SuperKEKB LS2 Upgrade plans

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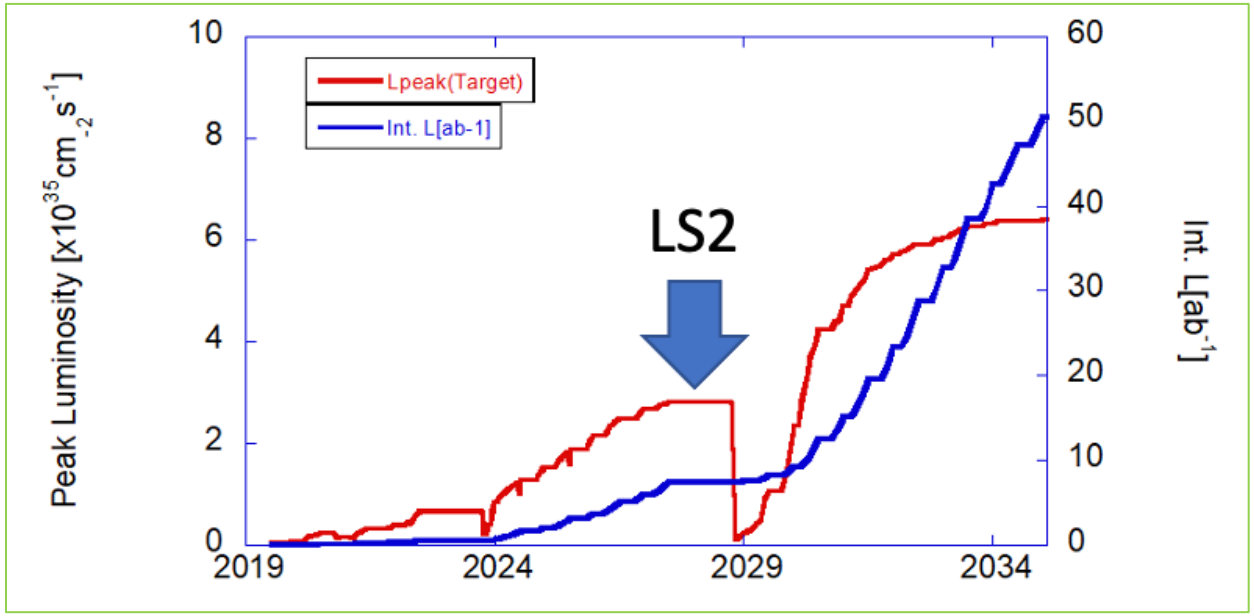
Contents

1. Introduction

- We need another long shutdown (LS2) to improve the machine performance beyond $\sim 2\times10^{35}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ and toward the target peak luminosity of $6\times10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$.

- It probably requires
  a. modifications of the IR
  b. an upgrade of the injection complex.



- The modifications must be effective enough that the integrated luminosity lost during LS2 is recovered quickly afterwards, aiming for the target.

2. Main Ring (IR)

Three scenarios are under consideration.

1. Moderate scale modification around 2027 (more than 1 year shutdown):
   - New QC1 with larger physical aperture, installed closer to the IP for larger dynamic aperture, keeping the boundary as is.
     - R&D work on Nb_3Sn quadrupole magnet is necessary.
     - Evaluate the impact of modifications on machine performance by 2025 at the latest.
2. Larger scale modification, in addition to 1:
   - New anti-solenoid configuration, which probably requires detector modifications.
     - Optical evaluation of the anti-solenoid field profile and coil design needed.
     - R&D work on Nb_3Sn thin solenoid is necessary.
     - New cryostats and a cryogenic system for anti-solenoid coils need to be designed and fabricated.
3. Much Larger scale modification sometime later (~203x)
   - New ideas to be sought for, by the ITF, for example.

➢ **SuperKEKB-wide effort needs to be made to establish a reliable model through extensive machine studies after LS1.**

Status

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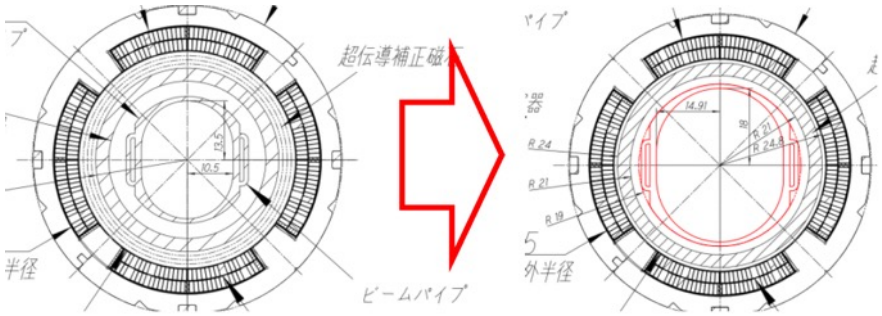
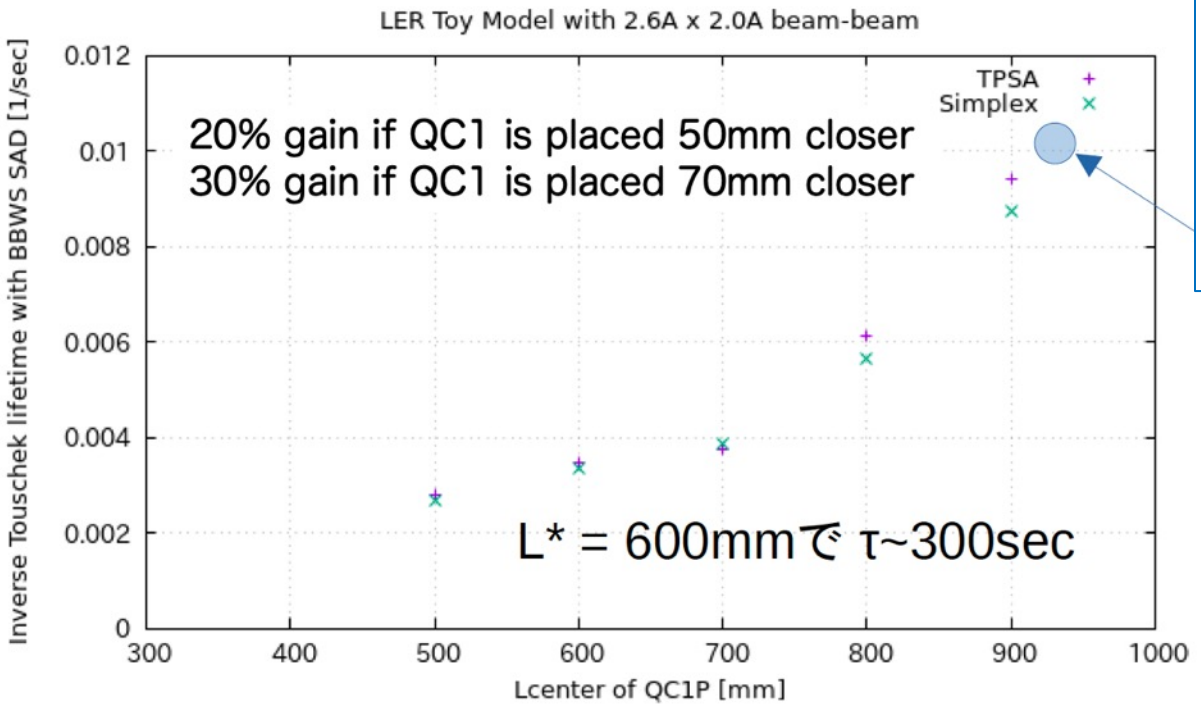
1. Moderate scale modification around 2027 (more than 1 year shutdown):

New QC1(Nb_3Sn)

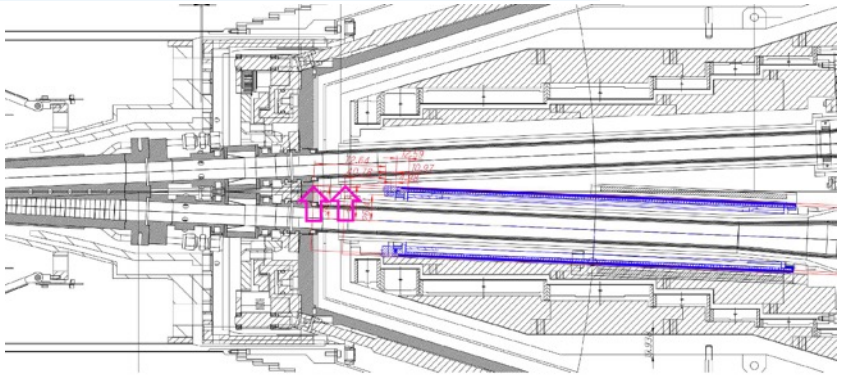
- winding correction coils (NbTi) outside of quadrupole coils for larger physical aperture
- moving closer to the IP for larger dynamic aperture
- keeping the detector boundary as is.





Moving QC1P **50mm to** IP.
Touschek lifetime extends by **20%**

Moving QC1P **70mm to** IP.
Touschek lifetime extends by **30%**



RVC modification probably needed

Status

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2. Larger scale modification

Detector solenoid cancellation between IP and QC1

In addition to 1. (previous page)

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Concept

- make the beam trajectory parallel to the QC1 magnet axis.
- Zero coupling/zero chromaticity between the IP and QC1.
- minimize ε_y by redesigning the solenoid field profile $B_Z(S)$. $\varepsilon_y \propto \int B_x^4$

Expected

- The offsets of QC1P and QC2P and the rotation of QC1E/QC2E are expected to be considerably smaller than the present values with the new design.
- Wider working area in tune space (next page)
- IR nonlinearity reduction (next page)

Solenoid field profile must satisfy

$$\int B_x(s)\,ds=0 \qquad \int \left(\int_0^s B_x(s')\,ds'\right)ds=0$$

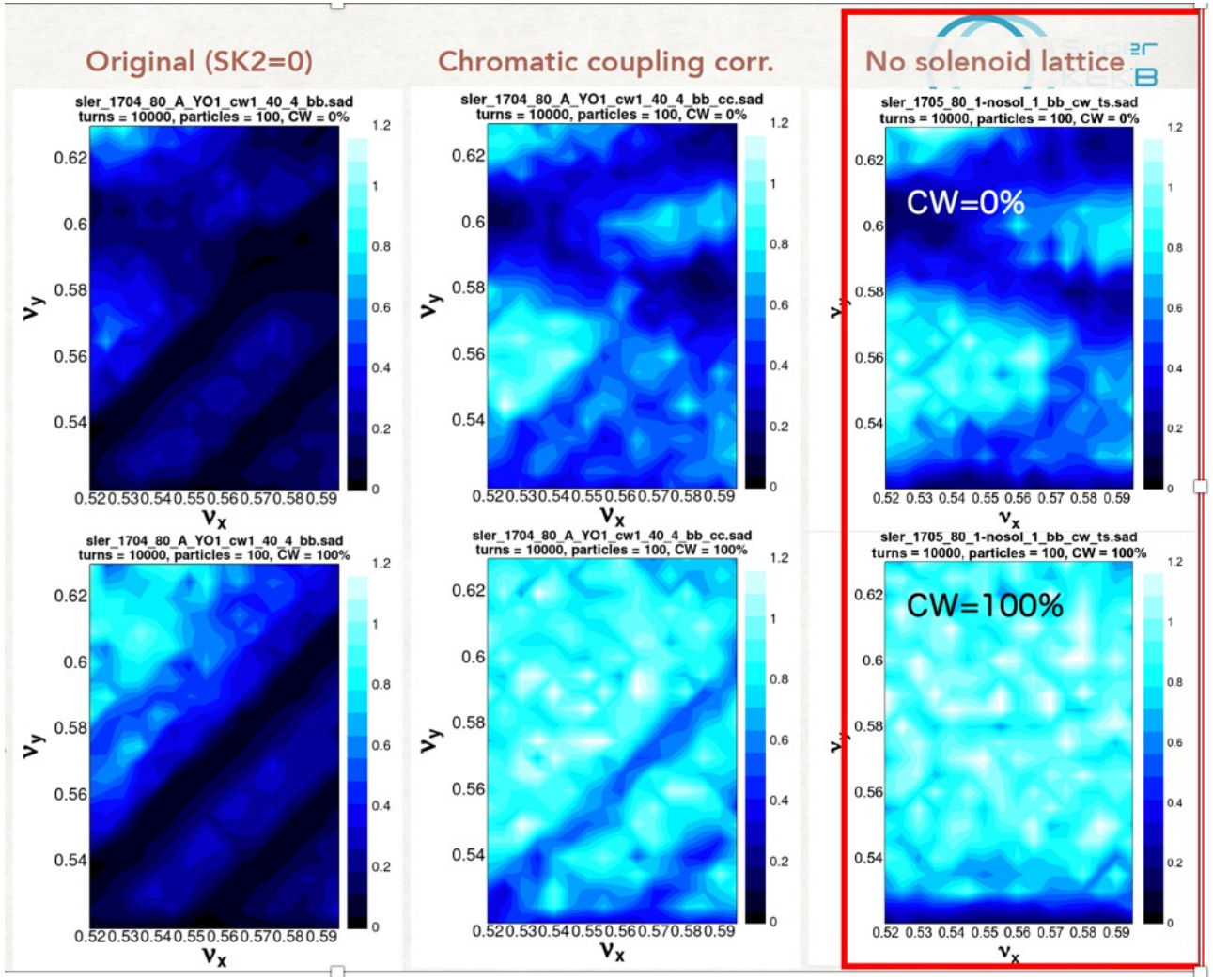
$$\int B_s(s)\,ds=0 \qquad \int \frac{dB_x(s)}{dx}\,ds=0$$

$\int Bx^4\,ds$

2. Larger scale modification

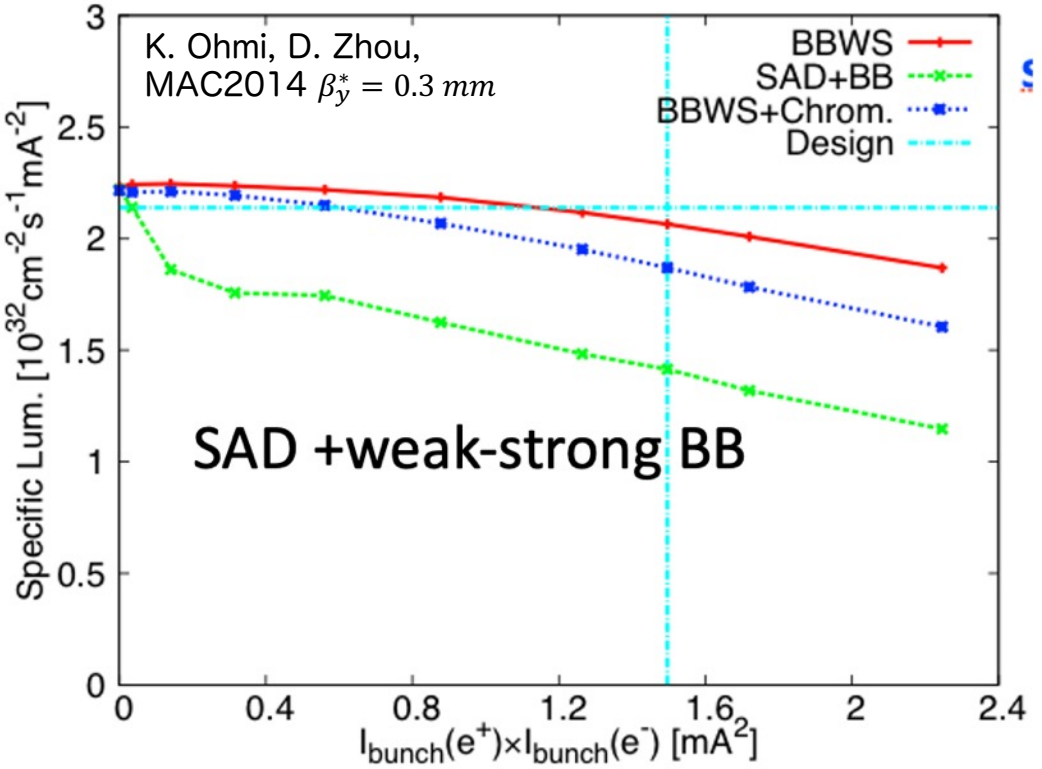
Detector solenoid cancellation between IP and QC1

Wider working area in tune space



K. Oide Mar, 2020
$\beta_y^* = 1\,mm$

IR nonlinearity reduction

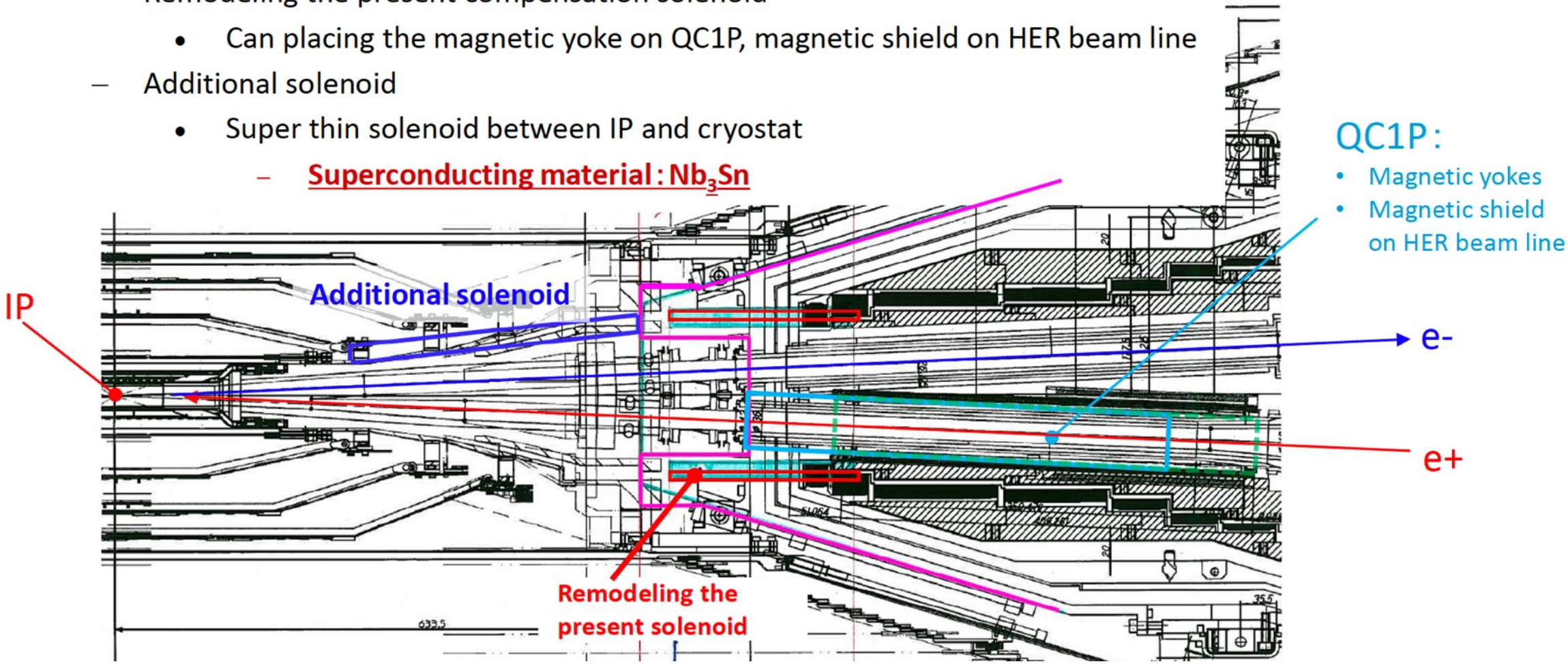


Luminosity degradation, which arises from IR nonlinearity and beam-beam effects may be recovered.
→further simulation work is necessary.

2. Larger scale modification

Detector solenoid cancellation between IP and QC1

- Remodeling the present compensation solenoid
  - Can placing the magnetic yoke on QC1P, magnetic shield on HER beam line
- Additional solenoid
  - Super thin solenoid between IP and cryostat
    - **Superconducting material : Nb_3Sn**



Detector modification is needed.

3. Much Larger scale modification

New ideas to be sought for, by the ITF (Chair, Y. Ohnishi) working groups, for example.

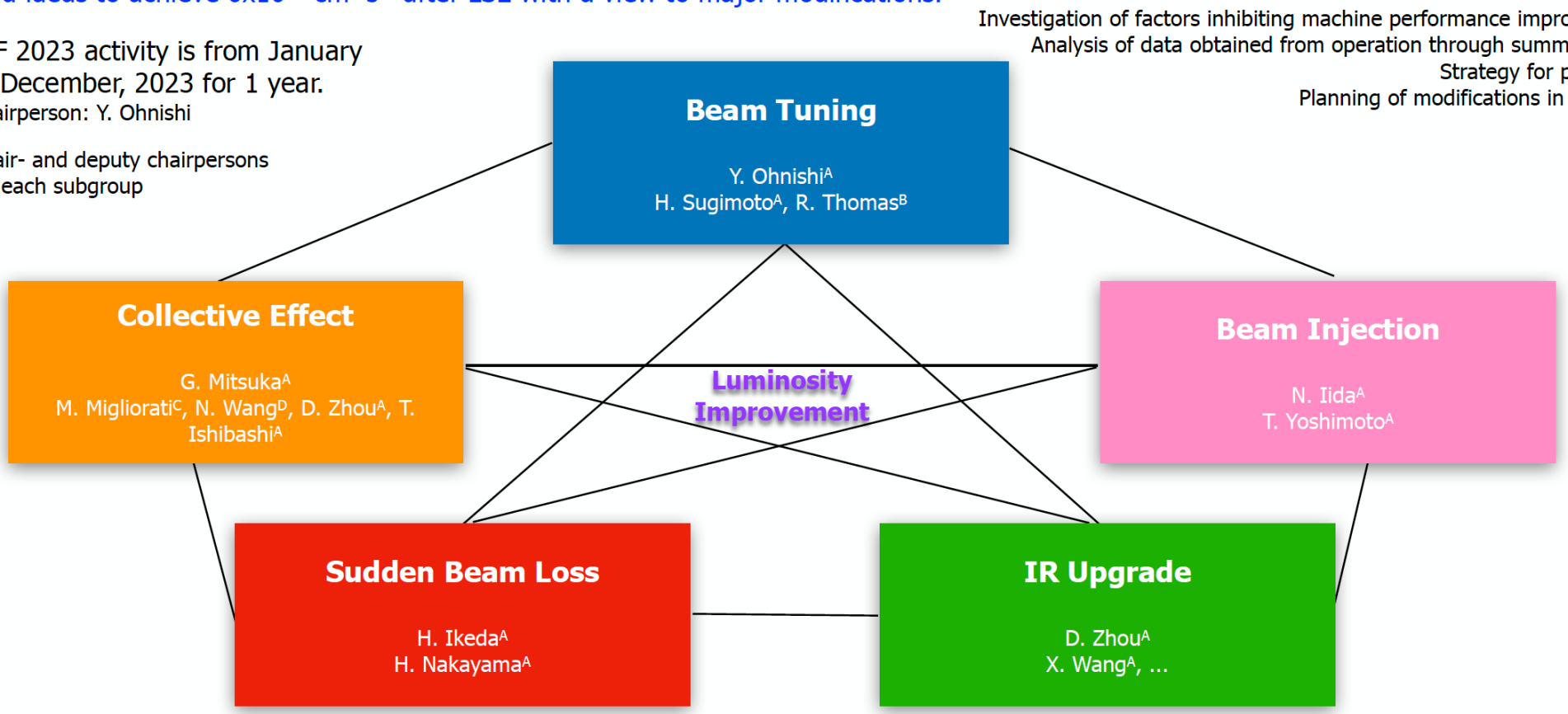
ITF is organized under the B-Factory promotion office.

61 researchers are joined to the ITF.
(26 researchers from foreign institutes ~43 %)

Find a realistic path to achieve 10^{35} $cm^{-2}s^{-1}$ in the post LS1 (1st long shutdown since mid. of 2022).
Find ideas to achieve $6x10^{35}$ $cm^{-2}s^{-1}$ after LS2 with a view to major modifications.

ITF 2023 activity is from January to December, 2023 for 1 year.
Chairperson: Y. Ohnishi

Chair- and deputy chairpersons for each subgroup



A) KEK, B) CERN, C) UNIROME1, D) IHEP

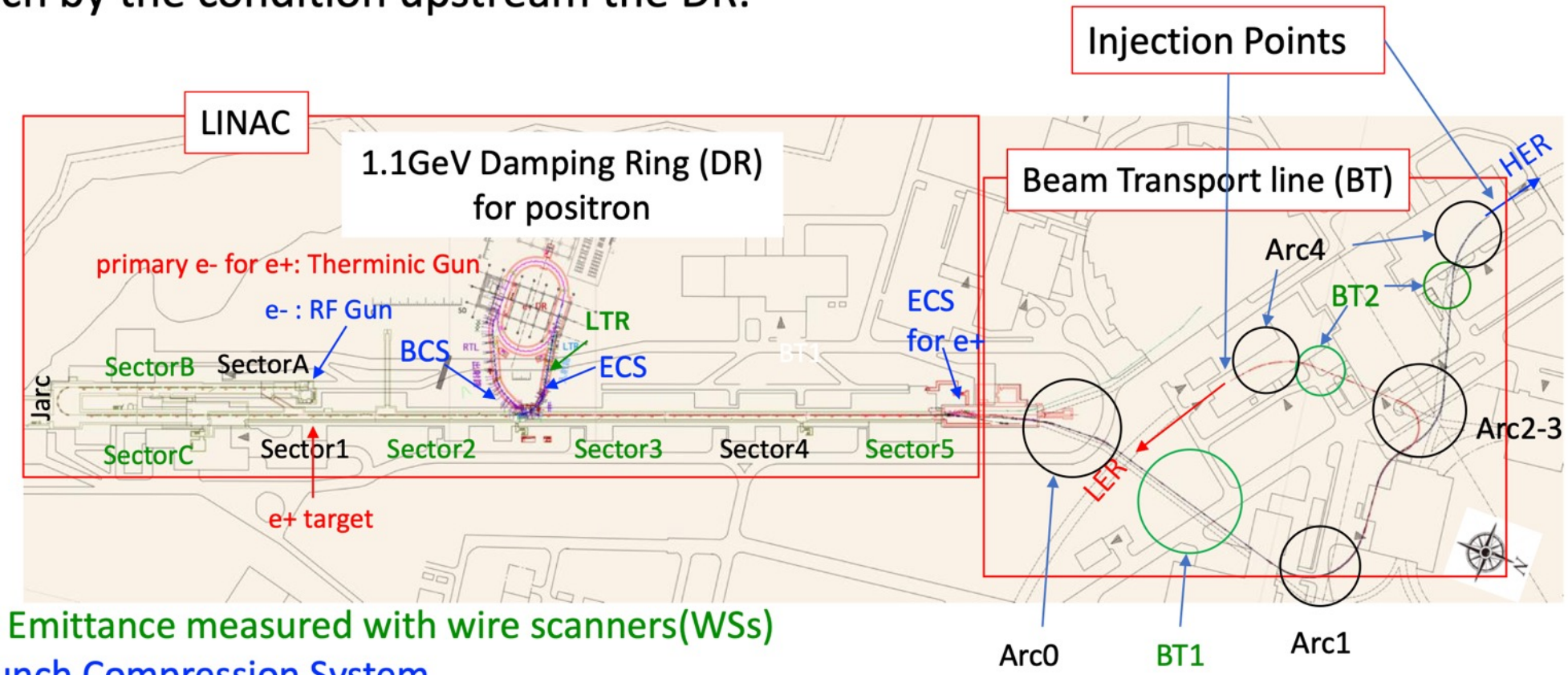
International Task Force (ITF)

Y. Ohnishi

3. Injector complex

e+ beam injects into LER via DR:
The injection BG is not affected very much by the condition upstream the DR.

e- beam directly injects into HER:
The injeciton BG is directly affected by the condition of RF-gun, LINAC, and BT.



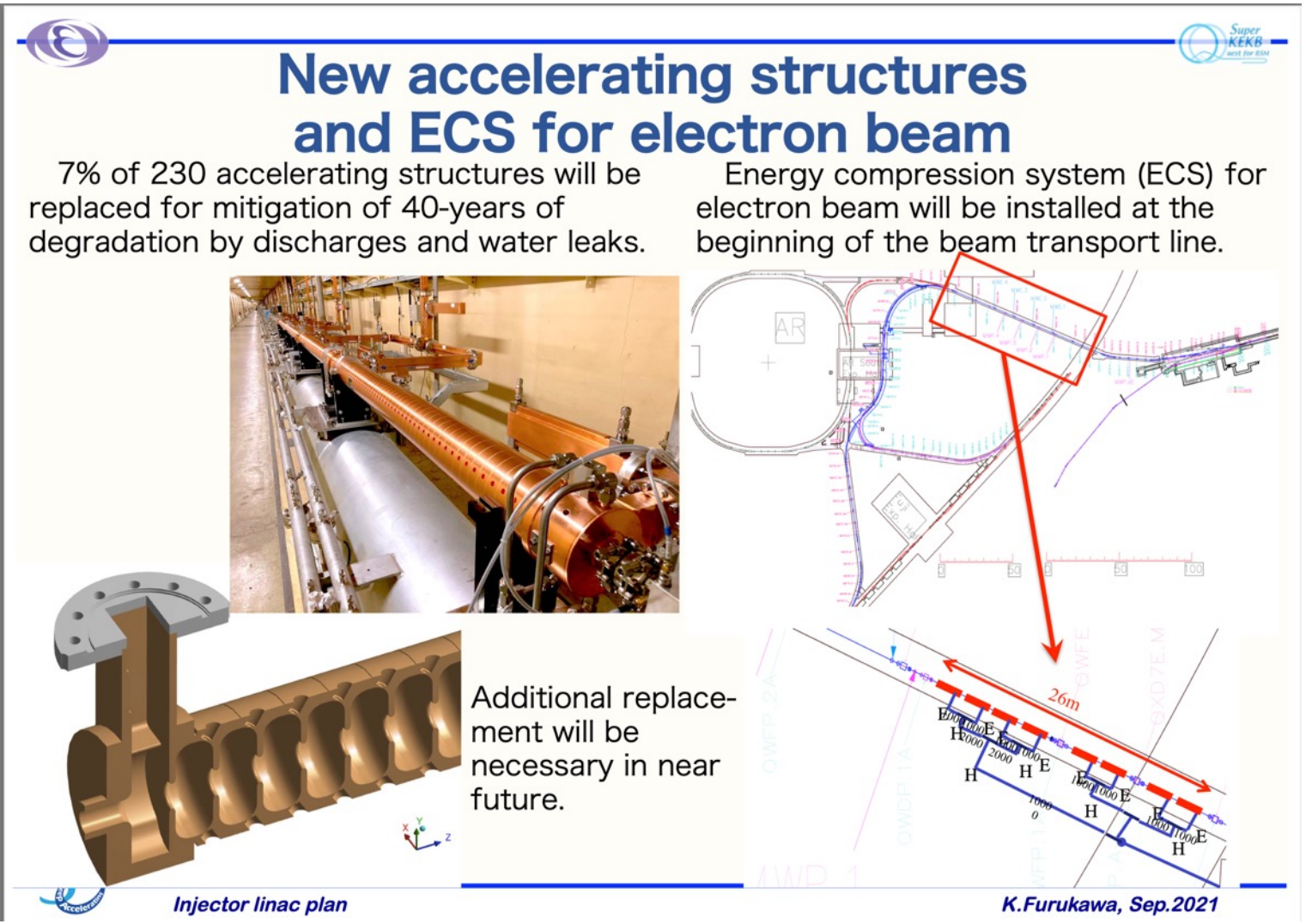
Green: Emittance measured with wire scanners(WSs)
BCS: Bunch Compression System
ECS: Energy Compression System

3. Injector complex

- Injector upgrade work during LS1
  - Pulsed Quads (x8) at J-ARC for the simultaneous dedicated matching of HER/LER injection beam
  - Pulsed Quads (x4) at Sector1, 2 for low beta optics of HER injection beam
  - New accelerating structure
  - Replacement of air conditioners at SectorA, B (in the accelerator tunnel)
  - Fast kicker for 2nd bunch orbit correction

- Injector upgrade plan/ideas after LS1
  - e- ECS installation in the current e- BT line
  - New e- BT line construction in PF-AR BT tunnel
    - To mitigate emittance growth due to ISR and CSR effect
  - Replacement of vacuum duct with the narrower one to mitigate CSR effect
  - Modification of SY3 dump line for the pulse-by-pulse beam diagnostics (2024)

BT e- ECS



In line with the budget rules, components of a new ECS and fabrication of components for a cooling water system were approved and fabricated in 3 years.

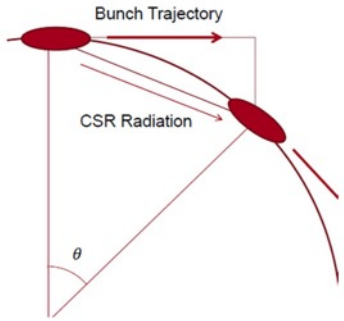
- Linac group has just started the study of the effectiveness and feasibility of e- ECS, including beam loss rates.
- Additional radiation shields might be needed to incorporate e- ECS.
- Comprehensive study is ongoing.

New BT line for HER

New BT line for the HER has been proposed, aiming at keeping the CSR/ISR emittance growth under control.

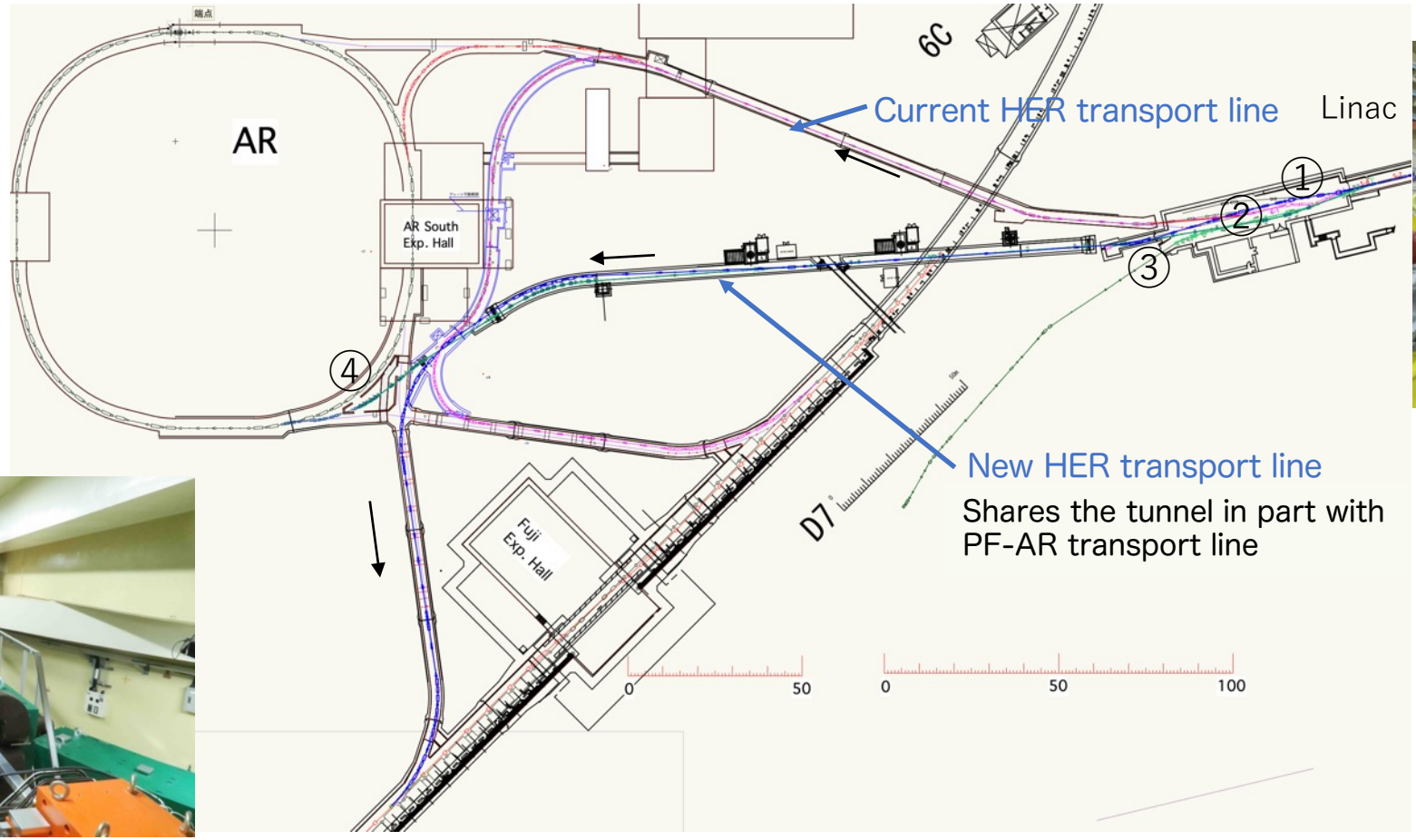
→ISR induced emittance growth of the new BT line decreased to 1/3 of that in the current BT line (simulation).

From ARC: Qualify the reduction in terms of CSR emittance growth as well.



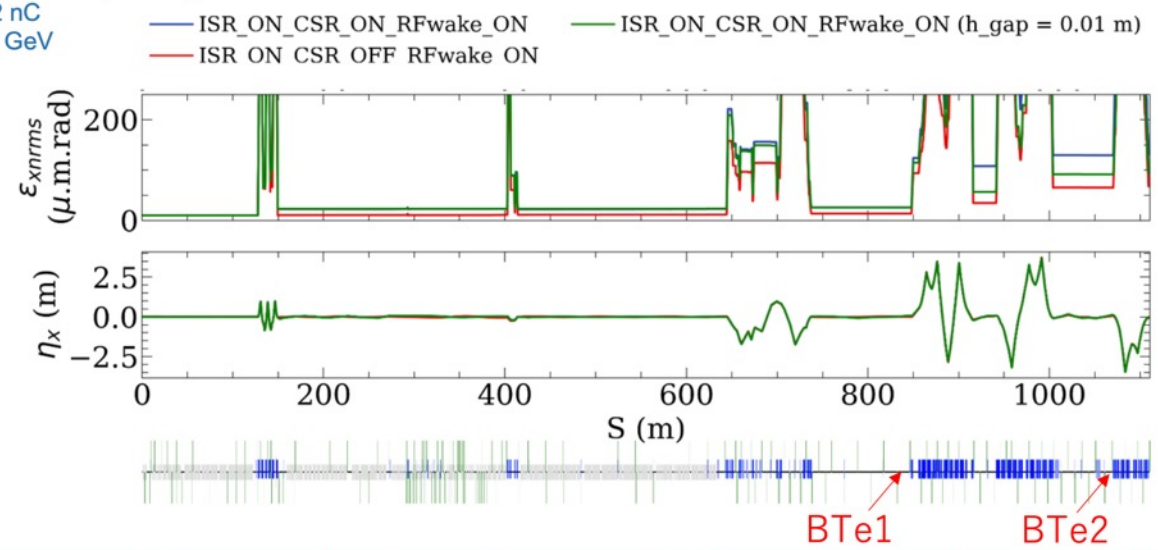
Picture by: SSSEPB 2015 linac and bunch compressor lecture #2, Tor Raubenheimer

Coherent/Incoherent
Synchrotron Radiation



Narrower beam duct for CSR shielding

Conditions in simulations:
- Linac RF phase: 86 deg (for minimum energy spread)
- CSR model: steady-state parallel-plate CSR model
- Bunch charge: 2 nC
- Beam energy: 7 GeV
- Jarc R56: 0.3

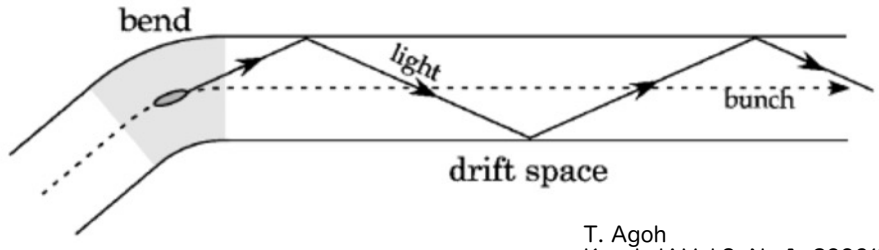


Model	x/y nemit (pi.um.rad) @ BTe1	x/y nemit (pi.um.rad) @ BTe2
ISR + CSR + RFWAKE (h=32 mm)	**26/12**	**129/12**
ISR + RFWAKE	14/10	65/11
ISR + CSR + RFWAKE (h = 10 mm)	25/11	91/11

- In the BTe, lower duct heights (h = 10 mm) partially mitigate CSR effects.

Horizontal emittance growth
CSR is one of the causes.

CSR shielding by
- operating with a vertical bump
- reducing the beam-pipe aperture←

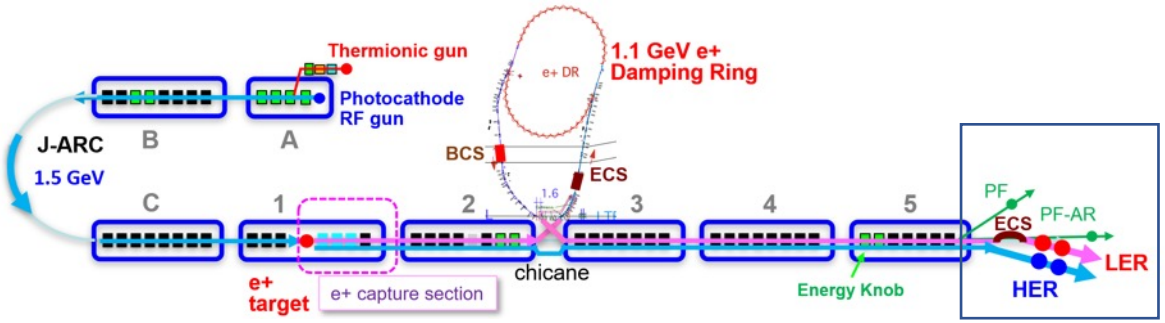


T. Agoh
Kasokuki Vol.3, No.1, 2006(24-30)

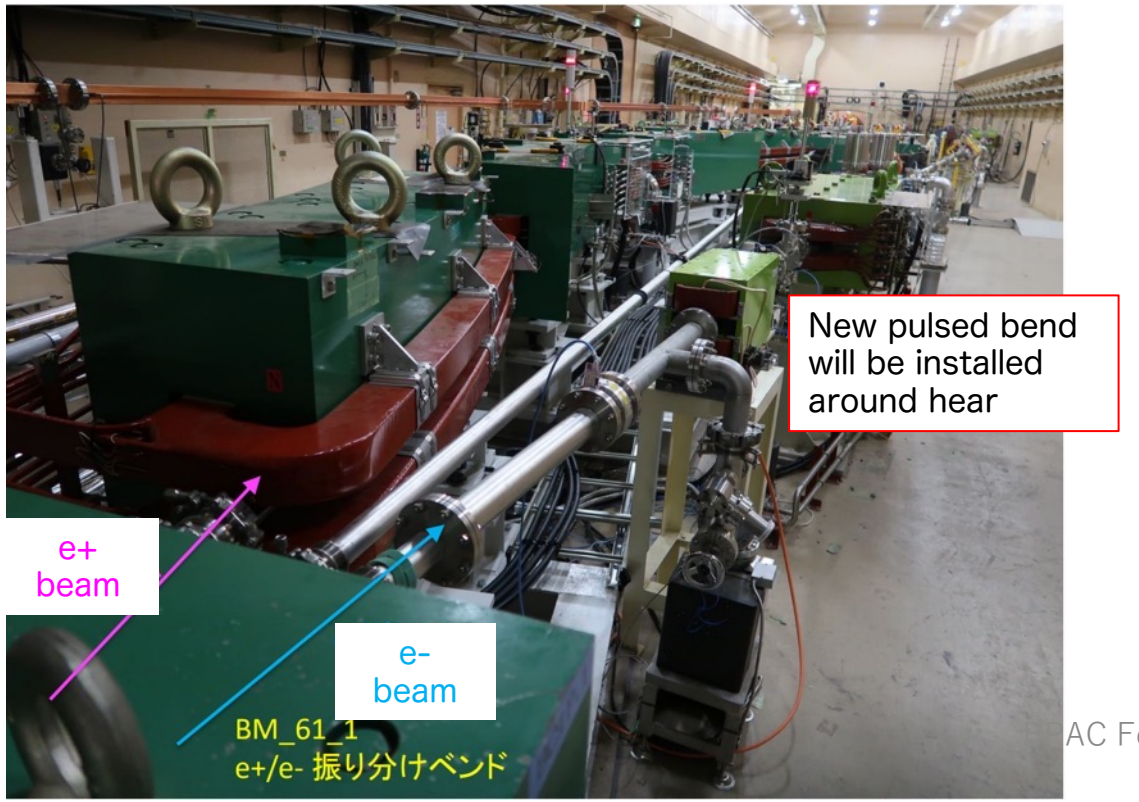
or
- Changing the BT layout to a new (more) straight line (previous page)

ARC:
Detailed optics investigation, 3D model for the CSR and so on should be done.

Dump line modification for pulse-by-pulse beam diagnostics during injection

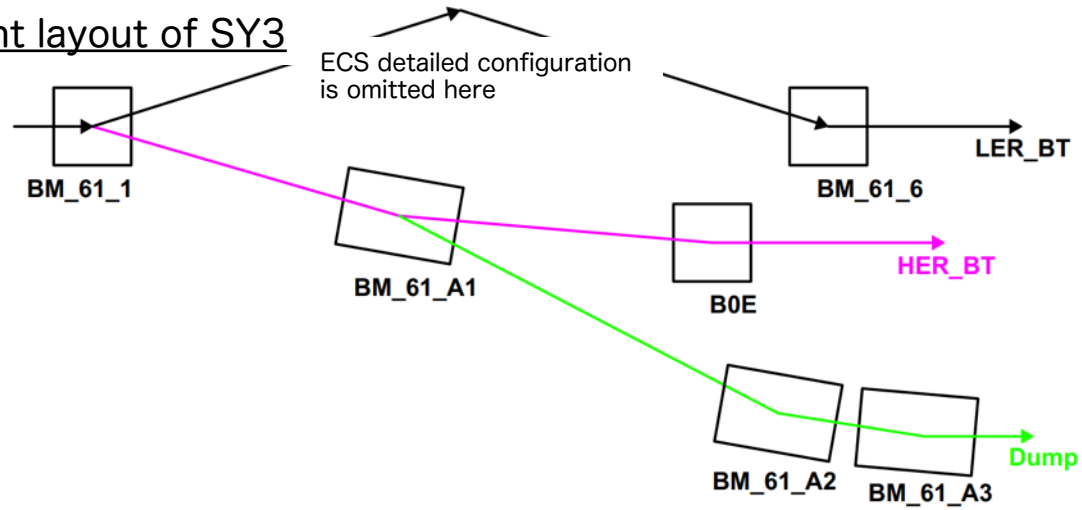


SY3:3rd beam Switch Yard

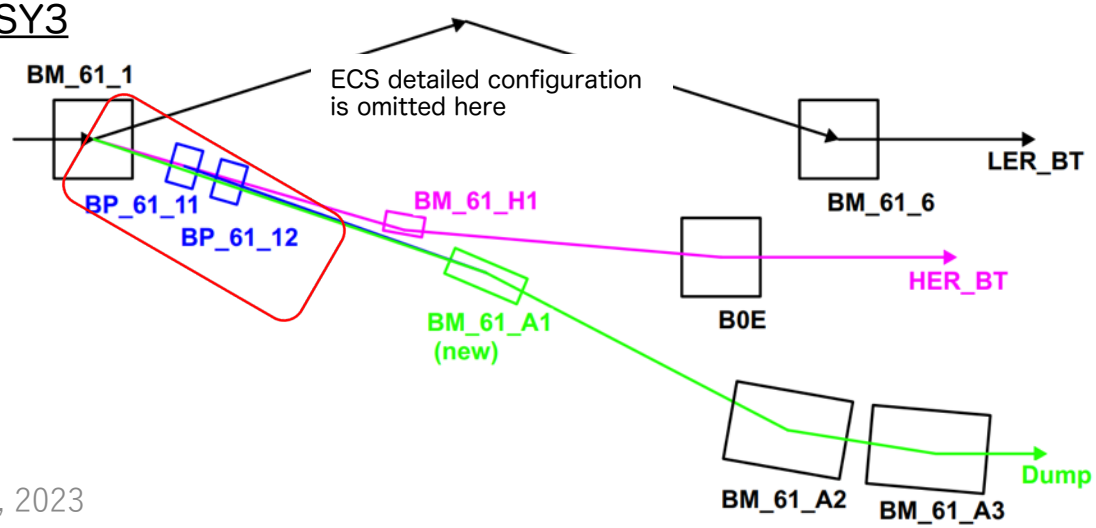


New pulsed bend will be installed around hear

Current layout of SY3



Future layout plan of SY3



4. Summary (MR & Injector complex)

- The MR/Injector complex modification ideas/plans are being considered for LS2
  - SuperKEKB-wide effort needs to be made to establish a reliable model through extensive machine studies after LS1.
  - R&D work also needed.
- We continue our efforts to improve the machine performance after LS1 and to develop a strategy for LS2.

Preliminary

1. Moderate scale modification around 2027

preparation 3.5 years, shutdown 1.5 years

Items	#		2022	2023	2024	2025	2026	2027
QC1	2(L/R)	(Nb_3Sn)		R&D	Prototype	Fabrication		Assembly Installation tests, field measurements
Cancel coil Leak field to HER	(b3, b4)x2(L/R)	(NbTi)			Fabrication			
Corrector coil	a1,b1,a2,b4 (L) +? a1,b1,a2,a3 (R)+?					BNL* 1.5 months/coil		
Cryostat front part	2(L/R)						Fabrication	

2. Larger scale modification

preparation > 5 years, shutdown > 2 years

Items	#		2022	2023	2024	2025	2026	2027
Solenoid coils	?	(NbTi)		Optical evaluation of field profile ↔ Conceptual Design			Detail design	
QC1	2(L/R)	(Nb_3Sn)		R&D	Prototype			
Corrector coil	a1,b1,a2,b4 (L) +? a1,b1,a2,a3 (R)+?	(Nb_3Sn)				Design	Fabrication	
Iron shield for leak field to HER	2(L/R)							Design
Cryostats for solenoid coils	New 2(L/R) Modified 2(L/R)							Design