ePIC hpDIRC Annual Meeting 2026 **Cosmic Ray Telescope**

C. Ayerbe Gayoso, J. Barrantes, A. Cage, J. Datta, K. Dehmelt, A. Deshpande, S. Dutta, R. Dzhygadlo, A. Garrett, K. Gnanvo, I. Hossain, C. Hyde, Y. Ilieva, G. Kalicy, A. Lehmann, P. Nadel-Turonski, K. Peters, C. Schwarz, J. Schwiening, **N. Shankman**

GSI Jefferson Lab

The Catholic University of America

FAU Friedrich-Alexander-Universität Erlangen-Nürnberg

Old Dominion University

University of South Carolina

Stony Brook University

Center for Frontiers in Nuclear Science

eRD103 Project R&D for EIC

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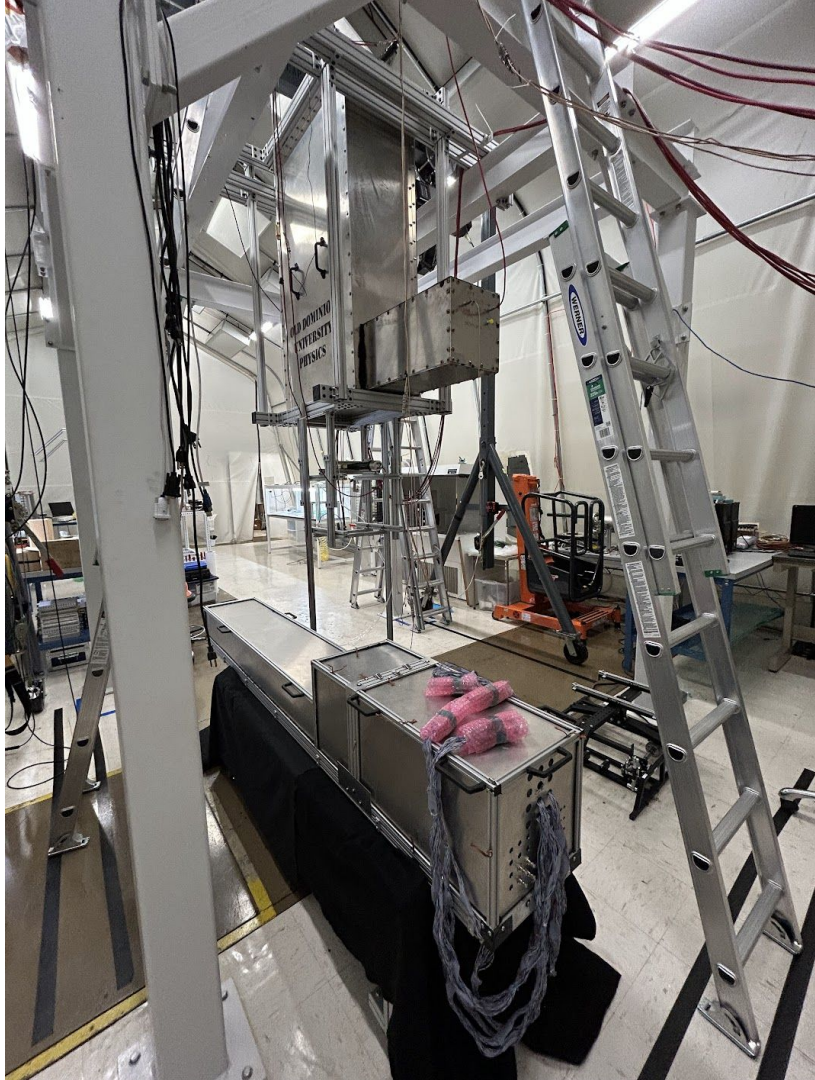
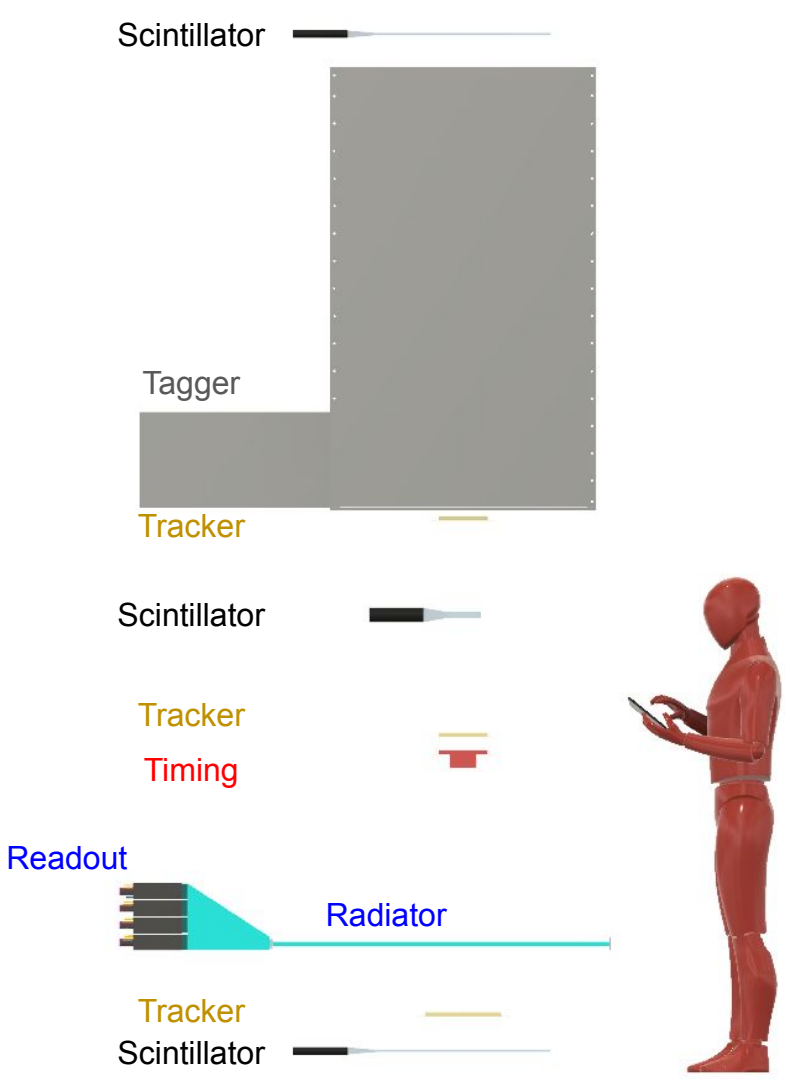


Cosmic Ray Telescope

- Scintillators
- Cherenkov Momentum Tagger
- μRWELLs
  - 0.5 mrad angular resolution (goal)
- Timing Detector
- DIRC Prototype
  - bar/lens/prism
  - MCP-PMT array, electronics
- DAQs
- Motion platform



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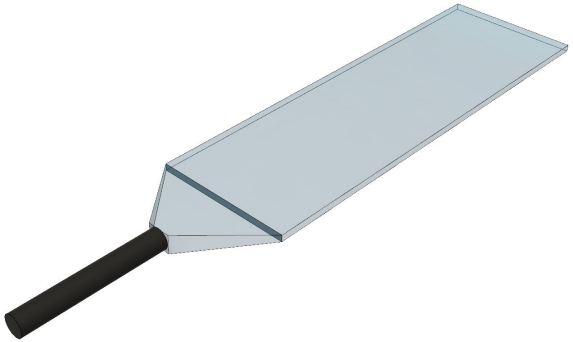
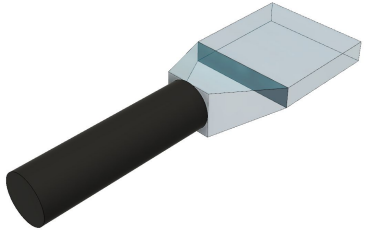
Scintillators/PMTs

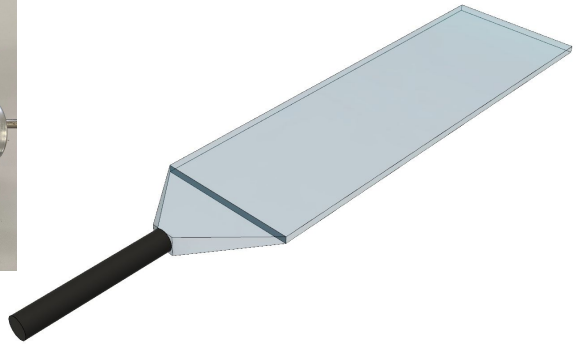
- Top
  - 64 x 20 x 1 cm
  - Height ~ 3.78 m
- Mid
  - 12.75 x 12.75 x 2.5 cm
  - Height ~ 1.65 m
- Bot
  - 64 x 20 x 1 cm
  - Height ~ 0.07 m

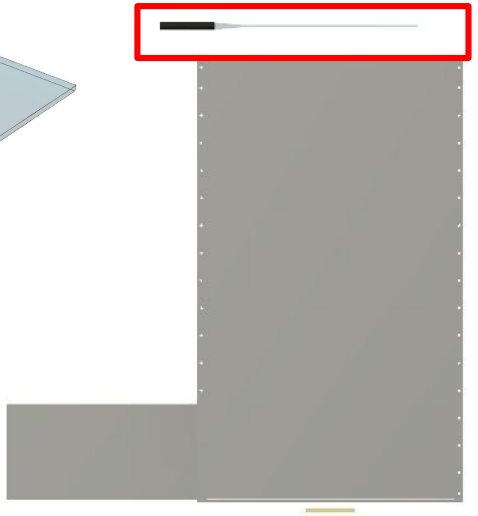
Bot scintillator

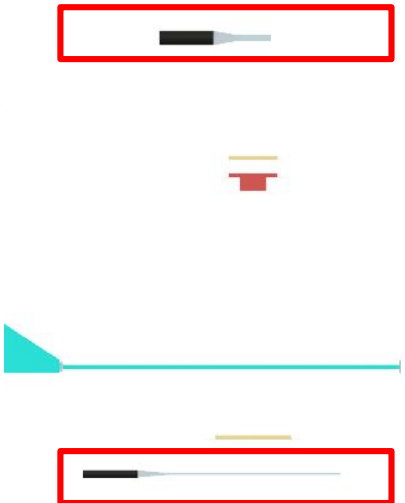
Mid scintillator











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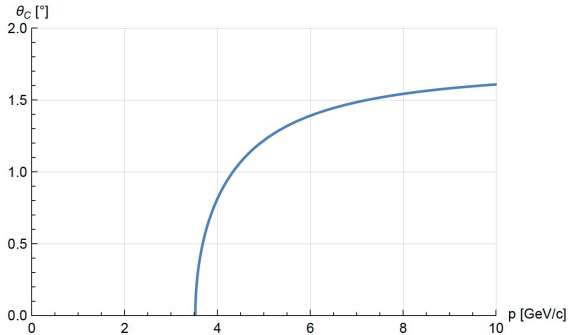
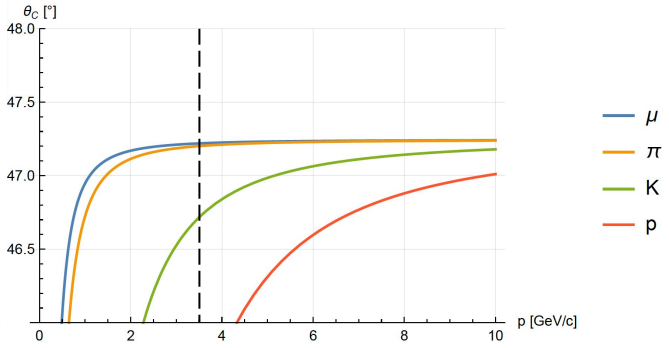
CO_2 Cherenkov Momentum Threshold Tagger

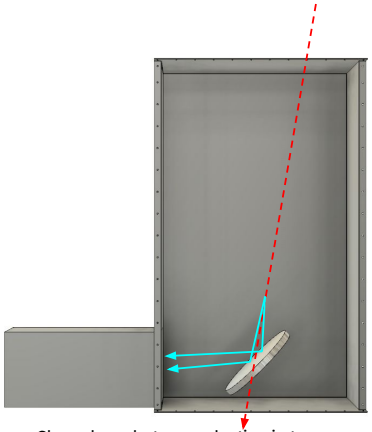
Cherenkov radiation produced for muons with p > 3.5 GeV/c



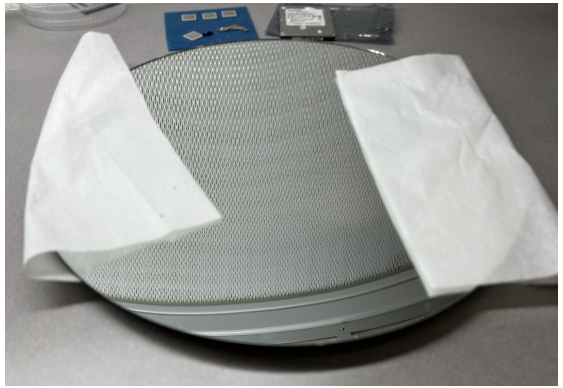
The Cherenkov angle as a function of momentum for a muon in CO_2



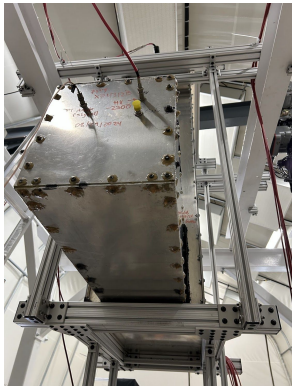
Cherenkov angle vs. momentum



Cherenkov photon production in tagger



UV enhanced mirror



Tagger electronic output

Tagger and 8020 support

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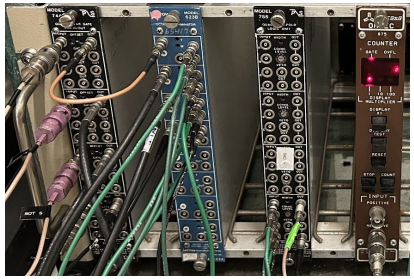
3 Scintillator + Tagger Hit Rate

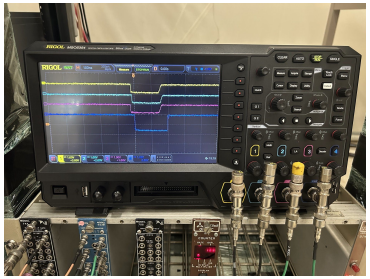
36 μ/hour (±0.892)

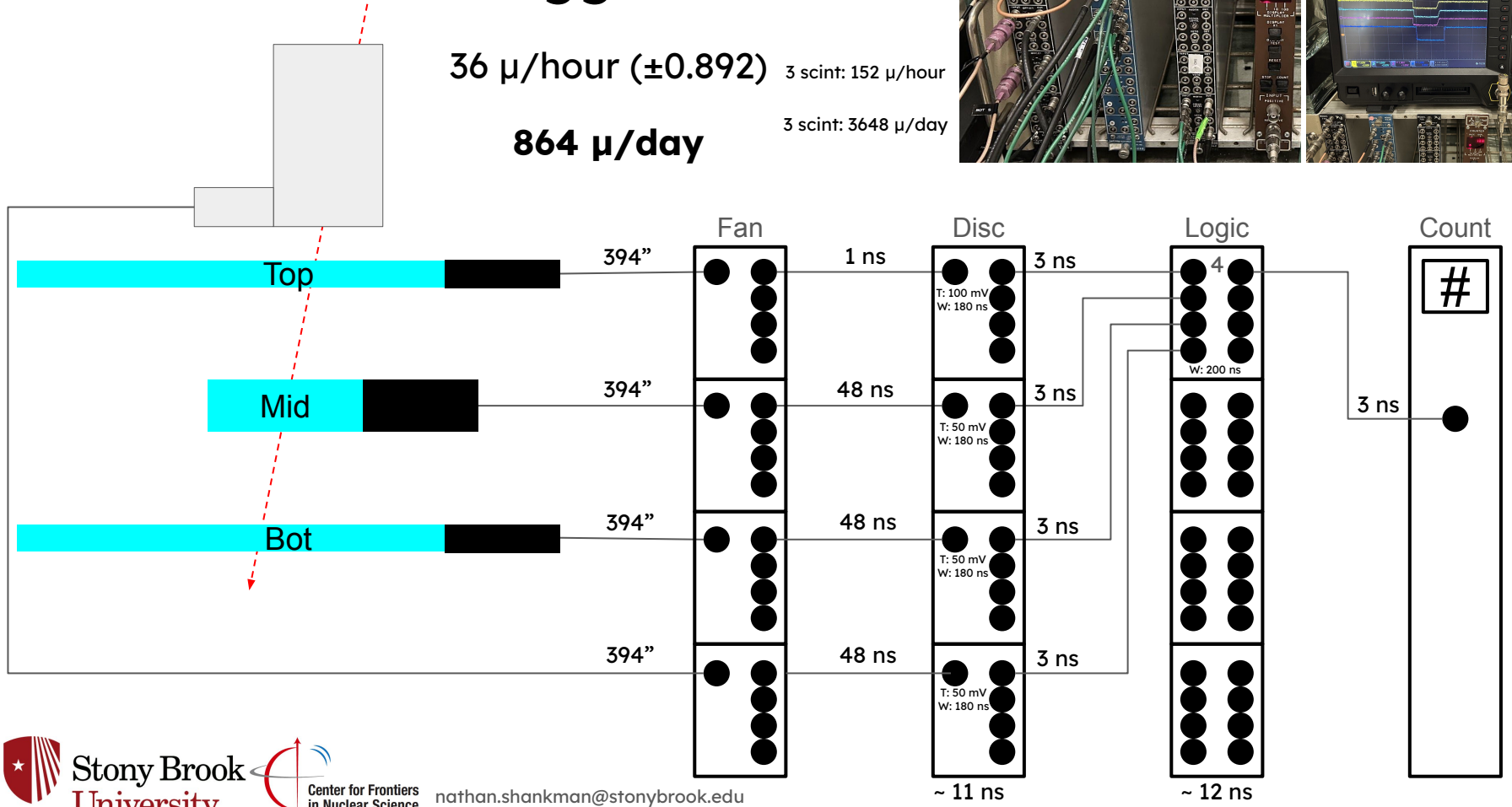
3 scint: 152 μ/hour

3 scint: 3648 μ/day

864 μ/day







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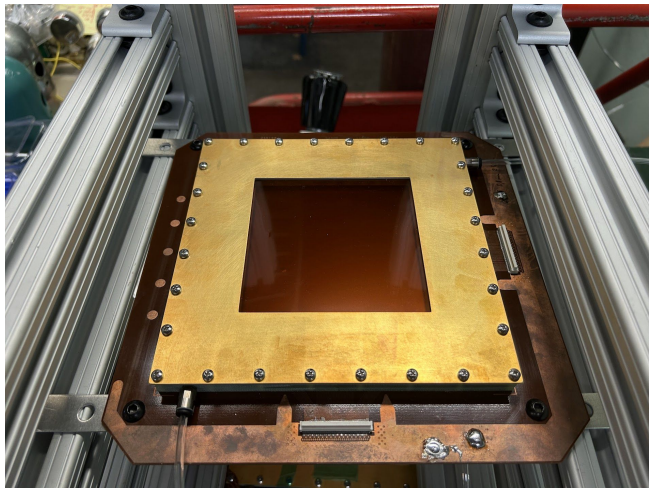
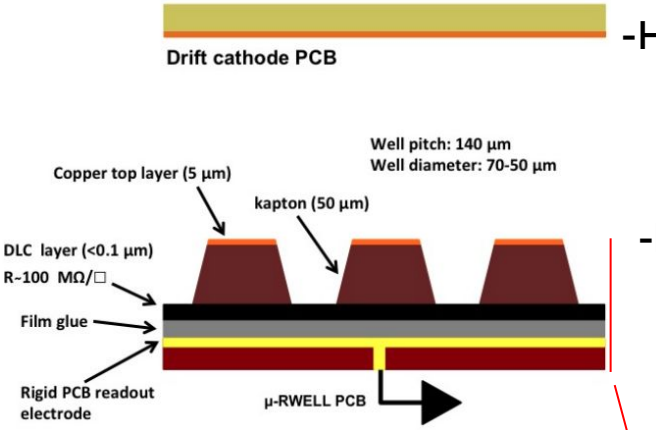
µRWells (trackers)

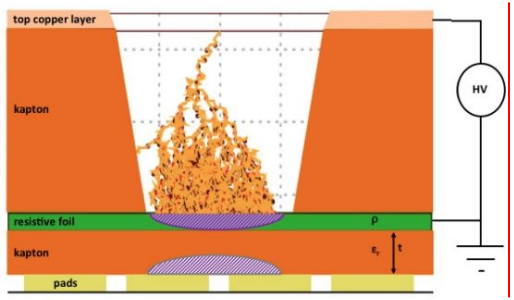
- Top - 10 x 10 cm
- Mid - 10 x 10 cm
- Bot - 10 x 20 cm
- APV25
- rcdaq
- Ar:CO_2 at 80:20 (addition of Isobutane later)



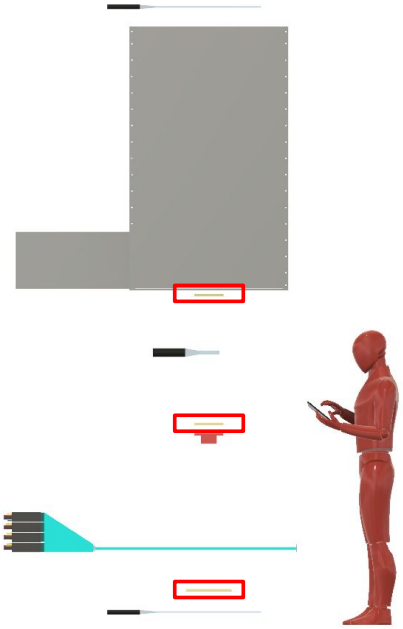
10 x 10 µRWell



µRWell schematic*



µRWell avalanche sketch*



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* Figures adapted from Poli Lener, Marco, et al. "Sissa: The micro-rwell detector." PoS (2019): 019
** Bencivenni, G., et al. "The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD." Journal of Instrumentation 10.02 (2015): P02008-P02008

Testing

- Voltage ramp ups in N_2
- Voltage ramp ups in $Ar:CO_2$ (80:20)
  - Isobutane soon
- X-ray scans
  - Top ✓
  - Mid ✓
  - Bot
- Bottom is being worked on as we speak
- Issues ramping up including the drift cathode not being wired properly
- Top and Mid being flushed with N_2

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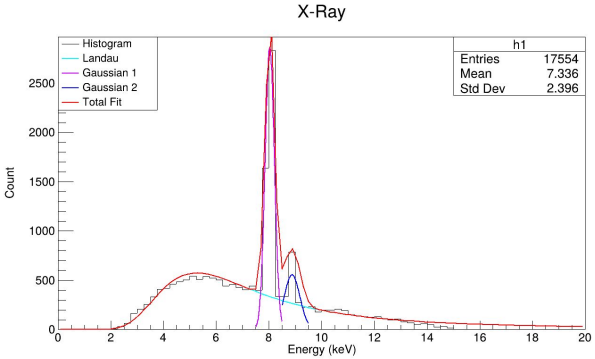
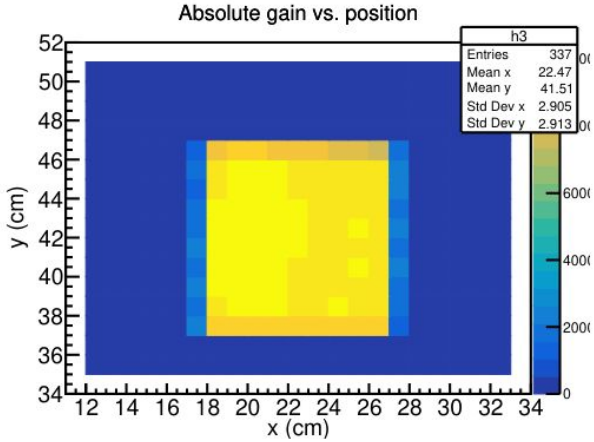
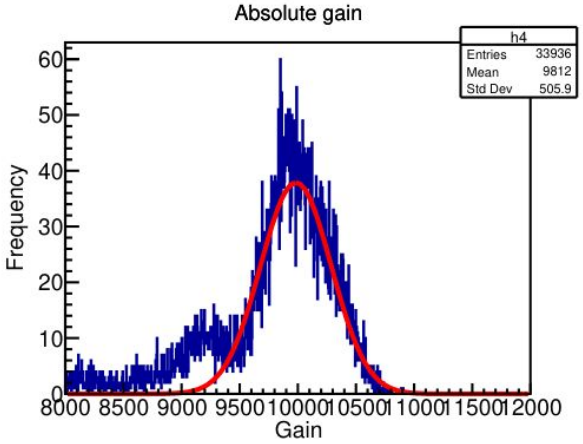
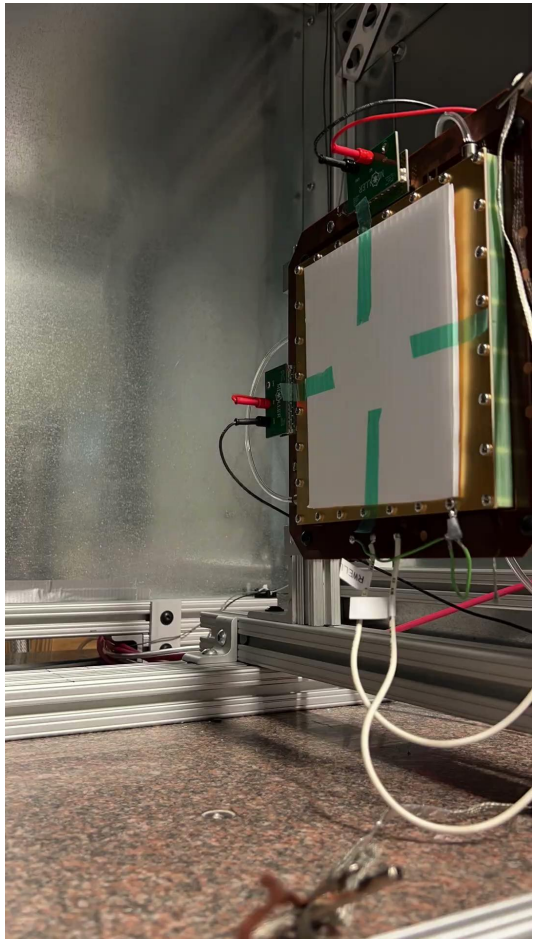
Gain Scans

- 8 keV X-Ray Gun
- X+Y signals are shorted and read out together (for now)
- Even so, signal too weak for gain (won't be a problem)
- We are using RWELL current for gain









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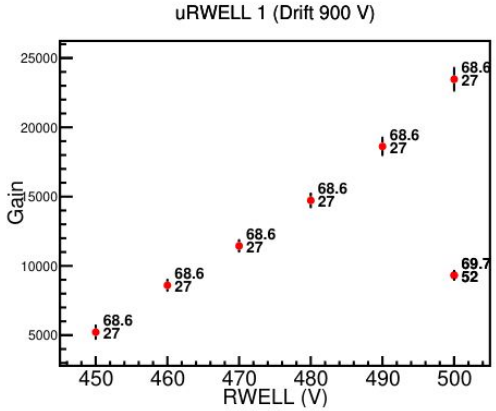
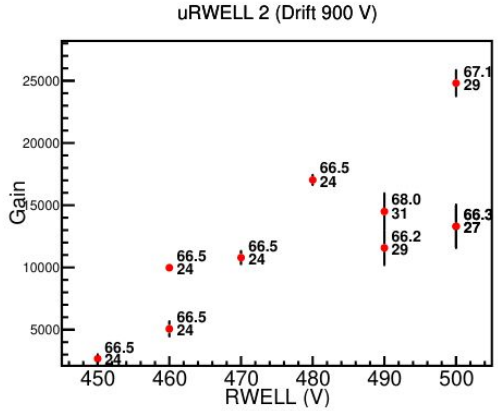
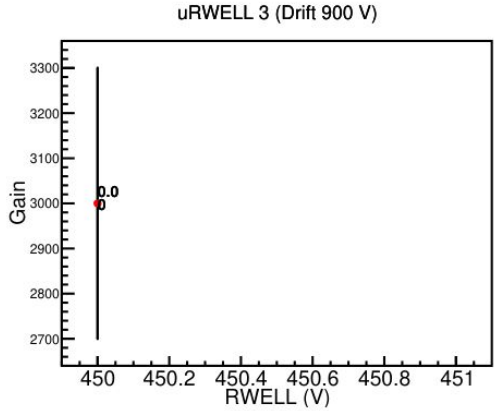
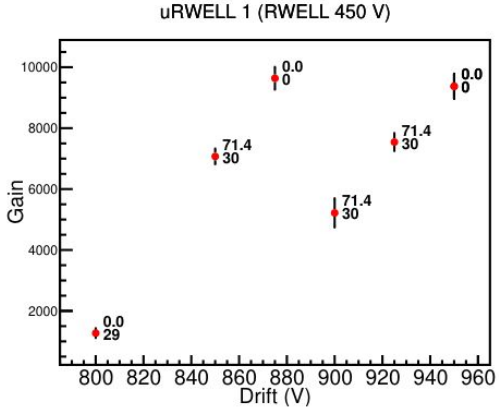
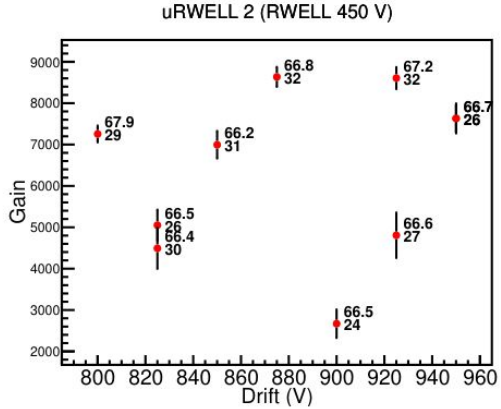
Gains

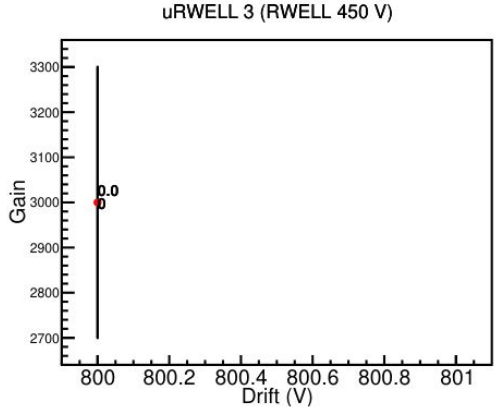












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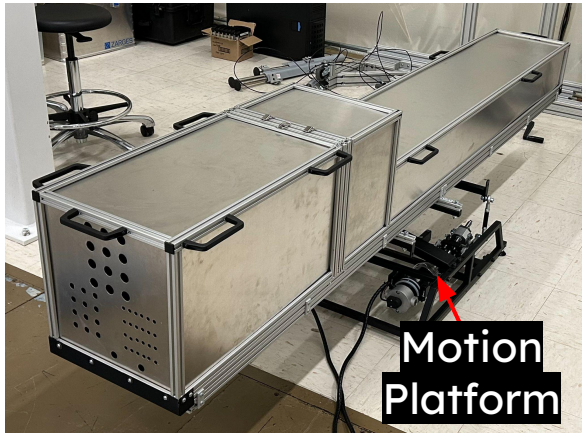
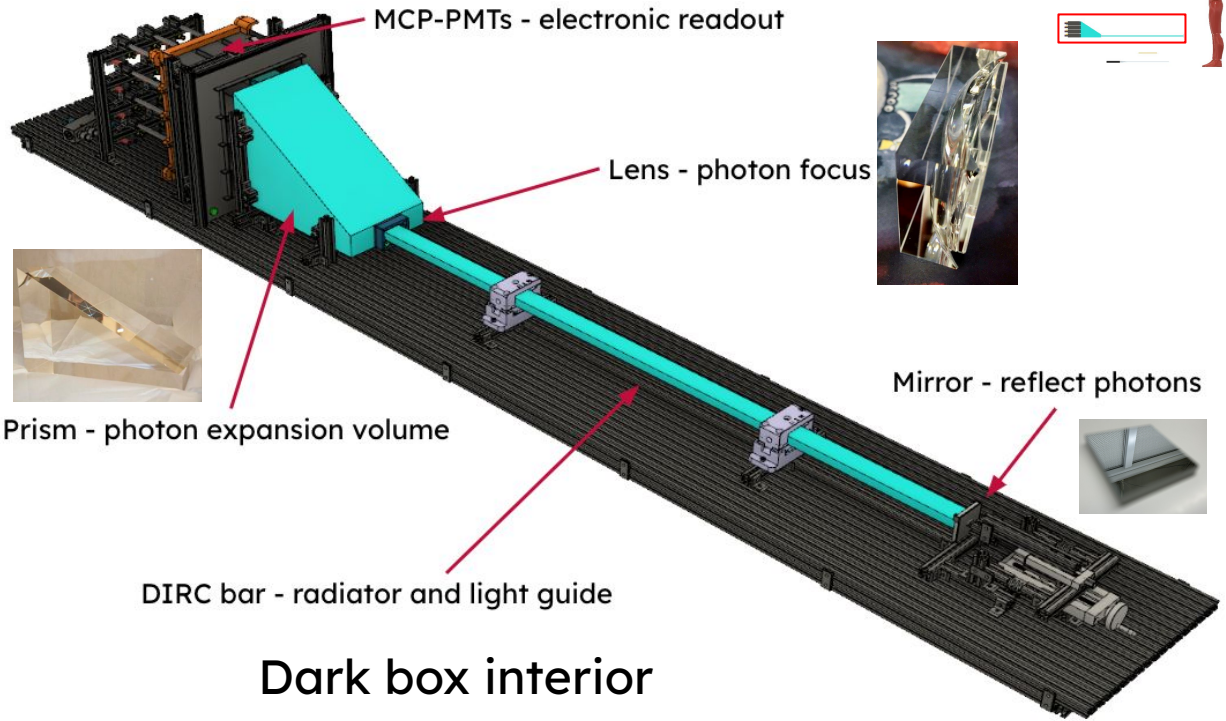
Dark Box

- Easy access to DIRC components
- Motion Platform
  - Multiple incident angles
  - ±20° Pitch and Roll (capability)





Dark box interior

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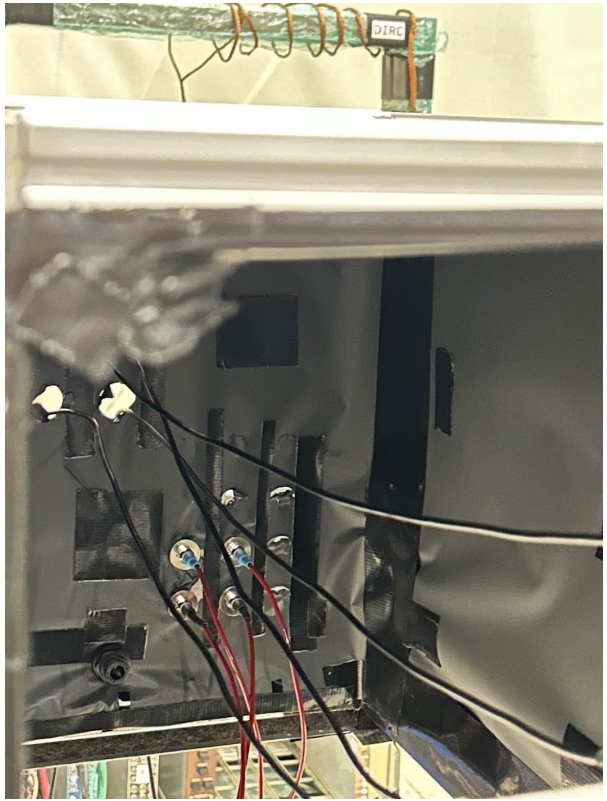
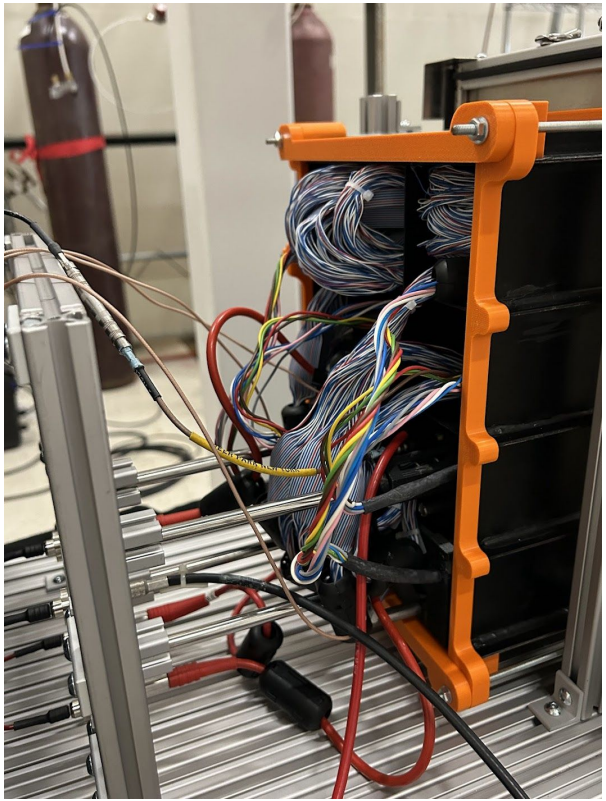
MCP-PMTs





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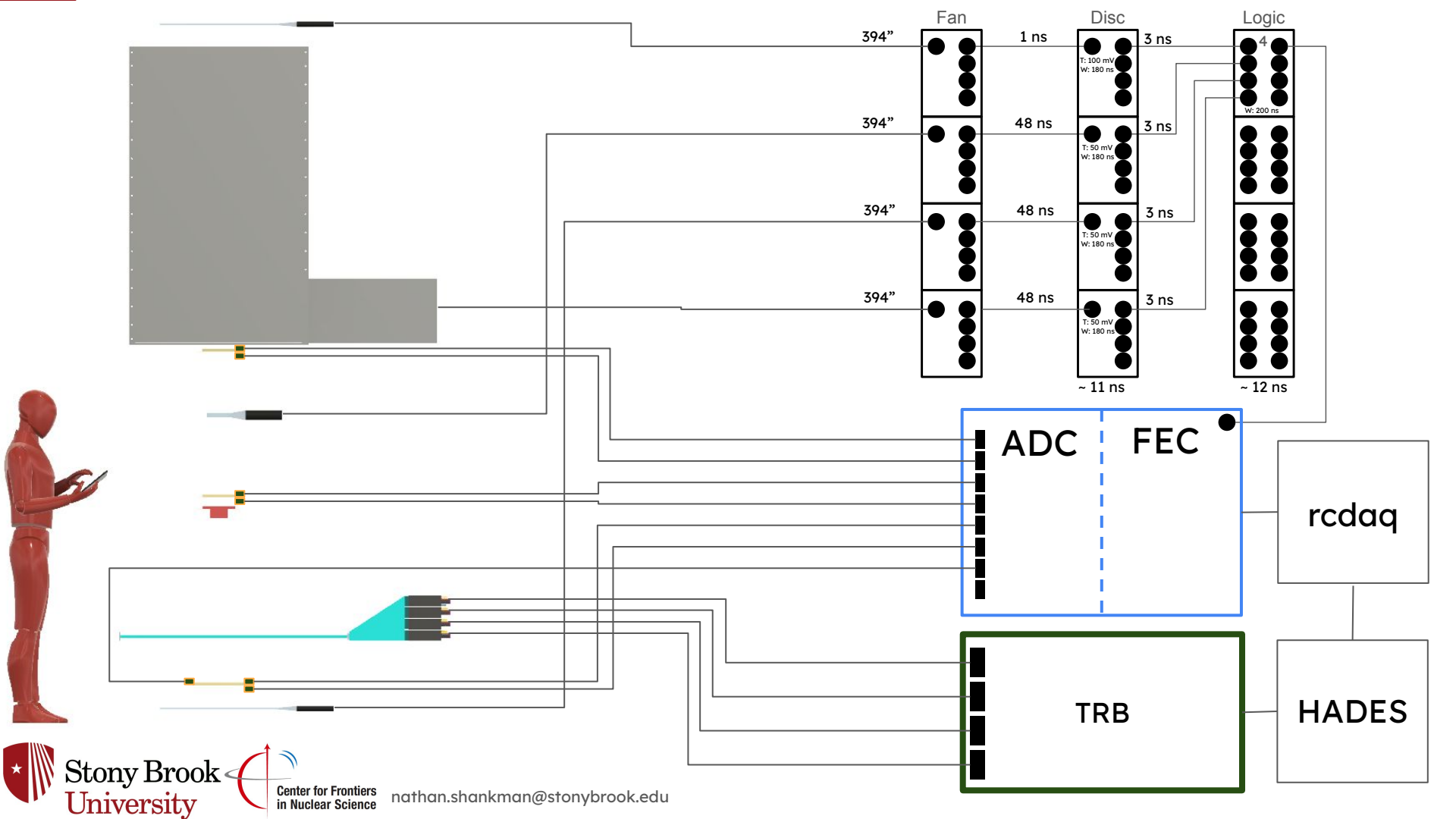

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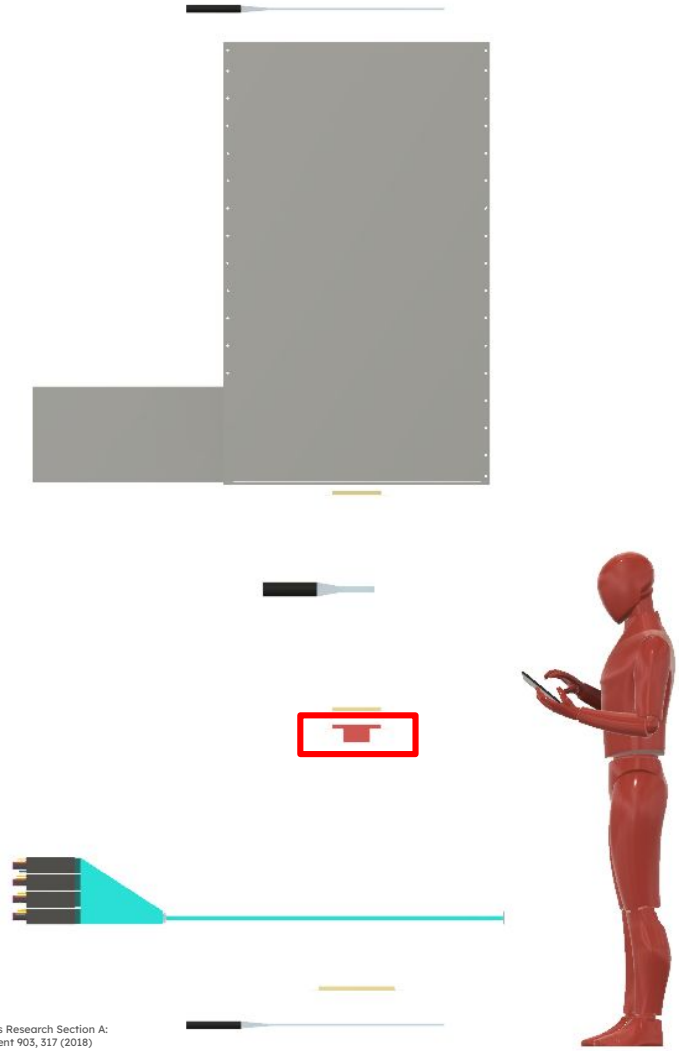
Timing Detector

Current plan: scintillator with SiPMs (ps timing resolution)



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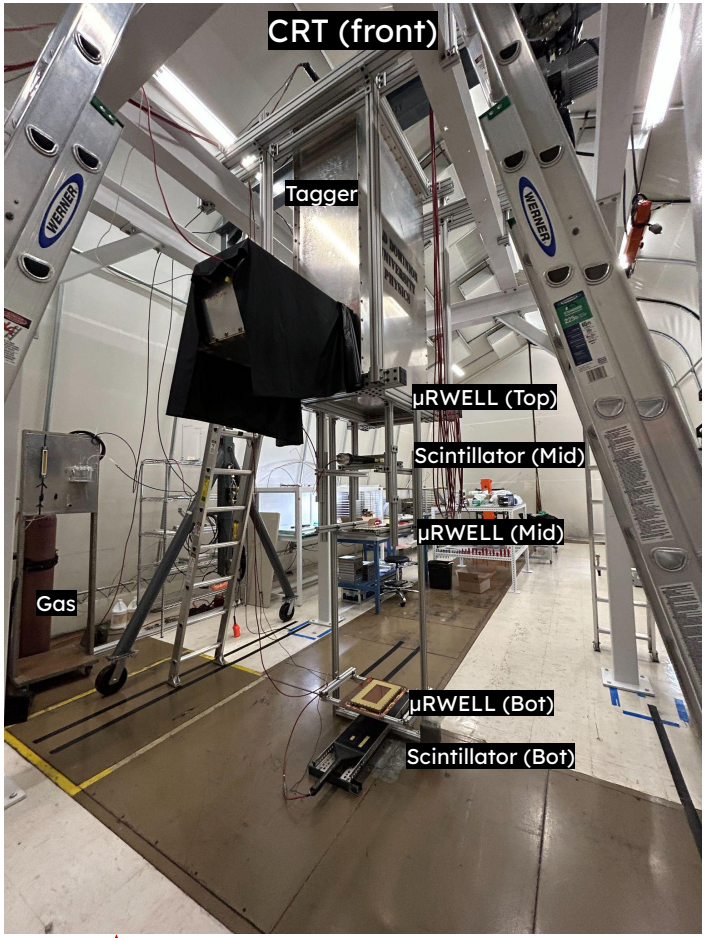
1. J. Bortfeldt et al., Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 903, 317 (2018)



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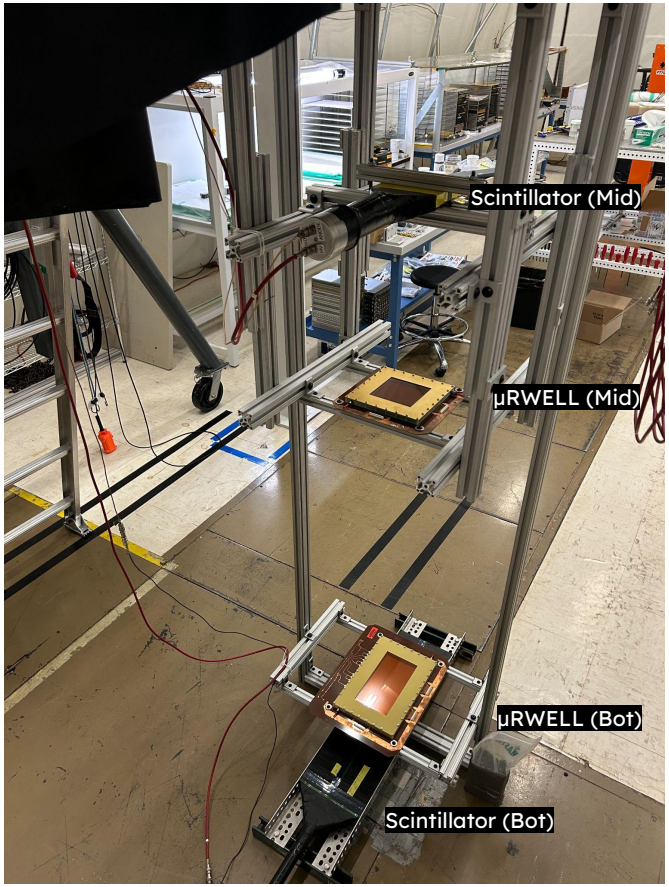

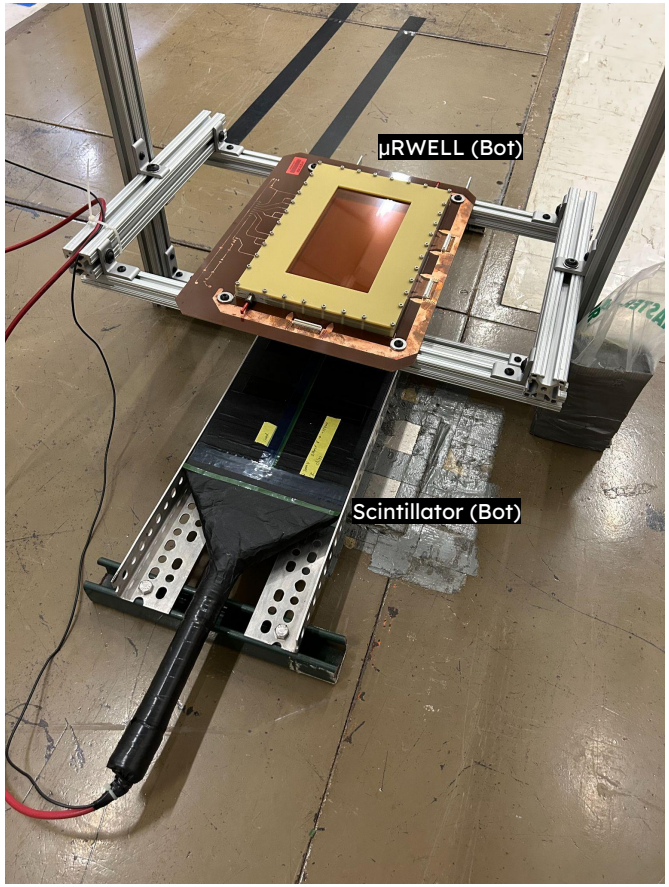

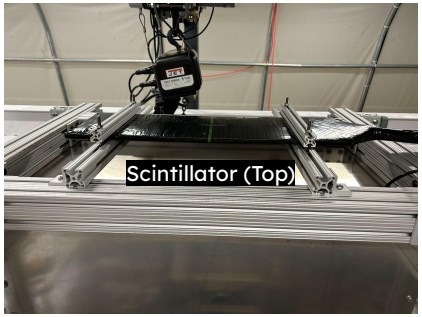

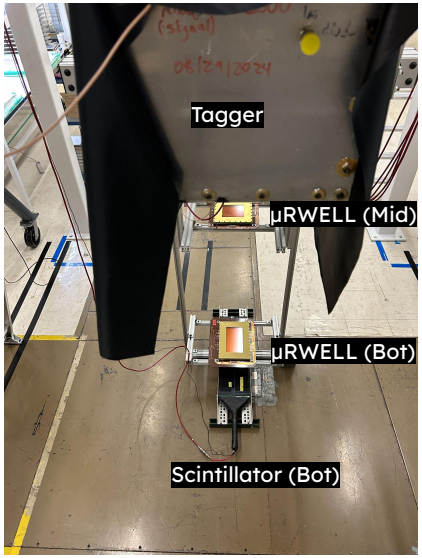

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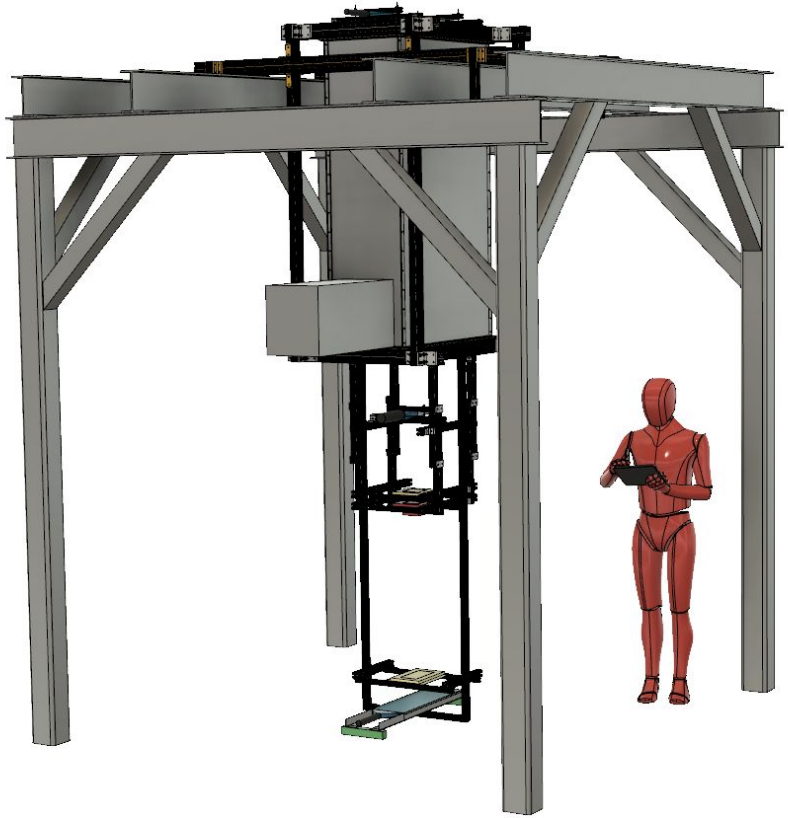

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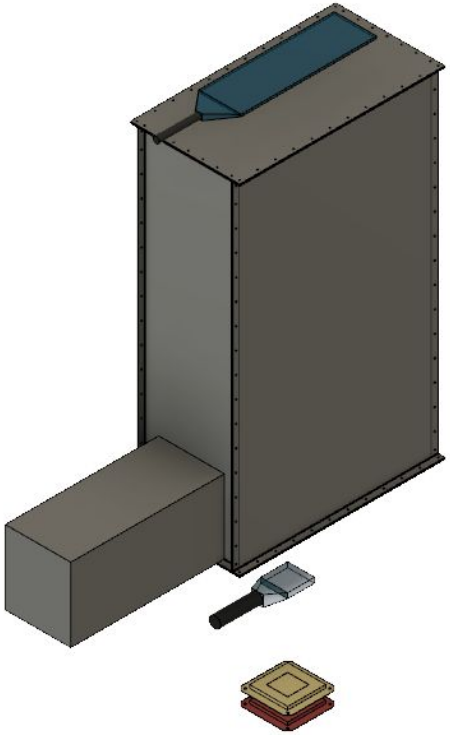
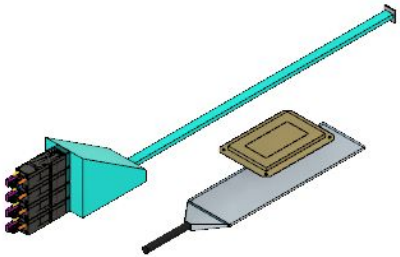
Summary

- Current work:
  - Trackers
    - rcdaq functionality
    - 20 x 10 gain scans
    - gas lines in clean tent
  - MCP-PMT laser testing (LEMO)
- Next steps:
  - scintillators+tagger+trackers coincidance
  - scintillators+tagger+trackers+MCP-PMTs(LEMO) coincidance
  - track reconstruction
  - CRT commissioning
  - HADES functionality
  - ring reconstruction
  - hpDIRC prototype commissioning
  - rcdaq+HADES coincidence
  - hpDIRC CRT commissioning





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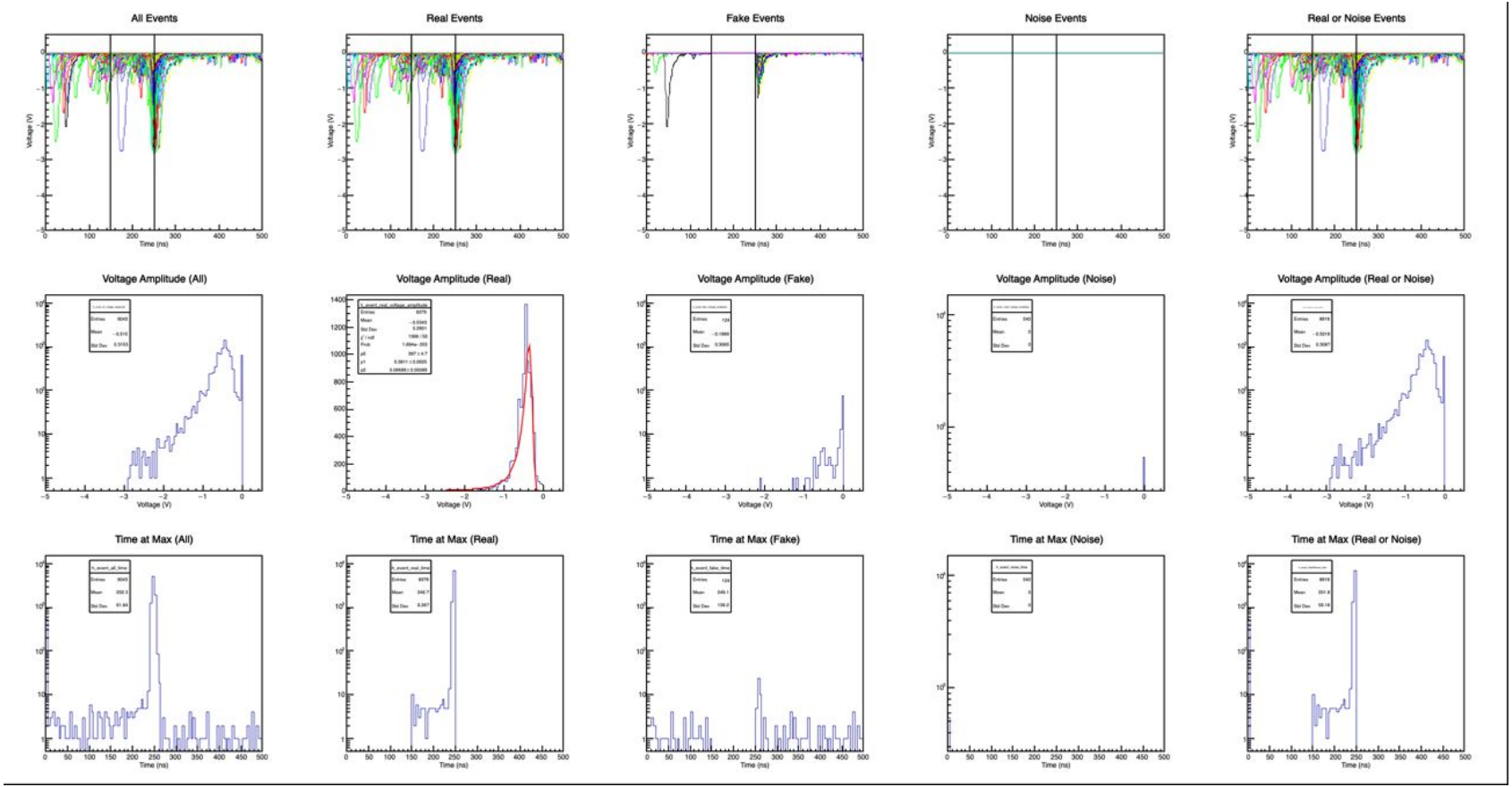
TOP



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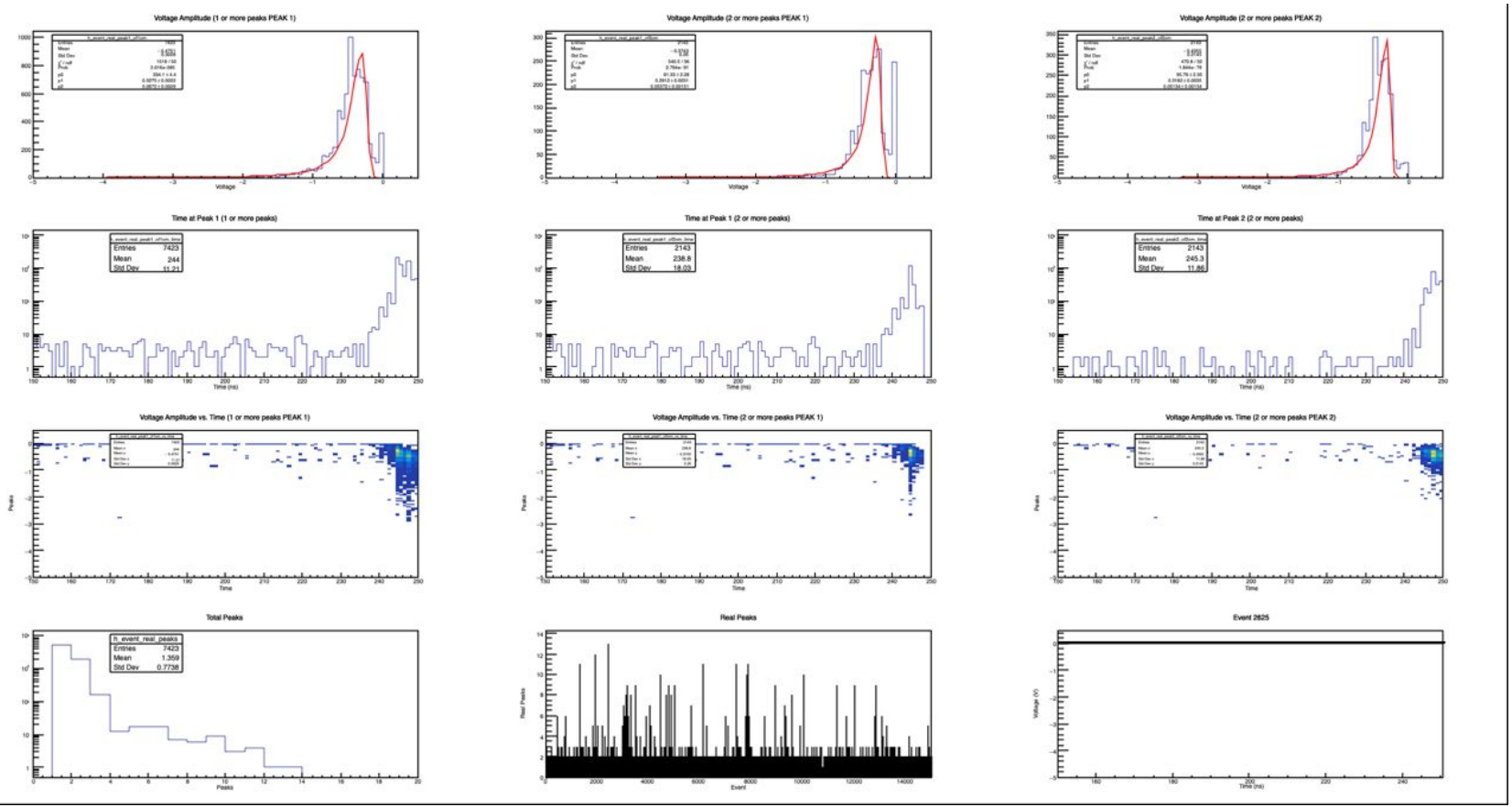
TOP



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TOP

```
Processing osc.C("Top_2000V_fan_Mid_2250V_Bot_2000V_logicMidBot_tn1000mV_vsp500mV_ts50ns_metal_15000E_01.txt")...

1st loop through file for total events, total points per event, and volt scale ...
2nd loop through file for gathering data ...
Looping over data vector ...

Execution time: 19s

Total events ............................ 15000
Total real events ....................... 8379     55.86%
Total fake events ....................... 124     0.826667%
Total noise events ...................... 540     3.6%
Total repeat events ..................... 5957     39.7133%

Total real events with 0 peaks ........... 1620
Total real events with 1 or more peaks ... 7423
Total real events with 2 or more peaks ... 2143
Mean peaks per real event ................ 1.35915

Real Amplitude Mean ..................... 0.381074 ± 0.0668911
Info in <TCanvas::Print>: file output/png/Top_2000V_fan_Mid_2250V_Bot_2000V_logicMidBot_tn1000mV_vsp500mV_ts50ns_metal_15000E_01_c1.png has been created
Peak 1 Mean (1 or more peaks)............. 0.327541 ± 0.067196
Peak 1 Mean (2 or more peaks)............. 0.291217 ± 0.0537211
Peak 2 Mean (2 or more peaks)............. 0.318212 ± 0.0513407
Info in <TCanvas::Print>: file output/png/Top_2000V_fan_Mid_2250V_Bot_2000V_logicMidBot_tn1000mV_vsp500mV_ts50ns_metal_15000E_01_c2.png has been created
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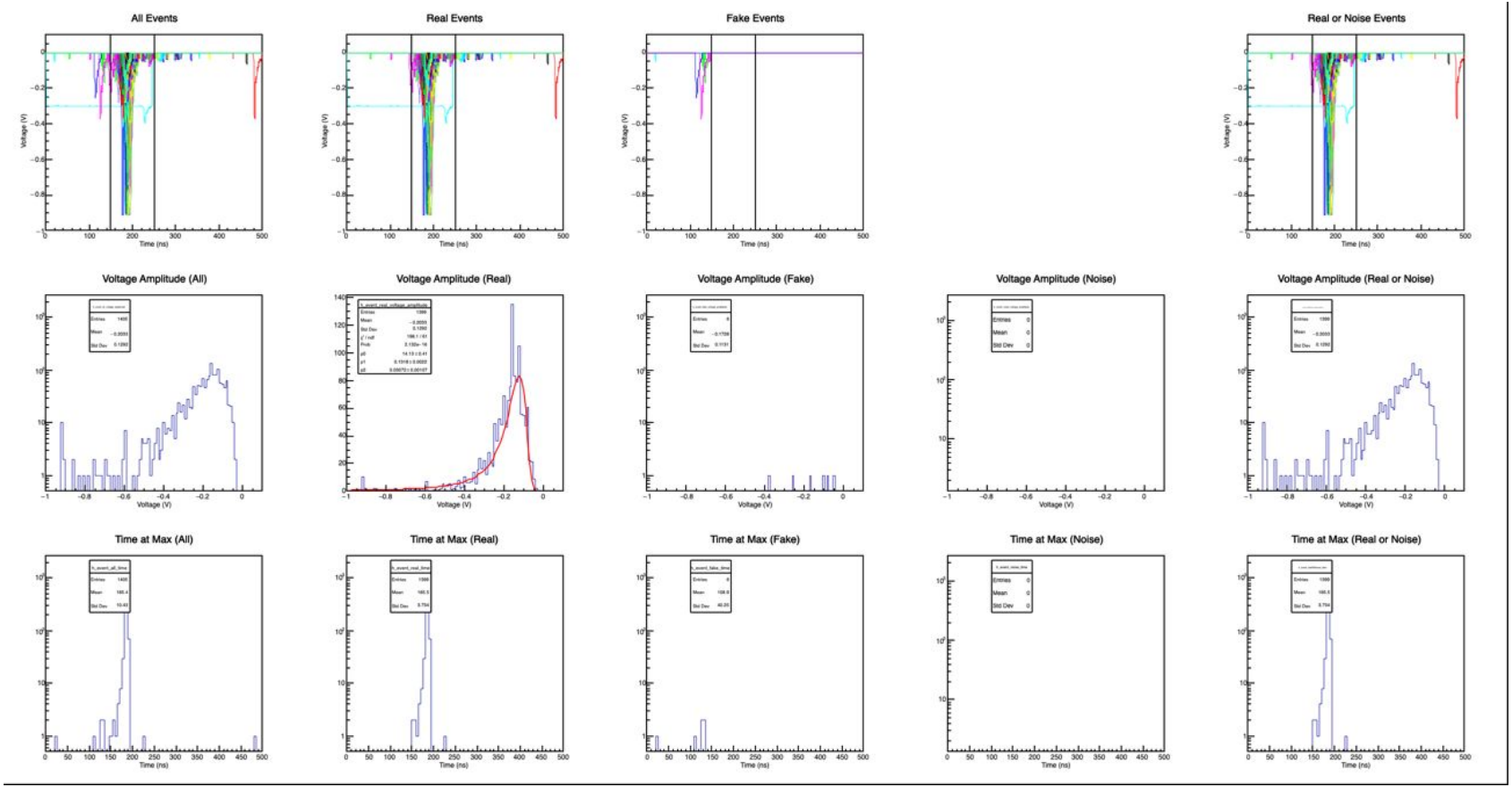

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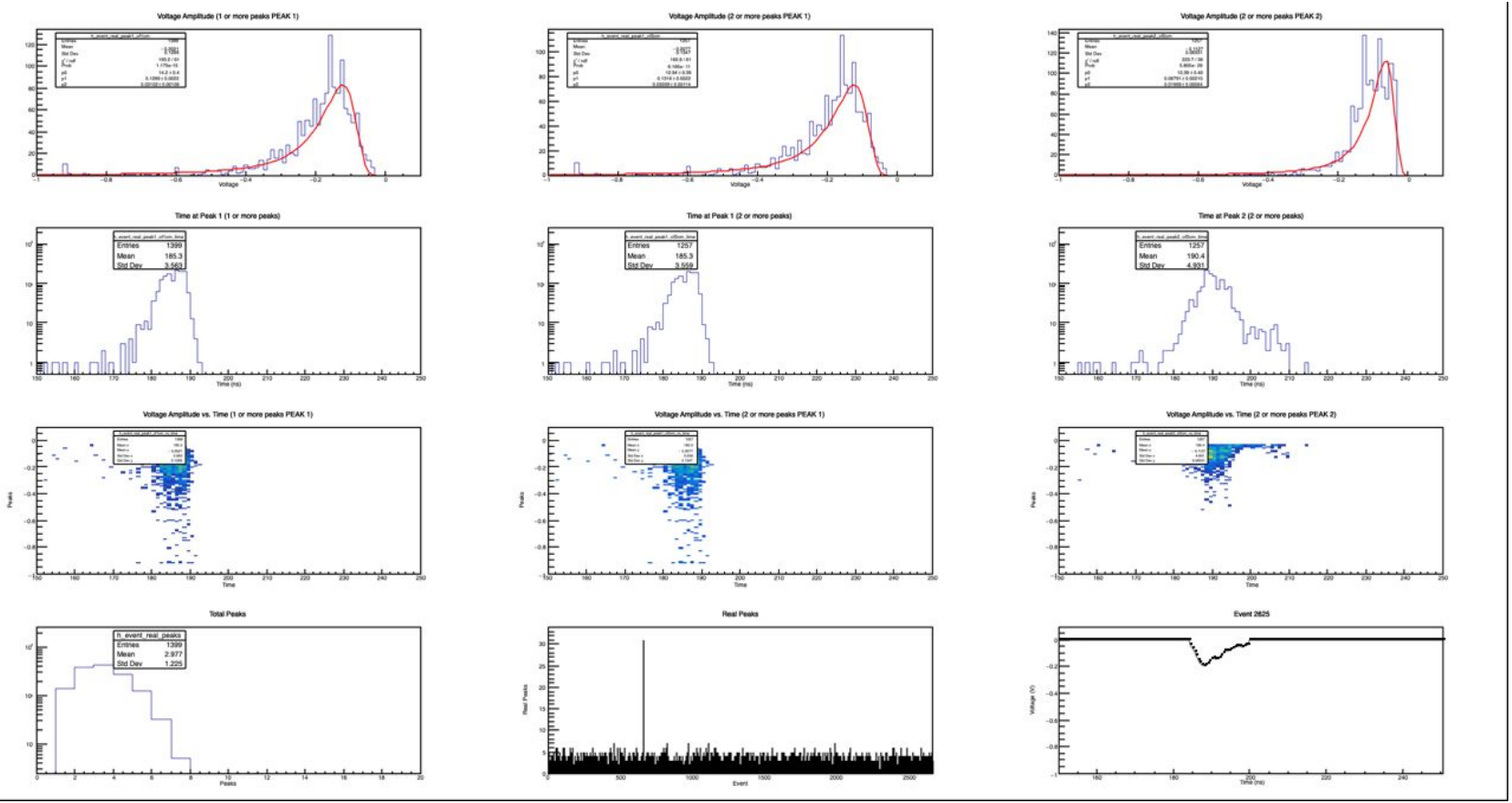

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MID

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Processing osc.C("Mid_2250V_fan_Top_2000V_Mid_2250V_Bot_2000V_logicTopMidBot_tn1000mV_vsp100mV_ts50ns_2654E.txt")...

1st loop through file for total events, total points per event, and volt scale ...
2nd loop through file for gathering data ...
Looping over data vector ...

Execution time: 3s

Total events ............................ 2654
Total real events ....................... 1399     52.7129%
Total fake events ....................... 6     0.226074%
Total noise events ...................... 0     0%
Total repeat events ..................... 1249     47.061%

Total real events with 0 peaks .......... 6
Total real events with 1 or more peaks ... 1399
Total real events with 2 or more peaks ... 1257
Mean peaks per real event ............... 2.97711

Real Amplitude Mean ..................... 0.131752 ± 0.0307151
Info in <TCanvas::Print>: file output/png/Mid_2250V_fan_Top_2000V_Mid_2250V_Bot_2000V_logicTopMidBot_tn1000mV_vsp100mV_ts50ns_2654E_c1.png has been created
Peak 1 Mean (1 or more peaks)............ 0.129895 ± 0.0310232
Peak 1 Mean (2 or more peaks)............ 0.131577 ± 0.0320896
Peak 2 Mean (2 or more peaks)............ 0.0679115 ± 0.0196885
Info in <TCanvas::Print>: file output/png/Mid_2250V_fan_Top_2000V_Mid_2250V_Bot_2000V_logicTopMidBot_tn1000mV_vsp100mV_ts50ns_2654E_c2.png has been created
```
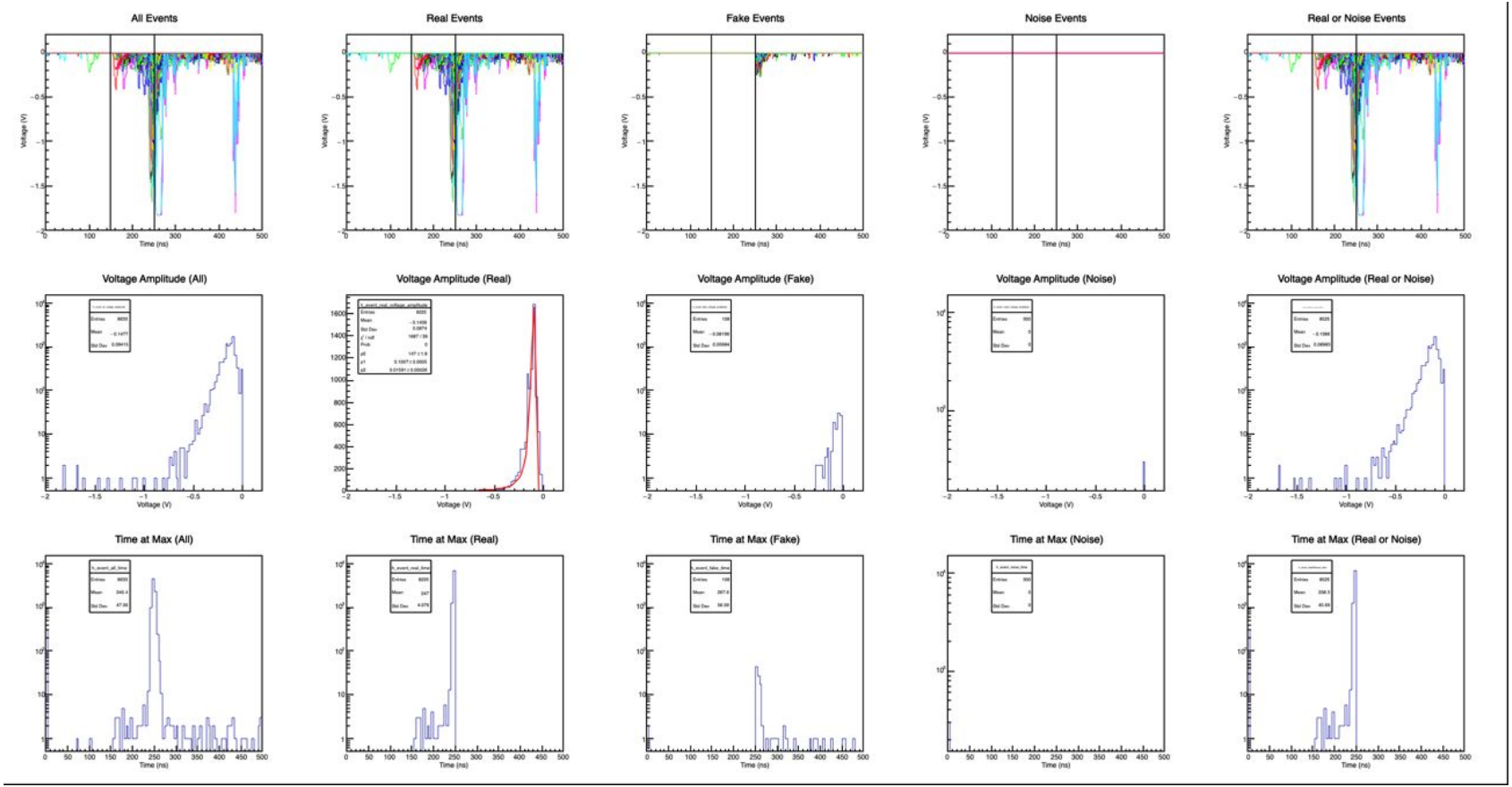

BOT



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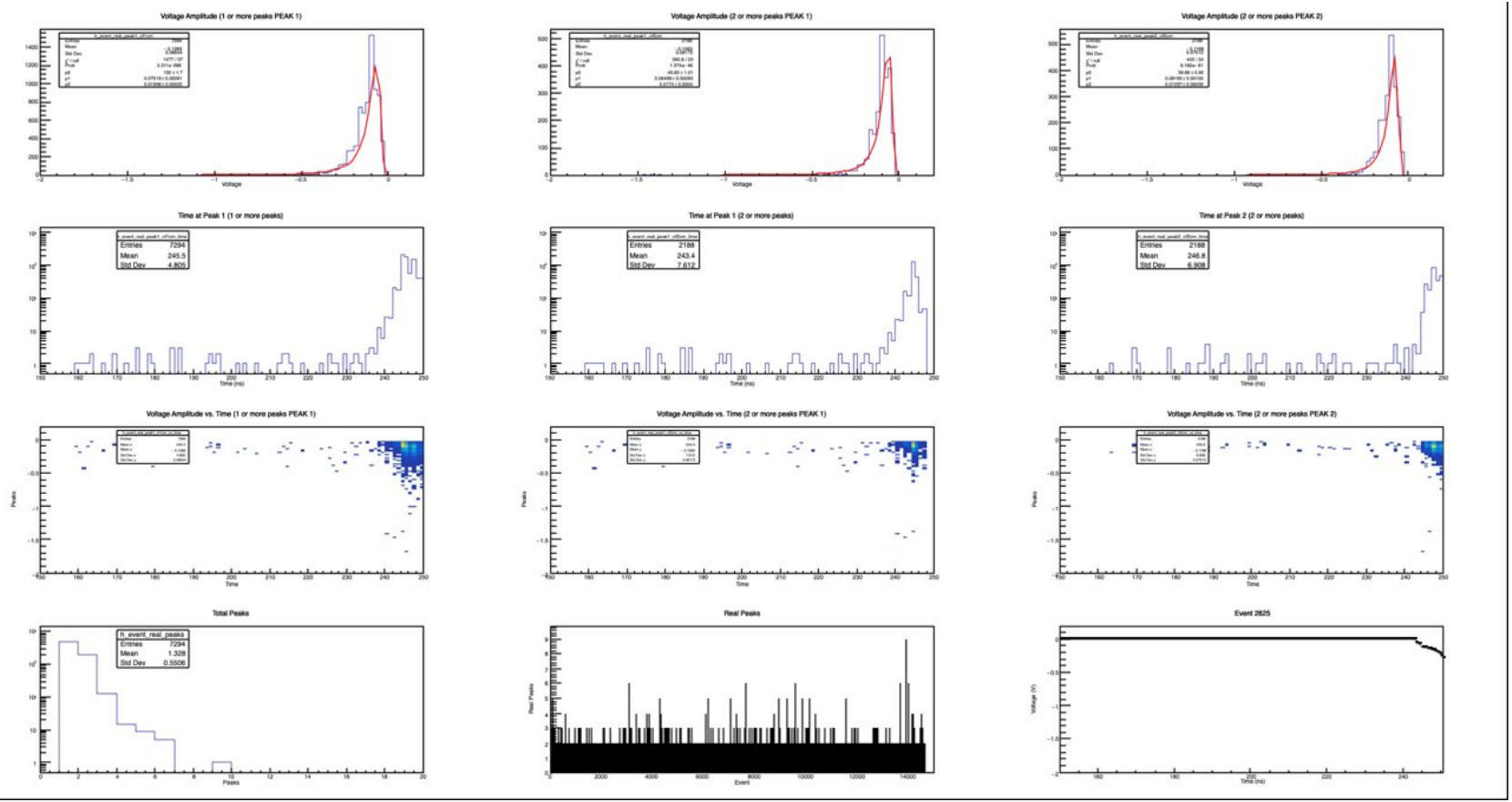
BOT



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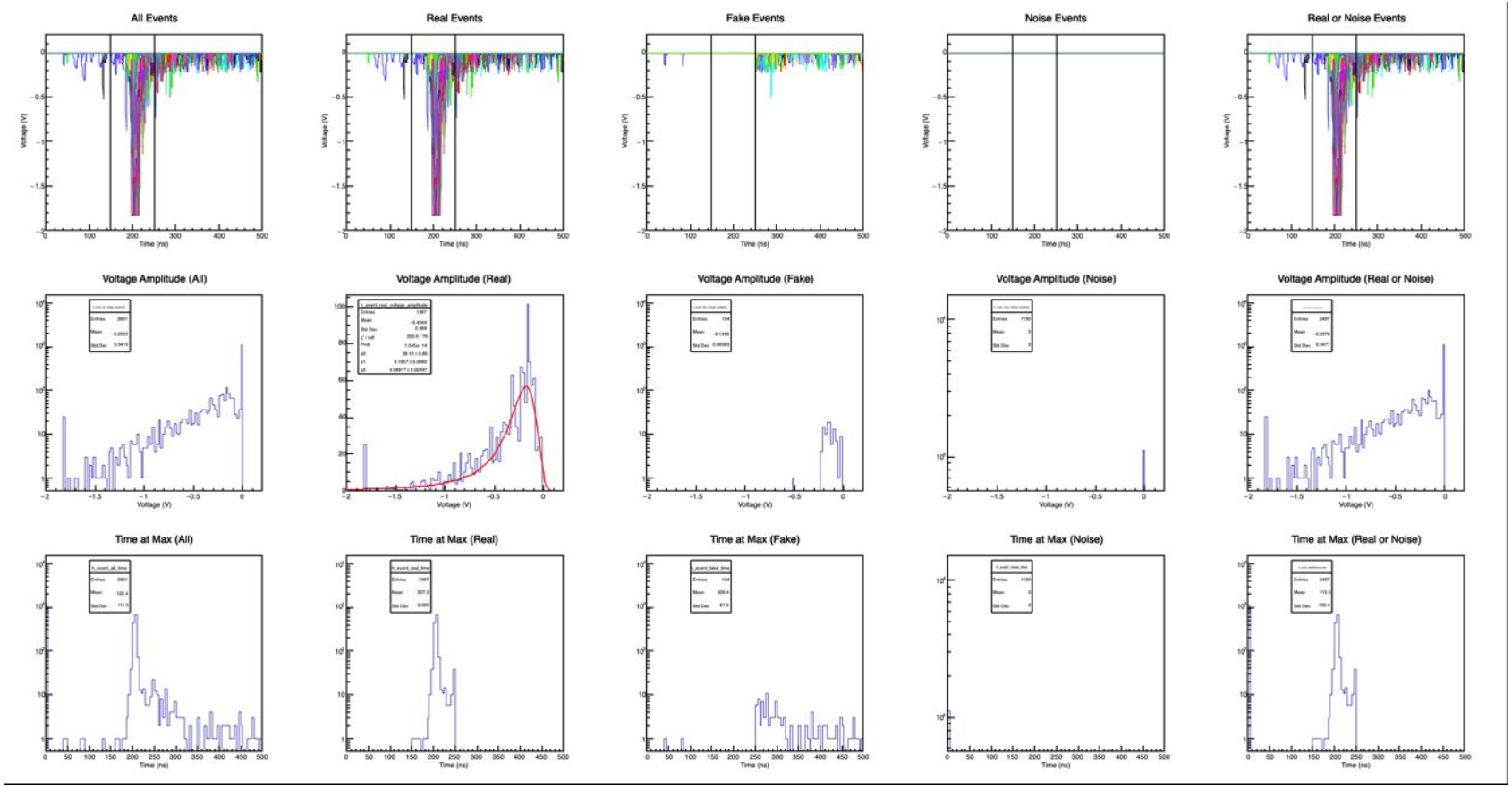
BOT

```
Processing osc.C("Bot_2000V_fan_Top_2000V_Mid_2250V_logicTopMid_tn1000mV_vsp200mV_ts50ns_metal_15000E_02.txt")...

1st loop through file for total events, total points per event, and volt scale ...
2nd loop through file for gathering data ...
Looping over data vector ...

Execution time: 19s

Total events ............................ 15000
Total real events ....................... 8225     54.8333%
Total fake events ....................... 108     0.72%
Total noise events ...................... 300     2%
Total repeat events ..................... 6367     42.4467%

Total real events with 0 peaks .......... 1339
Total real events with 1 or more peaks ... 7294
Total real events with 2 or more peaks ... 2188
Mean peaks per real event ............... 1.32849

Real Amplitude Mean ..................... 0.100709 ± 0.0159125
Info in <TCanvas::Print>: file output/png/Bot_2000V_fan_Top_2000V_Mid_2250V_logicTopMid_tn1000mV_vsp200mV_ts50ns_metal_15000E_02_c1.png has been created
Peak 1 Mean (1 or more peaks)............. 0.075193 ± 0.0199838
Peak 1 Mean (2 or more peaks)............. 0.0649924 ± 0.0174047
Peak 2 Mean (2 or more peaks)............. 0.081954 ± 0.0159689
Info in <TCanvas::Print>: file output/png/Bot_2000V_fan_Top_2000V_Mid_2250V_logicTopMid_tn1000mV_vsp200mV_ts50ns_metal_15000E_02_c2.png has been created
```

TAG



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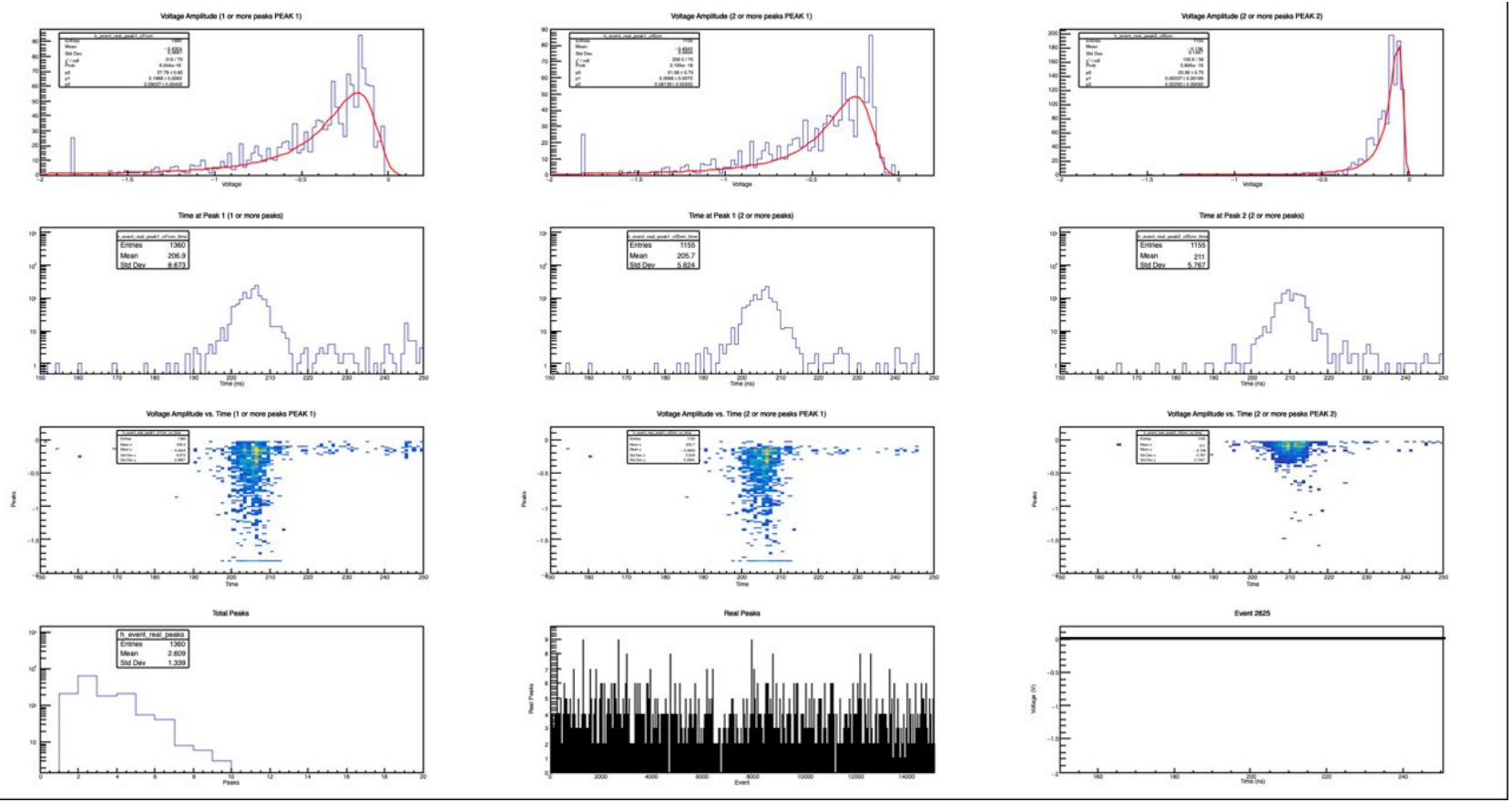
TAG



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TAG

```
Processing osc.C("Tag_2300V_fan_Top_2000V_Bot_2000V_logicTopBot_tn1000mV_vsp200mV_ts50ns_metal_15046E.txt")...

1st loop through file for total events, total points per event, and volt scale ...
2nd loop through file for gathering data ...
Looping over data vector ...

Execution time: 19s

Total events ............................ 15046
Total real events ....................... 1367     9.08547%
Total fake events ....................... 104     0.691214%
Total noise events ...................... 1130     7.5103%
Total repeat events ..................... 12445     82.713%

Total real events with 0 peaks ........... 1241
Total real events with 1 or more peaks ... 1360
Total real events with 2 or more peaks ... 1155
Mean peaks per real event ................ 2.60882

Real Amplitude Mean ..................... 0.195705 ± 0.0891694
Info in <TCanvas::Print>: file output/png/Tag_2300V_fan_Top_2000V_Bot_2000V_logicTopBot_tn1000mV_vsp200mV_ts50ns_metal_15046E_c1.png has been created
Peak 1 Mean (1 or more peaks)............. 0.198849 ± 0.0903701
Peak 1 Mean (2 or more peaks)............. 0.268628 ± 0.0813931
Peak 2 Mean (2 or more peaks)............. 0.0633683 ± 0.0229211
Info in <TCanvas::Print>: file output/png/Tag_2300V_fan_Top_2000V_Bot_2000V_logicTopBot_tn1000mV_vsp200mV_ts50ns_metal_15046E_c2.png has been created
```