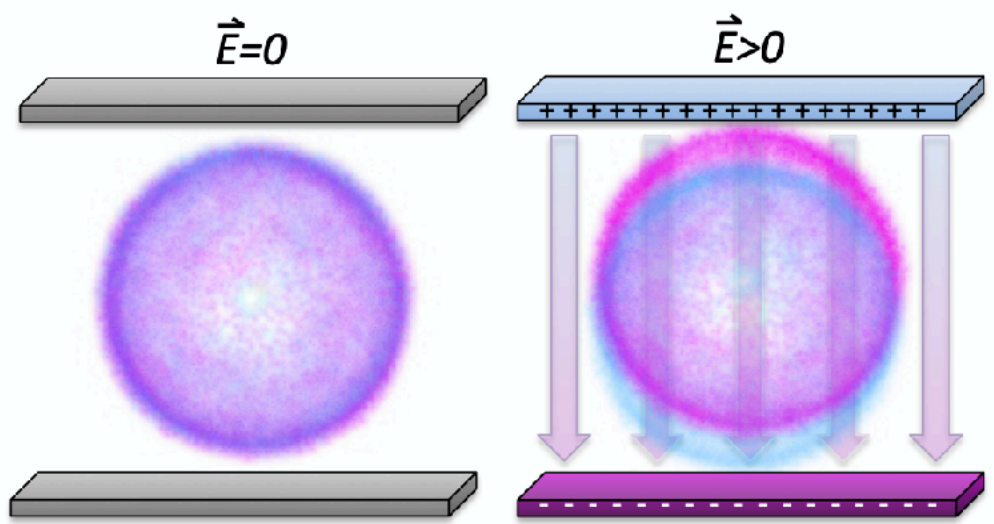
Run Plan and Analysis Preparation for Charged & Neutral Pion Polarizability Experiments
May 25, 2022
GlueX Collaboration Meeting

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



$$E \approx \frac{0.1 GeV}{1\ fm} = 10^{23} \frac{volts}{m}$$

Pion surrounded by pion cloud

Pion core surrounded by displaced pion cloud: displacement gives E.M. polarizability

Small numbers because hadrons are “stiff”!

Electric polarizability $= \alpha \approx 10^{-4} \times Volume$

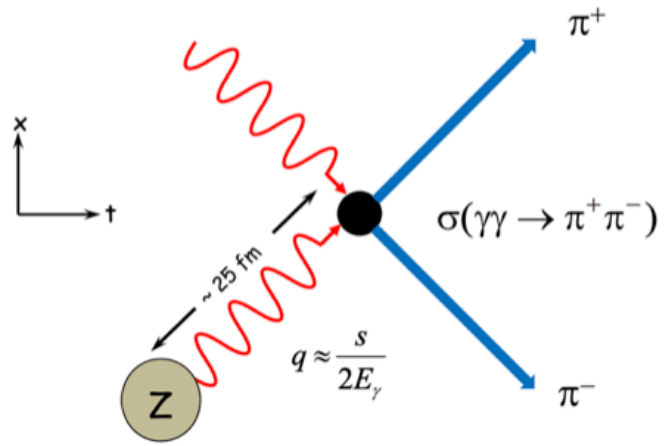
Magnetic polarizability $= \beta \approx 10^{-4} \times Volume$

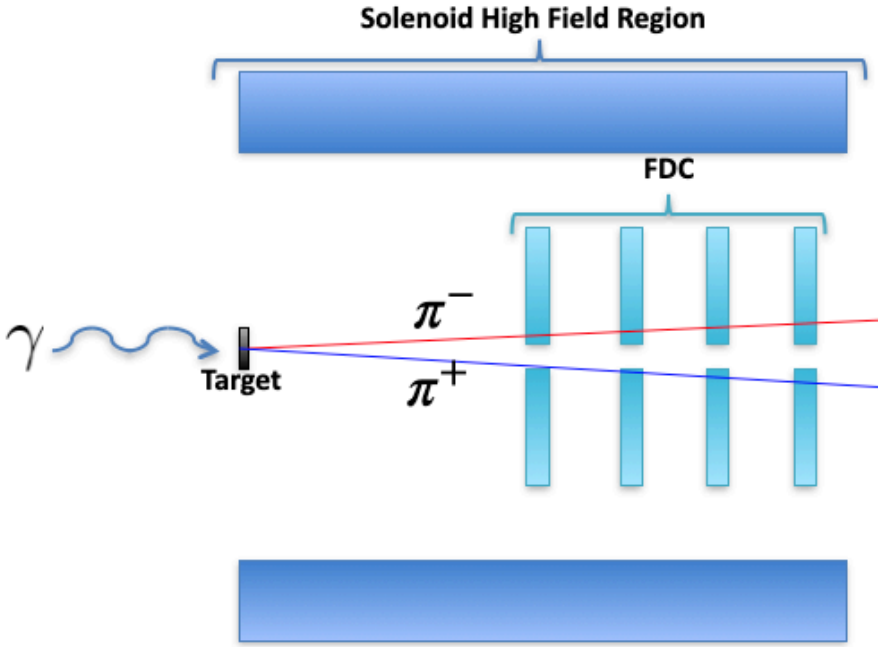
Polarizabilities encode information about the excited states of hadrons: test effective field theories for QCD

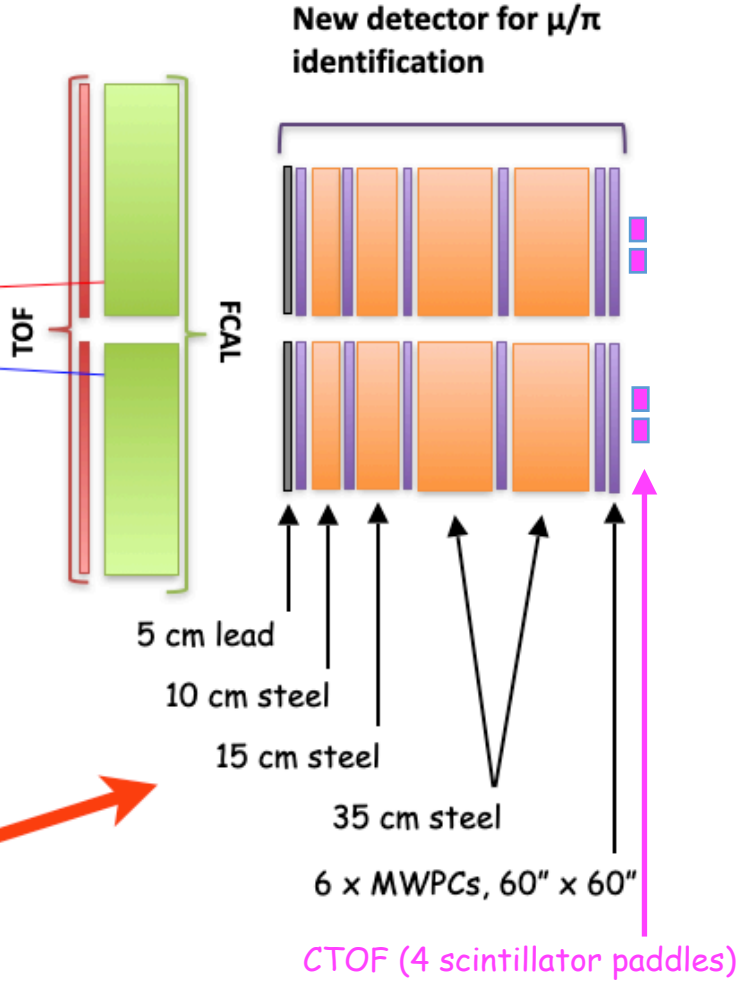
CPP and NPP experiment at Jlab GlueX

Primakoff process:

very low-t photoproduction $\gamma A \rightarrow \pi^+\pi$







Geant4 simulations give acceptable π/μ identification with 5 cm of lead, 95 cm of steel, and 6 muon chambers.

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)

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: GlueX-doc-5420-v1
- 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

Software

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

Commissioning and Run plan

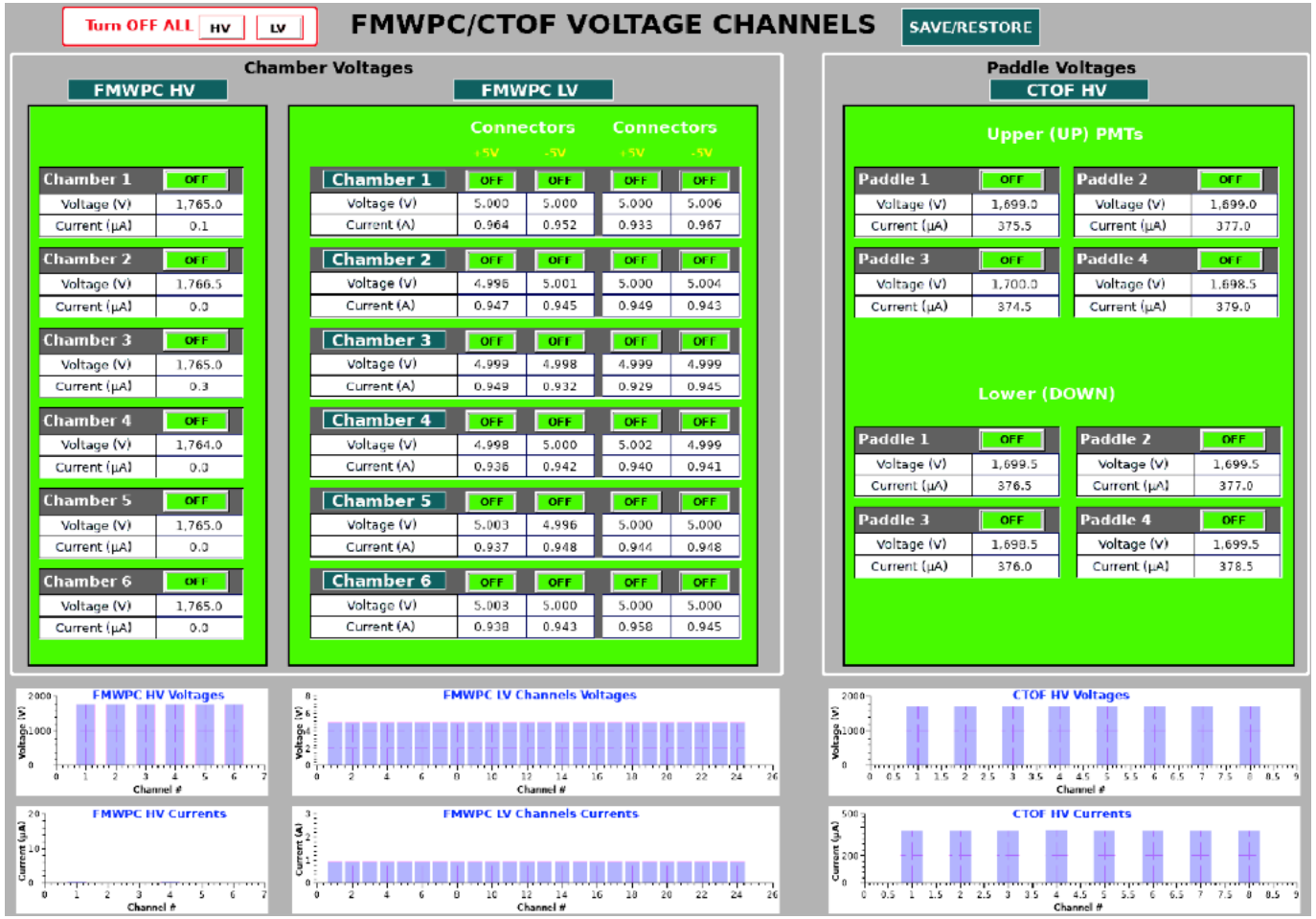
Chambers installed in hall D

First 4 chambers and absorbers

Last absorber with last two chambers

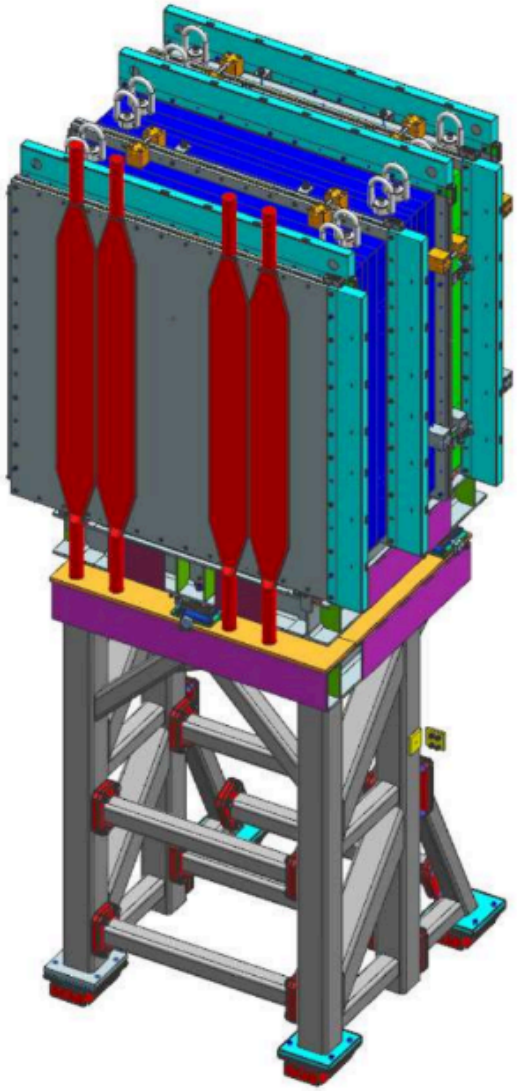
Electronics (FMWPCs and CTOF)

- **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

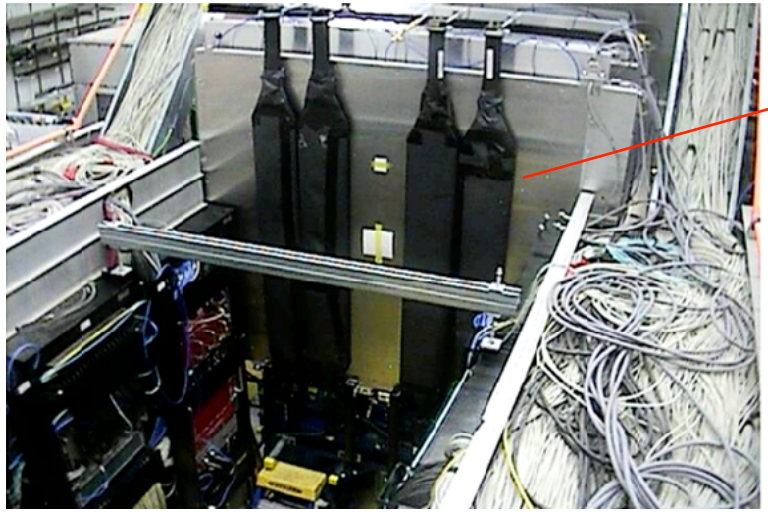


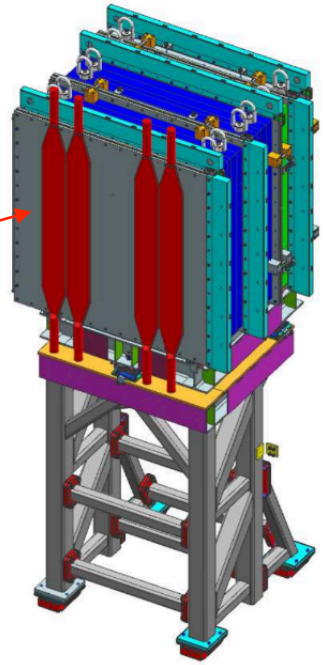
CTOF FP Trigger Test 5/8/22

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

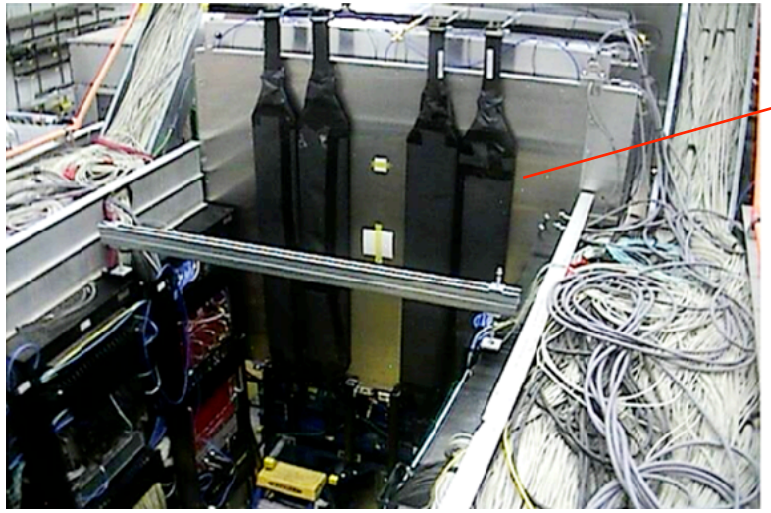


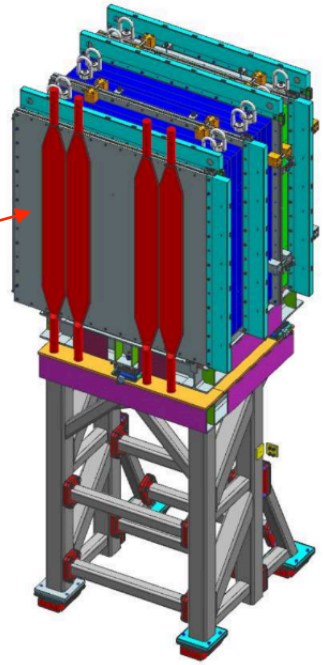
CTOF FP Trigger Test 5/8/22



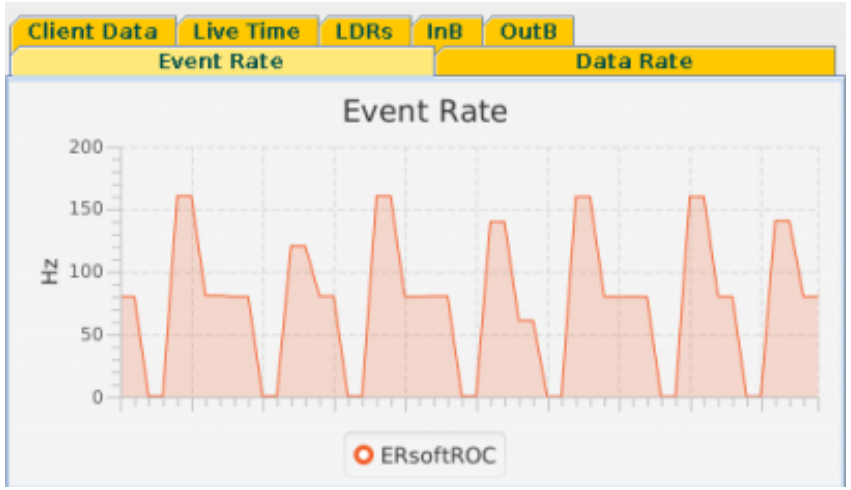


CTOF FP Trigger Test 5/8/22

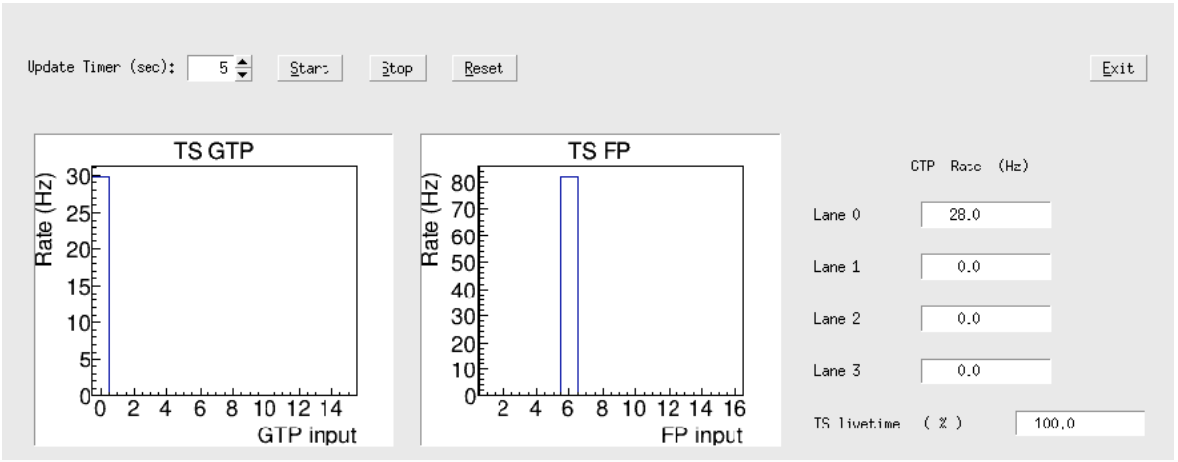




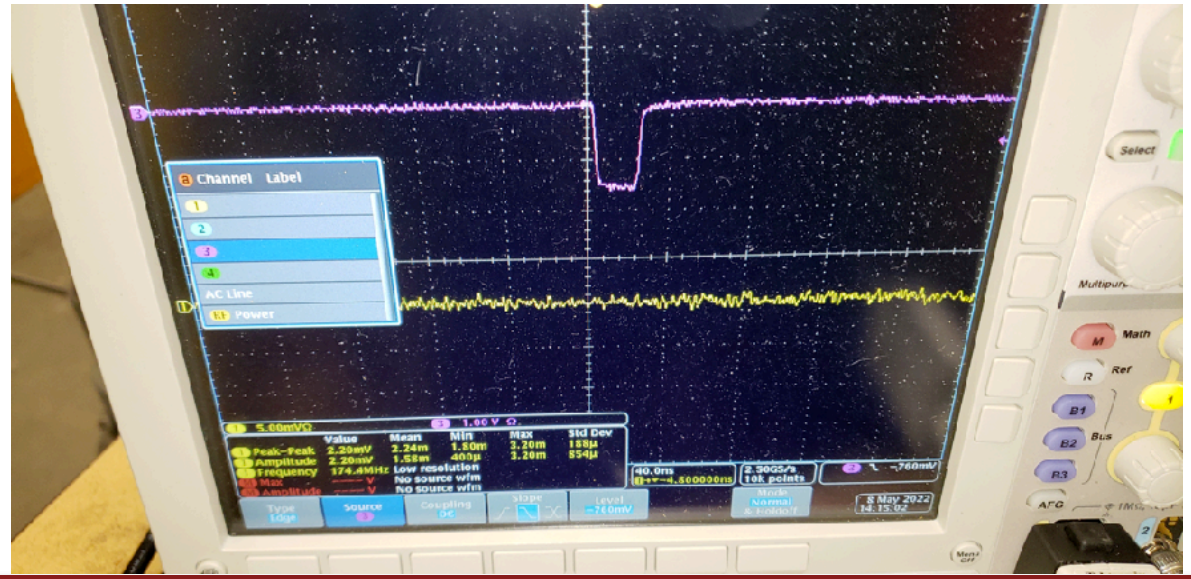
DAQ rate



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

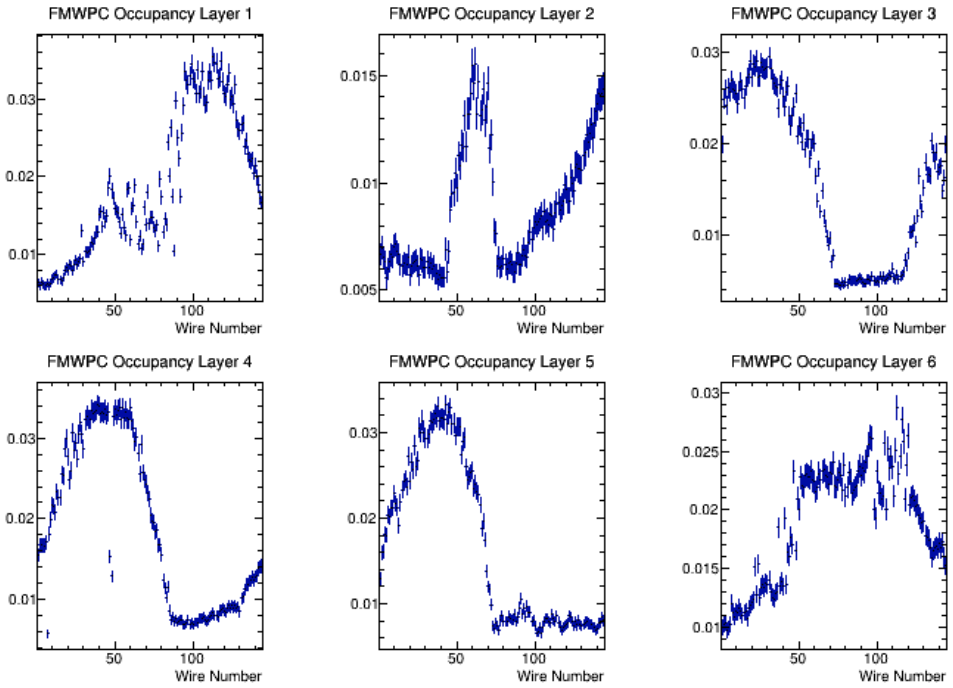


NIM signal produced by OR of CTOF paddles (provided by Beni)

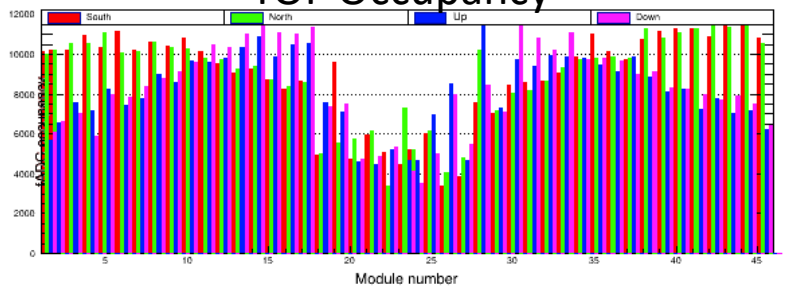


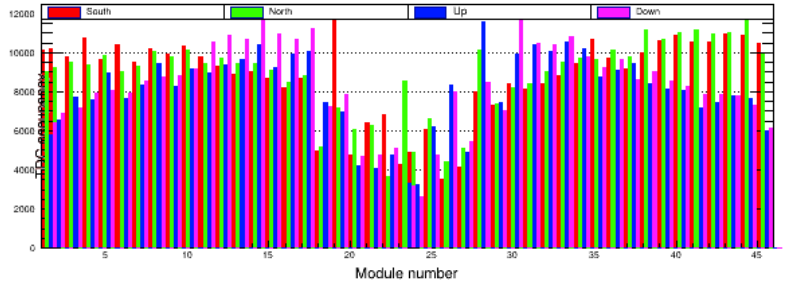
Run100238 Cosmic Test

FMWPC Occupancy

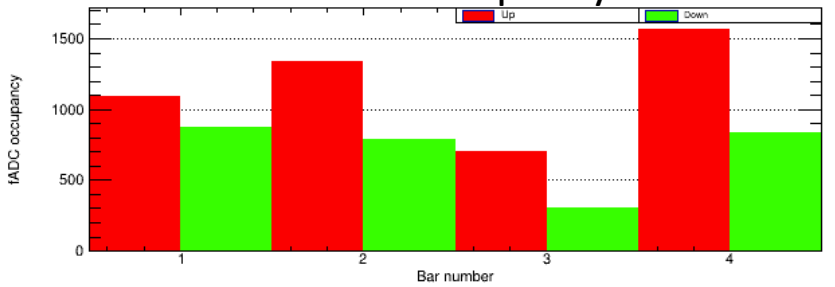


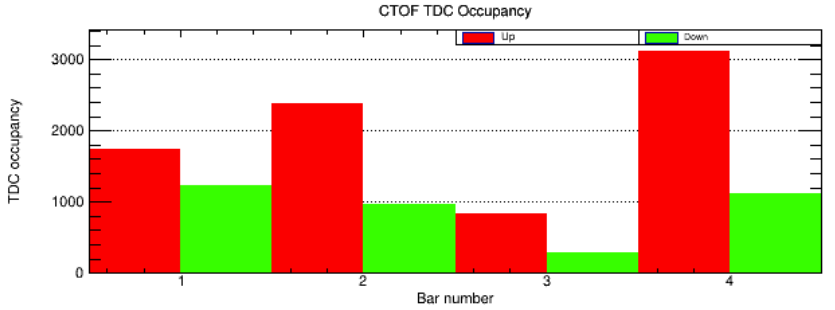
TOF Occupancy





CTOF Occupancy

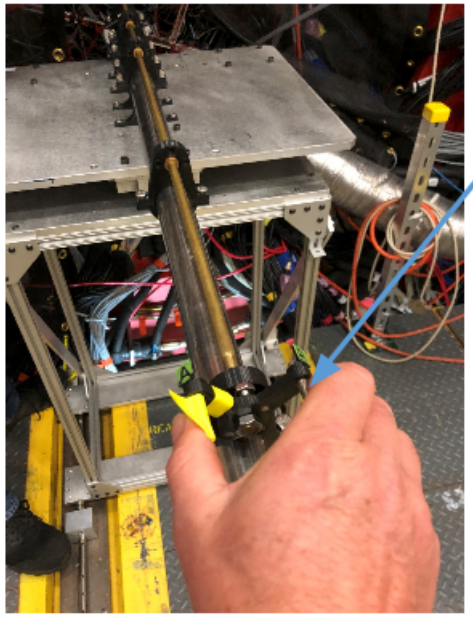




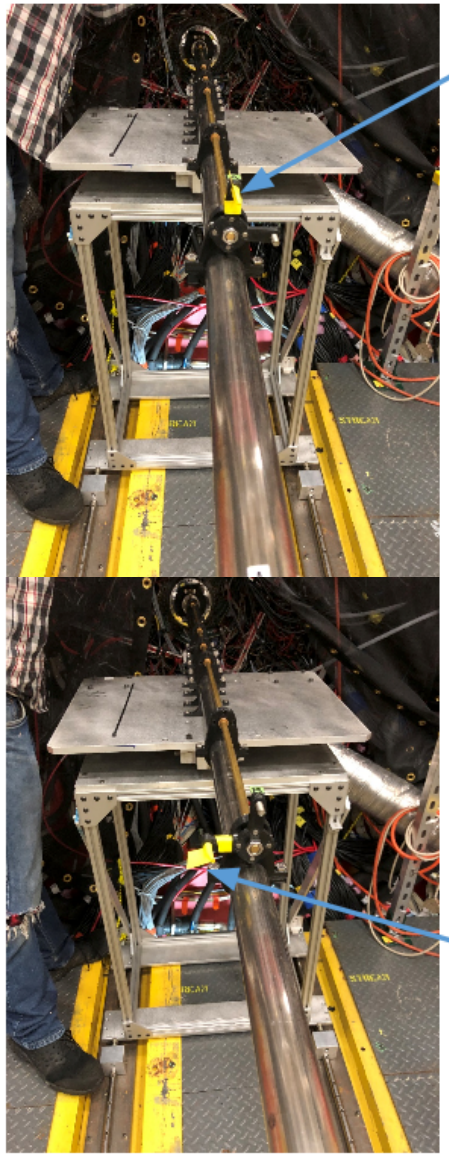
Target

- Use the 5% R.L. enriched ^{208}Pb 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 ^{208}Pb 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

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
- 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.

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

AI for Experiment Control and Calibration

Scientific Achievement

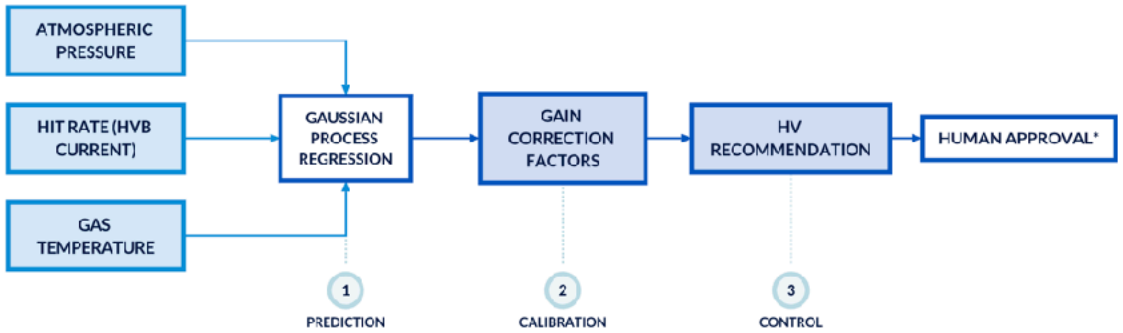
A ML system to calibrate and control the GlueX Central Drift Chamber.

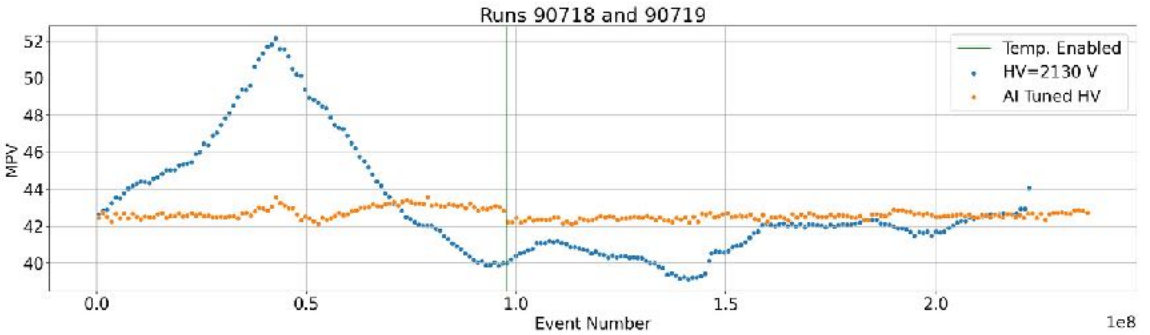
Significance and Impact

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

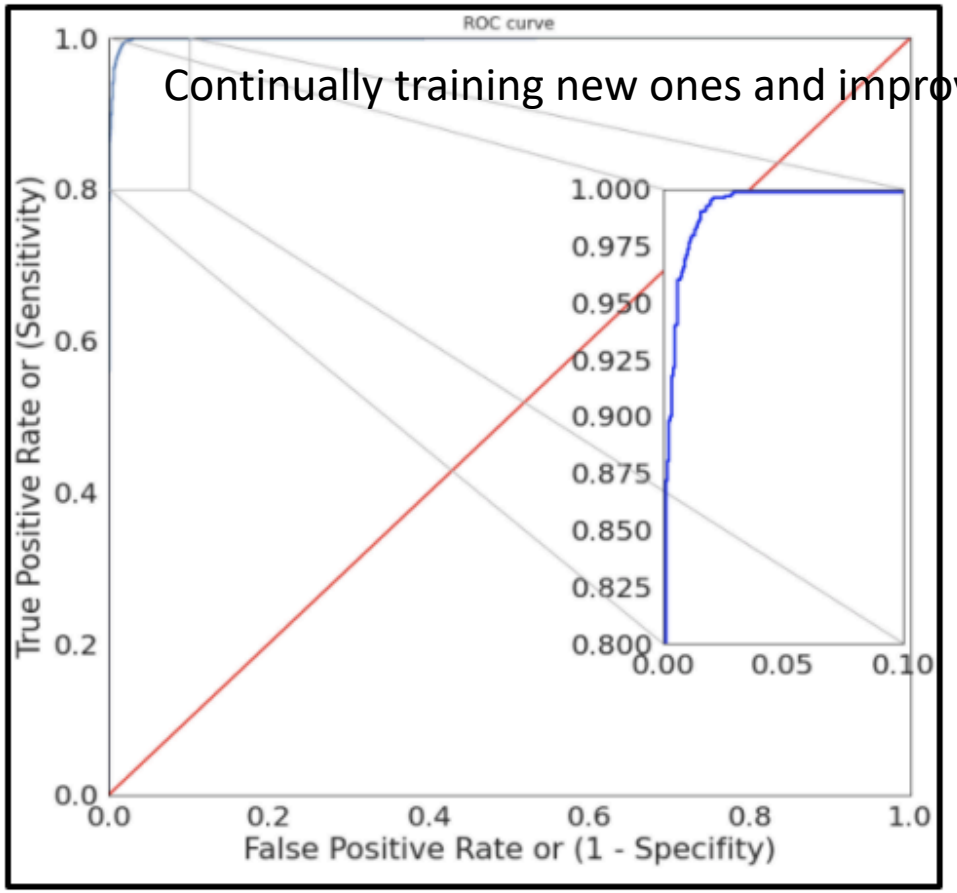
- Thursdays at 12:30 pm on zoom, listed on CPP meeting page

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

Multivariate Analysis for μ/π

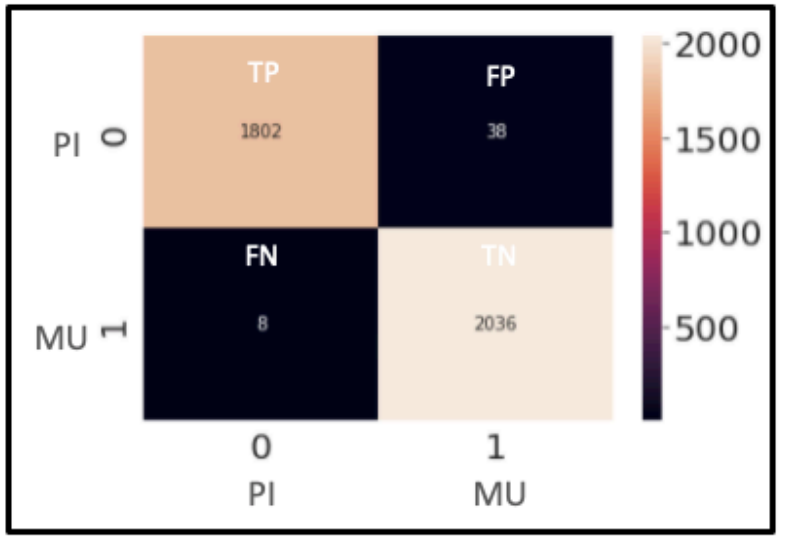
Roc curve



Continually training new ones and improving things

Classification report

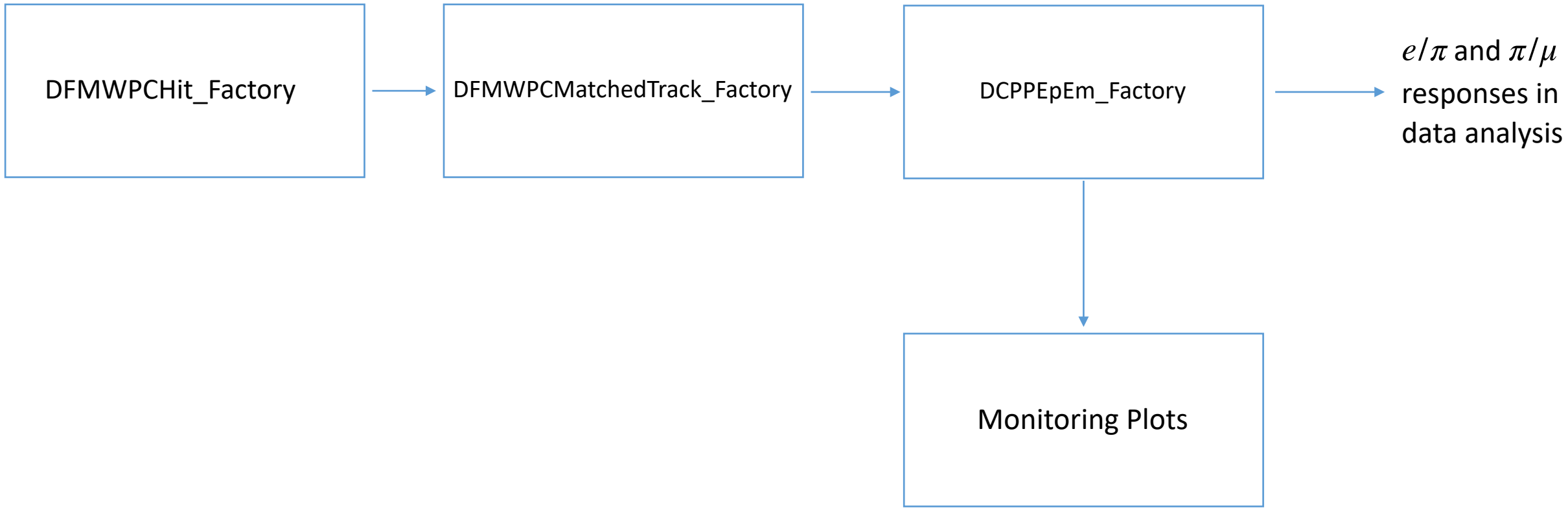
	classification_ report			
	precision	recall	f1-score	support
0.0	0.98	0.99	0.99	1887
1.0	0.99	0.98	0.99	1997
accuracy			0.99	3884
macro avg	0.99	0.99	0.99	3884
weighted avg	0.99	0.99	0.99	3884



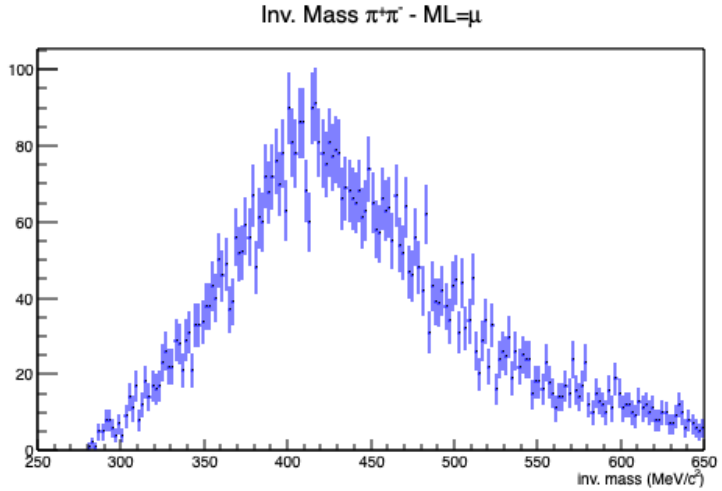
Confusion_Matrix

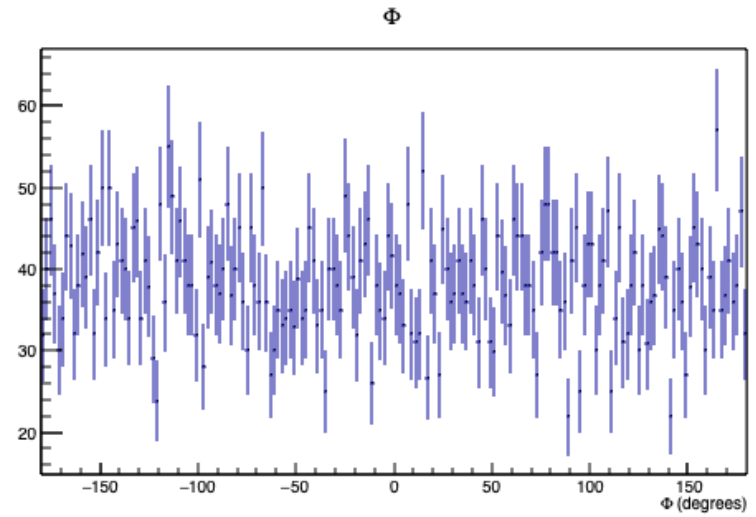
David Lawrence, Malachi Schram, Nikhil Kalra

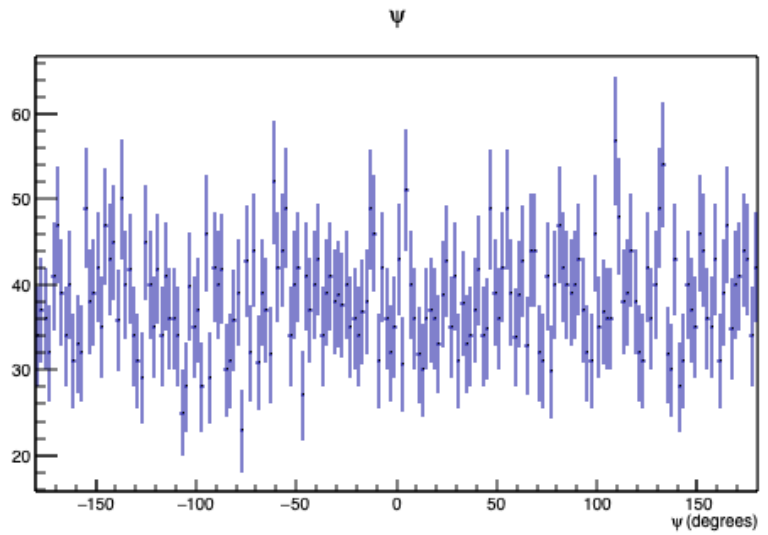
DRAFT SLIDE


DFMWPCHit_Factory
DFMWPCMatchedTrack_Factory
DCPPEpEm_Factory
e/π and π/μ responses in data analysis
Monitoring Plots

Draft slide


Inv. Mass π⁺π⁻ - ML=μ
inv. mass (MeV/c²)


Φ
Φ (degrees)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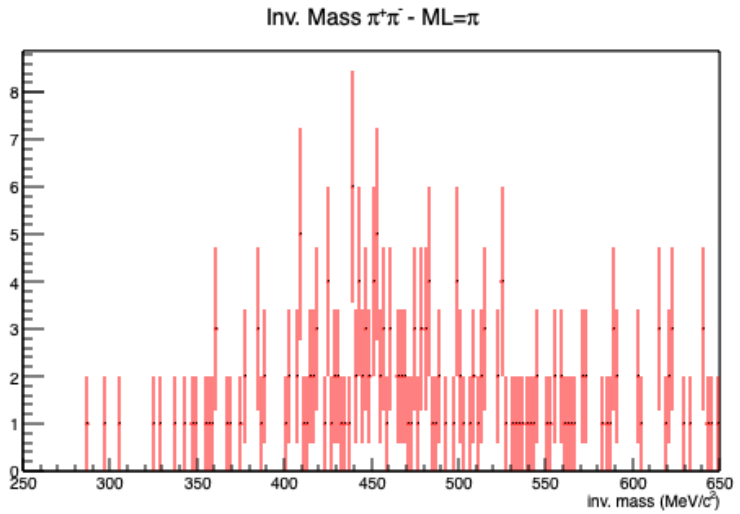
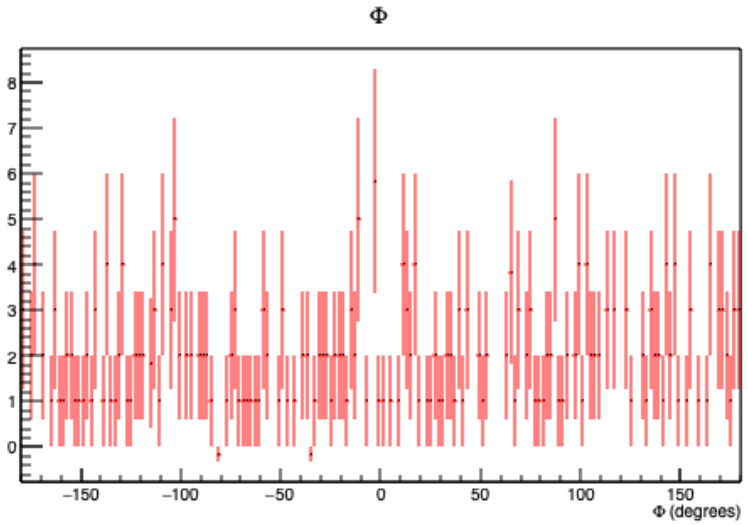
Ψ (degrees)


Inv. Mass π⁺π⁻ - ML=π
inv. mass (MeV/c²)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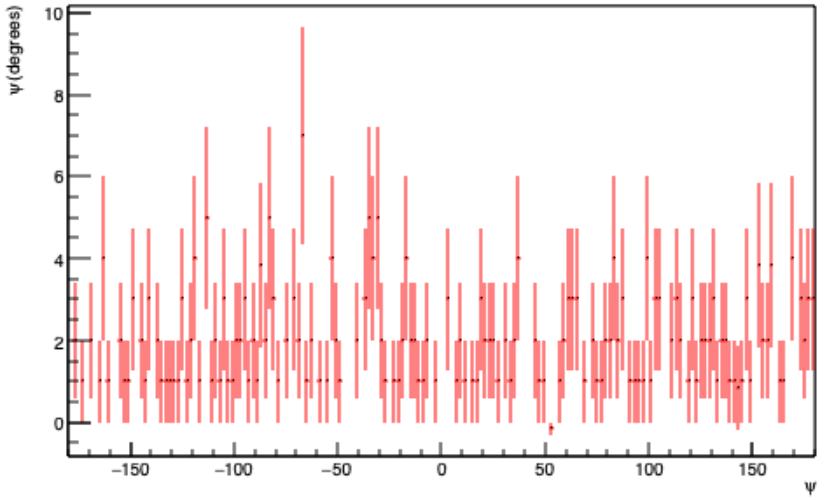
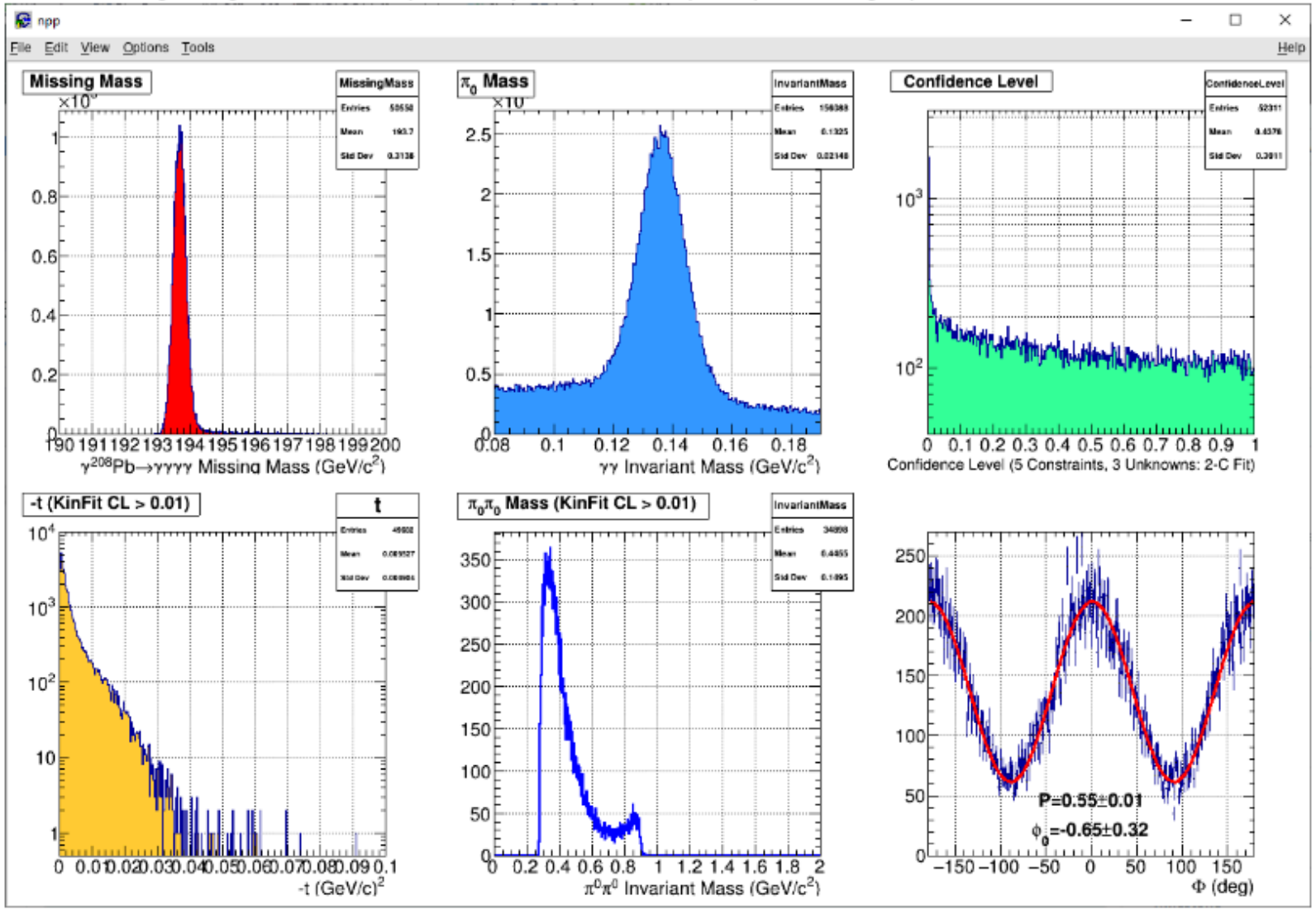
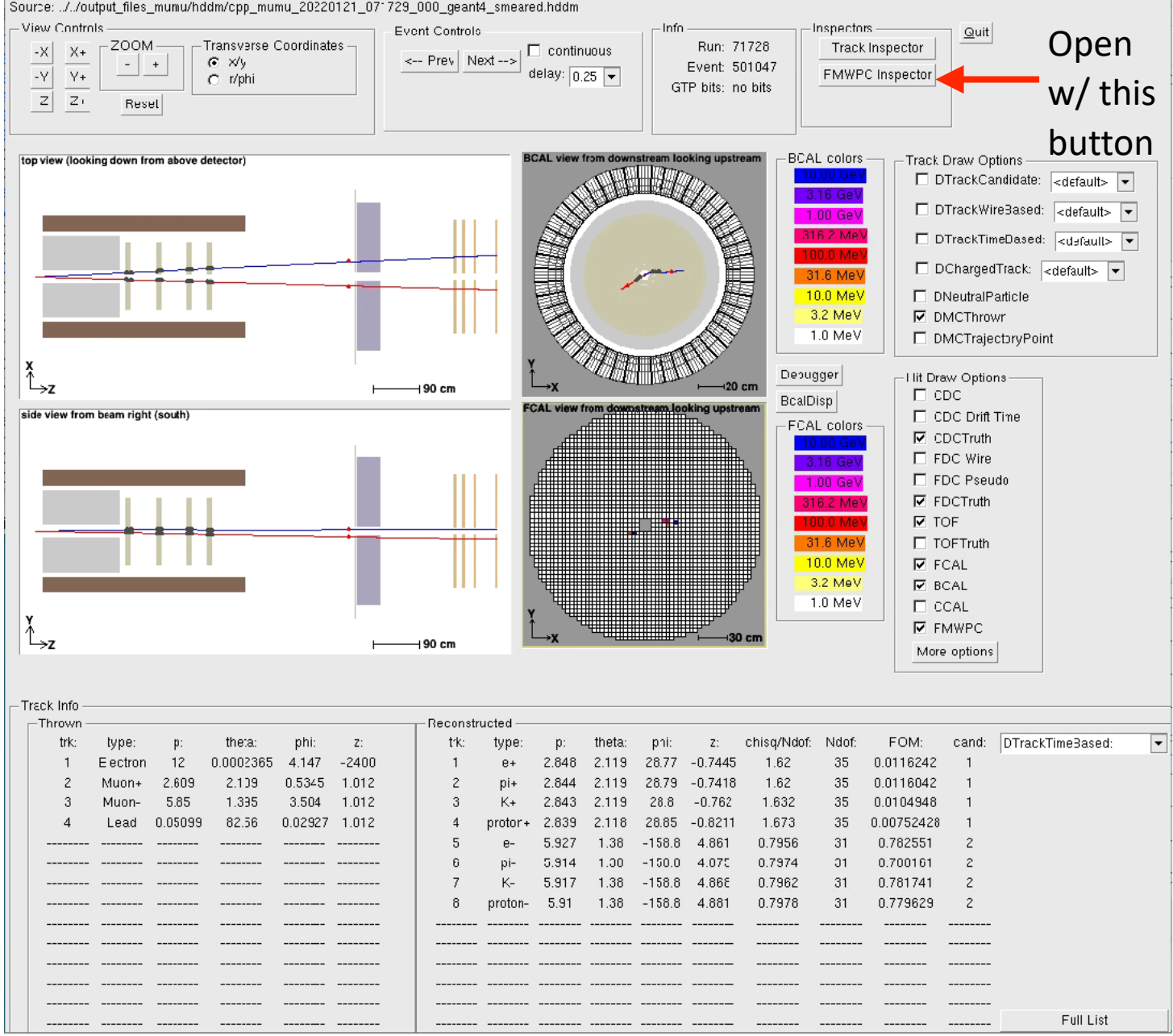

Ψ (degrees)
Ψ

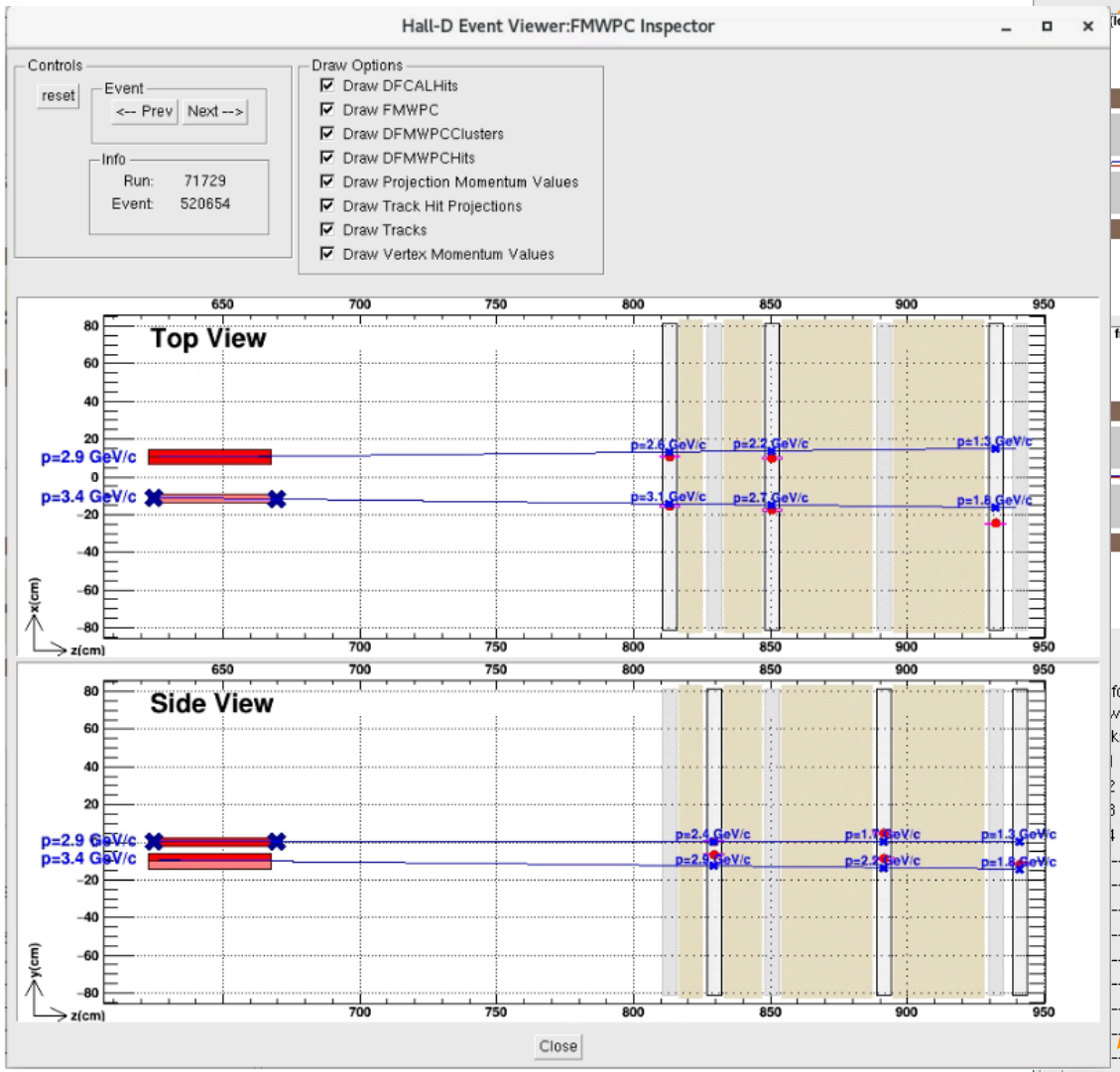
New monitoring histograms for NPP experiment (example for sample of pure MC signal):

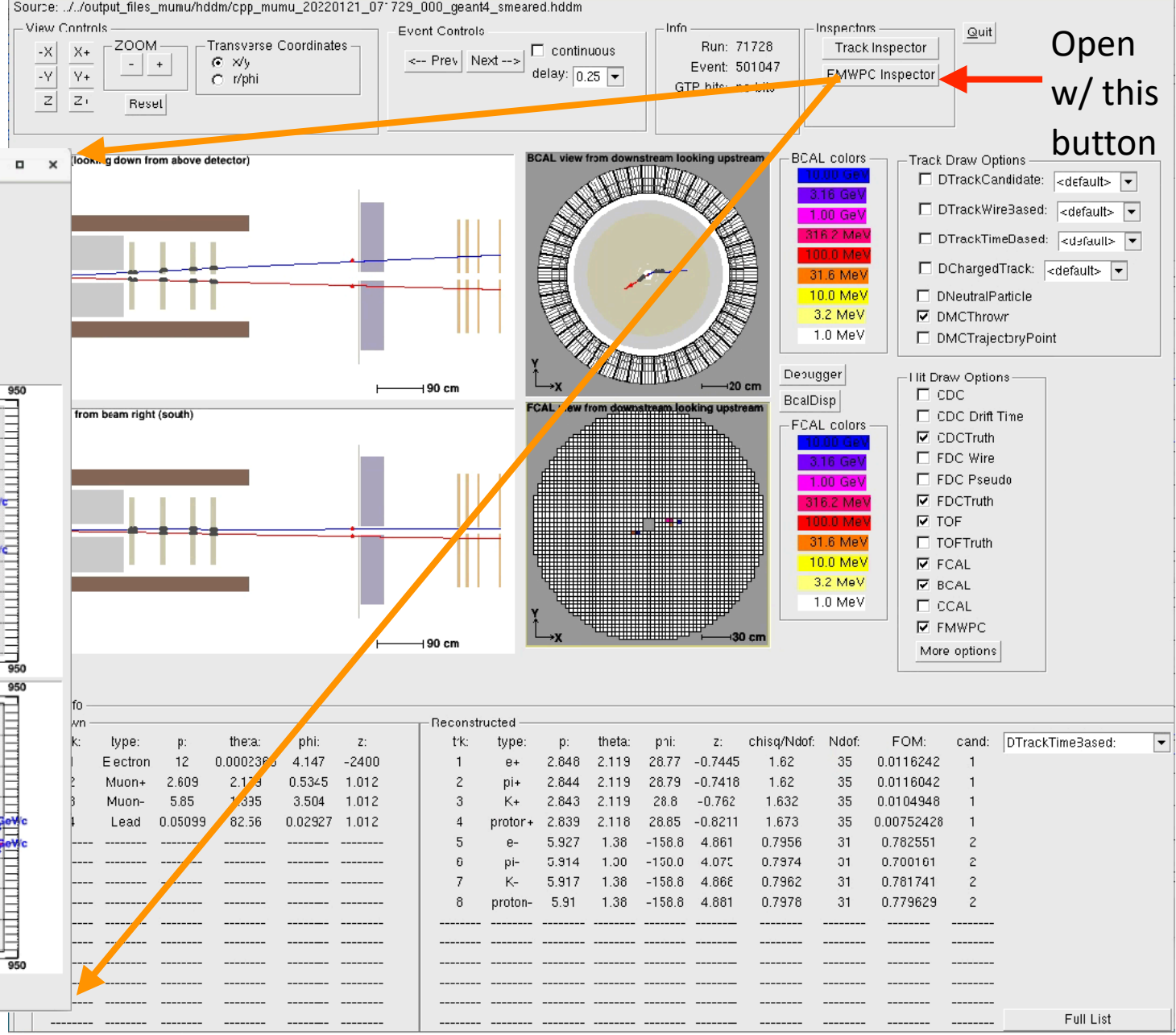


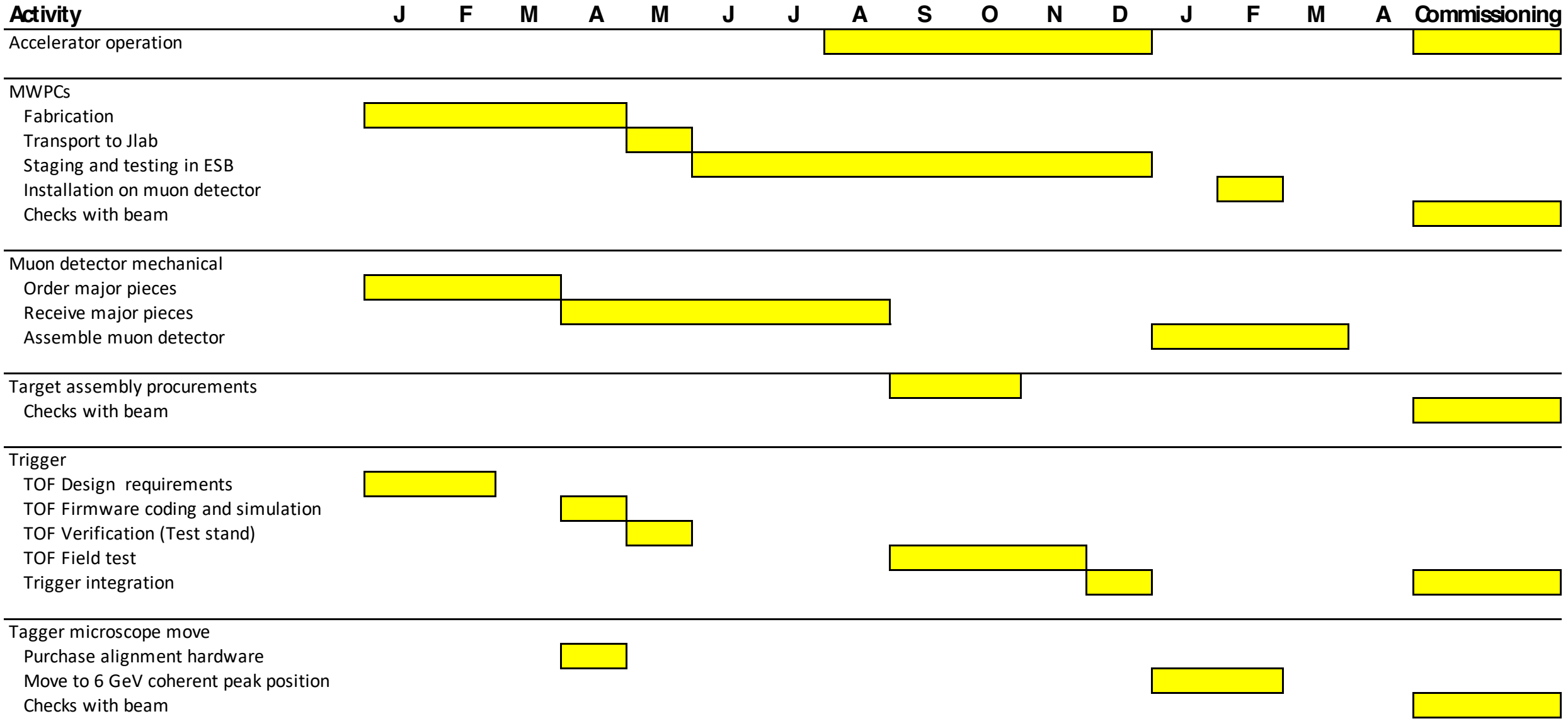
FMWPC Inspector in HDView2



FMWPC Inspector in HDView2






Activity
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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
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

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.