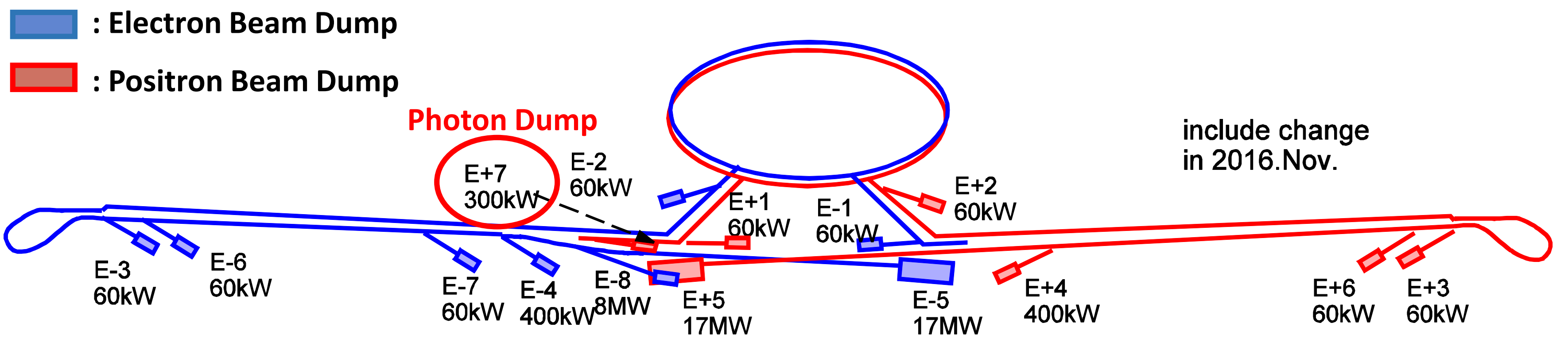
Photon Dump Design and R&D plan

Yu Morikawa

ILC Beam Dumps

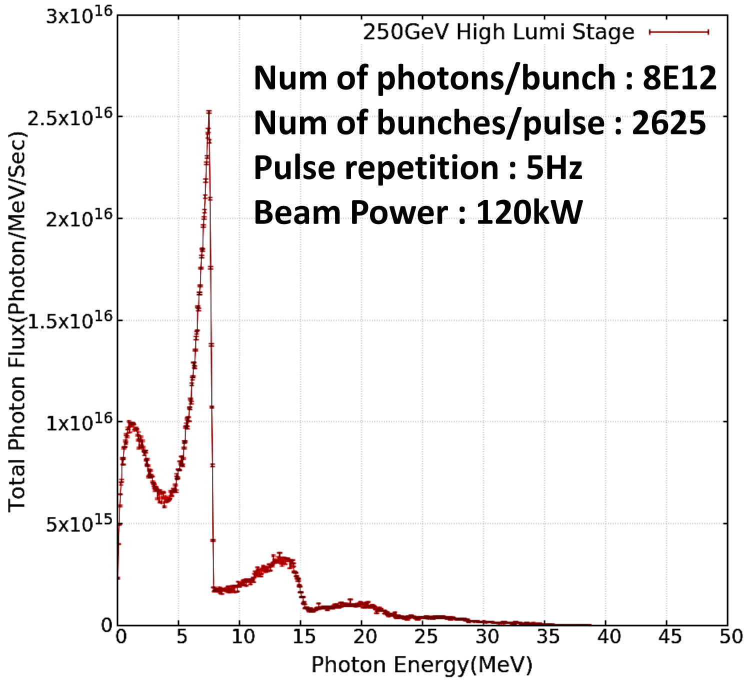


Total 15 Beam dumps in ILC . Beam dumps are classified into 5 types.

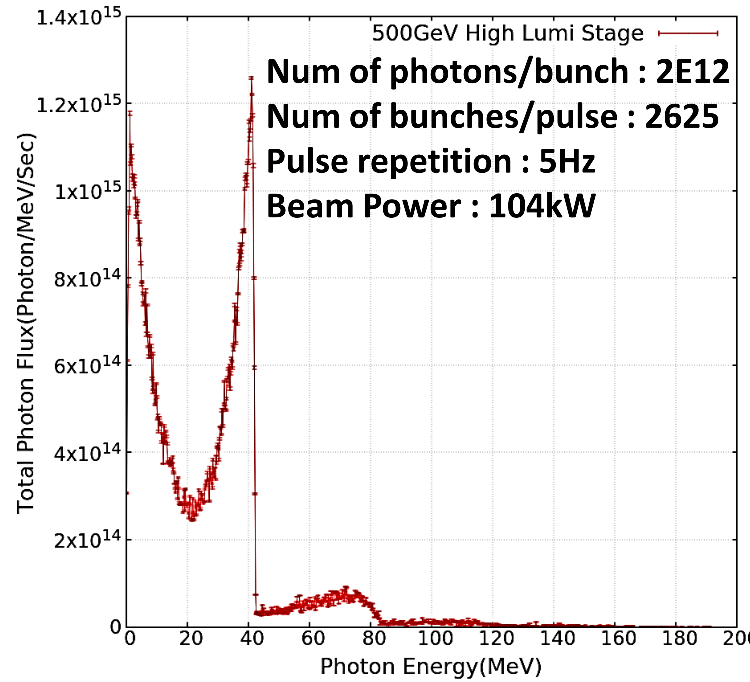
Type	Power	Purpose	Absorber	Place
A	60kW	Tune-up	Solid material	9[E-1,E-2,E-3,E-6,E-7,E+1,E+2,E+3,E+6]
B	400kW	Tune-up & Emergency	Solid material	2[E-4,E+4]
C	300kW	Photon Dump	Water ? Graphite ?	1[E+7]
D	8MW	5 + 5 Hz Operation	Liquid-water	1[E-8]
E	17MW	Main Beam-Dump	Liquid-water	2[E-5,E+5]

Undulator photon beam property

Photon Energy Spectrum@250GeV stage



Photon Energy Spectrum@500GeV stage



Photon Beam	250GeV stage	500GeV stage
Num of photons/bunch	8E12	2E12
Num of bunches/pulse	1312, 2625	
Pulse repetition	5Hz	
Peak Photon Energy	7MeV, 14MeV…	41MeV, 73MeV…
Beam power	60kW, 120kW	52kW, 104kW

Calculation by Yokoya-san

We have 2 design candidates photon dump.
Water Curtain and Graphite design.

Water Curtain Design

Base design and calculation by Peter Sievers[1]
CAD design and energy deposition & flow simulation by me
[1]CERN

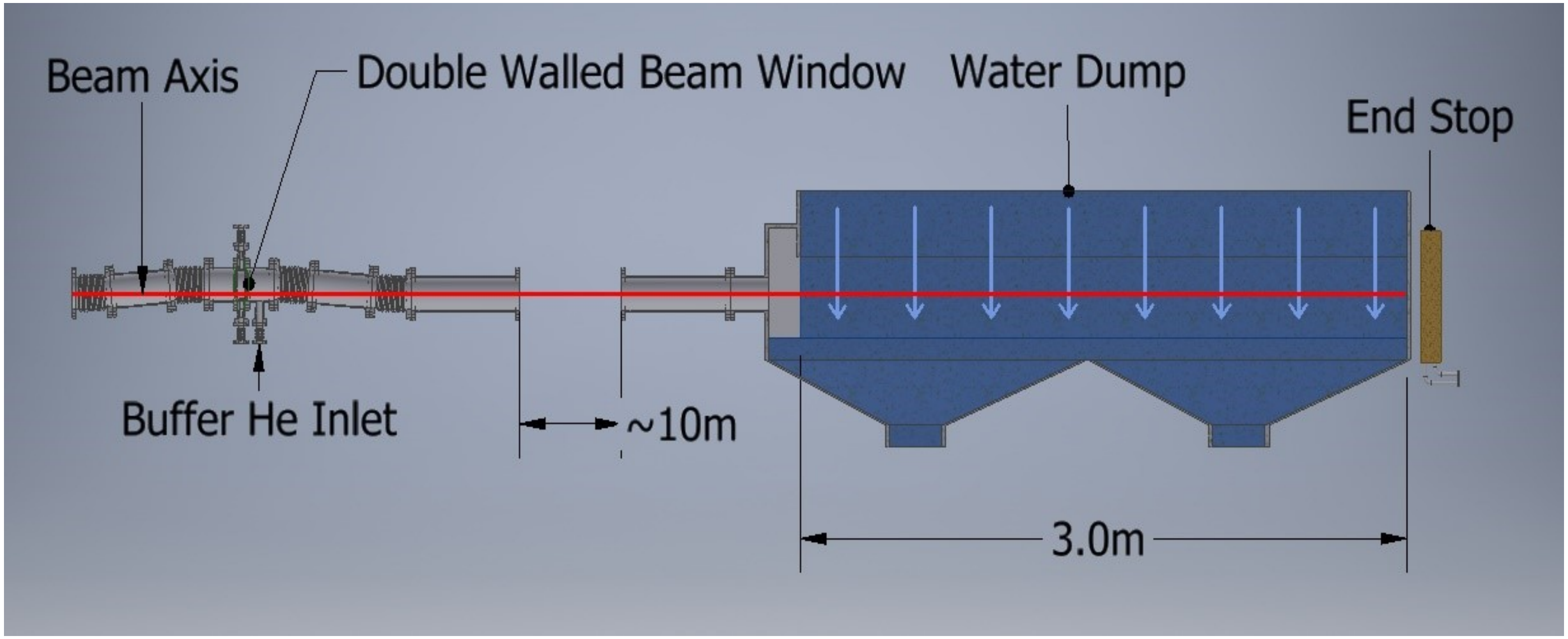
Design of Water Curtain

【Base Idea】

①Beam incidents to falling water(**Water Curtain**)
  This system can accept water boiling.

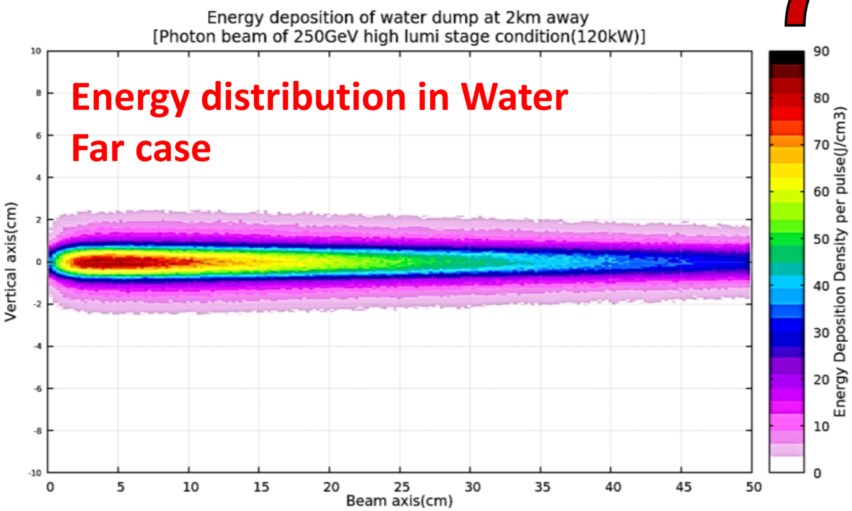
②**Double Walled Beam Window** Cooled by Helium gas.
  This window is tumbled to reduce the radiation damage.

【Base Design】

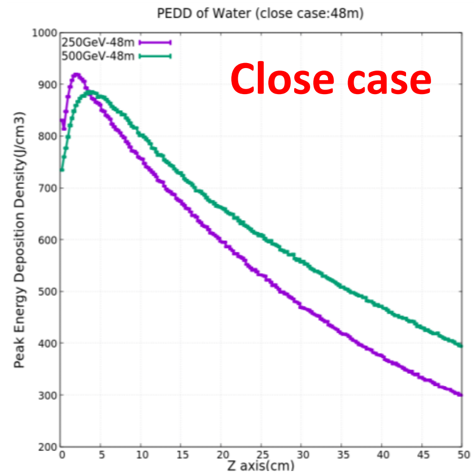


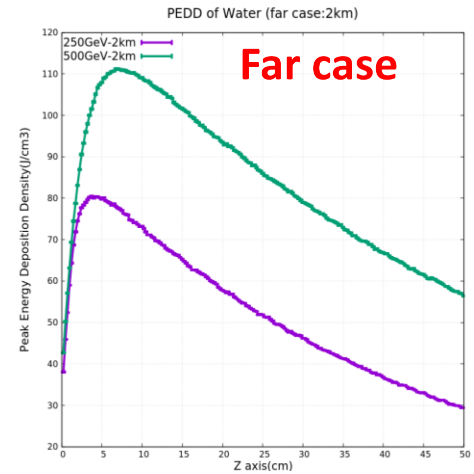
This design can be installed at close position of positron target.
We evaluate the close case(48m case) and far case(2km away).

Thermal analysis of Water Curtain



Peak Energy Deposition Density along Beam Axis

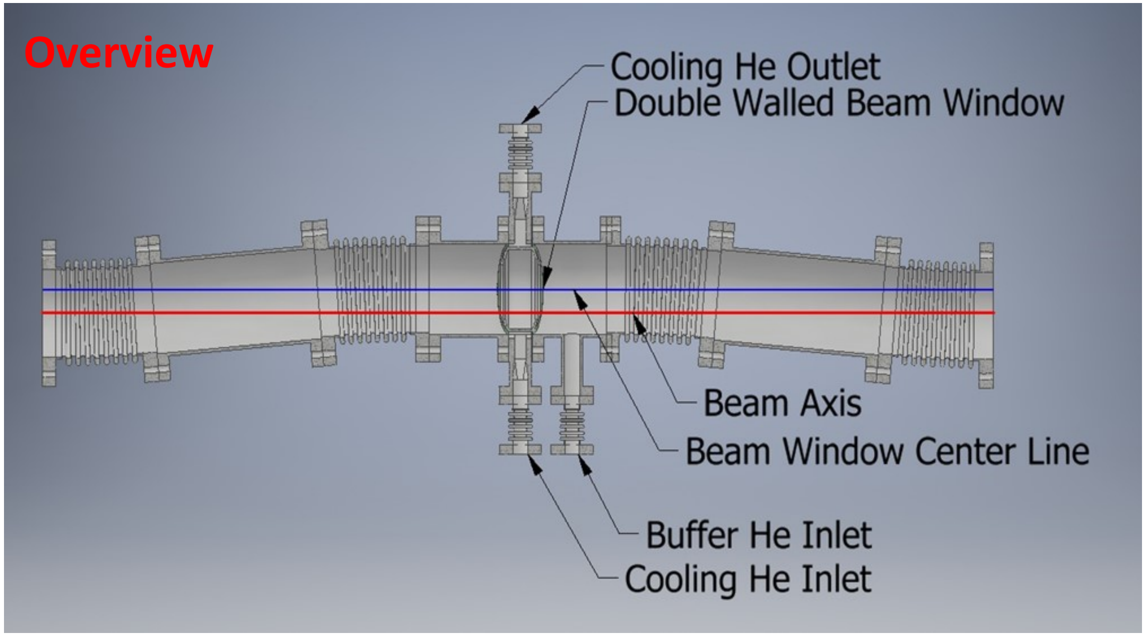


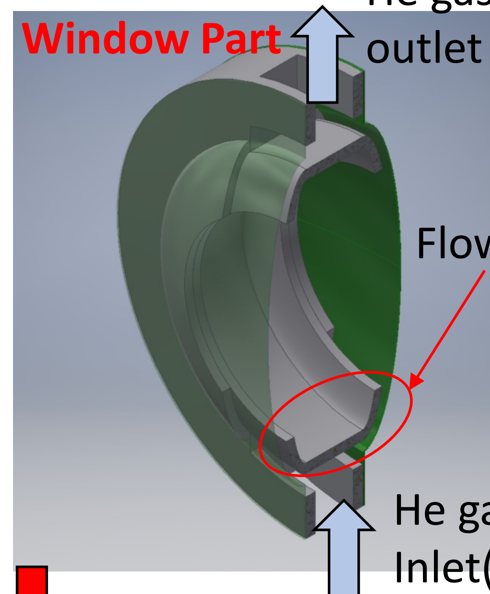


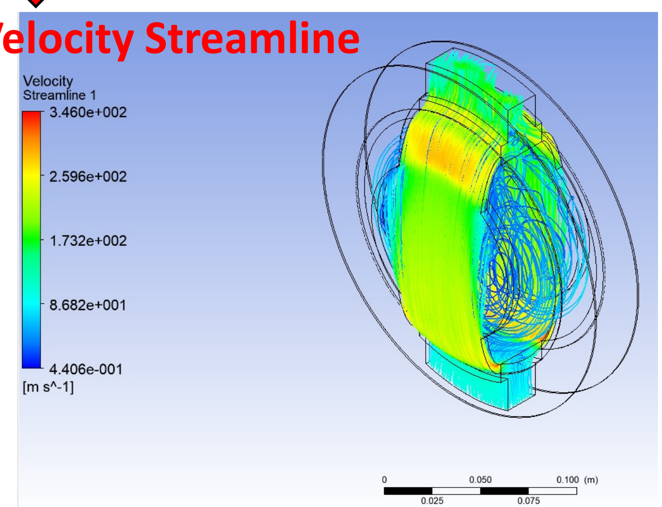
	500 GeV Close dump	250 GeV Close dump	500 GeV Far dump	250 GeV Far dump
ΔT/pulse (K) at z=0	174.	190.	12.	12.
ΔT/pulse (K) at z=5-10 cm	210.	219.	26.5	19.1

In far case, it’s possible to operate without boiling the water.

Base Design of Double Walled Window







- Elliptical shape ϕ15cm(long axis), ϕ4cm(Short axis)
- Tumbling Window by bellows system.
  Tumbling radius=3cm, 1.9sec/turn(0.53Hz)
- Helium gas cooling
  Gas velocity of introductory part:100m/sec,
  Heat transfer coefficient : ~0.1W/cm2K

Analysis of Double Walled Window

Thermal stress per pulse

Beam Conditions	Window thickness (mm)	0.1	0.2	0.3	0.4
250 GeV – close	PEDD(J/g)	113.3	198.1	280.3	358.5
	ΔT/pulse(K)	227.	396.	560.	717.
	σ (MPa)	340.	594.	840.	1076.
250 GeV – far	PEDD(J/g)	4.3	7.2	9.9	12.7
	Δt/pulse(K)	8.6	14.4	19.8	25.4
	σ(MPa)	12.9	21.6	29.7	38.1
500 GeV – close	PEDD (J/g)	68.8	127.5	189.6	254.1
	ΔT/pulse(K)	137.6	255.	379.	508.
	σ (MPa)	206.	383.	569.	762.
500 GeV - far	PEDD (J/g)	3.7	6.9	9.9	13.1
	ΔT/pulse(K)	7.4	13.8	19.8	26.2
	σ (MPa)	11.	21.	30.	39.

Peak Temperature and Lifetime of window(far case)

Beam Condition	250 GeV	250 GeV	500 GeV	500 GeV
Window thickness d (mm)	0.2	0.4	0.2	0.4
Peak Temperature (oC)	34.5	48.5	34.	49.3
Av. Power (W)	16.2	43.3	3.9	10.9
Dpa/5000 h	0.25	0.25	0.71	0.71
Lifetime (h) :DPA=0.5	10 000	10 000	3 600	3 600

In close case, the thickness of beam window should be less than 0.1mm.
In far case, the thickness of beam window can be more than 0.4mm.

Graphite Design

Base design and calculation by me.

Design of Graphite Photon Dump

【Base Idea】

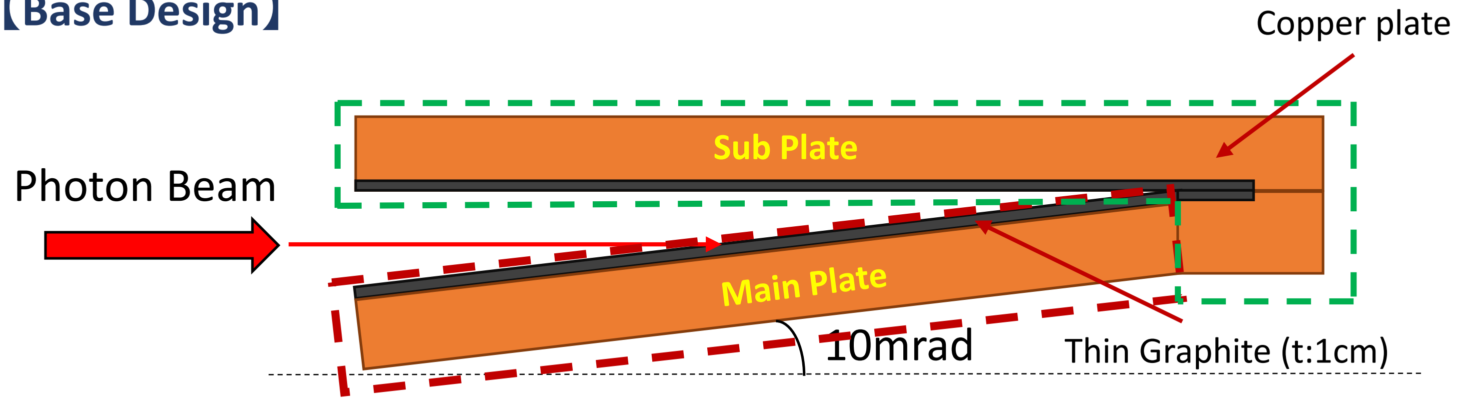
①To enlarge the photon beam spot on beam dump

・**putting long distance** between positron target and beam dump(**2km**).

②To absorb beam heat only by thin Graphite

・**tilting beam dump** (**10mrad** (almost horizontal))

【Base Design】



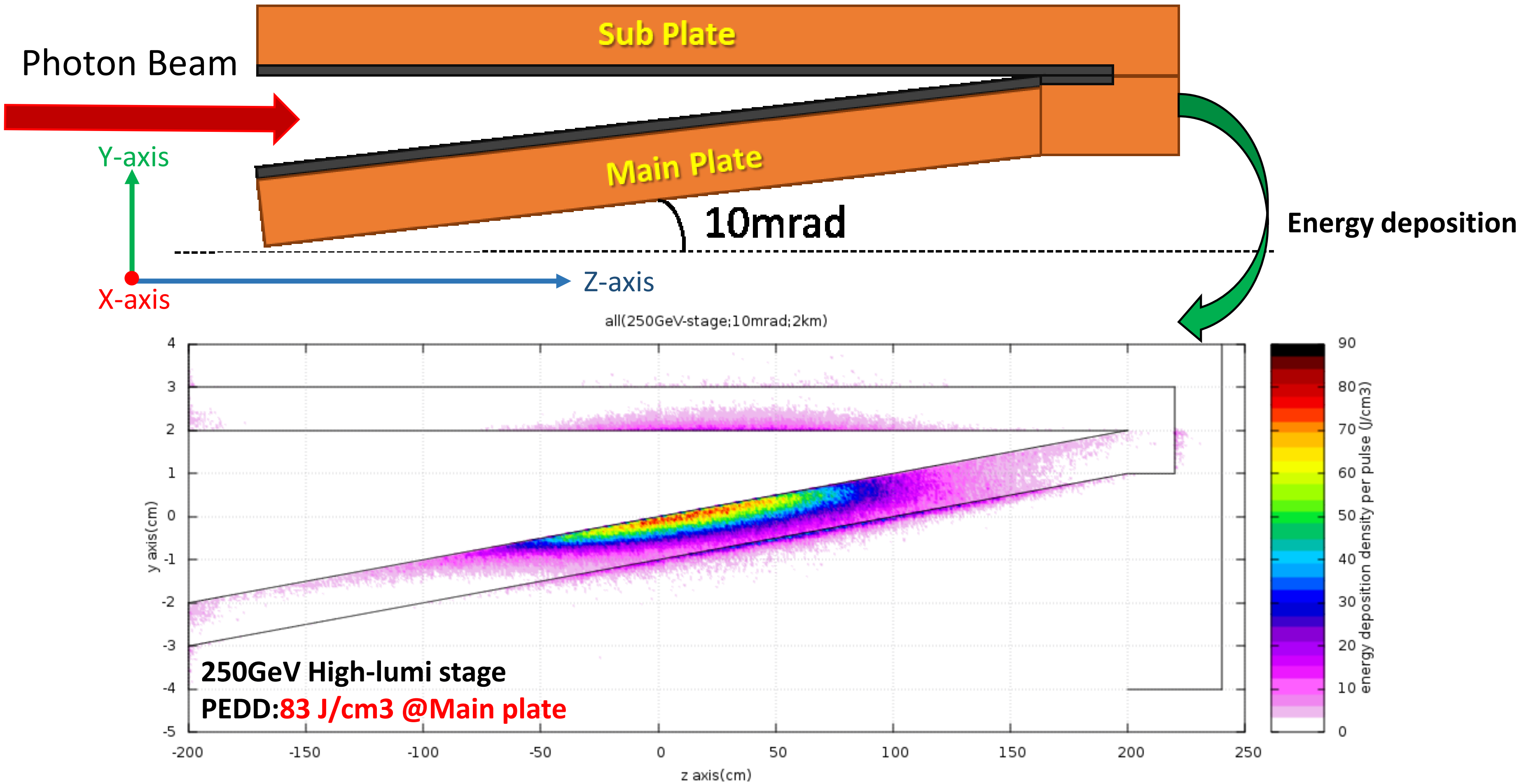
Main Plate : **78kW** deposited (65% of total) ⇒ Primary Beam

Sub Plate : **42kW** deposited (35% of total) ⇒ Secondary (scattered) Beam

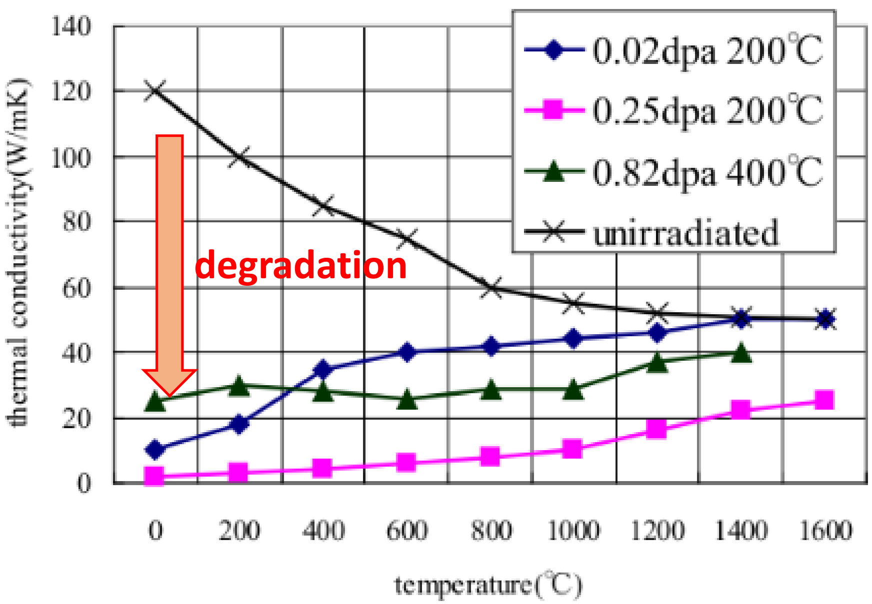
Cooling mechanism : Only cooling water in copper

No cooling, protection gas : No need to introducing the beam window

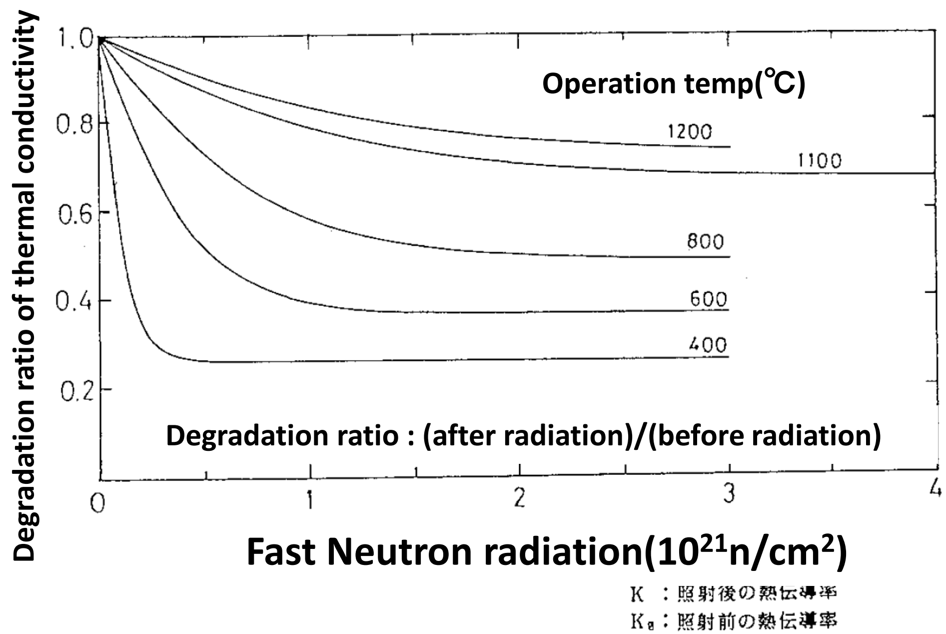
Energy deposition – Graphite dump



Degradation of Graphite thermal conductivity



Degradation by radiation*1

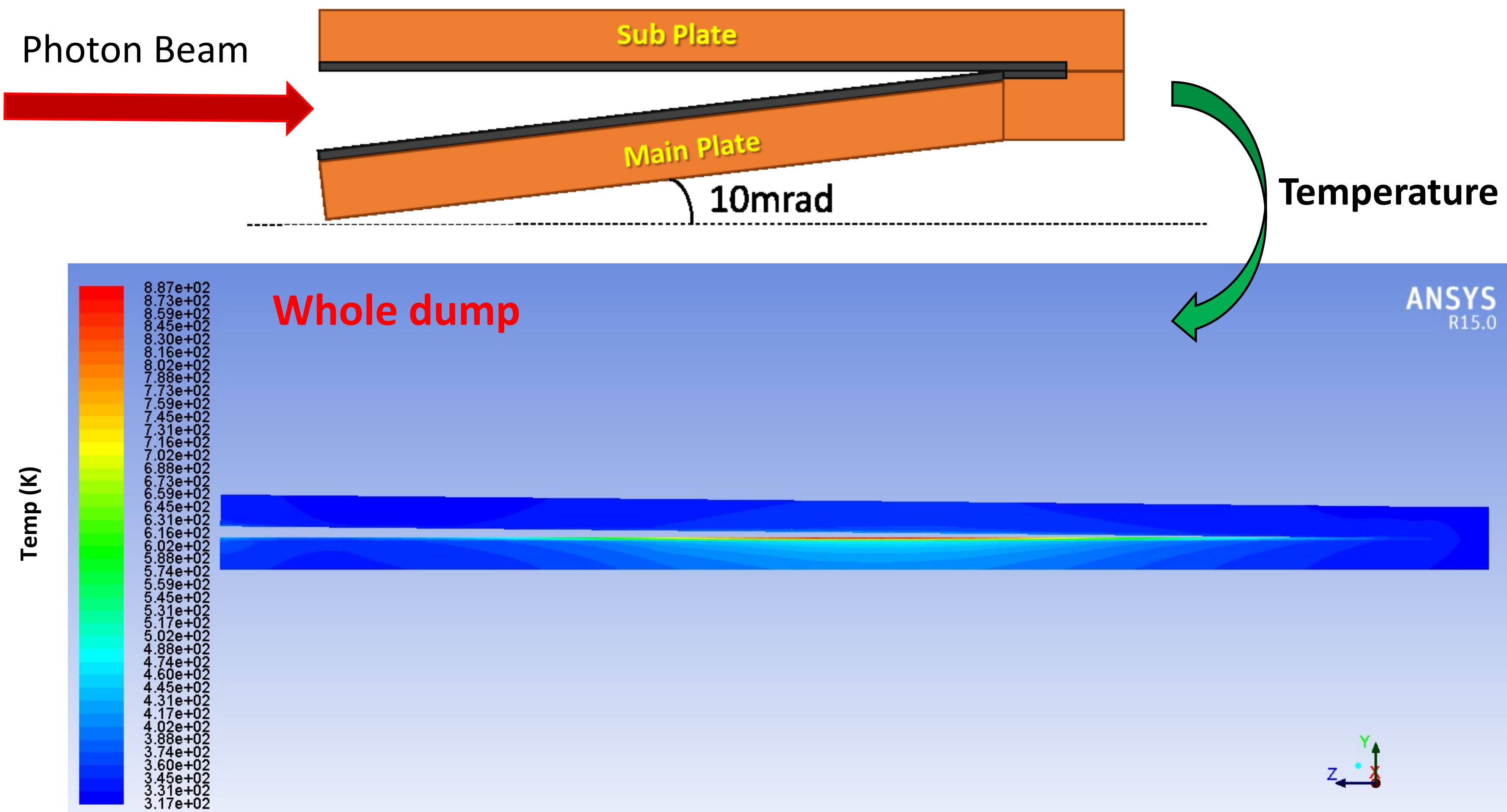


Anneal effect*2

- Thermal conductivity is degraded by radiation.
- High temperature operation reduces degradation of thermal conductivity.(anneal effect)

*1 Neutron irradiation effect to thermal conductivity (T. Maruyama et al., Journal of Nuclear Materials 195(1992) 44-50.)
*2 An explication of design data of the graphite structural design code for core components of high temperature engineering test reactor (Ishihara M, Iyoku T, Toyota J, Sato S, Shiozawa S (1991) ,JAERI-M report 91–153)

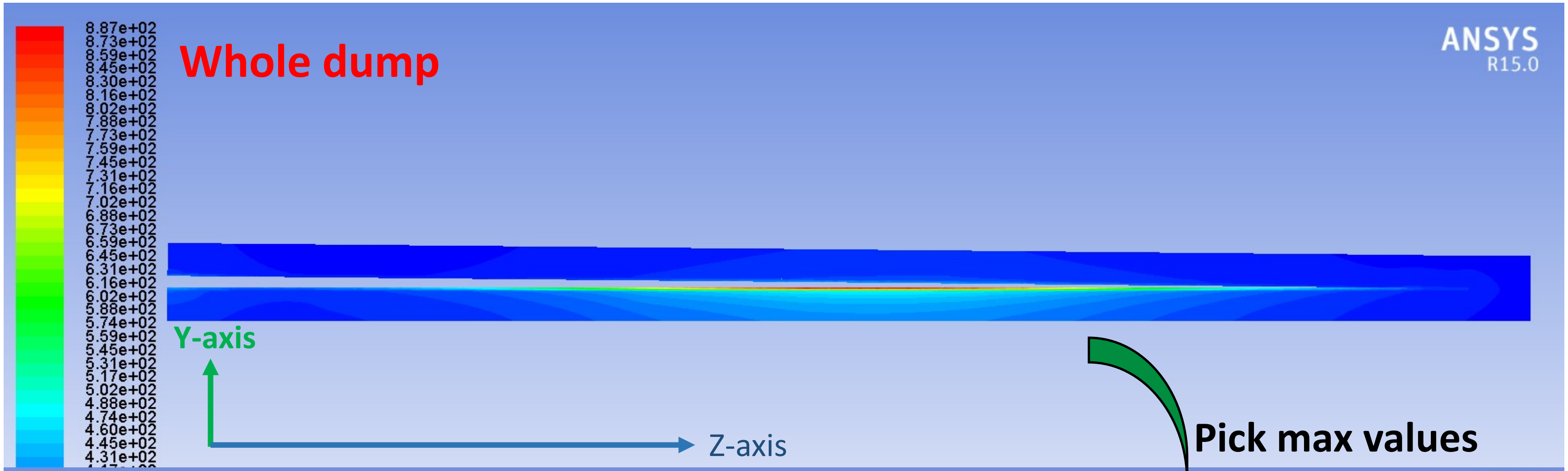
Temperature distribution Graphite conductivity：20W/(Km)



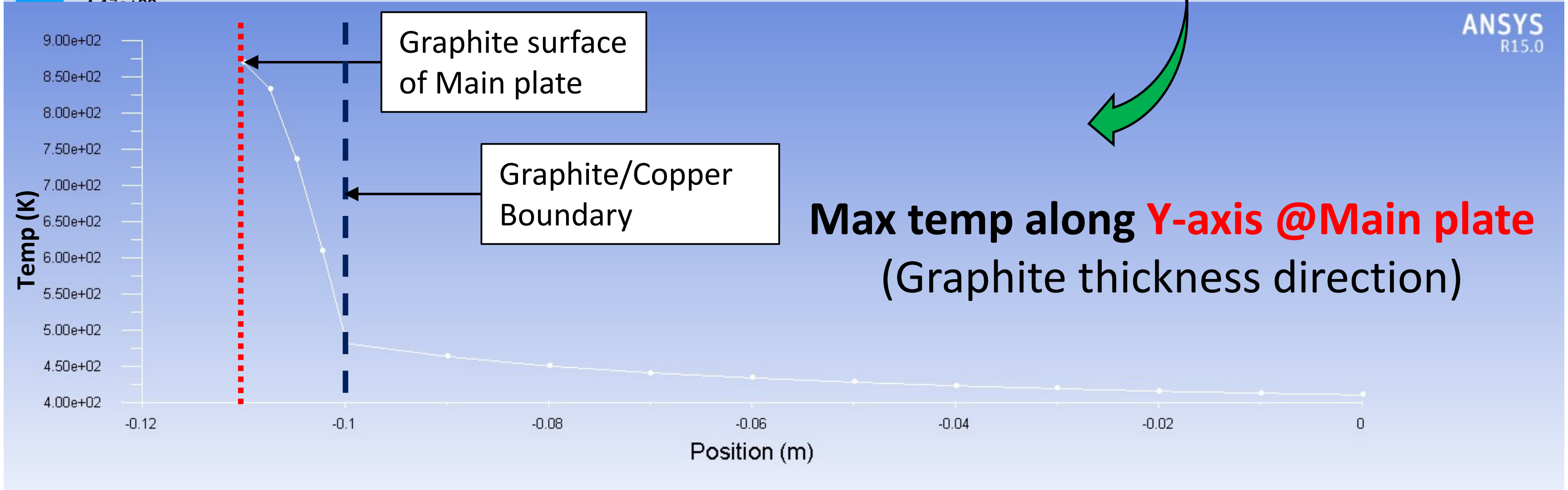
- **Max temp for 250GeV-High lumi stage : 614℃(887K) @ Main plate**
  143℃(416K) @ Sub plate

Temperature distribution Graphite conductivity：20W/(Km)

Beam



Pick max values

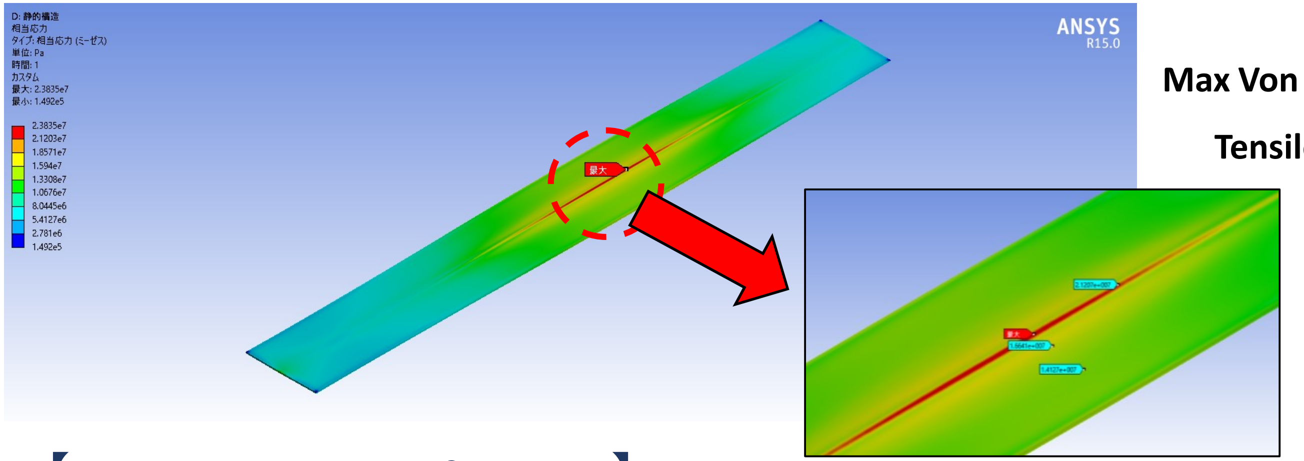


Max temp along Y-axis @Main plate
(Graphite thickness direction)

- **The temp gradient in graphite is very high,**
  ⇒Max temp strongly depends on graphite thermal conductivity.

Thermal Stress – Graphite dump

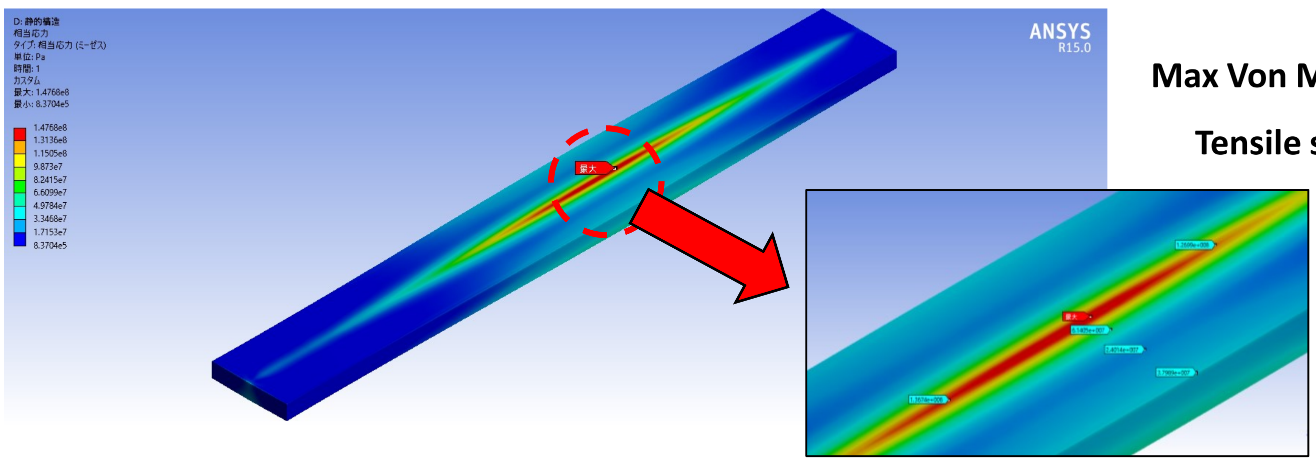
【Von Mises Stress of Graphite】



Max Von Mises stress of Graphite-plate : 24MPa

Tensile strength of Graphite-plate:37MPa

【Von Mises Stress of Copper】



Max Von Mises stress of Copper-plate : 148MPa

Tensile strength of Copper-plate : 200MPa

Technical Issues

◆ Water Curtain dump

・Beam window durability

⇒Combination of thin window and high flow velocity helium and tumbling
Each element has already been put into practical use in various accelerator.
We should conduct mock-up test to prove this systems.

◆ Graphite dump

・Radiation damage : degradation of thermal conductivity, material deformation

・Bonding method of copper and graphite

・High temperature and thermal stress
If thermal conductivity degraded to 10W/mK ,
Temperature exceeds 1000℃ in 250GeV high-lumi stage.

R&D plan

◆ Total Designing

・ ILC R&D team is requested to make more detailed design for construction.
We should start to make design including utilities, maintenance scheme.

◆ Collaborative R&D with qualified industry

・To clear the technical issues, I'm going to start discussion with industry.
Manufacturing way of the beam window system, bonding method Cu/C etc.

Summary

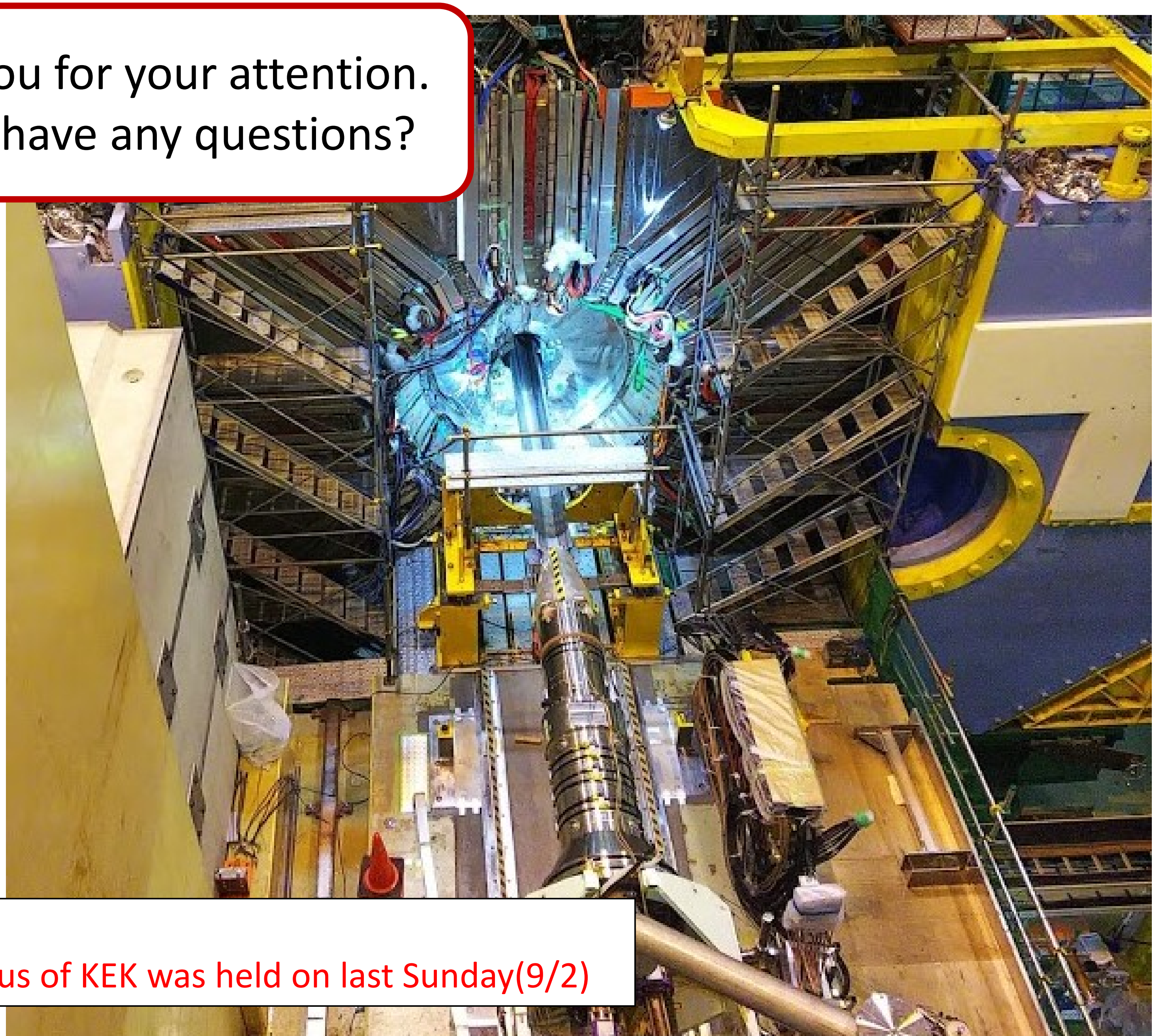
◆ Base Design of Photon dump

- We have 2 design candidates. Water Curtain and Graphite design.
- Basic thermal analysis was already done.
  I think next issue is how we can make the robust system with industrial technology.

◆ R&D plan

- Total Designing.
  Making detailed design including utilities, maintenance scheme.
- Collaborative R&D with qualified industry. (I already contacted some companies.)
  Manufacturing way of the beam window system, bonding method Cu/C etc.

Thank you for your attention.
Do you have any questions?



BELL2
Open campus of KEK was held on last Sunday(9/2)