Preliminary Study on Storage Ring Vacuum System for SPring-8 Upgrade Project

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Requirements and Constraints

Technical requirements

1. Energy & Current => 6 GeV & 100 mA
2. Bore Radius of QM and SM => 17 mm
3. BM field => Not uniform but longitudinally varies in three steps
4. Gas Scattering Lifetime =>
   ~10 h (during commissioning) & 100 h (after beam self-cleaning)
5. Lattice => Dense with magnets (shown later)

Time constraints

Fiscal Year	~2018	2019	2020
	Existing SPring-8 Operation	Black-out	NEW SPring-8
Manufacturing			
Dismantlement, Installation, Alignment, Evacuation			Integrated Test
Beam commissioning & fully outgassed			

User Operation Start

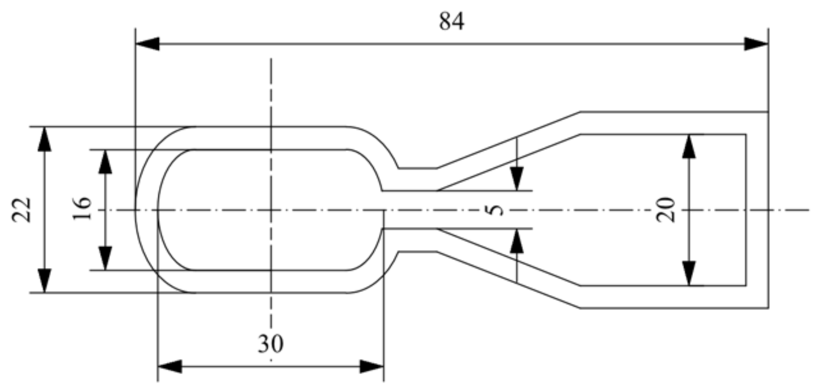
Design Concept (1)

<Basic Policy>

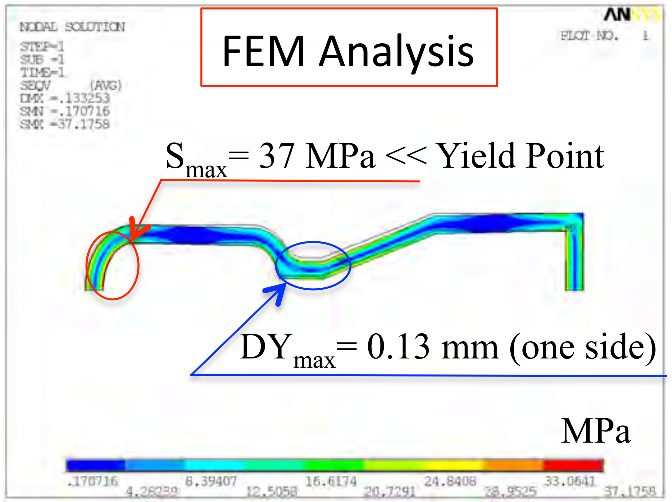
Taking advantage of the established technologies at SPring-8 as much as possible due to the time constraint.

1. Vacuum Chamber

Straight :
1) Extruded aluminum alloy (A6063T5) as in the SPring-8 case.
2) Correspond to the multi-pole magnets with small-bore radius.
3) Cooling channels should be added.
4) Conducting conventional structural analysis in parallel.



Straight Chamber Cross Section (Tentative)



Bending :
Both the material and manufacturing process are under study, because it is necessary to change the curvatures of electron beam orbit in the chamber corresponding to the longitudinally varying magnetic field.

Design Concept (2)

2. Baking Strategy

- NOT "green field" occupies an important place to our baking strategy.
- At present, *we are considering NOT proceeding with in-situ baking.*
- Alternative procedures are under consideration, which shall be suitable for an off-line preparation including pre-baking.
- This approach has the advantages

1) Decrease the number of bellows or make the length of bellows shorter.
2) The accuracy of BPM position would not be influenced by deformation and displacement caused by in-situ baking.

3. Pumping System

- *Negative* about adapting NEG coating on the inner surface of vacuum chambers.
  1) NEG coating over the entire circumference conflicts with the baking strategy of "NOT proceeding with in-situ baking".
  2) As it has essentially low sorption capacity resulting in the short life span of pumping ability, frequent re-coating would be necessary compared with NEG strip or NEG cartridge.
  3) The baking temp. of 180°C is very close to the thermal limitation of A6063T5.
- *Localized pumping system with cartridge-type NEG pump, some of which integrates SIP for the evacuation of CH_4 and noble gases, will be inserted in the ante-chamber instead of the existing NEG strip considering the superiority of pumping speed.*
- TMP during the commissioning as a countermeasure against NOT in-situ baking.

Design Concept (3)

4. Photon Absorbers (CR & AB)

- BM radiation will be handled by only CR & AB (NOT irradiate chamber wall).
- Each chamber of CR & AB will be equipped with a large capacity pumping unit.
- Glidcop or OFC as the situation demands based on FEM analysis result.

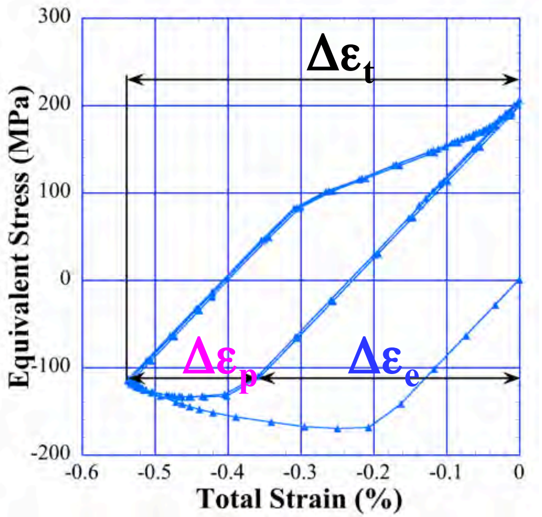
Max. Temperature < 200°C
Max. Eqv. Stress < Yield Point

YES → ***OFC***

NO → ***Glidcop***

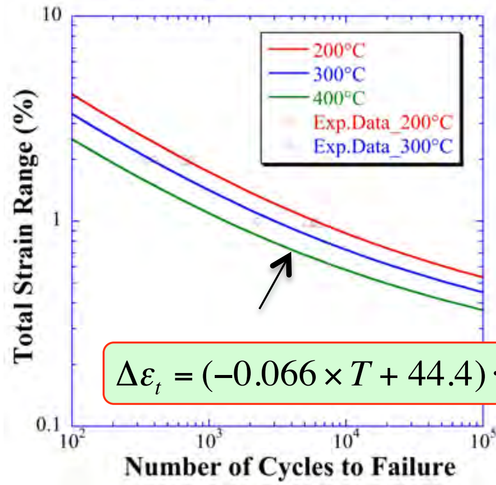
How to estimate thermal limitation of Glidcop?

- Low-cycle fatigue prediction by elasto-plastic analysis.
- Number of cycles to failure > 10,000 cycles



Hysteresis Loop by E-P analysis

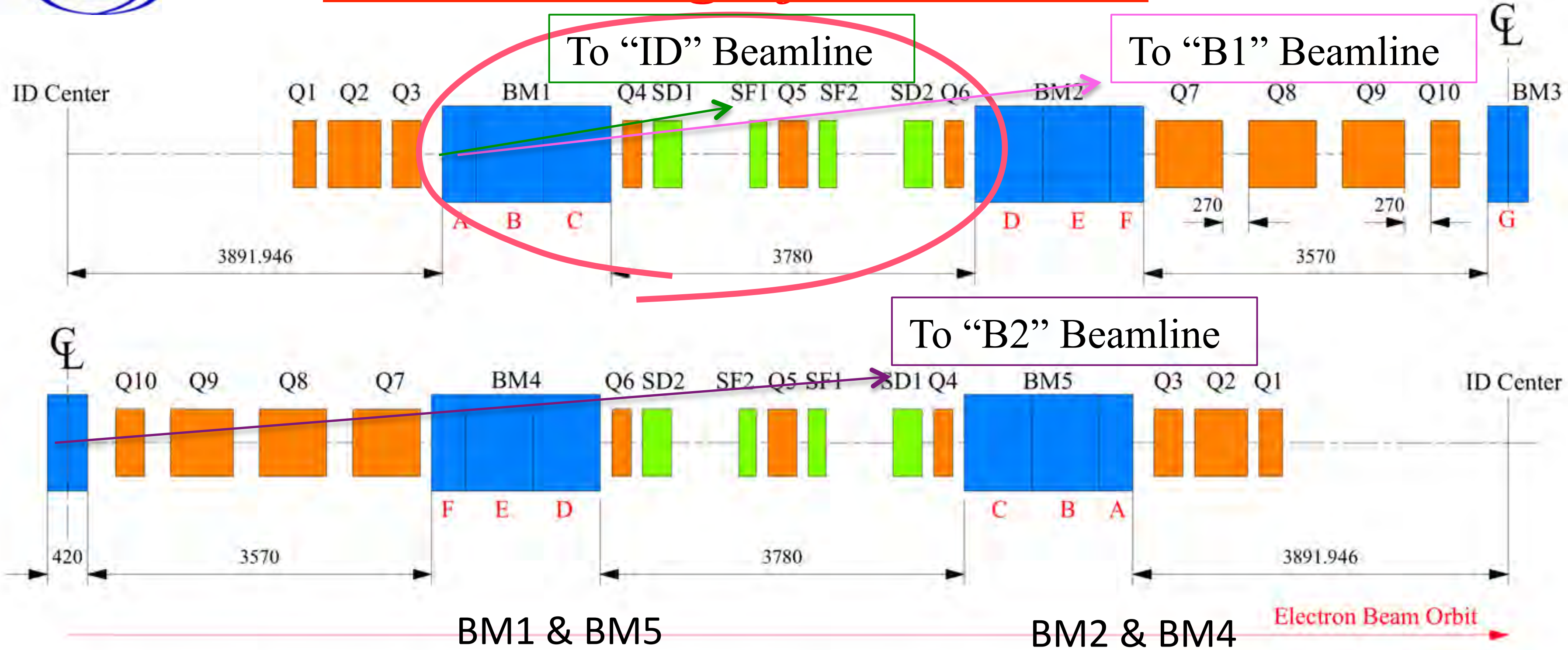
+



$$\Delta\varepsilon_t = (-0.066 \times T + 44.4) \cdot N_f^{-0.48} + (-0.0015 \times T + 1.4) \cdot N_f^{-0.086}$$

→ Fatigue Life Evaluation

Lattice Design for unit cell



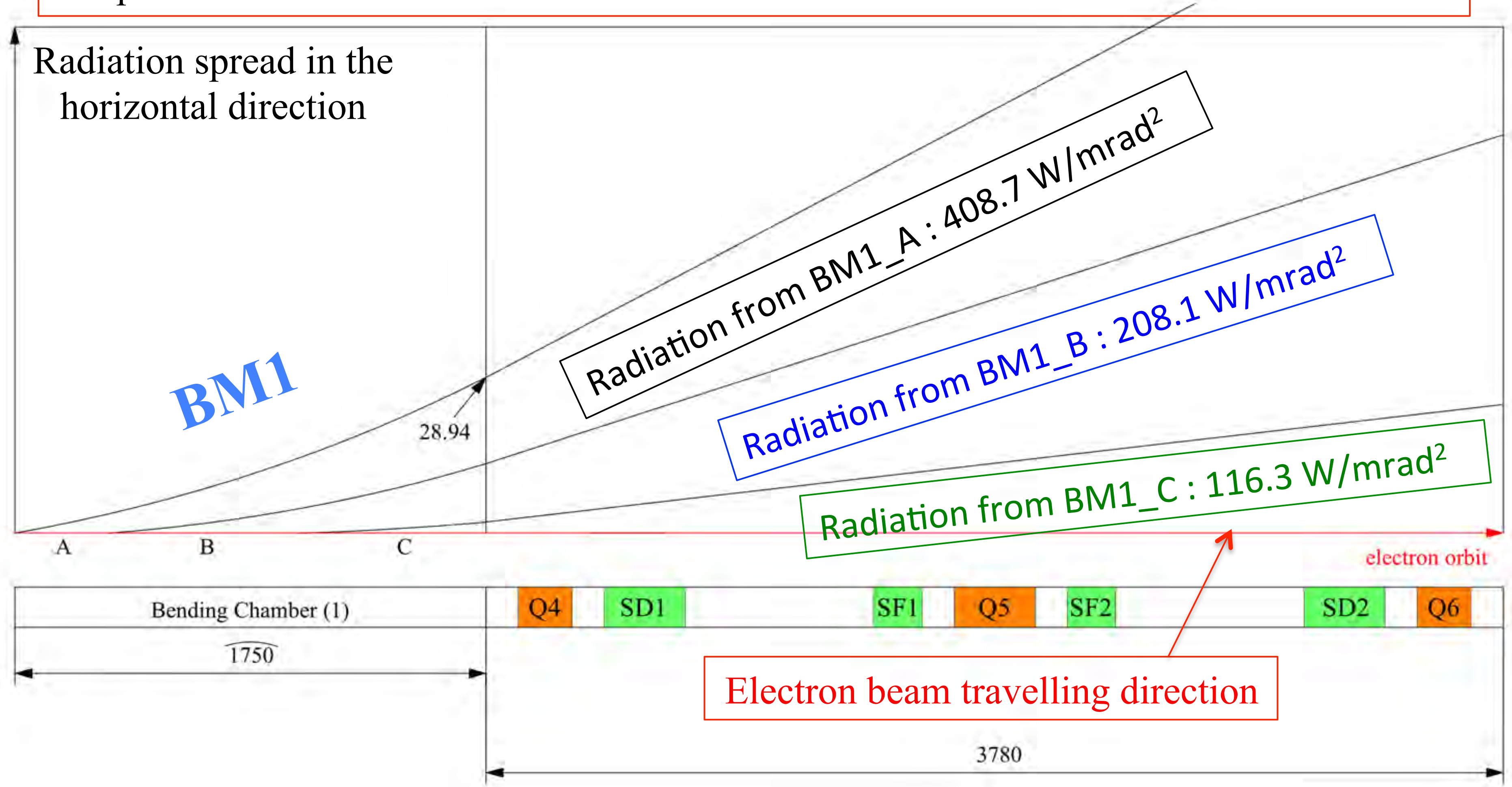
@6GeV, 100mA

	A	B	C	D	E	F	G
	BM1 & BM5			BM2 & BM4			BM3
B (T)	0.58	0.30	0.17	0.22	0.39	0.78	0.95
Power (W/mrad)	53.0	27.0	15.1	20.1	36.0	70.7	86.9
Power Density (W/mrad^2)	408.7	208.1	116.3	154.9	277.2	544.5	669.4

Specification of Bending Magnets

Ray Tracing for BM1 (1)

- As the bending chamber orbit is drawn by a straight line for the sake of convenience, synchrotron radiation orbits emitted from the bending magnet are drawn in a curve.
- Photon absorbers should be distributed properly at the space between magnets to prevent the inside wall of a vacuum chamber from being irradiated by the radiation spread as well as to extract the user beam to a beamline.



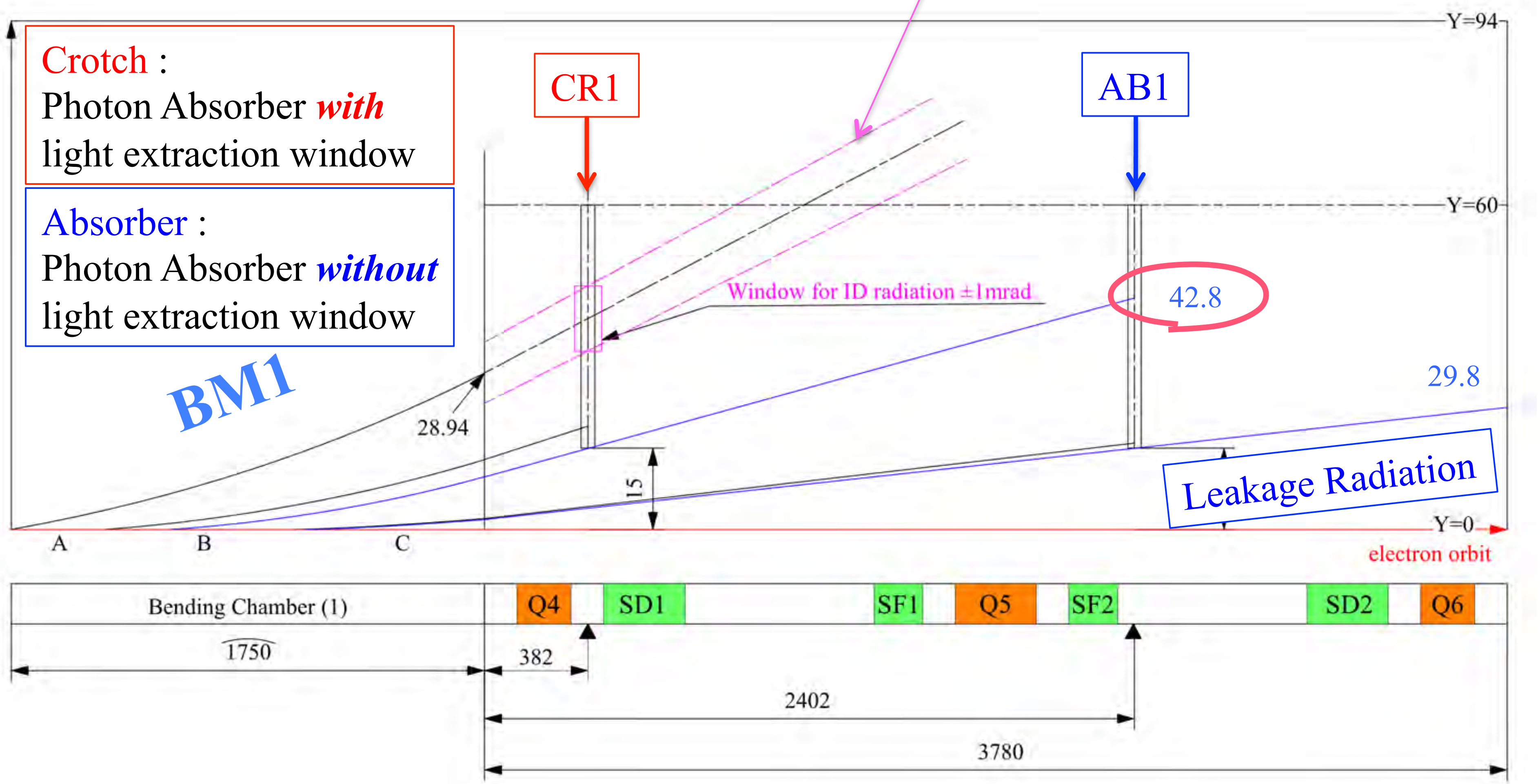
Ray Tracing for BM1 (2)

@SLAC_131210

- *CR1 will be laid out at the space between Q4 and SD1 and it has a window for extraction of ID radiation.*
- *Radiation cut by CR1 will spread to be 42.8 mm from the electron orbit at AB1 position.*

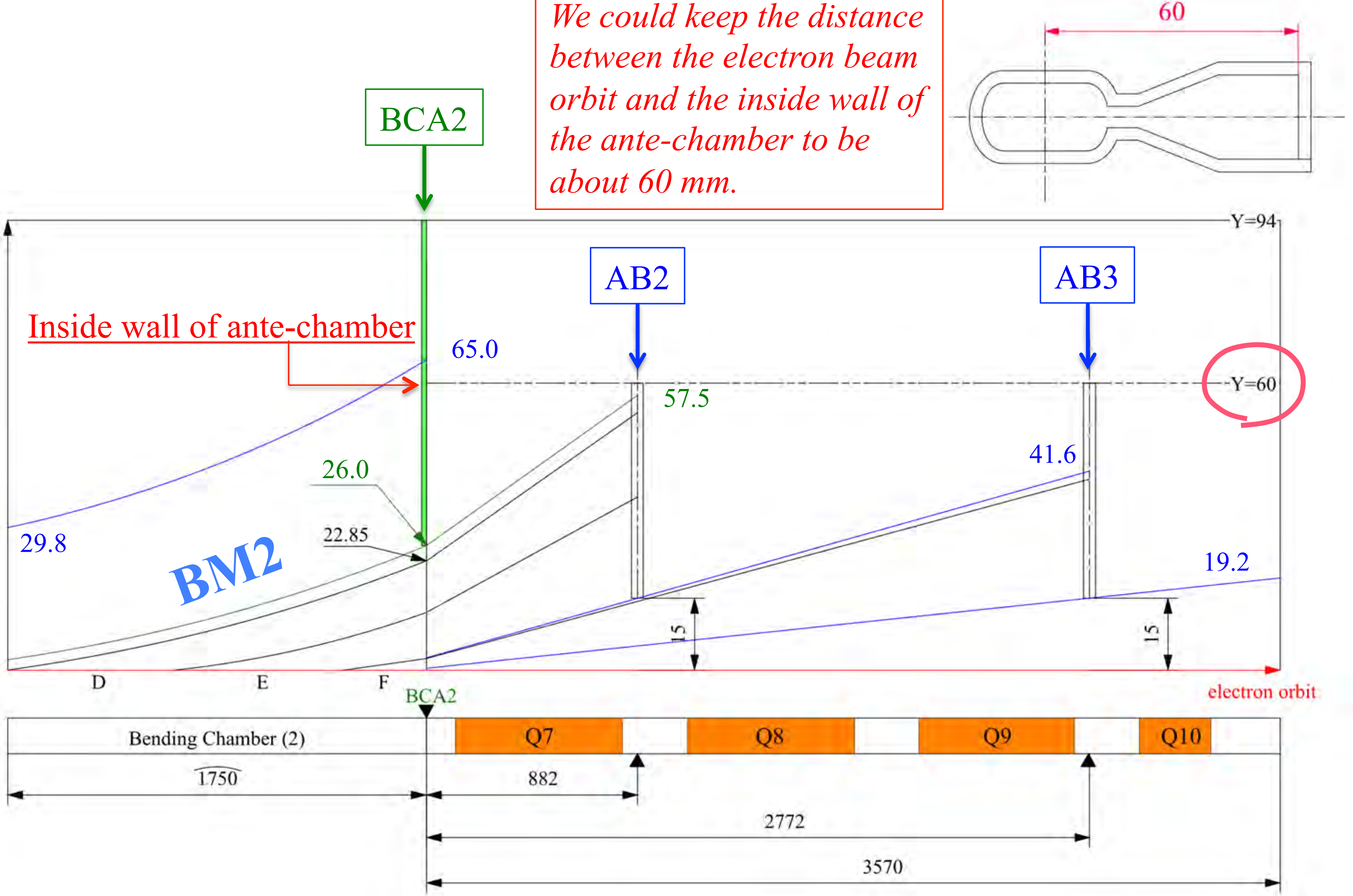
ID radiation with a divergence angle of ±1mrad

radiation spread in the horizontal direction

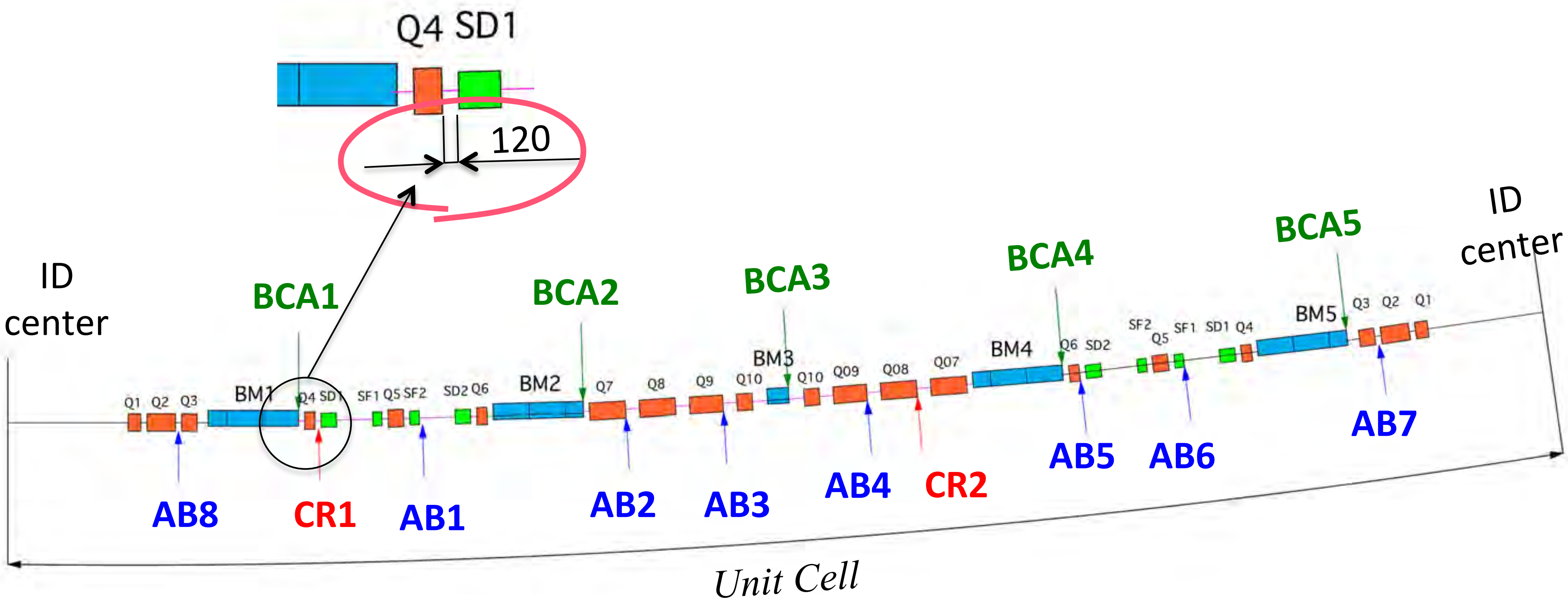


Ray Tracing for BM2

We could keep the distance between the electron beam orbit and the inside wall of the ante-chamber to be about 60 mm.



Distribution map of photon absorbers for unit cell



- *Arrangement of a pair of photon absorbers in each straight section will be able to deal with the new lattice design.*

- *By adding supplementary absorbers of BCA, we are optimistic about the miniaturization of the ante-chamber section.*

- *Because there is a very narrow space between magnets where CR or AB will be inserted, designing a compact heat-absorbing body with adequate cooling ability is our new task.*

Power Distribution on Photon Absorbers for unit cell

	CR1	AB1	BCA2	AB2	AB3	BCA3	AB4	CR2	BCA4
Absorbed Power (kW)	0.649	0.180	0.114	0.641	0.604	0.184	0.902	0.524	***0.461***
Radiation Income Angle (mrad)	13.41	6.67	6.52	21.55	8.81	2.60	10.89	6.03	5.31
*1) Peak Power Density (W/mm^2)	128.7	20.5	3.7	174.8	64.4	***33.0***	***210.0***	97.2	23.6

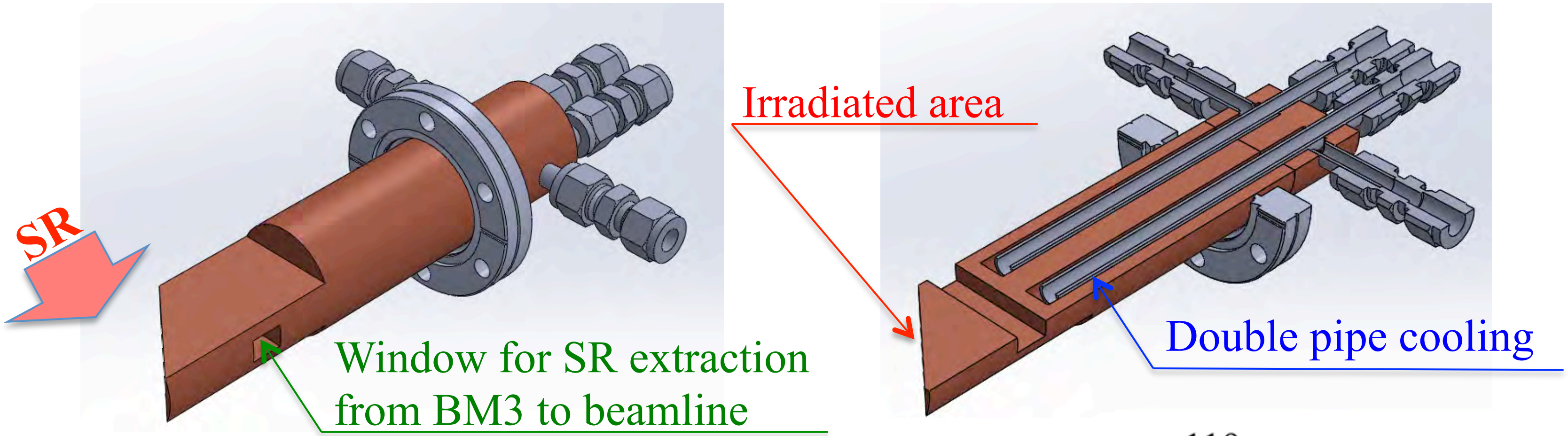
	AB5	AB6	BCA5	AB7	(ID absorber)	AB8	BCA1	Total	SPring-8
Absorbed Power (kW)	***1.112***	0.424	0.103	0.206	(0.585)	0.017	0.065	6.770	Max. 5.40
Radiation Income Angle (mrad)	17.20	12.69	5.13	10.30	(14.15)	0.32	1.23	142.8	—
*1) Peak Power Density (W/mm^2)	171.4	18.2	5.0	112.2	—	7.7	4.5	—	Max. 340

*1) Normal incidence angle

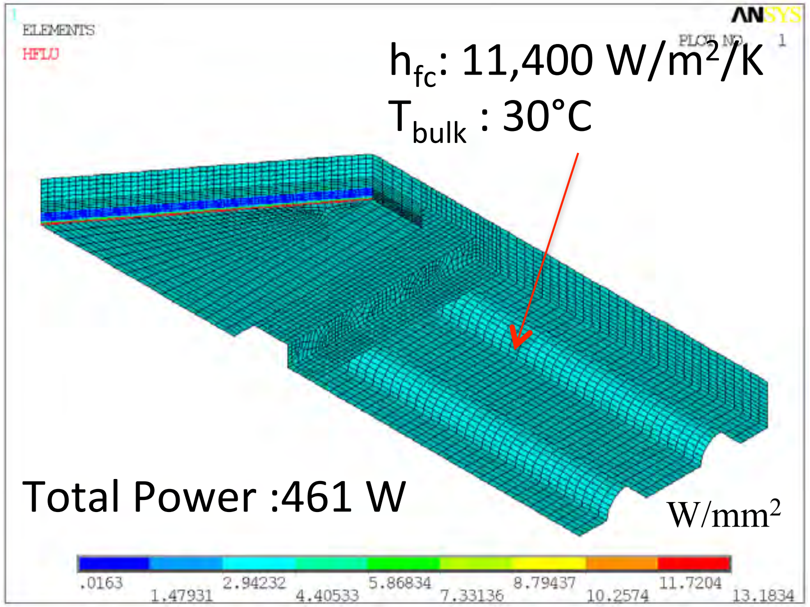
The absorbed power decreases significantly, whereas the peak power density doesn't so remarkably decrease, mainly because the distance becomes shorter.

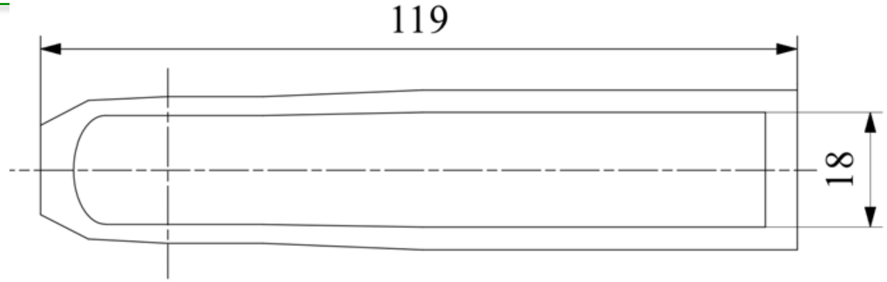
Design and Analysis for BCA4 (1)

Model for BCA4: (left) external view, (right) cross-sectional view



Half Modeling



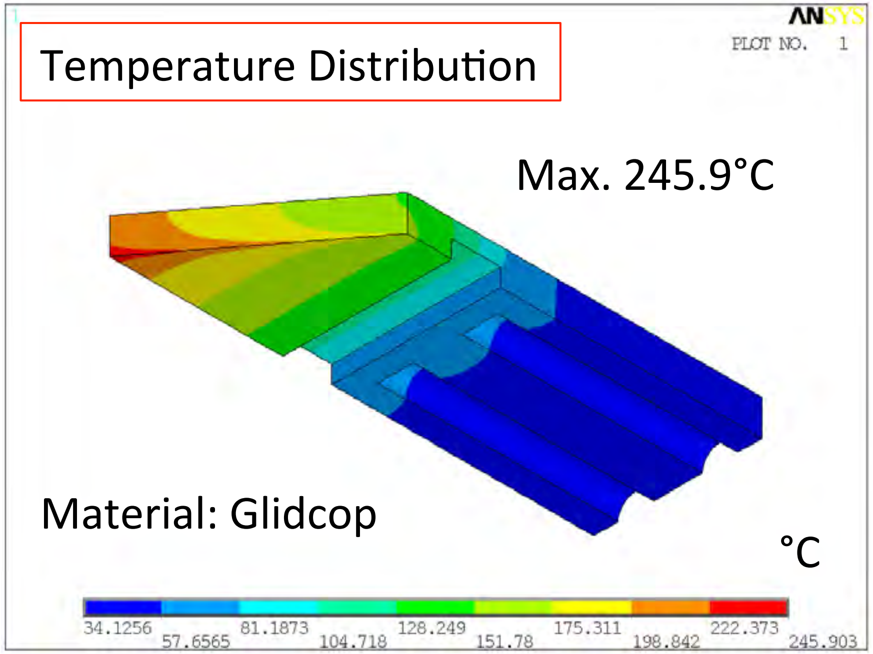


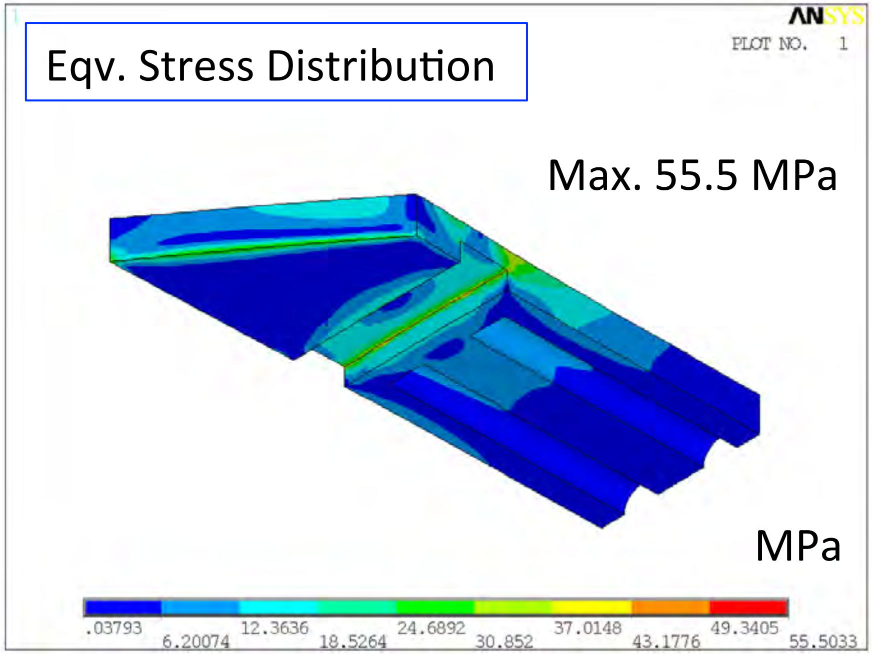
Bending Chamber Cross Section (Tentative)

- Window configuration prevents cooling channels to get close to the irradiated area.
- The thickness of the irradiated section is 16 mm in order that it can be inserted into a narrow bending chamber slot.

Negative impact on the cooling performance

Design and Analysis for BCA4 (2)





- The maximum temperature reaches about 250°C locally.
- Considering an effect of radiation heat on the aluminum chamber, we should make effort to suppress the maximum temperature as low as possible.

- Result of thermo-mechanical analysis with a consideration of plastic property shows that the maximum equivalent stress is just 55 MPa even at a corner, which is below than even the yield point of 82 MPa at 400°C.
- Not necessary to check up the low-cycle fatigue issue.

Summary and Future Plans

1. **We have just started a preliminary study on storage ring vacuum system for the SPring-8 upgrade project.**

2. **Some important design concepts are proposed for vacuum chamber, baking strategy, pumping system and photon absorbers based on the given boundary conditions.**

3. **Judging from the ray tracing, it became clear that an arrangement of a pair of photon absorbers in each straight section would be able to deal with the new lattice design.**

4. **By adding a supplementary absorber of BCA at the most downstream side of each bending chamber, we are optimistic about the miniaturization of the ante-chamber section.**

5. ***Designing a compact heat-absorbing body with adequate cooling ability is one of our next targets.***