Contributions Made to the Fermilab Test Beam Facility

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Introduction

The Fermilab Test Beam Facility (FTBF) is a unique facility that provides scientists from all over the world the opportunity to use characterized charged particle beams to determine the behavior of their detectors. [1] In order to characterize the charged particle beams, FTBF uses a data acquisition (DAQ) software to store and analyze data from facility provided detectors.

This poster elaborates on two contributions made to FTBF. The first is the integration of Maximum Integrated Data Acquisition System (MIDAS), which is a data acquisition software developed by TRIUMF, to the FTBF DAQ. MIDAS uses modular networking and a central database to analyze and store data, respectively, from the detectors that characterize the test beam. [2] The second contribution is the development of a time of flight system (TOF), which is a detector that identifies particles by determining the mass of a particle from measuring the time difference between a particle with a known momentum interacting with two detectors separated by a known distance (Figure 2).

MIDAS

To characterize the test beam at FTBF, MIDAS uses frontends, a program that accesses and reads data from hardware, to communicate with FTBF's hardware—CC-USB CAMAC controllers and wire chambers. These frontends were modified from the original TRIUMF code to work on FTBF's systems. Trial and error was the main process in adapting the frontends. To control these frontends, MIDAS uses a master frontend, which is triggered to start the frontends when the trigger server detects a beam spill, a bunch of accelerated particles. Once the master frontend runs the frontends and data is collected, the event builder says an event has occurred and describes it with the data gathered. This data is then sent to ROME (ROOT based Object Oriented MIDAS Extension), a data analyzer, and to a database. The master frontend was also modified, in a similar manner to the frontends, to work with FTBF, and ROME was installed to the FTBF computers. The final results are data files and histograms of that data (Figure 1).

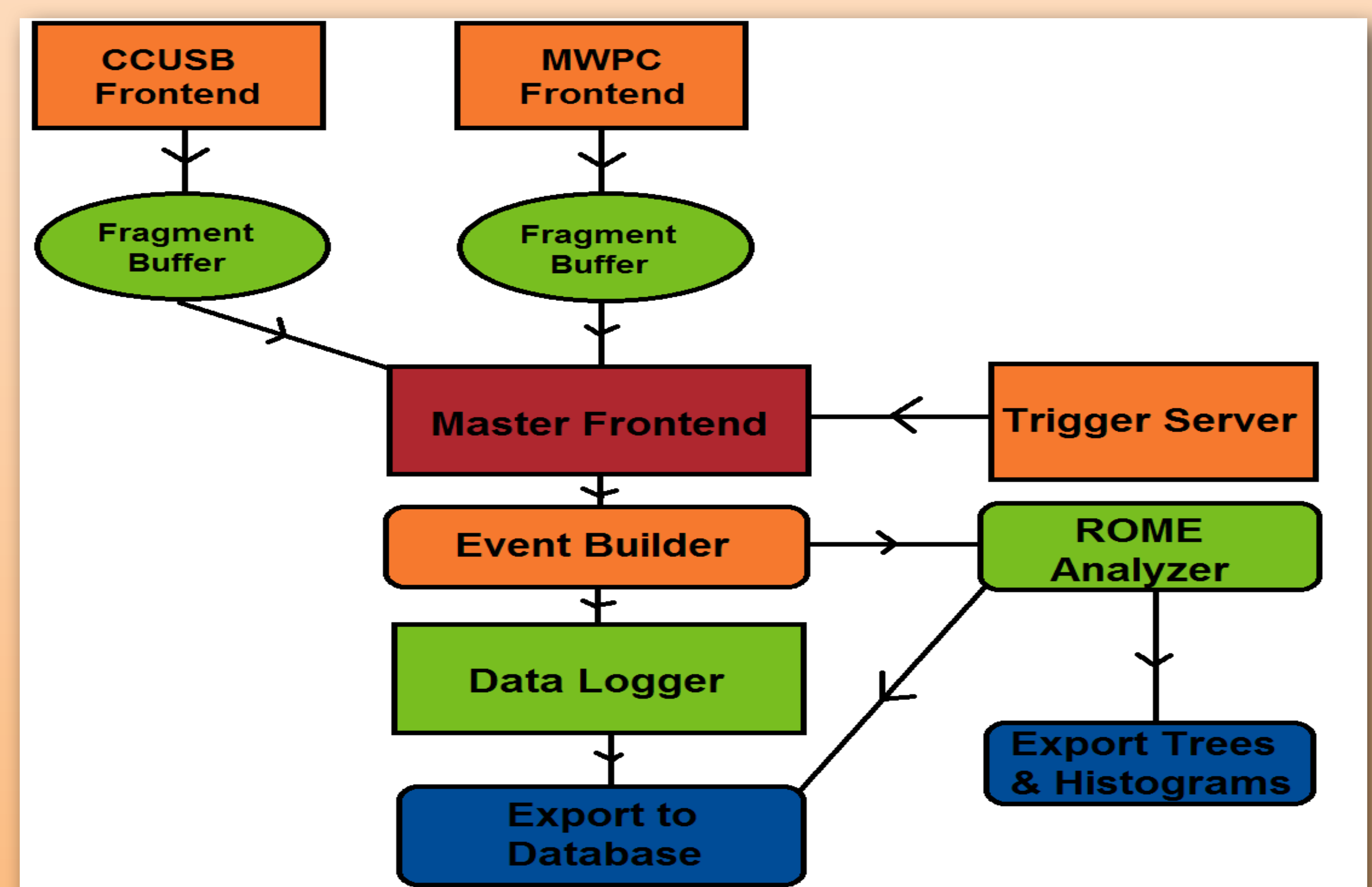

Figure 1: A flowchart outlining the basic steps FTBF's MIDAS DAQ takes to gather, analyze, and store data.

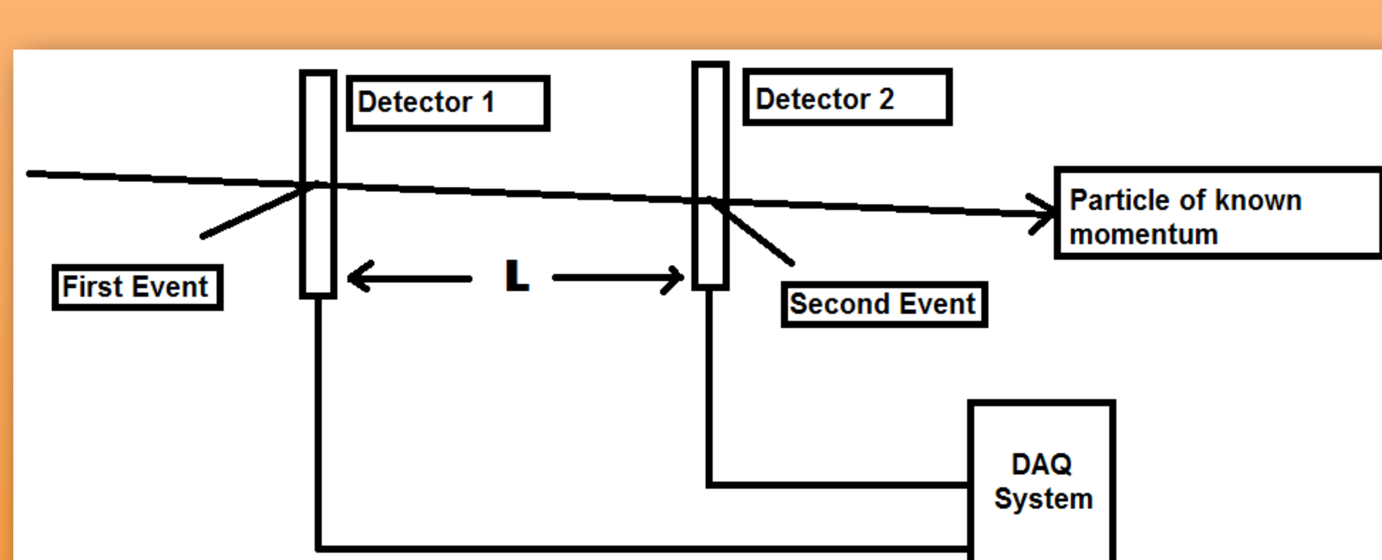

Figure 2: A general outline of how a time of flight (TOF) is structured. That is, a particle of known momentum travels through the first detector and is time-stamped. Then that particle travels through the second detector and is time-stamped. The difference in time is used to determine the mass of the particle.

Time of Flight System

The first step to developing the time of flight (TOF) system was to calculate the time differences between two particles with the same momentum traveling a distance. Since the particles in the test beam are relativistic [1], one can use special relativity to determine this time difference, which turns out to be the equation: $|\Delta t| = d*c*|m_1 - m_2|/(2*p^2)$ where d, the distance traveled; c, the speed of light; m_1 and m_2, the mass of the different particles; and p, the momentum of the particles (Table 1).

There are two parts of a TOF that can greatly improve the time resolution, the uncertainty in when a particle was detected, of your detector. The first is the material used to emit photons that will later be detected. There are two common types of materials, scintillators and Cherenkov radiators, both of which have their pros and cons. Since the goal is to improve timing resolution and scintillators can be rather slow, ~100ps [3], quartz, a Cherenkov radiator, was used in the design; the second factor in improving time resolution is the photodetectors. Since MCP-PMT's (microchannel plate photomultiplier tube) have a time resolution on the order of 10ps [3], MCP-PMTs were used in the design of the TOF (Figure 3).

Discussion

Throughout the integration of MIDAS, there have been countless issues from simple directory problems to MIDAS crashing because the data from the spills were too large. While MIDAS, at this point, is able to gather, analyze and store data, its stability is questionable. On many occasions, what was mistaken for successfully installing MIDAS ended in failure. That being said, the next step in the process would be to keep a record of issues and their solutions. Along with that, more frontends should be added, such as those for a lead glass calorimeter and a TOF.

As for the TOF, the type of detector and the type of material to produce photons have been chosen for the TOF design. The next step is to consider what hardware other than the detector itself will reduce the time resolution. The final steps should be constructing out of the design materials and hardware, testing to determine the time resolution, and implementing the TOF to identify particles in the test beam.

References

[1] http://ftbf.fnal.gov/

[2] https://midas.triumf.ca/MidasWiki/index.php/Midas_documentation

[3] A. Ronzhin, M. G. Albrow, M. Demarteau, S. Los, S. Malik, A. Pronko, E. Ramberg, A. Zatserklyaniy, Development of a 10-ps level time of flight system in the Fermilab Test Beam Facility, *Nucl. Instr. and Meth.* A623 (2010) 931-941.

Acknowledgments

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Table 1: Difference in time of flight between two particles (ps)

	at 9 GeV/c						at 11 GeV/c						at 13 GeV/c						
Length (m)	Proton to Kaon	Proton to Pion	Proton to Muon	Kaon to Pion	Kaon to Muon	Pion to Muon	Proton to Kaon	Proton to Pion	Proton to Muon	Kaon to Pion	Kaon to Muon	Pion to Muon	Proton to Kaon	Proton to Pion	Proton to Muon	Kaon to Pion	Kaon to Muon	Pion to Muon	Key
2	26.2	35.43	35.77	9.23	9.57	0.34	17.54	23.72	23.94	6.18	6.41	0.23	12.56	16.98	17.14	4.42	4.59	0.16	>1000 ps
4	52.4	70.85	71.54	18.46	19.14	0.68	35.08	47.43	47.89	12.35	12.81	0.46	25.11	33.96	34.29	8.85	9.17	0.33	1000ps >500ps
6	78.6	106.28	107.31	27.68	28.71	1.03	52.61	71.15	71.83	18.53	19.22	0.69	37.67	50.94	51.43	13.27	13.76	0.49	500ps >250ps
8	104.8	141.71	143.08	36.91	38.28	1.37	70.15	94.86	95.78	24.71	25.62	0.92	50.23	67.92	68.57	17.69	18.35	0.66	250ps >100ps
10	131	177.13	178.84	46.14	47.85	1.71	87.69	118.58	119.72	30.89	32.03	1.15	62.79	84.9	85.72	22.11	22.93	0.82	100ps > 20ps
12	157.2	212.56	214.61	55.37	57.42	2.05	105.23	142.29	143.67	37.06	38.44	1.37	75.34	101.88	102.86	26.54	27.52	0.98	
14	183.39	247.99	250.38	64.59	66.99	2.4	122.77	166.01	167.61	43.24	44.84	1.6	87.9	118.86	120.01	30.96	32.11	1.15	
16	209.59	283.41	286.15	73.82	76.56	2.74	140.31	189.72	191.56	49.42	51.25	1.83	100.46	135.84	137.15	35.38	36.69	1.31	
18	235.79	318.84	321.92	83.05	86.13	3.08	157.84	213.44	215.5	55.59	57.66	2.06	113.01	152.82	154.29	39.8	41.28	1.48	
20	261.99	354.27	357.69	92.28	95.7	3.42	175.38	237.15	239.45	61.77	64.06	2.29	125.57	169.8	171.44	44.23	45.87	1.64	
22	288.19	389.69	393.46	101.5	105.27	3.76	192.92	260.87	263.39	67.95	70.47	2.52	138.13	186.78	188.58	48.65	50.45	1.8	
24	314.39	425.12	429.23	110.73	114.84	4.11	210.46	284.59	287.33	74.13	76.87	2.75	150.68	203.76	205.72	53.07	55.04	1.97	
26	340.59	460.55	465	119.96	124.41	4.45	228	308.3	311.28	80.3	83.28	2.98	163.24	220.74	222.87	57.49	59.63	2.13	
28	366.79	495.97	500.77	129.19	133.98	4.79	245.54	332.02	335.22	86.48	89.69	3.21	175.8	237.72	240.01	61.92	64.21	2.3	
30	392.99	531.4	536.53	138.41	143.55	5.13	263.07	355.73	359.17	92.66	96.09	3.44	188.36	254.7	257.16	66.34	68.8	2.46	
100	1309.96	1771.34	1788.45	461.38	478.49	17.11	876.92	1185.77	1197.23	308.86	320.31	11.45	627.85	848.99	857.19	221.13	229.34	8.2	

Table 1: A spreadsheet comparing the differences in time of flights of particles.

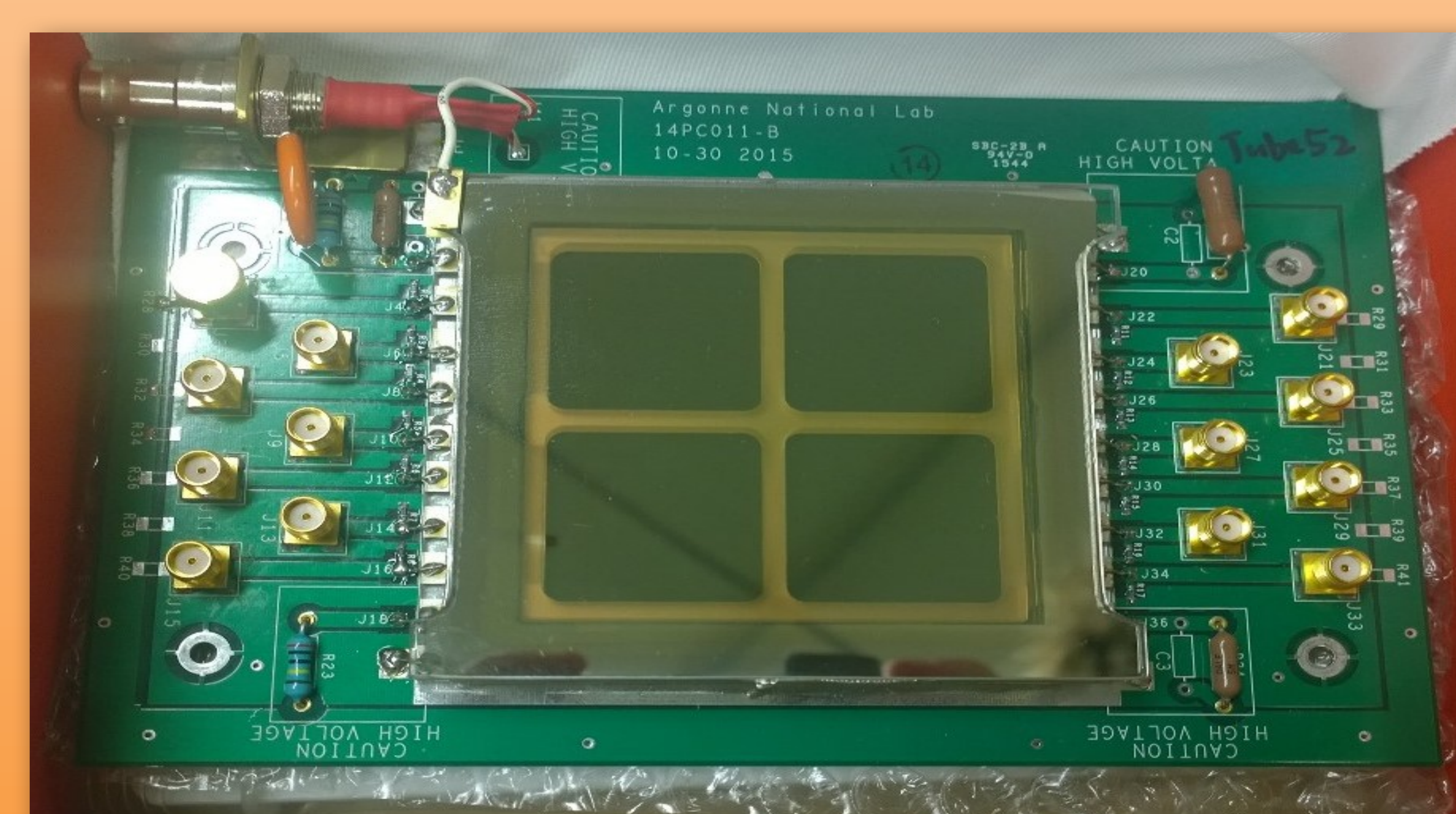

Figure 3: A MCP-PMT is a photon detector that uses a photocathode to produce electrons. These electrons are then pushed through small glass capillaries by an electric field. When traveling through the glass, more electrons are produced through secondary emission and are captured by an anode. The MCP-PMT shown above was being tested by the LArIAT team at Fermilab.

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