Muon g-2/EDM experiment at J-PARC

15th Tau workshop

Sep 27, 2018

Tsutomu Mibe (KEK)

for the J-PARC g-2/EDM collaboration

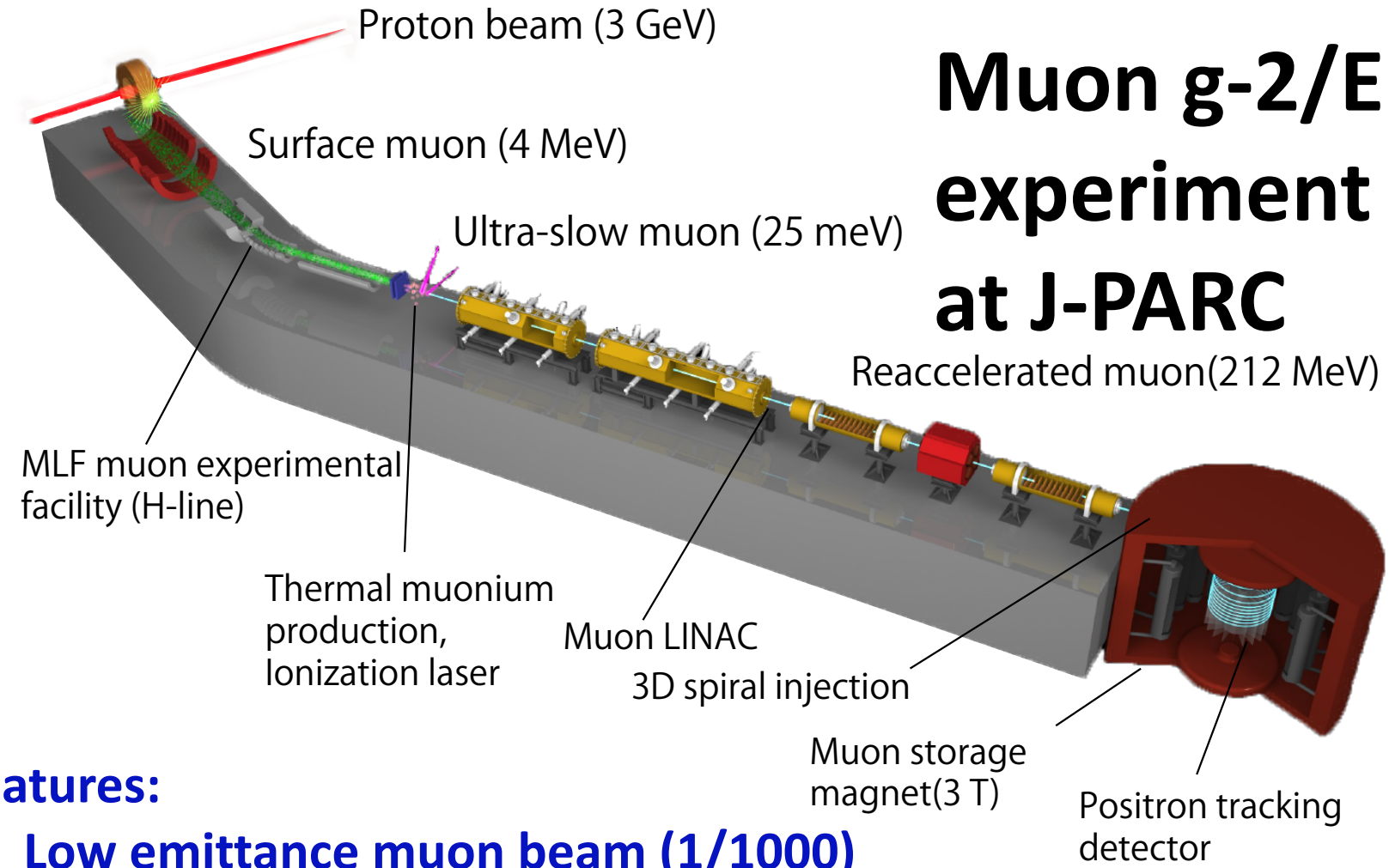
www.g-2.kek.jp

International school on muon dipole moment and hadronic effects

Sep 17-21, 2018 @BINP

https://indico.inp.nsk.su/event/14/

Muon g-2/EDM experiment at J-PARC



Features:

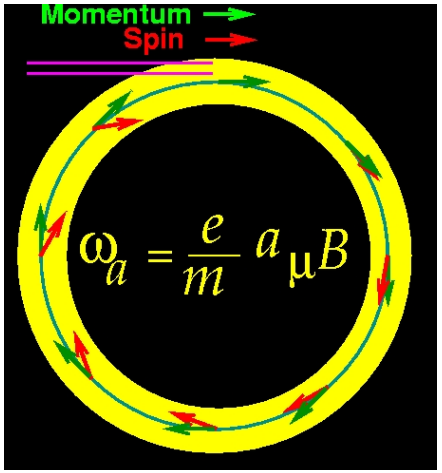
- **Low emittance muon beam (1/1000)**
- **No strong focusing (1/1000) & good injection eff. (x10)**
- **Compact storage ring (1/20)**
- **Tracking detector with large acceptance**
- **Completely different from BNL/FNAL method**

The Collaboration

99 “current” members from 41 institutions, 7 countries.

Collaboration meeting in Kyushu University
(December, 2017)

muon g-2 and EDM measurements



In uniform magnetic field, muon spin rotates ahead of momentum due to g-2 ≠ 0

general form of spin precession vector:

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} - \left(a_\mu - \frac{1}{\gamma^2 - 1}\right)\frac{\vec{\beta}\times\vec{E}}{c} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c}\right)\right]$$

BNL E821 approach
γ=30 (P=3 GeV/c)

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c}\right)\right]$$

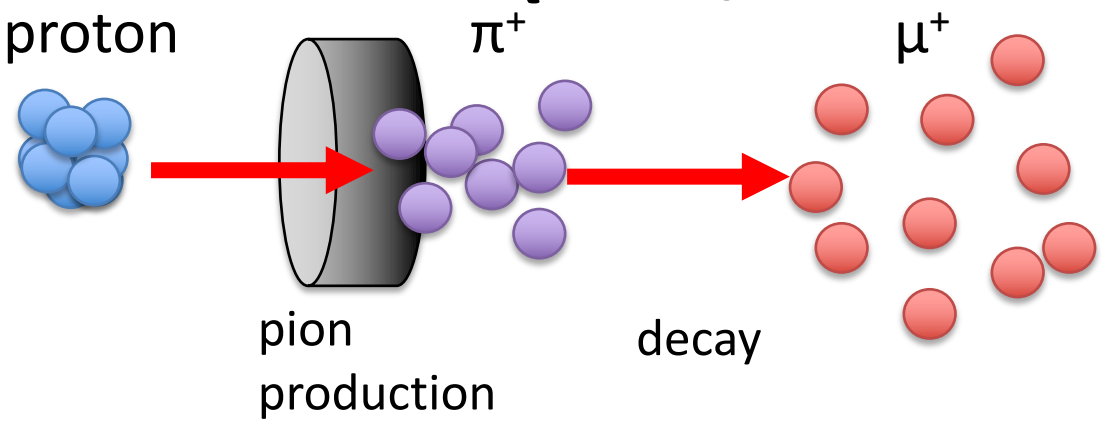
FNAL E989

J-PARC approach
E = 0 at any γ

$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\left(\vec{\beta}\times\vec{B}\right)\right]$$

J-PARC E34

Conventional muon beam (BNL, Fermilab)

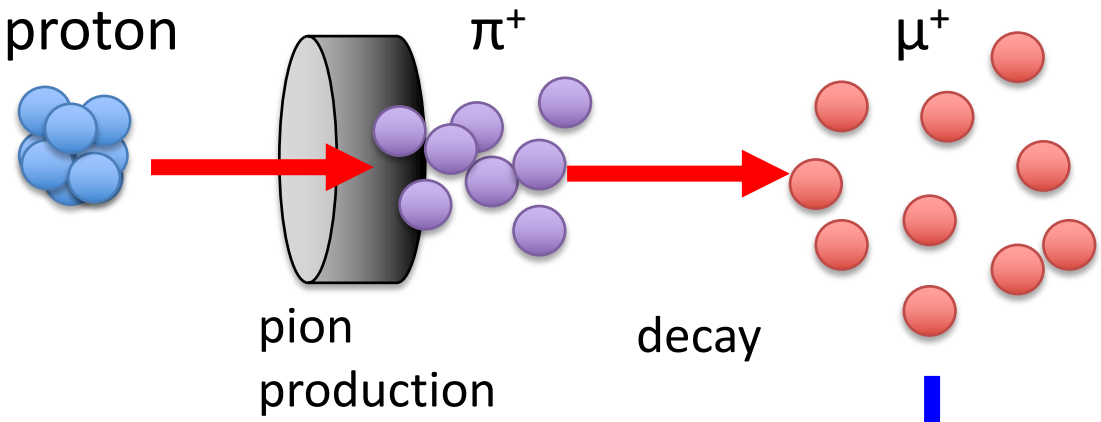


emittance

~1000π mm ·mrad

Strong focusing
Muon loss
BG π contamination

Muon beam at J-PARC



emittance
~1000π mm ･mrad

Strong focusing
Muon loss
BG π contamination

cooling

μ^+

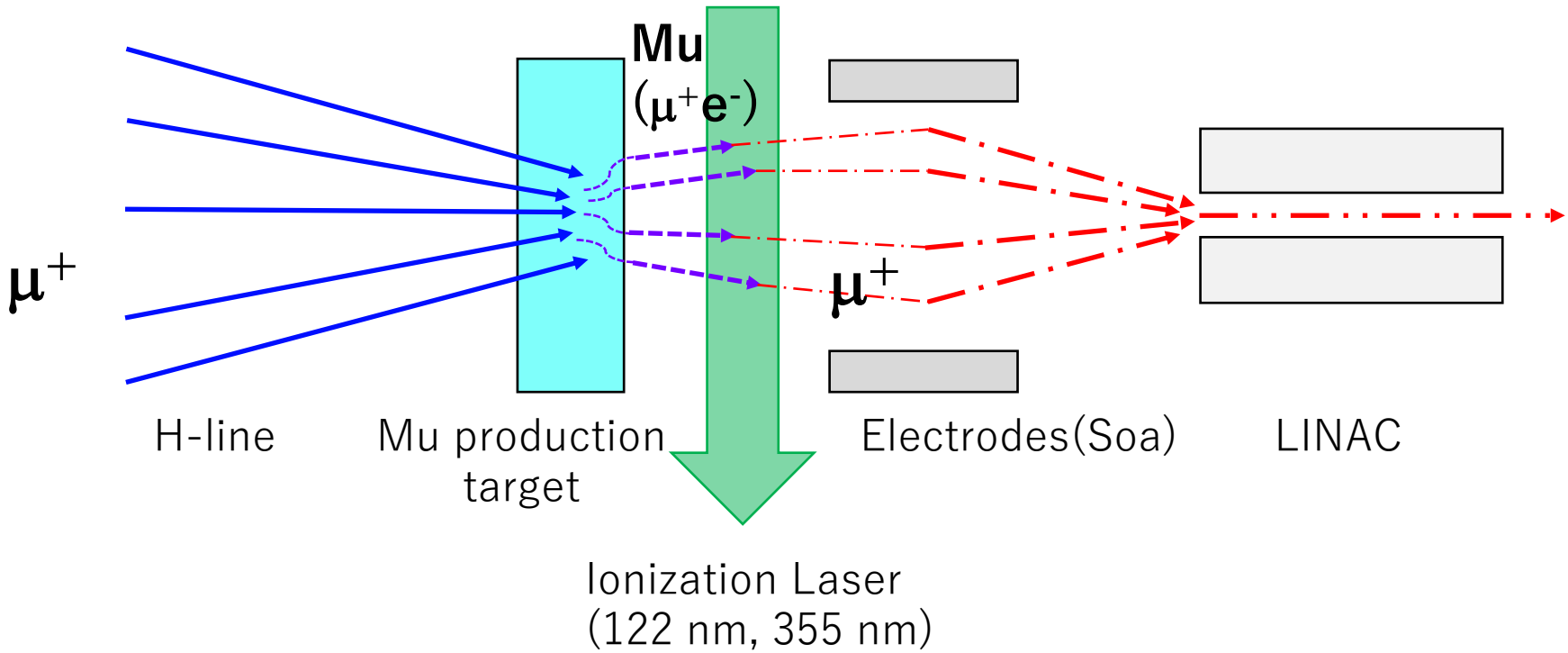
emittance
1π mm ･mrad

Reaccelerated thermal muon

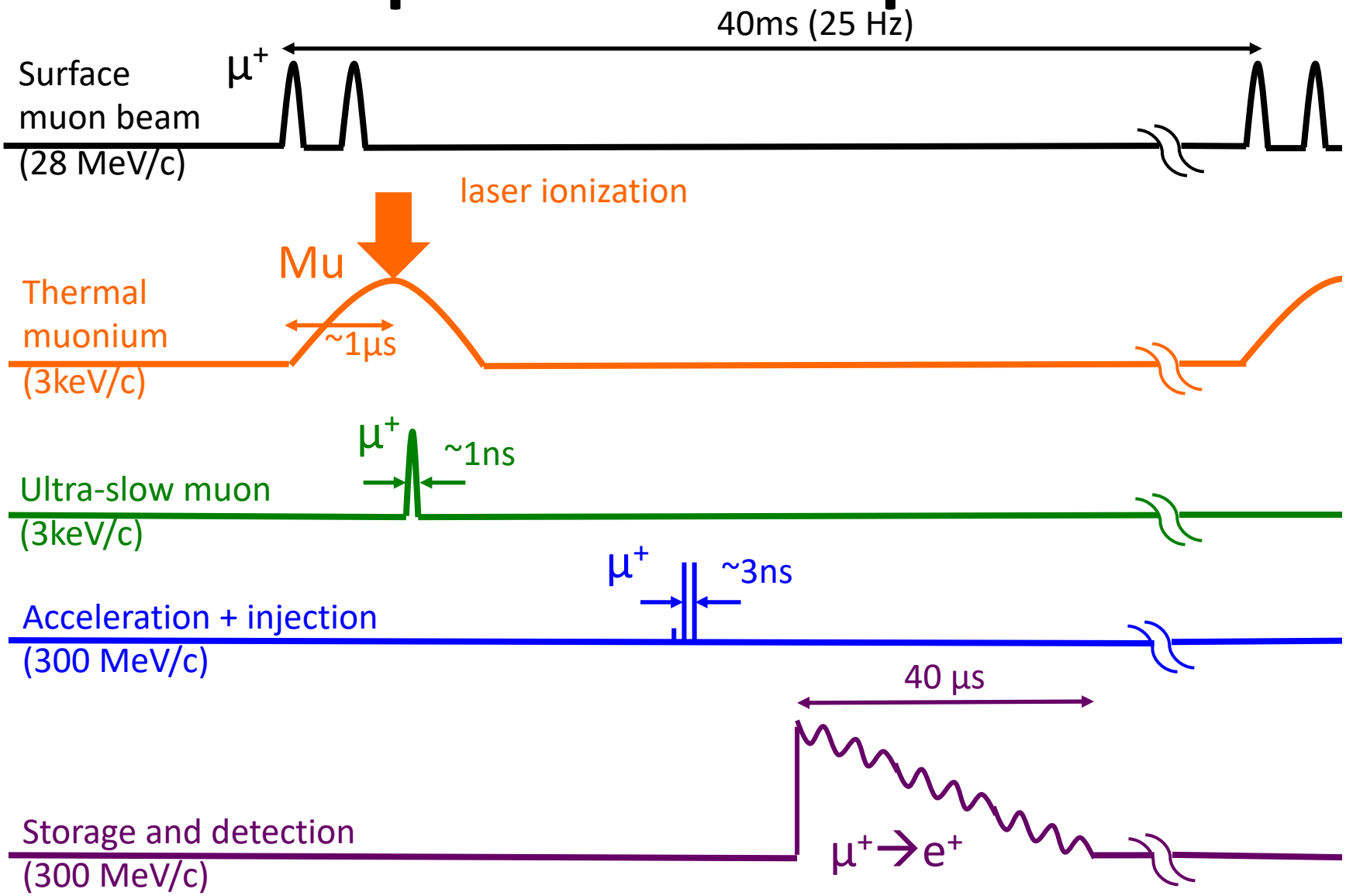
Free from any of these

Re-accelerated thermal muon

	surface muon	thermal muon	accelerated muon
E	3.4 MeV	30 meV	212 MeV
p	27 MeV/c	2.3 keV/c	300 MeV/c
Δ p/p	0.05	0.4	4×10^{-4}

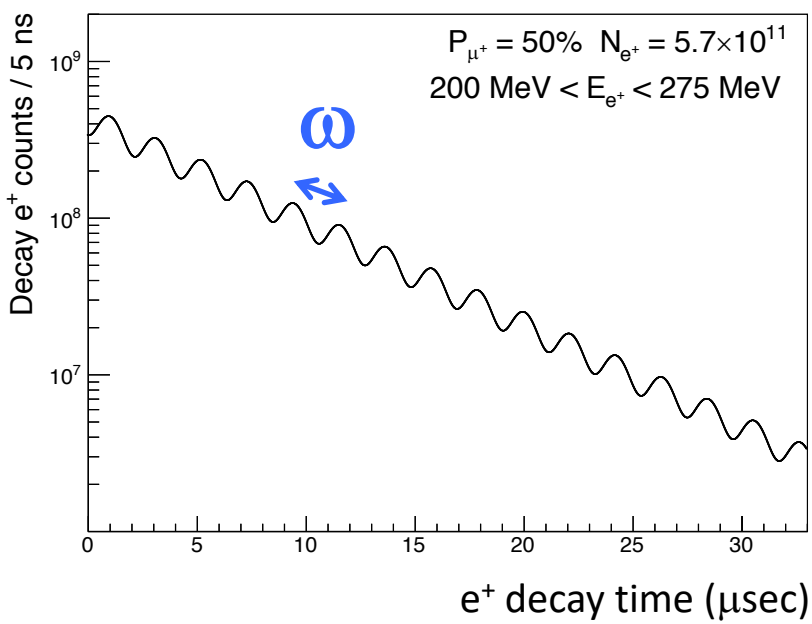


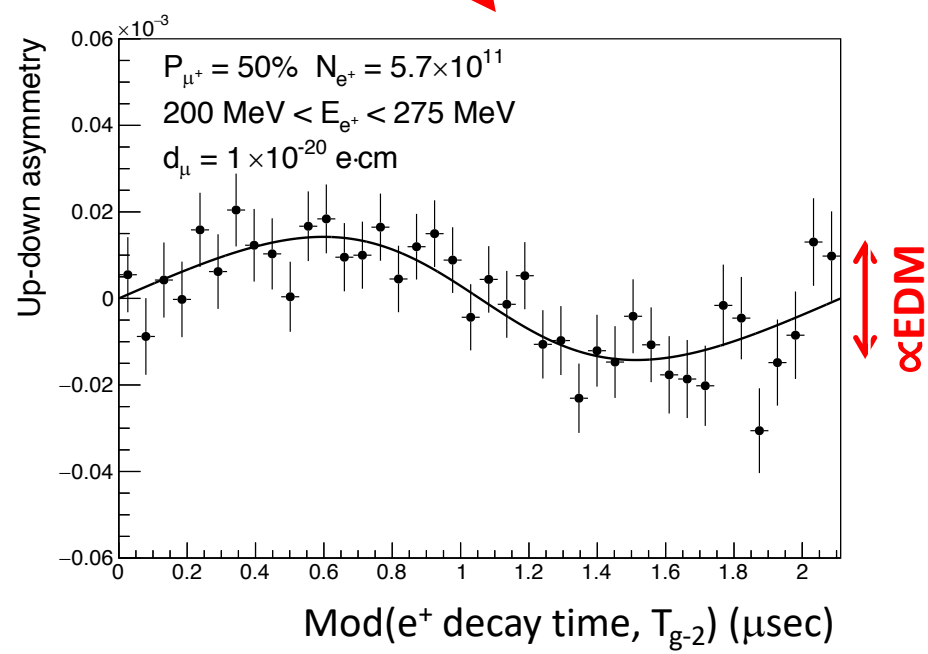
Experimental sequence



Expected time spectrum of e^+ in $\mu \rightarrow e^+\nu\nu$ decay

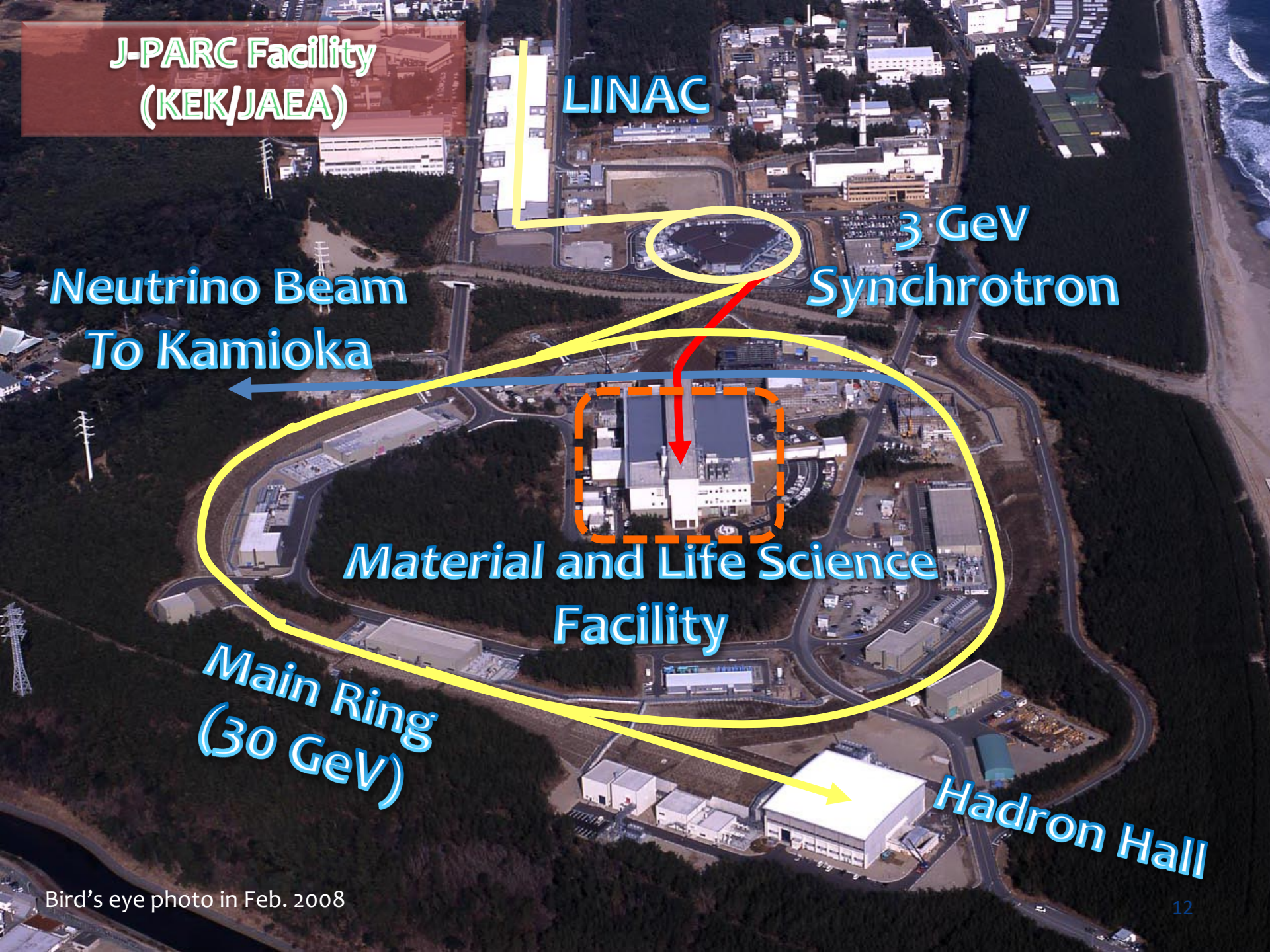
$$\vec{\omega} = -\frac{e}{m}\left[a_\mu \vec{B} + \frac{\eta}{2}\left(\vec{\beta} \times \vec{B}\right)\right]$$





Expected uncertainties

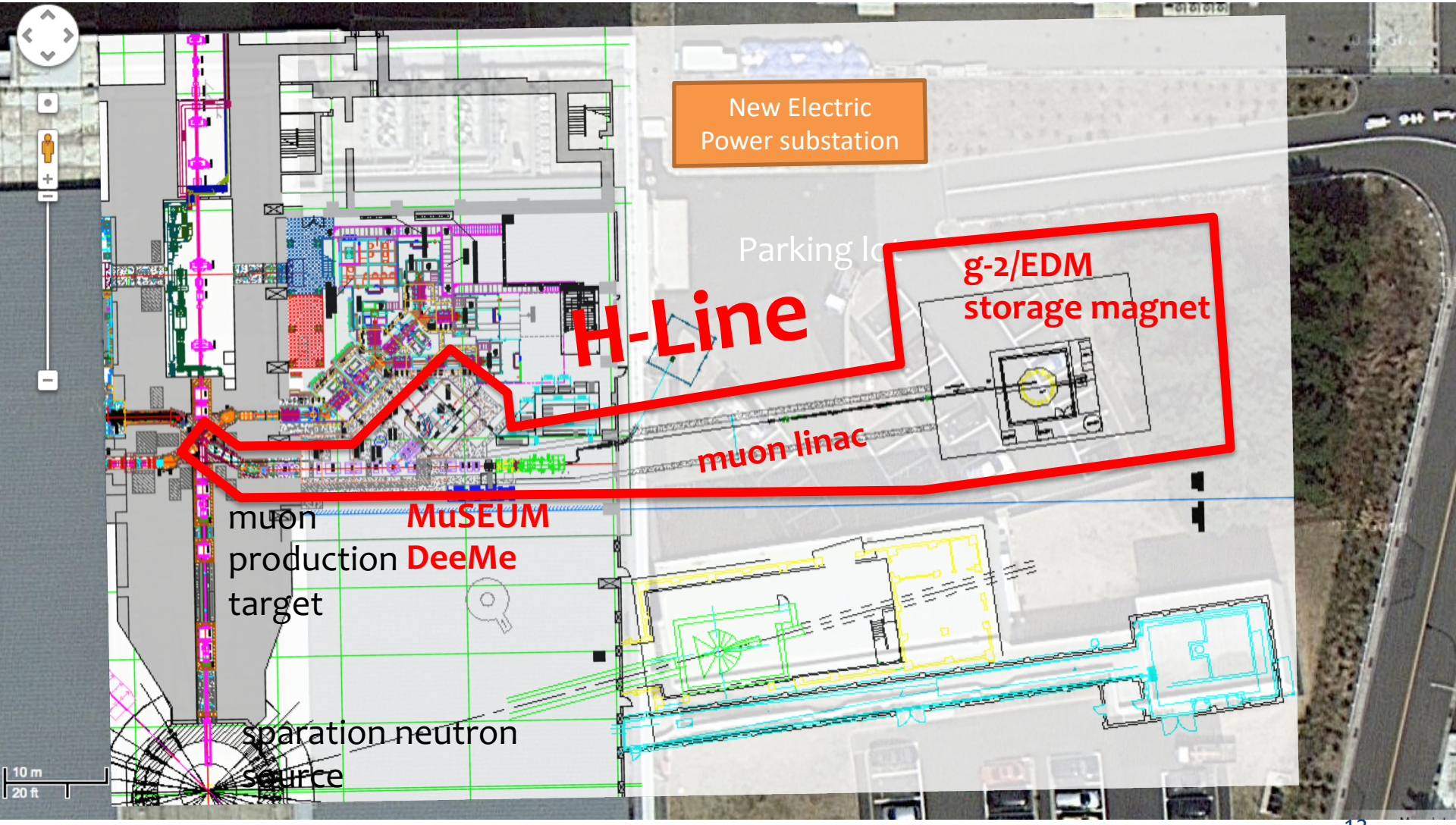
	Estimation
Total number of muons in the storage magnet	5.2×10^{12}
Total number of positrons	0.57×10^{12}
Effective analyzing power	0.42
Statistical uncertainty on ω_a [ppb]	450
Statistical uncertainty on ω_p [ppb]	100
Uuncertainties on a_μ [ppb]	460 (stat.) < 70 (syst.)
Uncertainties on EDM [10^{-21} e·cm]	1.4 (stat.) 0.36 (syst.)



Bird's eye photo in Feb. 2008

Proposed experimental site

Material and Life science Facility in J-PARC



H-line being constructed!

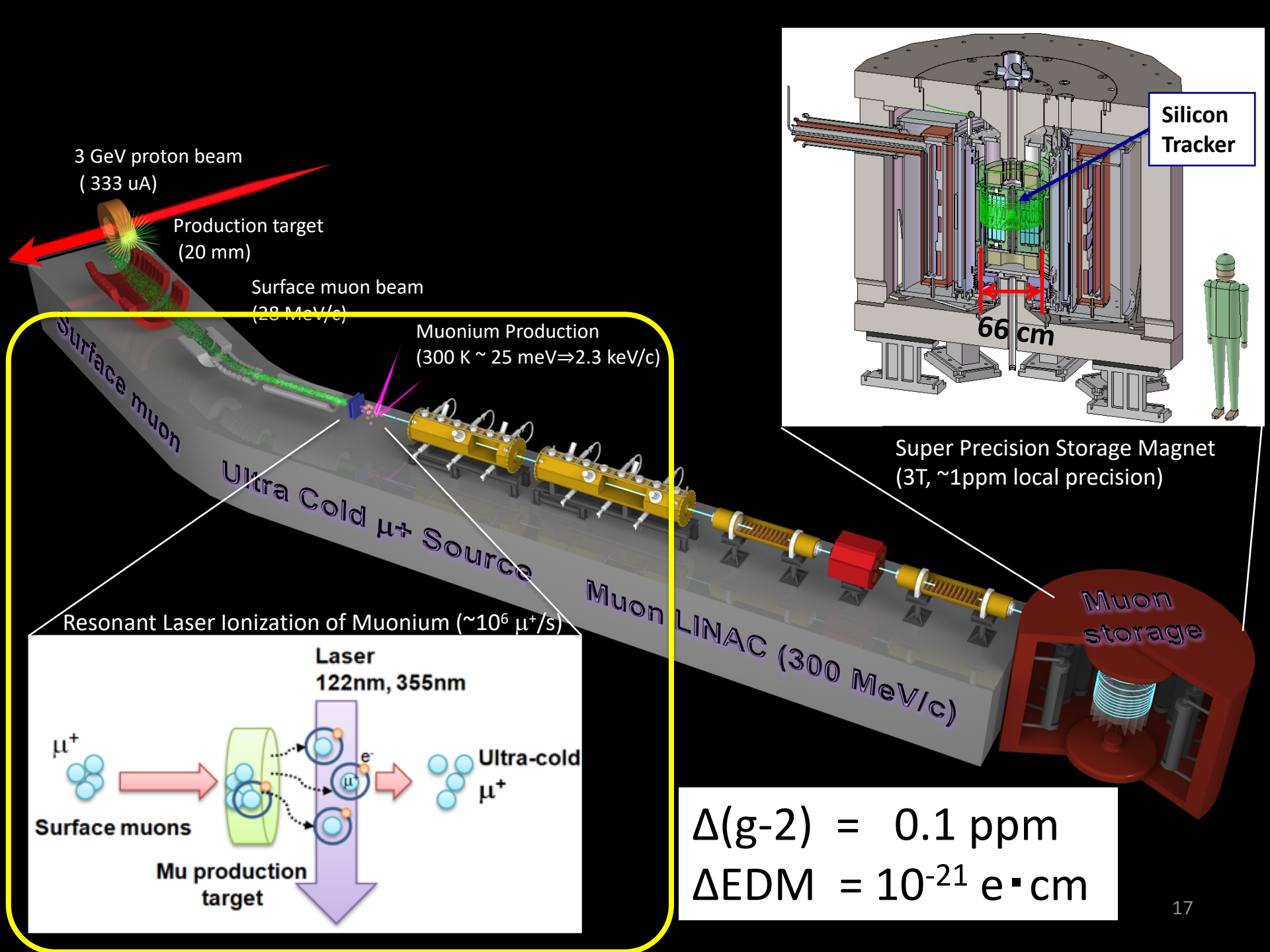
Photo by T. Yamazaki

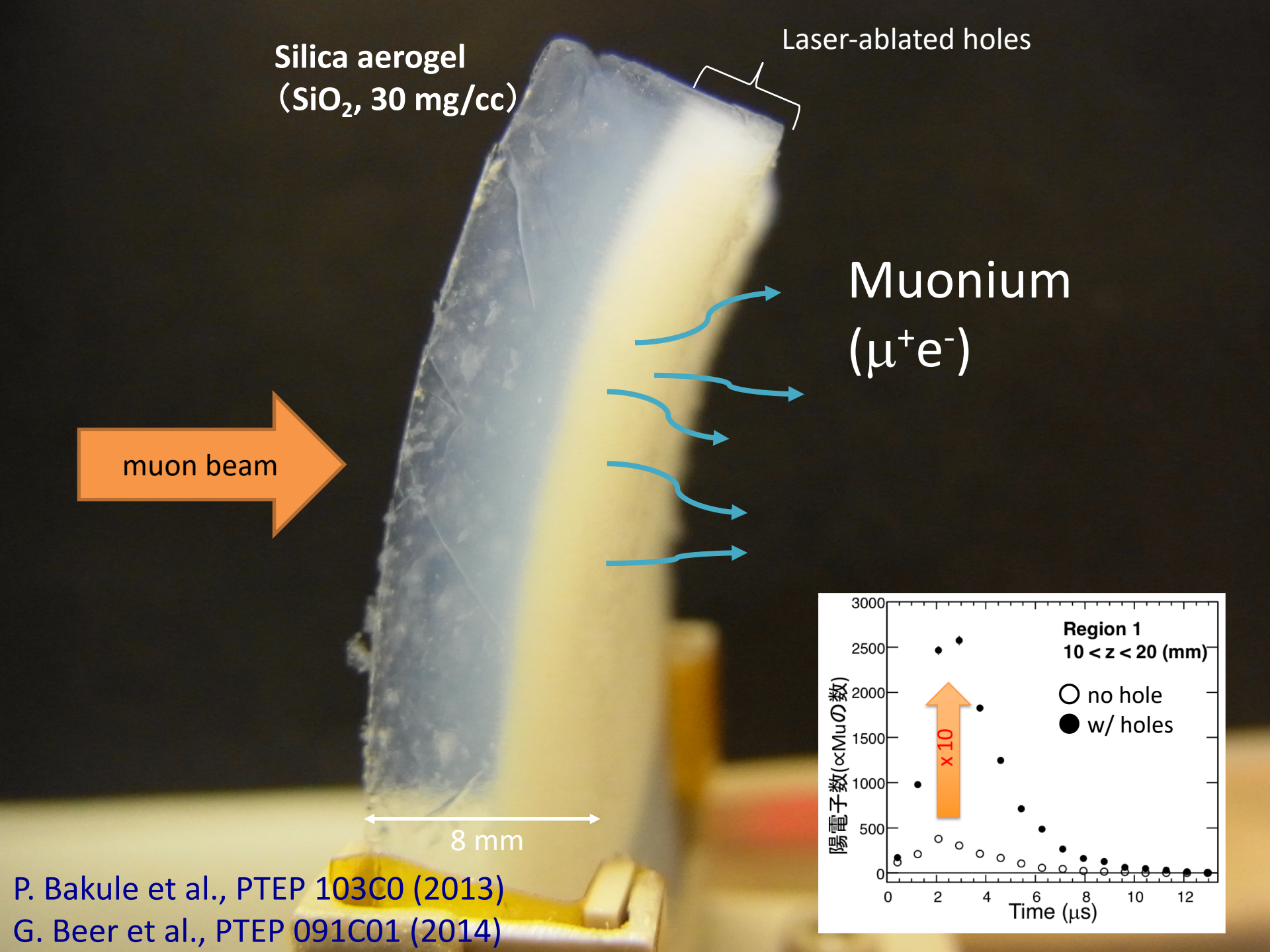
Photo by T. Yamazaki

H-line being constructed!

New power station being constructed

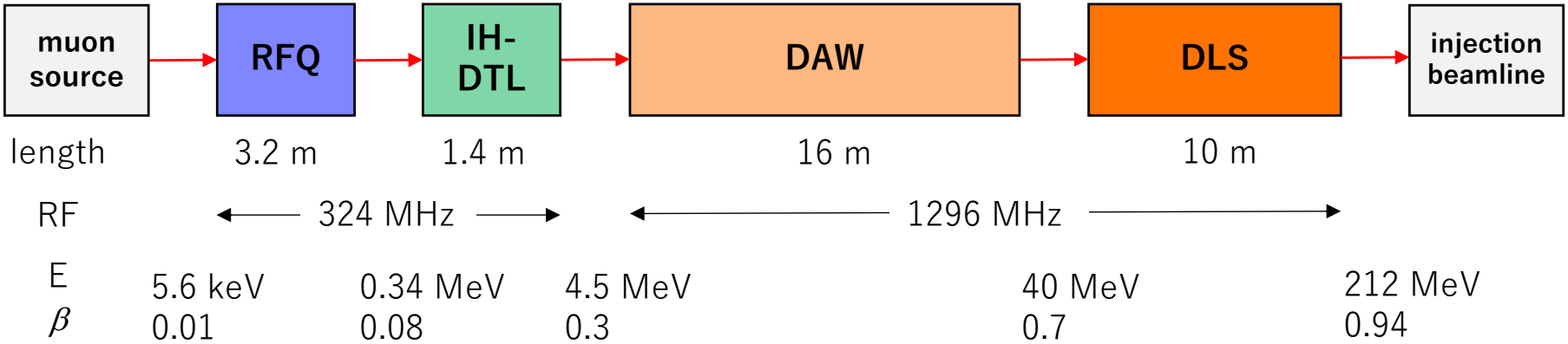
Photo by T. Yamazaki


3 GeV proton beam
(333 uA)
Production target
(20 mm)
Surface muon beam
(28 MeV/c)
Muonium Production
(300 K ~ 25 meV⇒2.3 keV/c)
Surface muon
Ultra Cold μ+ Source
Muon LINAC (300 MeV/c)
Muon storage
Silicon Tracker
66 cm
Super Precision Storage Magnet
(3T, ~1ppm local precision)
Resonant Laser Ionization of Muonium (~10⁶ μ⁺/s)
Laser
122nm, 355nm
μ+
Surface muons
Mu production target
e-
μ+
Ultra-cold μ+
Δ(g-2) = 0.1 ppm
ΔEDM = 10-21 e▪cm

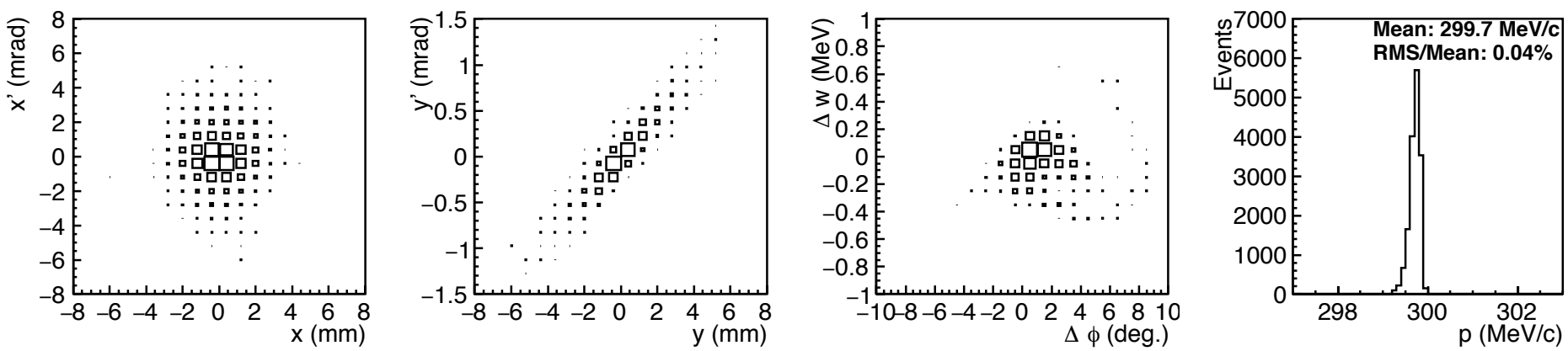


P. Bakule et al., PTEP 103C0 (2013)
G. Beer et al., PTEP 091C01 (2014)

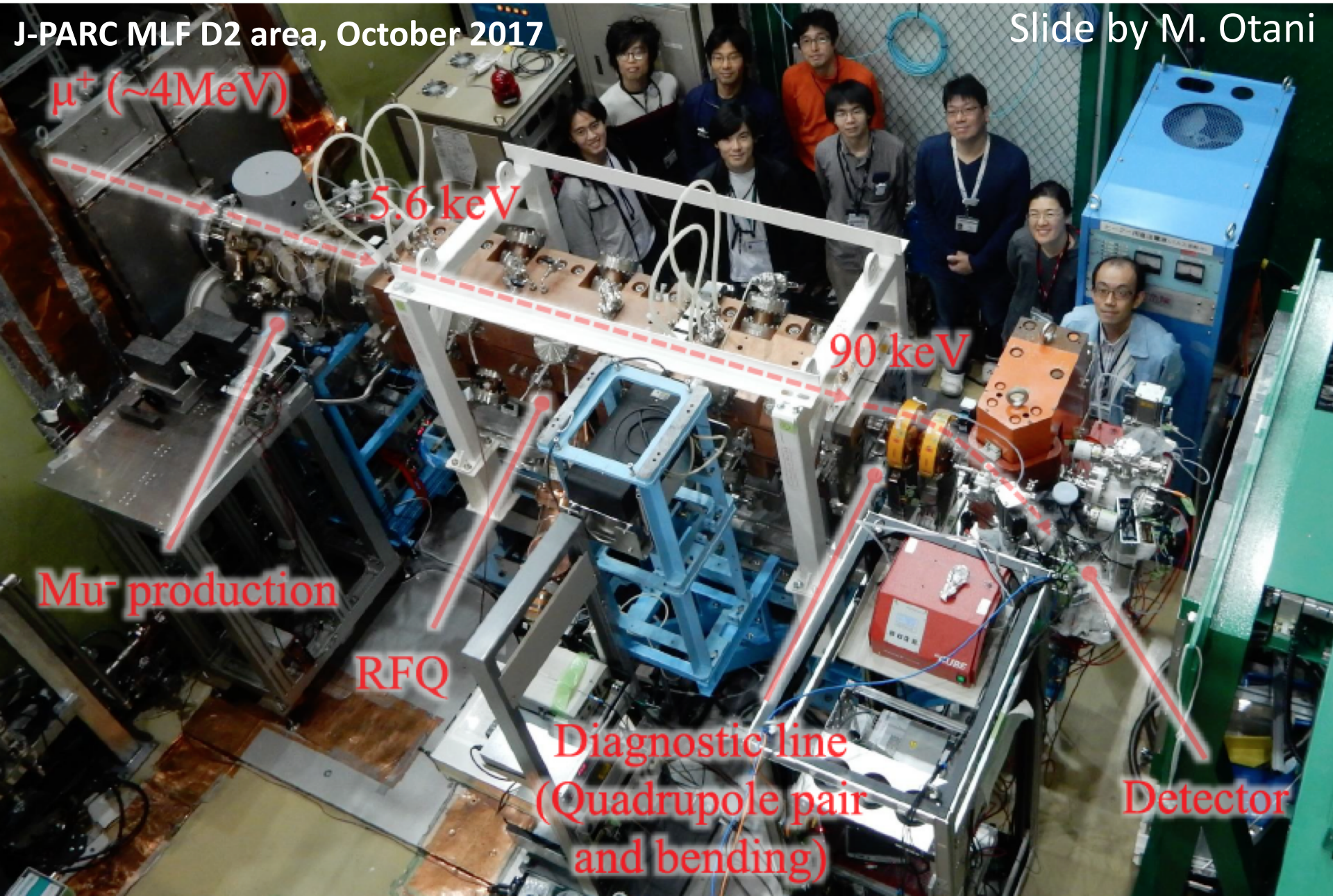
Muon LINAC



Phase space distributions after muon LINAC (simulation)



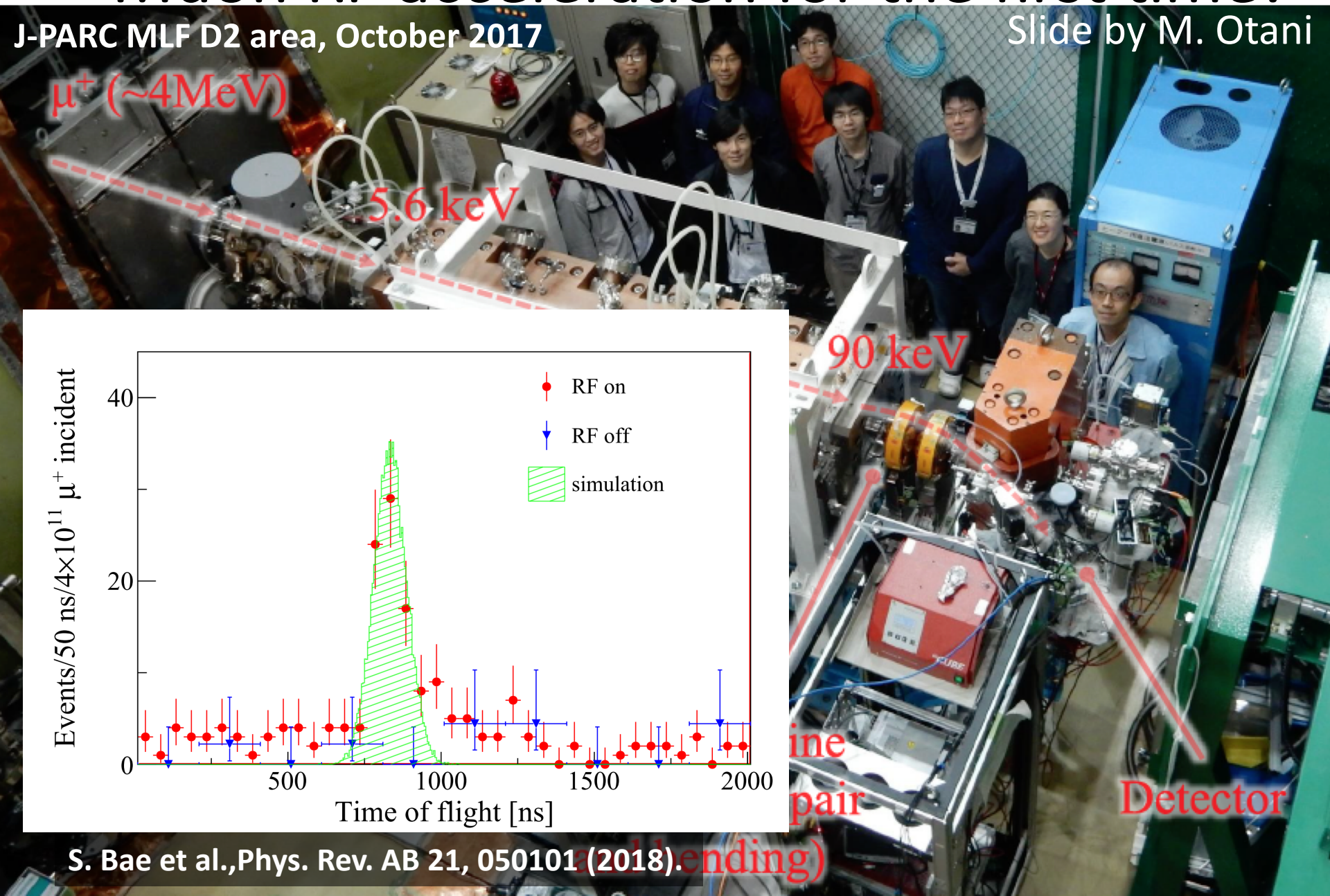
Muon RF acceleration for the first time!



Muon RF acceleration for the first time!

J-PARC MLF D2 area, October 2017

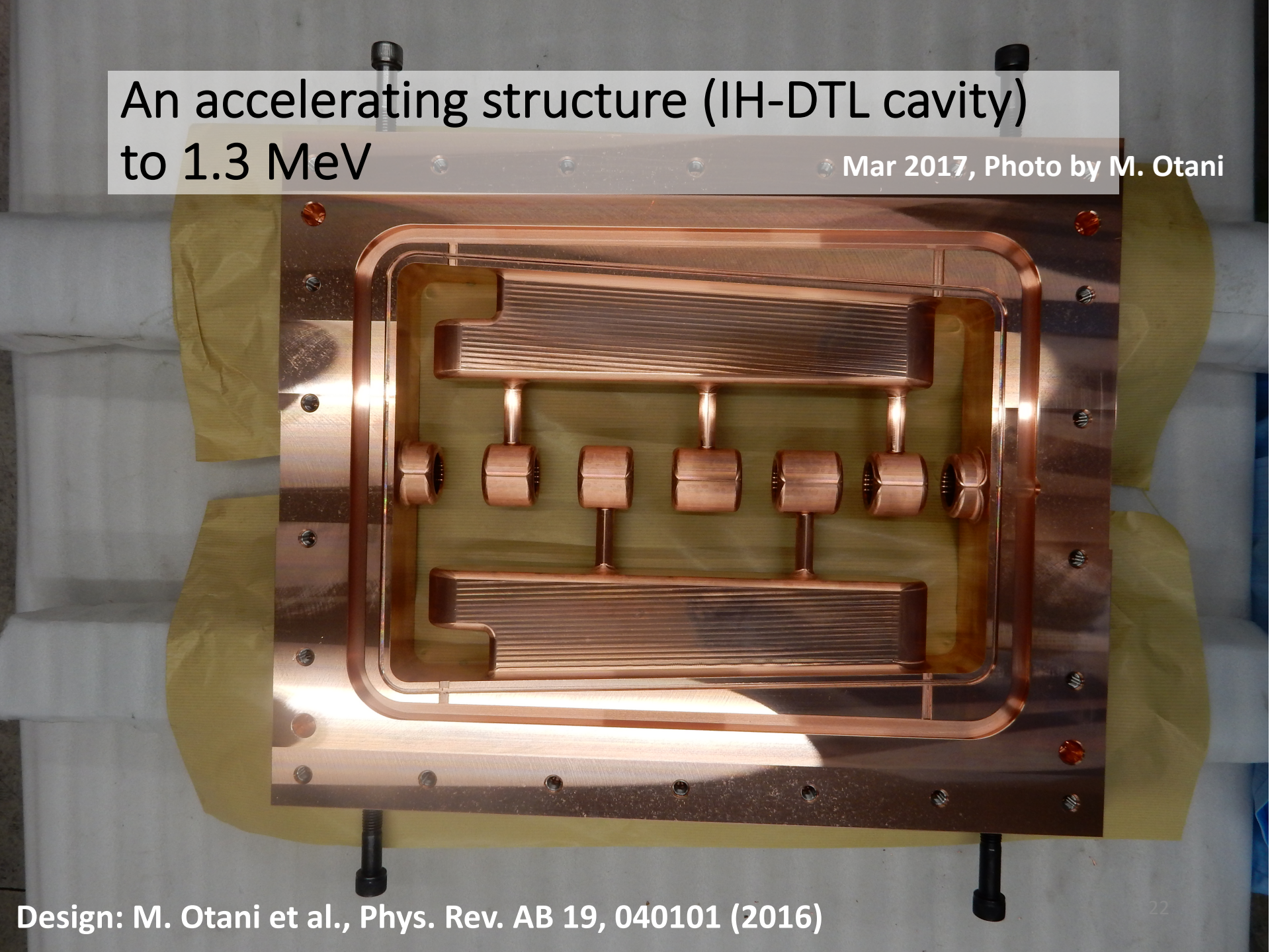
Slide by M. Otani



S. Bae et al.,Phys. Rev. AB 21, 050101 (2018).

An accelerating structure (IH-DTL cavity) to 1.3 MeV

Mar 2017, Photo by M. Otani

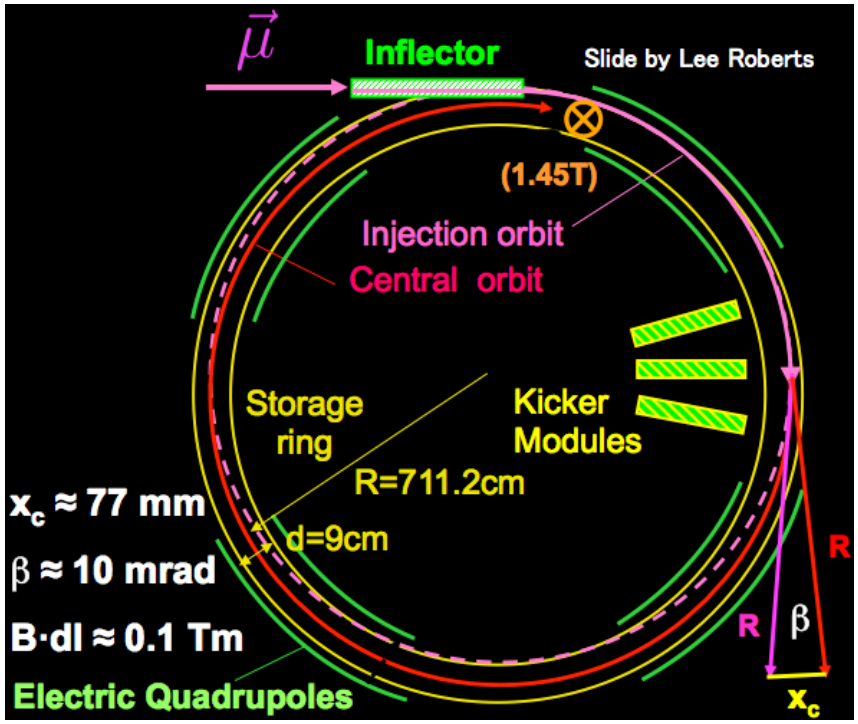


Design: M. Otani et al., Phys. Rev. AB 19, 040101 (2016)

Muon beam injection and storage

Horizontal injection + kicker

(BNL E821, FNAL E989)

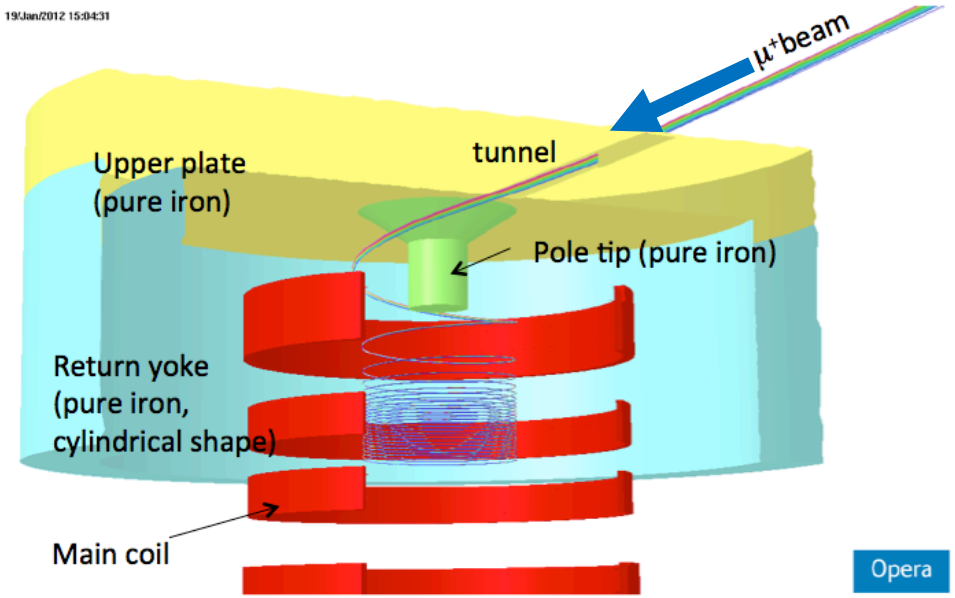


Injection efficiency : 3-5%(*)

(*) PRD73,072003 (2006)

3D spiral injection + kicker

(J-PARC E34)

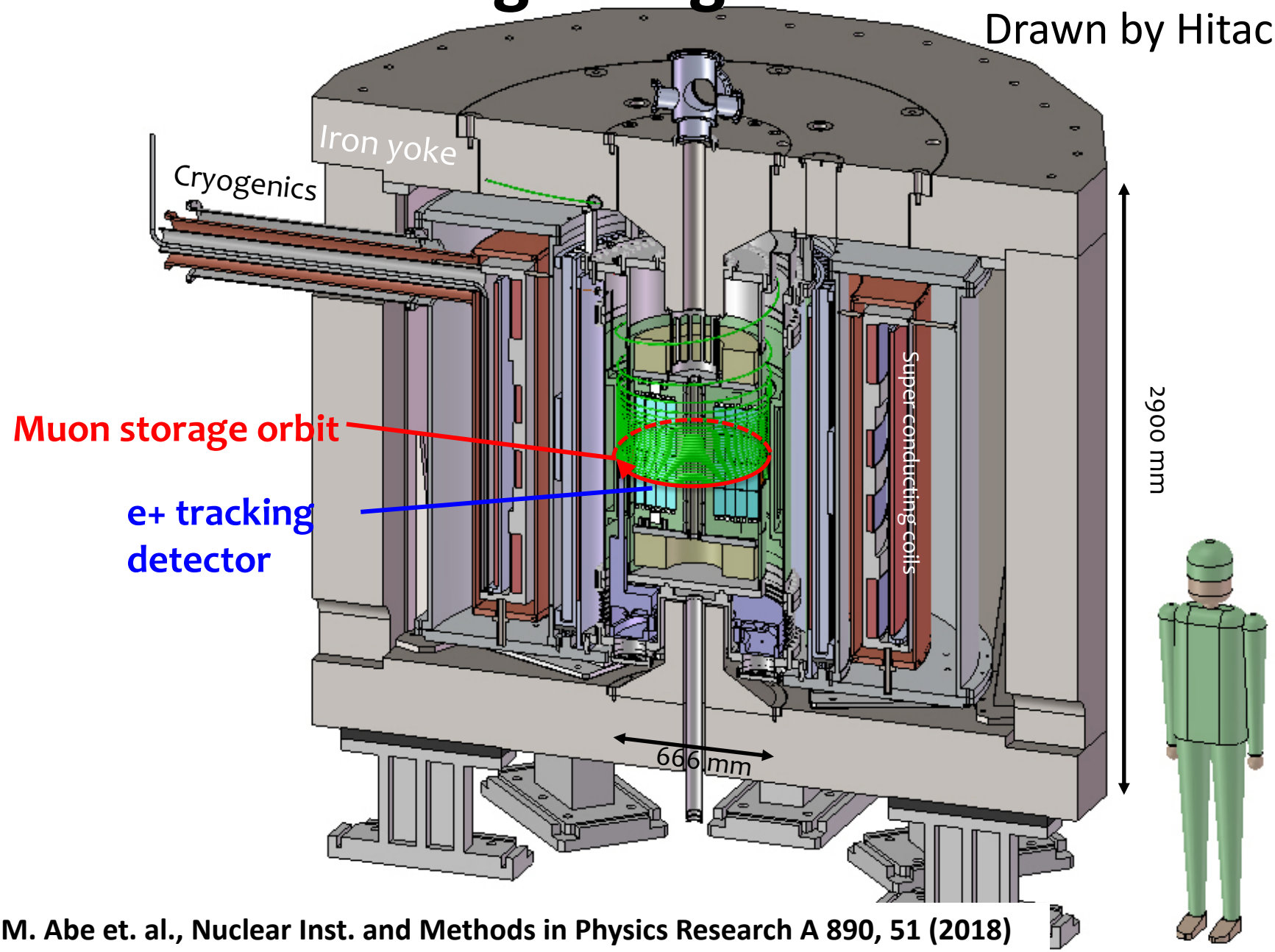


Injection efficiency : ~85%

H. Iinuma et al., Nucl. Instr. And Methods. A 832, 51 (2016)

Muon storage magnet and detector

Drawn by Hitachi Co.

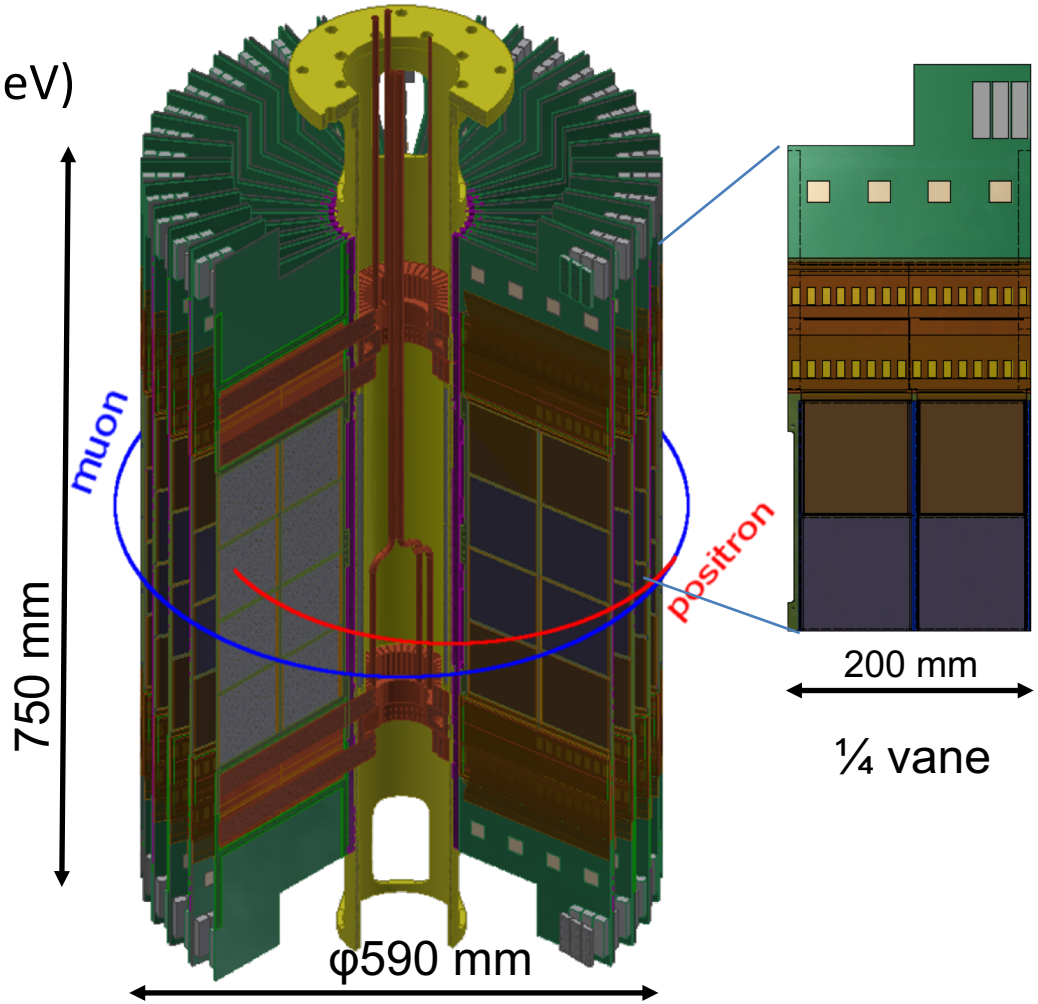


M. Abe et. al., Nuclear Inst. and Methods in Physics Research A 890, 51 (2018)

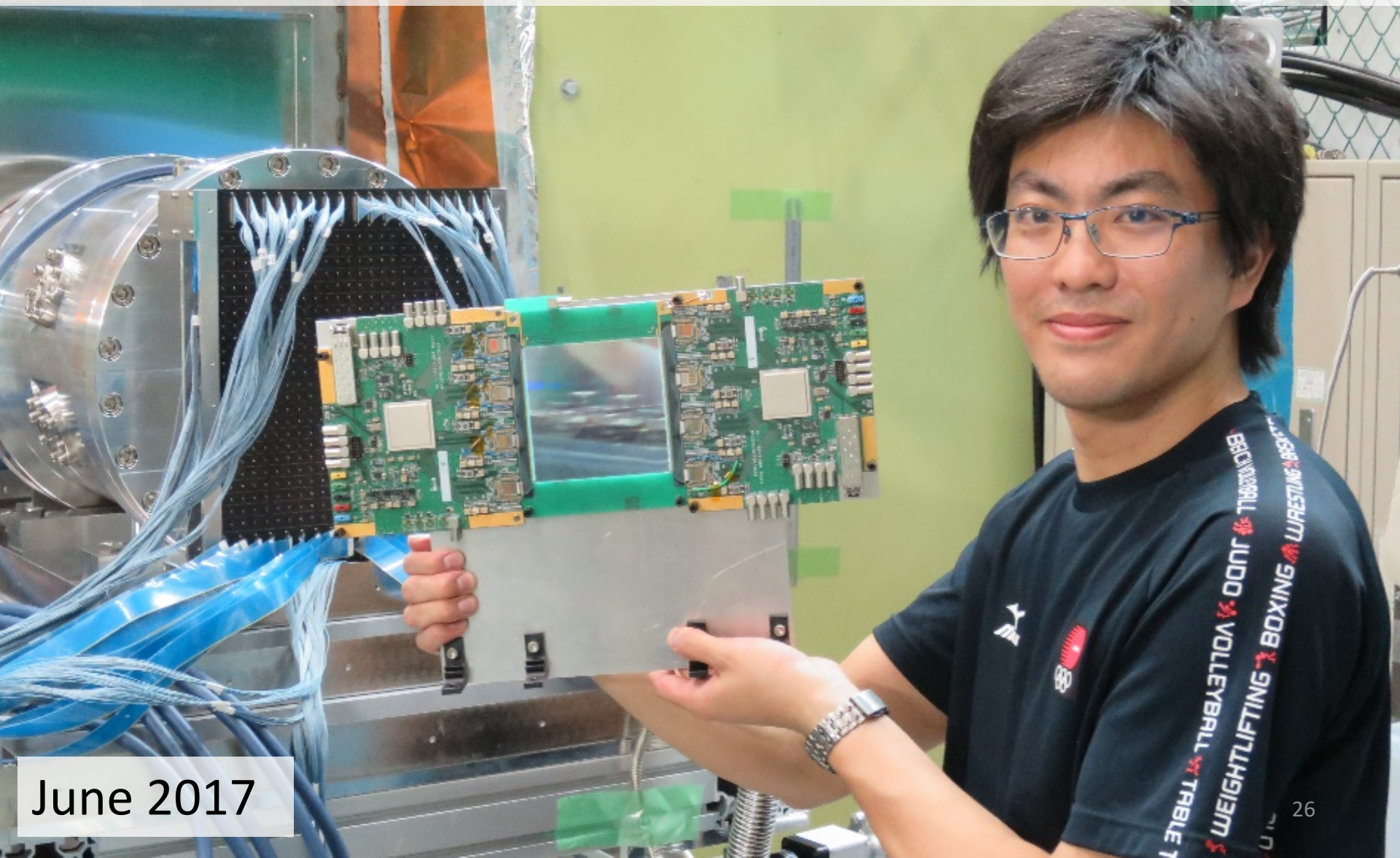
Positron tracking detector

- Requirements
  - Detection of e+ (100<E<300 MeV)
  - Reconstruction of momentum vector
  - Stability over rate changes （1.4 MHz → 14 kHz）

- Specifications
  - Sensor: p-on-n single-sided strip
  - Number of vanes: 40
  - Number of sensors : 640
  - Number of strips : 655,360
  - Area of sensors : 6.24 m^2



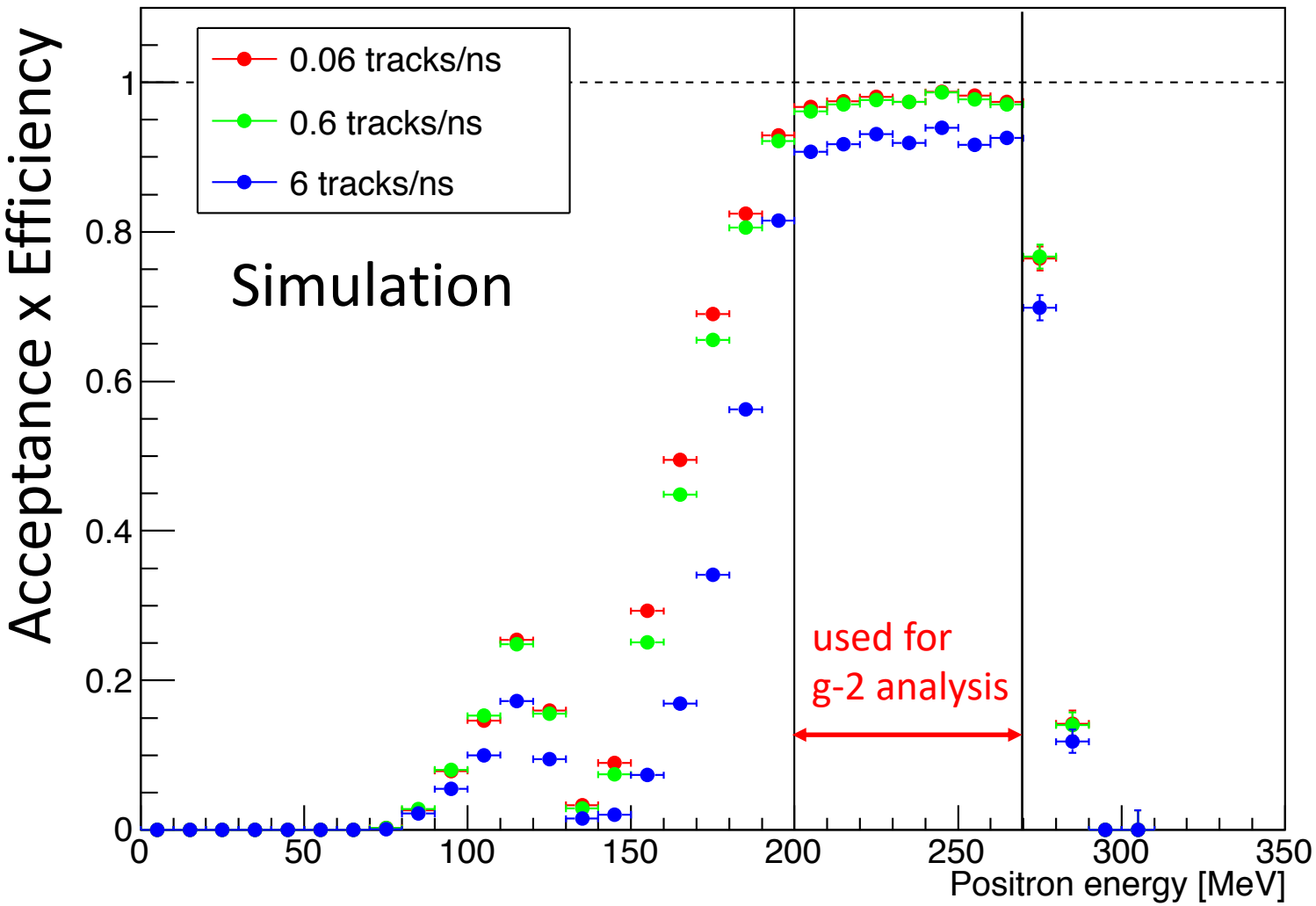
First test module tested with muon at J-PARC



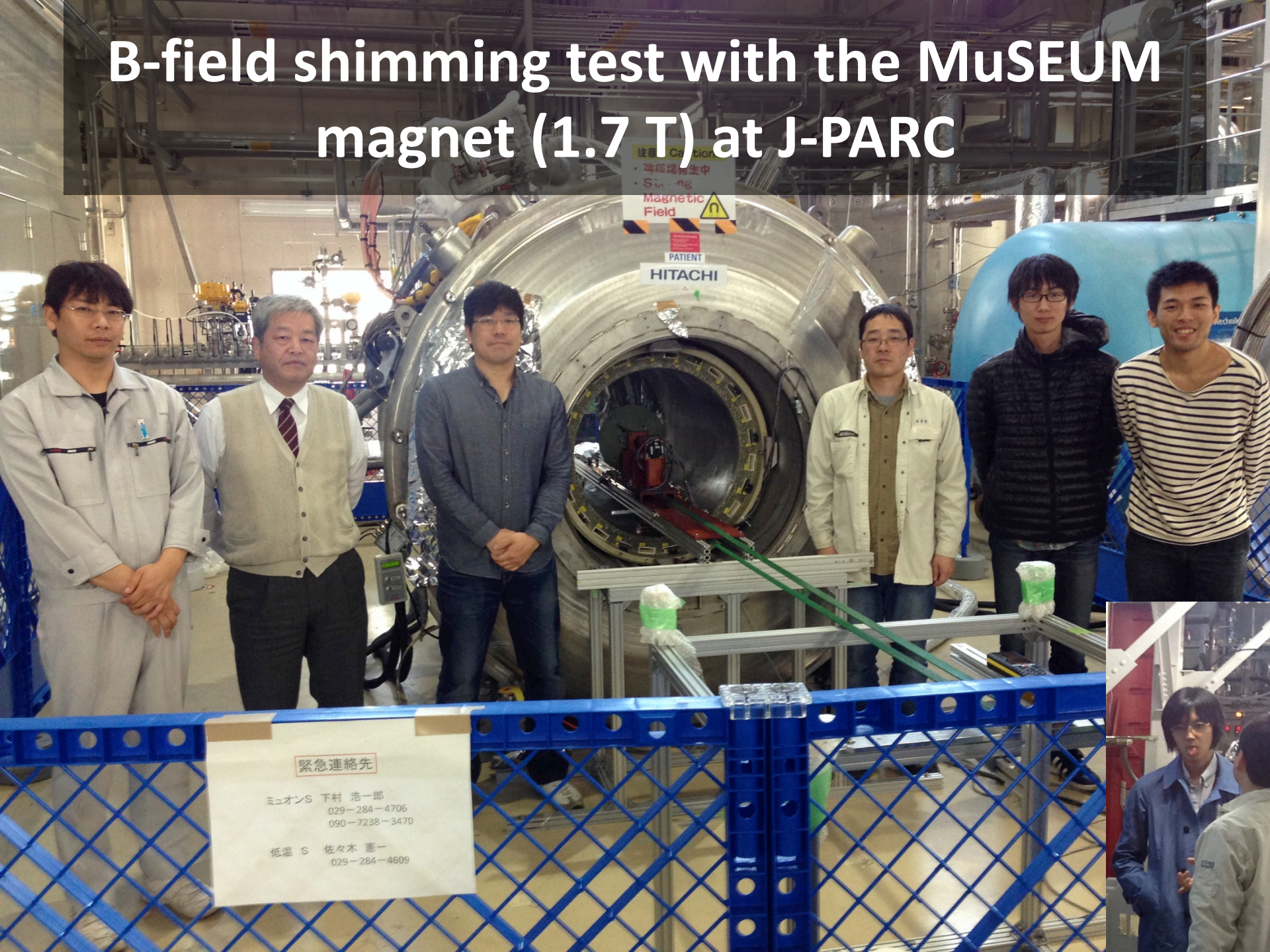
June 2017

Detector acceptance and reconstruction efficiency

Yamanaka + Sato



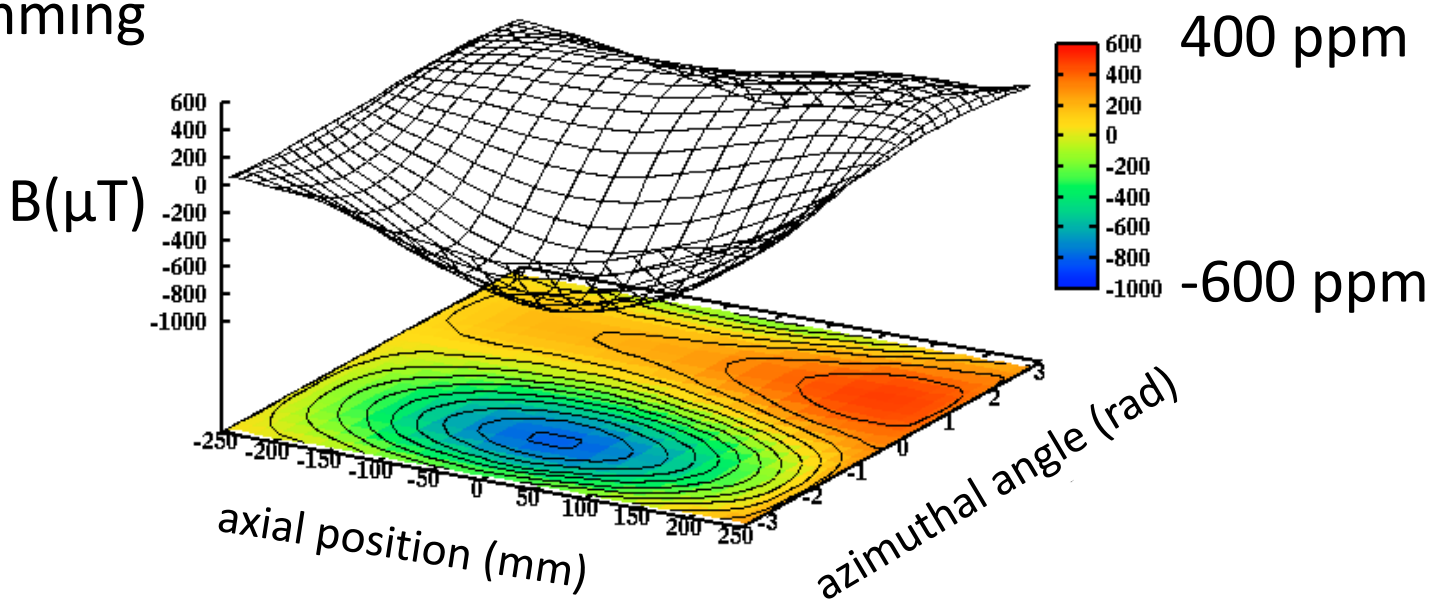
B-field shimming test with the MuSEUM magnet (1.7 T) at J-PARC



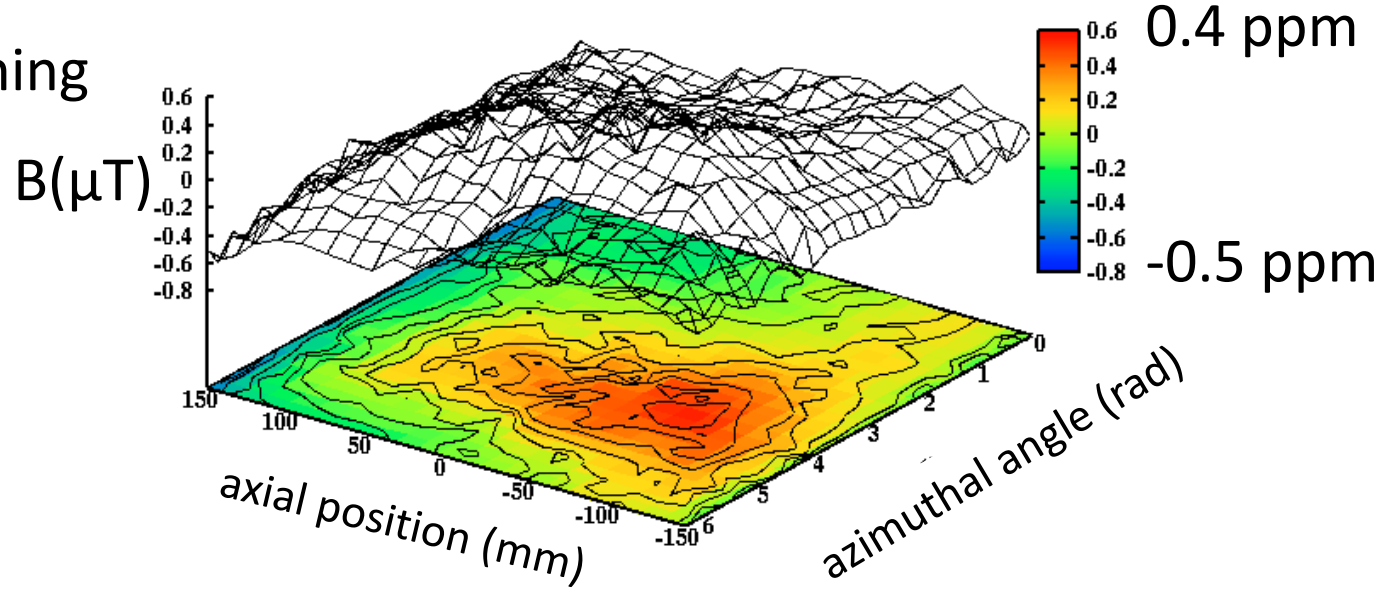
Plots by K. Sasaki

Field shimming by iron arrays

Before shimming



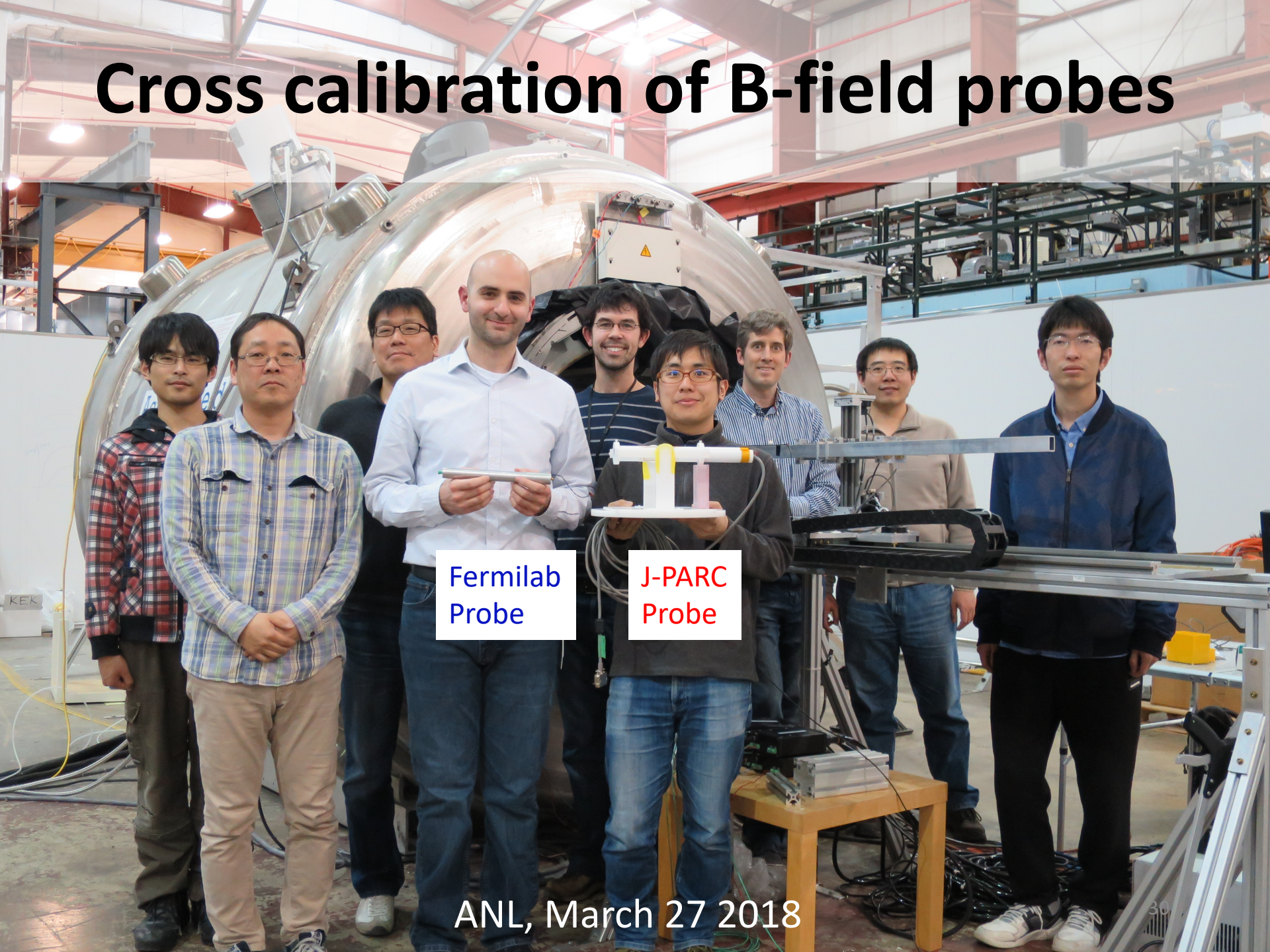
After shimming



r = 140 mm

51.0000, 216.000 scale: 1.00000, 1.00000

Cross calibration of B-field probes



ANL, March 27 2018

Final report from TDR review (May 2018)

0. Executive Summary

The focused review committee has reviewed the updated TDR and collaboration responses to our recommendations. While there is substantial work ahead to successfully deliver all of the necessary development and studies to assure success of the experiment, the committee believes that the E34 collaboration has made significant progress and is well positioned to address remaining issues and therefore unanimously recommends that E34 proceed to Stage-2.

Summary

- The **J-PARC muon g-2/EDM experiment** will measure g-2 and EDM with completely different method.

- **Features:**
  - **Low emittance muon beam (1/1000)**
  - **No strong focusing (1/1000)**
  - **Good injection eff. (x10)**
  - **Compact storage ring (1/20)**
  - **Tracking detector with large acceptance**
  - **Completely different from BNL/FNAL method**

- **We are moving to R&D to construction phase.**
- **In coming years,**
  - Construction of muon beamline (H-line)
  - Demonstration of “muon cooling”
  - Re-acceleration to 1 MeV