Nuclear Emulsion Films with HIMAC heavy ion beams

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Abstract

By adding suitable amount of Rh compound ($Na_3RhCl_6 \cdot 5H_2O$) during the production of nuclear emulsion gel, it enabled to reduce the sensitivity of the nuclear emulsion films and realized the selection of heavy nuclei by using image processing system suitable for minimum ionized particles. We have carried out the beam exposure of desensitized nuclear emulsion films in October, 2019 at Heavy Ion Medical Accelerator in Chiba(HIMAC). When charged particles passed through the nuclear emulsion films, the track were measured as a series of silver grains of which size is typically less than one micrometer, and we traditionally determine their charge amount by measuring ionization loss signals such as grain density, delta-ray count. In this study, we measured the energy losses of heavy ion beams in desensitized emulsion films exposed horizontally to emulsion layer, and we have estimated the desensitization effect for heavy ion deltections.

GRAINE2018

Gamma-**Ra**y **A**stro-**I**mager with **N**uclear **E**mulsion

- Space observation experiment using a nuclear emulsion mounted on a balloon
- High-resolution observations of Vela Pulsar, the brightest gamma-ray object in the sky
- **Observation of cosmic ray heavy nuclear composition using a desensitized nuclear emulsion**

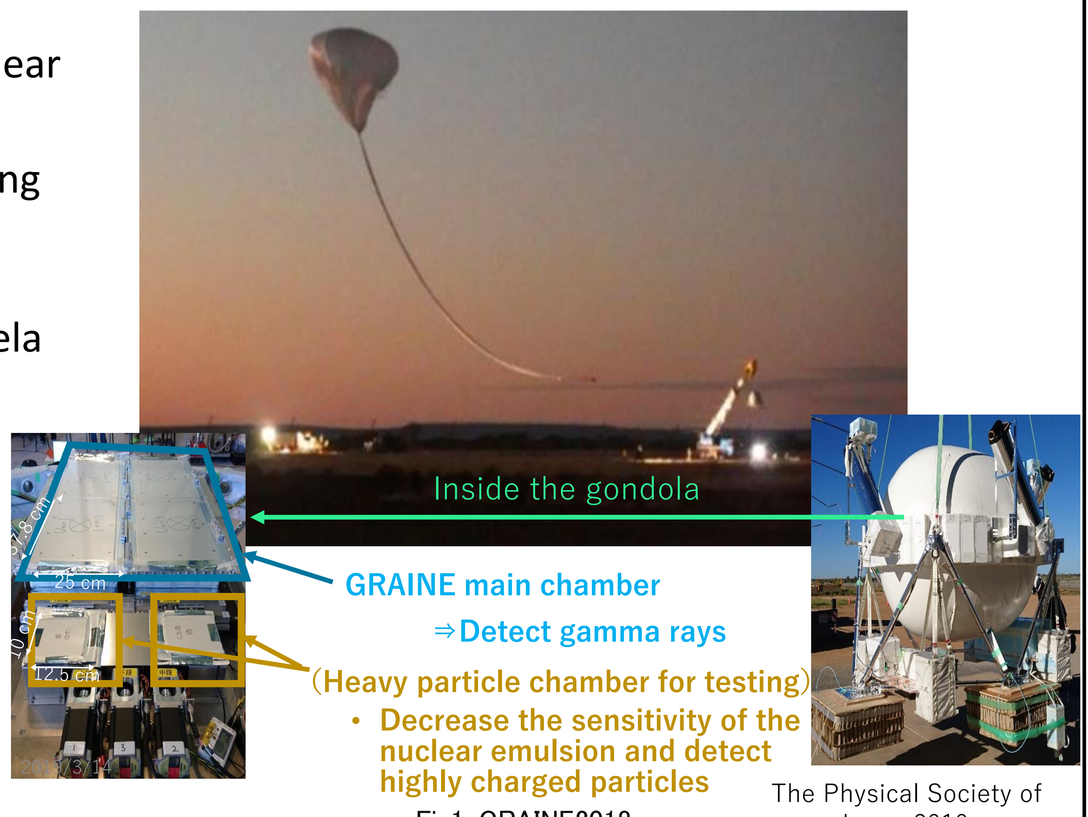


Fig1. GRAINE2018

HAIMAC

・Date: October, 20,23, 2019

・Horizontal beam irradiation on the nuclear emulsion
- ・Carbon beam 400 MeV per nucleon
- ・Iron beam 500 MeV per nucleon

・Types of nuclear emulsion (5 cm x 5 cm)
- ・Medium Low Silver
- **・ Rh5.0 (5.0 μmol / Ag mol)**
- ・ Rh10.0 (10.0 μmol / Ag mol)
- ・Low Silver Rh5.0
- ・Low Silver Rh10.0
- ・CR-39

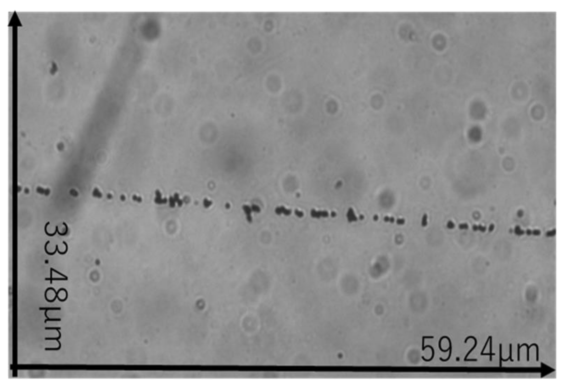


Fig2. Tracks generated by irradiating a low-sensitivity nuclear emulsion with a carbon beam

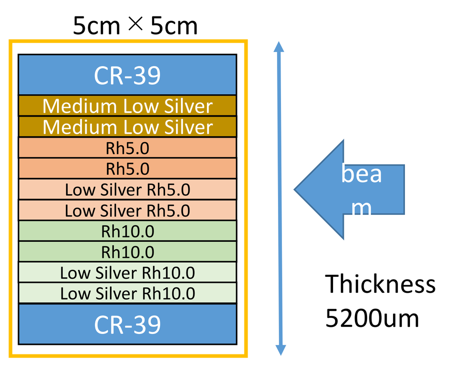
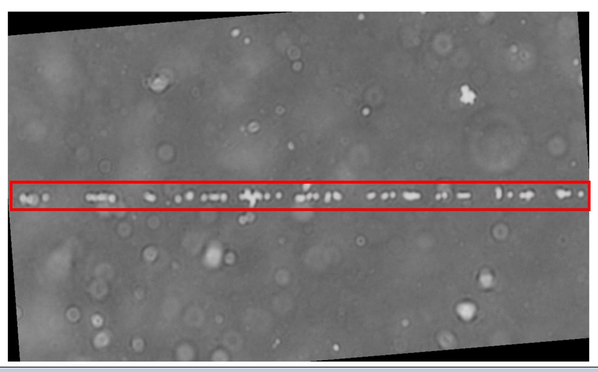


Fig3. Detector consists of emulsion and CR-39.

Grain Count using the ImageJ

1. Rh5.0 nuclear emulsion, horizontally irradiated Carbon beam and Iron beam
2. Image acquisition, black and white inversion, angle change, area selection (1 μm width)
3. Profile processing using ImageJ (calculates the average brightness value in the width direction)
4. Threshold processing (**green line: brightness value 135**)
5. Find the area of the reference grain and the area of each track grain.(Conventional: Count the number of particles ⇒ "Number of silver particles / 100 μm")The "area" is calculated and analyzed by converting it to the number of grain density. **"Development of analysis method considering fluctuation of particle size."**
6. Determination of particle size distribution and particle number density.



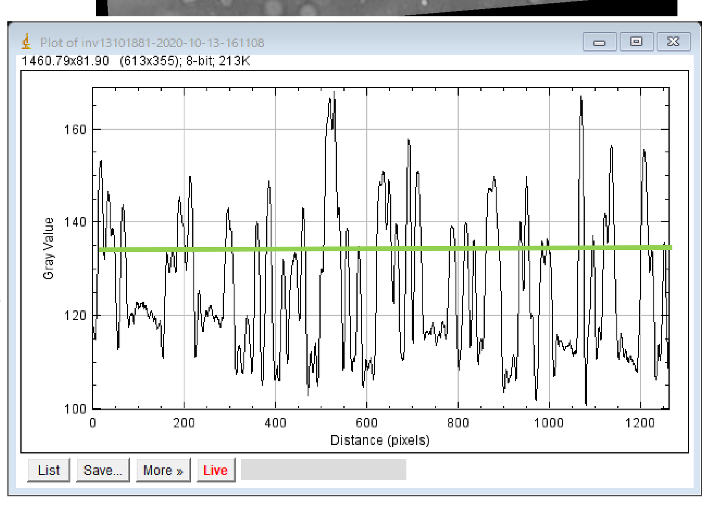


Fig4. Area selection of the acquired image

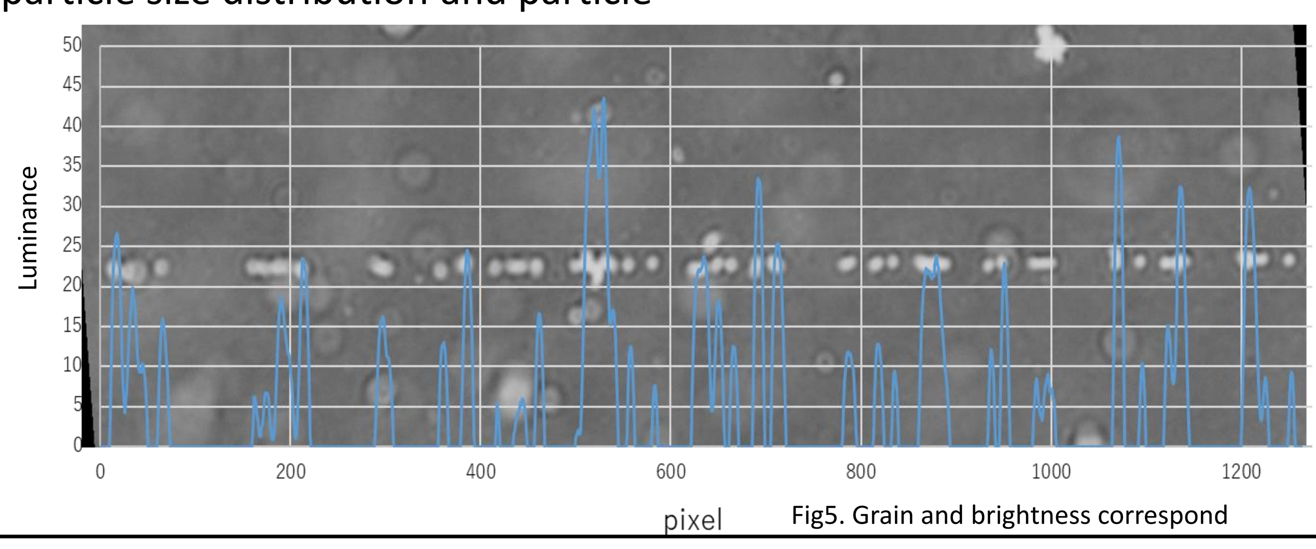


Fig5. Grain and brightness correspond

Fe tracks in Rh10.0 nuclear emulsion

When the charge is large (heavy ions), the grains (silver particles) that form tracks are continuous.

- Normal sensitivity nuclear emulsion (upper right)
- δ rays emitted along the track.

- Low sensitivity with Rh10.0 (lower right)
  - By suppressing the generation of δ rays, track detection by an image processing device (Nagoya University: HTS *) becomes possible.

*HTS: HyperTrackSelector = Automatic track reader (Nuclei with δ rays are treated as noise during image processing because the sensitivity is adjusted to the minimum ionization loss particles)

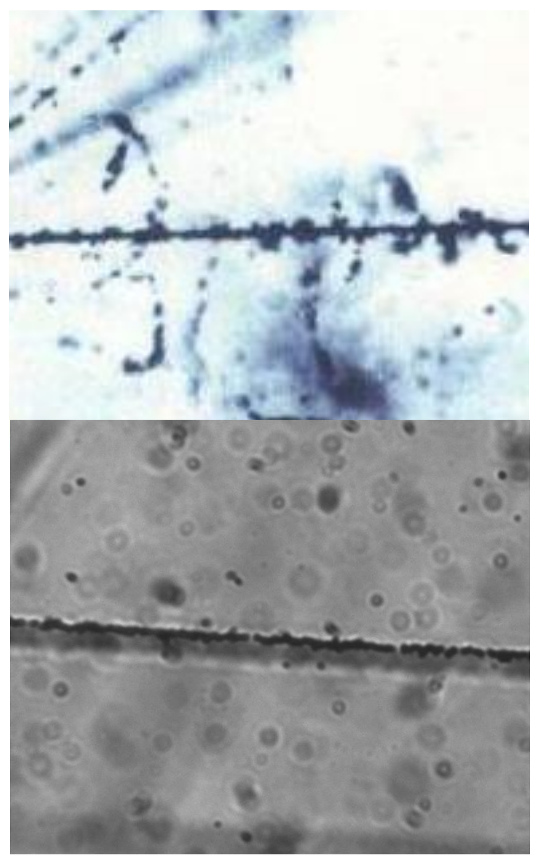


Fig4. Rh10.0・Fe - top

Grain area distribution (after standardization)

- Particle size in C, Fe beam, Rh5.0 nuclear emulsion
- Measured at three locations top, middle, and bottom of the nuclear emulsion
- Energy decreases upstream and about 5 cm downstream (ΔE)
- Result: There are quite a few large grains on both C and Fe
  ⇒ Think it is better to use the area method

Table1. Carbon and Iron energy loss

	Carbon 400MeV/u	Iron 500MeV/u
β	0.71	0.76
γ	1.42	1.53
γβ	1.02	1.16
ΔE	55.4MeV	37MeV

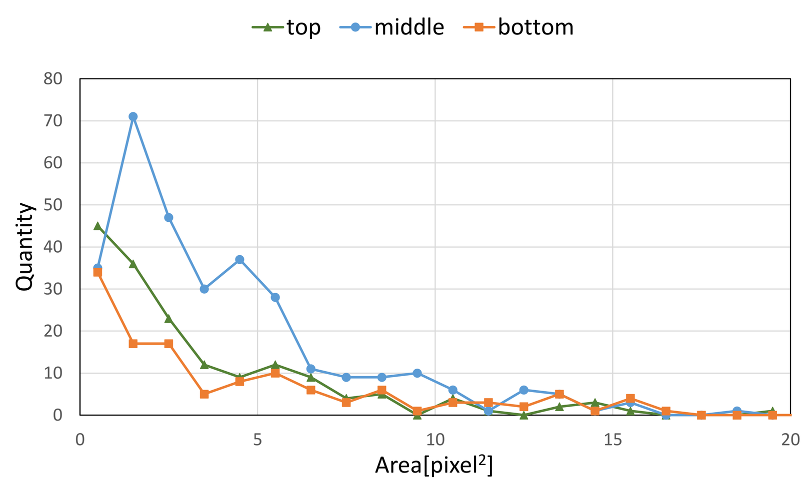


Fig6. Area distribution of C beam

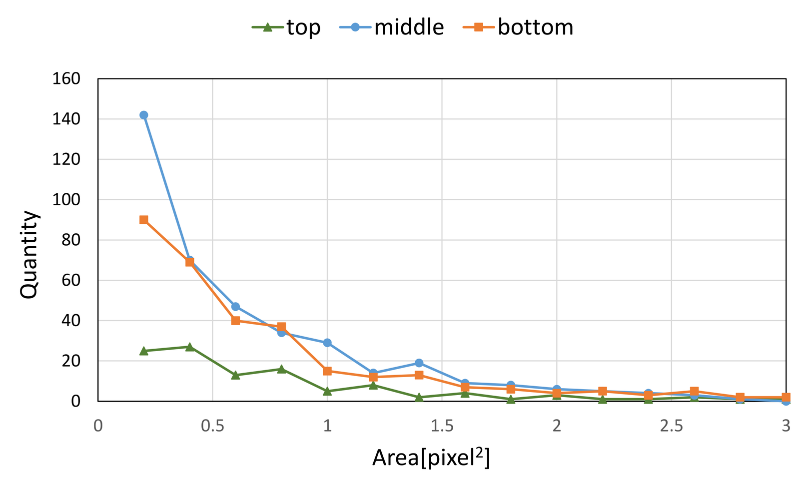


Fig7. Visual grain count Area distribution of Fe beam

Grain Count using the program

- Create a program so that the operation is similar to the counting method in ImageJ
- Measured the energy losses of heavy ion beams (From Bethe Bloch's formula)
  - 400MeV/u C , 55.4MeV/u
  - 500Mev/u Fe , 37.0MeV/u
- Observation position dependence of grain density obtained by conventional method (visual count) and area method
  1. **Even with the area method, we were able to obtain results similar to those of the conventional method.**
  2. The energy change due to the ionization loss was obtained.
  3. It is possible to determine the grain density for heavy nuclear tracks such as C and Fe in the nuclear emulsion plate to which Rh5.0 is added (reduced sensitivity).
  4. Even with the method aimed at automatic analysis, it has become possible to capture changes in energy using the conventional visual method and grain counting method using ImageJ.

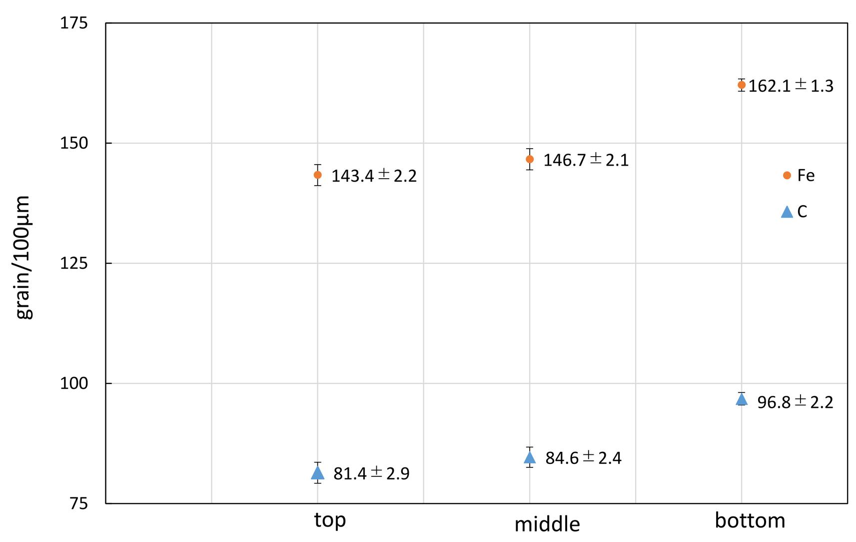


Fig8. Visual grain density

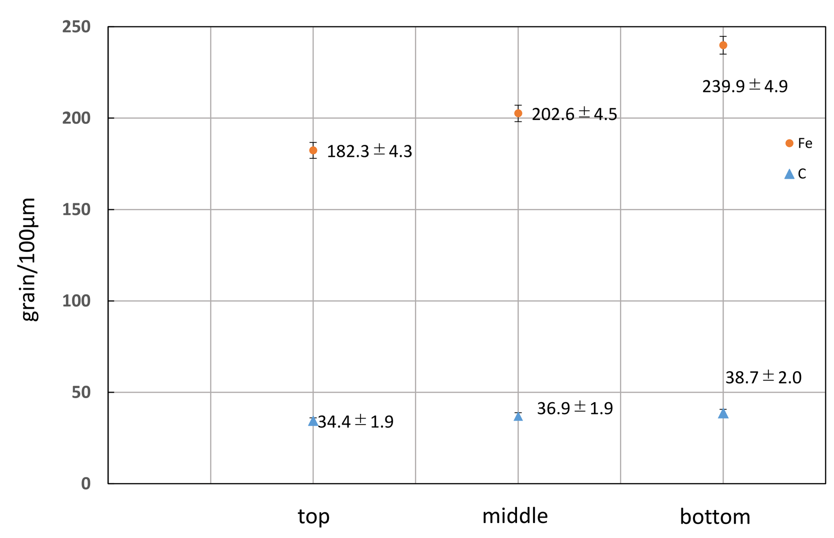


Fig9. ImageJ grain density

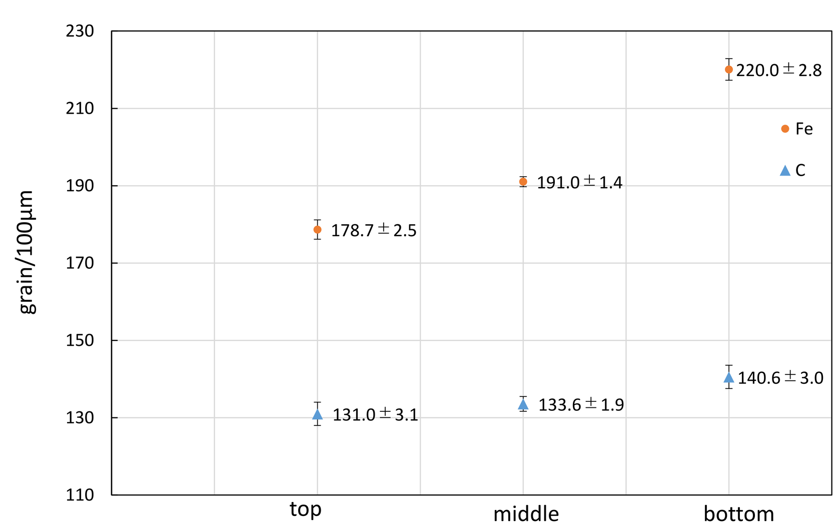


Fig10. Program grain density

Summary

- The amount of ionization was observed from the grain densities of the C and Fe beams that were horizontally irradiated on the desensitized nuclear emulsion. It was confirmed that the influence of δ rays could be suppressed by lowering the sensitivity.
- For both C and Fe beams, the amount of ionization was calculated by the conventional grain counting method and the area method developed this time, and it was confirmed that the beam energy decreased due to the ionization loss.
- By the area method, observation results equal to or better than the conventional ones were obtained.

Reference

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