The JPARC Neutrino Target

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for T.Nakadaira

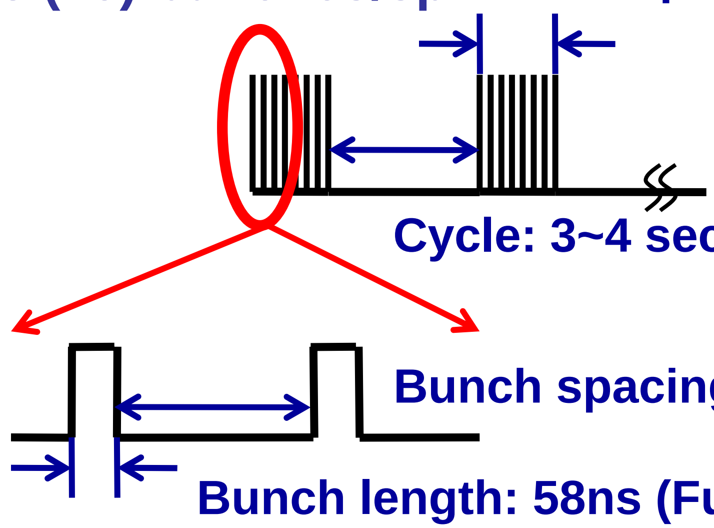
& J-PARC ν beam-line construction group

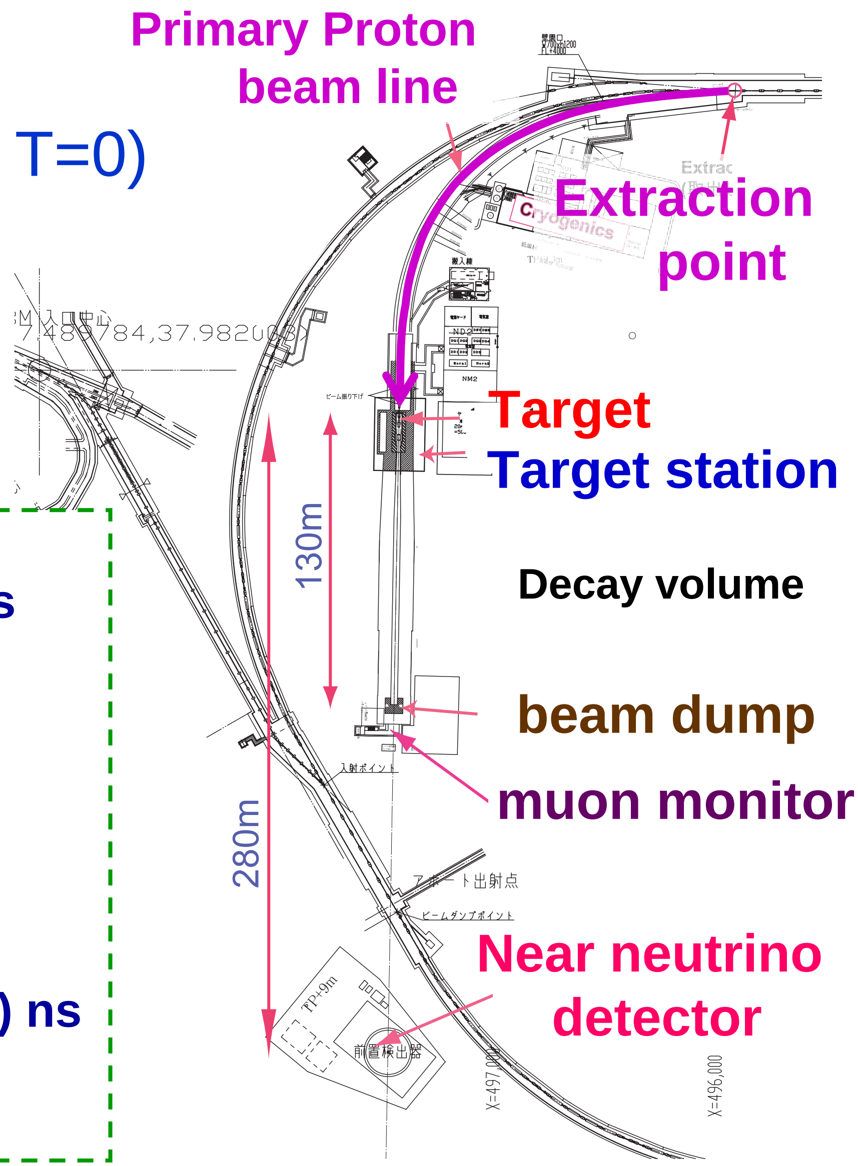
(I borrowed most of all the transparencies from Nakadaira-san)

J-PARC neutrino beam line

Proton Energy	50GeV
	(40/30GeV @ T=0)
# of Protons / pulse	3.3×10^{14}
Beam Power	750kW
	→ 4MW @ Phase II

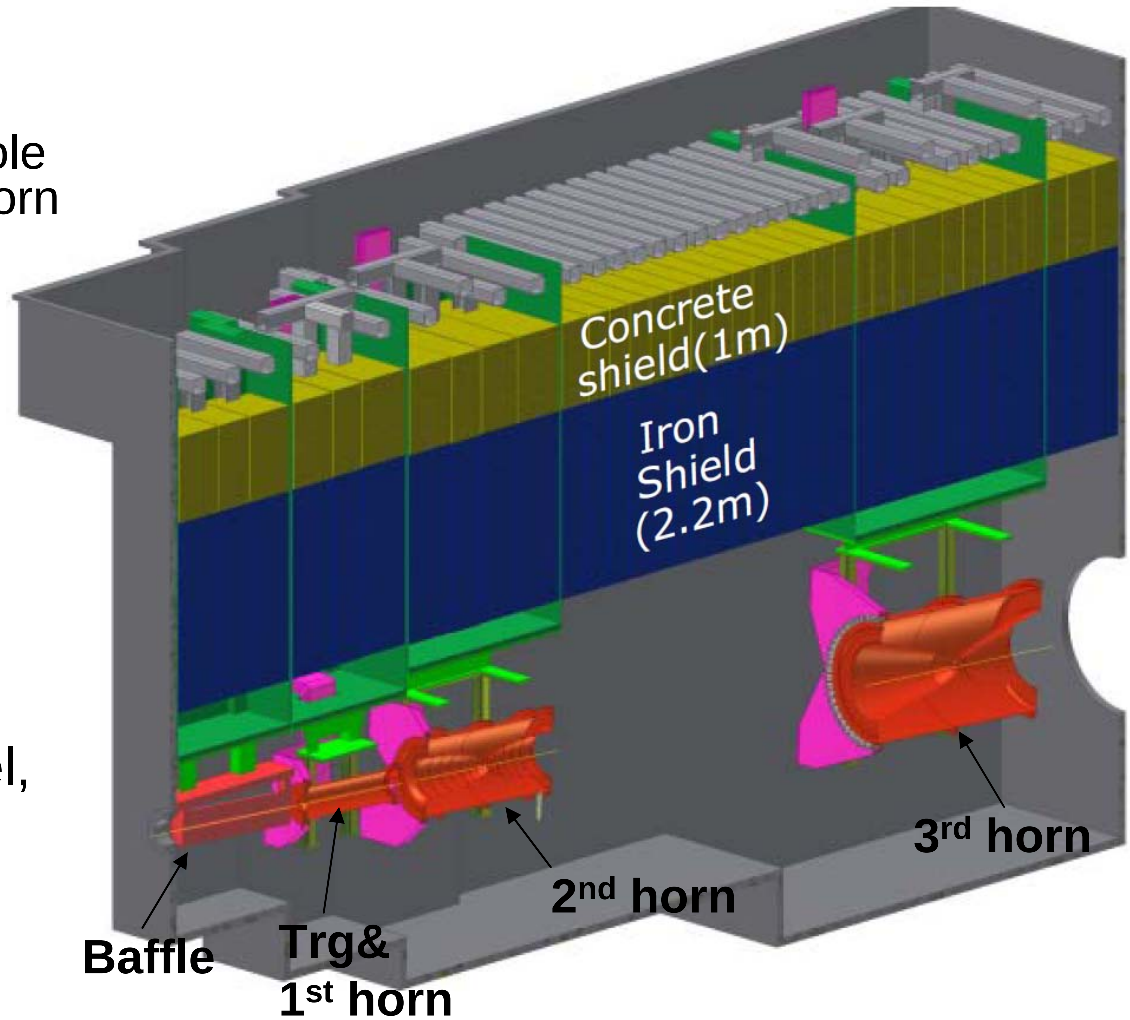
Bunch structure

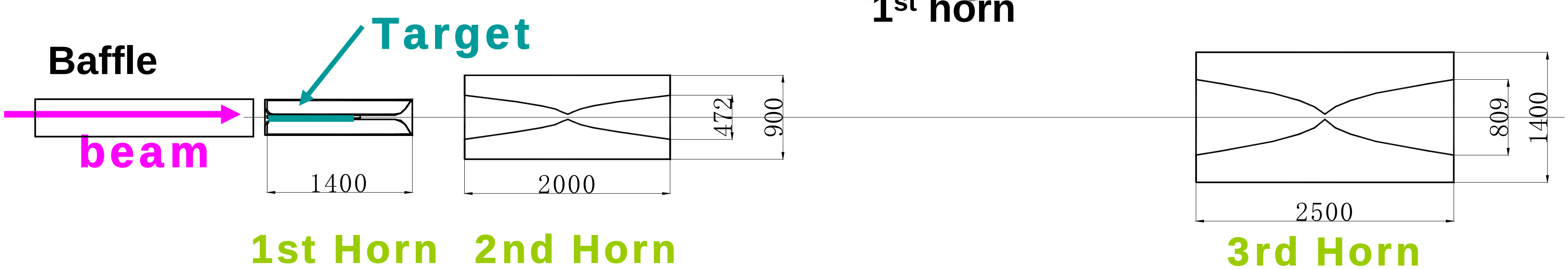




Target Station

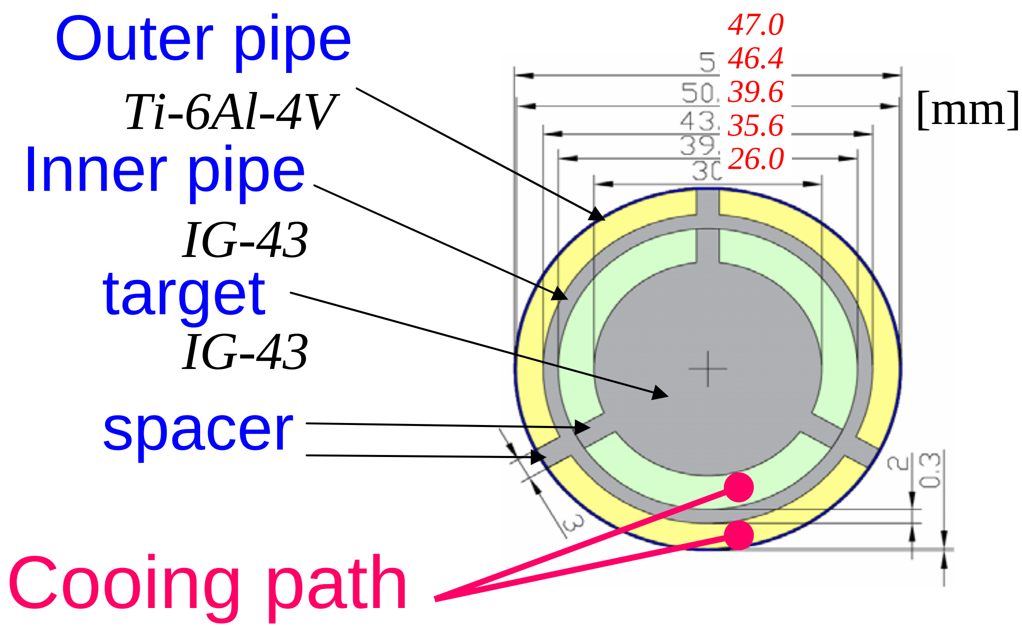
- Accommodate
  - Baffle: Graphite, 32mmϕ hole x 1.7m long to protect 1st horn
  - Target
  - 3 Horns
- Area filled with Helium gas
  - reduce Tritium, NOx production
- Highly radio-activated
  - ~1Sv/h,
  - Need remote-controlled maintenance system
- Need cooling (Helium vessel, radiation shield,..)



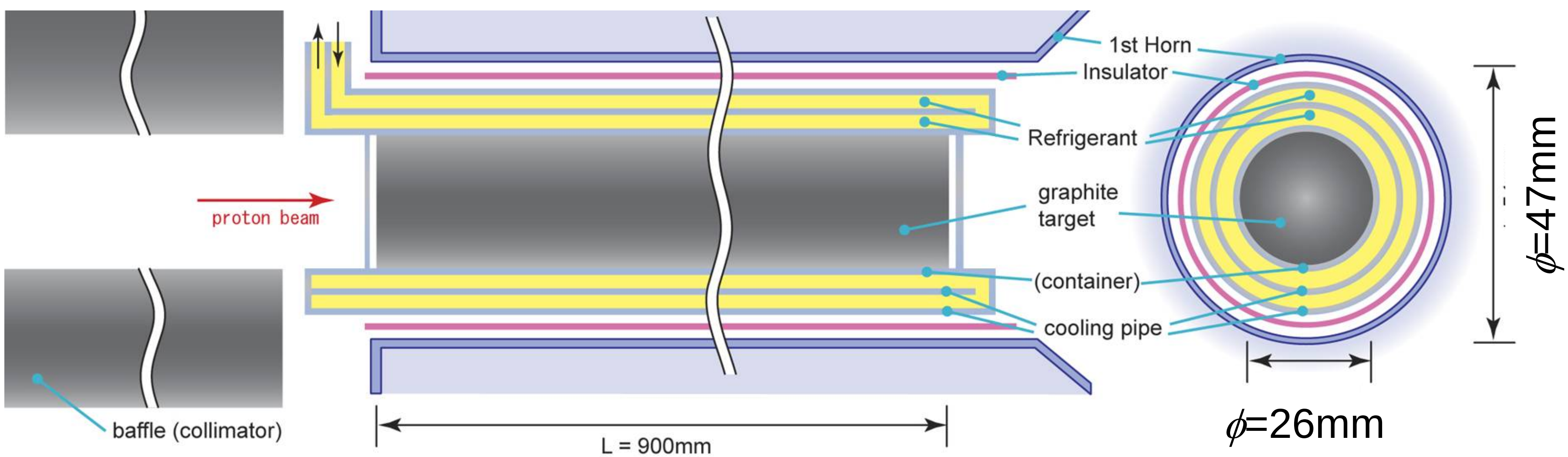


Target dimension

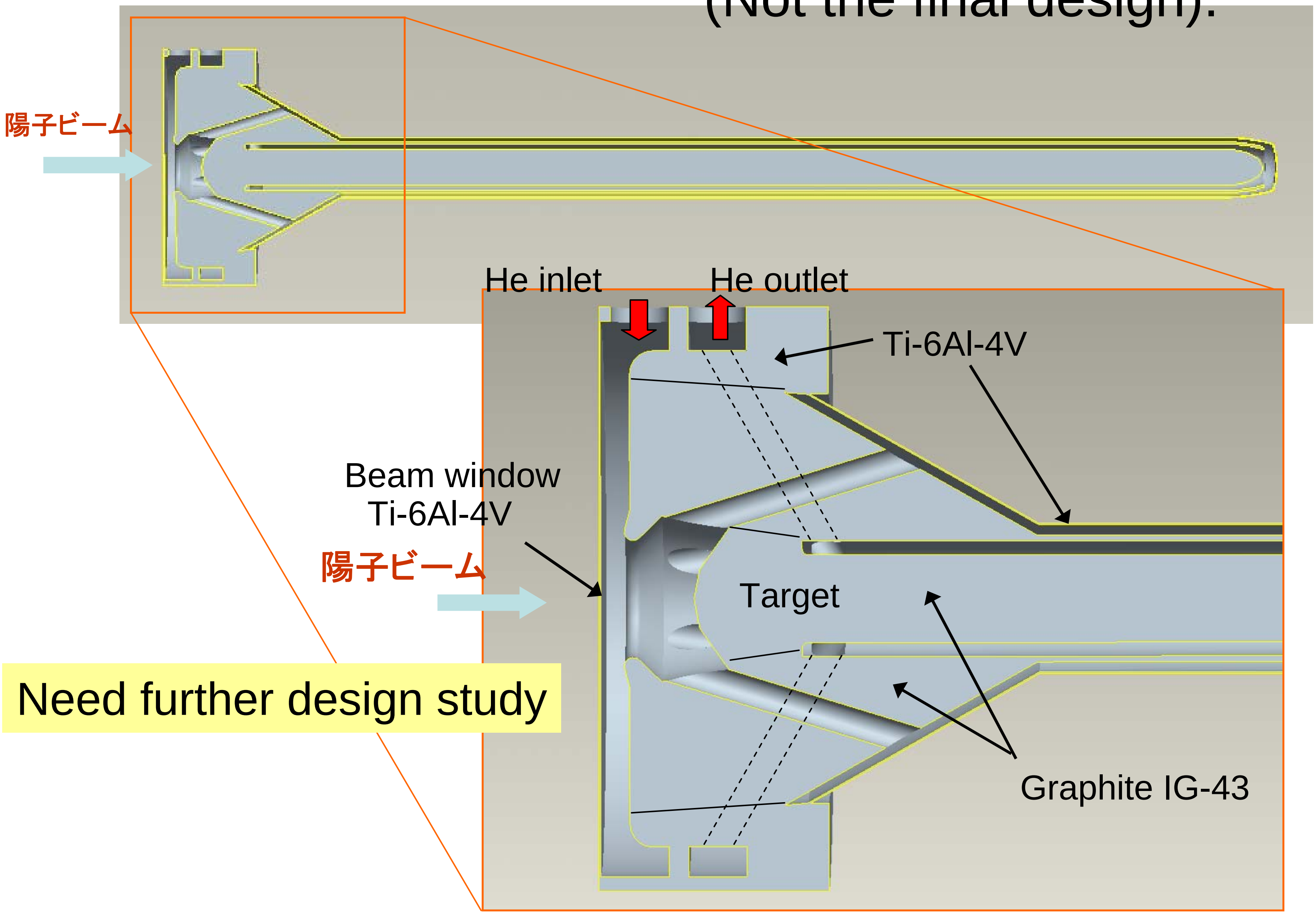
- Co-axial 2 layer cooling pipe: Graphite / Ti-6Al-4V, Helium cooling



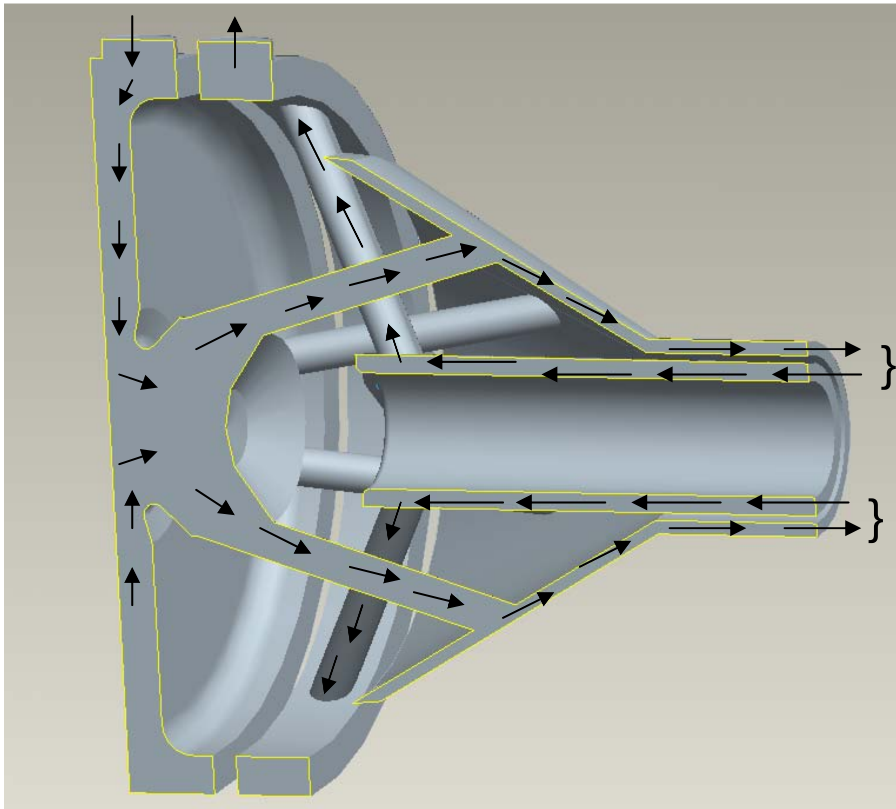
Sectional area
= 4.6×10^{-4} [m^2]

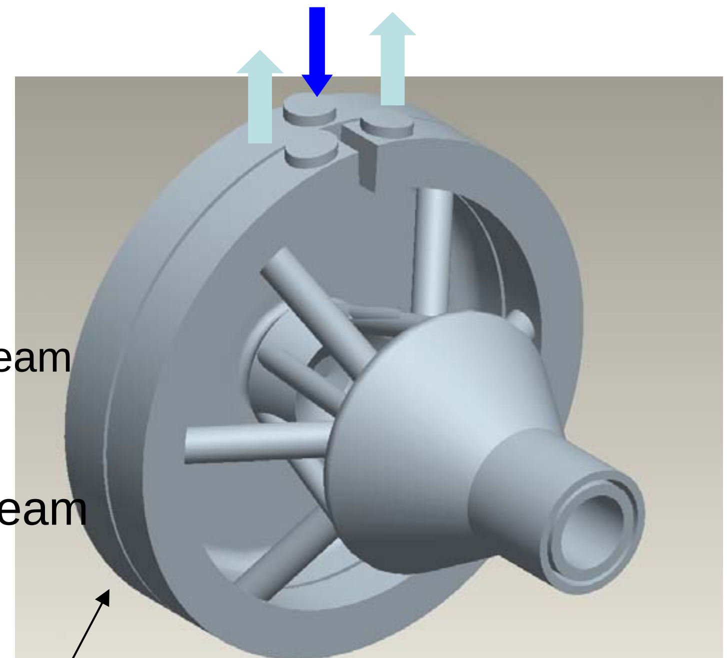


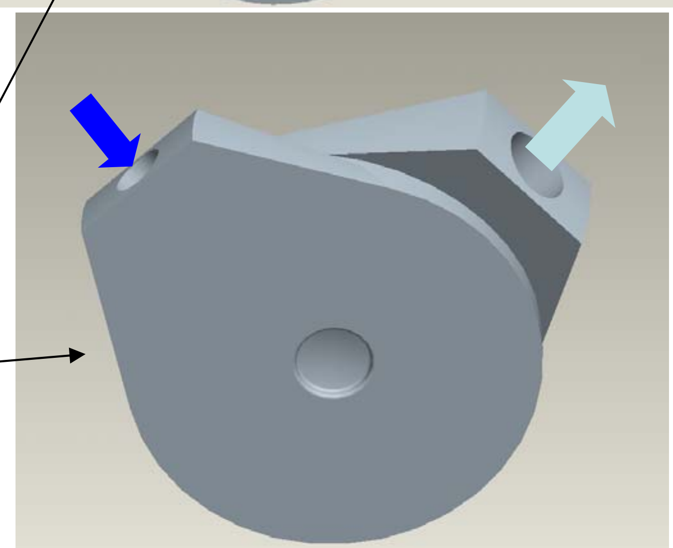
One design of the target & surrounding cooling pipe (Not the final design).



Need further design study







Design of inlet and outlet
of He Gas is not fixed.

Target cooling : Water or Helium?

	Water Cooling	Helium Gas cooling
Advantage	☺Very Efficient ← High Heat transfer ratio ☺ Already tested. ☺ Simple circulation system	☺We can control T_{target} to minimize the irradiation effect. (T_{target} = 400 ~ 800 °C) ☺ Reduce radioactive waste water ☺ No target container is needed
Disadvantage	☠large Irradiation effect ← $T_{target} \leq 300°C$ to avoid the water boiling: T_{target} @ surface < 100°C ☠Target container is needed. ☠ΔP_{water}= ~2MPa due to the temperature rise by a beam hit. ☠Huge radioactive waste water	☠ Very High flow rate ~ 2000 l/min [0.5MPa] ~ 12000 l/min [0.1MPa] ☠ Circulation system is complicated. ☠ Special treatment for the high temperature gas (200°C) is necessary.

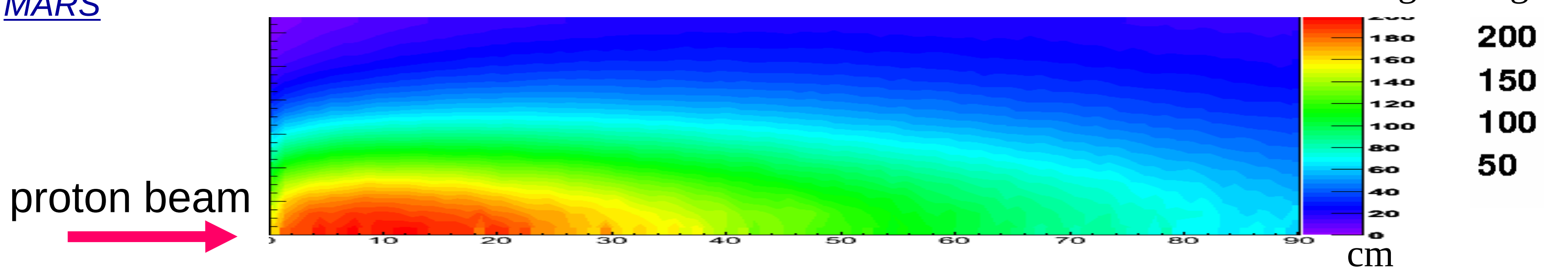
Target : Conceptual design

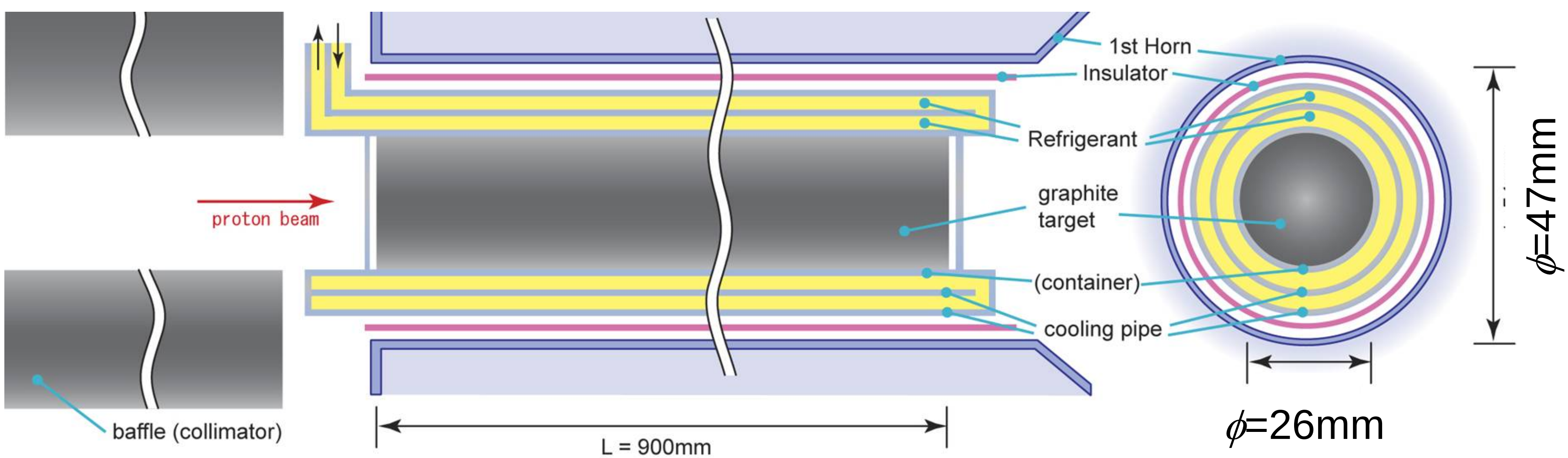
- Core: Isotropic-Graphite : IG-43 (Toyo Tanso Co. Ltd)
  - Energy deposit… Total: ~40kJ/spill (30GeV)

    → $\Delta T \approx 200K$. $\sigma_{eq} = 7.5$ [MPa] ↔ Tensile strength = 37.2 [MPa]

MARS

Distribution of the energy deposit in the target (w/ 1 spill)

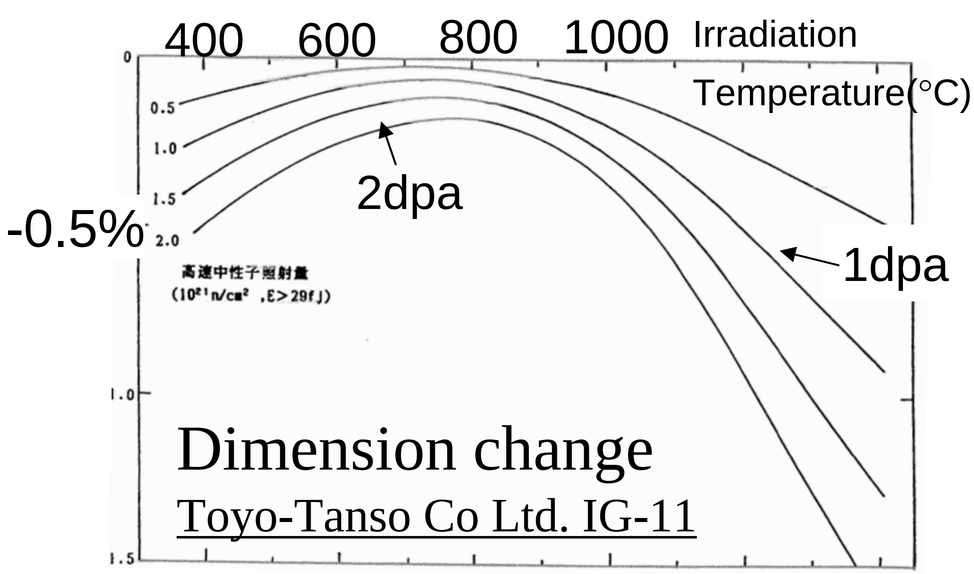


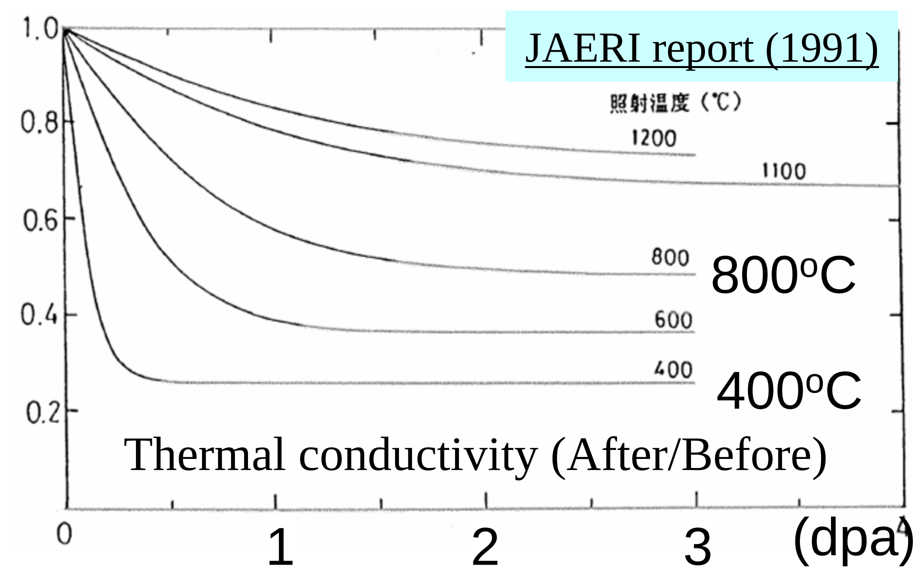


R_{target}	13 [mm]
ΔR (target ~ horn)	3[mm]
Energy deposit (30GeV, $\sigma_x = \sigma_y$ =4.24mm)	
Target	39.3 [kJ/spill]
Inner Pipe	3.5 [kJ/spill]
Outer Pipe	1.1 [kJ/spill]
Insulator	1.5 [kJ/spill]
Targeting Efficiency For Gaussian beam	99.09% (0.91%loss)
Helium flow (T_{gas} < 200°C, suction=0.03MPa)	
Cross section	459.3 [mm^2]
Flow rate	491 [Nm^3/h]
Avg. speed @ target	246 [m/s]
ΔP @straight part+1st hex	0.0833 [MPa]

Irradiation Effect of Graphite

- **Expected radiation damage of the target**
  - The approximation formula used by NuMI target group : 0.25dpa/year
  - MARS simulation : 0.15~0.20 dpa/year
- **Dimension change** : shrinkage by **~5mm in length** in 5 years at maximum.
  ~75μm in radius
- **Degradation of thermal conductivity** … decreased by **97%** @ 200 °C
  70~80% @ 400 °C
- **Magnitude of the damage strongly depends on the irradiation temperature.**
  - It is better to keep the temperature of target around <u>**400 ~ 800 °C**</u>

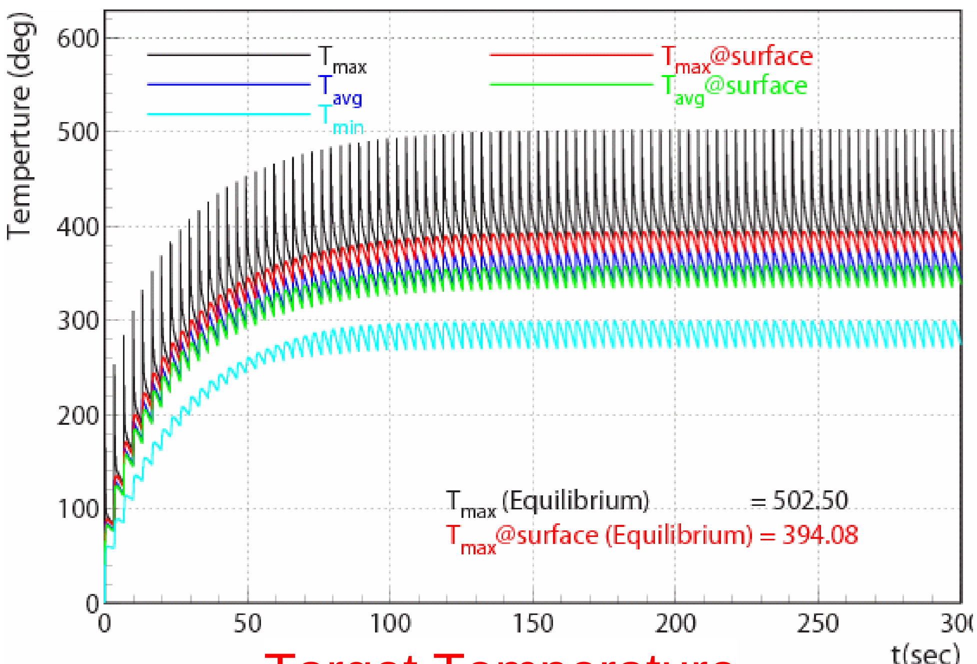




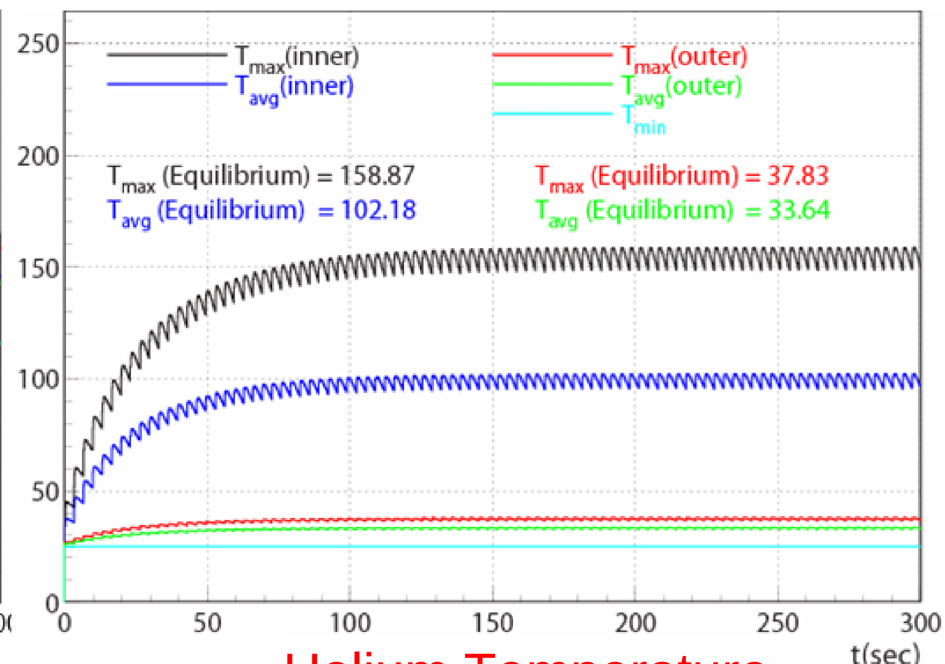
FEM simulation of He cooling

- Assumptions: 0.19MPa
  He Initial temperature: 25 °C
  He flow rate: 6000 [l/min] → 194 [m/sec]
  Heat convection rate: 820 [W/m²/K]

(**50GeV,ϕ=15mm**)



Target Temperature

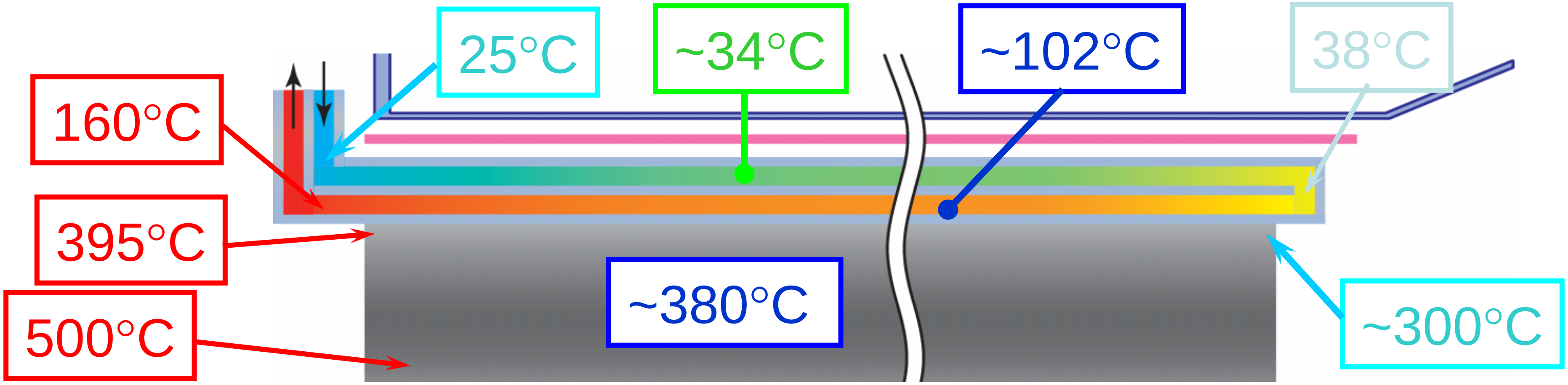


Helium Temperature

Max: ~ 500 °C
Min: ~ 300 °C
Avg. : ~380 °C

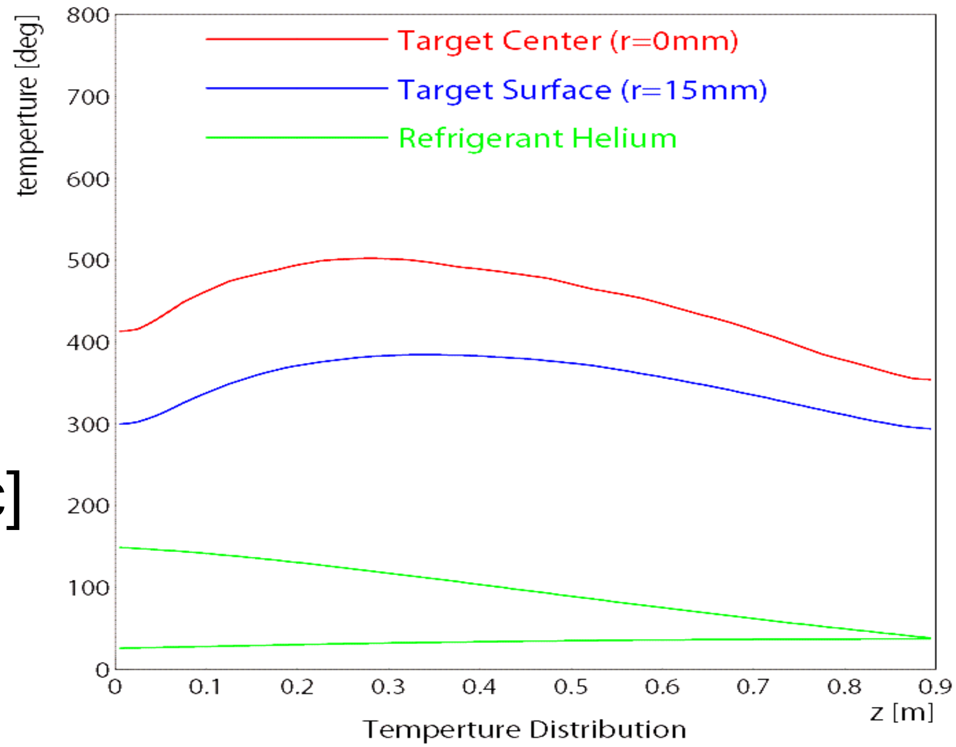
Max: ~160 °C
(ΔT = 135 °C)
Avg. : ~40 °C

FEM simulation of He cooling



(50GeV,ϕ=15mm)

- Assumptions: 0.19MPa (←Possible pressure drop at the downstream of target is taken into account.)
- He Initial temperature: 25 °C
  He flow rate:
  6000 [l/min] → 194 [m/sec]
  Heat convection rate:
  820 [W/m²/K]



fin.