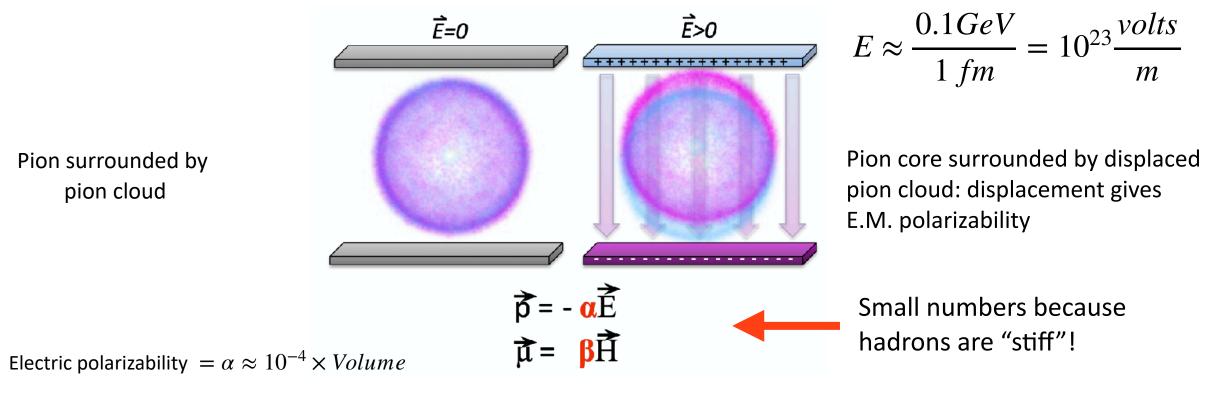
Run Plan and Analysis Preparation for Charged & Neutral Pion Polarizability Experiments May 25, 2022 GlueX Collaboration Meeting

Andrew Schick

With: Alex Austregesilo, Albert Fabrizi, David Hornidge, Mark Ito, Nikhil Kalra, Ilya Larin, David Lawrence, Rory Miskimen, Elton Smith, Simon Taylor, Beni Zihlmann

NEED GOOD PHOTO FOR BACKGROUND; MAYBE OVERHEAD VIEW OF MWPCS; PIC FROM TOP OF SOLENOID TOWARD DOWNSTREAM PLATFORM? (BENI?)

"Thought experiment": measure pion electromagnetic polarizability by placing pion in a capacitor at very high electric field



Magnetic polarizability $= \beta \approx 10^{-4} \times Volume$

Polarizabilities encode information about the excited states of hadrons: test effective field theories for QCD

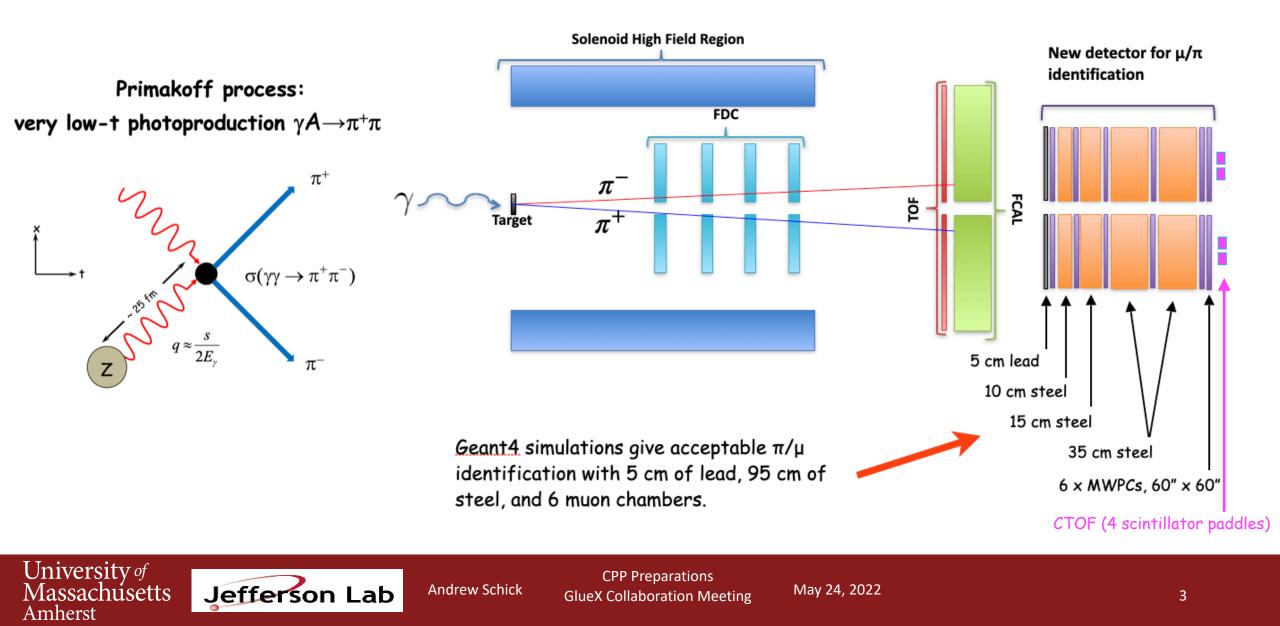
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CPP and NPP experiment at Jlab GlueX



CPP and NPP Running Conditions

Configuration	Nominal GlueX I	Charged Pion Polarizability	Neutral Pion Polarizability				
Electron Beam Energy	11.6 GeV	11.6 GeV	11.6 GeV				
Coherent Peak Energy	8.4-9.0 GeV	4.5-6 GeV	4.5-6 GeV				
Current	150 nA	27 nA	27 nA				
Radiator thickness	50 μm diamond	50 μm diamond	50 μm diamond				
Collimator aperture	5 mm	3.4 mm	3.4 mm				
Peak polarization	35%	73%	73%				
Tagging ratio	0.6	0.56	0.56				
Flux 5.5-6.0 GeV	-	11 MHz	11 MHz				
Flux 8.4-9.0 GeV	20 MHz	-	-				
Flux 0.3-11.3 GeV	367 MHz	56 MHz	56 MHz				
Target Position	65 cm	1 cm	1 cm				
Target, length	LH2, 30 cm	²⁰⁸ Pb, 0.03 cm	²⁰⁸ Pb, 0.03 cm				
Start Counter and DIRC	Nominal	Removed	Removed				
Tagger microscope	Nominal for Peak at 9 GeV	Moved for Peak at 6 GeV	Moved for Peak at 6 GeV				
Muon Detector	None	Installed behind FCAL	Not needed				
Trigger	FCAL/BCAL (40 kHz)	TOF (30 kHz)	FCAL/BCAL (10 kHz)				

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Talk Overview

Hardware

- Muon detector: Forward Multi-Wire Proportional Chambers and CTOF
 - Description of FMWCP and CTOF for Shift Takers
- Tagger Microscope moved to cover 6 GeV coherent peak: <u>GlueX-doc-5420-v1</u>
- Target and modifications to target area to use solid Pb target
- Trigger
 - CPP will use a trigger based on the TOF (new)
 - NPP will use the FCAL/BCAL trigger with a high threshold
- CDC AI

<u>Software</u>

- FMWPC Library
 - DFMPWCHit_Factory, DFMPWCMatchedTrack_Factory, DCPPEpEm_Factory
 - Event viewer
- Monitoring Plots for CPP and NPP

Commissioning and Run plan

Chambers installed in hall D

First 4 chambers and absorbers



Last absorber with last two chambers

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Electronics (FMWPCs and CTOF)

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- LV, HV, Gas, cables, fADCs—it's all hooked up and good to go!
- MWPCs use their own gas system w/ premixed 90:10 Ar:CO2
- 1 fADC borrowed from CDC. CDC
 will operate with 75% of its electronics
- All systems will be used except for DIRC, CCAL, and the Start Counter

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Turn OFF ALL HV		VOLTAGE CHAN	NNELS SAVE/RESTORE							
FMWPC HV	Chamber Voltages		Paddle Voltages CTOF HV							
	Connectors	Connectors	Upper (UP) PMTs							
	+5V -5V	+5V -5V								
Chamber 1 OFF	Chamber 1 OFF OFF	OFF OFF	Paddle 1 OFF Paddle 2	OFF						
Voltage (V) 1,765.0	Voltage (V) 5.000 5.000	5.000 5.006	Voltage (V) 1,699.0 Voltage (V)	1,699.0						
Current (µA) 0.1	Current (A) 0.964 0.952	2 0.933 0.967	Current (µA) 375.5 Current (µA)	377.0						
Chamber 2 orr	Chamber 2 OFF OFF	OFF OFF	Paddle 3 OFF Paddle 4	OFF						
Voltage (V) 1.766.5	Voltage (V) 4.996 5.001	5.000 5.004	Voltage (V) 1,700.0 Voltage (V)	1.698.5						
Current (µA) 0.0	Current (A) 0.947 0.945	0.949 0.943	Current (µA) 374.5 Current (µA)	379.0						
Chamber 3 OFF	Chamber 3 OFF OFF	OFF OFF								
Voltage (V) 1.765.0	Voltage (V) 4.999 4.998	4.999 4.999								
Current (µA) 0.3	Current (A) 0.949 0.932	2 0.929 0.945	Lower (DOWN)							
Chamber 4 OFF	Chamber 4 OFF OFF	OFF OFF								
Voltage (V) 1,764.0	Voltage (V) 4.998 5.000	5.002 4.999	Paddle 1 OFF Paddle 2	OFF						
Current (µA) 0.0	Current (A) 0.936 0.942	2 0.940 0.941	Voltage (V) 1,699.5 Voltage (V)	1,699.5						
Chamber 5 OFF	Chamber 5 OFF OFF	OFF OFF	Current (µA) 376.5 Current (µA)	377.0						
Voltage (V) 1,765.0	Voltage (V) 5.003 4.996		Paddle 3 OFF Paddle 4	OFF						
Current (µA) 0.0	Current (A) 0.937 0.948		Voltage (V) 1,698.5 Voltage (V)	1.699.5						
currenc (pro oto			Current (µA) 376.0 Current (µA)	378.5						
Chamber 6 OFF	Chamber 6 OFF OFF	OFF OFF								
Voltage (V) 1,765.0	Voltage (V) 5.003 5.000									
Current (µA) 0.0	Current (A) 0.938 0.943	0.958 0.945								
FMWPC HV Voltages	FMWPC LV Channels	Voltages	2000 CTOF HV Voltages							
1000	26 8 ₄ 4		2 81000							
			A design of the second s							
0 1 2 3 4 5 6 Channel #	7 0 2 4 6 8 10 12 14 Charmel #	16 18 20 22 24 26	0 100000000000000000000000000000000000	.5 7 7.5 8 8 .						
201 FMWPC HV Currents	3: FMWPC LV Channels	Currents	500 3 CTOF HV Currents							
0	3_2	3.								
10-	() 1 1 1		툴 200 · · · · · · · · · · · · · · · · ·	+ +						
• †iiii										
0 1 2 3 4 5 6 Channel#	7 0 2 4 6 B 10 12 14 Channel #	16 18 20 22 24 26	0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6 Channel #	.5 / /.5 8 8.						

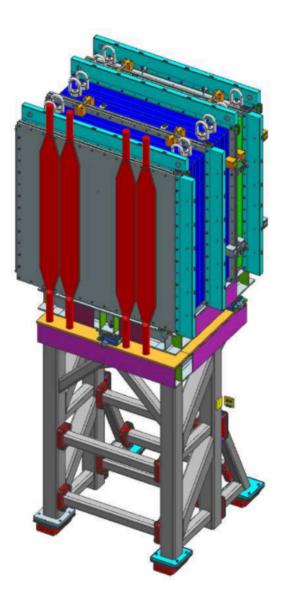
May 24, 2022

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CTOF FP Trigger Test 5/8/22

CTOF = Scintillators at back of wire chambers—read out at both ends. Test MWPC efficiency, and also to create a muon trigger that will be added to the front panel trigger supervisor



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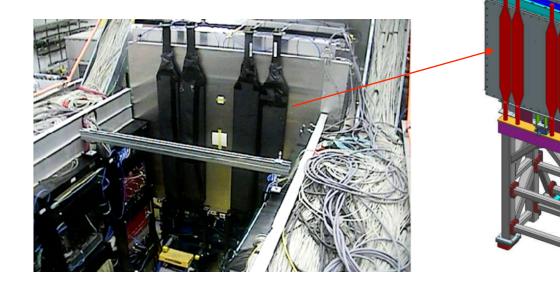


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CTOF FP Trigger Test 5/8/22



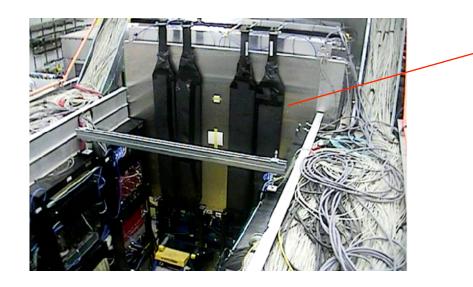
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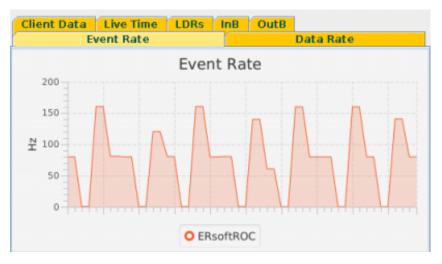
CTOF FP Trigger Test 5/8/22



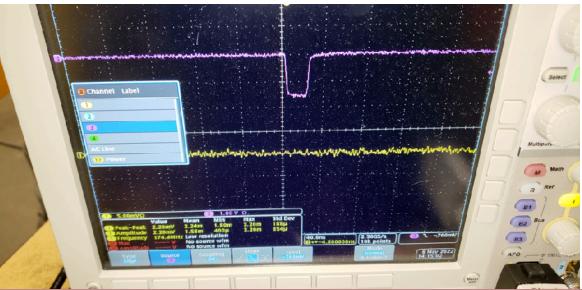
Trigger rate (bit 6 on the right plot is the TS front panel trigger generated by the CTOF paddles)

Update Timer (sec): 5 🛓 Start 3	top <u>R</u> eset	Exit
TS GTP 30 25 15 10 0 2 4 6 8 10 12 14 GTP input	TS FP [H] 70 90 60 40 30 20 10 2 4 6 8 10 12 14 16 FP input	CTP Race (Hz) Lane 0 28.0 Lane 1 0.0 Lane 2 0.0 Lane 3 0.0 TS livetime (X)
I Iniversity of		

DAQ rate



NIM signal produced by OR of CTOF paddles (provided by Beni)



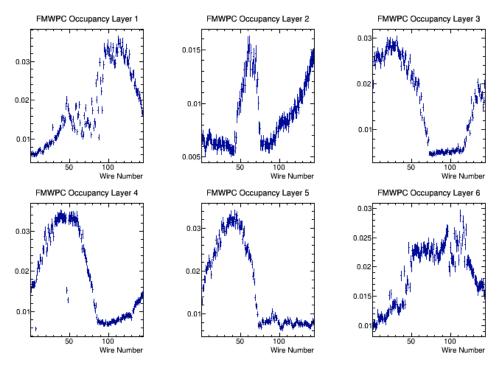
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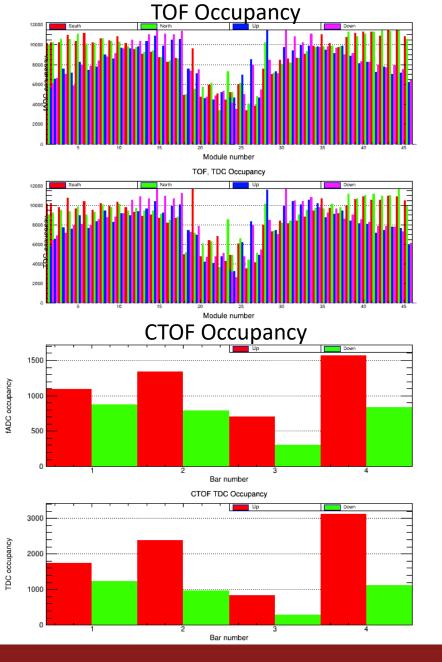
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Run100238 Cosmic Test



FMWPC Occupancy



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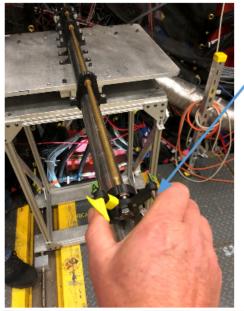
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Target

- Use the 5% R.L. enriched ²⁰⁸Pb target from PrimEx I: see NIM A 612, 46 (2009)
- Position the target position at z=1 cm, near the front face of the solenoid
- Need a quick and reproducible way to remove the ²⁰⁸Pb target and insert an empty target frame

Switching between full and empty



Grab threaded studs to rotate clockwise 90° to put lead in beam, rotate ccw 90° to put blank frame in beam

Yellow flag pointing up Lead Target in Beam

> Empty Target in Beam

> > Yellow flag pointing Beam Left

> > > 12

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CPP and NPP Trigger (THIS SLIDE NEEDS HELP)

 Sasha Somov recorded few runs in raw mode at the end of SRC run for the firmware testing

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- Firmware was made by Hai Dong specifically for TOF trigger.
- Ilya determined the rates to be 25% higher compared to what we measured year ago during dedicated runs.
- 25% higher rates well within our safety margin.

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- 1. the novel TOF trigger
- 2. FCAL/BCAL trigger with 1 GeV total energy threshold
- 3. PS trigger (the same way as it is organized for GlueX
- 4. Random trigger (frequency increased for the test to 1kHz)
- 5. FP trigger using CTOF

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Scientific Achievement

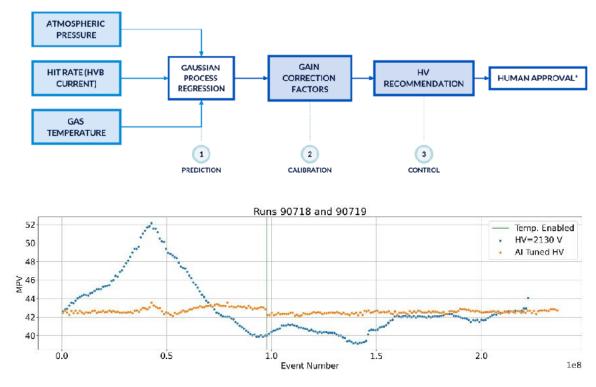
A ML system to calibrate and control the GlueX Central Drift Chamber.

Significance and Impact

The ML system recommends anode voltages and calibration values for the detector in response to changing environmental conditions. This in turn stabilizes the response of the detector throughout the duration of the experiment and reduces the calibration efforts required afterwards.

Research Details

- Gaussian process regression uses EPICS measurements to predict calibration values and determine voltage settings throughout the experiment.
- Successfully tested during PrimEx (Oct-Nov 2021) and fully automated during cosmic tests.
- Application to other detector systems at the Lab in progress.



Top plot: ML system used to predict calibration values and HV settings for the CDC. Bottom plot: MPV values obtained from Landau fit to pulse height for constant HV (blue) and ML-tuned HV (orange). Using the tuned HV settings stabilizes the CDC chamber gain in response to changes in environmental conditions.



CPP software

Started holding weekly CPP software meetings to address needs prior to summer run

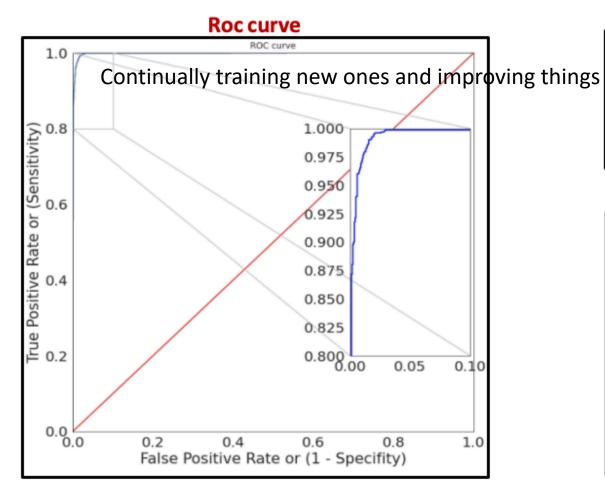
• Thursdays at 12:30 pm on zoom, listed on CPP meeting page

Achieved goals

- AI/Machine Learning
 - MWPC Neural Net for μ/π separation, TMVA Neural Net for e/π separation
- DFMWPCHit_Factory: for creating calibrated MWPC hits from non-calibrated MWPC hits
- DFMWPCMatchedTrack_Factory: for producing objects to be used with ML models e.g. E_{fcal}/p , # of MWPC wires hit, X,Y of projected track to face of MWPCs
- DFMWPCEpEm_Factory: for actually applying the μ/π , e/π inferences on their respective models
- Monitoring plugins for producing kinematic plots in real time
- Updated HDView2 for CPP

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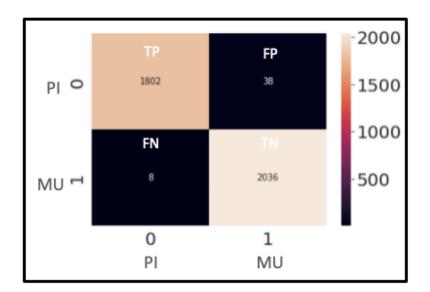
Multivariate Analysis for μ/π



David Lawrence, Malachi Schram, Nikhil Kalra

Classification report

	cl precision	assificat recall	support			
0.0	0.98 0.99	0.99 0.98	0.99 0.99	1887 1997		
accuracy macro avg weighted avg	0.99 0.99	0.99 0.99	0.99 0.99 0.99	3884 3884 3884		



Confusion_Matrix

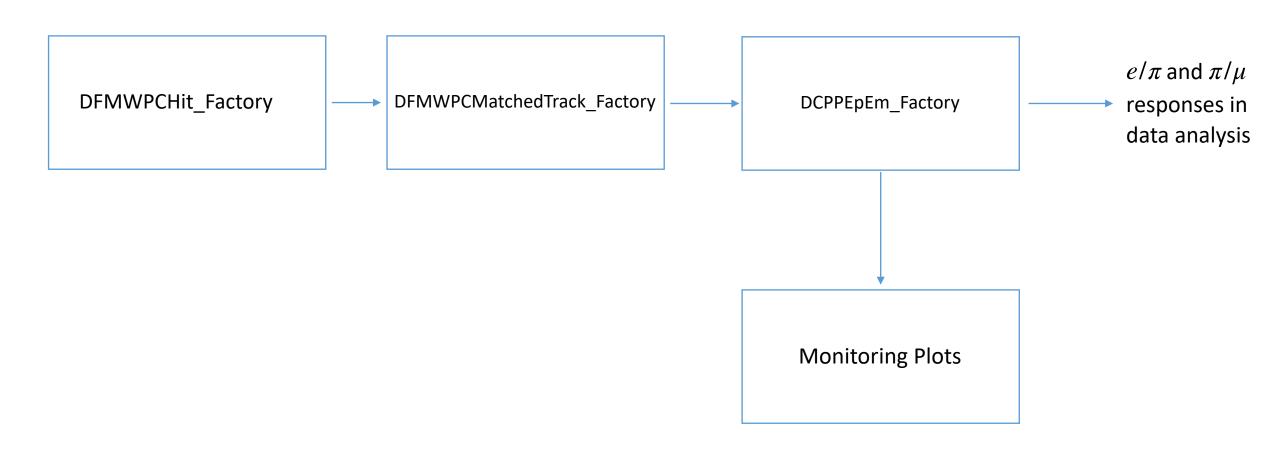
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DRAFT SLIDE



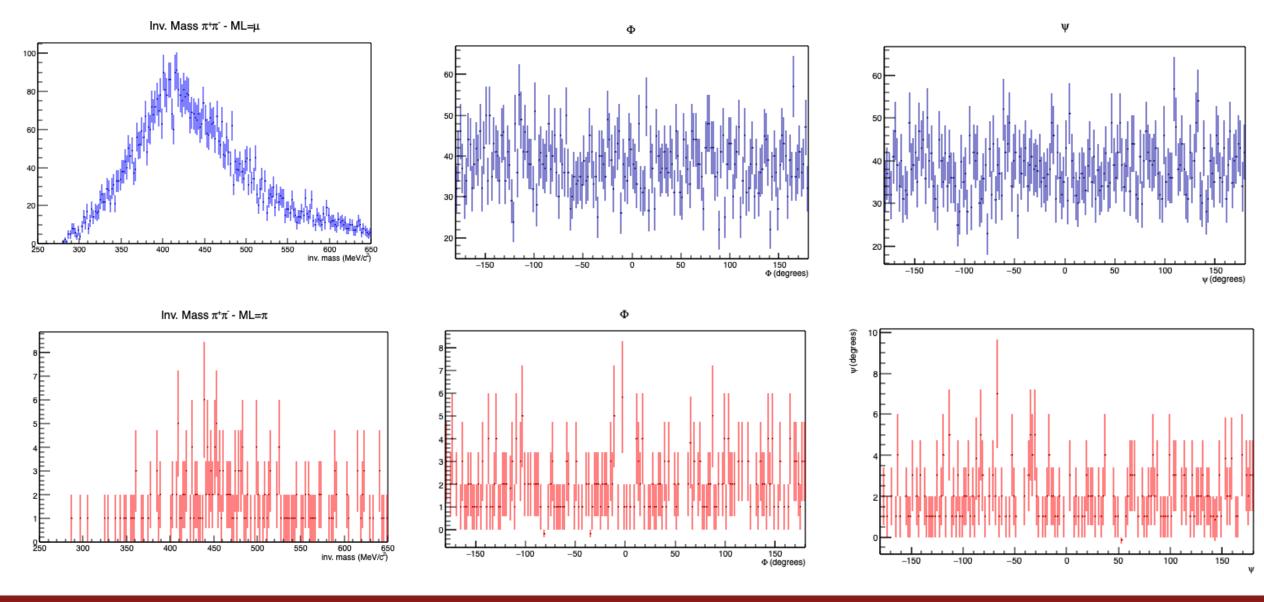
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Draft slide

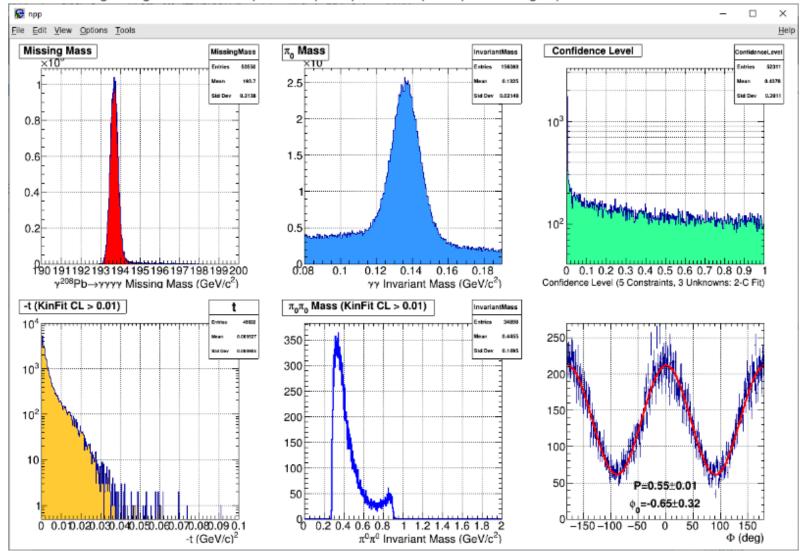


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New monitoring histograms for NPP experiment (example for sample of pure MC signal):

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FMWPC Inspector in HDView2

Source: .././output_files_mumu/hddm/cpp_mumu_20220121_071729_000_geant4_smeared.hddm View Controls Inspectors Event Controls <u>Q</u>uit Open ZOOM Transverse Coordinates Run: 71728 Track Inspector -X X+ Continuous ⊙ X/y <-- Prev Next --> - + Event: 501047 -Y Y+ delay: 0.25 👻 **FMWPC** Inspector O r/phi w/ this GTP bits: no bits Z Zi Reset button from downstream to BCAL colors Track Draw Options top view (looking down from above detector) DTrackCandidate: defaults DTrackWireBased: <default> 💌 1.00 GeV 316.2 MeV DTrackTimeDased: <dsfault> -DChargedTrack: <default> 🔻 31.6 Me\ 10.0 MeV DNeutralParticle 3.2 MeV DMCThrowr 1.0 MeV DMCTrajectoryPoint Depugger I lit Draw Options ⇒z —|90 cm E CDC BcalDisp FCAL side view from beam right (south CDC Drift Time FCAL colors CDCTruth FDC Wire 3.16 Ge FDC Pseudo 1.00 GeV FDCTruth ✓ TOF 31.6 Me¹ TOFTruth 10.0 MeV FCAL 3.2 MeV 🔽 BCAL 1.0 MeV CCAL FMWPC ⊢z -|90 cm More options -Track Info -Throw Reconstructed FOM: DTrackTimeBased: trk theta Z: ťk: chisg/Ndof: Ndof: cand: 12 0.0002365 4.147 -2400 2 848 2.119 28.77 -0.74451.62 35 0.0116242 2.609 2.109 0.5345 1.012 -0.7418 1.62 35 0.0116042 2 nia 2 844 28.79 2119 5.85 1.335 3.504 1.012 - 3 K+ 2 843 -0.762 1.632 35 0.0104948 2.11928.8 1.673 82.56 1.012 2.839 28.85 -0.8211 35 0.05099 0.02927 2 1 1 8 0.00752428 5.927 1.38 -158.8 4.861 0.7956 31 0.782551 5.914 1.00 -150.0 4.075 0.7974 01 0.700161 5.917 1.38 -158.8 4.868 0.7962 31 0.781741 1.38 4.881 0.7978 -158.8 -31 0.779629 5.91 Full List

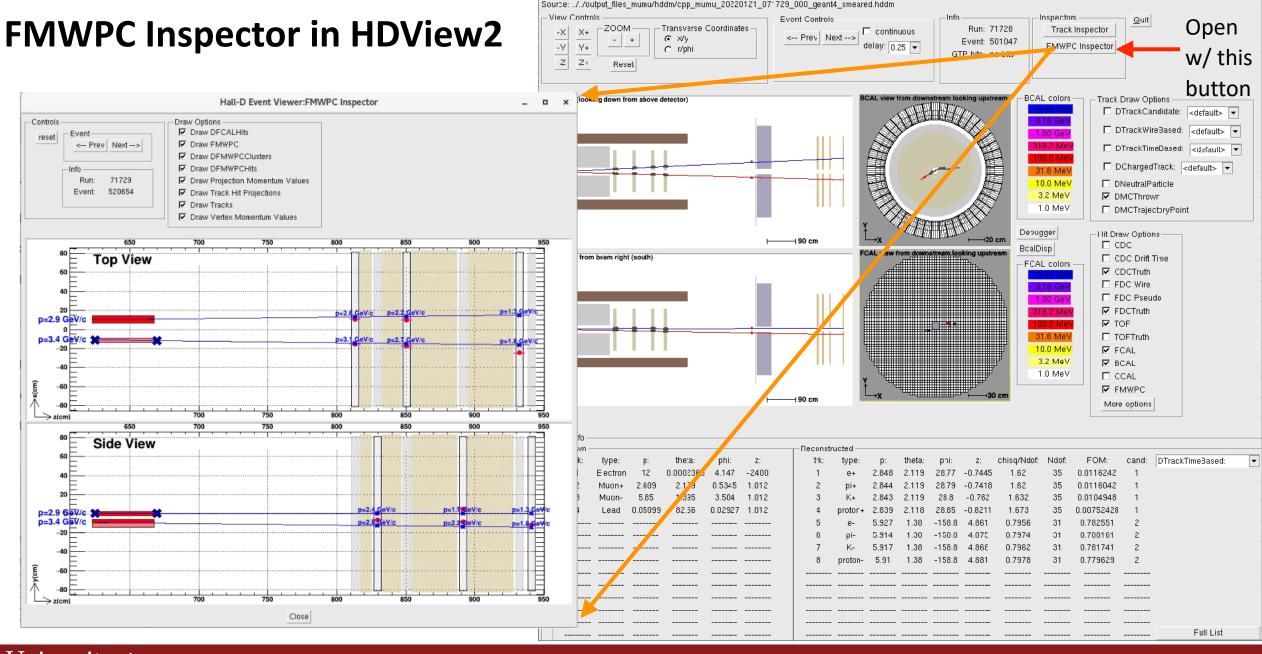
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Activity	J	F	Μ	Α	Μ	J	J	Α	S	0	Ν	D	J	F	Μ	Α	Commissioning
Accelerator operation																	
MWPCs Fabrication Transport to Jlab Staging and testing in ESB]				
Installation on muon detector Checks with beam																	
Muon detector mechanical Order major pieces Receive major pieces Assemble muon detector																	
Target assembly procurements Checks with beam								L									
Trigger TOF Design requirements TOF Firmware coding and simulation TOF Verification (Test stand) TOF Field test Trigger integration]]		[]				
Tagger microscope move Purchase alignment hardware Move to 6 GeV coherent peak position Checks with beam]												
University of Massachusetts Amherst	on L	.ab	And	rew Schi	ck			arations ation Mee	eting	May	24, 202	2					22

Draft Commissioning Steps

- 1. Setup photon beam operation at 50 nA.
- 2. Check microscope and hodoscope operation in new configuration
- 3. Align diamond to 6 GeV coherent edge
- 4. Check rates in microscope in new position
- 5. Check radiation and backgrounds rates in Hall D with Pb target
 - Check rates and beam stability at 30 nA
 - Check currents and hit distributions in the MWPCs
- 6. Complete a HV scan for the TOF and CDC. Adjust voltages accordingly, especially those of the TOF in advance of trigger studies.
- 7. Take data for adjustment of the FCAL PMT gains.
- 8. Optional: Check rates for two collimator configurations (5 and 3.4 mm)? Use profiler to stabilize the beam during test.
- 9. Compare empty vs full target rates
- 10. Adjustable Pb absorber (upstream of muon detector)
- 11. Commission trigger
 - Charged Trigger (TOF)
 - Neutral Trigger (FCAL/BCAL)
 - Calibration triggers (CTOF, random, PS)
 - Compare empty/full trigger rates
- 12. PS Magnet
 - Set nominal value for CPP=2/3* nominal GlueX. Take some data at the nominal GlueX setting for reference.
- 13.Beam energy calibration
 - May need to repeat periodically





Data taking operations

- TAC runs (x2): *near the beginning and end of CPP running*
- HARP scans
- Establish Beam Polarization: 0,0,90,90, amorphous (tentatively ~10% amo.)
- Straight track running
- Running with full target and empty target. Ratio of empty vs full will be determined during commissioning.
- Data production with CPP, NPP and CTOF triggers on full target.