Beam Injection Scheme for SPring-8-II

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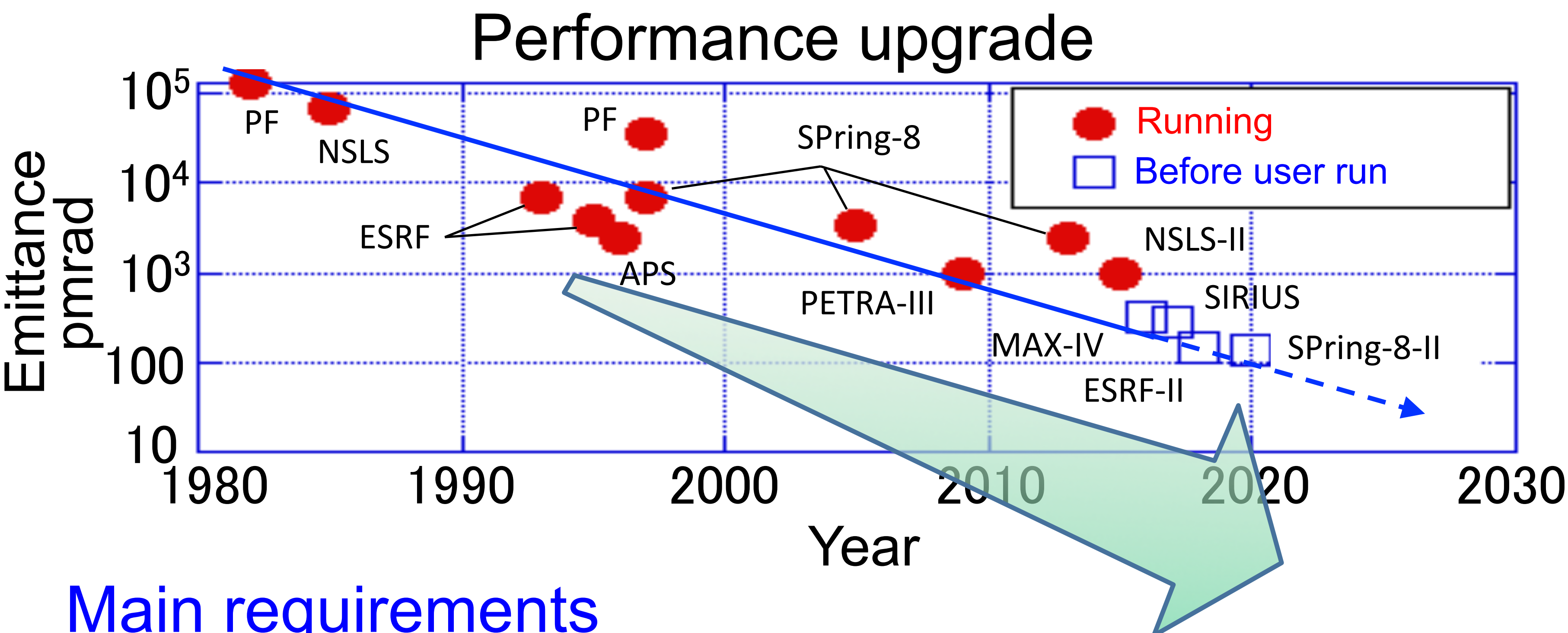
Outline

1. Introduction
2. Our approach
3. Optics design
4. Strategic component development
5. Time schedule
6. Summary

Trend and requirements



Main requirements

1) Smaller injection beam amplitude
2) Transparent beam injection
3) Topping up
4) Low construction and running costs
5) Energy efficiency (lower power consumption)

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Why off-axis injection?

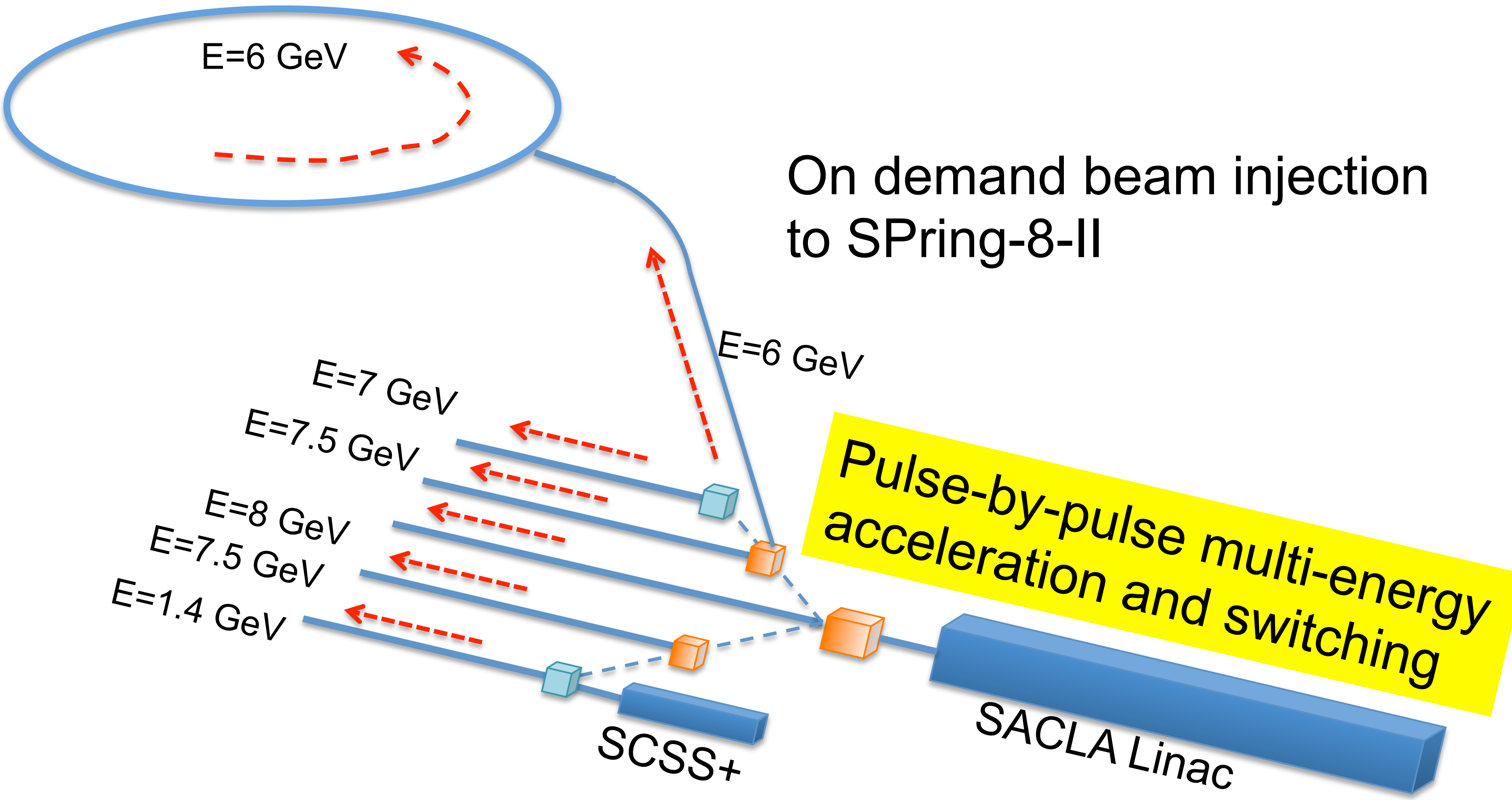
Scheme / Item	Off-axis	RF Multi-pole	On-axis	Off-energy Beta Osc. Free
Small 3D Inj. Amplitude	○	△	○	△
Transparency	○	○	○	○
High Stored Current	○	○	△	○

Beam injection scheme for SPring-8-II

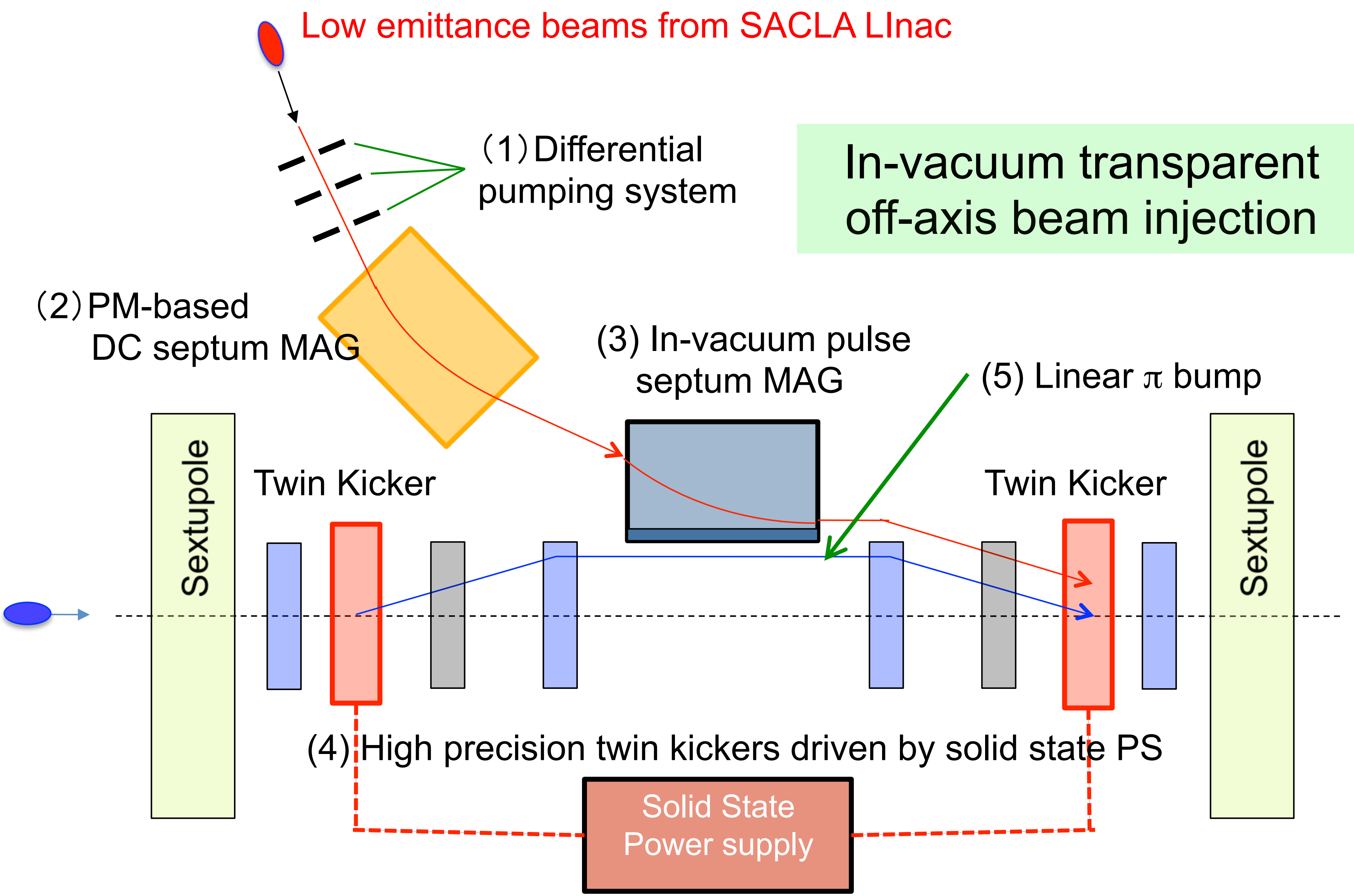
New "Off-axis beam injection" based on (1) low emittance injection beam, (2) In-vacuum pulse septum and (3) a perturbation-free linear π-bump.

- One order smaller amplitude → a few mm
- One order higher transparency → stored beam oscillation smaller than 10 μm
- Usual top-up operation keeping the stored beam

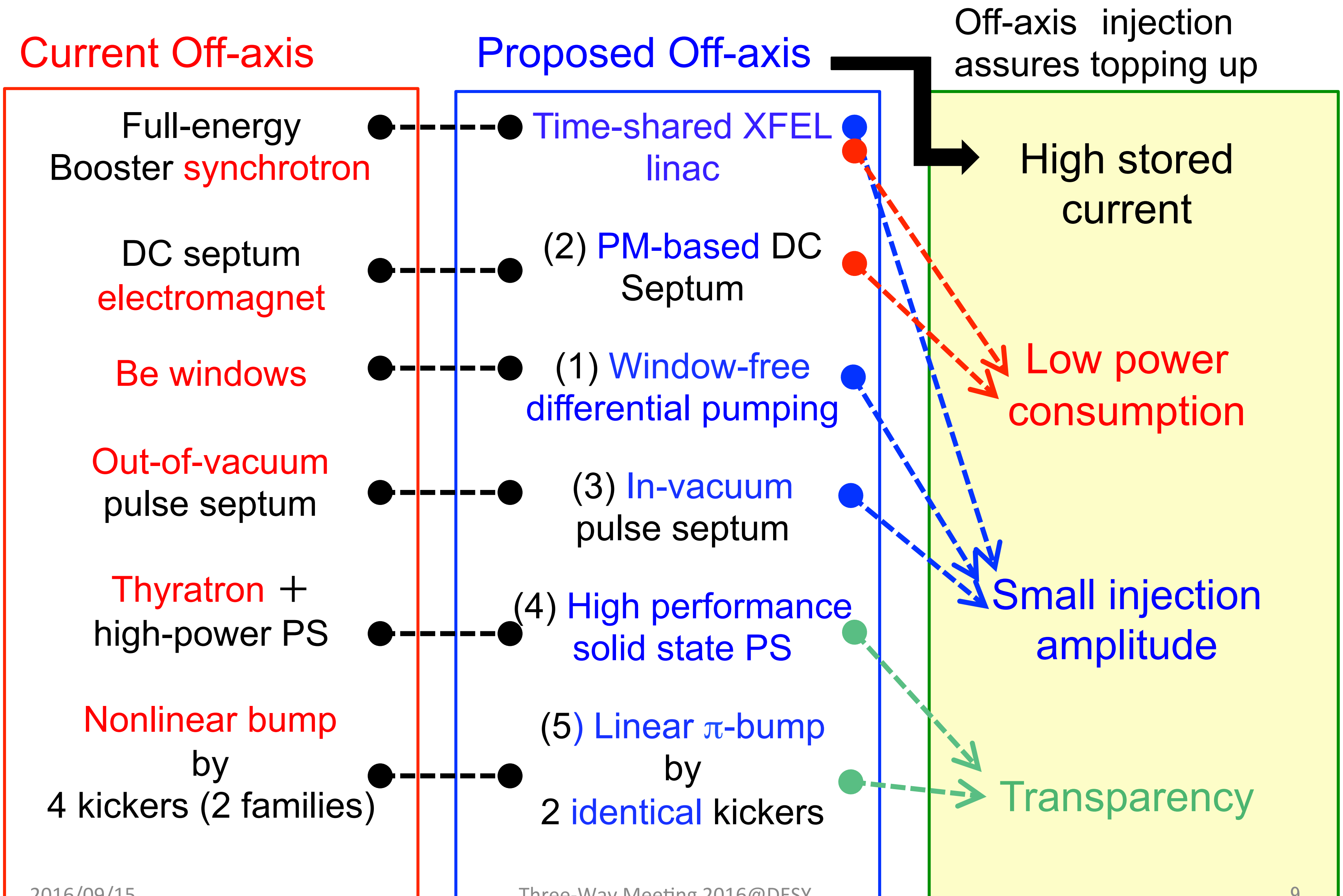
Beam injector for SPring-8-II
- Timeshared use of XFEL linac -



Ring beam injection section



Features of proposed scheme



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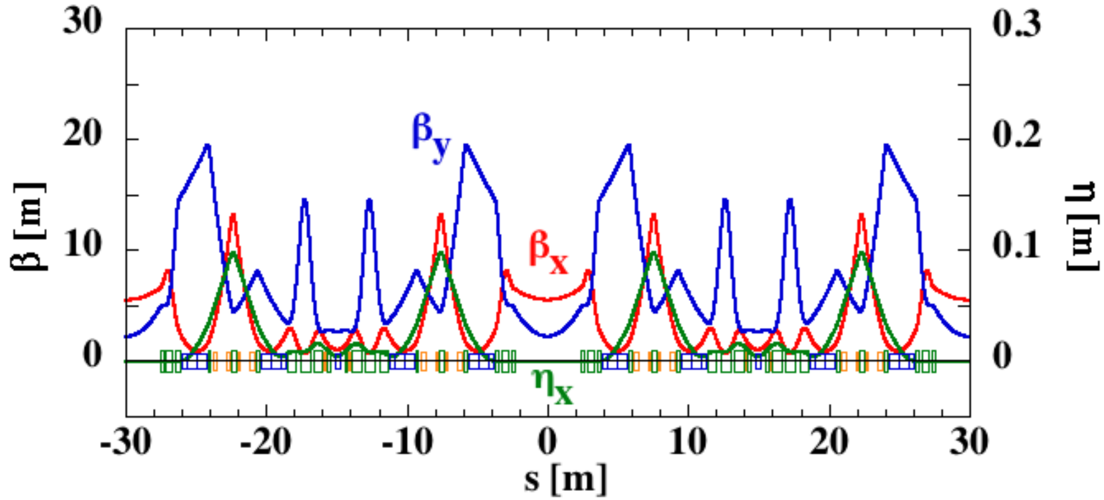
Injection cell of SPring-8-II

The whole ring optics is composed of 42 regular cells , 4 straight cells, and 2 injection cells.



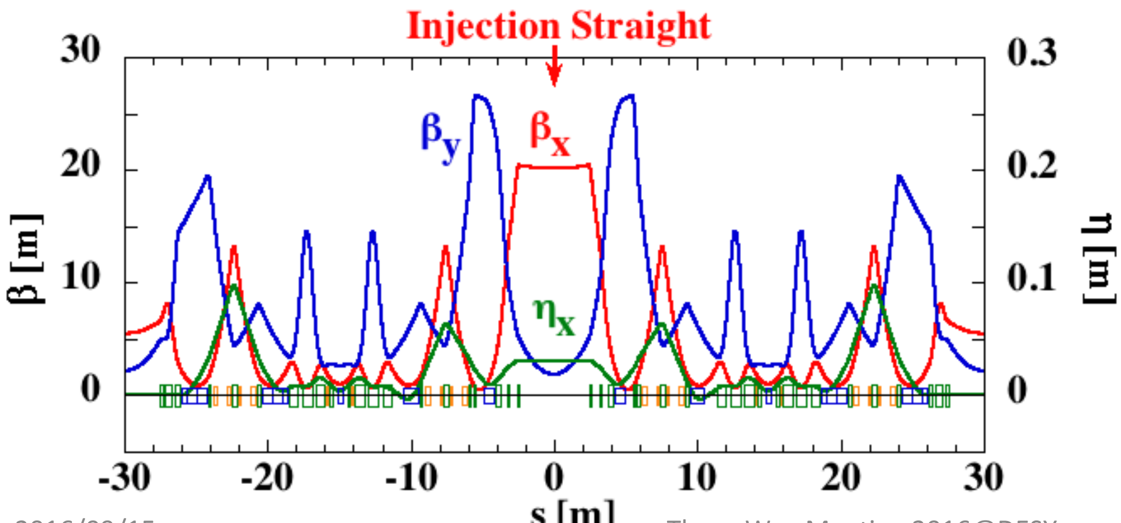
Normal cell:

β_x = 5.5m

β_y = 2.2m

η_x = 0.0m

(ν_x, ν_y)=(2.366, 0.922)



Injection cell:

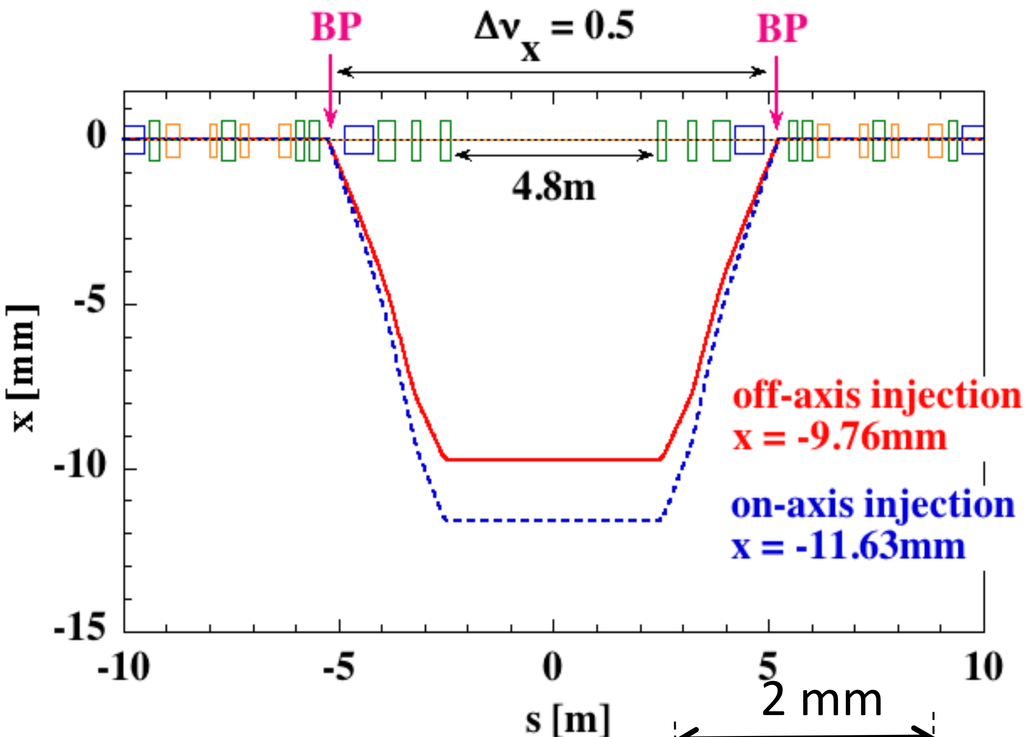
β_x = 20.118m

β_y = 1.860m

η_x = 0.031m

(ν_x, ν_y)=(2.366, 0.922)

Bump orbit composition and injection amplitude

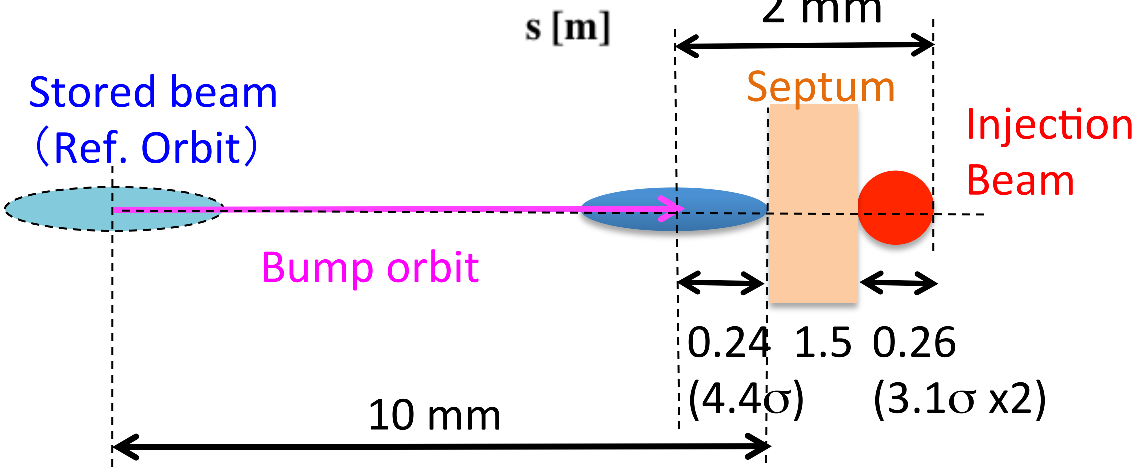


Kicker installation space

= ~ 0.6 m

Kick angle = -3.18 mrad

for -9.76 mm



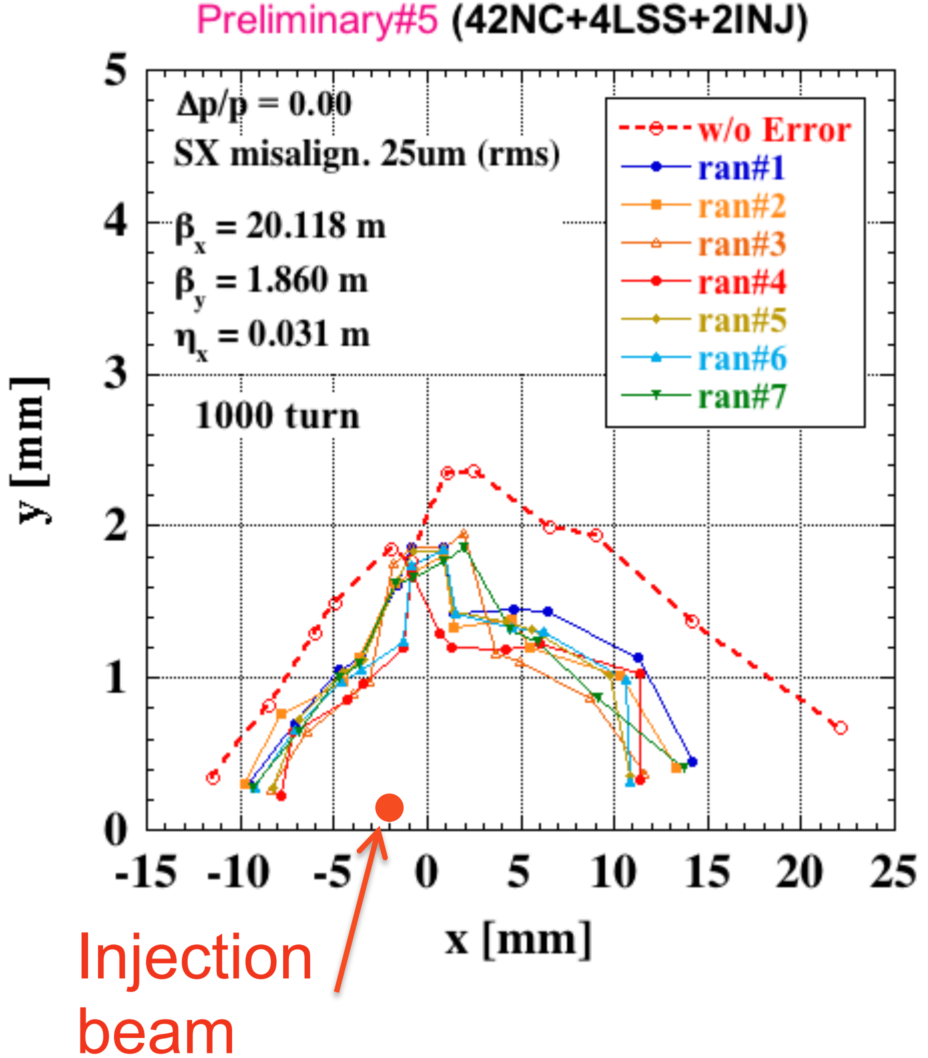
Injection amplitude

= 2 mm

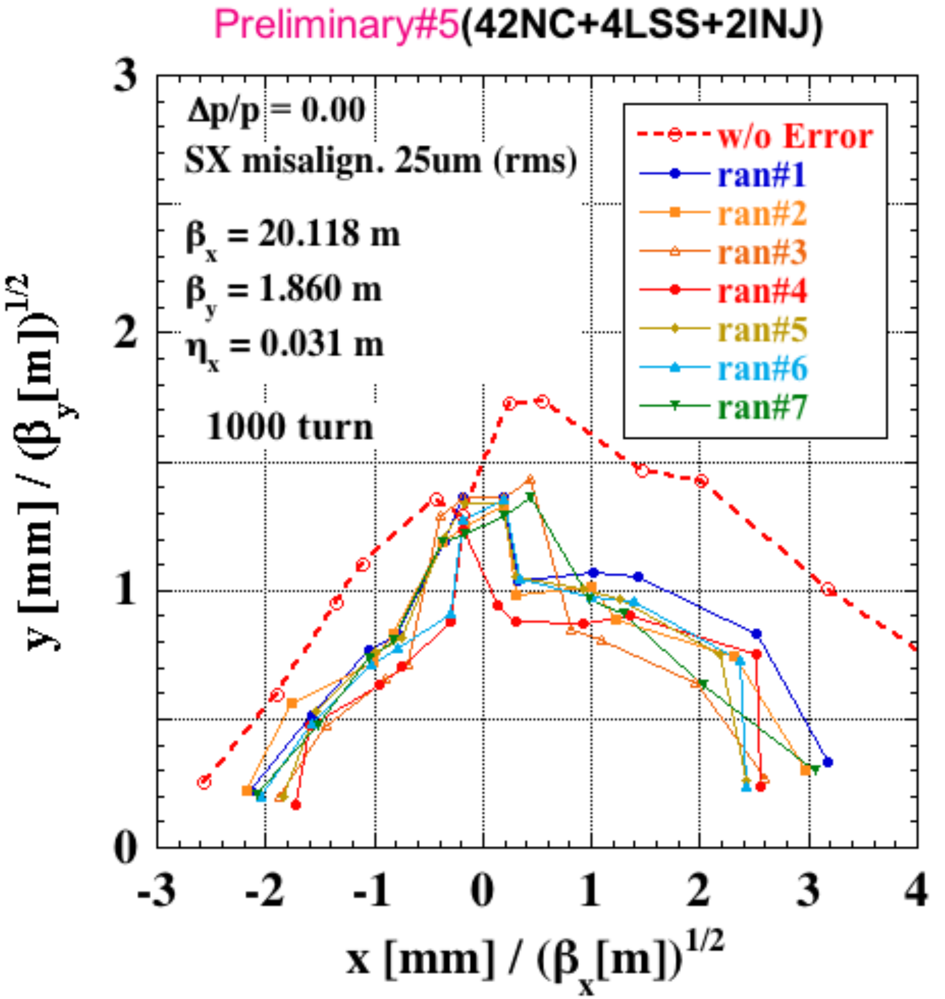
Target effective septum thickness = 1.5 mm

Expected DA at injection point

Absolute DA



Normalized DA



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Parallel development of two main subjects

(1) Timeshare use of SACLA linac as an injector for SPring-8-II

- XFEL requires a high peak current of ~10 kA, which is inadequate for beam injection to SPring-8-II
- In a pulse-by pulse manner, (a) beam temporal profile, (b) beam delivery route, and (c) beam acceleration timing should be changed according to the use

(2) In-vacuum transparent off-axis beam injection

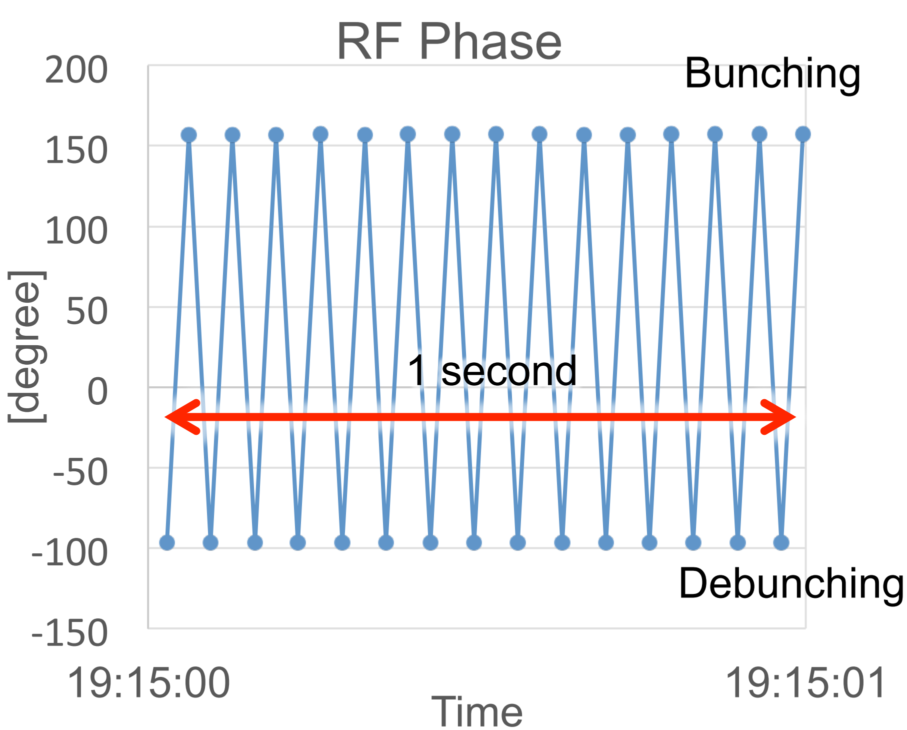
- Following three key components are essential for the system development
- (d) PM based DC septum, (e) in-vacuum pulse septum, and (f) twin kickers driven by a single solid state high power PS

(a) Shot-by-shot RF parameter switching to control E-beam temporal profile

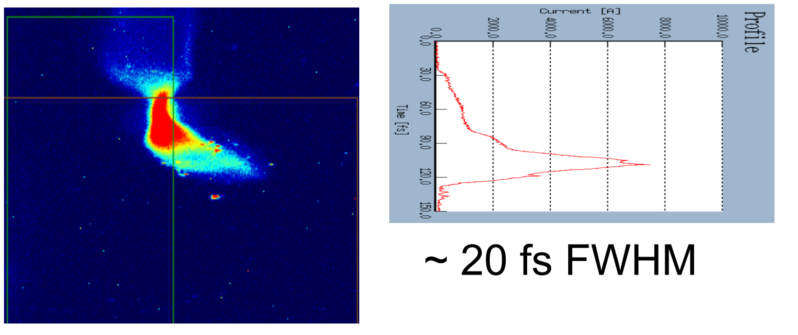
Two methods under development

(I) Ethernet based "event information" delivery system
(II) Trigger pulse based "event information" delivery system

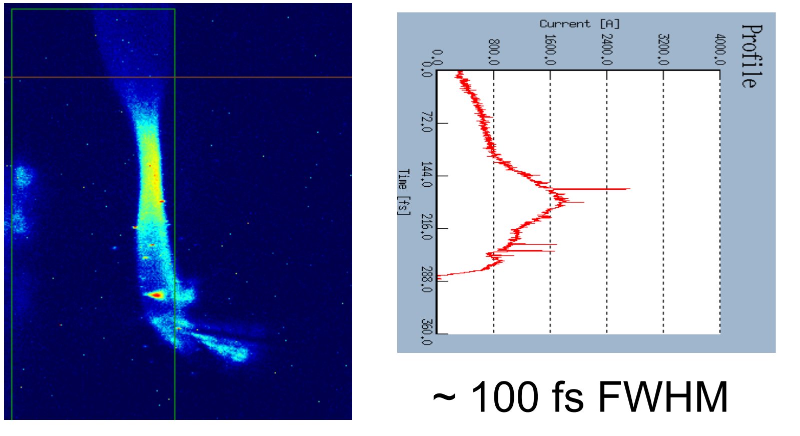
Test result obtained by (I)



Longitudinal Beam Profile from RF Deflector System

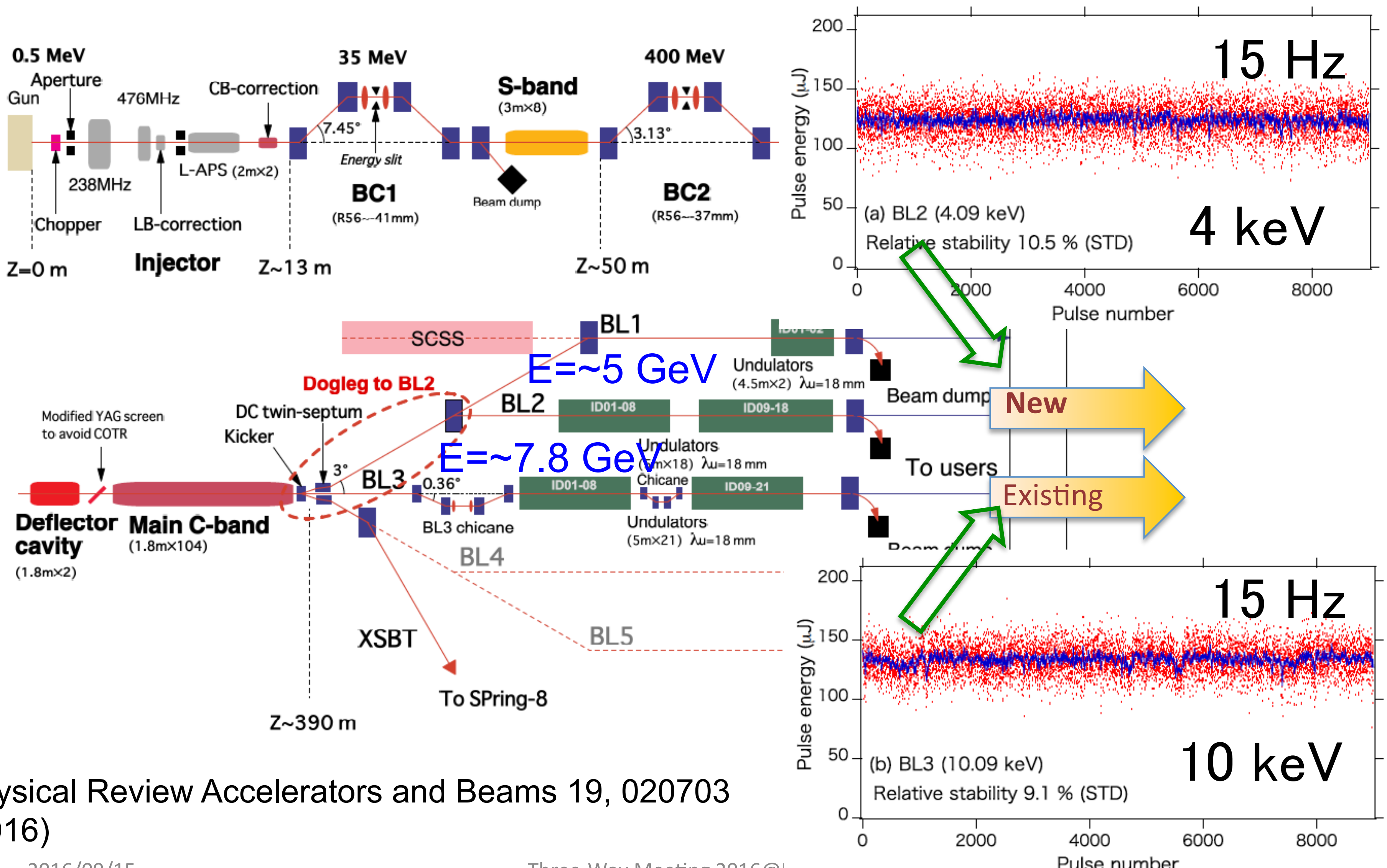


~ 20 fs FWHM



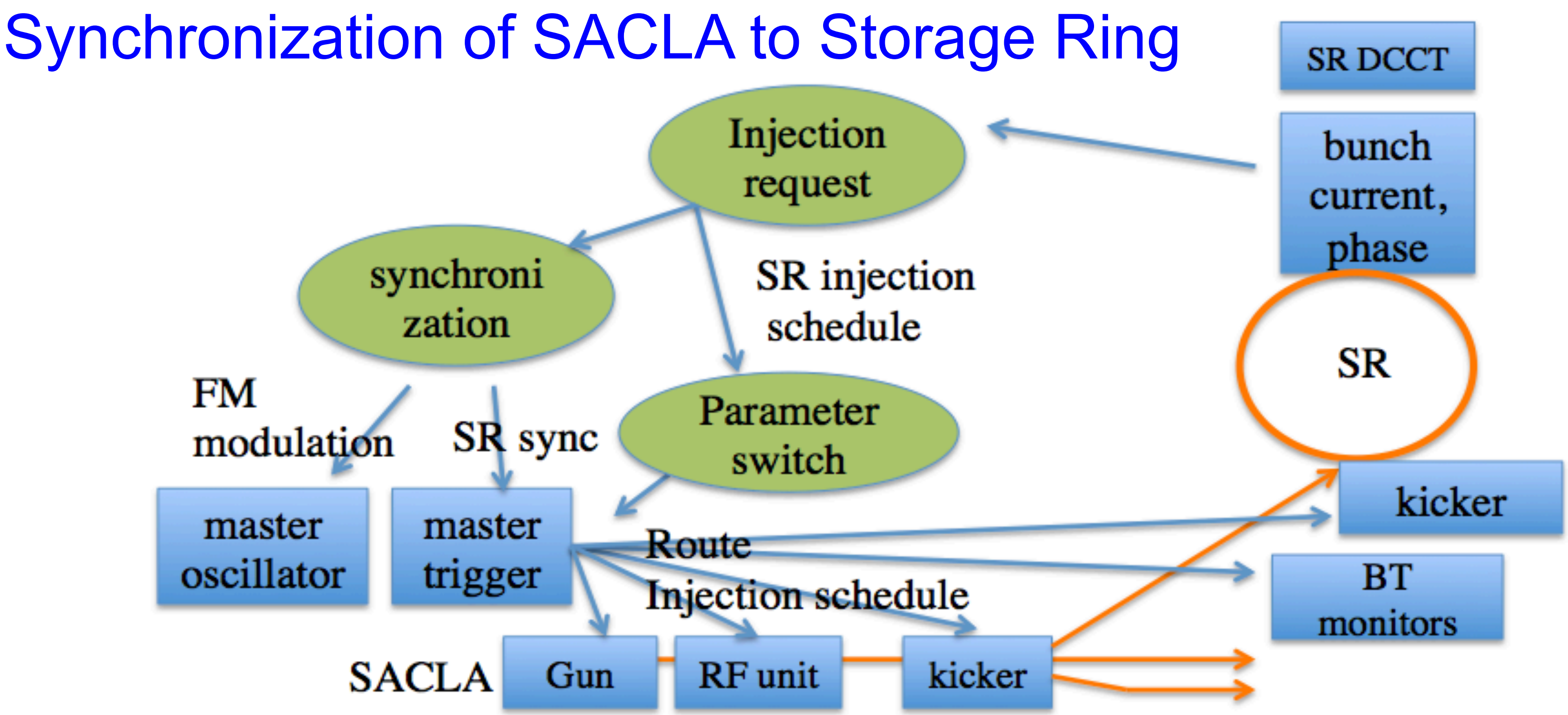
~ 100 fs FWHM

(b) Shot-by-shot beam route switching to deliver E-beam to both XFEL BLs and SPring-8-II



Physical Review Accelerators and Beams 19, 020703 (2016)

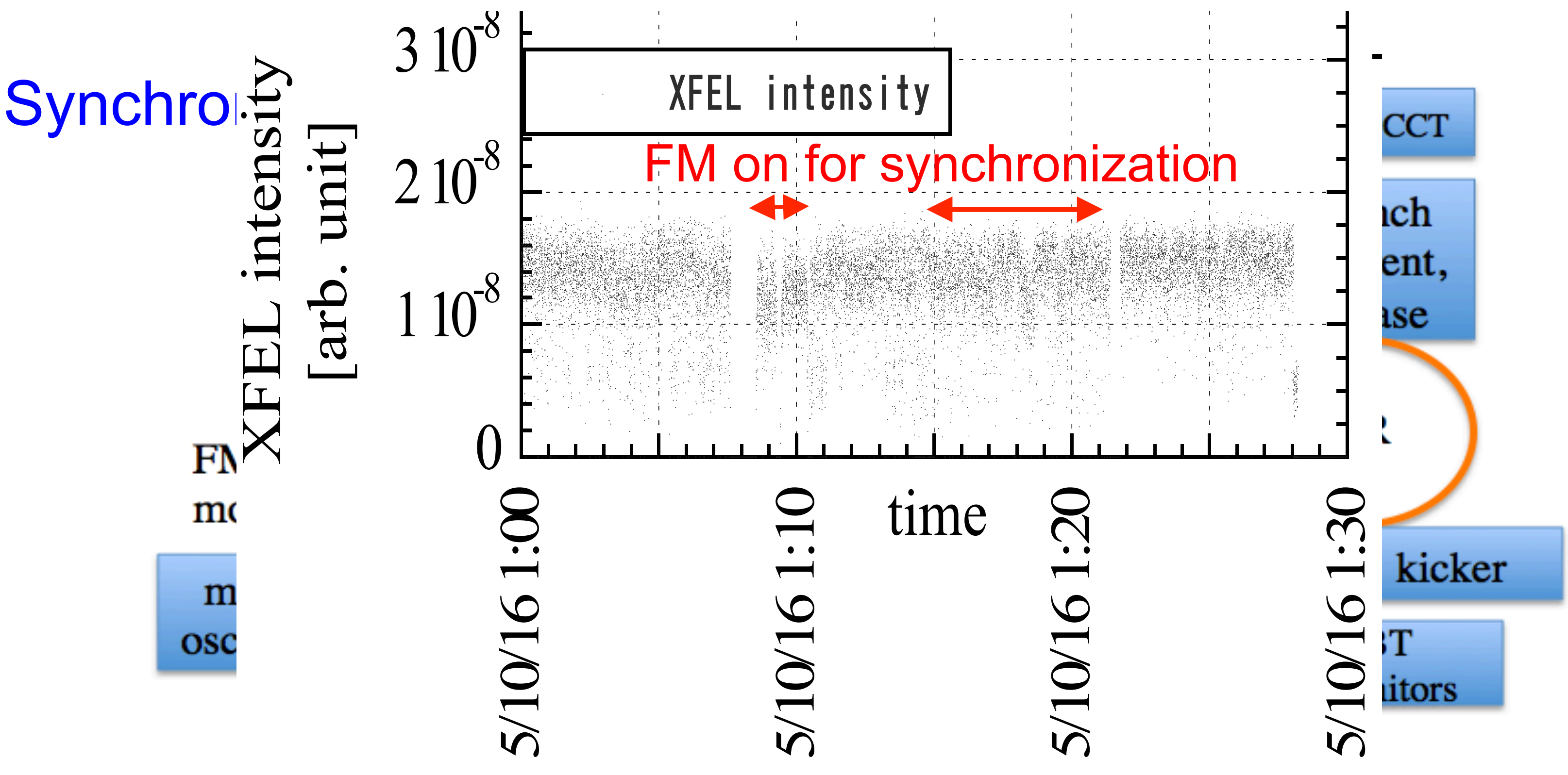
(c) Synchronization system enabling on-demand beam injection for SPring-8-II



Prototype of the synchronization system tested at SACLA.

- Timing jitter of 1.2 ps rms obtained, which satisfies target value
- Small influence to the XFEL performance

(c) Synchronization system enabling on-demand beam injection for SPring-8-II



Prototype of the synchronization system tested at SACLA.

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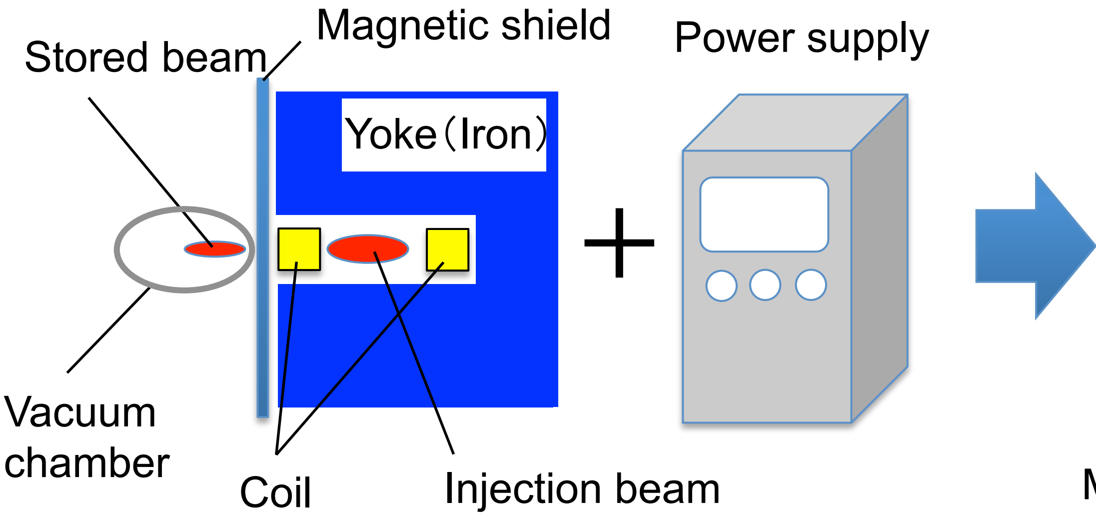
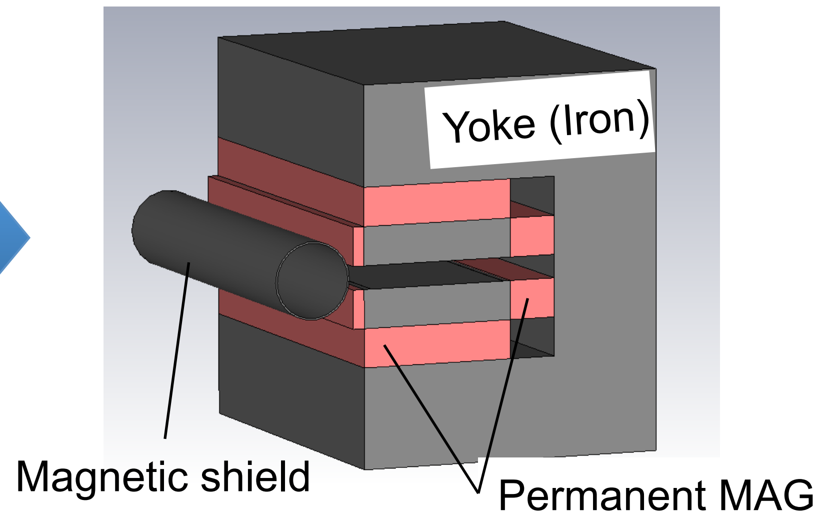
(d) PM-based DC septum magnet

Conventional（Electro MAG）



Permanent magnet-based



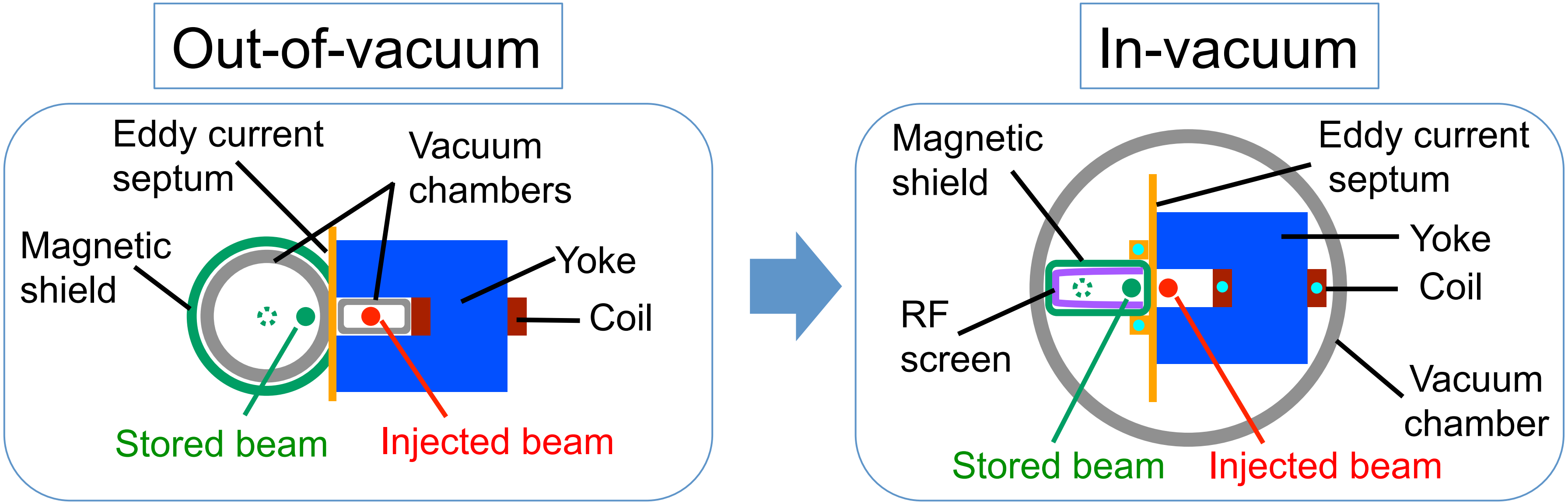
- Electric power reduction
- Simplification of cooling water system

Essential countermeasures

1) Leakage field suppression — Difference of integrated field between bump on and off less than 10^{-5} T･m

2) Demagnetization — Adoption of SmCo PM、Field correction by Outer plate

(e) In-vacuum pulse septum magnet



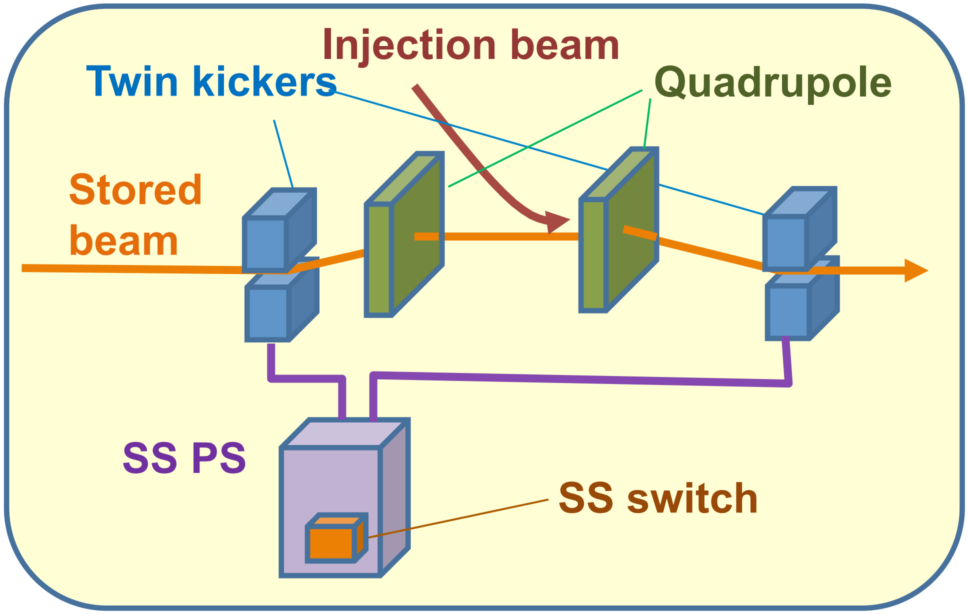
- In-vacuum beam injection
- Smaller injection beam amplitude

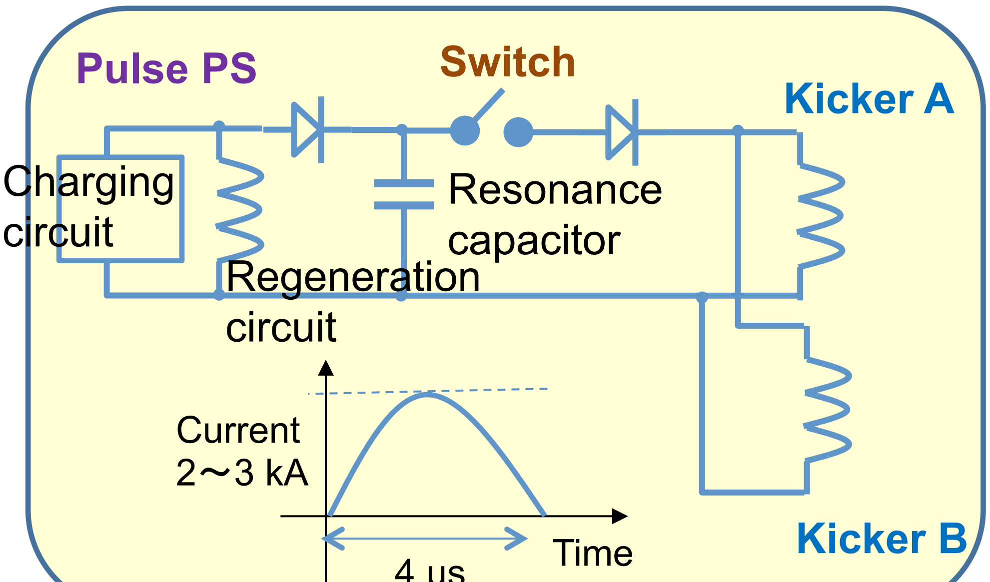
Critical Issues

1) Vacuum - Minimizing outgassing (material, coating, yoke structure, heat treatment), Optimizing pumping system

2) Magnet - Leakage field suppression
Thin septum conductor and magnetic shield

(f) Twin kickers driven by a single solid state PS





Tentative parameters

Item	Specifications
Beam energy	6 GeV
Kick angle	3.5 mrad
Stability	< 5μrad（Target 1μrad）
Magnetic field	0.2 T
Excitation current	2.6 kA
Current stability	< 0.1%（Target 0.01%）
Pulse width	4 μs
Magnet Inductance	3.5 μH
Capacitance	400 nF
Charging voltage	25 kV
Timing jitter	< 1ns

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Development status

(1) Timeshare use of SACLA linac as an injector for SPring-8-II

Proof-of-principle experiments accomplished for (a) pulse-by-pulse temporal profile control and (c) timing synchronization. (b) beam route switching will be accomplished as a final form by the end of FY2016.

→ Test beam injection to SPring-8 scheduled in FY2018

（2）In-vacuum transparent off-axis beam injection

3-years R&Ds started this year for (d) PM-based DC septum, (e) in-vacuum pulse septum, and (f) twin kickers driven by a single solid state high power PS since.

All R&D items will be completed by the end of FY2018.

Summary

1. A new beam injection scheme has been proposed for SPring-8-II, which timeshares the SACLA linac as an injector and adopts an in-vacuum transparent off-axis injection scheme.

2. The new injection system under development satisfies simultaneously high injection performance, i.e., a small injection amplitude and high transparency, and substantial energy-saving required for SPring-8-II.

3. All the developments are expected to finish in FY2018.