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High Intensity Beam Handling for Nuclear and Particle Physics at J-PARC

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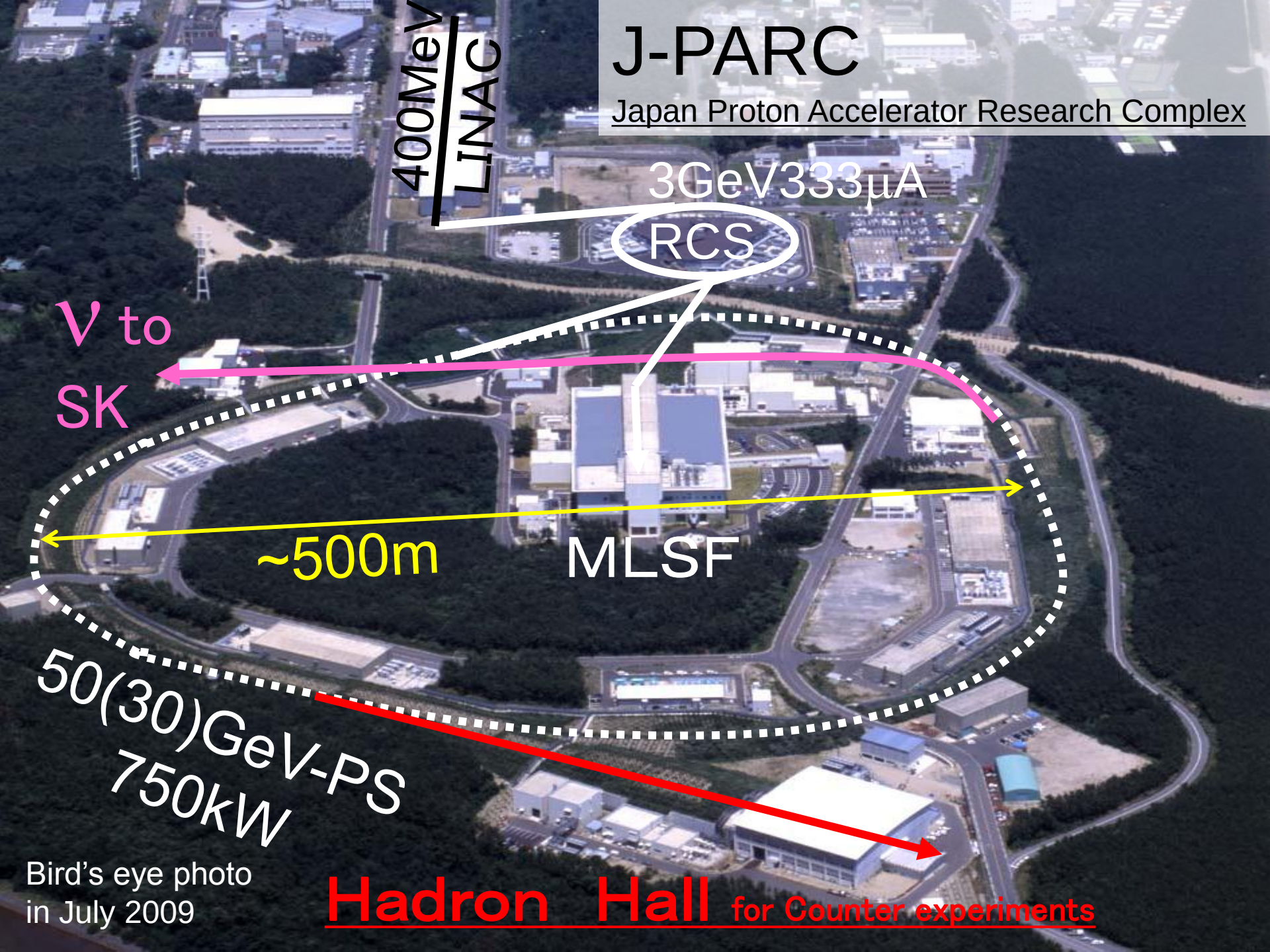
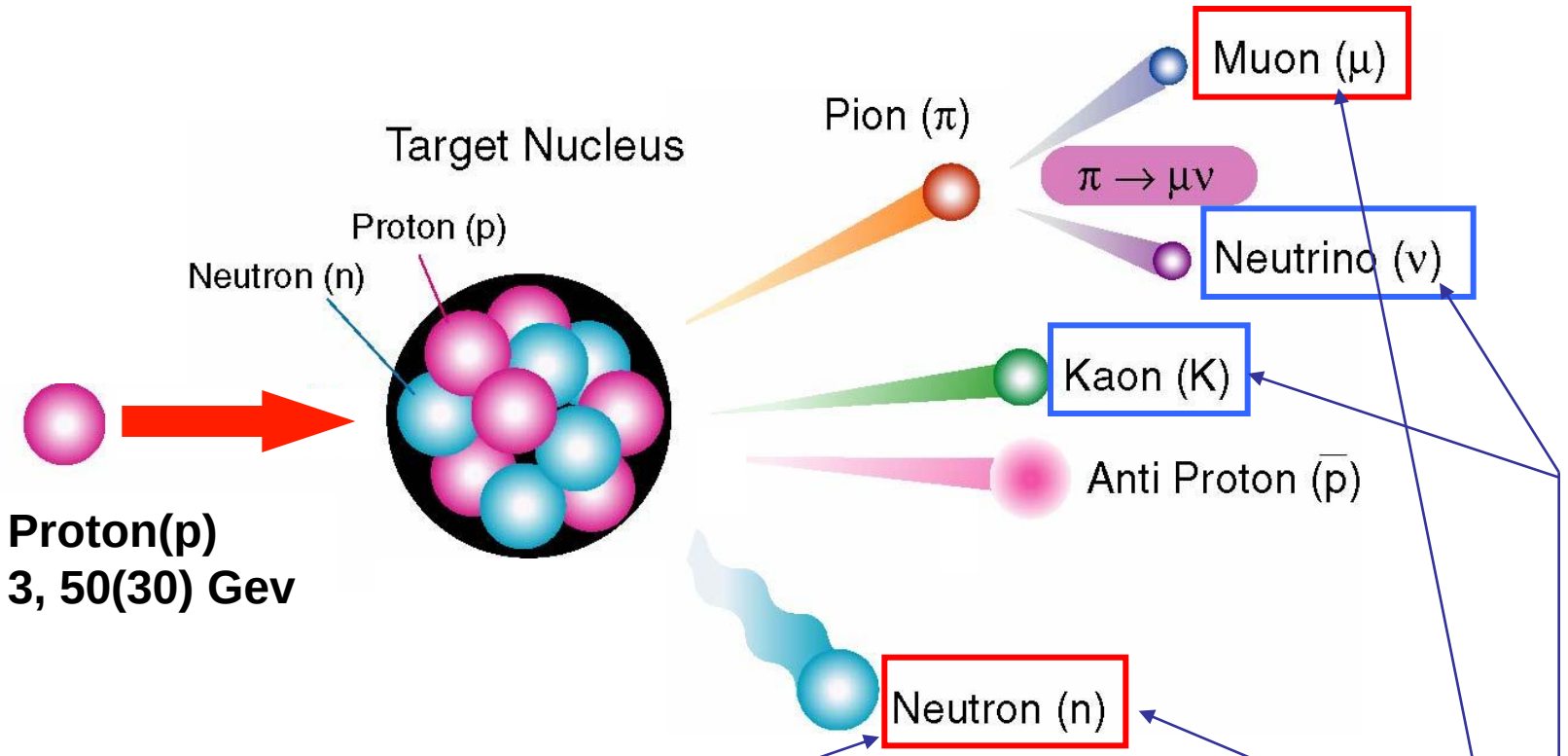
J-PARC
Japan Proton Accelerator Research Complex
J-PARC at Tokai-mura, Ibaraki-ken


J-PARC
Japan Proton Accelerator Research Complex
Bird’s eye photo
in July 2009


J-PARC
Japan Proton Accelerator Research Complex
400MeV LINAC
3GeV333μA
RCS
ν to SK
~500m
MLSF
50(30)GeV-PS
750kW
Bird's eye photo in July 2009
Hadron Hall for Counter experiments

Goals at J-PARC



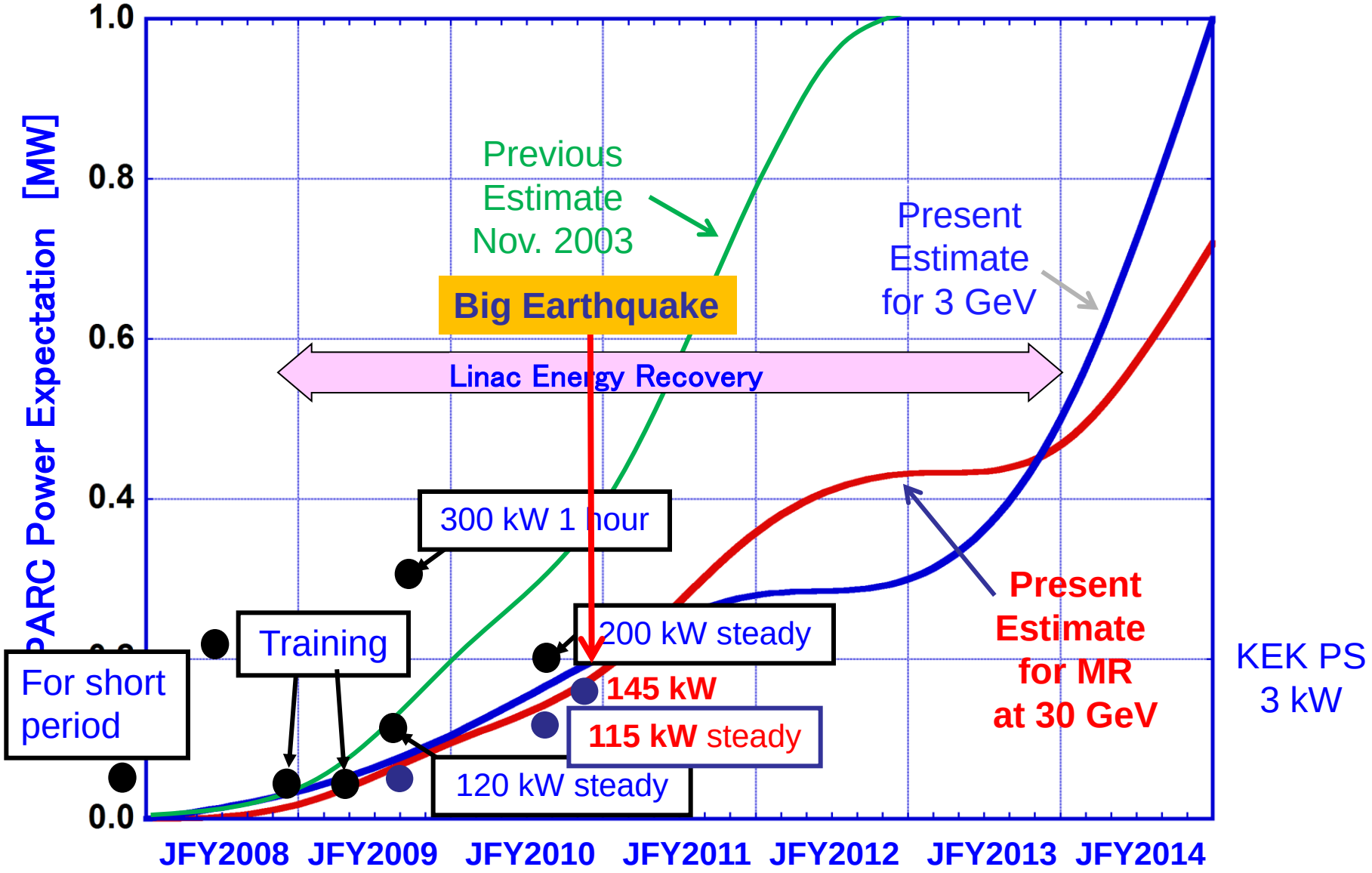
Need to have high-power proton beams

→ MW-class proton accelerator (current frontier is about 0.1 MW)

Materials & Life Sciences at 3 GeV
Nuclear & Particle Physics at 50 GeV
R&D toward Transmutation at 0.6 GeV

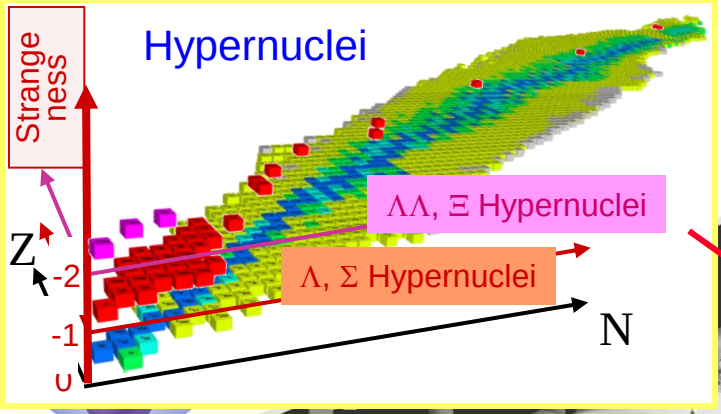
Power Capability of J-PARC

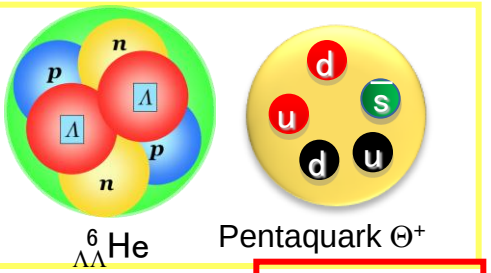
Slow Extraction; 99.6% efficiency for 5kW was achieved!

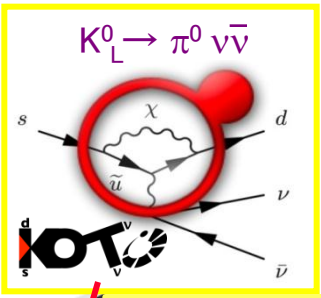


Nuclear & Hadron Physics at J-PARC

High Density Nuclear Matter, Nucelar Force

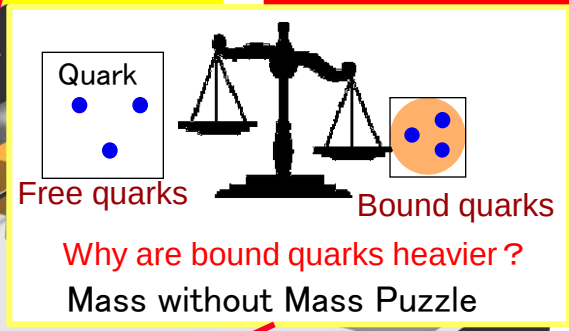






Confinement

Origin of Mass



High Density Nuclear Matter, Nucelar Force

Kaonic atom

Kaonic nucleus

COMET Beam line

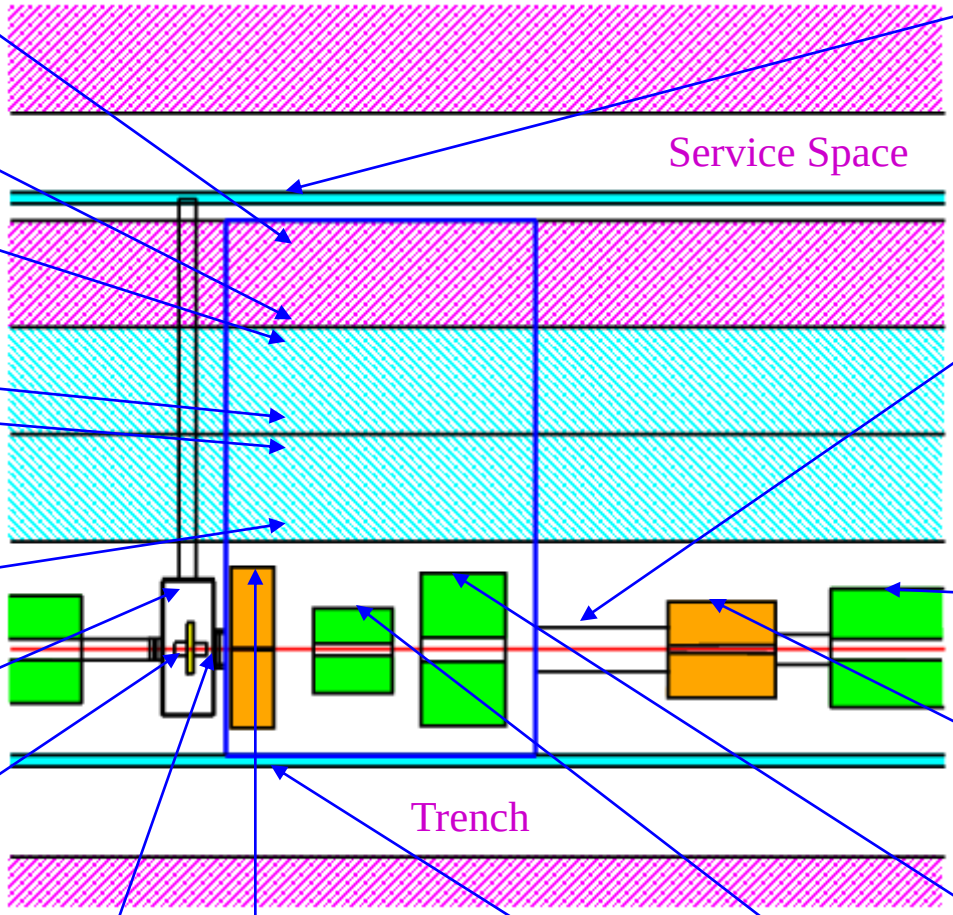
μ-e conversion

$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$

e^-

Residual Dose

30Days Operation/1Day Cooling
1Year Operation/Half Year Cooling



Concrete
7.9 μSv/h
0.03 μSv/h

Concrete
5.3 mSv/h
1.6 μSv/h

Iron
60 μSv/h
11 μSv/h

Iron
430 μSv/h
160 μSv/h

Iron
1.1 mSv/h
460 mSv/h

Iron
170 mSv/h
460 mSv/h

T1 Vessel
2.2 Sv/h
850 mSv/h

T1 Target
650 Sv/h
230 Sv/h

Vacuum Seal
30 Sv/h
11 Sv/h

Collimator
380 mSv/h
100 mSv/h

Iron Base
560 mSv/h
210 mSv/h

D1
530 mSv/h
270 mSv/h

Q1
62 mSv/h
33 mSv/h

Collimator
710 mSv/h
420 mSv/h

q1B
110 mSv/h
49 mSv/h

Vacuum Duct
SUS 3.2 Sv/h
1.2 Sv/h
Ti 1.1 Sv/h
97 mSv/h

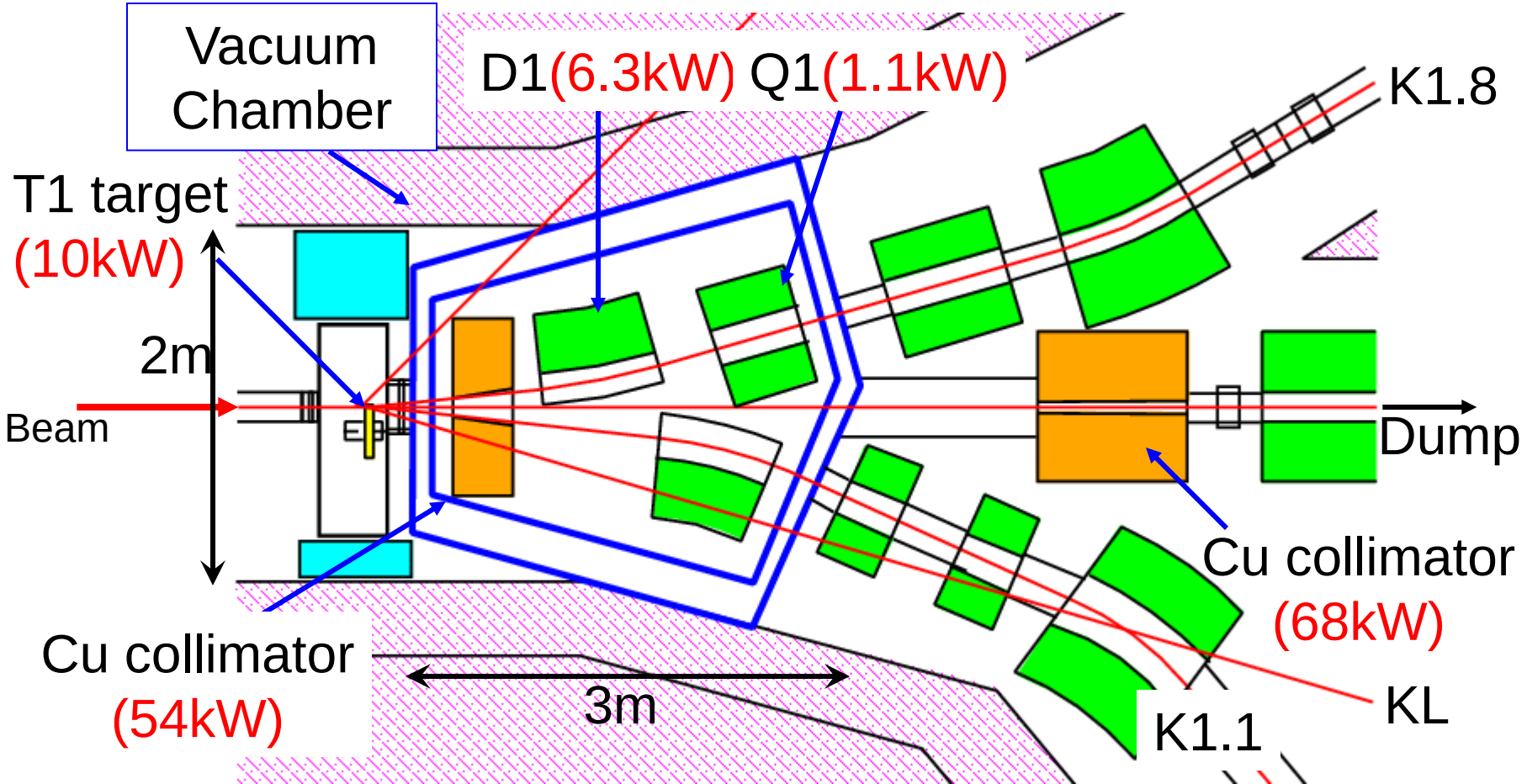
Water Pipe (SUS)
8.4 μSv/h
2.4 μSv/h

Downstream of T1 Target

How to solve 200kW Heat Problem?

Magnets → **Upstream Collimator**

Beam Ducts → **Big Vacuum Chamber instead of Ducts**

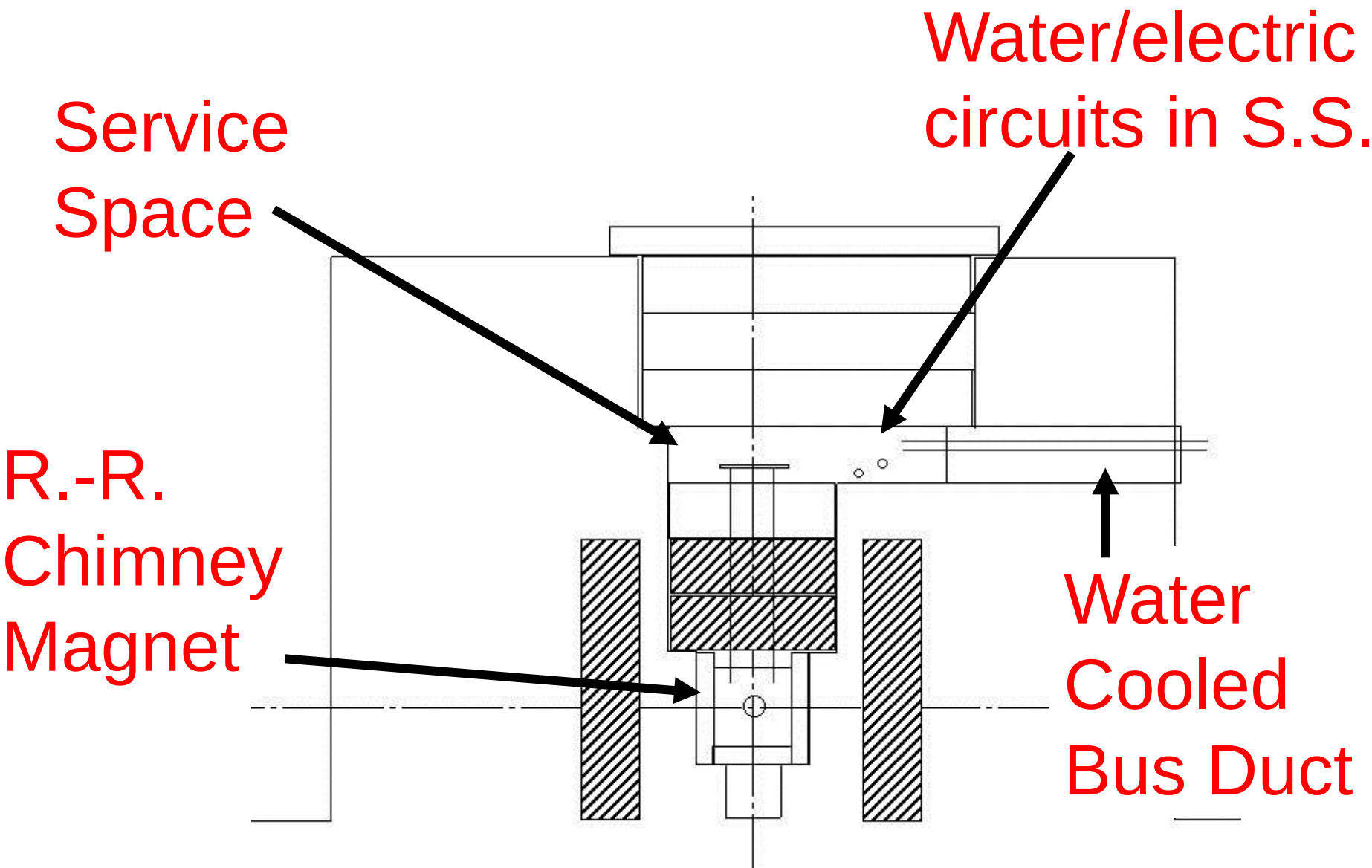


High Intensity Beam Handling

- Beam Transport Devices (Magnets etc.) should be radiation/heat resistant.
- Beam Transport Devices should be replaced easily and quickly in the case of trouble.
- **High Intensity Handling should be designed as a system.**
  - Power/water/Vacuum lines,
  - Daily operation/maintenance,
  - Radiation shields,


JFE メカニカル
40/40+20/t/20t

Hadron Hall Systematization; as High Power Beam Facility



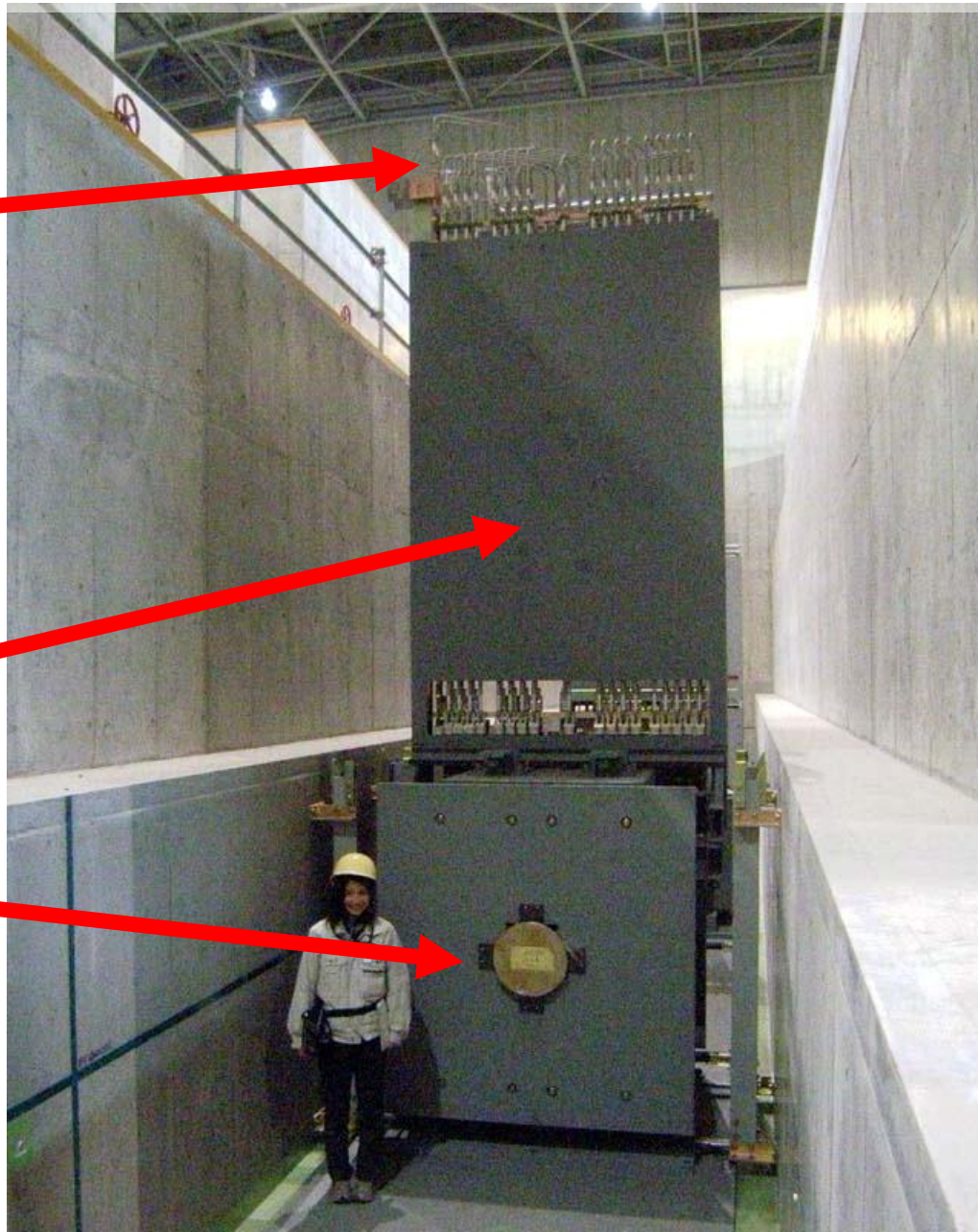
Radiation Resistant **Chimney** Magnet

Water Manifold &
Electric Connection
at Service Space Level

Completely Inorganic

Chimney

MIC Magnet

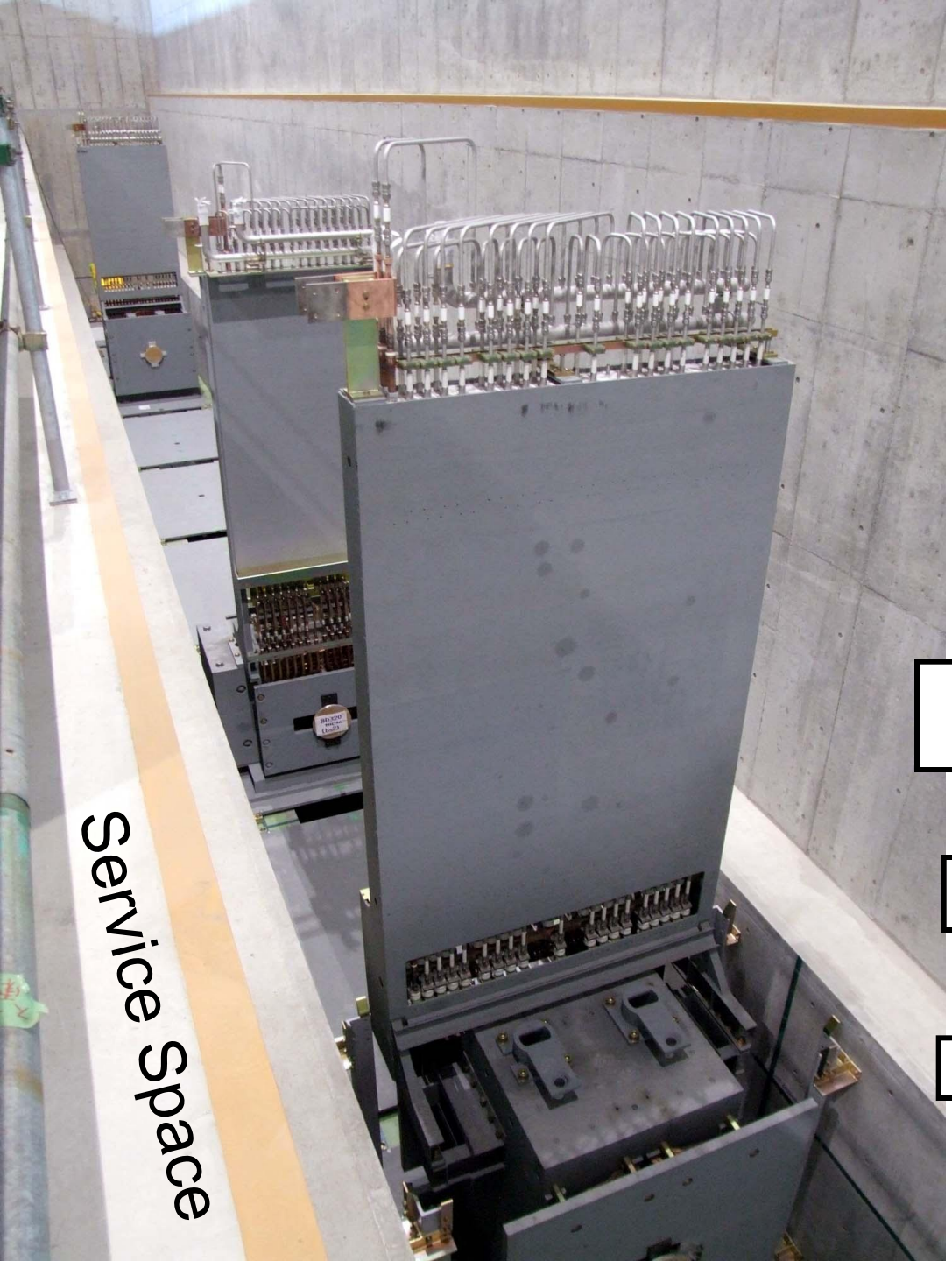


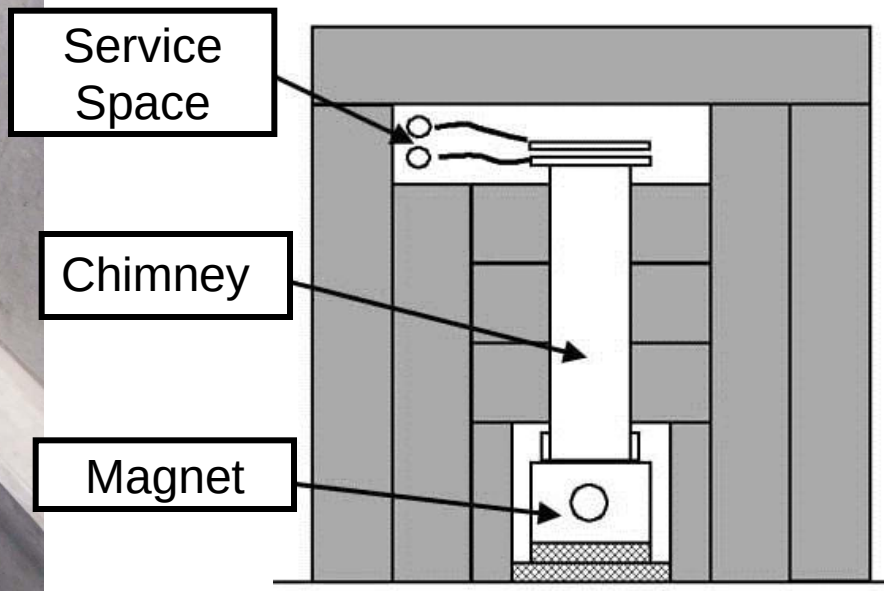
Chimney

magnet

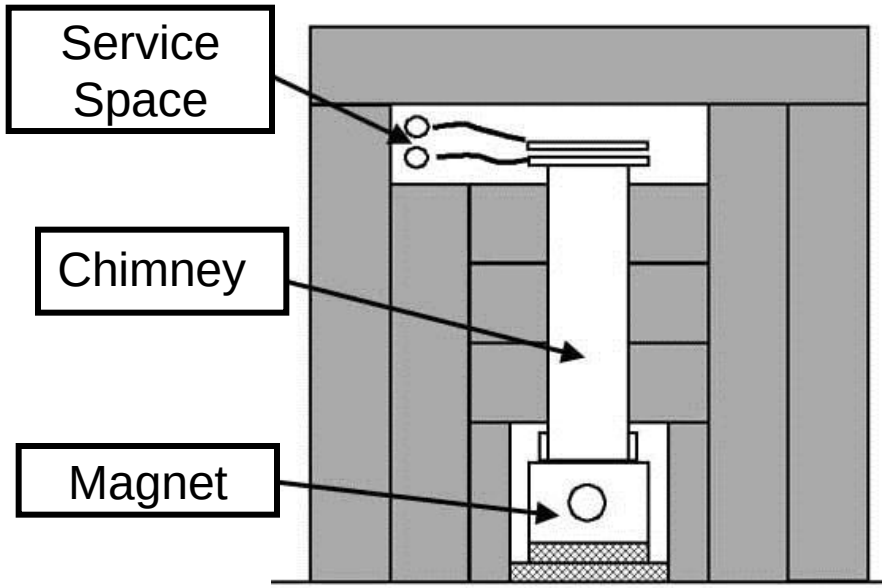
Lift up test

Chimney magnets aligned on line at Hadron Hall

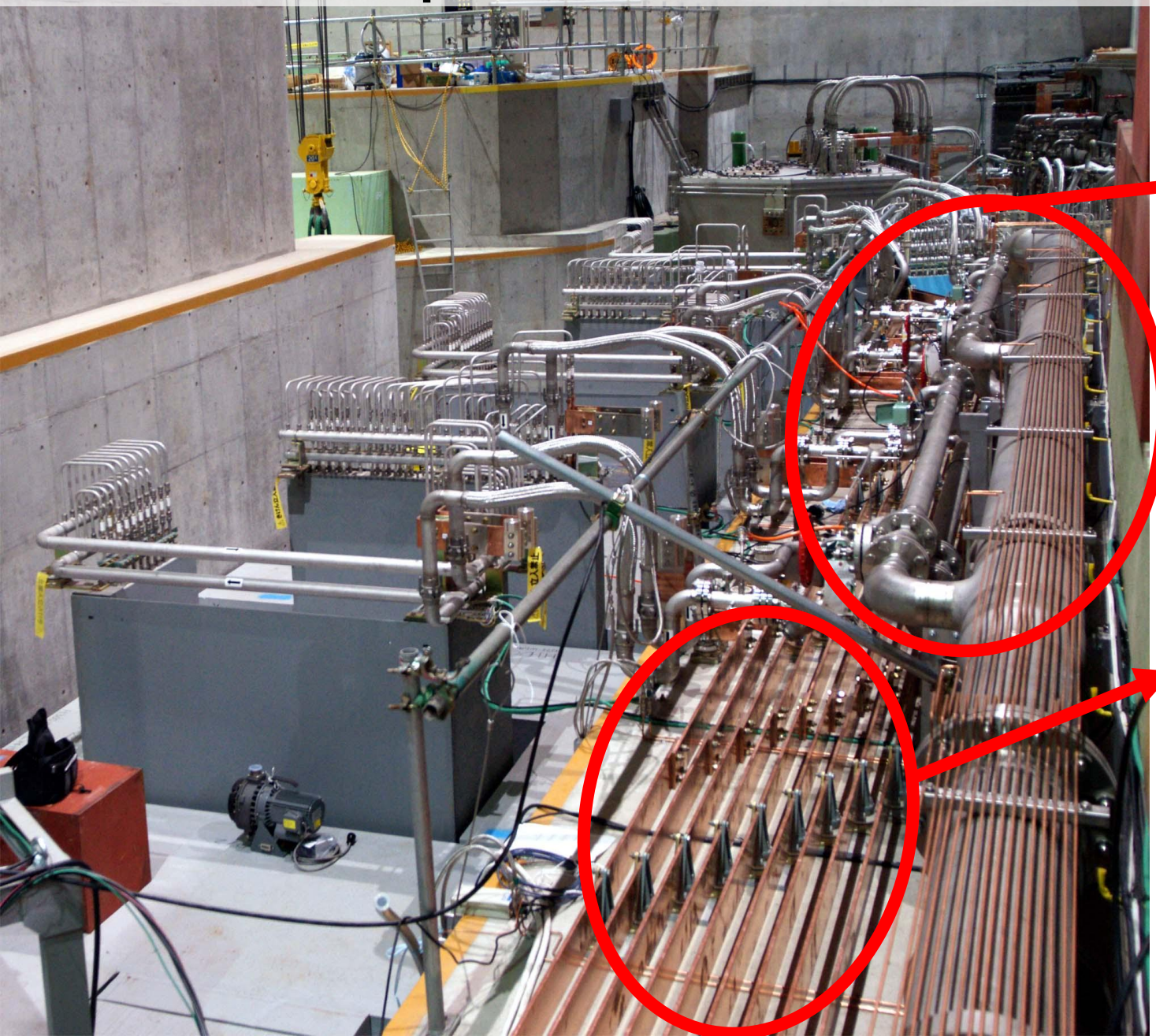




Chimney magnets aligned on line at Hadron Hall with radiation shields



Service Space; Water/Electric circuits



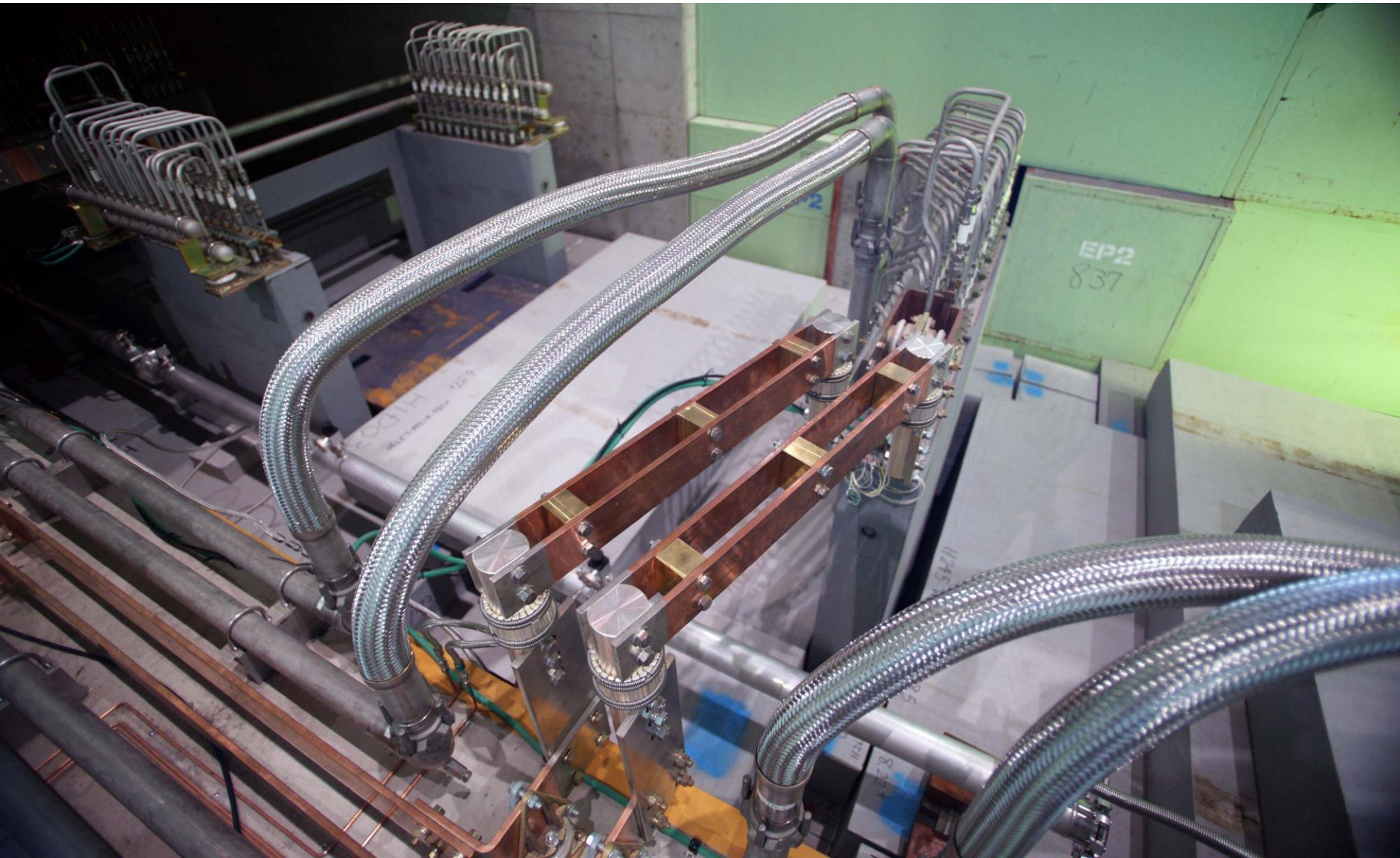
Water Piping

Inorganic; using steam piping technology

Electric Circuits

Inorganic; using Cu B.B.

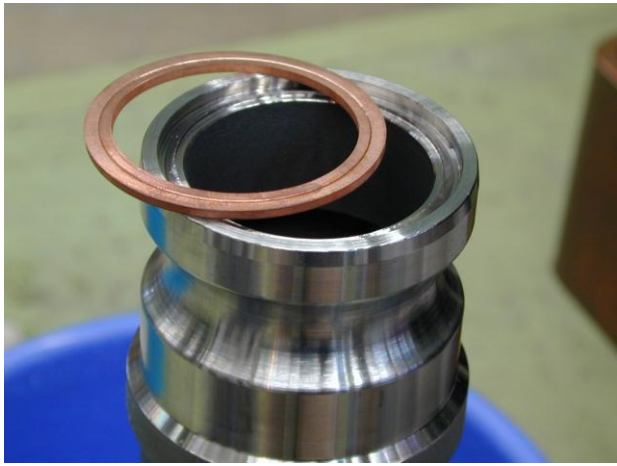
Bridges for Water & Electric Power; Quick Disconnect System



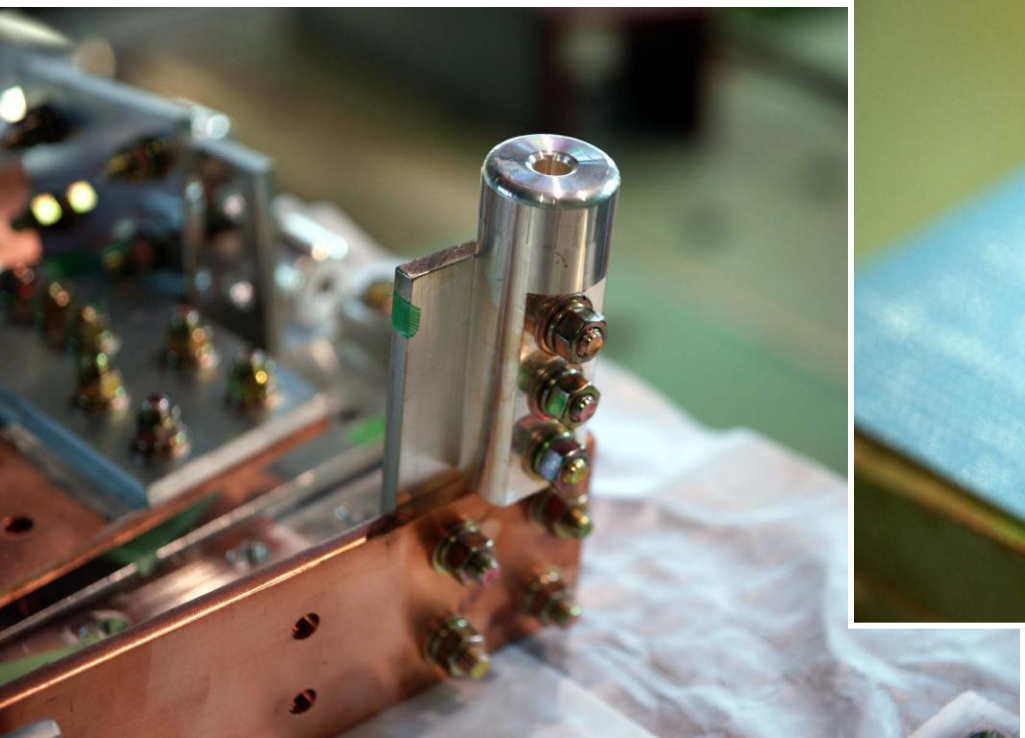
Water Connector

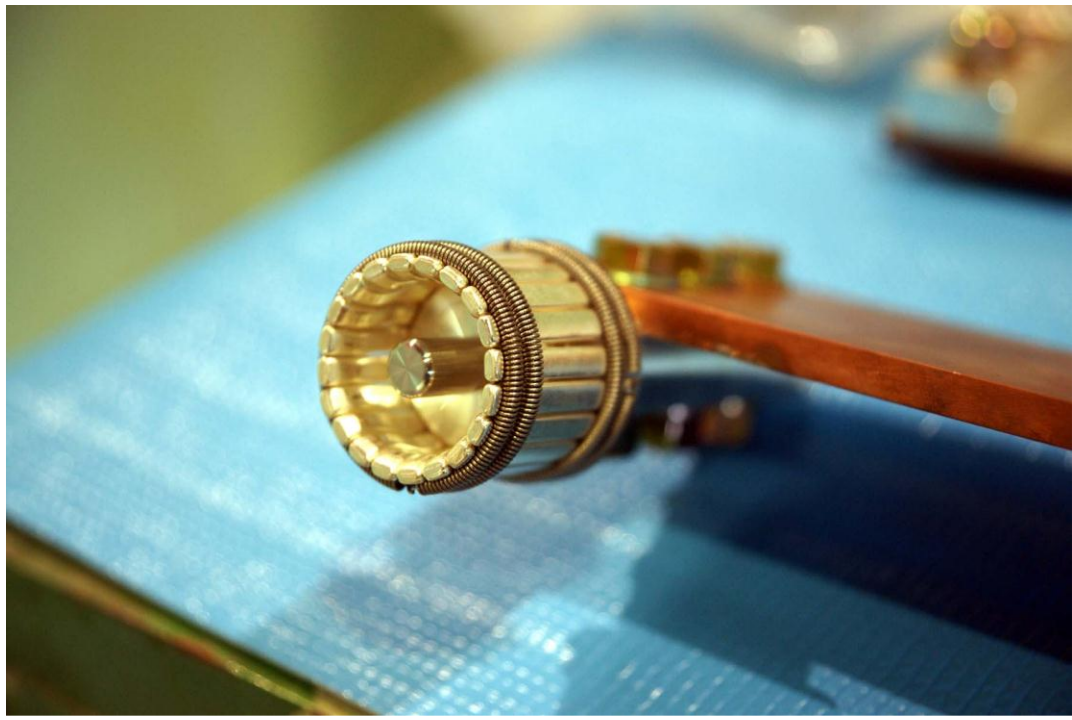
Metal sealed lever coupler

- Normal operation with 2MPa
- Normal operation temperature : 15～80℃
- Two inch. Diameter
- Cu-ring annealing @750℃
- Deficit depth > 0.2mm

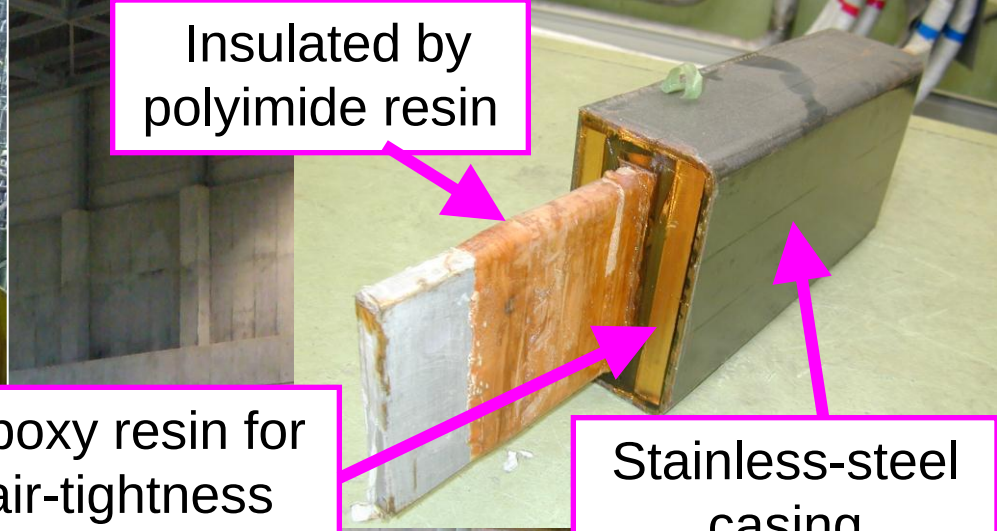


Q.D. Electric Power Connector





Quick Disconnect device



Insulated by polyimide resin

Epoxy resin for air-tightness

Stainless-steel casing

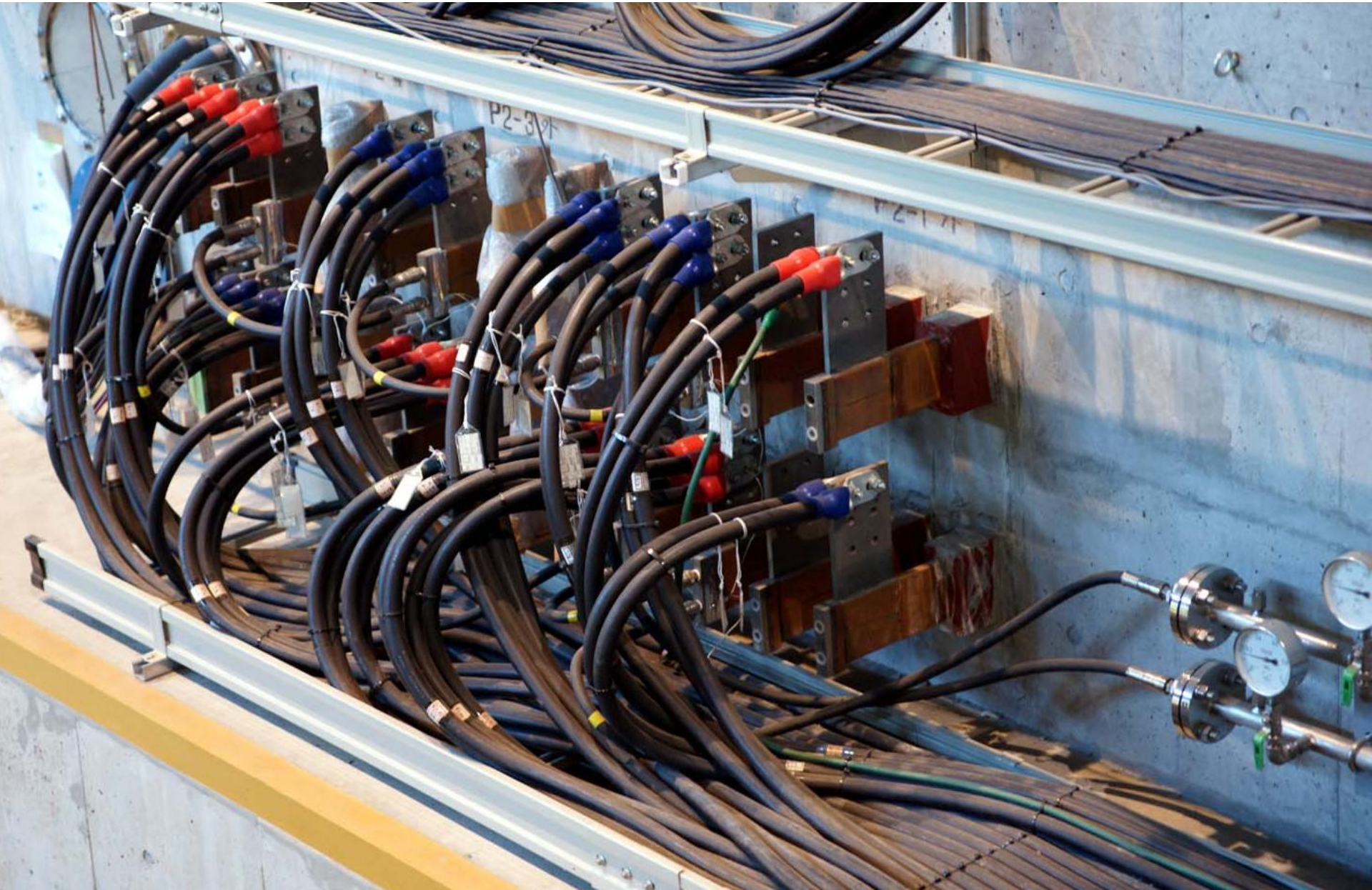
PS Station

Shield Penetrating Bus Duct;

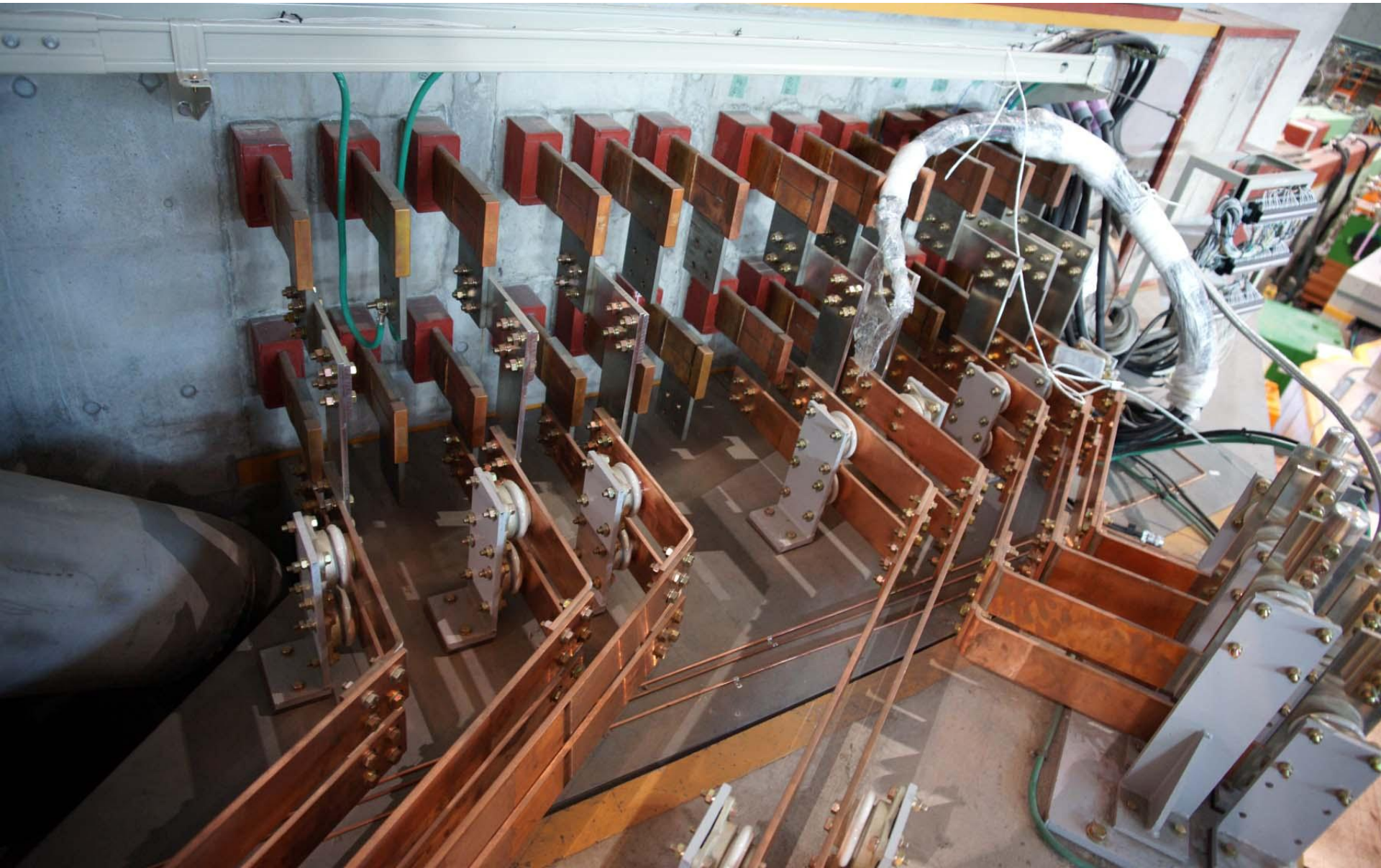
Constructed as a part of Radiation Shield

No Labyrinth Structure was necessary

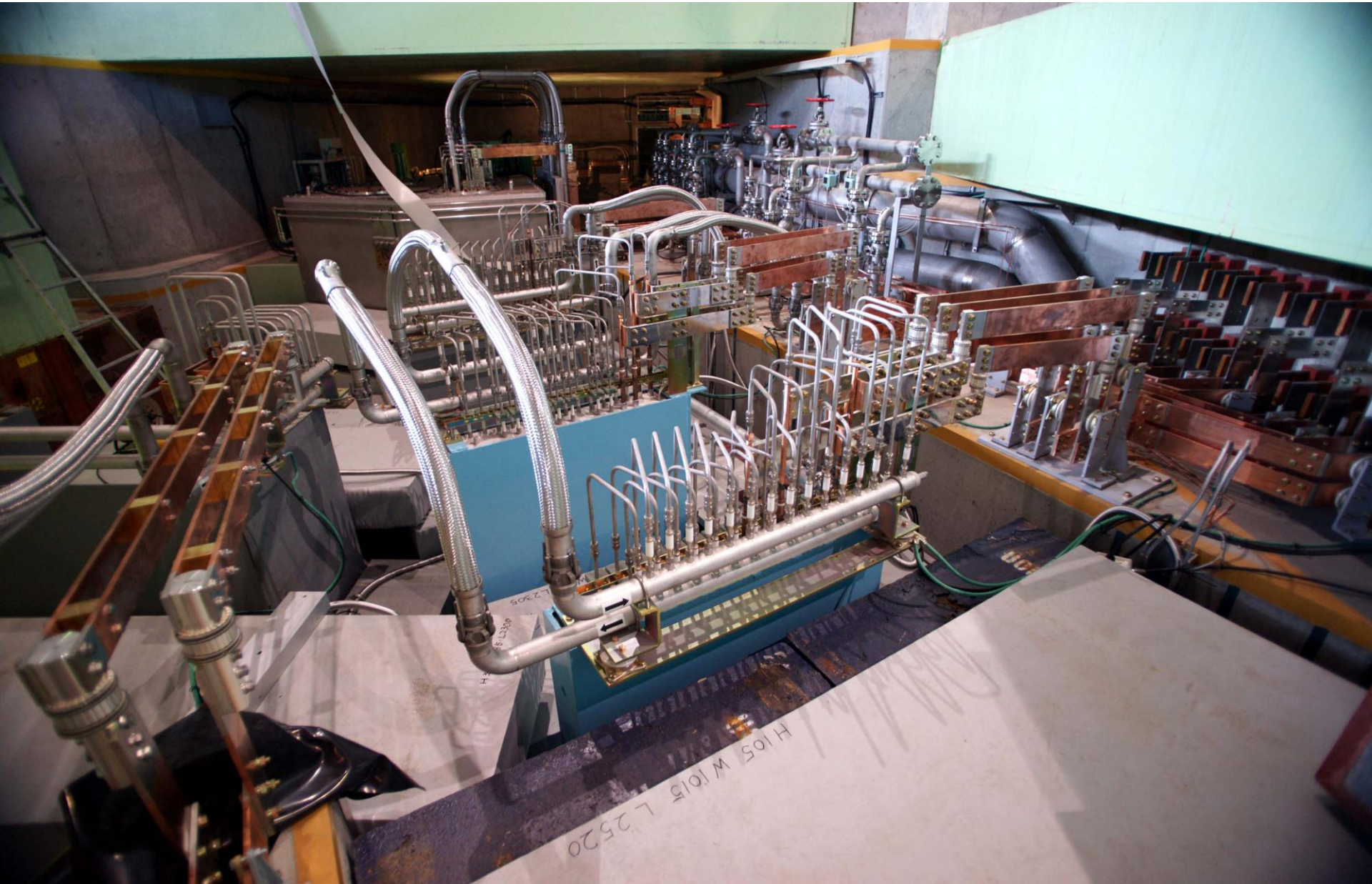
Shield Penetrating Bus Duct (Outside)



Shield Penetrating Bus Duct (Inside)



Service Space near T1 Target

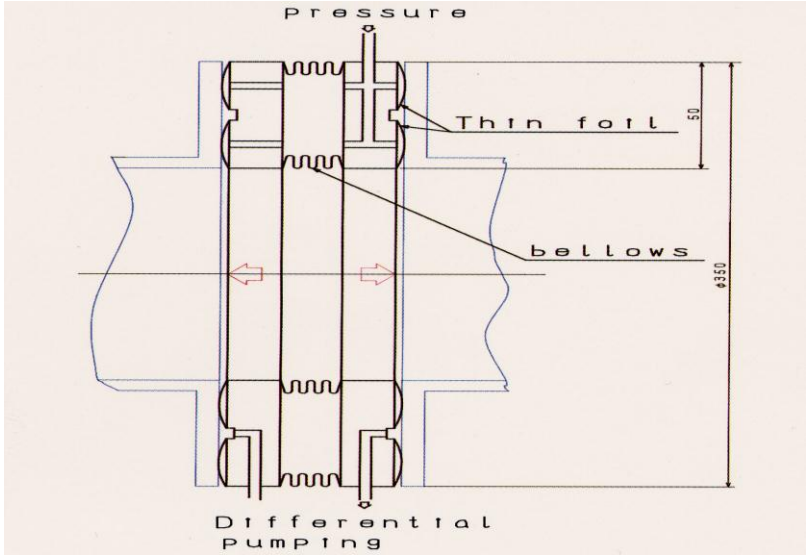


Pillow Seal for Vacuum Connection

Our first one (1989) for KEK-PS
Effective Dia. = 30cm, Leak rate ~10^{-8}Pa･m^3/s

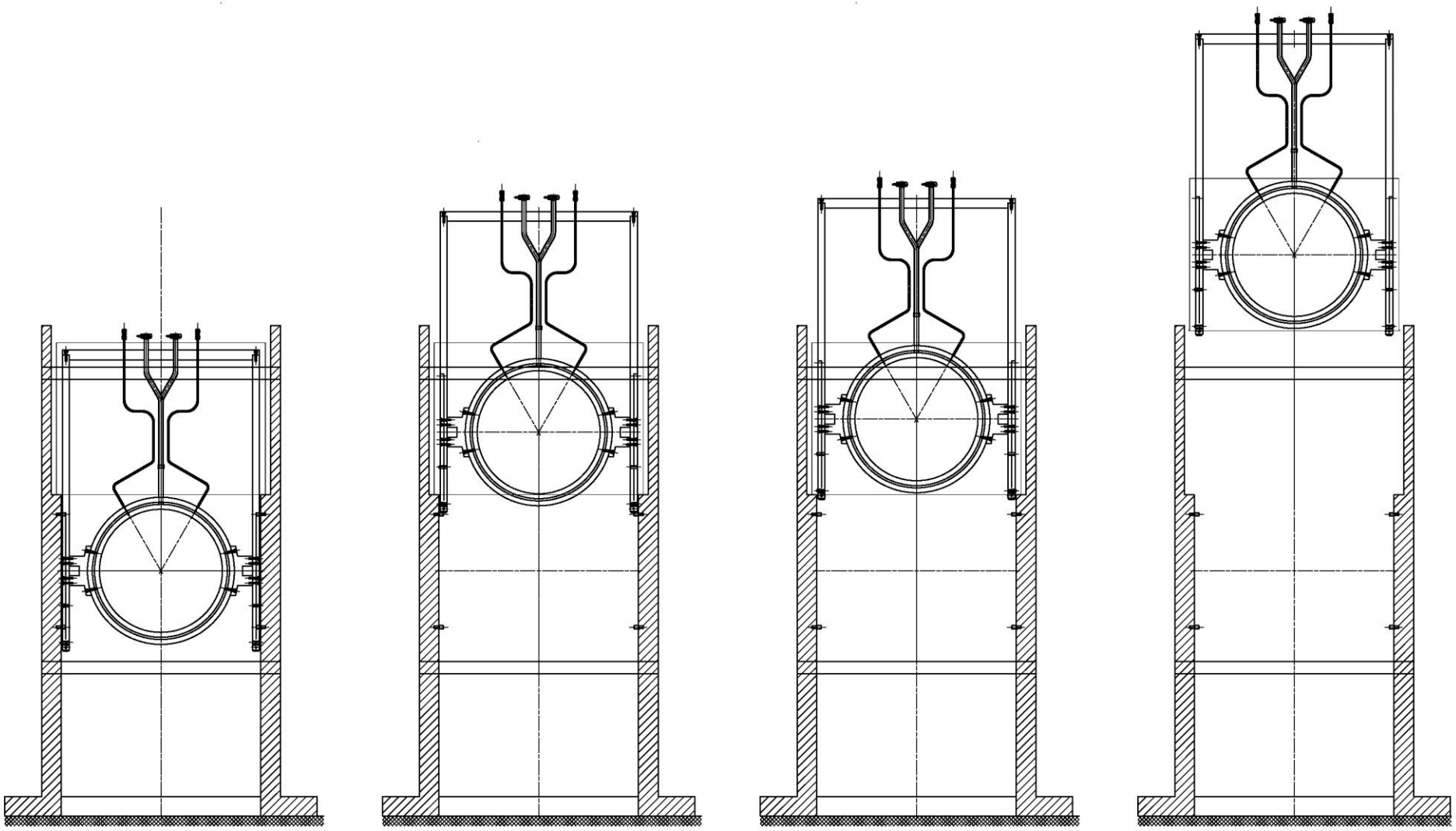
On non-flat…

On dust….

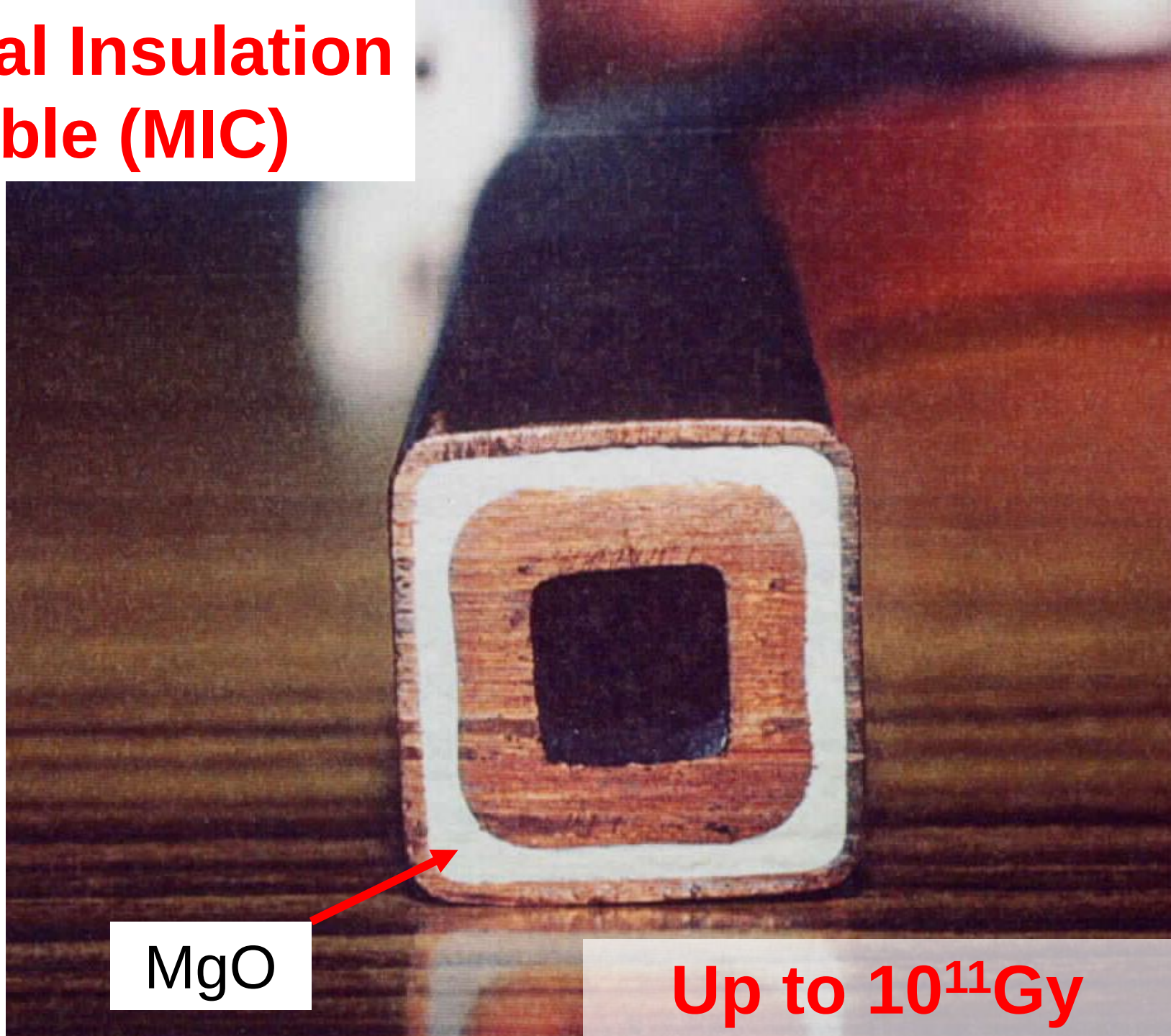


- Now, Leak rate is ~4x10^{-12}Pa･m^3/s
- Effective Dia. >50cm

Pillow Seal for Vacuum Connection



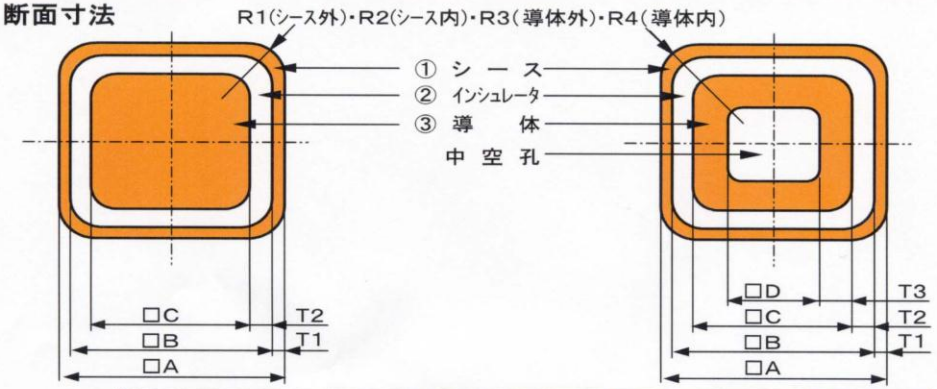
Mineral Insulation Cable (MIC)



MIC

日立 無機絶縁導体
HITACHI Mineral Insulation Cable (MIC)

1. 断面寸法



寸法(mm) ＼ 仕様			中実タイプ		中空タイプ		
			MIHC-1000A-S	MIHC-2000A-S	MIHC-2000A-H	MIHC-2500A-H	MIHC-3000A-H
① シース	外径	A	14.0	18.0	19.8	23.8	28.0
	肉厚	T1	0.7	0.7	1.0	1.1	1.5
	外R	R1	1.2	1.2	2.0	3.0	4.0
	内R	R2	0.8	0.8	1.0	1.9	2.5
② インシュレータ	外径	B	12.6	16.6	17.8	21.6	25.0
	肉厚	T2	1.7	1.7	1.7	1.8	2.5
③ 導体	外径	C	9.2	13.2	14.4	18	20.0
	内径	D	—	—	10.0	10	10.0
	肉厚	T3	—	—	2.2	4.0	5.0
	外R	R3	2.6	2.6	2.5	4.0	3.0
	内R	R4	—	—	0.8	1.3	1.0
断面積 (mm^2)	① シース		36.6	47.8	72.6	95.3	150.6
	② インシュレータ		79.4	106.6	114.0	153.2	227.4
	③ 導体		78.8	168.4	101.4	208.8	293.1
	合計		194.8	322.8	288.1	457.3	671.1
中空穴断面積 (mm^2)			—	—	99.5	98.5	99.1
単重 (kg/m)	① シース		0.327	0.427	0.649	0.852	1.347
	② インシュレータ		0.187	0.250	0.268	0.360	0.534
	③ 導体		0.705	1.506	0.907	1.867	2.621
	合計		1.218	2.183	1.824	3.078	4.502
製造可能長さ (m)			60	60	60	60	30

2. 仕 様

品番・名称 ＼ 仕様	材 質	化学成分	硬度 (Hv1kg)	導電率 (%,20℃)
① シース	C1220−O	Cu 99.90%以上	40〜50	-
② インシュレータ	MgO	MgO 98.0%以上	—	-
③ 導体	C1020−O	Cu 99.96%以上	40〜50	100以上

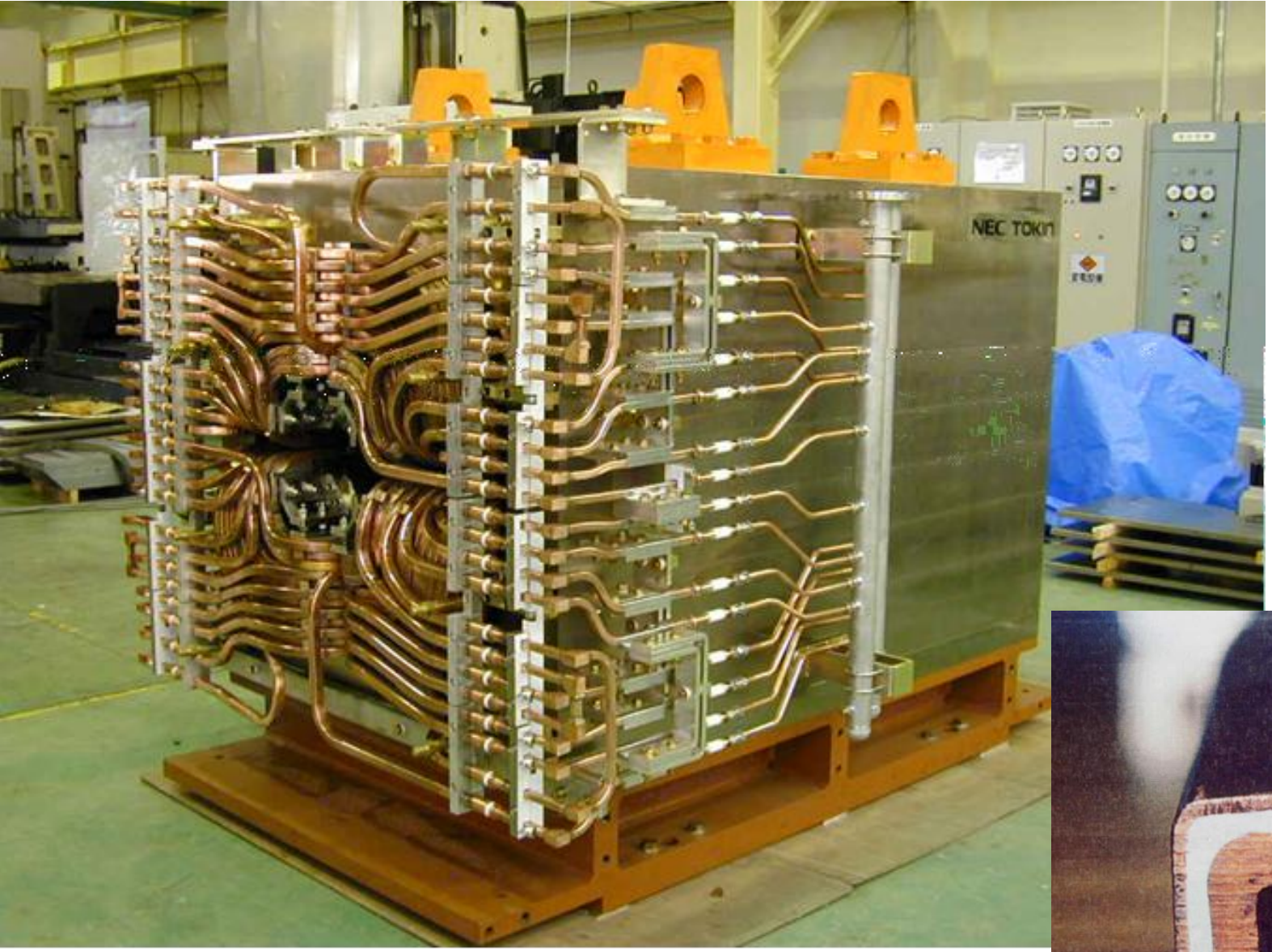
3. 納入形態

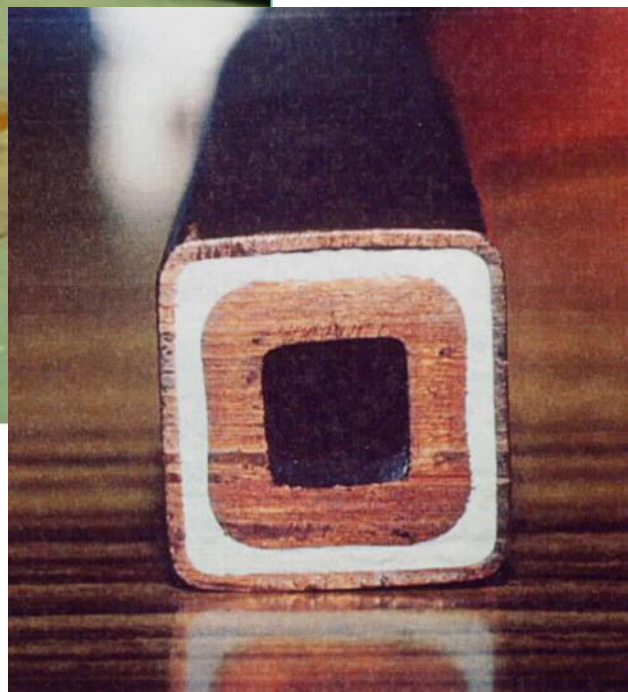
外径 φ1800程度のゼンマイ巻き

※「MIC」は、文部科学省 高エネルギー加速器研究機構殿・株式会社 トーキン殿との共同開発品です

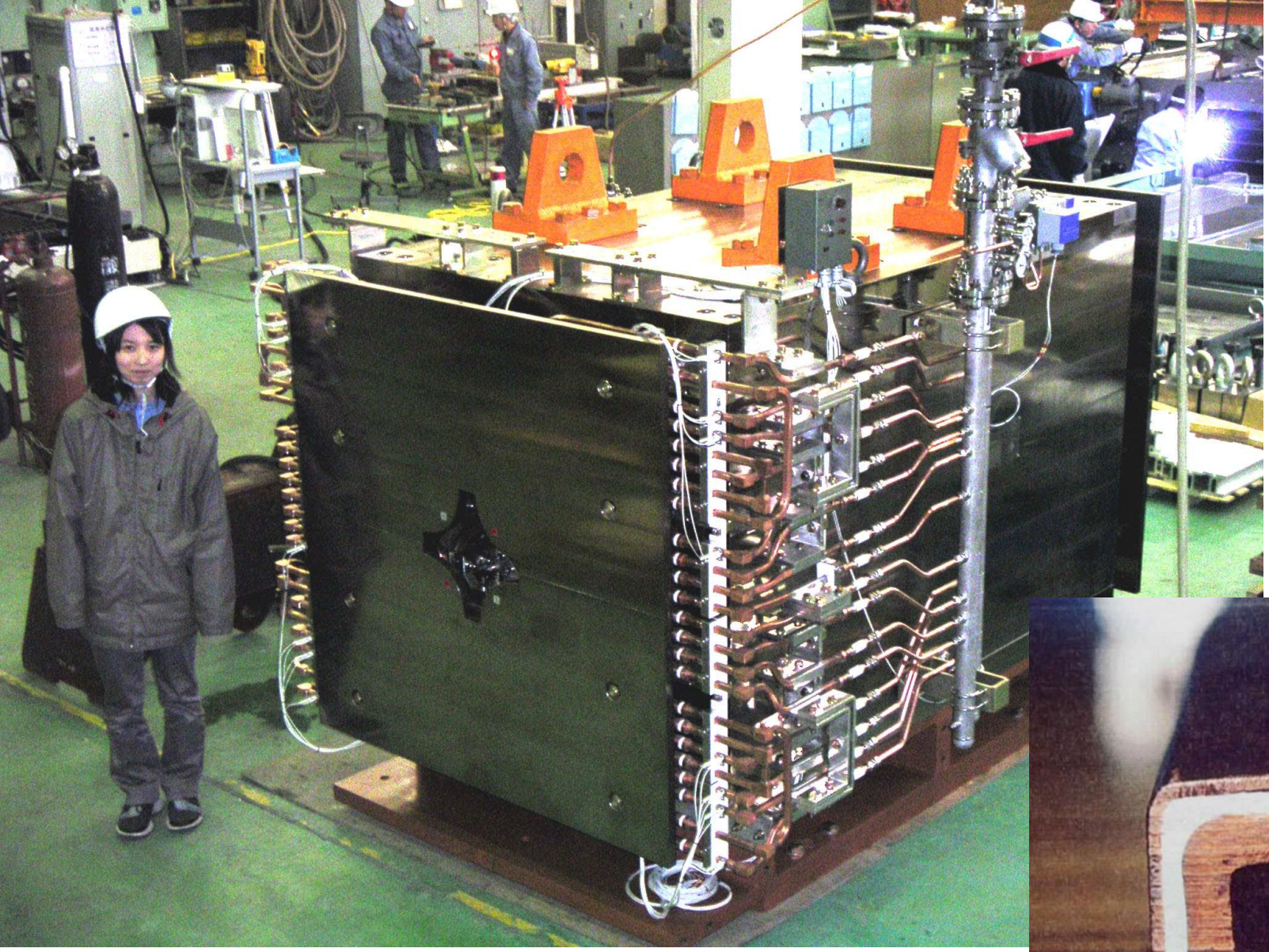
日立電線株式会社

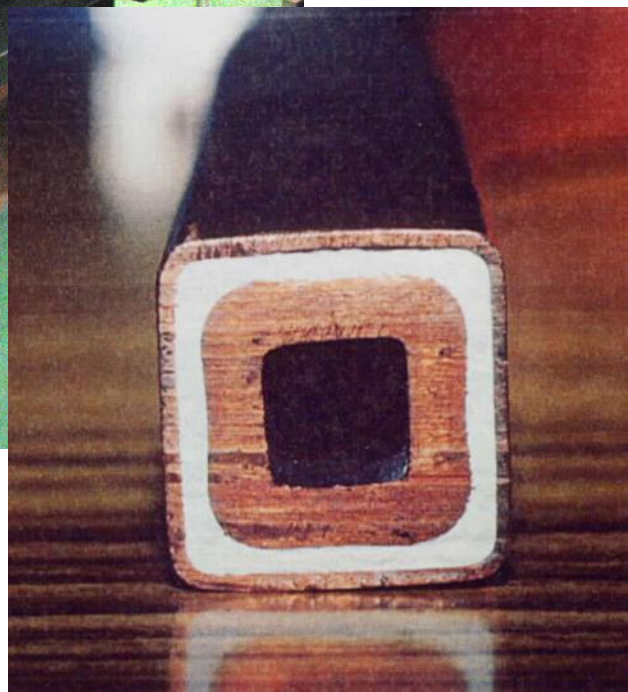
土浦工場 技術部 TEL:0298-26-7426 FAX:0298-23-2442
茨城支店 伸銅営業課 TEL:0294-24-4821 FAX:0294-22-3049





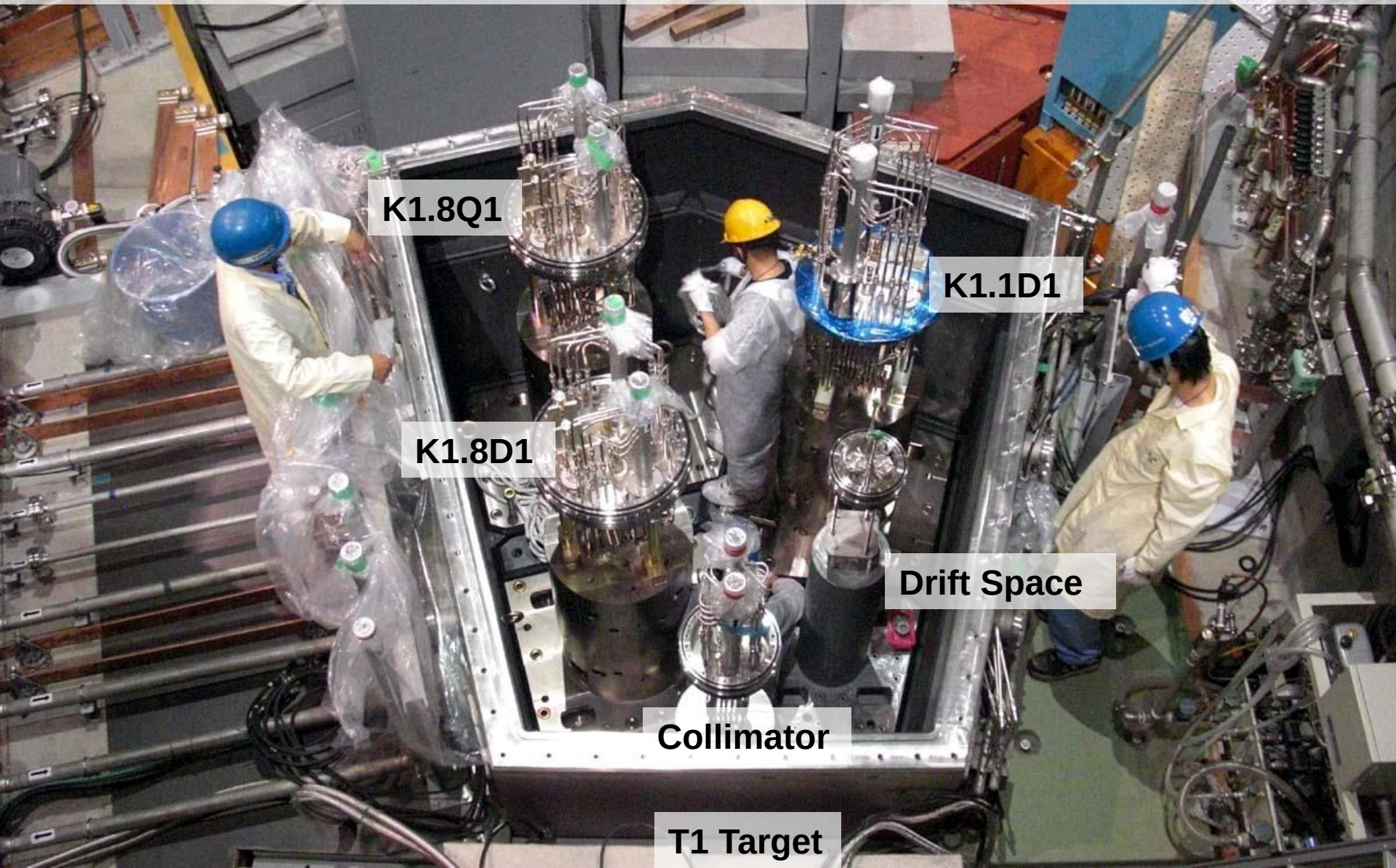
Radiation resistant magnet for J-PARC (Q440MIC)
2500A-200V、～30t



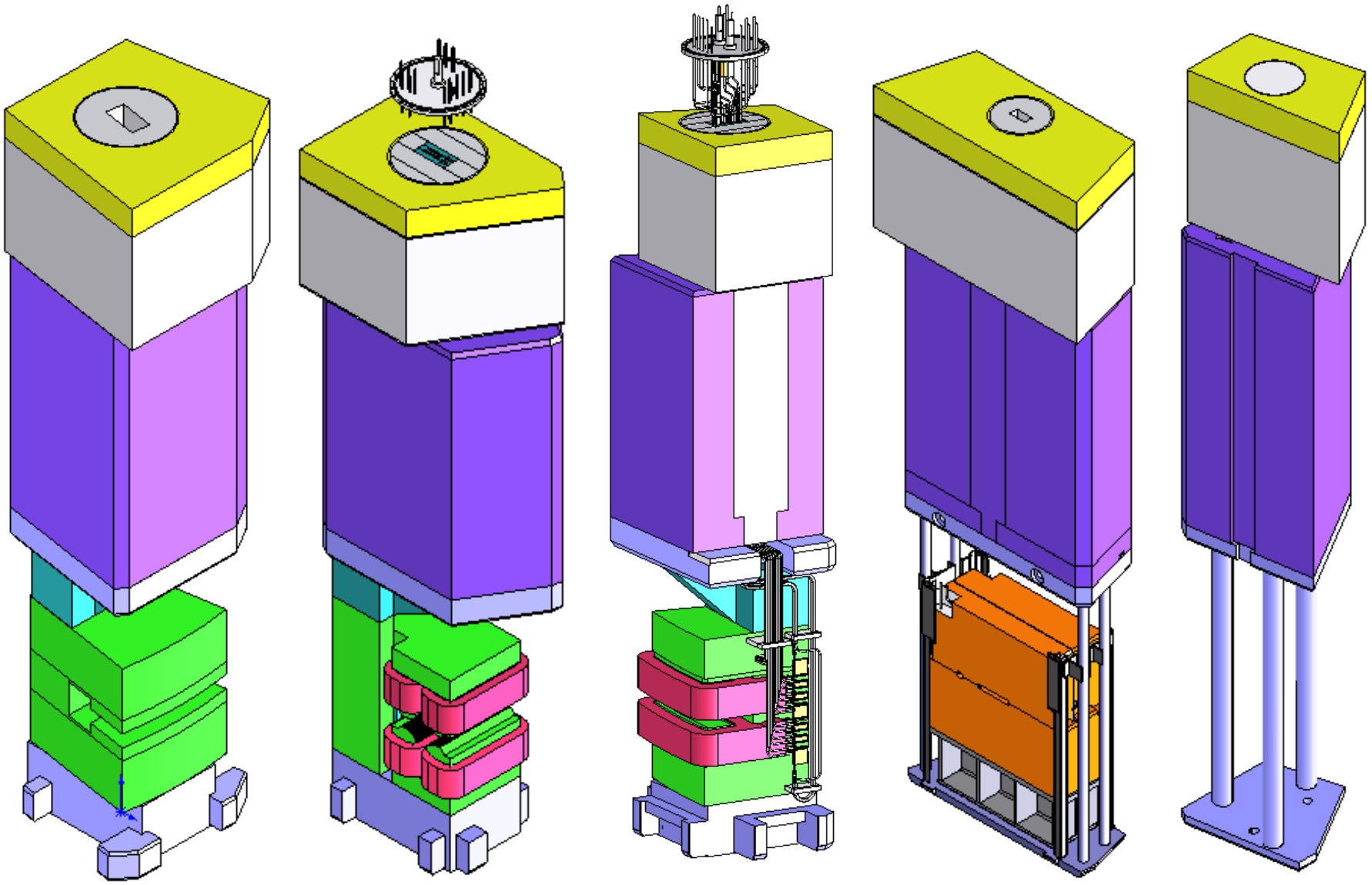


Radiation resistant magnet for J-PARC (Q440MIC)

Special Chimney Magnets near T1

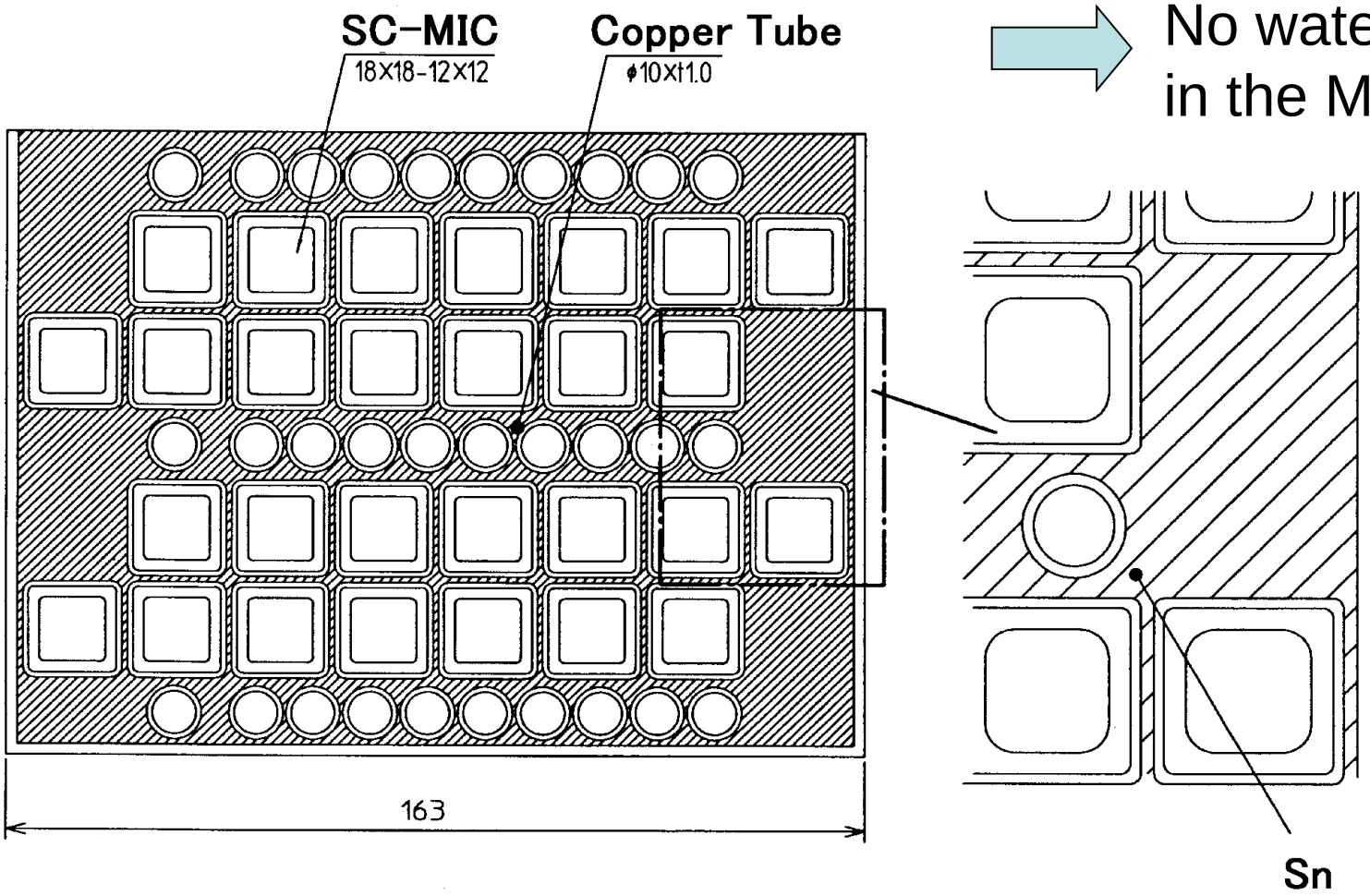


Modules



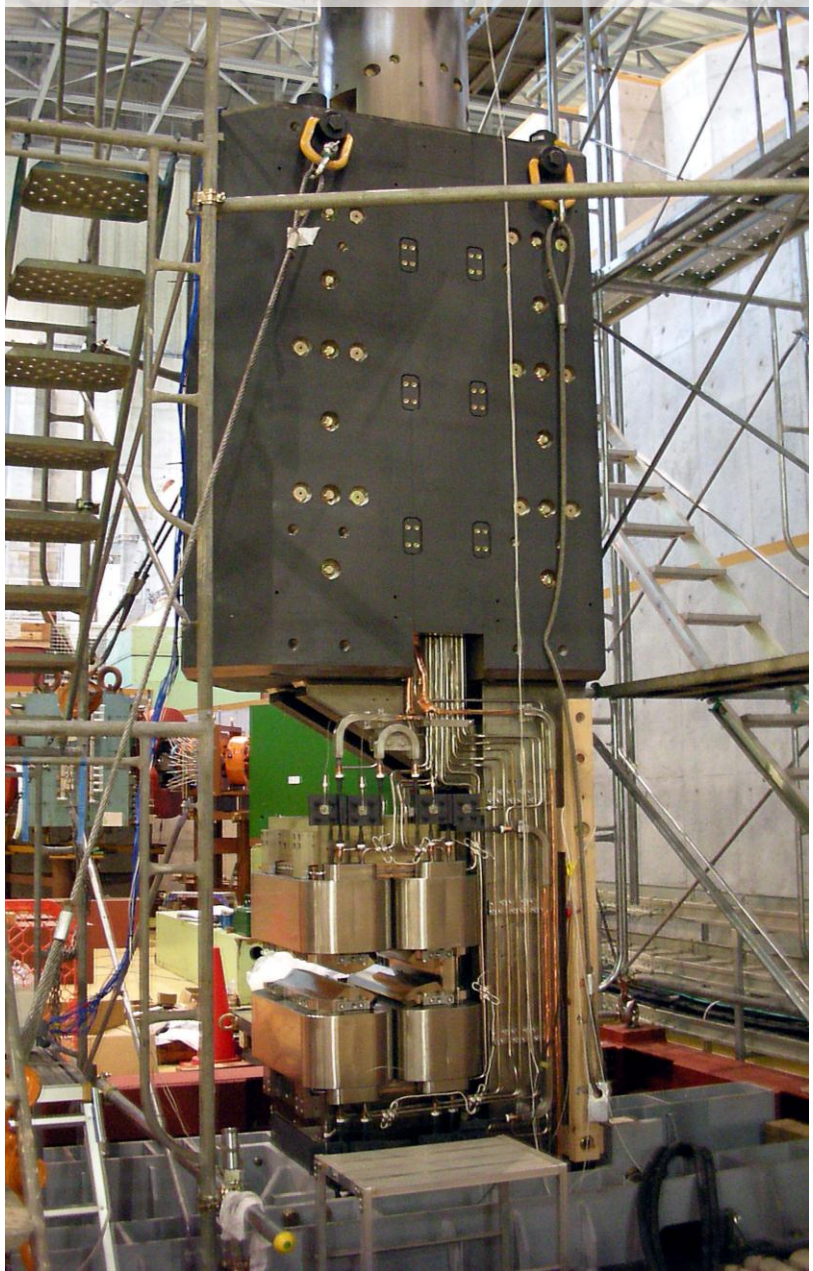
K1.1D1 K1.8Q1 K1.8D1 Collimator Drift Space

Solid MIC with Indirect Water Cooling



- SC-MIC is sandwiched by cooling tubes.
- Whole coil is impregnated by tin.

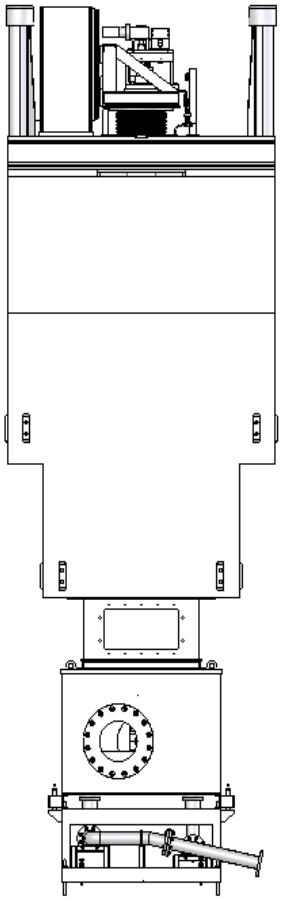
Super Radiation Hard Magnet: K1.8Q1

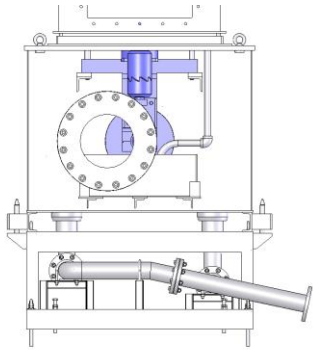


Central Vacuum Chamber

주식회사 지 엠
GOOD MORNING ENGINEERING CO. LTD

T1 Target Area

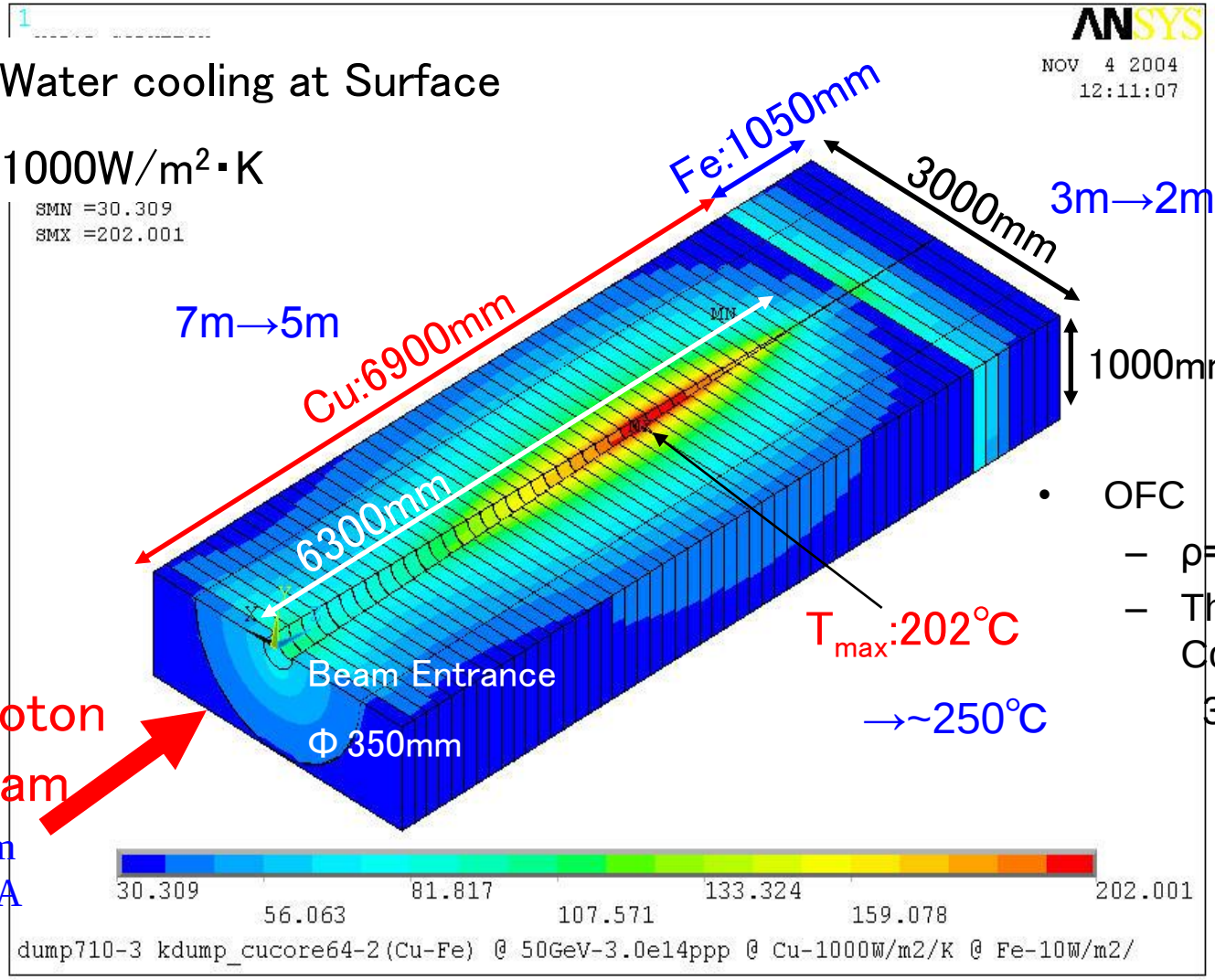




Beam Dump

Beam Dump - Heat analysis by MARS & ANSYS

K. Agari (calculated by A. TOYODA & M. MINAKAWA)

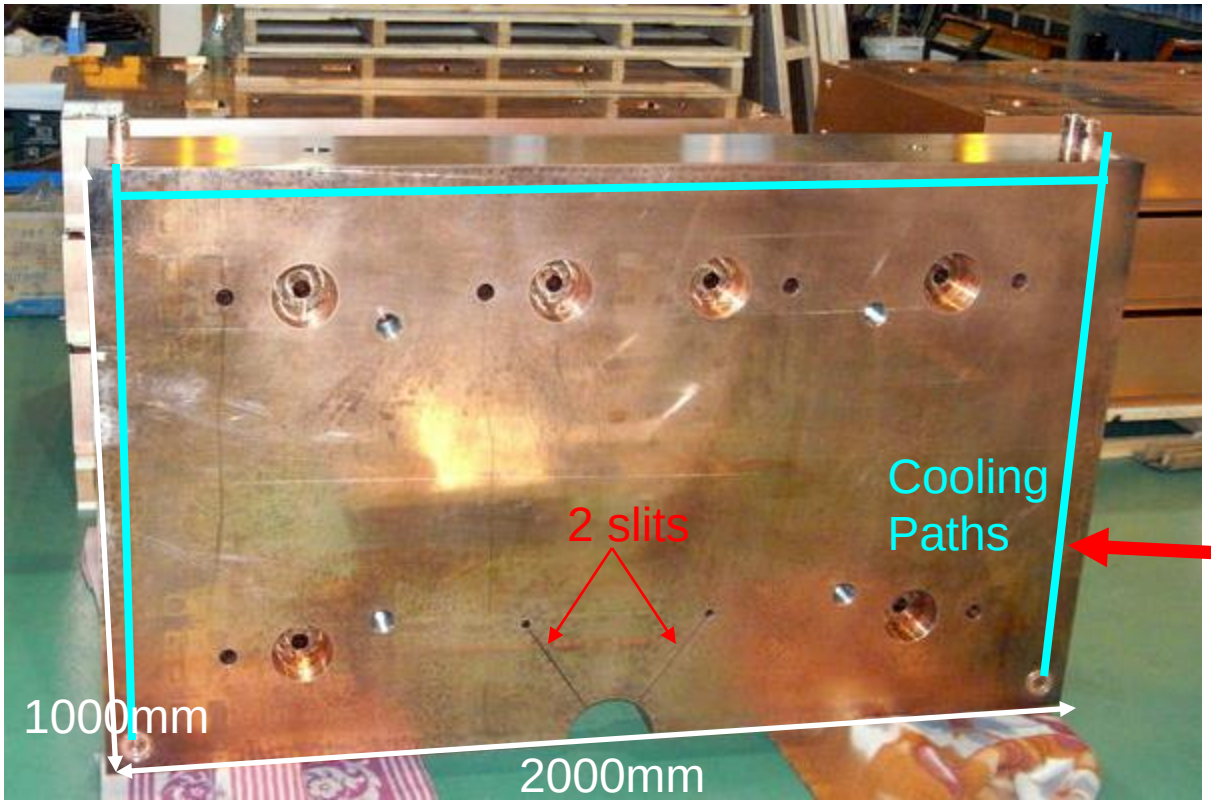


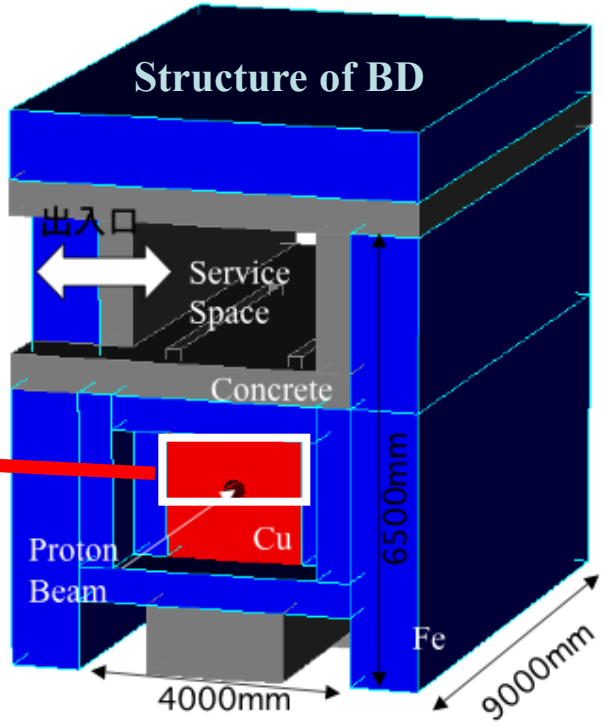
Proton beam
50GeV-15μA
(750kW)

- OFC
  - ρ=8.9[g/cm³]
  - Thermal Conductivity
    390 [W/m/K]

We have to reduce the volume of Cu…

750kW Full Beam Dump

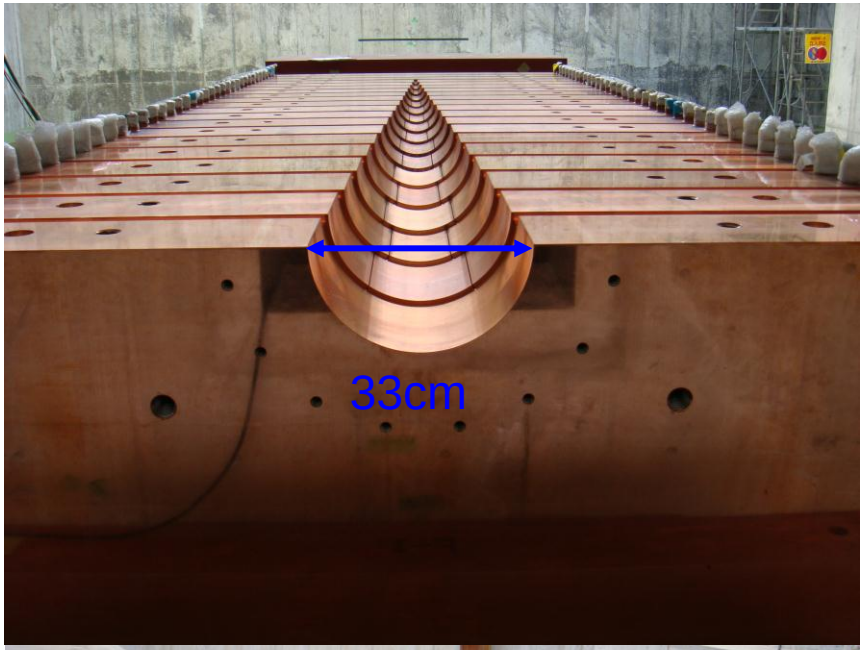


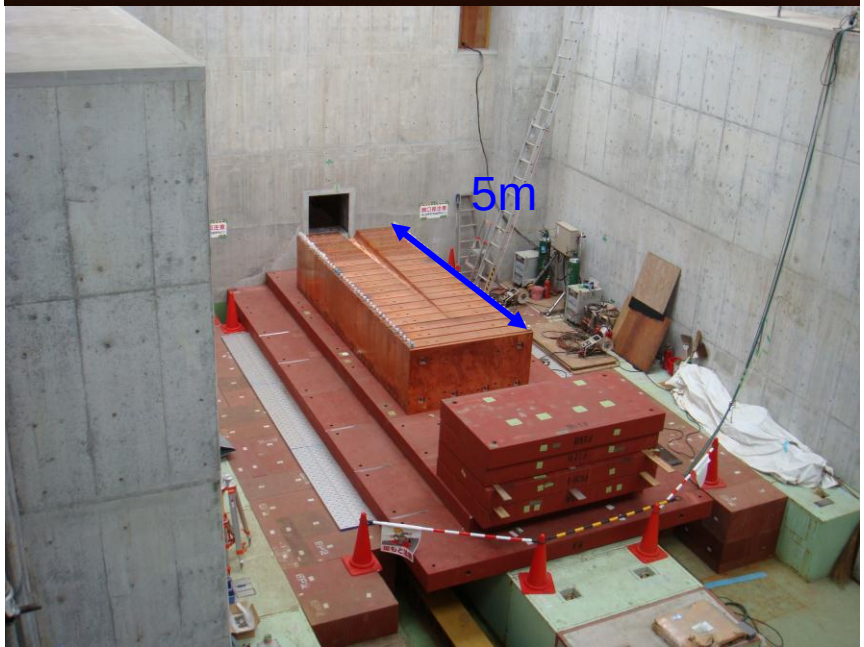


- Manufacture of Copper core (2m x 2m x 5m)
- 250 mm thick Copper plates
- 1/3 in FY 2006, 2/3 in FY 2007, set in FY2008
- 100% of Iron Blocks were purchased in 2006
- Concrete blocks will be transferred from Tsukuba in 2008.

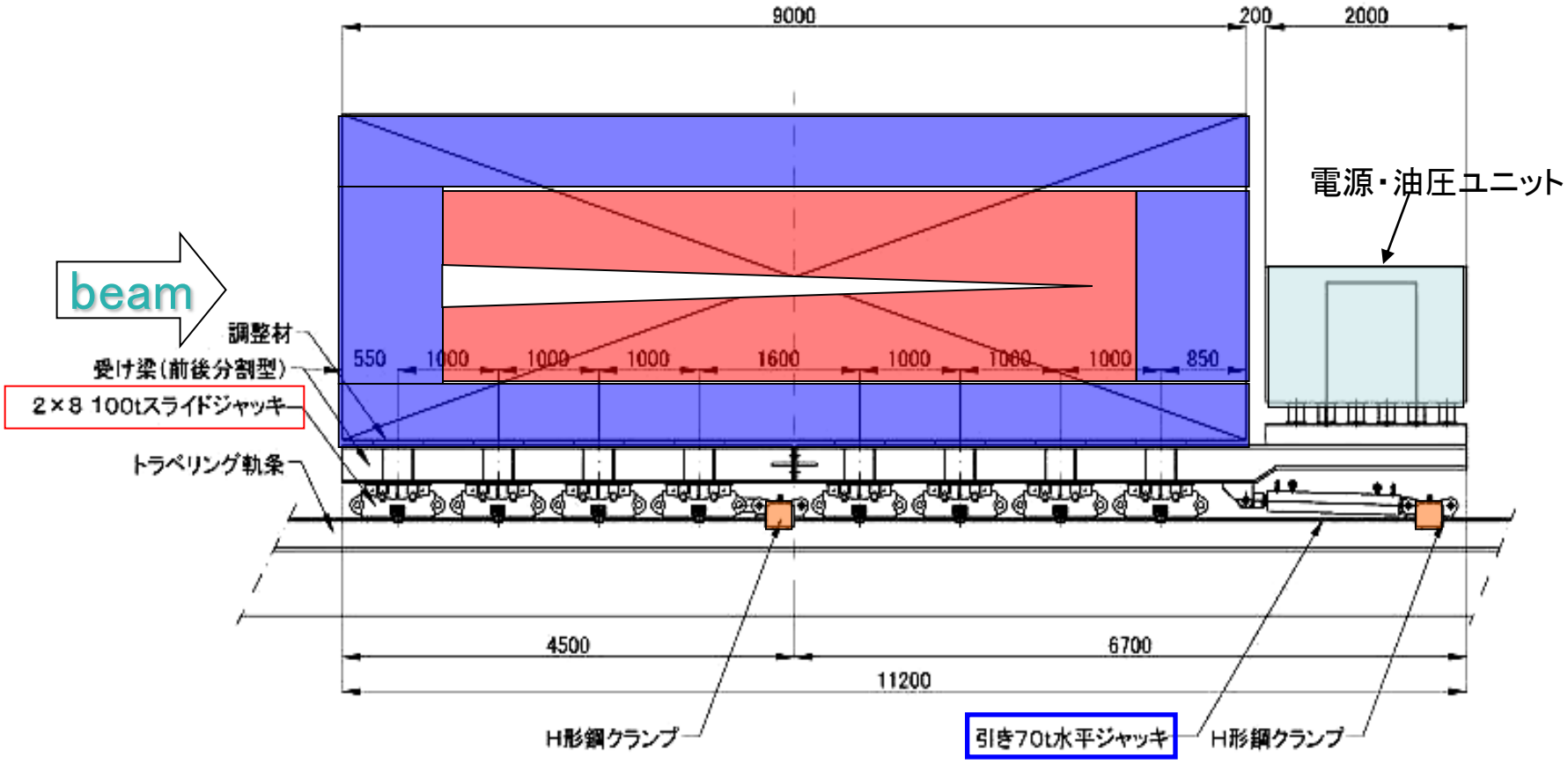
Conical hole and Temp. analysis with ¼ model

ビームダンプ設置工事





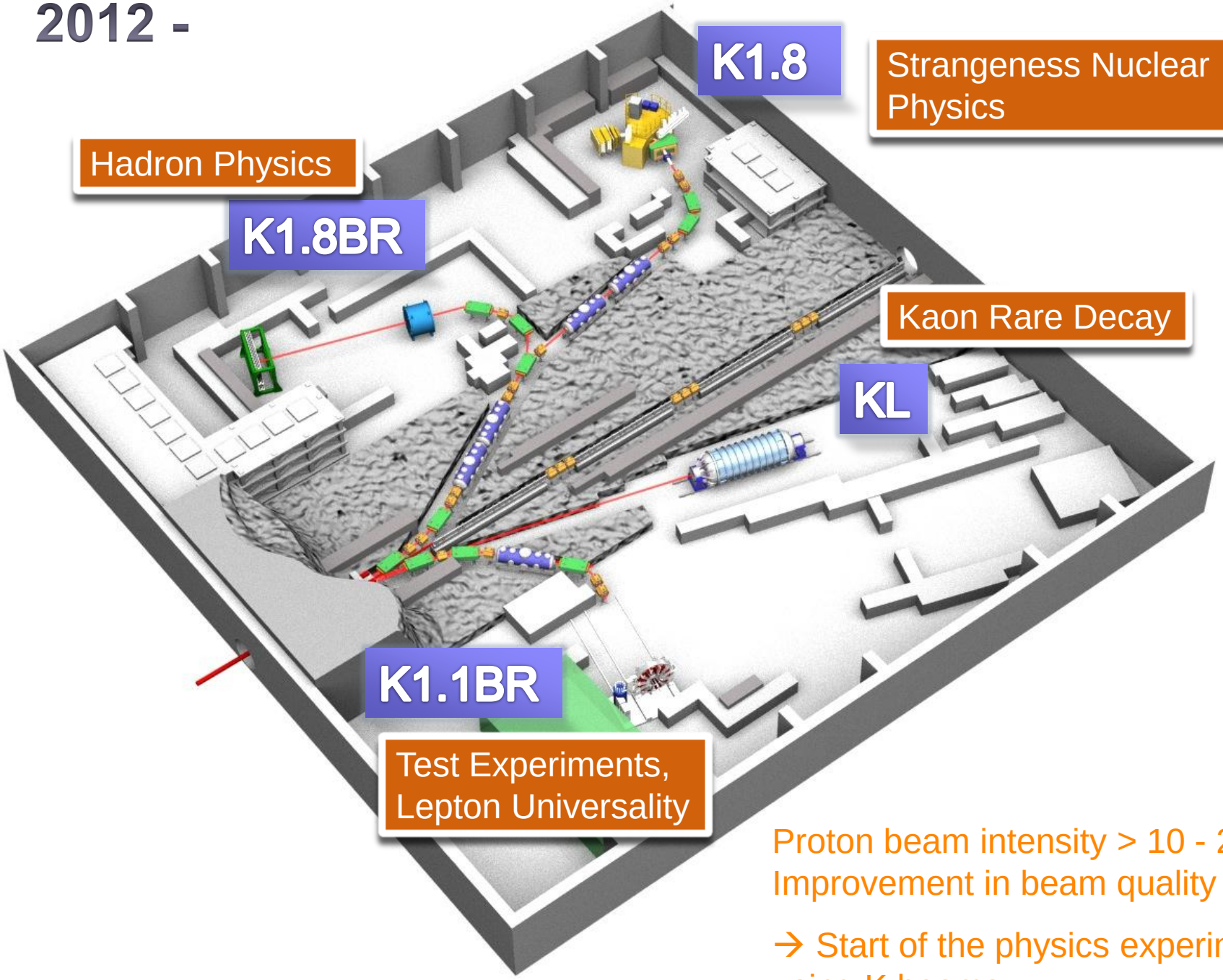
Structure of traveling devices



An “Inchworm” Method.

Complete remote operation with just LAN Cable!

2012 -



Proton beam intensity > 10 - 20kW
Improvement in beam quality

→ Start of the physics experiments using K beams

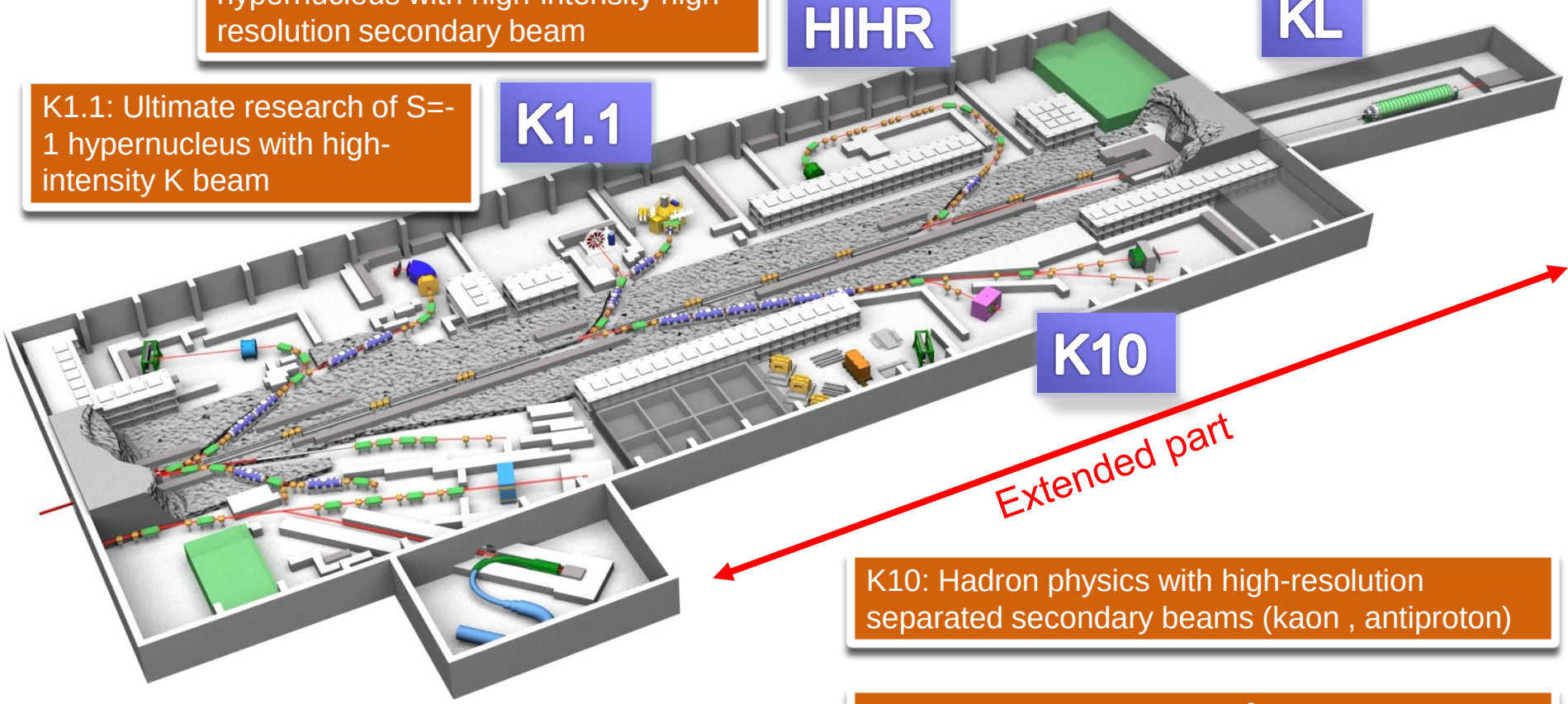
201X -

Extension of the Hadron Hall

Extend the small Phase-1 Hadron Hall to fulfill the demand from the users.
Contents are being discussed based on the voice from the community. A working group has been formed under an endorsement by the HUA. The Nuclear Physics Committee of Japan defined the extension as the highest priority large-scale project after the new primary beam line.

HIHR: Precise measurement of hypernucleus with high-intensity high-resolution secondary beam

K1.1: Ultimate research of S=-1 hypernucleus with high-intensity K beam



K10: Hadron physics with high-resolution separated secondary beams (kaon , antiproton)

KL: From the discovery of K^0 rare decay to a search for physics beyond the Standard Model

Conclusions 1

- Primary proton beam line of J-PARC Hadron Experimental Hall was constructed as Radiation Resistant Magnet System.
- R.-R. Magnet with Chimney was a key technology of the R.-R. Magnet System.

  (This is important, however, insufficient!)
- All the peripherals were re-designed and constructed as a part of true R.-R. Magnet System.
- For this purpose, Service Space was prepared within the radiation shield.

Conclusions 2

- Electric Power Distribution Circuits in S.S. were assembled by Copper Bus Bars. No cables were inside.
- Water Distribution Circuits in S.S. were constructed as inorganic piping system by using steam piping technology.
- Shield Penetrating Water Cooled Bus Duct was initially installed as a part of radiation Shield. No labyrinth Structure was necessary.
- Bridges between Chimney and S. S. circuits were made with quick disconnect devices.

- Target Area and Beam Dump
  - Special care should be necessary.
  - However there are several solutions! Depending on the accelerator energy.
  - Our solution is Pentagon vacuum chamber and BEAMDUMP with Conical hole.