Negative muonium ion source for muon accelerators

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supported by KAKENHI (JSPS)

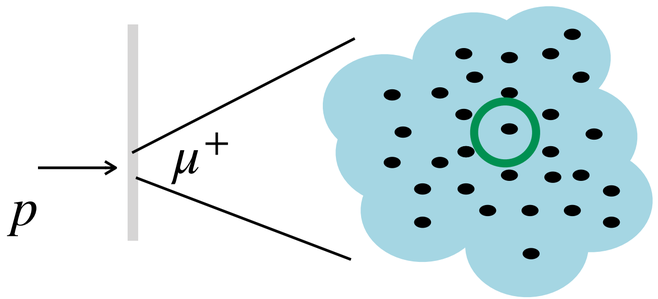
Motivation of this study

- High-energy muon beams are essential for physics and applications
- Muon Collider requires extremely high luminosity
- Current muon production limited by large emittance and low efficiency

Scientific Background

- Muons are produced from pion decay in hadron collisions
- Resulting muons have broad momentum distribution and large emittance
- Cooling requires reducing 6D phase-space volume by factor of 10^6

Irradiate the target with
a hadron beam
to generate muons.



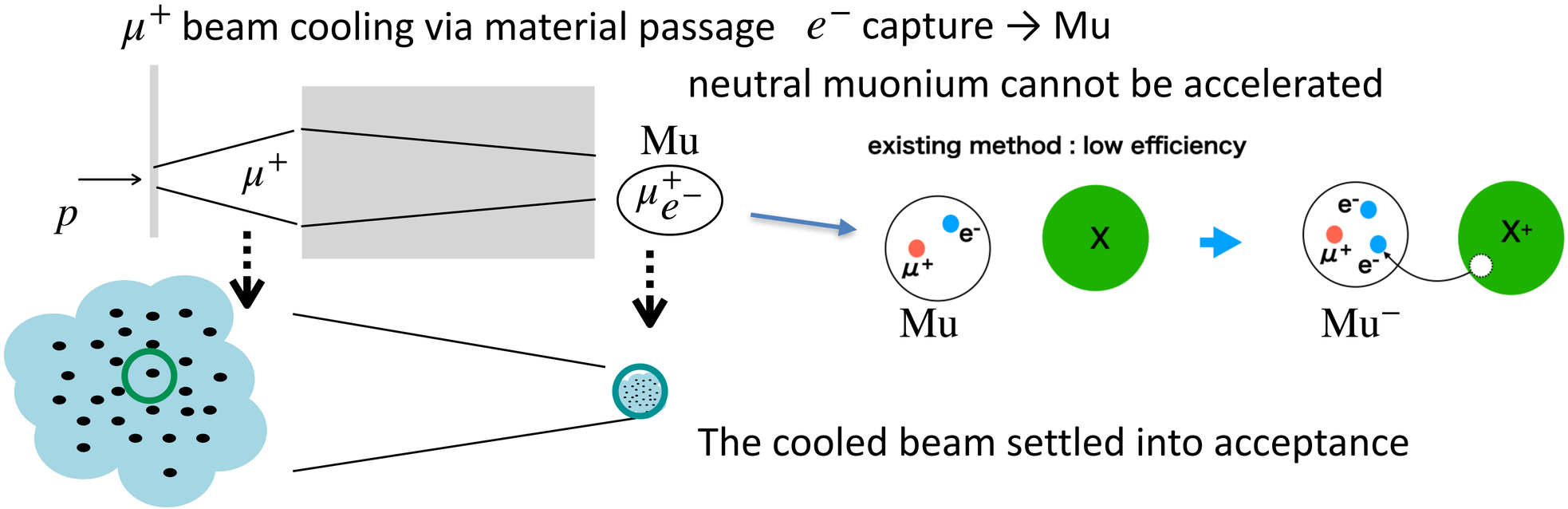
Beam spread far exceeding
the acceptance

6D phase space

acceptance of
the accelerator

Problem in Current Approaches

- Cooling via mateial passage
- After cooling, positive muons capture electrons → Muonium atoms (Mu)
- Neutral Mu cannot be directly accelerated → need to ionize MU some how
- Existing ionization methods → low efficiency ($\mathrm{Mu}^-/\mathrm{Mu}$< 10^-4)

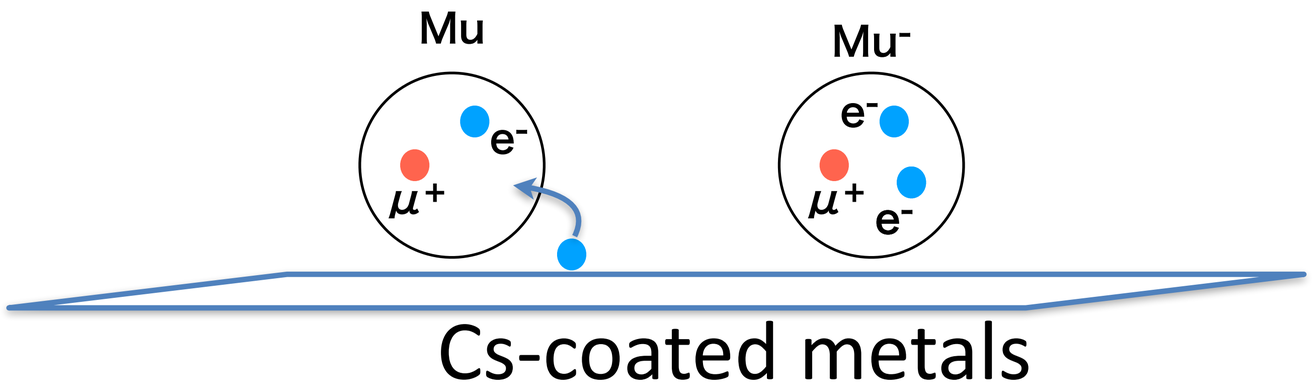


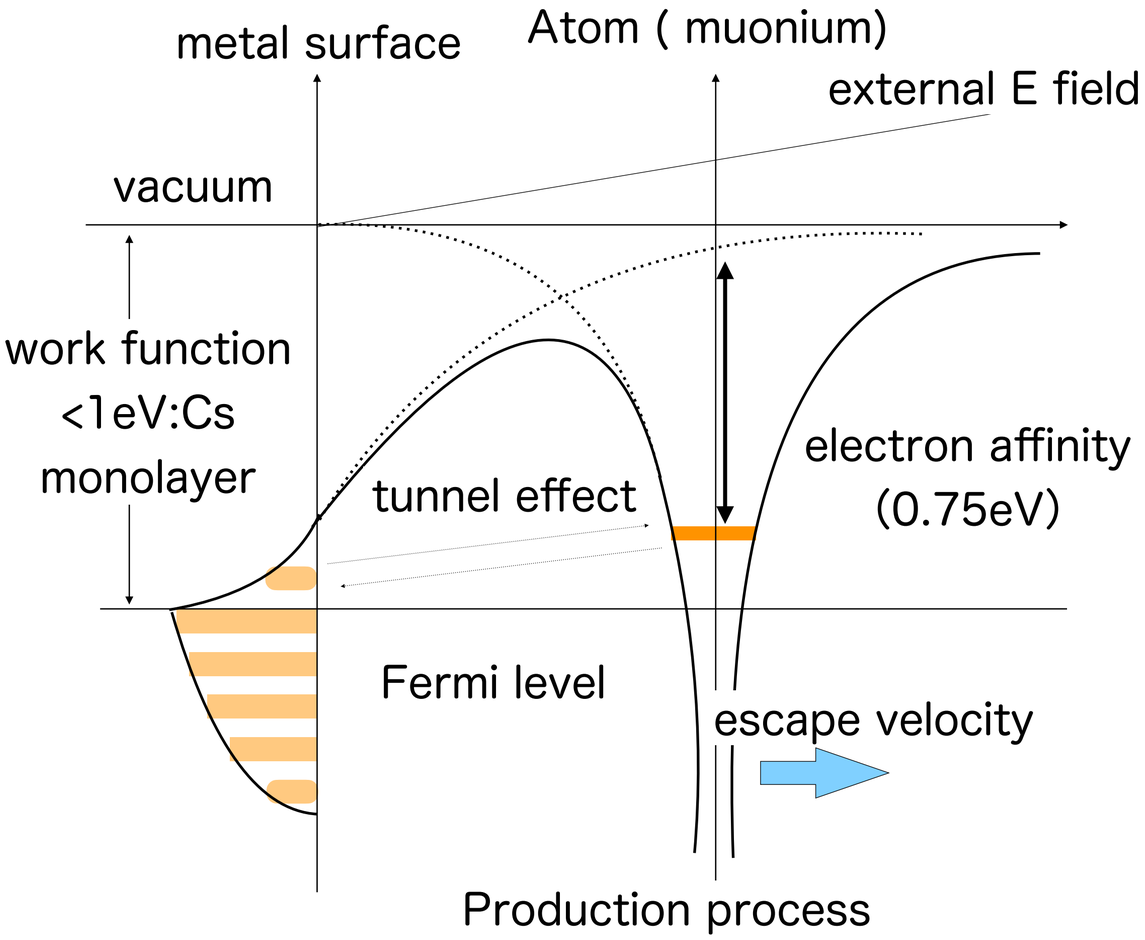
Why Negative Muonium Ions?

- Negative ions enable charge-exchange multi-turn injection
- Widely used in high-intensity proton accelerators
- Can significantly increase luminosity for Muon Collider

Concept of new method

- Hydrogen , Muonium almost the same EM characteristics
- Similar method in H- ion sources (e.g., J-PARC) can be used for Mu-
- Metal surface – Mu interaction enables efficient Mu- ionization
- Based on plasma-assisted, low-work-function surfaces (Cs-coated metals)





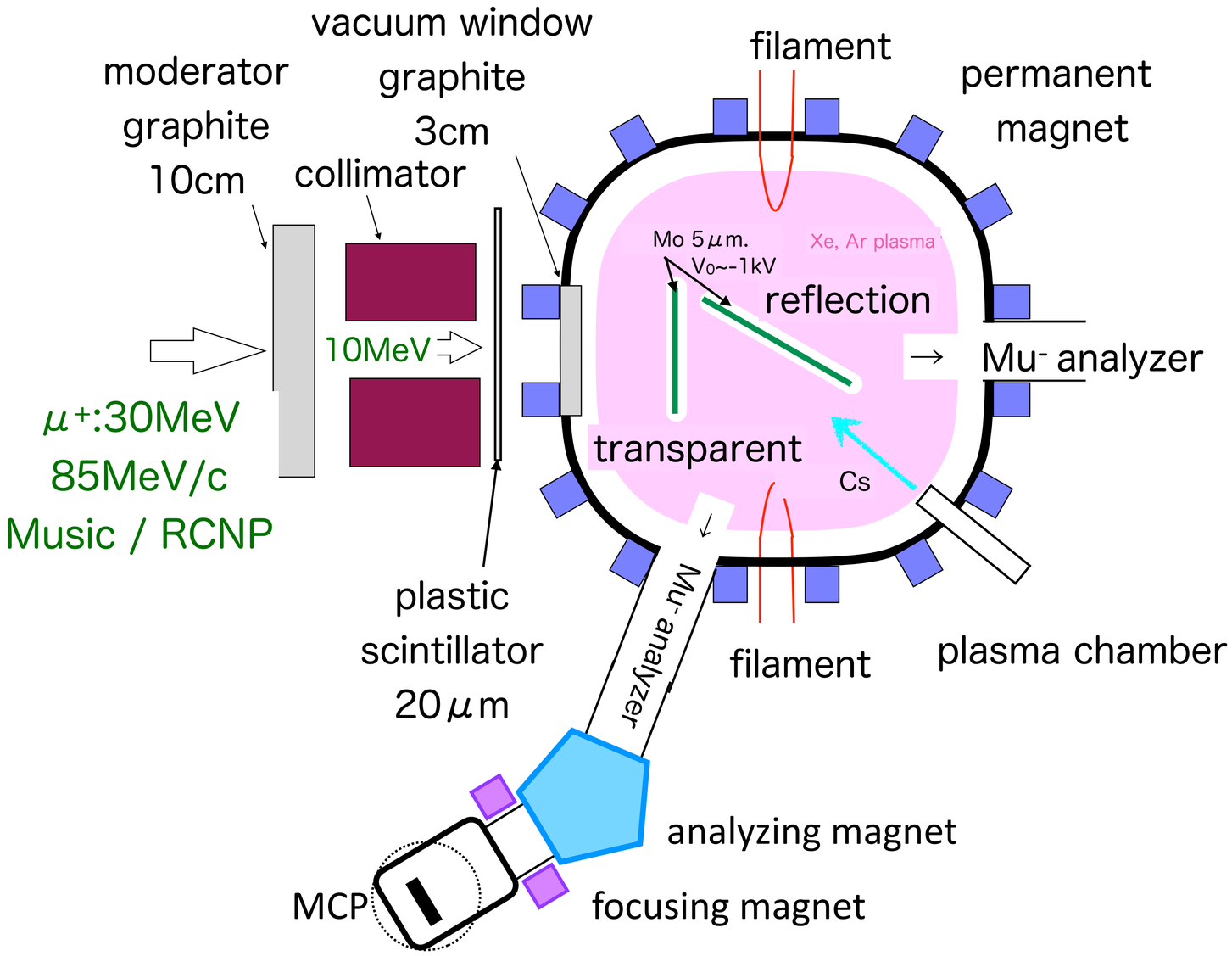
Core Scientific Questions

- 1. Is Mu–metal surface interaction efficient for Mu- production?
- 2. Does Cs coating lower work function and enhance ionization?
- 3. Does ionization efficiency depend on Mu energy?
- 4. Can Mu- beam meet collider requirements?($\varepsilon_{x/y}$ 10～25 μm)

study aiming to

- Evaluate Mu- generation efficiency experimentally and theoretically
- Quantitative assessment of beam emittance and intensity
- Explore alternative materials for efficiency (e.g. electrides, oxide semi-conductors)
- Expected 10^2–10^3 times efficiency increase vs charge-exchange
- Potential ionization probability ~10%

Experimental Setup



- 30 MeV μ+ beam from MUSIC
- energy degrade (<10 MeV/c)
- Pass through plastic scintillator and thin metal foil (Mo, 5 μm)
- Plasma chamber with Cs vapor enhances ionization
- Measure Mu- yield with MCP and TOF detectors

Study Plan (3 Years)

- Year 1: Develop apparatus at Kyoto University
- Year 2: Perform Mu- generation tests at RCNP and/or J-PARC
- Year 3: Analyze results, compare with theory, evaluate feasibility

Summary

- Proposed: plasma-assisted, metal-surface Mu- source
- If successful → transformative technology for future muon accelerators
- expected impact:
  - High-brightness Mu- source → breakthrough for Muon Collider
  - New scenario for high-energy physics experiments
  - Applications in material science and imaging (inspections of reactors, volcanoes, buildings)