The K_{LL} experiment

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(on behalf of the WAPP collaboration)

The spokespersons

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WAPP Collaboration: ~60 Collaborators from ~20 institutions

Scientific goals of WAPP I & II

The goal for the pioneering measurement of the polarization transfer observable A_{LL} for single π^- photoproduction in the wide-angle regime is to address the following questions:

- What is the nature of the interaction mechanism of meson photoproduction from the nucleon at $s, -t, -u \gg \Lambda^2_{QCD}$?
- Does the twist-3 contribution dominate the twist-2 contribution in the wide angle regime, as suggested by the updated handbag mechanism cross section calculations?

We propose to measure A_{LL} for negatively charged pion photoproduction in the wide angle regime by using the SBS as the proton arm and BB as the pion arm. There, three aspects will be tested:

1. Does A_{LL} equal -K_{LL}?
2. Does A_{LL} have any dependence on cm. angle at $s = 9$ GeV^2 and large $-u$, $-t$?
3. Does A_{LL} have any s dependence at $s > 9$ GeV^2?

Pion photoproduction in the wide angle regime

- Wide angle pion photoproduction is an interesting and a powerful took to study the interaction mechanism in the wide angle regime

- Calculations with twist 2 only fall short by two orders of magnitude

- Twist 3 contributions performed for π^0 are not only important but dominant in the wide angle regime

- A solution (handbag approach in the framework of GPDs) has been proposed

- An independent test of the polarization observables A_{LL} and K_{LL} is timely and necessary

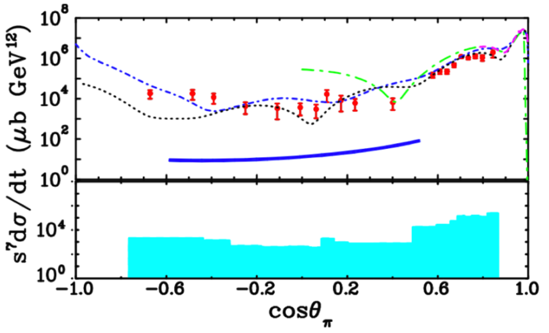


FIG. 5. Differential cross section of π^0 photoproduction. The CLAS experimental data at $s = 11$ GeV^2 are from the current experiment (red solid circles). The plotted uncertainties are statistical. The systematic uncertainties are presented as a shaded area in the subpanel. The theoretical curves for the Regge fits are the same as in Fig. 4 and the Handbag model by Kroll *et al.* [12] (blue double solid line).

$$A_{LL}^{twist-2} = K_{LL}^{twist-2}$$

$$A_{LL}^{twist-3} = -K_{LL}^{twist-3}$$

$$K_{LL} = \frac{d\sigma(+,\rightarrow) - d\sigma(-,\rightarrow)}{d\sigma(+,\rightarrow) + d\sigma(-,\rightarrow)}$$

$$A_{LL} = \frac{d\sigma(+\rightarrow) - d\sigma(-\rightarrow)}{d\sigma(+\rightarrow) + d\sigma(-\rightarrow)}$$

Helicity correlation observables

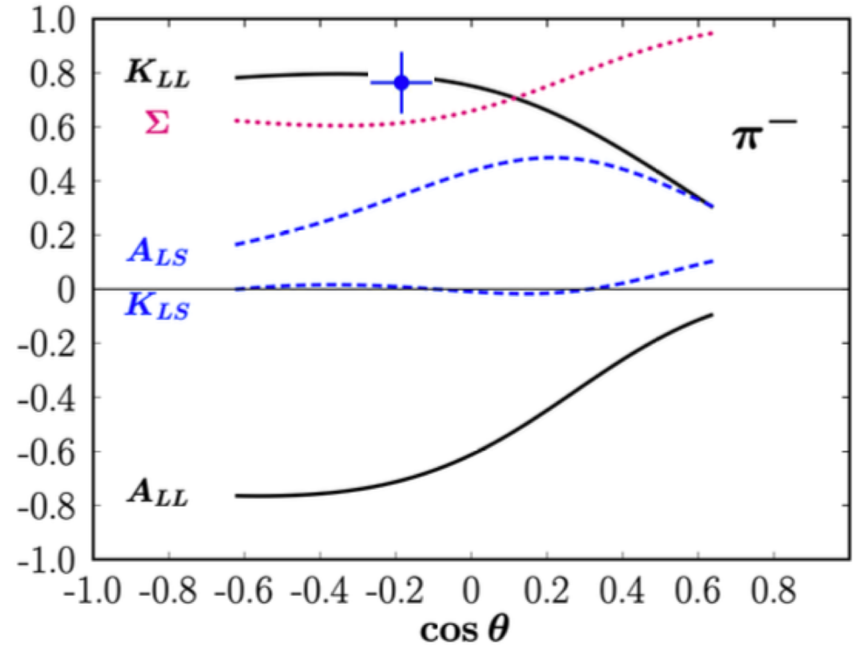
- Helicity correlations A_{LL} and K_{LL} provide tests of the handbag mechanism
- Twist 3 contribution dominates twist 2
- Predictions made for π^0 and π^-

$$K_{LL} = \frac{d\sigma(+,\rightarrow) - d\sigma(-,\rightarrow)}{d\sigma(+,\rightarrow) + d\sigma(-,\rightarrow)}$$

$$A_{LL} = \frac{d\sigma(+\rightarrow) - d\sigma(-\rightarrow)}{d\sigma(+\rightarrow) + d\sigma(-\rightarrow)}$$

$$A_{LL}^{twist-2} = K_{LL}^{twist-2}$$

$$A_{LL}^{twist-3} = -K_{LL}^{twist-3}$$



E_γ	$< s >$	$< -t >$	$< -u >$	K_{LL}	K_{LS}
GeV	$(\mathrm{GeV}/c)^2$	$(\mathrm{GeV}/c)^2$	$(\mathrm{GeV}/c)^2$	accuracy	accuracy
4.5-5.5	9.3	4.6	2.9	±0.05	±0.05

$$4.0 \leq E_\gamma \text{ (GeV)} \leq 6.6$$

$$\begin{aligned} E_e &= 6.6 \text{ GeV} \\ \langle s \rangle &= 9.3 \text{ GeV}^2 \\ \langle -t \rangle &= 4.6 \text{ GeV}^2 \\ \langle -u \rangle &= 2.9 \text{ GeV}^2 \\ \langle \cos(\theta_{CM}) \rangle &= -0.22 \end{aligned}$$

- Acceptance-averaged Mandelstam variables are all sufficiently “large” for applicability of the handbag approach

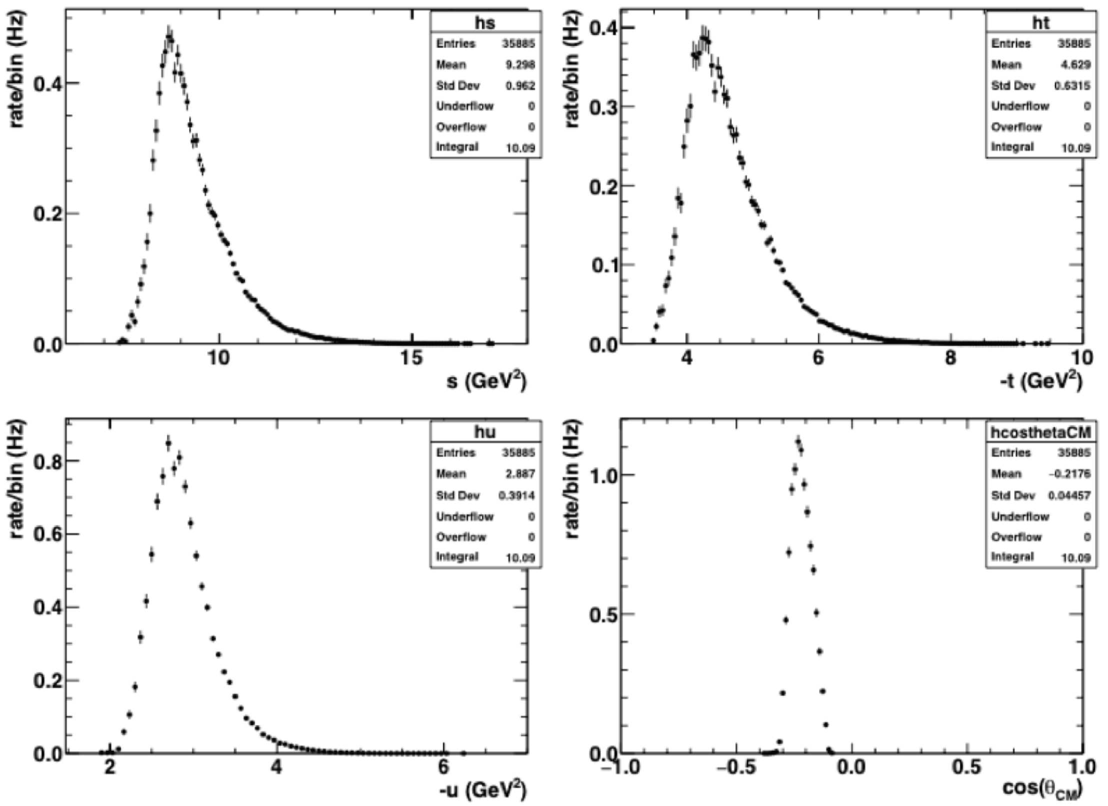


Figure 11: Distributions of s, $-t$, $-u$, and $\cos\theta_{CM}$ within the combined BigBite-SBS acceptance, from *g4sbs*, the SBS GEANT4-based Monte Carlo simulation package. See text for details.

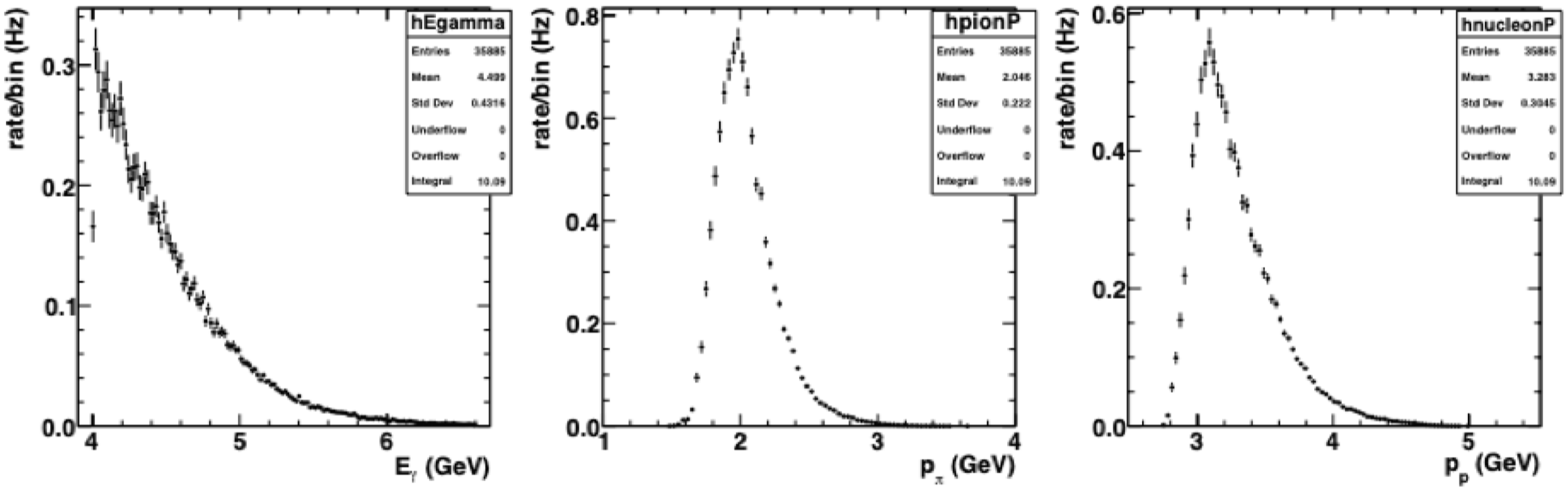


Figure 12: Distributions of E_γ, the incident photon energy, p_π, the π^- momentum in BigBite, and p_p, the proton momentum in SBS. Note that 4 GeV was the lower limit placed on E_γ for "signal" event generation.

$$s^7 \frac{d\sigma}{dt}(\gamma p \to \pi^+ n) \;=\; 0.828 \times 10^7 (1-z)^{-5}(1+z)^{-4} \;\left(\text{nb/GeV}^2 \cdot \text{GeV}^{14}\right)$$

Energy deposition in the preshower and shower

- GEn-RP trigger designed to have increased e^- efficiency
- Threshold cuts have to be applied on at the trigger level to suppress e^- and increase pion detection efficiency
- Need to demonstrate the feasibility of such a configuration change

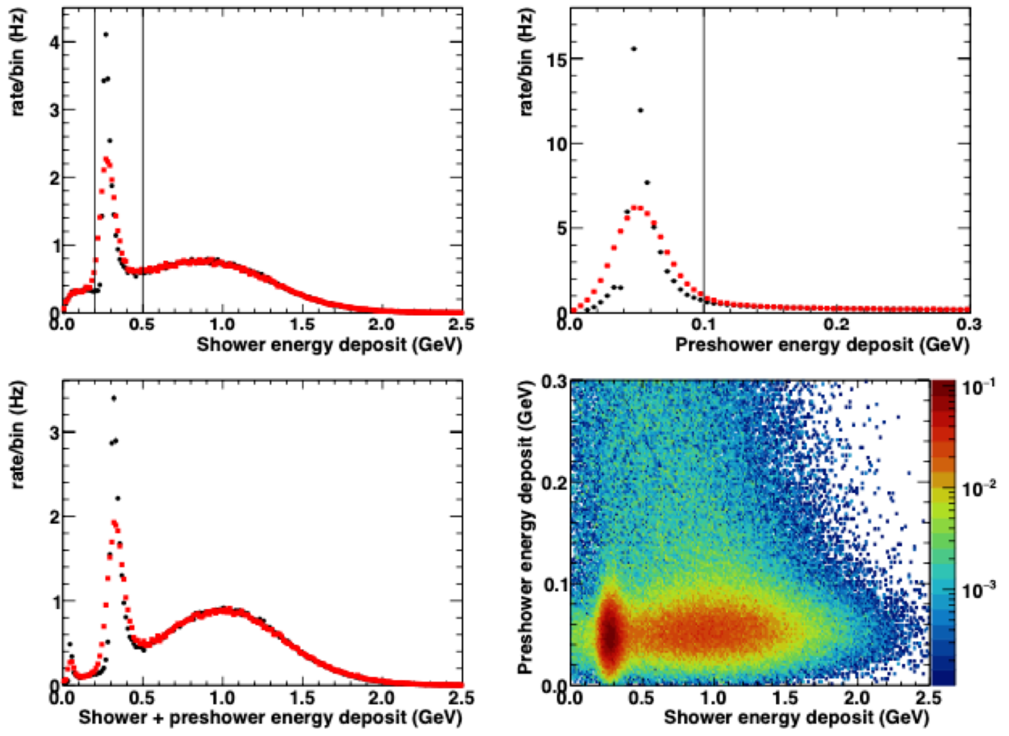
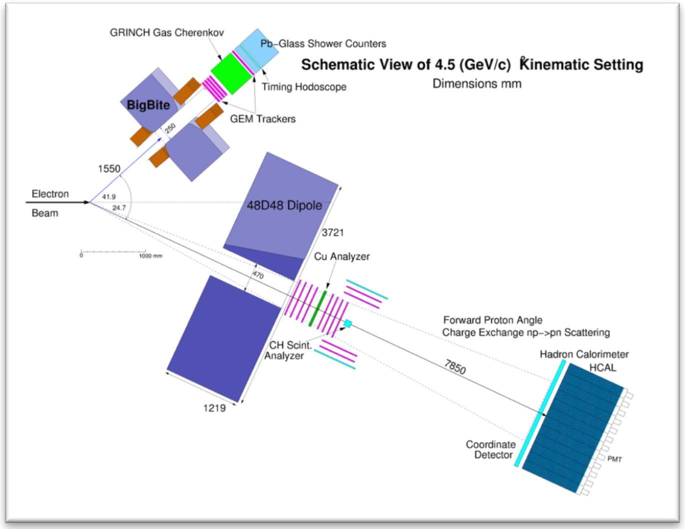


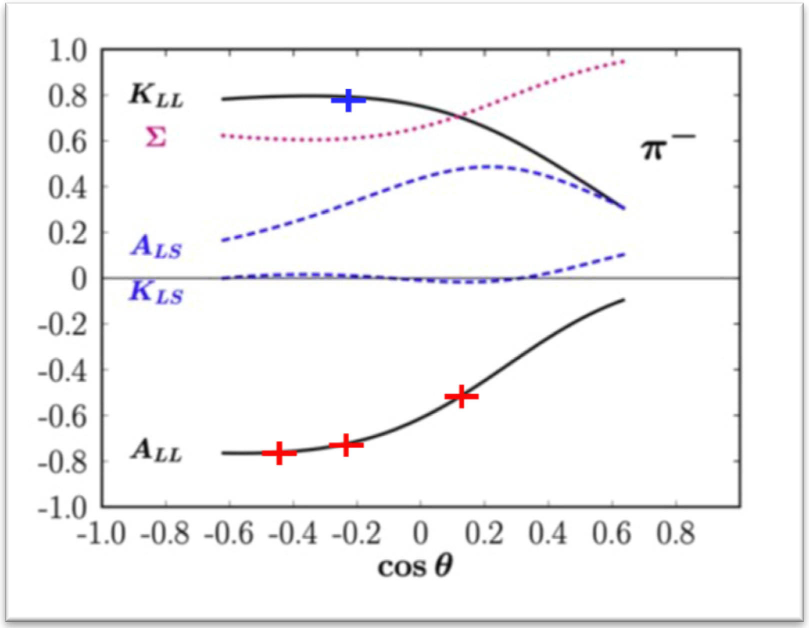
Figure 13: Simulated preshower and shower energy depositions by good signal π^-, illustrating the BigBite trigger logic for charged pions. Black circles represent the "true" energy depositions, while red squares represent the energies smeared by the calorimeter energy resolution. Top Left: shower energy deposition. The vertical lines at 0.2 GeV and 0.5 GeV represent possible thresholds. Top Right: preshower energy deposition, illustrating dominant minimum-ionizing peak. The vertical line illustrates the "veto" threshold above which triggers will be rejected, as they are predominantly electron and photon-induced. Bottom left: Sum of shower and preshower for good signal π^-. Bottom right: correlation between preshower and shower signals, smeared for detector resolution.

Experimental setup and projections

- 2 PAC days of 6.6 GeV electron beam (photons in the range 4.0 – 6.0 GeV) for K_{LL} to reach 5% statistical uncertainty
- LD2 target with 6% Cu radiator upstream
- BigBite as the e- arm and the SBS as the nucleon arm
- No spectrometer changes required going from GEn-RP to KLL which reduces overhead



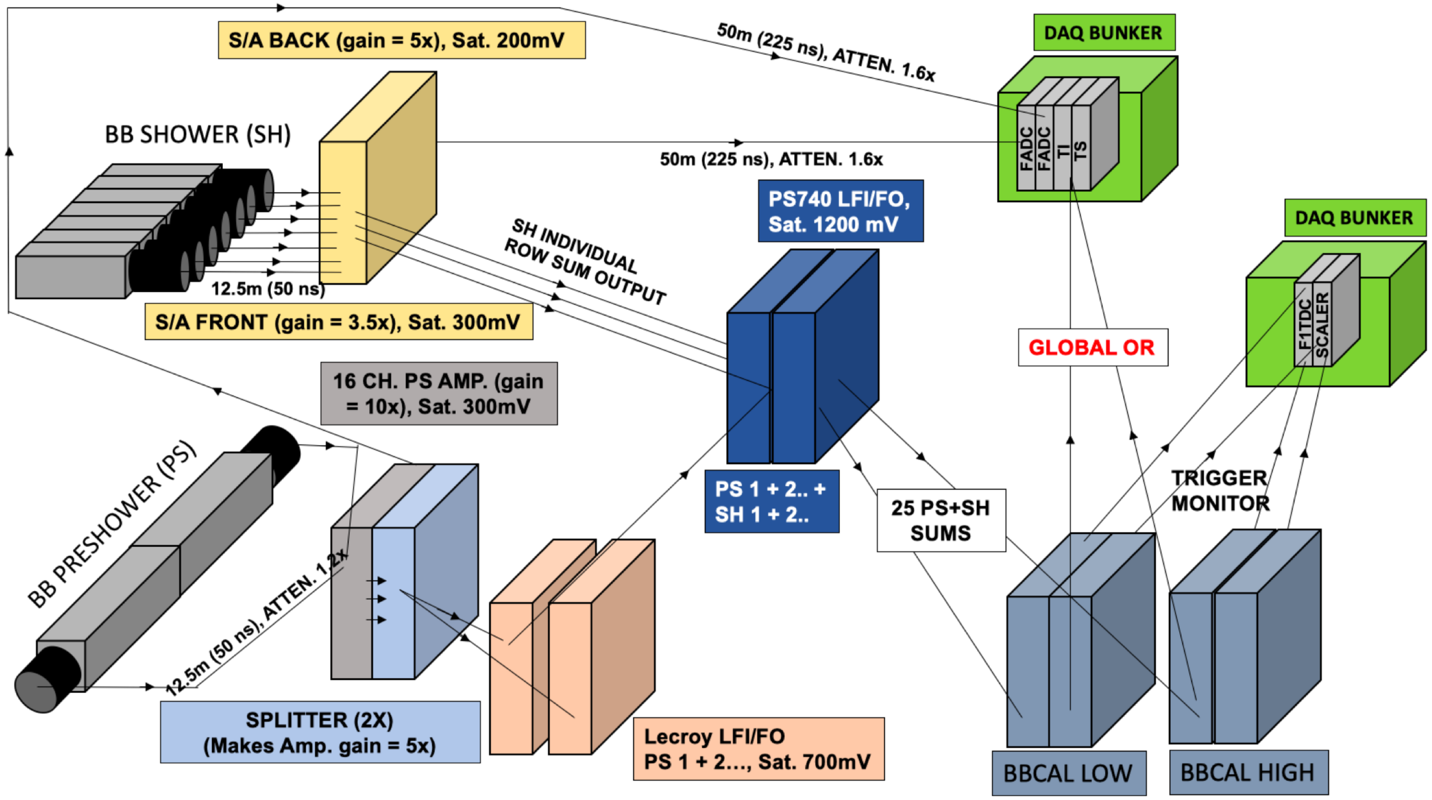
Experimental setup for K_{LL}



Projections for A_{LL} and K_{LL}

Trigger setup (what's implemented and readily available?)

- BBCALLO
  - Has remotely programmable thresholds
- BBCALHI (copy of trigger from BBCAL but could be set at a different threshold)
  - Need to setup a raspberry pi to remotely adjust and monitor the thresholds but should be easy to implement
- BBCALLO in VETO with BBCALHI already setup by Mark Jones but has not been commissioned
- This trigger setup could be used or a firmware based trigger could be implemented



Schematic of trigger setup for BBCAL

Target

- A 15 cm deuterium target with a radiator was already present during GMn running

- Need to remind Dave Meekins to implement it back onto the target ladder

Hall A Target Configuration October 2021 to February 2022

Jefferson Lab
Thomas Jefferson National Accelerator Facility

3 Target list and lifter positions

The following lifter positions were determined by alignment of the system.

Target name	Lifter position	Target Material
Loop 1 15 cm + Rad#1	34,823,321	10 cm Loop 1
Loop 1 15 cm	31,040,225	
Loop 2 15 cm + Rad#2	27,172,761	10 cm Loop 2
Loop 2 15 cm	23,389,665	
Loop 3 15 cm + Rad#3	19,532,441	10 cm Loop 3
Loop 3 15 cm	15,749,345	
15 cm dummy	12,877,884	Aluminum 7075
15 cm dummy + raditor	11,577,404	
Optics #1 (5 foil)	10,863,441	Carbon
Optics #2 (4 foil)	10,169,148	Carbon
BeO	8,896,060	BeO
Carbon Hole (5 mm)	8,180,796	Carbon
Carbon Hole (2 mm)	7,465,532	Carbon
Carbon (0.5%)	6,750,268	Ti
Home	0	N/A

https://logbooks.jlab.org/files/2022/03/3987411/TGT-RPT-22-002.pdf

Summary

- Wide angle pion photoproduction is an interesting and a powerful took to study the interaction mechanism in the wide angle regime

- A solution (handbag approach in the framework of GPDs) has been proposed and an independent test of the polarization observables is timely and necessary

- With minimal beam time request and experiment configuration change, we can test something fundamental that will contribute to the 3D picture of the nucleon