J-PARC Muon g-2

A quick status update

- The latest CM 31 (Dec 2025): https://kds.kek.jp/event/57310/timetable/?view=standard
- INFN team has also joined the collaboration (Napoli, Pisa, Rome Tor Vergata, Trieste)

CM30 (June 2025)

CM31 (June 2025)

- Jan-Mar (2026)
  - MEXT funding decision
  - J-PARC PN PAC (Jan 21-23)
  - KEK SAC (Feb 24-26)
  - J-PARC IAC (Mar 9)
  - IPNS progress review (Spring)

Support letter to DG

The experimental world average is dominated by the Fermilab Muon $g-2$ experiment, based on the same experimental method as all $g-2$ experiments in the last 50 years starting from the CERN III experiment. While its value agrees with the SM prediction based on lattice-QCD calculations for the hadronic-vacuum-polarization (HVP) contribution, the uncertainty on the theoretical prediction is four times larger than that of the experiment. The decision in the 2025 White Paper of the Muon $g-2$ Theory Initiative to rely solely on lattice QCD for the HVP contribution is due to unsolved puzzles on the SM theory side, particularly issues concerning the experimental inputs in the dispersive method, and their resolution may have profound implications for the comparison. In short, the question "Does the SM agree or disagree with the experimental value of the muon's anomalous magnetic moment?" has not yet been satisfactorily answered.

The Muon $g-2$ Theory Initiative
Steering Committee

December 14, 2025

Dr. Shoji Asai
Director General
Inter-University Research Institute Corporation
High Energy Accelerator Research Organization (KEK)
1-1 Oho, Tsukuba, Ibaraki, 305-0801
Japan

Dear Asai-san,

We are writing to express our strong support for J-PARC's muon $g-2$/EDM experiment, which proposes a highly innovative measurement of the muon anomalous magnetic moment, $g-2$. Confronting its precision measurement with theoretical predictions constitutes one of the most important low-energy tests of the Standard Model (SM) of particle physics.

The experimental world average is dominated by the Fermilab Muon $g-2$ experiment, based on the same experimental method as all $g-2$ experiments in the last 50 years starting from the CERN III experiment. While its value agrees with the SM prediction based on lattice-QCD calculations for the hadronic-vacuum-polarization (HVP) contribution, the uncertainty on the theoretical prediction is four times larger than that of the experiment. The decision in the 2025 White Paper of the Muon $g-2$ Theory Initiative to rely solely on lattice QCD for the HVP contribution is due to unsolved puzzles on the SM theory side, particularly issues concerning the experimental inputs in the dispersive method, and their resolution may have profound implications for the comparison. In short, the question "Does the SM agree or disagree with the experimental value of the muon's anomalous magnetic moment?" has not yet been satisfactorily answered.

Recent changes in the SM prediction have shown that a well-established method (the dispersive approach) for determining the HVP contribution has been challenged by an innovative and independent approach, namely lattice QCD. The aim of the J-PARC muon $g-2$/EDM experiment is precisely this: to provide an independent verification of the method employed in the direct measurements of the muon $g-2$ over several decades.

Thanks to significant ongoing efforts both using data-driven, dispersive techniques and lattice QCD, the Muon $g-2$ Theory Initiative anticipates substantial improvements in the SM prediction in the coming months and years. This includes, crucially, comparisons among the different methods, as detailed in the 2025 White Paper that summarizes the status of the SM prediction at this point in time. These new results will be compiled in another White Paper, planned to appear before the end of this decade.

As the theoretical picture sharpens, the forthcoming J-PARC measurement will provide essential new experimental input that represents an independent validation based on a distinct, complementary methodology. As the case of the SM prediction shows, independent checks are of vital importance in this endeavor, but for a conclusive validation the J-PARC experiment should strive to match the precision of the Fermilab experiment. We, therefore, strongly support recent efforts by the collaboration towards this goal.

In summary, the J-PARC muon $g-2$/EDM experiment, with its innovative methodology, is in the unique position to test the existing muon $g-2$ measurements, which are the culmination of 50 years of experimental development. Its timely completion would have an amplified impact on the comparison between SM theory and experiment, which will sharpen the constraints on physics beyond the SM. This view is widely shared within the Muon $g-2$ Theory Initiative, as indicated in the 2025 White Paper.

We thank you very much for your attention.

Sincerely,
Gilberto Colangelo (Universität Bern)
Achim Denig (Johannes Gutenberg-Universität Mainz)
Aida X. El-Khadra (University of Illinois Urbana-Champaign)
Martin Hoferichter (Universität Bern)
Christoph Lehner (Universität Regensburg)
Laurent Lellouch (Aix Marseille Université)
B. Lee Roberts (Boston University)
Thomas Teubner (University of Liverpool)
Hartmut Wittig (Johannes Gutenberg-Universität Mainz)
…
…

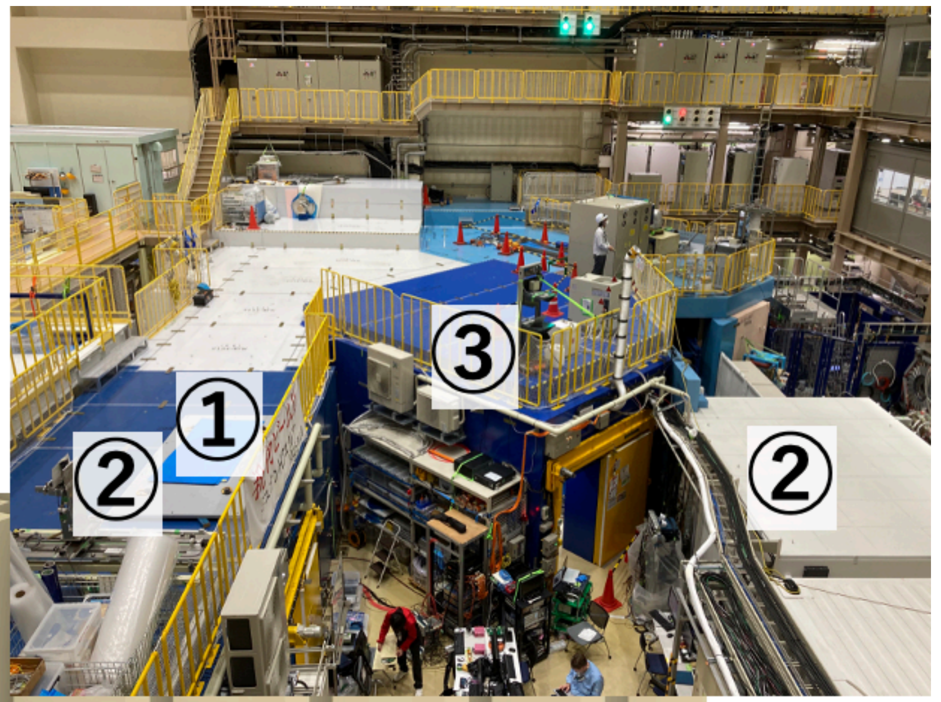
- 192 signers from the international community as of Today
- To be submitted this week

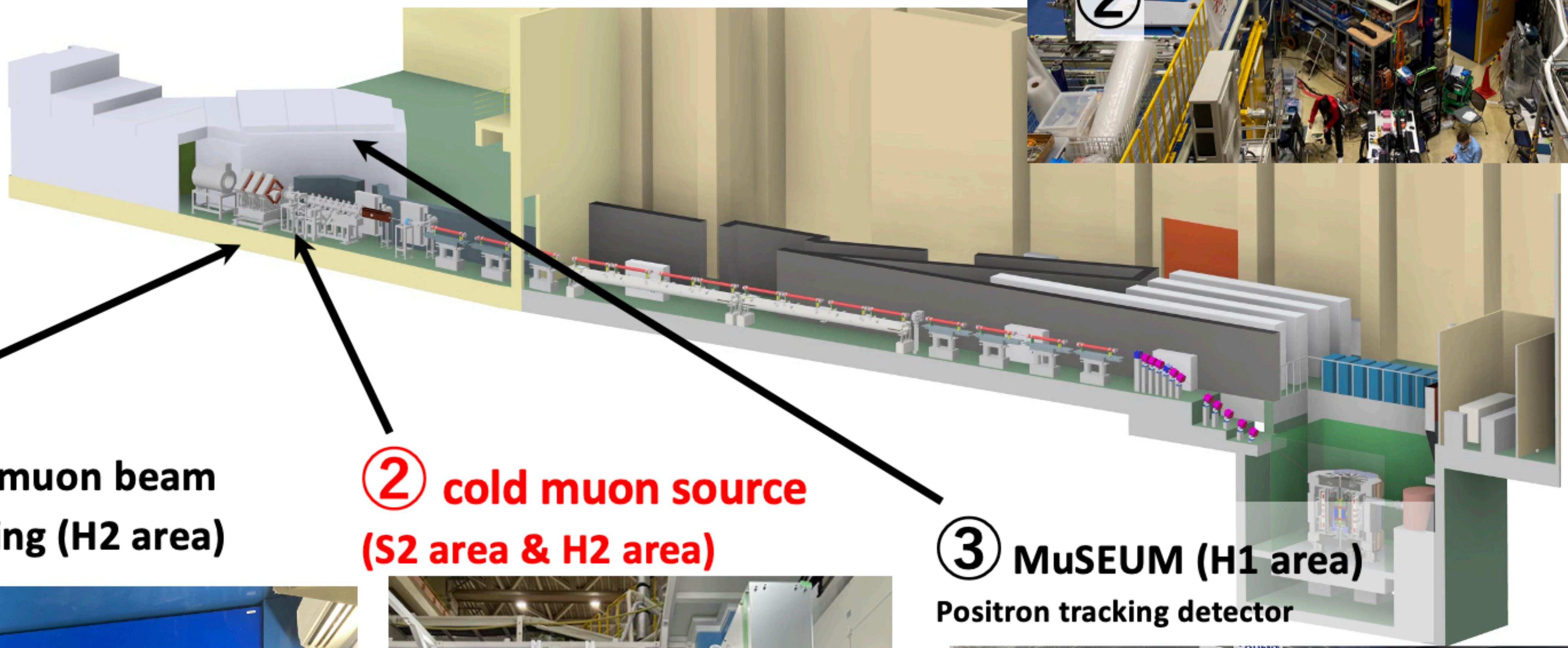
J-PARC Muon g-2

Major test beam activities

Test experiments at MLF

Three experiments are currently running at J-PARC MLF since October 29.



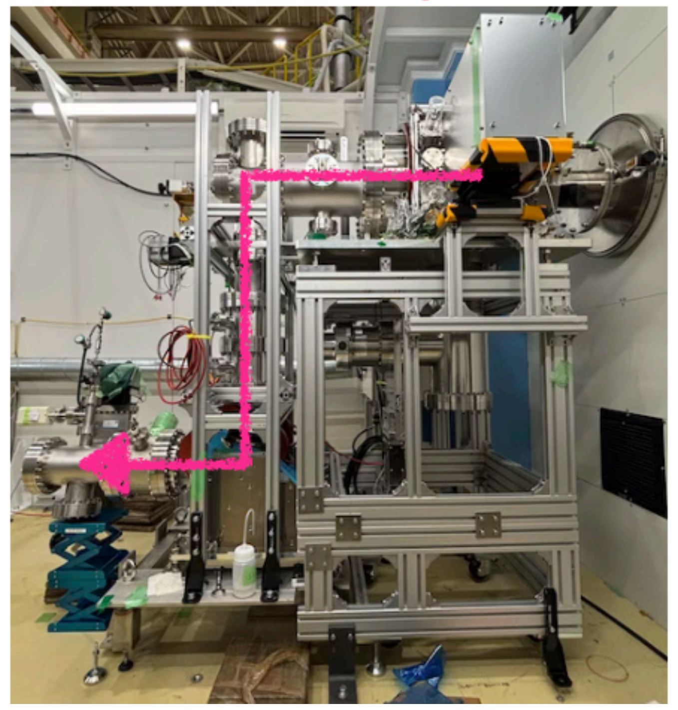


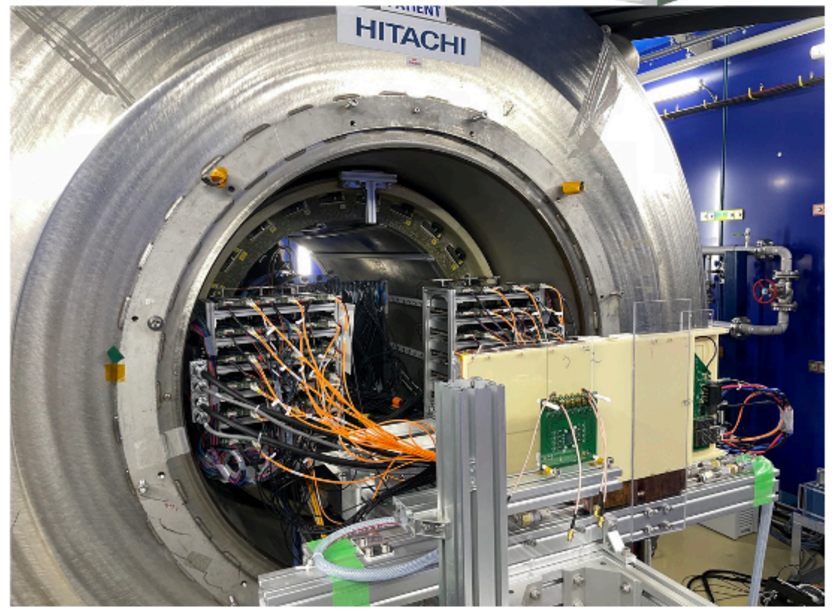
① Surface muon beam commissioning (H2 area)

② cold muon source (S2 area & H2 area)

③ MuSEUM (H1 area)

Positron tracking detector





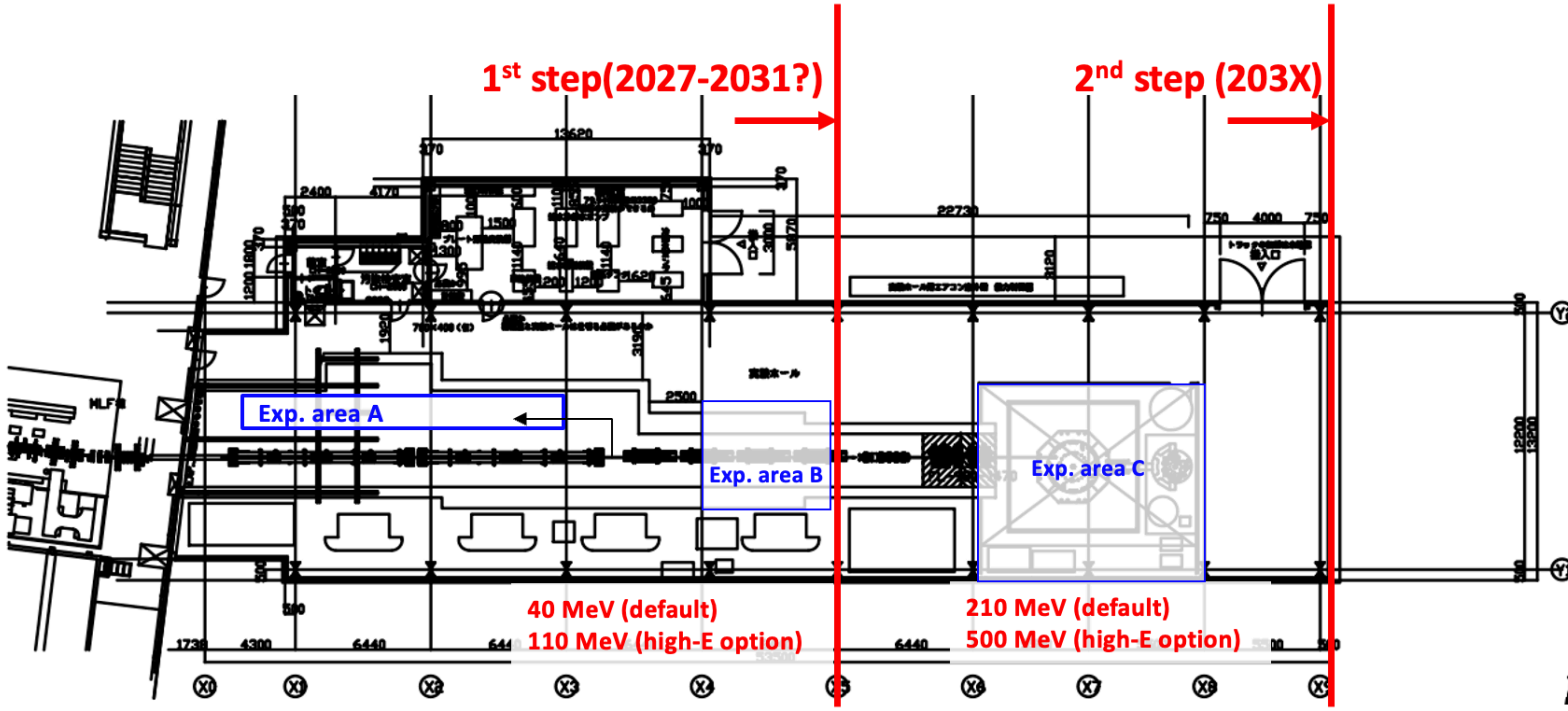
Step-by-step implementation scenario

Comments & suggestions from KEK DG in early November.

0) **funding challenge** to all the projects in KEK

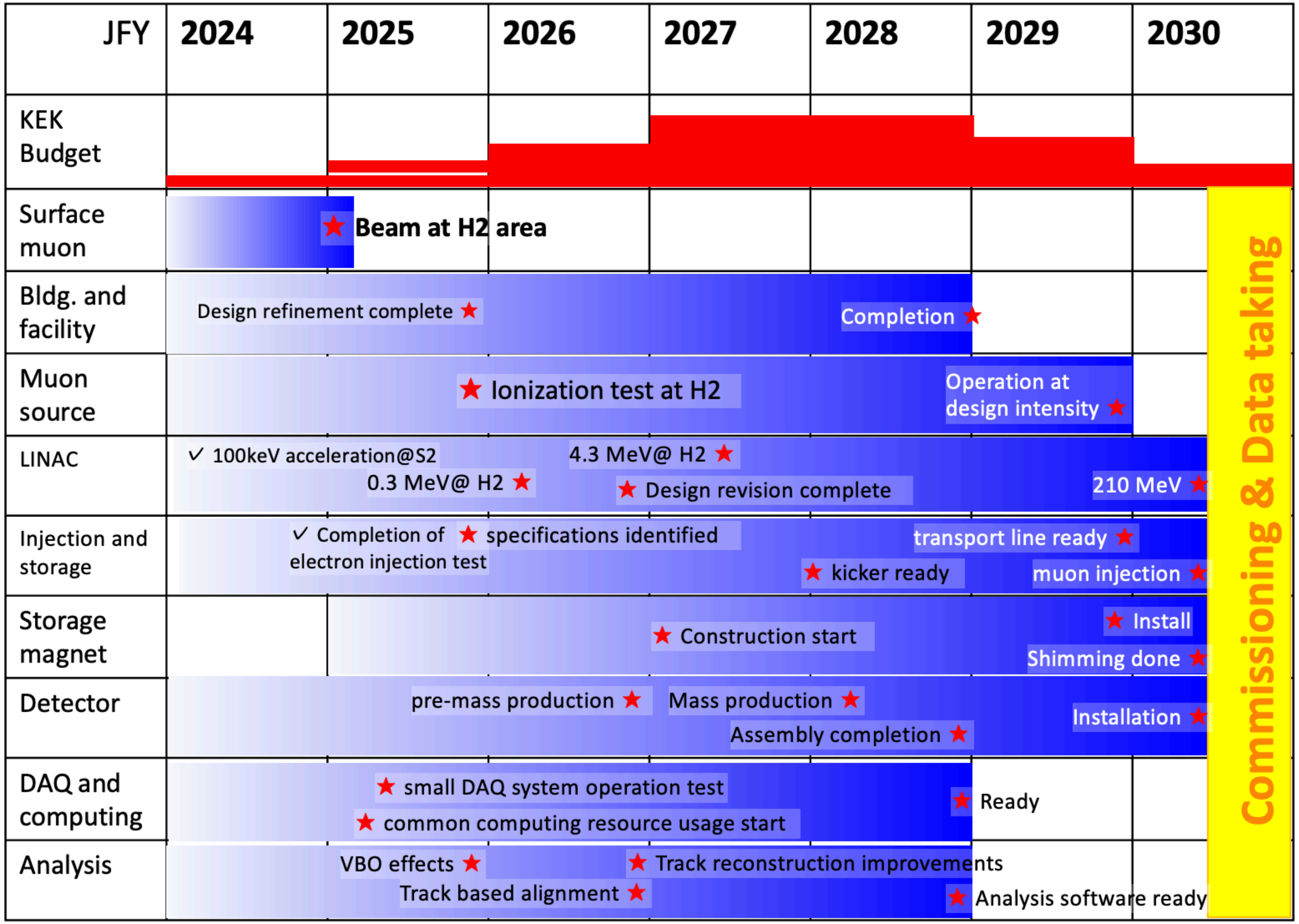
1) construction of the muon accelerator with **a half-size building** as the first step.

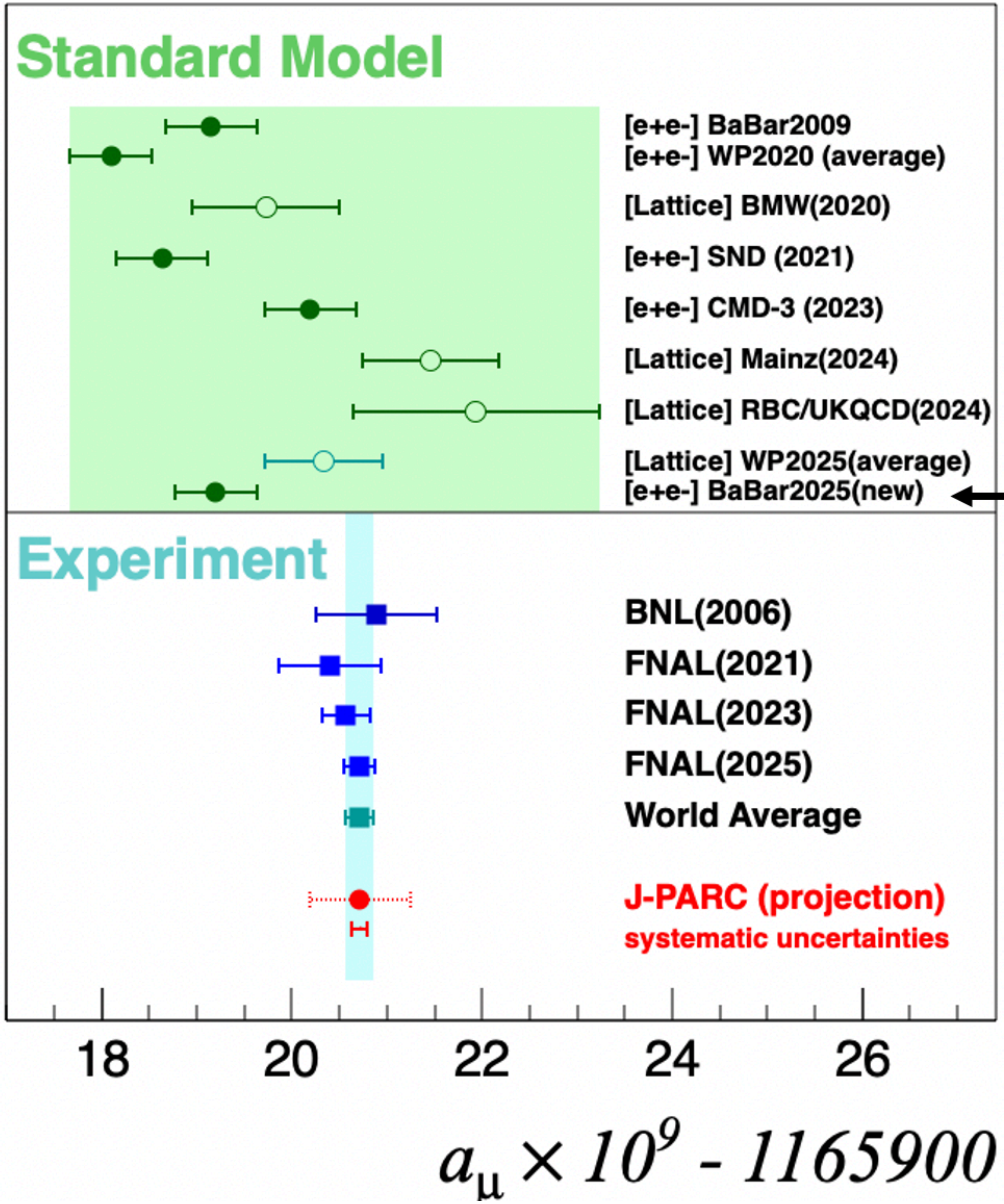
2) experiment should consider making **improvements in experimental precision**. → **HSSG** !!



We would like to discuss these possibilities and develop a collaboration plan during this meeting

The schedule has remained unchanged since April 2025





The NEW BaBar measurement confirmed their 2009 result.

More to come from SND, KLOE, BES III, Belle II and MuonE

We started studies to improve the precision (goal: surpass the FNAL precision)

High Sensitivity Study Group (HSSG) has been established. Graziano and Tsutomu will lead this effort

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

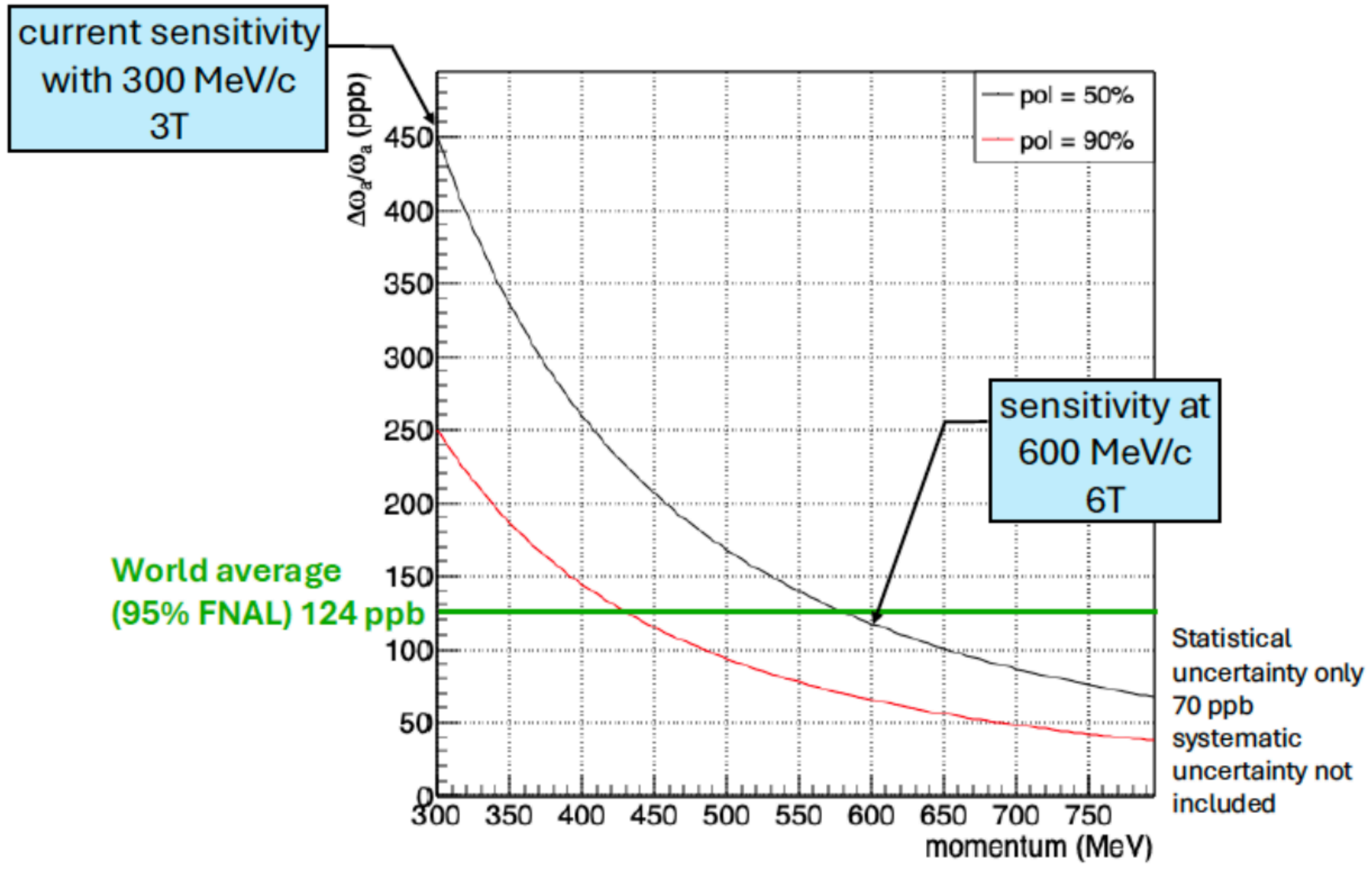
High Sensitivity Study Group (HSSG)

Motivation

The statistical precision of the anomalous spin precession angular frequency ω_a is determined as

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

valuable	definition	value
ω_a	anomalous spin precession frequency, $a_\mu \cdot (eB/m)$	$2\pi/2\ \mu s$
B	magnetic field strength	3 T
γ	Lorentz gamma factor, E/m	3
p	momentum of muon	300 MeV/c
τ	muon lifetime at rest	2.2 μs
P	muon polarization	50%
N	number of detected decay positron	6×10^{11}
A	average analyzing power of positron	0.42



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

1. Higher momentum (γ): Muon acceleration (300 MeV → 600 MeV)
2. Higher B field (3T → 6T)
3. Improve the polarization (P): 50% → 75% (?)

High Sensitivity Study Group (HSSG)

- **HSSG group. Initial members:**
  - Graziano Venanzoni (Chair), Tsutomu Mibe
  - B-field and Injection : Shinji Ogawa, Ken'ichi Sasaki, Ce Zhang, Graziano Venanzoni (on behalf of ASG) + Lorenzo, Saara Chikh (Master student)
  - Acceleration: Masashi Otani, Elia Bottalico
  - High-Pol: Shusei Kamioka, Jonathan Tinsley + Shreya Pipraiya (PhD)
- **Mandate:**
  - Investigate potential / feasibility for higher sensitivity measurements
  - Establish pros and cons
  - Estimation of possible costs
  - Write a document (report)
- **Timeschedule:**
  - June 2026 to complete the studies; December 2026 to distribute (internally) the report. In case of success the report can be the base for an addendum/upgrade of the proposal

Slides by Graziano

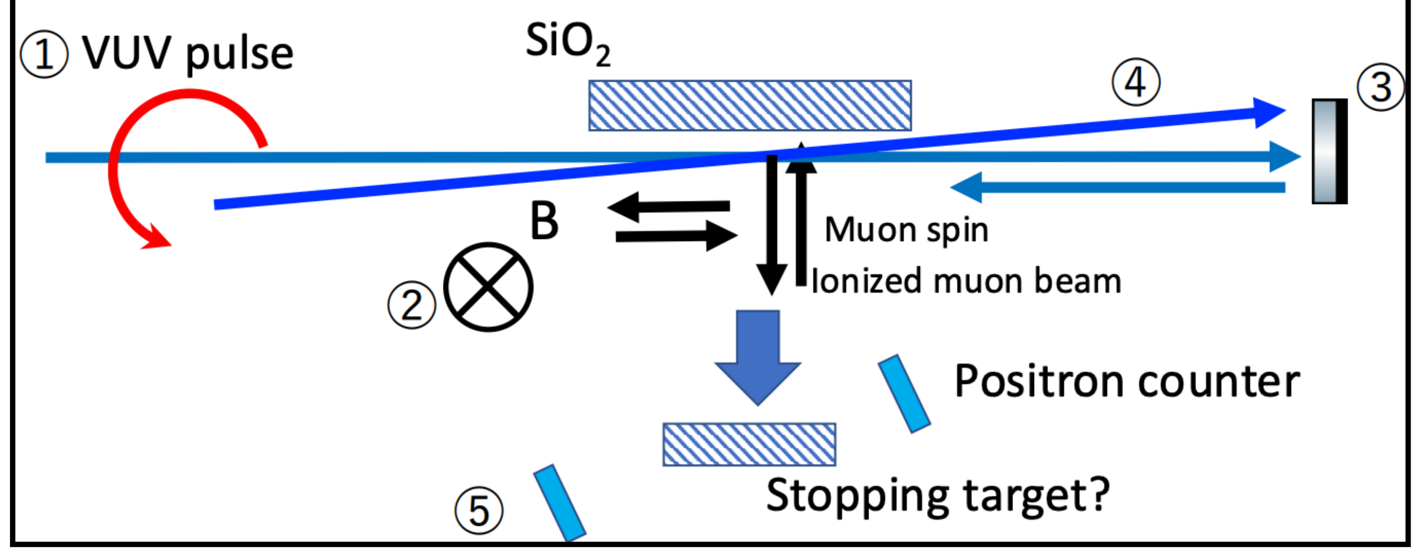
Today

- Elia will talk about **high energy linac** design
- Saara will explain **3D injection towards 6T** magnetic field
- Another item, the **high polarization** - there is a proposal of demonstration experiment by S Kamioka and Shreya will likely contribute to it

- **Thank you!**

Minimum demonstration

1. Circularly polarized VUV pulse
2. Appropriate B-field to rotate Mu spin by 90 degree
3. A reflection mirror to reflect VUV pulse
4. Appropriate 355nm pulse irradiation timing
5. Muon spin polarization detection system (detector/chamber)
   - 5.7keV before acceleration or 340keV after RF-acceleration



Goal

1. Measurement of **relative increase** of spin polarization
   - If possible, determination of absolute value of polarization
   - Understand the increase by comparing with simulation
   - Comparison of the spin polarization under different experimental conditions
2. Understanding practical challenging of the system
   - Alignment of reflection VUV mirror (how to align it???)
   - Damage of the reflection mirror.
   - Designing optical pass so that 355nm pulse does not hit VUV reflection mirror.
   - Muon spin polarization measurement (with low muon beam intensity???)

Feedback into the final design?

backup

J-PARC Muon $g-2$/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

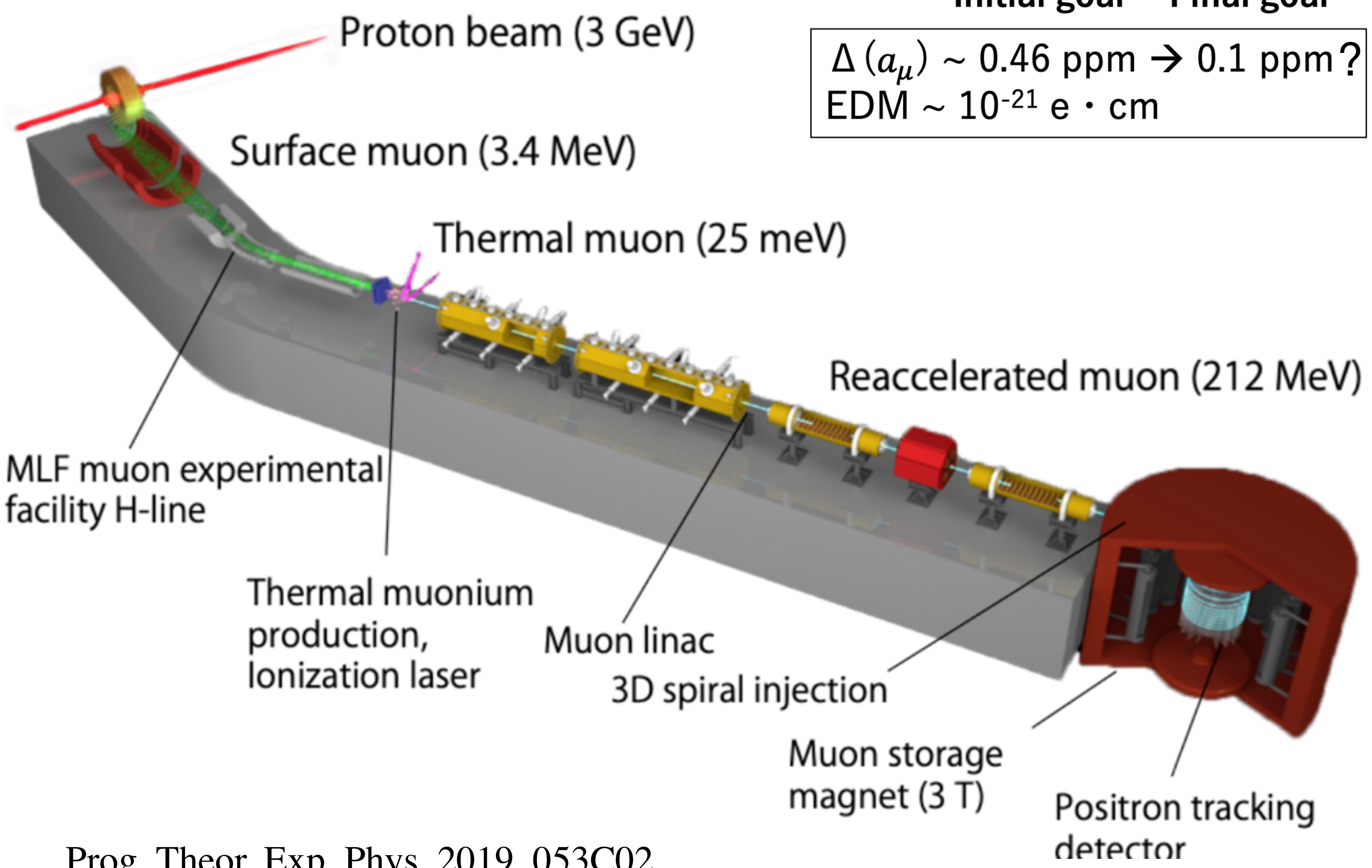
3D spiral injection

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

Storage ring

- Compact storage ring
- Tracking detector

	Initial goal	Final goal
$\Delta(a_\mu)$	~ 0.46 ppm →	0.1 ppm ?
EDM	~ 10^{-21} e・cm	



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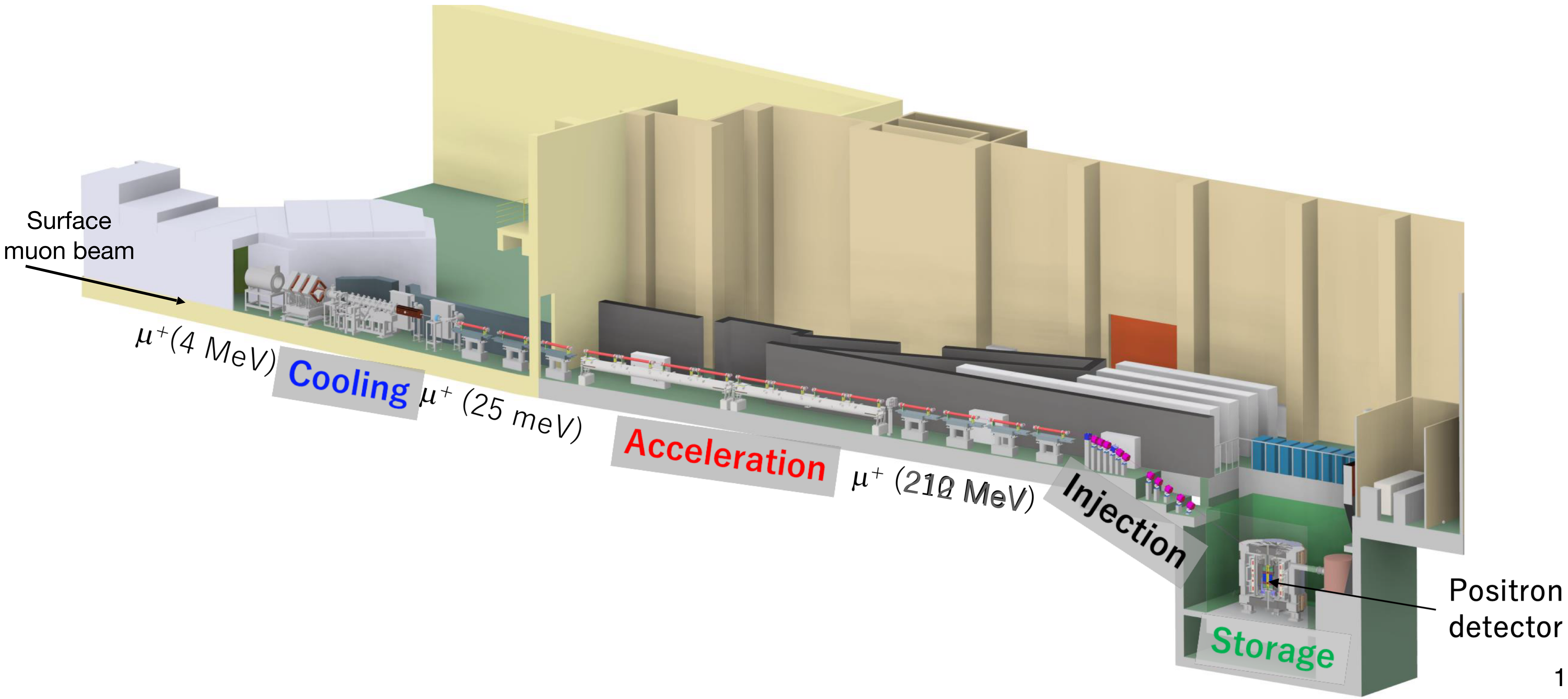
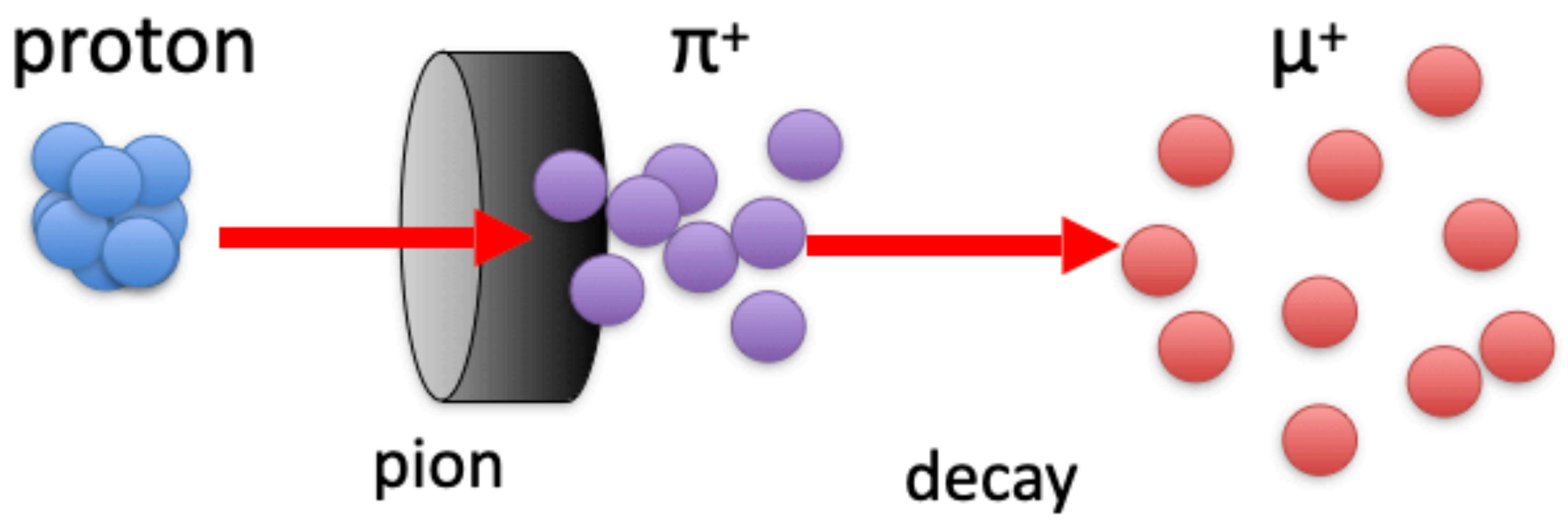
J-PARC Muon $g-2$/EDM experiment (E34)



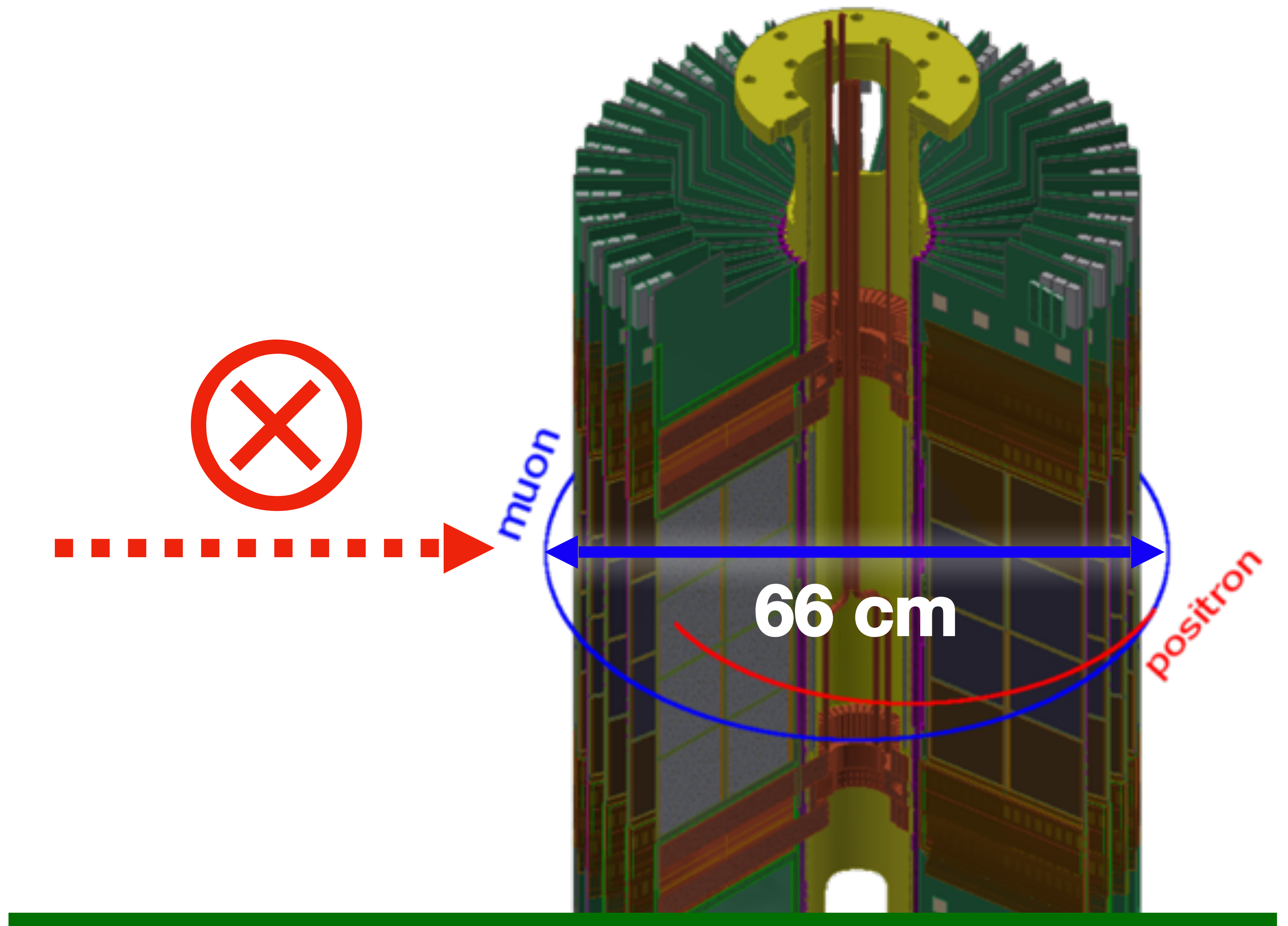
Muon cooling

the key to all the downstream differences



emittance

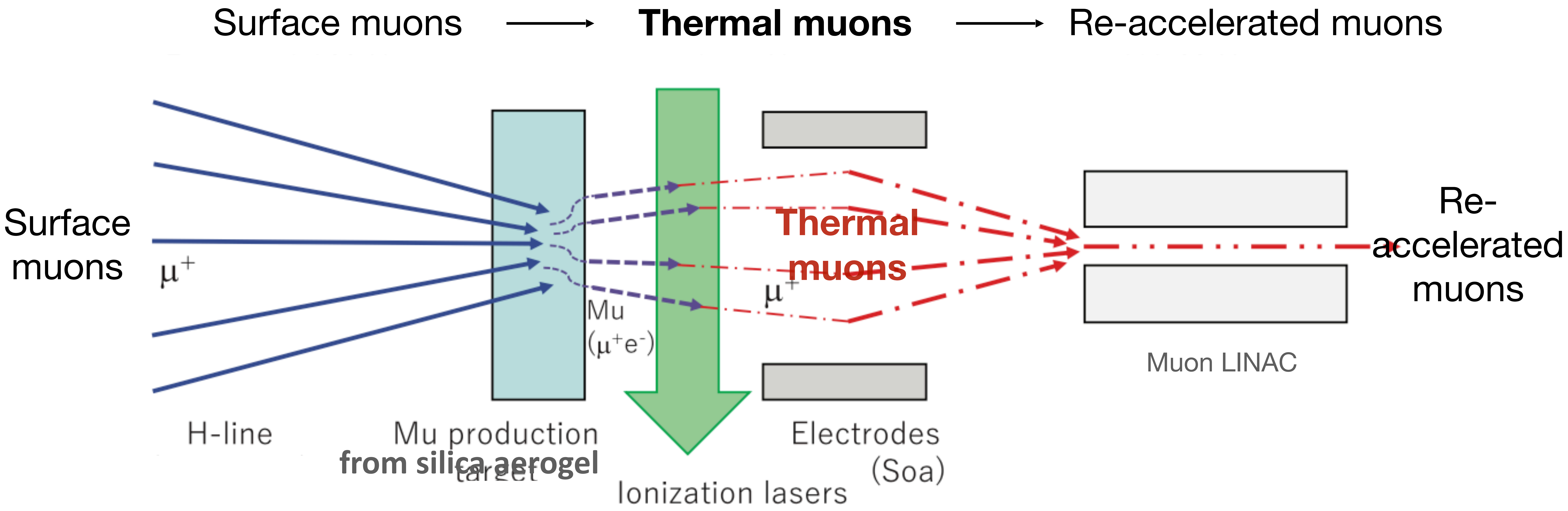
~1000π mm · mrad



	Fermilab Muon g-2	J-PARC Muon g-2/EDM
Muon momentum	3.09 GeV/c	300 MeV/c
Storage Field	B = 1.45 T	B = 3 T (Solenoidal)
Cyclotron period	149 ns	7.4 ns
Muon orbit diameter	14 m	66 cm
Focusing field	Electric quadrupole	E = 0, very weak magnetic

Thermal Muon Source

- Surface muon cooling by <u>laser ionization of muonium (Mu)</u> to thermal muon



Key issues in the thermal muon source

- The thermal muon per injecting surface muon is low (10^{-3}).
- What has been achieved now (10^{-5}) is even lower
- Muonium production and laser efficiency are two key weak points

Table 4. Breakdown of estimated efficiency.

Subsystem	Efficiency	Subsystem	Efficiency
H-line acceptance and transmission	0.16	DAW decay	0.96
Mu emission	0.0034	DLS transmission	1.00
Laser ionization	0.73	DLS decay	0.99
Metal mesh	0.78	Injection transmission	0.85
Initial acceleration transmission and decay	0.72	Injection decay	0.99
RFQ transmission	0.95	Kicker decay	0.93
RFQ decay	0.81	e^+ energy window	0.12
IH transmission	0.99	Detector acceptance of e^+	1.00
IH decay	0.99	Reconstruction efficiency	0.90
DAW transmission	1.00		

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