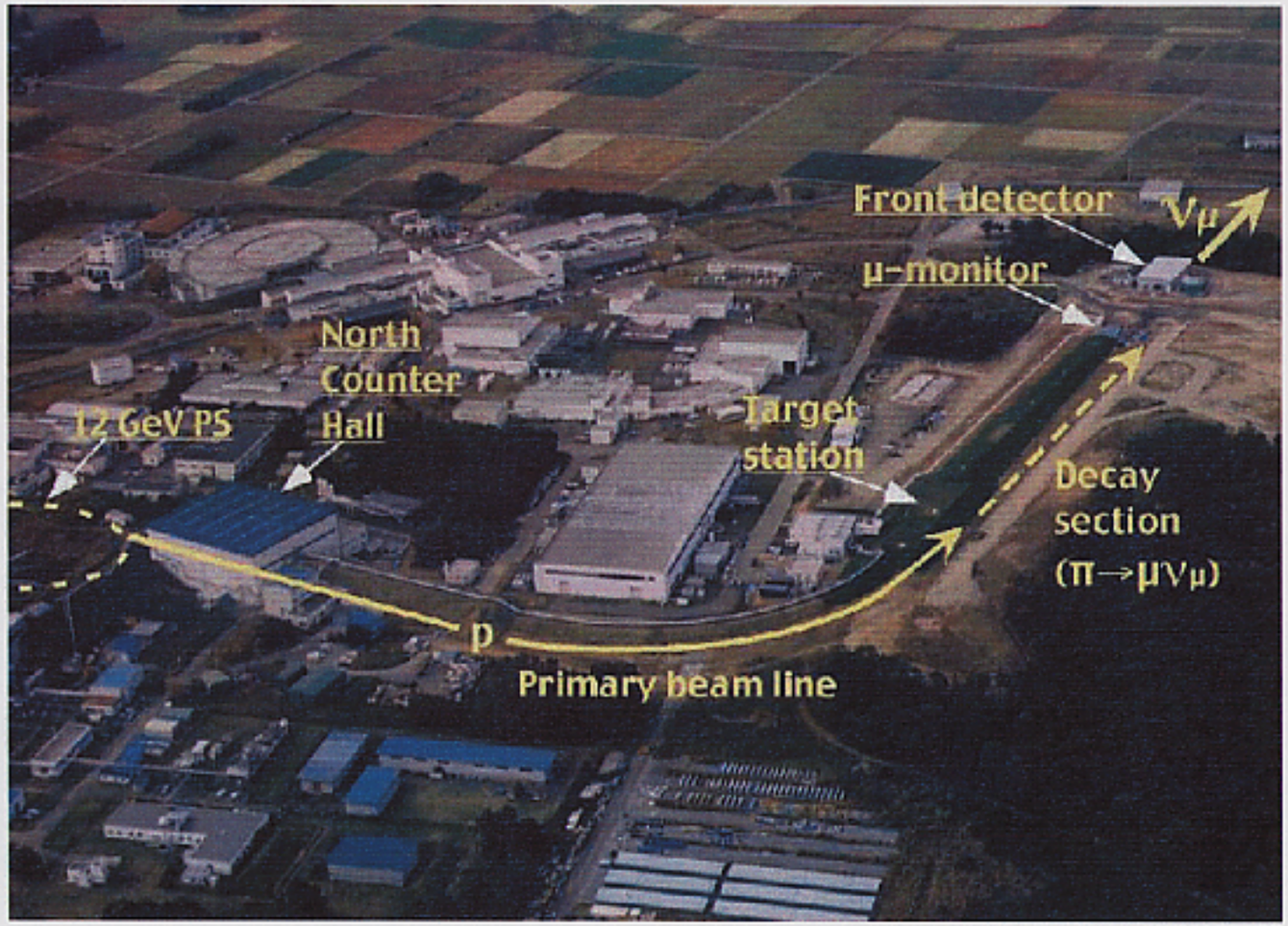
Design and Operation of K2K Decay Volume and Beam Dump

Yoshinori Sato
on behalf of
KEK-PS Beam Channel Group
KEK Radiation Science Center

Overview of K2K neutrino beamline

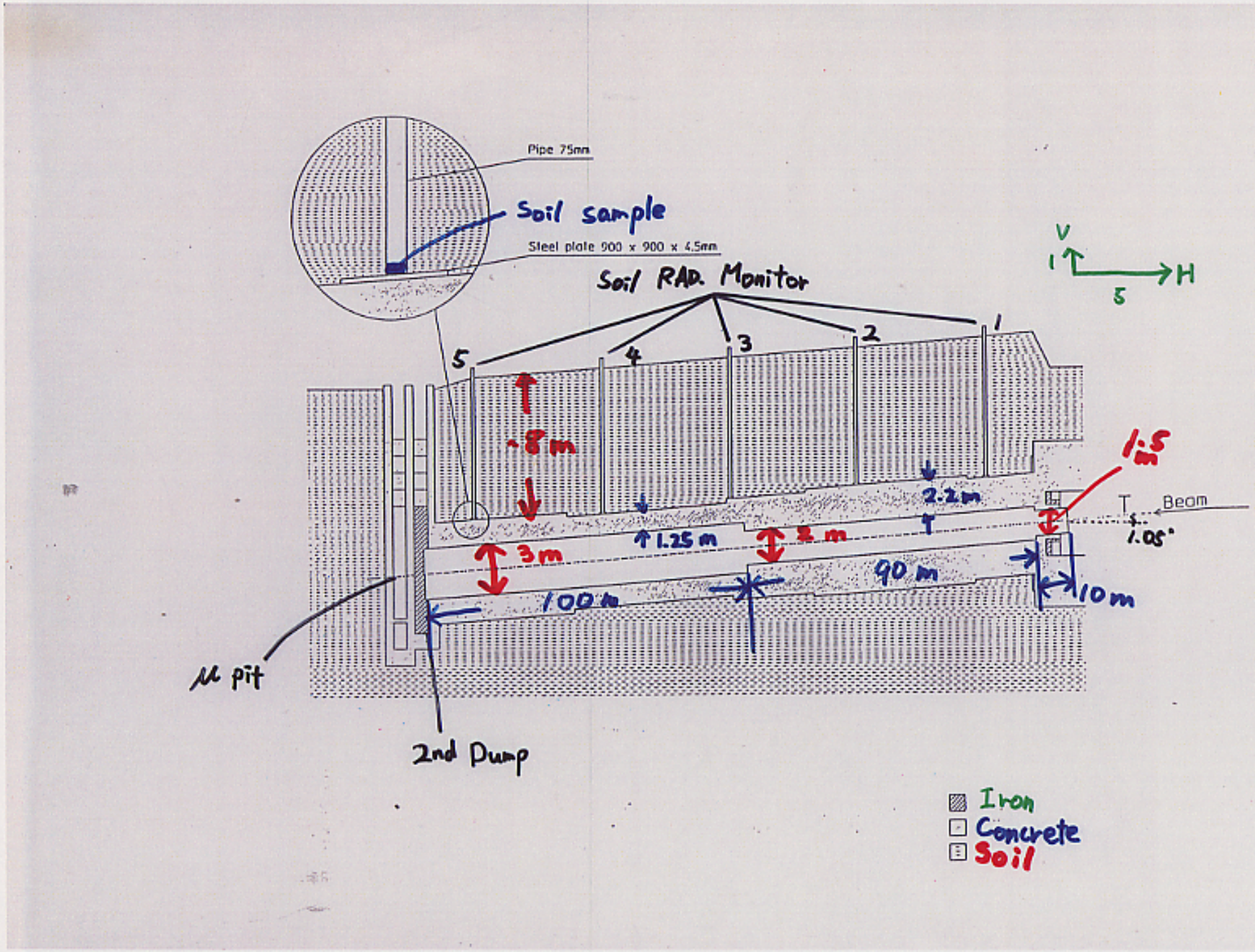


Boundary conditions for the design of decay volume (DV)

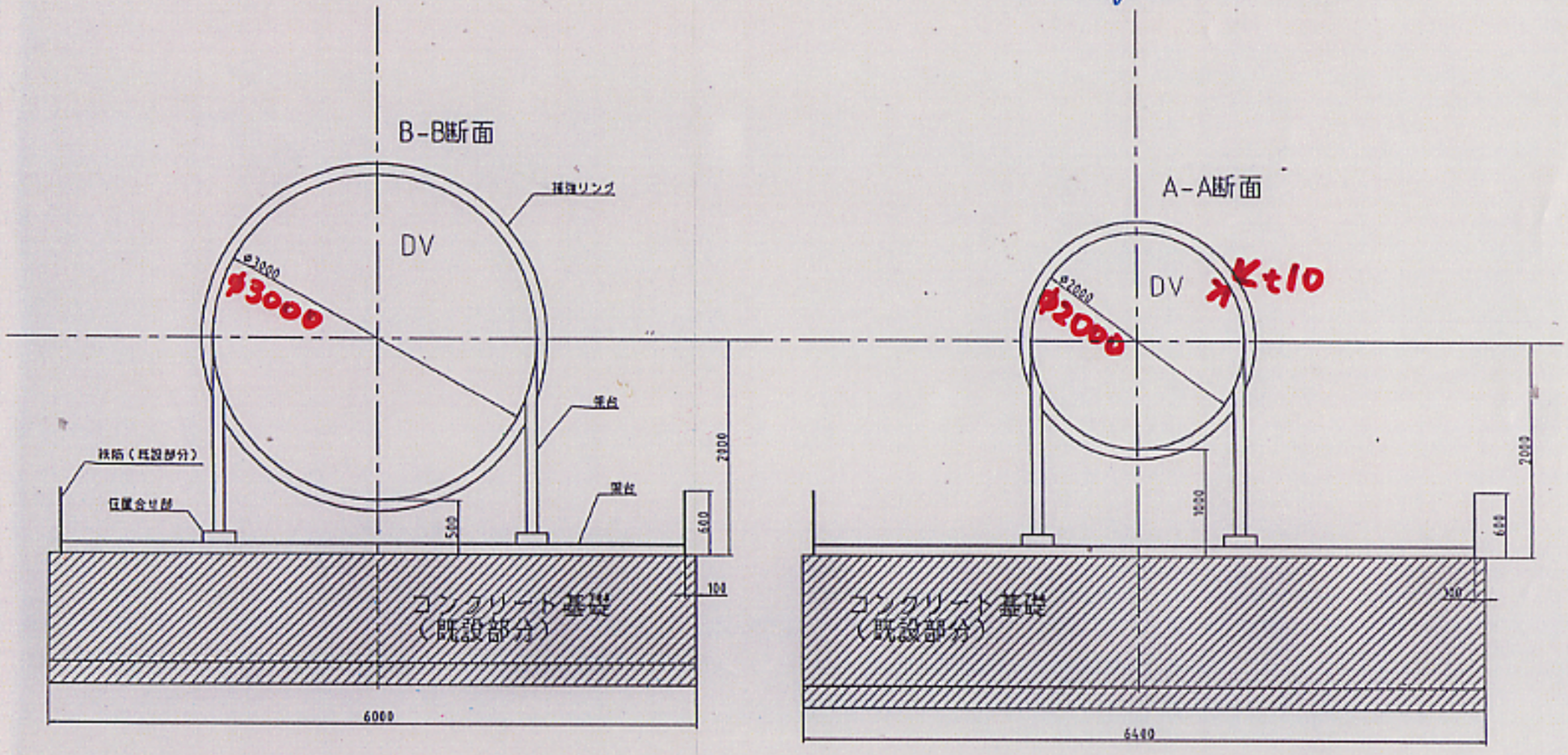
- Enough decay length for 1-3 GeV pion ($\beta\gamma c\tau$ = 55-167 m)
  - L=200 m is determined by the location of Front Detector, the site boundary, and COST.
- Minimize inner material
  - Filled with He gas (λ_I(He)=3.64 km at STP c.f. λ_I(Air)=0.73 km)
  - Sealing method
- Radiation protection
  - Dose rate at the surface of soil
  - Tritium production in He gas
  - Activation of soil and water in underground
- Mechanical strength
- Temperature rise
  - Negligible for 12 GeV-PS

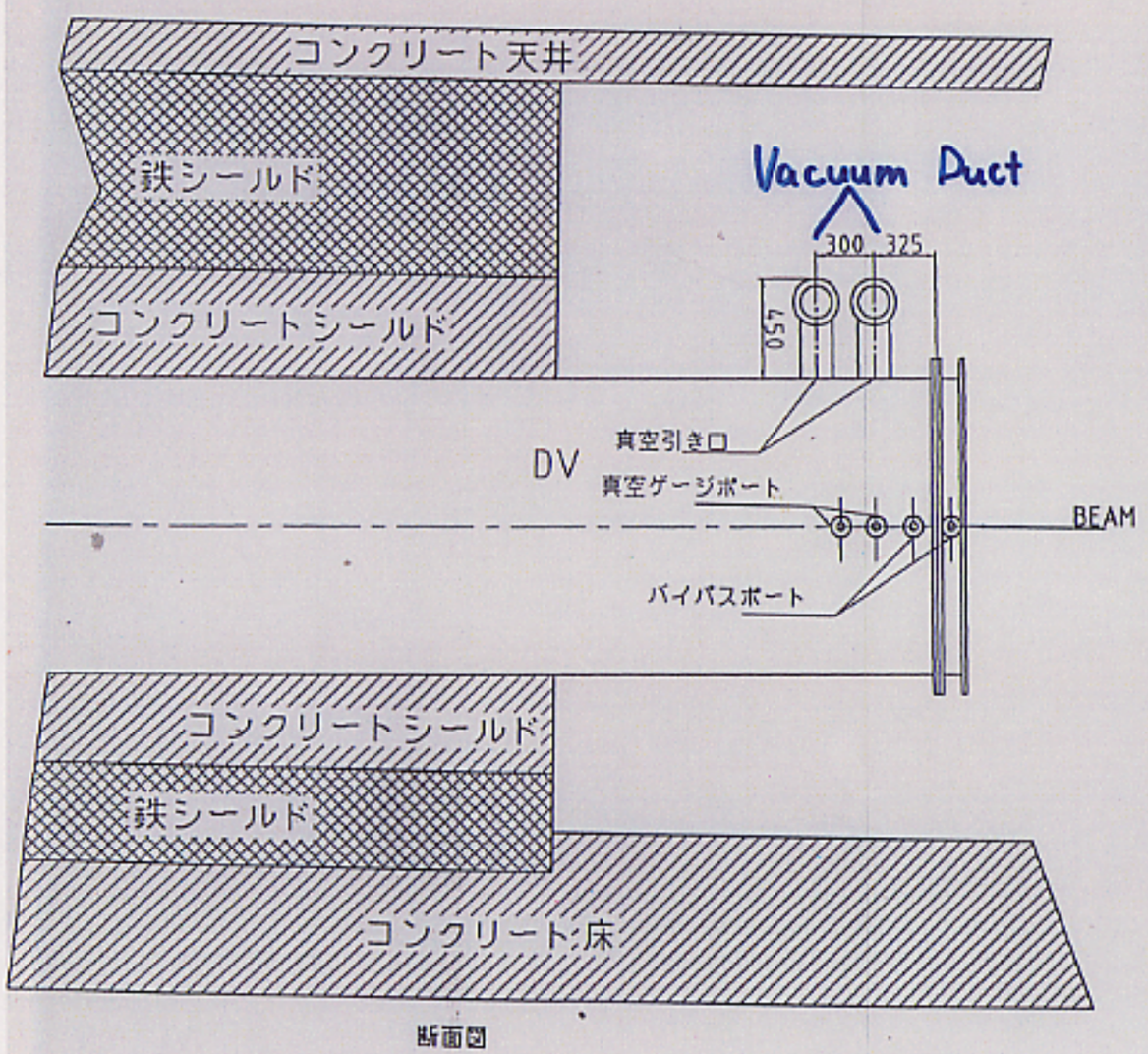
Boundary conditions for the design of beam dump (BD)

- Radiation protection
  - Dose rate at the surface of soil
  - 100% loss of 12 GeV, 6×10^{12} ppp
- Temperature rise
  - Negligible for 12 GeV-PS

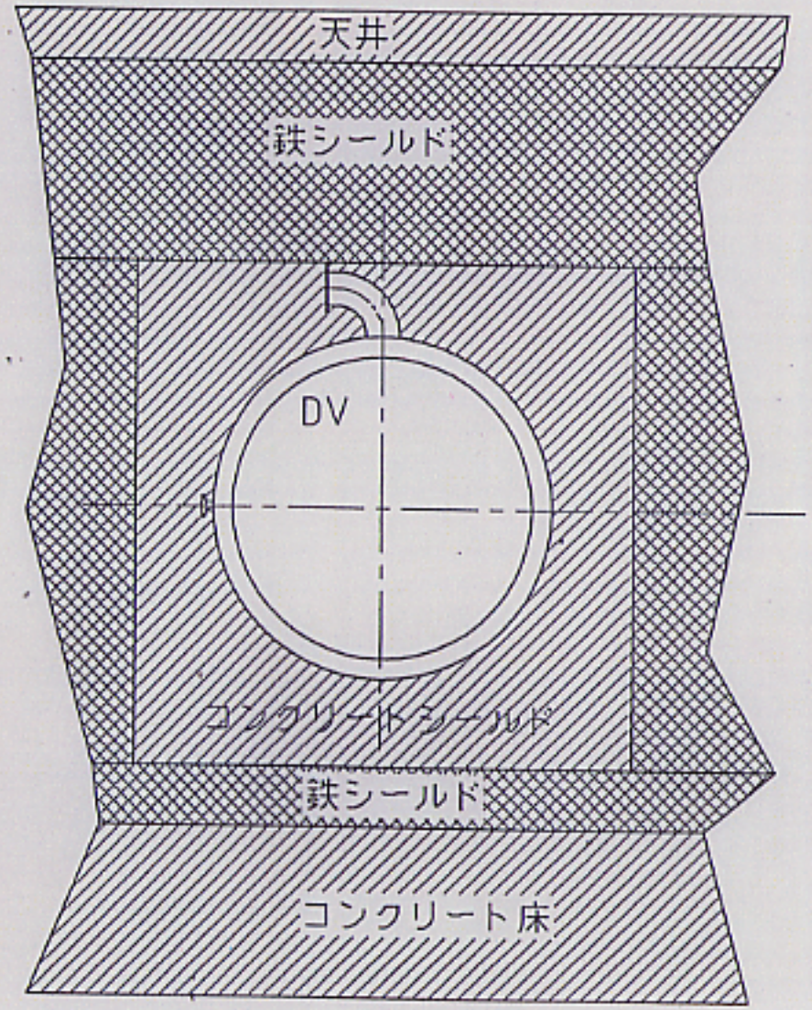

Pipe 75mm
Soil sample
Steel plate 900 x 900 x 4.5mm
Soil RAD. Monitor
V
1
5
H
5
4
3
2
1
.8m
2.2m
1.25m
2m
3m
1:5
Beam
1.05°
90m
100m
10m
M pit
2nd Pump
Iron
Concrete
Soil

Total weight = 1168 t

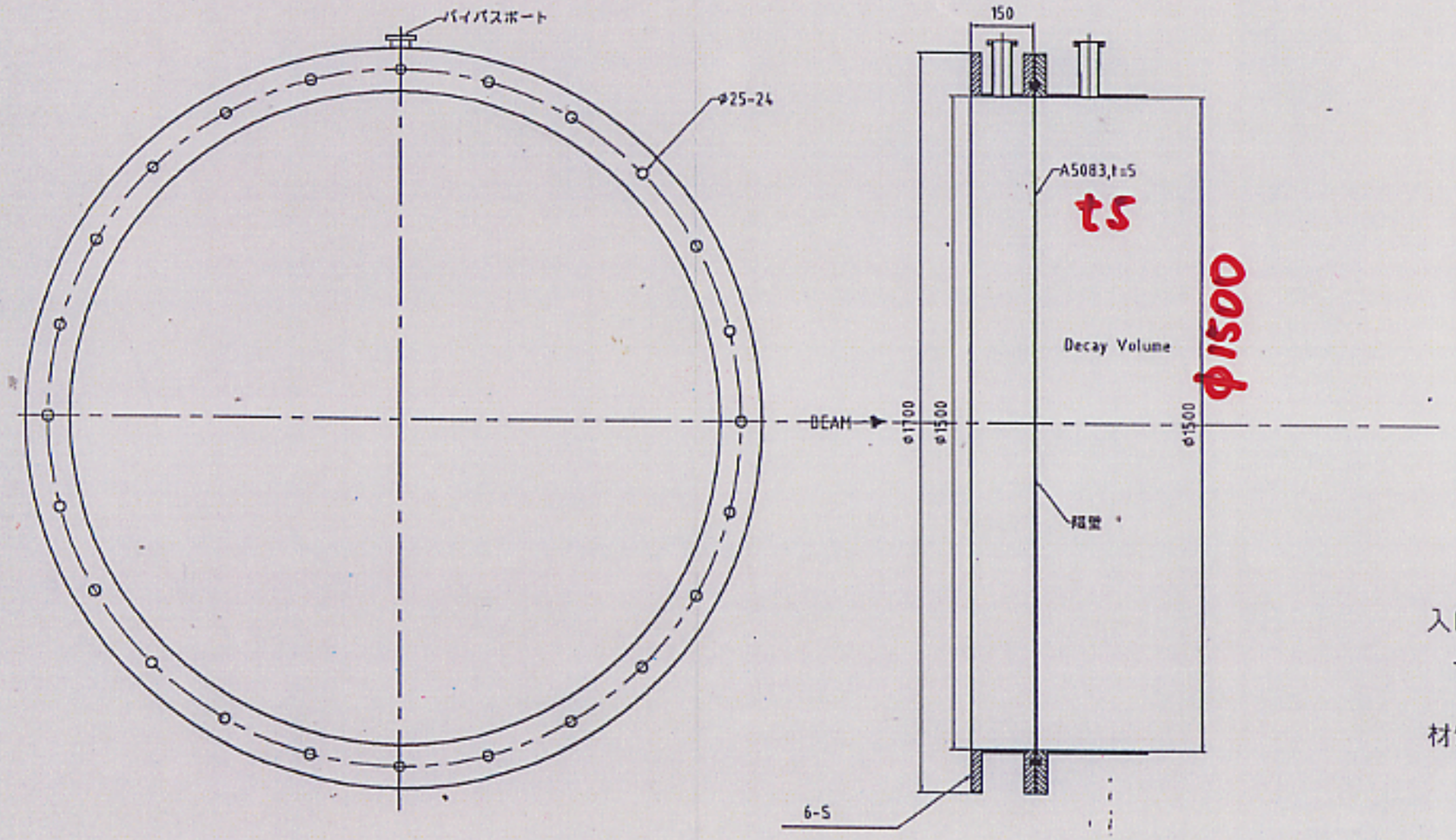




断面図

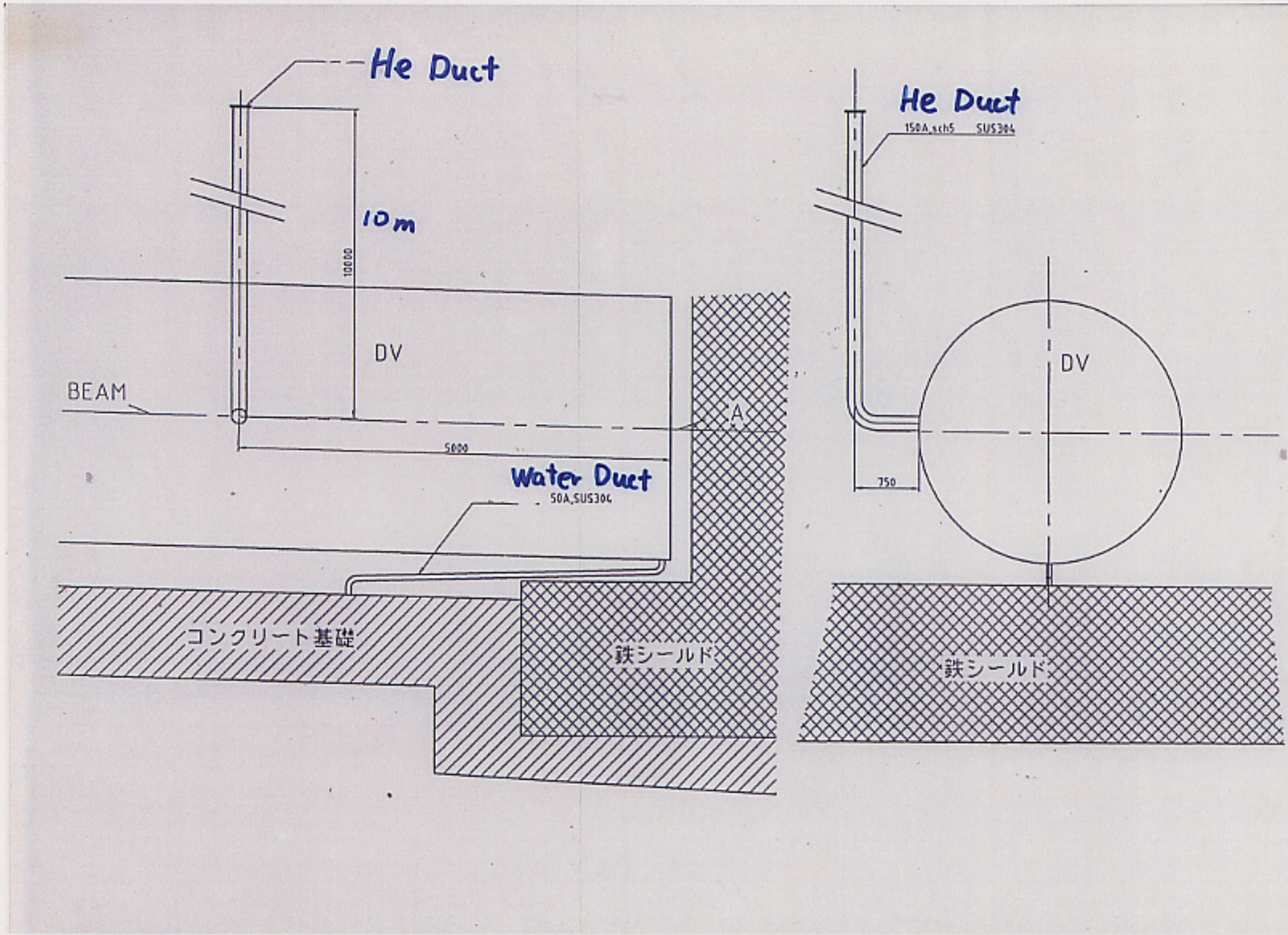


BEAM VIEW

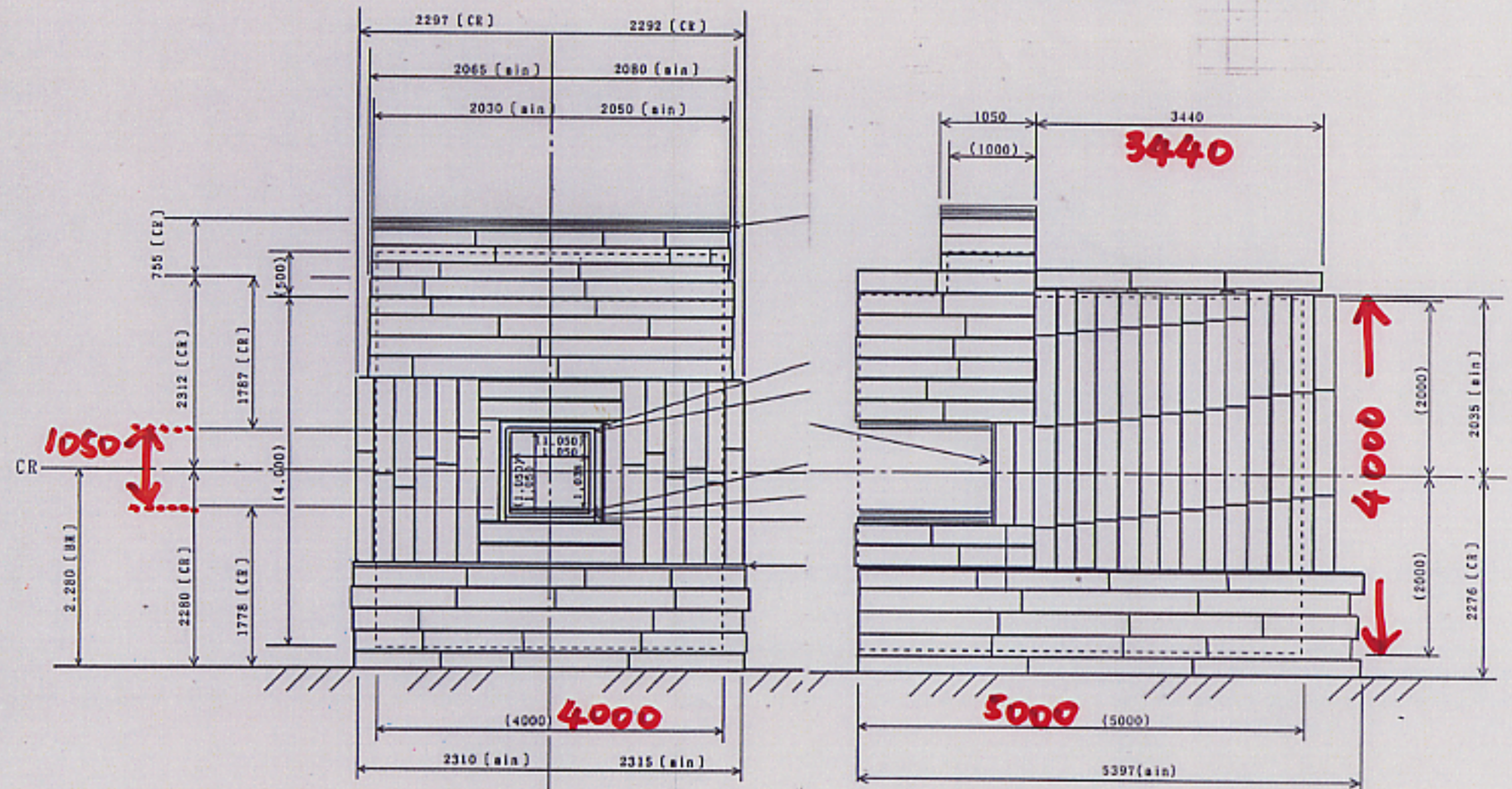


入口フランジ
及び
隔　壁

材質　　SUS304

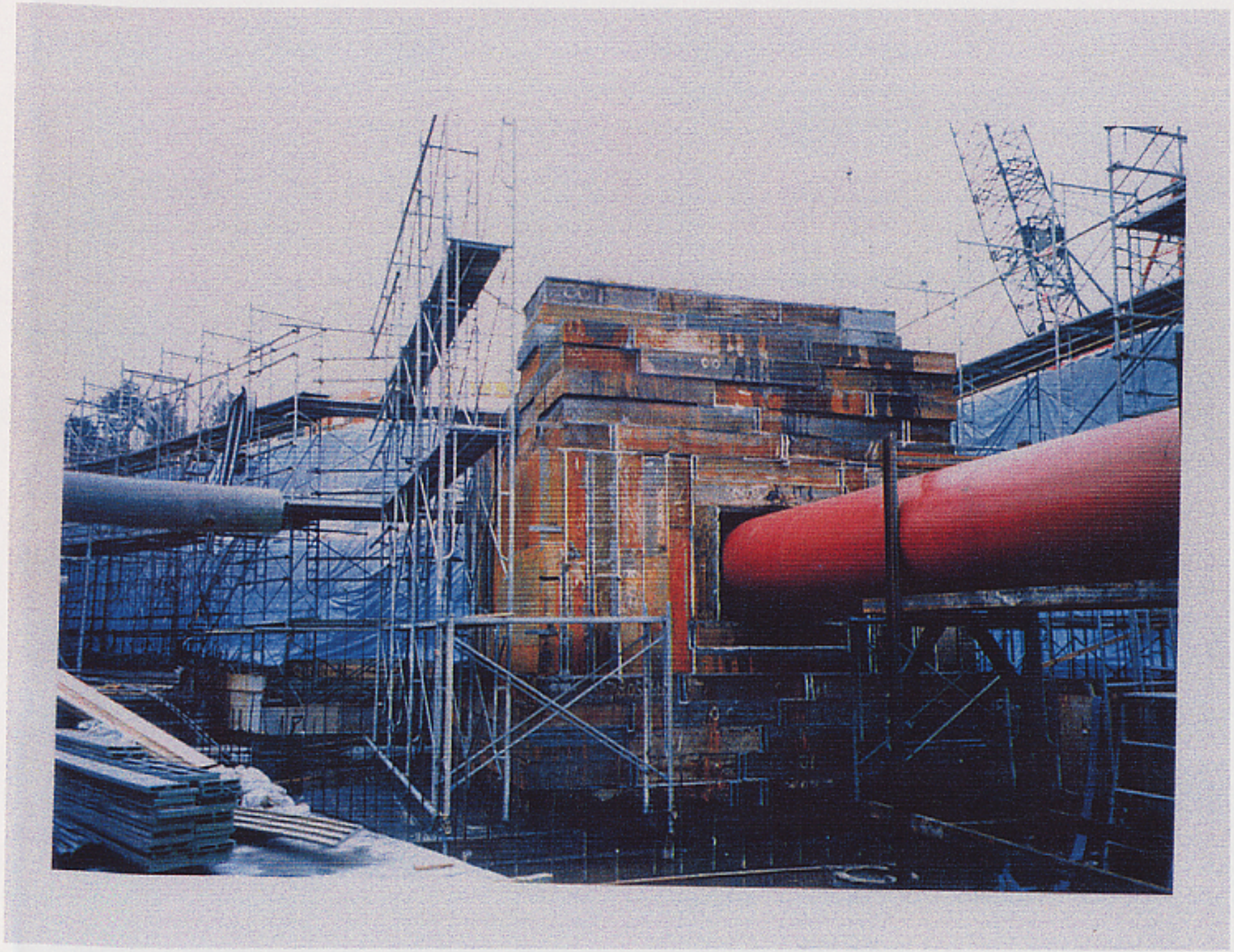

He Duct
10m
10000
DV
BEAM
5000
Water Duct
50A,SUS304
コンクリート基礎
鉄シールド
A
He Duct
150A,sch5 SUS304
DV
750
鉄シールド

Total weight ~ 840t



Front View

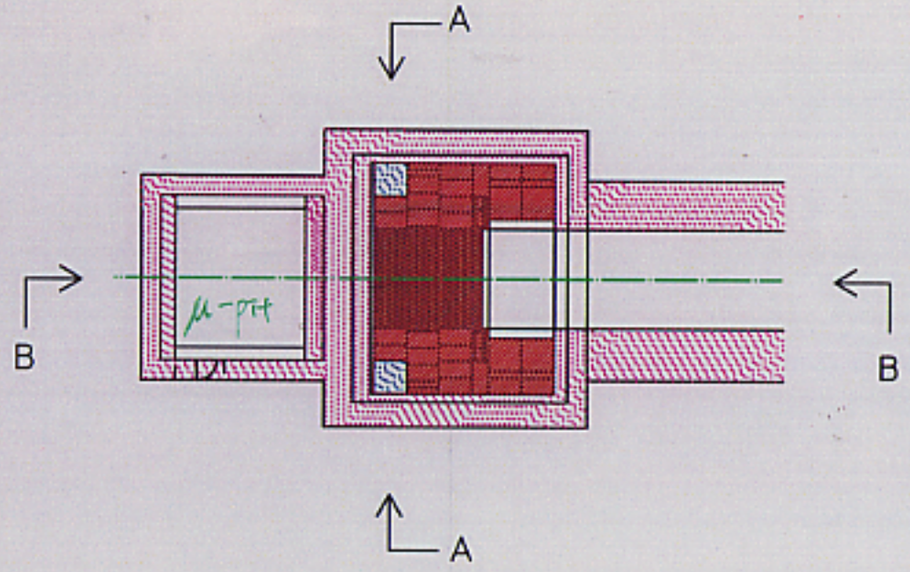
Side View



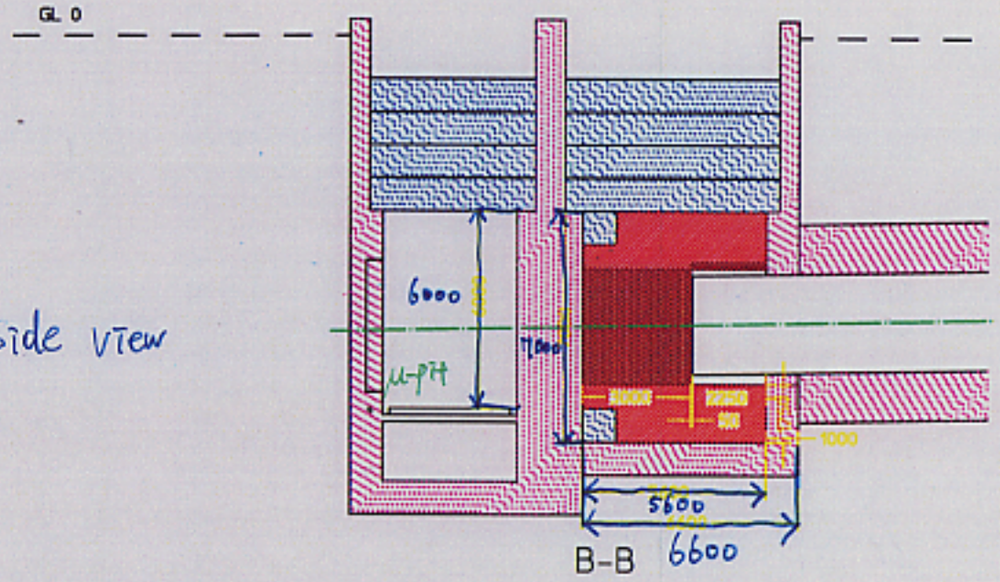
2nd Dump

Total weight ~ 1400t

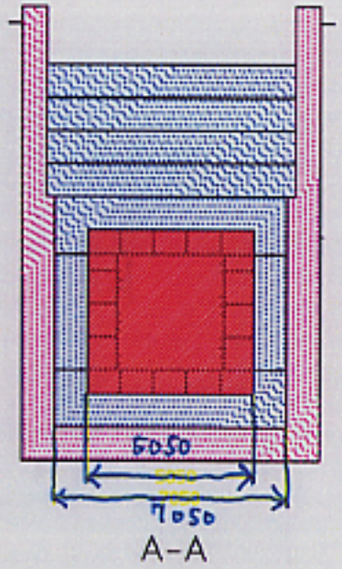
Top view



Side view



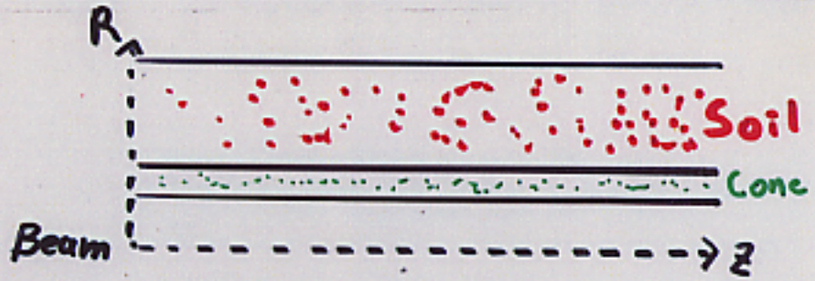
Back view

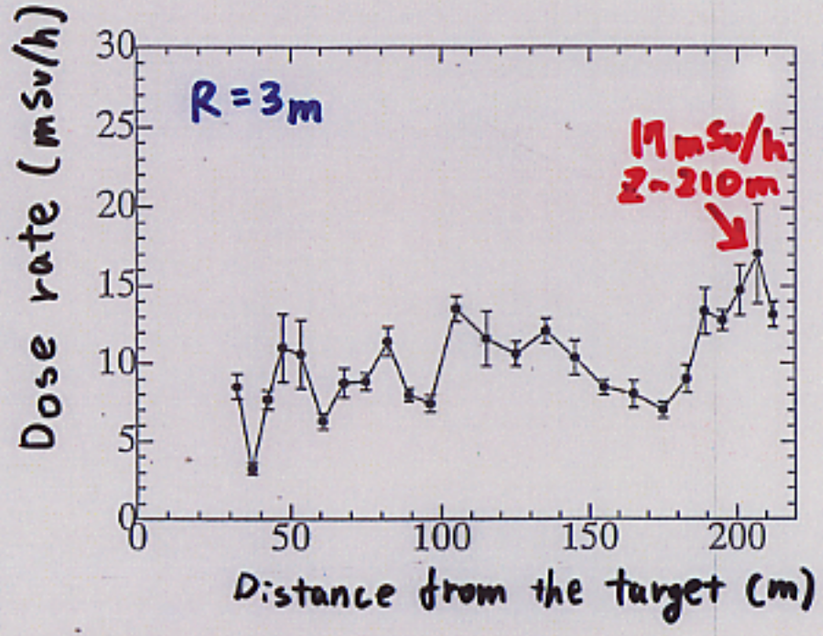


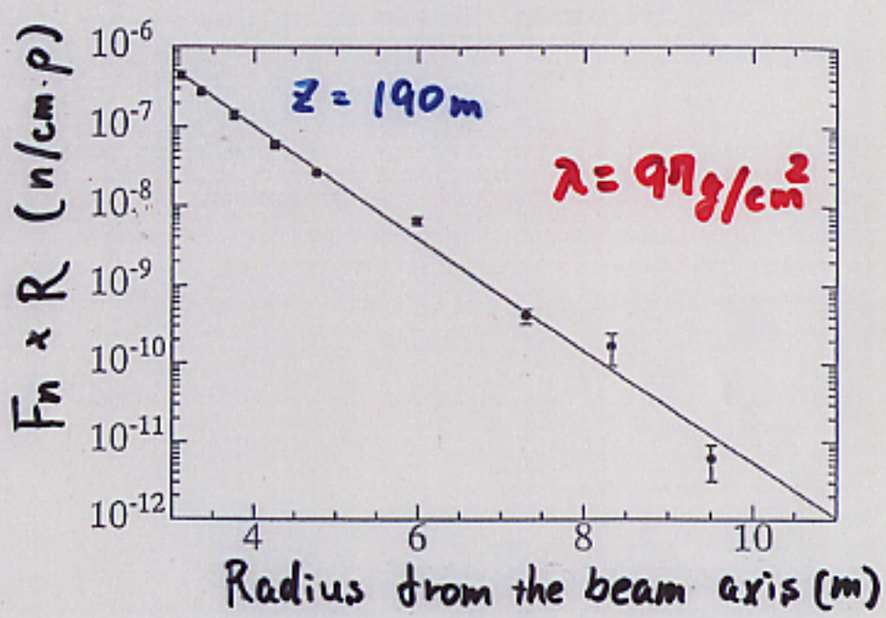
Radiation protection of Decay Volume and Beam Dump

- Dose rate at the surface of soil < 20μSv/hr
- Activation of soil and water
  - Limit for soil
    - < 3.7 Bq/g in whole soil
    - < 4 Bq/cm^2 at the surface of the DV concrete shield
  - Limit for water in the underground
    - < 10 μSv/yr

Evaluation of dose rate by MARS







Dose rate at the surface : 0.004 μSv/h ≪ 20 μSv/h

Measurment : < 0.1 μSv/h

Chemical & Radioactive analysys of sample soil

表３．１　乾燥した土壌の成分(化学分析と放射化分析によって求めた)

単位　重量%

元素	地層A	地層B	地層C	地層D	地層E	地層F	原子量	原子番号
O	58.5	61.4	56.1	54.7	55.7	57.4	16.00	8
Na	0.98	0.63	0.92	0.87	0.87	1.14	22.99	11
Mg	0.73	0.43	0.29	0.31	0.24	0.39	24.31	12
Al	8.33	10.9	8.94	5.98	7.77	7.60	26.98	13
Si	20.8	17.1	28.1	33.2	27.3	27.1	28.09	14
P	0.043	0.0607	0.0082	0.0027	0.0085	0.0108	30.97	15
K	0.76	0.59	1.49	1.86	0.90	1.43	39.10	19
Ca	0.78	0.27	0.24	0.24	0.45	0.37	40.08	20
Sc	0.0025	0.0029	0.0020	0.0015	0.0021	0.0018	44.96	21
Ti	0.72	0.80	0.44	0.24	0.43	0.41	47.88	22
V	0.0041	0.0032	0.0015	0.001	0.001	0.0008	50.94	23
Cr	0.0175	0.018	0.0078	0.0047	0.0101	0.0063	52.00	24
Mn	0.12	0.084	0.051	0.052	0.098	0.070	54.94	25
Fe	8.15	7.74	3.37	2.56	6.18	4.02	55.85	26
Co	0.0029	0.0023	0.0015	0.0012	0.0023	0.0021	58.93	27
Cu	0.0060	0.0055	0.0018	0.0010	0.0020	0.0012	63.55	28
Zn	0.0076	0.0081	0.0071	0.0046	0.0056	0.0060	65.39	30
Eu	0.00011	0.00016	0.00012	0.00008	0.00011	0.00011	151.96	63

Production rate of radionuclei in Soil

表３．２　各地層の土壌に核破砕反応によって生成する放射性核種（半減期＞１日）とフラックス当たりの生成量（飽和放射能、単位：$\mu Bq \cdot g^{-1} \cdot n^{-1} \cdot cm^2 \cdot s$）

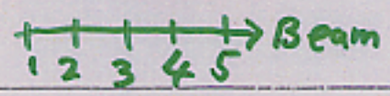
核　種	半減期		地層A	地層B	地層C	地層D	地層E	地層F
H－3	12.3	Y	935.	966.	933.	919.	932.	940.
Be－7 *	53.3	D	125.	68.3	83.2	90.8	91.4	84.5
Na－22 *	2.602	Y	44.5	20.5	52.7	65.0	38.9	54.1
Si－32	650	Y	115.	62.9	143.	189.	135.	132.
P－32	14.28	D	24.7	14.5	14.8	15.5	18.6	15.5
P－33	25.30	D	24.7	14.5	14.8	15.5	18.6	15.5
S－35	87.4	D	24.6	14.5	14.8	15.5	18.6	15.5
Ar－37	35.0	D	24.6	14.3	14.8	15.5	18.6	15.5
Ar－39	269	Y	24.6	14.3	14.8	15.5	18.6	15.5
Ar－42	33.0	Y	24.6	14.3	14.8	15.5	18.6	15.5
Ca－45	165	D	22.2	13.1	9.87	8.51	15.8	11.1
Ca－47	4.536	D	22.2	13.1	9.87	8.51	15.8	11.1
Sc－44m	2.44	D	19.8	12.6	9.09	7.61	14.5	9.92
Sc－46 *	83.8	D	22.3	16.4	15.1	6.71	10.8	17.6
Sc－47	3.42	D	19.8	12.6	9.09	7.61	14.5	9.92
Sc－48	43.7	H	19.8	12.6	9.09	7.61	14.5	9.92
Ti－44	48.2	Y	19.8	12.6	9.09	7.61	14.5	9.92
V－48 *	15.97	D	4.32	2.14	1.95	1.56	3.14	2.72
V－49	330	D	18.0	11.2	7.88	6.88	13.5	8.91
Cr－51 *	27.7	D	16.4	7.70	5.91	4.63	11.2	9.31
Mn－52 *	5.59	D	4.65	1.51	11.7	14.3	2.69	2.25
Mn－54 *	312.5	D	32.2	15.8	12.3	9.56	23.1	18.6
Fe－55	2.7	Y	17.7	11.0	7.74	6.72	13.2	8.71
Fe－59 *	44.6	D	6.18	4.49	2.58	1.15	4.01	4.30
Co－56 *	78.8	D	0.56	0.30	0.26	0.18	0.38	0.34
Co－57 *	271	D	0.89	0.66	0.67	0.34	0.57	0.69
Co－58 *	70.8	D	0.18	0.07	0.08	0.06	0.11	0.14
Co－60 *	5.271	Y	25.1	13.7	8.52	5.61	11.4	19.4
Ni－63	100.1	Y	0.03	0.02	0.02	0.01	0.01	0.01
Zn－65	244.1	D	0.01	0.01	0.01	0.01	0.01	0.01
全放射能			640.	1366.	1432.	1463.	1492.	1458.

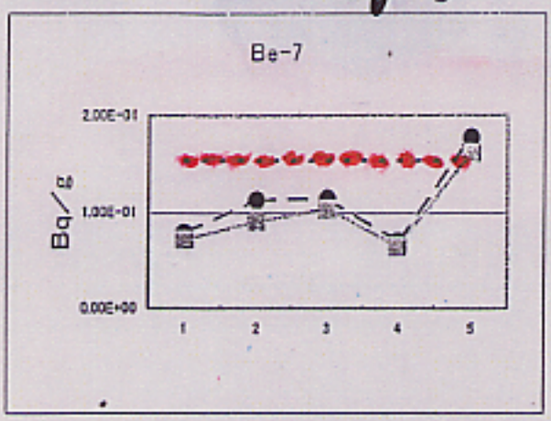
注）
（１）１０ｍまでの地層の厚さを考慮した全放射能の平均値　１４６０ $\mu Bq \cdot g^{-1} \cdot n^{-1} \cdot cm^2 \cdot s$
（２）*で示す核種には実験値を用いており、他の核種は核破砕反応の断面積を３０ｍｂと仮定した

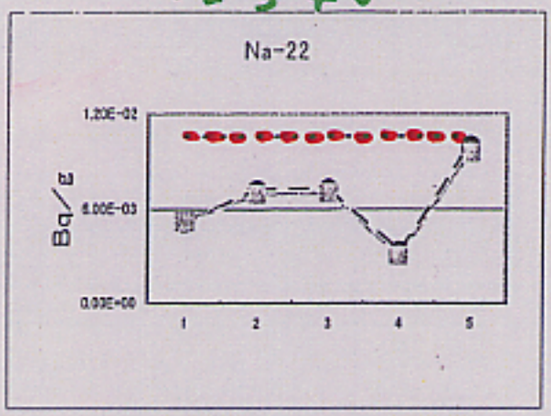
Radioisotopes in soil

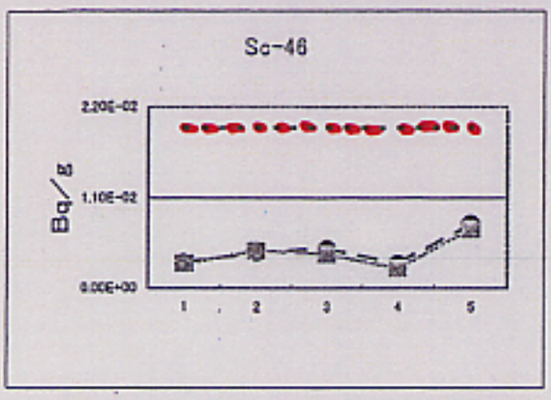
--- MARS

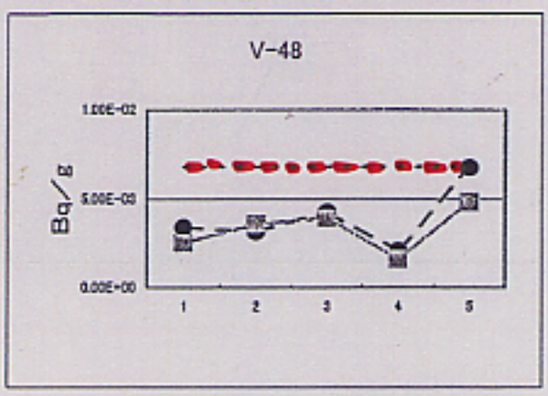
Limit : < 3.7 Bq/g

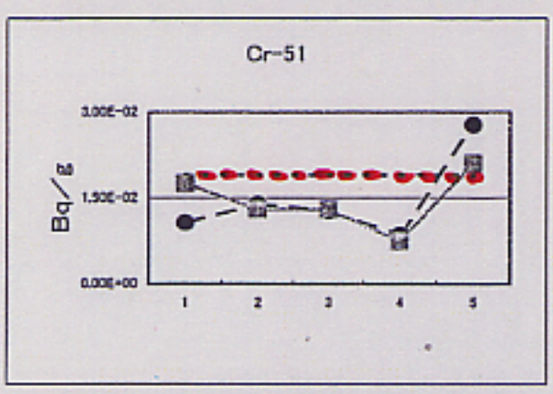


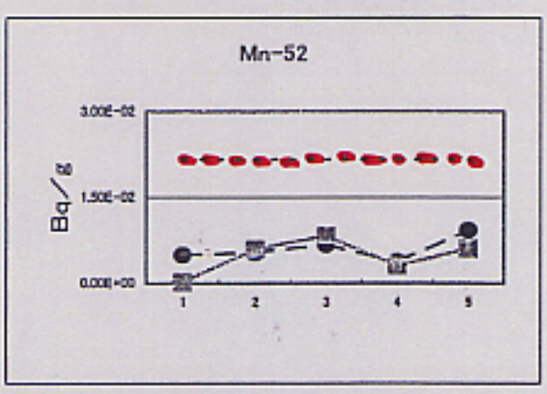


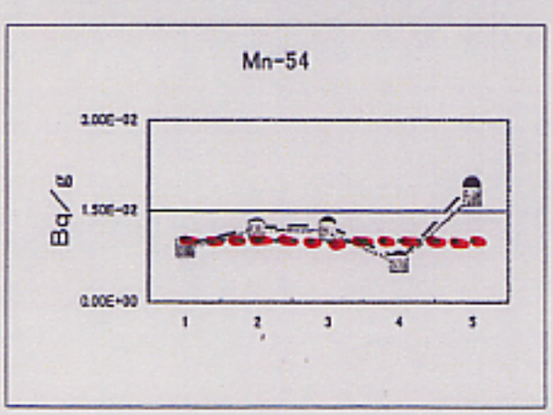


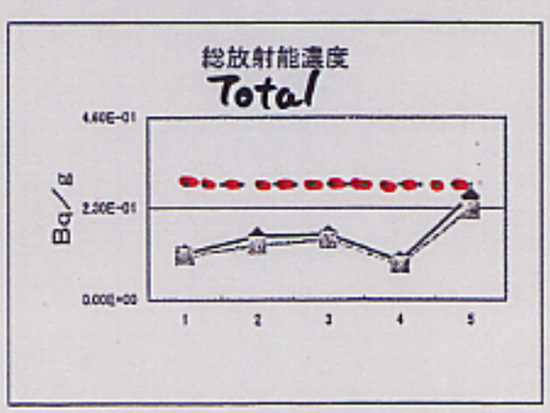






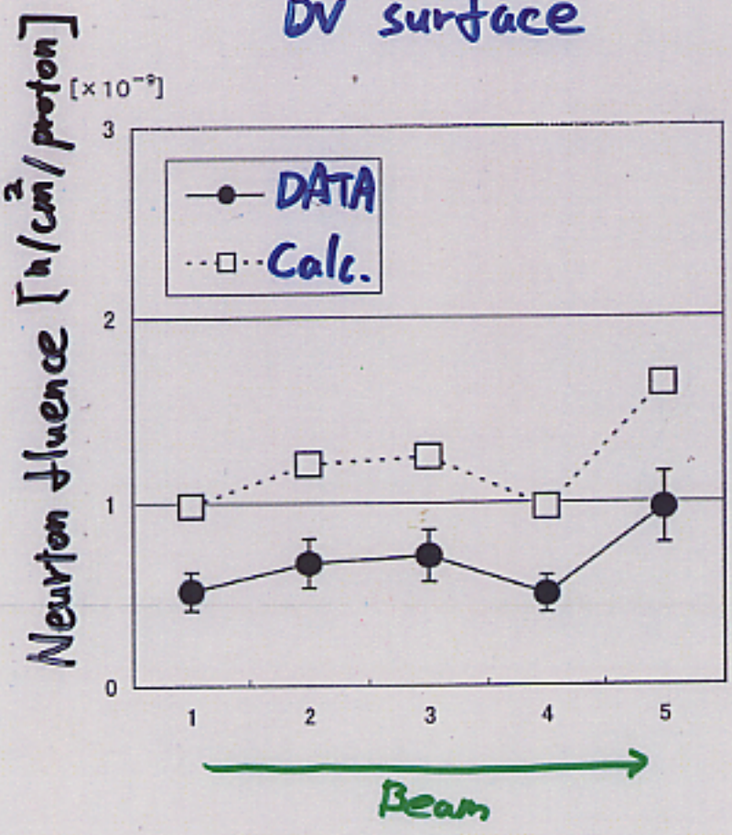


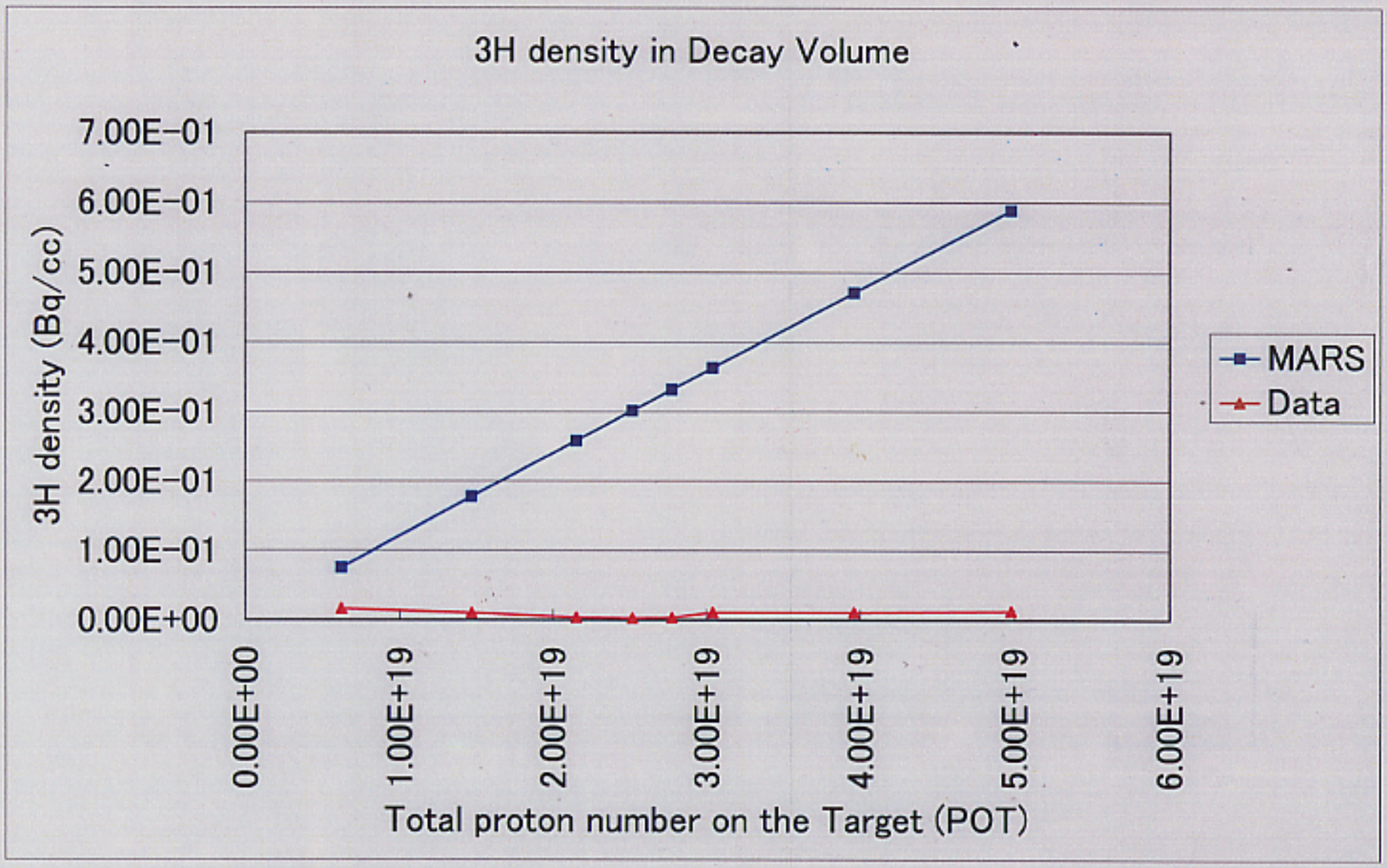




●: 3.5 cm from DV surface
■: 8.0 cm from DV surface

Neutron fluence at 6cm from DV surface




3H density in Decay Volume
7.00E-01
6.00E-01
5.00E-01
4.00E-01
3.00E-01
2.00E-01
1.00E-01
0.00E+00
3H density (Bq/cc)
0.00E+00
1.00E+19
2.00E+19
3.00E+19
4.00E+19
5.00E+19
6.00E+19
Total proton number on the Target (POT)
MARS
Data

Concluding remarks

- Decay volume and beam dump constructed in the K2K neutrino beam line have been safely operated since 1999 without any serious problem about radiation protection under the current operating conditions of KEK 12GeV PS.
- Estimated radioactivity in soil, water, and He agree well with measurements.
- In the future JHF-ν project, cooling system and radiation protection caused by 100 times stronger beam power than the current one must be seriously treated.