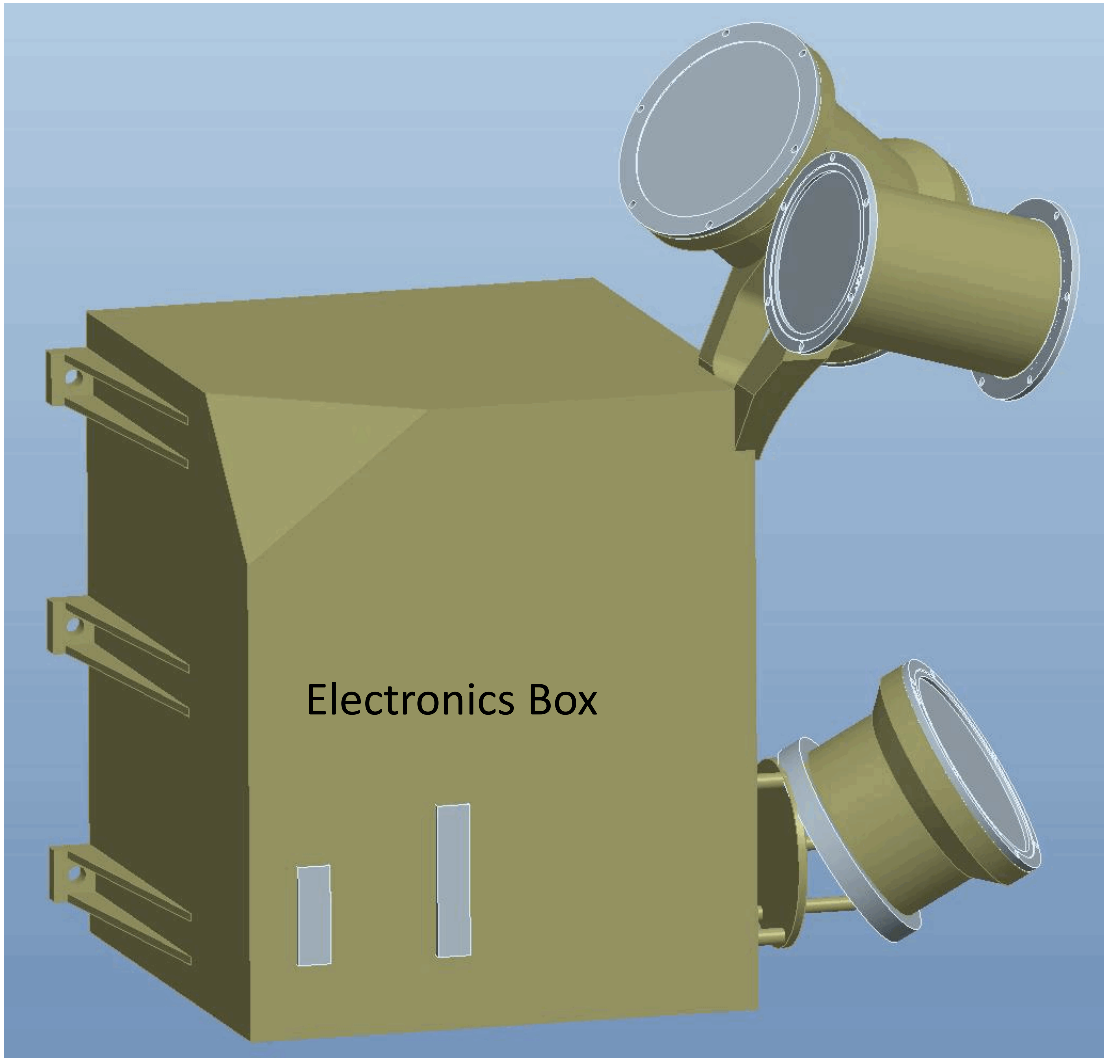
# Review of Suitability of PHASIC Design Parameters for the Meeting Science Requirements of the ISIS/EPI-Hi Instrument for Solar Probe Plus

# Introduction: Sensor System

- EPI-Hi is designed to measure energetic nuclei from ~1 to ~100 MeV/nuc and electrons from ~0.5 to ~5 MeV including:
    - identification of major elements
    - identification of $^{3}He$
    - energy spectra
    - angular distributions
    - timing
- the sensor system consists of three solid-state detector telescopes including:
    - one double-ended Low Energy Telescope designated LET1
    - one single-ended Low Energy Telescope designated LET2 largely identical to LET1 but omitting the end that is blocked by the SPP spacecraft
    - one double-ended High Energy Telescope (HET)

# EPI-Hi Configuration

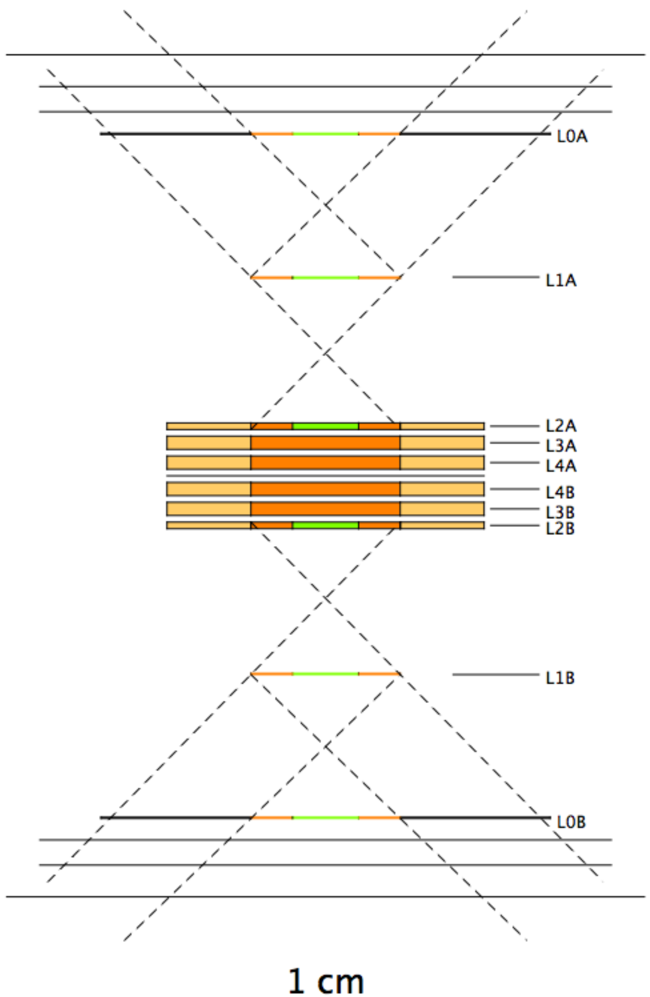
LET1 (double ended)

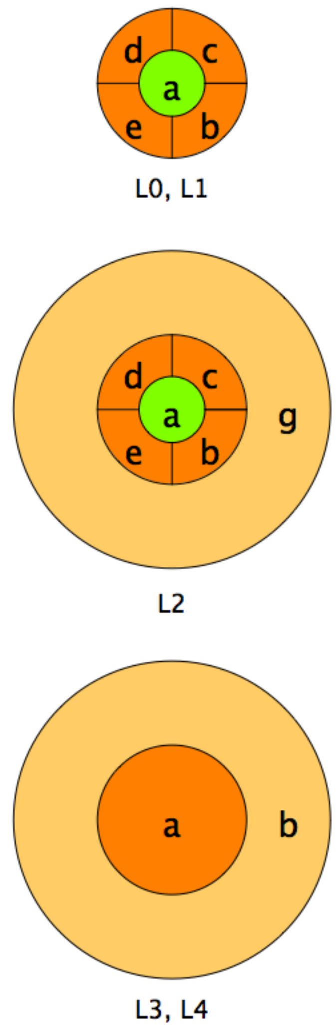



HET (double ended)

LET2 (single ended)

EPI–Hi LET1



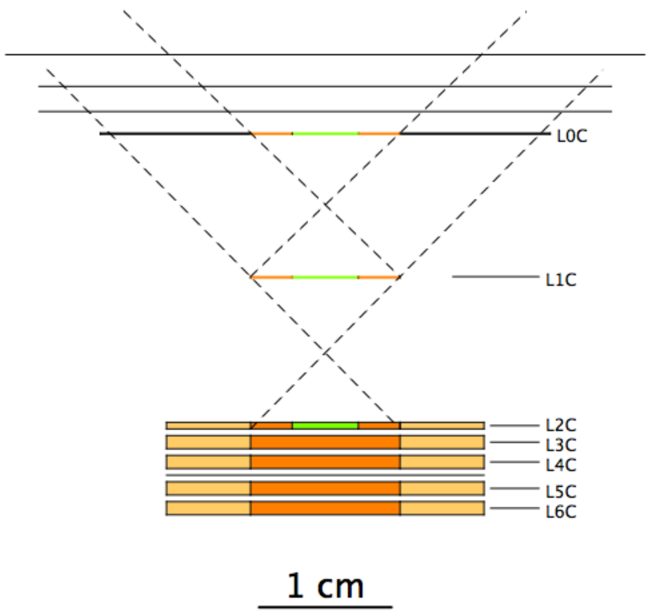



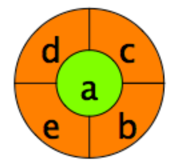

**EPI-Hi LET1 Telescope Detector Elements**

| ID | Thickness | Segmentation | Active Areas |
|---|---|---|---|
| L0 | 12 $\mu$m | bull's eye<br>4 annular quadrants | 0.2 $cm^2$<br>0.2 $cm^2$ each |
| L1 | 25 $\mu$m | bull's eye<br>4 annular quadrants | 0.2 $cm^2$<br>0.2 $cm^2$ each |
| L2 | 500 $\mu$m | bull's eye<br>4 annular quadrants<br>annular guard | 0.2 $cm^2$<br>0.2 $cm^2$ each<br>3.5 $cm^2$ |
| L3, L4 | 1000 $\mu$m | bull's eye<br>annulus | 10.6 $cm^2$<br>37.1 $cm^2$ |

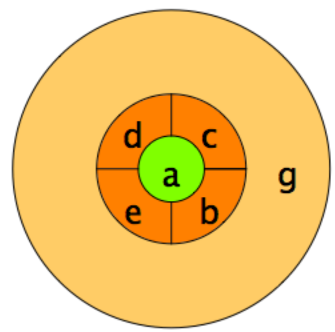
Note: active Si is shown in color, inactive materials in black or grey.

## EPI–Hi LET2

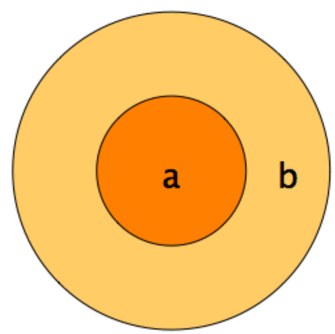


L0, L1



L2

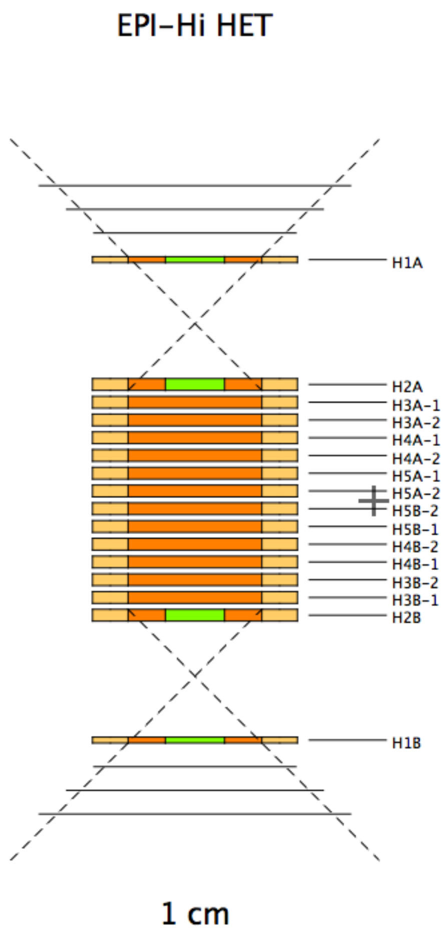


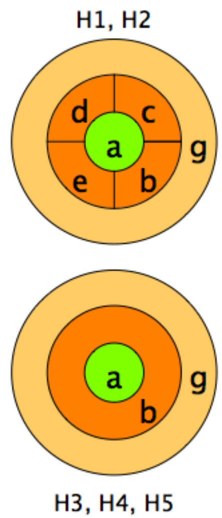
L3, L4, L5, L6

**EPI-Hi LET2 Telescope Detector Elements**

| ID | Thickness | Segmentation | Active Areas |
|---|---|---|---|
| L0 | 12 $\mu$m | bull's eye<br>4 annular quadrants | 0.2 cm$^2$<br>0.2 cm$^2$ each |
| L1 | 25 $\mu$m | bull's eye<br>4 annular quadrants | 0.2 cm$^2$<br>0.2 cm$^2$ each |
| L2 | 500 $\mu$m | bull's eye<br>4 annular quadrants<br>annular guard | 0.2 cm$^2$<br>0.2 cm$^2$ each<br>3.5 cm$^2$ |
| L3, L4, L5, L6 | 1000 $\mu$m | bull's eye<br>annulus | 10.6 cm$^2$<br>37.1 cm$^2$ |

Note: active Si is shown in color, inactive materials in black or grey.




**EPI-Hi HET Telescope Detector Elements**

| ID | Thickness | Segmentation | Active Areas |
|---|---|---|---|
| H1 | 500 $\mu$m | bull's eye | 0.2 $cm^2$ |
| | | 4 annular quadrants | 0.2 $cm^2$ each |
| | | annular guard | 1.35 $cm^2$ |
| H2 | 1000 $\mu$m | bull's eye | 0.2 $cm^2$ |
| | | 4 annular quadrants | 0.2 $cm^2$ each |
| | | annular guard | 1.35 $cm^2$ |
| H3, H4, H5 | 2 $\times$ 1000 $\mu$m | bull's eye | 1.0 $cm^2$ |
| | | annular guard | 1.35 $cm^2$ |

Note: active Si is shown in color, inactive materials in black or grey.

# Introduction: Front End Electronics

- Measurements of particle energy losses in the solid state detectors are made using a Caltech-designed ASIC that is packaged with associated passive components in a hybrid circuit. The ASIC and the hybrid in which it is incorporated are called the ``PHASIC''
- The PHASIC was originally developed for the LET and HET instruments on the STEREO mission. They have continued to perform well in these applications from launch in 2006 through the present.
- EPI-Hi requires an new version of the PHASIC in order to meet the harsher radiation requirements of the SPP mission. The goal is to achieve total dose tolerance >100 krad versus the ~12-20 krad of the STEREO PHASIC.
- Although most of the SPP PHASIC design has been directly adapted from the STEREO version, several performance enhancements have been incorporated. The most significant of these is an increase of the dynamic range from ~10000 (full scale/threshold) to at least 23000 to allow measurements from electrons through Z=30 nuclei.

# Present Status and Near-Term Plans

• Design of the SPP PHASIC has been completed and the layout is approaching completion. Details of the ASIC design and validation were successfully reviewed (6 Dec 2012).

• The SPP PHASIC design is about to be submitted for fabrication of a prototype ASIC using a non-rad-hard process equivalent to that used to make the STEREO ASIC. This ASIC will be installed in refurbished hybrids left over from STEREO in order to:

  • obtain ASICs for testing on a significantly shorter time scale and at significantly lower cost than is possible for the final rad-hard parts.

  • test the performance in comparison to expectations based on Spice simulations

  • provide PHASICs that can be used in developing pulse height analysis boards for the EPI-Hi engineering model (EM)

# Objective and Scope of this Review

- Parameters for use in the PHASIC design were selected to optimize the ASIC for use with the EPI-Hi detector telescopes to meet the measurement objectives of EPI-Hi.
- This review is intended to confirm the adequacy of the ASIC that has been designed for meeting these objectives.
- Parameters that should be considered include:
    - full scale energy
    - threshold energy
    - channel resolution
    - noise performance
    - capabilities for measurements at high count rates
- Some parameters are programmable so that the PHASIC will be suitable for use with a variety of different detector designs.  For programmable parameters the suitability of the range of programmability should be considered.

# PHASIC Functional Description

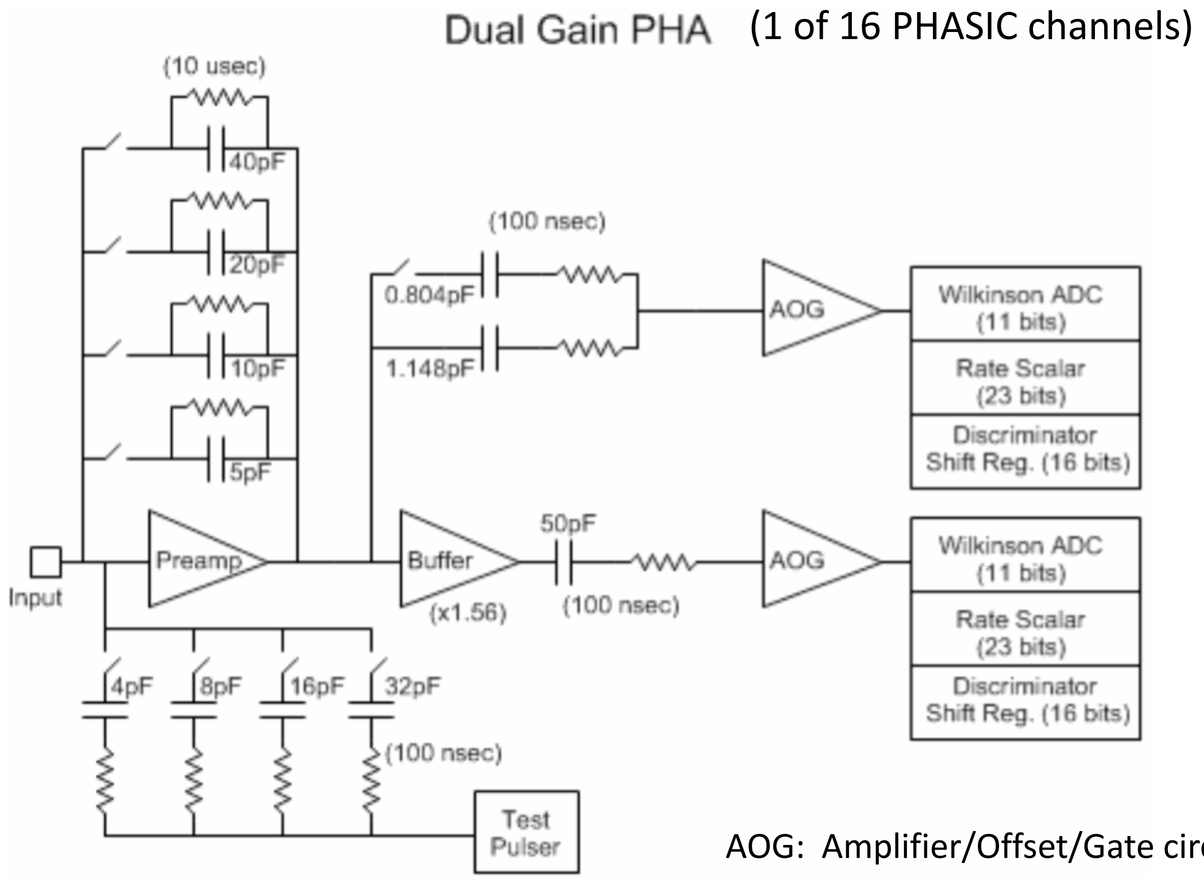
- The SPP PHASIC includes 16 identical dual-gain pulse height analysis circuits, each of which processes signals from a different detector element.
- Each pulse height analysis circuit consists of a single charge sensitive amplifier and two parallel gain and shaping chains each of which is followed by a discriminator, peak detector, and Wilkinson rundown ADC.
- The preamplifier sensitivity is programmable using a 4-bit binary value designated $N_f$ that determines the feedback capacitance according to

$$C_f = N_f \times 5 \text{ pF} \quad (N_f = 1, 2, ..., 15)$$

- Additional 1-bit programmability is included in one of the shaping amplifiers such that the ratio between the gains of the two chains can be selected to be either 40:1 or 68:1.
- The Wilkinson ADC for each chain provides 11-bit digitization (2048 channels). In addition, the peak detector circuit is configured such that an input of 0 MeV results in an offset channel value ~48.

Table 1. PHA Chip Specifications

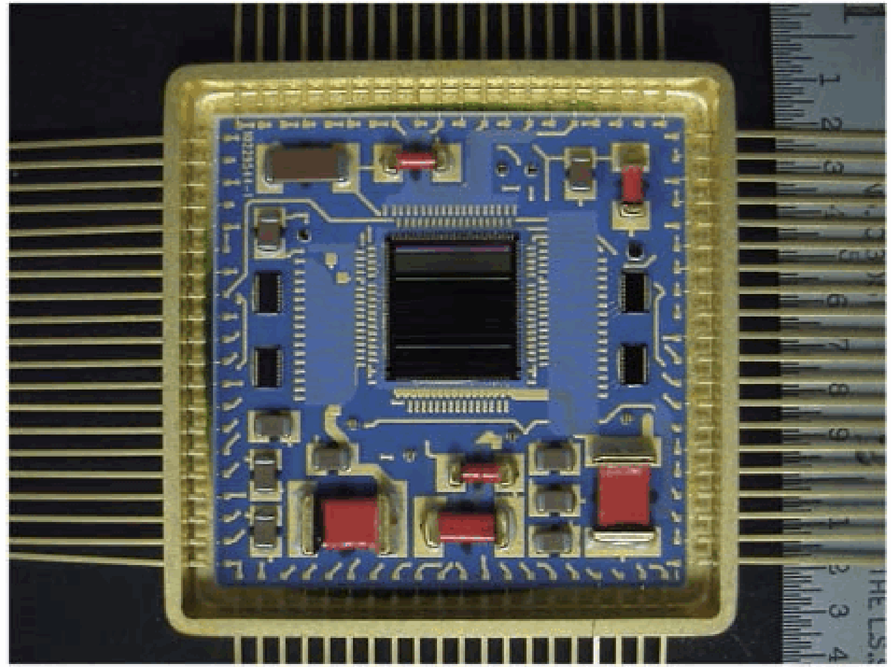
| | |
|---|---|
| Number of dual-gain PHAs | 16 |
| Chip size | 7.4 mm by 7.4 mm |
| Power | 11 mW per active PHA |
| Dynamic range | Up to 23000 (F.S./trig. thresh) |
| Integral non-linearity | <0.05% of F.S. |
| Differential non-linearity | <1% |
| High/Low gain ratio | 68 or 40, configurable |
| ADC type | Wilkinson |
| ADC resolution (both gains) | 11 bits, 12th bit overflow |
| Shaping | Bipolar, 1.9 usec to peak |
| Preamp feedback cap. | 5-75 pF, programmable in 5 pF steps |
| Preamp full scale output swing | 4.0 Volts |
| Cross-talk between adj. PHAs | <0.2% |
| Radiation Tolerance | >100 Krad, no latchup below 80 MeV/(mg/cm2) |
| Gain temp. coef. | <50 ppm/deg. C |
| Offset temp. coef. | <0.1 channel/deg. C |
| Operating temp. range | -30 to +50 deg. C |
| Leakage current balancing | up to 32 uA with 10 bit resolution |
| Threshold programmability | up to 6% of F.S. (each gain) with 10 bit resolution |




AOG: Amplifier/Offset/Gate circuit

## STEREO PHASIC

**Fig. 25** Photo of the PHASIC hybrid. The package dimensions are 31.8 mm × 31.8 mm. The PHASIC chip (located in the center) has dimensions of 7.4 mm × 7.4 mm



Mewaldt et al., Space Sci. Rev. 136, 285, 2008

SPP PHASIC is being designed with the constraint that it be compatible with the hybrid packaging used for the STEREO PHASIC:

- results in a significant cost reduction compared with developing a new hybrid
- allows use of leftover STEREO hybrids (with chip removed) for packaging early engineering units of SPP PHASIC

# PHASIC Threshold Requirements

- The required detection threshold is driven by the need to measure Z=1 particles (protons and electrons) at moderate-to-high velocities.
- In the LET telescopes the threshold determines the highest energy to which protons can be detected since their energy loss in the thin front detectors falls below threshold before they penetrate the entire LET stack. The energy at which this occurs should be high enough to provide some overlap with the lower-end of the HET energy response.
- The threshold also determines the efficiency for detecting electrons.
    - In LET, the thin detectors (L0, 12 µm and L1, 25 µm) are not required for electron measurements. No directional information (other than front-back) is obtained.
    - In HET, the H1 and H2 detectors (500 µm and 1000 µm, respectively) do provide some directional information, but broadened by electron scattering.
- Memo by Dick Mewaldt (which includes the figures shown on the next two slides) explains the threshold requirements in more detail.

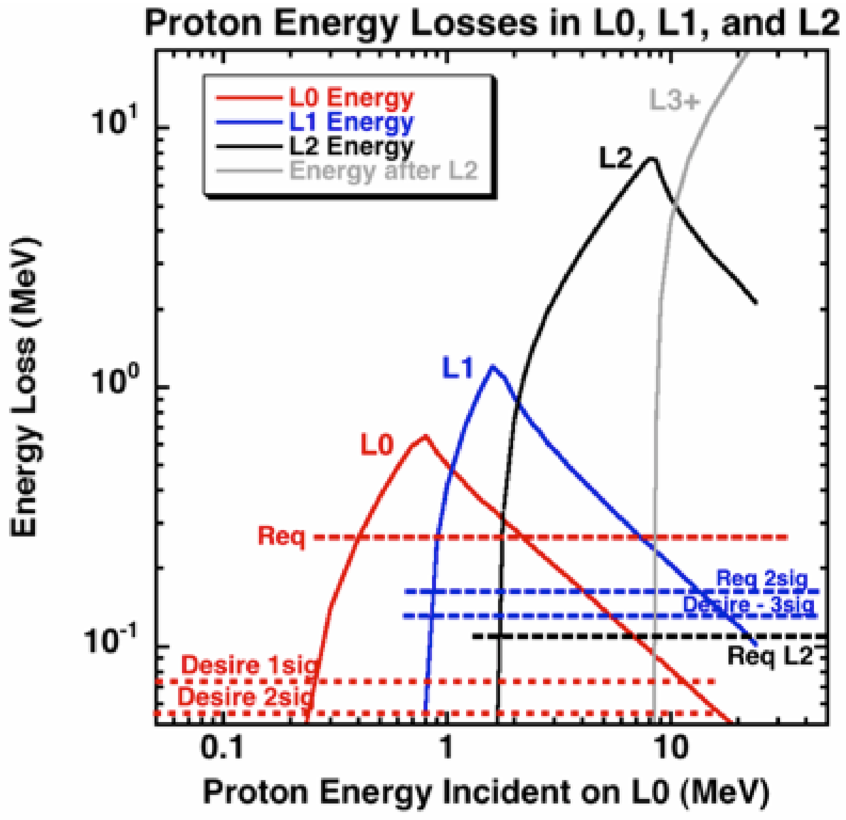



Figure 2: Energy-loss profiles for L0, L1, L2, and L3+later devices due to normally incident protons. Also shown are recommended requirements and goals for the triggering threshold for Lo, L1, and L2 (note color coding).

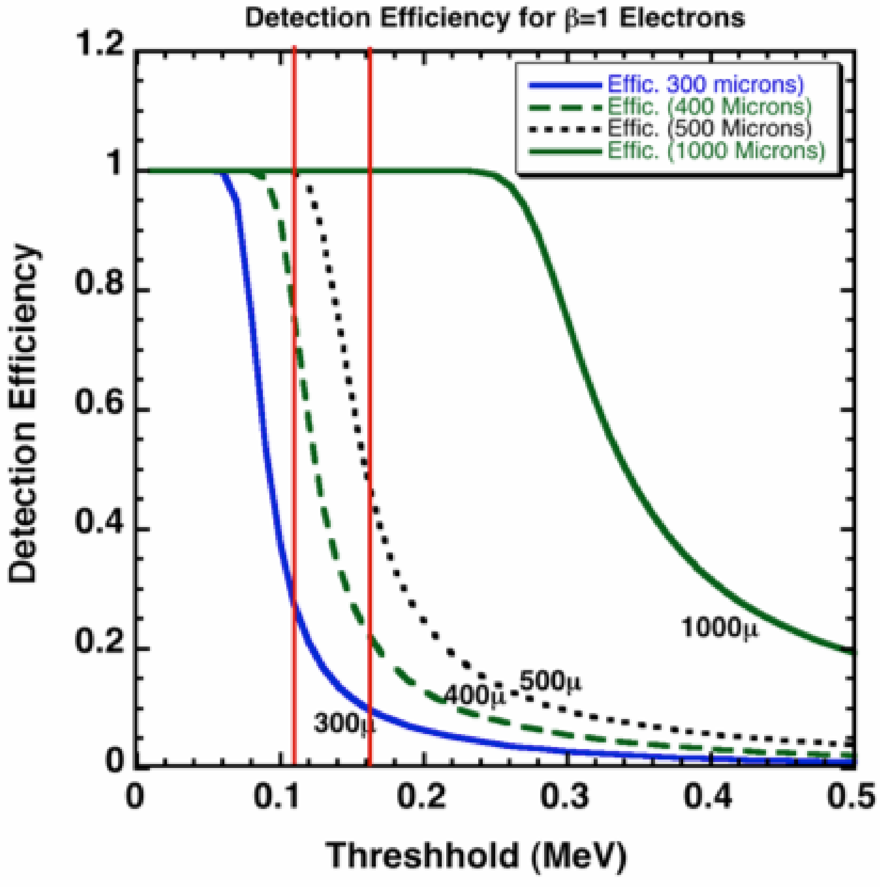



Figure 3. Electron detection efficiency for various thickness detectors as a function of the detection threshold (simulations by Allan Labrador).

# Parameters Used in Monte Carlo Simulations

MacintoshHD:Users:mew:SOLAR_PROBE:EPIHI:PHASIC:[epihi_pha_param004.xlsx]pha param
11-Feb-13

| Det ID | # of Det | Det Active Thk (um) | Det Active Area (cm2) | Det Dielec Const | Det Cap (pF) | Trk Thk (um) | Trk Area (cm2) | Trk Dielec Const | Trk Cap (pF) | Det+Trk Cap (pF) | WRC case id | WRC cdet (pF) | WRC cin (pF) | WRC disc rms (Mev) | Noise Scale Factor | Nf | Gain Ratio | LG FS (MeV) | HG FS (MeV) | HG Disc rms Noise (MeV) | HG Noise Ratio Disc/PD | HG PD rms Noise (MeV) | LG PD rms Noise (MeV) | HG Thresh (MeV) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L0a | 1 | 10 | 0.196 | 11.9 | 206.9 | 0.345 | 0.0049 | 3.9 | 49.05 | 255.9 | l0-0a | 284 | 30 | 0.0192 | 1.000 | 1 | 40 | 267.38 | 6.68 | 0.0192 | 1.00 | 0.0192 | 0.0399 | 0.1152 |
| L0b,c,d,e | 1 | 10 | 0.202 | 11.9 | 212.4 | 0.345 | 0.0024 | 3.9 | 24.45 | 236.9 | l0-0a | 284 | 30 | 0.0192 | 1.000 | 1 | 40 | 267.38 | 6.68 | 0.0192 | 1.00 | 0.0192 | 0.0399 | 0.1152 |
| L1a | 1 | 25 | 0.196 | 11.9 | 82.8 | 0.345 | 0.0024 | 3.9 | 24.45 | 107.2 | l1 | 93 | 40 | 0.0082 | 1.107 | 1 | 40 | 267.38 | 6.68 | 0.0091 | 1.00 | 0.0091 | 0.0399 | 0.0545 |
| L1b,c,d,e | 1 | 25 | 0.202 | 11.9 | 85.0 | 0.345 | 0.0015 | 3.9 | 15.00 | 100.0 | l1 | 93 | 40 | 0.0082 | 1.052 | 1 | 40 | 267.38 | 6.68 | 0.0086 | 1.00 | 0.0086 | 0.0399 | 0.0518 |
| L2a | 1 | 500 | 0.196 | 11.9 | 4.1 | 500 | 0.0091 | 11.9 | 0.19 | 4.3 | h1,l2-0 | 20 | 60 | 0.0188 | 1.000 | 6 | 68 | 2727.27 | 40.11 | 0.0188 | 1.78 | 0.0106 | 0.2395 | 0.1128 |
| L2b,c,d,e | 1 | 500 | 0.202 | 11.9 | 4.2 | 500 | 0.0066 | 11.9 | 0.14 | 4.4 | h1,l2-0 | 20 | 60 | 0.0188 | 1.000 | 6 | 68 | 2727.27 | 40.11 | 0.0188 | 1.78 | 0.0106 | 0.2395 | 0.1128 |
| L2g | 1 | 500 | 3.521 | 11.9 | 74.2 | 500 | 0.0015 | 11.9 | 0.03 | 74.2 | h1,l2-0 | 20 | 60 | 0.0188 | 1.678 | 6 | 68 | 2727.27 | 40.11 | 0.0315 | 1.78 | 0.0177 | 0.2395 | 0.1893 |
| L3a | 1 | 1000 | 1.003 | 11.9 | 10.6 | 1000 | 0.0066 | 11.9 | 0.07 | 10.6 | h2,l3 | 40 | 80 | 0.0321 | 1.000 | 10 | 68 | 4545.45 | 66.84 | 0.0321 | 1.78 | 0.0180 | 0.3992 | 0.1926 |
| L3b | 1 | 1000 | 3.521 | 11.9 | 37.1 | 1000 | 0.0015 | 11.9 | 0.02 | 37.1 | h2,l3 | 40 | 80 | 0.0321 | 1.000 | 10 | 68 | 4545.45 | 66.84 | 0.0321 | 1.78 | 0.0180 | 0.3992 | 0.1926 |
| H1a | 1 | 500 | 0.196 | 11.9 | 4.1 | 500 | 0.0033 | 11.9 | 0.07 | 4.2 | h1,l2-0 | 20 | 60 | 0.0182 | 1.000 | 6 | 68 | 2727.27 | 40.11 | 0.0182 | 1.78 | 0.0102 | 0.2395 | 0.1092 |
| H1b,c,d,e | 1 | 500 | 0.202 | 11.9 | 4.2 | 500 | 0.0024 | 11.9 | 0.05 | 4.3 | h1,l2-0 | 20 | 60 | 0.0182 | 1.000 | 6 | 68 | 2727.27 | 40.11 | 0.0182 | 1.78 | 0.0102 | 0.2395 | 0.1092 |
| H1g1 | 1 | 500 | 0.603 | 11.9 | 12.7 | 500 | 0.0020 | 11.9 | 0.04 | 12.8 | h1,l2-0 | 20 | 60 | 0.0182 | 1.000 | 6 | 68 | 2727.27 | 40.11 | 0.0182 | 1.78 | 0.0102 | 0.2395 | 0.1092 |
| H1g1+g2 | 1 | 500 | 1.348 | 11.9 | 28.4 | 500 | 0.0035 | 11.9 | 0.07 | 28.5 | h1,l2-0 | 20 | 60 | 0.0182 | 1.106 | 6 | 68 | 2727.27 | 40.11 | 0.0201 | 1.78 | 0.0113 | 0.2395 | 0.1208 |
| H2a | 1 | 1000 | 0.196 | 11.9 | 2.1 | 1000 | 0.0033 | 11.9 | 0.04 | 2.1 | h2,l3 | 40 | 80 | 0.0321 | 1.000 | 10 | 68 | 4545.45 | 66.84 | 0.0321 | 1.78 | 0.0180 | 0.3992 | 0.1926 |
| H2b,c,d,e | 1 | 1000 | 0.202 | 11.9 | 2.1 | 1000 | 0.0024 | 11.9 | 0.03 | 2.1 | h2,l3 | 40 | 80 | 0.0321 | 1.000 | 10 | 68 | 4545.45 | 66.84 | 0.0321 | 1.78 | 0.0180 | 0.3992 | 0.1926 |
| H2g1 | 1 | 1000 | 0.603 | 11.9 | 6.4 | 1000 | 0.0020 | 11.9 | 0.02 | 6.4 | h2,l3 | 40 | 80 | 0.0321 | 1.000 | 10 | 68 | 4545.45 | 66.84 | 0.0321 | 1.78 | 0.0180 | 0.3992 | 0.1926 |
| H2g1+g2 | 1 | 1000 | 1.348 | 11.9 | 14.2 | 1000 | 0.0035 | 11.9 | 0.04 | 14.2 | h2,l3 | 40 | 80 | 0.0321 | 1.000 | 10 | 68 | 4545.45 | 66.84 | 0.0321 | 1.78 | 0.0180 | 0.3992 | 0.1926 |
| H3a | 2 | 1000 | 1.003 | 11.9 | 10.6 | 1000 | 0.0024 | 11.9 | 0.03 | 21.2 | h3 | 30 | 80 | 0.0463 | 1.000 | 15 | 68 | 6818.18 | 100.27 | 0.0463 | 1.78 | 0.0260 | 0.5988 | 0.2778 |
| H3a+g1 | 2 | 1000 | 1.606 | 11.9 | 16.9 | 1000 | 0.0044 | 11.9 | 0.05 | 33.9 | h3 | 30 | 80 | 0.0463 | 1.036 | 15 | 68 | 6818.18 | 100.27 | 0.0480 | 1.78 | 0.0269 | 0.5988 | 0.2877 |
| H3g1 | 2 | 1000 | 0.603 | 11.9 | 6.4 | 1000 | 0.0020 | 11.9 | 0.02 | 12.8 | h3 | 30 | 80 | 0.0463 | 1.000 | 15 | 68 | 6818.18 | 100.27 | 0.0463 | 1.78 | 0.0260 | 0.5988 | 0.2778 |
| H3g1+g2 | 2 | 1000 | 1.348 | 11.9 | 14.2 | 1000 | 0.0044 | 11.9 | 0.05 | 28.5 | h3 | 30 | 80 | 0.0463 | 1.000 | 15 | 68 | 6818.18 | 100.27 | 0.0463 | 1.78 | 0.0260 | 0.5988 | 0.2778 |

yellow: PHASIC parameters
green: detector parameters
clear: derived quantities

# Performance Checks

- Monte Carlo simulations were performed to check the ion response of the EPI-Hi telescopes using the SPP PHASIC for processing the signals.
- The Monte Carlo included:
  - requirement that pulses exceed a threshold of PHASIC assumed to be set at 6x the rms noise in the high gain analysis chain
  - rms noise derived using Spice model of PHASIC and taking into account detector capacitance, feedback and FET gate capacitances, wiring capacitances, and in some cases additional capacitances used for stabilizing the charge amplifier
  - digitization using high- or low-gain ADC depending on whether pulse height exceeds the full scale of the high-gain ADC
  - isotropic distribution of incident particles with an assumed $E^{-2}$ intensity spectrum
  - Bohr/Landau fluctuations in particle energy losses
  - detector dead layers
  - estimated detector thickness non-uniformity

# Performance Checks (cont.)

- The ion Monte Carlo did not include:
  - ion multiple scattering
  - ion channeling in the Si crystals
  - dead-layer non-uniformity
  - Landau/Vavilov energy loss fluctuations beyond those covered by Bohr's formula (Gaussian approximation)
  - pulse pileup effects (relevant under high-rate conditions)
  - cross talk among electronic channels (on-board correction planned, as done for STEREO/LET)

# Element Response

• For each range (i.e., detector in which particles can stop) plot the energy loss in the last detector penetrated versus the energy in the stop detector

• Assumed composition is that typical of large SEP events, but with only the most-common isotope included for each element.

• Need to check that the major elements can be identified in each range: H, He, C, O, Ne, Mg, Si, Fe. Other elements will also be included in the on-board analysis, but are not required.

• Dashed lines indicate LG full scale, HG full scale, and required trigger threshold. In some cases a second, lower threshold value is also indicated as a goal.

• An additional goal is to place the HG full scale between the He and C tracks (to the extent that that is possible) to simplify analysis of data during high rate periods when processing of HG signals may be omitted for some detector elements in order to limit geometrical factor for H and He and thereby reduce dead time.

# Level 1 Measurement Requirements for Energetic Particles

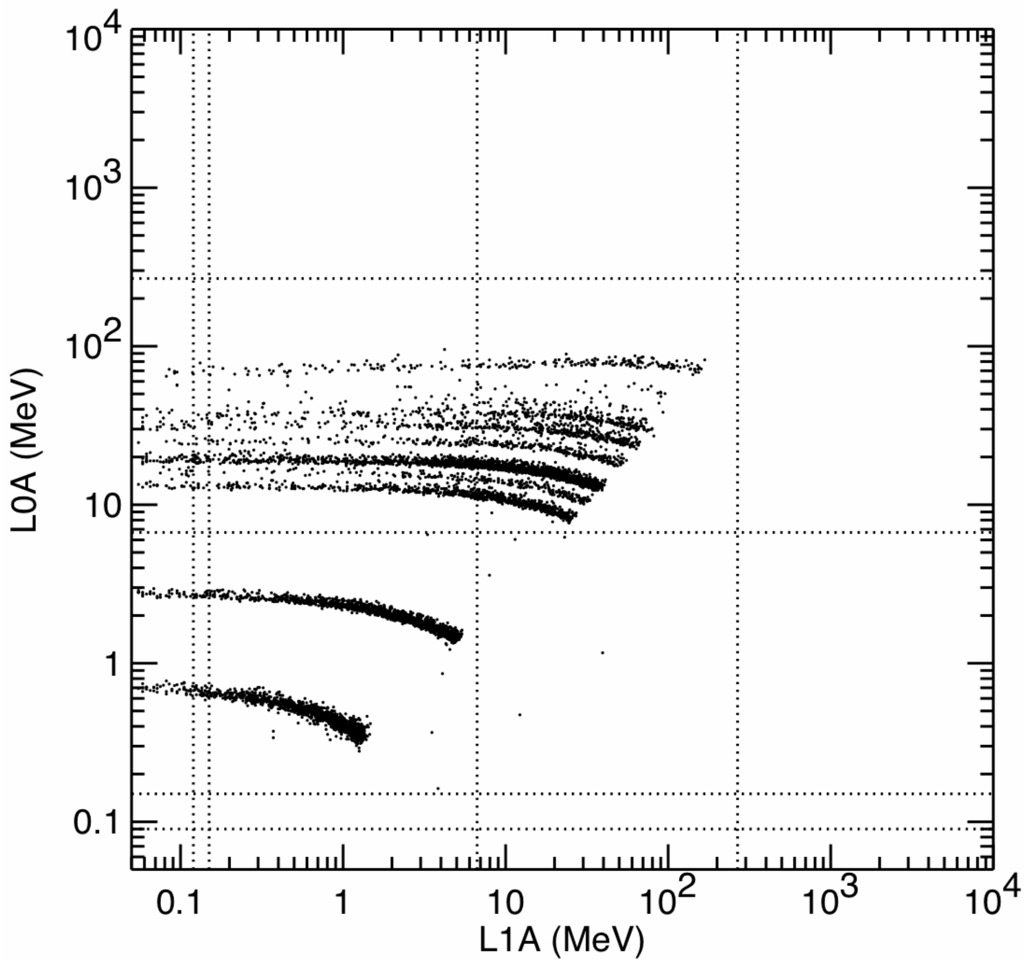
**Table 4.4** Baseline Energetic Particle Measurements

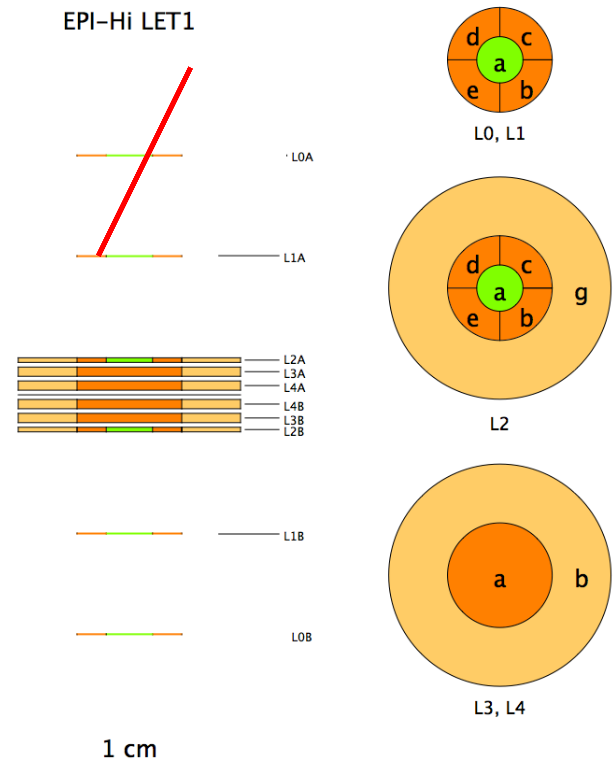
| Req | Meas. | Energy range (1) | Highest cadence (2) | FOV (3) | Angular sector | Composition (4) |
|---|---|---|---|---|---|---|
| **4.1.1.8** | Energetic electrons | ≤0.05 to ≥3 MeV | ≤1 sec (select rates) | ≥π/2 sr in sunward & anti-sunward hemispheres | ≤45° sectors | n/a |
| **4.1.1.9** | Energetic protons and heavy ions | ≤0.05 to ≥50 MeV/nuc | ≤5 sec (selected rates) | ≥π/2 sr in sunward & anti-sunward hemispheres | ≤30° sectors | at least H, He, $^3$He, C, O, Ne, Mg, Si, Fe |

Notes:
1. Combined energy range of all sensors; small gaps in energy coverage are acceptable
2. Additional rates at lower cadences, as appropriate for expected statistics and bit rate allocation
3. Combined sky coverage of all sensors, some regions densely sampled rather than 100% covered
4. Measured species; not all measured under all conditions

- EPI-Hi covers the energy range above ~1 MeV/nuc for ions and above ~0.5 MeV for electrons
- EPI-Lo covers lower energies

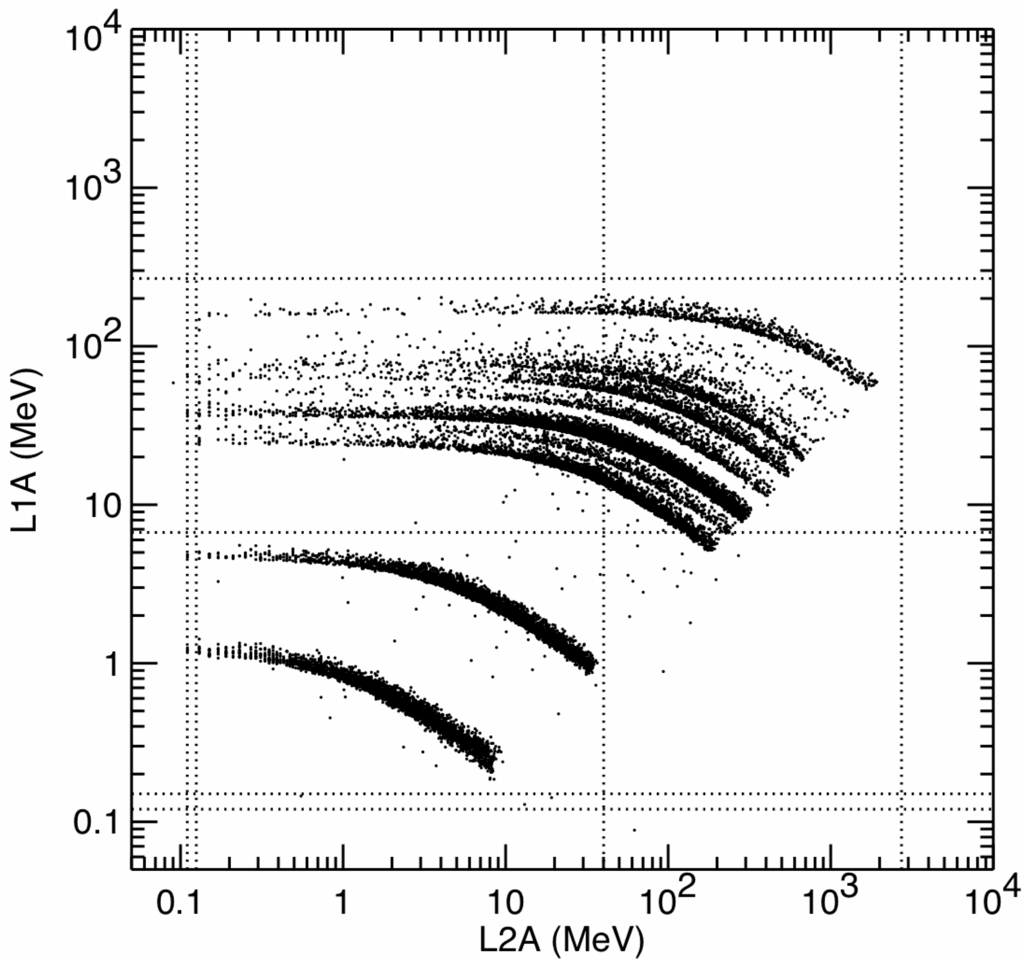
Coincidence Requirement:
( ( L0A_HIT AND L1AA_HIT ) OR $
( L0AB_HIT AND L1AB_HIT ) OR $
( L0AC_HIT AND L1AC_HIT ) OR $
( L0AD_HIT AND L1AD_HIT ) OR $
( L0AE_HIT AND L1AE_HIT ) ) AND $
( ~L2A_HIT )

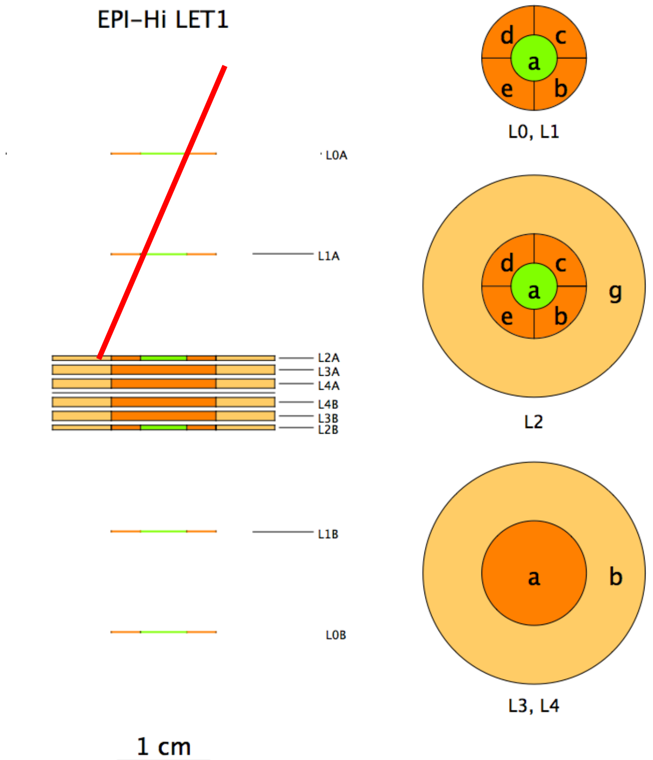



only active Si is shown

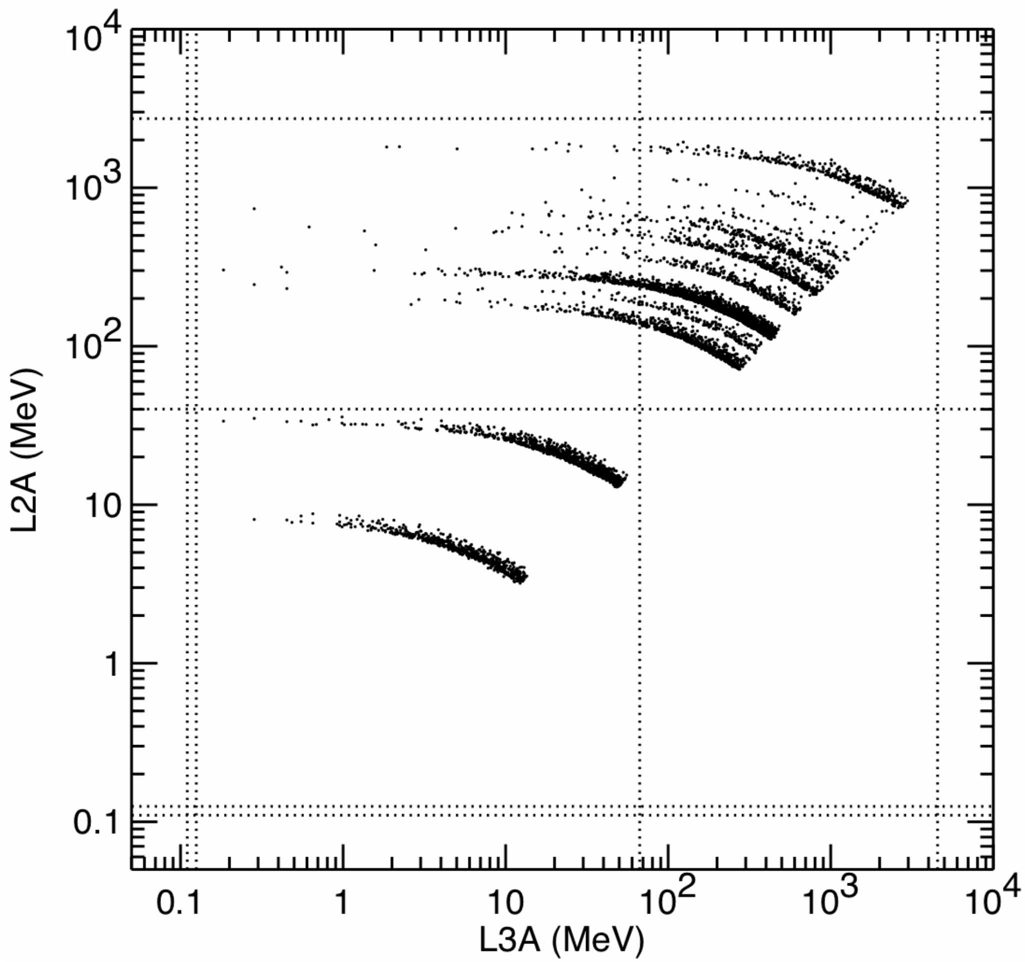
Coincidence Requirement:
( L1A_HIT AND L2A_HIT ) AND $
( ~L2AG_HIT AND ~L3A_HIT )

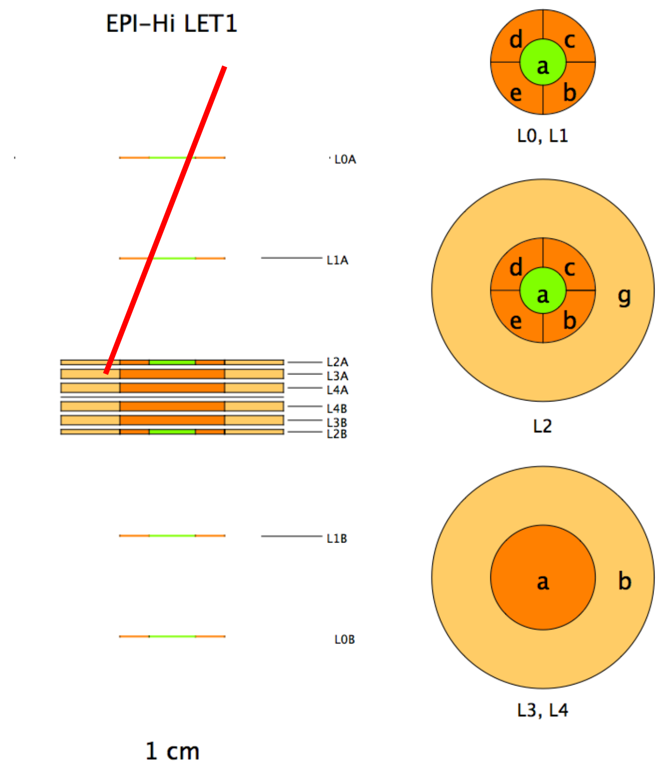



only active Si is shown

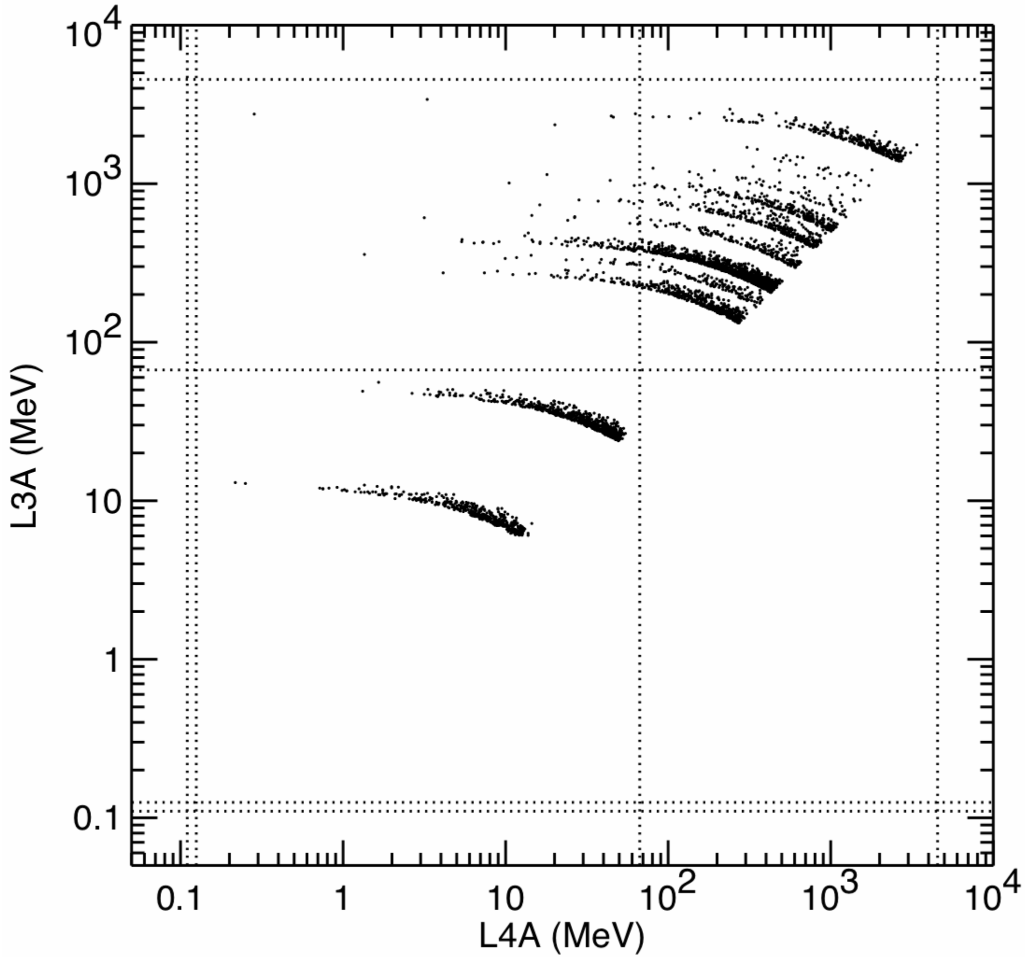
Coincidence Requirement:
( L1A_HIT AND L2A_HIT AND L3A_HIT ) AND $
( ~L2AG_HIT AND ~L4A_HIT )

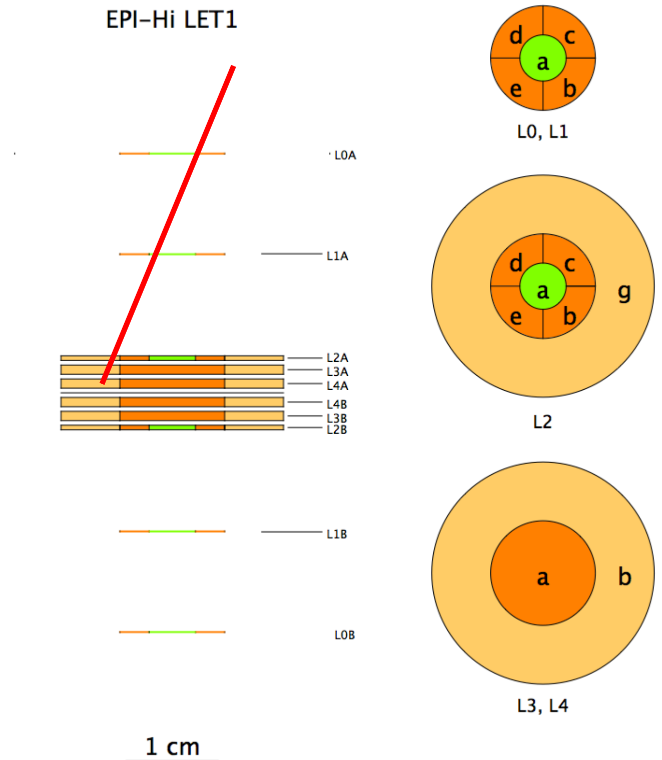



only active Si is shown

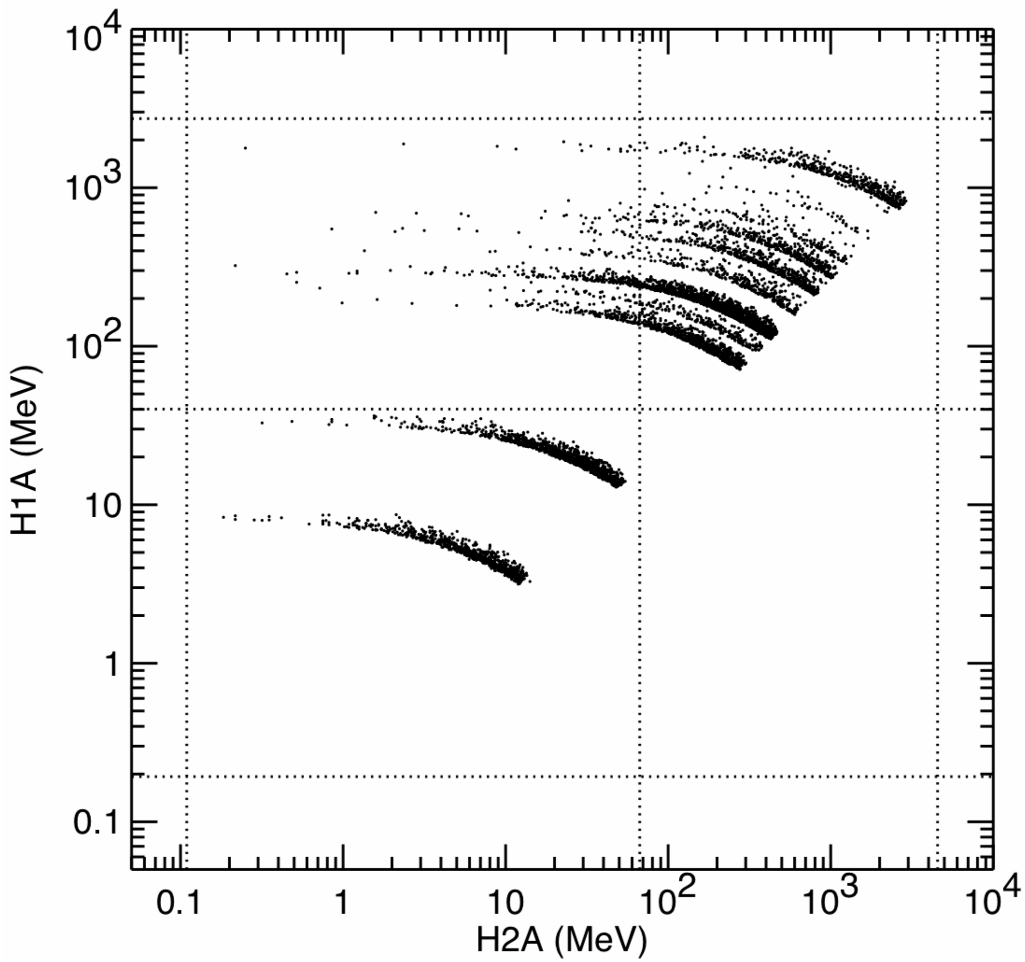
Coincidence Requirement:
( L1A_HIT AND L2A_HIT AND L3A_HIT AND L4A_HIT ) AND $
( ~L2AG_HIT AND ~L4B_HIT )

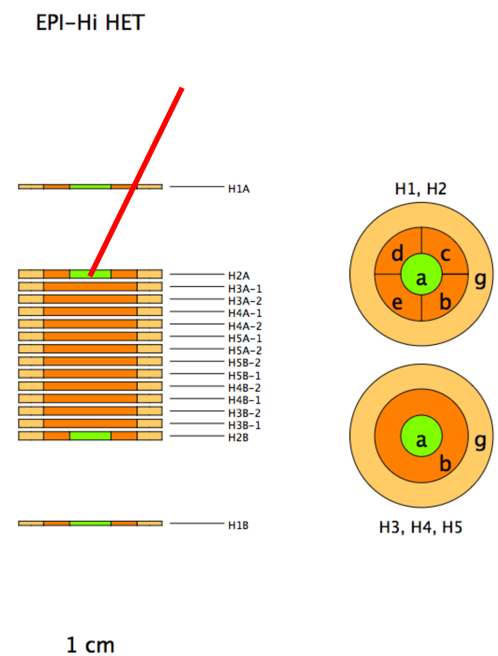



only active Si is shown

Coincidence Requirement:
( H1A_HIT AND (~H1Ag_HIT) ) AND $
( H2A_HIT AND (~H2Ag_HIT) ) AND $
( ~H3A_HIT ) AND ( ~H3Ag_HIT )

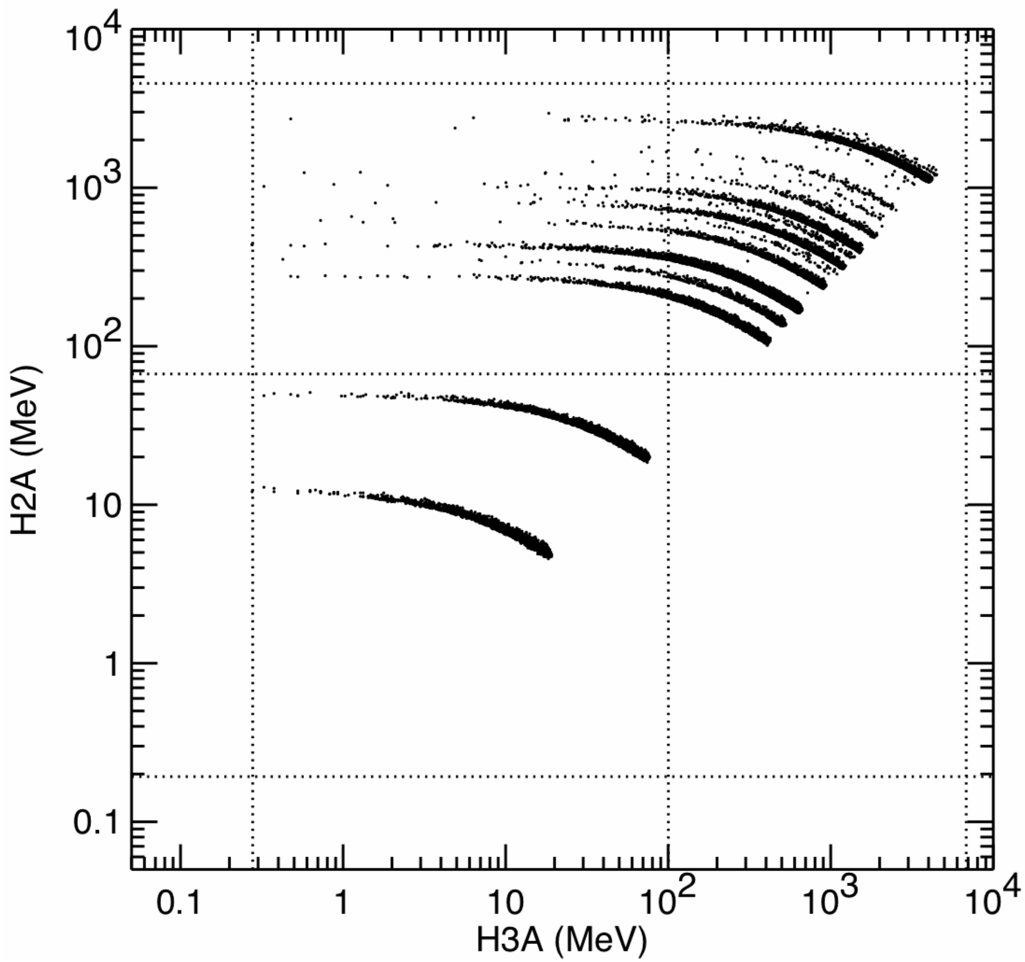


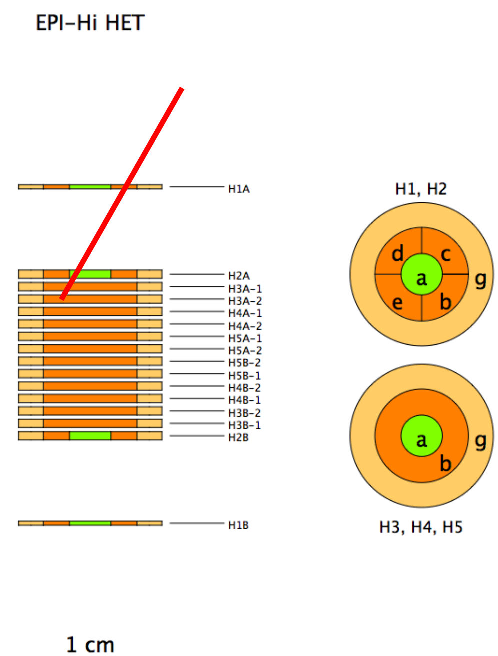




only active Si is shown

Coincidence Requirement:

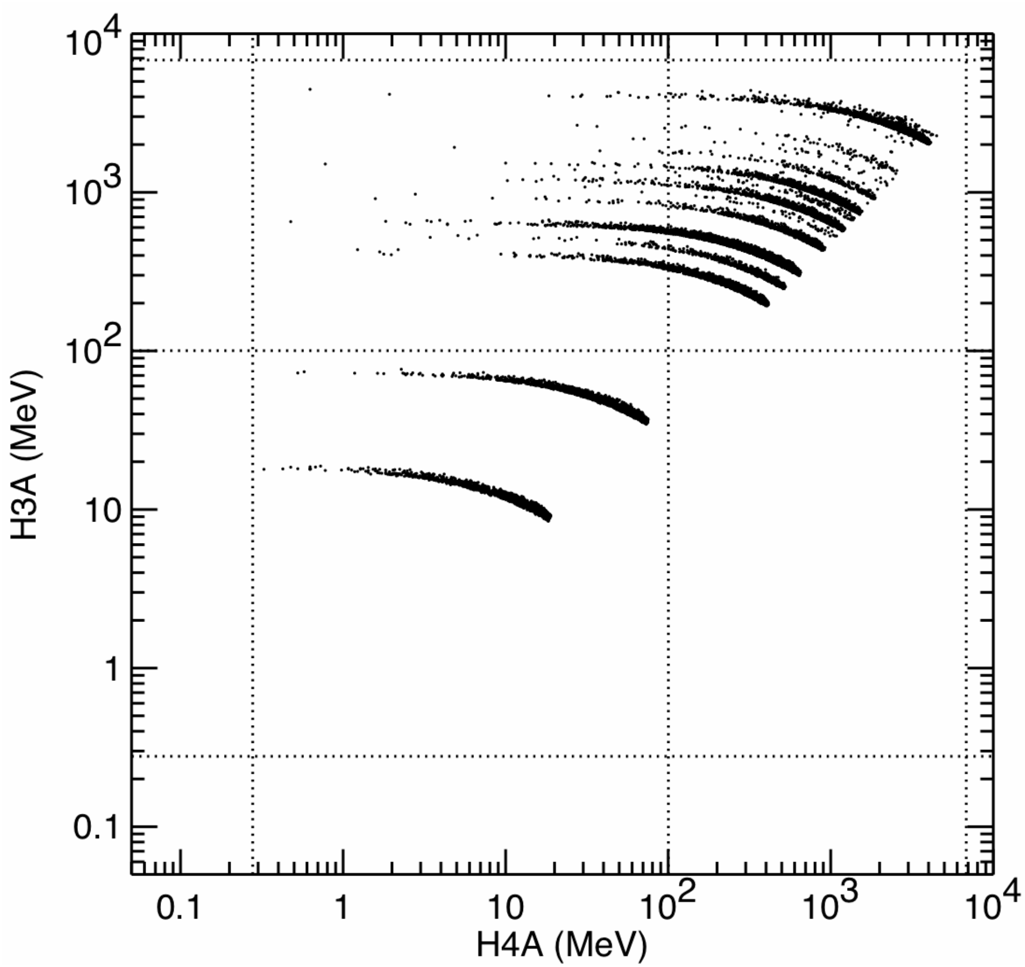
```
( H1A_HIT AND (~H1Ag_HIT) ) AND $
( H2A_HIT AND (~H2Ag_HIT) ) AND $
( H3A_HIT AND (~H3Ag_HIT) ) AND $
( ~H4A_HIT ) AND ( ~H4Ag_HIT )
```

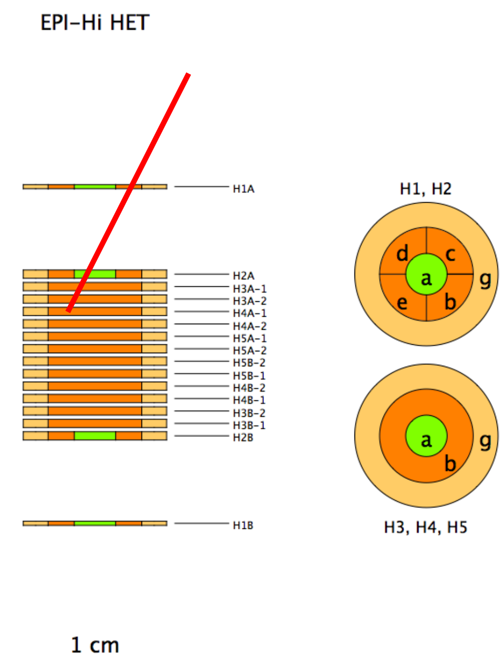



only active Si is shown

Coincidence Requirement:
( H1A_HIT AND (~H1Ag_HIT) ) AND $
( H2A_HIT AND (~H2Ag_HIT) ) AND $
( H3A_HIT AND (~H3Ag_HIT) ) AND $
( H4A_HIT AND (~H4Ag_HIT) ) AND $
( ~H5A_HIT ) AND ( ~H5Ag_HIT )

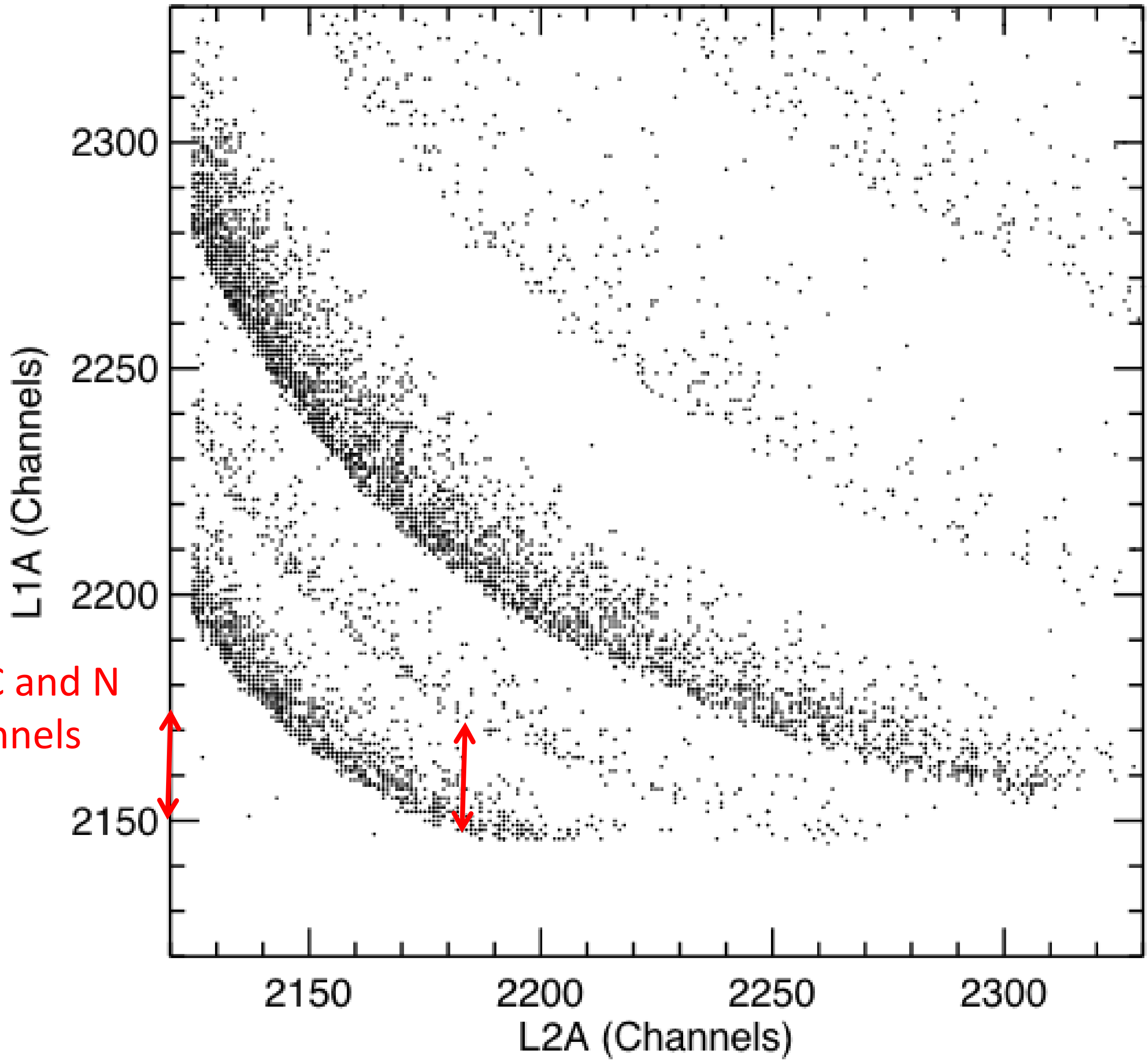


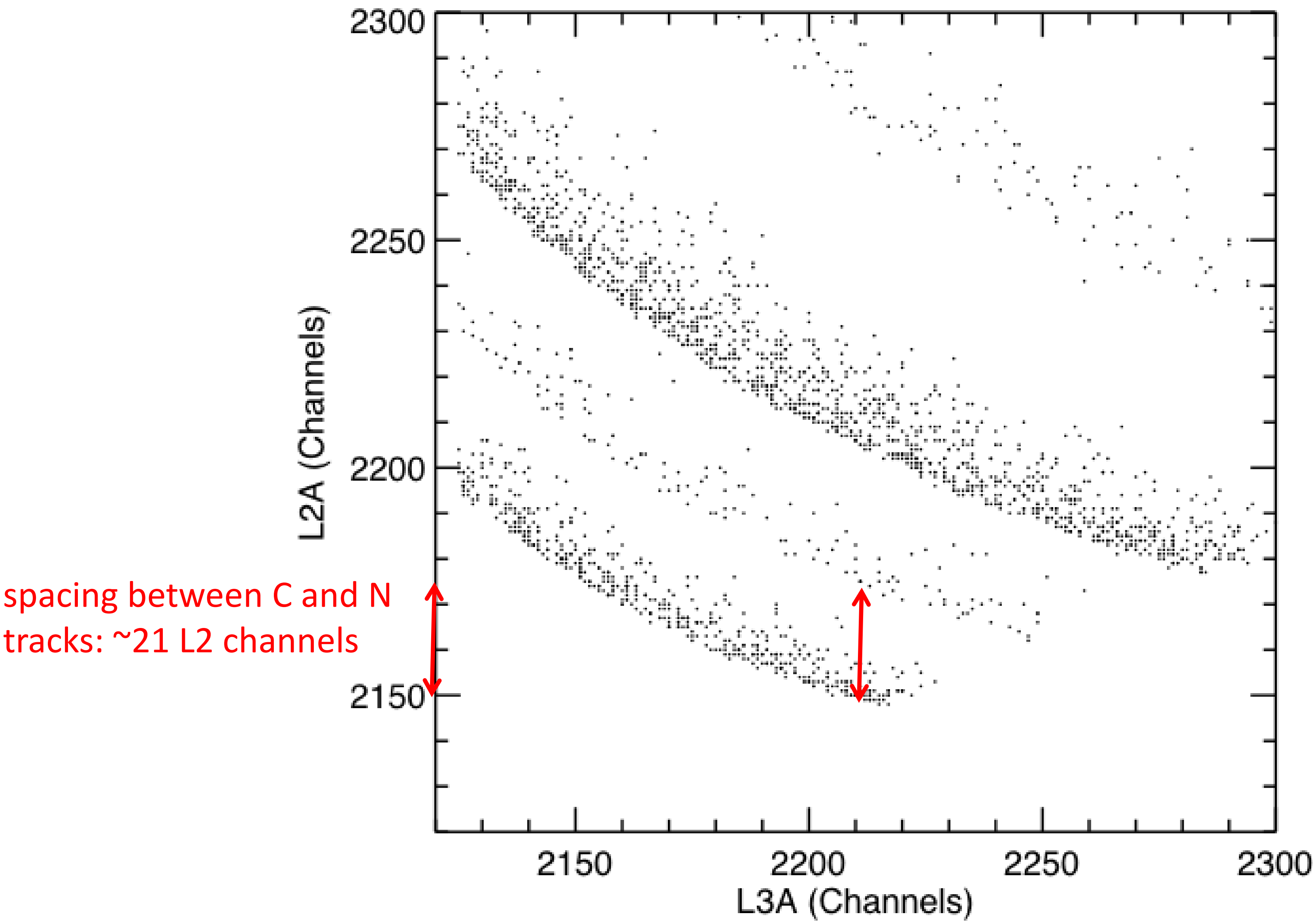

only active Si is shown

# Channel Width Effects on Element Identification

- On-board element identification is done by applying an angle correction to the measured pulse heights to map measured ΔE-E' point onto the nominal response track for particles incident at 0° to the detector normal.
- A region ("species box") in this angle-corrected channel number space is defined for each element of interest and the on-board software determines the atomic number for each event by determining which region it fall into.
- The width of the ADC channels needs to be small enough compared to the track spacing so that edges of the species boxes can be used to separate tracks with sufficient accuracy.
- Channel width effects are of greatest concern near the lower edge of the low gain analysis chain where the elements C, N, and O tend to fall.
- The following plots show these regions for L1A vs L2A and L2A vs L3A before applying the angle corrections. The points on the plots correspond to discrete LG ADC channels.
- After angle corrections, the tracks will be concentrated along the lower edge of the non-angle-corrected tracks shown on the plots.




spacing between C and N tracks: ~21 L1 channels


2300
2250
2200
2150
L2A (Channels)
2150
2200
2250
2300
L3A (Channels)
spacing between C and N
tracks: ~21 L2 channels

# Isotope Response

- The only isotopic composition measurement requirement is $^{3}He/^{4}He$, which is a key indicator of an impulsive SEP event origin.
- Measurement of $^{3}He/^{4}He$ is only required over a portion of the energy range and a portion of the geometrical acceptance.
- A reasonable goal is to measure $^{3}He/^{4}He$ down to values of ~10%.
- Mass resolution is dominated by the range of angles in an angular acceptance bin (selected by pixels hit in the front two or three detectors), next most important contribution is expected to be due to Bohr/Landau fluctuations, assuming the thickness uniformity goals for thin LET detectors are met.
- The $^{3}He$ measurement is typically most useful at the lowest energies since impulsive event energy spectra tend to be soft; higher energy $^{3}He$ can be encountered in large, gradual events due to acceleration of $^{3}He$ from a suprathermal seed population.
- An additional isotopic composition measurement goal is $^{22}Ne/^{20}Ne$ (the $^{21}Ne$ abundance is typically negligible), which can be enhanced by factors up to ~6 in impulsive events.

# Isotope Response Plots

• Equal abundances of $^{3}$He and $^{4}$He (or $^{22}$Ne and $^{20}$Ne) at equal E/M are assumed in order to illustrate track separations and widths.

•The contribution of the PHASIC to the mass resolution depends on noise level and channel width.

• The best isotope resolution is obtained for particles having incidence directions close to the normal to the detectors because secθ is flat near 0°.

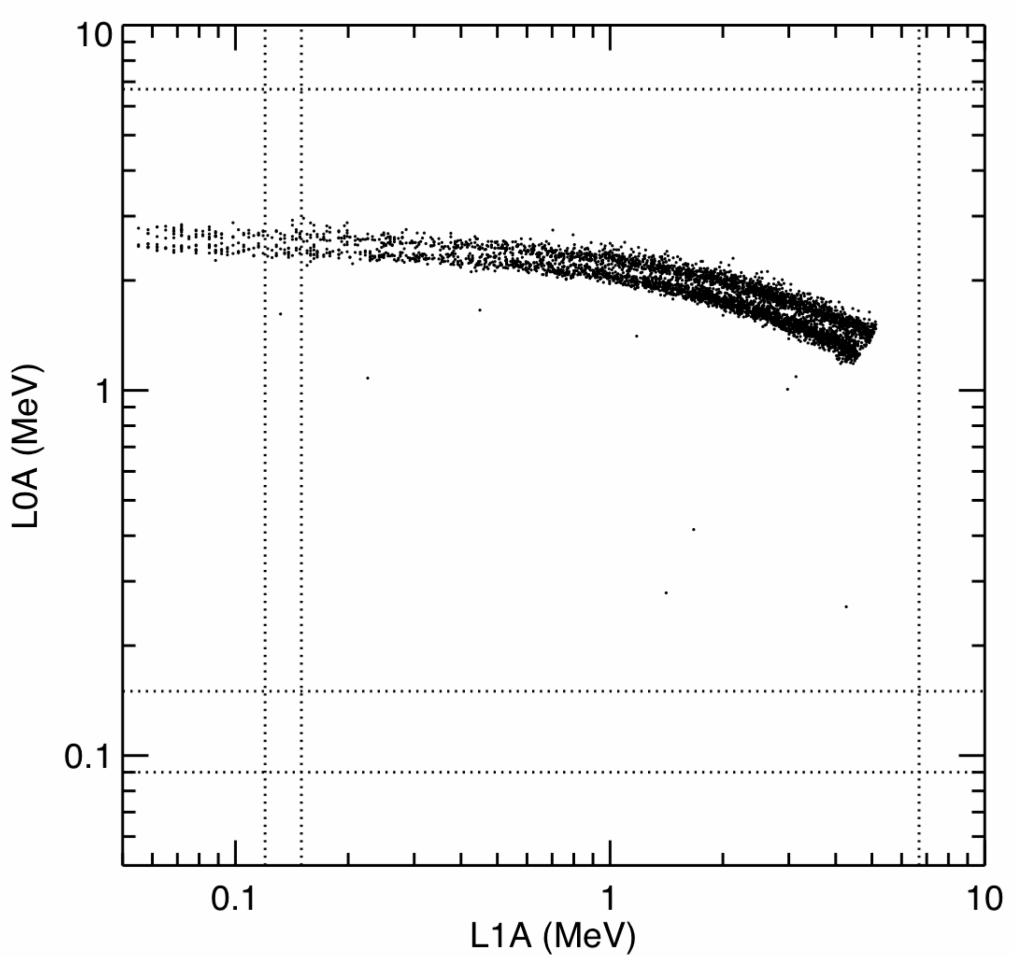
• For purposes of determining whether the PHASIC performance will be suitable for He isotope measurements it is sufficient to look at simulations for incidence directions least affected the spread in incidence angles.

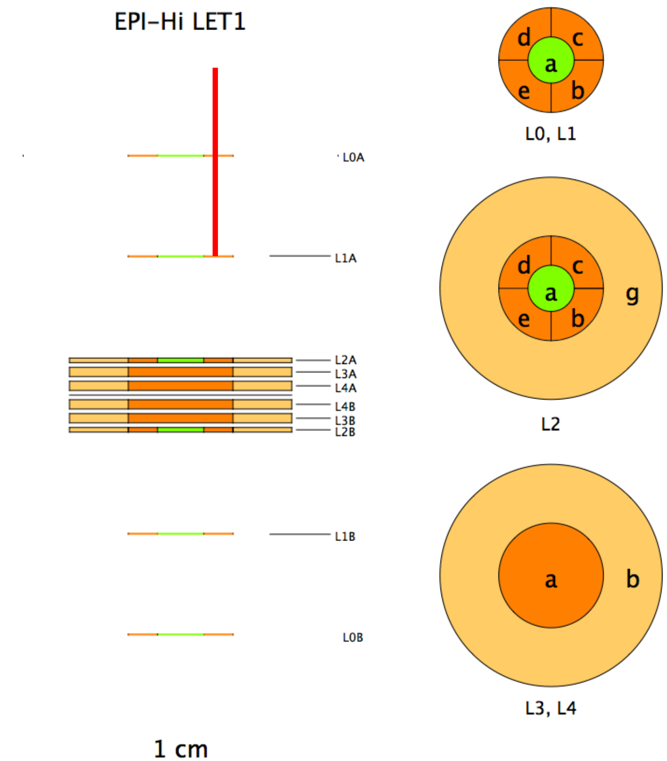
• Cases for LET are shown. HET cases are shown only where there is no LET case with the same ΔE and E' detector thicknesses. When the detector thicknesses are the same the PHA gains and channel widths are the same and the HET noise may be slightly better than that for LET (due to smaller detector capacitance).

Coincidence Requirement:
```
( ( L0AA_HIT  AND L1AA_HIT ) OR $
  ( L0AB_HIT  AND L1AB_HIT ) OR $
  ( L0AC_HIT  AND L1AC_HIT ) OR $
  ( L0AD_HIT  AND L1AD_HIT ) OR $
  ( L0AE_HIT  AND L1AE_HIT ) )   AND $
( ~L2A_HIT )
```

# He isotopes stopping in L1A

- only aligned pixels in L0A and L1A used for trajectory
- ~20% of the L0A vs L1A geometrical acceptance



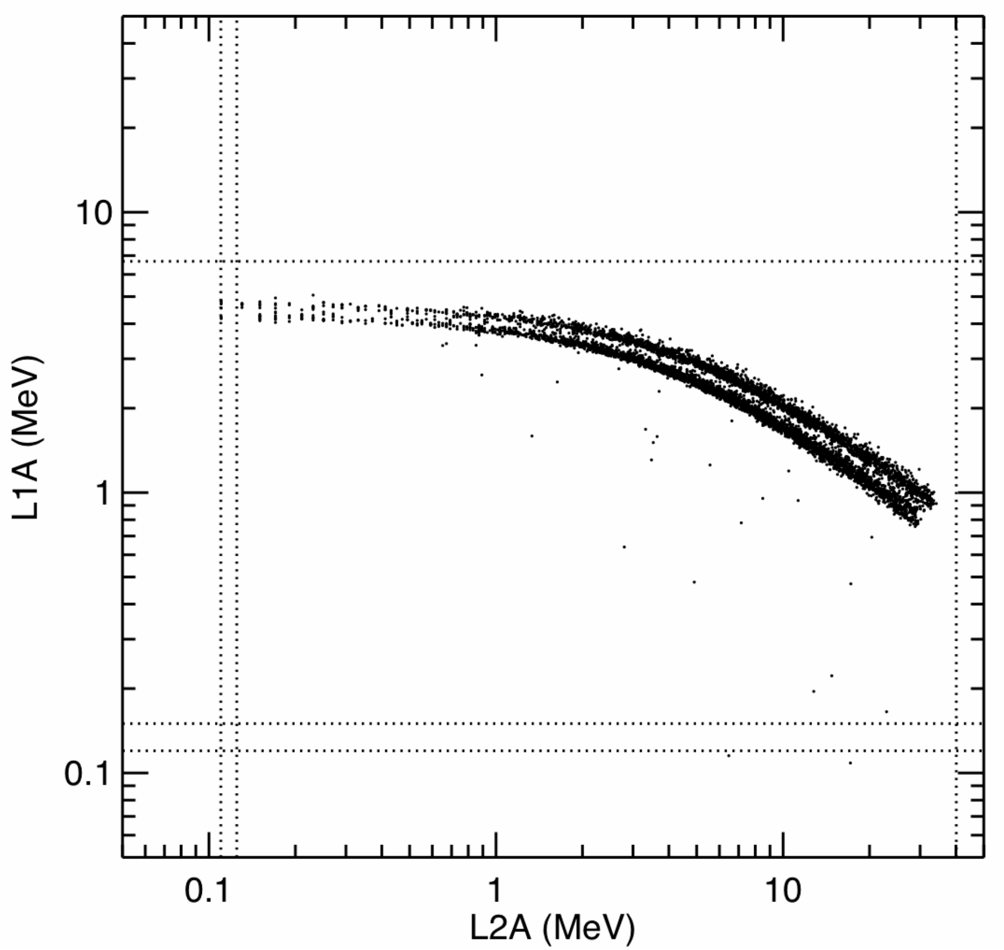



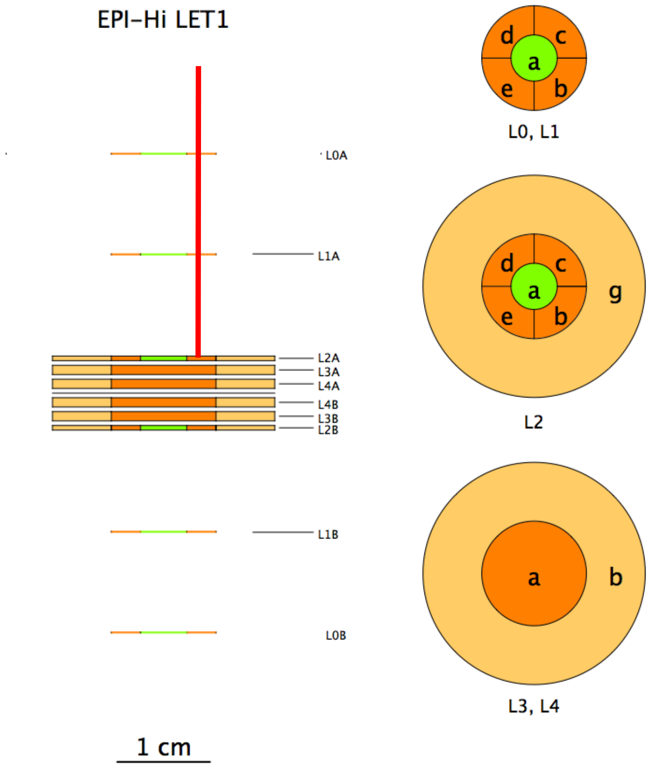

only active Si is shown

Coincidence Requirement:
( ( L1AA_HIT AND L2AA_HIT ) OR $
( L1AB_HIT AND L2AB_HIT ) OR $
( L1AC_HIT AND L2AC_HIT ) OR $
( L1AD_HIT AND L2AD_HIT ) OR $
( L1AE_HIT AND L2AE_HIT ) ) AND $
( ~L2AG_HIT AND ~L3A_HIT )

# He isotopes stopping in L2A

- only aligned pixels in L1A and L2A used for trajectory
- ~20% of the L1A vs L2A geometrical acceptance



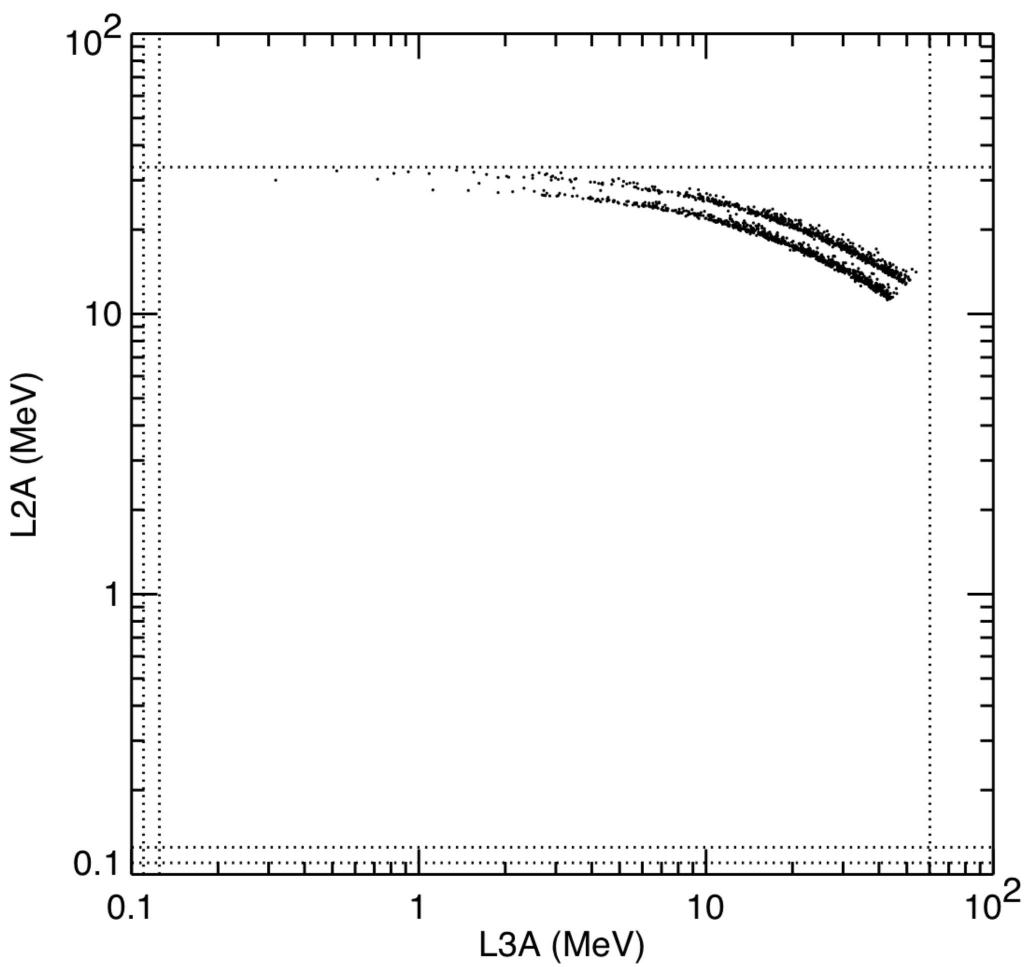



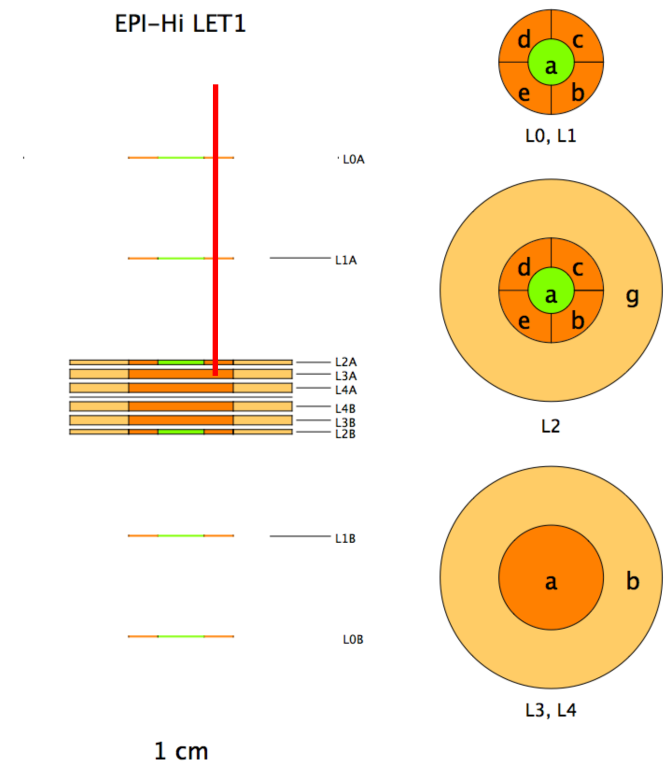

only active Si is shown

Coincidence Requirement:
( ( L1AA_HIT AND L2AA_HIT ) OR $
( L1AB_HIT AND L2AB_HIT ) OR $
( L1AC_HIT AND L2AC_HIT ) OR $
( L1AD_HIT AND L2AD_HIT ) OR $
( L1AE_HIT AND L2AE_HIT ) ) AND $
( L3A_HIT AND ~L2Ag_HIT AND ~L4A_HIT )

# He isotopes stopping in L3A

- only aligned pixels in L1A and L2A used for trajectory
- ~20% of the L2A vs L3A geometrical acceptance



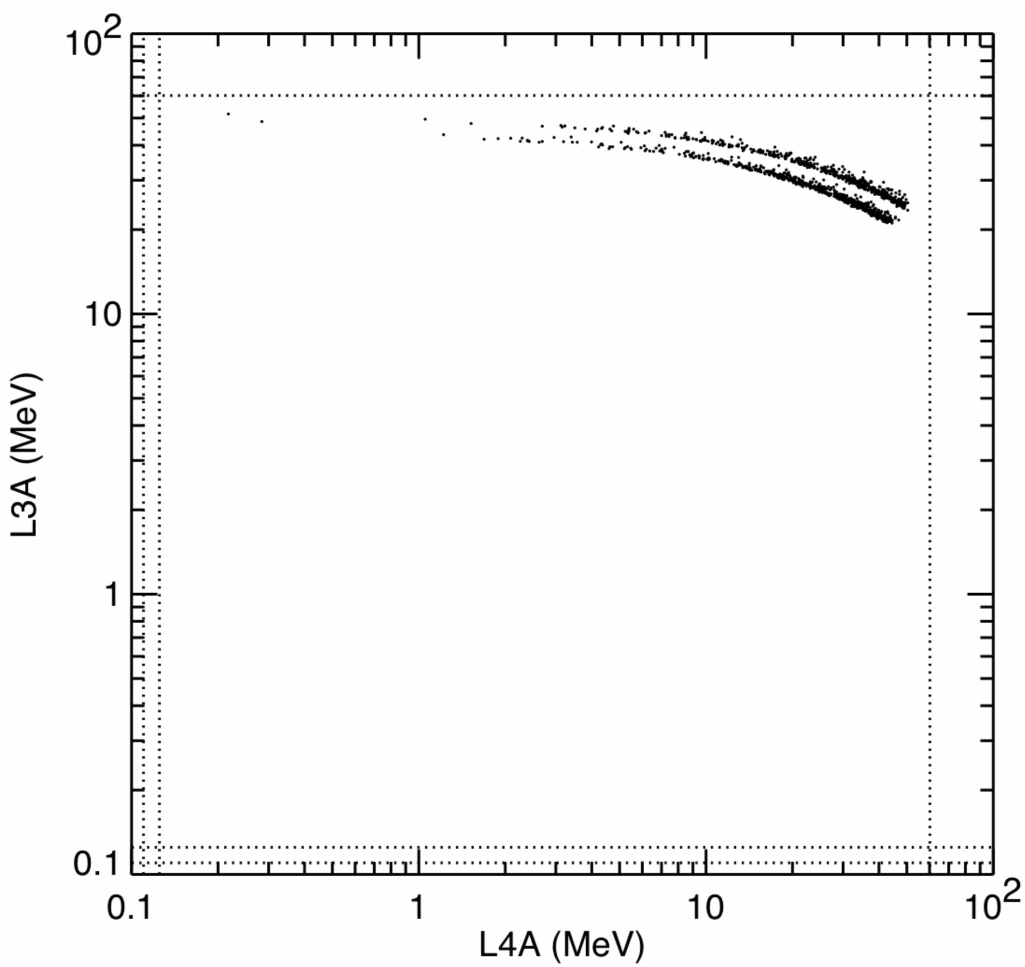

only active Si is shown

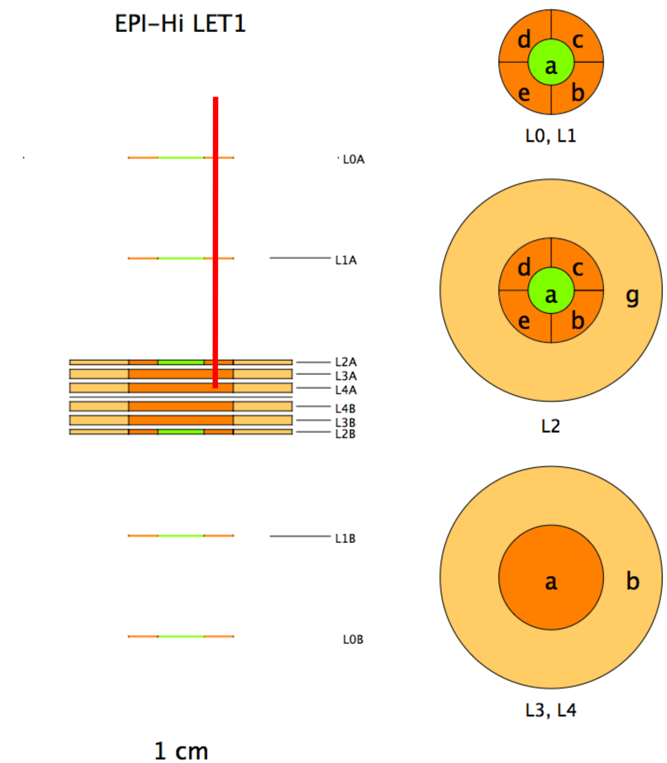
Coincidence Requirement:

```
( ( L1AA_HIT  AND L2AA_HIT ) OR $
  ( L1AB_HIT  AND L2AB_HIT ) OR $
  ( L1AC_HIT  AND L2AC_HIT ) OR $
  ( L1AD_HIT  AND L2AD_HIT ) OR $
  ( L1AE_HIT  AND L2AE_HIT ) )   AND $
( L3A_HIT AND L4A_HIT AND ~L2Ag_HIT AND ~L4B_HIT )
```

# He isotopes stopping in L4A

- only aligned pixels in L1A and L2A used for trajectory
- ~20% of the L3A vs L4A geometrical acceptance



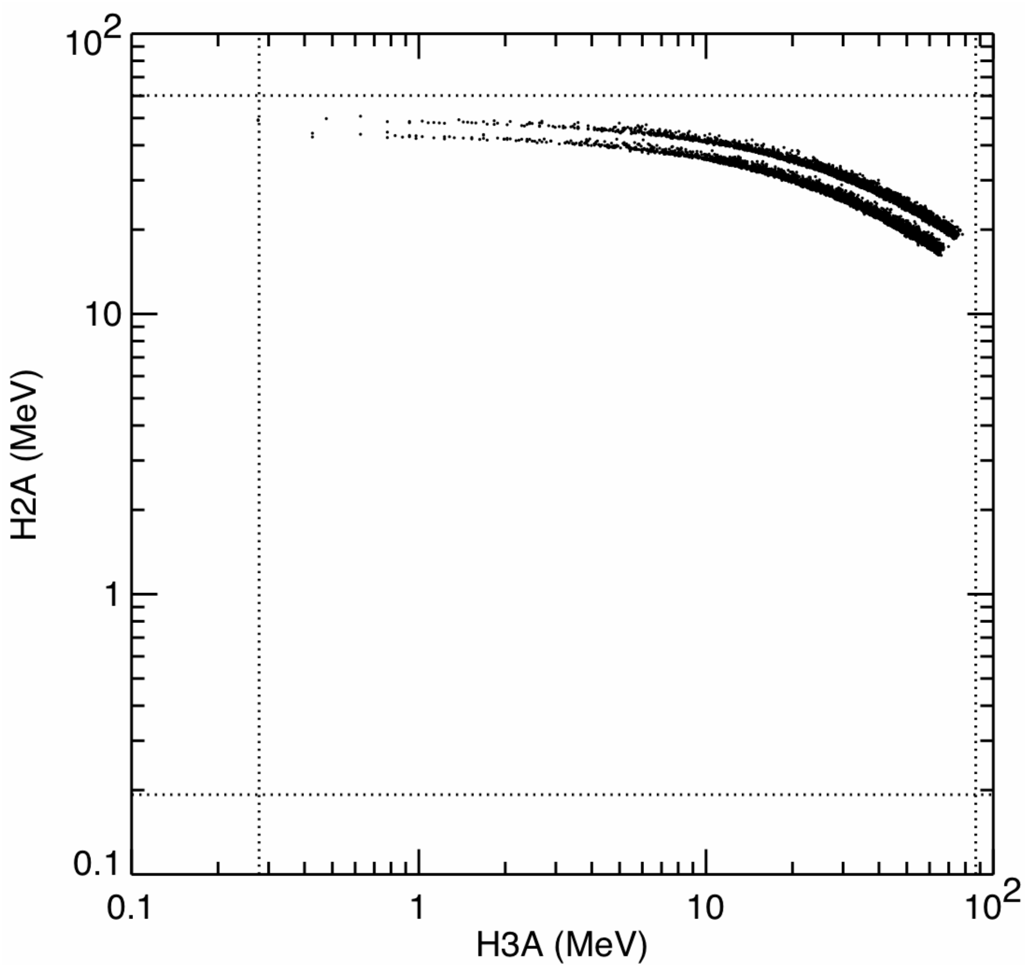



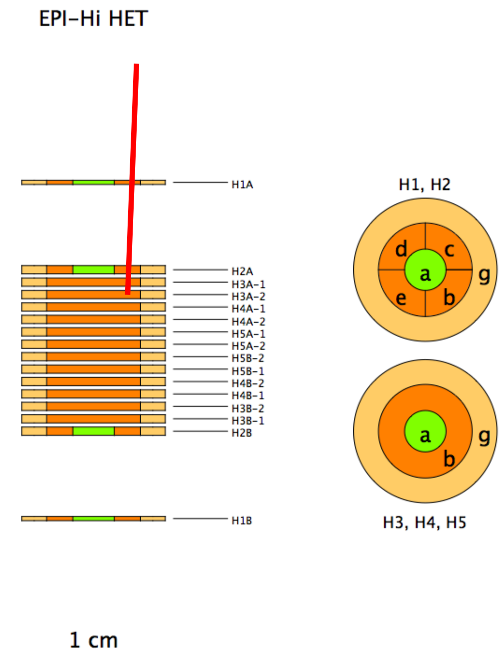

only active Si is shown

```
Coincidence Requirement:
  ( ( H1AA_HIT AND H2AA_HIT ) OR $
    ( H1AB_HIT AND H2AB_HIT ) OR $
    ( H1AC_HIT AND H2AC_HIT ) OR $
    ( H1AD_HIT AND H2AD_HIT ) OR $
    ( H1AE_HIT AND H2AE_HIT ) ) AND $
  ( ~H1AG_HIT  AND ~H2AG_HIT ) AND $
  (  H3A_HIT   AND ~H3AG_HIT ) AND $
  ( ~H4A_HIT   AND ~H4AG_HIT )
```

# He isotopes stopping in H3A

- only aligned pixels in H1A and H2A used for trajectory
- >~20% of the H2A vs H3A geometrical acceptance



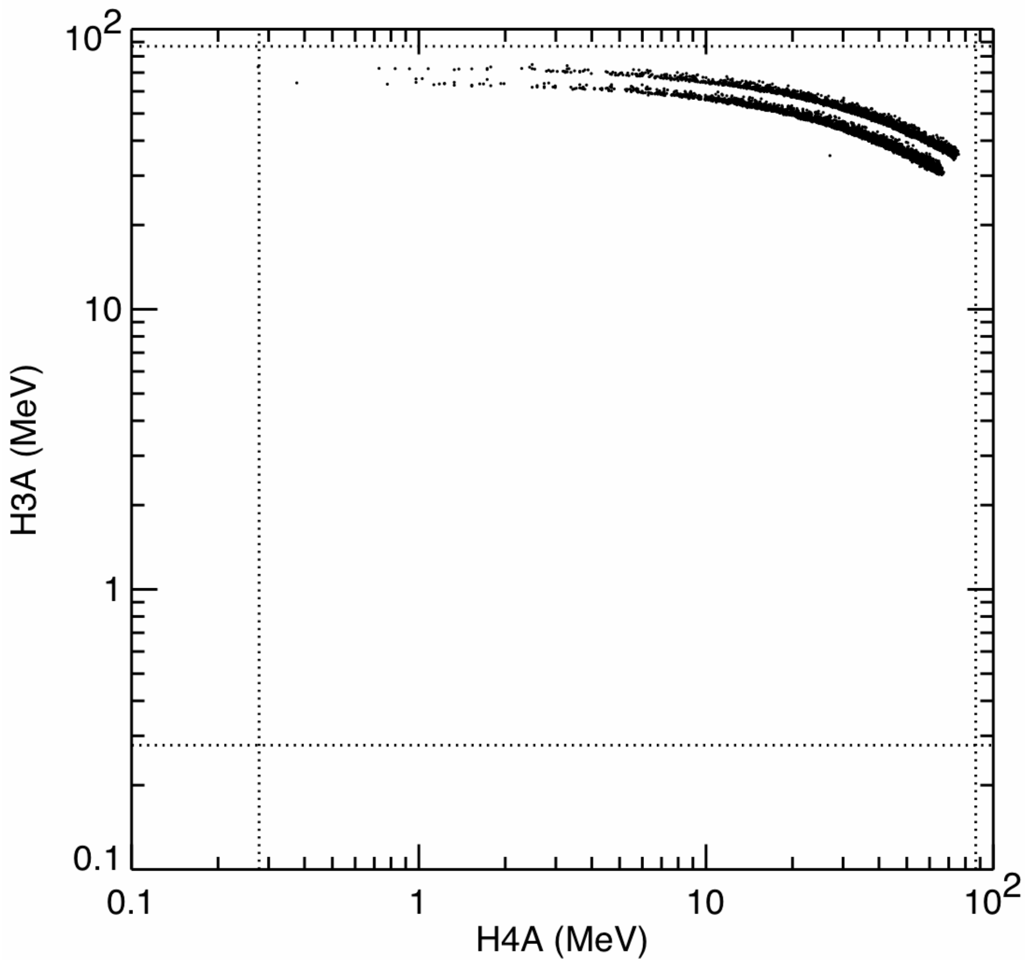



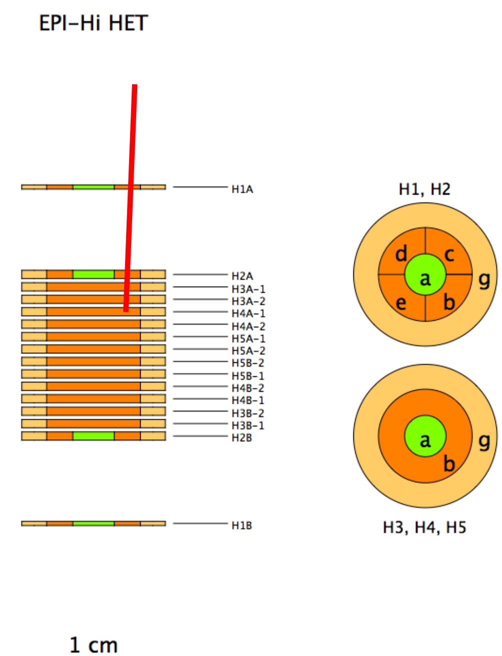

only active Si is shown

```
Coincidence Requirement:
  ( ( H1AA_HIT AND H2AA_HIT ) OR $
    ( H1AB_HIT AND H2AB_HIT ) OR $
    ( H1AC_HIT AND H2AC_HIT ) OR $
    ( H1AD_HIT AND H2AD_HIT ) OR $
    ( H1AE_HIT AND H2AE_HIT ) ) AND $
  ( ~H1AG_HIT  AND ~H2AG_HIT ) AND $
  (  H3A_HIT   AND ~H3AG_HIT ) AND $
  (  H4A_HIT   AND ~H4AG_HIT ) AND $
  ( ~H5A_HIT   AND ~H5AG_HIT )
```

# He isotopes stopping in H4A

- only aligned pixels in H1A and H2A used for trajectory
- >~20% of the H3A vs H4A geometrical acceptance



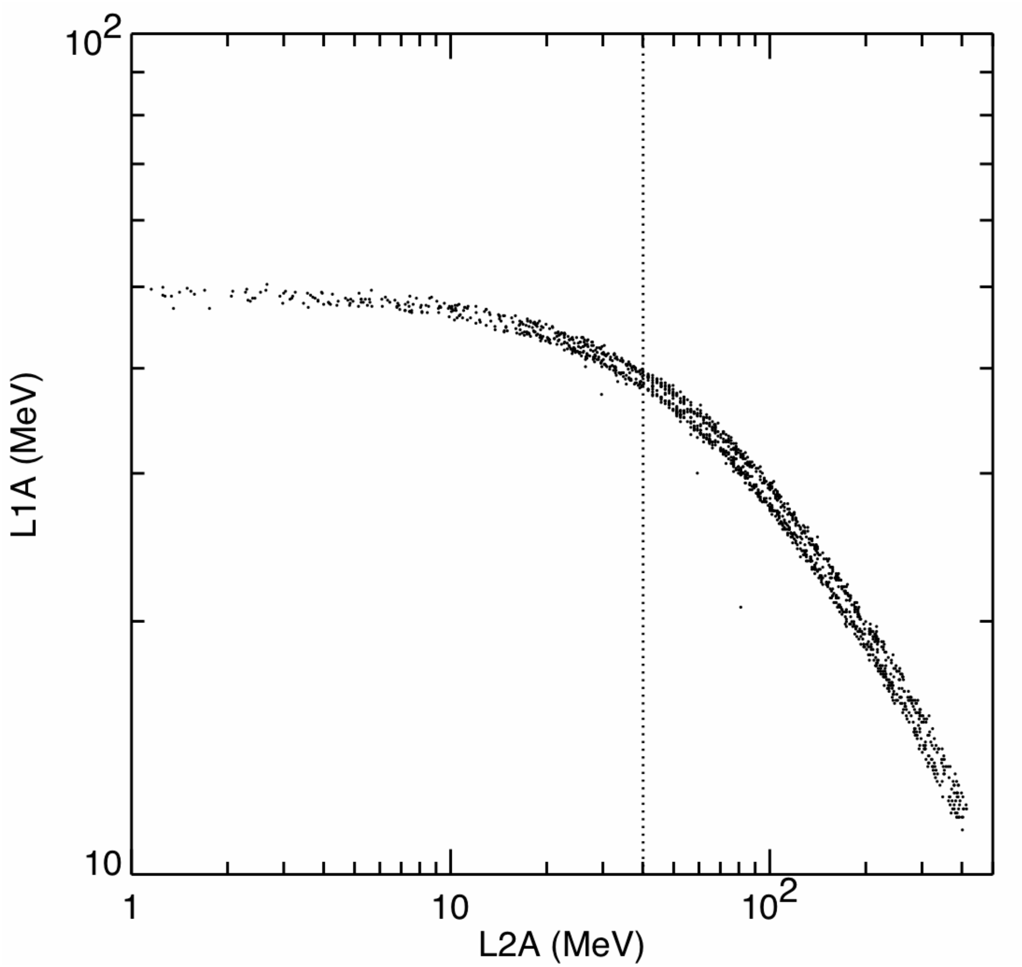



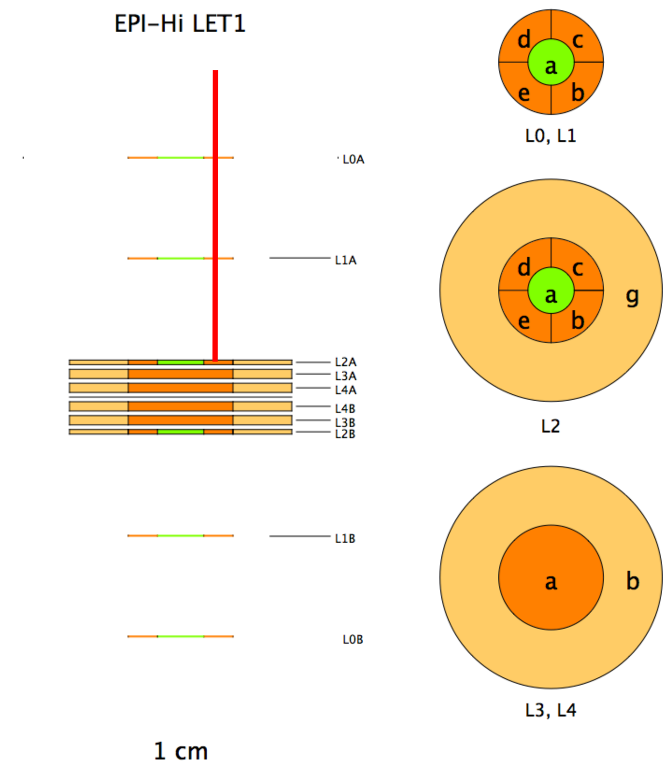

only active Si is shown

```
Coincidence Requirement:
  ( ( L0AA_HIT AND L1AA_HIT AND L2AA_HIT ) OR $
    ( L0AB_HIT AND L1AB_HIT AND L2AB_HIT ) OR $
    ( L0AC_HIT AND L1AC_HIT AND L2AC_HIT ) OR $
    ( L0AD_HIT AND L1AD_HIT AND L2AD_HIT ) OR $
    ( L0AE_HIT AND L1AE_HIT AND L2AE_HIT ) )   AND $
  ( ~L2AG_HIT AND  ~L3A_HIT )
```

# One example of $^{20}Ne$—$^{22}Ne$ isotope separation

- aligned pixels in L0A, L1A and L2A used for trajectory
- small portion of geometrical acceptance




only active Si is shown

# Count Rate Effects

• The SPP PHASIC has the same pulse shaping as the STEREO PHASIC (bipolar with 1.9 μs time to peak) and similar run-down rate for the Wilkinson ADC. Thus pulse pile-up effects and dead time per event should be similar.

• As with STEREO/LET and HET, EPI-Hi will use a “dynamic threshold” scheme in which the high gain analysis channel will be turned off for selected detector segments when count rates get too high. This reduces the geometrical factor for measuring H and He while preserving the full geometrical factor for heavier nuclei. STEREO measurements have shown that this approach is effective in extending measurement capabilities to high count rates.

• EPI-Hi is intended to measure energetic particle intensities significantly higher than those commonly encountered near 1 AU. To deal with these higher intensities the EPI-Hi telescopes have been made significantly smaller and more compact and have additional passive shielding surrounding the detector stacks. Thus the instrument modifications to handle the high intensities are in the telescope designs, not by means of PHASIC design changes.

• A quantitative study of the intensities that can be measured by EPI-Hi is going to be undertaken in the near future.

# Dynamic Threshold System on STEREO/LET