μ-e転換事象の発見に向けて MuSICとCOMET実験

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2017/08/04

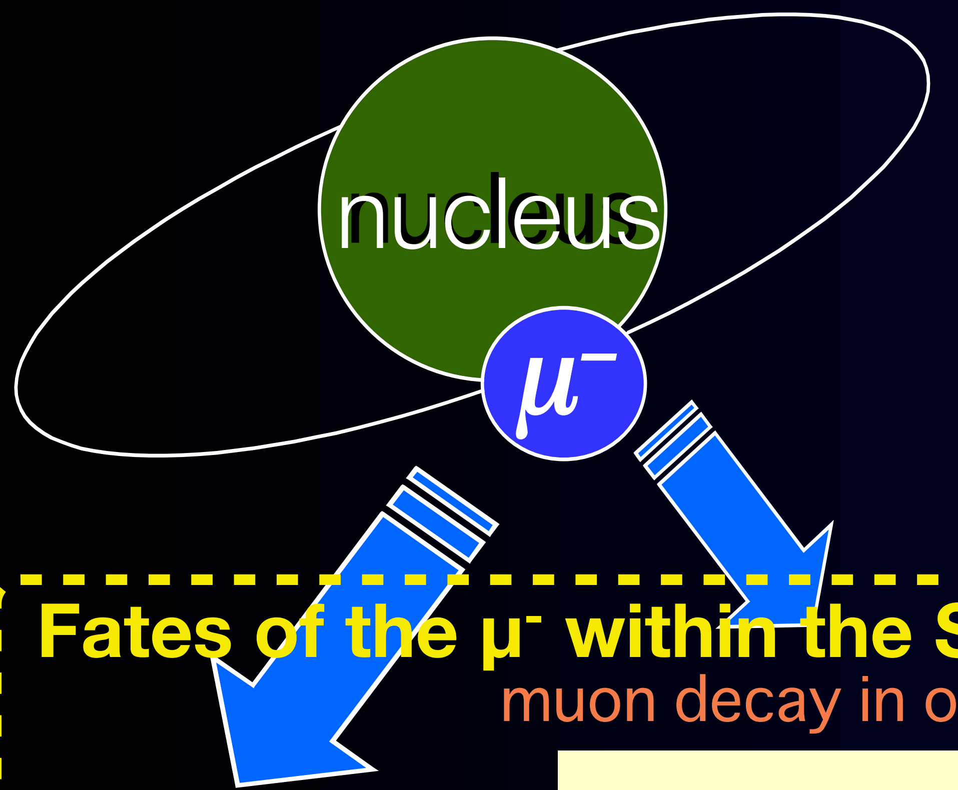
内容

- μ-e転換事象探索
- 実現に向けて
  - MuSIC@RCNP
  - COMET実験@J-PARC
- まとめ

μ-e Conversion Search

- When a μ⁻ in stopped in a material, ...

1s state in a muonic atom



Fates of the μ⁻ within the SM

muon decay in orbit

$$\mu^- \rightarrow e^- \nu \bar{\nu}$$

nuclear muon capture

$$\mu^- + (A,Z) \rightarrow \nu_\mu + (A,Z-1)$$

Beyond the SM

$$\mu^- + (A,Z) \rightarrow e^- + (A,Z)$$

μ-e conversion

Forbidden by the SM, because
the lepton flavor is changed to μ-flavor to e-flavor.

Event signature :

a single mono-energetic electron of 105MeV (for Al)

in the SM + ν masses

μ-e conversion can be occur via ν-mixing, but expected rate is well below the experimentally accessible range. Rate ~O(10^{-54})

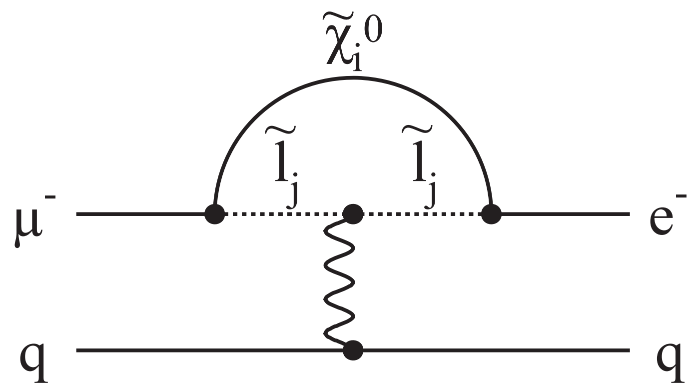
Discovery of the μ-e conversion is a clear evidence of new physics beyond the SM.

in the SM + new physics

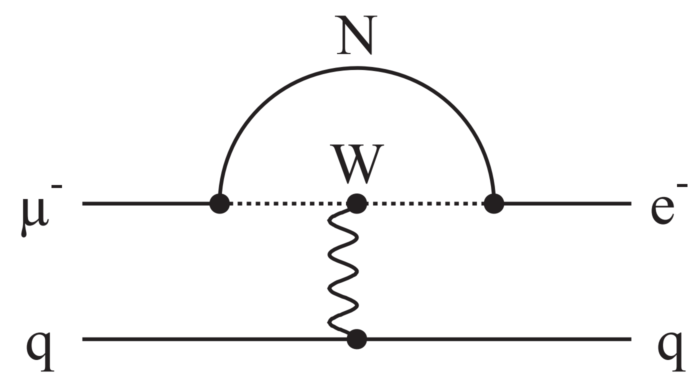
A wide variety of proposed extensions to the SM predict observable μ-e conversion rate.

Possible Contributions to cLFV

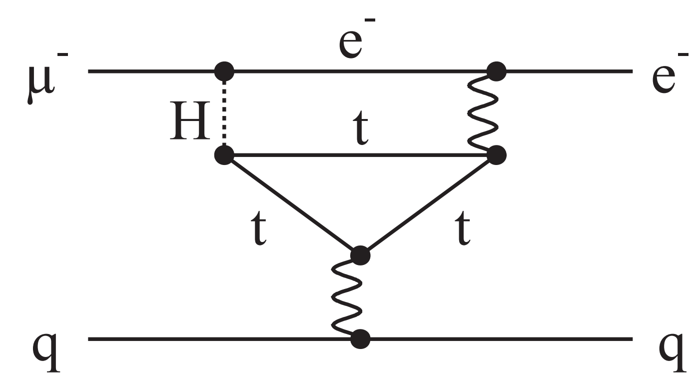
Many models predict a sizable cLFV BR.



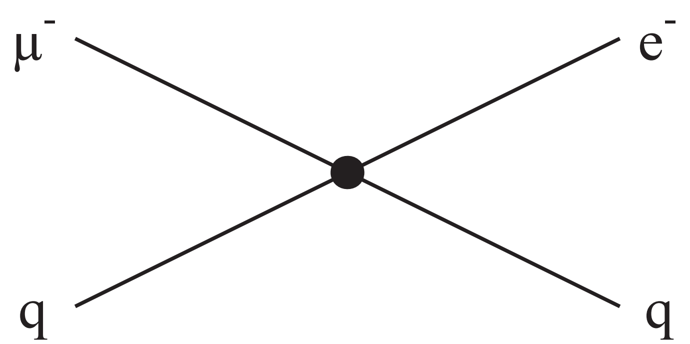
Supersymmetry



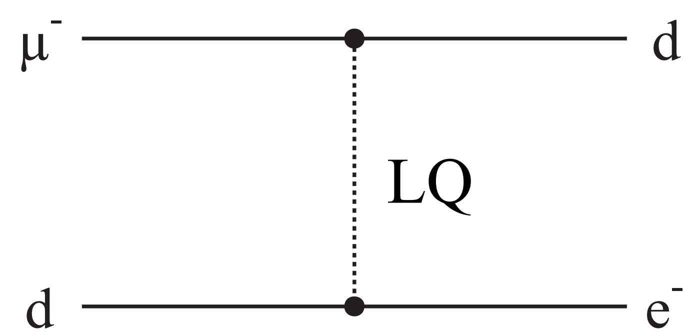
Heavy neutrinos



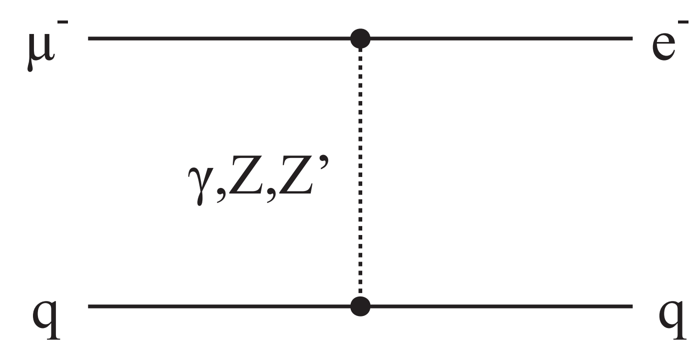
Two Higgs Doublets



Compositeness

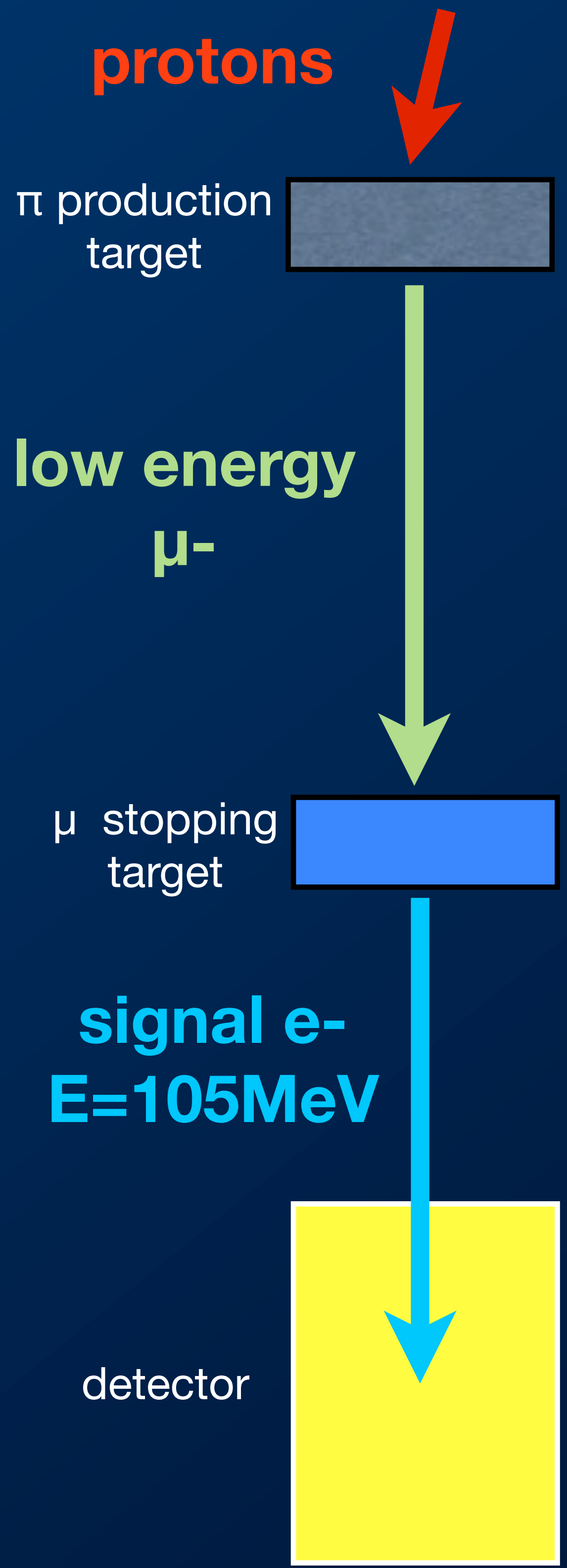


Leptoquarks



Anomalous Coupling

How to search the μ-e conversion



- Inject proton beam to a pion production target to generate a huge amount of muons.
- Stop the muons in a stopping target.
  - Al target for COMET and Mu2e
  - Muonic atoms are produced
  - μ lifetime in Al ~ 864ns
    - 40% μ : decay in the 1s orbit (DIO)
    - 60% μ : captured to the nulear
- Look for the signal electron with E=105MeV.

Key points:
(1) Very intense muon beam
(2) Background suppression

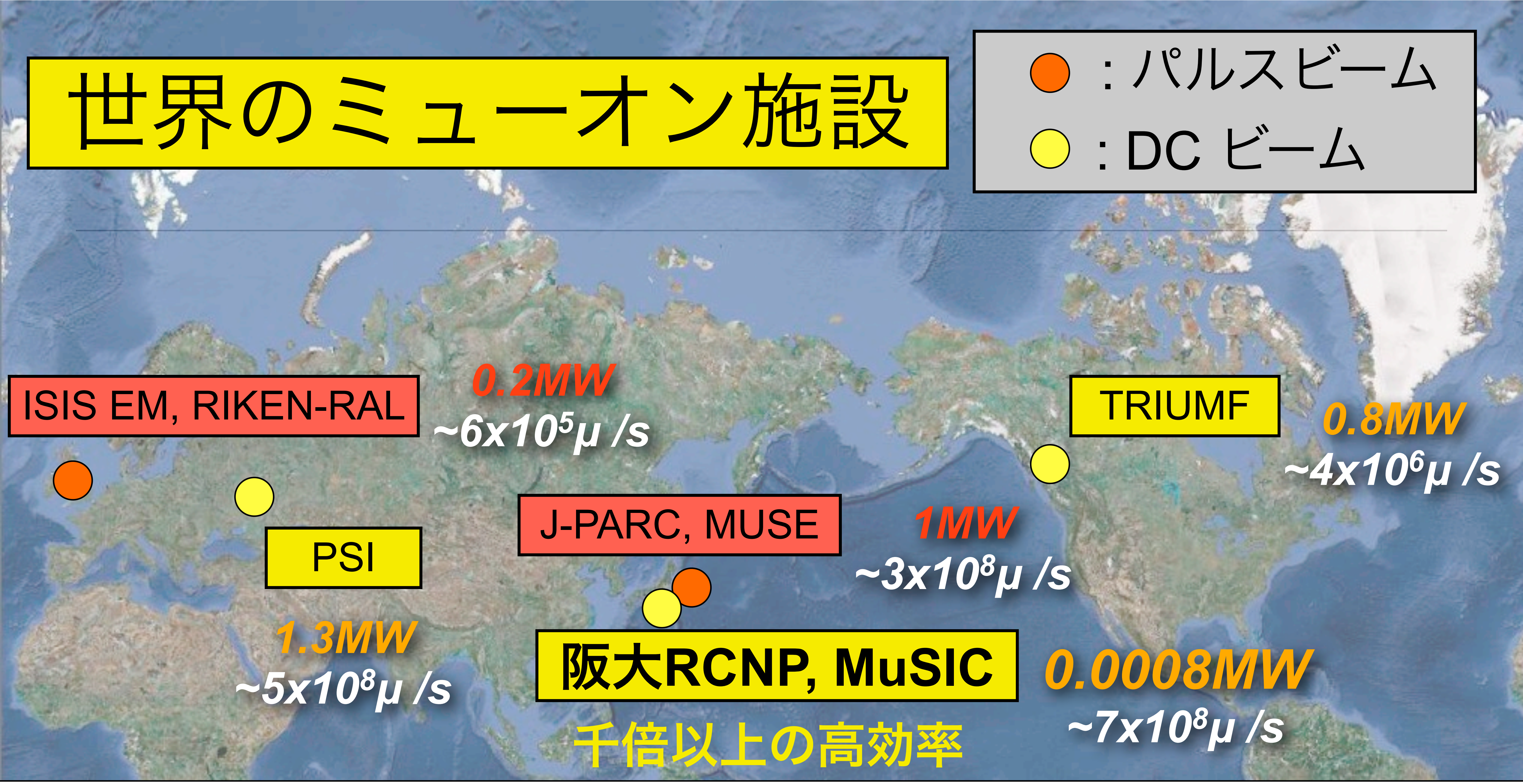
Current Upper Limits and Coming Precisions

- **Current limits** (90% CL)
  - BR(μ^-Au→e^-Au) < 7×10^{-13} (SINDRUM-II@PSI)
  - BR(μ^-Ti→e^-Ti) < 4.3×10^{-12} (SINDRUM-II@PSI)
  - BR(μ^-Ti→e^-Ti) < 4.6×10^{-12} (TRIUMF)

- **Precision of coming measurements** (90% CL)
  - BR(μ^-C→e^-C) < 2.3×10^{-13} (DeeMe@J-PARC-MLF)
    - 2016~
  - BR(μ^-Al→e^-Al) < 7×10^{-15} (COMET Phase-I@J-PARC-HardonH)
    - 2019~
  - BR(μ^-Al→e^-Al) < 6×10^{-17} (COMET Phase-II@J-PARC-HadronH)
    - 2021~
  - BR(μ^-Al→e^-Al) < 6×10^{-17} (Mu2e@FNAL)
    - 2021~

10000倍の感度向上

10^{17}個のμ-が必要→1年間の実験を仮定すると10^{10}μ-/秒の強度



Laboratory/ Beam line	Country	Proton beam power	Time structure	μ^+ yield per proton beam power [μ/sec/W]	Available μ^+ intensity [μ/sec]
RCNP MuSIC	Japan	784 W(392 MeV, 2 μA)[1][1]	DC	**8.5×10^5 [μ/s/W]**	**6.7×10^8 [μ/s]**
PSI μE4	Switzerland	1.3 MW(590 MeV, 2.2 mA) [3]	DC	**3.3×10^2**	**4.3×10^8**
TRIUMF M20A	Canada	70 kW(500 MeV, 140μA) [5]	DC	**5.0×10^1**	**3.5×10^6**

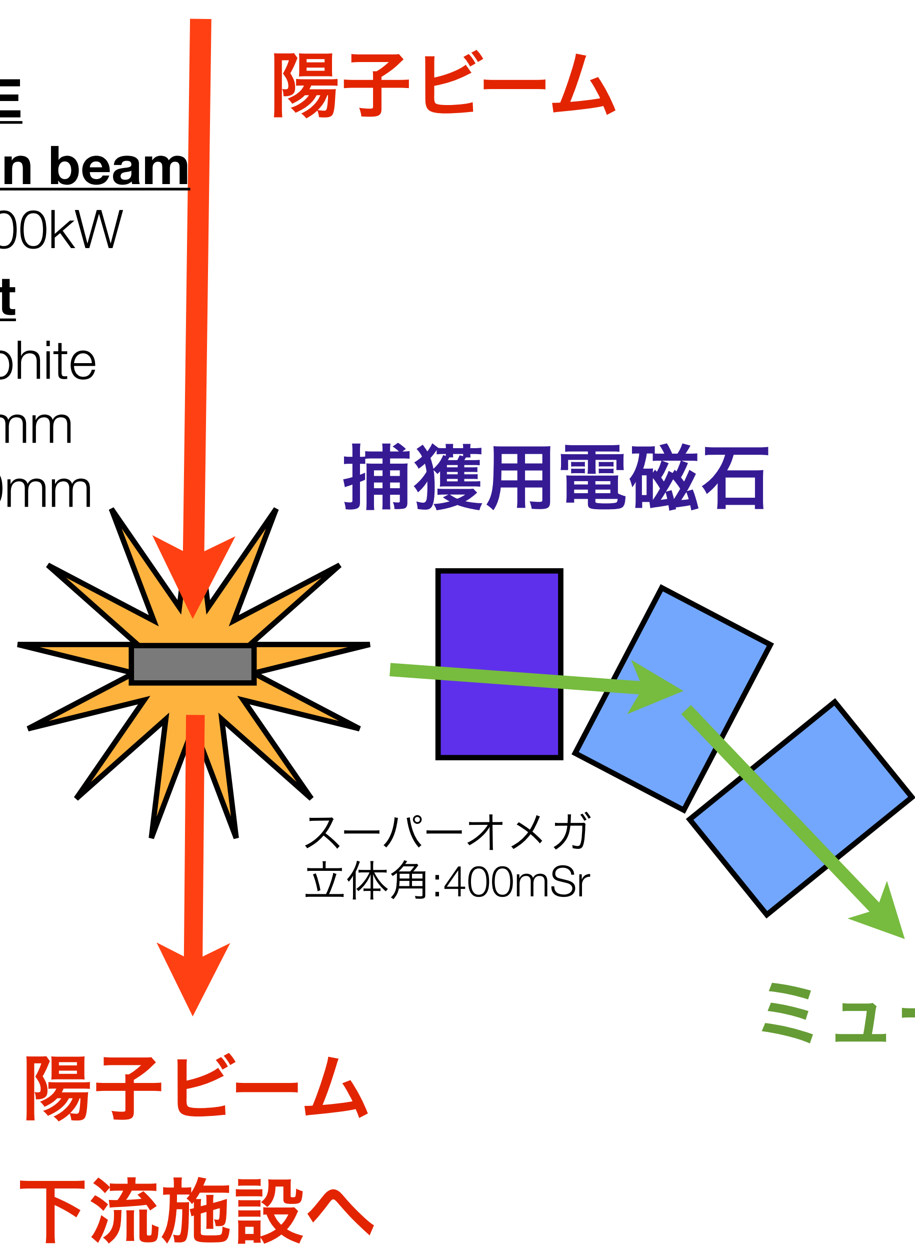
[1] An upgrade program of the RCNP cyclotron facility is in progress to increase 400 MeV proton beam intensity to more than 5 μA.[1]

大強度ミューオン源MuSIC

ミューオン生成方式のポイント

従来のミューオン施設

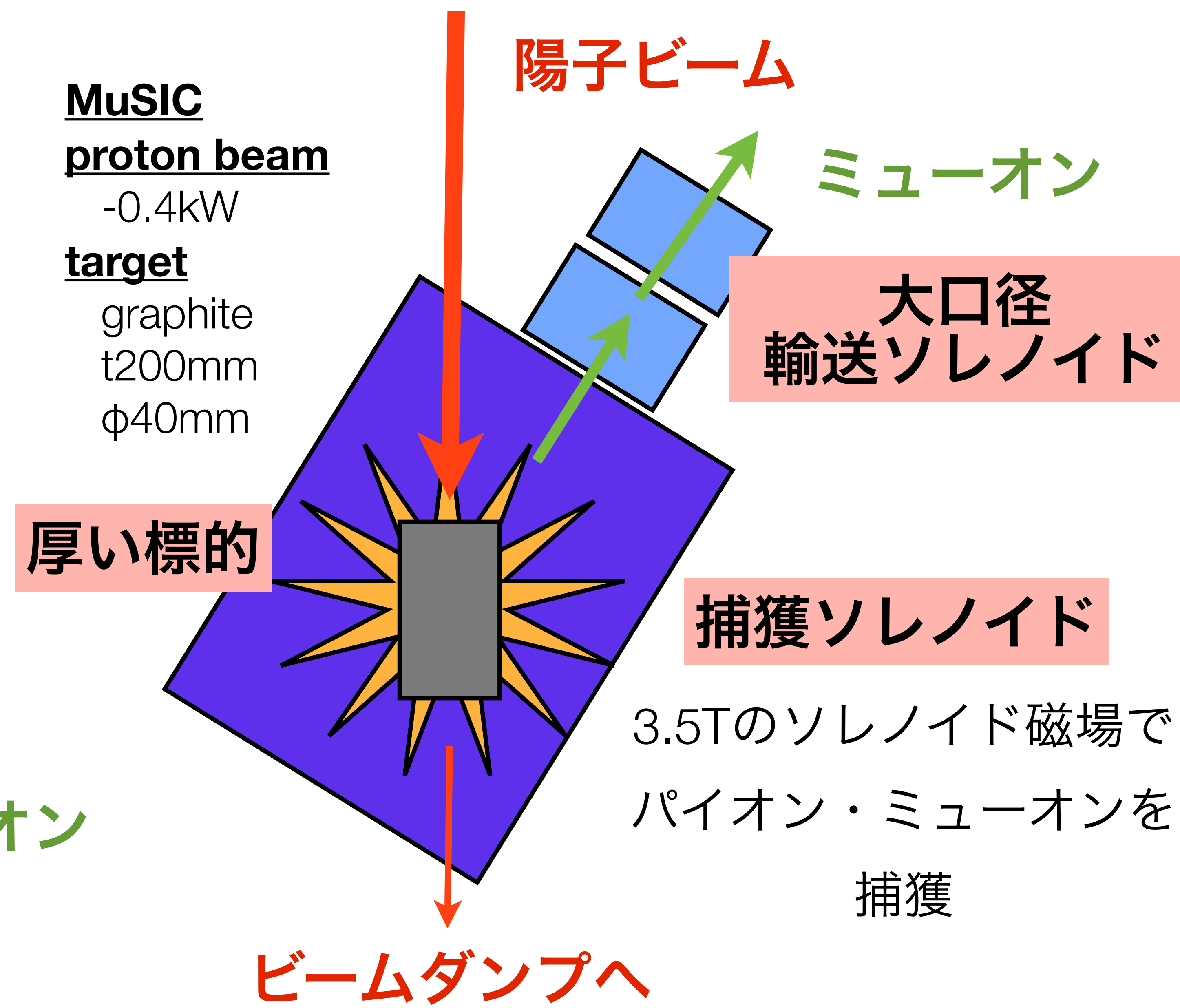
MUSE
proton beam
-1000kW
target
graphite
t20mm
φ70mm



新パイオン捕獲システム

数千倍の生成効率

MuSIC
proton beam
-0.4kW
target
graphite
t200mm
φ40mm

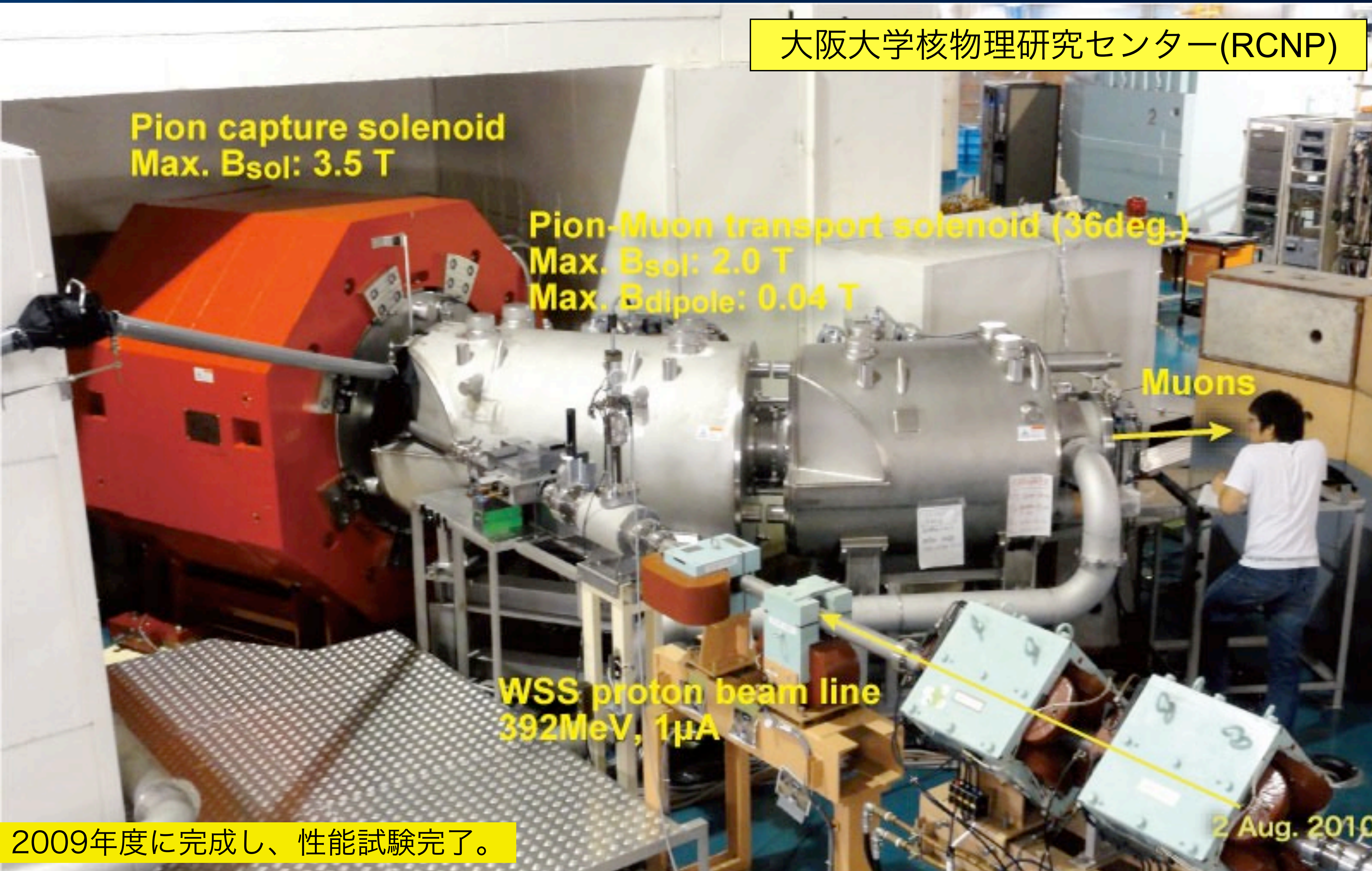


3.5Tのソレノイド磁場でパイオン・ミューオンを捕獲

厚い標的&大立体角で捕獲
&高効率輸送系

世界初のパイオン捕獲システム：MuSIC

大阪大学核物理研究センター(RCNP)

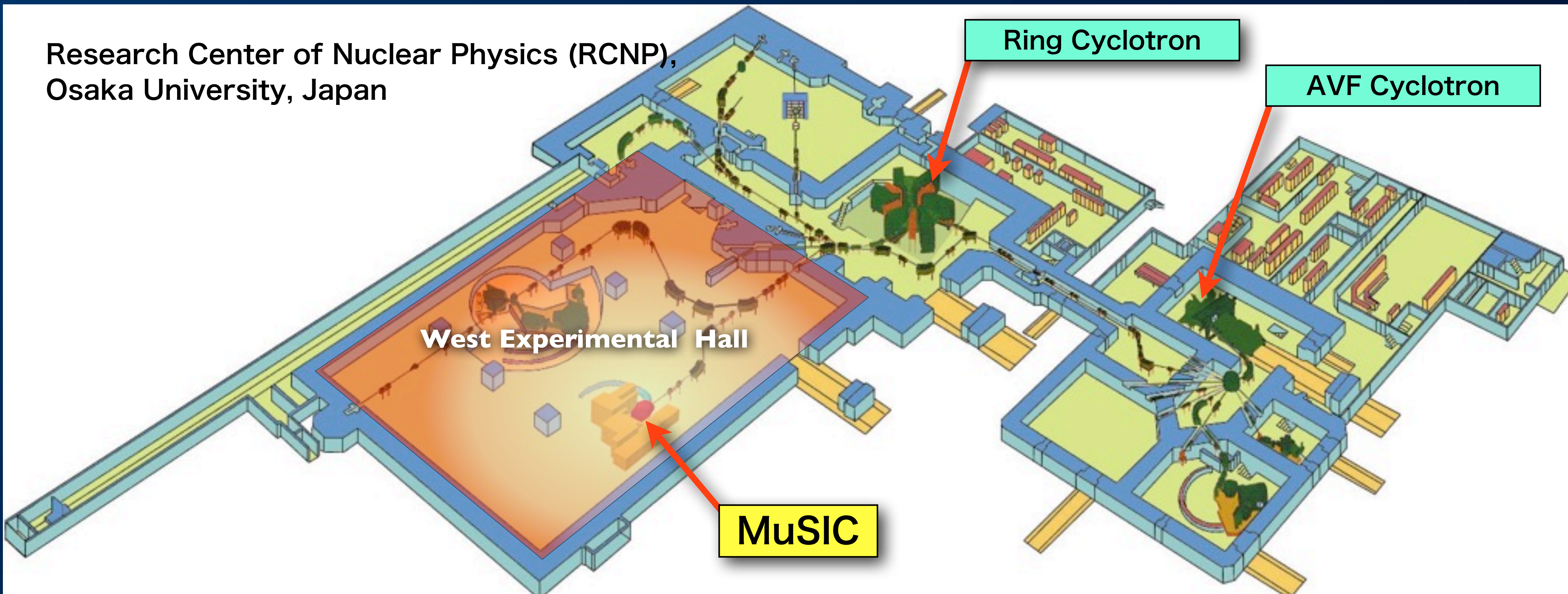


2009年度に完成し、性能試験完了。

MuSIC計画の概要

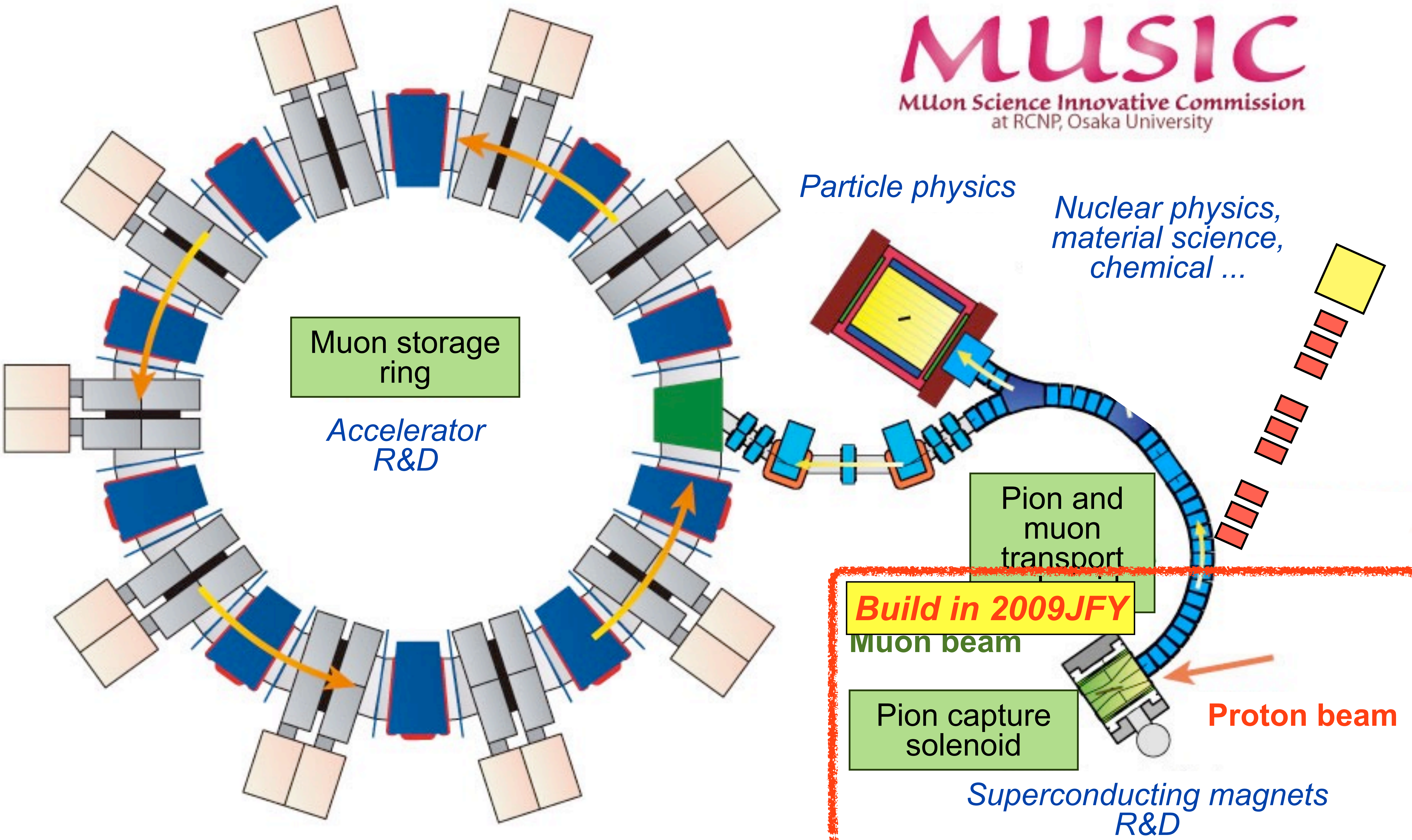
- **MuSICとは**
  - 核物理研究センターリングサイクロトロンからの392MeV陽子ビームを使って、世界最高強度のDCミューオンビーム源を建設し、ミューオン科学を展開する。
  - 目標強度は毎秒10^{8-9}μ@392MeV,1μA陽子ビーム。
- **大強度ミューオン源の技術的ポイント**
  - 世界初の大立体角超伝導パイオン捕獲システムの実現
  - 従来のミューオン施設に比べて数千倍のミューオン生成効率
    - ECOミューオン源
  - 世界初の大口径超伝導ソレノイド輸送チャンネル
- **建設フェイズの第一段階で確認すべき重要事項**
  - ミューオン生成効率の確認（完了）
  - 高放射線環境下でのシステム稼働確認（完了）
- **RCNPにおけるミューオン科学展開（進行中）**
  - 新ミューオンラインの建設（2013年度完了）
  - ユーザーへのDCミューオンビーム供給(2015年度~)

MuSIC@阪大RCNP

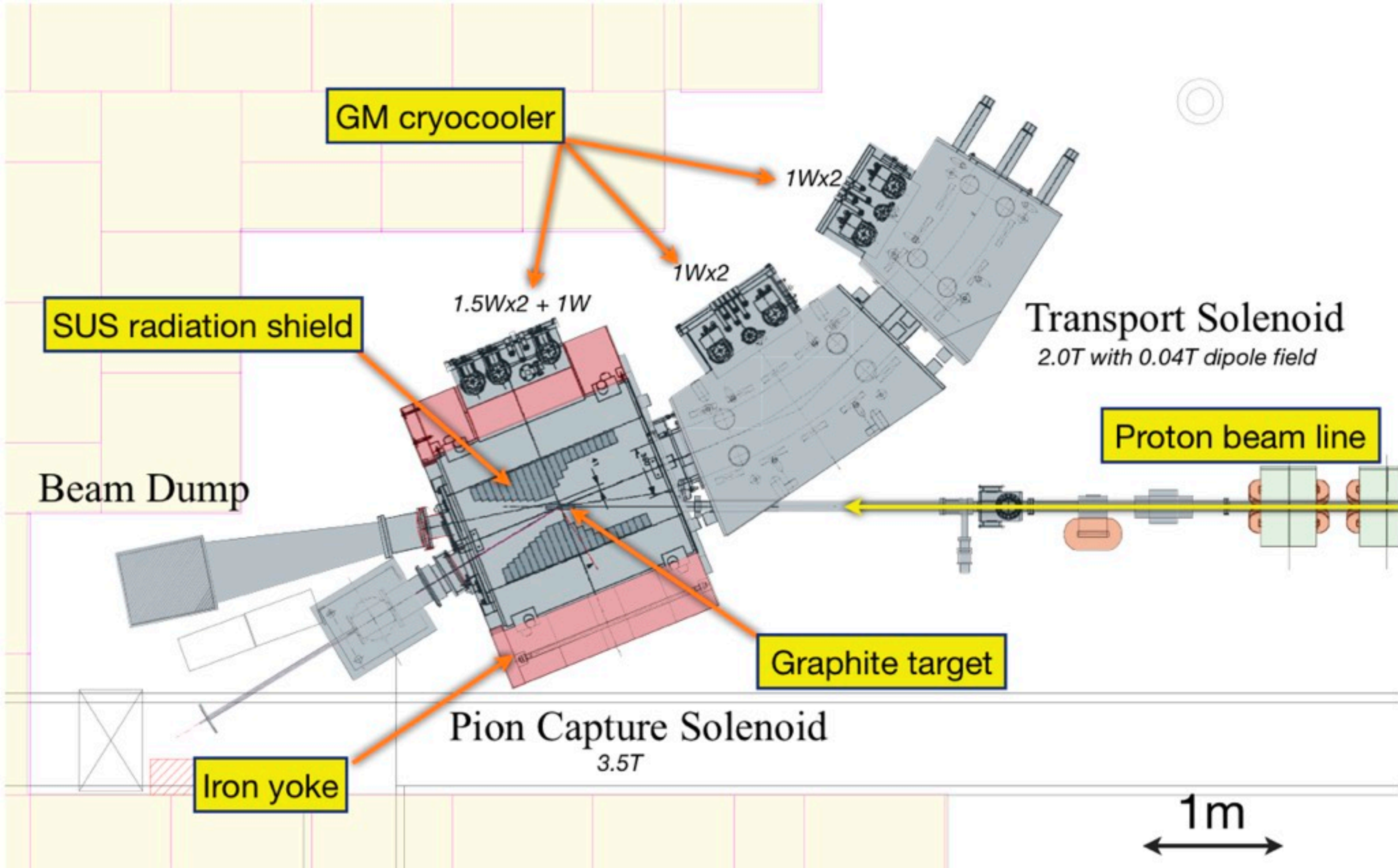


- RCNPの２つのサイクロトロン加速器により最終的に陽子ビームは、運動エネルギー392MeV,まで加速される。ビーム電流3μAまで可能。
  - 5μA まで増強する計画あり。
- MuSICは、一番大きな実験室（西実験室）に設置されている。

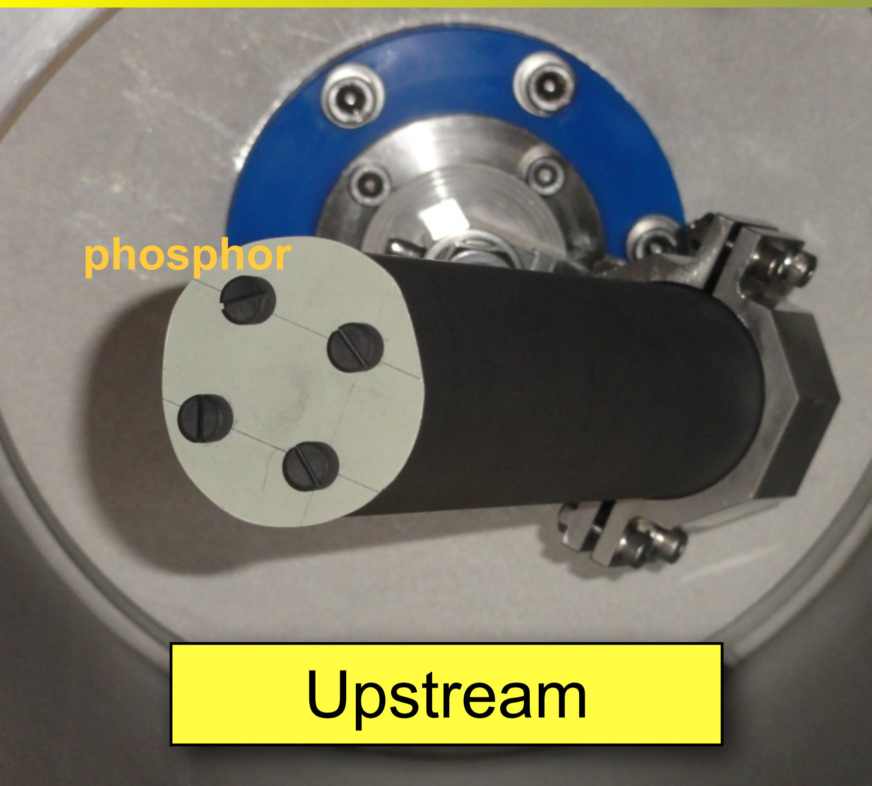
MuSIC全体のレイアウト案

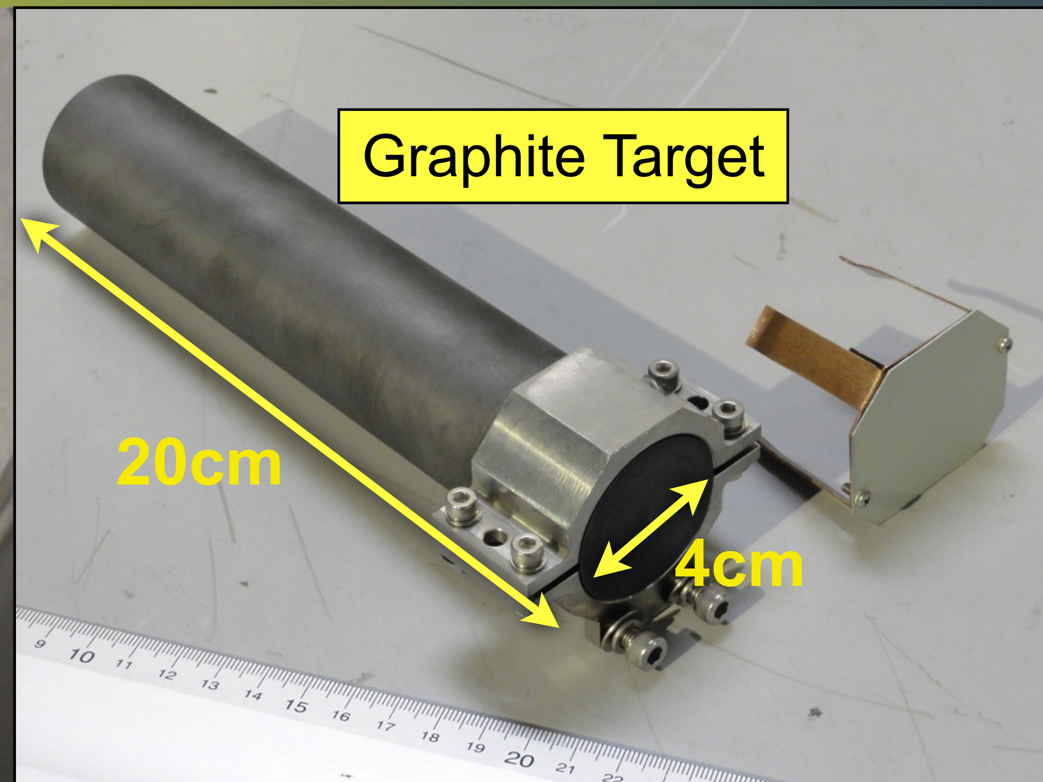


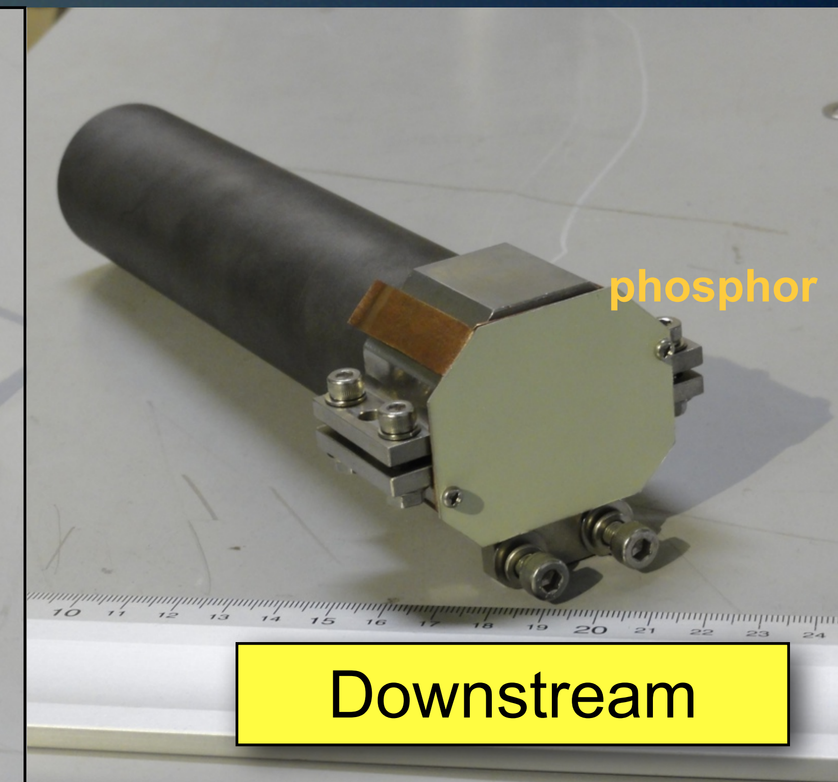
MuSIC: パイオン捕獲部

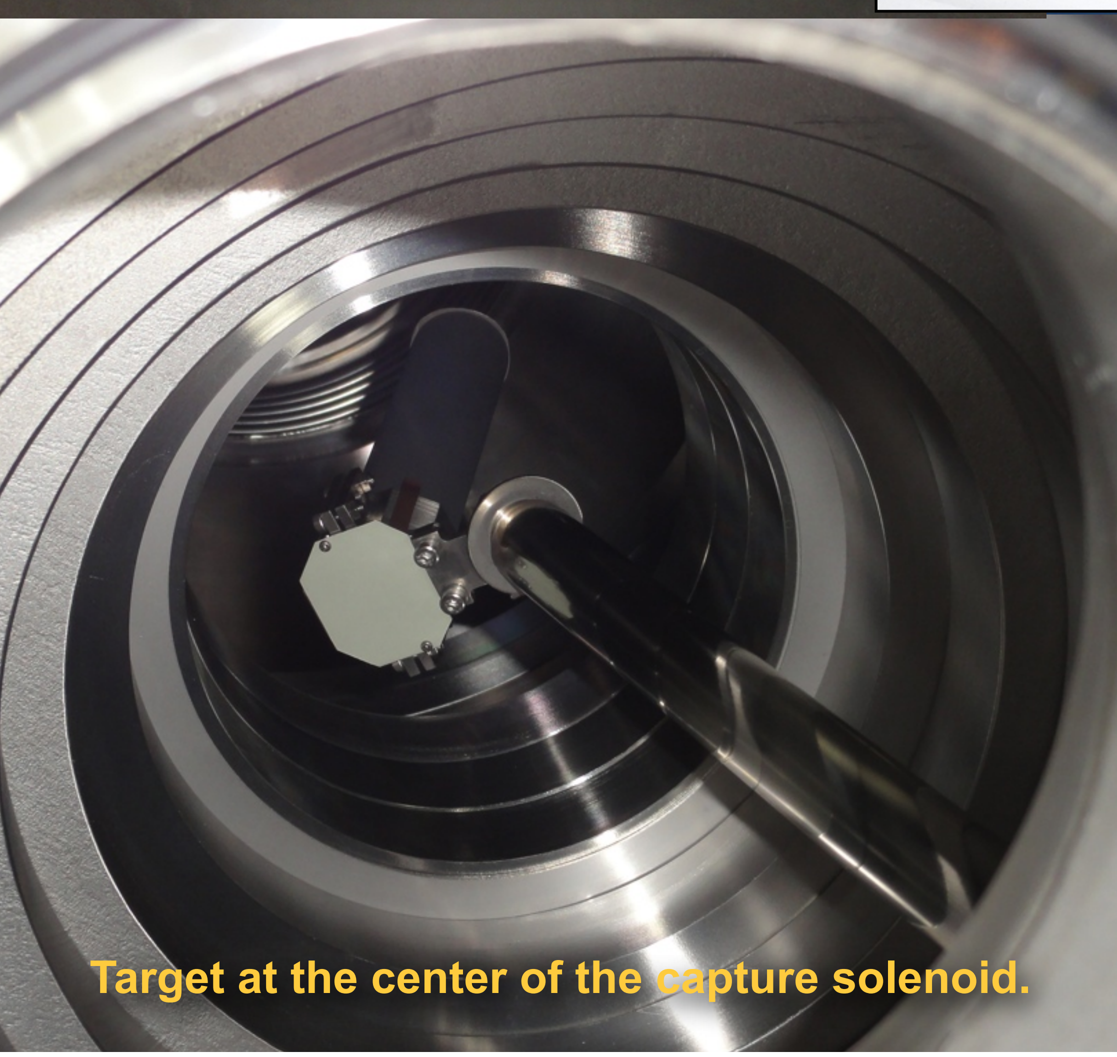


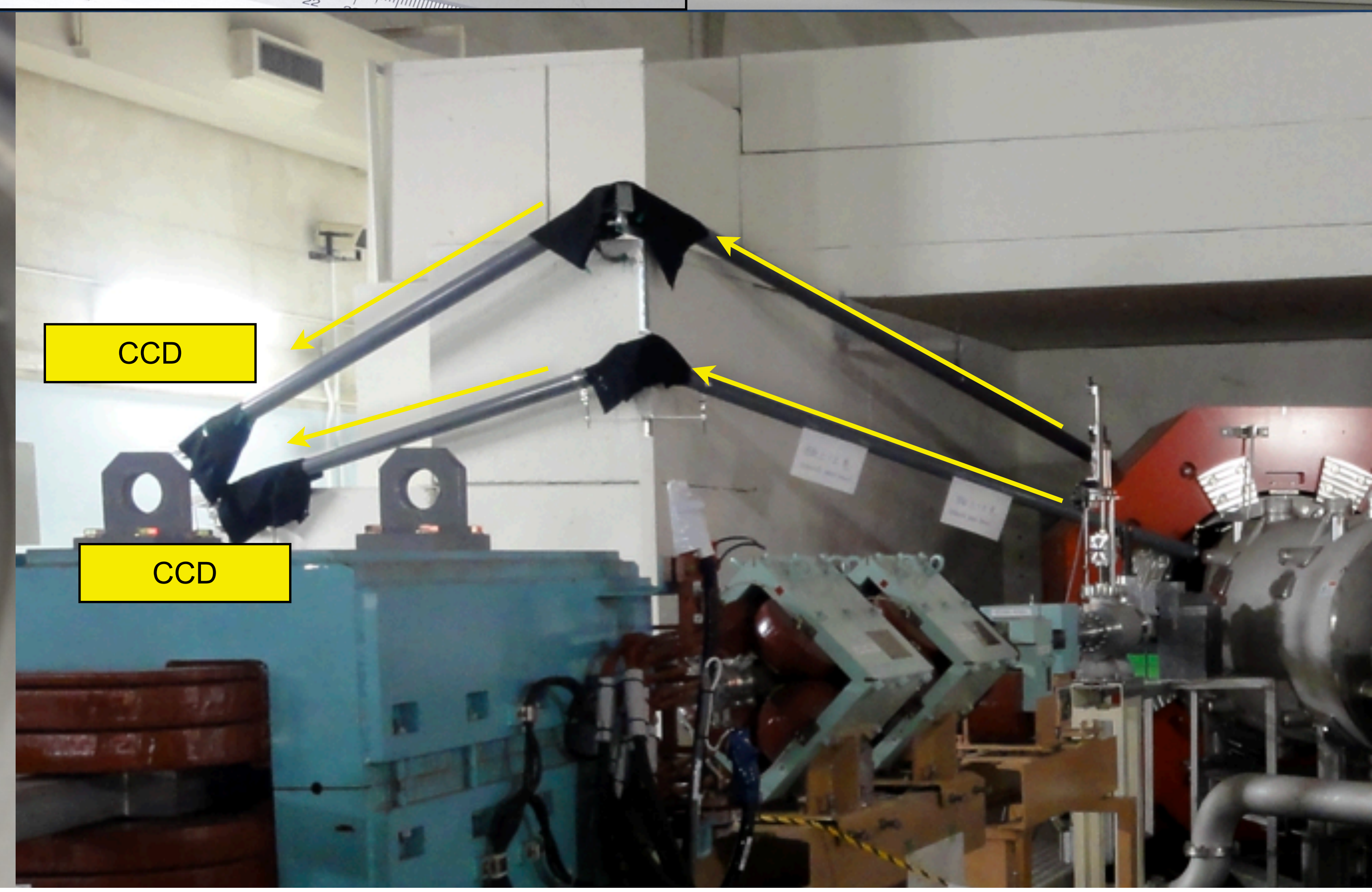
Proton Beam Monitoring on the Target







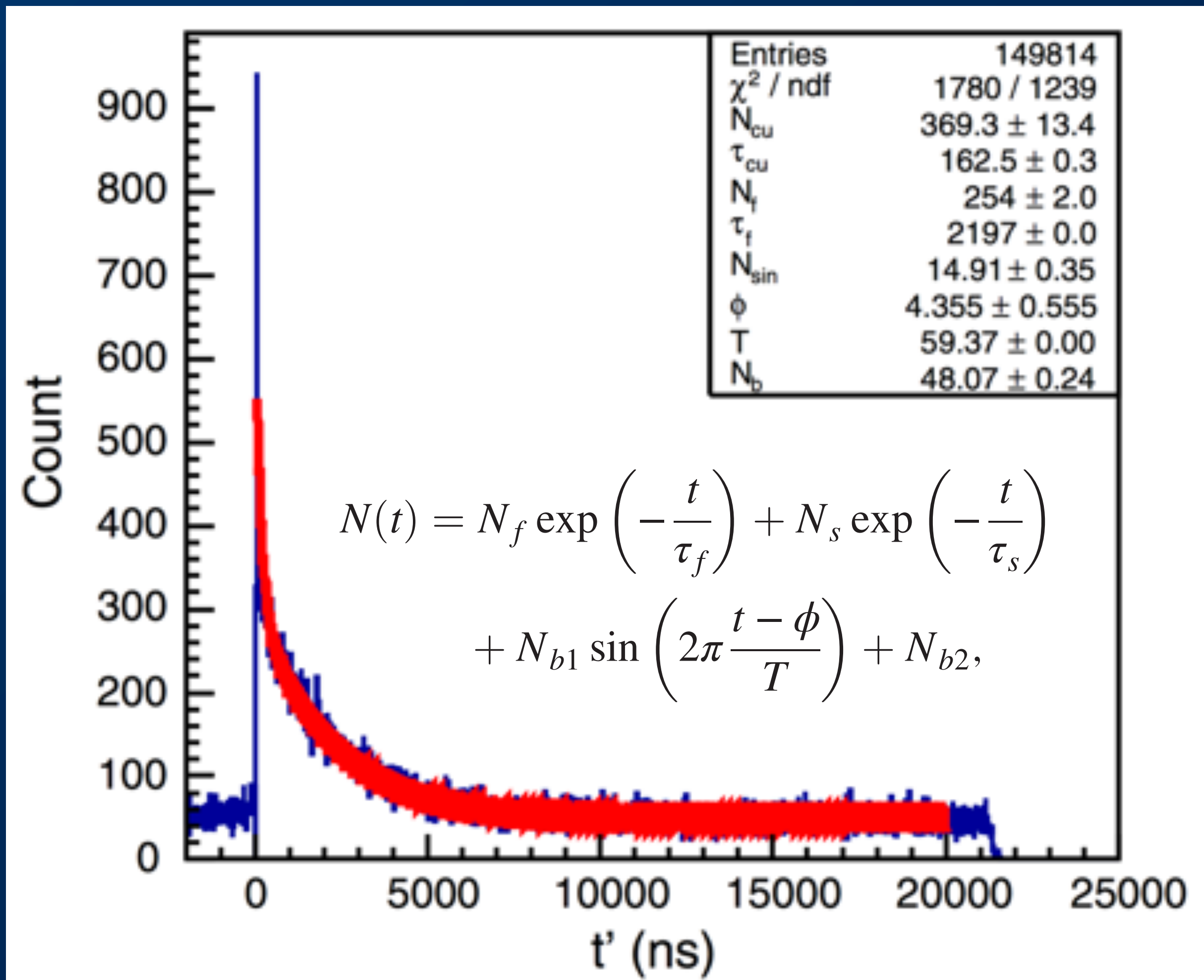




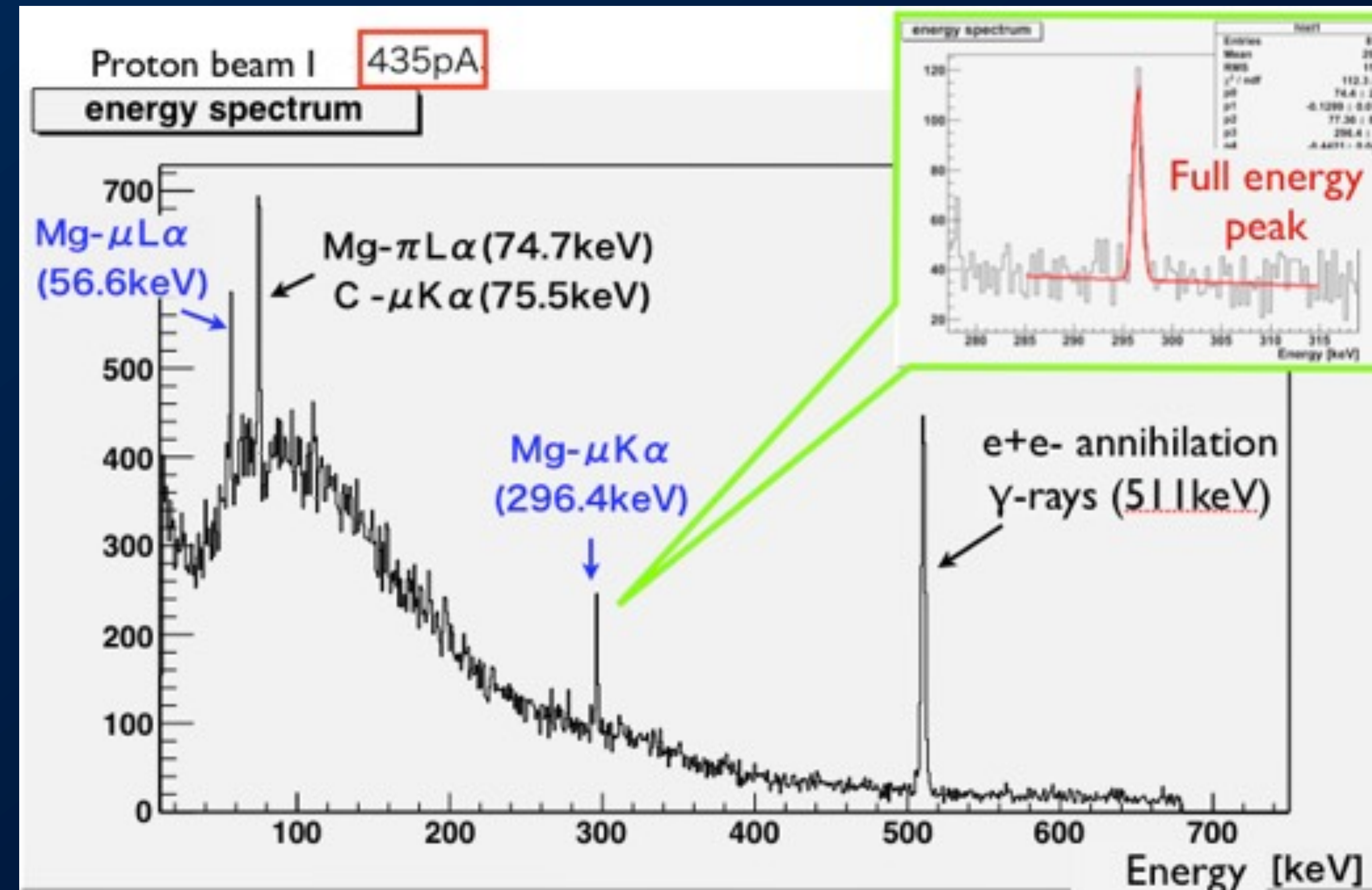
S. Cook, et. al., Phys. Rev. Acc. and Beam **20**, 030101 (2017)

Muon yield @ the solenoid exit

Muon life（Stopping target: Cu）



Muonic X-rays（Stopping target: Mg）



Measured muon yield at the exit of the 36° transport solenoid

	measurement
positive muon [μ^+/sec for 400W]	$(4.2 \pm 1.1) \times 10^8$
negative muon [μ^-/sec for 400W]	$(3.6 \pm 0.4) \times 10^7$

The μ production efficiency shows good agreements with the design value.

PHYSICAL REVIEW ACCELERATORS AND BEAMS **20,** 030101 (2017)

Editors' Suggestion

Delivering the world's most intense muon beam

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(Received 25 October 2016; published 15 March 2017)

A new muon beam line, the muon science innovative channel, was set up at the Research Center for Nuclear Physics, Osaka University, in Osaka, Japan, using the 392 MeV proton beam impinging on a target. The production of an intense muon beam relies on the efficient capture of pions, which subsequently decay to muons, using a novel superconducting solenoid magnet system. After the pion-capture solenoid, the first 36° of the curved muon transport line was commissioned and the muon flux was measured. In order to detect muons, a target of either copper or magnesium was placed to stop muons at the end of the muon beam line. Two stations of plastic scintillators located upstream and downstream from the muon target were used to reconstruct the decay spectrum of muons. In a complementary method to detect negatively charged muons, the x-ray spectrum yielded by muonic atoms in the target was measured in a germanium detector. Measurements, at a proton beam current of 6 pA, yielded $(10.4 \pm 2.7) \times 10^5$ muons per watt of proton beam power (μ^+ and μ^-), far in excess of other facilities. At full beam power (400 W), this implies a rate of muons of $(4.2 \pm 1.1) \times 10^8$ muons s^{-1}, among the highest in the world. The number of μ^- measured was about a factor of 10 lower, again by far the most efficient muon beam produced. The setup is a prototype for future experiments requiring a high-intensity muon beam, such as a muon collider or neutrino factory, or the search for rare muon decays which would be a signature for phenomena beyond the Standard Model of particle physics. Such a muon beam can also be used in other branches of physics, nuclear and condensed matter, as well as other areas of scientific research.

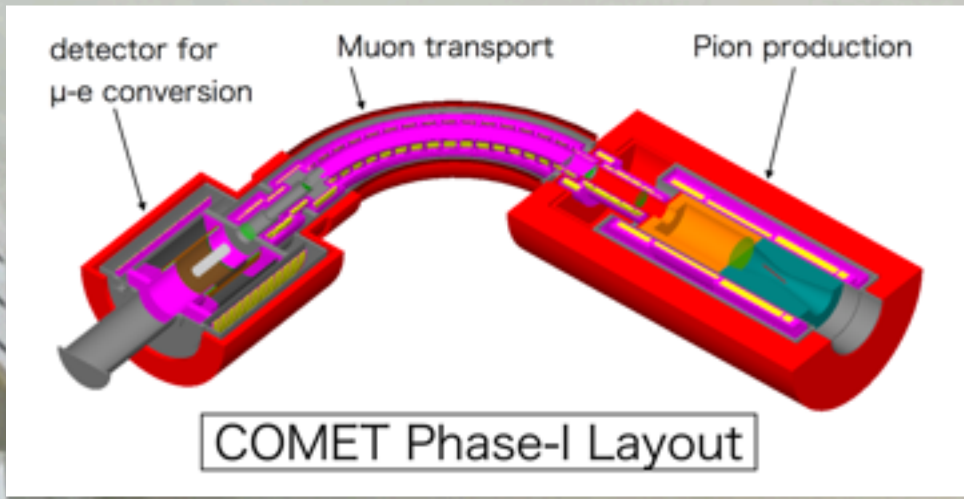
DOI: 10.1103/PhysRevAccelBeams.20.030101

MuSIC Pion Capture followed by ...

- MuSIC successfully demonstrated a muon intensity = $10^8 \mu$/s is available with a 431W proton beam. It correspond to ~ $10^6 \mu^+$/s/W and ~ $10^5 \mu^-$/s/W, over a factor of 1000 higher than other muon facilities.
- For COMET (elementary particle physics)
  - combine with 56kW proton beam at J-PARC can make $>10^9 \mu^-$/s for μ-e conversion experiments. The COMET collaboration is building another pion capture system for COMET at J-PARC hadron hall.

COMET SC magnets for $10^{10}\mu^-/s$ beam

- A 90-deg. muon transport solenoid has been constructed in 2015.
- A 5.5 Tesla pion capture solenoid will be delivered to J-PARC in 2019.



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- For COMET (elementary particle physics)
  - combine with 56kW proton beam at J-PARC can make $>10^9 \mu^-$/s for μ-e conversion experiments. We are building another pion capture system for COMET at J-PARC hadron hall.
- For RCNP
  - The directer decided to start muon program at RCNP-MuSIC by extending MuSIC with a muon beamline, which consists of normal-conducting magnets.

Examples of DC Muon Science at MuSIC

- **+ Particle Physics :**
  - search for $\mu \to eee$ (muon LFV) $10^{8-9}\mu^+$/sec
    - DC continuous beam is critical
- **± Materials Science :**
  - μSR (a μSR apparatus is needed) $10^{5-6}\mu^\pm$ /sec, polarized
- **- Nuclear Physics :**
  - nuclear muon capture (NMC) $10^{4-5}\mu^-$/sec
    - nuclear matrix element study for $0\nu\ \beta\beta$ decay
  - pion capture and scattering
- **- Chemistry :**
  - chemistry on pion/muon atoms $10^{4-5}\mu^-$/sec
- **- Non-destructive element analysis**
  - archaeology, asteroid explorer (Hayabusa-2) $10^{4-5}\mu^-$/sec
- **Accelerator / Instruments R&D**
  - (for PRISM/neutrino factory/muon collider) :
    - Superconducting solenoid magnets
    - FFAG, RF
    - cooling methods
    - muon acceleration, deceleration, and phase rotation

Stage-2

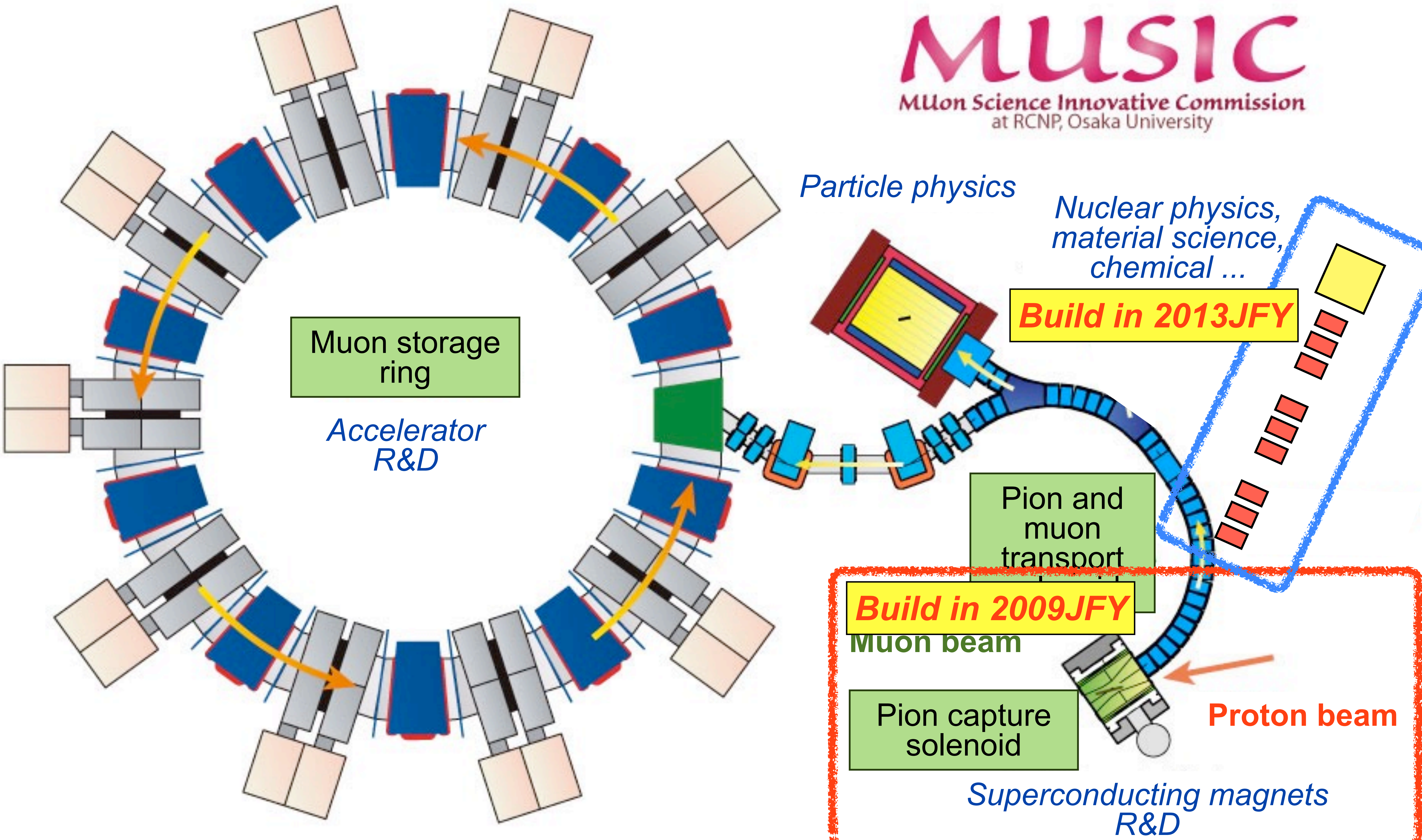
Needs a long SC solenoid channel.

A beam line can be consist of Q,D magnets.

Stage-1

MuSIC-M1 beamline has been constructed!

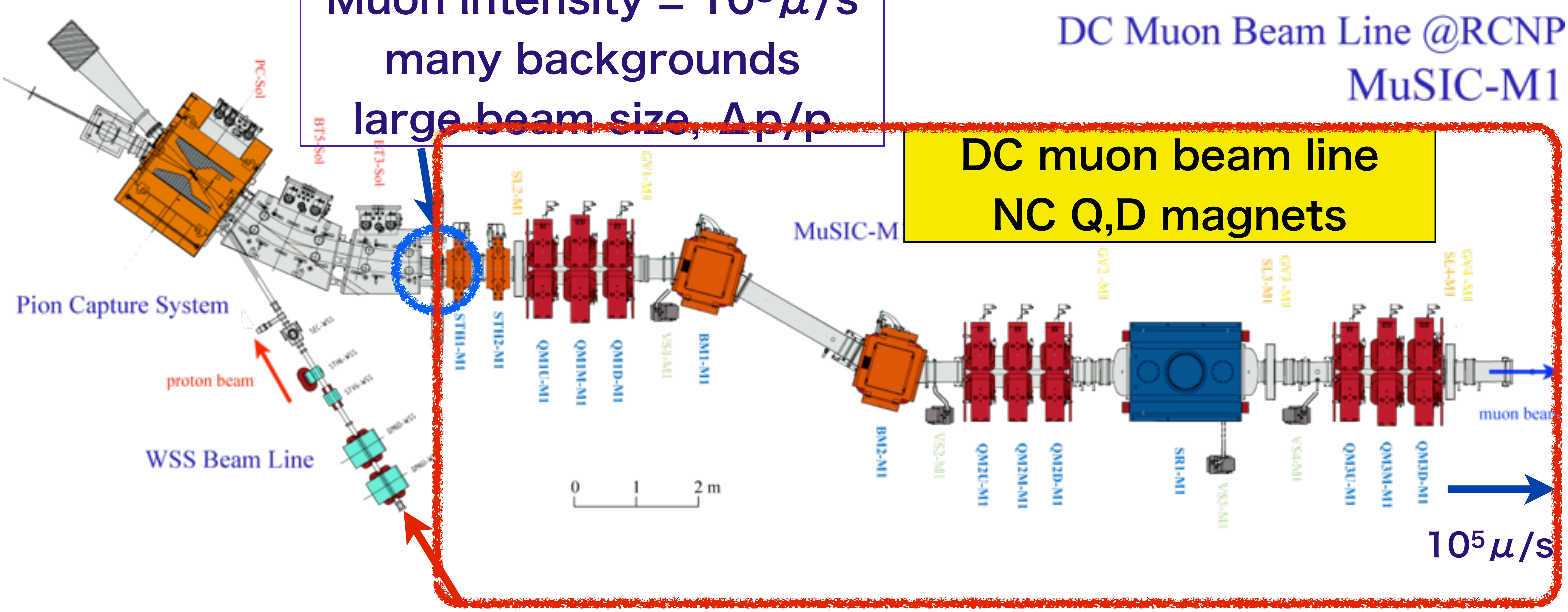
MuSIC全体のレイアウト案



A New DC muon beam line: RCNP-MuSIC

Pion capture system
SC solenoids

Muon intensity = $10^8 \mu/s$
many backgrounds
large beam size, $\Delta p/p$



DC muon beam line
NC Q,D magnets

$10^5 \mu/s$

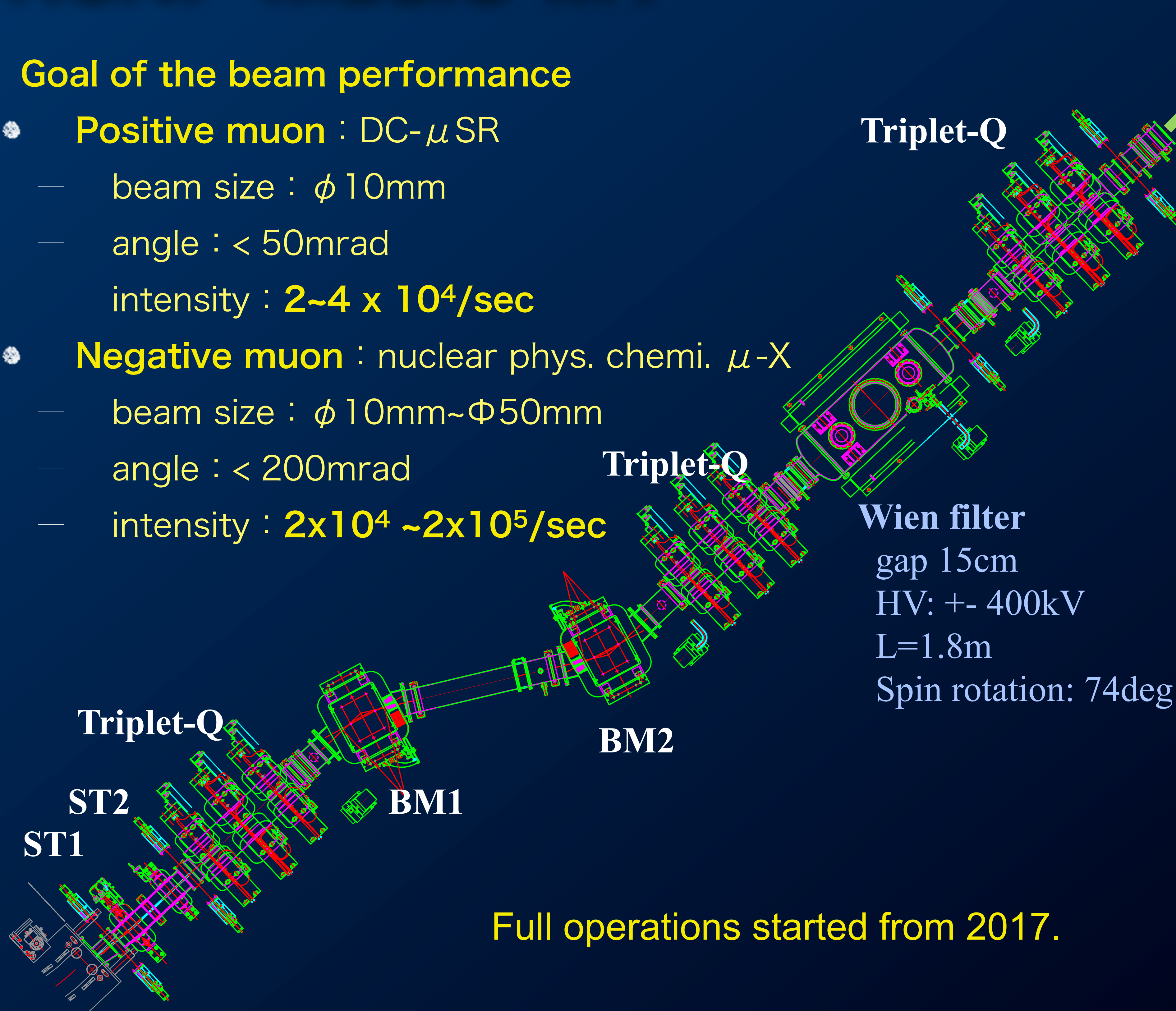
Proton beam 392MeV, $1 \mu A$
from the ring cyclotron

The DC muon beam line in Japan

RCNP-MuSIC-M1 constructed in 2013JFY

Goal of the beam performance

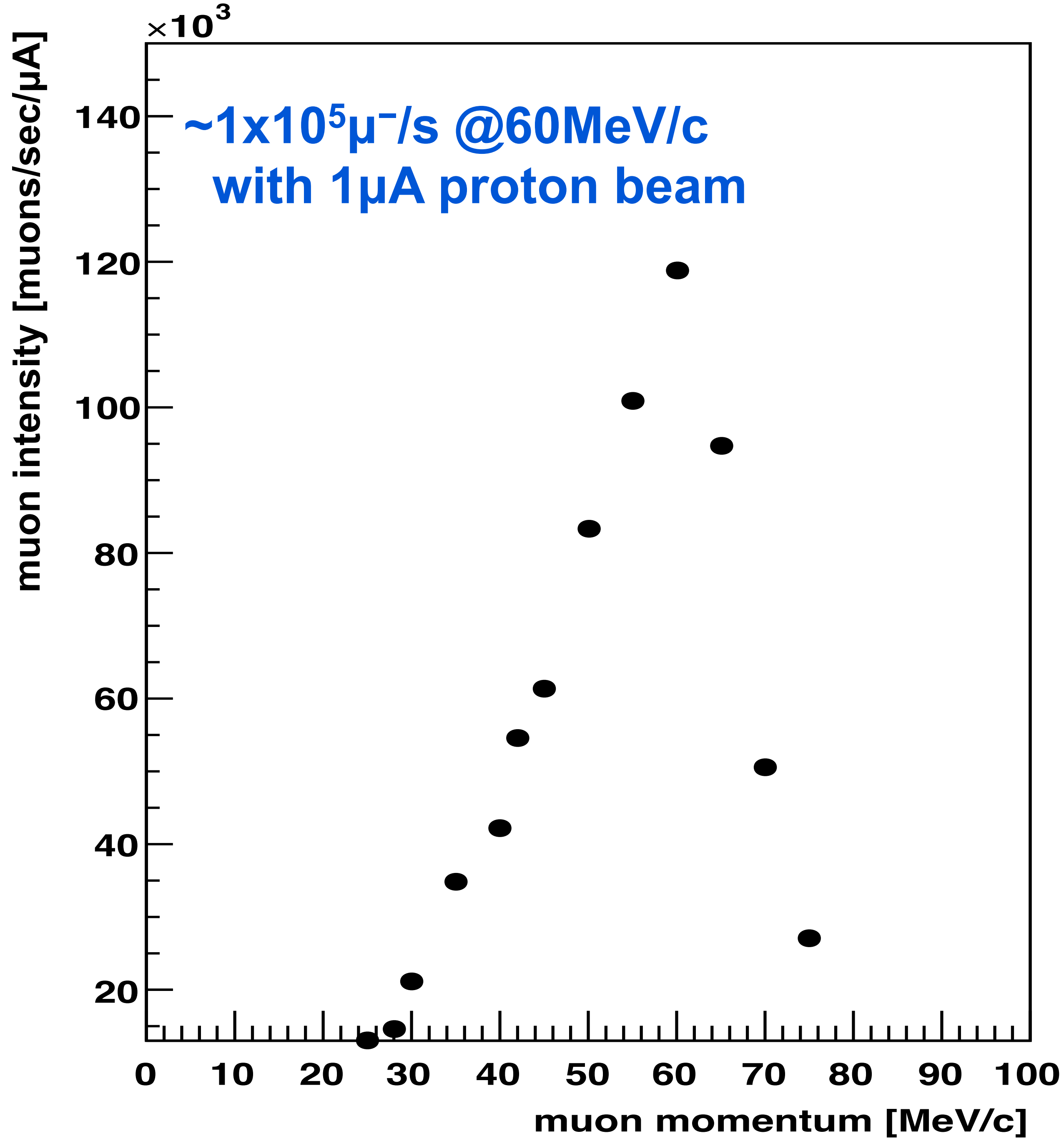
- **Positive muon** : DC-μSR
  - beam size : ϕ10mm
  - angle : < 50mrad
  - intensity : **2~4 x 10^4/sec**
- **Negative muon** : nuclear phys. chemi. μ-X
  - beam size : ϕ10mm~Φ50mm
  - angle : < 200mrad
  - intensity : **2x10^4 ~2x10^5/sec**



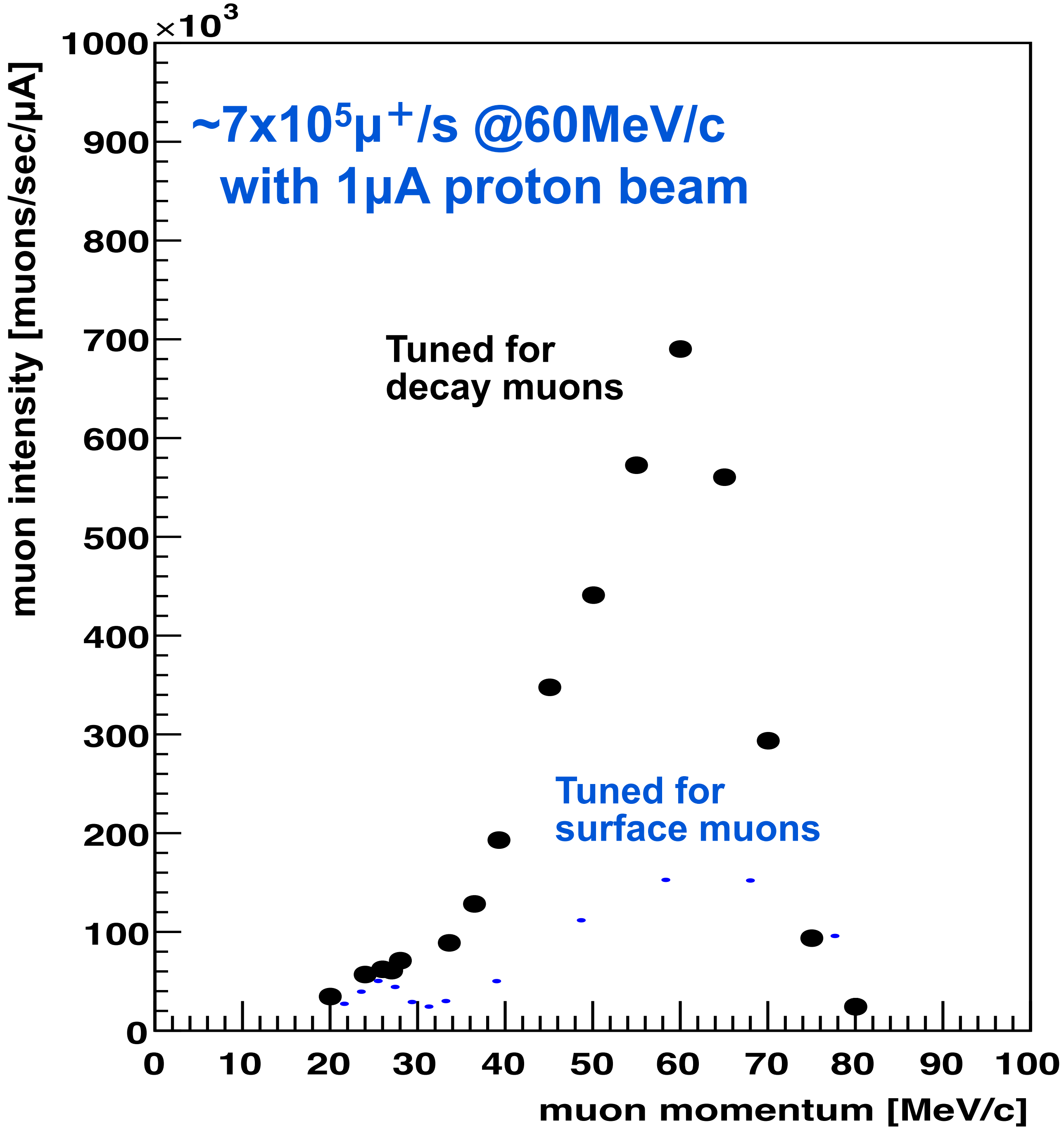
Full operations started from 2017.

MuSIC-M1: Measured μ intensity

Negative muon

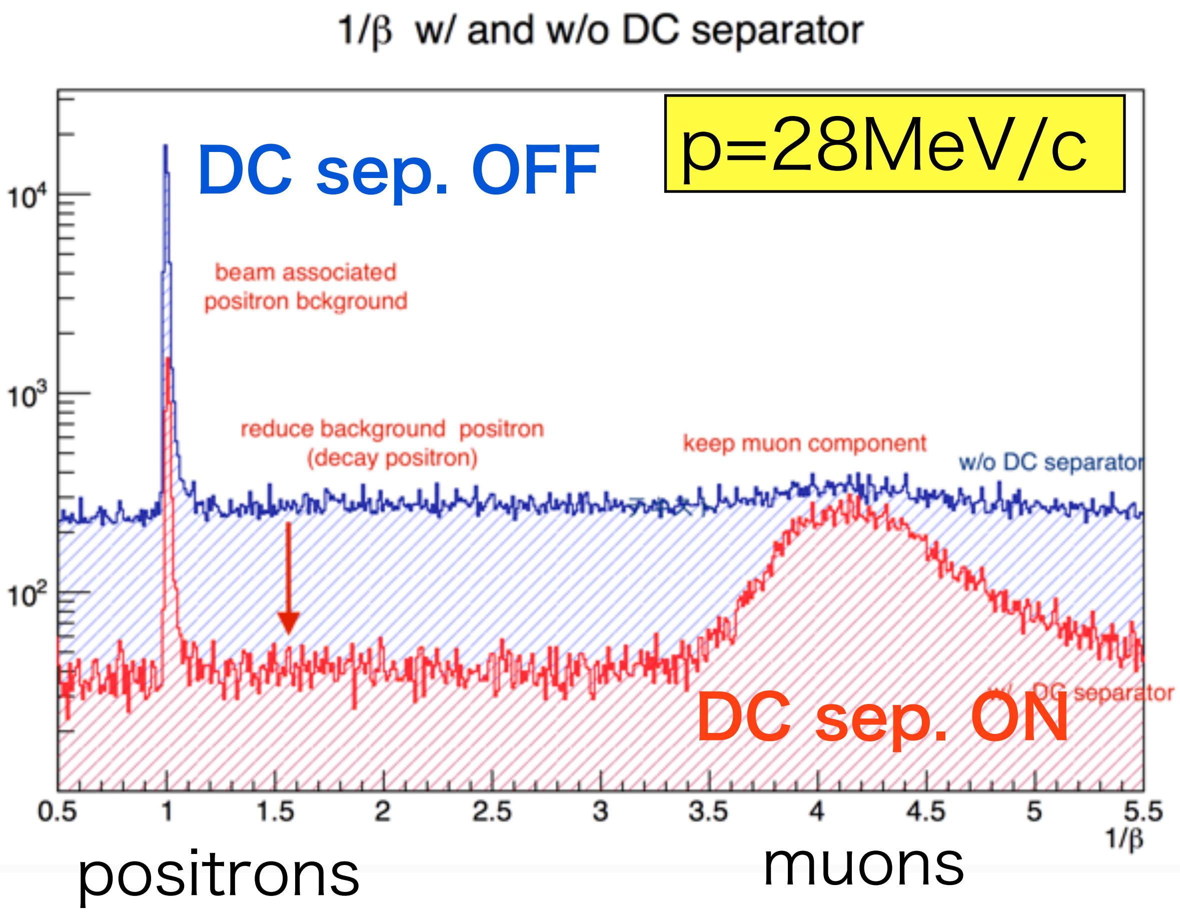


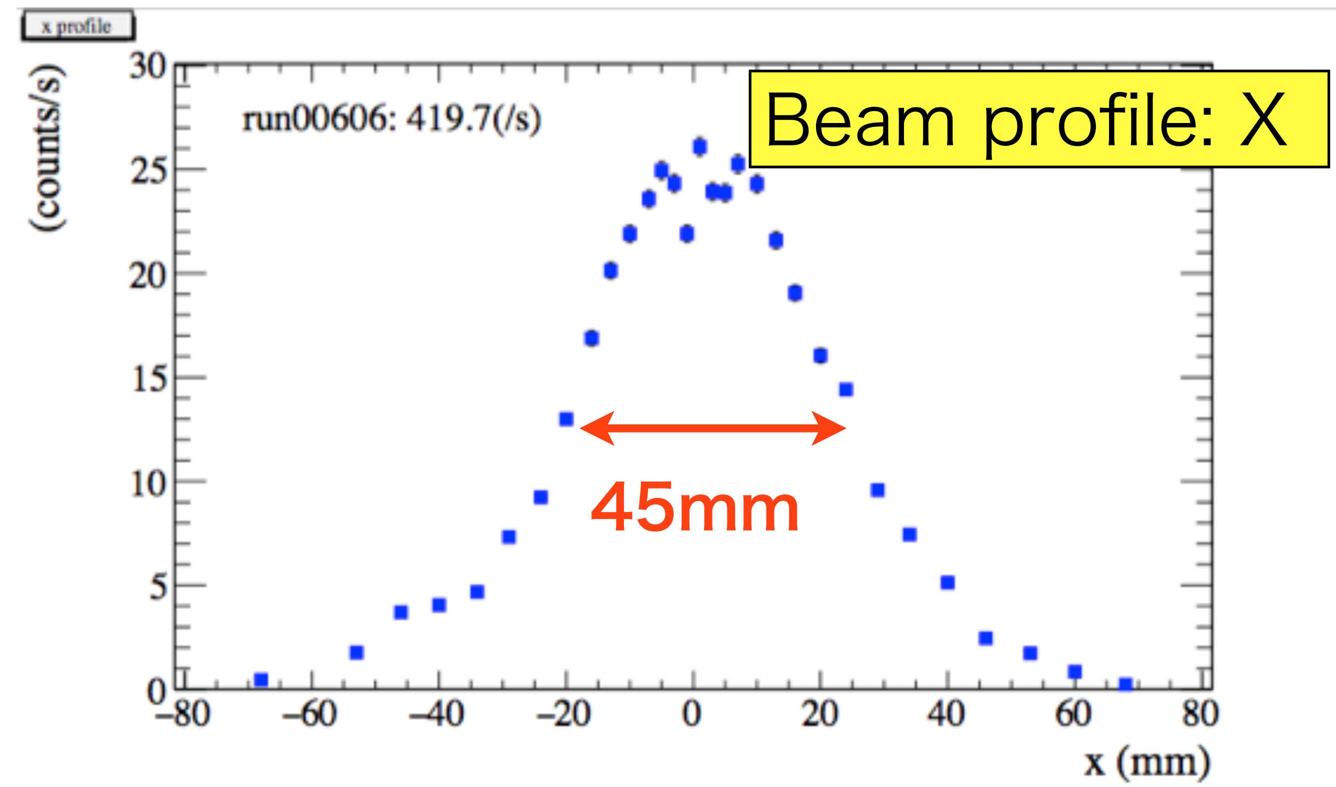
Positive muon

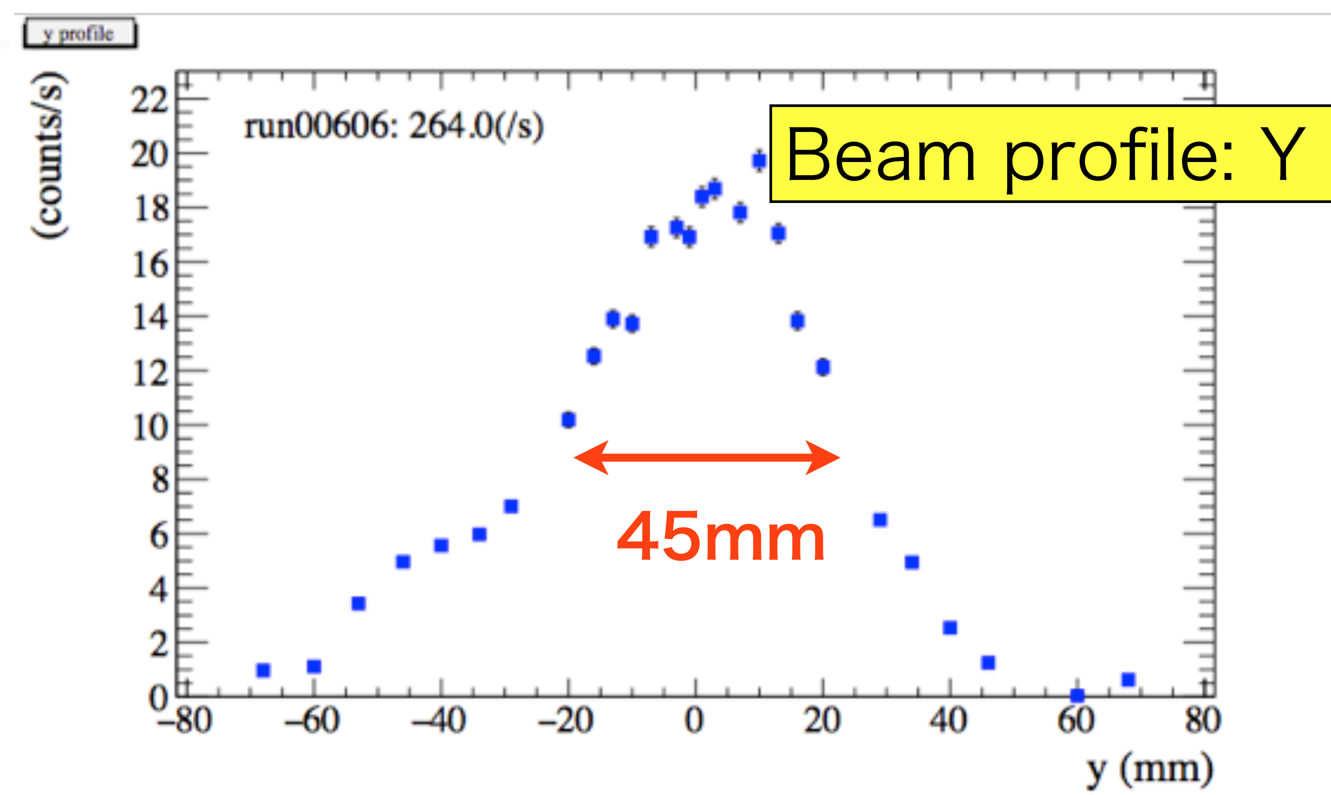


Notes: Muon was measured a 40cm x 40cm counter with 20nA proton beam, then normalized with 1μA. The tuning to get focused beam will be done in this year.

Particle separation and beam size







DC Sep.	e^+/μ^+ for 28MeV/c
Off	6.8
On(±100kV)	<0.15

Status of Muon Experiments at the MuSIC

20nA

E411: Nov. 2015 **Done**

- "Development on non-destructive elemental analysis of planetary materials by using high intensity μ- beam", K. Terada, (Osaka U.)

G02/E475 : 28-29 May 2016, Impact project **Done**

- "Reaction Mechanism of Muon Nuclear Capture on Pd Isotopes", by H.Sakurai(RIKEN),

1.1μA

G02/E475: Feb.-Mar. 2017 **Done**

- "Reaction Mechanism of Muon Nuclear Capture on Pd Isotopes", by T.Matsuzaki(RIKEN),

E467: June 2017 **Done**

- "Development of muonic X-ray measuring system and precise determination of muon capture probabilities for iron compounds", by K.Ninomiya(Osaka U.),

E476: June 2017 **Done**

- "Measurement of the muon capture on 3He by using of the high intensity continuous μ-beam", K.Takahisa(RCNP),

E490: June 2017 **Done**

- "Muonic X-ray analysis of planetary materials: Development on Isotopic measurement and Muonic X-ray imaging", K. Terada, (Osaka U.)

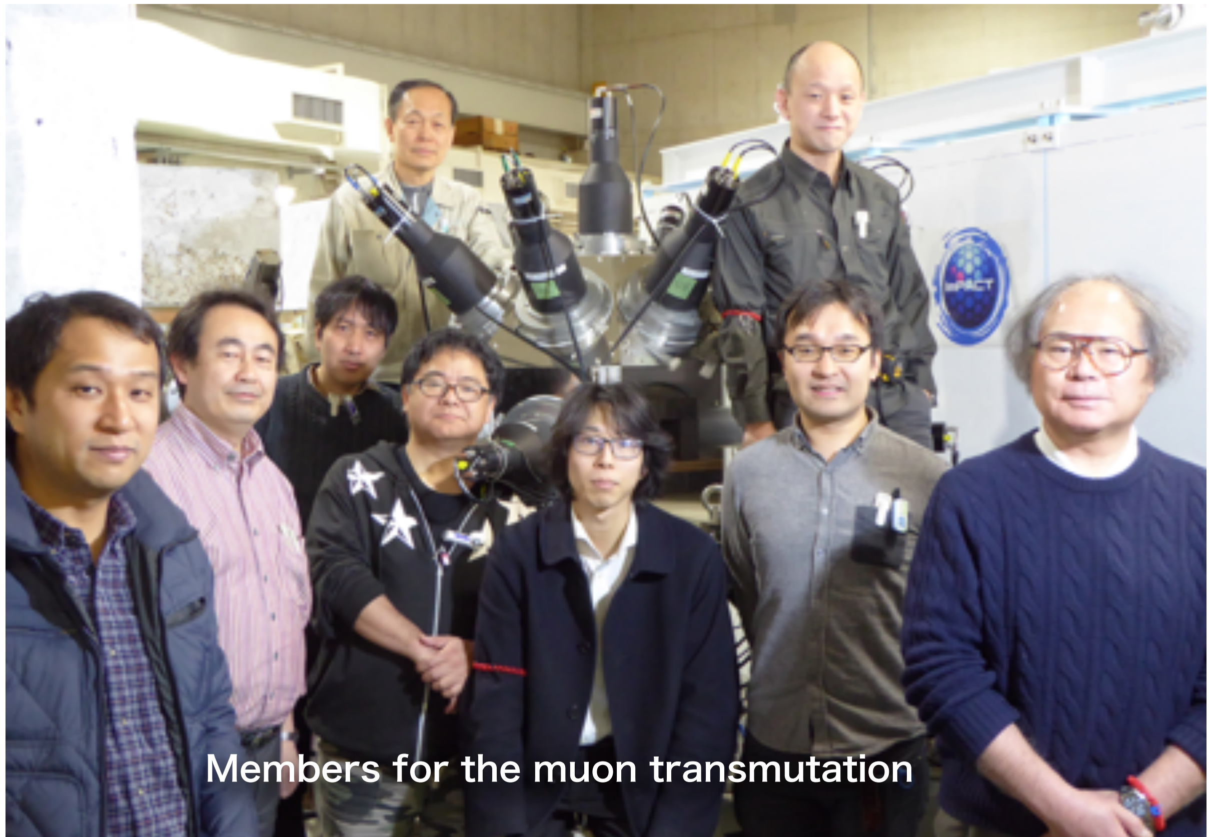
E489: in Feb. 2018?

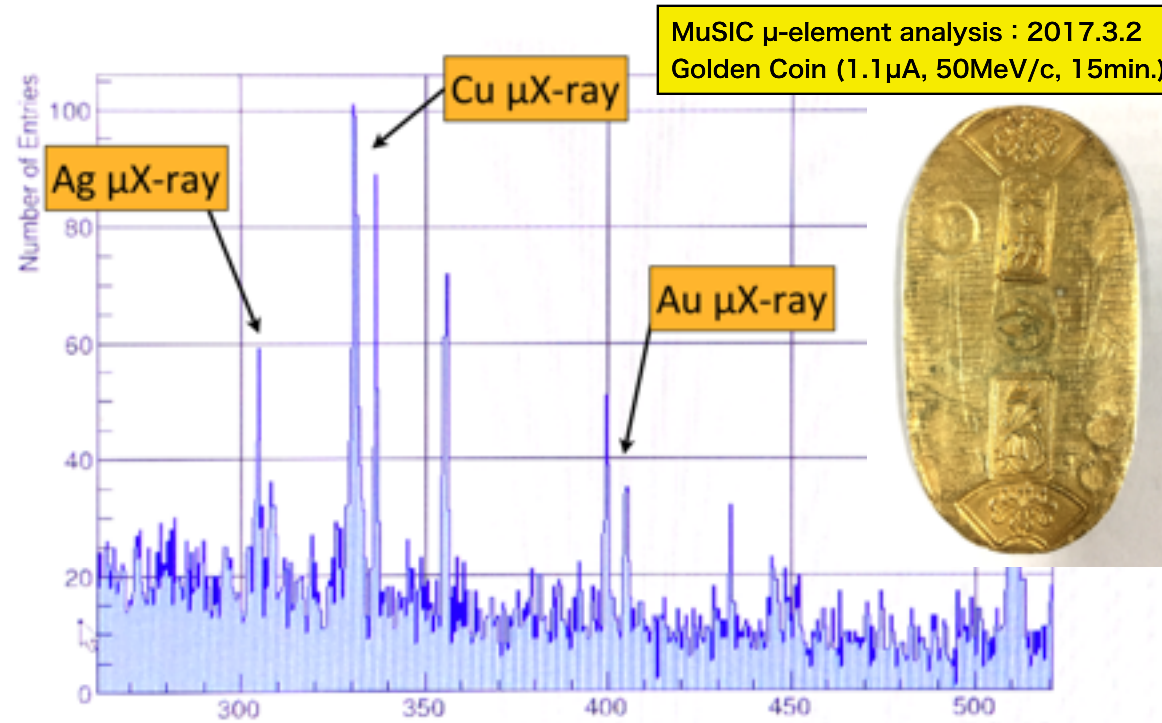
- "Muon-gamma spectroscopy for neutrino nuclear responses", Izyan Hashim (Universiti Teknologi Malaysia)

E517: in 2018? **← the first official μSR user's experiment**

- "Study of Novel Superconductivity in Layered Structural Superconductor by means of μSR technique at MuSIC", Wataru Higemoto (JAEA)

Pictures for 1.1μA operations

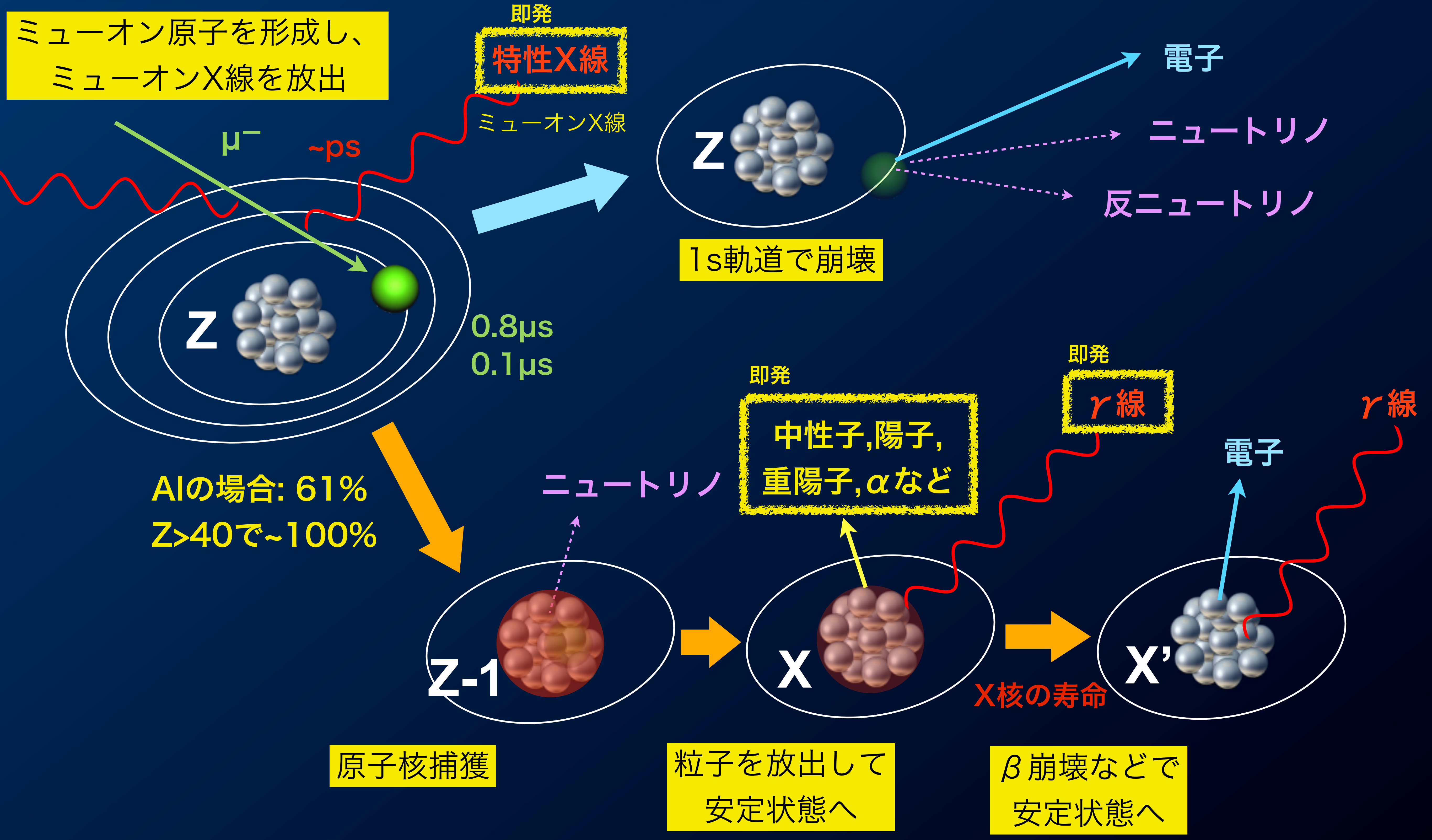

Members for the muon transmutation



Muonic X-rays from Koban were clearly observed in a short time for the μ-element analysis.


Detector for the Members for the muon transmutation

負電荷ミューオンが物質中に停止すると起こる現象



負ミューオン実験におけるパルスとDCビームの違い

J-PARC-MUSE：パルスミューオンビーム

世界最高強度

数百ナノ秒

ミューオン強度：毎秒10^8個

繰り返し：40ミリ秒（J-PARC-MUSEの場合）

ミューオン

時間

ミューオンX線
即発γ線
中性子、陽子など

遅延γ線

パイルアップ、難しい

高統計、高S/N

RCNP-MuSIC：DCミューオンビーム

ミューオン強度：毎秒$10^{4\sim5}$個

繰り返し：10~100マイクロ秒（RCNP-MuSICの場合）

ミューオン

時間

ミューオンX線
即発γ線
中性子、陽子など

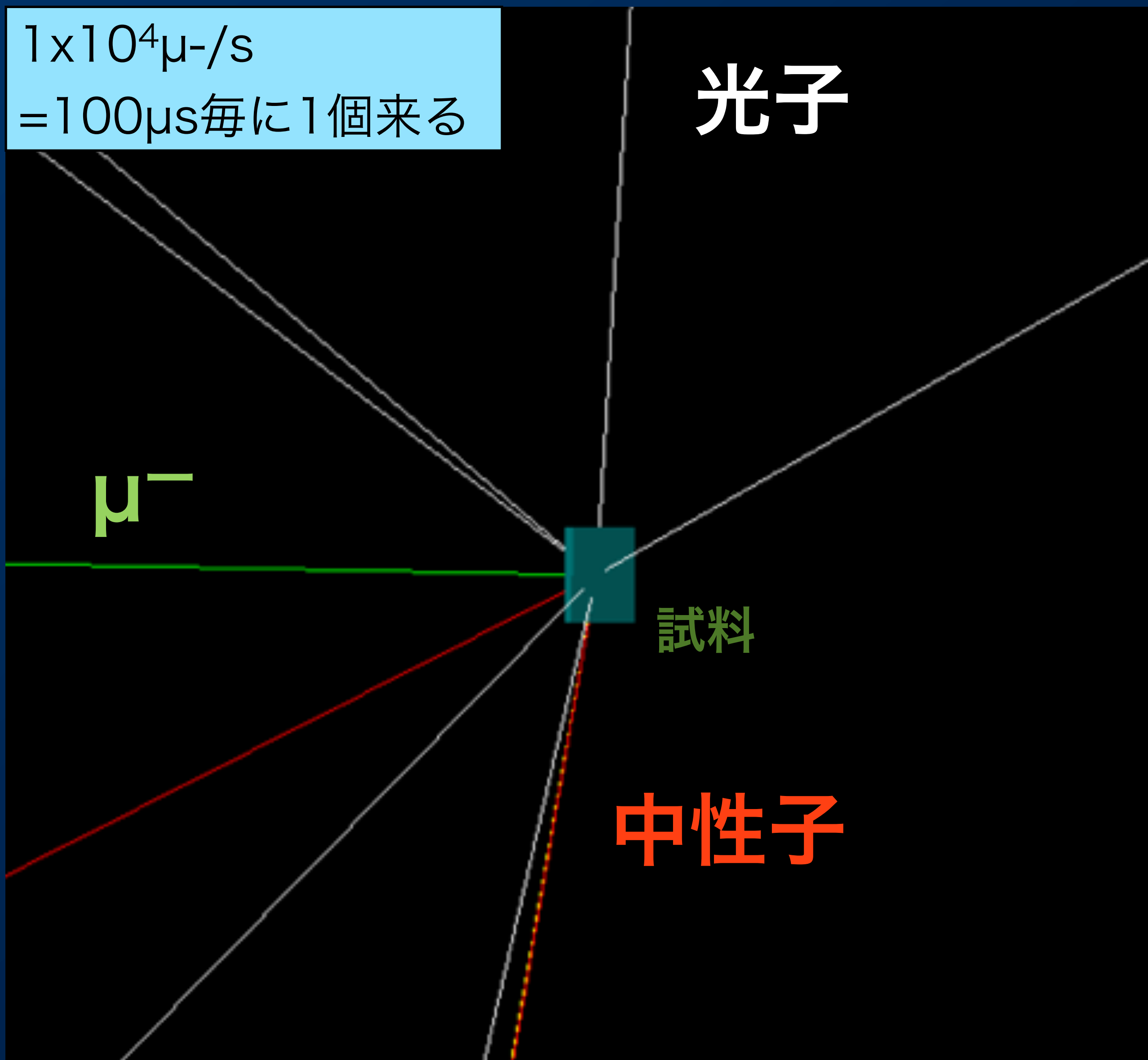
遅延γ線

高統計、高S/N、同時計測

低統計、 低S/N、

負ミューオン実験におけるパルスとDCビームの違い

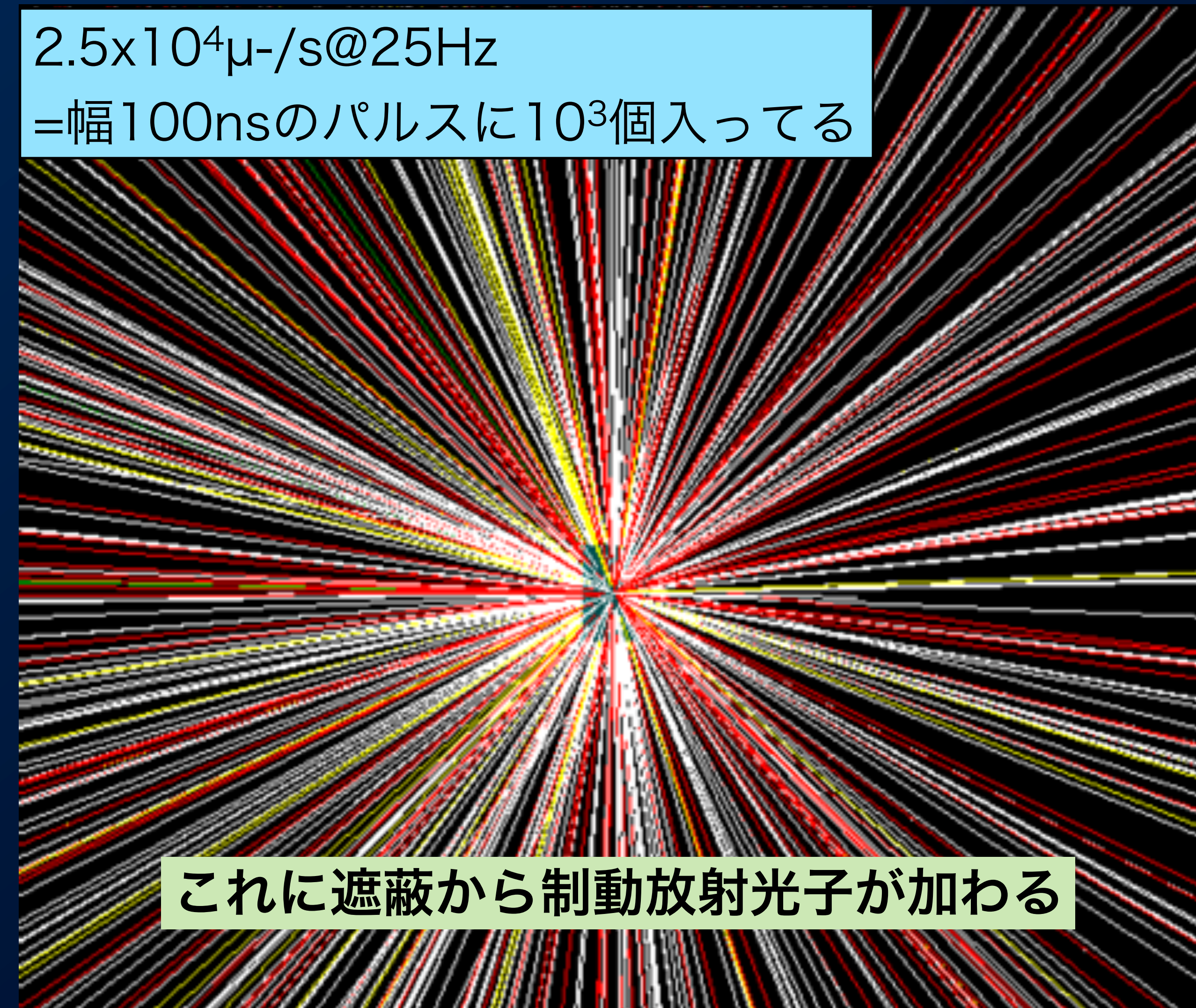
DCミューオンビーム



100μs毎にμ⁻を1事象ずつ測定できる。

ビームレート(10⁴Hz)でデータ貯まる。
光子や中性子等の同時計測が可能。

パルスミューオンビーム



1検出器1ヒットになるように検出器を離す必要がある。

25Hz/検出器でデータ貯まる。
同時計測は難しい。

MuSICで究極の負ミューオン X線γ線分光測定の可能性

大立体角Ge検出器：CAGRA

クローバー型Ge検出器アレイプロジェクト

CAGRA (Clover Array Gamma-ray spectrometer at RCNP/RIBF for Advanced research)

Co-spokespersons:

大阪大学核物理研究センター

井手口　栄治、青井　考

登録・問い合わせ：　ml-clover@rcnp.osaka-u.ac.jp

メーリングリスト：　ml-cagra@rcnp.osaka-u.ac.jp

研究協力者：

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A. 東北大学　理学部、B. ANL、C. LBNL、D. Yale、

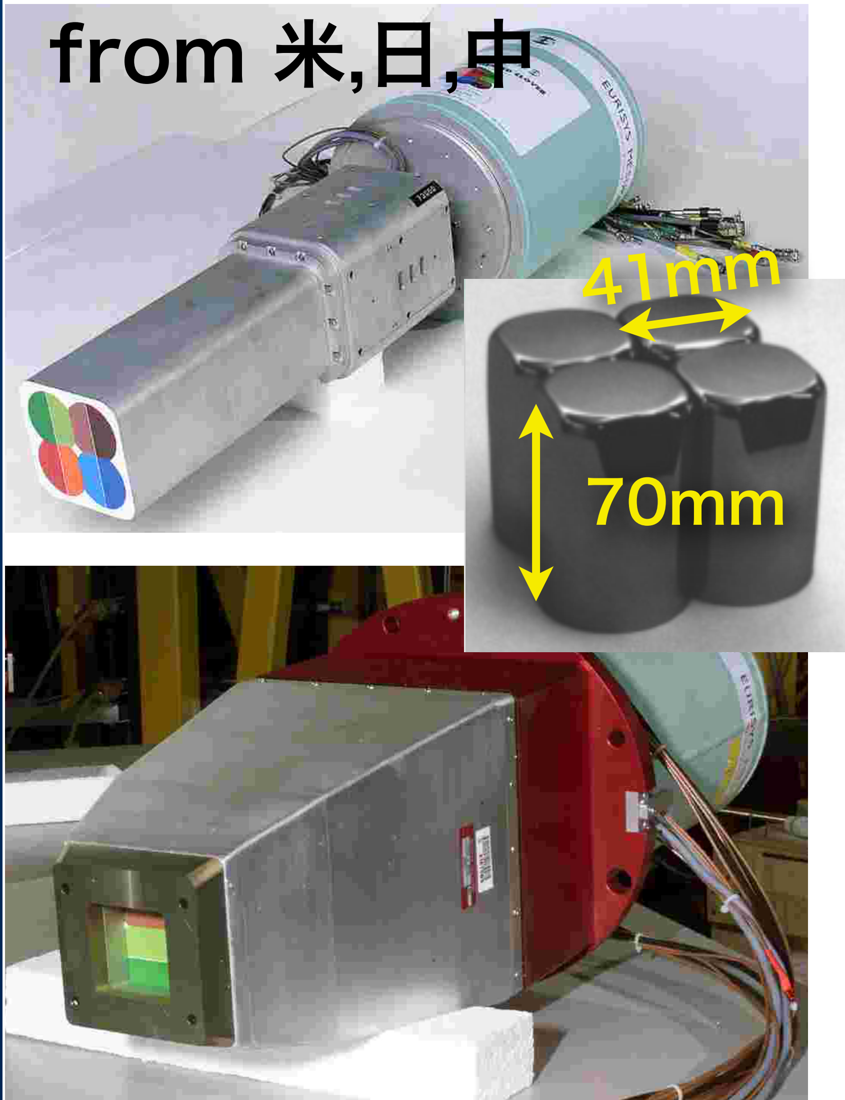
E. 大阪大学核物理研究センター、F. 大阪大学理学研究科、

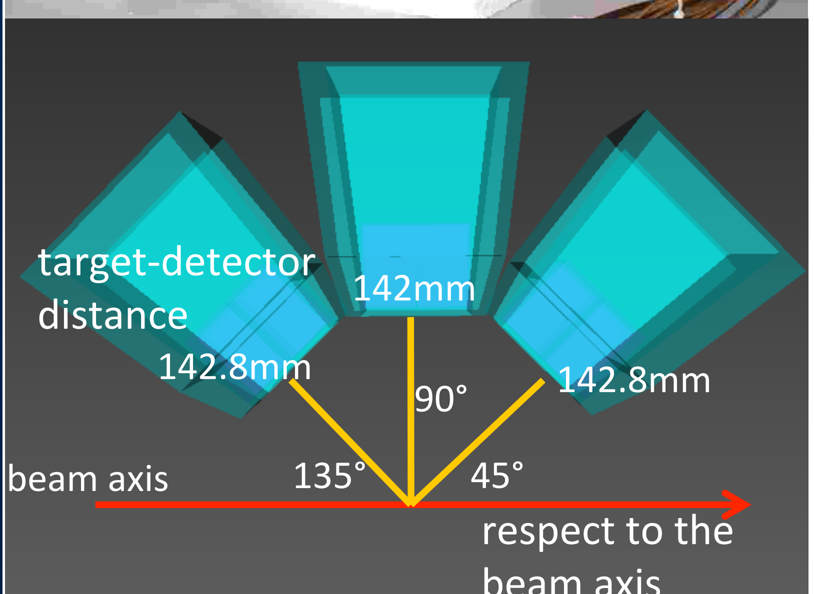
G. 東京大学・原子核科学研究センター、H. 甲南大学、I. 京都大学理学研究科、J. 岡山大学理学部物理学科、K. 九州大学・大学院理学研究院

2015/09/23　RCNP将来計画検討会　3

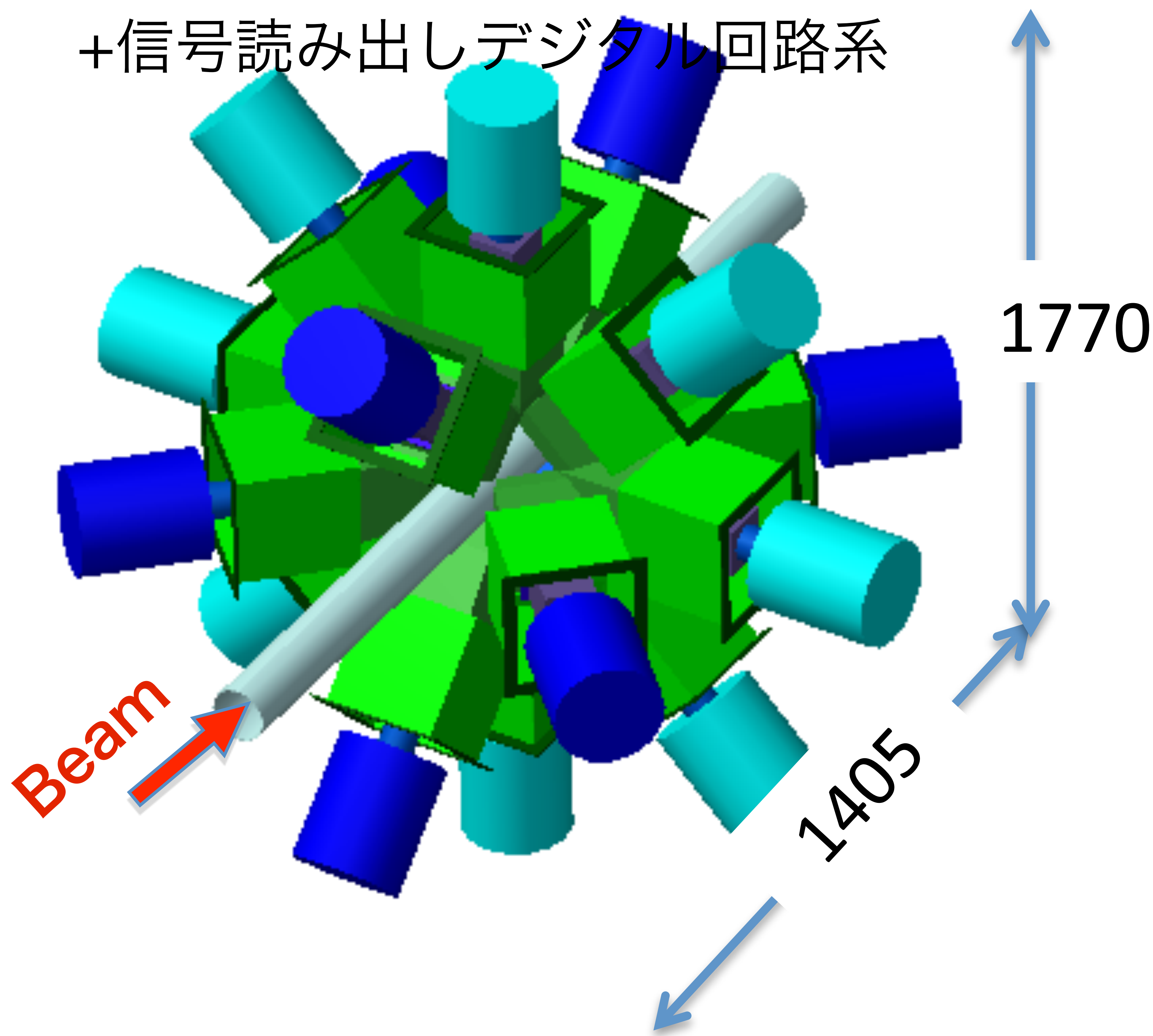
井手口氏のスライドより

大立体角Ge検出器：CAGRA



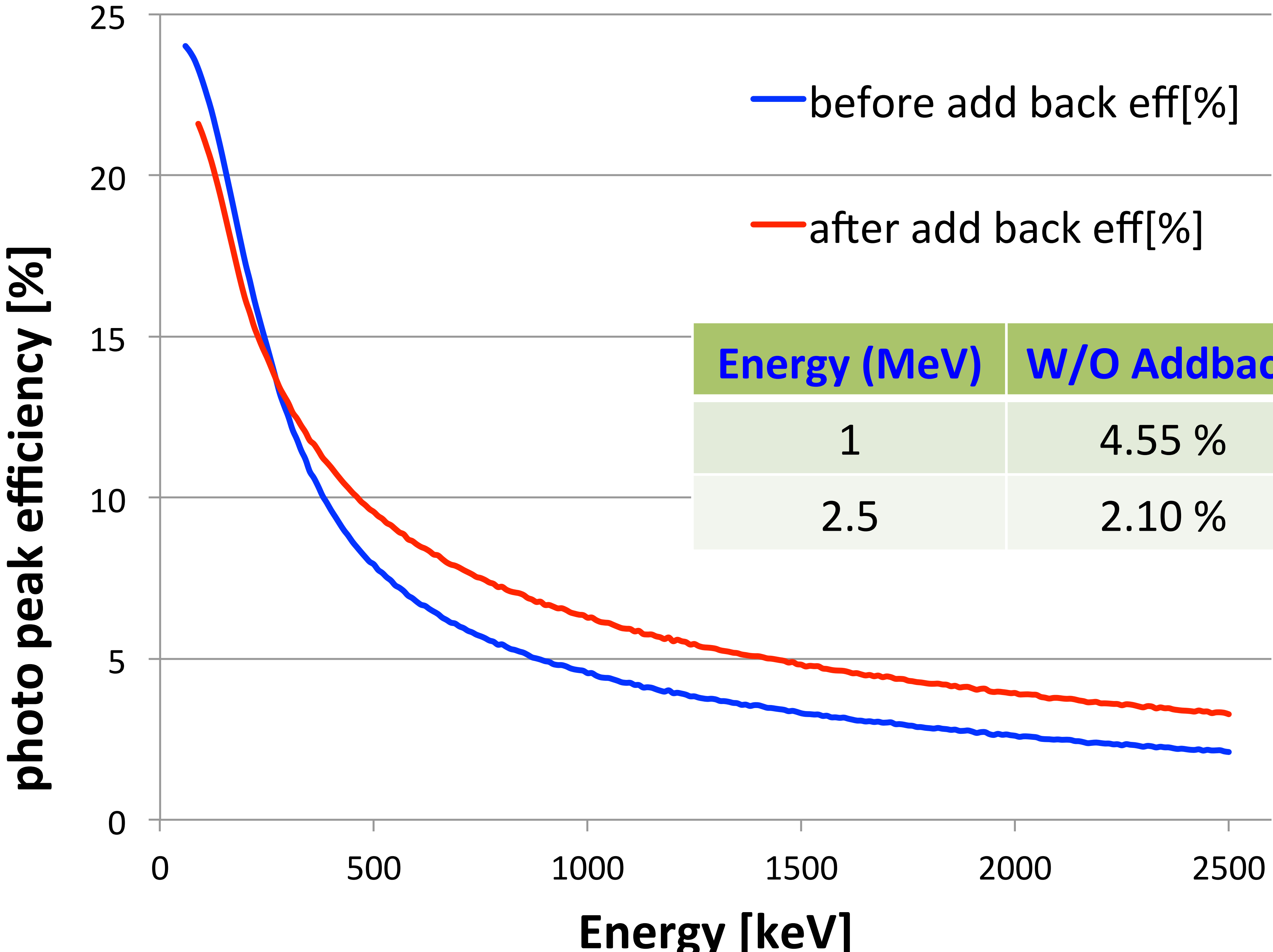


BGOコンプトン抑止器付きGe検出器x16台
+信号読み出しデジタル回路系



大立体角Ge検出器：CAGRA

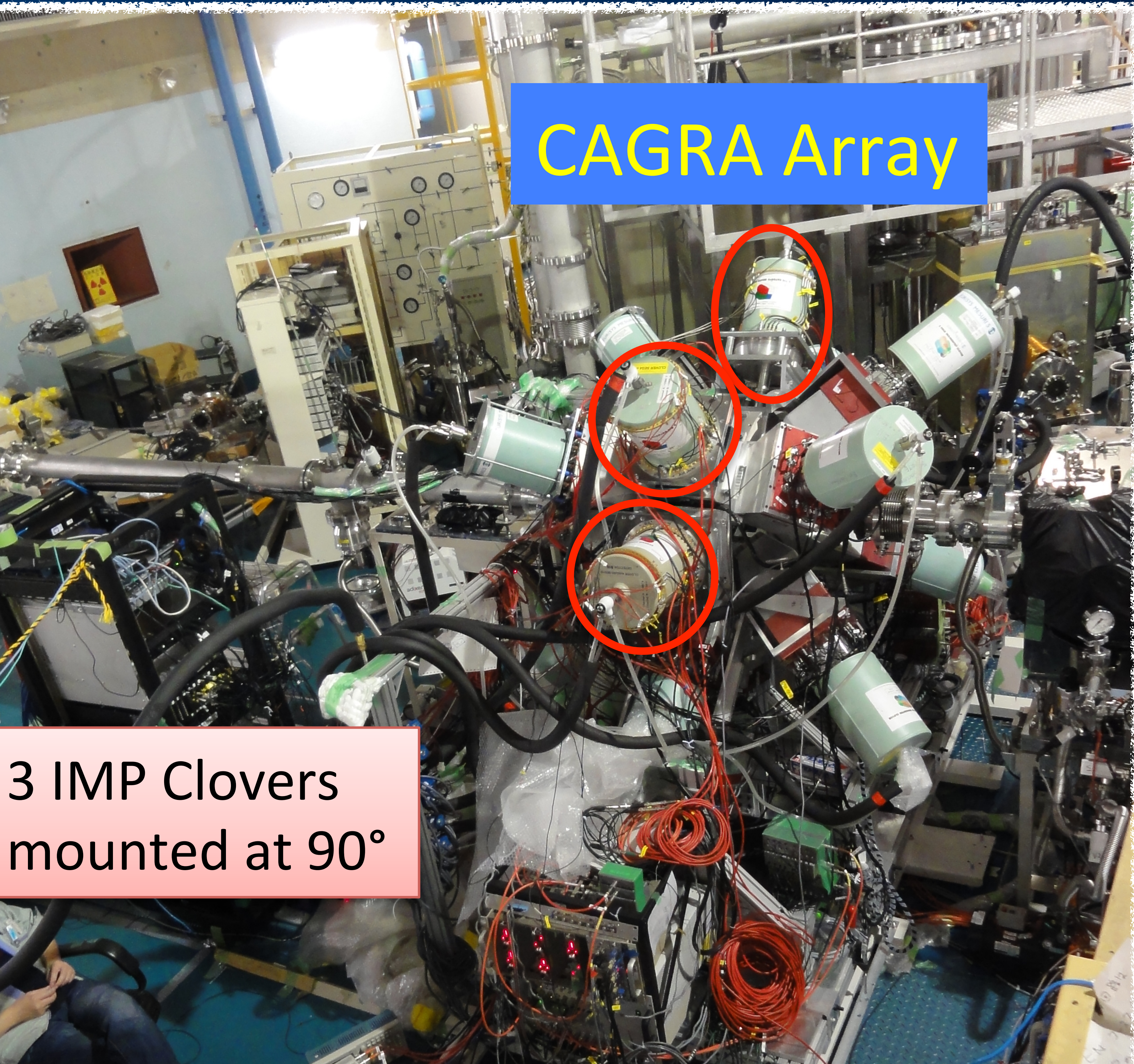
光電ピークの検出効率（シミュレーション）

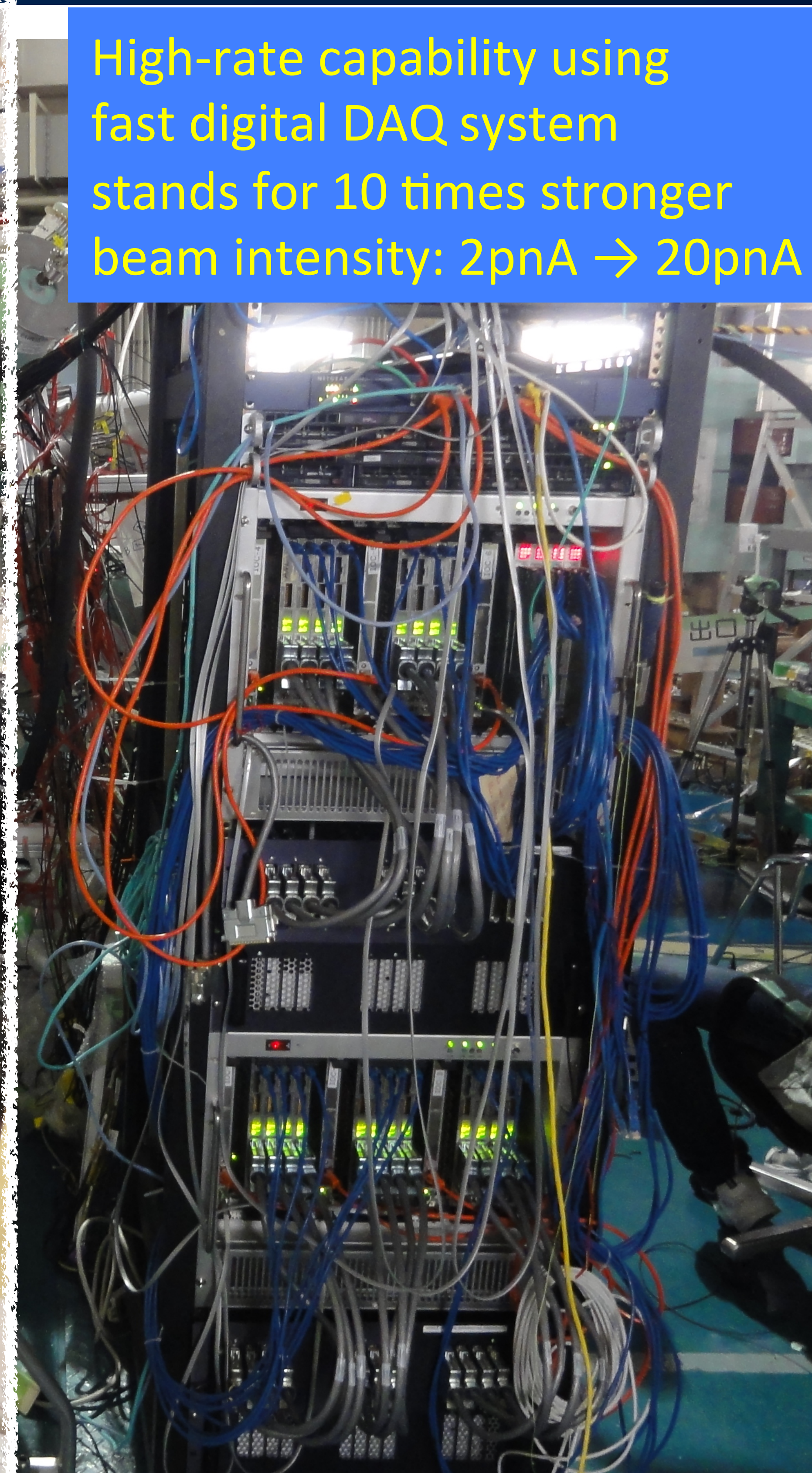


Energy (MeV)	W/O Addback	W/ Addback
1	4.55 %	6.27 %
2.5	2.10 %	3.28 %

* Add back: 各結晶のエネルギーを足し合わせること

CAGRA@RCNP


CAGRA Array
3 IMP Clovers mounted at 90°

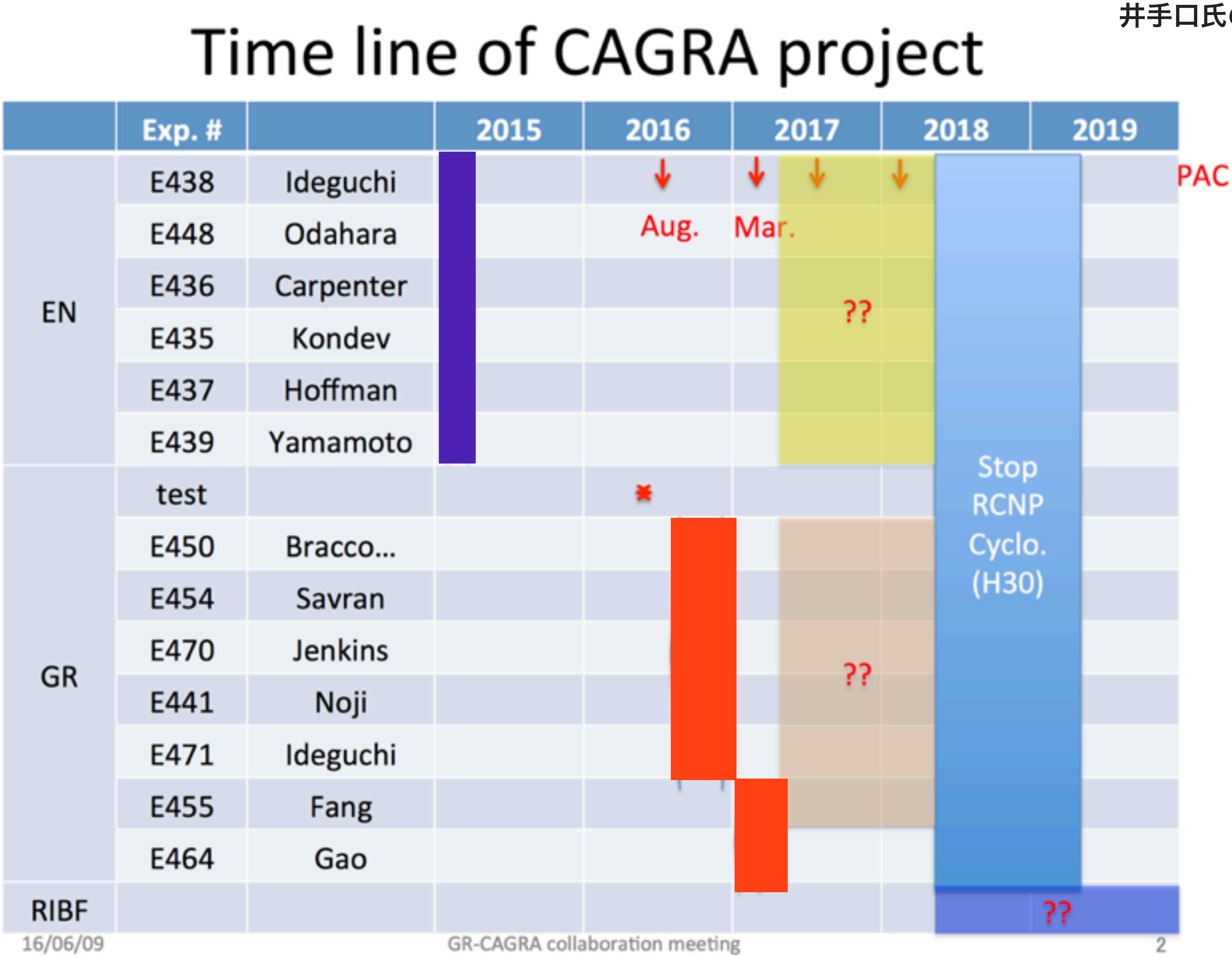

High-rate capability using fast digital DAQ system stands for 10 times stronger beam intensity: 2pnA → 20pnA

RCNPでのCAGRA実験キャンペーン

井手口氏のスライド

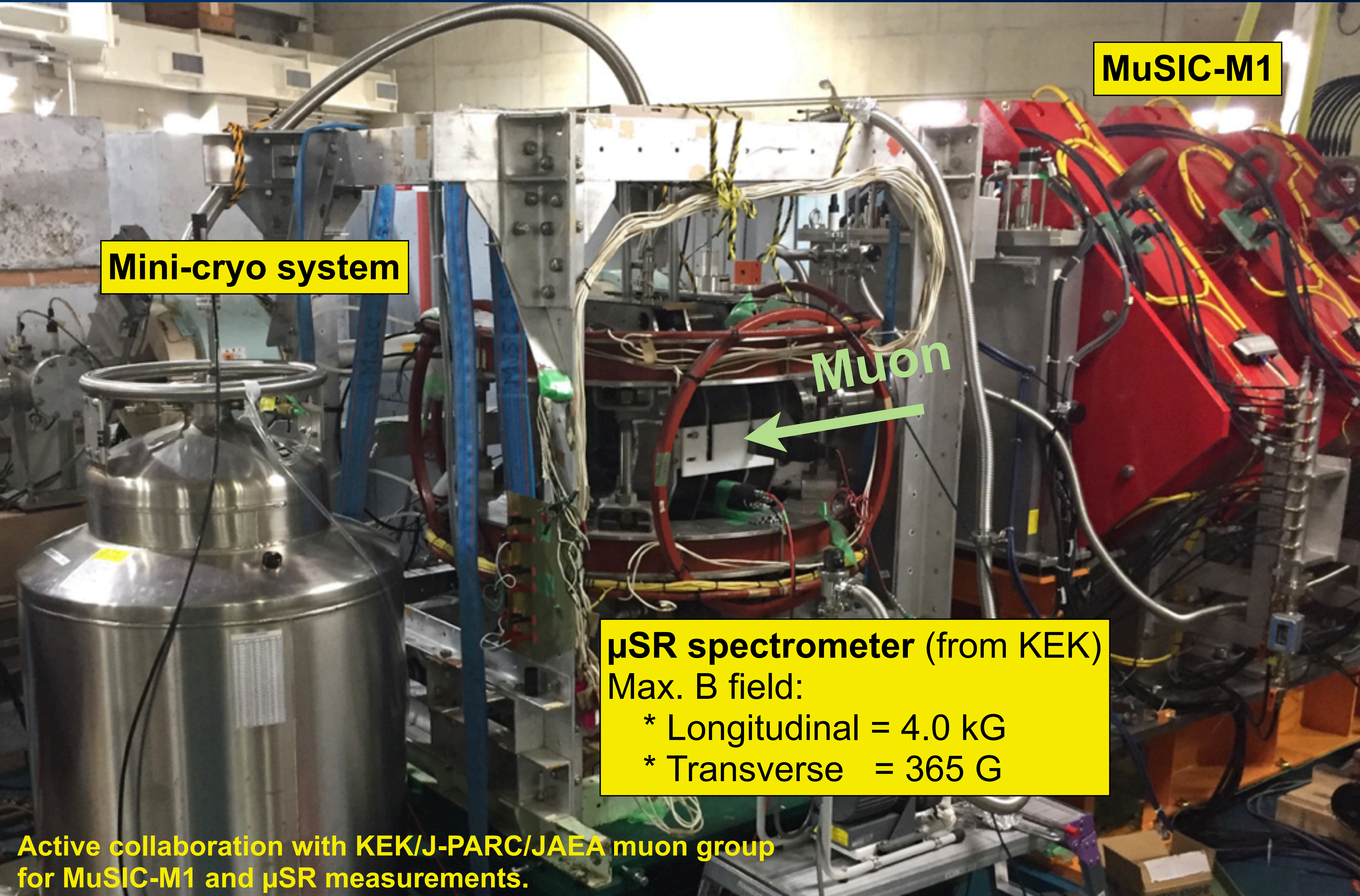
2015年
6実験

2016年
7実験



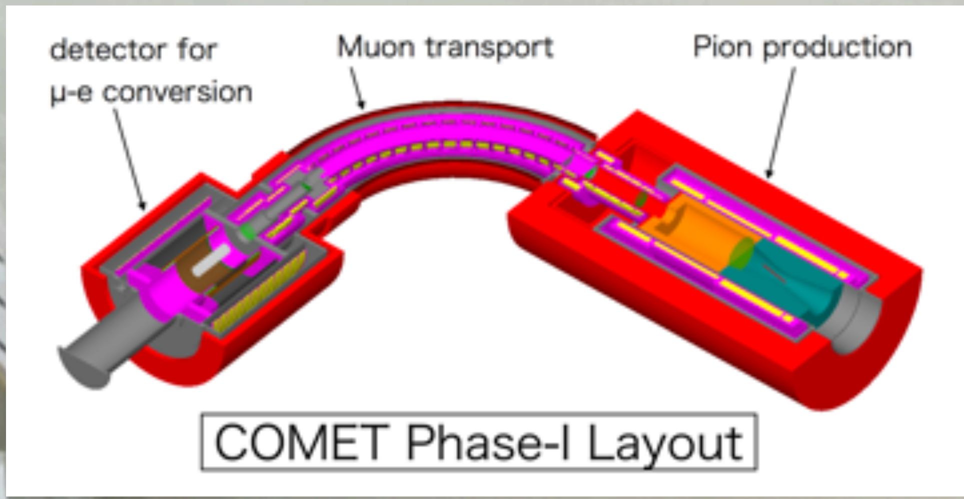
201X年@with MuSICキャンペーンをやりませんか？

MuSIC-M1: μSR spectrometer



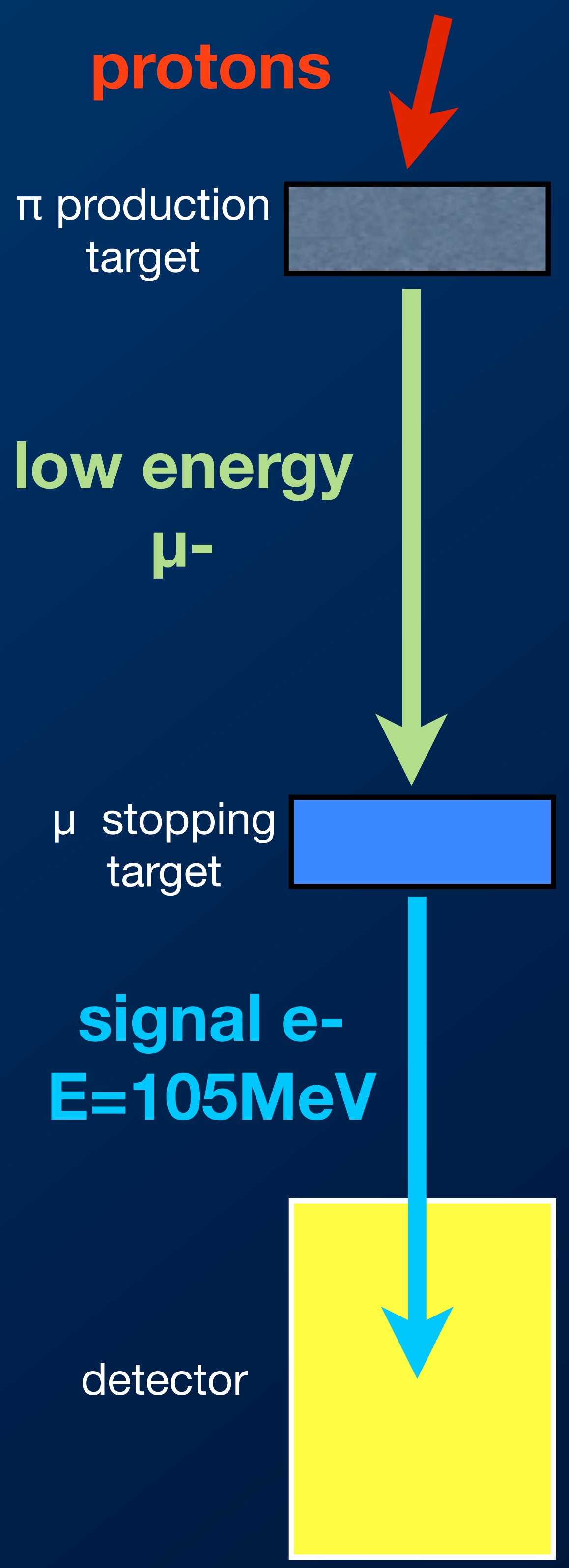
COMET SC magnets for $10^{10}\mu^{-}$/s beam

- A 90-deg. muon transport solenoid has been constructed in 2015.
- A 5.5 Tesla pion capture solenoid will be delivered to J-PARC in 2019.



COMET実験@J-PARC

How to search the μ-e conversion



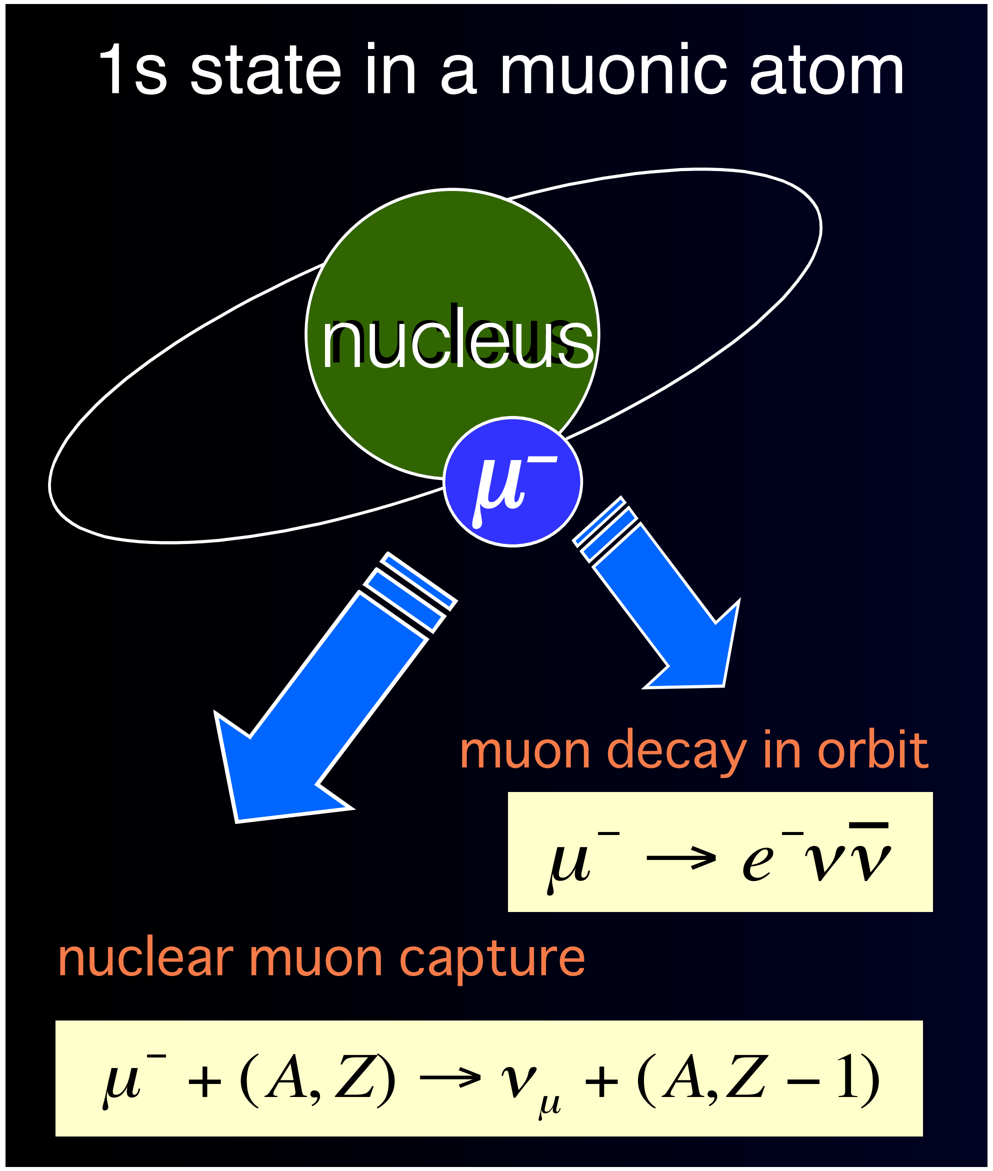
- Inject proton beam to a pion production target to generate a huge amount of muons.
- Stop the muons in a stopping target.
  - Al target for COMET and Mu2e
  - Muonic atoms are produced
  - μ lifetime in Al ~ 864ns
    - 40% μ : decay in the 1s orbit (DIO)
    - 60% μ : captured to the nulear
- Look for the signal electron with E=105MeV.

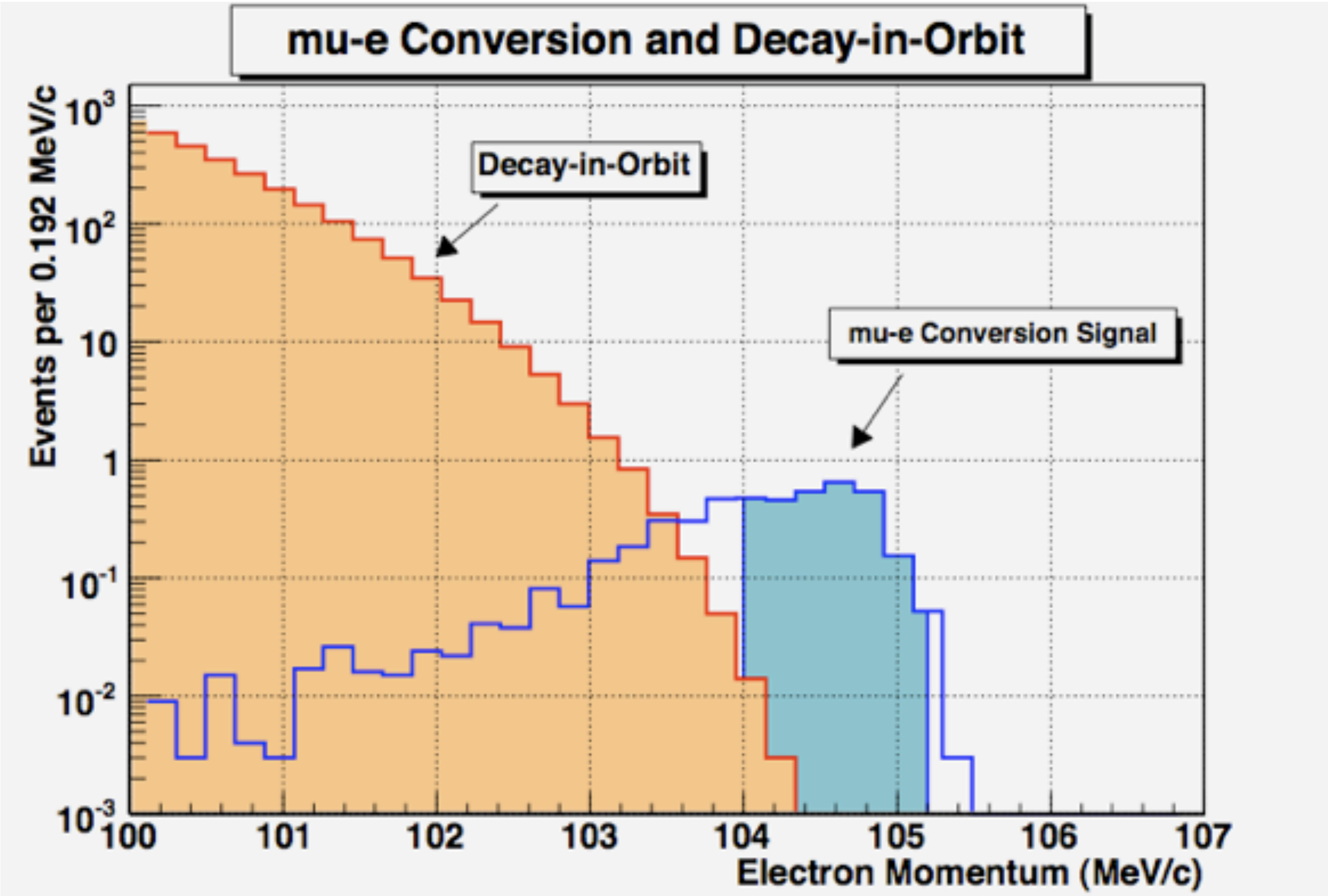
Key points:
(1) Very intense muon beam (by MuSIC)
(2) Background suppression

Backgrounds of μ-e conversion search

	Type	Background
Intrinsic physics	Physics	Muon decay in orbit
	Physics	Radiative muon capture
	Physics	Neutron emission after muon capture
	Physics	Charged particle emission after muon capture
Beam related	Prompt Beam	Beam electrons (prompt)
	Prompt Beam	Muon decay in flight (prompt)
	Prompt Beam	Pion decay in flight (prompt)
	Prompt Beam	Other beam particles (prompt)
	Prompt Beam	Radiative pion capture(prompt)
	Others	Electrons from cosmic ray muons

Background 1 : Decay in orbit





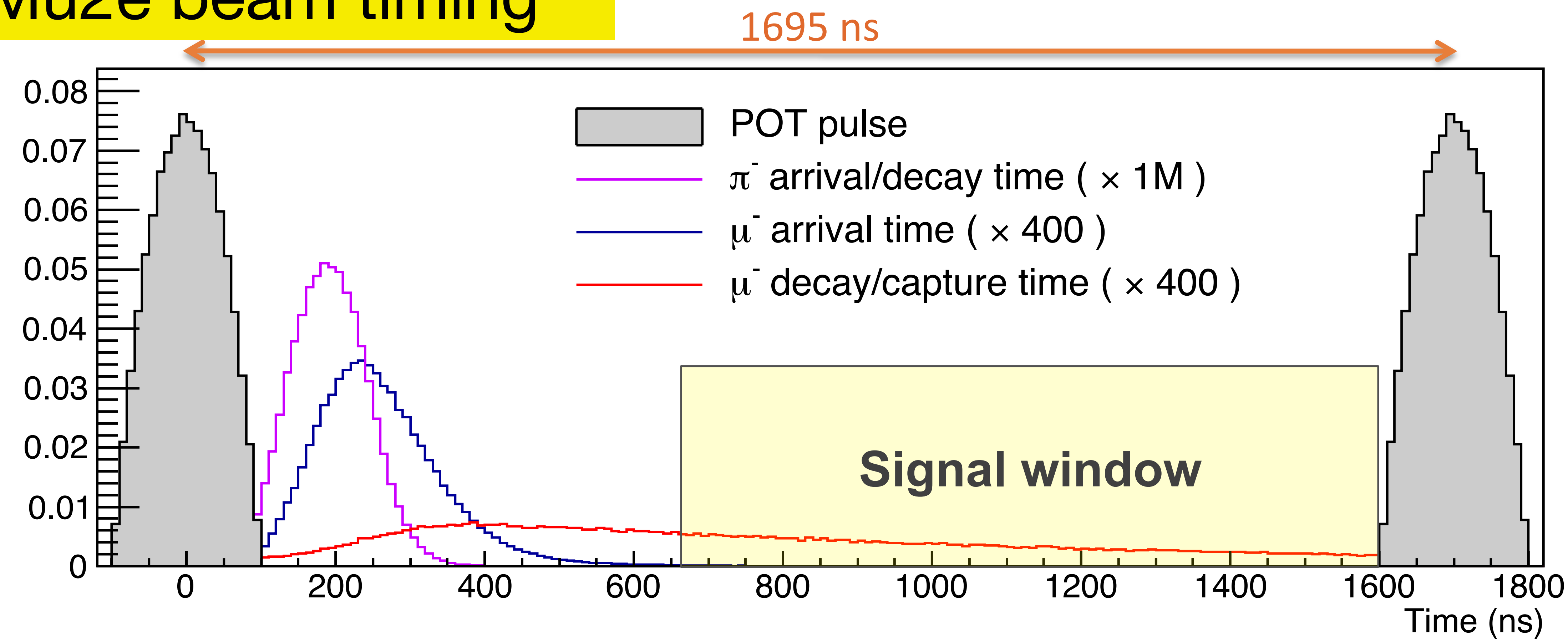
- To distinguish the signals from the DIO backgrounds, electron energy must be reconstructed with sufficient resolution. To achieve SES of 10^{-16}, $\sigma_e < 300$keV.

Background 2 : Radiative pion capture

- When π- stopped in the stopping target might emit e- with E_e<139.6MeV.
- We adopt three solutions to suppress this BG.

$$\pi^- + A \rightarrow \gamma + A', \gamma \rightarrow e^- + e^+$$

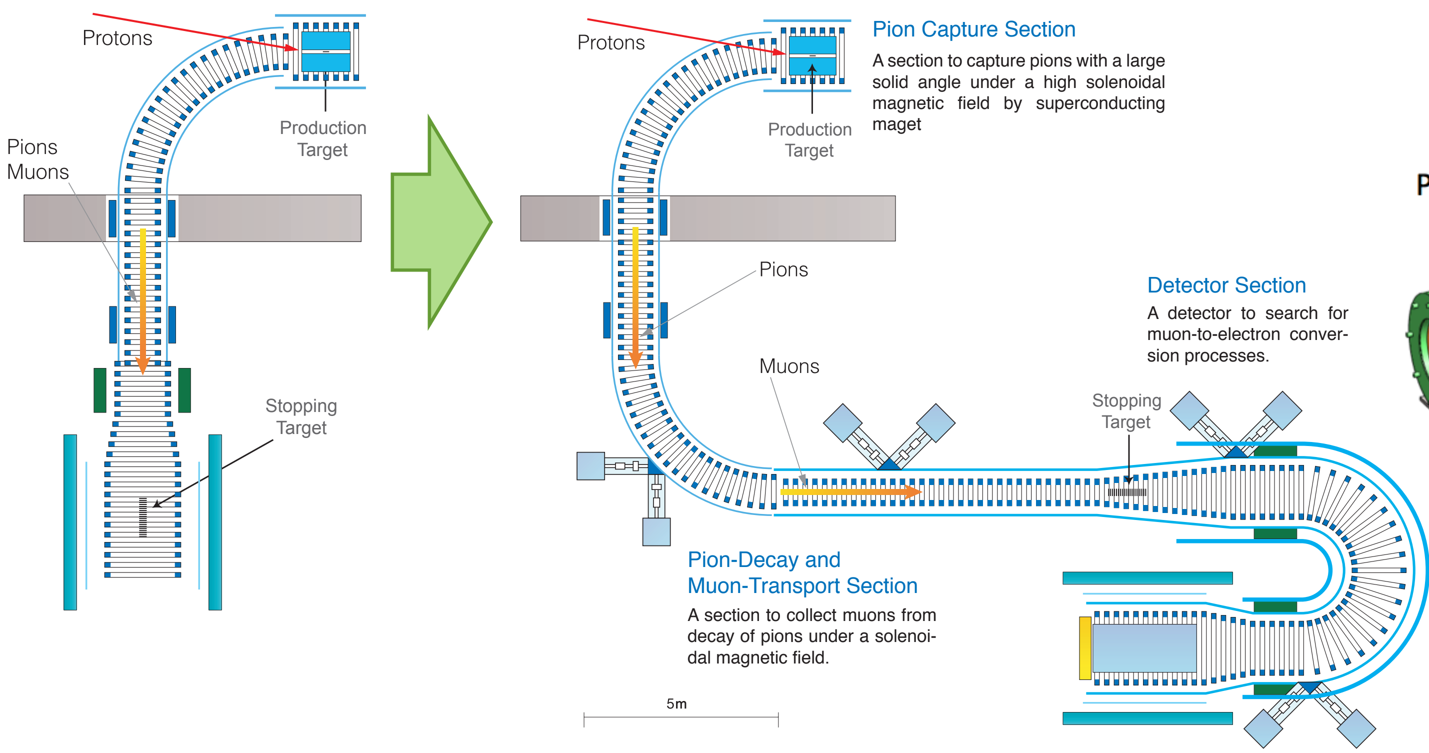
Mu2e beam timing



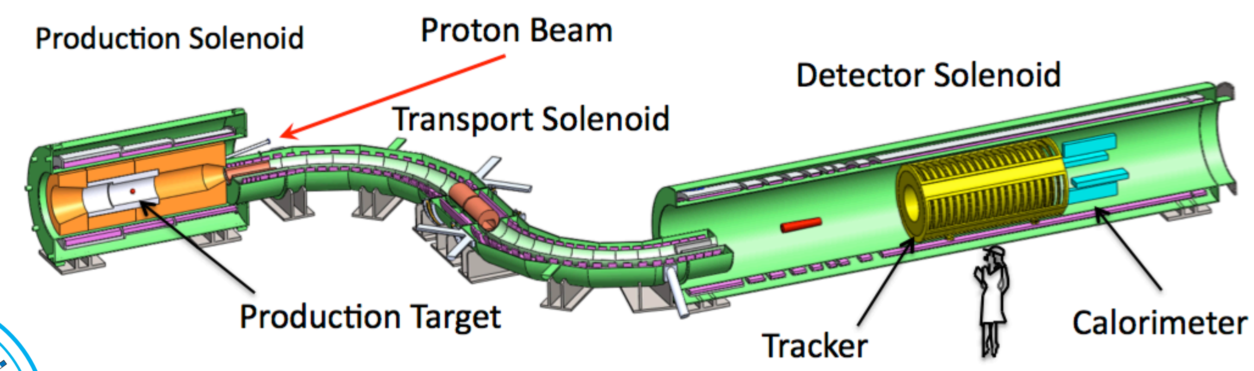
1. Put a long transfer line before the stopping target
2. Wait for ~ 700ns to open the signal window.
3. Make pulsed proton beam with extinction level < 10^{-12}~10^{-11}.

COMET and Mu2e

COMET @J-PARC



Mu2e @FNAL



COMET Phase-I :

physics run 2020-

BR(μ+Al→e+Al)<7×10^{-15} @ 90%CL

*8GeV-3.2kW proton beam, 110 days

*90deg. bend solenoid, cylindrical detector

*Background study for the phase2

COMET Phase-II :

physics run 2021-

BR(μ+Al→e+Al)<6×10^{-17} @ 90%CL

*8GeV-56kW proton beam, 2 years

*180deg. bend solenoid, bend spectrometer, transverse tracker+calorimeter

Mu2e :

physics run 2021-

BR(μ+Al→e+Al)<6×10^{-17} @ 90%CL

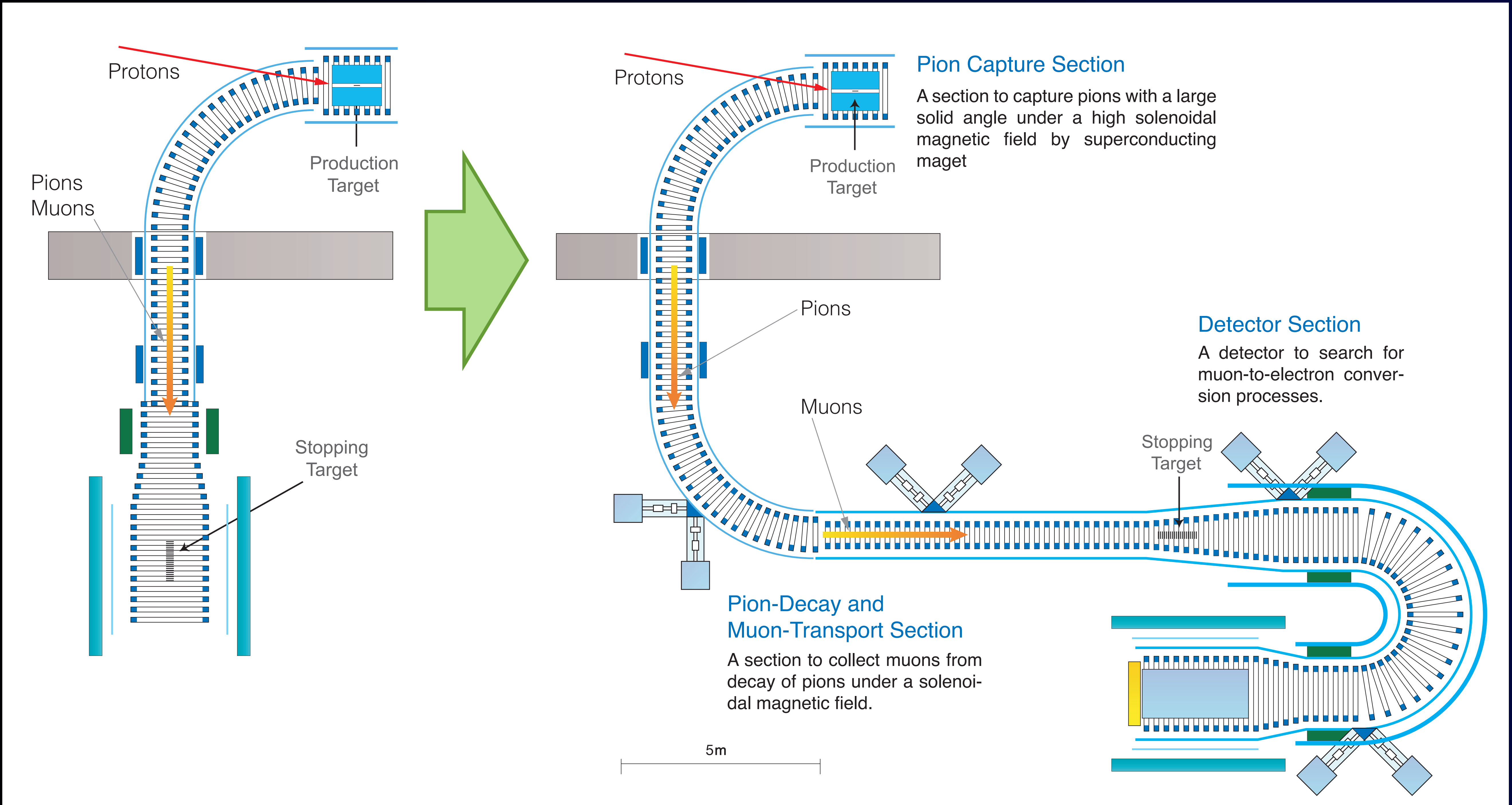
*8GeV-8kW proton beam, 3 years

*2x90deg. S-shape bend solenoid, straw tracker+calorimeter

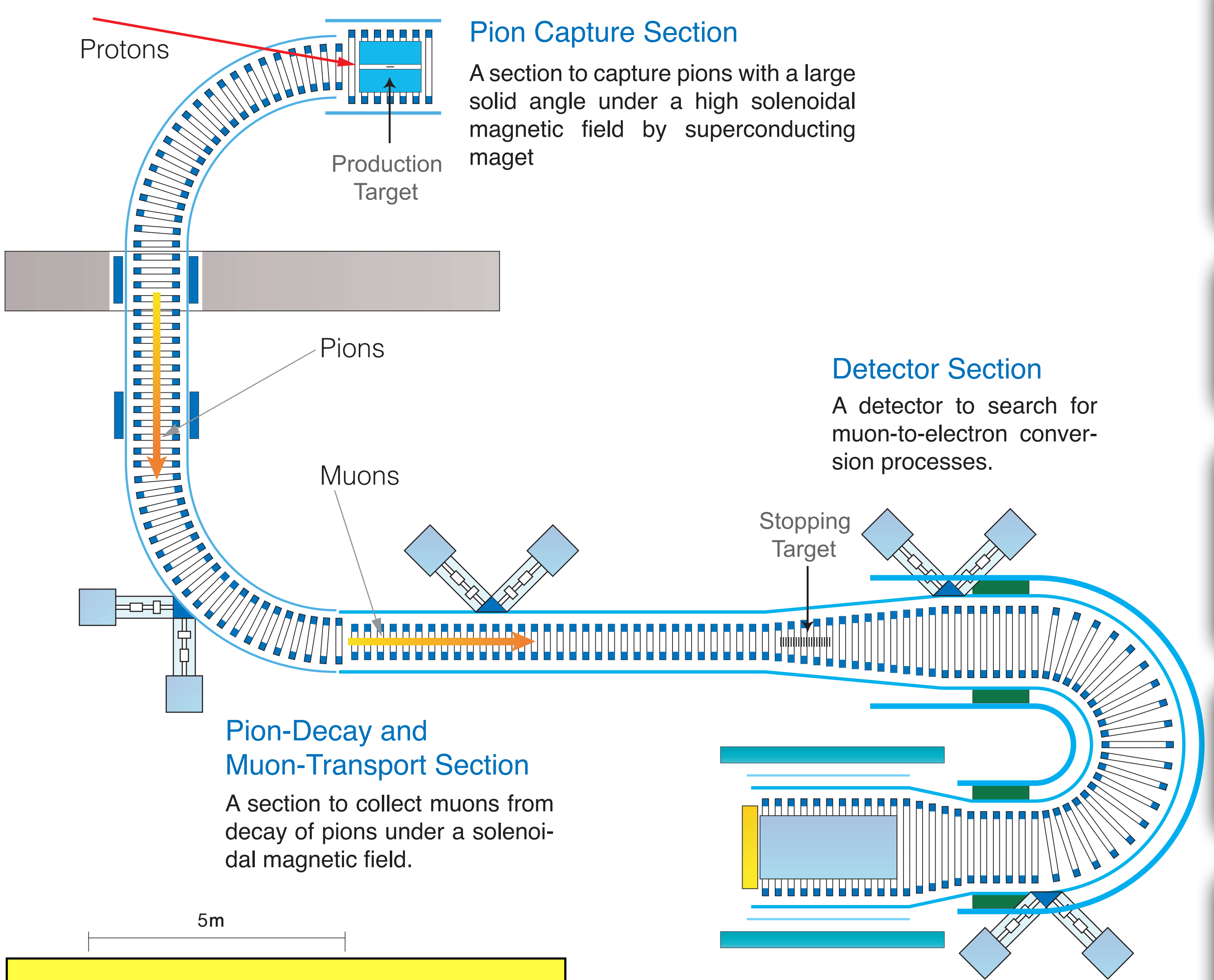
- Design of the both experiments are based on the MECO@BNL experiment

COMET

COMET Phase-I　　COMET Phase-II



Key Points of COMET Phase-II (S.E.S 10^{-17})



COMET Phase-II :

physics run 2020-

BR(μ+Al→e+Al)<6x10^{-17} @ 90%CL

*8GeV-56kW proton beam, 2 years

*180deg. bend solenoid, bend spectrometer, transverse tracker+calorimeter

Intense Pulsed Proton Beam

8GeV-56kW (2x10^7 sec)

width~100ns, separation>1μs

Extinction level < 10^{-11} — reduce beam related BG

Pion Capture Solenoid

5T superconducting — 10^{11} μ^-/sec

Long Transport Solenoid

L >10m

Curved 180deg Solenoid — eliminate energetic μ (>75 MeV/c) and pions

Thin Stopping Target

Al 200μm x 17 — improve e^- energy resolution

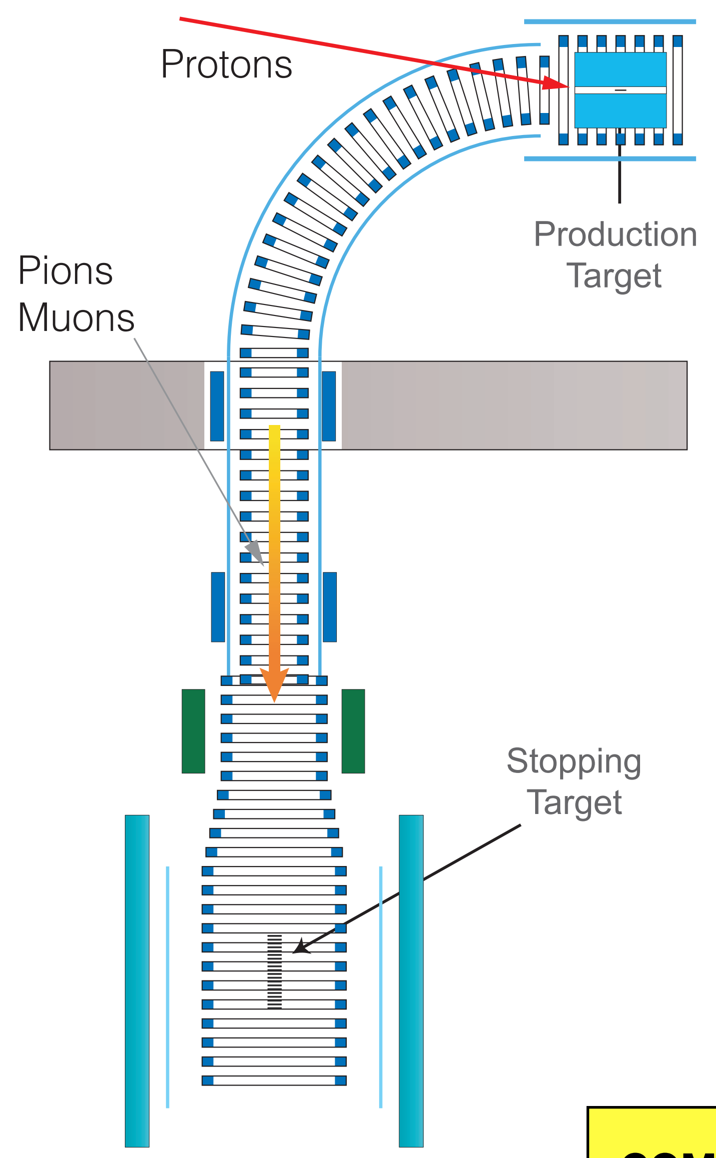
Electron Spectrometer

Curved Solenoid — reduce detector hit rate

Low-mass Tracker

Straw chamber in Vacuum — improve e^- energy resolution

Key Points of COMET Phase-I (S.E.S 10^{-15})



COMET Phase-I :

physics run 2017-

BR(μ+Al→e+Al)<7×10^{-15} @ 90%CL

*8GeV-3.2kW proton beam, 110 days

*90deg. bend solenoid, cylindrical detector

*Background study for the phase2

Intense Pulsed Proton Beam

8GeV-3.2kW (110 days)

width~100ns, separation>1μs

Extinction level < 10^{-13}

reduce beam related BG

Pion Capture Solenoid

5T superconducting

10^{11} μ^-/sec

Long Transport Solenoid

L >10m

Curved 90deg Solenoid

eliminate energetic μ (>75 MeV/c) and pions

Thin Stopping Target

Al 200μm x 17

improve e^- energy resolution

Electron Spectrometer

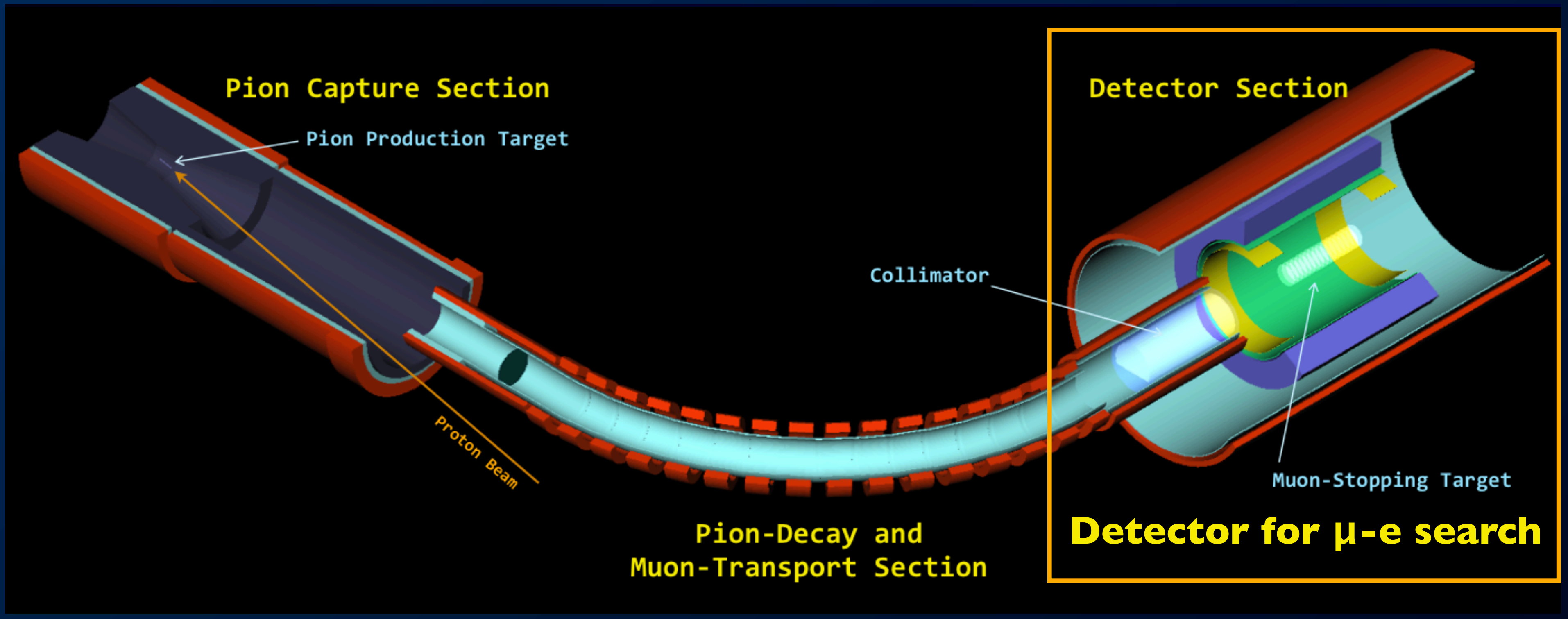
Curved Solenoid

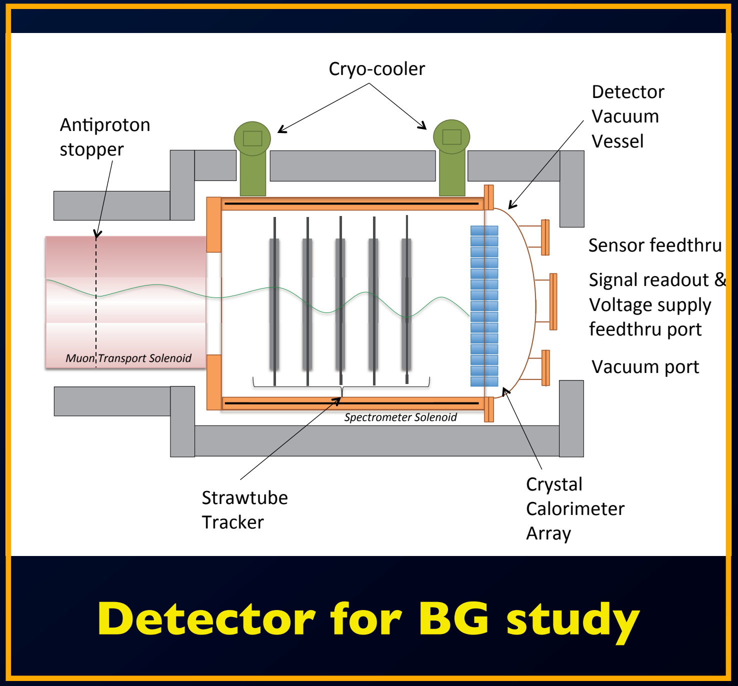
Low-mass Tracker

Cylindrical drift chamber

Goal of COMET Phase-I

- **Background Study for COMET Phase-II**
  - direct measurement of potential background sources for the full COMET experiment by using the actual COMET beamline constructed at Phase-I
- **Search for μ-e conversion**
  - a search for μ^-–e^- conversion at intermediate sensitivity which would be more than 100 times better than the SINDRUM-II limit

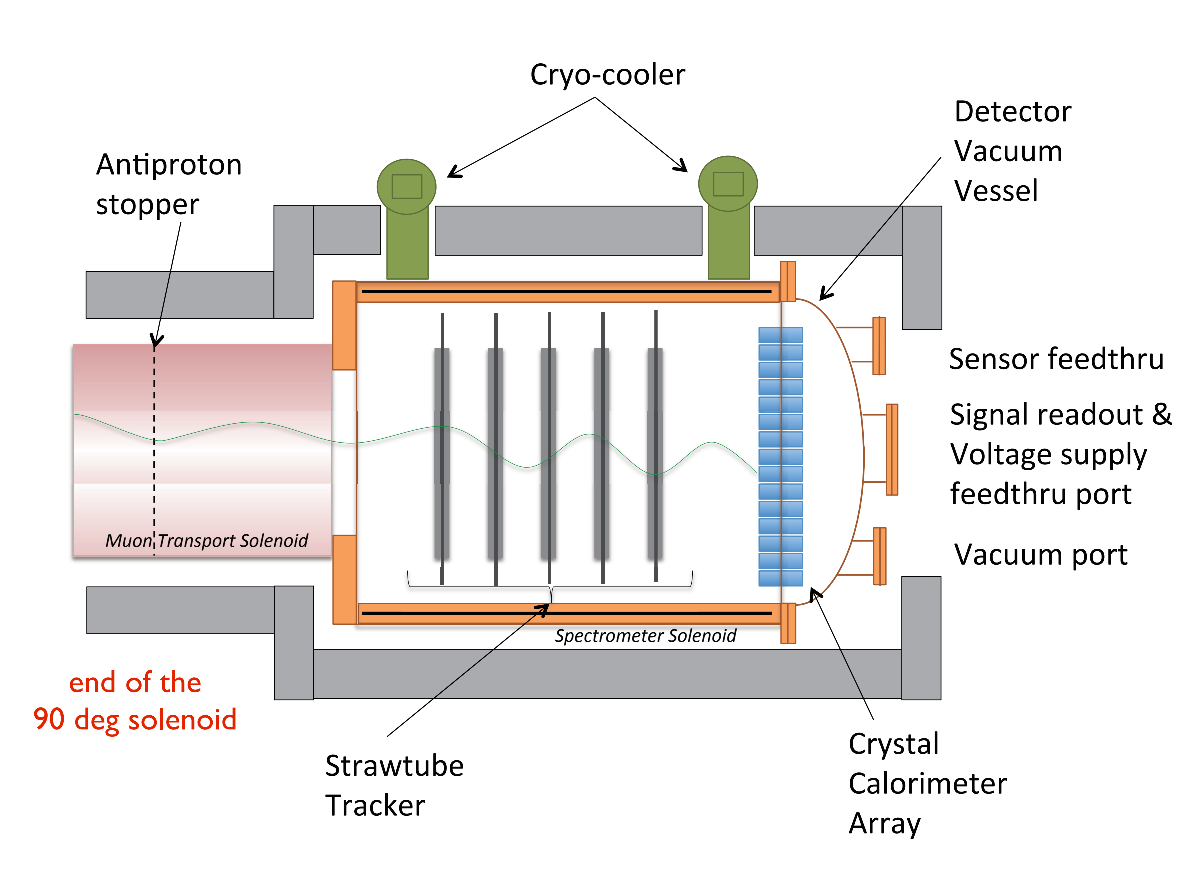




Background Study

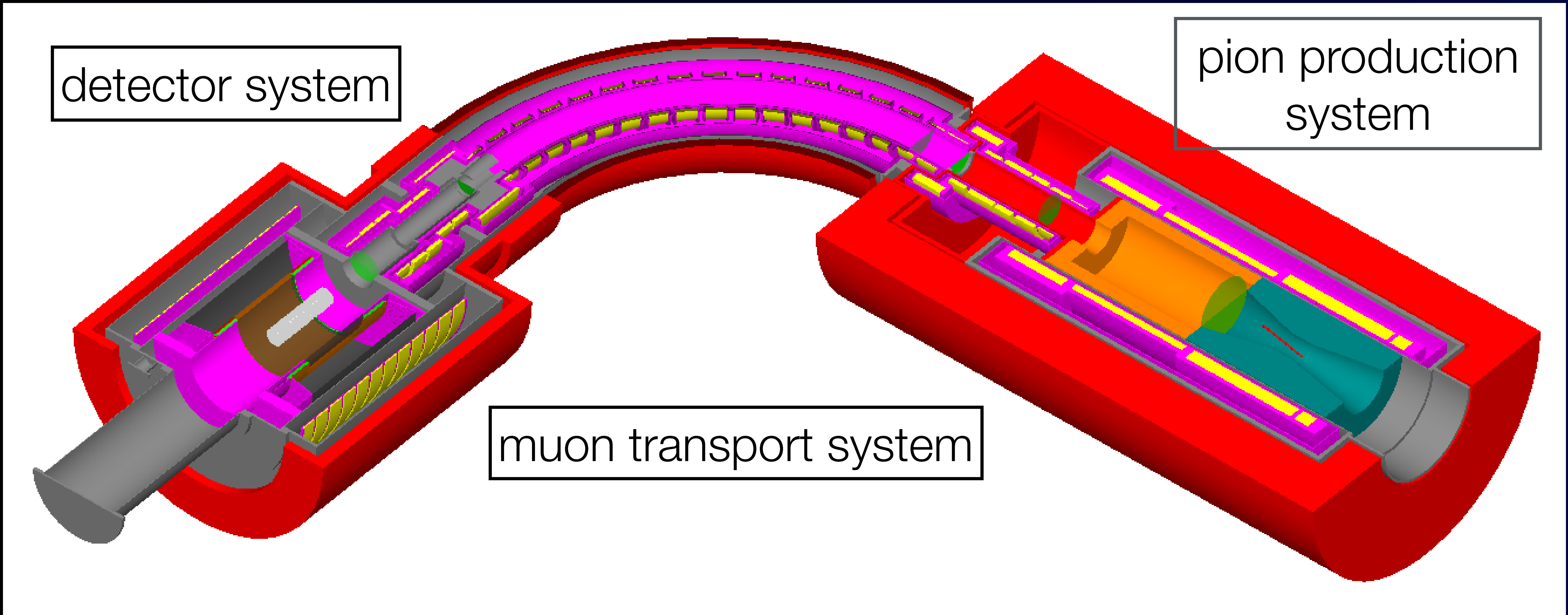
- Measure almost all background schematic layout
- Sources
  - muons, pions, electrons, neutrons, antiprotons, photons
- Same detector technology used in COMET Phase-II
  - SC spectrometer solenoid
  - straw tube transverse tracker
  - crystal calorimeter
- Particle ID with dE/dX and E/P

schematic layout



aim to know the known BG &
aim to know the unknown BG

Layout of COMET Phase-I



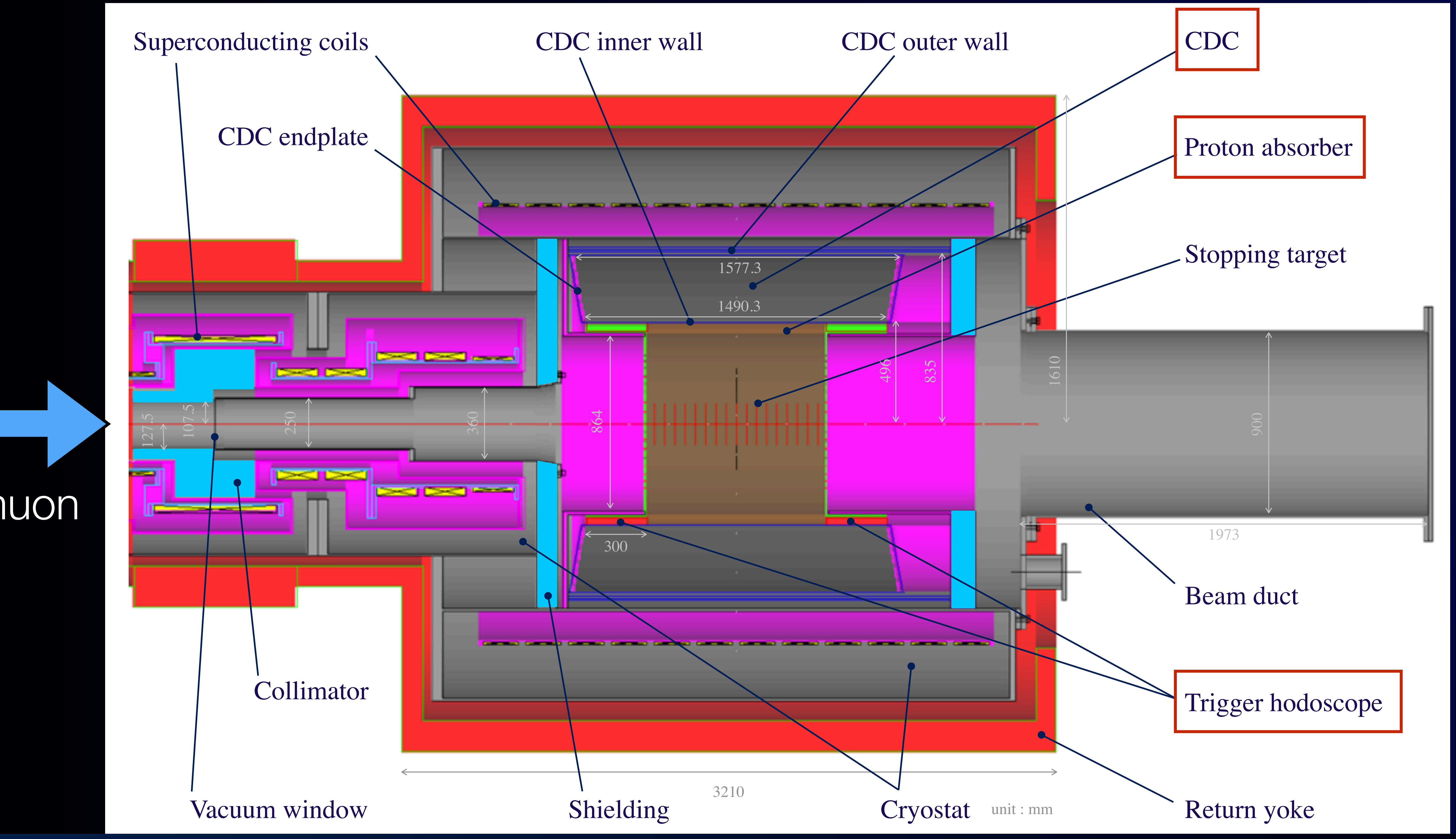
COMET Phase-I detector：

About 10^{16} muons are stopped in the target. Electron from μ-e conversion will be measured

COMET muon beam-line：

$6x10^9$ muon/sec with 3kW beam produced. The world highest intensity.

COMET Phase-I : Detector (CyDet)



COMET Phase-I : S.E.S.

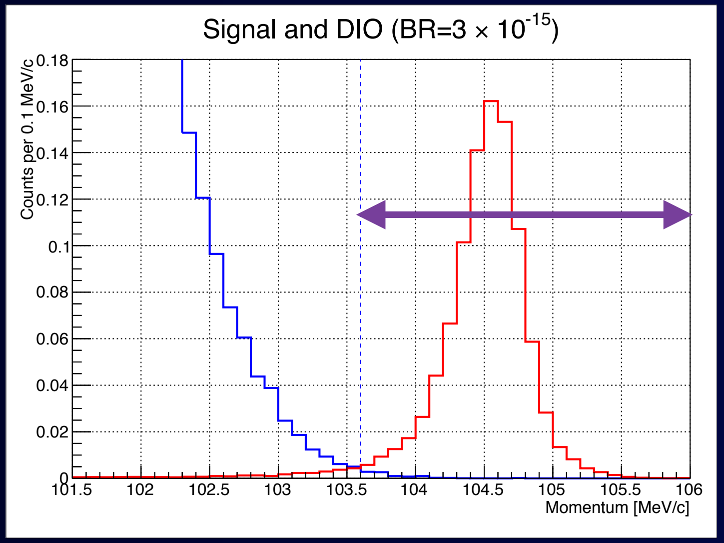
- **Single event sensitivity**

$$B(\mu^- + Al \to e^- + Al) \sim \frac{1}{N_\mu \cdot f_{cap} \cdot A_e},$$

- N_μ is a number of stopping muons in the muon stopping target. It is 1.23×10^{16} muons.
  - 8GeV, 3 kW proton beam power, with 110 days running.
- f_{cap} is a fraction of muon capture, which is 0.6 for aluminum.
- A_e is the detector acceptance, which is 0.043.

Table 28: *Breakdown of the $\mu^- N \to e^- N$ conversion signal acceptance.*

Event selection	Value	Comments
Geometrical acceptance	0.37	
Track quality cuts	0.66	
Momentum selection	0.93	103.6 MeV/c < P_e <106.0 MeV/c
Timing window	0.3	700 ns < t < 1100 ns
Trigger efficiency	0.8	
DAQ efficiency	0.8	
Track reconstruction efficiency	0.8	
Total	0.043	



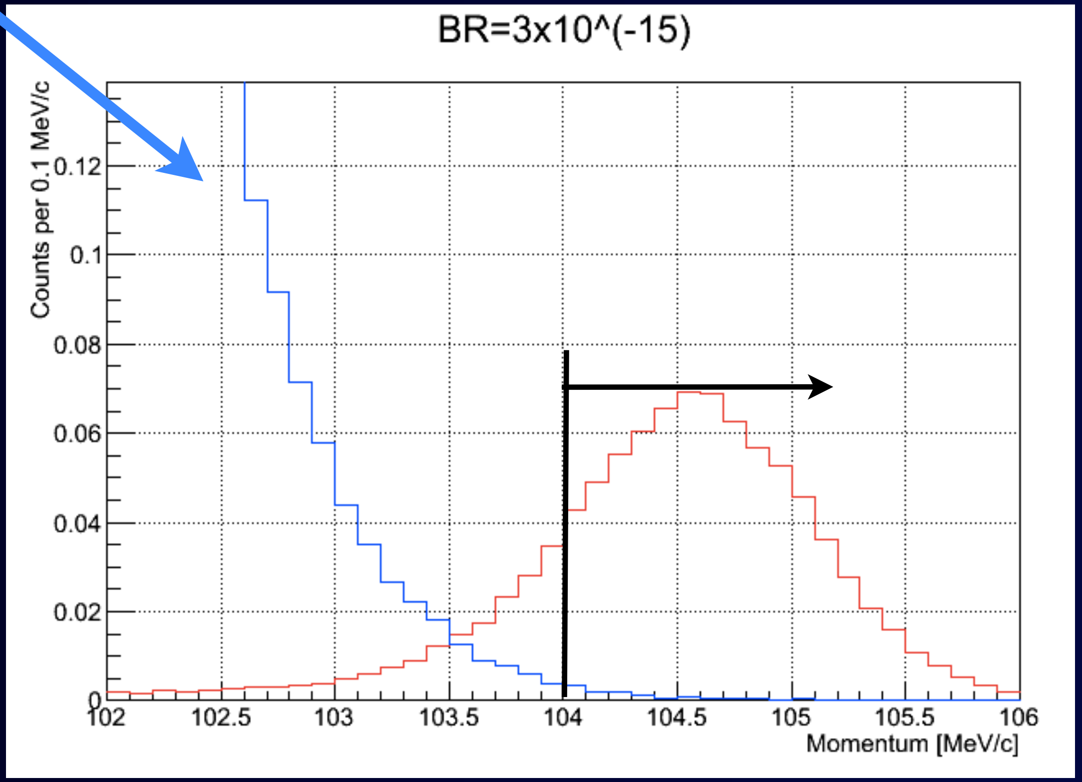
$$B(\mu^- + Al \to e^- + Al) = 3.1 \times 10^{-15}$$

$$B(\mu^- + Al \to e^- + Al) < 7 \times 10^{-15} \quad (90\% C.L.)$$

COMET Phase-I : Backgrounds

Background	estimated events
Muon decay in orbit	0.01
Radiative muon capture	< 0.001
Neutron emission after muon capture	< 0.001
Charged particle emission after muon capture	< 0.001
Radiative pion capture	0.0096*
Beam electrons Muon decay in flight Pion decay in flight	< 0.00048*
Neutron induced background	~ 0*
Delayed radiative pion capture	0.002
Anti-proton induced backgrounds	0.007
Electrons from cosmic ray muons	< 0.0002
Total	0.03

DIO



with proton extinction factor of 3×10^{-11}

Expected BG events are about 0.03 at S.E.S. of 3×10^{-15}.

COMET : Collaboration

164 collaborators, 37 institutes

COMET Collaboration meeting@KEK 26-30 Jan 2015

The COMET Collaboration

(Sep. 2014)

R. Akhmetshin[6,28], V. Anishchik[4], M. Aoki[29], R. B. Appleby[8,22], Y. Arimoto[15], Y. Bagaturia[33], Y. Ban[3], W. Bertsche[22], A. Bondar[6,28], S. Canfer[30], S. Chen[25], Y. E. Cheung[25], B. Chiladze[32], D. Clarke[30], M. Danilov[13,23], P. D. Dauncey[11], J. David[20], W. Da Silva[20], C. Densham[30], G. Devidze[32], P. Dornan[11], A. Drutskoy[13,23], V. Duginov[14], A. Edmonds[35], L. Epshteyn[6,27], P. Evtoukhovich[14], G. Fedotovich[6,28], M. Finger[7], M. Finger Jr[7], Y. Fujii[2], Y. Fukao[15], J-F. Genat[20], M. Gersabeck[22], E. Gillies[11], D. Grigoriev[6,27,28], K. Gritsay[14], E. Hamada[15], R. Han[1], K. Hasegawa[15], I. H. Hasim[29], O. Hayashi[29], M. I. Hossain[16], Z. A. Ibrahim[21], Y. Igarashi[15], F. Ignatov[6,28], M. Iio[15], M. Ikeno[15], K. Ishibashi[19], S. Ishimoto[15], T. Itahashi[29], S. Ito[29], T. Iwami[29], Y. Iwashita[17], X. S. Jiang[2], P. Jonsson[11], V. Kalinnikov[14], F. Kapusta[20], H. Katayama[29], K. Kawagoe[19], V. Kazanin[6,28], B. Khazin[§6,28], A. Khvedelidze[14], M. Koike[36], G. A. Kozlov[14], B. Krikler[11], A. Kulikov[14], E. Kulish[14], Y. Kuno[29], Y. Kuriyama[18], Y. Kurochkin[5], A. Kurup[11], B. Lagrange[11,18], M. Lancaster[35], H. B. Li[2], W. G. Li[2], A. Liparteliani[32], R. P. Litchfield[35], P. Loveridge[30], G. Macharashvili[14], Y. Makida[15], Y. Mao[3], O. Markin[13], Y. Matsumoto[29], T. Mibe[15], S. Mihara[15], F. Mohamad Idris[21], K. A. Mohamed Kamal Azmi[21], A. Moiseenko[14], Y. Mori[18], N. Mosulishvili[32], E. Motuk[35], Y. Nakai[19], T. Nakamoto[15], Y. Nakazawa[29], J. Nash[11], M. Nioradze[32], H. Nishiguchi[15], T. Numao[34], J. O'Dell[30], T. Ogitsu[15], K. Oishi[19], K. Okamoto[29], C. Omori[15], T. Ota[31], H. Owen[22], C. Parkes[22], J. Pasternak[11], C. Plostinar[30], V. Ponariadov[4], A. Popov[6,28], V. Rusinov[13,23], A. Ryzhenenkov[6,28], B. Sabirov[14], N. Saito[15], H. Sakamoto[29], P. Sarin[10], K. Sasaki[15], A. Sato[29], J. Sato[31], D. Shemyakin[6,28], N. Shigyo[19], D. Shoukavy[5], M. Slunecka[7], M. Sugano[15], Y. Takubo[15], M. Tanaka[15], C. V. Tao[26], E. Tarkovsky[13,23], Y. Tevzadze[32], N. D. Thong[29], V. Thuan[12], J. Tojo[19], M. Tomasek[9], M. Tomizawa[15], N. H. Tran[29], I. Trek[32], N. M. Truong[29], Z. Tsamalaidze[14], N. Tsverava[14], S. Tygier[22], T. Uchida[15], Y. Uchida[11], K. Ueno[15], S. Umasankar[10], E. Velicheva[14], A. Volkov[14], V. Vrba[9], W. A. T. Wan Abdullah[21], M. Warren[35], M. Wing[35], T. S. Wong[29], C. Wu[2,25], G. Xia[22], H. Yamaguchi[19], A. Yamamoto[15], M. Yamanaka[24], Y. Yang[19], H. Yoshida[29], M. Yoshida[15], Y. Yoshii[15], T. Yoshioka[19], Y. Yuan[2], Y. Yudin[6,28], J. Zhang[2], Y. Zhang[2]

Me

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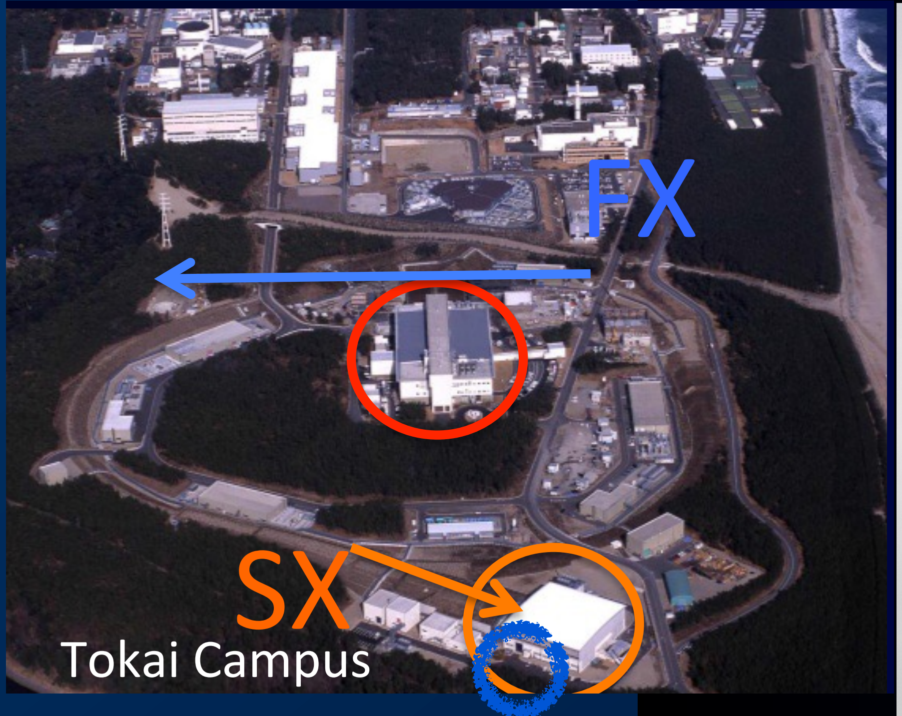
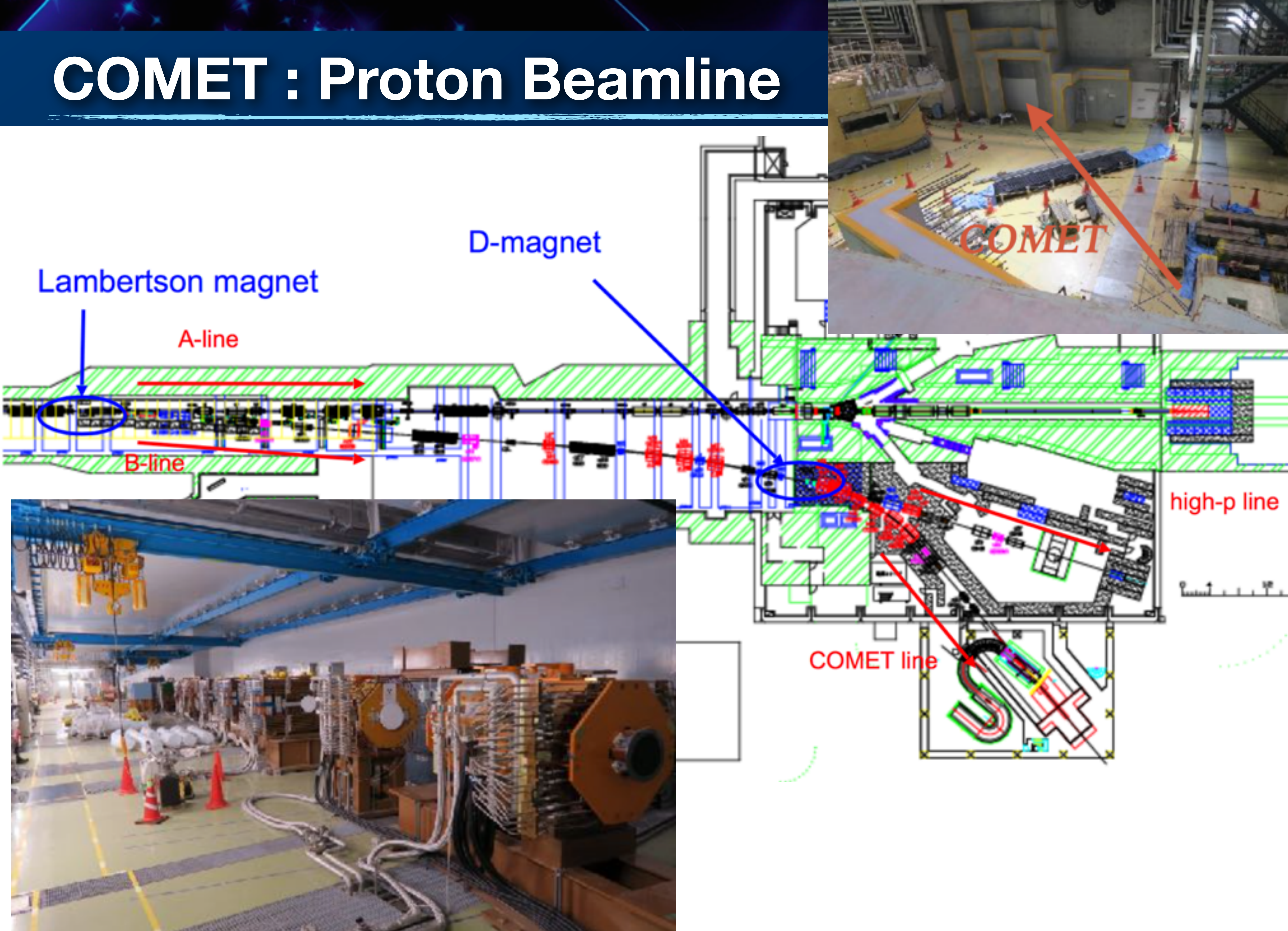
[3] *Peking University, Beijing, People's Republic of China*
[4] *Belarusian State University (BSU), Minsk, Belarus*
[5] *B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Belarus*
[6] *Budker Institute of Nuclear Physics (BINP), Novosibirsk, Russia*
[7] *Charles University, Prague, Czech Republic*
[8] *The Cockcroft Institute, Daresbury Laboratory, Warrington, UK*
[9] *Czech Technical University, Prague, Czech Republic*
[10] *Indian Institute of Technology, Bombay, India*
[11] *Imperial College London, London, UK*
[12] *Institute for Nuclear Science and Technology, Hanoi, Vietnam*
[13] *Institute for Theoretical and Experimental Physics (ITEP), Russia*
[14] *Joint Institute for Nuclear Research (JINR), Dubna, Russia*
[15] *High Energy Accelerator Research Organization (KEK), Tsukuba, Japan*
[16] *King Abdulaziz University, Saudi Arabia*
[17] *Institute for Chemical Research, Kyoto University, Kyoto, Japan*
[18] *Research Reactor Institute, Kyoto University, Kyoto, Japan*
[19] *Kyushu University, Fukuoka, Japan*
[20] *Laboratory of Nuclear and High Energy Physics (LPNHE), CNRS-IN2P3 and University Pierre and Marie Curie (UPMC), Paris, France*
[21] *National Centre for Particle Physics, Universiti Malaya, Kuala Lumpur, Malaysia*

COMET Status: Experimental Hall

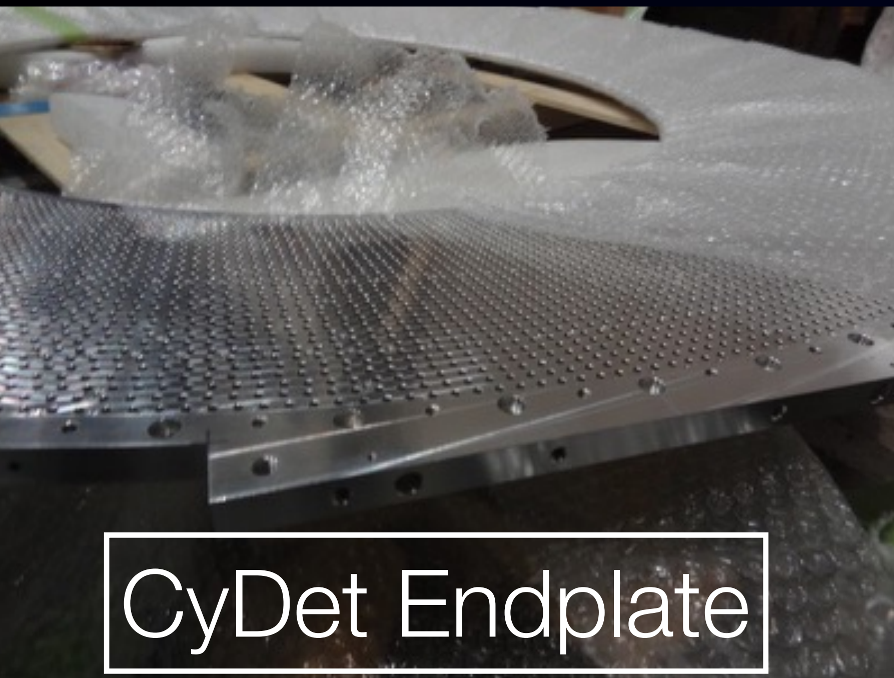
- COMET building completed!



COMET : Proton Beamline



COMET Status: CDC

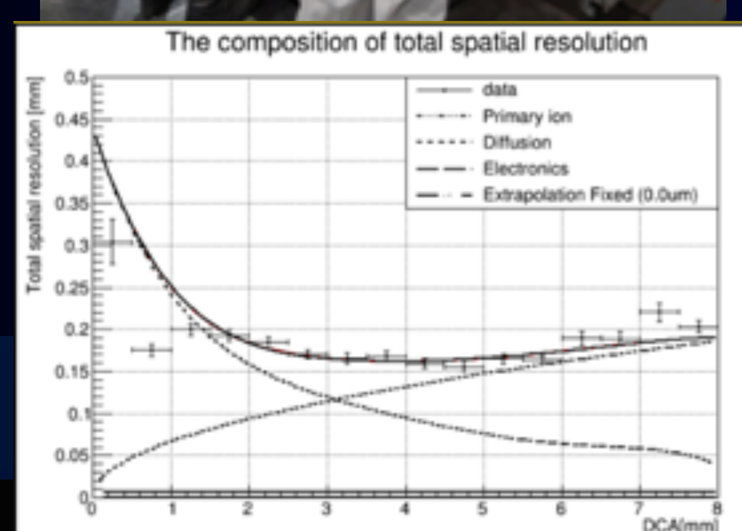


CyDet Endplate

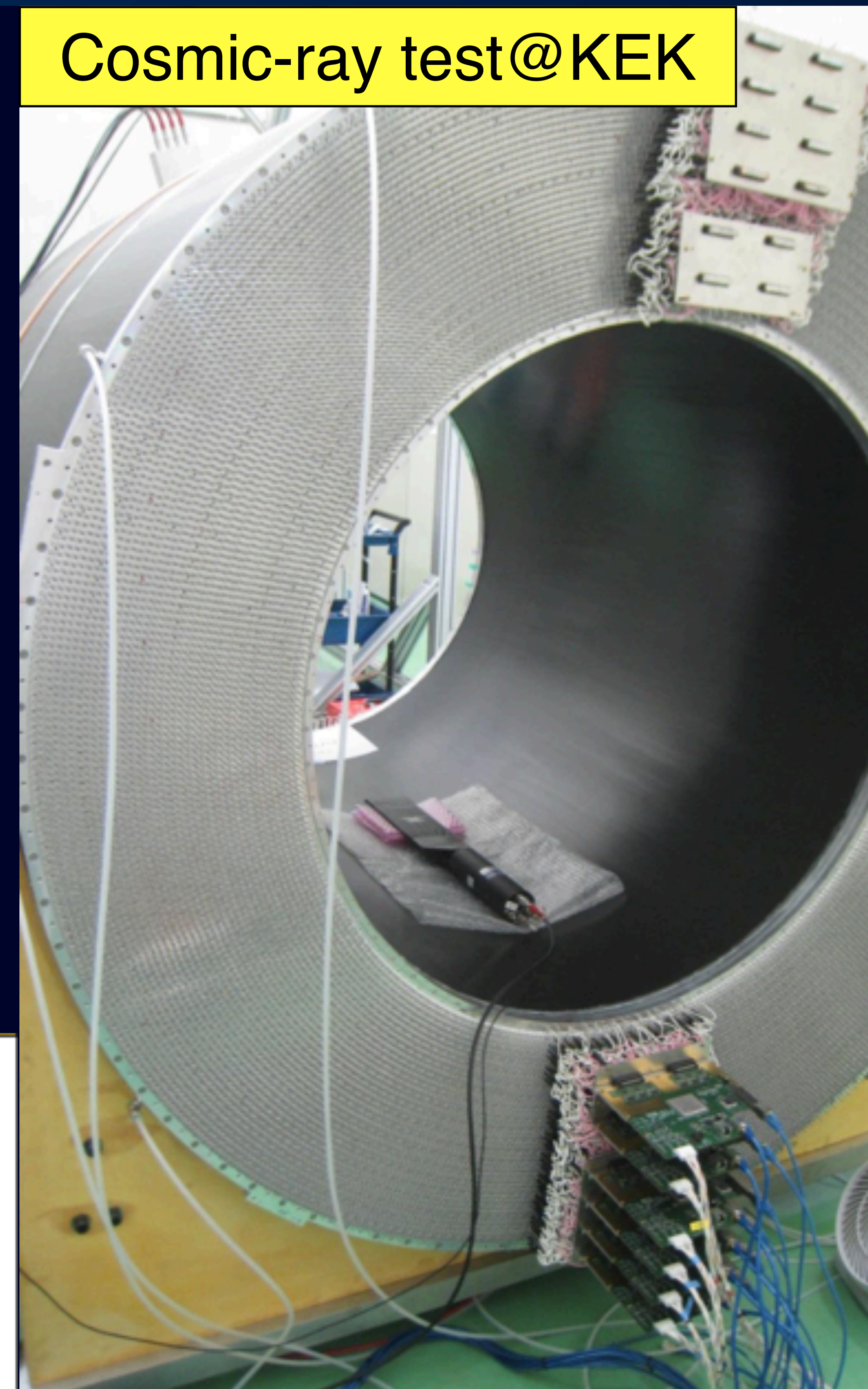
CyDet Outer wall

テキスト

CyDet assembly

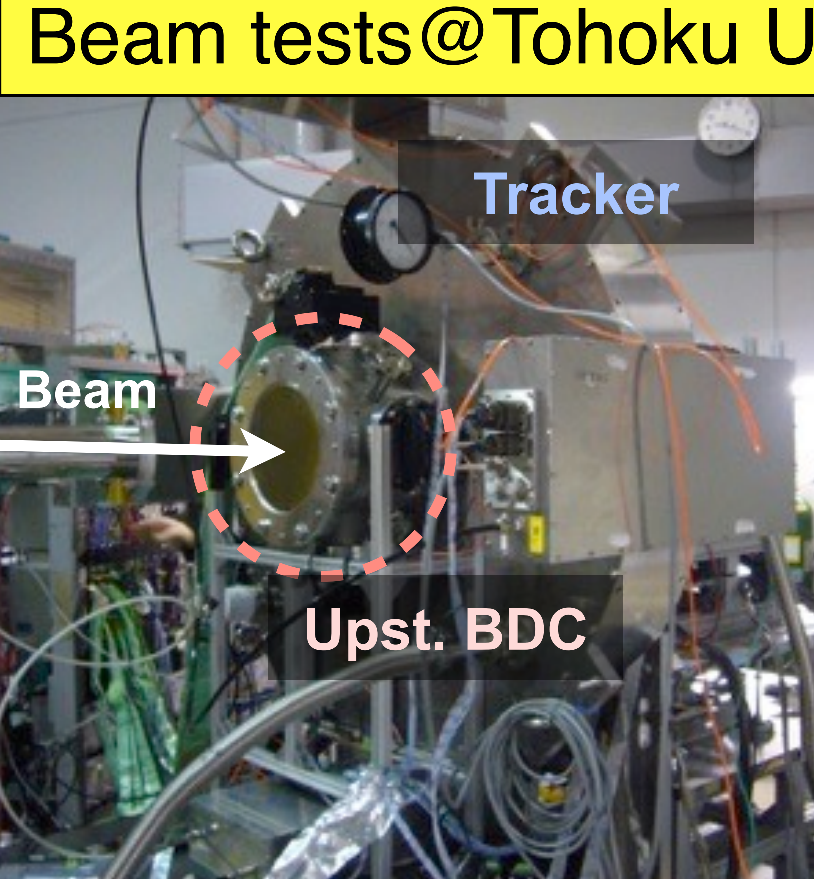


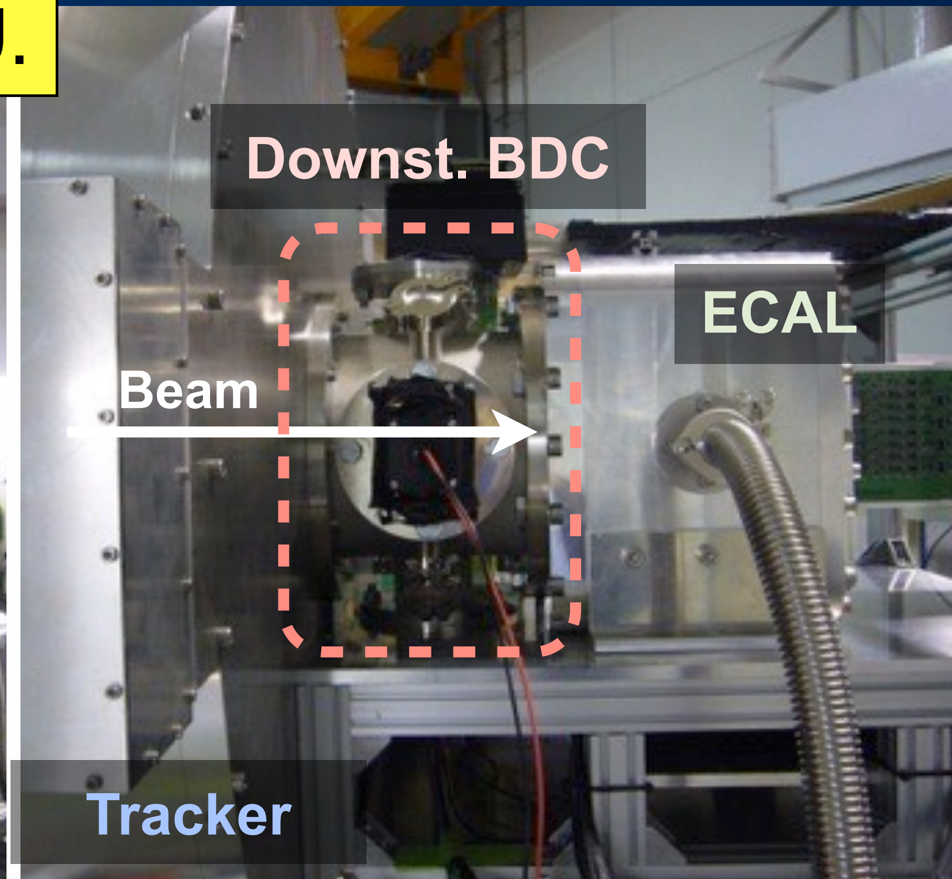
Cosmic-ray test@KEK

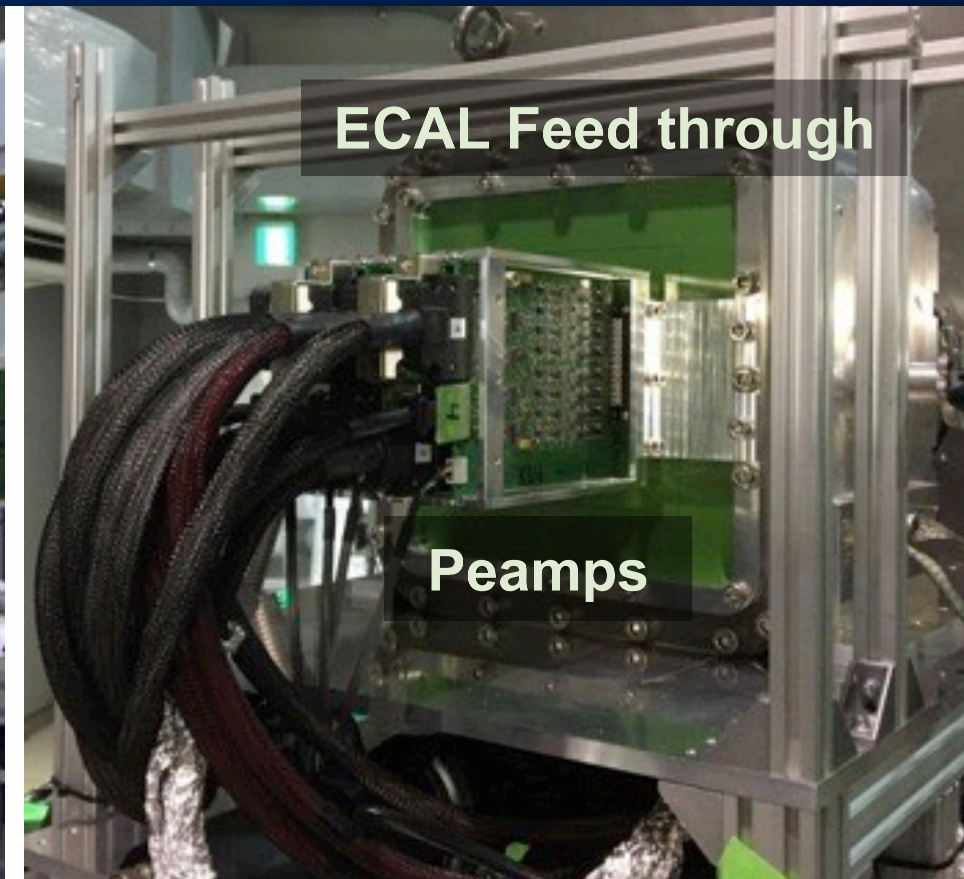


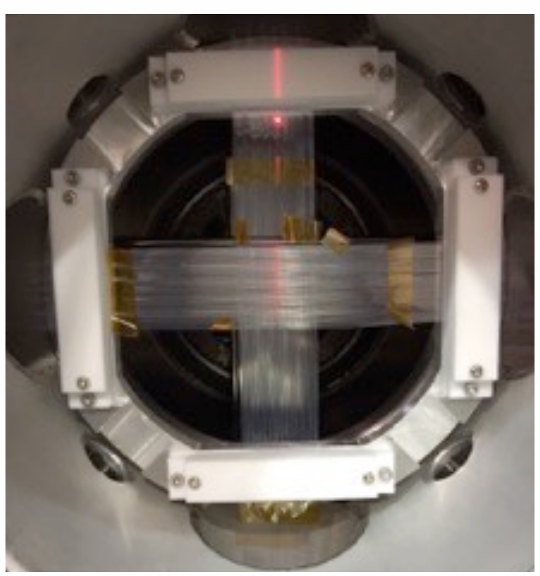
COMET Status: Straw Tracker

Beam tests@Tohoku U.

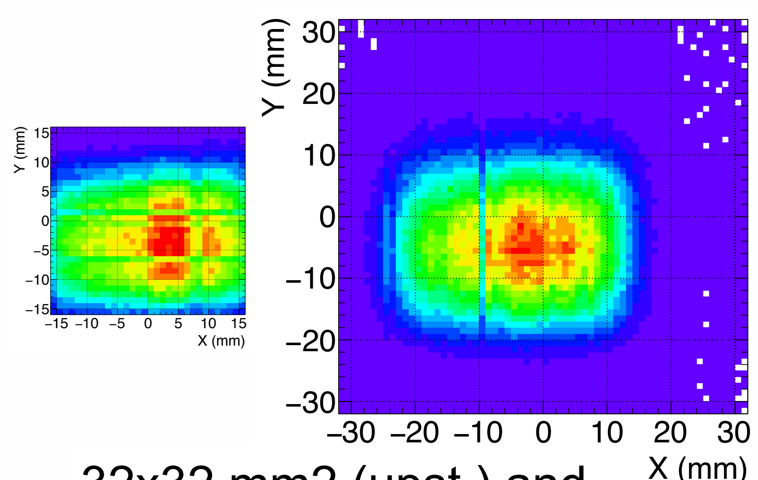




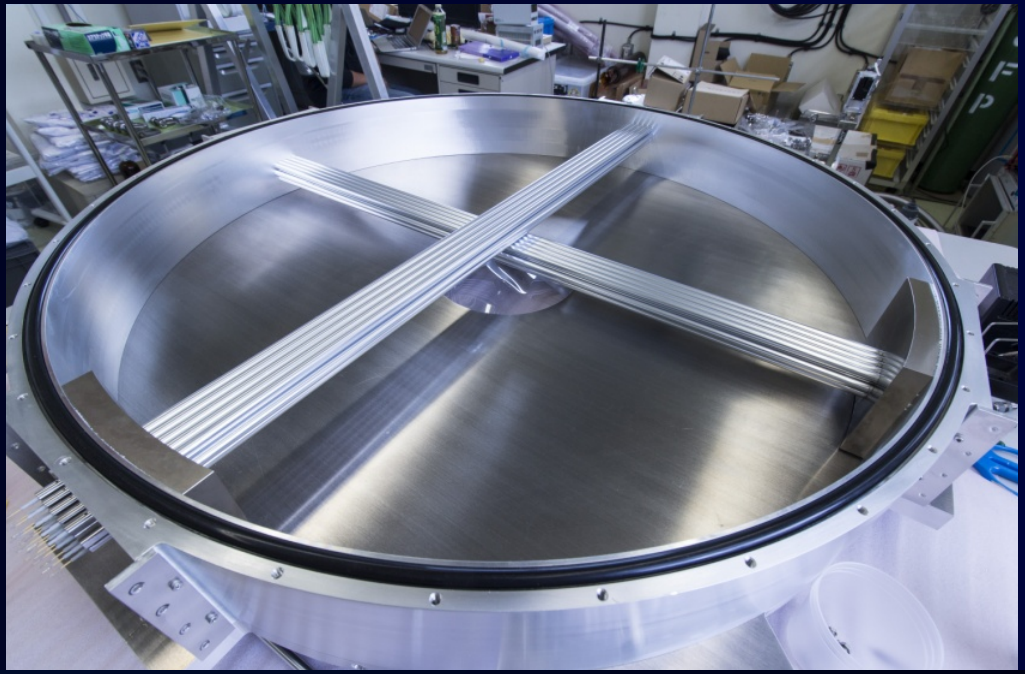




Assembled BDC



32x32 mm2 (upst.) and
64x64 mm2 (downst.)



まとめ

- 大阪大学で大強度ミューオン源MuSICの開発に成功し、従来より1000倍以上効率よくミューオンを生成することができるようになった。
- 阪大核物理研究センターに日本初のDCミューオン施設が稼働し、~10^6μ/秒の強度のミューオンが利用できる。
  - 物性物理、原子核物理、
  - 非破壊元素分析、核変換、核融合基礎研究
- J-PARCではMuSICを応用して、10^{10}μ/秒の負ミューオン生成。μ-e転換を探索するCOMET実験の準備が進んでいる。2020年頃から物理Runなのでお楽しみに。
- COMET実験の後に何をすべきか？