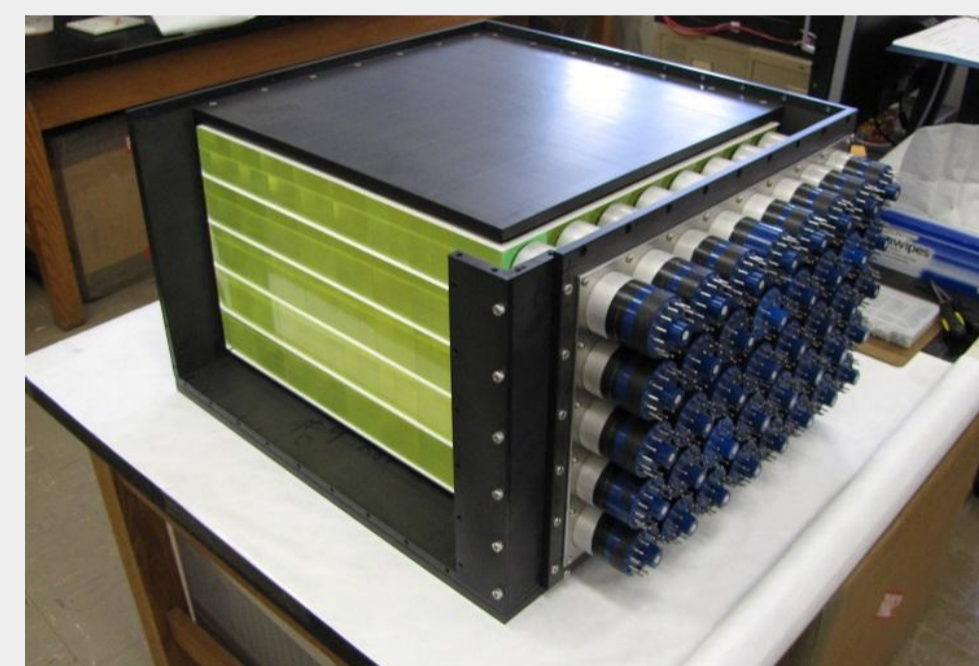


Jah'Shawn Ross, North Carolina Central University
with the Virginia Tech Center for Neutrino Physics REU

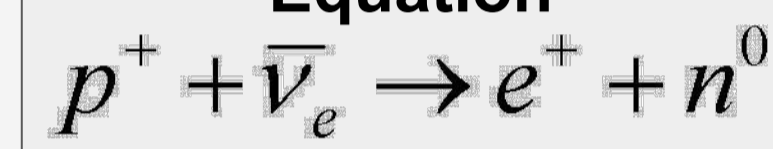
Introduction

CHANDLER (Carbon Hydrogen Antineutrino Detector with a Lithium Enhanced Raghavan optical lattice) is a reactor neutrino detector technology. The CHANDLER technology consists of layers of wavelength shifting plastic scintillator cubes separated by thin sheets of lithium-6 loaded zinc sulfide. In inverse beta decay, when an electron antineutrino scatters off a proton, it creates a positron and a neutron. Lithium-6 is used to capture the neutron. The light that is produced by the scintillator cubes is then guided to the PMTs by total internal reflection.

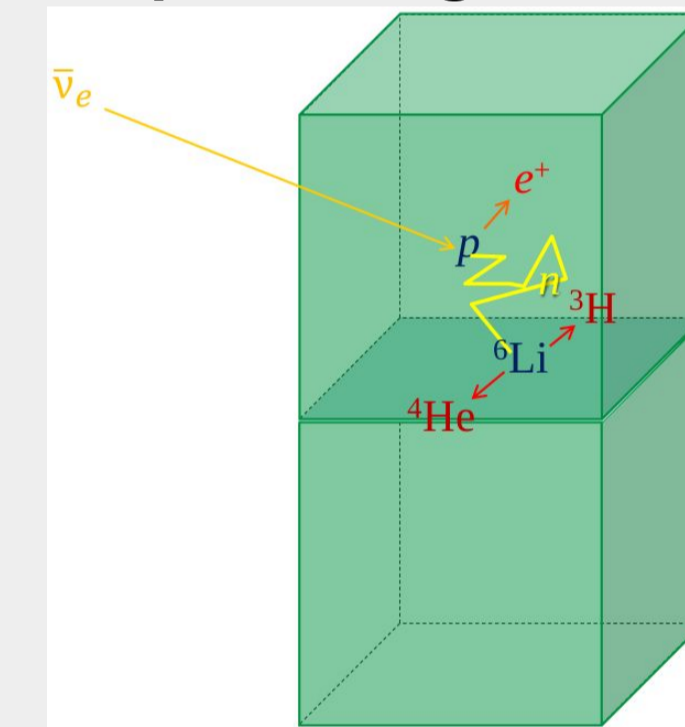
MiniCHANDLER



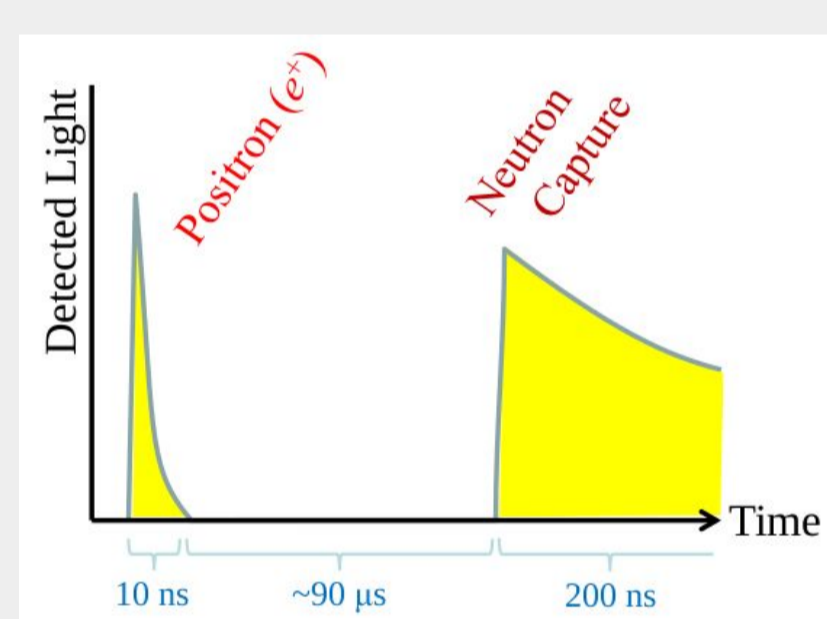
Inverse Beta Decay Equation



Plastic Scintillators producing IBD



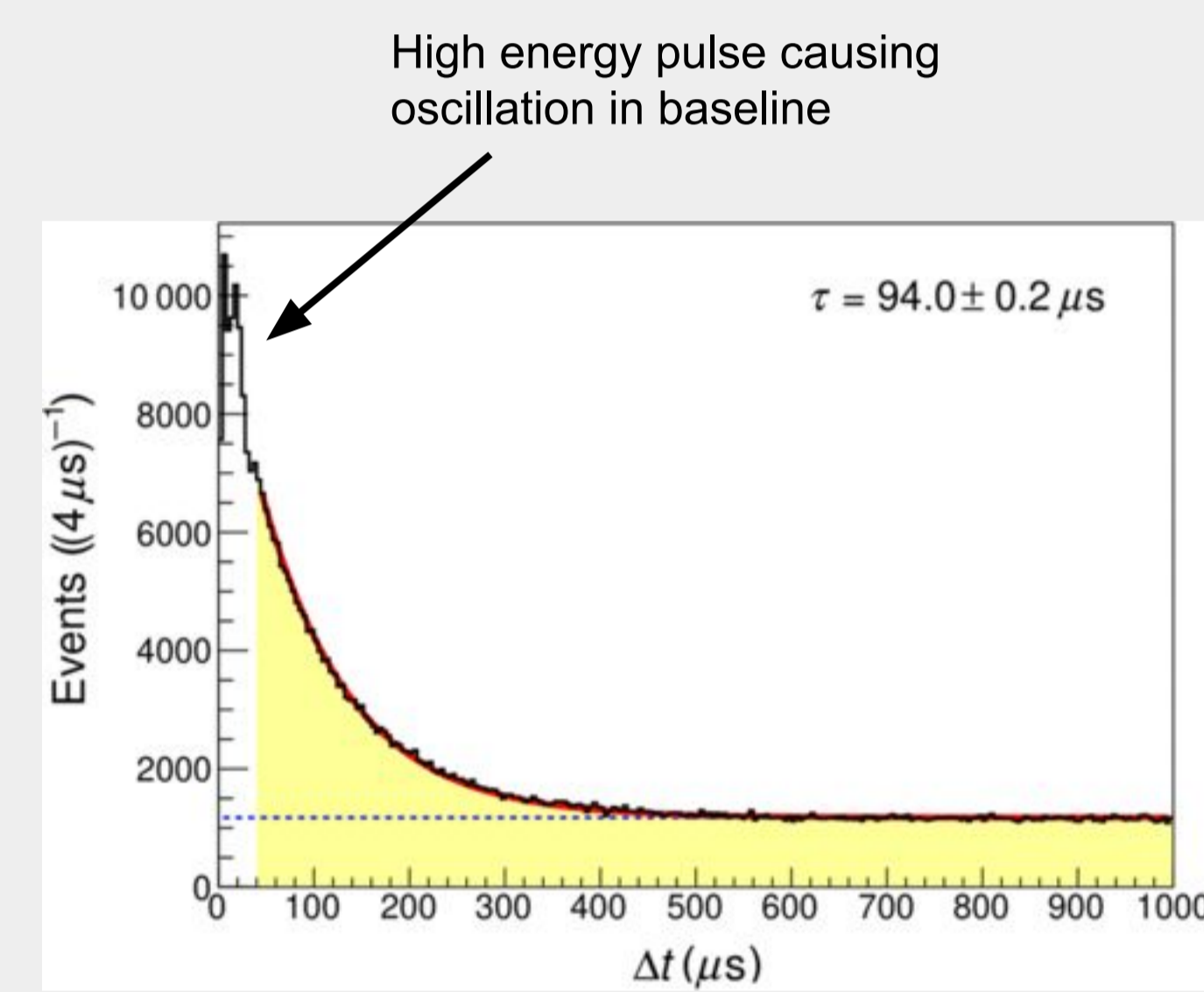
Detected light over time of Positron and Neutron



Old Electronics

The old electronics for MiniCHANDLER consisted of shapers and CAEN digitizers with a 12-bit ADC. The 12-bit ADC was not able to effectively measure higher energy neutron proton recoils, because it exceeds the range. Another problem with the old electronics was that there was cross-talk between neighboring channels, due to the single-ended input of the PMT signal. Moreover, the trigger algorithm would fail under high energy pulses, because it would cause large oscillations in the baseline. These oscillations caused retriggers and at times the inability to read low pulse height neutron signals. If the trigger threshold was set to a normal level the digitizer would send too much information, using too much bandwidth. To compensate for this the trigger threshold was raised, which led to missing vital information.

Old Electronics Rack

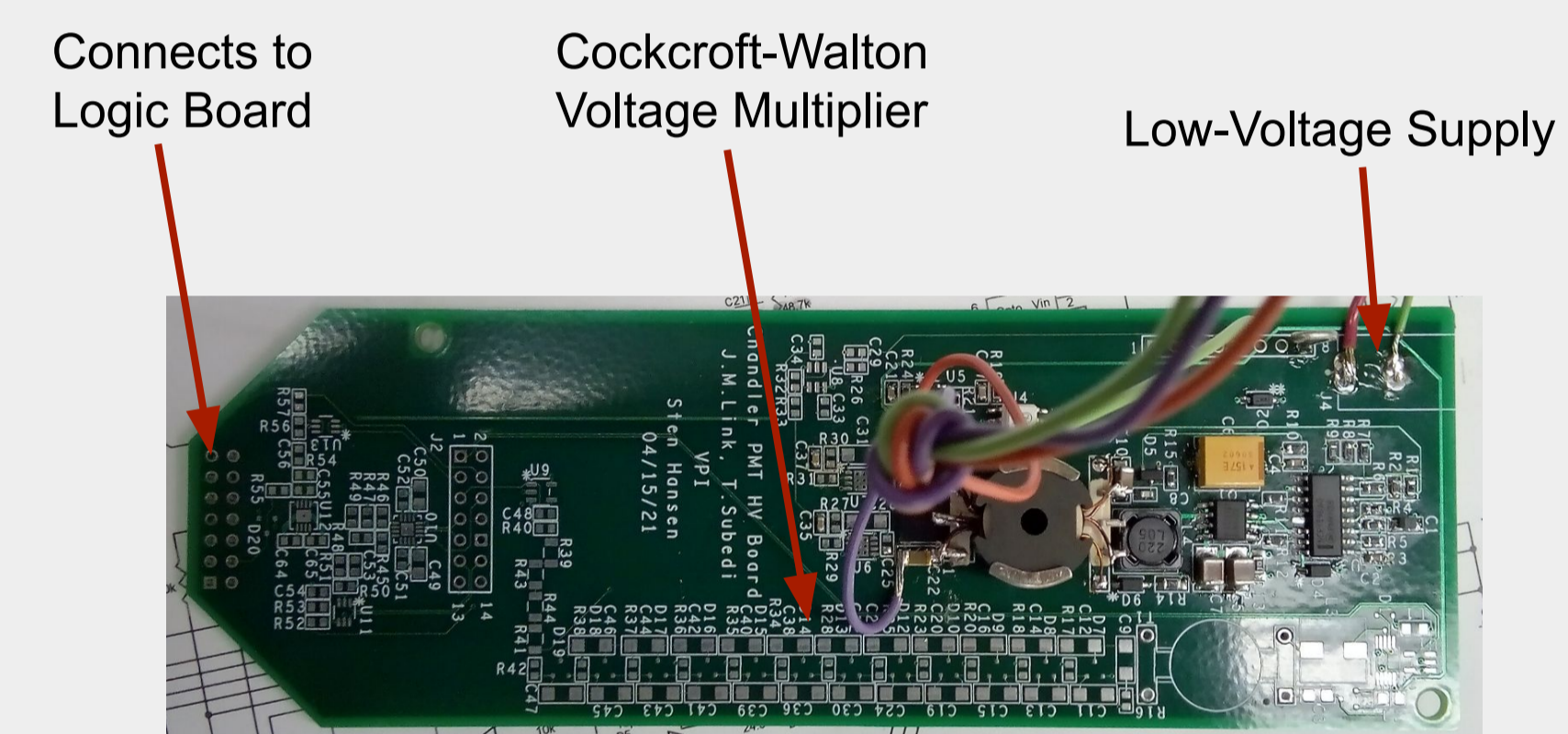
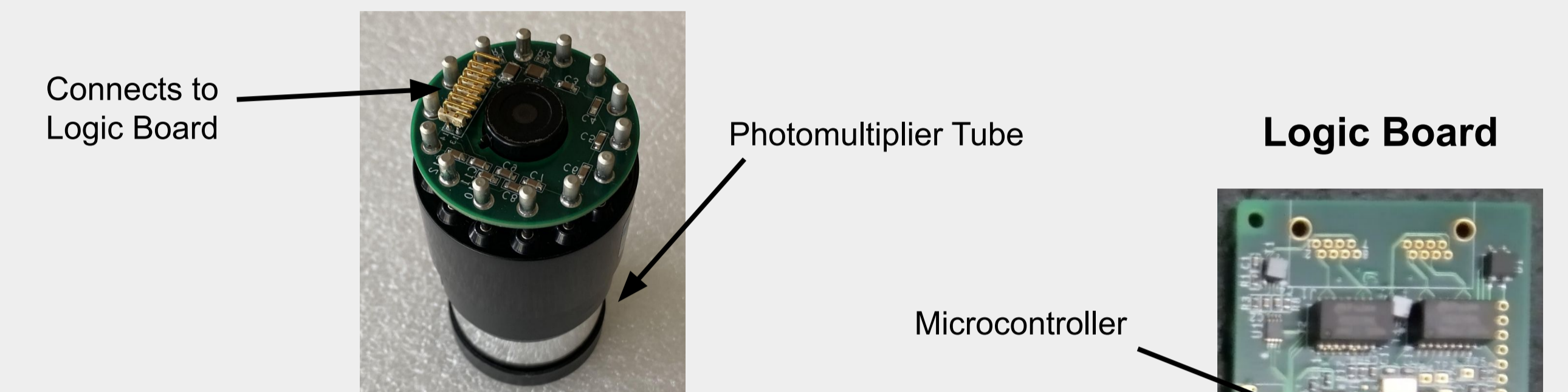


Delta-time histogram of gamma and neutron events

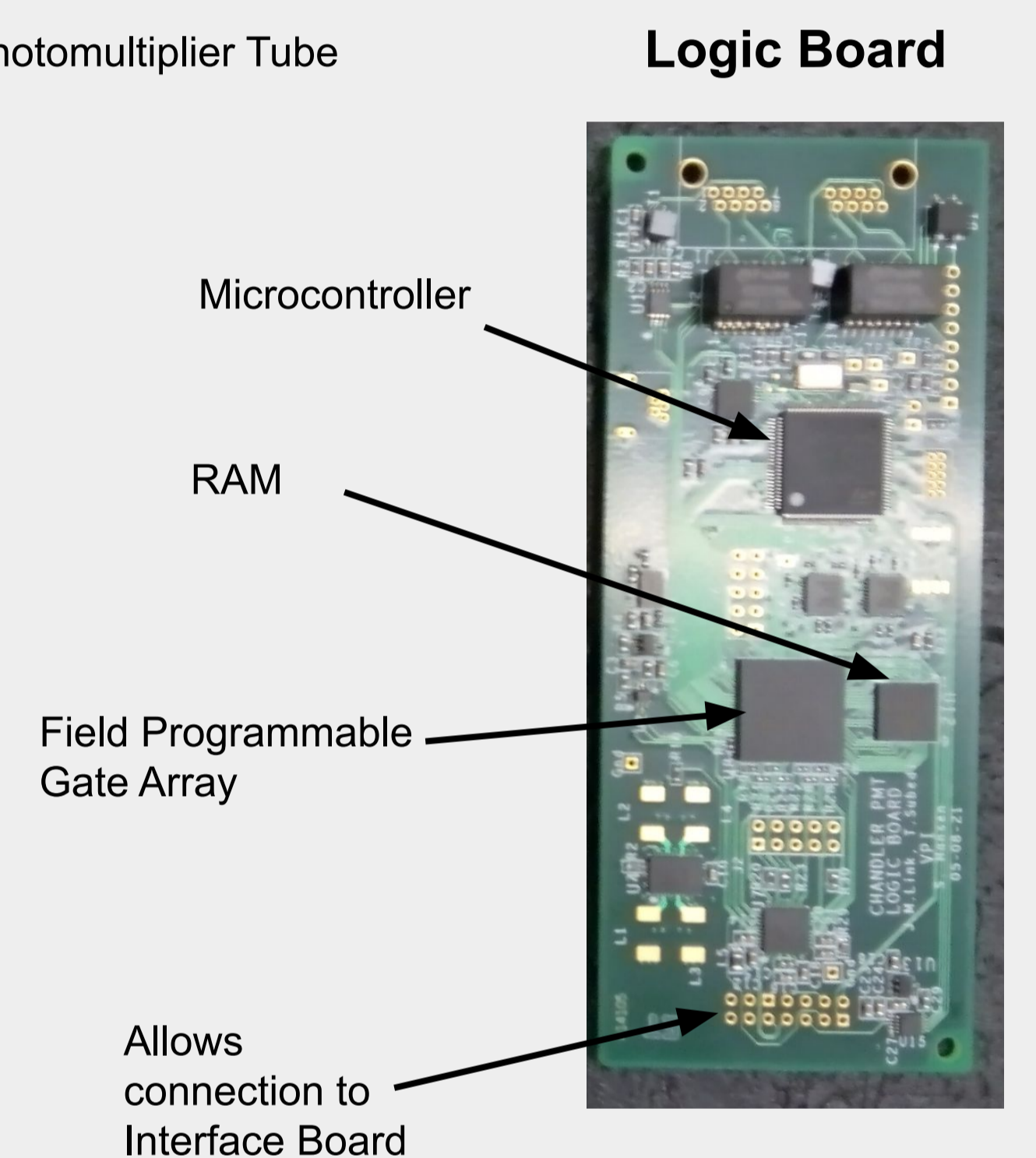
New Electronics

The development of the new electronics is geared toward improving the old electronics. The new electronics will have no crosstalk, better dynamic range, no oscillating after effects, take up less space, and be cheaper. One addition to the new electronics that improves flexibility is the FPGA. The FPGA allows for more complex codes to be used, which can be used to fix some of the previous problems. One problem that is going to be improved because of the FPGA is the trigger algorithm which has the running baseline code.

Photomultiplier Tube Interface Board



High-Voltage Board



Read Out Firmware

The FPGA uses VHDL as the coding firmware. The running baseline code characterizes the baseline allowing the pretrigger window to be analyzed. The running baseline will send out the sum of the ADC counts, moving average, ADC values squared, sum of ADC squared, and moving average squared. These all could be used as important indicators to compensate for the running baseline not being perfectly flat. Two pretrigger windows are expected. These are a relatively flat baseline and exponential decay.

Running Baseline Code (MA/Sum)

```

process(clk, reset)
begin
if reset = '1' then
counter <= '000';
waddress <= 'X'##"0";
raddress <= 'X'##"0";
MA <= std_logic_vector(unsigned(MA) + unsigned(MA));
else
if rising_edge(clk) then
if counter <= '1' then
counter <= counter + 1;
waddress <= waddress + 1;
raddress <= raddress + 1;
Measured <= std_logic_vector(unsigned(MA) + unsigned(MA));
MA <= std_logic_vector(unsigned(MA) + unsigned(MA));
if counter <= 1 then
sum <= sum + resize(unsigned(ADC), 16);
counter <= counter + 1;
waddress <= waddress + 1;
raddress <= raddress + 1;
else
sum <= sum + resize(unsigned(ADC), 16) - resize(unsigned(Q), 16);
counter <= counter + 1;
waddress <= waddress + 1;
raddress <= raddress + 1;
end if;
end if;
end process;

```

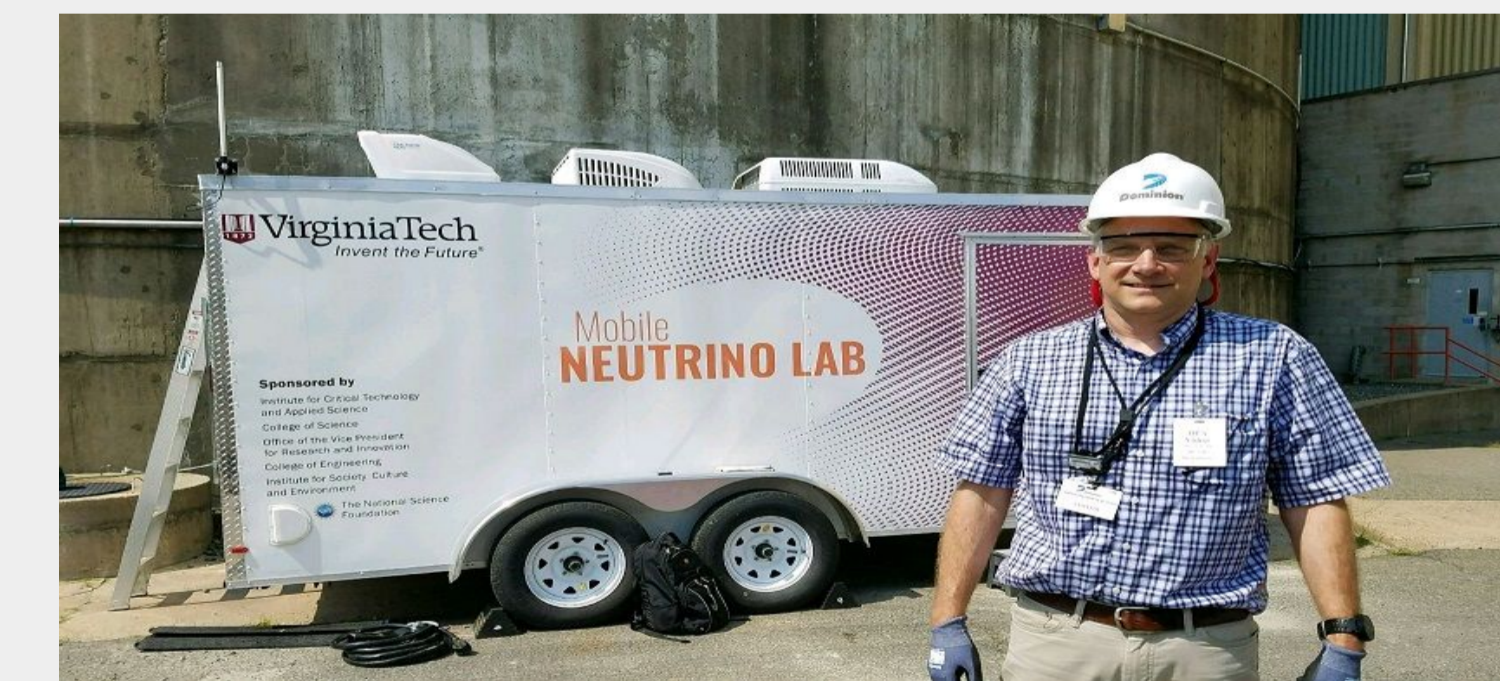
Neutron Hit Simulation

/chandlerrunningbaseline_vhd_tst/ADC	489	X	(200)	202	199	203	204	216	262	371	563	724	1034	967	822	710	593
/chandlerrunningbaseline_vhd_tst/1/sum	7569	0	202	401	604	808	1024	1286	1657	2220	2954	3888	4955	5777	6487	7080	7580
/chandlerrunningbaseline_vhd_tst/1/1/squared	239121	0	40804	161209	41616	81656	108644	137641	176969	238756	332059	436156	535089	627684	704100	751649	800000
/chandlerrunningbaseline_vhd_tst/1/MA	442	X	(0)	12	25	37	50	64	80	103	138	184	249	309	361	405	442
/chandlerrunningbaseline_vhd_tst/1/MASquared	164025	0	144	144	165	186	250	406	640	1060	1804	2886	4601	6201	7541	10321	130321
/chandlerrunningbaseline_vhd_tst/1/MASquaredOverN	30473	0	250	3025	3760	4620	5760	7200	8960	11200	14000	18400	23600	29600	36400	44000	52400
/chandlerrunningbaseline_vhd_tst/1/ASquaredSum	4007574	0	42804	80405	121614	169230	223856	278530	338171	403190	473190	548890	629890	715890	807890	905890	1009890
/chandlerrunningbaseline_vhd_tst/clk	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Neutron Decay Simulation

/chandlerrunningbaseline_vhd_tst/ADC	No Data	X	(7500)	10500	9800	10000	8200	6000	5500	4700	4000	3400	3000	2700	2200	2000	1850
/chandlerrunningbaseline_vhd_tst/1/sum	No Data	0	10500	20300	30300	38500	44500	50000	54700	58700	62100	65100	67800	70000	72000	72850	73850
/chandlerrunningbaseline_vhd_tst/1/1/squared	No Data	0	110250000	36600000	108000000	167200000	206000000	220500000	240900000	260200000	278400000	295000000	310000000	323400000	335200000	345800000	355200000
/chandlerrunningbaseline_vhd_tst/MA	No Data	X	(0)	656	1248	1893	2496	3271	3721	4231	4681	5081	5441	5761	6041	6281	6491
/chandlerrunningbaseline_vhd_tst/1/MASquared	No Data	0	436336	155776	359344	622656	1028160	1401600	1730400	2012400	2246400	2532000	2768400	3045600	3264000	3414400	349681
/chandlerrunningbaseline_vhd_tst/1/MASquaredOverN	No Data	0	582656	1789125	4814315	8324625	12346875	16866875	21886875	27306875	33126875	39346875	45966875	52986875	60406875	68226875	76446875
/chandlerrunningbaseline_vhd_tst/1/ASquaredSum	No Data	0	110250000	206290000	306290000	372530000	425530000	473780000	517780000	557780000	594780000	628780000	659780000	687780000	712780000	734780000	753780000
/chandlerrunningbaseline_vhd_tst/clk	No Data	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHANDLER Applications



Fuel composition can be observed without having to do traditional monitoring methods. This could be a viable option over traditional monitoring methods because they can be costly and detrimental to the operations at the nuclear plant.



CHANDLER technology could be used after a nuclear accident to detect criticality in the reactor core.

Acknowledgements

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Sources

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