Photon-Neutron Separation in HCAL for the Highest Q^2 point of $\mathrm{G_E^n}$-II Experiment
and
Implementation of a 2nd BigBite Analog Trigger for the WAPP Experiment

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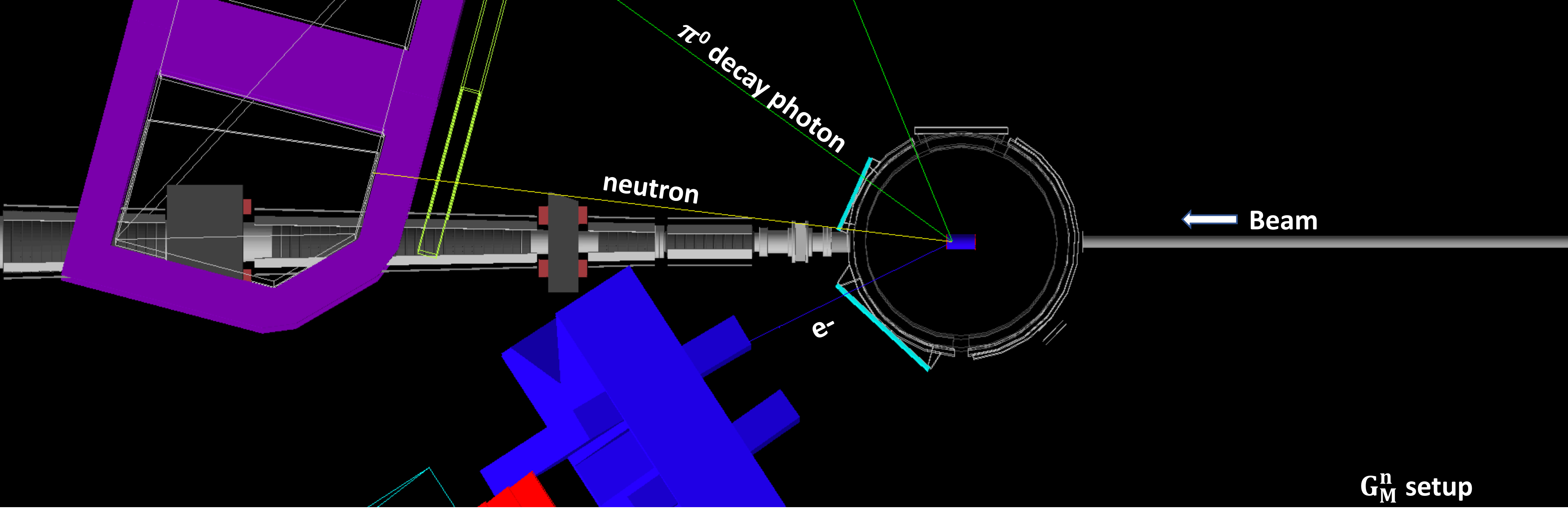
Outline

- Part I : Photon-Neutron Separation in HCAL for G_E^n-II
  - G_E^n-II ERR Recommendation
  - Modifying the Inelastic Generator
  - Time of Flight (TOF) Measurement
  - Full Optical Photon Simulation
  - Primary Conclusion and Future Work
- Part II : Implementation of 2^{nd} Trigger for the WAPP experiment
  - Checking Front End NIM Modules and Cables for BB Analog Trigger
  - The Implementation of second Trigger for WAPP
- Future Plans and Acknowledgements

Part I : Photon-Neutron Separation in HCAL for the Highest Q^2 point of G_E^n-II Experiment

G_E^n-II ERR Recommendation

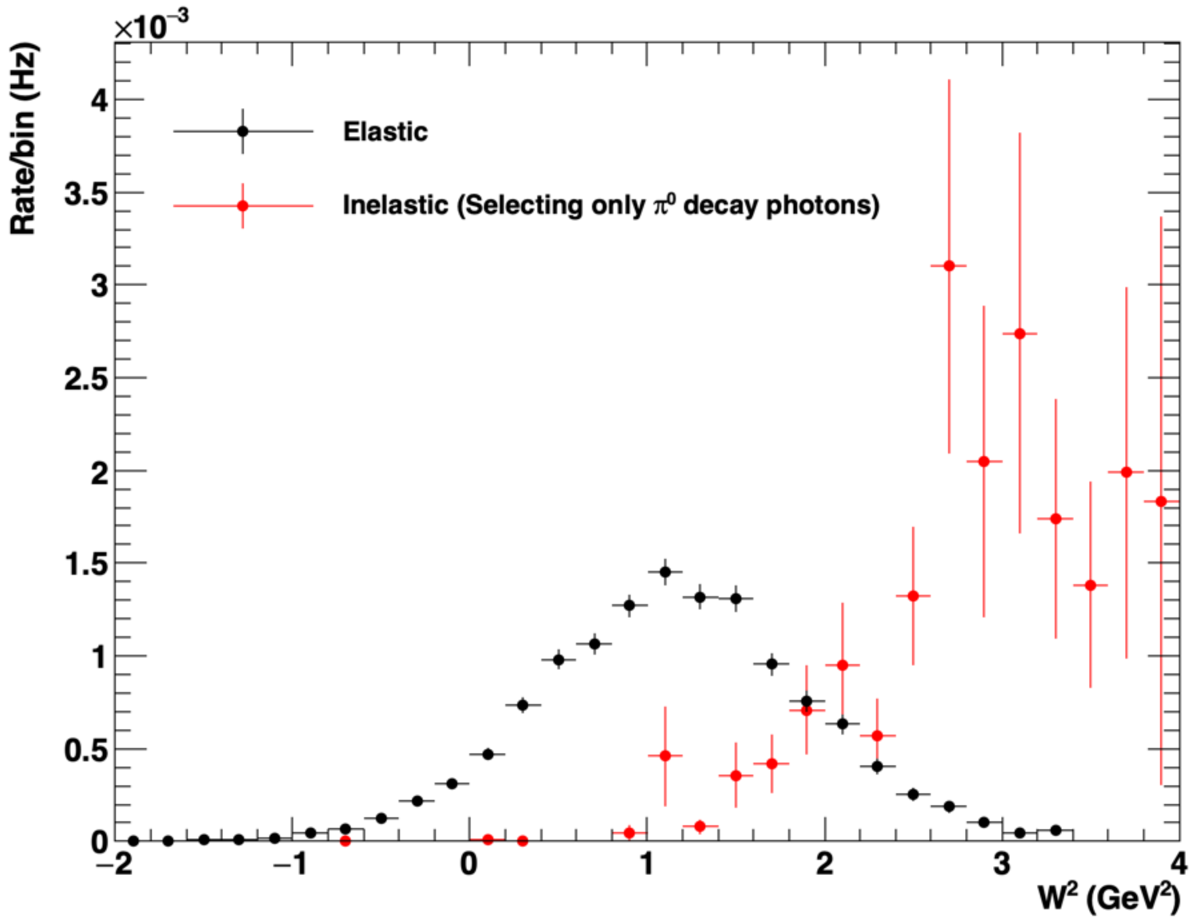
- The recommendation: “Demonstrate sufficient neutron-photon separation in HCAL, especially important for the highest Q^2 point where neutrons $\beta \approx 1$”.
- At $Q^2 = 10.2\ GeV^2$, we get $p_n \approx 6.3 \frac{GeV}{c} \Rightarrow \beta \approx 0.99$.
- The difference in TOF between such high energy neutrons and π^0 decay photons is going to be $\sim 0.6\ ns$, which is comparable to the expected time resolution of HCAL.
- The goal of our study is two-fold:
  - Estimation of the photon contamination in the quasi-elastic sample.
  - Examine methods for the separation of photons and neutrons ($\beta \approx 0.99$) in HCAL.



Modifying the Inelastic Generator in g4sbs

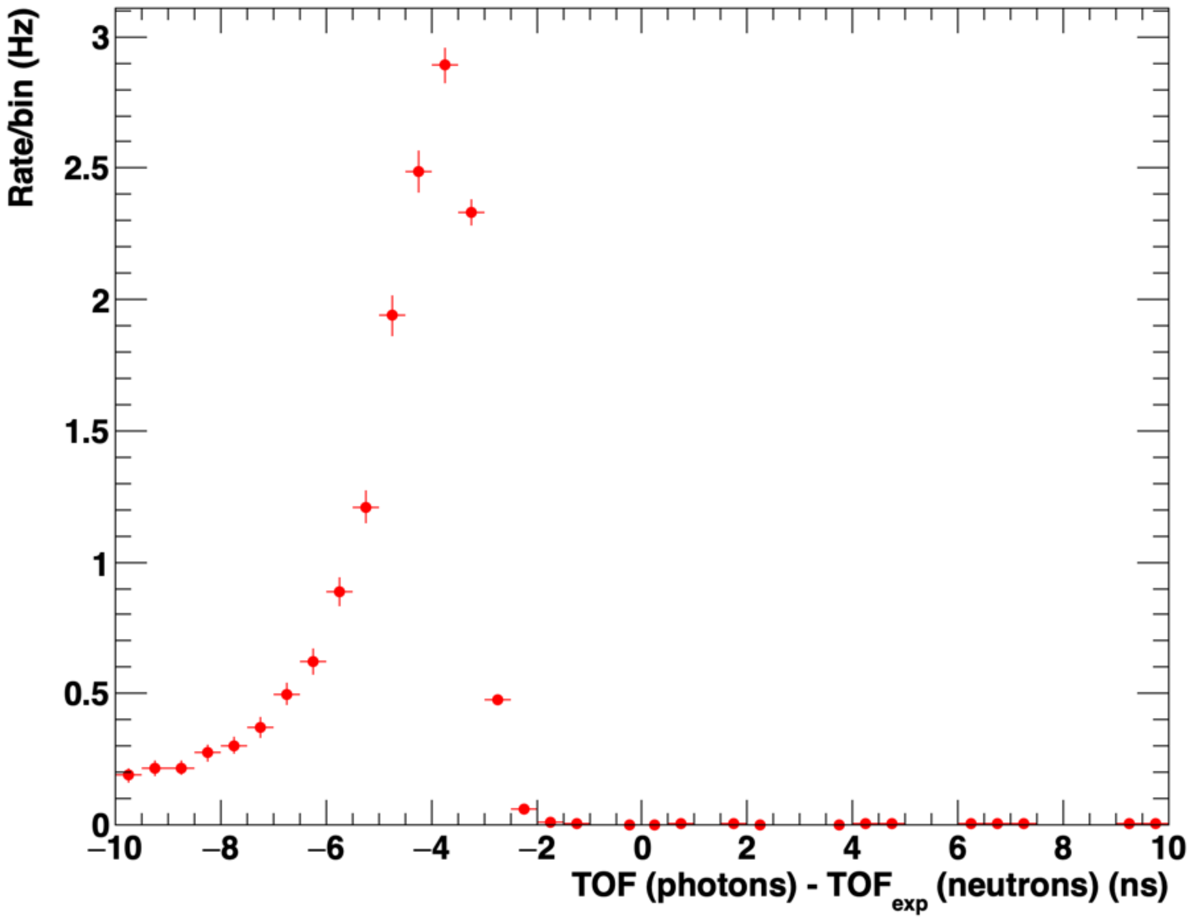
- Modified generator produces final state nucleons as well as pions.
- The picture shows an event, $\gamma^* + n \rightarrow \pi^0 + n$, in the G_M^n experimental setup.
- G_M^n setup provides a clearer view of the target chamber.

W^2 Distribution



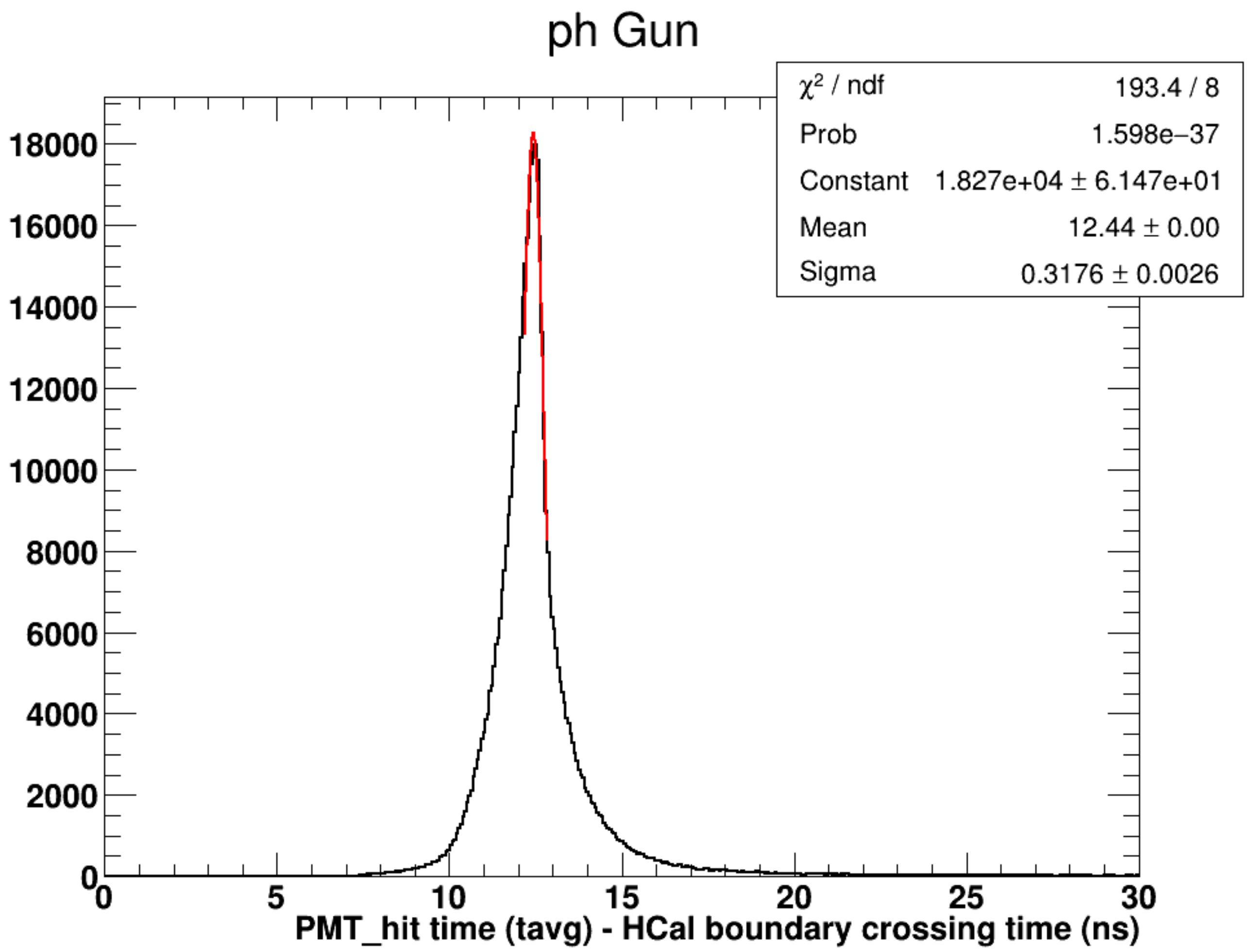
- W^2 distribution for quasi-elastic and inelastic events.
- Cross-section model based on Christy-Bosted parametrization of the inclusive structure functions combined with an assumption of πN final state has been used.
- Threshold of 8.8 MeV/module of HCAL has been assumed.
- Cuts on missing perp. momentum and missing par. momentum have been imposed.
- Preliminary Estimation: For $W^2 < 2\ GeV^2$, we get fractional inelastic contamination (due to π^0 decay photons) of $\sim 26\%$ (before applying any timing related cut).

Time of Flight (ToF) Measurement



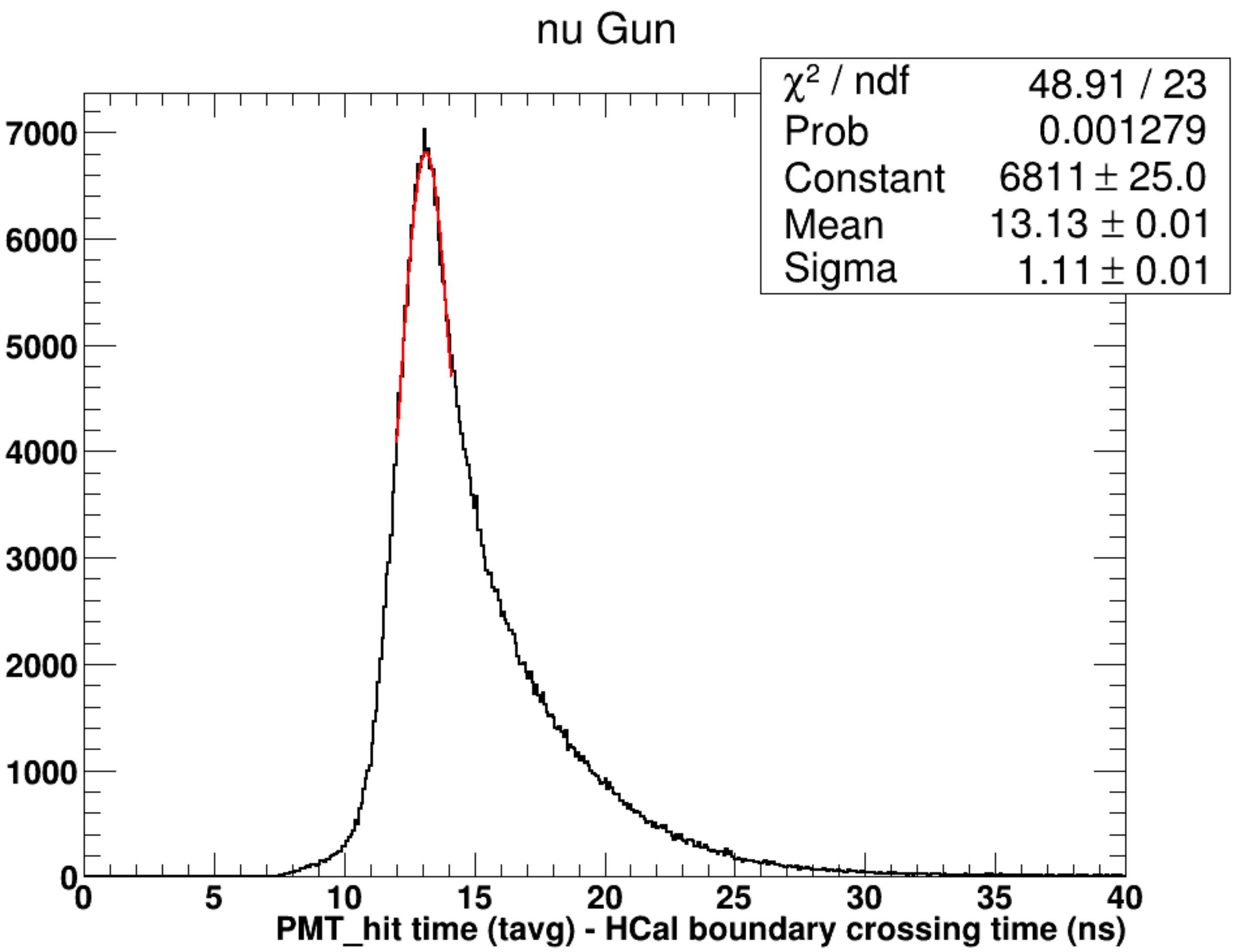
- We selected hits caused by π^0 decay photons.
- This allowed us to plot the difference between measured photon TOF and the expected neutron TOF based on the timing of energy deposition in scintillator.
- As you can see in the picture, that calculation gave us an astonishing answer. The difference turned out to be ~ 4 ns!
- The origin of such a big difference was unclear. Our initial guess was that the difference may have something to do with the shower development mechanism. So, we quickly concluded that we must run full optical photon simulations of HCAL for both photons and neutrons to understand it better.

Primary Findings from the Optical Photon simulation



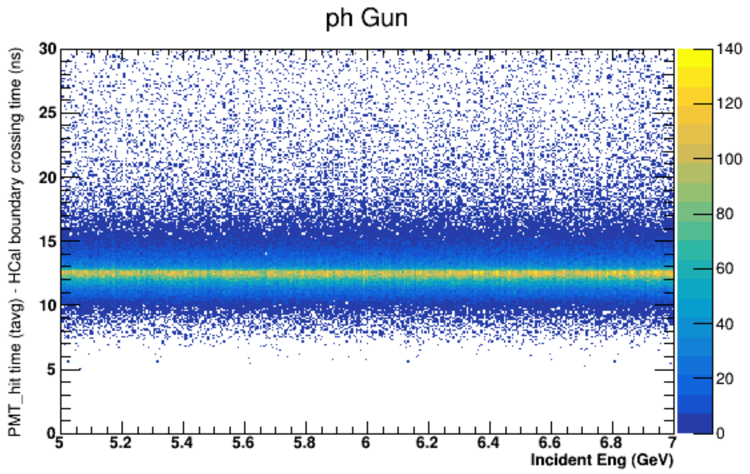
- We have looked at the delay between the average global detection time (since, $t = 0$) of all optical photons detected by PMTs and the HCAL boundary crossing time of the particle responsible for the hit.
- As you can see, for photons the distribution peaks at $\sim 12.5\ ns$.

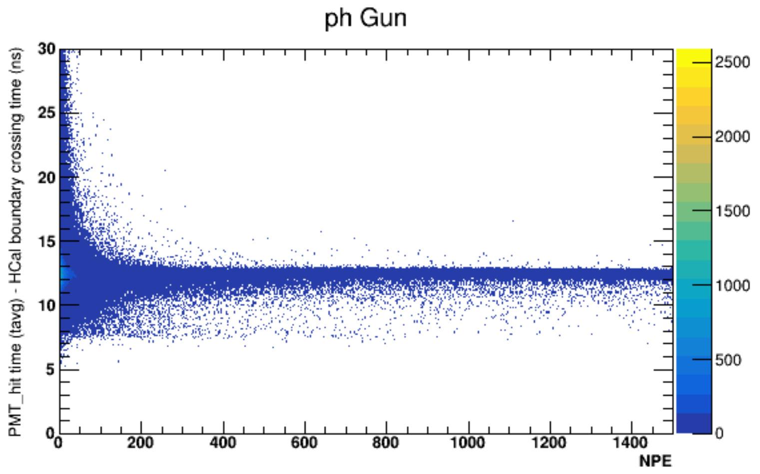
Primary Findings from the Optical Photon sim. cntd.

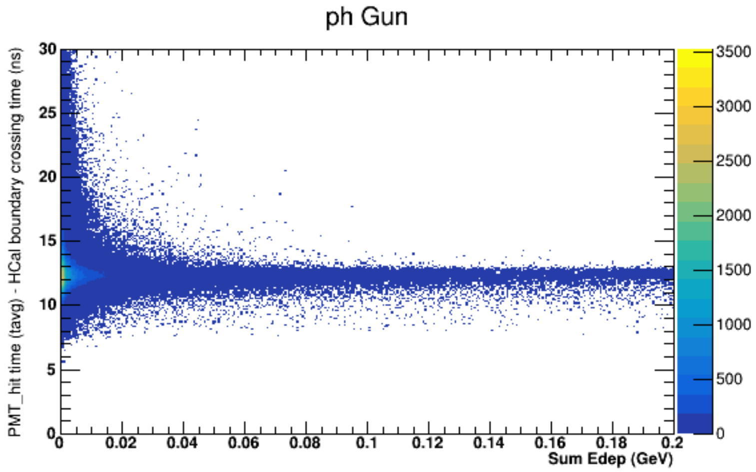


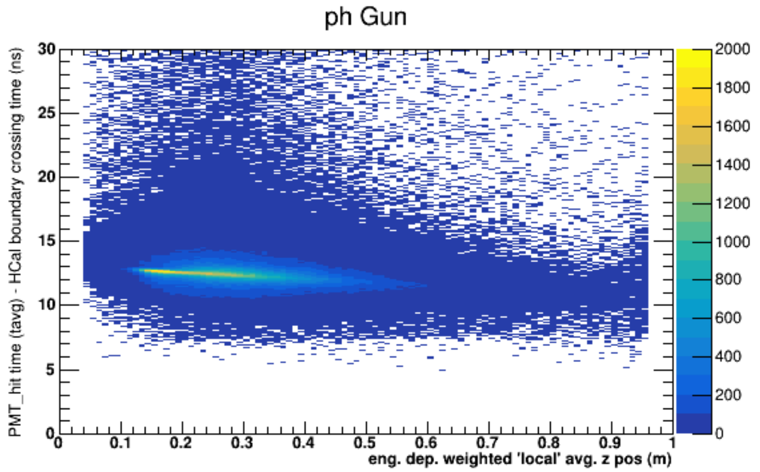
- For neutrons, the distribution peaks at around $13.14\ ns$.
- Threshold assumption: $8.8\ MeV/module$ of HCAL.
- Unlike the case for photons, the distribution has a longer tail here.
- The difference in the means for photons and neutrons is $\sim 0.6\ ns$ which is independent of their TOF.
- It is much less than $4\ ns$. This forced us to conclude that the TOF difference we calculated looking at the energy deposition data for inelastic events, gave us misleading answer.
- This is understandable because the timing of the signals is not based on when the shower is formed but when the photons are detected by the PMTs.

Primary Findings from the Optical Photon sim. cntd.

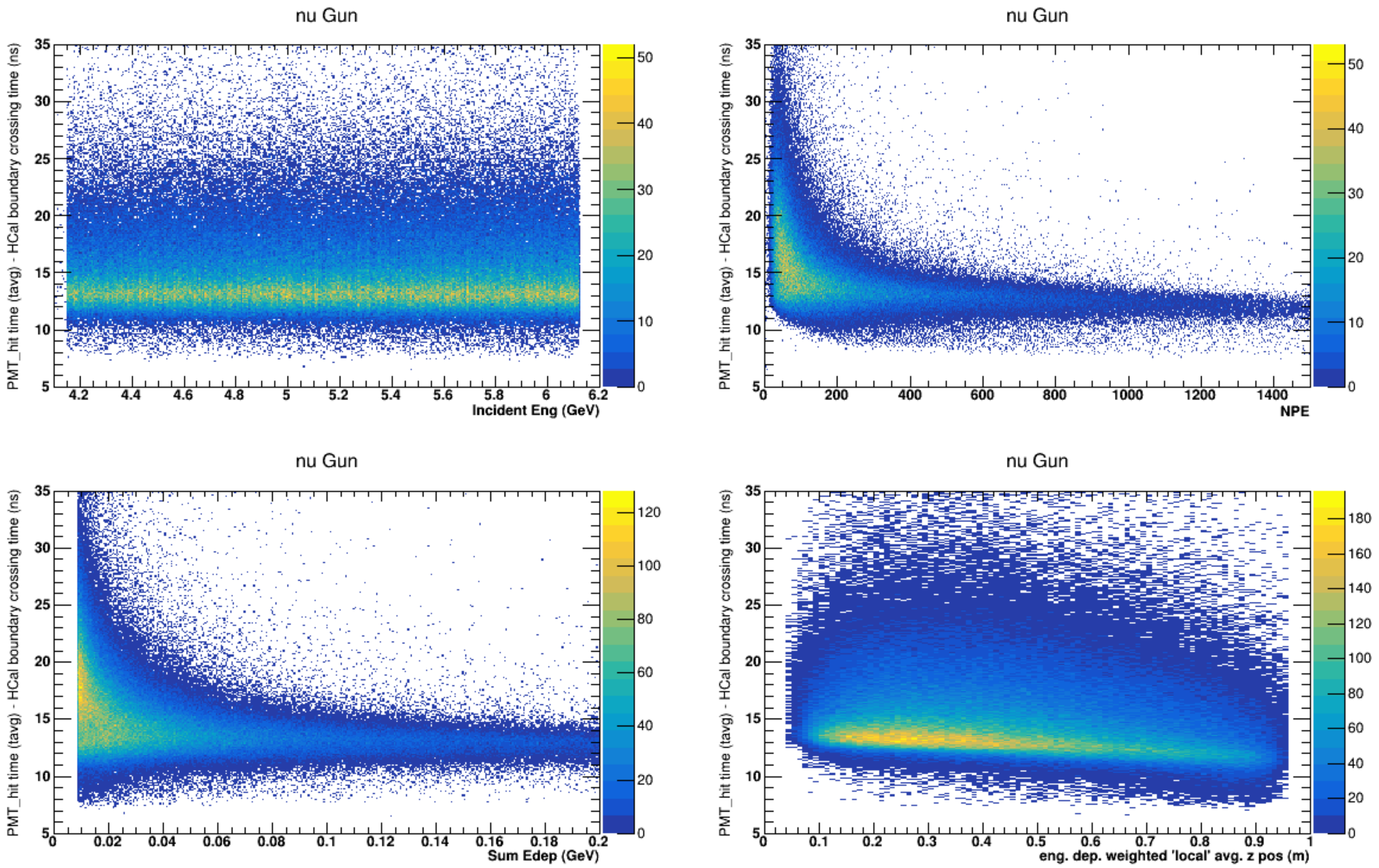








Primary Findings from the Optical Photon sim. cntd.

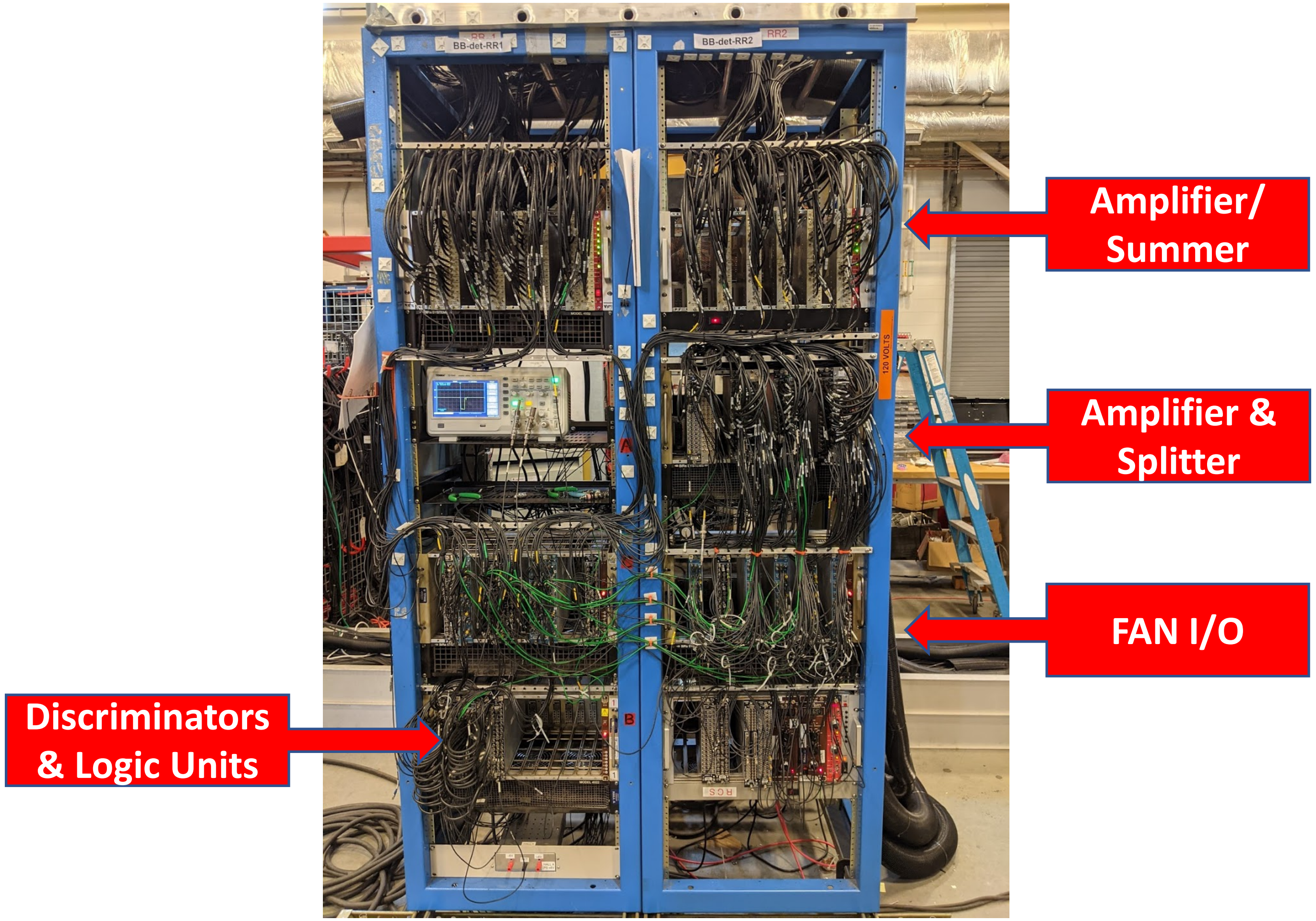


Primary Conclusion and Future Work

- At $Q^2 = 10.2\ GeV^2$ for $\mathrm{G_E^n}$-II experiment, Time of Flight (TOF) gives us only limited discrimination between photons and neutrons.
- Although, there is a significant difference in the shape of the signal for photons and neutrons. Signals due to neutrons tend to have longer tail.
- Neutrons penetrate much deeper into the HCAL whereas the photons deposit most of their energy near the front of the calorimeter.
- Our current goal is to study these behavior in more depth and find a way to use this difference in the shape of the signals to differentiate between photons and neutrons which have TOF difference comparable to the timing resolution of the HCAL.

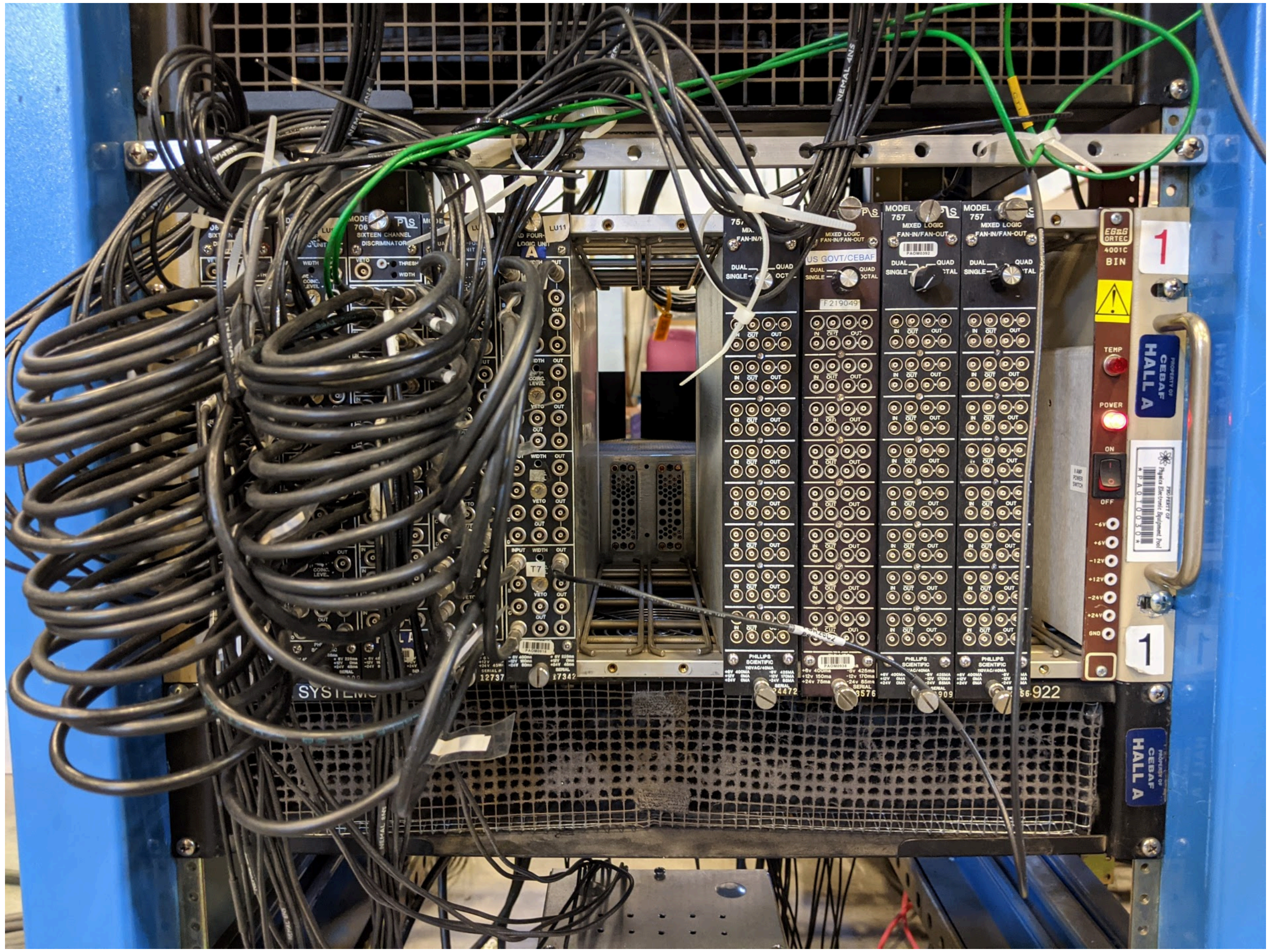
Part II : Implementation of a 2^{nd} BigBite Analog Trigger for the WAPP Experiment

Troubleshooting the Existing BigBite Analog Trigger



- Checked all the cables carrying signals from BB SH/PS to the Amplifier/Summer modules.
- Found a couple of summer modules which were giving large offsets ($\sim 160mV$). We got them calibrated.
- We also discovered that the PS signals were a little noisy which could be problematic for the WAPP experiment. Filtering capacitors have been installed in the Splitter modules to get rid of that problem.
- All the problems are solved. So right now, the existing analog trigger for BigBite is properly calibrated and working as per expectation.

Implementation of the 2nd BigBite Trigger



- All the modules are available.
- Found the cables as well (Thanks to Chuck Long!).
- Performing few tests to ensure that the modules are working properly.
- Planning on using different kind of Logical Modules to make the place less congested.
- Should be finished in less than a week.

Future Plans and Acknowledgements

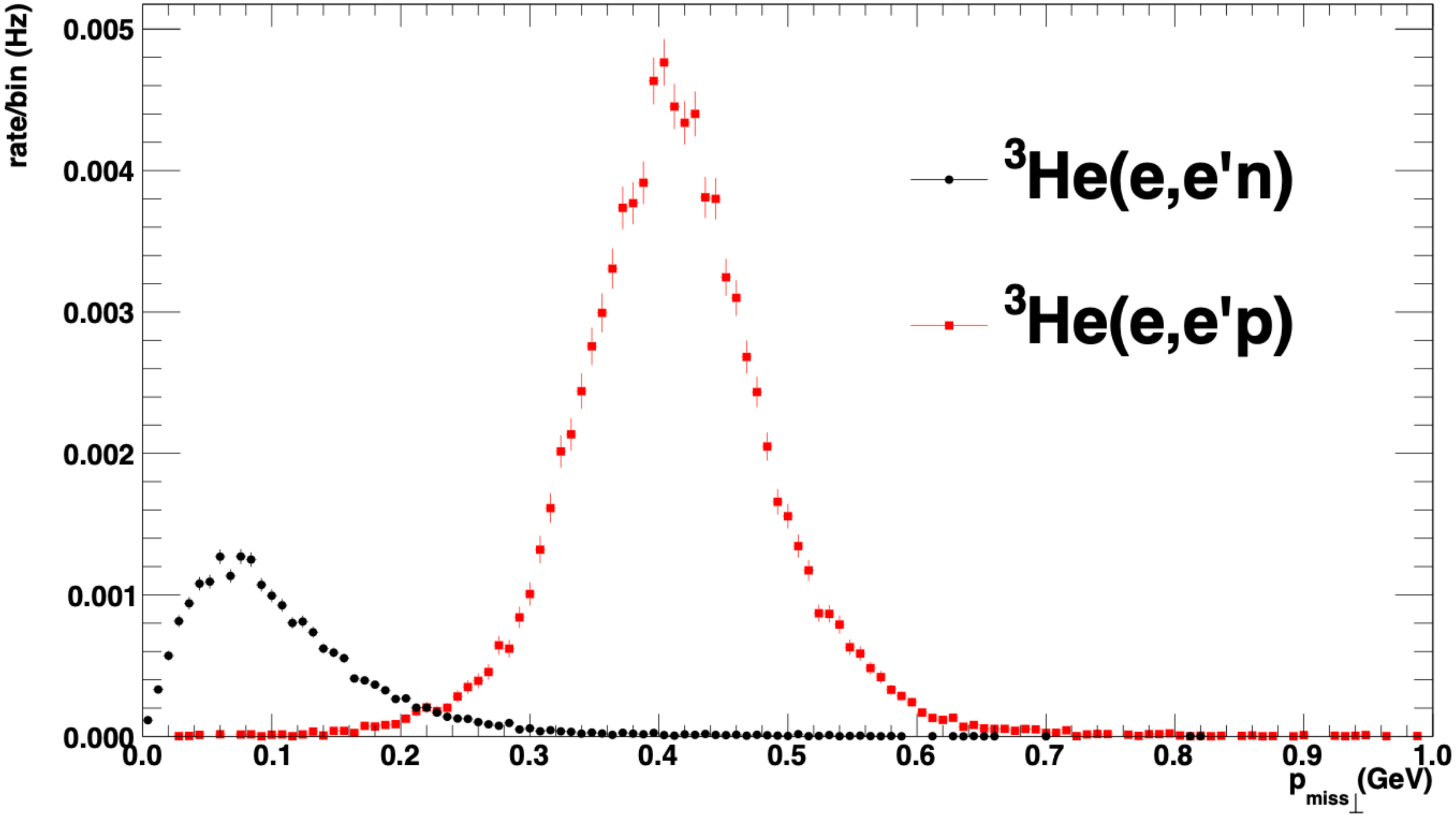
- Want to do my thesis on either one of the experiments in $\mathrm{G_M^n}$ run group or on $\mathrm{G_E^n}$-II.
- Right now, my focus is on contributing as much as I can to help start running the experiments on time.
- I would like to thank Prof. Andrew Puckett for all his support and guidance throughout the course of this project and beyond.
- Bogdan B. Wojtsekhowski's supervision and guidance has helped me understand the BB trigger system quickly enough to make a progress in reasonable amount of time. Thank you, Bogdan!
- I would also like to thank Eric Fuchey and Juan Carlos Cornejo for always being there to answer my questions.
- Looking forward to meet more people and work with them.

Thank you for your attention!

Questions?

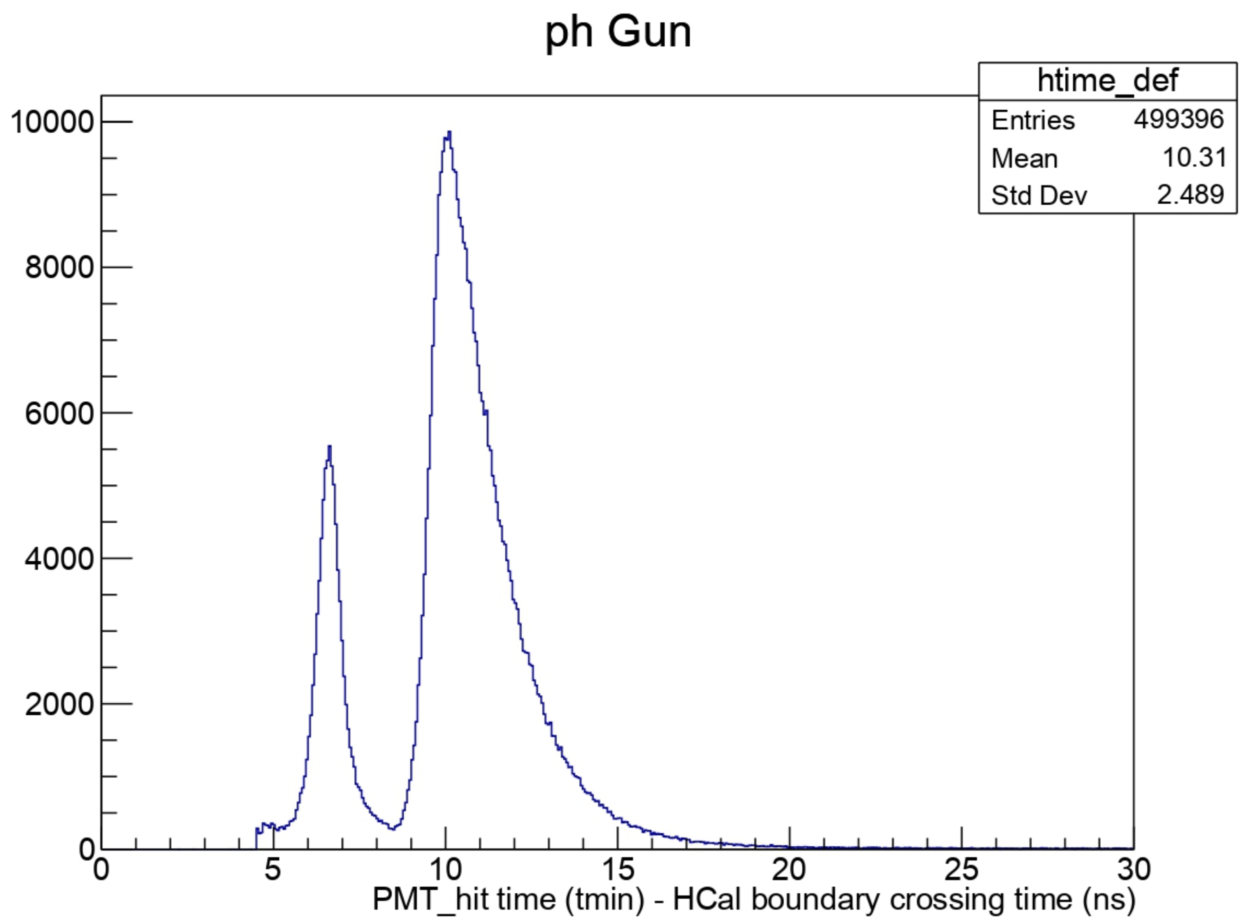
Backup Slides

Missing Perp. Momentum distribution



Plot Credit: Andrew Puckett

A Slight Digression: An Interesting Result



- The plot shows the distribution of delay between the average global detection time (since t=0) of the first optical photon detected by PMT and the HCAL boundary crossing time of the particle responsible for the hit.
- The double peak nature of this distribution is interesting and yet to be understood.
- A possible explanation could be reflection.
- This plot is for photons, but we see the same kind of behavior for neutrons as well.