



# **ATF2 STATUS AND OPERATION 2023-2024**

**Alexander Aryshev**

(on behalf of ATF team)

KEK: High Energy Accelerator Research Organization,  
e-mail: [alar@post.kek.jp](mailto:alar@post.kek.jp)

**LCWS2024, 9 July 2024.**

# Outline

- ATF upgrade strategy
- IPBSM new laser system
- ATF timing/RF system upgrade
- Magnet movers
- New FF magnets (QD0FF and QF1FF)
- Other upgrades
- Summary

# ATF upgrade strategy

Linac

Damping ring

ATF parameters beam parameters at the beginning of the extraction line.

Beam energy	1.28 GeV
Fractional energy spread	$6.4 \times 10^{-4}$
Bunch charge	$\sim 1 \times 10^{10}$ electrons
Bunch frequency	1.56 to 6.24 Hz
Bunch length	30 ps
Vertical emittance $\epsilon_y$	$5 \times 10^{-11}$ m rad
Horizontal emittance $\epsilon_x$	$1.6 \times 10^{-9}$ m rad

- **Increase machine stability**
  - Timing and its distribution system
  - LLRF system including FB
- **Improve quality of the beam diagnostics and control**
  - Monitors upgrades
  - Automated software tools

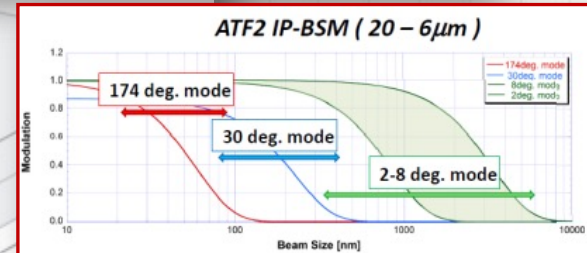
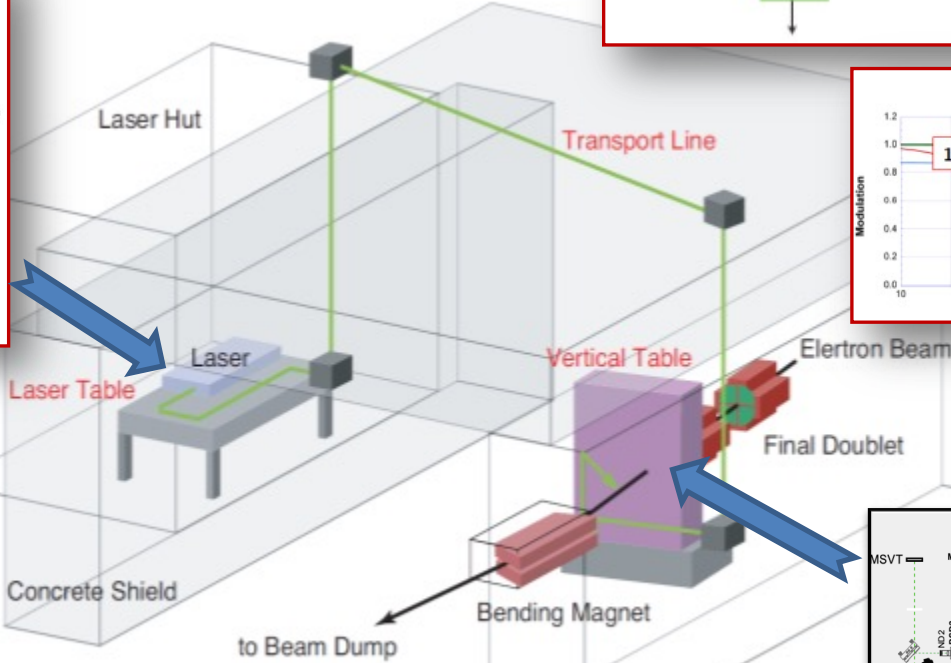
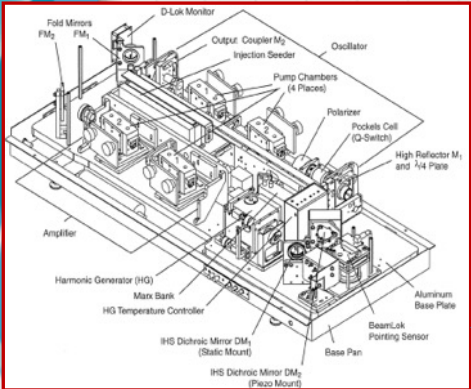
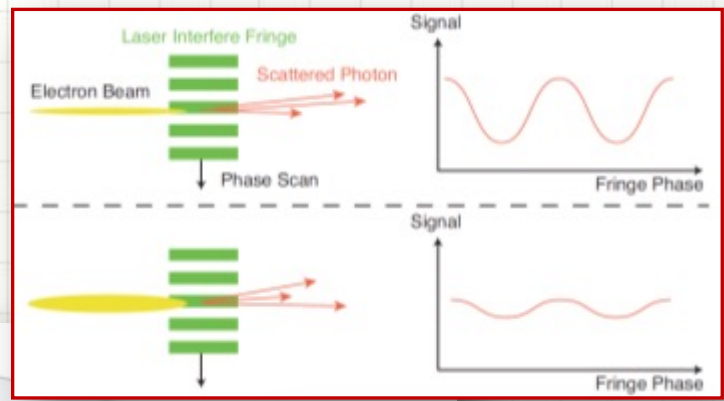
ATF Extraction line

ATF-II Extraction line

- Continue development of the nanometer beam technologies for ILC via:
  - Introduction of a new, but reliable technological approaches
  - Employment of the recent advances in machine tuning including these based on AI.
- Keeping developments towards ATF2/3 collaboration goals – achievement of a 37 nm vertical beam size at IP and beam position stabilization down to a few nm.

# IP-BSM overview

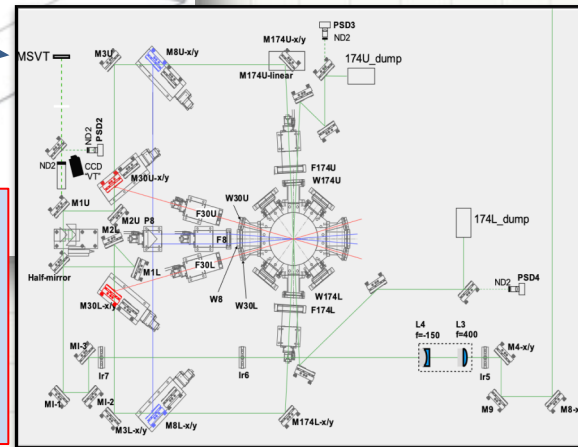
Spectra-Physics Quanta-Ray PRO 350



## Laser beam specs @IP:

- $E_{532nm} = 250 \text{ mJ} \pm 3\%$
- Pulse =  $8 \text{ ns} \pm <0.5 \text{ ns}$  (FWHM)
- Rep. rate = 6.24 Hz
- $M2 \sim 1.8 - 2.2$  (vs tuning)

- Establish the ILC final focus method with same optics and comparable beamline tolerances
- ATF2 Goal :  $37 \text{ nm} \rightarrow \text{ILC } 6 \text{ nm}$ 
  - Achieved  $41 \text{ nm}$  (2016)
  - obtained a good repeatability





# IPBSM status and plans

We are systematically reaching measurements in 174deg. mode. (8 deg. and 30 deg. allow a fast and reliable tuning of the ATF FF beamline to focus the beam down to sub-100nm vertical size).

## Improvements since 2020

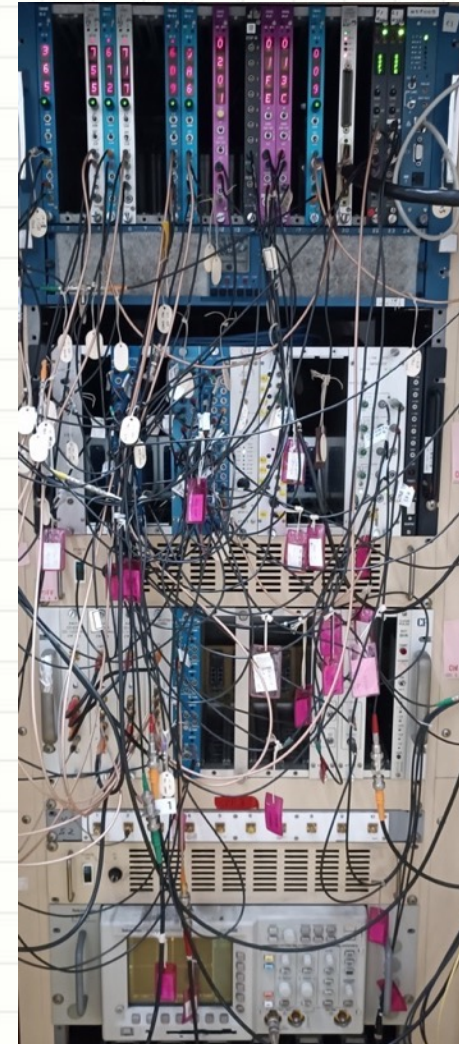
- Laser table support and enclosure
  - Rebuilt (better temp.- & vibro- insulation)
- Laser transport line:
  - Total rebuilt (fixed mirror holders, solid frame)
  - Expansion/reduction factors were optimized
- Vertical table
  - Mirror support was partially rebuilt
  - Solid laser beam references
  - New alignment protocol (back-reflectors)
  - Laser position sensors
  - Laser profile CCD camera
- Laser Mode stability:
  - Laser tuning and thermal stabilization is improved.
- Fringe stability:
  - Improved via laser beam jitter reduction

## New laser system in 2025

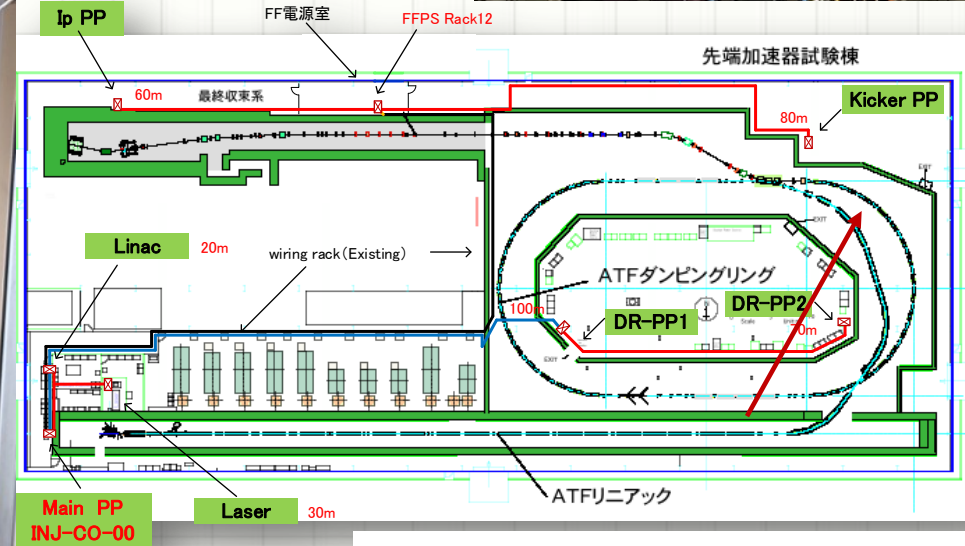
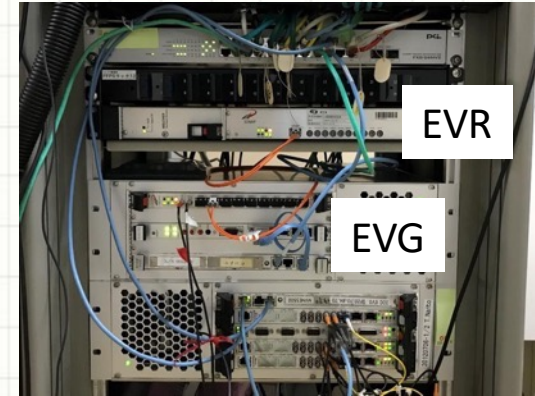
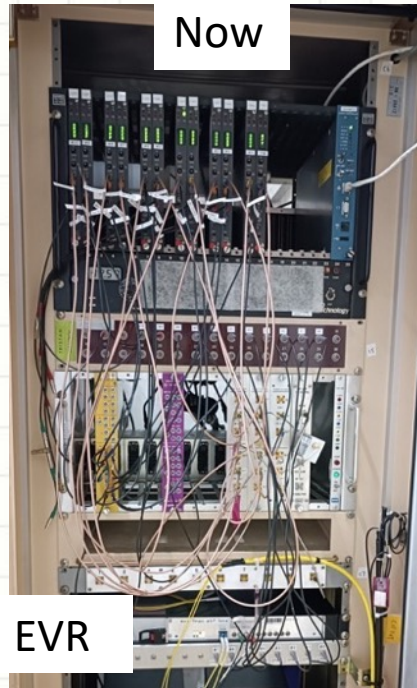
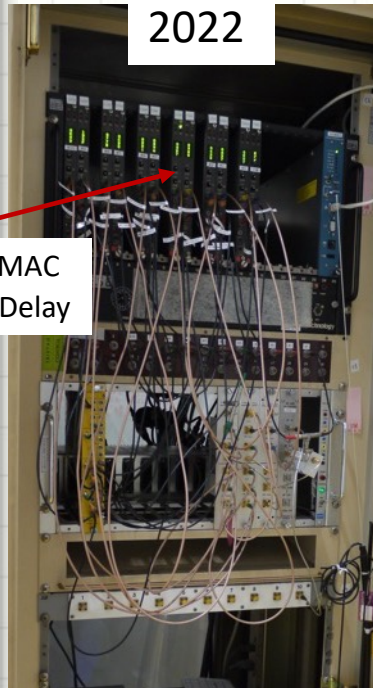
- The following laser type and laser beam parameters were considered:
  - Nd:YAG Q-switched laser
  - Pulse energy  $\sim 400\text{mJ}$
  - Energy per pulse stability  $< 2\%$  rms
  - $M2 < 2$
  - Relatively long coherence length
- 3 Companies is now contacted
- Short list for bidding will be prepared by fall 2024
- Official bidding by the end of 2024
- Order placement end of JFY 2024
- Delivery of the new system by fall 2025

# ATF Timing system upgrade motivation

- Timing system provides:
  - Precise Synchronization between accelerator subsystems.
  - Triggers and Gates for DAQ.
  - Triggers for diagnostic systems.
  - Inhibit and Interlock signals.
- It is linked with LLRF system which includes:
  - RF generation/distribution for:
    - Accelerator cavities.
    - Digital delays.
    - Feedbacks
    - etc
- Outdated key CAMAC and NIM components.
- Low precision.
- Short range of Digital Delay.
- Complexity of the system:
  - Distribution of Initial Trigger and RF clocks.
  - Sensitivity for electrical noise.
  - Legacy wiring/modules.
  - Constant maintenance.
- Since 2021 in a collaboration with KEKB we started a study on EVENT-based Timing system.



# ATF timing system upgrade



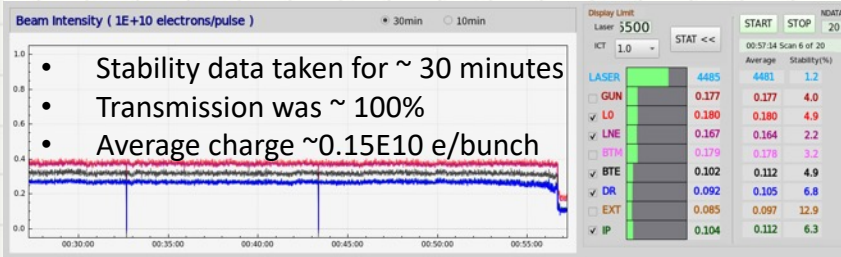
Timing fiber distribution upgrade in 2023

- After successful tests in the fall of 2021:
  - 12-core fiber cable was installed between ATF master timing and ATF FF local timing hut.
  - Event Generator connected to ATF master timing.
  - Event Receiver was installed to control ATF FF timing.
- 2022 operation shows better stability and higher precision of the new system.
- **2023/2024 all key ATF subsystems were switched to Event timing.**

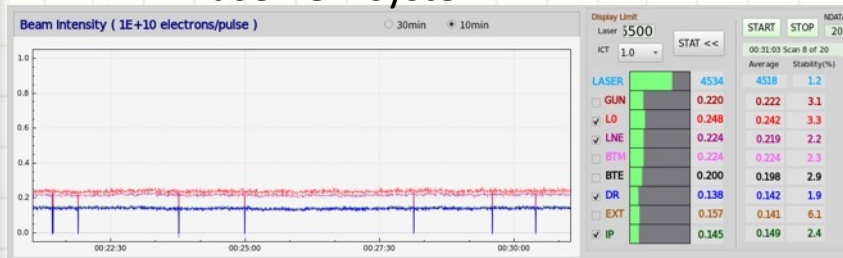


# ATF timing status and plans

April 2023, only FF uses new timing system



March 2024, RF Gun laser, Linac, FF, IP use new system



Peak-to-Peak data below shows about 2 times improvement!

e- charge at:	2023	2024
Linac End	~0.01	~0.005
IP	~0.01	~0.005

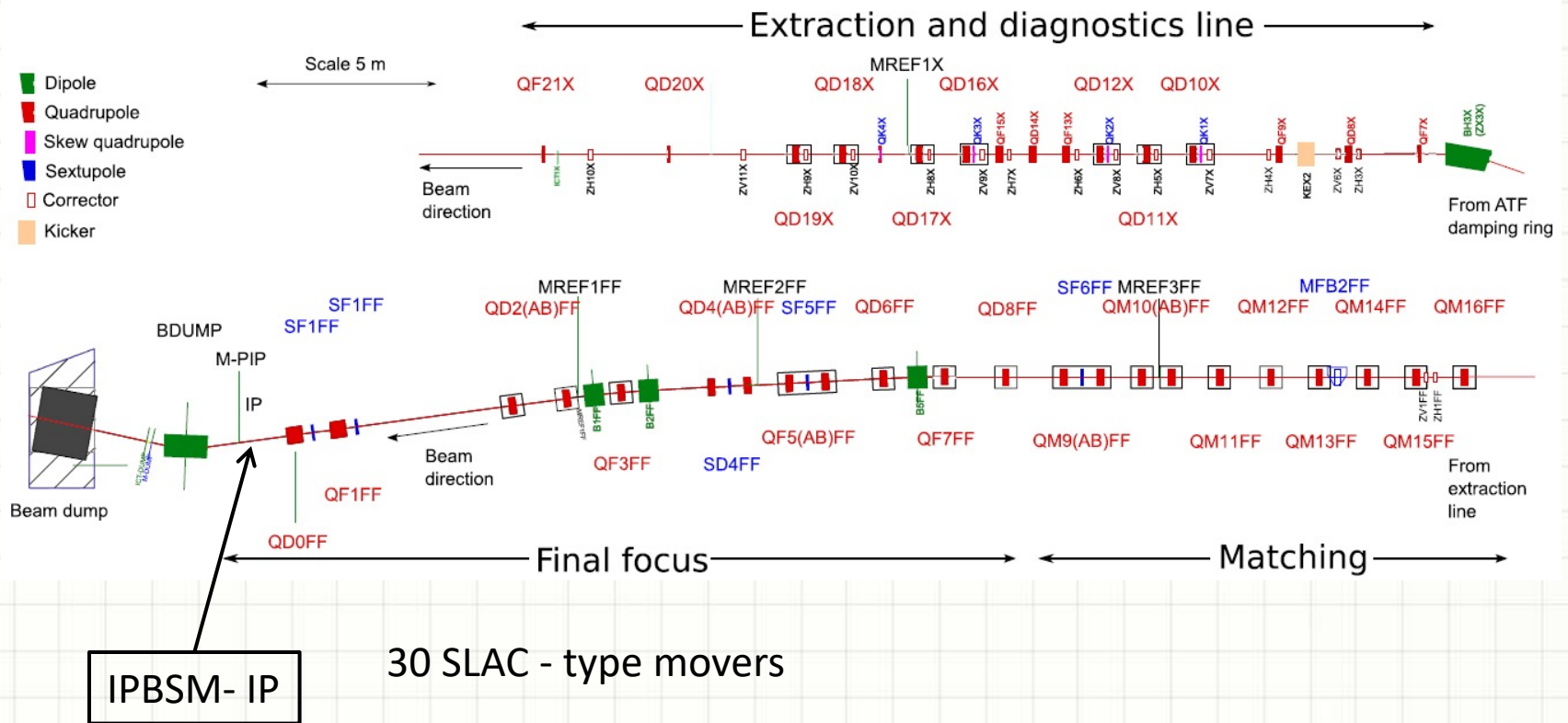
- All major subsystems and beam diagnostics apparatus already switched to a new timing system.
- Operation with electron beam confirms stability improvements.
- 2-train mode operation is established and confirmed
- “Bucket selection” for 2-train operation mode is also confirmed.
- **There are still a few improvements to make:**
  - 3-train operation mode.
  - Complete ATF system switching.
  - Removing old RF distribution system (used for timing).



# ATF2 beam line

highlighting the quadrupoles containing cBPMs and IPBSM IP

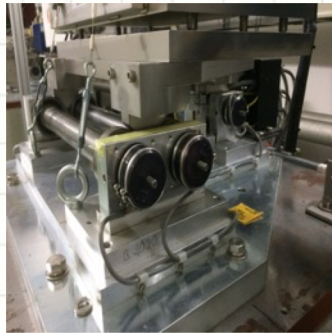
- Dispersion correction
- Orbit correction
- BBA



# Magnet mover system (system is in operation)



Motors.

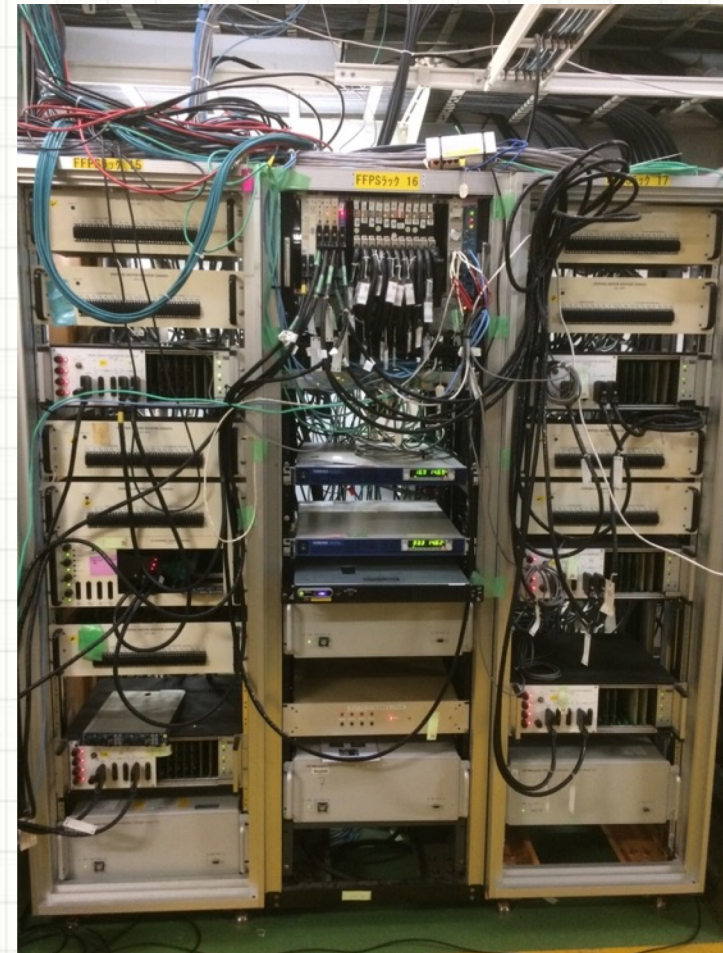


Potentiometers.



LVDTs.

Control racks.

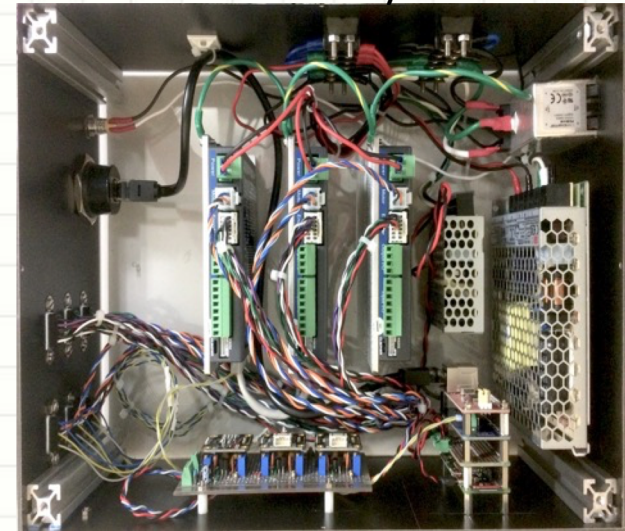


- Problems:
  - Control hardware (motor drivers, ADCs, etc.) is very old, some of it is custom made with no documentation, some of it is not supported anymore.
  - As a result - it is very hard to quickly locate and fix the problem if one occurs.
  - No clear system in hardware organization. Many types of hardware collected over the years.



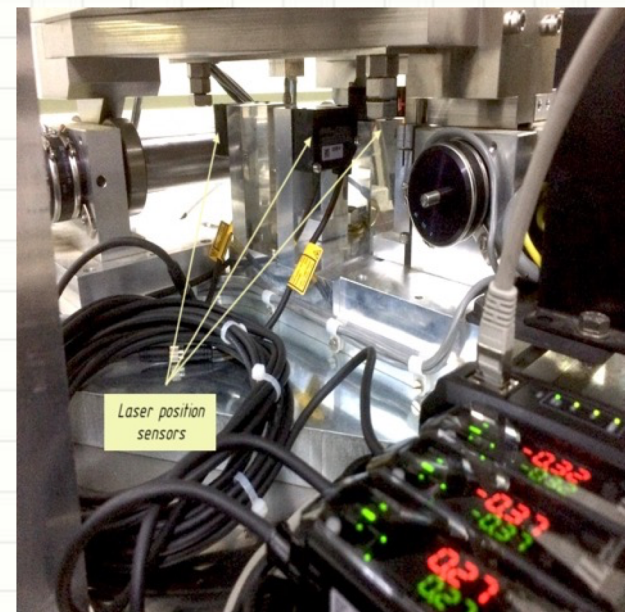
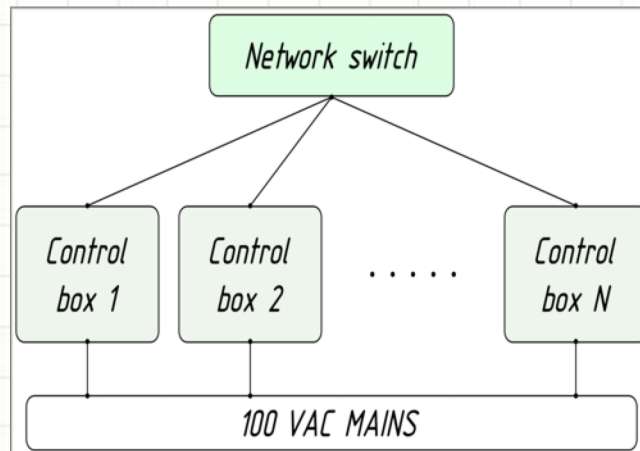
# Magnet mover Upgrade plan

- Fully distributed system with one control box per magnet.
- New control system software architecture allowing easy integration/replacement of new devices.
- Regular calibration and alignment checking.



Control box prototype.

General system concept.



Calibration bracket.

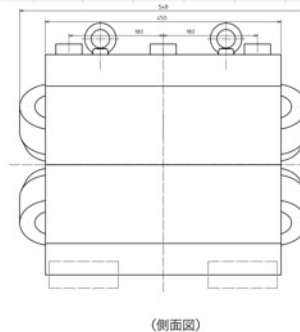
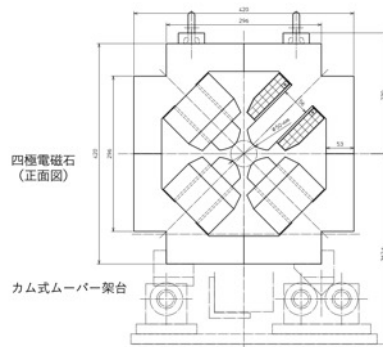
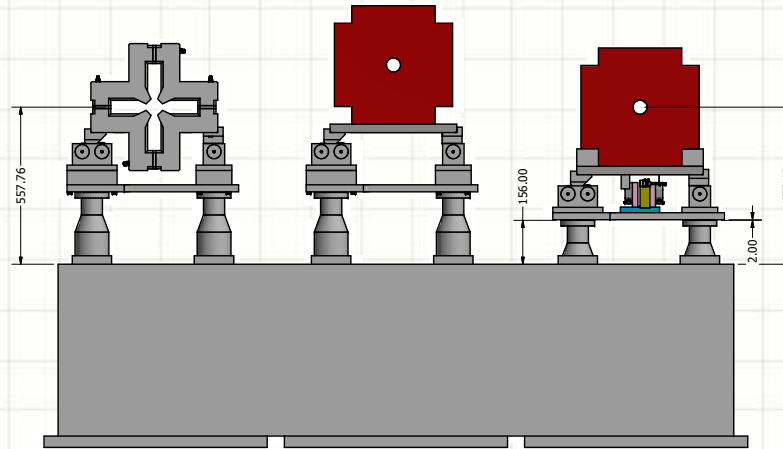
# Magnet mover Summary and plan

- 5 final prototype of the mover control and position readout is made and installed (5 magnet movers).
- Another 25 new mover controllers are now under assembling. These will be installed during 2024 summer shutdown.
- After installation, mechanical calibration and other final tests will be performed.



# ATF FF Q-doublet upgrade

QD0FF  
Installed during  
summer 2023



QF1FF

- Bidding in July 2024
- Delivery in March 2025
- Installation in May 2025

# Summary and other upgrades

All, above mentioned, upgrades are ongoing and already show improvements of the machine stability, beam diagnostics and control.

There are other, very important upgrades :

- **ATF2 wakefield study**
  - Y. Abe, Jul 9, 2024, 11:15 AM
- **ATF LLRF and feedbacks**
  - K.Popov, Jul 9, 2024, 11:30 AM
- **Linac/BT BPM system**
  - Electronics partially replaced to improve signal s/n ratio.
  - Additional calibration will be performed during summer shutdown 2024.
- **Machine Learning studies**
  - M.Kurata, Jul 10, 2024, 10:00 AM