# Foreseen Issues because of Uniqueness of ESS

## - What are differences from J-PARC -

## What can we learn from the lesson learnt at J-PARC ?

## MA's view

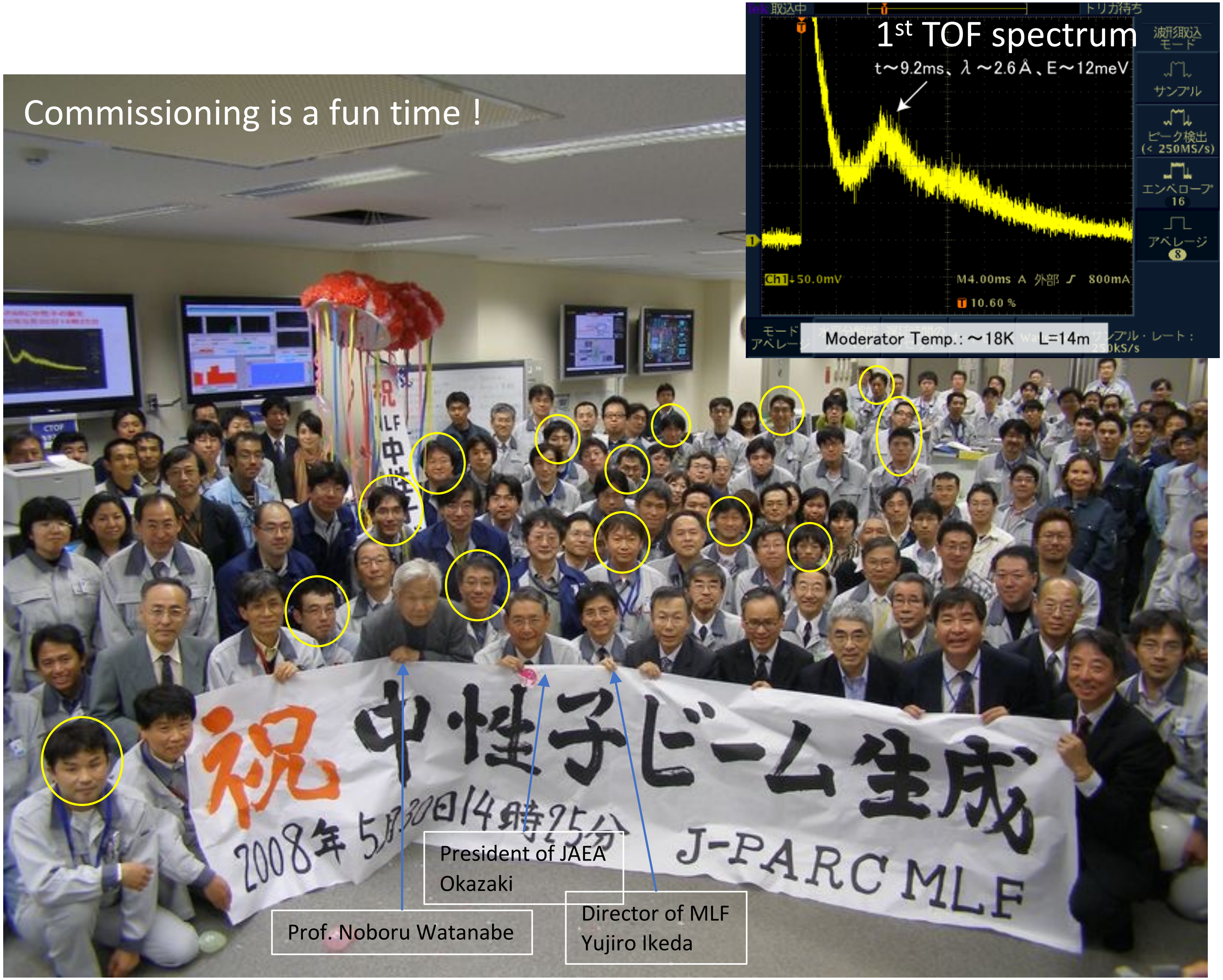
Consider, unique characters of ESS different from other existing spallation sources

ESS's uniquenesses are as following;

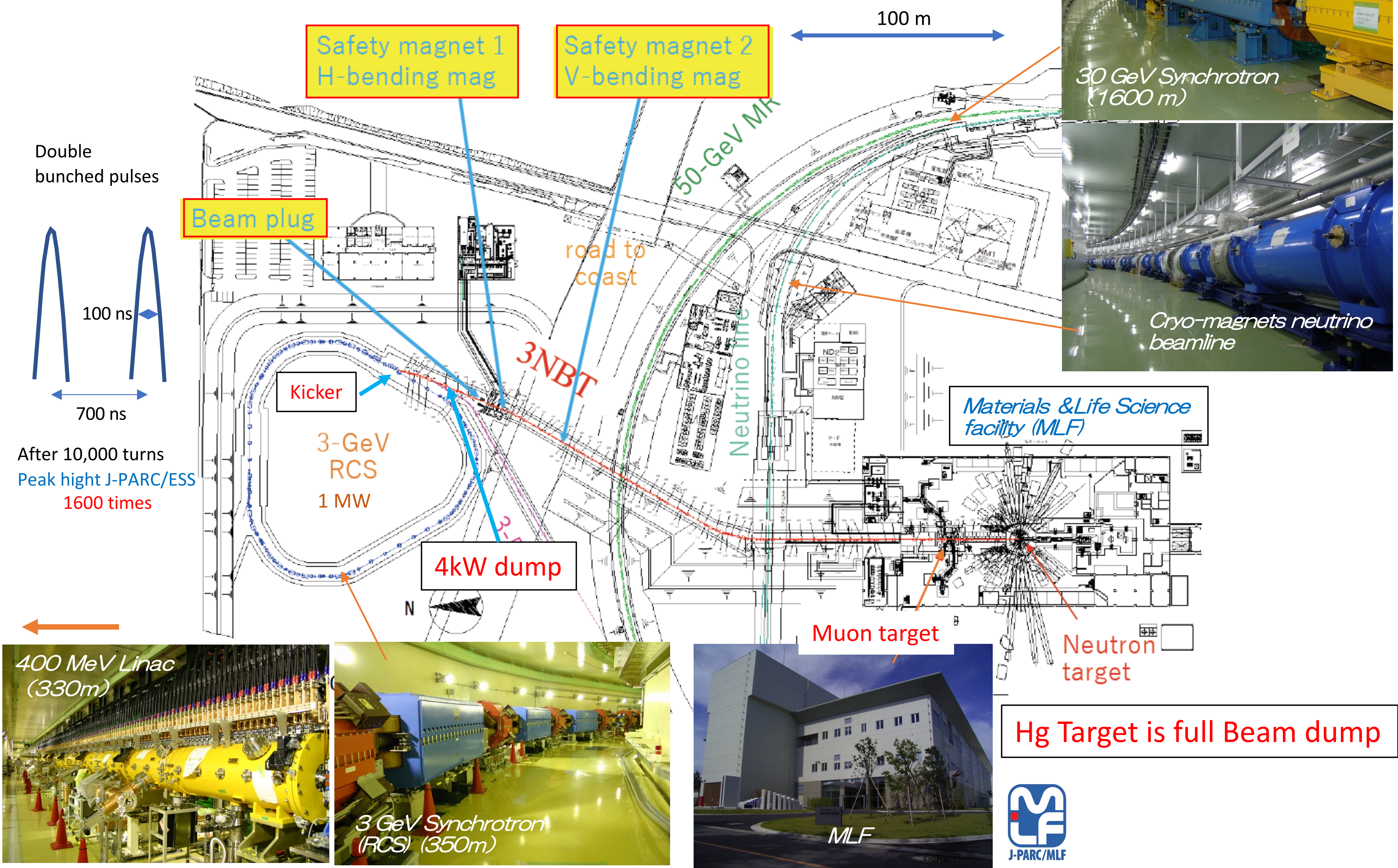
1. 5MW long pulsed source
2. rastering injection from accelerator to target
3. Rotating target, Helium cooling
4. No heavy shutter in the Monolith shield.
5. Thin butterfly moderator.
6. Bunker's big common volume
7. Instrument installation will not be completed.  (but this happens at any sources.)
8. Proton energy ramping-up results in a change of neutron production volume
9. Timing: insensitive to jitter ?

# First Production of Neutrons in 2008 May 30th (1st -BOT).

Presenters from J-PARC

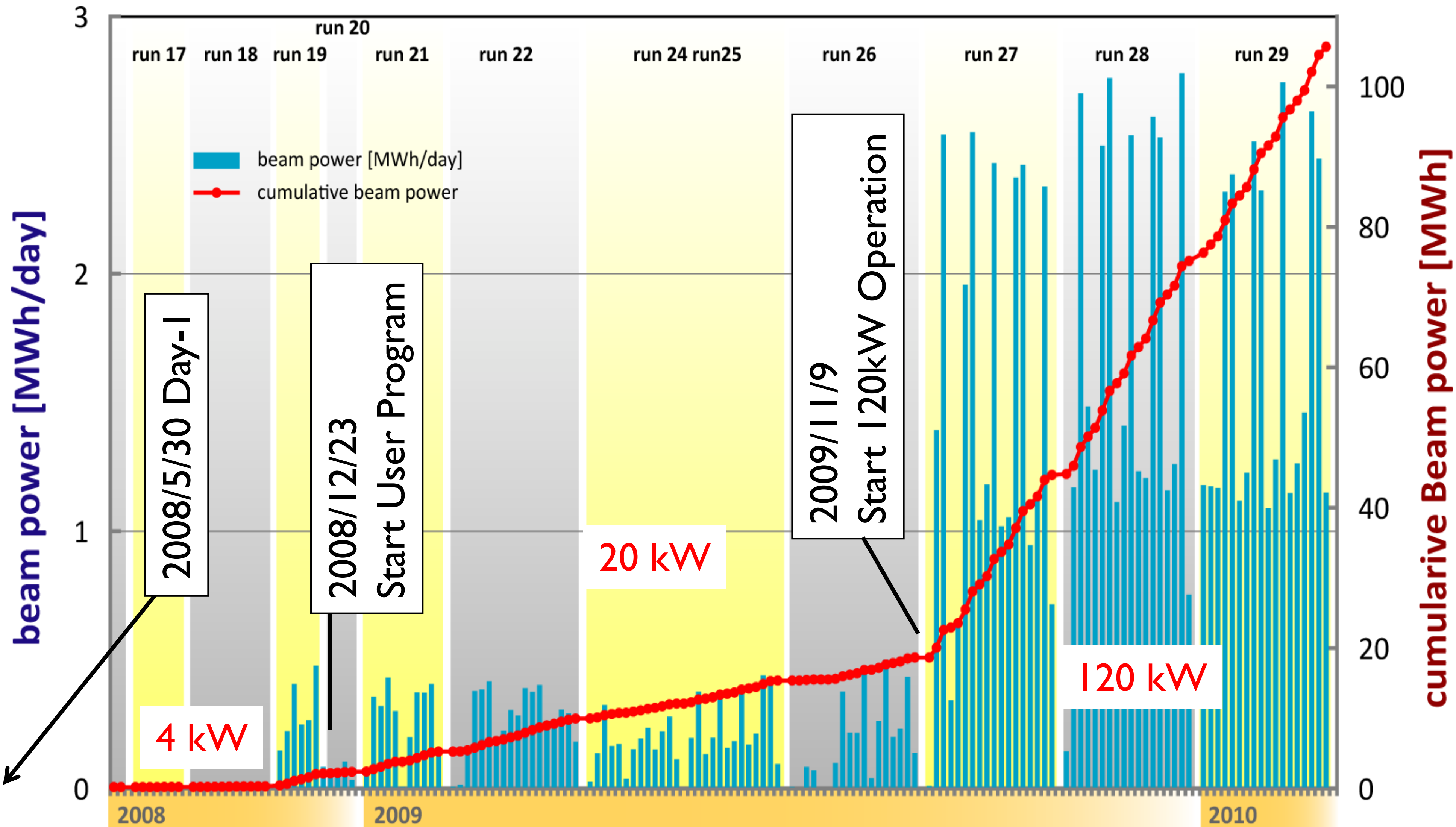


# J-PARC's Accelerator System to Target



# Operation History since Day-1 (May 30, 2008)

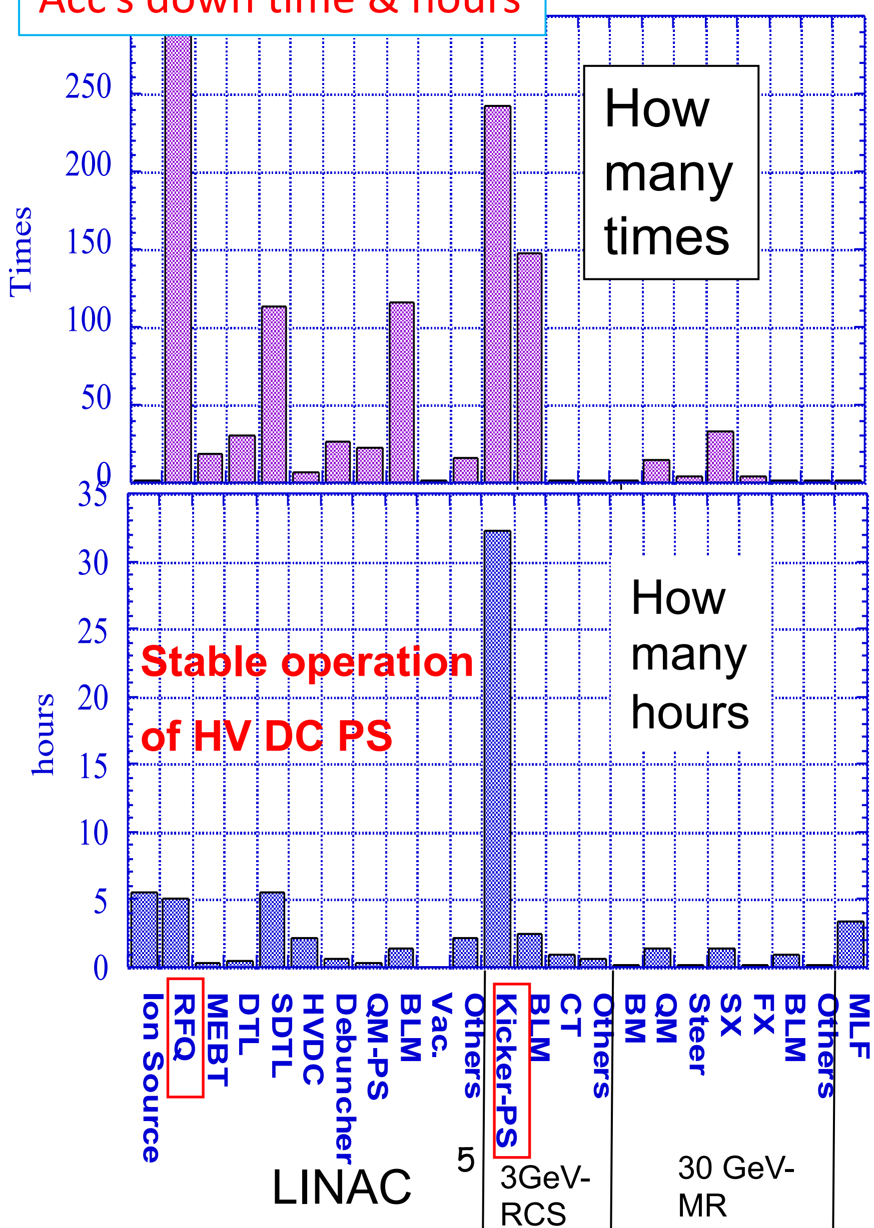
(started with 4kW) , (one-run: 2 weeks)



# Acc. Status in 2009 - 2010, 120 kW , 3Y after $1^{st}$ BOT

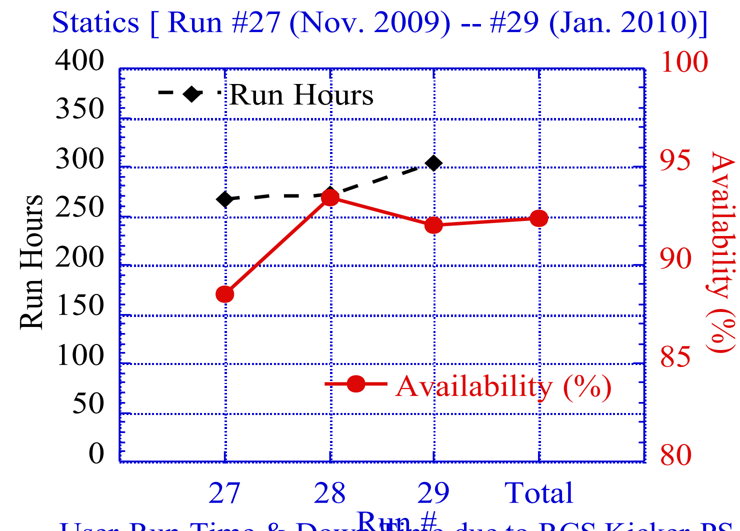
## 1000 trips in 3 cycles (in 2 x 3 Weeks)

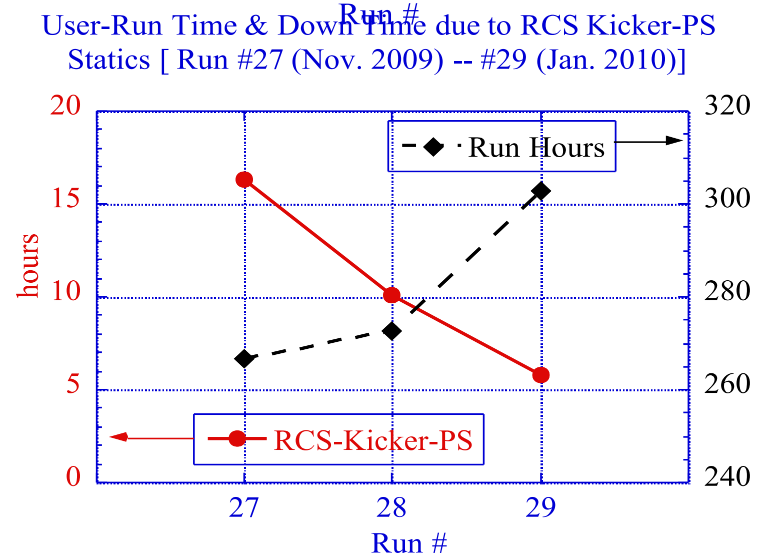
Acc's down time & hours




**Availability** in MLF User Run [ Run #27 ~ #29 ]

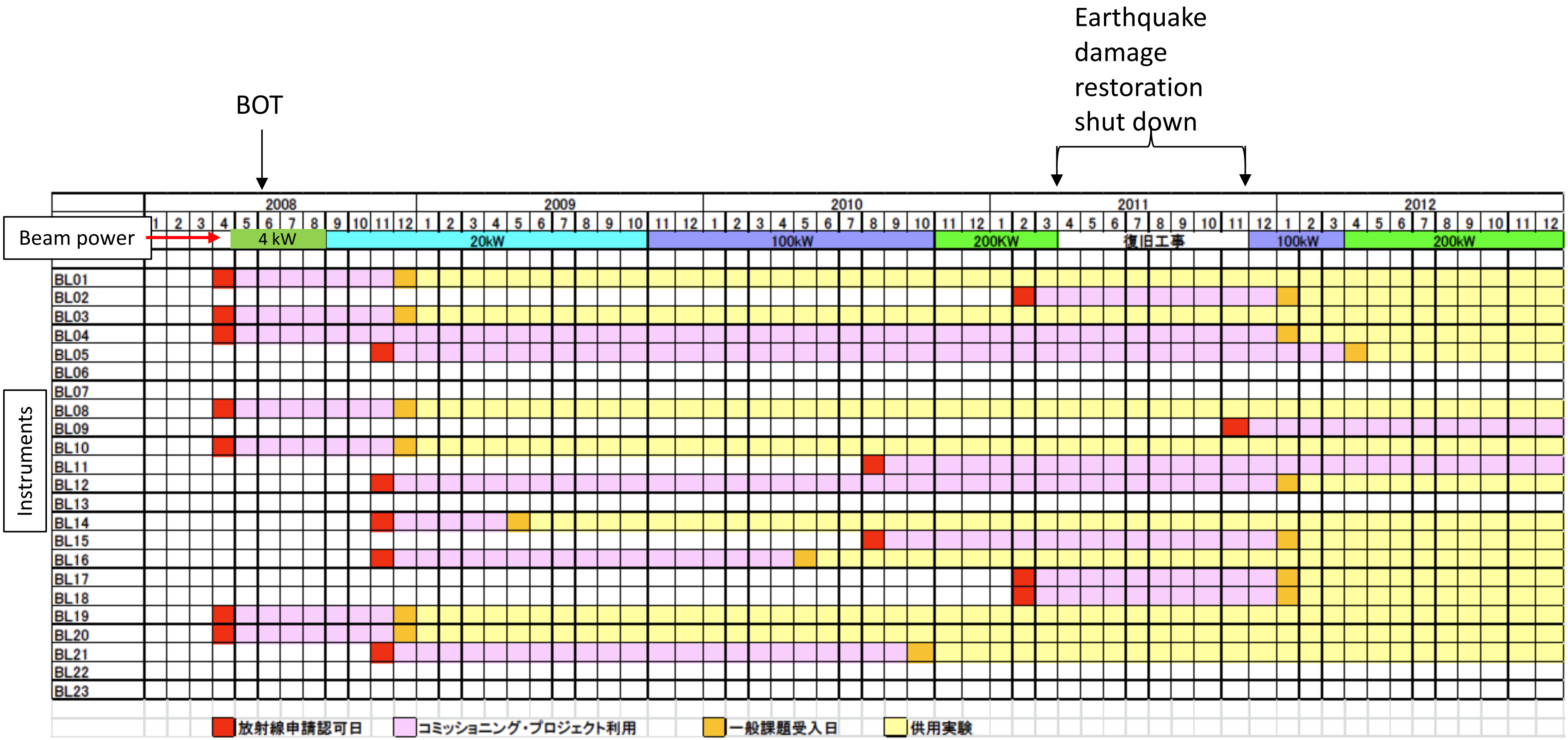
***92.4 % / 842.3 hours***



# Instrument installation/operation history as of 2012

(almost no difficulty in successive installations)




Getting Parmission /Licensing to use

Commissioning and Inst Team's own use

User Program started

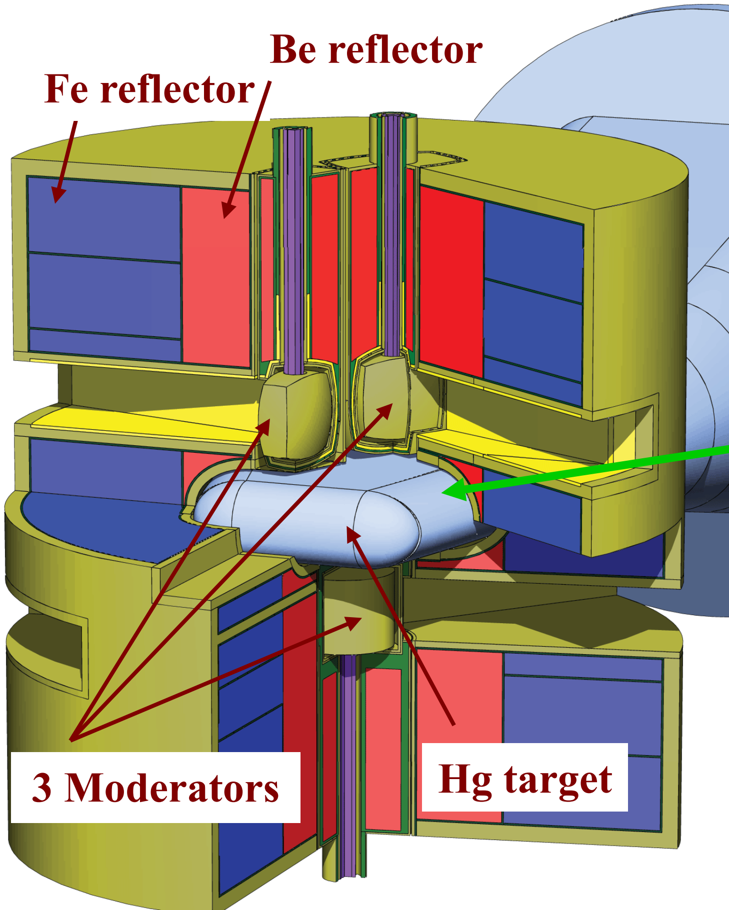
User Program

20 instruments built by 2015

# Hg target, moderators, and reflector system

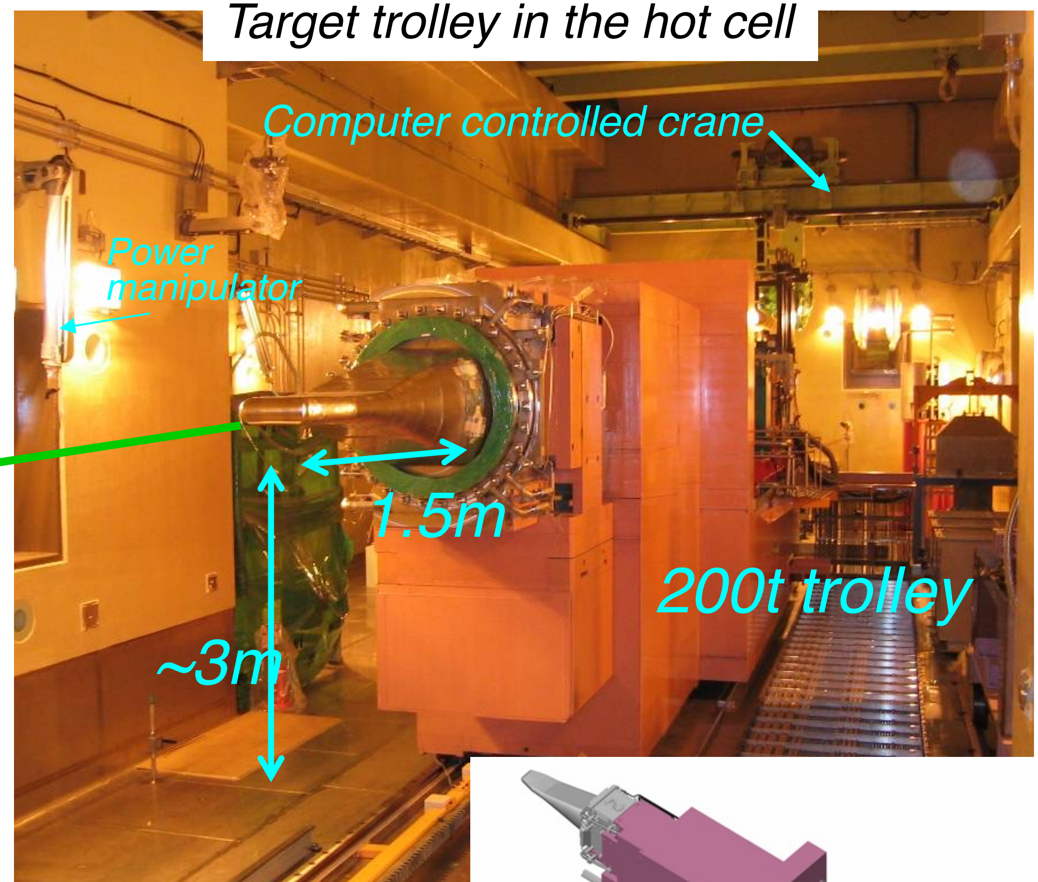
*(Target sits still on beam. Easily maintained at hot cell)*

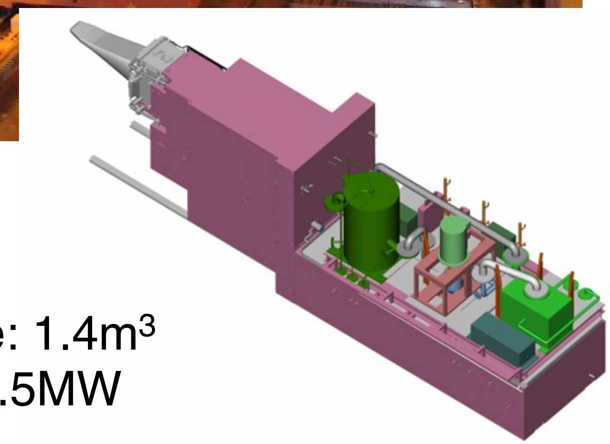
*TRM assembly*




*3 moderators*
*Coupled moderator,*
*Decoupled one,*
*Poisoned decouple one*

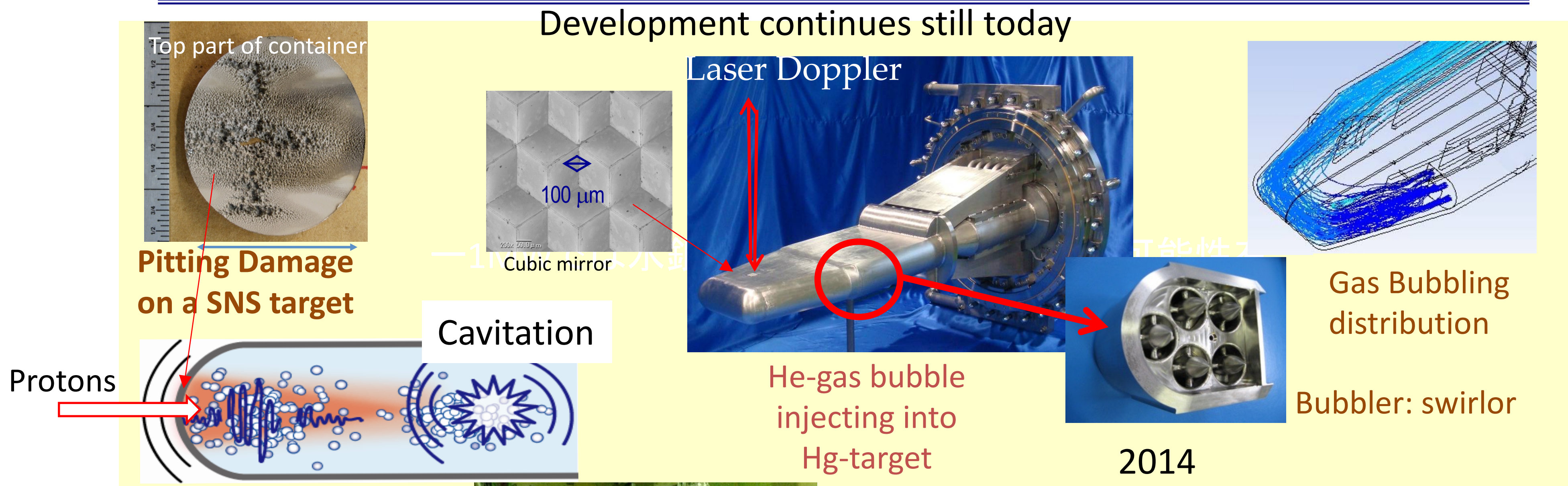
*Target trolley in the hot cell*

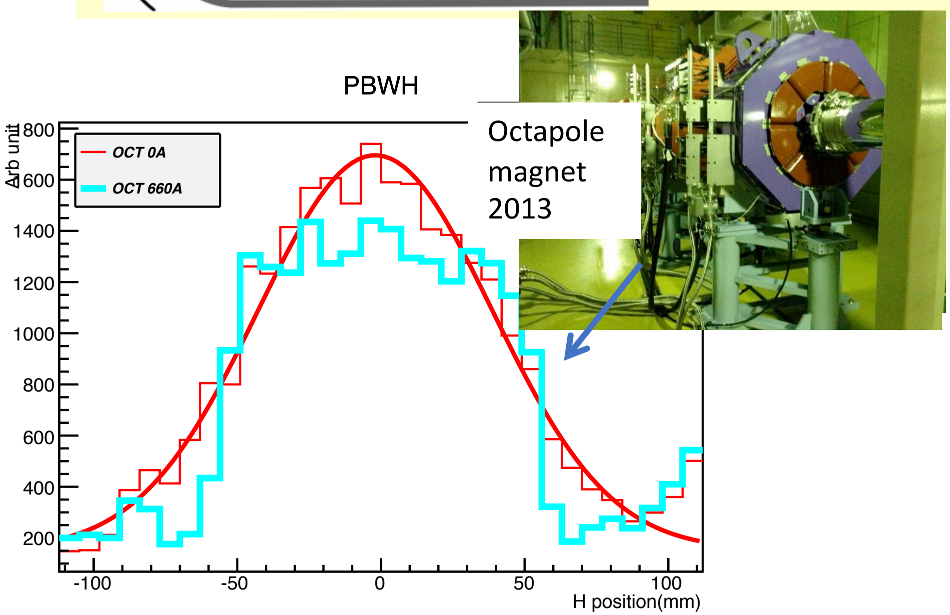


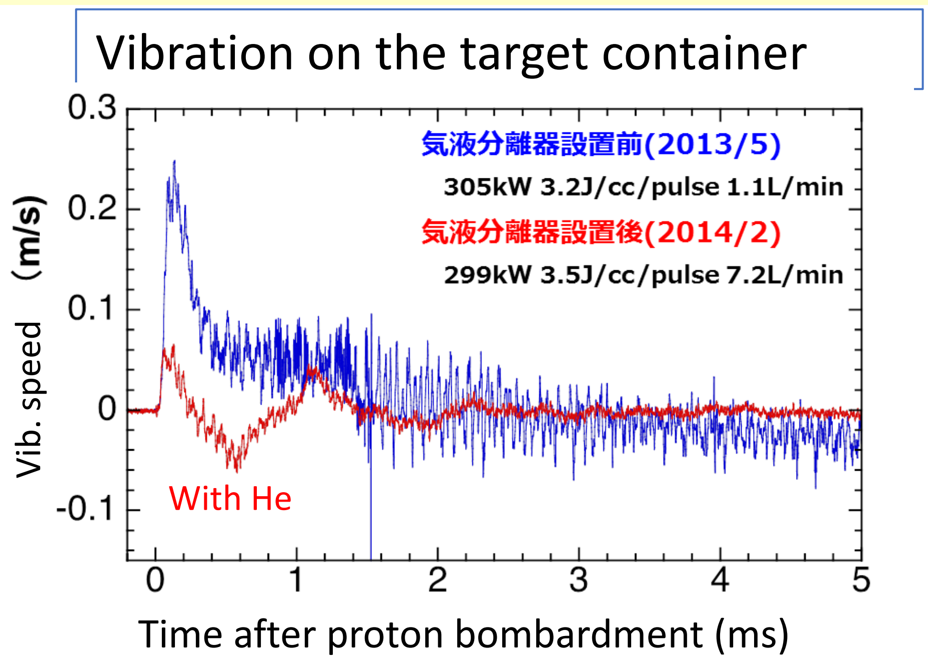
Hg flow:1m/s     Hg Volume: 1.4$m^3$
Heat deposition at 1MW: 0.5MW

# Unexpected damage on designing phase (the pitting problem)
# Develop mitigation; He-gas bubble injection & flattening of Proton Beam



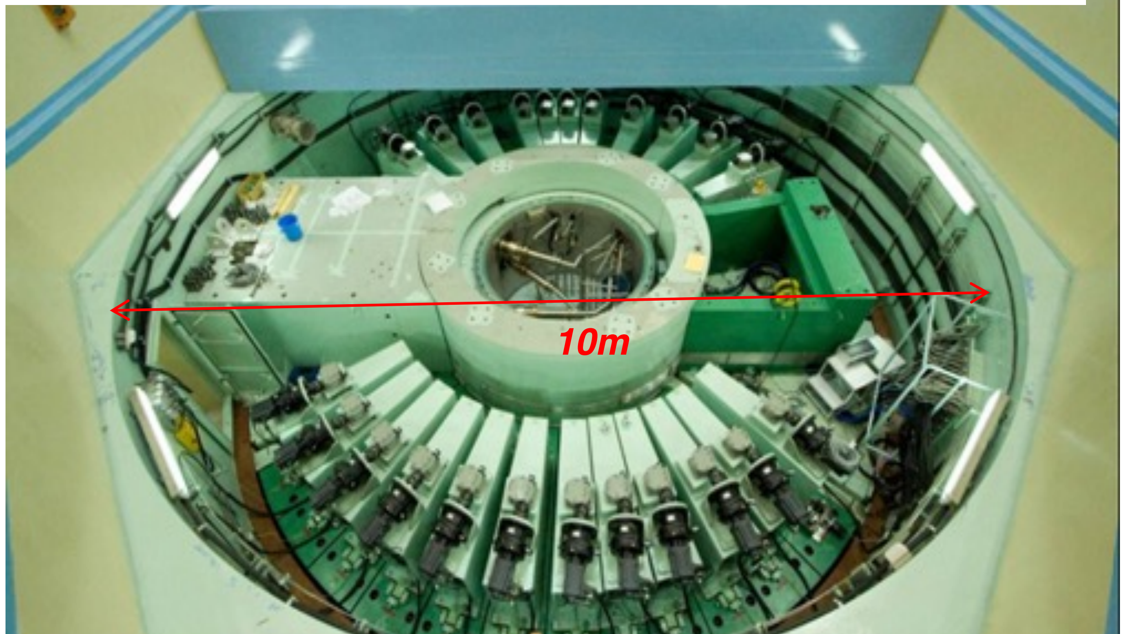




Beam flattened to reduce the power density

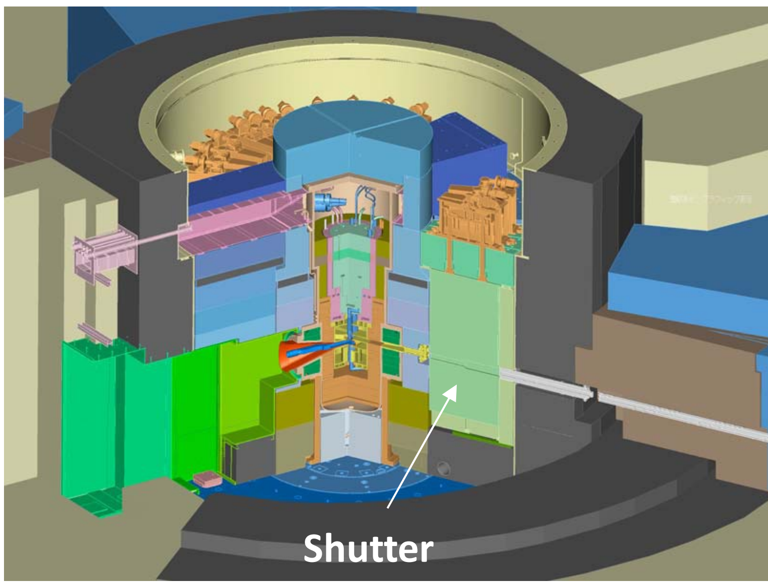


# Heavy Shutter (25t) in Monolith with Optics

*(Shut neutrons to instruments. Easily maintained from the top)*




Heavy Beam shutters in Monolith ($2m^w$, $4m^h$, 25t)

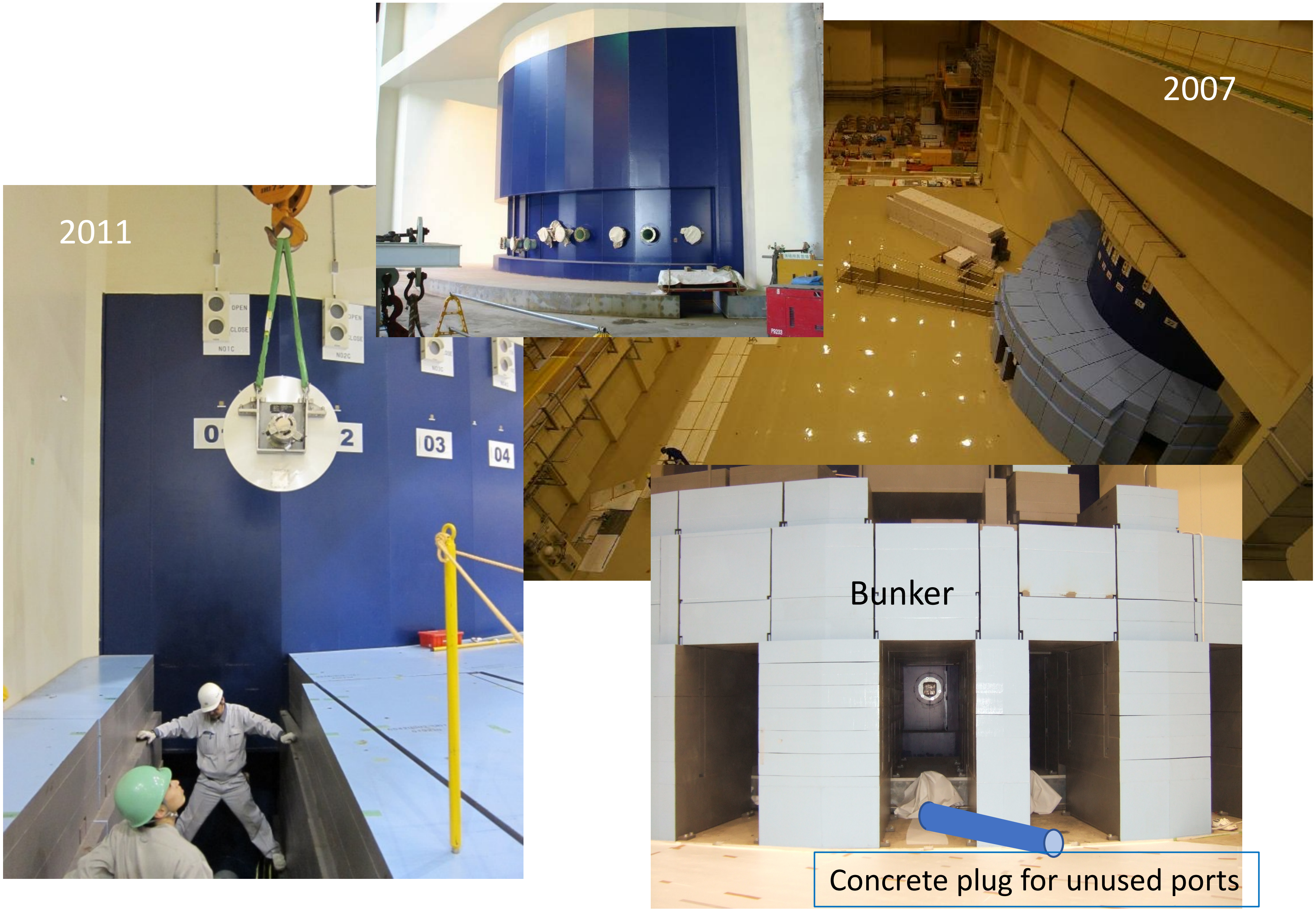


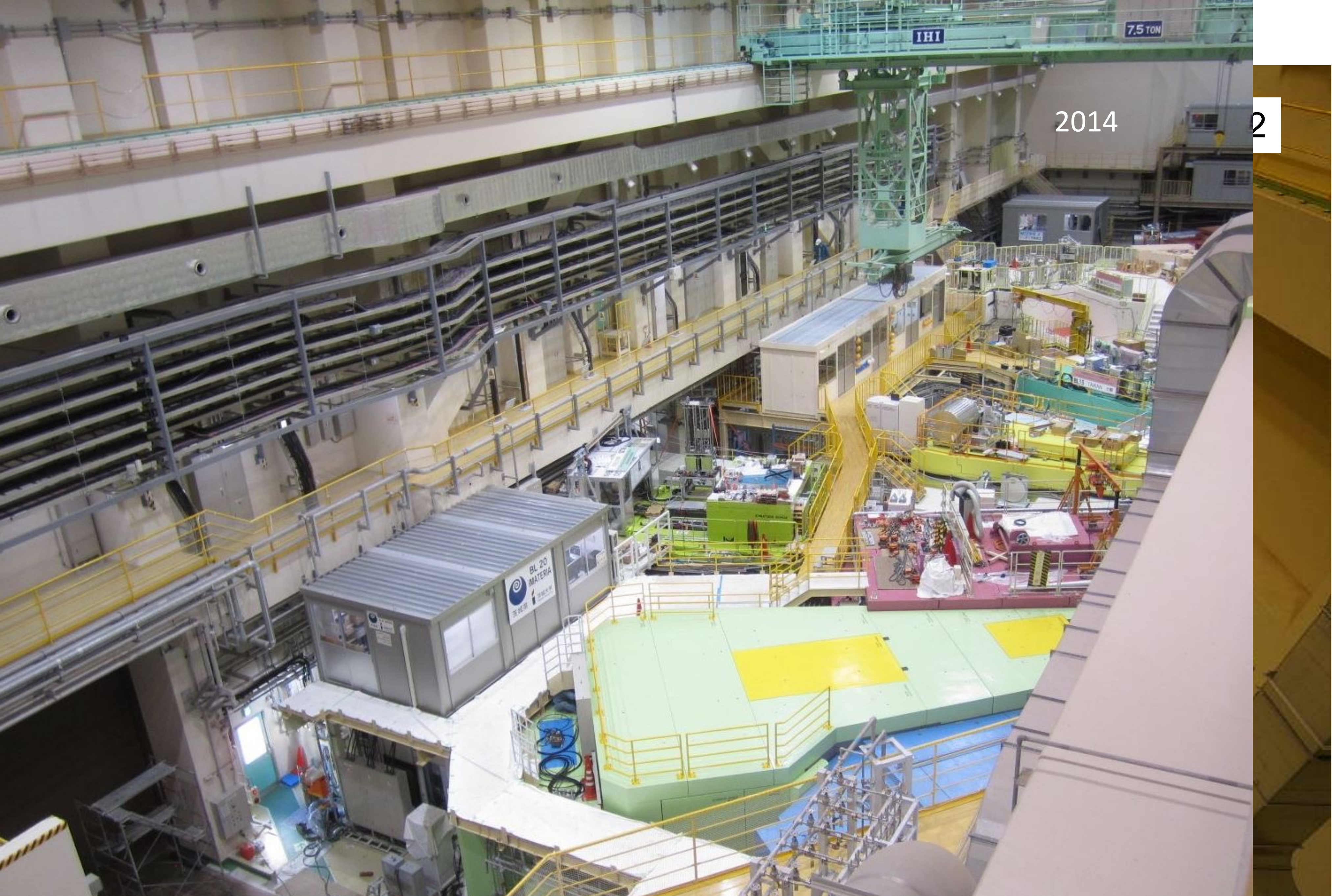

Moderator/reflector system

# Bunker surrounds Monolith (Bulk Shield) .

Each beam port is essentially separated.

Allowed different inst. installation phase together with shutter-close and temp. shields





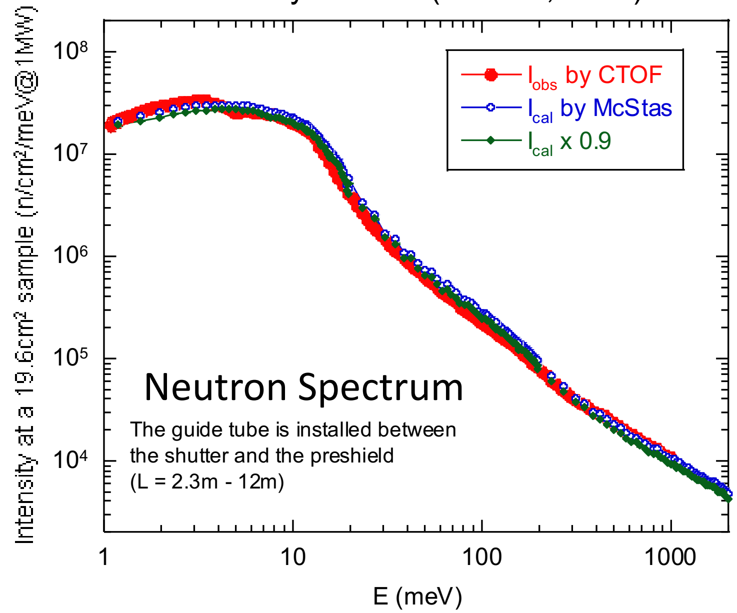

Construction and commissioning/operation co-existable with shutter and temp. shield

# Confirmation of designed performances

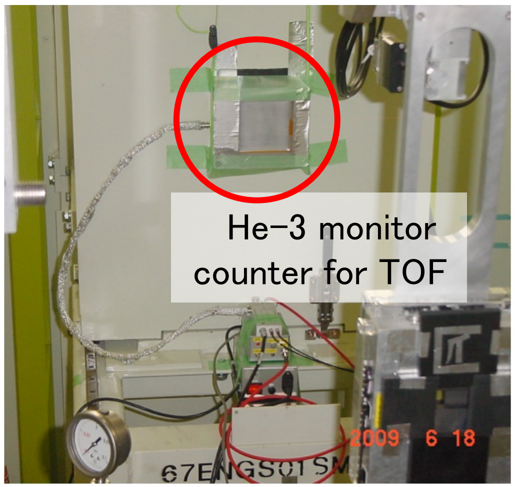
## *Importance of collaboration between Target & Inst. Teams*

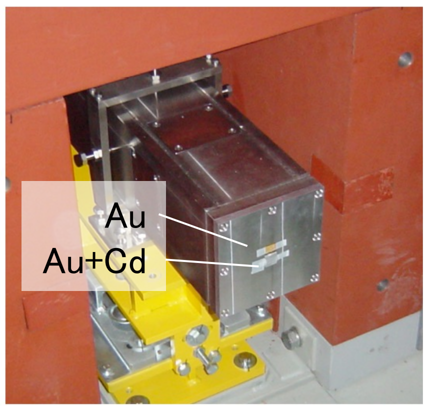
Development of Neutronics code
PHITS (~ MNCP): precision (±20%)
Energy in $10^9 \Rightarrow 10^{-3}$eV order of 12
Intensity $10^{17} \Rightarrow 10^8$ order of 9

Intensity at BL01 (Dec. 25, 2008)

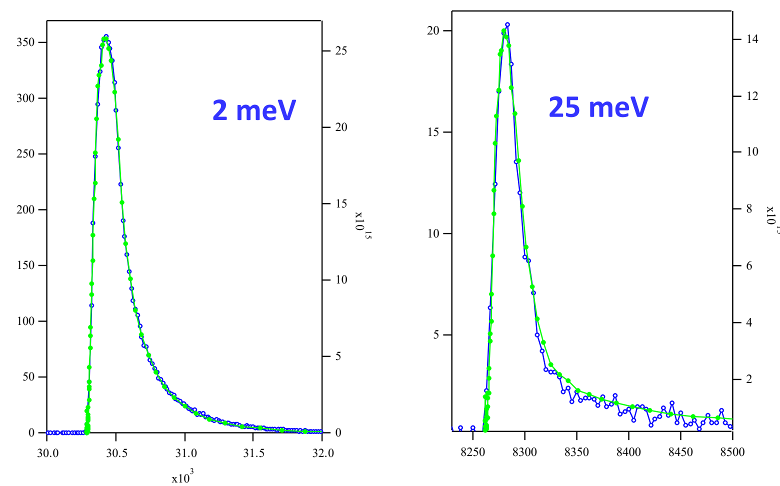



## Observation of absolute flux



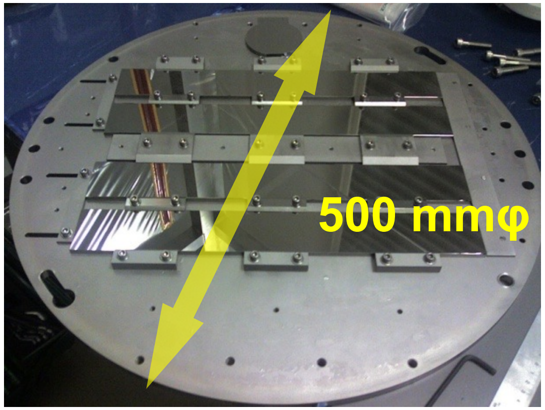

## Peak structure (calc./obs.)



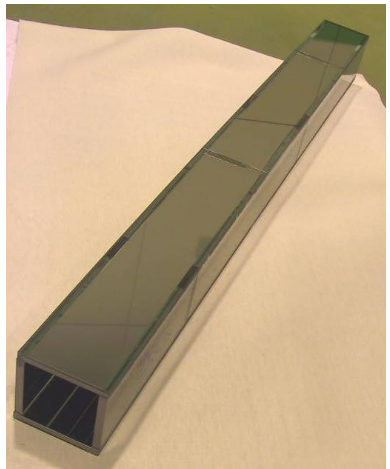

1. Confirmation of the calculations of JSNS
2. Finding out something wrong in BL alignment

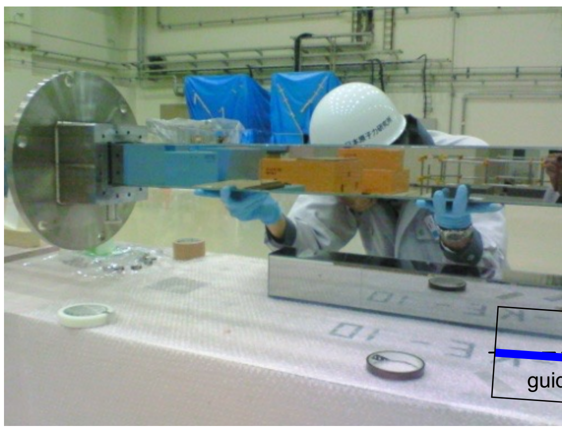
# Neutron guide miss-alignment at BL14

Home made guide & in-house installation

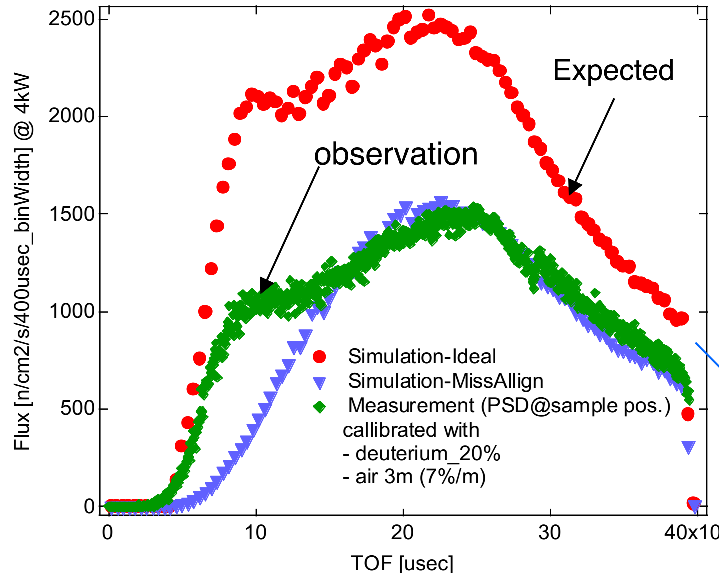



*m*=4
1000 mm
(float glass)

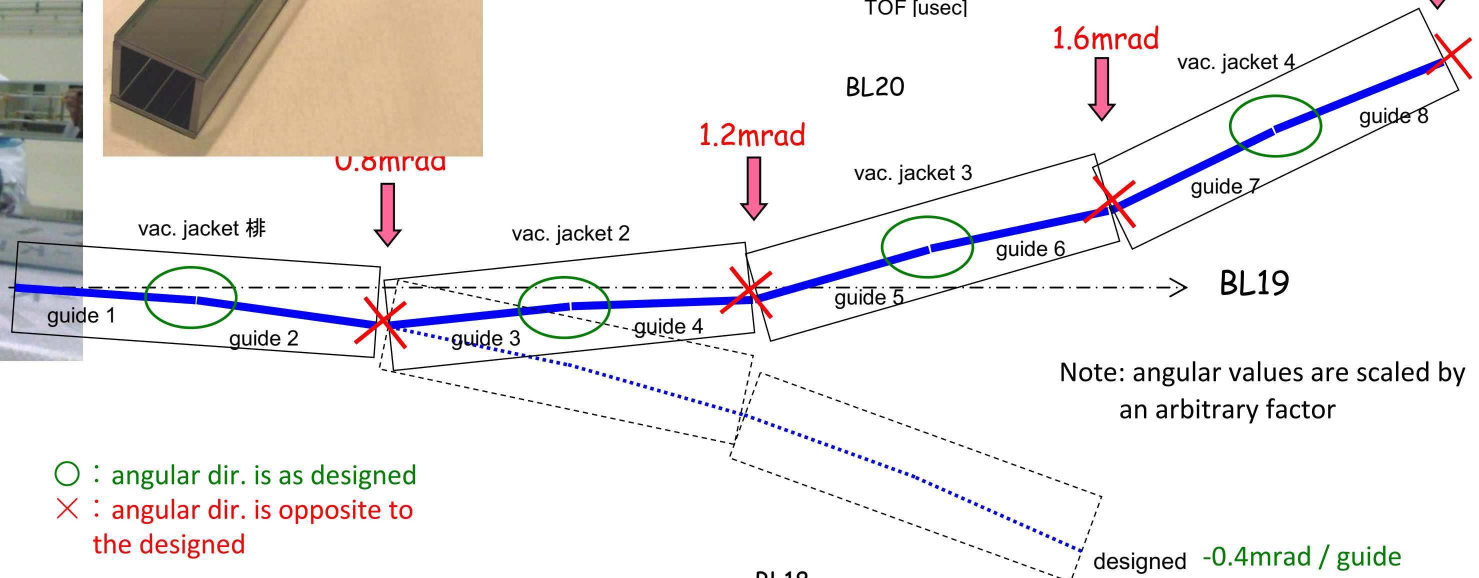




## BL19 (similar problem in BL14)




Observed flux was 50-60% of designed. (simulation)




Note: angular values are scaled by an arbitrary factor

-0.4mrad / guide
(to BL18 side)

Alignment scheme helped by accelerator group

Jacket design was not robust for evacuation

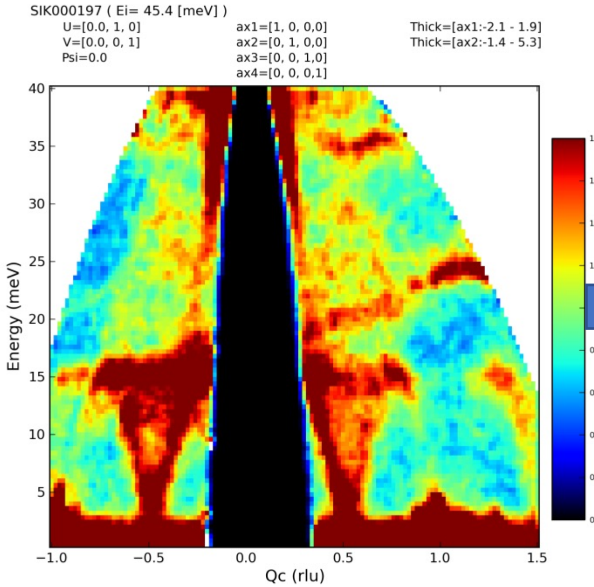
# Background Suppression takes time

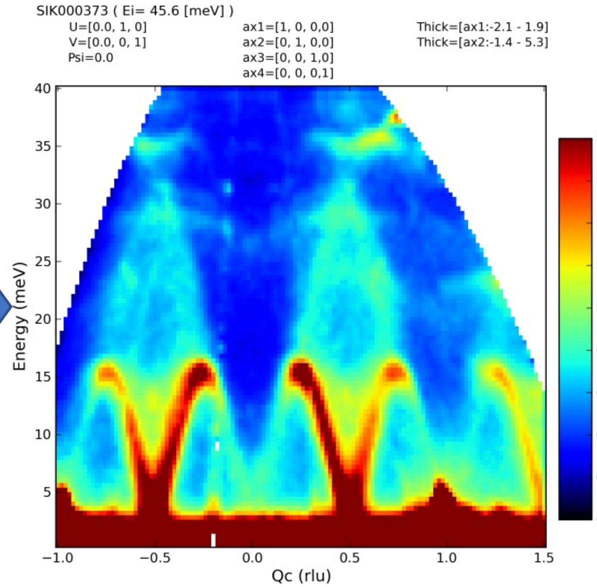

**Low background level is especially important for spectrometer**

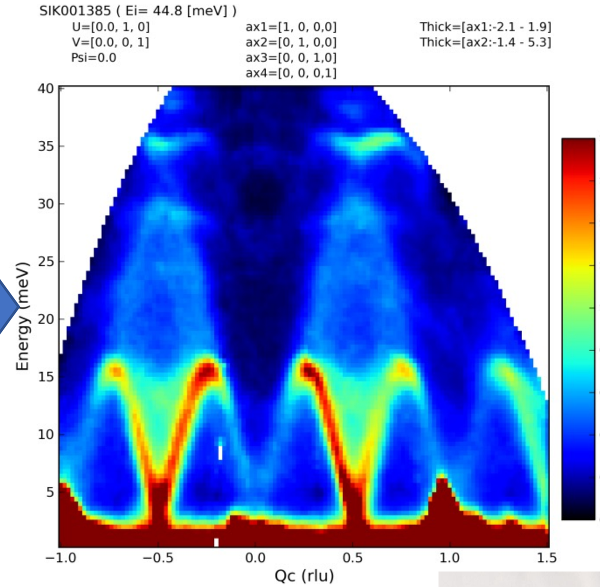
**Quantum Magnetic Excitations in $CuGeO_3$ on 4SEASONS**

**(Bench mark sample is needed)**

| **2009.6** | **2009.11** | **2012.01** (3y after BOT) |
| --- | --- | --- |
| ~20 kW | ~100 kW | (~200 kW) |



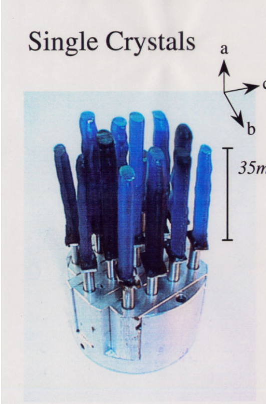




- First measurement full of background

- Addition of several shielding materials
- Addition of detectors around the beam center

- Installation of **To** chopper
- Further addition of shielding



# ESS

# ESS Accelerator system

**Design Drivers:**

High Average Beam Power

5 MW (2MW)

High Peak Beam Power

125 MW

High Availability

95%

**Key parameters:**

-2.86 ms pulses

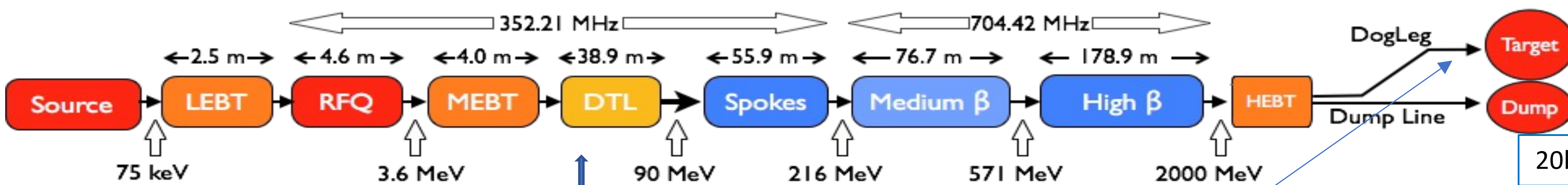
-2 GeV (0.8GeV)

-62.5 mA peak

-14 Hz

-Protons (H+)

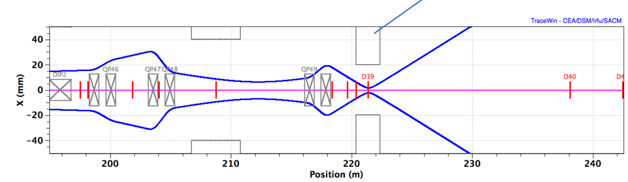
-Low losses




20kW dump

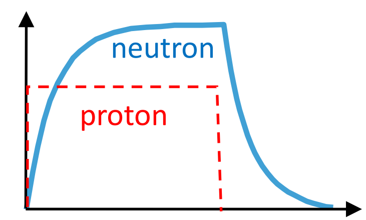
BOT

Under commissioning

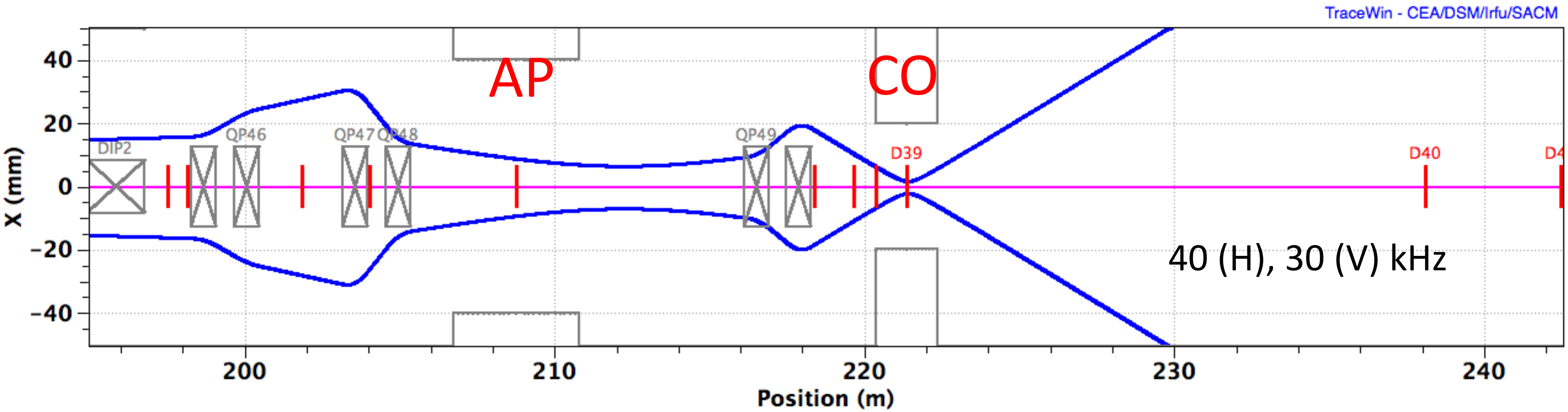



Proton Beam Rastering

2.86 ms long pulse

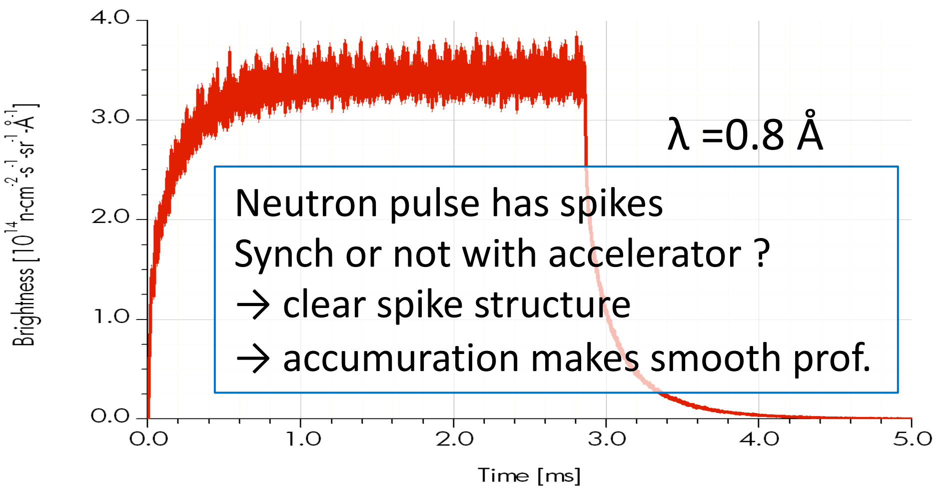


# Rastering Proton injection to Target
# (spreading heat deposition)



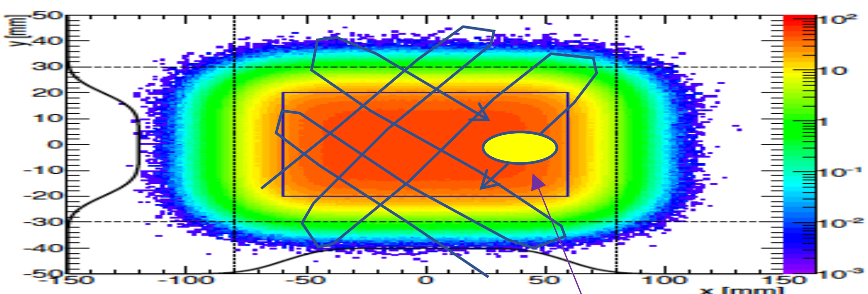

Time to the final protons to target after a failure detection : *20μs (2.5kW/spot, 5kW/cm²)*

*(Redundancy of magnets may prevent deadly failure, but in a case at low Ep it may give damage )*




Neutron pulse has spikes
Synch or not with accelerator ?
→ clear spike structure
→ accumuration makes smooth prof.

Proton distribution on target

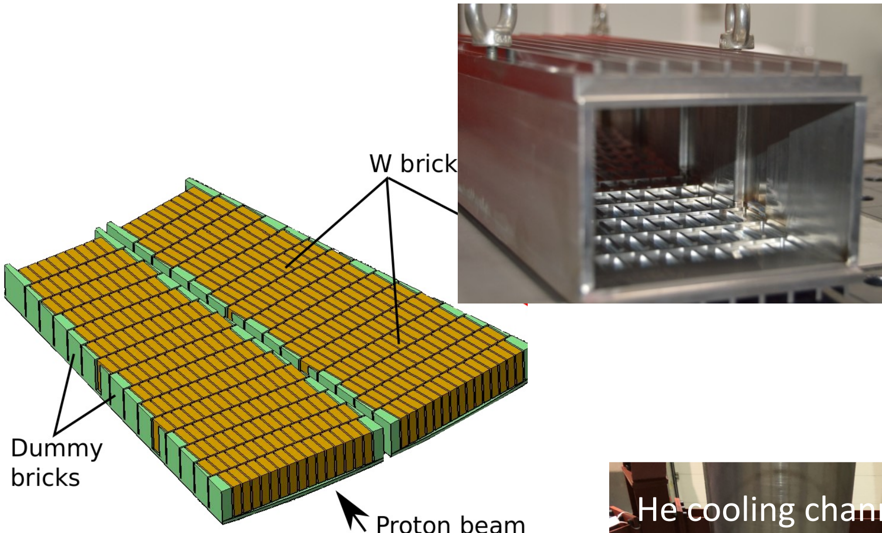



Spot size at Target
13 x 5 mm

# Rotating W target

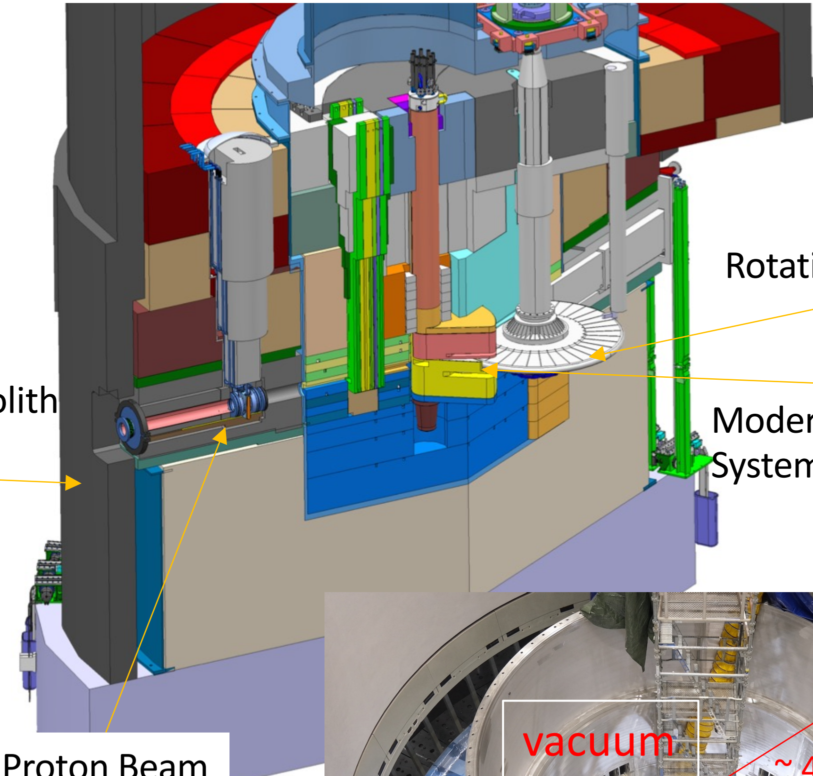
(2.5m diam, ~0.5Hz,
He gas cooling, 10atm)

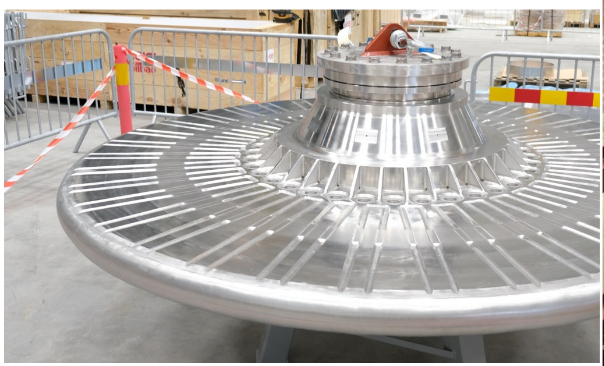
(7000 bricks of 10 x 30 x 80 mm each)

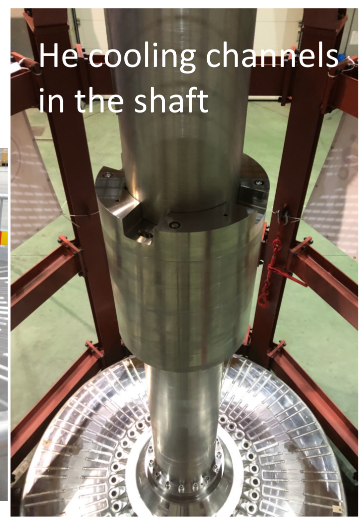


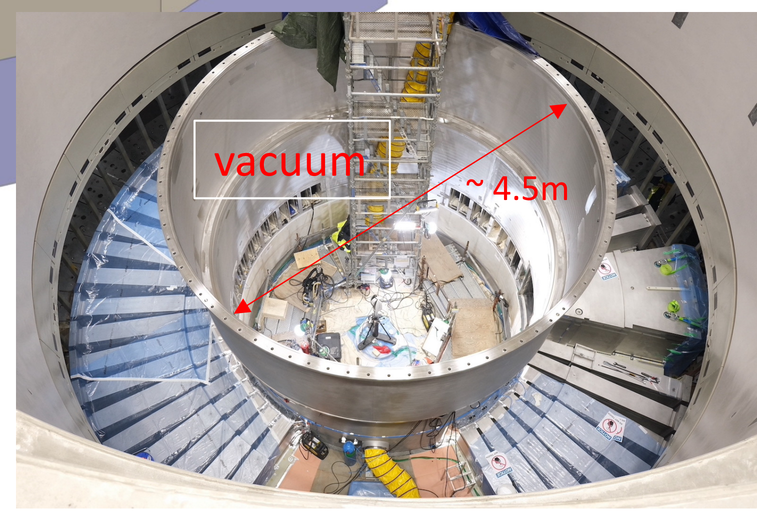

Target Monolith

To omit Proton-Beam-Window ($t_{1/2}$=0.5y) → vacuum



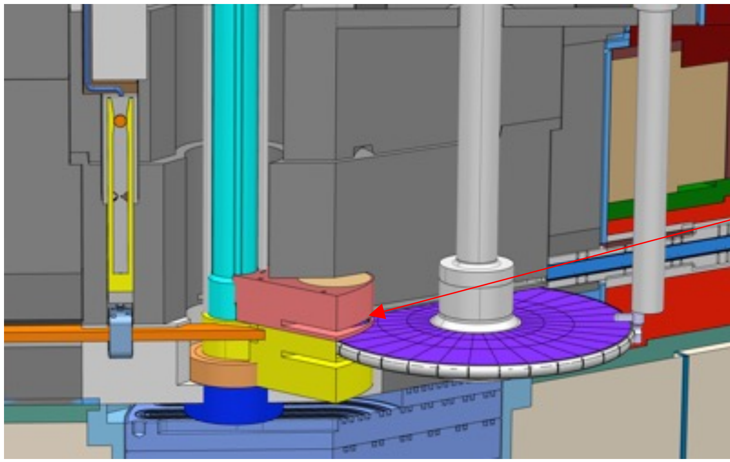





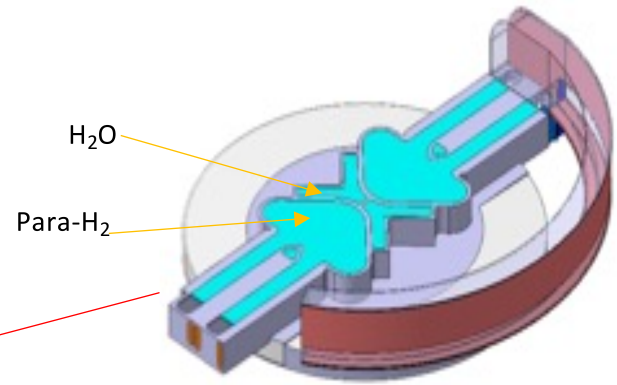




Rotation synchronizes with proton beam (~ 0.5 Hz (25.5 rpm))

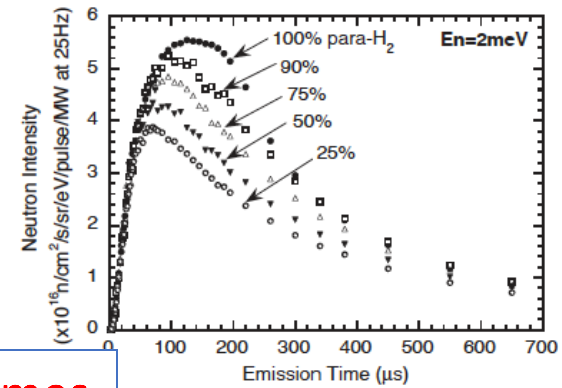
# ESS's Thin moderator (butterfly shape)



Butterfly shape moderator




**Para-Hydrogen fraction is a key**



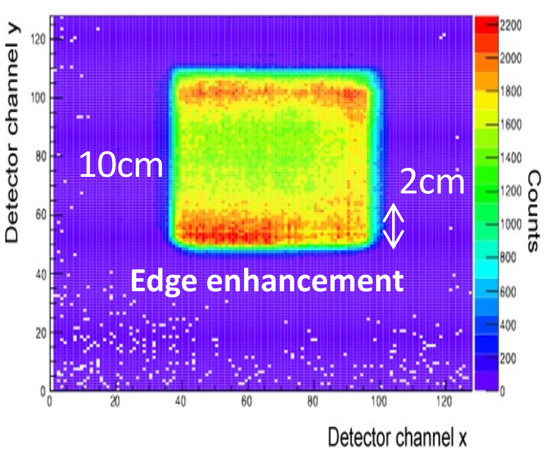

Kai et al. 2004

**Brightness enhancement of 3 times**

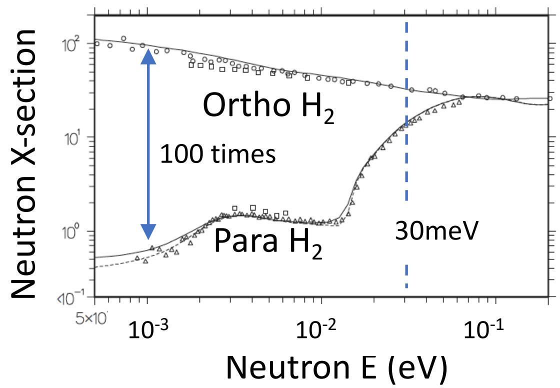
In comparison to J-PARC's volume moderator

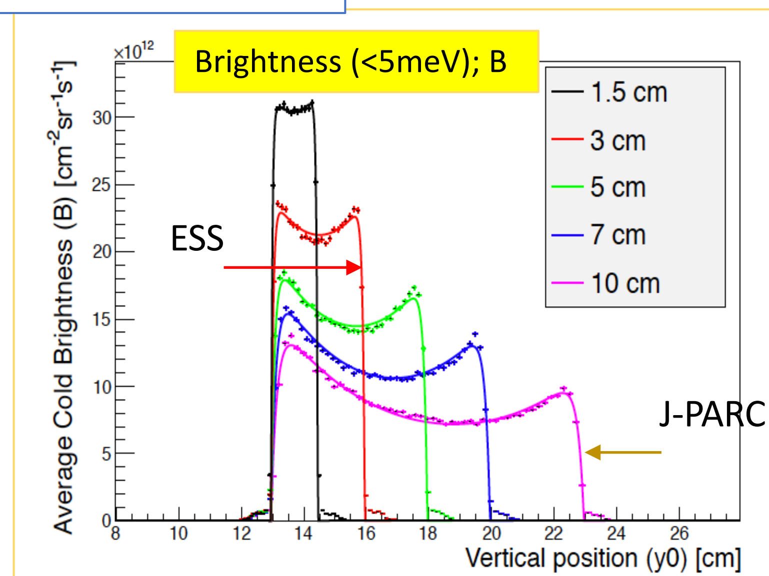
(15 times vs J-PARC (1MW) at 5MW of ESS)

Brightness map of BL04 moderator at J-PARC




Hydrogen n. X-section (Para and Ortho $H_2$)



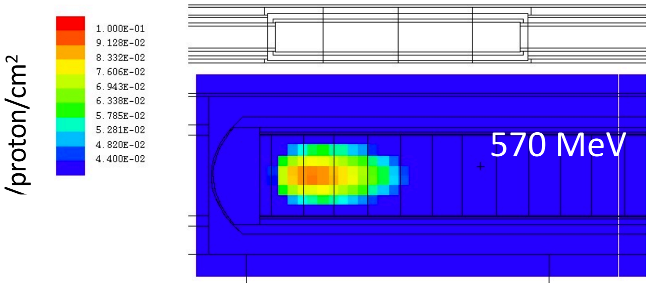

Brightness vs Moderator height per MW

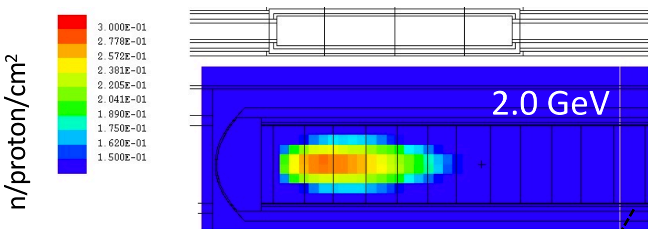
Experiment (Harada et al.) at J-PARC confirmed calculation (Kai et at. 2003)

# Power Ramping-up and increasing Ep

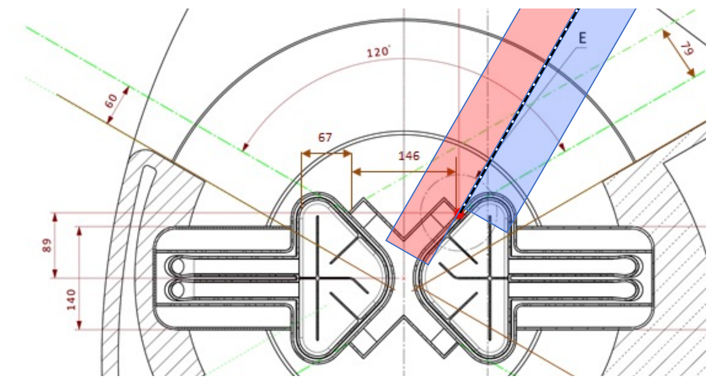
(Design is for 2GeV)

Changing Ep changes neutron production volume in the target




Heterogeneous shape of moderator gives complication to the flux at different ports.

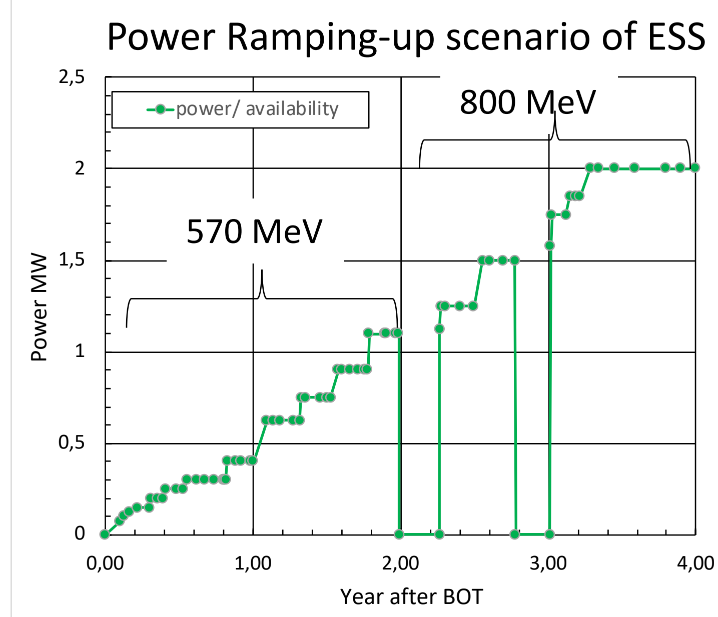



Flux of Instruments will have quite complicated dependences with Ep, Wp, shape of Moderator and port position of Inst.

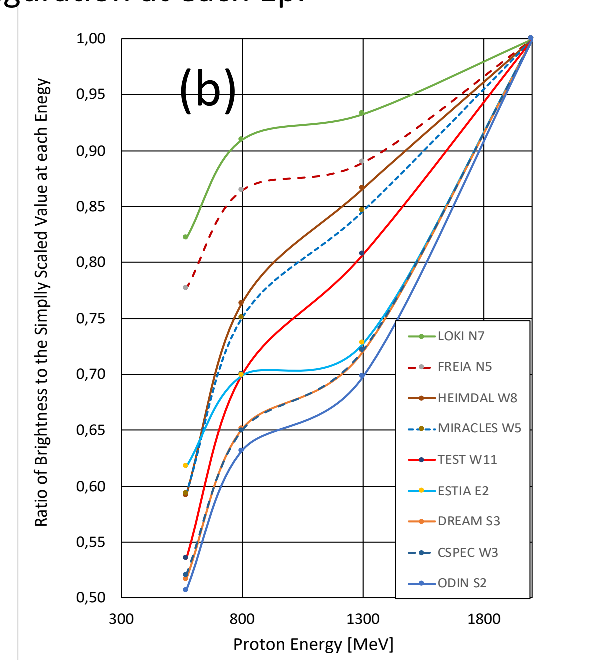
Neutronics Calc. & Absolute flux observation is indispensable.

Collaboration btw TD & NSS indispensable

(J-PARC: always 3GeV, Only Wp changed)

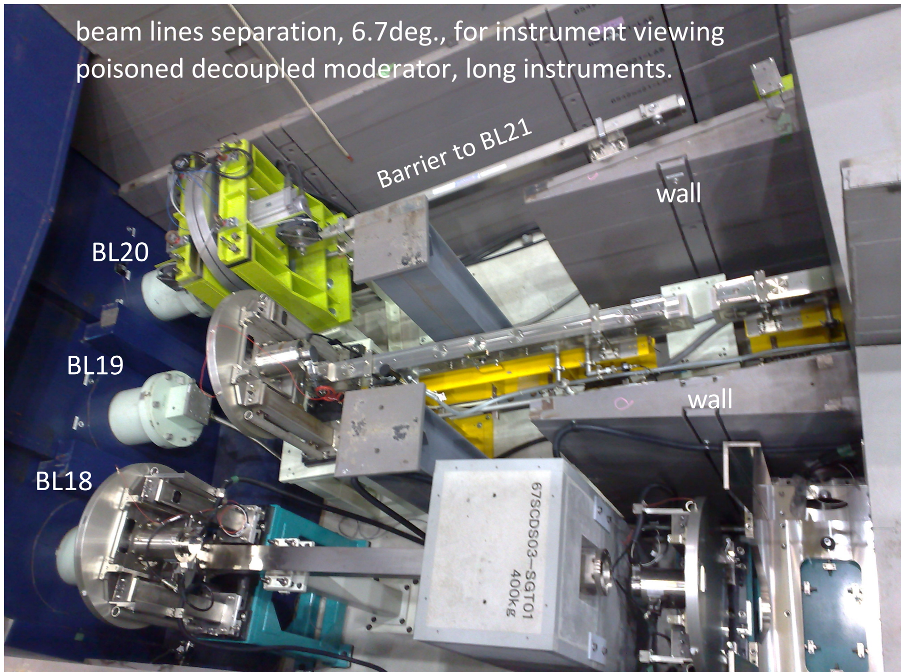



Relative Inst. Performance against the best configuration at each Ep.



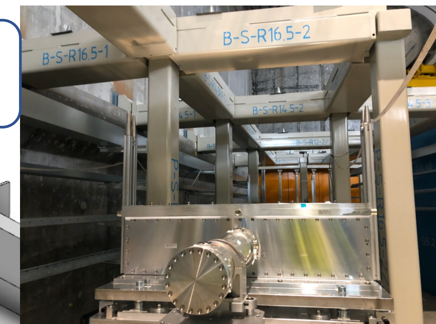
Bunker Shield and Monolith ( 5.5m radius vs 7.5m of J-PARC)
Narrow beam separation 5°- 6 ° after J-PARC's long instruments
→ 42 beam ports
(some ports are already blocked by neighbour and already unusable)

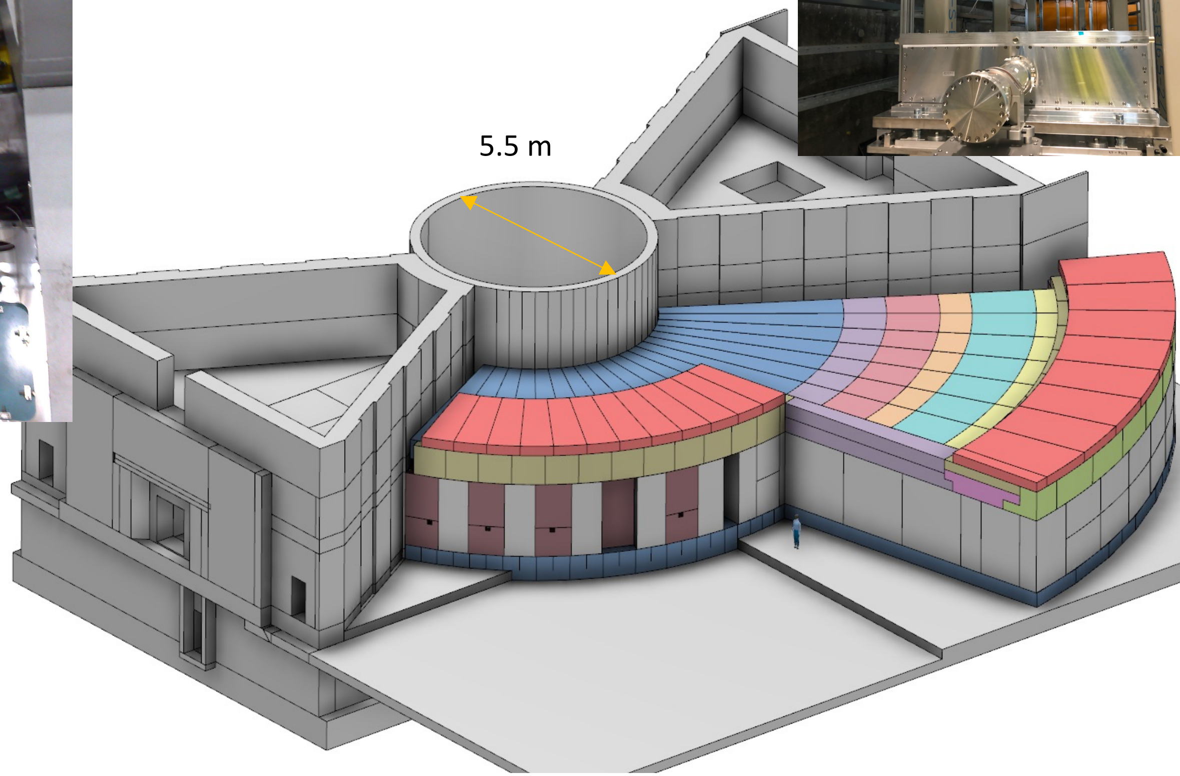
ESS's narrow beam separation was taken from J-PARC.
(6 x 6.7°, 6 x 12°, 11 x 15° → 23 beam lines )




Common volume in bunker at J-PARC

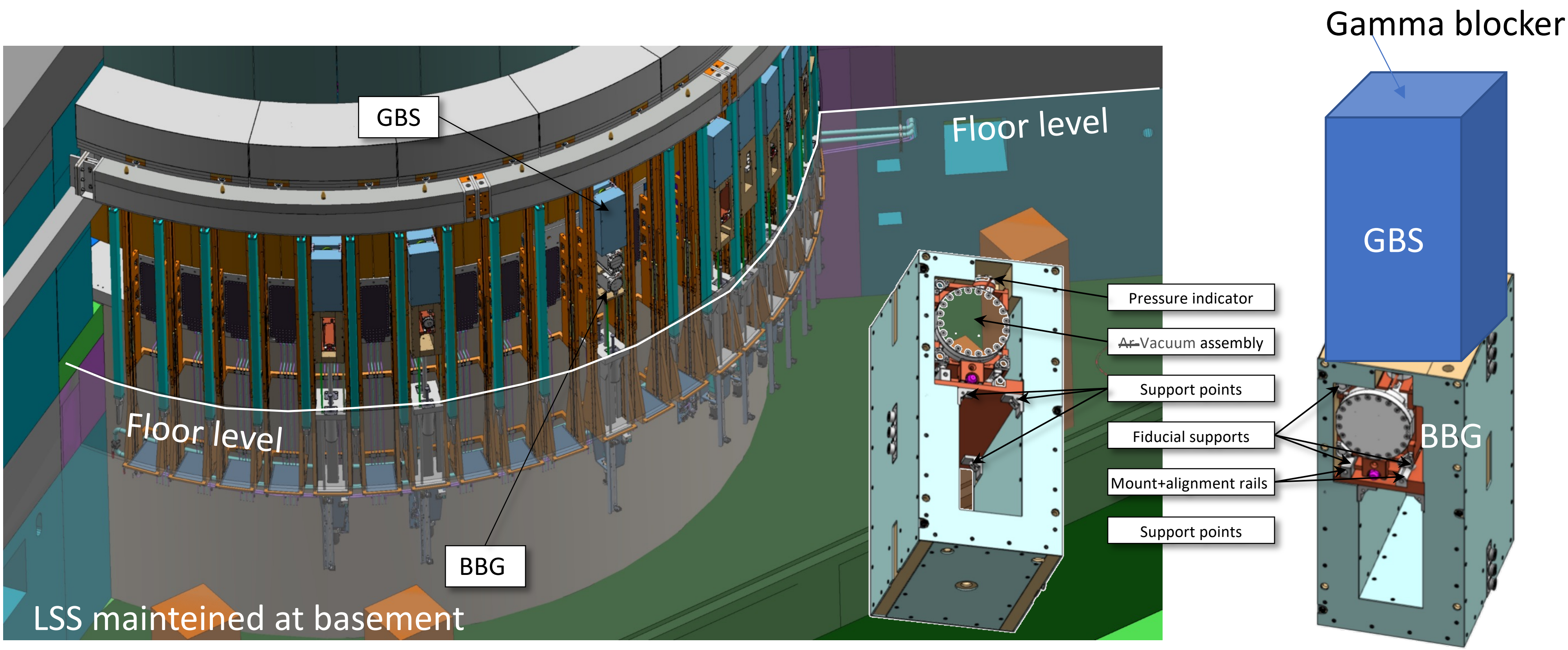
Bunker has a common volume.



# Light Shutter System (LSS)

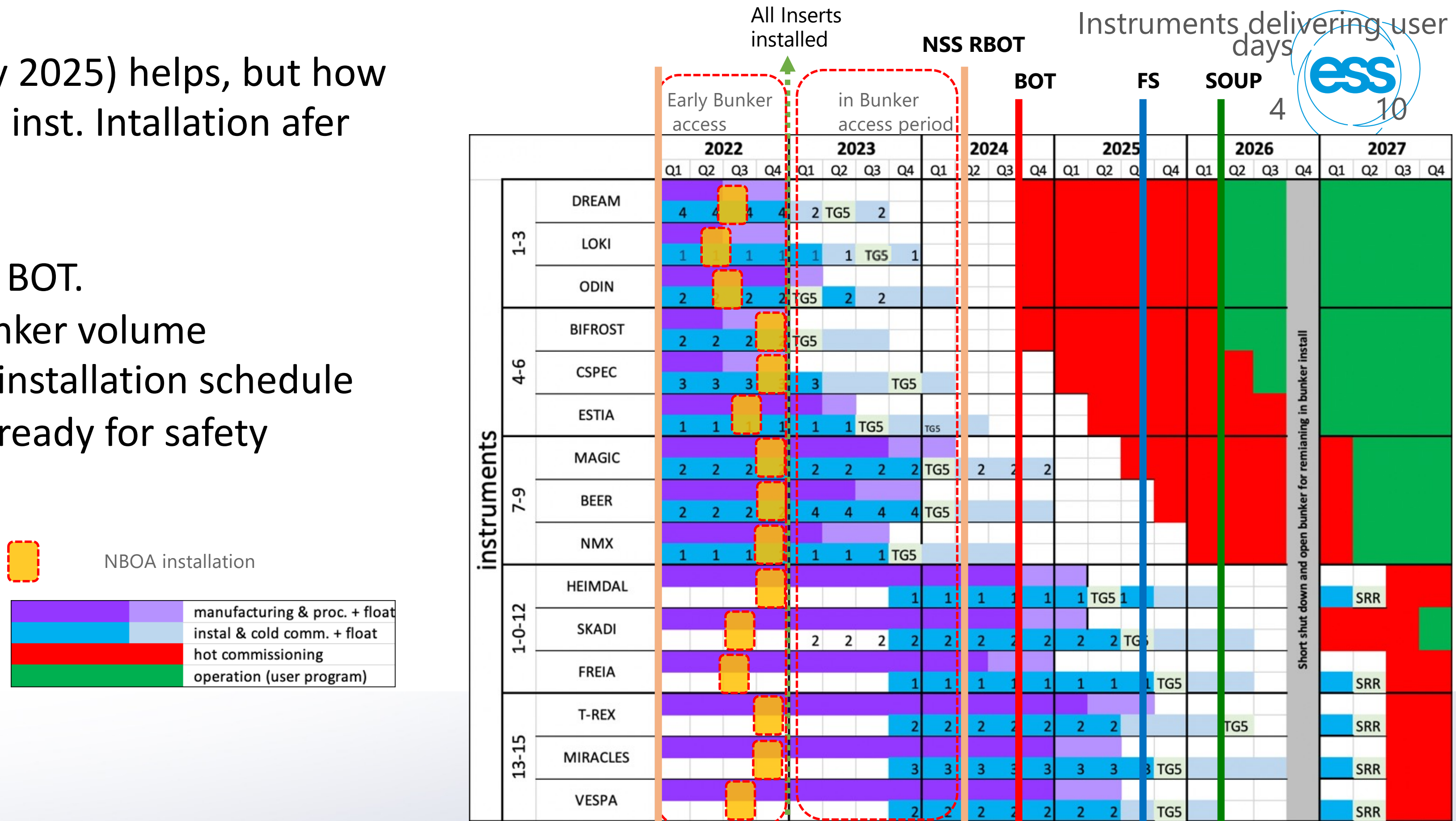
Beam separation 5° - 6°,
ESS intended to have pulse shaping chopper as much close to source as possible.
Monolith diam. is 5.5m much thinner than 7.5 m of J-PARC
Rotating target, 2.5m diam.
→ ESS could not have heavy shutter in Monolith, but LSS outside Monolith instead.
But LSS is built as a Gamma blocker from the source during shut-down maintenance;
Open LSS on BOT, Close LSS during shut-down.

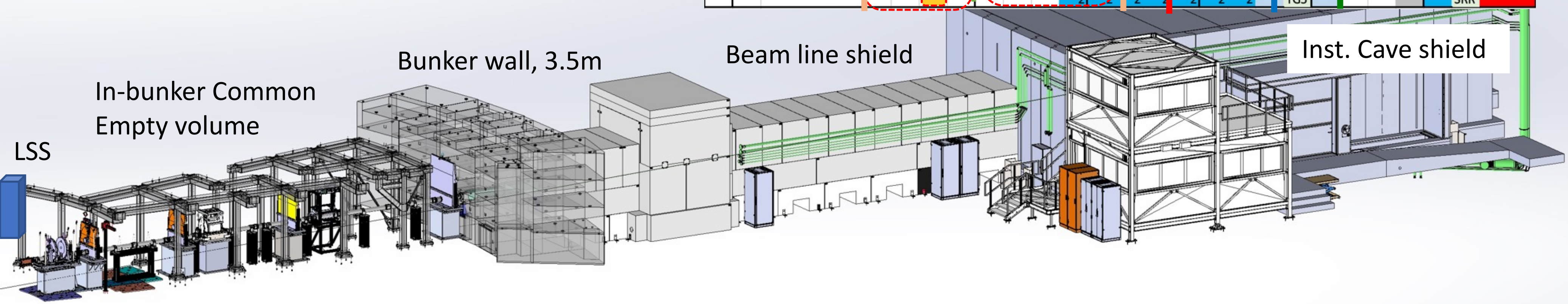


# Inst installation schedule

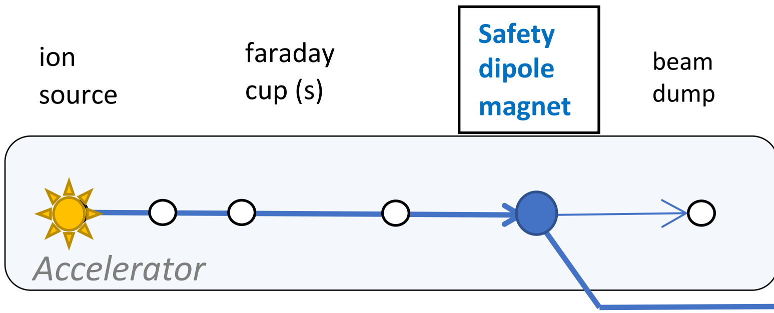
Delay of BOT (May 2025) helps, but how we can secure the inst. Intallation afer 1st BOT.

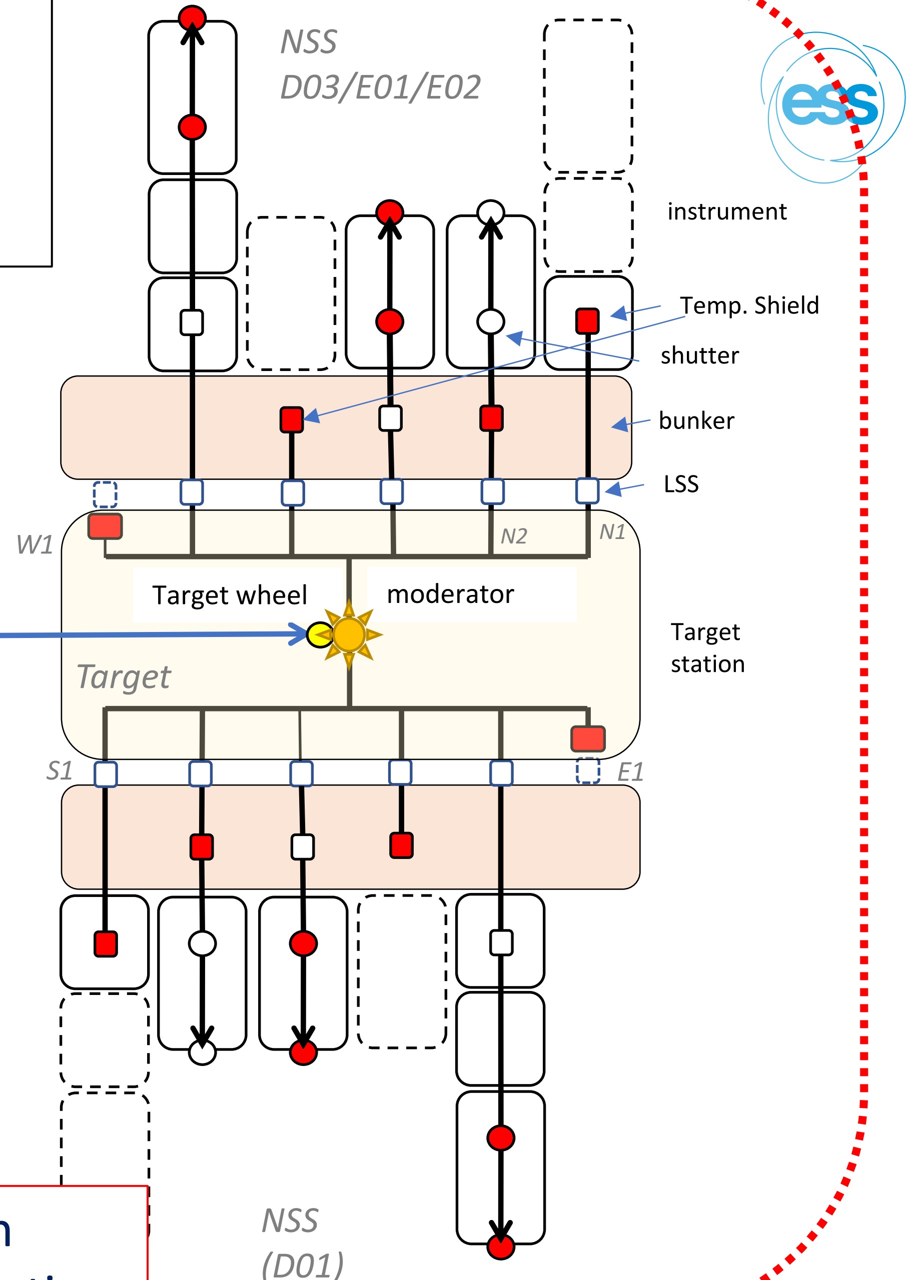
1) All LSS open on BOT.
2) Common in-bunker volume
3) Heterogenious installation schedule
4) Some inst. Not ready for safety system.



Earlier in-bunker installation helps, but how we can secure the safety of the entire system by having a proper installation plan of instruments, which are not equipped with the safety system yet, MPS, PPS.
We may need a temporally shield.




In order to transit to the dump mode to the production mode, all other system to be "under centralised control" electronically or administratively. (Iain Sutten)

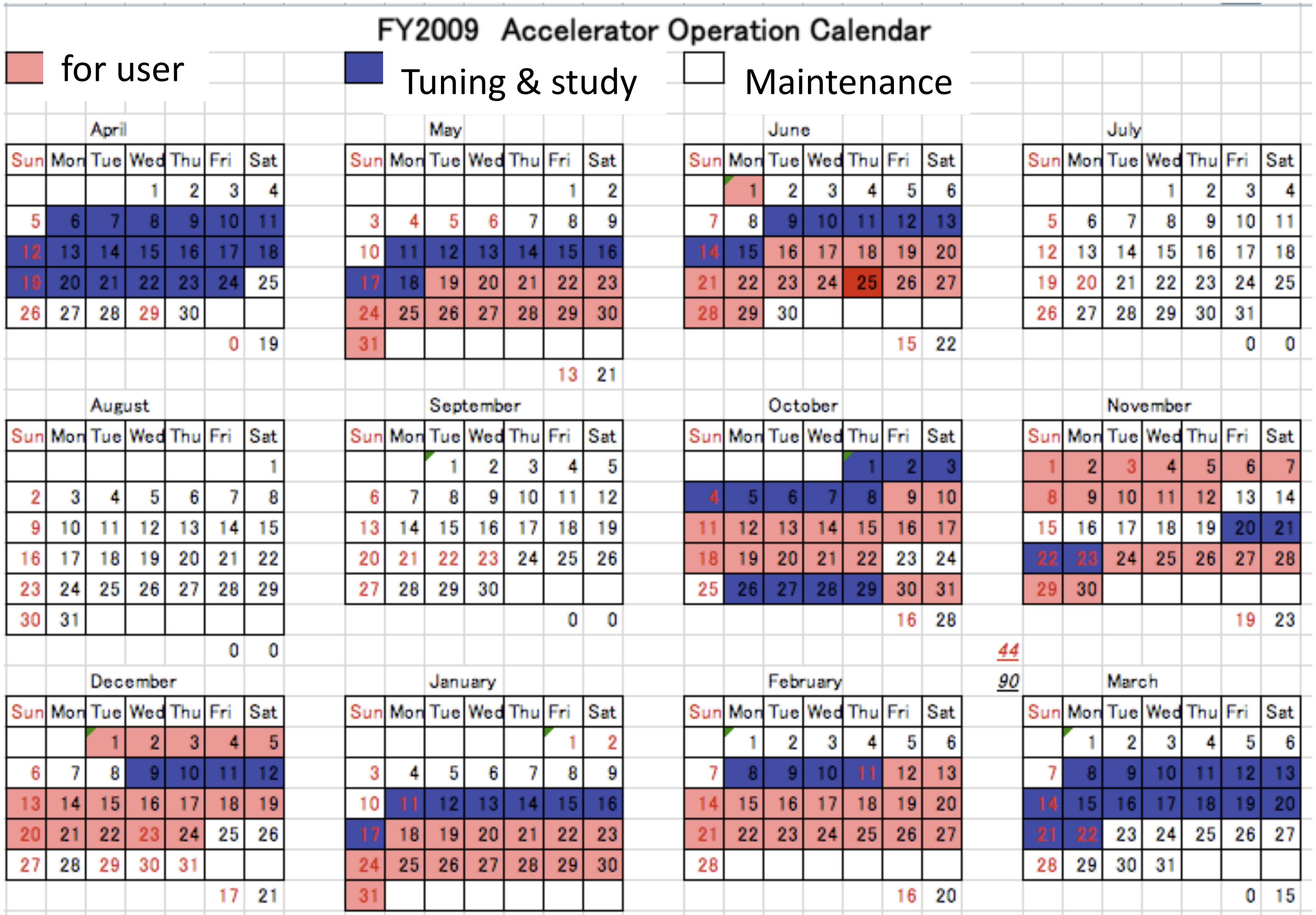
New Operation Directorate should have a lead an integrated commissioning and orchestrated operation.

Backup

# Operation mode in JFY 2009 (20kW)

one week Tuning/Study, 2 weeks user run.

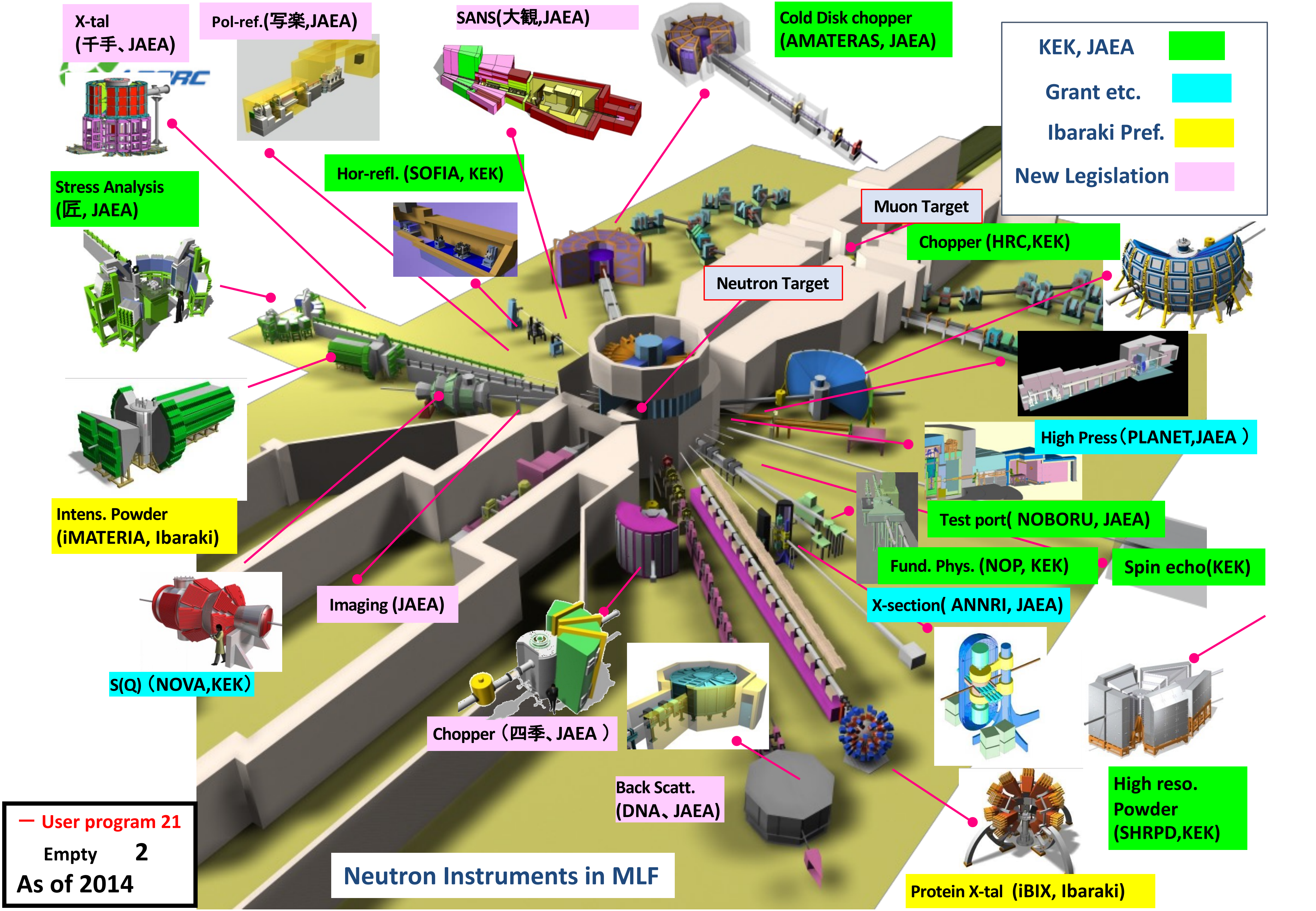
$2^{nd}$ year after $1^{st}$ BOT



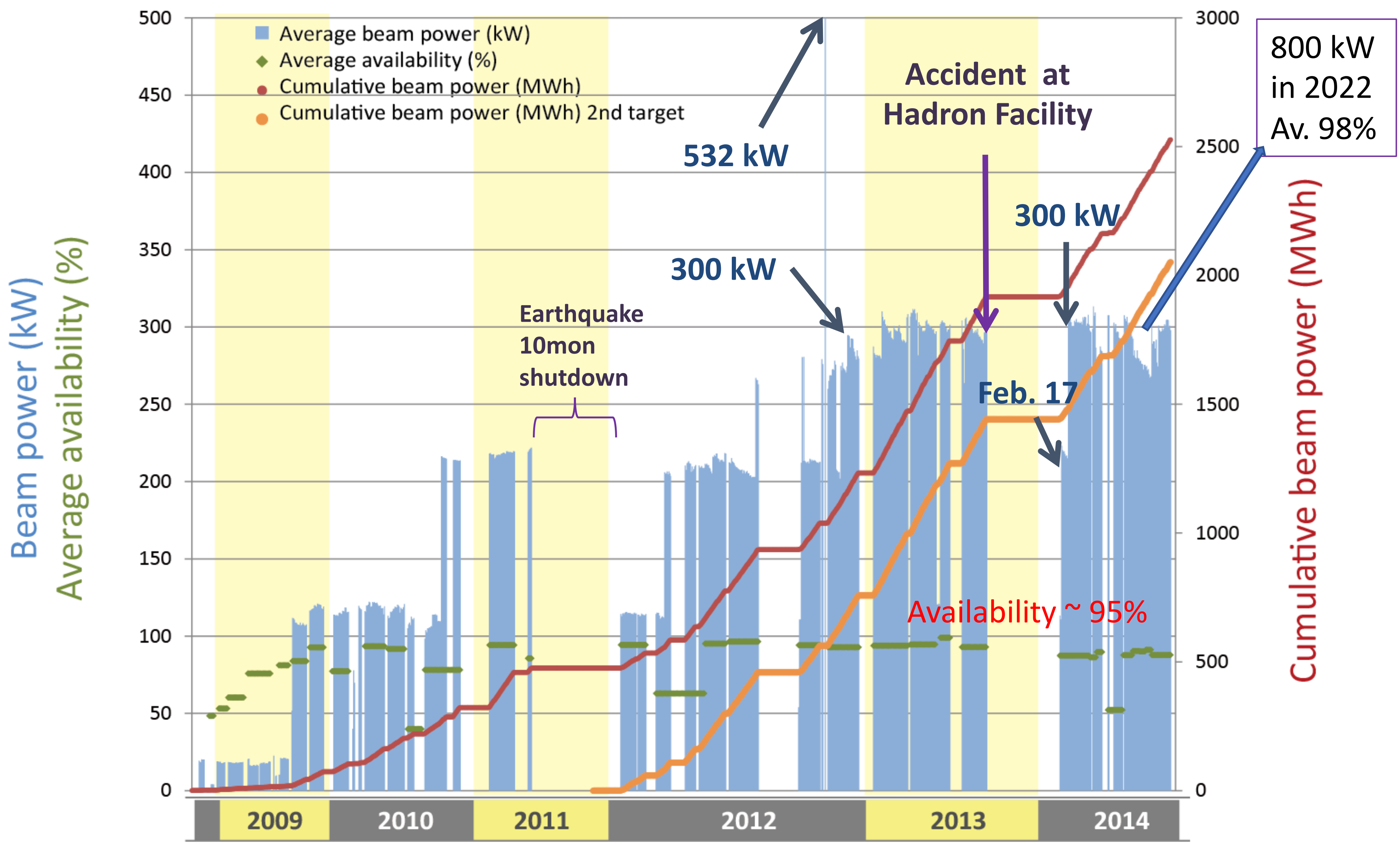

Total operation time 190 days, user operation 110 days.

Conditioning of RFQ. Beam stop 4 hours every day.

(20 hours user run and 4 hours RFQ conditioning)


X-tal
(千手、JAEA)
Pol-ref.(写楽,JAEA)
SANS(大観,JAEA)
Cold Disk chopper
(AMATERAS, JAEA)
KEK, JAEA
Grant etc.
Ibaraki Pref.
New Legislation
Stress Analysis
(匠, JAEA)
Hor-refl. (SOFIA, KEK)
Muon Target
Chopper (HRC,KEK)
Neutron Target
High Press（PLANET,JAEA ）
Intens. Powder
(iMATERIA, Ibaraki)
Test port( NOBORU, JAEA)
Fund. Phys. (NOP, KEK)
Spin echo(KEK)
Imaging (JAEA)
X-section( ANNRI, JAEA)
S(Q)（NOVA,KEK）
Chopper（四季、JAEA ）
Back Scatt.
(DNA、JAEA)
High reso.
Powder
(SHRPD,KEK)
— User program 21
Empty 2
As of 2014
Neutron Instruments in MLF
Protein X-tal（iBIX, Ibaraki)

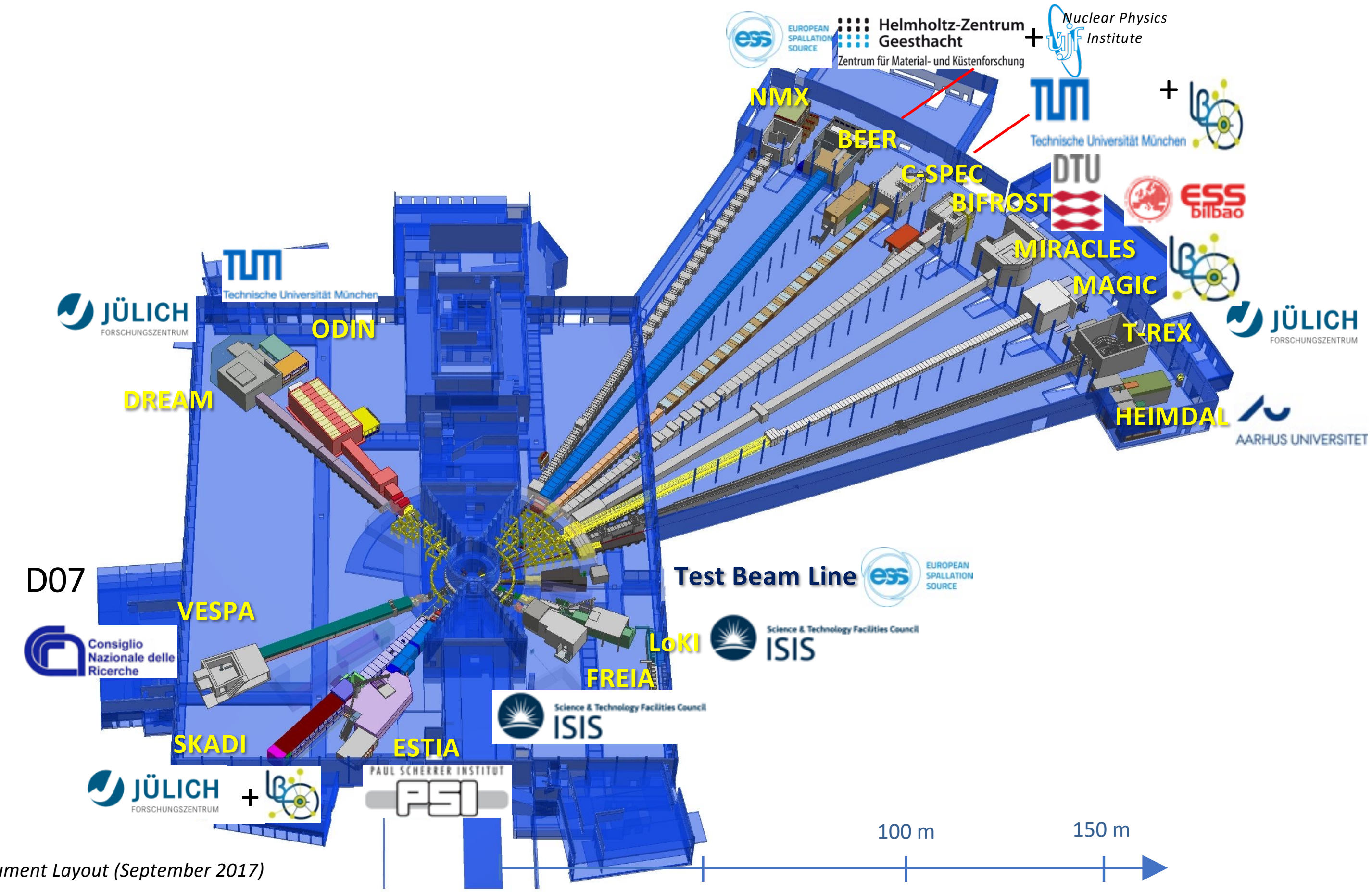
# Beam Power History at MLF




* as of 26th of June 2014

1) Narrow beam separation enabled 42 ports. (pro)
2) Shorter diam. of Monolith enabled Pulse Shaping Chopper closer to the source earning wider band-width. (pro)
3) Unable to have heavy shutter in Monolith (con)
4) Only LSS outside Monolith but as a gamma blocker on shutdown-maintenance (con)

3) & 4) give difficulty of maintenance and further installation of instruments



ESS Instrument Layout (September 2017)

# Inst installation schedule and Layout of a instrument

Delay of BOT could help, but how we can secure the inst. intallation afer 1st BOT.

1) All LSS open on BOT.
2) Common in-bunker volume
3) Heterogenious installation schedule
4) Some inst. Not ready for safety system.