Belle2 General Meeting
10 October, 2022

Linac status and upgrade during LS1

KEK e+/e- injector linac group
Takuya Kamitani

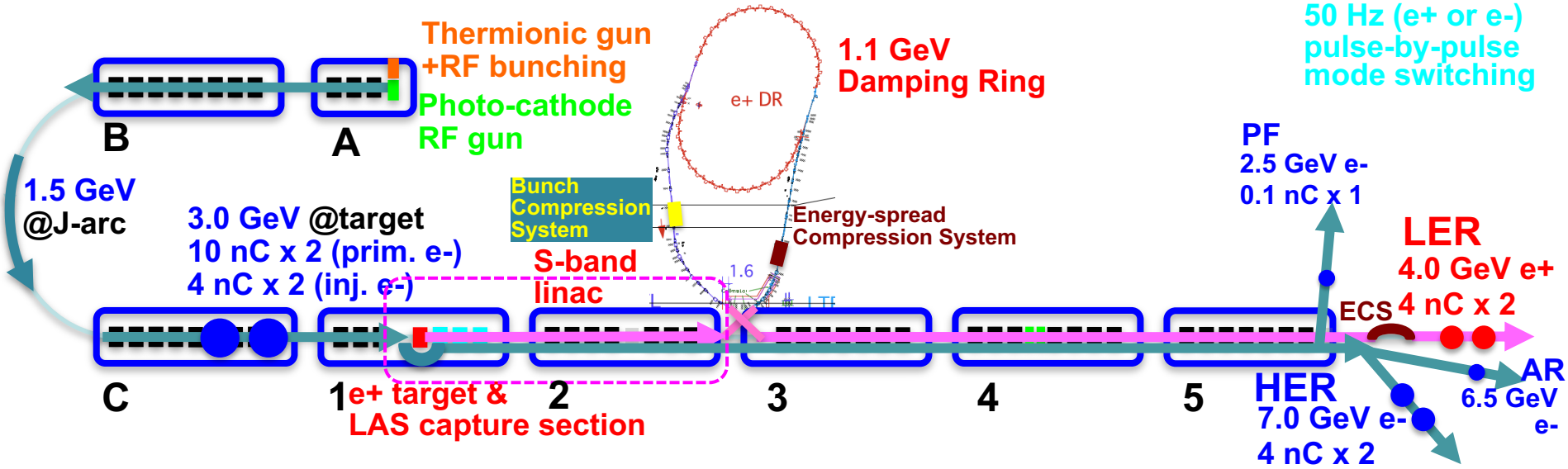
Contents of my talk

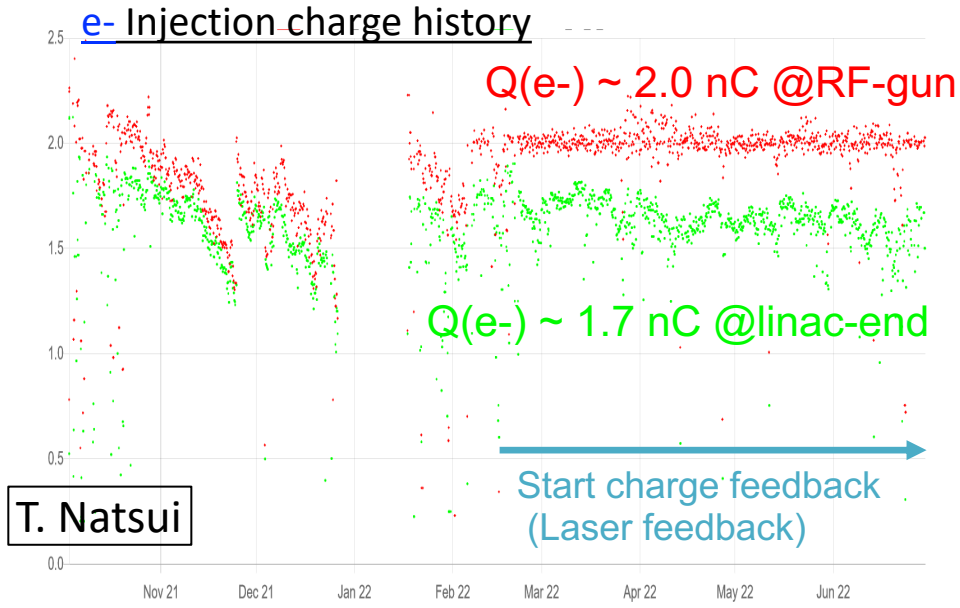
- Linac status
  - operation history (injection beam charge)
  - recent improvement
    [1] RF-gun laser window replacement & addnl. pumping
    [2] RTL (from DR to Linac) Fast kicker
    for DR extraction angle difference compensation

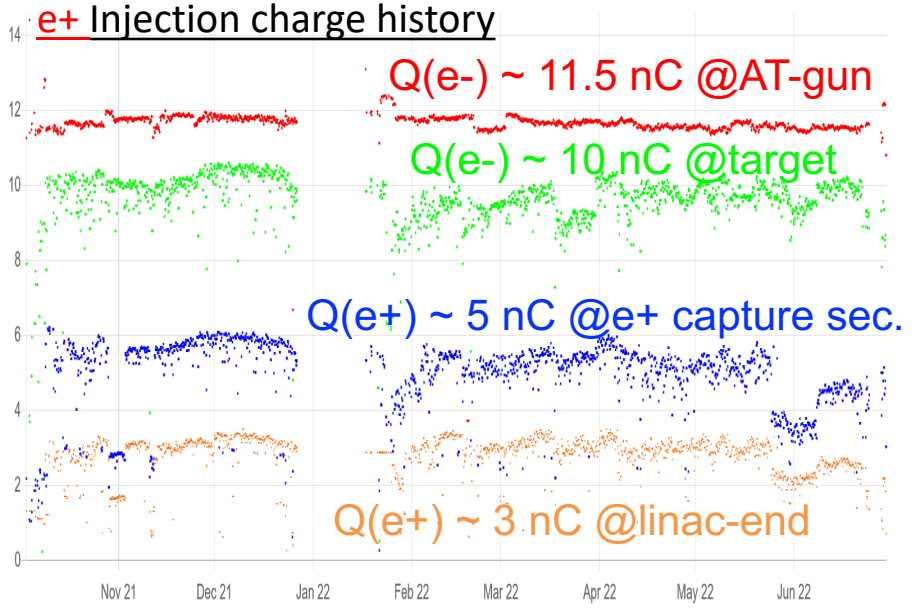
- Linac upgrade items during LS1
  - [1] Pulsed quads at J-arc matching section
  - [2] Pulsed quads at e+/e- compatible optics region
  - [3] Linac Fast kicker for bunch orbit difference tuning

Linac Status

- **Linac stably injects e-/e+ beams to HER, LER, PF & AR.**



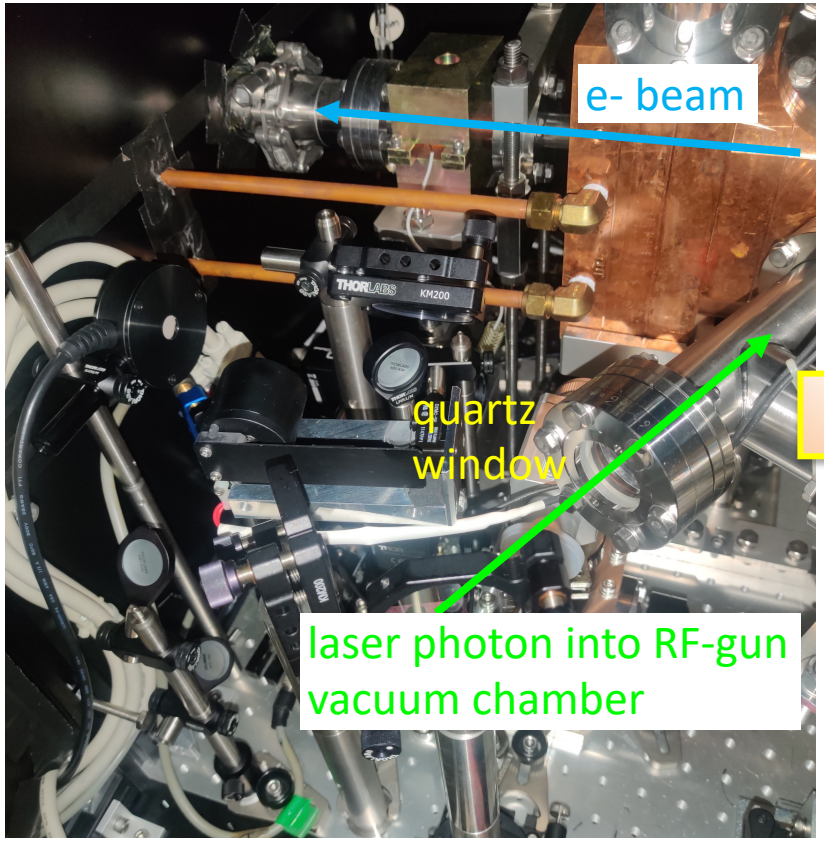


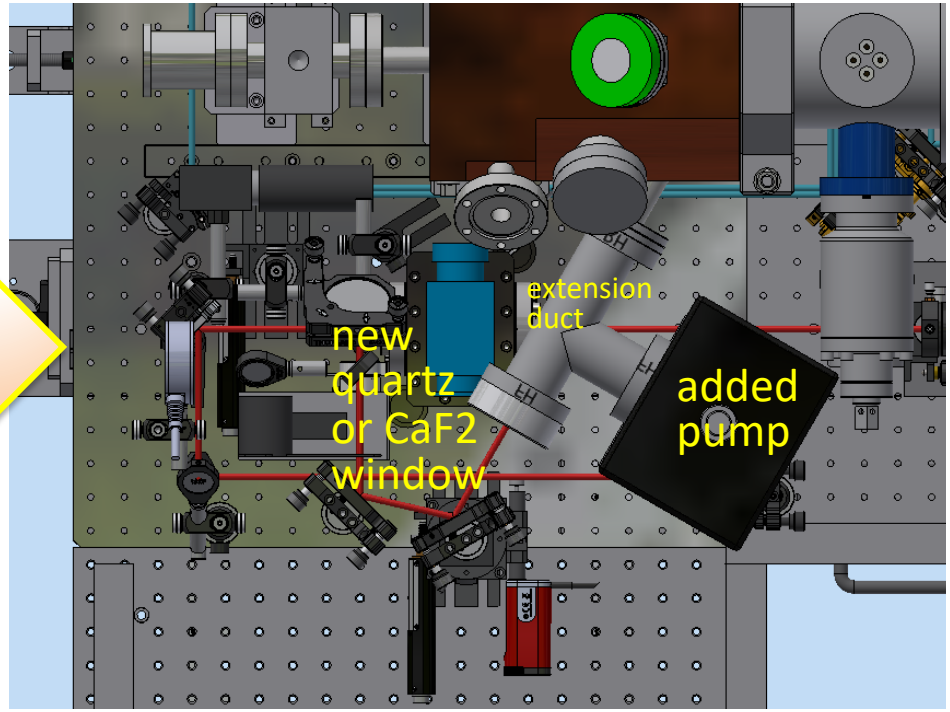


[1] RF-gun laser window replacement

- laser photon intensity attenuated
  by dirt on inner surface of the quartz window
- Replaced the window to new one
- Added an ion pump to mitigate degradation

X. Zhou





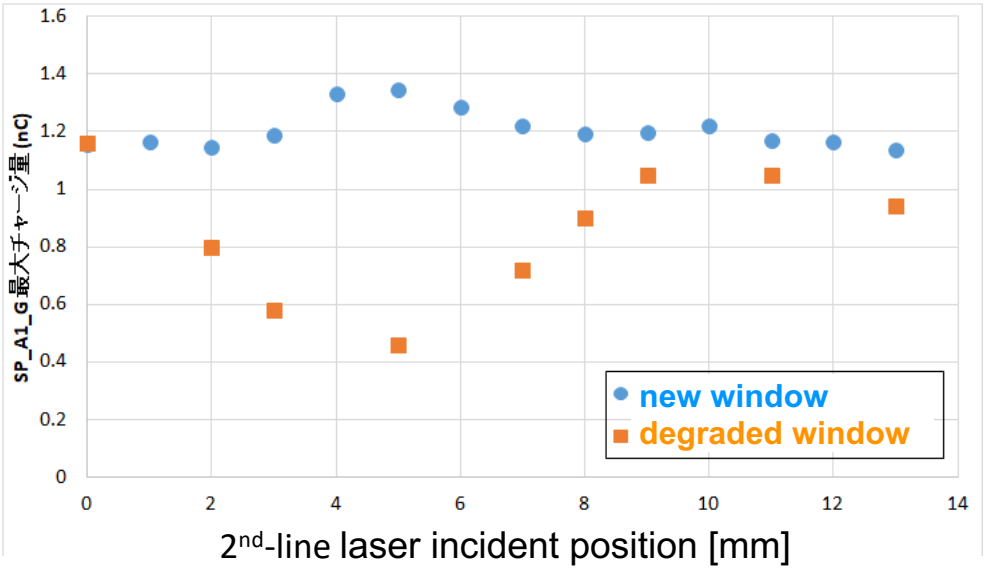
e- beam intensity recovered

- RF-gun uses 2 lines of laser
- photon transmission degraded to 40% due to dirt on window and dependent upon incident position
- e- beam intensity recovered by window replacement

M. Yoshida

e- intensity by 1st-line laser

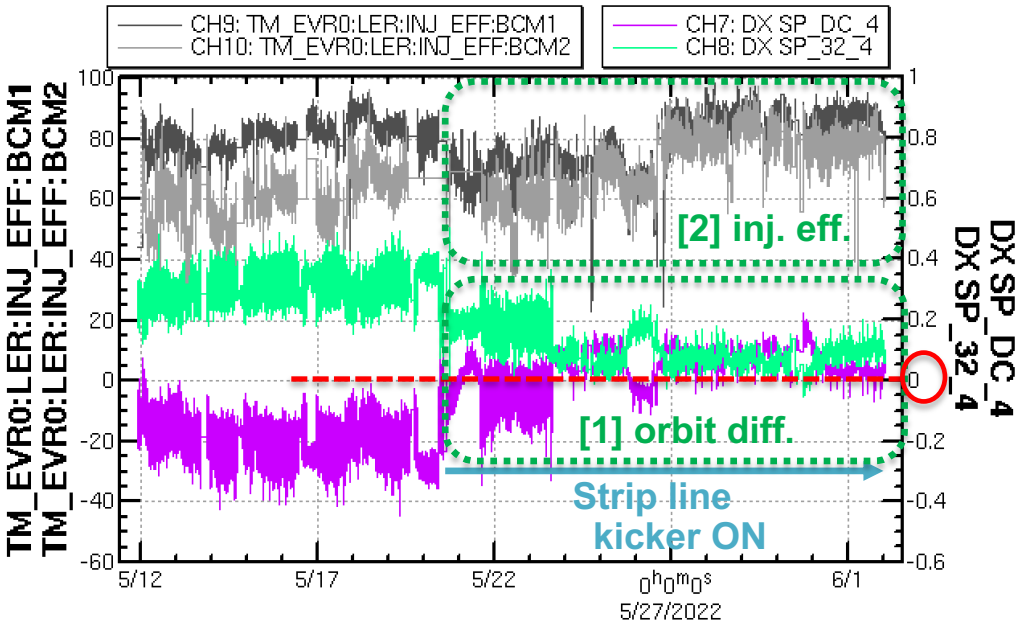
e- intensity by 2nd-line laser

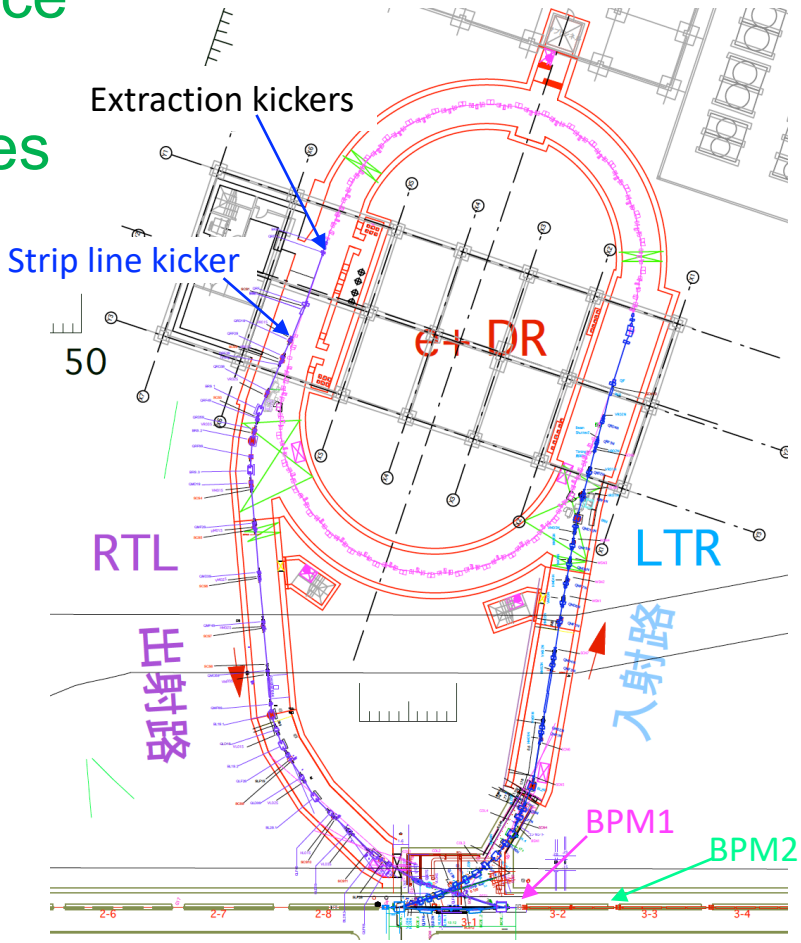


[2] RTL bunch orbit difference reduction

- DR extraction kicker pulse shape made difference in 1st/2nd e+ bunch orbits and injection efficiencies
- Fast strip line kicker installed for compensation
- [1] Reduced bunch orbit difference at BPM1 and 2
- [2] Coincided injection efficiencies at LER

N. Iida

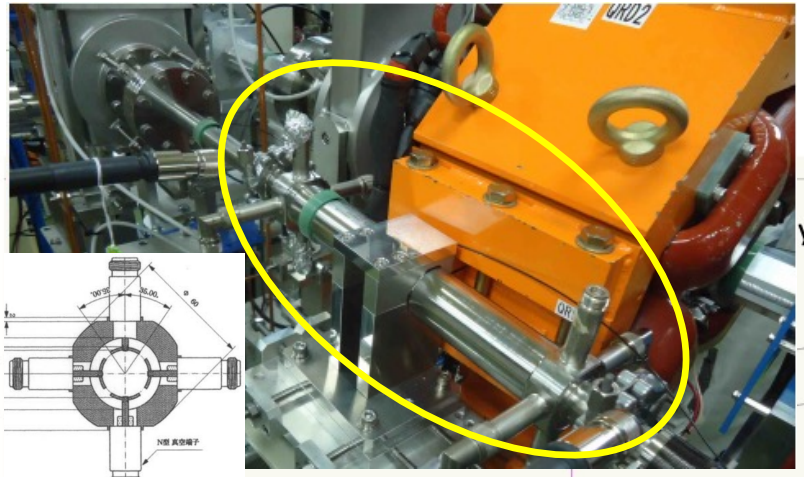


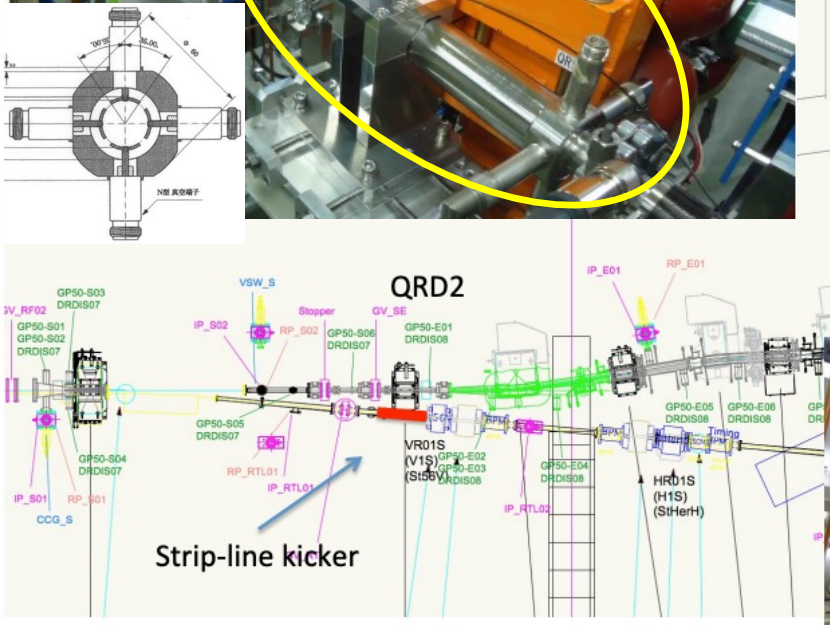


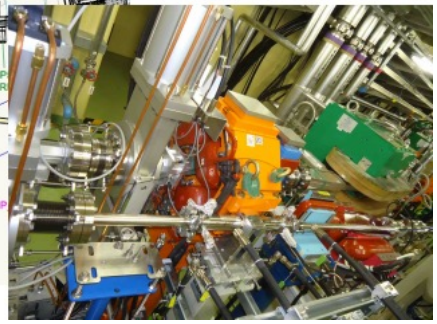
fast strip line kicker

- Fast strip line kicker in RTL (DR to Linac) kicks only 2nd bunch
  (originally developed for KEK ATF)
- Electric field type kicker
  kick angle 0.14 mrad with +/- 8 kV
  pulse length ~ 20 ns

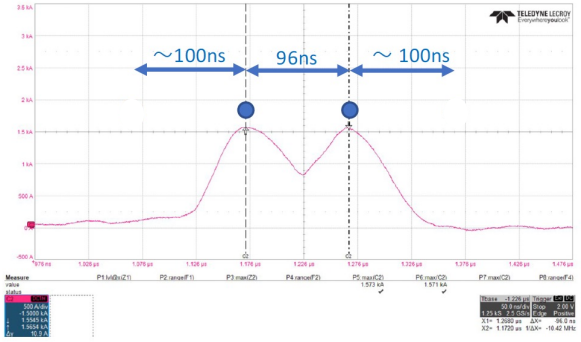
K. Kodama, T. Naito



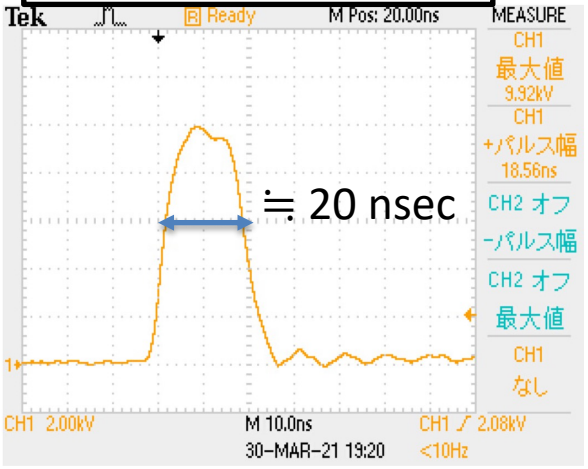




DR Extraction Kicker pulse

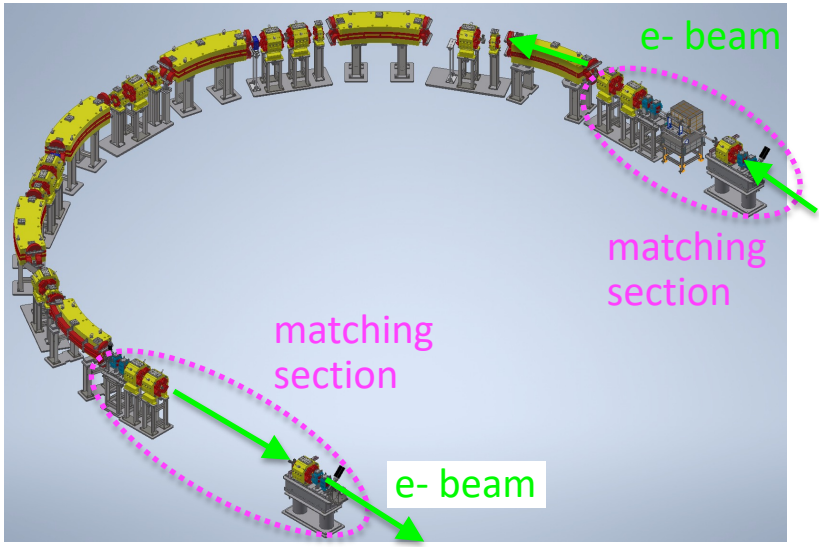


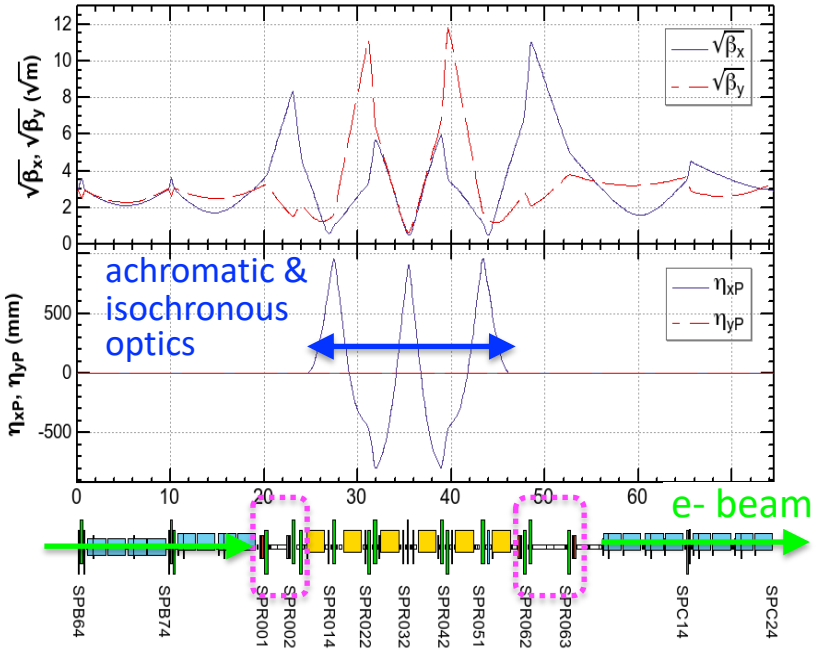
Strip Line Kicker pulse



Upgrade item [1] pulsed quad @J-arc

- beam optics situation @J-arc
  - 180-degree J-arc has a special optical design, so beam matching to periodic focusing systems in straight lines is essential to avoid beam loss and degradation.
  - optical mismatch tend to cause a particle loss in primary e- beam of large emittance (KBP).
  - tuning of quads for matching often makes emittance degradation in injection e- beam (KBE).





- motivation of pulsed quad
  - pulsed quads in matching section enables independent beam optics matching for each mode

Y. Seimiya, Y. Okayasu

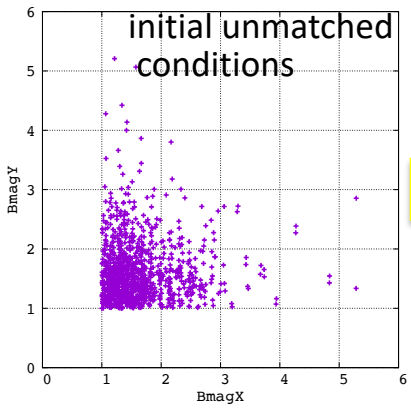
optics matching simulation

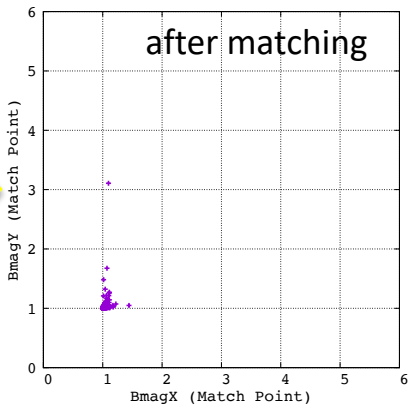
- number of quads: 4 in entrance and 4 in exit (3 + 3 at present)
- matching performance is evaluated by simulations with random initial Twiss parameters.
- almost all cases, good matching result ($Bmag_{x,y}$ ~ 1) obtained within designed field strength.

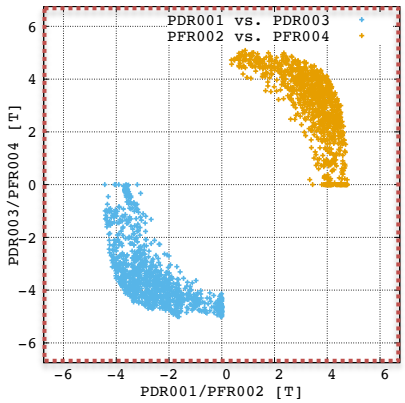
Y. Seimiya

field strengths after matching
(plot boundary shows design limit)

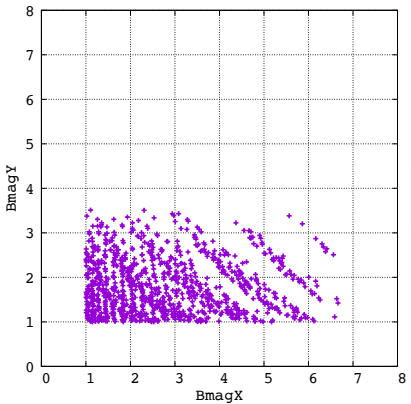
at J-arc entrance

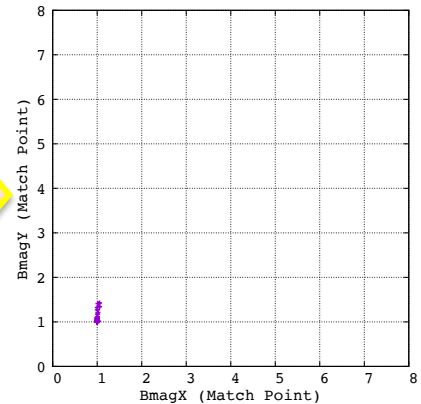


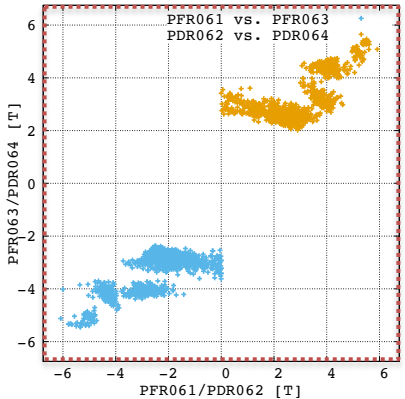




at J-arc exit



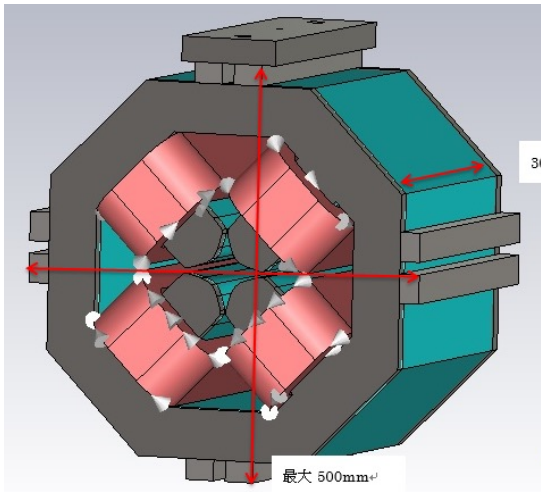




specification of pulse quad for J-arc

- requirement on field strength is minimized by simulation while keeping the beam matching performance and margin.
- bore size remains the same for sufficient aperture.
- current and turns/coil are optimized, however, requires larger capacity pulse power supply.
- magnet (size) and ceramic duct are designed to be almost comparable to existing DC quad and duct.

parameters	DC quad R0_01 type	new pulsed quad R0_01
bore diameter [mm]	44	44
field gradient [T/m]	26.1	21
max. current [A]	56	600
pole length [mm]	300	300
effective length [mm]	323	333
B'L [T]	8.43	7
nI [A.turn]	5040	4200
turn of coil /pole	90	7
inductance [mH]	200	1.5

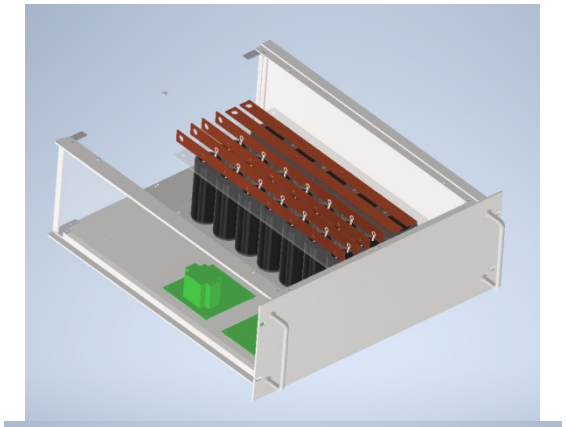


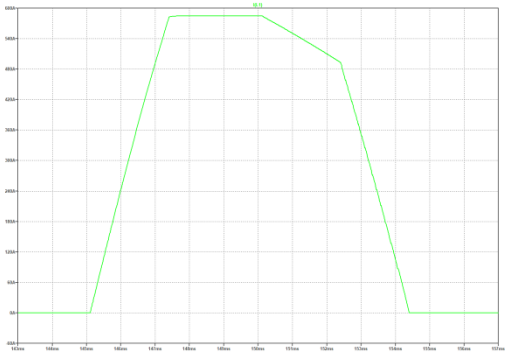
K. Yokoyama

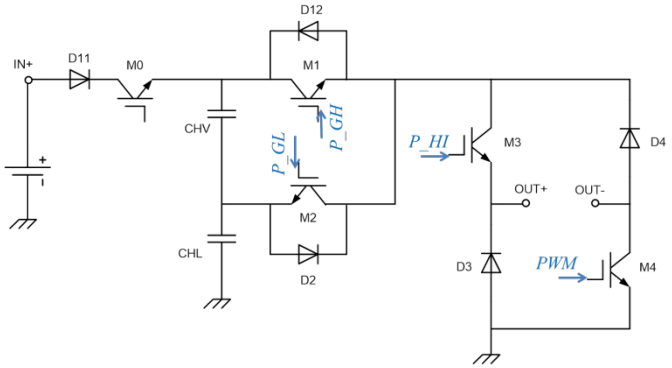
new pulse power supply

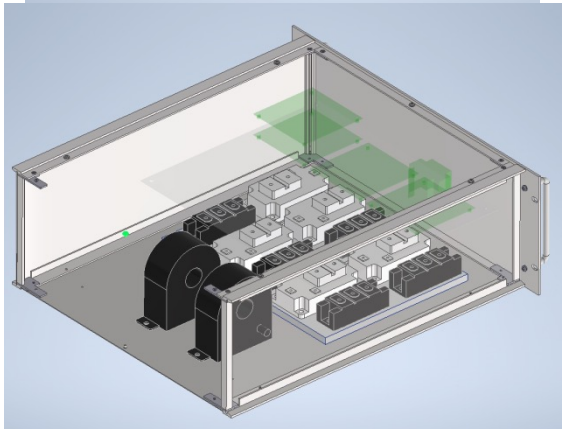
- new pulse driver for J-arc pulsed quads is developing.

	3-5 sector type	New pulse driver
Max Voltage [V]	230	400
Max Current [A]	330	600
Magnet inductance [mH]	1	1.5
Control method	I_D-V_{GE} analog control	Pulse Width Modulation









T. Natsui

Upgrade item [2] pulsed quad in Sect-1, 2

- e+/e- beam optics situation in Sect-1, 2
  - beam optical design in the region (after e+ capture section to LTR entrance) is optimized for e+ beam transmission
  - unfortunately, plenty of DC quads are used for this optics
  - e- beam (with higher energy) experiences very weak focusing with large betatron function
  - slight orbit deviation causes emittance growth of e- beam

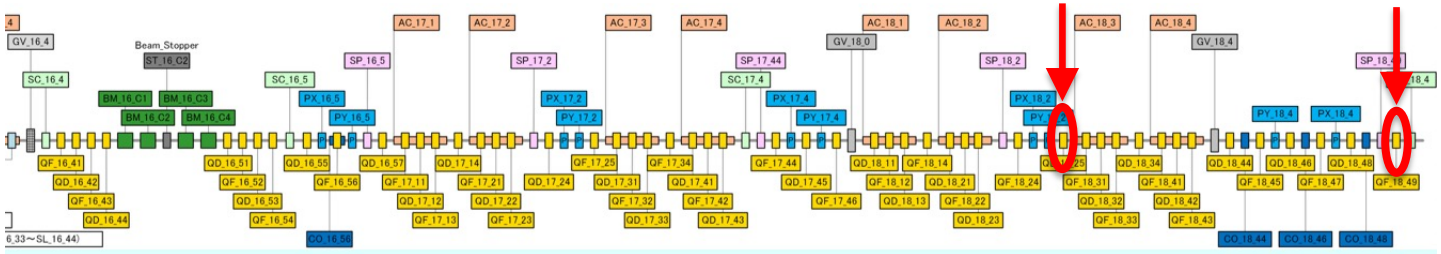
- motivation of pulsed quad installation
  - beam optics simulation shows that installation of only four pulse quads achieves significant reduction of the betatron function and suppression of emittance growth

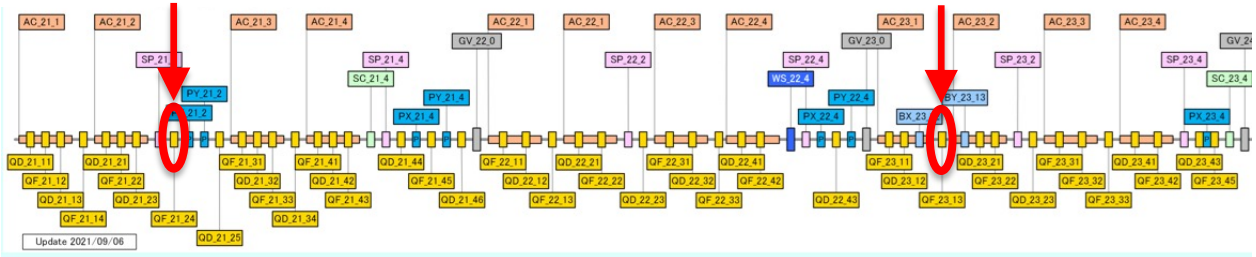
magnet layout in Sector-1, 2

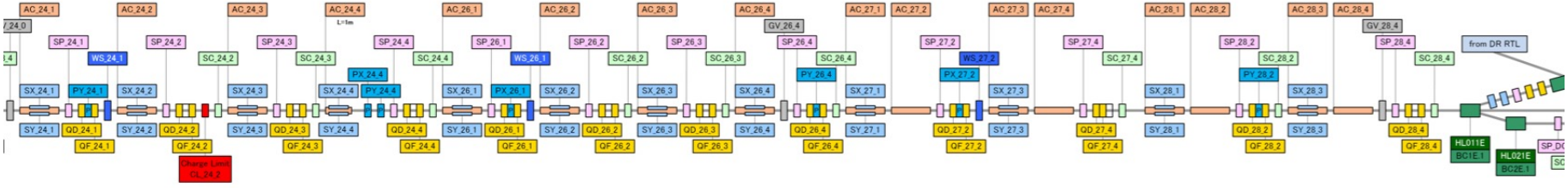
- quads wrapping around the accelerating structure cannot be pulsed because of eddy current in the copper
- only quads in between the structures can be pulsed
- four quads shown below are replaced with pulsed magnets

beam line layout in Sector-1, 2

Y. Seimiya





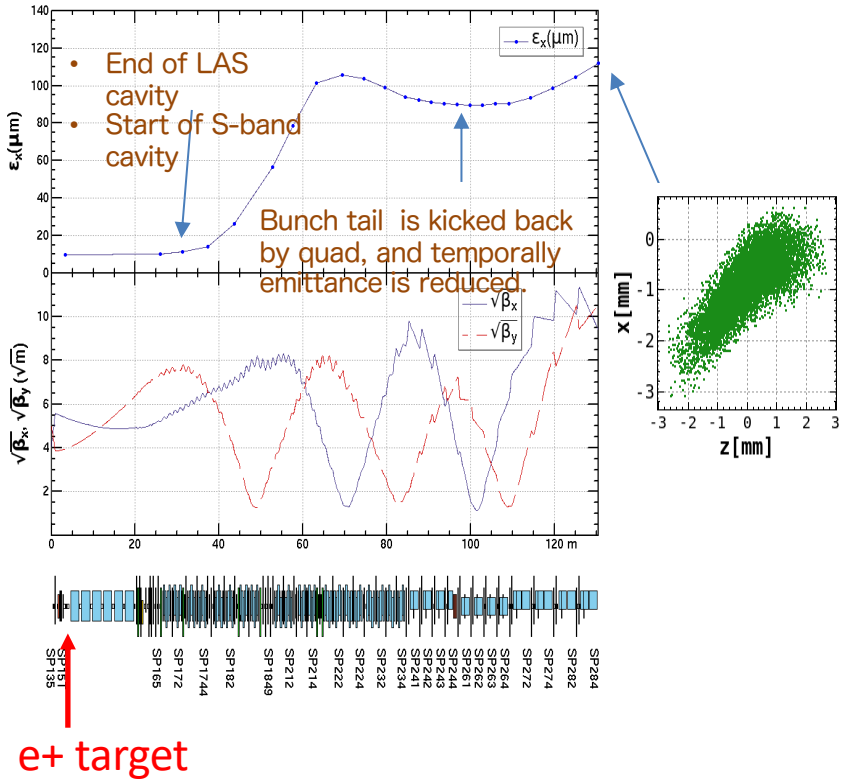


emittance growth reduction by low beta optics

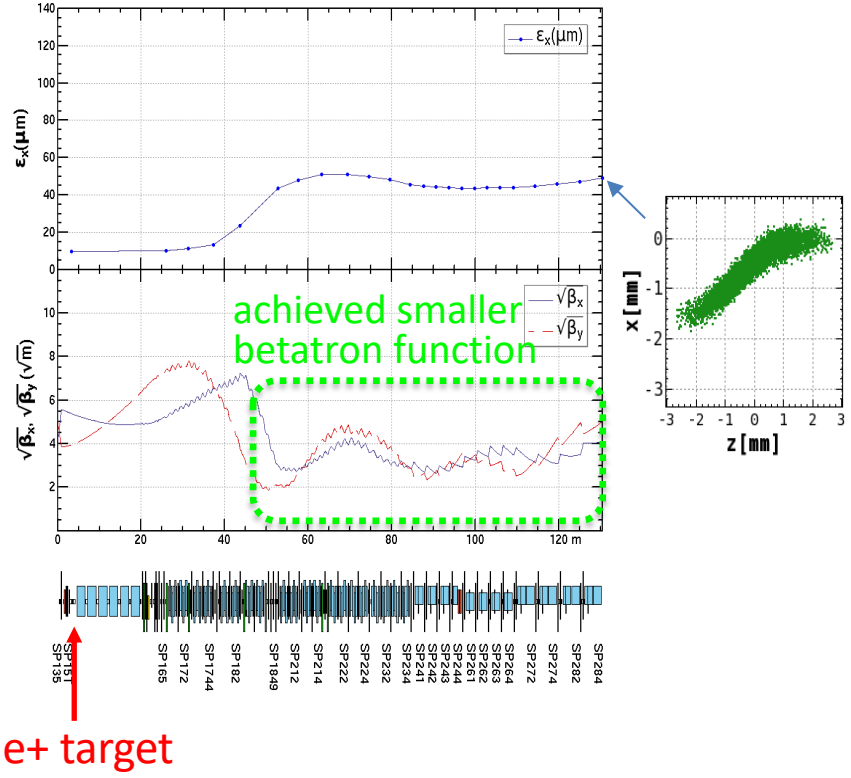
- lower betatron function can be achieved by setting four pulsed quads to e- oriented focusing strength
- it can reduce emittance growth rate less than half

Y. Seimiya

$\Delta\gamma\varepsilon x$ ~ 100 um, $\overline{\beta x} = 45.2$ m



$\Delta\gamma\varepsilon x$ ~ 40 um, $\overline{\beta x} = 16.3$ m



specification of pulse quad for Sector-1, 2

- requirements on bore size and field strength are minimized by simulation while keeping the performance.
- magnet (size) and ceramic duct are designed to be replaceable with existing DC quad and duct.
- current and turns/coil are optimized to be compatible with the existing pulse power supply.

parameters	DC quad 17_14 type	new pulsed quad 17_14
bore diameter [mm]	44	32
field gradient [T/m]	20.9	23.6
max. current [A]	80	300
pole length [mm]	160	160
effective length [mm]	173.8	168.0
B'L [T]	3.63	3.96
nI [A.turn]	3760	2400
turn of coil /pole	47	8
inductance [mH]	32.3	0.94

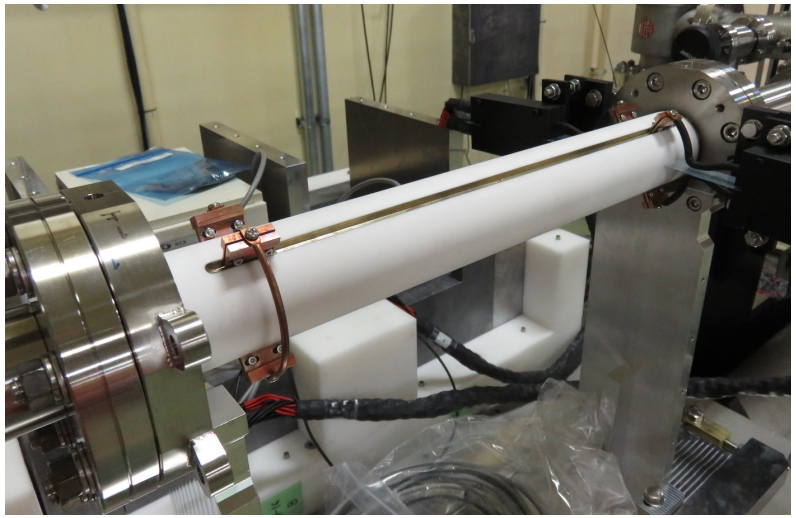
K. Yokoyama

Upgrade item [3] Linac Fast Kicker

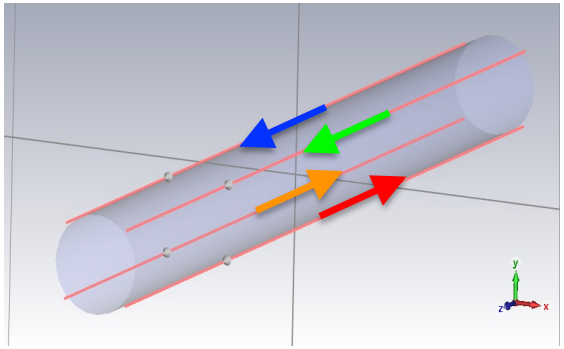
- 1st/2nd bunch orbit difference tuning is important because of
  - Injection efficiency improvement for both of bunches
  - Suppression of emittance growth with orbit offset in linac
  - Reduction of beam loss due to orbit difference

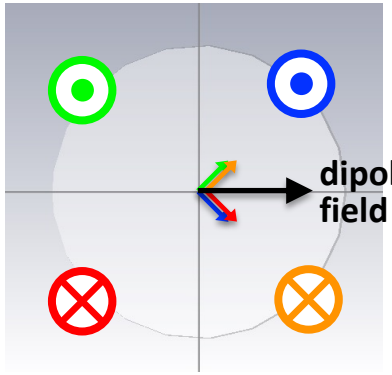
- Requirements for the linac fast kicker
  - pulse rise time < bunch interval (96 ns)
  - sufficient kick angle ~ 0.4 mrad @1.5 GeV
    BL = 2.0×10^{-3} T.m

Ceramic chamber type Fast Kicker



C. Mitsuda





- CCiPM : Ceramics Chamber with integrated Pulsed Magnet
- Magnetic field type kicker
- This kicker has four parallel coil wires.
- The current configuration described above
  (parallel and anti-parallel currents) generates
  horizontal dipole magnetic field, (vertical beam kick).

Pulse power supply for fast kicker

- Characteristics of pulse power supply
  - SiC FET high-voltage switch
    (supplied by Nexfi company)
  - pulse rise time < 96 ns
    to kick only 2nd bunch
  - max current 1000 A
  - mac voltage 20 kV
  - precise timing control
    for kick angle fine tuning
  - switch module installed in the tunnel
    close to kicker magnet
    (needs thick radiation shield)

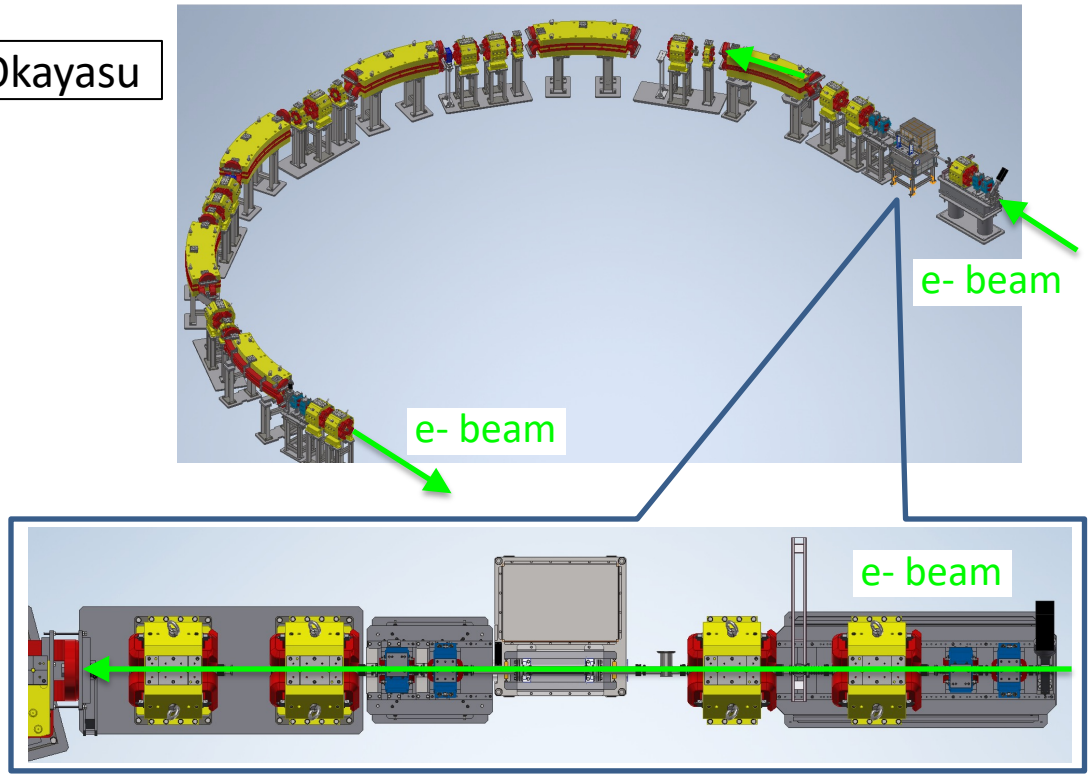
Y. Enomoto, T. Natsui, Y. Okayasu

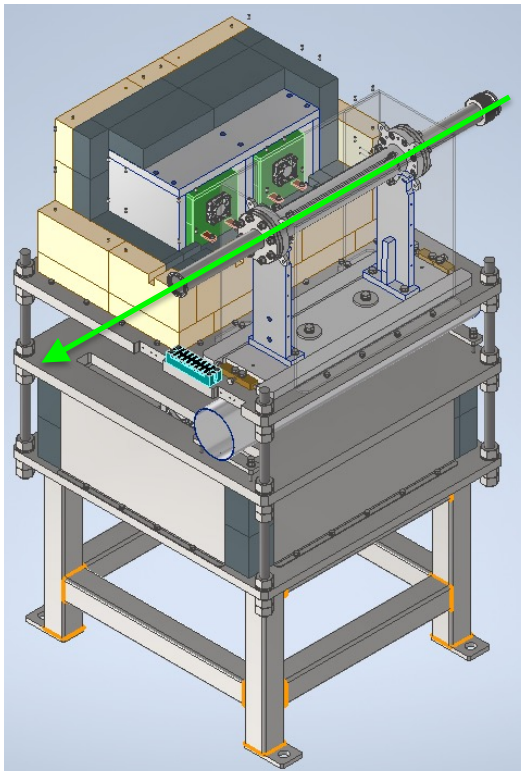
first prototype
pulse power supply
at test stand

Fast Kicker Installation

- The first prototype of ceramic chamber type fast kicker has been installed in summer of 2022 in J-arc.
- Stand-alone operation test and beam-kick test in this winter.

Y. Okayasu





- Next two kickers will be installed at linac Sector-4 and 5 in summer of 2023 for the operation after LS1

Summary & schedule

- Linac status & recent improvements
  - Linac stably injects e-/e+ beams to HER, LER, PF & AR.
  - [1] e- beam intensity recovered by RF-gun laser window replacement
  - [2] e+ bunch orbit difference compensated with fast strip line kicker

- Linac upgrade items during LS1
  - [1] Installation of 8 pulsed quads at J-arc matching section
    for independent optics matching for each mode (summer of 2023)
  - [2] Installation of 4 pulsed quads at Sector-1, 2
    for e- beam betatron function reduction (summer of 2023)
  - [3] Installation of ceramic chamber type fast kicker
    for 1st, 2nd bunch orbit difference tuning
    first prototype (installed in summer of 2022),
    operation test (this winter)
    2nd, 3rd model (summer of 2023)