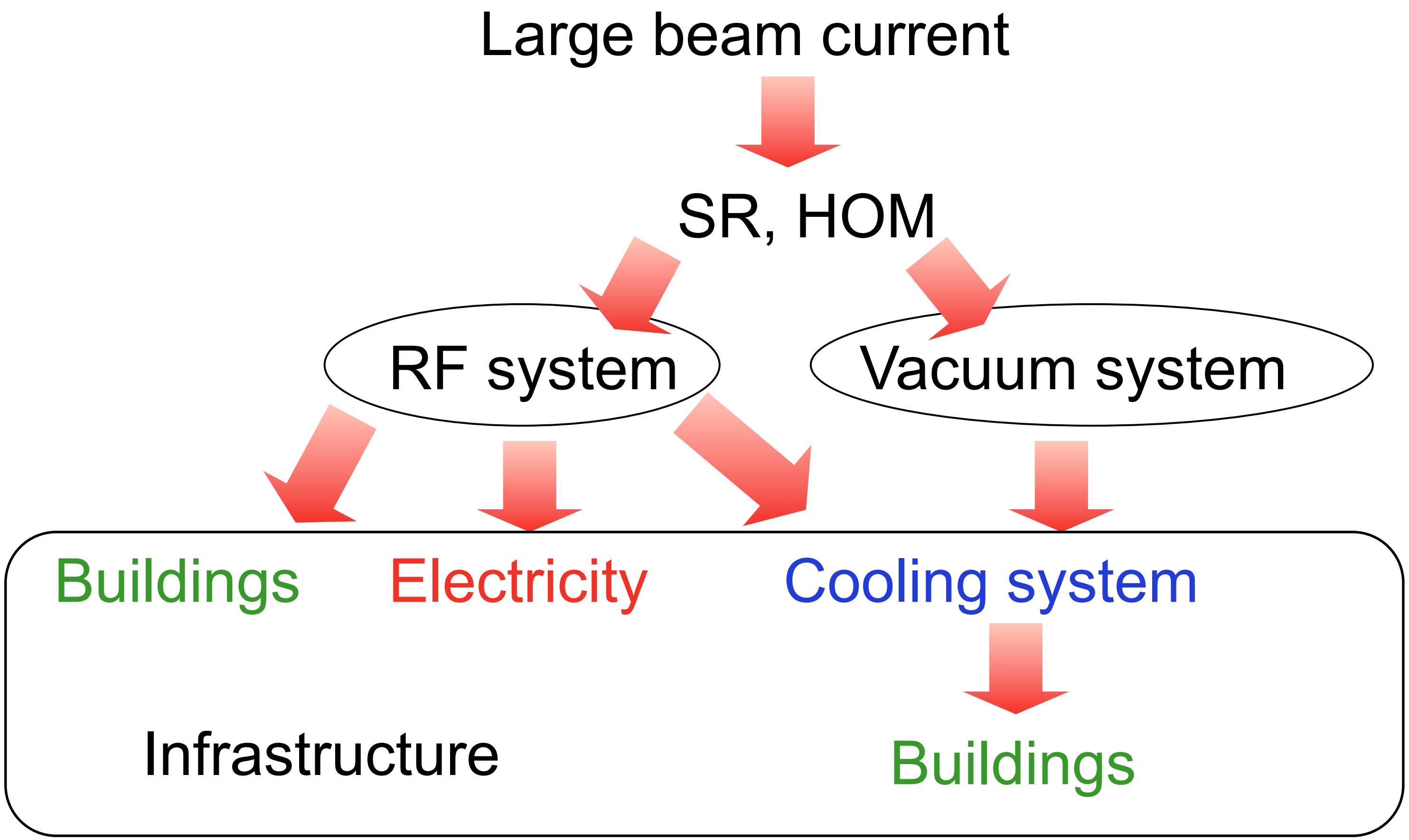
Infrastructure for SuperKEKB



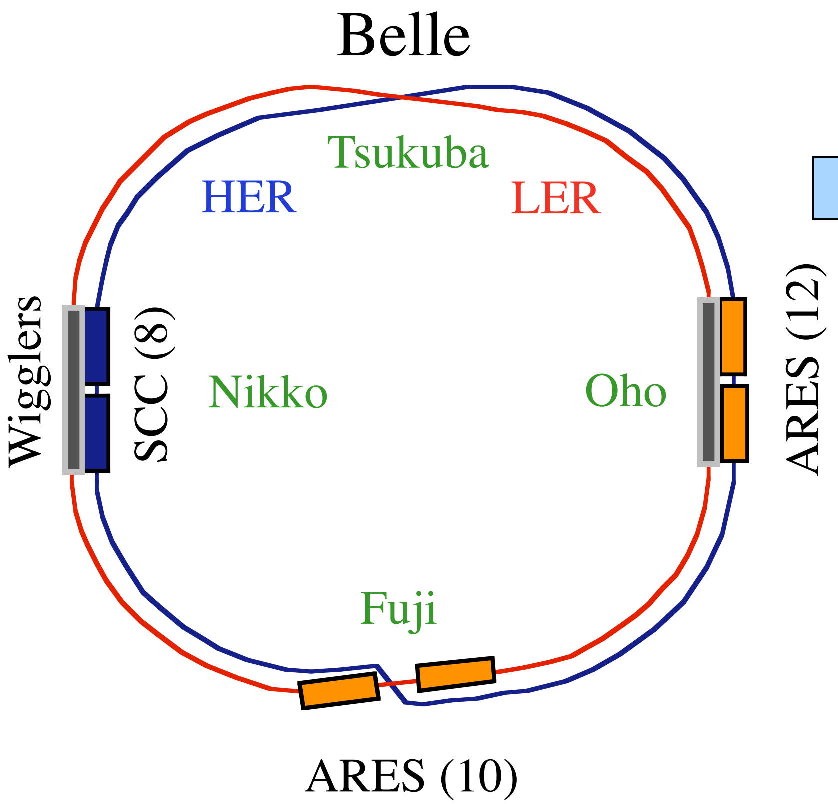
Infrastructure for SuperKEKB

- Power consumption
  - Synchrotron Radiation (SR)
  - Higher Order Mode (HOM)
  - Need many RF systems to support beam power
  - Magnets

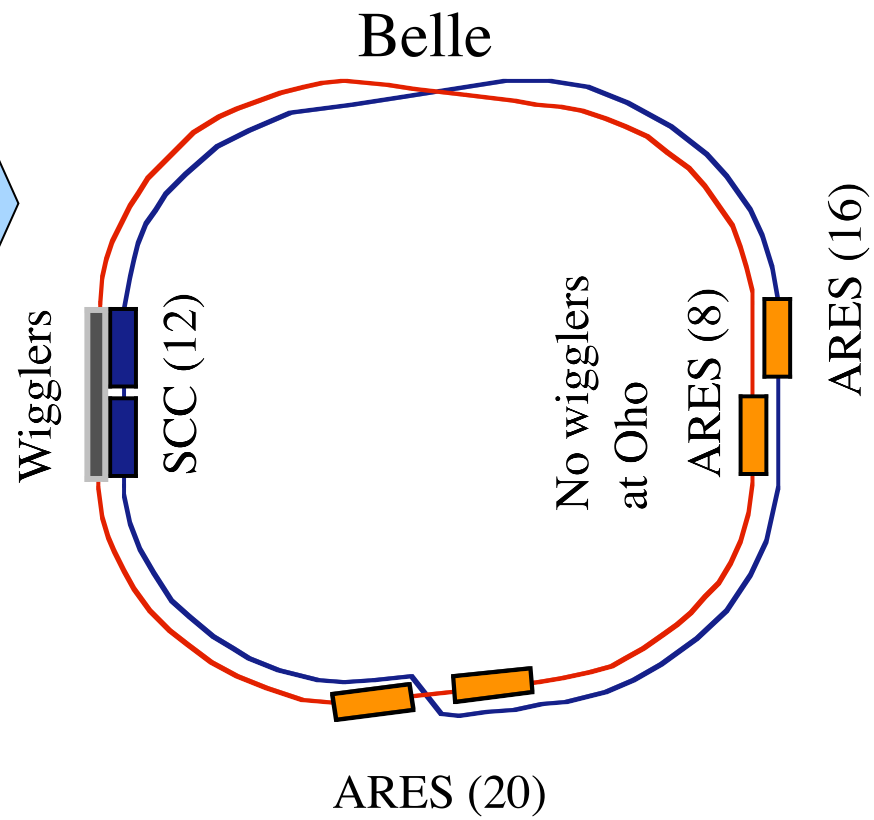
← 9.4 A/4.1 A
Short bunch length (3 mm)

- Electricity
  - We have 4 substations for KEKB ring at KEK.
- Cooling system
  - Air cooled heat-exchanger+Chillers+Water pumps for vacuum chamber
  - Air cooled heat-exchanger+Water pumps for other components
  - VAPODINE system for collector cooling in klystrons
- Buildings

Upgrade of accelerator



Layout of KEKB
(design)



Layout of SuperKEKB

Power consumption

- Synchrotron radiation (SR)

$$P_{SR} \propto \frac{N\gamma^4}{\rho}$$

N: no. of particles   γ: Lorentz factor
ρ: bending radius

  - Wigglers are assumed as a half of KEKB.

	KEKB 2001		KEKB design		Super KEKB	
	LER	HER	LER	HER	LER	HER
Beam current (A)	1.25	0.78	2.6	1.1	9.4	4.1
Energy Loss (MeV)	1.6	3.5	1.6	3.5	1.2	3.5
SR power (MW)	2.0	2.7	4.2	3.9	11.3	14.3
Total power (MW)	4.7		8.0		25.6	

  - We keep 8 MW cooling capacity for vacuum chamber at present. (Cooling for RF dummy load provides 3.6 MW.)
  - SR power becomes 3 times larger than KEKB design.
  - Cooling power of 25 MW is needed for SuperKEKB.

Power consumption (cont'd)

- Higher Order Mode (HOM)

$$P_{HOM} = T_0 \cdot \kappa(\sigma_Z) \frac{I^2}{N_b}$$

$\kappa(\sigma_z)$: Loss factor σ_z: Bunch length
I: Beam current N_b: No. bunches

	KEKB 2001		KEKB design		Super KEKB	
	LER	HER	LER	HER	LER	HER
Beam current (A)	1.25	0.78	2.6	1.1	9.4	4.1
Number of bunches	1153		5120		5120	
Bunch length (mm)	5.5	5.7	4.0		3.0	
Loss factor (V/pC)	26	36	26	36	40	50
HOM power (MW)	0.35	0.19	0.34	0.09	7.1	1.7
Total power (MW)	0.54		0.43		8.8	

8.8 MW !

- RF cavities, resistive walls, bellows are considered for estimation of loss factors.
- We have to reduce loss factors since I and N_b are determined by luminosity requirement.

Power consumption (cont'd)

- Beam power is a sum of SR and HOM power.
- RF system should compensate beam power.
- Many cavities and klystrons are needed !
- There are power loss at klystrons and cavities.
  - Efficiency of klystrons (ε_{kly}) is ~60 % for AC plug power.
  - Efficiency of cavities (ε_{cavity}) :
    - ~80% (LER ARES)
    - ~75% (HER ARES)
    - ~95% (HER SC)
- Relation of beam power and AC plug power:

$$P_{AC} = P_{beam} / \left(\varepsilon_{kly} . \varepsilon_{cavity} \right)$$

Power consumption (cont'd)

- RF system: Total AC power needs 73 MW.

	KEKB 2001		KEKB design		Super KEKB	
	LER	HER	LER	HER	LER	HER
Beam current (A)	1.25	0.78	2.6	1.1	9.4	4.1
SR power (MW)	2.0	2.7	4.2	3.9	11.3	14.3
HOM (MW)	0.35	0.19	0.34	0.09	7.1	1.7
Beam power (MW)	2.35	2.89	4.54	3.99	18.4	16.0
AC power	4.90	5.77	9.46	7.97	40.0	33.0
Total AC power (MW)	10.7		17.4		73.0	

- Magnets(include power supplies): 7.5 MW
- Beam transport lines: 1.3 MW
- Total is ~100 MW for SuperKEKB.

$180K/day

(100/(150+25 MW) ~60 %)

  – including power consumption on infrastructures.

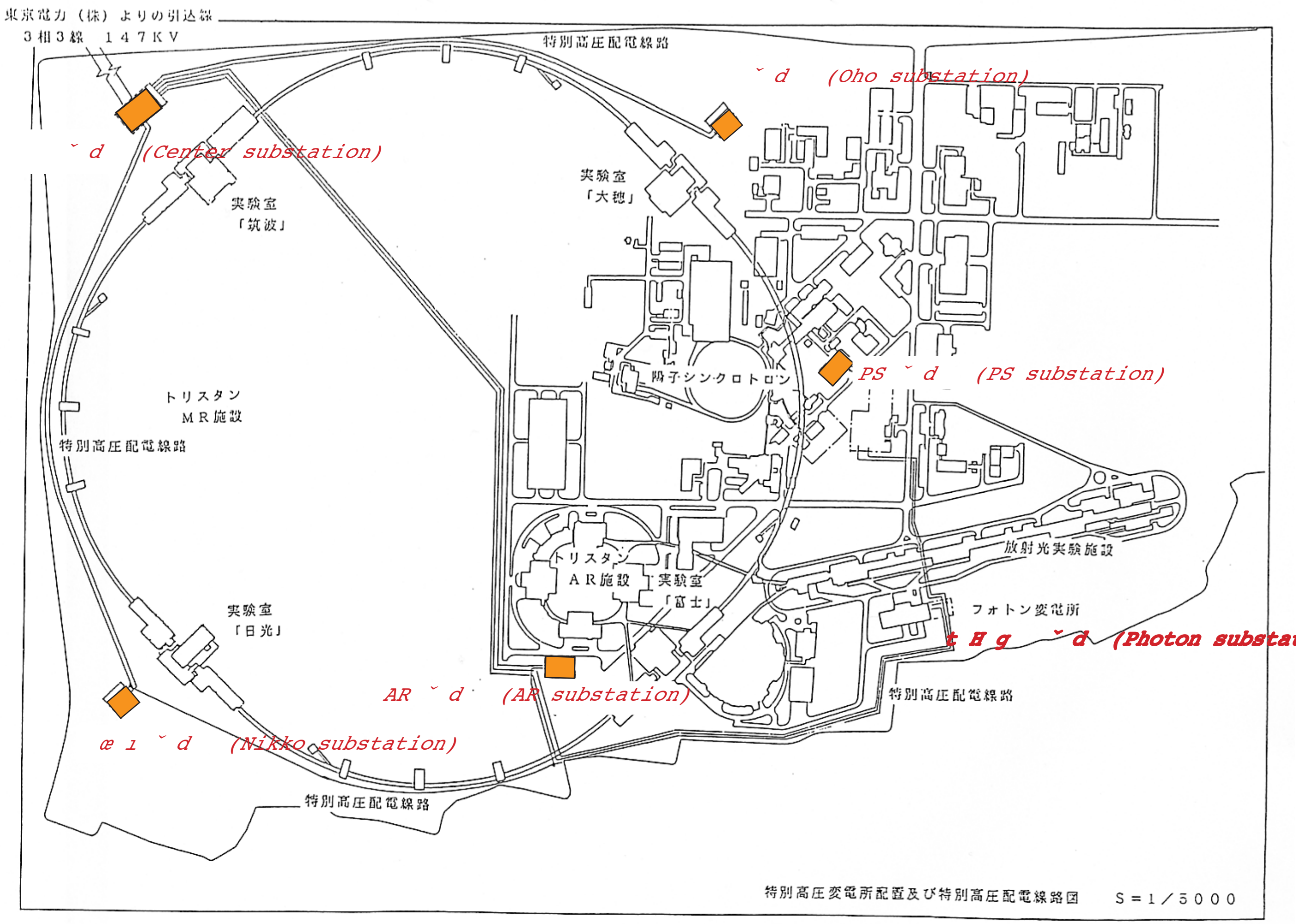
Electricity

Total:
150+25 MW

4 substations
for KEKB

1 substation
for PS

1 substation
for injector&PF



Electricity (cont'd)

- Distribution of power consumption due to RF:
  - Fuji: 28.6 MW
  - Oho: 34.4 MW
  - Nikko: 10 MW
- Substations: Oho, Nikko, AR(for AR and Fuji)
- However, each substation is 32 MW capacity.

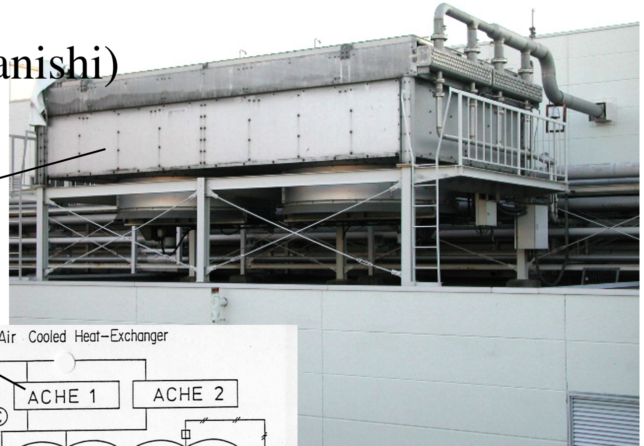
  (AR substation has 51.5 MW capacity)
- We assume that Proton Synchrotron (PS) will be shutdown before starting SuperKEKB.
- PS substation has 56 MW capacity.

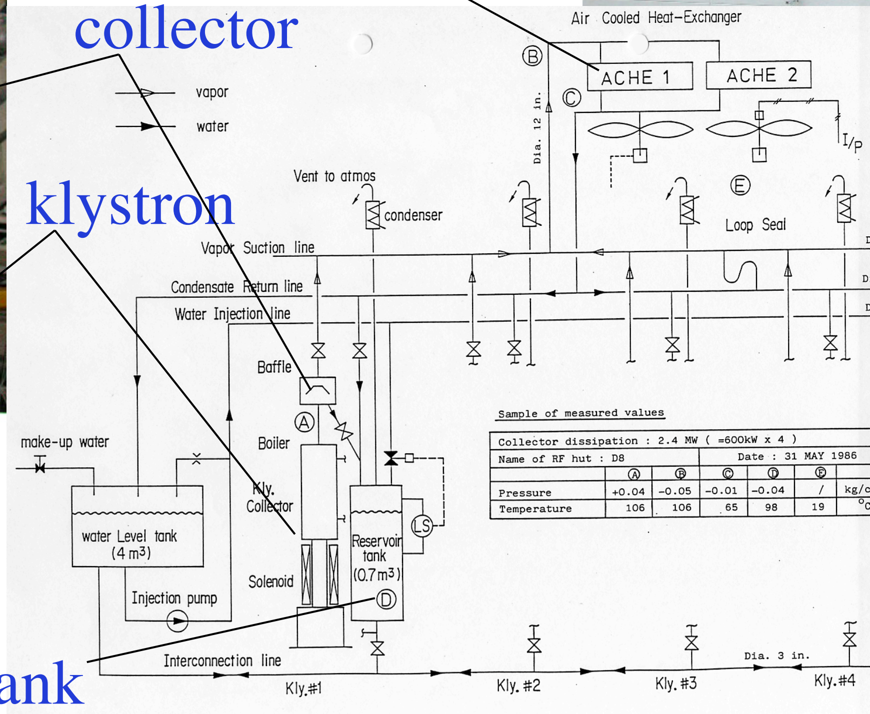
Cooling system

- Klystron power loss is 32 MW out of 38.6 MW of total RF power loss.
- We have special cooling system for klystrons.
  - VAPODINE system
  - The system is compact.
- SR and HOM power loss: 34 MW
  - Heat distribution is assumed to be uniform along ring.
  - We consider 12 sections for cooling of vacuum chamber.
  - Heat load for each section is ~3 MW.
  - Air cooled heat-exchanger+Chiller+Pumps

Cooling system (cont'd)

- VAPODINE for klystrons (RF Group, H. Nakanishi)



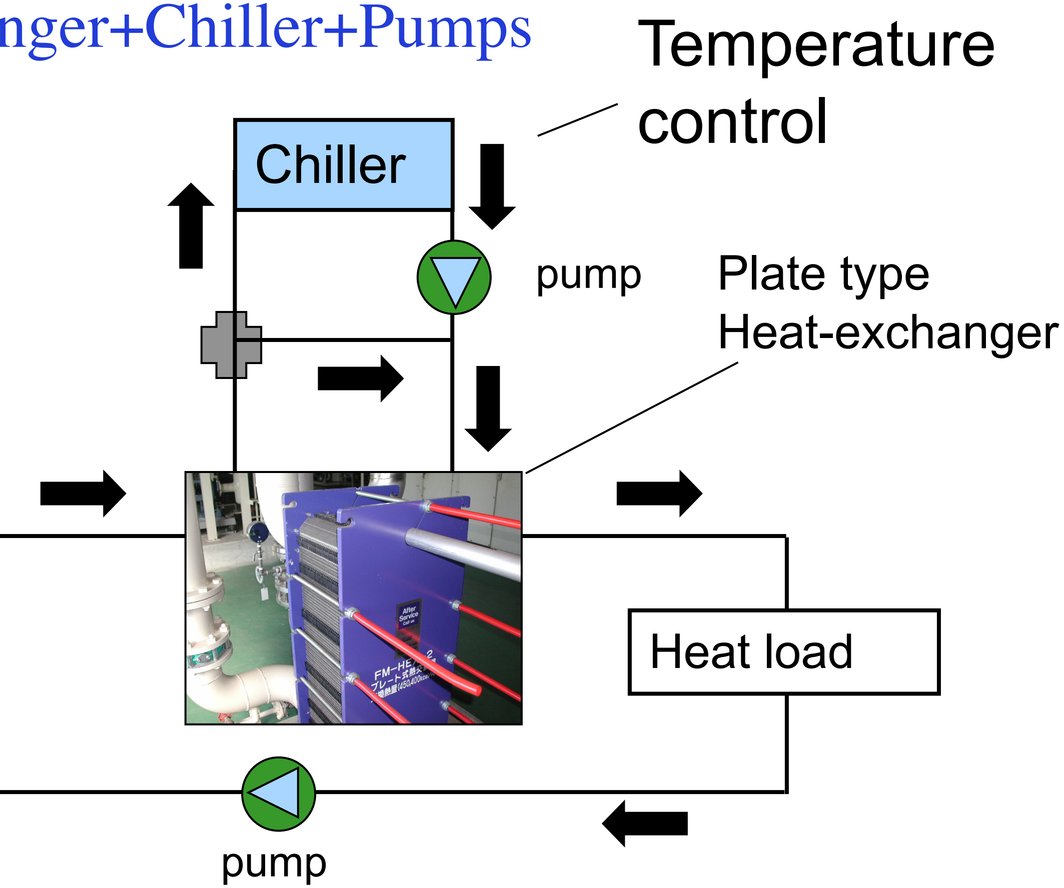


Cooling system (cont'd)

Cooling system for vacuum chamber is :

- Air cooled heat-exchanger+Chiller+Pumps
- Flow rate: 2000 l/min
- Incoming: 45 °C.
- Outgoing: 24 °C.

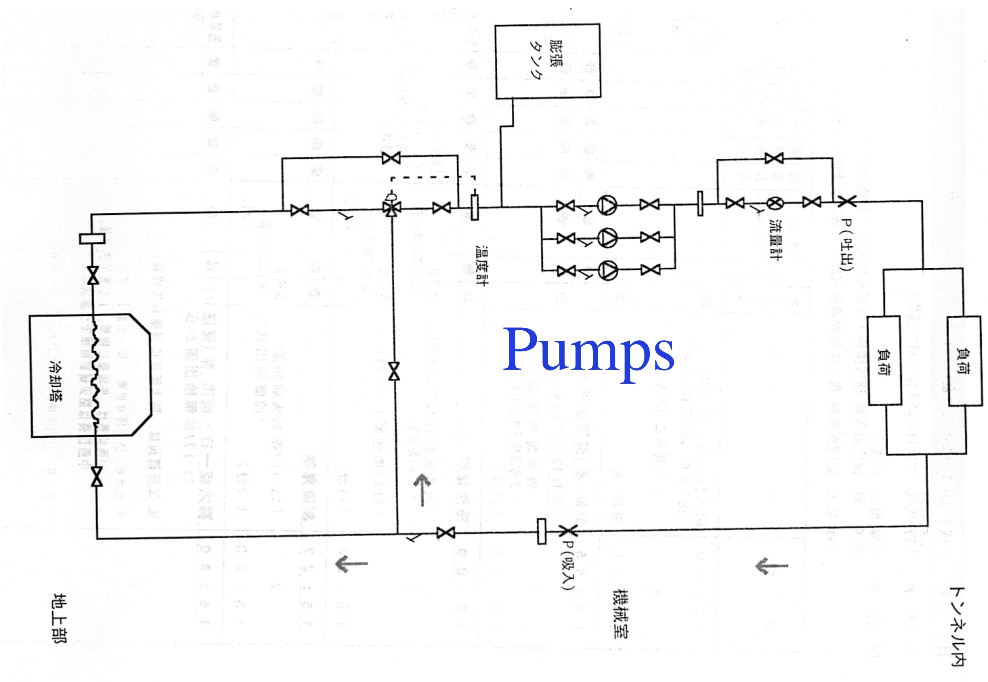
Air cooled heat-exchanger



Cooling system (cont'd)

- Cooling system for magnets, cavities, dummy loads is air cooled heat-exchanger+pumps. (No chiller)
- The system is simple and reliable.

Air cooled heat-exchanger



Pumps

Inside of tunnel

Buildings

- Buildings for vacuum chamber cooling system:
  - 4 Buildings exist at straight sections (Fuji, Nikko, Tsukuba, Oho) + additional 2 buildings for each arcs (2x4).
  - Area of ~300 m^2 is needed for chillers and pumps at each building.
- Buildings for RF systems
  - Total number of klystrons to be installed is 66.
  - We must prepare buildings as early as possible to install RF units (klystrons, power supplies, dummy loads,…)
- Buildings for R&Ds, test benches, temporary usage(?).