MEDSI CHICAGO2020

Design Study of Vacuum System for a 4th Generation Storage Ring in Korea

Taekyun Ha
(Pohang Accelerator Laboratory, S. Korea)

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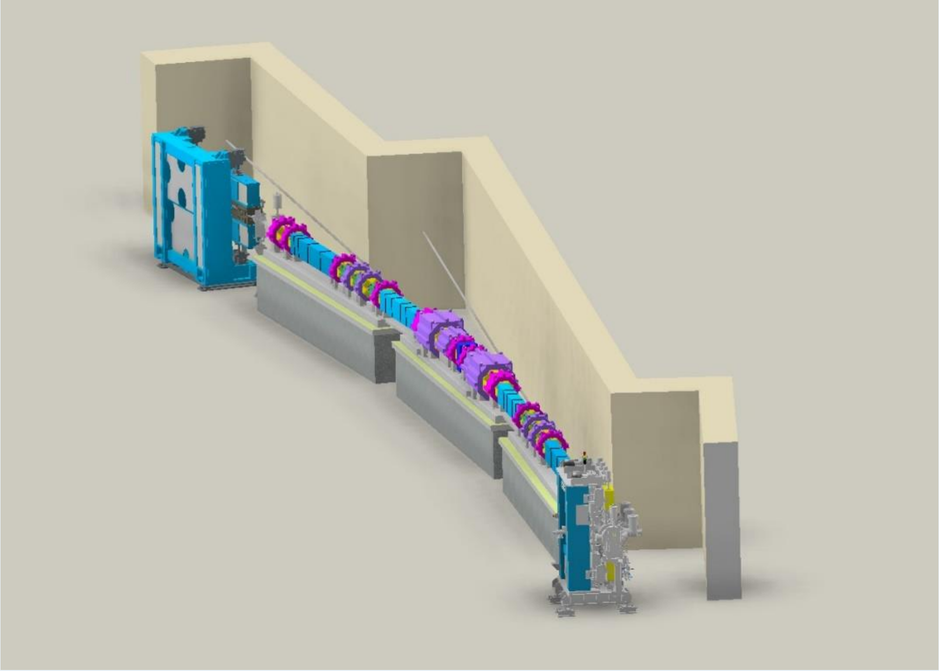

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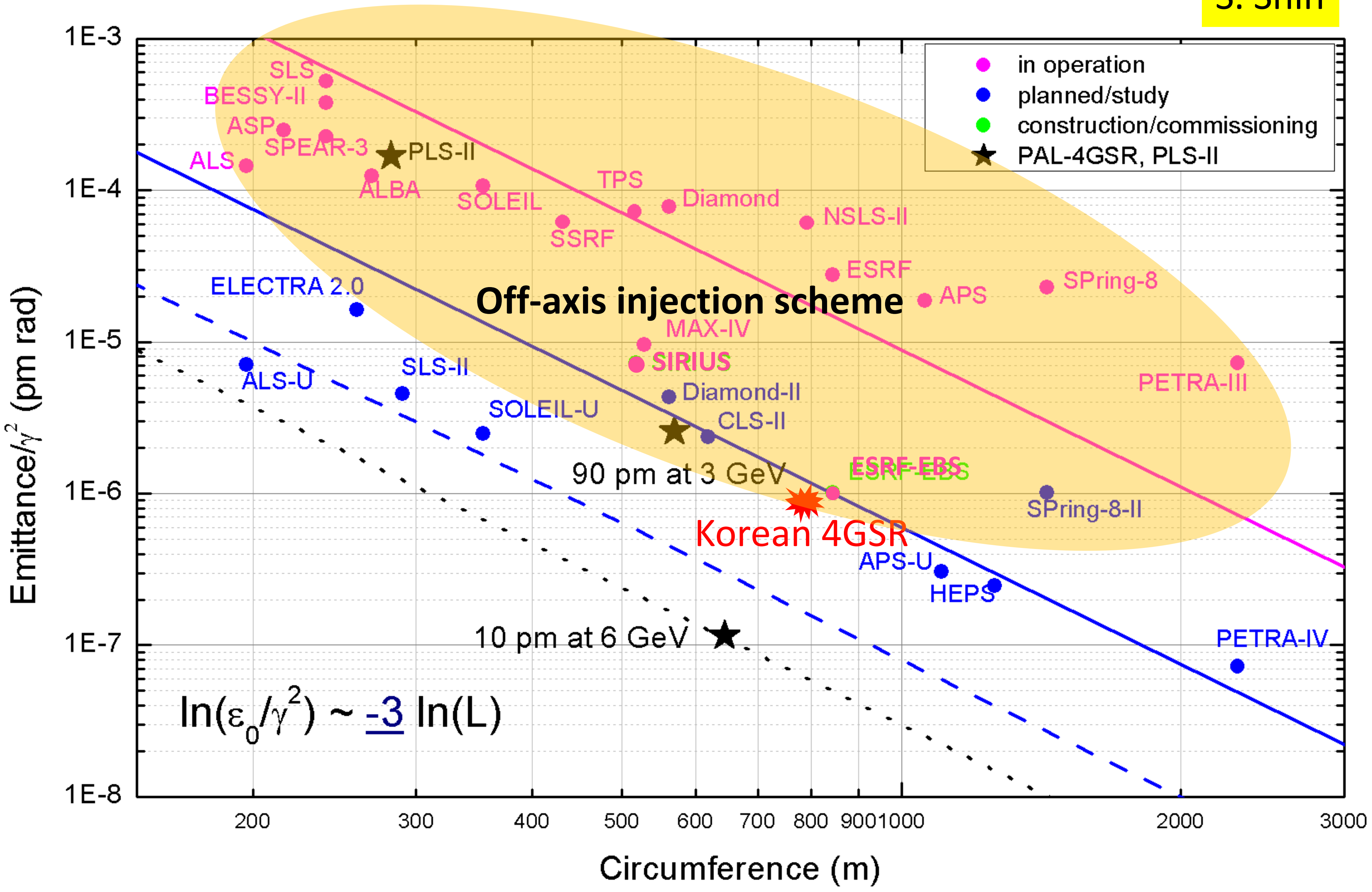
Contents

Overview of Korean 4GSR Project

- ◯ Government approval on July 2021
- ◯ **Objective** World-best level light source to support for industrial R&D and pioneering research
- ◯ **Facility**
  - **Storage ring** Emittance: **58 pm rad**
    Beam energy: **4 GeV**
    Circumference: **800 m**
  - **Injector** Booster Ring with a 200 MeV Linac
  - **Beam lines** 10 beam lines at the 1st stage (out of 40 beam lines)
- ◯ **Period** 2021.7 ~ 2027.6
- ◯ **Budget** ~ 1 billion $
- ◯ **Area** 540,000m²
- ◯ **Location** Chung-ju city

Worldwide light sources (emittance vs. circumference)

S. Shin



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Brilliance (Korean 4GSR vs. PLS-II)

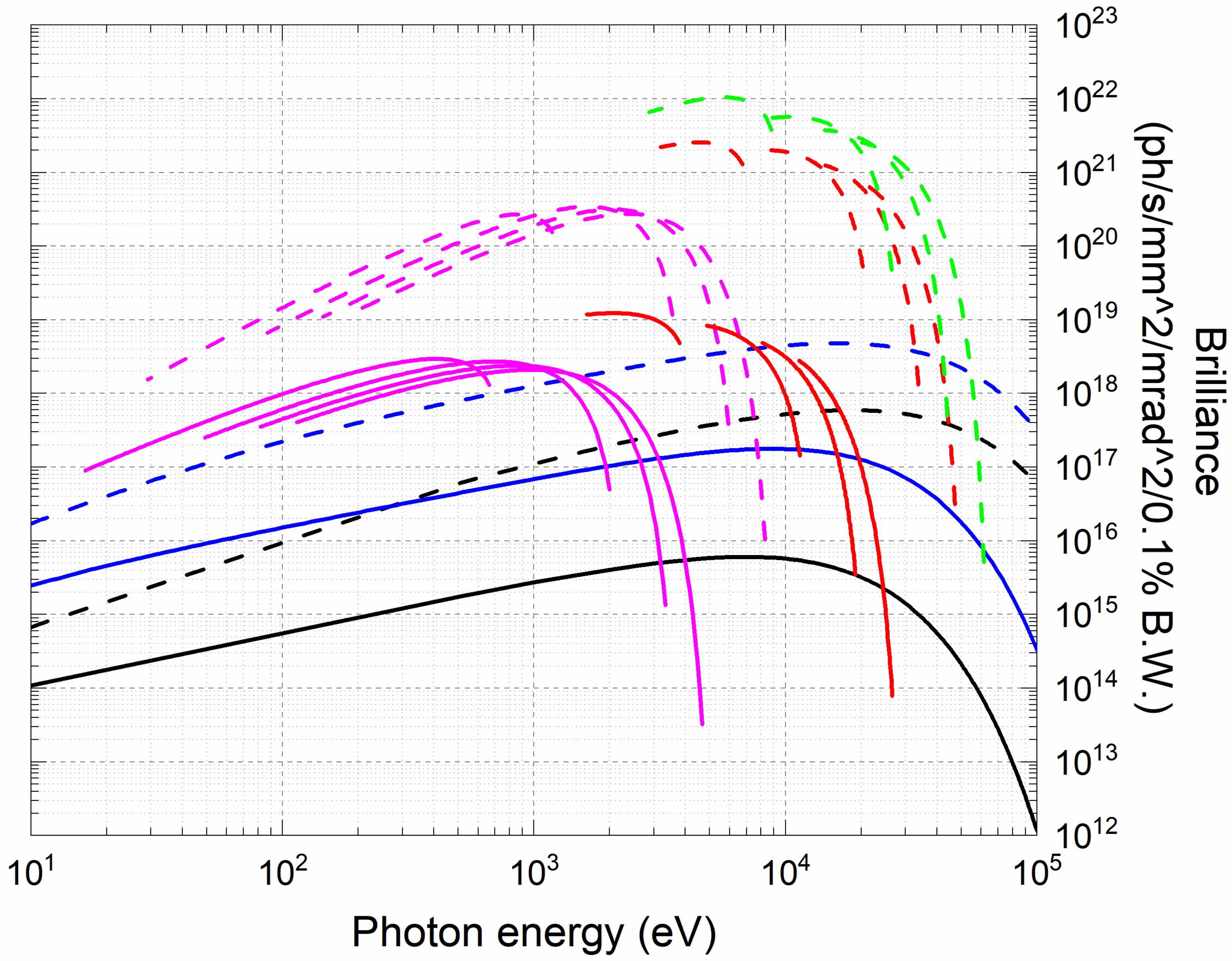
BM: Line(PLS-II), Dot(4GSR)

Wiggler: Line(PLS-II), Dot(4GSR)

Out vacuum undulator: Line(PLS-II), Dot(4GSR)

In vacuum undulator: Line(PLS-II), Dot(4GSR)

Cryogenic undulator: Line(4GSR)



Design features of Korean 4GSR

❖ **High photon beam performance from storage ring**

- The best performance be in the range of 10 ~ 30 keV
- Capability to generate photon beam up to 100 keV

❖ **Considering well demonstrated technologies for the design**

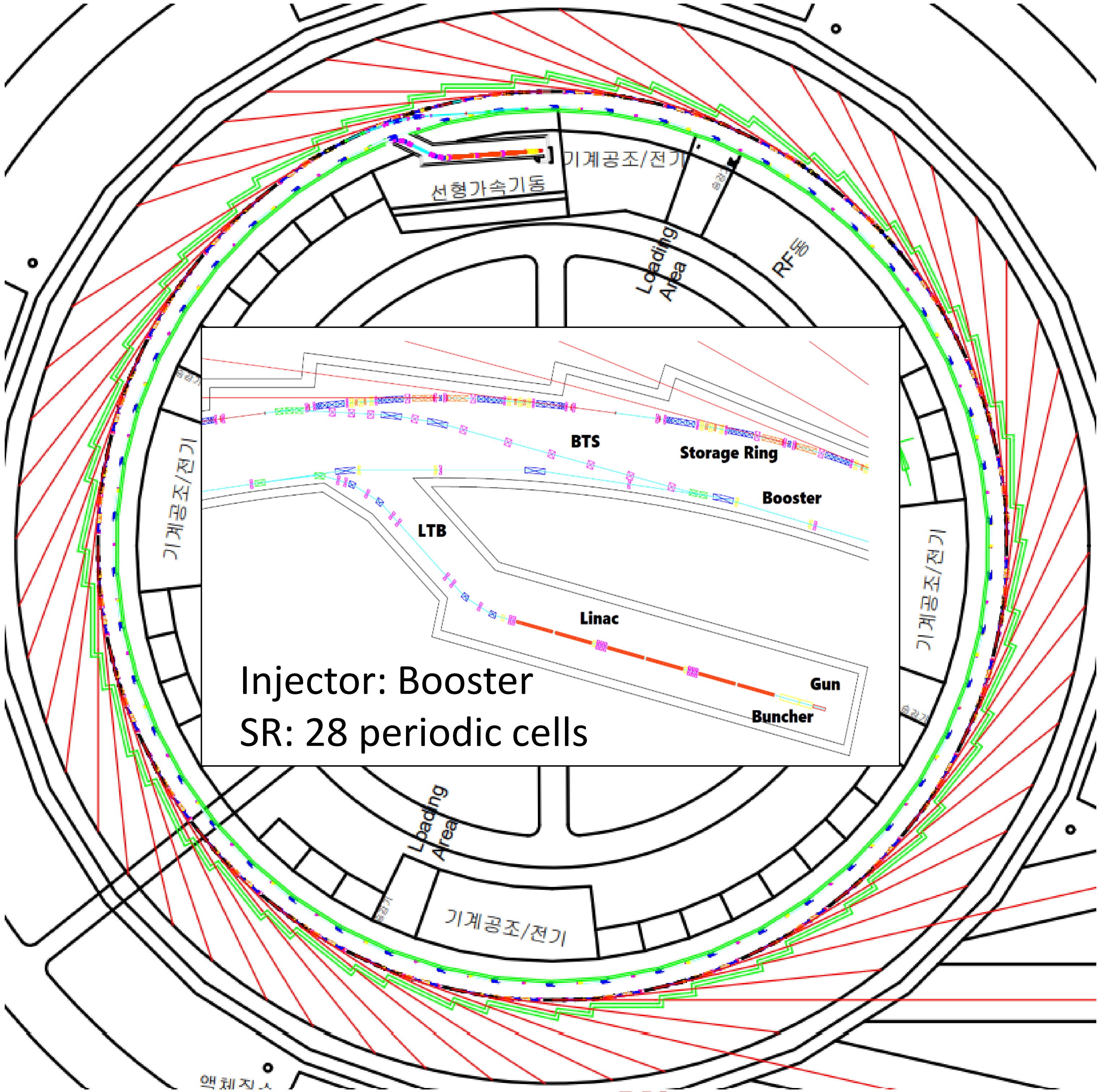
- Off-axis injection with conventional injection scheme
- Balanced technologies for magnet and vacuum systems
- On schedule user service and full performance

❖ **Synergy with PLS-II and PAL-XFEL**

- Supporting full range of synchrotron radiation application

Main parameter

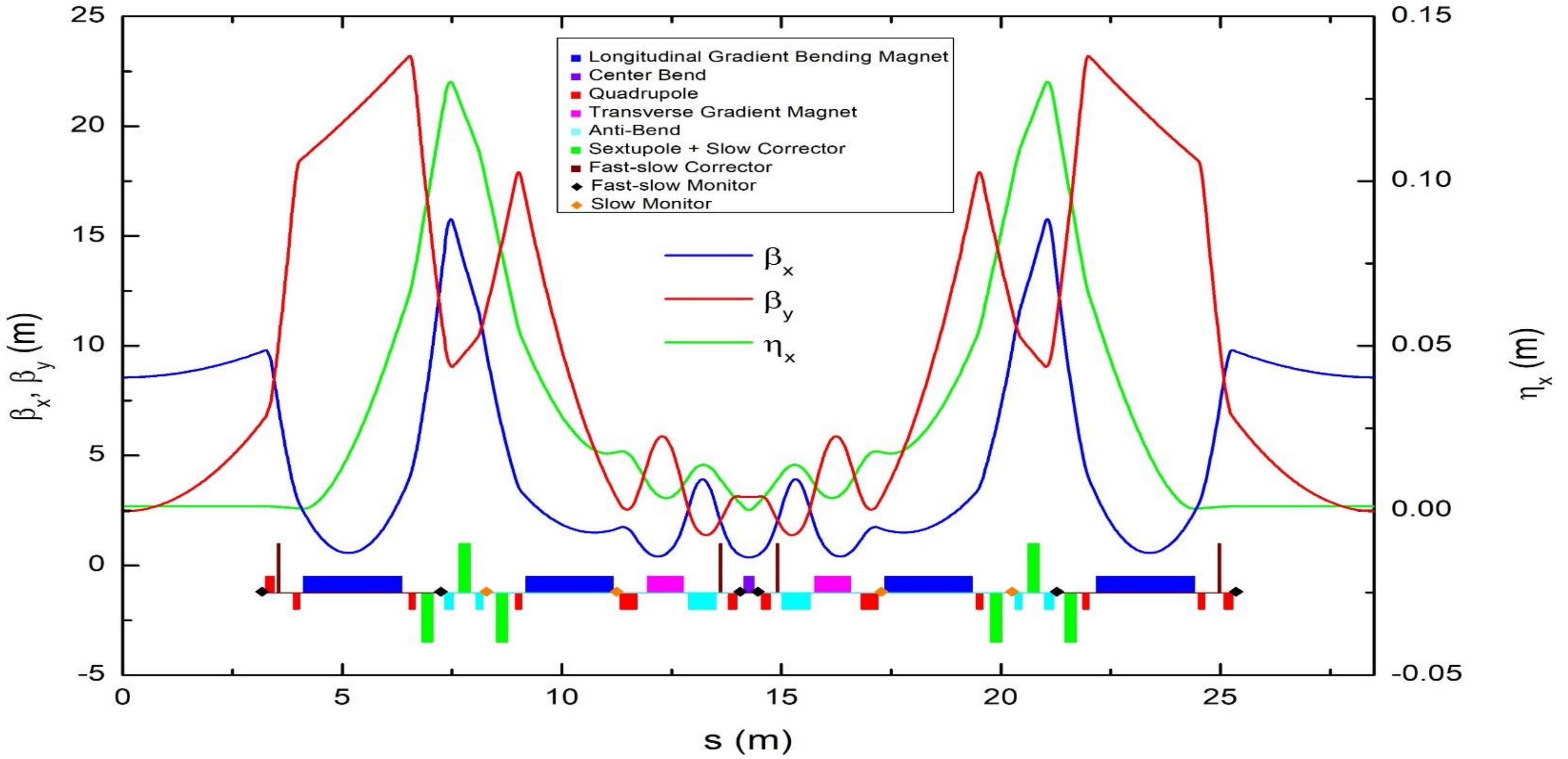
Parameter	Units	PLS-II	Korean 4GSR
Electron energy	GeV	3	**4**
Beam current	mA	400	400
Horiz. Emittance	pm	5800	**58** (RB: 39)
Vert. Emittance	pm	~ 58	~ 5.8 (RB: 39)
Bunch length (rms)	ps	20	13 (50 with HC)
Circumference	m	280	**800**
Harmonic #		470	1332
RF frequency	MHz	500	500
Beam stability @ ID (x/y)	μm	< 4 / 2	< 2.5 / 0.45
Injection mode		Top-up	Top-up



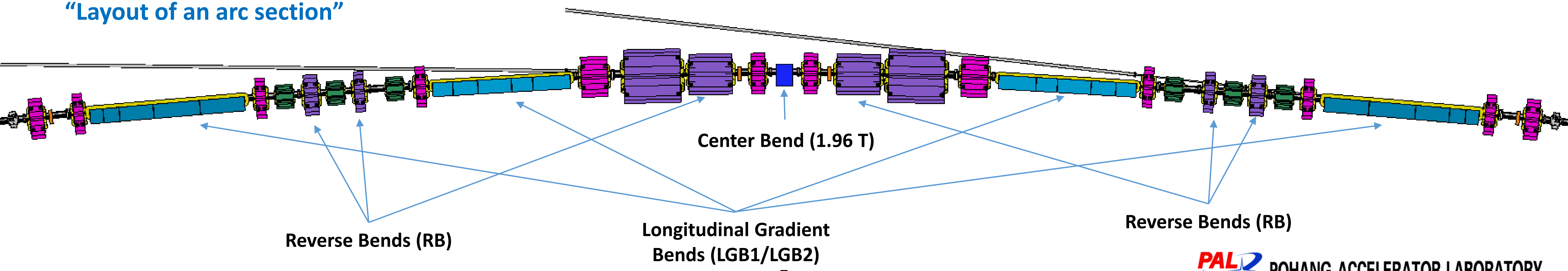
Injector: Booster
SR: 28 periodic cells

Hybrid multi-bend achromat

"Linear lattice design"



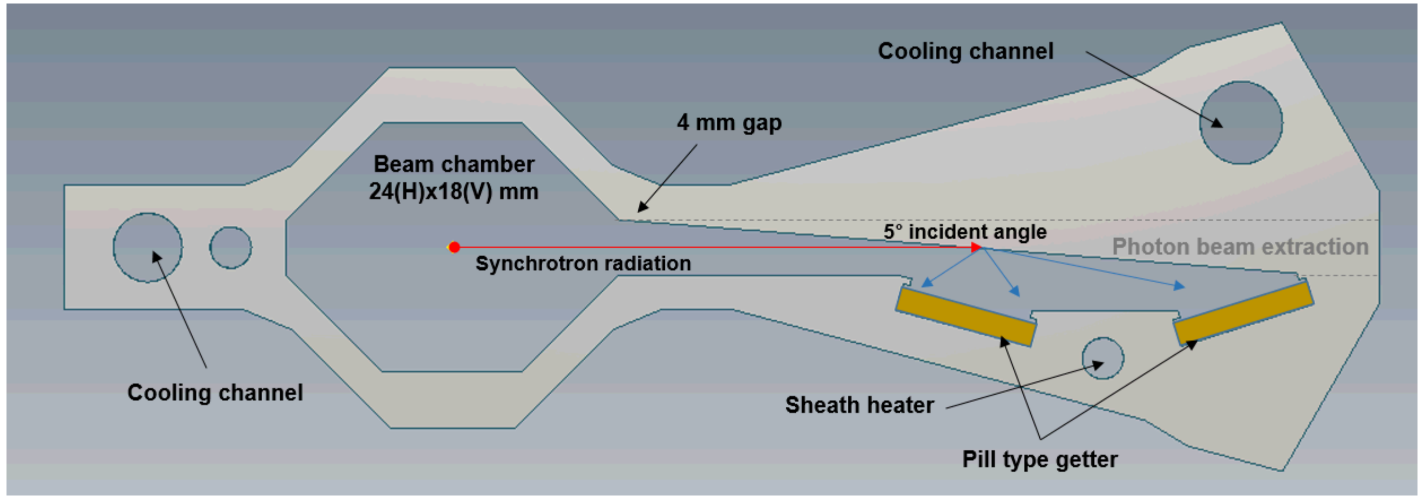
"Layout of an arc section"



Vacuum System Overview

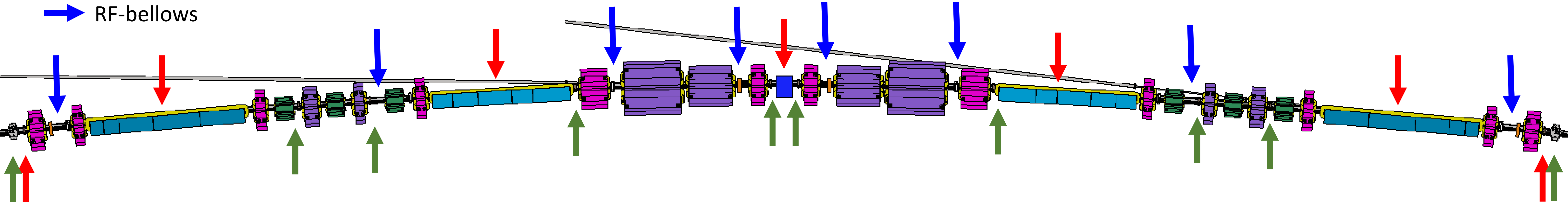
1. Required average vacuum pressure is low 10^{-9} mbar (CO equivalent).
2. PSD gas is pumped by distributed pill-type NEGs and lumped sputter ion pumps.
3. 5 ° Inclined side chamber wall absorbs SR photon beams.
4. Thermo-mechanical analysis results show that both aluminum and copper alloy are suitable for the SR vacuum chamber material.
5. Booster ring vacuum chambers are made of 1 mm-thick stainless steel and pumped with lumped Sputter ion pumps.

✓ **Cross section of the SR vacuum chamber**



BPM
Lumped vacuum pumps (SIP)
RF-bellows

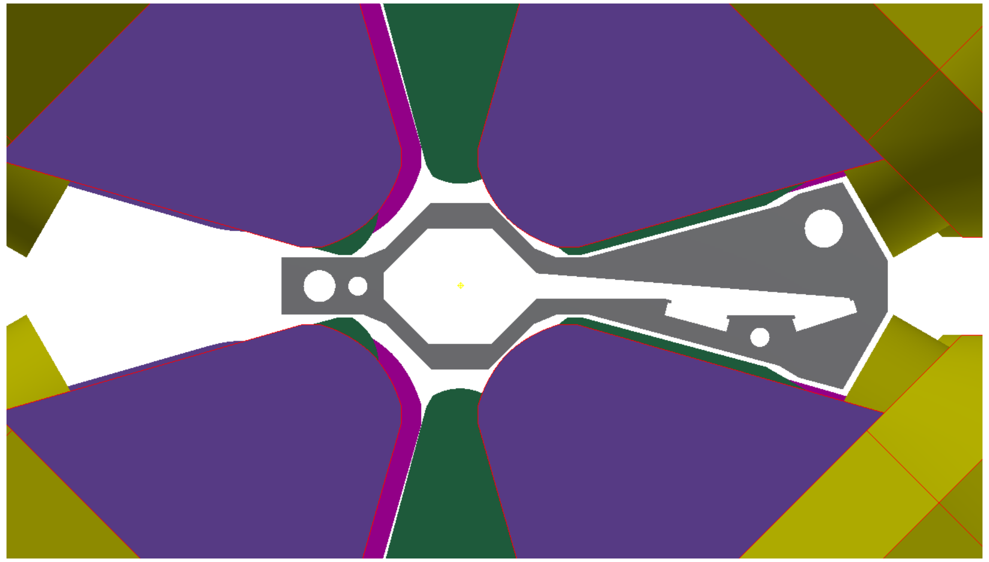
✓ **Layout of an arc section**



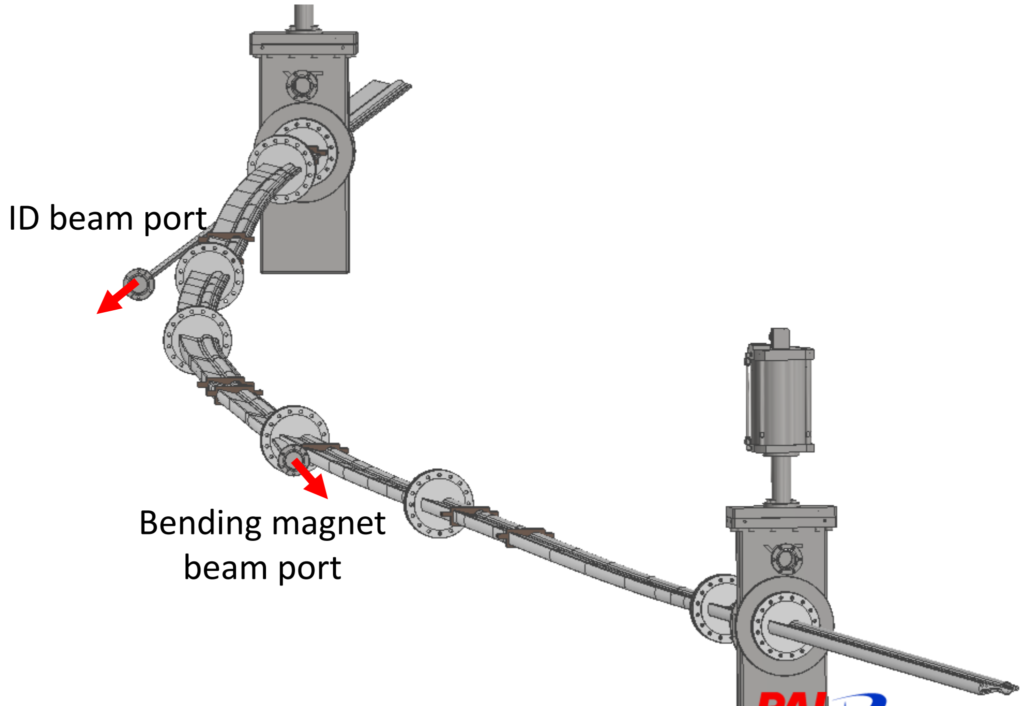
SR Vacuum chamber

- Beam chamber cross section is octagon shape (24 mm (H) x 18 mm (V)) except for center bend.
- Vertical aperture of the center bend chamber is 10 mm.
- Eight RF-bellows are used for installation and to reduce stress.
- Two gate valves are located at the end of the arc section.
- Seven sputter ion pumps are installed for noble gas pumping.
- The clearance between the vacuum chamber and the magnets is larger than 0.6 mm.

✓ **Clearance**



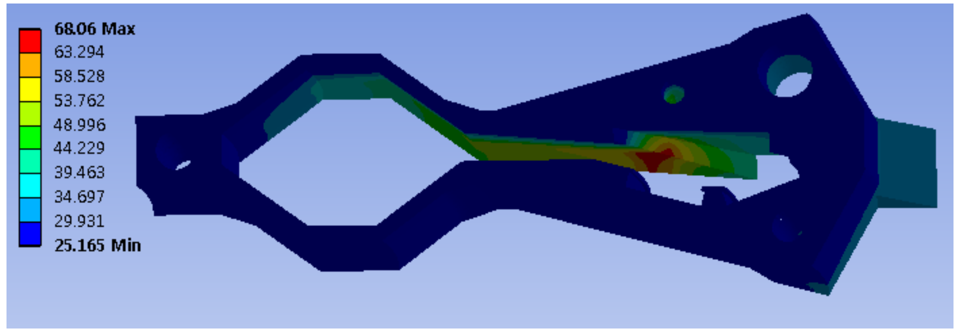
✓ **Vacuum chambers of an arc-section**



Thermo-mechanical analysis

❖ Handling of SR heat load and chamber material

- Most intense thermal load is 0.77 W/mm² from the center bend.
- Thermal analysis results show that both aluminum and Cu alloy can be used for the vacuum chamber material.
  - Aluminum chamber can be fabricated by extrusion, bending and welding.
  - Cu alloy chamber can be fabricated by machining of two pieces (top and bottom) and welding.
- Temperature of the sharp edge at a beam exit branch is 68℃ (endurable).

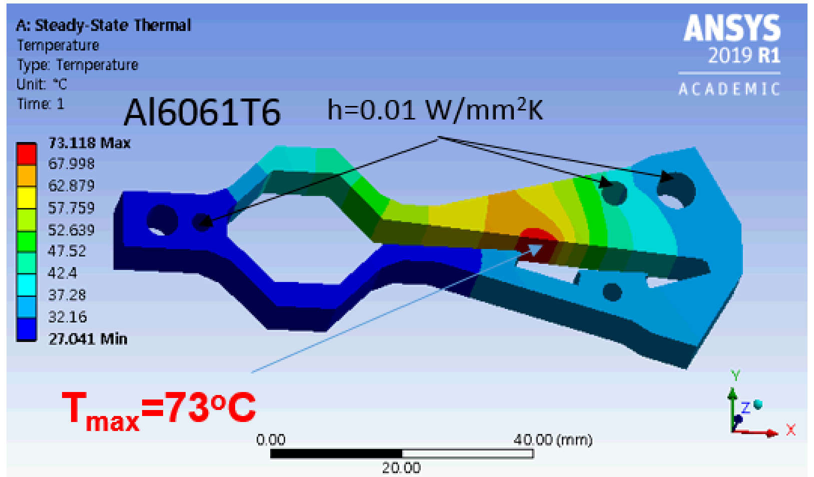


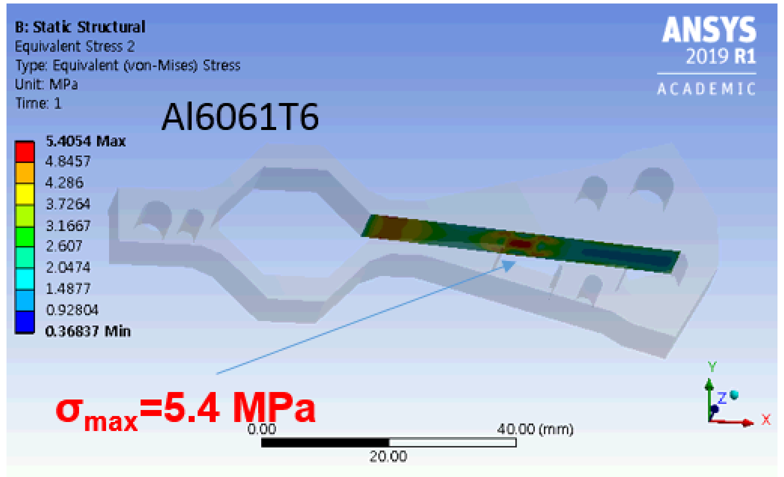
❖ Heat load from Center Bends

	B	Bend angle	Total power	Source distance	Inc_angle (H)	Inc_angle (V)	Foot print V-height	Thermal load
Center bend	1.96 T	1.6°	6 kW	2.25 m	2.35°	5°	0.44 mm	**0.77 W/mm²**

❖ Results

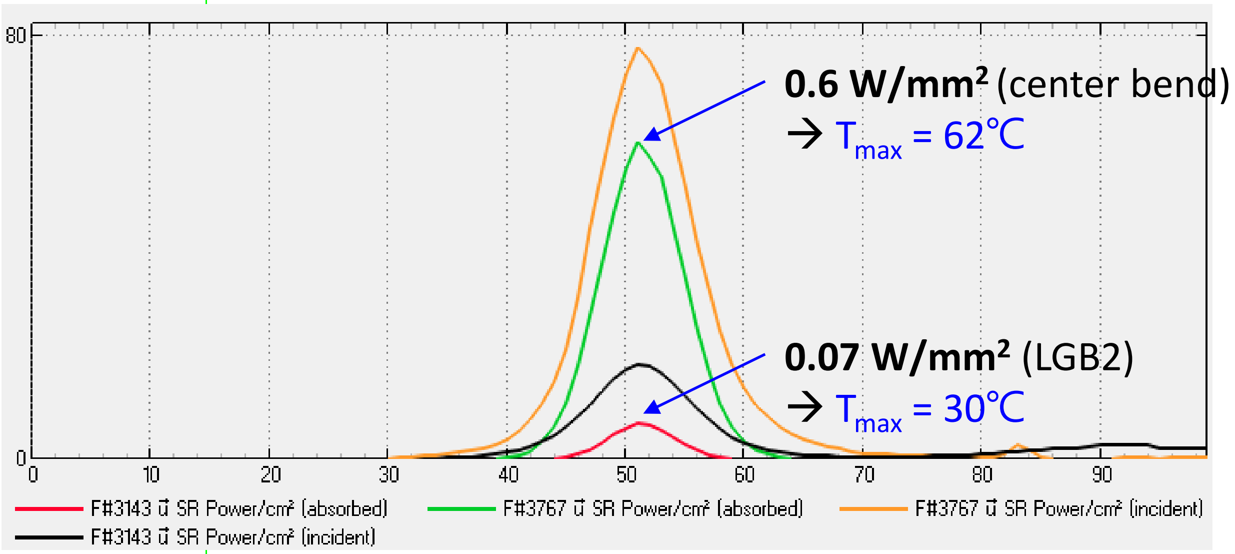
Material	T_{max} (chamber)	T_{max} (Water channel)	σ_{max}	σ_{yield} (Cold worked)
Al6061T6	**73°C**	**46°C**	**5.4 MPa**	214 MPa
OFC Cu (C10100)	**58°C**	**40°C**	**9 MPa**	120 MPa
CuCrZr (C18150)	**60°C**	**41°C**	**11 MPa**	210 MPa

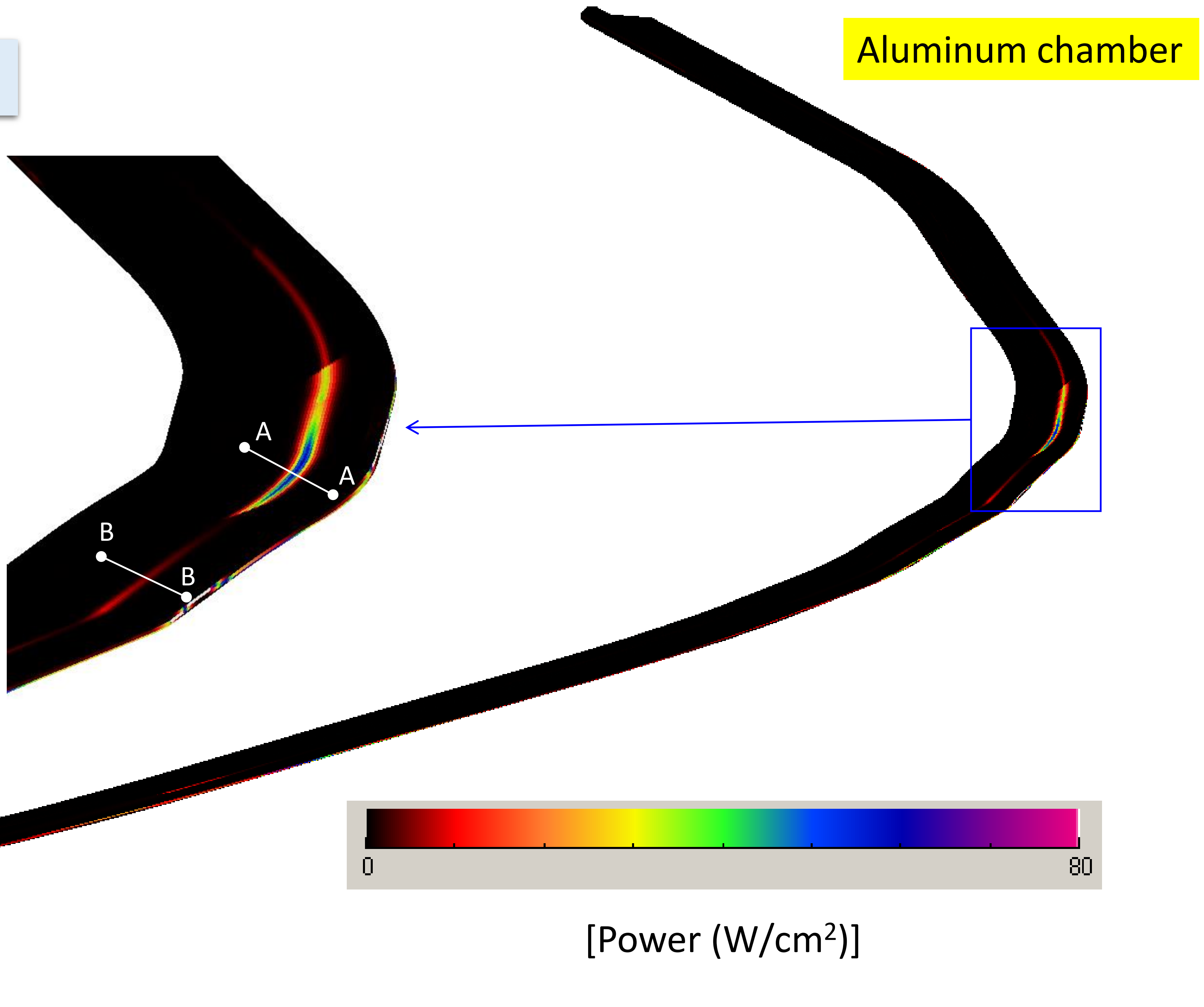




SR heat load (Synrad+)

SR power
- from C-bend (line AA): — incident, —absorbed
- from LGB2 (line BB): — incident, —absorbed

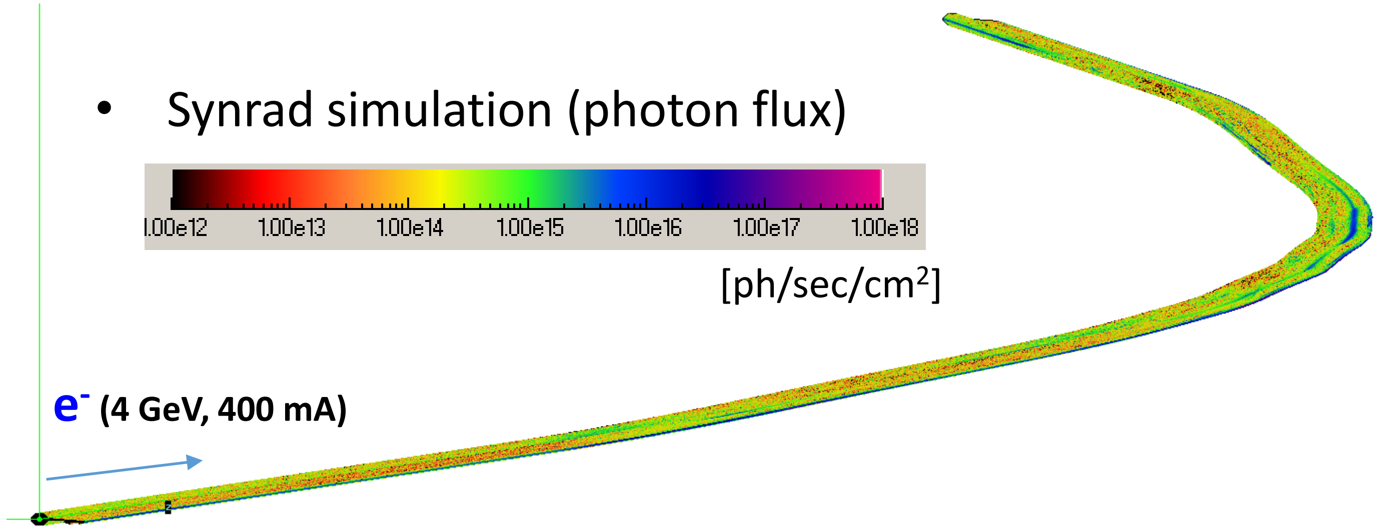




Dynamic pressure calculation

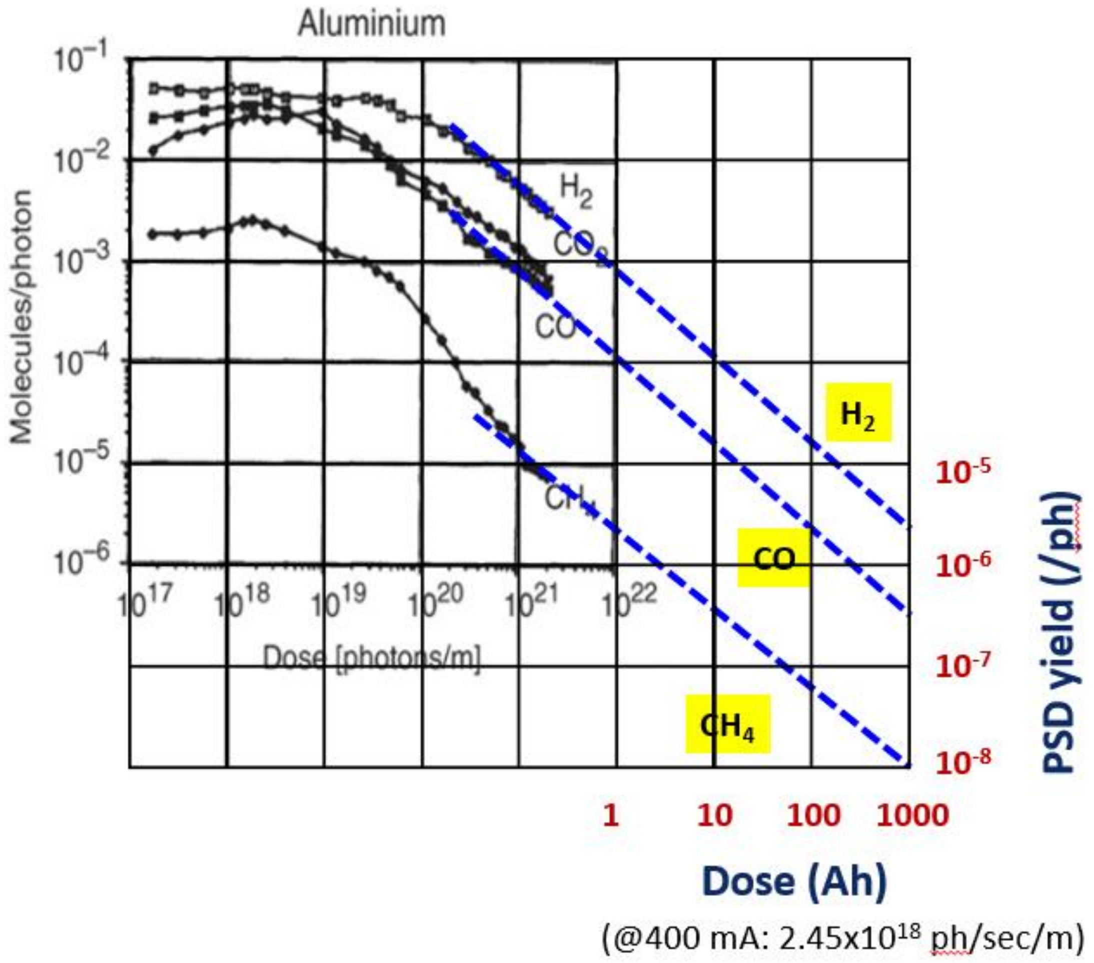
❖ Photon stimulated desorption

- Total SR flux is 4.9E19 ph/sec by Synrad+ simulation
- PSD yield of 1E-6 /ph is used with assumption of 1000 Ah beam dose.
- Total photon stimulated desorption calculated by Synrad is 3.8E-6 mbar l/s.



η = 1E-6/ph
Q_{tot} = 3.8E-6 mbar l/s

✓ PSD yields of Aluminum

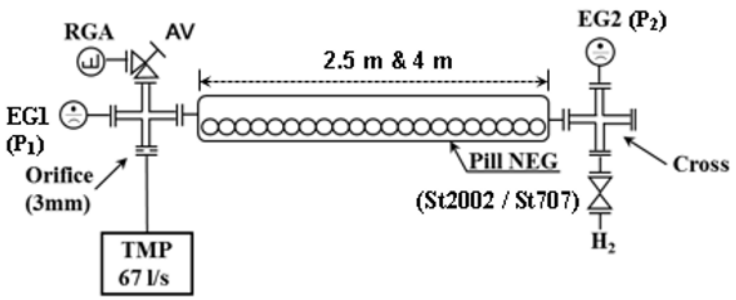


"A. Mathewson, AIP Conf. Proc. 236 (1), 313 (1991)"

Dynamic pressure calculation

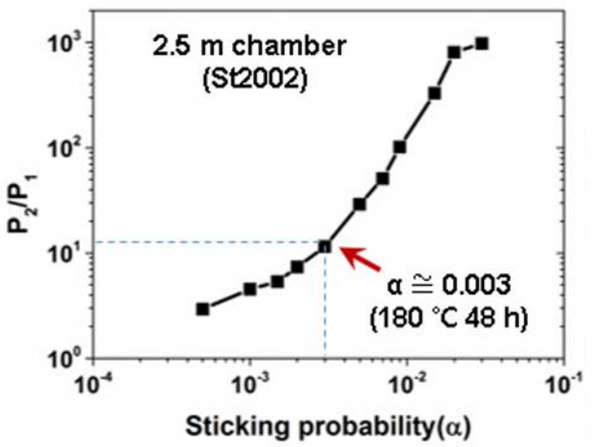
"Pumping speed of pill-type NEG"

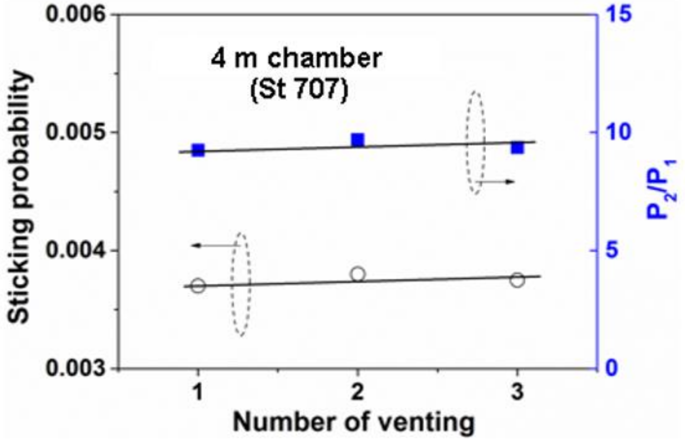
Set up



- The pressure(P_2) is kept constant (1×10^{-6} mbar) by injecting the H_2 gas
- TMP evacuate the gases that can't be pumped by pill NEG slowly.
- Molflow+ was used for calculation of sticking probability from ratio of pressure.
- Sticking probability: $\alpha \propto P_2/P_1$

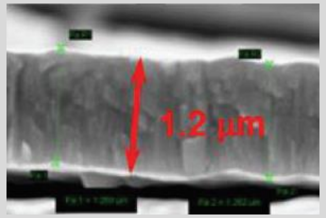
Results of H_2 sorption





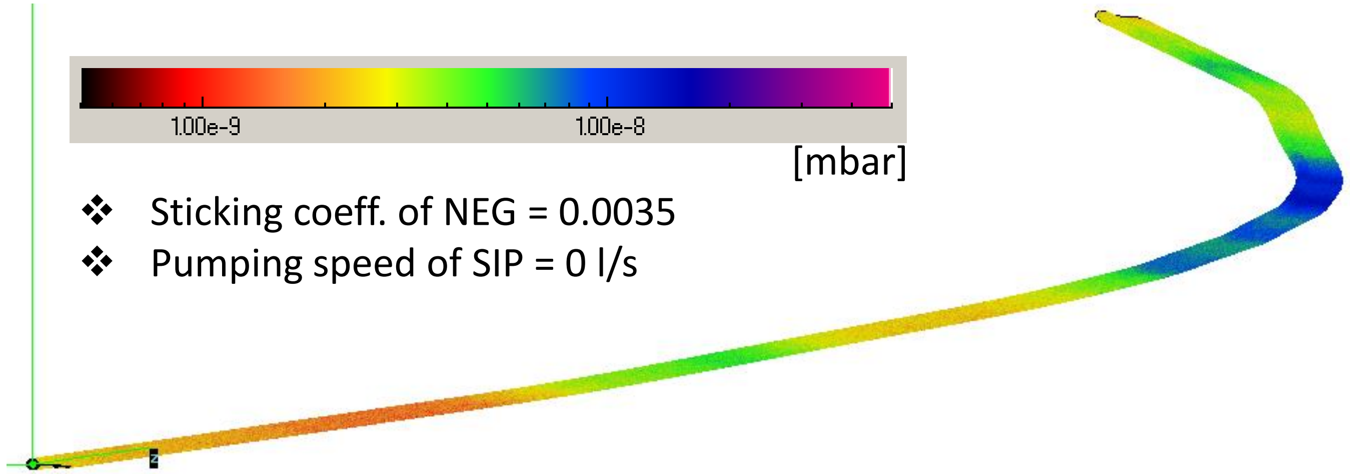
- Pill NEG have a value of sticking probability about 0.003 → 1/5 of a NEG coated chamber roughly.
- Sticking probability is substantially constant after three additional venting.

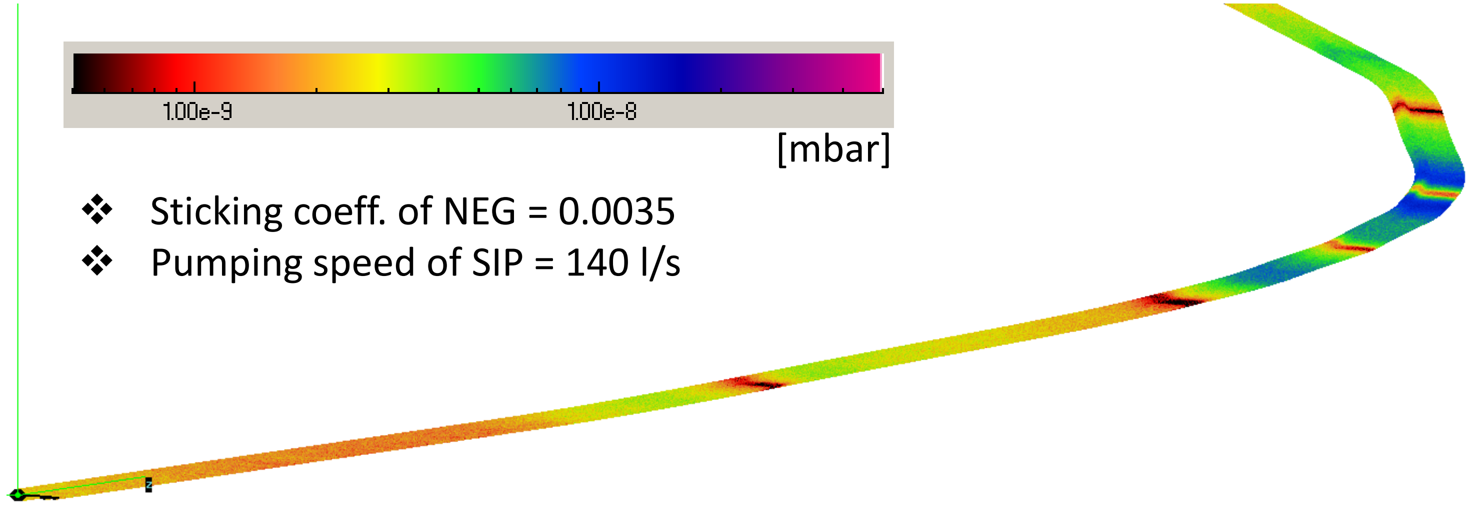
"NEG film vs. Pill-type getter"

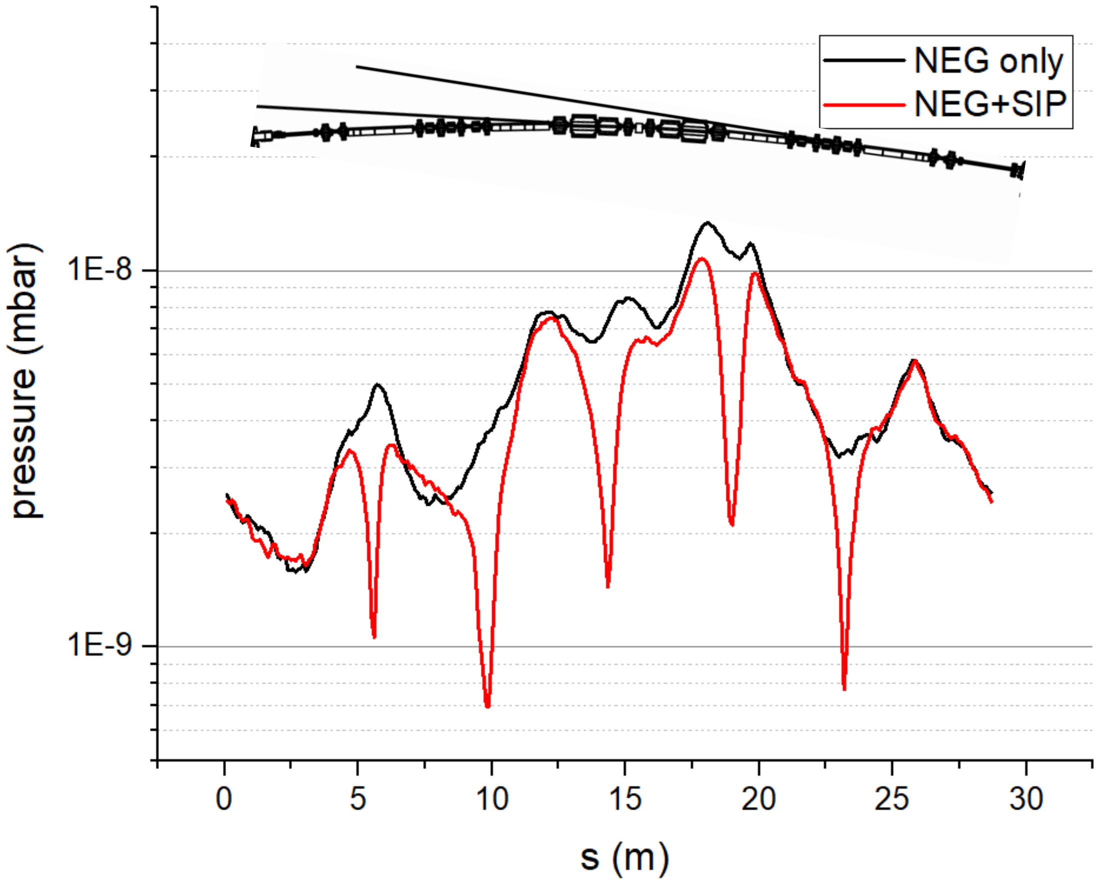
Type	NEG film (~1 μm)[11] 	Pill-type NEG 	Note
Facture	Sintering	Compressing	
Activation	200℃, 1 d	180℃, 1 ~ 2 d	
Pumping speed per length	-	Low (< 1/10)	Surf. Area ↓
Sticking probability (α)	**0.015** (200°C, 24 h)	**0.003 ~ 0.0037** (180°C, 48 h)	
α (after two additional venting)	0.015 → 0.008	Substantially constant	
Capacity (H_2)	-	1000×	Thickness↑
Disadvantages	Aging after venting	Particle	

Dynamic pressure calculation

- **H_2 pressure distribution (Molflow+)**
  - 0.0035 is used for the sticking coefficient of pill-type NEG.
  - Average pressure with only pill getter pumps is 5E-9 mbar and 4E-9 mbar with additional 7 sputter ion pumps.
  - Wire heater is inserted into the side channel of the vacuum chamber for 180℃ bake-out.



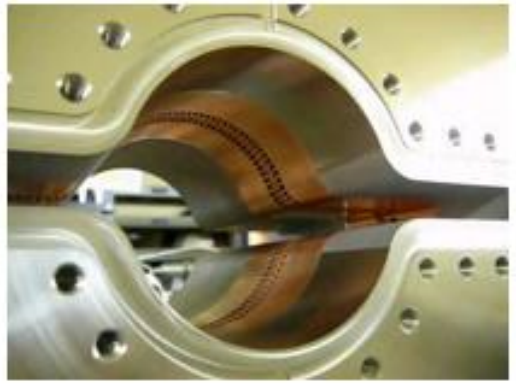




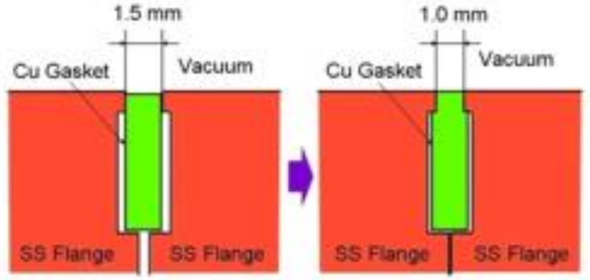
RF bellows and flange joints

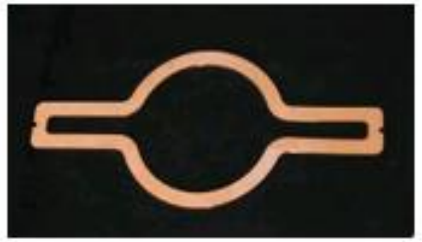
- BPMs will have short RF-bellows at both ends if the space is available.
- Jointing method between the BPM chamber and the RF-bellows will be studied.
- Conventional flange joints with wide thick RF-spring is considered preferentially and MO-type or VAT-type flange joints are considered as a second option.

SuperKEK[15]



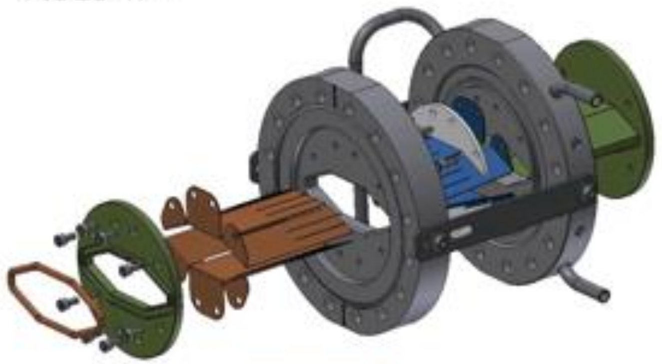
Comb type RF-shielding





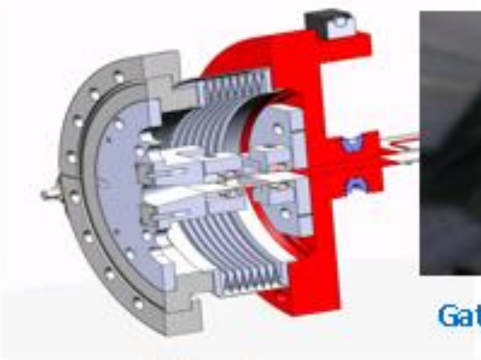
Mo-type flange

NSLS-II[2]

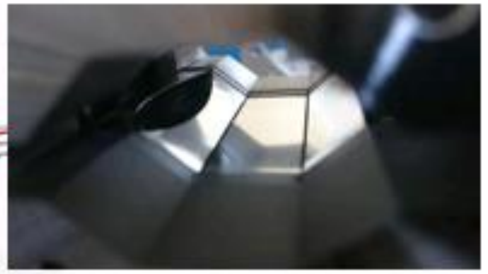


Wide thick fingers

ESRF EBS[3]



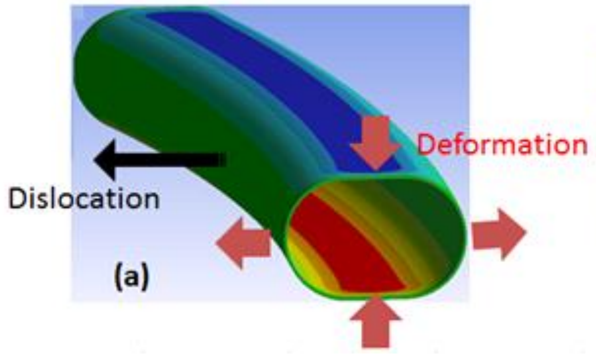
Sliding fingers



Gate valve with wide fingers

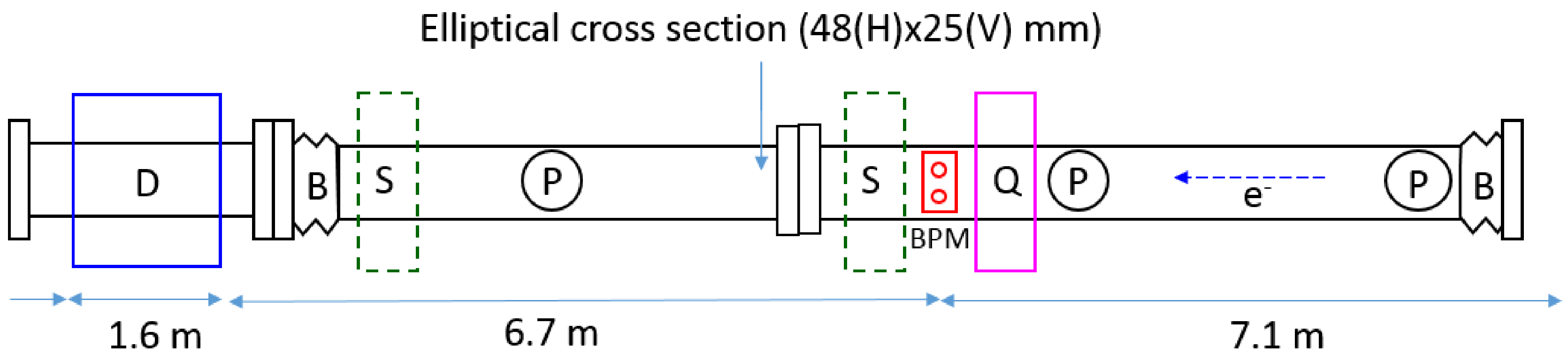
Booster Vacuum System

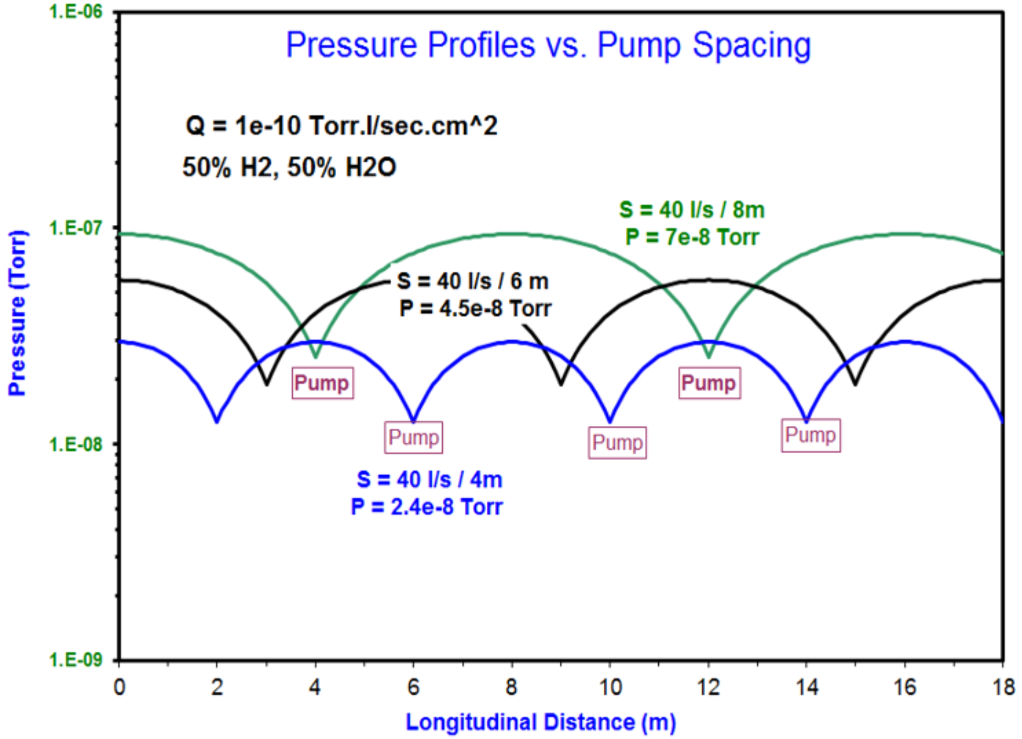
- Booster ring vacuum chambers are made of stainless steel with 46 mm (H) x 25 mm (V) aperture.
- Thickness of the stainless steel chamber at the magnet position is 1 mm.
- Three sputter ion pumps for one periodic cell are considered for vacuum pumping and monitoring.



Fatigue stress limit @1E7 cycles	
Stainless steel 316L	150 MPa
INCONEL 625	690 MPa

(b)





Summary

- **Conceptual Design of a Vacuum System for a 4GSR studied in PAL is presented**
  - Simple design to handle PSD gas loads with pill-type getter pumps and the inclined side wall to absorb SR
    - ✓ Distributed gas pumping and photon absorption
    - ✓ Pill-type getters can be installed in bent vacuum chambers
  - Pumping speed of the commercial pill-type getter is not high enough
  - Activation temperature of the pill-type getter is not low enough

- **Further studies**
  - Extrusion and bending test for the aluminum chambers
  - Improvement of pumping efficiency of the pill-type getters (new materials, 3D-printing, …)
  - Development of Bi-metal welding technique for the BPM chambers (STS-Al)
  - NEG coating of 3rd LGB chamber where the pressure is too high

Thank you!

Taekyun Ha (PAL)
E-mail: hatae@postech.ac.kr