
# Application of Desensitized Nuclear Emulsion films for Chemical Composition Study of Cosmic-ray Nuclei in GRAINE 2018

**Atsushi Iyono,**[a,*] **Saya Yamamoto,**[a,b] **Shigeki Aoki,**[c] **Hiroki Rokujo,**[b] **Satoru Takahashi**[c] **and for the GRAINE collaboration**

*a Okayama University of Science,*

*1-1 Ridai-cho, Okayama,Okayama 700-0005,Japan*

*b Nagoya University, Department of Physics,*

*Furo-cho, Chikusa-ku, Nagoya, 464-8602, Japan*

*c Kobe University,Faculty of Human Development,*

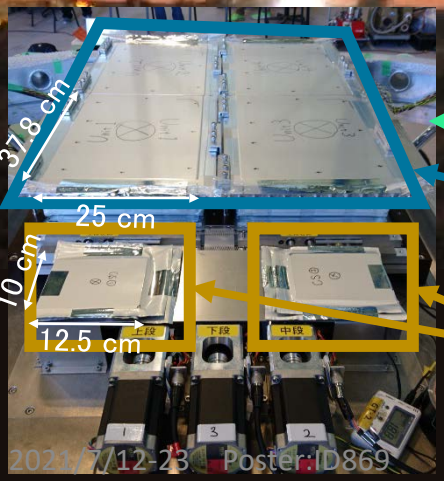
*3-11, Tsurukabuto, Nada-ku, Kobe-shi, Hyogo 657-8501, Japan*

# Abstract

We have developed the desensitized nuclear emulsion films suitable for the detection of heavy cosmic ray nuclei by using the high speed image processing systems (HTS) which was utilized at Nagoya University. And we have carried out our balloon flight of nuclear emulsion telescope for high resolution gamma-ray imaging of Vela Pulsar in April, 2018. We have deployed the emulsion chamber which consisted of several sensitivity type of desensitized nuclear emulsion films in this balloon flight. We are going to report the results of this pilot studies of the application of desensitized films for the detection of cosmic ray nuclei, and the potential of sensitivity control of nuclear emulsion films suitable for image analysis.

# GRAINE2018:
## Gamma-Ray Astro-Imager with Nuclear Emulsion

- Purposes:
  - Overall performance test of nuclear emulsion telescope
  - To detect a gamma-ray source, Vela Pulsar
- Flight: April 2018, Alice Springs, Australia
  17h21m（level flight(36 km-37 km)：14h44m）
- Aperture：3780 $cm^2$




Gondola

**GRAINE Main chamber**

**Gamma ray detection**

**CRN chamber utilizing desensitized nuclear emulsion films**

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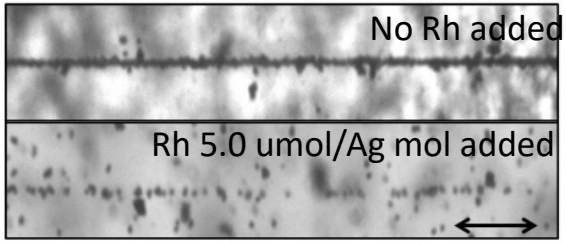
# Desensitized nuclear emulsion films:

- Installing two test chamber in GRAINE2018 gondola to examine the performance of desensitized nuclear emulsion films for identifying cosmic ray nuclei
- Examining the production models of cosmic ray nuclei
- Detecting charged tracks of cosmic ray nuclei by using HTS （Hyper-Track Selector）with desensitized films.
- Calibrating PHV（Pulse Height Volume）obtained from HTS image analysis by using CR-39 solid state track detector.

# Emulsion films for CRN chamber

## ■ Nuclear emulsion films

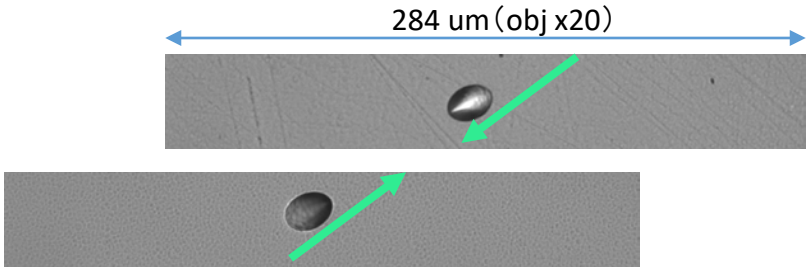
- High-volume-occupancy gels : silver bromide crystals taking up approximately 55% of the gel's volume. Middle-volume-occupancy gels: approximately 45%.
- To desensitize the nuclear emulsion film, sodium hexachlororhodate (III) 5-hydrate (rhodium compound, $Na_3 RhCl_6 \cdot 5H_2 O$) was added when producing the nuclear emulsion gel



HIMAC Carbon beam

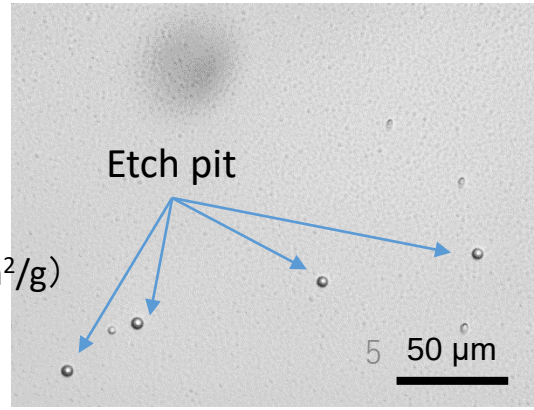
## ■ CR-39

- Solid-state track detector for detecting Z>2 charged particles by measuring the etch pit size under the microscope.
- Etch pit size, cone directions for measuring the Z/β, zenith angle and orientation.



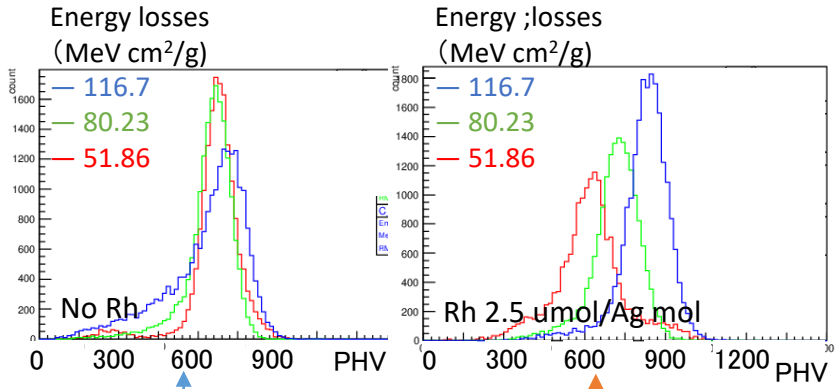
CR39 etch pit in the CRN chamber

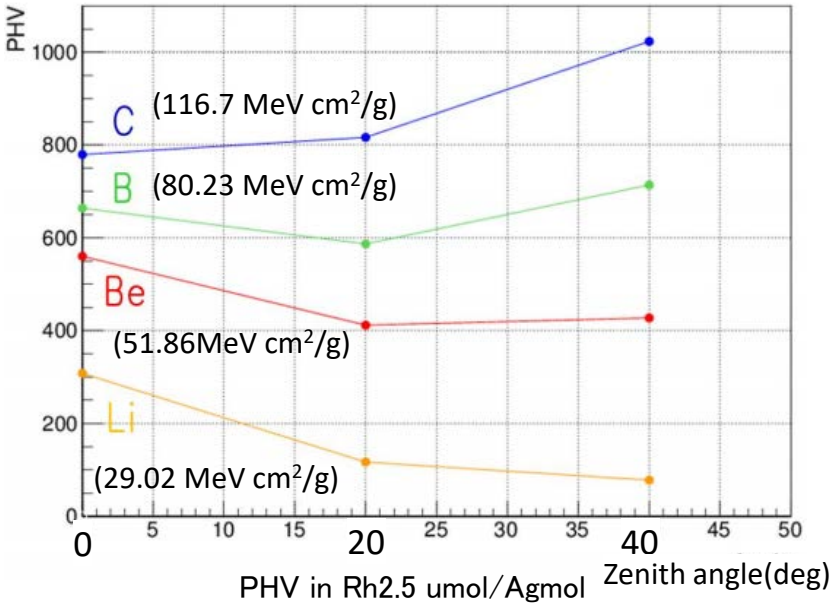
HIMACCbeanm
CR-39（116.7 MeV $cm^2$/g）

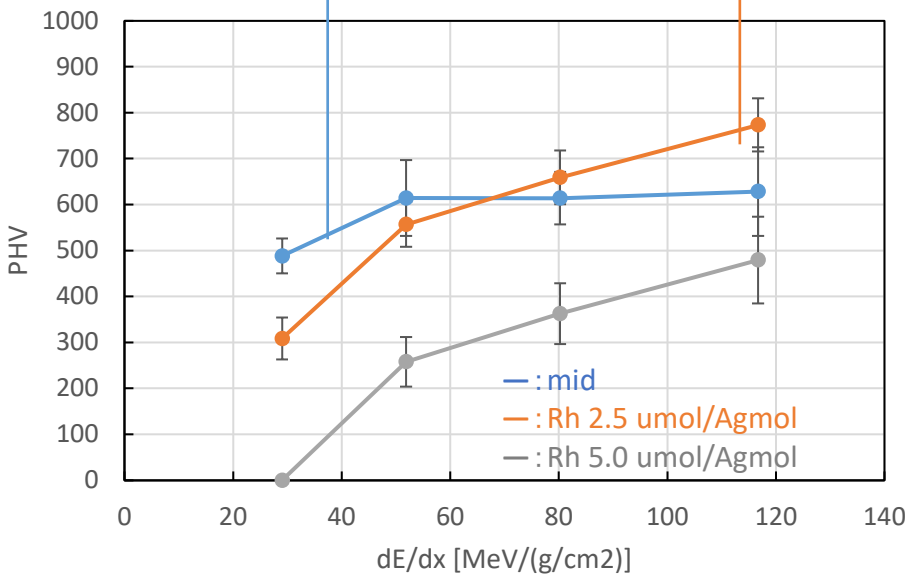


# Perfomance of desensitized nuclear emulsion films（HIMAC2017,2018beam)

- Rh compounds（$Na_3RhCl_6 \cdot 5H_2O$）make nuclear emulsion film desensitized effectively.
  - Two types of Rh compound amount
    - 2.5 umol/Agmol
    - 5.0 umol/Agmol
- In 2017, 350 MeV/nのLi，Be，B，C beams experiment
  - Zenith angle dependency of PHV



# Chamber structure of CRN chamber GRAINE2018

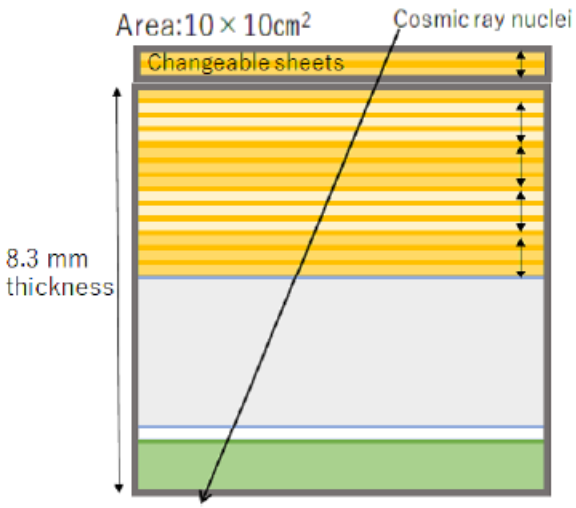


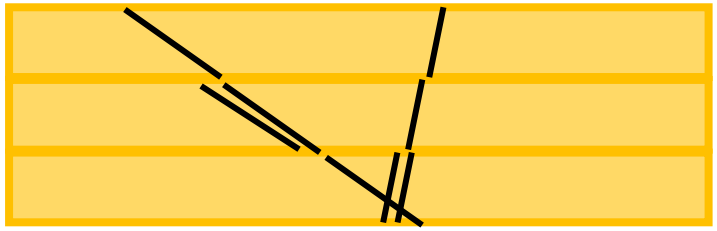

**Figure 3:** The CRN chamber structure. The area of top side is 10×10 $cm^2$ and its thickness was 8.3mm. At the furtherest downstream, CR-39 plates was allocated for the calibration of various sensitivity of emulsion films.

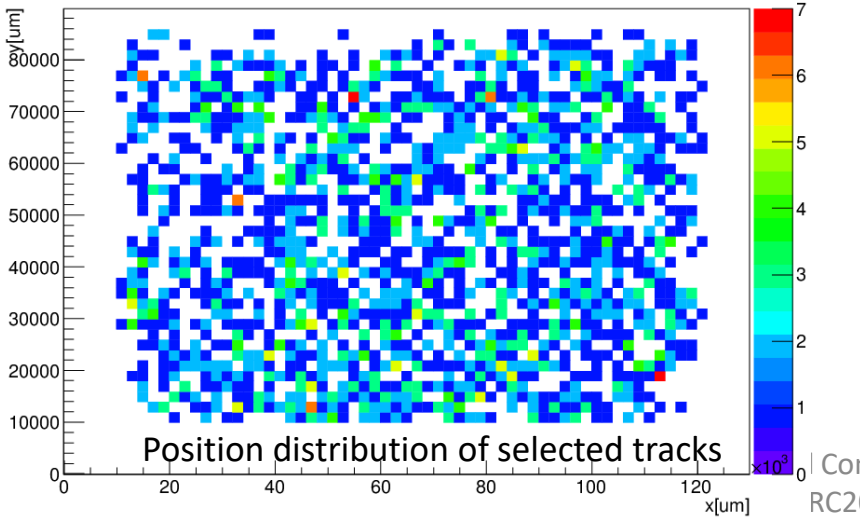
| Gel type of emulsion gel ① to ④ | plates | Thickness mm |
|---|---|---|
| ①ripening | 2 | 0.3 |
| ②non ripening | 1 | 0.3 |
| ①ripening | 3 | 0.3 |
| ③non ripening Rh25 | 3 | 0.3 |
| ④non ripening Rh50 | 3 | 0.3 |
| ①ripening | 3 | 0.3 |
| Acrylic block | 1 | 3 |
| Glassine Paper | 1 | - |
| CR39 | 1 | 1 |
| Laminate film | 1 | 0.18 |

**Figure 4:** Various sensitivity type of nuclear emulsion films were used in this flight. Ripening type and non-ripening type were also used as well as desensitized nuclear emulsion films.

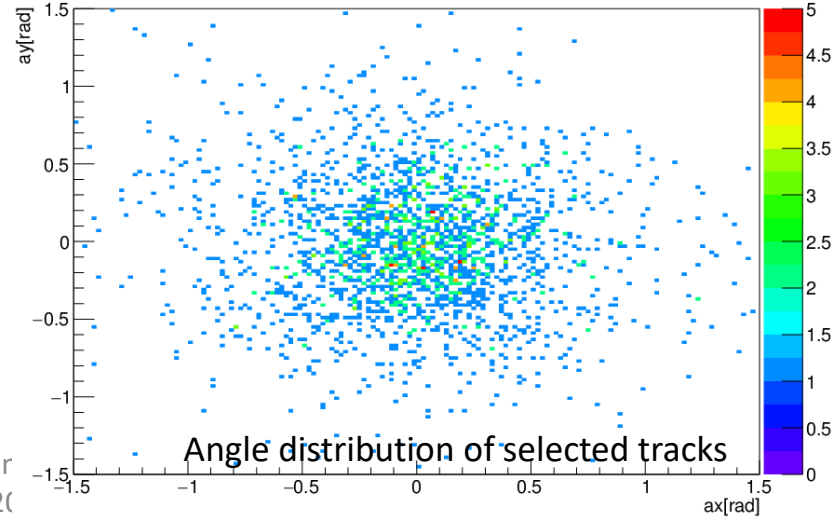
# Criteria for track selection

1. Track Identification:
   - Coincidence of HTS track signals in the continuing three emulsion films
2. Differences of position and direction of each combination were restricted
   - Position differences <5 um
   - Angular differences<0.02 rad





Position distribution of selected tracks



Angle distribution of selected tracks

# Result: PHV distributions for each zenith angle range

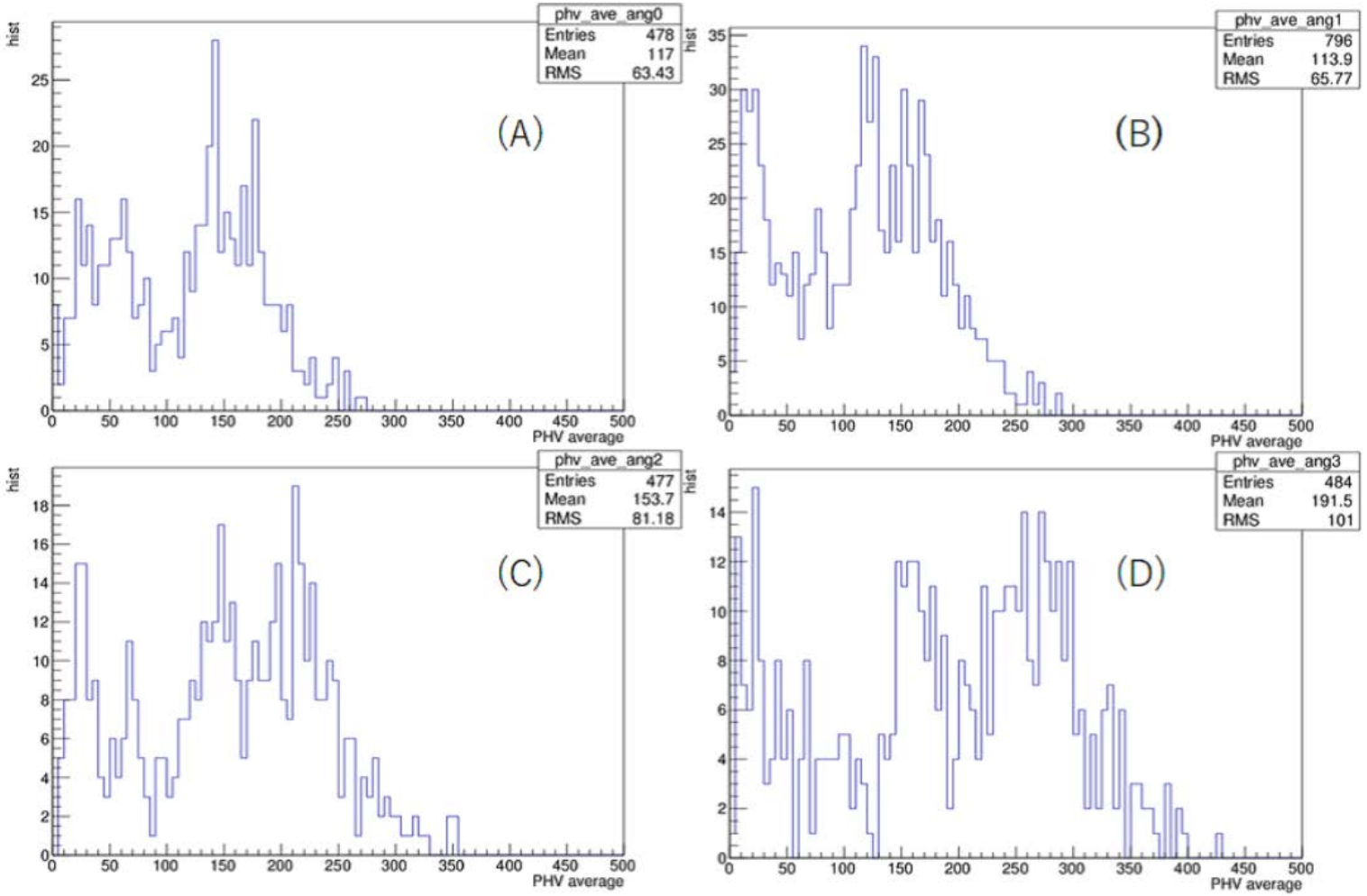



**Figure 5:** The PHV distribution for each zenith angle region : $\tan\theta < 0.25$ in (A), $0.25 \geq \tan\theta < 0.5$ in (B), $0.5 \geq \tan\theta < 0.75$ in (C) and $0.75 \geq \tan\theta$ in (D) respectively. The horizontal axes represent the mean PHV values obtained from three RH25 emulsion films.

# Results:
# PHV distribution in requiring the existence of track in Rh50 highly desensitized nuclear emulsion

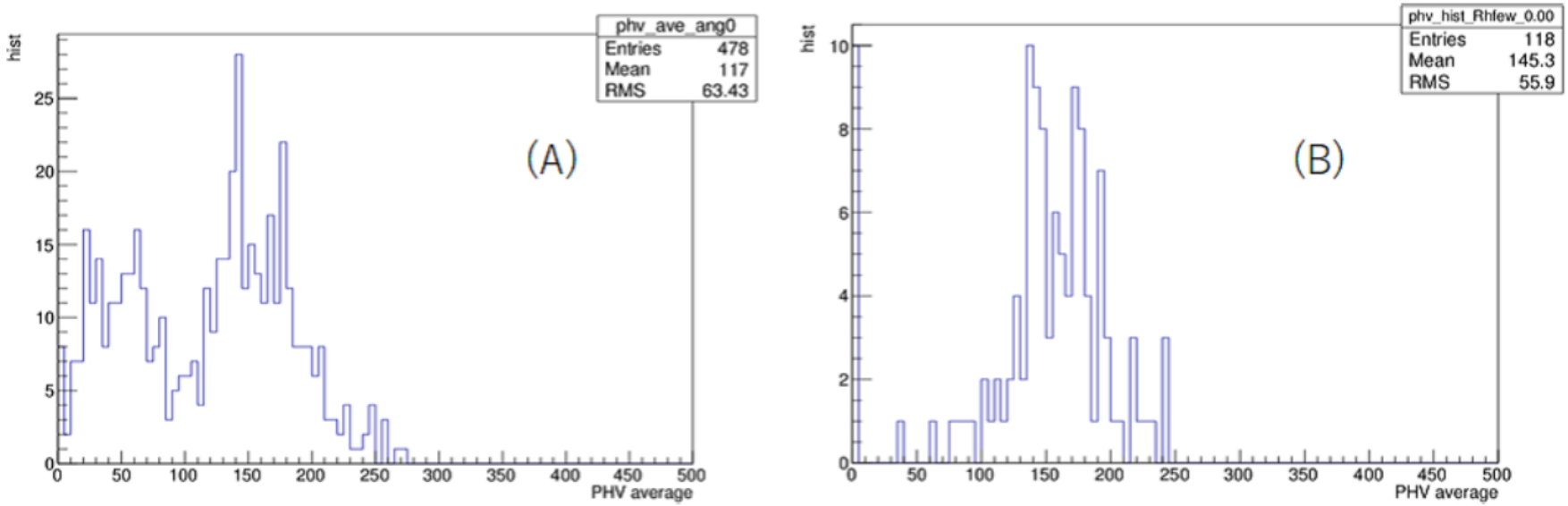



**Figure 6:** The PHV distribution for each zenith angle region : $\tan\theta < 0.25$. (A):RH25 films solely and (B): RH25 and RH50 films coincidence required. The horizontal axes still represent the mean PHV values obtained from three RH25 emulsion films.

# Correlation between PHV and CR-39 etch pit size

- 97 cosmic ray nuclei were matched in the emulsion films and the furthermost downstream CR-39 plates

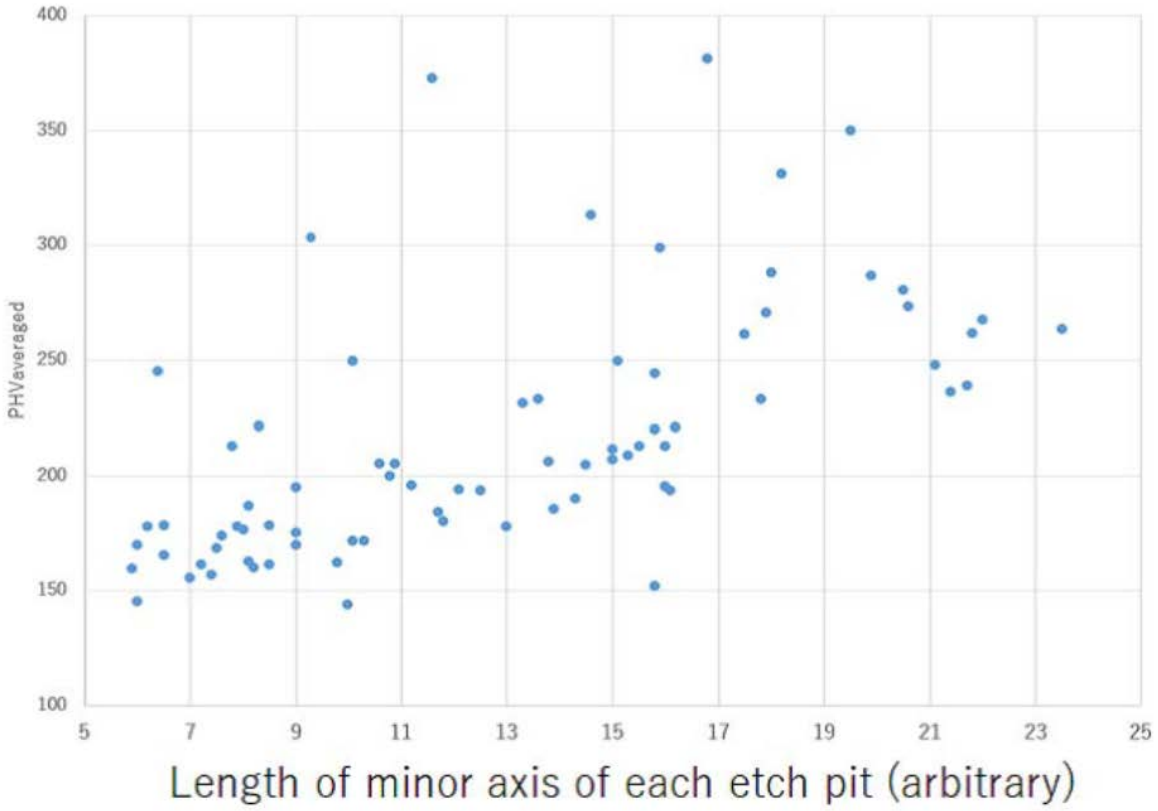



**Figure 7:** The PHV distribution for each zenith angle region : $\tan\theta < 0.25$. (A):RH25 films solely and (B): RH25 and RH50 films coincidence required. The horizontal axes still represent the mean PHV values obtained from three RH25 emulsion films.

# Conclusions

The desensitized nuclear emulsion gels adding Rh compounds were applied on the a film base, various sensitivity of nuclear emulsion films were produced. And we exposed the emulsion chambers which consists of ordinal sensitivity and desensitized ones to the cosmic ray nuclei in GRAINE balloon flight experiment for astronomical gamma-ray search at Australia, in April 2018. We have obtained PHV signals in both RH25 and RH50 desensitized films for cosmic ray nuclei, and can select heavier nuclei by triggering RH50 film coincidence. Finally, these desensitized PHV signals were well correlated with the CR-39 etch pit size(minor axis length).

In 2023, GRAINE experiments are going to carry out the astronomical gamma ray study with 10 times larger statistics by using several ten times large area emulsion chambers, and their multiple flights. This will provide the direct measurement of cosmic ray nuclei abundance by optimizing the desensitization degree of nuclear emulsions for high speed image analysis system HTS.

**Acknowledgments**

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