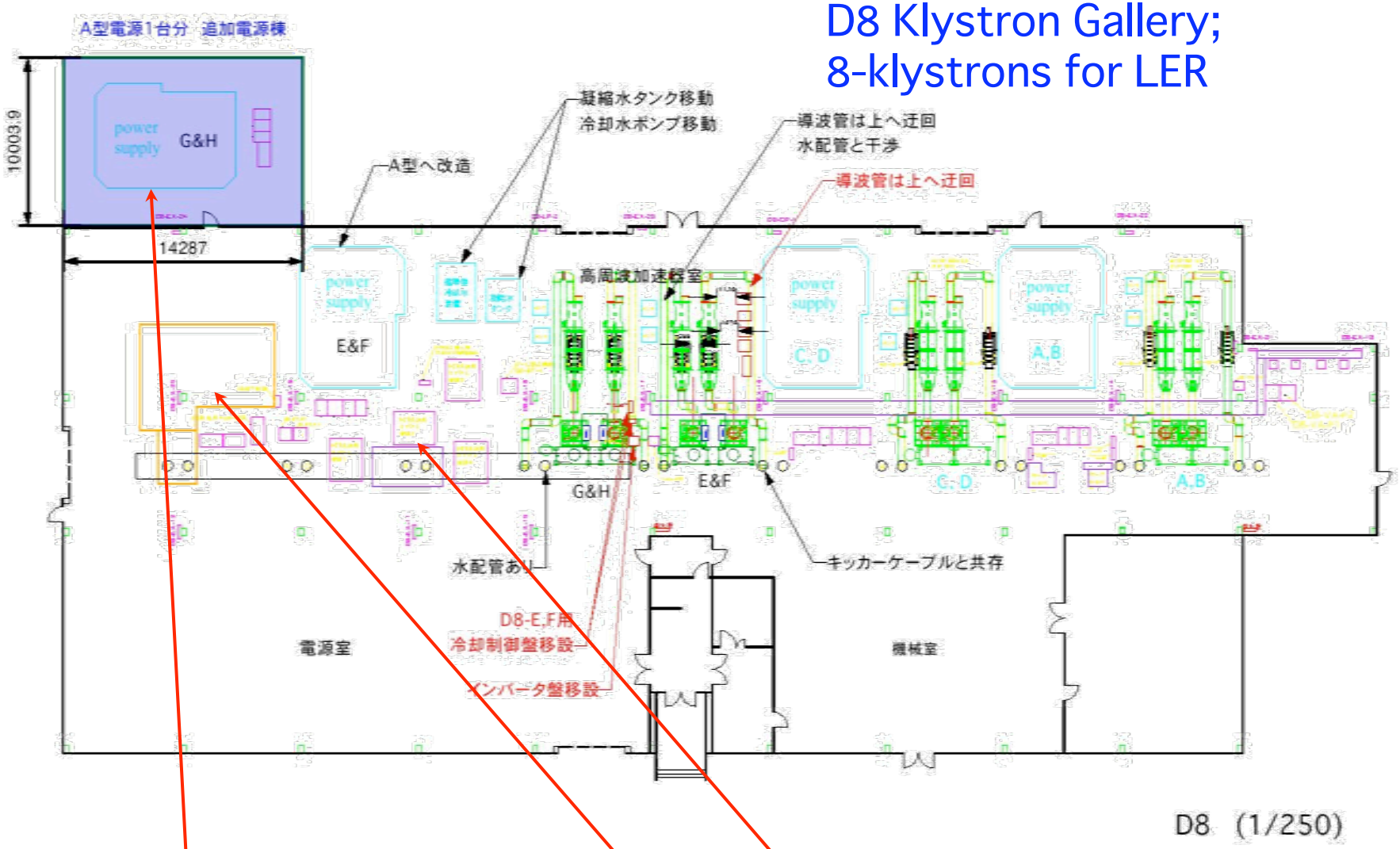
Need Area Extension;
For RF-control & KPS

Present D8 Klystron Gallery;
5-klystrons for LER



D8電源棟 (1/250)

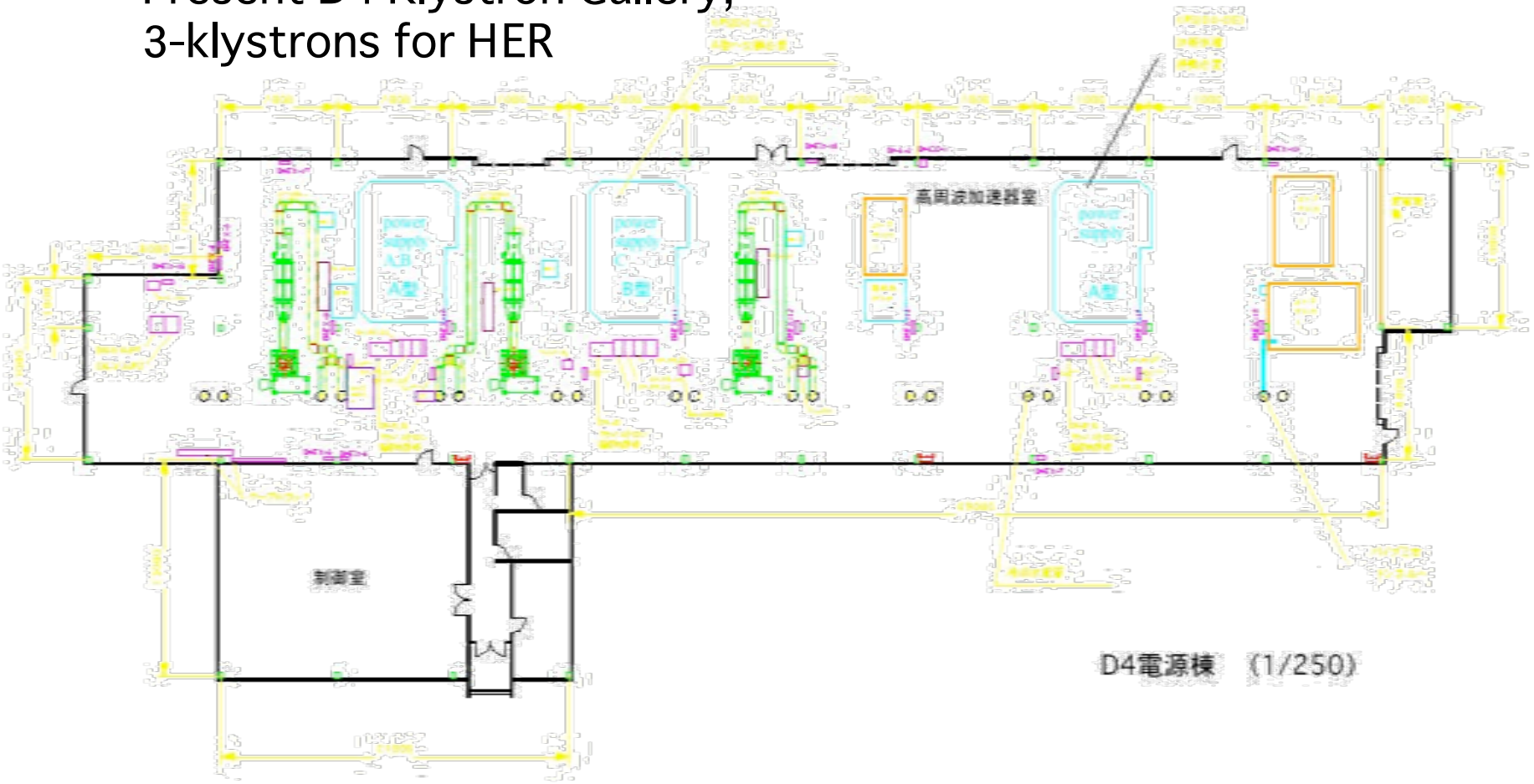
D8 Klystron Gallery; 8-klystrons for LER



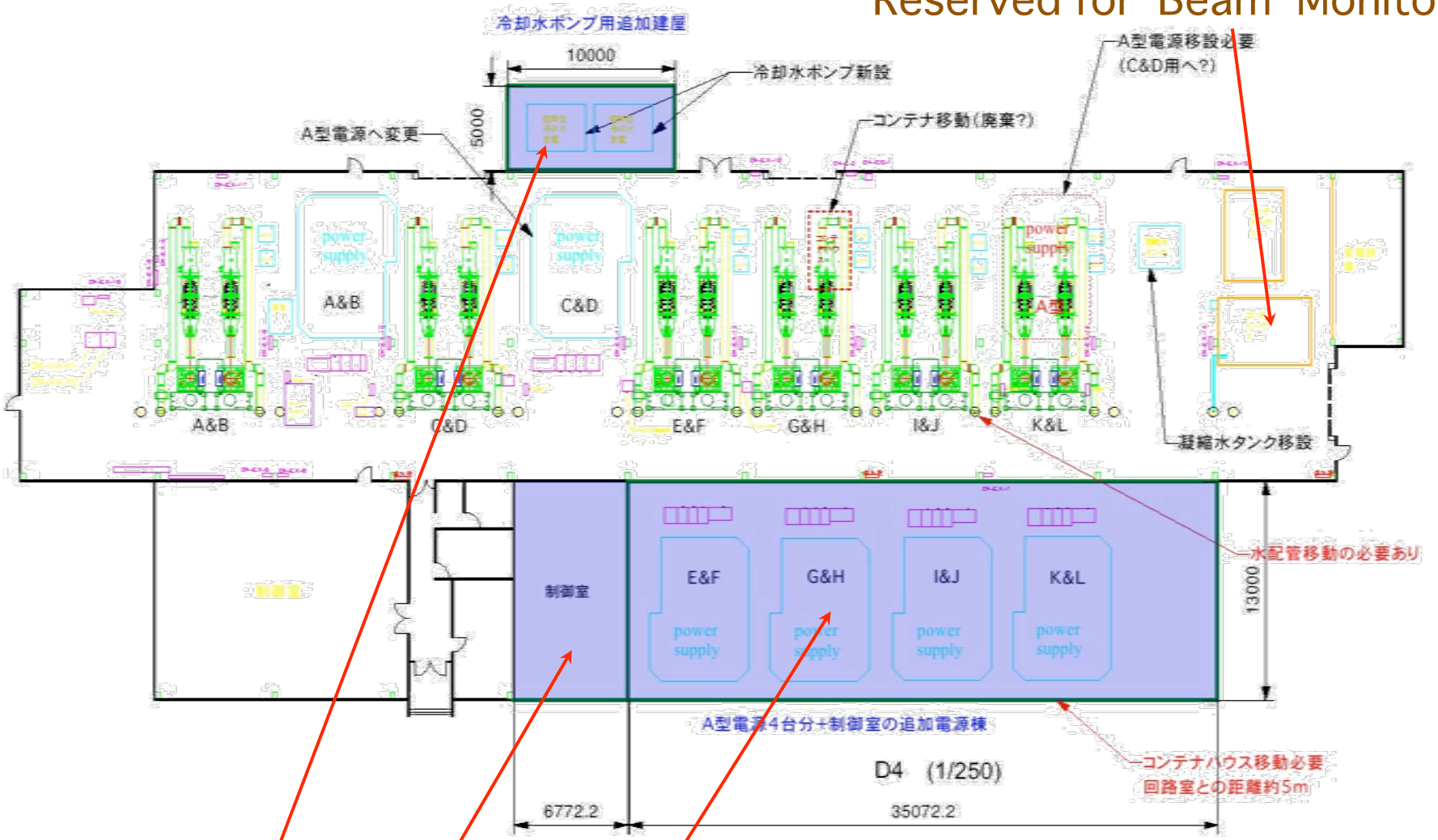
Need Area Extension;
For KPS

Reserved for
Kicker/Septum &
Beam Monitor

Present D4 Klystron Gallery;
3-klystrons for HER



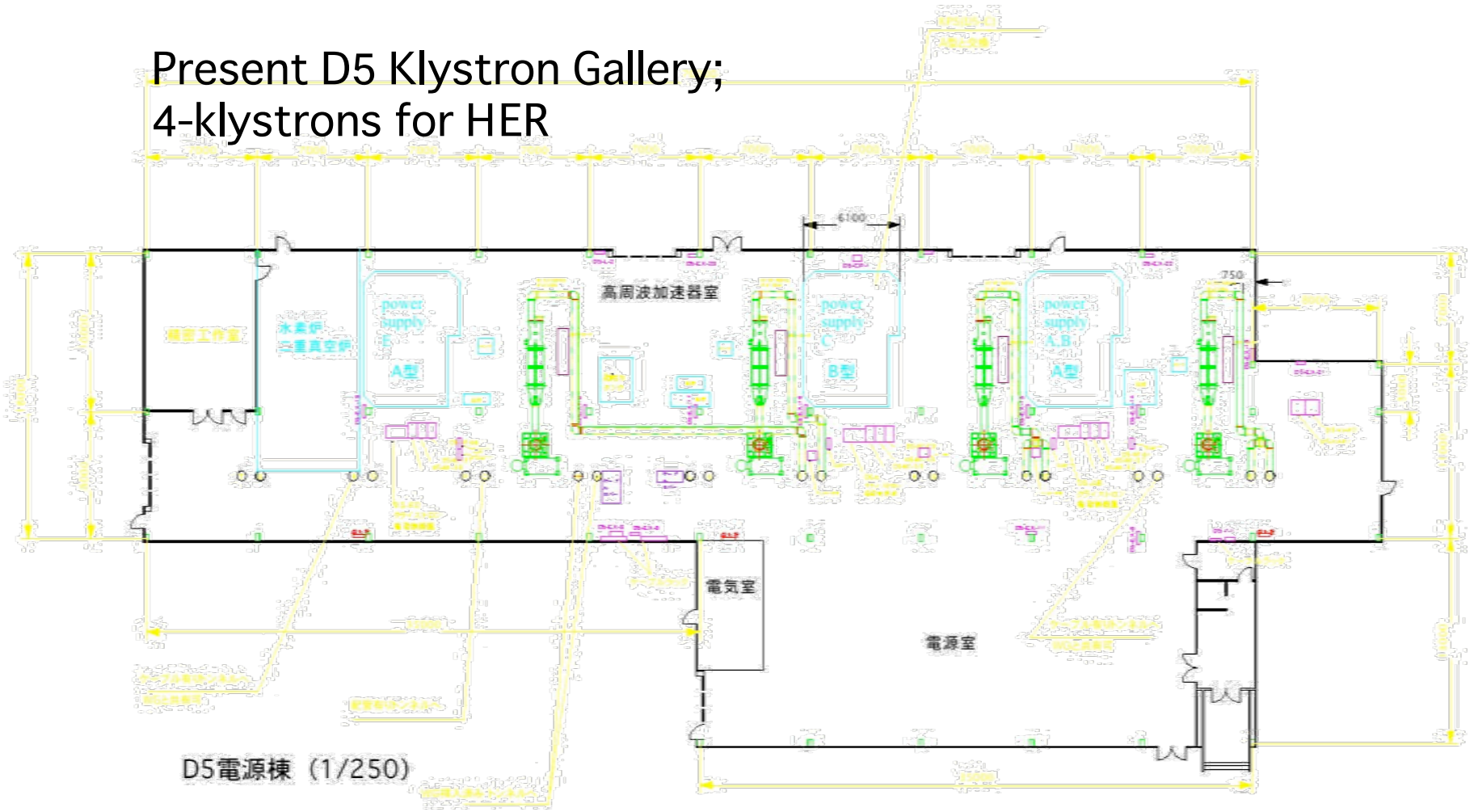
Reserved for Beam Monitor

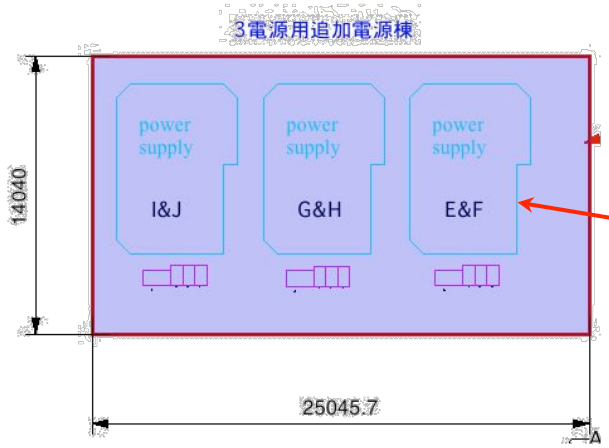


Need Area Extension;
For Pump , RF control & KPS

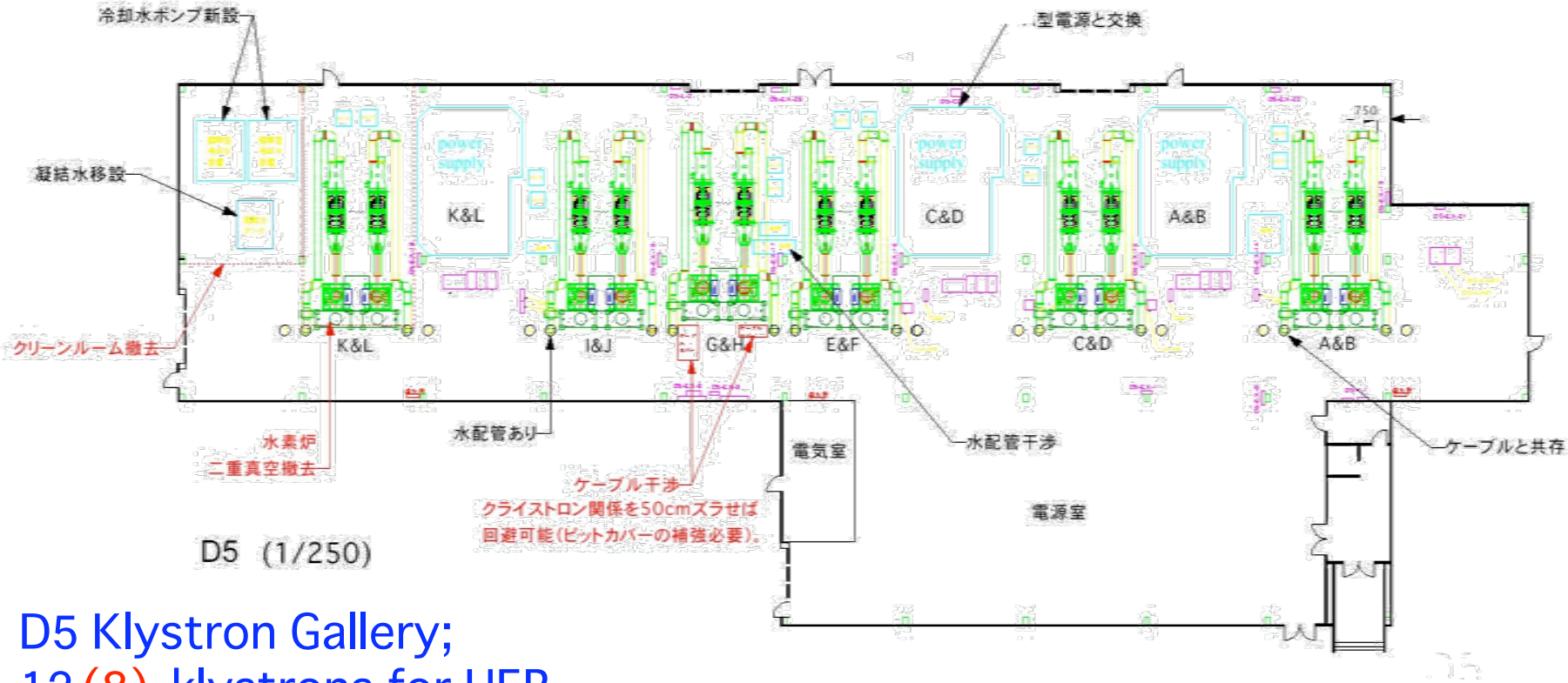
D4 Klystron Gallery;
12-klystrons for HER

Present D5 Klystron Gallery;
4-klystrons for HER





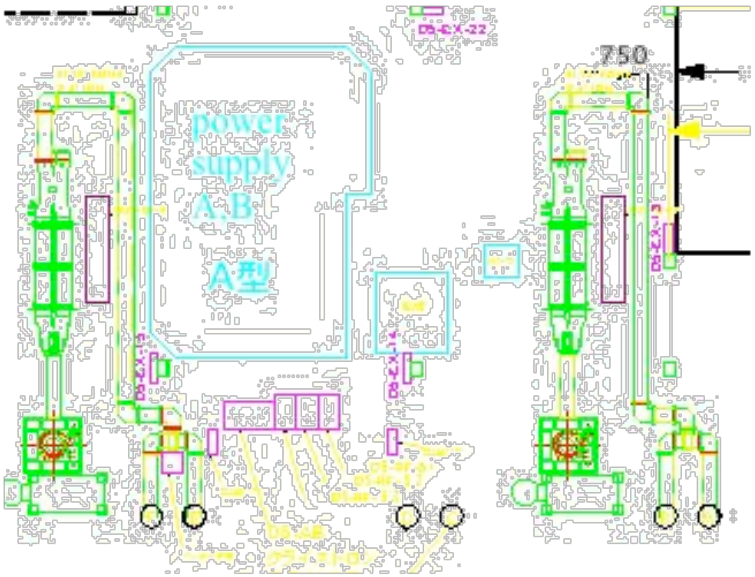
Need Area Extension;
For KPS
(need ground breaking for this area)



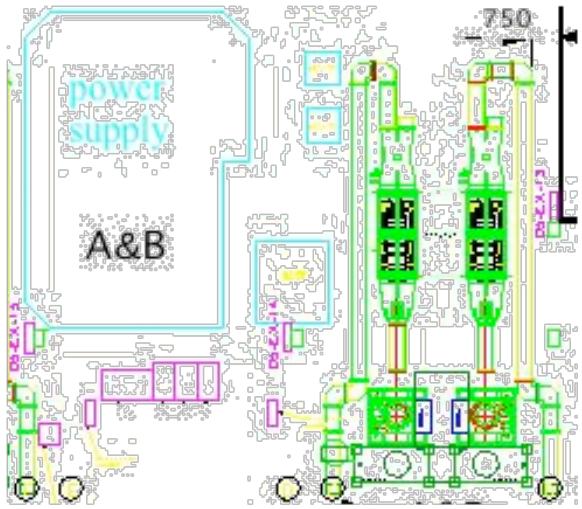
D5 Klystron Gallery;
12 (8)-klystrons for HER
& 0 (4)-klystrons for LER

To Change RF-unit Layout

Squeeze Space between the RF-unit;
1) Replace B-type KPS to A-type.
2) Rearrange Klystron Socket position &
Vapor Suction Pipe position, & relevant cabling/piping.

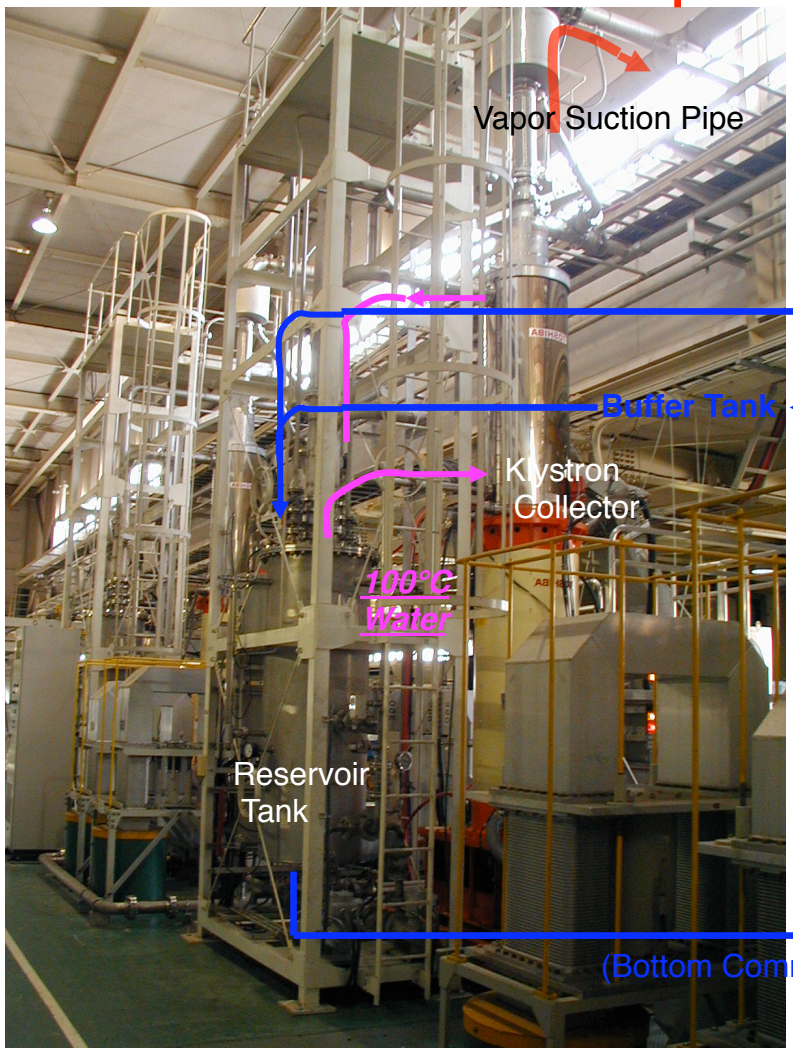


Present Layout;
(D5-A & B)



SuperKEKB Layout

Conception of Vapor Cooling

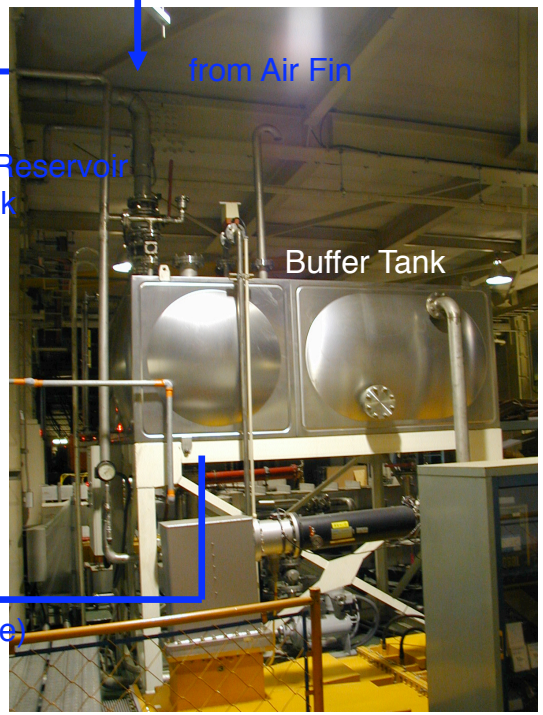


Vapor

Condensed Water

from Air Fin

To Reservoir Tank



(Bottom Common Pipe)

Vapor Cooling; Modification

KEKB; One Vapor Cooling System(one Air-Fin-Cooler) / Gallery

----> SuperKEKB; Two Vapor Cooling Systems / Gallery

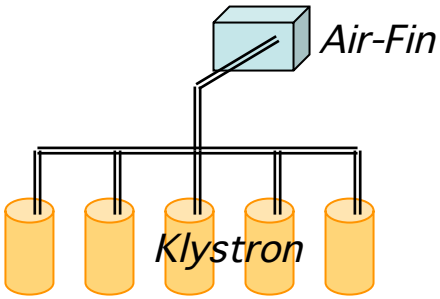
: Add 2nd Air-Fin-Cooler/ Vapor Suction Pipe

Comment on Operation;

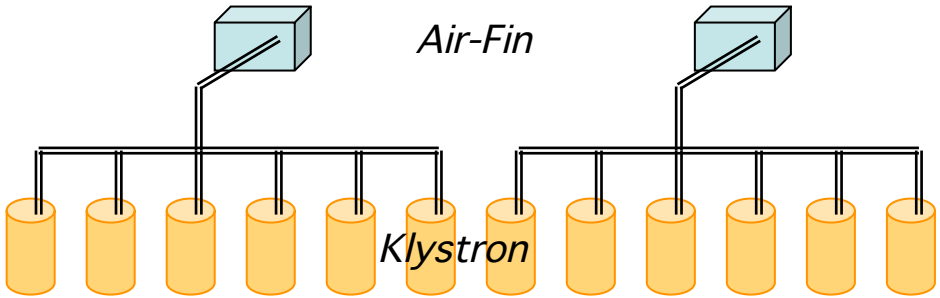
The Idea is simple, but actual Operation is complicated for Parallel Vapor Cooling, because each Pressure are changed.

---> Good Vapor Conductance may be Key Issue.

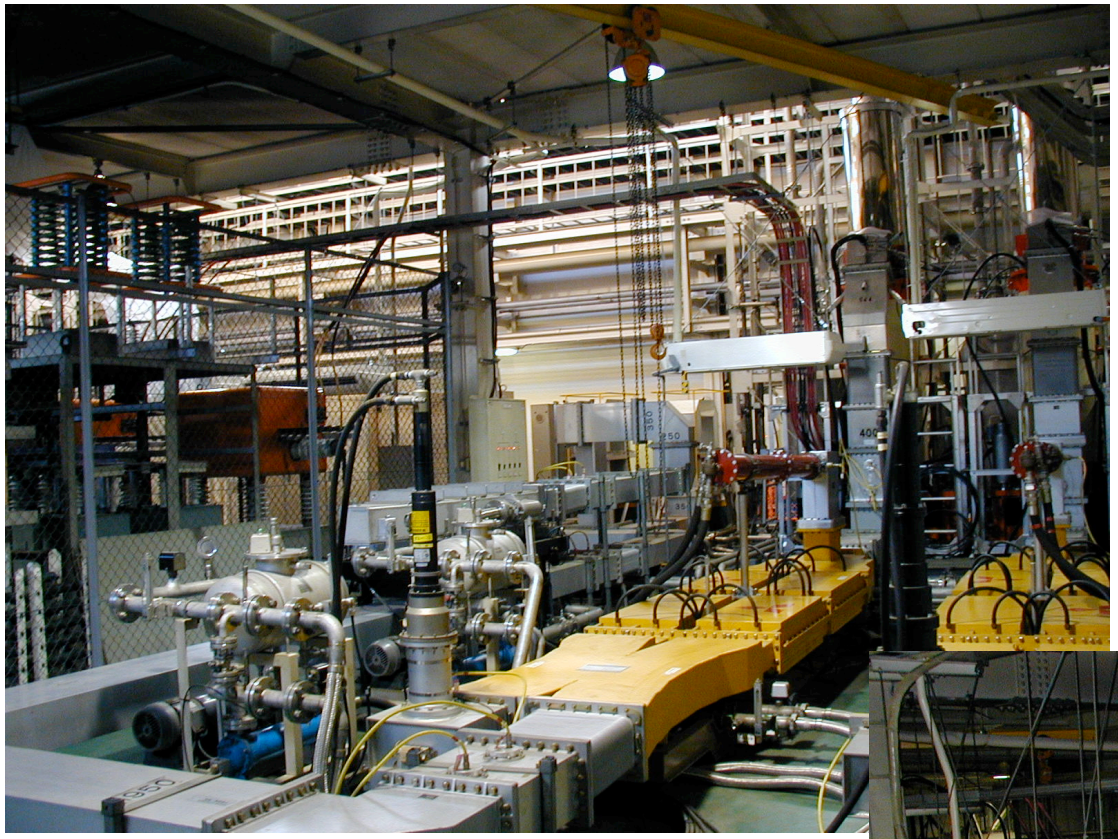
---> Add one more system, even Cooling Power ~5-6MW/Air-Fin(in design).



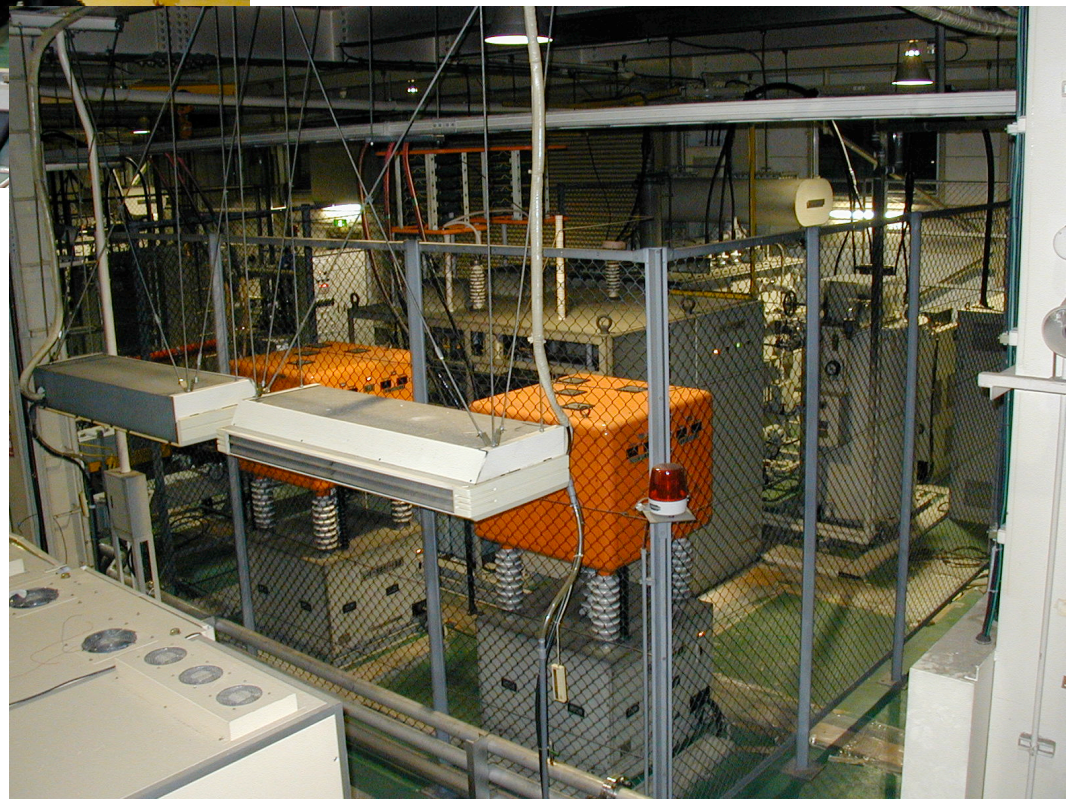
KEKB: D7/D8



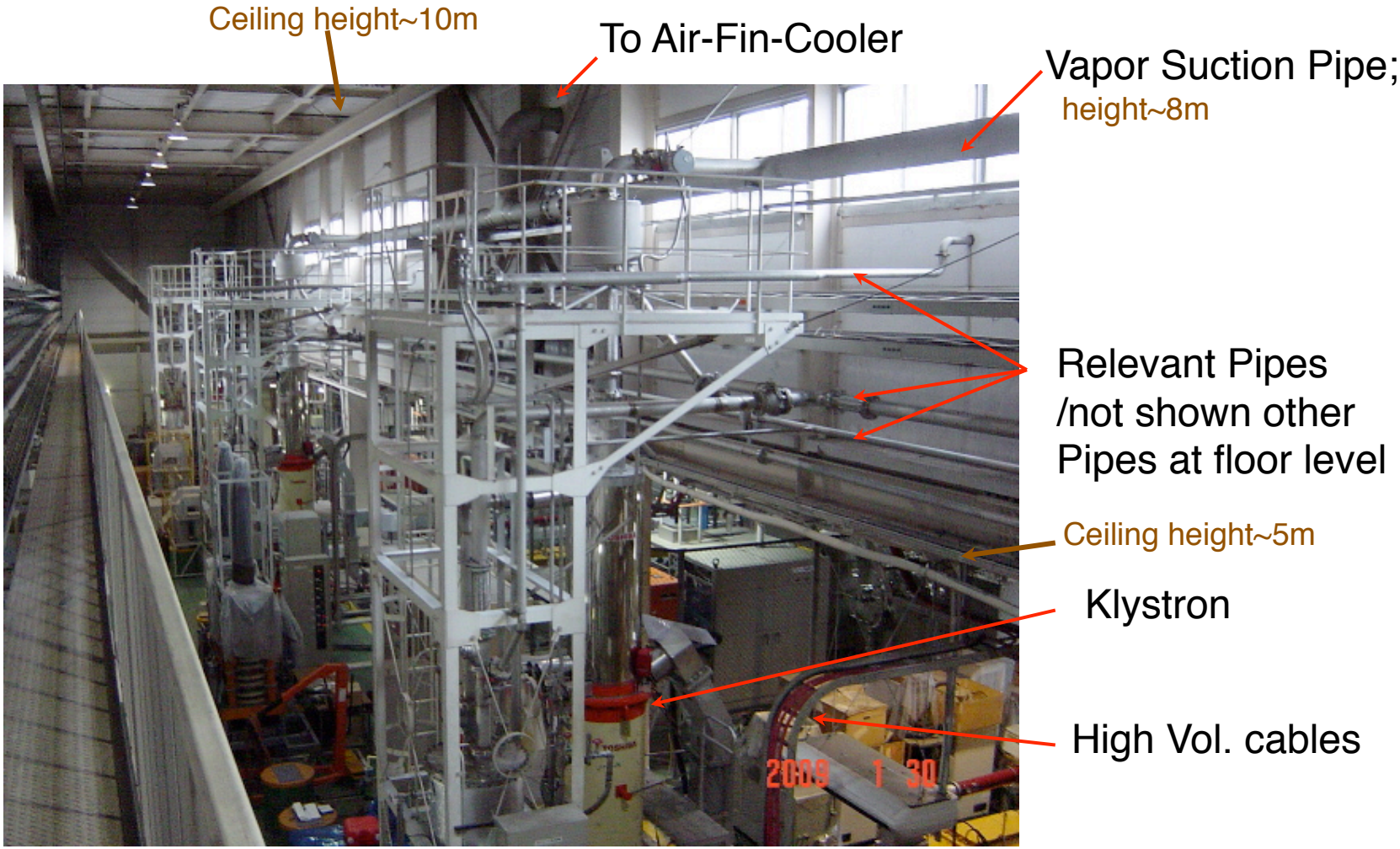
SuperKEKB: D4/D5



Two Klystrons Stand side by side;
(D7-A & B units).
In SuperKEKB, all stations will be the similar Layout.

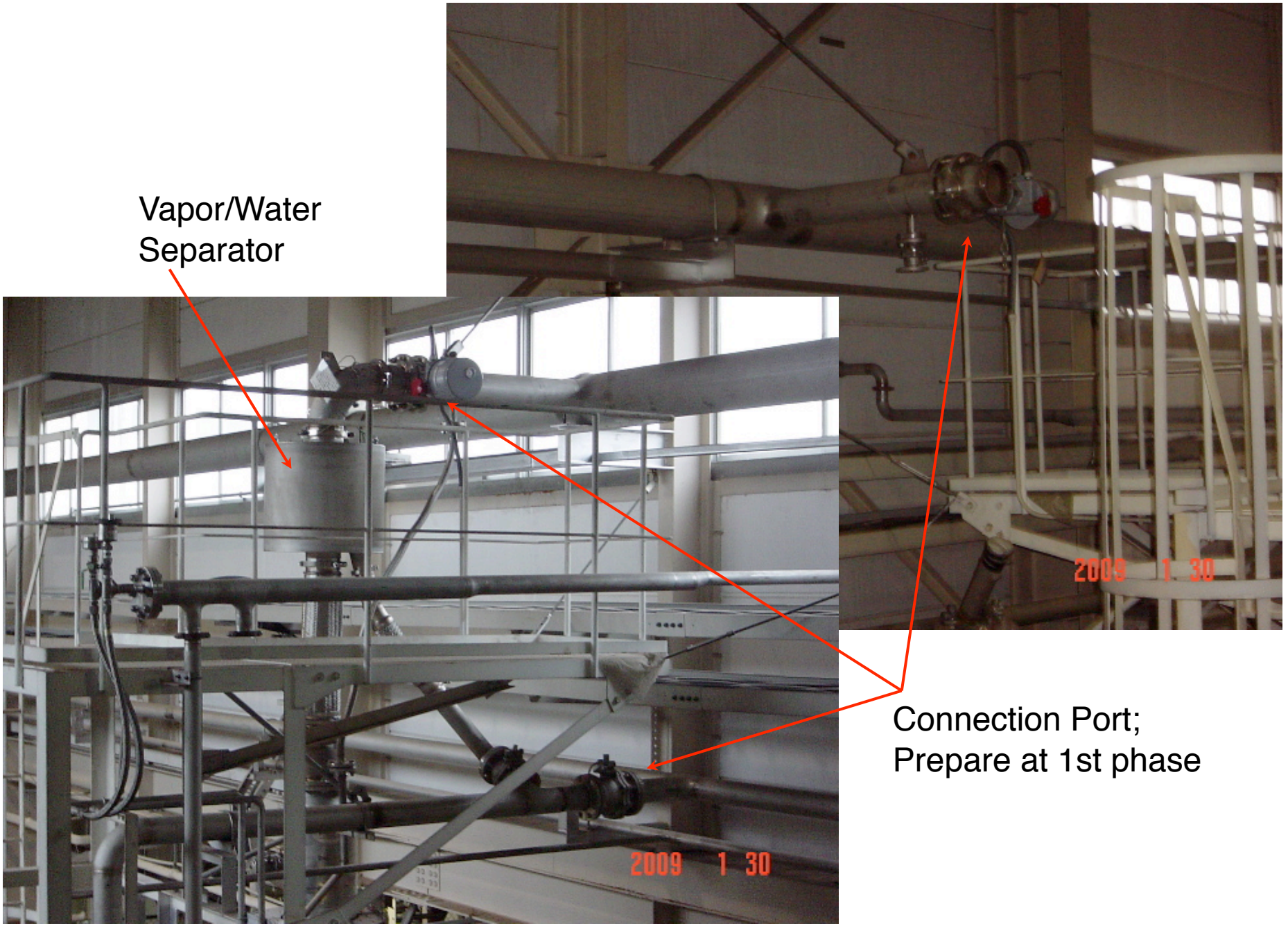


KPS: DC -90kV, 20A x 2
Suppression of the Corona Sparking,
lead to Stable Operation.
Eliminate almost all fake Crowbar Work.



D4 Klystron Gallery

Present only 3 klystrons
---> 12 klystrons at SuperKEKB


Vapor/Water
Separator
Connection Port;
Prepare at 1st phase
2009 1 30
2009 1 30

Strategy To Increase RF-unit;

1st phase: At the initial long shut down(~3years?);

0) Build the area/space for KPS & for RF-control.
1) Available RF-unit(include KPS) will be rearranged.
2) Prepare Vapor Suction Connection Ports & relevant Cabling/Piping.
3) Add Vapor Suction Pipe for 2nd Air-Fin-Cooler.

2nd-Nth phase: At the short shut down(~half years?);

1) Add RF-units; Cavity/ Klystron/ Wave Guide/ Cooling…
2) Add 2nd Air-Fin-Cooler ; if Kly# >5/Gallery.
3) N~3-5??; finish upgrade RF-source after N-years SuperKEKB Commissioning.

Infrastructure; Electricity

Power Station	Station total (MW)	Magnet (MW)	He-refrig. (MW)	RF (MW)	Utility (MW)	BT (MW)
Tsukuba (D1,D2)	4.6	1.4	0.4	0	2.8	
	8	1.5	0.5	2	4	
Oho (D4,D5)	8.8	2.2		4.9	1.7	
	41.2	2.2		36	3	
Fuji (D7,D8)	16.1	1.1		11.2	2.3	1.5
	29.6	1.1		24	3	1.5
Nikko (D10,D11)	14.8	3.8	2.5	6.2	2.3	
	16	3.8	2.5	6.7	3	

← KEKB
← Super KEKB

	Present KEKB 071121 (MW)	Super KEKB (MW)
B-Factory	44.3	94.8
KEK-total	63.6	~120

Need Power Up of the Power-Station (add Bank).

Infrastructure; Cooling Water

	Unit	Vacuum Chamber	ARES Cavity	ARES Home	Kly-Body, KPS, W.G.	Magnet	TOTAL
Disp. Power; SuperKEKB	MW	33.6	12	3	7.5	5.4	61.5
Cooling Water; SuperKEKB	L/min	31200	31150	4000	11200	15650	93200
					21900		21900
Cooling Water; Present KEKB	L/min	7200	10000		11200	15650	44050
					21900		21900

Comments;

1) Cooling except Vapor-Cooling are listed.
2) Total Water-Flow of Facilities are listed.
3) Brown indicate Not Pure-water(~Tap Water quality).
4) Need(add) New Cooling Facility(include piping/AFC) for Vac/ ARES ; 4 new facility buildings are needed.
5) Same(Present) ΔT are assumed for Flow-Rate estimation.

4 New Facility Building;
at Arc sections.
1） Vacuum Chamber

Upgrade Present Facility;
2） ARES Cavity
3） ARES-HOM
4） Klystron/WG

Present Facility;
5） Magnet／Mag.PS

Power Balance; Check the Estimations

Injecting Electric Power ; ~95MW

94.8MW = 68.7(RF) + 8.6(Mag) + 3(He-refrg) + 1.5(BT) + 13(Utility)

Dissipating Heat Power ;

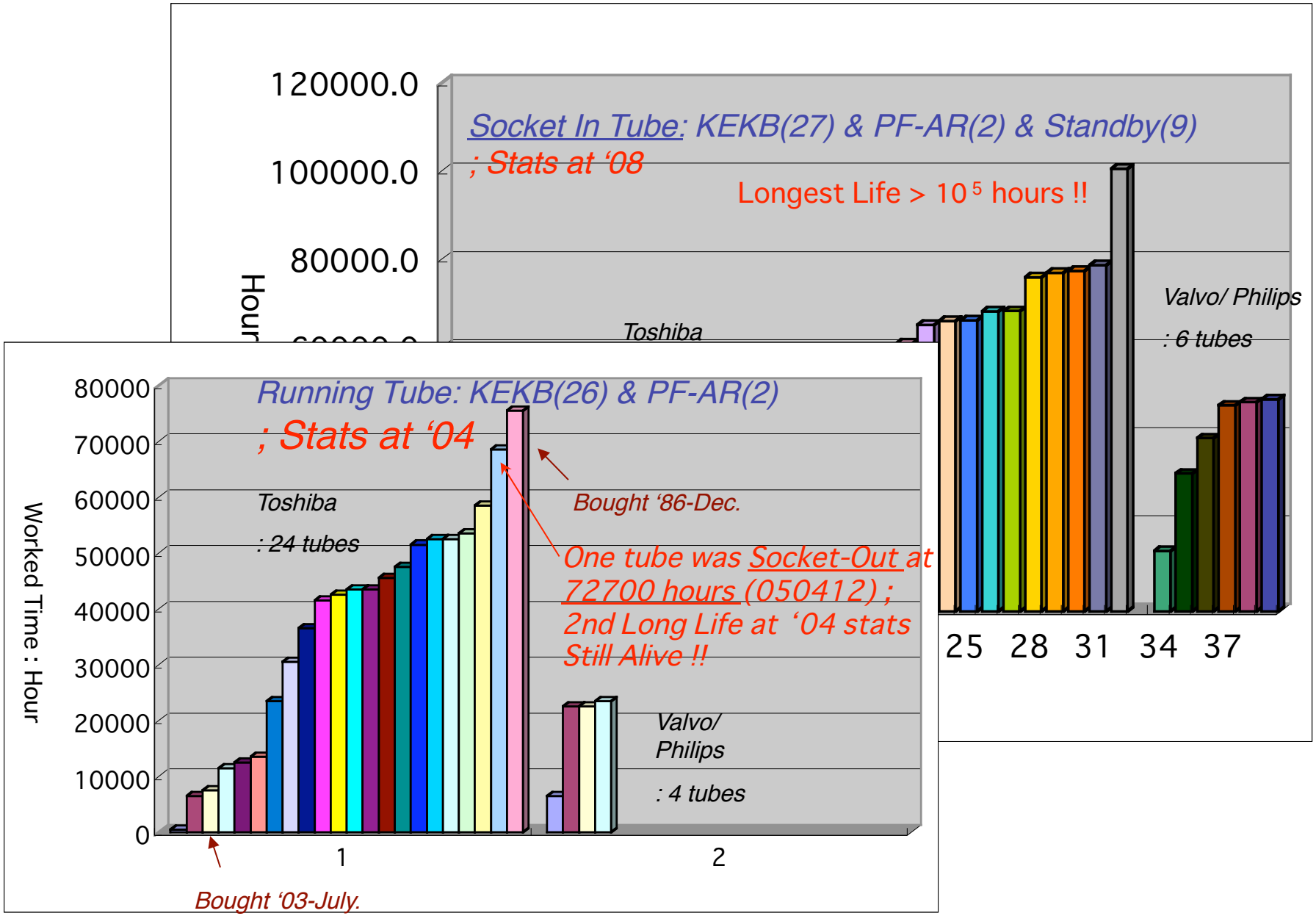
61.5(Water; Vac & ARES) + ~24(Vapor; Kly) = ~86MW

Others(Utility);

Water Cooling Facility(Plate-Heat-Exchanger, Pump, Air-Fin-Cooler), Air-Conditioner, ⋯ ---> ~10MW

95MW <---> ~96MW : Consistent !?

Klystron Worked Time: (M.Yoshida; 08/12/25)



Conclusion

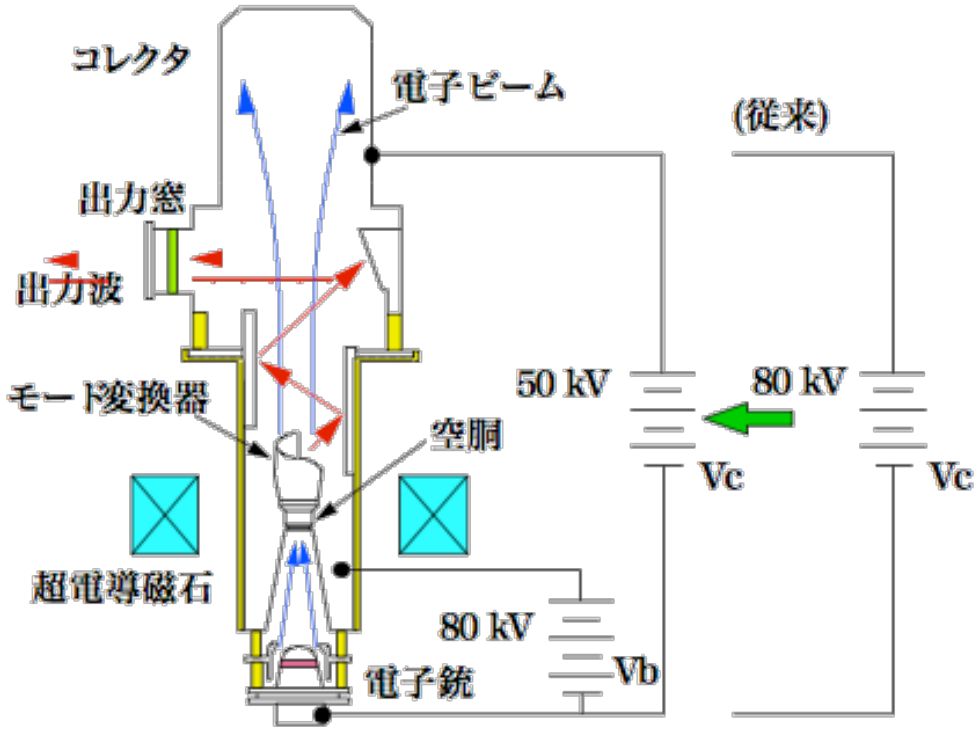
Based on the Present Design, Upgrading of the RF-Source & Relevant Infrastructure may be Feasible.

But, Huge Electric Power is needed; 95MW(120MW in KEK).

So, seek the possibilities,

1) Low intensity (low beta) machine design,
and also,

2) Save/Recover Energy;
Generate Electricity by Vapor Heat Power;
~10% ?? CPD-Klystron; Collector Potential Depression ; completely unknown its feasibility.
etc.



エネルギー回収型ジャイロトロンの概略図

CPD-Gyratron

従来効率 ＝ 1000kW / 80kV / 40A＝31%

回収後効率 ＝ 1000kW / 50kV /40A＝50%

RF : 6.6kV AC Plug Power for Klystron

Kly. Gallery	Klystron #		AC Plug Power : 6.6kV				
			KEKB		Super KEKB		
For Acc. Cavity	KEKB	Super KEKB	300A	150A	300A	150A	
Fuji:D7	5	8	2	1	4		
Fuji:D8	5	8	2	1	4		
Oho:D4	3	12	2	1	6		
Oho:D5	4	12	2	1	6		
Nikko:D10	4	4	2		2		
Nikko:D11	4	4	2		2		
TOtal	25	48	12	4	24		
For Crab Cavity							
Nikko:D10		(1)				(1)	*If HER Crab added*
Nikko:D11	2	2		1		1	

Replace 150A(for B-type KPS) to 300A(for A-type) & Add new 300A power line.

LER: Klystron Power Supply

Upgrade KPS name	Present KPS type	1st Upgrade status	Comment	KPS method	Nth Upgrade status
D7-AB	A	A-old		90kV/20A x 2; IVR	
D7-CD	A	A-old		90kV/20A x 2; IVR	
D7-EF			New KPS/ Install to new Gallery	~95kV/20A x 2; Switching	A-new:1
D7-GH	B	A-old/(new)	Exchange to A-type; If old <--> D4-ED/ new if possible		(A-new:12)
D8-AB	A	A-old		90kV/20A x 2; IVR	
D8-CD	A	A-old		90kV/20A x 2; IVR	
D8-EF			New KPS/ Install to new Gallery	~95kV/20A x 2; Switching	A-new:2
D8-GH	B	A-old/(new)	Exchange to A-type; If old <--> D1-AB/ new if possible		(A-new:13)
			(below two KPS ; not decided for LER or HER)		
D5-IJ			New KPS/ Install to new Gallery; (if used for LER)	~95kV/20A x 2; Switching	A-new:3
D5-KL			New KPS/ Install to new Gallery; (if used for LER)	~95kV/20A x 2; Switching	A-new:4

HER: Klystron Power Supply

Upgrade KPS name	Present KPS type	1st Upgrade status	Comment	KPS method	Nth Upgrade status
D4-AB	A	A-old		90kV/20A x 2; IVR	
D4-CD	B	B(/A-new)	Exchange to new A-type; if possible		A-new:5
D4-EF	(A)		(Not used at 1st; move to D7-GH)	(90kV/20A x 2; IVR)	A-new:6
D4-GH			New KPS/ Install to new Gallery	~95kV/20A x 2; Swi	A-new:7
D4-IJ			New KPS/ Install to new Gallery	~95kV/20A x 2; Swi	A-new:8
D4-KL			New KPS/ Install to new Gallery	~95kV/20A x 2; Swi	A-new:9
D5-AB	A	A-old		90kV/20A x 2; IVR	
D5-CD	B	B(/A-new)	Exchange to new A-type; if possible		A-new:10
D5-EF	A	A-old		90kV/20A x 2; IVR	
D5-GH			New KPS/ Install to new Gallery	~95kV/20A x 2; Swi	A-new:11
			(below two KPS ; not decided for LER or HER)		
D5-IJ			New KPS/ Install to new Gallery; (if used for HER)	~95kV/20A x 2; Switching	A-new:3
D5-KL			New KPS/ Install to new Gallery; (if used for HER)	~95kV/20A x 2; Switching	A-new:4