Analysis status of low-Z particles stopping in CALET

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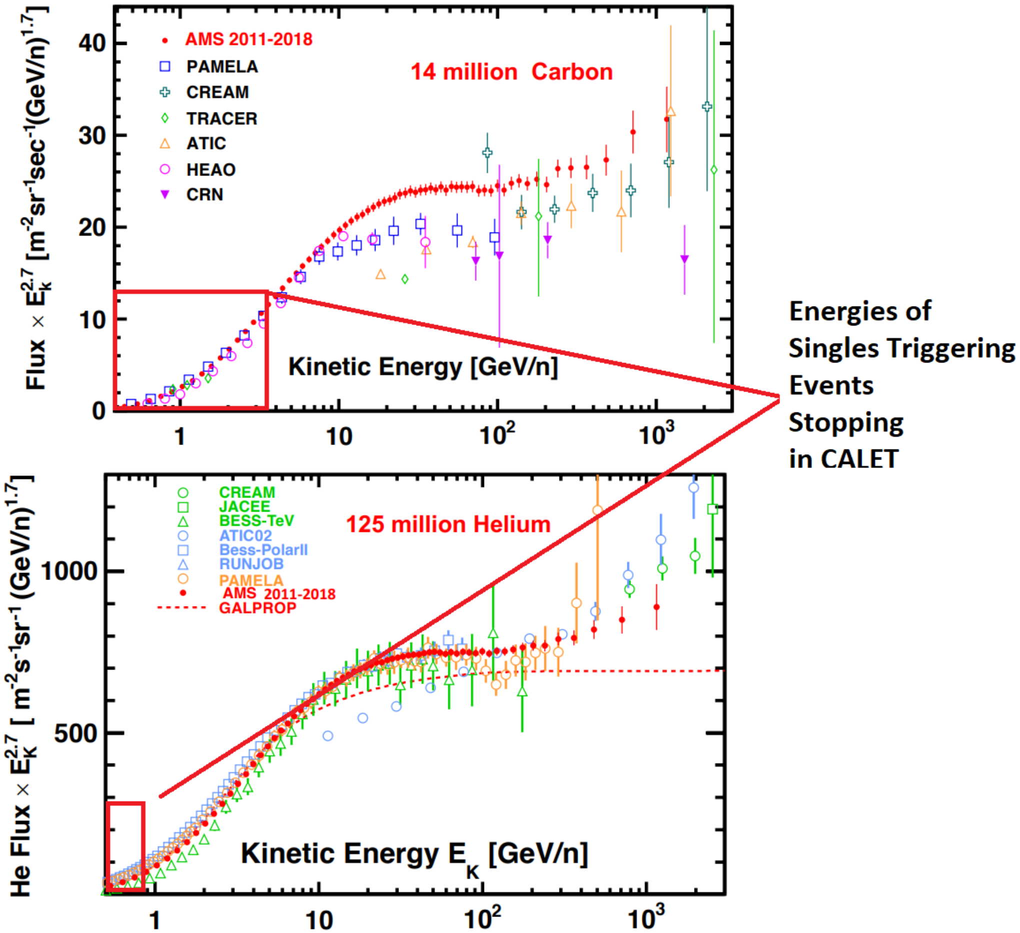
Goals

Select events that come to stop via ionization losses in the instrument.

These events only deposit energy along the track of the particle.

Successful identification of these events should allow extension of CALET measurements to lower energies.

Because of high helium abundance initially develop technique for selecting stopping Helium events and then extend to higher Z.



AMS Carbon He (Q. Yan ICRC 2019)

Fig.1 Region of expected energies of stopping events in CALET for Carbon and Helium in comparison to existing measurements

Initial Strategy

Evaluate regions of orbit where particles of low enough energy to stop are likely to be encountered.

Based on in flight trigger run mode operation select a trigger run mode that is both operated in regions where low energy particles like to be encountered and has good efficiency of triggering on low energy events.

Using simulated data determine selection cuts to identifying incident helium that deposits its energy in the detector via ionization loss as indicated by fIntInfo.fProc = “stop”.

Compare selection parameters in simulated data to flight data.

Determine number of candidate events in subset of flight data.

Simulated Data Set

Reproduce dataset from calibration paper(Niita et al. 2015) to provide reasonable spectrum of primaries with effects of magnetic cutoff taken into account.

Received set of primaries protons, helium, and albedo particles, generated from ATMNC3 code and simulation run in Epics9.27 Cosmos8.038 converted to UO and then simulated pass 3.1 L2

Because simulations were performed on analysis machines at LSU only limited number of events have been run.

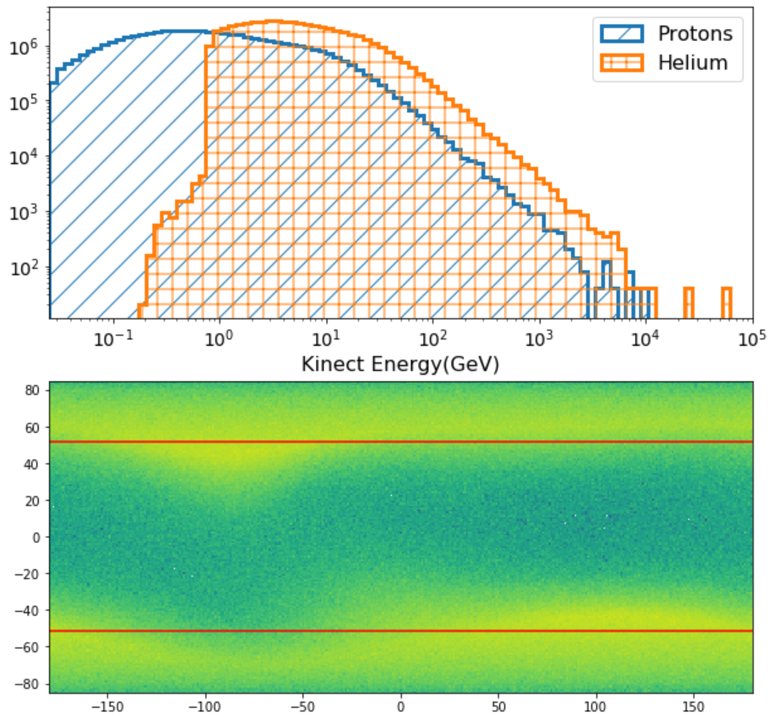


Fig.2 Top sample spectra for protons and helium 4 used, bottom spatial distribution of helium primaries a in geographic latitude and longitude.

Selection of Trigger Mode

Simulation of normal incident helium in EPICS had previously show similar efficiency to event in energy range for Low Energy Electron(LEE), Low Energy Gamma(LEG), and Singles Helium (SiHe) run modes.

Examined Latitude and Longitudes triggers where operated 2015-2018.

LEG primarily run at low latitudes: not suitable.

SiHe: Run over entire Orbit except SAA at a set time each day.

- Initially investigated but upon examination of flight data discovered onboard additional selection parameters discard events likely to be stopping events.

LEE: Run for short time each orbit at high latitude, chosen for further analysis.

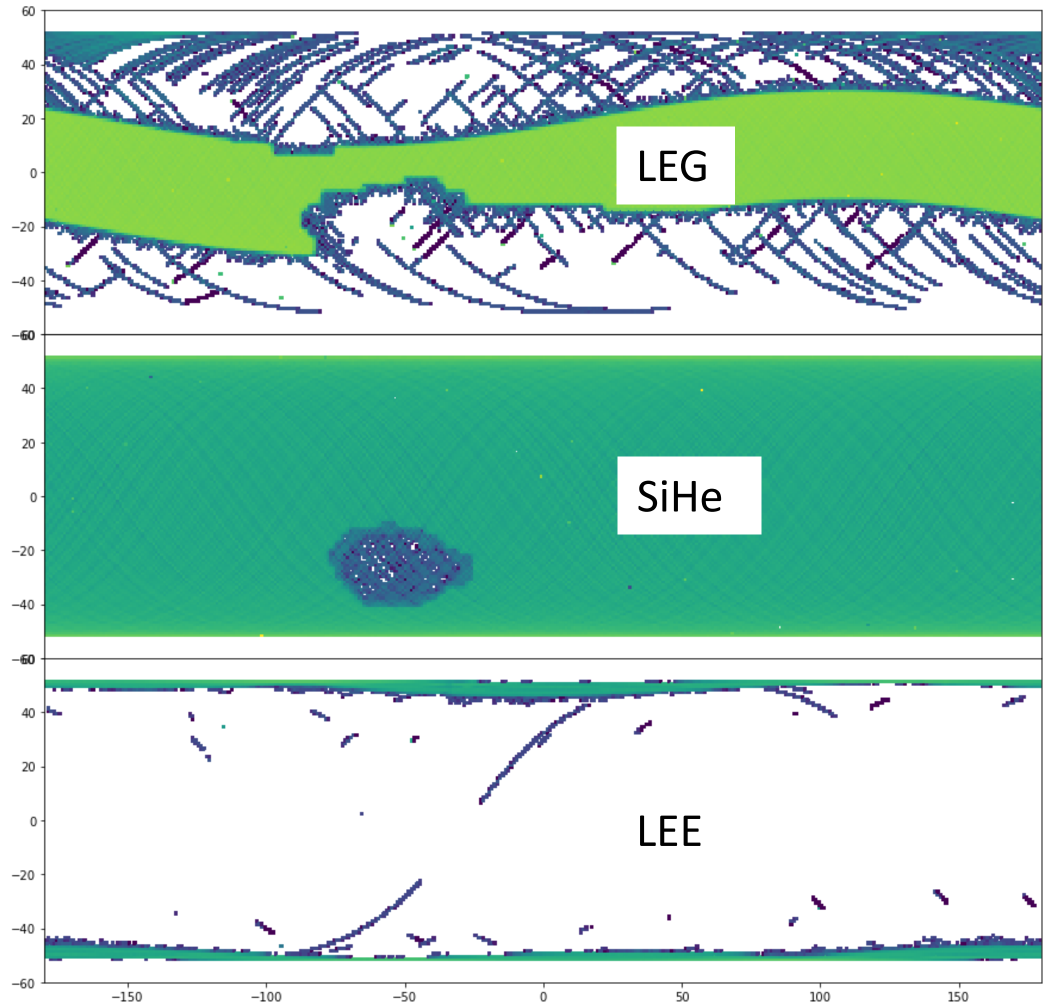


Fig.3 Run time of CALET Singles trigger modes in geographic latitude and longitude..

Geometry

Reconstructed track is critical to successfully identifying stopping events.

Track should look similar to those of MIPs used for calibration, use singles tracking algorithm.

Want to ensure events comes to a stop in the instrument and does not escape out the side or the bottom.

Choose events that pass all the way through from top to bottom of the instrument use Geometry A+B. (Require passing though CHD and Top and Bottom of TASC)

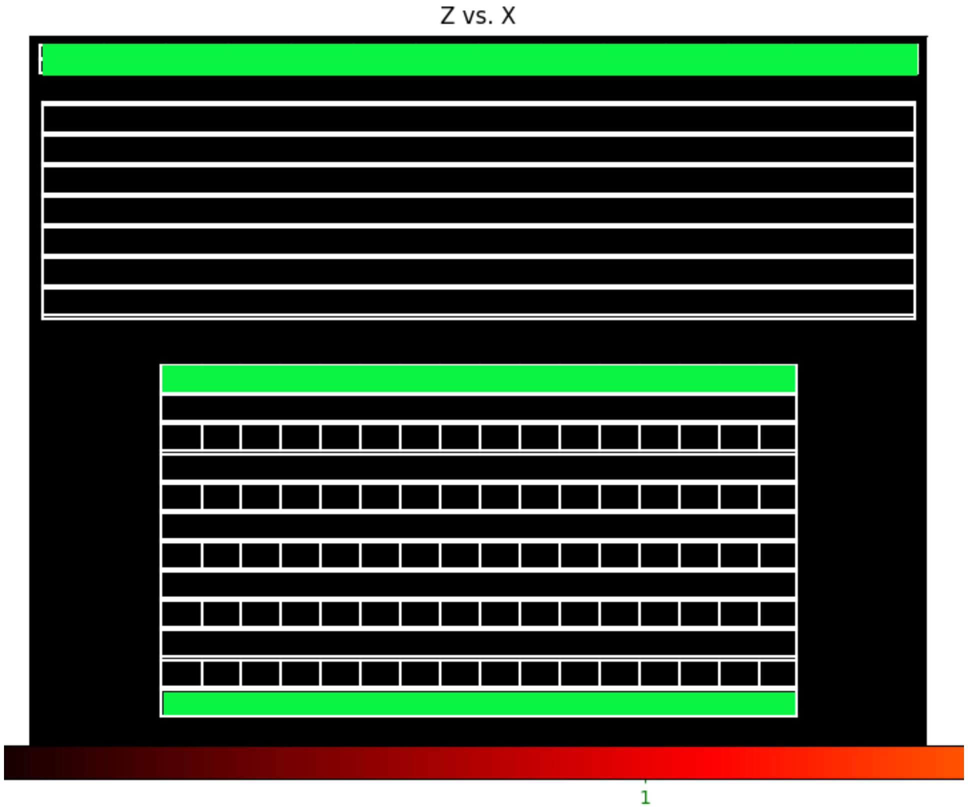


Fig. 4

Comparison of Simulation Data to Flight Data

Initial comparison made with 1 month of flight data (September 2017)

Proton and Helium MIP peaks visible in both simulated and flight data.

Using sum CHDX*cos(Θ_z) for both,

Calculated a weighting factors for both the He and P events to match the height of these peaks.

$W_p = \frac{n_{p,f,1MIP}}{n_{p,mc,1MIP}}$: where $n_{p,f,1MIP}$ are the number

of events in flight data from .5- 2 MIP and $n_{p,mc}$ are the number of events in that range in the proton MC dataset

$W_{He} = \frac{n_{he,f} - W_p * n_{p,mc,4MIP}}{n_{he,mc,4MIP}}$: where $n_{he,f}$ are the

number of events in flight data from 4- 6 MIP and $n_{p,mc,4MIP}$, $n_{he,mc,4MIP}$ are the number of events

in that range in the proton and He MC dataset.

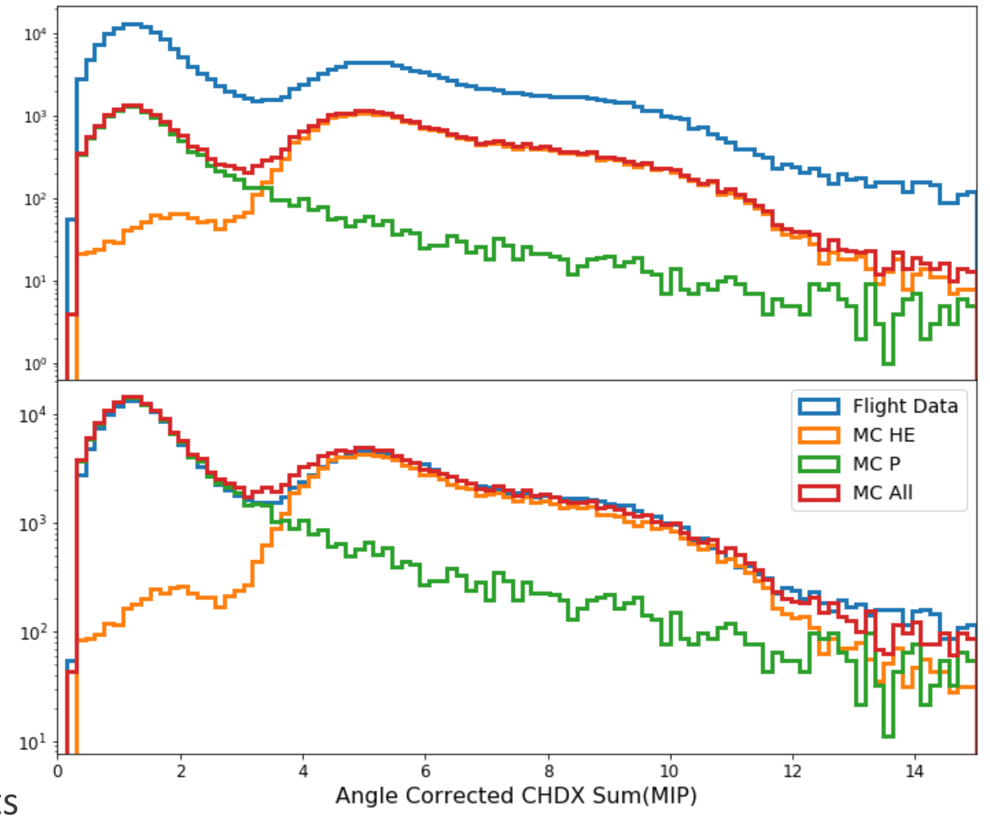


Fig.5 Top unweighted CHDX sum of MC He and proton sample with 1 month of flight data. Bottom after applying weighting factors to MC data.

TASC Sum Cut

Since there is a maximum amount of energy the stopping events can deposit, majority of high energy showering events can be removed with an upper limit on TASC sum.

Require a TASC sum < 130 MIP

Rejection efficiency

$$R_{rej} = 1 - \frac{N_{N,f}}{N_{N,i}} = .401$$

Retention efficiency

$$R_{ret} = \frac{N_{S,f}}{N_{S,i}} = .996$$

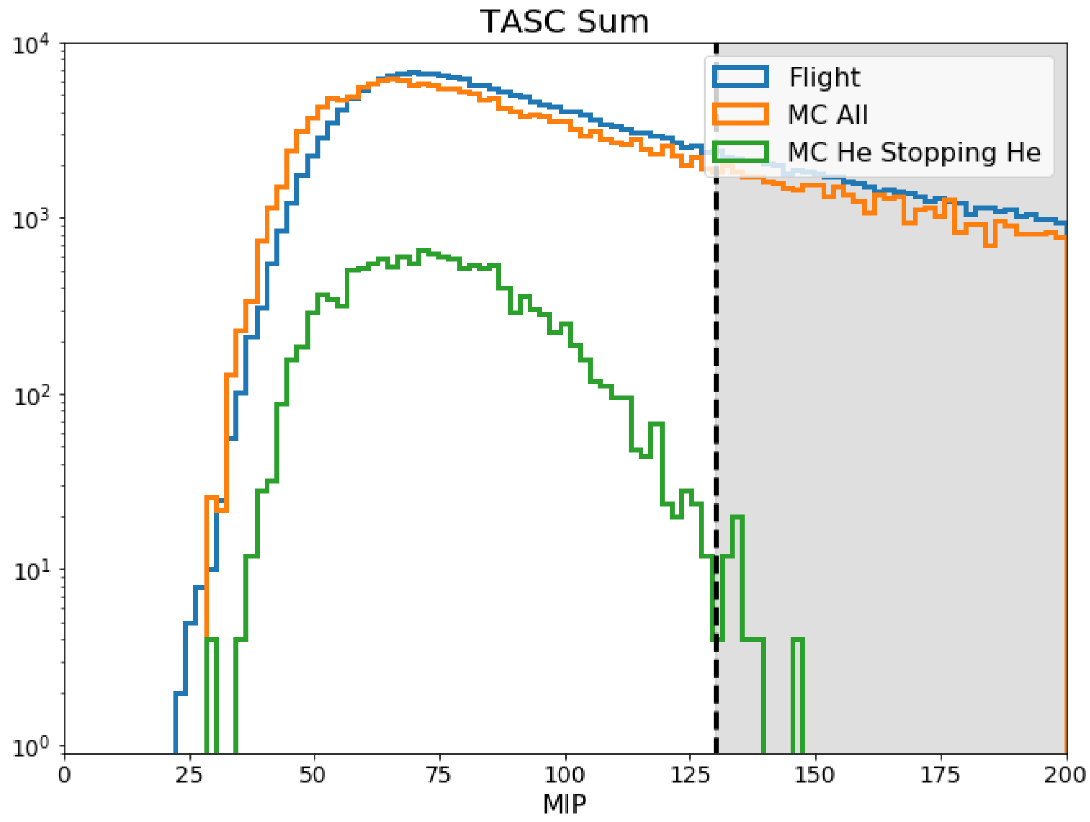


Fig..6 TASC Sum Deposit with cut region shown in gray.

Charge Cut

Helium that will stop within the TASC are lower energy that minimum ionizing particles.

Their energy deposits in the CHD should be at a higher energy with the but should be within a range where they do not reach the TASC to trigger but do not penetrate all the way through.

Require both CHDX and CHDY sums to be between 6-13 MIP.

R_{rej}=.769

R_{ret}=.981

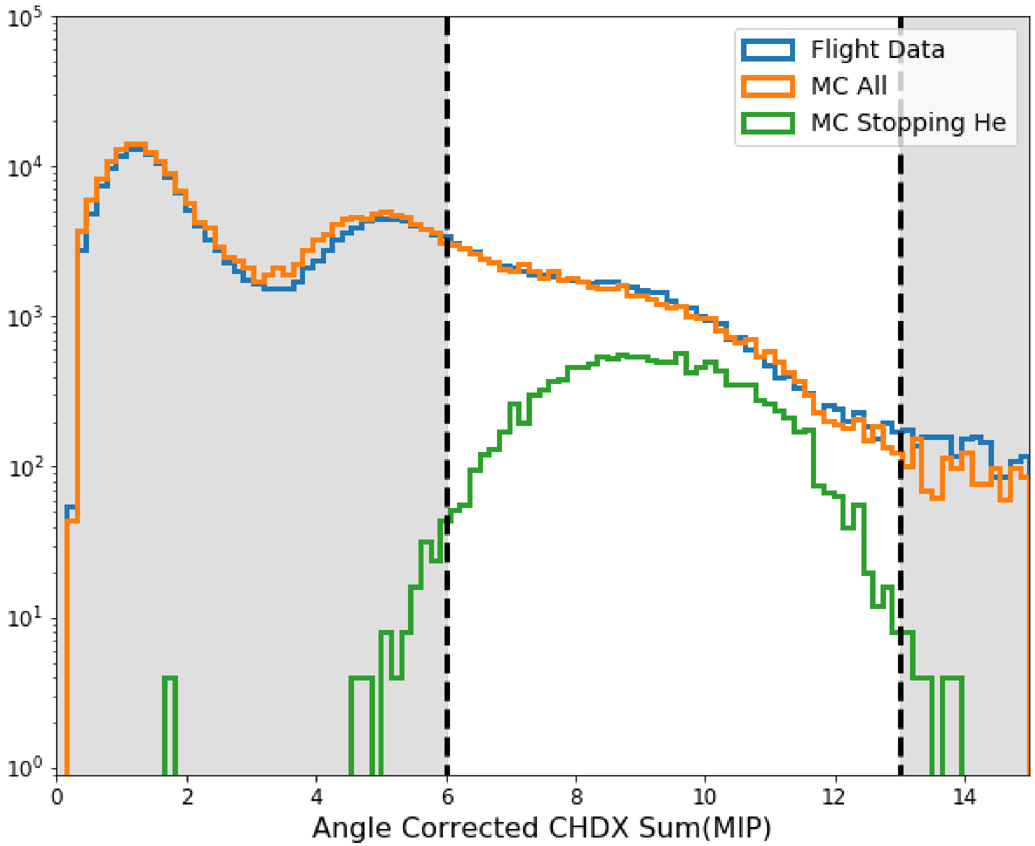


Fig.7 CHDX sum cut for charge of stopping He events selection, a similar cut is made on CHDY

On Track Energy Deposits

Since expect nuclei to travel in straight line and not create secondaries sort TASC energy deposits into 3 categories.

On Track: Energy deposits from TASC logs that the reconstructed track passes through (for inclined tracks may include multiple logs in single layer).

Off Track: Energy deposits from the other TASC logs.

Adjacent: Off track deposits immediately next to the On Track log(s) in the same layer.

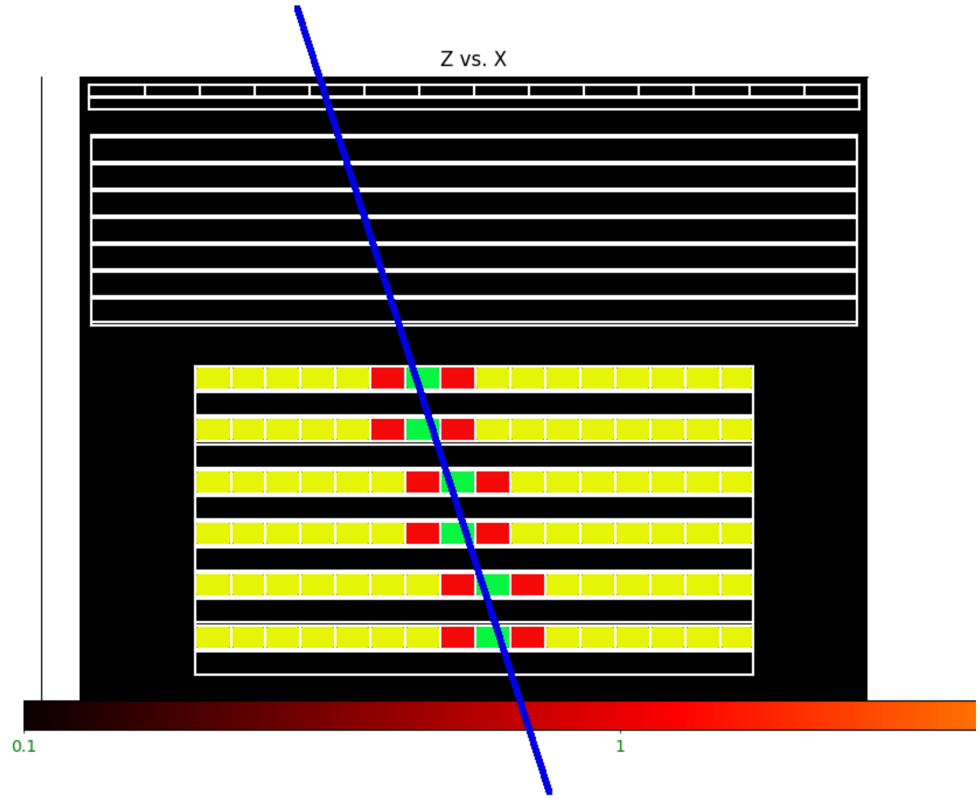


Fig.8 A sample track through the TASC with On Track deposits shown in green, Adjacent in red and Off Track in yellow.

Top and Bottom Layer of TASC Cuts

First look at the On Track Deposits in TASC X-1 and TASC Y-6

In TASC X-1 have a minimum cut looking for large deposit expected, removing higher energy events or events with inaccurate tracks.

A maximum cut to remove events higher energy event that have begun to shower.

In TASC Y-6 maximum cut to remove events penetrating through the TASC.

R_{rej}=.389

R_{ret}=.936

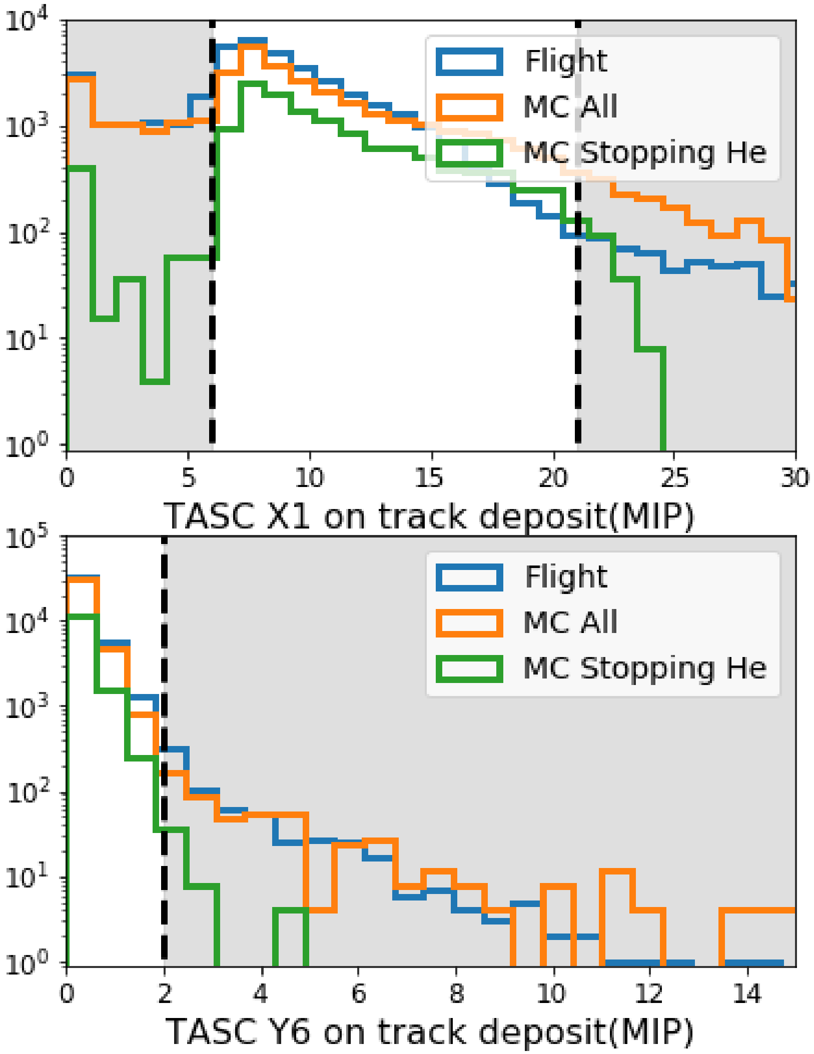


Fig.9 On track deposits for TASC X1(TOP) and Y6(Bottom) for both flight data and MC data.

Maximum On track Deposit Layer Sum

Expect a large deposit in one of the layers as the particle reaches the peak of the Bragg Curve.

There is an upper limit where it starts to penetrate to the next layer.

In flight data the deposits seem shifted to lower values.

R_{rej}=.124

R_{ret}=.993

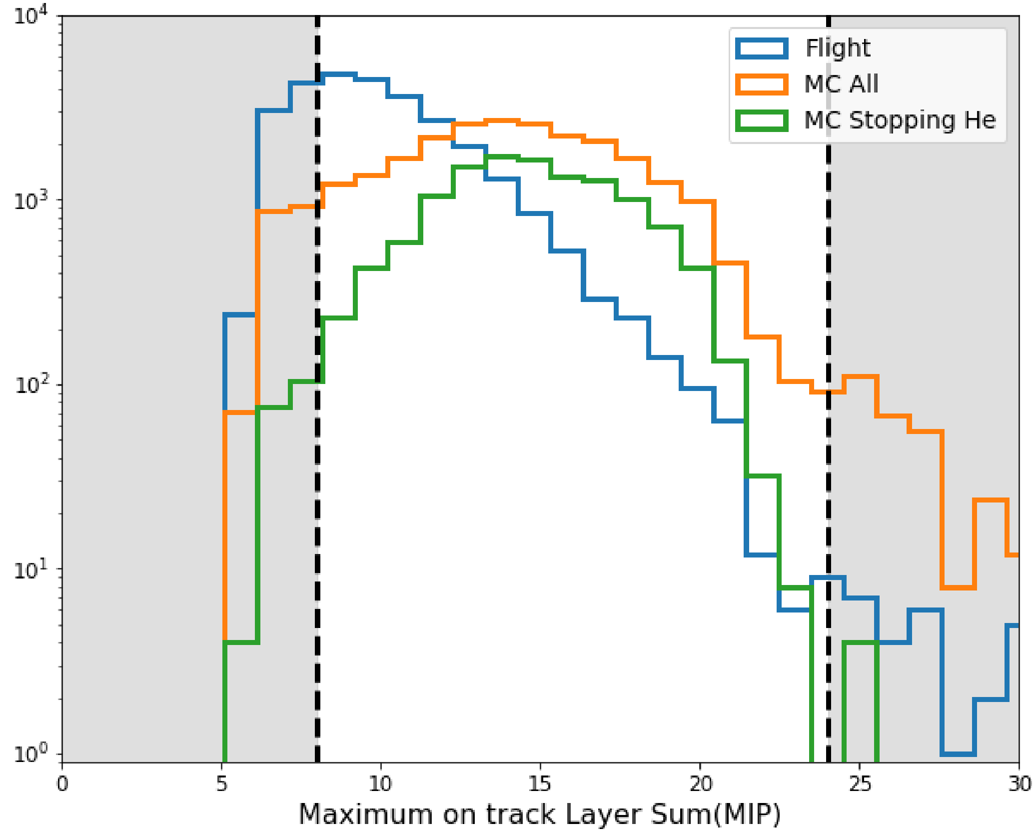


Fig.10 Maximum layer of sum of On Track deposits for both MC and flight data..

Track Adjacent Deposit sum

For stopping events expect all the deposits to be along the track.

Look excess deposits immediately adjacent to the track to remove colliding events by taking the sum of the adjacent logs.

Cut on a maximum at the point where the stopping events become subdominant, < 4 MIP

R_{rej}= .536

R_{ret}=.750

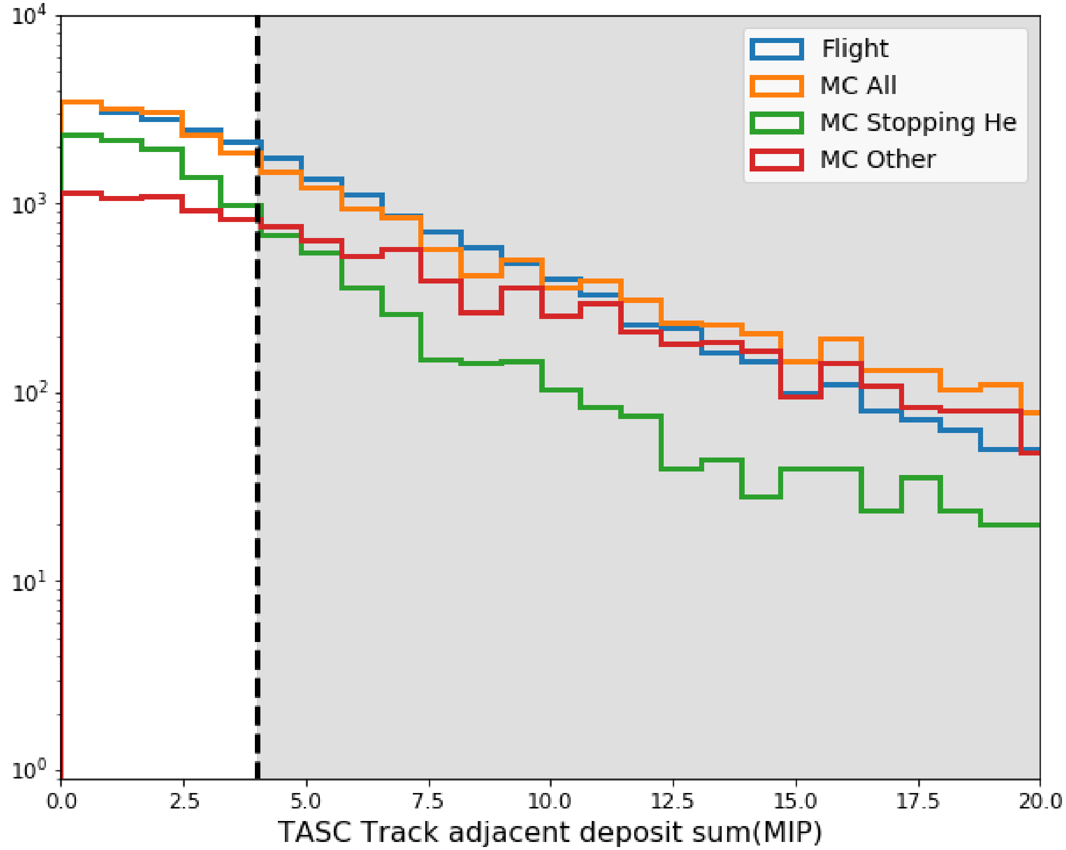


Fig.11 Adjacent sum of TASC deposits, with stopping He being dominant in the region below 4 MIP

DE/Dx vs Total E (Simulation)

After applying preceding cuts take the average of CHDX and CHDY as $\frac{dE}{dX}$.

Take sum on the On Track TASC deposits as Total Kinetic energy.

Stopping events seem to be in reasonable agreement with dE/dX calculation.

Possibility of selection between interacting and stopping events along black line.

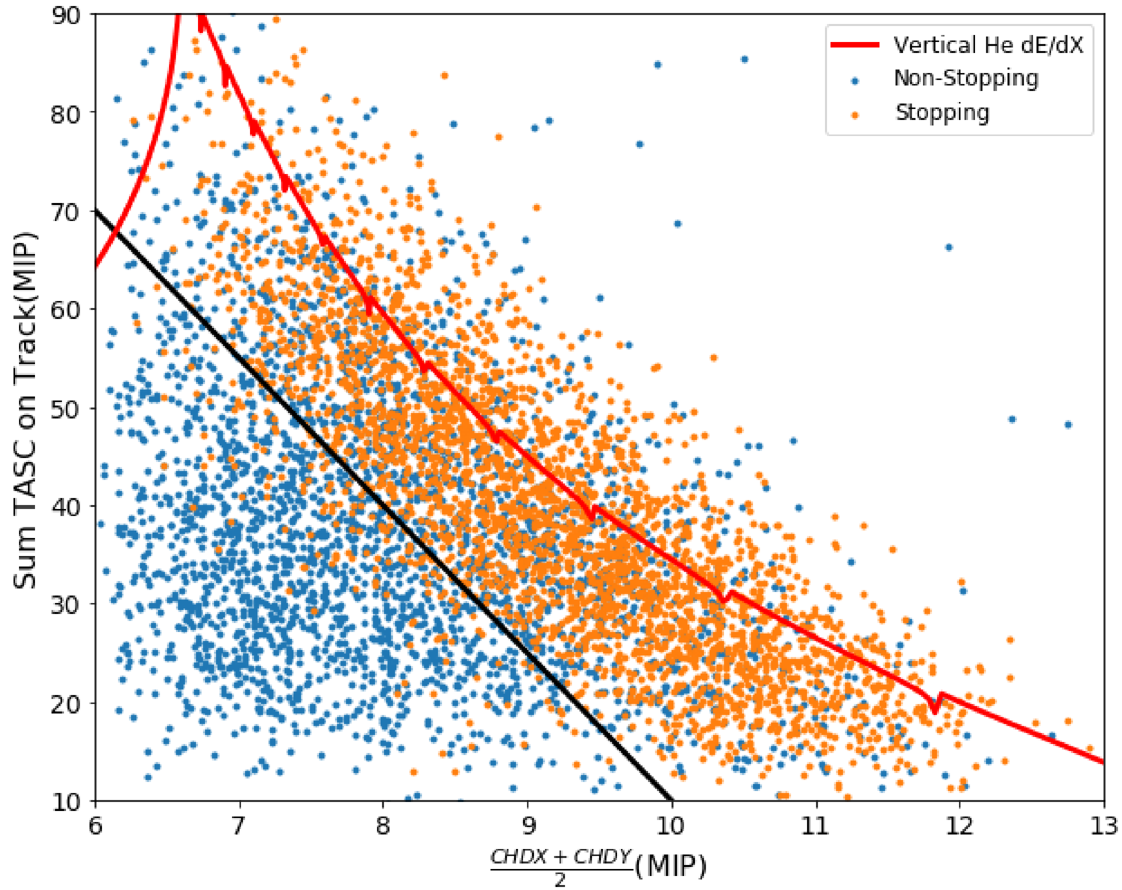


Fig.12 Remaining sample of MC events with stopping events shown in orange, remaining contaminating events shown in blue.

DE/Dx vs Total E (Flight)

Flight TASC energy deposits seem to be shifted lower similar to the maximum deposit.

Requires further examination.

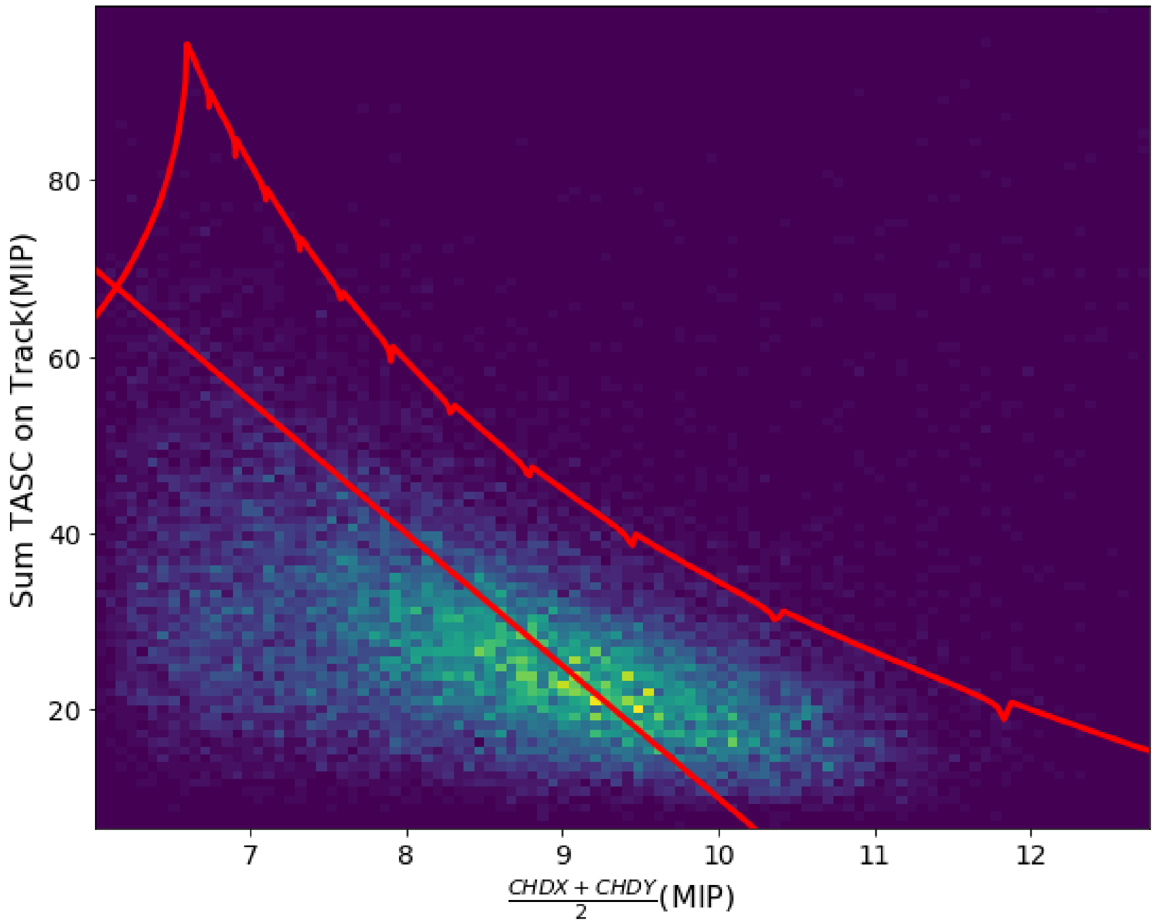


Fig.13 Remaining sample after applying previous cuts, red straight line is in same location as black line as possible separation on fig 12

Candidates from Flight Data

Simulation sample after applying previous cuts (No $\frac{dE}{dX}$ vs E cut)

64% Stopping events

36% Other Events

Retained 68% stopping events

Rejected 96.5% other events

Applied Cuts to 1 month of flight data yielded ~7,000 events.

Performed visual inspection of some candidates to look for examples of likely events and obvious showering events.

Stopping Candidate

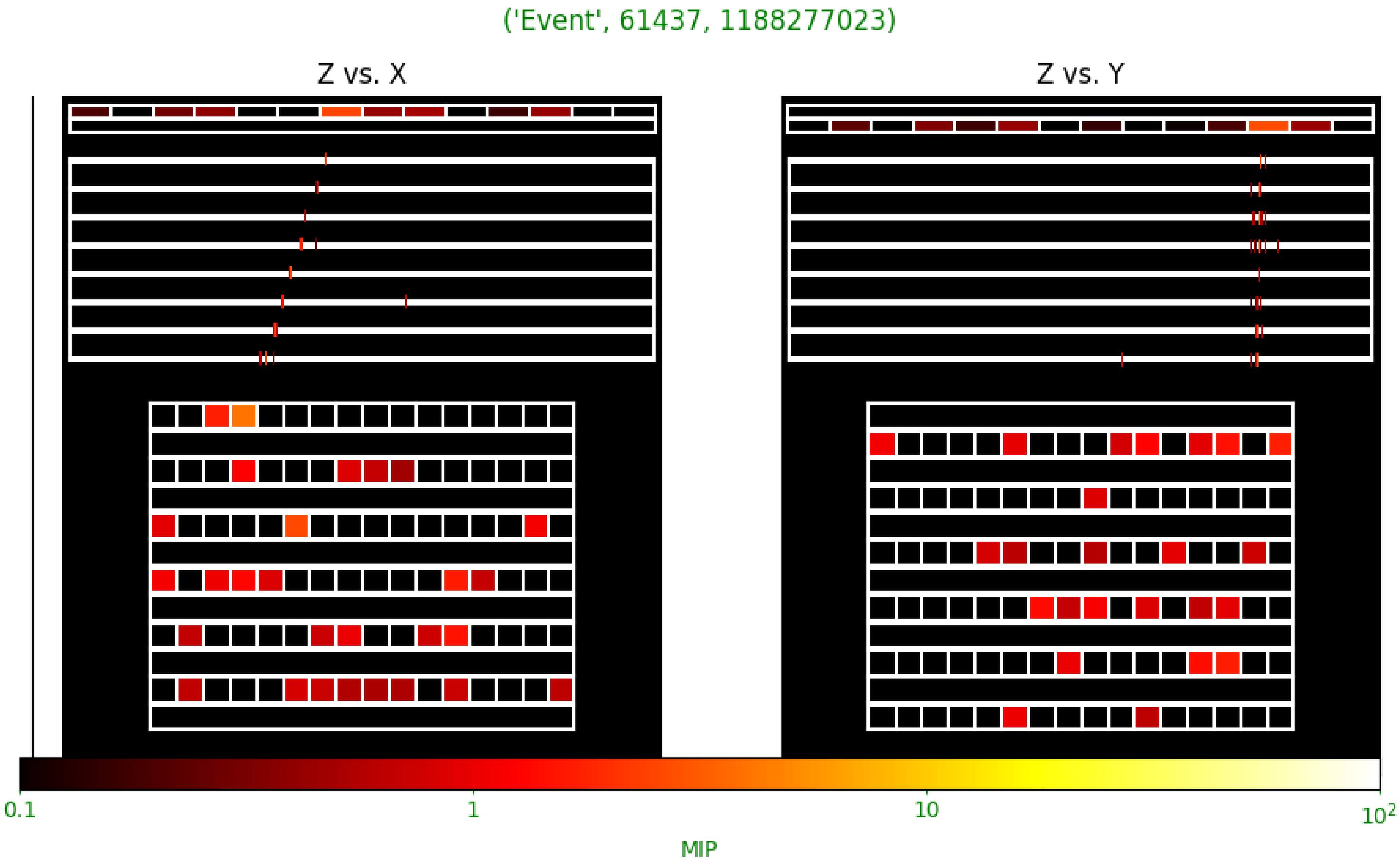


Fig.14 “Good” Stopping candidate from flight data

Stopping Candidate(Obvious Shower)

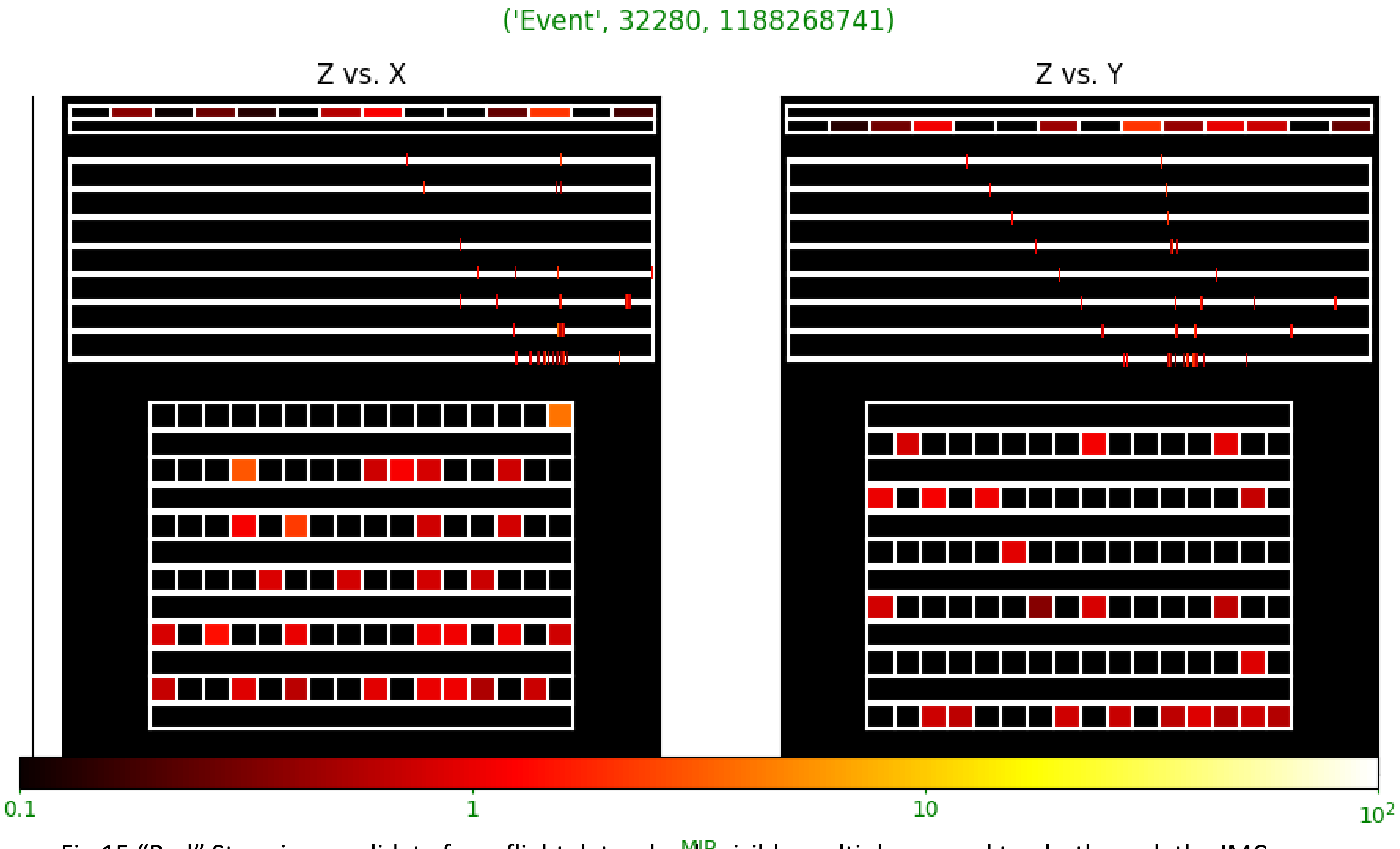


Fig.15 “Bad” Stopping candidate from flight data, clearly visible multiple upward tracks through the IMC

Future Work

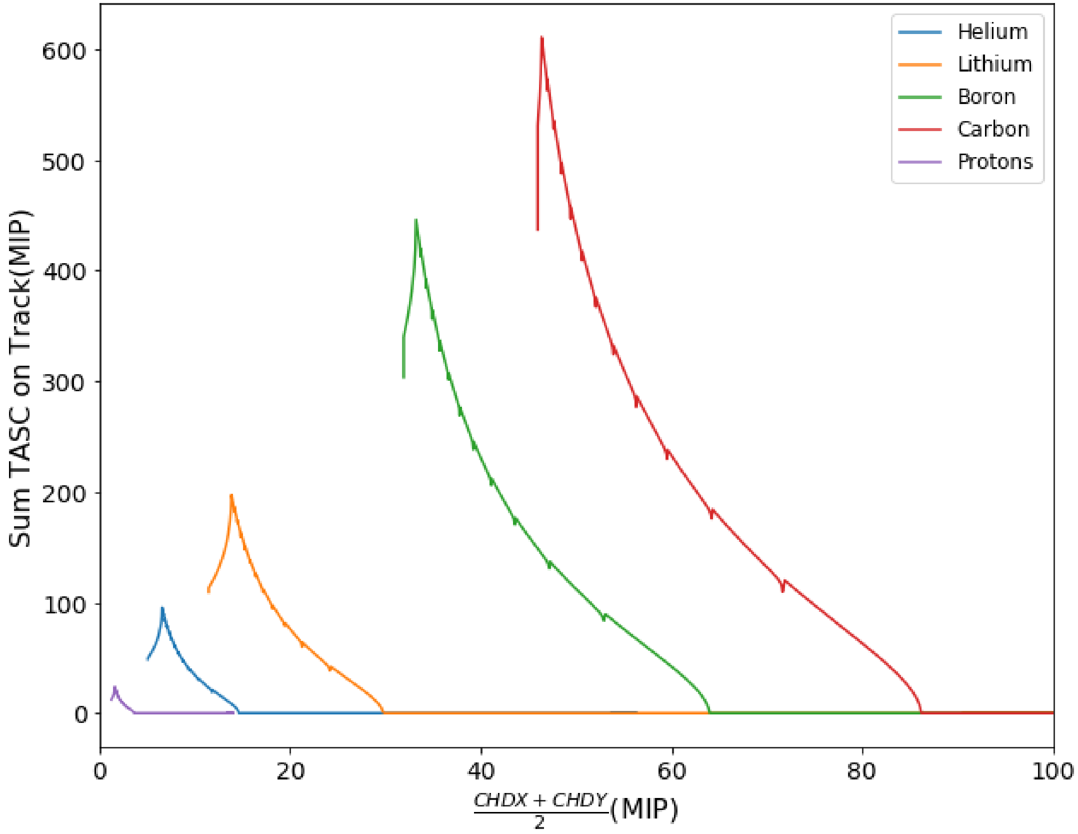
Need further investigation as why flight data TASC deposits seem lower compared to simulation.

Develop track-based cuts for IMC and CHD to remove shallow showering or upgoing events.

Current cut values selected visually, develop systematic method for selection of cut values.

Additional simulation for improved statistics. (Only ~3000 triggering stopping events in original sample).

Backup Slides



dE/dX calculation for protons through Carbon

Normal Incident EPICs Sims

	All Incident		LE Gamma		LE Electron		Single P		Single He	
	E (GeV)	F	E (GeV)	F	E (GeV)	F	E (GeV)	F	E (GeV)	F
He-4	<2.34	.4	.66-1.65	.34	.66-1.64	.33	.64-2.34	.3	.64-2.34	.3
B-11	<11.4	.3	2.8-11.4	.19	2.8-11.9	.19	2.8-11.4	.19	2.8-11.4	.19
C-12	<15.3	.3	3.7-15.3	.18	3.7-15.3	.18	3.7-15.3	.18	3.7-15.3	.18
O-16	<25.8	.28	5.8-25.8	.15	5.8-25.8	.15	5.8-25.8	.15	5.8-25.8	.15