

# Toward Analysis Note

PART 1

Zulkaida Akbar

# Part 1

- Basic Cut
- Kinematic Fitting
- Monte Carlo

# Basic Cut : Vertex Cut

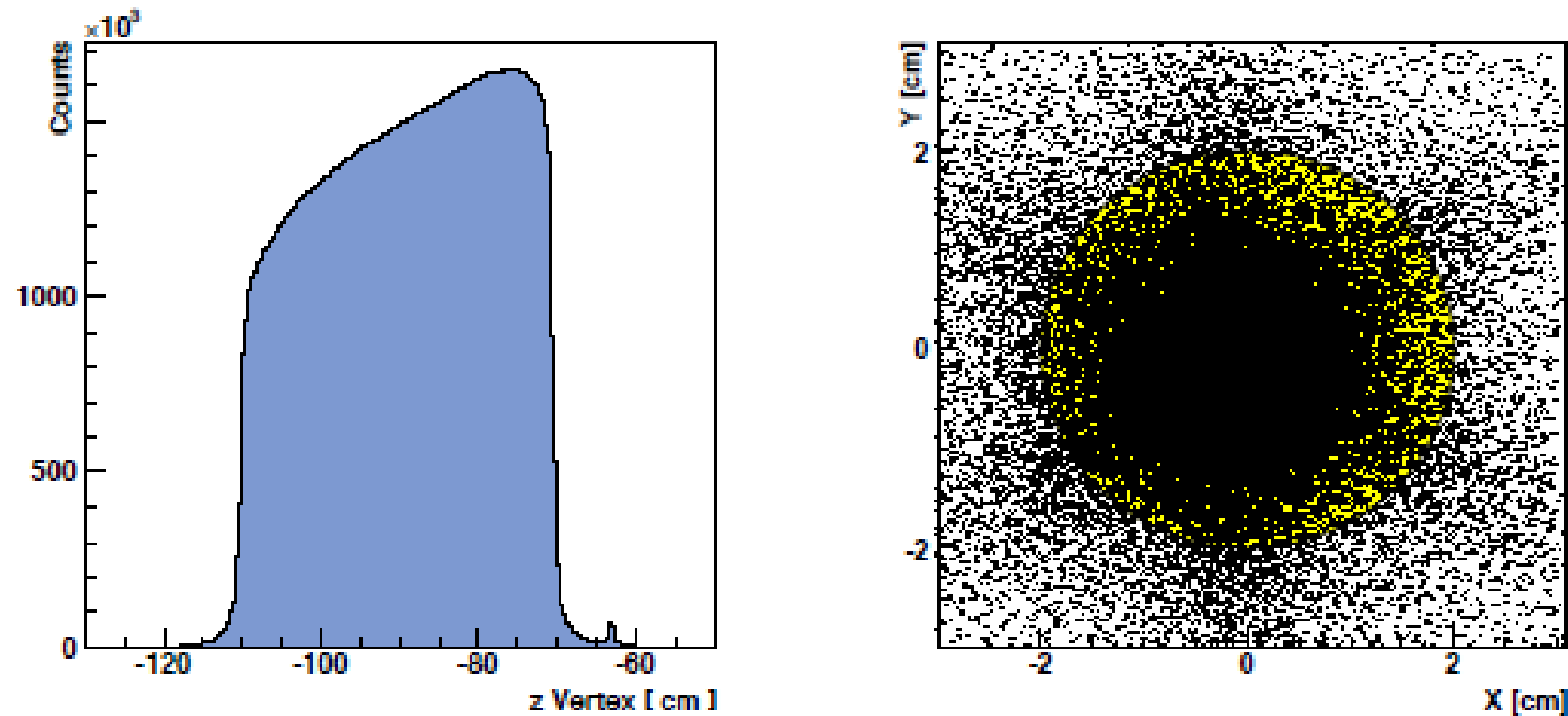


Figure 4: *Left: The  $z$ -vertex distribution (axis along the beam line) of all reconstructed particles we used in our FSU analyses. The shape of the liquid hydrogen target is clearly visible. The small enhancement at about  $z = -63$  cm originates from the exit window of the vacuum chamber. Right: The  $x$ - vs.  $y$ -vertex distribution from g12 based on our full statistics (Period 1 & 2). The circle indicates our cut of  $x^2 + y^2 < 2 \text{ cm}^2$ .*

# Basic Cut : Timing

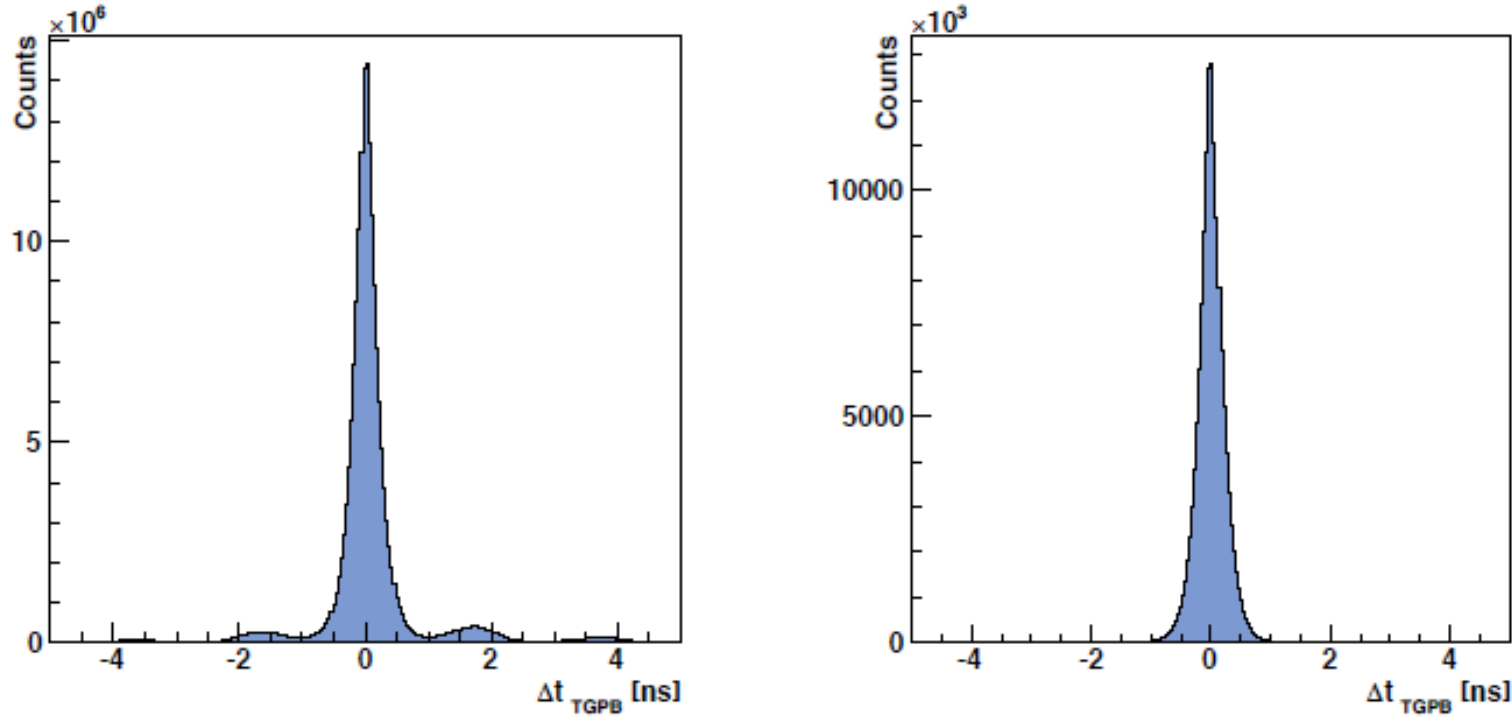


Figure 1: *Left: Example of a coincidence-time distribution,  $\Delta t_{\text{TGPB}}$ , for the inclusive  $p\pi^+\pi^-$  final-state topology. The 2 ns bunching of the photon beam is clearly visible in the histogram. Right: Distribution of  $\Delta t_{\text{TGPB}} = t_{\text{event}} - t_\gamma$  for the selected photon (one entry per event) after PID cuts. The event vertex time,  $t_{\text{event}}$ , was based on Equation 4. We only considered events which had exactly one candidate photon in the same RF bucket per track; each identified track had to be associated with the same photon.*

# Basic cut : Delta Beta Cut

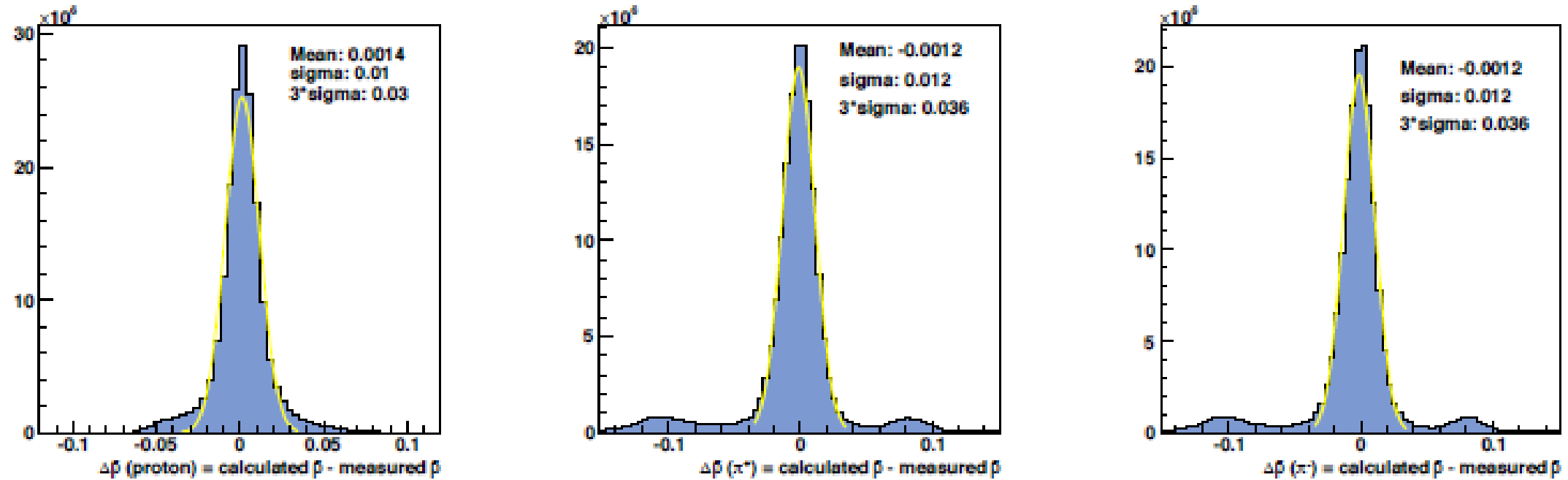


Figure 2: Distributions of  $\Delta\beta = \beta_c - \beta_m$  for protons (left) as well as for the  $\pi^+$  (middle) and for the  $\pi^-$  (right) from the g12 experiment (full statistics used in our FSU analyses, Period 1 & 2 (see Table 1)). The quantity  $\beta_c$  was calculated based on the particle's PDG mass [5]. Events in the center peak were selected after applying a  $|\beta_c - \beta_m| \leq 3\sigma$  cut. See text for more details.

# Basic Cut : Effect of Delta Beta Cut

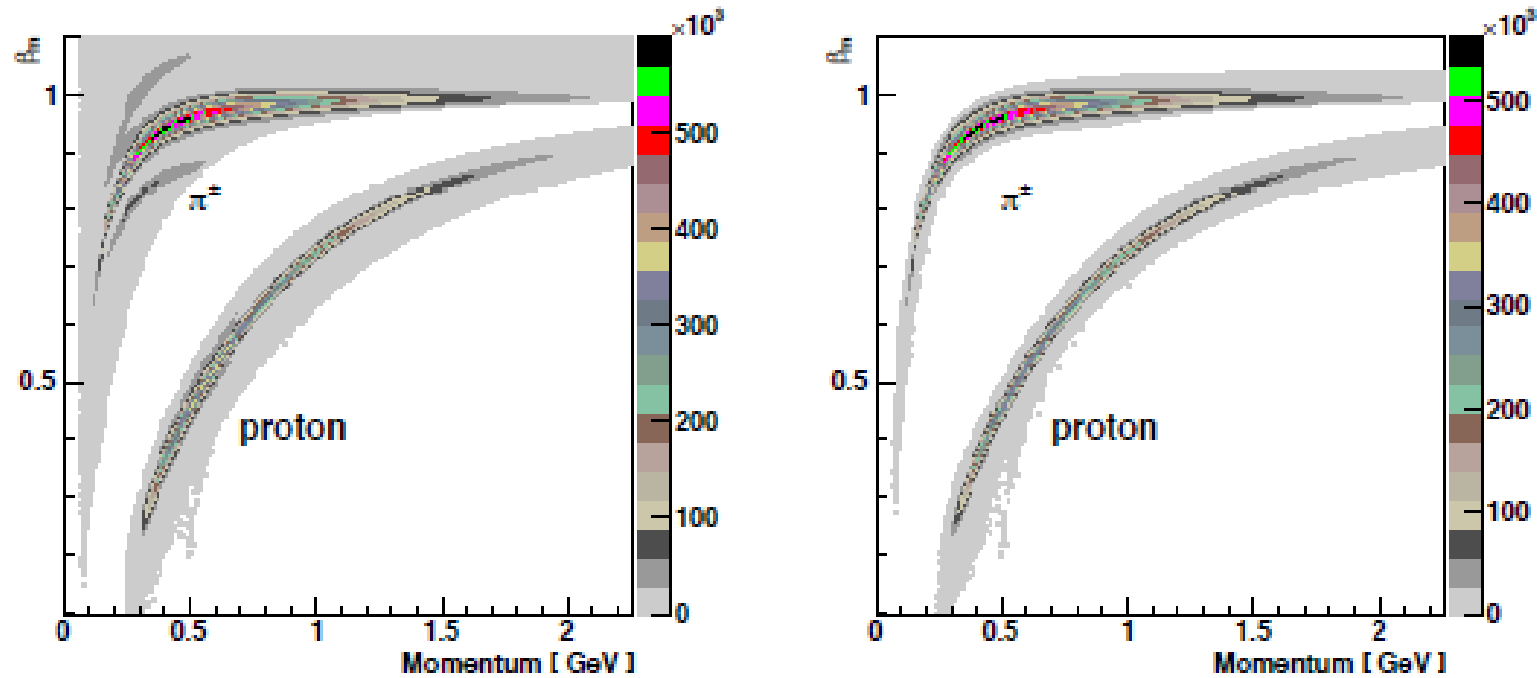


Figure 3: *Left: The measured  $\beta_m$  versus the measured momentum taken from PART on a logarithmic color scale. Note a thin horizontal line at one for electrons, and the broad stripes for pions (top) followed by protons (bottom). Right: The measured  $\beta_m$  versus the measured momentum after applying the  $3\sigma$  cut based on the difference  $\Delta\beta = \beta_c - \beta_m$ . Clean pion and proton bands are visible. These figures were made using the full statistics used in our FSU analyses, Period 1 & 2 (see Table 1)*

# Additional cut : cut on forward pi0

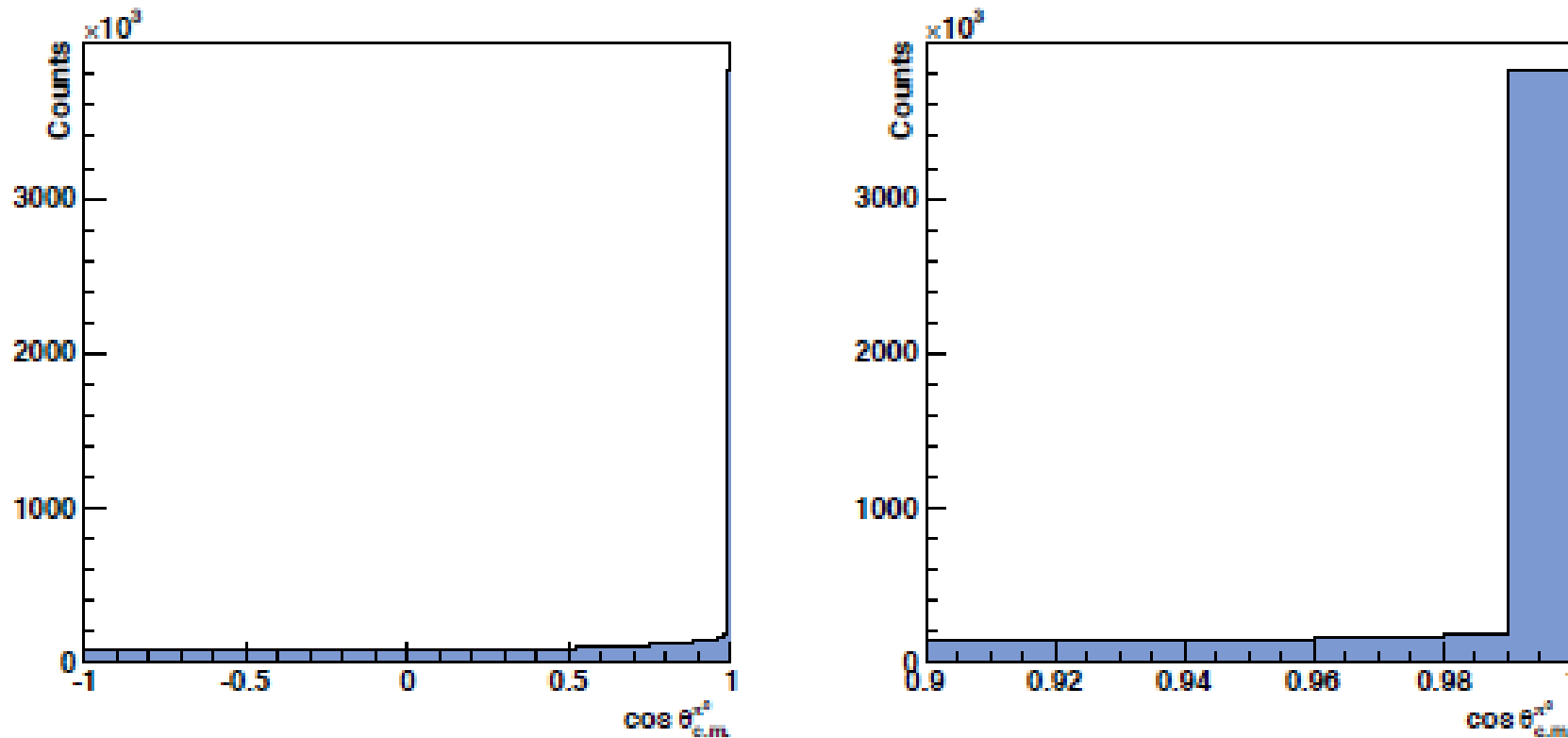
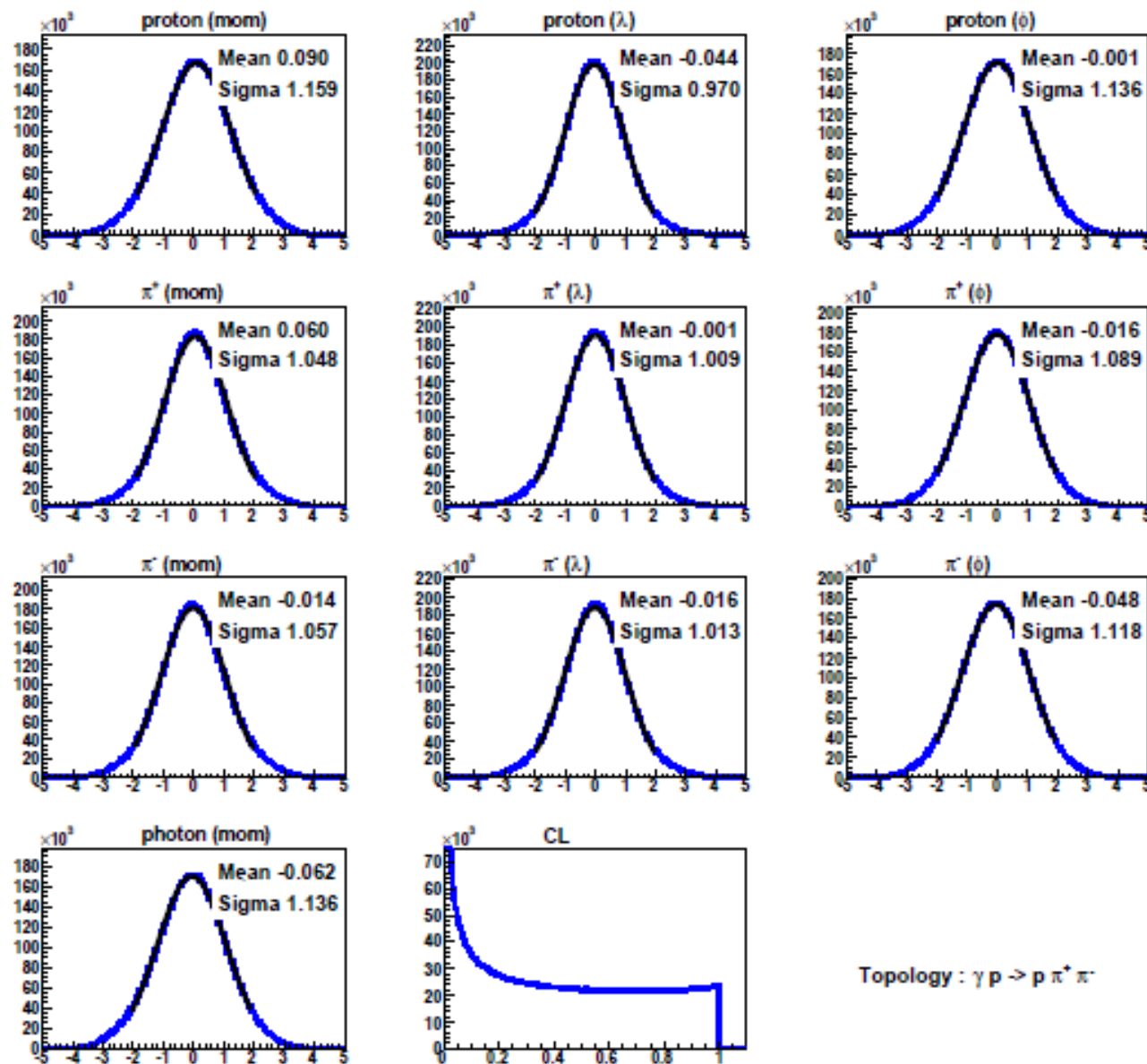


Figure 17: *Left: The  $\cos \theta_{c.m.}^{\pi^0}$  distribution of all 18 million  $\gamma p \rightarrow p \pi^+ \pi^- (\pi^0)$  events which pass a  $p > 0.001$  CL cut. This figure shows an excess of events in the very forward region. Right: The same figure except zoomed in on the forward region.*

# Kinematic Fitting





Fine tune to 2 pion Channel

P scale : 1.94

Res scale : 2.0

Figure 6: The  $g_{12}$  pull and confidence-level distributions for the exclusive reaction  $\gamma p \rightarrow p \pi^+ \pi^-$  (full statistics of Period 1 & 2). A summary of the mean and  $\sigma$  values of the fits can also be found in Table 3.

|  | proton |           |        | $\pi^+$ |           |        | $\pi^-$ |           |        | $\gamma$ |
|--|--------|-----------|--------|---------|-----------|--------|---------|-----------|--------|----------|
|  | mom.   | $\lambda$ | $\phi$ | mom.    | $\lambda$ | $\phi$ | mom.    | $\lambda$ | $\phi$ | E        |

CLAS-g12:  $\gamma p \rightarrow p\pi^+\pi^-$

|           |       |        |        |       |        |        |        |        |        |        |
|-----------|-------|--------|--------|-------|--------|--------|--------|--------|--------|--------|
| $\bar{x}$ | 0.090 | -0.044 | -0.001 | 0.060 | -0.001 | -0.016 | -0.014 | -0.016 | -0.048 | -0.062 |
| $\sigma$  | 1.159 | 0.970  | 1.136  | 1.048 | 1.009  | 1.089  | 1.057  | 1.013  | 1.118  | 1.136  |

CLAS-g12:  $\gamma p \rightarrow p\pi^+\pi^- (\pi^0)$

|           |       |       |        |        |        |        |        |        |        |       |
|-----------|-------|-------|--------|--------|--------|--------|--------|--------|--------|-------|
| $\bar{x}$ | 0.140 | 0.001 | -0.211 | -0.150 | -0.023 | -0.192 | -0.194 | -0.029 | -0.164 | 0.190 |
| $\sigma$  | 1.167 | 1.182 | 1.173  | 1.193  | 1.178  | 1.161  | 1.194  | 1.179  | 1.143  | 1.209 |

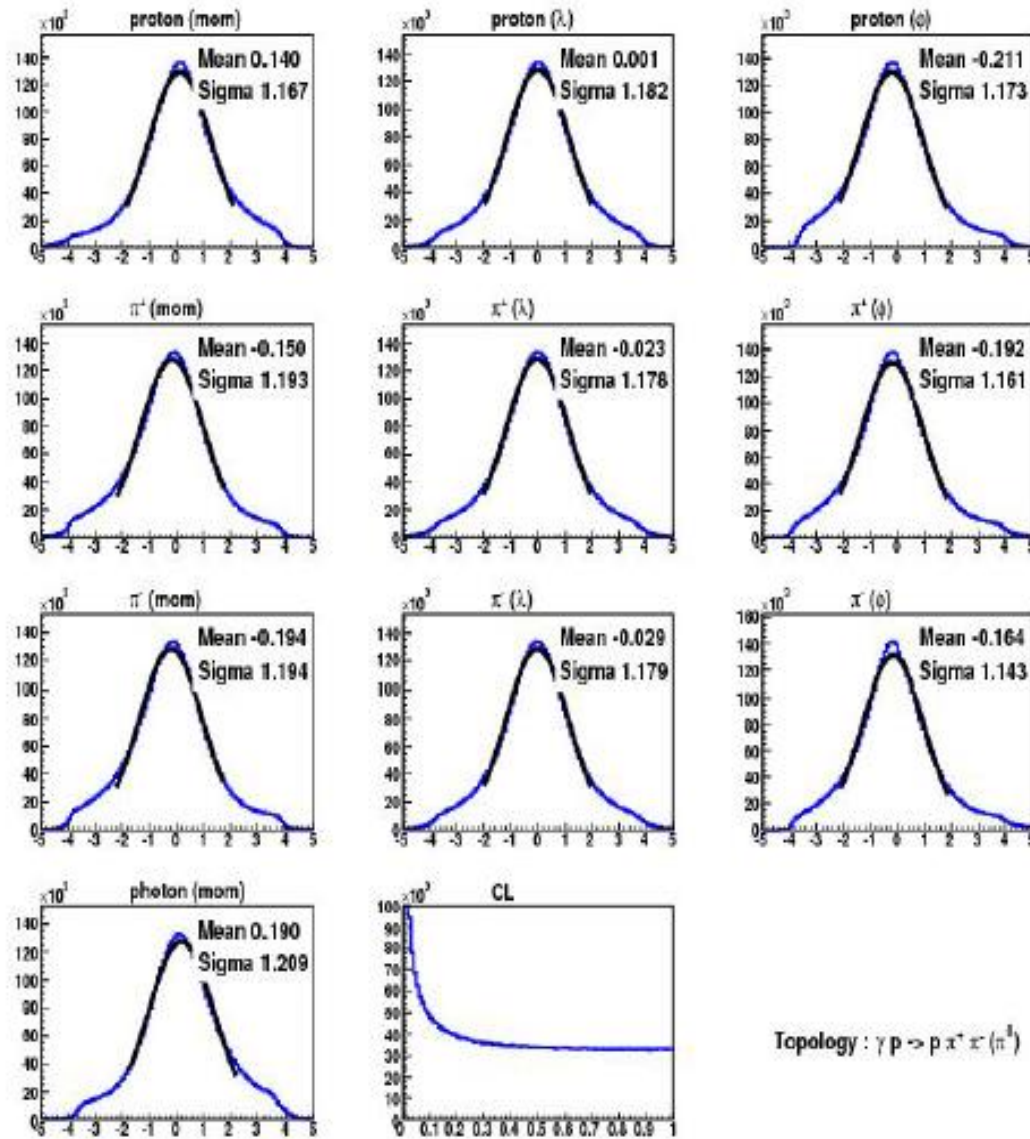
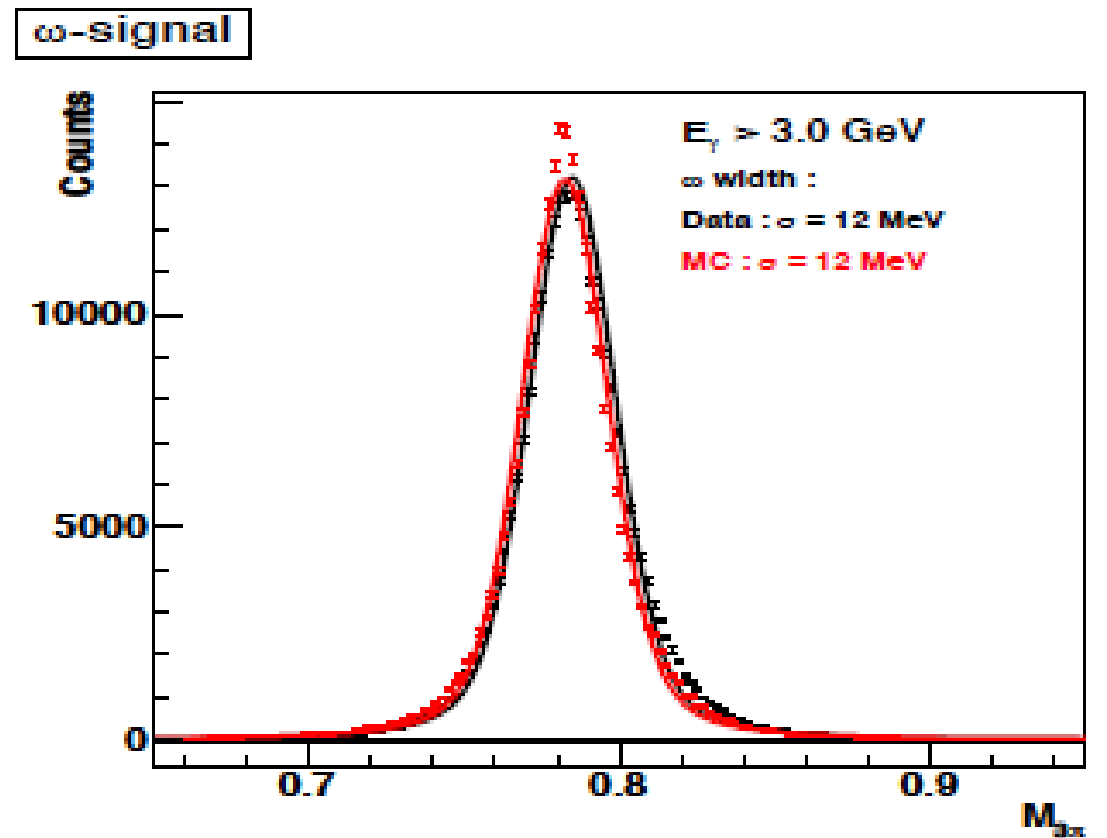
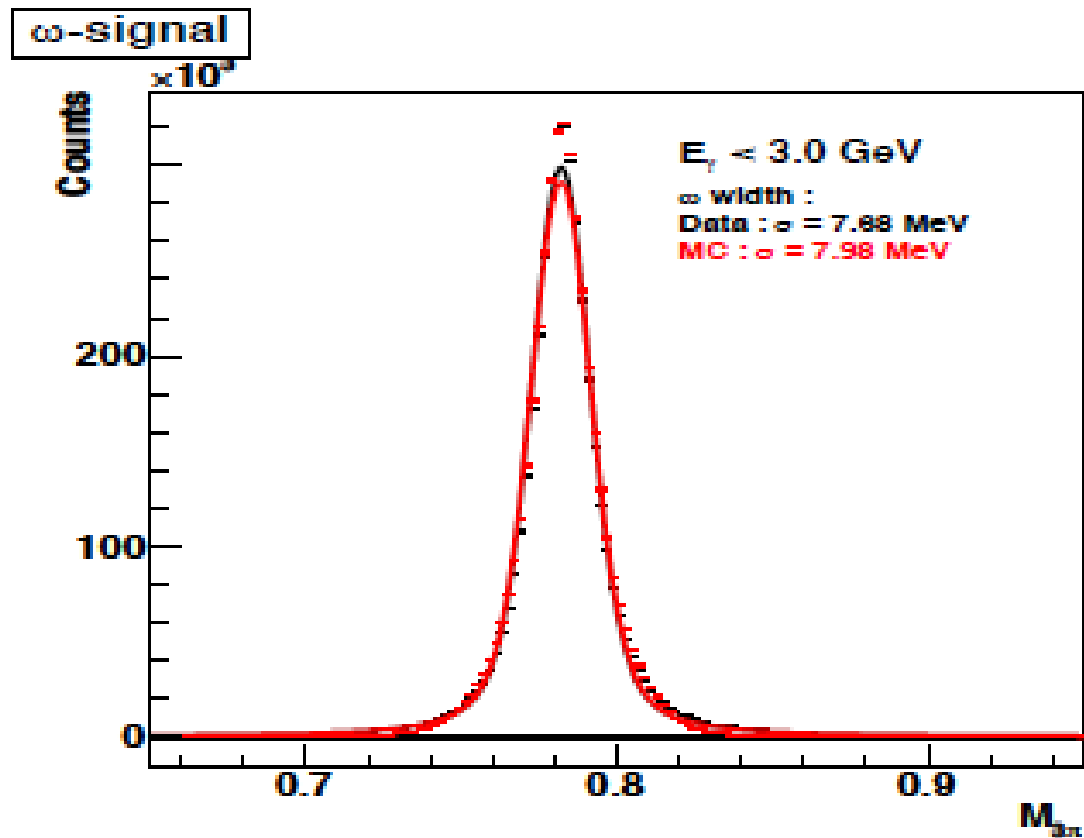


Figure 7: The  $gl2$  pull and confidence-level distributions for the reaction  $\gamma p \rightarrow p \pi^+ \pi^- (\pi^0)$  (full statistics of Period 1 & 2). Note that the pull distributions are not Gaussian over the full range owing to the missing-particle hypothesis. The confidence-level distribution looks nicely flat, though. A summary of the mean and  $\sigma$  values of these fits can also be found in Table 3. *Bad resolution.*

Monte Carlo

# MC : Quality Check of the resolution



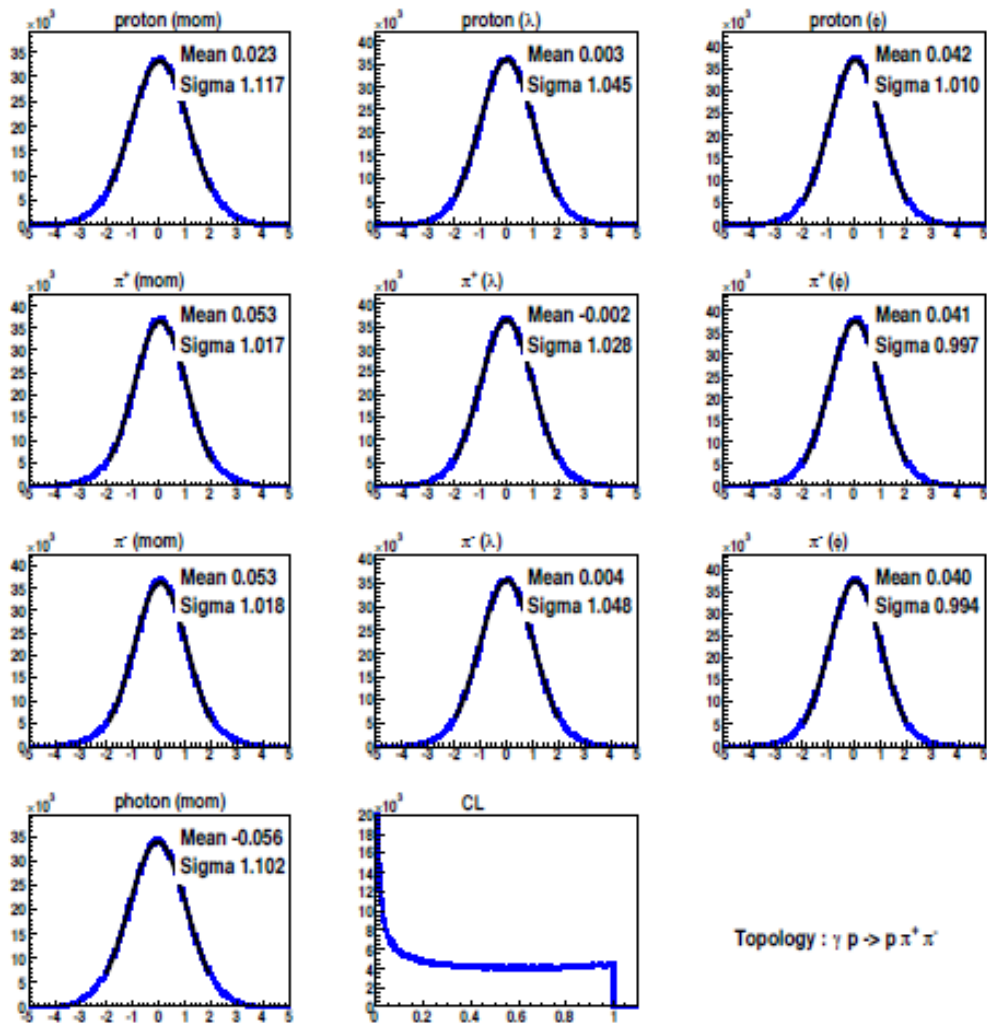


Figure 14: Monte Carlo (reaction:  $\gamma p \rightarrow p\omega \rightarrow p\pi^+\pi^-$ ) pull and confidence-level distributions for the four-constraint fit to  $p\pi^+\pi^-$  (check for energy and momentum conservation, no mass constraint) along with the mean and  $\sigma$  values of the fits. A summary of the mean and  $\sigma$  values of these fits (for data and Monte Carlo) can also be found in Table 5.

Fine tune to 2pion MC :

MC Flag : True

P scale : 1.4

Res scale : 1.4

Topology :  $\gamma p \rightarrow p\pi^+\pi^-$

|  | proton |           |        | $\pi^+$ |           |        | $\pi^-$ |           |        | $\gamma$ |
|--|--------|-----------|--------|---------|-----------|--------|---------|-----------|--------|----------|
|  | mom.   | $\lambda$ | $\phi$ | mom.    | $\lambda$ | $\phi$ | mom.    | $\lambda$ | $\phi$ | E        |

Monte Carlo:  $\gamma p \rightarrow p\pi^+\pi^-$

|           |       |       |       |       |        |       |       |       |       |        |
|-----------|-------|-------|-------|-------|--------|-------|-------|-------|-------|--------|
| $\bar{x}$ | 0.023 | 0.003 | 0.042 | 0.053 | -0.002 | 0.041 | 0.053 | 0.004 | 0.040 | -0.056 |
| $\sigma$  | 1.117 | 1.045 | 1.010 | 1.017 | 1.028  | 0.997 | 1.018 | 1.048 | 0.994 | 1.102  |

Monte Carlo:  $\gamma p \rightarrow p\pi^+\pi^- (\pi^0)$

|           |       |       |       |       |       |       |       |       |       |        |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| $\bar{x}$ | 0.040 | 0.018 | 0.024 | 0.027 | 0.000 | 0.024 | 0.022 | 0.004 | 0.030 | -0.052 |
| $\sigma$  | 1.078 | 1.054 | 1.081 | 1.045 | 1.056 | 1.015 | 1.055 | 1.056 | 1.004 | 1.086  |

Table 5: Final mean ( $\bar{x}$ ) and  $\sigma$  values of Gaussian fits to our g12 pull distributions after applying all corrections. Note that the values for  $p\pi^+\pi^- (\pi^0)$  are based on distributions which cannot be perfect Gaussians owing to the missing-particle hypothesis.

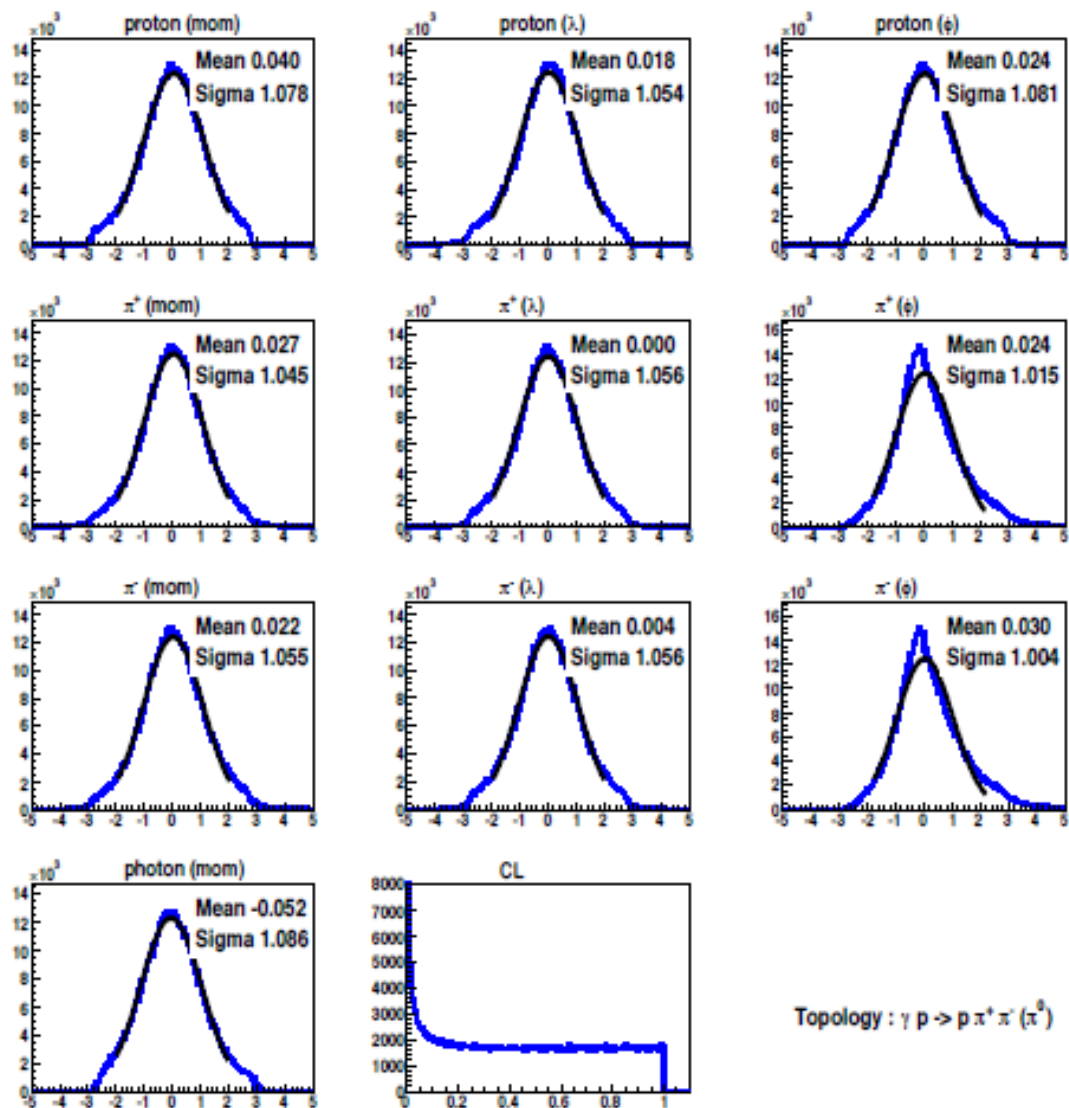


Figure 15: Monte Carlo (reaction:  $\gamma p \rightarrow p \omega \rightarrow p \pi^+ \pi^- \pi^0$ ) pull and confidence-level distributions for the one-constraint fit to  $p \pi^+ \pi^- (\pi^0)$  (no  $\omega$ -mass constraint) along with the mean and  $\sigma$  values of the fits. Note that the pull distributions are not Gaussian over the full range owing to the missing-particle hypothesis. A summary of the mean and values of these fits (for data and Monte Carlo) can also be found in Table 5.



# NorMalized Slope

$$\bar{a} = \frac{a}{a/2 + b}, \quad (11)$$

where  $a$  is the slope and  $b$  is the intercept obtained by fitting the confidence-level distribution

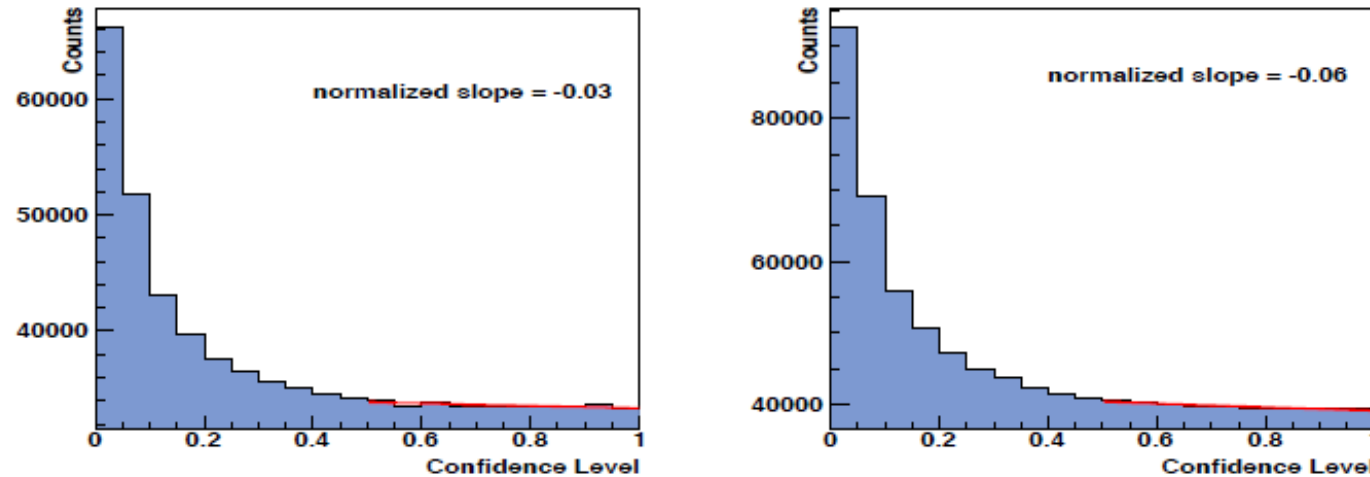


Figure 10: Examples of normalized slopes from confidence-level distributions for the proton (left) and for the  $\pi^-$  (right): Normalized slopes have been extracted by fitting the distributions in the range (0.5, 1) to a linear function.

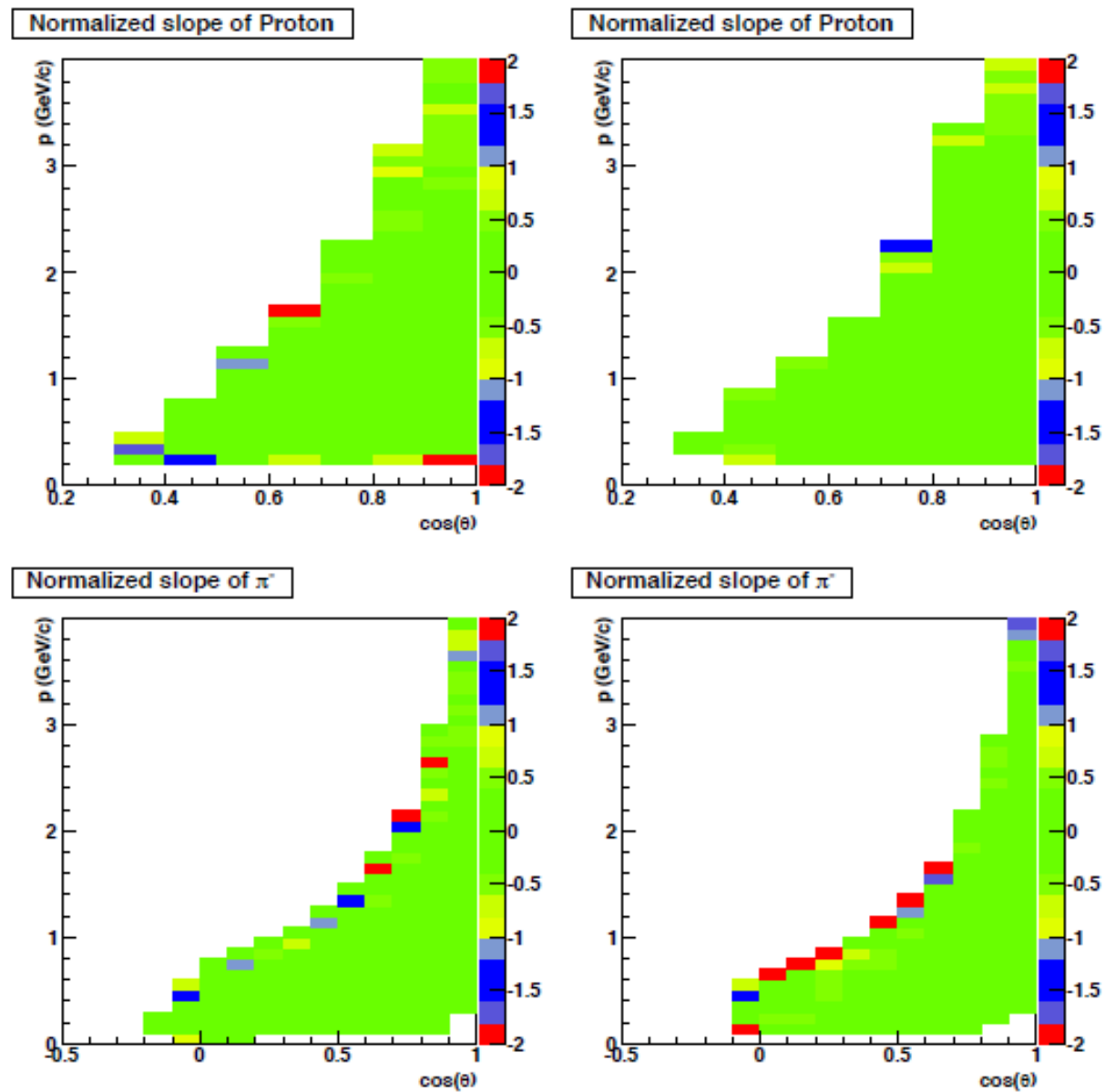


Figure 16: *Confidence Level Checks. Normalized confidence-level slopes presented in  $\cos\theta$  versus  $p$  [GeV/c] distributions for the proton (top row) and for the  $\pi^-$  (bottom row). The results for the g12-data are shown on the left and for Monte Carlo on the right. Notice that - excluding edge bins with low statistics - all kinematic regions have  $|\bar{a}| < 0.5$ .*

# MC : Vertex distribution

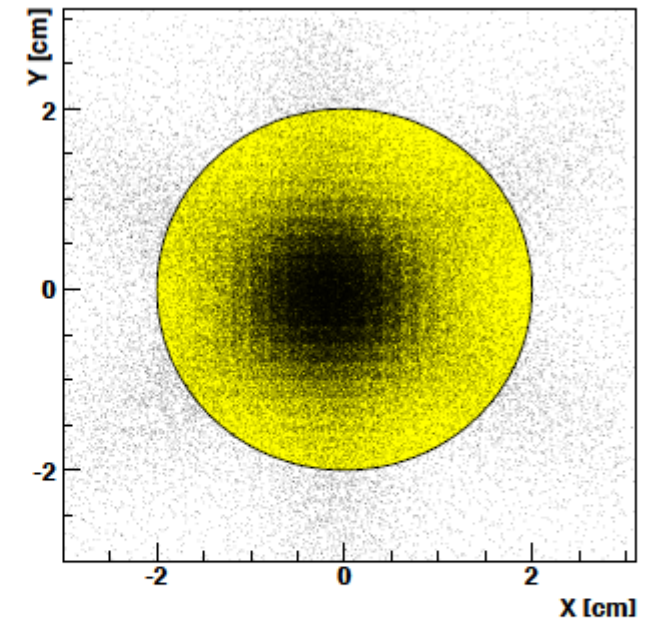
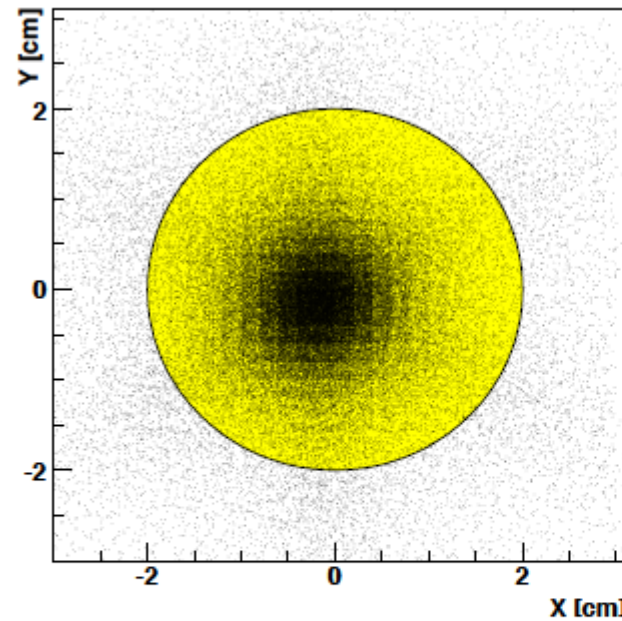
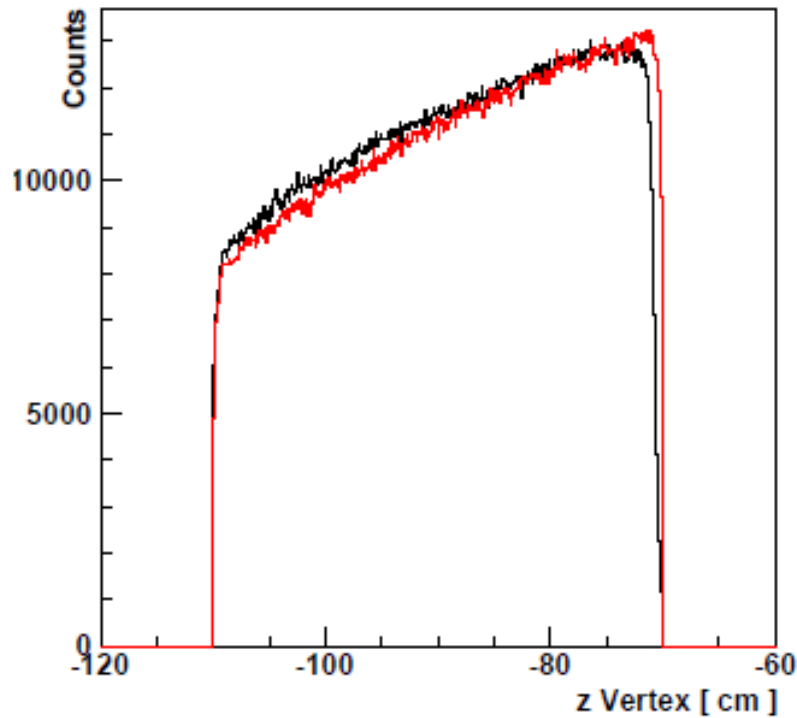
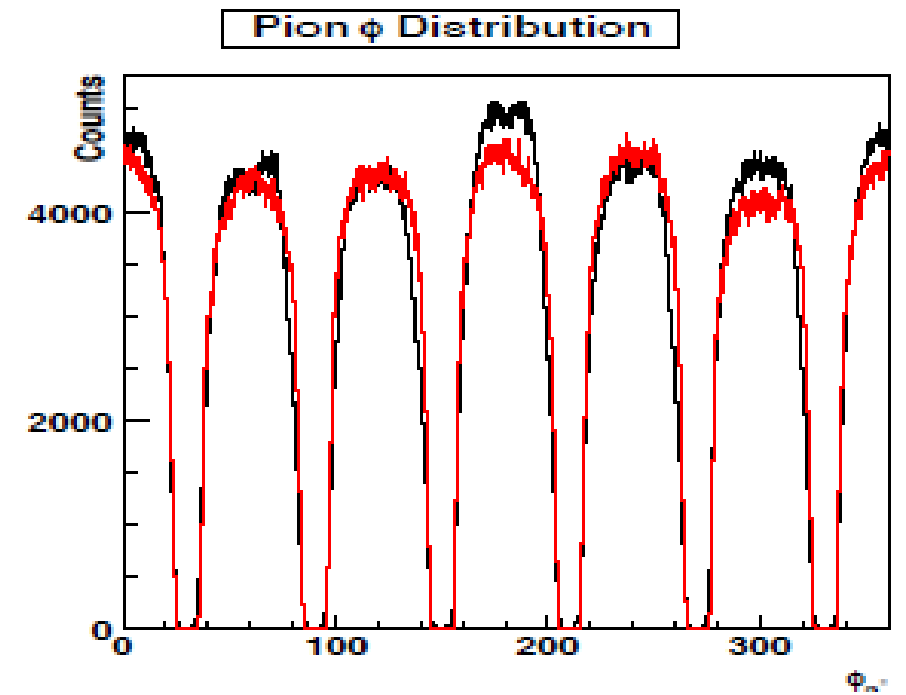
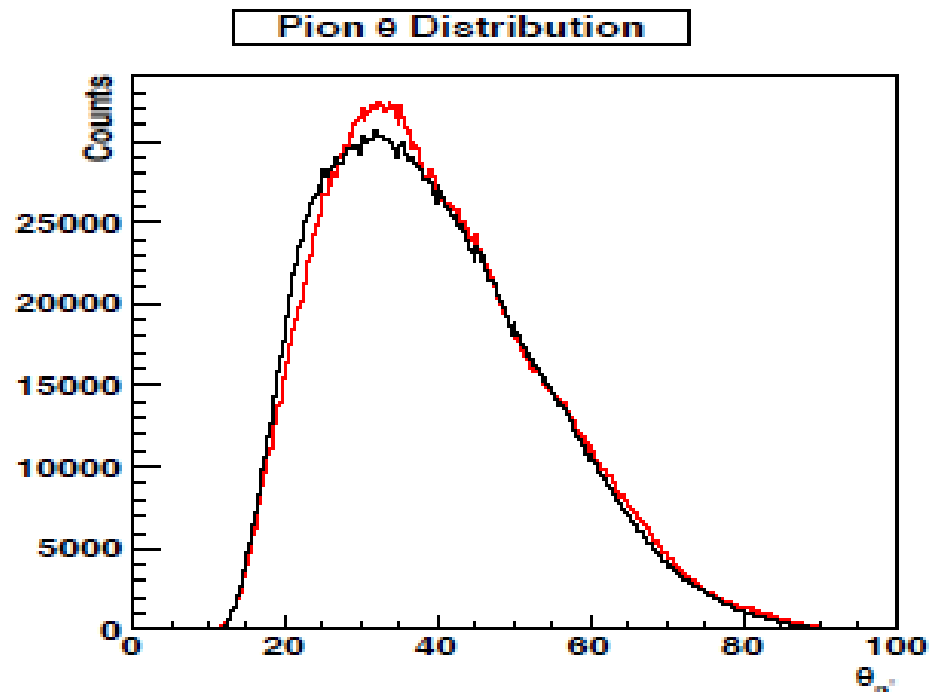
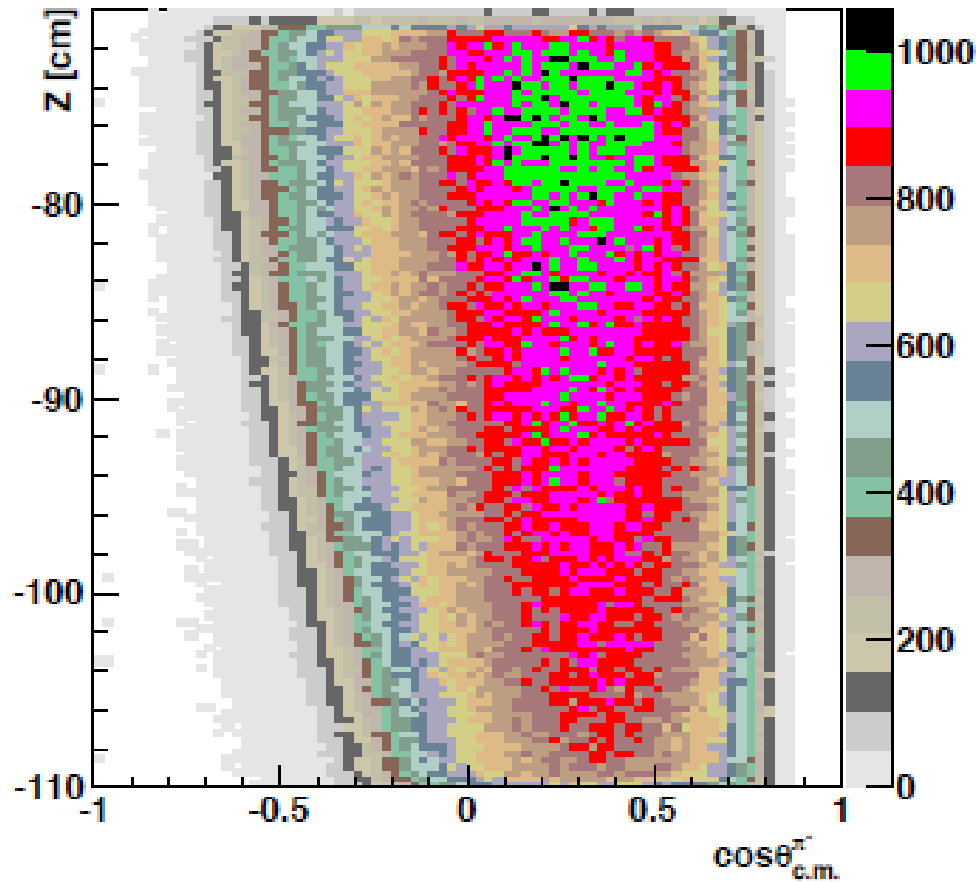


Figure 13: *Left: The x- vs. y-vertex (event) distribution of  $\gamma p \rightarrow p \pi^+ \pi^- \pi^0$  events from g12 based on our full statistics (Period 1 and 2). Right: The x- vs. y-vertex (event) distribution of  $\gamma p \rightarrow p \omega \rightarrow p \pi^+ \pi^- \pi^0$  Monte Carlo events based on all 175 million generated events. The circle on both figures indicates our cut of  $x^2 + y^2 < 2 \text{ cm}^2$ . These distributions are in very good agreement.*

# MC : Angel distribution



**z-Vertex Versus  $\cos\theta_{c.m.}^{\pi^-}$  distributions**



**z-Vertex Versus  $\cos\theta_{c.m.}^{\pi^-}$  distributions**

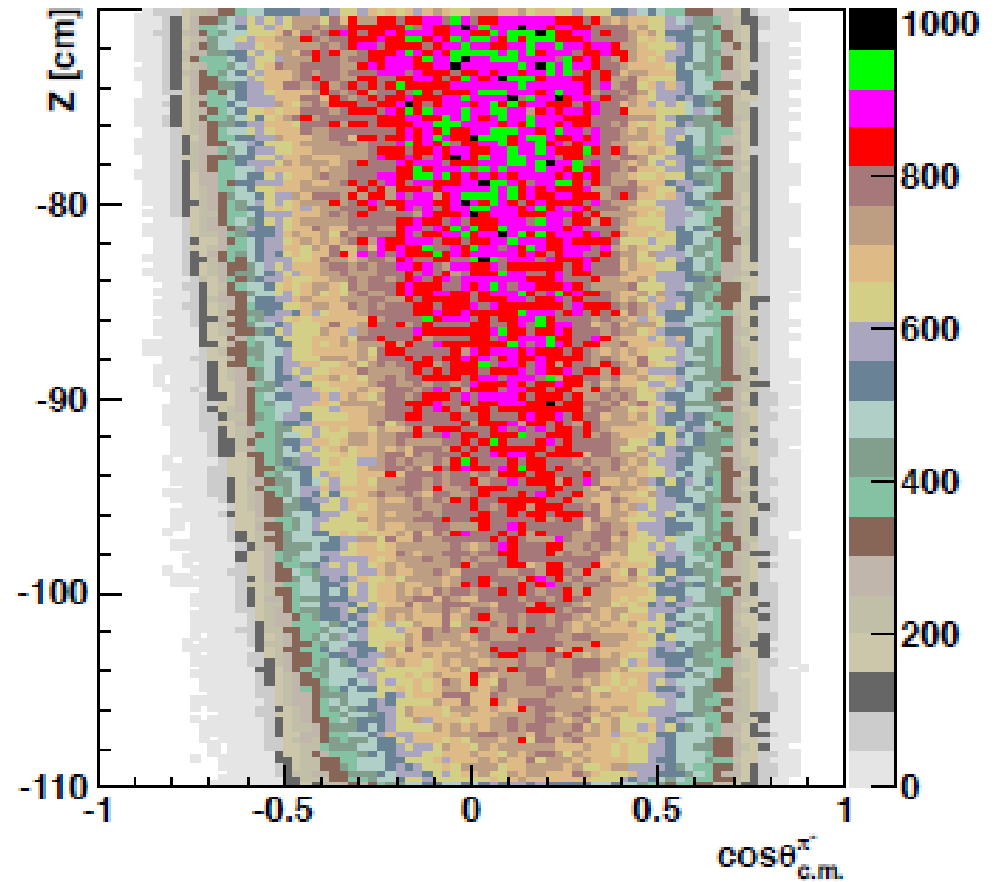
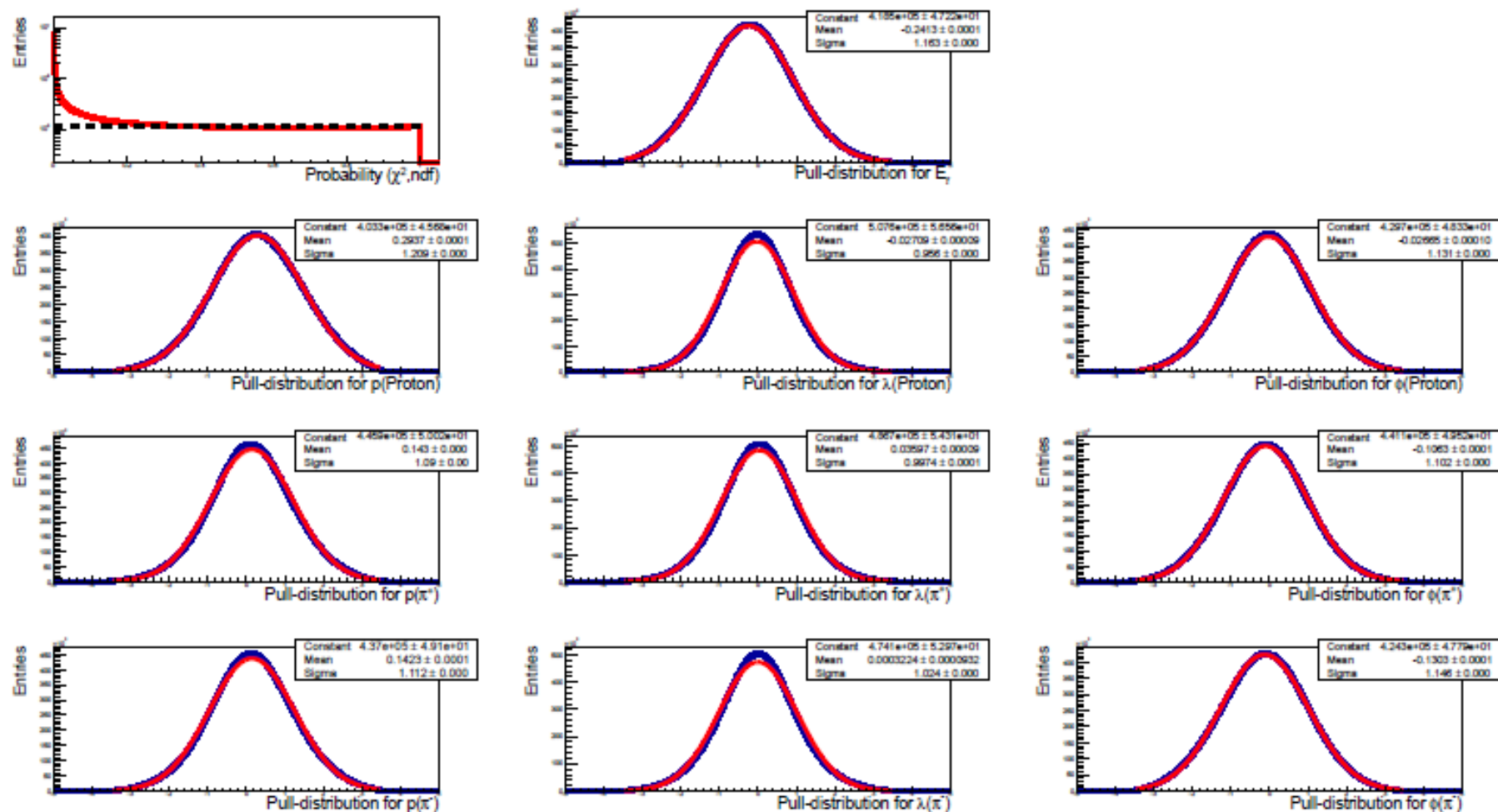


Figure 12: The  $z$ -vertex vs.  $\cos\theta_{c.m.}^{\pi^-}$  distributions using a logarithmic color scale for data (left) and Monte Carlo events (right); the distributions are very similar. In the very backward region of the target, an angle range of only about  $-0.6 < \cos\theta_{c.m.}^{\pi^-} < 0.8$  is covered, whereas  $-0.8 < \cos\theta_{c.m.}^{\pi^-} < 0.8$  is covered in the very forward region.

Back up Slide

# Tuning of the Kinematic Fit to $\gamma p \rightarrow p\pi^+\pi^-$ : Pull-Distributions

Run-wise correction applied



# Backup: $\gamma p \rightarrow p\pi^+\pi^-(\pi^0)$ : with/without correction

Run wise correction

