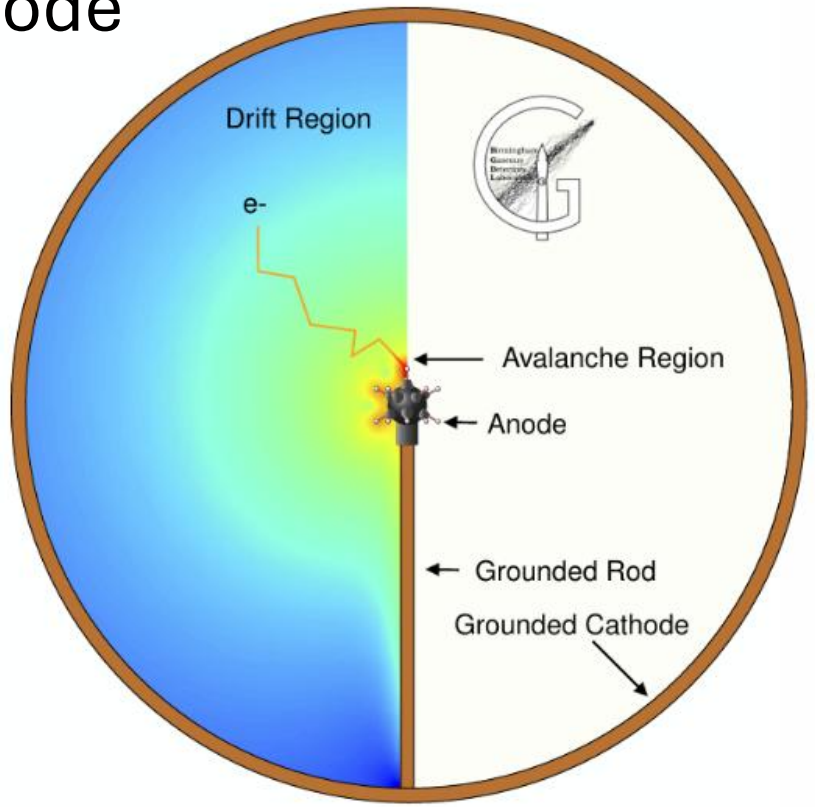
Study of Shared Signal Events in a Nitrogen-Filled Spherical Proportional Counter Exposed to a Neutron Beam

Julia Fock

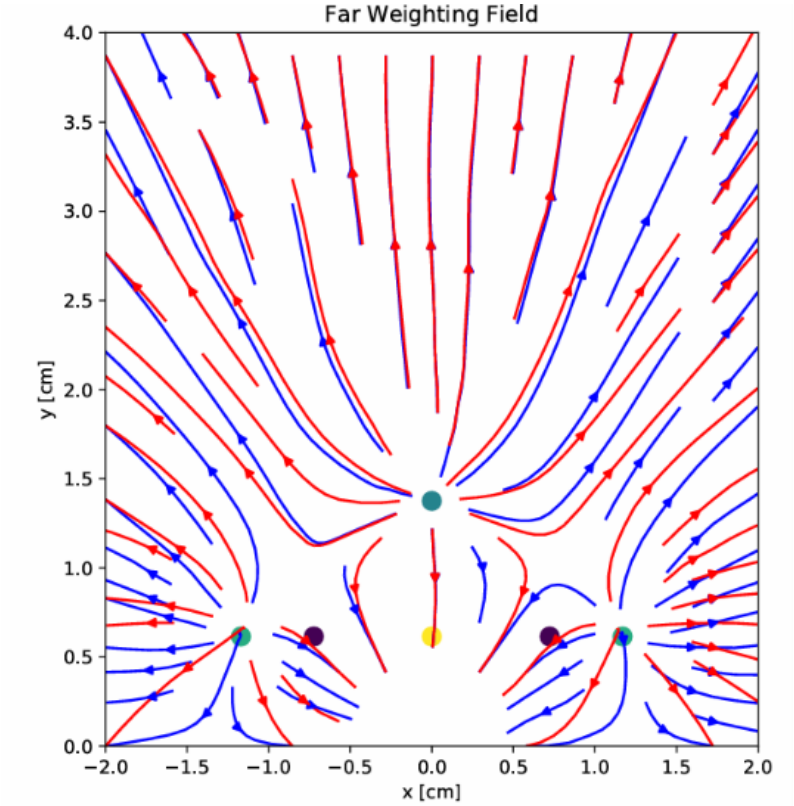
Signal Formation

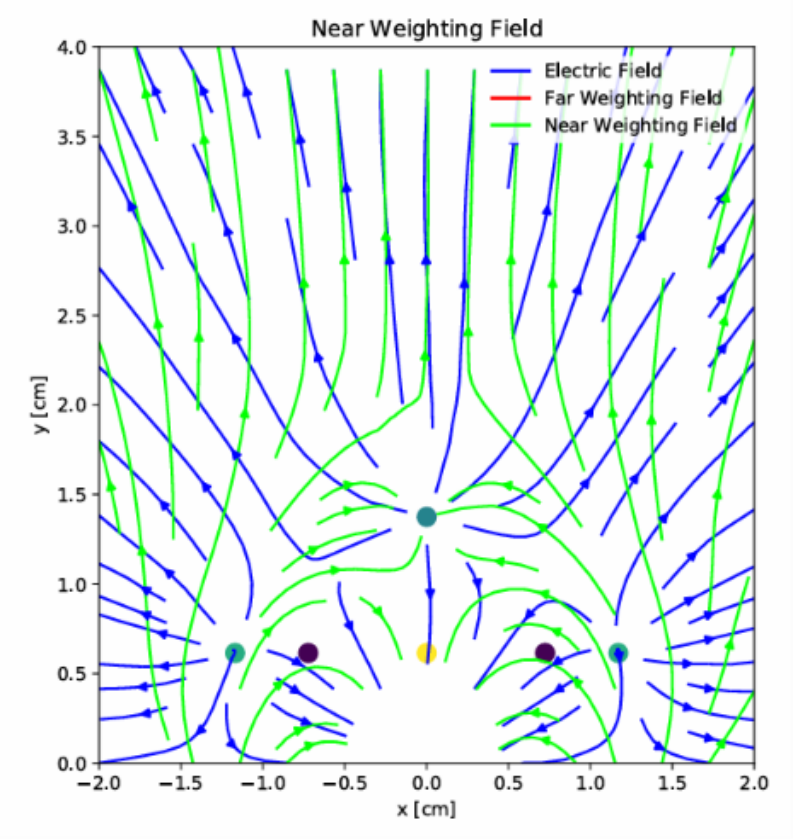
- Energy deposition in the gas produces primary electron-ion pairs
- Primary electrons drift towards the anode and initiate a Townsend avalanche in the high-field region near the anode
- **Shockley-Ramo theorem:** moving charges induce a current on an electrode before they are physically collected



Weighting Fields

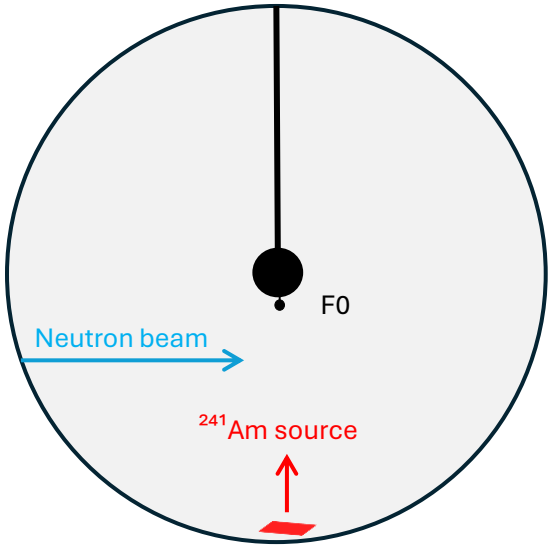
- The weighting fields of non-collecting anodes have the opposite sign in the avalanche region



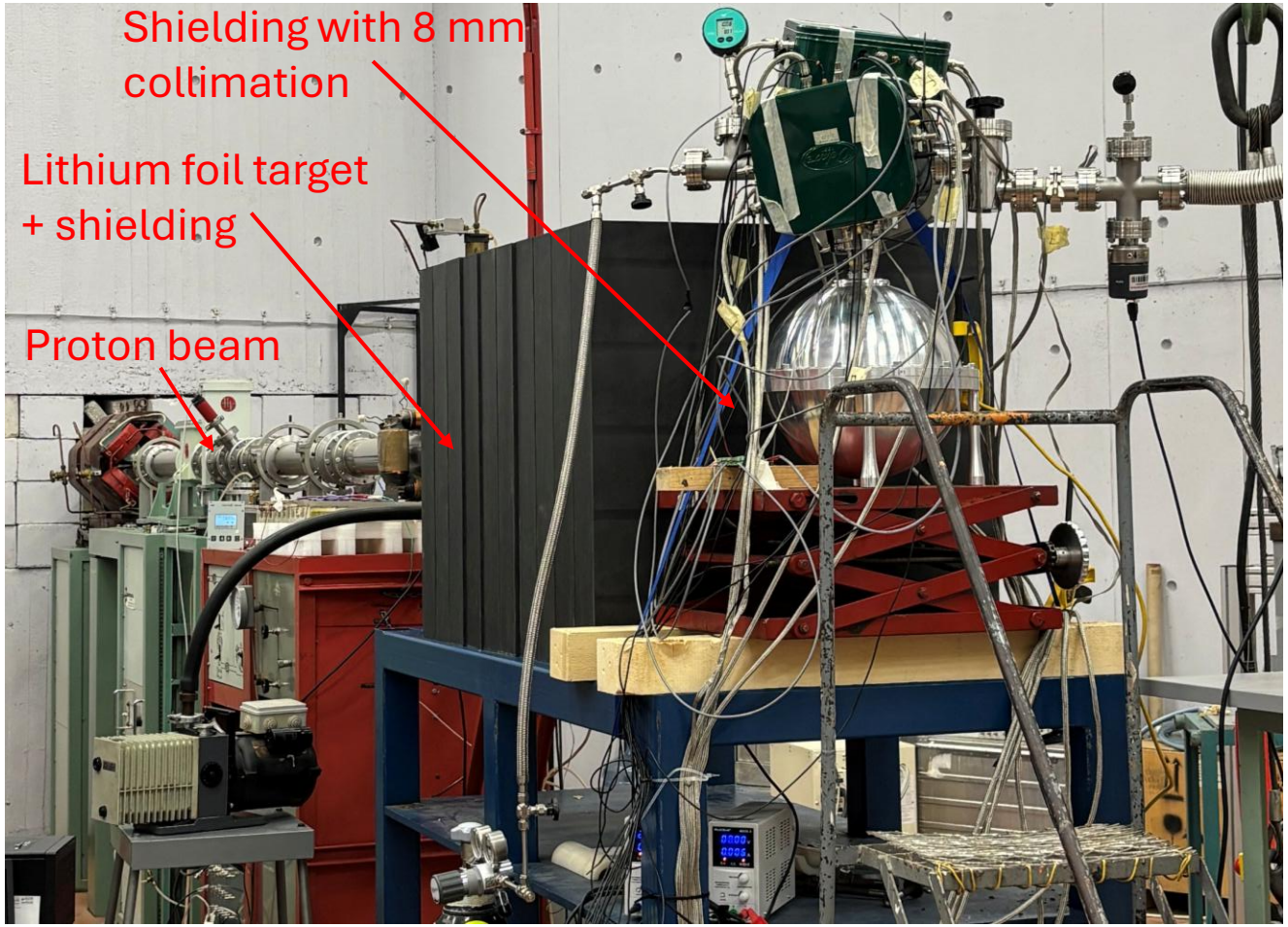


Neutron Beam Measurement in Nitrogen Gas

- Measurement champagne in March 2026 at NCRS “Demokritos“
- Collimated **mono-energetic neutron** beam
- 30 cm diameter SPC filled with **1 bar N_2**
- 11-anode ACHINOS sensor at **4.2 kV** with single anode read-out
- In-situ calibration: **^{241}Am α-particle** source
- **Trigger F0**

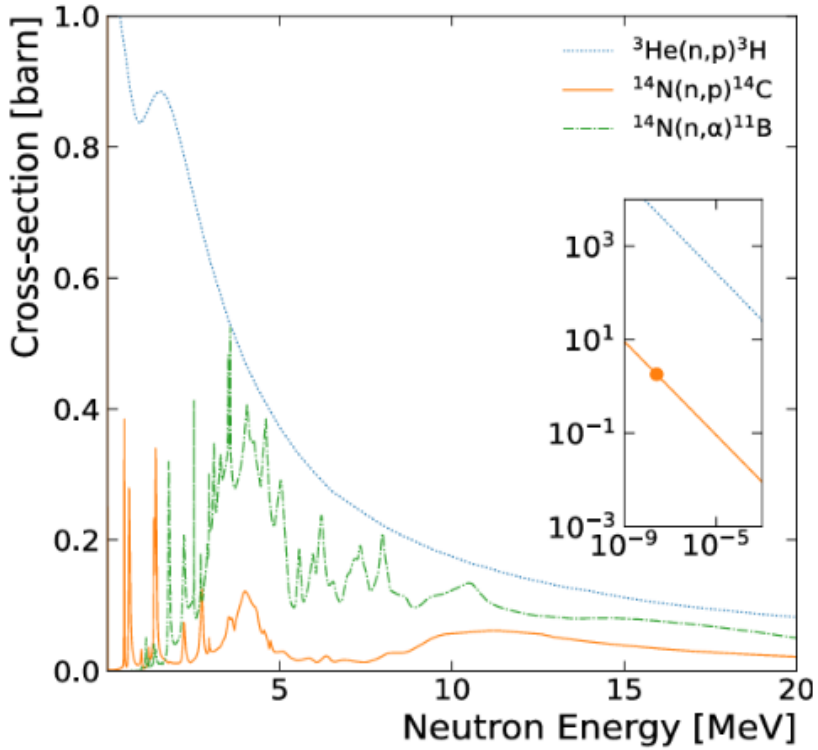


Neutron Beam Measurement in Nitrogen Gas

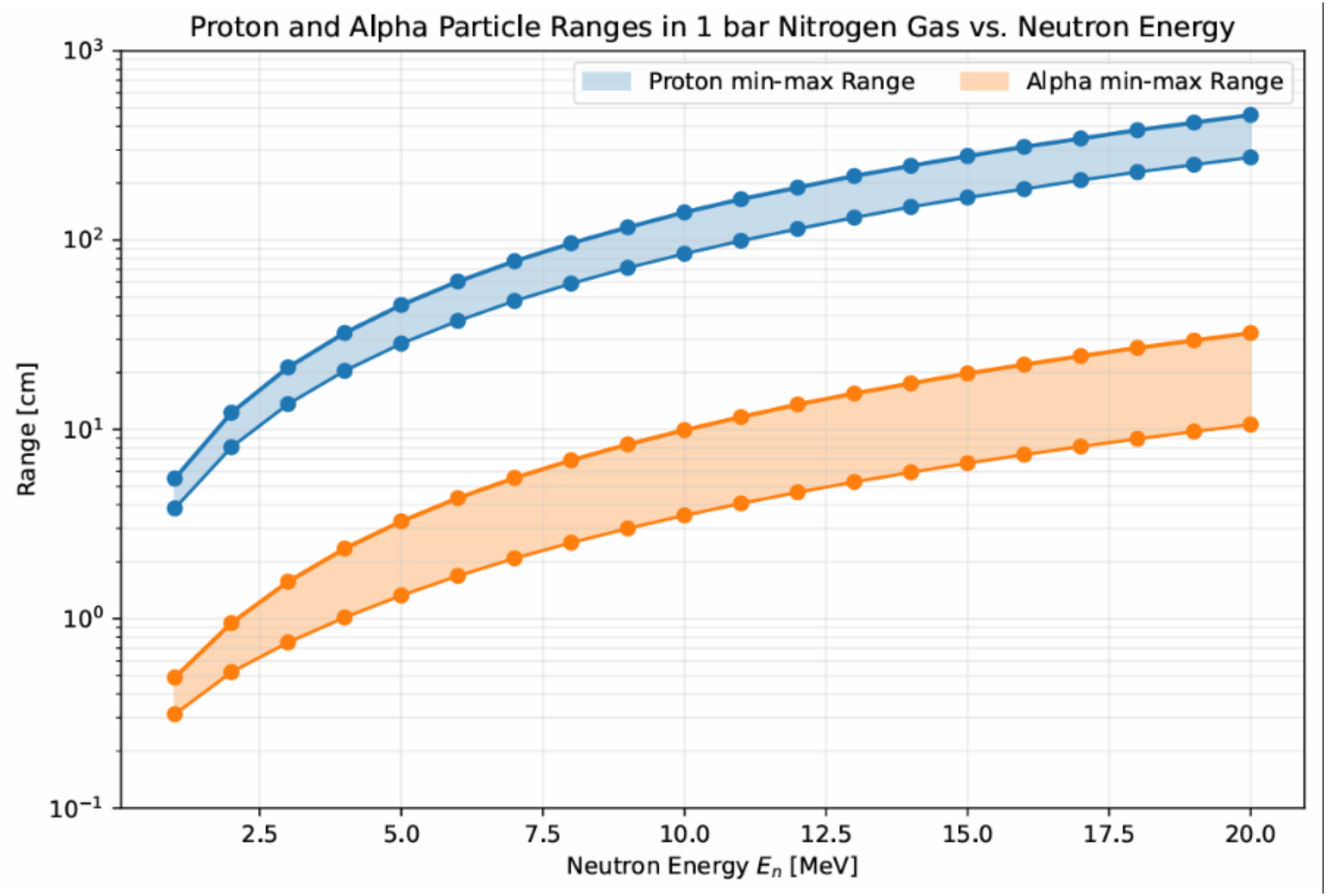


$$^{14}\mathrm{N} + \mathrm{n} \rightarrow {}^{14}\mathrm{C} + \mathrm{p} + 625\,\mathrm{keV}$$

$$^{14}\mathrm{N} + \mathrm{n} \rightarrow {}^{11}\mathrm{B} + \alpha - 159\,\mathrm{keV}$$

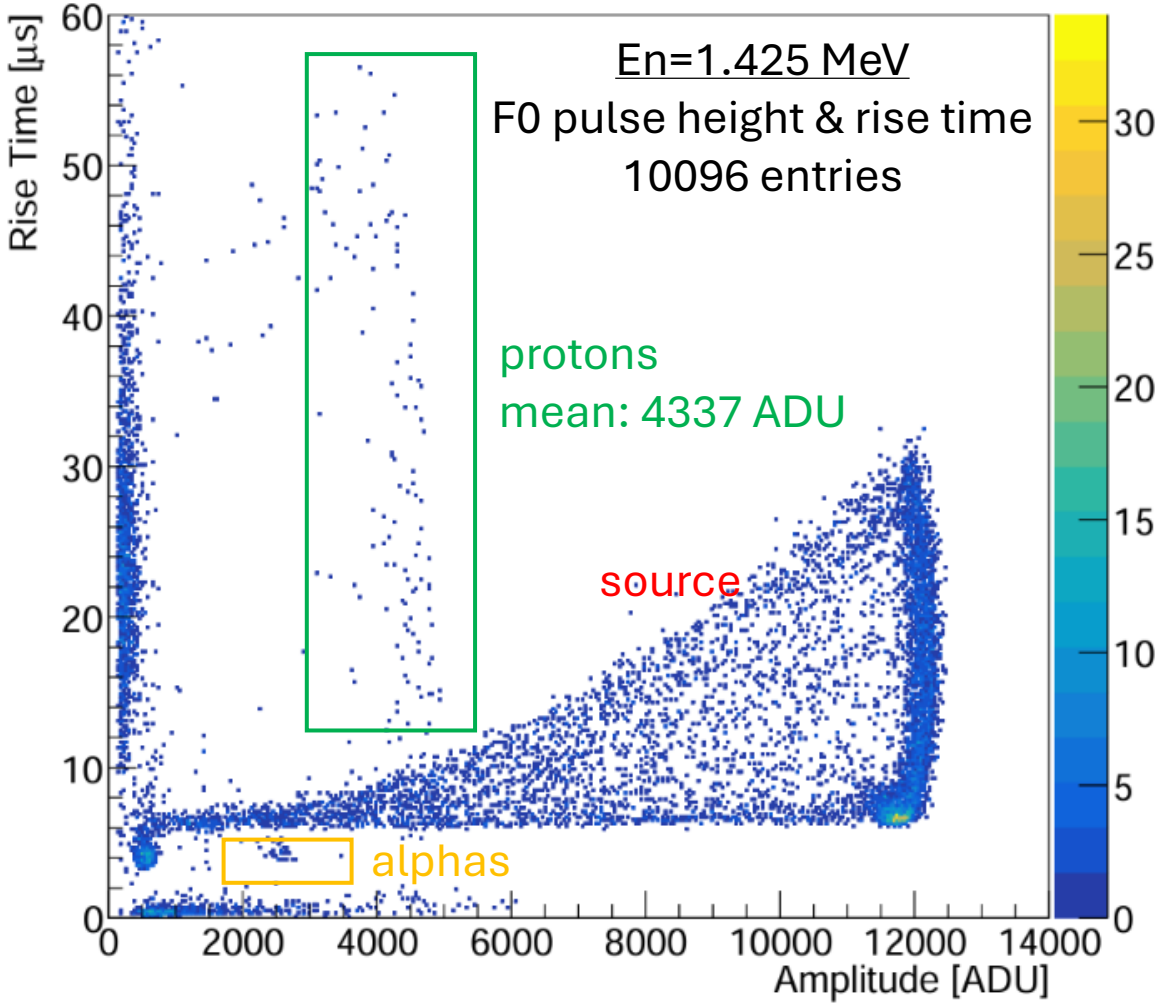


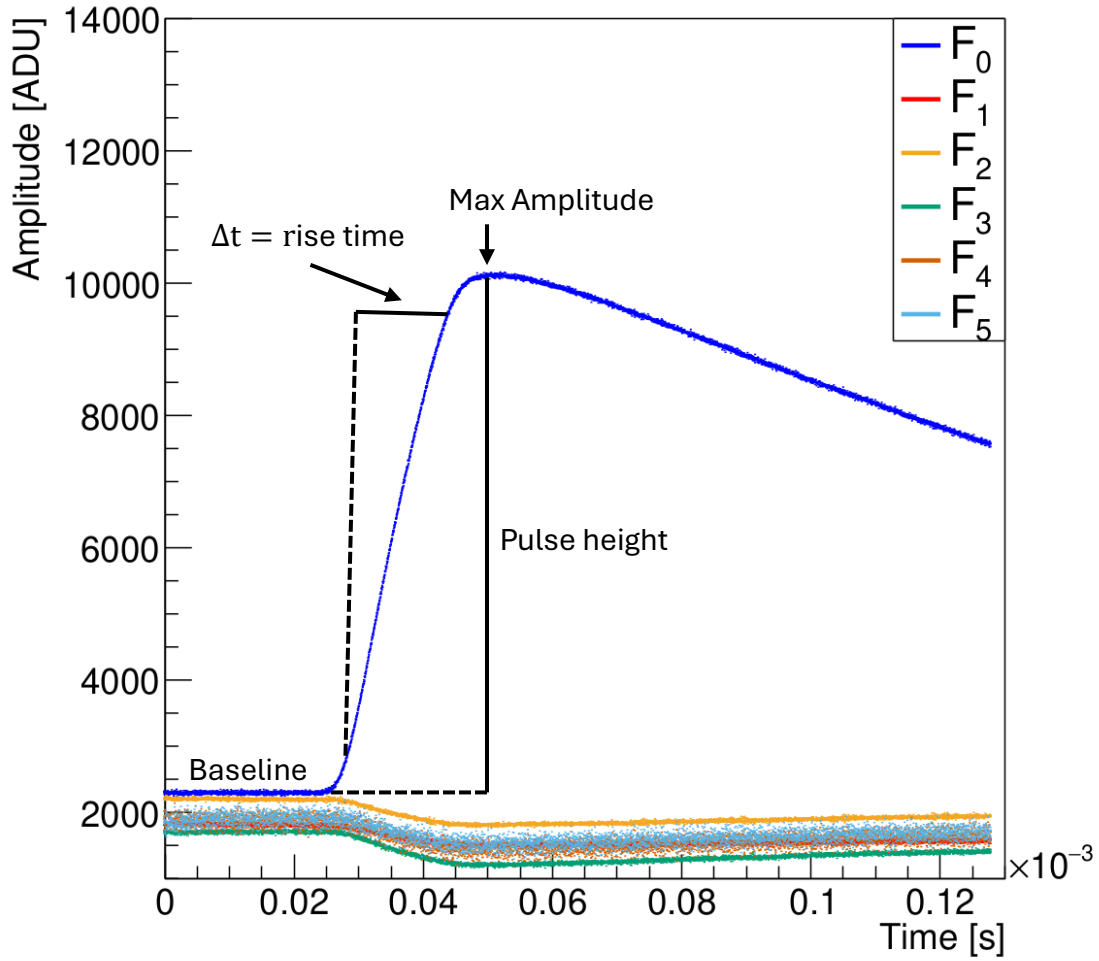
Ranges in Nitrogen Gas



Pulse-Shape Discrimination

Only F0 has signal

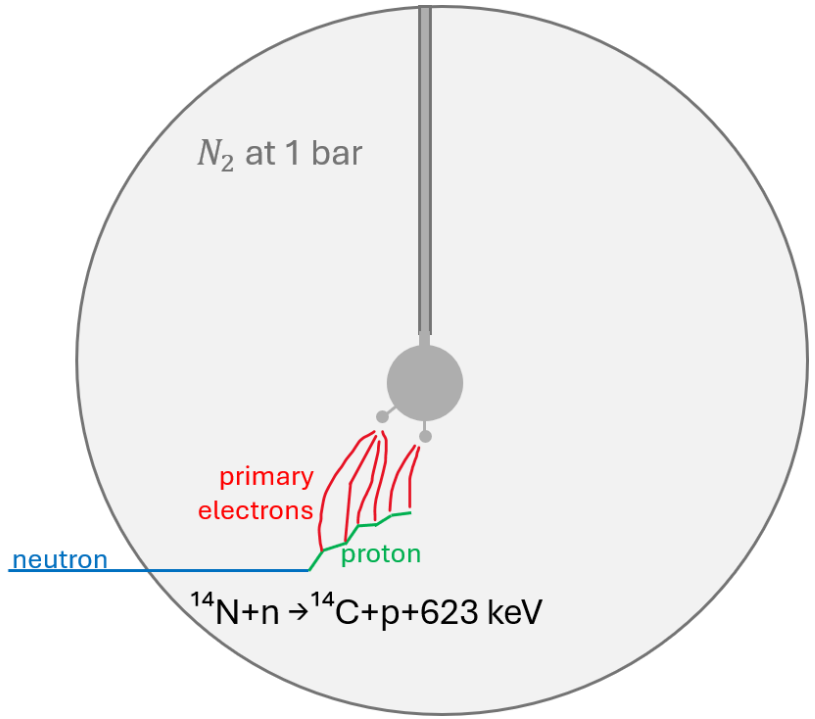




Shared Signal Events

- Primary electrons are collected by more then one anode
- Events are discarded in previous analysis

Can we recover these events to improve statistics?



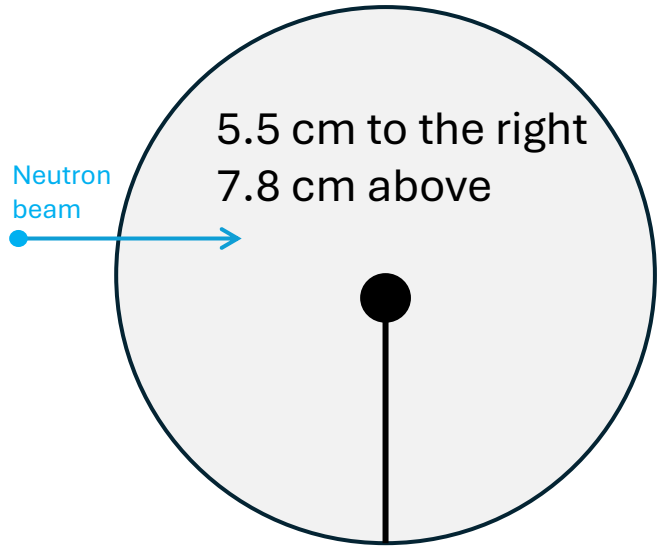
Simulation (Geant4, Garfield ++, Gmsh/Emler)

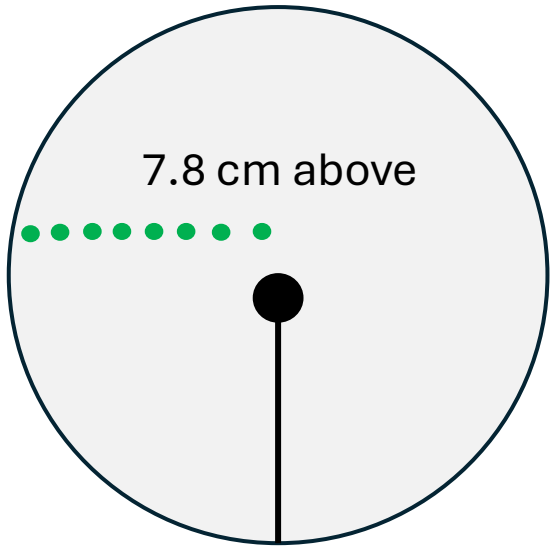
Neutrons:

- 1.424 MeV
- Direction along z-axis

Protons:

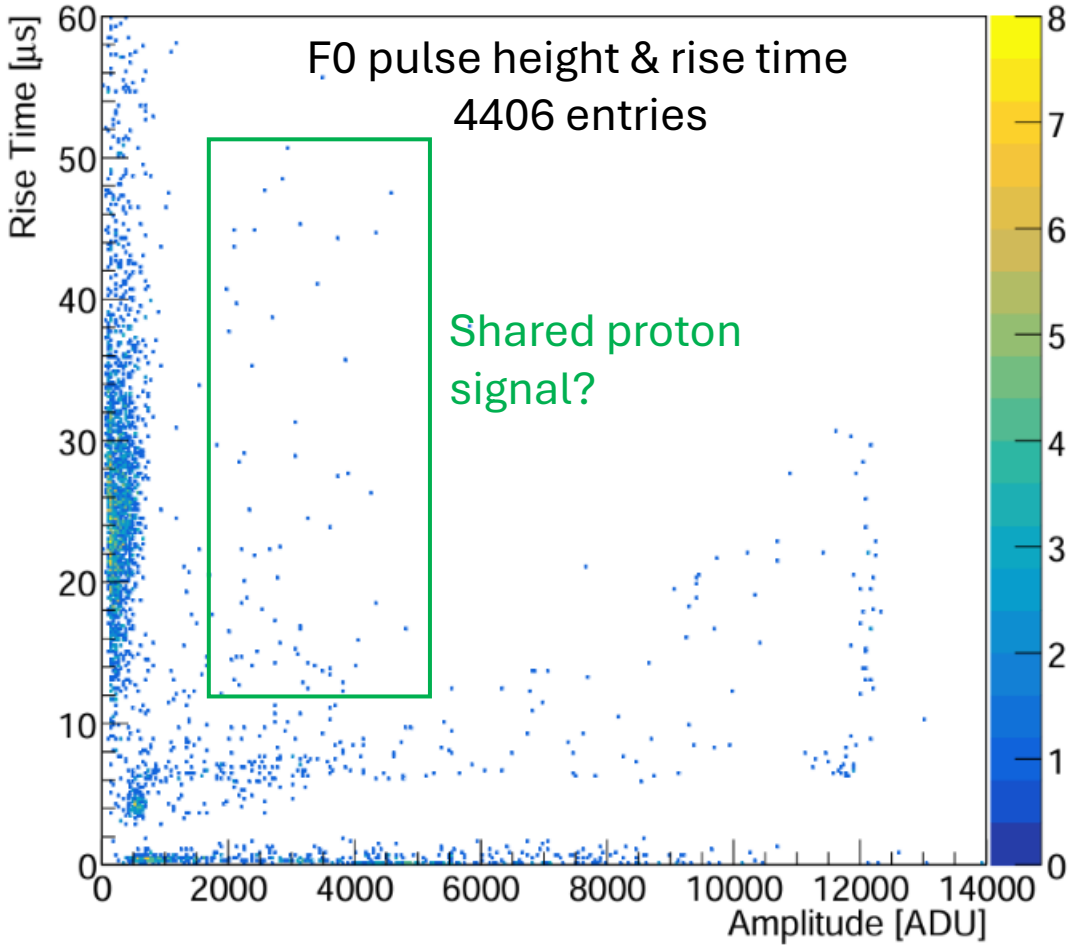
- 1.9 MeV
- Random direction

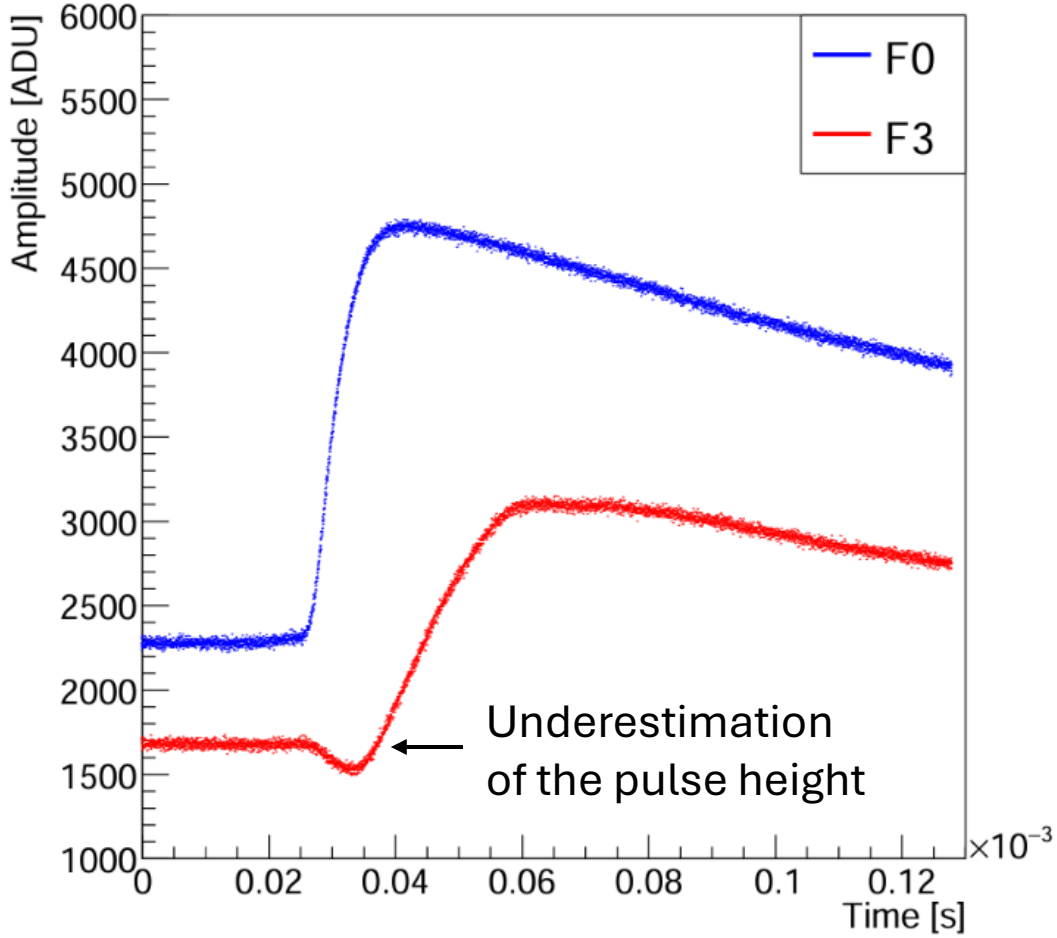




Not F0 Events

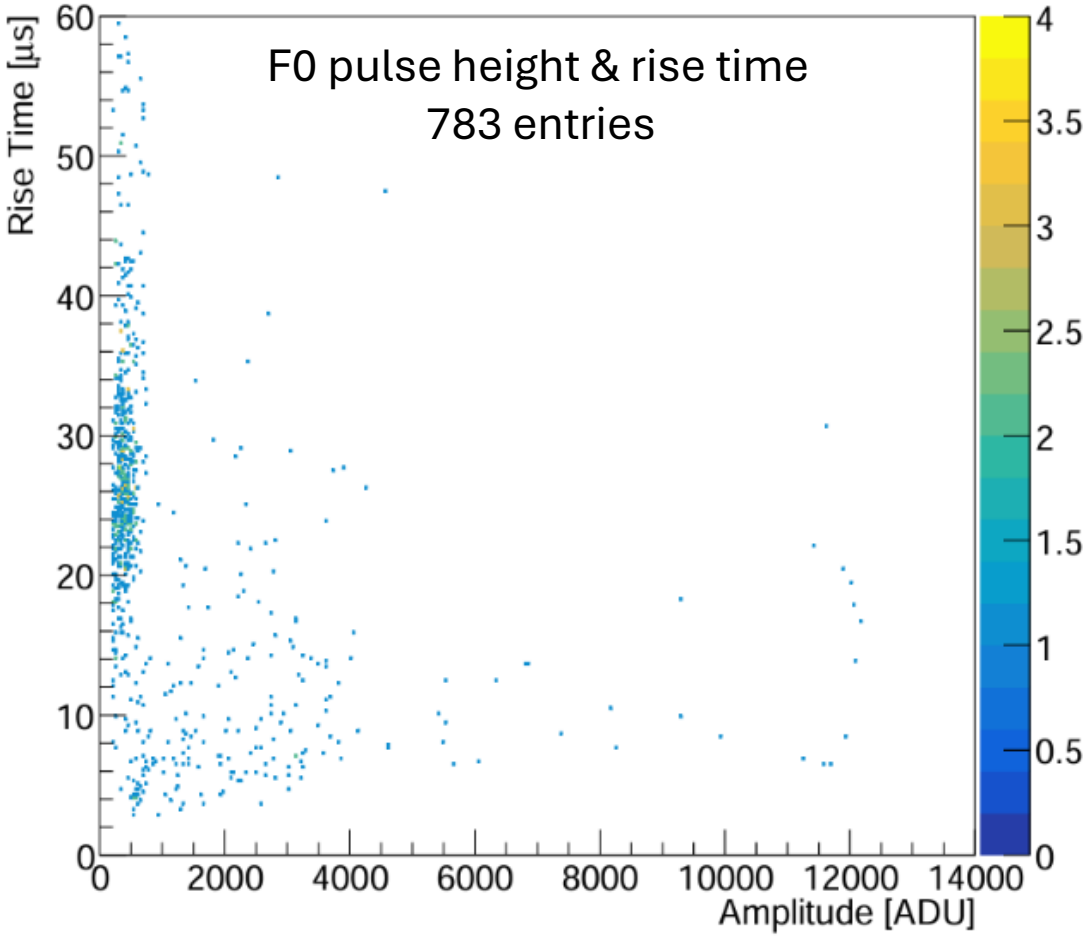
F0 & other channels have signal:





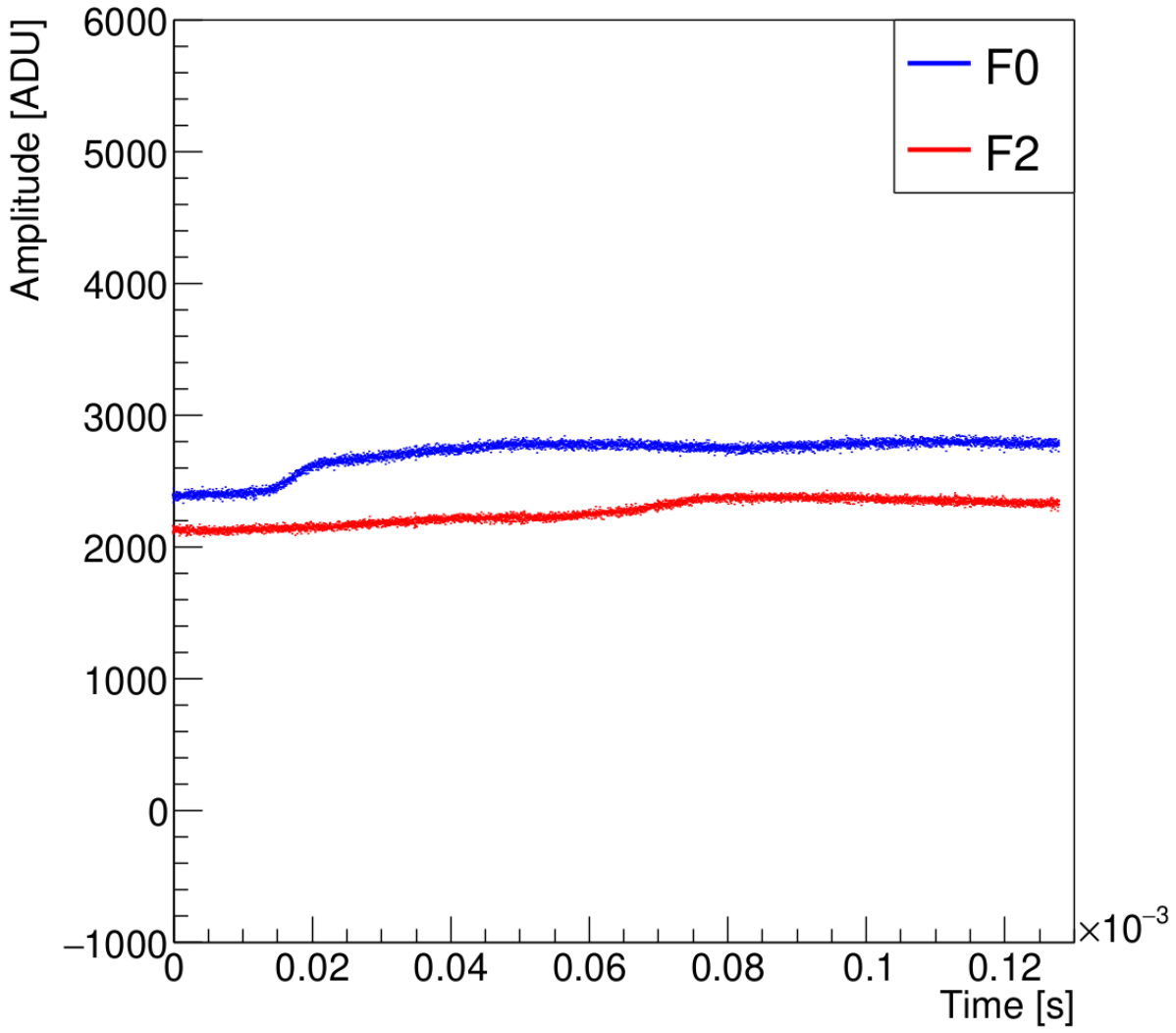
Selection of Shared Events

- Shared between 2 far channels
- Pulse height > 200 ADU
- Rise time > 2 μs
- Rise time < 60 μs



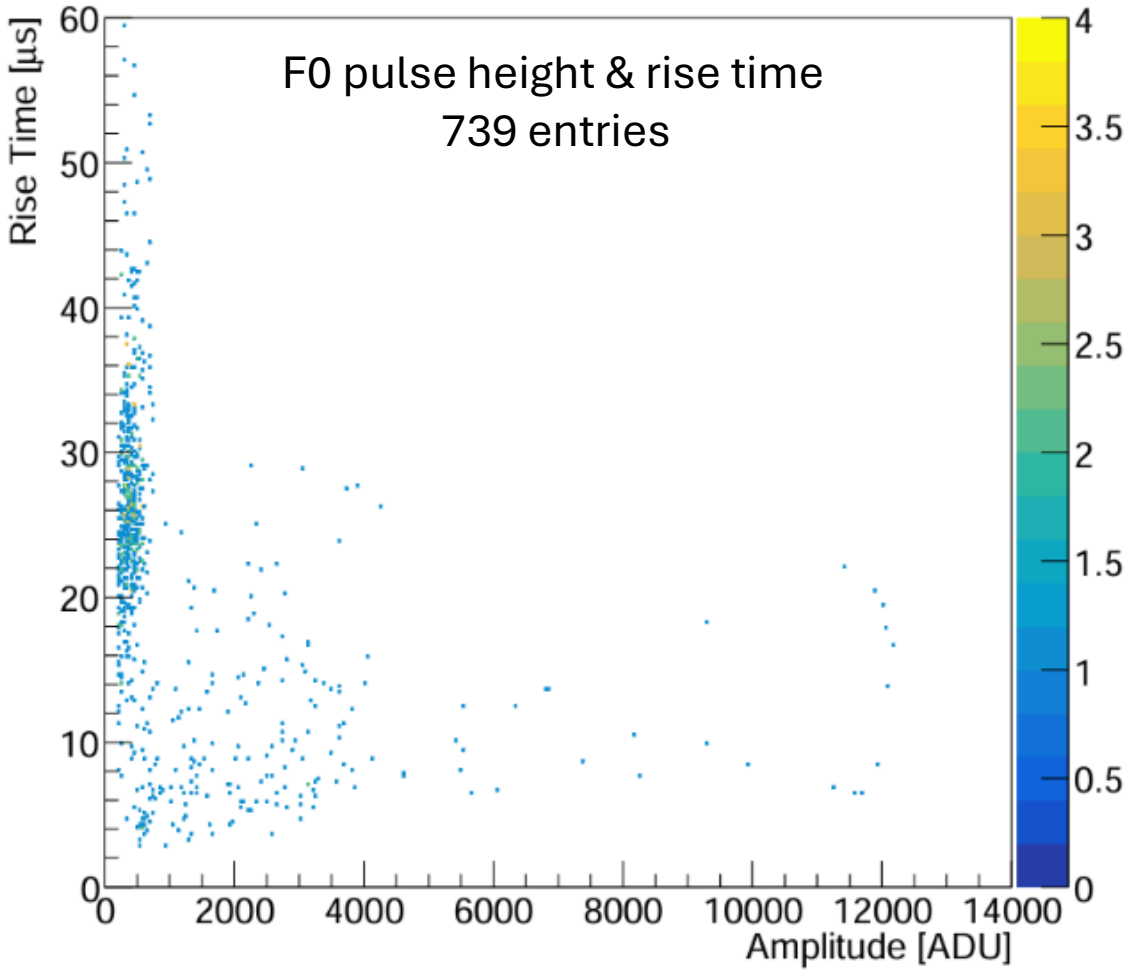
Selection of Shared Events

- Shared between 2 far channels
- Amplitude > 200 ADU
- Rise time > 2 μs
- Rise time < 60 μs
- Max Amplitude in first half

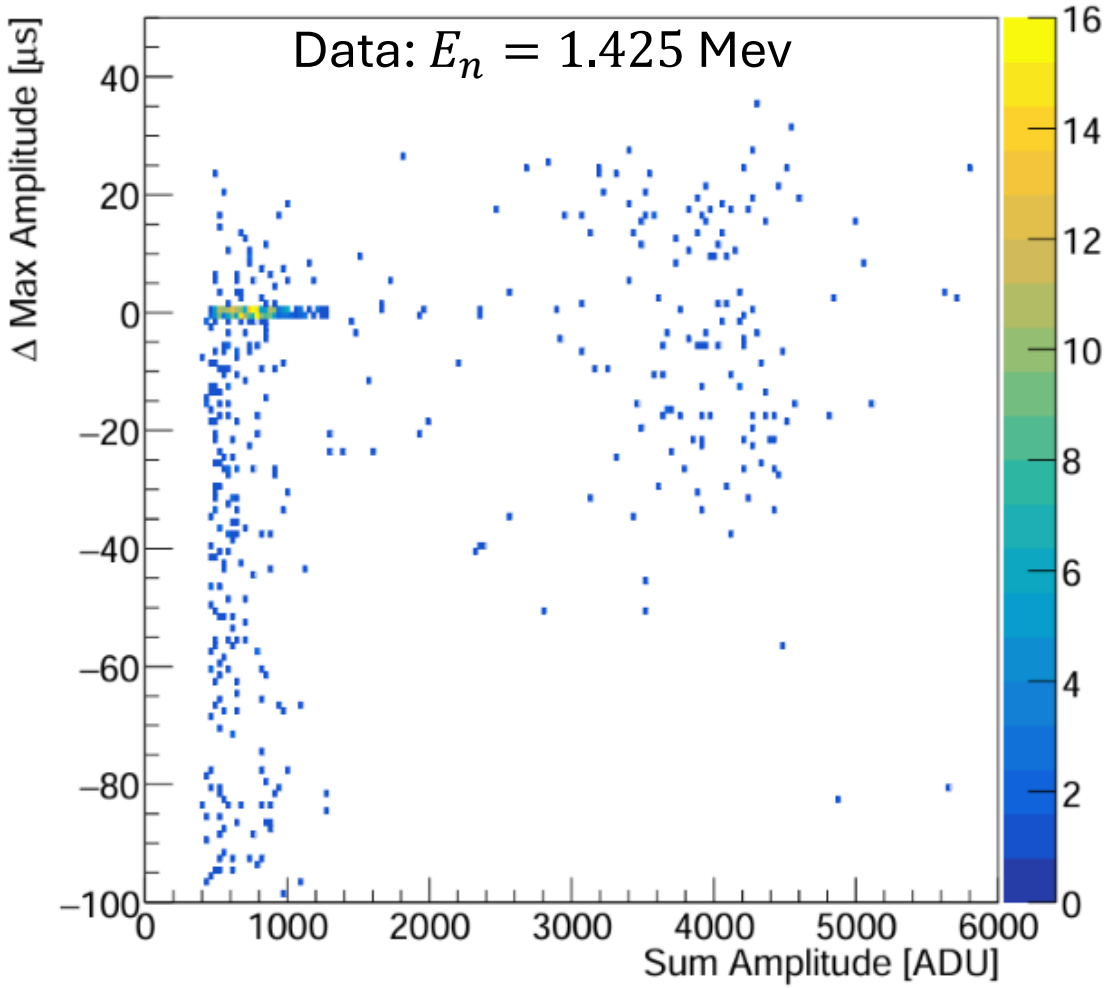


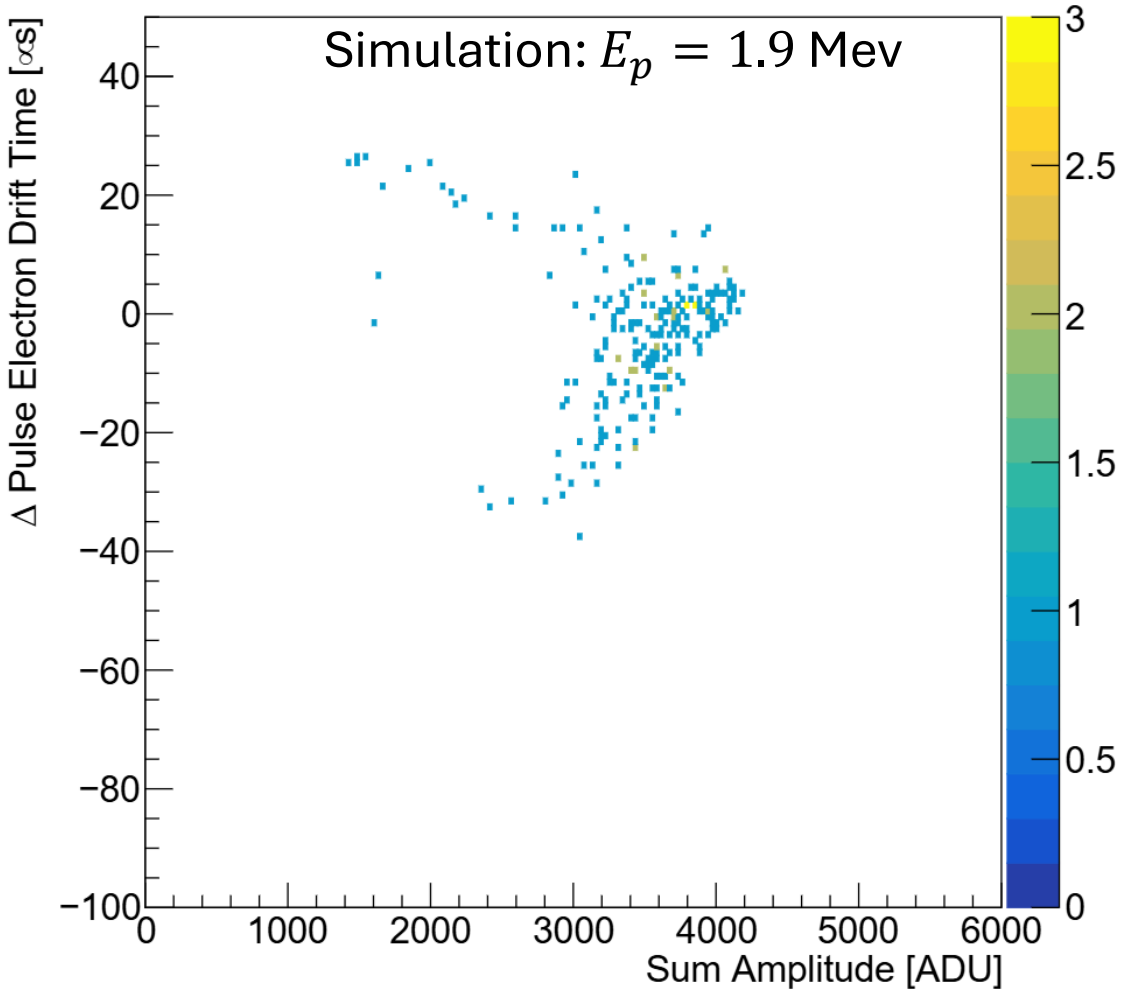
Selection of Shared Events

- Shared between 2 far channels
- Pulse height > 200 ADU
- Rise time > 2 μs
- Rise time < 60 μs
- Max Amplitude in first half



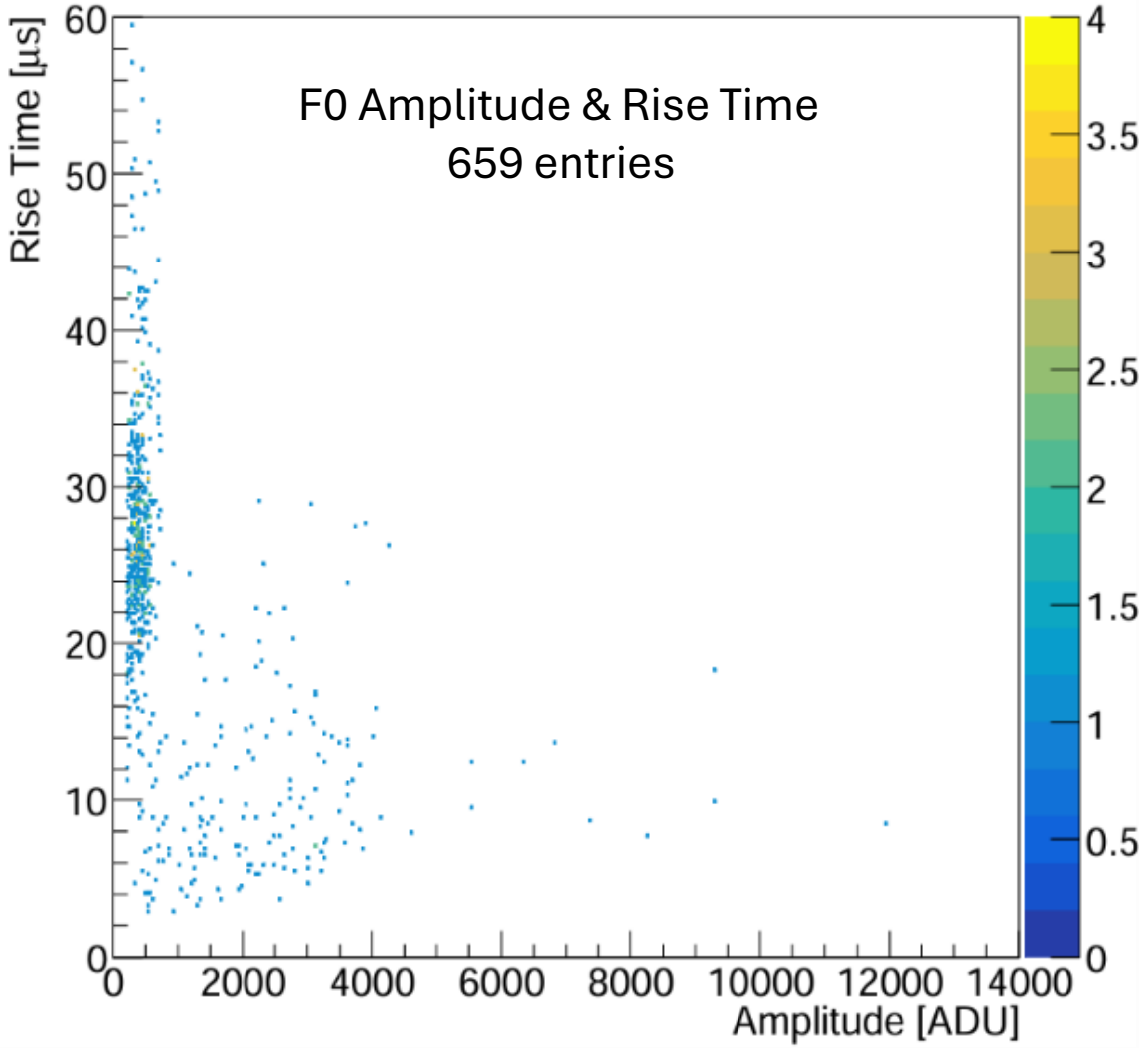
Timing of Shared Signal Events



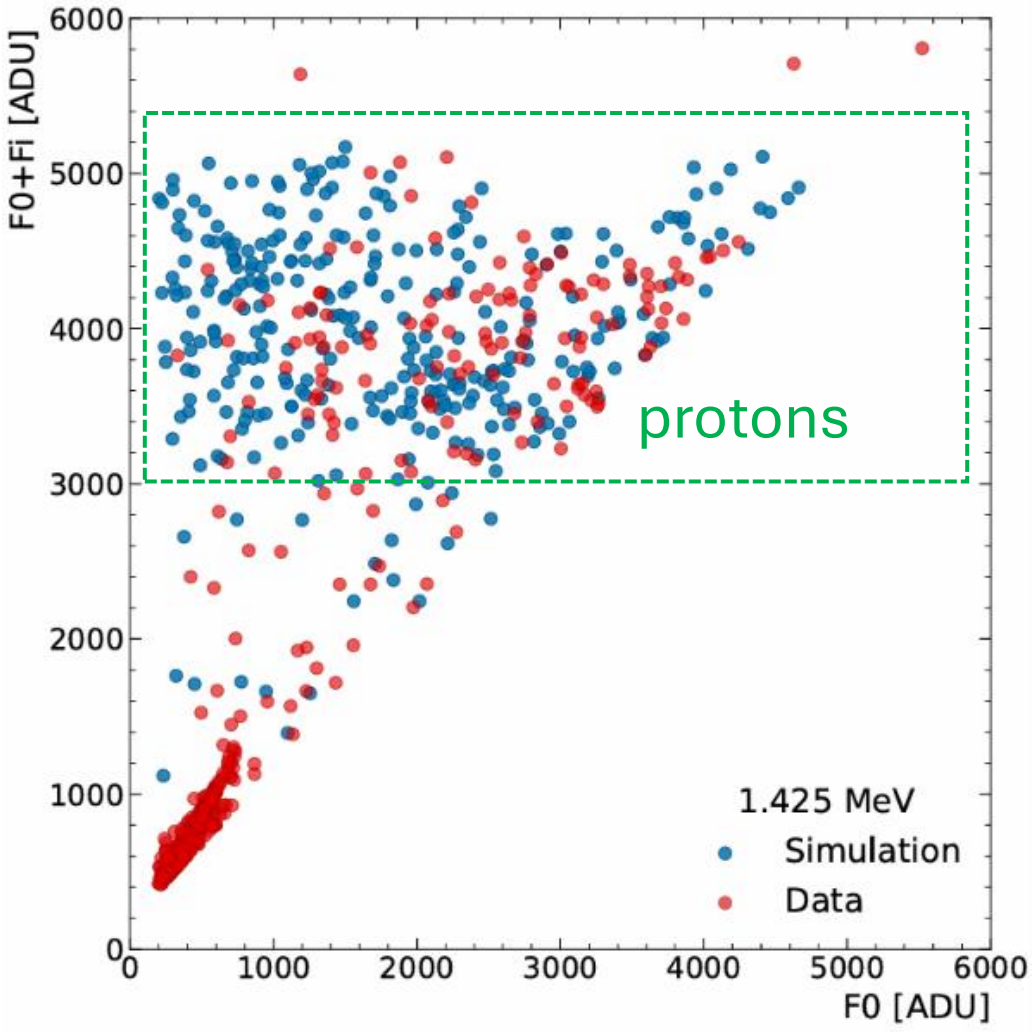


Selection of Shared Events

- Shared between 2 far channels
- Pulse height > 200 ADU
- Rise time > 2 μs
- Rise time < 60 μs
- Max Amplitude in first half
- Δ Max Amplitude < 60 μs

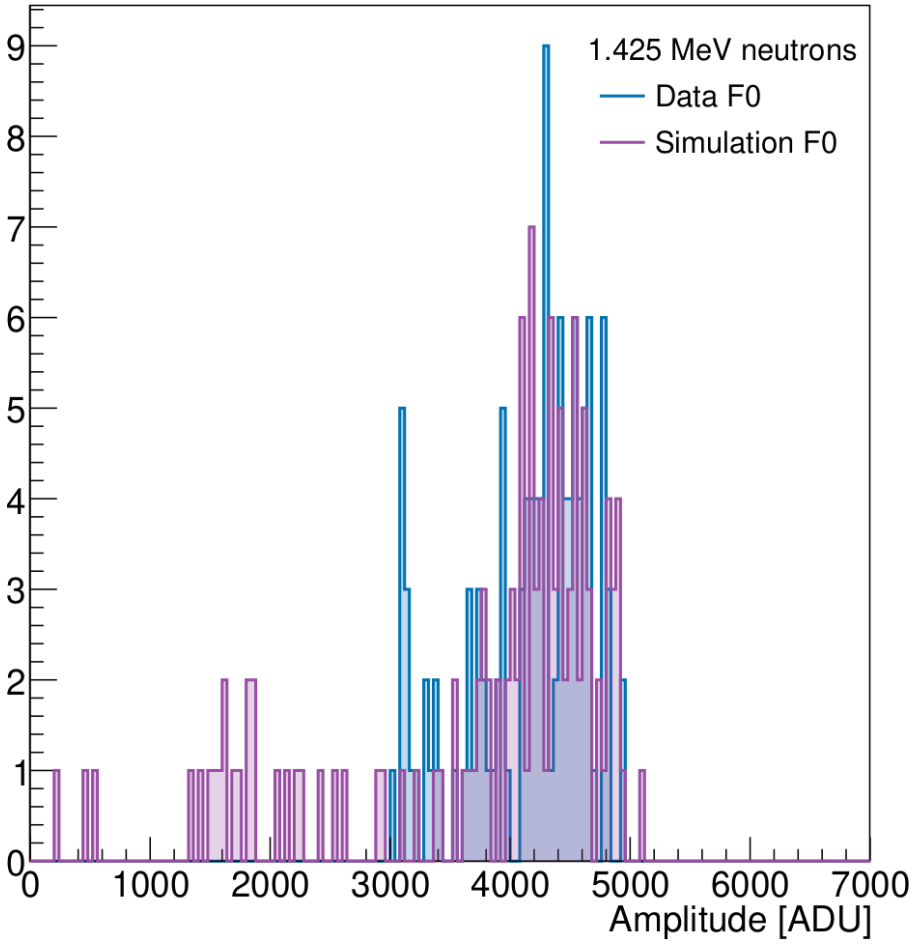


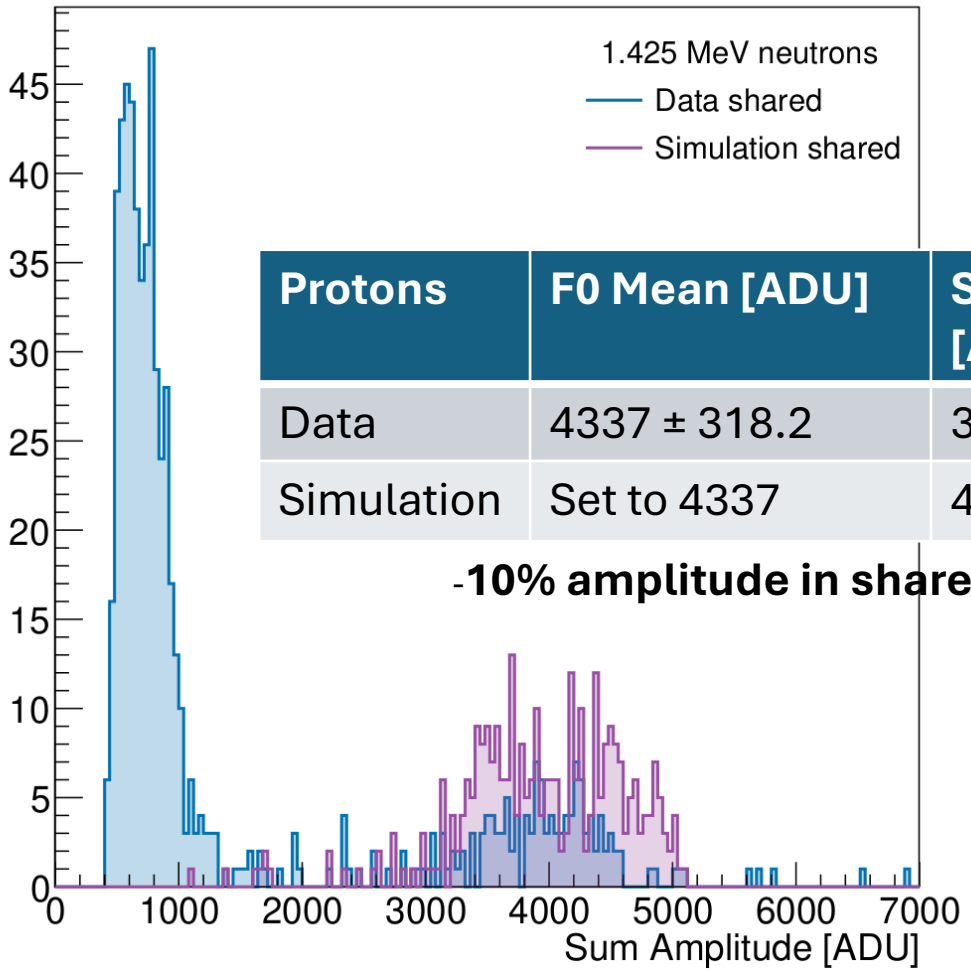
Shared Signal Event Ratio



Protons	Ratio (#shared / #F0)
Data	1.1
Simulation	2.9

Simulation to Data Comparison

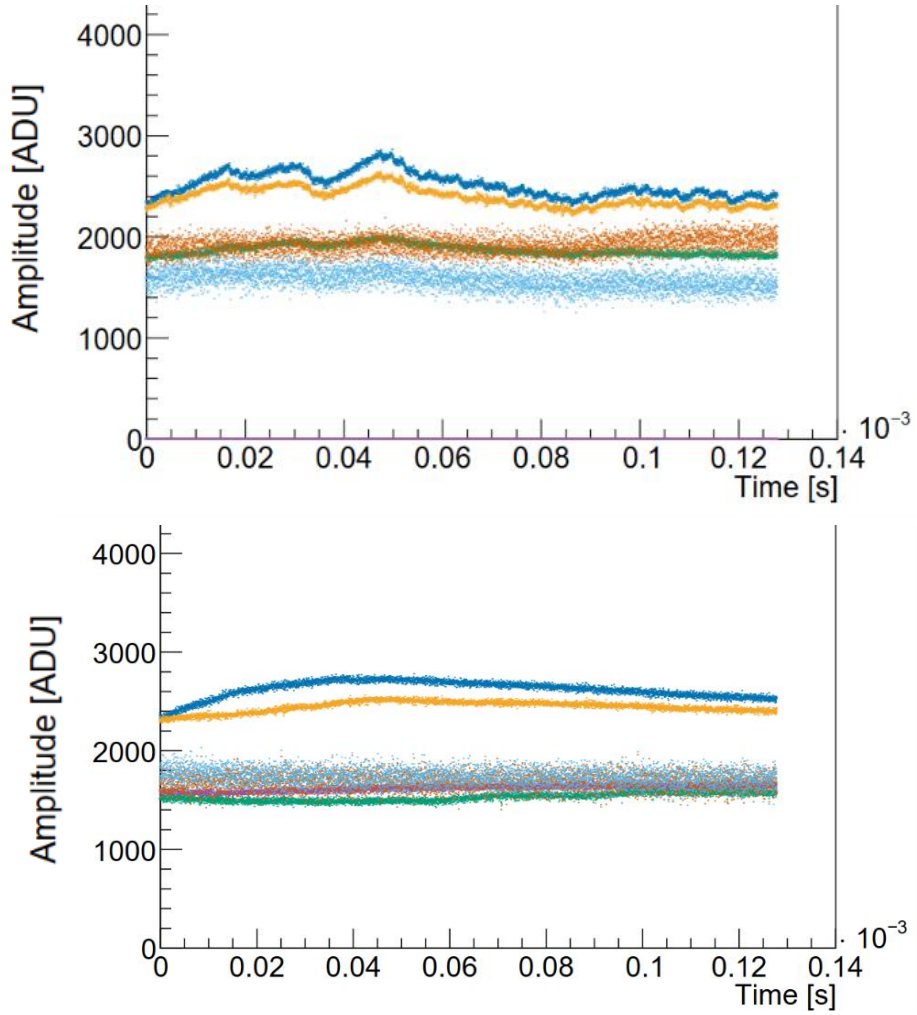


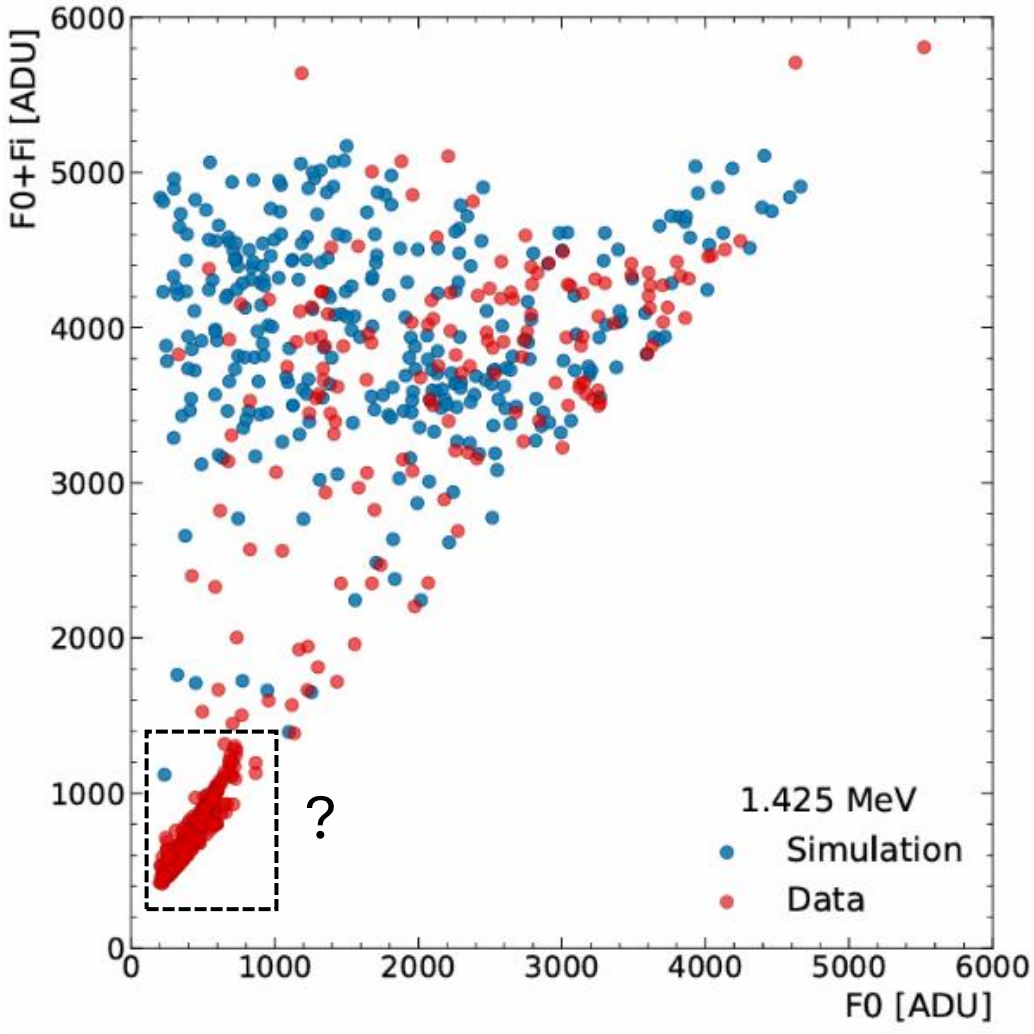


Protons	F0 Mean [ADU]	Shared Mean [ADU]
Data	4337 ± 318.2	3932.25 ± 568.81
Simulation	Set to 4337	4028.11 ± 719.23

-10% amplitude in shared event

Low Amplitude Events





Next Steps

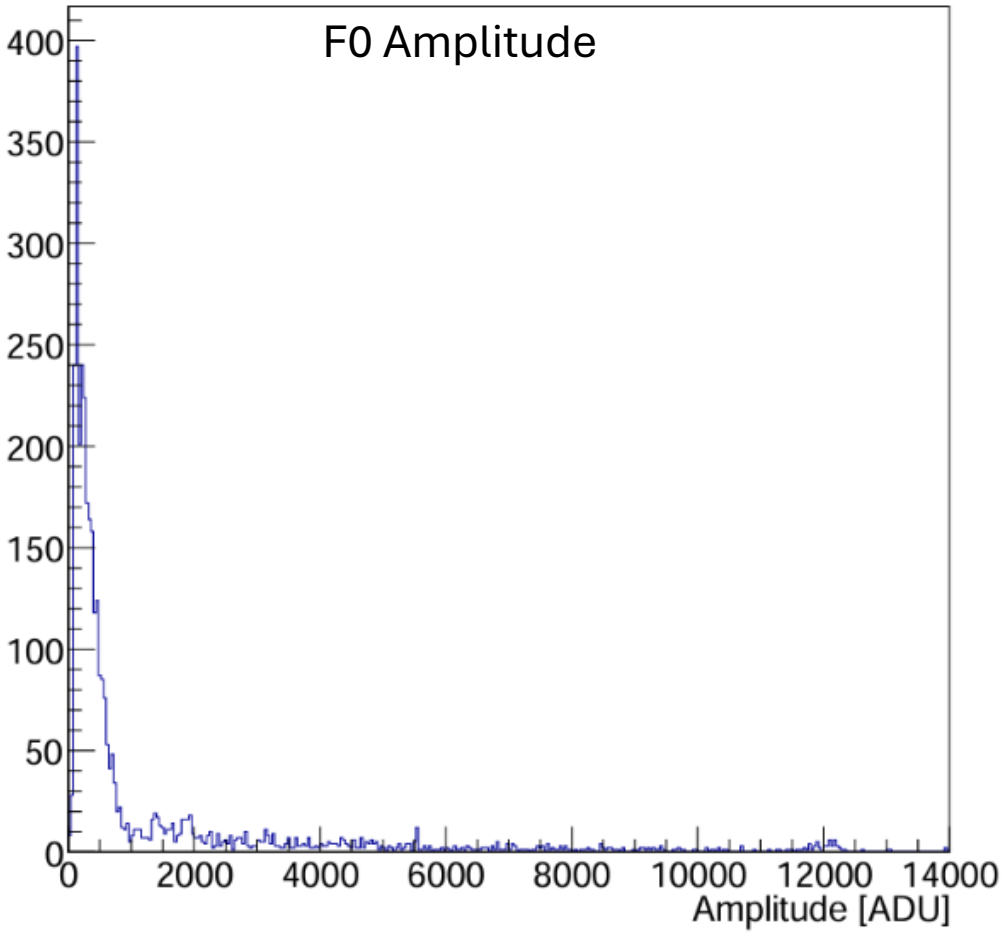
- How can we cut the noise without applying an amplitude cut?
- Why do we have different shared/F0 ratio in simulation?

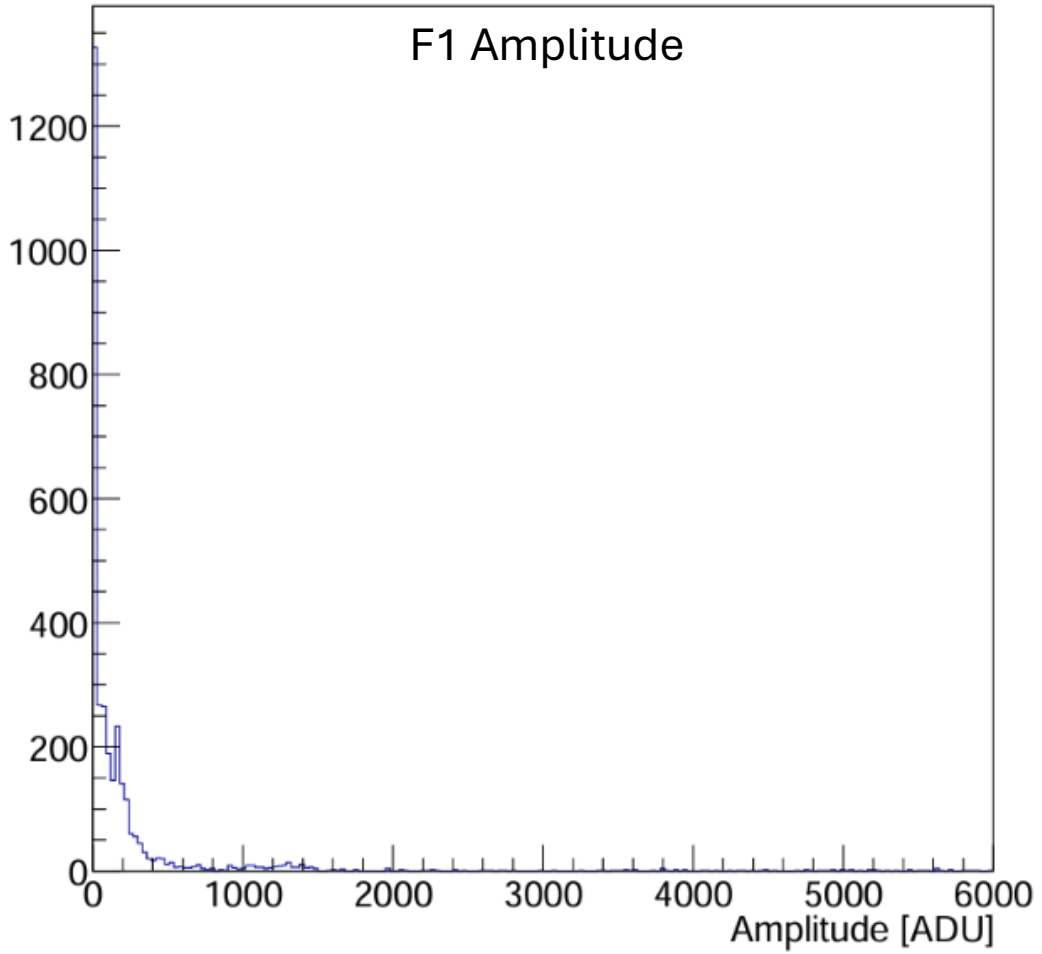
- 1.425 MeV neutron simulation (started over the weekend)
  - Waveforms for shared events

Backup

Amplitude Cut: 200 ADU

$E_n = 1.424$ Mev





Scaling

- Data:

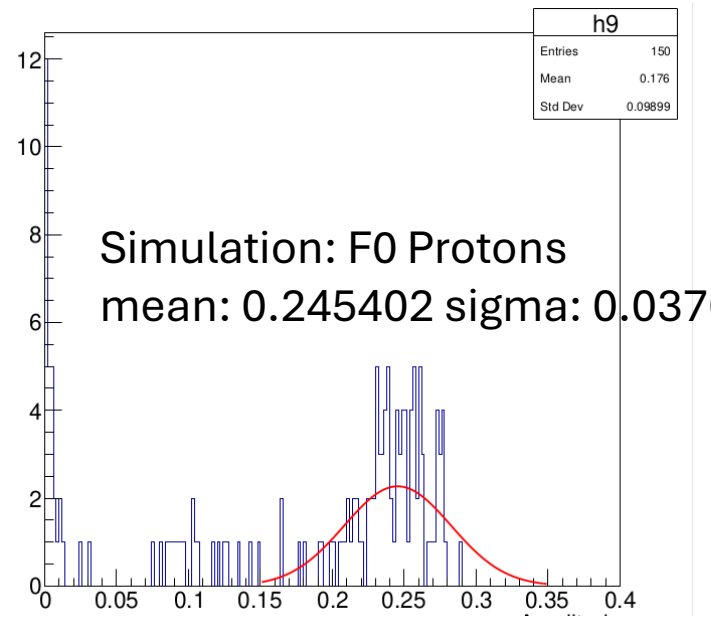
Protons	Fit Range	Mean [ADU]
F0	3000 - 5500 ADU & rise > 13 μs	4337
Shared Signal	2837 - 5837 ADU	3932.25 ± 568.81

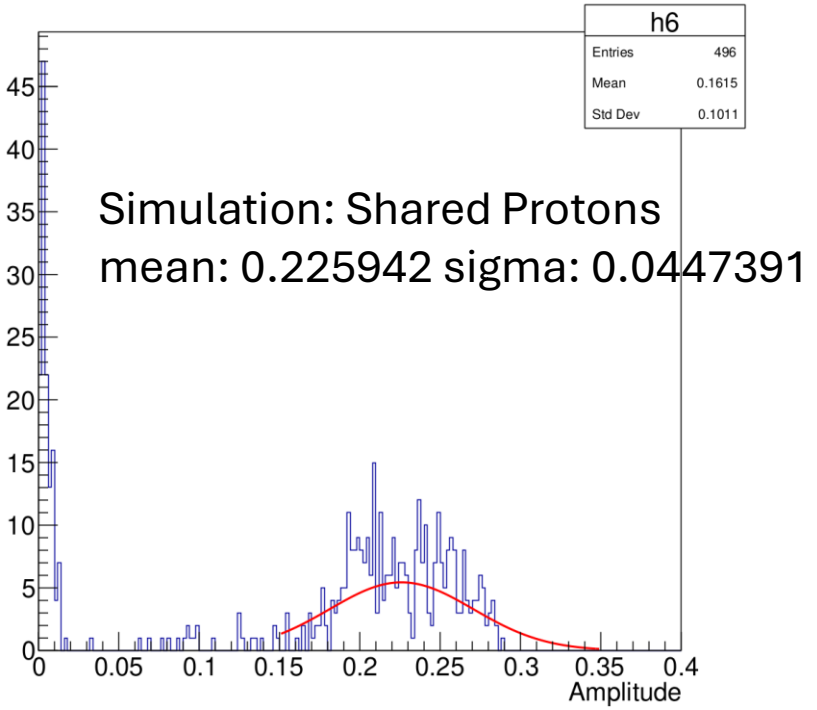
- Simulation:

Protons	Fit Range	Mean [ADU]
F0	0.15 - 0.35	0.25 set to 4337
Shared Signal	2000 - 6000	4028.11 ± 719.23

hard to fit

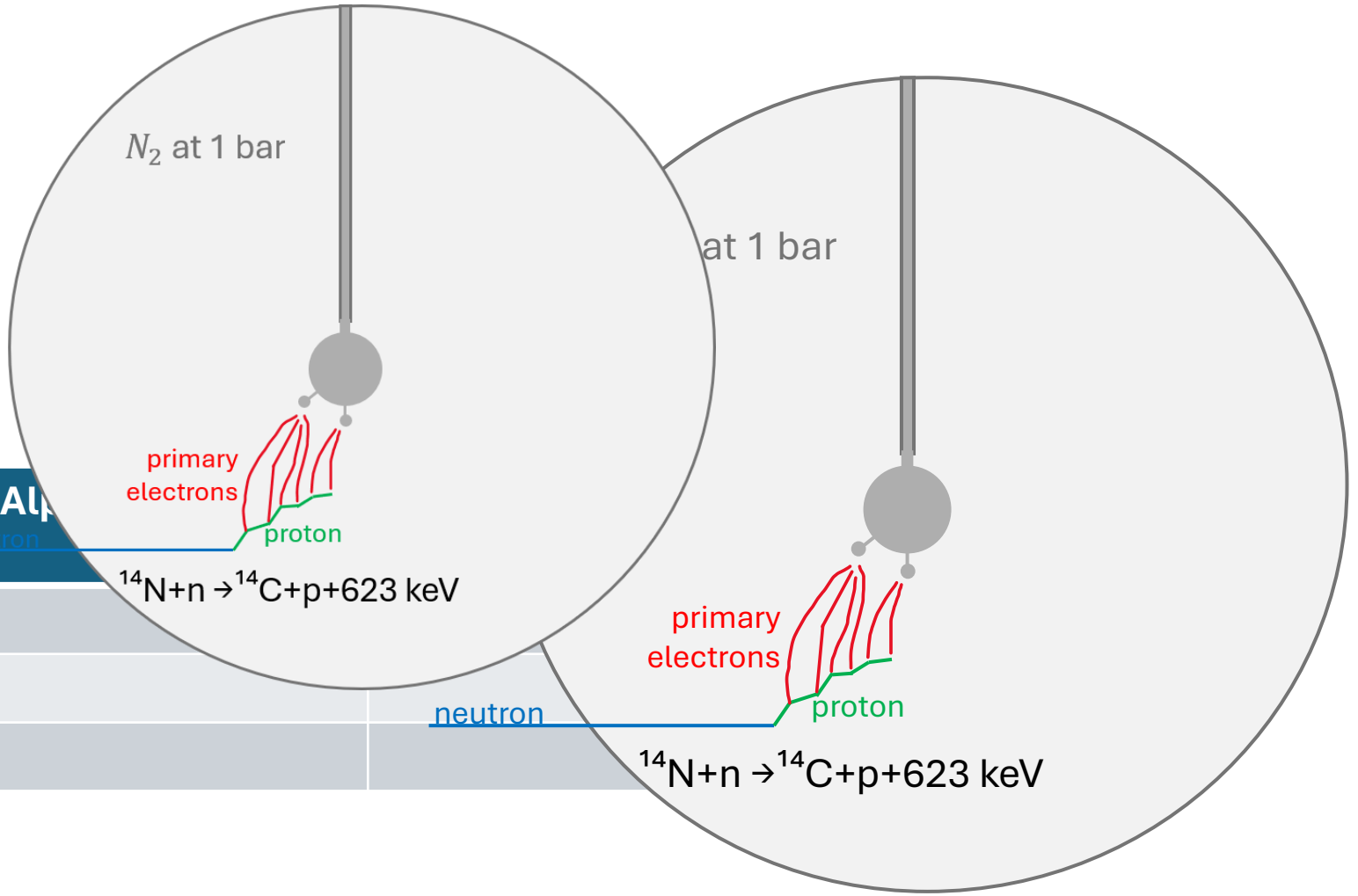
Scale: 17673.1



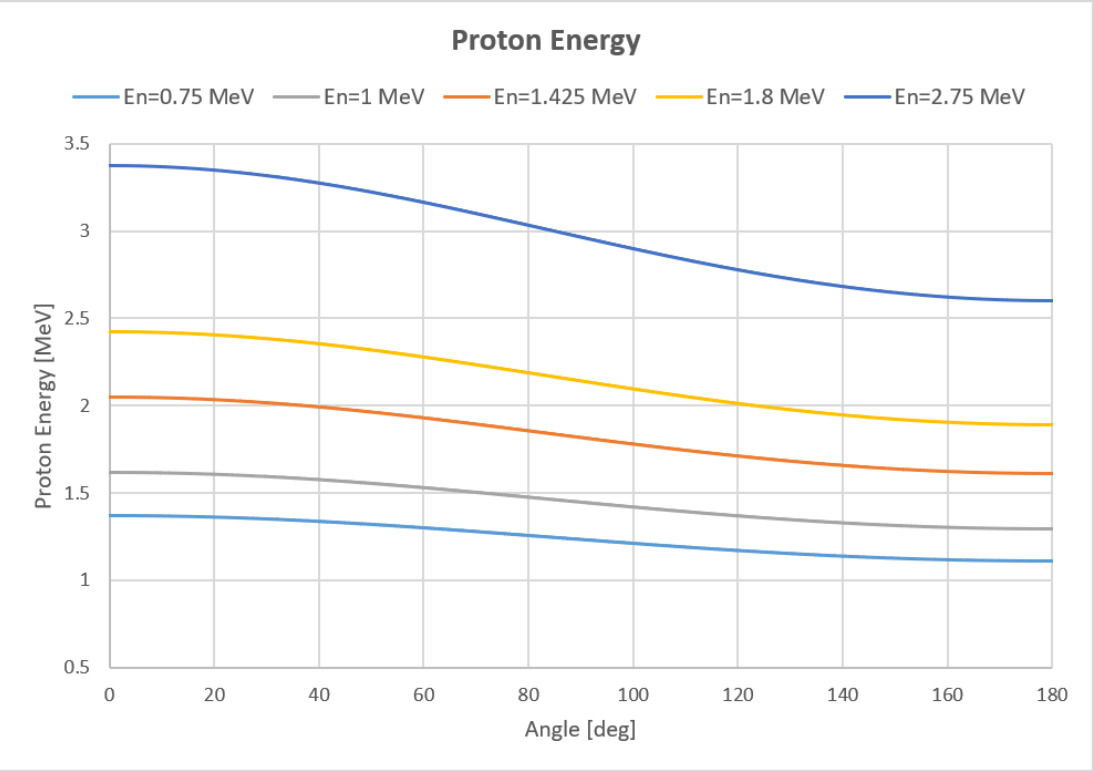


Shared Signal Events

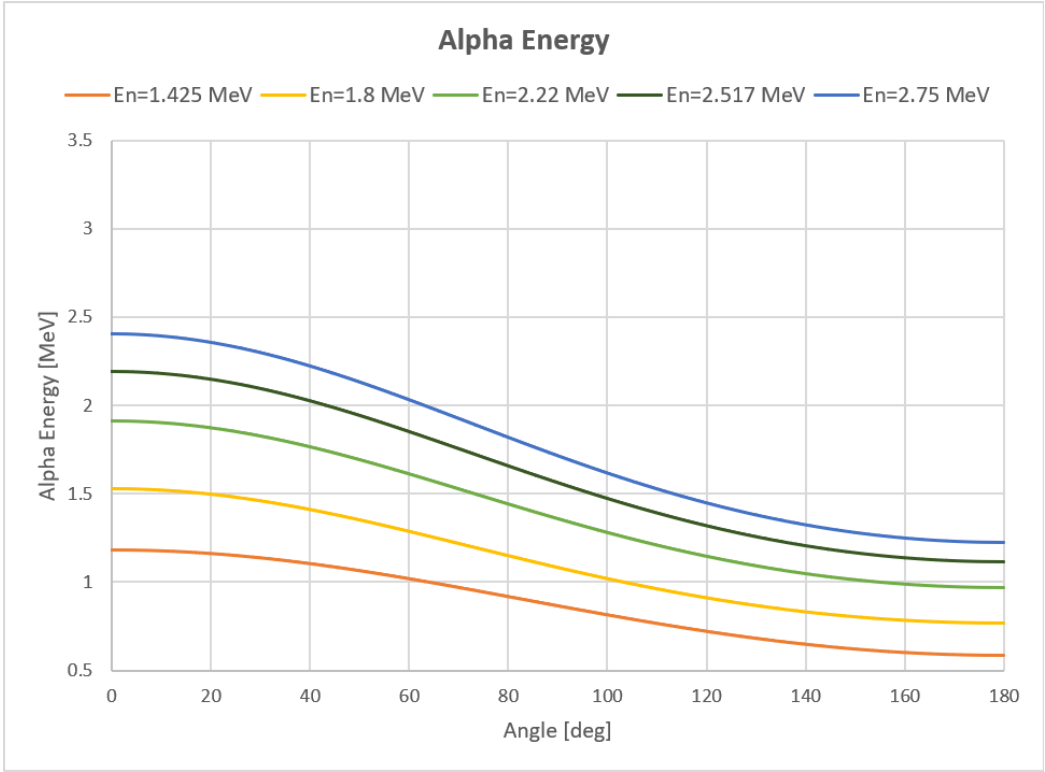
Neutron Energy [MeV]	Proton Range [cm]	Al
0.75		
1.425		
2.75		



Kinematics



En [MeV]	Max Ep [MeV]	Min Ep [MeV]
0.75	1.369	1.11
1	1.621	1.296
1.425	2.047	1.613
1.8	2.423	1.894
2.75	3.374	2.604



En [MeV]	Max Ea [MeV]	Min Ea [MeV]
1.425	1.181	0.588
1.8	1.527	0.768
2.22	1.915	0.97
2.517	2.189	1.112
2.75	2.405	1.224