

Magnetic Horns and Target of K2K

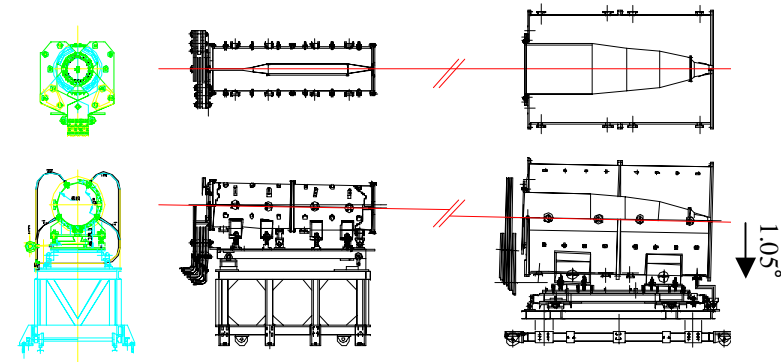
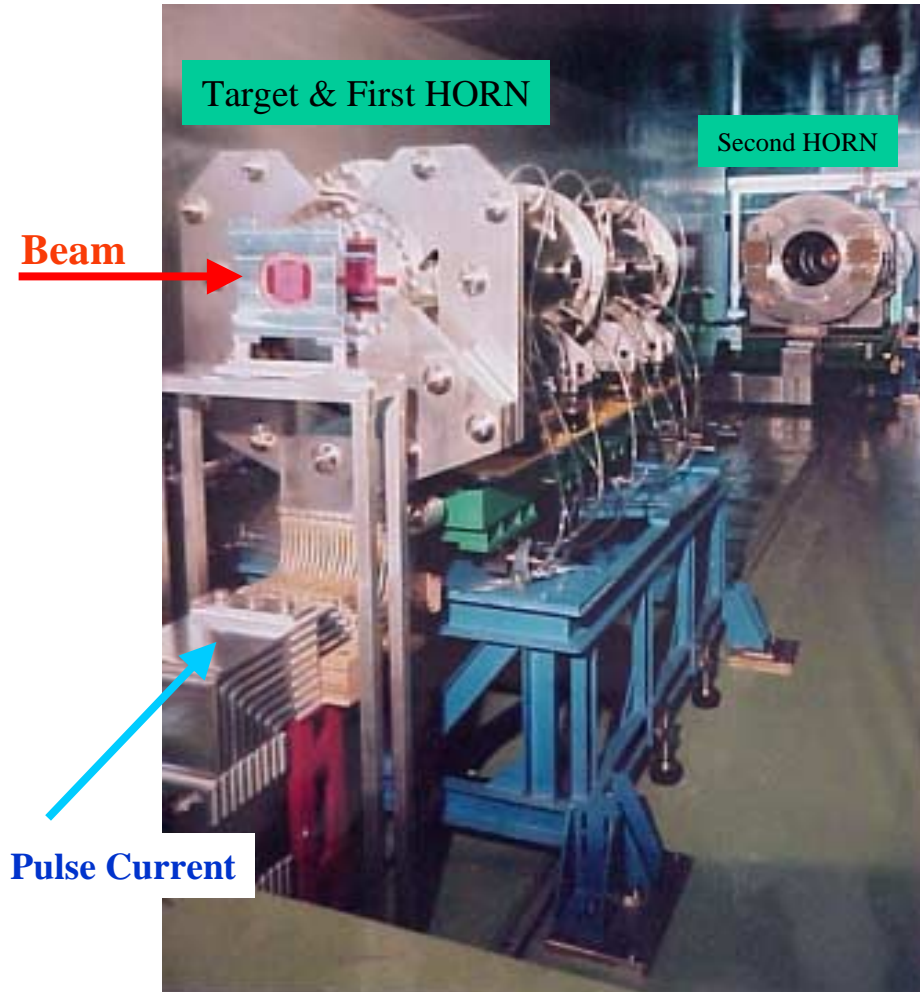
Y. Yamanoi (KEK)

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- Summary

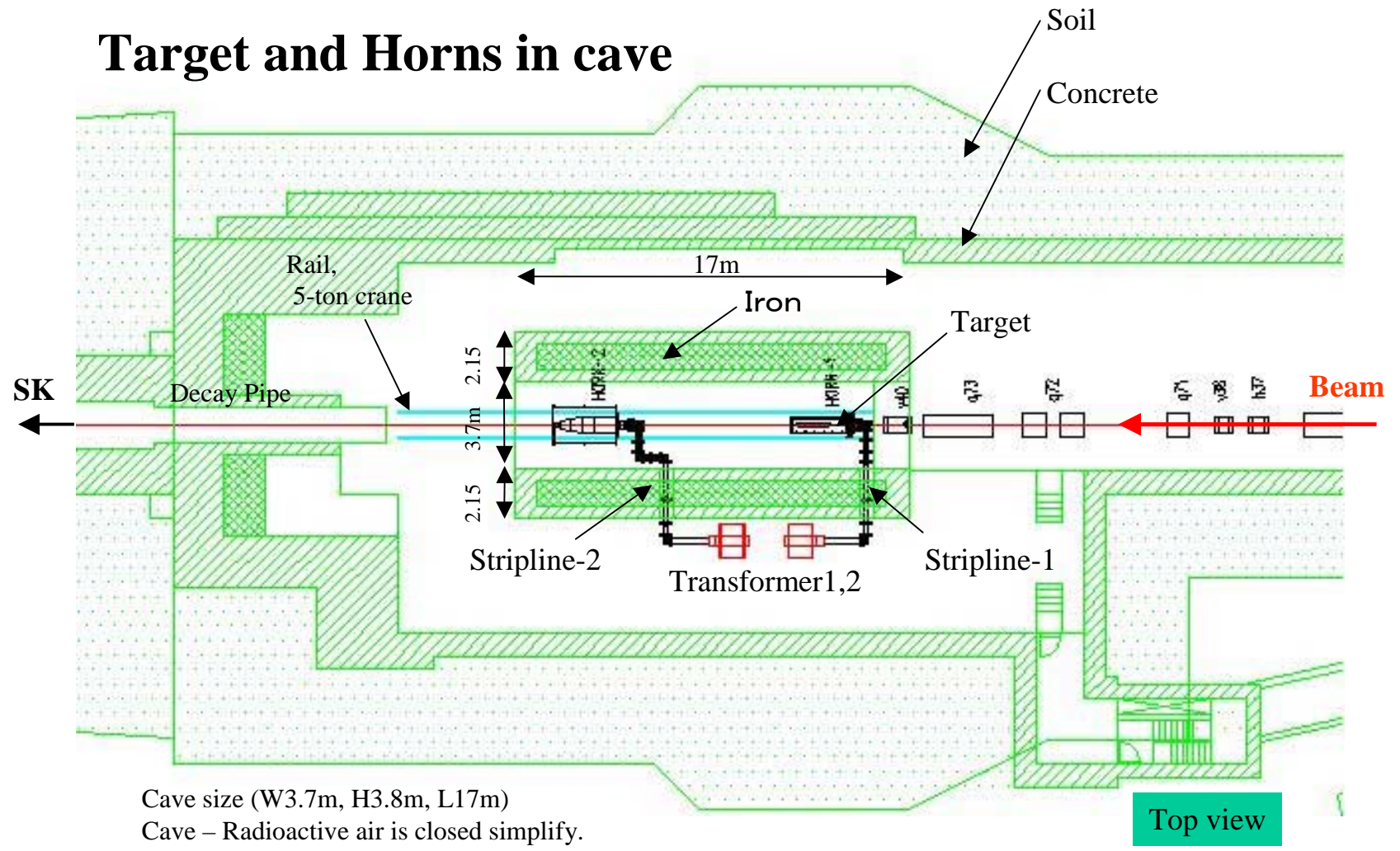
Target and Horns layout

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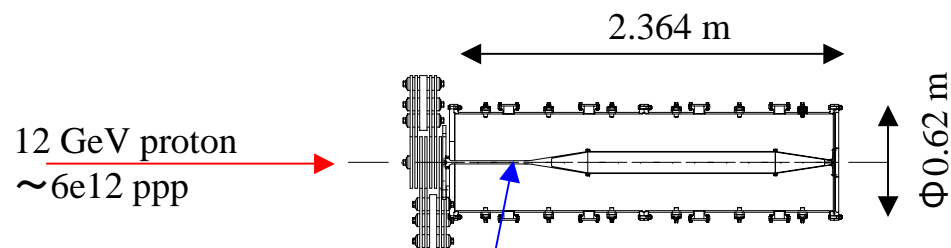
- Built-in production target (ϕ 30mm)
- (Blue) Removable train:
 - A distance between horns is about 8.06 m.
- (Green) Adjustment table:
 - decline to Super-Kamiokande with 1.05°
 - Accuracy is equal to about 0.04 mrad.
- Operation current 250k Amp at both horns
- High pulsed current 2.5ms width, 2.18s cycle
- Total Joule's heat=7740 kcal/h

Target and Horns in cave

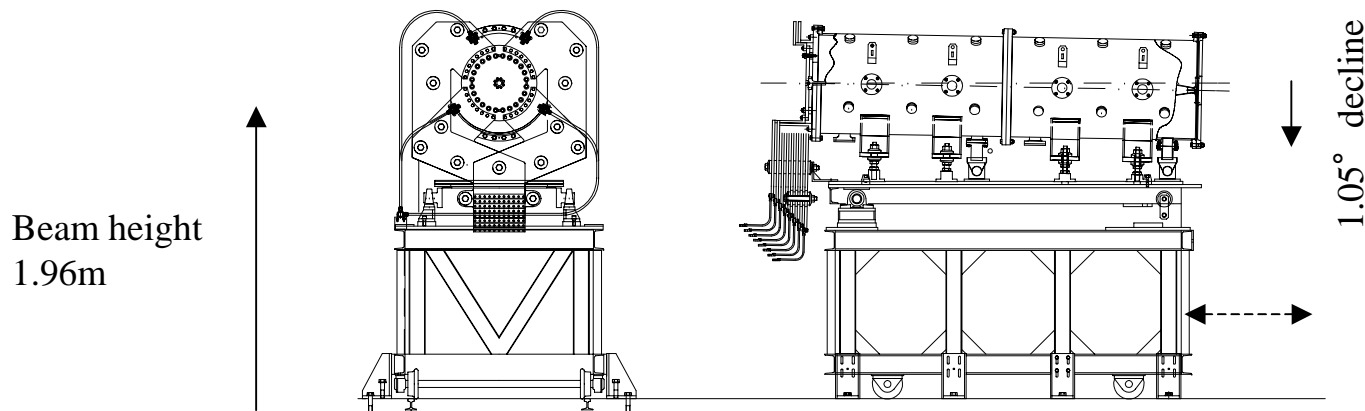


Cave size (W3.7m, H3.8m, L17m)
Cave – Radioactive air is closed simplify.
Both transformers is set inside beam line.
Stripline-1 : 9.3m, (Cross section t15mmx320mm)
Stripline-2 : 12.0m, (Cross section t15mmx320mm)

First Horn



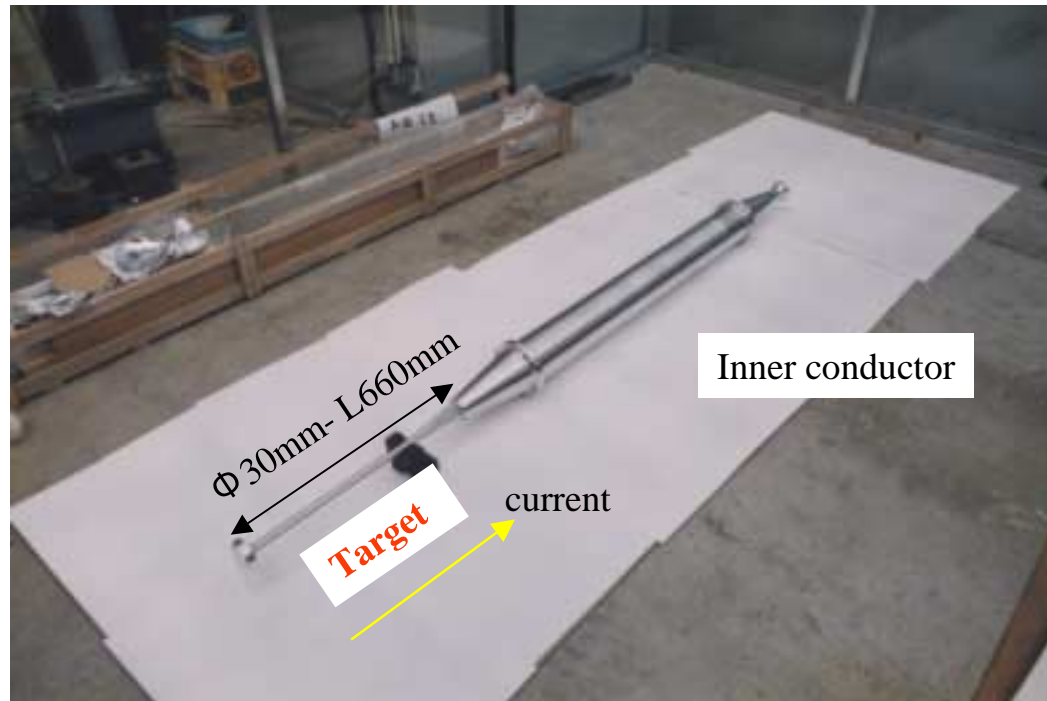
Built-in production target (ϕ 30mm)



- 12GeV PS cycle=2.18 s
- Built in target (ϕ 30mm-L660mm)
- Operation current 250 kAmp
- Thermal load total 14.4 kJ/pulse (6.6 kW)
(Joule's heat) 12 kJ/pulse, (incident beam) 2.4 kJ/pulse
- Water spray cooling on target and inner conductor (4x6=24 nozzles, 300kPa)
- For minimize π absorption: Aluminum alloy conductor (A6061)

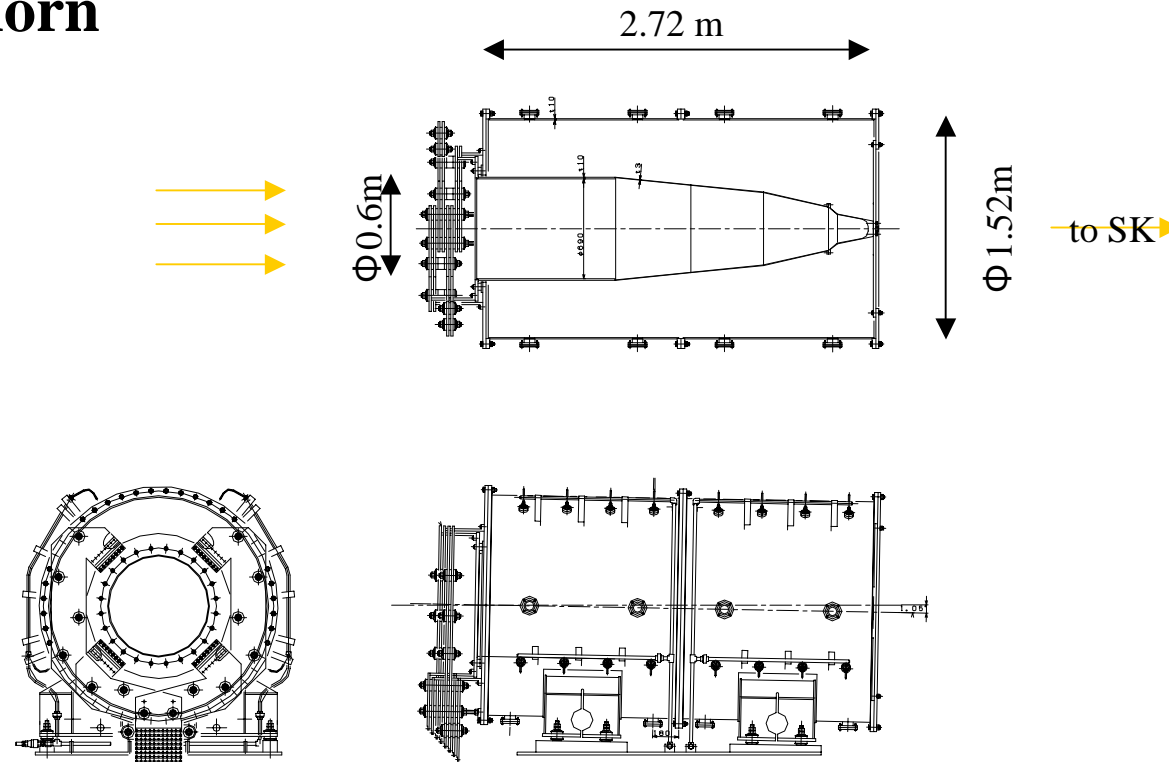
Inner conductor and Target

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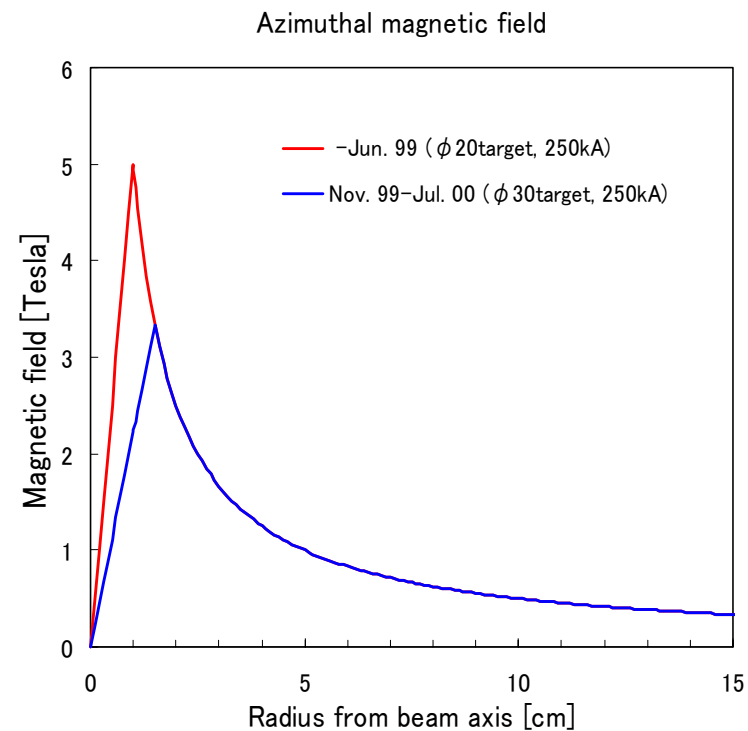
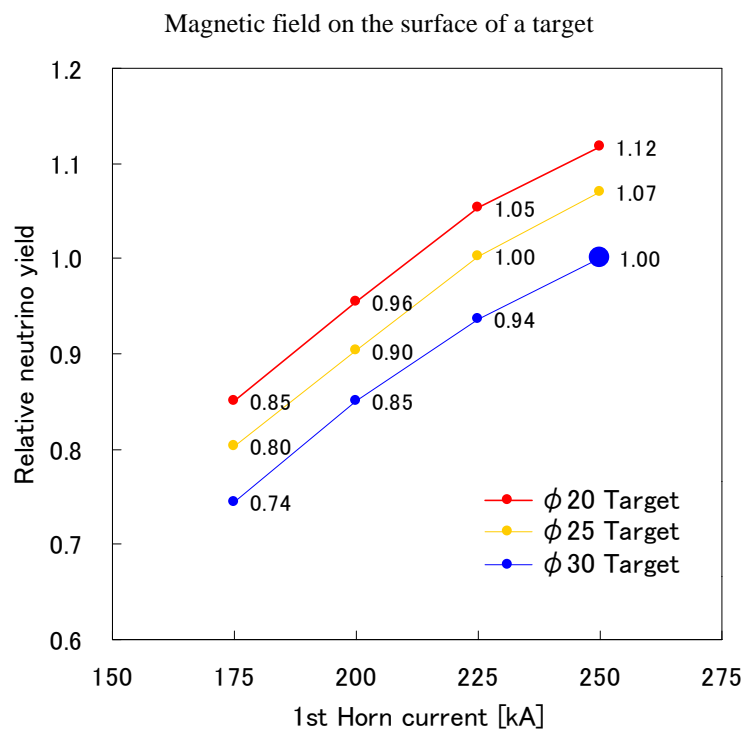
- Target rod, thin wall cylinder, tail cone
- Pulse current passes through on the target.
 - Conductive target
- Aluminum A6061, $\phi 30\text{mm}$ - $L660\text{mm}$, $\sim 1.67 \times \lambda_I$
- Joule heat 12kJ/pulse
- Spray cooling \sim Heat transfer rate $1100\text{W/m}^2 \cdot \text{K}$
- $T_{\text{average}} \sim 60^\circ\text{C}$, $\Delta T \sim 15^\circ\text{C}$

Second Horn



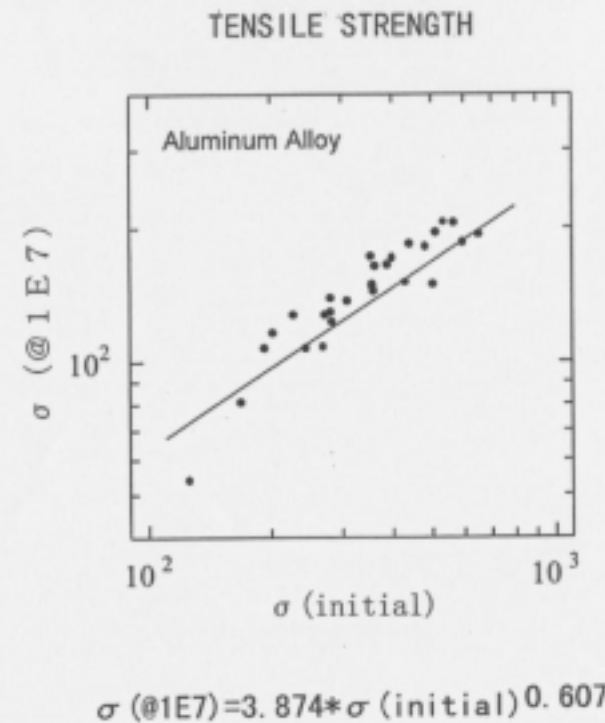
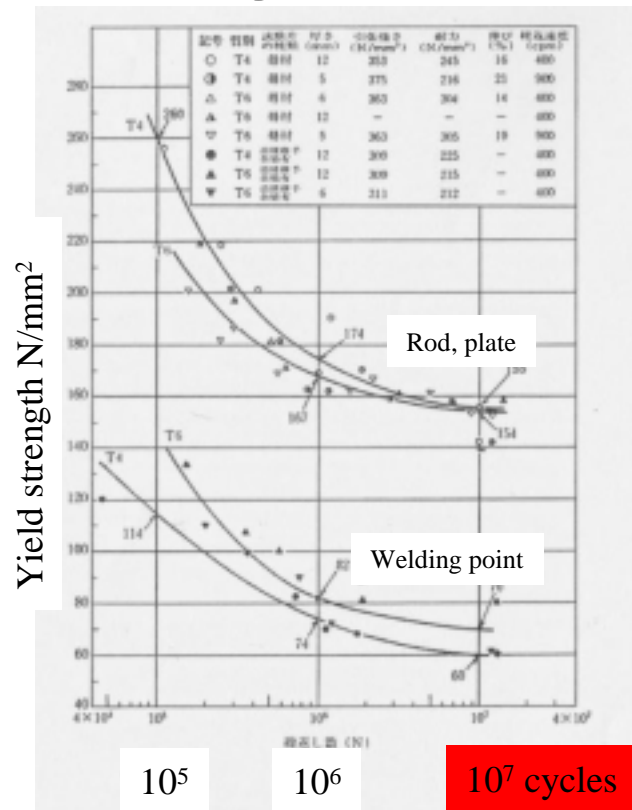
- Length 2.72 m, Outer diameter 1.52m
- Large acceptance
- Conical inner conductor: thickness 3mm, welding joint
- The inner conductor was assembled in the center within a accuracy of $\pm 3\text{mm}$.
- For minimize π absorption: Aluminum alloy conductor (A6061)
- Water spray cooling on target and inner conductor

Neutrino flux with Horn current



The magnetic field on the surface of a target is strengthened.
→ Neutrino yield increases. But ...

Yield strength



	initial	@1E7
A6061-T6	359 N/mm ²	138 N/mm ²
-T651	320	128
-T651	337	133
-T651	316	127

Safety factor for Target rod
 ϕ 20mm: 2.5 \rightarrow 1.0 (1E7 excitations)
 ϕ 25mm: 3.9 \rightarrow 1.5
 ϕ 30mm: 5.7 \rightarrow 2.2

Target rod is thin.
 A risk of breaking down during operation also increases.

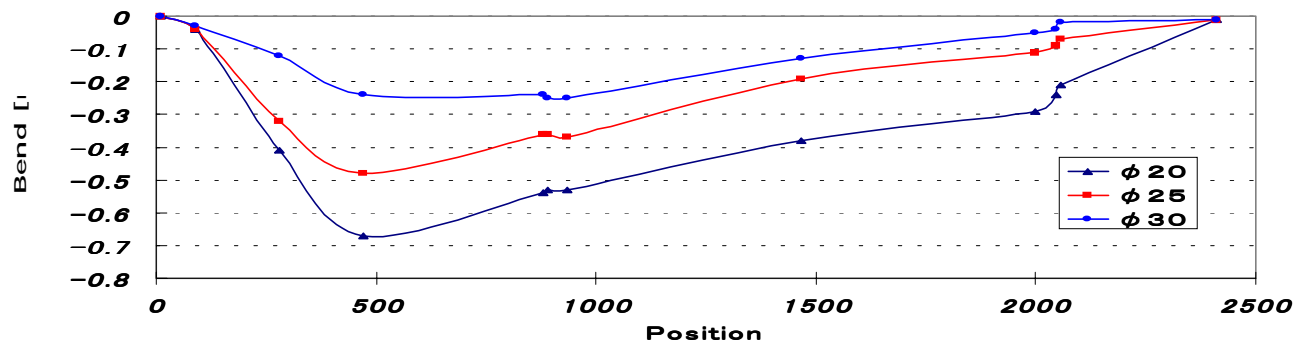
Bending & Vibration

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Fixed end

Fixed end



Bending displacement δ (mm)=0.24, 0.48, 0.67

Measured frequency spectrum (FFT);
195, 437, 928, 1572, 2188 Hz, ...

$$\text{Longitudinal frequency: } f_n = \frac{n}{4L} \sqrt{\frac{Eg}{\rho}}, f_1 = 1673 \text{ Hz}$$

$$\text{Twist frequency: } f_n = \frac{n}{4L} \sqrt{\frac{Gg}{\rho}}, f_1 = 1027 \text{ Hz}$$

$$\text{Bending frequency: } f_n = \frac{1}{2\pi} \frac{\alpha_n^2}{L^2} \sqrt{\frac{EIg}{\rho}}, f_1 = 207 \text{ Hz}$$

Calculation:

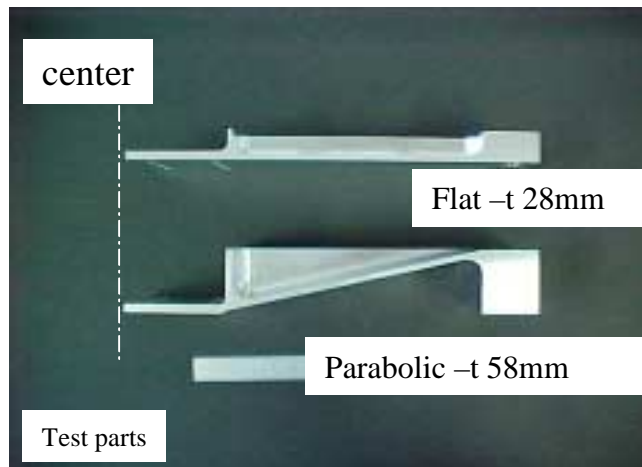
Excitation pulse = 195.3 Hz

Longitudinal = 1673, 3346, 5019, ...

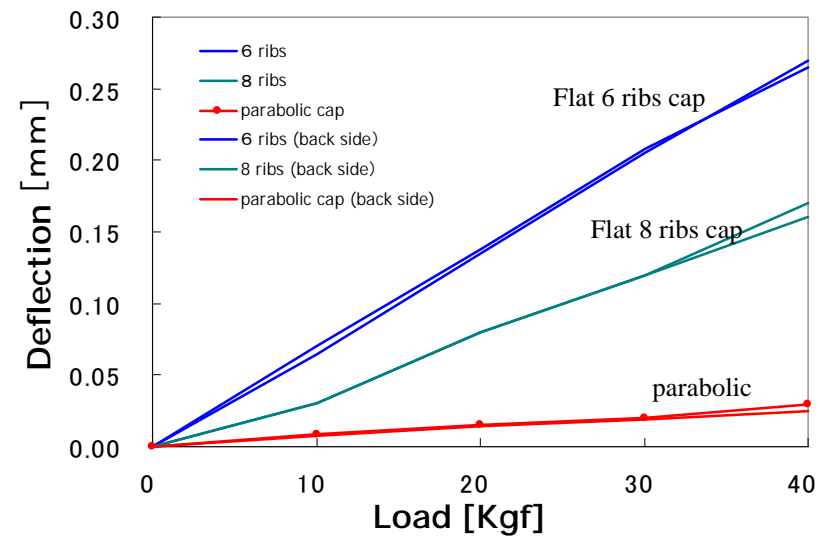
Twist = 1027, 2055, 3082, ...

Bending = 207, 827, 1861, ...

The new disk for supporting inner conductor firmly



- Spring constant up
 - Flat 8 ribs disk = $30 \mu\text{m/kgf}$
 - New parabolic disk = $9 \mu\text{m/kgf}$



Measurement of dumping time



Flat disk with 8 ribs



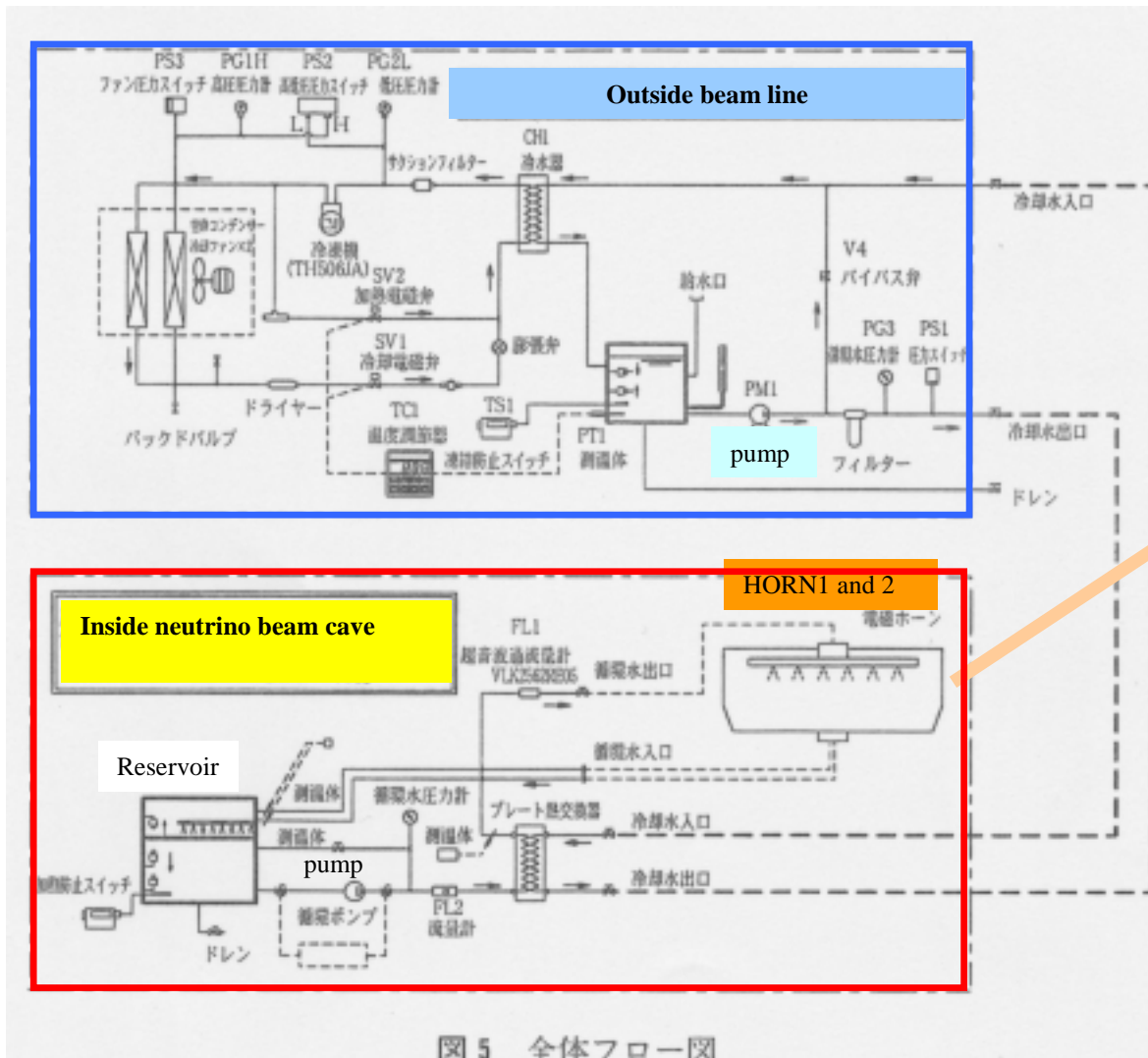
Parabolic disk with 8 ribs

Result:

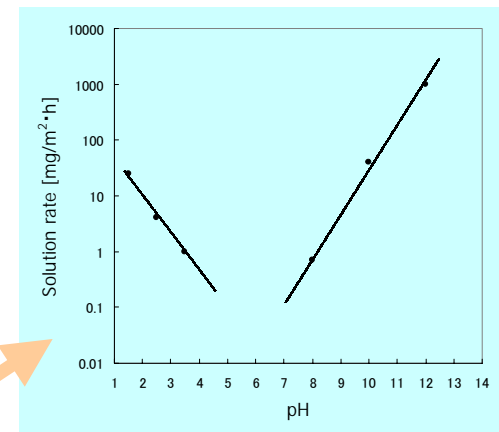
$\frac{1}{2}$ decay time constant : 96ms \rightarrow 19ms
Dumping time was able to be suppressed.

- Un-contacting Photoelectric Sensor with laser light beam
- Resolution $1.5 \mu\text{m}$, response time 0.15ms

Spray cooling system



pH v.s. Solution rate



- Spray pressure = 300kPa
- Total flow = 60 lit./min.
- Floating ion: $[Al(H_2O)_2(OH)_4]^-$
- pH control \cong 7.5
- Conductance \cong 50 μ S/cm
- Self healing
- Corrosion \leftrightarrow Alumite growth
- Neutralize of cooling water every 2 weeks

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Alumite growth

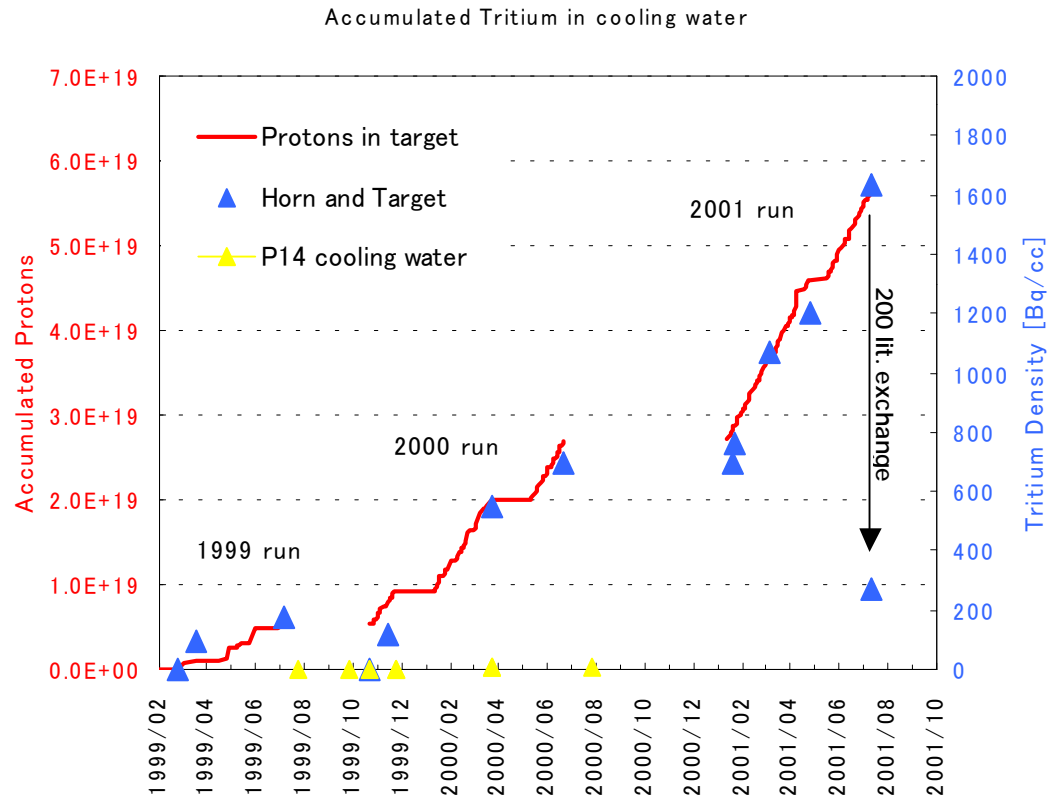
New

1 year used



- (Silver color): Ag-coating 5~8 μ m
- (Black alumite growth): No coating

Tritium accumulation



Dirty cooling water=270 liter
Major isotope products
H-3, Be-7, Na-22, V-48,
Mn-52, Mn-54, Co-56,
Co-57, Co-58, Zn-65, Y-88,
Tritium density=1633 Bq / cc
(2.96E+19 incident protons)
Eliminator: Ion Exchange Resin
(AMBERLITE)
IR120 Na (cation)
IRA410 Cl (anion)



Eliminator unit

Reservoir,
Pump unit

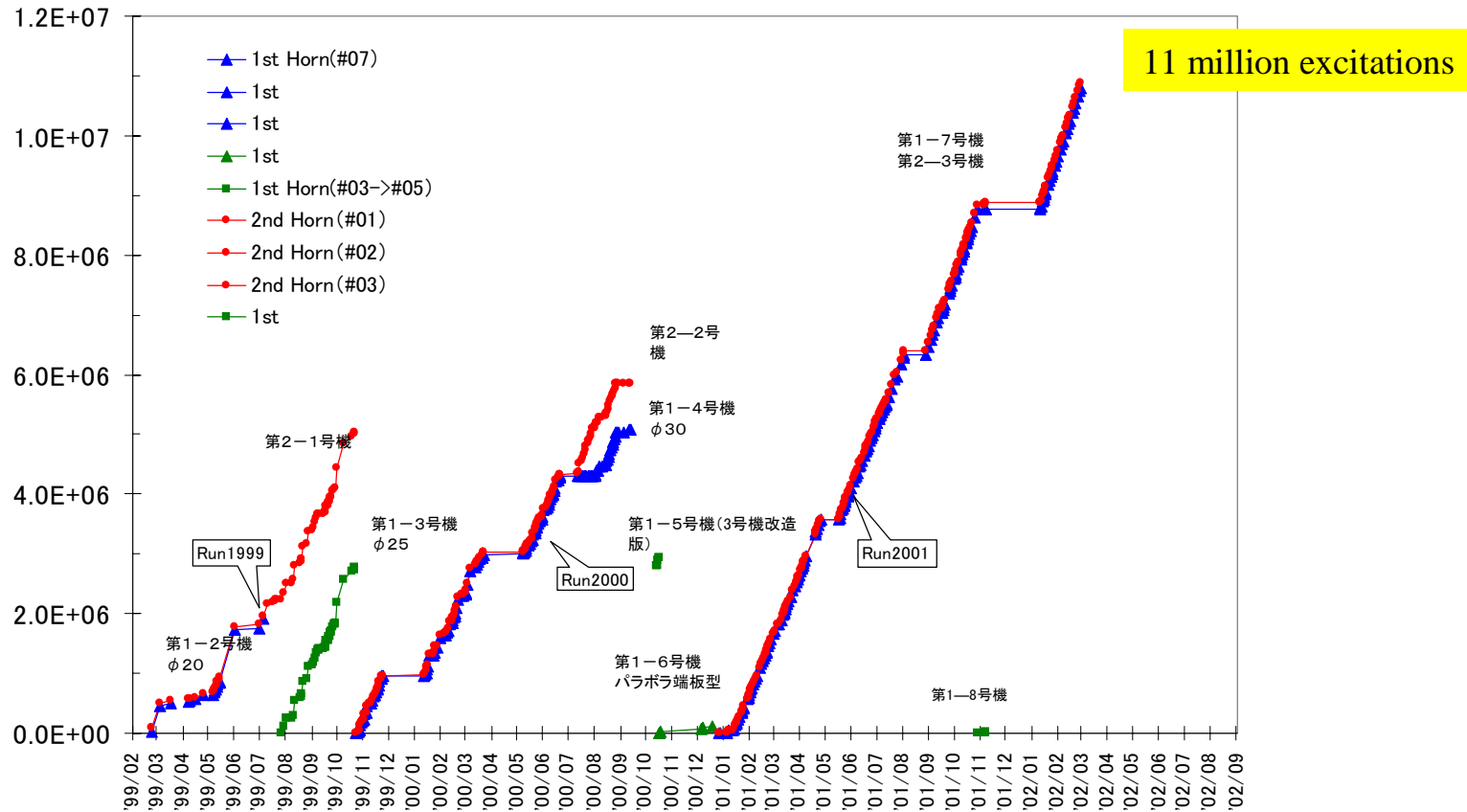
Effect of Ion exchange resin eliminator

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Isotope	Half-life	Radioactivity concentration(Bq/cc)		removal rate %
		before	after	
H-3	12.3 y	9.40e+2	9.89e+2	---
Be-7	53.3 d	1.15e+2	1.17e-1	100
Na-22	2.6 y	9.85e-1	1.44e-3	100
Sc-46	83.8 d	7.46e-1	8.23e-3	99
Mn-52	6.0 d	3.11e+0	no detect	100
Mn-54	312.1 d	1.87e+0	no detect	100
Co-56	77.2 d	1.74e+0	4.47e-3	100
Co-57	271.7 d	2.46e+0	7.20e-4	100
Co-58	70.9 d	8.49e+0	no detect	100
Fe-59	44.5 d	1.49e-1	no detect	100
Co-60	5.3 y	2.47e-1	no detect	100
Zn-65	244.3 d	3.53e-1	no detect	100
Se-75	119.8 d	1.69e-1	3.04e-3	98
Rb-83	86.2 h	1.42e+0	no detect	100
Rb-84	32.8 d	2.11e-1	no detect	100
Y-88	106.7 d	2.78e+0	1.36e-3	100
Zr-88	83.4 d	3.94e-1	8.65e-3	98
Tc-95m	61.0 d	2.15e-1	no detect	100
Ag-105	41.3 d	4.34e-1	1.42e-2	97

- K2K experiment 10Jan,2001 →12 Jul,2001 (Incident protons=2.82e+19)
- Dirty cooling water 270 liter
- Most radioactive isotopes are removable. Tritium can not be remove.

Under durability-test



Summary

- Mechanical failure has not happened at all since last year.
- End cap modification was very successful.
However there is still an indefinite failure in long-term operation.
- pH control in a cooling water succeeded and advance of corrosion was suppressed.
- The result of a durable test reached to 1.1×10^7 excitations. (now running)