Vacuum System of SPS-II: Challenges of Conventional Technology in Thailand New Generation Light Source

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On behalf of SPS-II working groups

THAI SYNCHROTRON NATIONAL LAB

Siam Photon

Siam Photon Source II (SPS-II)

- **High-energy** *and* **high-intensity** *synchrotron light source*
- *Located at the Eastern Economic Corridor (EEC) area in the* **EECi** *(EEC of innovation) district*
- *Aim to strengthen scientific community in both* **academic** *and* **industrial research**
- **Scientific opportunities:** *Biomedical research, food and agriculture, industrial catalyst, advanced materials, environment, microelectronics and spintronics and archaeology and paleontology*
- *Currently in the design and prototyping stage* – **plan for opening to users in 2029**

Courtesy: Prapaiwan Sunwong

SPS VS SPS-II

Comparison of Technical Specification between SPS and SPS-II Machine

	SPS-I	SPS-II	Advantage of SPS-II over SPS-I
Electron Energy	1.2 GeV	3.0 GeV	Higher Energy of Hard X-ray Photon
Beam current (max)	150 mA	300 mA	Larger Intensity of Synchrotron Radiation
Lattice Structure	DBA *Double Bending Achromat*	DTBA *Double Triple Bending Achromat*	Lower Electron Emittance
Operation Mode	Decade	Top-Up	Constant Photon Beam Brightness
Circumference	81.3 m	327.5 m	Greater Operational Flexibility
No. of IDs beamline (for Insertion / Straight Session)	4/8	21/28	More IDs for Beamline
Emittance	60.5 nm·rad	< 1 nm nm·rad	Higher Brilliance

Courtesy: Pat Photongkam

Challenges

Local manufacturing technology

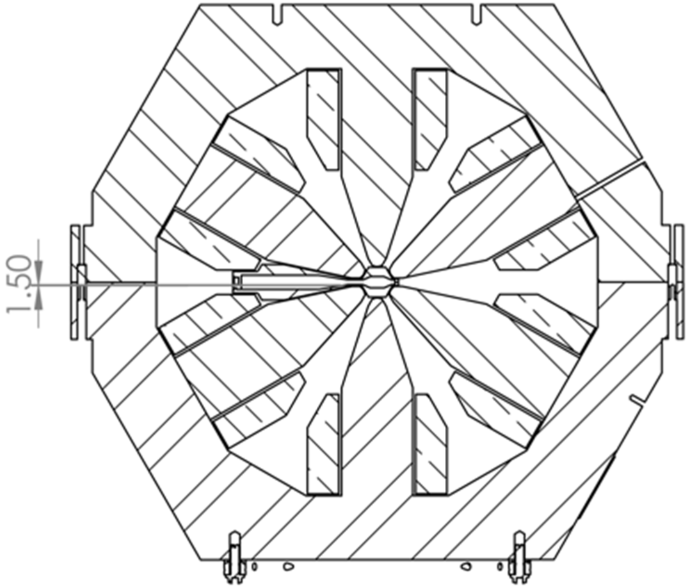
- 50% of main components aim to be manufactured domestically. Especially, Magnets, UHV chambers, and High precision girders.

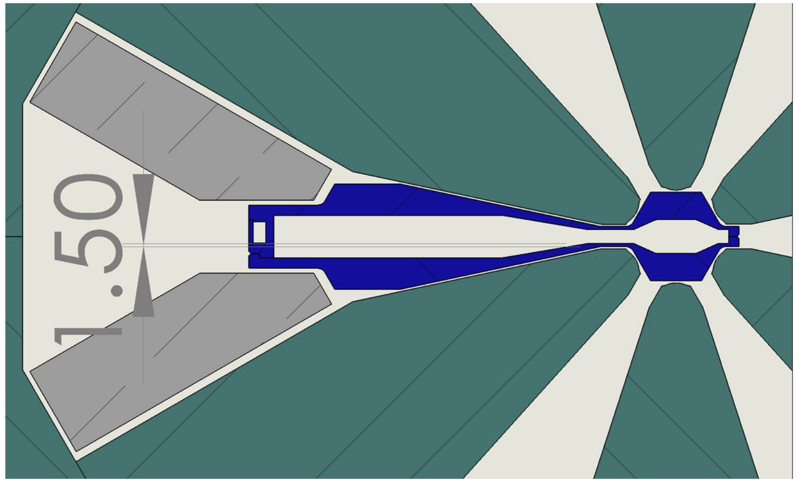
Space limitation

- Small magnet bore aperture vs BSC >> less chamber thickness & less conductance
- Dense magnets >> no space for pumps and other equipment (bellow, gate valve, etc.)

Impedance

- RF-shield bellow, flange & gasket,





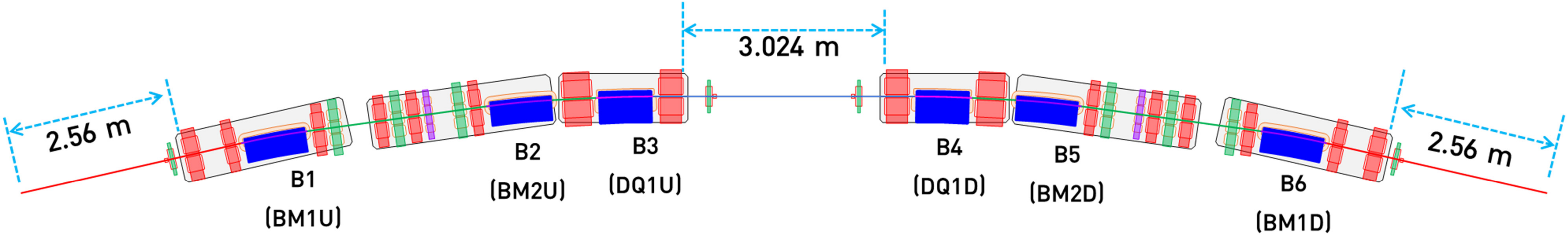
Selection of Vacuum Chamber Material

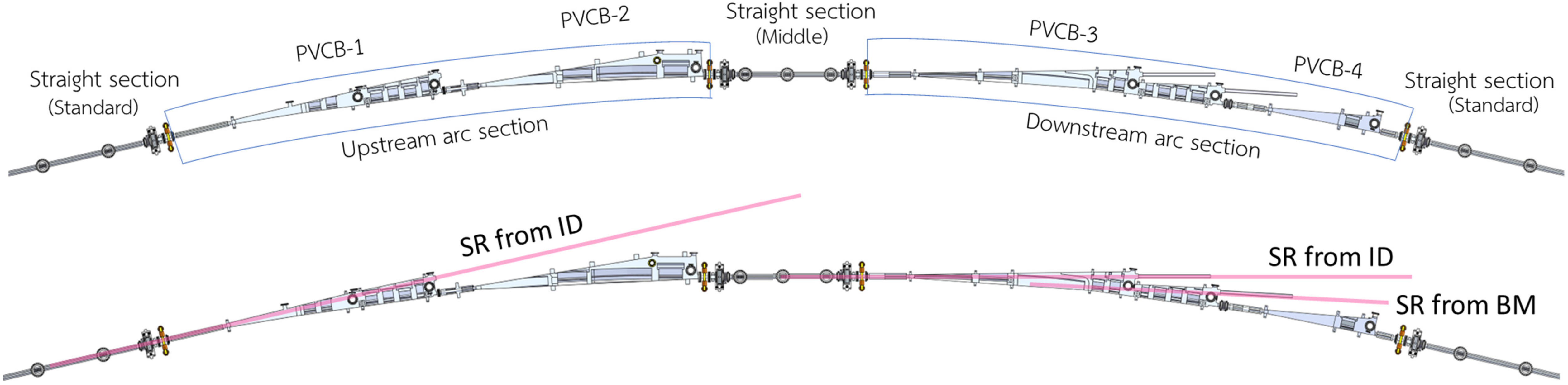
Specifics	Aluminium	Stainless Steel	Copper
Initial PSD rate	Low	Low	Low
Mechanical strength	*Acceptable*	Excellent	*Good*
Thermal expansion	Large	*Small*	*Small*
Thermal conductivity	Excellent	Poor	*Excellent*
Weld ability	Difficult	Excellent	*Good*
Bi-metal flanges	*Yes*	*No*	*Yes*
Cooling channels	*Extrusion*	*Brazed*	*Brazed*
Fabrication cost	Low	*Average*	Expensive
Precision	Good	Poor	*Acceptable*
Radiation shielding	Poor	*Average*	*Excellent*
Necessary Tech. R&D	*1. Oil-less Machining* *2. Precision Welding*	*1. Copper plating* *2. Precision Machining* *3. Demagnetization* *4. Vacuum firing*	*1. Clean brazing furnace* *2. Extremely high heat load absorber*

The decision to proceed with aluminum was based on the following factors:

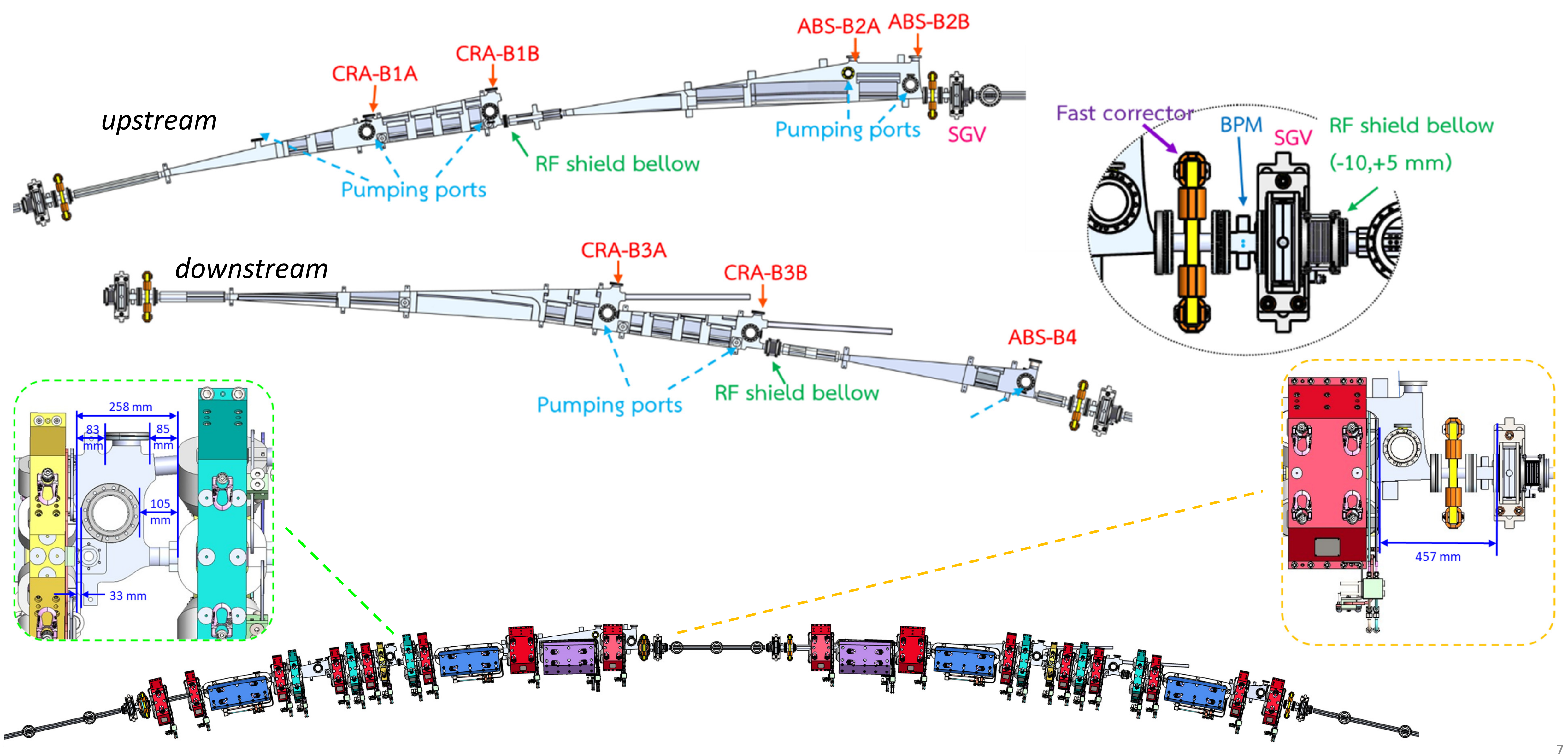
1) *A short R&D period to complete the copper plating process and quality testing.*
2) *Advice from our advisor, Prof. Chen, especially regarding the welding process.*
3) *The advantages of aluminum, including its lightweight nature, high strength-to-weight ratio, corrosion resistance, thermal conductivity, high-precision machinability, and cost-effectiveness.*

Storage ring: DTBA lattice and chamber sections



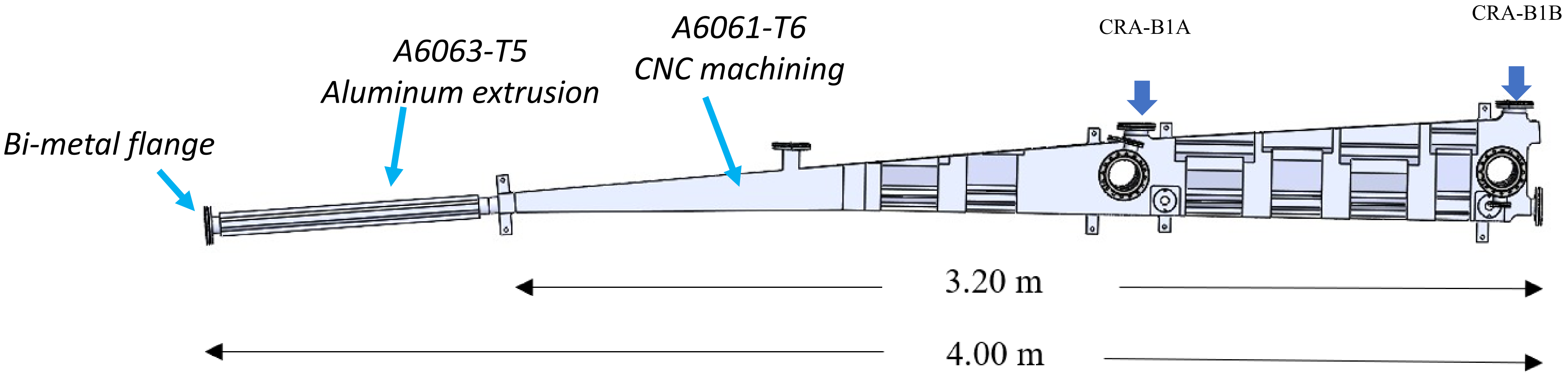


Arc section



CRA-B1A
CRA-B1B
ABS-B2A
ABS-B2B
upstream
Pumping ports
RF shield bellow
Pumping ports
SGV
Fast corrector
BPM
SGV
RF shield bellow
(-10,+5 mm)
downstream
CRA-B3A
CRA-B3B
ABS-B4
Pumping ports
RF shield bellow
258 mm
83 mm
85 mm
105 mm
33 mm
457 mm

Bending chamber design



Material properties

Material property	Al6061-T6	Al6063-T5
Density (kg/m^3)	2,700.0	2,700.0
Ultimate stress (MPa)	310.0	185.0
Yield stress (MPa)	276.0	145.0
Modulus of elasticity (GPa)	68.9	69.0
Poisson's ratio	0.33	0.33
Coefficient of Thermal Expansion (e-6/°C)	23.2	23.4
Melting point (°C)	588.0	616.0

Structural tolerances

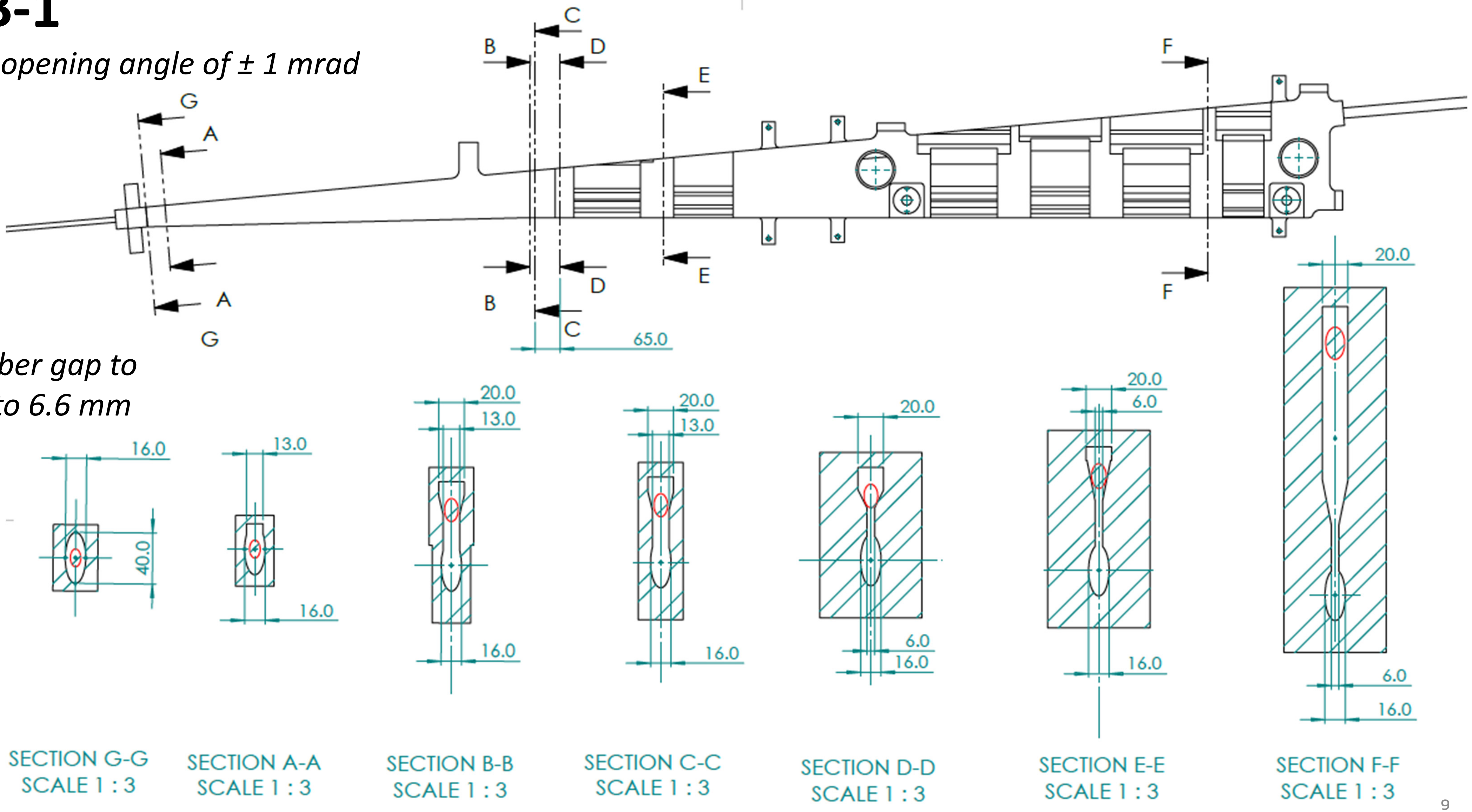
Total deformation	< 1 mm
Longitudinal deformation	< 1 mm
Vertical and horizontal deformation	< 0.1 mm (beam duct) < 0.3 mm (antechamber)
Safety factor	> 2

Bending chamber design

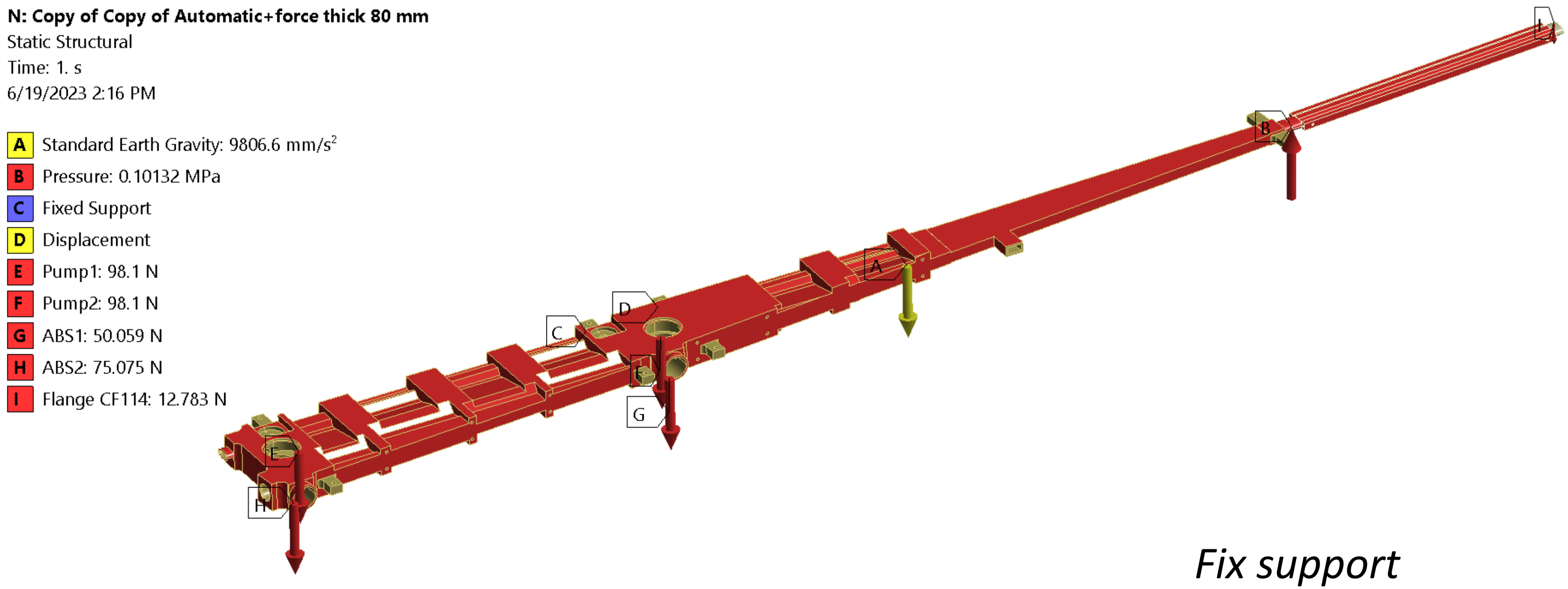
PVCB-1

Vertical opening angle of ± 1 mrad

Increase antechamber gap to 13 mm then taper to 6.6 mm



Chamber structural simulation: PVCB-1



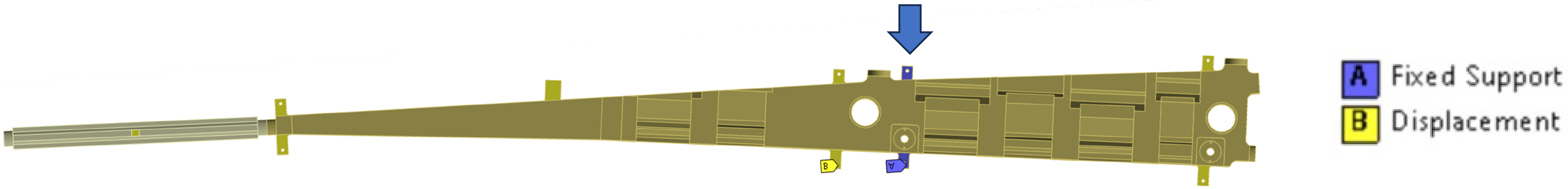
Input parameters

1. Forces due to

- *Chamber weight*
- *Atmospheric pressure*
- *Pumps*
- *Photon absorbers*

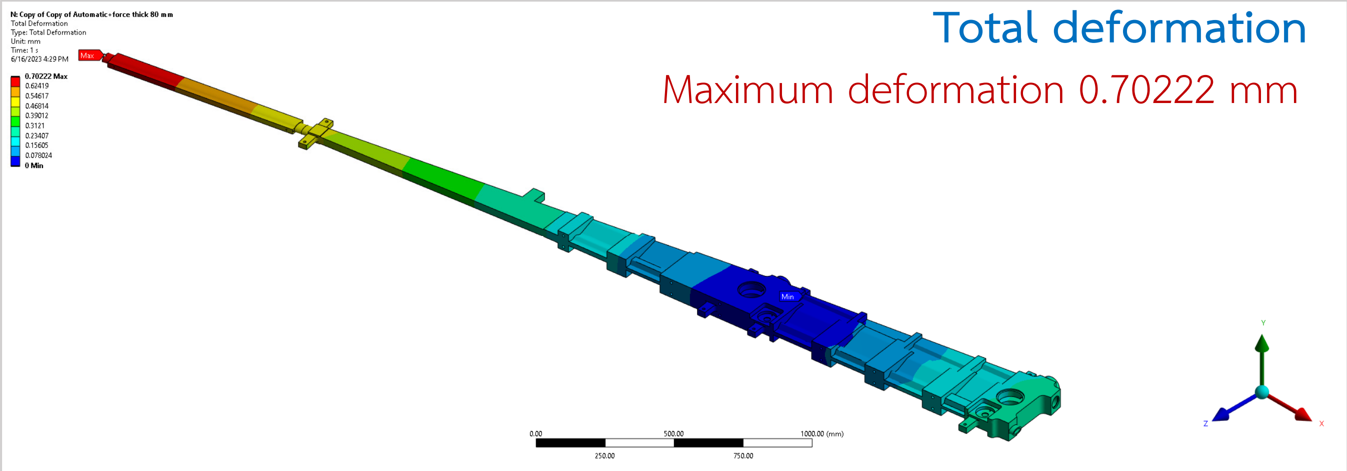
2. Temperature: 35°C

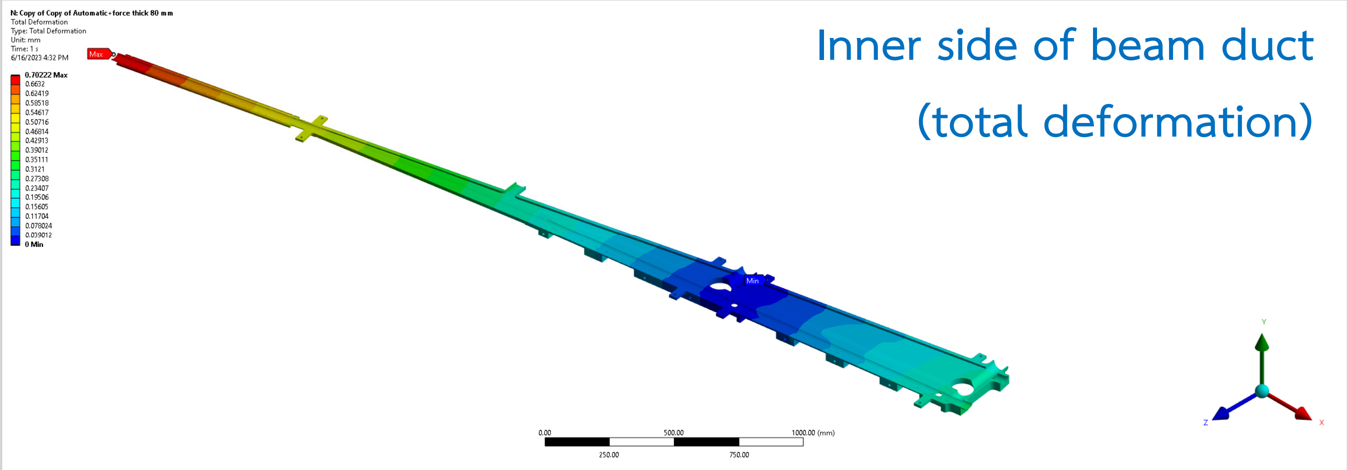
Fix support

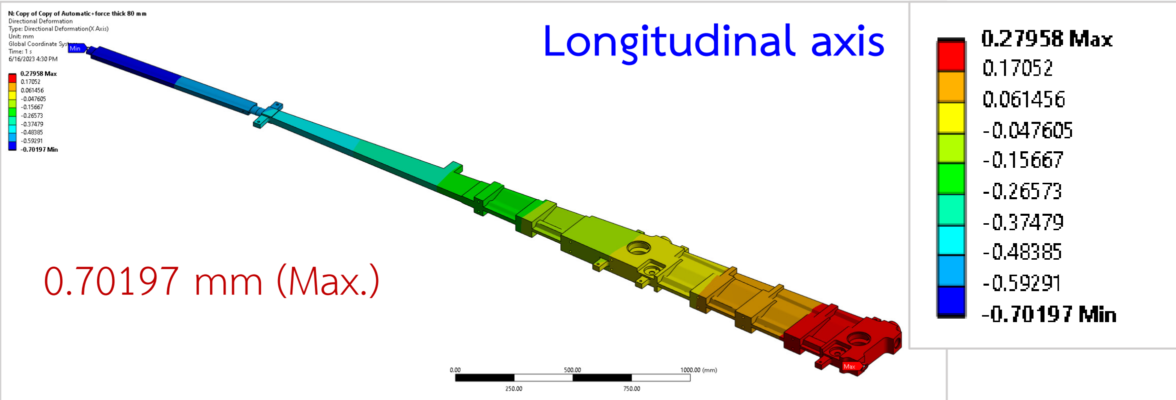


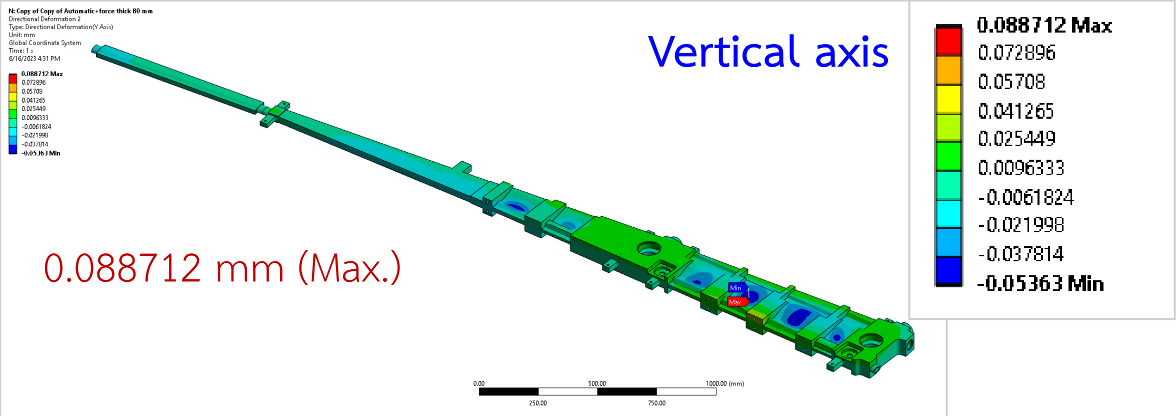
1 fixed support and 4 displacements (The chamber can move freely on longitudinal direction)

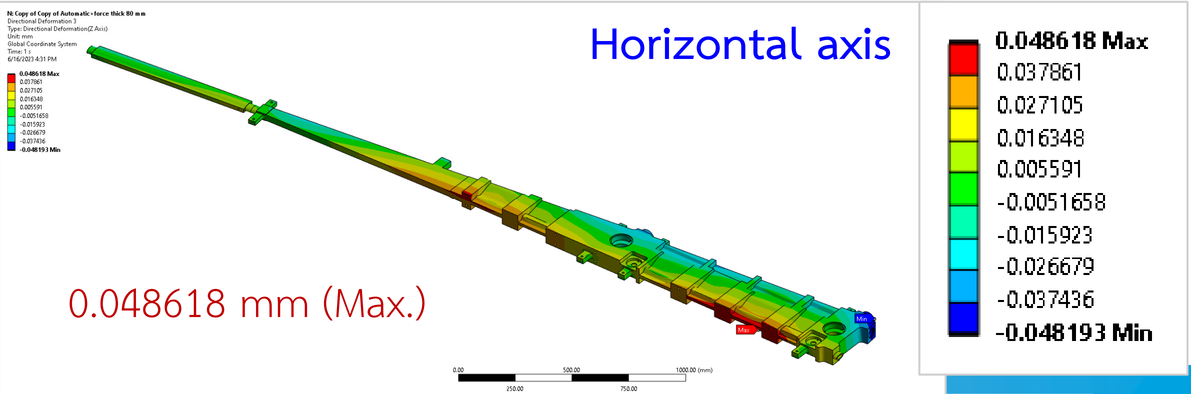
PVCB-1 simulation: deformation



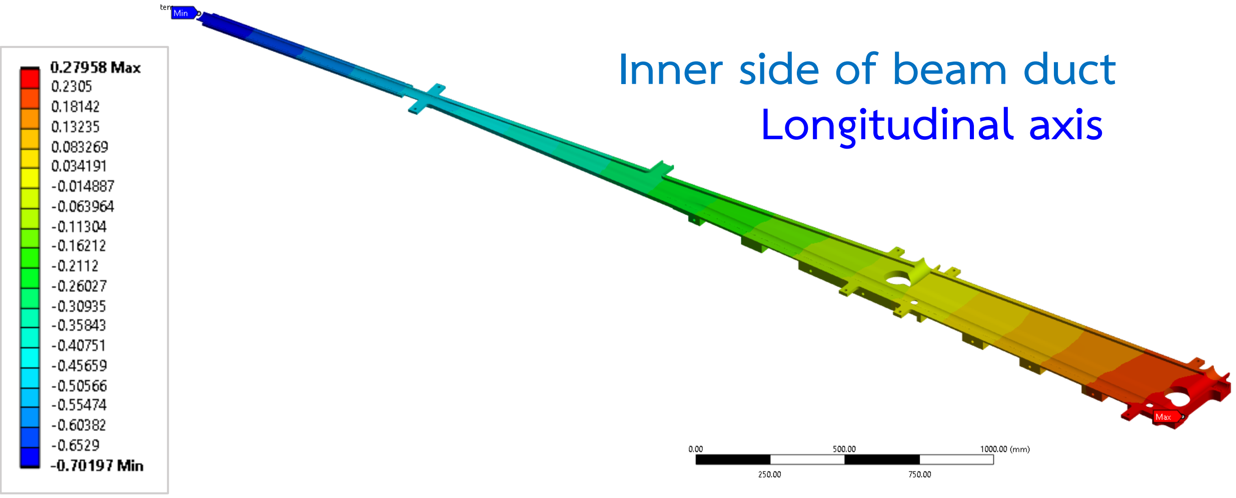






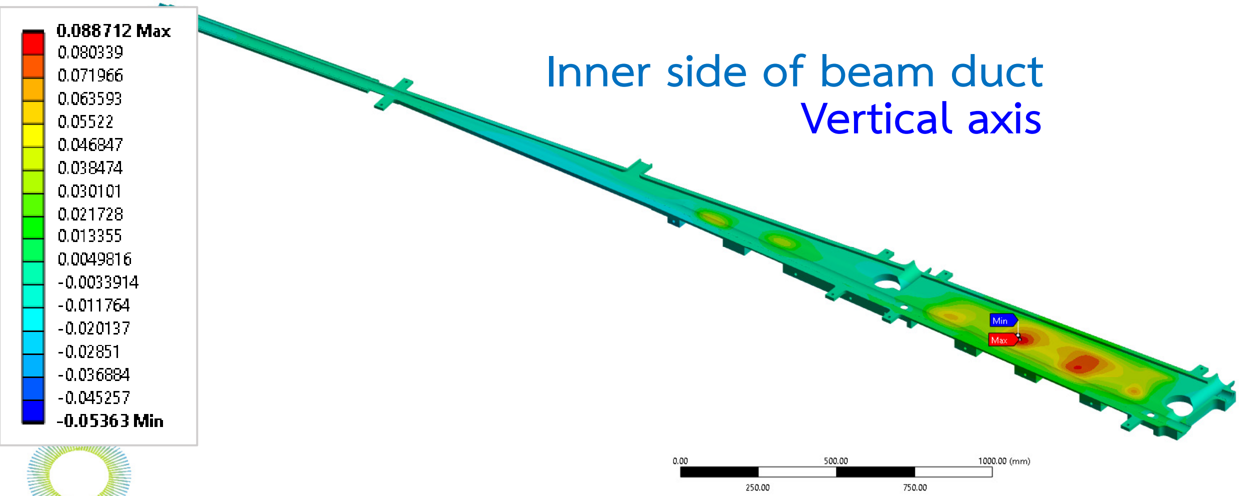


PVCB-1 simulation: deformation

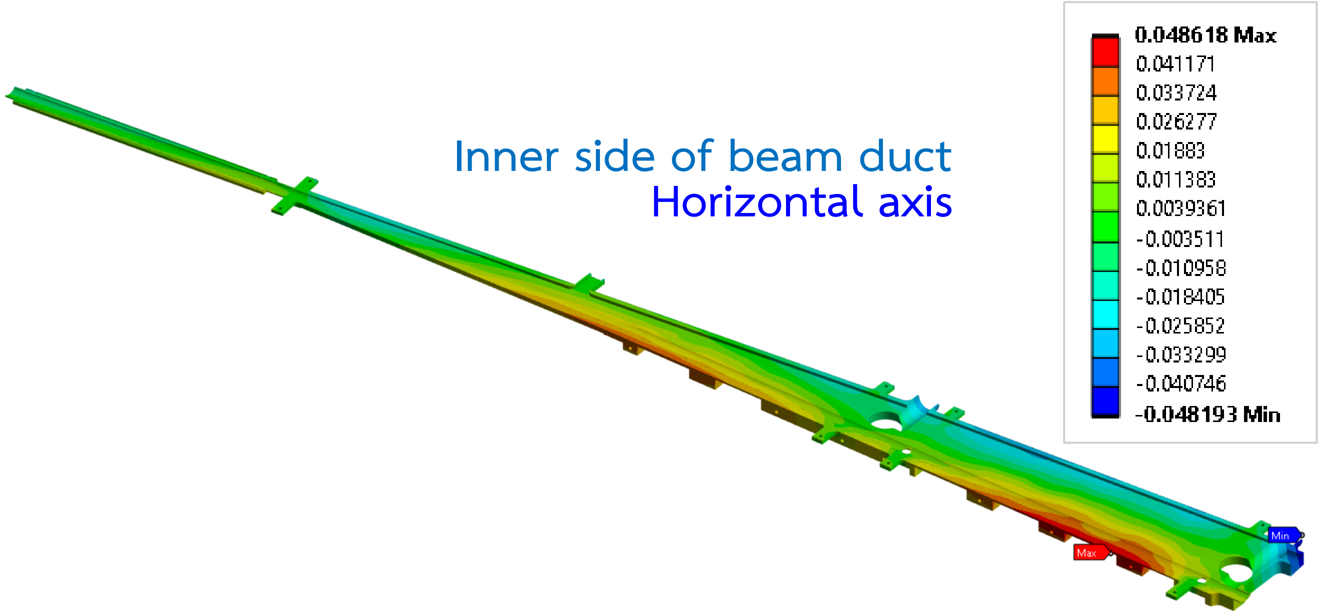


Inner side of beam duct
Longitudinal axis

Simulation result	Max. value
Total deformation (mm)	0.70222
Longitudinal directional deformation (mm)	0.27958 (+)
Vertical directional deformation (mm)	0.088712 (-)
Horizontal directional deformation (mm)	0.048618 (+)



Inner side of beam duct
Vertical axis

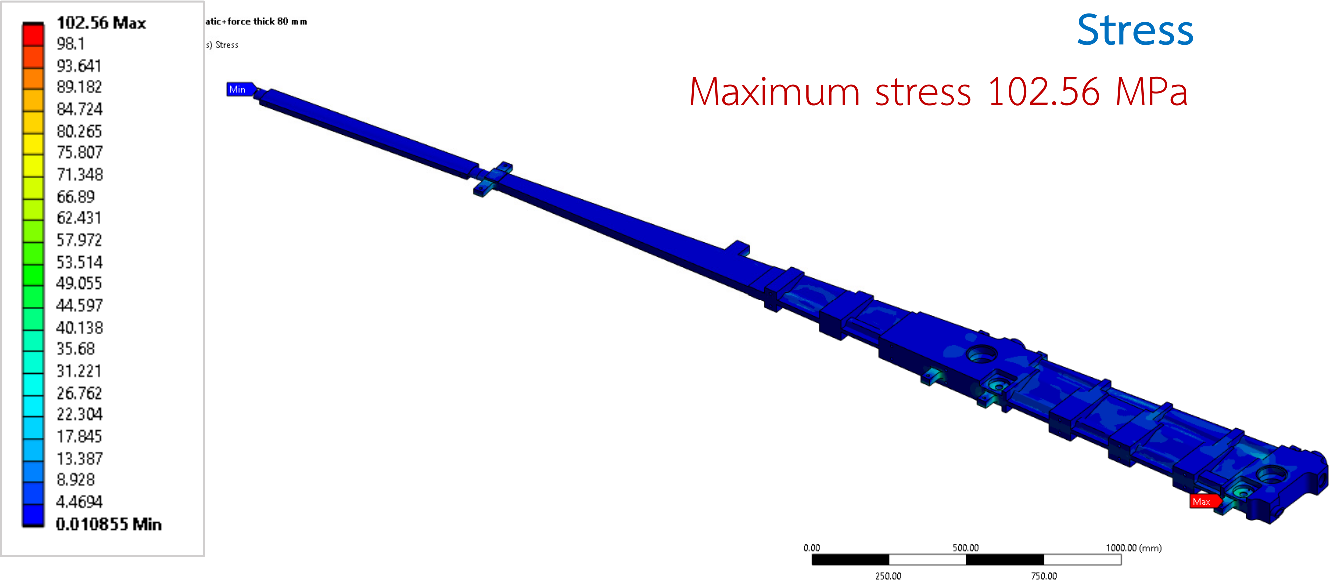


Inner side of beam duct
Horizontal axis

PVCB-1 simulation: stress and safety factor

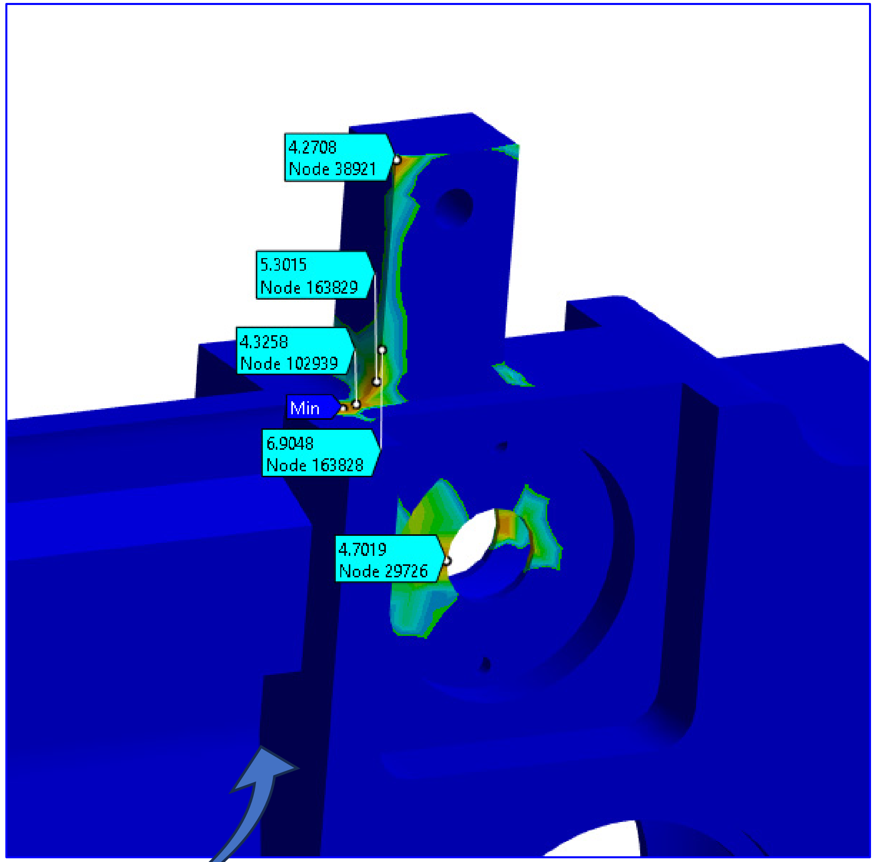
Stress

Maximum stress 102.56 MPa



Safety factor

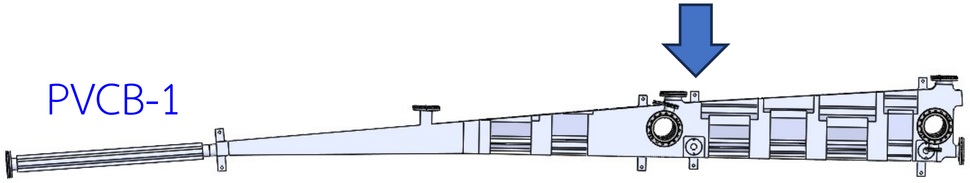
Minimum 2.6912



Chamber structural simulation result

Fix support

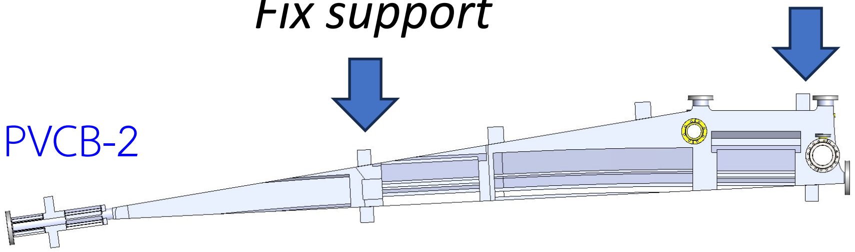
PVCB-1



Fix support

Fix support

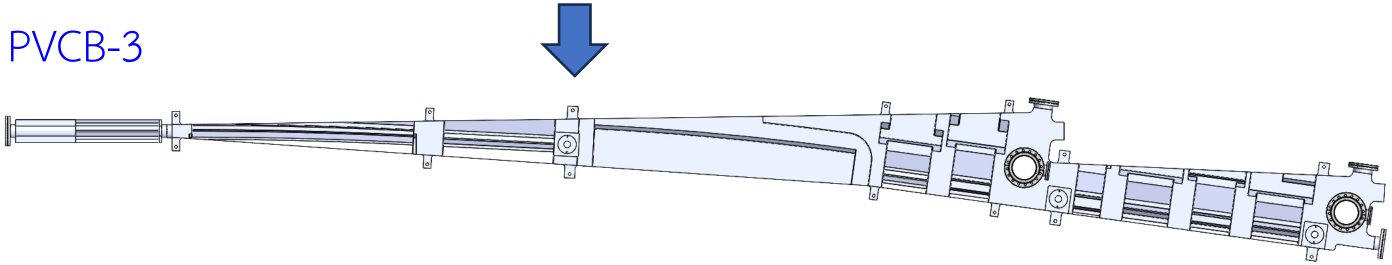
PVCB-2



Simulation result	PVCB-1	PVCB-2	PVCB-3	PVCB-4
Max. Equivalent stress (MPa)	*102.56*	*104.22*	*124.91*	*99.381*
Min. Safety factor	*2.7*	*2.2*	*2.2*	*2.5*
Max. Total deformation (mm)	*0.70*	*0.22*	*0.75*	*0.44*
Max. Longitudinal directional deformation (mm)	*0.28 (+)*	*0.216 (-)*	*0.750 (+)*	*0.444 (-)*
Max. Vertical directional deformation (mm)	*0.089 (-)*	*0.078(-)*	*0.113 (-)*	*0.065 (-)*
Max. Horizontal directional deformation (mm)	*0.049 (+)*	*0.045(-)*	*0.076 (-)*	*0.055 (+)*

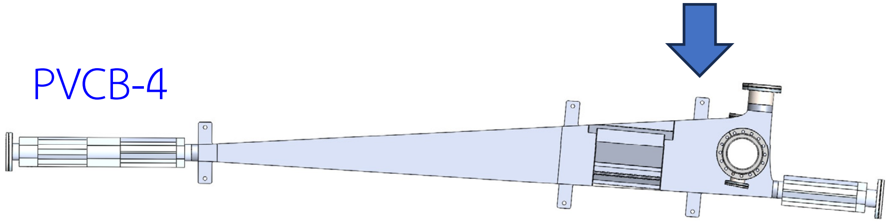
Fix support

PVCB-3

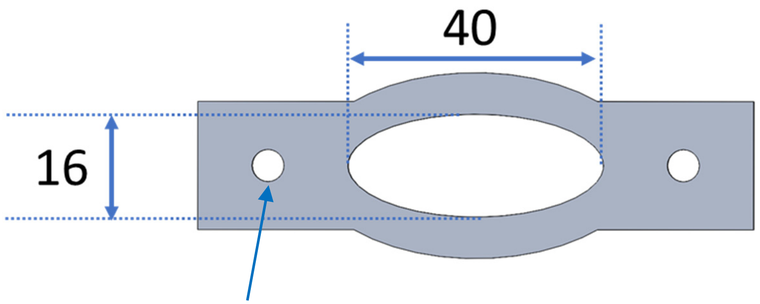


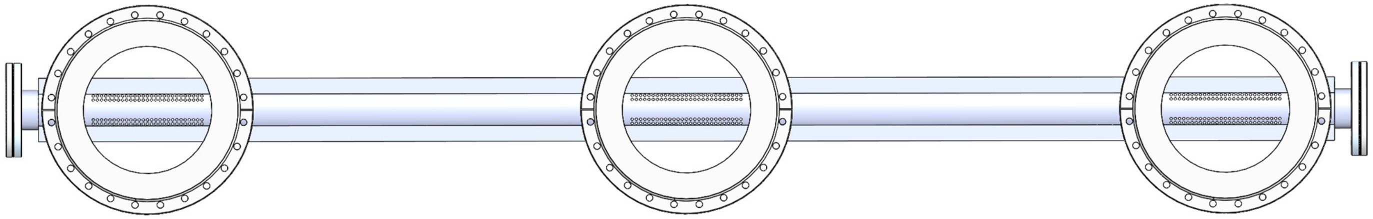
Fix support

PVCB-4

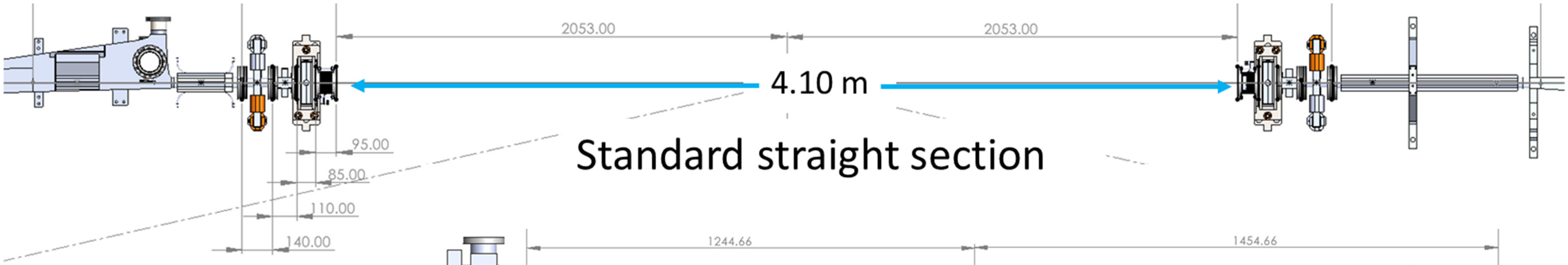


Straight section

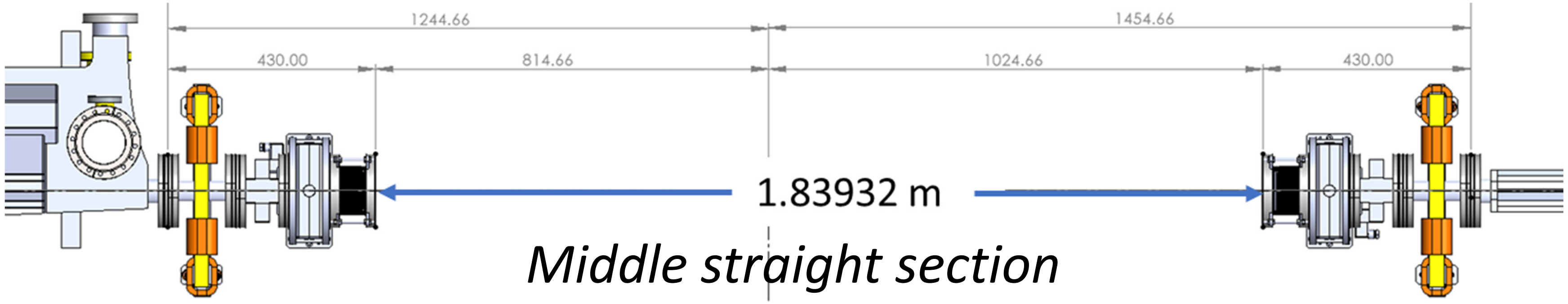




Aluminum vacuum chambers in straight section have been designed based on TPS model aiming for beam cleaning

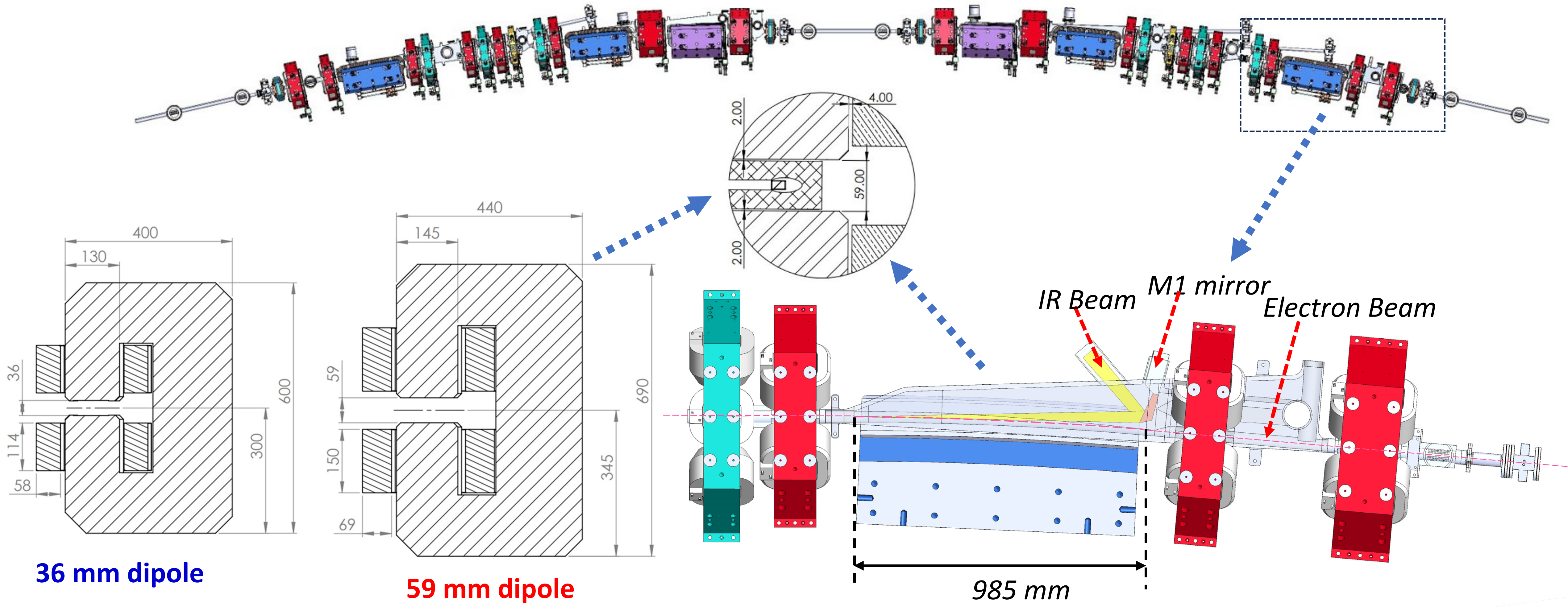


Standard straight section



Middle straight section

Bending chamber for IR beamline

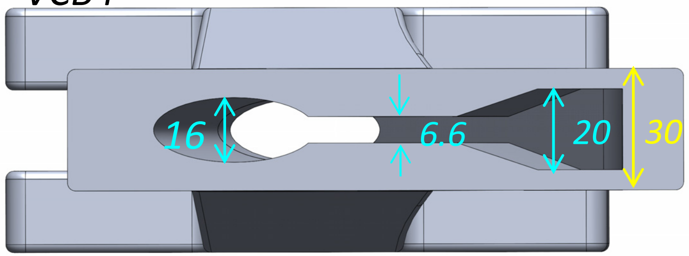


36 mm dipole

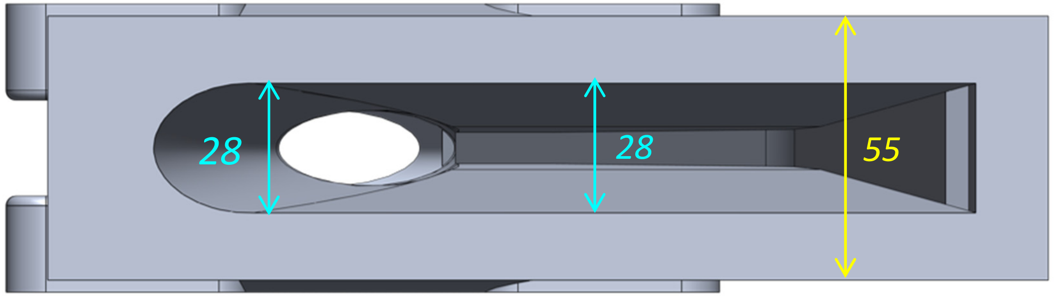
59 mm dipole

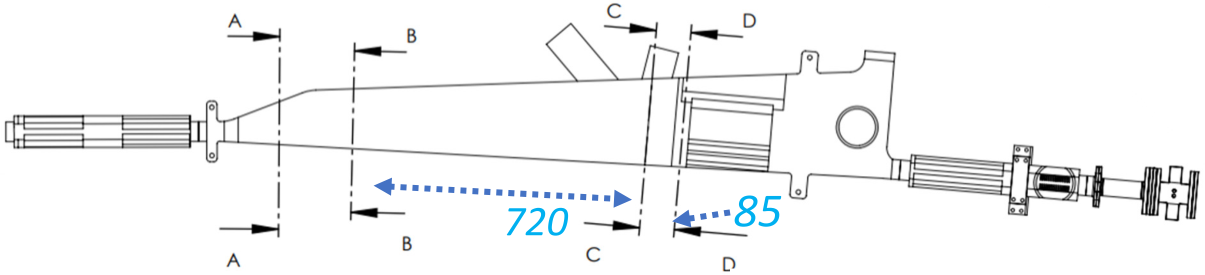
Bending chamber for IR Beamline

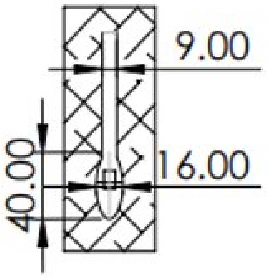
VCB4



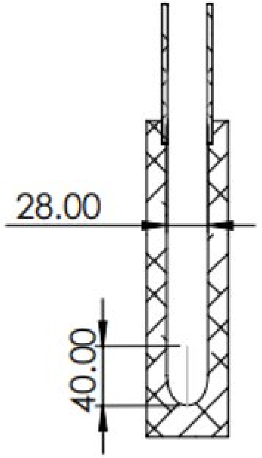
VCB4-IR



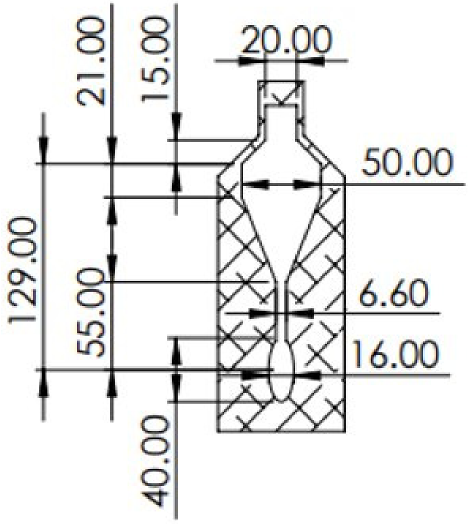




SECTION B-B

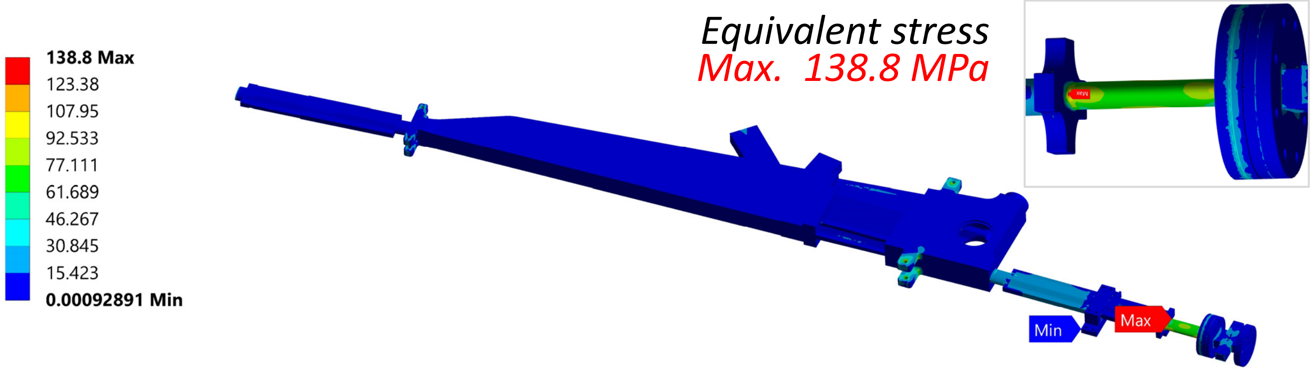


SECTION C-C

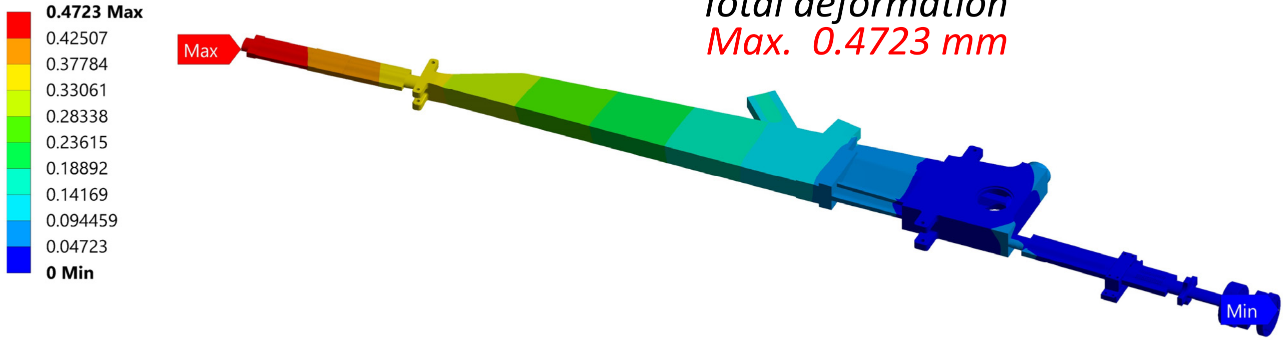


SECTION D-D

Equivalent stress
Max. 138.8 MPa



Total deformation
Max. 0.4723 mm



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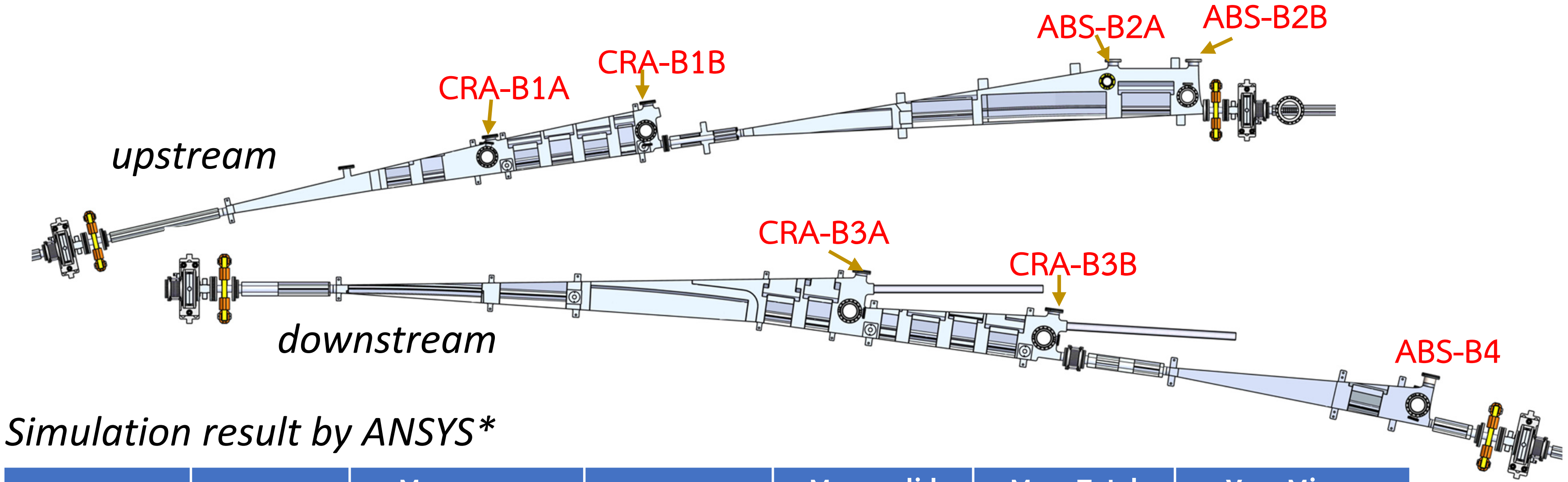
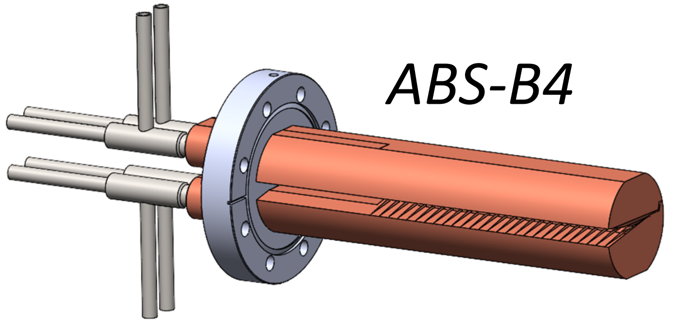
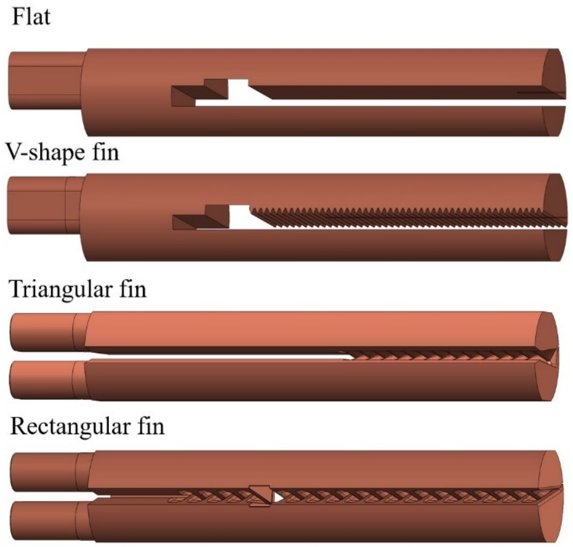
Photon absorbers

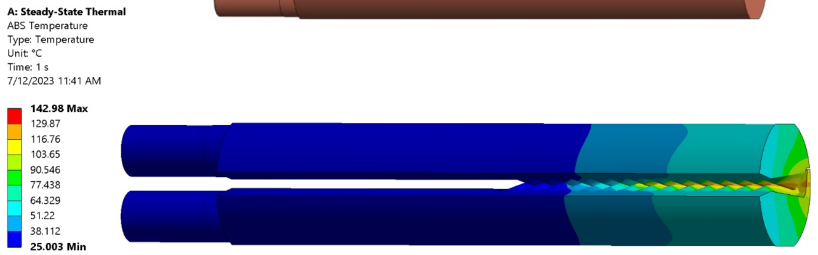






*Simulation result by ANSYS**

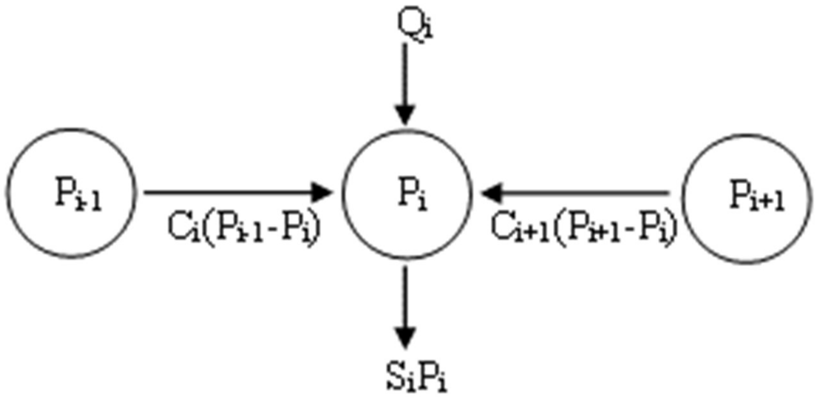
Absorbers	Total heat load (kW)	Max power density (W/mm²)	model	Max. solid temperature (°C)	Max. Total Deformation (mm)	Von-Mises stress (MPa)
CRA-B1A	1.30	57.53	Rectangular	132.75	0.053	64.059
CRA-B1B	3.52	32.94	V-shape	130.99	0.248	52.542
ABS-B2A	1.36	35.05	Flat	134.19	0.064	75.103
ABS-B2B	5.35	133.95	Rectangular	121.22	0.260	34.337
CRA-B3A	2.39	82.14	Flat	120.08	0.169	57.660
CRA-B3B	4.54	34.83	Rectangular	95.47	0.195	56.903
ABS-B4	4.16	181.19	Triangular	145.31	0.150	99.137



Temperature contours of ABS-B4

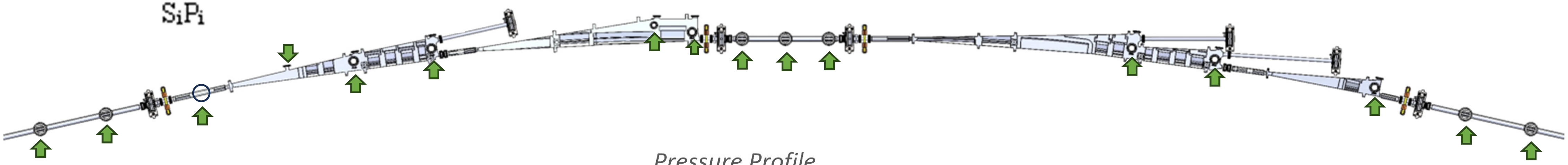
* *The convection heat transfer coefficient of 10,000 W/m²°C*
The power calculated using current of 600mA

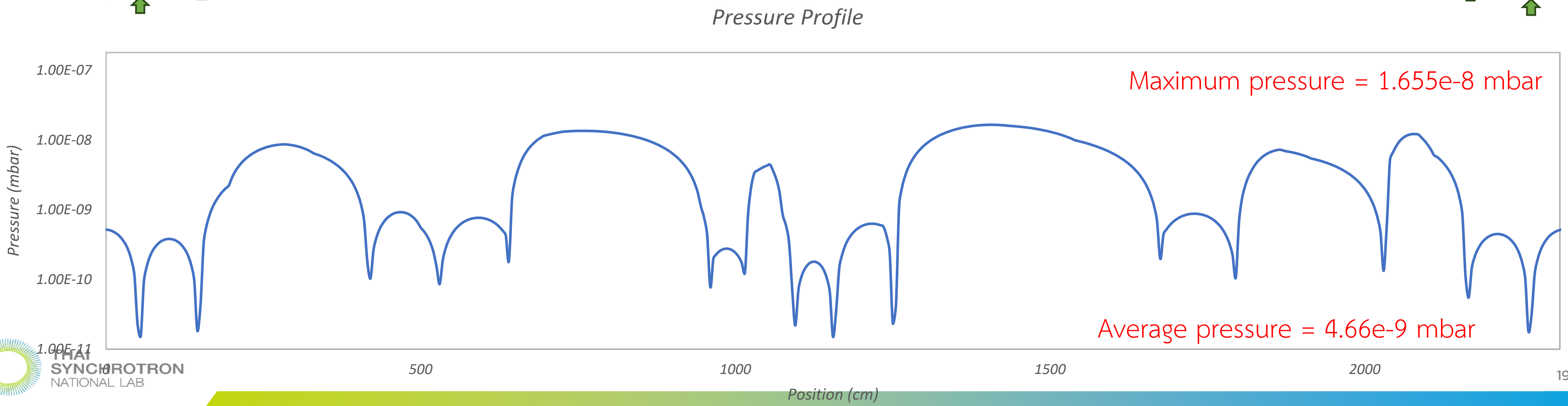
Pressure profile – Original design



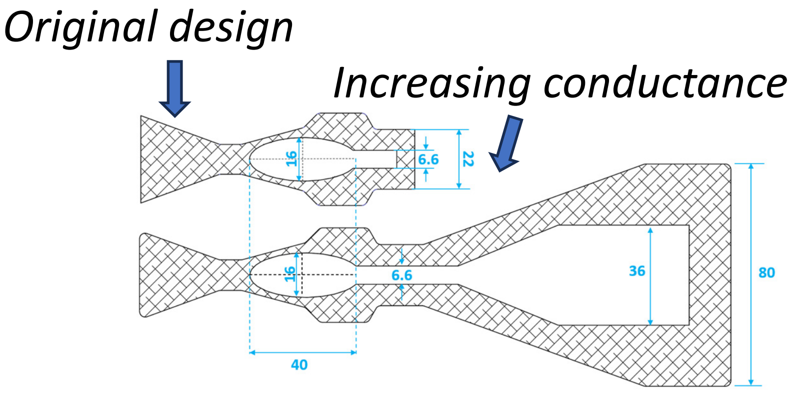
$$S_iP_i = Q_i + C_i(P_{i-1} - P_i) + C_i + 1(P_{i+1} - P_i).$$

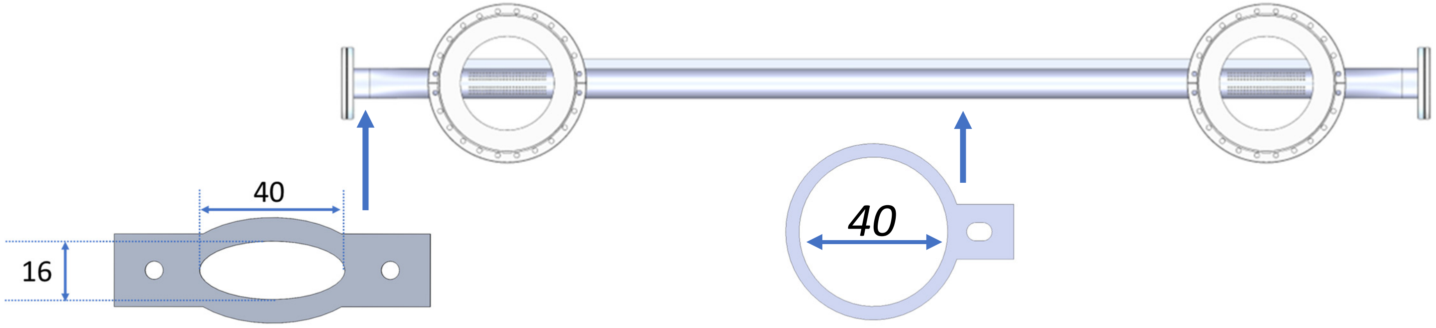
S : pumping speed (l/s),
P : pressure (mbar),
Q : outgassing rates = photon flux × PSD yield (η ≈ 1e-6 mol./ph),
C : conductance ($C_{Bending}$ ≈ 80 l/s , $C_{Straight}$ ≈ 20 l/s).

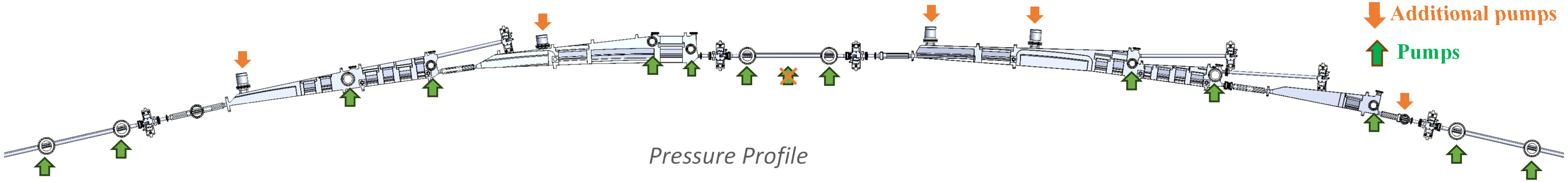


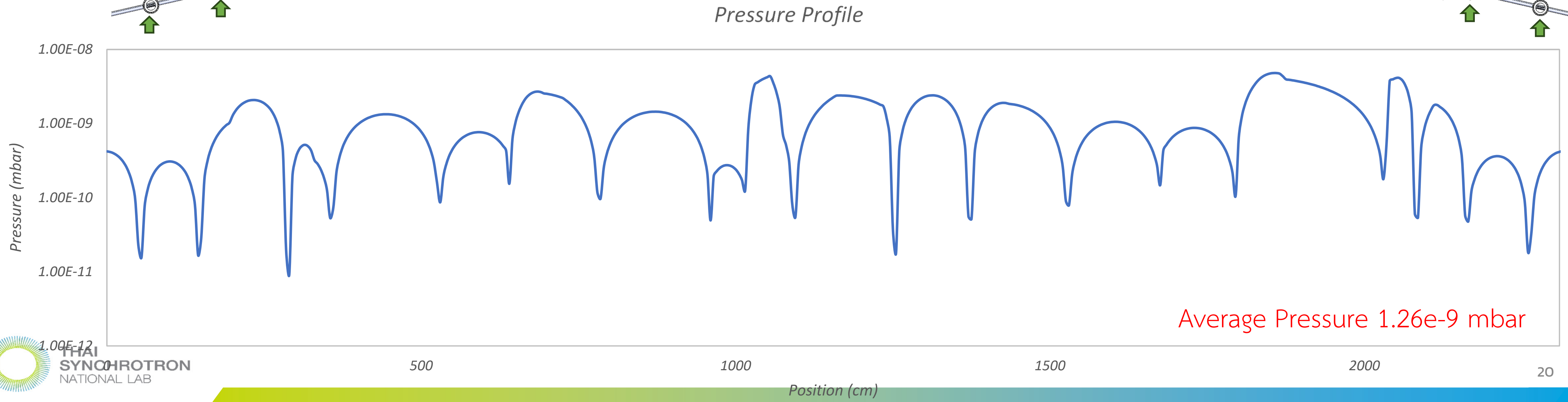


Pressure profile – Improved design





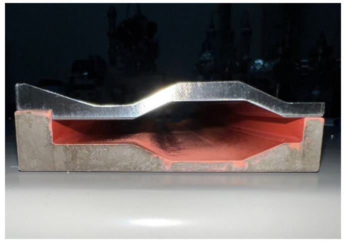


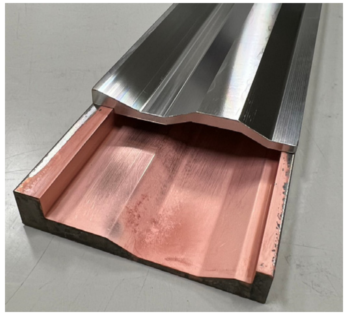


Vacuum Chamber Prototype for Storage Ring

SUS316L vacuum chamber prototype:

- *Frist prototype was development.*
- *UHV performance test was done.*
- *Copper platting inside the chamber was preliminary tested.*

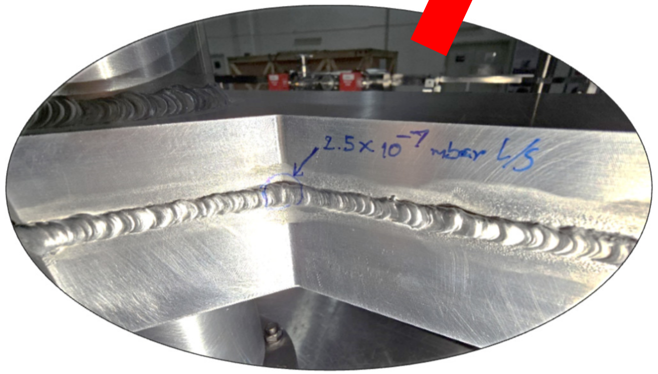




SUS316L chamber and copper plating is not continuously developed.

Aluminum vacuum chamber prototype:

- *Frist prototype was developed.*
- *Preliminary vacuum leak was check and small leakage was found with leak rate 2.5 x 10^{-7} mbar·l/s.*

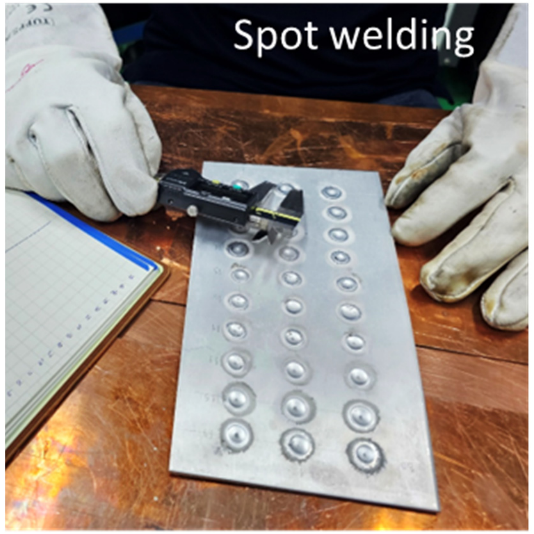


- *Leakage was successfully fixed, leak rate better than 5.0 x 10^{-9} mbar·l/s*
- *UHV performance test was done.*

Infrastructure and technology development

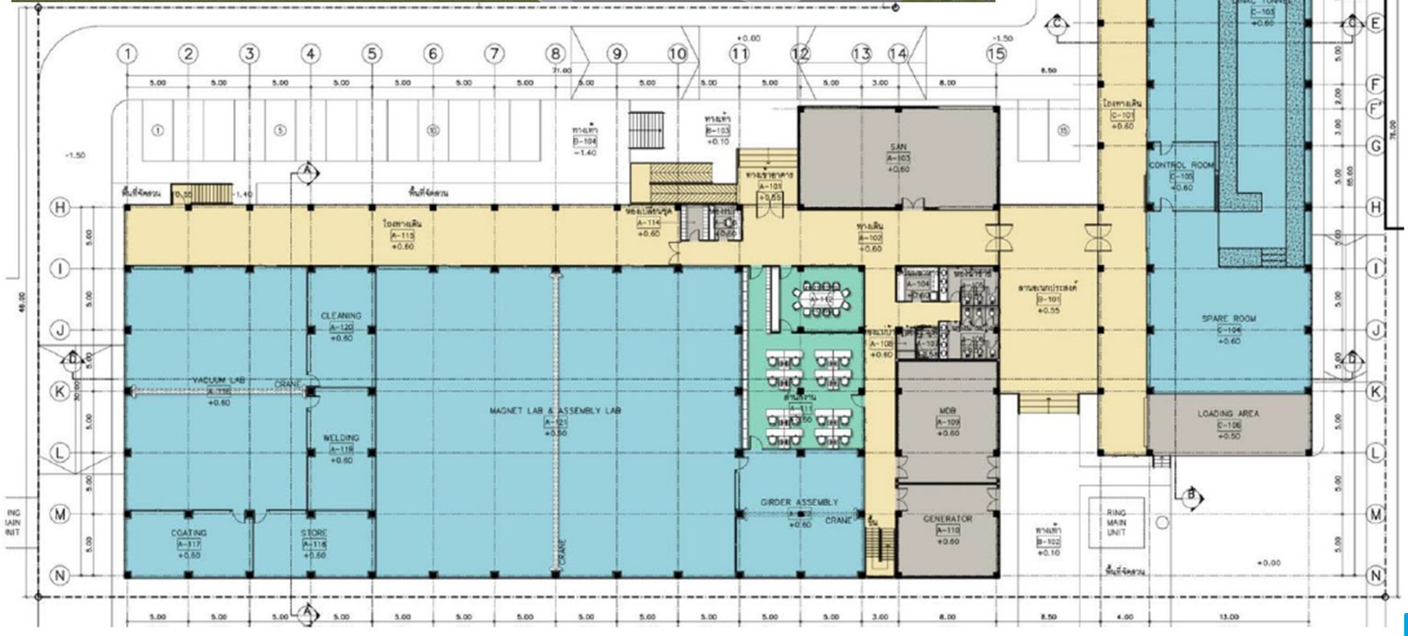
Aluminum welding

- *Technician's welding skill.*
- *Develop welding machine*



Welding practicing

Pilot plant



Conclusion

- Siam Photon Source II (SPS-II) is Thailand's first 4th generation synchrotron light source. It will provide high-energy and high-brightness synchrotron radiation for both academic and industrial research.
- The vacuum system is expected to play a crucial role in enhancing the country's manufacturing capability. Most of the main components in the system are planned to be domestically fabricated through technology transfer. The project will prioritize local economic advantages by utilizing conventional vacuum technology.
- Conventional technology without NEG coating presents several challenges, including limited space for pumps, absorbers, and beam position monitors (BPMs), which can result in the sacrifice of straight section length.
- The bulky chambers require optimization of their thickness to achieve the best strength.
- Prototypes of vacuum chambers have been created to assess local manufacturing capabilities and pinpoint areas for improvement.
- High-precision machining, welding, and surface treatment techniques, such as oil-less machining and chemical cleaning, are the critical technologies that must be developed to meet the project's requirements.
- Two welding technicians have received training, and a pilot plant has been constructed, which includes clean rooms for cleaning, welding, and assembly.

THANK YOU

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