HET/EPT Onboard Data Pipeline

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presenting the work of
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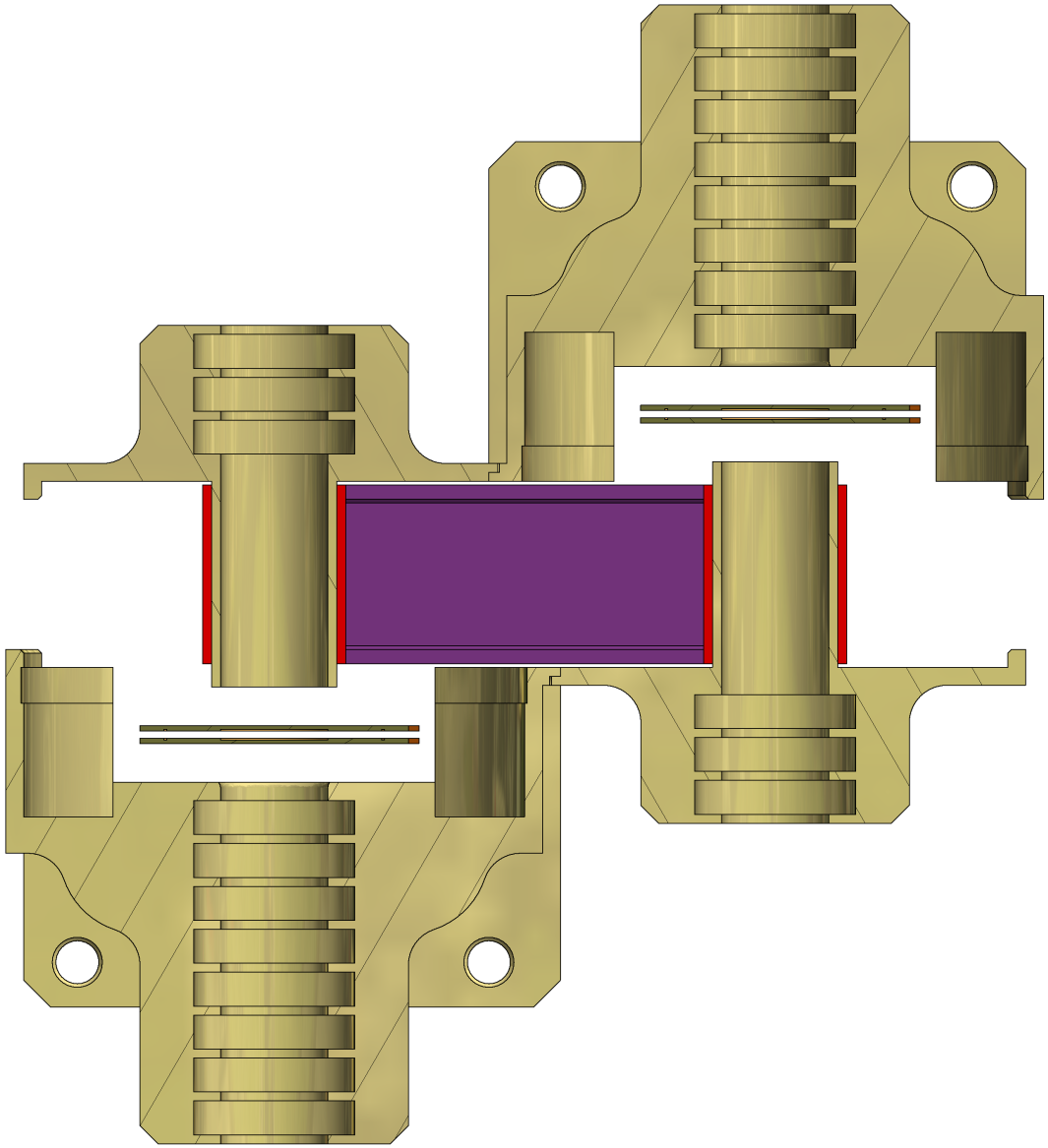
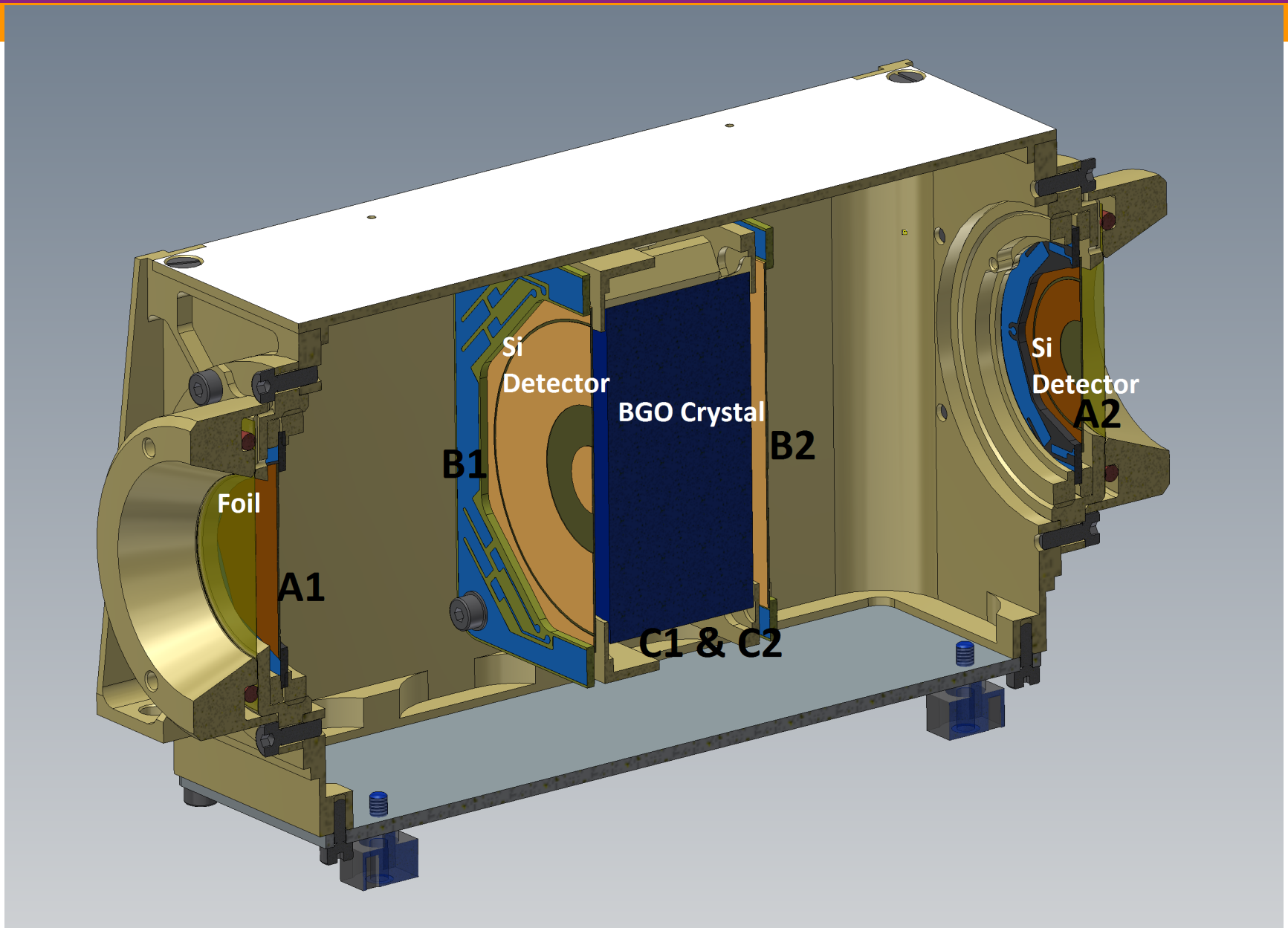
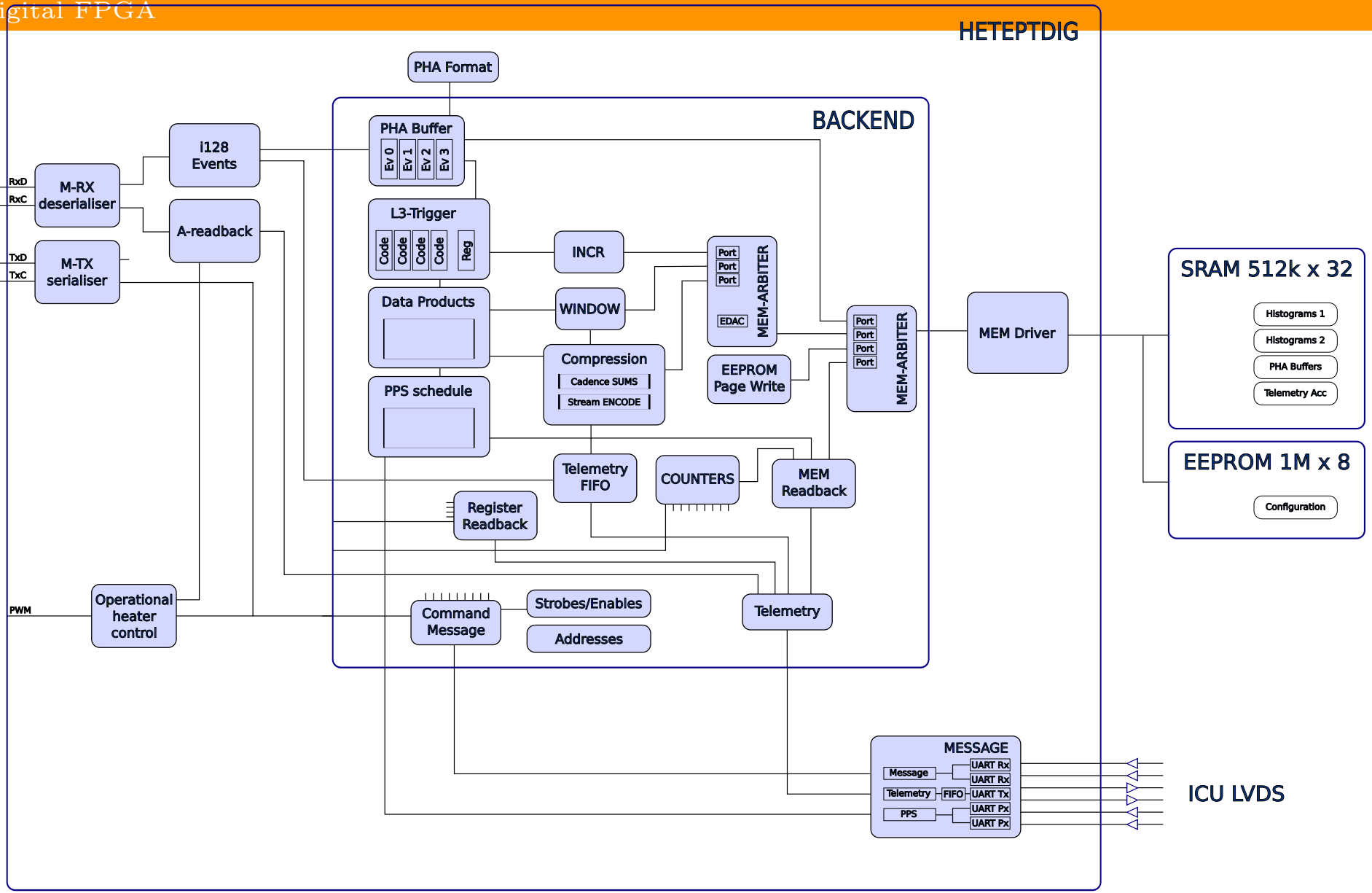
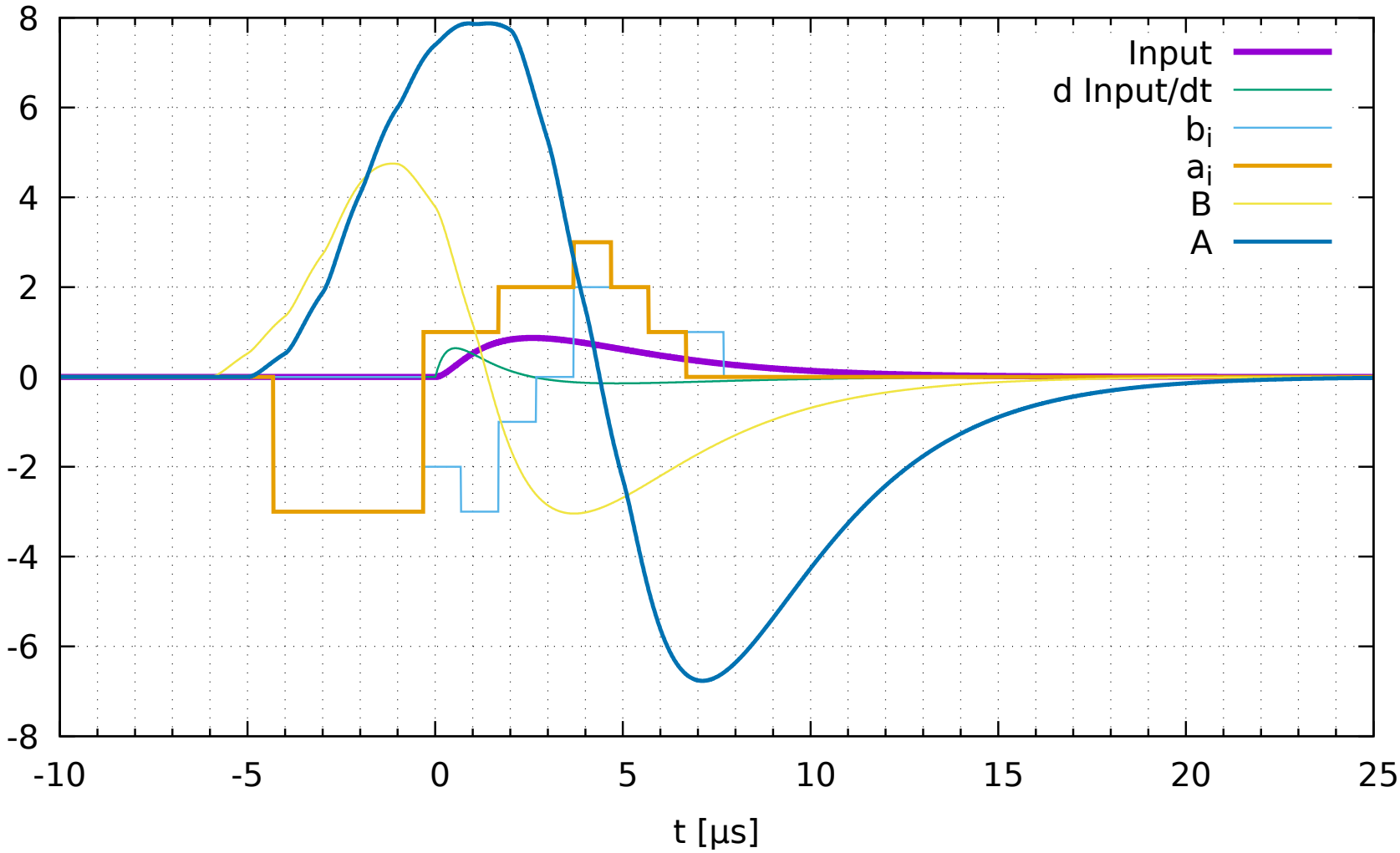



Si
Detector
BGO Crystal
B2
B1
Foil
A1
C1 & C2
Si
Detector
A2


HETEPTDIG
BACKEND
PHA Format
PHA Buffer
Ev 0
Ev 1
Ev 2
Ev 3
i128 Events
A-readback
RxD
RxC
M-RX deserialiser
TxD
TxC
M-TX serialiser
L3-Trigger
Code
Code
Code
Code
Reg
INCR
Data Products
WINDOW
Compression
Cadence SUMS
Stream ENCODE
PPS schedule
Port
Port
Port
EDAC
MEM-ARBITER
EEPROM Page Write
Port
Port
Port
Port
MEM-ARBITER
MEM Driver
SRAM 512k x 32
Histograms 1
Histograms 2
PHA Buffers
Telemetry Acc
EEPROM 1M x 8
Configuration
Telemetry FIFO
COUNTERS
MEM Readback
Register Readback
PWM
Operational heater control
Command Message
Strobes/Enables
Addresses
Telemetry
MESSAGE
Message
Telemetry
FIFO
PPS
UART Rx
UART Rx
UART Tx
UART Px
UART Px
ICU LVDS

Filter coefficients:

```
0.00385 0.690 7.873 -0.089 0.98 [0, 0, 0, -3, -3, -3, -3, 1, 1, 2, 2, 3, 2, 1, 0, 0]
```



Nominal L1

Channel	Threshold	9	8	7	6	5	4	3	2	1	0
A1	59.22 keV									×	
A2	59.22 keV									×	
A3	59.22 keV							×			
A4	59.22 keV							×			
C1	24.44 keV										×
C2	24.44 keV										×
C3	24.44 keV								×		
C4	24.44 keV								×		
A11H	48.96 keV				×						
A11L	1980 keV				×						
A12H	48.96 keV				×						
A12L	1980 keV				×						
A21H	48.96 keV		×								
A21L	1980 keV		×								
A22H	48.96 keV		×								
A22L	1980 keV		×								
B11H	48.96 keV			×			×				
B11L	1980 keV			×			×				
B12H	48.96 keV			×			×				
B12L	1980 keV			×			×				
B13G	49.82 keV			×							
B21H	48.96 keV	×				×					
B21L	1980 keV	×				×					
B22H	48.96 keV	×				×					
B22L	1980 keV	×				×					
B23G	49.82 keV	×									
C1H	3989 keV										
C1L	9836 keV										
C2H	3989 keV										
C2L	9836 keV										

Channel	Threshold	9	8	7	6	5	4	3	2	1	0
A1	59.22 keV						×			×	
A2	59.22 keV						×			×	
A3	59.22 keV						×	×			
A4	59.22 keV						×	×			
C1	24.44 keV						×				×
C2	24.44 keV						×				×
C3	24.44 keV						×		×		
C4	24.44 keV						×		×		
A11H	48.96 keV				×	×					
A11L	1980 keV				×	×					
A12H	48.96 keV				×	×					
A12L	1980 keV				×	×					
A21H	48.96 keV		×			×					
A21L	1980 keV		×			×					
A22H	48.96 keV		×			×					
A22L	1980 keV		×			×					
B11H	48.96 keV			×		×					
B11L	1980 keV			×		×					
B12H	48.96 keV			×		×					
B12L	1980 keV			×		×					
B13G	49.82 keV			×		×					
B21H	48.96 keV	×				×					
B21L	1980 keV	×				×					
B22H	48.96 keV	×				×					
B22L	1980 keV	×				×					
B23G	49.82 keV	×				×					
C1H	3989 keV					×					
C1L	9836 keV					×					
C2H	3989 keV					×					
C2L	9836 keV					×					

Nominal

	Any	None	All	Readout
0	x	.....x.	.....	xxxx.....
1	.....x..	.....x...	.....	....xxxx.....
2	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx	.....
3	xxxxxxxxxx	xxxxxxxxxx	xxxxxxxxxx	.....
4	...x.x....	xx.....	.....	.....xxxx....xxxxxxxxxxxxx
5	...xxx....	.....	.....	xxxxxxxxxxxxxxxxxxxx
6	.x..x.....	..xx.....	.....	.....xxxxxxxxxx..x.xxxxxx
7	.x..xx....	.....	.....	xxxxxxxxxxxxxxxxxxxx

Test

	Any	None	All	Readout
0	x	.....x.	.....	xxxx.....
1	.....x..	.....x...	.....	....xxxx.....
2	.....x....	.....	.....	xxxxxxxx.....
3	....x.....	.....	.....	xxxxxxxxxxxxxxxxxxxx
4	..xx.....	xx.....	.....	.....xxxx....xxxxxxxxxxxxx
5	x.xx.....	.....	.....	xxxxxxxxxxxxxxxxxxxx
6	xx.....	..xx.....	.....	.....xxxxxxxxxx..x.xxxxxx
7	xxx.....	.....	.....	xxxxxxxxxxxxxxxxxxxx

Each channel records a *pulse age* between 0 and 15 μs. Age=0 when the pulse height reconstructed is lower than the previous one and no peak was observed. Age=1 when the reconstructed pulse height is rising. Age greater than one means that the considered pulse heigth is a maximum that was observed that many microseconds ago.

The coincidence window is defined by three configurable pulse age limits: *min/trig/max*. When a pulse age reaches *max*, it is reset to zero. At least one channel of each L3 trigger condition must have reached age *trig*, and all required channels in an *all* trigger must have reached age *min*.

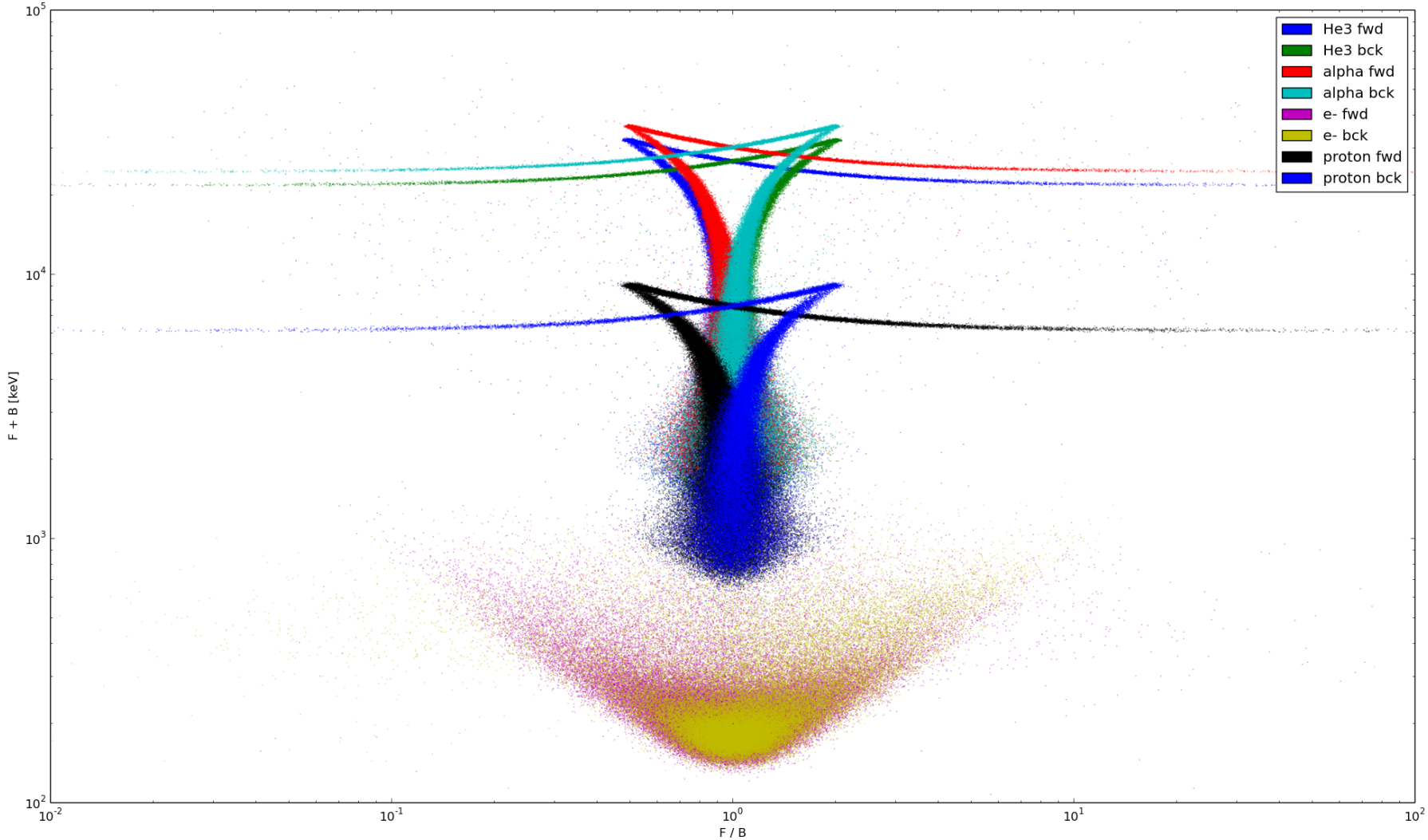
Currently we consider $min/trig/max = 2/5/8$.

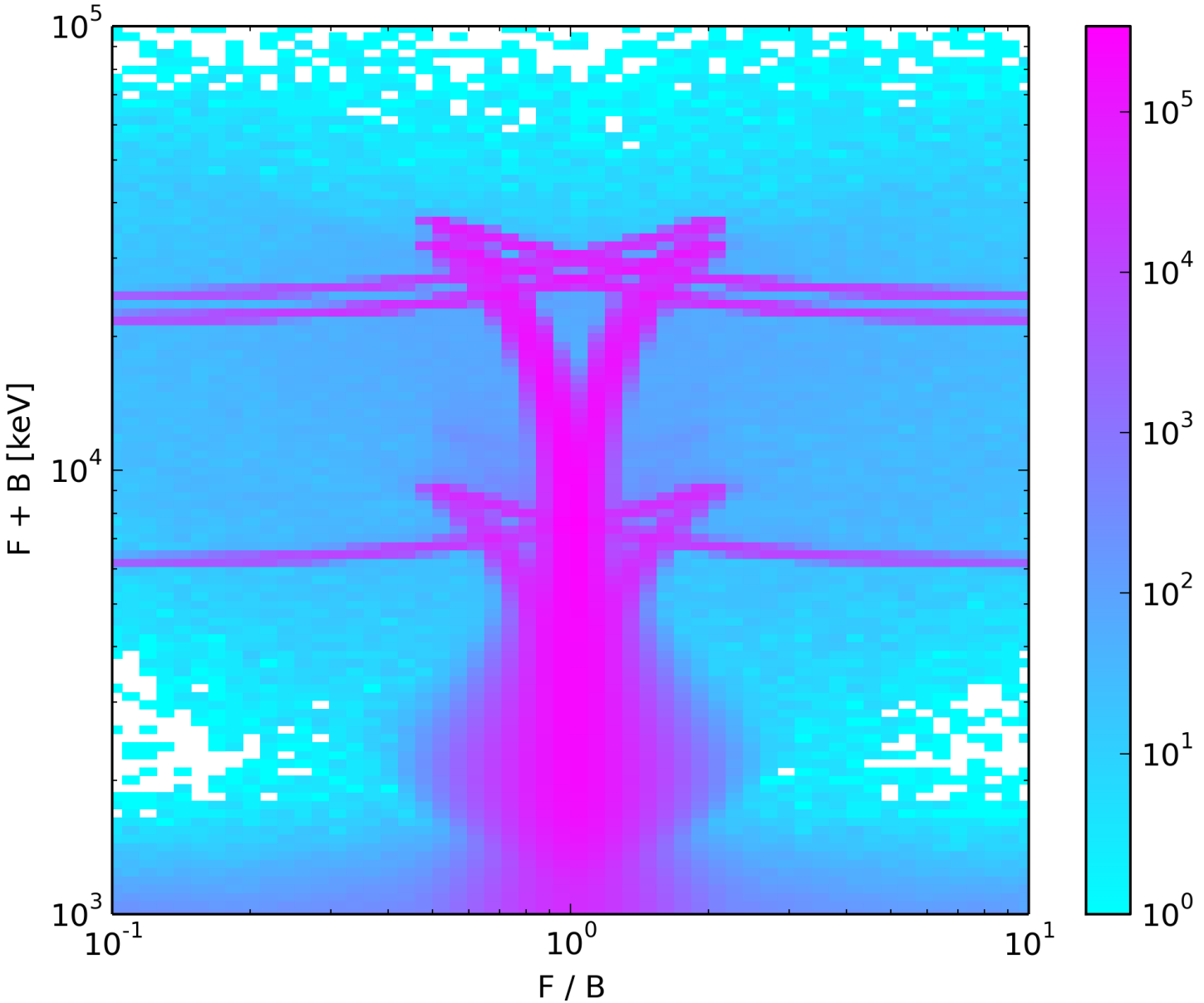
```
ITF 100 0x57ea 0x003fffff 0x18 0 10513 0 9 -6 0 12 44
0 113 0 18 0 -1 0 6 0 9 -11 0 9 10 6 218 0 0 0 0 0 0
0 0 0 7 3 0 1 2 7 5 0 5 0 2 0 1 0 3 0 0 2 6 3 5 0 0
0 0 0 0 0 0 0 0 -4 0 0 7 0 27 0 3 0 3 0 6 0 -1 1 0 -5
-4 0 34 0 0 0 0 0 0 0 0
```

```
ITF 44 0x57ea 0x3fc00000 0x05 0 31887 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -4 3 3 5 3 31 1 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 7 1 4 2 5 2 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 0 -4 0 -4
-4 7 -3
```

STOP		cc00 0000 0--- ---- ---- ---- ---- ----
NOP		cc00 0000 10-- ---- ---- ---- ---- ----
GOTO	u_{10}	cc00 0000 11-- --uu uuuu uuuu ---- ----
LOG	R_x	cc00 0001 ---- ---- ---- ---- xxxx xxxx
POKE	$R_d = R_x$	cc00 0010 ---- ---- dddd dddd xxxx xxxx
BITC	$R_x\{u_5\}$	cc00 0011 n0SC ---- ---u uuuu xxxx xxxx
BITS	$R_x\{u_5\}$	cc00 0011 n1SC ---- ---u uuuu xxxx xxxx
BRNG	$R_x\{v_5 : u_5\}$	cc00 0100 ---- --vv vvvu uuuu xxxx xxxx
TRIM	R_x, u_8, v_8	cc00 0101 vvvv vvvv uuuu uuuu xxxx xxxx
MULI	$R_x * m_{12} \gg e_4$	cc00 0110 eeee mmmm mmmm mmmm xxxx xxxx
PHA	$R_x + u_{16}$	cc00 0111 uuuu uuuu uuuu uuuu xxxx xxxx
ADD	$R_x \gg i_4 + R_y \gg j_4$	cc00 1000 yyyy yyyy jjjj iiii xxxx xxxx
SUB	$R_x \gg i_4 - R_y \gg j_4$	cc00 1001 yyyy yyyy jjjj iiii xxxx xxxx
HIST	$R_x \gg i_4 + R_y \gg j_4$	cc00 1100 yyyy yyyy jjjj iiii xxxx xxxx
HIST	$R_x \gg i_4 - R_y \gg j_4$	cc00 1101 yyyy yyyy jjjj iiii xxxx xxxx
CMP	$R_x + u_8 <=> R_y$	cc01 0ooo yyyy yyyy uuuu uuuu xxxx xxxx
CMP	$R_x <=> R_y + u_8$	cc01 1ooo yyyy yyyy uuuu uuuu xxxx xxxx
ADDI	$R_x + i_{21}$	cc1i iiii iiii iiii iiii iiii xxxx xxxx

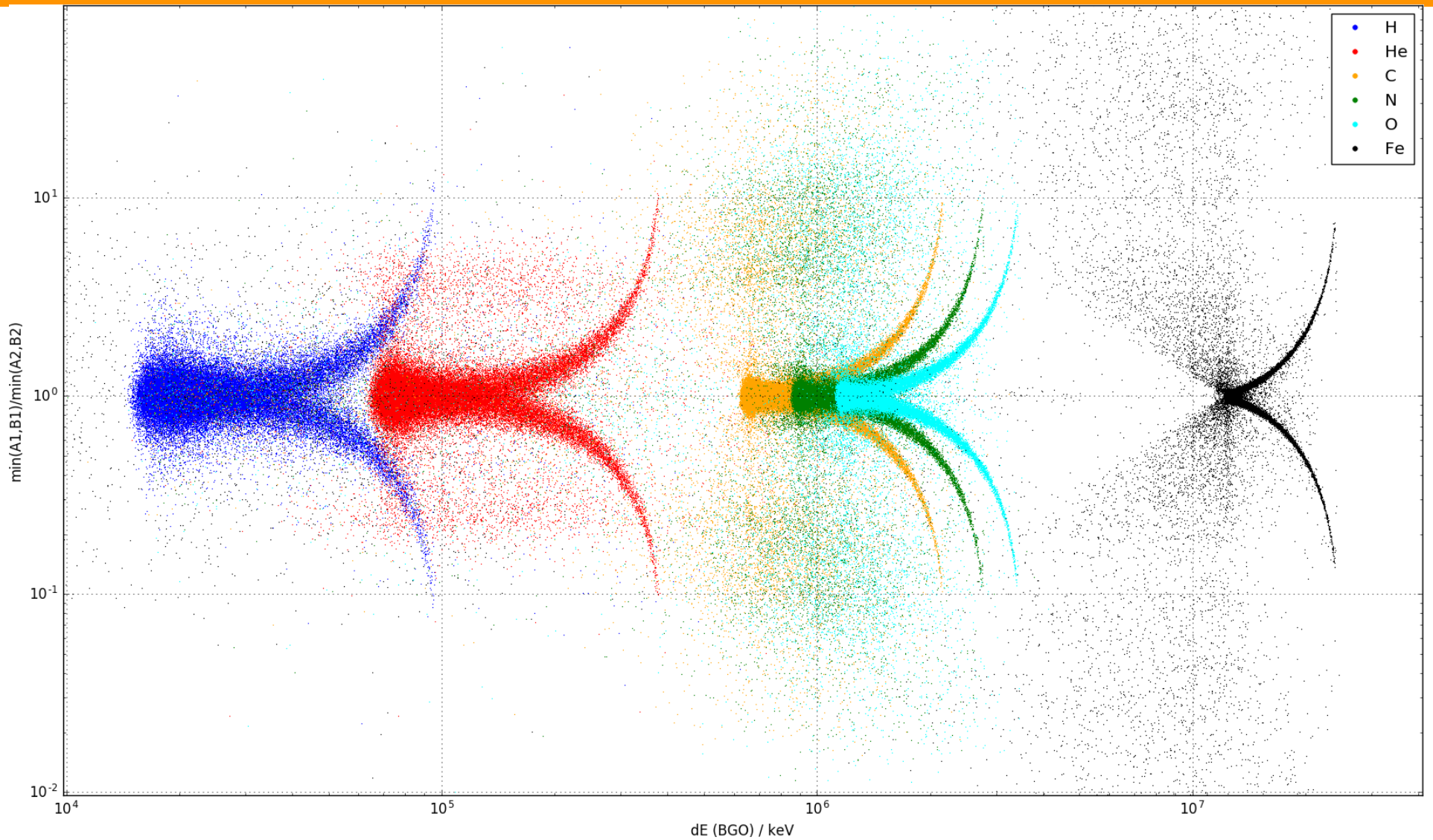
- Stopping EPT: four histograms.
  256 bins from 2 keV, 16 bins/octave.
- Penetrating EPT: $\log_2(F+B)$ vs $\log_2(F/B)$.
  $F+B$: 128 bins from 1 MeV, 16 bins/octave.
  F/B: 64 bins from 1/4 to 4.


He3 fwd
He3 bck
alpha fwd
alpha bck
e- fwd
e- bck
proton fwd
proton bck
F + B [keV]
F / B
10^5
10^4
10^3
10^2
10^{-2}
10^{-1}
10^0
10^1
10^2

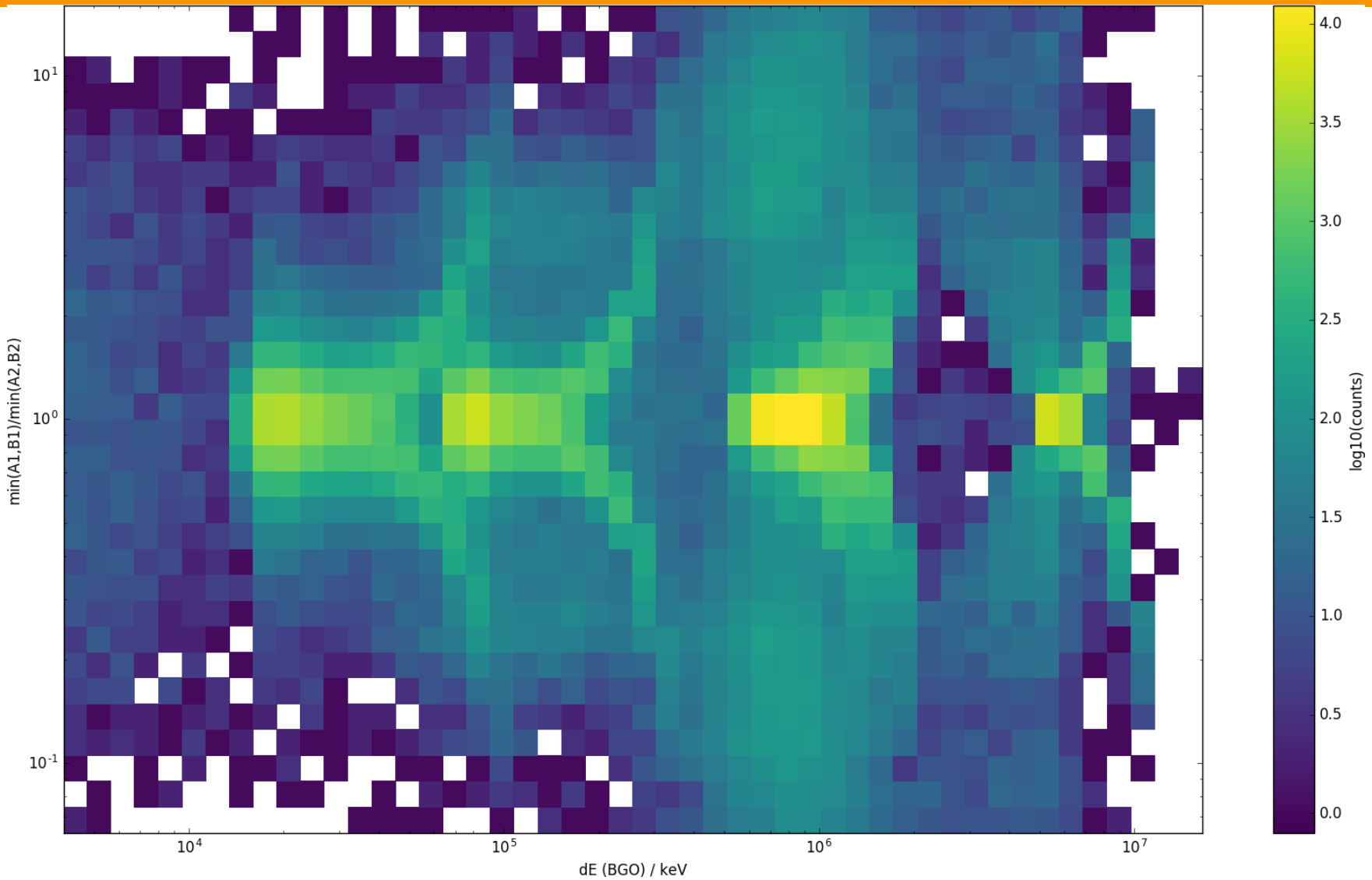

10^5
10^4
10^3
F + B [keV]
10^{-1}
10^0
10^1
F / B
10^5
10^4
10^3
10^2
10^1
10^0

- Require coincidence $ABBA$.
- $A_1 = \max(A_{11}, A_{12}), \ldots$
- $\mathrm{LET}_1 = \min(A_1, B_1), \ldots$
- Histogram: $\log_2\left(\frac{\mathrm{LET}_1}{\mathrm{LET}_2}\right)$ vs $\log_2(C)$.
- C: 48 bins from 4 MeV, 4 bins/octave.
- $\mathrm{LET}_1/\mathrm{LET}_2$: 32 bins from 1/16 to 16.

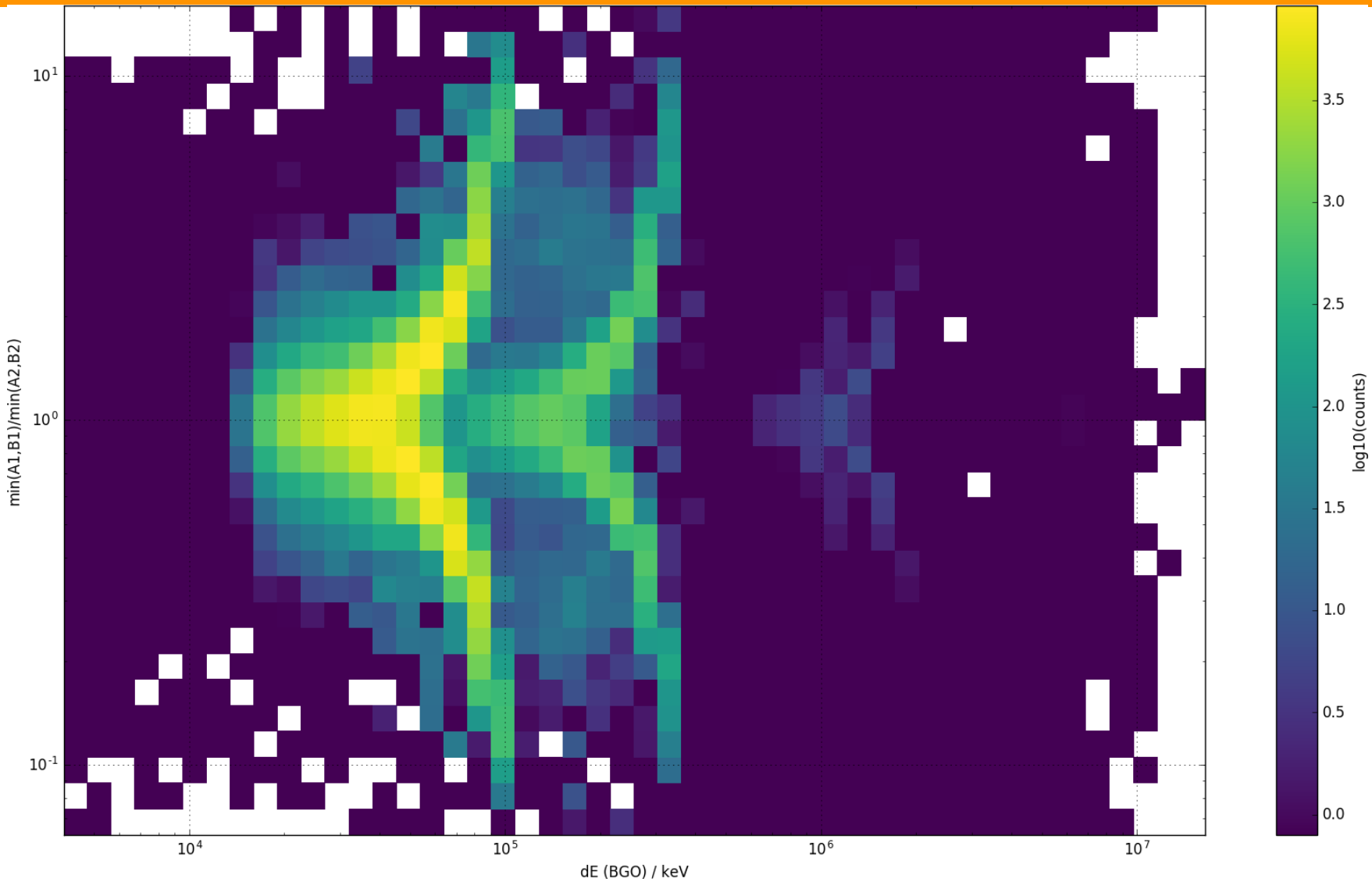
HET penetrating



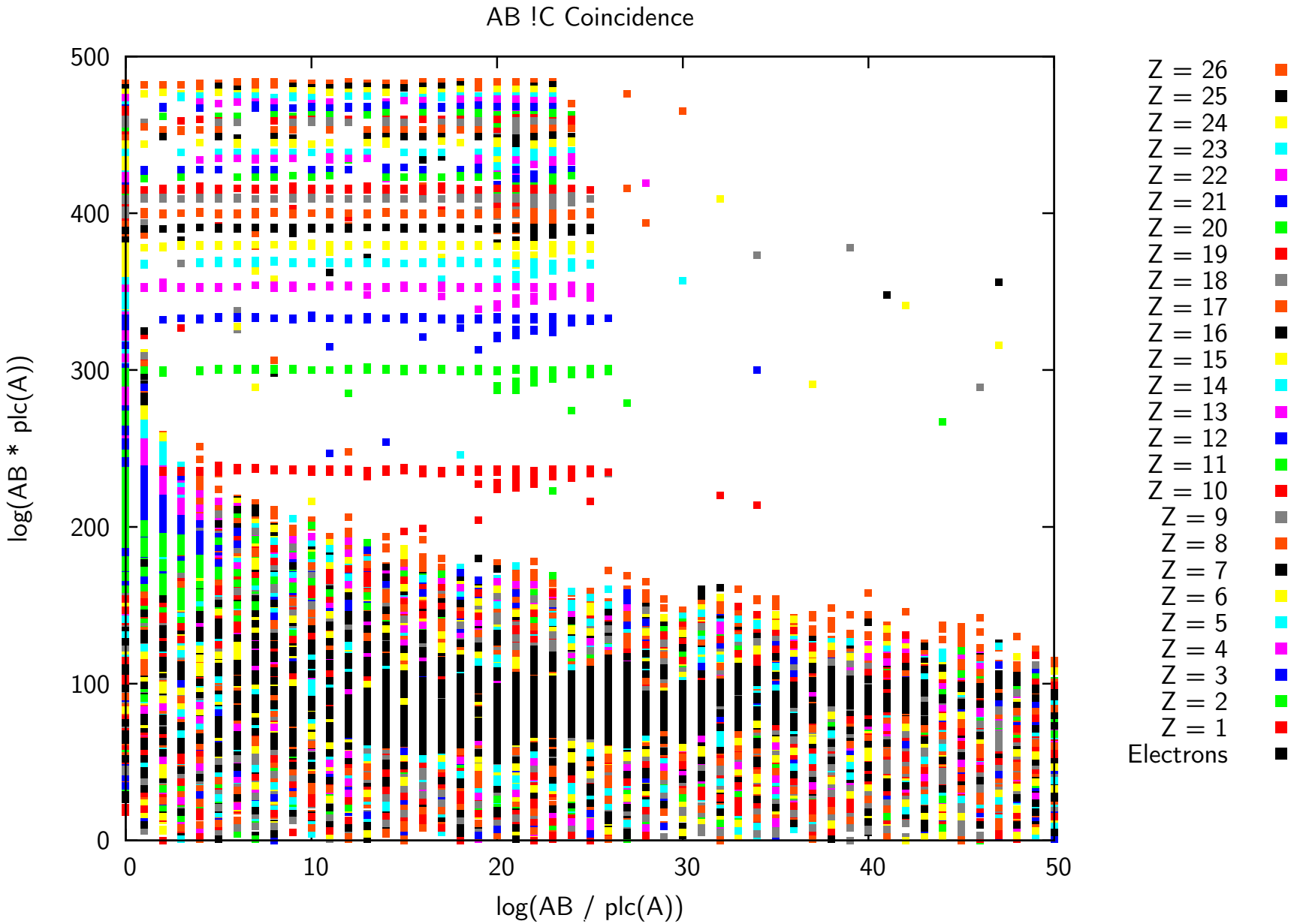
HET penetrating

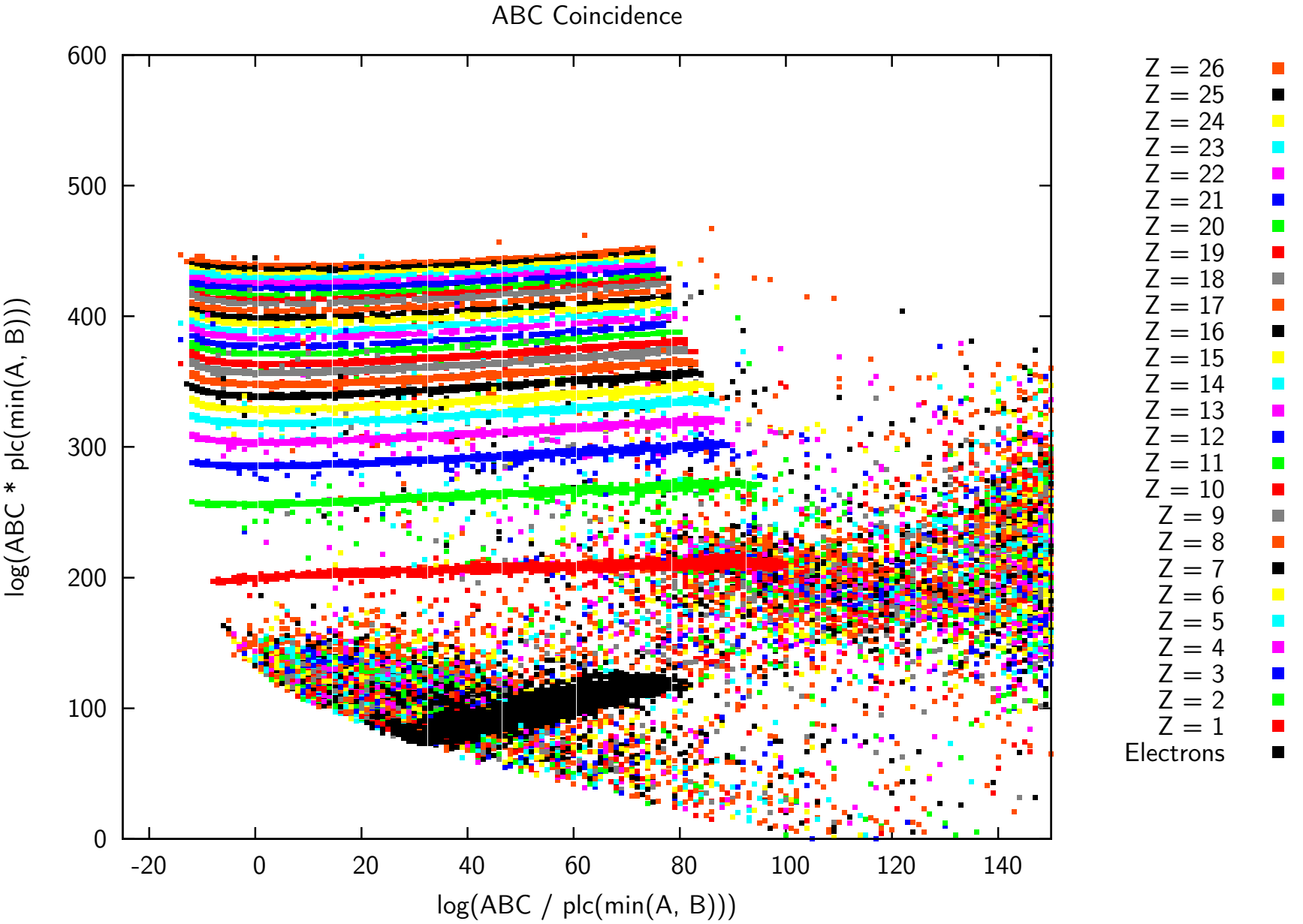


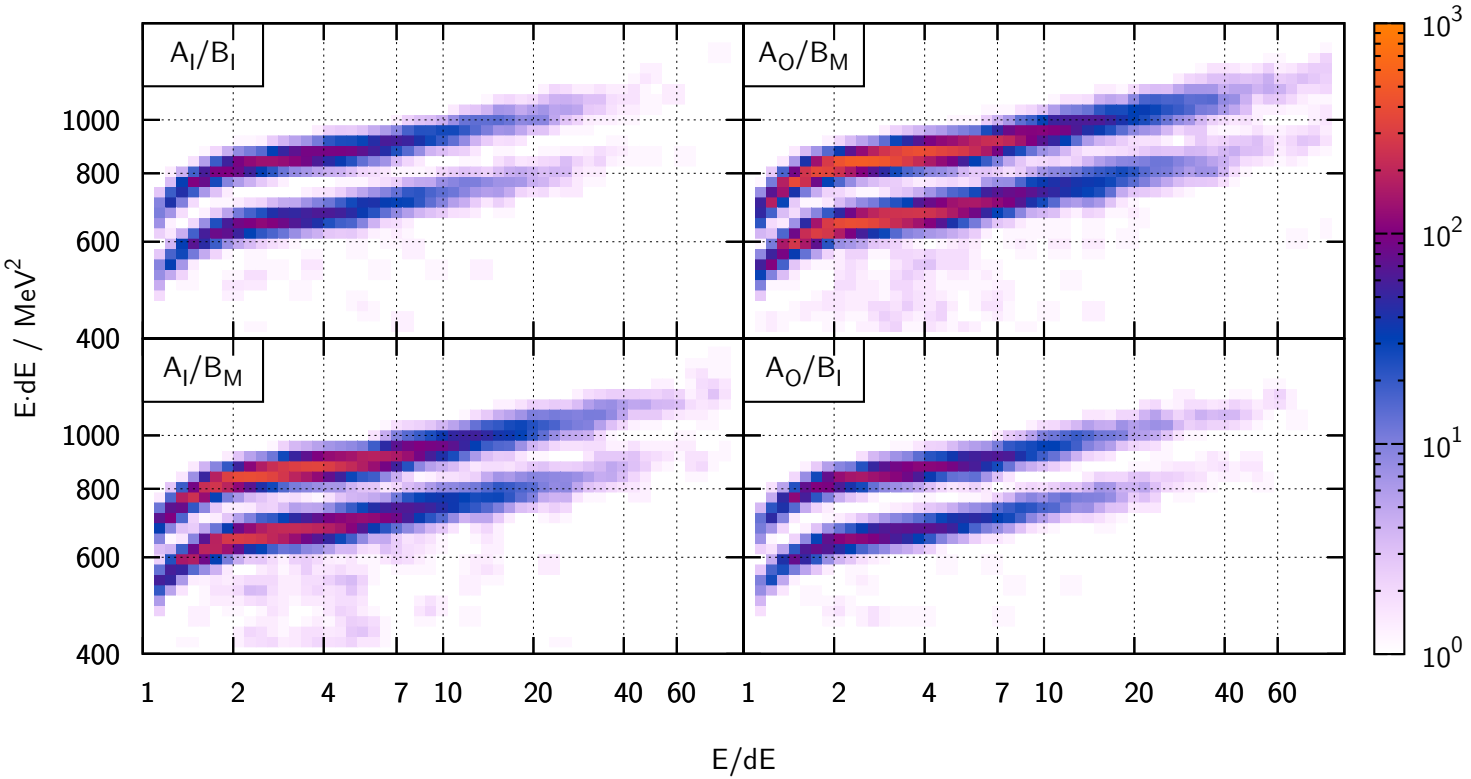
HET penetrating



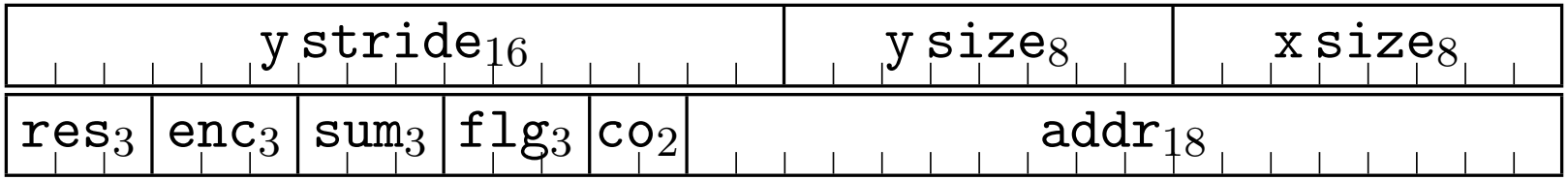
- Stopping in B:
  Histogram $\log_2(A(A+B))$ vs $\log_2(\frac{A+B}{A})$.
- Stopping in C:
  Histogram $\log_2(\min(A,B)(A+B+C))$ vs $\log_2(\frac{A+B+C}{\min(A,B)})$.


AB !C Coincidence
log(AB * plc(A))
log(AB / plc(A))
0
100
200
300
400
500
0
10
20
30
40
50
Z = 26
Z = 25
Z = 24
Z = 23
Z = 22
Z = 21
Z = 20
Z = 19
Z = 18
Z = 17
Z = 16
Z = 15
Z = 14
Z = 13
Z = 12
Z = 11
Z = 10
Z = 9
Z = 8
Z = 7
Z = 6
Z = 5
Z = 4
Z = 3
Z = 2
Z = 1
Electrons


ABC Coincidence
log(ABC * plc(min(A, B)))
log(ABC / plc(min(A, B)))
600
500
400
300
200
100
0
-20
0
20
40
60
80
100
120
140
Z = 26
Z = 25
Z = 24
Z = 23
Z = 22
Z = 21
Z = 20
Z = 19
Z = 18
Z = 17
Z = 16
Z = 15
Z = 14
Z = 13
Z = 12
Z = 11
Z = 10
Z = 9
Z = 8
Z = 7
Z = 6
Z = 5
Z = 4
Z = 3
Z = 2
Z = 1
Electrons


A_I/B_I
A_O/B_M
A_I/B_M
A_O/B_I
E·dE / MeV^2
E/dE
1000
800
600
400
1
2
4
7
10
20
40
60
10^3
10^2
10^1
10^0

DPS



$\texttt{y stride}_{16}$	Address offset between rows	
$\texttt{y size}_{8}$	Number of rows	$1 \ldots 256$
$\texttt{x size}_{8}$	Number of Columns	$1 \ldots 256$
$\texttt{res}_{3}$	Reset cadence	$= \texttt{sum}_{3}$
$\texttt{enc}_{3}$	Encoding cycle cadence	
$\texttt{sum}_{3}$	Summing cadence	
$\texttt{flg}_{3}$	*Add*, *Clear*, *Send* flags	
$\texttt{co}_{2}$	Compression format	
$\texttt{addr}_{18}$	Memory address	

TODO