ACAT 2013

DATA ANALYSIS OF TRACKS OF HEAVY-ION PARTICLES IN TIMEPIX DETECTORS

Presenter:

Son Hoang

University of Houston

05 - 16 - 2013

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OUTLINE

Introduction

- Timepix devices
- Dose-Equivalent calculation

Angle calculation

- Azimuthal angle
- Polar angle

Volcano effect

Interactions

Experimental results

Future works

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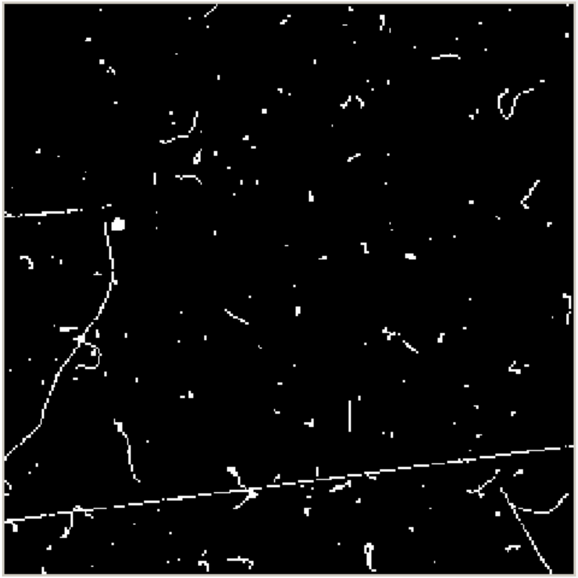
INTRODUCTION

Develop a Space Radiation Dosimeter

- Estimate LET
- Compute Dose, Dose-Equivalent



Characterize ionizing radiation in space

- Detect and visualize primary and secondary radiation
- Identify a source of a heavy ion particle
- Measure energy

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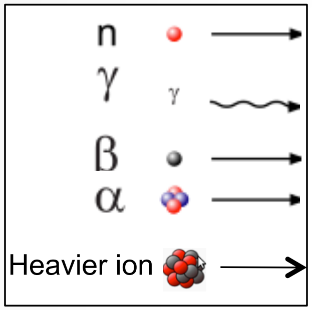
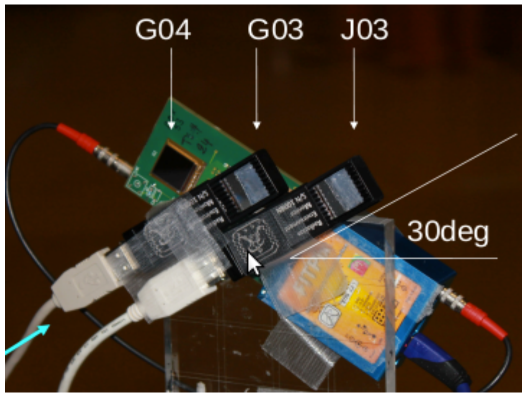
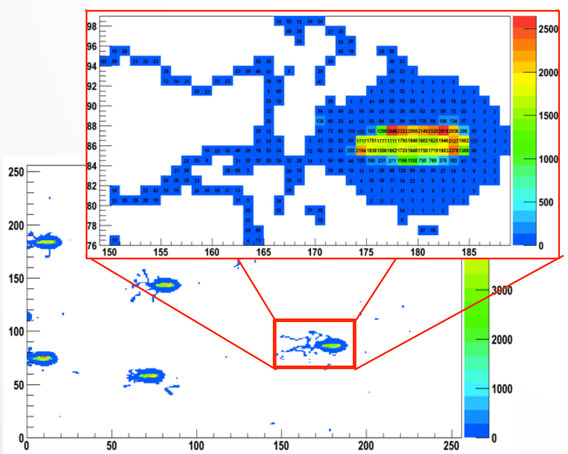
INTRODUCTION







Pattern recognition

Dose ?

LET ?

Dose-equivalent ?

Energy ?

Type of Ion ?

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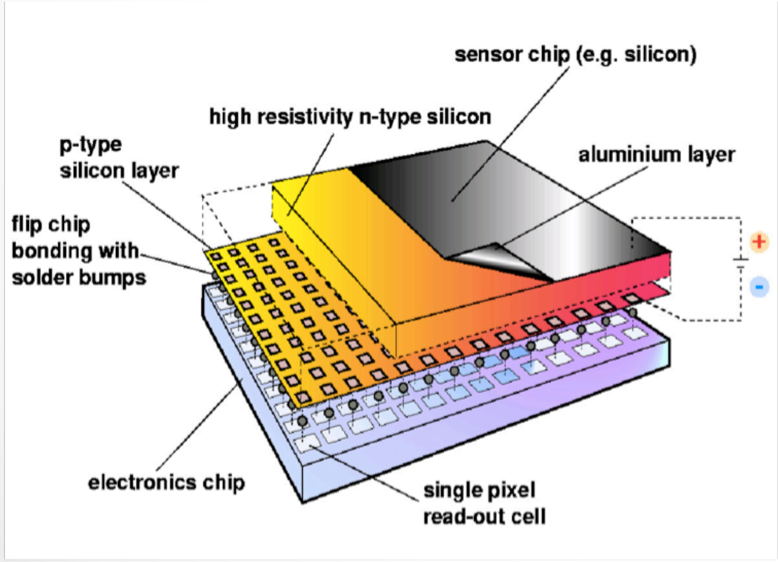
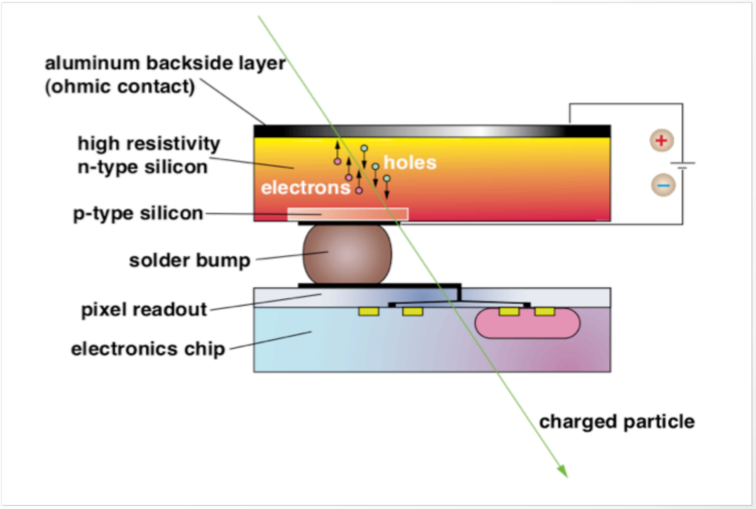
TIMEPIX DEVICE

- Hybrid semiconductor CMOS-based pixel detector
- Overlying Si sensor layer attached
- 256 x 256 square pixels
- 55 µm square pixel



Timepix configuration



Pixel circuitry

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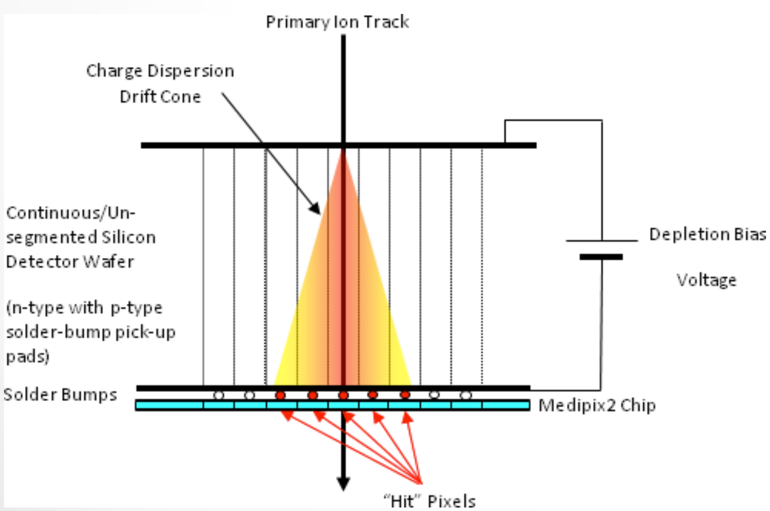
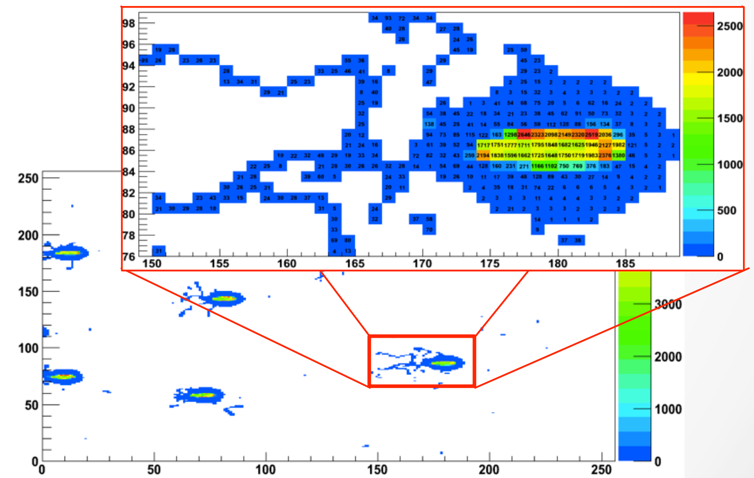
TIMEPIX DEVICE

- A charged particle ionizes atoms along its path
- A core of charge carriers is produced
- Charges drift along and diffuse perpendicular to an applied bias-voltage field
- Charges collected by the underlying pixels
- 256x256 pixel image



Charge diffusion and collection



Timepix output

DOSE & DOSE-EQUIVALENT

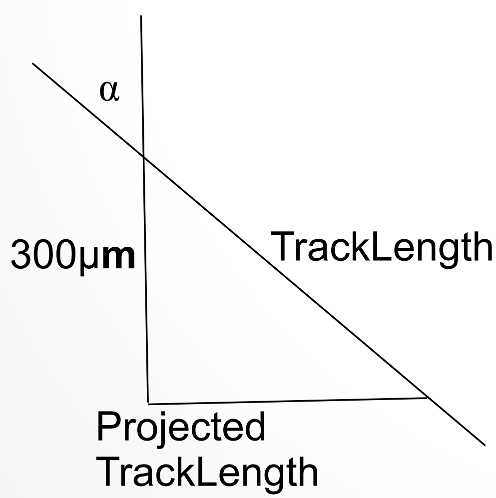
$D_{Si} = E_{TimePix}$ (in KeV) {1 / [0.14 g x 6.24 x 1012 KeV/Gy g }

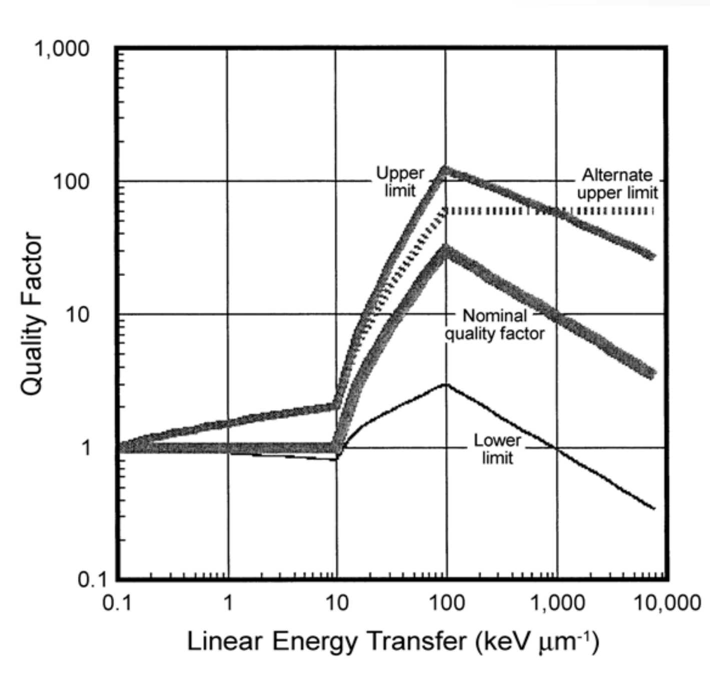
$= E_{TimePix}$ (in KeV) { 1.153 x 10 -12 } Gy

H = Q(LET) . Dsi (Sv)

LET = $E_{TimePix}$ {1 / TrackLength}

TrackLength = 300 {1/cos(α)}





Quality factor as a function of LET

ANGLE CALCULATION

- Facilitate LET, Dose-Equivalent calculation
- Provide an important feature for ion identification
- Challenges
    - Cluster rotation
    - Delta-ray existence
    - Plasma effects
    - Bias-voltage variation
    - Cluster variation (depends on types of Ion and velocity)

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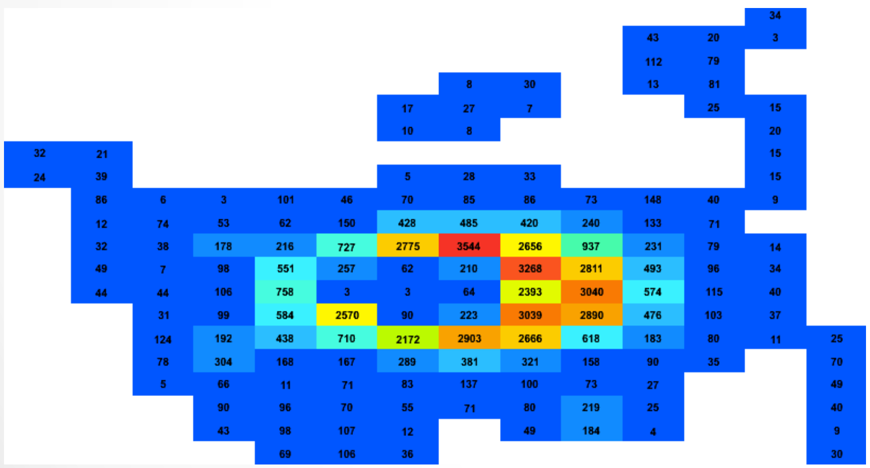
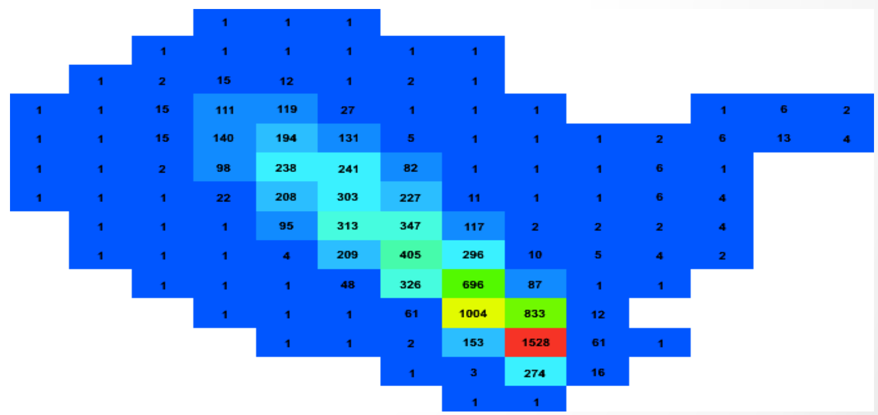
CHALLENGES

- Cluster rotation
- Delta-ray existence
- Plasma effect



Fe-400MeV-30degree with delta-ray and plasma effect



C-230MeV-60degree with azimuthal -60

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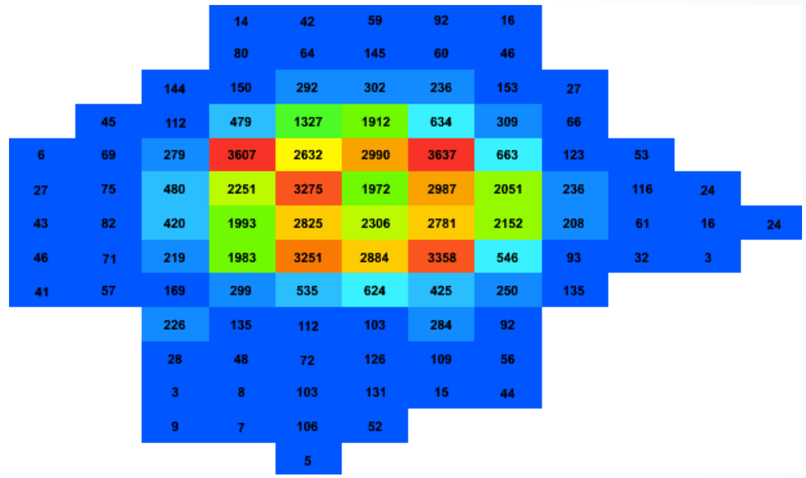
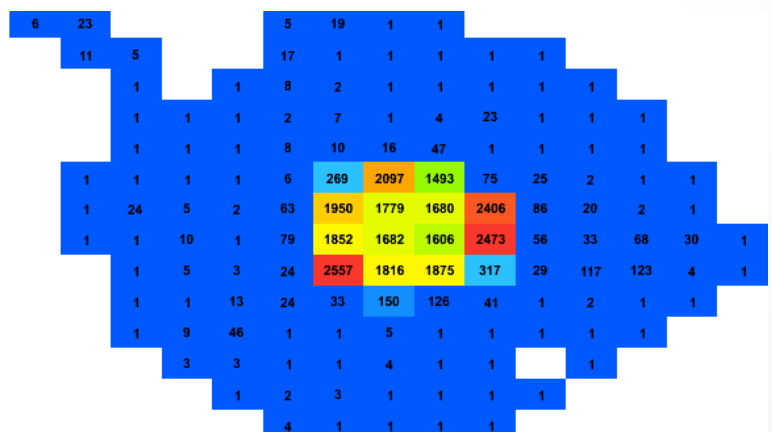
BIAS-VOLTAGE VARIATION

Fe-400MeV-15V

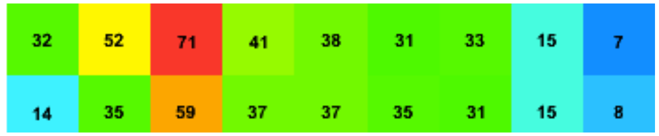


Fe-400MeV-100V



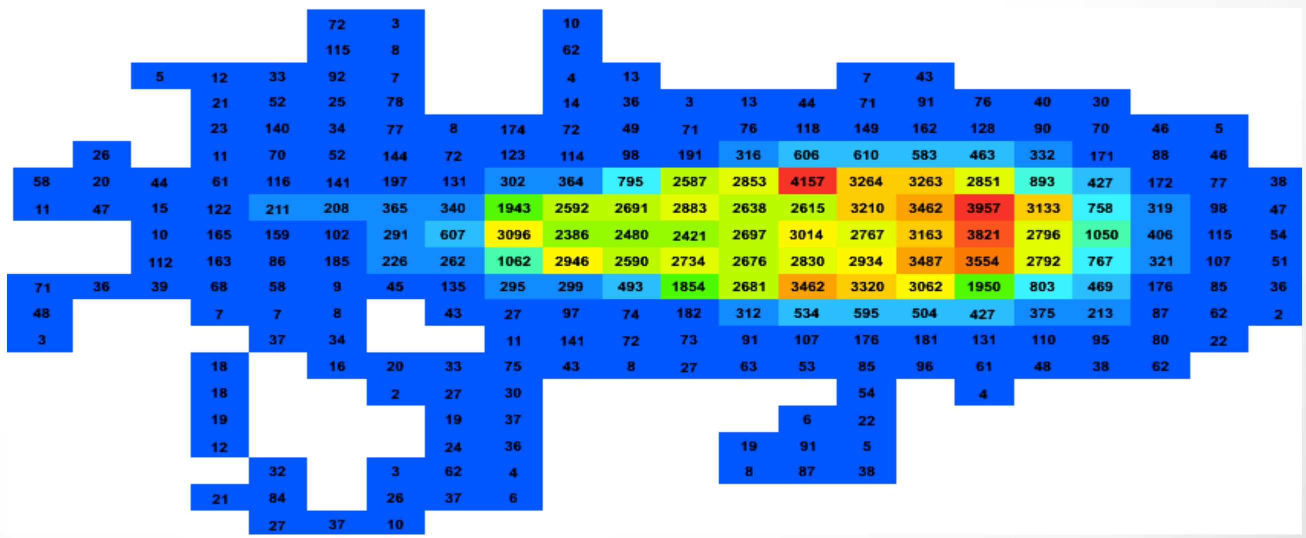
CLUSTER VARIATION

H-100MeV-15V-60degree



C-400MeV-15V-60degree

Fe-400MeV-15V-60degree



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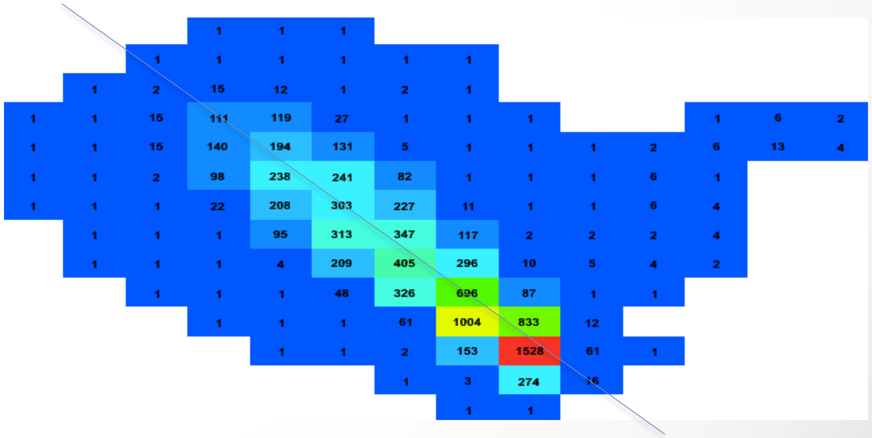
AZIMUTHAL ANGLE

$$\beta_0 = \frac{\Sigma e_j x_j \cdot \Sigma x_i y_i e_i - \Sigma x_i^2 e_i \cdot \Sigma e_j y_j}{\Sigma e_j x_j \cdot \Sigma e_i x_i - \Sigma x_i^2 e_i \cdot \Sigma e_j}$$

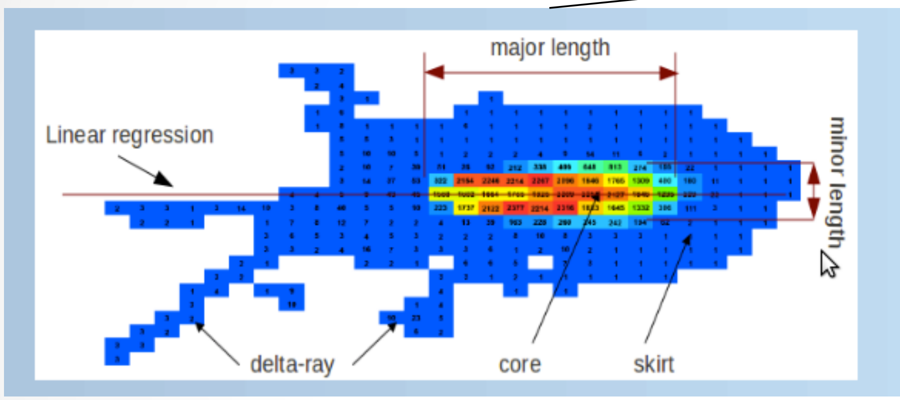
$$\beta_1 = \frac{\Sigma e_j y_j \cdot \Sigma x_i e_i - \Sigma x_i y_i e_i \cdot \Sigma e_j}{\Sigma e_j x_j \cdot \Sigma e_i x_i - \Sigma x_i^2 e_i \cdot \Sigma e_j}$$

a = -atan(m)
X = cos(a)*x – sin(a)*y
Y = sin(a)*x + cos(a)*y

$y = \beta_0 + \beta_1 x$



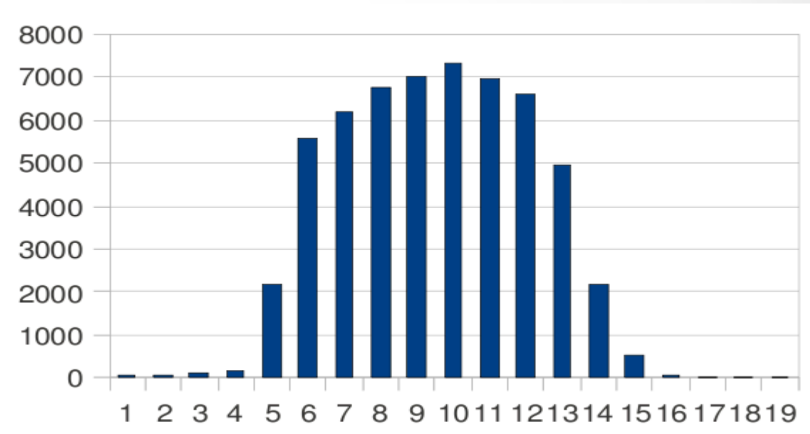
POLAR ANGLE



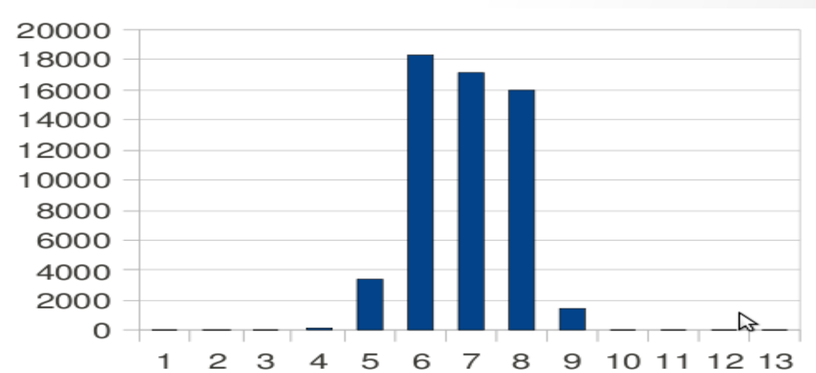
$$\tan\alpha = \frac{55}{300}\left(M - \frac{N}{2M - N}N\right)$$

M = major length
N = minor length

$$LET = \frac{E\cos\alpha}{300}$$



Cluster profile on X-axis



Cluster profile on Y-axis

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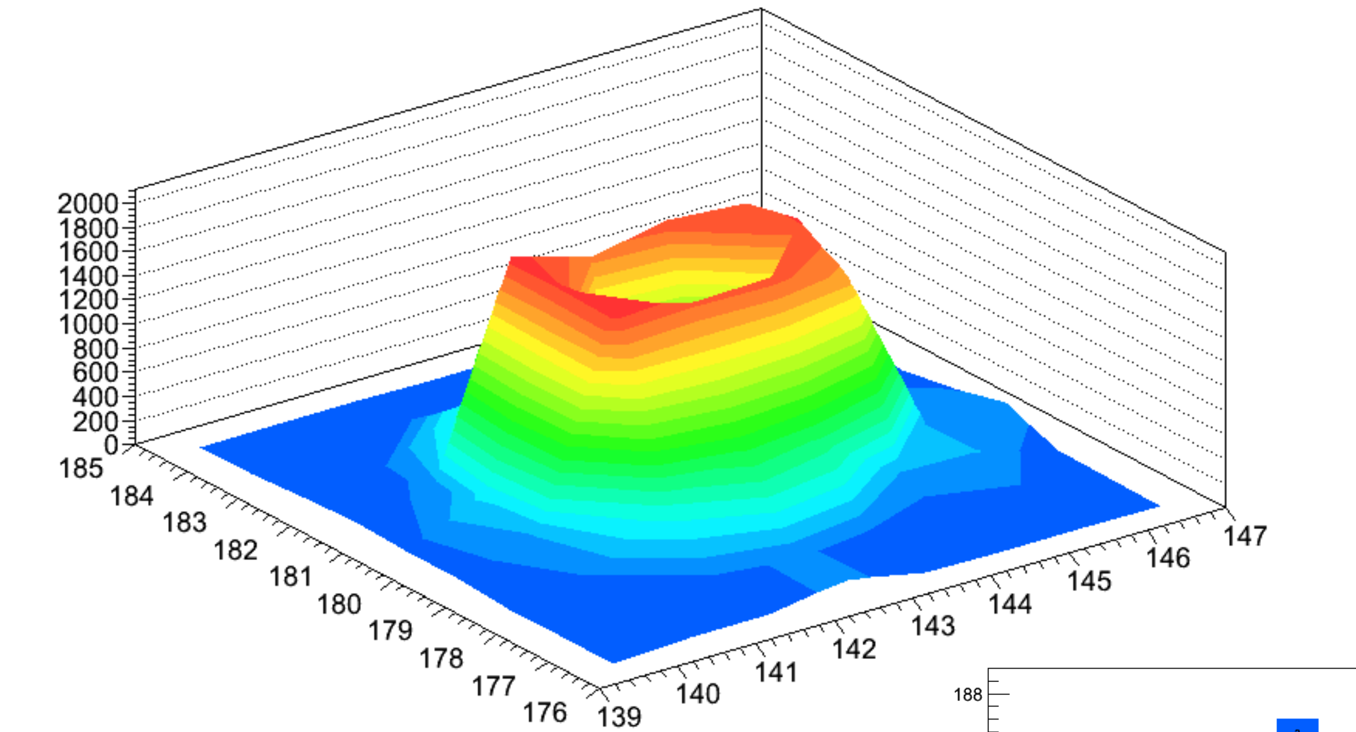
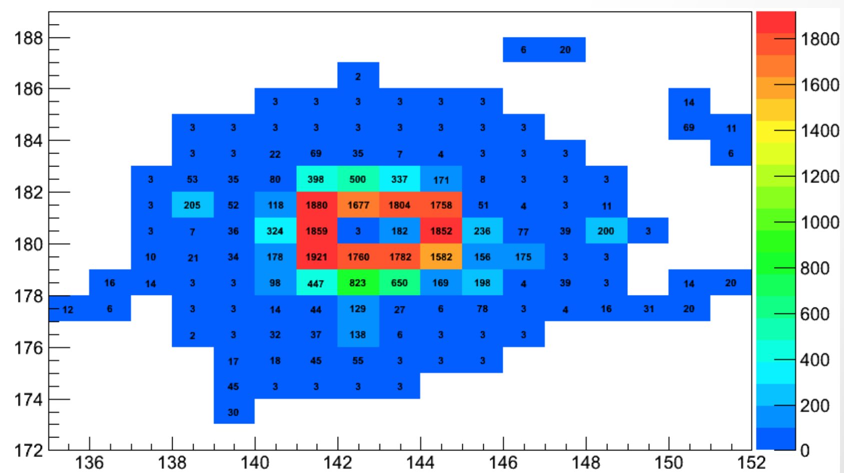
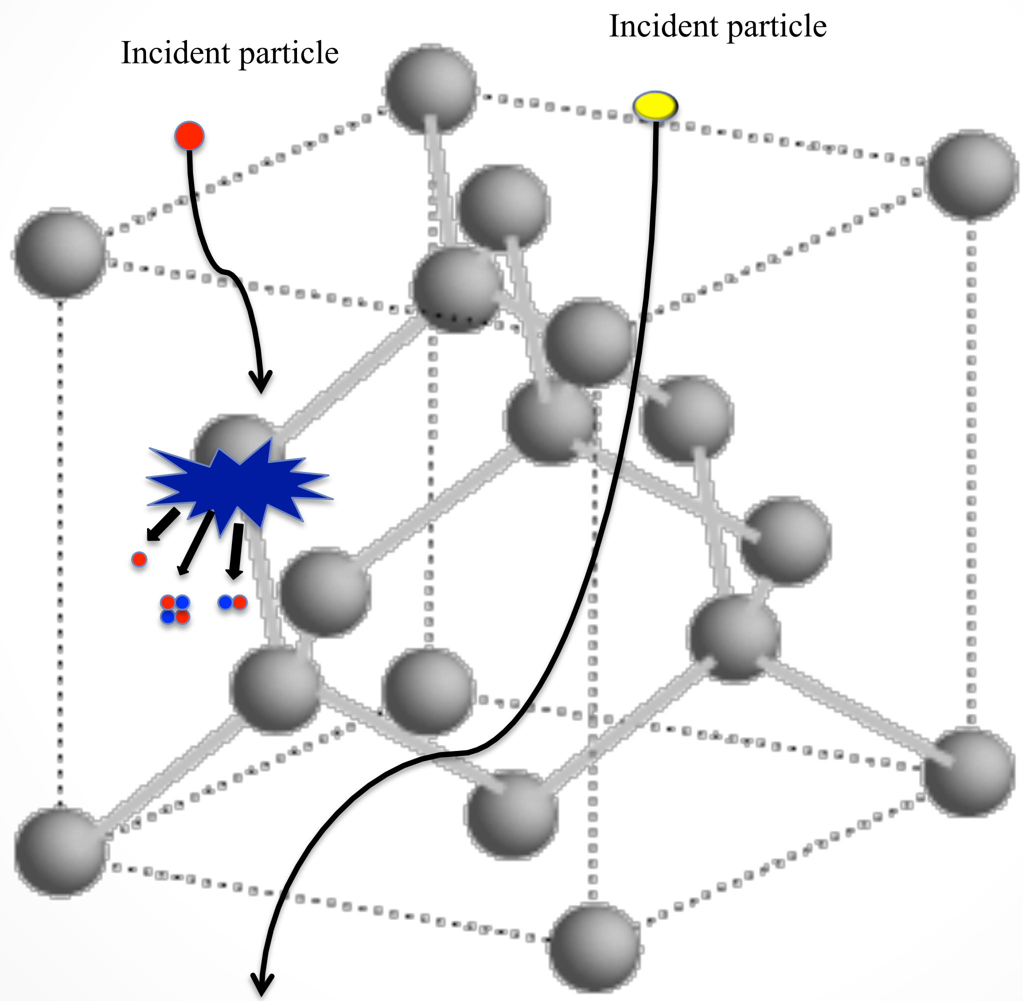
VOLCANO EFFECT



Fe-400MeV-0degree



NUCLEI INTERACTION



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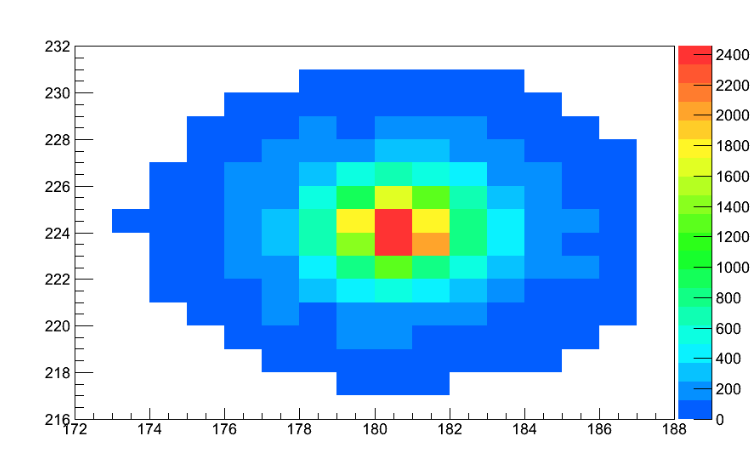
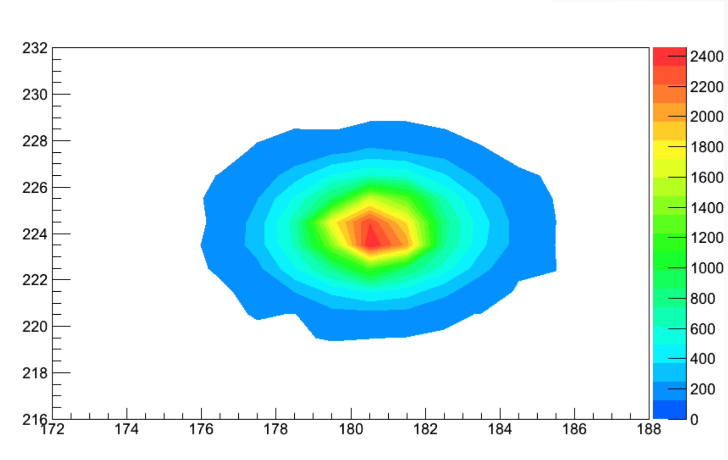
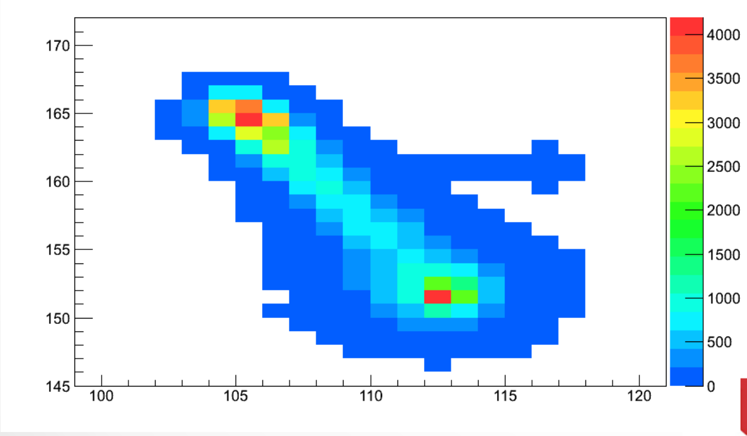
INTERACTIONS

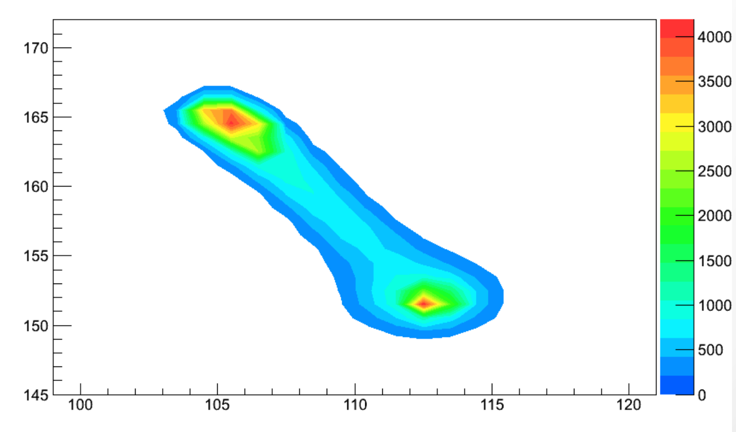
1. Vertical interaction





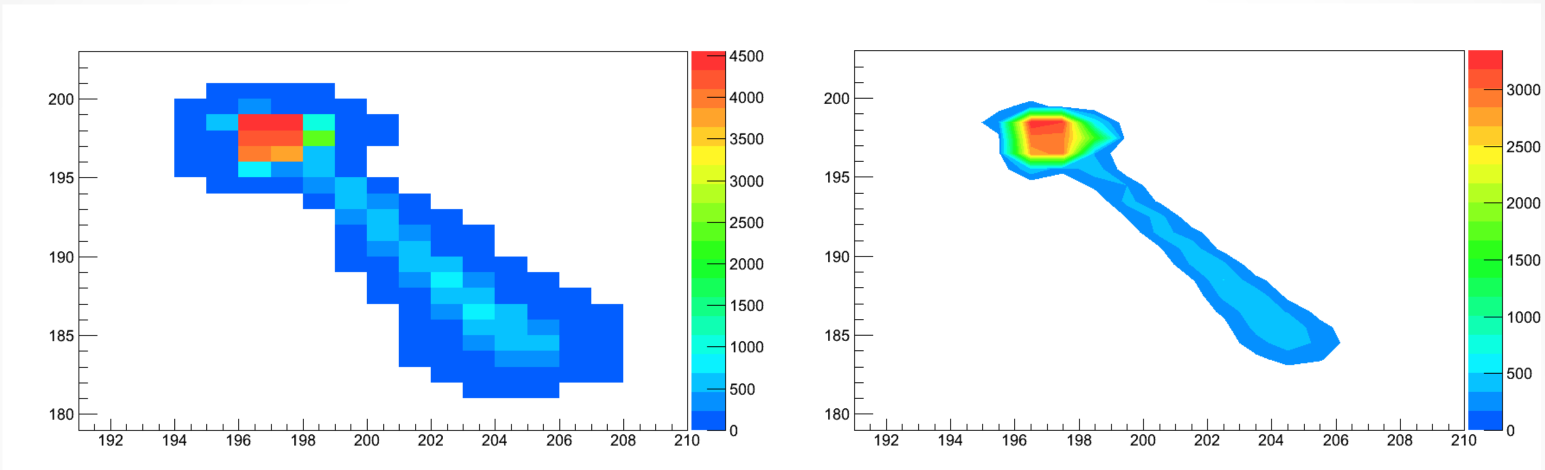
2. Multiple peaks interaction



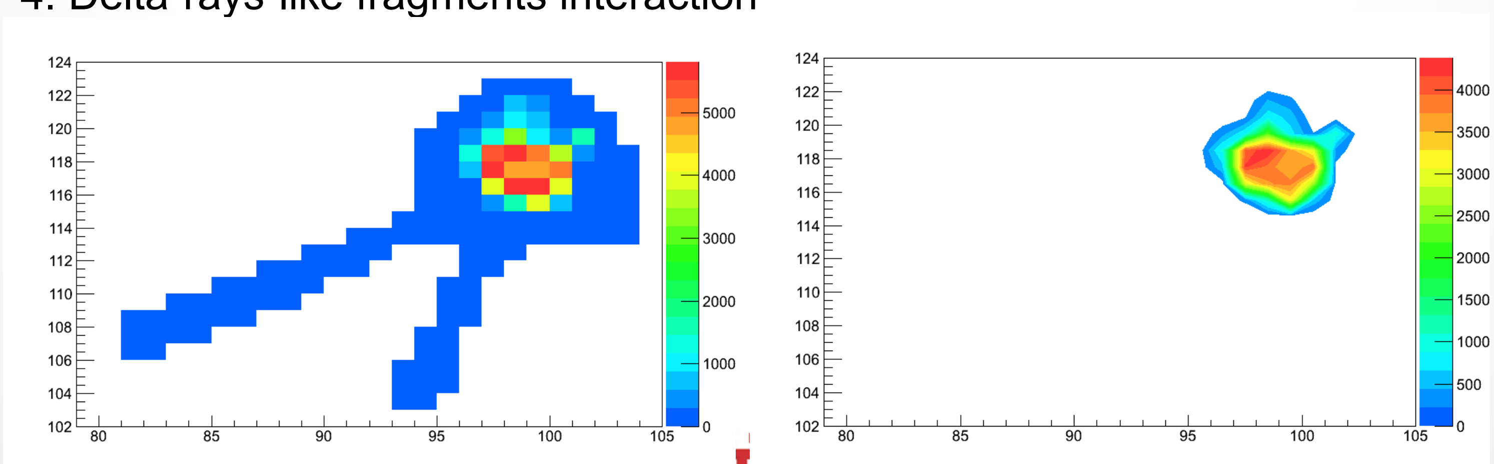


INTERACTIONS

3. Visible fragments interaction



4. Delta-rays-like fragments interaction



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EXPERIMENTAL RESULTS

- Angle and LET
- HIMAC & NSRL Data
  - H-100MeV, He-100MeV, C-300MeV, N-290MeV, O-430MeV, Si-400MeV, Fe-400MeV
  - 0, 30, 60, 75 degree
  - 1000 Frames
- ISS Data
- Pre-processing
  - Remove overlapping clusters
  - Ignore clusters of no interest

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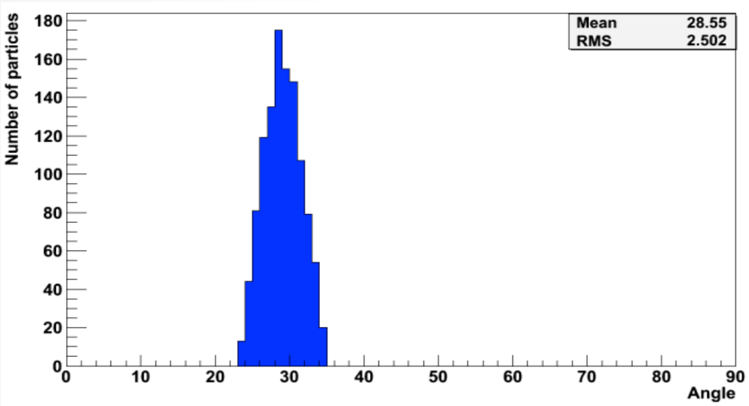
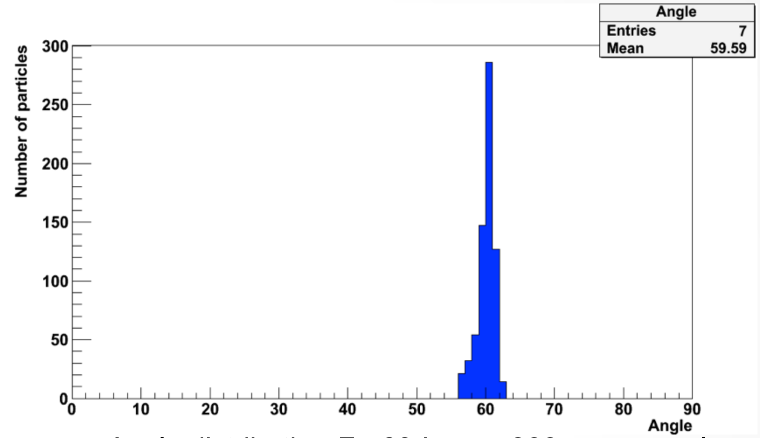
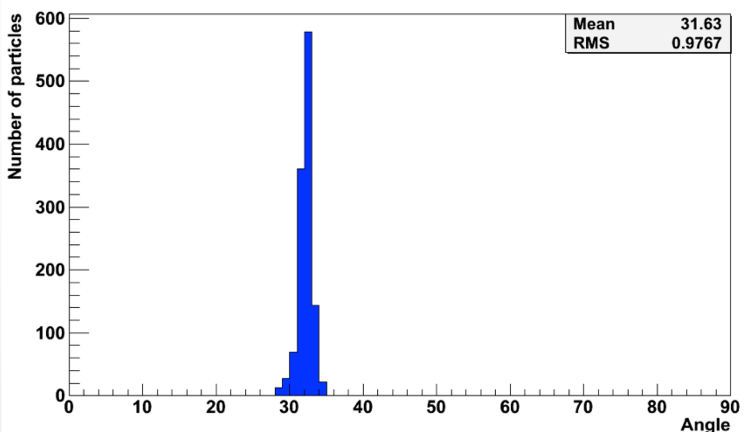
ANGLE DISTRIBUTION



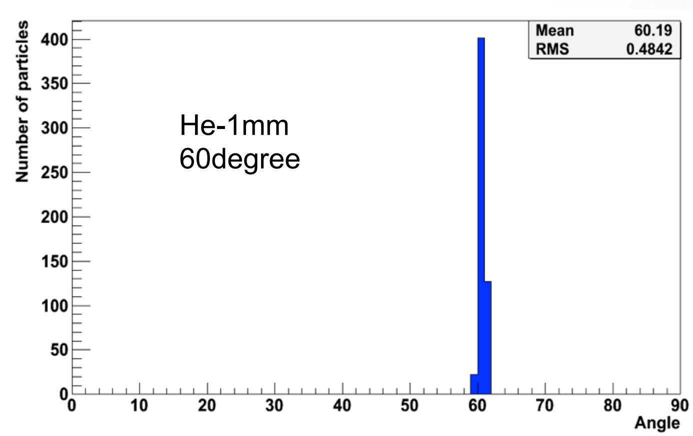
Angle distribution-Fe-30degree 300um sensor layer



Angle distribution-Fe-60degree 300um sensor layer



Angle distribution-He-30degree 1mm sensor layer



Angle distribution-He-60degree 1mm sensor layer

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EXPERIMENTAL RESULTS - ANGLE

	0 degree		30 degree		60 degree		75 degree	
	Mean	RMS	**Mean**	RMS	**Mean**	RMS	**Mean**	RMS
H-100MeV	**0.6**	1.3	**30.2**	3.8	**59.7**	1.2	**74.5**	1.3
He-100MeV	**2.1**	6.8	**30.2**	3.7	**60.1**	1.3	**74.7**	1.5
C-300MeV			**29.7**	4.3	**60.9**	3.6		
O-430MeV	**4.3**	6.2	**29.7**	3.6	**60.1**	1.3	**74.7**	0.6
N-290MeV	**4.3**	6.6	**29.1**	3.6	**60.5**	1.1	**75.2**	0.6
Si-400MeV	**2.6**	3.5	**25.5**	4.6	**59.5**	1.8	**73.6**	1.1
Fe-400MeV	**3.8**	4.5	**24.1**	5.2	**61.6**	1.1	**75.9**	1.5

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EXPERIMENTAL RESULTS - LET

	SRIM LET	0 degree		30 degree		60 degree		75 degree	
	KeV/um	**Mean**	RMS	**Mean**	RMS	**Mean**	RMS	**Mean**	RMS
H-100MeV	1.36	**1.4**	0.3	**1.3**	0.3	**1.26**	0.3	**1.3**	0.3
He-100MeV	5.42	**5.5**	0.75	**5.67**	0.54	**5.7**	0.6	**6.0**	0.54
C-300MeV	23.0			**25.4**	3.6	**26.6**	4.1		
O-430MeV	35.0	**32.2**	7.7	**38.8**	5.4	**39.6**	4.8	**41.0**	4.4
N-290MeV	32.0	**31.0**	7.6	**29.1**	2.8	**31.9**	2.7	**33.0**	2.8
Si-400MeV	110.0	**106.0**	18.8	**113.0**	24.2	**125.0**	17.0	**140.0**	14.8
Fe-400MeV	377.0	**374.0**	40.4	**380.0**	49.0	**328.0**	40.5	**340.0**	23.8

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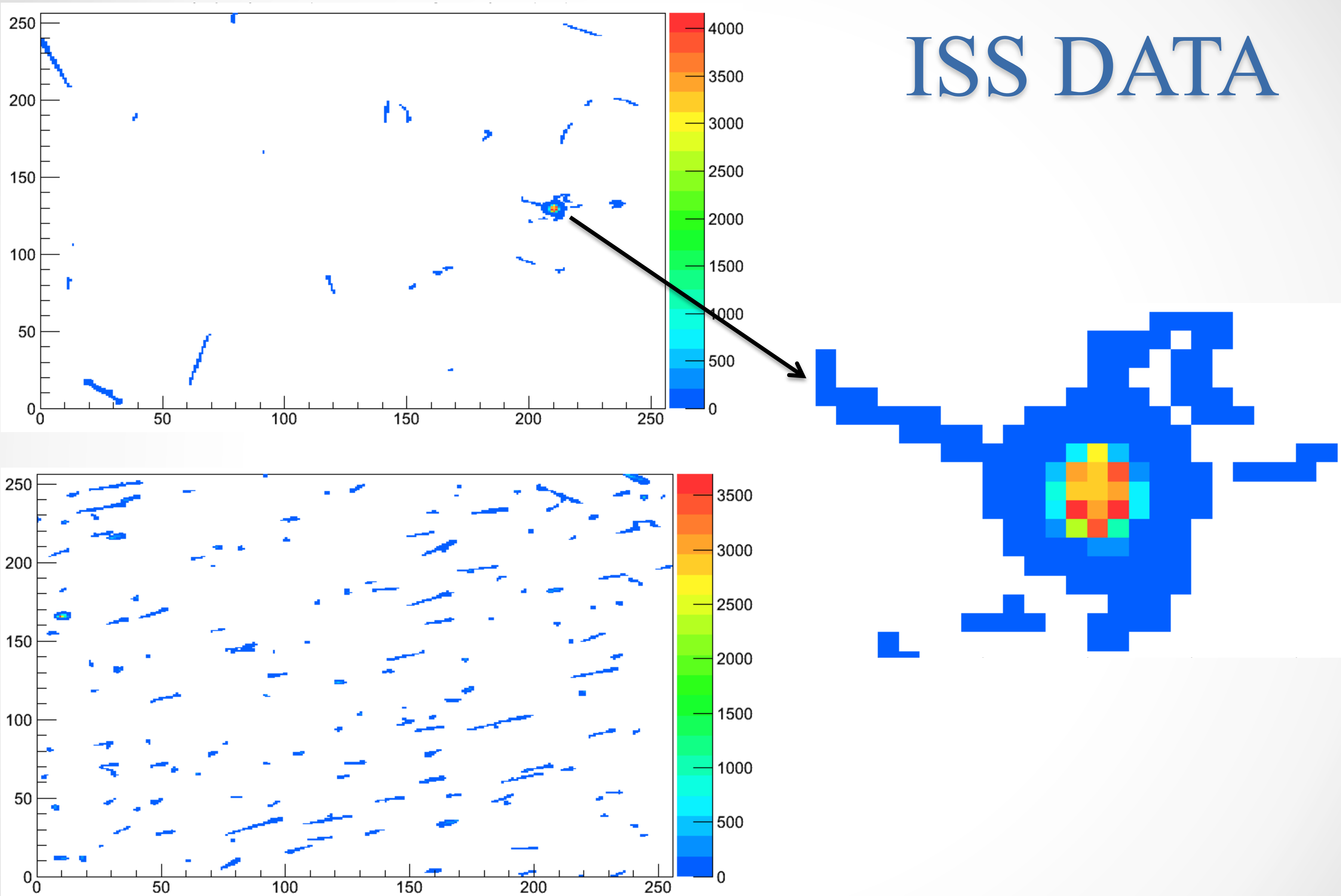
ISS DATA



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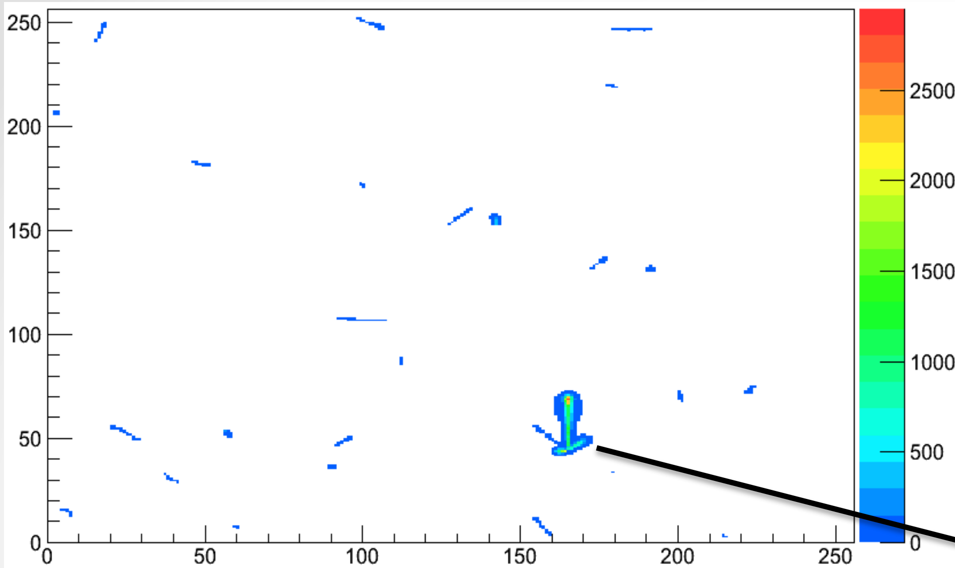
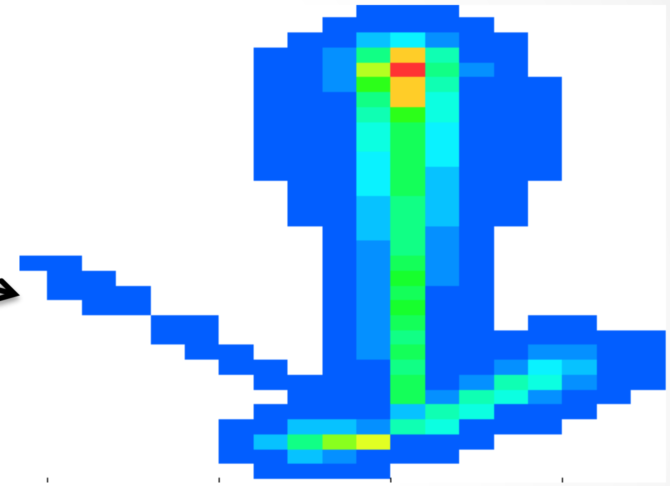
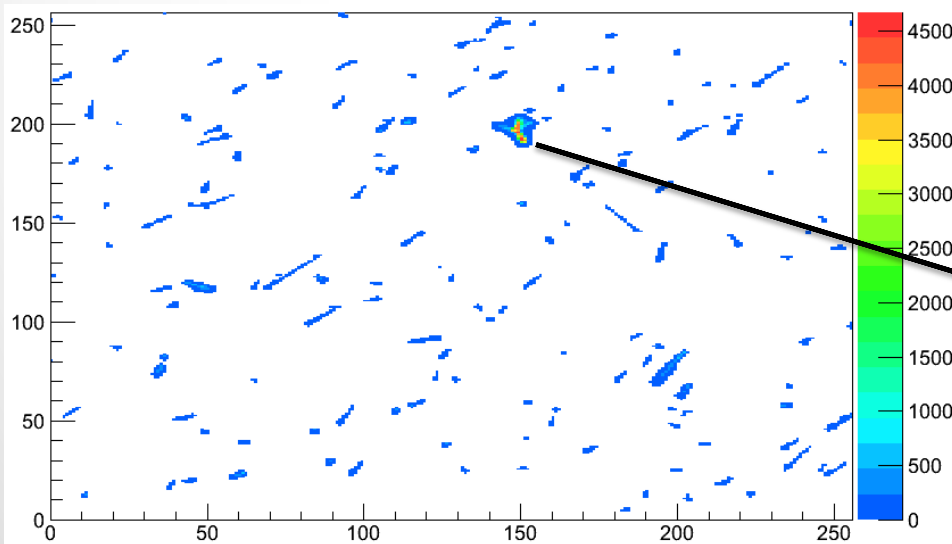
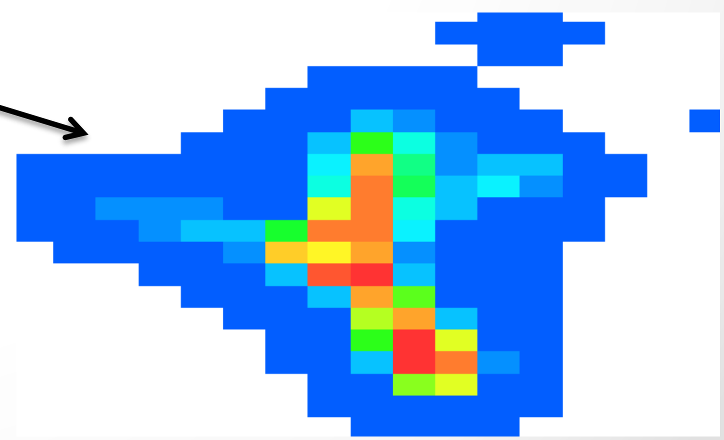
ISS DATA









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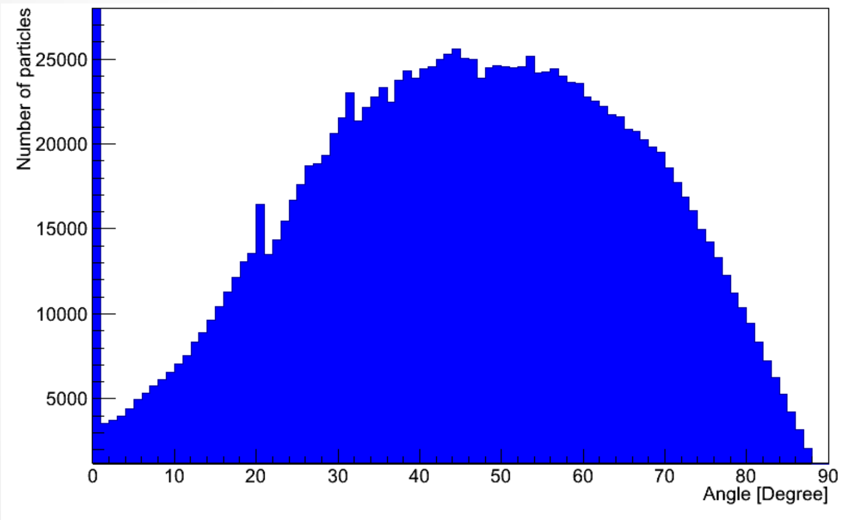
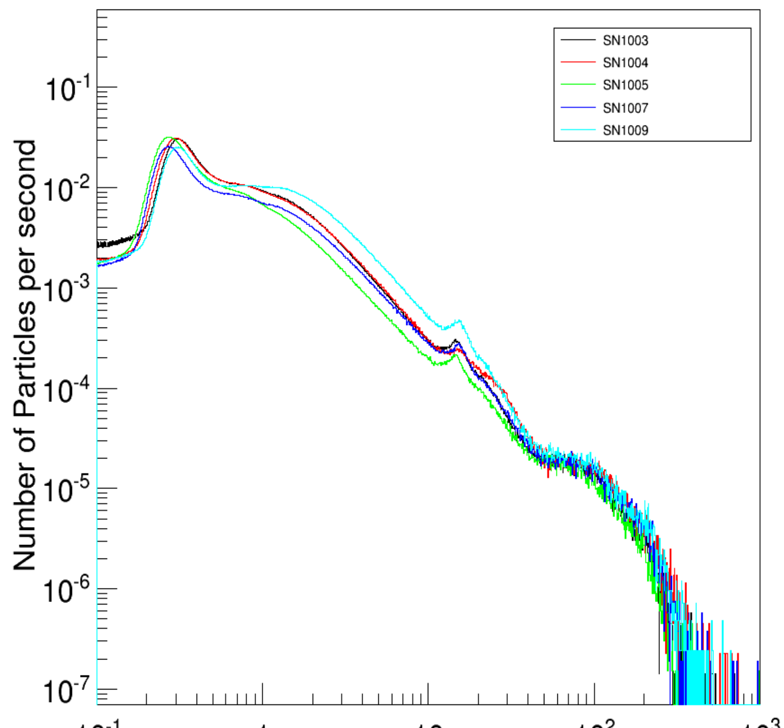
ISS DATA

Angle distribution



LET Distribution



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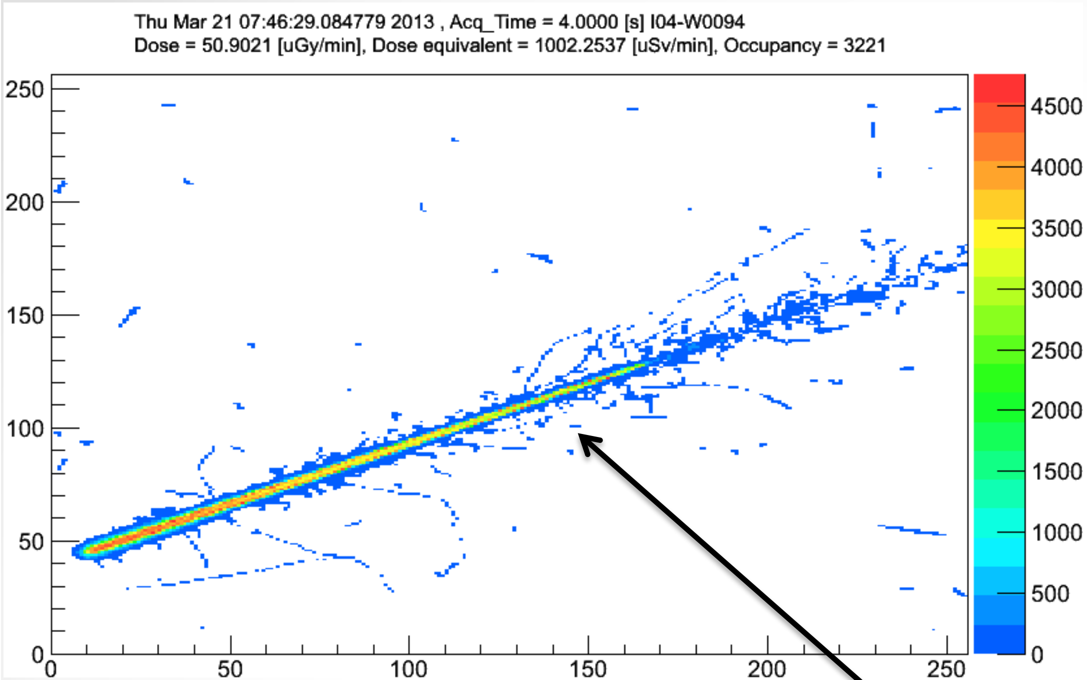
ISS DATA



Thu Mar 21 07:46:29.084779 2013 , Acq_Time = 4.0000 [s] I04-W0094
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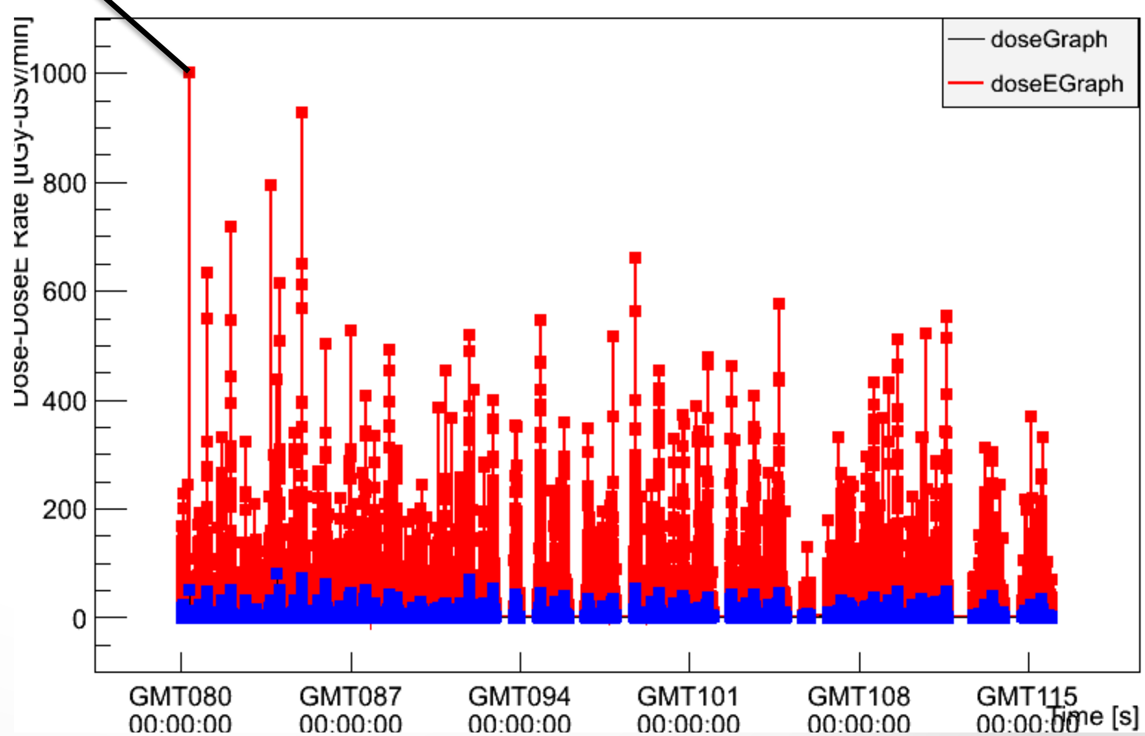

doseGraph
doseEGraph
GMT080 00:00:00
GMT087 00:00:00
GMT094 00:00:00
GMT101 00:00:00
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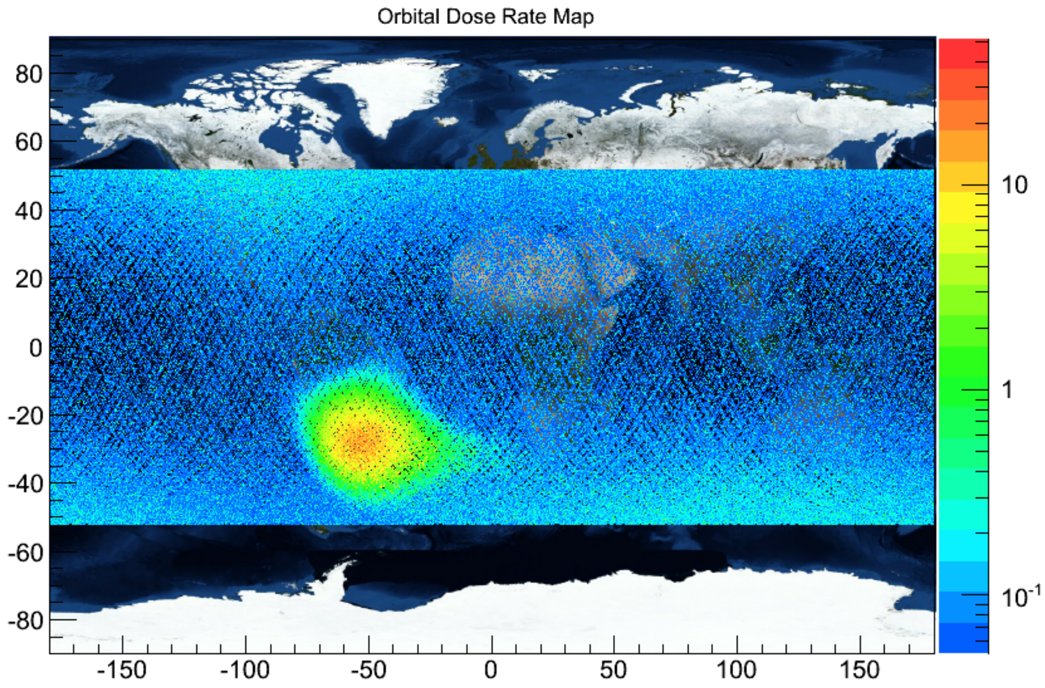
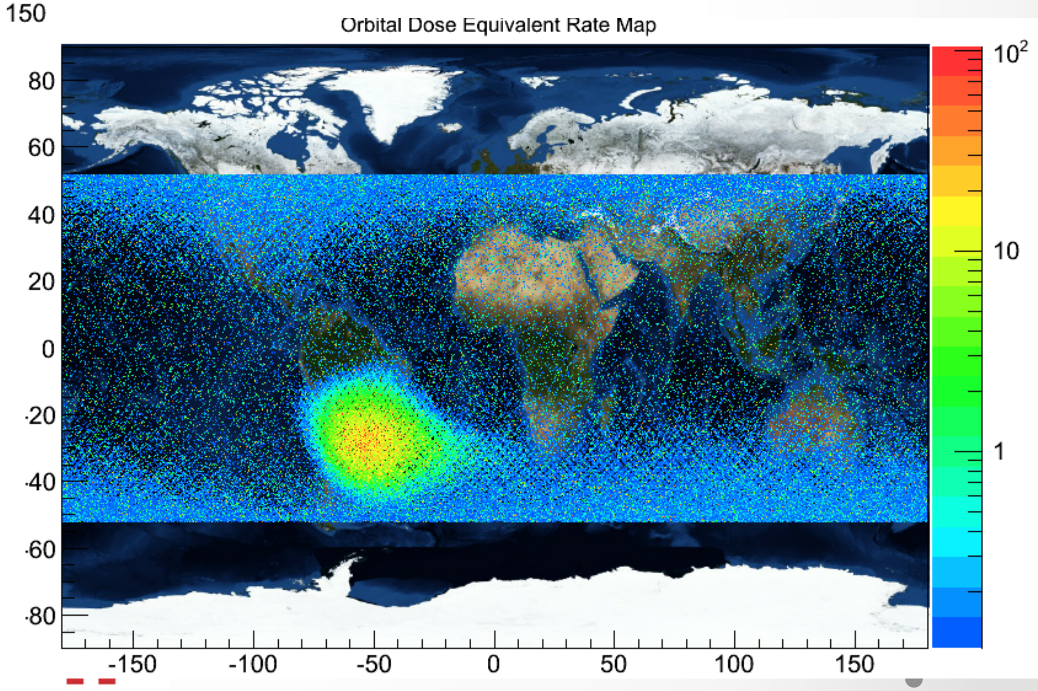
GMT115 00:00:00
Time [s]

ISS DATA





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CONCLUSIONS

- Detection and visualization of primary and secondary particles.
- Angle calculation.
- LET estimation method.
- Dose-equivalent calculation.
- Plasma effect correction.
- Interactions identification.
- Development data analysis tools for processing HIMAC ISS data.

FUTURE WORK

- Improve methods of plasma effect correction and interaction identification
- Recover overlapping particles
- Explore more relevant features that facilitate discriminating types of particles.
- Do feature selection and model selection for ion classification
- Optimize algorithms for an embedded system (DSP/ARM)
- Develop a software for data analysis framework processing ISS data

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PUBLICATIONS

[1] **Hoang S.**, Pinsky L., Vilalta R. (2012), *LET Estimation for Heavy Ion Particles based on a Timepix-based Si Detector*. International Conference on Computing in High Energy and Nuclear Physics (CHEP-12), New York, USA.

[2] Stoffle N., Pinsky L., **Hoang S.**, Idarraga J., Kroupa M., Jakubek J., Turecek D., and Pospíšil S., *Initial Results on Charge and Velocity Discrimination for Heavy Ions using Silicon Timepix Detectors.* In the 14th International Workshop on Radiation Imaging Detectors, Figueira da Foz, Coimbra, Portugal.

[3] Pinsky L., Empl A., **Hoang S.**, Stoffle N., Jakubek, J., Vykydal Z., Turecek D., Pospisil S.; Kitamura H., Ploc O., Uchihori Y., Yasuda N., Amberboy C., Hauss J., Lee K., Semones E., Zapp N., Parker R., and Cooke D., *Preparing for the First Medipix Detectors in Space*. Proceedings of the IEEE Aerospace Conference, Big Sky, Montana, March, 2012.

[4] Vilalta R., Kuchibhotla S., **Hoang S.**, Valerio R., Ocegueda F., and Pinsky L. (2012), *Classification of Sources of Ionizing Radiation in Space Missions: A Machine Learning Approach.* Acta Futura 5.

[5] Vilalta R., Kuchibhotla S., Ocegueda-Hernandez F., **Hoang S.**, Pinsky L. (2011) *Machine Learning for Identification of Sources of Ionizing Radiation During Space Missions*. Workshop on AI in Space: Intelligence Beyond Planet Earth. International Joint Conference on Artificial Intelligence (IJCAI-11), Barcelona, Spain.

[6] Stoffle N., Pinsky L., Empl A., **Hoang S.**, Pospisil S., Jakubek J., Turecek D., Vykydal Z. (2011), *Simulation of Van Allen Belt and Galactic Cosmic Ray Ionized Particle Tracks in a Si Timepix Detector*. International Comic Ray Conference, Beijng, China.

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