Ionization yield measurement using gaseous detector for dark matter searches

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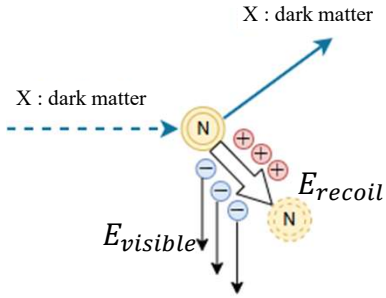
Introduction

What is ionization yield ?



E_{recoil} : *Nuclear recoil enegy*
$E_{visible}$: *Ionization energy loss*
Y : Ionization yield

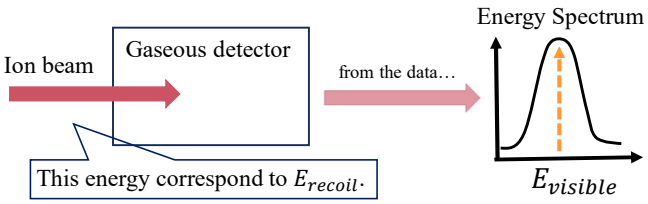
$$E_{visible} = Y \times E_{recoil}$$

- Direct dark matter searches aim to detect nuclear recoil signals induced by dark matter interactions.
- Most of gaseous detectors measure only the ionization loss, which differs from the actual energy loss of nuclear recoil.

➡ We determined the ratio between the two energies through experiment.

The method of measuring Ionization yield

We performed the measurement **in a low-energy ion beam facility at Kanagawa University.**

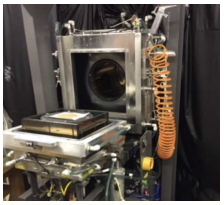


1. We injected known energy ion beams into a gaseous detector
2. We compared the measured energy with an ion beam energy.
3. We investigated the energy dependence by varying the ion beam energy.

Overview

Beam facility

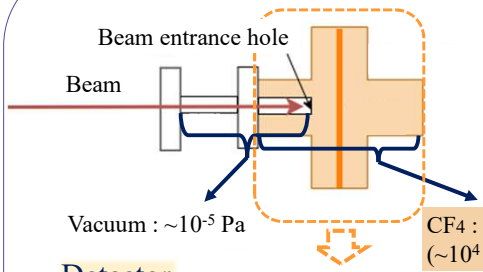
- Low-energy ion beam irradiating equipment
- Acceleration voltage : 5 – 200 kV
- Ion type : H+, He+, B+, C+, N+, O+, F+, … Xe+



Experimental conditions

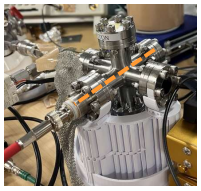
- Measurement period : September 3rd – 5th, 2025
- Ion type : **Fluorine**
- Beam energy : 5 – 50 keV
- Gas : **CF4 (0.06 atm)**
  ⇒ CF4 is used in NEWAGE experiment.

Beam line and detector



Detector

- A single wire chamber
- A chamber form is six cross type.



Beam entrance hole

It has two important roles in this experiment

1. Separating the vacuum from the gas region
2. Injecting ion beam into the detector

We used a 10 μm-thick stainless steel film with a small injection hole which the diameter is about **1 μm**.

The prior study

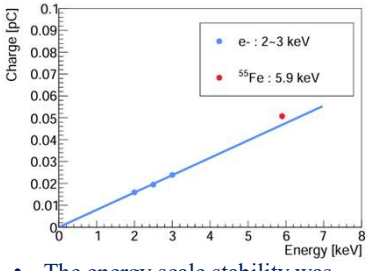
Experiment using the COMIMAC facility

EAS Publ. Ser. 53 (2012) 119

Results

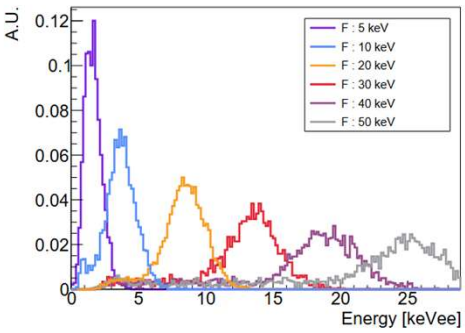
Energy calibration

An electron-gun (2 – 3 keV) was used as the primary source for the energy calibration.



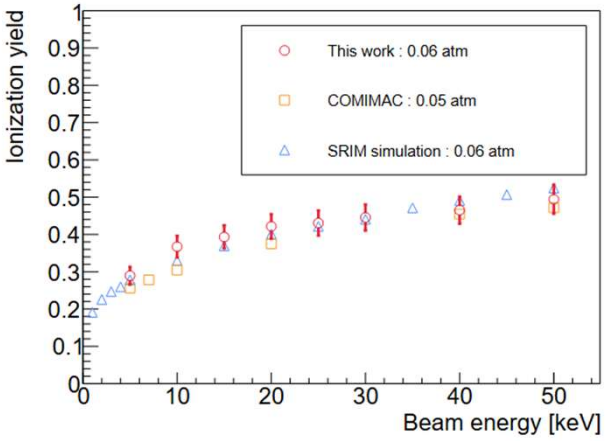
- The energy scale stability was monitored with an ^{55}Fe X-ray (5.9 keV) source before and after each ion-beam run.
- The residual between of ^{55}Fe and electron-gun measurement is **7.7 %**, and assigned as a systematic uncertainty in the ionization yield measurement

Energy spectrum



- The beam-origin peaks were clearly observed in all measurements.
- The correlation between the beam energies and measured one is observed.
- We can also confirm that energy is being lost through mechanisms other than ionization.

Fluorine ion ionization yield



- **The measured ionization yield was consistent with the prior study and SRIM simulation.**

Conclusion

- Search for nuclear recoil events induced by dark matter (direct detection) ⇒ Precise measurement of the ionization yield is essential.
- Conducted a low-energy ion beam experiment at Kanagawa University.
- The ionization yield of fluorine ions in CF4 at 0.06 atm was measured.
- Established a method in Japan for measuring ionization yield for gaseous detector using a low-energy ion beam facility.
- The paper submitted !! [arXiv:2602.17126]