BT

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(BT group)

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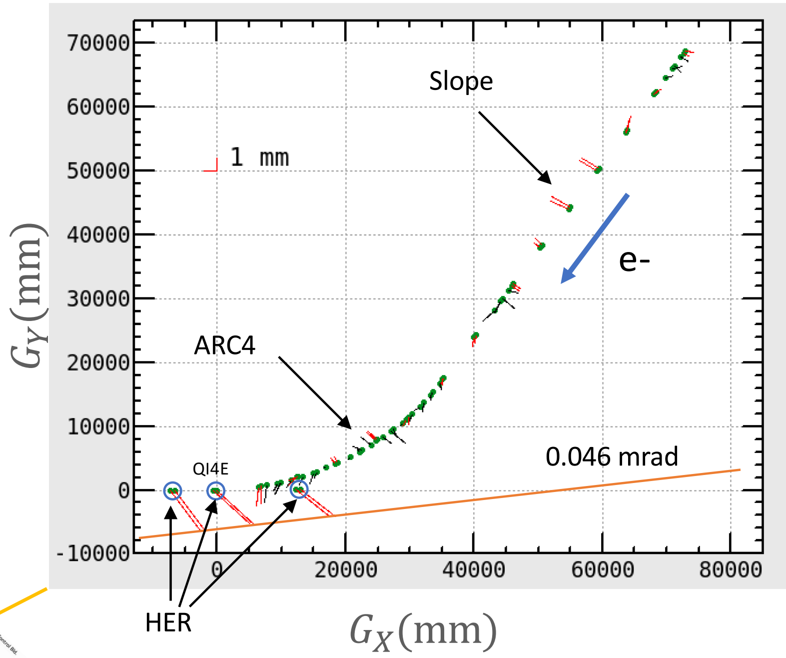
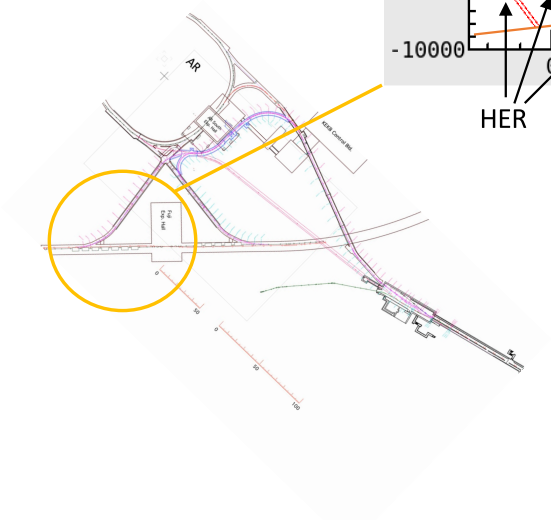
1. To improve injection efficiency

- Injection orbit changes and re-alignment at BT ARC4
- Field quality improvement of HER Septum 1
- Injection aperture improvement for HER

Injection orbit changes and re-alignment of BT e ARC4 **(Kikuchi)**

Survey results for magnets of the Electron BT and HER quadrupoles in the injection region (2018)





Green: design
Red: misalignment of quads
Blue: misalignment of bends

Findings:

- HER line is inclined relatively to the BT design by $\theta = .046\text{mrad}$.
- Quadrupole of HER at the injection point (QI4E) has relative offset to the design by $(\Delta G_X, \Delta G_Y) = (2.90, -2.73)(\text{mm})$
- Final quadrupole in the BT has misalignment of $(-.18, -1.42)(\text{mm})$

Countermeasure:

- Septum angles were adjusted to absorb the relative misalignment to the current HER line.
- During LS1, re-alignment will be performed for the four quadrupoles which have large misalignment greater than 1 mm.

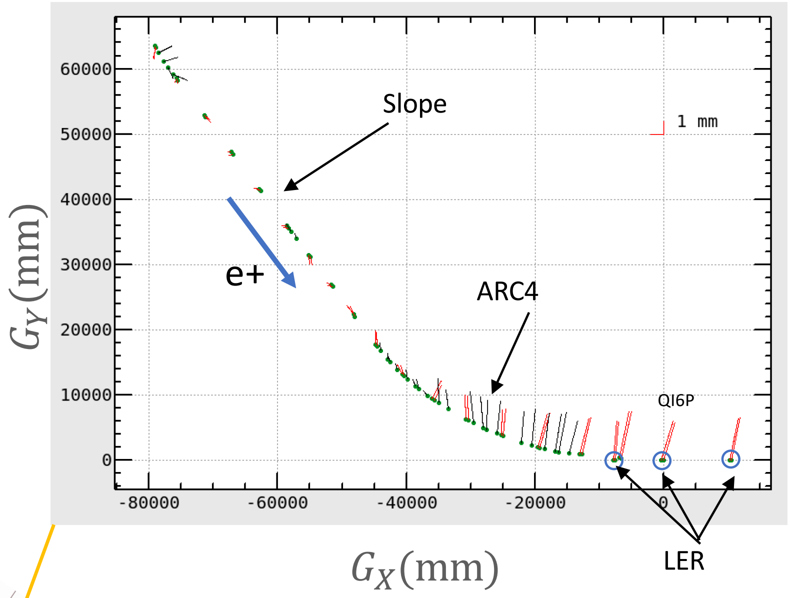
- Example of septum angle adjustment

$X_{inj} = 36\text{mm}$ $Px_{inj} = 2.44\text{mrad}$

	mrad	mrad	SKB-design
SE1	38.60	44.59	39.49
SE2	37.82	28.08	35.35
SE3	36.01	37.5	37.5
SE4	35.24	37.5	37.5
Sum	147.69	147.69	149.84

Injection orbit changes and re-alignment of BT p ARC4 **(Kikuchi)**

Survey results for magnets of the Positron BT and LER quadrupoles in the injection region (2018)



Green: design
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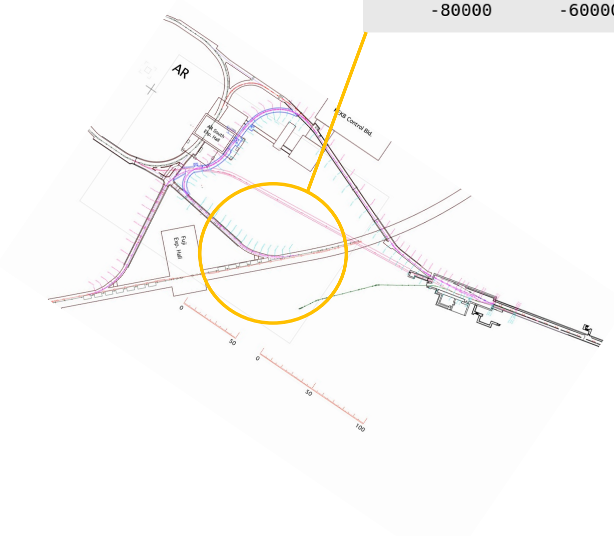


- Septum angle adjustment

$X_{inj} = 34.1\text{mm}$ $\quad Px_{inj} = 4.10\text{mrad}$

	mrad	SKB-operation July 2021*)
SP1	53.105	54.057
SP2	44.129	44.090
Sum	97.234	98.147

*) $X_{inj} = 32.76\text{mm}, Px_{inj} = 5.535\text{mrad}$

Findings:

- Both of BT line and LER have misalignment by $\Delta G_Y \sim 2.5\text{mm}$.
- Relative positions between BT and LER are almost correct.

Countermeasure:

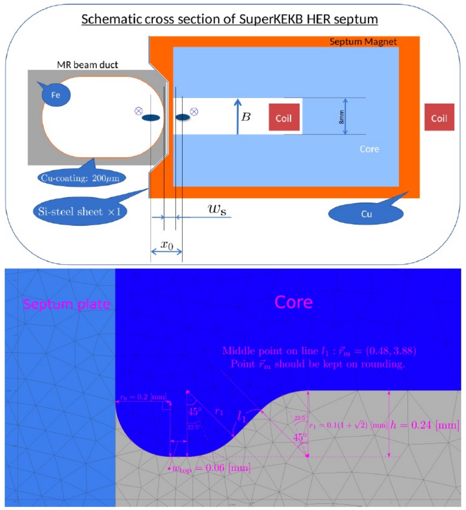
- Design of BT line was adjusted to match the misalignment of BT. Bend angle of ARC4 was adjusted by $\Delta\theta/\theta = 1.816\times10^{-4}$.
- Residual misalignment to the new design will be corrected.
- Septum angle are adjusted to match the current position of the injection quadrupole (QI6P).

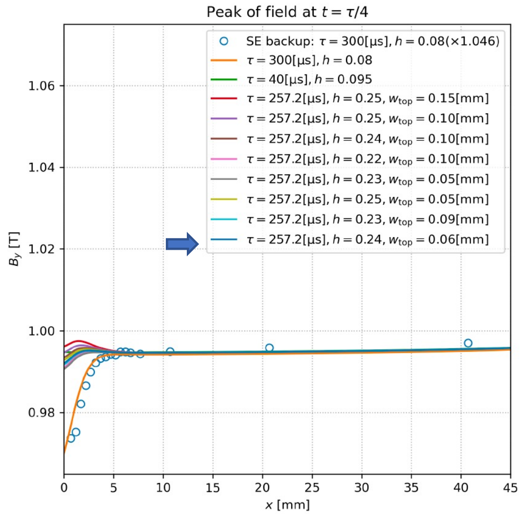
HER Septum 1: Field quality improvement (1) (Mori)

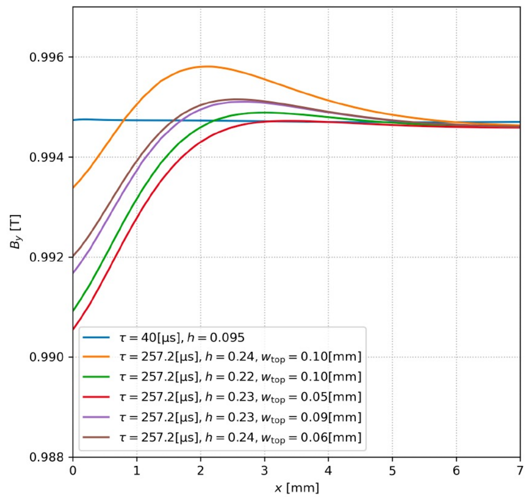
- It has been found that a fringe field near the septum plate has a sizable multipole component. A tracking simulation shows multipoles induces a vertical non-Gaussian tail, which could be a cause of a beam background as well as a bad injection efficiency.
- Adjustment of Q-magnets at upstream of the BT line for optics matching does not work completely for non-linear components.
- Improving the field quality of HER septum 1, which is nearest one to the injection point is important for injection efficiencies and backgrounds.
- Field quality would be improved by (1) reducing the pulse width of 300 → 257 μs by changing power supply's main capacitor and (2)Fine tuning of shim shape for the reduced pulse width.
- HER injection amplitude could be reduced from 11 to 8 mm in total.
  - 2mm (by field improvement of septum magnet) + 1mm (by injection aperture improvement) could be reduced.

HER Septum 1: Field quality improvement (2) (Mori)

Simulation studies are performed and we decided shim shape as shown in the lower left figure: the flat top width h=0.24 mm, wtop=0.06mm.





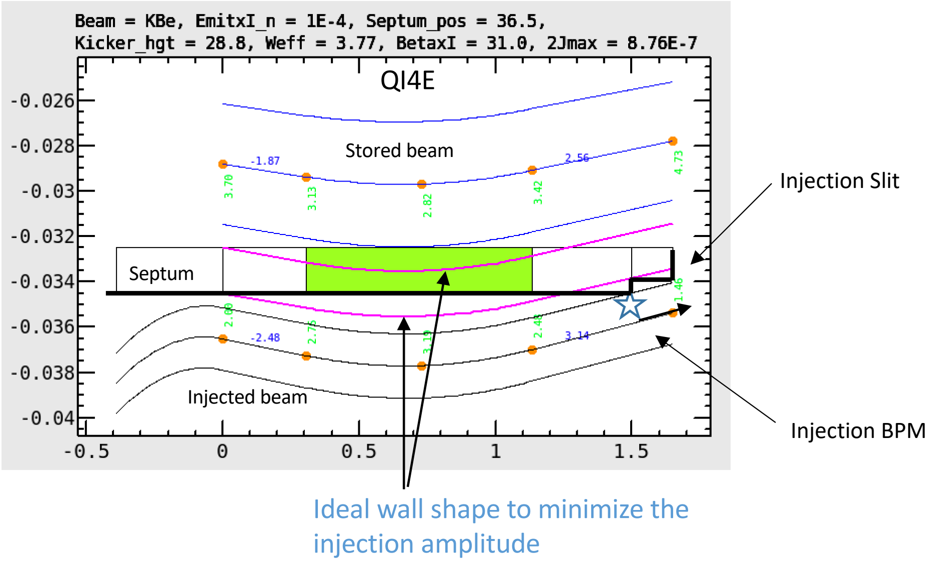


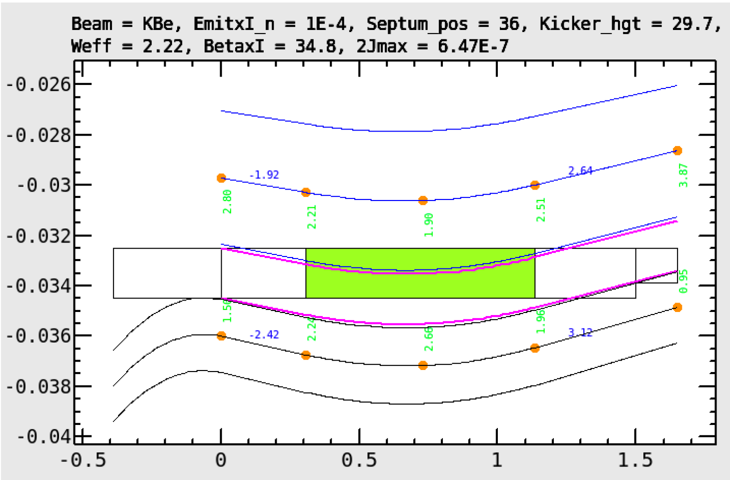
Issue for fabrication

- We noticed the silicon steel plate (JFE 0.35mm inorganic coating) used so far are not available any more. Another candidates (0.15 mm inorganic coating or 0.35 mm organic coating) are found but it must be evaluated for punching accuracy and outgas performance.
- Therefore, the fabrication is delayed and installation will be scheduled in summer 2024.

Injection aperture improvement for HER (Kikcuhi)

HER injection orbit and the chamber wall



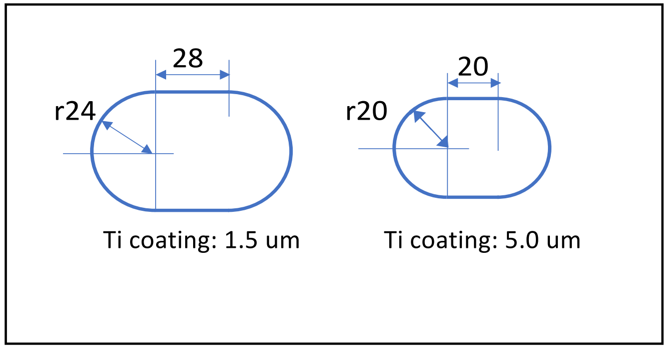


- In the current configuration the injected beam is expected to touch the quad chamber before it touches the septum wall.
- Very high residual radiation-activity, which was found at the flange of the “Injection BPM” chamber, supports this hypothesis.
- Kicker orbit changes cannot avoid this geometrical conflict because it interferes with the constraint from the abort orbit.
- A new chamber for QI4E was designed which has enough clearance to the injected beam (see Vac-group report).
- The “ideal shape” of the chamber wall was partially incorporated in the new design, which minimize the injection aperture.
- If the “ideal shape” is realized injection aperture will decrease from $0.88\mu m$ to $0.65\mu m$.

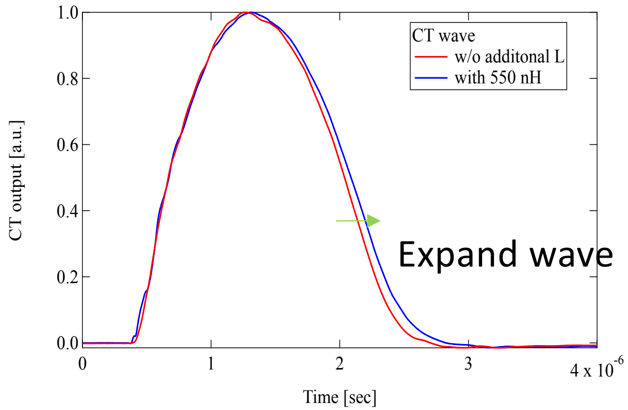
2. Hardware issues and updates

- LER kicker issues
  - Leakage of LER injection bump orbit
  - self-firing troubles of thyratron tube
- DR extraction kicker stability issue
  - DR kicker temperature stability improvement
  - Temperature stability improvement of facility cooling water
  - Fast kicker for 2nd bunch in RTL
- Monitor upgrades
  - BT-BPM
  - Radiation profile monitors (BT-SRM, Screen)
  - CSR monitor

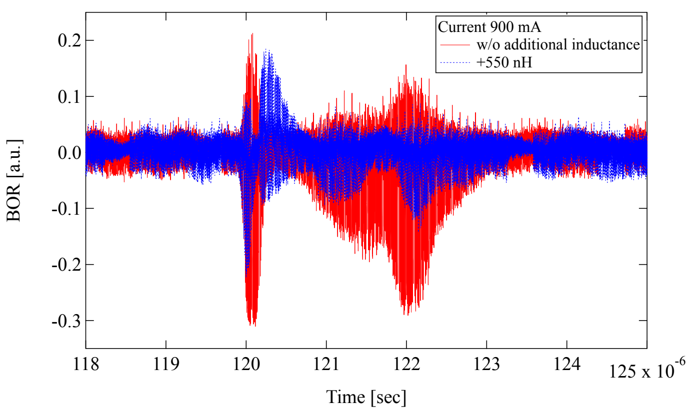
LER Kicker: Leakage of LER injection orbit bump (Kodama and Mimashi)



K1(left) and K2(right) duct shape



Additional inductance effect for K1 CT wave

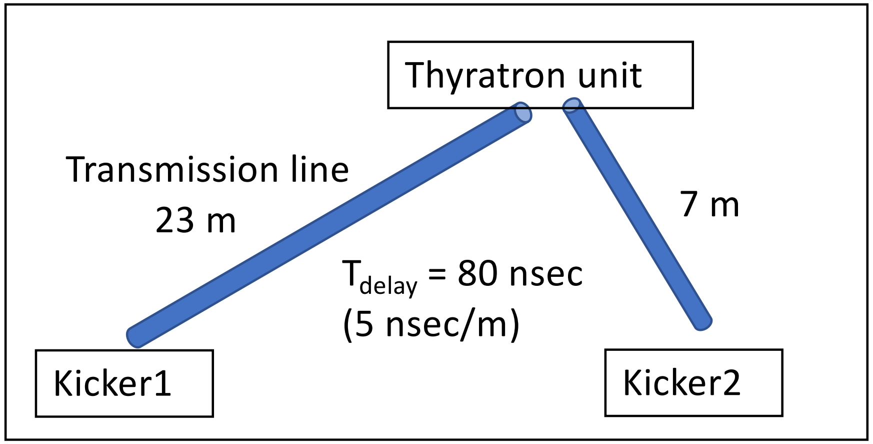


Additional inductance effect for BOR

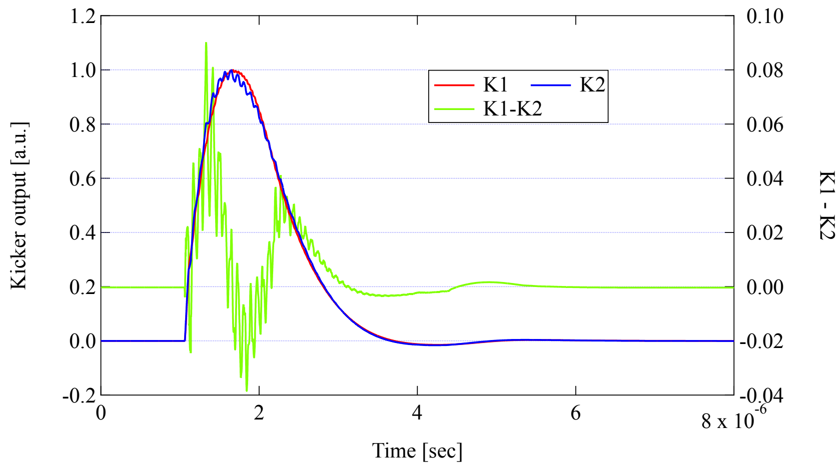
- Leakage of LER injection orbit bump was observed by BOR while kicker's current waveforms are almost same between K1 and K2. The horizontal oscillation is coupled to the vertical. This may cause the luminosity degradation.
- Leakage kick might comes from the differences of ceramic duct shape and Ti coating thickness.
- We have tried to expand K1 current waveform with additional inductance of 550 nH in series. But the leakage couldn't be reduced as we expected.
- Need to manufacture new K2-type ceramic ducts and replace K1 ducts to new one in 2024. (The budget was not allowed in 2022.)

LER kicker: Self-firing troubles and coutermeasure (Kodama, Naito and Mimashi)

- Self-firing troubles in 2021-2022
  - By using the thyratron which had been stocked for a long time but new one, self-firing had been occurred several times.
  - Self-firing of new thyratrons recently purchased had also occurred.
- Countermeasure for self-firing
  - Prepare test stand for incoming inspection and aging of thyratrons.
  - R&D of the double kicker driven by one thyratron unit.
    - Double kicker has different output between K1 and K2 due to different cable length to make the time delay. K1:K2 ratio will be fixed for the double kicker. If optics accepted this condition, we will continue to design double kicker system.

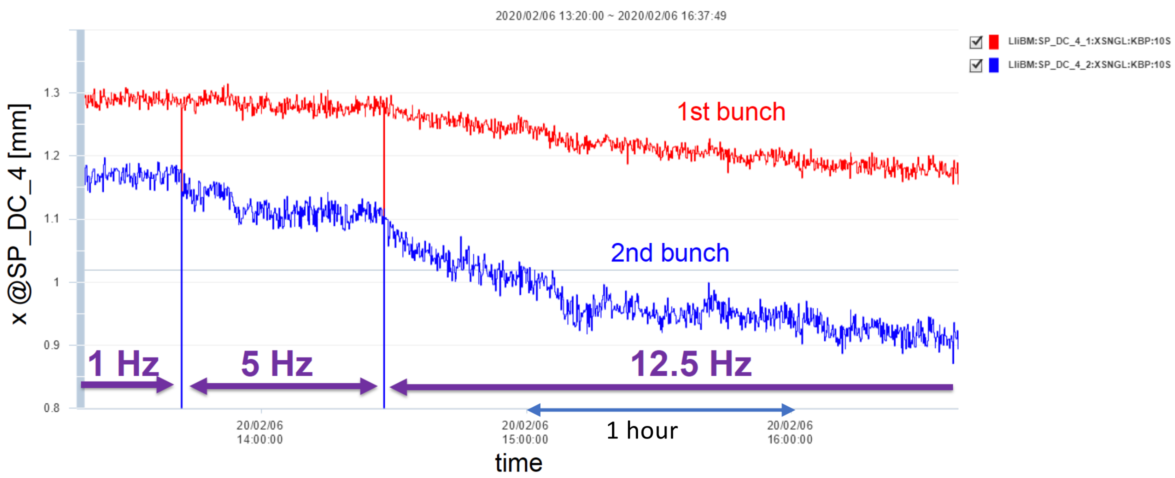


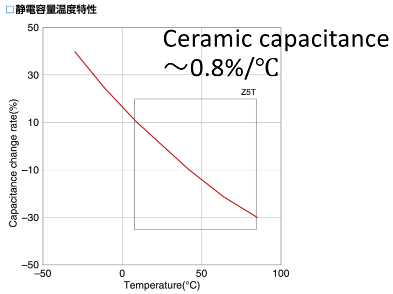
Schematic image of double kicker system

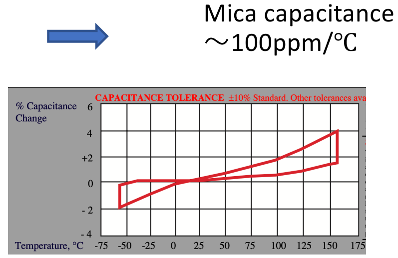


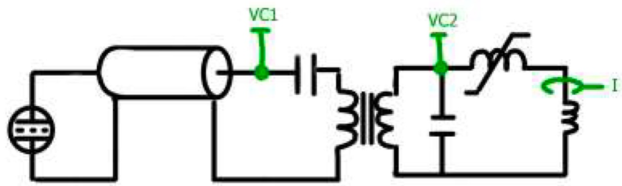
Simulated Kicker waves for double kicker system(1)

DR ext. kicker stability (Tawada)

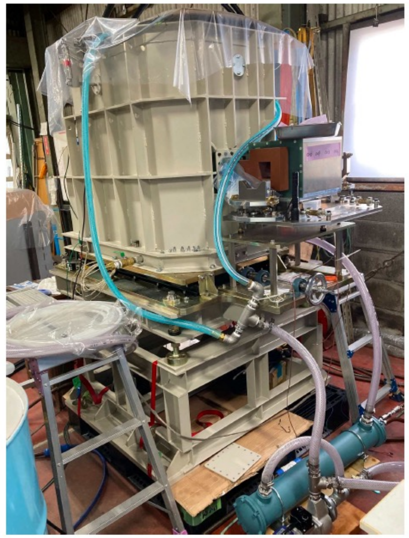








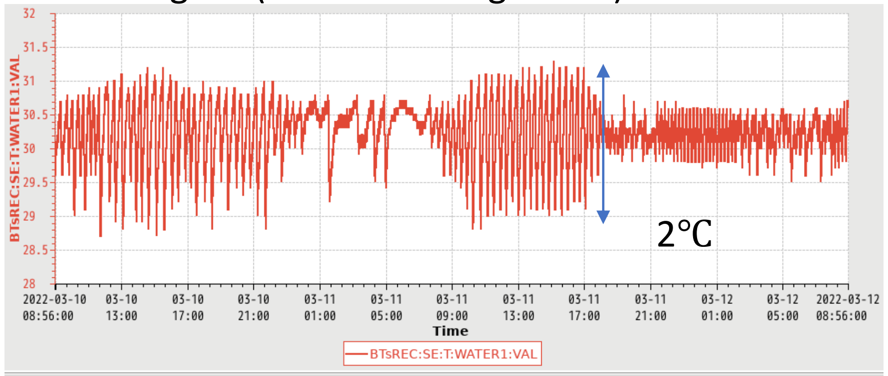
- Slow orbit drift was observed at the Linac BPM. These orbit drift changes when the repetition changed, which is more prominent in the 2nd bunch.
- It takes long time to reach the equilibrium for the high repetition rate (> 2 hour for 12.5Hz).
- This may be due to the temperature dependence both of capacitance and FINEMET core, which is used as a saturable inductance in the magnetics switch and thus determines the fire timing. We will replace the capacitor from a ceramic to a mica type, which is less temperature dependent. And cooling system of FINEMET will be improved by using a water-cooled forced circulating oil.



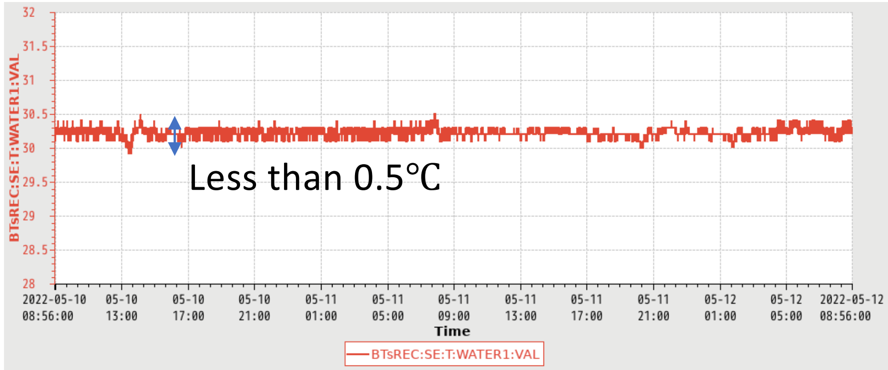
Temperature stability improvements of facility cooling water (T. Naito)

The temperature control parameters of the facility cooling water were optimized. In order to minimize the temperature change, the on/off temperatures of the cooling towers are set to different value and the PID parameters of the three-directional valve are set to the long interval.

DR magnet (M22-B cooling water)



Before improvements

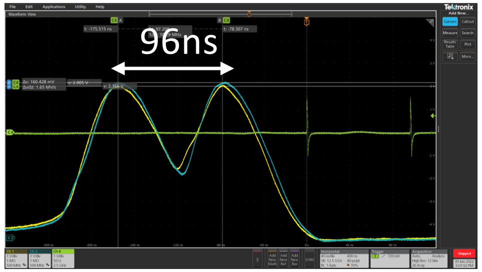


After improvements

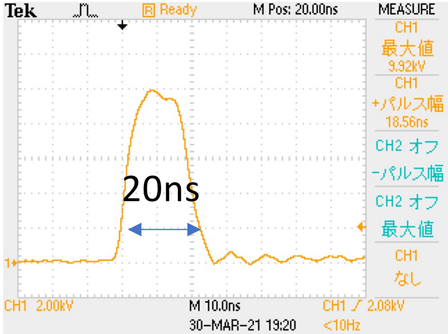
The temperature change was reduced from 2deg to less than 0.5deg. The most of time, the temperature kept to 0.1 or 0.2 deg.

The other region of the the facility cooling water in BT, KEKB-BT magnet (AS-PWP-5 cooling water) and Septum magnet (FM-PWP-3 cooling water) can be stabilized by using same method.

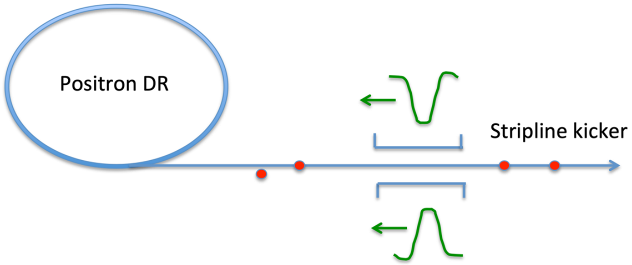
DR-RTL: Fast Kicker (Naito and Kodama)

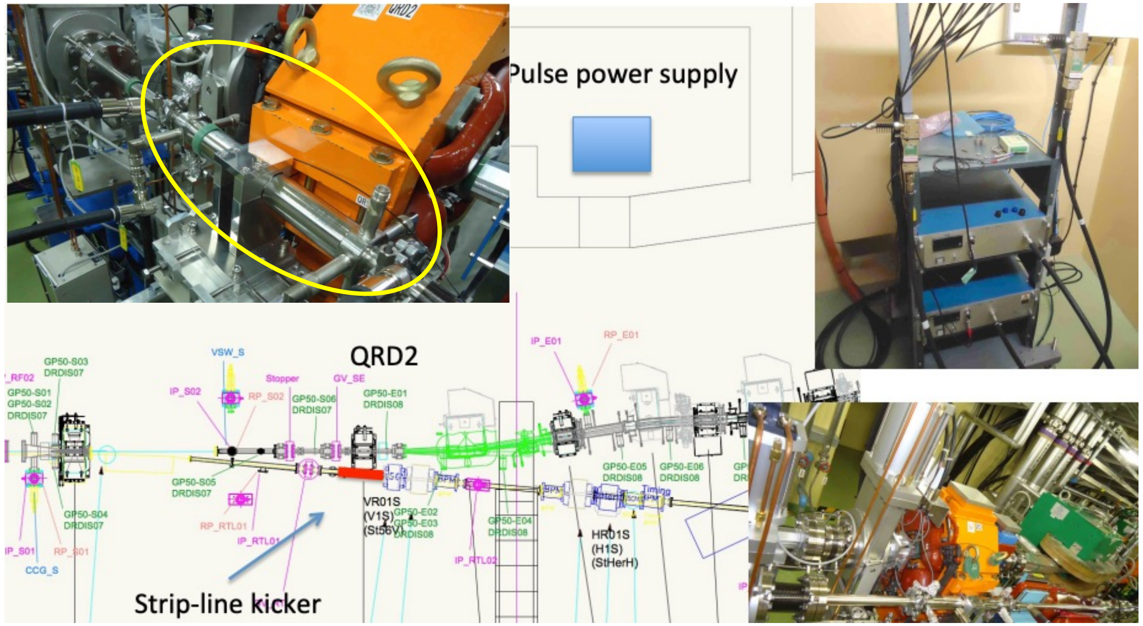


DR extraction kicker

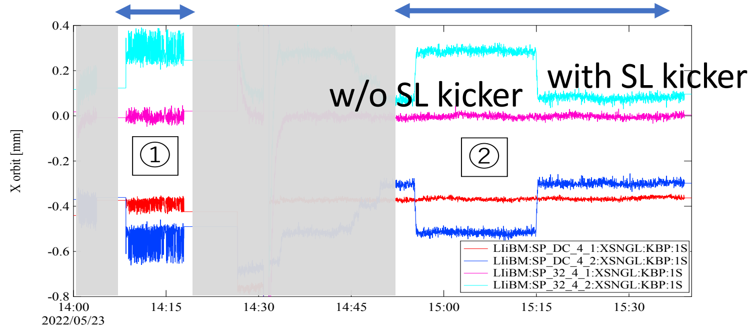


DR-RTL fast kicker





- It takes time to adjust kick angles (～5mrad) of two bunches extracted from DR, because two successive kicker pulses are overlapped each other and they are interrelated in the fire-timing as well as in the pulse height.
- Installed a fast kicker system to kick 2nd bunch only to RTL.
  - Stripline kicker for ATF (L=0.33m) are reused and PS are newly built.
  - Kick angle: 0.14 mrad with ±8kV, pulse width:20ns, Horz./Vert.
  - Kick angle could be larger if longer kicker is used.



Stripline kicker test with beam

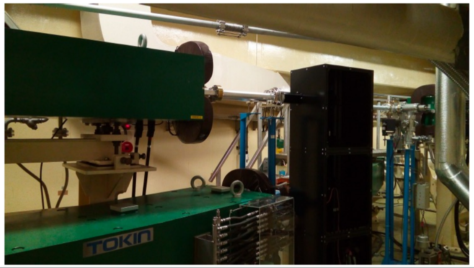
BT-BPM status: (Mori)

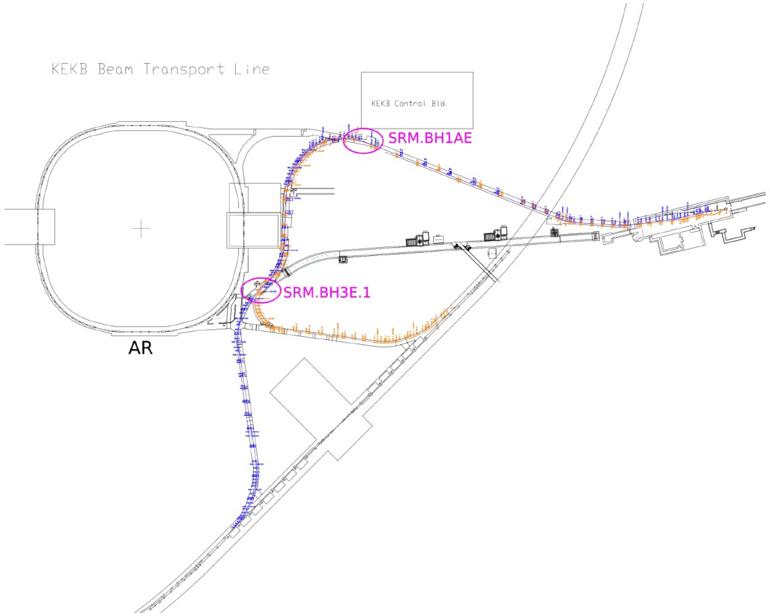
- Old BT-BPM Oscilloscopes
  - Eight old oscilloscopes (Tektronix DPO7104, 4-ch, 1 GHz, 8-bit) have been used for BT-BPMs since 2007 and hardware troubles have occurred several times.
  - Those should be updated and Rhode & Schwarz RTO2014 (4-ch, 2 GHz, 10-bit), which was only one candidate and can work at 50Hz repetition rate but it was sold out last year. We are looking for a oscilloscope or digitizer which meets the required specifications.
  - Some BPM must be re-cabled not to make the 2^{nd} bunch signals overlapped each other.
- Libera SPE
  - Libera SPE will be ready for BPMs at BT end of e-/e+ lines, which have direct cables , during next run.
  - It can receive EVR data buffers and change parameters by event code (31=e-/41=e+) and mark it by ShotID.
  - Switching of e-/e+ is performed by RF switch, which is prior to Libera SPE.

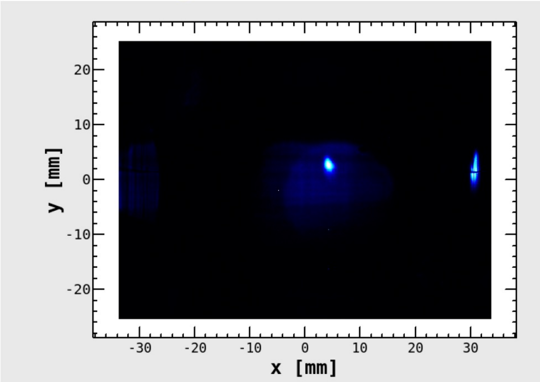
BT-SRM (Synchrotron Radiation Monitor): (Mori)

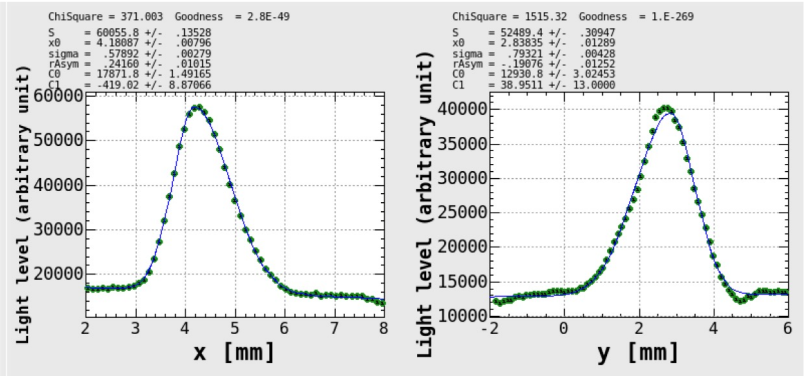
- SRM for e- was installed at the beginning of ARC3 (BH3E.1) and second one will be installed at ARC1 (BH1AE).
- We have just started to measure the beam profile. The measured beam sizes are good agreement with the rough calculation. But it is still preliminary and the further check is needed.

SRM@BH3E.1









Design parameters at B-magnet:

$$\beta_x = 2.79 \text{ [m]}$$
$$\beta_y = 131 \text{ [m]}$$
$$\eta_x = 0.369 \text{ [m]}$$

Assumption:

$$\gamma\varepsilon_x = 300 \text{ [}\mu\text{m]}$$
$$\gamma\varepsilon_y = 70.0 \text{ [}\mu\text{m]}$$
$$\delta = 1.50 \times 10^{-3}$$

Rough estimation of beam sizes:

$$\sigma_x = \underline{0.606} \text{ [mm]}$$
$$\sigma_y = \underline{0.818} \text{ [mm]}$$

$$\sigma_x = \underline{0.578} \pm 0.003, \sigma_y = \underline{0.793} \pm 0.004$$

BT-OTR monitors : (Mori)

- Changing fluorescent screen monitors to OTR monitors in BT e±-lines.
- Will measure the bunch-by-bunch beam profiles by using an imaging intensifier (Hamamatsu C14245), which can control gate width with accuracy of a few ns.
- The beam profile data can be related to BPM's position data by using ShotID or event timing.

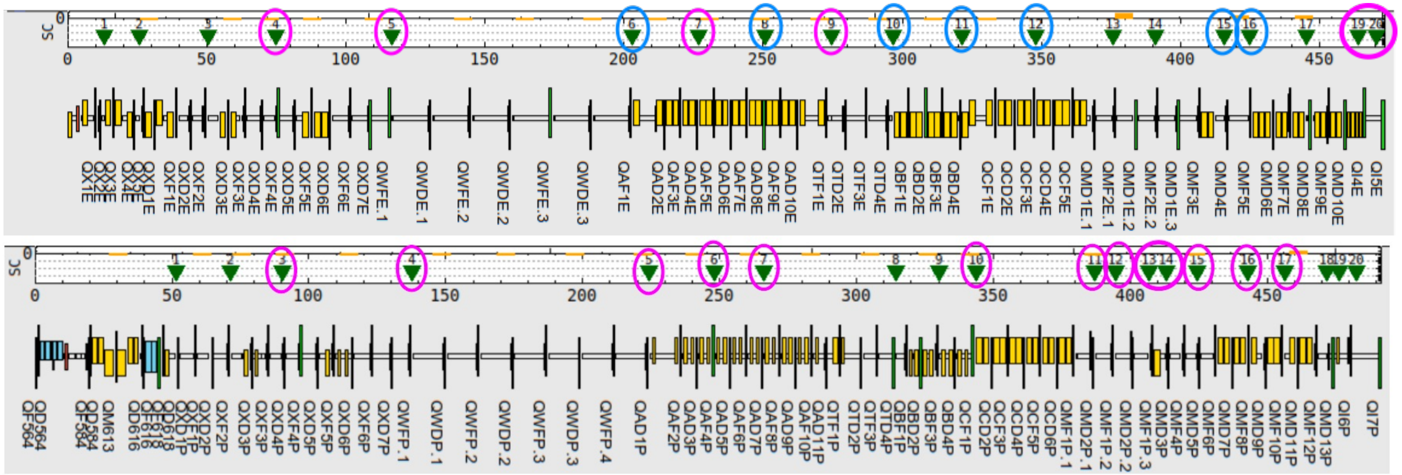
Locations of OTR monitor at BT line

Linac END

BT End

e^-

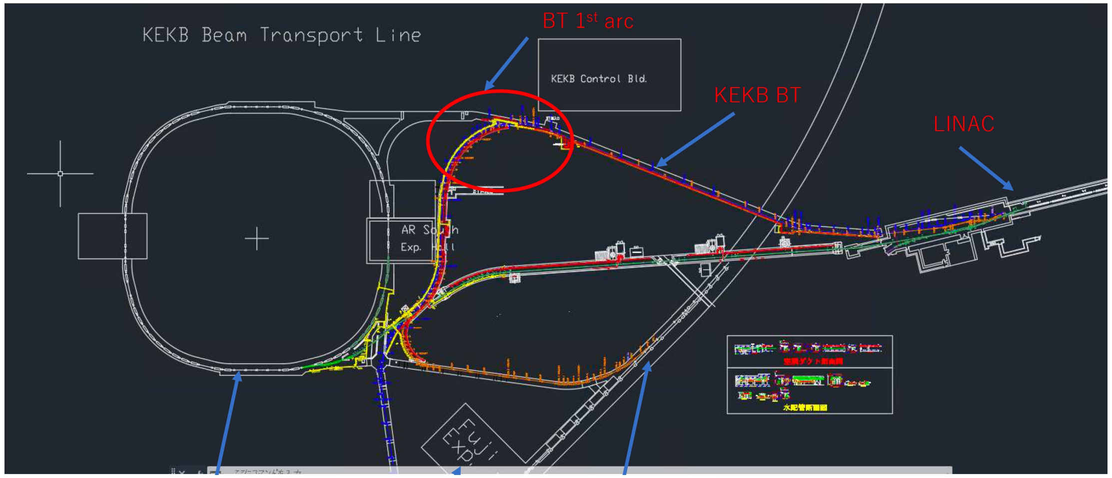
e^+

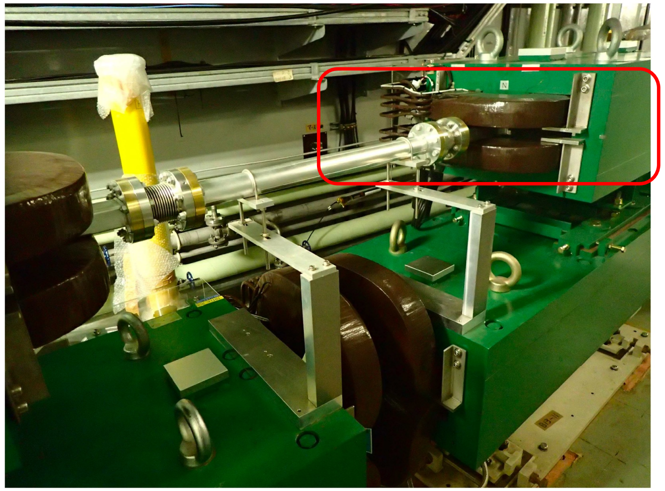


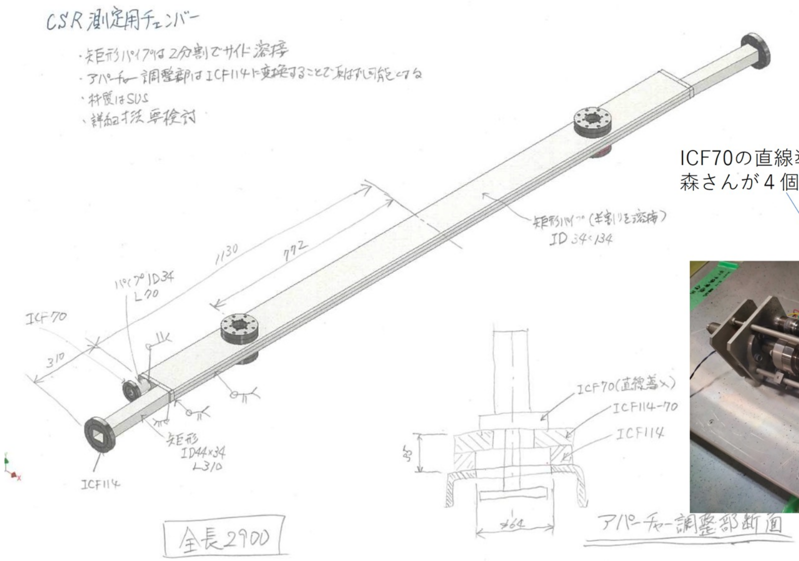
○: OTR monitors already in use.

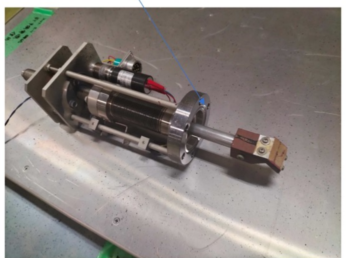
○: OTR monitors which will be ready until the end of LS1.

Emittance growth: CSR monitor (Terui)

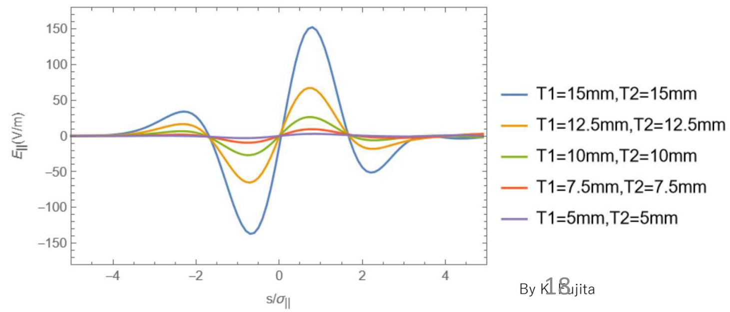








- Plan to replace one vac. chamber of BTp 1st arc bending magnet with a branch pipe to monitor CSR. (No space for BTe.)
- Gap height of vac. chamber can be changed.
- Simulations for infinite parallel plates with various gap height are also on-going by Fujita-san. Smaller gap height is preferable to reduce CSR effect.



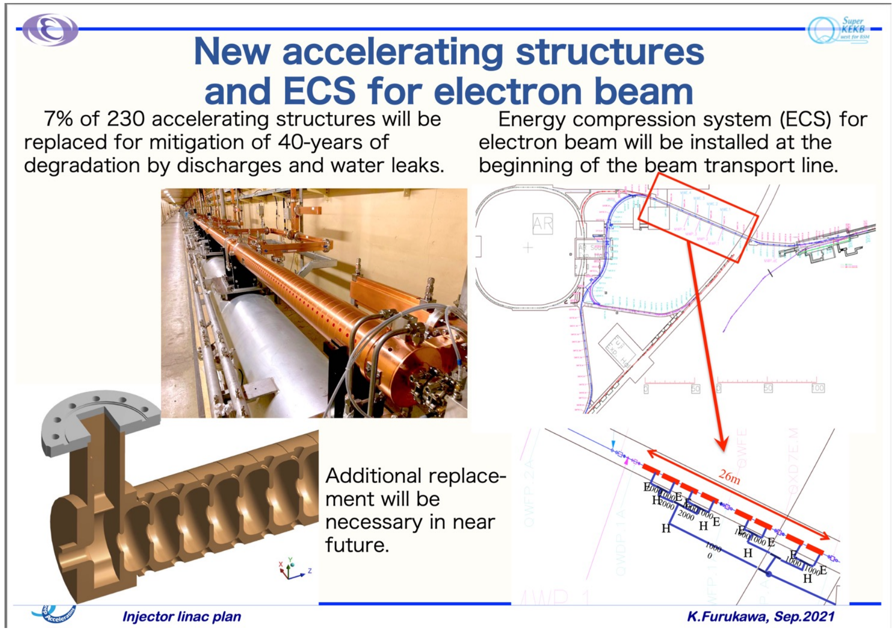
Upgrade plans in BT

- BT e- ECS by Linac group
- New BT e- Line for HER

BT e- ECS

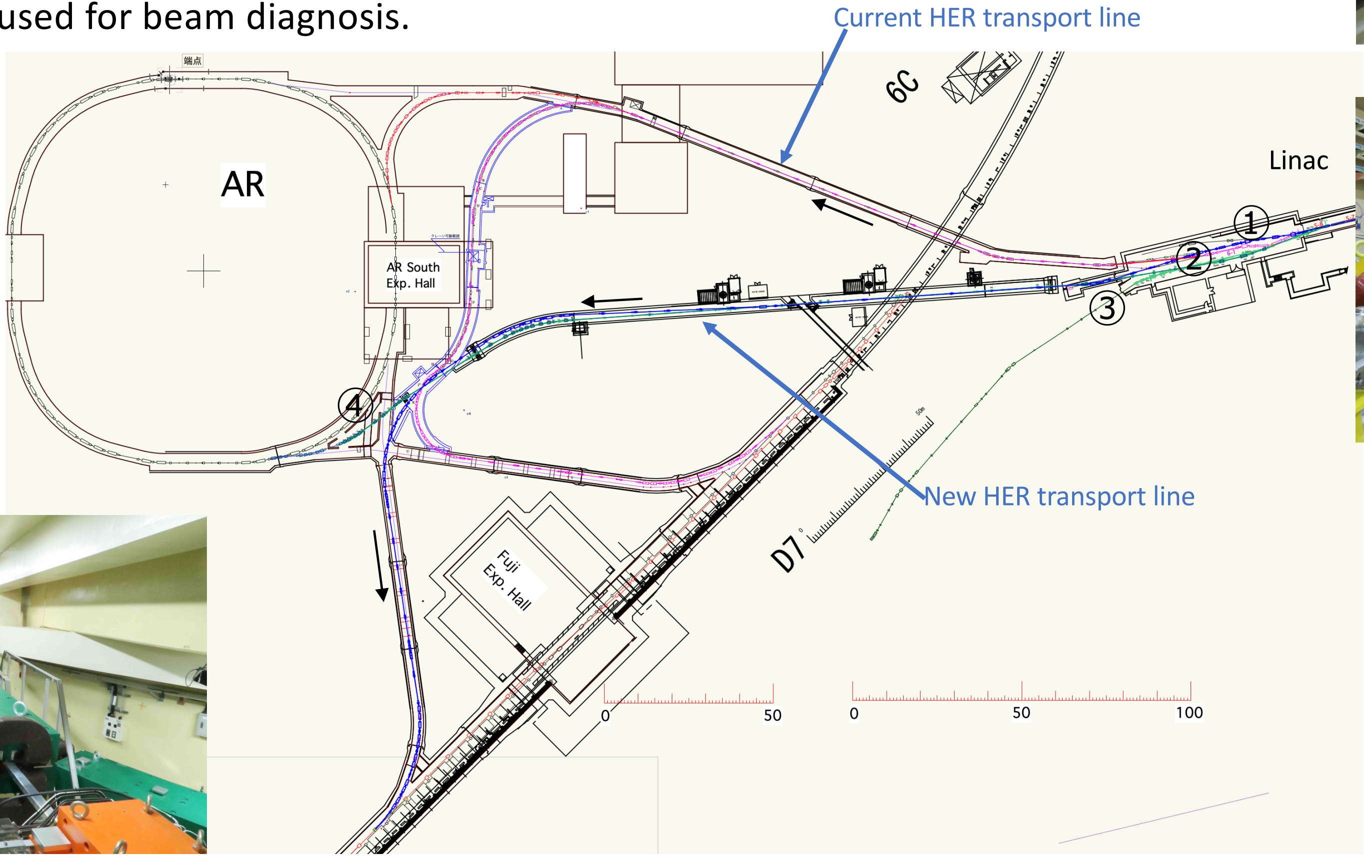
- Because the budget of 1.7 oku-yen (1.25M$) for e- ECS fabrication had been already approved, the e- ECS components and the facility cooling water system must be fabricated in three years.
- Linac group has just started the study of the effectiveness and feasibility of e- ECS, including beam loss rates.
- Because BT tunnel has poor radiation shields (0.4 m of concrete + 1.1 m of soil) for public area, additional radiation shields might be needed to incorporate e- ECS but it will be problems with maintainability.

The Twenty-Fifth KEKB Accelerator Review Committee

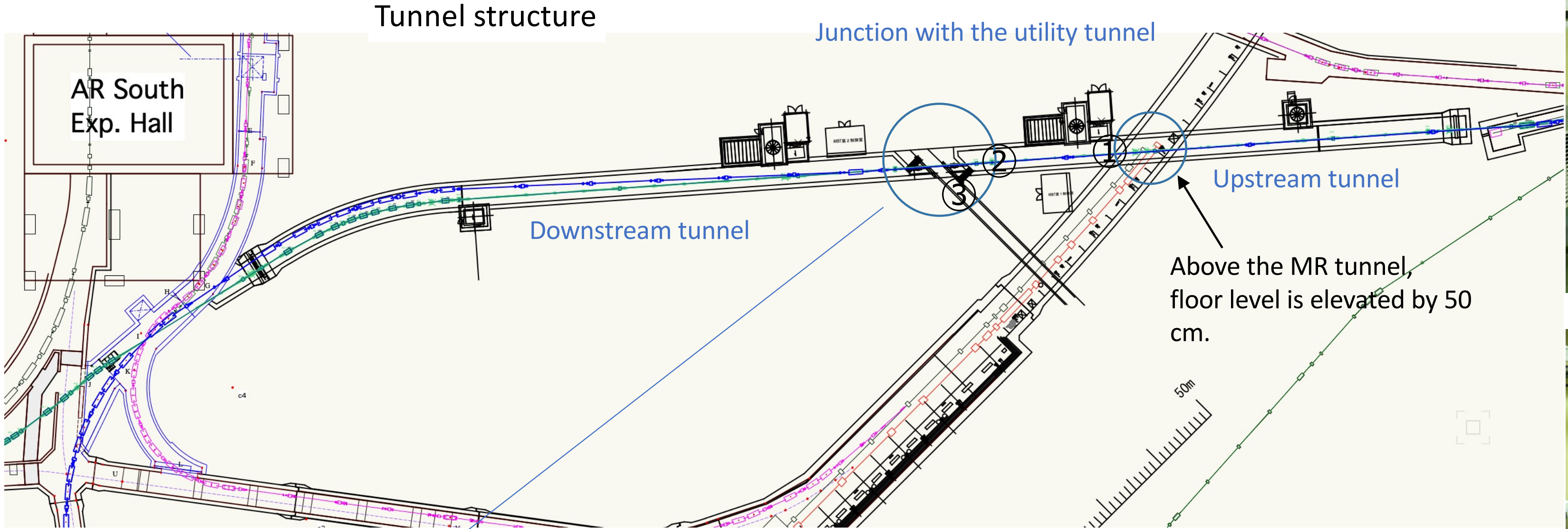


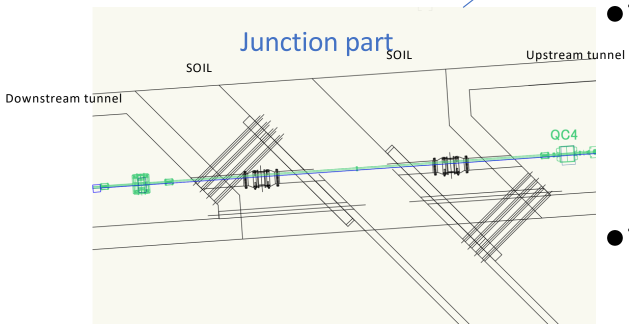
New BT line for HER (Kikuchi)

- New BT line for the HER has been proposed, that envisages ease of the CSR/ISR emittance growth.
- New line share the tunnel in part with PF-AR transport line.
- If we preserve the current BT e- line and can switch the beam pulse-by-pulse, the current line could be used for beam diagnosis.



New BT line for HER (Kikuchi)

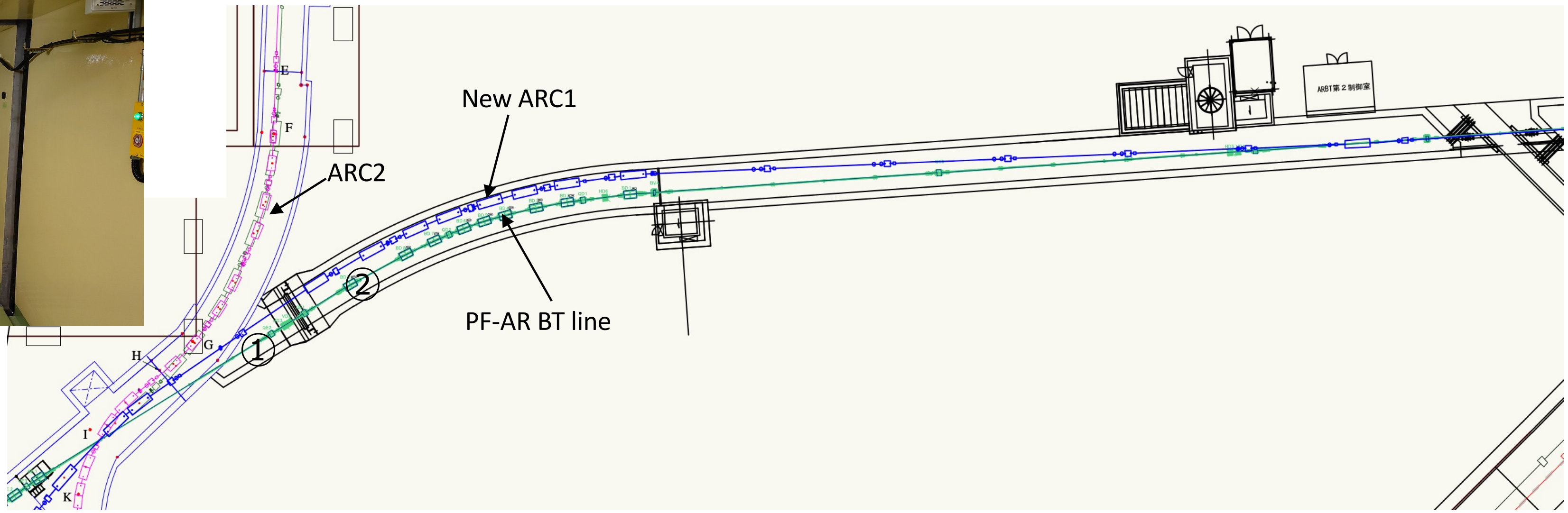




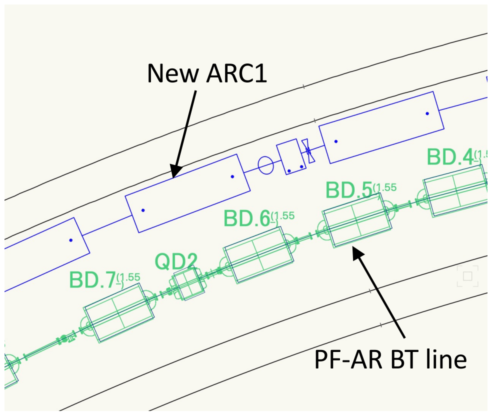
- The tunnel of PF-AR BT has two independent tunnels. They are loosely connected to the utility tunnel via bellows pipes which are embedded in soil. Beam pipes pass through the bellows pipes.
- The junction part has to be excavated to construct the new HER BT line.
- The utility tunnel houses many cable-ladders inside, and the BT line has to avoid collision with them; the beam pipe should pass in between the cable ladders, adjusting beam height with vertical translation.

New BT line for HER (Kikuchi)

Beam line

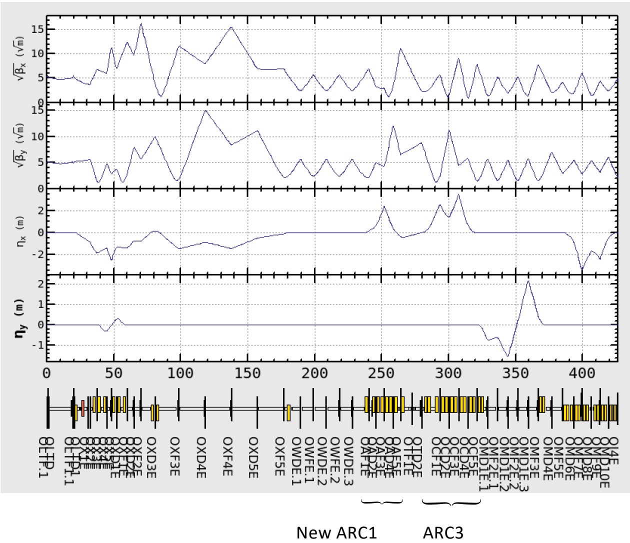


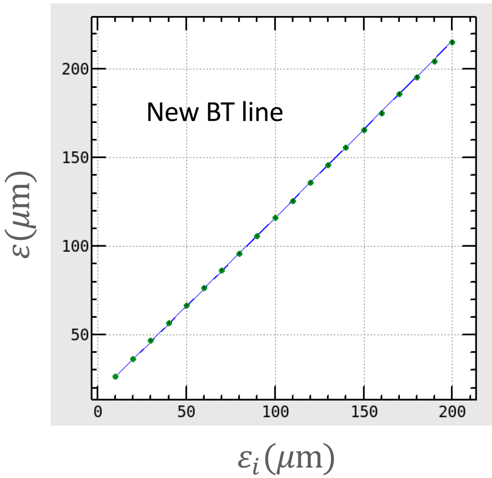
- ARC1 part is located side by side with the PF-AR line in the present plan .
- Beam level of the new line is 0.6 m lower than the PF-AR line.
- Transverse free space between the magnets of two lines are 0.5 m at minimum, which will make the maintenance work difficult.
- Bend angle is smaller than current ARC1. Since longer bend is preferable for the CSR we plan to reuse the bend in the ARC2, or to fabricate new bend that has smaller width.

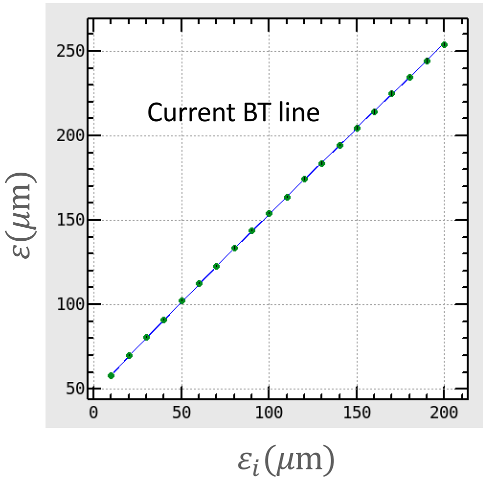


New BT line for HER (Kikuchi)

Optics







Emittance at Injection

- Emittance growth due to ISR

Results of tracking simulation are fitted to

$$\varepsilon = \sqrt{\varepsilon_q^2 + 2\varepsilon_p\varepsilon_i + \varepsilon_i^2} \simeq \varepsilon_q + \varepsilon_i$$

, where,

$$\begin{cases} \varepsilon_q = 16.79\ \mu\text{m}, \\ \varepsilon_p = 15.97\ \mu\text{m} \end{cases}$$ (New BT line)

$$\begin{cases} \varepsilon_q = 46.24\ \mu\text{m}, \\ \varepsilon_p = 57.35\ \mu\text{m} \end{cases}$$ (Current BT line)

- ISR induced emittance growth ε_q of the new BT line decreases to 1/3 of that in current BT line

Summary

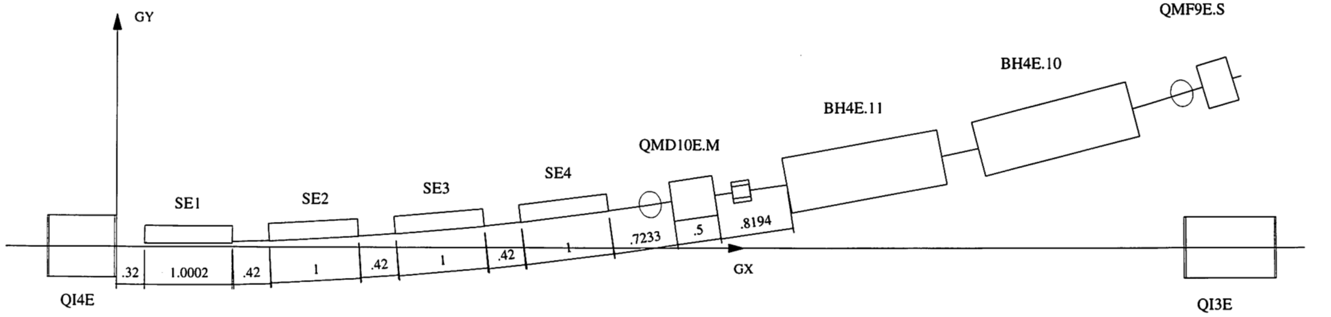
- For better injection efficiency, a few countermeasures will be performed.
- Some hardware have issues to be solved. The countermeasures are also in progress.
- The budget for e- ECS has already approved and the fabrication of ECS components are on-going. The effectiveness and feasibility study of e- ECS should be performed as soon as possible.
- New BT e- line for HER has just started to study. No apparent showstopper is found so far.
- Need to consider a consistent upgrade plan including e- ECS and New BT e- line for HER.

backup

Injection orbit changes and re-alignment of BT e ARC4 **(Kikuchi)**

- We have also found some mysterious discrepancy in the design
  - In design of SKB, alignment of BT line in the KEKB era was preserved except for septum magnets.
  - But we have found discrepancy in the design between SKB and KEKB:
    - At the entrance ofSE4 SKB design has $(\Delta G_Y, \Delta\chi_1) = (-2.5\mathrm{mm}, 2.08\mathrm{mrad})$ relative to KEKB design.
  - Considering misalignment of $\Delta G_Y = -2.73\mathrm{mm}$ for QI4E, net effect is a translation in G_Y for both of BT and HER by $\Delta G_Y \sim 2.5\mathrm{mm}$

Official Design of HER line in the KEKB era



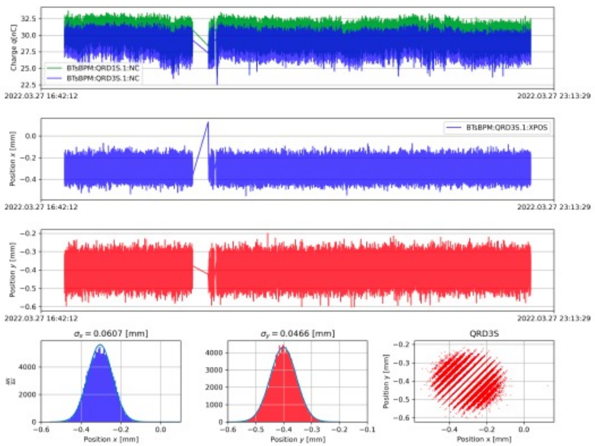
Element	GX(in)	GY(in)	CHI1(in)	GX(out)	GY(out)	CHI1(out)	GX(center)	GY(center)	L
BH4E.11	9.333249	1.04257	-0.217947	7.582857	0.719259	-0.147351			
QMD10E	6.772384	0.598962	-0.147351	6.277802	0.525553	-0.147351	6.52509	0.56226	0.50000
SE4	5.56232	0.419356	-0.147351	4.570578	0.291108	-0.109851	5.06765	0.34573	0.99999
SE3	4.153109	0.245064	-0.109851	3.157256	0.154088	-0.072351	3.65604	0.190238	0.99999
SE2	2.738355	0.123727	-0.072351	1.739791	0.070151	-0.034851	2.23958	0.08757	1.00000
SE1	1.320046	0.055517	-0.034851	0.32	0.039413	0.002649	0.82017	0.03809	1.00018
QI4E	0	0	0	-0.8	0	0			
QI3E	13.0807	0	0	12.0427	0	0			

注１：(GX,GY)座標系の原点はQI4Eの端板の外側とリングビームラインの交点である.
注２：CHI1は(-GX)軸から(+GY)軸方向に時計方向に測った角度である.
注３：QI4E,QI3Eは端板(t=19mm)を含めてかいてある．その他の電磁石ははコアを示している.

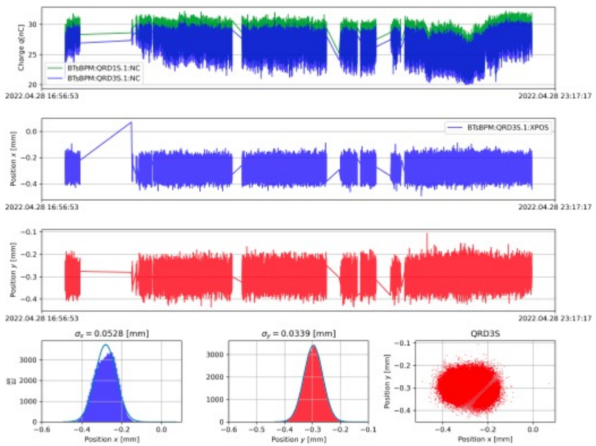
BT-BPM updates: (Mori)

BPM resolution improvement on RTL QRD with R&S RTO2014

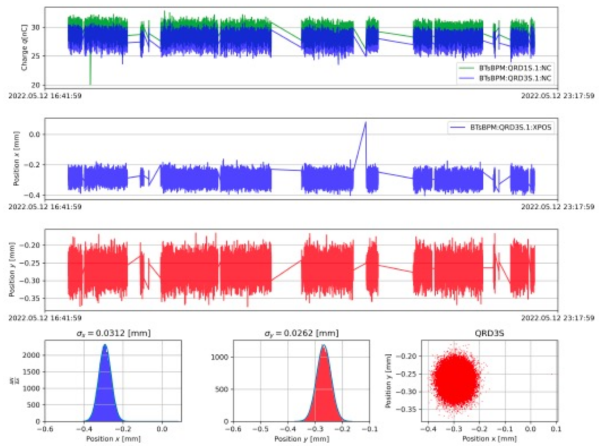
	Period	Oscilloscope mode	Signal processing	Resolution	
				σ_x [μm]	σ_y [μm]
(1)	start up - 4.26	normal (8-bit)	peak-to-peak	60.7	46.6
(2)	4.27 - 5.10	HD (10-bit)	peak-to-paek	52.8	33.9
(3)	5.11 - shutdown	HD (10-bit)	square-root-of-sum-of-squares	31.2	26.2



Period (1)



Period (2)

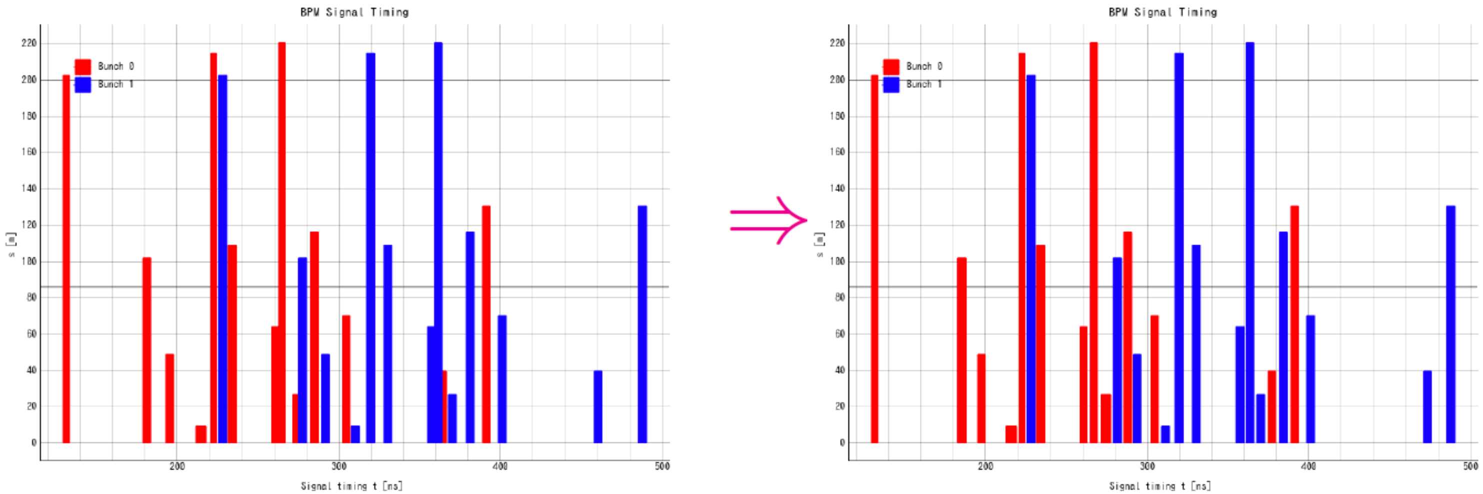


Period (3)

BT-BPM updates: (Mori)

Signal isolation in a two bunch operation

- It is planned to isolate every combined signal of two bunch by the adjustment of cable delays in the tunnel.



BPM	Delay [ns]
QX1E	1.0
QX5E	0.0
QXF1E	13.0
QXF2E	2.0
QXF3E	0.0
QXD4E	0.0
QXF6E	4.0
QXD7E	0.0
QWFE	3.0
QWDE	0.0
QAF1E	0.0
QAD2E	0.0
QAF3E	2.0

- Bar positions and widths represent signal timings and durations read by a channel of the most crowded one of oscilloscopes, respectively. The bar heights show the BPM location from the start of BT line.
- To add delays will isolate each signal from other, the isolated signals contribute to the energy resolution improvement.

DR-RTL: Fast Kicker (Naito and Kodama)

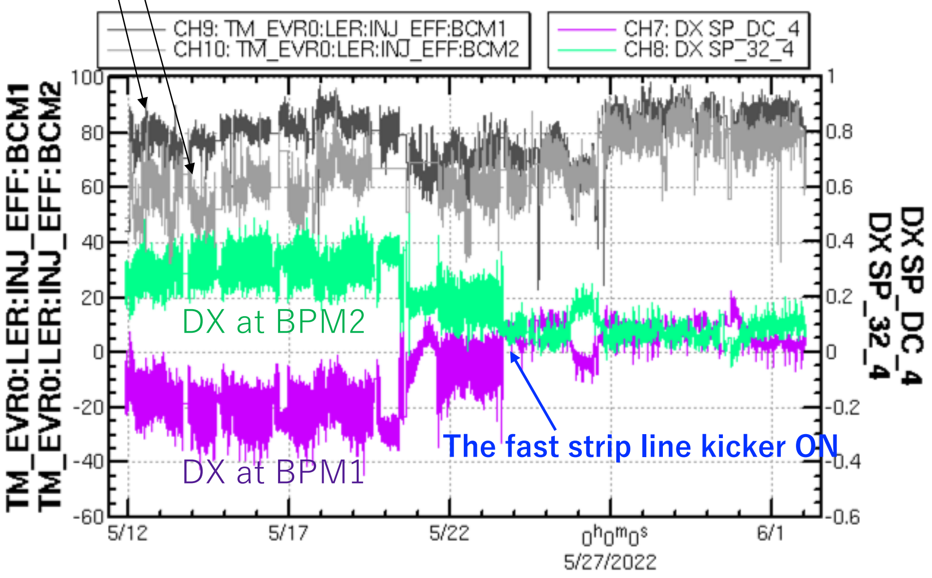
BITF_20220603_Iida

入射効率に関しては、小玉さんより物言い有り

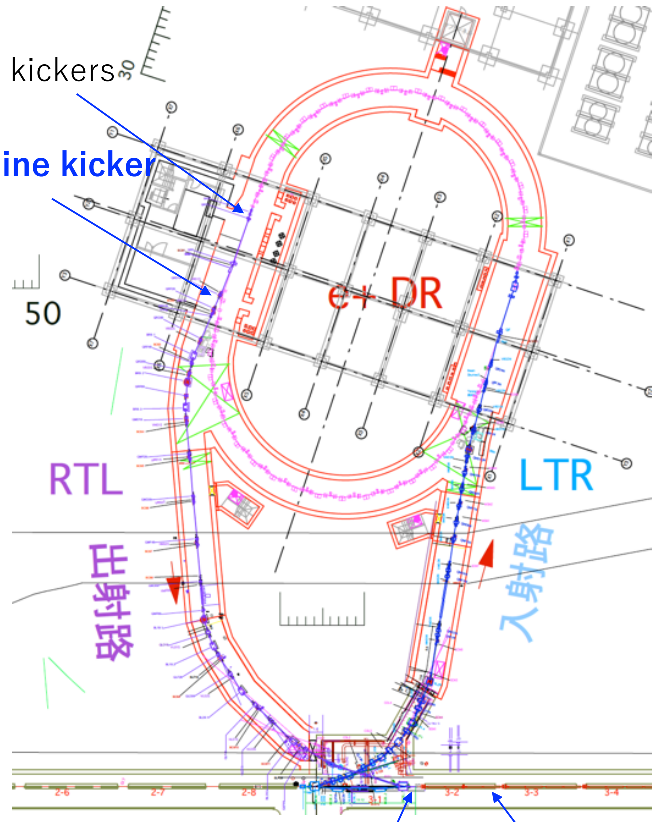
“Raw” injection efficiency of #1

“Raw” injection efficiency of #2

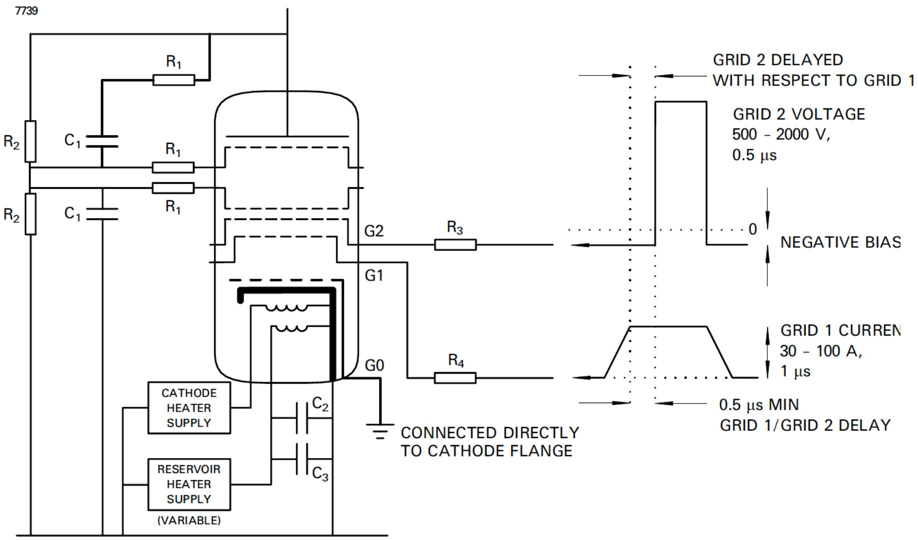
The efficiencies have been almost same since the kicker worked.

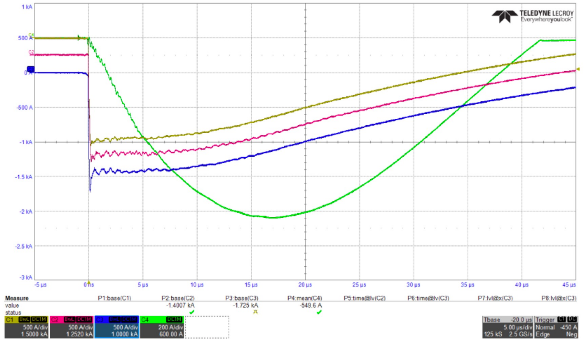


DX: Horizontal orbit difference (X_2-X_1)



HER/LER Abort Kicker : Trigger system





CH1（黄）：四極 1, 500A/div
CH2（赤）：四極 2, 500A/div
CH3（青）：水平, 500A/div
CH4（緑）：垂直 1, 200A/div
5us/div

- Rising time of abort kicker is less than 200 ns but It needs about 1 μs before the fire the thyratron by using Teledyne E2V triggering system.
- Will replace the trigger system to new one. (1 μs → 250 ns)