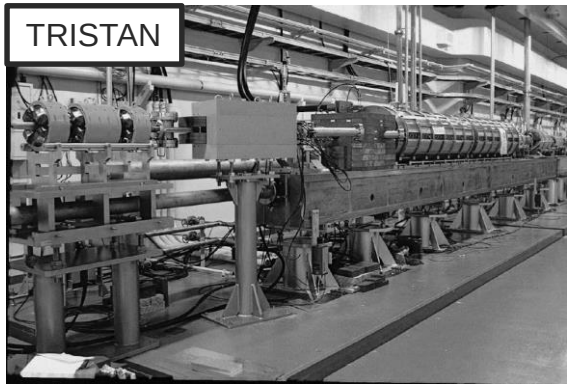
Present status and plan on E-driven positron source for ILC

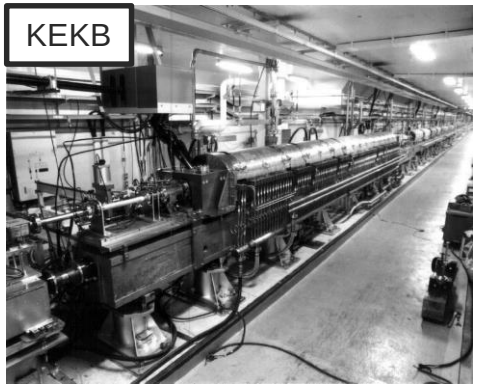
Y. Enomoto

On behalf of KEK iCASA positron group

TRISTAN

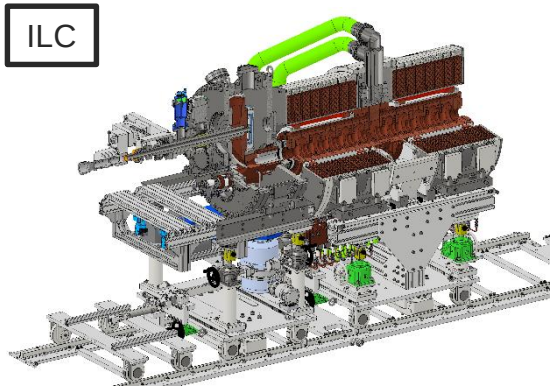


KEKB



SuperKEKB

ILC



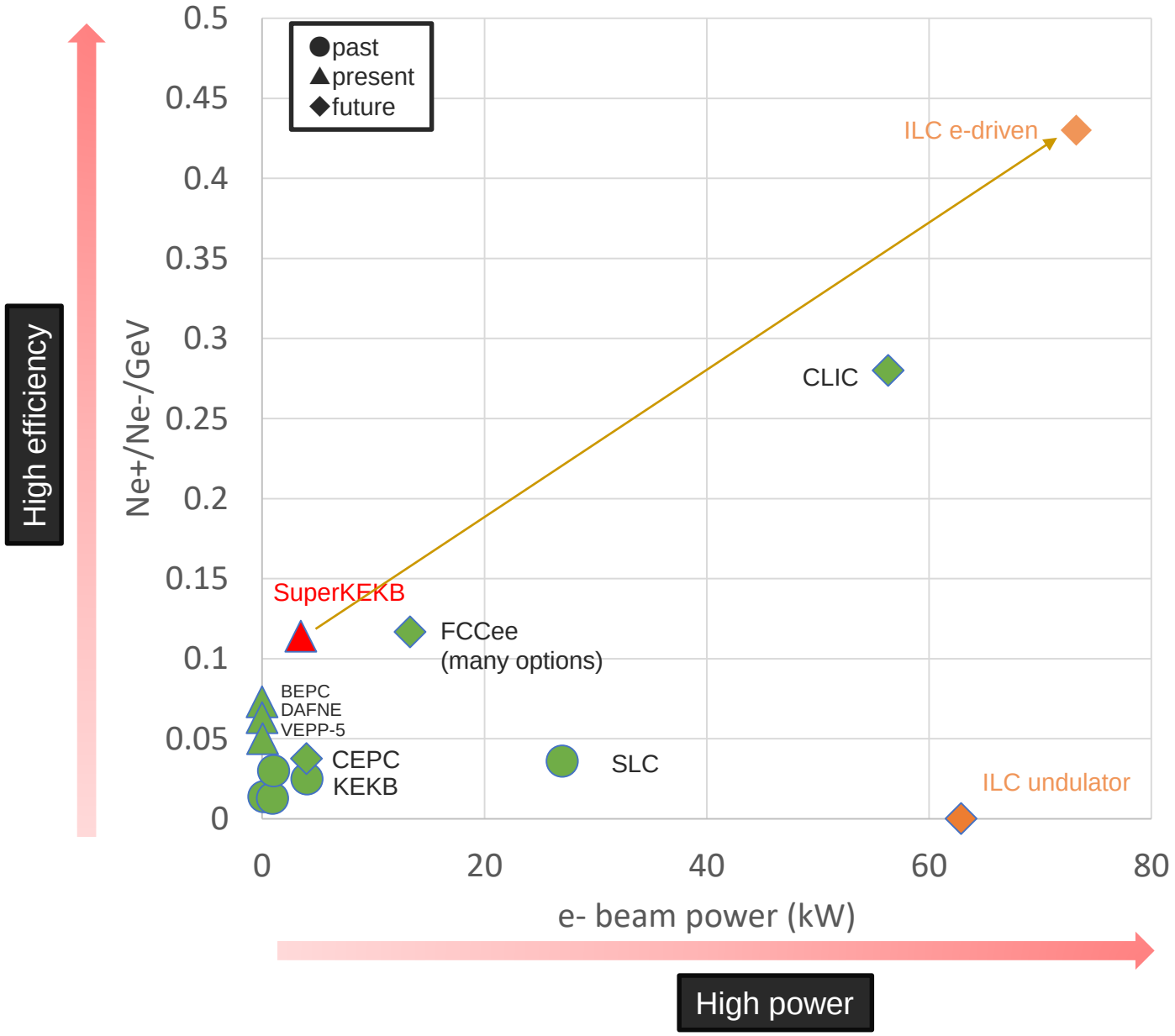
This work was supported by【MEXT Development of key element technologies to improve the performance of future accelerators Program】Japan Grant Number JPMXP1423812204.

Contents

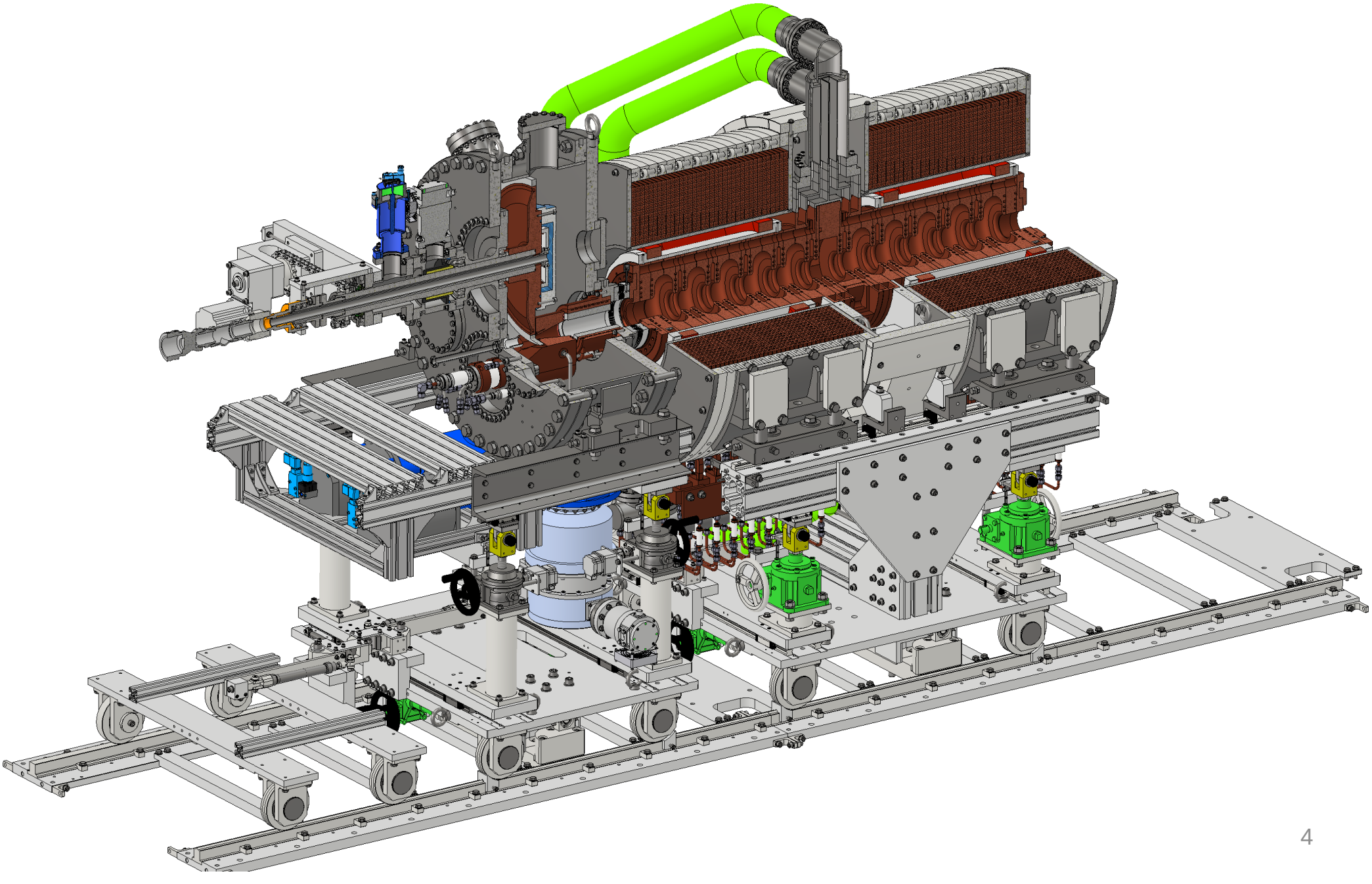
- Progress and status of the electron driven positron source for ILC
- Introduction to following talks
  - Design of the ILC electron-driven positron source and utilization of black-box optimization
  - Development of E-driven positron target
  - APS cavity design for ILC E-driven positron capture linac

Comparison of positron sources

	SKEKB	ILC
e- energy	3.2 GeV	3 GeV
e- charge/bunch	10 nC	3.7 nC
Repetition	50 (25) Hz	5 Hz
Num. bunches	2	1320 = (33+33) x 20
Total charge / s	1000 (500) nC	24667 nC
Beam power on target	3.2	74
yield	0.4	1.3

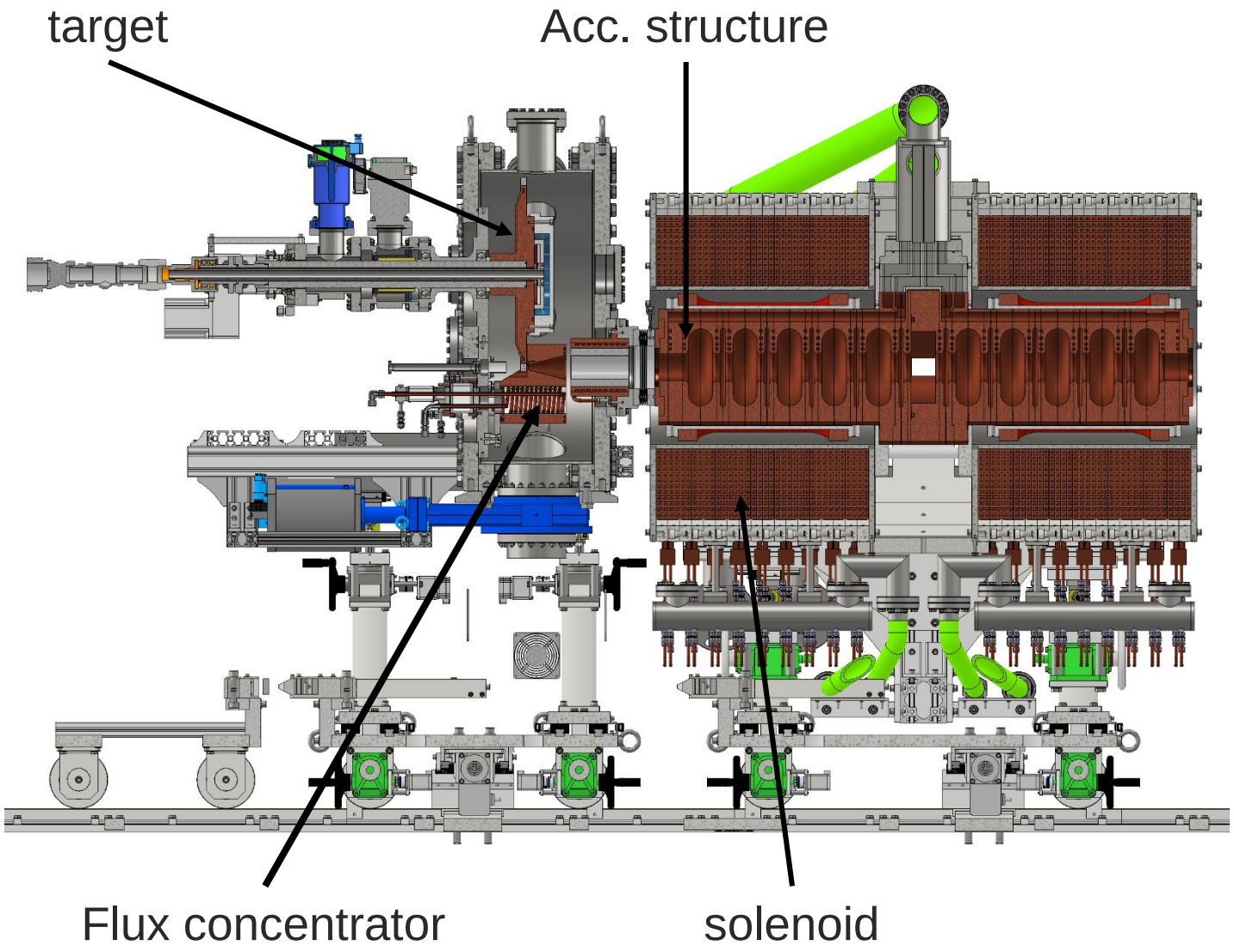


Progress and status of the electron driven positron source for ILC



Prototype to be built by JFY2027

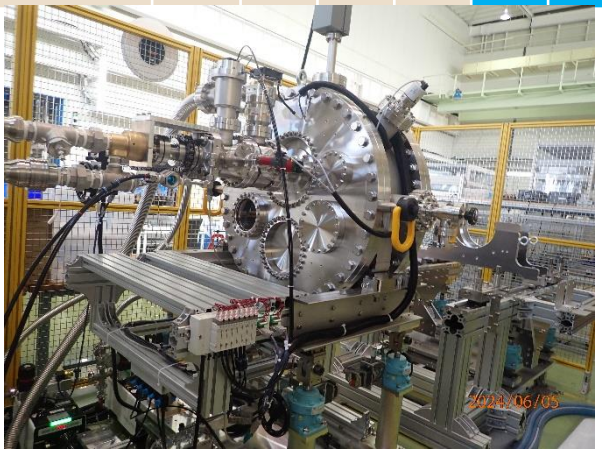
- Project started Sep. 2022
- Grant from MEXT during JFY2023 and JFY 2027
- Build prototype in KEK
- Prepare 3D model, drawings, EDR



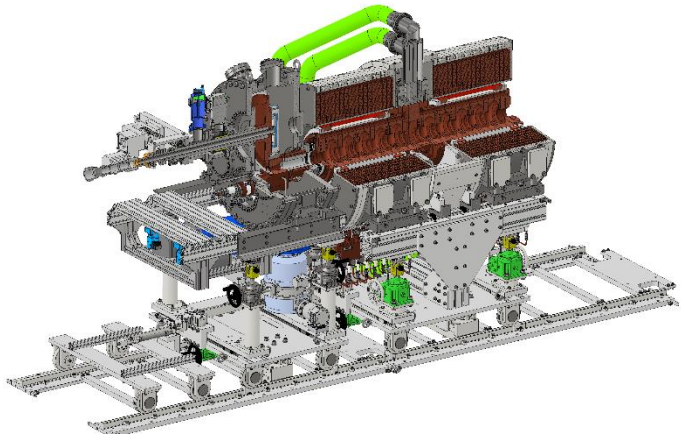
5 years-plan(as of 2024/3/28)

FY		2022	2023				2024				2025				2026				2027			
year			2023				2024				2025				2026				2027			
Quarter		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Test bench																							
High power test bench																							
W-Cu connection																							
Target unit	Rotation mechanism																						
	Disk																						
FC base	1st unit																						
magnet	Solenoid																						
	Power supply																						
Chamber, vacuum, support																							
Acc. structure	1st unit																						
FC power supply																							

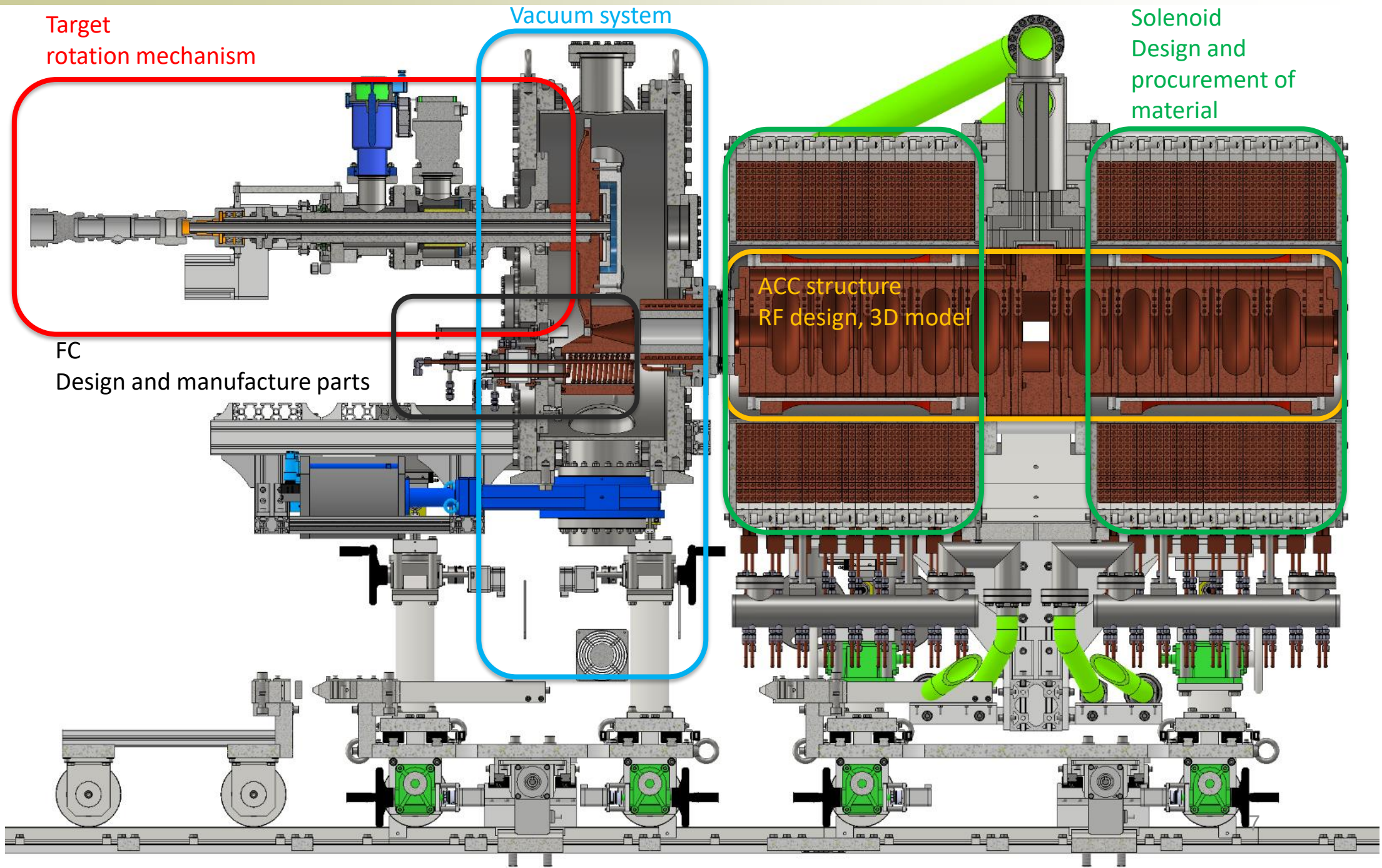
Design
Manufacuring
test



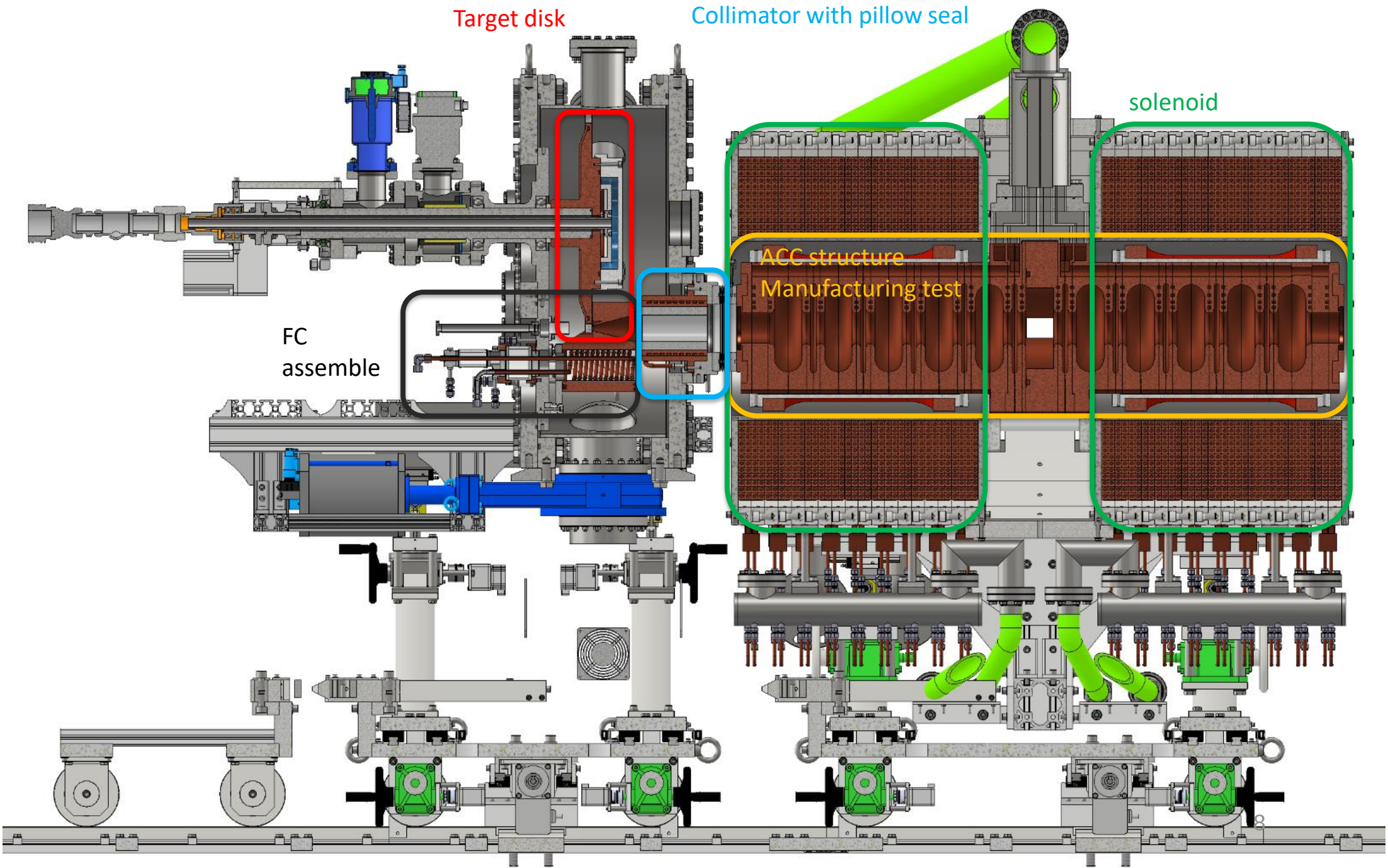
Now!



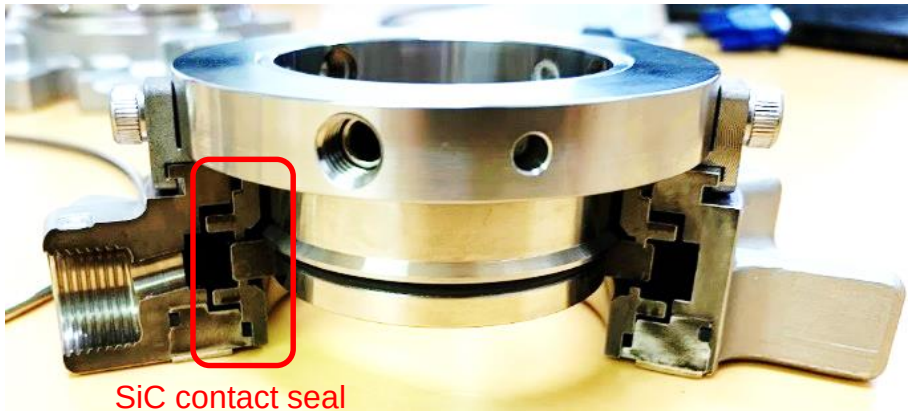
What we did in JFY2023

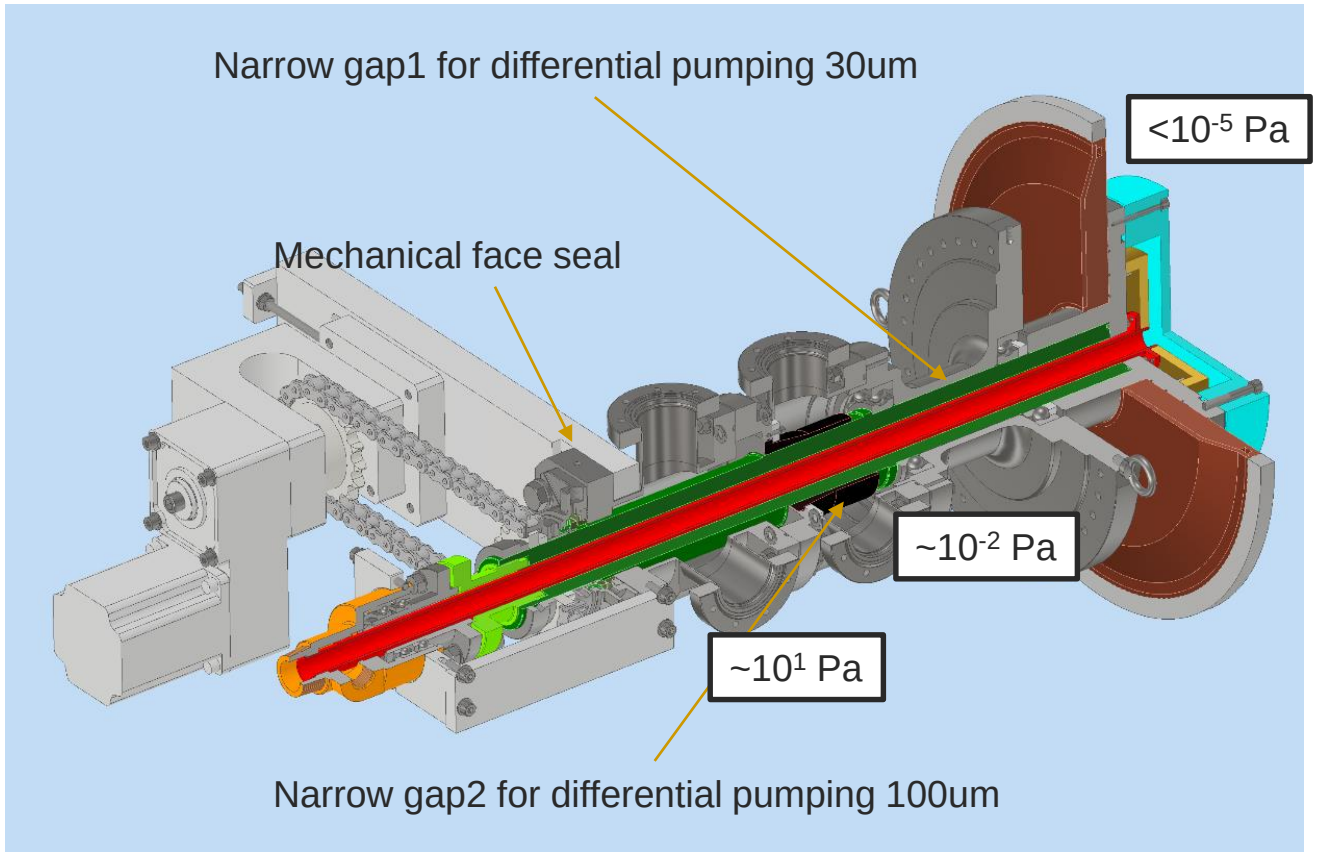


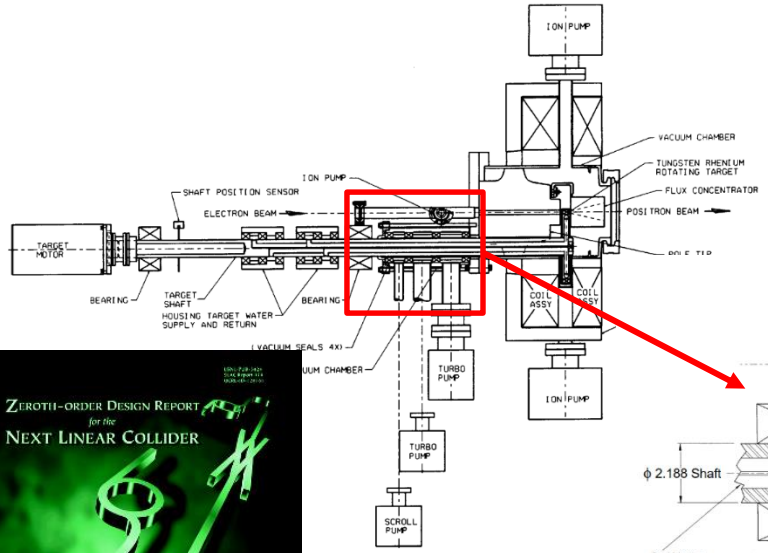
What we plan to do in JFY2024

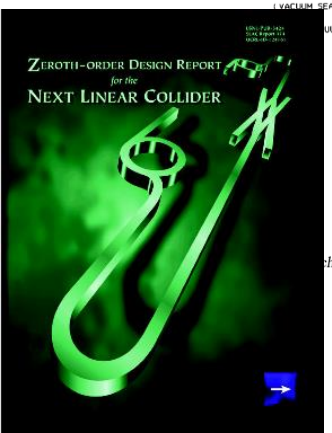


Rotating Target - concept









chematic of the NLC positron target system.

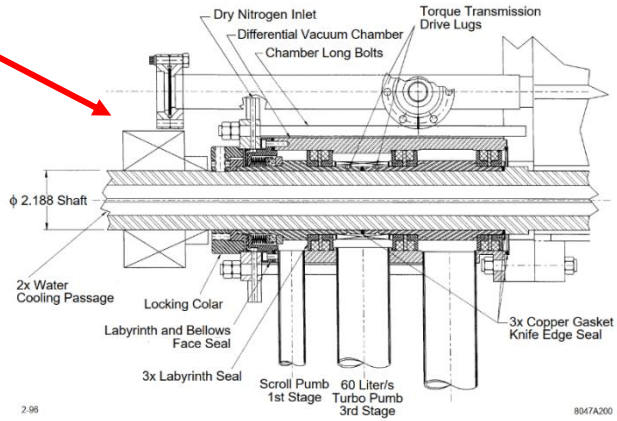
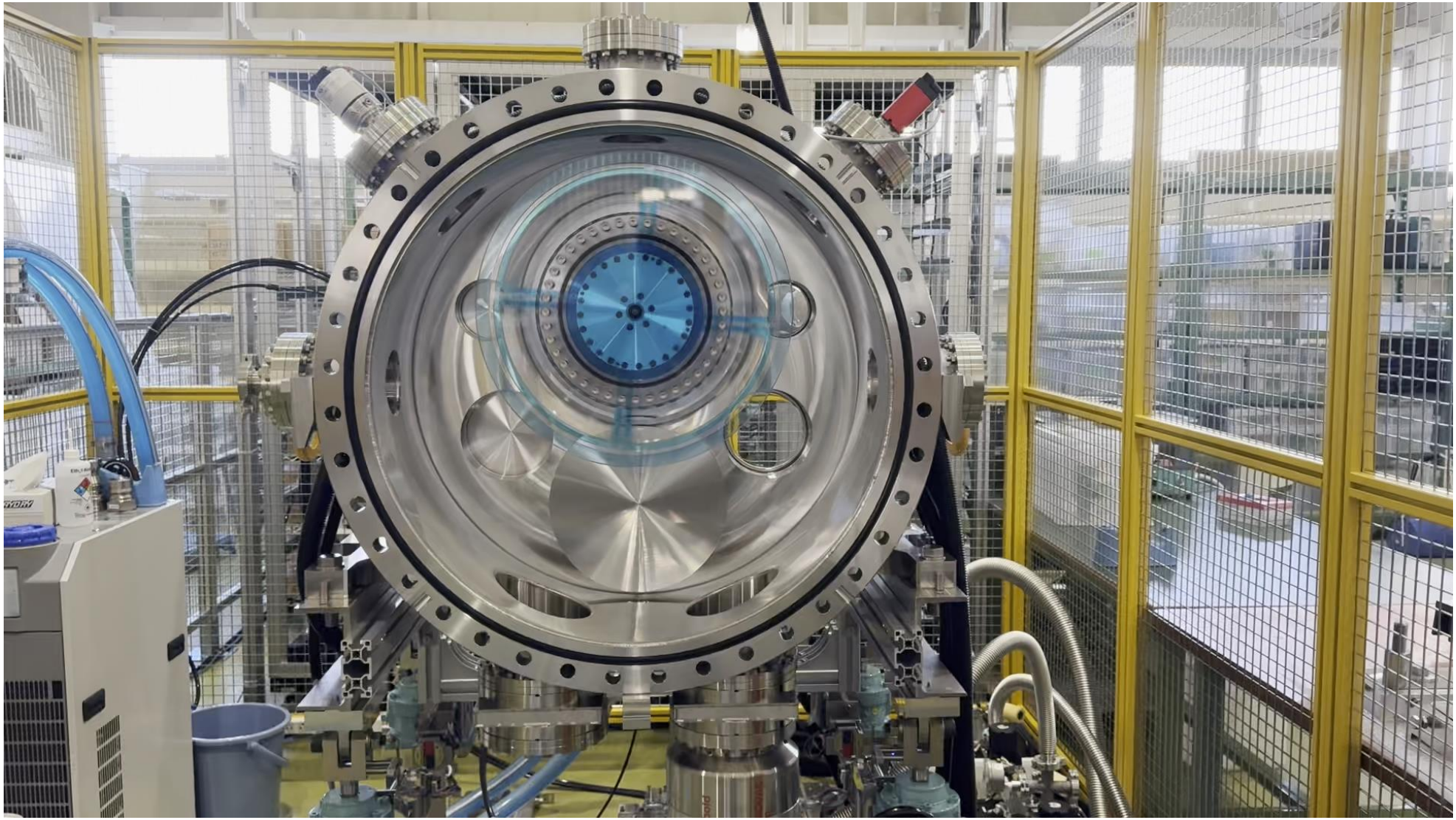


Figure 3-6. *NLC rotating target differential vacuum vacuum chamber and seals consept.*

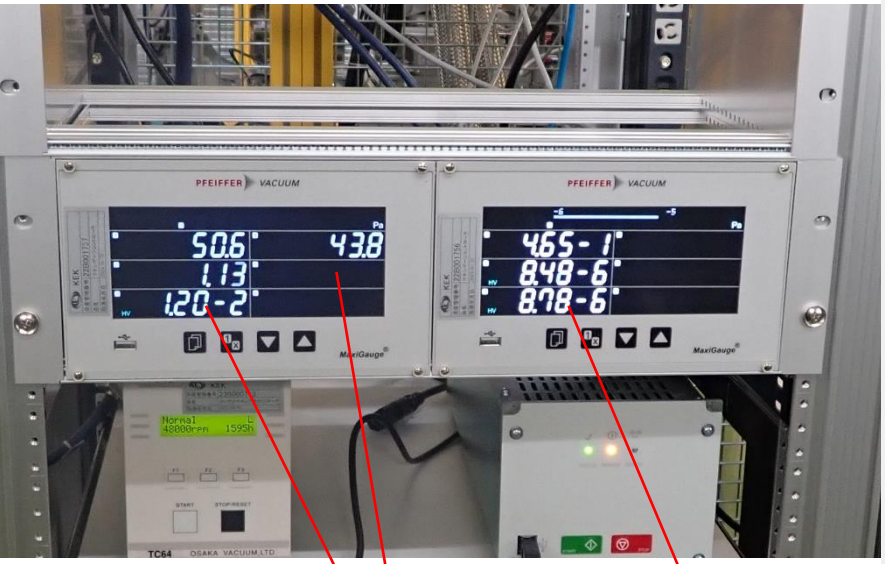
- Mechanical face seal and 2 stage differential pumping with very narrow gap (30 um, 100 um)
- Idea from design report of NLC

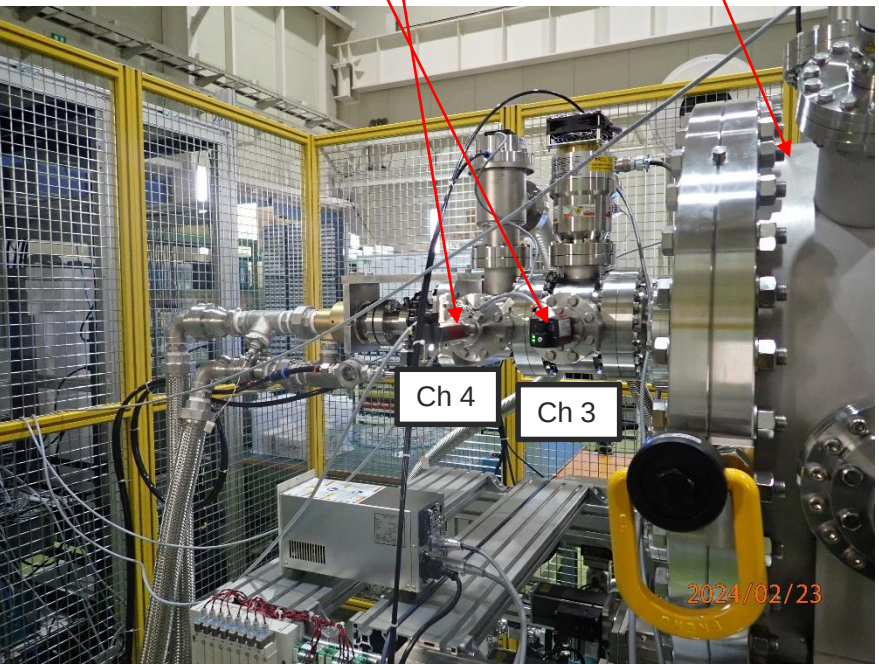
Rotating target - Rotation test with dummy disk

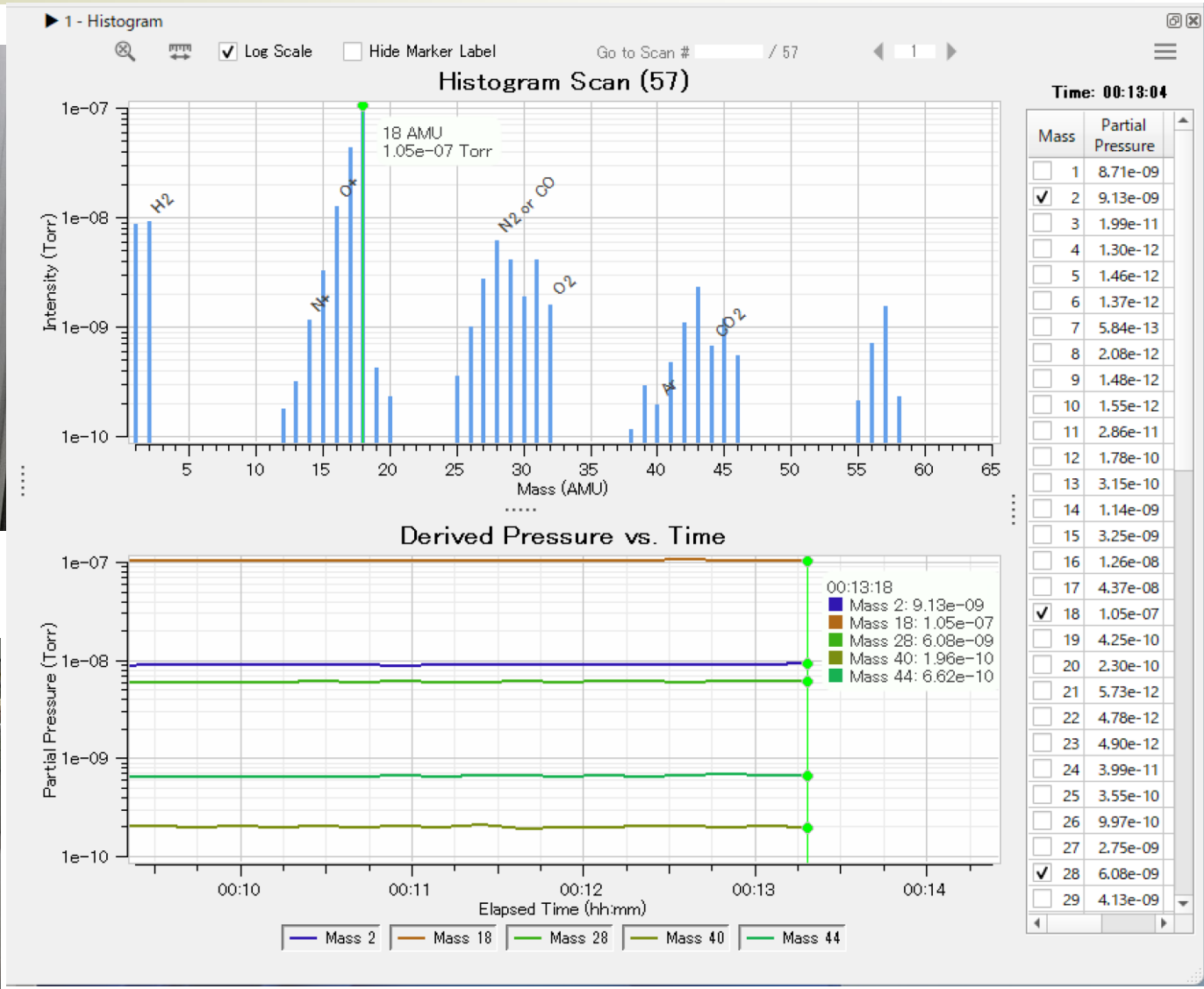


Cooling Water is flowing
Rotation speed is slower than design value

Rotating target Vacuum test w target



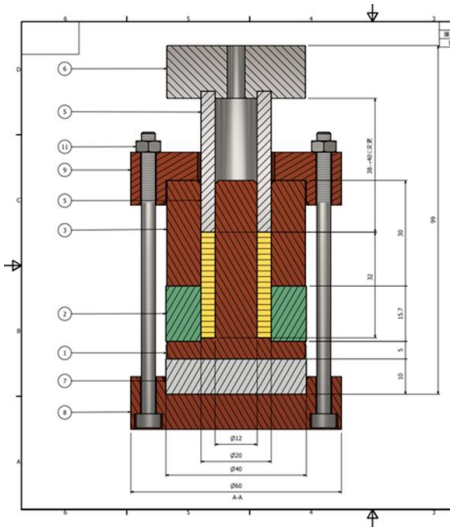


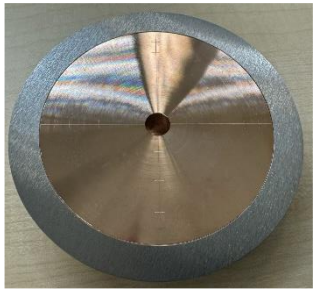


No significant pressure rise during rotation
Differential pumping works as designed

Rotating target - Bonding test of W-Cu

- W-Cu bonding is one of a challenge
  - Very different properties, melting point, thermal expansion…
- Bonding test by Φ40 and Φ100 W rings
  - Final disk size is Φ500
- Tested boding method
  - SPS(Toho)
    - Not good result till now
  - HIP(MTC)
    - Ongoing
  - Pressed fit with Li-Nitrogen (KEK)
    - Use this method for 1st prototype(Φ500)
    - Detail thermo-mechanical simulation to optimize interference and disk size



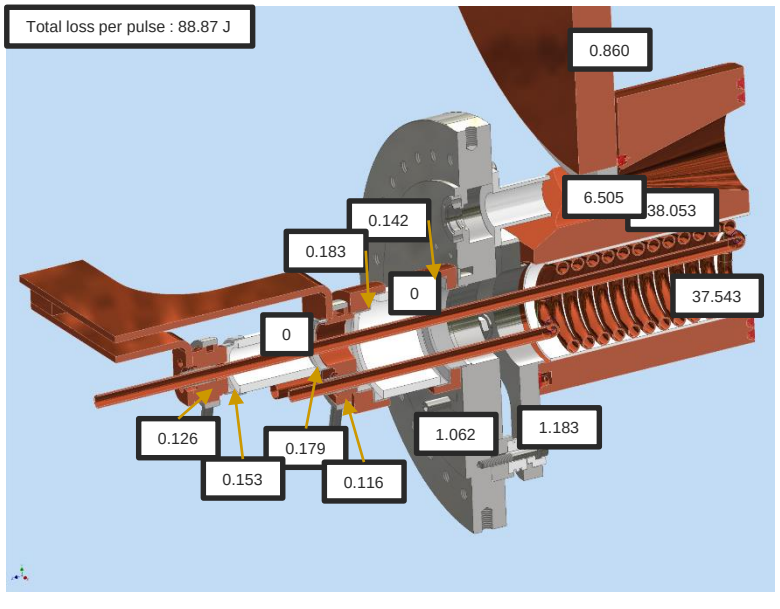


FC - concept

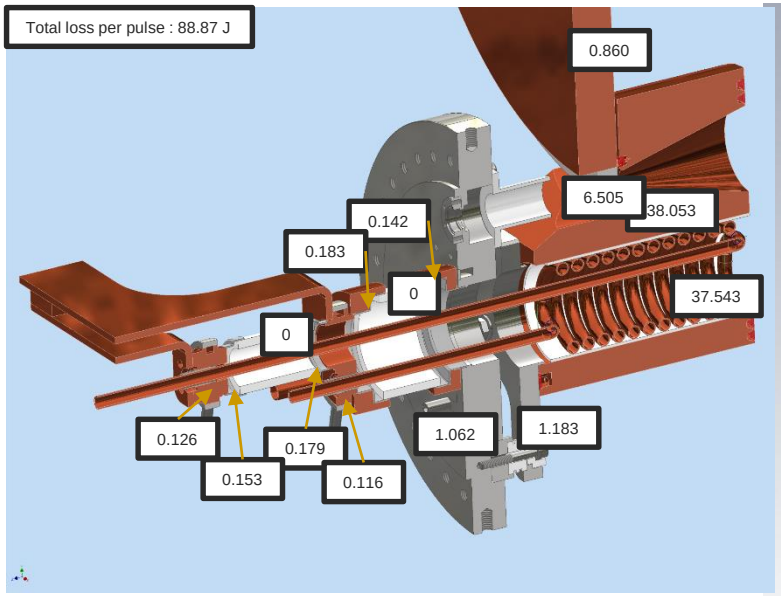
- Basic design and concept are the same as ones used in the previous project, SLC and SuperKEKB
- Engineering design to satisfy requirement, especially cooling mechanism is important
  - Simulation using CST
    - Method was established and validated through the design of FC for SuperKEKB
    - Cooling water path design
    - Heat resistant materials
      - CuCr (SH-1)
- High power pulsed power supply
  - Energy recovery type might be necessary to satisfy requirements
    - Design JFY2024
    - Prototype JFY2025 and 2026

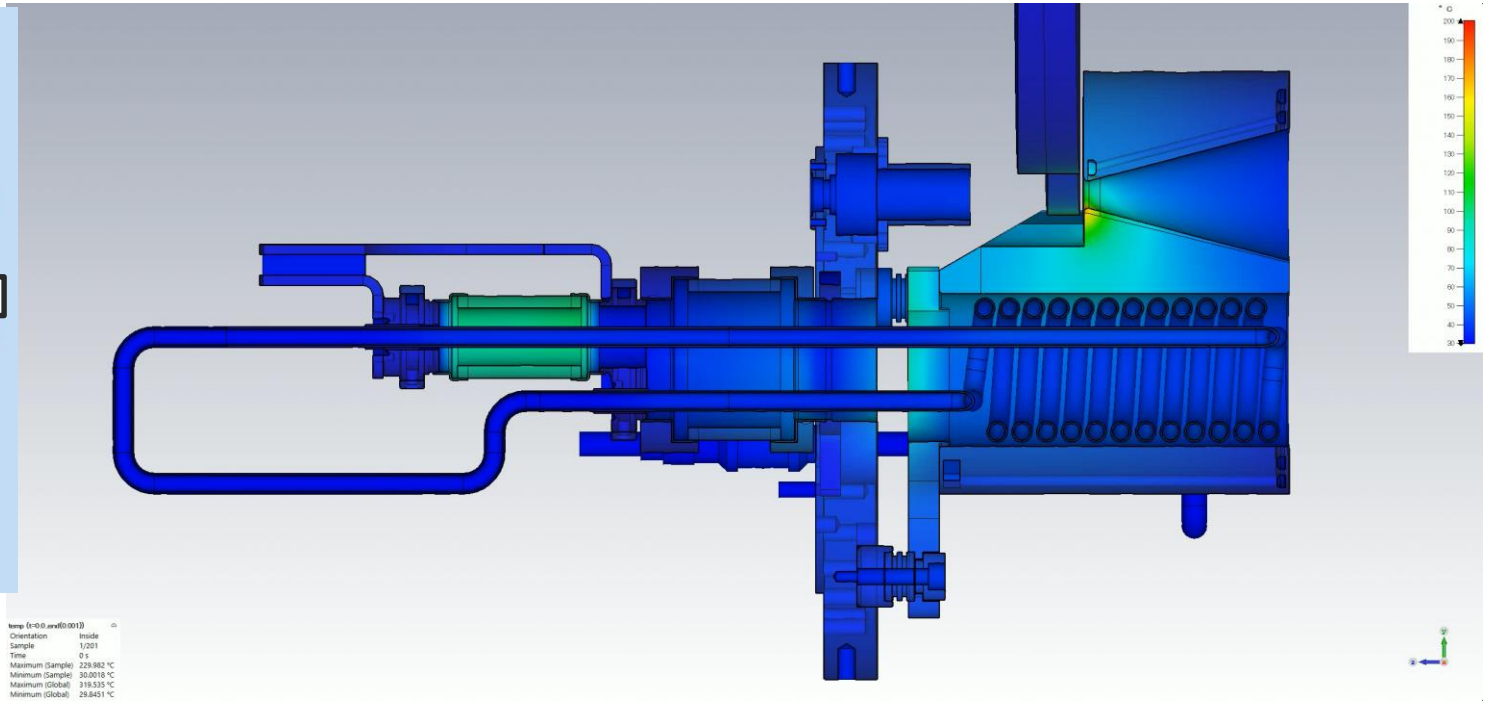
	SKEKB	ILC
voltage (kV)	20	20
current (kA)	12	35
repetition (Hz)	50	100 (300)
Pulse width (us)	6	11 (5-1-5)
Aperture (mm), diameter	7	12
Peak magnetic field (T)	3.5	5
Peak power (MW)	240	700
Average power (kW)	12	128
Ohmic loss (kW)	0.8	9

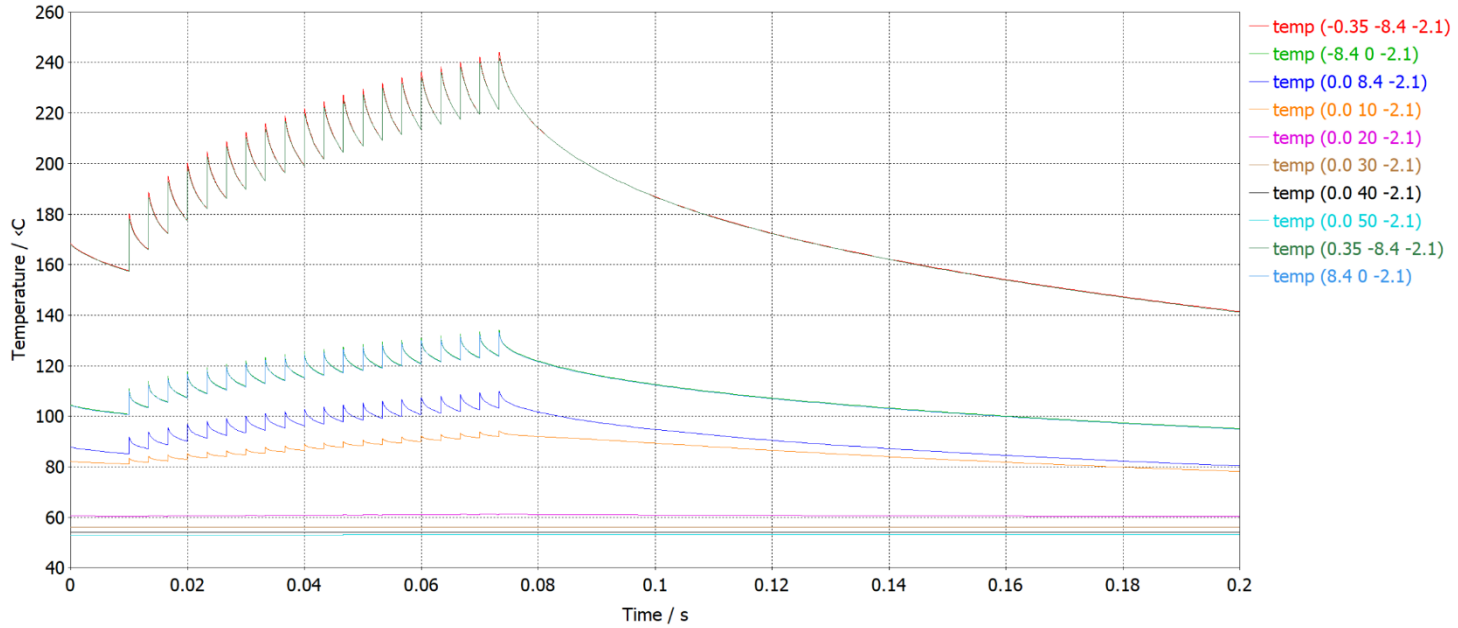
ILC ～ 10 x SuperKEKB in power



FC – thermal simulation



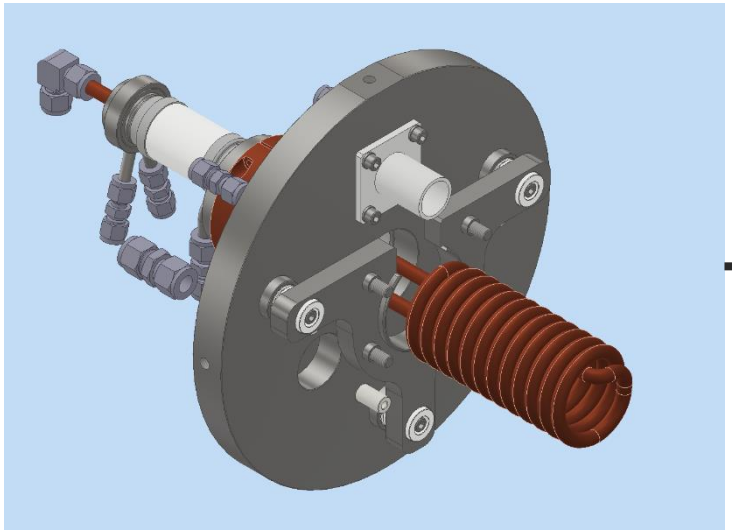




FC – prototyping

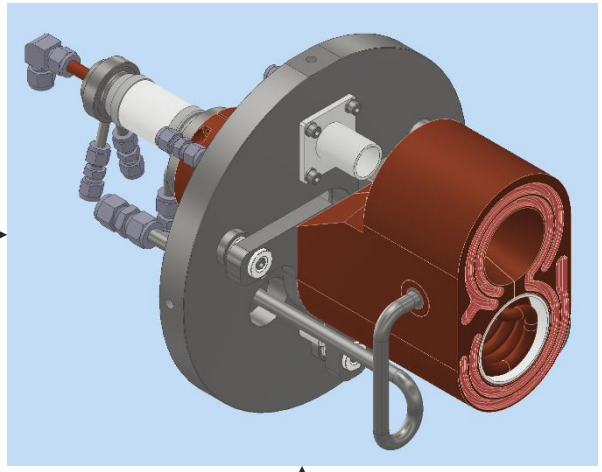
FY2023

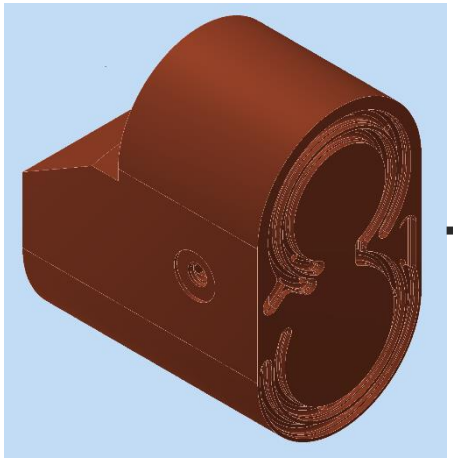
FY2024



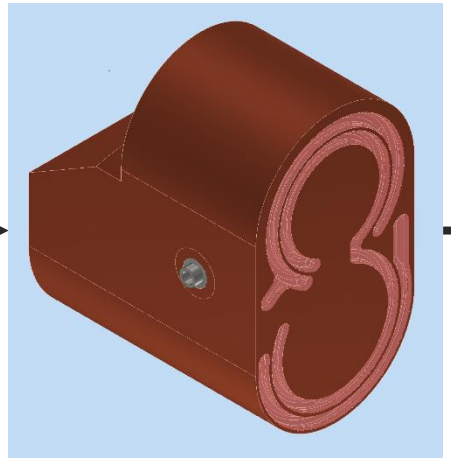
Parts(delivered)
feedthrough
flange, support
piping
electrode
bolt, pin, bush
coil

Welding & assembly

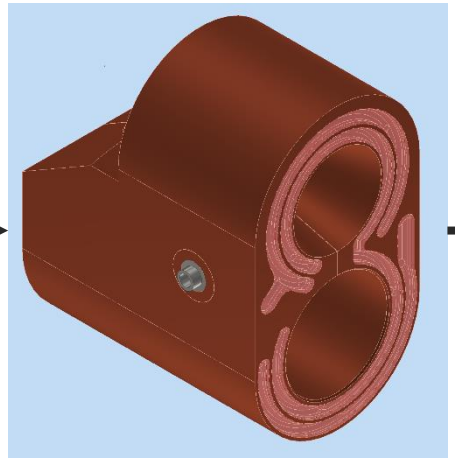




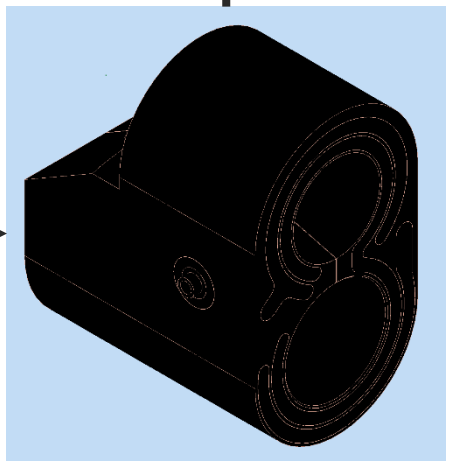
Machining done



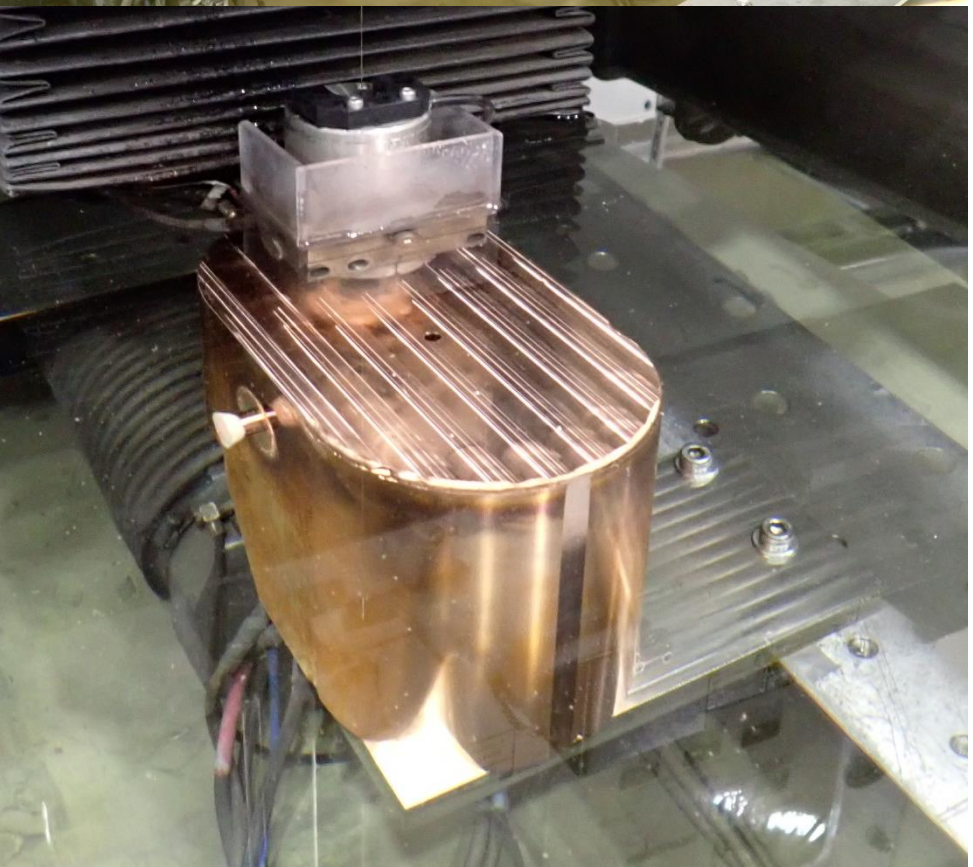
EBW done

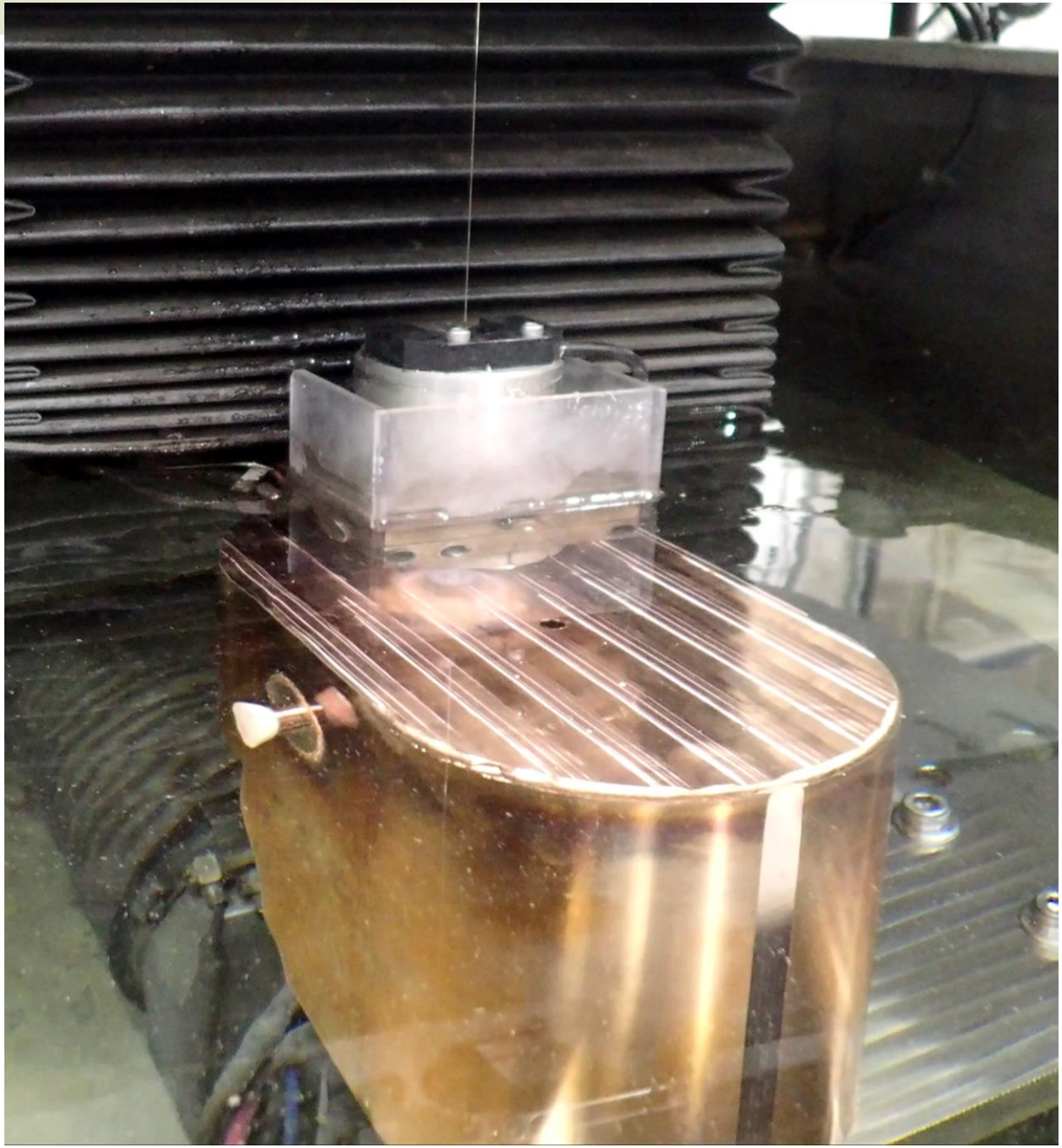


Secondary working
Milling & EDM
done



Black plating done





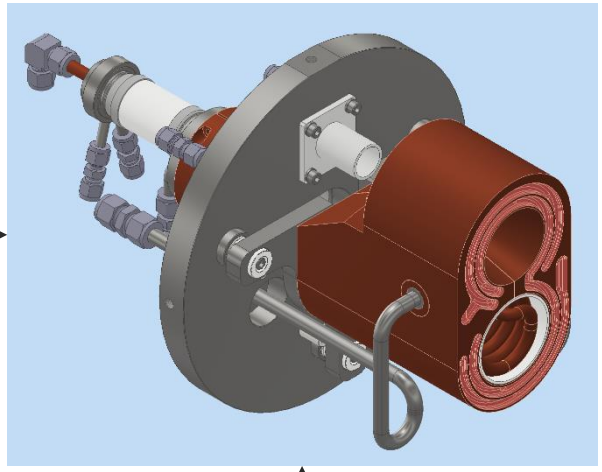
FC – prototyping

FY2023

FY2024

Parts(delivered)
feedthrough
flange, support
piping
electrode
bolt, pin, bush
coil

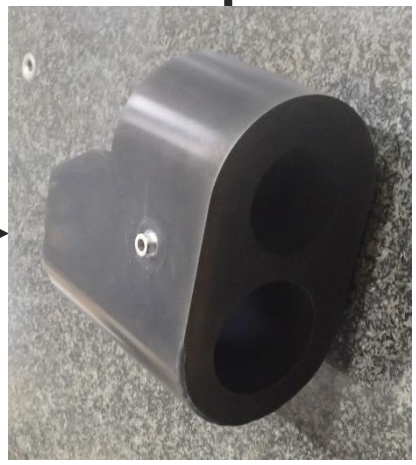
Welding & assembly ~August



Machining done

EBW done

Secondary working
Milling & EDM
done



Black plating done

Acc. Structure - concept

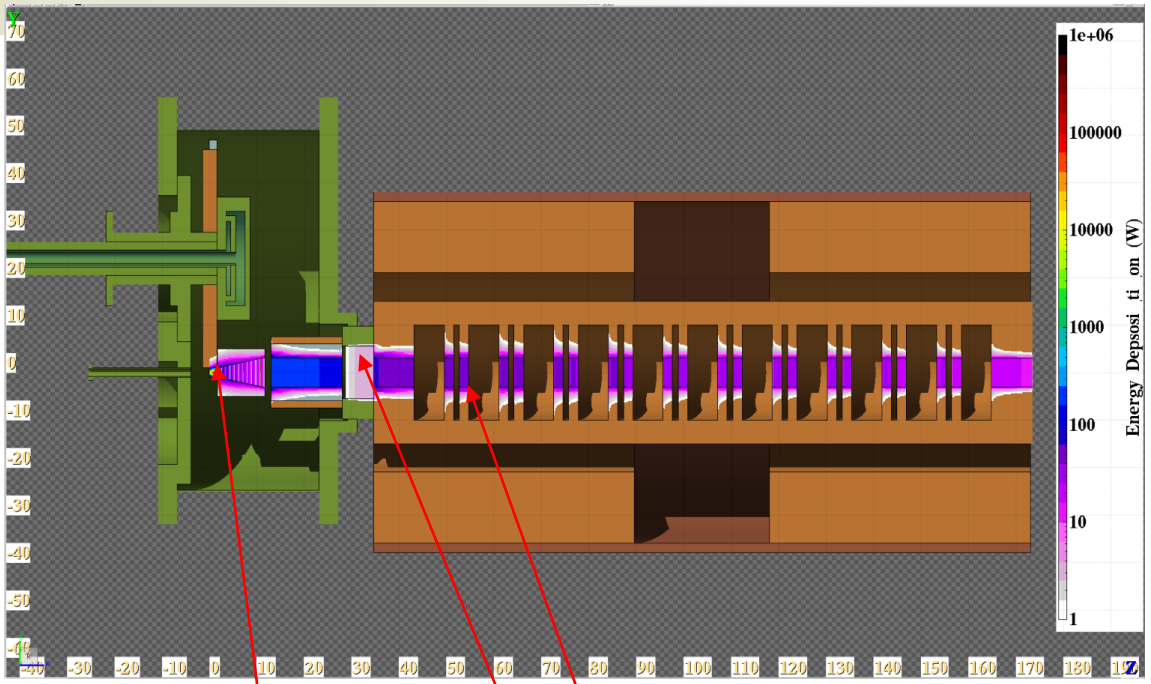
Challenges

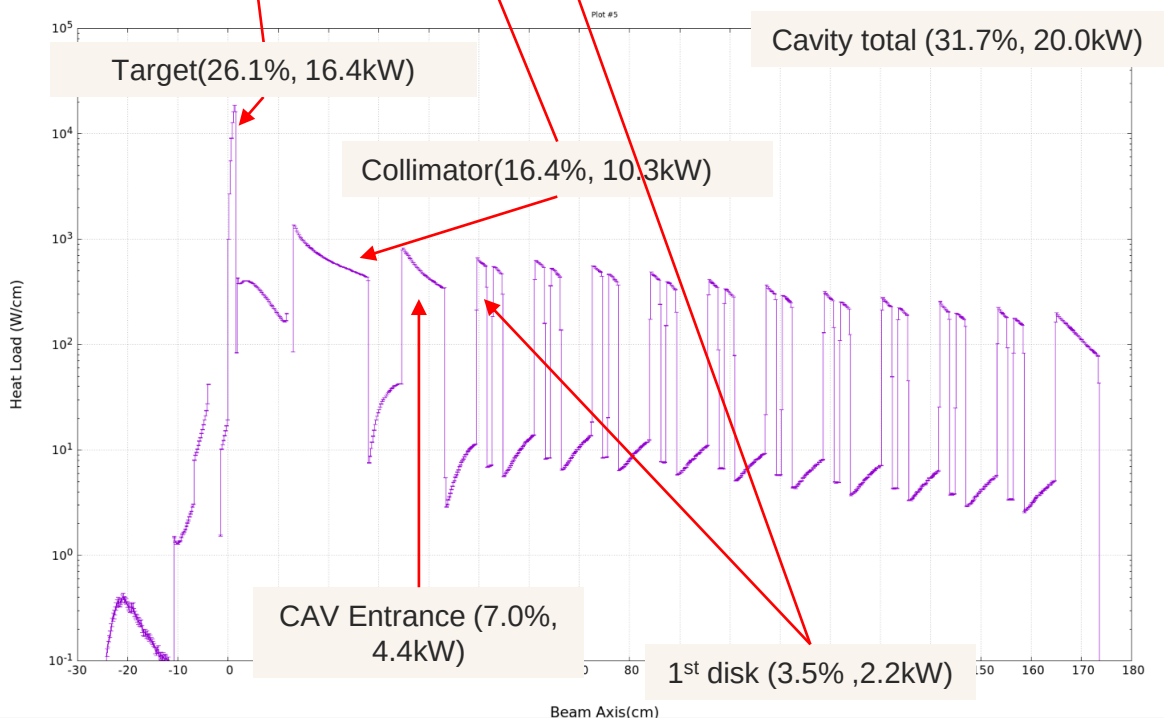
- **Beam loading compensation**
  - High beam current : > 0.6A
  - Multi bunch operation
- **Powerful cooling system is required.**
  - Very high heat load due to electromagnetic shower from the target
- **Remote beam flange connection**
  - High activation by shower from the target and the connection point is surrounded by solenoid coils

Design Policy

- **High group velocity**
- **Large coupling β**
- **Water channel in the**

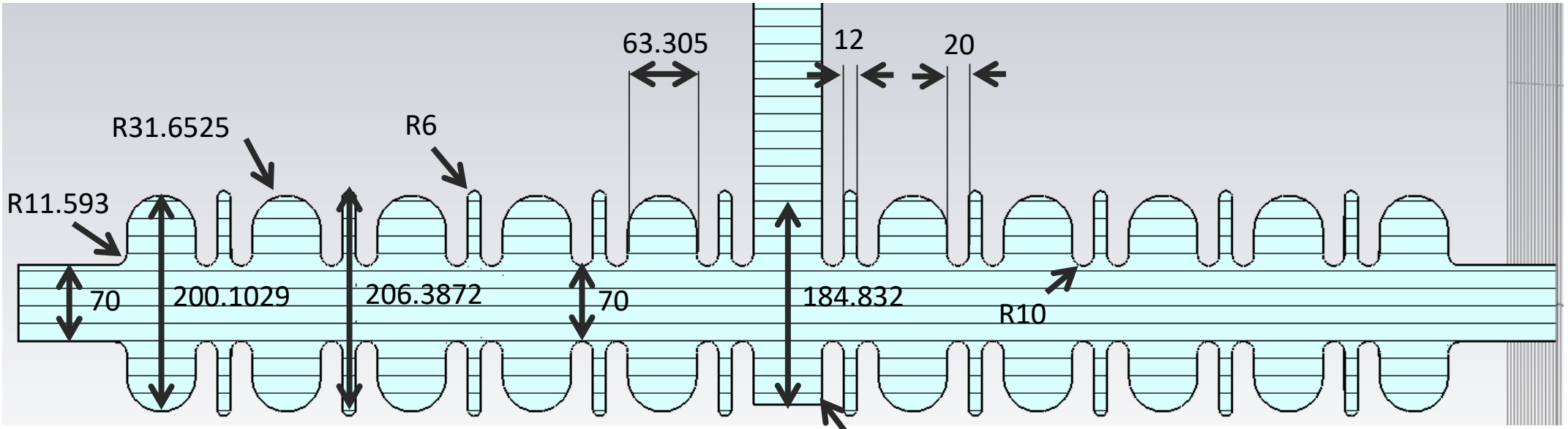
APS cavity with a bi-periodic structure that operates in the π/2 mode, which maximizes the group velocity.





Acc. Structure - RF design

RF design finished using CST and Superfish by M. Fukuda



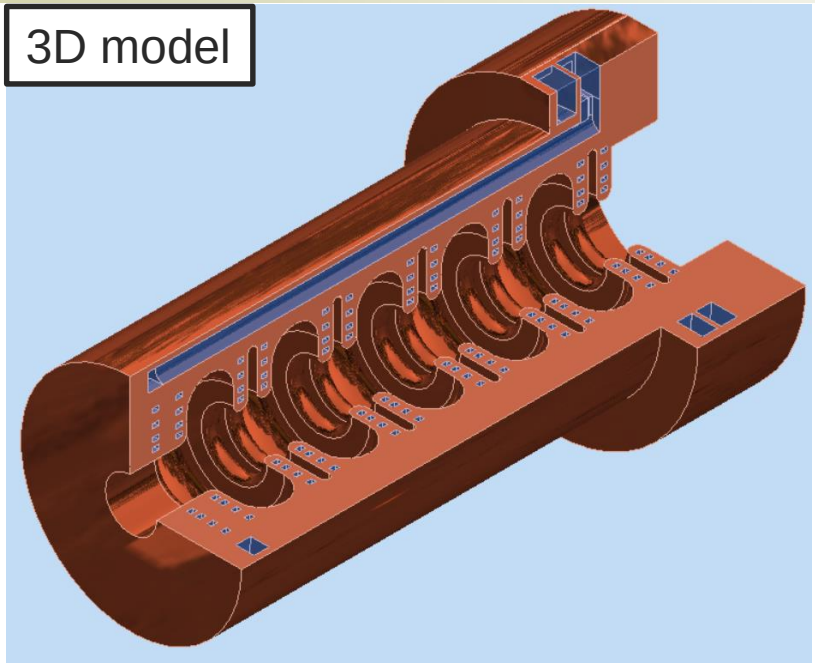
Coupling cell 2c: 206.3872

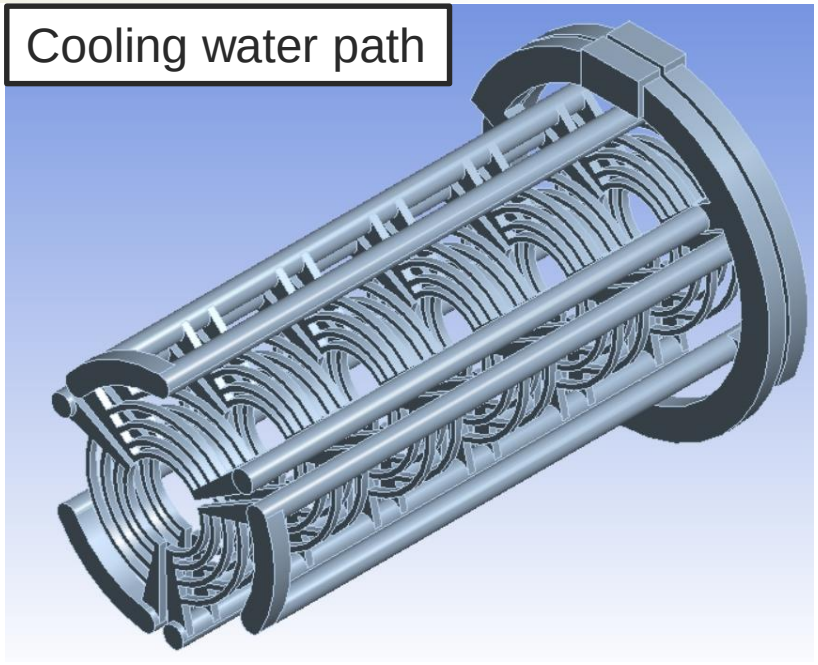
Prameters	value	Prameters	value
Resonant frequency (11π/21) [MHz]	1300	Q0	22806
Eacc [MV/m] (*1)	6.5	Qext	4513
Vacc [MV] (*1)	8.2	QL	3801
Ez max [MV/m] (*1)	13.6	Coupling β	5.05
Rsh [MOhm/m]	35.0	RF loss [1/W]	0.25
Transit-time factor (T)	0.78	RF loss (ave)[W] (*1) (*2)	625
Effective Rsh [MOhm/m] (Rsh*T*T)	21.3	Kilpatrick limit [MV/m] @ 1300MHz	32
Cavity length [m]	1.268	Max. Surface E-field [MV/m] (*1)	20 0.6 kilpatrick
Filling time [us]	1		

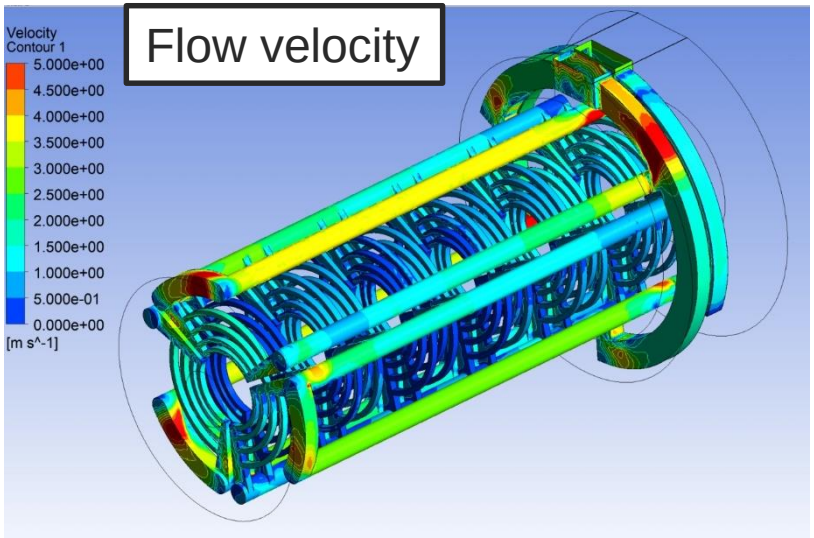
(*1) RF input power: 10MW (peak)
(*2) Pulse width 2.5us, Rep.Rate 100Hz

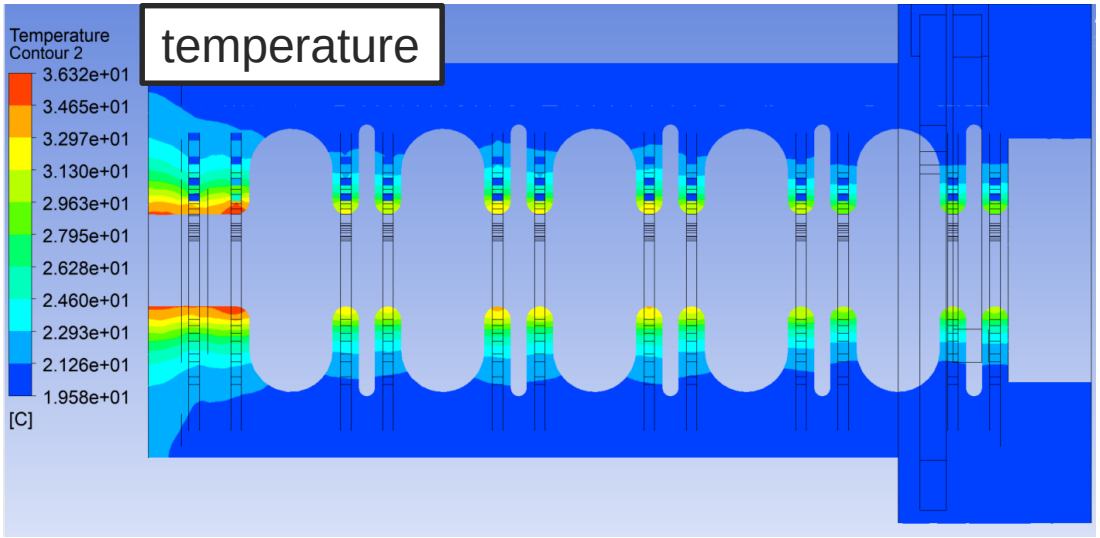
Acc. Structure - cooling design

- CFD simulation using ANSYS

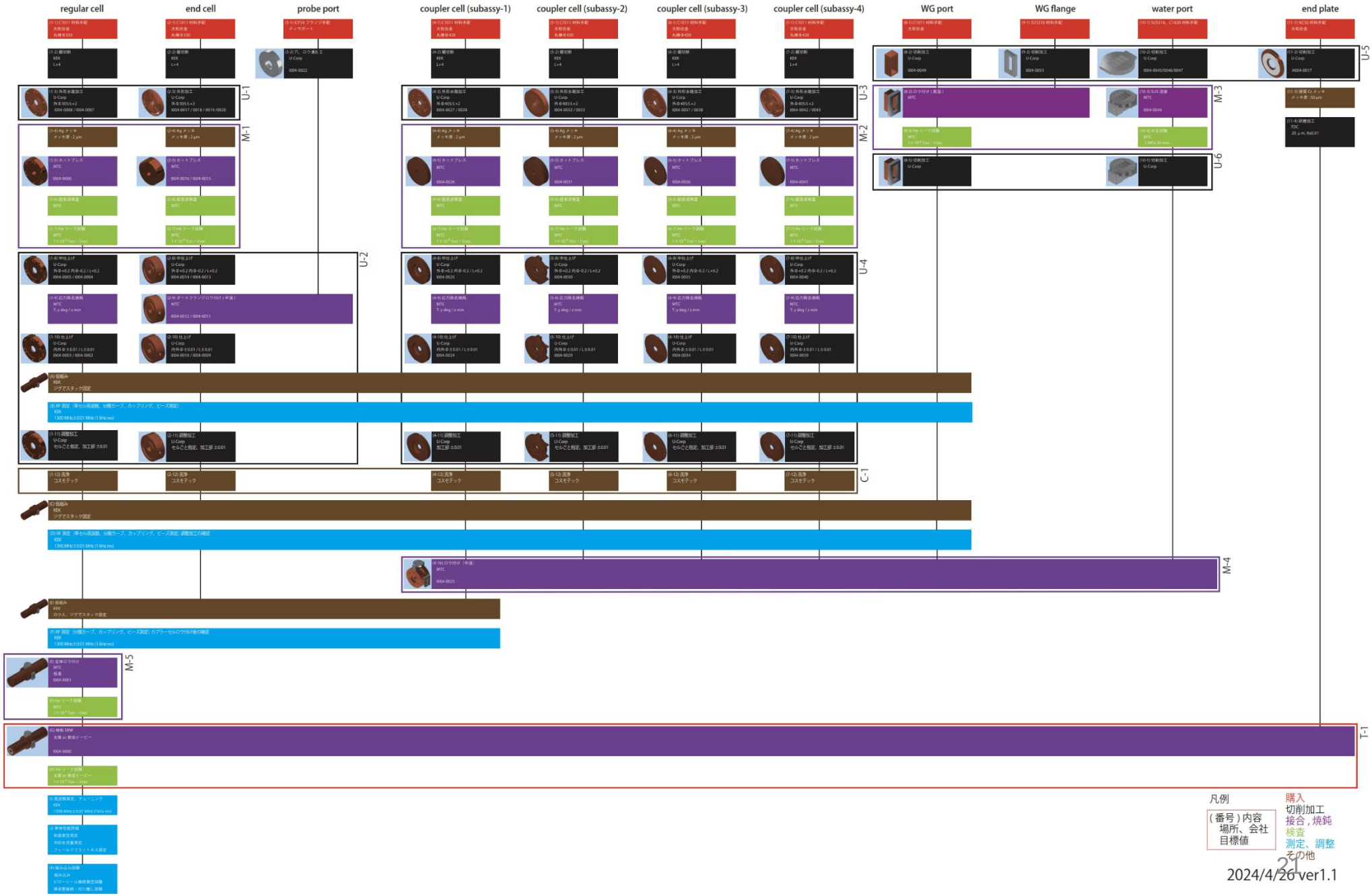






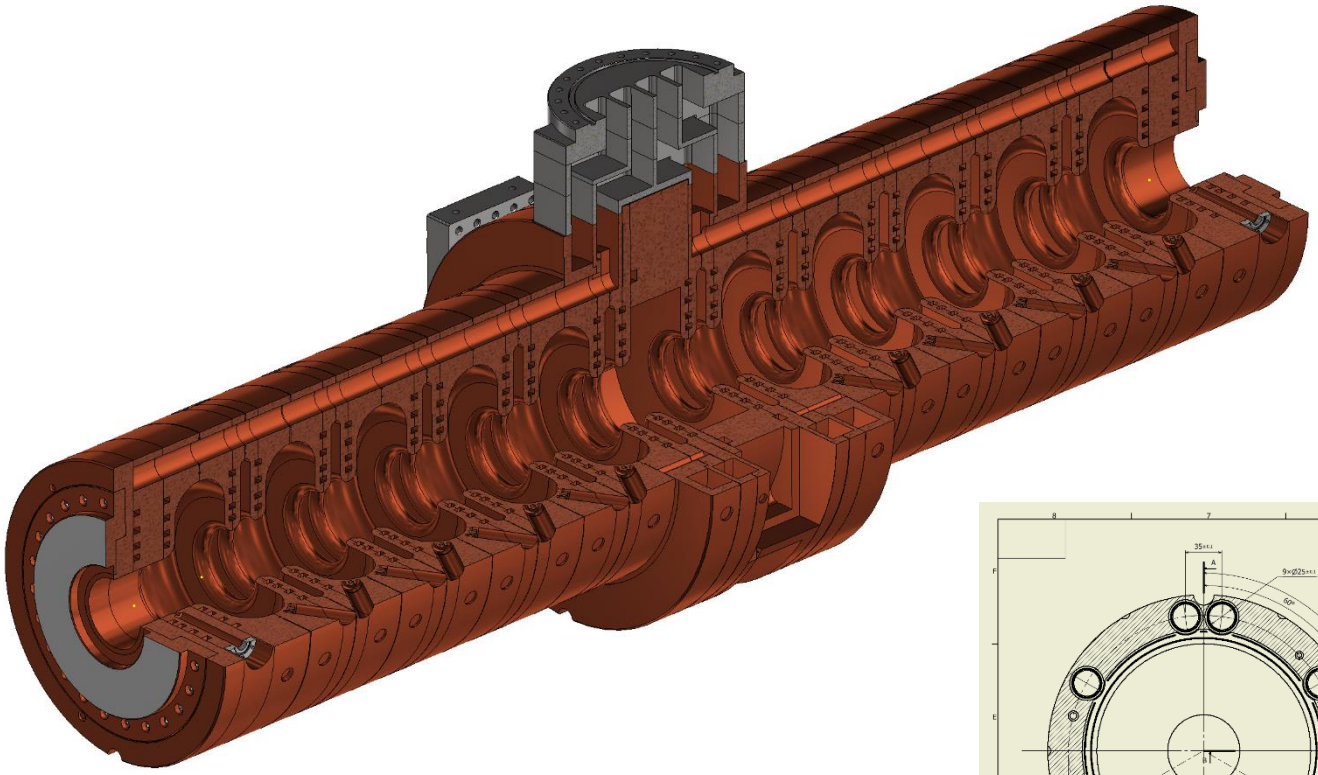


Acc. Structure - manufacturing process

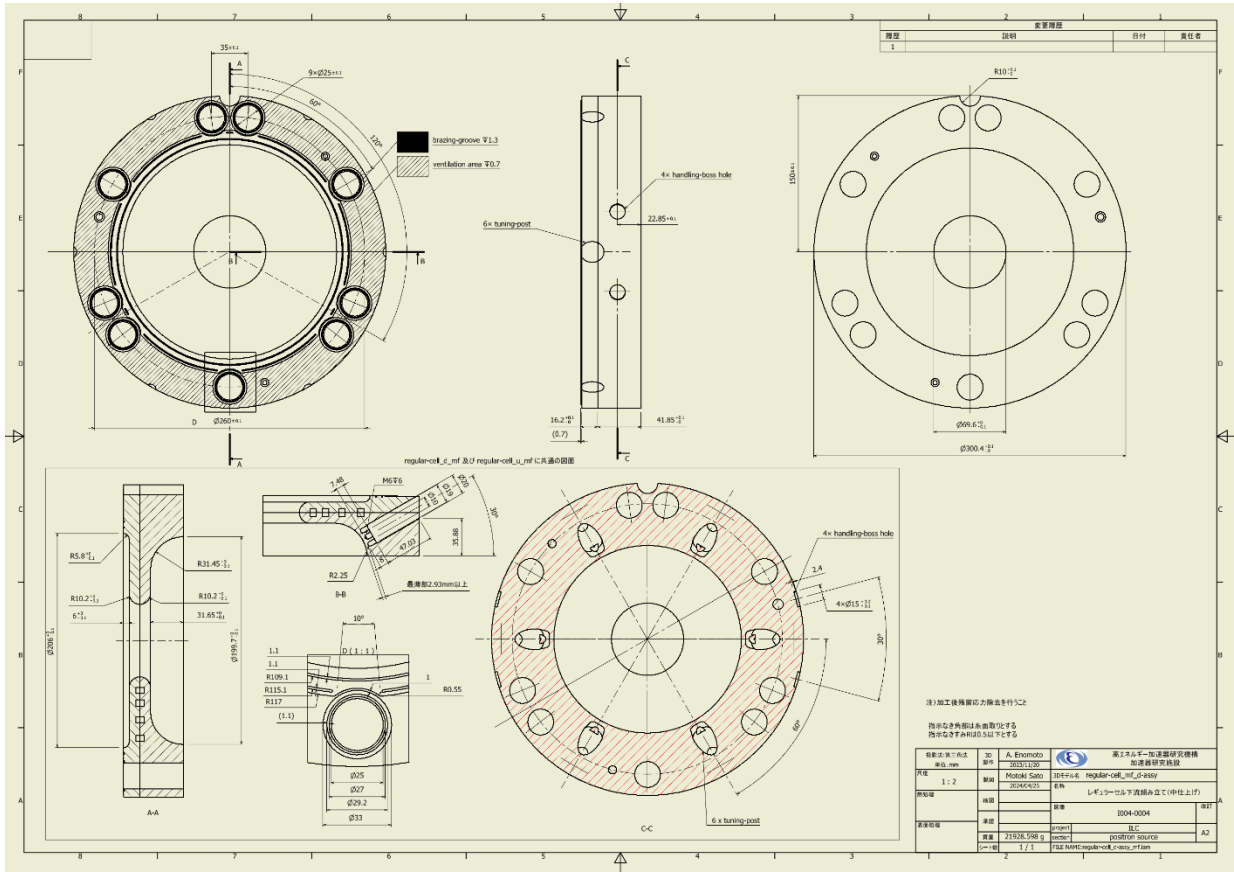


2024/4/26 ver1.1

Acc. Structure - prototyping



- 3D model is ready by A. Enomoto
- 2D drawings are 70% ready by M. Sato
- Material (C1011) has delivered
- Machining and hot press bonding test started



Simulation flow of positron source

collimater water flow (ANSYS / CFX, FLUENT)
flow velocity
Heat transfer coefficient
collimater temp (ANSYS / transient thermal)
temperature
collimater structure (ANSYS / transient mechanical)

radiation/activation (FLUKA)
Heat load

target water flow (ANSYS / CFX, FLUENT)
flow velocity
Heat transfer coefficient
target temp. (ANSYS / transient thermal)
temperature
target deformation/contact (ANSYS / transient mechanical)

particle shower generation (Gambet / Geant4)
Heat load
particle distribution

solenoid magnetic field (CST / M-static)
magnetic field

particle tracking and wake (CST / PIC)
*multi-bunch operation
particle distribution
particle tracking long range (SAD)

- Global optimization up to DR
  By S. Kuroguchi
- PIC simulation up to 1st Acc. Structure
  By M. Fukuda

are in progress

FC magnetic field (CST / LF time domain) (ANSYS / Maxwell)
magnetic field
Heat load
EM force

FC temp. (CST / Transient thermal)

FC structure (ANSYS / Transient mechanical)

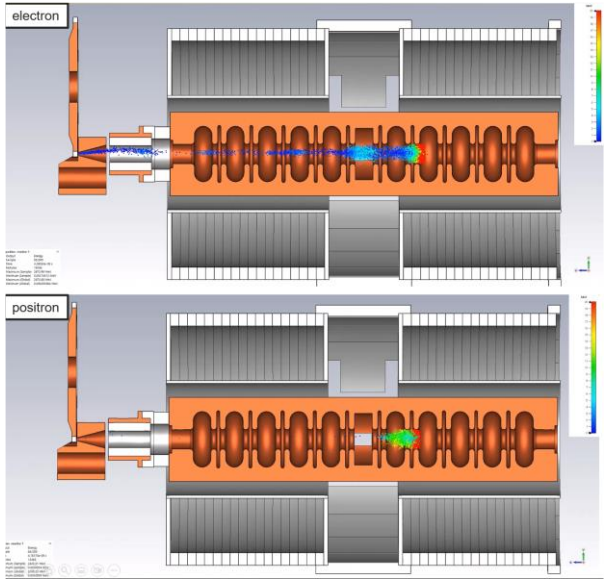
FC circuit paramater (CST / partial RLC)

FC transmission line circuit paramater (CST / partial RLC)

Acc. cavity RF field (CST / RF transient) (CST / RF frequency domain)
EM field
EM heat load

Acc. cavity thermal (CST / static thermal) (ANSYS transient thermal)
temperature
Acc. cavity deformation (CST / Mechanics) (ANSYS static mechanical)

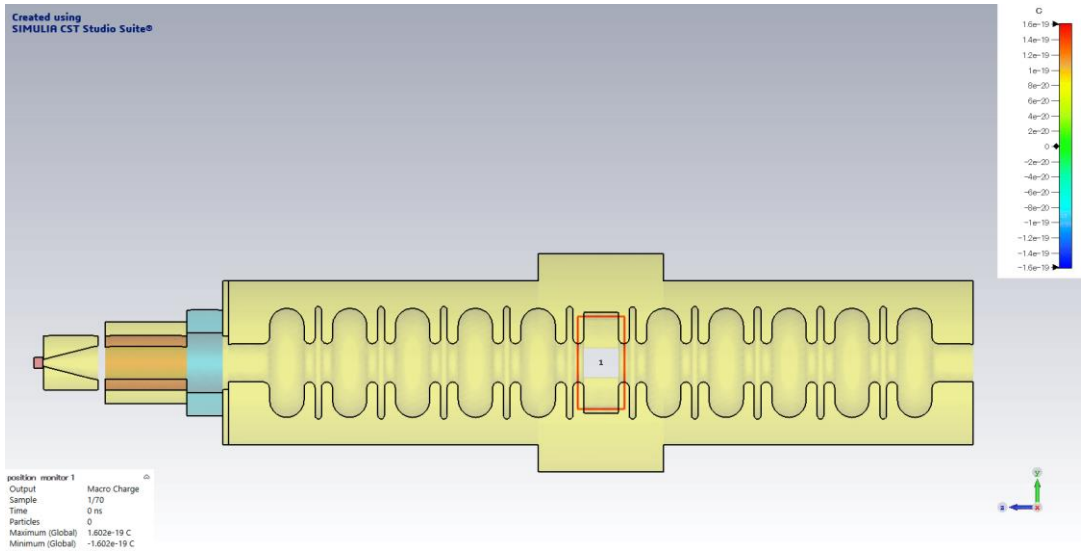
Acc. cavity water flow (ANSYS / CFX, FLUENT)
flow velocity
Heat transfer coefficient

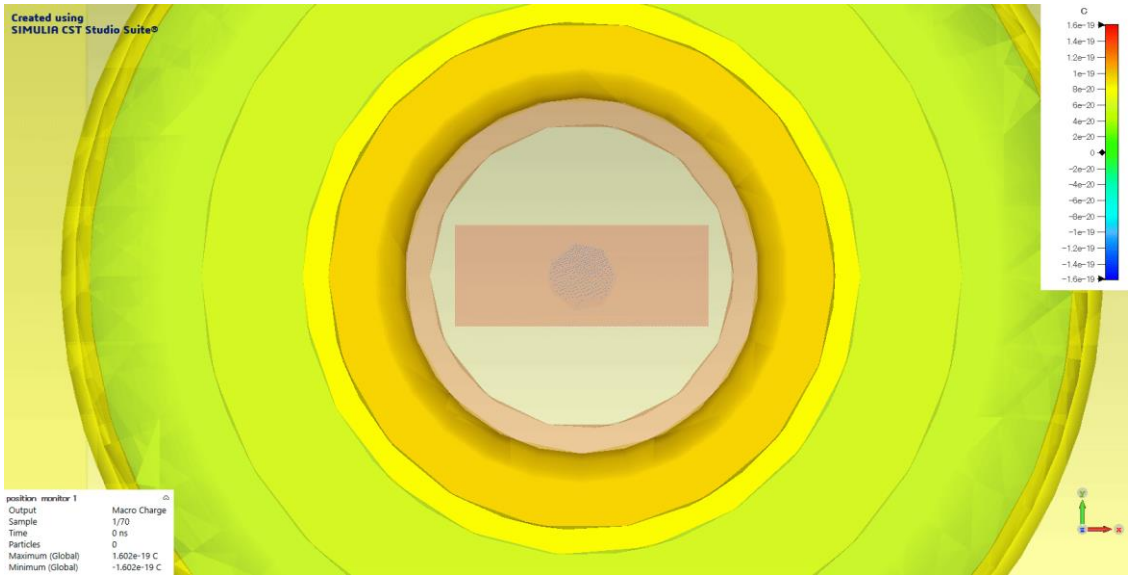


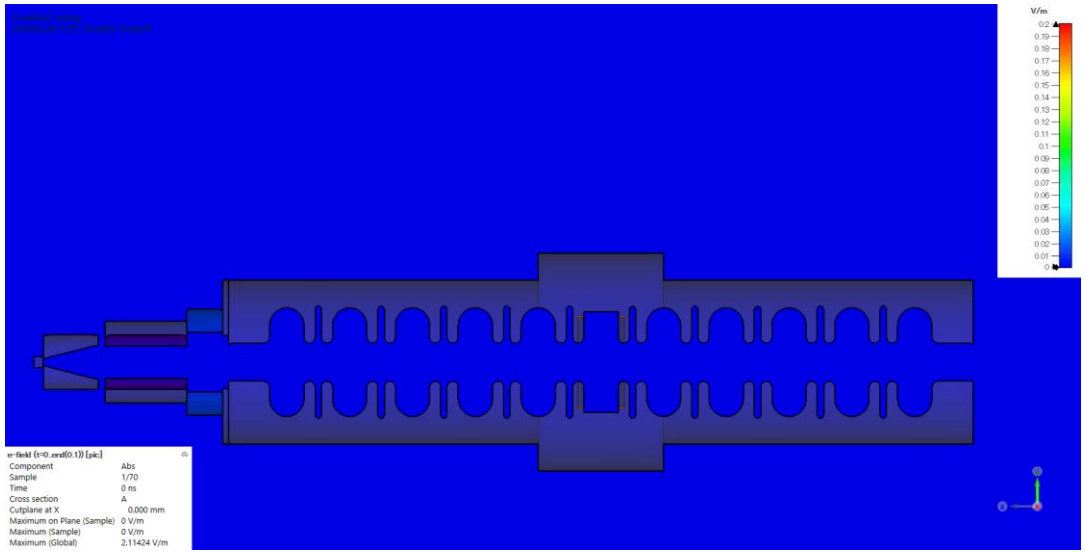
PIC simulation example

M. Fukuda

Blue:electron
Red:positron







Summary

- Prototype development of e-driven positron source for ILC is in progress
- Please focus on the following talks

Speaker	Topic	title
S. Kuroguchi	particle simulation	Design of the ILC electron-driven positron source and utilization of black-box optimization
Y. Morikawa	Target	Development of E-driven positron target
M. Fukuda	Acc. Structure	APS cavity design for ILC E-driven positron capture linac