Design of
Other Beam Dumps

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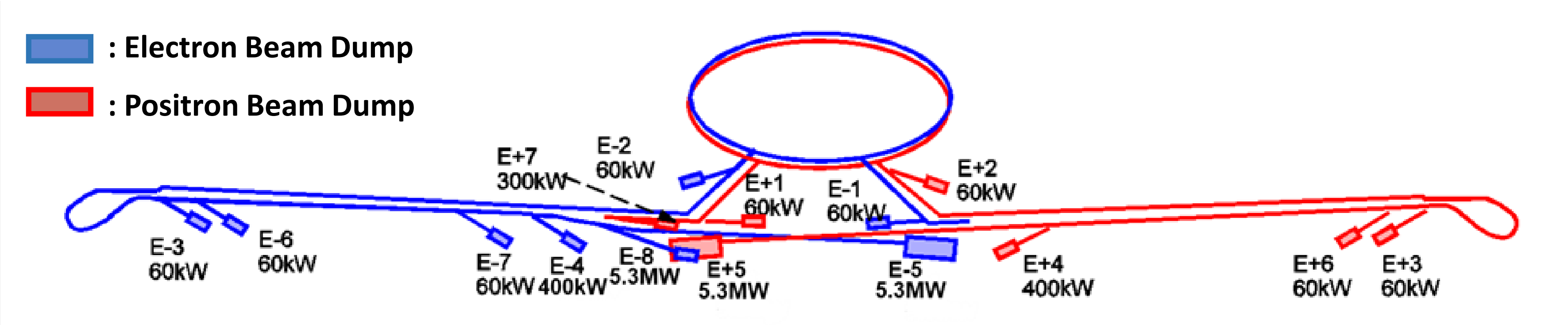
ILC Beam Dumps



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

Type	Power	Purpose	Absorber	Place
A	60kW	Tune-up & Emergency	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	5.3MW	Main Beam-Dump	Liquid-water	2[E-5,E+5]

This talk focus on type A & B beam dumps.
11 dumps are categorized these types.

Tuning beam dumps

Type A & B detail

Name	Purpose	E(GeV)	PB max(kW)	Acceptable Power(kW)
E-1	Electron injection to DR	5	100	60
E-2	Extraction of DR electron	5	100	60
E-3	Just before the electron bunch compression line	5	100	60
E-4	Electron main linac	125	2500	400
E-6	Electron bunch compression line	15	300	60
E-7	Emergency beam dump for Undulator protection	125	2500	60
E+1	Positron injection to DR	5	100	60
E+2	Tuning for extraction of DR positron	5	100	60
E+3	Just before the positron bunch compression line	5	100	60
E+4	Positron main linac	125	2500	400
E+6	Positron bunch compression line	15	300	60

PB max : Beam power of nominal operation of ILC250GeV .

Absorber Choice

Core Absorber	Name	Purpose	E(GeV)	Acceptable Power(kW)
Aluminum Alloy	E-1	Electron injection to DR	5	60
	E-2	Extraction of DR electron	5	60
	E-3	Just before the electron bunch compression line	5	60
	E-6	Electron bunch compression line	15	60
	E+1	Positron injection to DR	5	60
	E+2	Tuning for extraction of DR positron	5	60
	E+3	Just before the positron bunch compression line	5	60
	E+6	Positron bunch compression line	15	60
Graphite	E-4	Electron main linac	125	400
	E-7	Emergency beam dump for Undulator protection	125	60
	E+4	Positron main linac	125	400

Acceptable Beam Parameters

Base Criteria

◆ Cyclic fatigue

Cyclic fatigue occurs due to thermal stress induced by each bunch train.
Acceptable temperature rise for each bunch train(tol(dT_{inst})) can be estimated by the following equation. *

$$tol(\Delta T_{inst}) = (1-\nu)\frac{\sigma_u}{\alpha E}$$

ν:Poisson rate, σ_u : cyclic strength(from SN-curve), α:expansion rate, E : Young's modulus

(10^9 cyclic value)

Peak energy deposition density also limited ⇒ Aluminum alloy : 32J/g
Graphite : 240J/g (Tensile stress)

◆ Operation temperature

Operating temperature must be limited in consideration of softening temperature, oxidation rate, etc. Temperature rise of main absorber can be estimated by the following equation.

$$T_{absorber} \leq T_{steady} + \Delta T_{inst}$$

dP/dz : Longitudinal Power, λ : thermal conductivity
R : Absorber radius , σr : transverse size of shower, Rs : beam sweep radius

$$T_{steady} \sim \frac{dP/dz}{2\pi\lambda} ln\frac{R}{\sigma_r}$$ (non sweep beam)

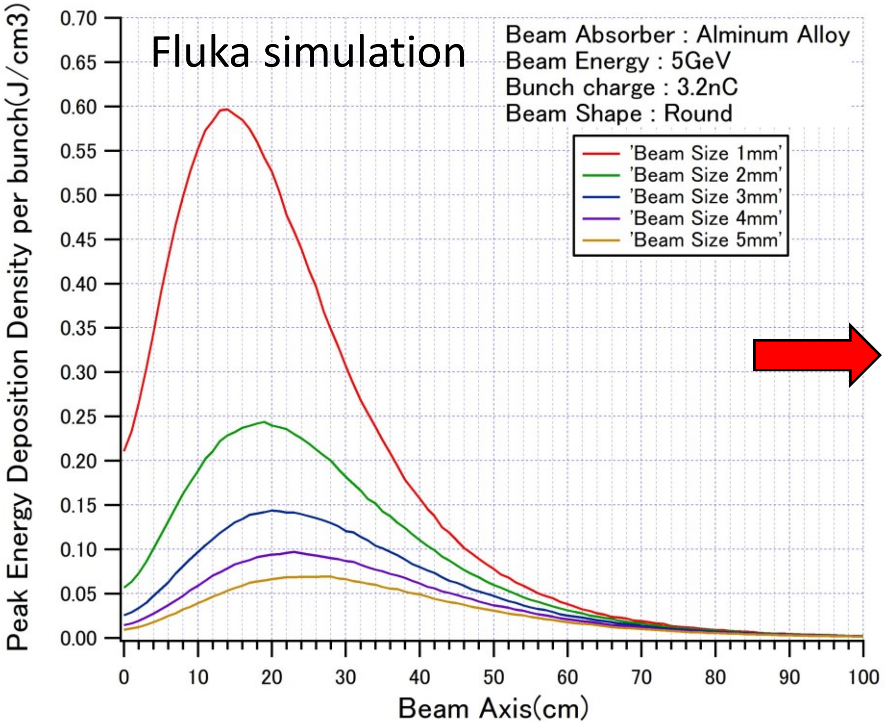
$$T_{steady} \sim \frac{dP/dz}{2\pi\lambda} ln\frac{R}{R_s}$$ (sweep beam)

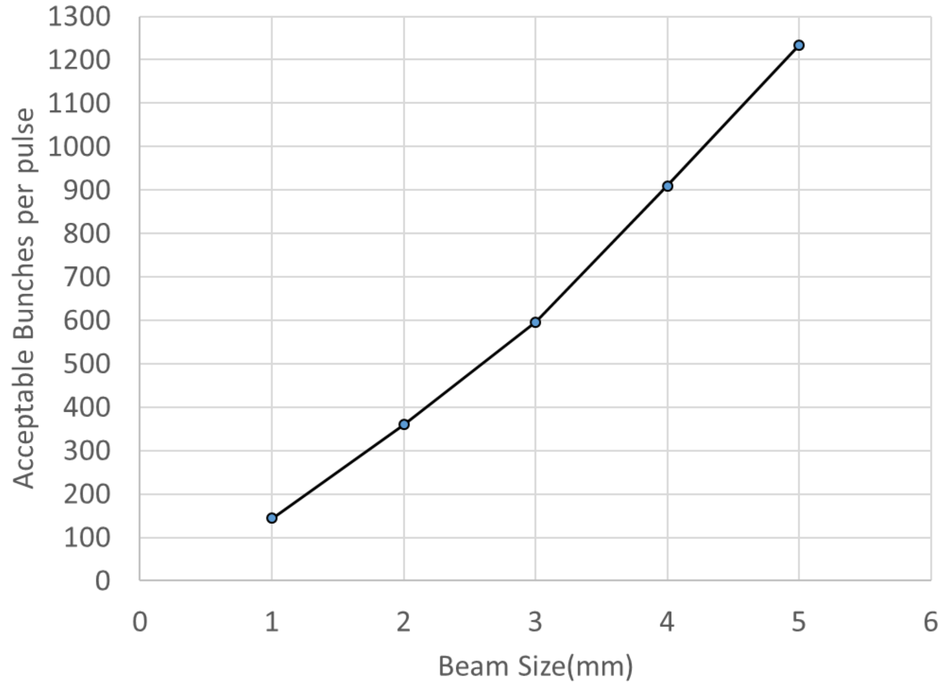
Acceptable maximum temperature ⇒ Aluminum alloy : 250℃
Graphite : 800℃

＊Layout Considerations on the 25GeV / 300kW Beam Dump of the XFEL Project, TESLA-FEL 2006-05

Acceptable bunches per pulse

(Aluminum alloy, 5GeV Beam)





Acceptable Peak energy deposition density : Aluminum alloy : 32J/g

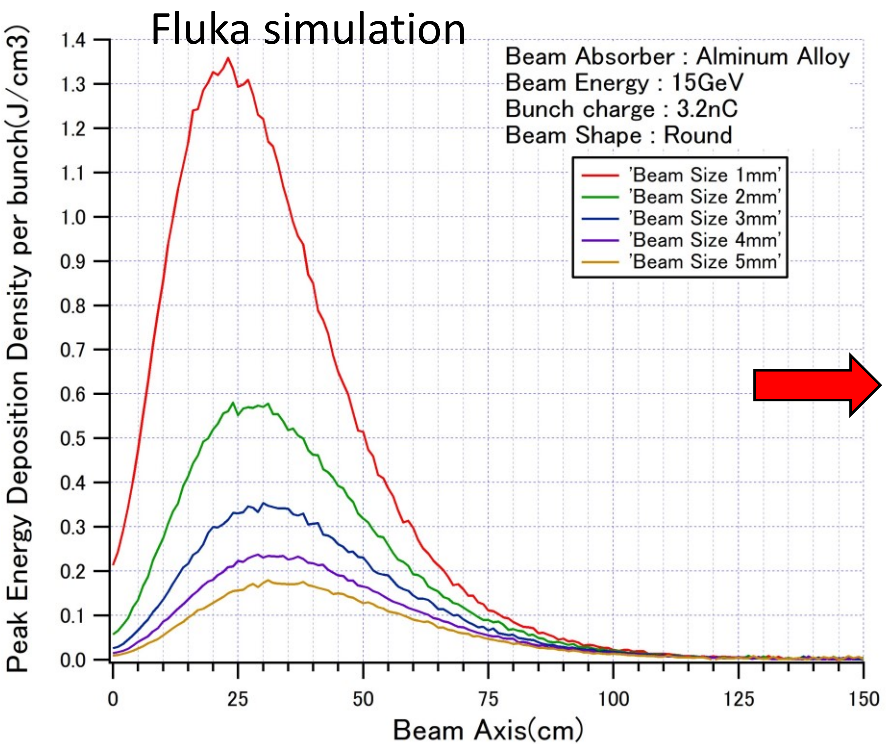
Acceptable Bunches per pulse : 32J/g × 2.7g/cm3 / max-pedd

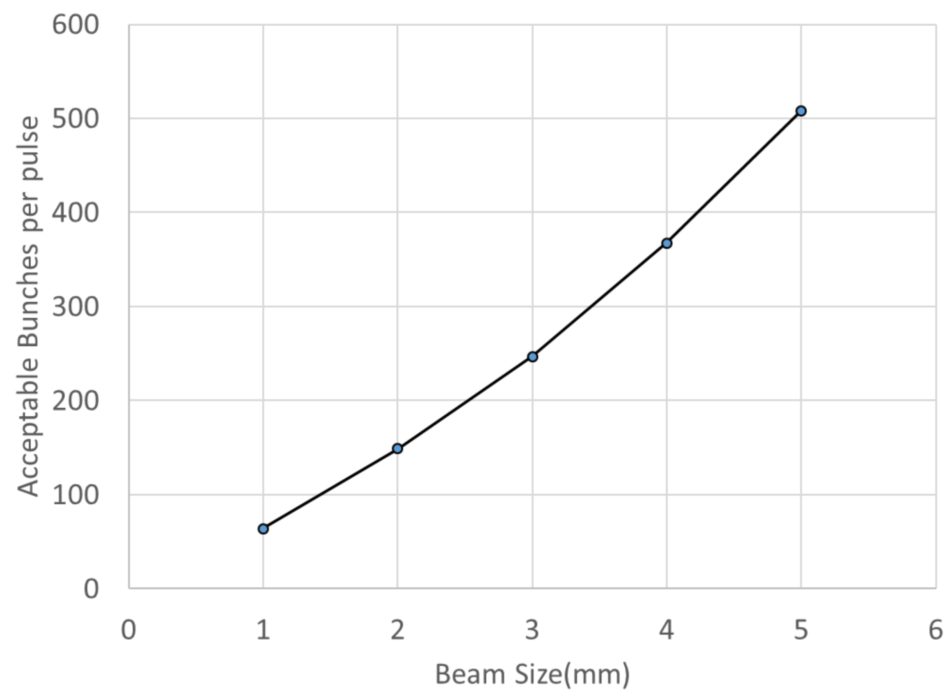
＊Beam size = SQRT($\sigma x^2 + \sigma y^2$)

＊Bunche charge is set to 2×10^{10}(3.2nC), ILC nominal.

Acceptable bunches per pulse

(Aluminum alloy, 15GeV Beam)





Acceptable Peak energy deposition density : Aluminum alloy : 32J/g

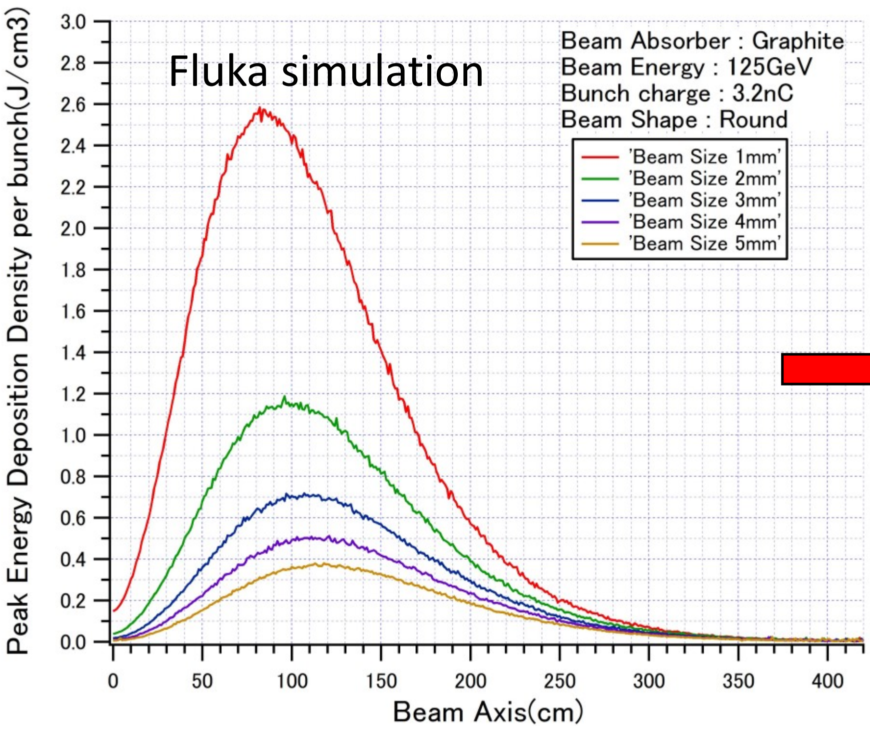
Acceptable Bunches per pulse : 32J/g × 2.7g/cm3 / max-pedd

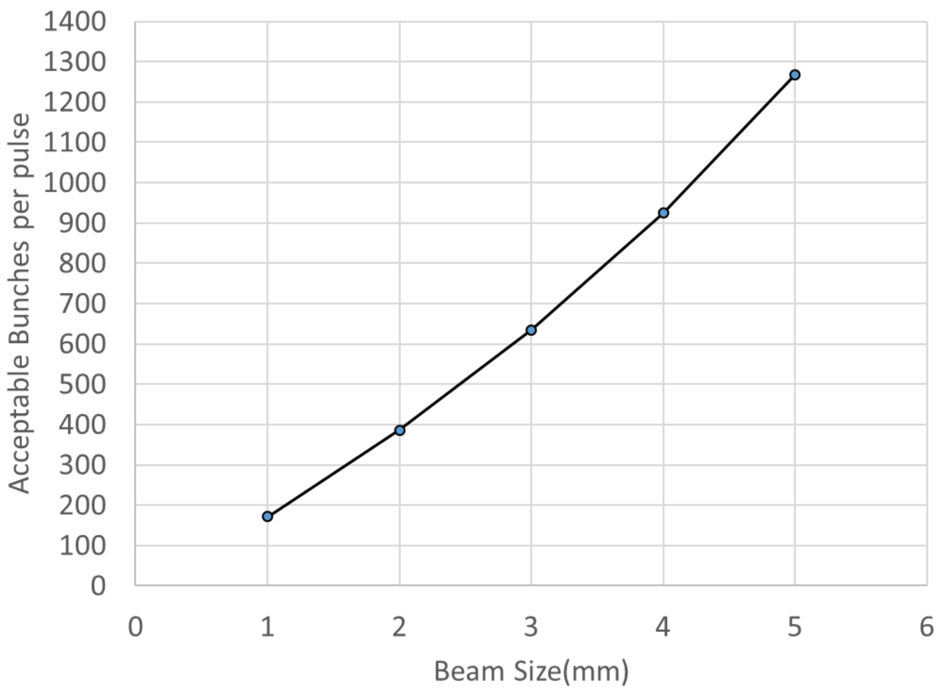
＊Beam size = SQRT($\sigma x^2 + \sigma y^2$)

＊Bunche charge is set to 2×10^{10}(3.2nC), ILC nominal.

Acceptable bunches per pulse

(Graphite, 125GeV Beam)





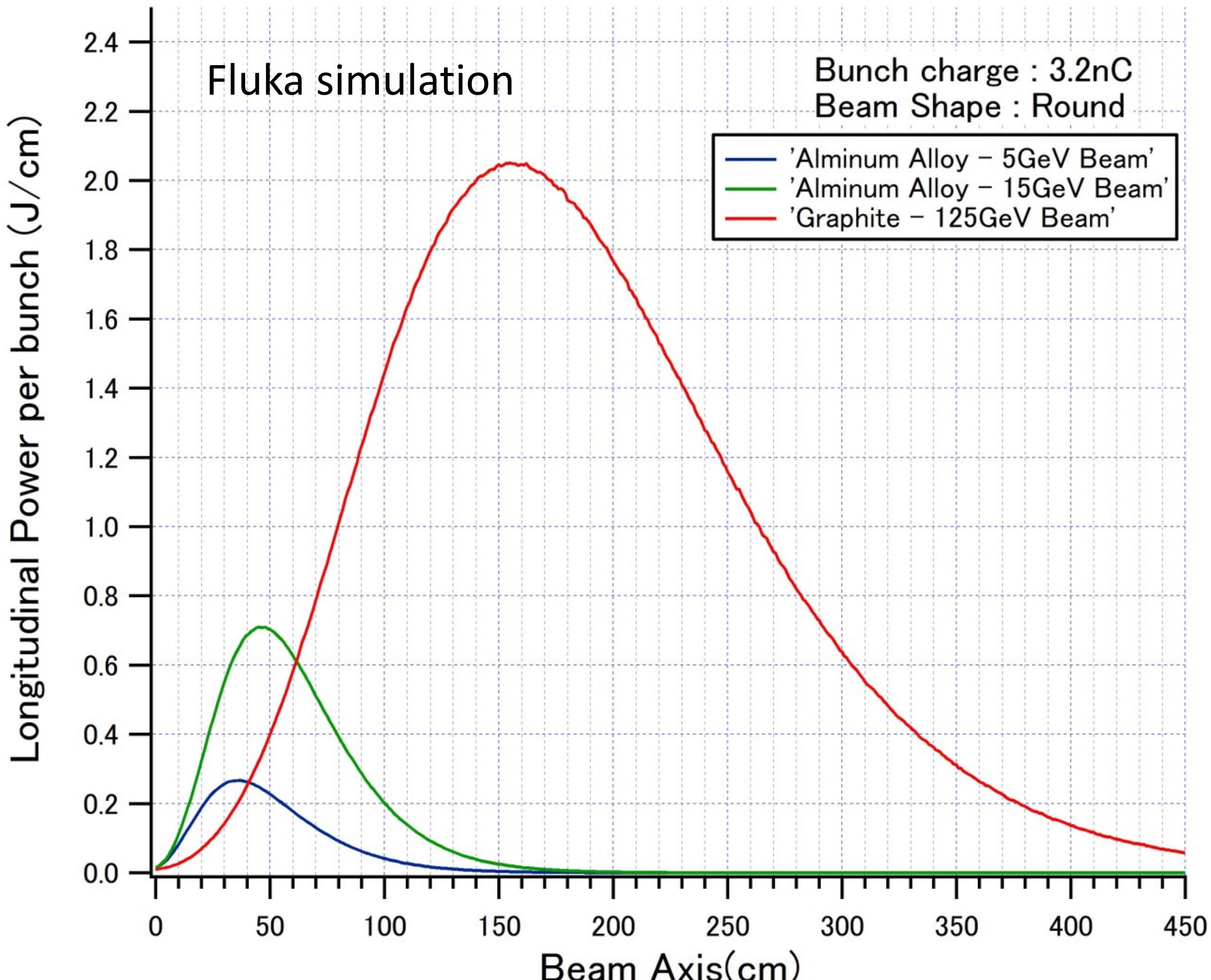
Acceptable Peak energy deposition density : Aluminum alloy : 240J/g

Acceptable Bunches per pulse : 240J/g × 1.85g/cm3 / max-pedd

＊Beam size = SQRT($\sigma x^2 + \sigma y^2$)

＊Bunche charge is set to 2×10^{10}(3.2nC), ILC nominal.

Longitudinal Power



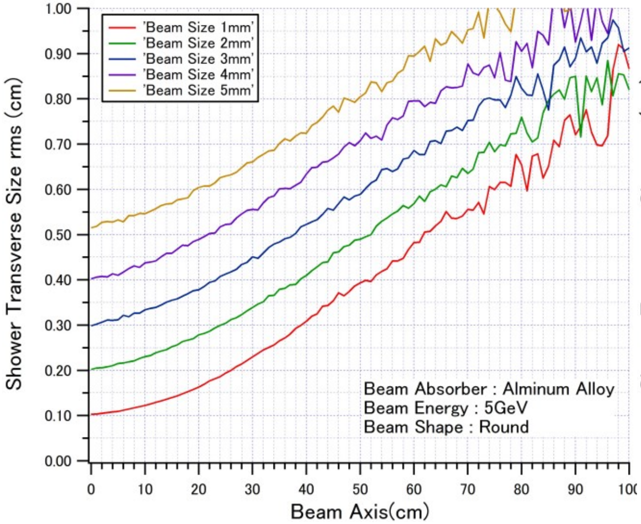
【Peak Longitudinal Power(peak dP/dz)】

Graphite(125GeV) : 2.05J/cm/bunch @z=160cm,

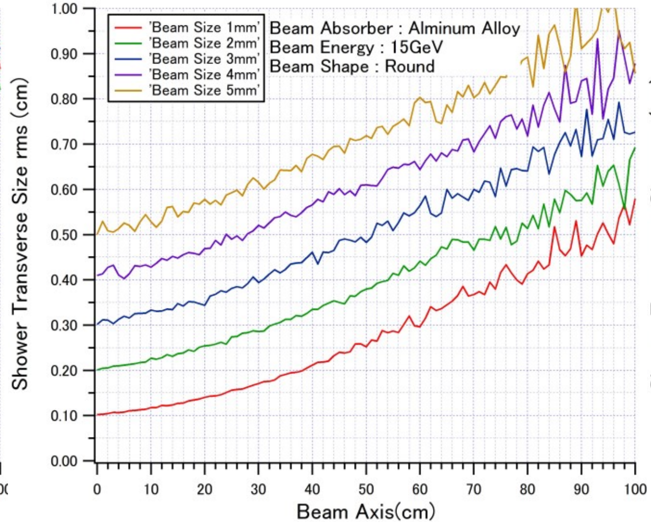
Aluminum(15GeV) : 0.7J/cm/bunch @z=45cm, Aluminum(5GeV) : 0.28J/cm/bunch @z=35cm,

Shower Spread along beam axis

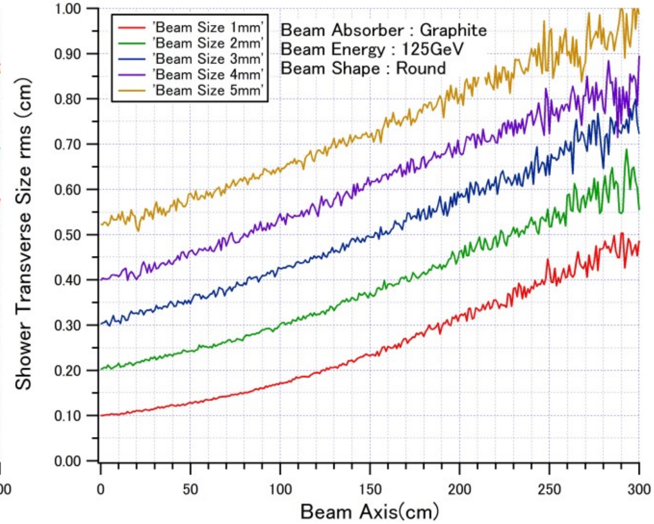
Aluminum, 5GeV Beam



Aluminum, 15GeV Beam



Graphite, 125GeV Beam



These graph shows transverse size of energy deposition distribution.

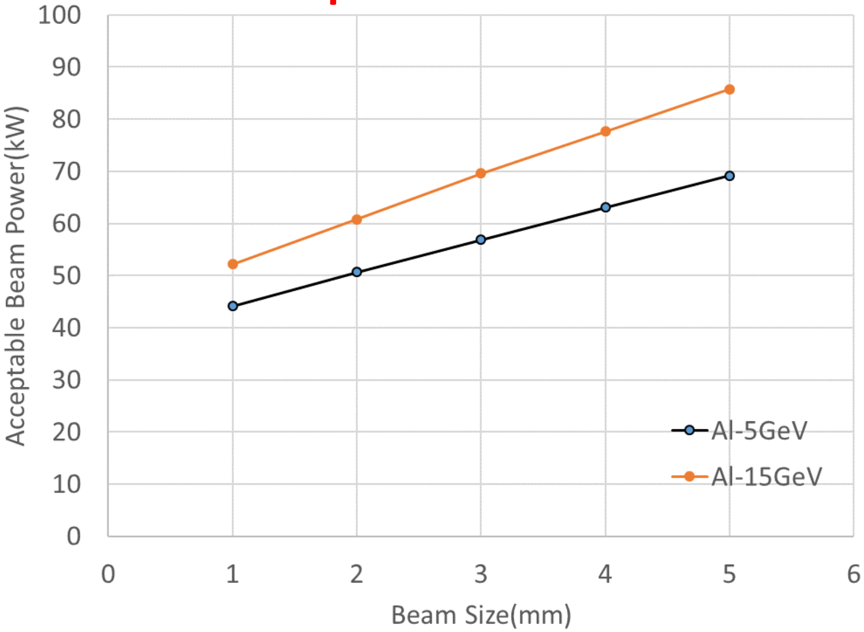
Transverse size affect the operation temperature. Especially peak dP/dz point.

Transverse size @ peak dP/dz point

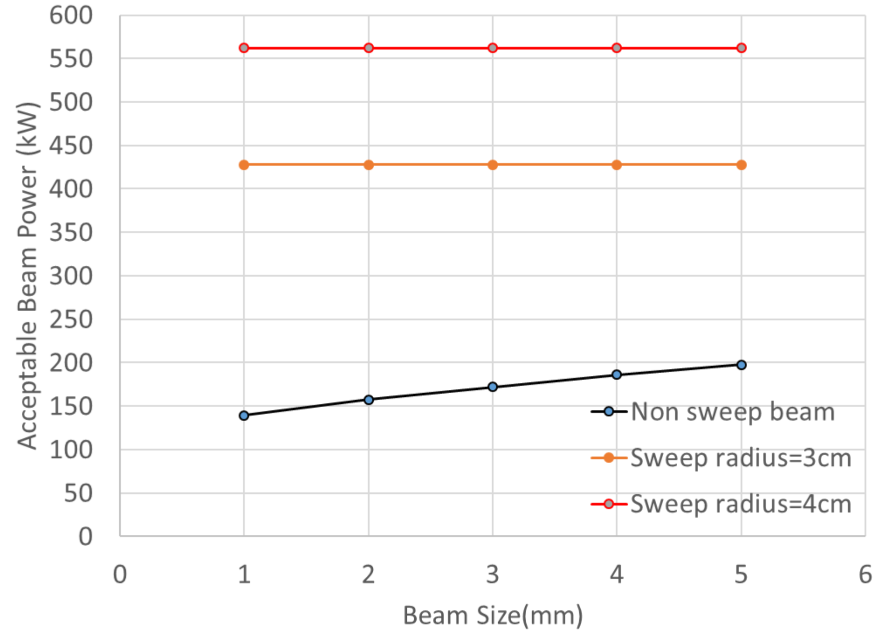
Beam Size	Al-5GeV@z=35cm	Al-15GeV@z=45cm	Gr-125GeV@z=160cm
1mm	2.6mm	2.5mm	2.5mm
2mm	3.7mm	3.7mm	3.8mm
3mm	4.8mm	5.0mm	5.0mm
4mm	5.9mm	6.2mm	6.3mm
5mm	7.0mm	7.4mm	7.4mm

Acceptable Beam Power

Aluminum Alloy, 5,15GeV Beam
Non sweep beam



Graphite, 125GeV Beam



- Aluminum beam dump :required acceptable power 60kW
  ⇒Beam size will be 2mm for Al-15GeV, 3.5mm for Al-5GeV
- Graphite beam dump :required acceptable power 400kW
  ⇒Beam Sweep is necessary. Sweep radius will be larger than 3cm.

＊These values are estimated by following equation.

$T_{steady} \sim \frac{dP/dz}{2\pi\lambda} ln \frac{R}{\sigma_r}$ (non sweep beam) $T_{steady} \sim \frac{dP/dz}{2\pi\lambda} ln \frac{R}{R_s}$ (sweep beam)

[Assumption]
R=4cm(Aluminum),10cm(Graphite), T_{steady}=200℃(Aluminum),600℃(Graphite), λ=1.68(Aluminum),0.7(Graphite-degraded value)

Summary - Acceptable Parameters

Key factor is Beam Size,
How much we can enlarge the beam size is quite important

◆ **Acceptable Bunch Number per pulse**

Beam Size(SQRT($\sigma x^2 + \sigma y^2$)) of 100bunch/pulse case

Al 5GeV dump : >~1mm
Al 15GeV dump : >~1.5mm
Graphite 125GeV : >~1mm

◆ **Acceptable Average Power**

Al 5GeV dump – 60kW : >~3.5mm*1
Al 15GeV dump - 60kW : >~2mm*1
Graphite 125GeV – 400kW : Sweep radius >~3cm*2 (hard for non sweep)
*1 If partial plastic deformation can be accept, beam size can be smaller.
*2 Should be careful about graphite degradation.

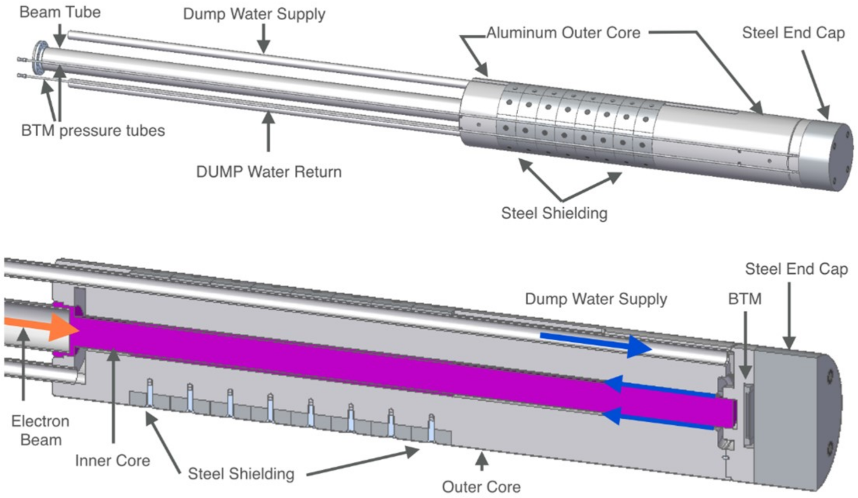
Base Design

Aluminum 5,15GeV dump

Base Design of Aluminum Dump

LCLS Ⅱ Main Dump

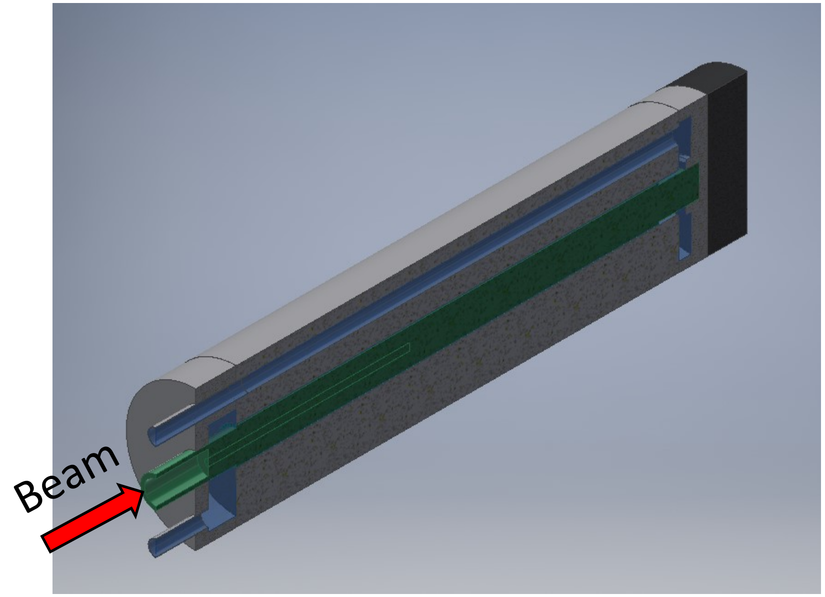
Max Power: 250kW



LCLS-II TN-17-12
LCLS-II Beam Dumps

ILC 5,15GeV Beam Dump

Max Power: 60kW



◆ LCLS Ⅱ Main Beam Dump would be good reference for ILC 5,15GeV dump.

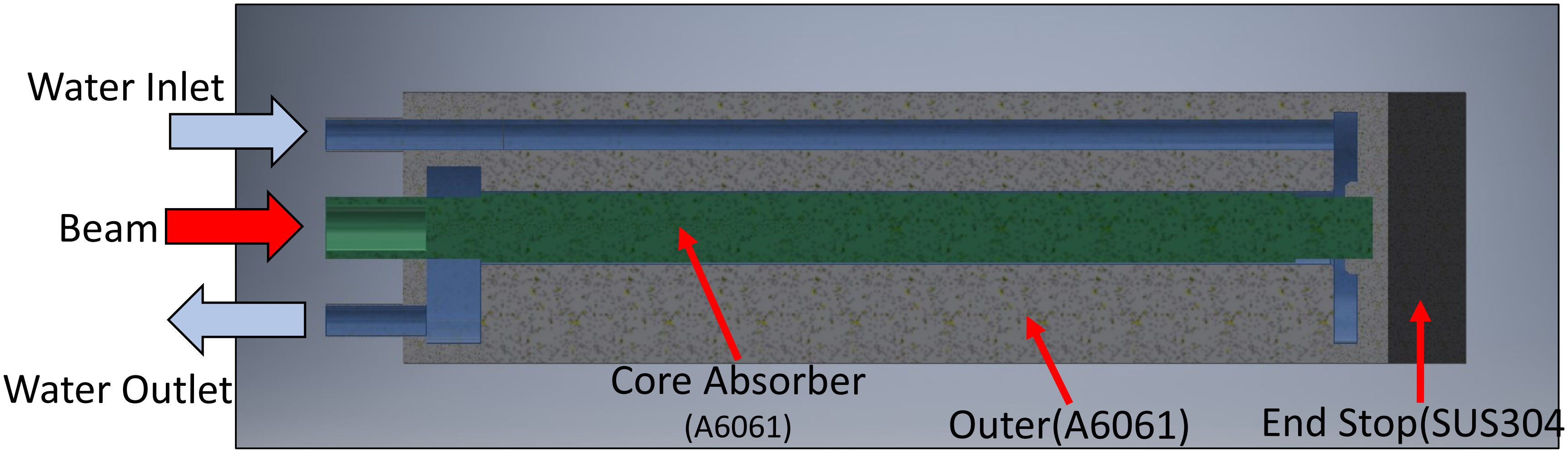
[LCLS Ⅱ Main Dump]

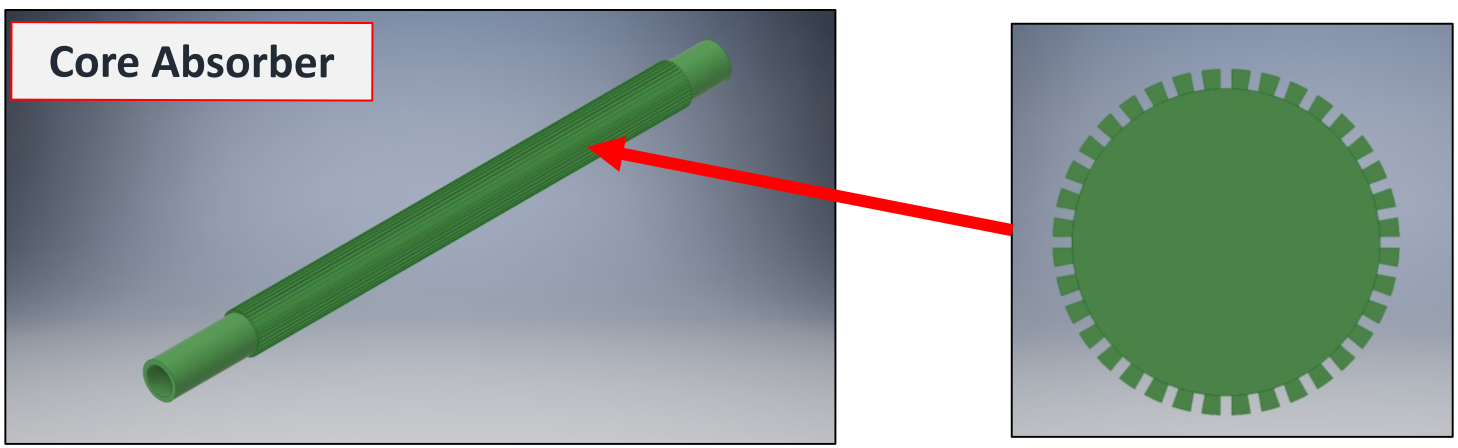
Material : A6061-T6 , Shape : Cylindrical : L1500mm × φ450mm

[ILC 5,15GeV Beam Dump]

Material : A6061-T6 , Shape : Cylindrical : ~L1500mm × φ450mm

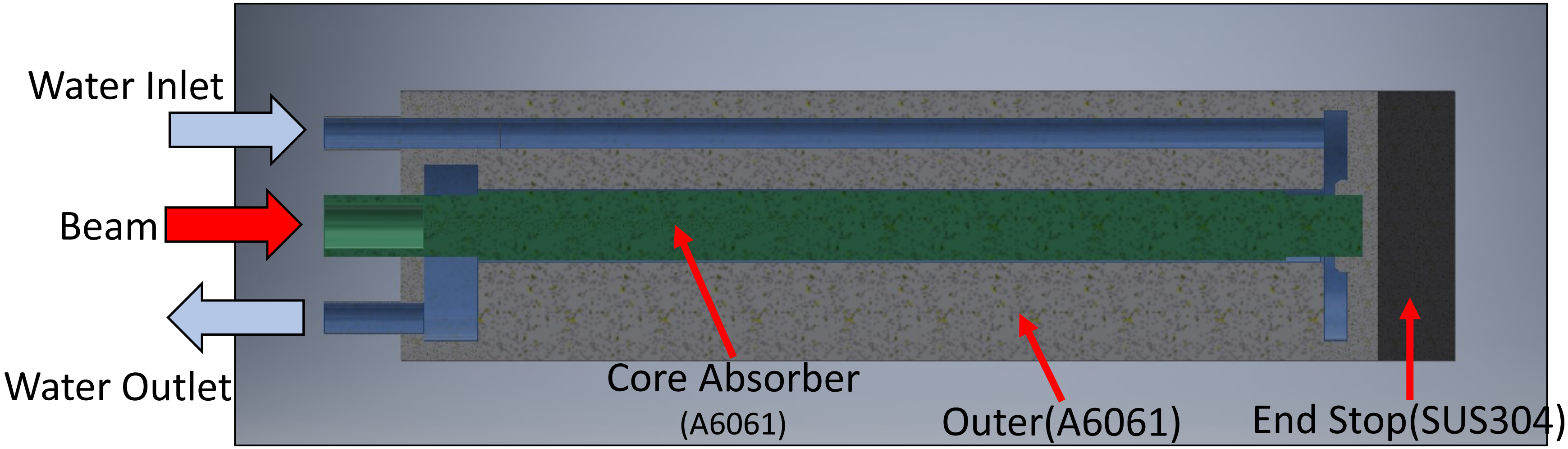
Base Design of Aluminum Dump

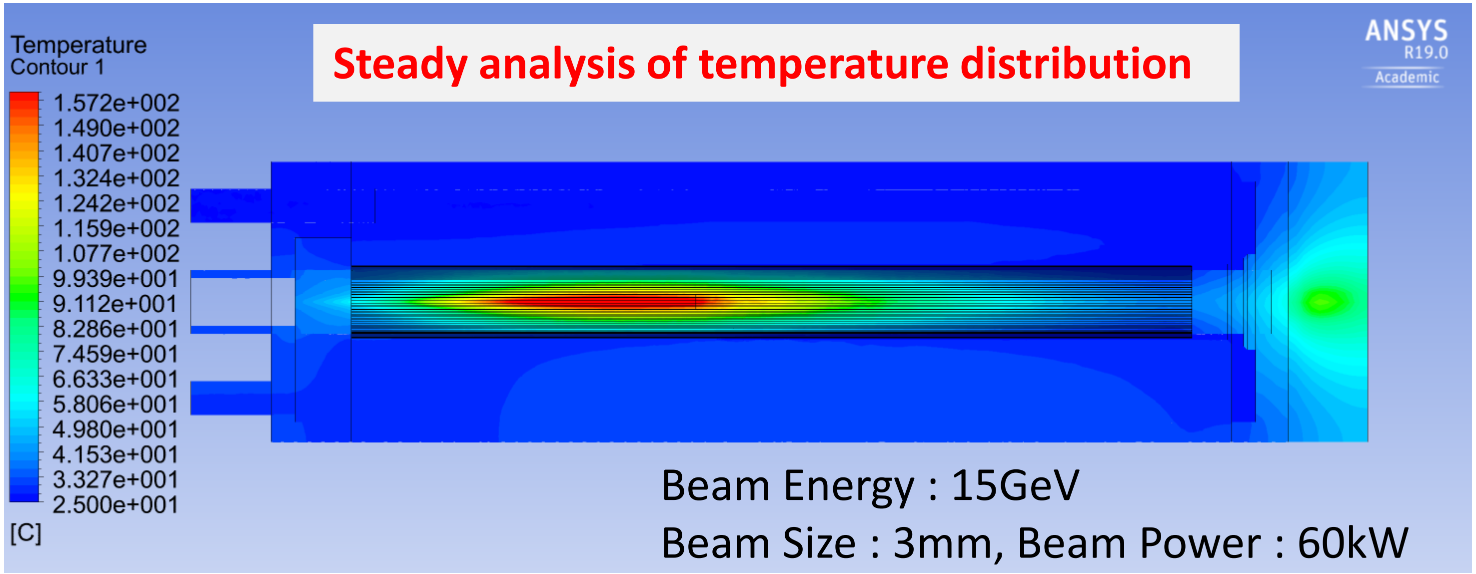




- Core Absorber is cooled directly by water.
  Temporary Design : L1200 × 80ϕ(mm).
  ＊Radiation Length(Aluminum) :9.0cm , Morier radius(Aluminum) : 4.4cm

Base Design of Aluminum Dump



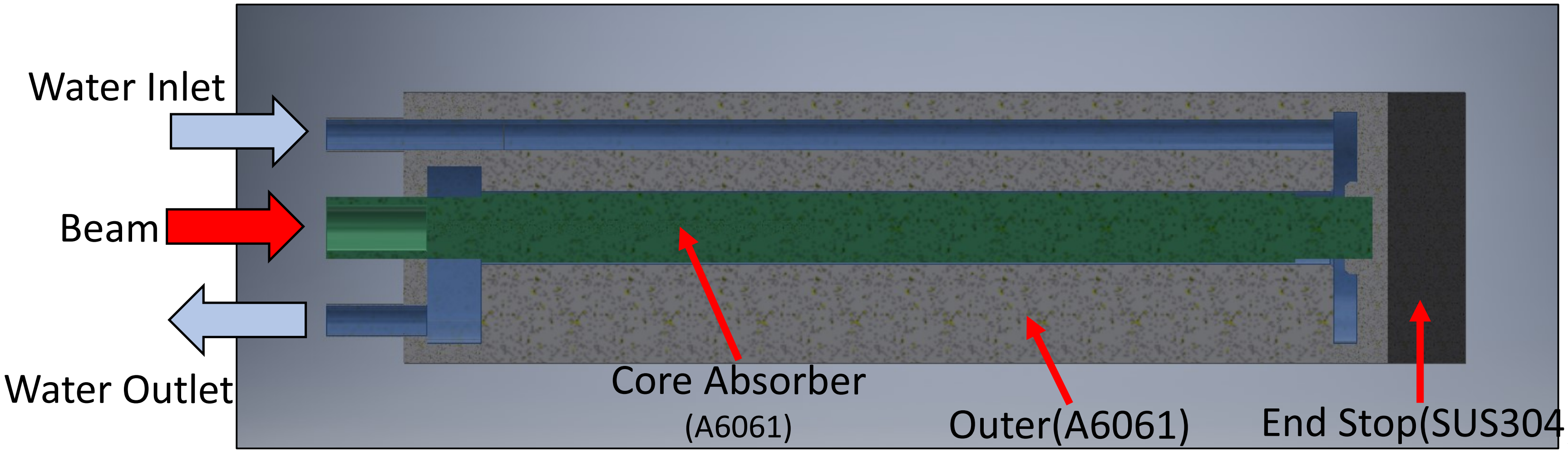


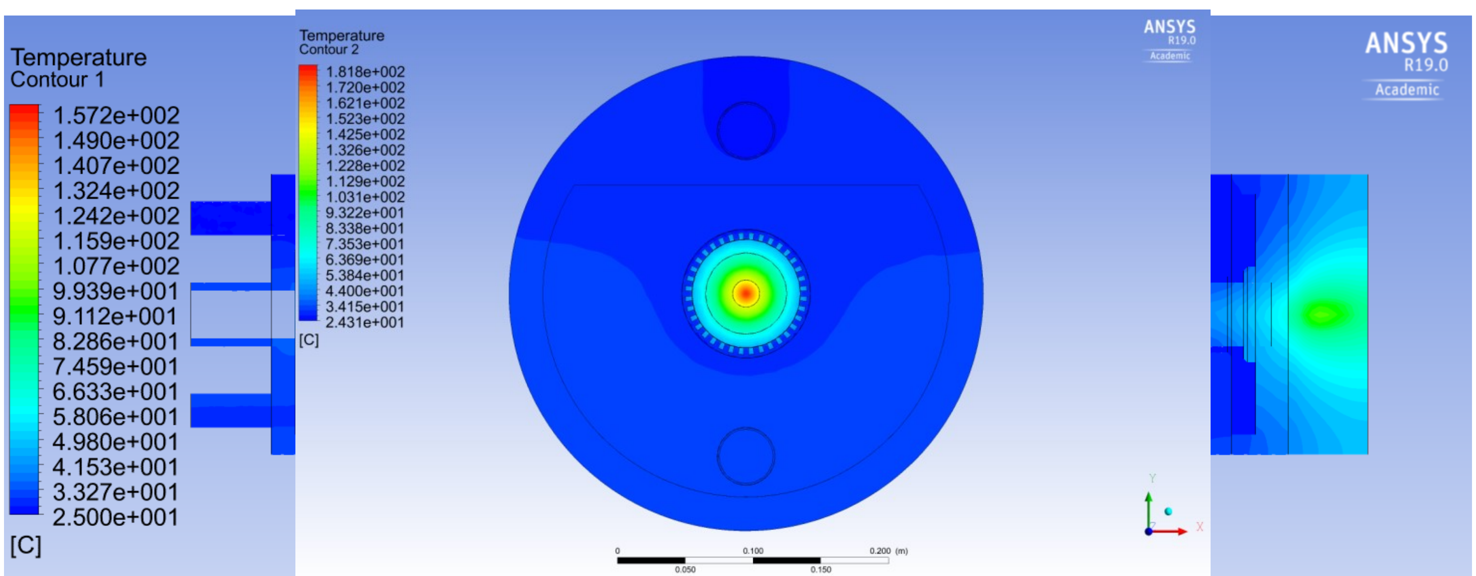
Beam Energy : 15GeV

Beam Size : 3mm, Beam Power : 60kW

Mass flow of Water :150L/min

Base Design of Aluminum Dump





Beam Energy : 15GeV

Beam Size : 3mm, Beam Power : 60kW

Base Design

Graphite 125GeV dump

Base Design of Graphite Dump

E-XFEL Main Dump

Max Power: 300kW

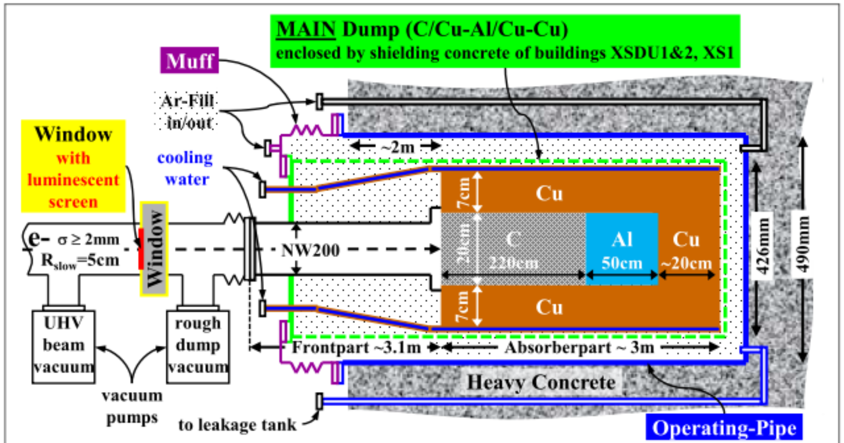
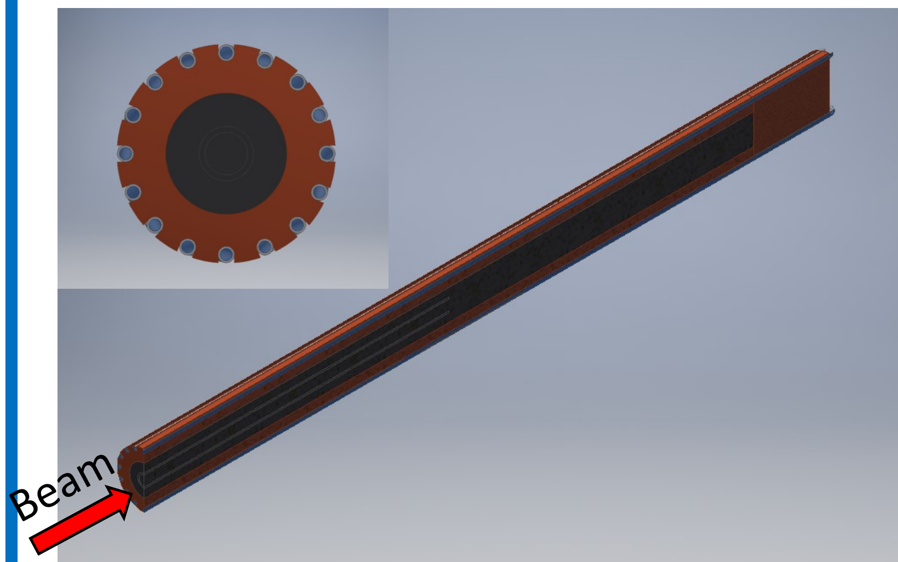


Figure 4: Schematic overview on the MAIN-dump system layout.

Description of the Beam Dump Systems for the European XFEL

ILC 125GeV Beam Dump

Max Power: 400kW



- E-XFEL Main Beam Dump would be good reference for ILC 125GeV dump.

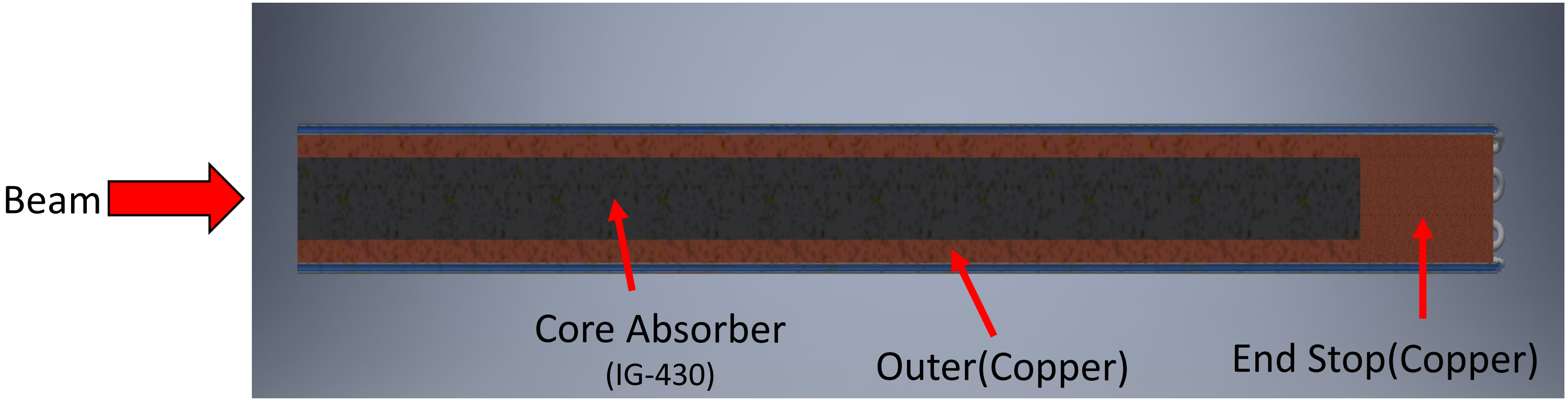
[E-XFEL]

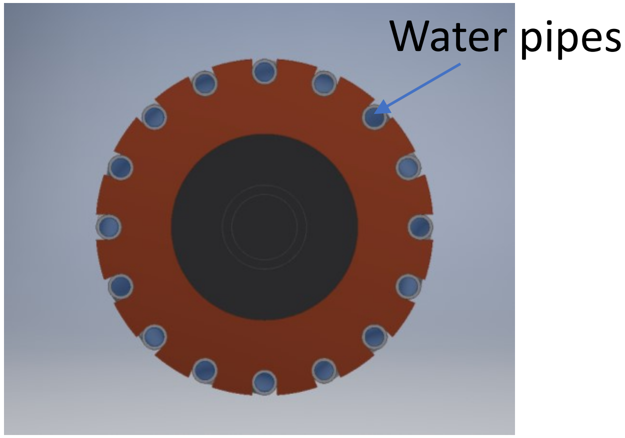
Main Absorber : Graphite , Energy ≦25GeV, Average Current≦40μA

[ILC 125GeV Beam Dump]

Main Absorber : Graphite(IG-430) ,Energy = 125GeV, Average Current≦3.2μA

Base Design of Graphite Dump





【Manufacture Issues】

・Graphite is shrink fitted into copper outer.
⇒Thermal contact resistance make temperature rise

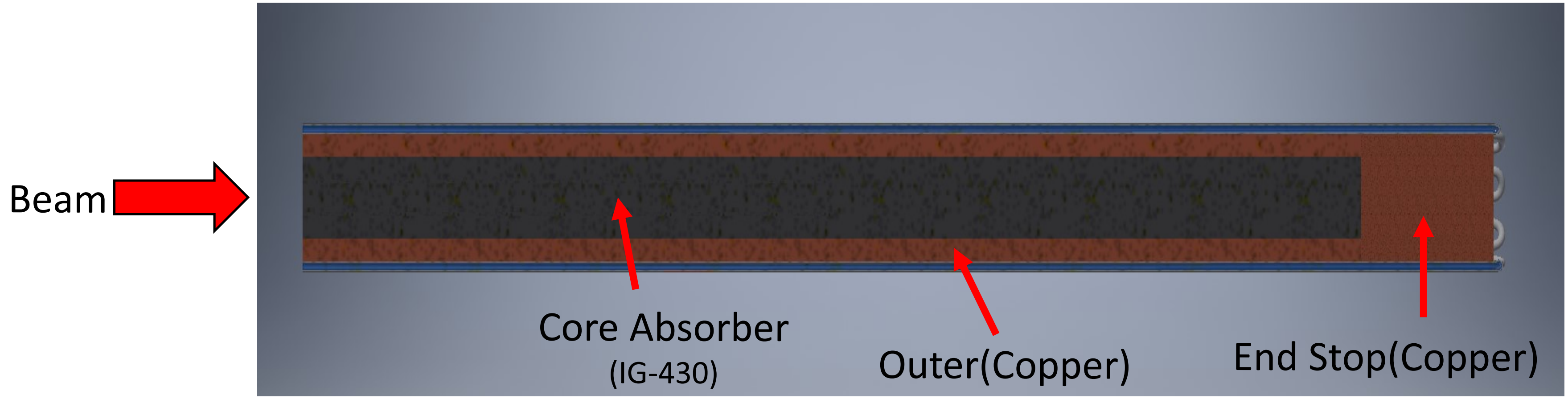
・Graphite/Copper part is divide to some pieces for manufacturing and connected by welding.

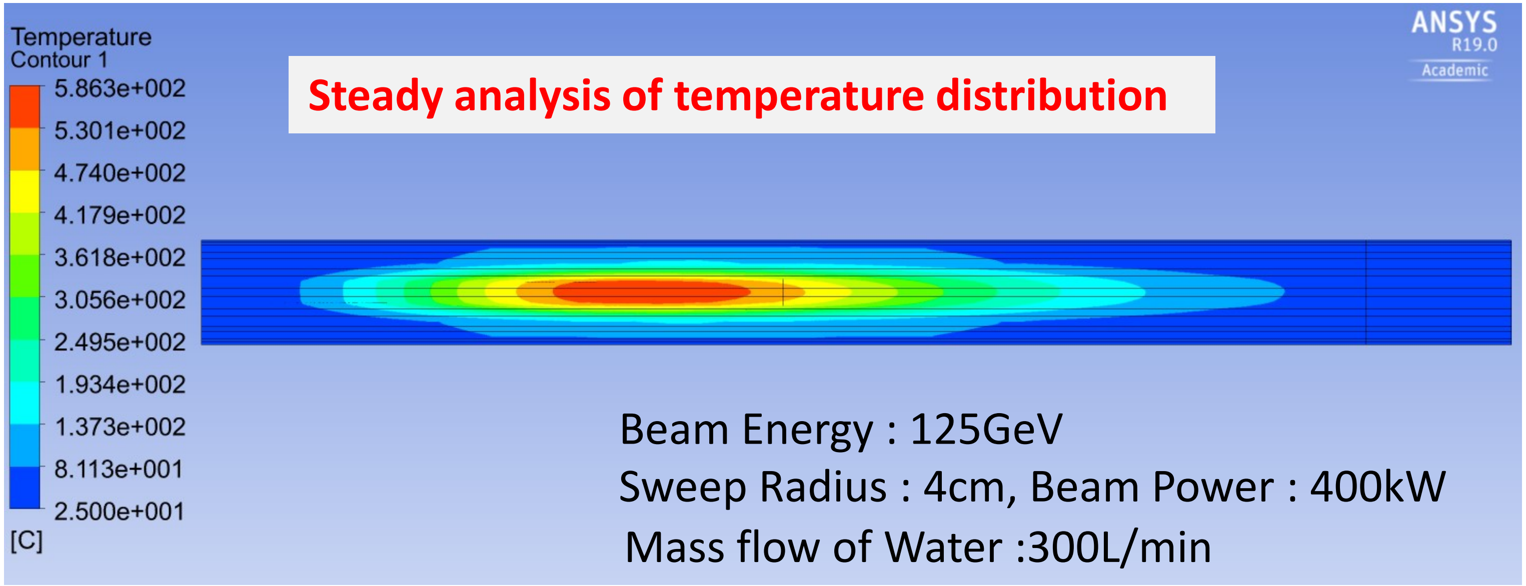
◆ Core absorber is cooled via copper outer.

Core Absorber(Temporary Design) : L4000 × 200ϕ(mm).

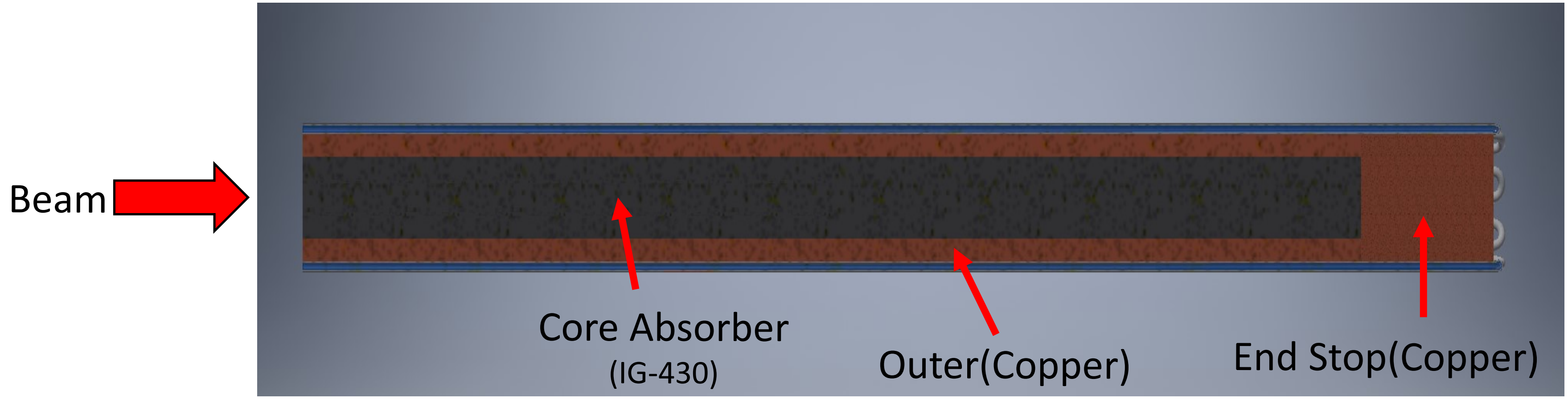
＊Radiation Length(Graphite) :23.9cm , Morier radius(Graphite) : 5.9cm

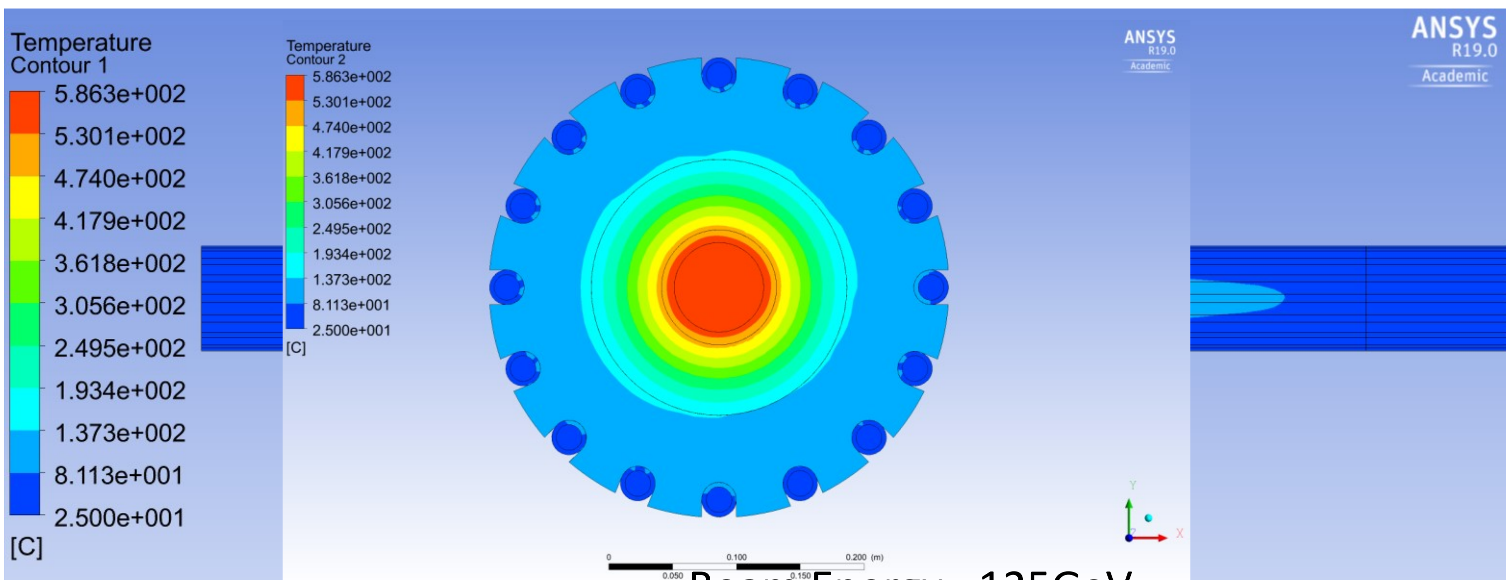
Base Design of Graphite Dump





Base Design of Graphite Dump





Beam Energy : 125GeV

Sweep Radius : 4cm, Beam Power : 400kW

Mass flow of Water :300L/min

Summary

◆Acceptable Beam Parameters

Key factor is Beam Size,
How much we can enlarge the beam size is quite important
We should make detail for tune phase operation , beam line for dump.

◆Base Design of other dumps

We can learn from world-wide experience(LCLS2, E-XFEL, etc ,,,)
Mechanical design of other dump would not be big issue.