

Negative Muonium Ion Production with a C12A7 Electrude Film

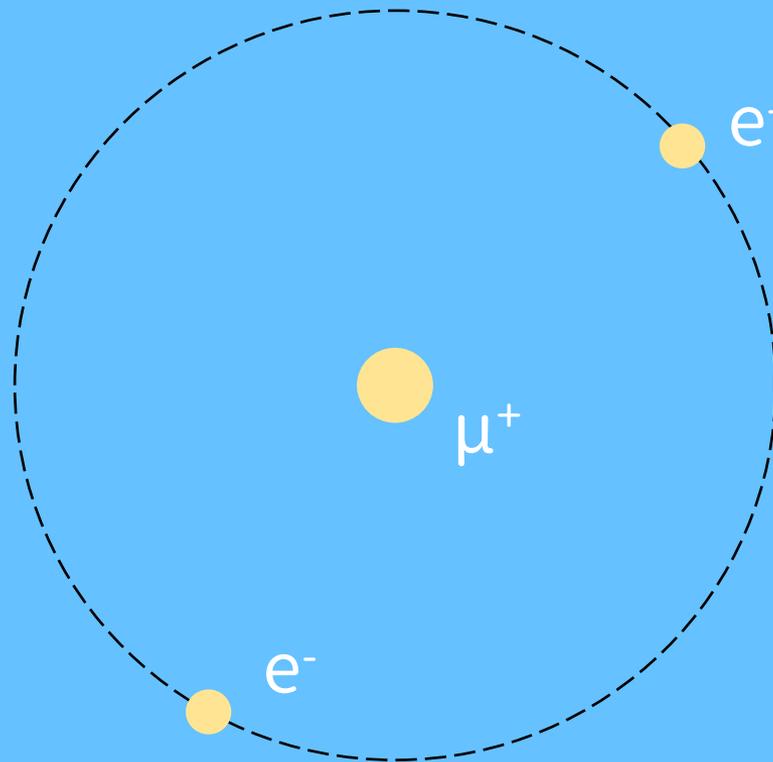
M. Otani (KEK)

Y. Fukao, K. Futatsukawa, N. Kawamura, S. Matoba, T. Mibe, Y.
Miyake, K. Shimoura T. Yamazaki (KEK)
K. Hasegawa, R. Kitamura, Y. Kondo, T. Morishita (JAEA/J-PARC)
T. Iijima, K.Inami, Y. Sue, M. Yotsuzuka, (Nagoya Univ.)
H. Inuma, Y. Nakazawa (Ibaraki Univ.)
K. Ishida (RIKEN), N. Saito (J-PARC), H. Yasuda (Univ. of Tokyo)



Negative Muonium Ion (Mu^-)

- Three body system of $\mu^+ e^- e^-$
- First observation in late 1980's
 - Foil method by Y. Kuang et al., Phys. Rev. A 35, 3172, 1987.
 - Moderator by D. Harshman et al., Phys. Rev. Lett. 56, 2850, 1986.



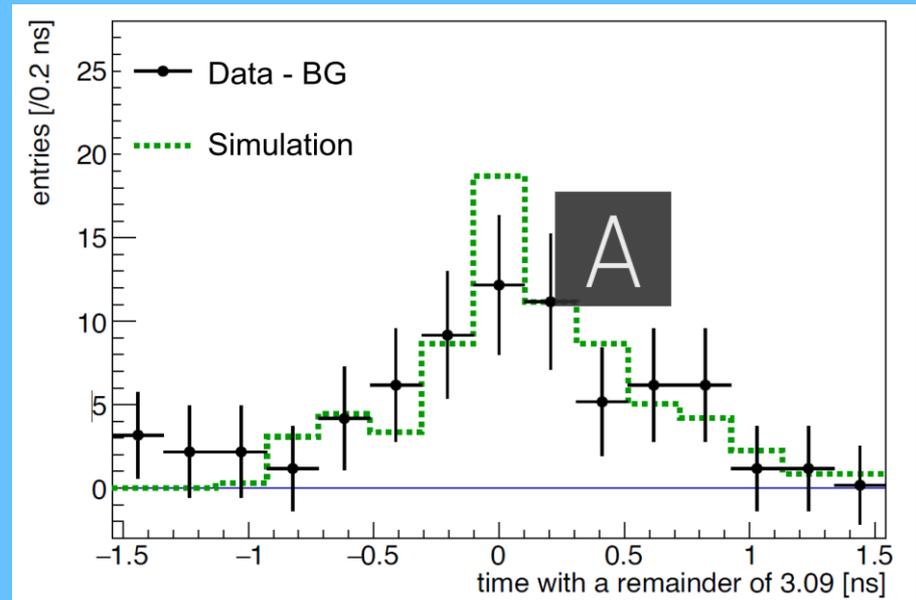
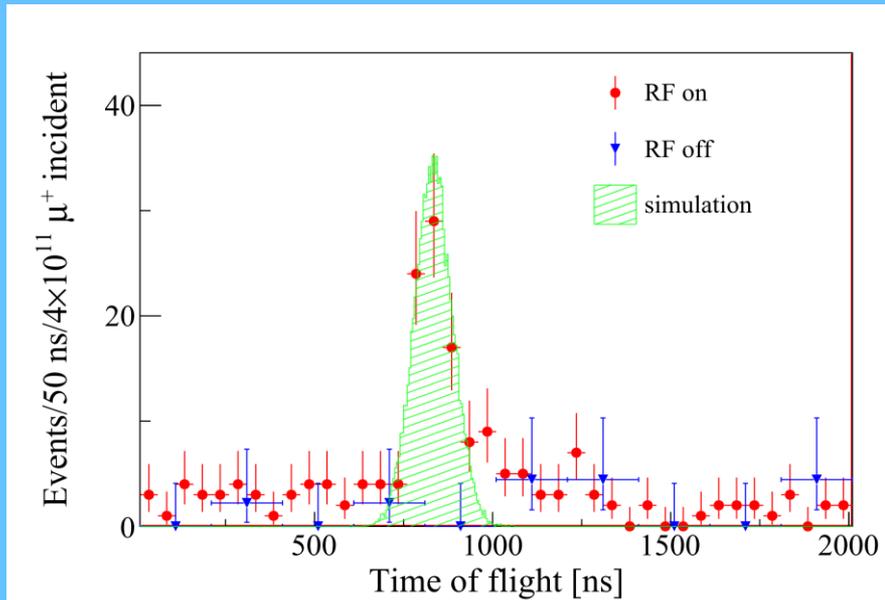
Mu⁻ as a probe

Recent progress in high-intensity machine gives opportunities to investigate secondary particles such as muon and its exotic state.

- Dedicated precise calculation because of the pure leptonic system.
 - Phys. Rev. A 69, 022501 (2004)
- Offers new mean for exotic reaction such as Mu ($\mu^+ e^-$) \rightarrow anti-Mu ($\mu^- e^+$)
 - Phys. B: At. Mol. Opt. Phys.25, 3059 (1992)
- Available as muon cooling method.
 - Neutral Mu/ μ^+ beam by succeeding acceleration and charge exchange.

Muon Acceleration with Mu-

- First acceleration presented by Y. Kondo in IPAC'18
 - Y. Kondo, M. Otani et al., Phys. Rev. AB, 21, 050101 (2018).
- Micro-bunch measurements by Y. Sue in IPAC'19



As Difficult As They Are Rare

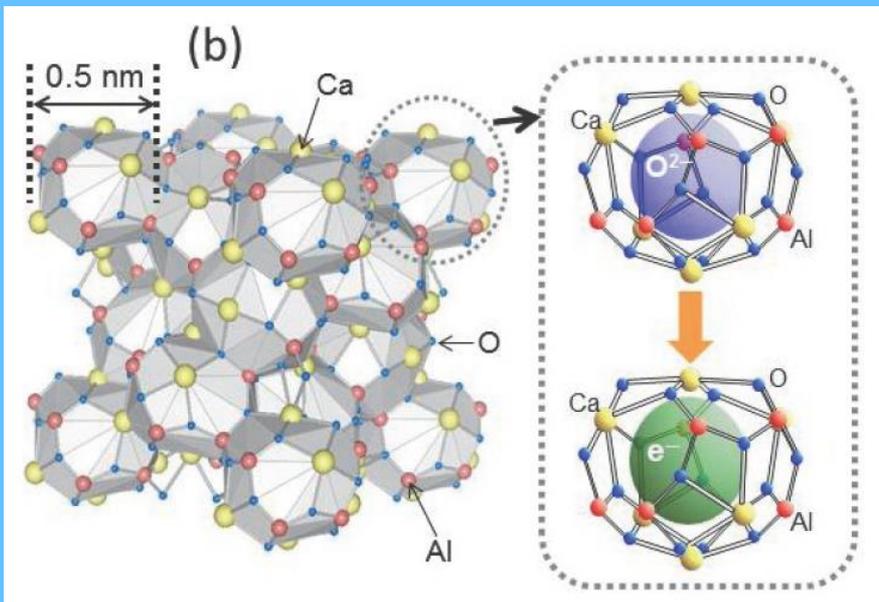
- Only $\sim 10^{-4\sim-5}$ / incident μ^+ become Mu^-
- Only single counting measurements up to now; need further measurements to understand the Mu^- formation.



- From the similarity to Ps^- and H^- , work function on the surface should be important.

C12A7 Electride (C12A7:e⁻)

- First invented by H. Hosono et al. in 2003.
 - Science 301, 626, 2003.



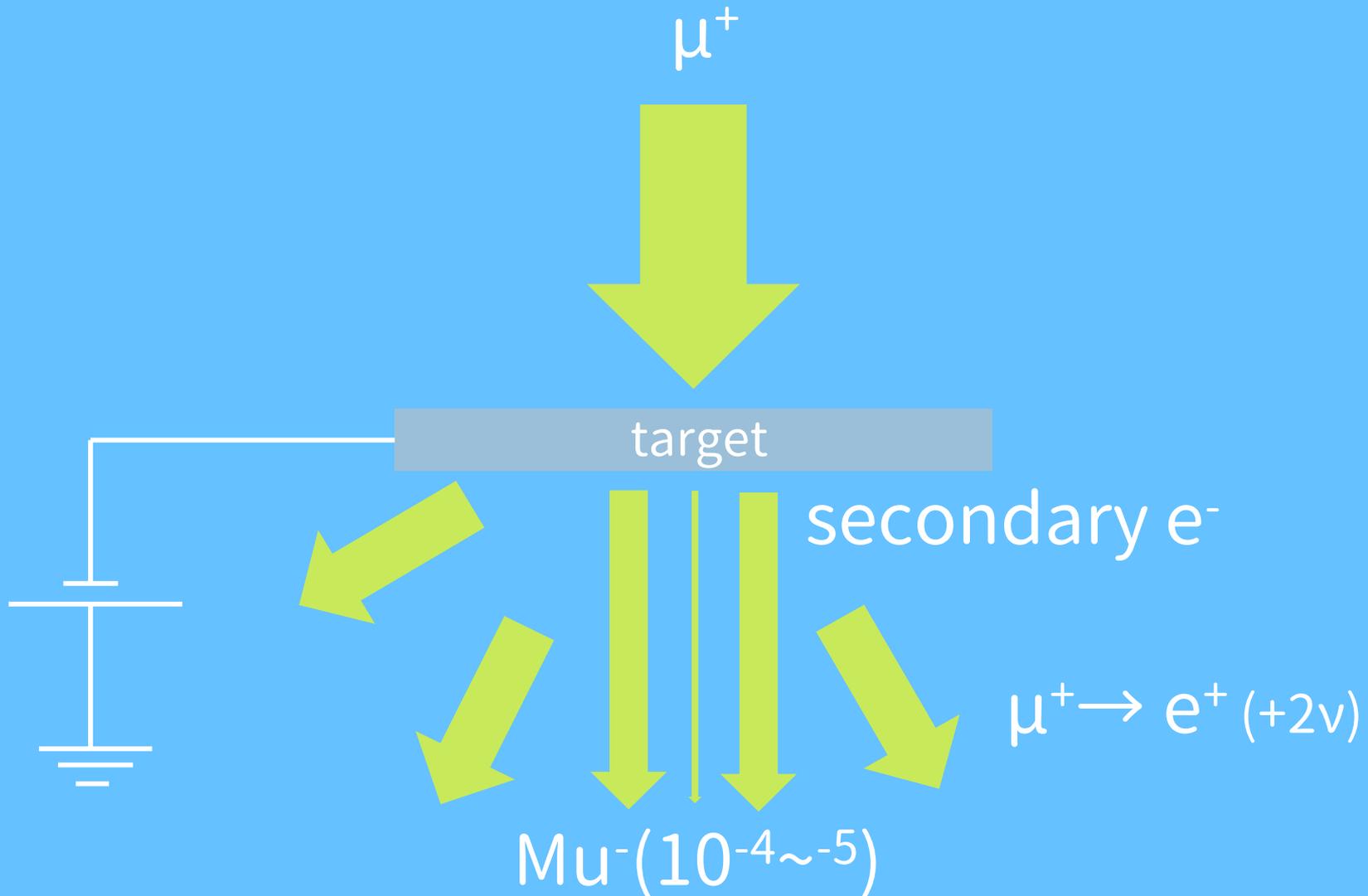
- Free O⁻ ion in alumina cement is replaced by e⁻
- Low-work function: 2.4-2.9 eV (cf. Al: 4.1 eV, Cs: 1.9 eV)
- Stable in atmosphere and vacuum.

- Started to be used for industrial use such as ammonia synthesis, OLED etc.
- We conducted Mu⁻ measurement with C12A7:e⁻

Experimental Site

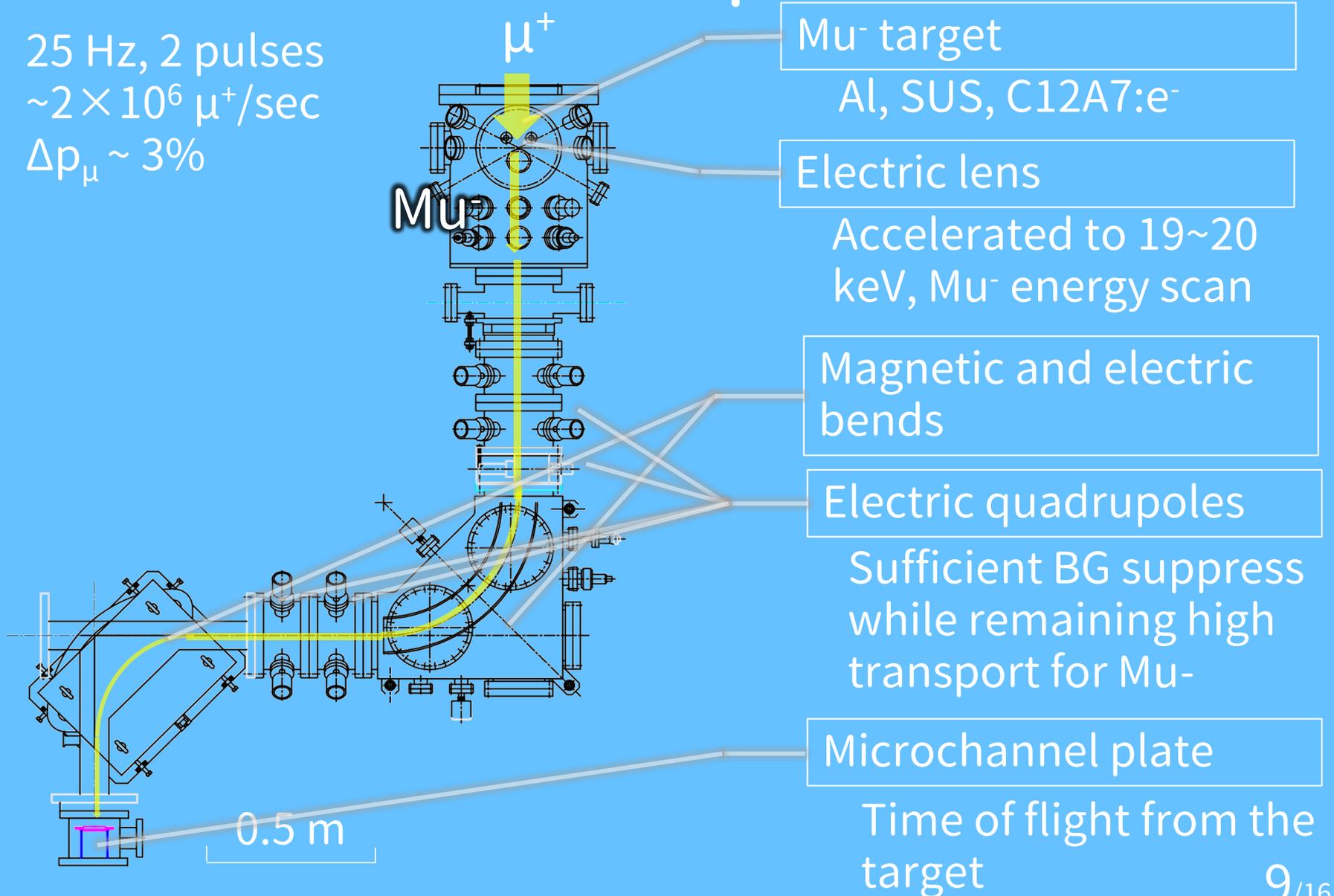


Mu⁻ measurement



Setup

25 Hz, 2 pulses
 $\sim 2 \times 10^6 \mu^+/\text{sec}$
 $\Delta p_\mu \sim 3\%$



Mu⁻ target

Al, SUS, C12A7:e⁻

Electric lens

Accelerated to 19~20 keV, Mu⁻ energy scan

Magnetic and electric bends

Electric quadrupoles

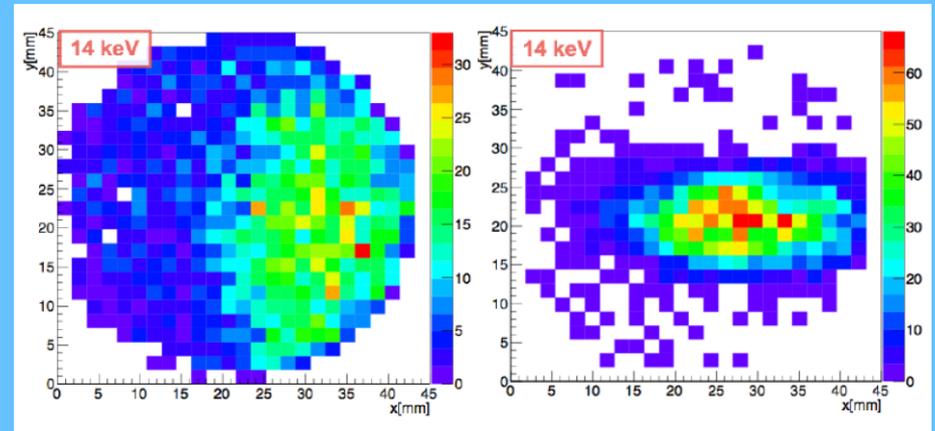
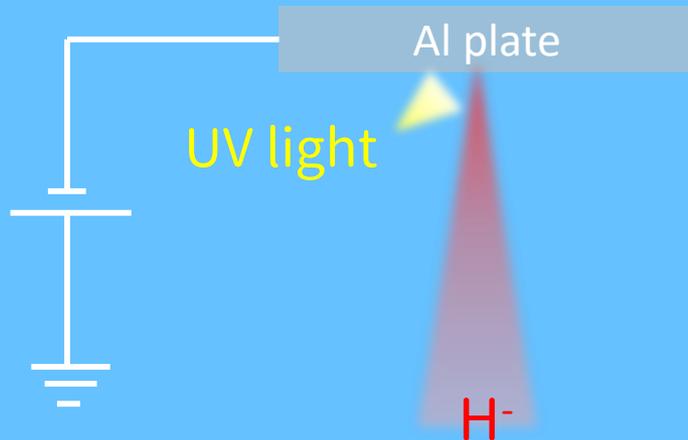
Sufficient BG suppress while remaining high transport for Mu⁻

Microchannel plate

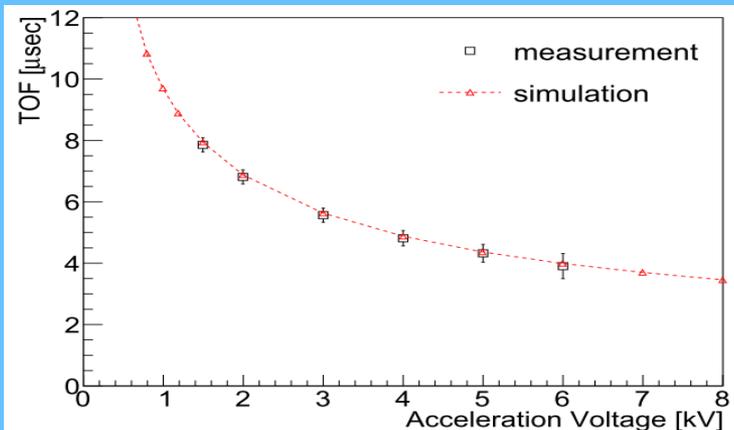
Time of flight from the target

Commissioning

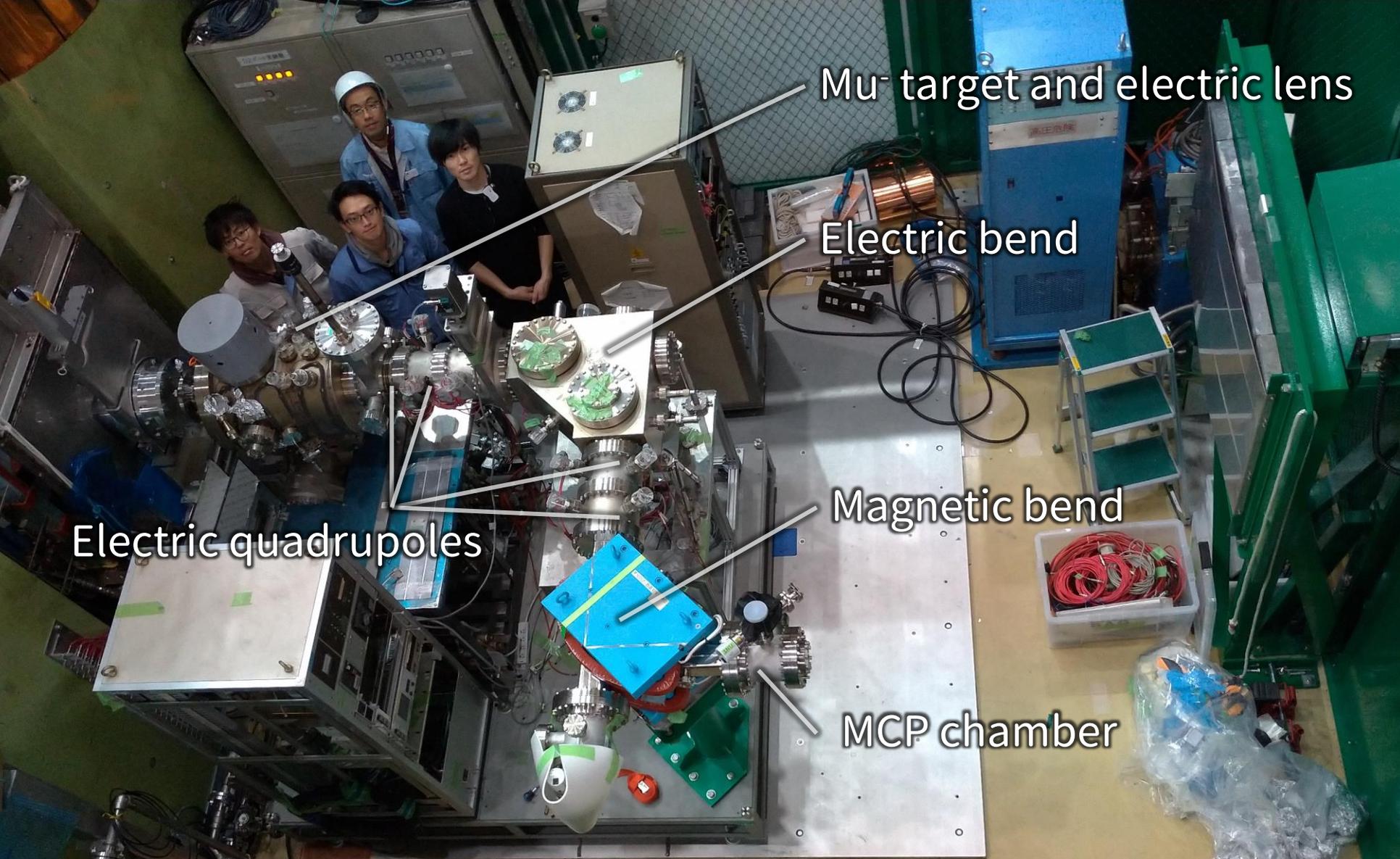
- With H⁻ generated by irradiating the target by UV light.
 - Y. Nakazawa et al., to be published in NIMA.



By R. Kitamura (JAEA/J-PARC)



Electric quadrupole and bending are commissioned



Mu⁻ target and electric lens

Electric bend

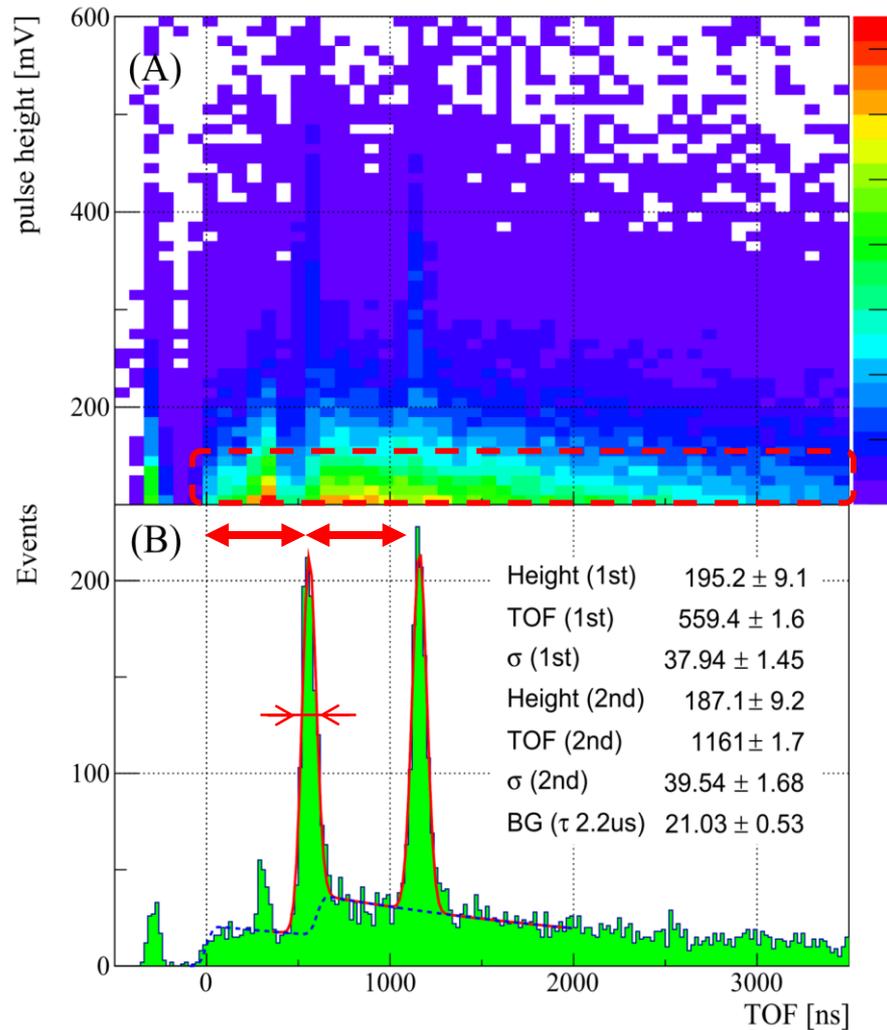
Magnetic bend

MCP chamber

Electric quadrupoles

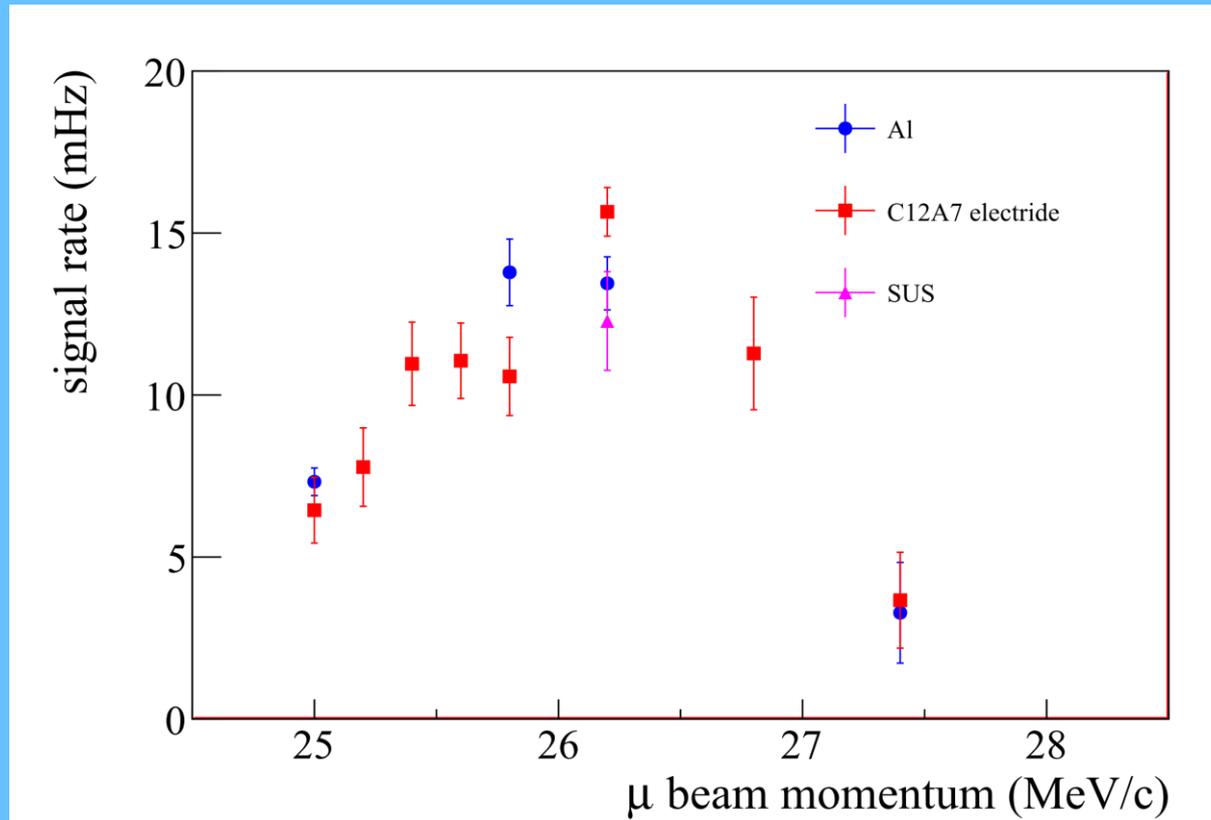
Experiment of the Mu⁻ Measurement (Jan. 27th – 30th , 2019)

Pulse Height & Time Of Flight



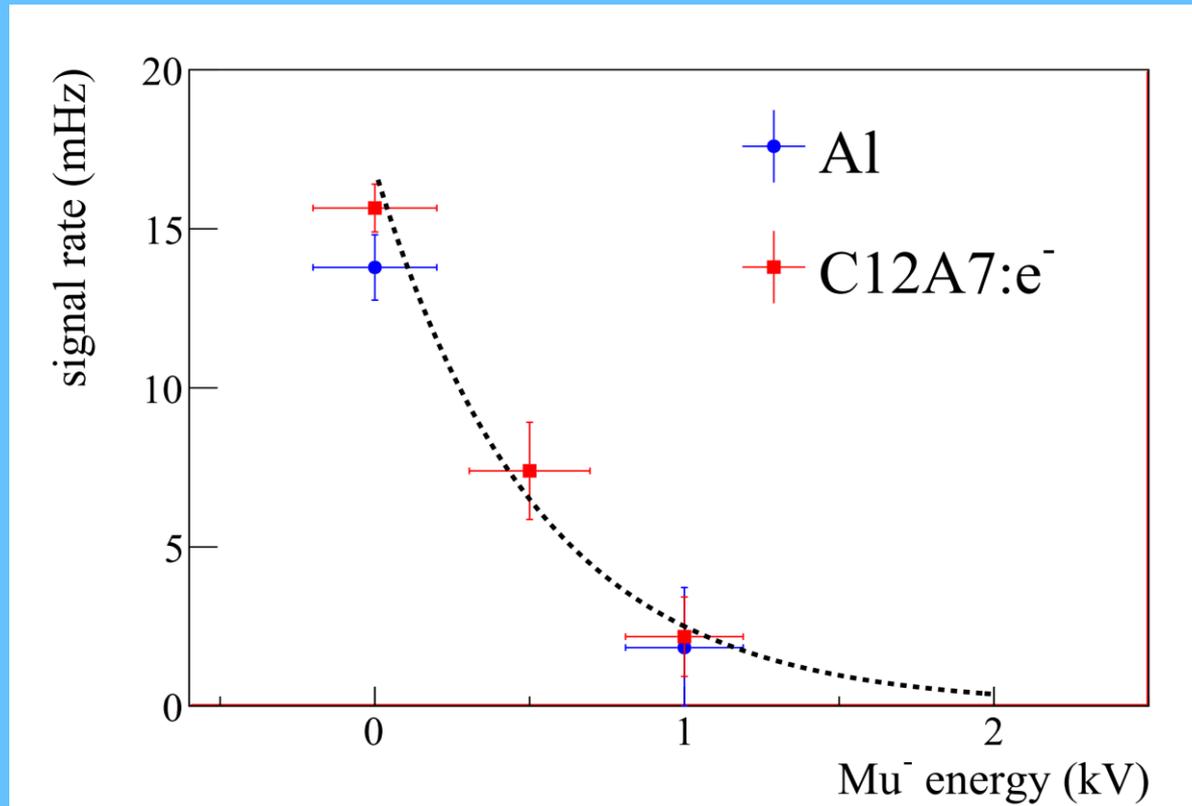
- Events with smaller pulse are decay- e^+
- Observed TOF is consistent to expectation with Mu- mass.
- Pulse interval is consistent to that of primary proton beam.
- Pulse width is consistent to that of primary proton beam.
- Succeeded in observing clear Mu⁻ signal.

Momentum Dependence



- Not big difference btw Al, SUS, and C12A7:e⁻.
- Dependence is being investigated by the simulation.

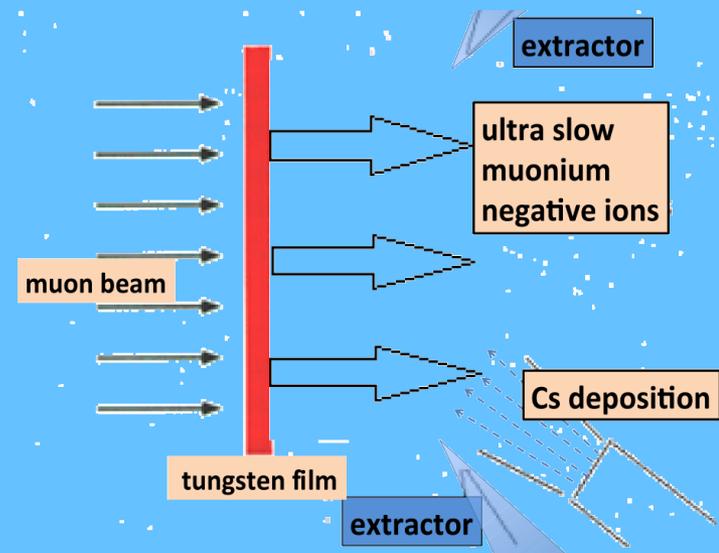
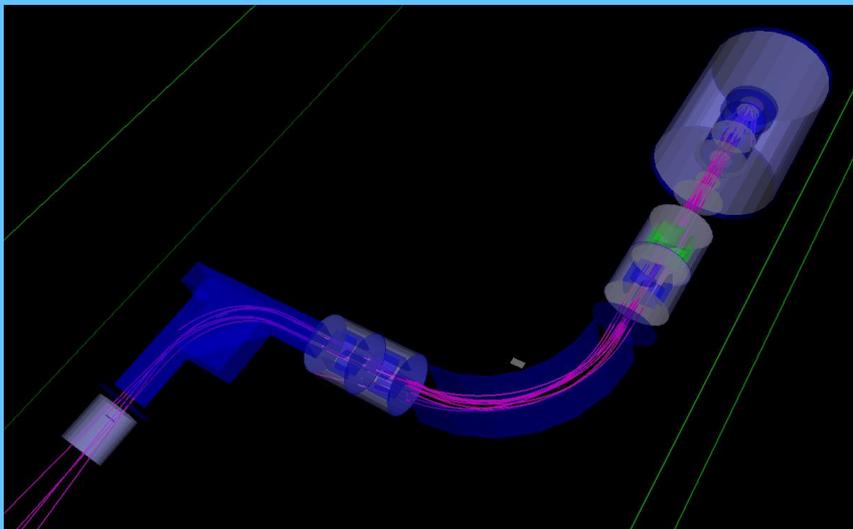
Mu⁻ Energy



- Dependence is consistent btw Al and C12A7:e⁻.
- Average energy is estimated to be ~0.2 keV, which is consistent to previous experiment.

Prospect

- Developing simulation to reveal the Mu^- formation process.
 - ✓ Mu^- beamline simulation
 - ✓ Incident μ^+ simulation
 - μ^+ stopping and Mu^- formation.
- Further measurements for enhancement of Mu^- yield.
 - Proc. of IPAC'17, pp. 2898-2901, 2017.



Summary

- Negative muonium ion (Mu^-) is old but new particle stimulating our interests.
- This is first systematic measurement for the Mu^- production using a low-work function material of C12A7: e^-
- We try to understand the Mu^- formation process because we really want more Mu^- s.

J-PARC 10th Anniversary & Symposium

- September 23-26, 2019, Tsukuba, Japan.



J-PARC Symposium 2019

[HOME](#) [Registration & Abstract Submission](#) [Program](#) [Financial Support](#) [Photo](#) [Important Dates](#) [Publication](#)

The 3rd J-PARC Symposium (J-PARC2019)
September 23-26, 2019, Tsukuba, Japan



We are pleased to announce that the 3rd J-PARC symposium (J-PARC2019) will be held on September 23-26, 2019 in Tsukuba, Japan. This is the first circular of the symposium.

J-PARC symposium

