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Thermal management of a high-end server

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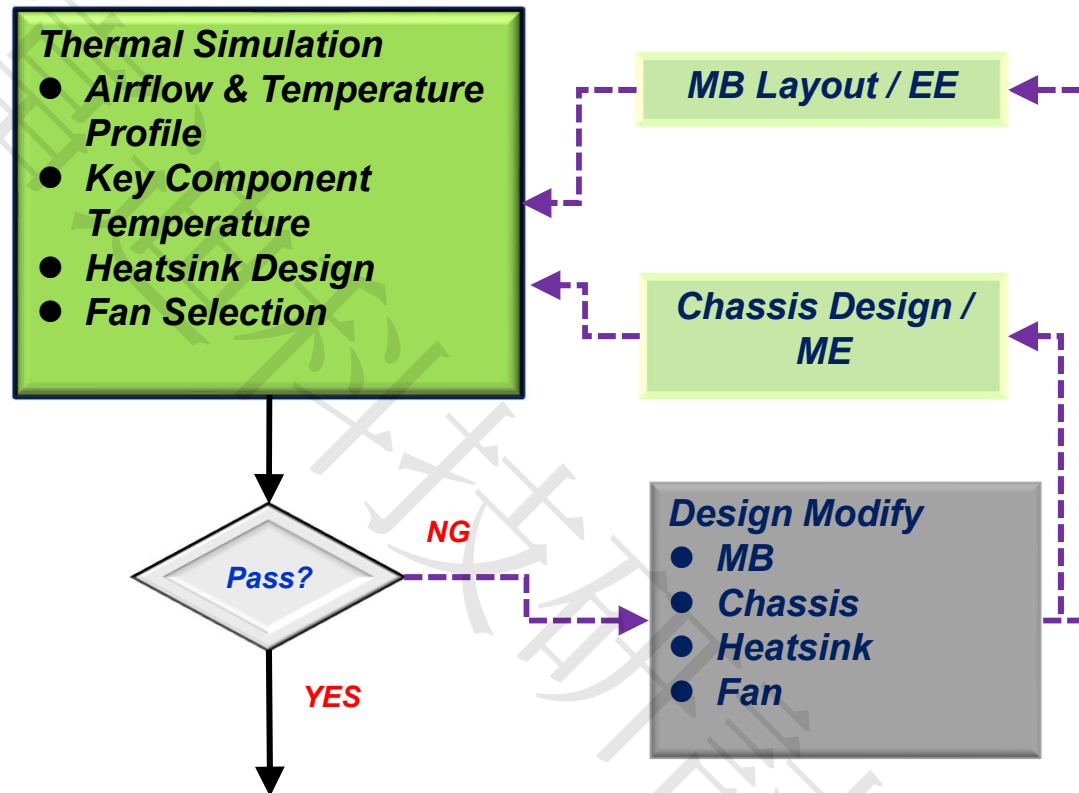
Standard thermal design rule:

- ✓ ***Product form factors***
- ✓ ***Operating and environmental boundary conditions including higher ambient operating temperatures***
- ✓ ***Real-Time operating system software***
- ✓ ***Standard power delivery requirements***

Reference applications are identified for business groups:

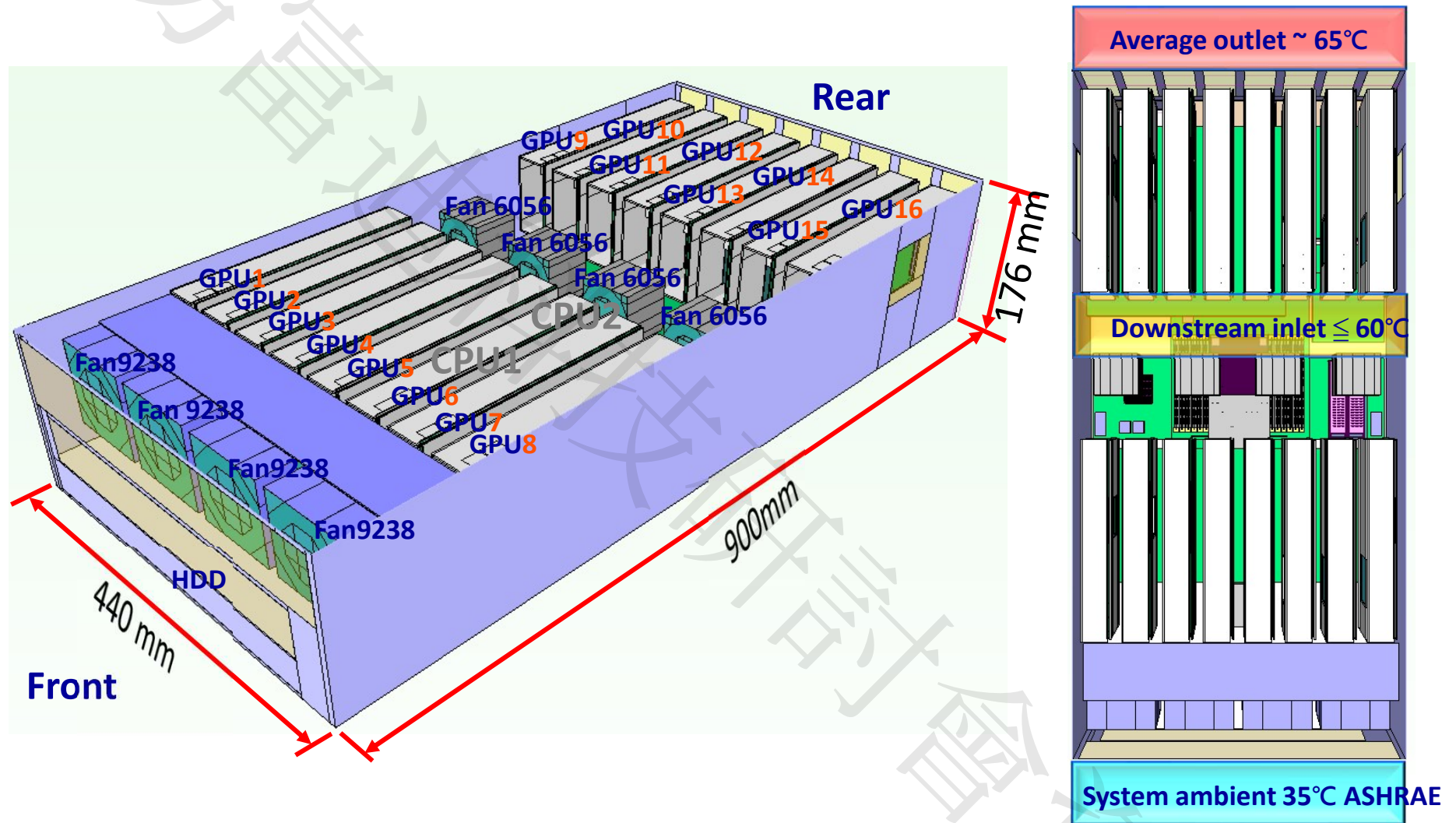
- ✚ Refer to TDP design at $T_a=35^{\circ}\text{C}$, fan and airduct design for worse case.***
- ✚ Refer to fan fail PQ curve measured data for fan fail design at $T_a=25^{\circ}\text{C} \sim 30^{\circ}\text{C}$ based on worse case fan and airduct design.***
- ✚ Refer to fan duty PQ curve measured data for system fan speed control / acoustic analysis at different ambient.***

Process Flow for Thermal Simulation



1. Thermal module performance vs. System flow rate verification
2. Airflow rate/ temperature variation
3. Server system thermal capability test with different stress/power levels (idle, 50%, 100%)
4. Serve system thermal capability test with different facility ambient temperatures
5. Fan failure/over temperature thermal protection mechanism verification

System (16 GPU Cards) overview

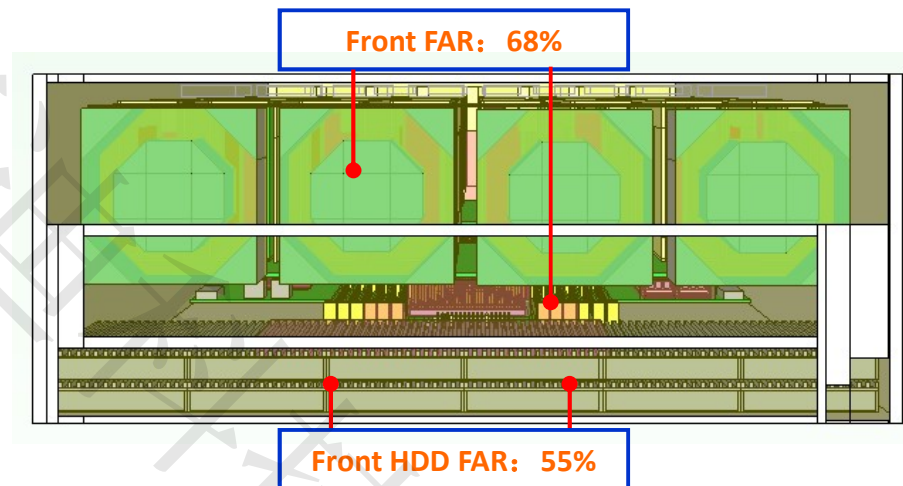


Risk consideration : Pressure drop between inlet/ outlet of failed fan, which caused airflow recycling of normal fans.

Strategy : Use dual rotor fan, one rotor acts regular fan and prevents airflow recycling once another rotor fail to lower over-heat risk in system.

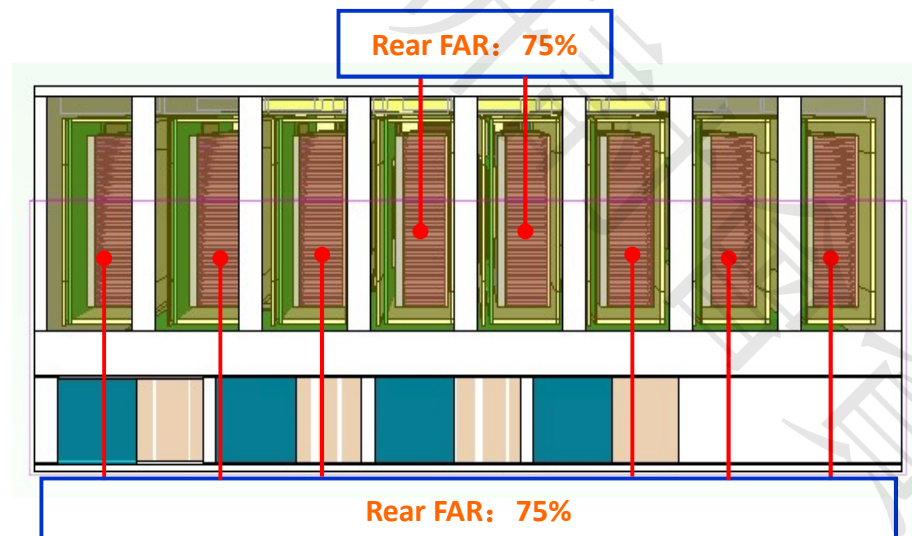
System Venting

Front view



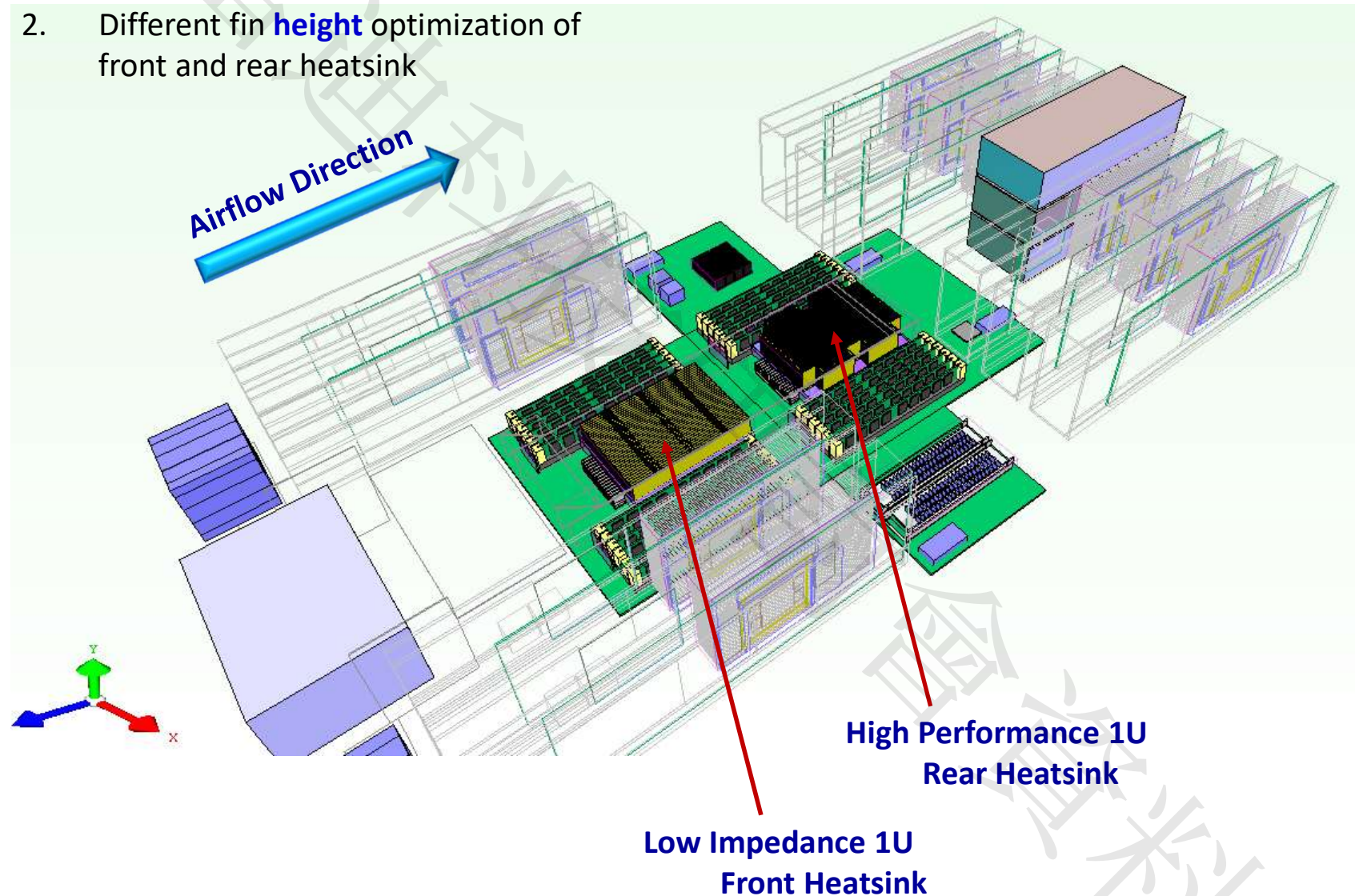
FAR: Free Air Ratio

Rear View

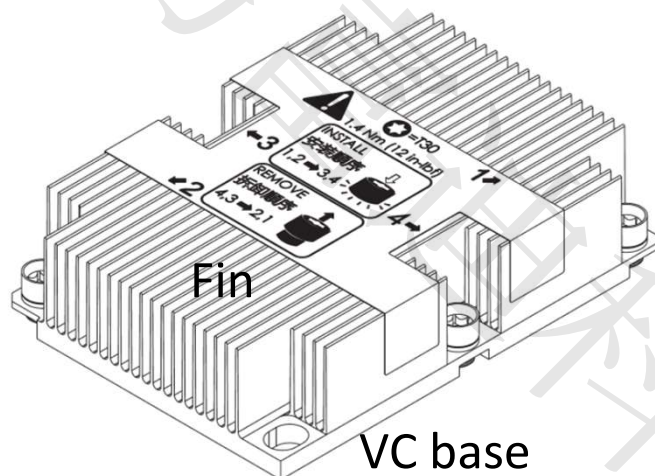


Flotherm Works on CPU Heatsink Design

1. Different fin **pitch** optimization of front and rear heatsink
2. Different fin **height** optimization of front and rear heatsink



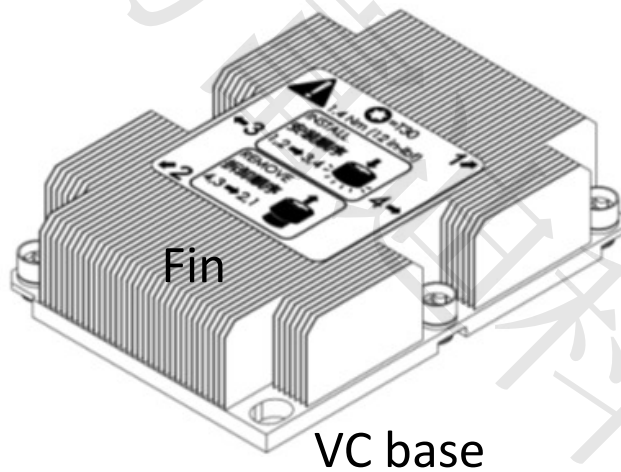
Front CPU 1U Heatsink Introduction



Item	TIM	
Chip	CPU	CPU VRD
Material	ShinEtsu -7783	Fujipoly
Conductivity	6 W/mK 0.15mm thickness	1.2W/mK 70% compressed
Quantity	1	1

Simulation parameters		
Condition	Stand alone	
Dimension	78x108x20 mm	
Material	Base	VC t=4.5mm
	Fin	Copper
Fin	Thickness	0.3mm
	Pitch	2.25mm
	Count	35pcs
Design performance	Power	205W

Rear CPU 1U Heatsink Introduction



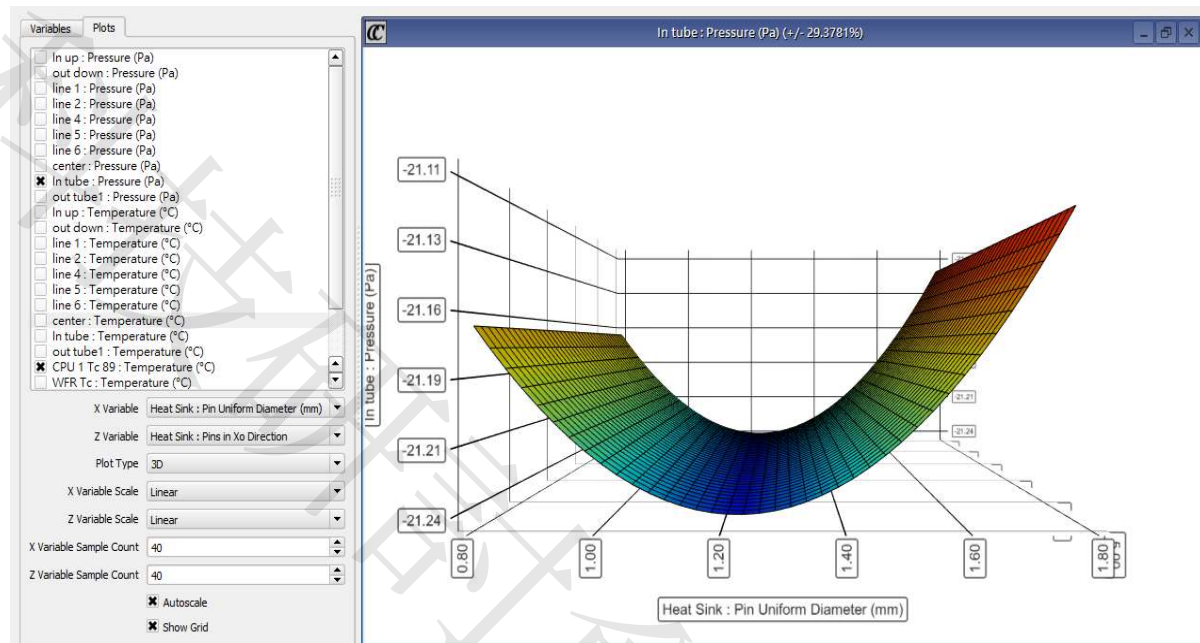
Item	TIM	
Chip	CPU	CPU VRD
Material	ShinEtsu -7783	Fujipoly
Conductivity	6 W/mK 0.15mm thickness	1.2W/mK 70% compressed
Quantity	1	1

Simulation parameters		
Condition	Stand alone	
Dimension	78x108x25.5 mm	
Material	Base	VC t=4.5mm
	Fin	Copper
Fin	Thickness	0.3mm
	Pitch	1.6mm
	Count	52pcs
Design performance	Power	205W

Response Surface Optimization of Heatsink Design

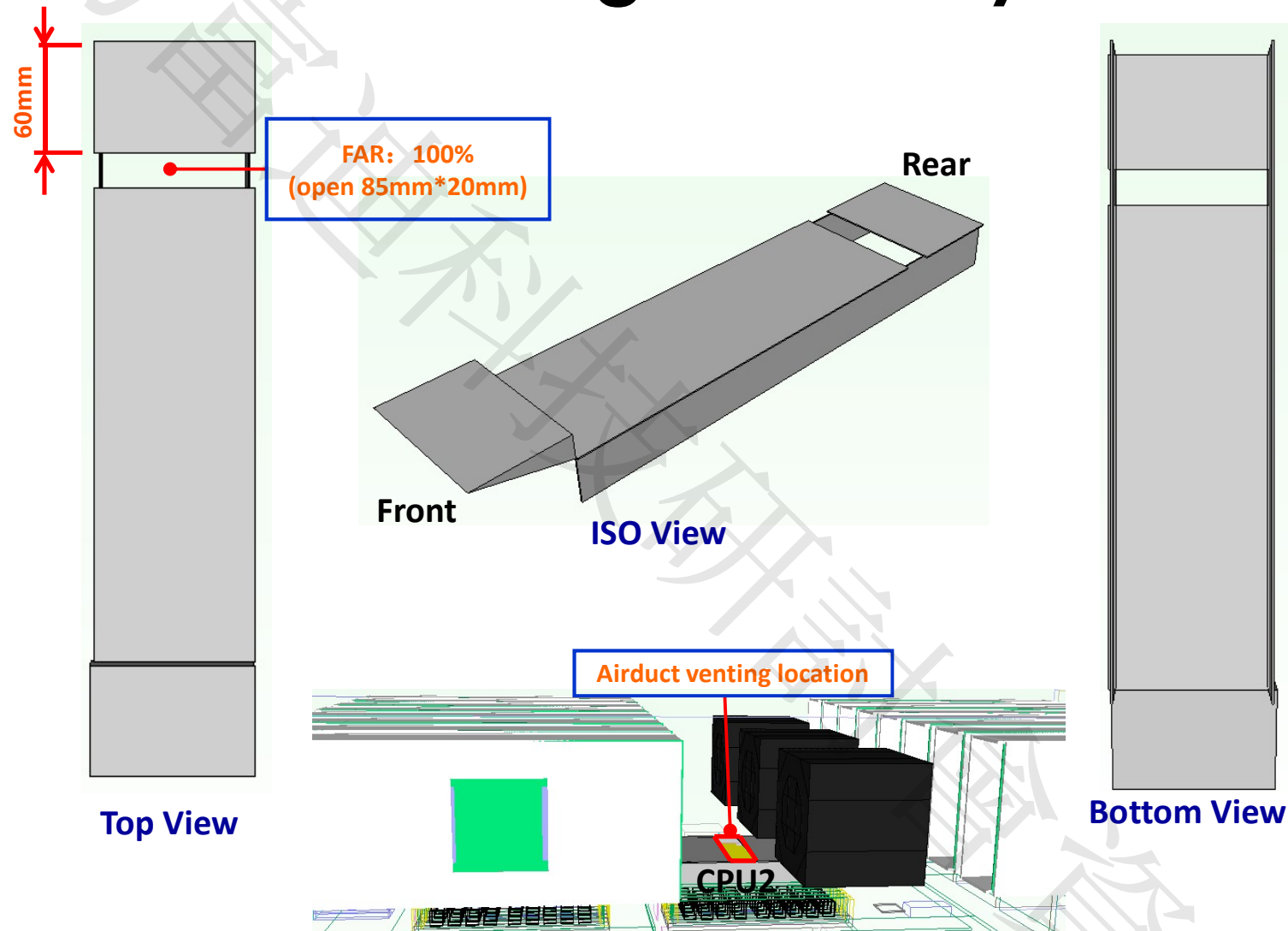
Thermal Performance and fin geometry

- *Optimal heatsink dimension parameters present better thermal performance by using proper design parameter of fin dimension.*
- *Increasing fin dimension then enhancing thermal conductivity but also rising flow impedance.*

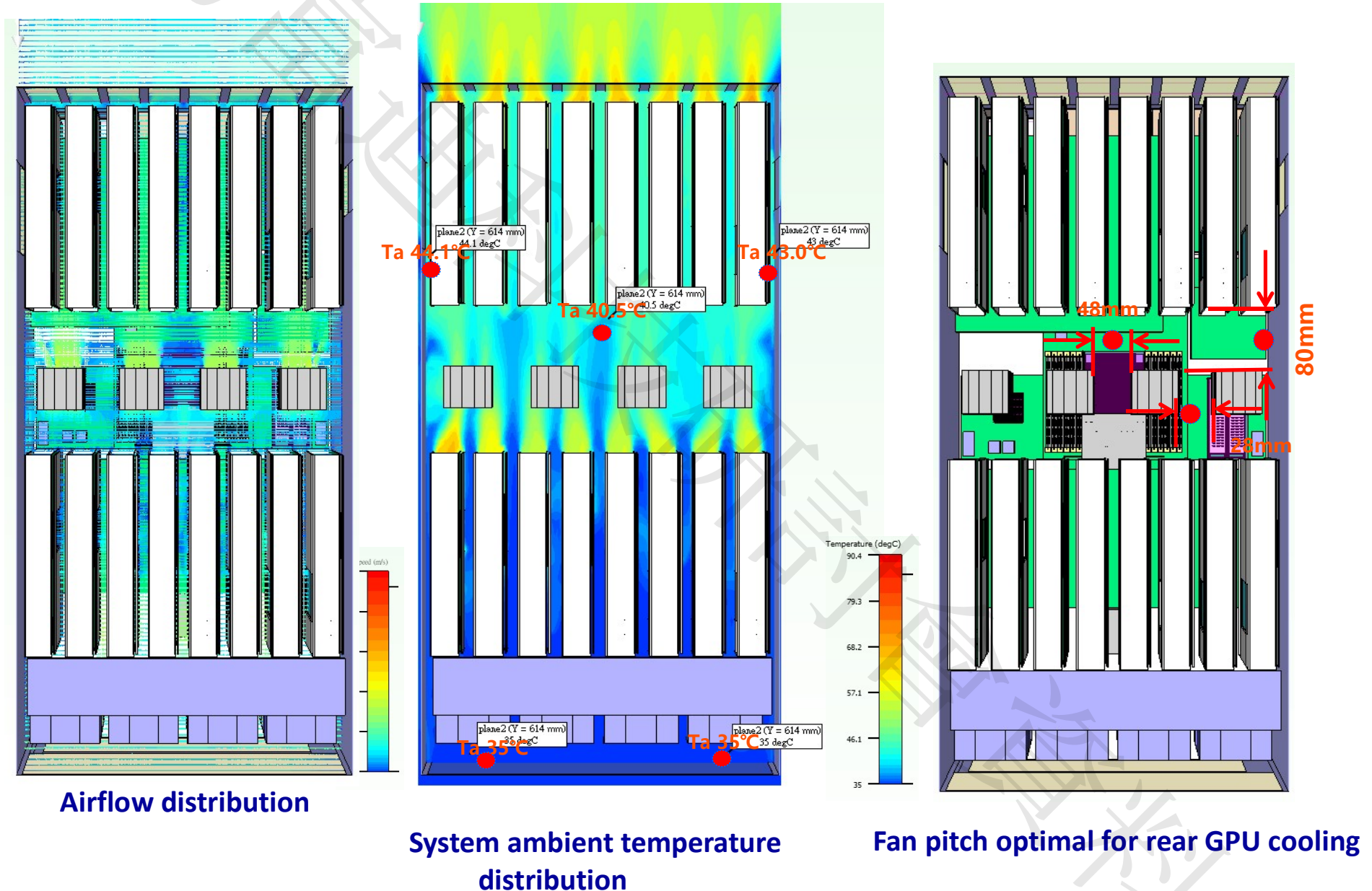


Flow rate optimization vs. Fin dimension by RSO

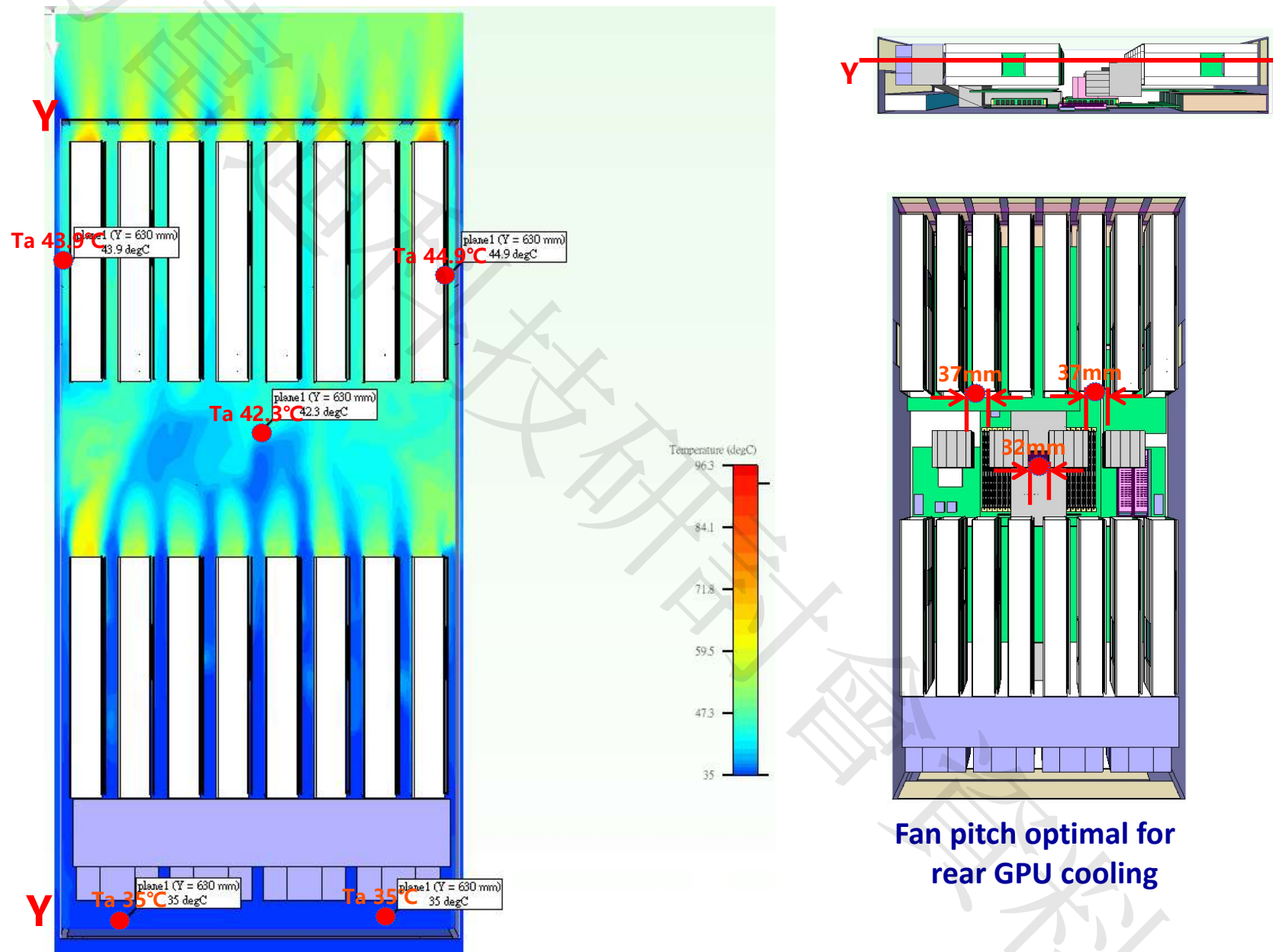
Air duct design for 4U System



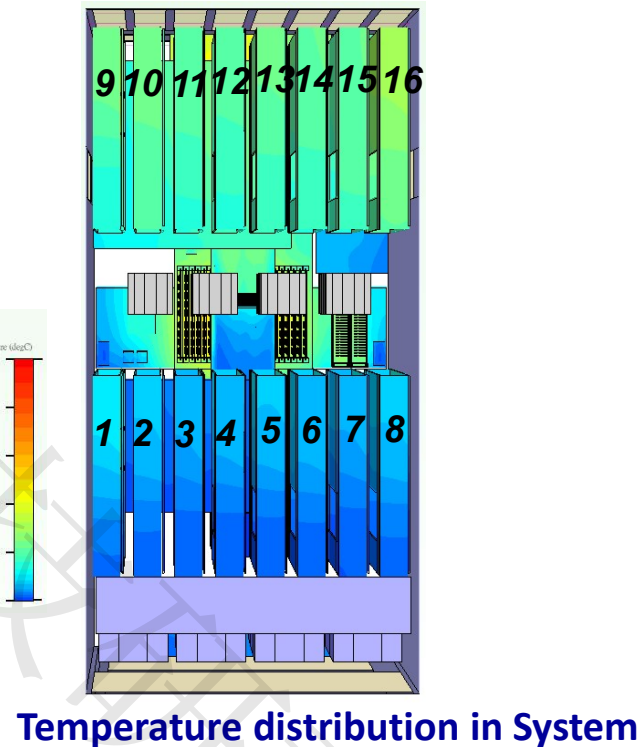
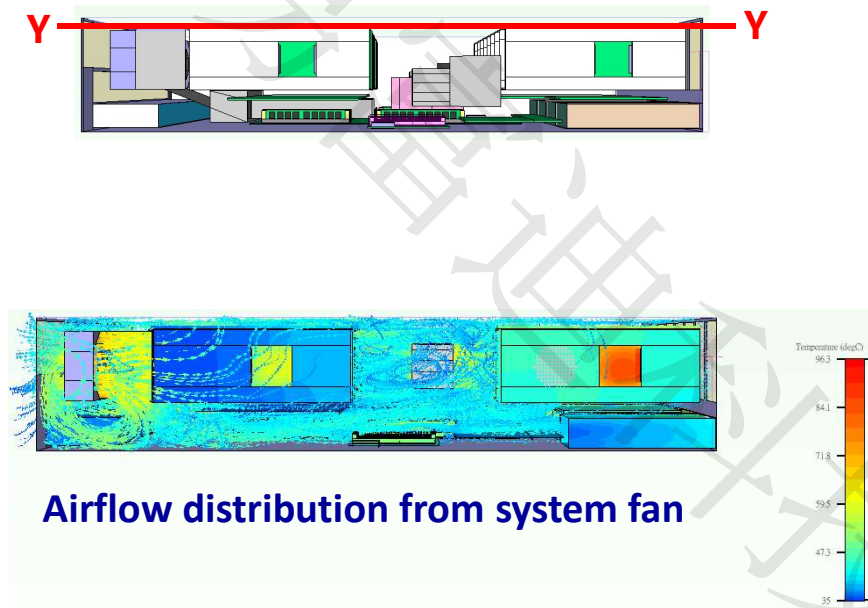
Rear GPU Fan Location Arrangement_Top View



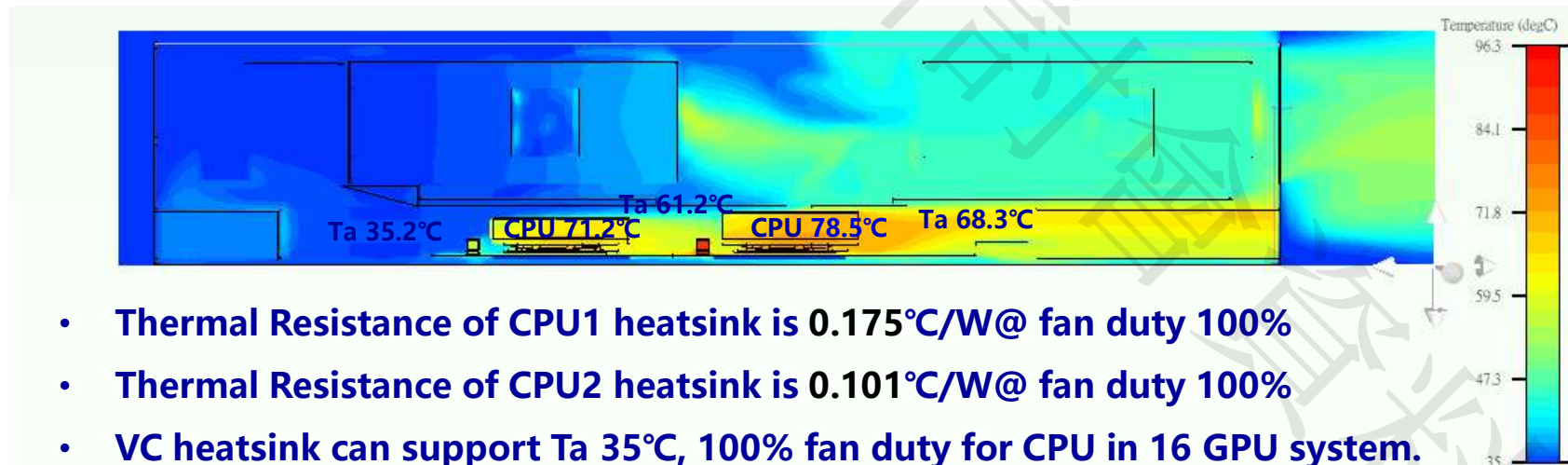
Rear GPU Fan Location Optimization Top View



Thermal Solution of Purley Processors and GPU Cards

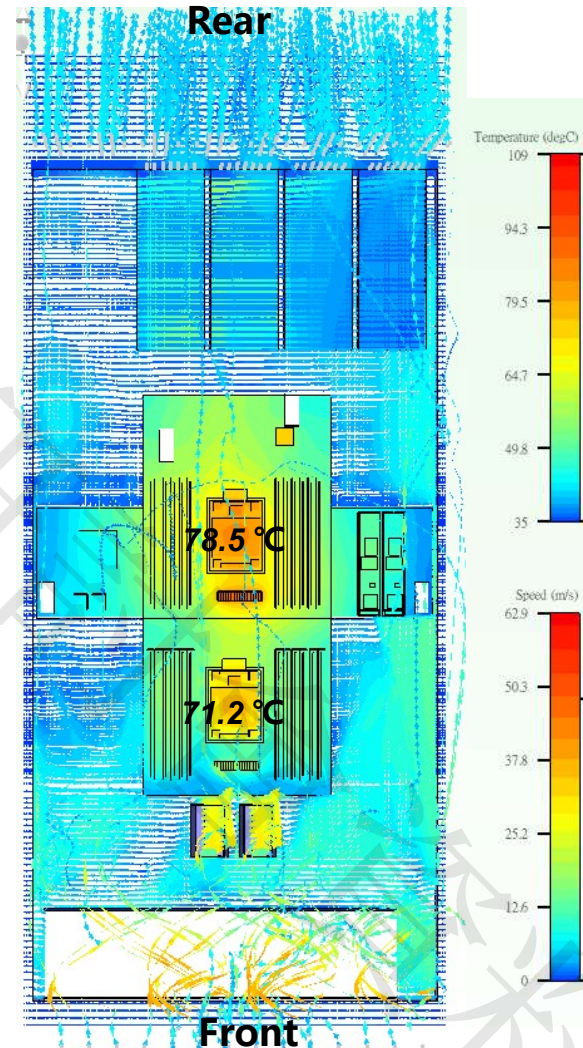
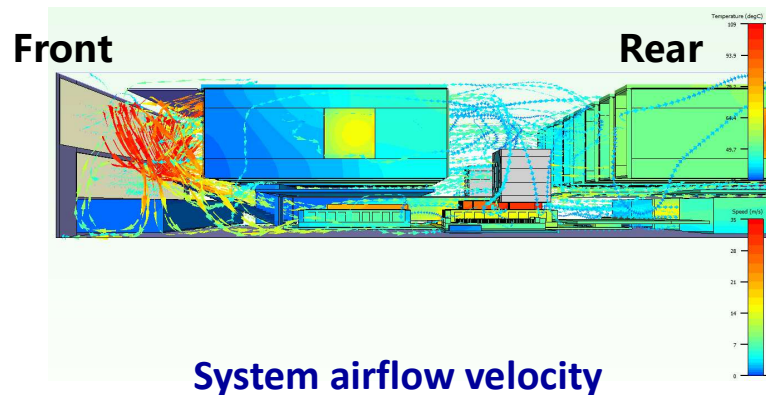
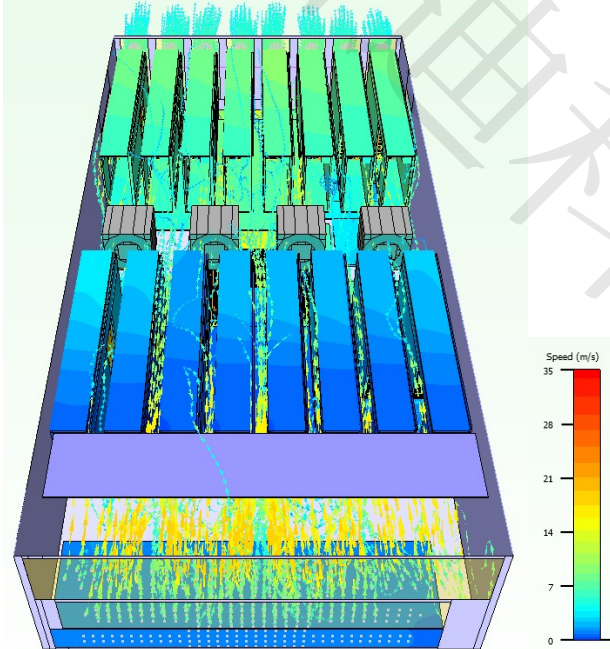


GPU1	77.3
GPU2	69.5
GPU3	65.1
GPU4	65.3
GPU5	66.5
GPU6	66.3
GPU7	65.4
GPU8	66.0
GPU9	86.4
GPU10	77.1
GPU11	84.2
GPU12	74.3
GPU13	73.9
GPU14	82.6
GPU15	74.5
GPU16	86.1



- Thermal Resistance of CPU1 heatsink is 0.175°C/W@ fan duty 100%
- Thermal Resistance of CPU2 heatsink is 0.101°C/W@ fan duty 100%
- VC heatsink can support Ta 35°C, 100% fan duty for CPU in 16 GPU system.

System Airflow Temperature Distribution Top View



System airflow temperature distribution top view

AGP System Simulation Results

100% Fan duty @ Ta=35°C:

T_c : Case Temperature
 T_j : Junction Temperature
 T_a : Inlet Ambient Temperature

Item	Power (W)	Spec. (°C)		Temp. (°C)				
				4U-001 config. original	4U-002 config. Added airduct	4U-003 config. Added CPU fan	4U-004 config.	T_{spec}
CPU 1 (Intel Xeon 8180)	205	84(T_c)	98(T_j)	94.5	85.9	78.9	71.2	T_c
CPU 2 (Intel Xeon 8180)	205	84(T_c)	98(T_j)	175.6	107.6	85.0	78.5	T_c
PCH (Intel C621)	15	86(T_c)	107(T_j)	70.5	71.1	70.6	70.4	T_c
RDIMM 1 (Front)	8	85	T_c	64.2	58.9	58.5	55.9	T_c
RDIMM 2 (Front)	8	85	T_c	59.1	57.2	57.9	56.9	T_c
RDIMM 3 (Rear)	8	85	T_c	90.2	66.7	71.2	60.9	T_c
RDIMM 4 (Rear)	8	85	T_c	98.3	69.5	67.0	62.7	T_c
CPU VRD 1 (94% efficiency)	12.3	125	T_c	64.4	65.4	59.1	57.3	T_c
CPU VRD 2 (94% efficiency)	12.3	125	T_c	123.7	100.4	92.4	90.2	T_c
GPU 1 (Nvidia Geforce V100) Front	250	87	T_c	71.6	66.3	69.9	77.3	T_c
GPU 2 (Nvidia Geforce V100) Front	250	87	T_c	63.8	61.7	64.2	69.5	T_c
GPU 3 (Nvidia Geforce V100) Front	250	87	T_c	60.7	62.1	71.1	65.1	T_c
GPU 4 (Nvidia Geforce V100) Front	250	87	T_c	63.8	61.9	68.4	65.3	T_c
GPU 5 (Nvidia Geforce V100) Front	250	87	T_c	80.7	91.7	72.1	66.5	T_c
GPU 6 (Nvidia Geforce V100) Front	250	87	T_c	86.0	97.6	73.6	66.3	T_c
GPU 7 (Nvidia Geforce V100) Front	250	87	T_c	70.4	73.1	86.0	65.4	T_c
GPU 8 (Nvidia Geforce V100) Front	250	87	T_c	98.8	74.1	73.5	66.0	T_c
GPU 9 (Nvidia Geforce V100) Rear	250	87	T_c	83.9	77.9	83.2	86.4	T_c
GPU 10 (Nvidia Geforce V100) Rear	250	87	T_c	73.8	75.0	77.4	77.1	T_c
GPU 11 (Nvidia Geforce V100) Rear	250	87	T_c	84.5	80.8	90.6	84.2	T_c
GPU 12 (Nvidia Geforce V100) Rear	250	87	T_c	89.1	80.5	81.2	74.3	T_c
GPU 13 (Nvidia Geforce V100) Rear	250	87	T_c	93.9	89.7	84.7	73.9	T_c
GPU 14 (Nvidia Geforce V100) Rear	250	87	T_c	95.6	95.8	89.2	82.6	T_c
GPU 15 (Nvidia Geforce V100) Rear	250	87	T_c	84.2	84.0	75.1	74.5	T_c
GPU 16 (Nvidia Geforce V100) Rear	250	87	T_c	95.7	100.9	83.6	86.1	T_c

AGP System Simulation Results (cont.)

T_c : Case Temperature
 T_j : Junction Temperature
 T_a : Inlet Ambient Temperature

100% Fan duty @ $T_a=35^\circ\text{C}$:

Item	Power (W)	Spec. ($^\circ\text{C}$)		Temp. ($^\circ\text{C}$)				
				4U-001 config. original	4U-002 config. Added airduct	4U-003 config. Added CPU fan	4U-004 config	T_{spec}
M.2	5	85	T_c	55.1	53.5	52.1	52.3	T_c
BMC (AST2500A2-GP)	1.4	90(T_c)	125(T_j)	118	83.1	72.5	69.6	T_c
Front HDD (U.2)	16	55(T_a)	85(T_c)	69.5	70.2	69.7	69.1	T_c
PSU inlet (1600W)	NA	55(T_a)	NA	66.7	58.9	70.7	51.3	T_a
Front right corner ambient		Ref		36.0	35.0	35.0	35.0	T_a
Front left corner ambient		Ref		35.1	35.7	35.1	35.0	T_a
Rear right corner ambient		Ref		38.4	39.0	44.8	43.9	T_a
Rear left corner ambient		Ref		37.7	51.2	37.7	44.9	T_a
Center of system ambient		Ref		103	60.1	55.0	42.3	T_a

	Fan model	Quantity		Fan size	Speed	Rated Voltage	Rated Current	Rated Power	Maximum Air Flow		Noise	Total power consumption (Watt)
	Axial/Blower	front	rear	(mm)	(rpm)	(V)	(A)	(Watt)	(CFM)	(inch H_2O)	(dBA)	
4U	Axial	4	0	92x92x38	13000/13000	12	4	48	182.4	2.94	72.1	409.2
	Axial	2	0	40x40x56	21500/18000	12	1.55	18.6	31.7	3.6	67.9	
	Axial	0	3	60x60x56	19200/19200	12	5	60	80.5	6.43	80.2	
4U-1	Axial	6	0	60x60x56	15300/14300	12	2.5	30	72.9	3.44	71.7	337.2
	Axial	2	0	40x40x56	21500/18000	12	1.55	18.6	31.7	3.6	67.9	
	Axial	0	4	60x60x56	15300/14300	12	2.5	30	72.9	3.44	71.7	
4U-2	Axial	4	0	92x92x38	13000/13000	12	4	48	182.4	2.94	72.1	349.2
	Axial	2	0	40x40x56	21500/18000	12	1.55	18.6	31.7	3.6	67.9	
	Axial	0	4	60x60x56	15300/14300	12	2.5	30	72.9	3.44	71.7	