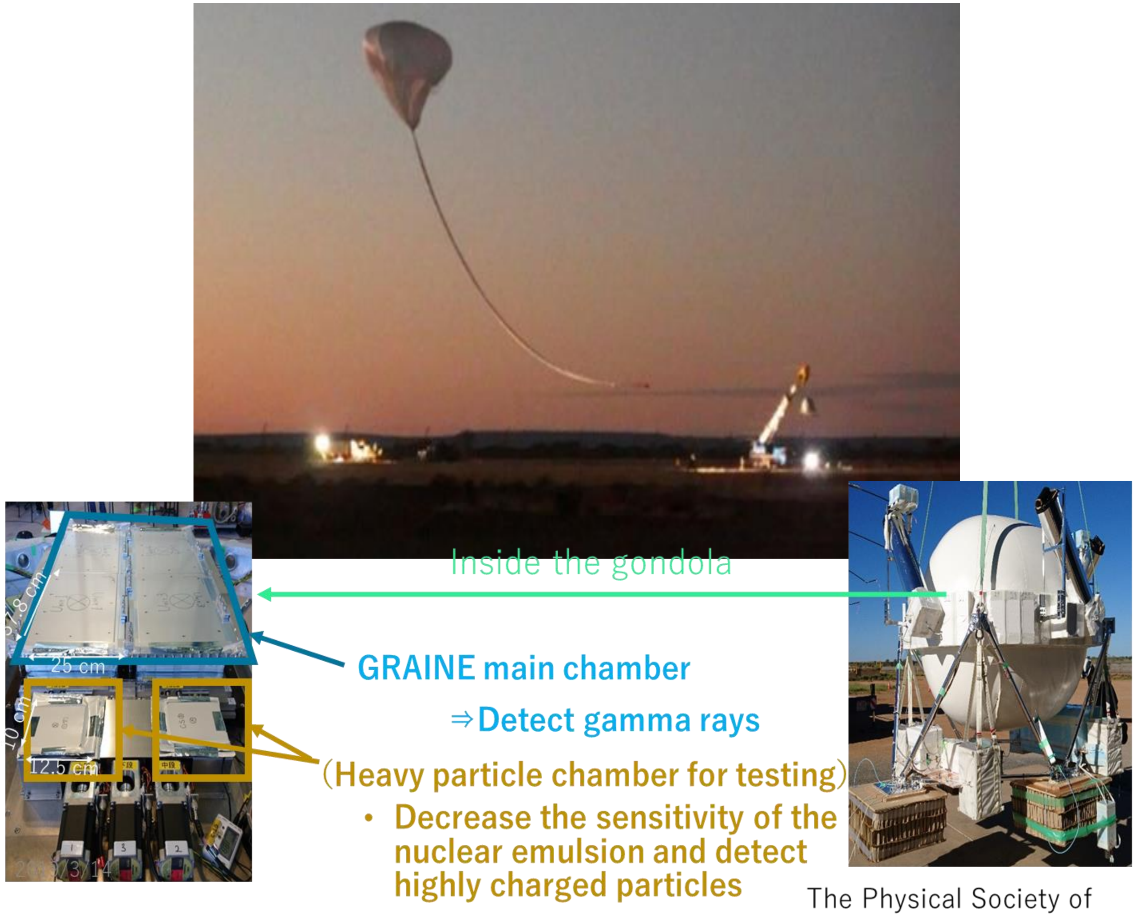
Nuclear Emulsion Films with HIMAC heavy ion beams

ICRC2021　Moegi Okuyama

- GRAINE2018

Gamma-**R**ay **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
- **Implementation of low-sensitivity nuclear emulsion ⇒Nuclide selection based on the difference in sensitivity has been realized.**



The Physical Society of Japan,2019
S.Yamamoto

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

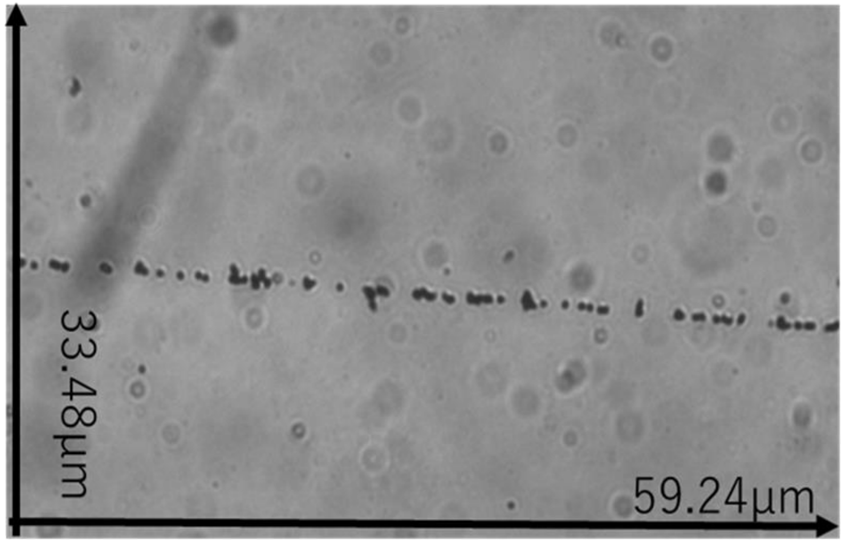


Fig2. Tracks generated by irradiating a low-sensitivity nuclear emulsion with a carbon beam

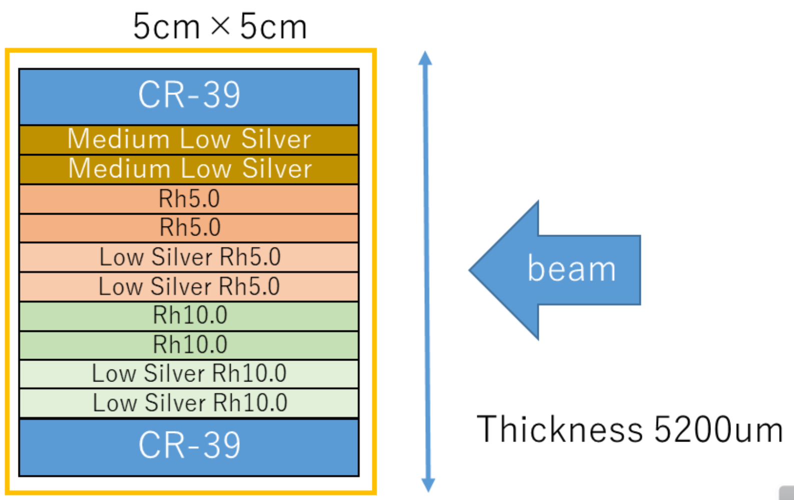


Fig.3 Detector consists of emulsion and CR-39.

- When the charge is large, the grains that form the track are continuous.
    - Normal sensitivity nuclear emulsion (upper right)
    - A δ line is emitted along the track.

    - Low sensitivity with Rh10.0 (lower right)
    - **Track detection becomes possible by suppressing the generation of δ rays.**

      ⇒ Purpose ：**Ionization measurement in a low-sensitivity nuclear emulsion is possible.**

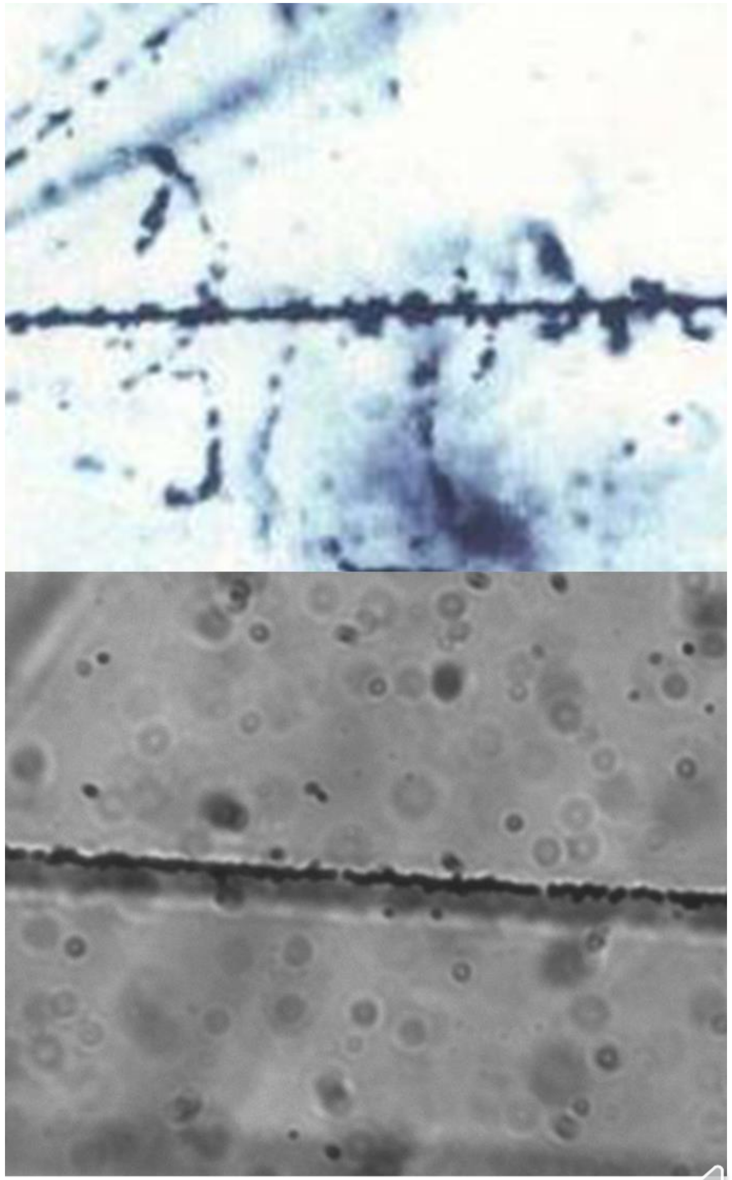


Fig4.Rh10.0・Fe-top

Rh5.0 nuclear emulsion, horizontally irradiated Carbon beam and Iron beam

1. Image acquisition, black and white inversion, angle change, area selection (1 μm width)
2. Profile processing using ImageJ (calculates the average brightness value in the width direction)
3. Threshold processing (green line: brightness value 135)

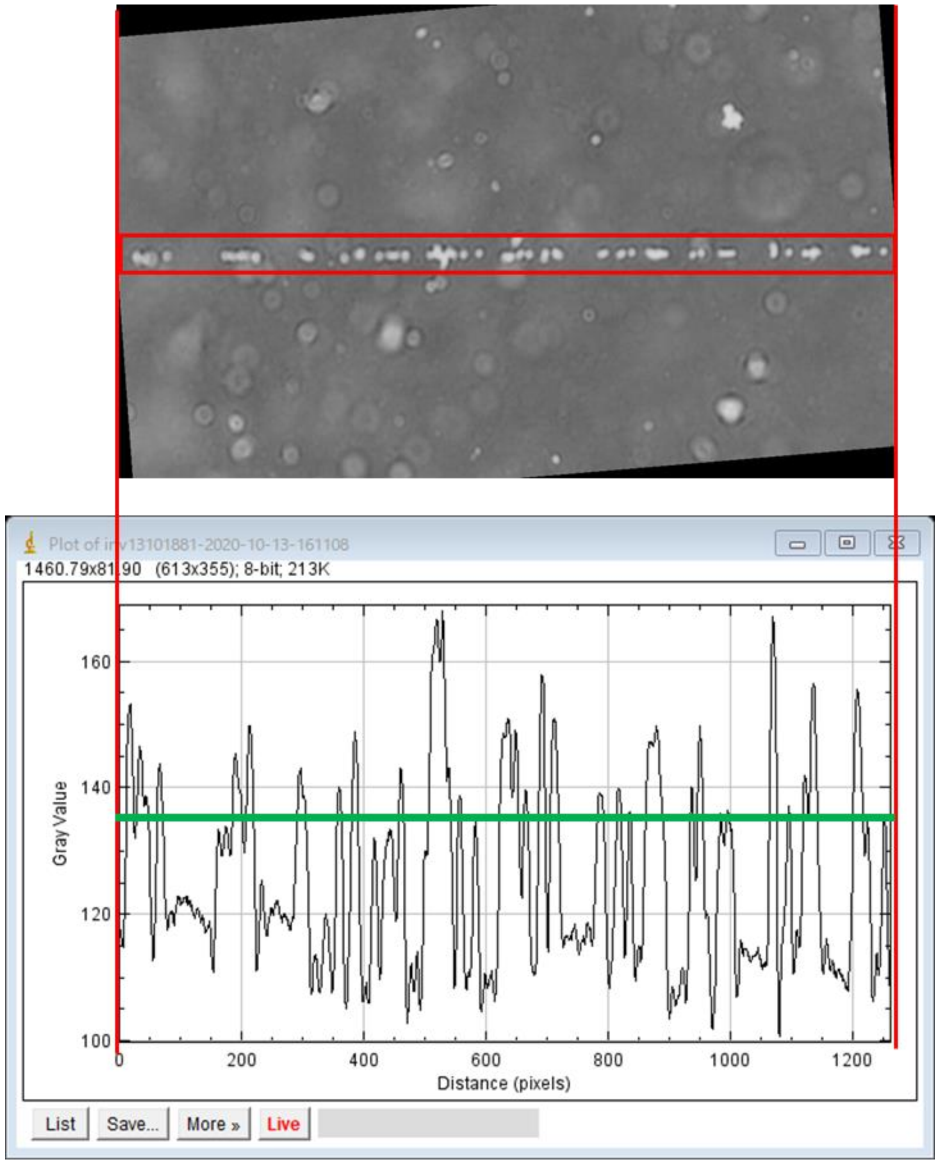


Fig5.Area selection of the acquired image

4. 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.“
5. Determination of particle size distribution and particle number density.

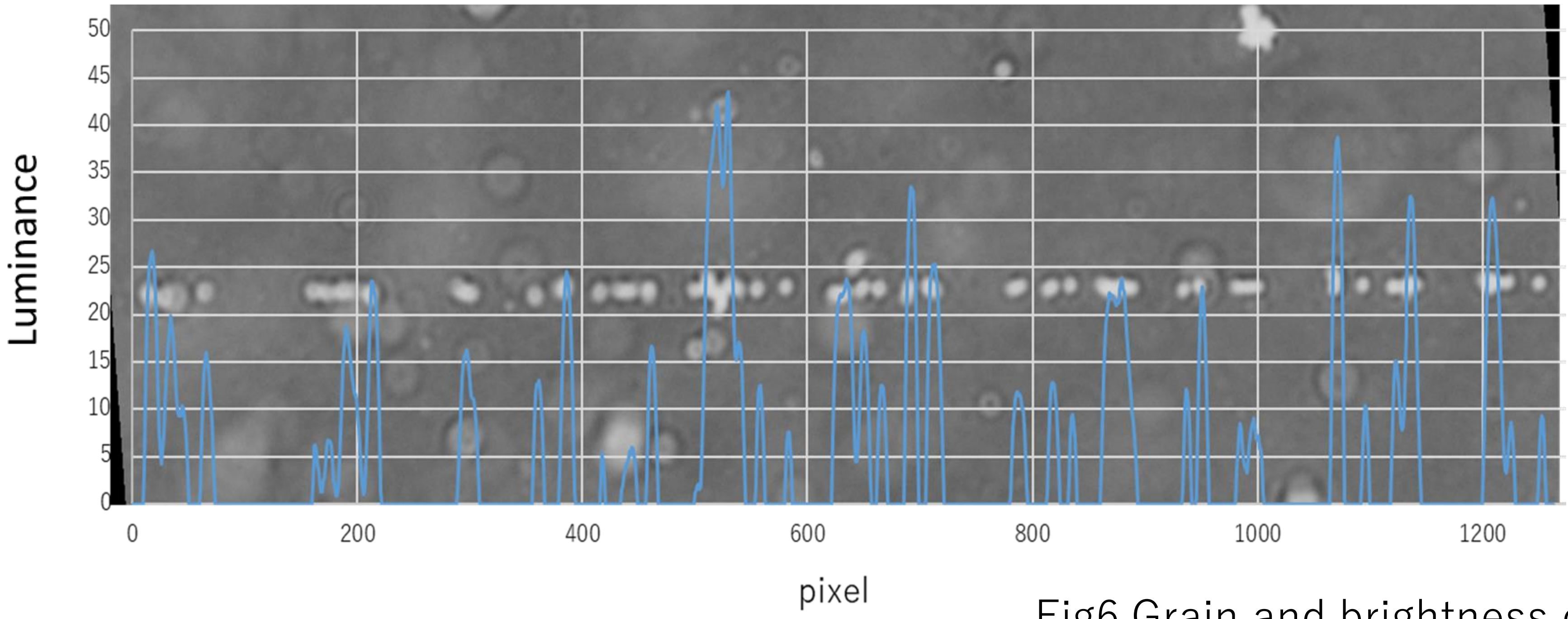


Fig6.Grain and brightness correspond

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 top and about 5 cm bottom (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
$\gamma\beta$	1.02	1.16
ΔE	55.4MeV	37MeV

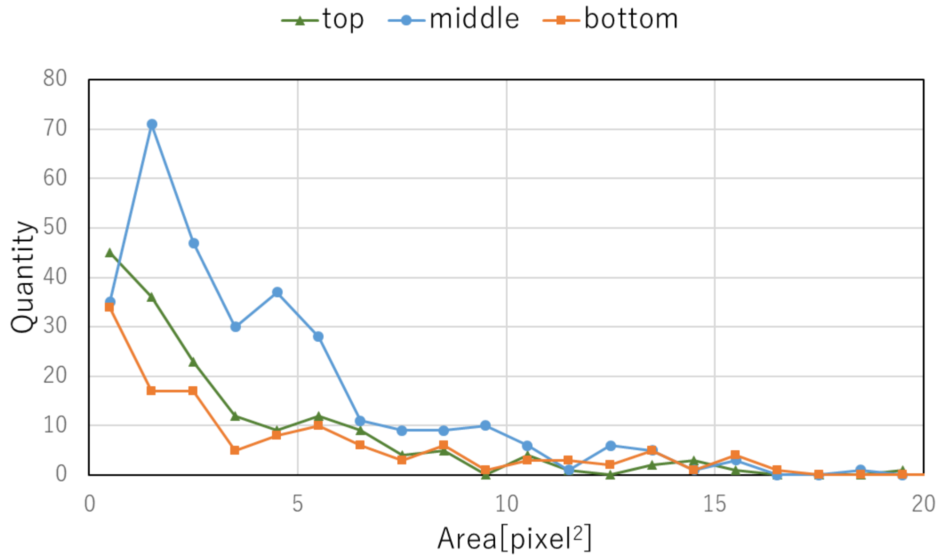


Fig7. Area distribution of C beam

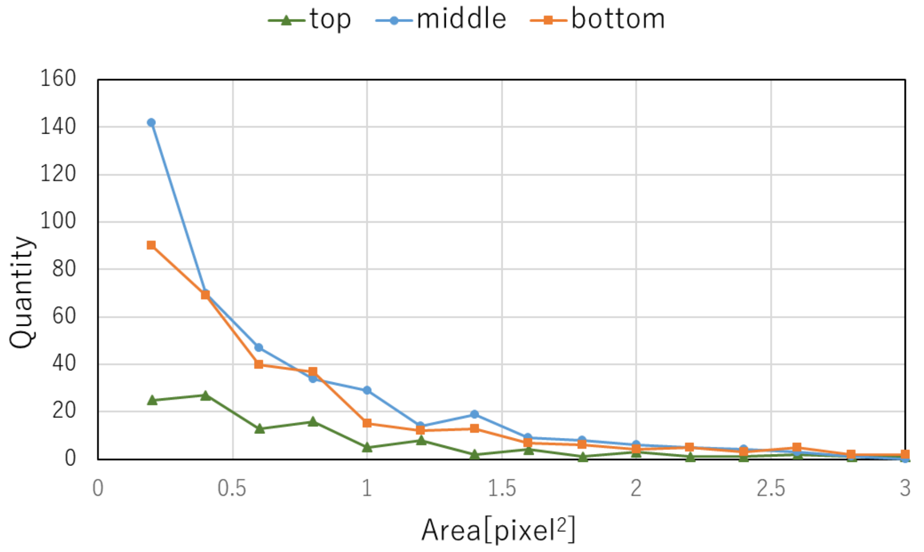


Fig8. Area distribution of Fe beam

- 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 silver particle 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.**

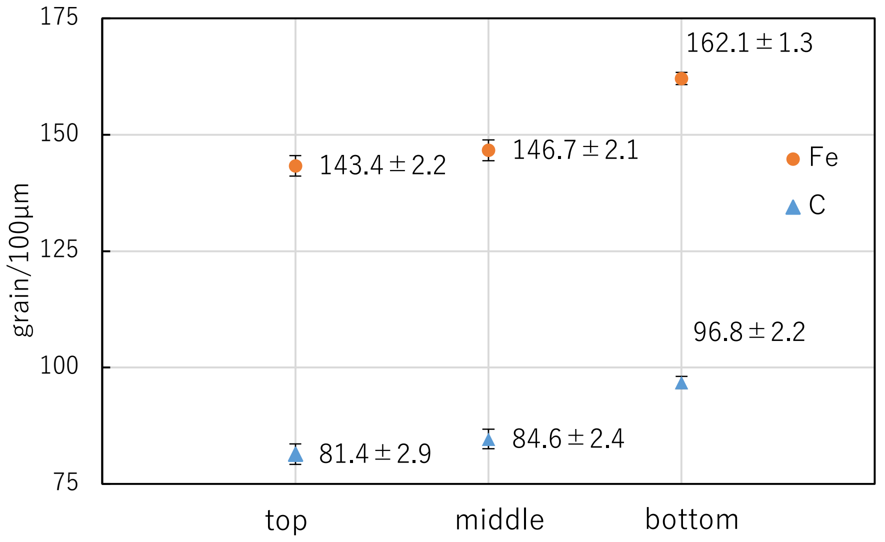


Fig9. Visual grain density

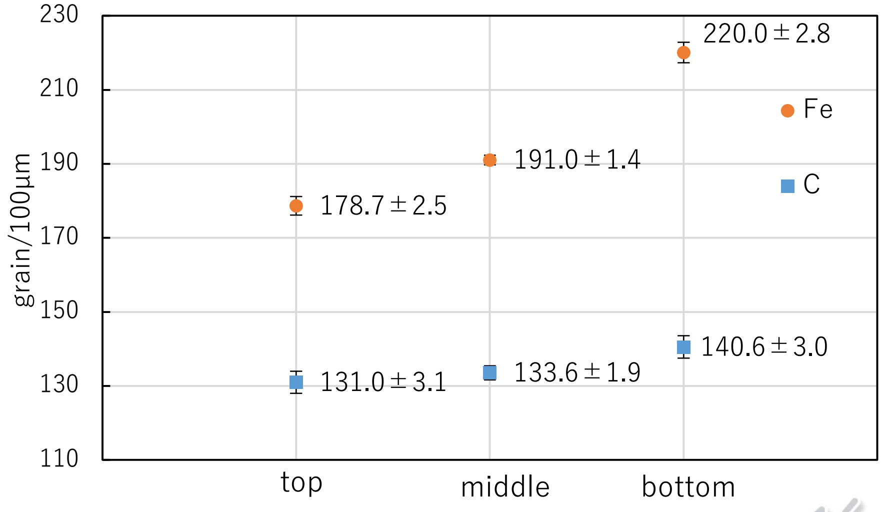


Fig10. Program grain density

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