Positron source

Y. Enomoto

Present status

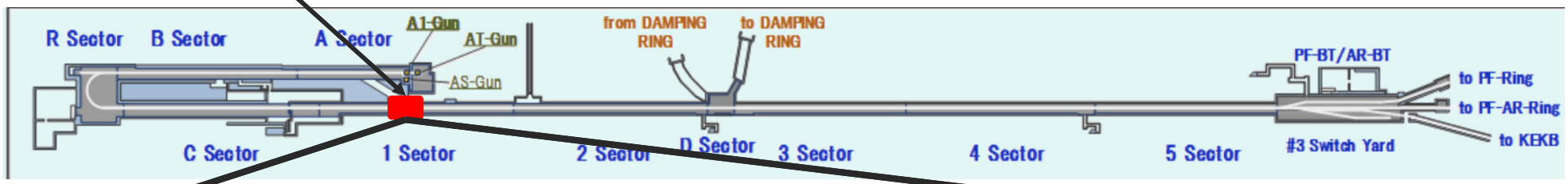
- Toward phase 2 → ready
  - Required 0.5 nC x 2
- Toward phase 3 → under development
  - Required 4 nC x 2

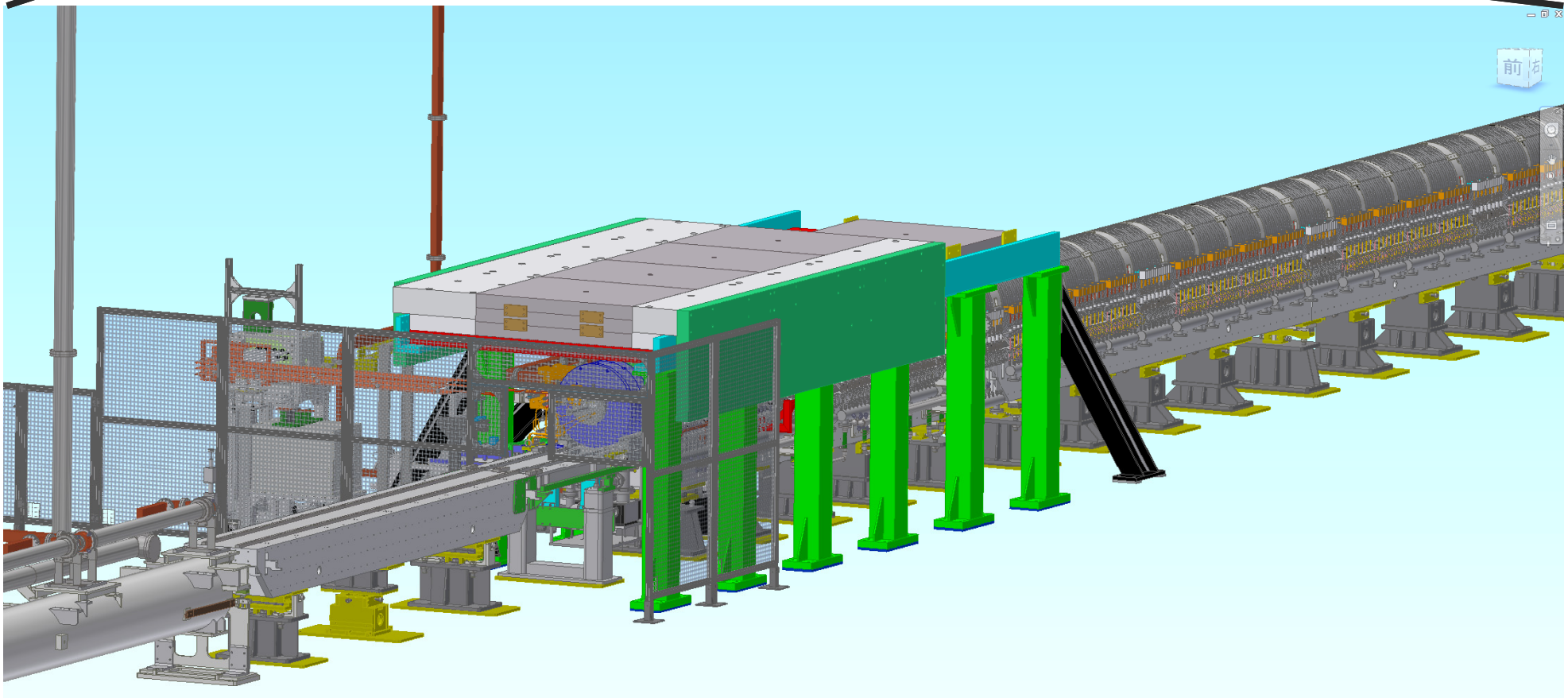
Outline

- Setup
- Toward phase 2
  - Improvements from phase 1
  - Quick Exchange mechanism
- Toward phase 3
  - Requirement and improvements toward phase 3
    - Increase primary electron charge and energy @ target
    - Increase positron production efficiency
    - Decrease loss between the target and the DR
    - Evaluate practical requirement
- Summary

Positron source setup 1

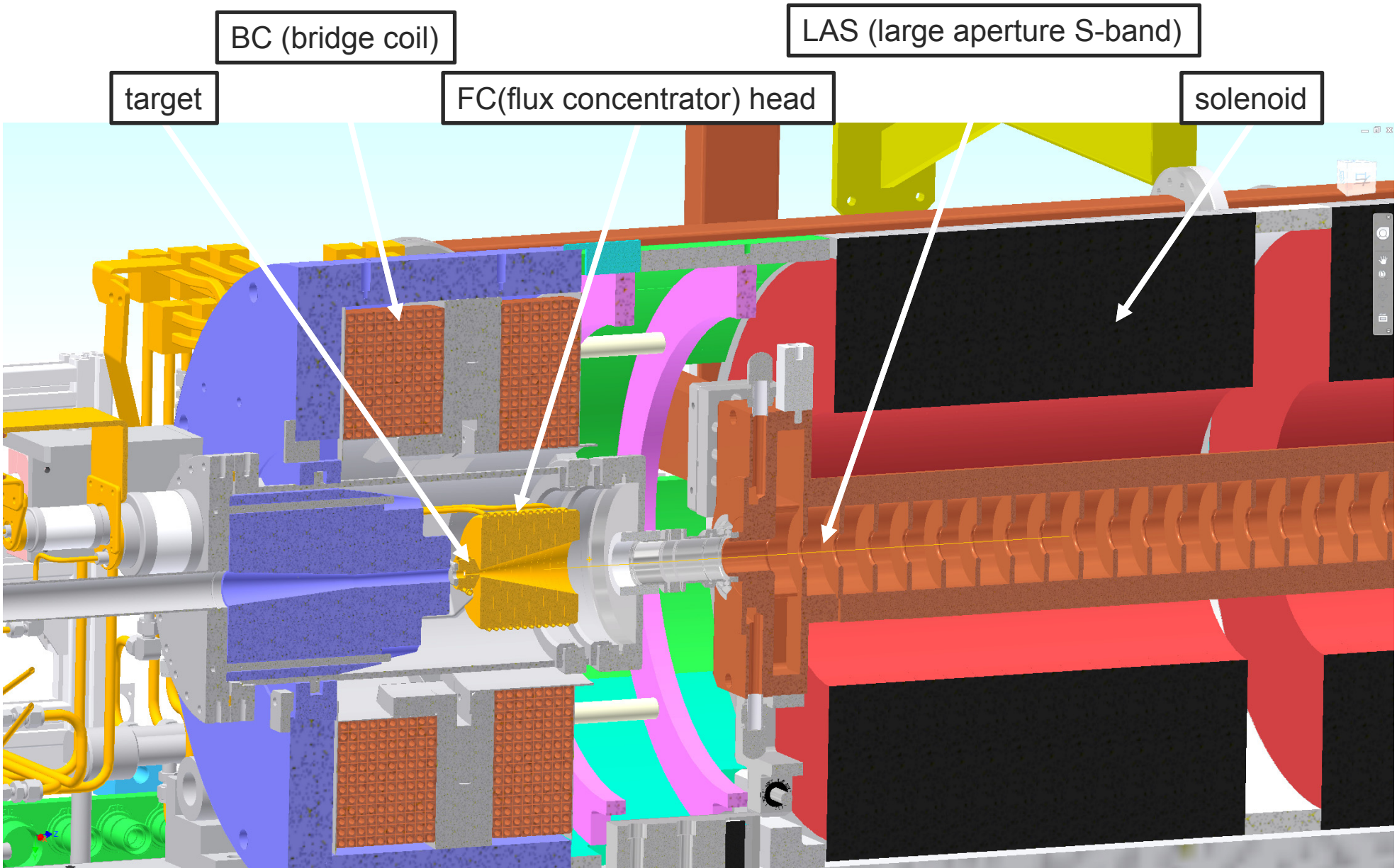
Positron target and capture section



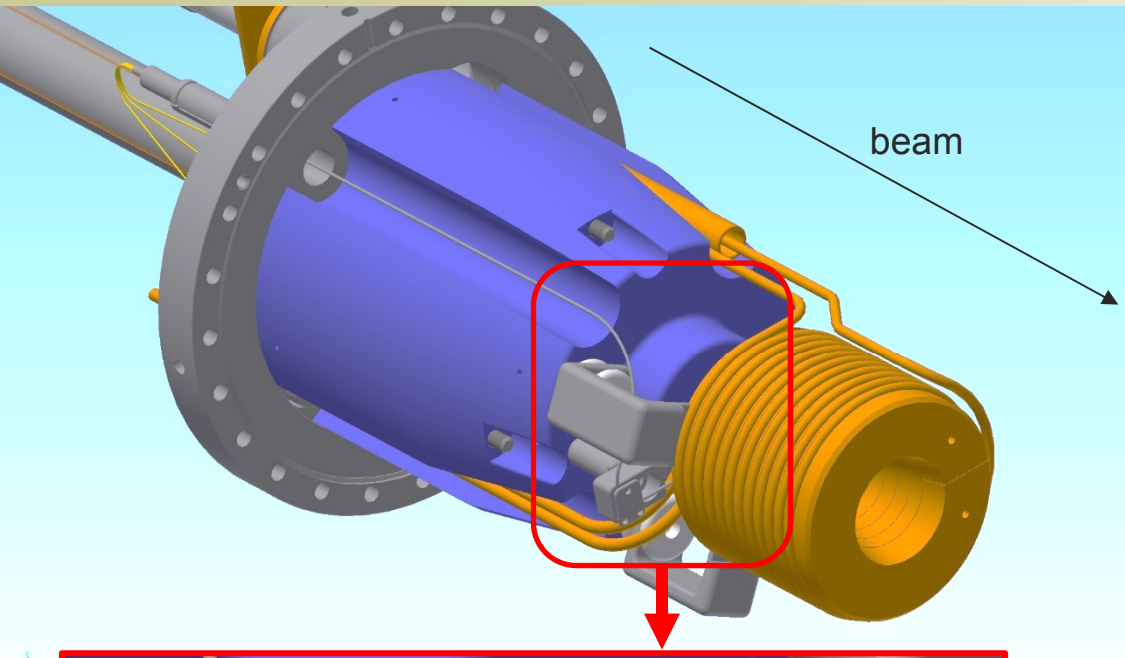


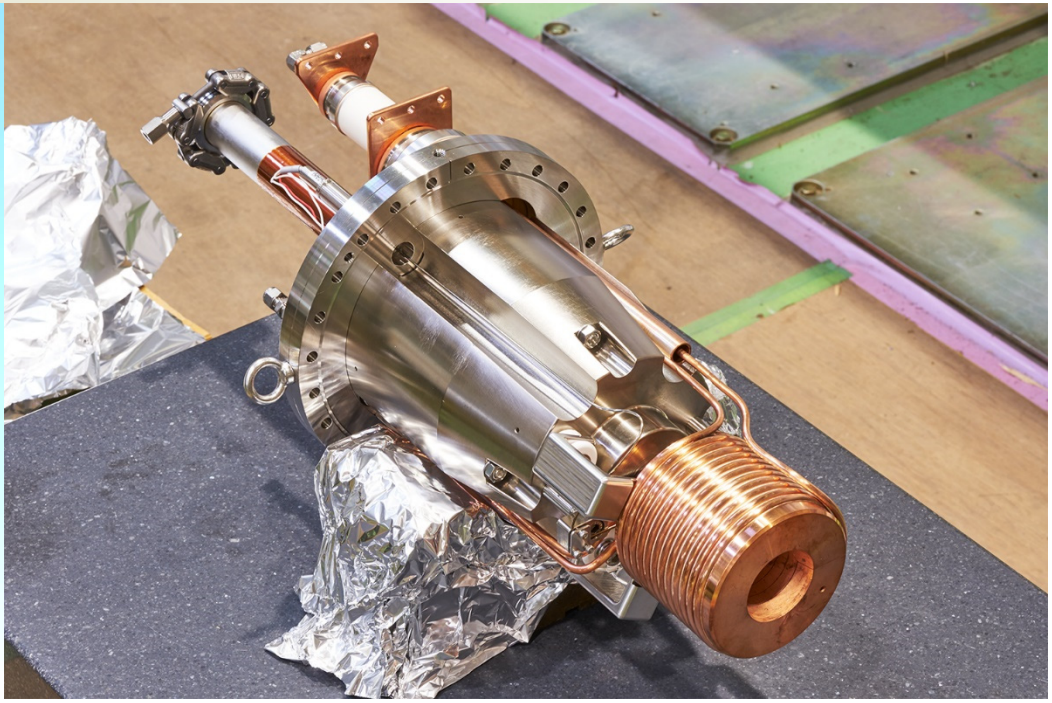
Positron source setup 2

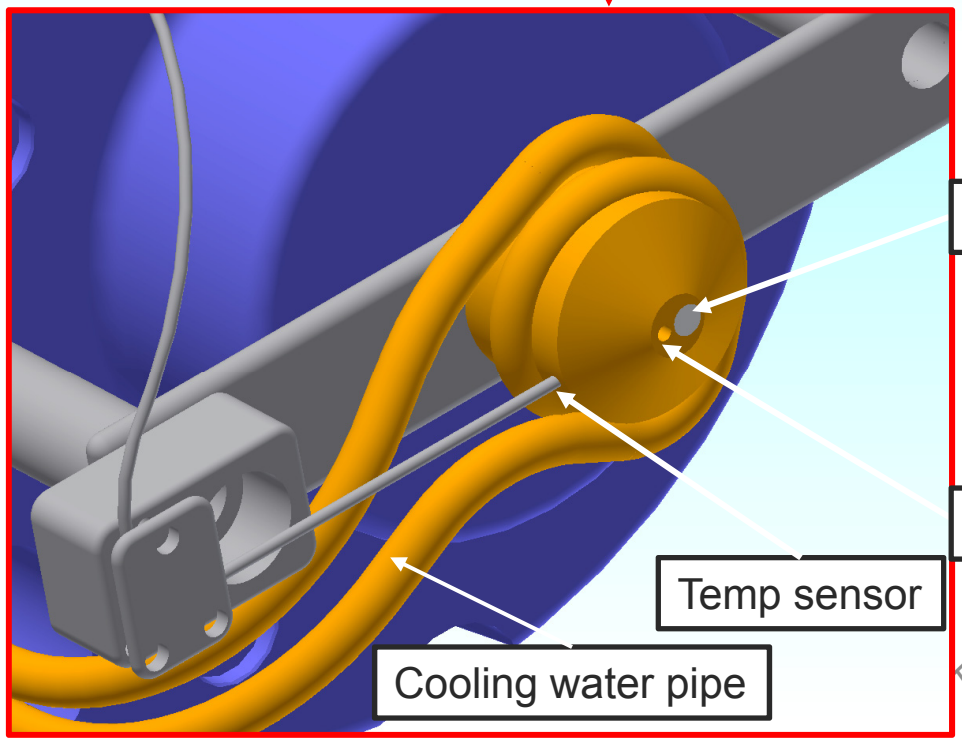
FC head + BC + target = FC assembly



Positron source setup 3

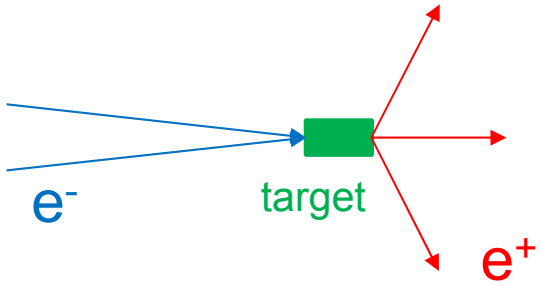




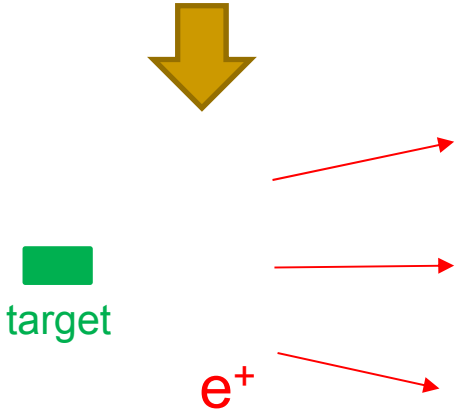


Positron source setup 4

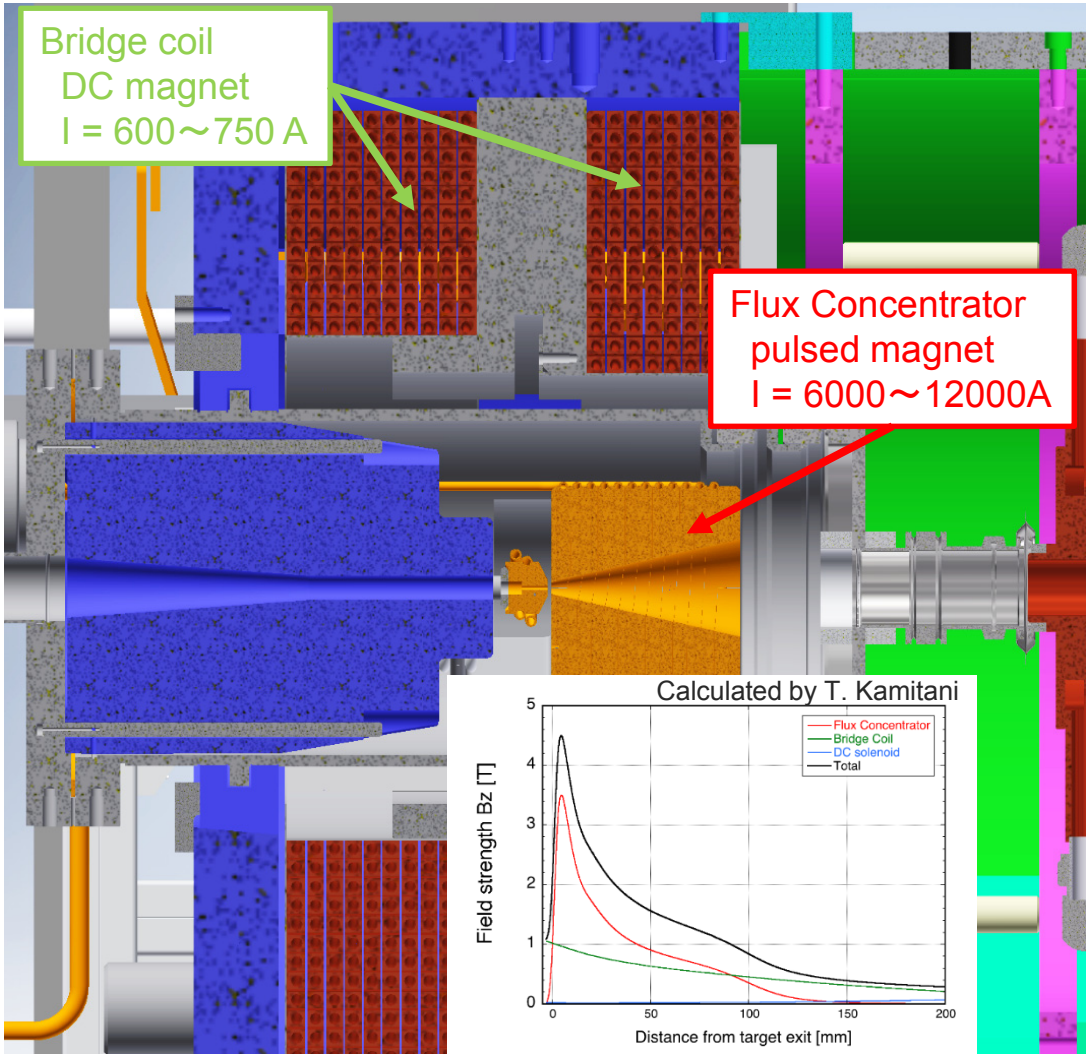
How the FC works?



- Electron hit small point of the target.
- Positron comes from small spot.
- Angle distribution is large.



- Adiabatically expand position distribution.
- Angle distribution decrease.
- Matched to the aperture of the following LAS.



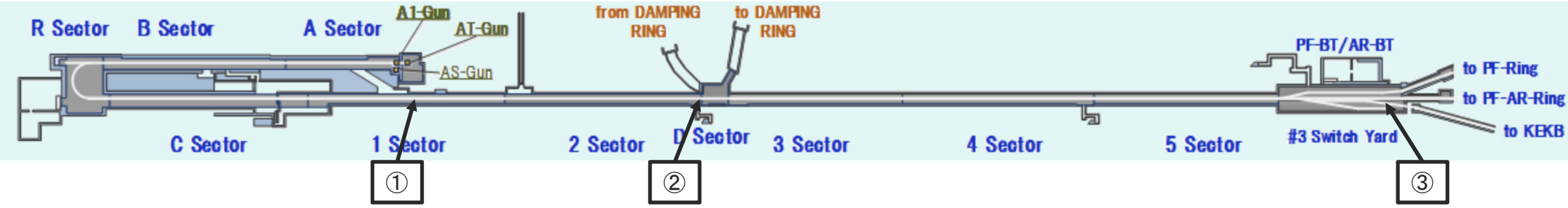
Ratio B @ target / B @ entrance of the LAS is important
stronger field is preferred in the following solenoid section
much stronger field is required @ target

Outline

- Setup
- Toward phase 2
  - Improvements from phase 1
  - Quick Exchange mechanism
- Toward phase 3
  - Requirement and improvements toward phase 3
    - Increase primary electron charge and energy @ target
    - Increase positron production efficiency
    - Decrease loss between the target and the DR
    - Evaluate practical requirement
- Summary

Improvements from phase 1

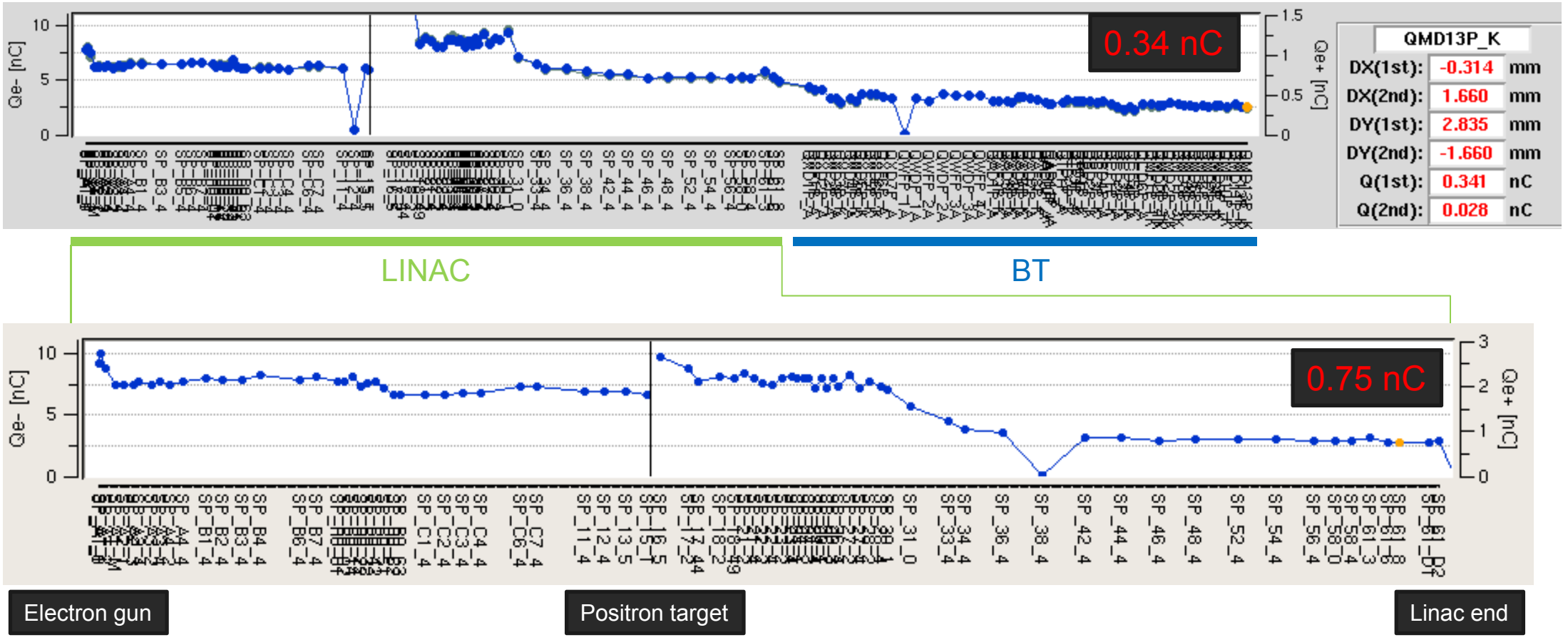
	Phase 1	Phase 2 (now)	Phase 3 (design)
FC assembly	#1	#2	
I_{FC}	5～6 kA	5～6 kA	12 kA
①Primary electron @ target	6.3 nC	6.9 nC	10 nC
②Positron @ entrance of LTR	1.9 nC	2.0 nC	>4 nC
③Positron @ LINAC end	0.75 nC	1.4 nC	>4 nC
Positron @ BT end	0.3 nC	1.4 nC?	4 nC
Replacement	Not considered	1 week	



More than four times positron to the ring
thanks to the DR
Quick replacement mechanism
Preparation against damage to the production system.

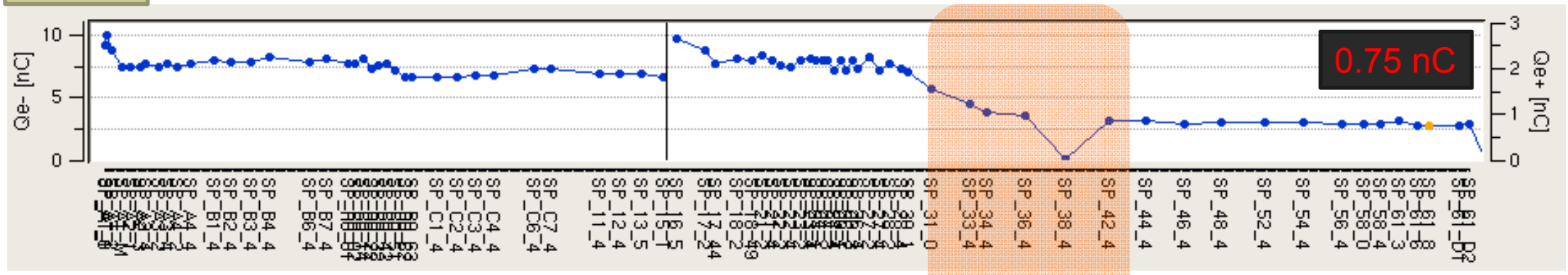
Charge along the beam line

Phase 1



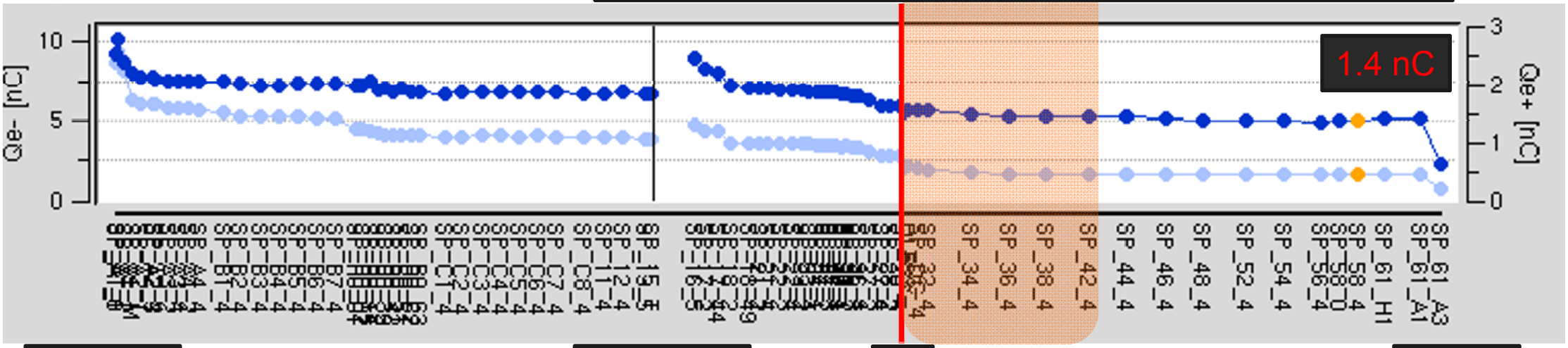
Charge along the beam line

Phase 1



Phase 2

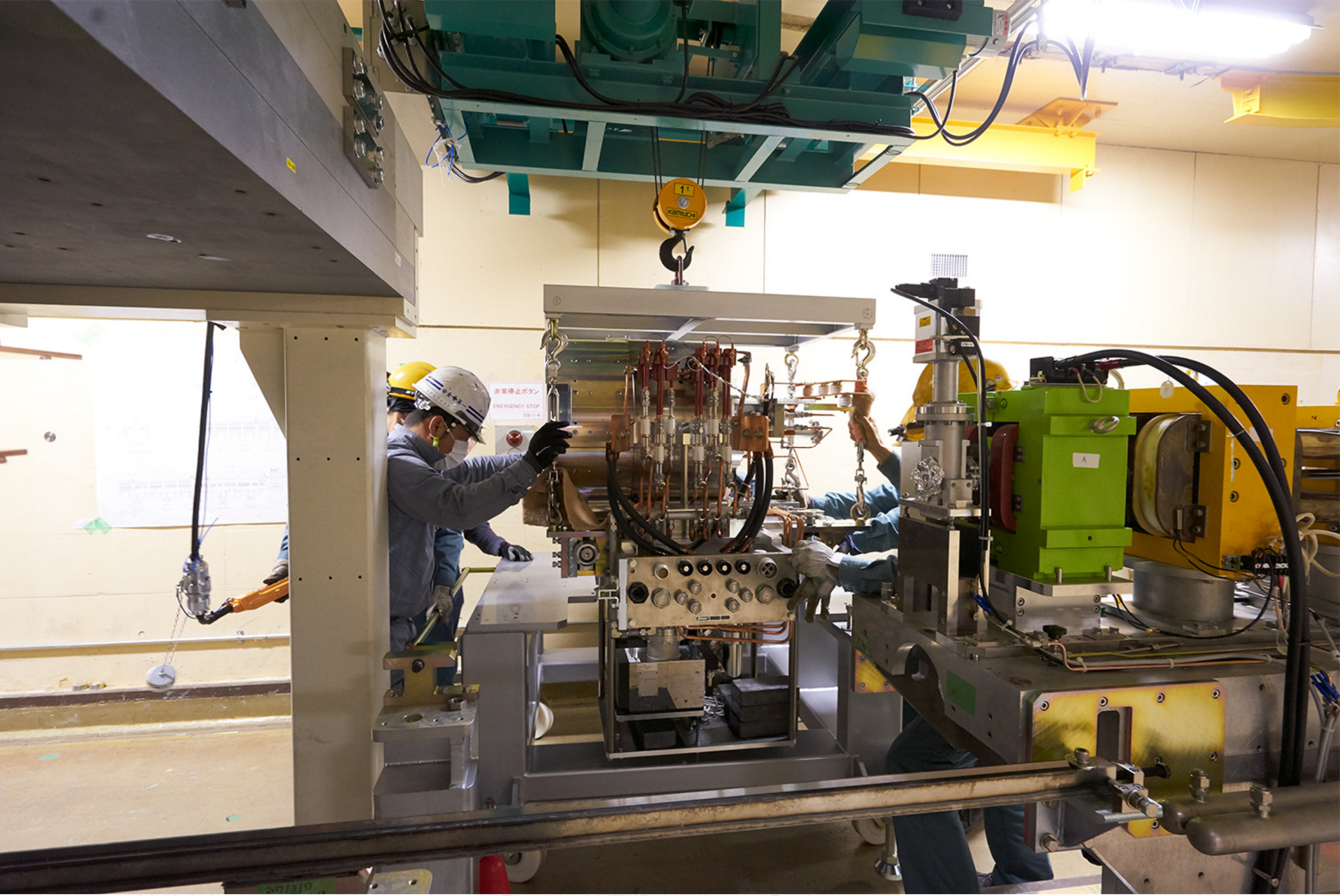
Loss in the 3 sector decreased thanks to the DR

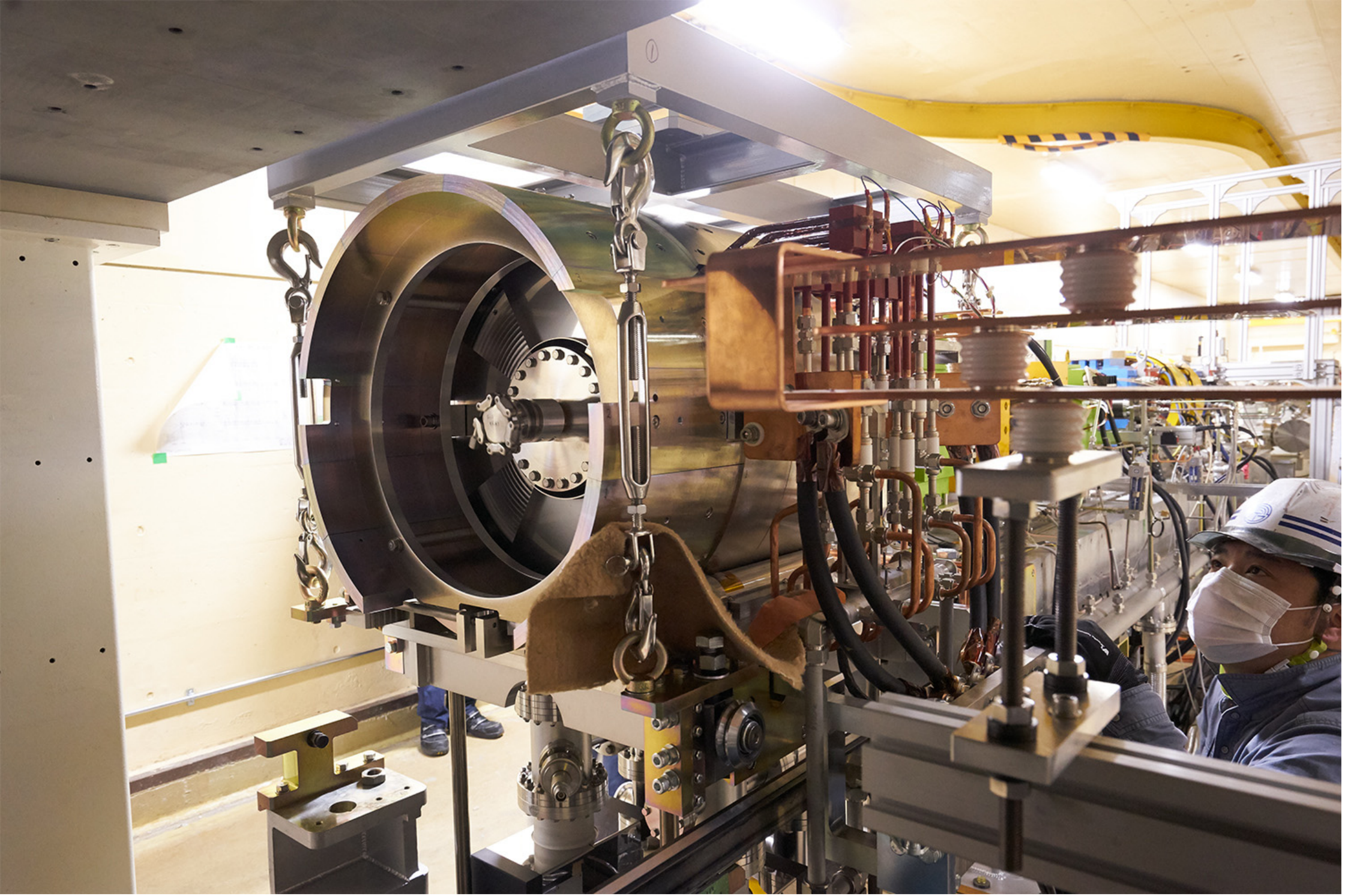


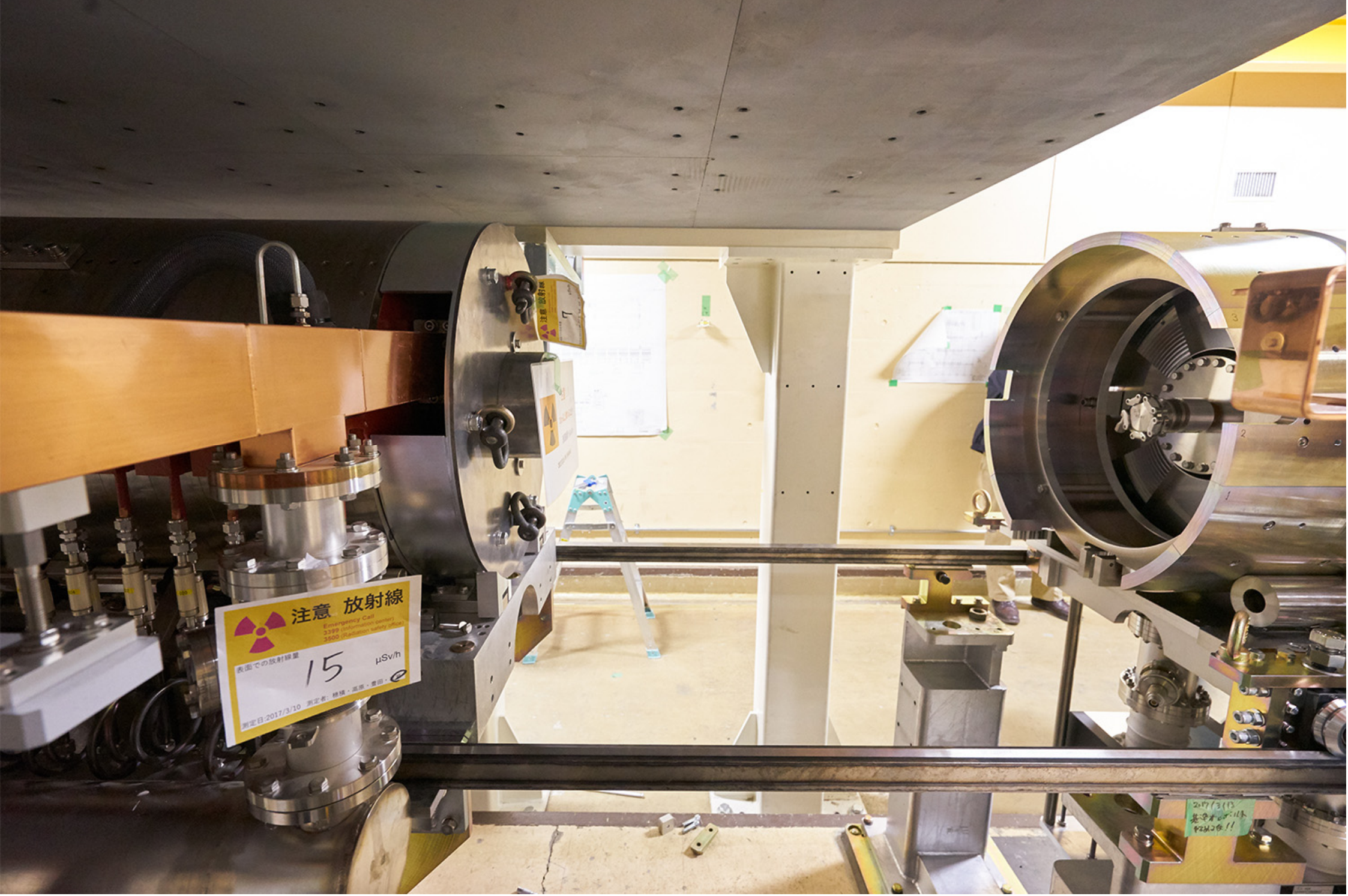
Quick exchange mechanism

- Before the installation of the quick exchange mechanism (phase 1), in case of emergency on the target / FC system,
  - Heavy exposure to radiation is inevitable.
  - Need long (>1 month) cooling time.

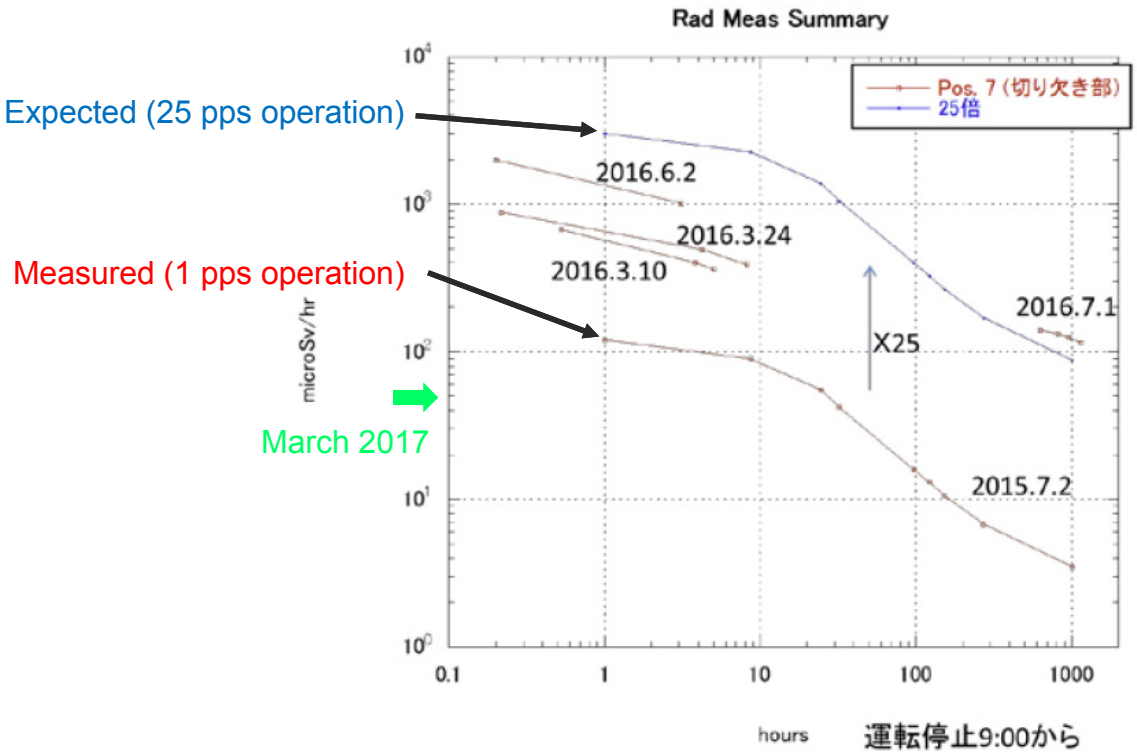
  Fortunately this did not happen
- The mechanism is installed
  - In March 2017. (8 months after the end of phase 1 operation)
  - Old assembly (used in phase 1) was replaced by new one using this mechanism.
  - We demonstrated that replacement work can be done within 1 week.


非常停止ボタン
EMERGENCY STOP
KAMIUCHI

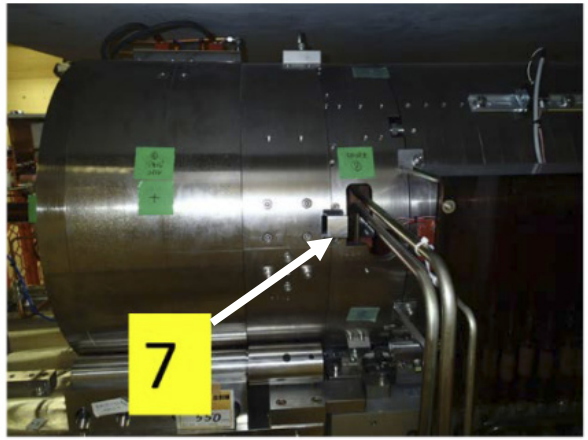



注意 放射線
Emergency Call
3399 (information center)
3500 (Radiation safety office)
表面での放射線量
15
μSv/h
測定日:2017/3/10 測定者:

Evaluation of radiation



Measured by S. Matsumoto



切り欠き部分のサーベイメーターでの計測

Cooling time	Radiation	dose	comment
8 months	50 uSv/h	< 10 uSv/day	Measured in March 2017
1 hour	3000 uSv/h	< 600 uSv/day	
100 hours	300 uSv/h	< 60 uSv/day	

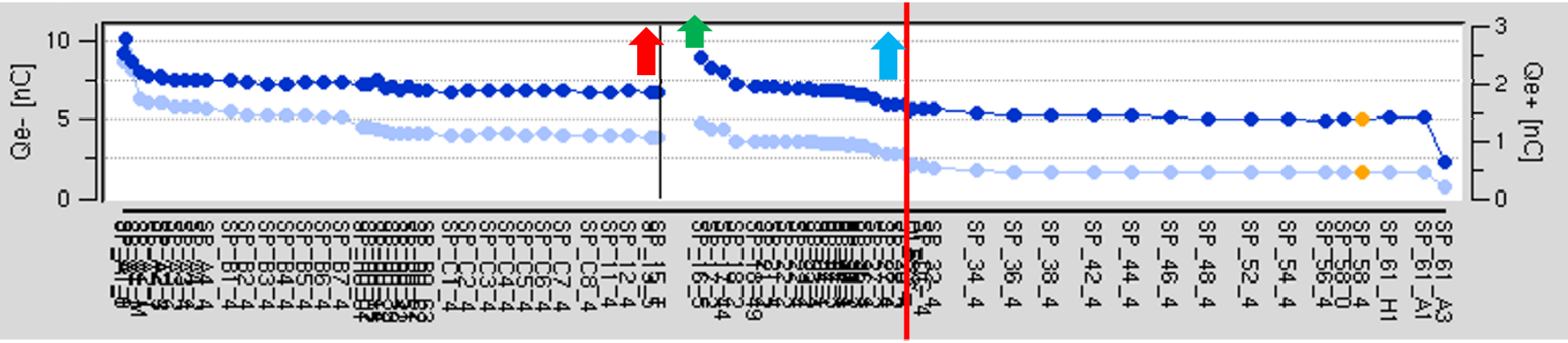
Radiation rate gets 1/10 at 100 hours after stopping operation

Outline

- Setup
- Toward phase 2
  - Improvements from phase 1
  - Quick Exchange mechanism
- Toward phase 3
  - Requirement and improvements toward phase 3
    - Increase primary electron charge and energy @ target
    - Increase positron production efficiency
    - Decrease loss between the target and the DR
    - Evaluate practical requirement
- Summary

Requirement and Improvements toward phase 3

- Provide 4 nC x 2 positron 25 Hz at injection point of the LER.
  - Big difference among phase 2 (0.5 nC), phase 3 (4 nC) and present (1.4 nC).



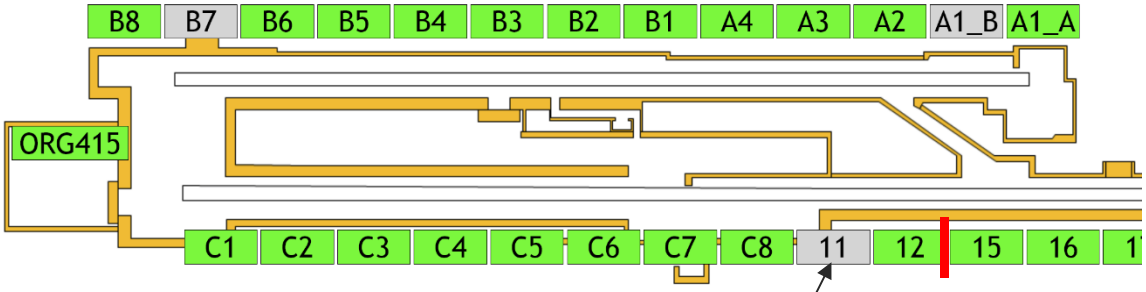
1. Increase primary electron charge and energy @ target
2. Increase positron production efficiency
3. Decrease loss between the target and the DR
4. Evaluate practical requirement

We do not have plan to meet everything.
Now we are in the stage to reconsider strategy and decide priority.

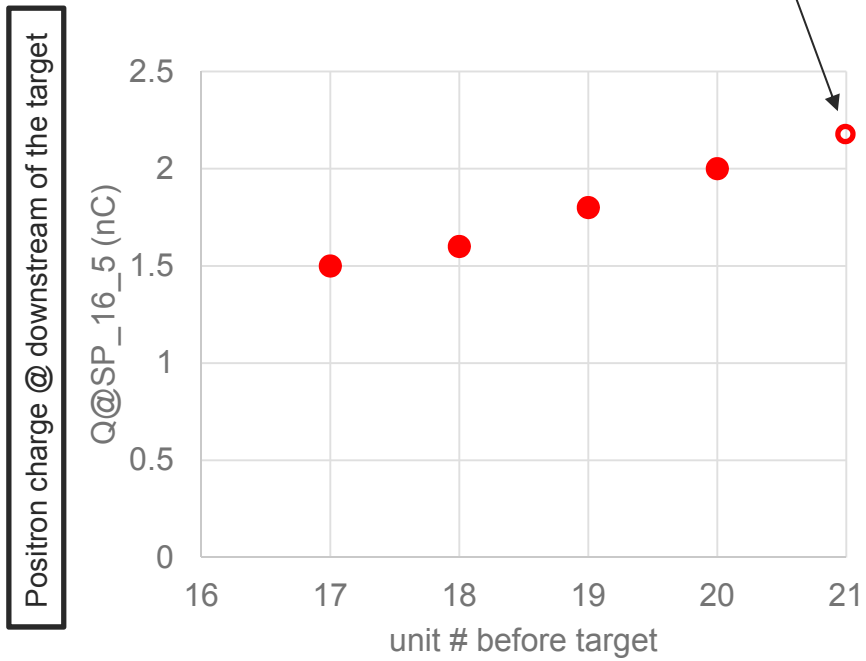
1. Increase primary electron charge and energy @ target

energy

- There are 21 (+1 standby B7) acceleration unit before the target
- We will re-install 1 unit in 2018
  - 5 % up in energy
- Some units are not in full power operation
  - A few % up in energy



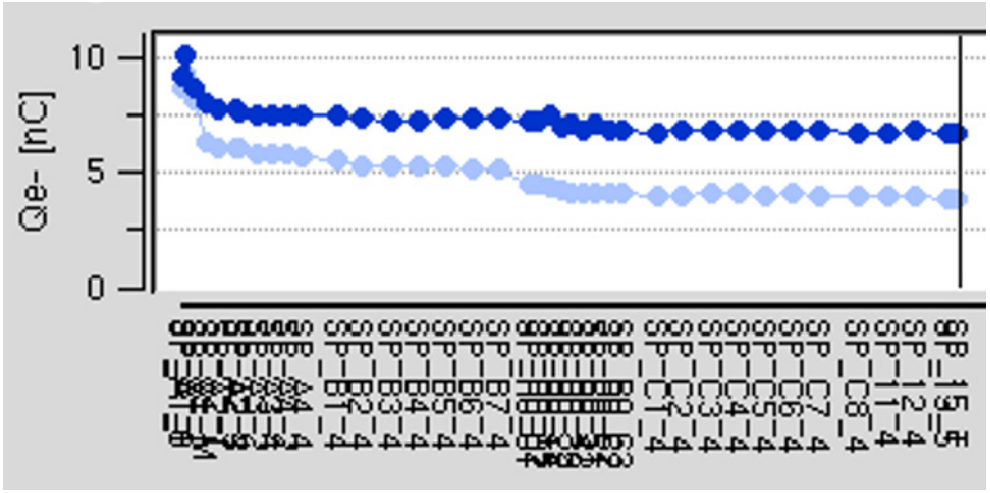
Unfortunately 1 unit was down due to water leak when we took the data
This will be repaired shortly



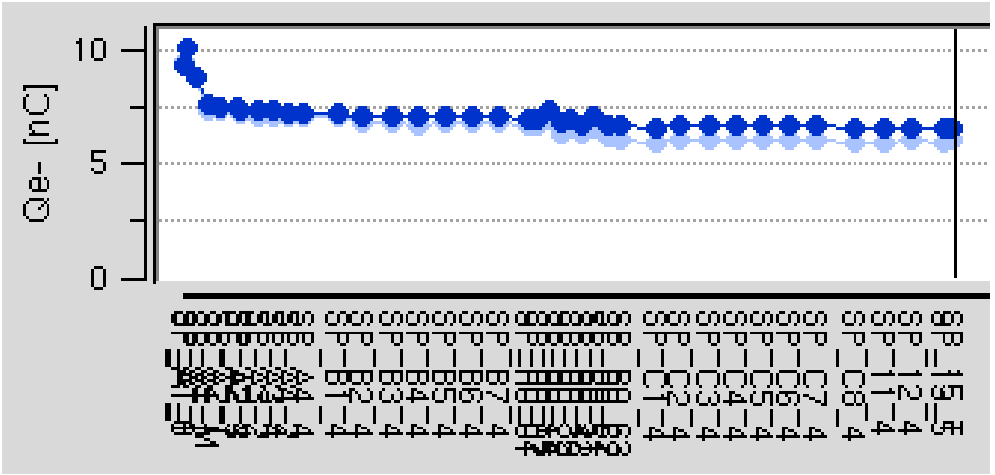
1. Increase primary electron charge and energy @ target

charge

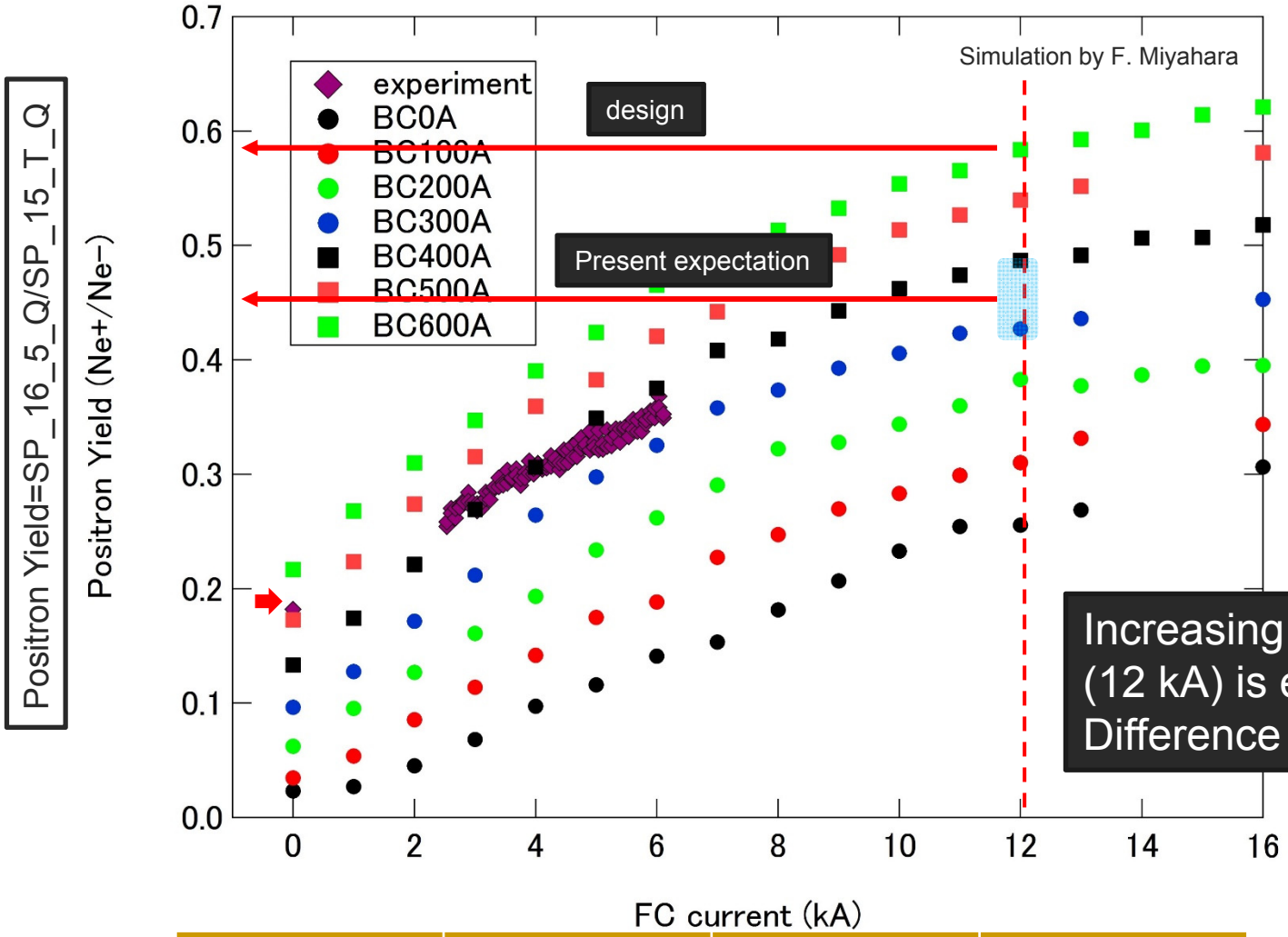
- Decrease loss in the first section
  - We have been trying but not easy…
- Increase 2nd bunch charge
  - Optimizing timing at the bunching section
- Increase charge at gun
  - High efficiency cathode has developed recently by the injector group



1st bunch
2nd bunch



2. Increase positron production efficiency



Parameter	simulation	Experiment
BC	600 A	600 A
SL_15_11	650 A	600 A
SL_16_11	650 A	400 A
SL_16_22	650 A	400 A
SL_16_33	650 A	650 A
ACC_15_1/2	10 MV/m	8.5 MV/m
ACC_16_1/2/3/4	12 MV/m	12 MV/m

Increasing FC current, positron yield of 0.45 (12 kA) is expected from experimental data. Difference from design is still not clear.

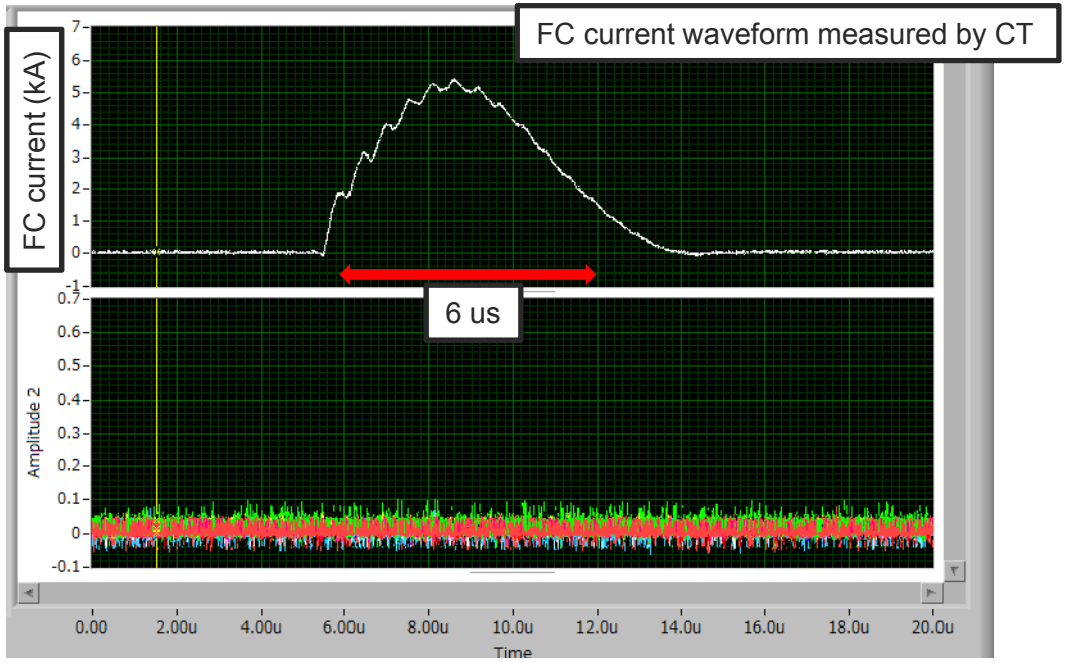
FC current (kA)	SP_15_T_Q (nC)	SP_16_5_Q (nC)	Positron Yield
0	6.93	1.26	0.18
6	6.93	2.50	0.36
12 (expectation)	6.93	3.12	0.45

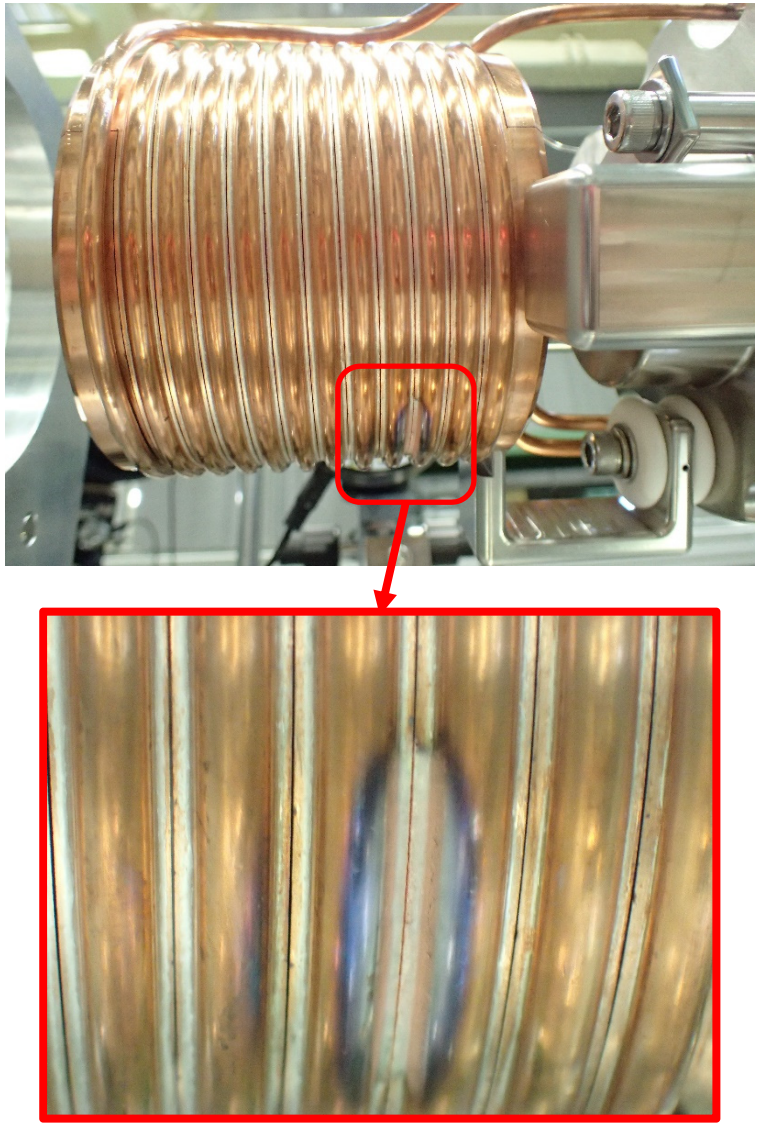
x1.25

2. Increase positron production efficiency

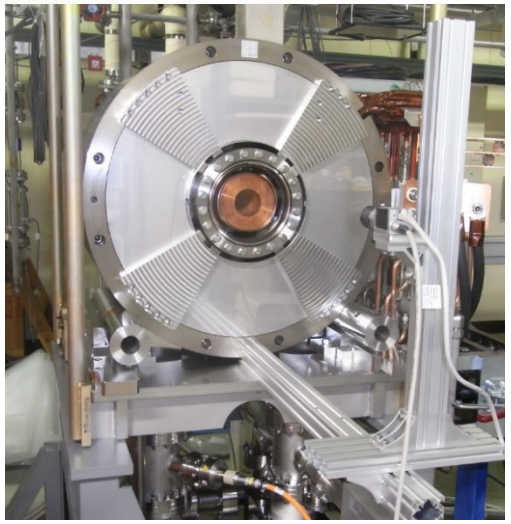
- 1 kV / turn @ 12 kA operation 6 us pulse width
- Slit gap = 0.2 mm

5 MV/m



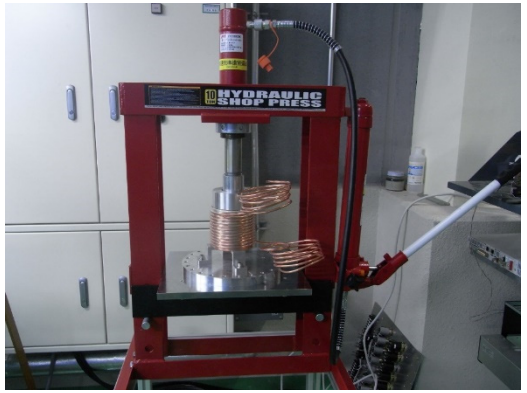


2. Increase positron production efficiency



- What we did during 2016～2017
  - Long term test with full assembly test stand
    - Test under almost the same condition as that in the tunnel.
    - Confirmed 12 kA operation in this test stand.
  - Work hardening process
    - Recommendation from specialist in SLAC.

Unfortunately situation was not improved



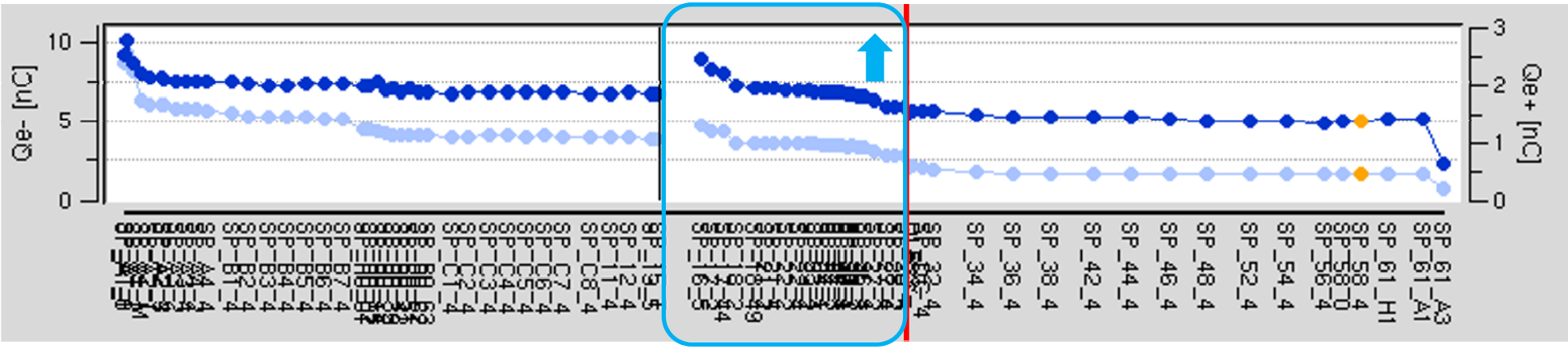
- What we plan to do in 2018
  - Test with longer pulse but reduced voltage
    - A modified pulsed power supply is under preparation by the RF group

$$V \propto L\frac{dI}{dt}$$

	FC current	Pulse width	Power supply voltage
Now	6 kA	6 us	9 kV
planned	12 kA	12 us	9 kV

  - Electromagnetic field simulation and optimization of the head shape
  - Consider other solution than FC
    - Recommendation from the previous domestic review
    - Only 1.25 times gain is expected even 12 kA operation.

3. Decrease loss between the target and the DR



- Increase some pulsed magnets in this section in 2018.
- No other concrete plan now.
- We need ideas and resources.

4. Evaluate practical requirement

Present working assumption

Life	360 s
Current	3.6 A
Injection bunch charge	4 nC
Injection rate	25* Hz x 2 bunch
Injection efficiency	50 %
Circulation frequency	10^5

$$\frac{dI}{dt} = \frac{3.6\ [\mathrm{A}]}{360\ [\mathrm{s}]} = 0.01\ [\mathrm{A/s}]$$

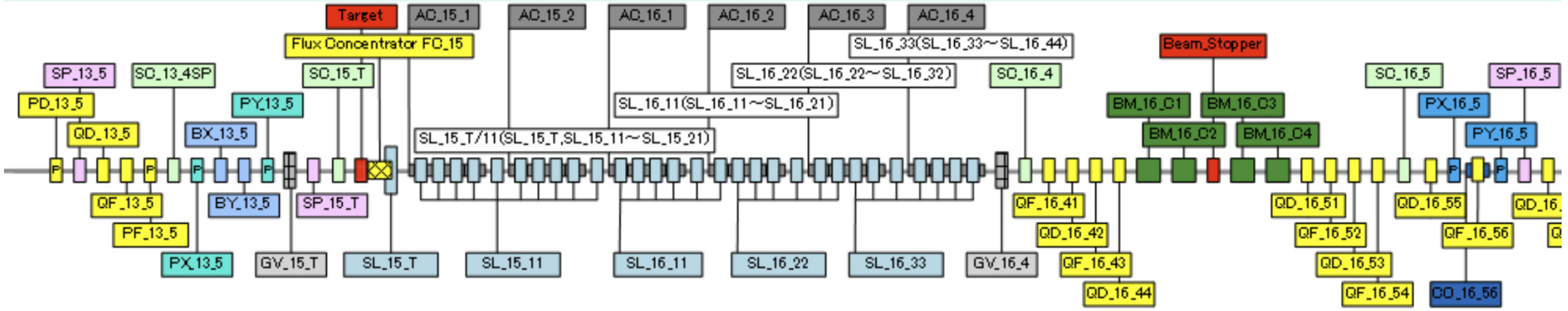
$$4\ [\mathrm{nC}] \times 25\ [\mathrm{Hz}] \times 2\ [\mathrm{bunch}] \times 50[\%] \times 10^5[\mathrm{Hz}] = 0.01\ [\mathrm{A/s}]$$

*The other 25 Hz will be used for HER injection
Injection rate balance between the HER and the LEC will be determined by the ratio of the life in each ring

No one knows precise life time in the LER now.
We expect the value gradually gets clear during phase 2 operation.

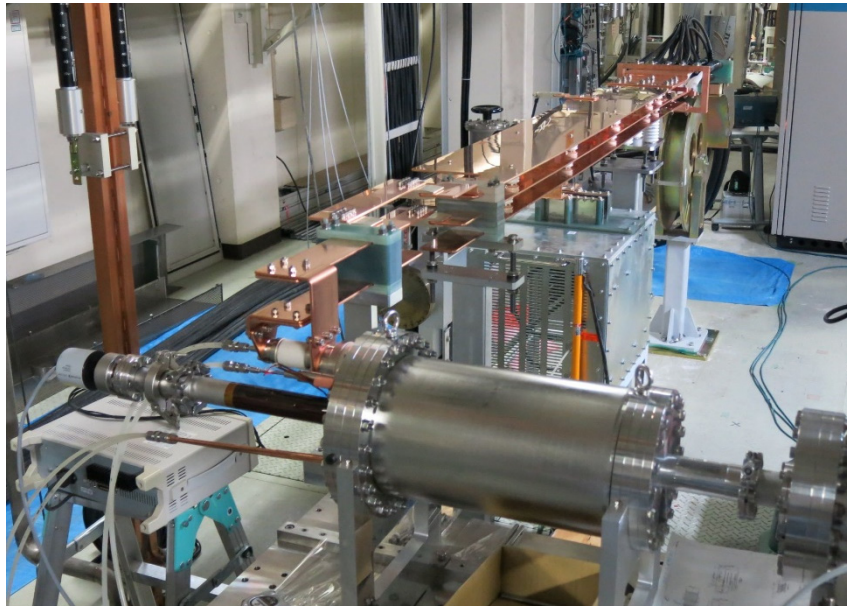
Summary

- We are ready for phase 2
  - 1.4 nC positron (requirement 0.5 nC)
  - Quick exchange mechanism
- We are in the stage to reconsider strategy and decide priority toward phase 3
  - Increase primary electron charge and energy @ target
  - Increase positron production efficiency
  - Decrease loss between the target and the DR
  - Evaluate practical requirement


Target
AC_15_1
AC_15_2
AC_16_1
AC_16_2
AC_16_3
AC_16_4
Flux Concentrator FC_15
SL_16_33(SL_16_33～SL_16_44)
Beam_Stopper
SP_13_5
SC_13_4SP
SC_15_T
SL_16_22(SL_16_22～SL_16_32)
SC_16_4
SC_16_5
SP_16_5
PD_13_5
PY_13_5
SL_16_11(SL_16_11～SL_16_21)
BM_16_C1
BM_16_C3
PX_16_5
QD_13_5
BX_13_5
SL_15_T/11(SL_15_T,SL_15_11～SL_15_21)
BM_16_C2
BM_16_C4
PY_16_5
QF_13_5
BY_13_5
SP_15_T
QF_16_41
QD_16_51
QD_16_55
PF_13_5
QD_16_42
QF_16_52
QF_16_56
PX_13_5
GV_15_T
SL_15_T
SL_15_11
SL_16_11
SL_16_22
SL_16_33
GV_16_4
QF_16_43
QD_16_53
QD_16_44
QF_16_54
CO_16_56

Fighting against discharge

- FC head #4
  - ～2015/9 test w/o BC @ test stand
    - 12 kA→OK
  - 2015/9 Installed into the beamline
    - Discharge happened at 9.5 kA after a few days operation.
  - 2015/9～2016/7
    - Reduced current (6 kA) operation during phase 1.
  - 2017/3
    - Replaced by FC head #5 (with assembly #2).

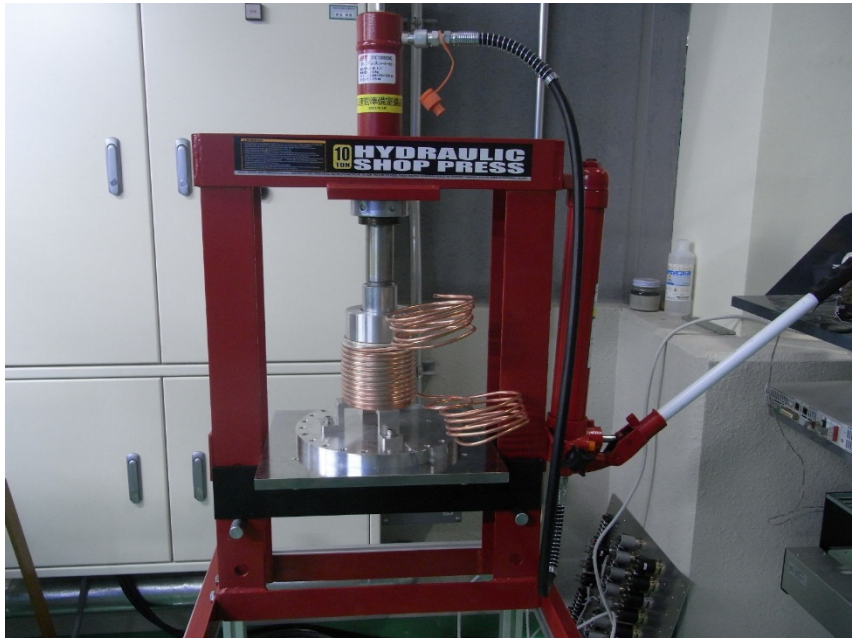


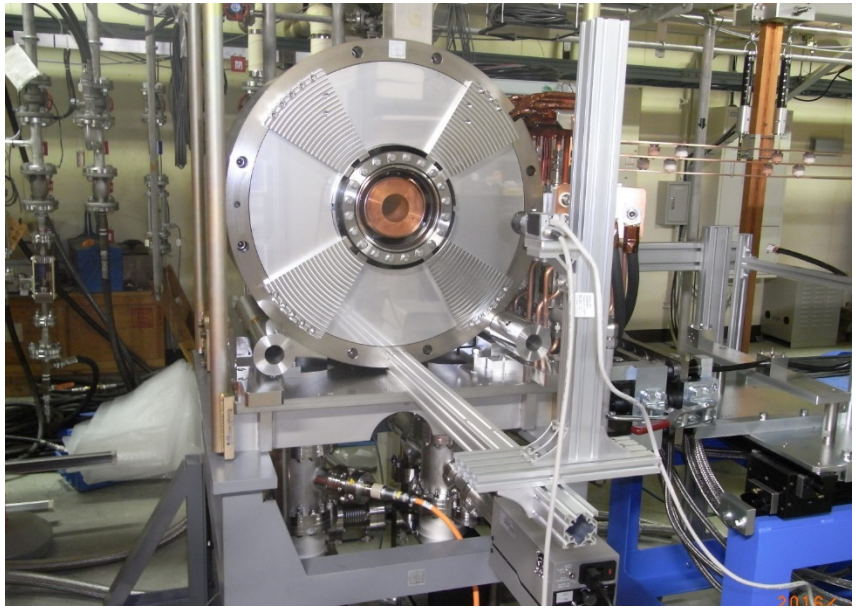
Visit specialist in SLAC.
Work-hardening process is important.
External magnetic field by BC is different.

Fighting against discharge

- FC head #5
  - 2016/6
    - Work-hardening process
  - ～2017/3 test w BC @ test stand
    - 12 kA→OK
  - 2017/3 Installed into the beamline
    - Discharge after a few days operation
  - 2017/3～2017/5
    - Not in operation
  - 2017/6～2017/9
    - Disassembled from the beamline
    - Observed
  - 2017/9
    - Re-installed in the beamline
  - 2017/10-
    - 6 kA operation

Reconstruct test stand
Try longer pulse operation





Fighting against discharge

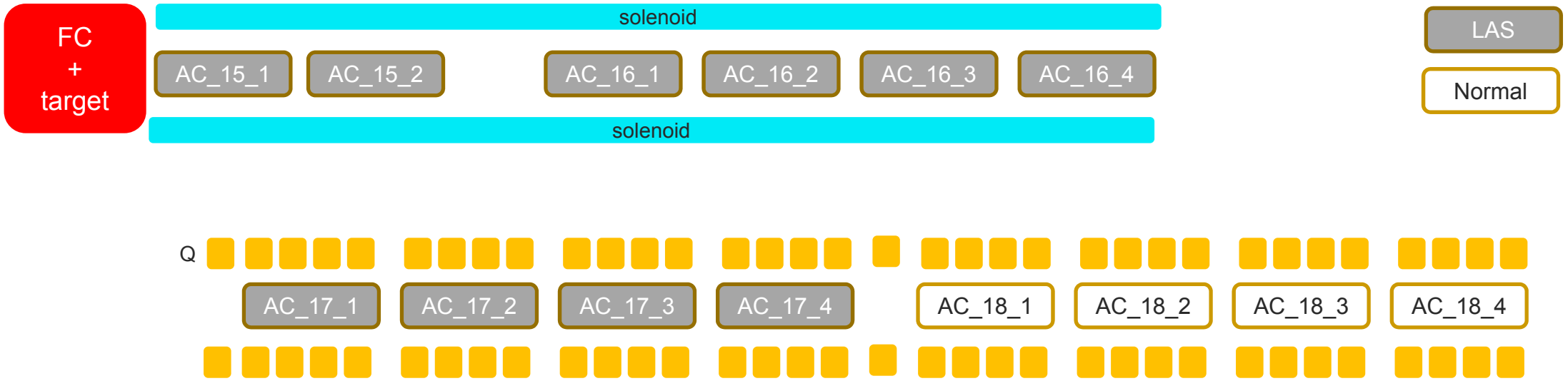
- FC head #6
  - 2017/10
    - Work-hardening process
  - ～2018/3 reconstruct test stand
  - 2018/4～
    - Try longer pulse operation

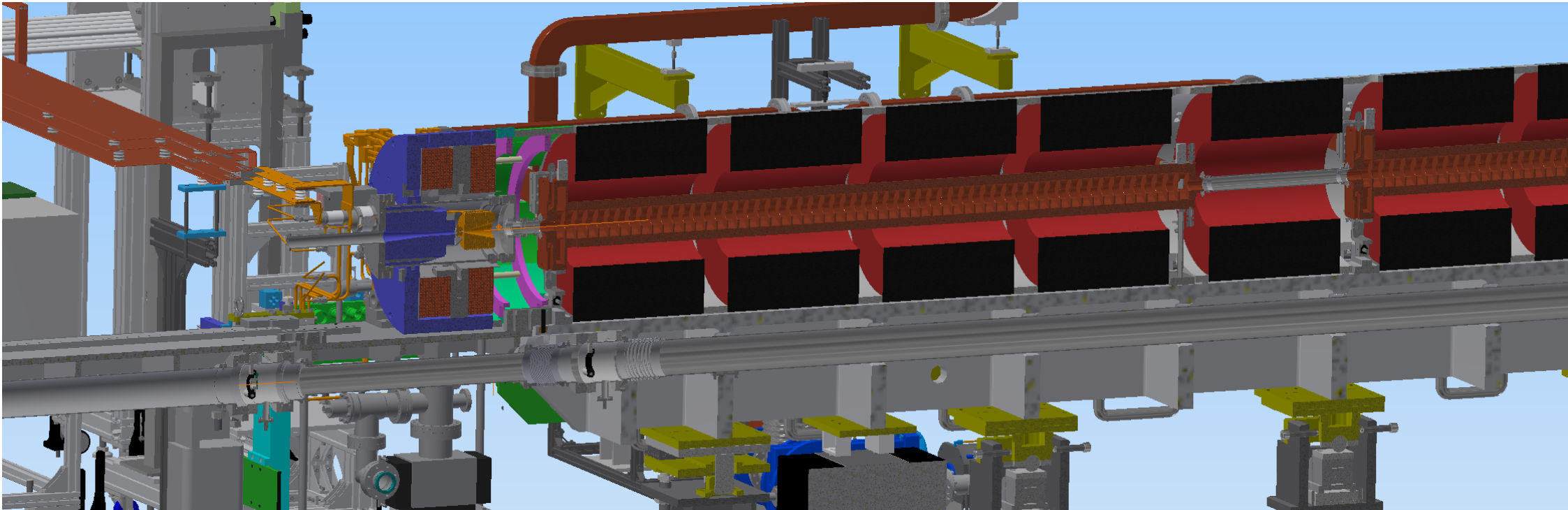
$$V \propto L\frac{dI}{dt}$$

	FC current	Pulse width	Power supply voltage
Now	6 kA	6 us	9 kV
planned	12 kA	12 us	9 kV

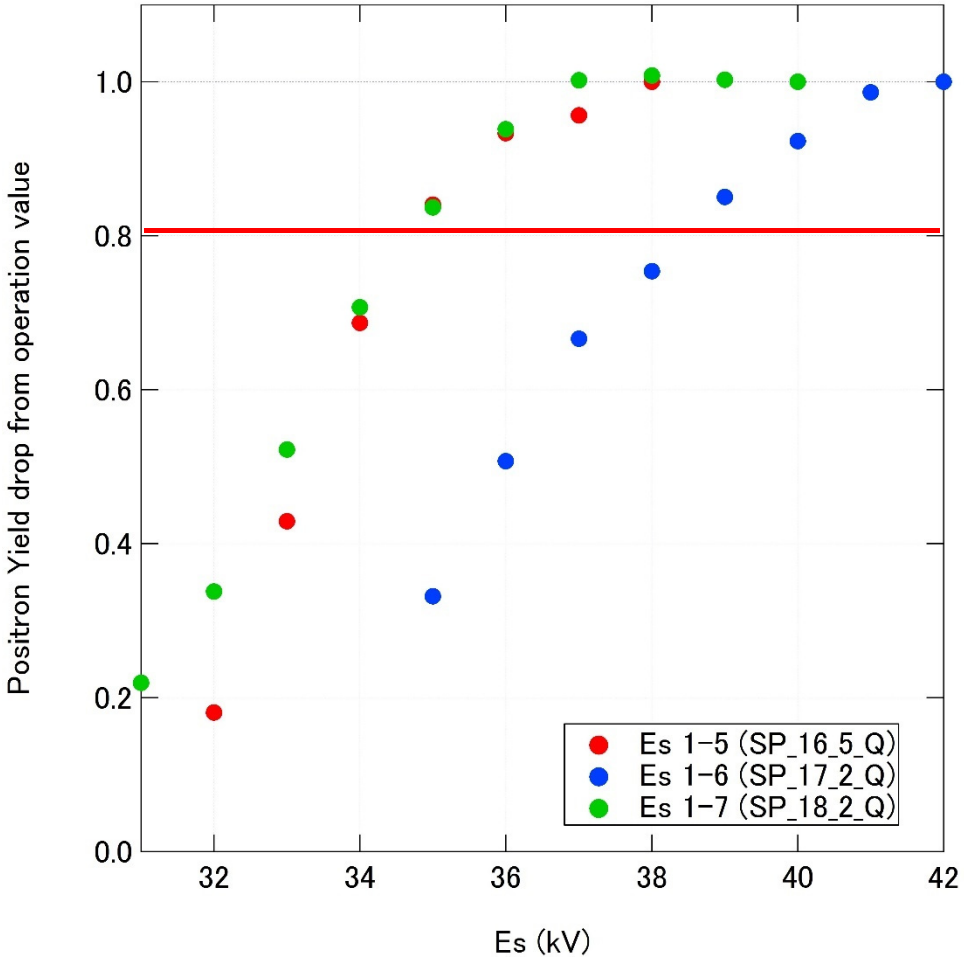
Previous test stand space was evacuated for the re-installation of 1-3 klystron
Energy of primary electron will be increased by 5 %
→positron charge will expected to be increased by 5%

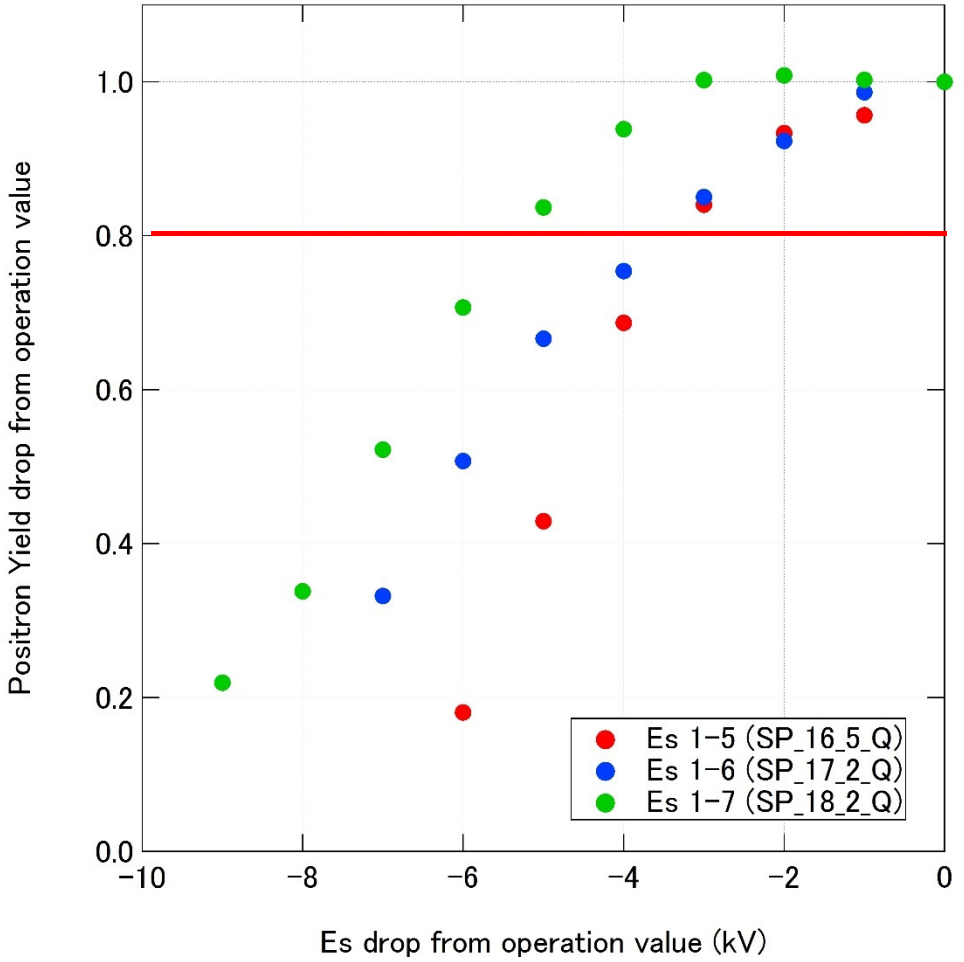
Capture section after target





Positron yield vs Acc voltage





	now	-20%
1-5	38 kV	35 kV (-3 kV)
1-6	42 kV	39 kV (-3 kV)
1-7	40 kV	35 kV (-5 kV)

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 GeV	7.0 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- 8 → 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)	