

CLAS-ANALYSIS 2016

Dalitz Plot Analysis of $\eta' \rightarrow \eta \pi^+ \pi^-$ from g12

1. Introduction

In this note we will explain the analysis details to obtain the Dalitz plot parameters of the decay of $\eta' \rightarrow \eta \pi^+ \pi^-$ meson. The final state particles proton, π^+ and π^- information from PART BOS bank are identified with the particle identification codes compiled in the “clas6-trunk” under the package CLASEVENT . We selected a data sample with all those events which has only one proton, π^+ and π^- in their final state and no matter how many neutral particles.

We started the analysis with well calibrated data as “.root” files with all events arranged as per the Run number, Event number and PID along with all other informations recorded by the experiment. The calibrated data is then corrected and further processed following the steps of “ g12 procedures working version.pdf ” and properly tuned Kinematic Fitter available at G12 Wikki. We have divided our analysis into the following subsequent sections.

- Event Selection : The Section 2 will cover analysis cut involved to tap the events of interest.
- Simulation : The Section 3 will explain our analysis model and will produce a cross check to the whole analysis
- Result : The Section 4 will report the final results of the measurement with a study of systematics.

The complete reaction under study is “ $\gamma p \rightarrow \eta'(\rightarrow \eta \pi^+ \pi^-) p$ ” and we do not detect η meson. This is a missing mass analysis using a fixed target g12 experiment, which has an energy of the photon beam ranging from 1.142 GeV to 5.425 GeV. However the threshold production of η' meson is 1.455 GeV and hence we analysed the data from the threshold to our maximum available energy.

2. Event Selection

We are interested in the photo-production of η' meson and its decay to η , π^+ and π^- mesons. The improvement in the identification of the particles, selection of an event and several cuts in the analysis to tap the events of interest is reported subsequent sub sections.

2.1. Run List

TABLE 1. List of runs included in the analysis

G12 Run List	G12 Run List	G12 Run List	G12 Run List	G12 Run List
56605	56653	56654	56655	56656
56660	56661	56665	56666	56667
56668	56669	56670	56673	56674
56688	56689	56690	56691	56692
56693	56694	56695	56696	56700
56701	56702	56703	56704	56705
56706	56707	56708	56710	56711
56712	56713	56714	56715	56716
56717	56718	56719	56720	56721
56722	56723	56724	56726	56727
56728	56729	56730	56731	56732
56733	56734	56735	56736	56737
56738	56739	56740	56741	56742
56743	56744	56748	56749	56750
56751	56752	56753	56754	56755
56756	56757	56758	56759	56760
56761	56762	56763	56764	56765
56766	56767	56768	56770	56771
56772	56774	56775	56776	56777
56778	56780	56781	56782	56783

56784	56787	56788	56791	56792
56793	56794	56798	56799	56800
56801	56802	56805	56806	56807
56808	56809	56810	56811	56812
56813	56814	56815	56821	56822
56823	56824	56825	56826	56827
56831	56832	56833	56834	56838
56839	56841	56842	56843	56844
56845	56849	56853	56854	56855
56856	56857	56858	56859	56860
56861	56862	56864	56865	56866
56870	56874	56875	56877	56879
56897	56898	56899	56900	56901
56902	56903	56904	56905	56907
56908	56914	56915	56916	56917
56918	56919	56921	56922	56923
56924	56925	56926	56927	56928
56929	56930	56932	56935	56936
56937	56938	56939	56940	56948
56949	56950	56951	56952	56953
56954	56955	56956	56958	56960
56961	56962	56963	56964	56965
56966	56967	56968	56969	56970
56971	56972	56973	56974	56975
56977	56978	56979	56980	56992
56993	56994	56996	56997	56998
56999	57000	57001	57002	57003
57004	57005	57006	57008	57009
57010	57011	57012	57013	57014
57015	57016	57017	57021	57022

57023	57025	57026	57027	57030
57031	57032	57062	57063	57064
57065	57066	57067	57068	57069
57071	57072	57073	57075	57076
57077	57078	57079	57080	57095
57096	57097	57100	57101	57102
57103	57106	57107	57108	57114
57115	57116	57117	57118	57119
57120	57121	57122	57123	57124
57125	57126	57127	57128	57130
57131	57132	57133	57134	57135
57136	57137	57138	57139	57140
57141	57142	57143	57144	57145
57146	57147	57148	57149	57150
57151	57152	57159	57160	57161
57162	57163	57164	57165	57166
57167	57168	57170	57171	57172
57173	57174	57175	57176	57177
57178	57179	57180	57181	57182
57183	57184	57185	57189	57190
57191	57192	57193	57194	57195
57196	57197	57198	57199	57200
57201	57202	57203	57204	57205
57206	57207	57208	57209	57210
57211	57212	57213	57214	57215
57216	57217	57218	57219	57220
57221	57222	57223	57224	57225
57226	57227	57228	57229	57233
57234	57235	57236	57249	57250
57251	57252	57253	57255	57256

57257	57258	57260	57261	57262
57263	57264	57265	57266	57267
57268	57270	57271	57272	57274
57275	57276	57277	57278	57279
57280	57281	57282	57283	57284
57285	57286	57287	57288	57290
57291	57293	57294	57295	57296
57297	57298	57299	57300	57301
57302	57303	57304	57305	57306
57307	57308	57309	57310	57311
57317	57308	57309	57310	57311

2.2. Selection of the Beam Photon

In an event we found that multiple bremsstrahlung photons were recorded as the incident beam. The multiple beam photon arises from 2.004 beam bunching spacing of the electrons in the storage ring. These electrons gives the bremsstrahlung photons in the radiator and creates multiple hits in the trigger and thereby satisfying trigger logic to record them. In this analysis we selected all the photons which falls within the timing window of $|\text{Tagger Time} - \text{StartTime}| \leq 1.002 \text{ ns}$, and consider each of them as an individual event.

2.3. Vetex Cut

In the g12 experiment the target was positioned -90 cm from the CLAS center. The target cell was 40 cm long and 2 cm in radius in the form of a cylinder filled with unpolarised liquid hydrogen. We used this target information and imposed it to all event vertexes. We required all events production vertex tracks to originate in the target region via the condition that $\sqrt{v_x^2 + v_y^2} \leq 2 \text{ cm}$ and $-110 \geq v_z \geq -70 \text{ cm}$.

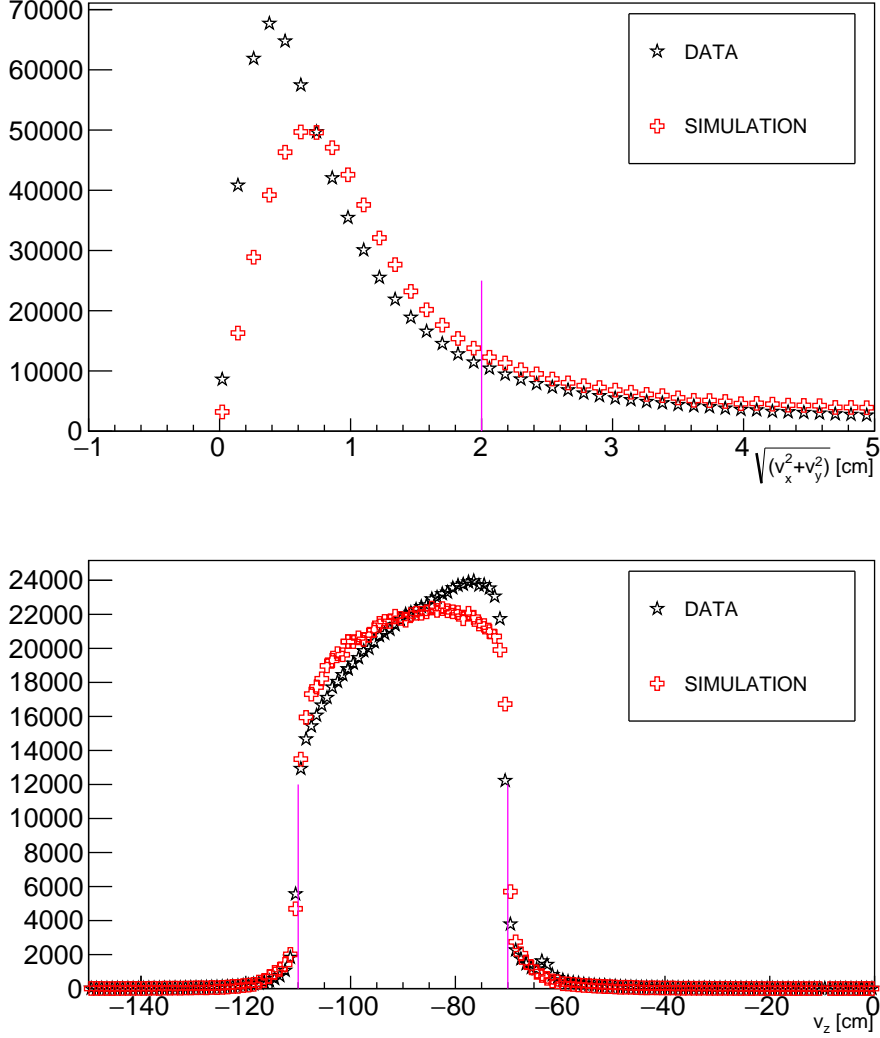


FIGURE 1. $[t_{pho} + t_{prop} - scvt]$ distribution from the simulation and data for proton, π^+ and π^- .

2.4. Timing Cuts on proton, π^+ and π^-

As a post PID improvement of the detected final state particles π^+ , π^- and proton, we introduced a vertex timing (t_{vert}) cut of particles in the analysis. The t_{vert} , vertex time is the instant of time the particle left the target. One can calculate it through the information of the TOF detectors as,

$$t_{vert}(TOF) = t_{TOF} - \frac{l_{TOF}}{c\beta}$$

where t_{TOF} and l_{TOF} are the measured time and length of particle in TOF sub detector. Here c is the velocity of light in vacuum and β is the Lorentz factor of the particle calculated by knowing the velocity(v) of particle as $\beta = \frac{v}{c}$. The same vertex timing (t_{vert}) information can also be calculated from the RF-corrected time instant of the photon (t_{photon}) crossing the target center measure by the tagger added with the t_{prop} , which is the propagation time from the center of the target to the track vertex. Given by,

$$t_{vert}(Tagger) = t_{photon} + t_{prop}.$$

The difference of the $t_{vert}(TOF)$ from $t_{vert}(Tagger)$ is shown in Fig. 2, and we make a cut of ± 1.0 ns around 0 ns for all the final state particles in both simulation and data.

3. G12 Corrections

The G12 Corrections were derived from the exclusive π^+ , π^- and proton reaction. We used the following corrections in the analysis :

- Beam Energy Correction : Is a correction to the incident beam photon energy and dependent on the Run number of the event. This correction is only applicable data and not to the simulated events.
- Removal of bad TOF paddle : This correction takes the Sector number, Paddle number as input. We used the correction to remove only those paddles that shows a significant drift on the resolutions of particle.
- Geometric Fiducial Cut : This cut removes the dead part of the detector from the $\theta - \phi$ map of the particle. We used it with the "nominal" option.

3.1. Kinematic Fitting

Kinematic fitter is a useful tool often used to get rid of unwanted background from signal channels and helps to improve the signal to background ratio. Any measurement

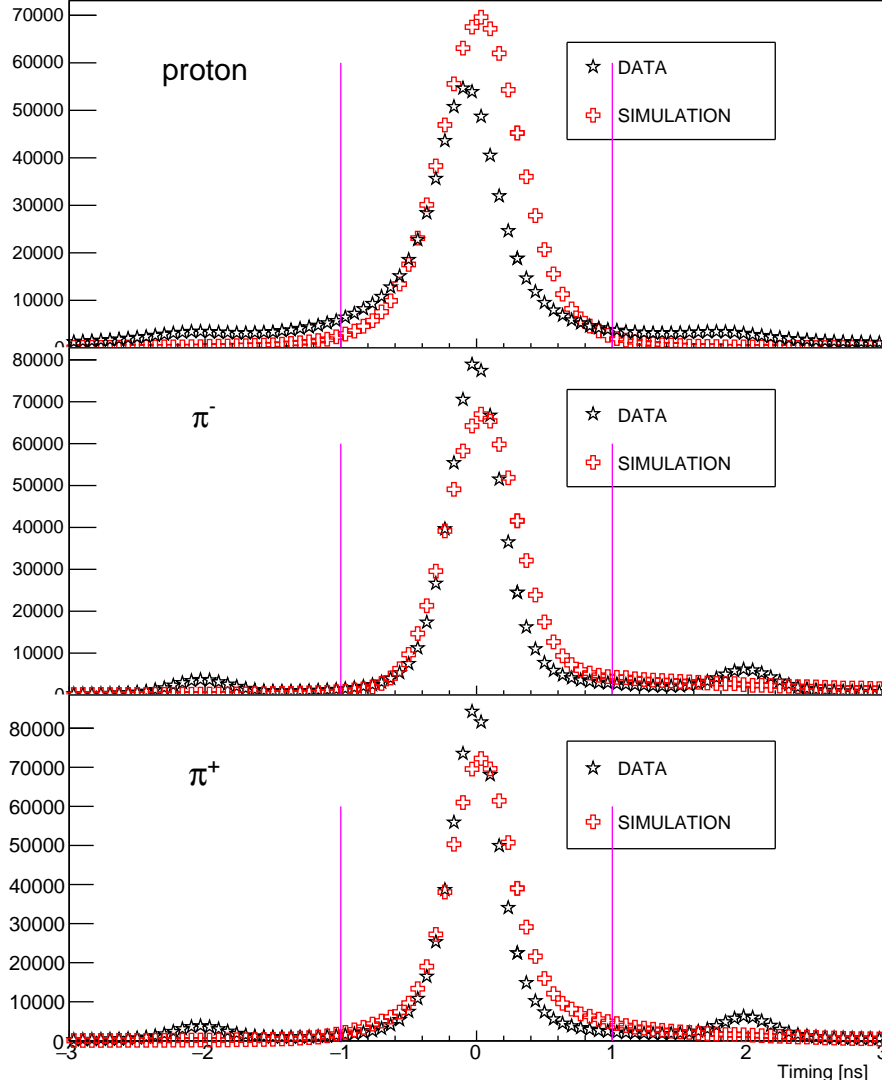


FIGURE 2. $[t_{vert}(TOF) - t_{vert}(Tagger)]$ distribution from the simulation and data for proton(Upper), π^+ (Middle) and π^- (Lower).

with a tool comes with an error, and it can be represented as a vector $\vec{\eta}$. We can also define the measurement as

$$\vec{\eta} = \vec{y} + \vec{\epsilon}.$$

Where the \vec{y} and $\vec{\epsilon}$ denotes the actual value of the measurement without error and $\vec{\epsilon}$ is the error associated with the measurement. The kinematic information of a physics channel along with the constraints imposed allows the fitter to calculate the probability and χ^2 of each event using Lagrange multipliers to perform a least-squares fit. The CLAS g12

Kinematic fitter takes the “TBER (Track Based Error)” matrix, vertex of information and lorentzvector of all particles as input, and returns Pull probabilities and χ^2 for each events. The Pull probabilities when fitted with Guassian, its mean and σ decides the quality of the covariance matrix and kinematic fit. In the ideal case of gaussian fitted to the Pulls of the particles should have zero mean and σ of one, which ensures that the fitter correctly calculates covariance matrix error.

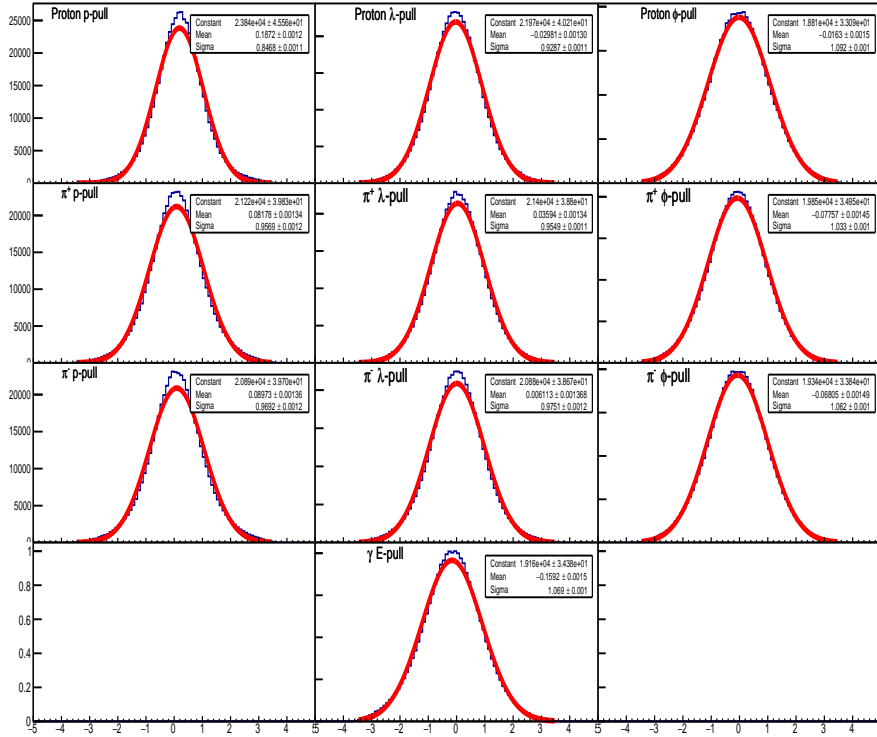


FIGURE 3. The Pull distributions for a (4-C) kinematic fit to $\gamma p \rightarrow \pi^+ \pi^- p$ from g12 data with run 56655 after a 1% Pull probability cut.

The CLAS g12 Kinematic fitter is tuned for 4C constrained reaction,

$$\gamma p \rightarrow \pi^+ \pi^- p.$$

The tuning were done for $\pi^+ \pi^-$ and p individually. To check the quality of covariance matrix we have shown the tuned pulls of the particles π^+ , π^- and p from the reaction hypothesis for the data with run 56655 and simulation after a 1% pull probability cut. The mean and sigma from of the particles are listed in the Table. 2.

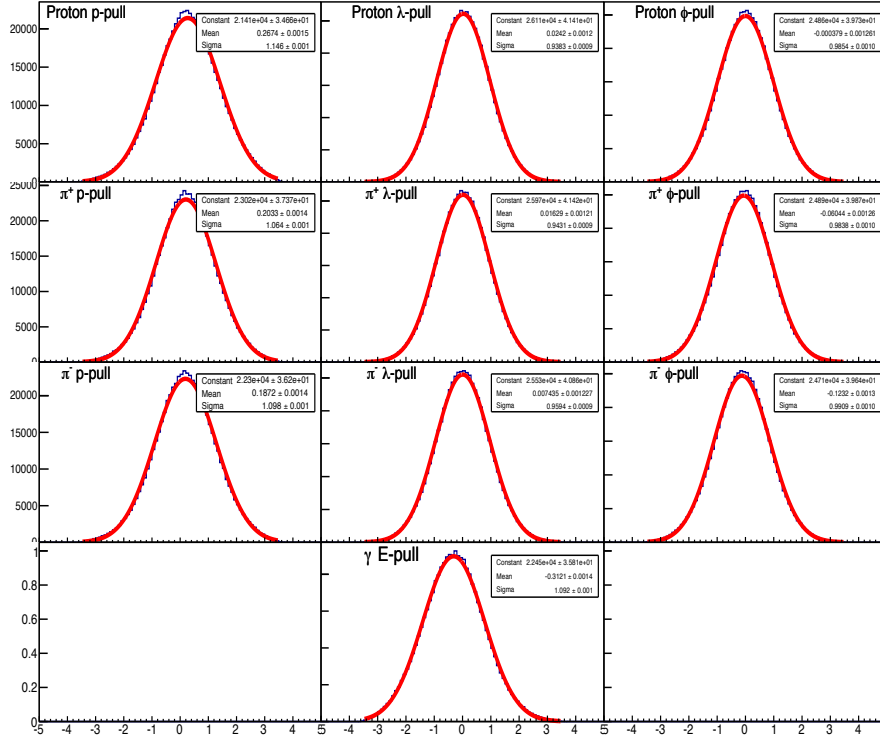


FIGURE 4. The Pull distributions for a (4-C) kinematic fit to $\gamma p \rightarrow \pi^+ \pi^- p$ from g12 simulation after a 1% Pull probability cut.

3.1.1. *Fit to the Analysis.* We use the tuned Kinematic fitter for the 4C constrained fit described above to the reaction hypothesis for our channel $\gamma p \rightarrow (\eta)_{\text{Missing}} \pi^+ \pi^- p$. We required the $M_x(p\pi^+\pi^-)$ has to be an η meson. Our reaction hypothesis has the same set of final state particles as for the tuned channel, hence we can comfortably use it without tuning it for our reaction hypothesis again. The Pull probability for the channel of our interest is shown in Fig. 5 and the dotted line at 0.01 shows the 1% Pull probability cut to reject events.

3.2. Simulation

Pluto, an event generator is used for this analysis. Pluto uses ROOT based programmes very commonly used in Hadron Physics experiments to generate hadronic production and decay. It gives user the freedom to include physics models with simple C++ based codes and to obtain outputs in any desired format. Our simulated events are

(A)			(B)		
	μ	σ		μ	σ
Proton p-pull	0.187	0.846	Proton p-pull	0.267	1.146
Proton λ -pull	-0.029	0.928	Proton λ -pull	0.024	0.938
Proton ϕ -pull	-0.016	1.092	Proton ϕ -pull	-0.000	0.985
π^+ p-pull	0.081	0.957	π^+ p-pull	0.203	1.064
π^+ λ -pull	0.035	0.954	π^+ λ -pull	0.016	0.943
$\pi^- \phi$ -pull	-0.077	1.033	π^+ ϕ -pull	-0.060	0.983
$\pi^- p$ - pull	0.089	0.969	π^- p-pull	0.187	1.098
$\pi^- \lambda$ -pull	0.006	0.975	π^- λ -pull	0.007	0.959
$\pi^- \phi$ -pull	-0.068	1.062	π^- ϕ -pull	-0.123	0.990
γ E-pull	-0.159	1.069	γ E-pull	-0.312	1.092

TABLE 2. The table shows the Gaussian mean (μ) and width (σ) for the pull distributions from a 4C kinematic fit of $\gamma p \rightarrow \pi^+ \pi^-$ to events from (A) data run 56655 and (B) from simulation after a 1% Pull probability cut.

modelled with bremsstrahlung photon, differential cross-section of η' and Dalitz plot parameters of $\eta' \rightarrow \eta \pi^+ \pi^-$ decay. We took the output of the PLUTO program in standard CLAS "gamp" file and processed it with CLAS simulation suit :

- The gamp files are first converted into the format of PART bank containing the event.
- GSIM: Geant3-based simulation in CLAS simulates the decay tracks of particles through the simulation and finally the digitized informations is sorted in the simulated "raw" banks.
- GPP: GSIM post-processor smears detector signal more accurately to reflect the actual resolution and to simulate the experimental conditions.
- a1c : It is used for reconstruction of simulated data and is the same program used during data reconstruction.

Cuts	g12 Run 56655	Simulation
Generated	—	10001500
Reconstructed	42947	855447
Vertex Cut	20092	505405
Timing Cut	11390	451470
Multiple E_γ	14986	—
Fiducial Cuts	10541	276432
$\text{Prob}((\eta)\pi^+\pi^-p) > 0.01$	1901	259136

TABLE 3. The table shows the cut flow of the analysis from g12 data run 56655 and simulated events.

The simulated events are then passed through same conditions of Section. 2.3, Section. 2.4, Section. 3 and Section. 3.1.

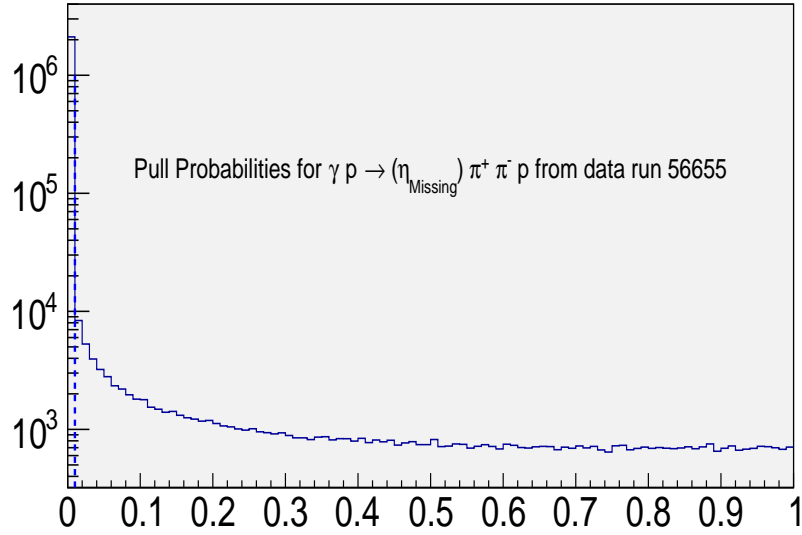


FIGURE 5. The Pull probability for a (1-C) kinematic fit to $\gamma p \rightarrow (\eta_{\text{Missing}}) \pi^+ \pi^- p$ from data run 56655.