

J-PARC Muon g-2

A quick status update

- The CM 32 just took place last week (24-26 June): <https://kds.kek.jp/event/59973/>



- Giovanni Cantatore gave a MUonE seminar in person

J-PARC Muon g-2

A quick status update

- The phase-1 studies of HSSG were concluded

(1) Magnet (6T) report by ASG

(2) Injection by Zejia & S. Ogawa

(3) Polarization by **Shreya** & S. Kamioka

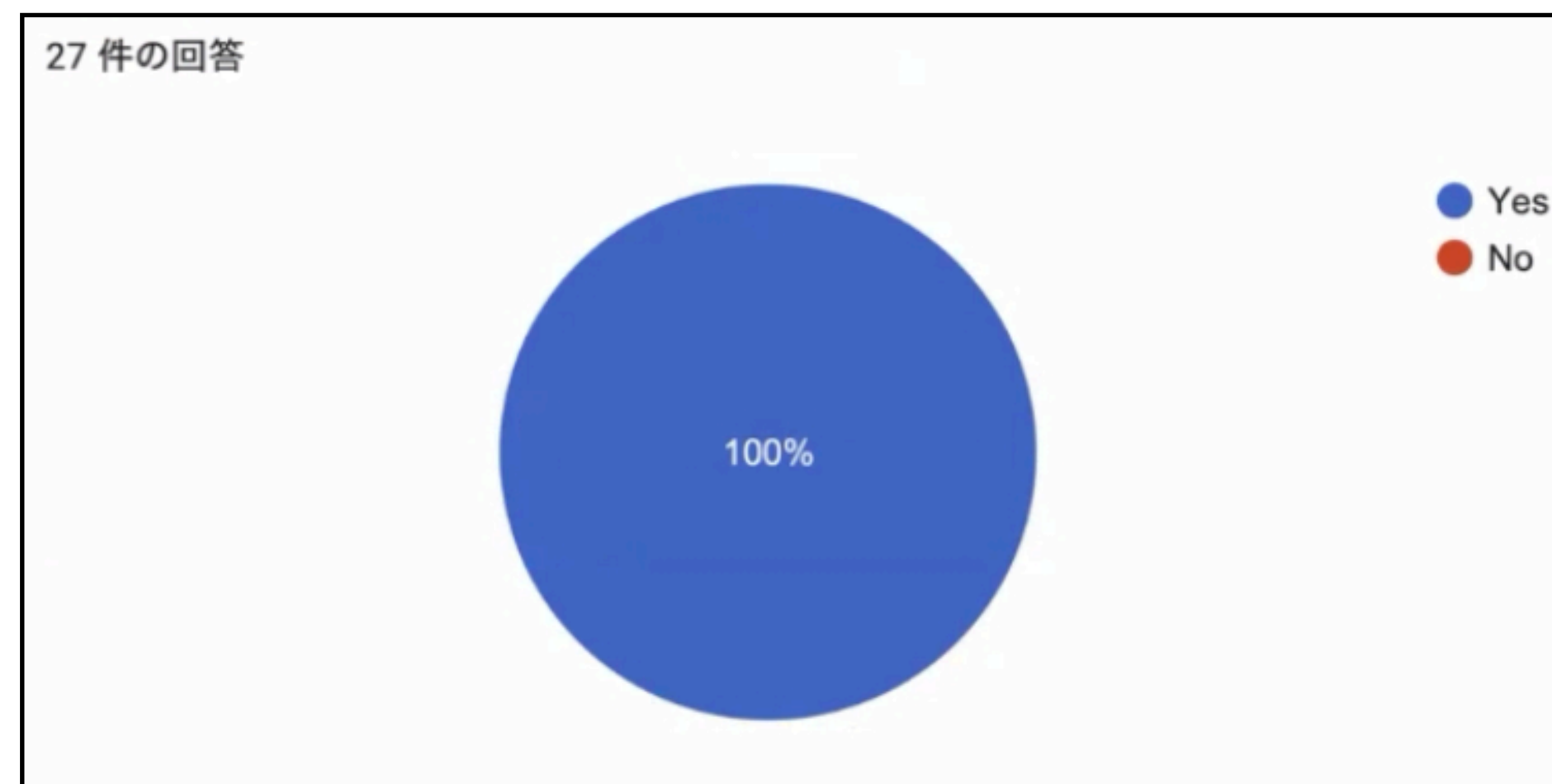
(4) LINAC by **Elia** & M. Otani

16:00 → 18:15	HSSG
	Convener: Takayuki YAMAZAKI (KEK IMSS)
16:00	Introduction to HSSG Session: where we are and next steps ? Speakers: Graziano VENANZONI (University of Liverpool and INFN Pisa), Tsutomu MIBE (KEK IPNS) gv_HSSG_CM32200...
16:10	Updates on high-polarization studies Speaker: Shusei KAMIOKA (KEK IPNS) 260625_CM32_SK.p... Shreya_JPARC_CM_...
16:30	Updates on high-energy linac Speakers: Elia BOTTALICO (University of Liverpool), Masashi OTANI (KEK (Acc.)) HSSG_CM32_JPAR...
16:50	Updates on kicker study at 6 T Speaker: Zejia LU (SJTU) Update_on_kicker_i...
17:05	Feasibility of injection at 6T, 600MeV/c Speaker: Shinji OGAWA (KEK IPNS) ogawaCM32_HSSGi...
17:20	Updates on 6-T magnet from ASG Speaker: Giovanni Valesi (ASG) JParc_6T Magnet F...
17:40	Discussion Speakers: Tsutomu MIBE (KEK IPNS), Graziano VENANZONI (University of Liverpool and INFN Pisa)

J-PARC Muon g-2

A quick status update

- A critical decision was made: “**Decision on go/not to go to HSSG's proposal**”
- The collaboration *agreed* to proceed with the Phase-2 of the high sensitivity study (towards 100 ppb). That’ a major step forward after almost one year of work and a significant contribution from Liverpool



Collaboration-wide Questionnaire

Comments

3 件の回答

In my opinion, even if we go for HSSG phase 2, the decision on ASG's phase 2 study should be made separately.
I am not opposed to ASG's phase 2 if the budget allows; however, we also need to pursue alternatives—other companies or an in-house study—because I do not think we can rely on them alone for our future.

If the 2027 report is successful, I would be in favour of having both an addendum to the TDR and a dedicated collaboration physics paper.

In both cases, if HSSG would be accepted or not, the undersatanding of the opportunities and limitations is very important for future studies.

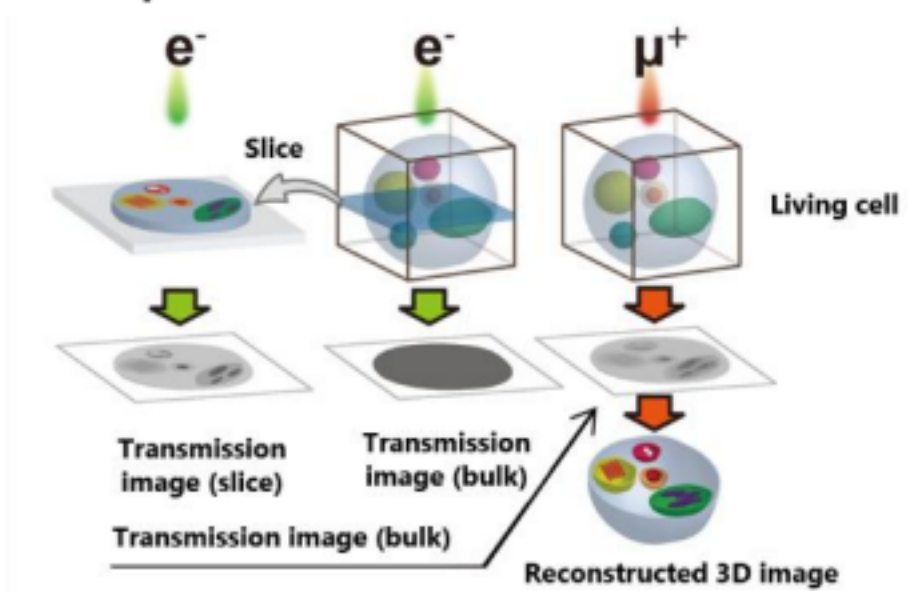
J-PARC Muon $g-2$

A quick status update

- A critical decision was made: “**Decision on go/not to go to HSSG's proposal**”
- The collaboration *agreed* to proceed with the Phase 2 of the high sensitivity study (towards 100 ppb). That’ a major step forward after almost one year of work and a significant contribution from Liverpool
- **Phase-2:**
“A 6-12 month detailed study aimed at assessing the feasibility of achieving a statistical uncertainty at the $O(100 \text{ ppb})$ level, with a final report expected in **2027** which could serve as the basis for an addendum to the TDR and/or a dedicated collaboration physics paper. ”

Status - upstream beamline

Transmission muon microscope ($T\mu M$)
Observe bulk samples utilizing the strong penetrative power of re-accelerated muons



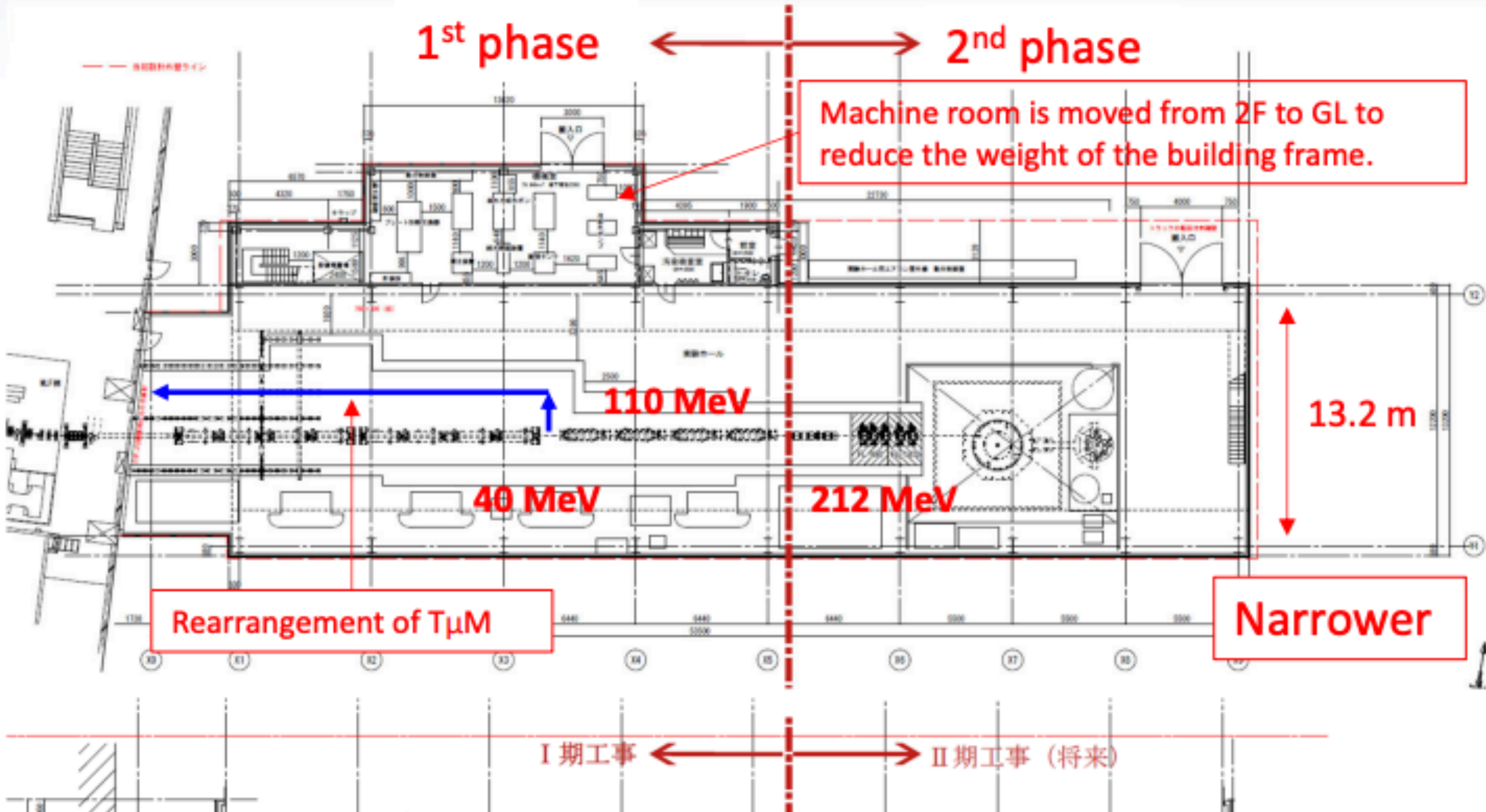
H-line

Redesign of the H-line experimental building

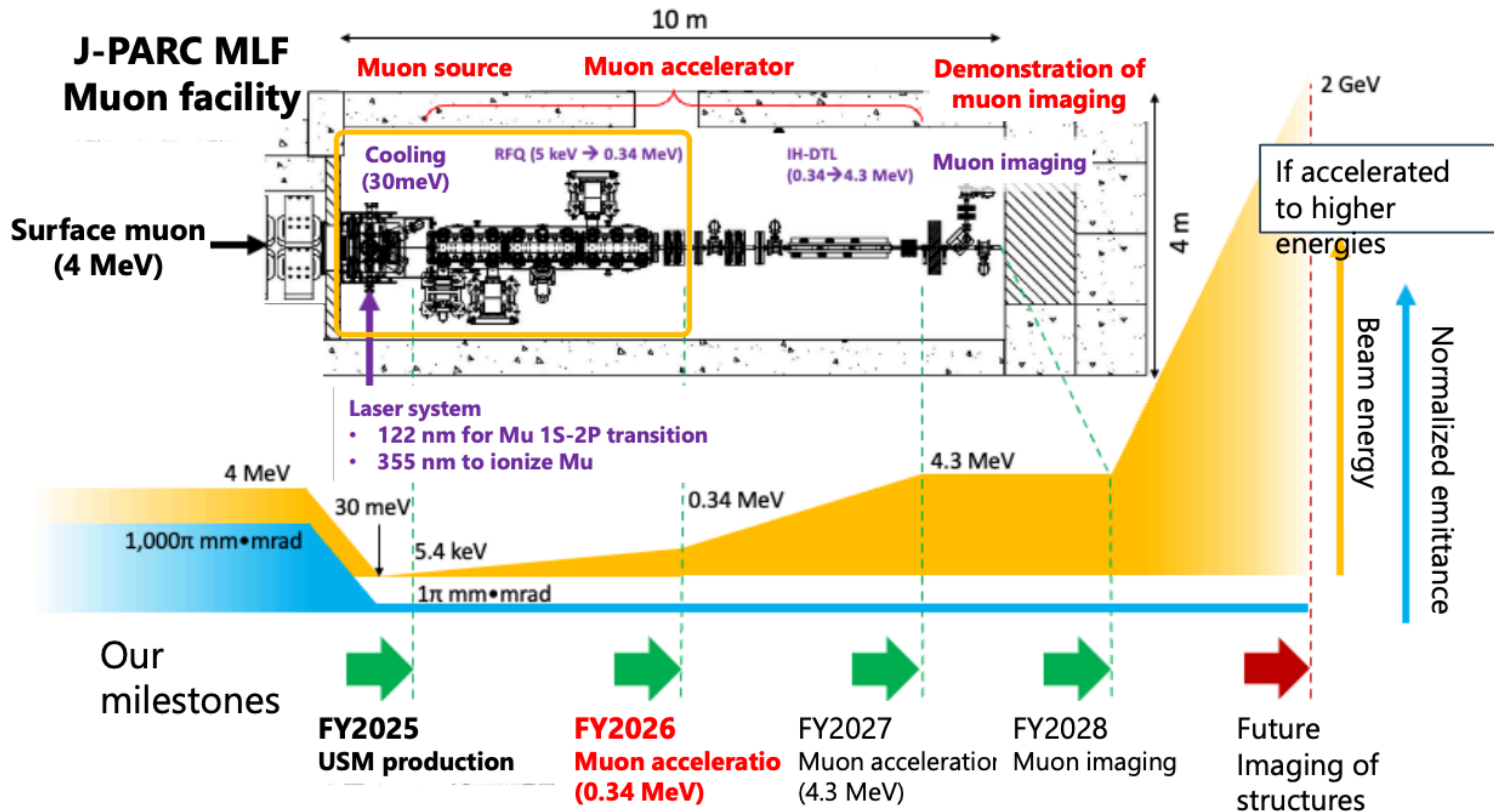
We are redesigning with KEK facilities department and a design firm to reduce construction cost.

Construction will be carried out in two phases.

- 1st : 40-110 MeV
- 2nd : 212 MeV or more



USM production and acceleration at H2 area

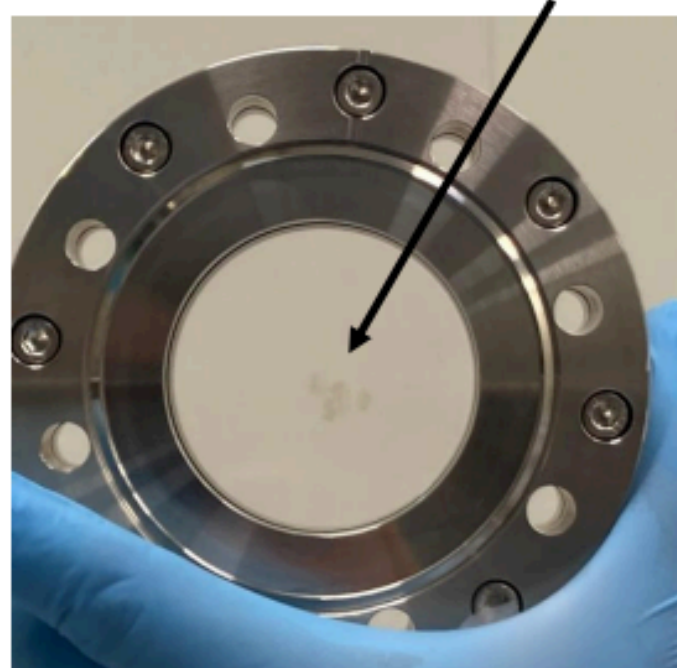


Status - cold muon source

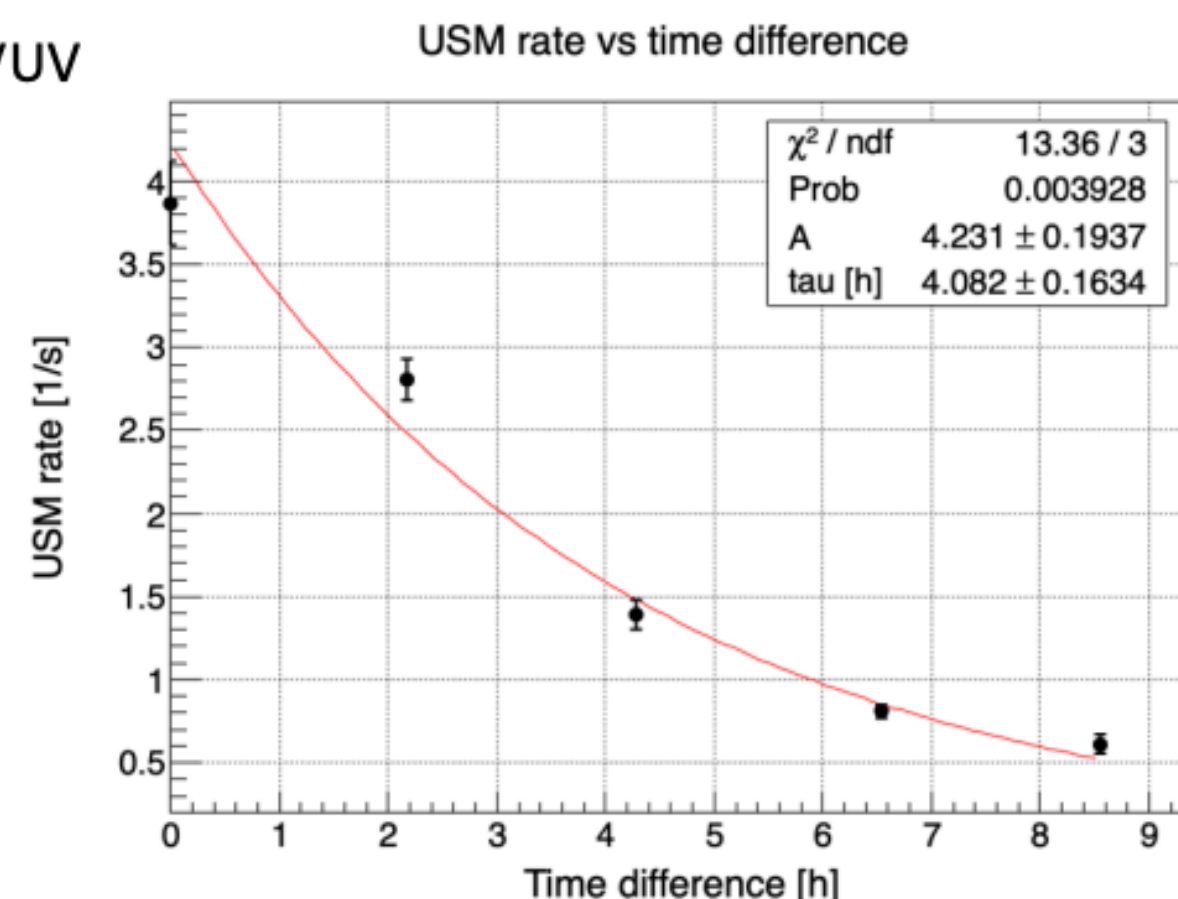
2nd beamtime in June 2026

- Successfully produced 10 muon/s @ RFQ. ($\times 200$ from previous acieration test).
- It was found that the **decrease of VUV energy is very quick**. $\rightarrow$ Optics degradation?
 - Laser tuning was necessary **almost everyday**.
- ✓ This degradation speed is **much faster than that of U-line laser**. Possible reason could be the vacuum environment???
 - 10^{-6}Pa @ U-line $\leftrightarrow$ 10^{-4}Pa @ H2 area

Evan after the 1st beamtime in Dec, when VUV energy is very low, the degradation of the windows was observed.



USM rate decay time is just 4 hours...



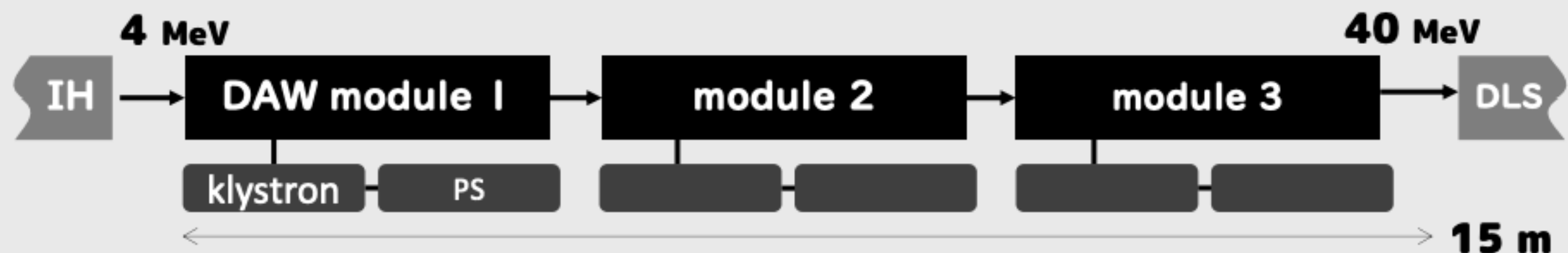
Towards the competition of phase-1

- **Optimization of VUV production:** Naively scaling from U-line's value, we can expect $\sim 8\mu\text{J}@122\text{nm}$ $\leftrightarrow$ ~ 3 times higher than the energy during beamtime. $\times 2\sim 3$ times more USM?
 - **Optimization of linewidth of 820nm:** another $\times 2\sim 3$ improvement in USM rate.
 - **Establishment of stable VUV production:** this could be the main challenge? We need to understand why the degradation is so quick.
 - **Further automation & data recording:** in the U-line, laser parameter measurement is also repeatedly performed automatically.
- **10 USM/s $\rightarrow$ 100 USM/s ???**

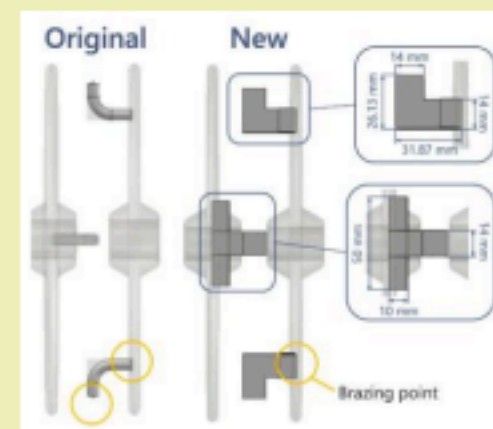
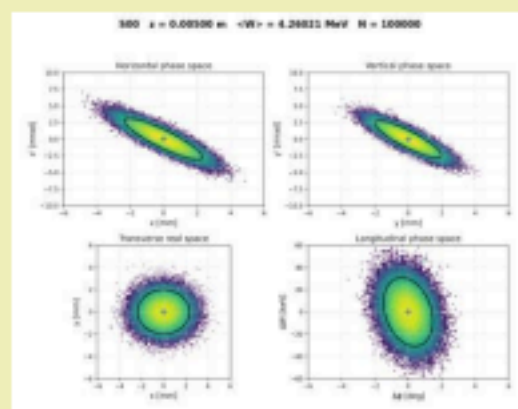
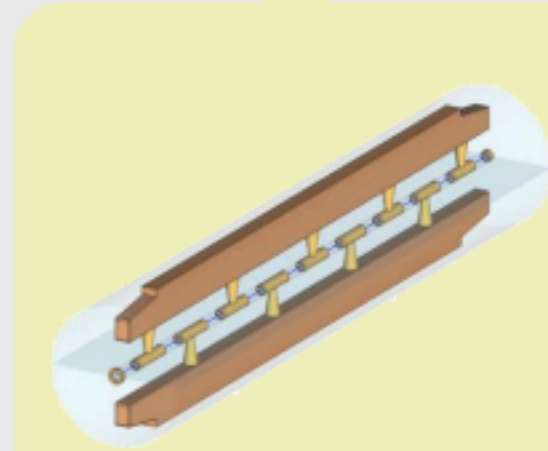
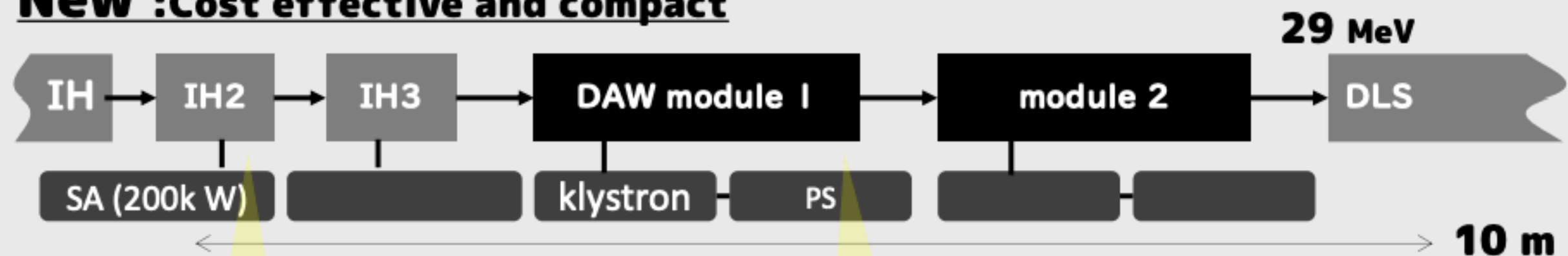
Status - LINAC

New Configuration

Current



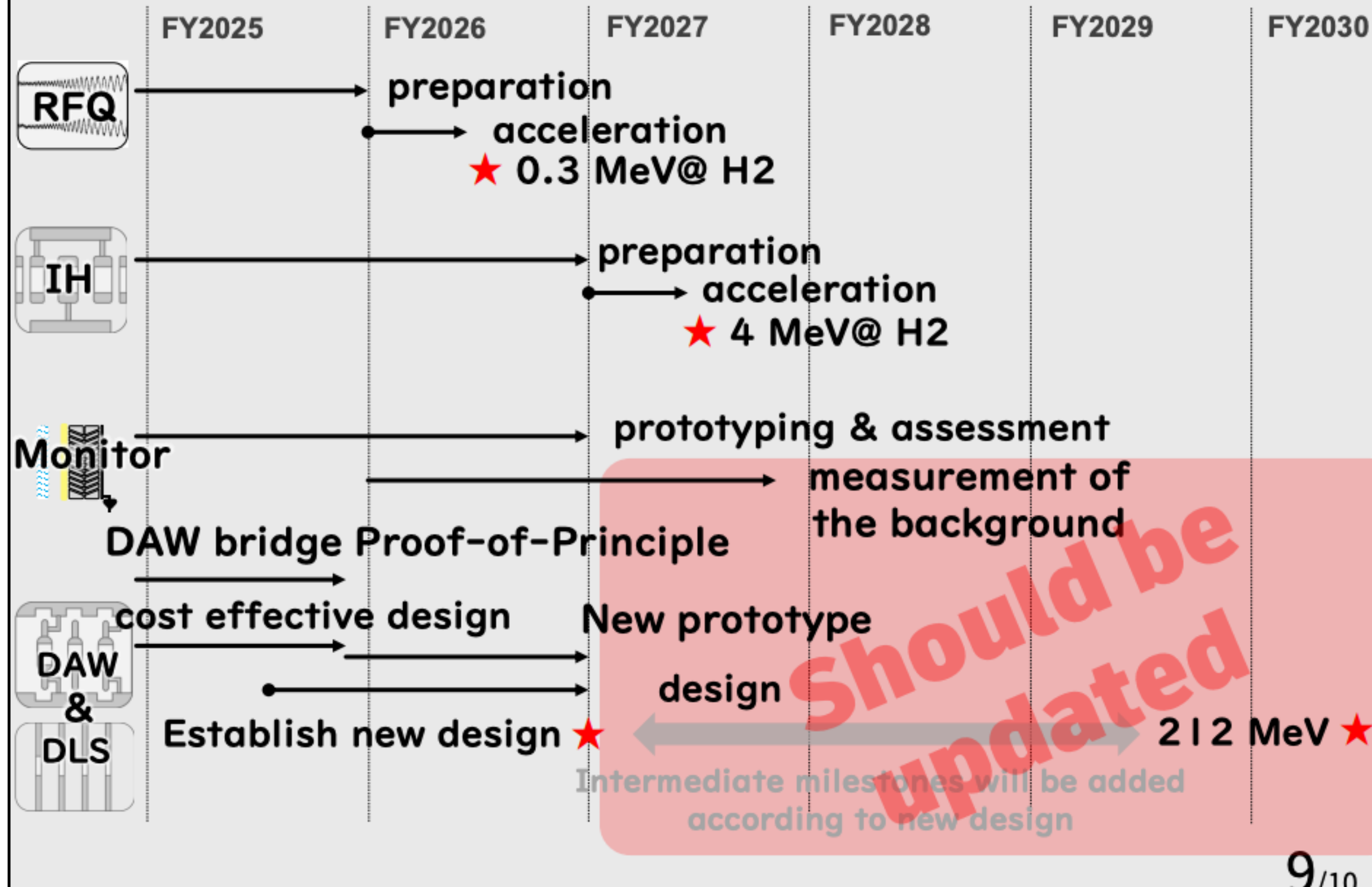
New :Cost effective and compact



Detail design is in progress for new configuration.
Full scale DAW will be fabricated and tested .

7/10

Schedule



9/10

Status - 3D injection

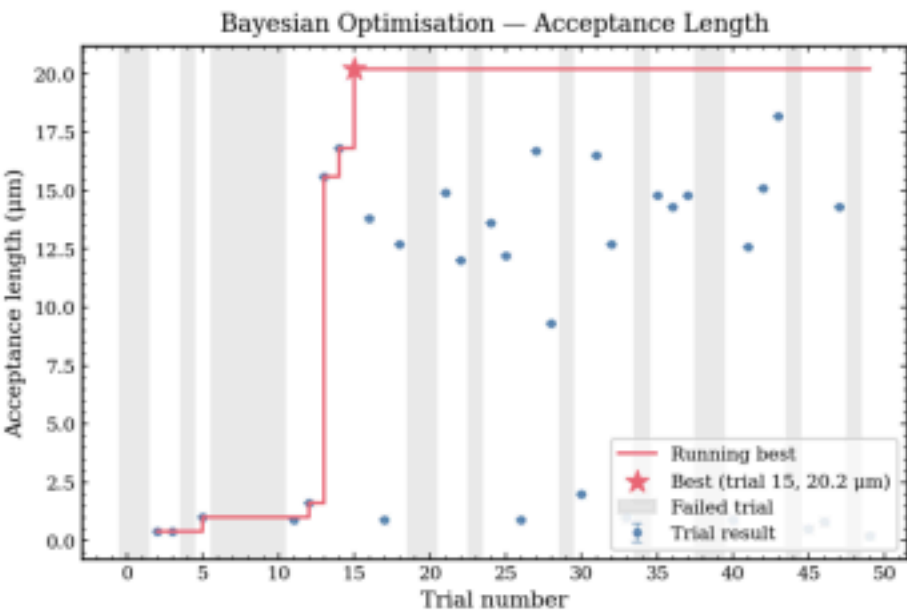
Finding in Zejia's study

- A third kicker coil enhances the acceptance under an applicable kicker voltage constraint.
 - Likely, not only for the 6T design but also for the 3T.
- **Assuming that B_r in the 6T magnet is the same as that in the 3T magnet** (except for simple scaling), the acceptance width becomes large enough.

Bayesian optimization

With the acceptance at injection point as optimize target.

Again, the best point cannot have much improvement.



Best acceptance: 20.2 μm

Parameter name	Range
Weak focus strength factor	1.41
Kicker time period	273 ns
Kicker z width	6.8 cm
Lower kicker top	-5.1 cm
Upper kicker bottom	18.8 cm
Upper kicker gap	3.5 cm
Kicker current (lower)	-1014 A
Kicker current (upper)	821 A

26/06/25, Feasibility of HSSG injection

2

Conclusion on 'feasibility of HSSG injection' 6

- **No show-stopper is seen for injection at 6T & 600 MeV/c**, assuming the static field is simply scaled from 3T.
- A third kicker coil enhances the acceptance under an applicable kicker voltage constraint.
- We need **conceptual design of the 6T magnet** so that we can then refine it to also fit the injection.

26/06/25, Feasibility of HSSG injection

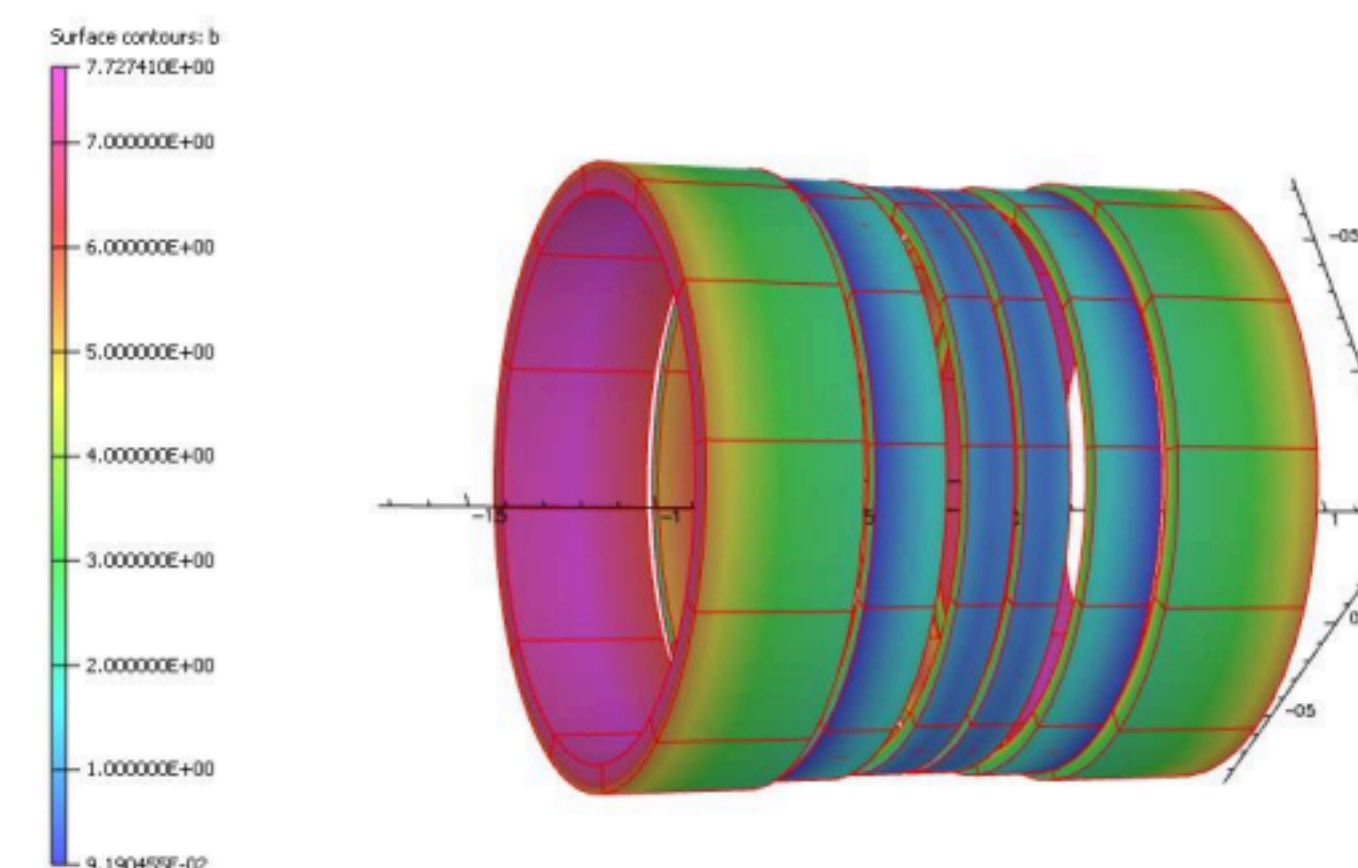
Status - 6T magnet

6T MAGNET: EVEN COILS DESIGN CONFIGURATIONS

Starting from 3T configuration and using a stochastic algorithm used for MRI magnets, solutions were found for 6T and then applied into OPERA with the addition of the iron yoke to see its contribution.

Data	Configuration 1			Configuration 2			Configuration 3		
	Coil1	Coil2	Coil3	Coil1	Coil2	Coil3	Coil1	Coil2	Coil3
Rinn [mm]	808.2	808.1	808.1	798.2	803.2	798.2	798.2	805.4	798.2
Rext [mm]	905	859.1	852.7	877.8	870	842.7	877.8	856.3	845.9
Zinn [mm]	522.9	179.5	15	457	165.3	15	465.4	219.4	15
Zext [mm]	999.3	408.5	152.3	991	334.7	127.1	907.5	425.4	152.3
Turns	208	100	60	233	74	39	193	93	60
Layers	58	32	28	50	42	28	50	32	30
Current	417.5			390			414		
B0 without iron [T]	5.88			5.45			5.40		
B0 with iron [T]	6.46				6.02			5.97	

6T COILS IN AIR (CONF. 3)



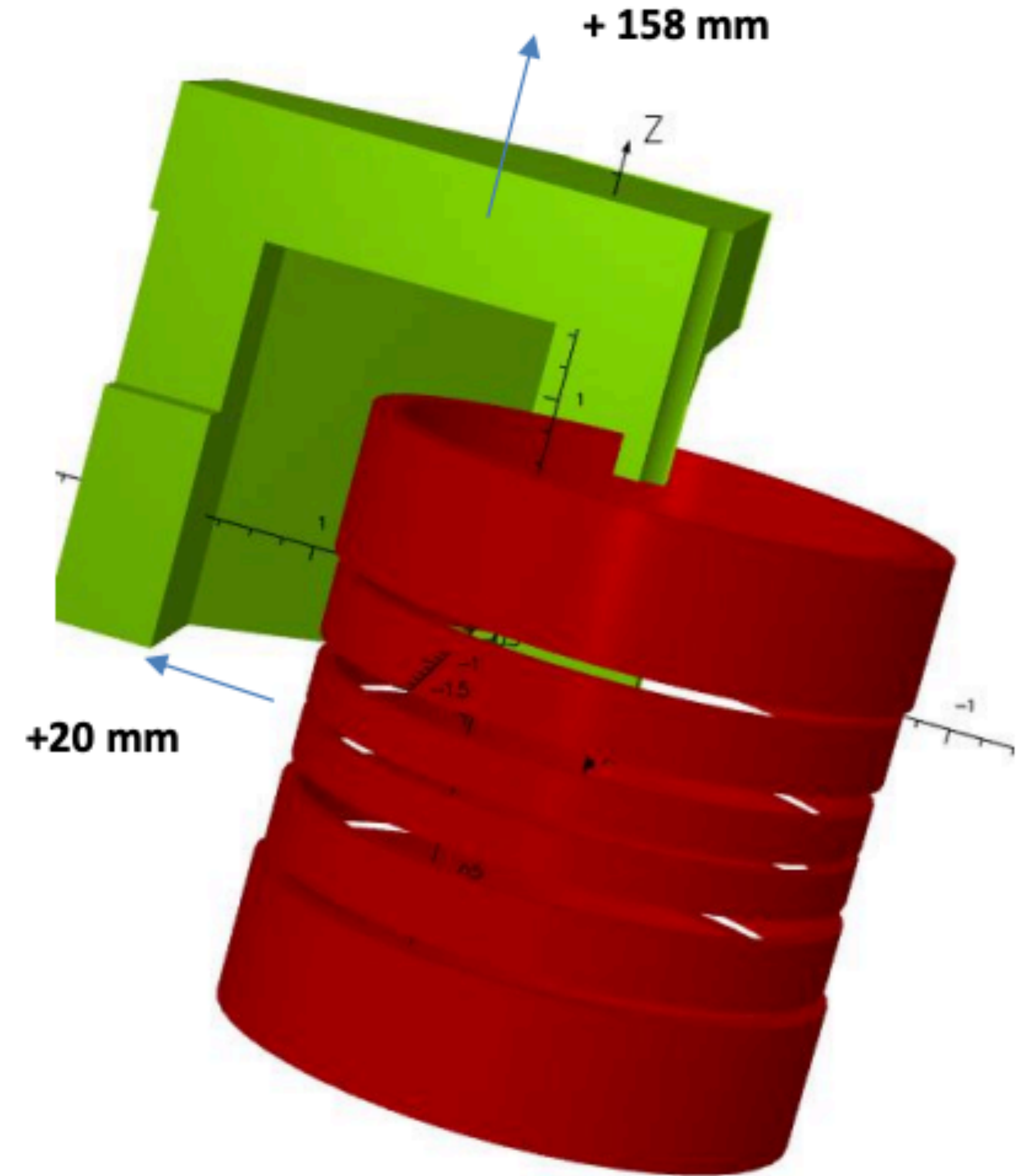
Next steps – iteration with Iron yoke variation

$B(0,0) = 5.9445 \text{ T}$
 $B_{zav} \text{ (storage region)} = -5.92 \text{ T}$
 $B_z(0.333,0) = -5.92 \text{ T}$
 $Pk2Pk = 1573 \text{ ppm}$
 $B_{max} \text{ on coils} = 8.11 \text{ T}$

Different yoke thickness variations have been evaluated.

To improve field homogeneity, the most effective parameters are:

- The dimension and geometry of the pole tip
- The radial and vertical distances between the coils and the yoke



Storage region:

R:[318; 348] mm – step 5 mm

Z: [-50; 50] mm - step 5 mm

At this final stage of the 6T pre-study, no critical issues have been identified:

1. New designs are achievable with an increase in coil dimensions by a factor of 1.5–2, depending on the iron configuration. This remains compatible with the existing experimental room.
2. Forces and maximum magnetic field remain within a manageable range.
3. Some design solutions appear feasible using the same conductor as in the 3T design.
4. In all cases, commercial conductors with improved performance are available to meet the requirements of the more demanding configurations explored



CONCLUSION AND NEXT STEPS (PHASE 2)

A Phase 2 feasibility study and conceptual design, should cover the following aspects:

- Magnet + yoke design to achieve the requested homogeneity
- Correction/functional coils
- Mechanical analysis
- Cryogenics
- Quench protection
- Manufacturing and Components tolerances
- Cost evaluation

An estimation of total cost range for the complete main magnet + (passive and active) shimming systems with the iron yoke is around **5-10 Million €**, including also:

- Mandatory Certifications
- Powering system
- Cooling system
- Final tests: Factory Acceptance Test (FAT) , Site Acceptance Test (SAT)
- Shipping to destination (Japan)
- Installation
- Final technical dossier and User Manual
- Cryogenic fluids are **excluded** from the estimation

Please note that the more detailed design activities planned for a **Phase 2** will allow for a significantly more accurate and refined cost estimation.

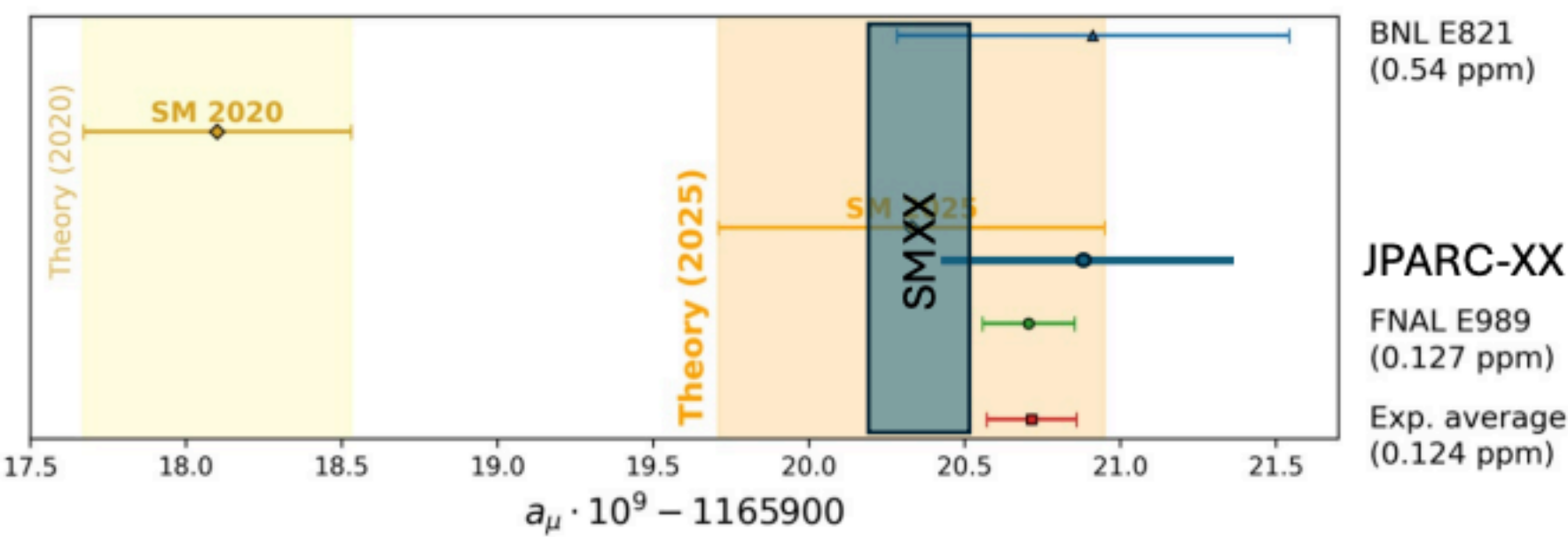
Summary

- At Phase-1 HSSG, no showstopper was found over all aspects
- The collaboration decided to go to HSSG phase-2
- In my opinion, this experiment was essentially saved by Liverpool through Graziano's leading effort
- Besides 6T magnet (w/ injection) for HSSG, Elia and Shreya will tell us about LINAC/polarization

backup

Reminder: Why HSSG

Status around 20XX (post-JPARC) (with 450 ppb; 3x improvement on theory)



BNL E821
(0.54 ppm)

Experimental error: **XXX** ppb
(FNAL+JPARC)

Theoretical error: **180** ppb (SM20XX)

JPARC-XX
FNAL E989
(0.127 ppm)

Cross check of Fermilab (storage ring method)

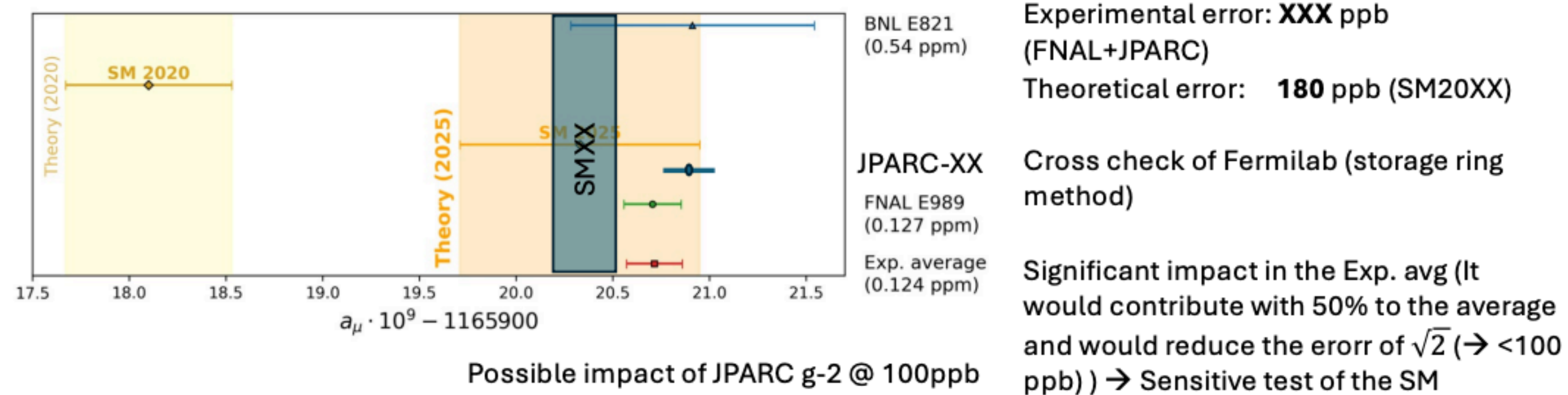
Exp. average
(0.124 ppm)

Limited impact in the Exp. Average (and SM test)

Possible impact of JPARC g-2 @ 450ppb

Reminder: Why HSSG

Status around 20XX (post-JPARC) (with 120 ppb; 3x improvement on theory)



$\rightarrow$ Importance of reducing the experimental uncertainty $\rightarrow$ High Sensitivity Studies: possibility to go at 100 ppb statistical uncertainty and beyond (!)

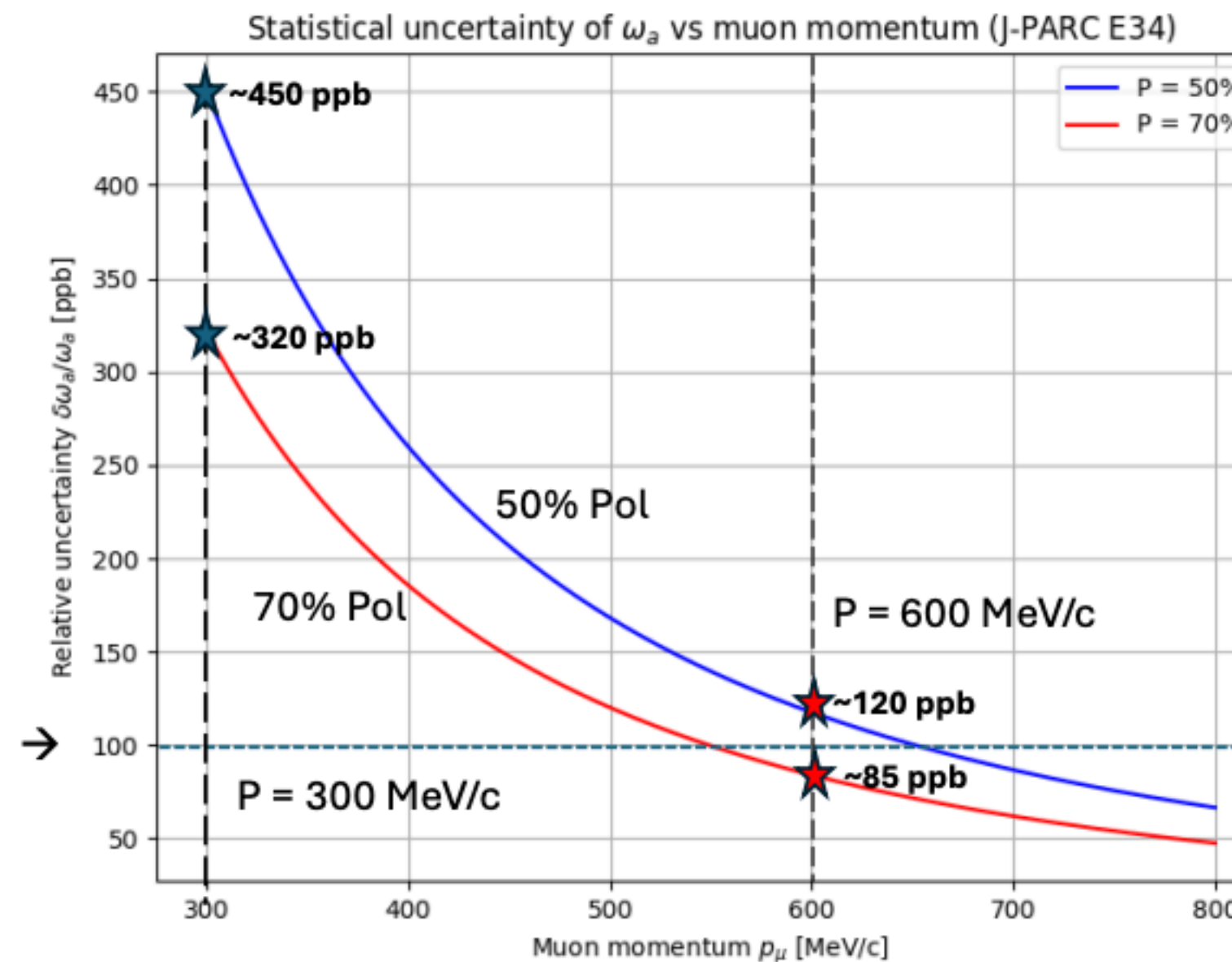
The improvement on the theory although challenging is possible (Lattice; scrutiny of old e+e- data; new e+e- data; MUonE;..)

Possibilities for improvement

[2512.20335](#)

$$\frac{\delta\omega_a}{\omega_a} = \frac{1}{\omega_a\gamma\tau P} \sqrt{\frac{2}{NA^2}}$$

E989 achieved
statistical error →



600 MeV with 50% (**70%**) polarization → ~120 (**85**) ppb statistical error

Competitive (**even better**) than Fermilab.

It requires upgrade of linac, magnet (6T) (**and muon polarization**)¹⁰

J-PARC Muon $g - 2/\text{EDM}$ experiment (E34)

Muon cooling

- Surface muon (3.4 MeV, large emittance)
→ thermal muon (0.2 eV, low emittance)

Muon LINAC

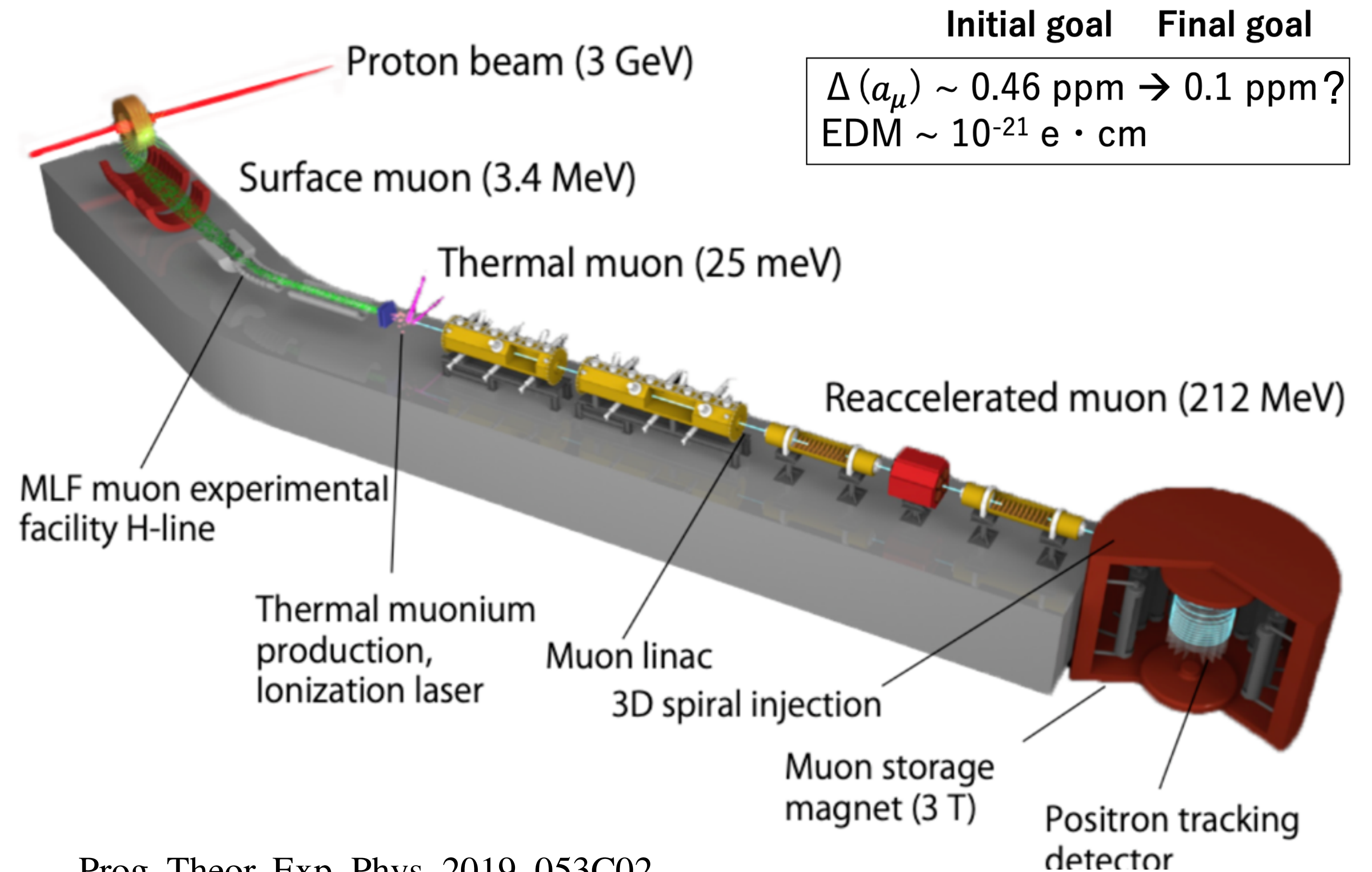
- Muon acceleration to 212 MeV

3D spiral injection

- Large kick angle within a few ns
- Good injection efficiency

Storage ring

- Compact storage ring
- Tracking detector



Prog. Theor. Exp. Phys. 2019, 053C02

J-PARC Muon $g - 2/\text{EDM}$ experiment (E34)

