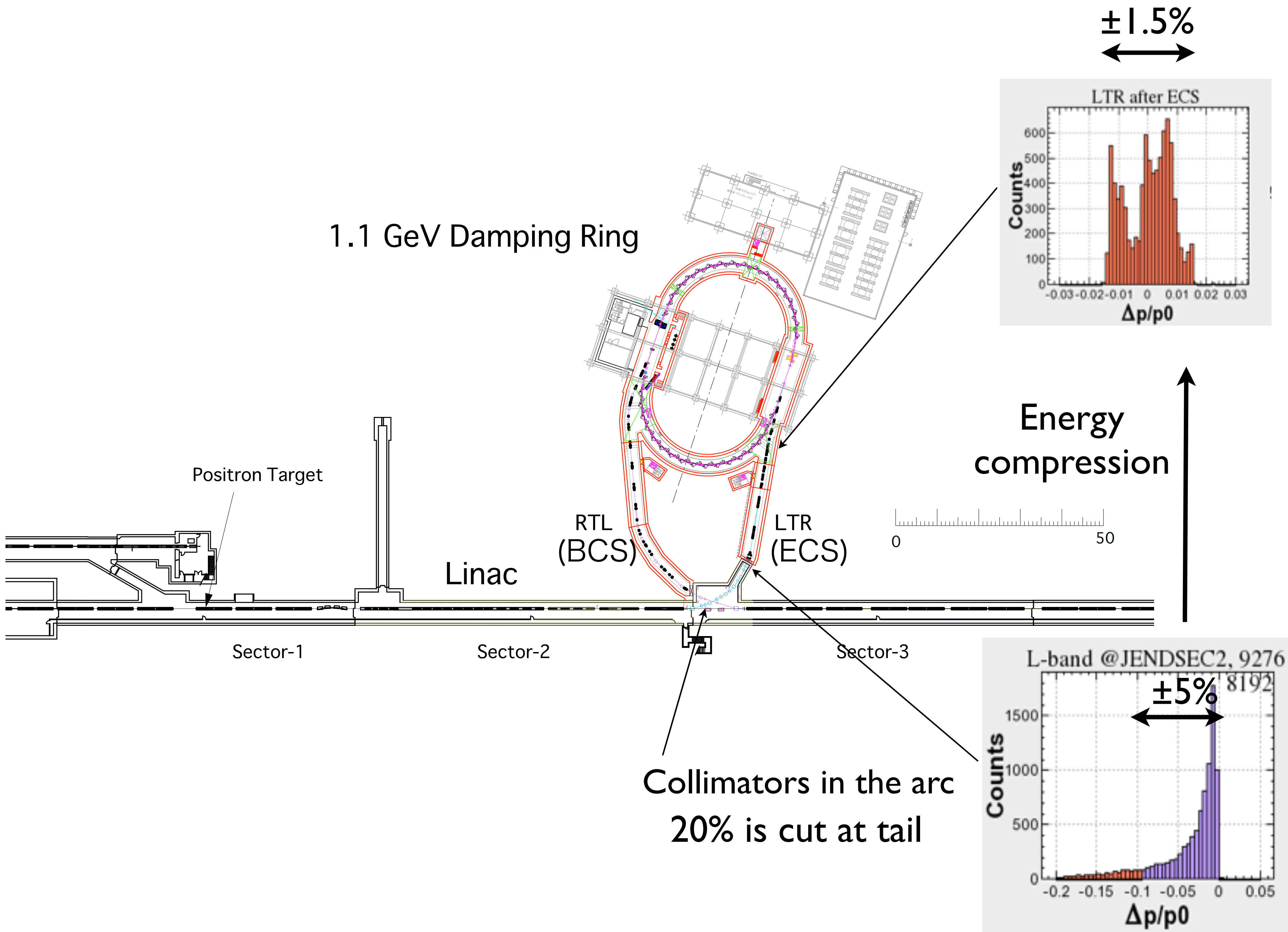
DR Status

Kikuchi, M.,

for the 21st KEKB Accelerator Review Committee,

14 June, 2016.

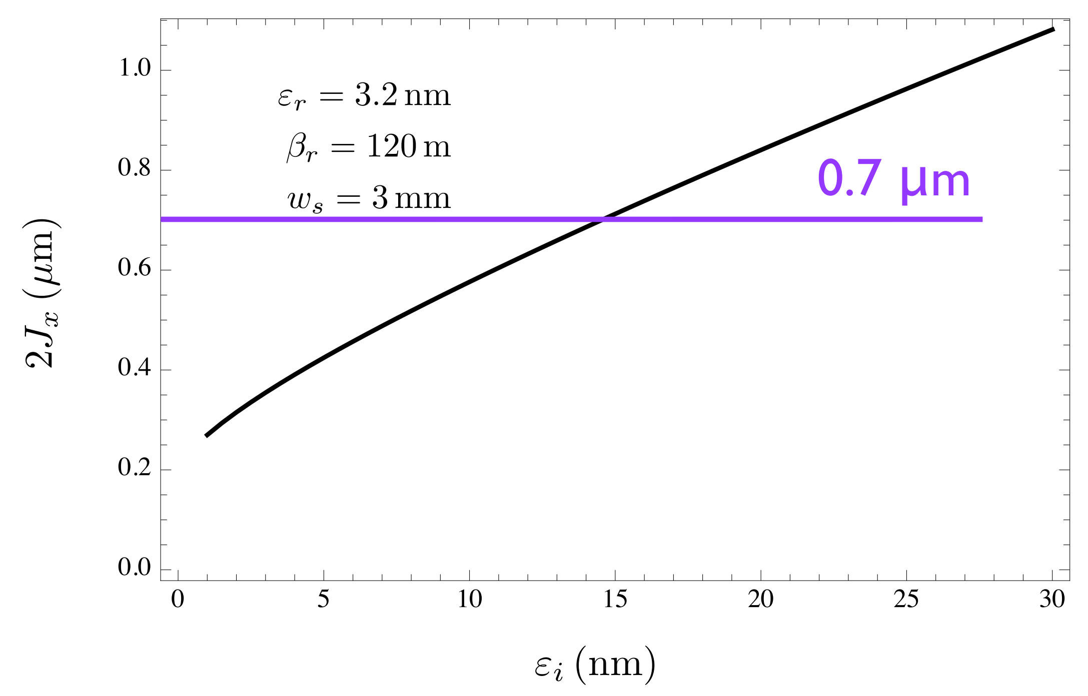
1. System layout



2. Brief summary of the lattice design

- Coherent oscillation amplitude(2Jx) is dominated by the septum width.
- Maximum coherent oscillation
  - must be less than the dynamic aperture of the LER:
    - 700 nm
- Emittance of injected beam should be less than 14.5 nm.

- Taking into account of acceleration to 4 GeV, the emittance of the DR should be < 53 nm.



Coherent oscillation amplitude vs. emittance of injected beam

- Emittance of ~50 nm is easy to achieve in ordinary rings.
  - Relatively high emittance is a unique feature of the DR for a circular collider.

- Damping time is a big issue.

Damping time and the lattice

$$\boxed{\varepsilon_{ext} = \varepsilon_0 + (\varepsilon_i - \varepsilon_0)e^{-2T/\tau}}$$

ε_{ext} : emittance at extraction

ε_i : emittance at injection

ε_0 : emittance of DR

T : store time

To satisfy $\varepsilon_{ext}/\varepsilon_0 < 1.05$

$\tau < 12.8 \text{ ms}$ ($\varepsilon_i = 1400 \text{ nm} \quad T = 40 \text{ ms}$)

$$\boxed{\tau^{-1} = \frac{r_e}{3T_0}\gamma^3 I_2}$$

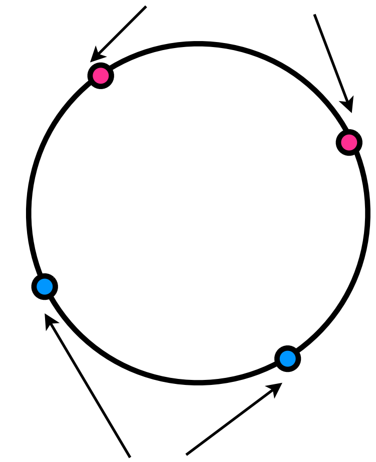
$$I_2 = \oint \frac{1}{\rho^2} ds = \oint \frac{d|\theta|}{|\rho|} = \frac{\Theta}{|\rho|}$$

Θ : total bend angle

T_0 : revolution time

For fixed T_0, $\tau^{-1} \propto \frac{\Theta}{|\rho|}$

Damping time and the lattice (2)



- T_0 > kicker rise/fall time + 2(bunch-separation) = 400 ns
  - We have chosen as T_0 = 450 ns.

- For ordinary FODO lattice, $\Theta = 2\pi \qquad I_2 = 2\pi/\rho$

$$\tau = 12.8 \text{ ms} \longrightarrow \rho = 1.67 \text{ m} \qquad B = 2.2 \text{ T}$$

- We need a large-aperture bend to accommodate a large emittance of the injected beam. Bend field is desirable to be less than, say, 1.5 T.

- A novel 'Reverse-bend FODO' lattice was adopted.

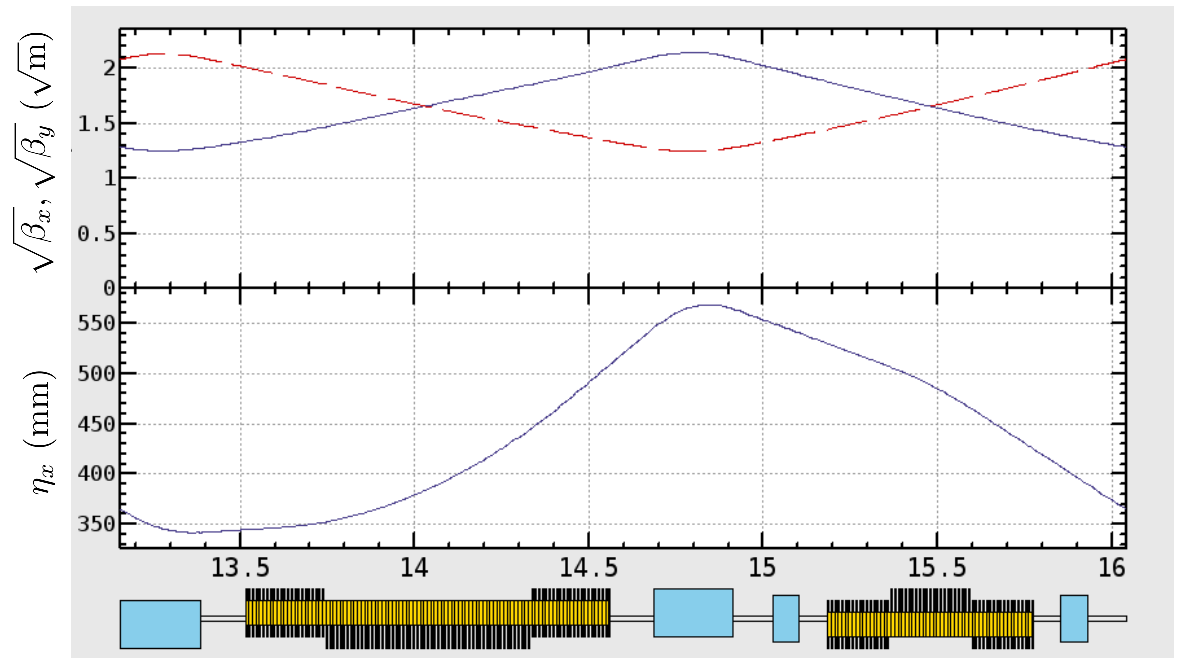
$$B_1 : \ \theta > 0 \qquad B_2 : \ -r\theta < 0 \qquad \Theta = \frac{1+|r|}{1-r} 2\pi$$

- Total bend angle can be increased by a factor of $(1+|r|)/(1-r)$.

$$r = 0.35 \longrightarrow B = 1.06 \text{ T}$$

Cost: Number of cells $\dfrac{N(\mathrm{RFODO})}{N(\mathrm{FODO})} = \dfrac{1+|r|}{1-r}$

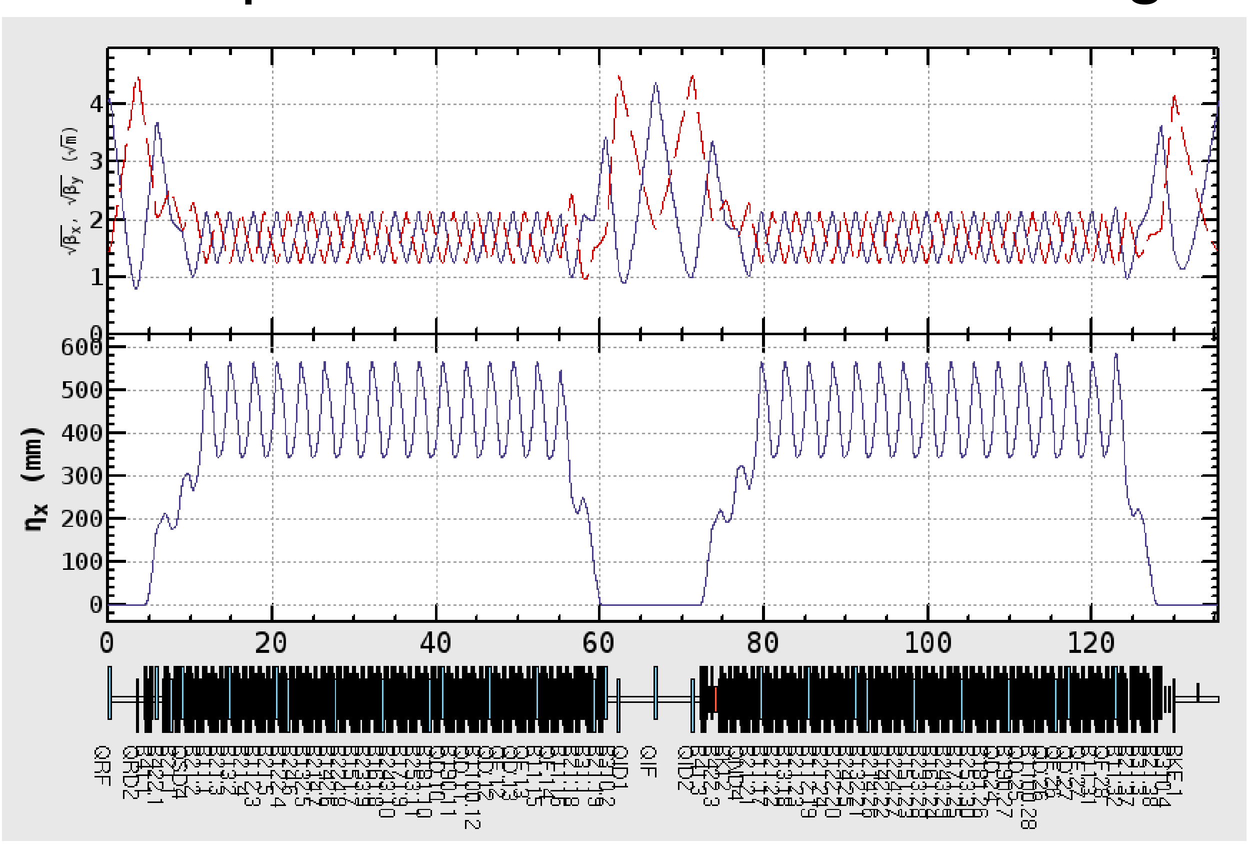
Optical functions of a single cell



QD B1 QF SF B2 SD

$\theta > 0$ $-r\theta < 0$

Optical functions of the entire ring



- High dispersion at B2 generates the emittance, but it is still less than 50 nm.

Parameters of the DR

Table 3: Parameters of the Damping Ring

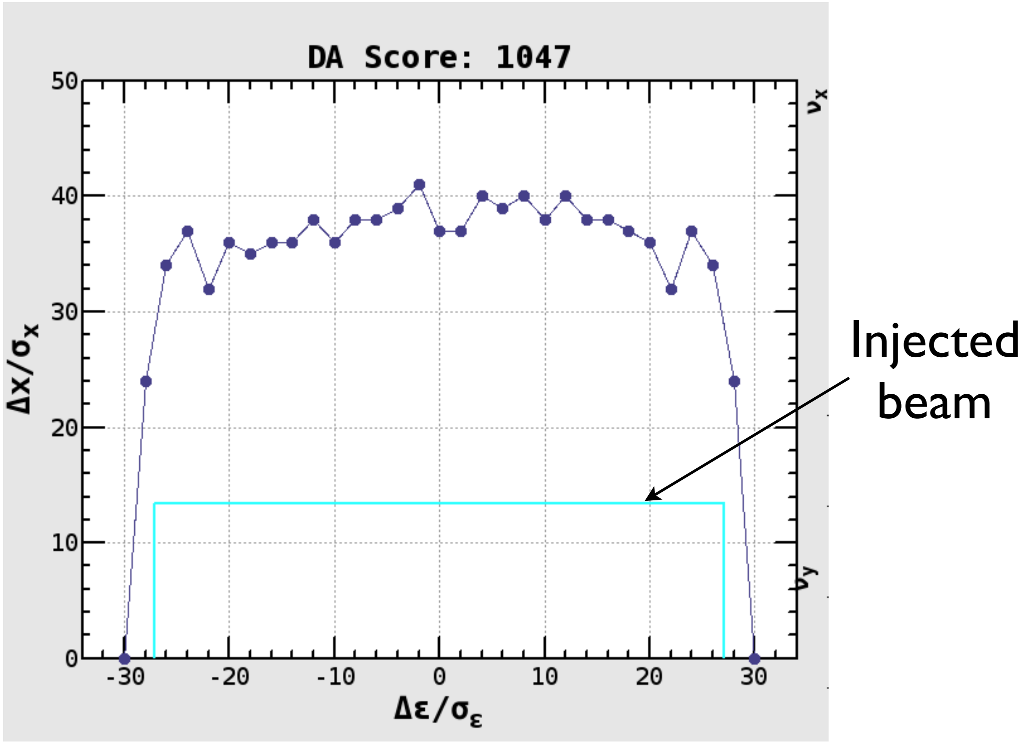
Energy		1.1		GeV
Number of bunch trains		2		
Number of bunches / train		2		
Circumference		135.498295		m
Maximum stored current		70.8		mA
Energy loss per turn		0.0847		MV
Horizontal damping time		11.57		ms
Injected-beam emittance		1400		nm
Equilibrium emittance (h/v)		41.5 / 2.08		nm
Coupling		5		%
Emittance at extraction (h/v)		42.9 / 3.61		nm
Cavity voltage	0.5	1.0	1.4	MV
Bucket height	0.81	1.24	1.5	%
Energy spread		5.5×10^{-4}		
Synchrotron tune	0.0152	0.0217	0.0257	
Equilibrium bunch-length	11.07	7.79	6.58	mm
Phase advance/cell (h/v)		64.39 / 64.64		deg
Momentum compaction factor		0.0142		
Bend-angle ratio		0.35		
Bend radius		2.7		m
Number of normal-cells		40		
RF frequency		509		MHz
Chamber size(normal cell)		$34^H \times 24^V$ w/ antechamber		mm

Dynamic Aperture

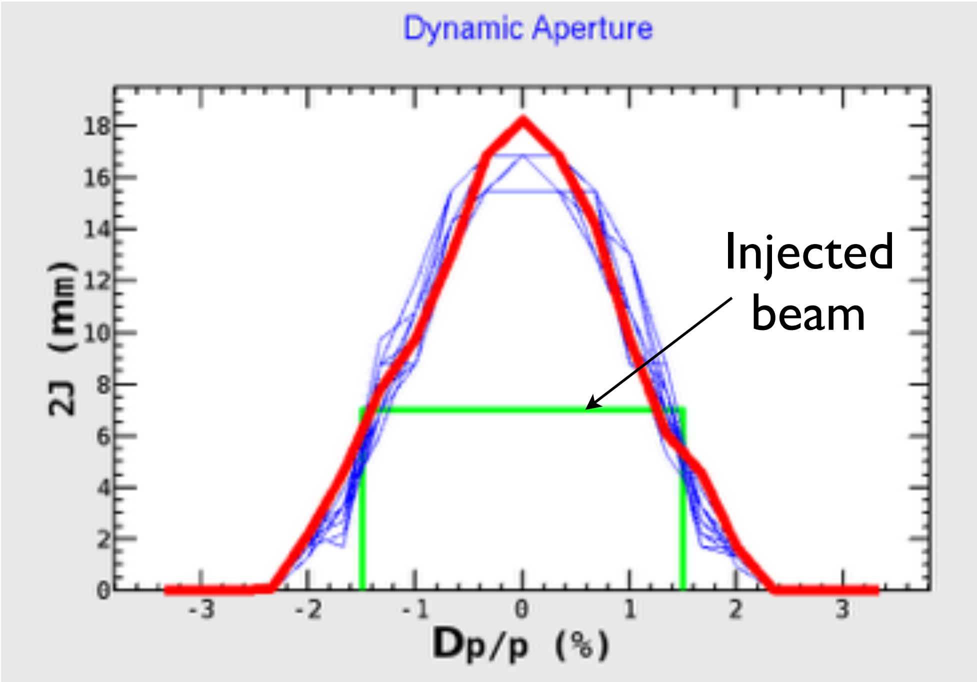
H.Sugimoto

ARC 2011

- Dynamic aperture is large enough to accept the Linac beam.



(with new model for Bend)



(with old, WRONG model for Bend)

- Slice model
- 3D field is multipole-expanded to fulfill the Maxwell eq.
- Fringe field is correctly taken into account.

- Slice model
- Integrated field in each slice is Taylor-expanded to yield multipoles

Microwave Instability due to CSR

Tracking simulation, Oide's code

H.Ikeda, IPAC'13

(c)

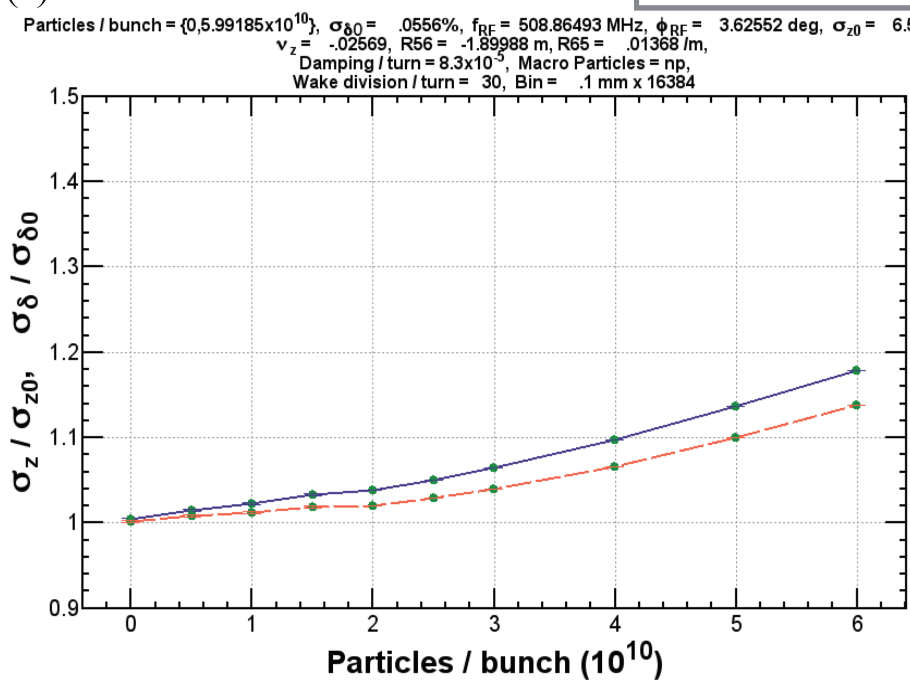


Figure 5: Energy spread and the bunch length as a function of the bunch intensity by tracking simulation with linac beam for different number of kick per turn. (a) single kick, (b) 5 kicks and (c) 30 kicks/turn. The red (blue) line shows the energy spread (bunch length).

Nth ~ 2e10

Vlasov-Fokker-Planck solver

L.Wang, IPAC'13

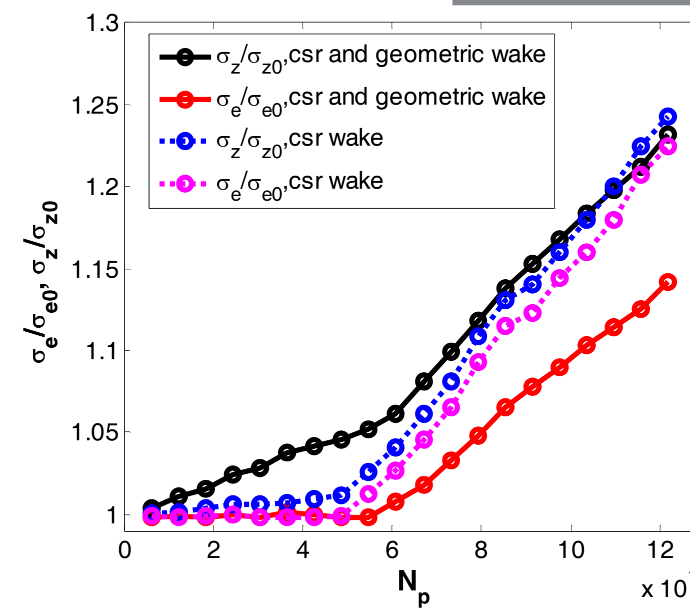


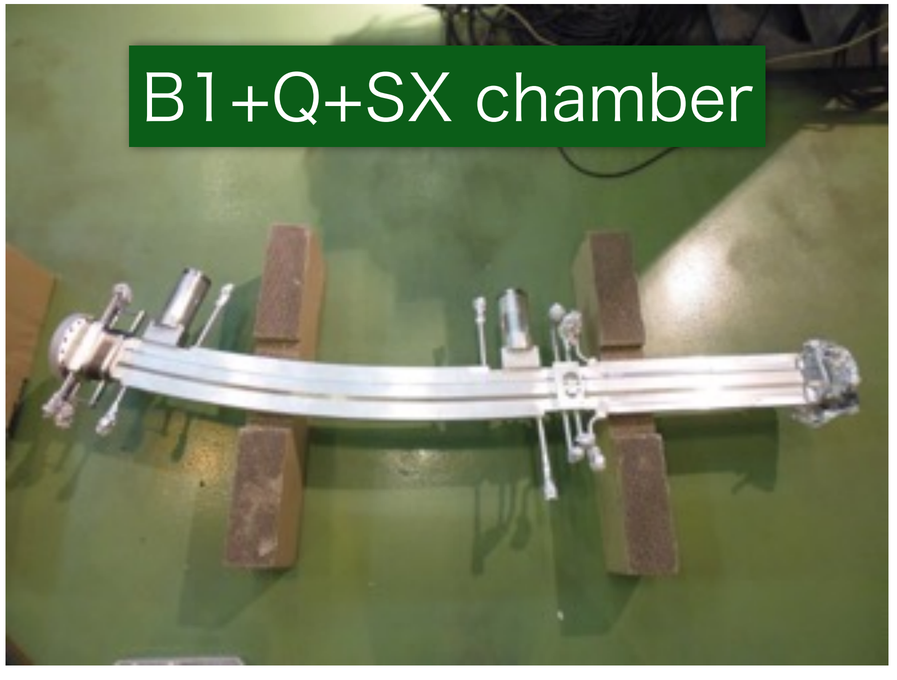
Figure 3: Bunch length and energy spread at different bunch intensity with various types of wake, The numerical parameters used are: **qmax**=8, **nn**=300, **ndt**=1024.

Nth ~ 5e10

- Threshold depends on the model, but the blow-up stays within 10%

3. Hardware status

- LTR / RTL beam line magnets: Installation completed
  - vac. chamber installation, beam instrumentation scheduled in 2016, 2017
- Ring Magnets
  - Installation completed
    - except for 6 steerings ,which is to be fabricated in FY2016
- Power supplies for the magnets
  - All installed, cabling completed. (except for steerings, to be delivered in 2017))
- Vacuum chamber
  - Chambers for the arc : installation underway.
  - Chambers for straights: ready to be installed

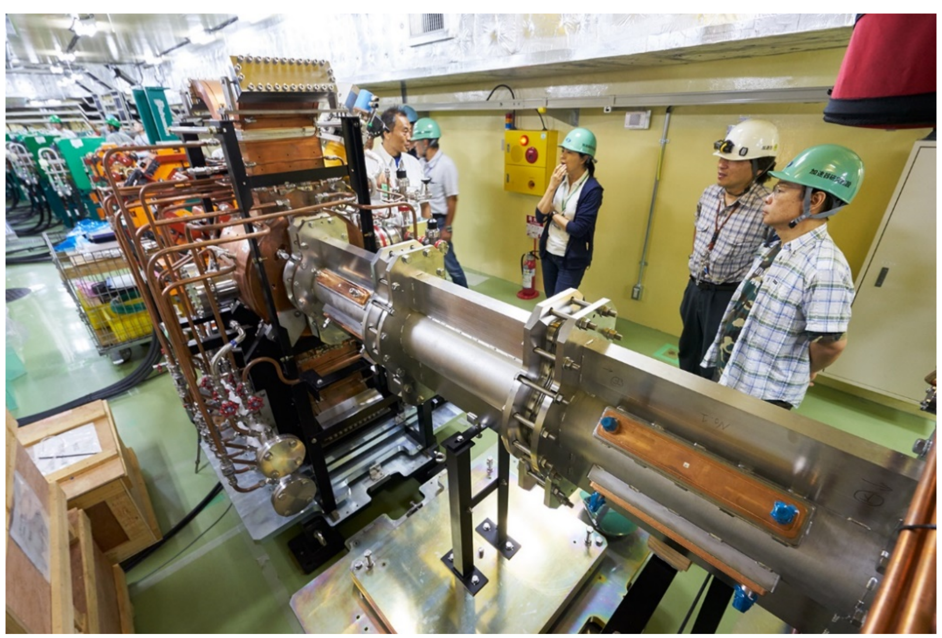


- Extruded aluminum
- w/ Antechamber
- w/ Grooved structure on top/ bottom surface to suppress the electron cloud
- w/ BPM chamber welded
- w/ Shielded bellows
- Water cooled

Hardware status (2)

- RF cavity development (reported in ARC15 and Abe's talk in this ARC)
  - Single cell cavity based on ARES
  - HOM absorber, newly designed
  - Operation of 0.8 MV/cavity was confirmed.
  - 0.95 MV/cavity recorded, limited by radiation
  - Two cavities have been fabricated

- Transported into the DR tunnel (June, 2016)
  - RF structure assembled in the tunnel for checks:



☑Space for waveguides, cable racks, cooling pipes, supports, etc.,
☑Cavity alignment method,
☑What's missing, and
☑Others.

Hardware status (3)

- Beam instrumentation

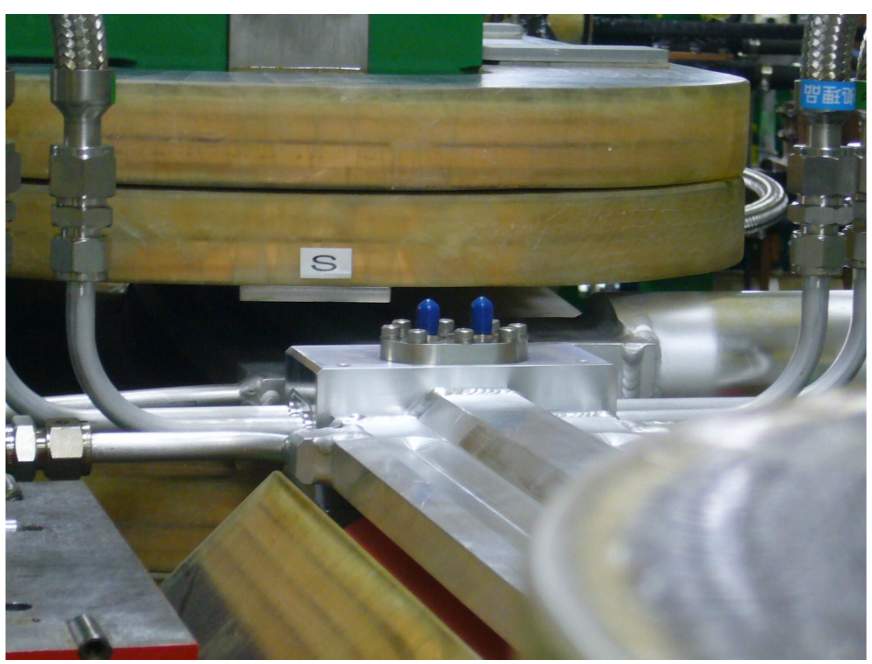
H.Ikeda

Completed:

- ☑ Fabrication of most of sensors, electronics and cables for BPM,FB,SRM,LM and DCCT
- ☑ Setting of racks for the monitors
- ☑ Cabling for BPMs between ground levels and the tunnel

Underway:

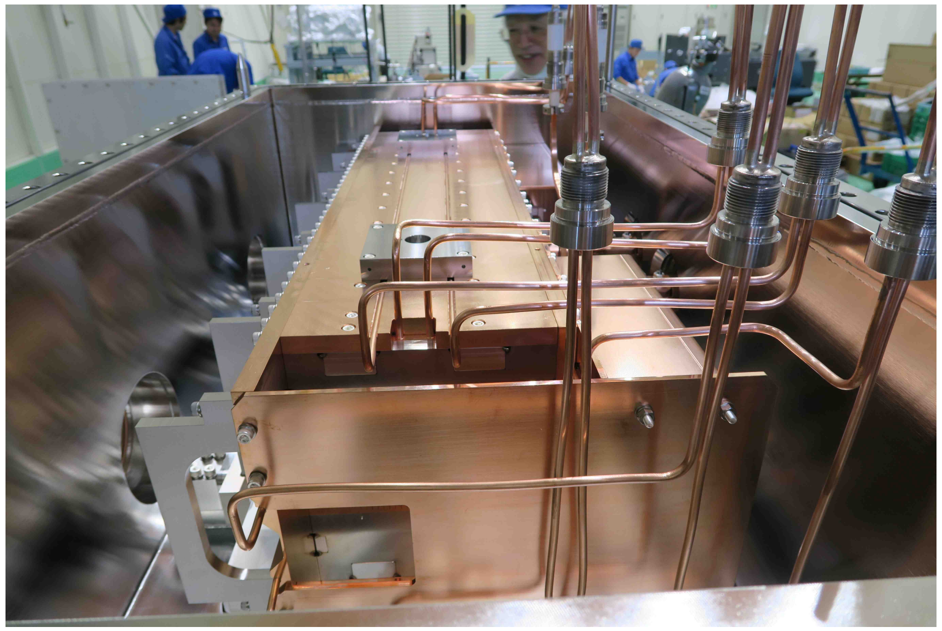
- Installation of BPM-support structure and vac. chambers
- Preparation of FB and DCCT support, SRM chamber



Hardware status (4)

Pulsed magnets

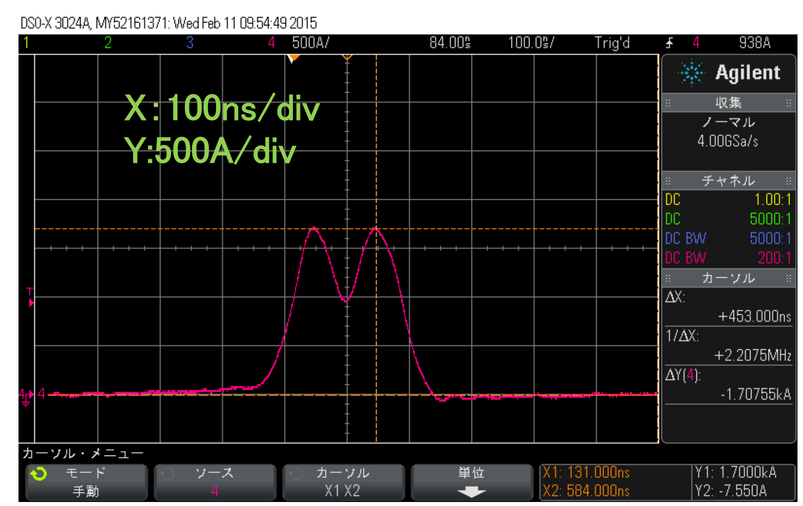
M. Tawada



Injection septum (In-vacuum)

Extraction septum (Out-vacuum)

Injection/extraction kicker



・Lumped type magnet with a saturable inductance switch

・Double half-sine pulse shape

Mile stones

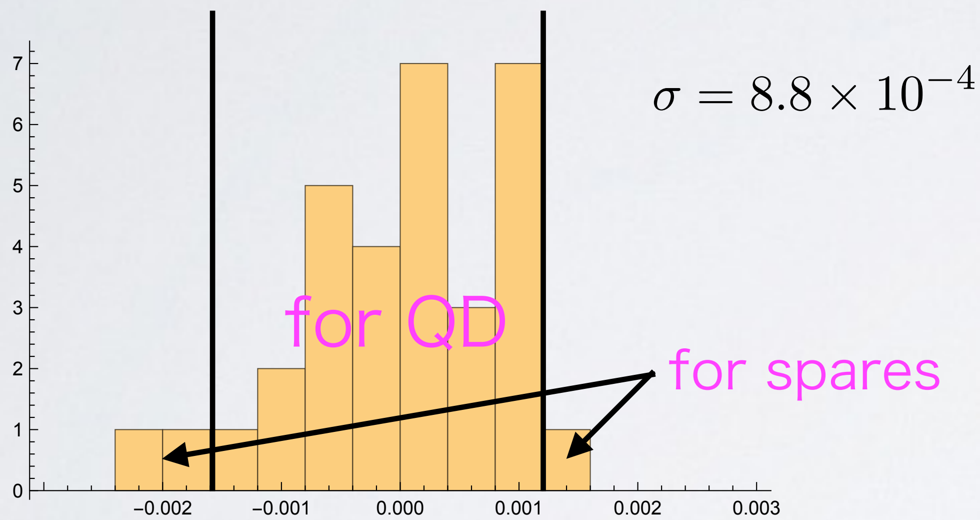
- ☑ 2012.12 Tunnel construction finished
- ☑ 2013.11 PS Building construction completed
- ☑ 2014.3 Conventional Facility (LCW and the electricity) constructed
- ☑ 2014.5~12 DR Construction phase-1 (Installation of power cables, etc)
- ☑ 2015.5~12 DR Construction phase-2 (Installation of magnets and BPM cables, etc)
- ☐ 2016.4~ DR Construction phase-3
  - Vac. chamber install
  - LCW piping to magnets
  - Magnet alignment first and second round
  - RF cavity install
  - etc.,

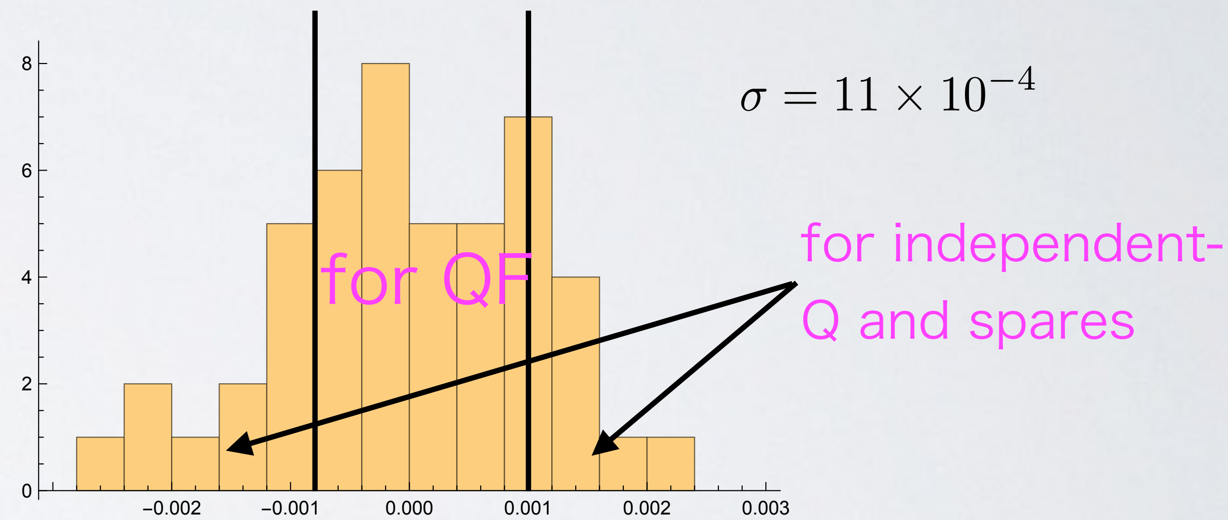
Field measurement and grouping

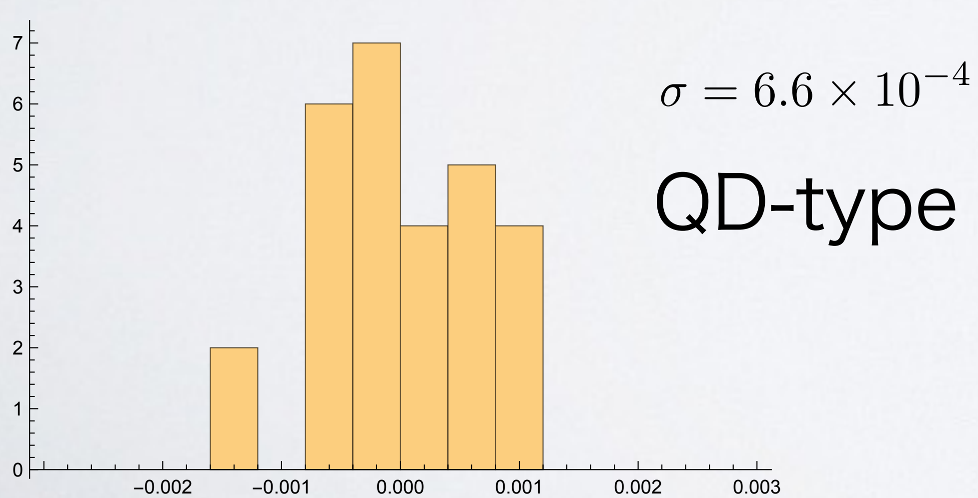
- Field measurement of quads

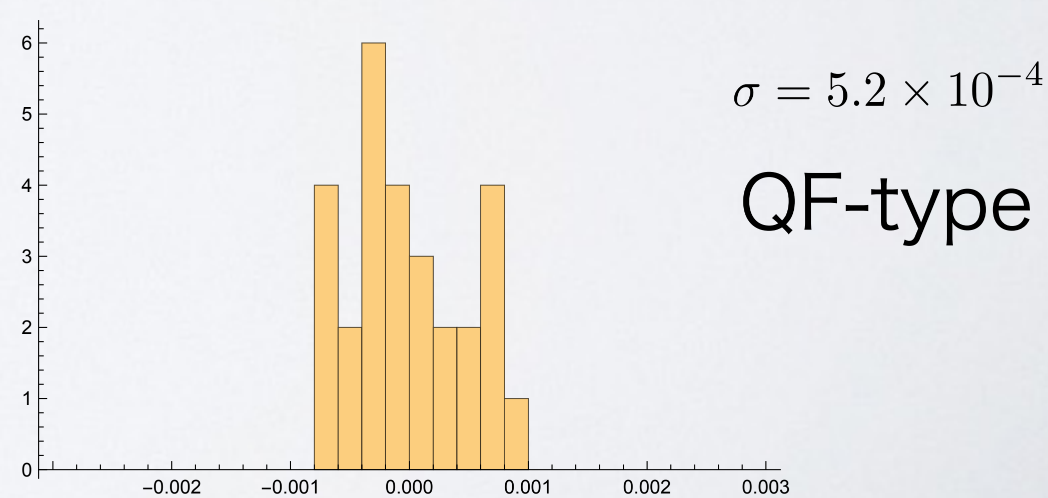
  By selection, rms=0.07% and 0.05% for the arc-QD and QF

  (Spec. rms < 0.1 %)







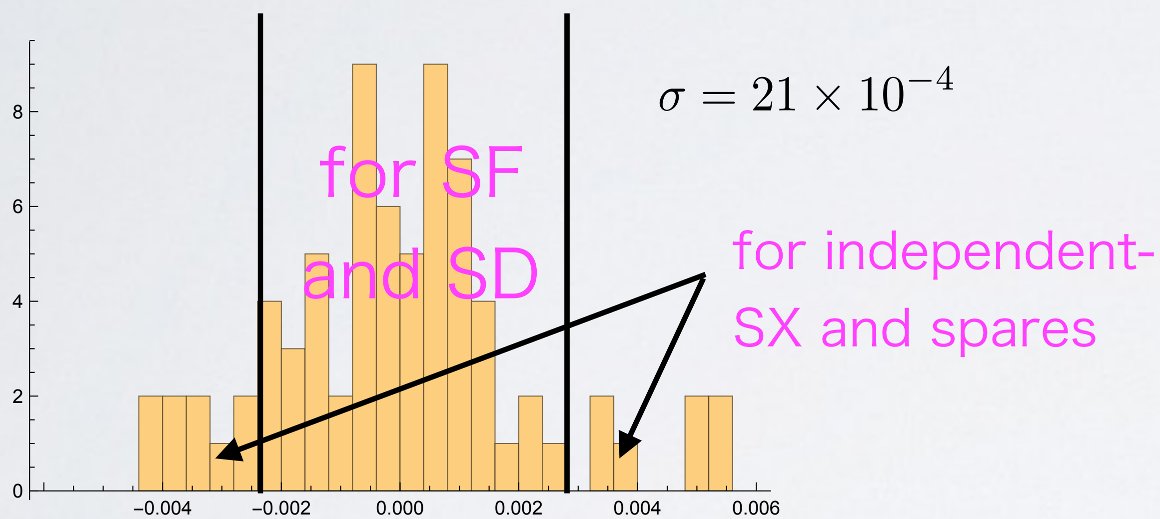


Field measurement and grouping (2)

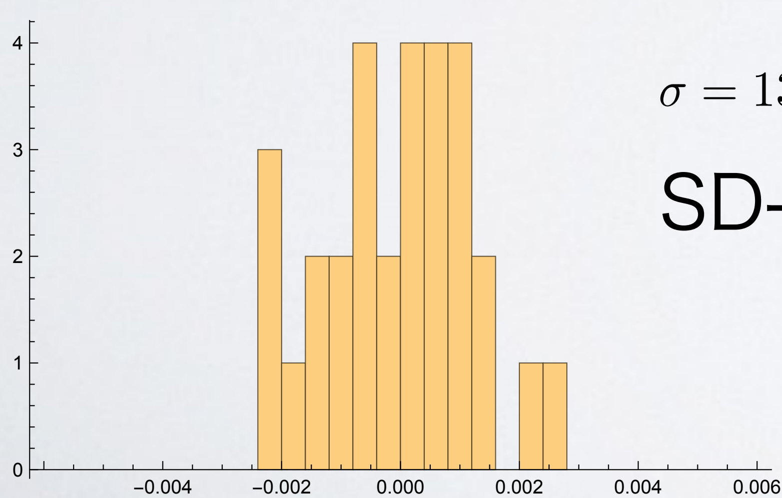
- Field measurement of sexts

By selection, rms=0.13% for the arc-SX and SF

(Spec. rms < 0.2 %)

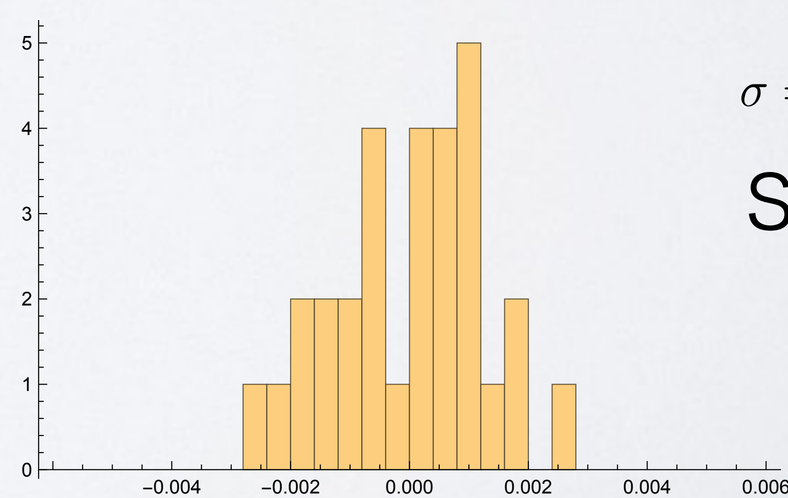


$\sigma = 21 \times 10^{-4}$



$\sigma = 13 \times 10^{-4}$

SD-type

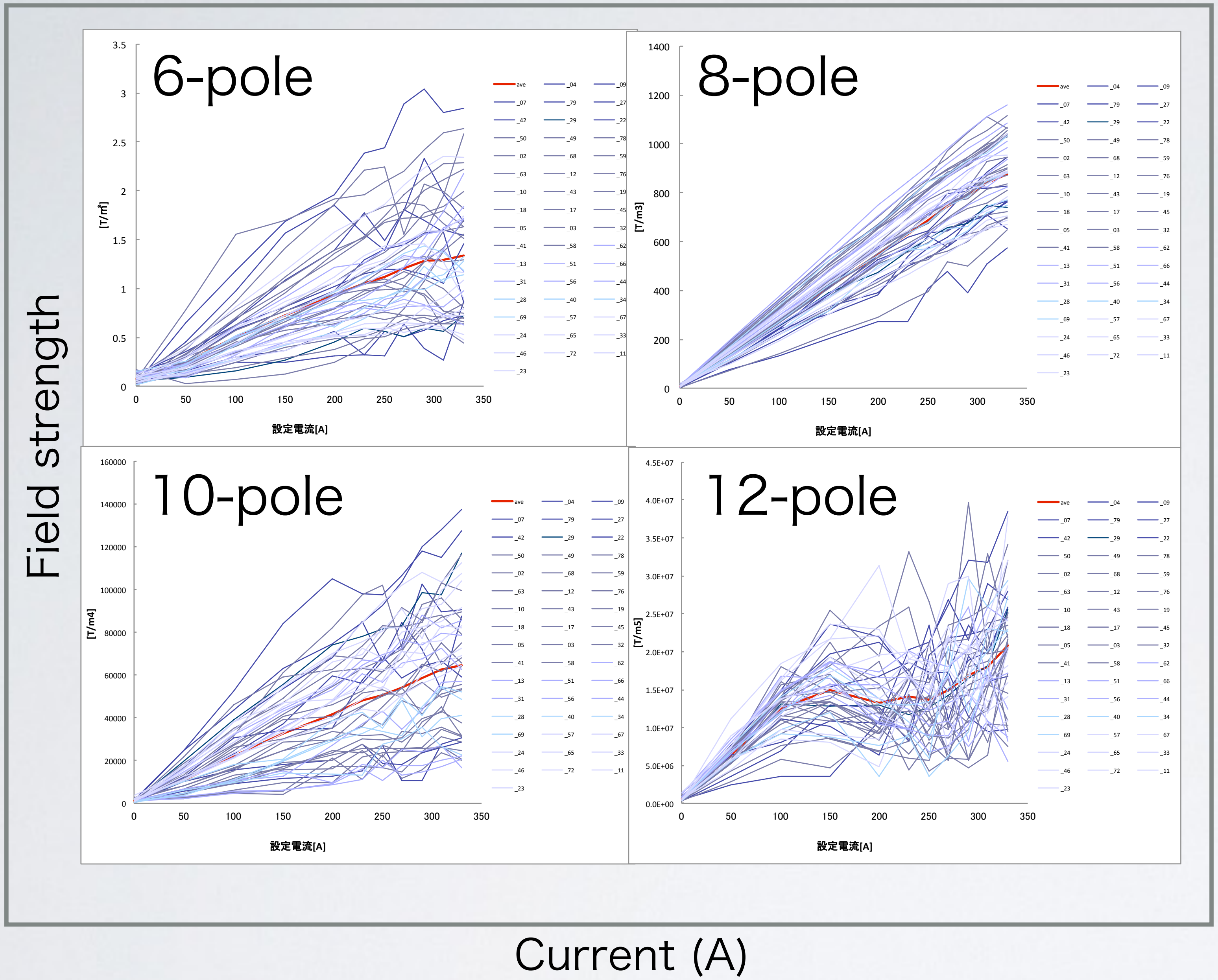


$\sigma = 13 \times 10^{-4}$

SF-type

• Multipole component of quads and sexts

Quadrupoles



Quadrupoles

Multipole n	Bn/B2 @ r= 12 mm	Spec	unit
3	3.0		10^{-4}
4	7.0		10^{-4}
5	1.6		10^{-4}
6	1.2	(3.7)	10^{-4}

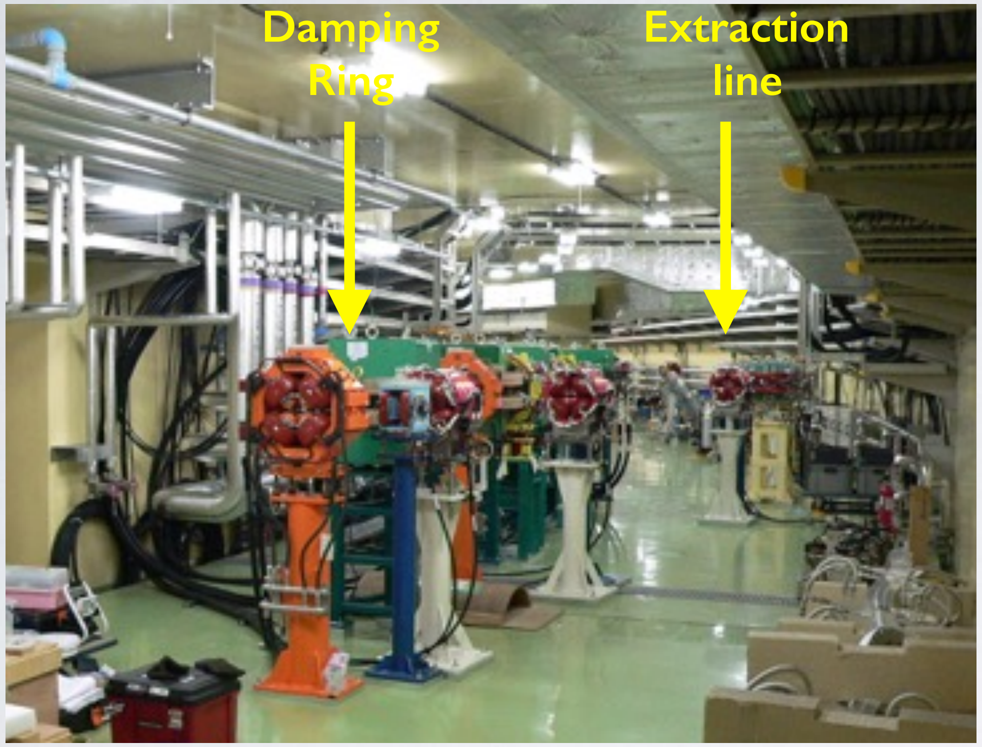
Sextuples

Multipole n	Bn/B3 @ r= 12 mm	Spec	unit
2	395 *)		10^{-4}
3	1		10^{-4}
4	10		10^{-4}
5	5.6		10^{-4}
6	7.1		10^{-4}
7	5.2		10^{-4}
8	4.9		10^{-4}
9	9.8	(8.7)	10^{-4}
10	5.0		10^{-4}

*) equals to 0.1 % of the arc quad

- Multipole spec. for Quad and Sext
  - determined from dynamic aperture
  - the number in () is based on the old model of bends.
  - should be examined using new optical model for bends.

4. Current status of the Damping Ring



DR and the extraction line

Installation of vac. chambers

Power supplies in the PS building

5. Construction plan