

# Radiation shielding

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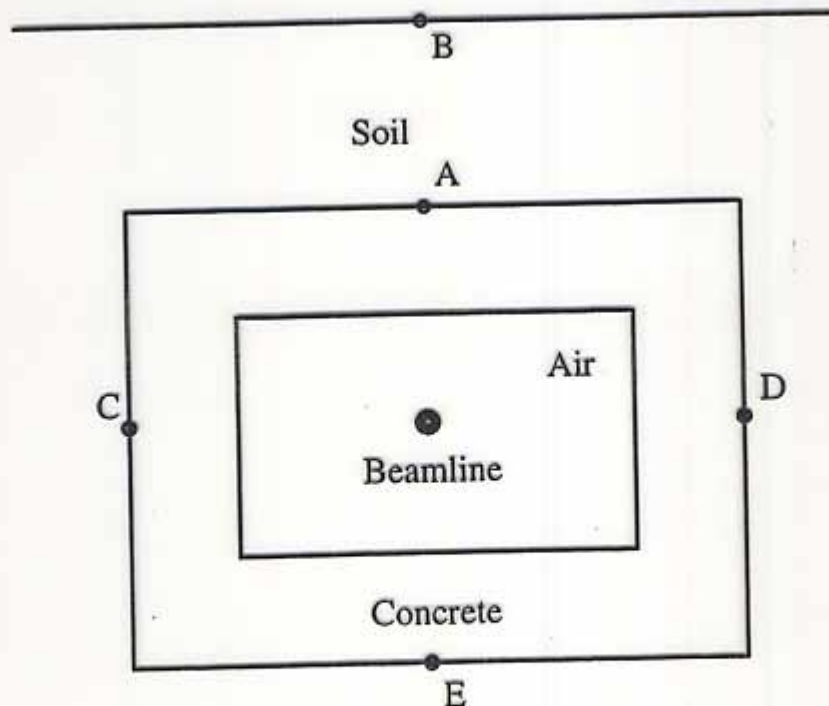
- Requirements for the radiation level from regulations

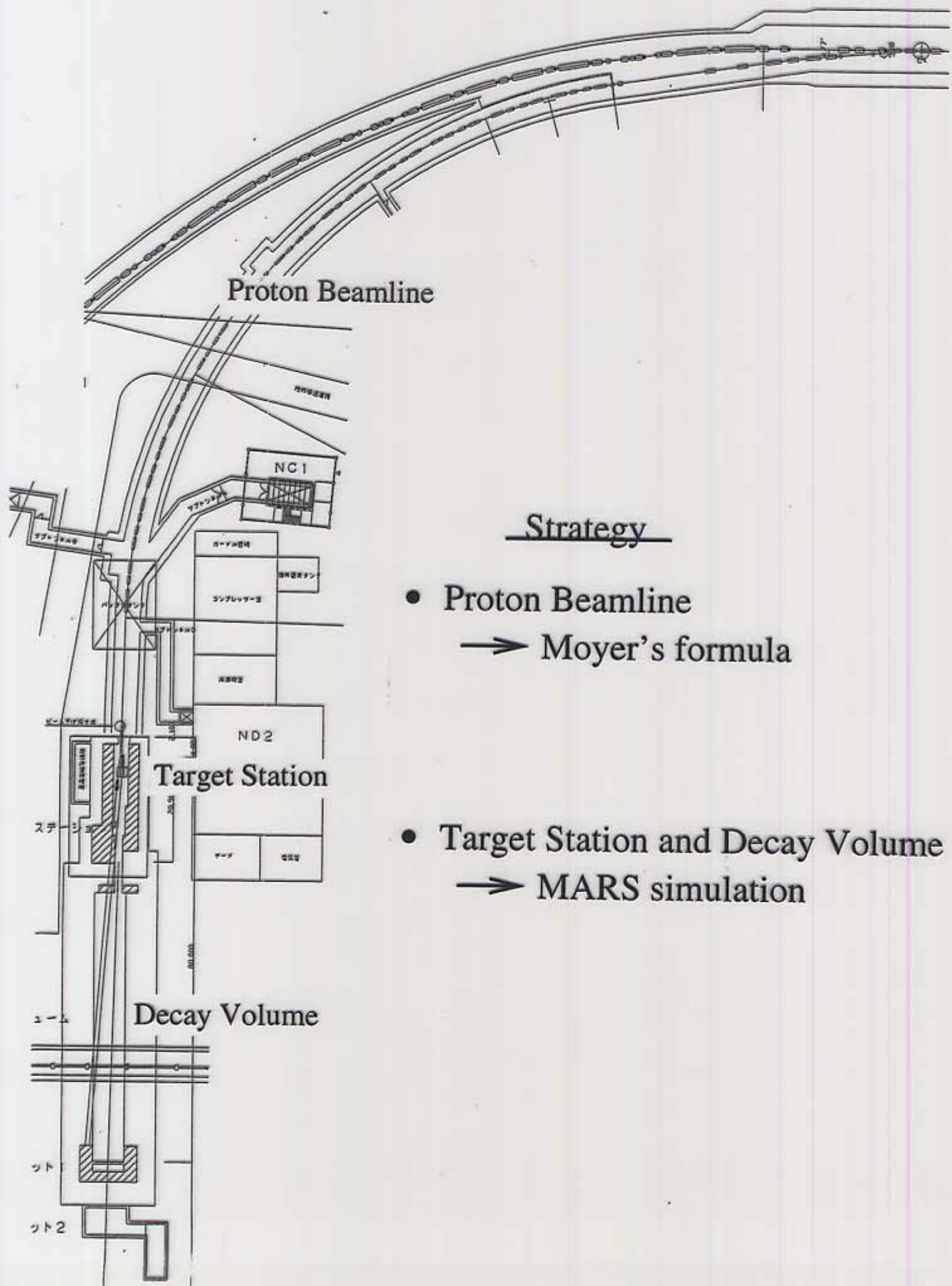
$H < 5\text{mSv/h}$  @ surface of the concrete

A,C,D,E

$H < 0.25\mu\text{Sv/h}$  @ surface of the Earth

B

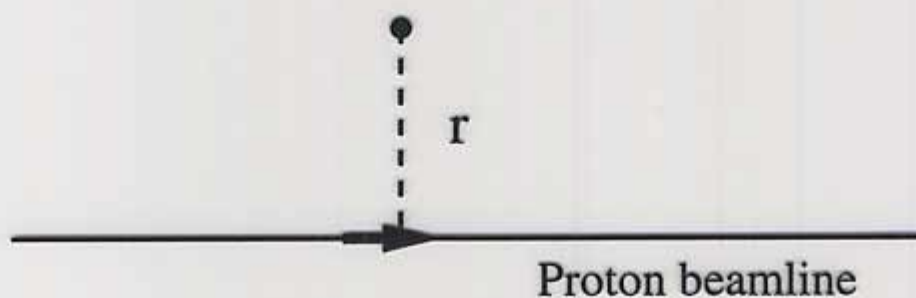




Strategy

- Proton Beamline  
→ Moyer's formula
  
- Target Station and Decay Volume  
→ MARS simulation

## Radiation shielding around the Proton Beamline by Moyer's formula

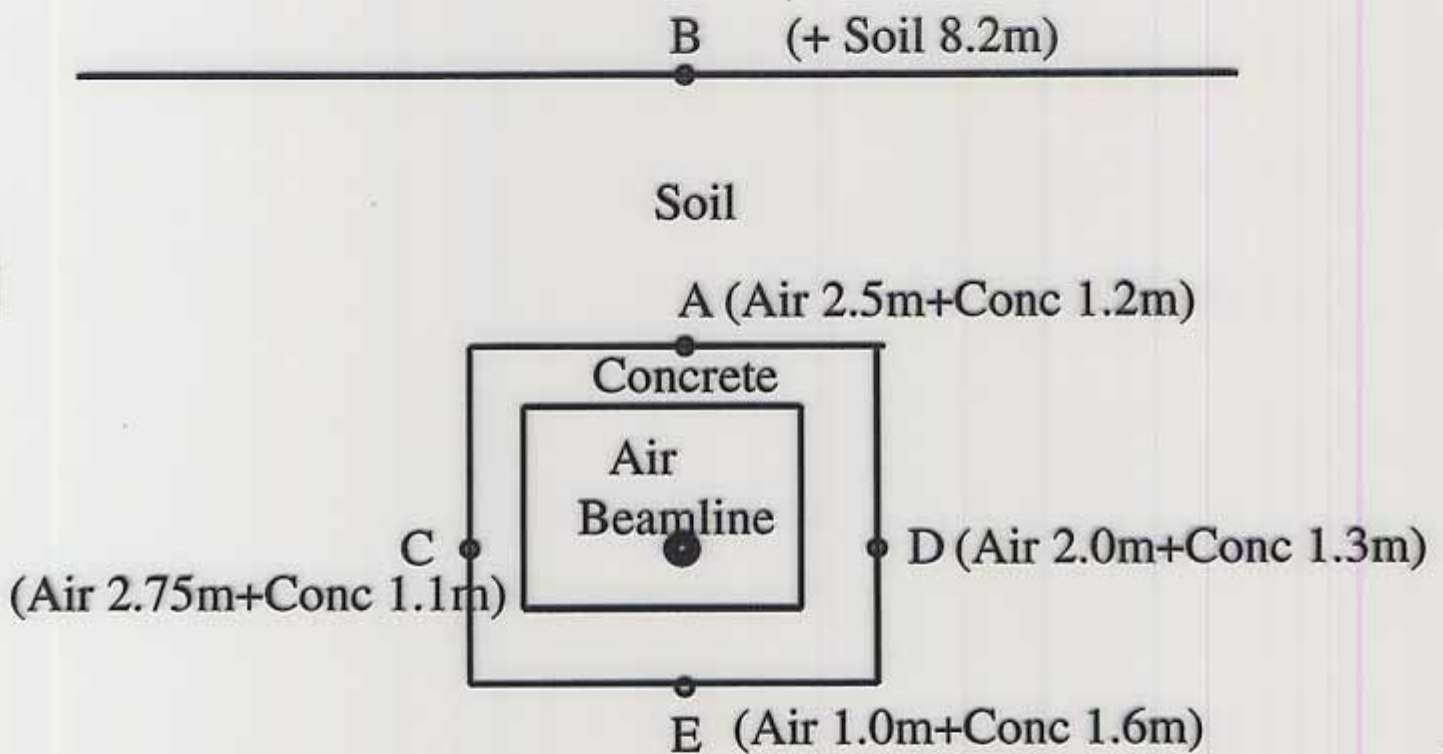


$$H(r) = H_0 \times \frac{\exp\left(-\int_0^r \rho(r') / \lambda \, dr'\right)}{r^2}$$

$$\begin{aligned}
 H_0 &= A \times (\text{beam loss}) = 9.0 \times 10^5 \text{ (n}^2 \mu \text{ Sv/h)} \\
 &= 30 \times H_0^{\text{K2K}}
 \end{aligned}$$

	Fe	Conc	Soil
density $\rho$ (g/cm <sup>3</sup> )	7.7	2.2	1.5
attenuation length $\lambda$ (g/cm <sup>2</sup> )	143	188	139

## Present Design of the shielding

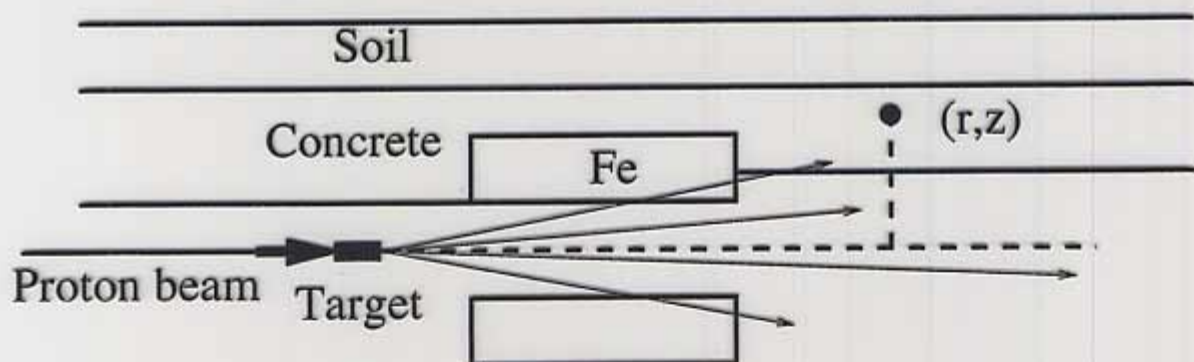


	Calculation		Requirement
A:	4.48mSv/h	↔	5mSv/h
B:	0.062 $\mu$ Sv/h	↔	0.25 $\mu$ Sv/h
C:	4.83mSv/h	↔	5mSv/h
D:	4.83mSv/h	↔	5mSv/h
E:	4.90mSv/h	↔	5mSv/h

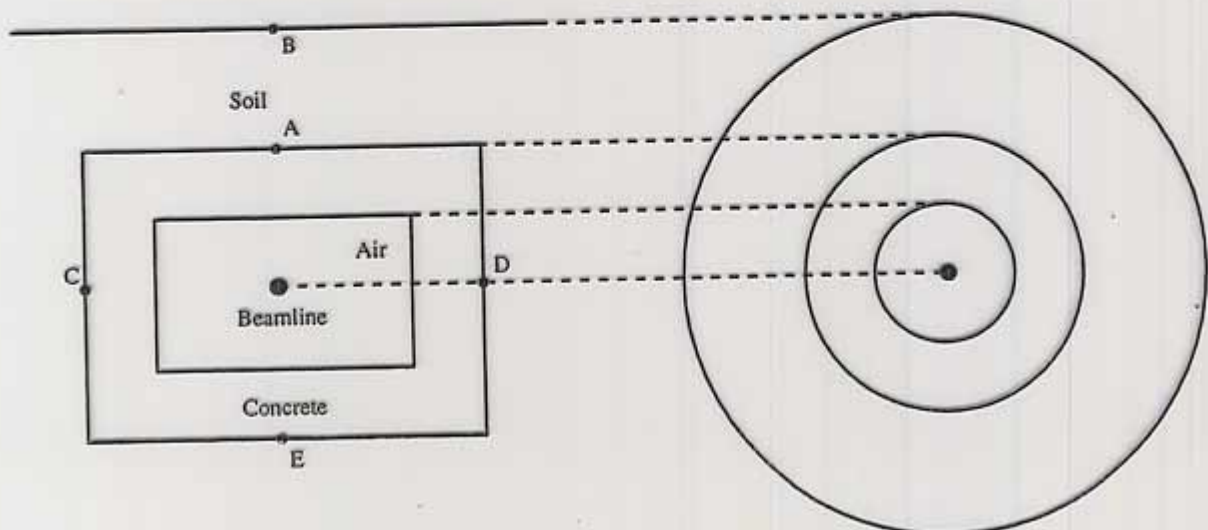


## Radiation shielding around the Target Station and Decay Volume by MARS simulation

- MARS is a simulation program of hadronic and electromagnetic cascades in shielding, accelerator and detector components
- Developed by N.V.Mokhov (Fermilab) et al.
- Define materials as a function of the position in the cylindrical coordinate  $(r,z)$  and initial beam. Radiation of the position can be obtained as a result of the simulation

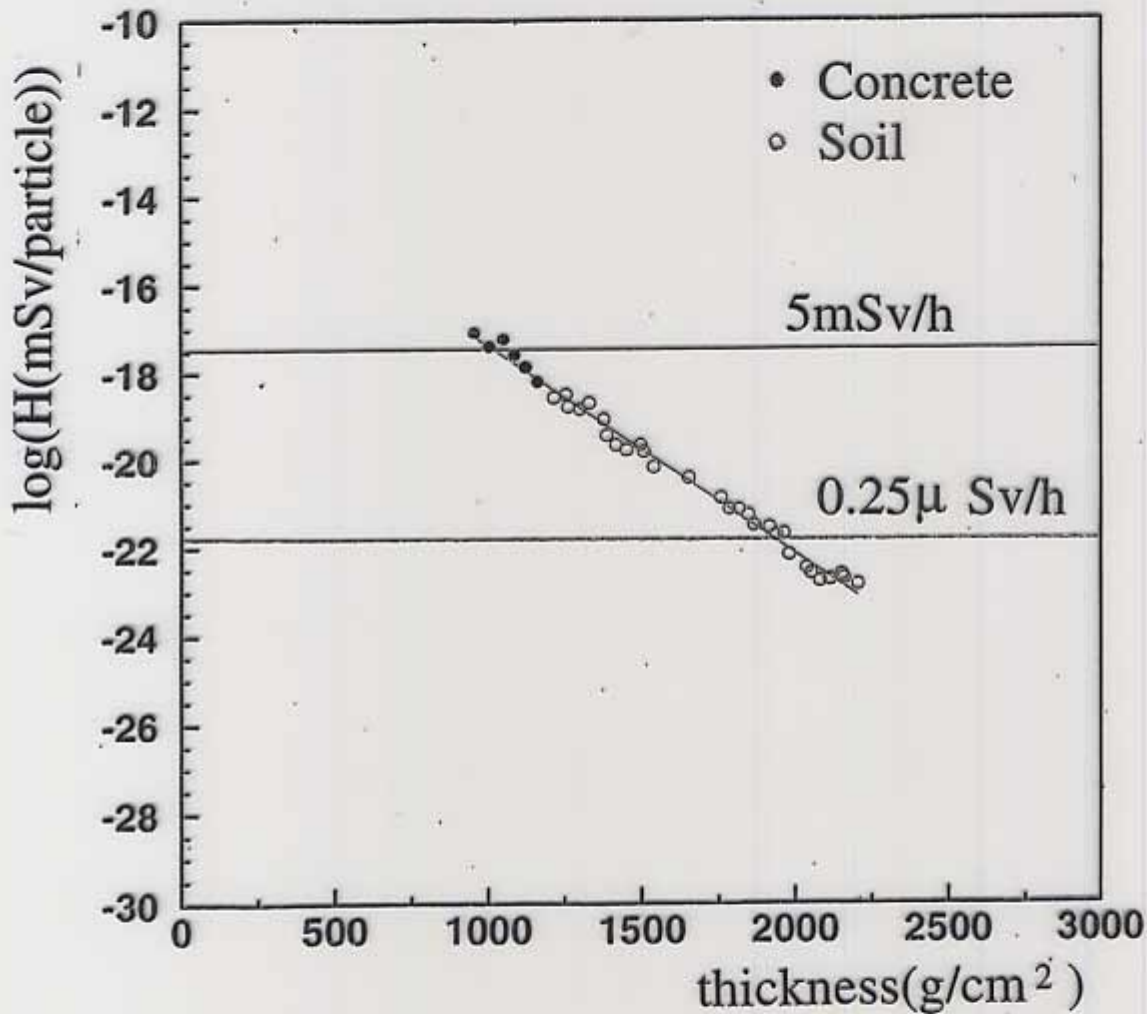


- Cylindrical geometry is used instead of real geometry



## Results of the MARS simulation

- Attenuation of the radiation as a function of material thickness for  $z = 40\text{m}$



- Effective attenuation length can be calculated.

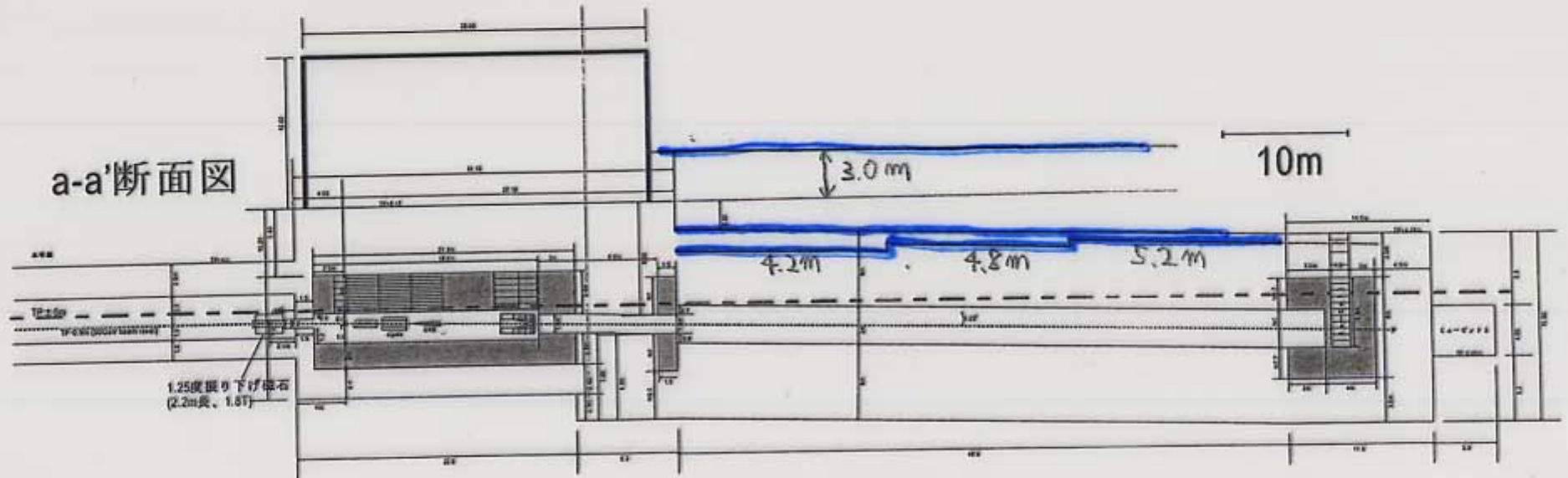
$$H = A \times \exp(-r_d / l_d)$$

$$l_d = 90 \sim 100 \text{ g/cm}^2$$

→ 1m thickness of the concrete reduce the radiation by a factor of 10

## Shielding for the Target Station and Decay Volume

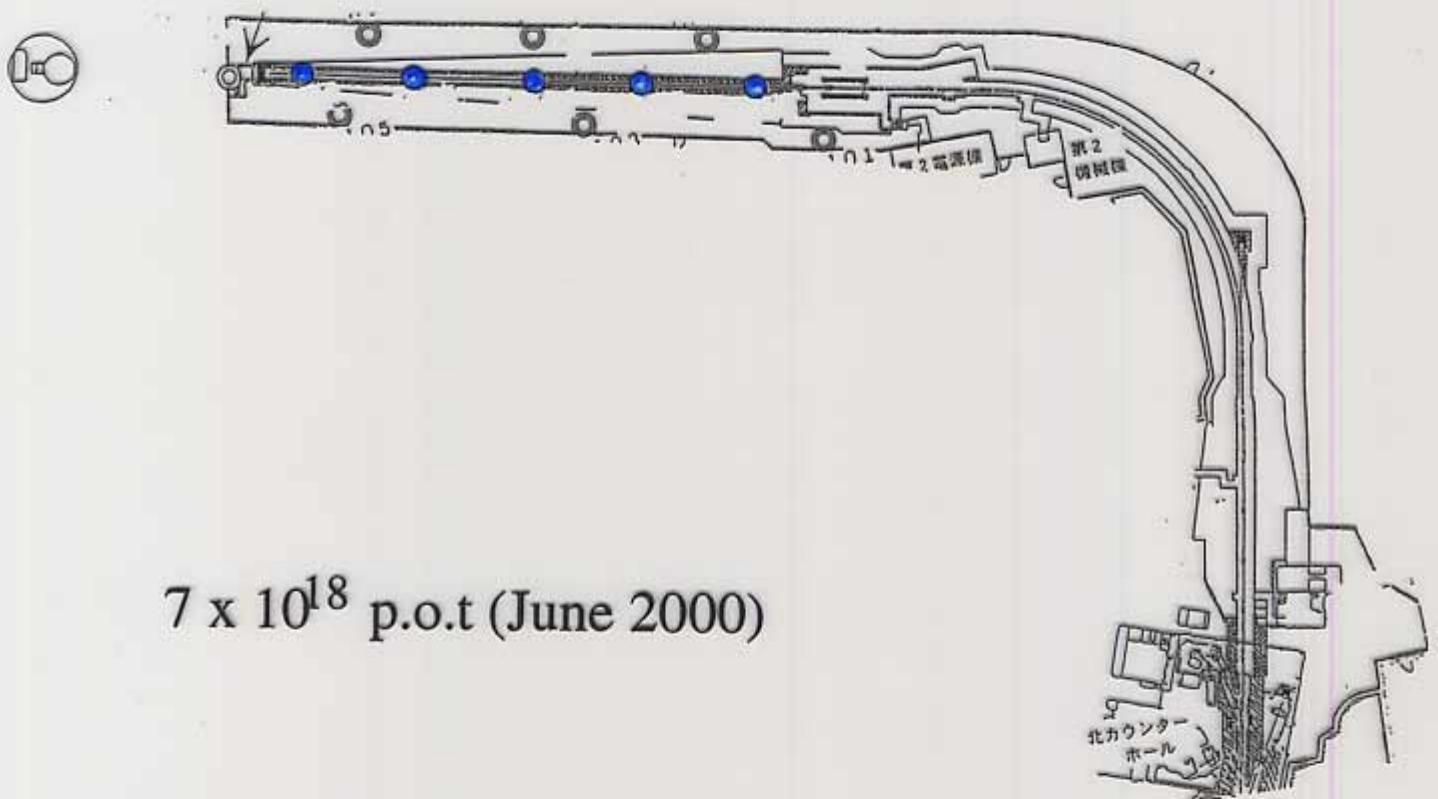
- The thickness of the concrete shielding should be 4.2m ~ 5.2m, where the original design is 6m.
- 3m of soil are needed over the ground level.





## Reliability of the MARS simulation

- Radioactivities were measured around the K2K decay volume and were compared with the MARS simulation (By T.Miura and T.Suzuki (rad. safty div.)



- Results on the soil in wells (surface of the concrete)  
Measurement : 0.77mSv/h  
MARS : 1.2 mSv/h  
Requirements : 5 mSv/h
- MARS results agree with measurements within a factor 2.



## Summary

- The thickness of the radiation shield are estimated by Moyer's formula (for proton beamline) and MARS simulation (for Target Station and Decay Volume)
- Calculations were done for the present design, and the procedure was established.
- K2K measurements show that the MARS calculation agree with the experimental data within a factor 2. MARS calculations are conservative.
- We are ready for the final geometry