Particle Charge and Velocity Discrimination Using Silicon Timepix Detectors

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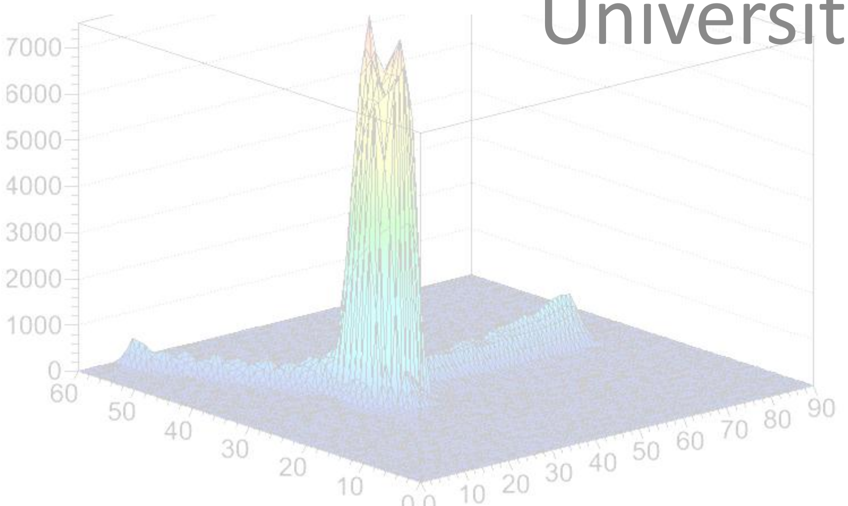

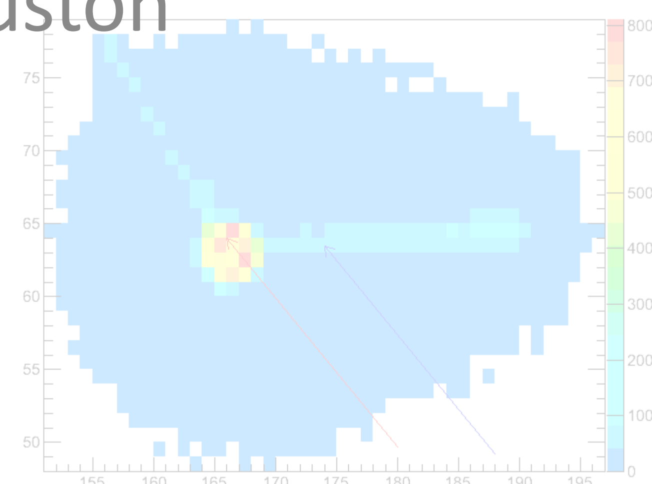

Collaborators

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Why try to resolve *z* and *v*

courtesy of www.nasa.gov

Charged particle telescope stacks are proven so why try to use a single layer Timepix detector for particle ID?

The end goal is to allow Si Timepix detectors to be used as operational monitors on manned spacecraft

Low-power, space-constrained environments impose limitations on power, data processing, and hardware envelope

Further, the extraction of particle field information allows flexibility in dose endpoint

Silicon Timepix Detectors

Timpix based devices are relatively low power, compact, robust, and have a large dynamic range

Silicon detectors provide data from a well-characterized material and provide a wide range of response to ionizing radiation from photons through heavy ions

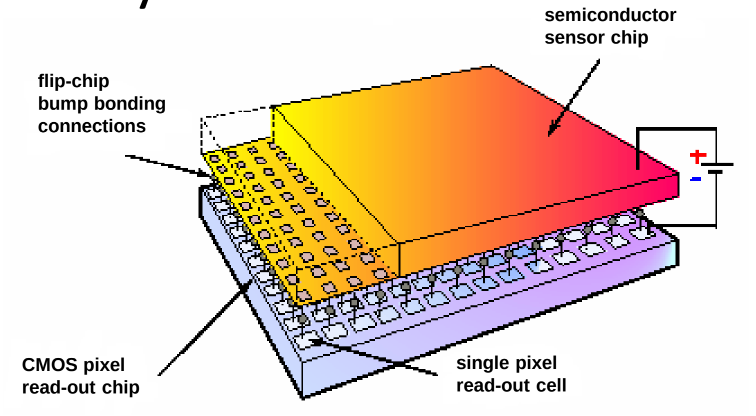
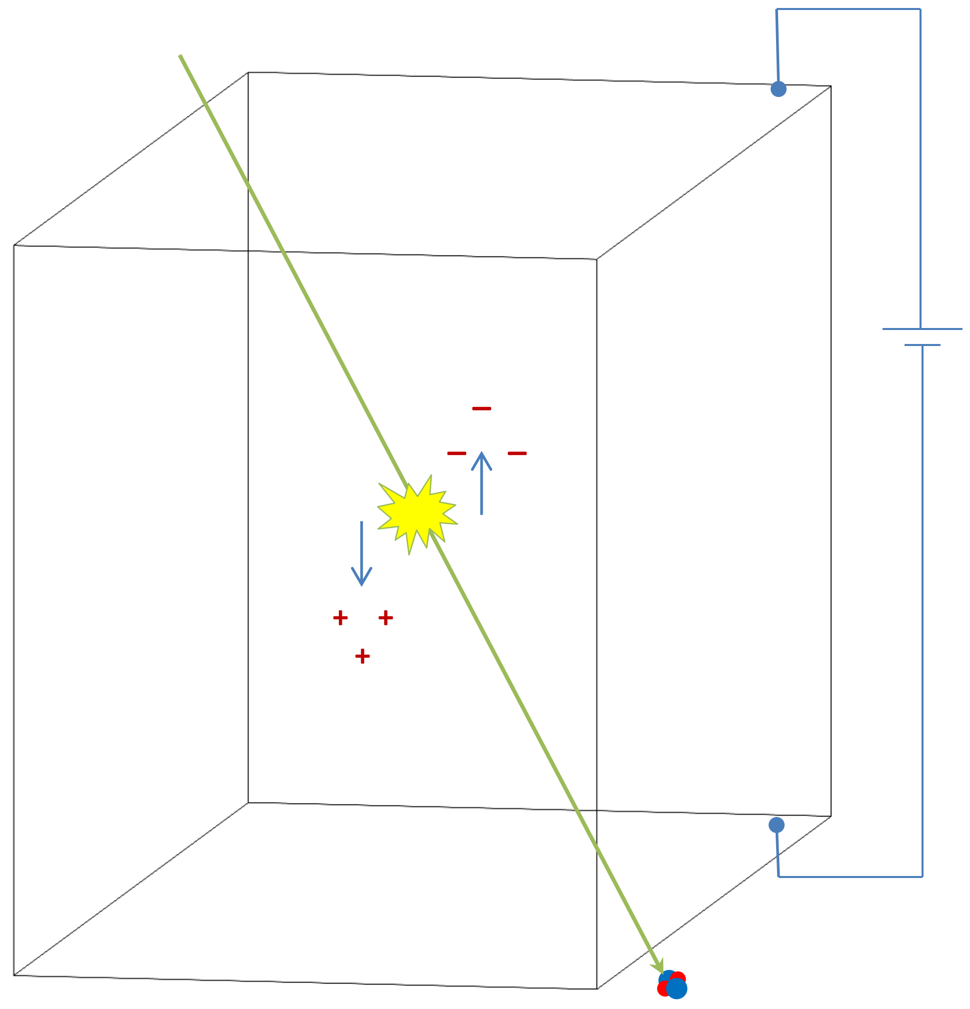


Image from Medipix collaboration website: http://medipix.web.cern.ch/medipix/img/medipix2/web_flipchip.gif

Charge Carrier Production

Ionization along the primary track results in production of free charge carriers

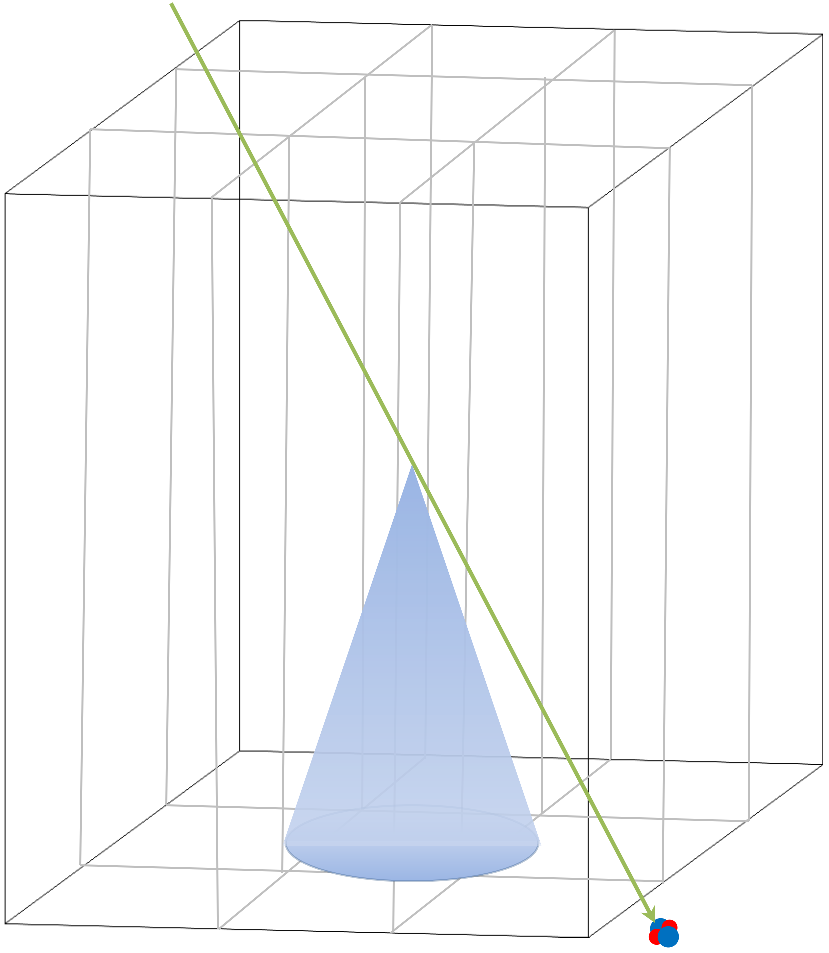
The charge cloud drifts under the influence of the applied bias



Charge Carrier Movement

Charge cloud diffusion creates motion perpendicular to the drift

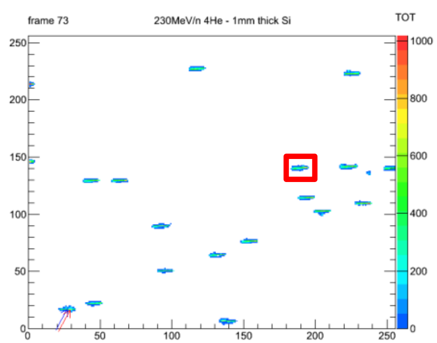
The resulting charge is collected at the back plane of the detector



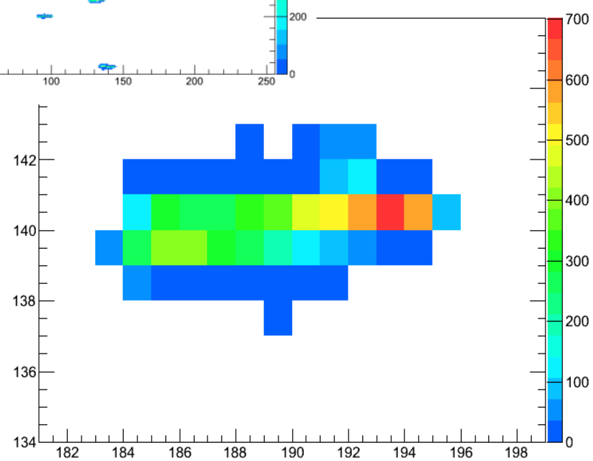
Dosimetry with Timepix

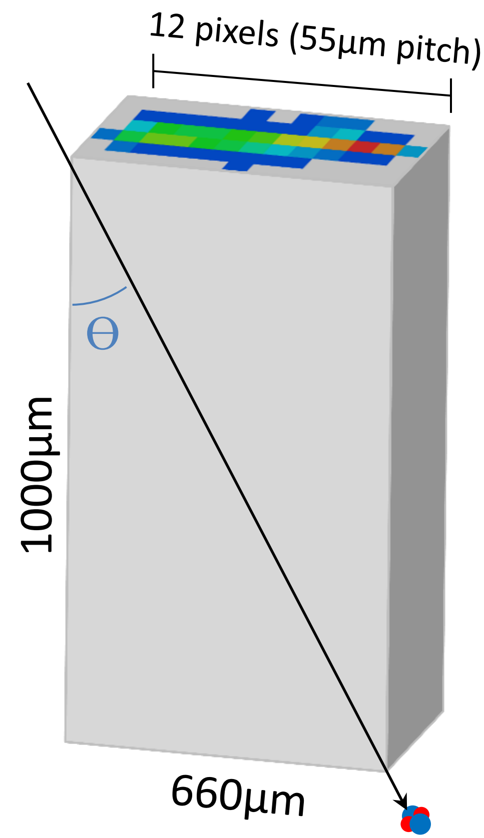
LET estimate from calibrated Time over Threshold data

- Sum energy in cluster
- Calculate angle of track



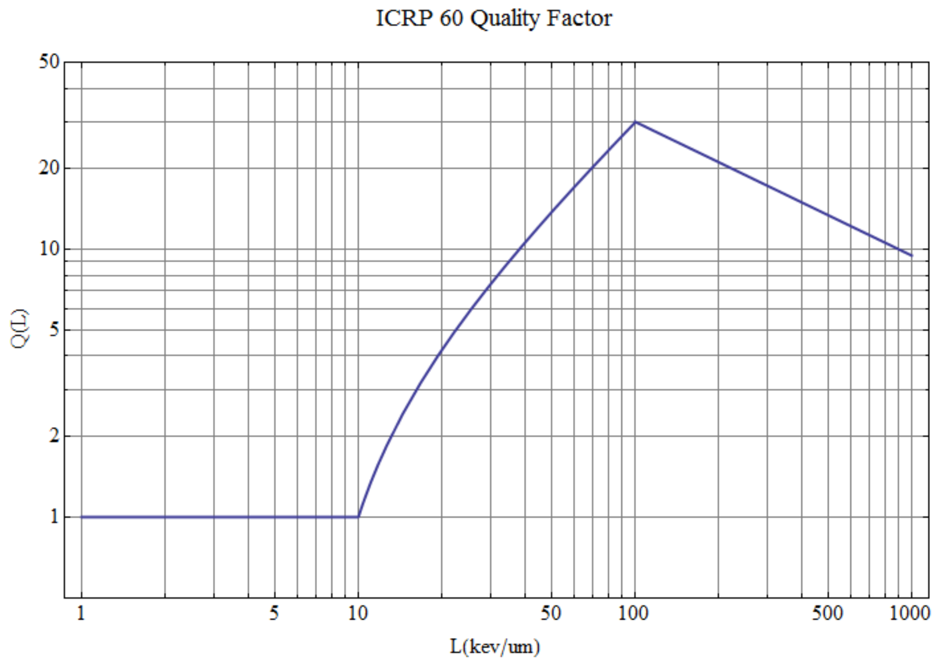
^{4}He ions at 30° from normal





Θ = 33.4°

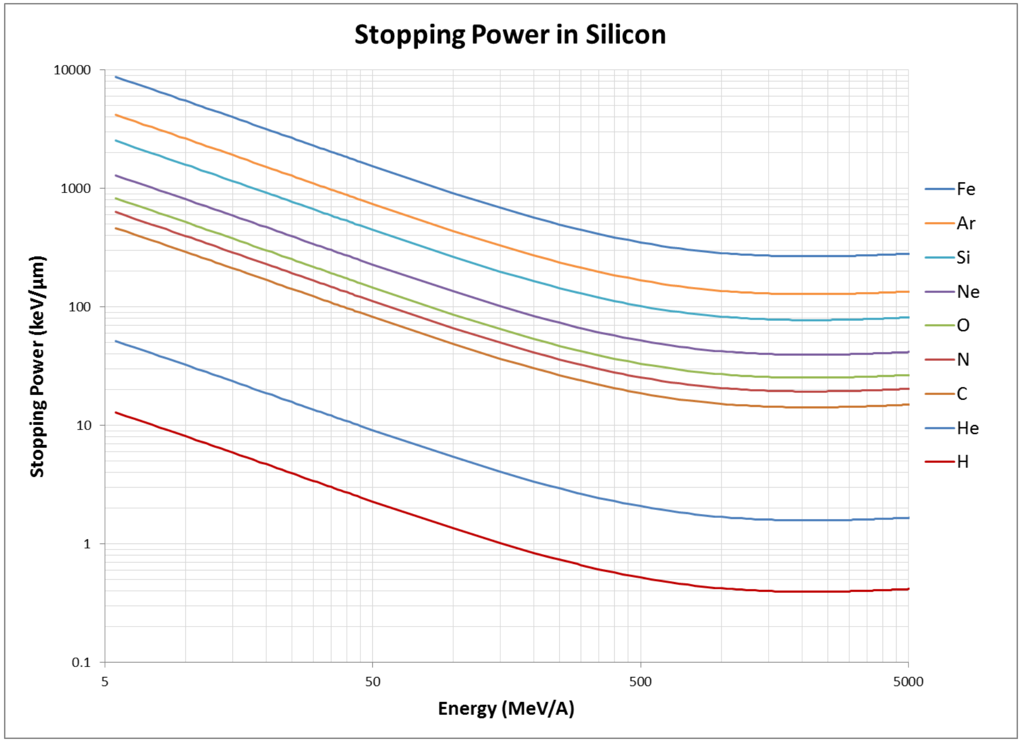
Dosimetry with Timepix



The resulting LET allows dose equivalent estimates based on the ICRP60 defined Q factor

This is the method used for the ISS Payload, but it is still tied to a specific endpoint definition

From LET to z^2/β^2



Minimum dE/dx (keV/µm)	
H	0.395
He	1.580
Li	3.555
Be	6.319
B	9.874
C	14.219
N	19.353
O	25.278
Ne	39.496
Si	77.413
Ar	127.968
Fe	266.996

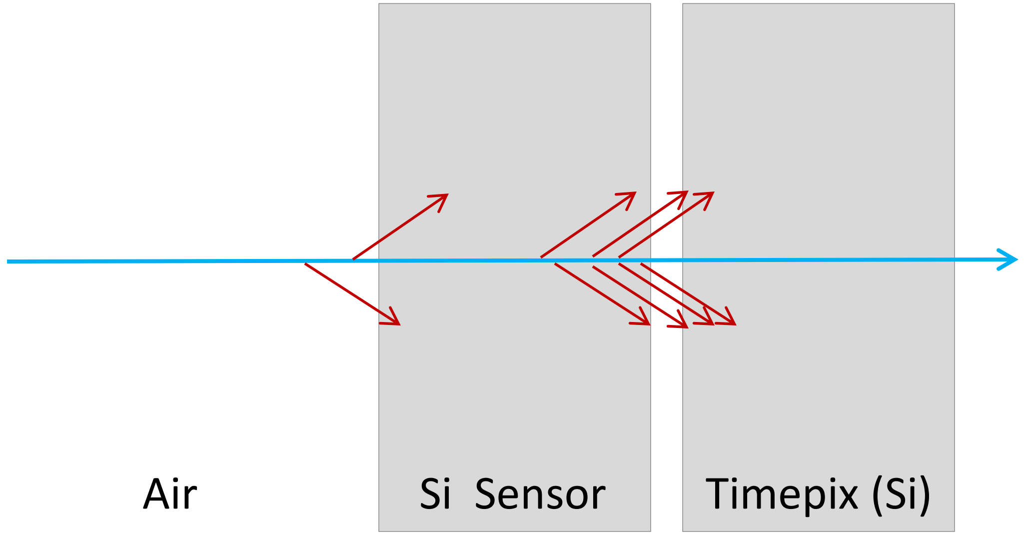
The ratio of charge to velocity can be extracted from stopping power estimates

This allows some differentiation based on assumption of the environment

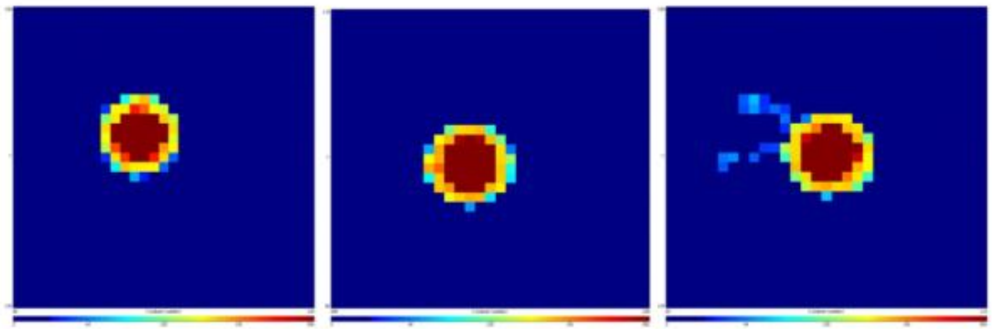
LET vs dE/dx

Remember LET and dE/dx are not the same

One cannot make the assumption of CPE at the detector boundaries



Separation of z and β with δ-rays



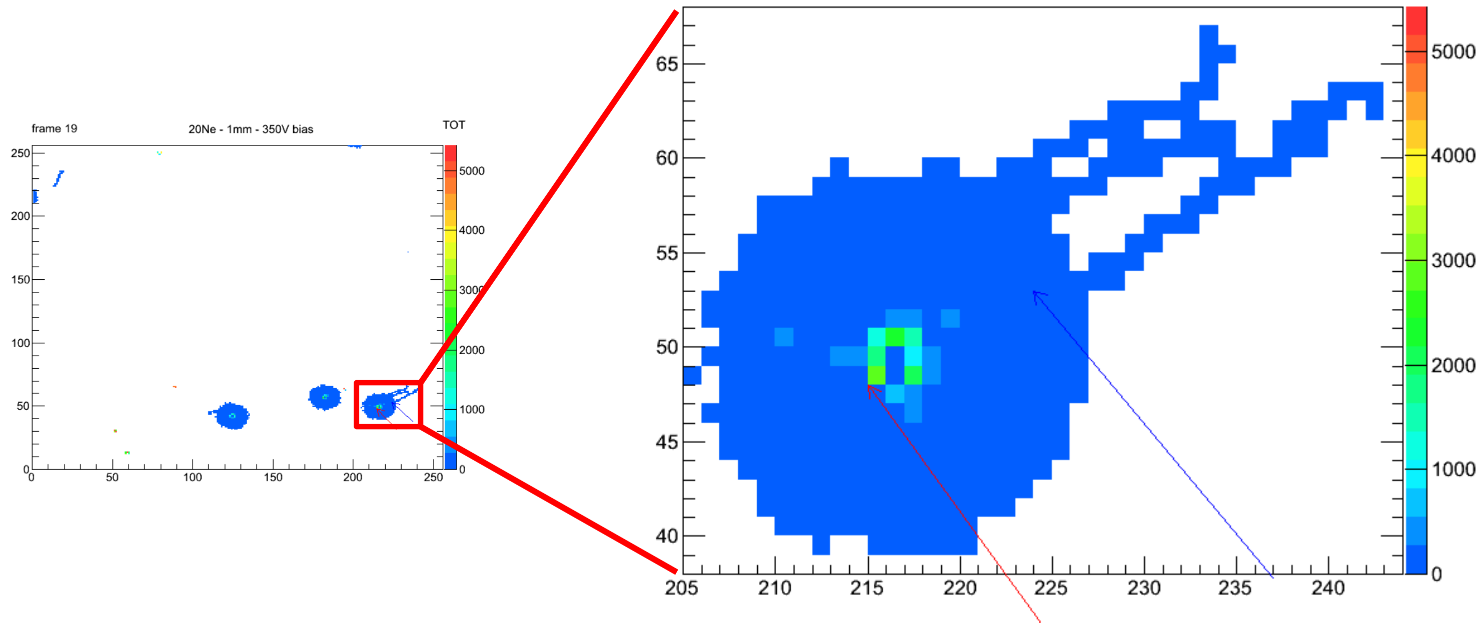
100 MeV/A ^{16}O (86.85 keV/um) | 180 MeV/A ^{20}Ne (90.08 keV/um) | 600 MeV/A ^{28}Si (95.15 keV/um)

The spectrum of the delta rays produced during ionization is influenced by ion charge

This leads to the following questions:

- Can we characterize delta rays with a Si Timepix?
- Can such a characterization be extended to allow particle ID?
- How well can we bin the particles with this ID?

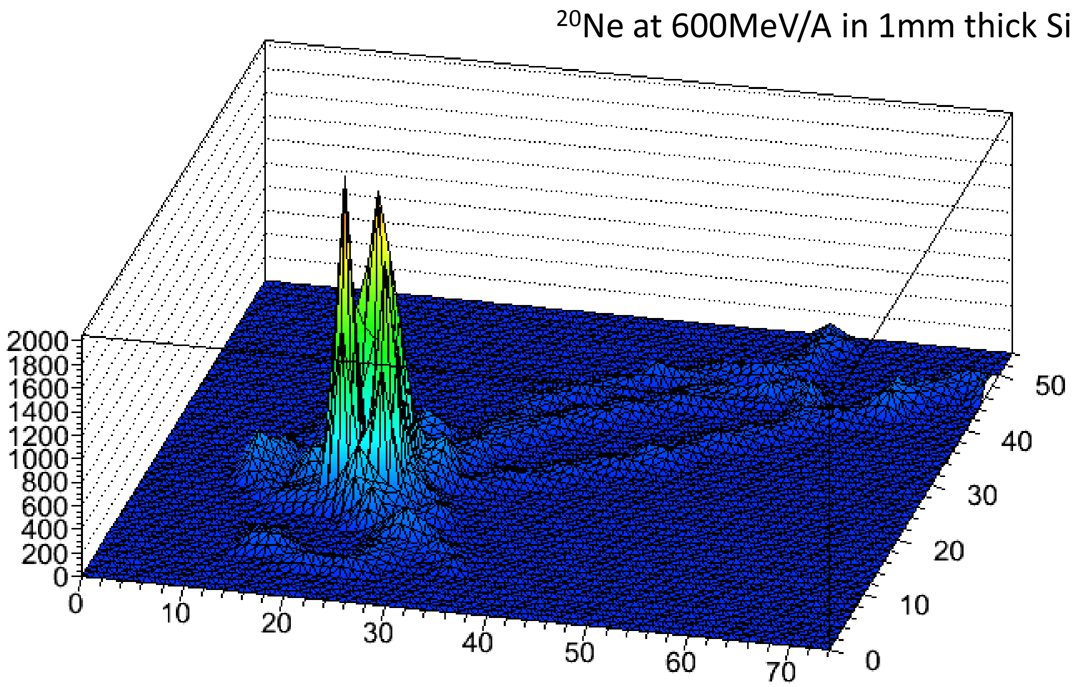
δ-ray detection with Si Timepix



Higher energy delta rays can be identified and the range can be estimated for those tracks

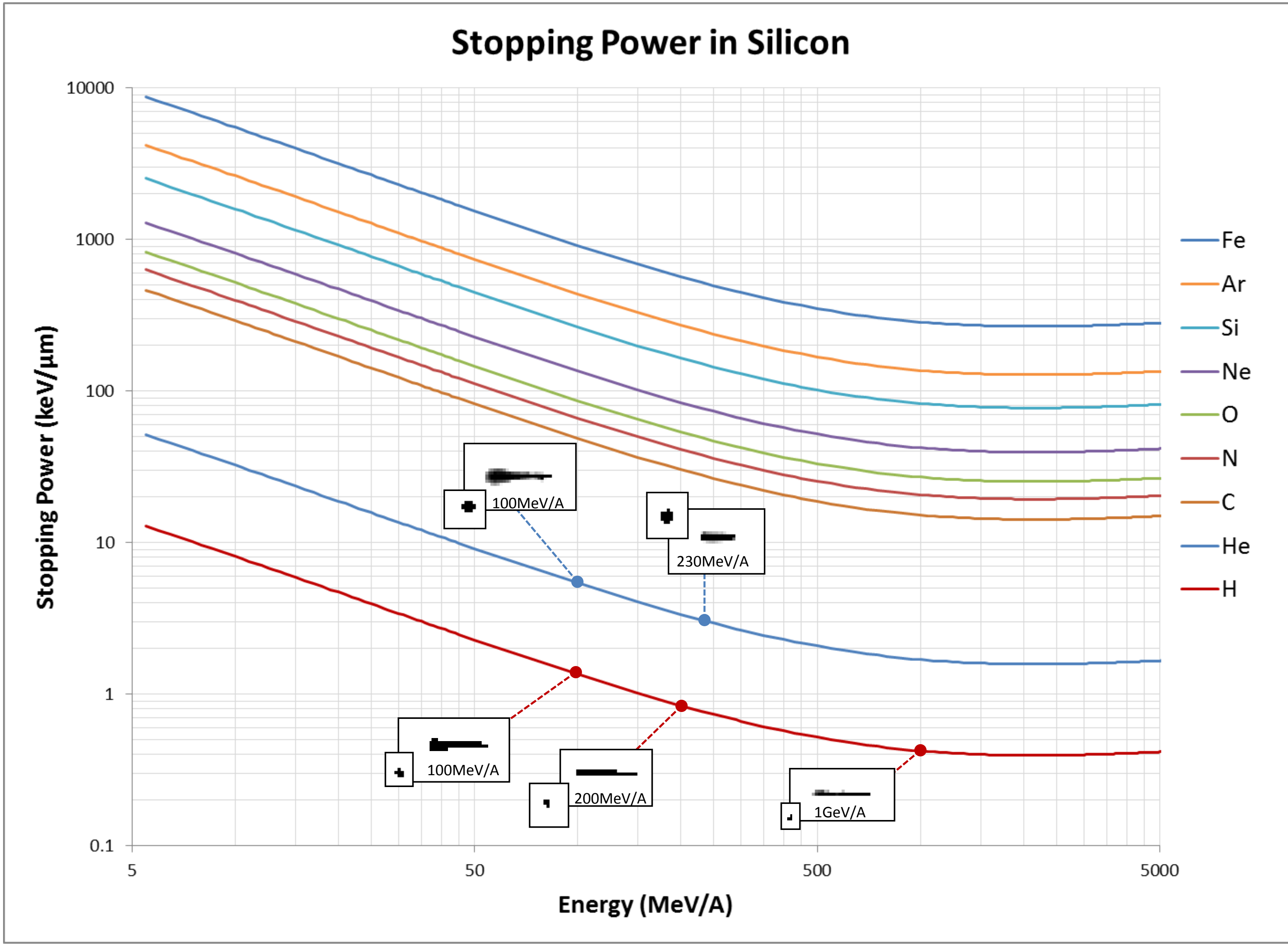
Lower energy delta rays show up as a broad, low count/energy base on the pixel cluster

δ-ray detection with Si Timepix



Delta ray production is visible in the cluster patterns in Timepix data

Thicker sensors show the effects more dramatically but are more affected by charge sharing effects



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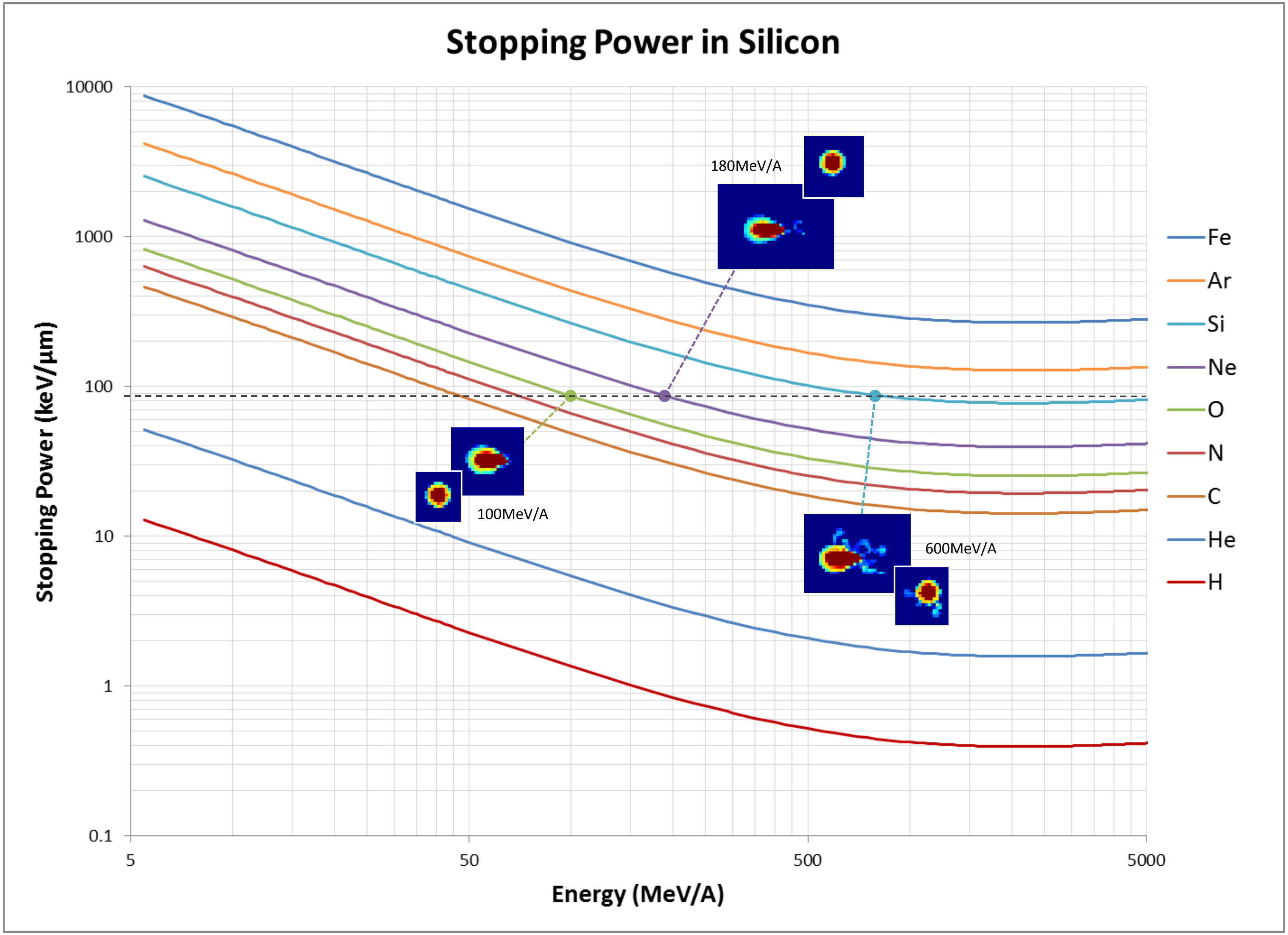

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ISS as a Test Bed

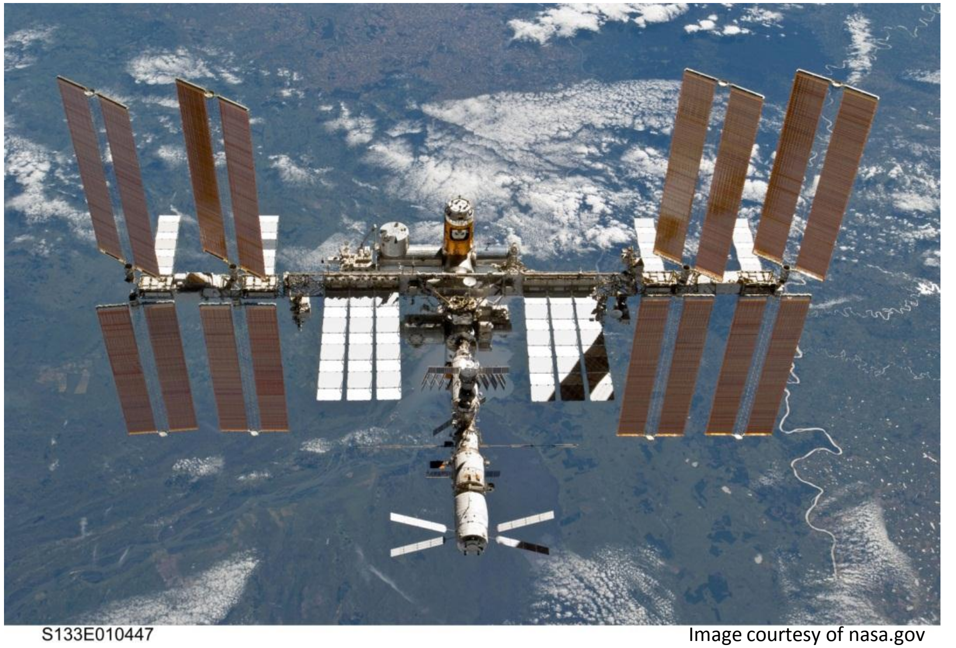


Image courtesy of nasa.gov

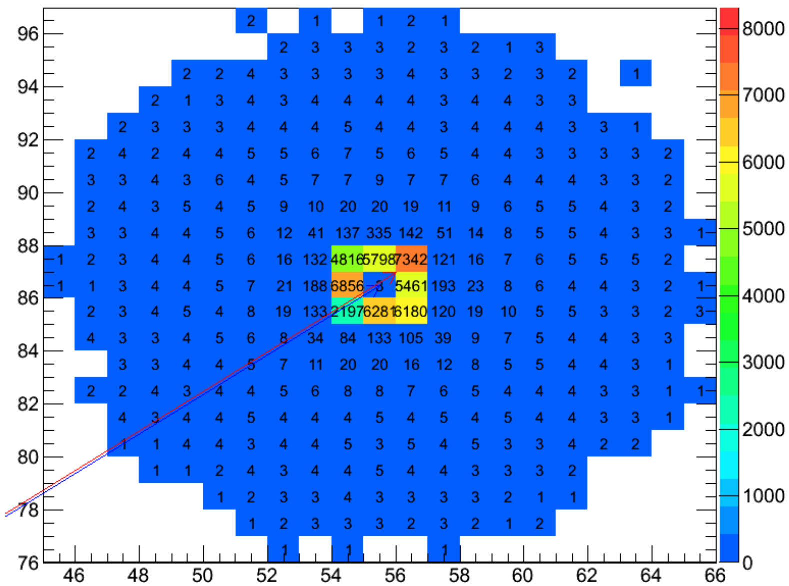
Ground based accelerators do not allow the energy range and mix of particle types found on-orbit

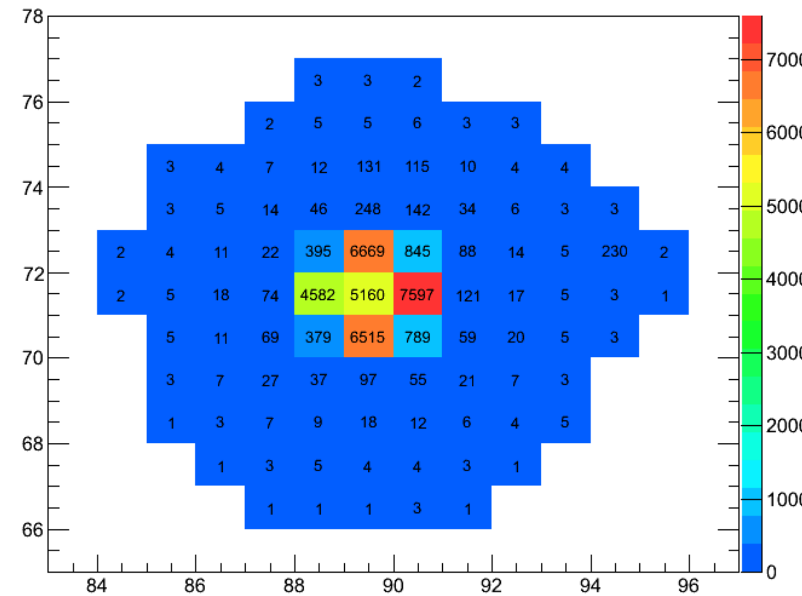
ISS based tests will allow us to experiment with detector settings to optimize future detector design

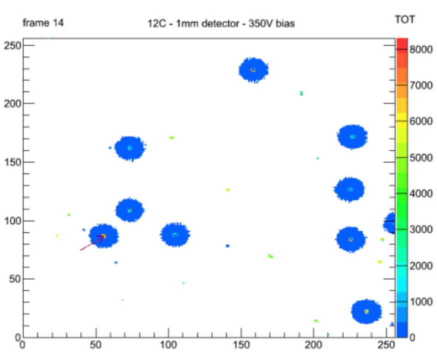
Choice of Si Detector Thickness

100MeV/A ^{12}C
350V bias in 1mm thick Si Detector

100MeV/A ^{12}C
200V bias in 500µm thick Si Detector







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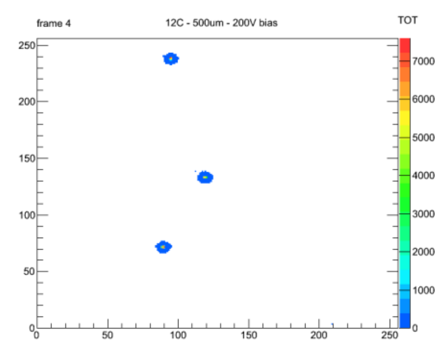


Next Steps

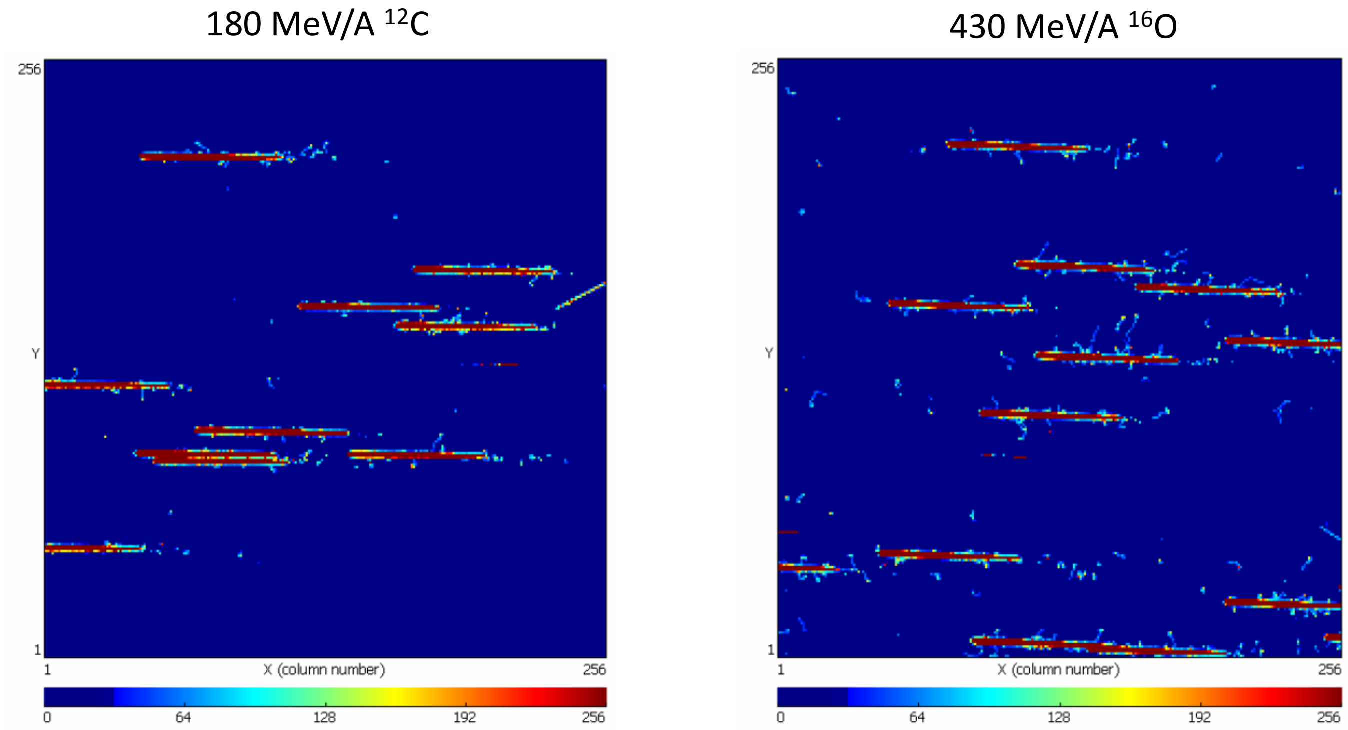
Much of the forward work deals with the determination of particle ID resolution/binning

Investigation of δ-ray spectra should provide some insight

Ion \ MeV/A	100	180	230	290	350	400	430	500	600	650	800
H	1.35	0.90	0.77	0.68	0.61	0.57	0.55	0.52	0.49	0.47	0.44
	231.1	432.9	566.6	734.9	911.6	1065.3	1160.4	1390.4	1739.0	1922.2	2506.7
He	5.42	3.60	3.09	2.70	2.45	2.29	2.22	2.08	1.94	1.89	1.78
	231.1	433.0	566.8	735.1	912.0	1065.8	1160.9	1391.0	1739.8	1923.1	2508.0
C	48.74	32.43	27.81	24.32	22.02	20.63	19.96	18.72	17.48	17.01	16.01
	231.19	433.09	566.94	735.32	912.18	1066.04	1161.19	1391.43	1740.36	1923.65	2508.85
N	66.34	44.14	37.85	33.10	29.97	28.09	27.17	25.48	23.79	23.16	21.79
	231.19	433.10	566.95	735.33	912.20	1066.06	1161.21	1391.45	1740.39	1923.69	2508.91
O	86.64	57.65	49.43	43.24	39.15	36.68	35.49	33.28	31.07	30.24	28.47
	231.19	433.10	566.95	735.34	912.21	1066.08	1161.23	1391.48	1740.42	1923.73	2508.96
Ne	135.38	90.08	77.24	67.56	61.17	57.32	55.45	52.00	48.55	47.26	44.48
	231.20	433.11	566.96	735.36	912.23	1066.10	1161.25	1391.50	1740.46	1923.77	2509.02
Si	265.35	176.55	151.39	132.41	119.89	112.35	108.68	101.92	95.15	92.62	87.18
	231.20	433.12	566.97	735.37	912.25	1066.12	1161.28	1391.54	1740.51	1923.82	2509.10
Ar	438.64	291.85	250.26	218.88	198.18	185.71	179.66	168.47	157.29	153.11	144.11
	231.20	433.12	566.98	735.38	912.26	1066.14	1161.29	1391.56	1740.53	1923.85	2509.14
Fe	915.19	608.92	522.15	456.68	413.49	387.48	374.85	351.51	328.18	319.46	300.67
	231.2	433.1	567.0	735.4	912.3	1066.2	1161.3	1391.6	1740.6	1923.9	2509.2

dE/dx (keV/μm)
Tmax (keV)

Summary



Si Timepix sensors are capable of distinguishing higher energy delta rays from the core ion track

The extraction and use of the delta ray spectrum is promising for identification of ion z and *v*