Review of Few of

Accelerator R&D Activities at PAL

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Pohang Accelerator Laboratory

PLS-II (2014): 3rd generation synchrotron light source

fs-THz (2007): Linac-based THz source

PAL-XFEL (2016): linac-based X-ray free electron laser

Accelerator R&D Activities at PAL

<PLS-II related>

- Storage ring injection upgrade (2017~2020)
- Electron beam stabilization (transverse feedback, …)
- High photon energy X-ray source
- fs-THz beamline source renovation (independent facility)

<PAL-XFEL related>

- Self-seeding
- EPU for soft X-ray

<Others>

- Klystron development (2016~2018)
- Ultimate storage ring
- Plasma wakefield acceleration
- High power FEL
- Compact storage ring

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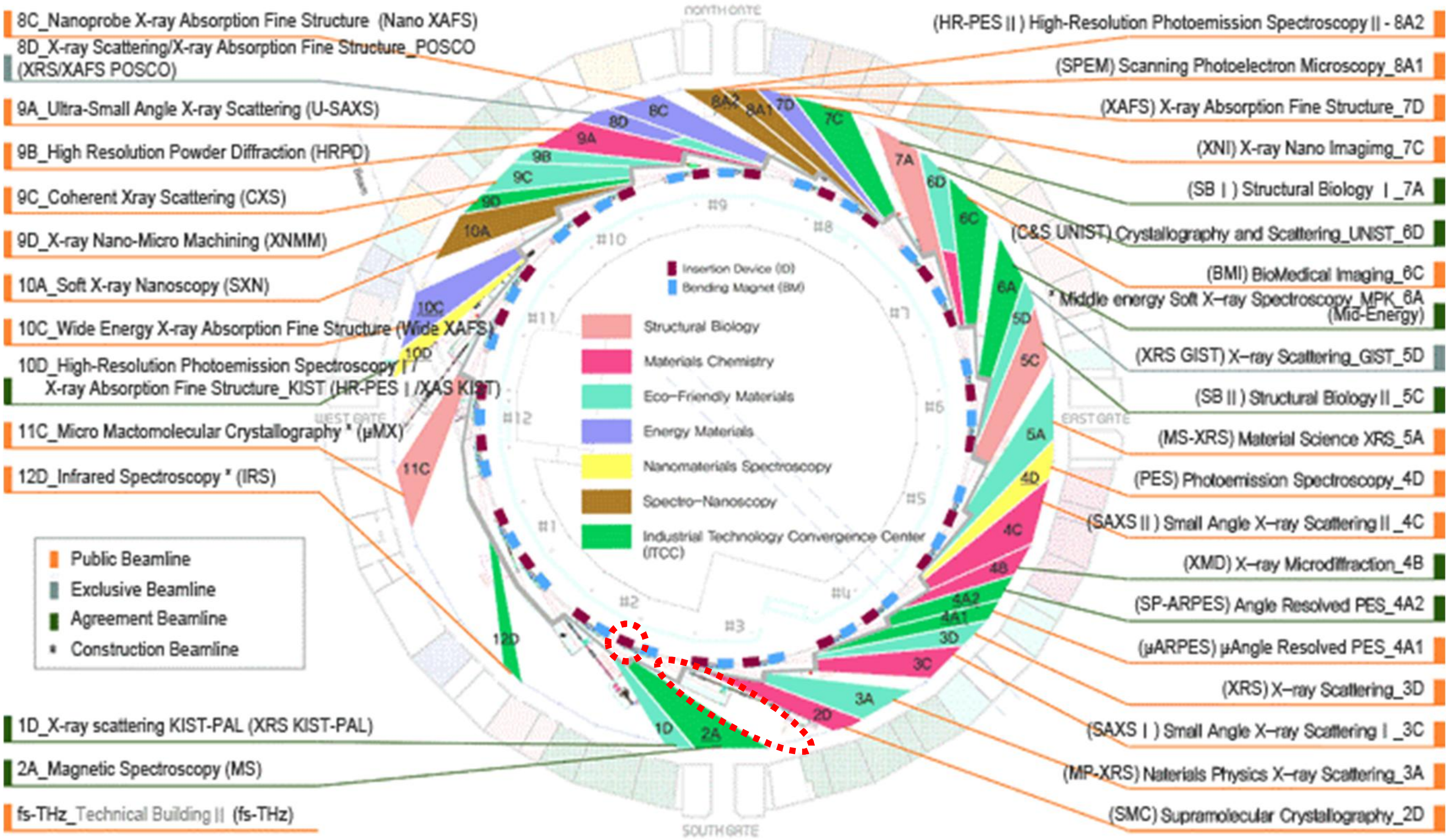
to be discussed in this talk

High Photon Energy X-ray Source

PLS-II Beamlines



PLS-II Insertion Devices

	Type	Period (mm)	B_{max} (T)	Quantity	Magnet length (m)
IVU20	In-vacuum undulator, planar	20	0.97	10	1.35 or 1.8
MPW10	Multipole wiggler, planar	100	1.80	1	2.0
MPW14	Multipole wiggler, planar	140	2.02	1	1.12
U68	Out-vacuum undulator, planar	68	0.90	1	3.06
EPU58	APPLE-II undulator, elliptic	58	0.684	1	3.20
EPU72	APPLE-II undulator, elliptic	72	0.79	2	2.58
EPU114	APPLE-II undulator, elliptic	114	0.88	1	3.53
Revolver	In-vacuum undulator, planar	10 (R10) 15 (R15) 20 (R20) 24 (R24)	0.606 (R10) 0.866 (R15) 1.050 (R20) 1.100 (R24)	1	1.02

Critical Energy vs Magnetic Field

Critical energy

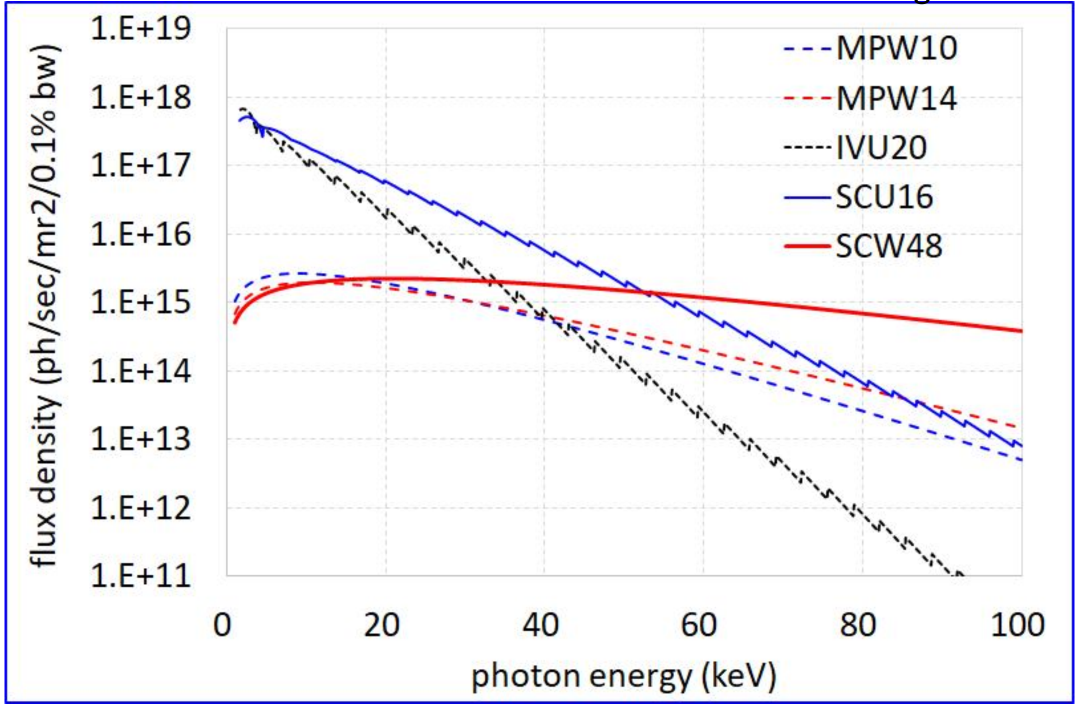
$\varepsilon_c = 0.67\ \mathrm{E(GeV)}^2\ \mathrm{B(T)}$

PLS-II short straight (2C slot)
- 3 GeV beam energy
- 48 mm period length, 16 periods

Bending field	Critical energy	Critical energy × 4	Radiation power
1.5 T	9 keV	36 keV	3.9 kW
2 T	12 keV	48 keV	7.0 kW
2.5 T	15 keV	60 keV	10.9 kW
3 T	18 keV	72 keV	15.7 kW
3.5 T	21 keV	84 keV	21.4 kW
4 T	24 keV	96 keV	30.0 kW
4.2 T	**25 keV**	**100 keV**	**30.9 kW**
4.5 T	27 keV	108 keV	35.4 kW
5 T	30 keV	120 keV	43.7 kW

Flux Density

calculated using SPECTRA

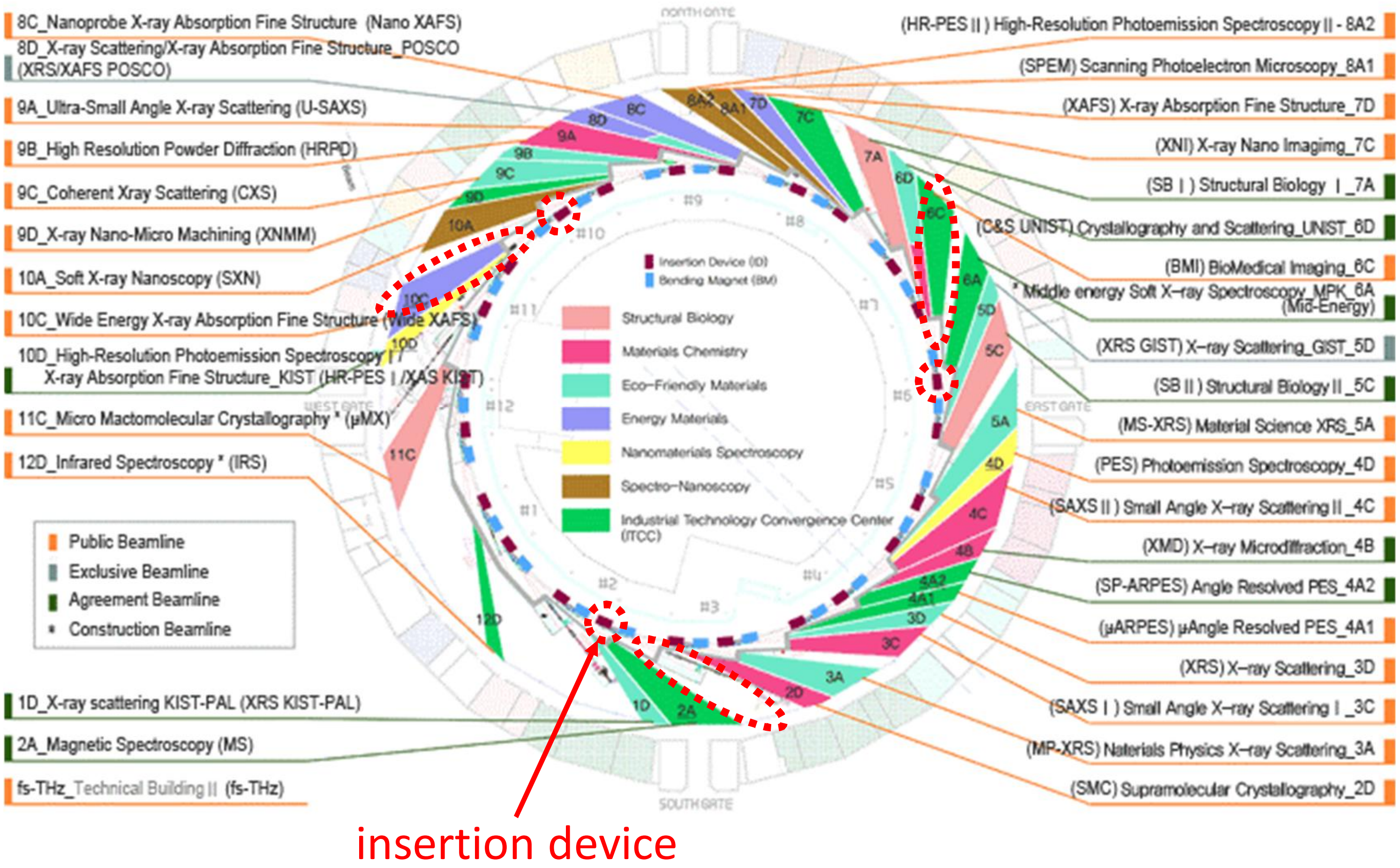


MPW10, MPW14, IVU20: operational
SCU16, SCW48: consideration

	MPW10	MPW14	IVU20	SCU16	SCW48
Period (mm)	100	140	20	16	**48**
B_{max} (T)	1.80	2.16	0.97	1.50	**4.20**
Critical energy (keV)	10.8	12.9			**25.1**
K	16.8	28.2	1.81	2.24	**18.8**
Number of periods	18	12	90	75	**16**
Magnet length (m)	1.8	1.68	1.8	1.2	**0.768**
Flux density at 35 keV	7.5E14	7.2E14	2.1E15	9.5E15	**2.15E15**
Flux density at 100 keV	4.8E12	1.3E13	3.6E10	8.1E12	**1.22E15**
Total power (kW)	13.3	20.1	3.9	6.1	**30.9**

High Energy X-ray Beamline

- 35~100+ keV for engineering materials (i.e., thick metal samples)
- 2C (short straight) potential candidate for new beamline
- Construction start in 2021 (plan)



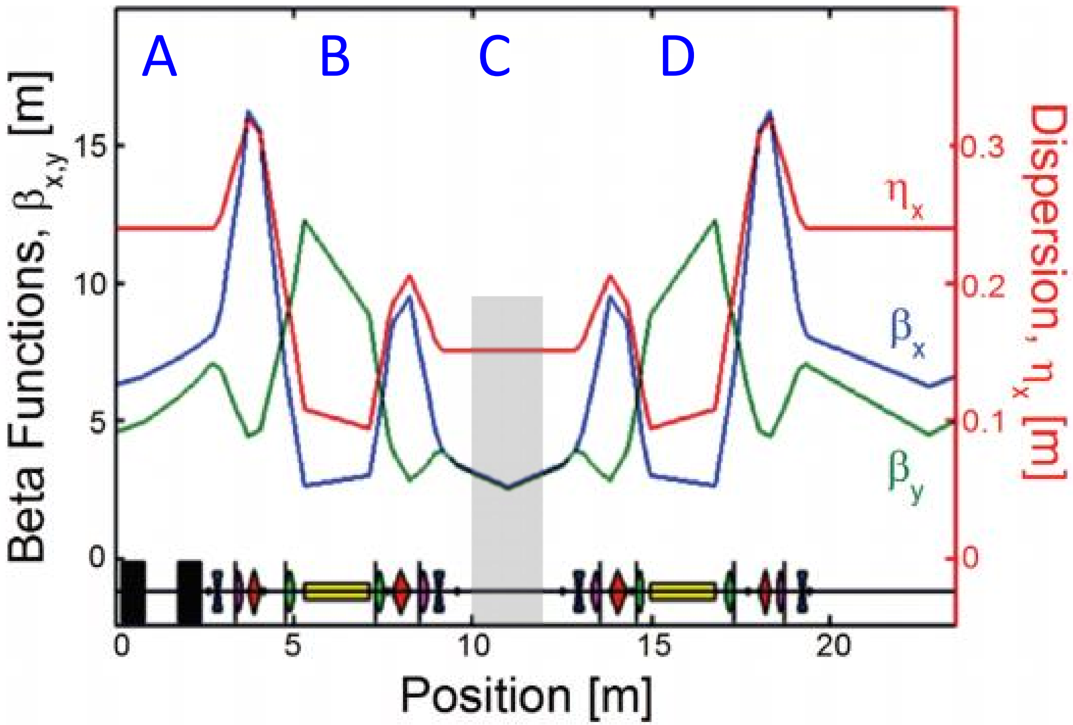
PLS-II Lattice

Dispersion function (x):

Short straight (C) ~ 0.16 m

Long straight (A) ~ 0.25 m

Dipole (B, D) < 0.1 m



I. Hwang et al., “Operation improvement by tuning of storage ring at PLS-II”, IPAC2016

Emittance Growth due to Other IDs

Emittance rise due to other IDs: 5.8 → 7.7 nm rad

Table 3. Insertion device's parameters and main optical effects.

Parameters	MPW10	MPW14	IVU
No of periods	20	8	66
Period length λ_p [cm]	10.0	14	2.0
Peak field B_0 [T]	1.8	2.02	0.81
Min pole gap [mm]	12.0	14.0	6.0
ρ_0 [m]	5.56	4.95	12.35
Deflecting parameter K	16.81	26.41	1.51
$\int k_y ds$ [m^{-1}]	0.0324	0.0228	0.0043
ΔQ_y	0.0065	0.0046	0.0015*/0.00086
$\Delta\beta_y/\beta_y$ [%]	4.5	3.2	1.04*/0.58
Emittance [nm-rad]	6.06	6.04	5.84*/5.83

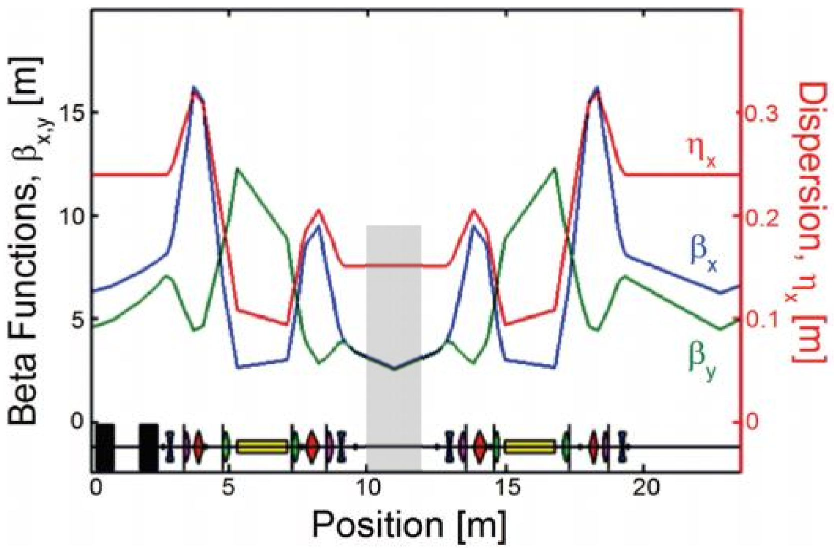
S. Chunjarean et al., "The effect of insertion devices on the beam dynamics in PLS-II", J. Korean Phys. Soc. 64, 1259 (2014)

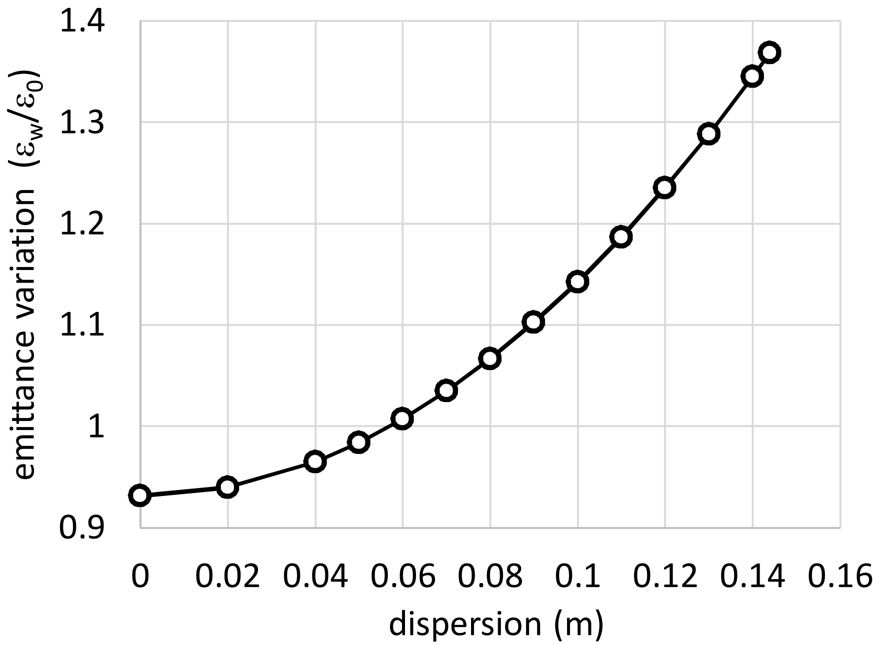
Lattice Adjustment

Dispersion is 0.16 m at the straight section

4.2 T, 0.77 m long superconducting wiggler → Emittance rise ~37%

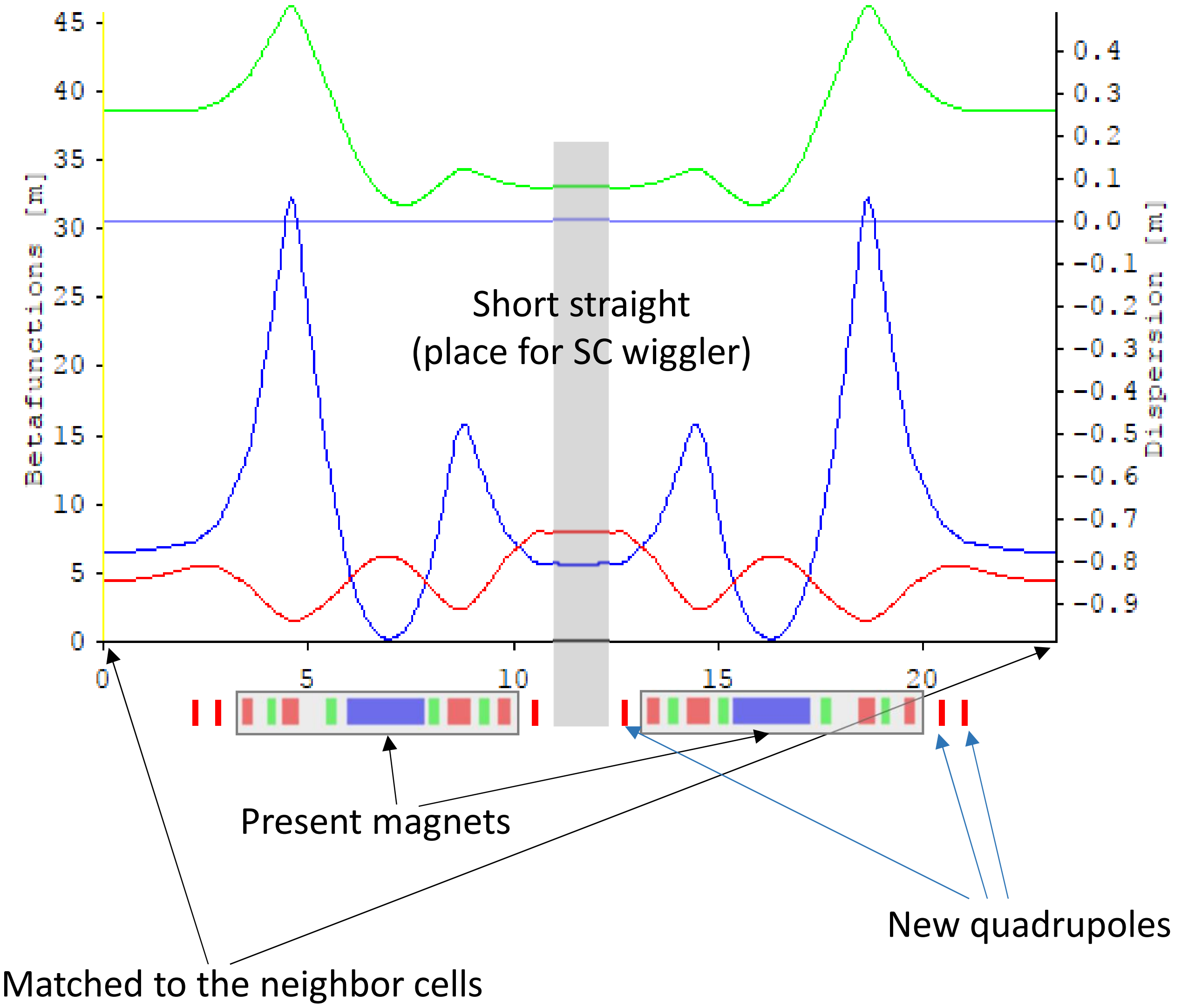
Dispersion should be reduced





Lattice Modification (2C, 6C, 10C)

OPA calculation by Jaeyu Lee



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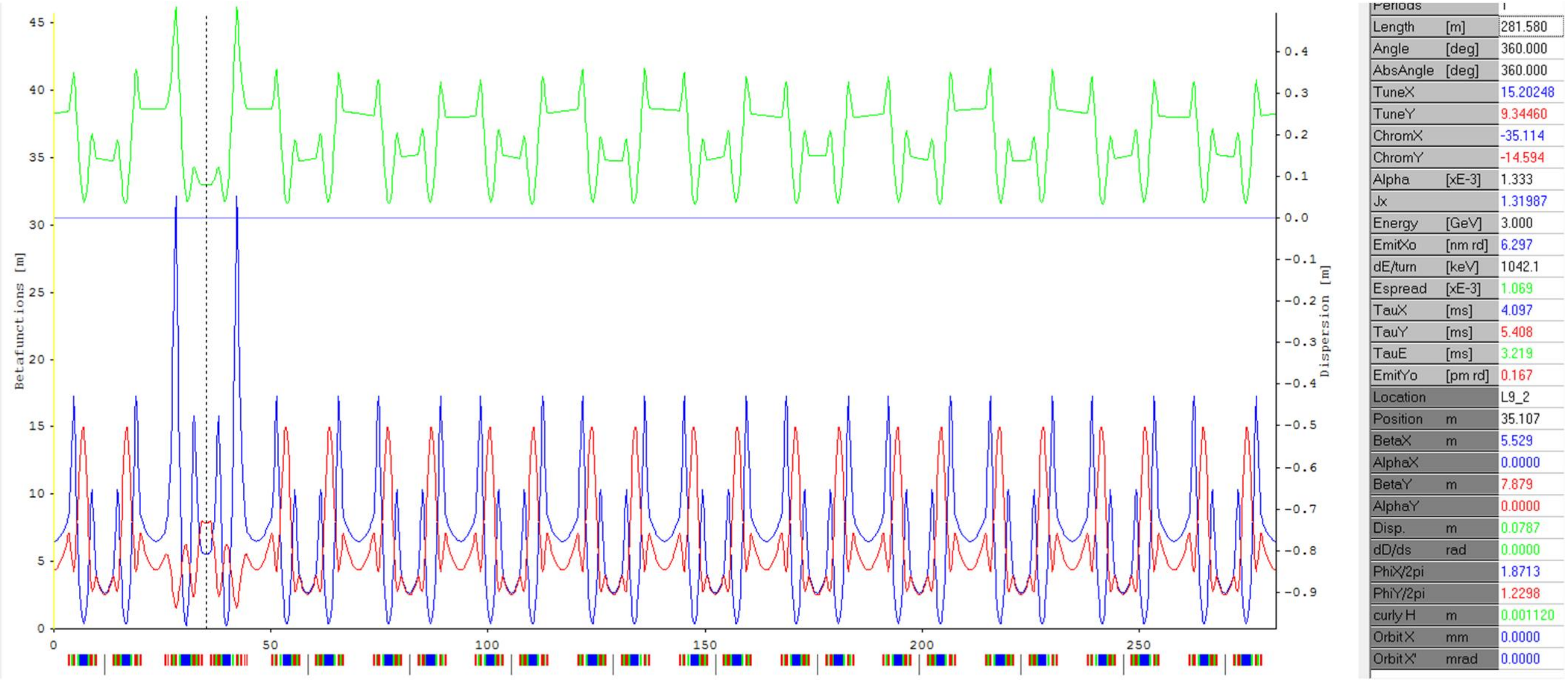
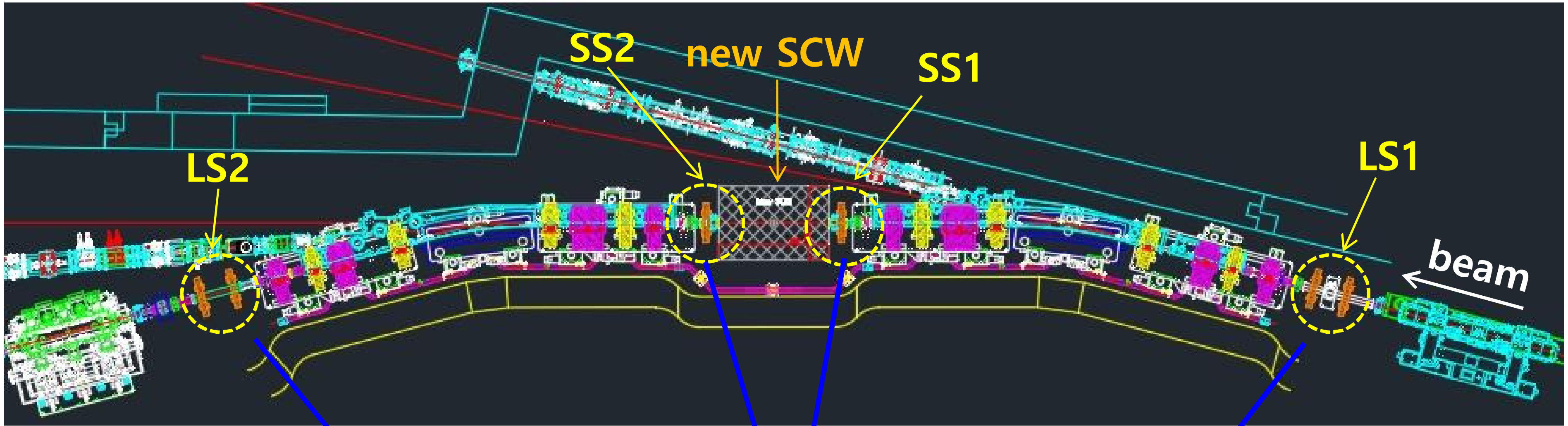


	Present lattice	New lattice w/o SCW	New lattice with SCW
Emit_x	5.8 nm (7.7 nm?)	6.3 nm (8.2 nm?)	6.2 nm (8.0 nm?)
Beta_x	2.65 m	5.53 m	5.53 m
Dispersion	0.1439	0.0787	0.0787

Modification Plan of Cell #2 (also for Cell #6 or #10)

Sangbong Lee



Short Straight
1 new quad at both ends
L_{eff} : 100mm

Long Straight
2 new quads at both ends
L_{eff} : 100mm

- **Total 6 new Quad**
- **New girders for new quads installation**
- **New correctors for SCW**
- **New quad chambers**

Fs-THz Beamline Source Renovation

Goal of fs-THz Beamline Renovation

Request from Bemaline Manager

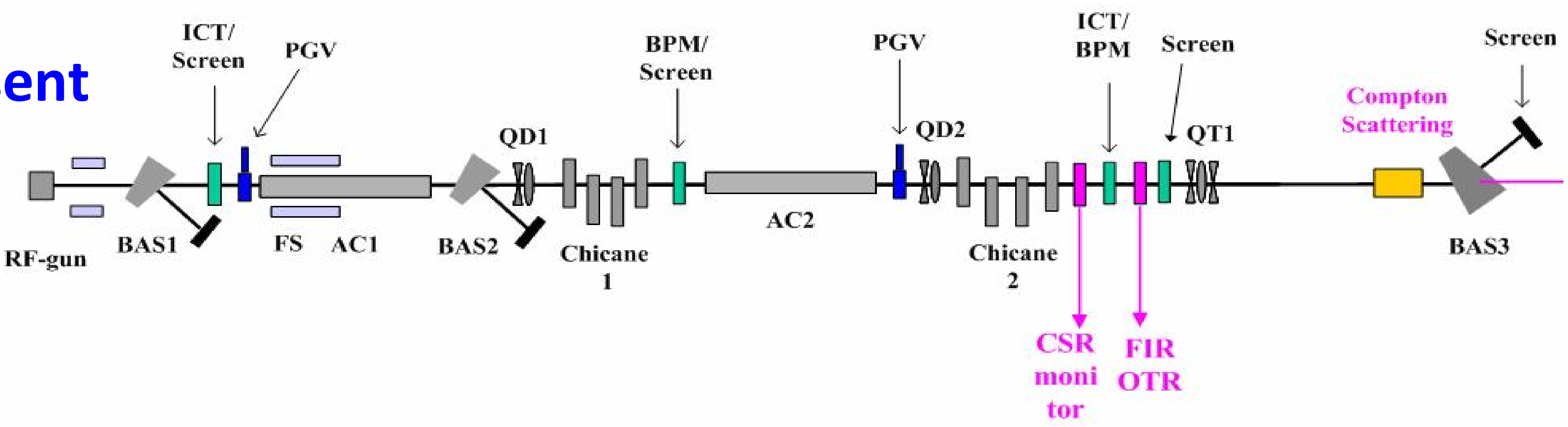
	Present	Upgrade
Pulse energy	Up to 5 uJ	**Up to 100 uJ**
Tuning range	0.3 ~ 3 THz	**0.3 ~ 20 THz**
Pulse repetition rate	10 Hz	60 → 500 Hz

Source Upgrade

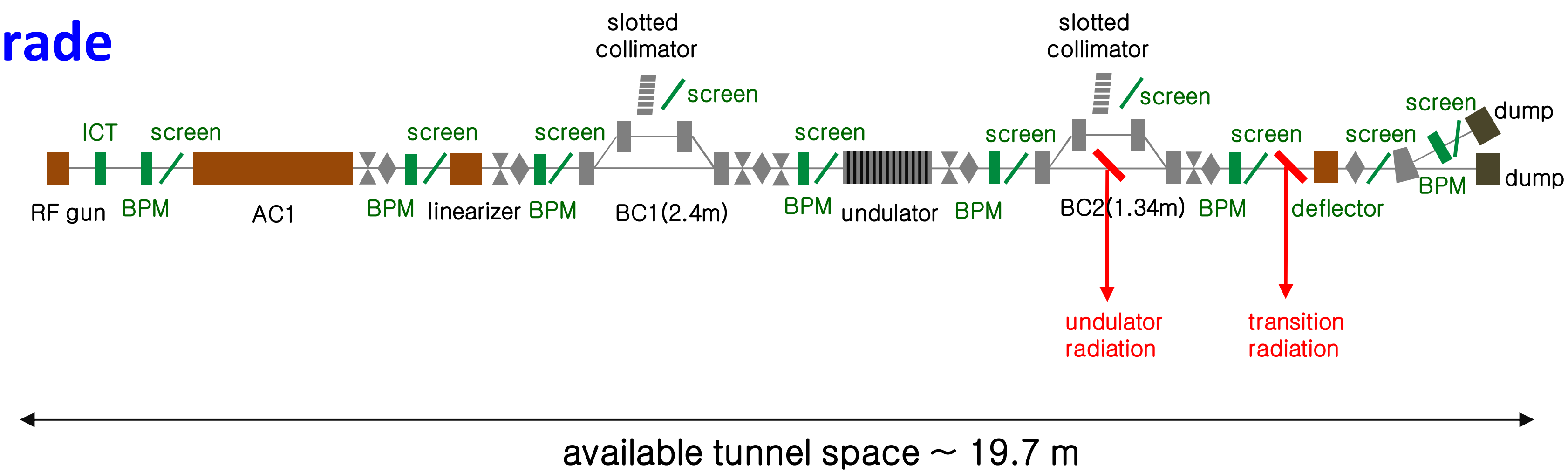
	Coherent transition radiation		Undulator radiation
Frequency range	0.3 ~ 10 THz		5 ~ 20 THz
Pulse length	<100 fs	few ps	few ps
Bandwidth	Wideband	Narrowband	Monochromatic
Wavelength Tuning	-	Bunch pattern	Bunch pattern + e-beam energy or undulator K
Pulse energy	Up to 100 μJ	Up to 100 μJ	Up to 100 μJ

Accelerator Components in fs-THz Beamline Tunnel

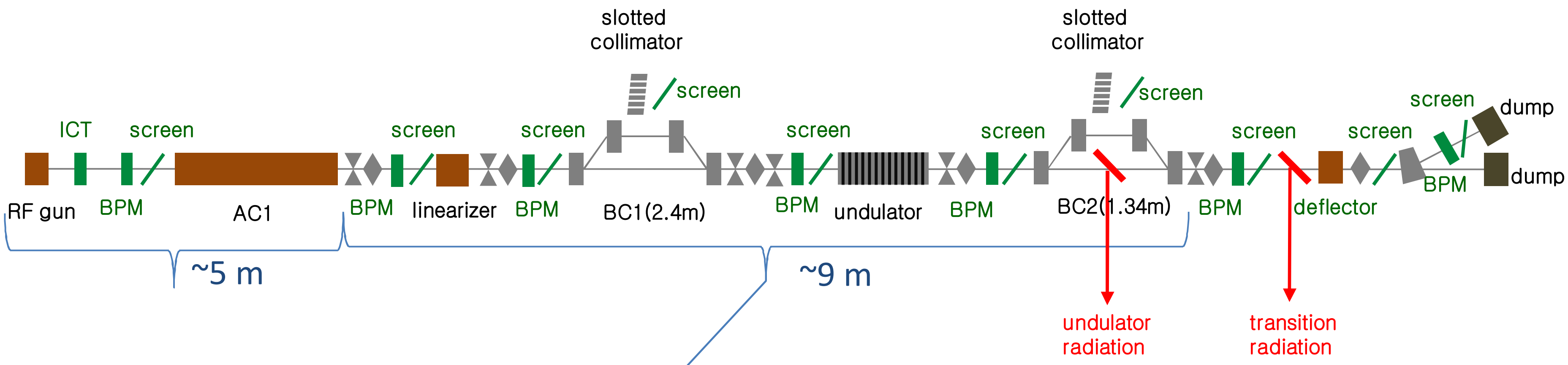
Present



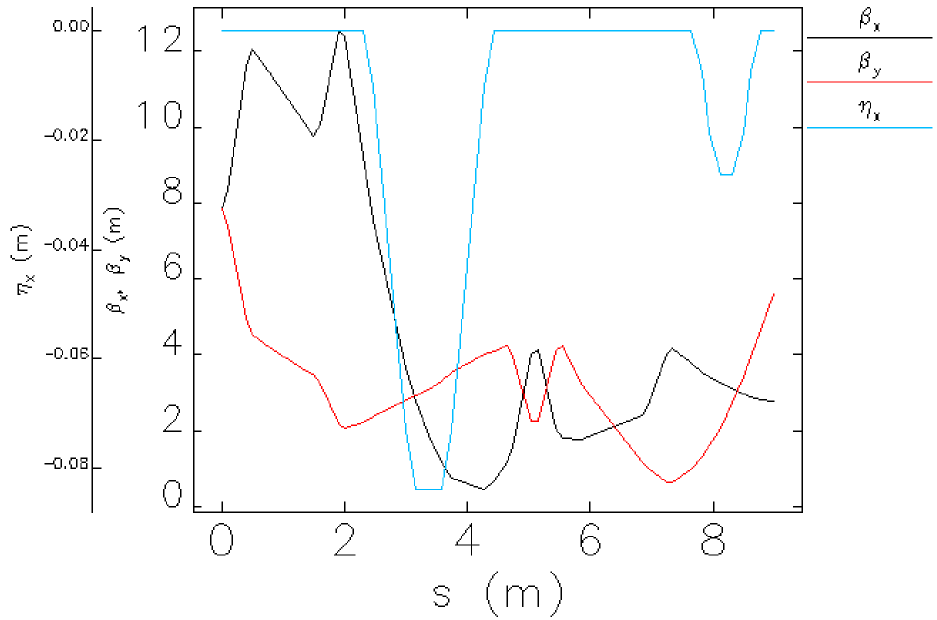
Upgrade



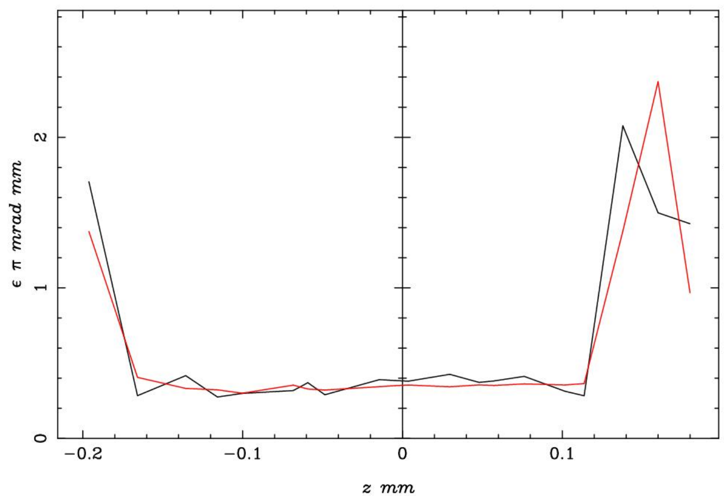
Electron Beam Optics (to be updated)



Twiss parameter

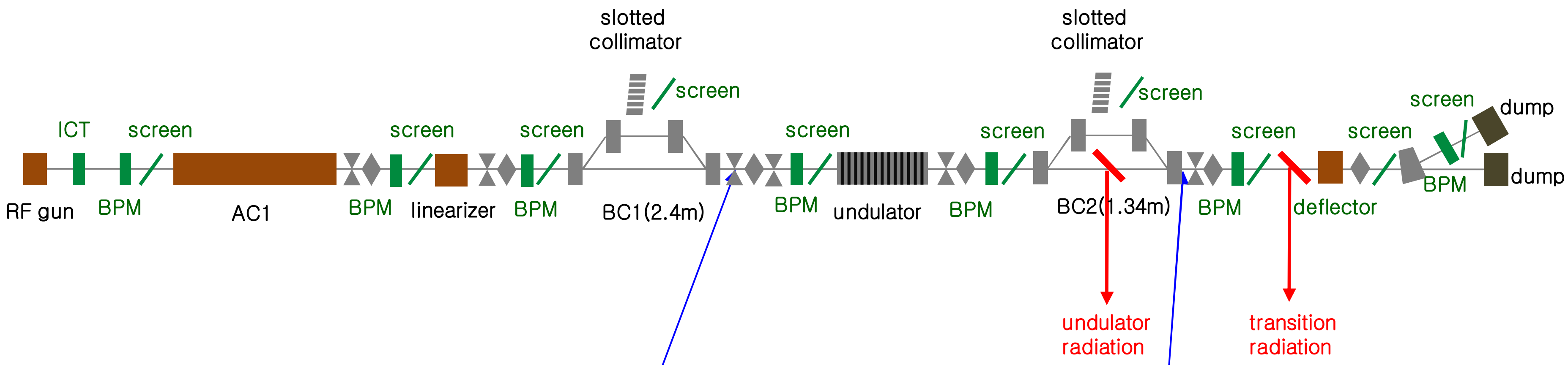


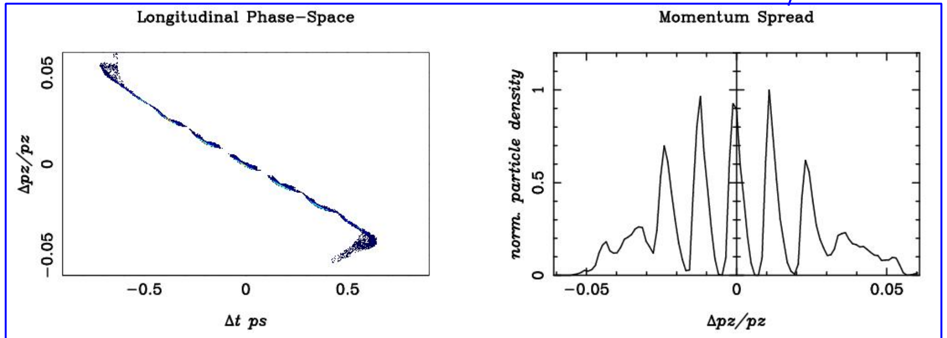
Slice emittance at BC2 end

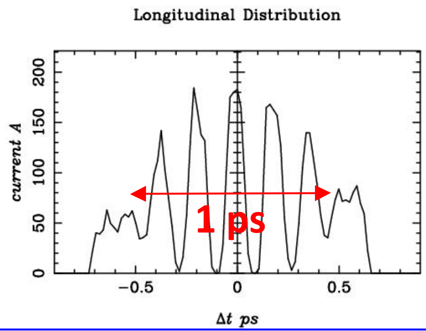


Simulation using Elegant and ASTRA

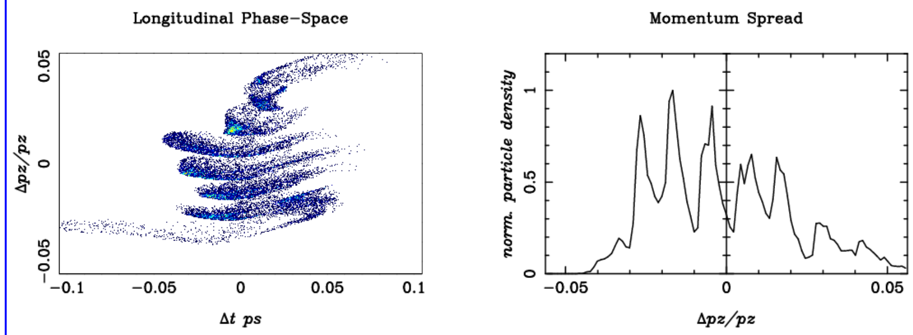
Electron Bunch Profile for THz Radiation

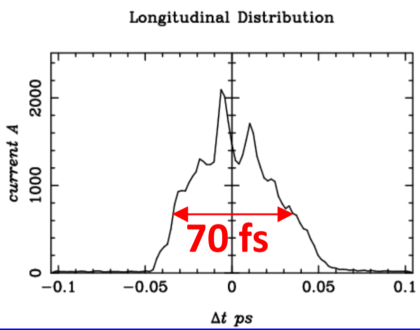






Micro-bunch generated for undulator radiation (to be updated)



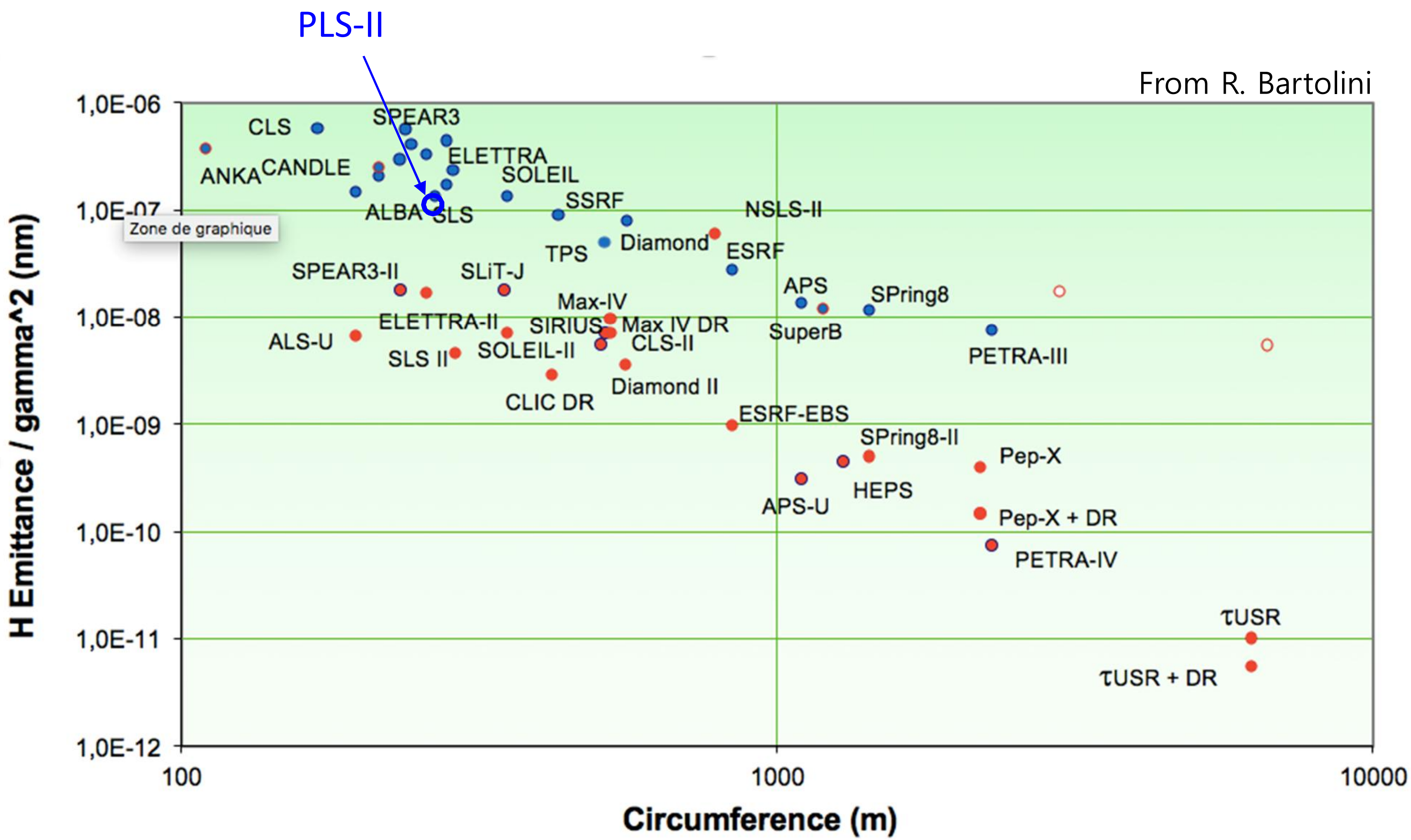


Critically compressed for transition radiation (to be updated)

Simulation using ASTRA

Ultimate Storage Ring

Ultimate Storage Ring

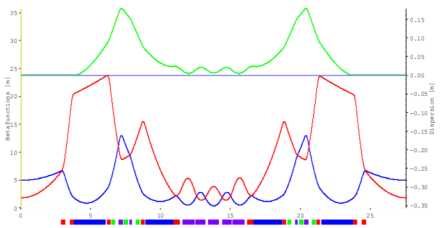


Plan for USR R&D (from USR study group)

2017		2018				2019	
3	4	1	2	3	4	1	2

- Study
- Draft lattice
- New concept in lattice
- Lattice finalization
- Study for MBA machine
- Machine design
- Final lattice 3D drawing & Spec. of machine
- Advanced concept

APS-U Type (550 m)



SLS-II Type (280 m)