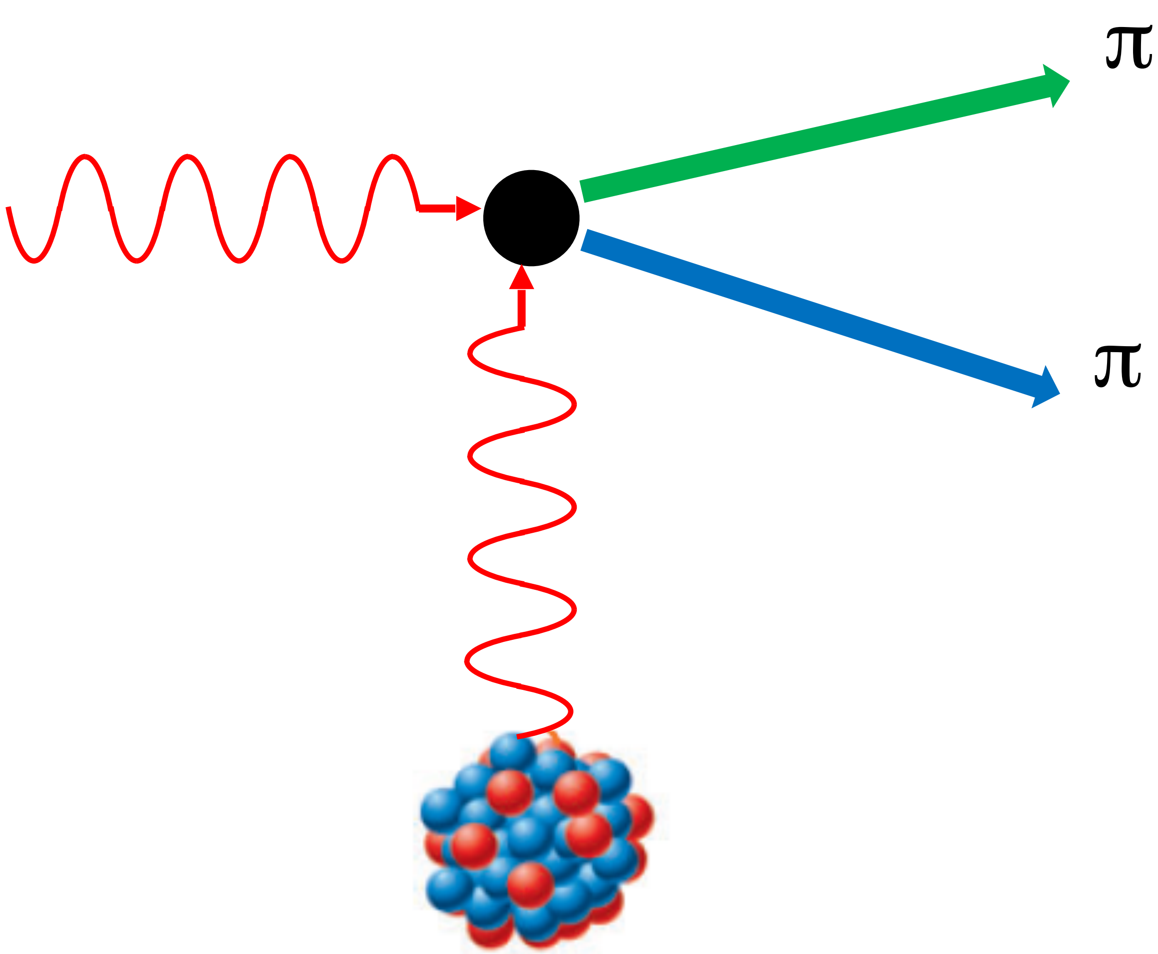
The Charged and Neutral Pion Polarizability Experiments: CPP and NPP

Spokespersons: M. Ito, I. Larin, D. Lawrence, R. Miskimen, E. Smith, B. Zihlmann

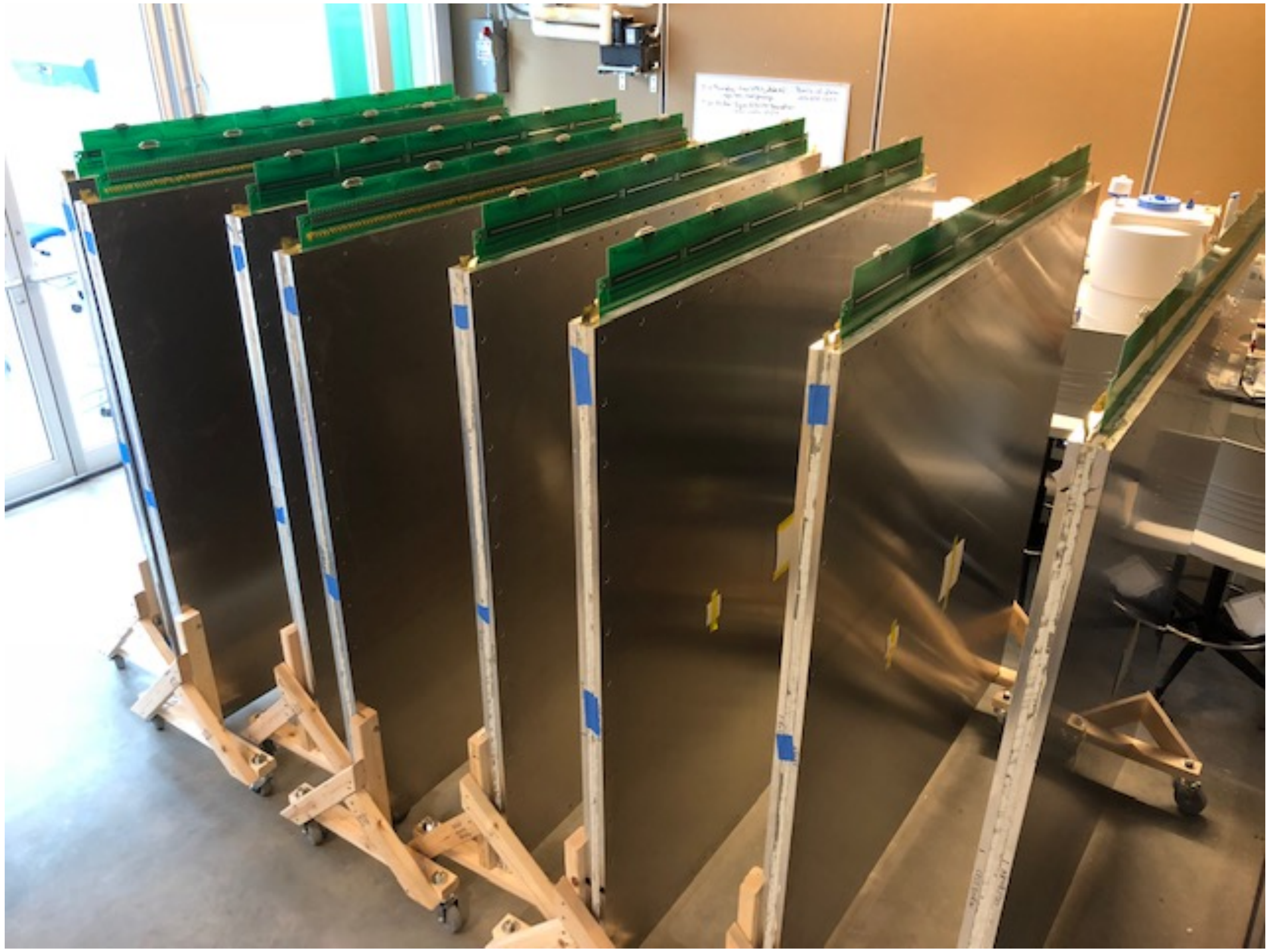
PDL: S. Taylor

Endorsed and supported by the GlueX Collaboration



- Preparations for CPP and NPP
  - i. Construction of the muon detectors
  - ii. Engineering for detector installation
  - iii. Time-of-flight trigger for CPP
  - iv. Moving the tagger microscope
  - v. Neural-net analysis for $e^{\pm}$, $\mu^{\pm}$, and $\pi^{\pm}$ identification
- Summary of run conditions and comparison with GlueX I
- Feedback from the ERR

i. Construction of the muon detectors



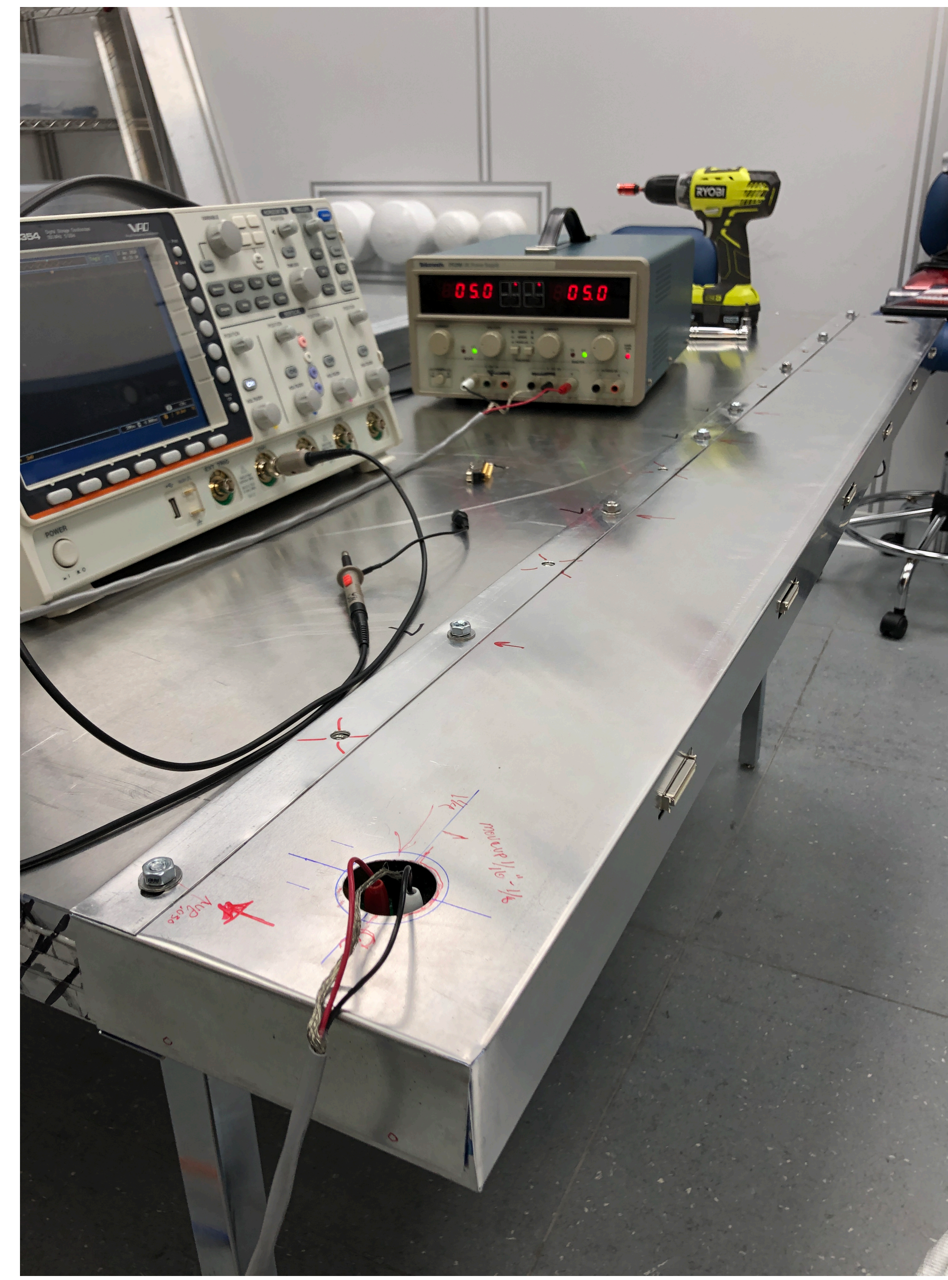
MWPC parameters:

Sense wire pitch: 1 cm
Wire to cathode plane distance: 1 cm
Sensitive area: 60 x 60 in^2
Number of channels: 144
Deadened region: 10 x 10 cm^2

Operating voltage: +1800 V
Gas mixture: Ar:CO_2 90:10
Gas flow rate: 5 cc/s
Approximate operating gain: 10^5
Max. drift time: approx. 300 ns

Status of wire chamber construction and installation at JLab

- Five chambers are ready for shipping to JLab
- Three additional chambers are being prepared
- Plan is to ship 8 chambers to JLab over the course of summer 2021 (only 6 chambers are needed for the experiment).
- The 2018 beam test indicated the need for better electronics grounding (completed), and the need for a metal enclosure for the preamp cards (assembly in progress).
- 20W of heat deposition within enclosure: plan to blow dry cooling air through enclosures

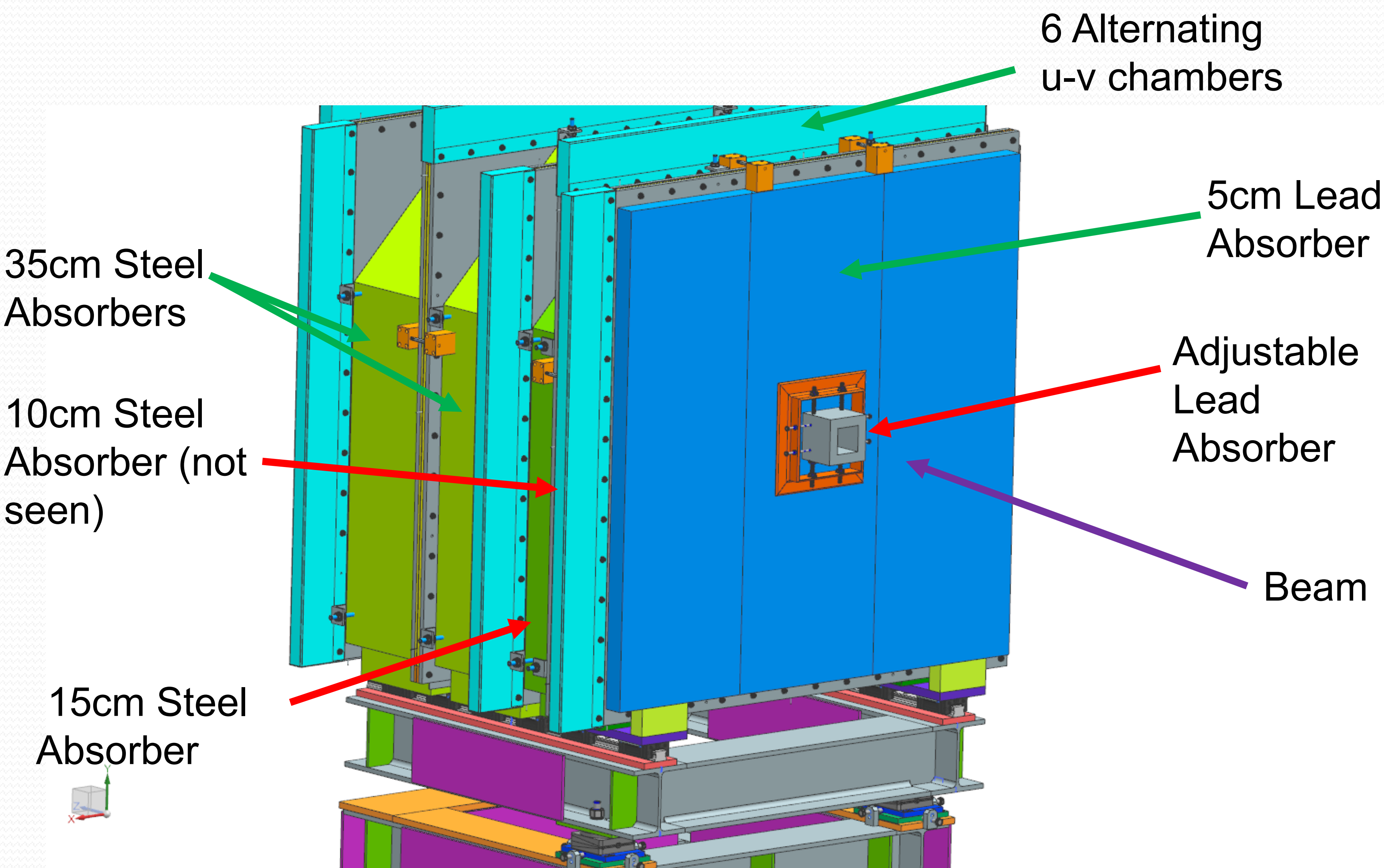


Status of wire chamber construction and installation at JLab (continued)

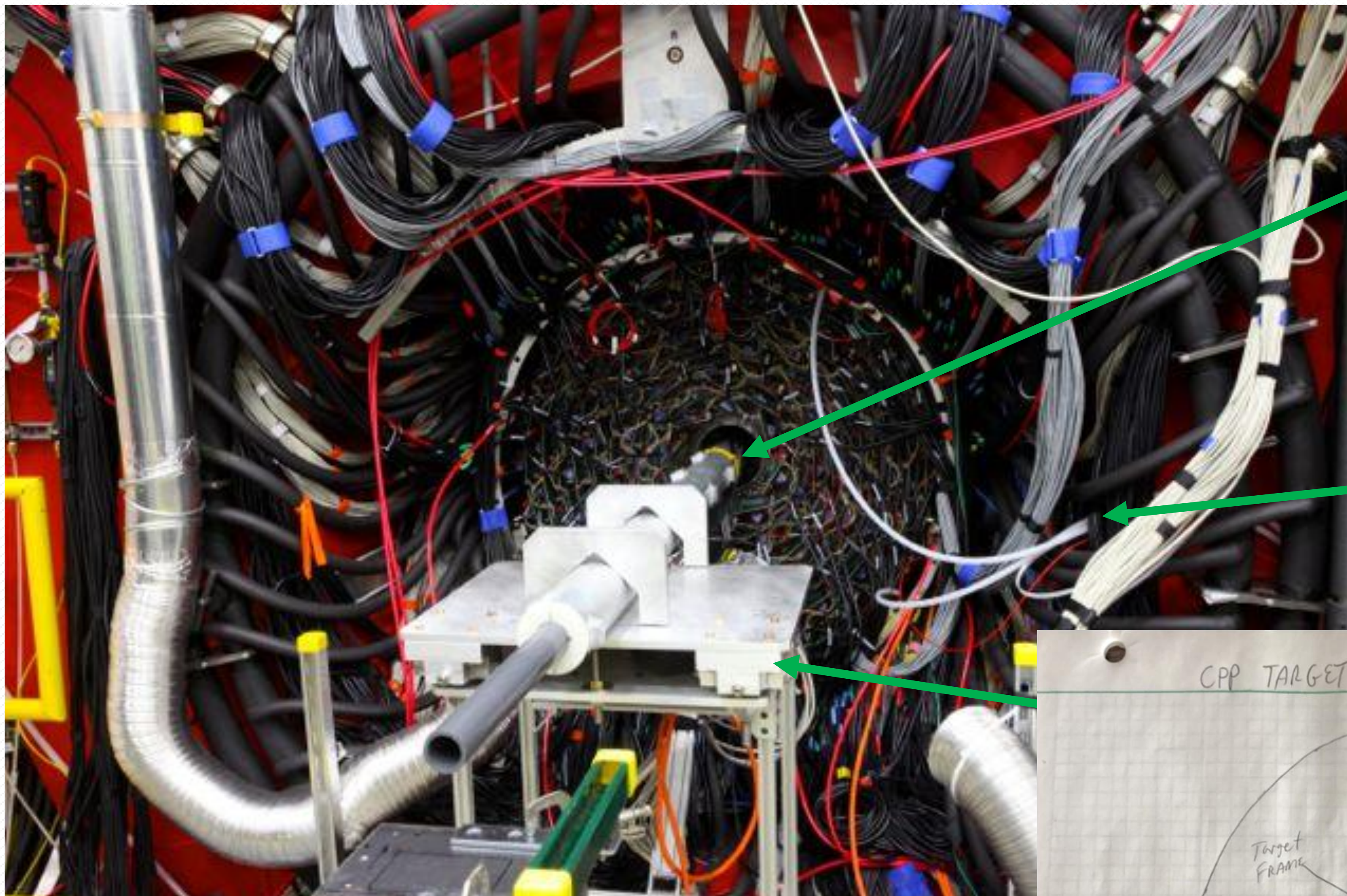
- The chambers use a modest flow of 30 cc/s of 90:10 Ar:CO_2 from the GlueX CDC gas system. Although we don't use the CDC, we will continue to flush gas through the CDC.
- FADC electronics from the CDC will be moved over to the muon detector setup, and an additional rack and crate installed.
- Work is in progress to fabricate the 36 signal cables + spares needed for the muon system.
- Providing high voltage +1800 V and low voltage +5V and -5V for the chambers is well in hand.

ii. Engineering for detector installation

CPP Detector

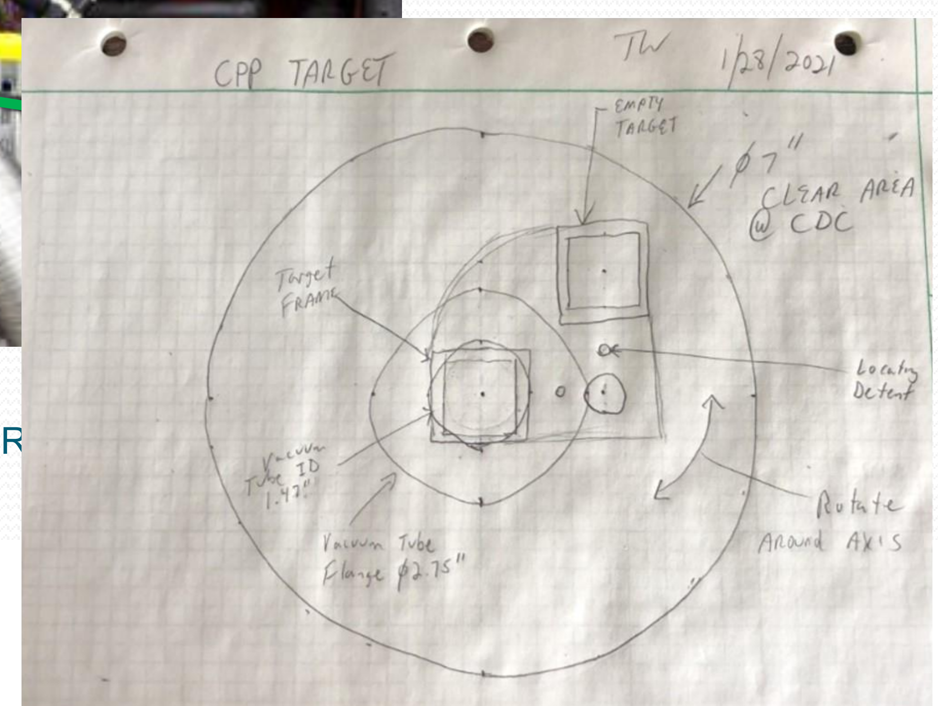


Existing Solid Target fixture



Lead target will be inside bore of CDC electronic boards

Change out area within 600G Magnetic Field of Solenoid

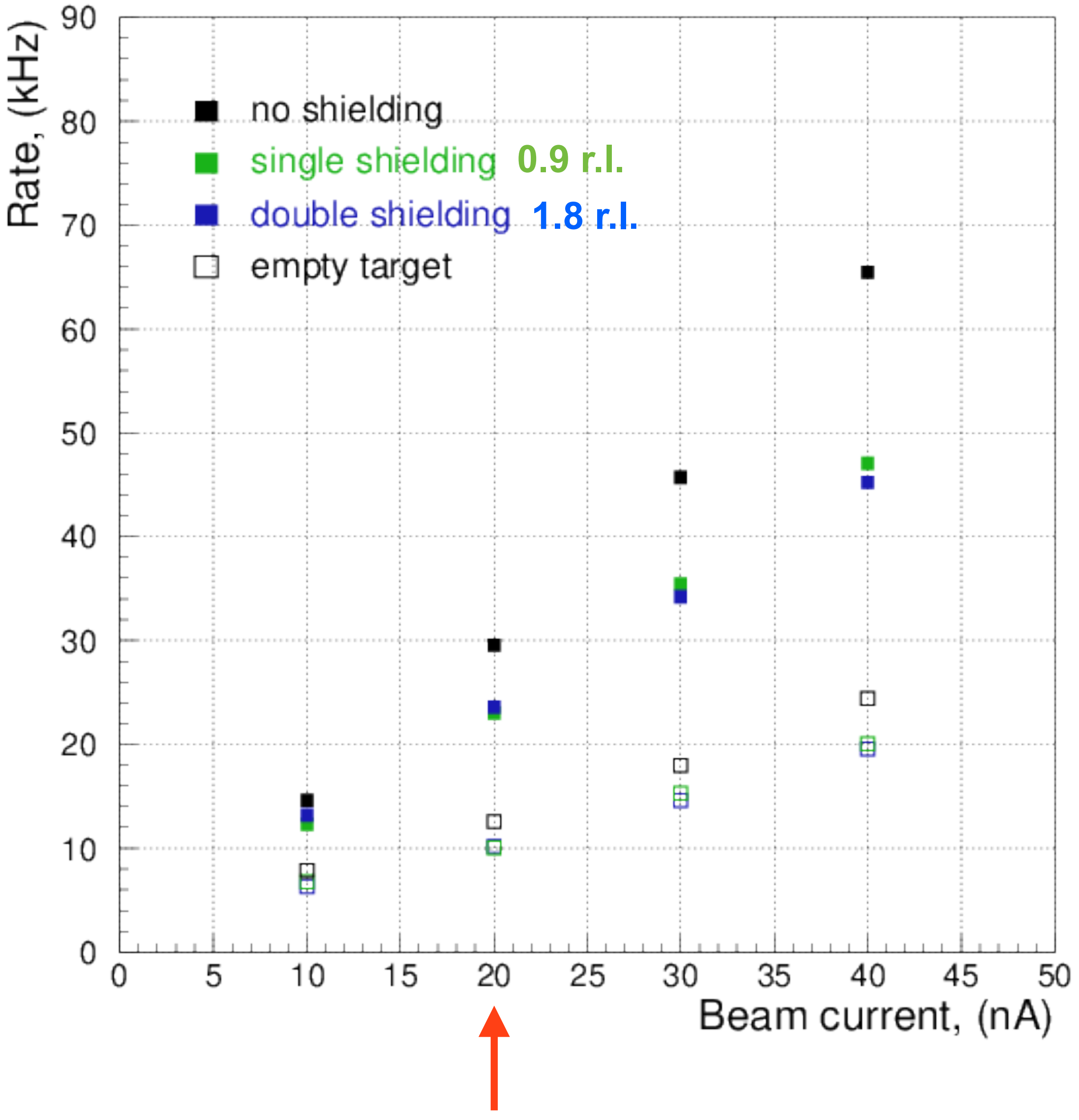


iii. Time-of-flight trigger for CPP

CPP uses non-standard trigger based on two charged tracks going forward into the time-of-flight system

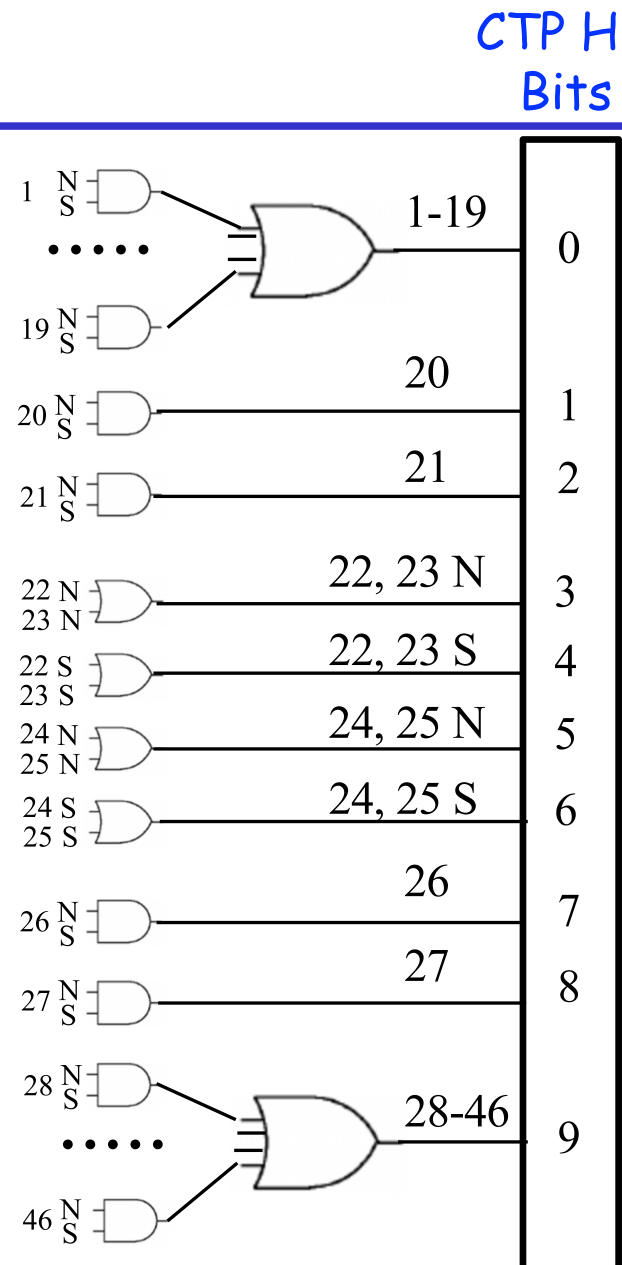
✓ Preliminary results from CPP trigger test in August, 2020

Extrapolated to CPP conditions with 5% RL ^{208}Pb target



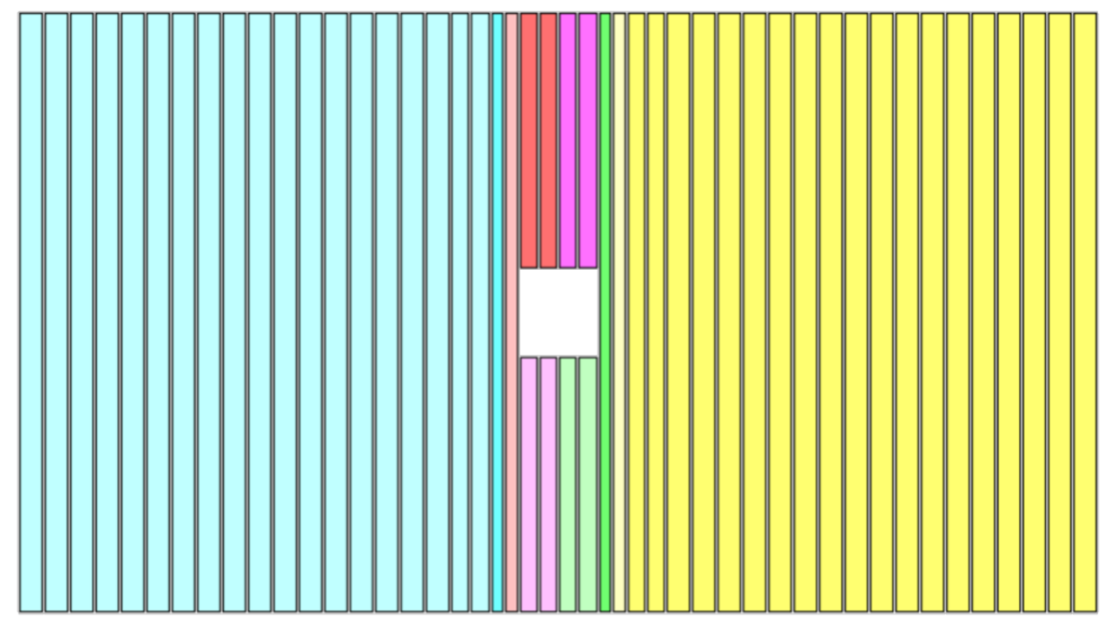
Nominal CPP beam current with 5 mm collimator

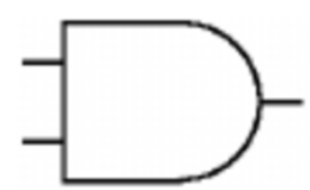
TOF trigger



Existing TOF trigger has same structure but different mapping

Graphic Representation for one plane. Repeat for second plane





- CPP trigger requires 2 or more shaded groups in both TOF planes to fire

Combined FCAL/BCAL and TOF triggers

- Responsibility: Fast Electronics (Chris/Hai) and Sasha Somov
- TOF trigger (CPP)
  - Ilya has developed a proposal for various TOF configurations that would provide an efficient trigger for CPP
  - The fast electronics group (Hai, Chris) has updated the former firmware requirement documentation to reflect the new TOF geometry and the new TOF trigger bit structure.
  - The trigger firmware upstream is agnostic to this new TOF-CTP firmware.
- FCAL/BCAL trigger (NPP)
  - The neutral trigger is the same as the usual GlueX trigger with optimized thresholds.
- The full experiment trigger would include the TOF and FCAL/BCAL triggers plus random, PS, and LED triggers.

Design Requirement	Done
Firmware coding and simulation	~ April
Verification (Test Stand)	~ May
Field test TOF and integration	Short beam test

iv. Moving the tagger microscope to 6 GeV

Geometry of Tagger

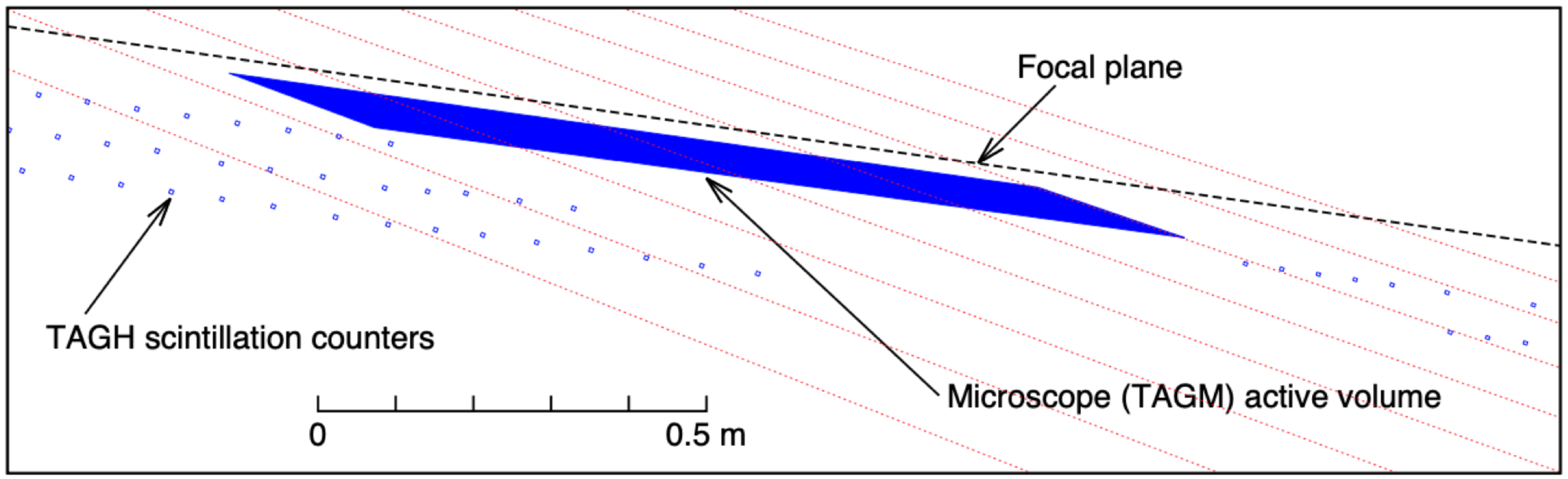
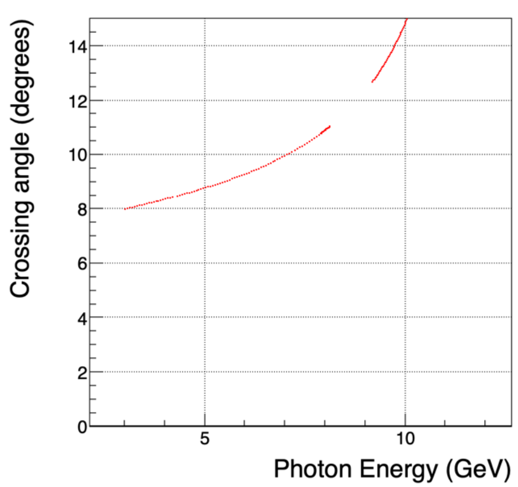
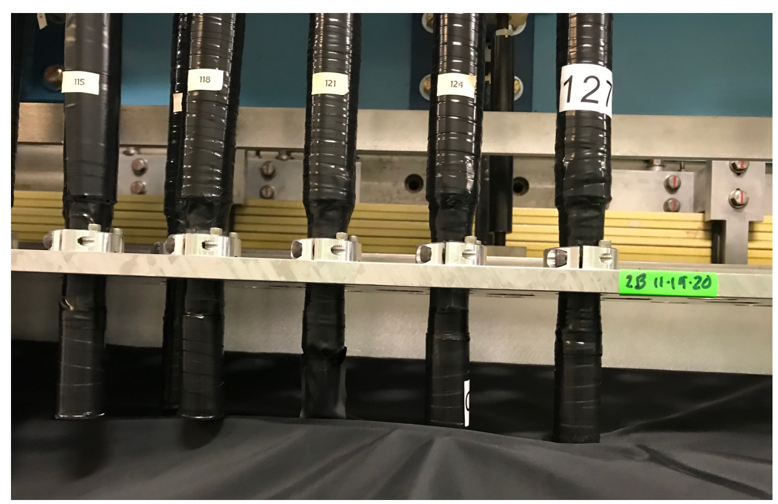


Figure 10: Schematic of electron trajectories in the region of the microscope. Shown are the three layers of hodoscope counters on either side of the microscope and the region covered by the microscope.





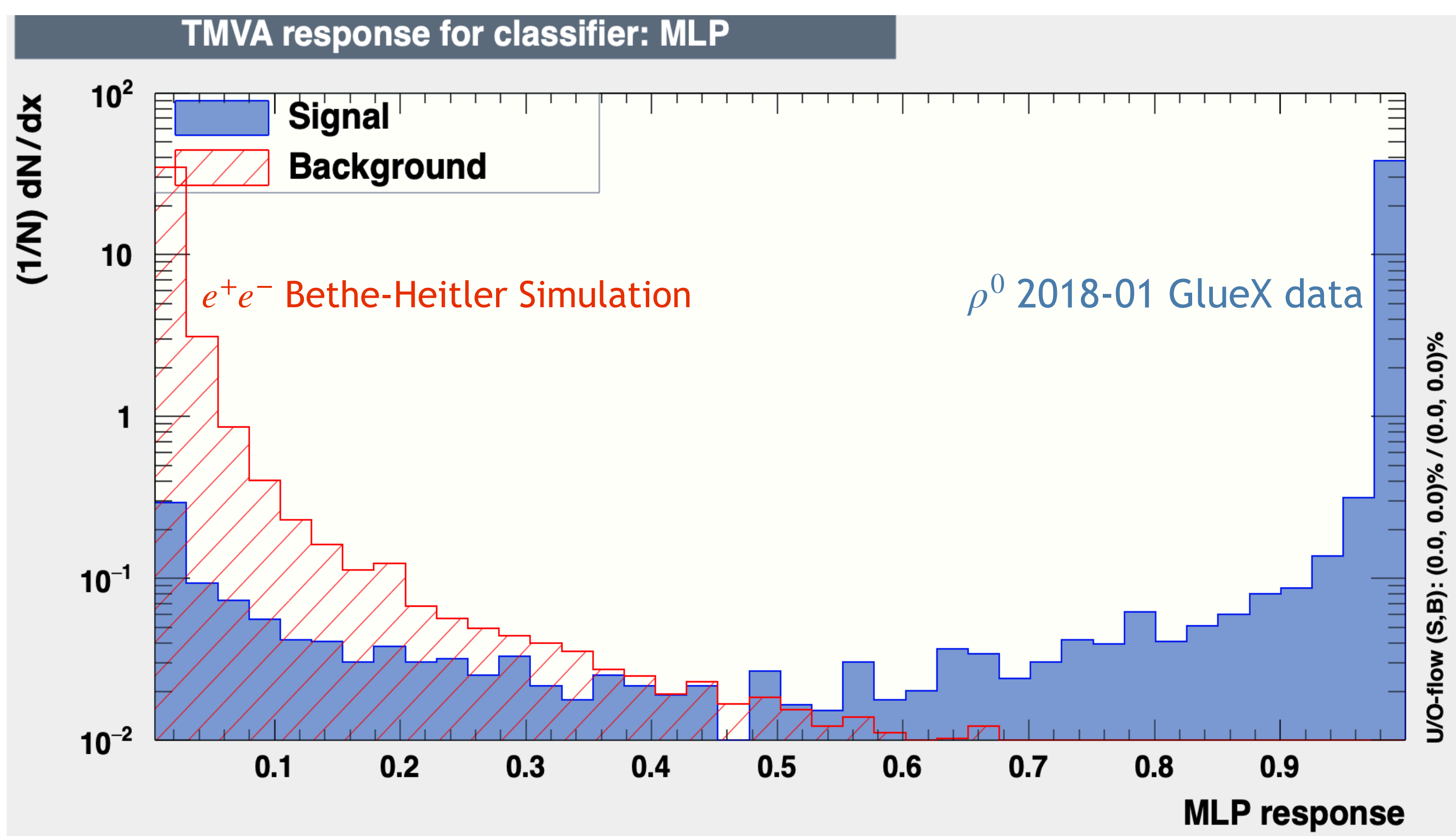
v. Neural-net analysis for $e^{\pm}$, $\pi^{\pm}$ and $\mu^{\pm}$ identification

$e^{\pm}/\pi^{\pm}$ identification based on these FDC and FCAL measurements

i. $E_{FCAL}/P_{kinematic-fit}$
ii. FCAL DOCA (distance between the shower and track projection)
iii. FCAL E9/E25 shower ratio (summed energies in 3x3 and 5x5 array of Pb-glass centered on the shower)
iv. likely include elasticity $= \left(E_1^{FCAL} + E_2^{FCAL}\right)/E_{tagger}$

✔ $e^{\pm}$ neural-net response trained on Bethe-Heitler $\gamma p \to e^+e^-$ simulation

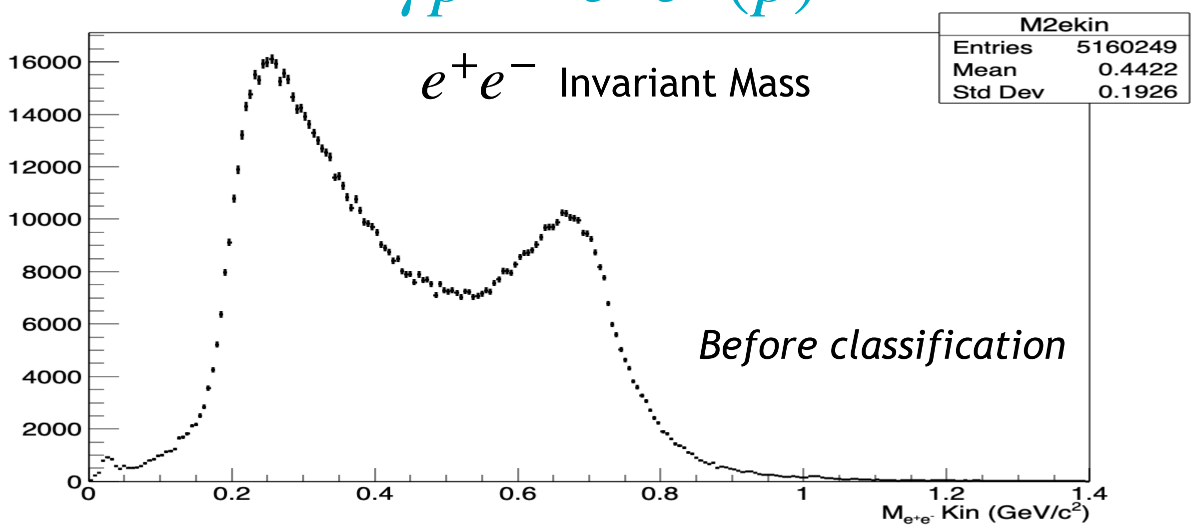
✔ $\pi^{\pm}$ neural-net response trained on GlueX $\gamma p \to \rho^0 \to \pi^+\pi^-$ data

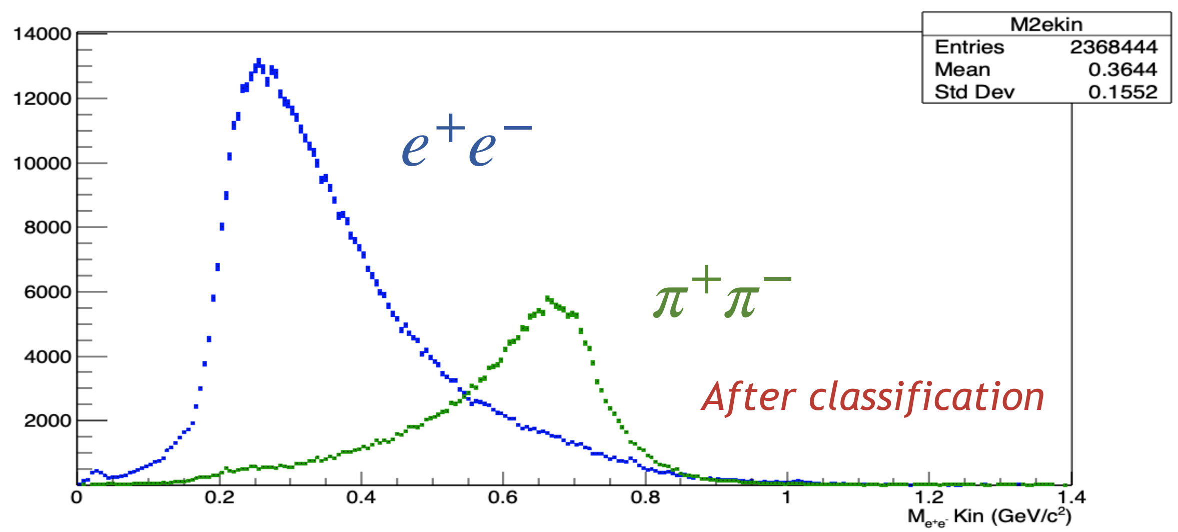


Benchmark studies in $e^{\pm}/\pi^{\pm}$ identification using GlueX data

2018 GlueX data containing BH pairs and ρ^0.
Use NN to classify and separate

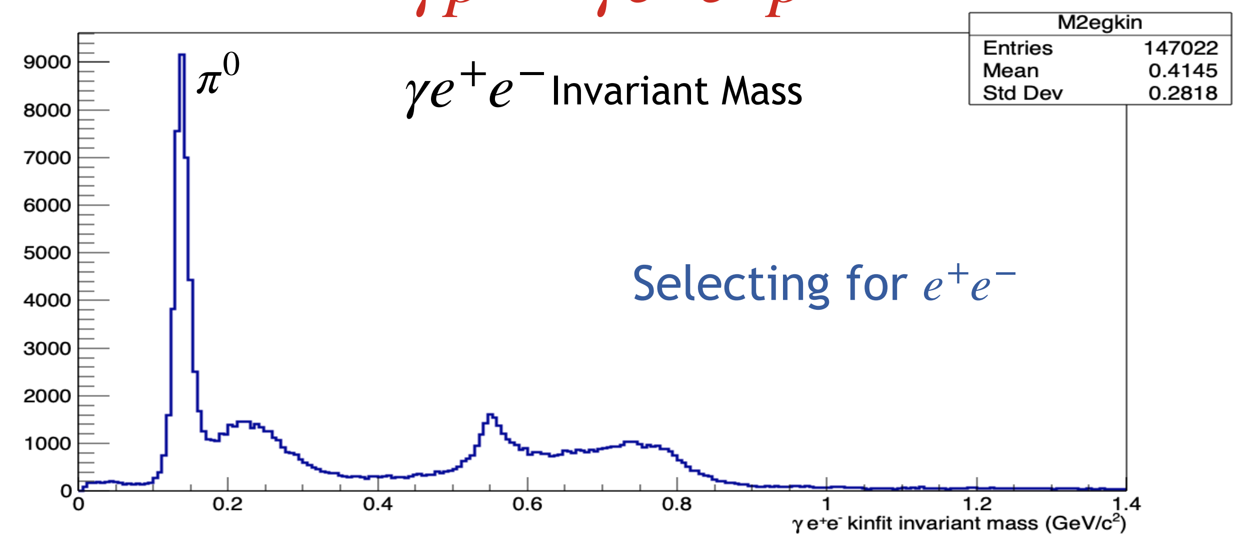
$\gamma p \to e^+e^-(p)$

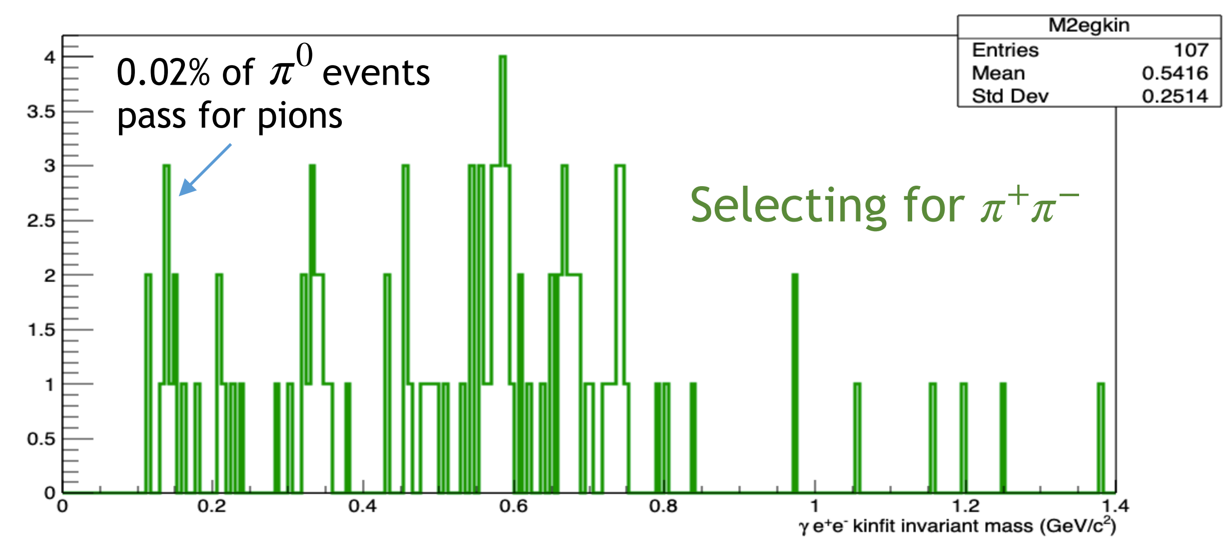




2018 GlueX data containing π^0 Dalitz decays

$\gamma p \to \gamma e^+e^-p$





Same neural net and cut on NN response used in both studies

$\mu^{\pm}/\pi^{\pm}$ identification based on these FDC, FCAL and MWPC measurements

i. $E_{FCAL}/P_{kinematic-fit}$
ii. FCAL DOCA (distance between the shower and track projection)
iii. FCAL E9/E25 shower ratio (summed energies in 3x3 and 5x5 array of Pb-glass centered on the shower)
iv. likely include elasticity $= \left(E_1^{FCAL} + E_2^{FCAL}\right)/E_{tagger}$

with

v. distribution of hits in the MWPCs:
   a. Pions range out in the iron whereas muons continue through
   b. Sum hits along projected tracks through the MWPCs
   (at 3 GeV/c multiple scattering $\sigma_{x,y} \approx 10\ cm$ in the last MWPC)

✔ $\pi^{\pm}$ neural-net response trained on CPP $\gamma A \rightarrow \rho^0 \rightarrow \pi^+\pi^-$ data

✔ $\mu^{\pm}$ neural-net response trained on Bethe-Heitler $\gamma A \rightarrow \mu^+\mu^-$ simulation. We may have data for $\gamma p \rightarrow \mu^+\mu^-$ taken during our Aug. 2020 trigger beam test.

- **Summary of run conditions and comparison with GlueX I**

Running Conditions

$\varepsilon < 10 \times 10^{-9}$ rad*m

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	5.5-6 GeV	5.5-6 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)

- **Feedback from the CPP/NPP ERR**

MWPCs: provide (i) detailed status of detectors, (ii) HV plateau and TOF distributions, (iii) efficiency measurements, and (iv) expected rates per MWPC plane

Trigger: provide (i) expected rate increase by having the target 60 cm upstream of the nominal position, (ii) a plan for measuring trigger efficiency, and (iii) expected data rates

Reconstruction, simulation and data analysis software: (i) work started, but no completion dates given, (ii) must have names assigned, (iii) how MWPC and TOF trigger efficiencies affect results, and (iv) publication timeline not given