Monitoring Oxygen Level in NTOF scintillators using cosmic raY muons (MOLY)

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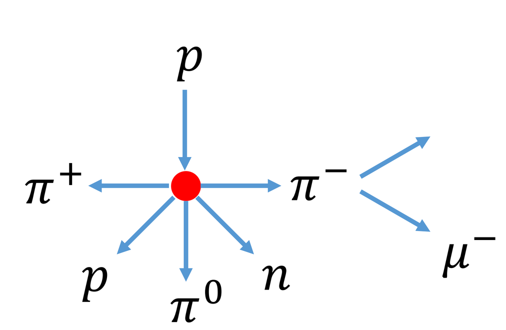
Introduction

High Energy Density Physics and Inertial Confinement Fusion facilities employ nTOF methods to measure neutron energies. Laser induced fusion facilities use the beam pulse as a start signal and Xylene scintillators as the stop signal to obtain the time of flight. To improve timing performance, the scintillator liquid is quenched with oxygen reducing the light production. However, oxygen reacts with the scintillator liquid causing the detector photo flash decay time to increase that reduces the energy resolution of the detector. An in-situ monitoring system which uses cosmic ray muons to determine the oxygen concentration, is being developed at SUNY Geneseo. The method uses a stack of one EJ200 plastic scintillator with the oxygenated xylene detector below it. As cosmic ray muons pass through the stacked detectors, a coincidence signal is produced by the electronics indicating an event has occurred within a few nanoseconds confirming a muon passed through the stack. The signal fit-parameters of the xylene are good indicators of the oxygen concentration. Over the summer of 2019, a proof of concept was deemed successful in measuring a difference in oxygen levels. Throughout the 2019-2020 school year, a larger detector has been built to amplify the count rate and expedite data acquisition.

Cosmic Ray Muons

Muons that we detect on the surface of the Earth are Secondary Cosmic Rays. A primary Cosmic Ray (High Energy Proton) collides with an atmospheric particle, producing various Mesons and Baryons. The π^- then decays into a Muon and an Anti-Muon Neutrino.



Experimental Setup

For proof of concept one EJ-200 Plastic Scintillator was placed above a BC-412 Plastic Scintillator and attached to a Photek 240 PMT. The plastic scintillator was biased using a Photek BPS1 High Voltage power supply.

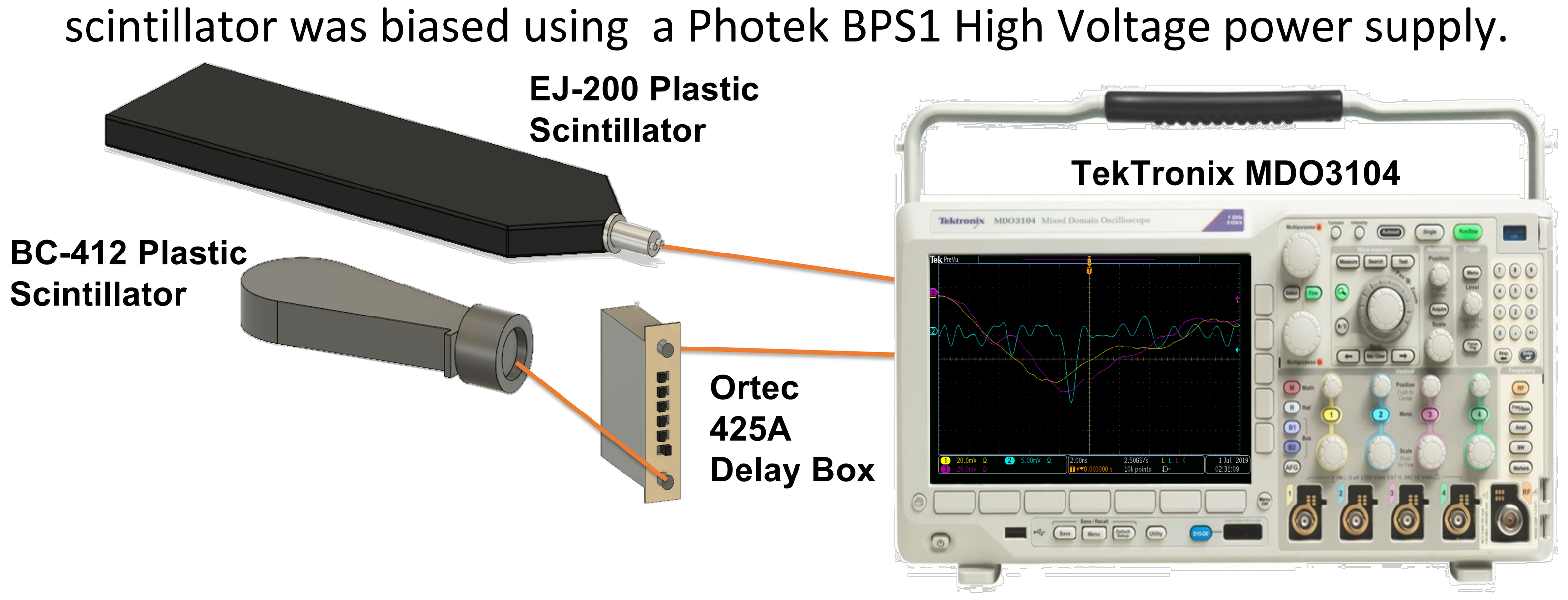


Figure 1: BC412 Plastic Scintillator attached to a Photek 240 PMT (left). Experimental diagram of one EJ-200 Plastic Scintillators placed in coincidence with the BC-412 Plastic Scintillator (right).

Double muon coincidences were achieved. The BC-412 Plastic Scintillator's signals were delayed by 32 *ns* with an Ortec 425A delay box.
Oxygenation was achieved by bubbling oxygen through a small needle for 30 minutes into the scintillation fluid. Then nitrogen was bubbled through the solution for 30 minutes to displace oxygen.

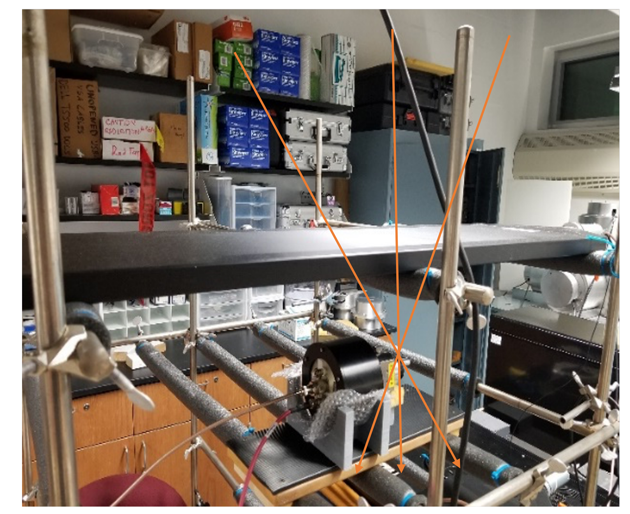


Figure 2: Top detector is an Ej-200 plastic scintillator. The bottom detector is the Xylene detector.

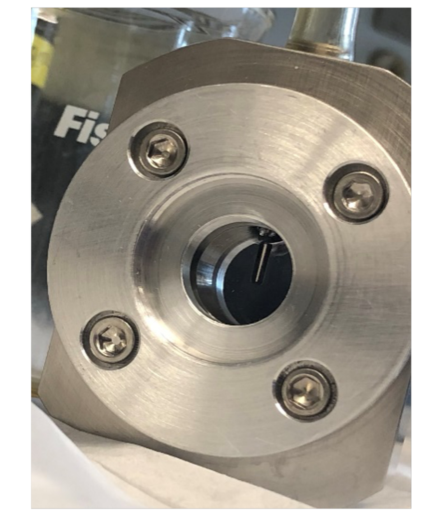


Figure 3: The xylene detector being bubbled with oxygen.

Experimental Method

The Tektronix MDO3104 Oscilloscope was configured to save the muonic signals from the xylene detector. These signals were fit with an Exponentially Modified Gaussian function. There are four free parameters: h, μ, σ and τ where h is the amplitude, μ represents the centroid relative to the scope trigger, σ is the temporal width of the gaussian and τ is the relaxation time of the exponential decay.

$$f(t;\, h,\, \mu,\, \sigma,\, \tau) = h \exp\left(-\frac{1}{2}\left(\frac{t-\mu}{\sigma}\right)^2\right)\frac{\sigma}{\tau}\sqrt{\frac{\pi}{2}}\,\mathrm{erfcx}\left(\frac{1}{\sqrt{2}}\left(\frac{\sigma}{\tau}-\frac{t-\mu}{\sigma}\right)\right) \qquad (1)$$

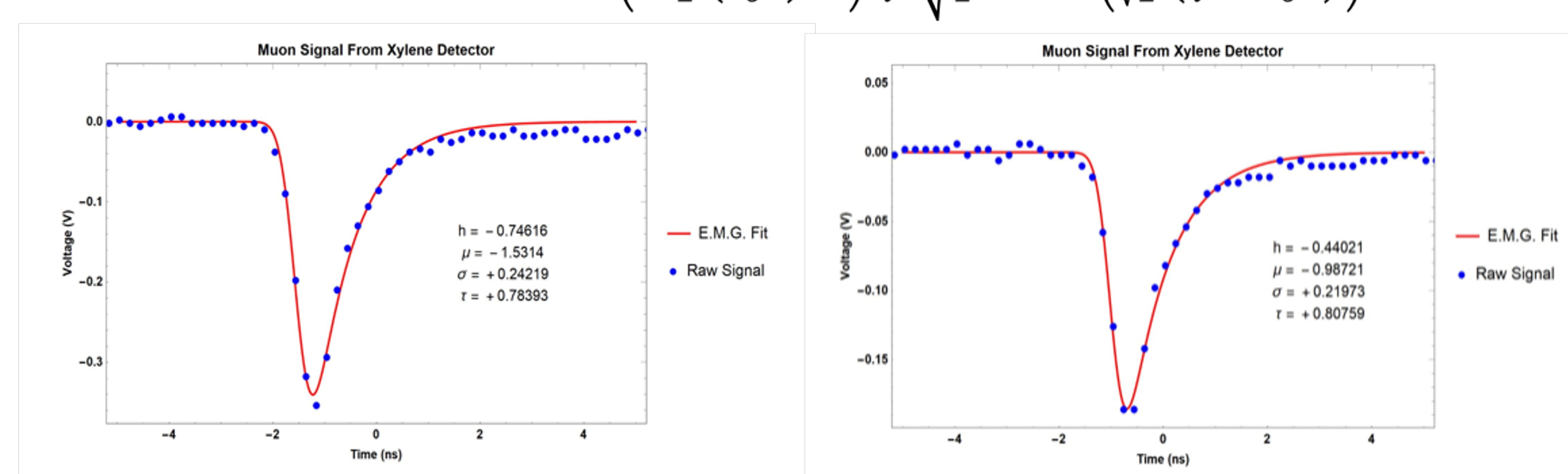


Figure 4: Examples of nominal signal fits.

Comparison of Oxygenated Xylene after 5 Weeks:

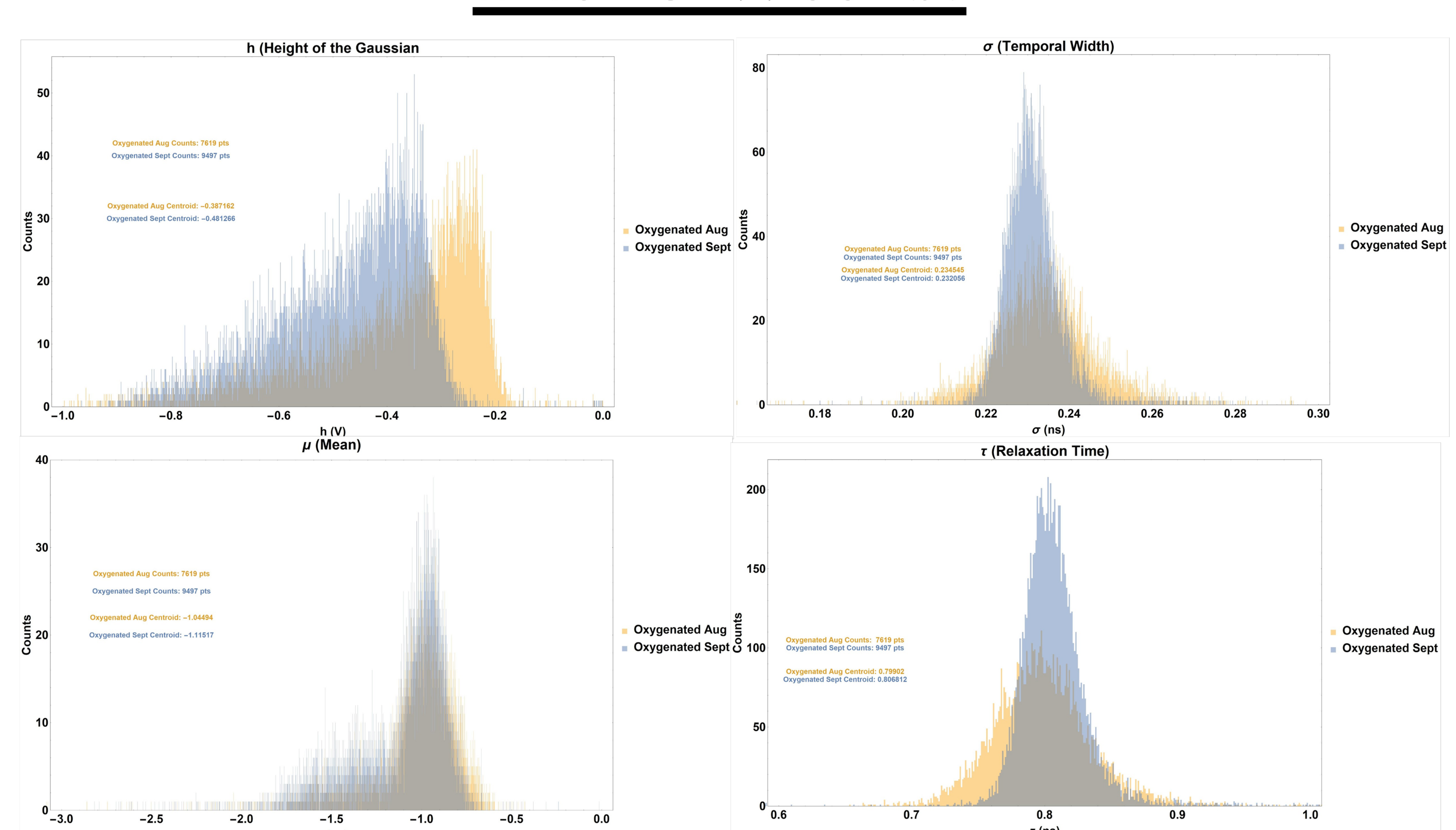


Figure 5: The plots above show histograms of the fit parameters for h, σ, μ, and τ respectively for the August run and September run

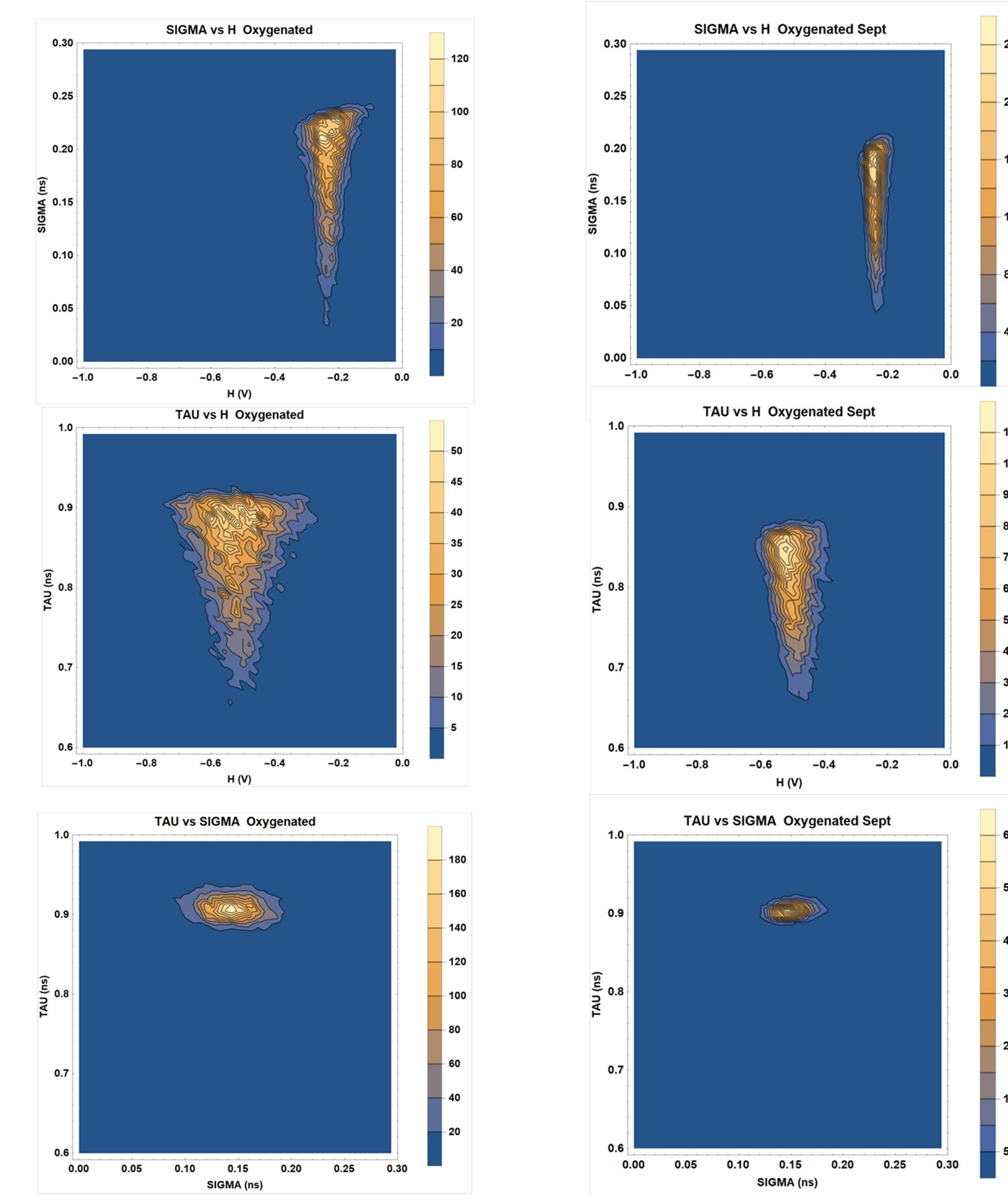


Figure 6: The plots above show 2 dimensional coincidence plots of the fit parameters for h, σ, μ, and τ respectively for the August run (left) and September run (right).

Future Work

A larger vessel has been constructed. Increasing the volume of scintillation fluid by 20,000%, from 5 mL to 1 L. Greatly increasing the count rate. Allowing the discrimination of lower energy and poor resolution signals. Muon signals from the xylene detector will be analyzed in order to develop an in-situ system for determining oxygen concentration . This will be done by changing the oxygen concentration in the xylene and monitoring signal fit parameters. The MOLY system will eliminate the need to remove scintillators and reoxygenate them in regular intervals from experimental setups on OMEGA and OMEGA EP.

Figure 7: Bubbling oxygen in xylene detector (left). Matthew Signor filling the xylene detector with the scintillator fluid (middle). Small Xylene vessel attached to the Photek PMT 240

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