SPring-8 Upgrade Project

RIKEN SPring-8 Center
Diffraction Limited SR Source Design Group
Hitoshi Tanaka

Outline

1. Target
2. Critical Conditions
3. Time Schedule
4. Ring Design Strategy
5. Design Progress
6. Summary

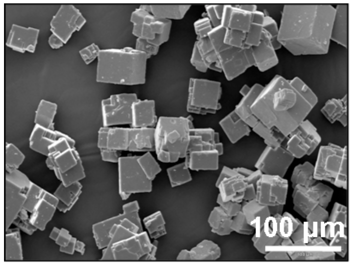

SACLA has taken off smoothly and
entered steady operation
SPring-8 upgrade is a next target
for accelerator troops

More direct observation providing new information

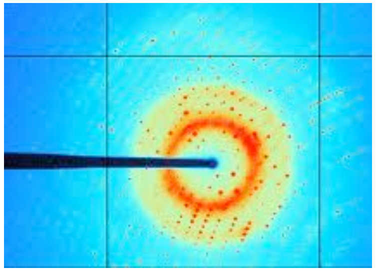
Key word: Coherence utilization

Research Target

Sample Production



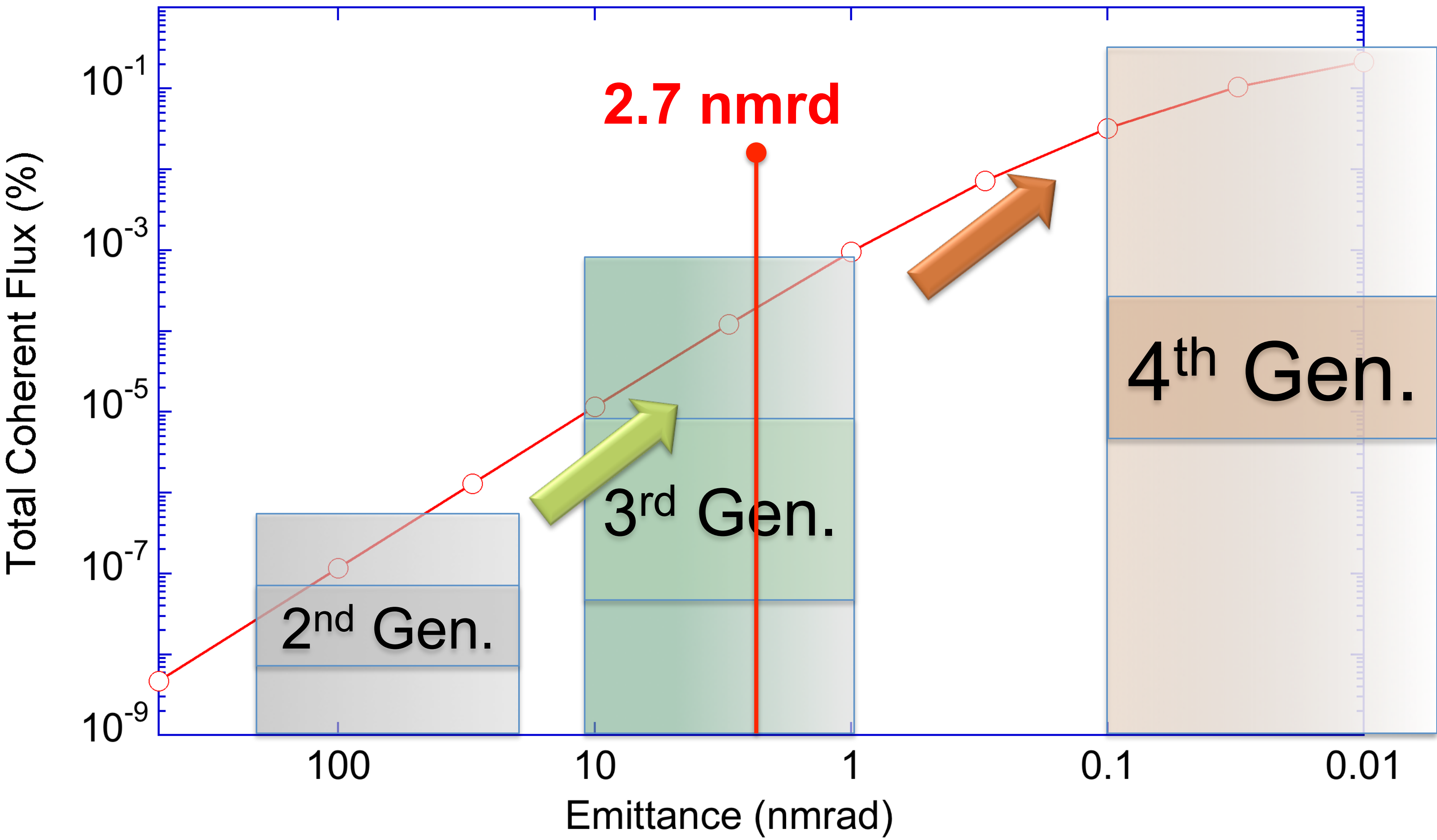
Data Acquisition



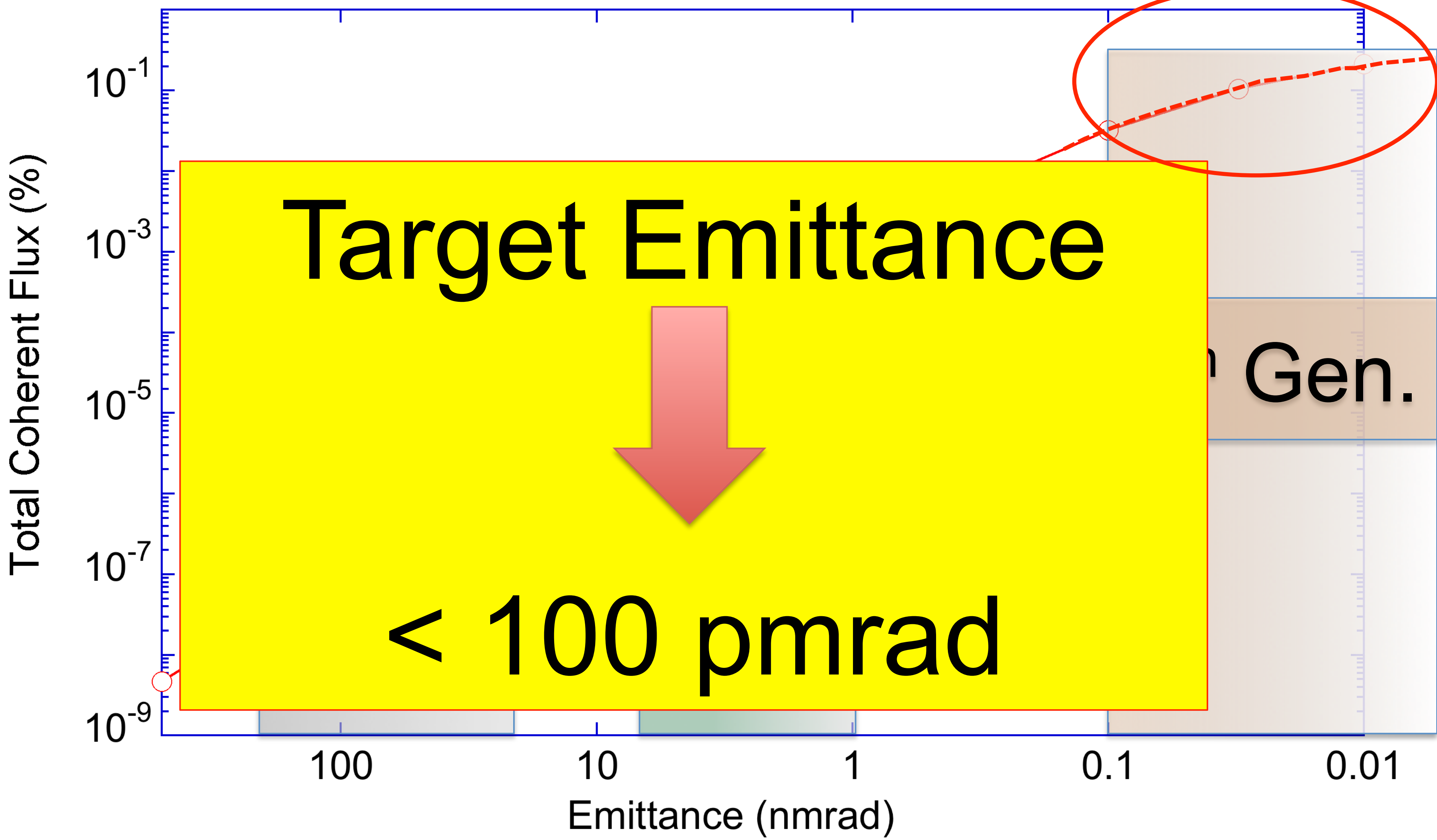
Simulation & Analysis

K computer

Natural Emittance Required



Natural Emittance Required



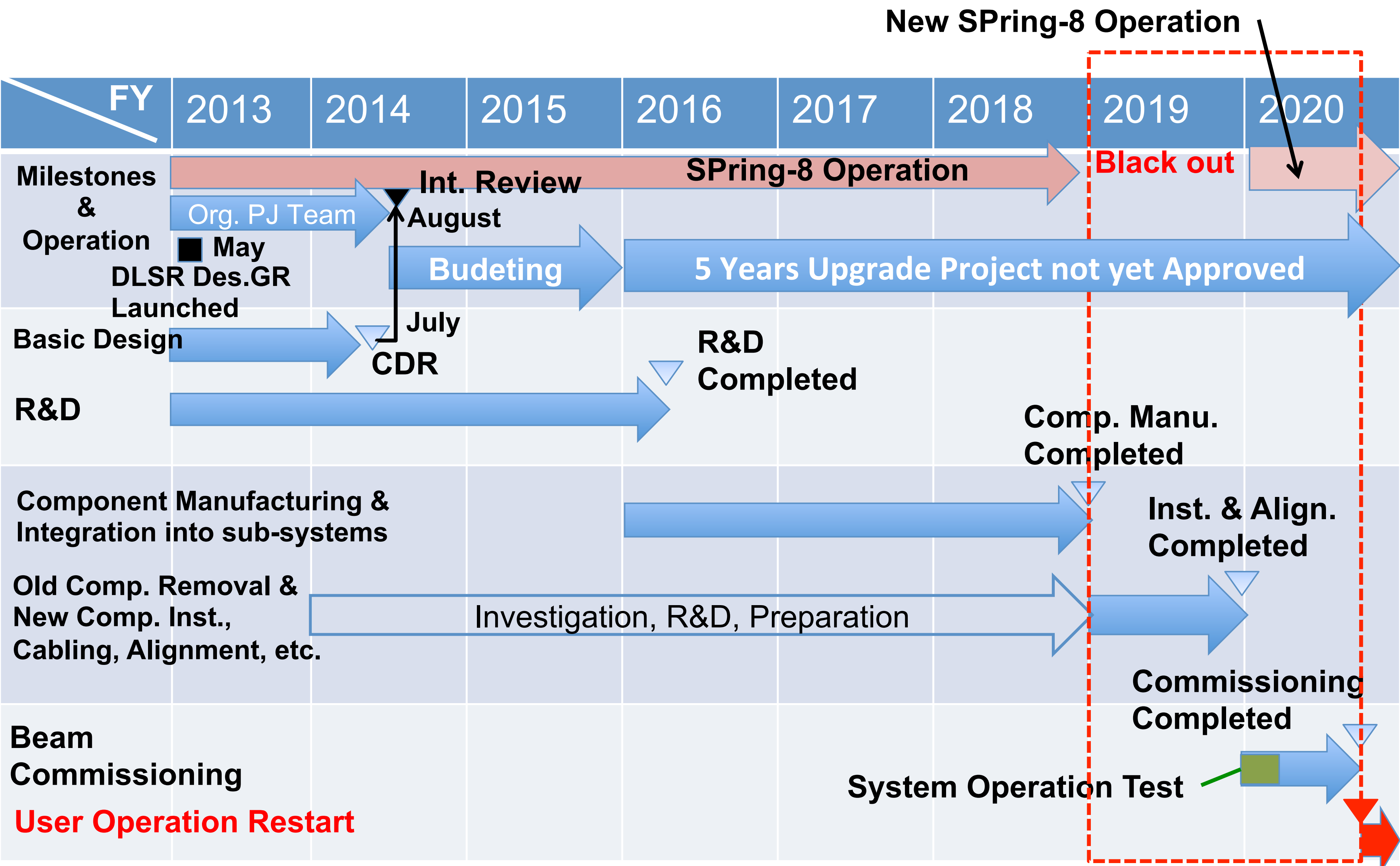
Target Emittance

< 100 pmrad

1. Target
2. Critical Conditions
3. Time Schedule
4. Ring Design Strategy
5. Design Progress
6. Summary

- Short black-out period
    - About 1 year for the removal and installation
    - Same ring injection point
- Keeping existing undulator beamline axes
    - Same unit cell length
    - Same structure with 4 straight cells + 44 normal cells
- Saving electric power and material
    - Using SACLA as the injector
    - Smaller beam chamber aperture

1. Target
2. Critical Conditions
3. Time Schedule
4. Ring Design Strategy
5. Design Progress
6. Summary



Less than 2 years from the shutdown to the restart of the user operation

1. Target
2. Critical Conditions
3. Time Schedule
4. **Ring Design Strategy**
5. Design Progress
6. Summary

Our approach to a lower emittance ring with sufficient beam stability comprises of

(1) nonlinearity suppression by using a relatively larger energy-dispersion arc and interleaved (phase-matched) sextupole pairs

(2) emittance reduction by combining several reduction schemes

Equation of natural emittance:

$$\varepsilon_{nat} = C_q \frac{\gamma^2 \langle H/\rho^3 \rangle}{J_x \langle 1/\rho^2 \rangle} \propto \frac{\gamma^2 \theta^3}{J_x}$$

- γ : Lorentz factor
- θ : Bending angle
- ρ : Bending radius
- H : H-function
- J_x : Damping partition number

Conventional reduction scheme:

1. Reduction of bending angle (θ) by increasing the number of bending magnets

Additional reduction schemes:

2. Reduction of stored energy (γ) with the help of advanced undulator design
3. Optimization of dipole field (ρ) in a dipole and / or inside unit cell)
4. Damping enhancement ($\langle H/\rho^3 \rangle / \langle 1/\rho^2 \rangle$) by additional radiation
5. Damping partition number (J_x) control

Emittance Reduction Budget

* Reference emittance here is 7 nmrad

No	Reduction Scheme	Dependence	Value (Old→New)	Reduction* Gain
1	Bend angle reduction	θ^3	2BA → 4BA	8.0 ~ 27.0
2	Beam energy reduction	γ^2	8 GeV → 6 GeV	1.8
3	Dipole field optimization	$<H / \rho^3> / <1 / \rho^2>$		~2.0
4	Damping enhancement	$<H / \rho^3> / <1 / \rho^2>$		1.4
5	Damping partition number control	$1 / J_x$	$J_x = 1 \rightarrow J_x = 2$	2
	Total			*90 ~ 30 pm.rad* 81 ~ 270

1. Target
2. Critical Conditions
3. Time Schedule
4. Ring Design Strategy
5. Design Progress
6. Summary

Ring Design Parameter (Preliminary)

	New Optics w scheme 1 to 3	Present Optics
Energy	**6 GeV**	**8 GeV**
Circumference	**1436 m**	**1436 m**
Unit cell structure	**Quad Bend**	**Double Bend**
Ring structure	**2 Injection Cells + 42 Unit Cells + 4 Straight Cells**	**44 Unit Cells + 4 Straight Cells**
Natural emittance with scheme 1 to 3	**0.278 nmrad**	**2.8 nmrad (NA)** **6.7 nmrad (Achro)**
β function@ID (β_x, β_y)	**(3.1, 1.2)**	**(31.2, 5.0)**
Tune (ν_x, ν_y)	**(118.83, 47.72)**	**(41.14, 19.35)**
Natural chromaticity (ξ_x, ξ_y)	**(-292, -225)**	**(-117, -47)**
Momentum compaction α_0	**2.45×10^{-5}**	**1.59×10^{-4}**

Emittance Reduction Budget

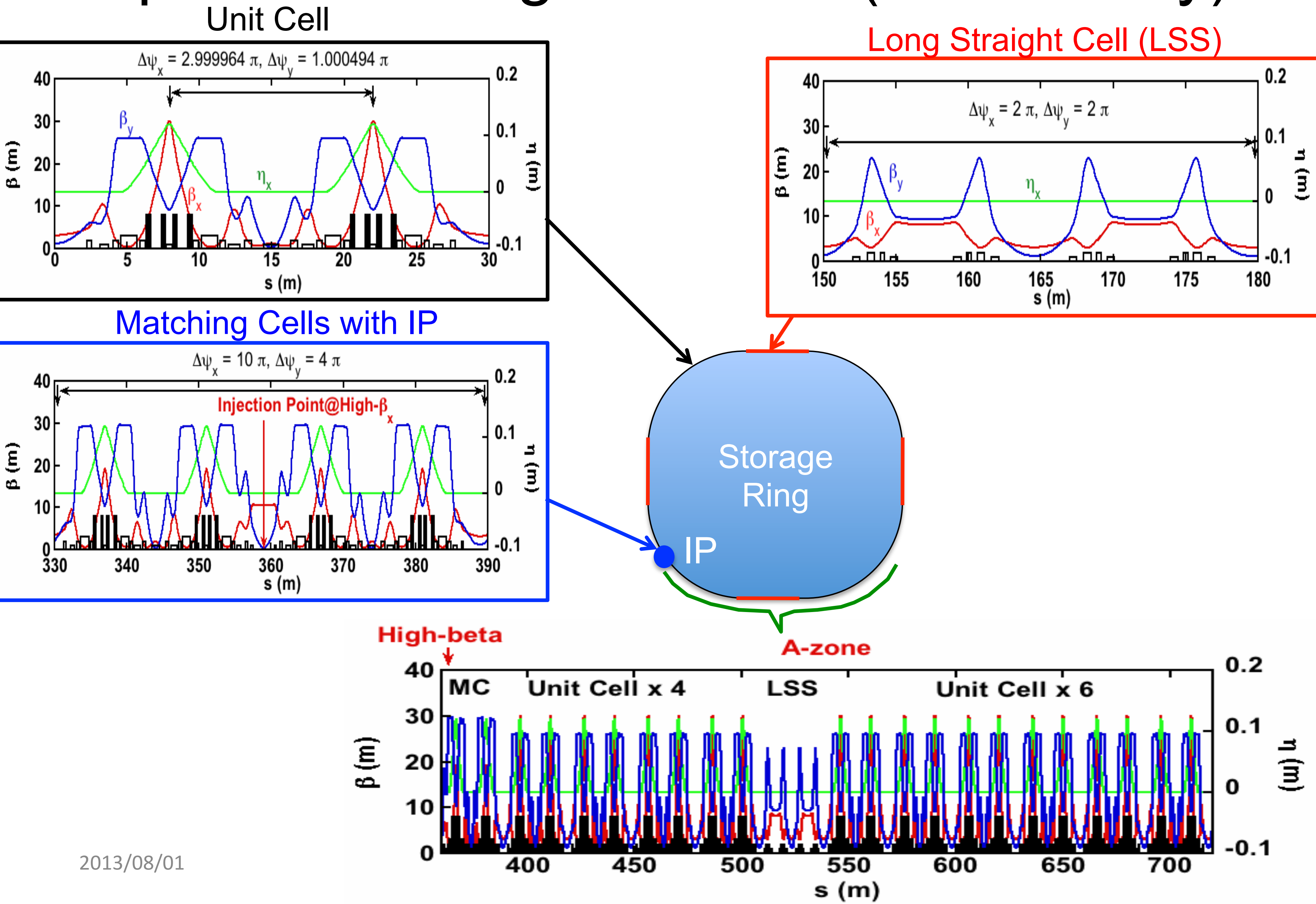
* Reference emittance here is 7 nmrad

No	Reduction Scheme	Dependence	Value (Old→New)	Reduction* Gain
1	Bend angle reduction	θ^3	2BA → 4BA	8.0 ~ 27.0
2	Beam energy reduction	γ^2	8 GeV → 6 GeV	1.8
3	Dipole field optimization	$<H / \rho^3> / <1 / \rho^2>$		~2.0
4	Damping enhancement	$<H / \rho^3> / <1 / \rho^2>$		1.4
5	Damping partition number control	$1 / J_x$	$J_x = 1 \rightarrow J_x = 2$	2
	Total			90 ~ 30 pm.rad 81 ~ 270

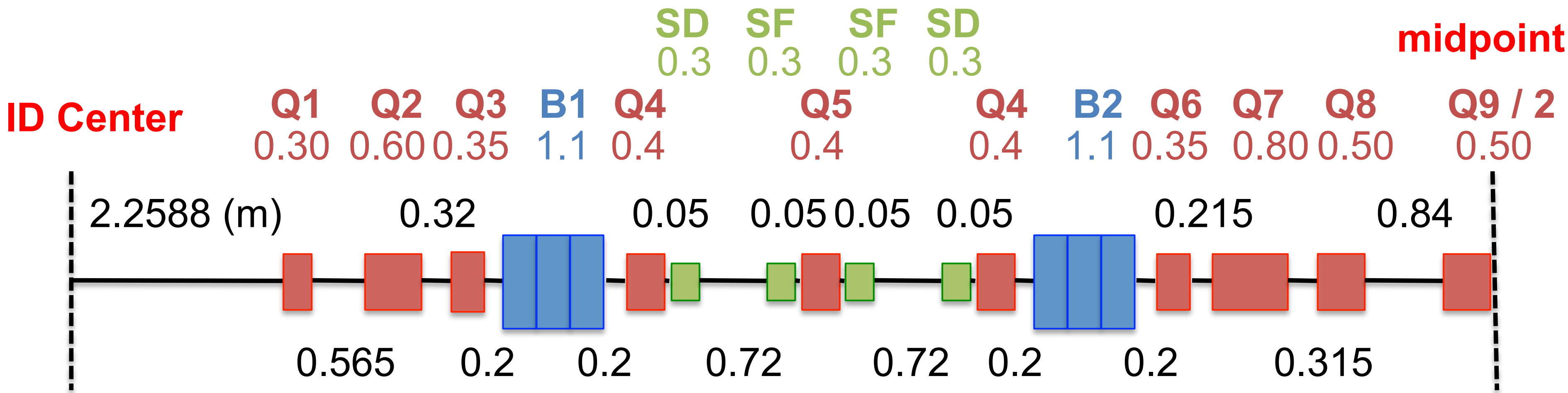
Ring Design Parameter (Preliminary)

	New Optics w scheme 1 to 3	Present Optics
Energy	6 GeV	8 GeV
Circumference	1436 m	1436 m
Unit cell structure	Quad Bend	Double Bend
Ring structure	2 Injection Cells + 42 Unit Cells + 4 Straight Cells	44 Unit Cells + 4 Straight Cells
Natural emittance with scheme 1 to 3	0.278 nmrad	2.8 nmrad (NA) 6.7 nmrad (Achro)
β function@ID (β_x, β_y)	(3.1, 1.2)	(31.2, 5.0)
Tune (ν_x, ν_y)	(118.83, 47.72)	(41.14, 19.35)
Natural chromaticity (ξ_x, ξ_y)	(-292, -225)	(-117, -47)
Momentum compaction α_0	2.45×10^{-5}	1.59×10^{-4}

Optics and Ring Structure (Preliminary)



Magnet Strength & Spacing (Preliminary)



Maximum Magnet Strength

Max. B	1.55 T
Max. Q	56 T / m
Max. Sx	1700 T / m^2
Max. Oct	under opt.

Magnet Bore Radius /

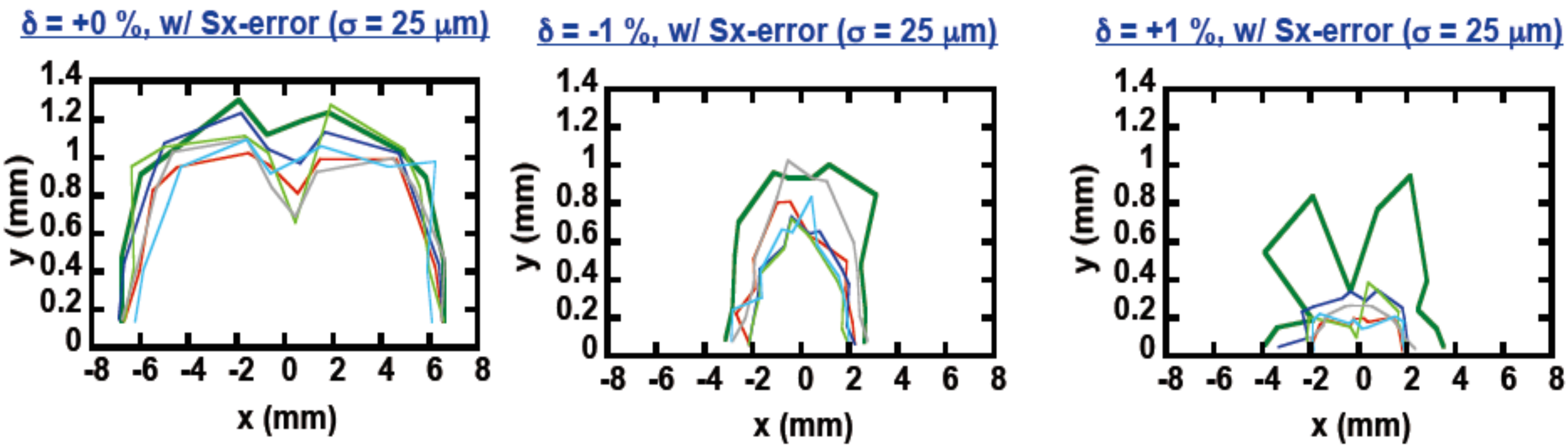
B	25 mm
Q & Sx	17 mm

Chamber Aperture (inside)

B	17(h) mm
Q & Sx	30(w)x16(h) mm

Dynamic Apertures (Preliminary)

- Full ring structure with 4 LSSs and MC providing IP
- DA @ Injection Point with (β_x,β_y)=(10.5m, 0.5m)
- Amplitude dependent tune-shift correction by Octapoles



Note: Hori. DA for beam injection is estimated to be 2 mm and DA (δ=0) corresponds to ~12 mm at present optics having β_x of 31.2 m at IP

Further Emittance Reduction

Damping partition number (*J_x*) control, which can be done with (1) static magnetic fields and (2) RF electro-magnetic fields

We are now investigating which scheme is the best for our ring upgrade

Scheme	Merit	Demerit
Magnet basis: Combined Bend	• High space factor • Decreasing QM number • Decreasing chromaticity	• J_i unchangeable • Alignment difficulty • Instability under large COD
RF EM Basis: Coupling Cavity	• J_i changeable • good matching with interleaved scheme • addable • High J_x attainable	• New & not established • RF sources required

Summary

- About 280 pmrad optics was designed with realistic component specifications and sufficient beam stability
- Towards below 100 pmrad, elaborate investigation has been continued
- Accelerator basic design will be completed in the next summer