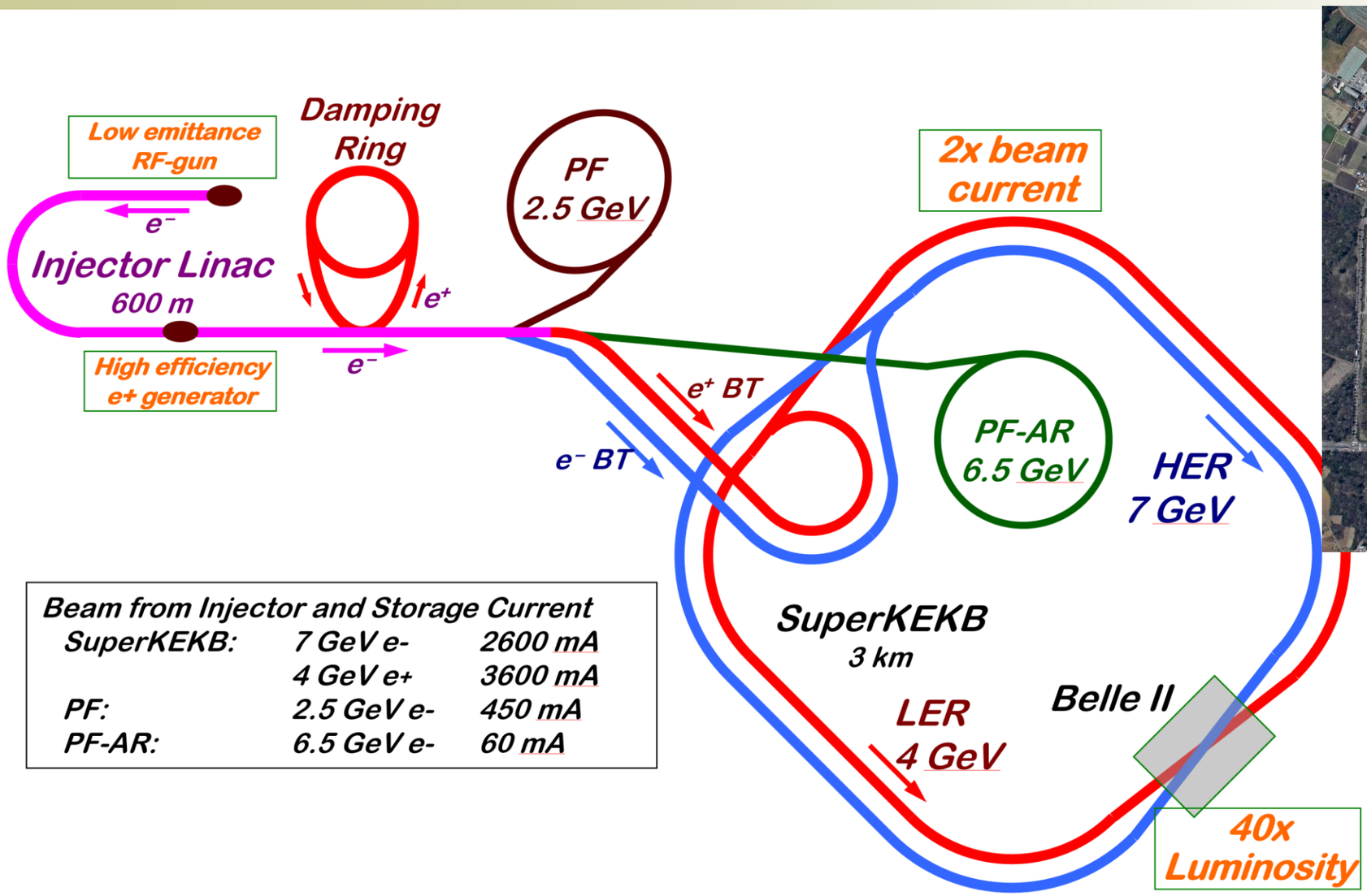
10 years in KEK

KEK Acc. Division
Yoshinori Enomoto

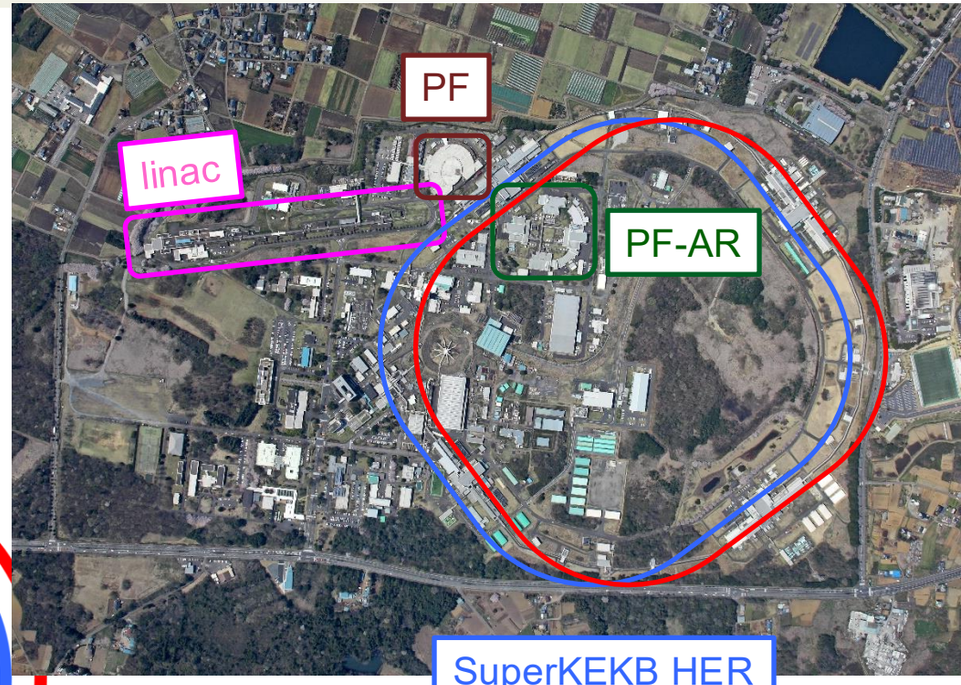
SuperKEKB in 2015

- I joined KEK electron positron injector group in 2015.
- KEKB ended in 2010 and SuperKEKB will start commissioning around 2016.
- Upgrade project was in the final phase.
- Several components were facing problem….
- That’s why I had a chance to join unrelated topics.
  - Pulsed magnet
  - Positron source
  - Mover

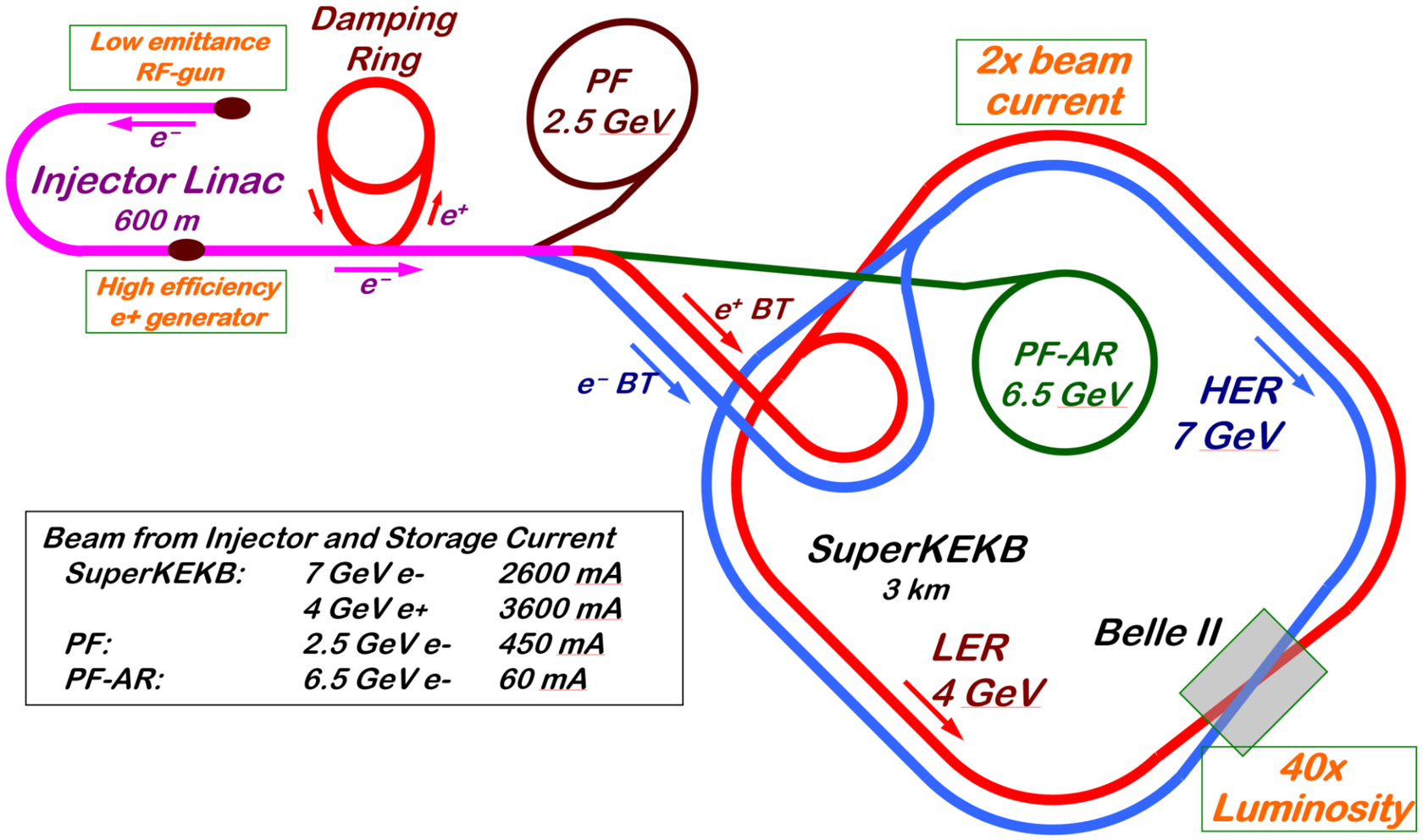
Accelerators in KEK Tsukuba



Beam from Injector and Storage Current		
SuperKEKB:	7 GeV e-	2600 mA
	4 GeV e+	3600 mA
PF:	2.5 GeV e-	450 mA
PF-AR:	6.5 GeV e-	60 mA



Accelerators in KEK Tsukuba



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	4 GeV e+	3600 mA
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- 4 rings and 1 linac
  - Two light source rings
    - PF, PF-AR
  - Two collider rings
    - SuperKEKB LER, HER
- Parallel configuration
  - No booster ring
- All storage rings
  - Full energy injection
  - Top-up injection
- Positron injection to LER

Requirements and progress on pulse-to-pulse operation

- Slow switch operation (-2009)

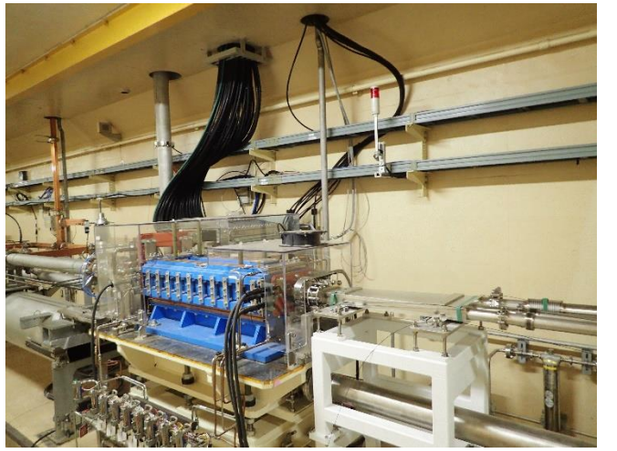
PF	PF-AR	KEB HER/LER	PF	PF-AR	KEKB HER/LER
20 min.	10 min.	7.5 hours	20 min.	10 min.	7.5 hours

- 3 ring injection with ***DC magnets (2010)***
  - PF pulsed bending magnet (switching magnet) was installed at the end of the linac.

PF-AR	PF, KEB HER/LER	PF-AR	PF, KEKB HER/LER
10 min.	7.8 hours	10 min.	7.8 hours

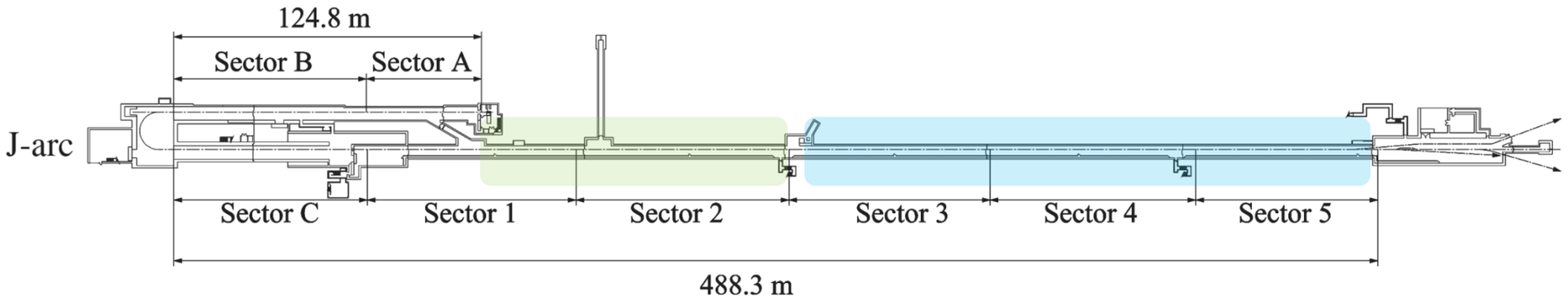
- Toward SuperKEKB (2018-)
  - Very short beam life time in the SuperKEKB rings (360 sec.).
    - 10 min. Interruption is not acceptable.
    - PF-AR direct injection line was constructed.
  - Small dynamic aperture
    - Low emittance beam is required for injection.
    - RF gun and positron dumping ring were installed.
    - For emittance preservation, optimization of the optics for each ring is required.

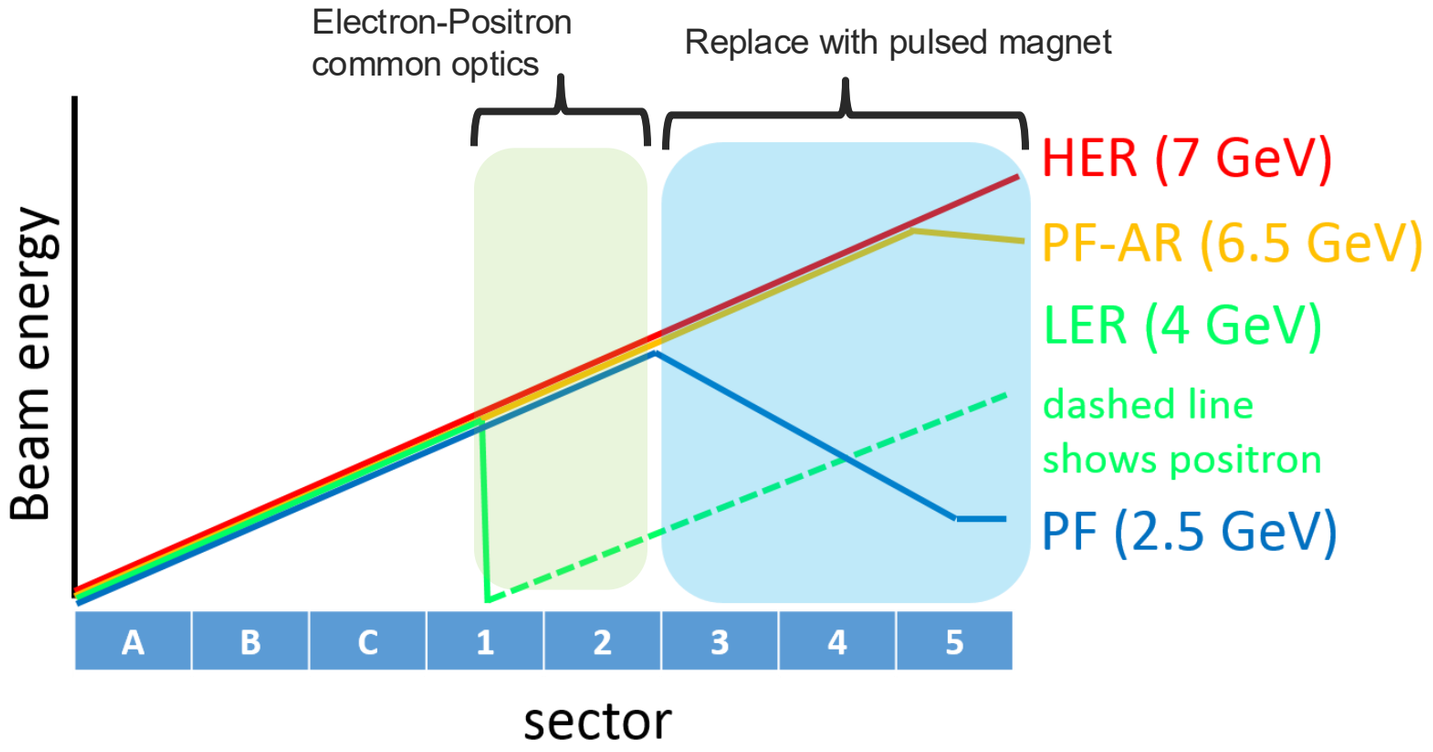
PF, PF-AR, SuperKEB HER/LER
always



PF pulsed bending magnet

Beam energy and structure of our linac

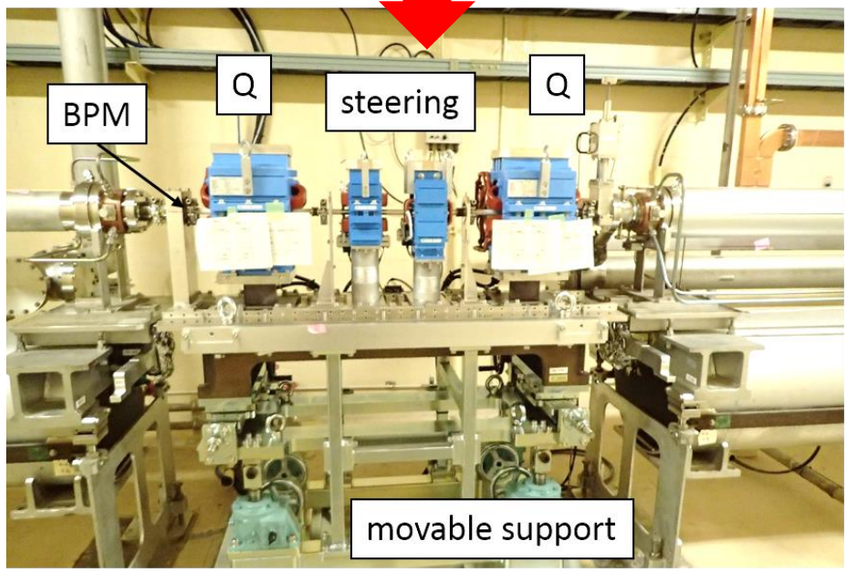




- 600 m long, 8 sectors
- Maximize common energy section to use DC magnets as much as possible
- Install pulsed magnets mainly in sector 3 to sector 5

26 quads and 26 steerings @ sector 3-5
10 steerings @ sector 1,2
2 quads @ positron production target

Replacement of magnets



type	L@1 kHz	R	max current	magnetic field	gap	Installed Num.
PX_16_5	2.4 mH	71 mohm	40 A	1040 AT	72 mm	1
PY_16_5	2.4 mH	71 mohm	40 A	1040 AT	72 mm	1
PX_17_2	2.6 mH	127 mohm	40 A	1440 AT	39 mm	4
PY_17_2	2.6 mH	126 mohm	40 A	1440 AT	39 mm	4
PX_32_4	2.9 mH	115 mohm	40 A	1440 AT	20 mm	13
PX_32_4	2.9 mH	115 mohm	40 A	1440 AT	20 mm	13
PM_32_4	1.0 mH	8 mohm	330 A	60 T/m	ϕ 20 mm	28

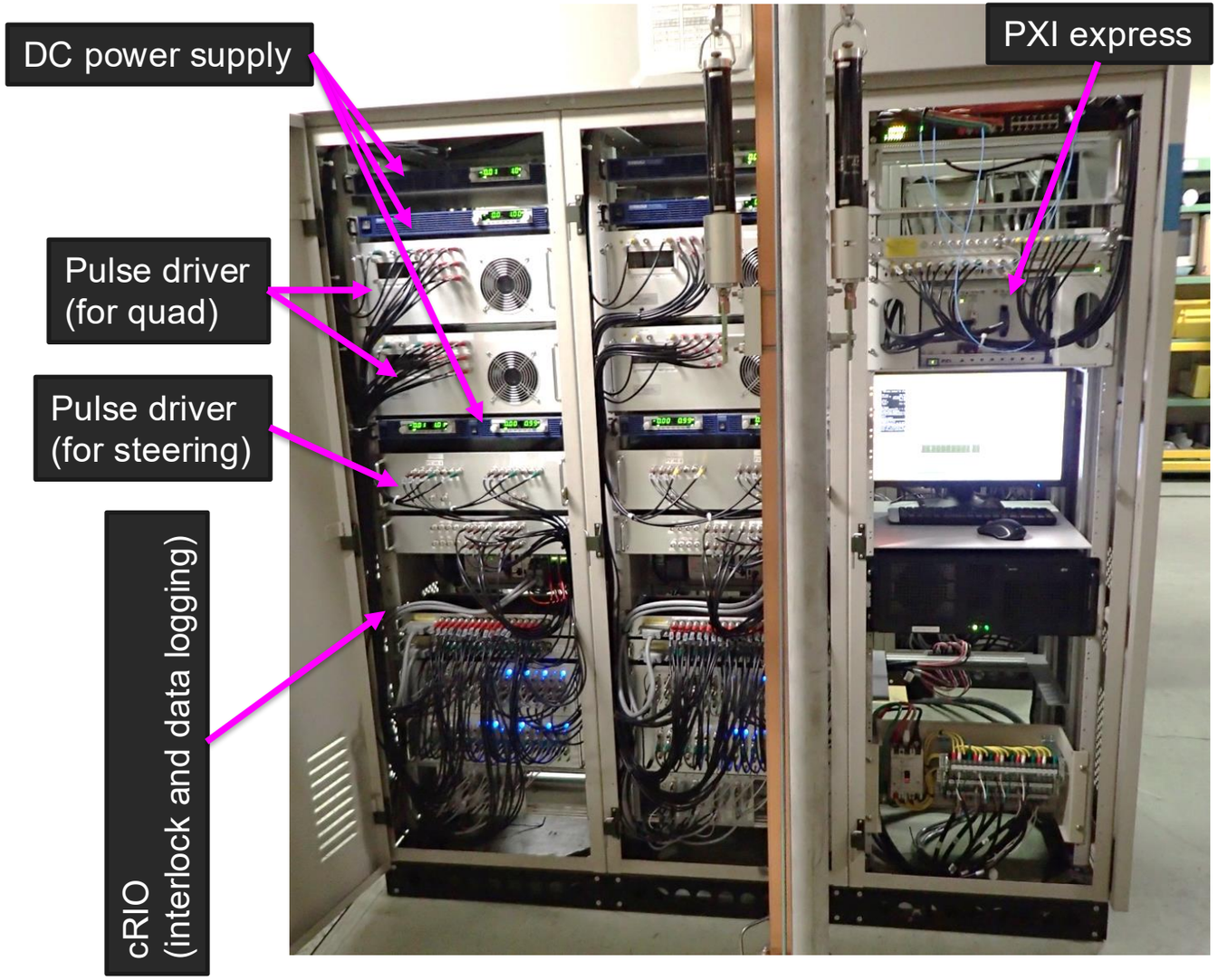
Maximum design current of steering magnets are 40 A but operated at 10 A

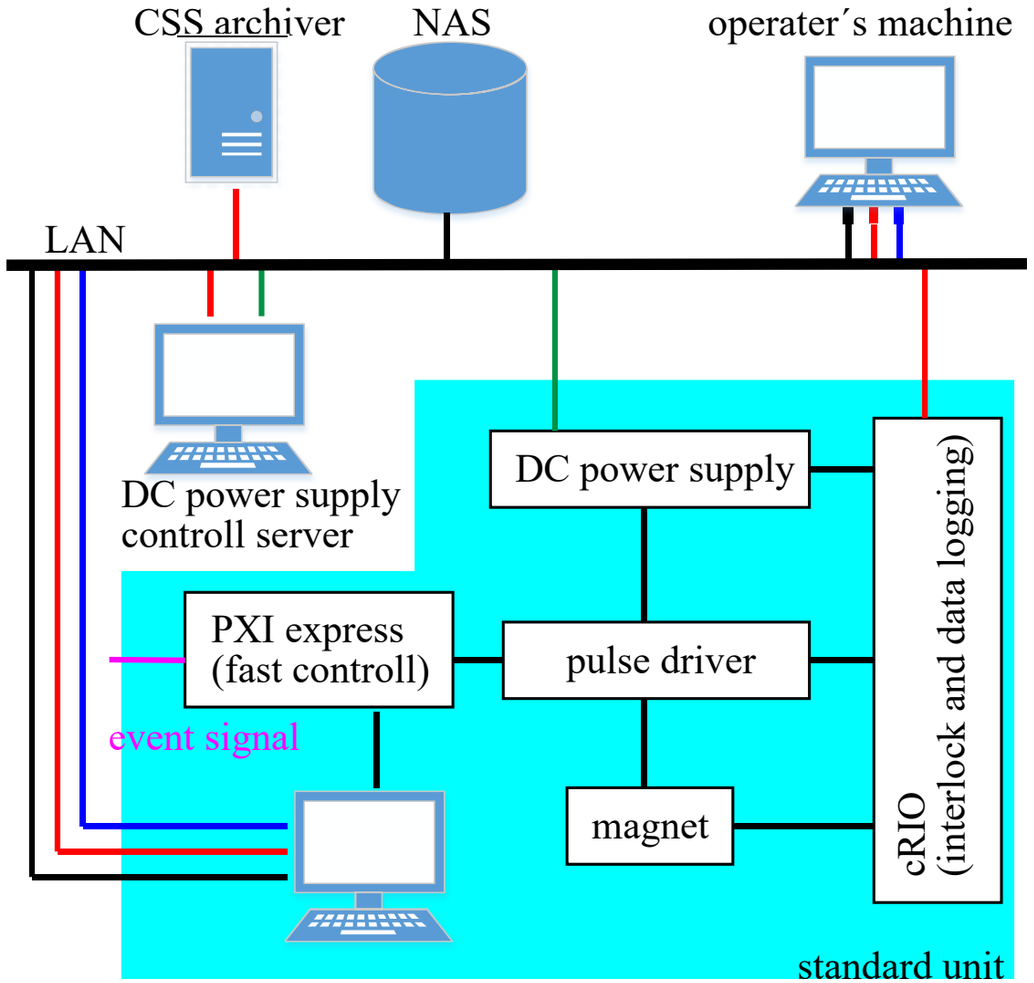
- 64 magnets were installed in 2017.
  - Several types of steering magnets
  - One type of quad magnet
- 52 magnets of them were installed as a common unit.
  - 2 x quad magnets.
  - horizontal and vertical steering magnets
  - BPM
  - Movable support

Replacement continues and finally more than 100 pulsed magnets were installed

System configuration of the pulsed power supplies

Standard power supply unit (4 x quad + 4 x steering)





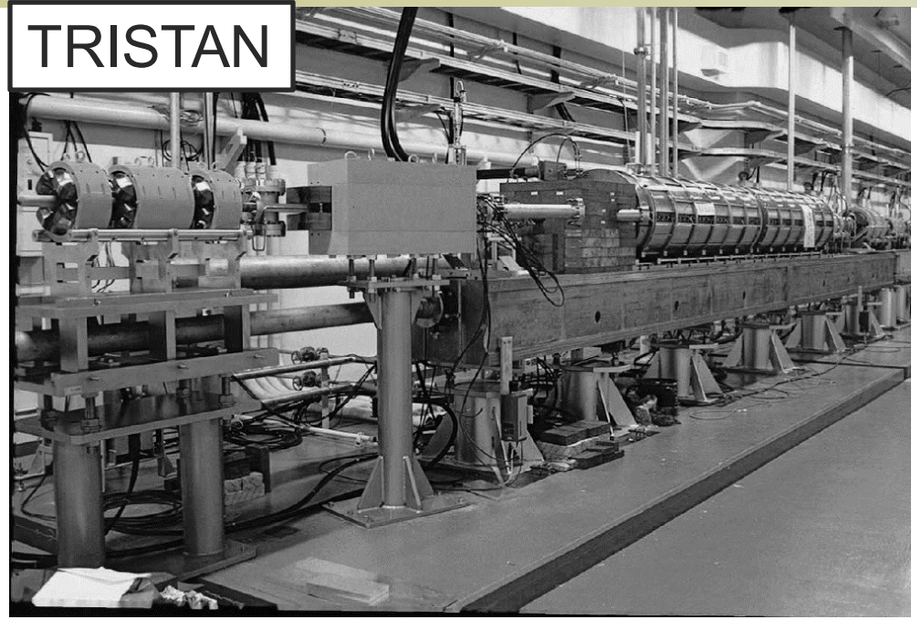
EPICS CA

LXI ver 1.3

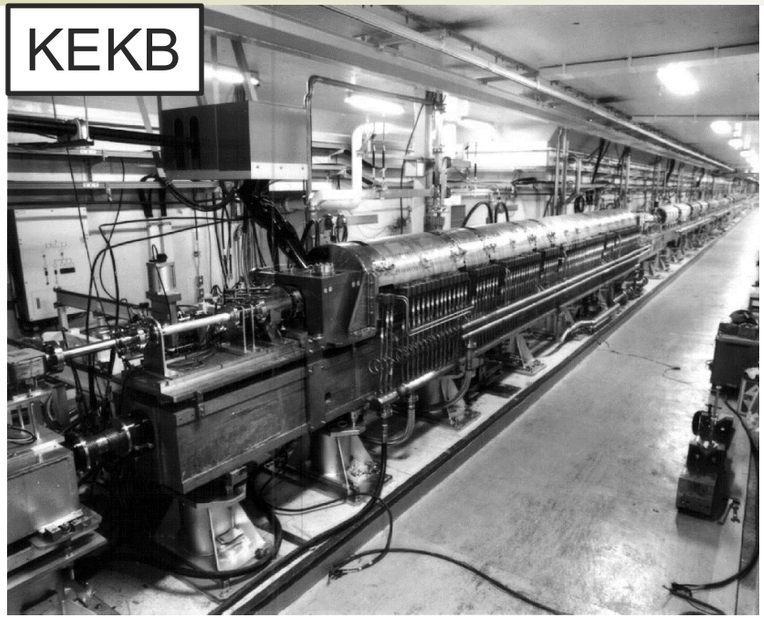
NI network shared variable

Positron source in KEK

TRISTAN



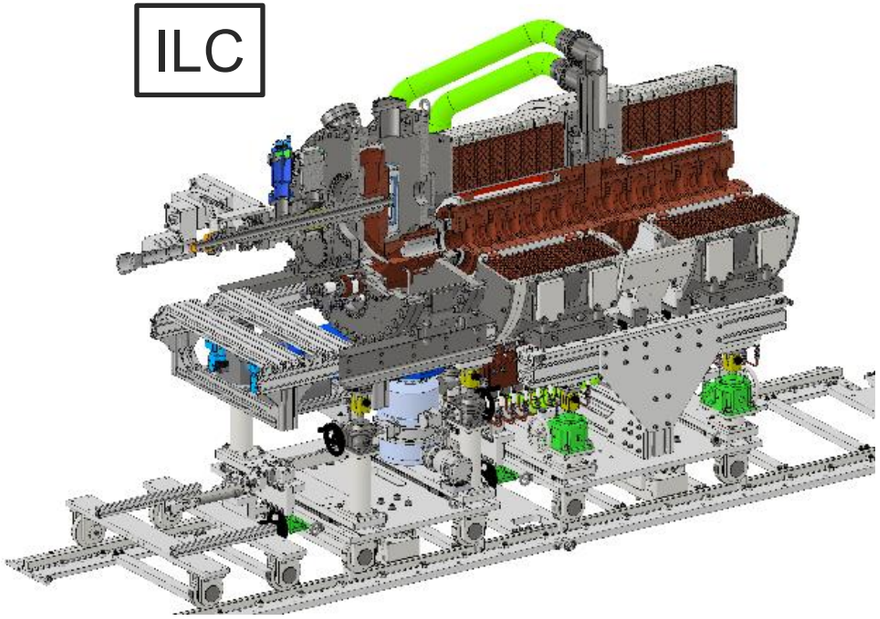
KEKB



- KEK has been developing and operating positron sources since 1980's

SuperKEKB

ILC



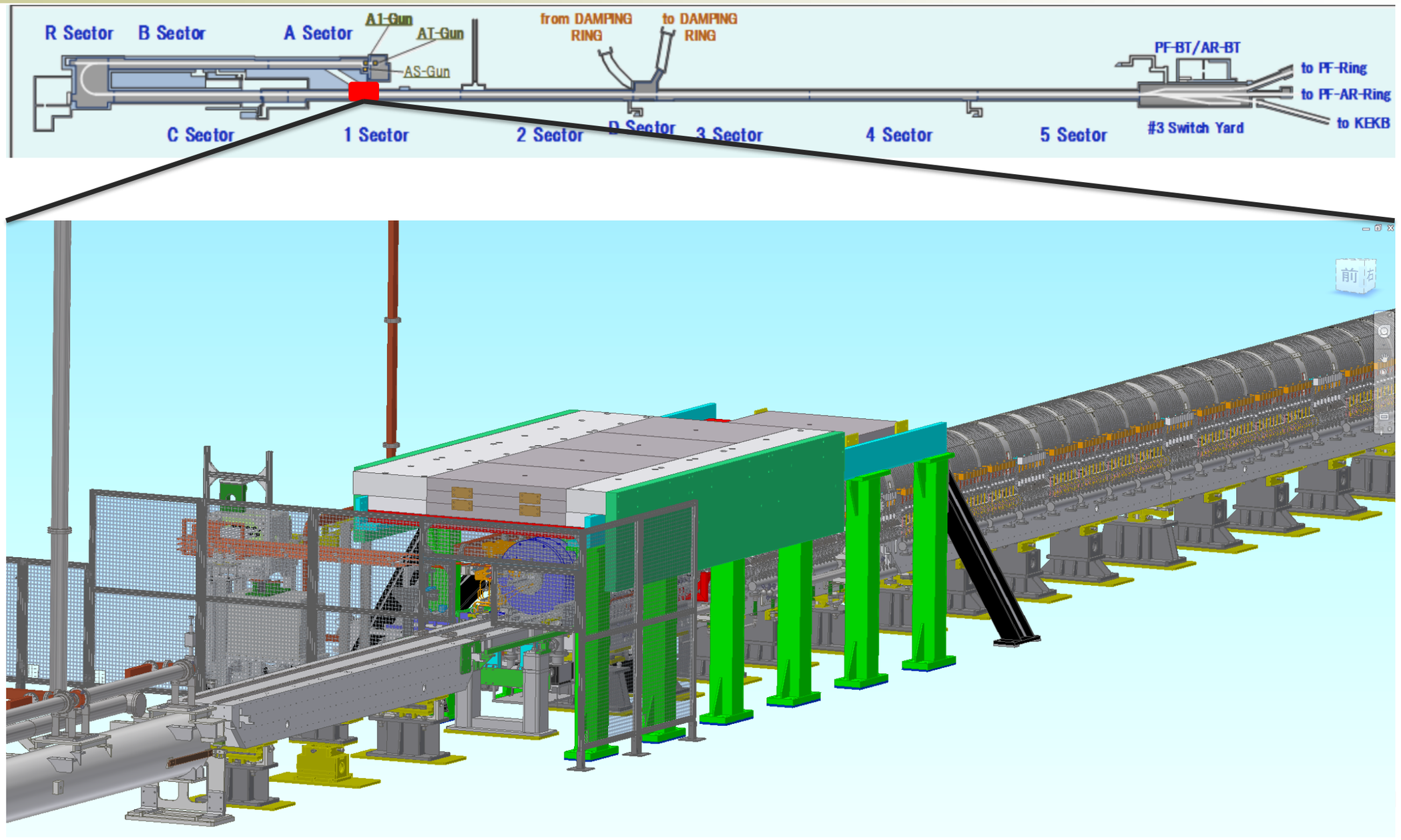
Required injector beam parameters

Stage	KEKB (final)		Phase-I		Phase-II		SuperKEKB (final)	
Beam	e+	e–	e+	e–	e+	e–	e+	e–
Energy	3.5 GeV	8.0 GeV	4.0 G	GeV	4.0 GeV	7.0 GeV	4.0 GeV	7.0 GeV
Stored current	1.6 A	1.1 A	1 A	1 A	1.5 A	1.2 A	3.6 A	2.6 A
Life time (min.)	150	200	100	100	–	–	6	6
Bunch charge (nC)	primary e- 10 → 1	1	primary e- → 0.4	1	0.5	1	primary e- 10 → 4	4
Norm. Emittance (γβε) (μrad)	1400	310	1000	130	200/40 (Hor./Ver.)	150	100/15 (Hor./Ver.)	40/20 (Hor./Ver.)
Energy spread	0.125%	0.125%	0.5%	0.5%	0.16%	0.1%	0.16%	0.07%
Bunch / Pulse	2	2	2	2	2	2	2	2
Repetition rate	50 Hz		25 / 50 Hz		25 / 50 Hz		50 Hz	
Simultaneous top-up injection (PPM)	3 rings (LER, HER, PF)		No top-up		Eventually		4+1 rings (LER, HER, DR, PF, PF-AR)	

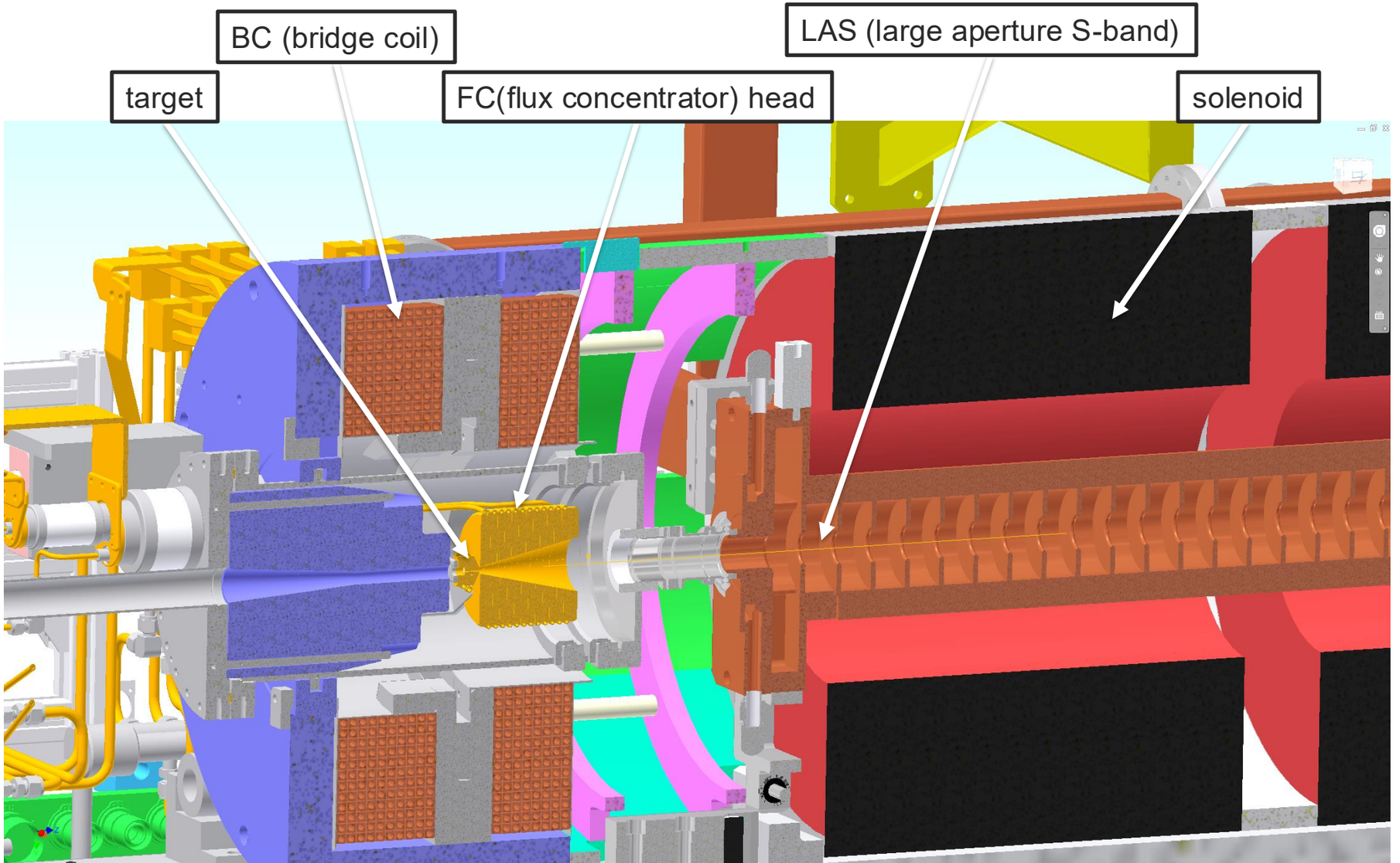
x2.25

1/25

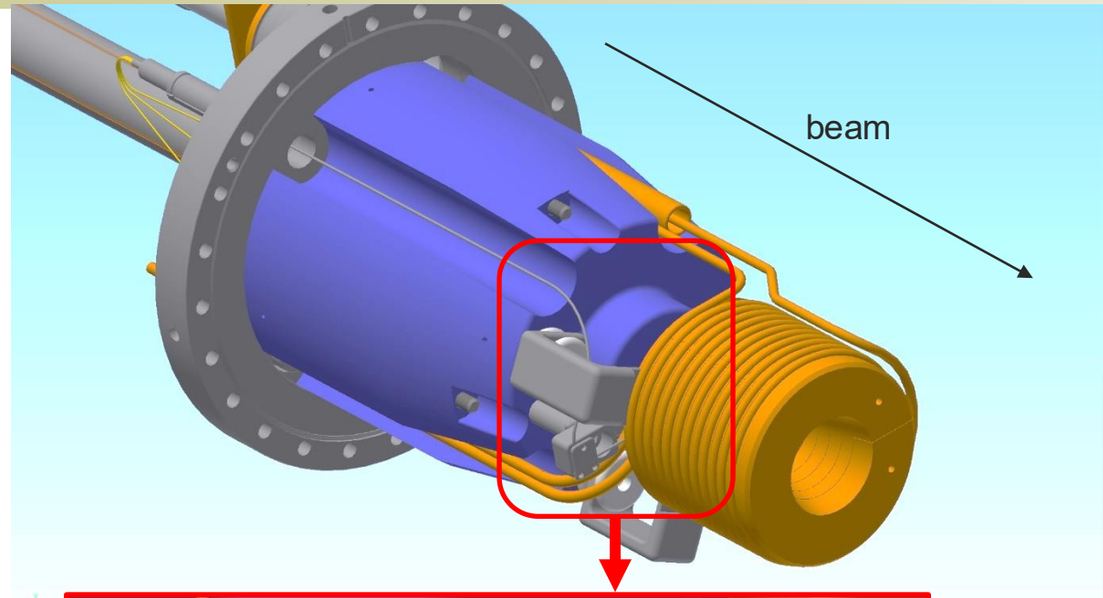
Positron source setup 1

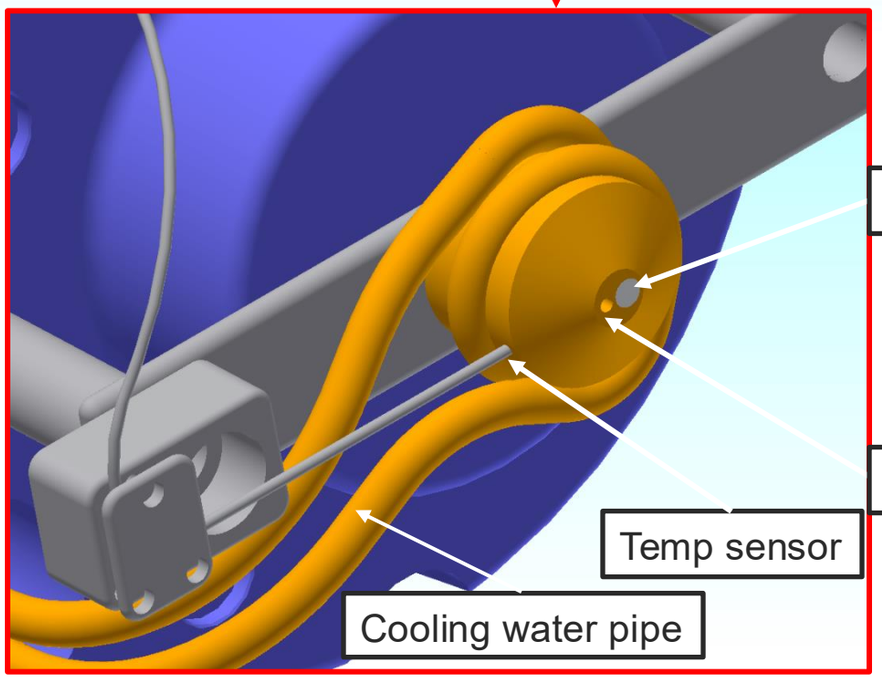


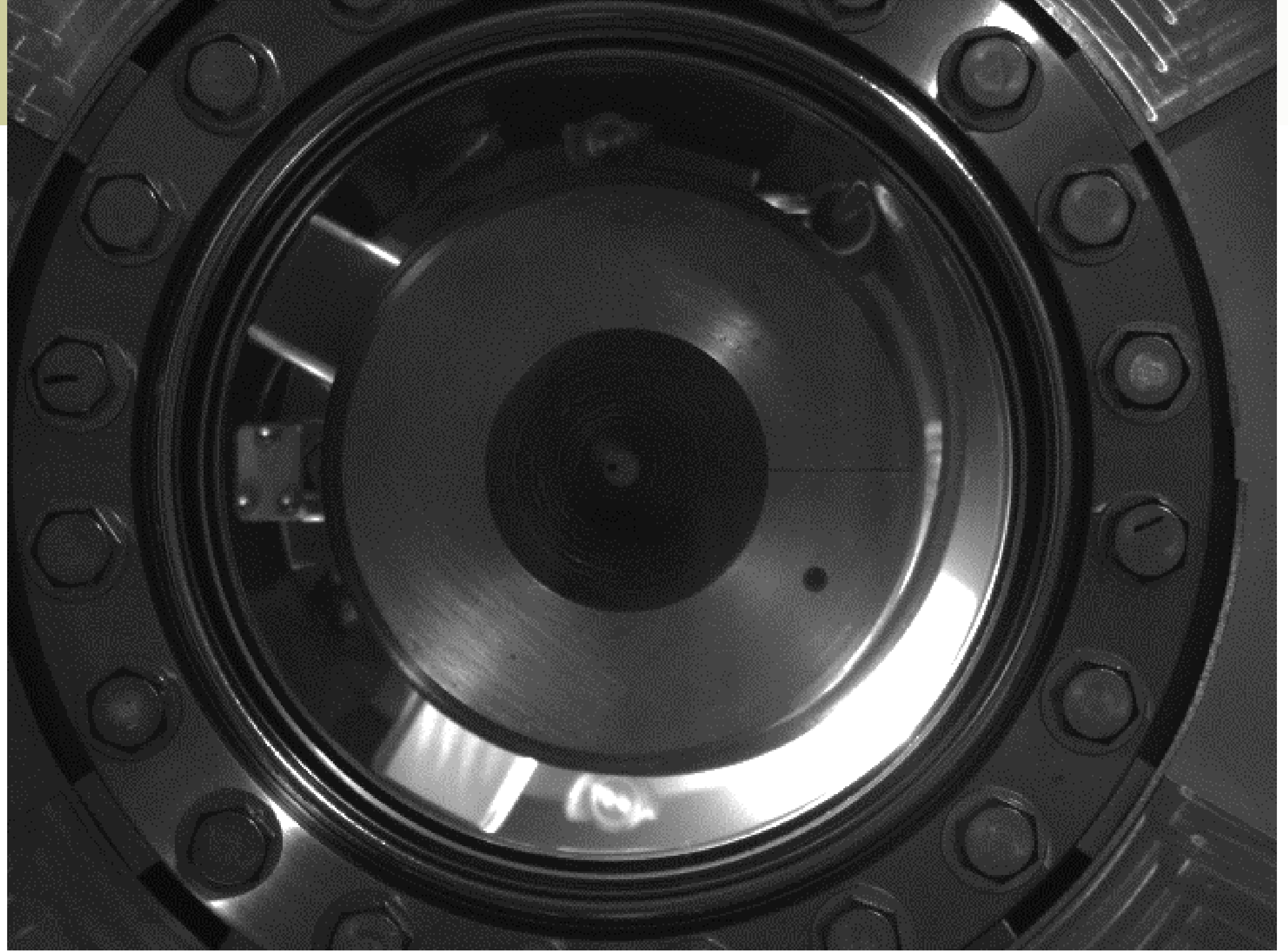
Positron source setup 2

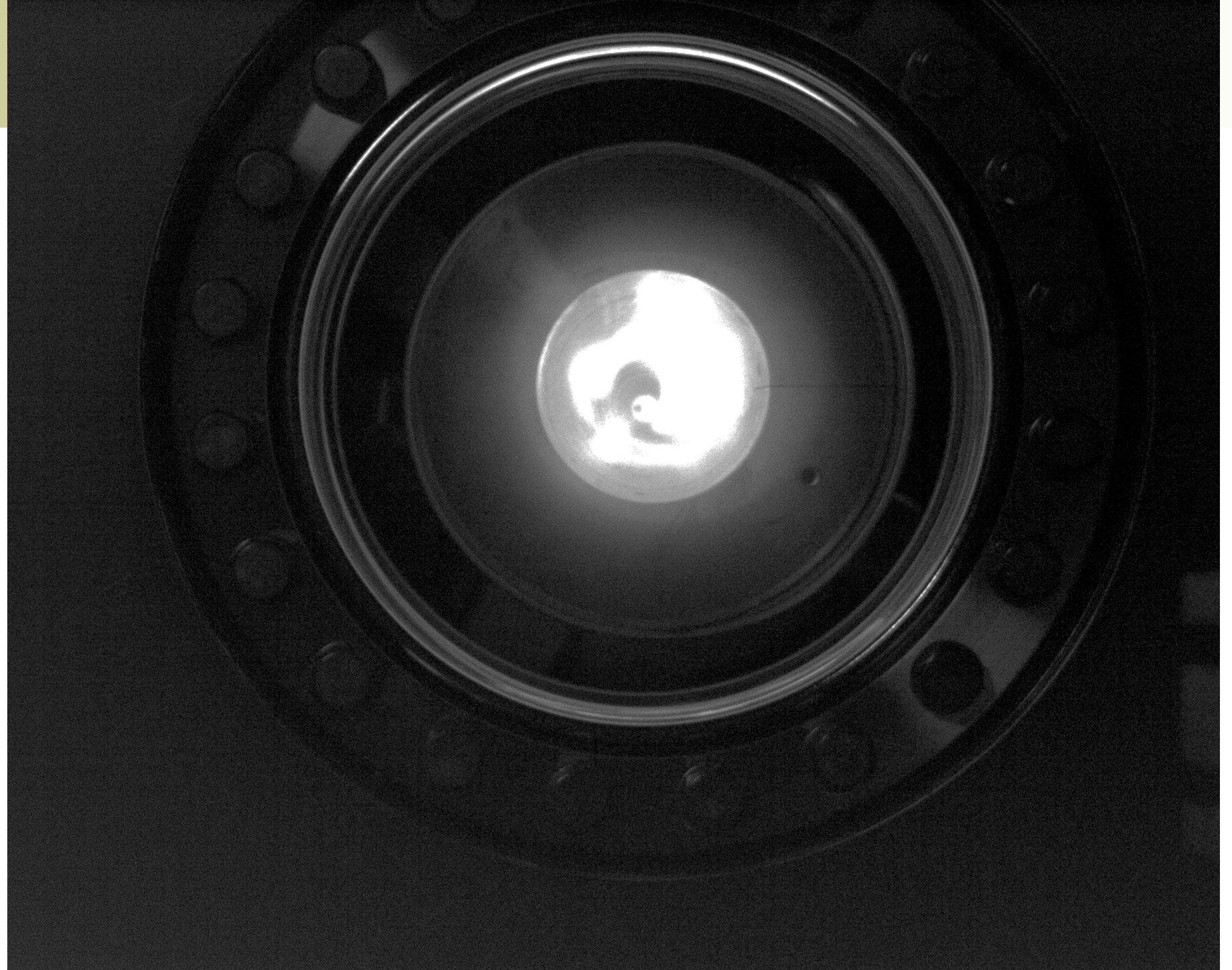


Positron source setup 3

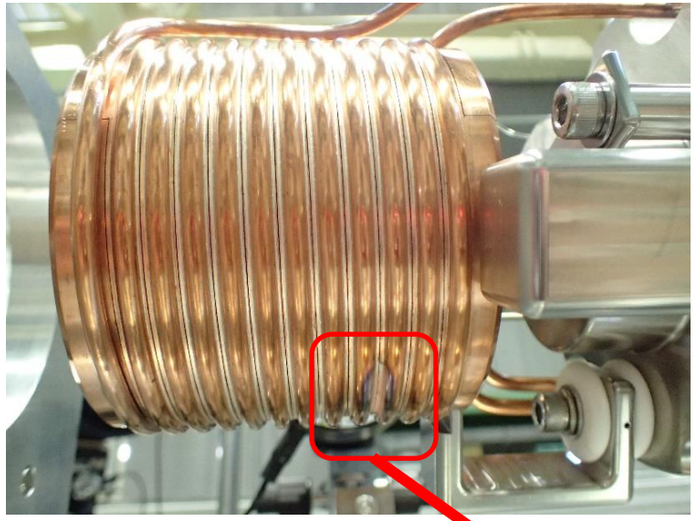


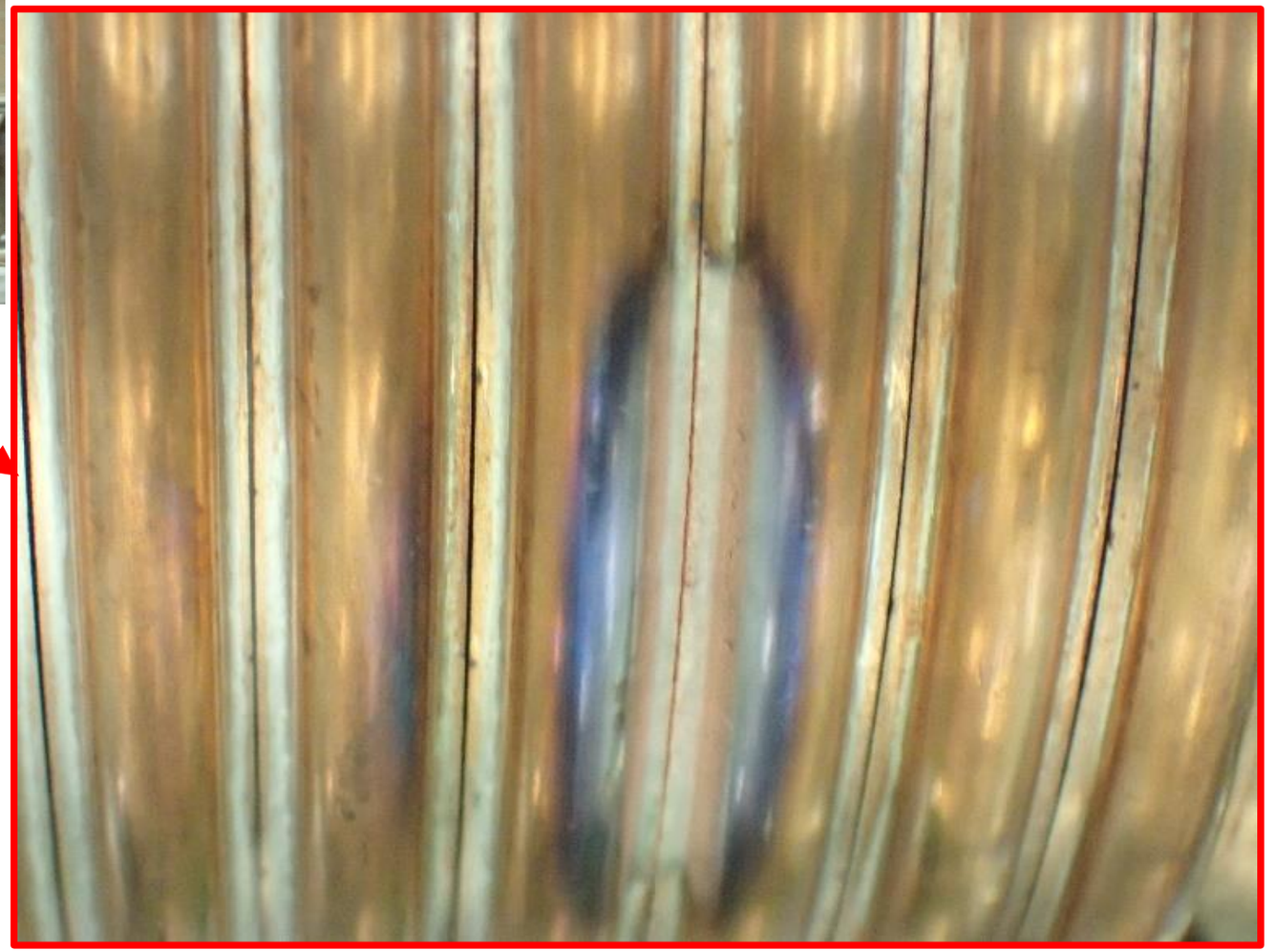






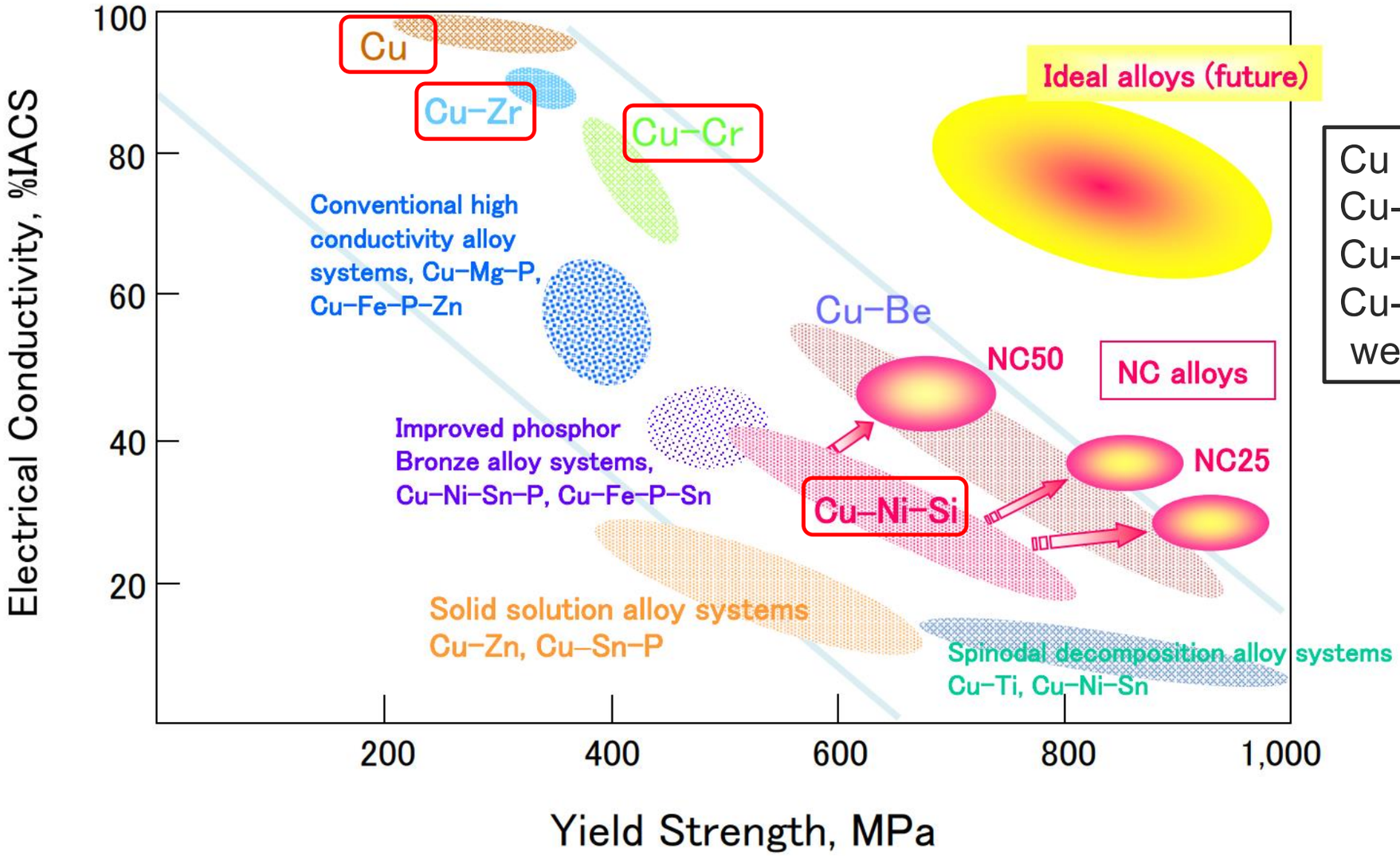
After large discharge…





Slit gap got narrow.
Not possible to apply high voltage unless the gap will be expanded.

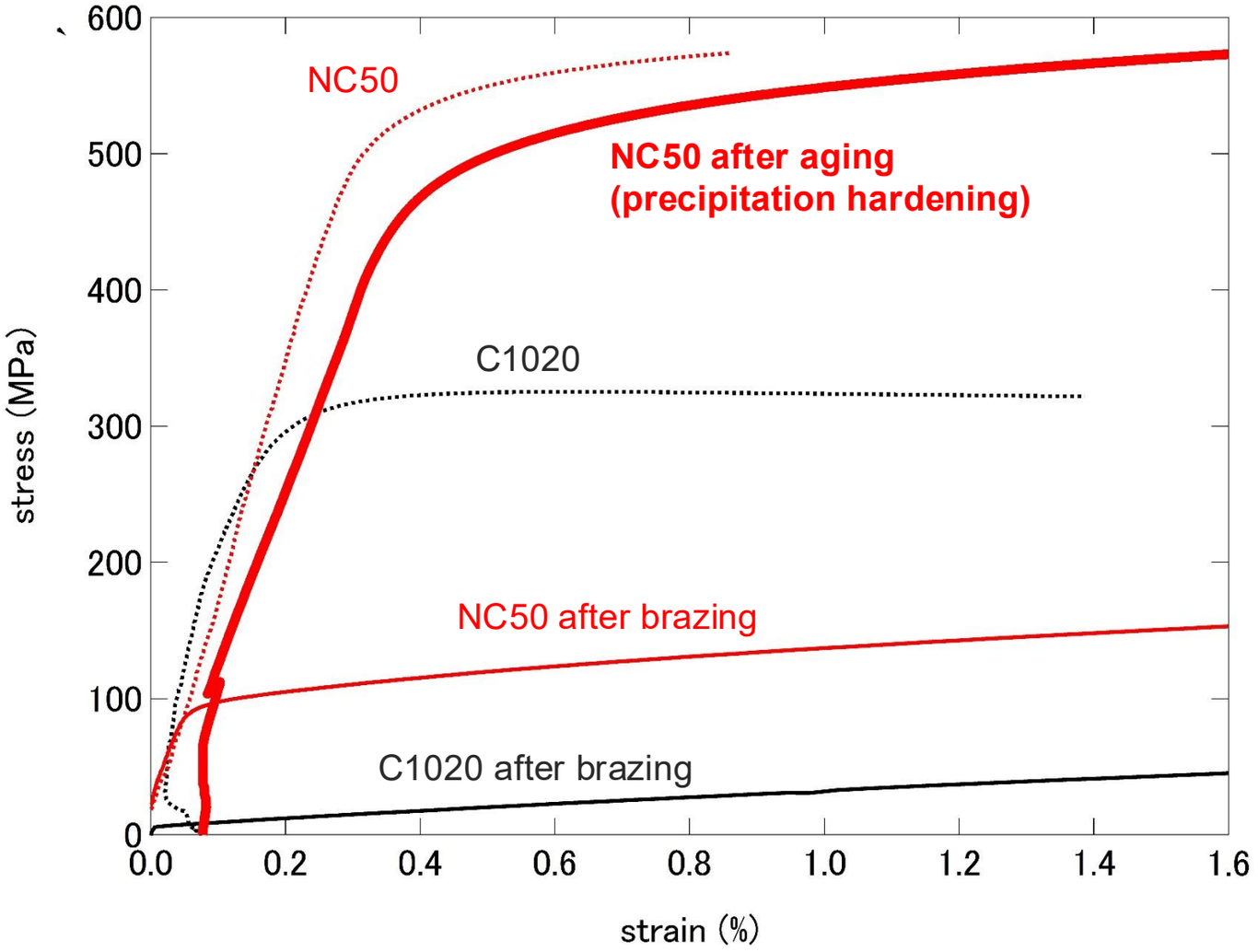
Cu alloys



Positions of various copper alloy systems in conductivity–strength map

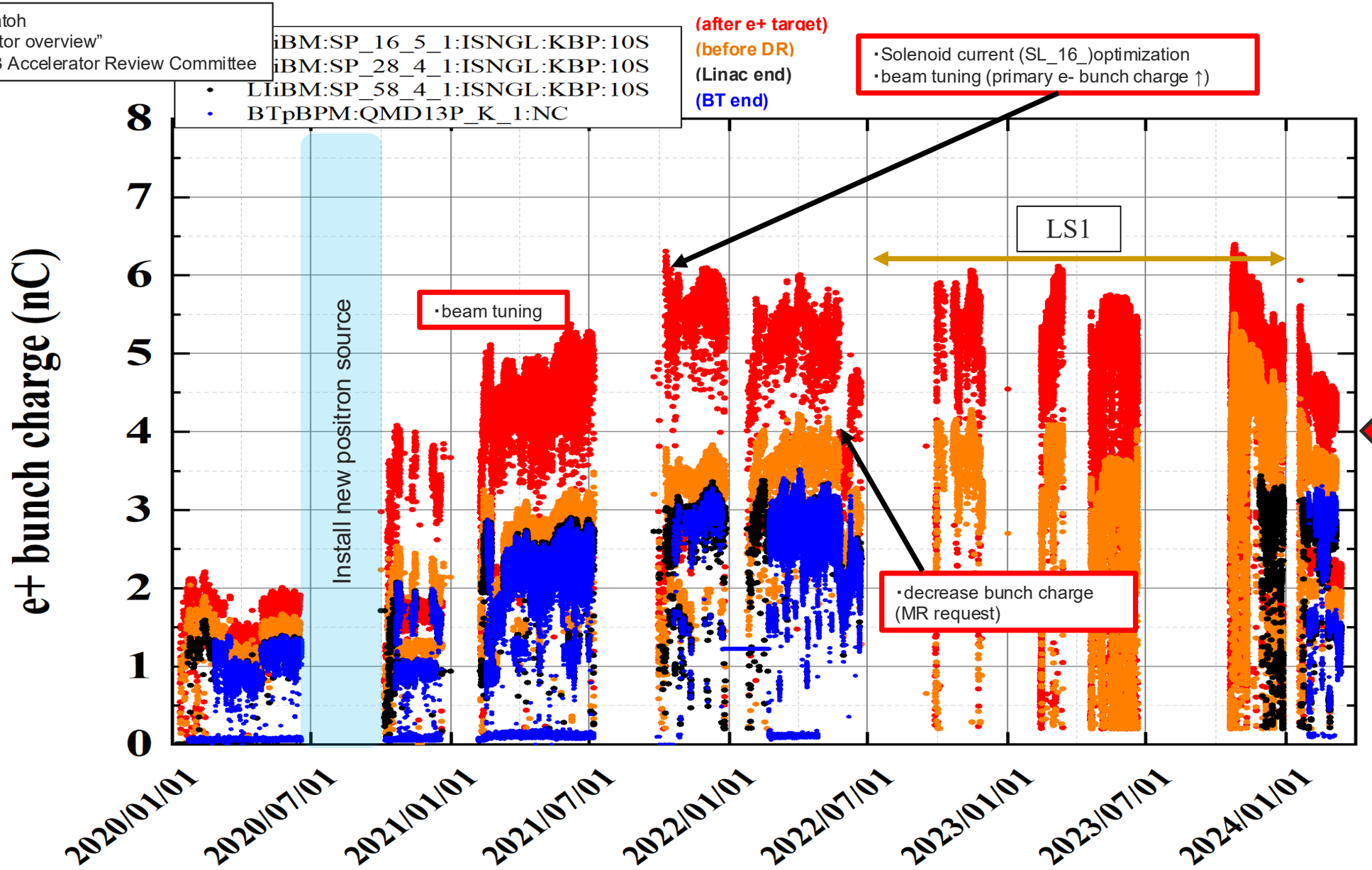
Cu
Cu-Zr
Cu-Cr
Cu-Ni-Si
were tested

Strain-stress curve for C1020 and NC50



History of bunch charge

M. Satoh
"Injector overview"
KEKB Accelerator Review Committee

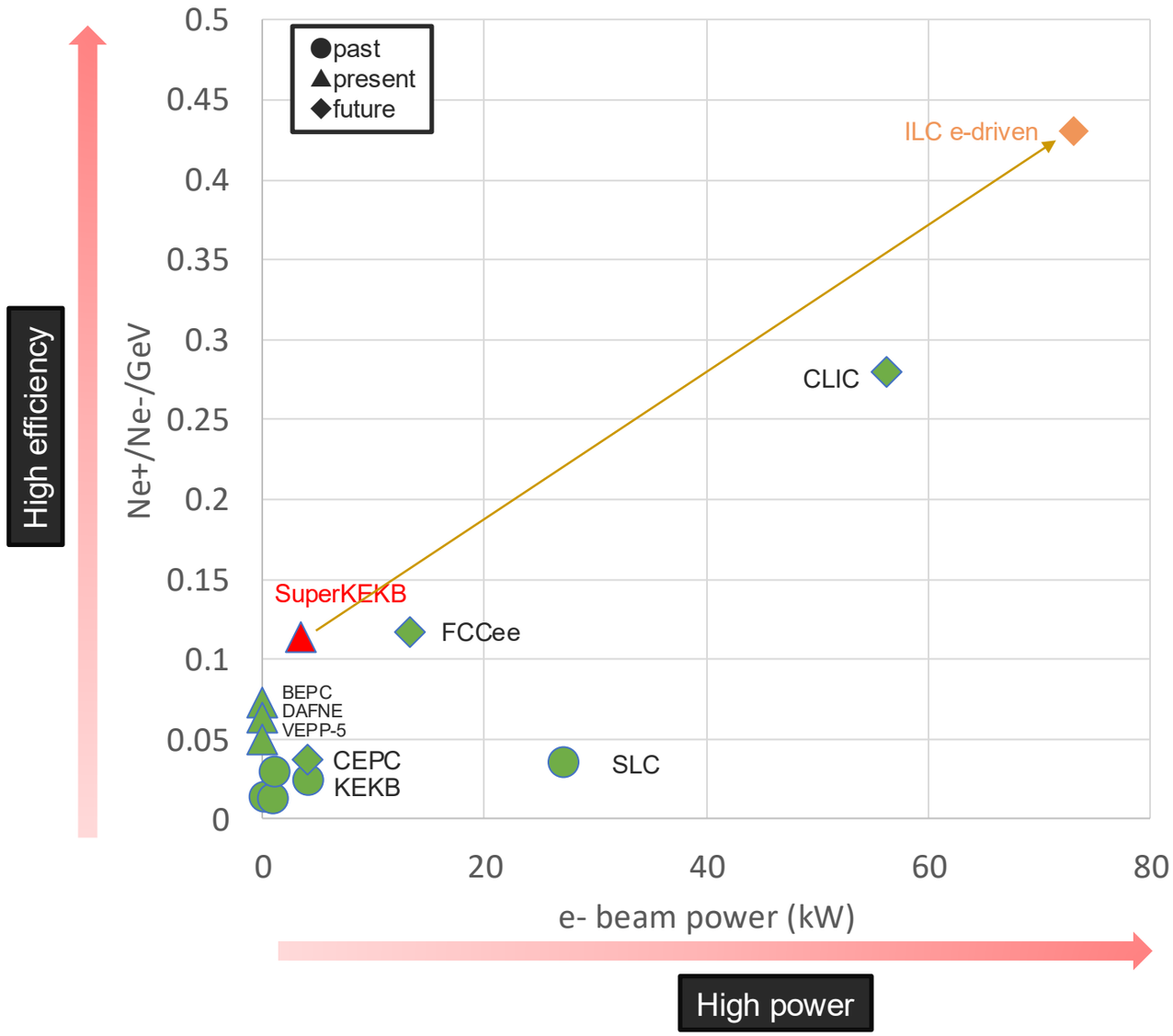


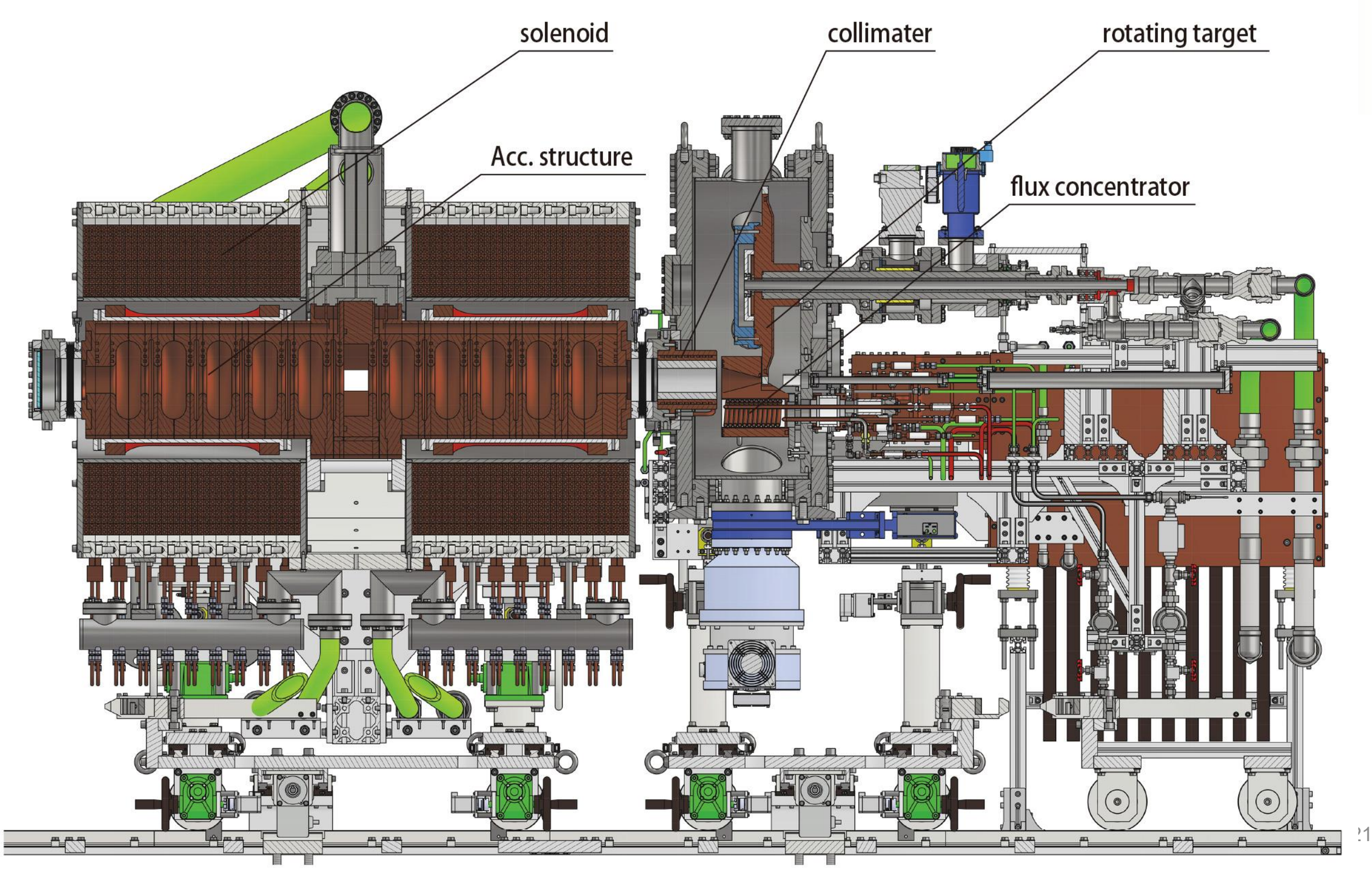
- New positron source was installed in 2020
- Bunch charge reached design value after a few years of beam tuning

Design value

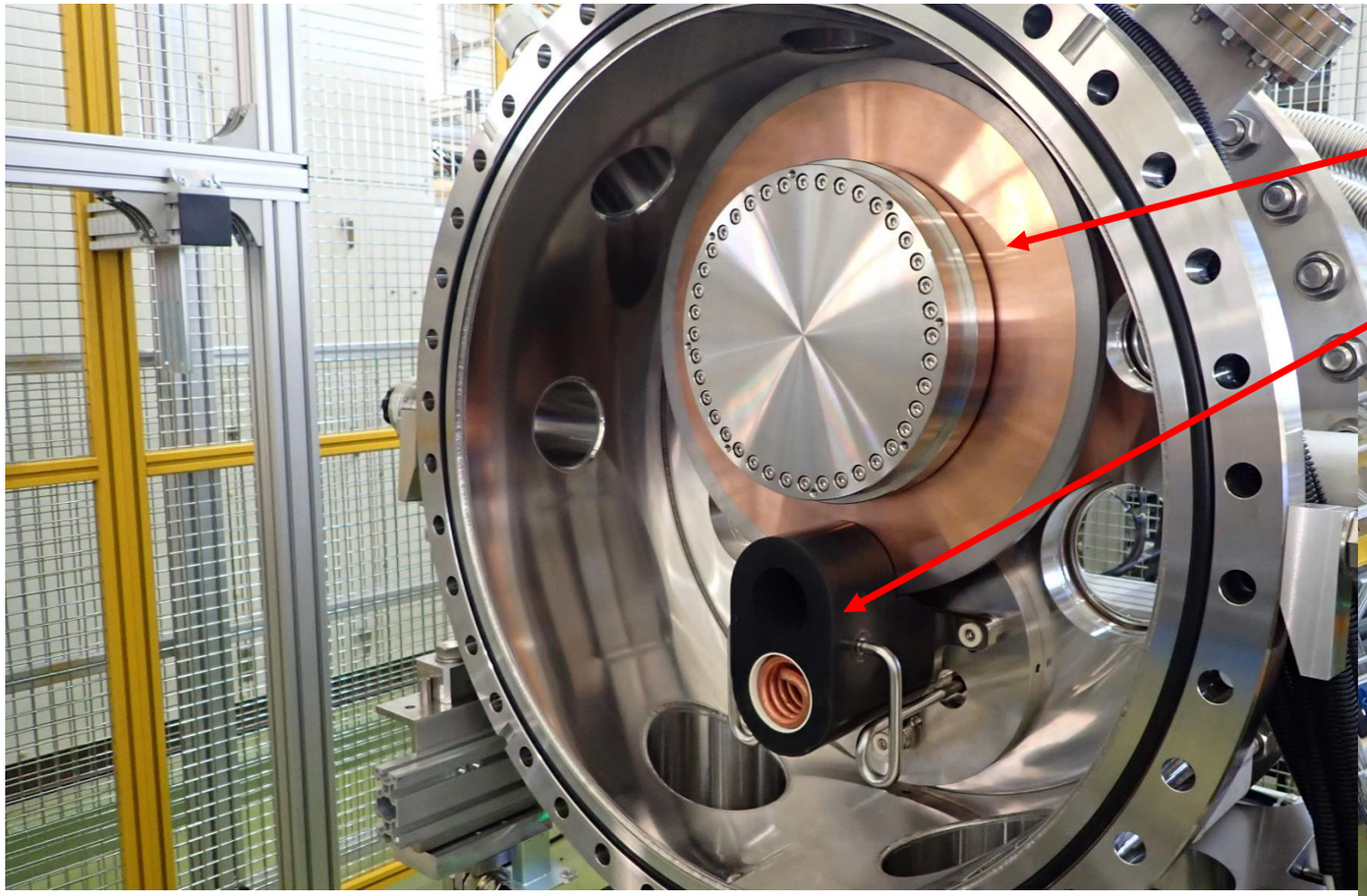
From SuperKEKB to ILC

- 2022/9 New group was launched to develop positron source for ILC
- 2023/4 5-years grant for selected time-critical work packages* was approved
  *Source, SRF, nano-beam
- Linear collider requires very intense sources
- Goals of the group is to demonstrate our design
  - Construct prototype
  - Arrange test environment



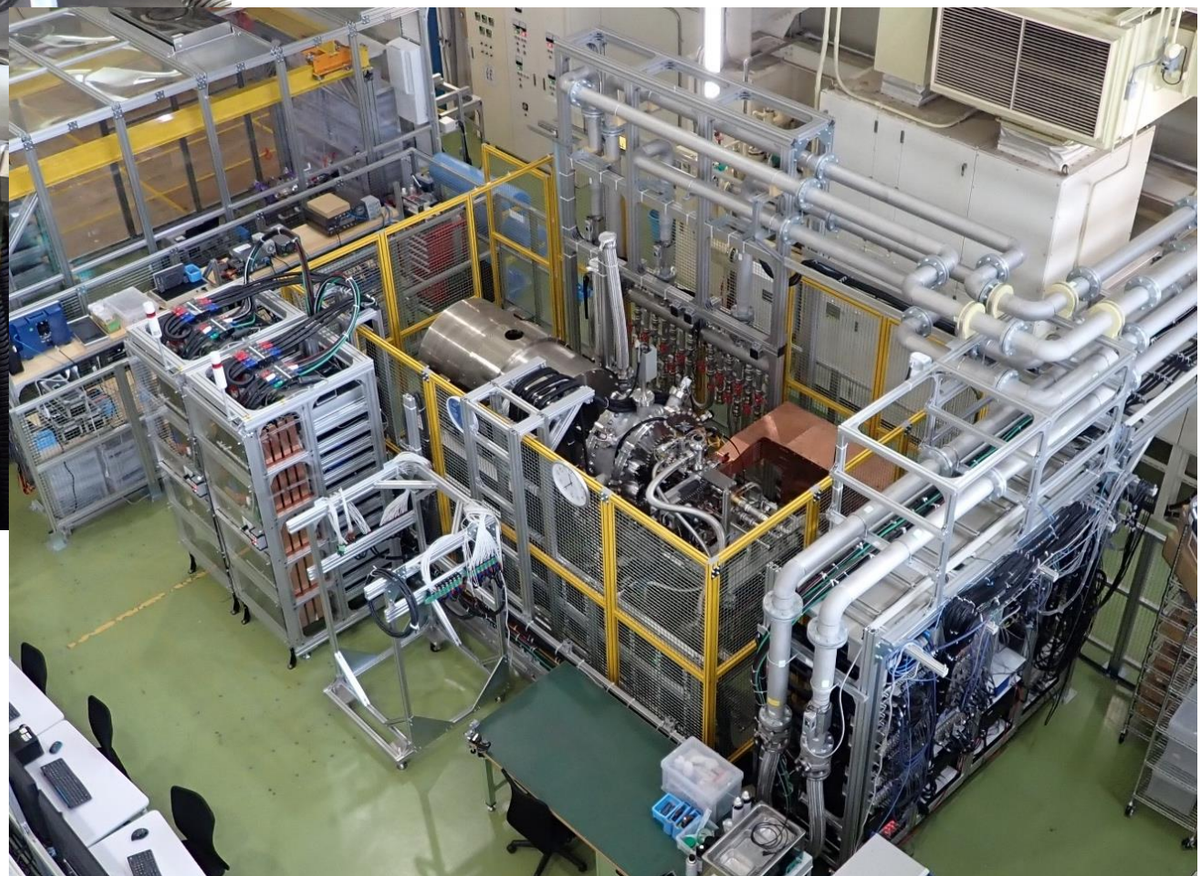

solenoid
collimater
rotating target
Acc. structure
flux concentrator

Present status



Rotating target

Flux concentorator



Development is progressing smoothly

Thank you for all the collaborators

- Pulsed magnet
  - T. Natsui, M. Satoh, K. Yokoyama
- Positron source
  - T. Kamitani, F. Miyahara
  - M. Fukuda, Y. Morikawa
- Group leader and division head
  - T. Higo, T. Ego, K. Furukawa, S. Michizono, H. Sakai
- Many collaborators outside KEK