Target system for hadron & neutrino beam lines at J-PARC

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for Nuclear/Particle physics group at J-PARC
(Hadron beam-line SG, Neutrino beam-line SG, Target/Monitor SG)

High-power Targetry for Future Accelerators
September 8, 2003

Contents

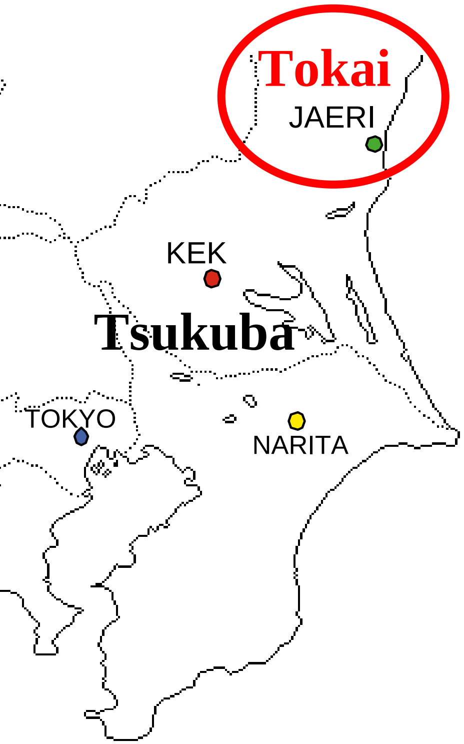
- Introduction of J-PARC
- Target and Target system for hadron beam line
- Target system for neutrino beam line

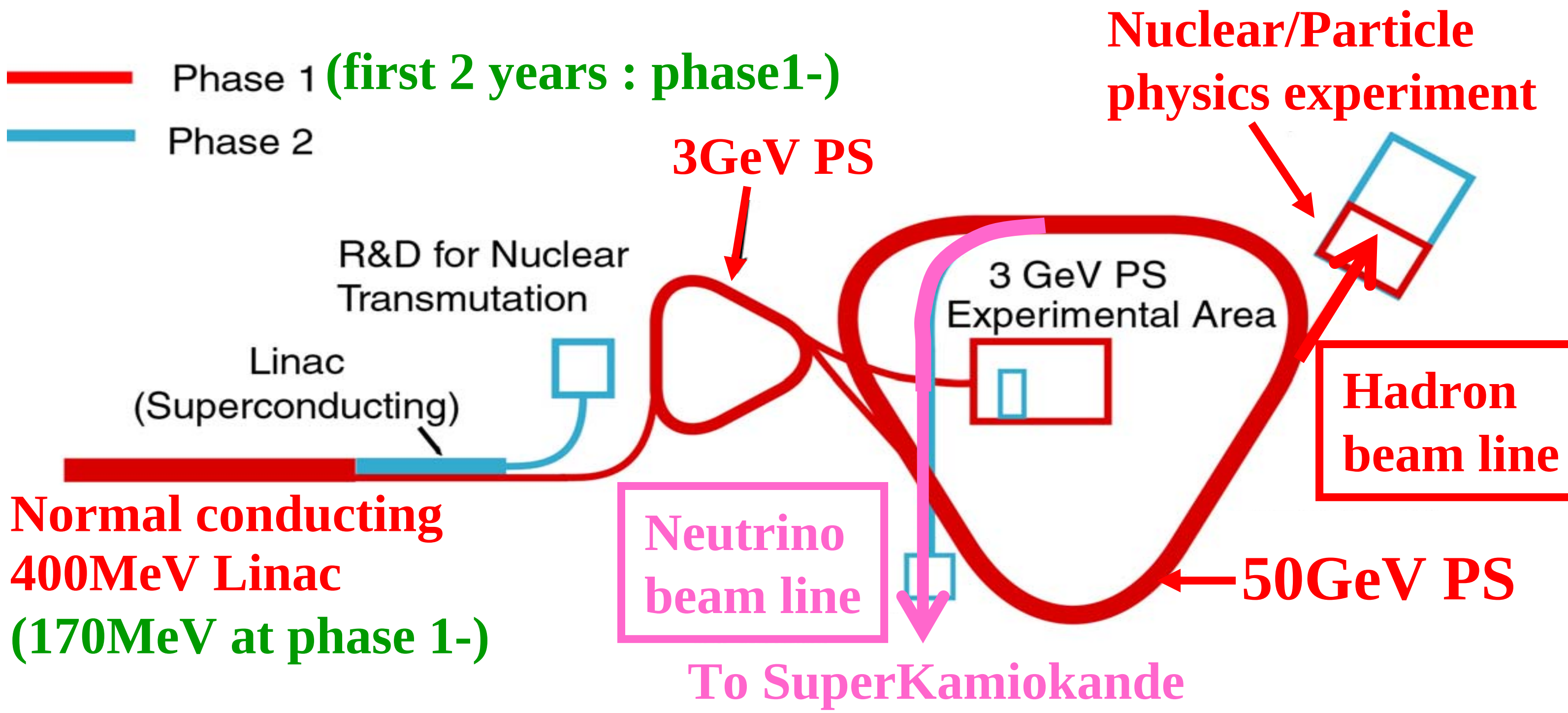
(Y.Hayato will talk about neutrino target tomorrow)

J-PARC

J-PARC:

Japan Proton Accelerator Research Complex





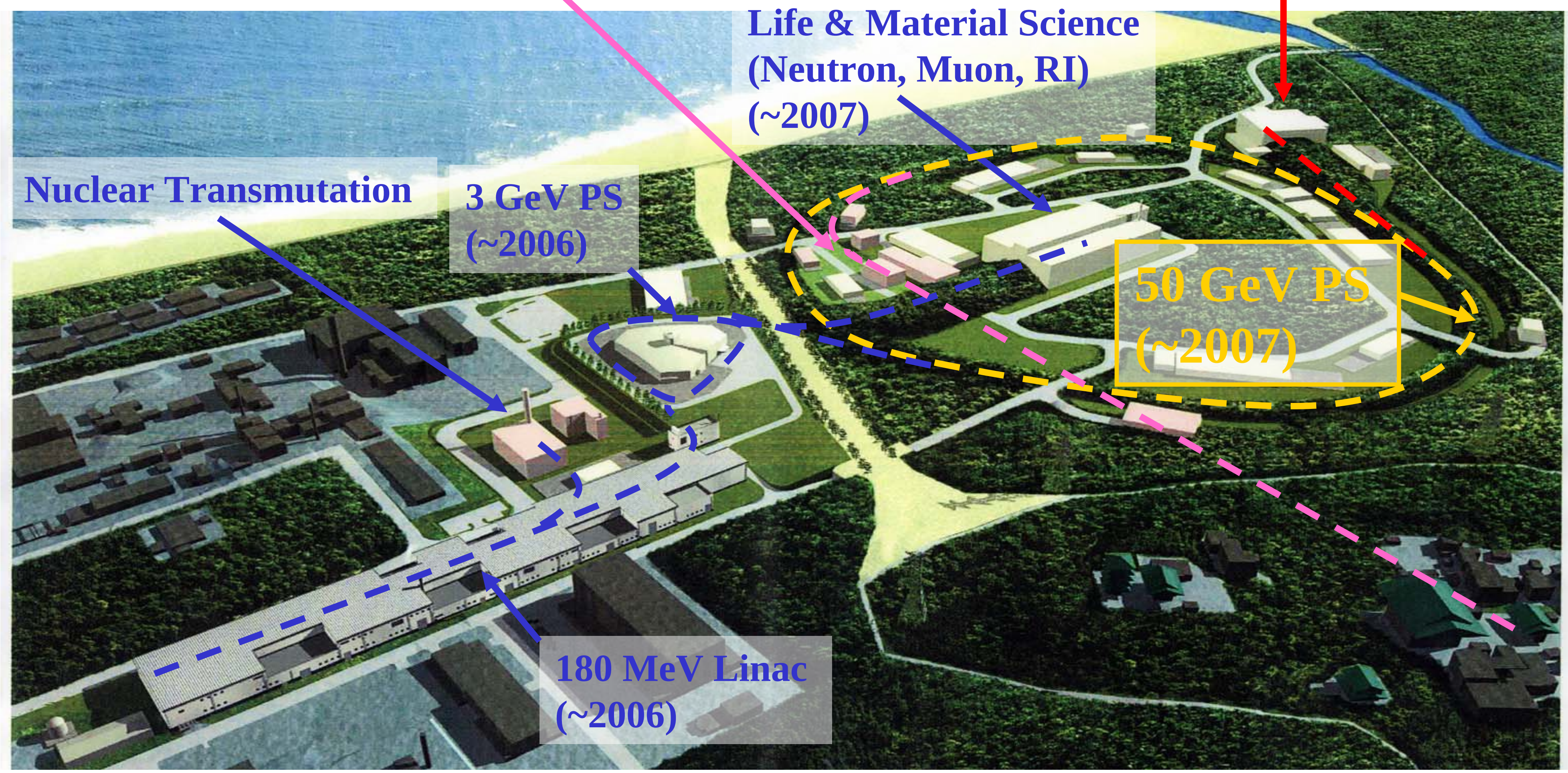
Phase 1:Approved in 2001, will be completed by 2007

Neutrino will be approved for FY2004-8(?)

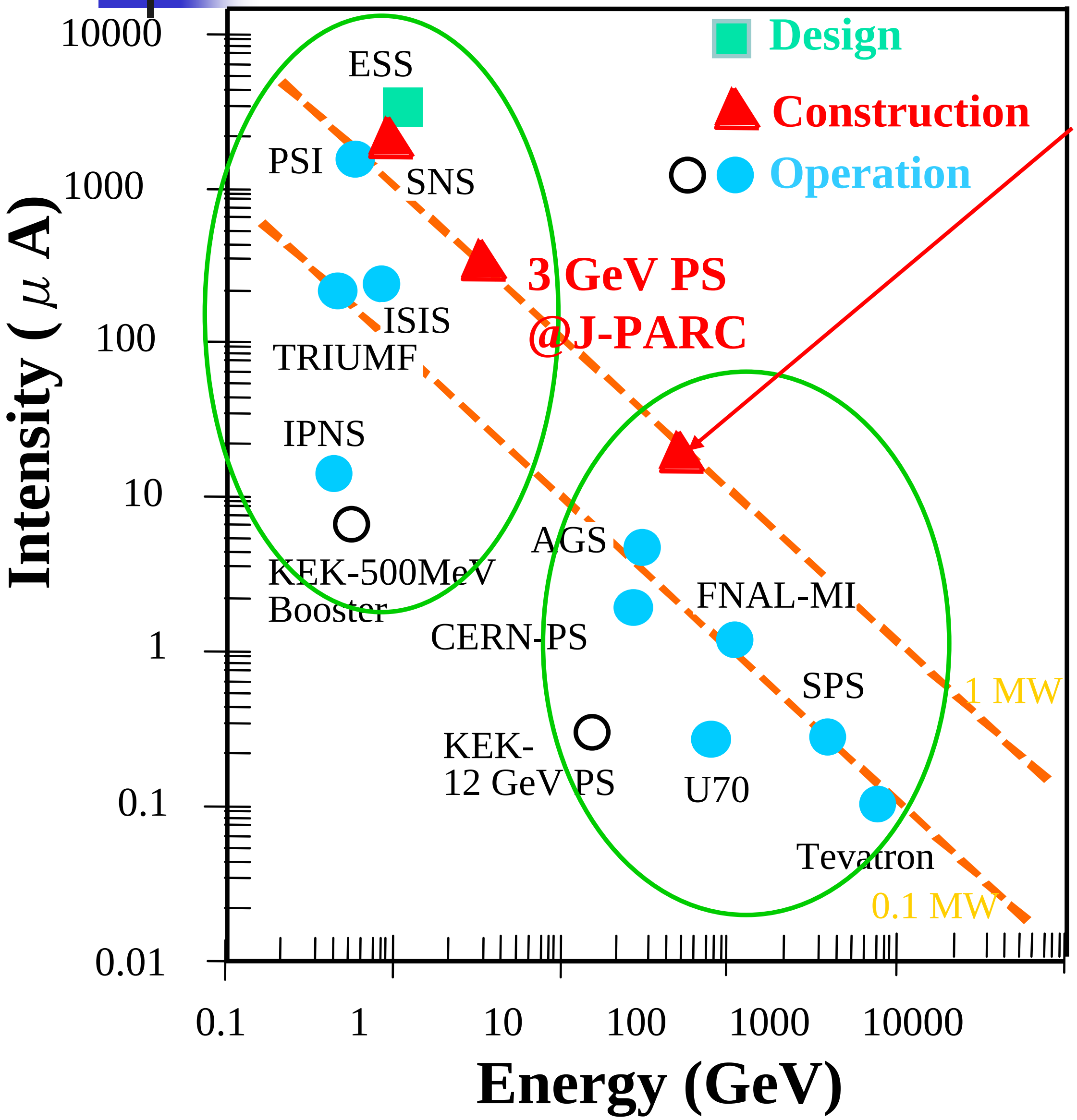
Site View of the Project

Facility for Neutrino Experiment (2004?~2008?)

Facility for Nuclear/Particle Physics experiment (~2007)



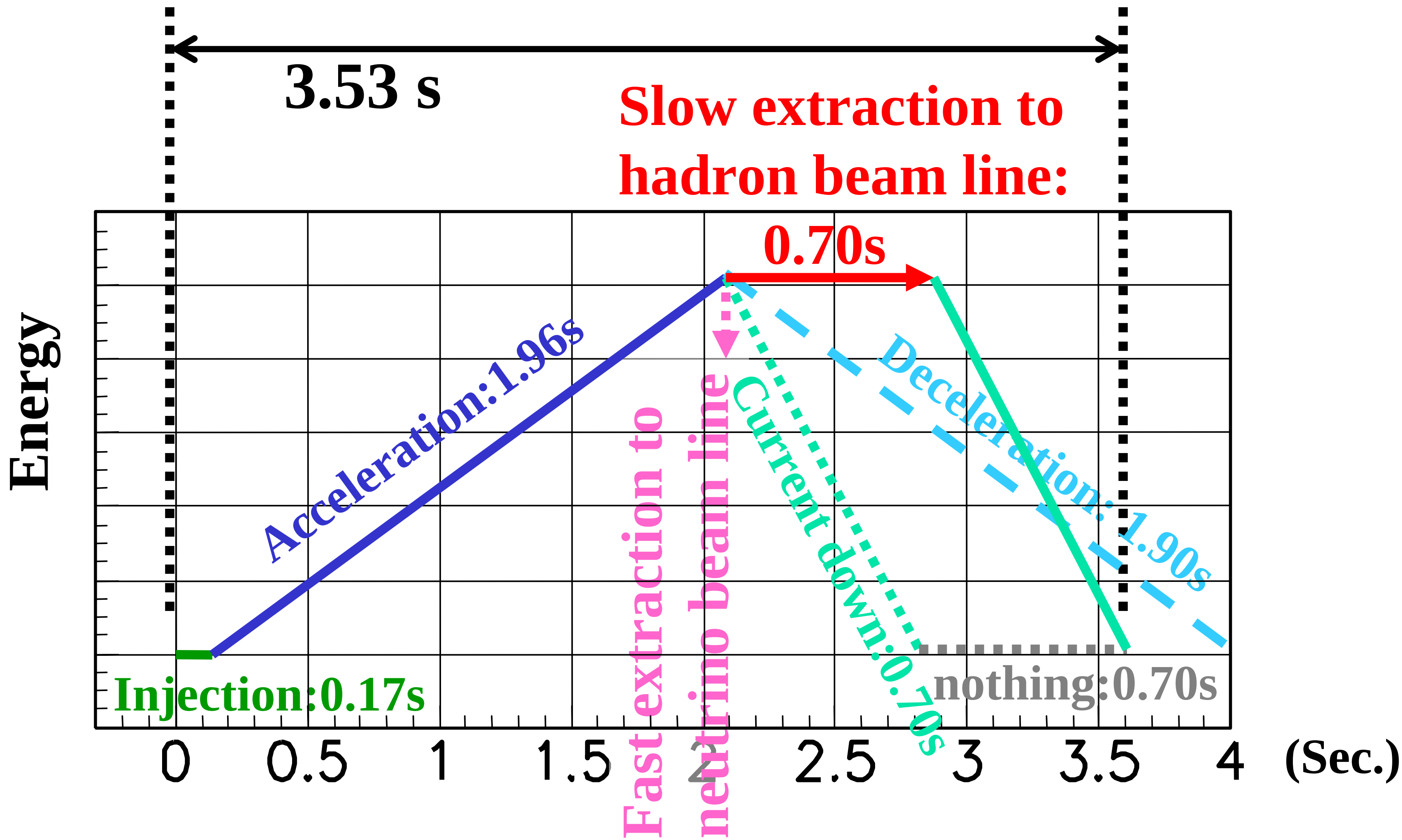
Machine power



50 GeV PS @J-PARC

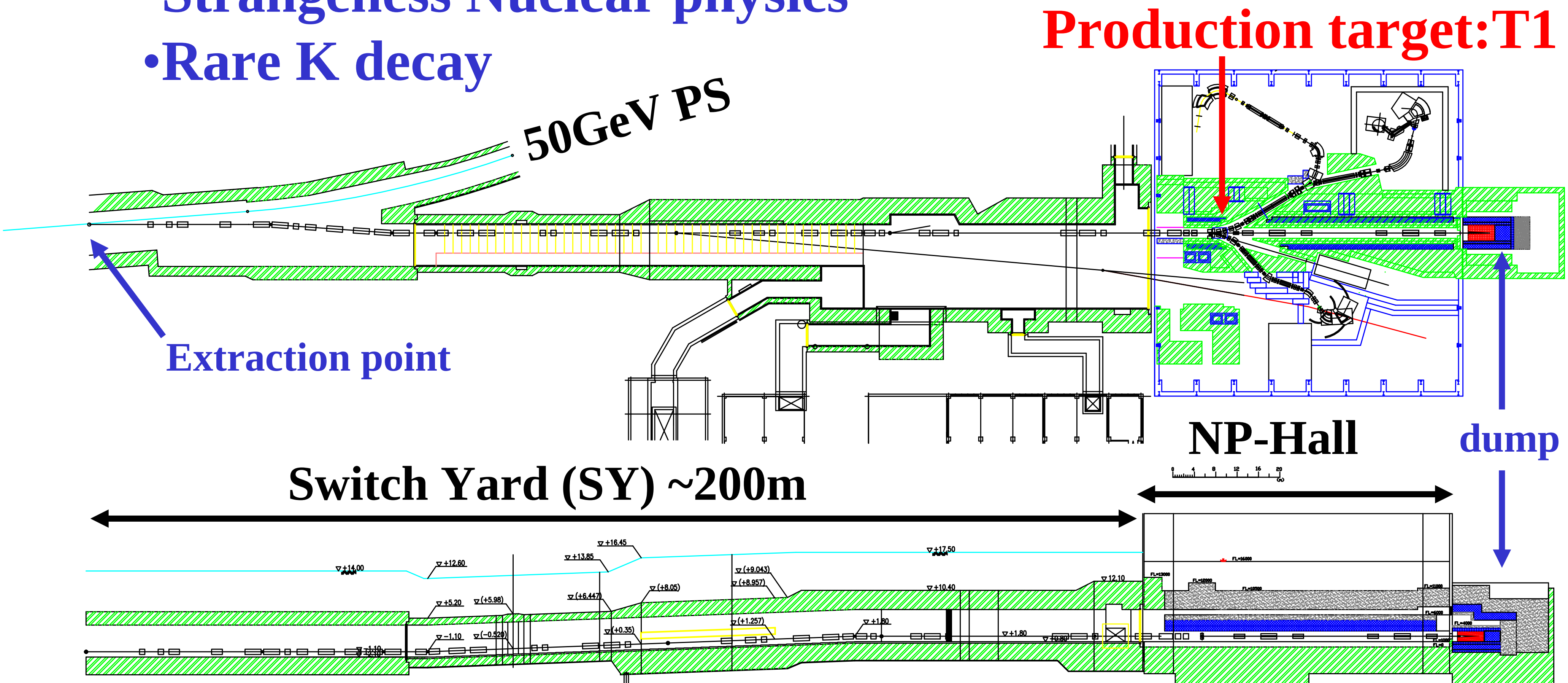
- **Beam Energy:**
  - **50GeV**
  - **(40GeV in Phase1-)**
- **Beam Intensity:**
  - **3.3×10^{14}ppp, 15 μA**
  - **(2×10^{14}ppp, 9 μA in Phase1-)**
  - **(18×10^{14}ppp, 80 μA in future)**
- **Beam Power:**
  - **0.75MW**
  - **(0.36MW at Phase1-)**
  - **(4MW in future)**

Acceleration/extraction cycle



Hadron beam line

- Slow extraction beam line
- Physics with high intensity secondary K beam
  - Strangeness Nuclear physics
  - Rare K decay

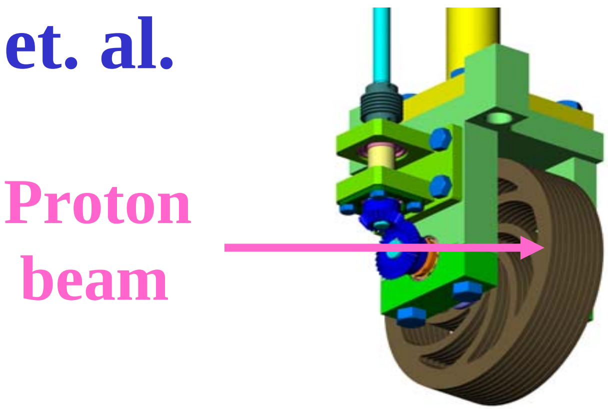


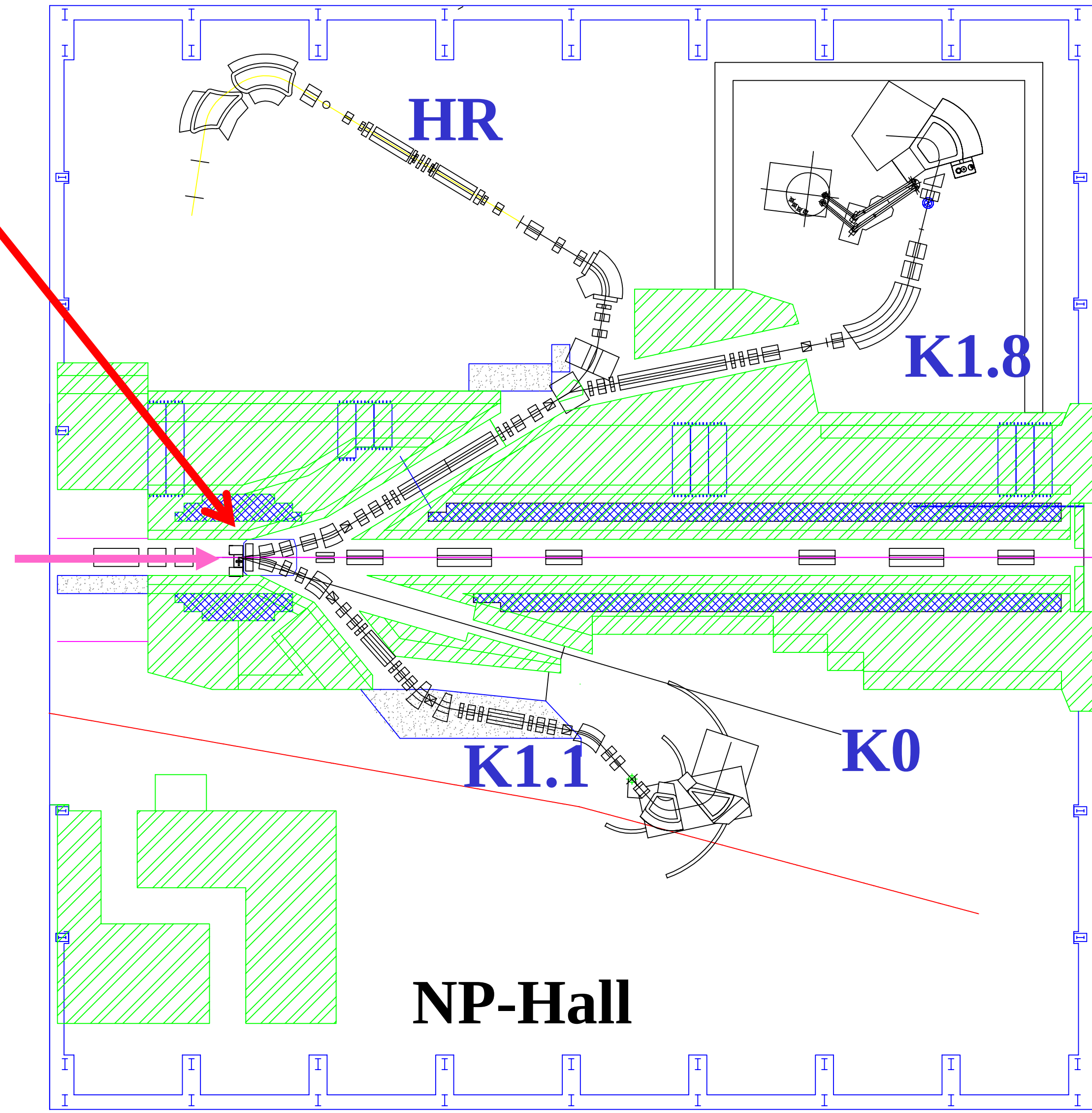
Target and secondary beam lines

Production target : T1

Rotating Nickel disks

- thickness: ~54 mm
- radius: ~24 cm
- cooled by water
- developed by **Y.Yamanoi** et. al.





Design of T1

$1.3x10^{21}$ protons/year on Target (4000 hours/year)

- Radiation shielding
- Max. yield of secondary beam

} ⇒ 30% interaction

- Temperature rise
- Point source for secondary beam

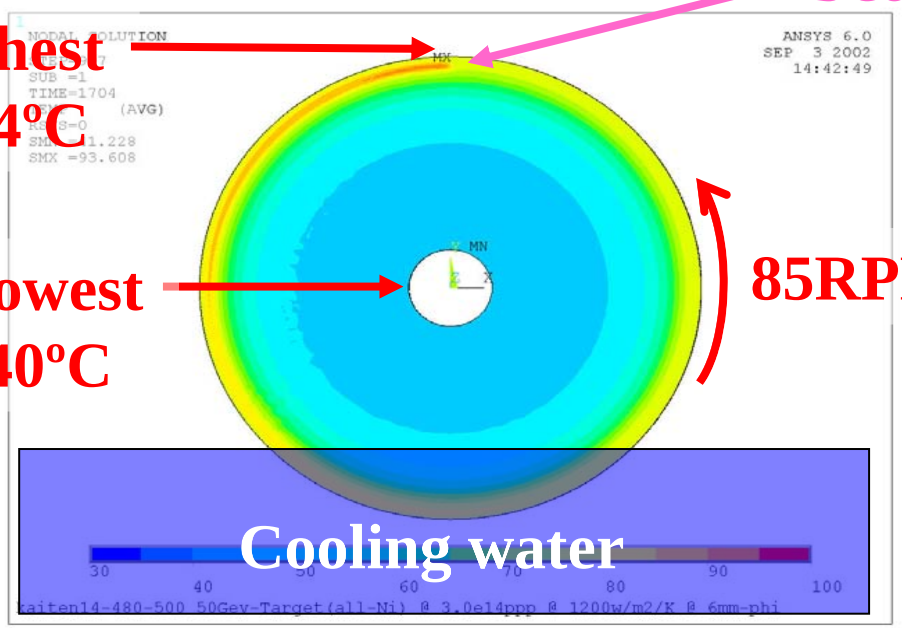
} ⇒ Ni target

	length of 30% interaction (cm)	max. heat density (J/cm^3)	density (g/cm^3)	specific heat (J/g/K)	temperature rise by a pulse (K)
Pt	3.15	25000	21.5	0.14	8590
Ni	5.31	5280	8.9	0.44	1340
Al	14.06	1940	2.7	0.87	820

Water cooling of T1

- **Rotating Ni disks**
  - **Diameter : 48cm, Thickness : 54 mm (9mm-t×6disks)**
  - **1 rotation per 0.7s (slow extraction period) : 85 RPM**
- **Partially cooled by water**

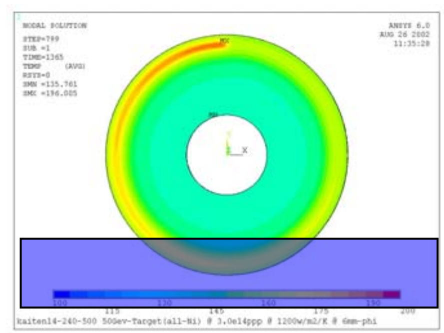
ϕ48cm x 54mm^t



ANSYS:

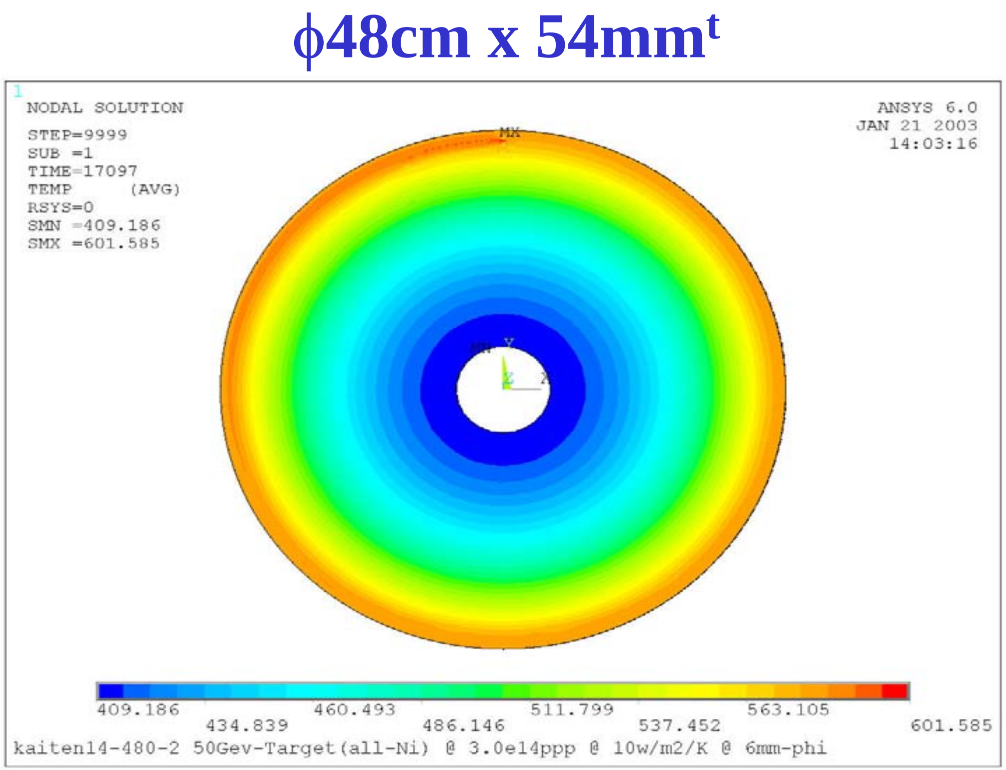
- **After 0.7s exposure**
- **1200 W/m^{2}K assumed**

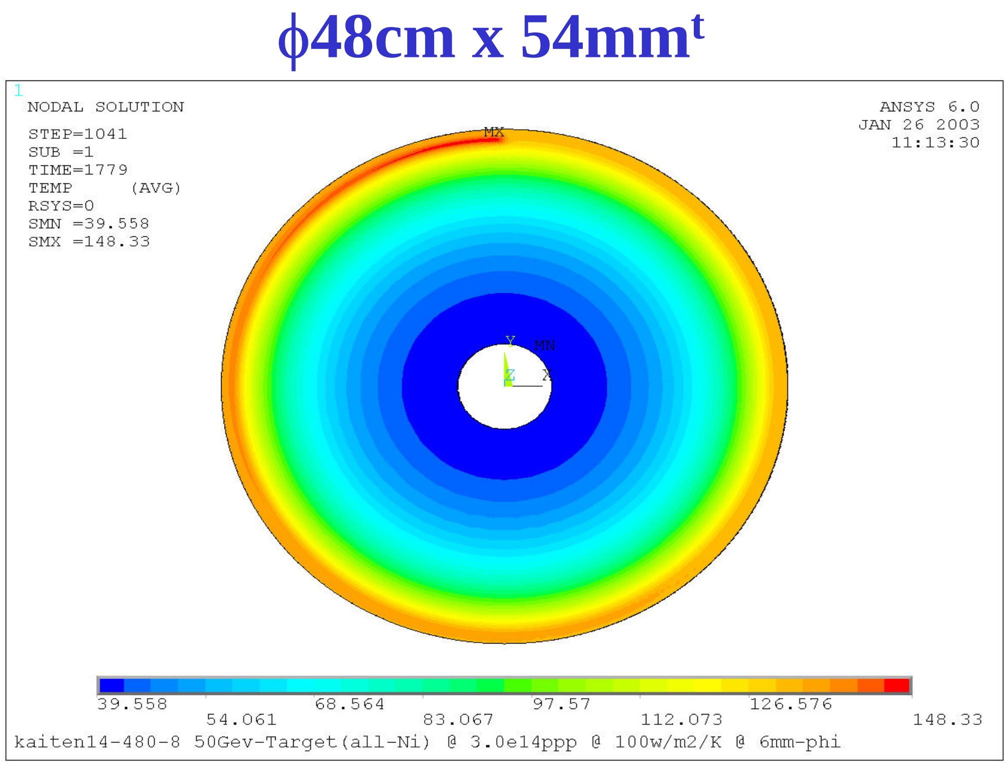
ϕ24cm x 54mm^t



Highest ~196°C
Lowest ~136°C

Gas cooling of T1





Natural convection
10 W/m^2K assumed
⇒ Highest ~ 602°C: too high
Lowest ~ 409°C

Forced convection
100 W/m^2K assumed
⇒ Highest ~ 148°C: still high
Lowest ~ 40°C

R&D for T1

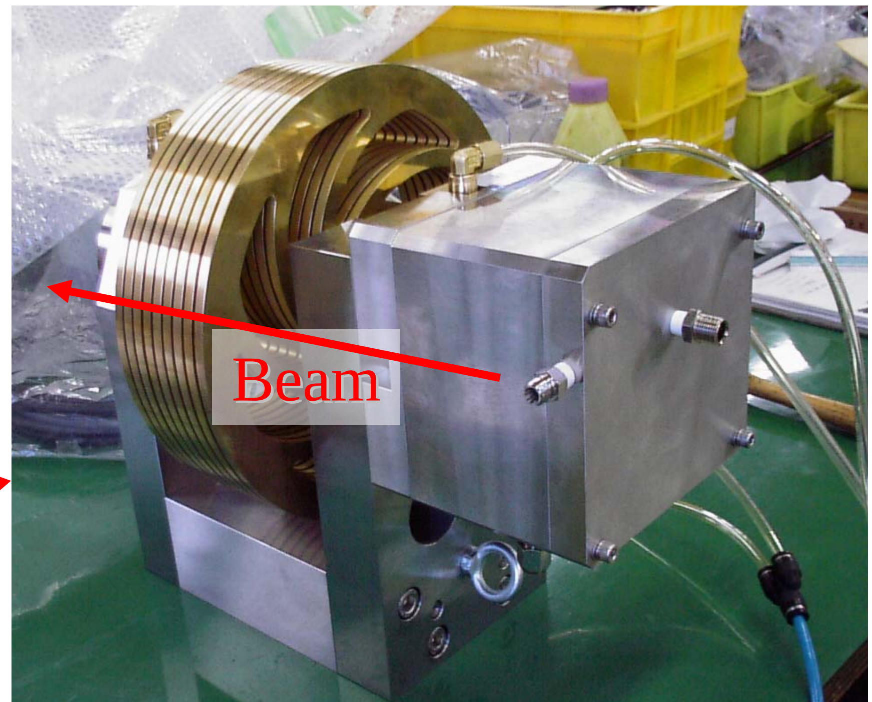
Items

- Optimization of diameter, thickness, # of disks(gaps)
- Rotation speed, Method of rotation
- Durability
- Container & shielding
- Cooling system
- Beam window & vacuum sealing
- Maintenance method

⇒

- **Prototypes**
- **Mockup**

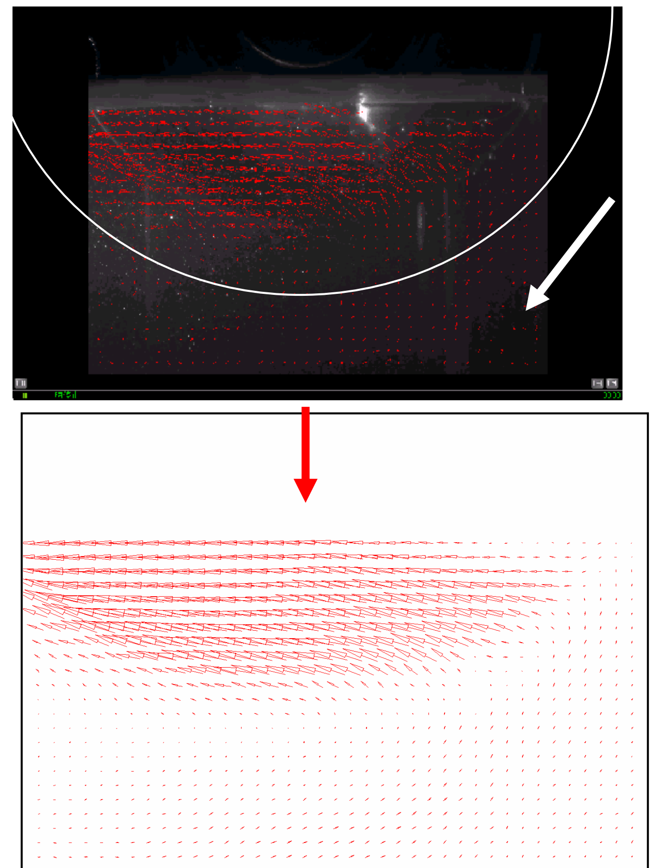
Nickel disks (ϕ24cm x 6mm^t x 9, 24kg)



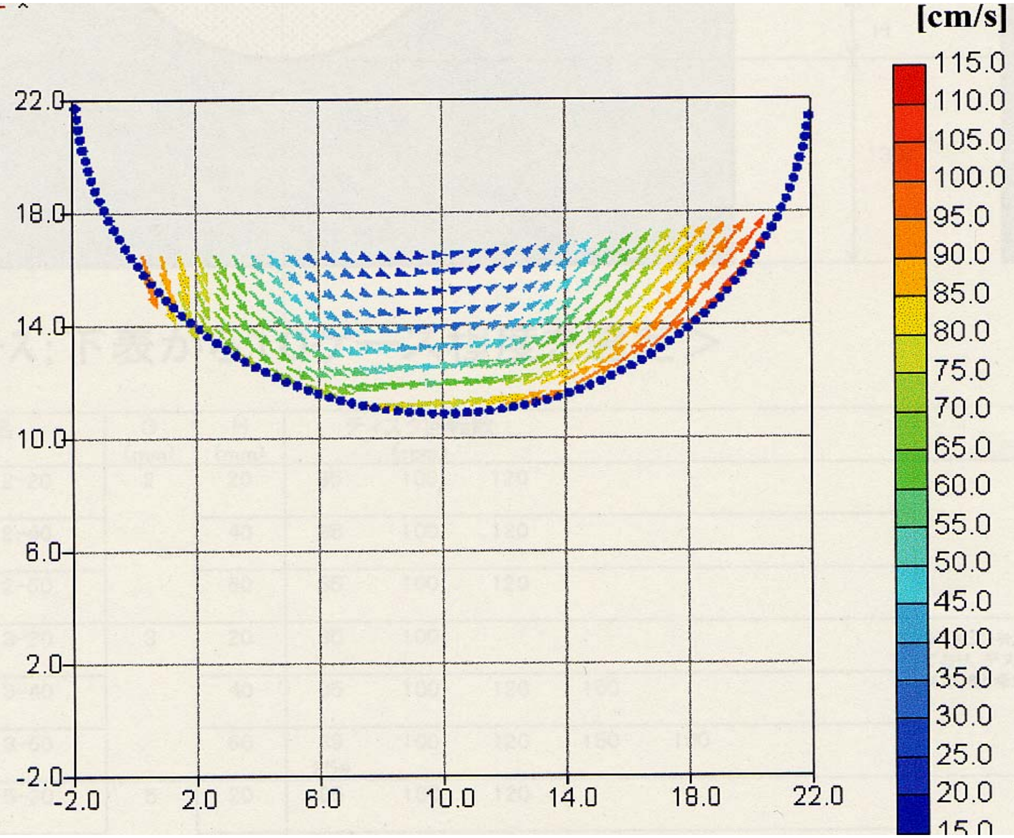
Water velocity at T1(1)

Relative velocity between disk and water

- affects on heat transfer coefficient
- measured by PIV(Particle Image Velocimetry)



Water velocity at T1(2)



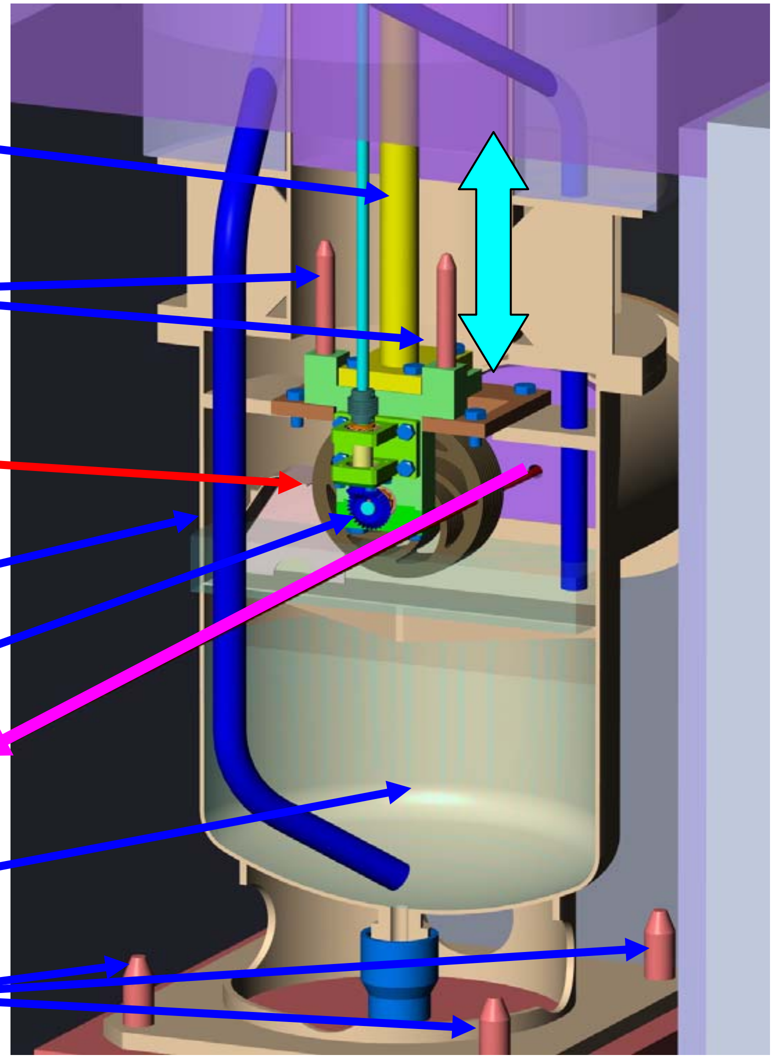
Measured relative velocity between disk and water (cm/s)

- Results:
  - Typ. velocity ~ 1 m/s @85RPM
  - Gap between disks should be > 2mm
  - RPM should be < 150RPM

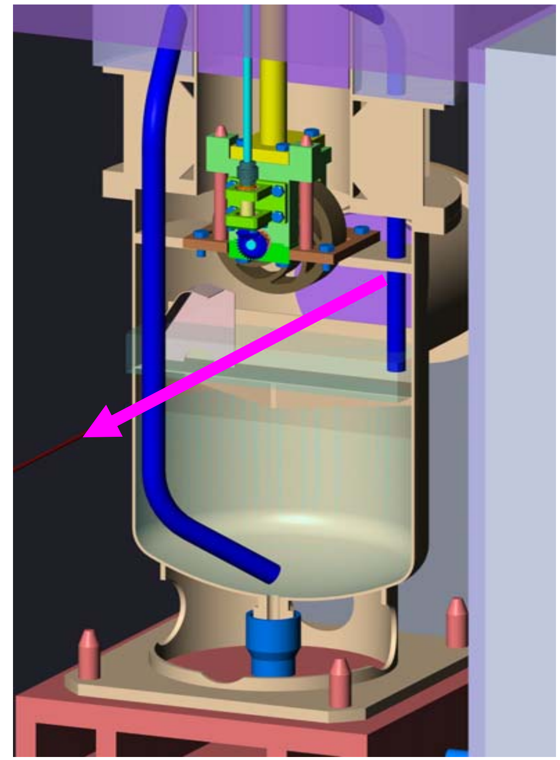
⇒Fluid simulation

- Reproduce relative velocity
- Estimate heat transfer coefficient
- Parameter survey on
  - Number of disks (gaps)
  - Gap length
  - Rotation speed
  - Depth in water
  - etc

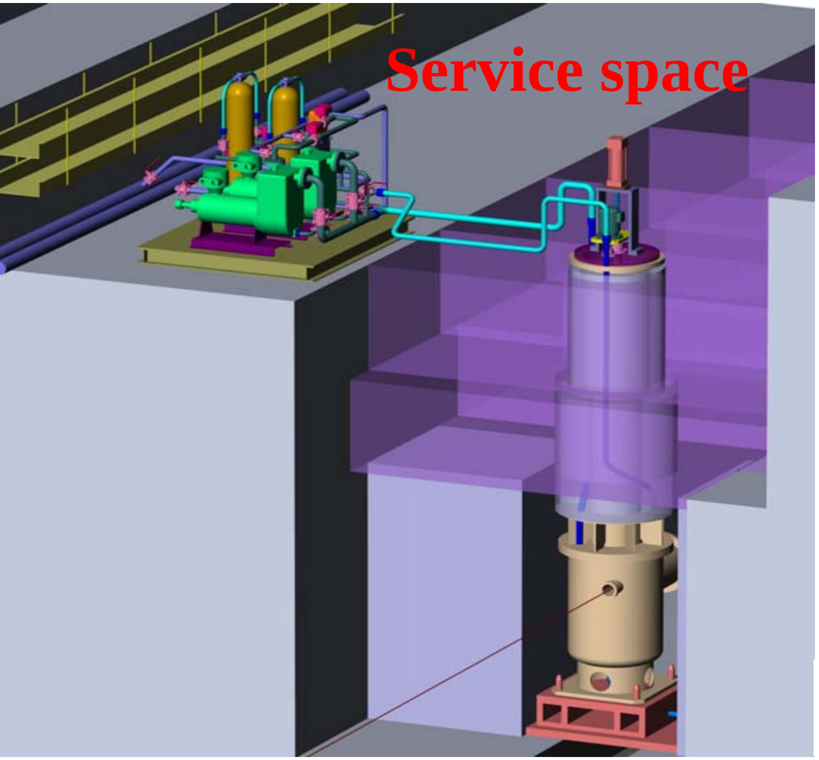
Container of T1

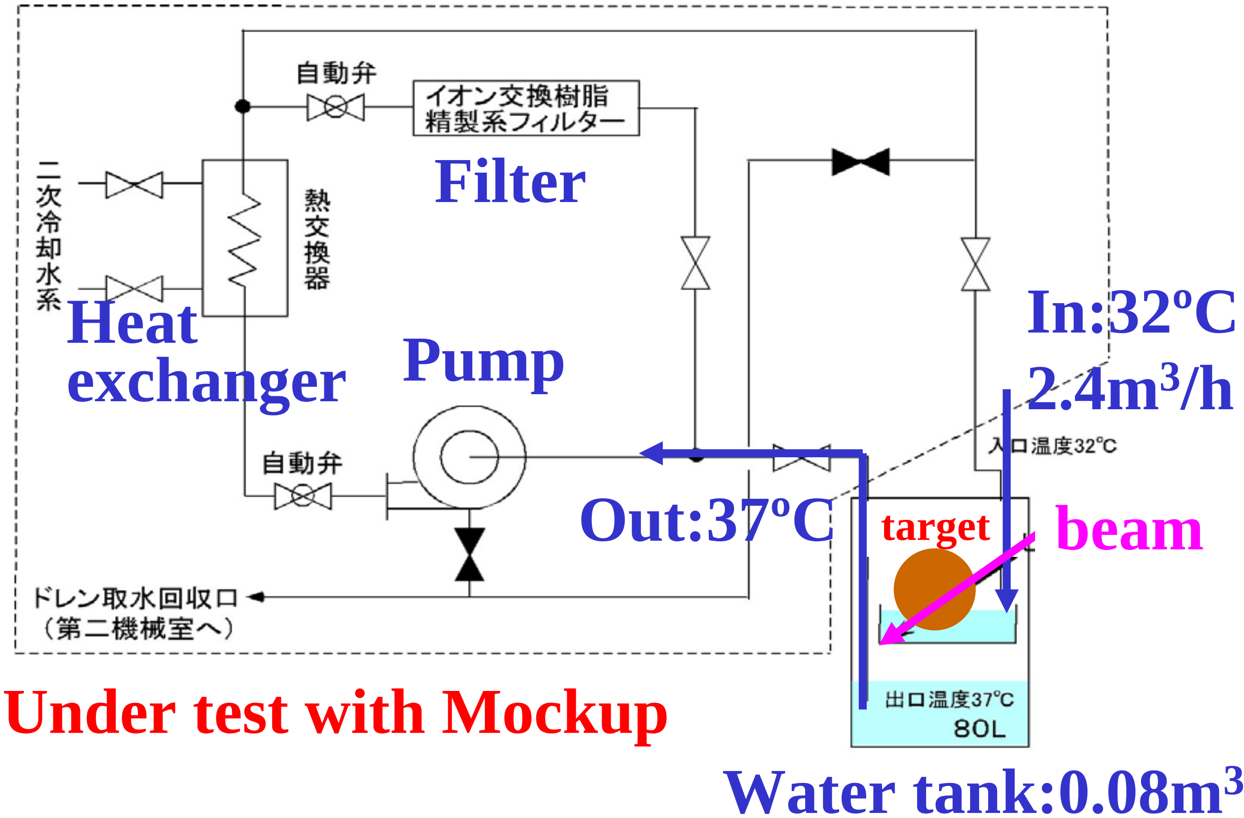


Target off



Cooling system of T1



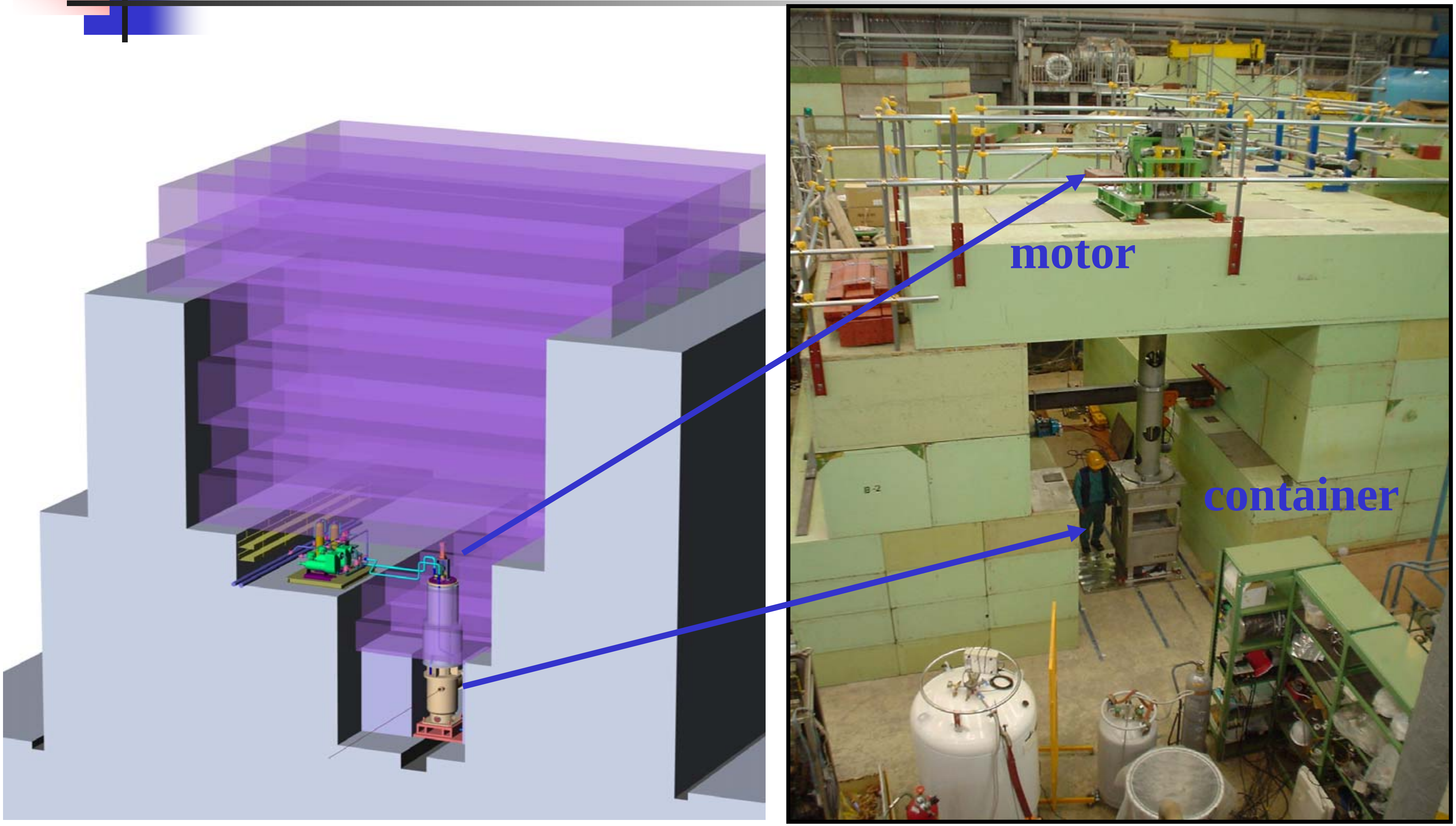


Under test with Mockup

Radioactivity of water after 30 days operation: ~24 kBq/cm^3

- Thinned into 15 Bq/cm^3 and thrown away
- (Thinned into 1.2 kBq/cm^3 and moved by tank track)

Mockup around T1

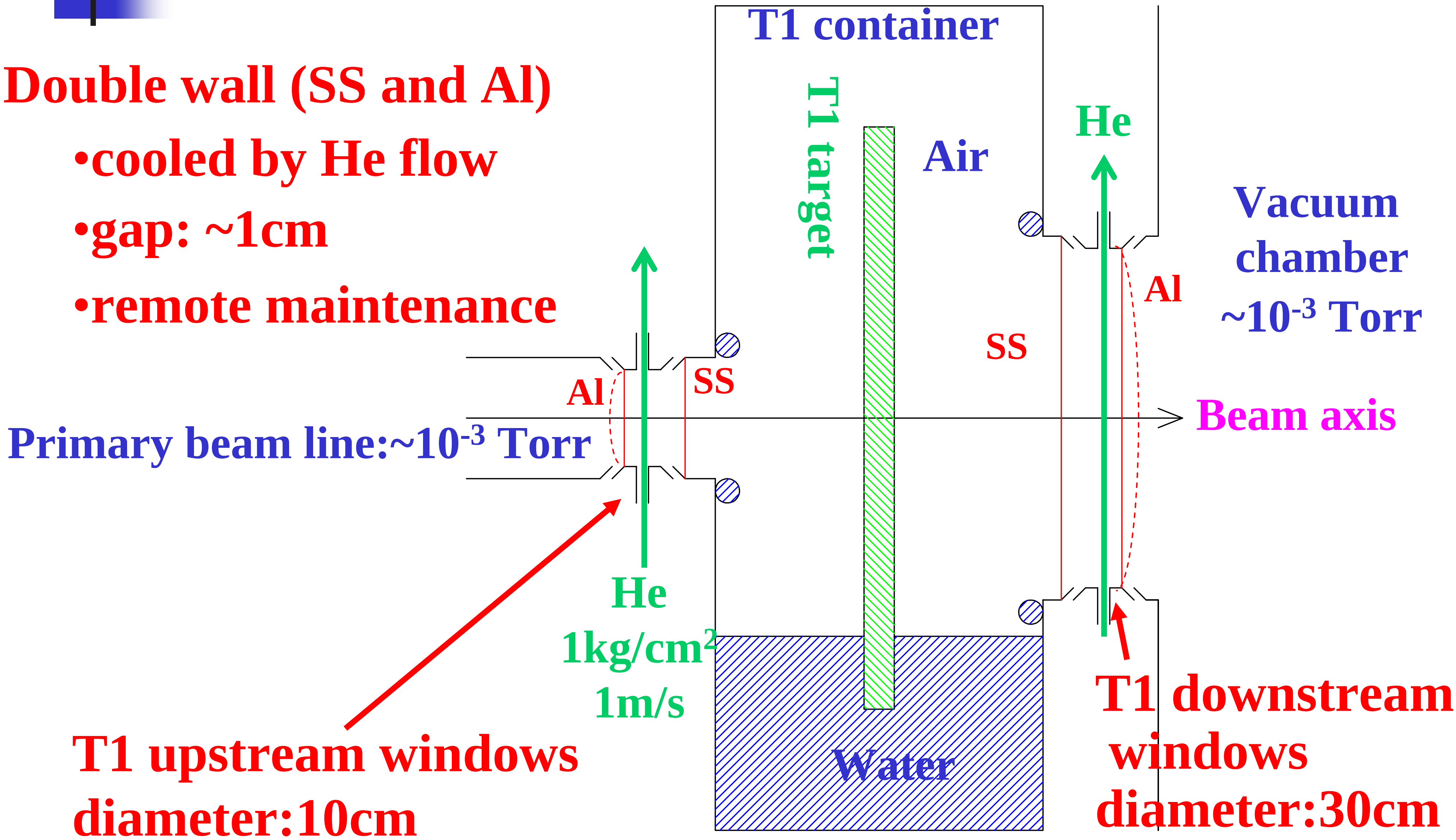


East counter hall at KEK

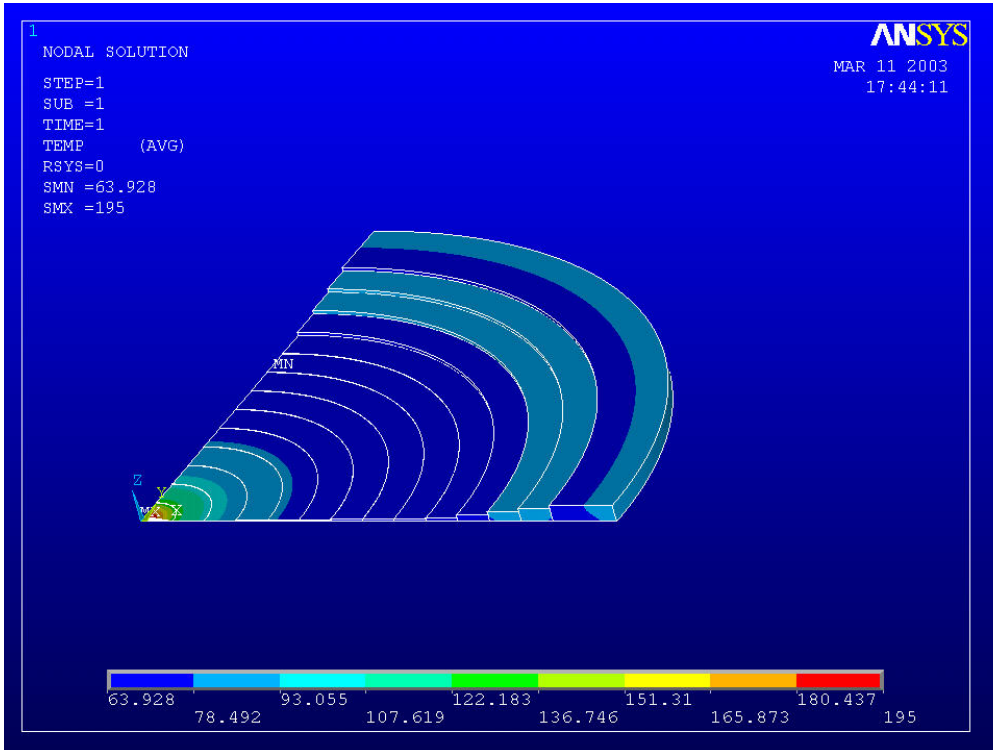
Beam window for T1

Double wall (SS and Al)

- cooled by He flow
- gap: ~1cm
- remote maintenance



T1 downstream window

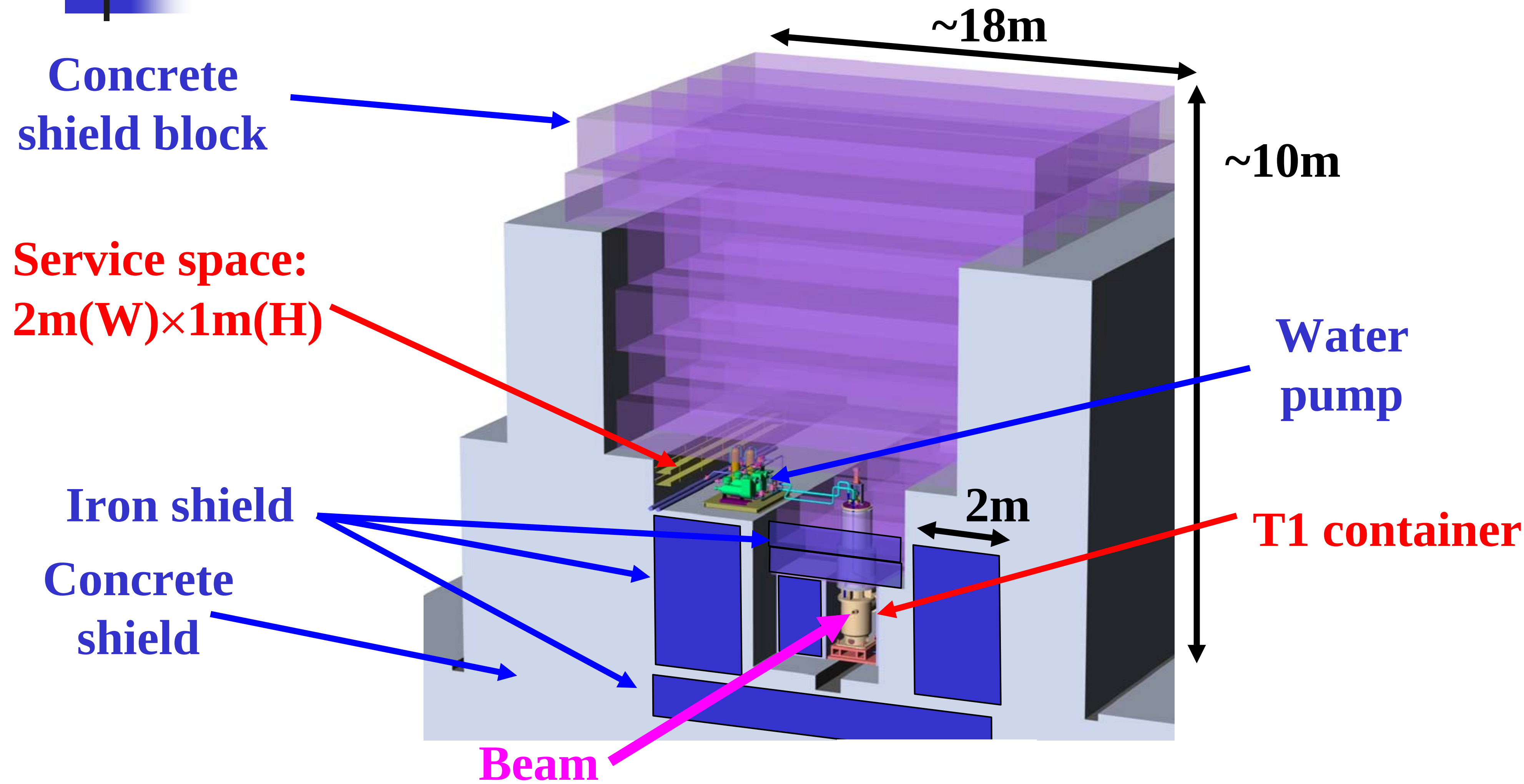


- Diameter: ~30cm
- Vacuum side: Aluminum
- Air(T1) side: SS
- 0.1mm-t at center
- 5mm-t at edge (water cooled)
- **Temperature rise of SS window at center**

  +170°C (forced convection by He flow(~1m/s) : 100W/m²K)

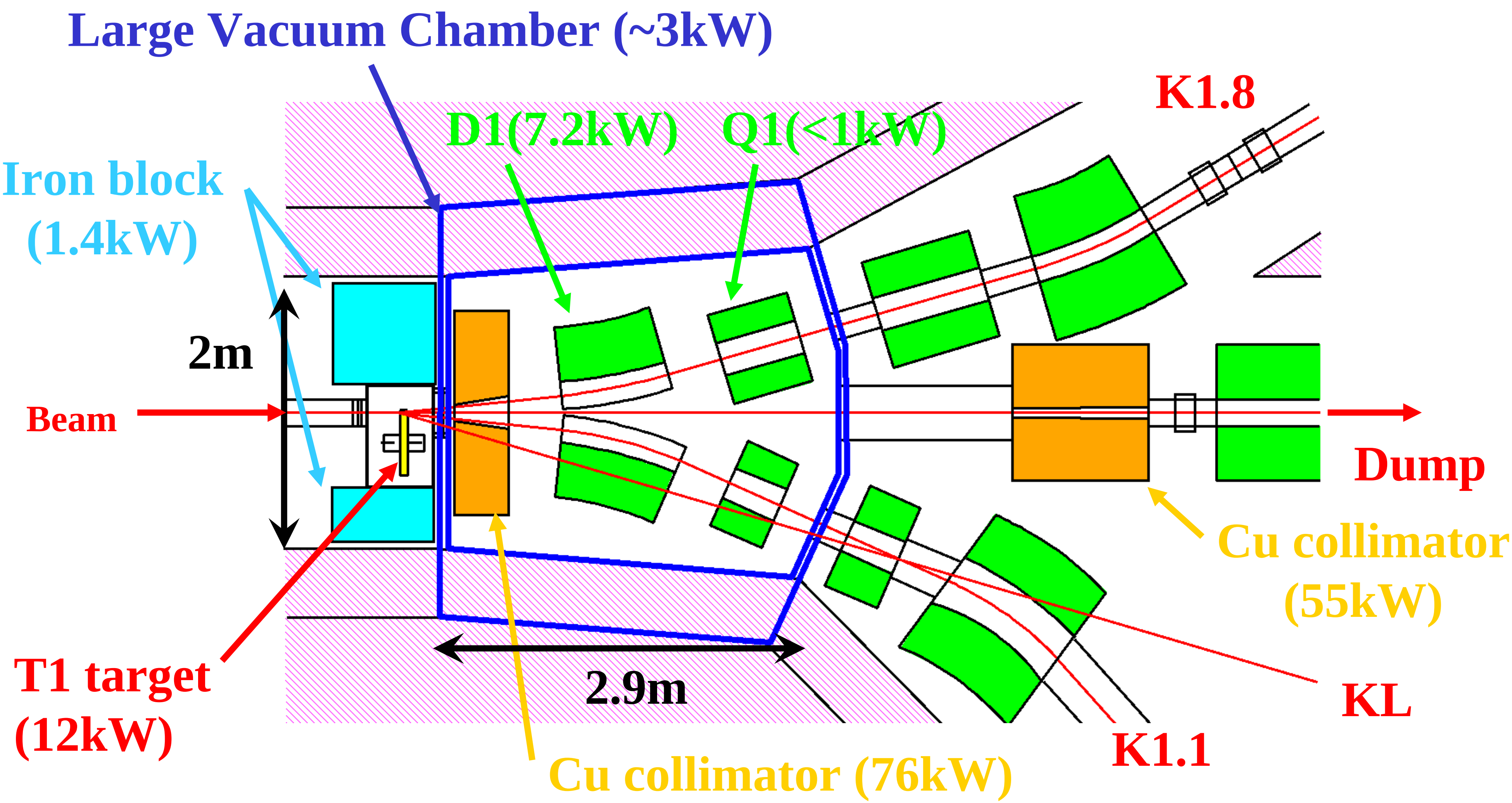
  +810°C (natural convection : 10W/m²K)

Shield around T1



The whole system will be tested by the T1 mockup.

Target Area



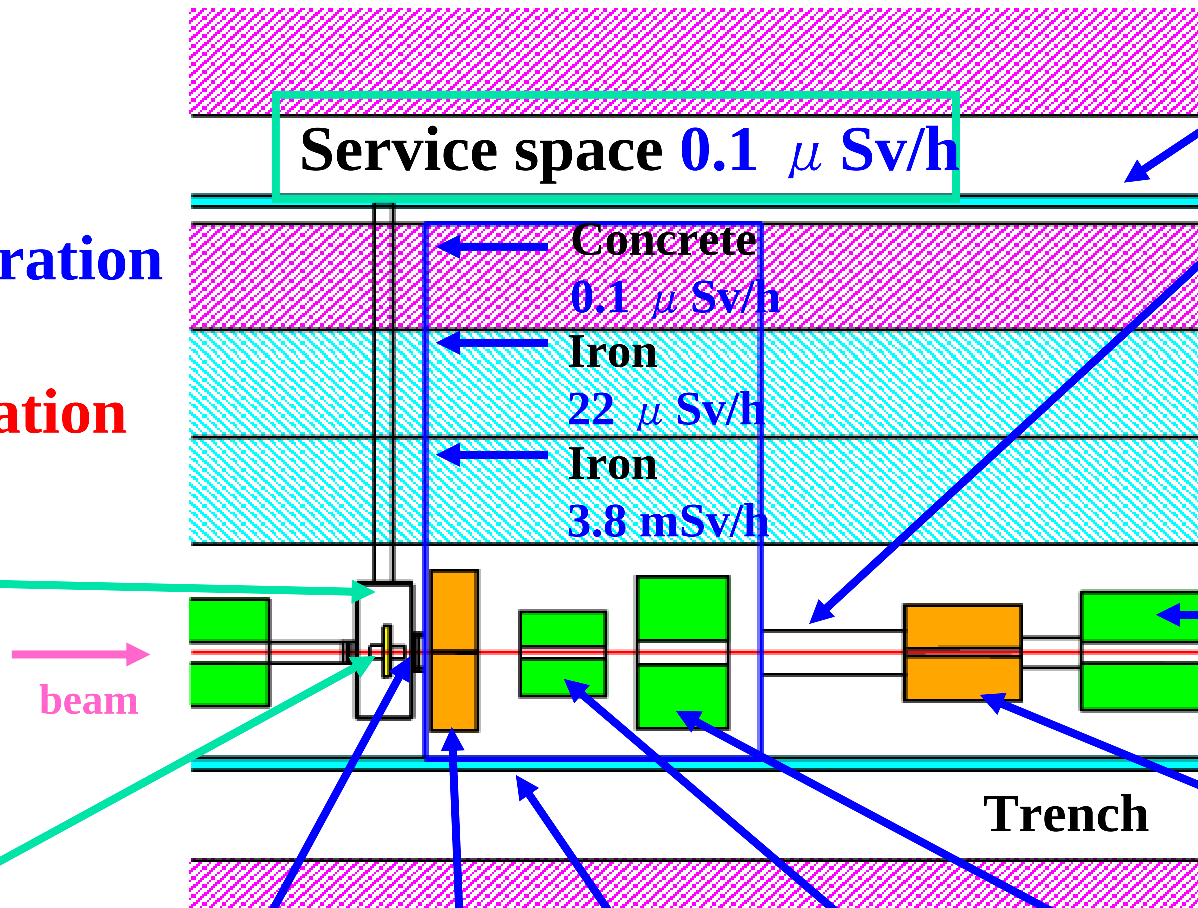
Large Vacuum Chamber (~3kW)
K1.8
D1(7.2kW)
Q1(<1kW)
Iron block
(1.4kW)
2m
Beam
Dump
Cu collimator
(55kW)
T1 target
(12kW)
2.9m
KL
K1.1
Cu collimator (76kW)

Residual dose around T1

Dose by MARS

One day cooling
after 30-days operation

Half year cooling
after 1-year operation

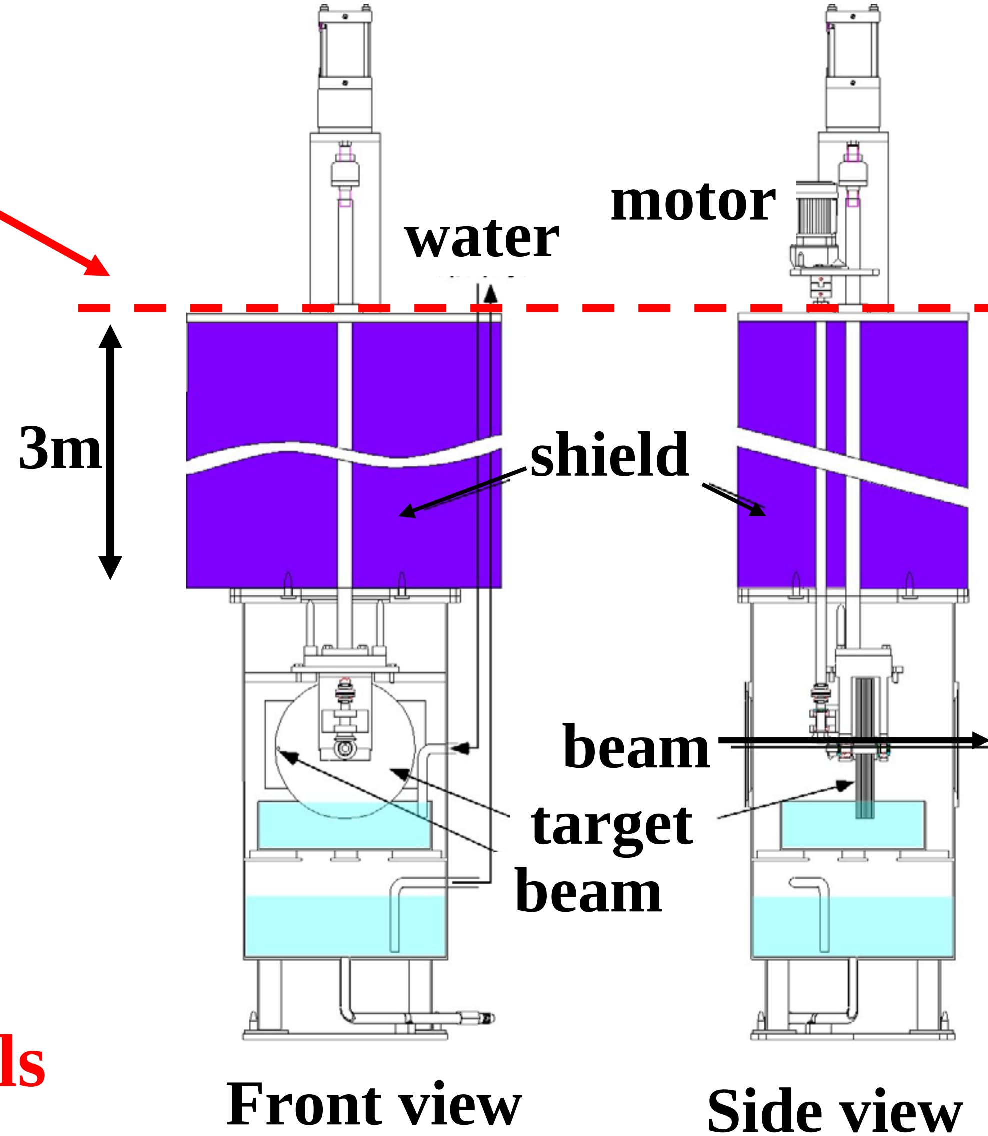


Remote maintenance for T1

Maintenance work
should be done at service space

1. Disconnect cables and cooling tubes.
2. Detach vacuum flanges.
3. Replace shields with cask.
4. Detach shaft, disks and upper plate, and move them to stock space.
5. Install new parts with cask.
6. Replace cask with shields.
7. Connect cables and tubes.

requires remote maintenance tools



Remote vacuum sealing

Design specification

- Inner Diameter: ≥30cm
- Metal sealing
- Small leak: $\sim 1\times10^{-10}$ Pa•m^3/s
- Remote operation
  - Operation time: 1~5 min.
  - Small force required

Candidate

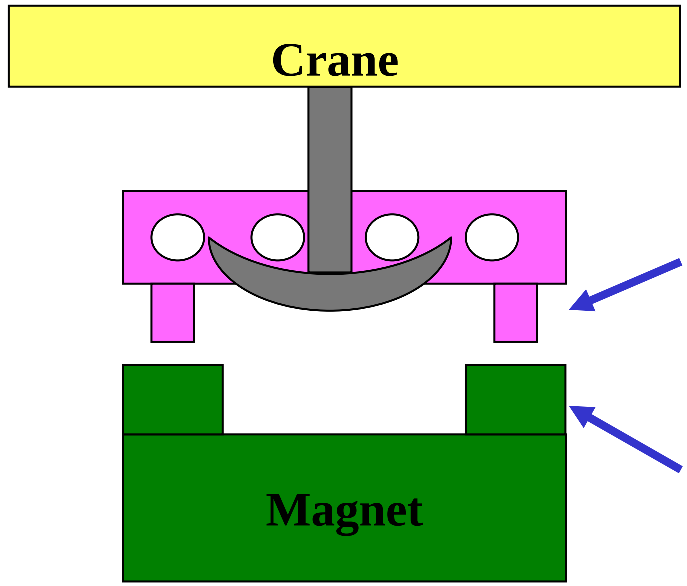
- Mechanical holding (V-block)
- Pillow seal
- Radial seal (under development)

Prototype of "Radial seal"
developed by Y.Yamanoi(KEK), M.Tsuchiya(IHI Ltd) and Usui Kokusai Sangyou Kaisya Ltd.

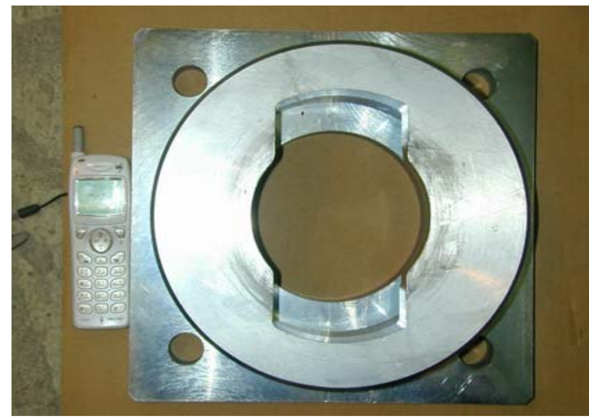
Remote lifting Tools

Specification

- Up to 40t
- Short height
- Remote connection
- Video camera viewing
- Two or four points lifting
- Interlock for one-side lifting

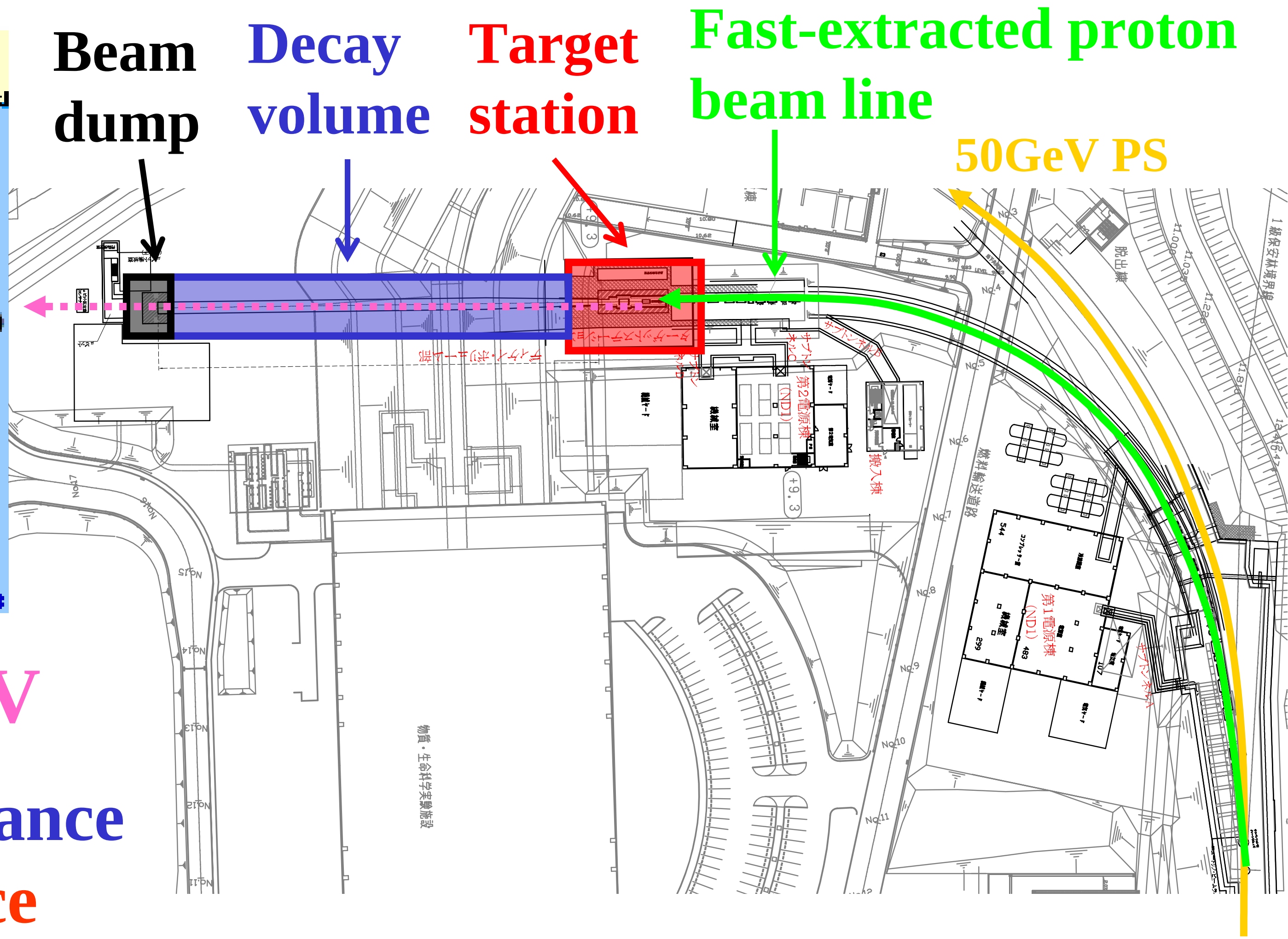


Under design



Lifting tools from CERN and PSI

Neutrino beam line



ν_μ beam of ~1GeV

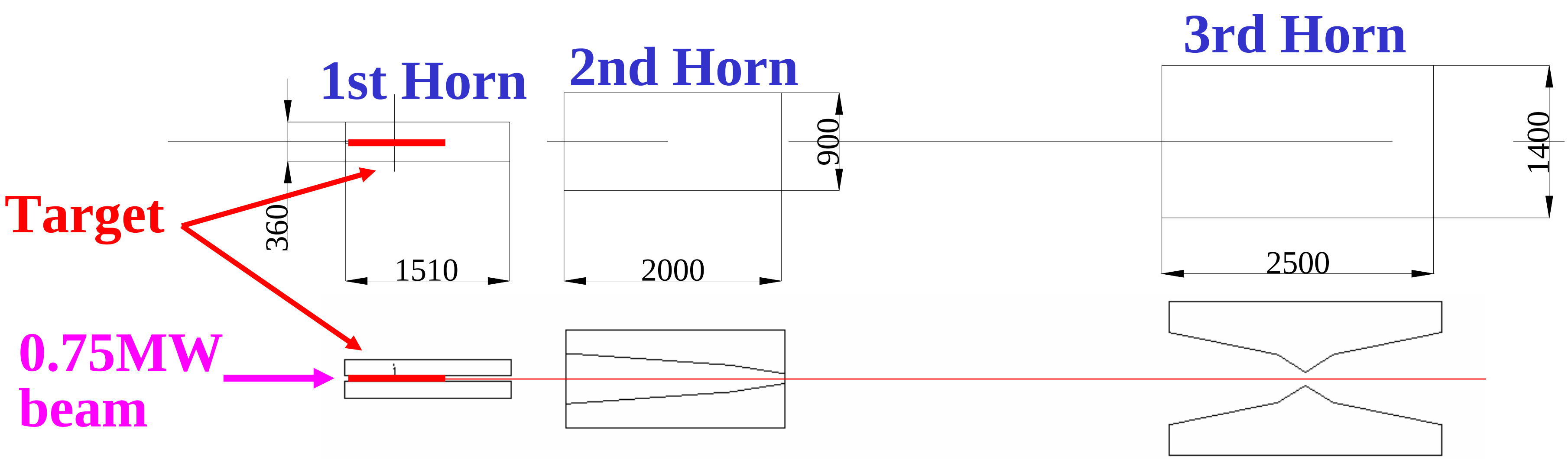
- $\nu_\mu \rightarrow \nu_x$ disappearance
- $\nu_\mu \rightarrow \nu_e$ appearance

Neutrino target

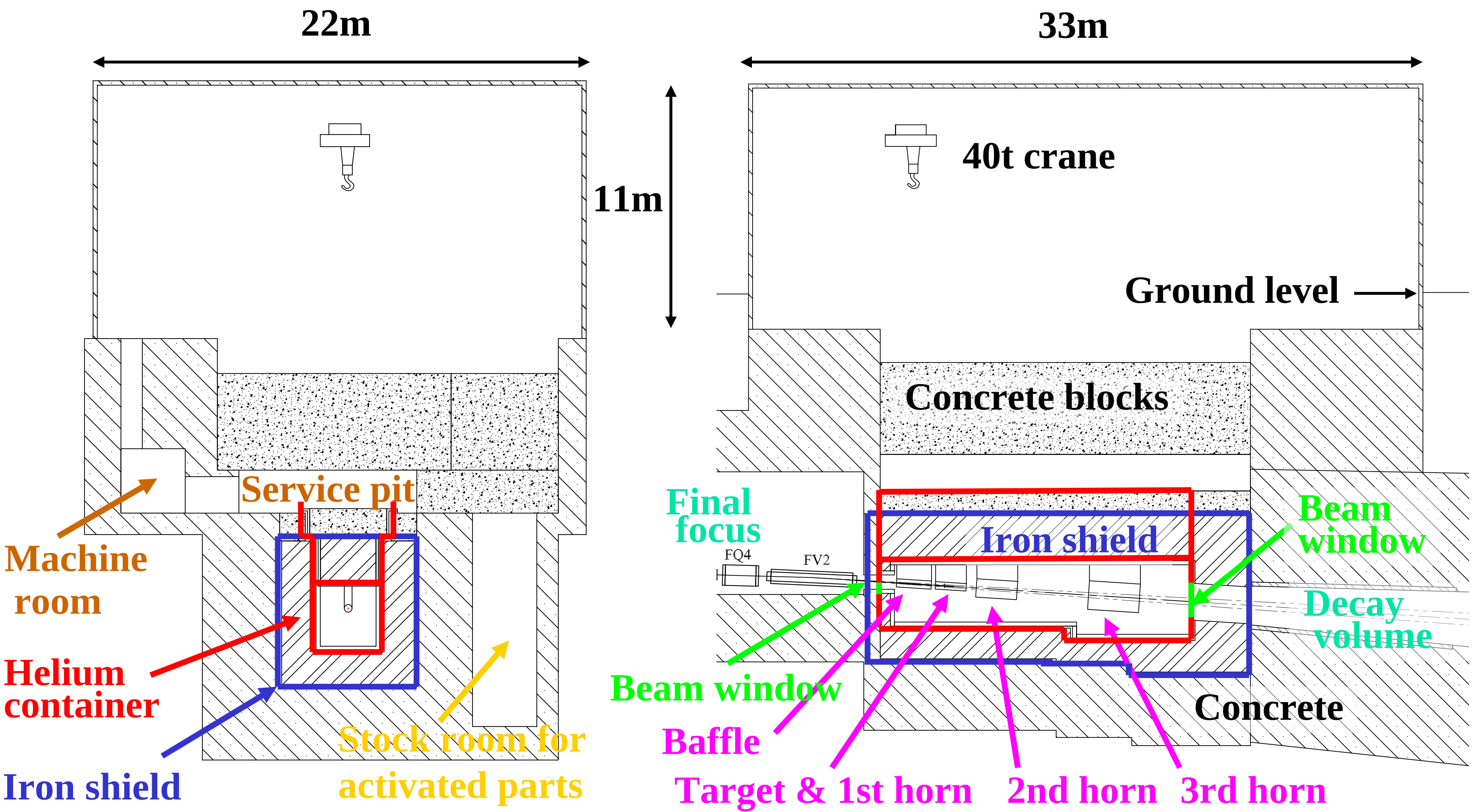
Graphite rod

- diameter:30mm, Length:900mm (80% interaction)
- beam size: σ_r ~6mm
- fixed inside 1st horn
- 20kw heat load: cooled by water

  ⇒ Hayato's talk tomorrow



Neutrino target station

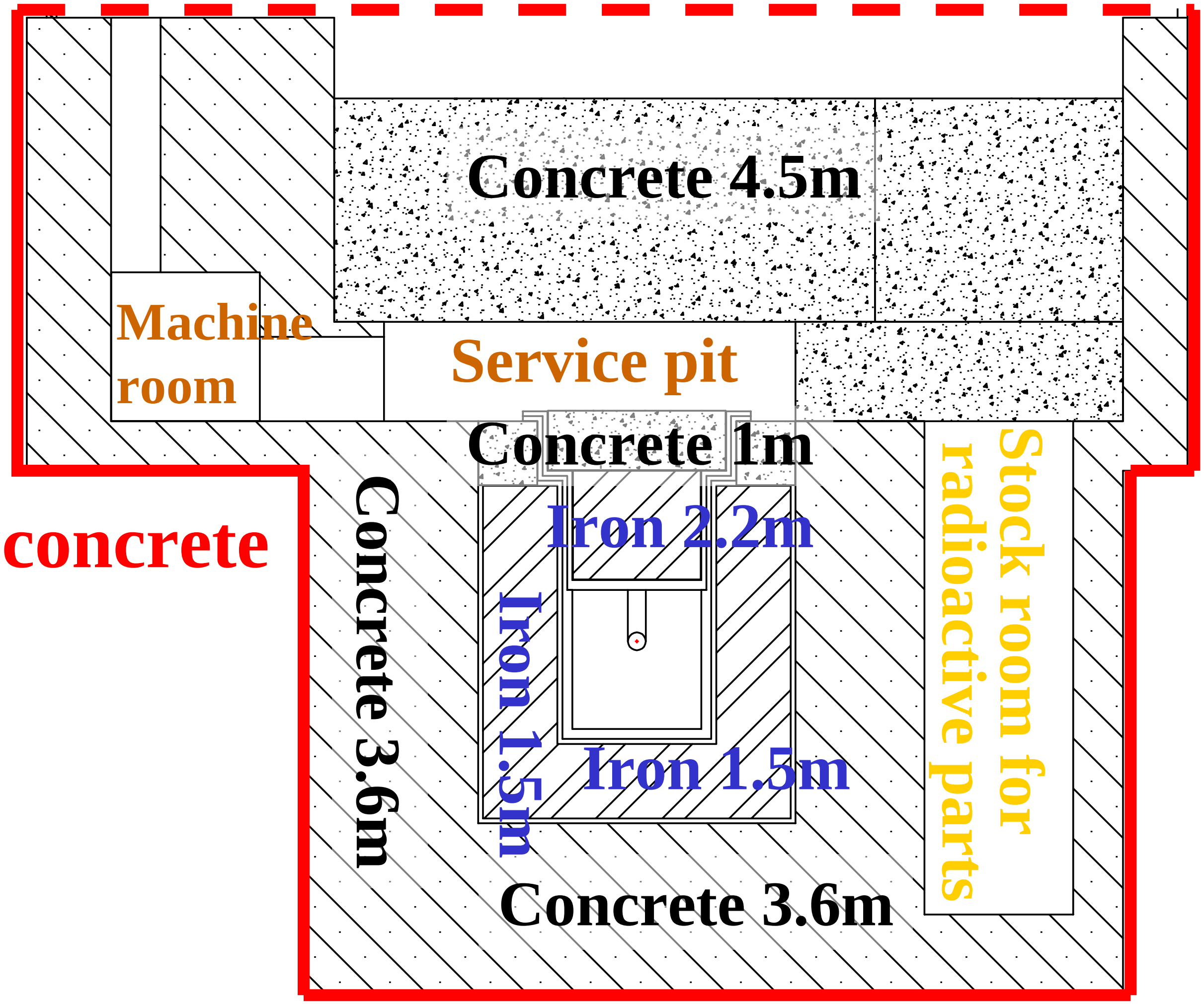


Radiation shield and dose

Floor: <12.5 μ Sv/h

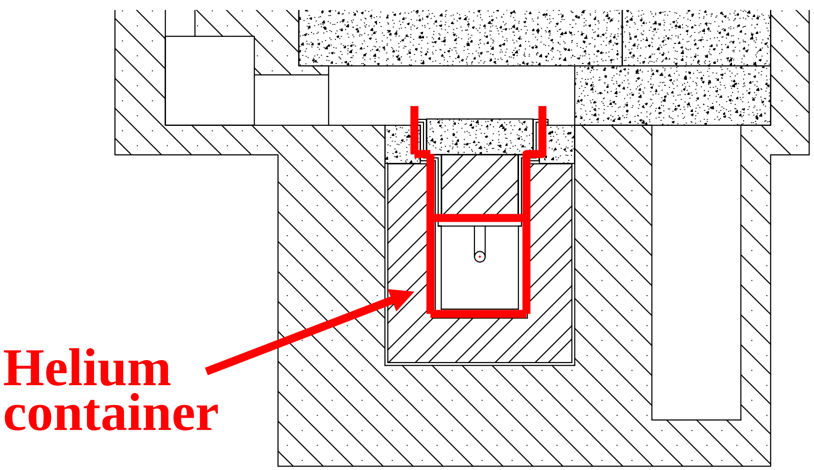
Radiation dose
in 0.75MW operation
(by MARS)

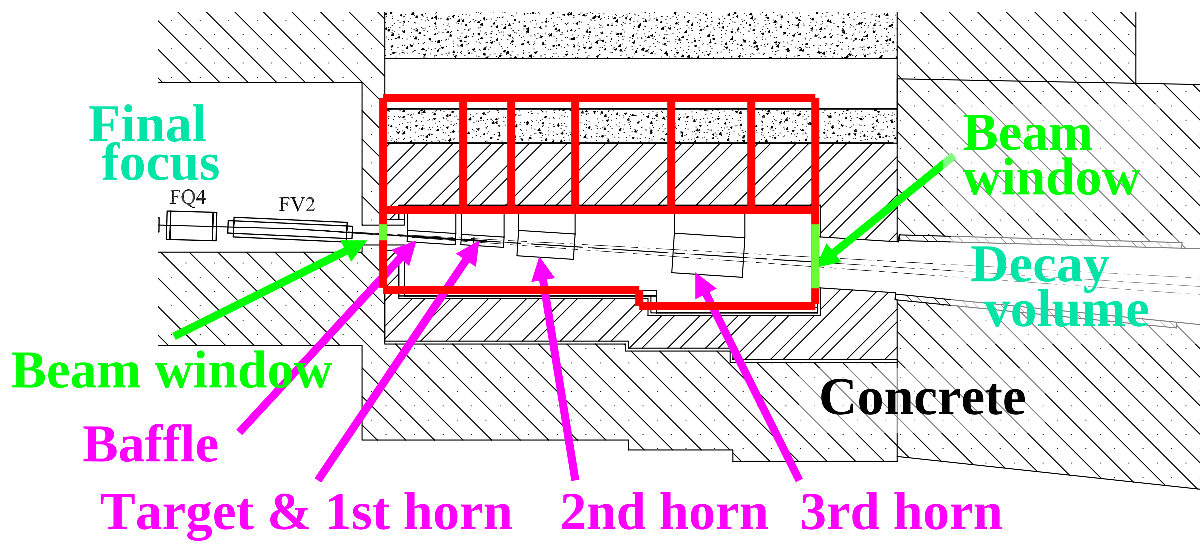
Outer surface of concrete
: <5mSv/h



Helium container

- Reduce radioactivity in gas and corrosion by NOx
- 3m(W)×6m(H)×15m(L), 20cm thick Aluminum
- Filled by 1 kg/cm^2 Helium gas (130m^3)
- Heat load ~170 kW: water cooled
- Under conceptual design





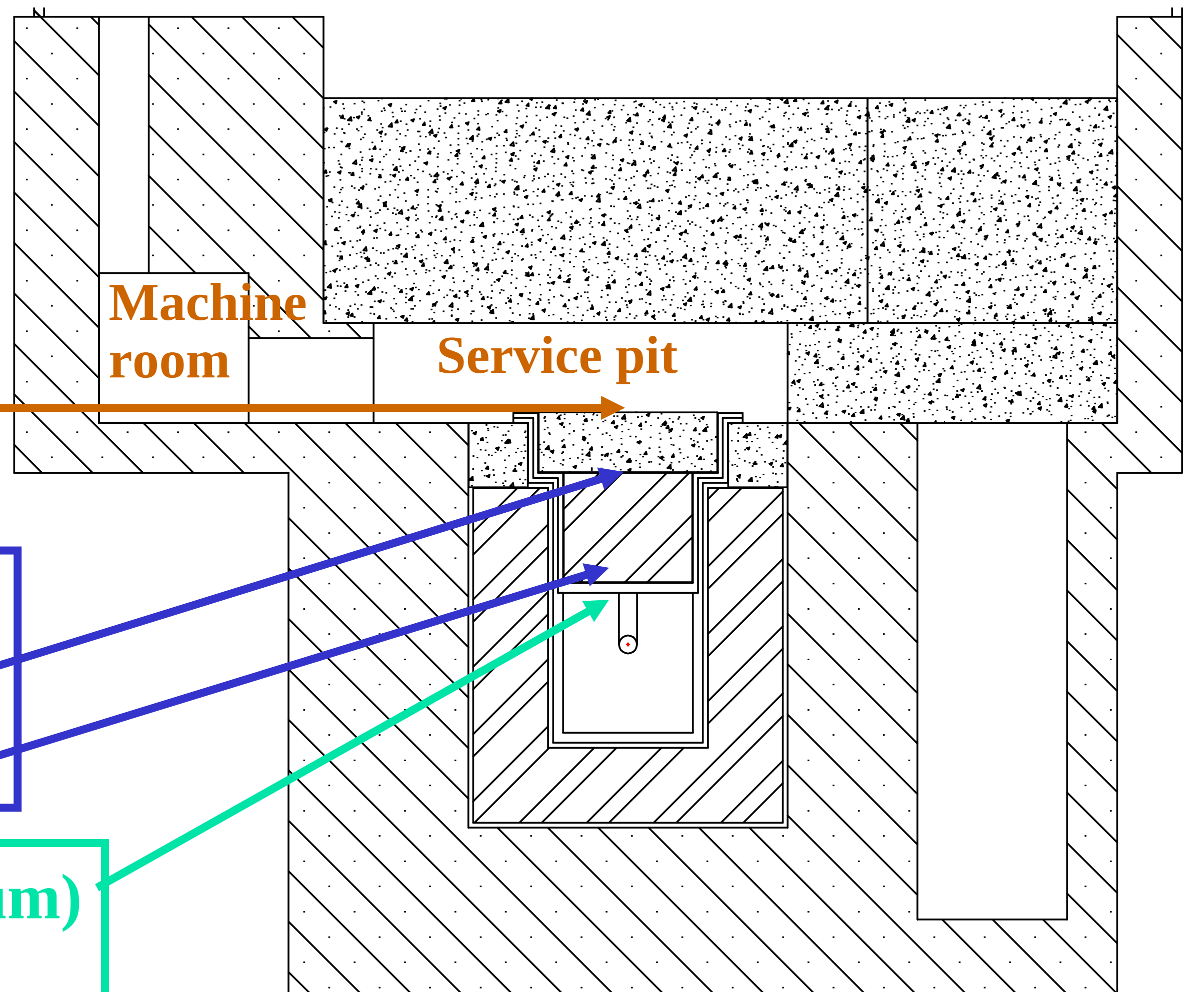
Residual dose

Residual does:

one (seven) day cooling

after one year operation

(by MARS)



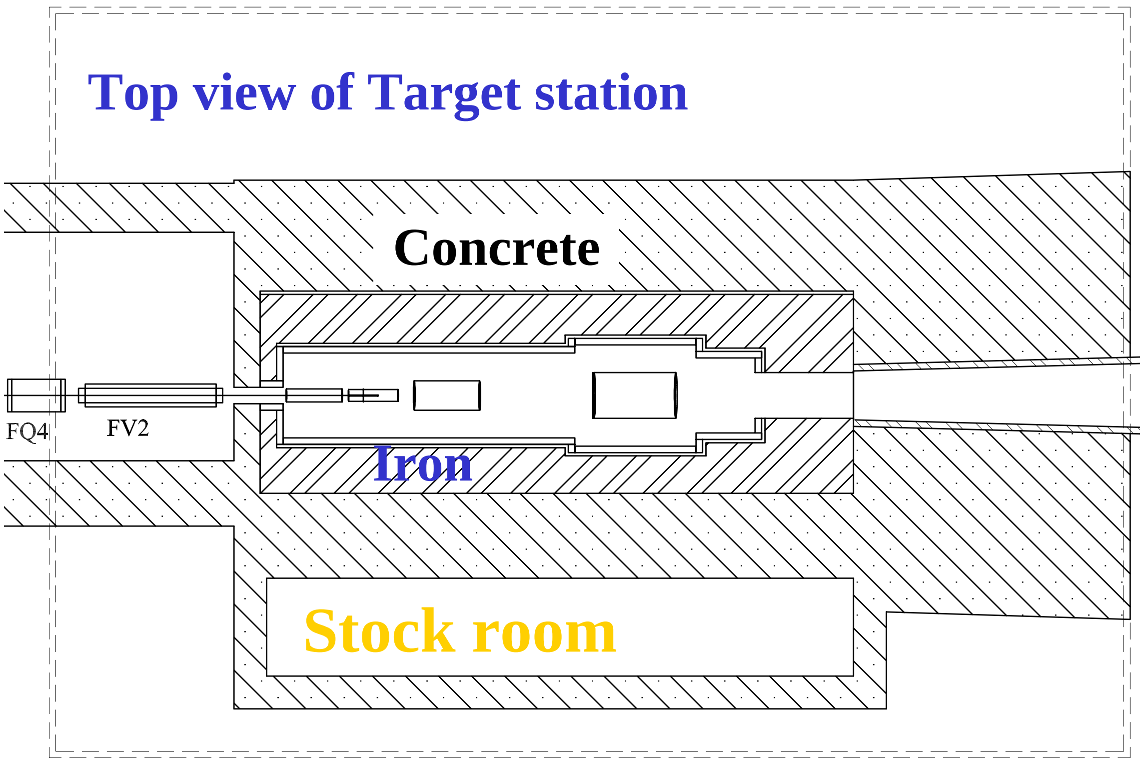
Floor of service pit
~0.007(0.004) μ Sv/h

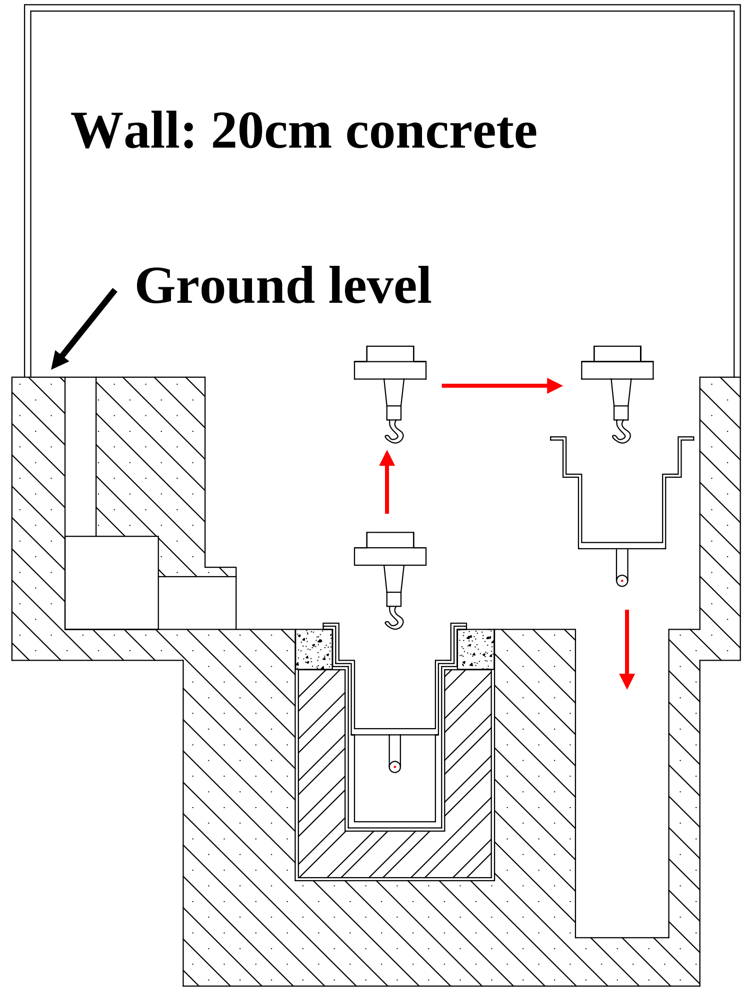
Upper iron shield
Outer : 22(16) μ Sv/h
Inner : 0.56(0.42) Sv/h

Helium container (Aluminum)
~0.65(0.17) Sv/h

Stock room for activated parts

- Stock broken and activated targets/horns etc (5~20 years?)
- Use cask and move under ground level





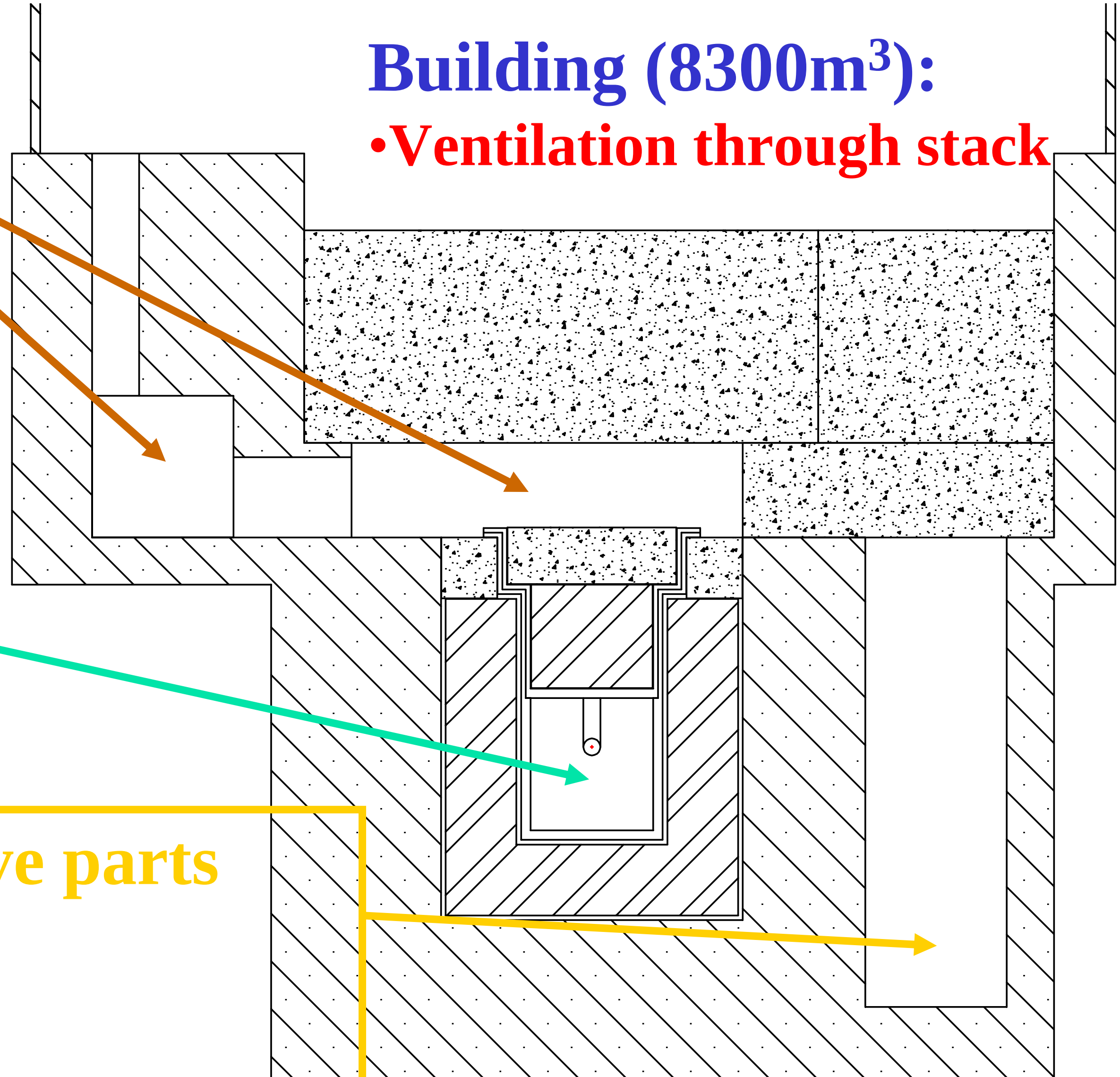
Control of air

Service pit($230m^3$)
Machine room($140m^3$)
Keep out in operation time
- Operation time:circulation
- Maintenance:ventilation

Helium container:
Keep out forever
- Circulation of Helium

Stock room for radioactive parts
Keep out forever
- Operation time:circulation
- Maintenance:ventilation

Building ($8300m^3$):
- Ventilation through stack



Cooling and radioactivity

After 3 weeks of 0.75MW operation,

- Target (heat load:20kW) :

  $0.001 m^3$ & $300 kBq/cm^3$

  ⇒ thinned into $20 m^3$ of 15 Bq/cm^3 and thrown away

- Horns (heat load:~30kW) :

  $0.6 m^3$ & $5 kBq/cm^3$

  ⇒ $200 m^3$ of 15 Bq/cm^3

- Iron shields & Helium container (heat load~210kW) :

  ~$0.1 m^3$, ~$30 kBq/cm^3$

  ⇒ ~$200 m^3$ of 15 Bq/cm^3

Summary

Target system for 0.75MW-50GeV beam at J-PARC

- under design and R&D stage
  and will be completed by 2007~2008
- Ni disks for hadron beam line
- Carbon rod for neutrino beam line
- Key points on target system
  - Radiation level and residual dose
  - Remote maintenance
  - Cooling
  - Cost, man power, schedule, etc.