2003/5/6 @KEK

R&D direction on horns and target

A.K.Ichikawa

KEK

R&D of Target and Horns are in progress

by Neutrino construction group and Target&Monitor group in KEK.

Especially,

Target

by Y. Hayato with KEK Target&Monitor group lead by Noumi

Horns

Conceptual design by A. K. Ichikawa

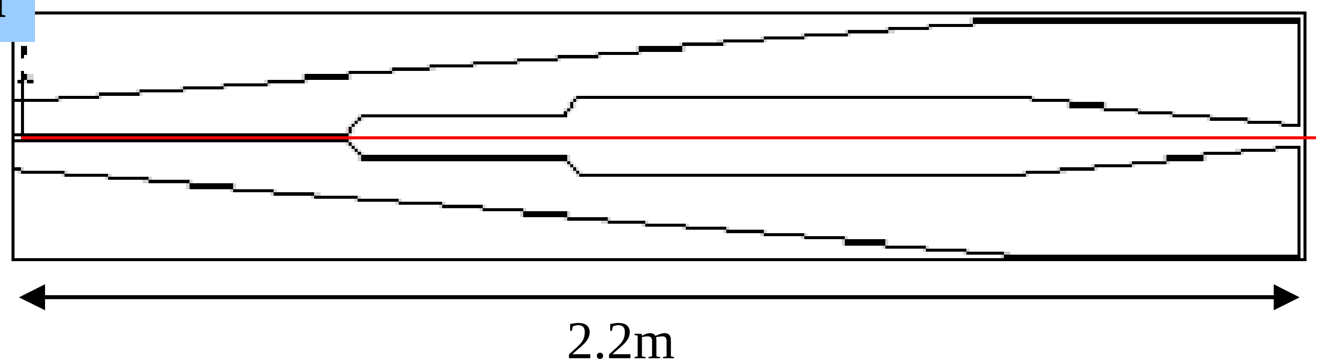
supported by Y. Yamanoi, Y. Suzuki and Target&Monitor group

Brief comments on the target and horns in the MC simulation

In the beam MC simulation,

horns proposed in BNL-E889 was used.

1st horn



- D_{in} = 1.9cm$^{\phi}$, I=250kA
- Sapphire target (Al_2O_3, ρ=4g/cm^3) D=0.64 cm, L=45cm

c.f. K2K Aluminum D_{in}=3.0cm$^{\phi}$, I=250kA

In addition, heat load from radiation

⇩

Need realistic design work

Target

Target for K2K

12kJ in 1.1μs

Al 30mm$^{\phi}$ x 660mm (Embedded in the horn)

Heat was generated by the horn-current

Target for J-Parc

2.6MJ in 5μs

Aluminum cannot withstand.

Only low-Z material such as graphite or beryllium.

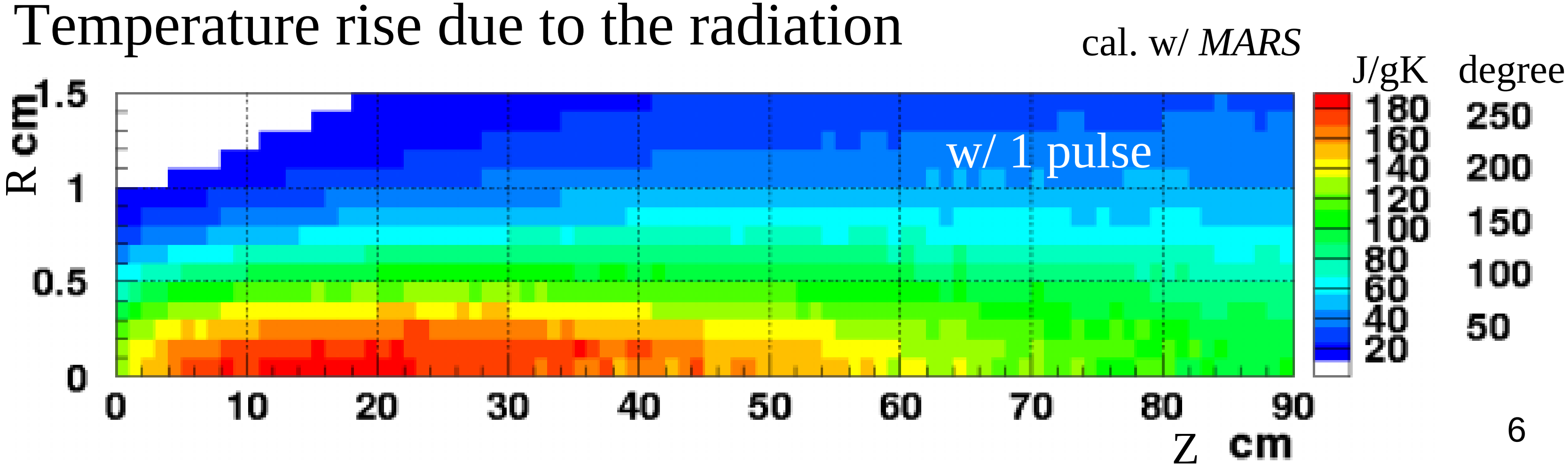
Graphite w/ water cooling

Density	~1.8g/cm^3
Melting point	~3600^{o}C

Good thermal conductivity

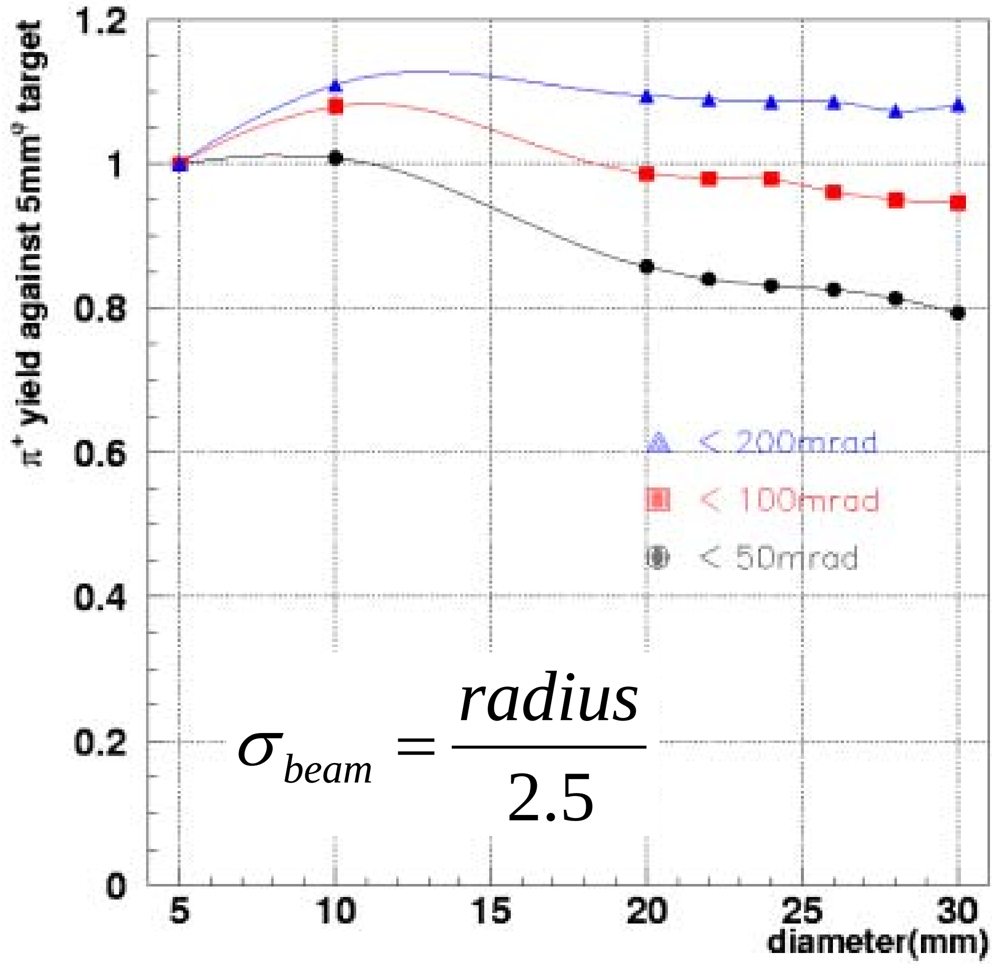
Mechanically strong

Temperature rise due to the radiation



Target Size

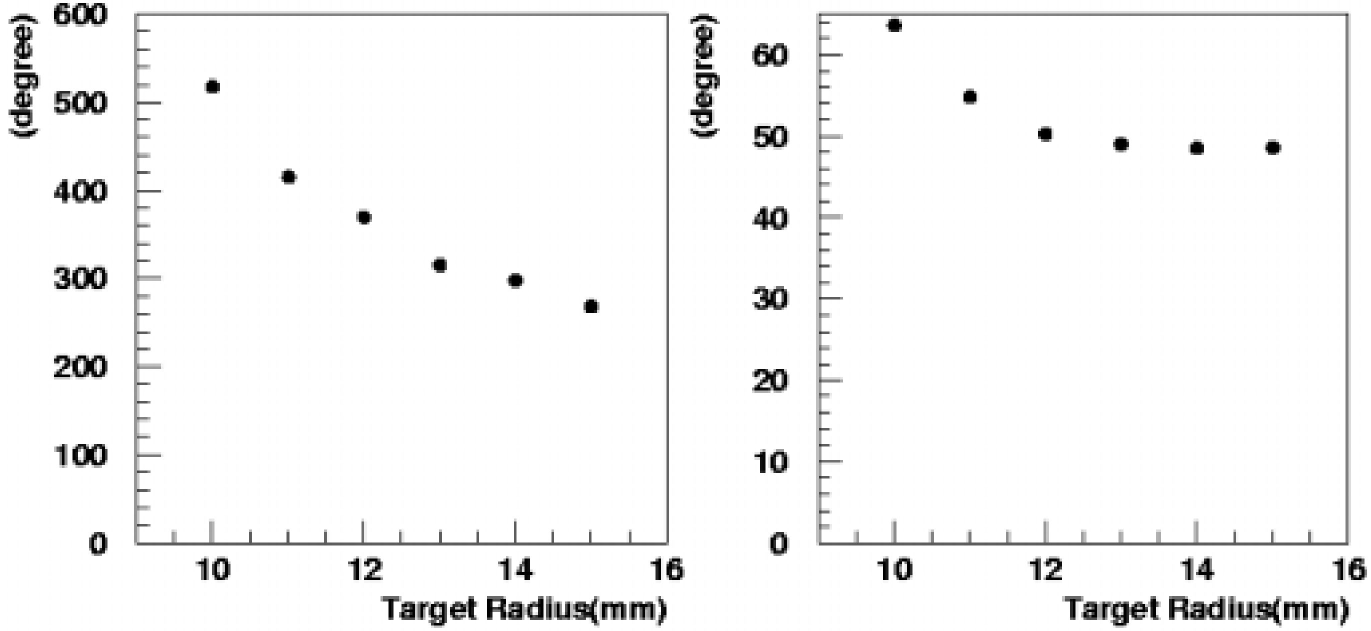
- Pion absorption



$$\sigma_{beam} = \frac{radius}{2.5}$$

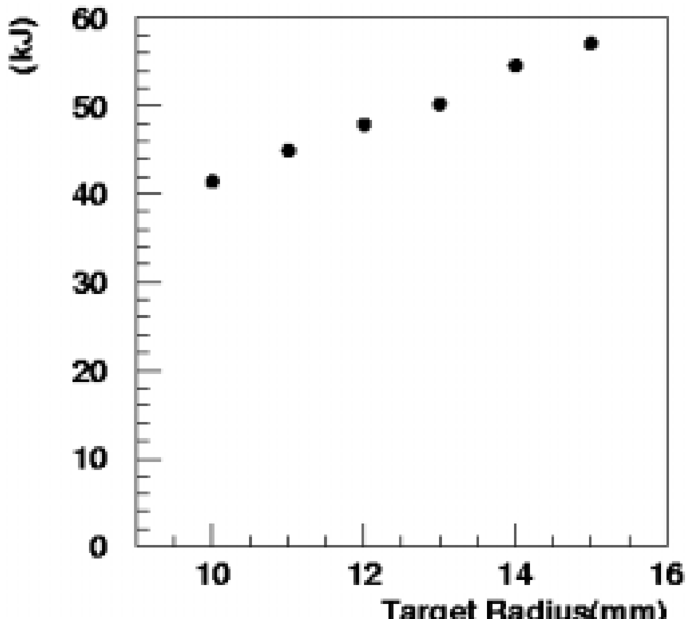
- Temperature rise
- Energy concentration
- Inner radius of the horn
- Beam size ~1cm

Temperature Rise



at center

at surface



Total Energy Deposit

Currently,

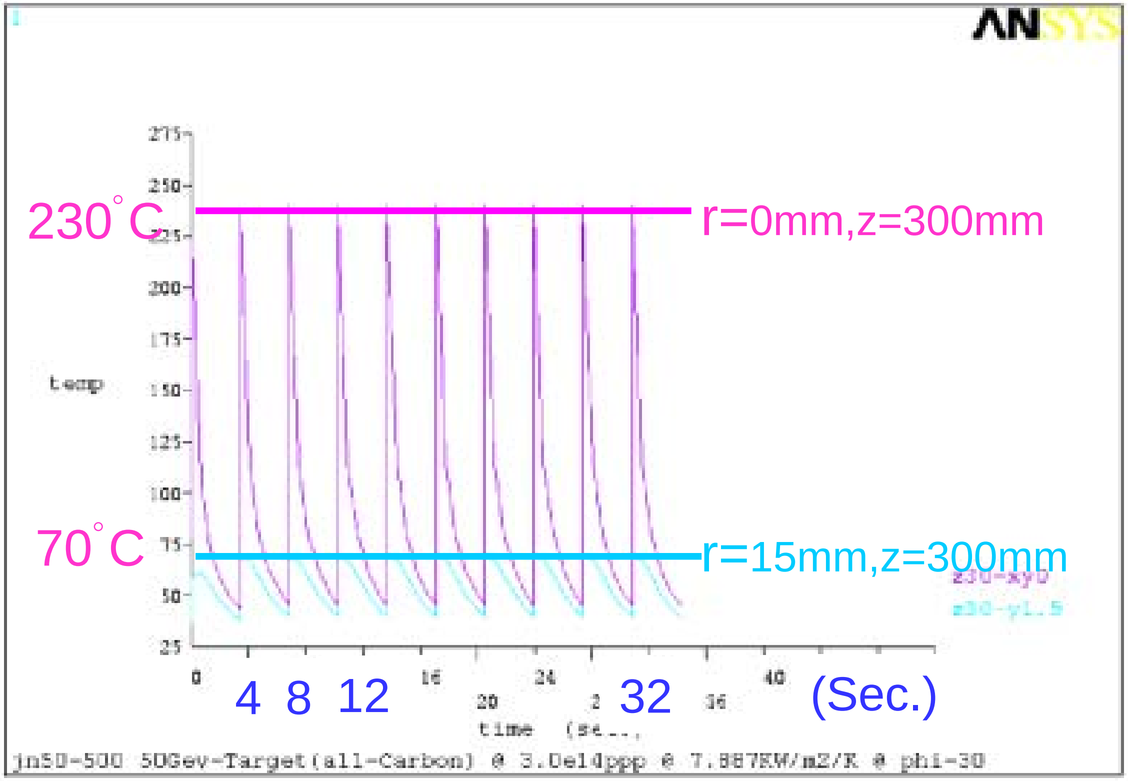
25mm$^{\phi}$~30mm$^{\phi}$ is being considered.

Time dependence of temperature

ΔT_{max}

~200°C at center

~40°C



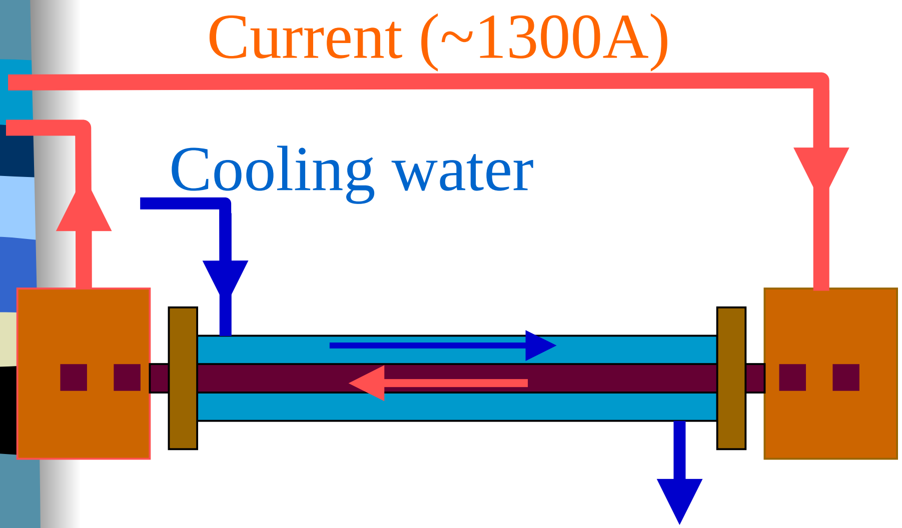
(Thermal convection coefficient on the surface should be larger than ~3000 W/m²/K to satisfy <100°C@surface condition.)

by Y. Hayato and M. Minakawa

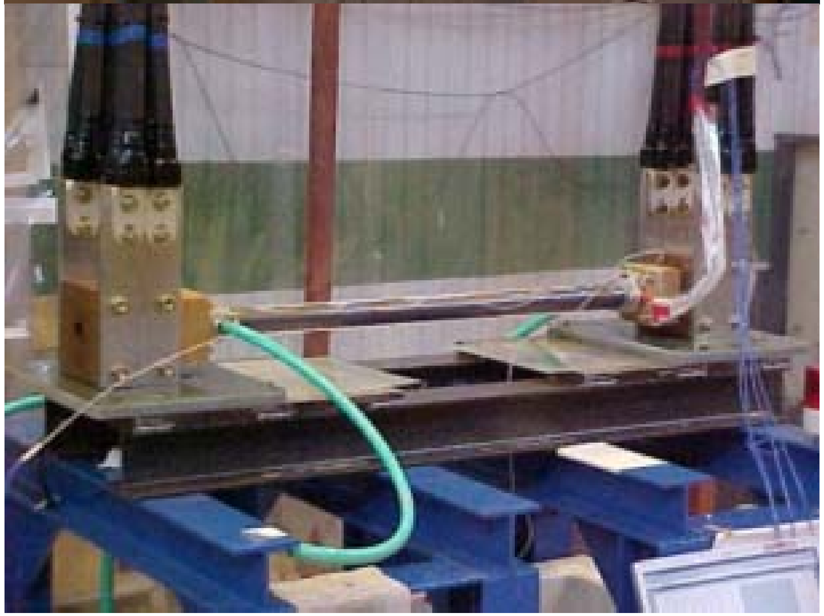
Cooling test

T.Oyabu *et al.*

Heat load by electric current



Cooling w/ surrounding water.



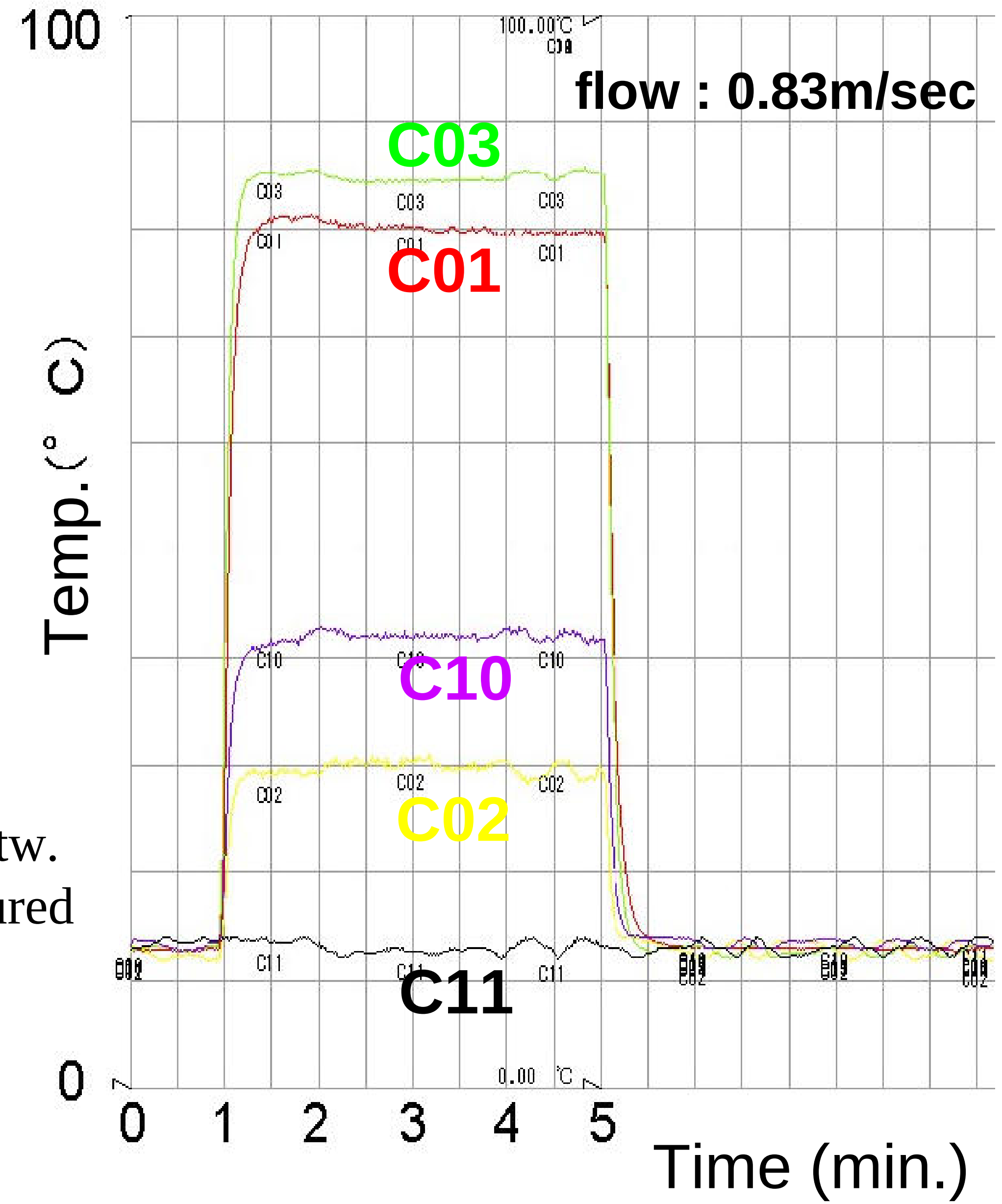
C01 Temp. at the surface of the target

C02 Water temperature

C03 Temp. at the center of the target

C10 Water temperature (out)

C11 Water temperature (in)



Heat convection coefficient btw. graphite and water was measured at various conditions.

Cooling Test w/ more realistic setups

By Y. Hayato

By A. K. Ichikawa

Thermal stress

Calculation by hand

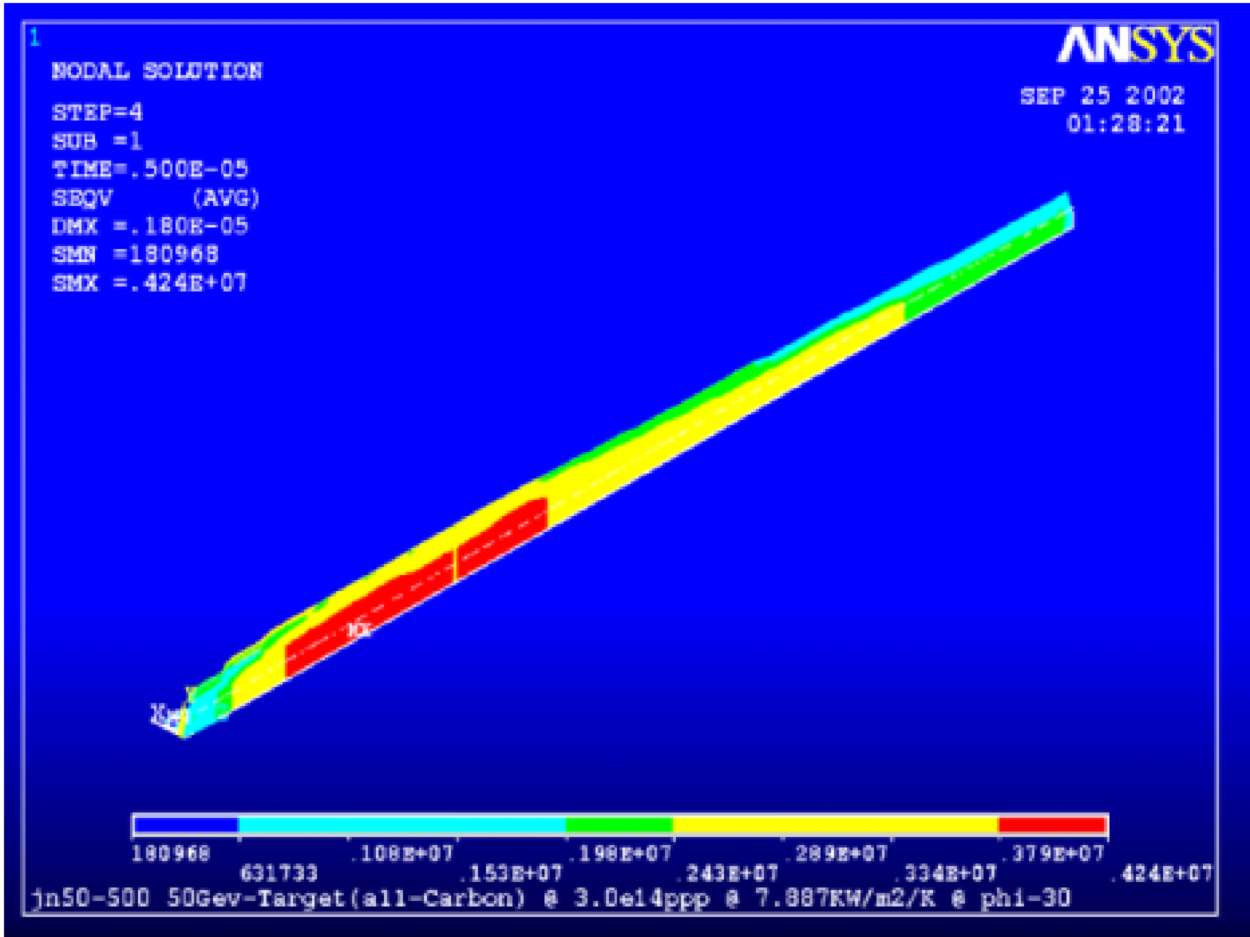
by Y. Hayato

$\sigma_{\text{quasi-static}}$ = 10~15MPa

$\sigma_{\text{dynamical}}$ = ~8Mpa

Safety factor ~3

Stress analysis using FEM just started.



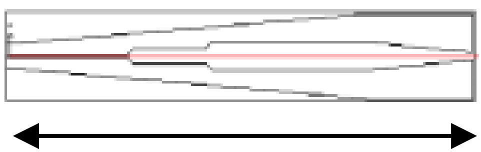
Horns

Scaling laws

W/ fixed current,

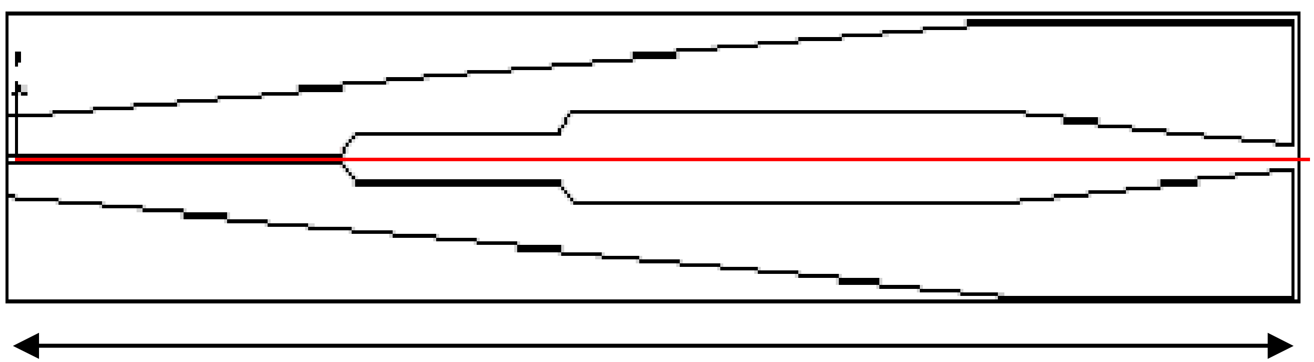
r x 2 → L x 2, Wx2 to obtain same optics.

D_{in} = 1.8cm$^{\phi}$



2.2m

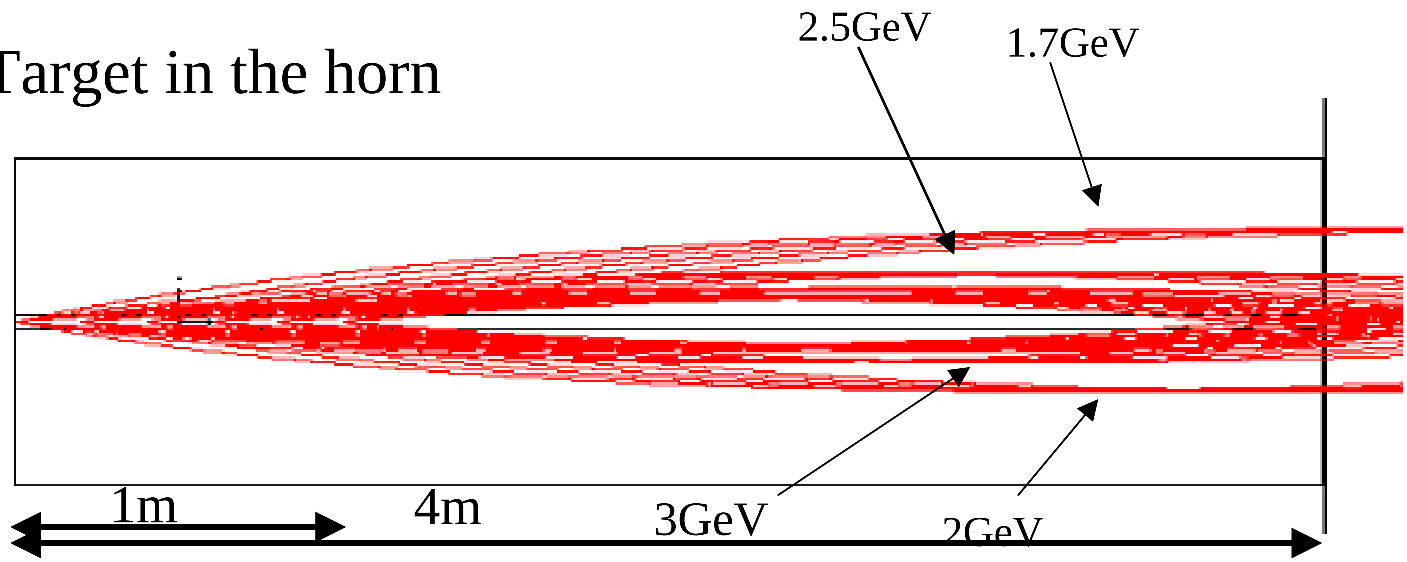
D_{in} = 5.2cm$^{\phi}$



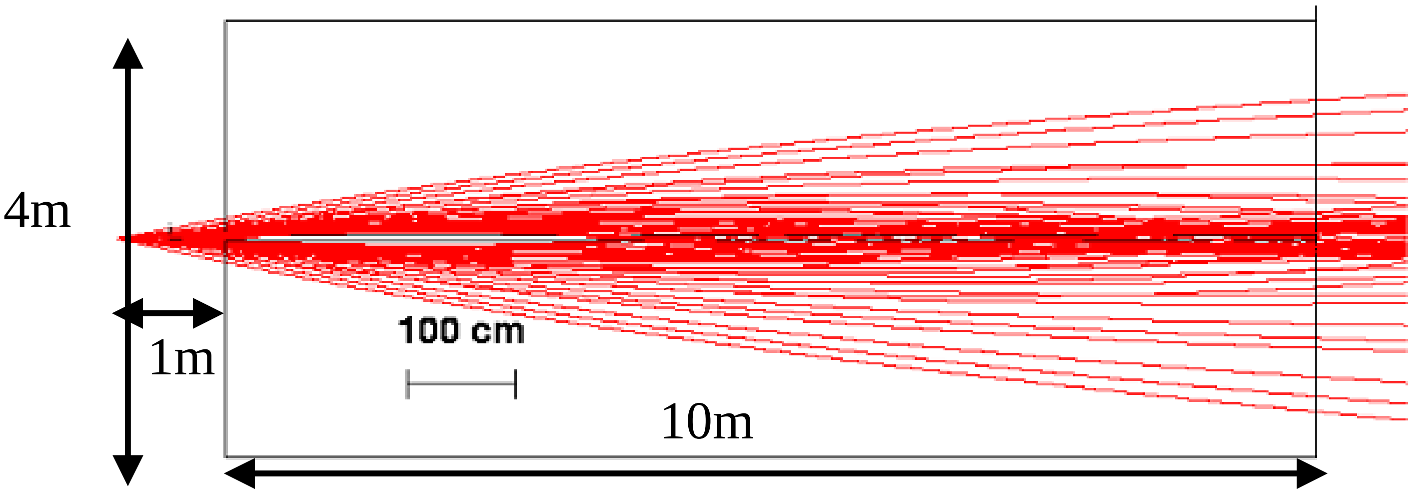
6.4m

Inner conductor 4.6cm$^{\phi}$ I = 250 kA

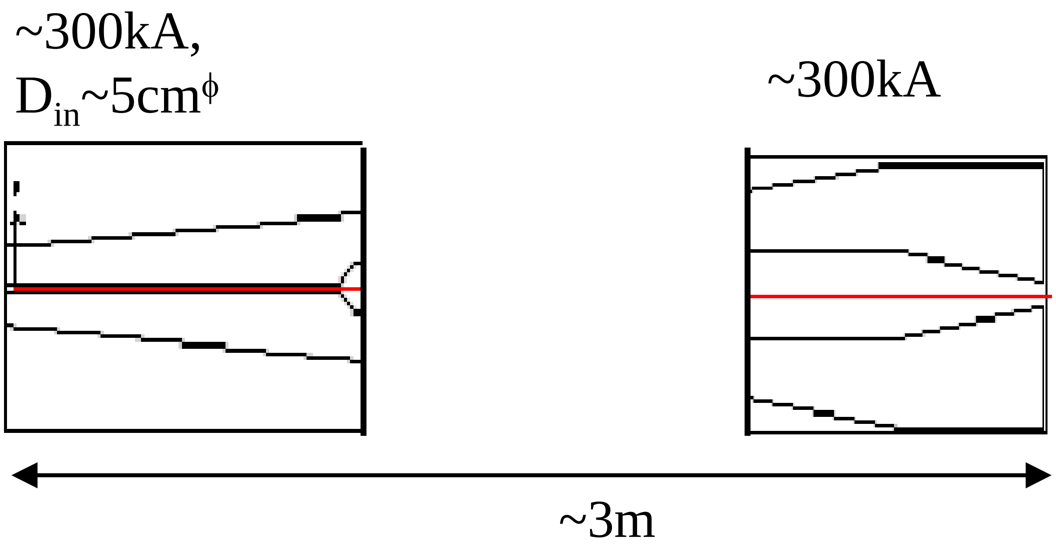
Target in the horn



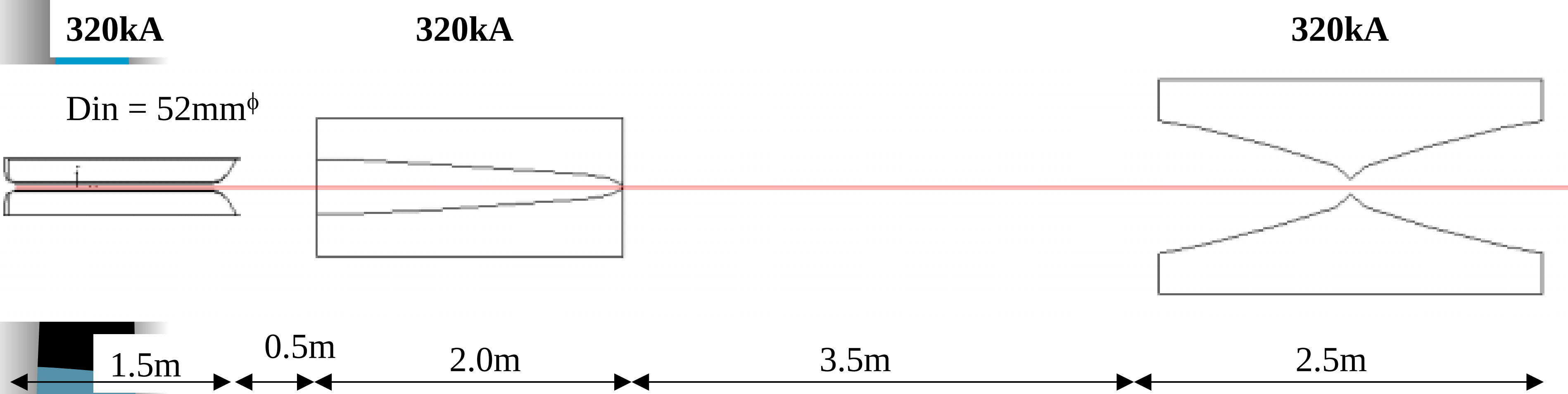
Target outside the horn



The idea for ‘1st horn’



J-Parc neutrino Horn System



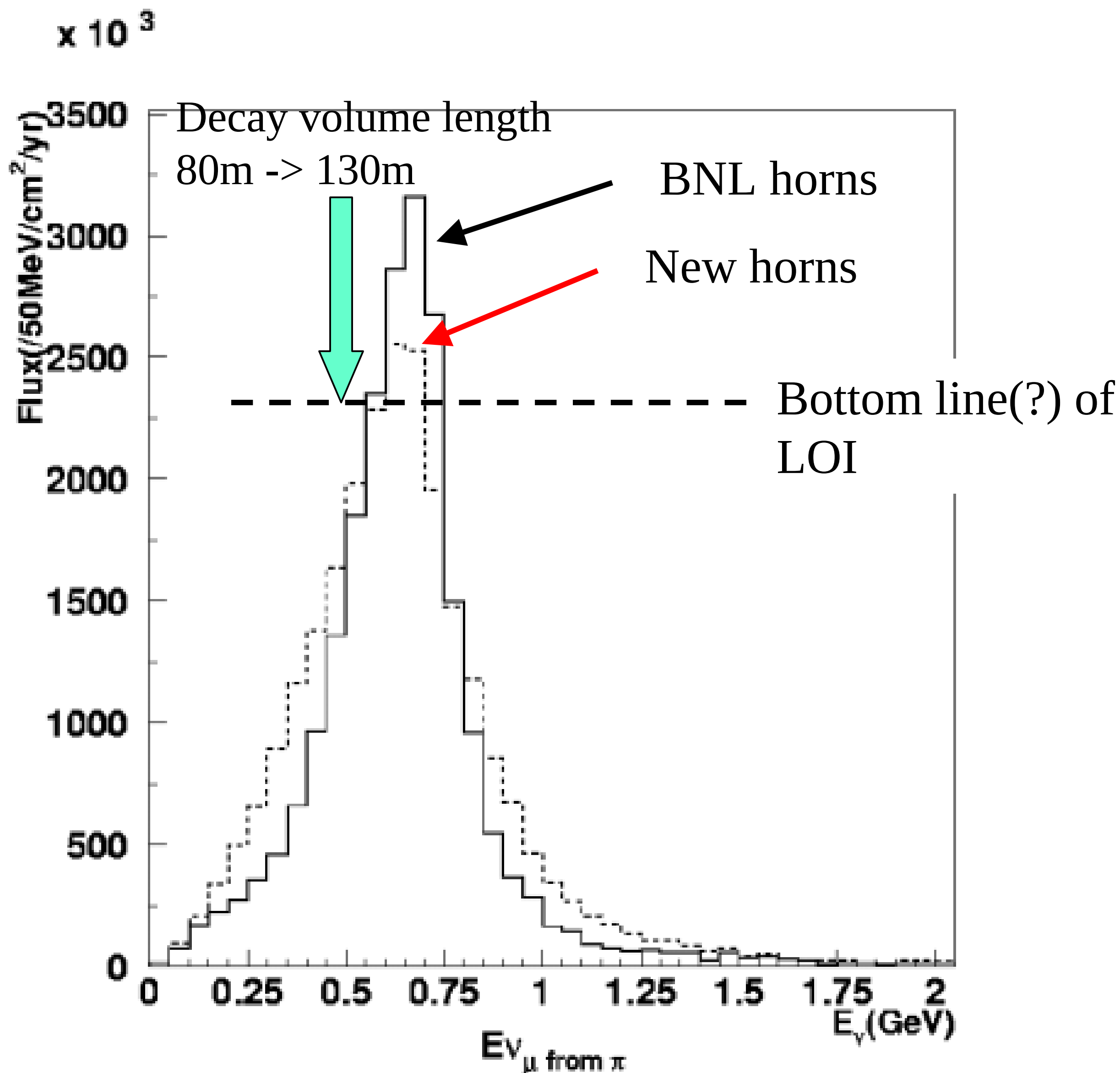
w/ smaller inner-conductor diameter,

the current may be reduced.

But careful examination is necessary both on the target and horn itself.

Flux

Comparison w/o Materials



Stress

Electromagnetic force on inner conductor

$$\boxed{\text{pressure} \propto \left(\frac{I}{r}\right)^2}$$

p=2.5MPa @r=28mm c.f. 4.7 MPa for *K2K*

Allowable stress

Aluminum 6061-T6(extrusion)

yield strength 282 MPa

10^8 cycle fatigue strength 69MPa

moisture x 0.43

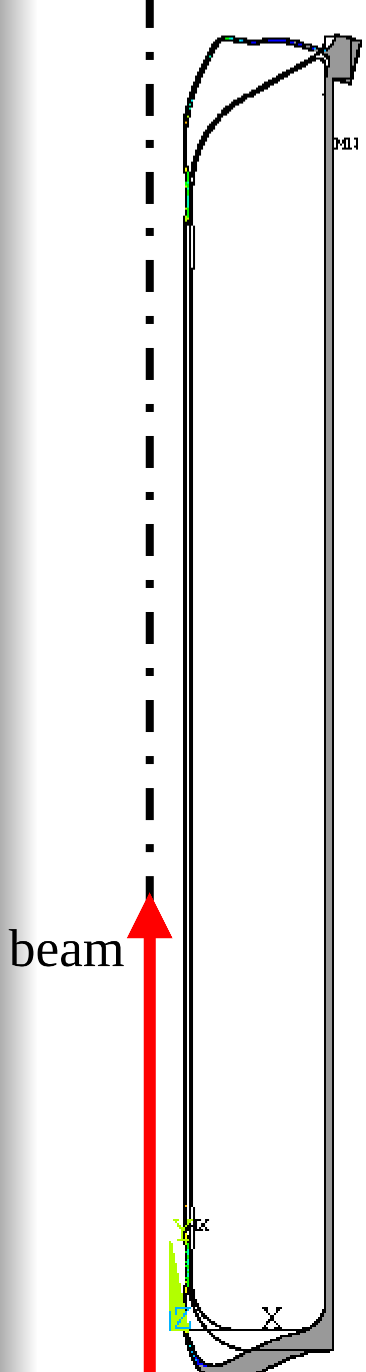
stress ratio x 0.85

allowable stress 25 MPa x f_{weld}

Ref. L.Bartoszek MiniBooNE horn review

http://www.bartoszekeng.com/mboone/mboone.htm

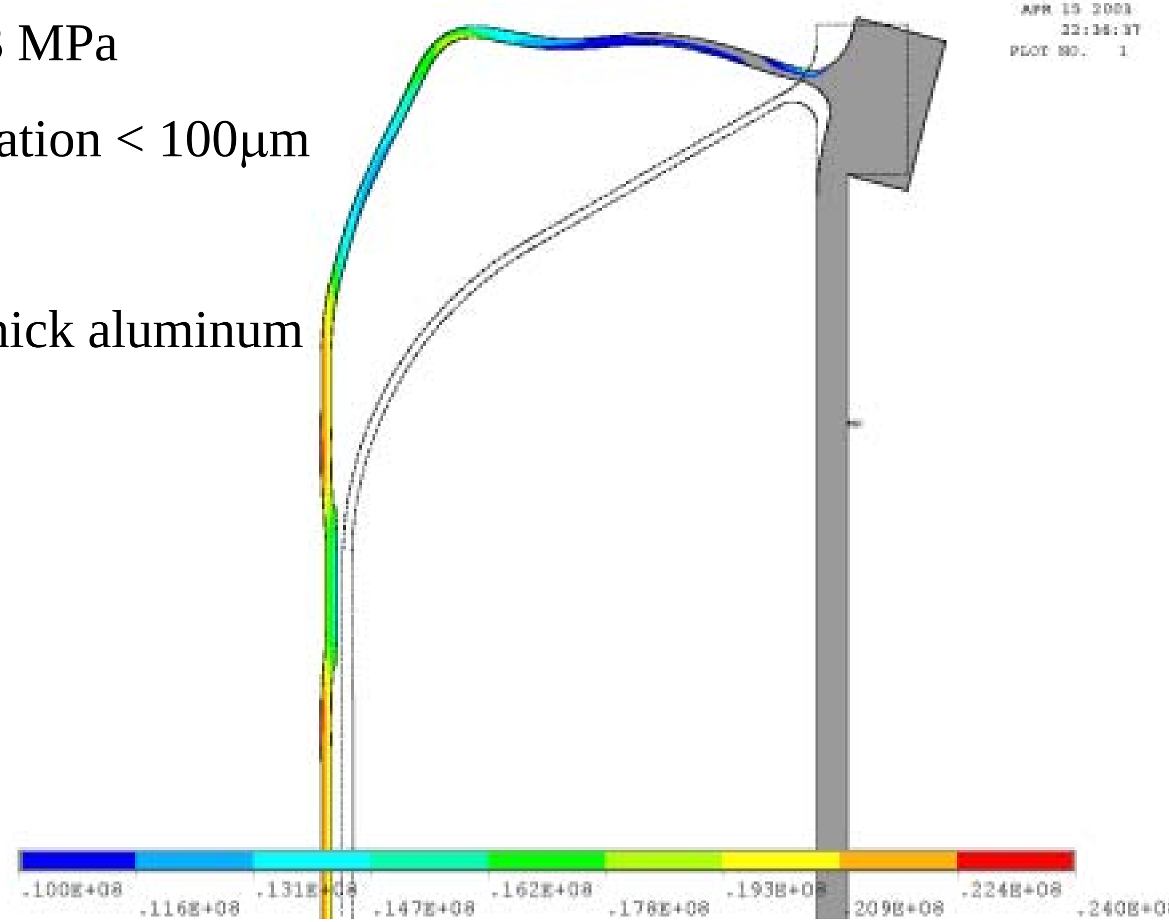
Stress analysis using ANSYS



σ_{eq} < 23 MPa

Deformation < 100μm

3mm thick aluminum



1st horn Cylindrical model

Only stress from Lorenz force is considered.

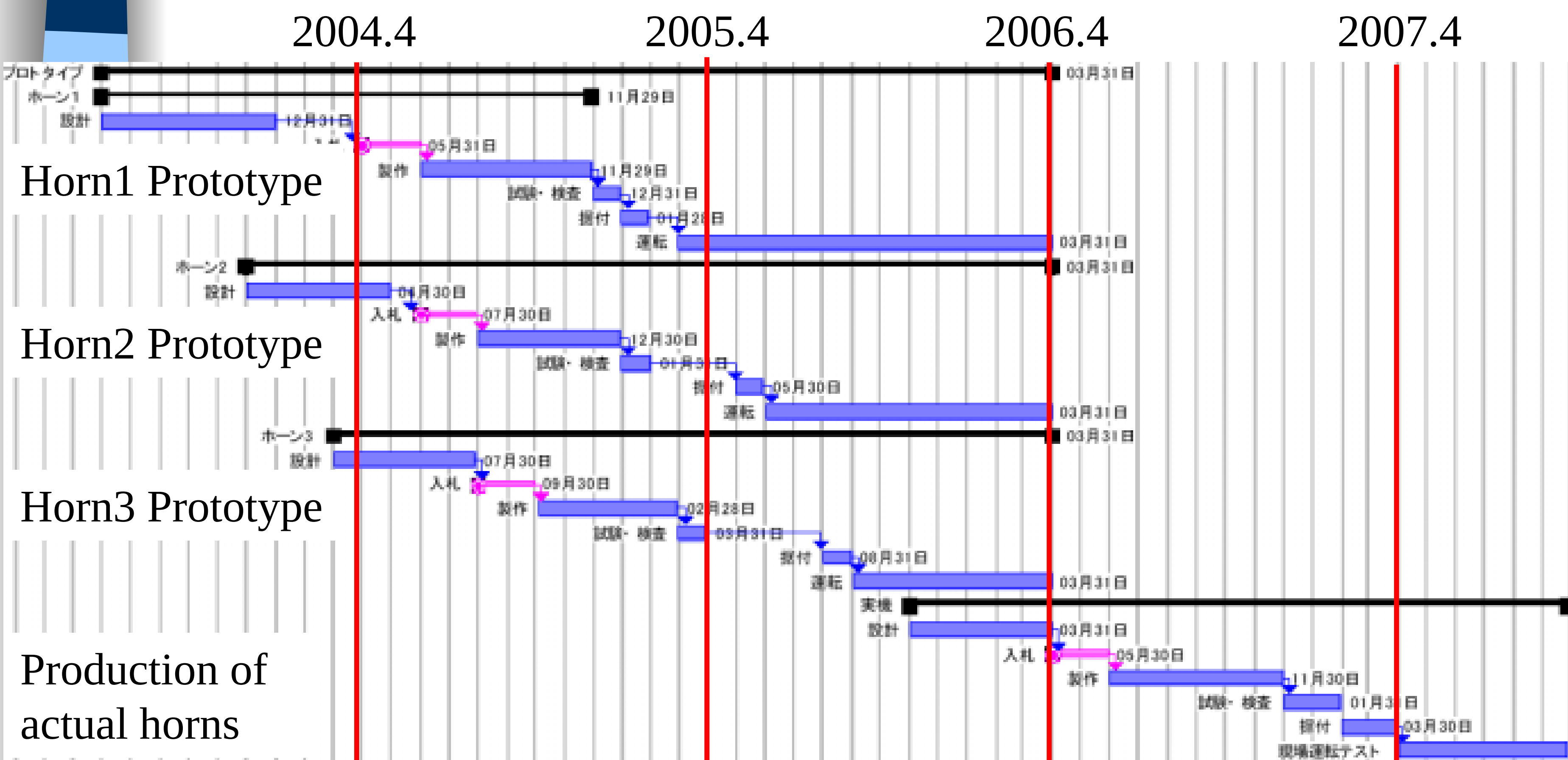
Stress from heat load should be considered.

Schedule (preliminary)

This year:

conceptual design as focusing device

examination of many items such as mechanical stress, cooling and power supply w/ **Y. Suzuki and Y. Yamanoi**



Example of Possible items expected to Foreign Institute

This is not a perfect list. More discussion is necessary.

Target :

Material itself

(graphite w/ good mechanical property, C-C composit, etc.)

Measurement of quality(strength, radiation resistivity, heat conduction etc.) of materials

Horns :

Independent stress analysis

Production of inner conductor

Summary

Target

Base line of the current design is

graphite of 25~30mm$^{\phi}$ surrounded by cooling water

In this year, cooling test and examination of various items such as mechanical stress calculation and cooling schemes will be conducted.

Horns

Base line of the current design is

3 horns with 320kA current.

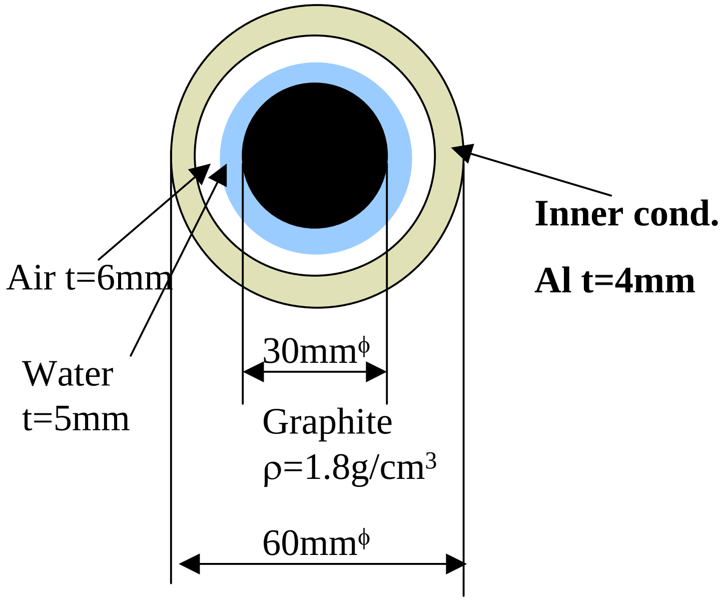
In this year, conceptual design will be completed and examination of various items such as mechanical stress, cooling and power supply will be conducted.

Supplement

Heat Load from Radiation

DIRECT ENERGY DEPOSITION (GEV/G PER INC.PARTICLE)
AS A FUNCTION OF DEPTH(DOWN) AND RADIUS(ACROS) IN CM

Z \ R	0.000E+00 – 1.500E+00	1.500E+00 – 2.000E+00	2.000E+00 – 2.600E+00	2.600E+00 – 3.000E+00
10.000	7.208E-04	9.355E-05	5.157E-05	2.922E-05
30.000	9.879E-04	2.595E-04	1.964E-04	9.382E-05
50.000	1.029E-03	3.665E-04	2.684E-04	1.565E-04
70.000	1.006E-03	4.255E-04	2.693E-04	2.063E-04
90.000	9.019E-04	4.486E-04	4.421E-04	2.402E-04
110.000	6.291E-04	3.214E-04	2.430E-04	2.338E-04
130.000	3.534E-04	1.995E-04	2.078E-04	1.851E-04
150.000	2.377E-04	1.384E-04	1.474E-04	1.605E-04
170.000	2.192E-04	1.193E-04	1.250E-04	1.349E-04
190.000	1.917E-04	1.161E-04	1.192E-04	1.134E-04
210.000	1.924E-04	9.384E-05	1.082E-04	9.616E-05
230.000	1.327E-04	9.592E-05	1.225E-04	8.818E-05



In the graphite target, 64kJ/3.3E14 protons in total

TEMPERATURE RISE (K) AT TO= 3.000E+02 PER 3.300E+14 PPP
AS A FUNCTION OF DEPTH(DOWN) AND RADIUS(ACROS) IN CM

Z \ R	0.000E+00 – 1.500E+00	1.500E+00 – 2.000E+00	2.000E+00 – 2.600E+00	2.600E+00 – 3.000E+00
10.000	4.944E+01	1.181E+00	6.512E-01	1.713E+00
30.000	[illegible]	[illegible]277E+00	2.480E+00	5.495E+00
50.000	[illegible]	[illegible].627E+00	3.390E+00	9.156E+00
70.000	6.675E+01	5.373E+00	3.400E+00	1.206E+01
90.000	6.056E+01	5.665E+00	5.582E+00	1.404E+01
110.000	7.943E+00	4.058E+00	3.069E+00	1.366E+01
130.000	4.462E+00	2.519E+00	2.624E+00	1.083E+01
150.000	3.001E+00	1.747E+00	1.861E+00	9.393E+00
170.000	2.767E+00	1.507E+00	1.578E+00	7.894E+00
190.000	2.421E+00	1.466E+00	1.506E+00	6.639E+00
210.000	2.429E+00	1.185E+00	1.366E+00	5.632E+00
230.000	1.675E+00	1.211E+00	1.546E+00	5.165E+00

$\Delta t \sim 14^{o}$

In total,

34kJ/3.3E14 protons = 10 kW @ 0.3Hz

cf. K2K heat load in the target from the current

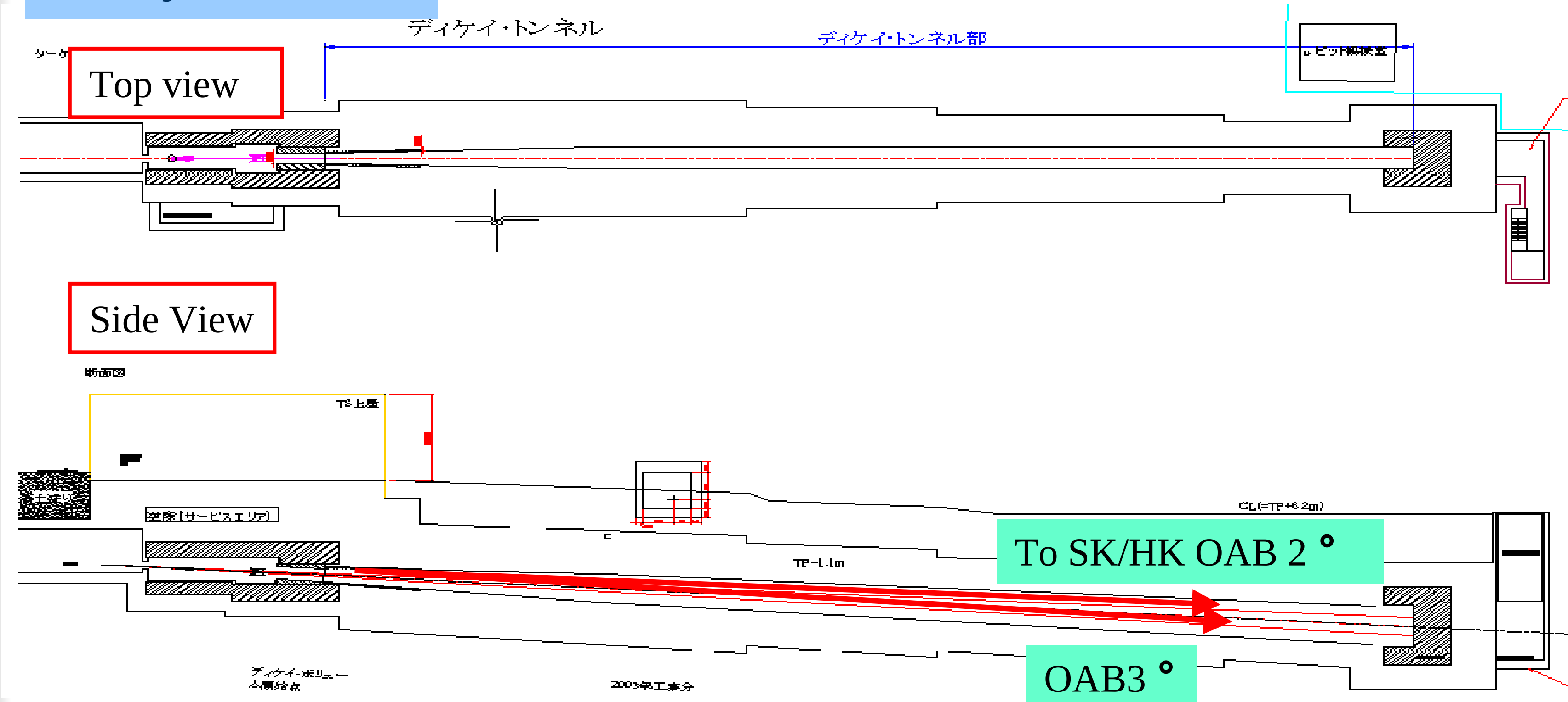
= 1.4 kW

(surface area ~x 7)

Change the neutrino beam energy

$\Delta m^2\ [10^{-3}eV^2]$	2.04 (90% A.R.)	2.18 (80% A.R.)	2.75 (best fit)	3.17 (80% A.R)	3.28 (90 % A.R)
$E_\nu[GeV]$	0.487	0.520	0.656	0.756	0.782
OA angle[deg.]	3.1	3.0	2.4	2.1	2.0

Decay Volume



jnubeam : neutrino beam simulation code

developed from K2K code

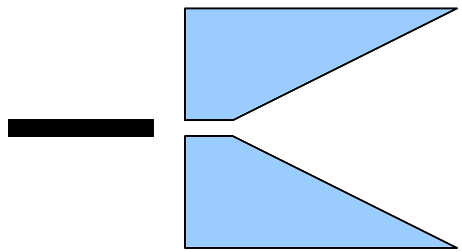
- DV shape : incorporate actual shape
- target & horns : still BNL-type.
- calculation of ν-flux at SK for all decays by weighting
- Hadron production model
    1. Models built-in Geant3. e.g. GFLUKA..
    2. Various models using Input via stdout | stdin.

        > MARS | jnubeam

        > FLUKA2000 | jnubeam

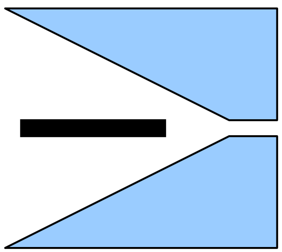
Types for the 1st horn

(a)



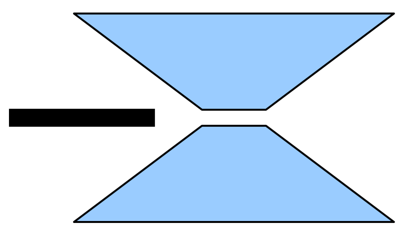
(μ-factory)

(b)



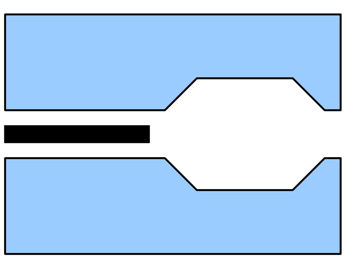
(2nd horn)

(c)



MINOS

(d)

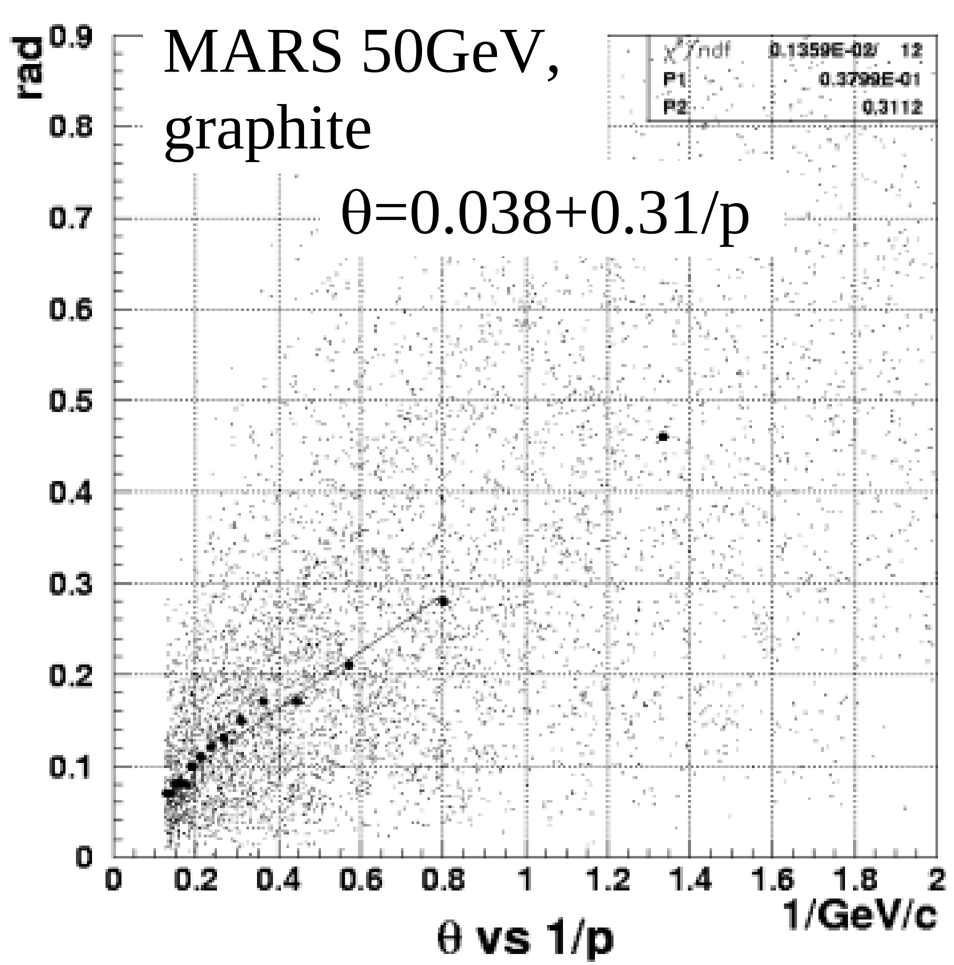


K2K, CERN, BNL

π production –Model-

Momentum and angle of π

$<\theta>=\text{const.}+\text{const.}/<p>$



MARS

50GeV : $\theta=0.038+0.31/p$

30GeV : $\theta=0.038+0.33/p$

GFLUKA+GCALOR

50GeV : $\theta=0.023+0.33/p$

30GeV : $\theta=0.025+0.32/p$

FLUKA2000

50GeV : $\theta=0.026+0.31/p$

30GeV : $\theta=0.033+0.31/p$

Momentum region of π's

w/ BNL-type horn, 2.5 ° OAB

π's contributing E_ν<1.2GeV