ProtoDUNE SP TPC response functions

ProtoDUNE-SP simulation task force

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Introduction

I have been looking at response functions

- I.e. the x, u and v waveforms we expect for a charge deposit
- Depend on the position of the deposit

Fig. 15b in ProtoDUNE-SP performance paper

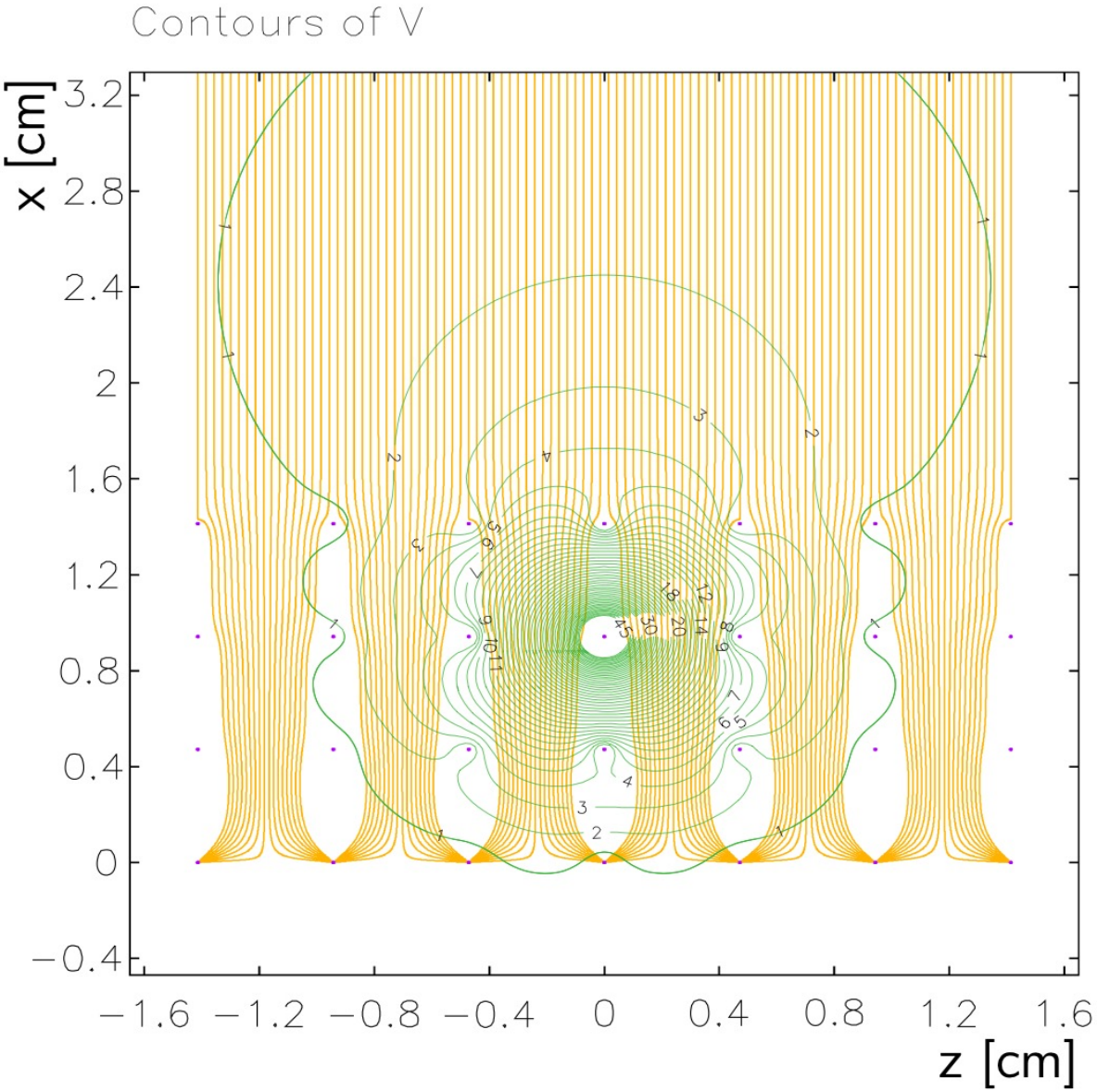
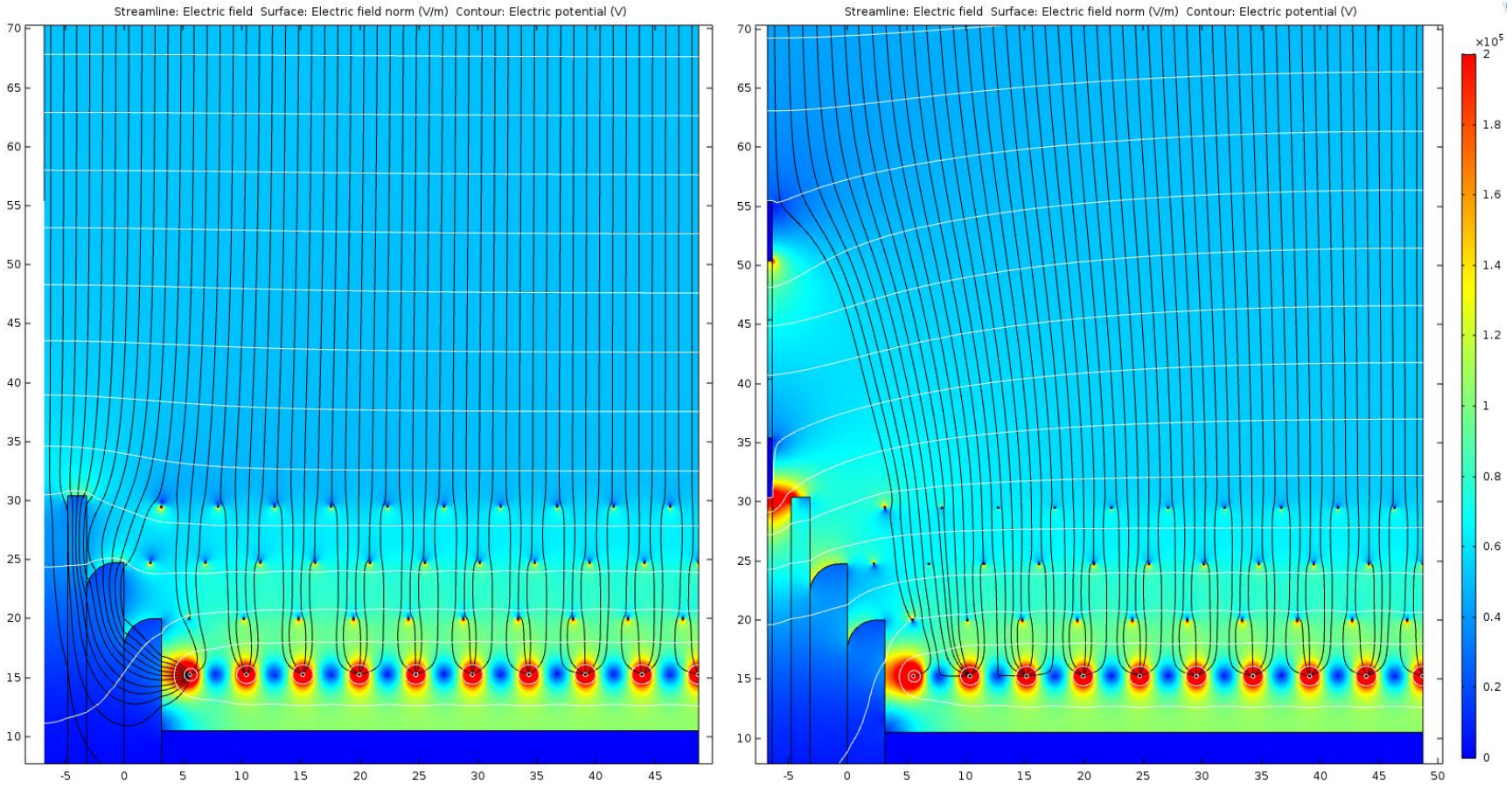
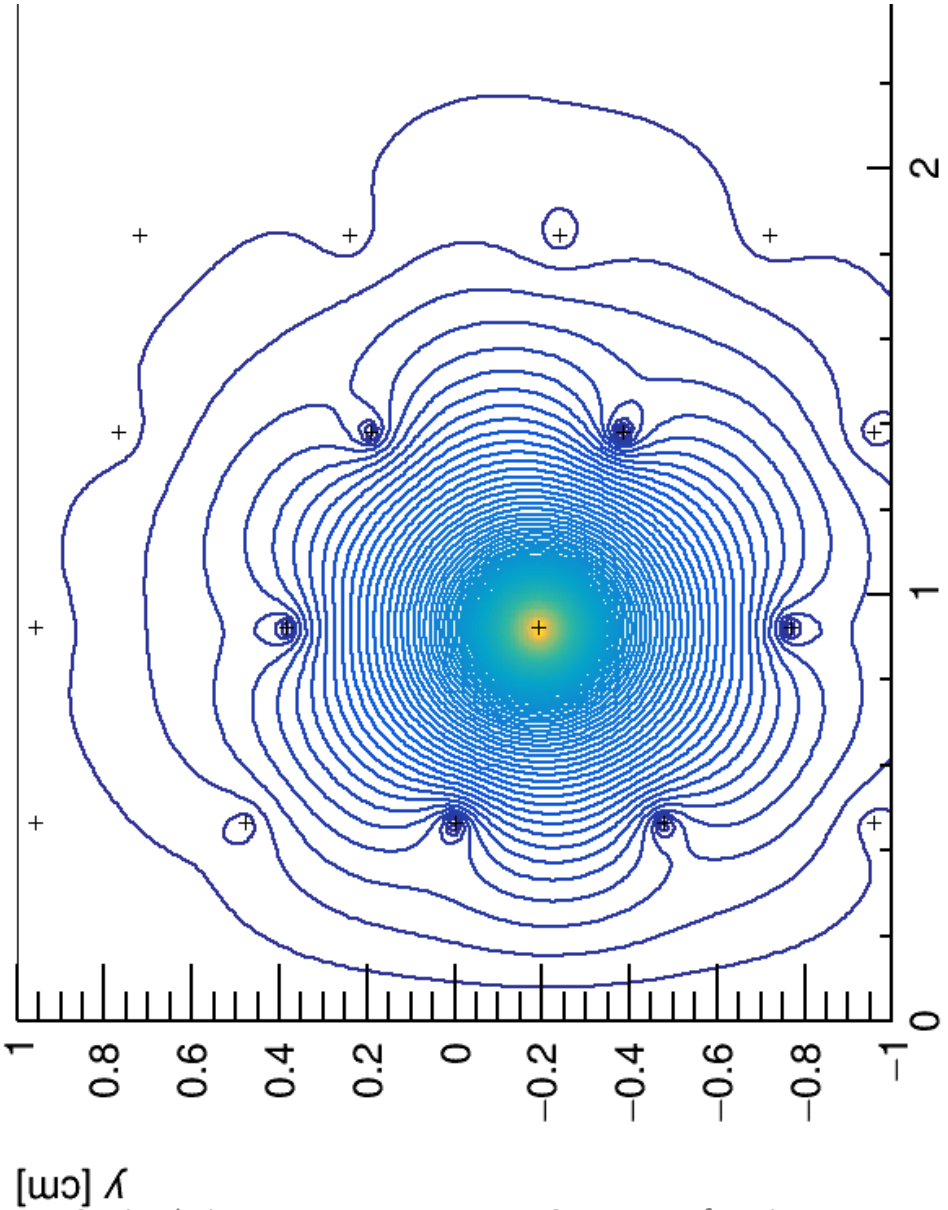


Figure 2.11 in ProtoDUNE-SP TDR

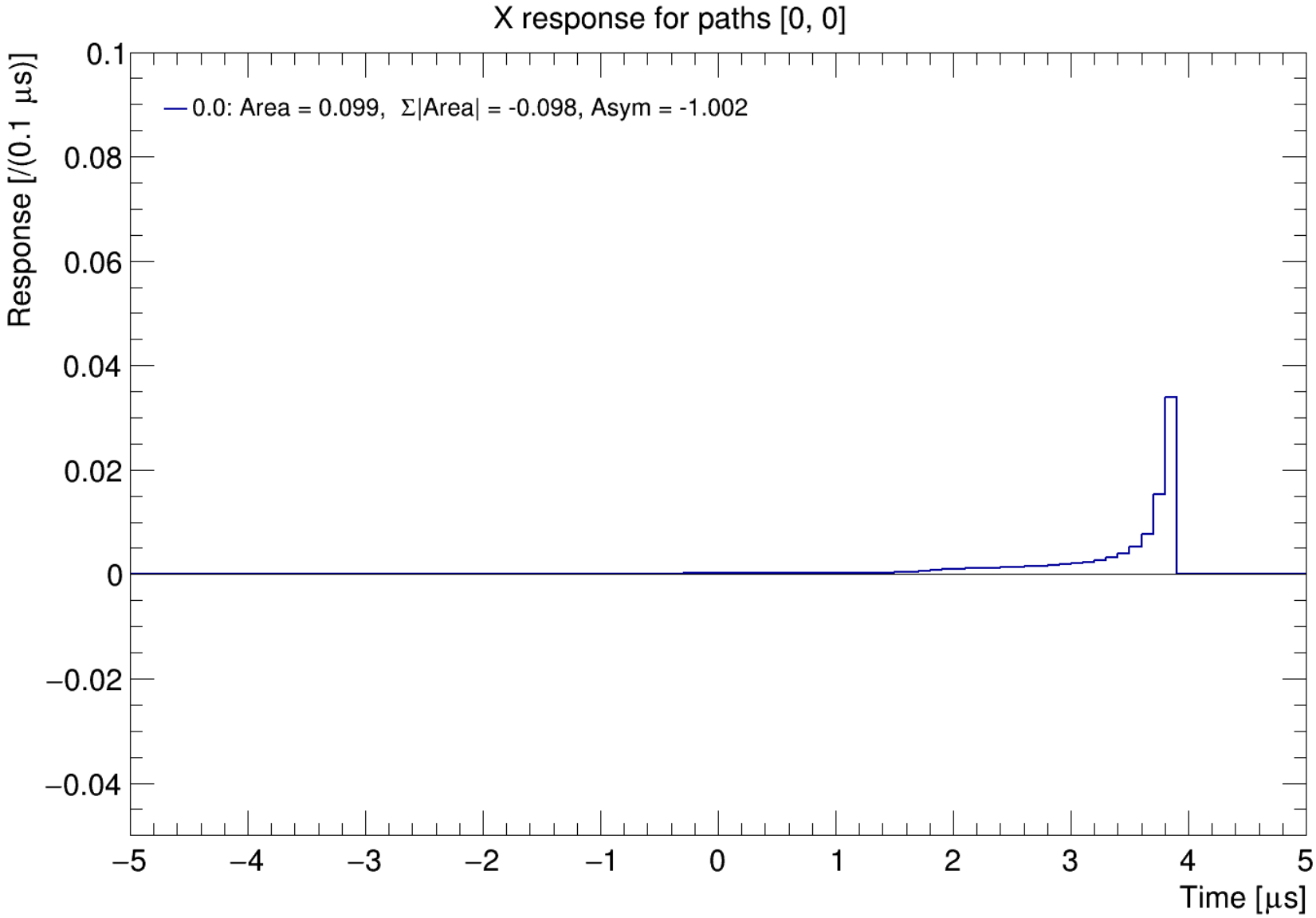


My Garfield v weighting field

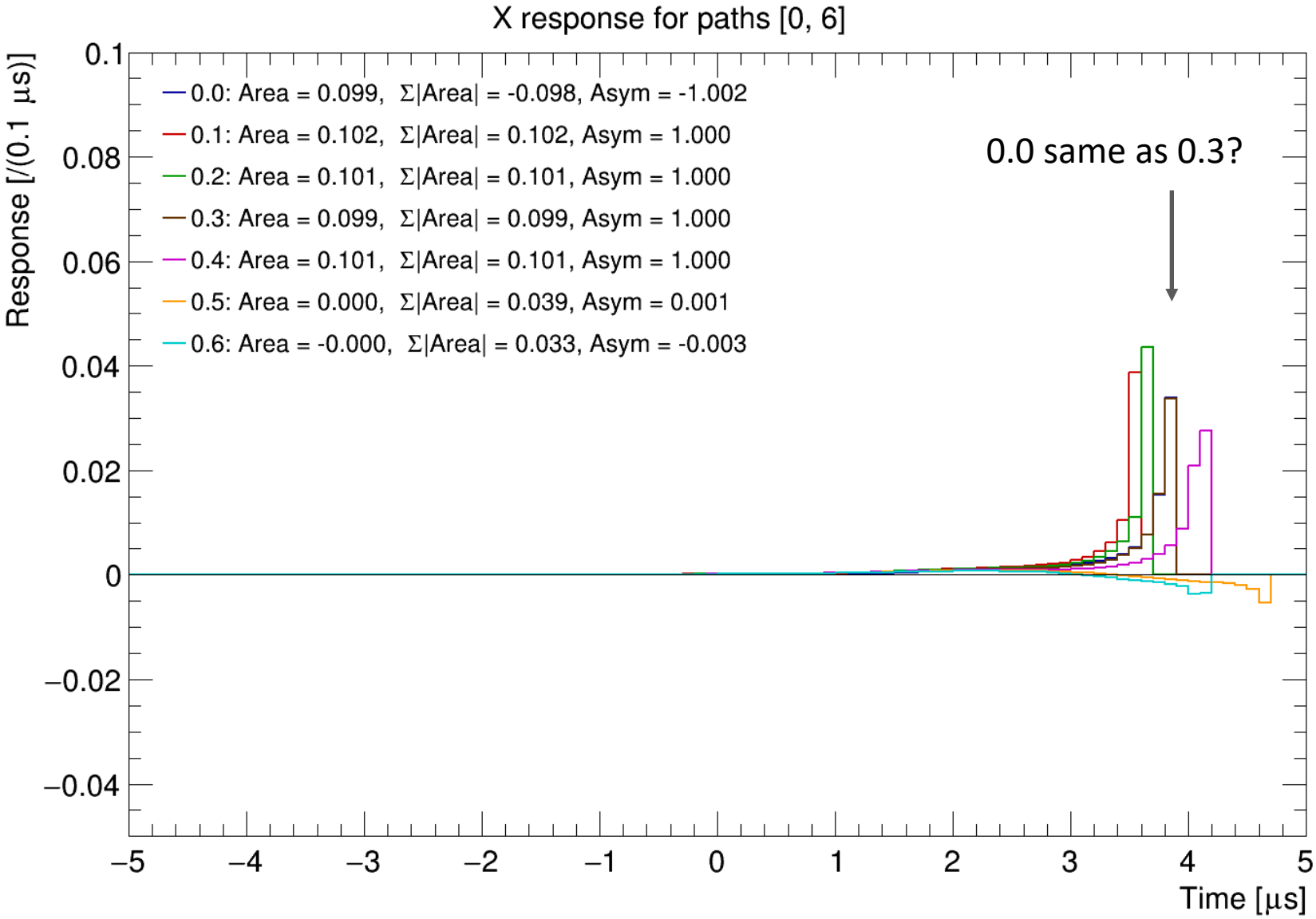


Individual paths (Wenqiang histogram)

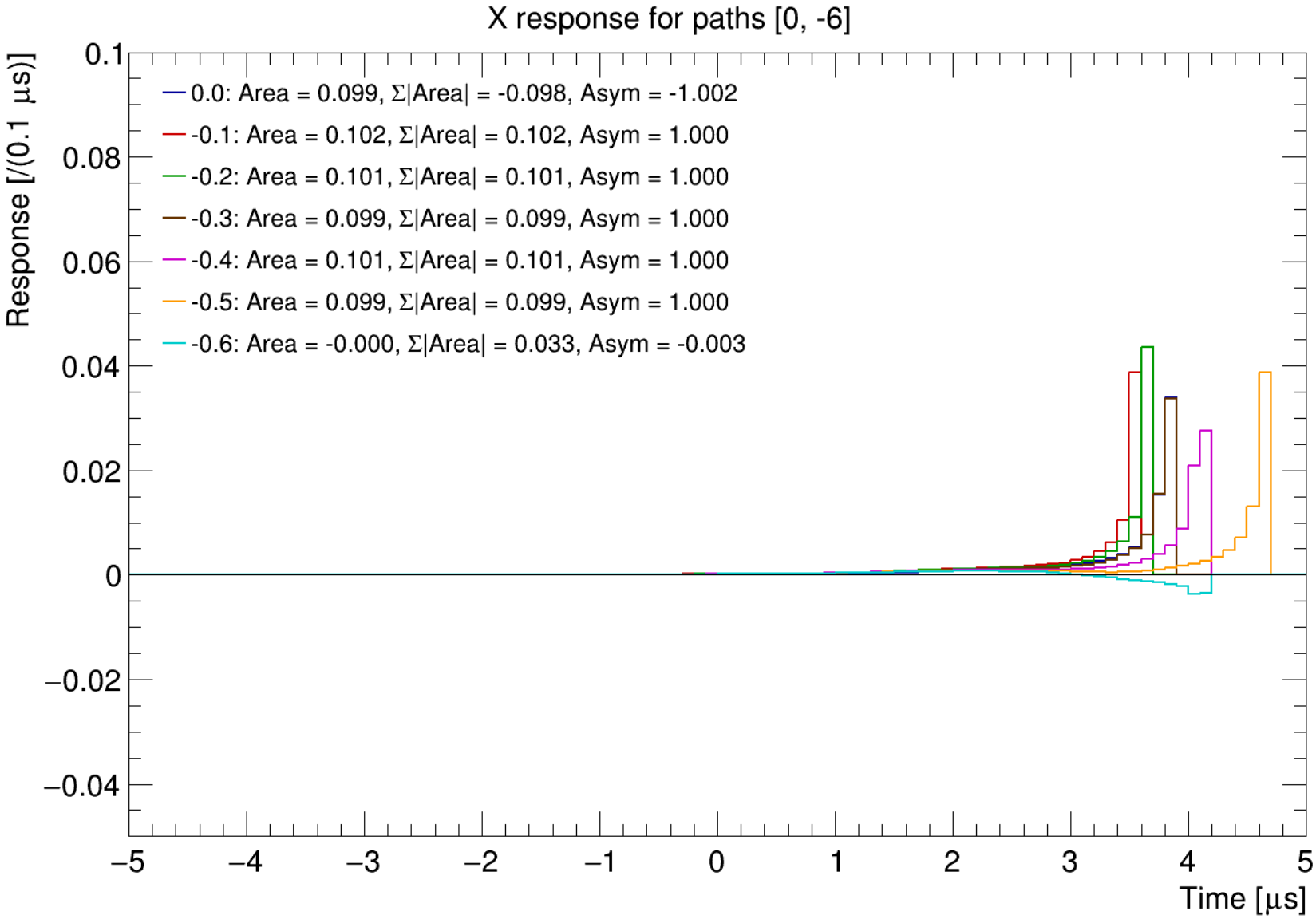
X: z = 0


X response for paths [0, 0]
0.0: Area = 0.099, Σ|Area| = -0.098, Asym = -1.002
Response [/(0.1 μs)]
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−5
−4
−3
−2
−1
0
1
2
3
4
5
Time [μs]

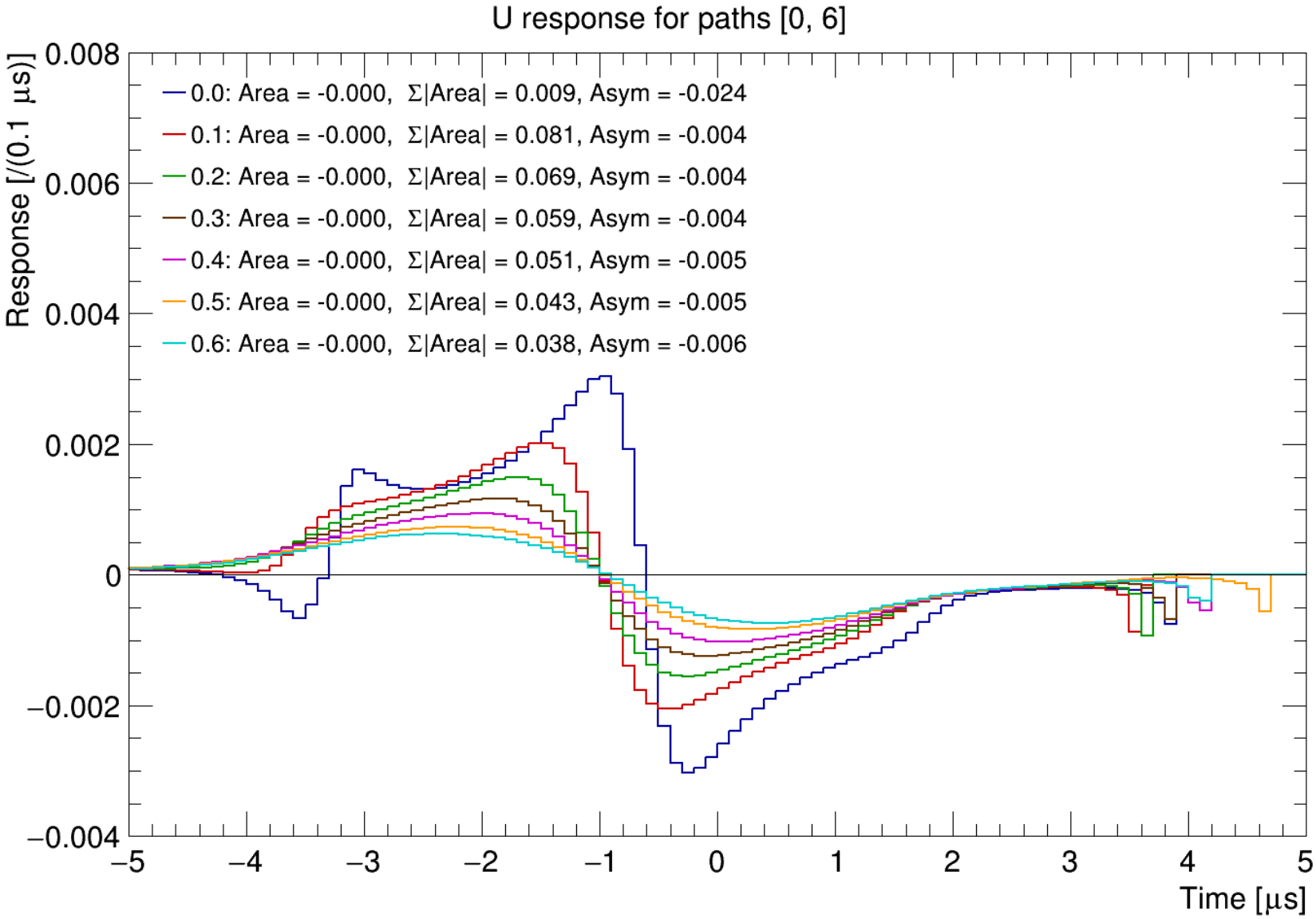
X: z > 0


X response for paths [0, 6]
Response [/(0.1 μs)]
Time [μs]
0.0: Area = 0.099, Σ|Area| = -0.098, Asym = -1.002
0.1: Area = 0.102, Σ|Area| = 0.102, Asym = 1.000
0.2: Area = 0.101, Σ|Area| = 0.101, Asym = 1.000
0.3: Area = 0.099, Σ|Area| = 0.099, Asym = 1.000
0.4: Area = 0.101, Σ|Area| = 0.101, Asym = 1.000
0.5: Area = 0.000, Σ|Area| = 0.039, Asym = 0.001
0.6: Area = -0.000, Σ|Area| = 0.033, Asym = -0.003
0.0 same as 0.3?

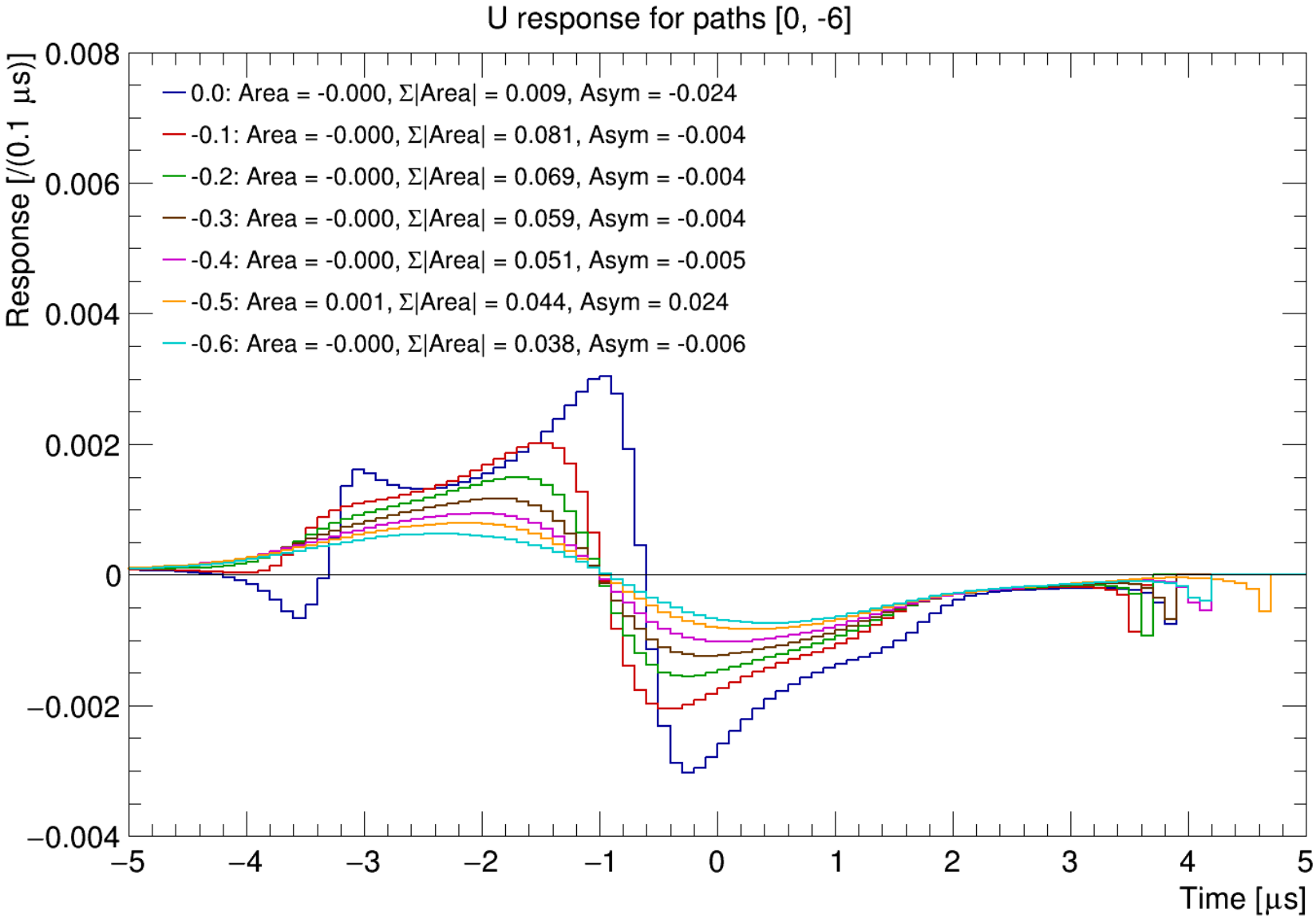
X: z < 0


X response for paths [0, -6]
Response [/(0.1 μs)]
Time [μs]
0.0: Area = 0.099, Σ|Area| = -0.098, Asym = -1.002
-0.1: Area = 0.102, Σ|Area| = 0.102, Asym = 1.000
-0.2: Area = 0.101, Σ|Area| = 0.101, Asym = 1.000
-0.3: Area = 0.099, Σ|Area| = 0.099, Asym = 1.000
-0.4: Area = 0.101, Σ|Area| = 0.101, Asym = 1.000
-0.5: Area = 0.099, Σ|Area| = 0.099, Asym = 1.000
-0.6: Area = -0.000, Σ|Area| = 0.033, Asym = -0.003
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−5
−4
−3
−2
−1
0
1
2
3
4
5

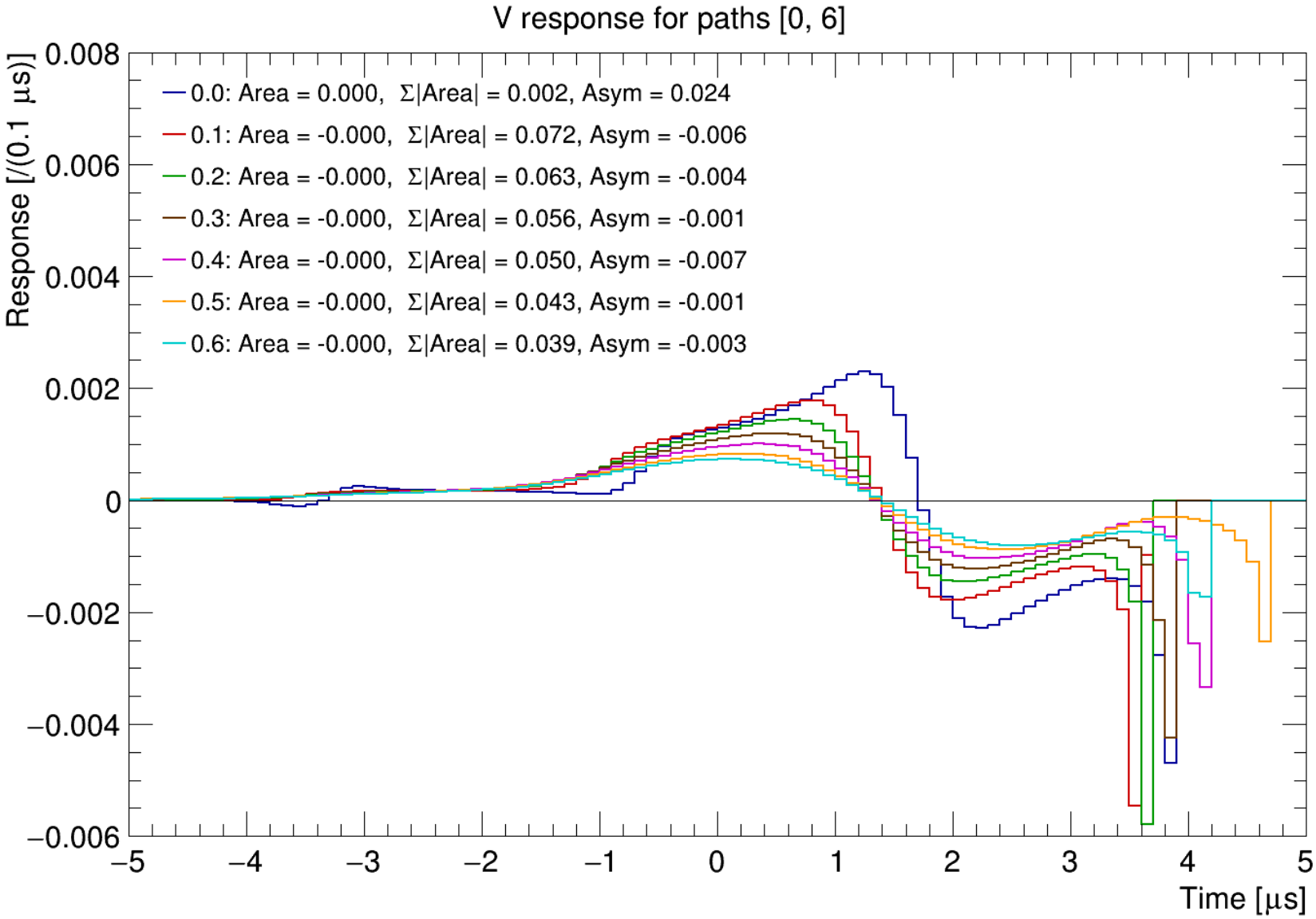
U: z > 0


U response for paths [0, 6]
Response [/(0.1 μs)]
0.008
0.006
0.004
0.002
0
−0.002
−0.004
0.0: Area = -0.000, Σ|Area| = 0.009, Asym = -0.024
0.1: Area = -0.000, Σ|Area| = 0.081, Asym = -0.004
0.2: Area = -0.000, Σ|Area| = 0.069, Asym = -0.004
0.3: Area = -0.000, Σ|Area| = 0.059, Asym = -0.004
0.4: Area = -0.000, Σ|Area| = 0.051, Asym = -0.005
0.5: Area = -0.000, Σ|Area| = 0.043, Asym = -0.005
0.6: Area = -0.000, Σ|Area| = 0.038, Asym = -0.006
−5
−4
−3
−2
−1
0
1
2
3
4
5
Time [μs]

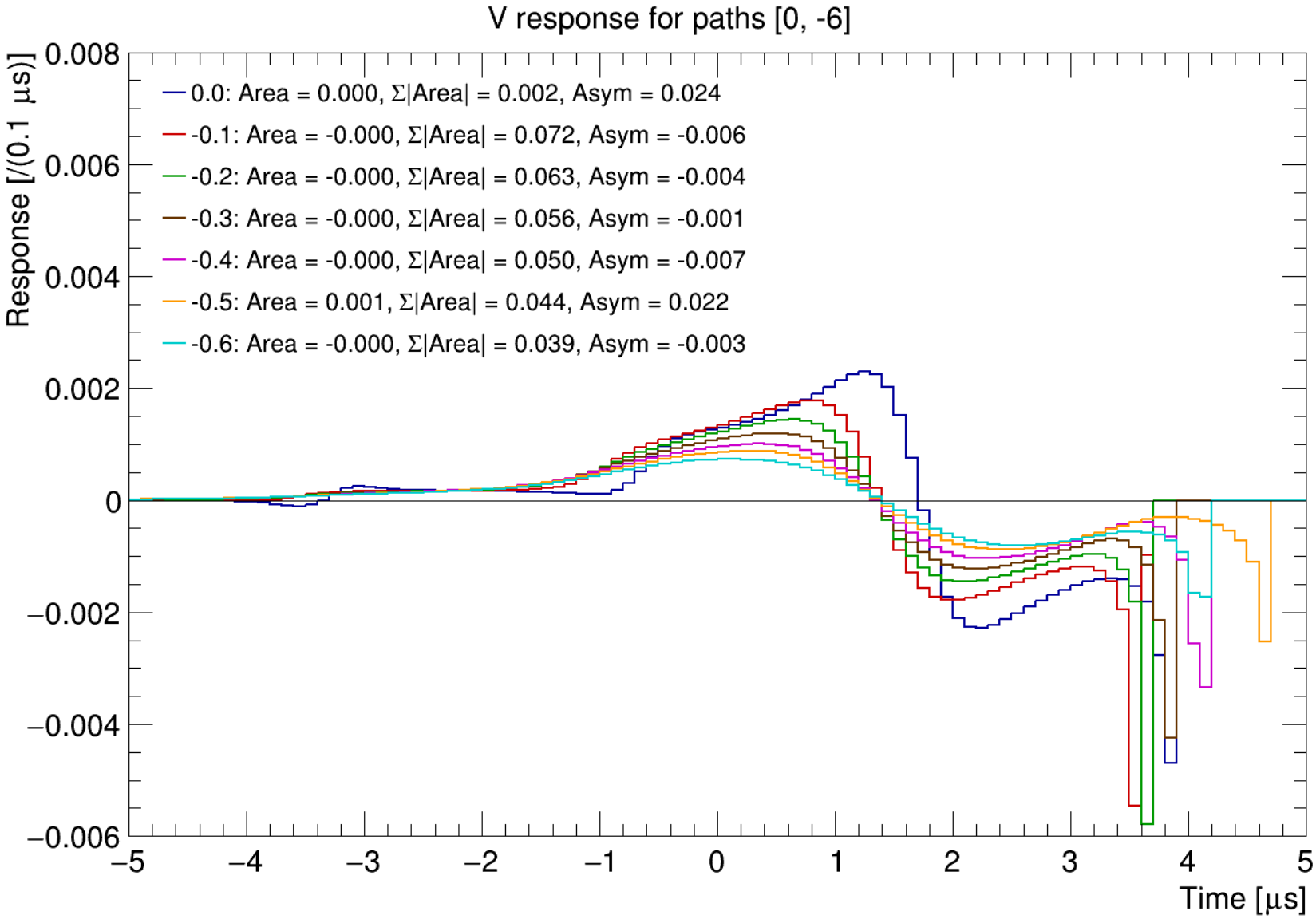
U: z < 0


U response for paths [0, -6]
Response [/(0.1 μs)]
0.008
0.006
0.004
0.002
0
−0.002
−0.004
0.0: Area = -0.000, Σ|Area| = 0.009, Asym = -0.024
-0.1: Area = -0.000, Σ|Area| = 0.081, Asym = -0.004
-0.2: Area = -0.000, Σ|Area| = 0.069, Asym = -0.004
-0.3: Area = -0.000, Σ|Area| = 0.059, Asym = -0.004
-0.4: Area = -0.000, Σ|Area| = 0.051, Asym = -0.005
-0.5: Area = 0.001, Σ|Area| = 0.044, Asym = 0.024
-0.6: Area = -0.000, Σ|Area| = 0.038, Asym = -0.006
−5
−4
−3
−2
−1
0
1
2
3
4
5
Time [μs]

V: z > 0


V response for paths [0, 6]
Response [/(0.1 μs)]
0.008
0.006
0.004
0.002
0
−0.002
−0.004
−0.006
0.0: Area = 0.000, Σ|Area| = 0.002, Asym = 0.024
0.1: Area = -0.000, Σ|Area| = 0.072, Asym = -0.006
0.2: Area = -0.000, Σ|Area| = 0.063, Asym = -0.004
0.3: Area = -0.000, Σ|Area| = 0.056, Asym = -0.001
0.4: Area = -0.000, Σ|Area| = 0.050, Asym = -0.007
0.5: Area = -0.000, Σ|Area| = 0.043, Asym = -0.001
0.6: Area = -0.000, Σ|Area| = 0.039, Asym = -0.003
−5
−4
−3
−2
−1
0
1
2
3
4
5
Time [μs]

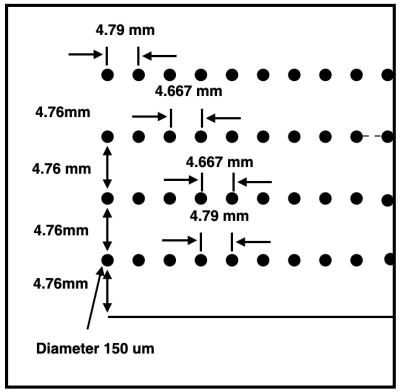
V: z < 0


V response for paths [0, -6]
Response [/(0.1 μs)]
0.008
0.006
0.004
0.002
0
−0.002
−0.004
−0.006
0.0: Area = 0.000, Σ|Area| = 0.002, Asym = 0.024
-0.1: Area = -0.000, Σ|Area| = 0.072, Asym = -0.006
-0.2: Area = -0.000, Σ|Area| = 0.063, Asym = -0.004
-0.3: Area = -0.000, Σ|Area| = 0.056, Asym = -0.001
-0.4: Area = -0.000, Σ|Area| = 0.050, Asym = -0.007
-0.5: Area = 0.001, Σ|Area| = 0.044, Asym = 0.022
-0.6: Area = -0.000, Σ|Area| = 0.039, Asym = -0.003
−5
−4
−3
−2
−1
0
1
2
3
4
5
Time [μs]

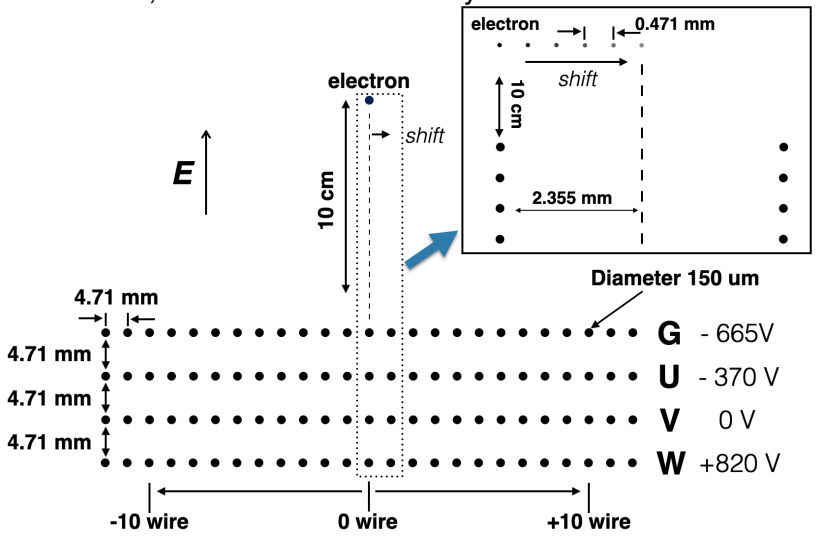
From Yichen

DUNE/ProDUNE simulation 1

- **Simulation Configurations**
  - A single electron set 10 cm away from the wire plane
  - Drift field = 500 V/cm
  - Geometry shown in the figure
    - The actual pitch and spacing varied for each plane
    - With perfect aligned wires and an average value of 4.71 mm wire pitch and plane spacing
  - Signals calculated for ±10 neighboring wires from the central axis
  - The starting point of the electron set at 0, 0.471, 0.942, 1.413, 1.884, 2.355 mm away horizontally
  - Both **Old** and **New** velocities were used, results with **New** velocity are used in the current analysis
- **Files:**
  - **cell_def/cell_dune_4.71.gar**
  - **results/ protodune_vCorr_rev1**



APA Geometry



GARFIELD simulation Summary

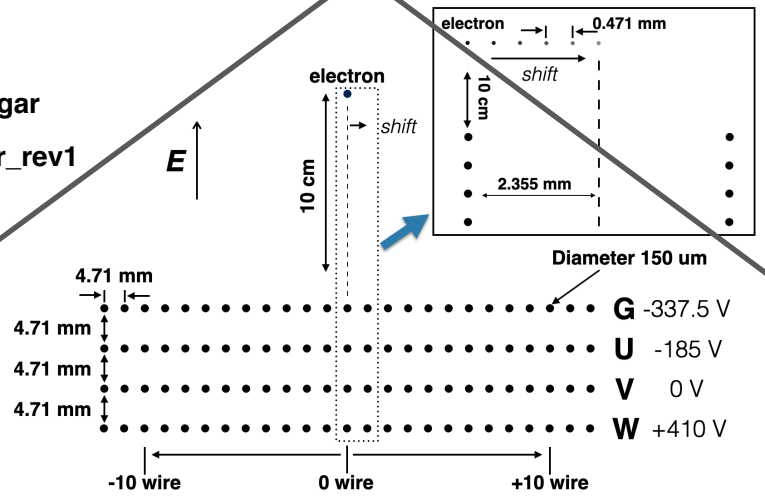
BROOKHAVEN NATIONAL LABORATORY

From Yichen

DUNE/ProDUNE simulation 2

- **Simulation Configurations**
  - A single electron set 10 cm away from the wire plane
  - Drift field = 273 V/cm, (requested by Elizabeth)
  - Geometry shown in the figure
  - Signals calculated for ±10 neighboring wires from the central axis
  - The starting point of the electron set at 0, 0.471, 0.942, 1.413, 1.884, 2.355 mm away horizontally
  - Only **Old** velocity are used in the current analysis

- **Files:**
  - **cell_def/cell_dune_4.71.gar**
  - **results/protodune_vCorr_rev1**



GARFIELD simulation Summary

BROOKHAVEN NATIONAL LABORATORY

Comments

Geometry

- Grid plane should be offset by a half wire
- Actual Z-projection of induction spacing is 20% larger than collection
  - But need the reduced spacing to get the correct transparency?
- We should vary the offsets of the induction wires
  - I.e. vary the y-position where we select the zx plane
  - Average over these to get deconvolution response
  - Use y-dependent response for simulation

Electron paths

- Avoid paths at collection or grid wires
  - E.g. sample at (i+1/2)/N instead of i/N, I = 0, 1, 2,
- Nice to have finer spacing than 0.1 wires
- Variation in induction response will contribute to uncertainty in charge measurement
  - May also explain our observed induction/collection scale discrepancy

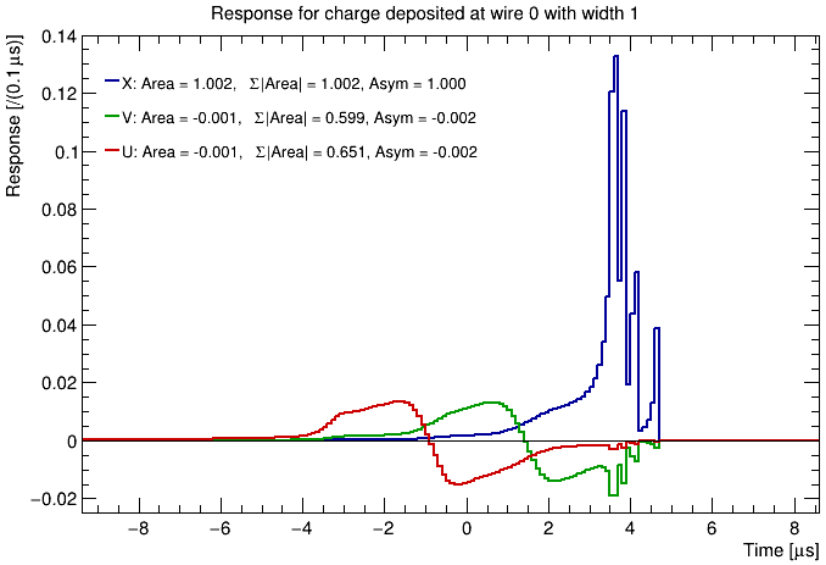
Comments (cont.)

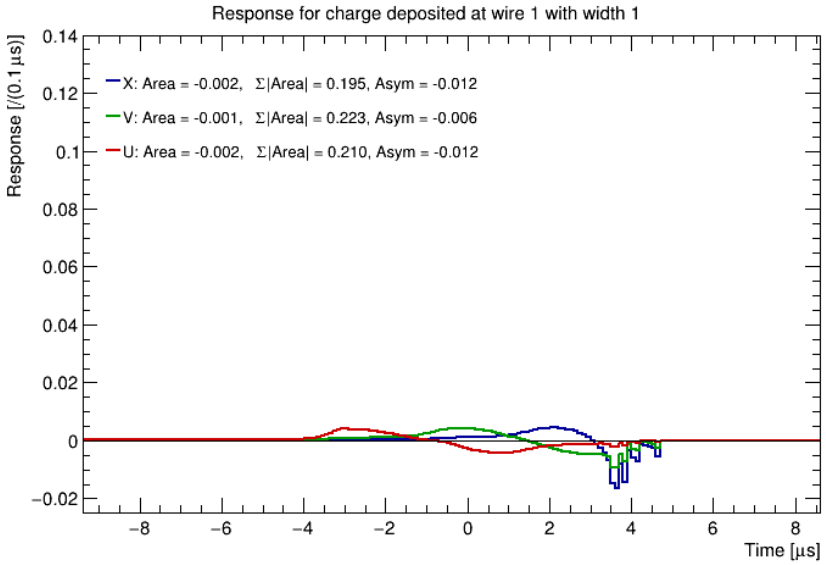
Field and drift velocity

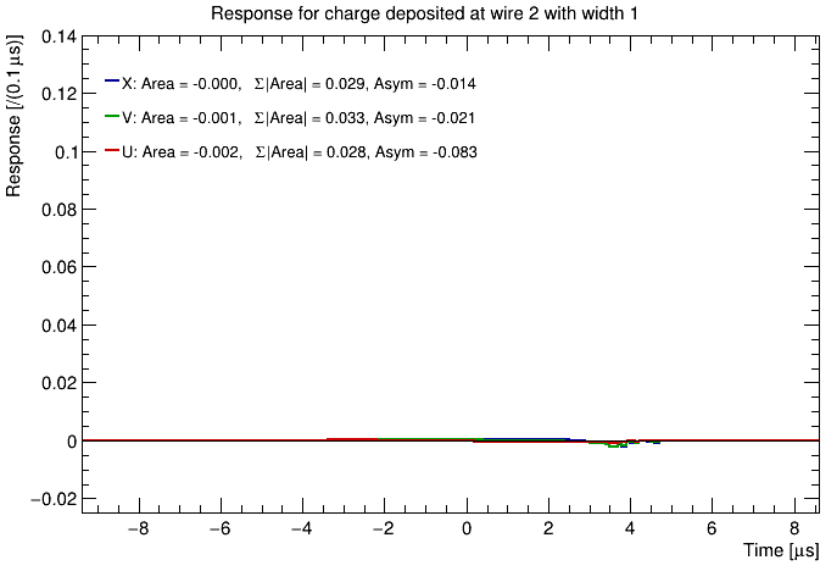
- Response depends on electric field and drift speed
  - Especially important for induction signals
- Check and vary these in response evaluation
- Compare with protoDUNE data
  - Use data-drive response for deconvolution?

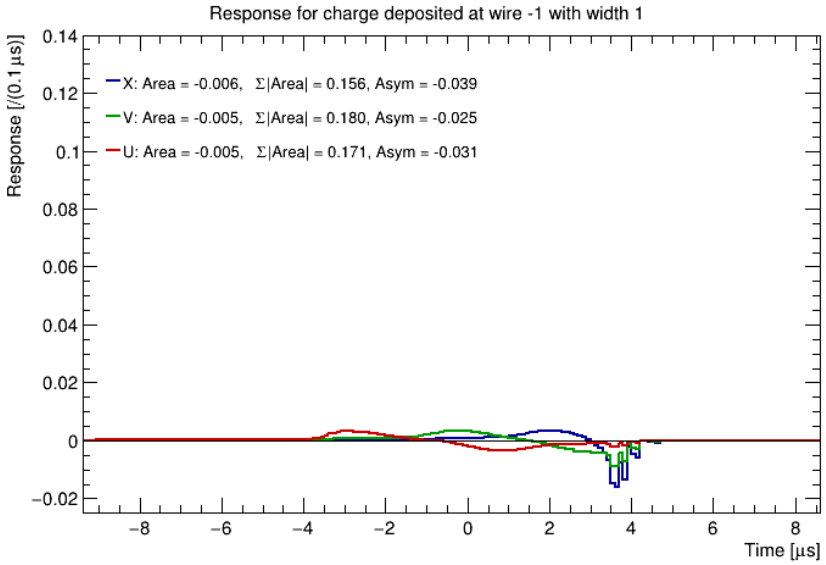
Extras

Wire response with wirecell map

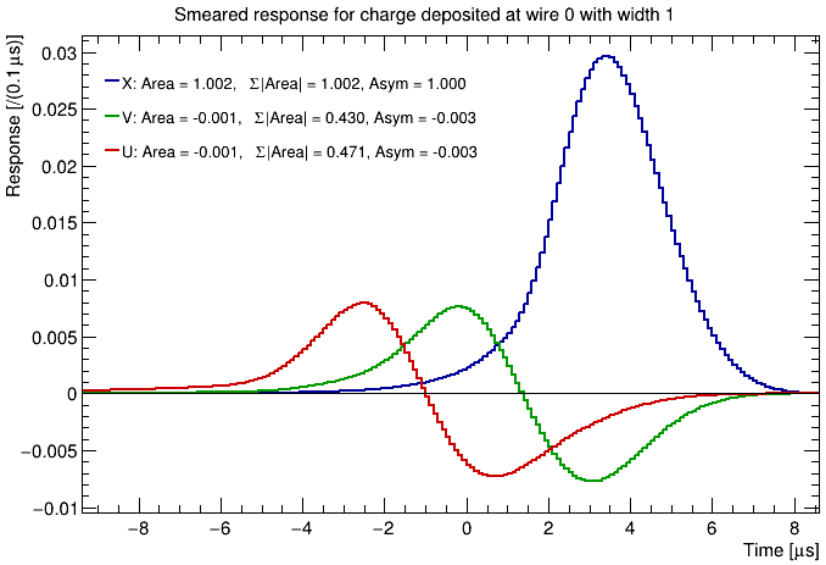


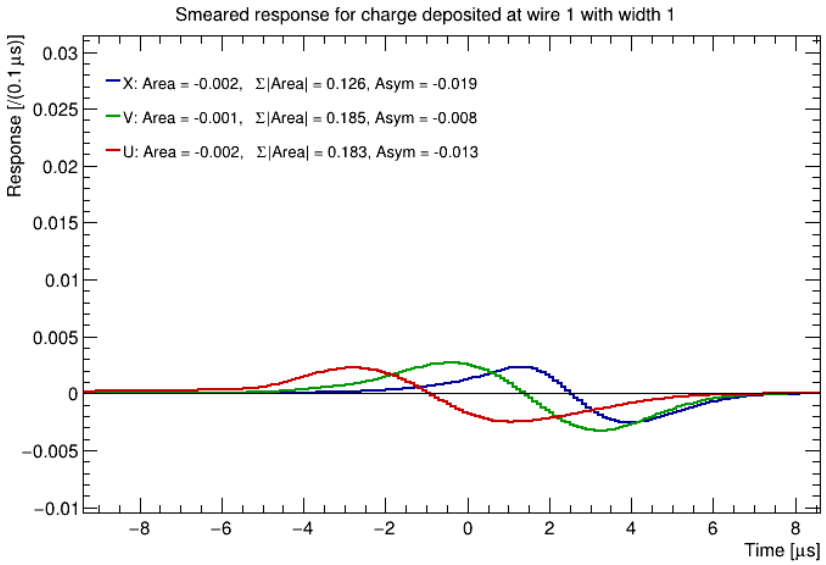


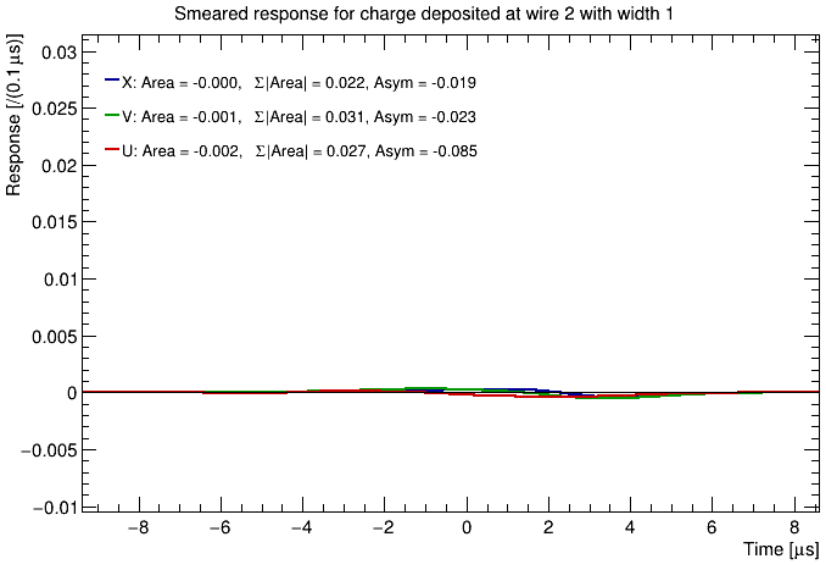


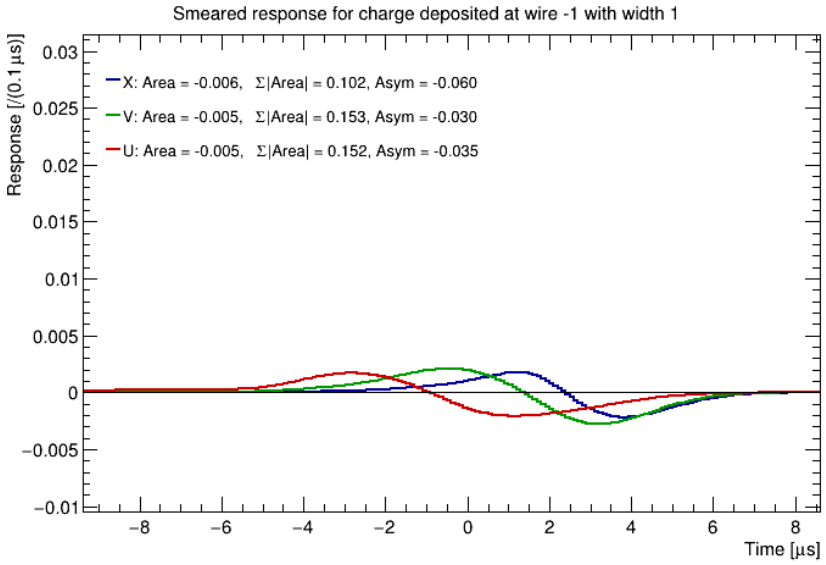


Preceding smeared with CE response

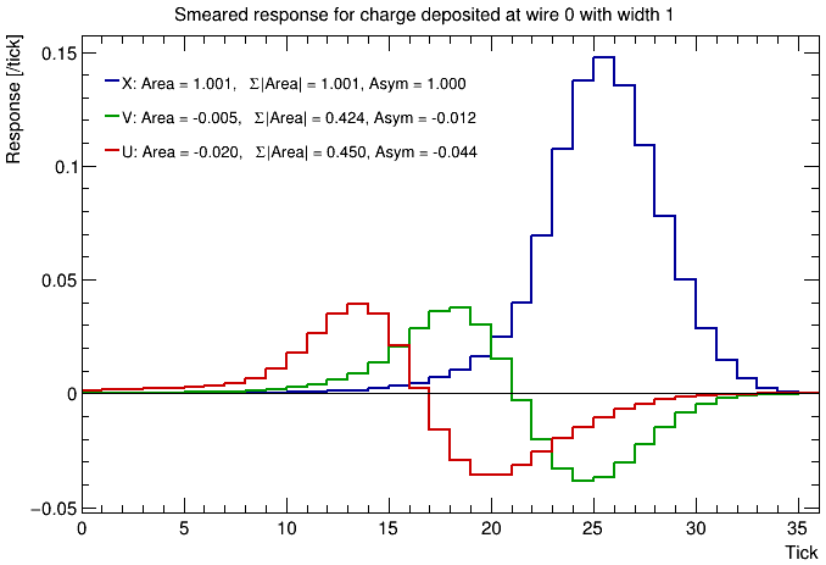


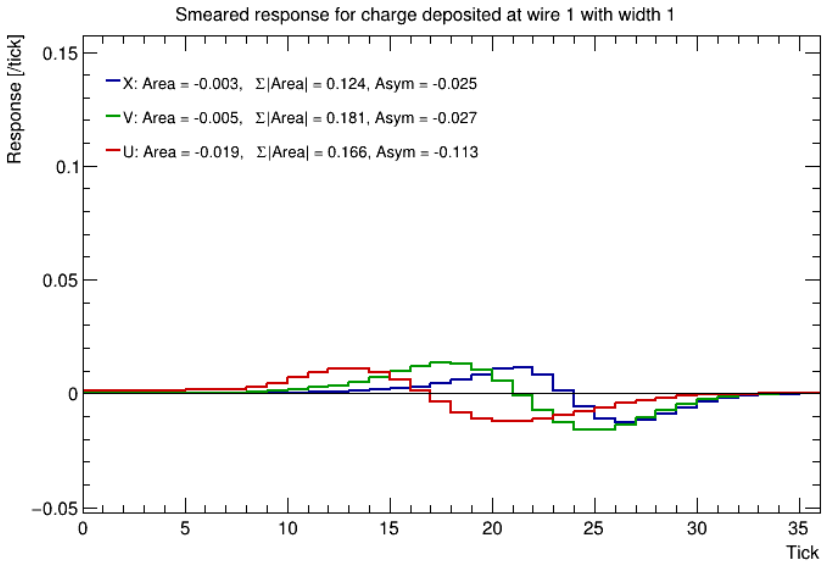


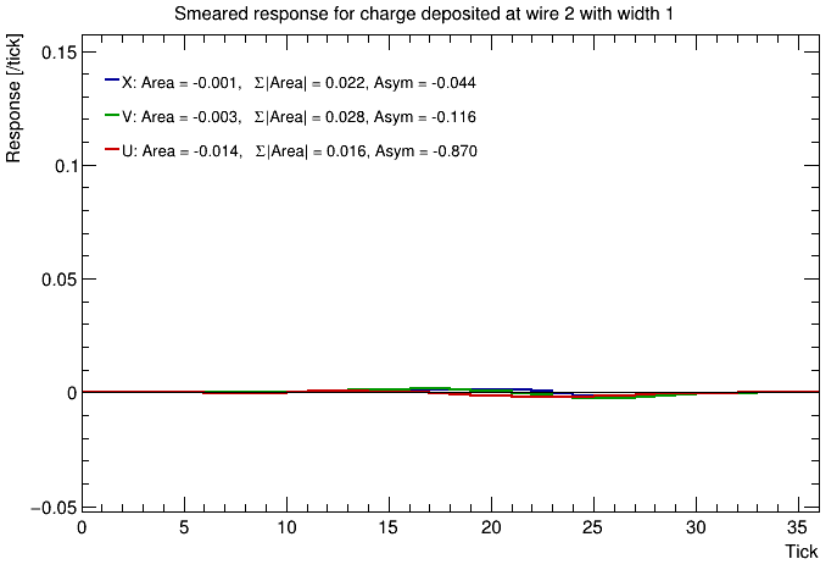


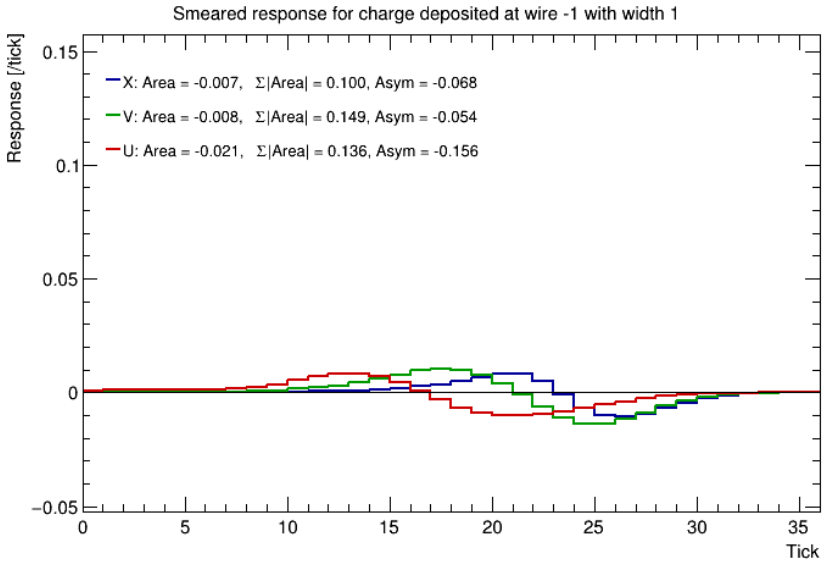


Preceding rebinned

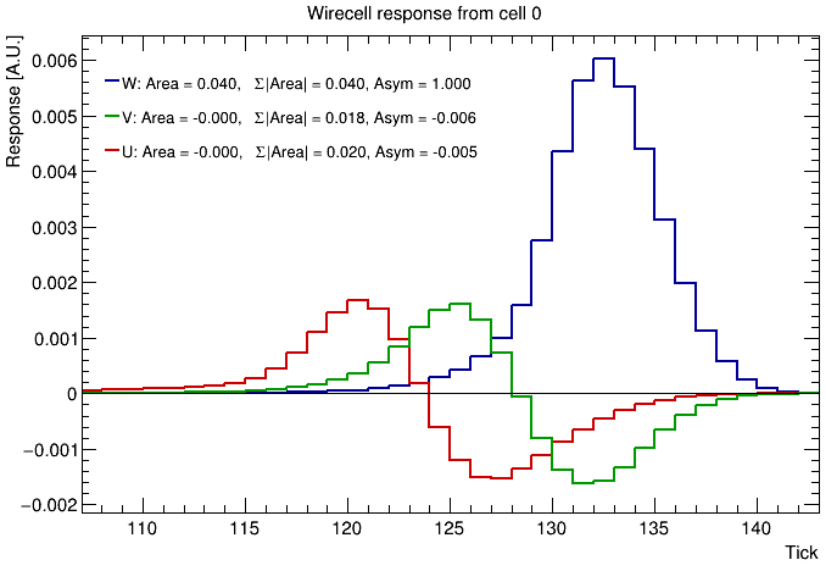


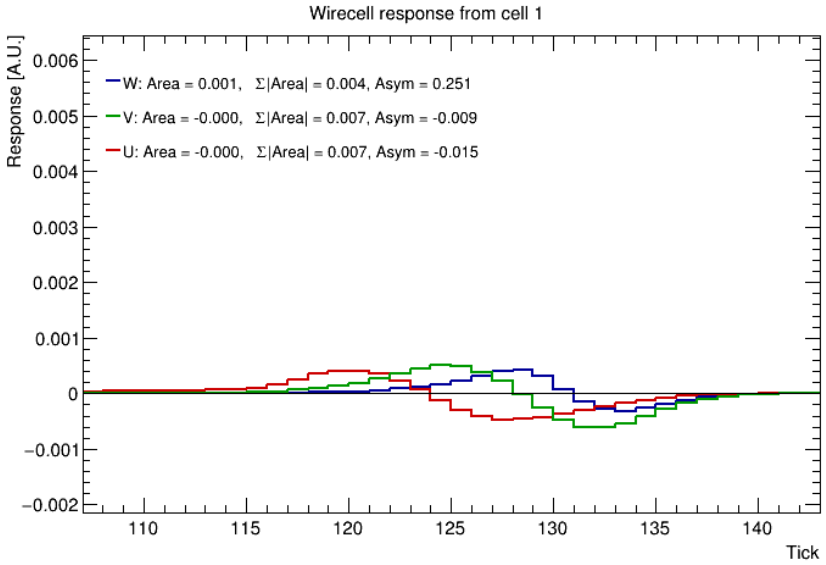


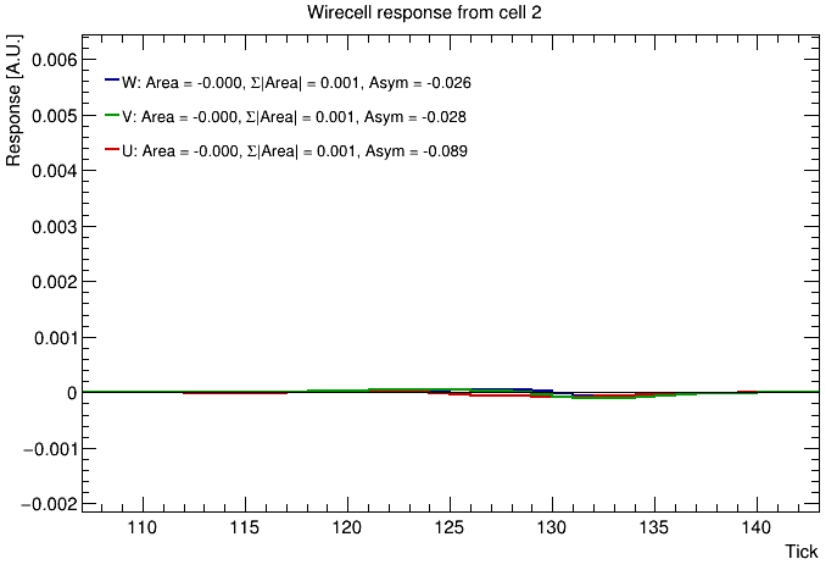


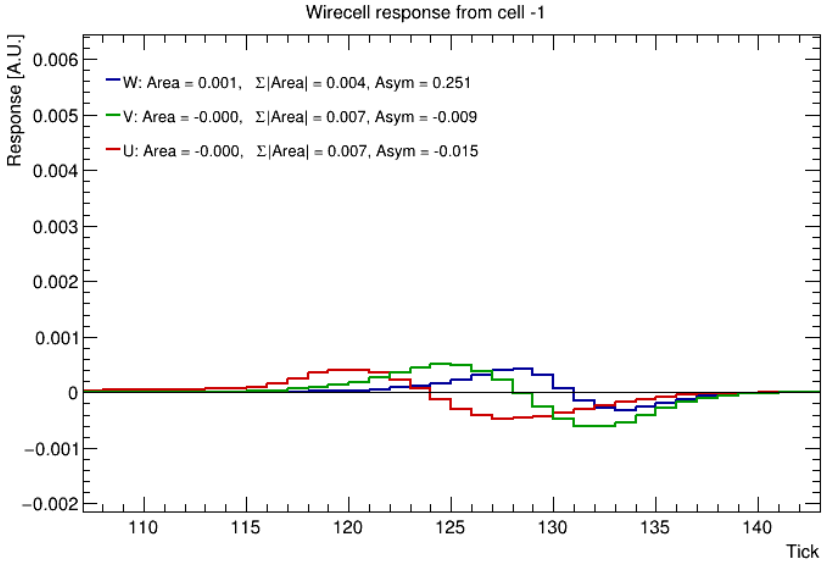


Wirecell smeared response from Wenqiang



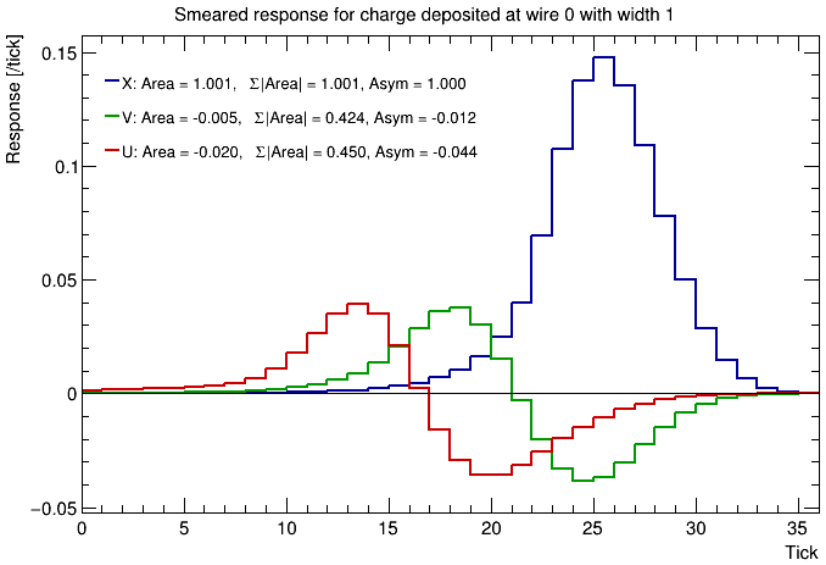


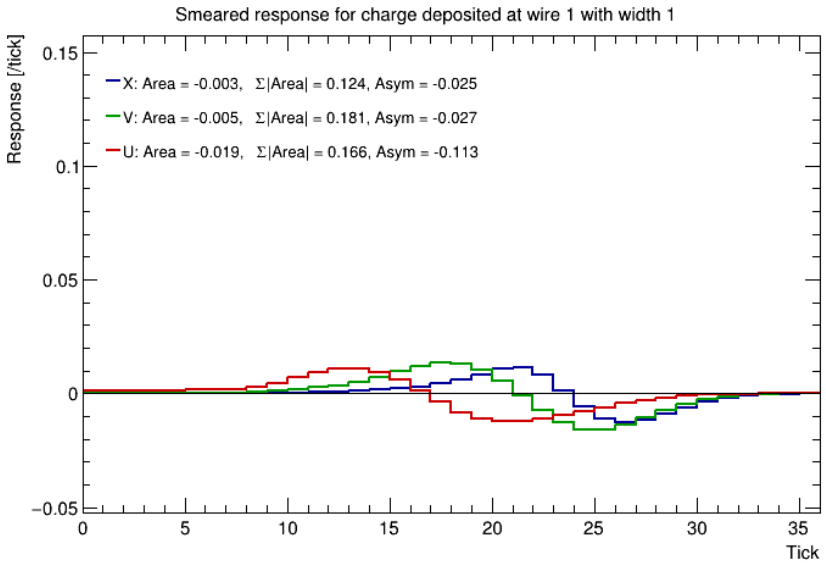


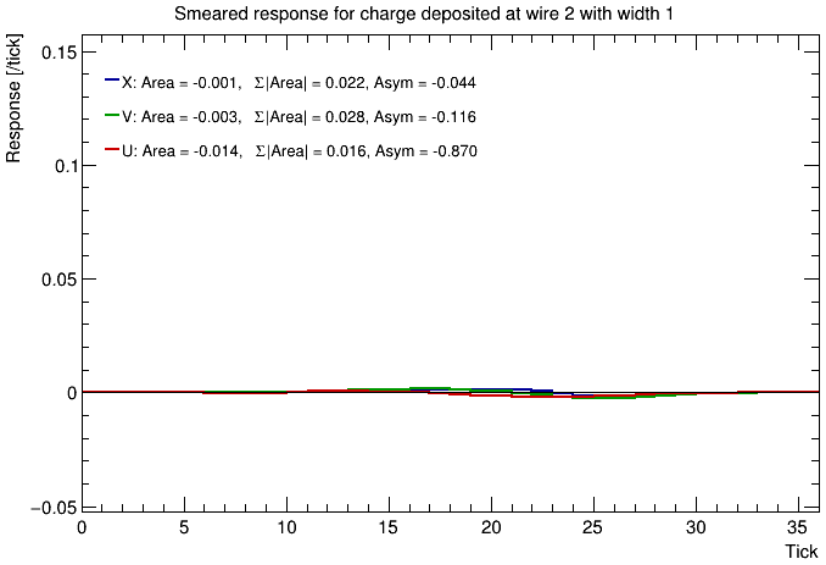


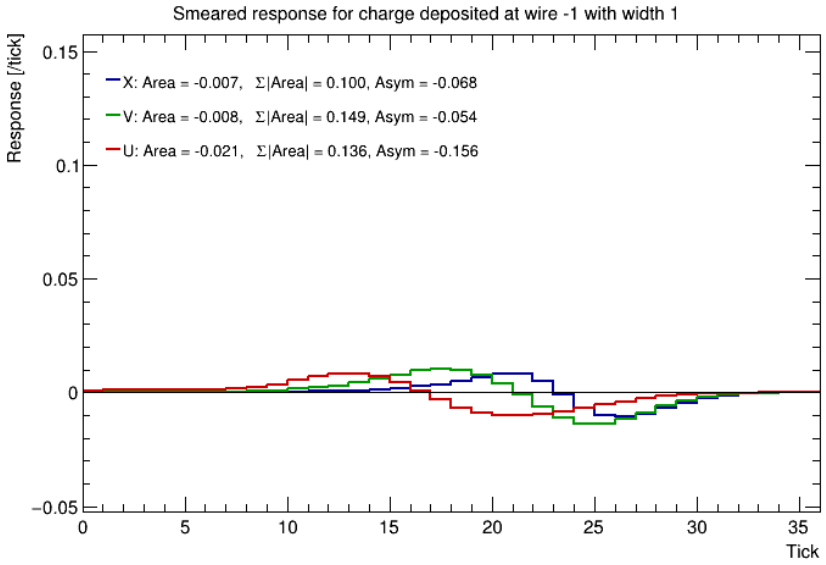
Rebinning with different offsets

Offset 0 (507)

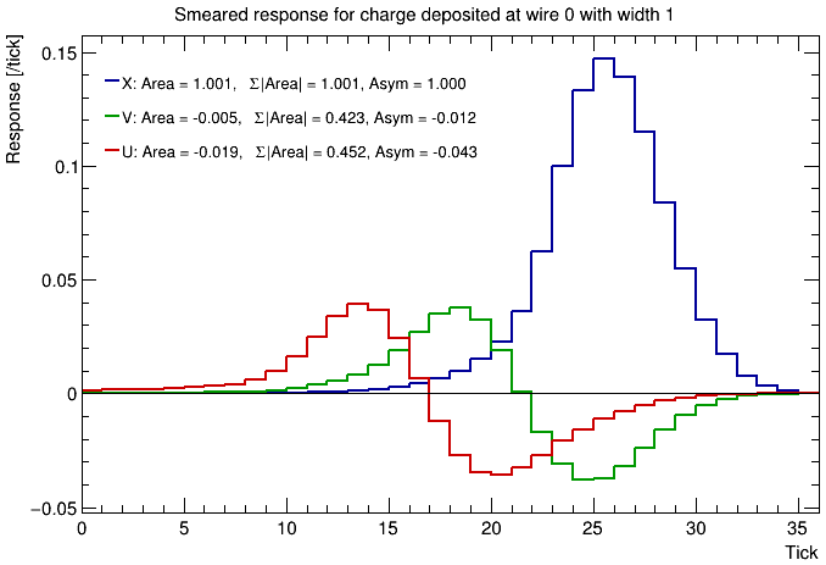

Smeared response for charge deposited at wire 0 with width 1
X: Area = 1.001, Σ|Area| = 1.001, Asym = 1.000
V: Area = -0.005, Σ|Area| = 0.424, Asym = -0.012
U: Area = -0.020, Σ|Area| = 0.450, Asym = -0.044
Response [/tick]
Tick

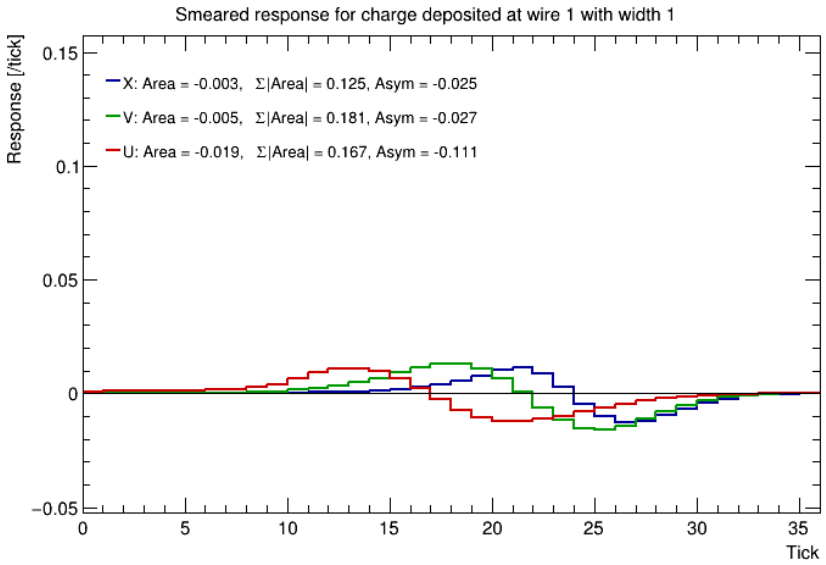

Smeared response for charge deposited at wire 1 with width 1
X: Area = -0.003, Σ|Area| = 0.124, Asym = -0.025
V: Area = -0.005, Σ|Area| = 0.181, Asym = -0.027
U: Area = -0.019, Σ|Area| = 0.166, Asym = -0.113
Response [/tick]
Tick

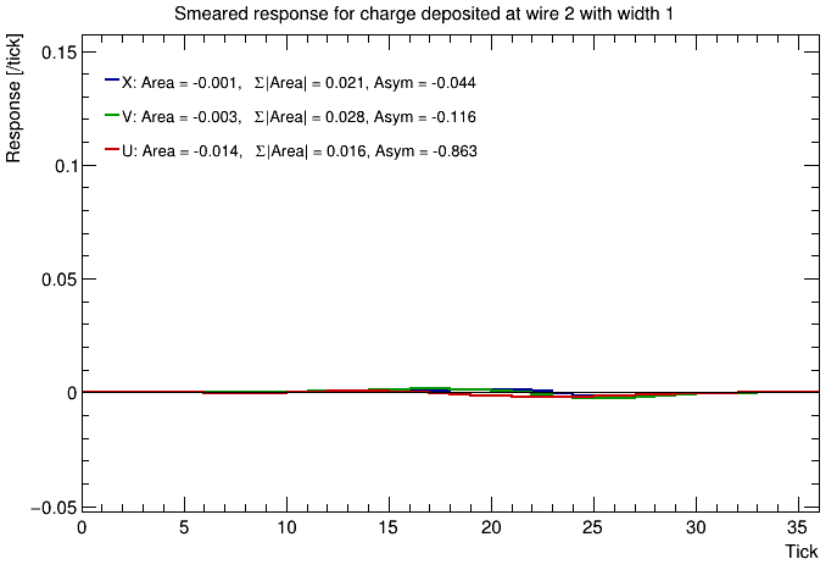

Smeared response for charge deposited at wire 2 with width 1
X: Area = -0.001, Σ|Area| = 0.022, Asym = -0.044
V: Area = -0.003, Σ|Area| = 0.028, Asym = -0.116
U: Area = -0.014, Σ|Area| = 0.016, Asym = -0.870
Response [/tick]
Tick

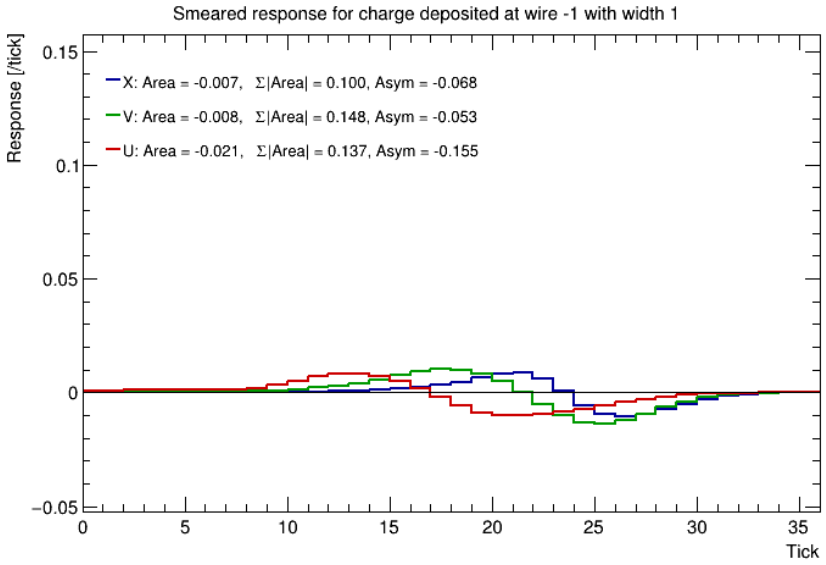

Smeared response for charge deposited at wire -1 with width 1
X: Area = -0.007, Σ|Area| = 0.100, Asym = -0.068
V: Area = -0.008, Σ|Area| = 0.149, Asym = -0.054
U: Area = -0.021, Σ|Area| = 0.136, Asym = -0.156
Response [/tick]
Tick

Offset 1 (506)

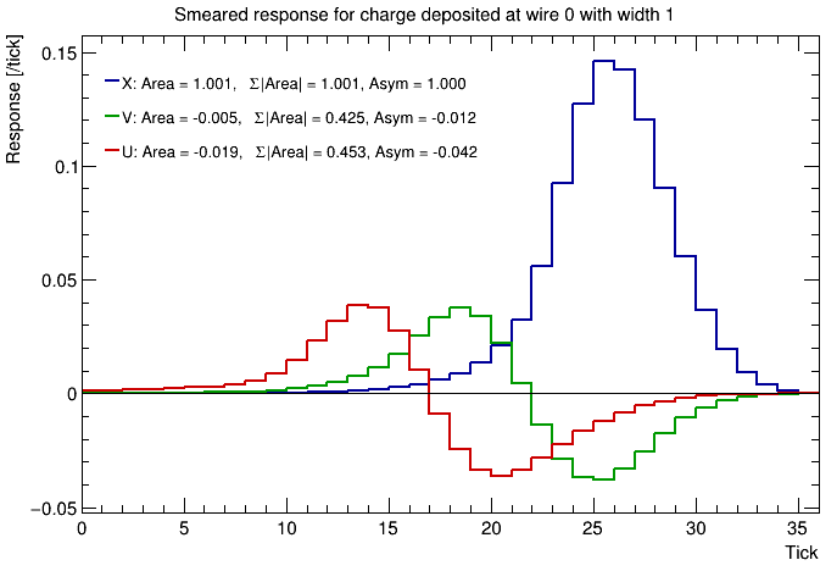

Smeared response for charge deposited at wire 0 with width 1
X: Area = 1.001, Σ|Area| = 1.001, Asym = 1.000
V: Area = -0.005, Σ|Area| = 0.423, Asym = -0.012
U: Area = -0.019, Σ|Area| = 0.452, Asym = -0.043
Response [/tick]
Tick

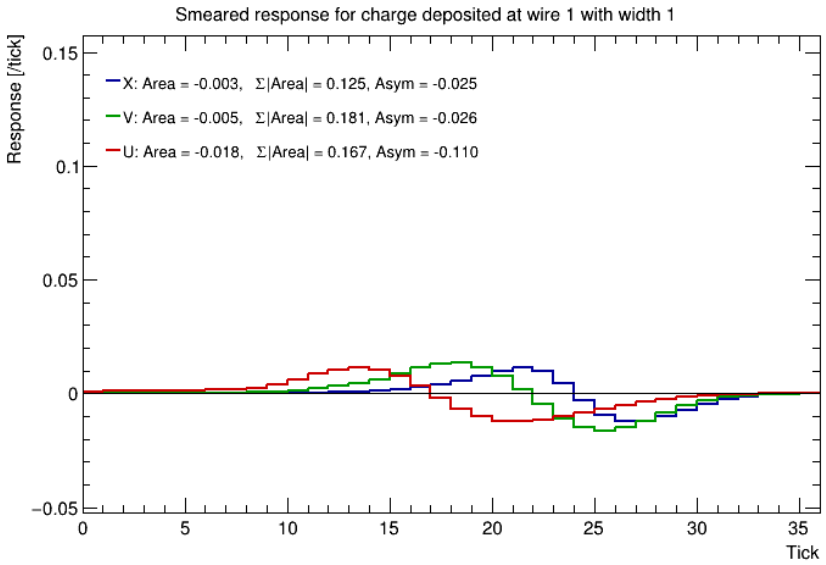

Smeared response for charge deposited at wire 1 with width 1
X: Area = -0.003, Σ|Area| = 0.125, Asym = -0.025
V: Area = -0.005, Σ|Area| = 0.181, Asym = -0.027
U: Area = -0.019, Σ|Area| = 0.167, Asym = -0.111
Response [/tick]
Tick

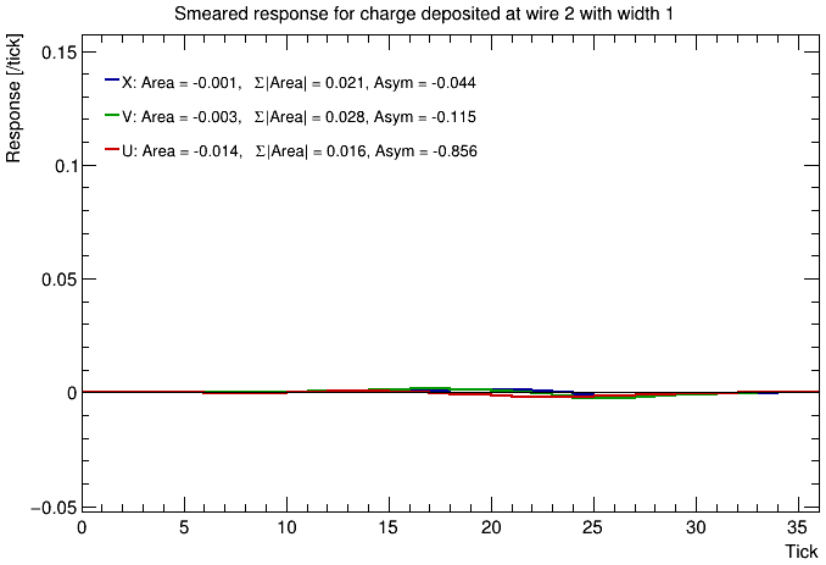

Smeared response for charge deposited at wire 2 with width 1
X: Area = -0.001, Σ|Area| = 0.021, Asym = -0.044
V: Area = -0.003, Σ|Area| = 0.028, Asym = -0.116
U: Area = -0.014, Σ|Area| = 0.016, Asym = -0.863
Response [/tick]
Tick

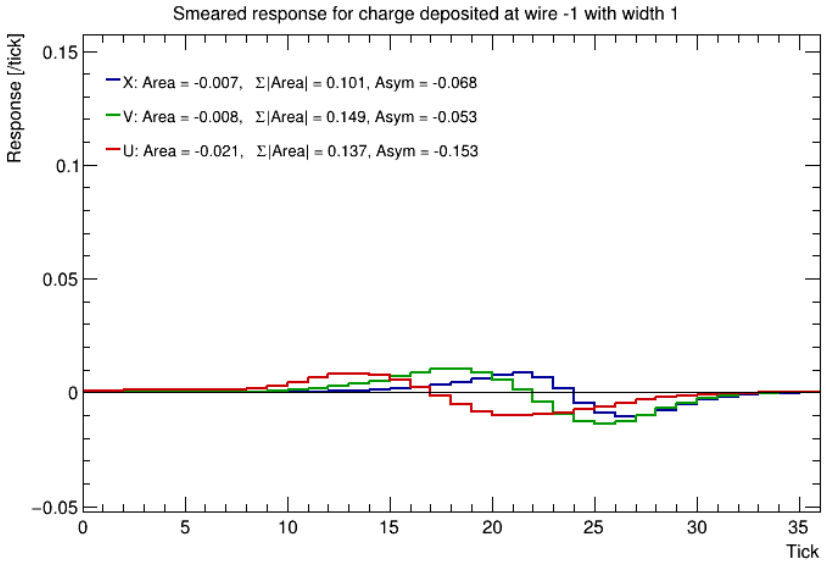

Smeared response for charge deposited at wire -1 with width 1
X: Area = -0.007, Σ|Area| = 0.100, Asym = -0.068
V: Area = -0.008, Σ|Area| = 0.148, Asym = -0.053
U: Area = -0.021, Σ|Area| = 0.137, Asym = -0.155
Response [/tick]
Tick

Offset 2 (505)

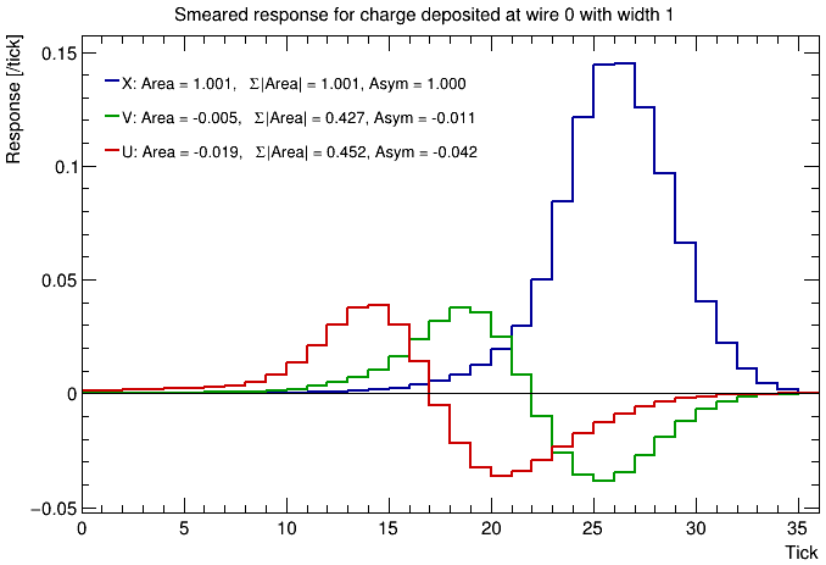

Smeared response for charge deposited at wire 0 with width 1
X: Area = 1.001, Σ|Area| = 1.001, Asym = 1.000
V: Area = -0.005, Σ|Area| = 0.425, Asym = -0.012
U: Area = -0.019, Σ|Area| = 0.453, Asym = -0.042
Response [/tick]
Tick

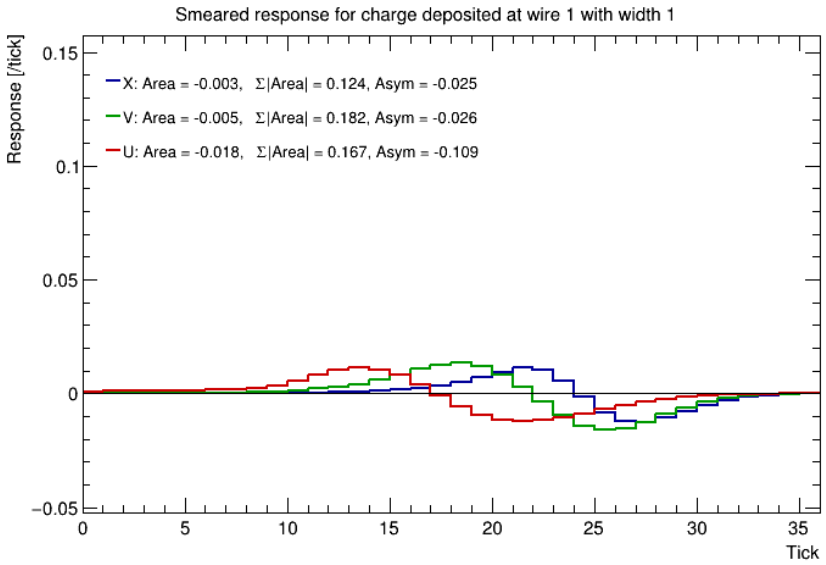

Smeared response for charge deposited at wire 1 with width 1
X: Area = -0.003, Σ|Area| = 0.125, Asym = -0.025
V: Area = -0.005, Σ|Area| = 0.181, Asym = -0.026
U: Area = -0.018, Σ|Area| = 0.167, Asym = -0.110
Response [/tick]
Tick

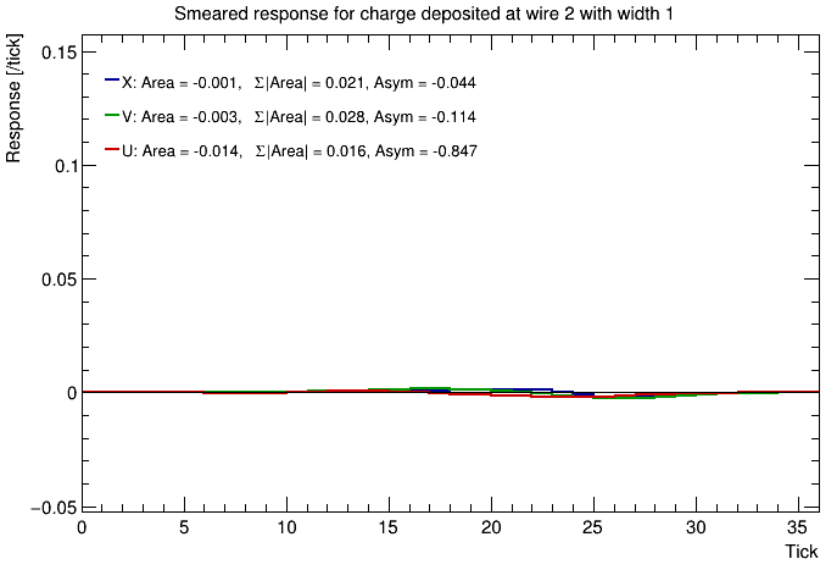

Smeared response for charge deposited at wire 2 with width 1
X: Area = -0.001, Σ|Area| = 0.021, Asym = -0.044
V: Area = -0.003, Σ|Area| = 0.028, Asym = -0.115
U: Area = -0.014, Σ|Area| = 0.016, Asym = -0.856
Response [/tick]
Tick

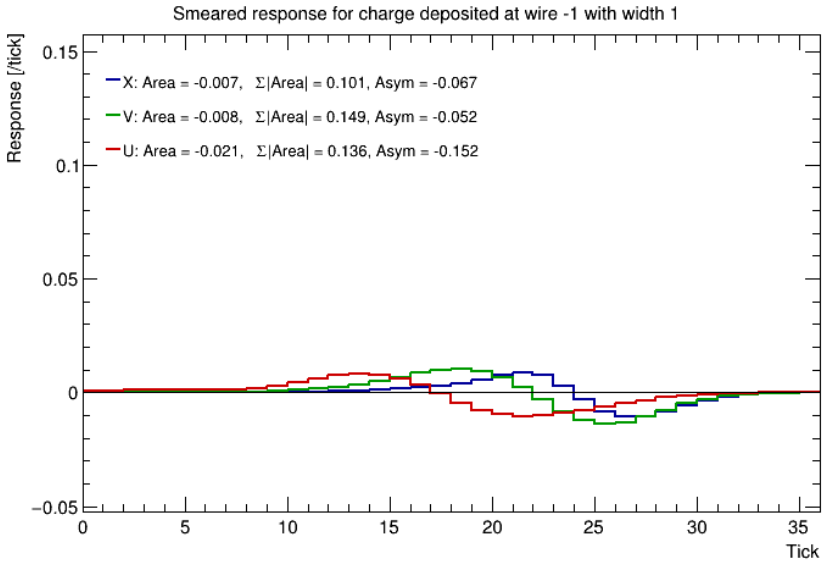

Smeared response for charge deposited at wire -1 with width 1
X: Area = -0.007, Σ|Area| = 0.101, Asym = -0.068
V: Area = -0.008, Σ|Area| = 0.149, Asym = -0.053
U: Area = -0.021, Σ|Area| = 0.137, Asym = -0.153
Response [/tick]
Tick

Offset 3 (504)

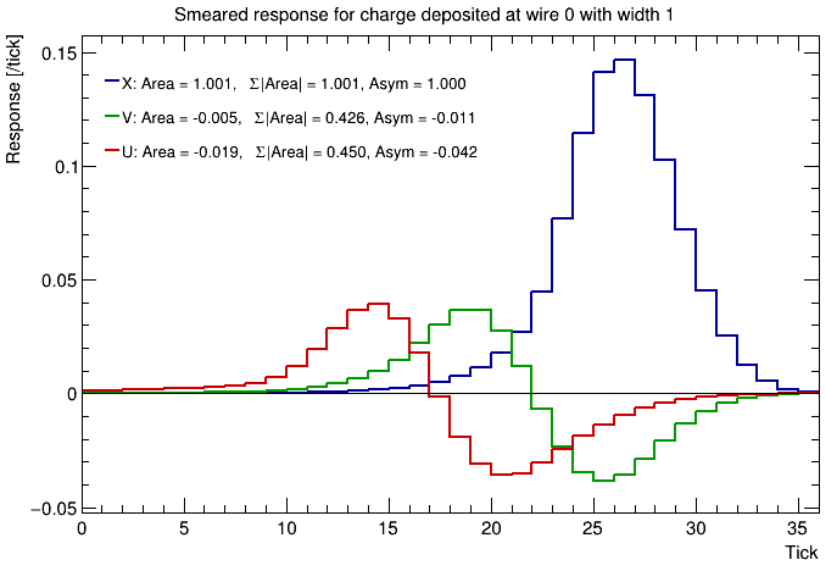

Smeared response for charge deposited at wire 0 with width 1
X: Area = 1.001, Σ|Area| = 1.001, Asym = 1.000
V: Area = -0.005, Σ|Area| = 0.427, Asym = -0.011
U: Area = -0.019, Σ|Area| = 0.452, Asym = -0.042
Response [/tick]
Tick

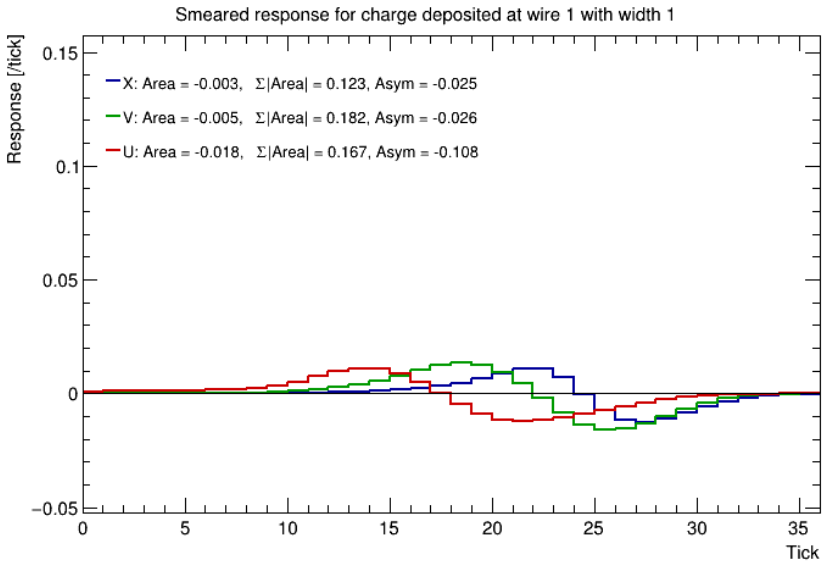

Smeared response for charge deposited at wire 1 with width 1
X: Area = -0.003, Σ|Area| = 0.124, Asym = -0.025
V: Area = -0.005, Σ|Area| = 0.182, Asym = -0.026
U: Area = -0.018, Σ|Area| = 0.167, Asym = -0.109
Response [/tick]
Tick

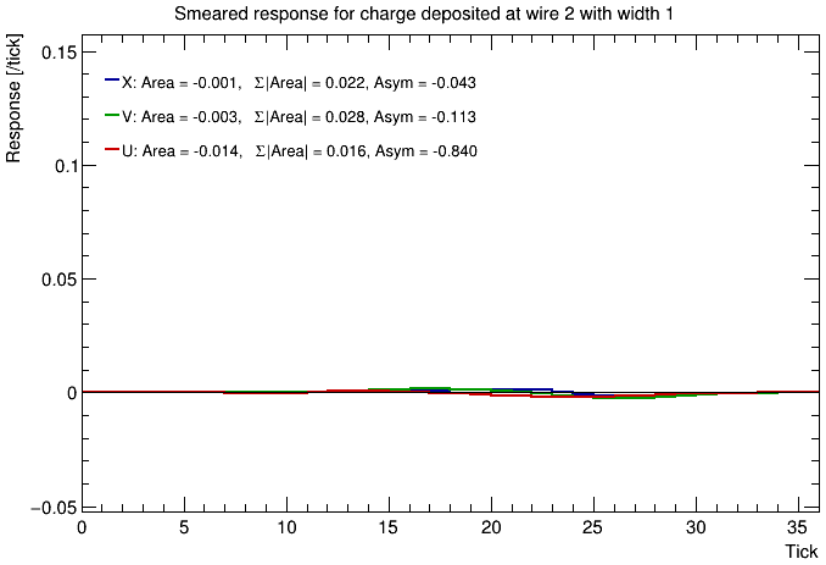

Smeared response for charge deposited at wire 2 with width 1
X: Area = -0.001, Σ|Area| = 0.021, Asym = -0.044
V: Area = -0.003, Σ|Area| = 0.028, Asym = -0.114
U: Area = -0.014, Σ|Area| = 0.016, Asym = -0.847
Response [/tick]
Tick

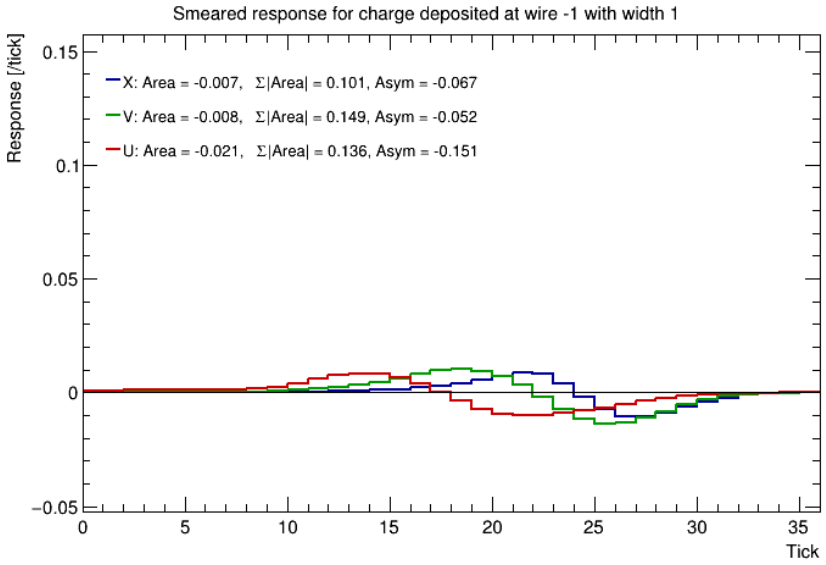

Smeared response for charge deposited at wire -1 with width 1
X: Area = -0.007, Σ|Area| = 0.101, Asym = -0.067
V: Area = -0.008, Σ|Area| = 0.149, Asym = -0.052
U: Area = -0.021, Σ|Area| = 0.136, Asym = -0.152
Response [/tick]
Tick

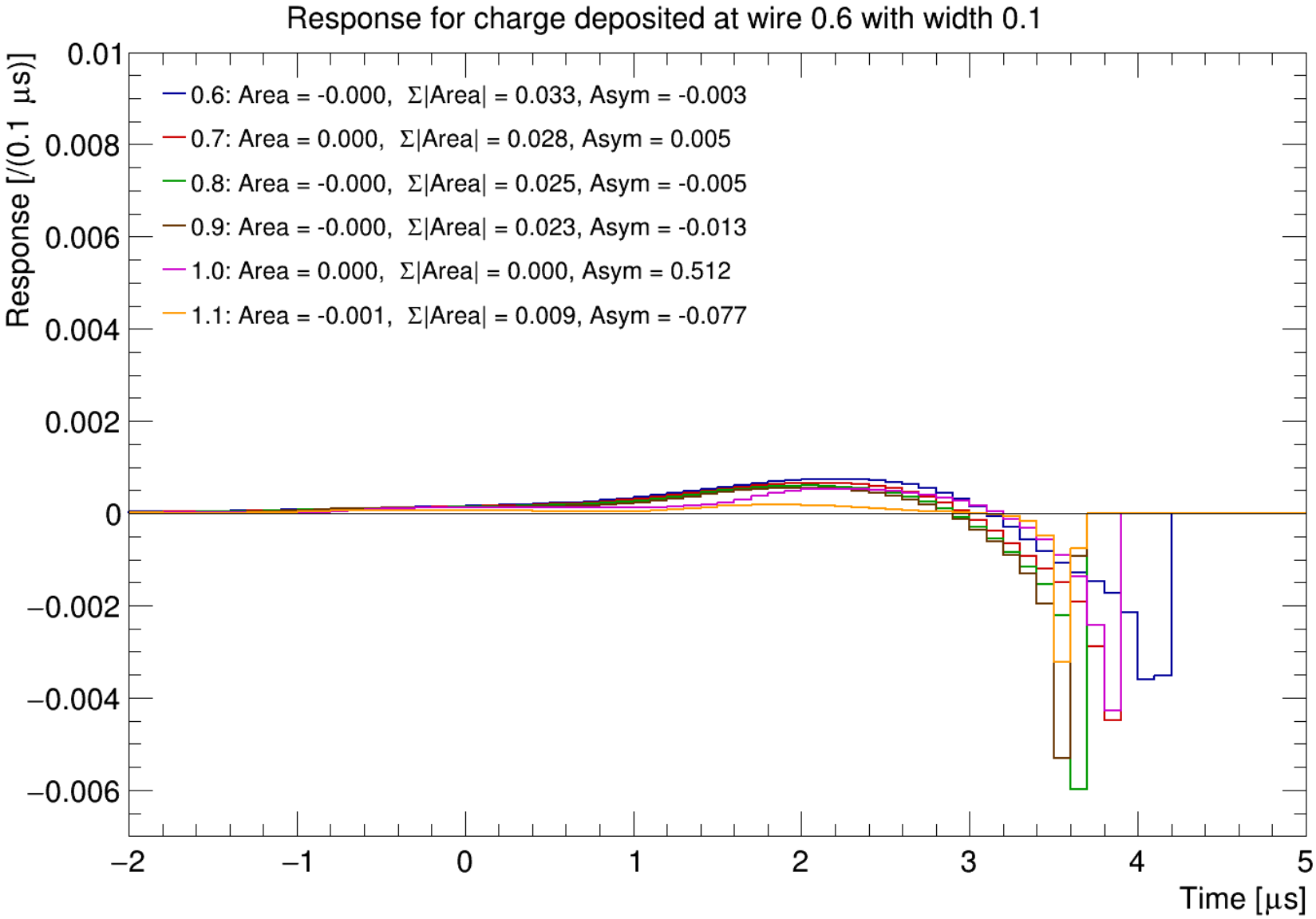
Offset 4 (503)

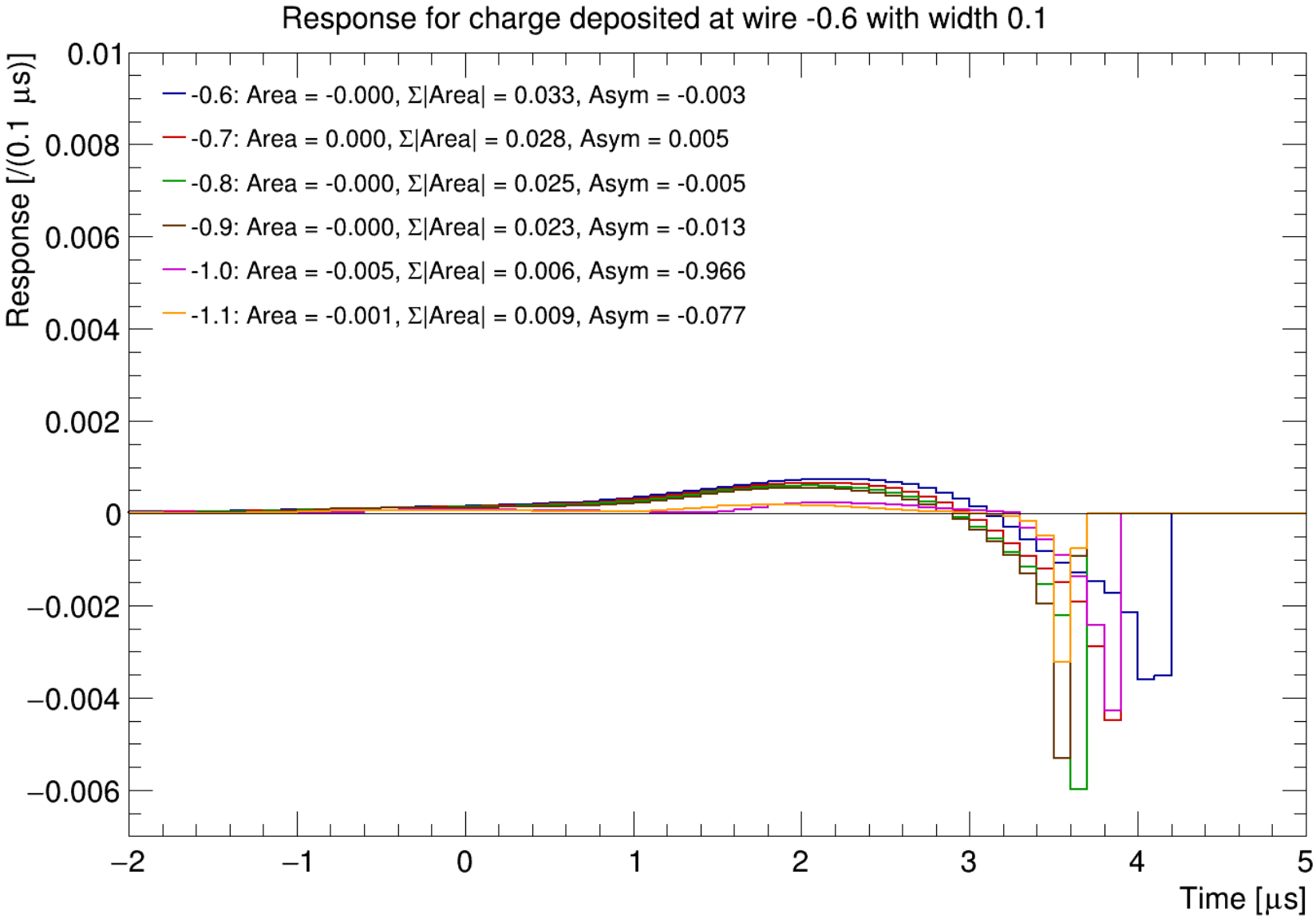

Smeared response for charge deposited at wire 0 with width 1
X: Area = 1.001, Σ|Area| = 1.001, Asym = 1.000
V: Area = -0.005, Σ|Area| = 0.426, Asym = -0.011
U: Area = -0.019, Σ|Area| = 0.450, Asym = -0.042
Response [/tick]
Tick


Smeared response for charge deposited at wire 1 with width 1
X: Area = -0.003, Σ|Area| = 0.123, Asym = -0.025
V: Area = -0.005, Σ|Area| = 0.182, Asym = -0.026
U: Area = -0.018, Σ|Area| = 0.167, Asym = -0.108
Response [/tick]
Tick


Smeared response for charge deposited at wire 2 with width 1
X: Area = -0.001, Σ|Area| = 0.022, Asym = -0.043
V: Area = -0.003, Σ|Area| = 0.028, Asym = -0.113
U: Area = -0.014, Σ|Area| = 0.016, Asym = -0.840
Response [/tick]
Tick


Smeared response for charge deposited at wire -1 with width 1
X: Area = -0.007, Σ|Area| = 0.101, Asym = -0.067
V: Area = -0.008, Σ|Area| = 0.149, Asym = -0.052
U: Area = -0.021, Σ|Area| = 0.136, Asym = -0.151
Response [/tick]
Tick


Response for charge deposited at wire 0.6 with width 0.1
0.6: Area = -0.000, Σ|Area| = 0.033, Asym = -0.003
0.7: Area = 0.000, Σ|Area| = 0.028, Asym = 0.005
0.8: Area = -0.000, Σ|Area| = 0.025, Asym = -0.005
0.9: Area = -0.000, Σ|Area| = 0.023, Asym = -0.013
1.0: Area = 0.000, Σ|Area| = 0.000, Asym = 0.512
1.1: Area = -0.001, Σ|Area| = 0.009, Asym = -0.077
Response [/(0.1 μs)]
0.01
0.008
0.006
0.004
0.002
0
−0.002
−0.004
−0.006
−2
−1
0
1
2
3
4
5
Time [μs]


Response for charge deposited at wire -0.6 with width 0.1
-0.6: Area = -0.000, Σ|Area| = 0.033, Asym = -0.003
-0.7: Area = 0.000, Σ|Area| = 0.028, Asym = 0.005
-0.8: Area = -0.000, Σ|Area| = 0.025, Asym = -0.005
-0.9: Area = -0.000, Σ|Area| = 0.023, Asym = -0.013
-1.0: Area = -0.005, Σ|Area| = 0.006, Asym = -0.966
-1.1: Area = -0.001, Σ|Area| = 0.009, Asym = -0.077
Response [/(0.1 μs)]
0.01
0.008
0.006
0.004
0.002
0
−0.002
−0.004
−0.006
−2
−1
0
1
2
3
4
5
Time [μs]