Status of Damping ring, beam transport line

20th KEKB ARC

M. Tawada

2015.02.24

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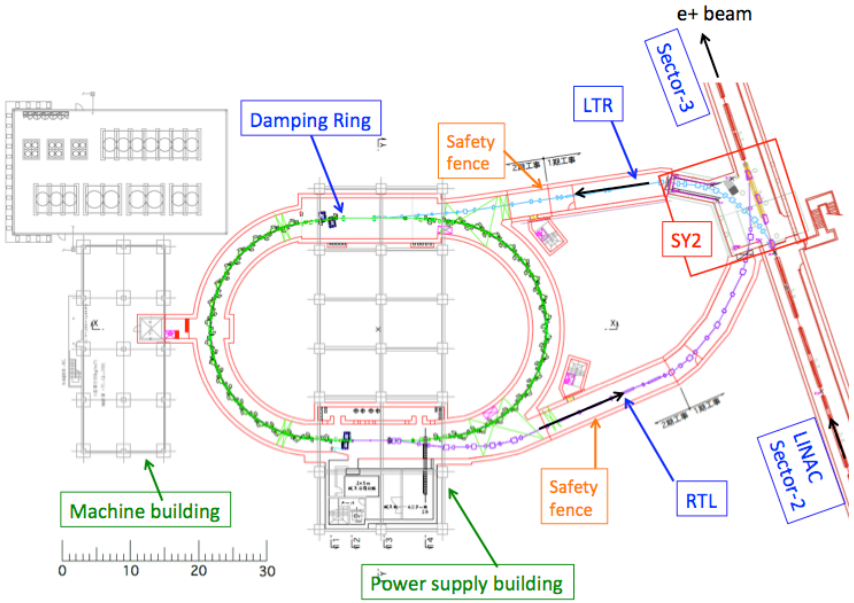
- Construction status of DR
- Status report of DR &BT component
  - Field measurements for DR magnet
  - DR Kicker
  - HER Septum magnet
  - Remodeling of HER septum power supply
  - Schedule for the new injection component
- DR install schedule & commissioning plan
- Summary

- Vacuum, RF and monitor of DR were presented by Shibata-san, Kobayashi-san and Ikeda-san, respectively.

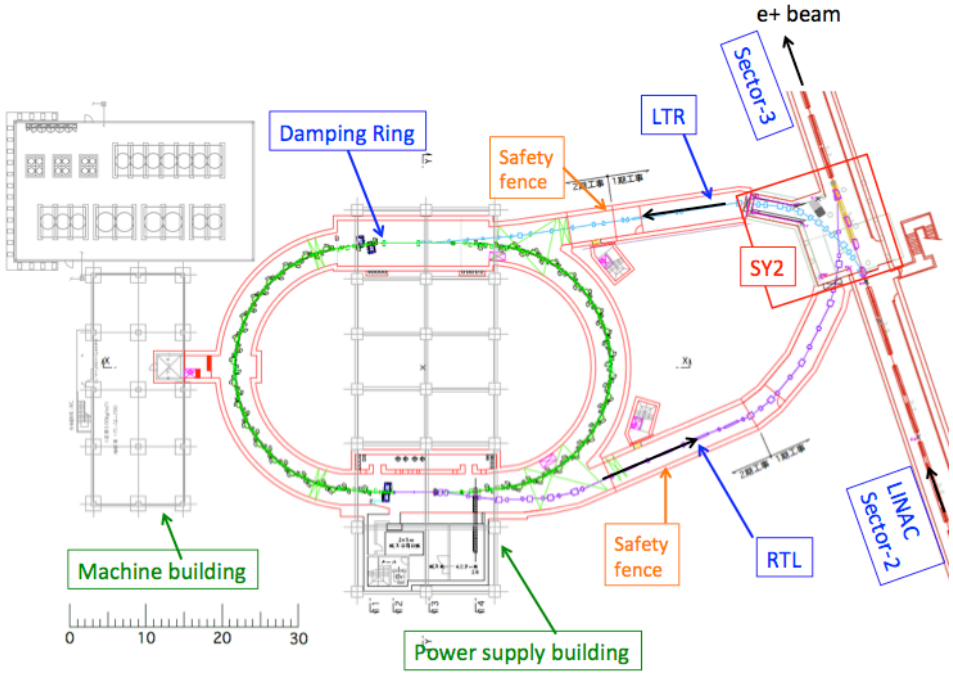
Damping Ring

- DR is newly constructed at the end of Sector-2 of the Linac.
- The positron beam of 1.1 GeV is injected into the DR.
- After circulating in the DR for 40 ms, the damped beam is injected back into the LINAC.
- LTR line with the energy compression system (ECS) is incorporated.
- RTL line with bunch compression system (BCS) is incorporated.



DR Beam transport lines (LTR & RTL)

- Magnet installation was almost completed for the beam transport lines.
- Power cables between PS and magnets were installed.
- Monitor cables also installed.

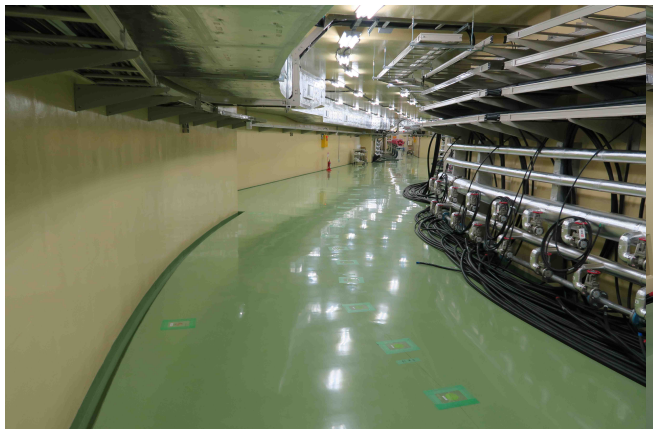


LTR

RTL

Damping Ring

- Cable racks were installed in the power supply building.
- Power cables for magnets were installed.
- All power supplies for the magnets were delivered. (except for steerings.)
- Ready for installation of the beam line components.



DR-North

DR-South

Power supply building

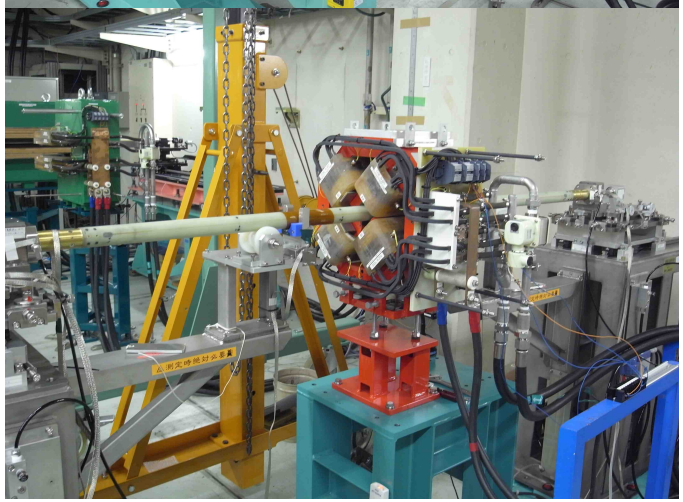
Status of DR & BT components

Field measurement for DR magnet

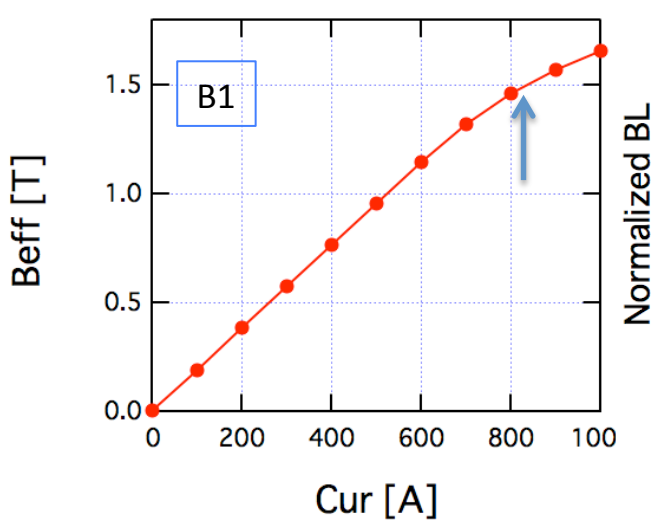
K. Harada & T. Ueda

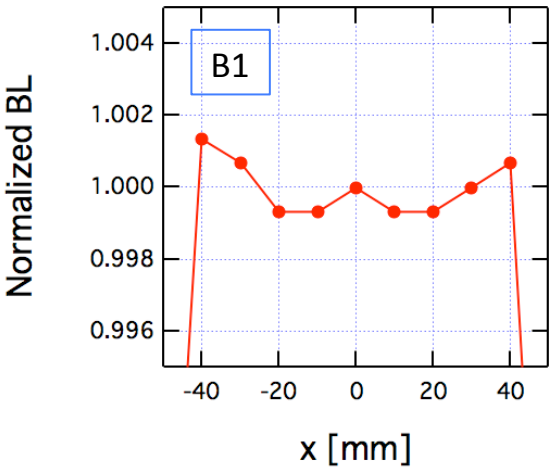
- Mass-measurements for B1-B4, QRD, QRF, Sx were completed.
- Due to the trouble with harmonic coil, mass-measurement for QF/QD/QS was delayed.
- End shim corrections are needed for QF/QD/QS . But it will be completed until June 2015.

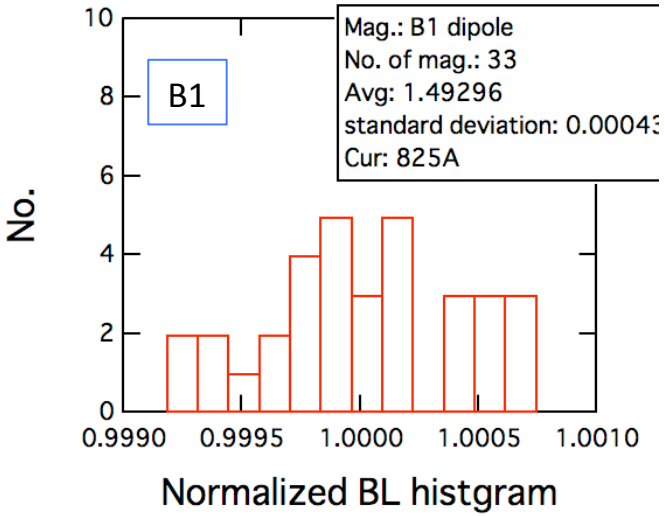
Magnet	No.	Mass-measurement
B1	33	completed
B2	39	completed
B3	5	completed
B4	5	completed
QF/QD/QS	52+26+1+1	Not yet
QRD	7+1	completed
QRF	3+1	completed
Sx	74+2	completed

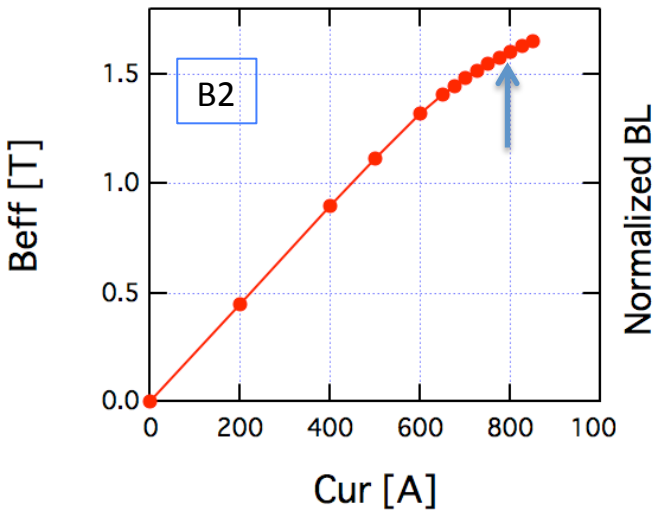


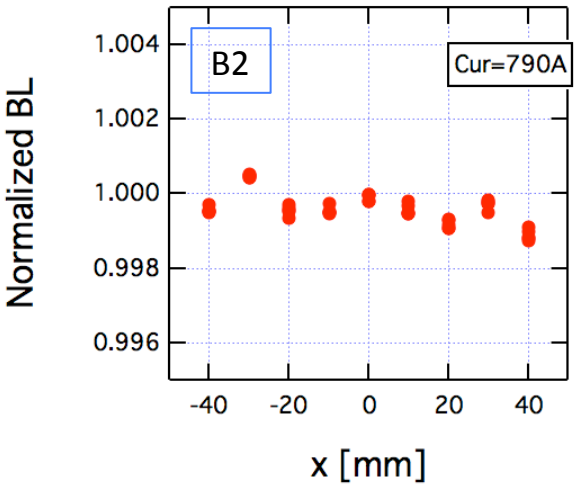
BL measured by long flip coil
(B1 & B2 dipole magnet)

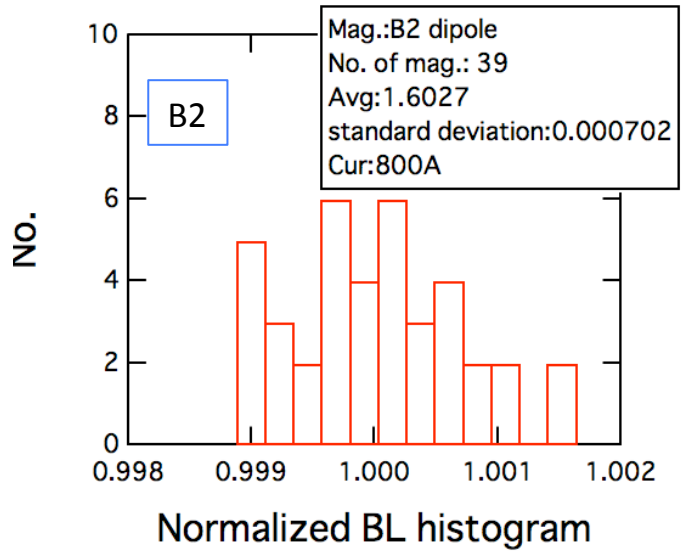








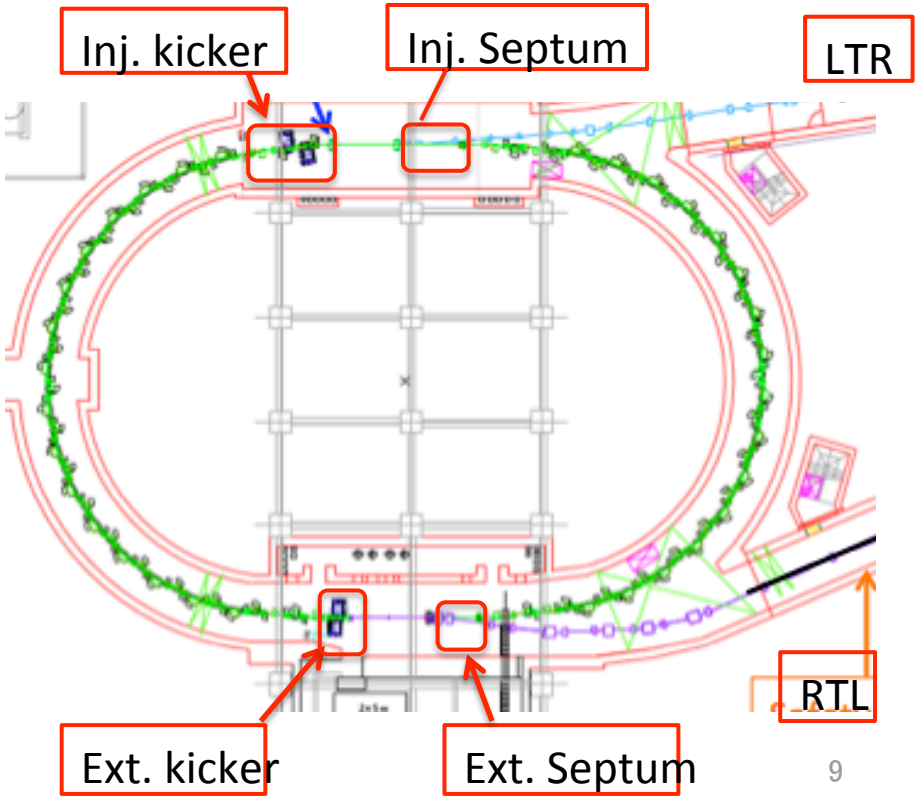




DR Inj. & Ext. Kicker

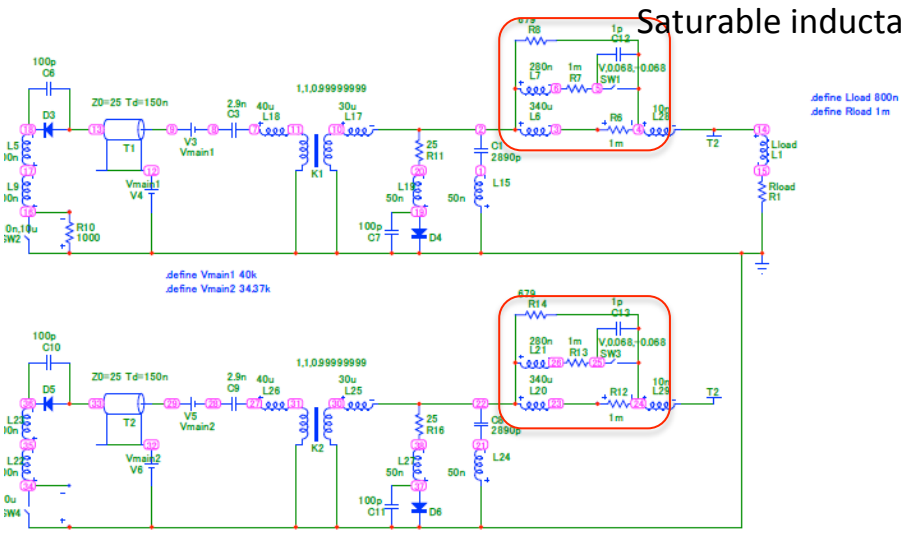
- DR has 2 trains, which are separated about 100ns and 2bunches per train, which are separated 96 ns.
- DR kicker has to inject or extract 2 bunches per pulse .
- Rise time and fall time must be < 100ns.
- 2 kicker magnets for injection and extraction, respectively.

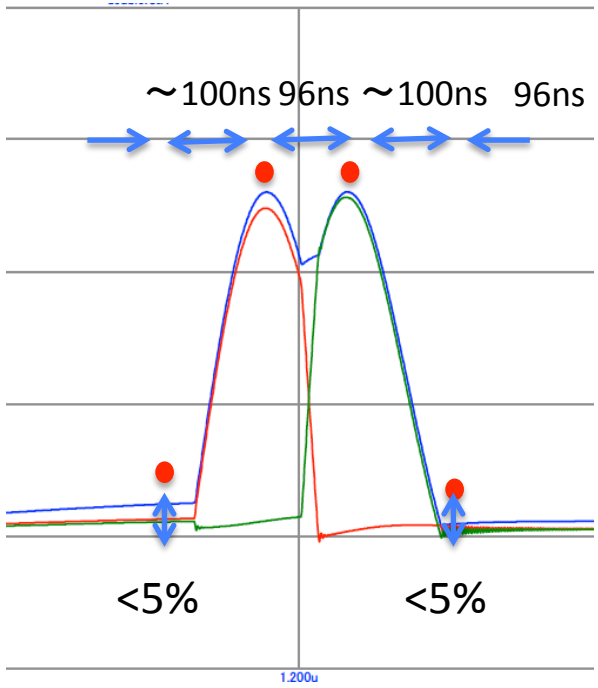
DR Kicker	
Total deflection angle (mrad)	5.2(inj.) 4.7 (Ext)
No. of bunch /pulse	2
Bunch space (ns)	96
Rise time (ns)	<～100
Fall time (ns)	<～100
Stability	<1% (Inj.) <0.1% (Ext.)
Max. repetition (Hz)	50



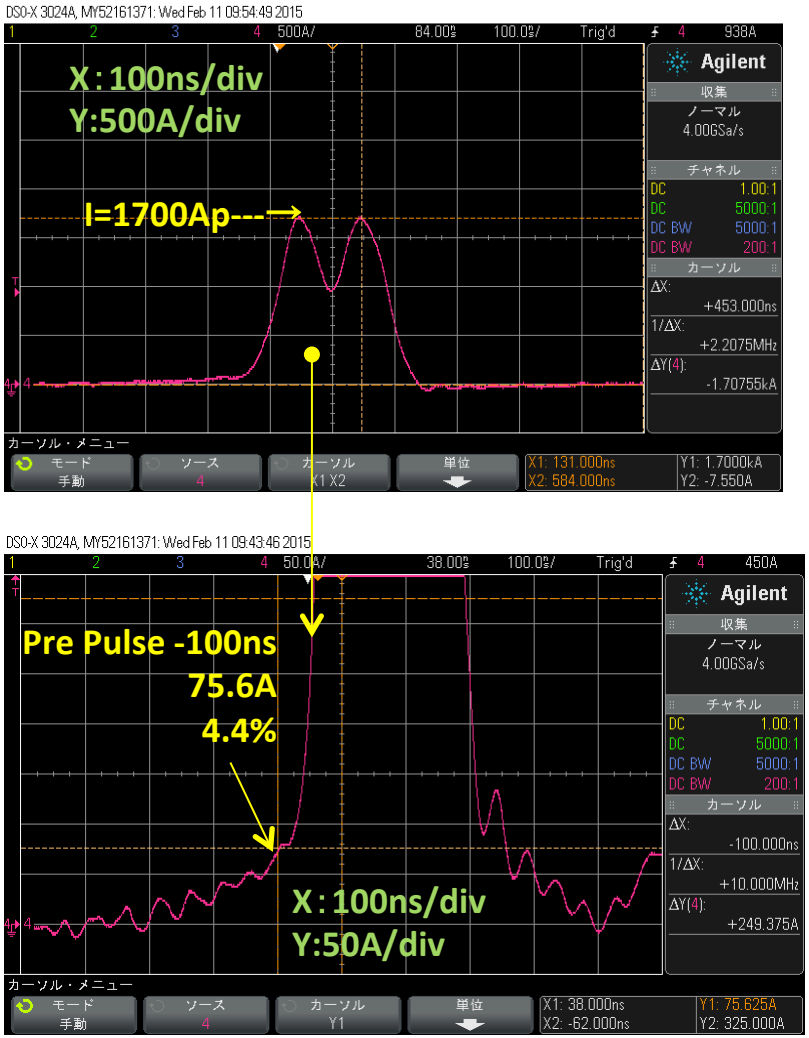
DR Inj. & Ext. Kicker

- DR kicker are designed as an inductive (lumped) type kicker.
- Inj. and ext. kicker are same design.
- Pulse shape : double half-sine. (Two half-sine pulses are overlapped each other.)
- Pre-pulse and tail noise should be < 5%.
- Bunch feedback system is indispensable to compensate the pre-pulse and tail noise kick.





DR Inj. & Ext. Kicker



Type	lumped
Pulse shape	Double half-sine
Pulse width (ns)	300
Length (mm)	240
Aperture (mm)	82(H) x 53 (V)
Mag. Inductance (uH)	0.8
Bmax (T)	0.04
Max Current (A)	1710 (Inj.) 1550 (Ext.)
Jitter (ns)	< ±9 (Inj.) < ±2 (ext)

- In order to achieve short rise time, a saturable inductance is used.
- Command charger is used to achieve the required stability.
- Because of severe jitter requirements, DC PS are used for the cathode's and reservoir's heater of the thyratrons.

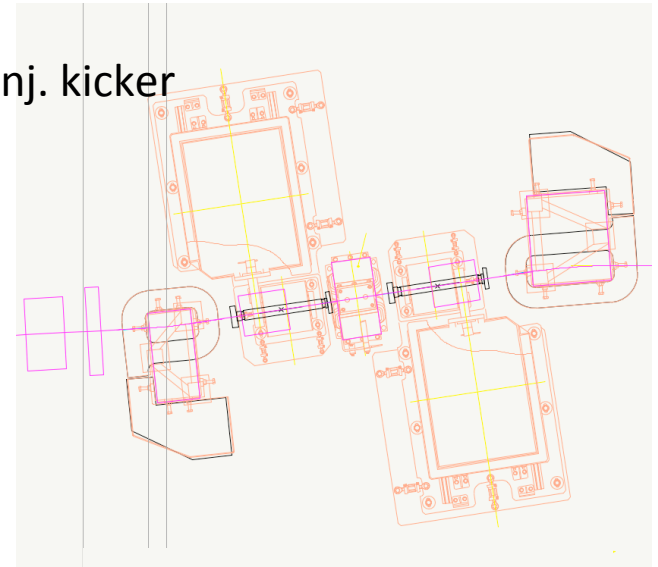
DR Inj. & Ext. Kicker

Issues:

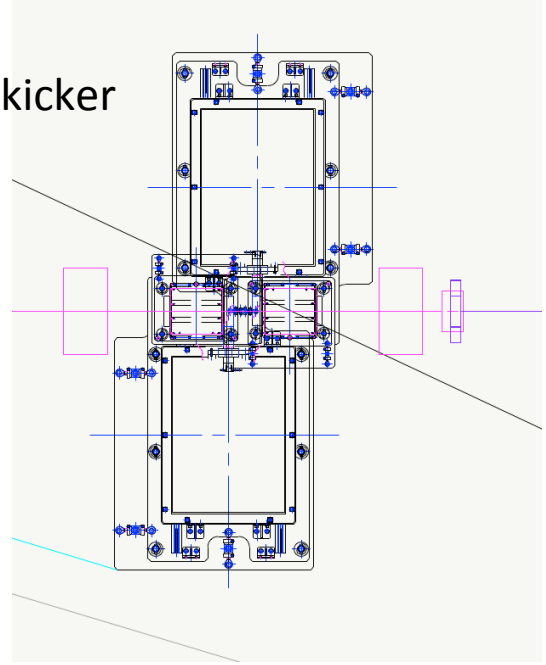
- Minimization of pre-pulse and tail noise.
- Radiation hardness problem.

  ⇒Radiation shields for the magnetic switch are needed.
- Timing jitter.
  - At first we use thyratron tube and we plan to replace it with solid-state switch later.
- Ceramic duct with Ti coating.
- Installation to DR tunnel.

Inj. kicker

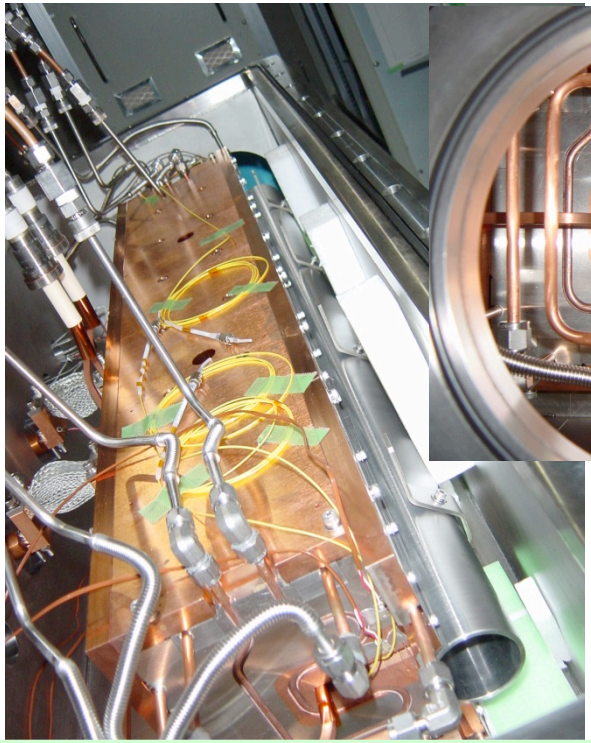


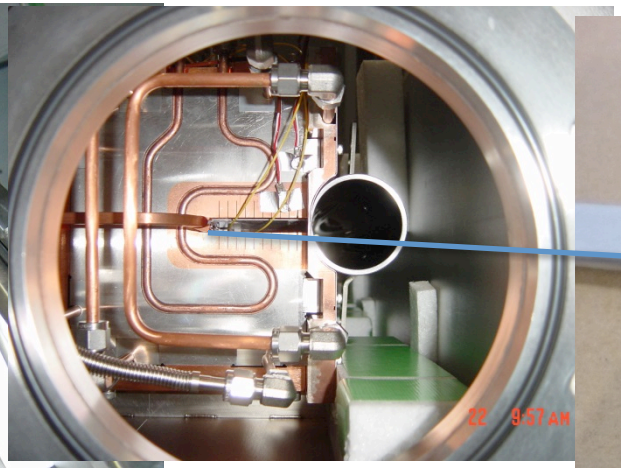
Ext. kicker



Prototype septum magnet trouble

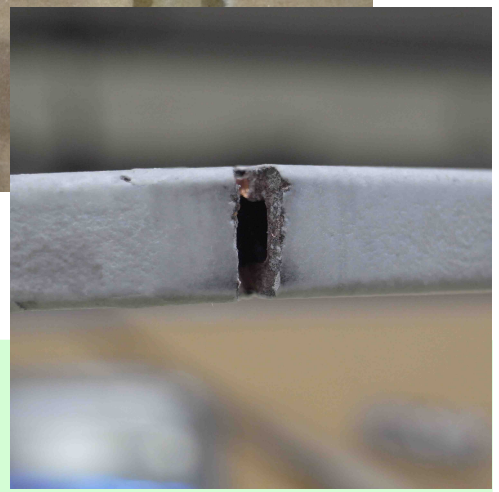
T. Mori





In-vacuum septum

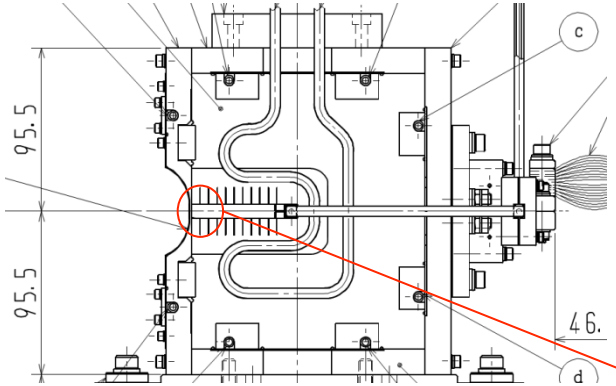
Cracked coil



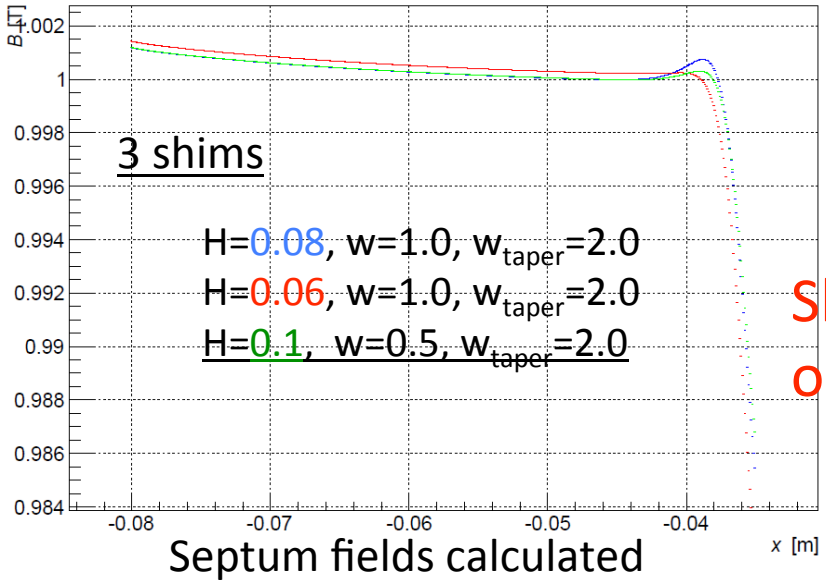
- Coil of prototype septum was broken with 1-hour operation with 50Hz.
- The reason is not clear.
  - Damaged coil?
  - Metal fatigue phenomenon by the coil vibration?
- Conductor size: 6x6-□3⇒6x8-ϕ4
  - We have tested with 6x8 coil for >20 hours operation with the prototype magnet.
  - ⇒ No problem. So, we continue to fabricate the production magnets.
- No. of coil hook: 9 (prototype magnet) ⇒ 17 (production magnet)
  - Stress for the coil can be expected to be reduced t o 1/4.

Shim Shape for Septum Core

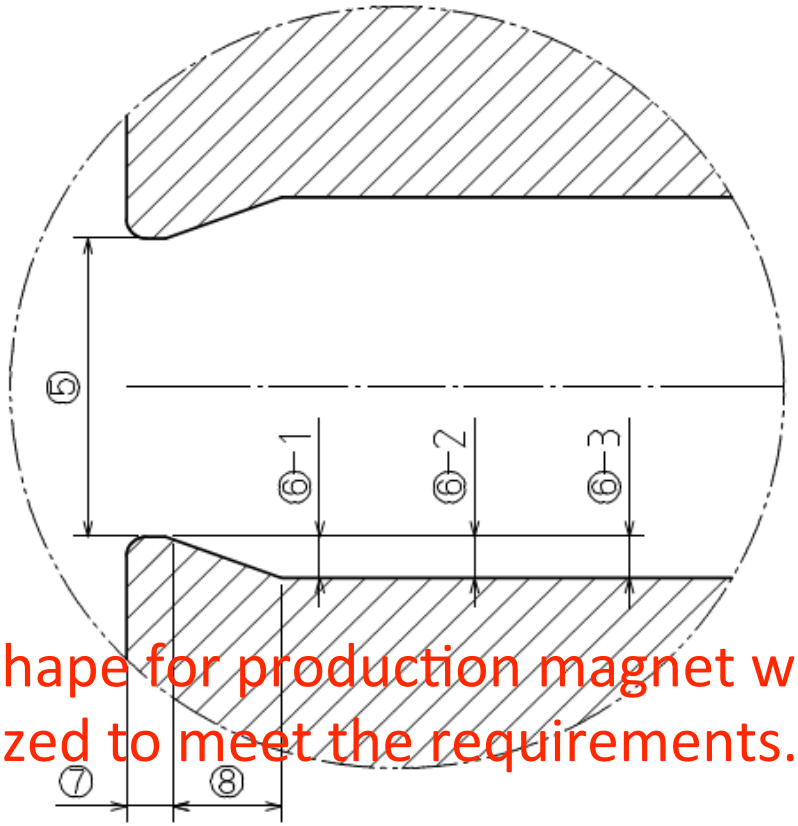
T. Mori



Septum end



Septum fields calculated

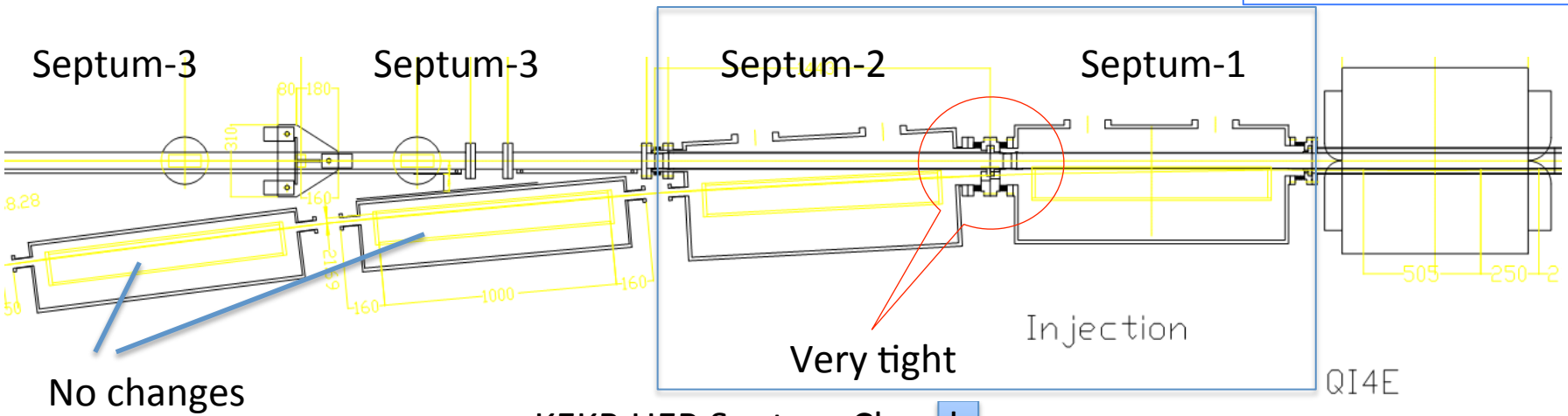


Shim shape for production magnet was optimized to meet the requirements.

- $⑥h = 0.08[\mathrm{mm}], ⑦w = 1[\mathrm{mm}], ⑧w_{\mathrm{taper}} = 2[\mathrm{mm}]$
- Non-linear distortion of injection beam through final septum with tracking: 5%
  - $2.5\sigma_x$ assumed

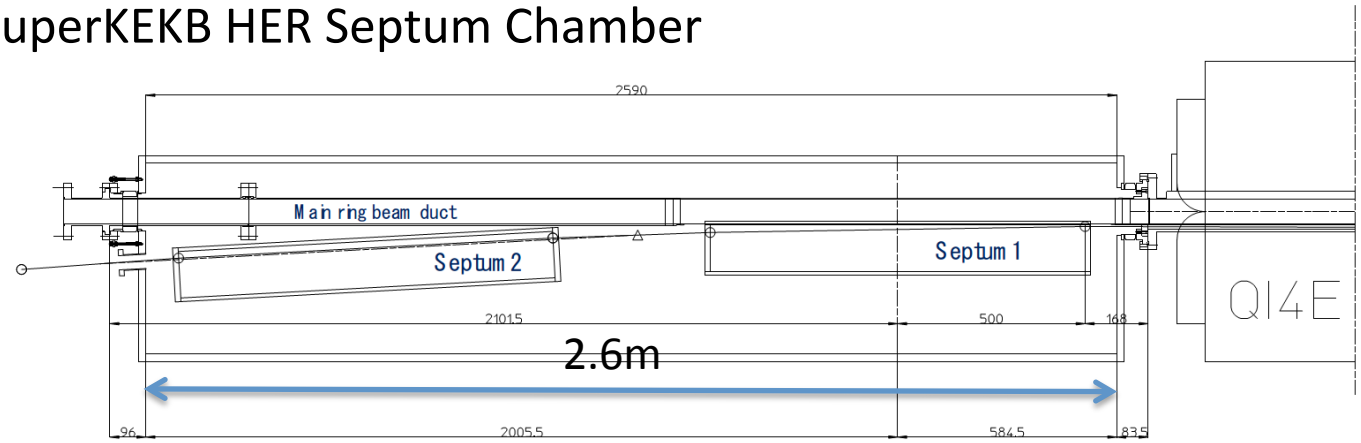
HER Septum Chamber Design

T. Mori & K. Kanazawa



KEKB HER Septum Chamber

SuperKEKB HER Septum Chamber

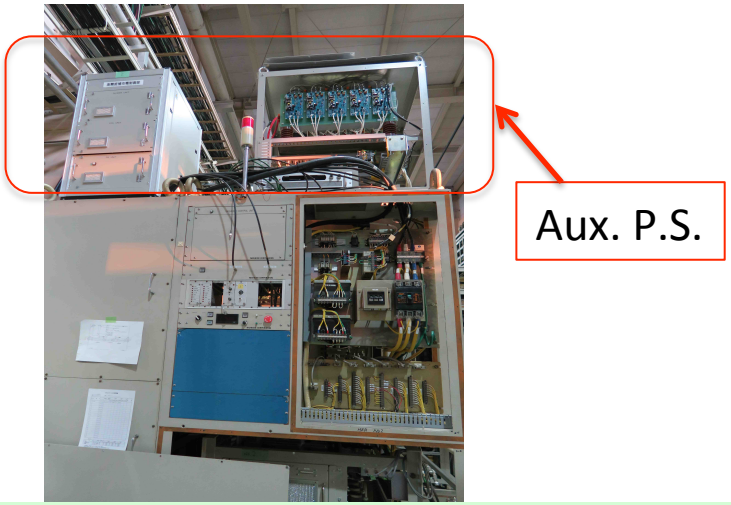


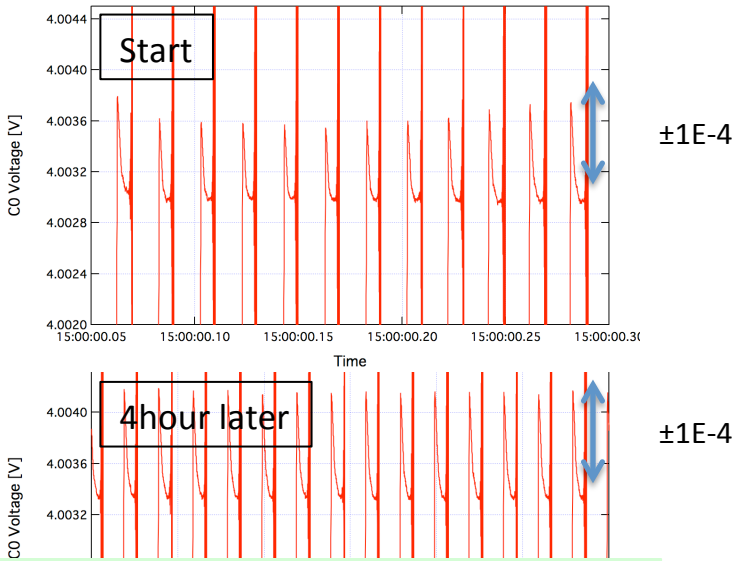
2-septum in 1-chamber

Stability improvement of septum PS

- Because stability of KEKB septum PS was not so good, operator had to adjust it frequently.
- Improve the stability of charging voltage.
  - Make the voltage monitor's response faster.
  - Replace the charger using thyristor to that using switching power supply.
  - Control charging timing by replacing diode to thyristor.
  - Introduce high precision auxiliary charger.

  ⇒ Stability<±1E-4 for 4 hours was achieved.



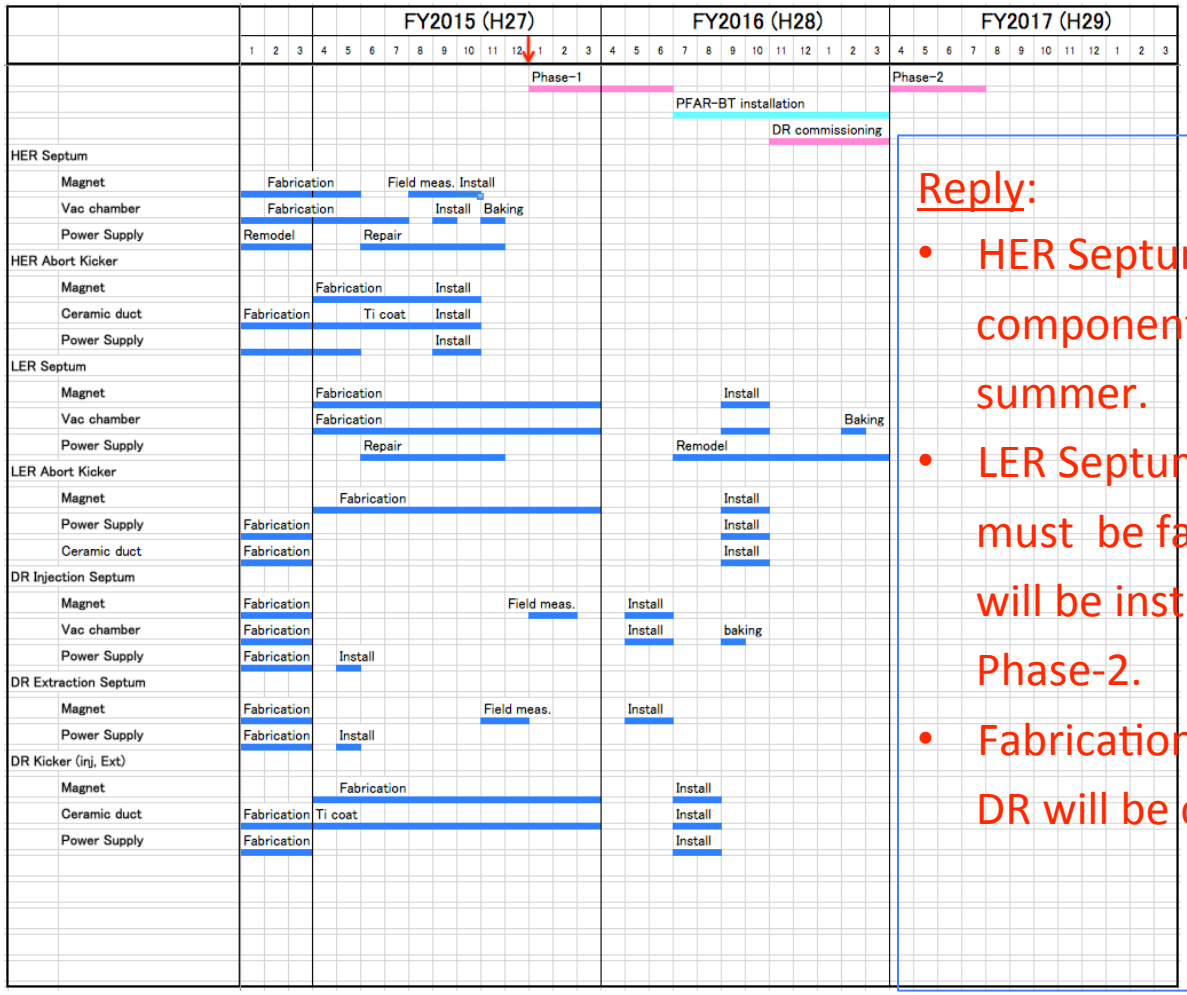


Issue:
During remodeling these PS, we found many parts, which are fabricated in KEKB were broken.
We need to repair these parts until the SuperKEKB operation.

19th KEKB ARC Recommendations:

Setup a solid schedule for the new injection components to be consistent with the DR schedule and meets the Phase II and Phase III milestones.

Schedule for the new injection components



Reply:

- HER Septum & HER Abort Kicker components will be fabricated until this summer.
- LER Septum, LER abort kicker compoents must be fabricated in FY2015. And these will be installed between Phase-1 and Phase-2.
- Fabrication of pulsed magnets and PS for DR will be completed in this fiscal year.

19th KEKB ARC Recommendations:
In order to complete the Damping Ring commissioning during a one-month period, a precise commissioning plan needs to be prepared with detailed procedures and decision trees and sufficient commissioning staff identified.

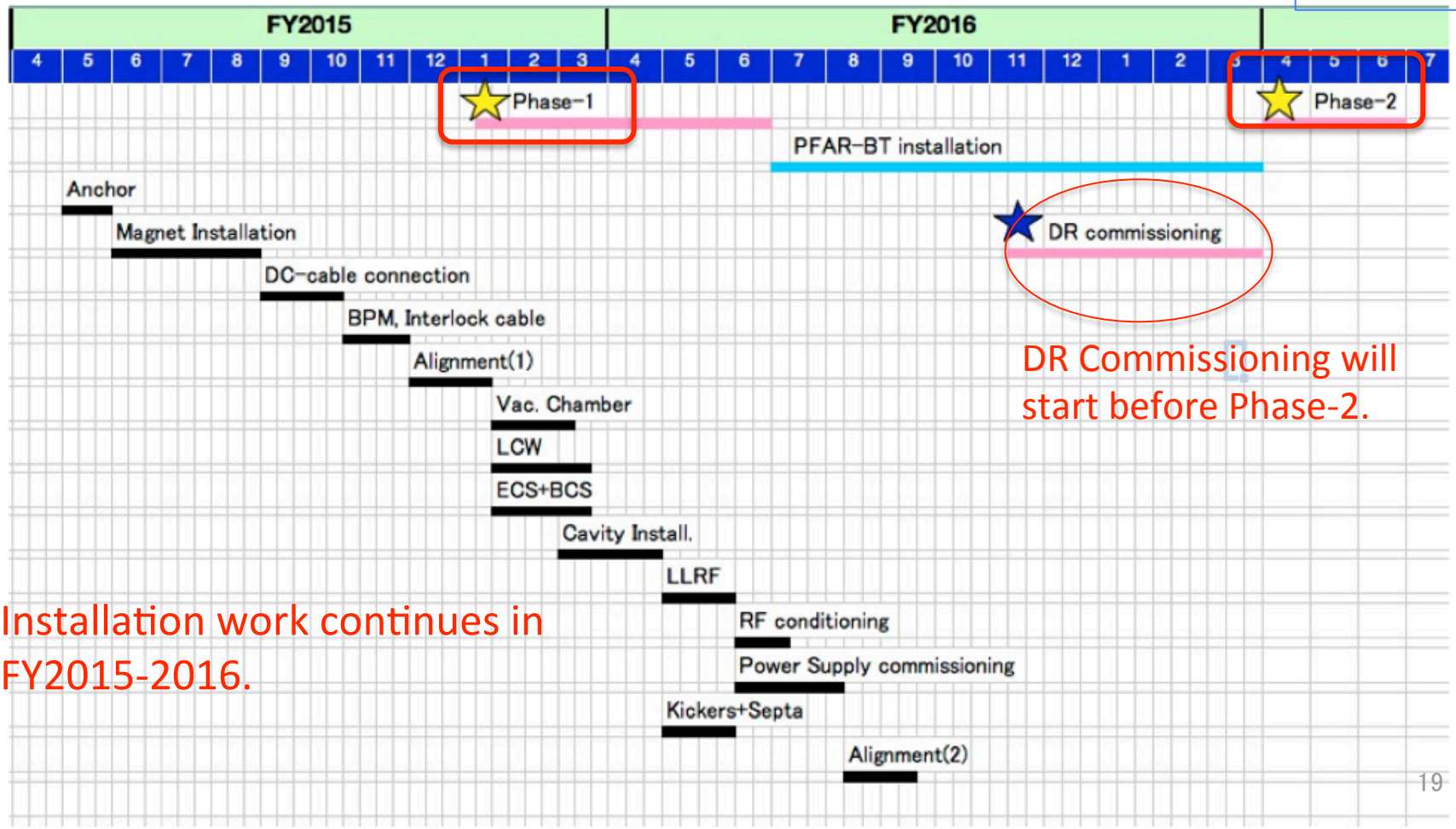
DR
Schedule & Commissioning Plan

Schedule (2)

M.Kikuchi(2014.11.6)
The time span between Phase-I and Phase-II is 10 months.
DR beam-commisioning can be started on LINAC beam mode just before Phase-II.

- Assumption: 'Second case'
- Installation of PFAR-BT between Phase-1 and Phase-2
- DR beam-commissioning before Phase-2
- Tunnel of upstream PFAR-BT must be closed before DR beam-commissioning

M. Kikuchi



DR Commissioning will start before Phase-2.

Installation work continues in FY2015-2016.

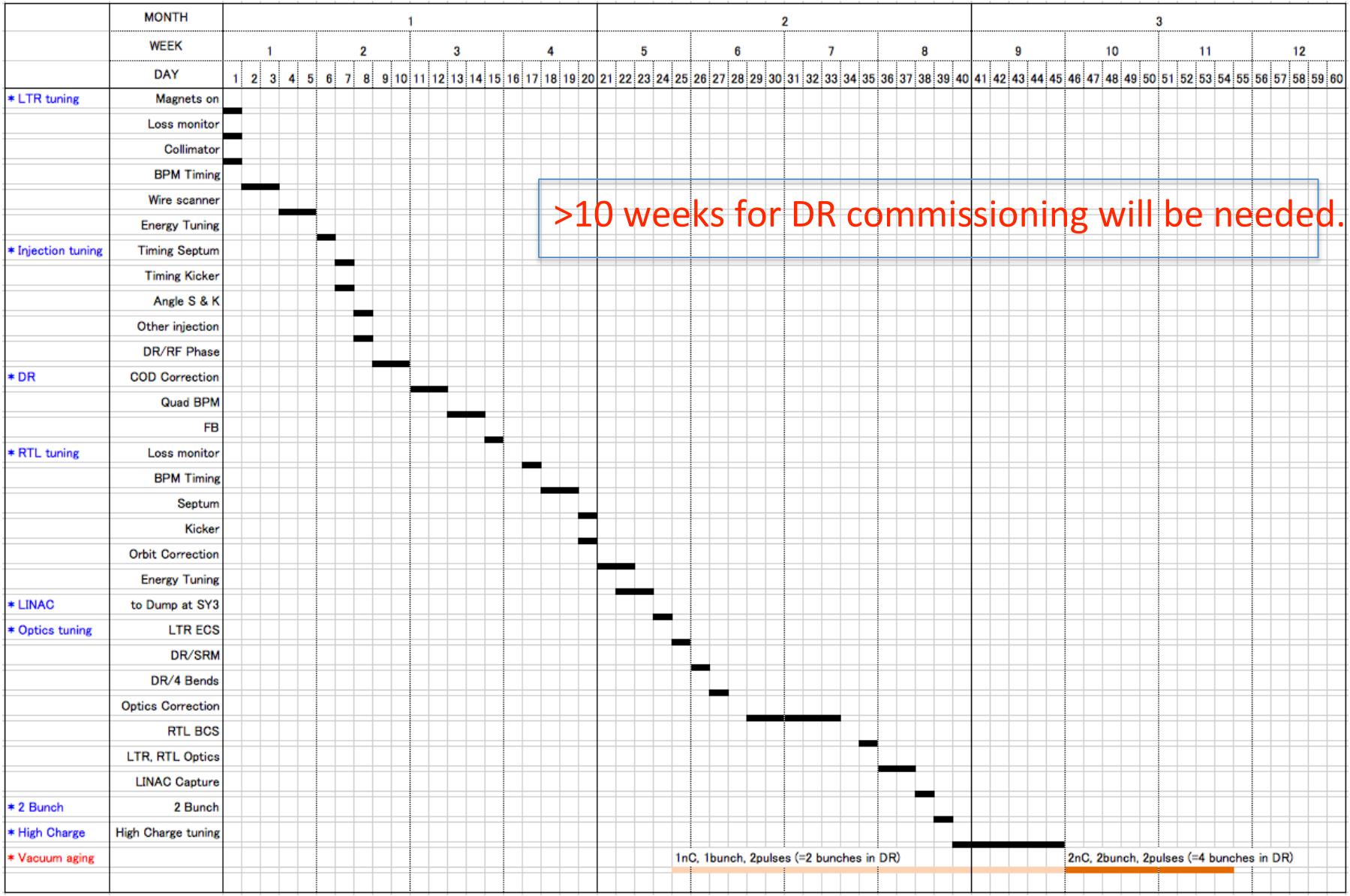
Precautions for DR commissioning

N. Iida

- LTR Injection
  - The power supply of injection kickers are located in DR tunnel.
    - The LTR beam tuning should be done in the state which some screen monitors at the end of LTR are put in.
- Night-time
  - For example, 1:00 – 9:00
  - LINAC tuning
  - When the beam tuning of DR is over, vacuum scrubbing can be done.
    - DR needs about 2 [A.Hr].

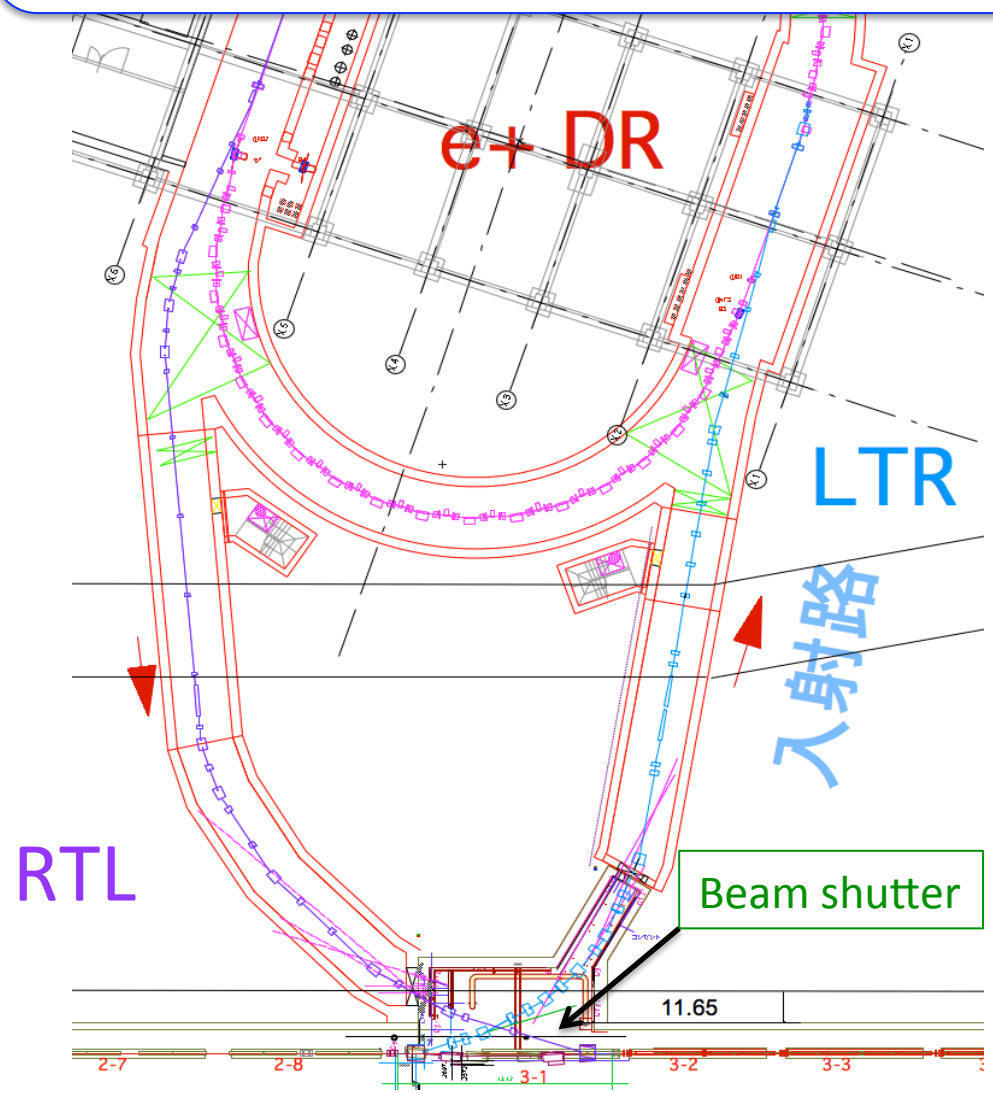
DR beam commissioning plan

N. Iida



19th KEKB ARC Recommendations:

The beam in the Damping Ring (DR) needs to be aborted when the SuperKEKB rings abort their beams. The location and design of this DR abort system needs to be finalized and constructed to be ready for high current operation of SuperKEKB.



N. Iida

DR beam extraction due to the LER abort

When the LER beam is aborted,

1) Close the beam gate.
2) Close the beam shutter at the end of RTL.
3) After confirming the beam shutter closed, the extraction kicker of DR fires.

Summary

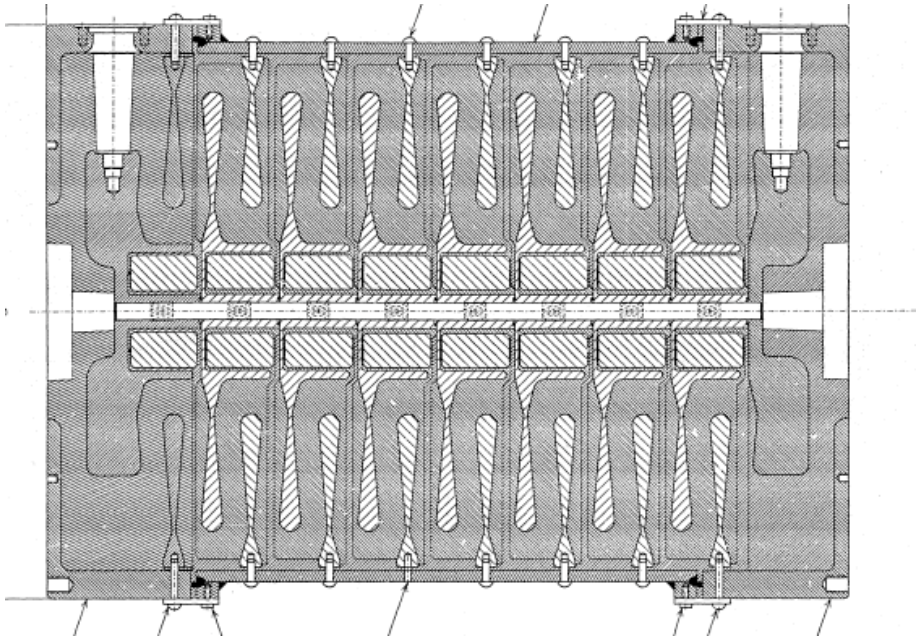
- DR
  - The DR tunnel is ready for installation of the beam line components of the DR.
  - Installation work for DR will continue in FY2015 and FY2016.
  - DR commissioning will start before Phase-2 and needs > 10 weeks.

- HER & LER
  - New injection components for HER will be fabricated until this summer and will be installed by the end of this autumn.
  - To check the reliability, we must have a long term operation of the production septum magnet before the installation.
  - Many parts of Septum PS were broken and must be repaired until SuperKEKB operation.

Backup

DR Inj. & Ext kicker
R&D transmission kicker

- Transmission kicker shows a better performance of rise time.
- R&D for transmission kicker (SLC type, i.e. out-vacuum molded type) are being performed.
- We need more time to develop it.

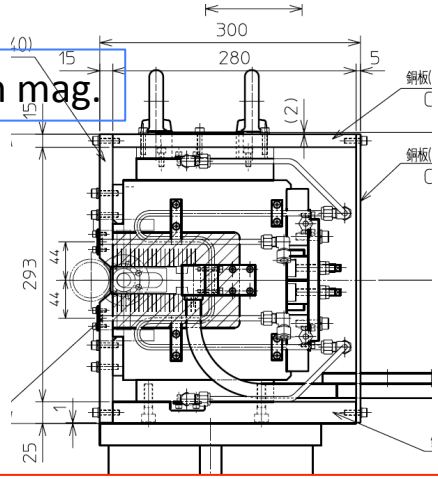


DR inj. & Ext. Septum

	Inj.	Ext
Deflection angle (mrad)	80	103
No.	1	1
Field strength (T)	0.36	0.47
Type	Eddy-current	Eddy-current
Aperture (mm)	70(H)x24(V)	70(H)x30(V)
No. of coil turns	1	1
Septum thickness (mm)	2.5	2.5
Waveform	Full-sine	Full-sine
Pulse width (μs)	300	300
Peak Current (A)	8000	12500
Max rep. (Hz)	50	50
Stability	<1E-3	<1E-4
	In-vacuum	Out-vacuum w/ ceramic duct

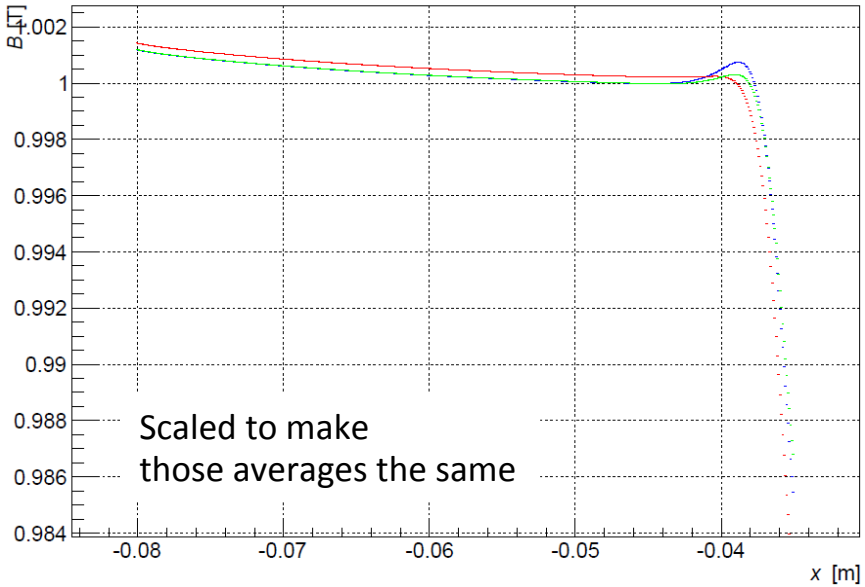
DR inj. Septum PS

DR Ext. Septum mag.

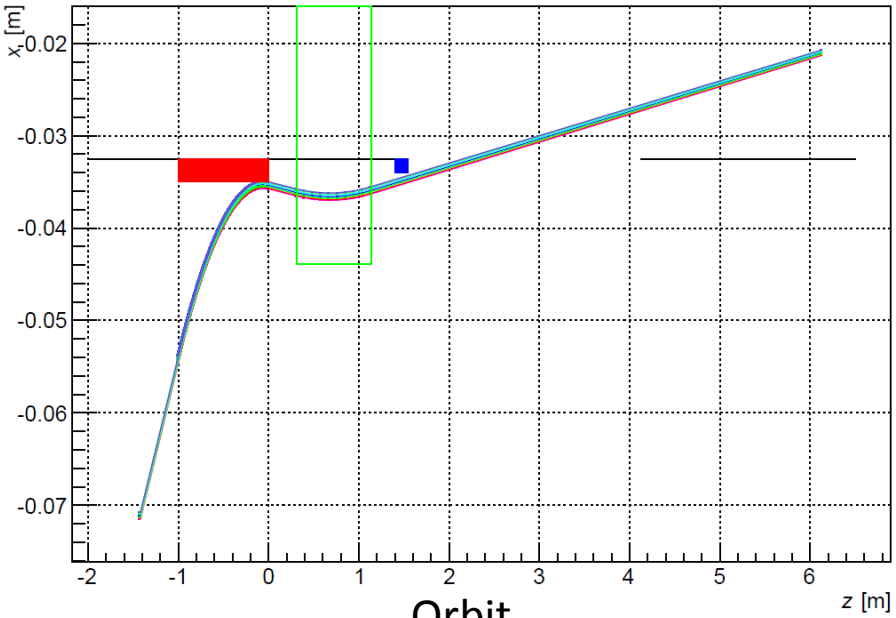


- No. of coil turns for DR ext. septum was changed 2 -> 1 to make the structure simple.

Tracking through Septum Field



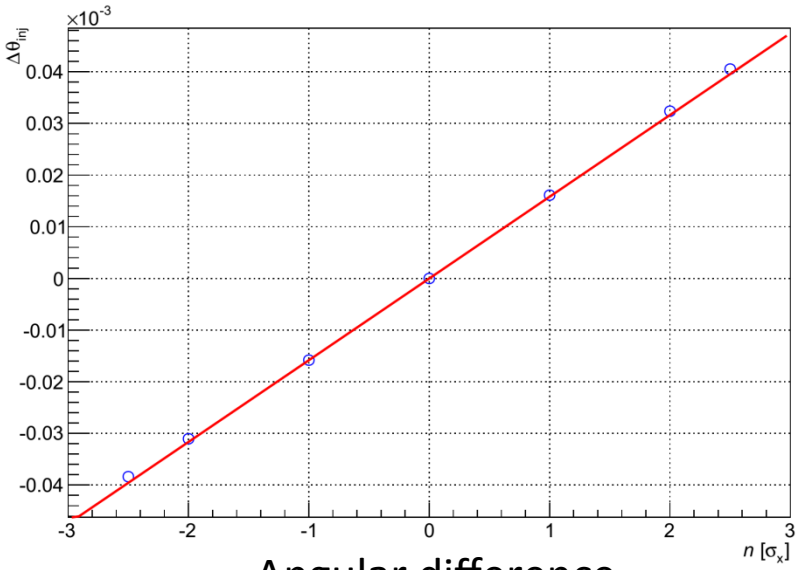
Septum field



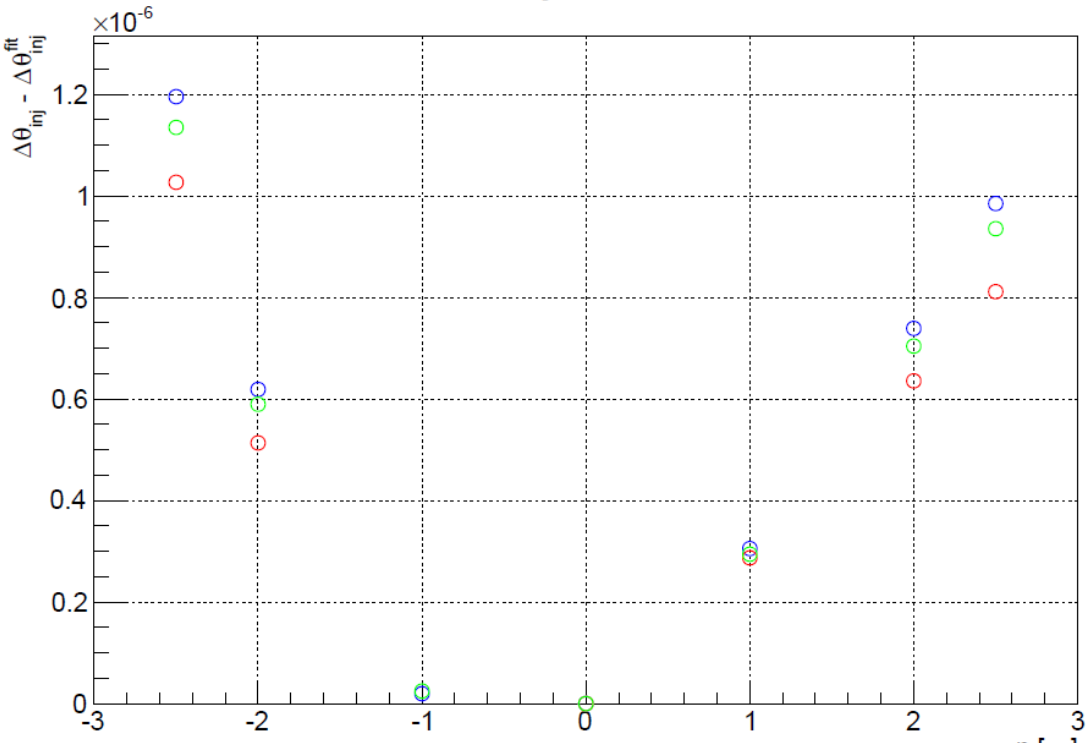
Orbit

- Septum fields calculated with 3 kinds of shims
  - h=0.08, 0.06, w=1.0, $w\downarrow$taper =2.0
  - h=0.1, w=0.5, $w\downarrow$taper =2.0
- Tracking with $\pm 2.5\sigma\downarrow x$ width beam with same momenta

Distortion of Injection Beam



Angular difference



Distortion of injection beam through final septum

- Divergence angle of injection beam: $2.5\times\sqrt{\varepsilon_x/\beta_x}=24.4\ [\mu rad]$; ~5% distortion
- No big difference between fields with 3 shims

$h=0.08$ is adopted; but tolerance is $20\mu m \Rightarrow h=0.08^{+0.01}_{-0.03}$