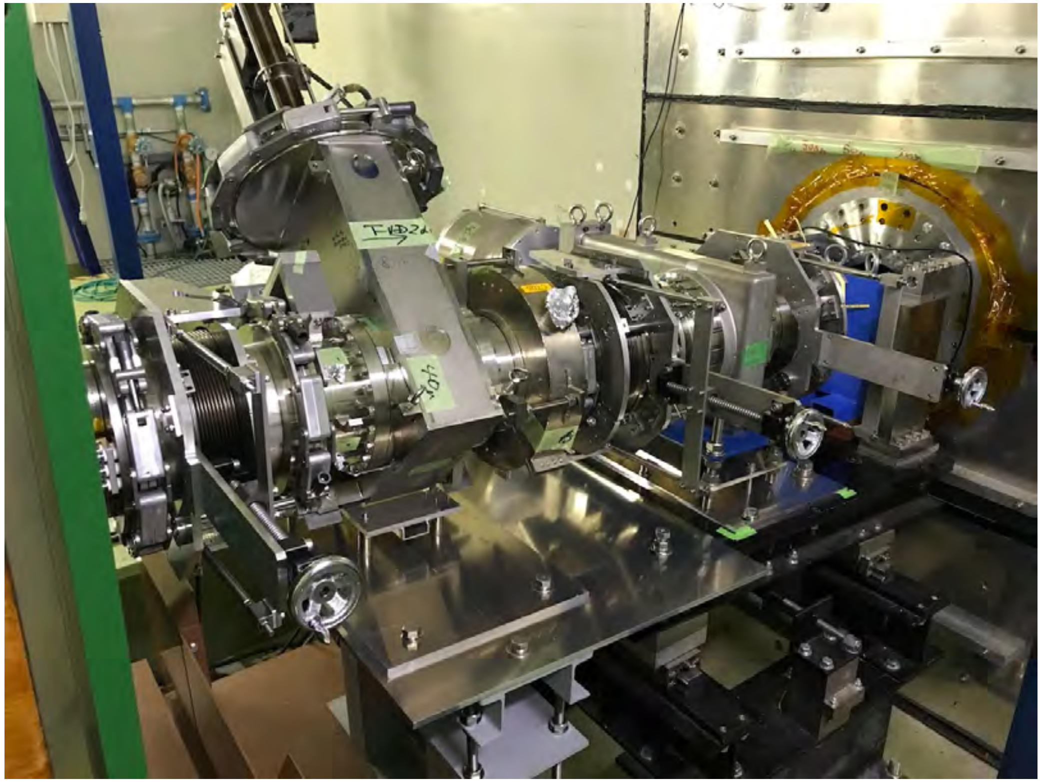
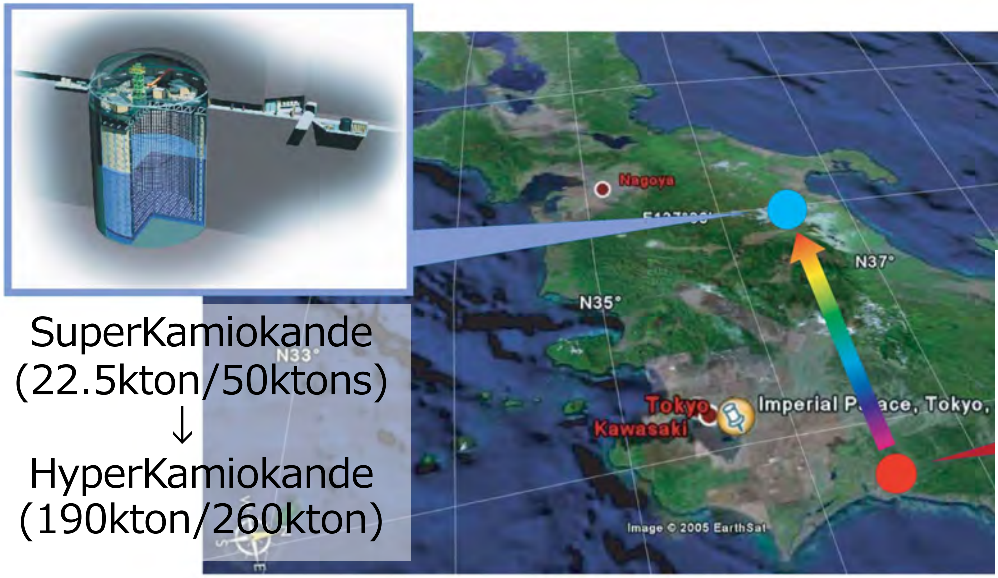
Maintenance Scenario at most-downstream FF in Hyper-K era
(J-PARC, Neutrino Experiment Facility)

NBI2022 at Abingdon

Yoshiaki Fujii, J-PARC/KEK

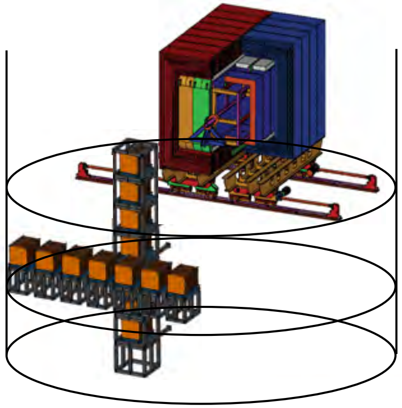


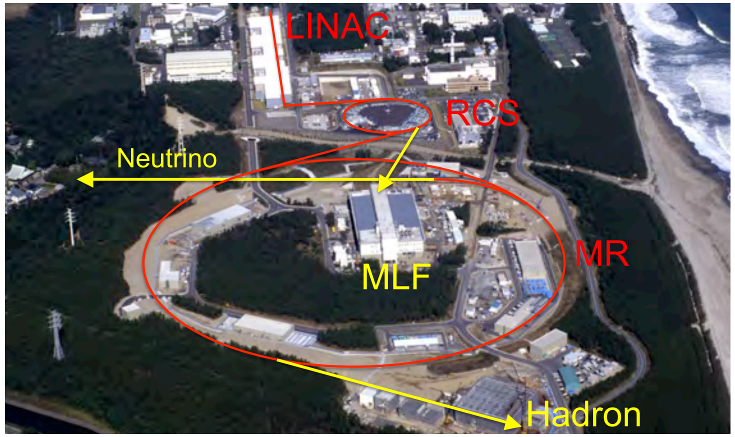
Neutrino Experiment Facility and T2K



SuperKamiokande
(22.5kton/50ktons)
↓
HyperKamiokande
(190kton/260kton)

J-PARC/NeutrinoExperimentFacility
Fx operation at 510kW at present.
Upgrade to 1.3MW in progress.





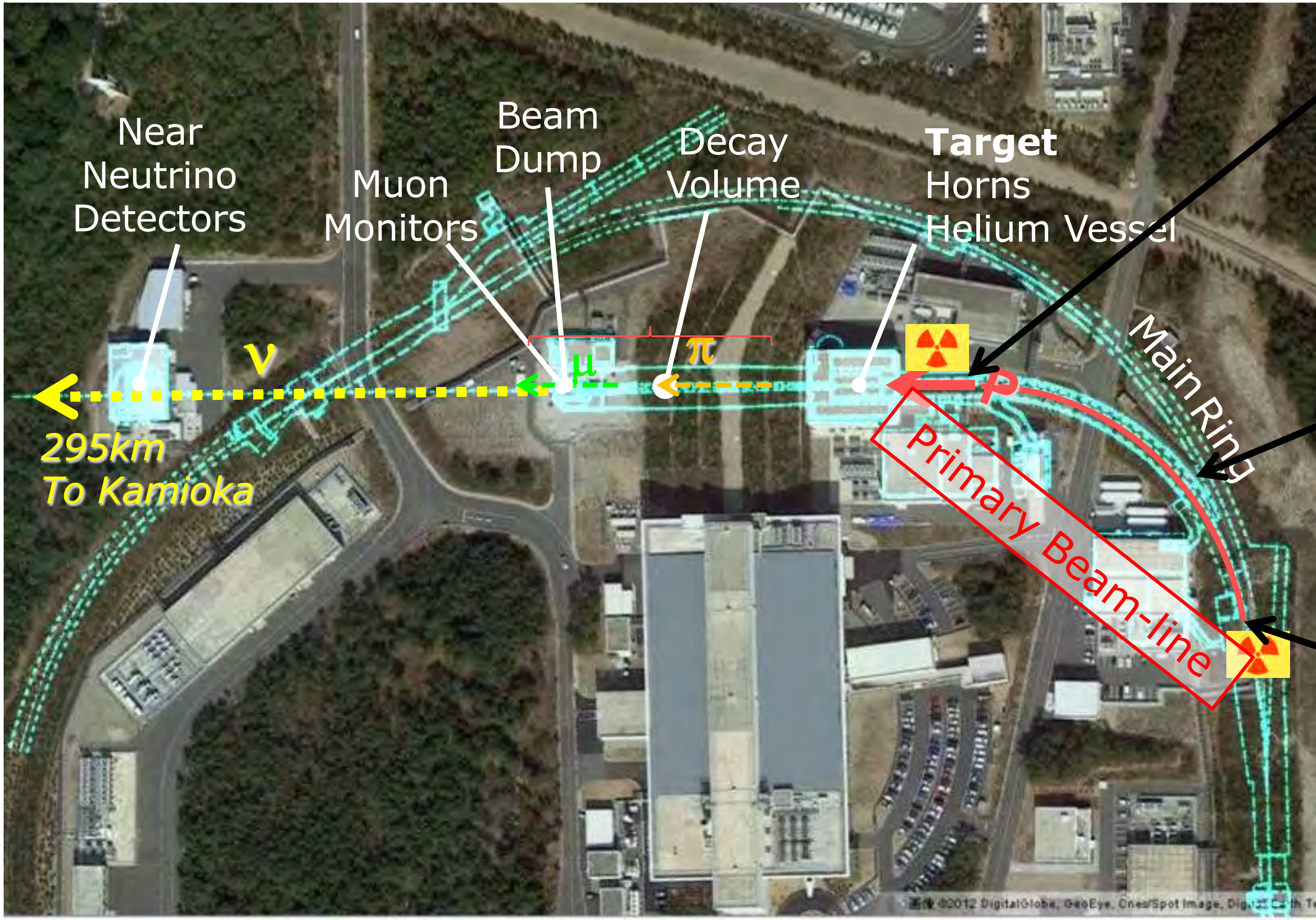
ND280 (off-axis) and INGRID (on-axis)
Measures neutrino just after generation.

T2K Experiment
- High-intensity muon neutrino beam is generated at J-PARC, Tokai, and directed to the SuperKamiokande, 295km away to the west.
- Detect twice with ND280 and with SuperK, and measure changes.
- Precision measurement of neutrino mixing parameters, and search for CP violation in neutrino oscillation.
- Neutrino-antineutrino difference at 95% confidence level obtained.

Primary Beamline

The purpose of the primary beam line is to deliver protons on the target with proper position, size, and angle accurately, stably and reliably. → Target Protection
Neutrino Beam Quality

Need accurate beam monitor & control
to minimize beam loss and possibility of unintentional beam orbit displacement/beam hit.



Final Focus (FF) : Normal-Conducting Magnets

Most-downstream part (boundary to TS) has very high residual radiation.

ARC section : Super-Conducting Magnets

Very low beam loss.

Preparation Section : Normal-Conducting Magnets

Fast-Extraction point has considerably high residual radiation.

Things to Discuss

Today's talk is NOT a status report but aiming at a discussion.
We'd like to hear opinions of experienced experts to further examine our designs of full-remote system at the FF of the primary beam line,
- within the constraint of existing infrastructures
- maximally re-using existing beamline devices.

Contents

・Necessity of remote mechanism

・Preset quick and hands-on maintenance

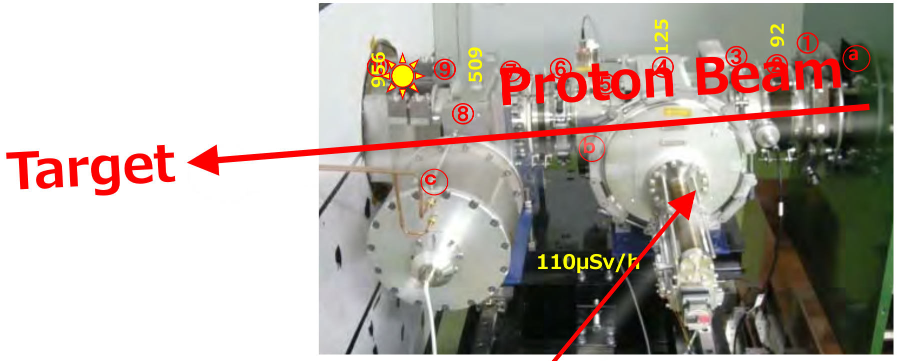
・Several candidates of remote mechanism

Discussions and comments during the talk is welcome.

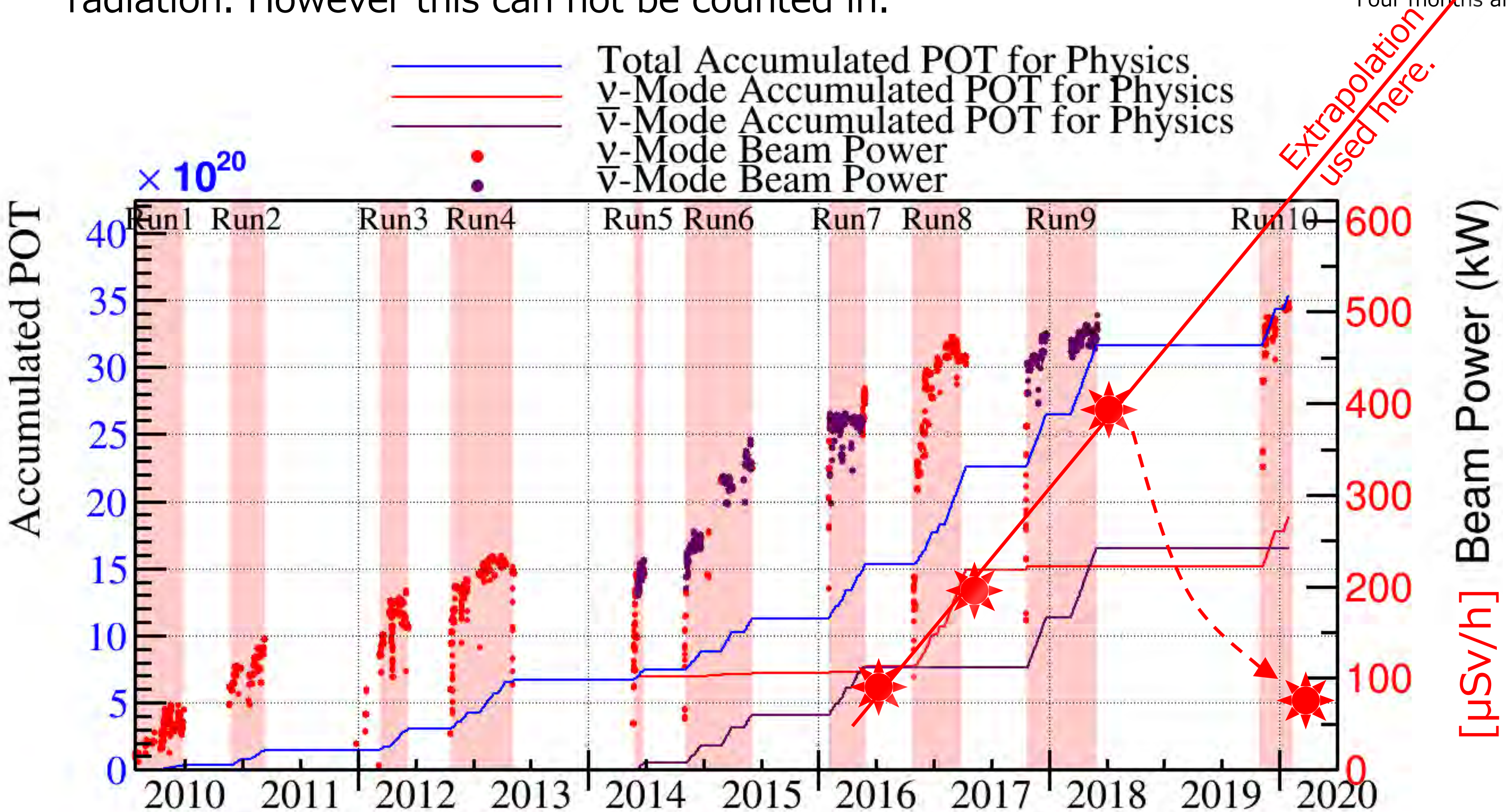
Necessity of remote mechanism

1-foot residual radiation after one-month cooling.

- Residual radiation one month after beam stop is regarded to be basically proportional to the integrated POT until that time.
- Two-years beam-off significantly reduces residual radiation. However this can not be counted in.



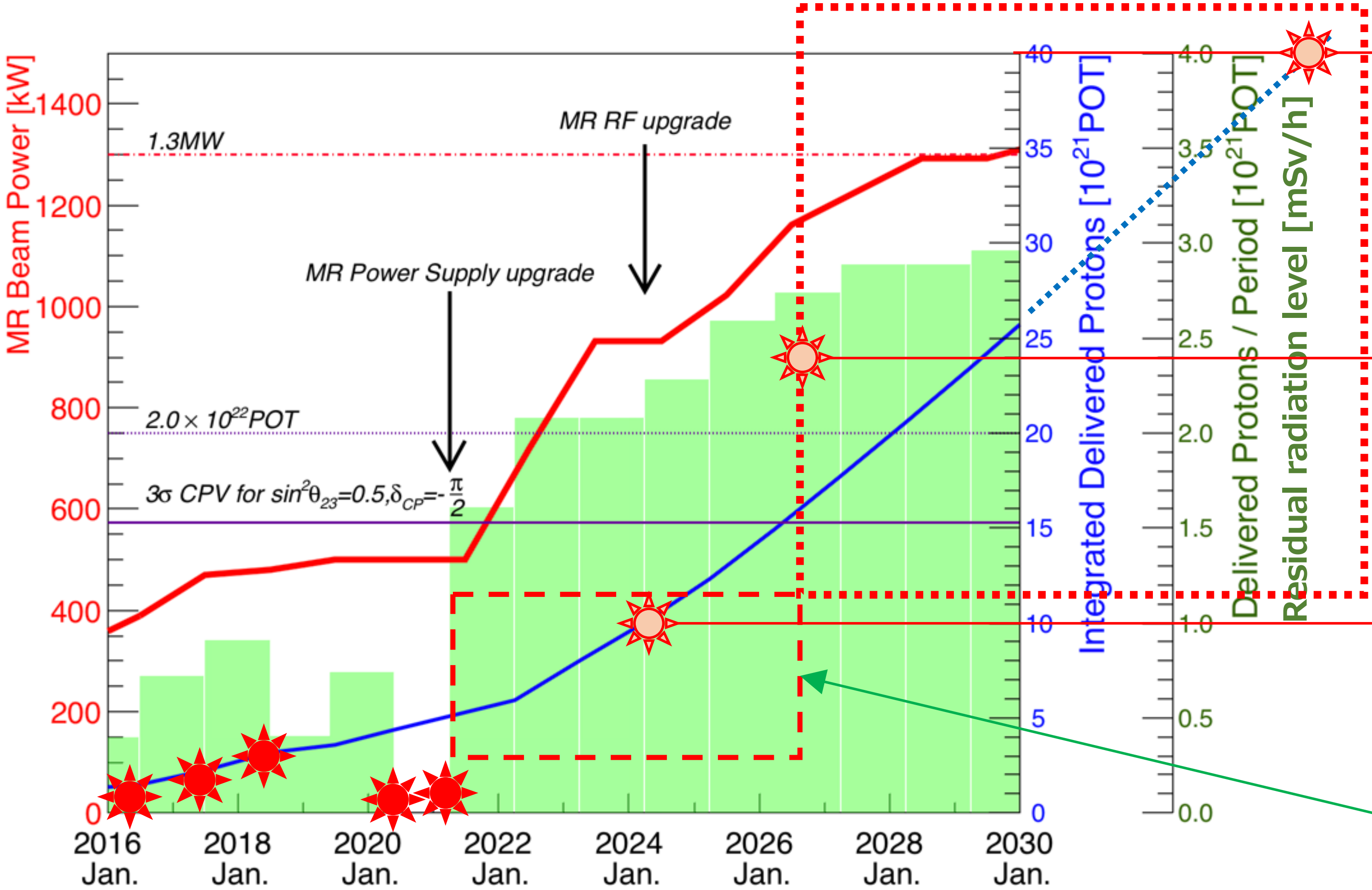
Four months after the beam stop.



Necessity of remote mechanism

Residual radiation extrapolated to HyperK-era
based on the POT-proportional assumption 2020.
No meaningful data point added since then.
Need to implement remote handling before HK starts, namely by 2027.

Neutrino Facility work guideline is 100μSv/day.
→ A few minutes of hands-on work a day.
→ Full-remote be designed for Hypere-K era.



4~5mSv/h@1foot after 1month cooling with 10years Hyper-K running.

T2K-II end
→ 2.4mSv/h @1foot
after one-month cooling
Now merged into HK era.

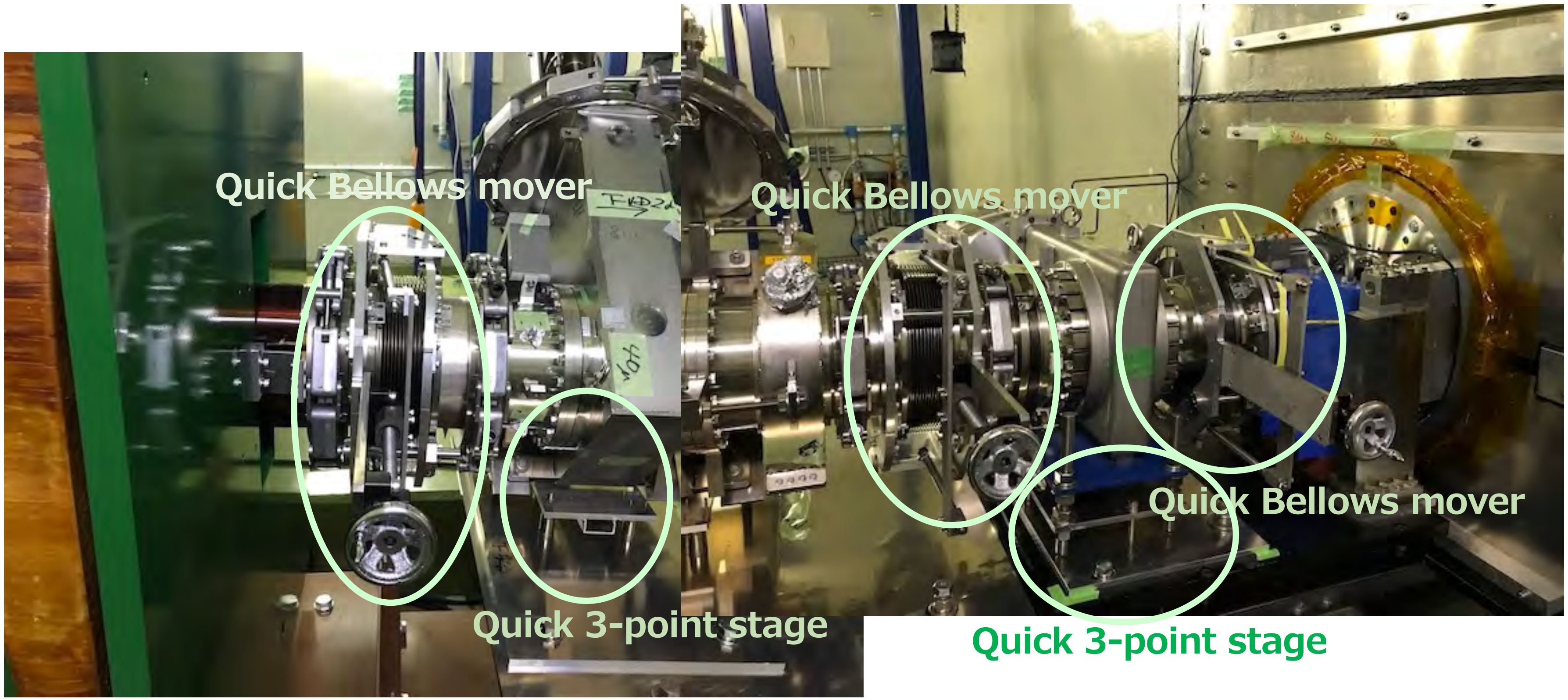
T2K inital goal accumulates 8x10^21POT in total.
→ 1mSv/h@1foot
after 1month cooling.
Hands-on maintenance was the design.

T2K-II era will be managed by quick/hands-on/semi-remote system

Present maintenance scheme : hands-on and quick

The target station of Neutrino Experimental Facility is equipped with a numerically controlled crane, manipulators, remote-handling shield blocks etc. for fully-remote maintenances.

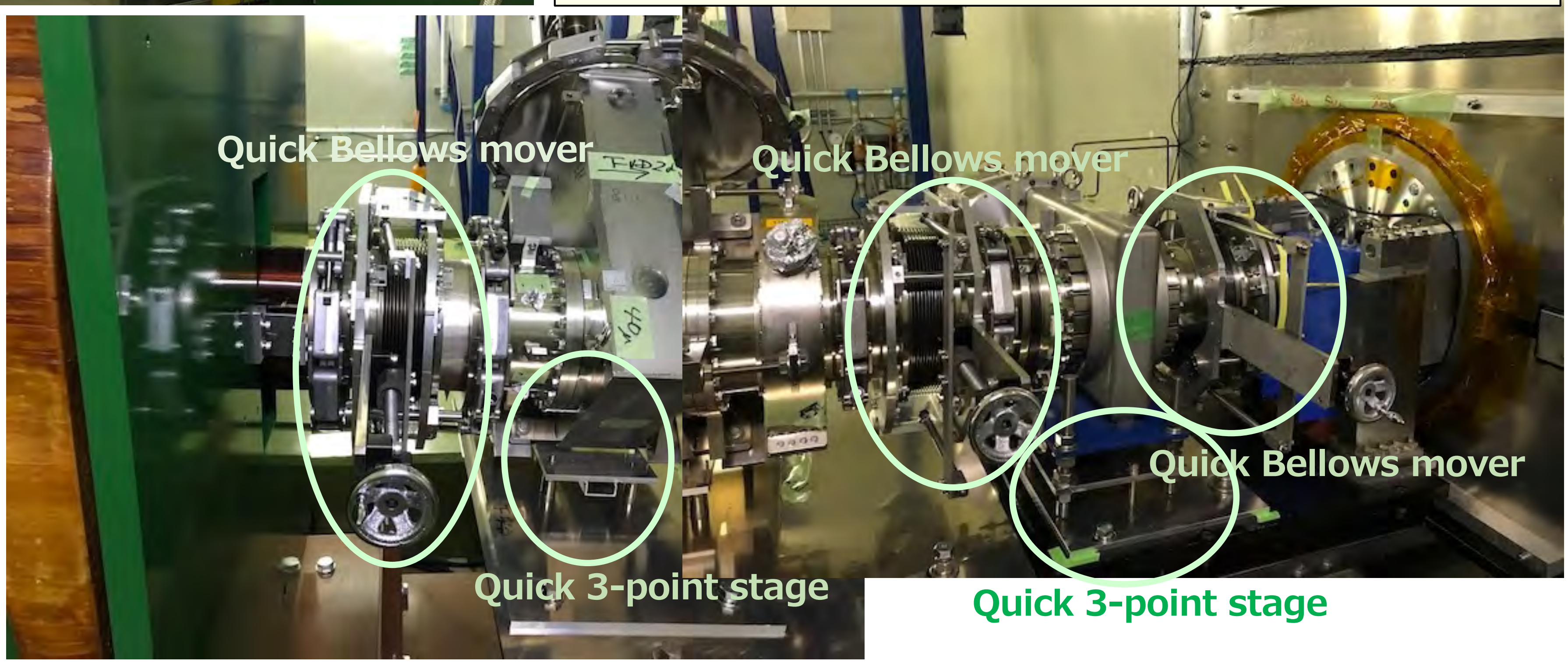
On the other hand, the primary beamline is designed with hands-on quick-handling maintenance since residual radiation level was expected to be not very high within T2K experiment period. Not only present devices but also infrastructures are **not** built to accommodate remote mechanisms used in the target station.



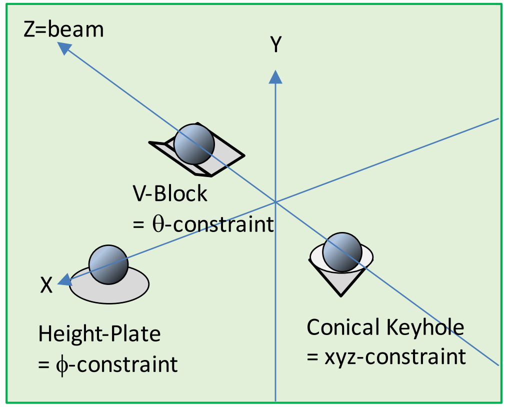
Present maintenance scheme : hands-on and quick

- **Quick 3-point stage** :
  No positioning needed. Just put on the lower-stage.
- **Quick bellow mover** :
  Just rotate a handle. Can be operated from distance.
- **Chain clamp** ; usual quick hands-on chain clamp.
  Semi-remote Garlock RH once installed but turned down.
- **Flange meet** ; male-female self-aligned flanges.
  Needs eye-inspection for parallel-ness confirmation.
- Gaskets ; Helicoflex-δ. Remove/install by hands.
- Manually-controlled electric hoist for line-out/Lin-in.

Monitor line-out/re-installation work in 2018 (110μSv/h@1foot) resulted in exposure of 60μSv/person in total.
→ T2K-II expects 600μSv/person in total → 100μSv/day x 6days.



Present hands-on/quick mechanism



- Quick 3-point stage :
  No positioning needed. Just put on the lower-stage.
  (The lower stage is precisely aligned at the initial installation.)

- Quick bellows mover :
  Just rotate a handle. Can be operated from distance. (Not now.)

- Chain clamp ; usual quick hands-on chain clamp adopted.

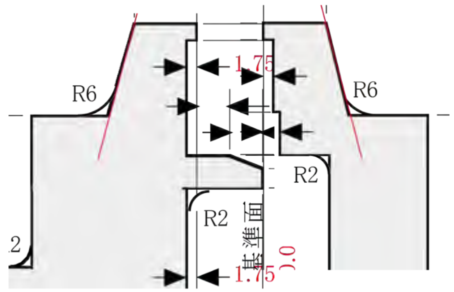
  Semi-remote Garlock RH once installed but turned down.
  - Can operate the screw from distance, in principle.
  - Less screws results in less reliability and ultra-high torque.
  - Stay-On → Bad visibility for flange meet confirmation.
    → More contraction of bellows needed.

- Flange meet ; male-female self-aligned flanges.
  Clearance = 0.2mm
  Needs eye-inspection for parallel-ness confirmation.

- Gaskets ; Helicoflex-δ. Remove/install by hands.

- Manually-controlled electric hoist for line-out/installation.

Hand-on so-far working well.
- Can work for a few hours under present radiation level.



Local Shield and Operation from Distance

We have made local shields with lead-glass window and with simple iron panel, aiming at beamline device maintenance from a bit of distance, hiding behind.

However, local shields are not in use so far.

- time-consuming operation
- bad viewing
- accurate/delicate operation difficult
- thick and heavy by necessity, and thus not easy to find shield placing point

No plan to use it in Hyper-K era either instead of a remote system

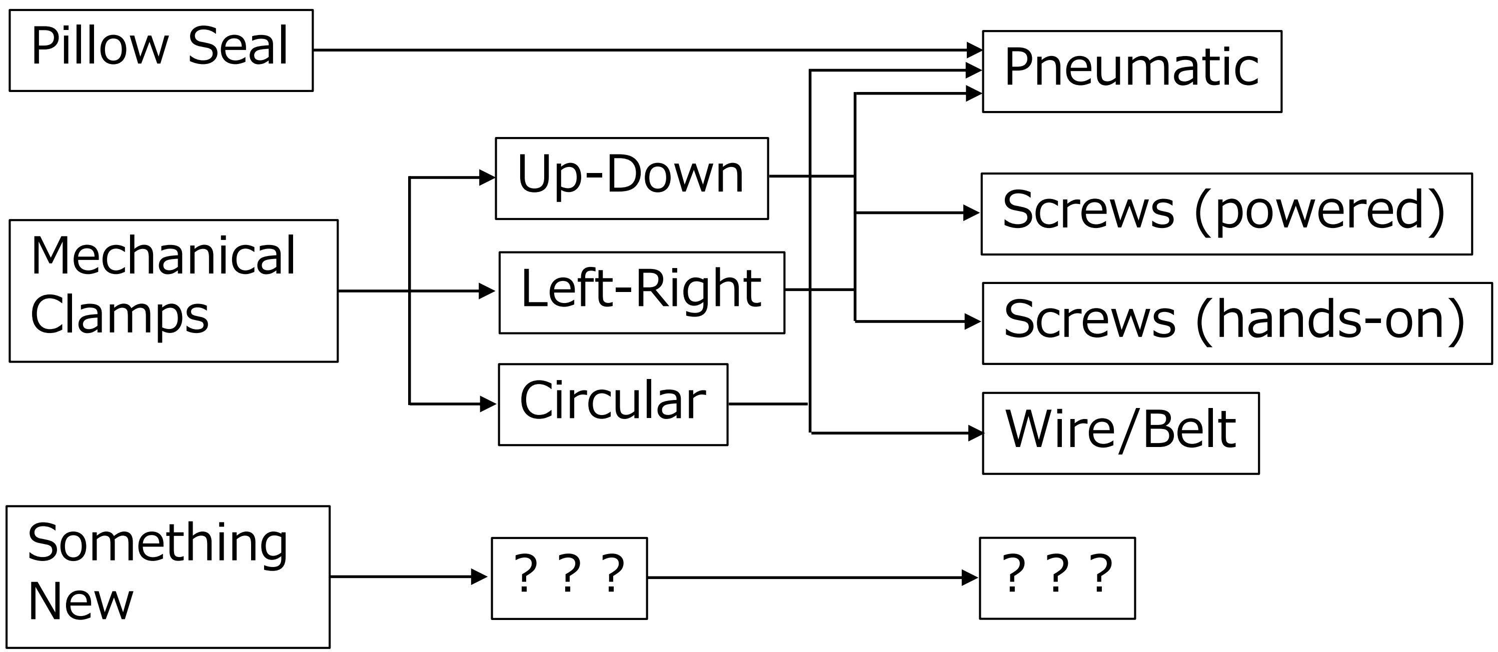
- Suffer defects above. Not a willing choice.
- Could be driven to use it if remote system design unsuccessful.

Remote Mechanism Candidates

In Hyper-K era, we will need remote maintenance scheme. However, we want to avoid full reconstruction of the infrastructure or beamline devices. Therefore we are examining some **compact full-remote system achievable with reasonable modification effort.**

Things to consider for several candidates of remote mechanism

- Line-in/line-out and positioning
- bellows expander/contractor
- male/female flange meet
- **clamp tightening/break-away ; most concern**
- how to replace gaskets
- serviceability
- matured-ness
- cost



Line-in/line-out and positioning

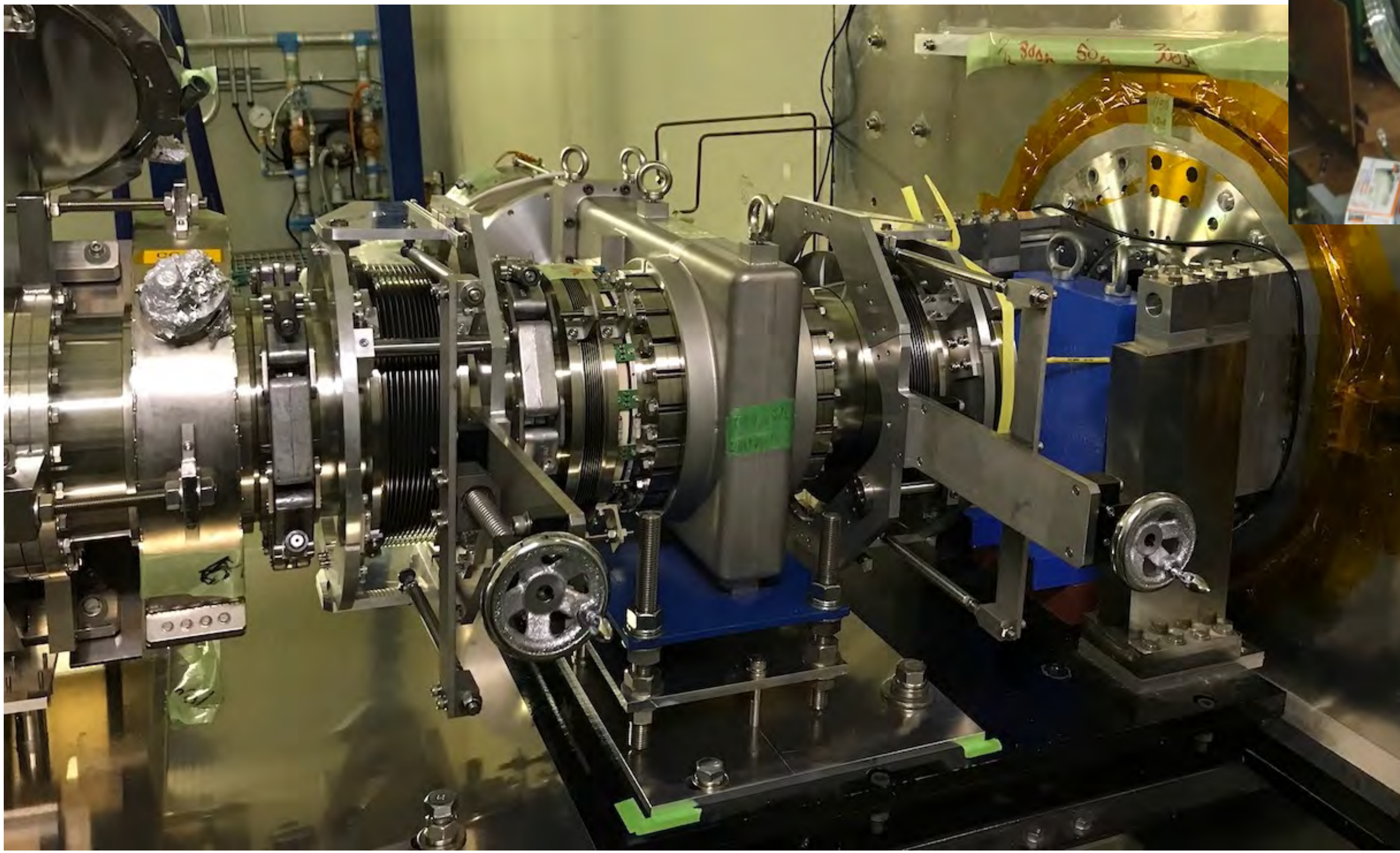
- Vertical precision rails (accuracy better than 100μ for beam monitors) and landing on a 1-point precision stage by gravity, driven by manually-controlled over-head hoist, is one possible solution.

  Vertical guides (~1mm accuracy, less expensive) and landing on 3-point precision stage by gravity, driven by manually-controlled hoist may be another possible solution.

- Numerically-controlled crane as the one in the target station is difficult to implement because ;
  - Cost is very high.
  - Intelligent semiconductor circuits can not stand for radiation at the final focus section during beam operation for years.
    - The TS crane sits in low-radiation area, where we can have access even during the beam operation.
    - Watching cameras at FF is periodically being replaced.
    - Present tunnel cranes have just motors and switches.

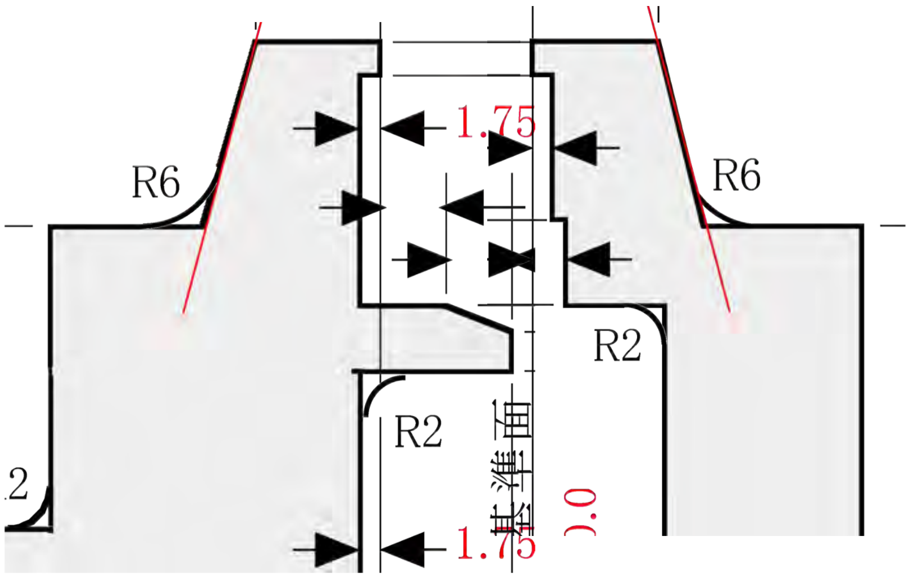
Bellows contractor/expander

- Fairly happy with present movers, operation at 1m from the beamline.
- Screw shaft can be extended to work more distantly, if necessary.
- Want to install also at low-radiation area for quick and easy work, but a bit expensive.



Male/Female flange meet

- So-so happy with present flanges.
- Concentricity is realized.
- Parallel-ness is not achieved sometimes by themselves.
  In those cases, hands-on adjustment needed.
  → Strongly-pushing bellows expander may achieve flange face meeting flatly.
  Or such brute force should not be done.
  Needs a bit more examination.



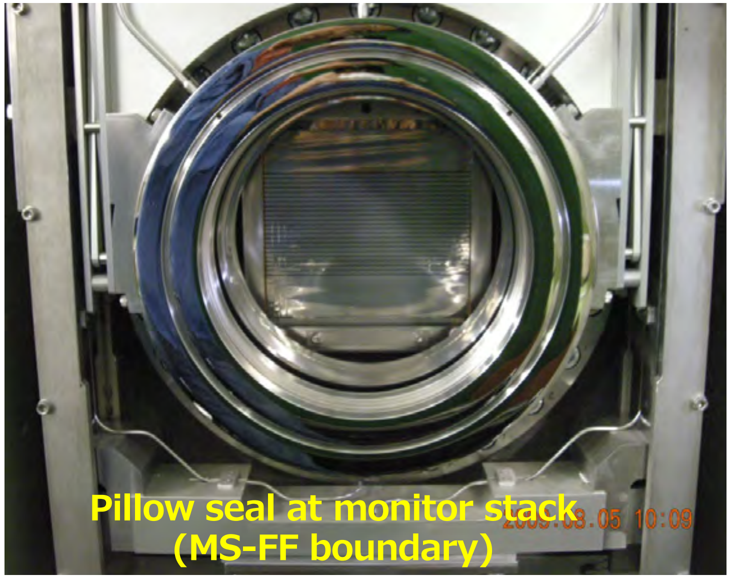
Remote mechanism candidates

Pillow seal (being used at TS)

- bellows mover ; naturally realized.
  Stroke is short. Needs line-in/line-out precision rails.
  (Over-head chain blocks only is not adequate.)
- flange meet ; naturally realized.
  Precision on concentricity and parallelness not too severe.
- clamp ; No need.
- how to replace gaskets ; No need.
  Replace all if surface damaged.
- serviceability
  Air-pressure be always applied and monitored.
  (Dry nitrogen cylinder array in use.)
- matured-ness ; in operation here and there.

Additional issue
- Needs rigid structure to stand for air-pressure of tons.
- Not suitable for very-high vacuum.
- Very Expensive.

This is one solution, and should work well.
Not a preferred option since present beamline components (beam monitors, gate valves, ceramic breaks) can not stand for the air pressure, and **total rebuild needed.**


Pillow seal at monitor stack
(MS-FF boundary)

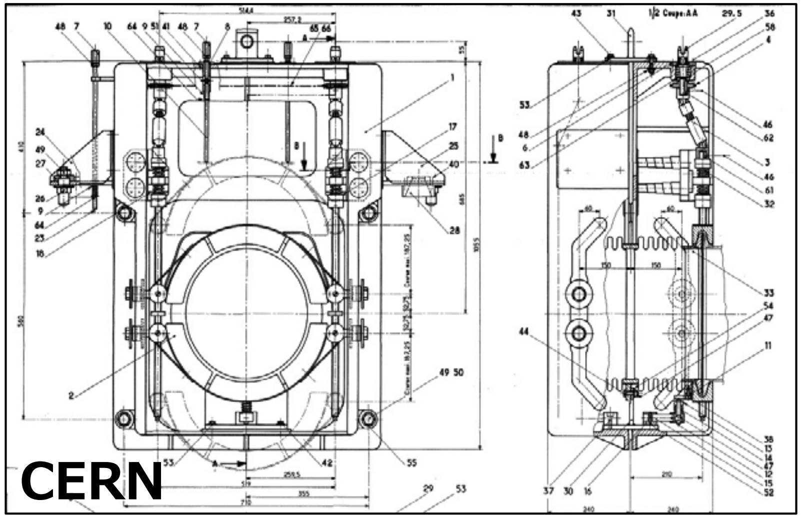

Pillow seal and beam window
(TS-MS boundary)

Remote mechanism candidates

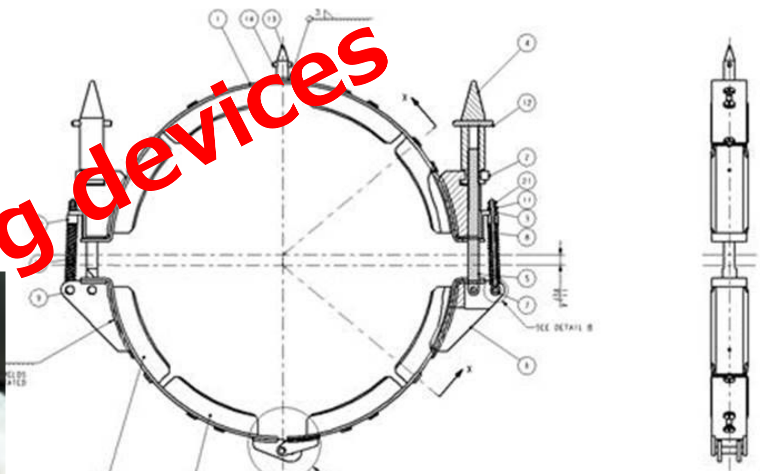
Mechanical Clamp (Vertical screws)

- flange meet ; Bad visibility due to stay-on clamps.
- clamp ; remote operation possible.
  By motors, or by hands from distance above.
  Probably need very high torque.
- how to replace gaskets
  Probably attach it to newly-installed device.
  Bad visibility due to stay-on clamps.
- serviceability ; simple and robust
- matured-ness ; in operation at several places.

Additional issue
- Heavy. Its own support needed.
  → Concentric alignment w.r.t. flange important.
- Thick. Large bellows contraction needed.
  Need to examine available space.
- Expensive.

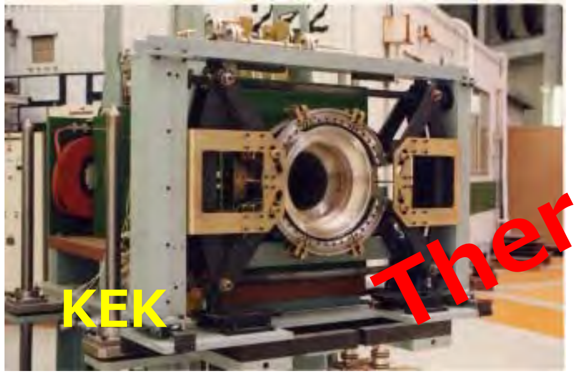


CERN



Rutherford

There are many working devices



KEK

CERN

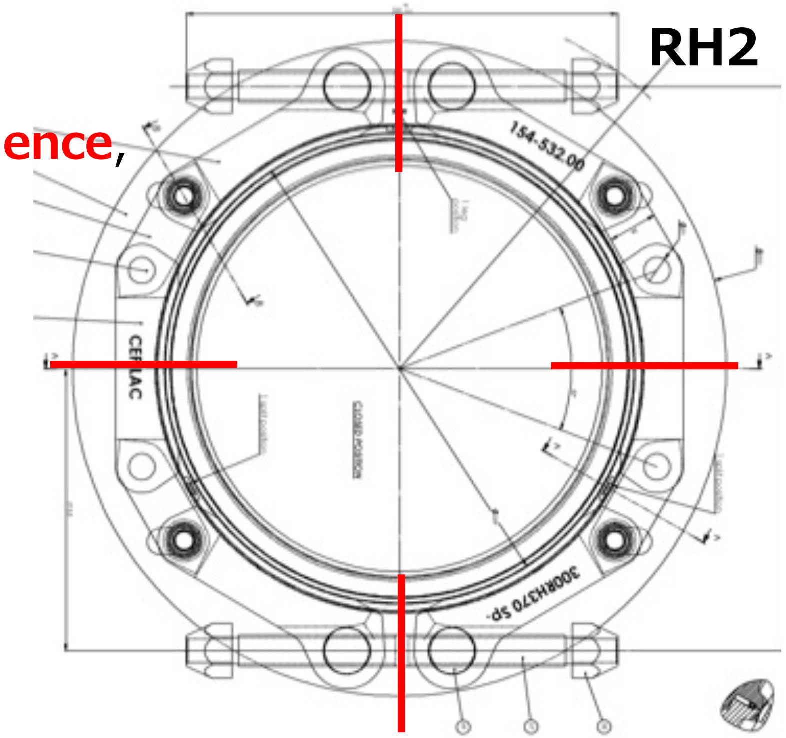
I can hardly convince myself that such big, heavy system is needed just to tighten blocks of the clamp.

Remote mechanism candidates

<u>Mechanical Clamp</u> (Horizontal screws; double or single)

- flange meet ; Bad visibility due to stay-on clamps.
- clamp ; semi-remote
  By hands from distance side-way with a long screwdriver.
  Need very high torque, especially for single-screw ones.
- how to replace gaskets
  Hands-on or attach to newly-installed device.
  Bad visibility due to stay-on clamps.
- serviceability ; simple and robust
- matured-ness ; Small one in operation at J-PARC.

Additional issue
- Thick. Large bellows contraction needed.
  However thinner than full-remote mechanical clamps.
- **Singifivant failure rate** in flange connection, in **MY experience**,
  due to bad visibility on flange meet and gasket fitting
  and lack of coherency and symmetry in block motion.
- Screwing can be done from distance,
  but hands-on care is necessary on flange meet.



What is needed on **RH2** for improvement might be ;
- Hold the side blocks on the center line exactly vertically.
- Hold the screws on the center line exactly horizontally.
- Tighten the two screws synchronously.
  → Should be done by tools, not by the clamp itself.

Remote mechanism candidates

Remote Manipulator

- No delicate action as human fingers.
- Slow.

To remove 1 chain clamp at 5mSv/h [3]
- Robot: 15-30 min (0μS);
- Torque wrench: 3 minutes (250μS);

By Lukasz Krzempek (CERN)

- Extremely expensive.

Could be one solution if radiation level of FF becomes **extremely** higher than present assumption of
- HyperK era results in 4~5mSv/h@1foot after 1month cooling with 10years-running.

Half of on-contact radiation at FF device comes from downstream target station, and half from the activated beamline devices themselves.
→ Line-out itself can not be a total solution.
Hands-on work can not be done on line-outed equipment.
→ No-repair, just throw away OR handle with manipulators.

Remote mechanism ; something new ?

? ? ? ? ? ? ? ?

There should exist more devices in the world. Simply I do not know.
I'd love to have your advices.

Not a closing but a beginning

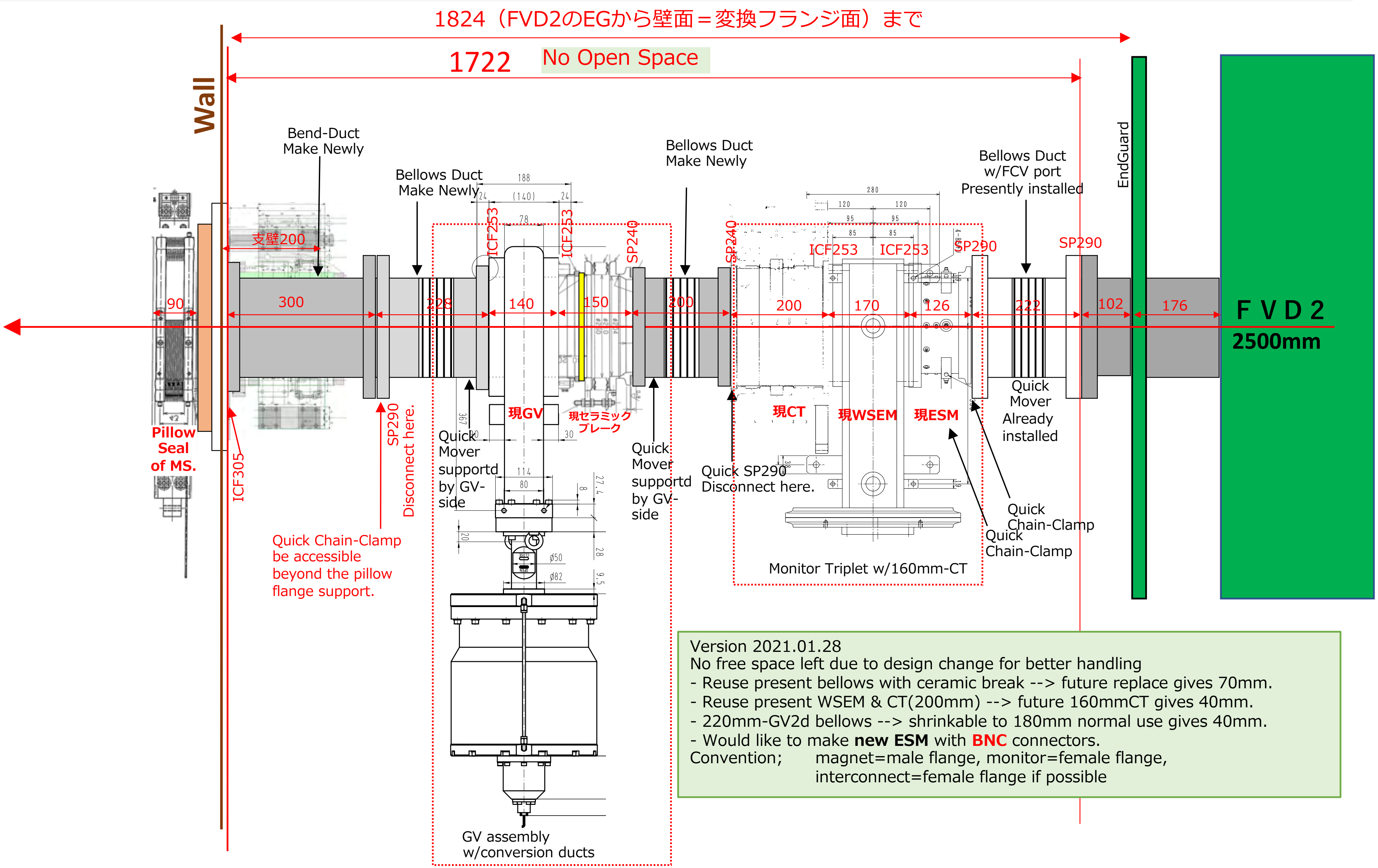
In Hyper-K era, we can not continue present hands-on/quick maintenance scheme.
→ What is the best for the next step ?

Things to keep considering for several candidates of remote mechanism to implement by the start of HyperK experiment;

- ☐ Line-in/line-out and positioning
- ☐ bellows expander/contractor
- ☐ male/female flange meet
- ■ **clamp tightening/break-away ; Most concern at present.**
  Prefers mechanical clamps
  → Personal opinion for now ; improving RH2 would be examined, though I know this is not very smart.
- ■ how to replace gaskets
- ■ serviceability
- ☐ matured-ness
- ☐ cost

Backup

Hand-on Quick Baseline layout (updated) with short FVD2（3m→2.5m）

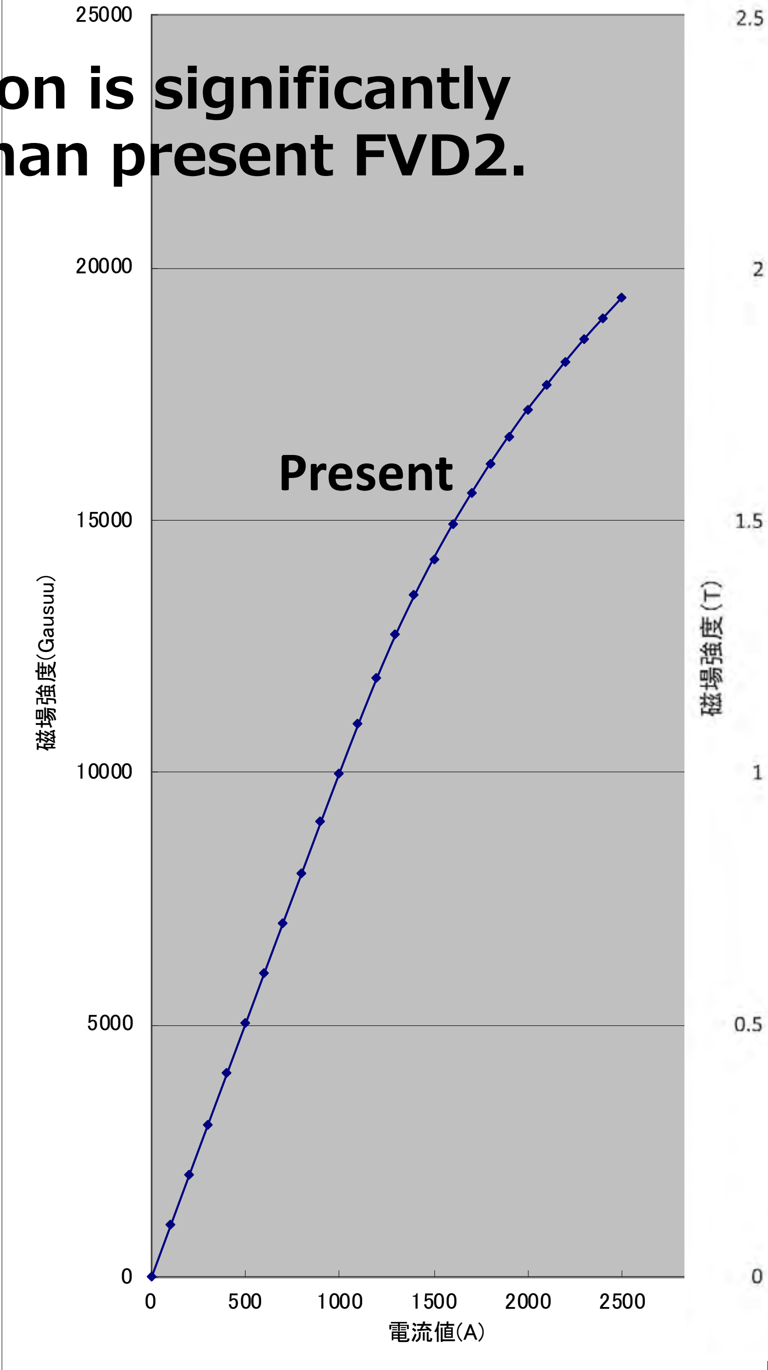


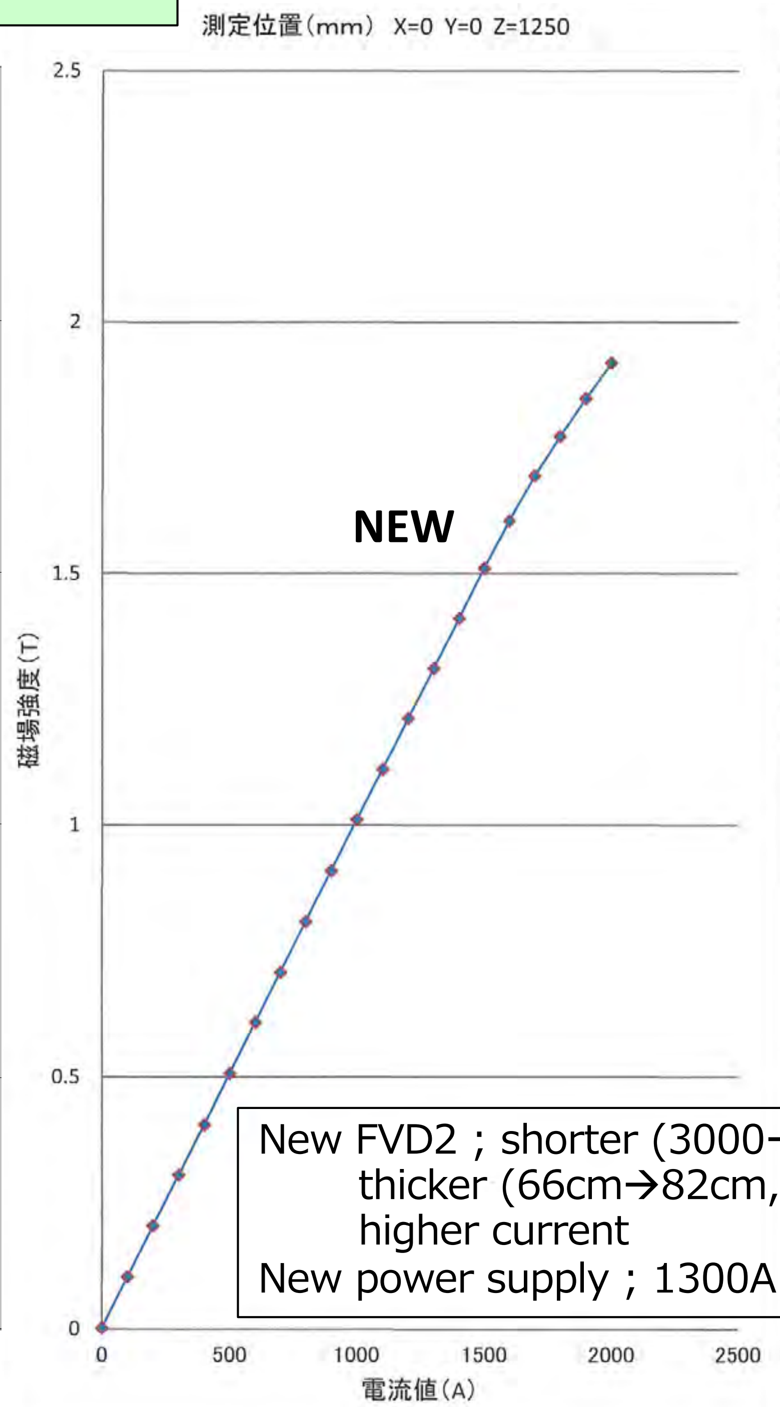
Version 2021.01.28
No free space left due to design change for better handling
- Reuse present bellows with ceramic break --> future replace gives 70mm.
- Reuse present WSEM & CT(200mm) --> future 160mmCT gives 40mm.
- 220mm-GV2d bellows --> shrinkable to 180mm normal use gives 40mm.
- Would like to make **new ESM** with **BNC** connectors.

Convention; magnet=male flange, monitor=female flange, interconnect=female flange if possible

New FVD2 magnetic field measurement

Saturation is significantly better than present FVD2.



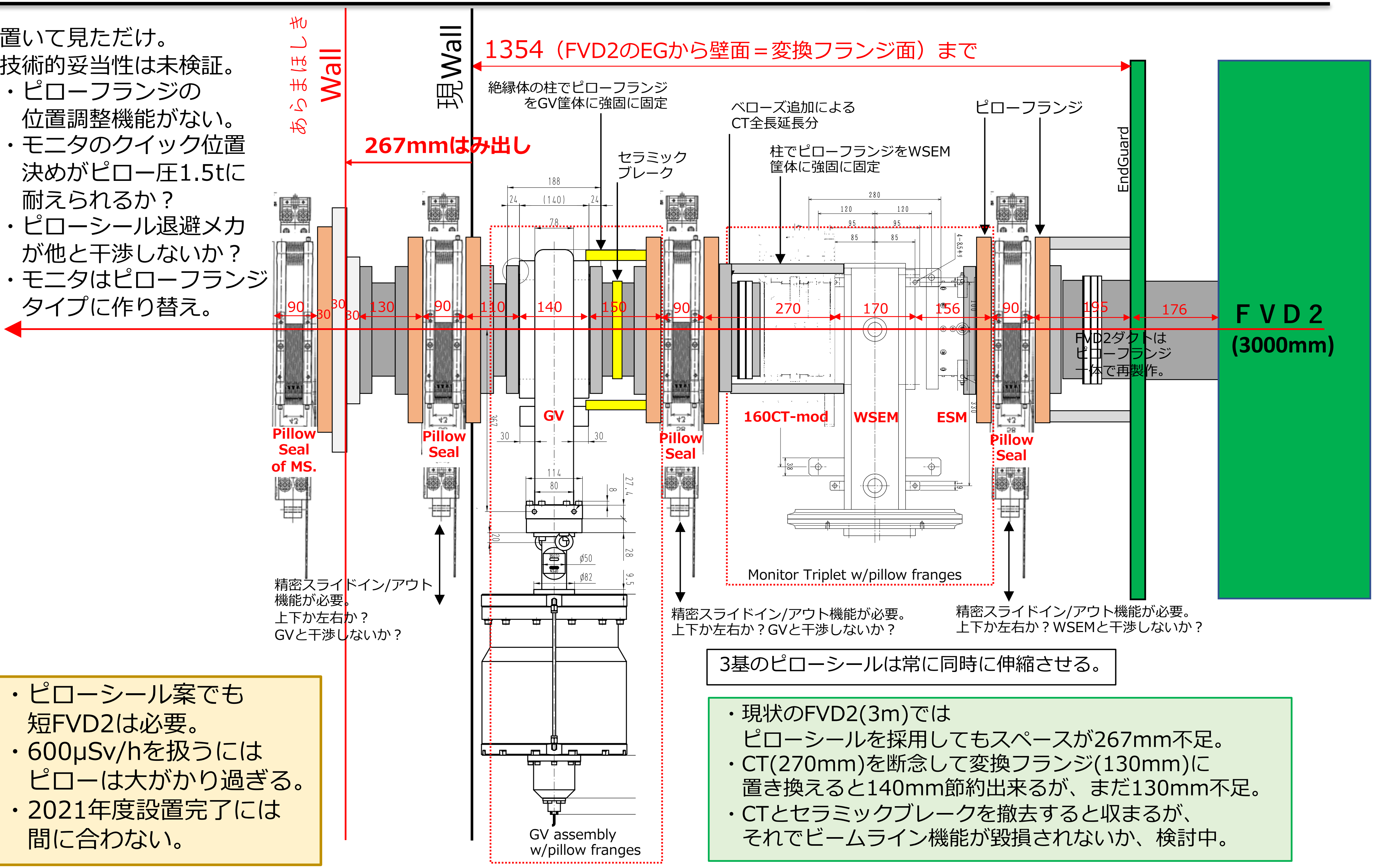


電流[A]	磁場Ty[T]
2000	1.9187
1900	1.8482
1800	1.7731
1700	1.6942
1600	1.6045
1500	1.51
1400	1.4113
1300	1.3119
1200	1.2127
1100	1.1114
1000	1.0113
900	0.9097
800	0.8087
700	0.7081
600	0.6087
500	0.5077
400	0.4059
300	0.3059
200	0.2049
100	0.1041
0	0.0029

New FVD2 ; shorter (3000→2500),
thicker (66cm→82cm, 27.1t→28.8t),
higher current
New power supply ; 1300A max → 2000A max

3. 現FVD2(3m)でピローシールなら実装できるか？

置いて見ただけ。
技術的妥当性は未検証。
・ピローフランジの
　位置調整機能がない。
・モニタのクイック位置
　決めがピロー圧1.5tに
　耐えられるか？
・ピローシール退避メカ
　が他と干渉しないか？
・モニタはピローフランジ
　タイプに作り替え。



3基のピローシールは常に同時に伸縮させる。

・ピローシール案でも
　短FVD2は必要。
・600μSv/hを扱うには
　ピローは大がかり過ぎる。
・2021年度設置完了には
　間に合わない。

・現状のFVD2(3m)では
　ピローシールを採用してもスペースが267mm不足。
・CT(270mm)を断念して変換フランジ(130mm)に
　置き換えると140mm節約出来るが、まだ130mm不足。
・CTとセラミックブレークを撤去すると収まるが、
　それでビームライン機能が毀損されないか、検討中。