Study of energy loss and track formation with Mica

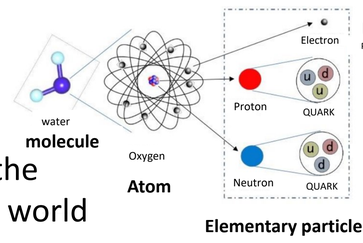
Yuki Ido, Tatsuhiro Naka
Toho University, Particle Physics Laboratory

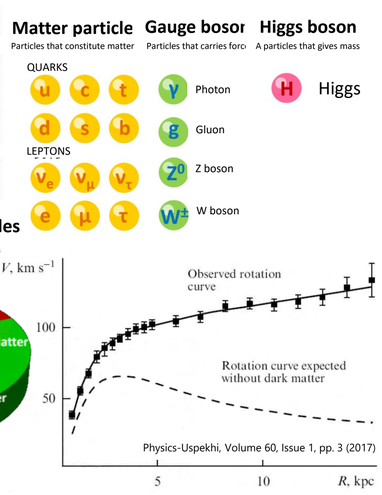
Workshop,
Cutting Edge Technology for Understanding the Earth
January 12, 2023

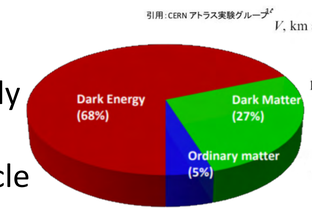
1.Introduction

1.1 The Dark Matter

Particle physics has now completed the Standard Model which describes the world of particles smaller than atoms. However, from astronomical observation, it is now known that the particles that we know only consists about 5% of the universe.
This is one of the gratest mystries of particle physics.







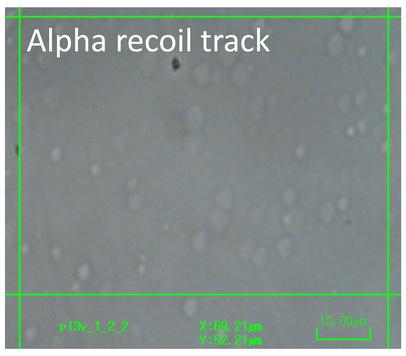
引用：CERN アトラス実験グループ

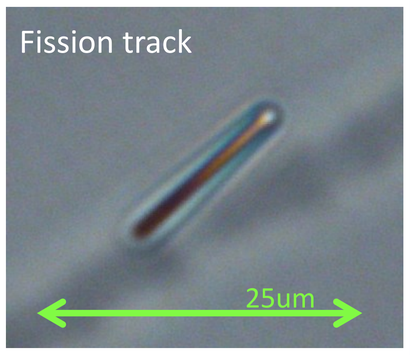
1.2 Stellar Archaeology

Stellar Archaeology is a section of astronomy which discusses how the galaxies form and evolve. Compared to convetional methods, this study has a potential to give completely different information to Stellar Archaeology.

1.3 Paleo-Detector

Paleo-Detector is a detector with proven results in Geoscience.





Can we apply this technique to Particle Physics?

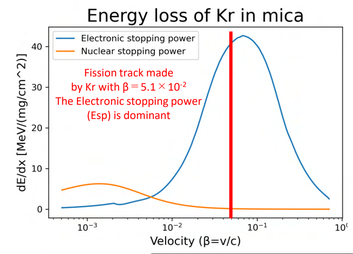
	Paleo-Detector	XENON1T Detector
Target mass	10mg-100g	1-10 ton
Integration time	1 Gyr	10yr
Exposure	0.01-100kg × Myr	0.001-0.01kg × Myr

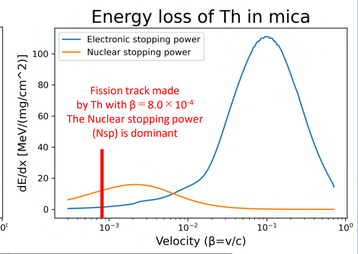
2.Research Agenda

2.1 The difference in the dominant energy loss mechanism might effect the track formation

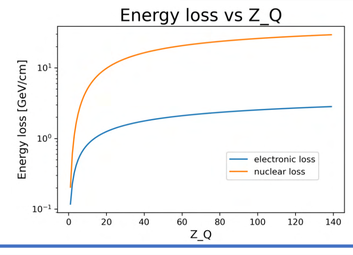
The difference in how the alpha recoil and fission tracks are seen might be attributed to the difference in the dominant stopping power.

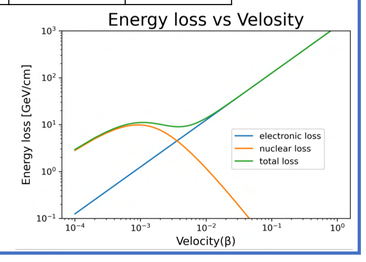
Nuclear stopping power is dominant for the Q-ball. Therefore, it is necessary to verify the threshold of track formation for Electronic stopping power(Esp) and Nuclear stopping power(Nsp).



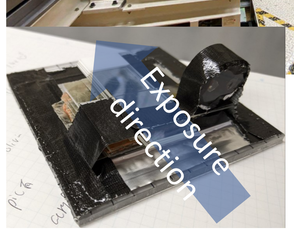


	Th	Kr
Energy	70keV	100MeV
Velocity （β= v/c）	8.0 E-4	5.1 E-2
Electronic stopping power [MeV/(mg/cm^2)]	1.41E+00	4.097E+01
Nuclear stopping power [MeV/(mg/cm^2)]	1.21E+01	1.268E-01

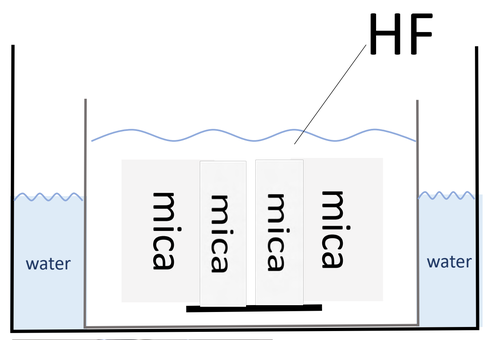




3.Method



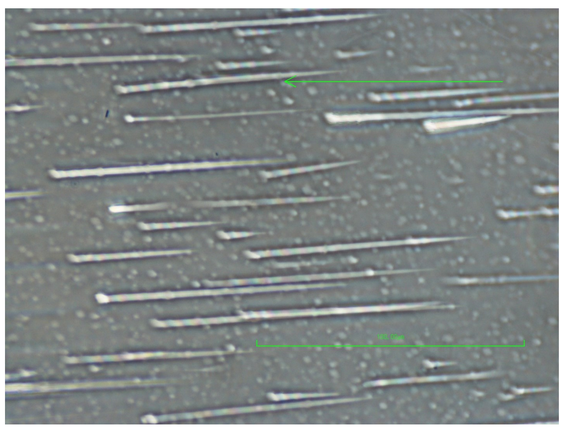
Exposure data
Nuclide：Fe
Energy：500MeV/n

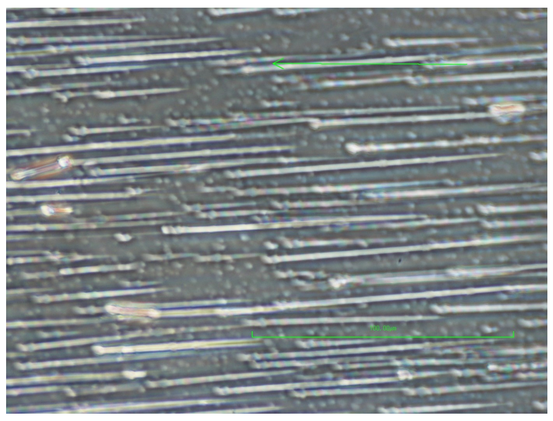


Etching data
Etching liquid：HF　46％
Tempereture：25℃

4.Results

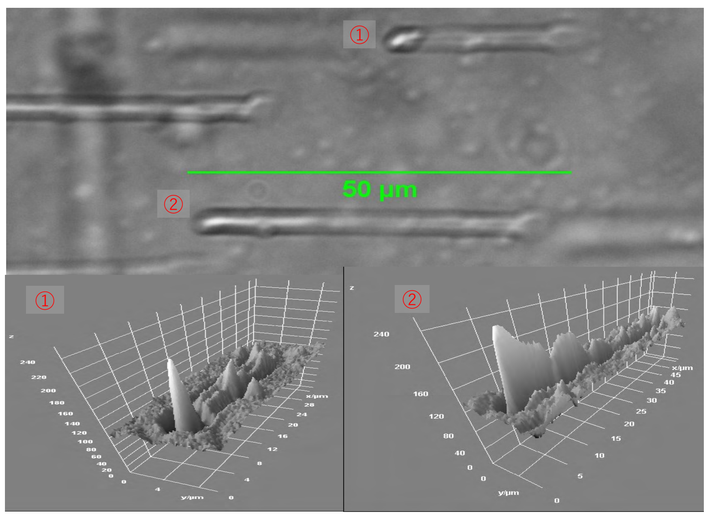
Images of tracks using a microscope.

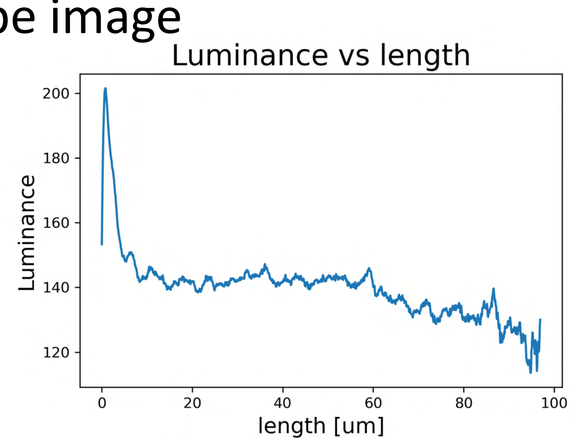




Sample of EC80min using a Phase contrast microscope with a 60-power object lens.

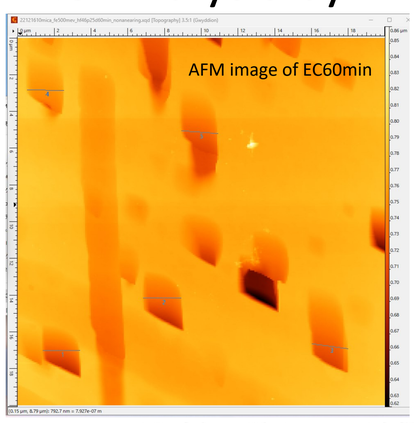
4.2 Analysis of optical microscope image

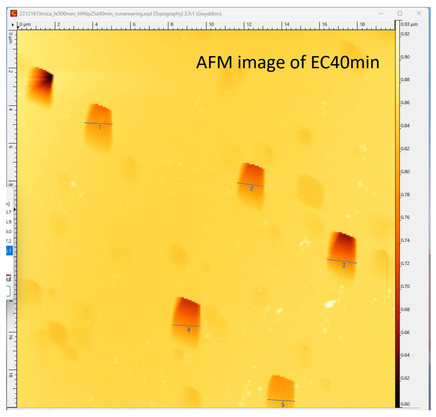


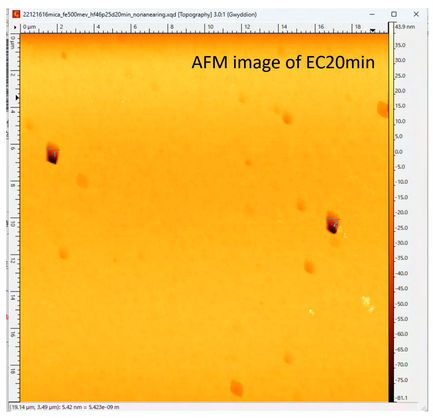


The luminance of the end was confirmed.
The dE/dx should be bigger for Alpha recoil tracks.
Is the phase difference in effect?

4.3 Analysis by AFM







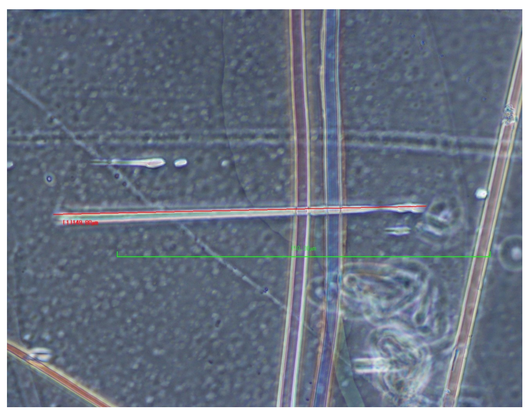
4.1 Determining the energy threshold

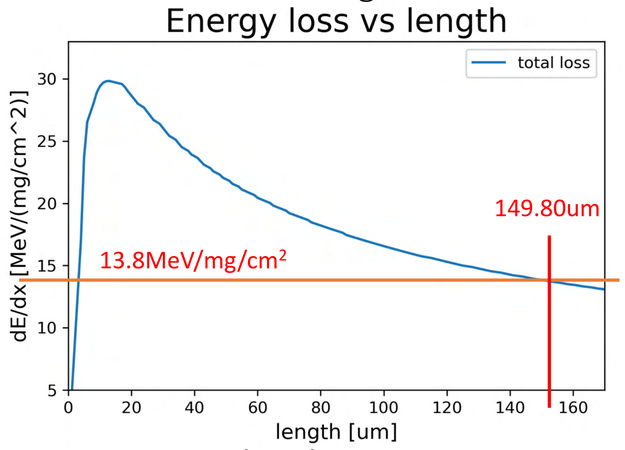
The length of tracks before etching is

$$l_{\text{origin}} = l_{\text{Experimental value}} \times 2 v_{EC} t_{EC}$$

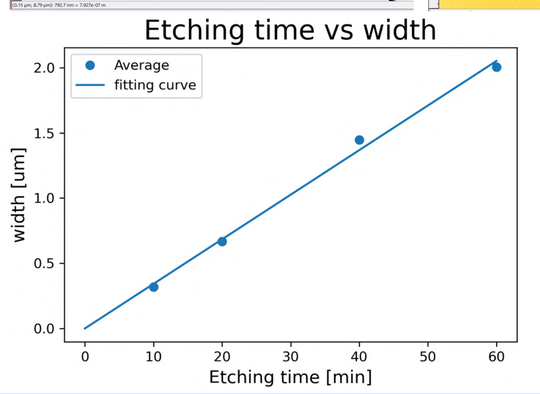
l_{origin} : original length　$l_{\text{Experimental value}}$: length observed by microscope
v_{EC} : etching speed　t_{EC} : etching time

Determine the energy threshold by comparing the l_{origin} to simulation





Reference：Uranium α recoil tracks are 13.5 [MeV/mg/cm^2]



As the etching time gets longer the width of each track is wider.
Measurements show that the etching speed was 1.0 um/h and the exposure angle was an average of 2.6 degrees.

What are ideal minerals?

- Few back ground Uranium
- Easy to work with (like mica)
- Extract from deeper mantle
- As old as possible (Couple hundred million years)

5.Prospects

- Further verification of the difference in track formation for Nsp and Esp, determine the threshold
  - lower energy ・exposing the sample vertically ・heavier particles
- Large scale scan using a scanning system→Updating Q-ball search region
- Application for searching other unknown particles using different minerals
- Expanding new research methods for Stellar Archaeology and Historical Geology