Measurement of polarization observables for the Λ hyperon for photon energies up to 5.45 GeV.

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Motivation

- For baryon spectroscopy, Constituent Quark Model is the currently accepted model in the non-pQCD regime.
- Missing baryon problem – predicted resonance are not conclusively observed.
- Missing resonances exist, may not be coupled with Nπ, where most of the world data available.
- Why K+Λ:
  - Self-analyzing Λ decay allow to measure single and double polarization observables; which helps to understand production mechanism.
  - Observed N* , already been verified coupled with K+Λ.
    - N(1710), N(1650), N(1875), N(1900) …
  - Λ Isospin I = ½ , tells us it only couple with N* not with Δ*.

Polarization observables

General form of cross section including polarization observables:

$$
\begin{aligned}
d\sigma = \frac{1}{2}\Big(& d\sigma_0 + \hat{\Sigma}[-P_L^{\gamma}\cos(2\phi_\gamma)] + \hat{T}[P_y^T] + \hat{P}[P_{y'}^R] \\
& + \hat{E}[-P_c^{\gamma}P_z^T] + \hat{G}[P_L^{\gamma}P_z^T\sin(2\phi_\gamma)] + \hat{F}[P_c^{\gamma}P_x^T] + \hat{H}[P_L^{\gamma}P_x^T\sin(2\phi_\gamma)] \\
& + \hat{C}_{x'}[P_c^{\gamma}P_{x'}^R] + \hat{C}_{z'}[P_c^{\gamma}P_{z'}^R] + \hat{O}_{x'}[P_L^{\gamma}P_{x'}^R\sin(2\phi_\gamma)] + \hat{O}_{z'}[P_L^{\gamma}P_{z'}^R\sin(2\phi_\gamma)] \\
& + \hat{L}_{x'}[P_z^T P_{x'}^R] + \hat{L}_{z'}[P_z^T P_{z'}^R] + \hat{T}_{x'}[P_x^T P_{x'}^R] + \hat{T}_{z'}[P_x^T P_{z'}^R]\Big) .
\end{aligned}
$$

Observable	Required Polarization		
	Beam	Target	Hyperon
Single Polarization			
$\frac{d\sigma}{d\Omega}$	-	-	-
Σ	linear	-	-
T	-	along y'	-
P	-	-	along y'
Beam and Target Polarization			
G	linear	along z	-
H	linear	along x	-
E	circular	along z	-
F	circular	along x	-
Beam and Hyperon Polarization			
$O_{x'}$	linear	-	along x'
$O_{z'}$	linear	-	along z'
$C_{x'}$	circular	-	along x'
$C_{z'}$	circular	-	along z'
Target and Hyperon Polarization			
$T_{x'}$	-	along x	along x'
$T_{z'}$	-	along x	along z'
$L_{x'}$	-	along z	along x'
$L_{z'}$	-	along z	along z'

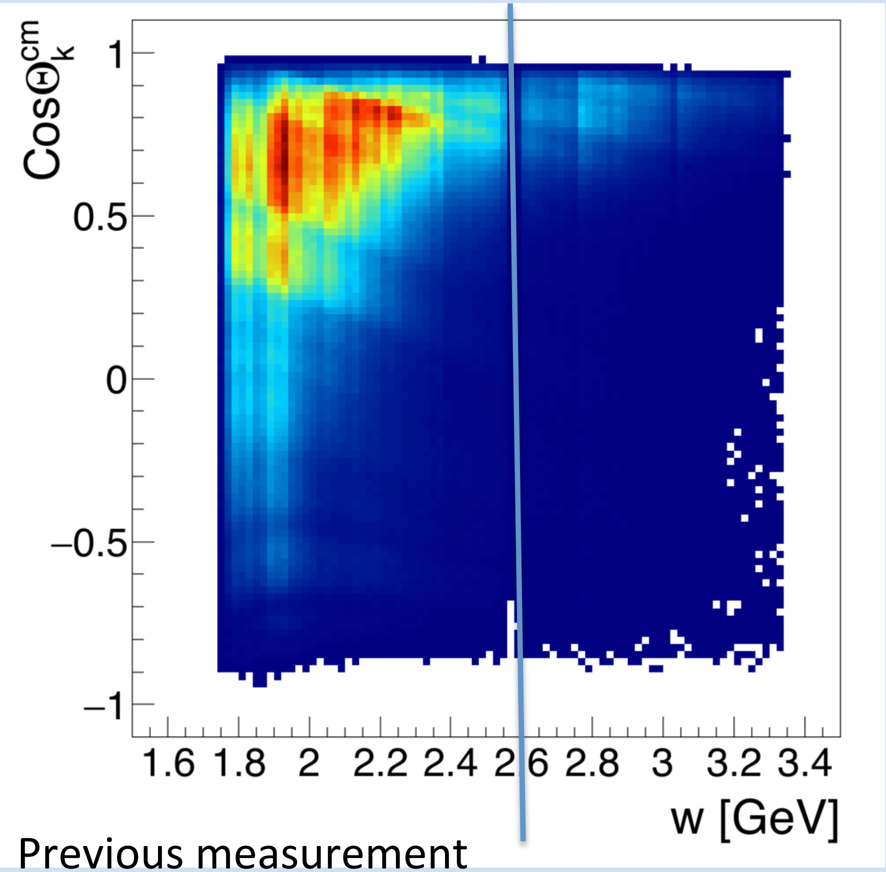
- Total 16 observables.
  3 single polarization observables.

  4 double polarization observables.

- Polarization observables are sensitive to interference from different states.
- With this experiment we are measuring 3 polarization observables.

Kinematic Coverage

- Pre-existing data for $\gamma + p \rightarrow K^{+} + \Lambda$ on polarization observables and cross sections from CLAS(JLab), LEPS, SAPHIR, GRAAL.
- Kinematic coverage:
  - CM energy up to 2.6 GeV.
- Able to extract polarization observables w > 2.6 GeV, where previous measurements are missing.
- Higher energies measurement helps us to constrain non-resonant contribution.

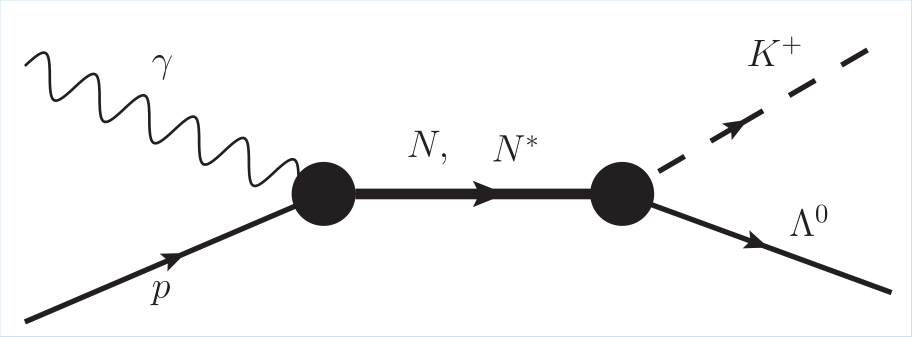


g12 Experiment and Analysis Reaction

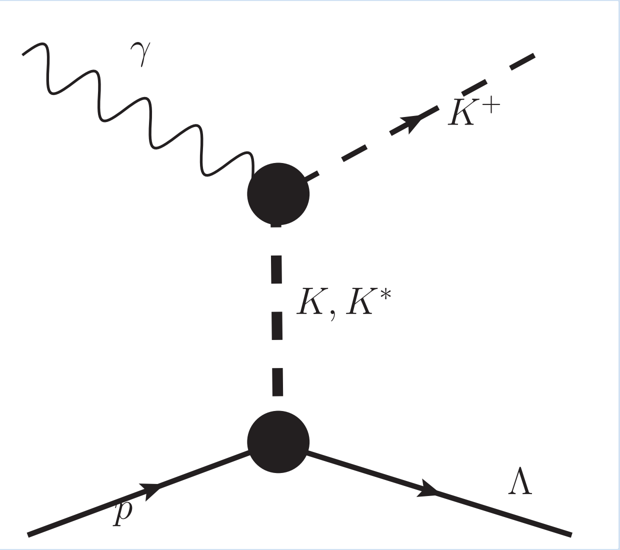
- Circularly polarized photon beam.
- Photon beam energy range 1.1 to 5.5 GeV.
- 40 cm long unpolarized hydrogen target.
- Large amount of meson photoproduction data were collected.

$$\gamma p \to K^+ \Lambda \hookrightarrow p\pi^-$$

Examples of Feynman diagram



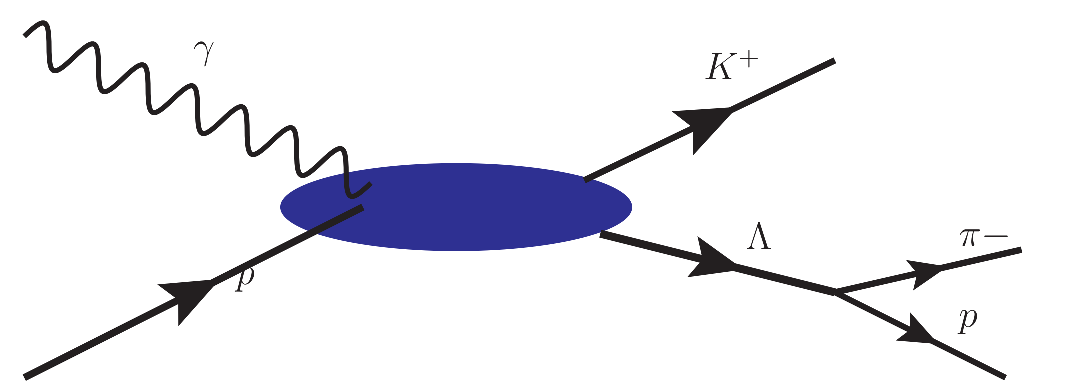
s – channel



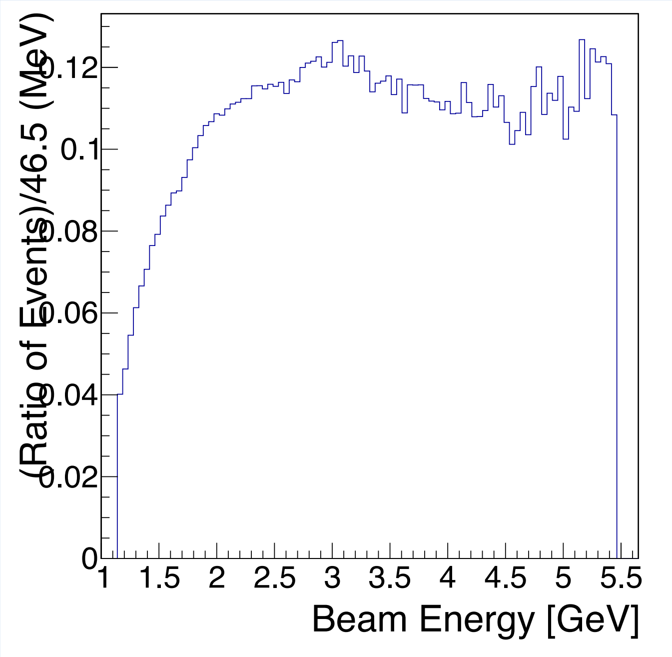
t – channel

Event Selection

- By considering the charge decay mode of Λ to $p\pi^-$, we can access $K^+\Lambda$ the final state.



- We are using two sets of analysis to understand our systematics(because of low π^- detection efficiency) of CLAS.
  - $K^+p\pi^-$ (3track)
  - $K^+p(\pi^-)$ (2track)

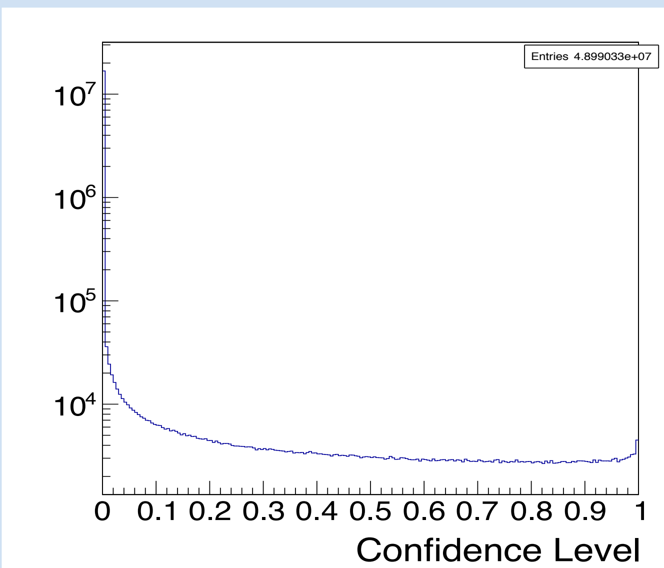


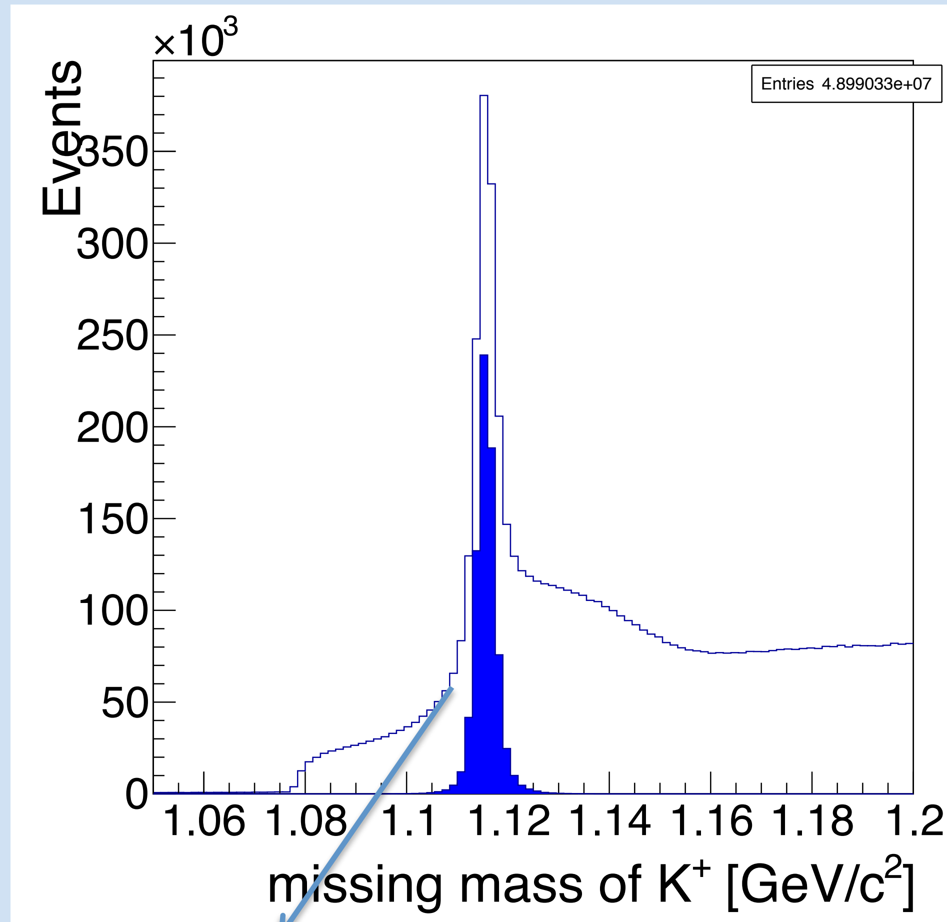
Event Selection: $K^+p\pi^-$ (3track) Topology

- ➔ Applied standard timing and vertex cuts.
- ➔ Applied g12 standard fiducial cuts.
- ➔ Knock out bad tof paddles.

Basic cuts

Kinematic Fitting



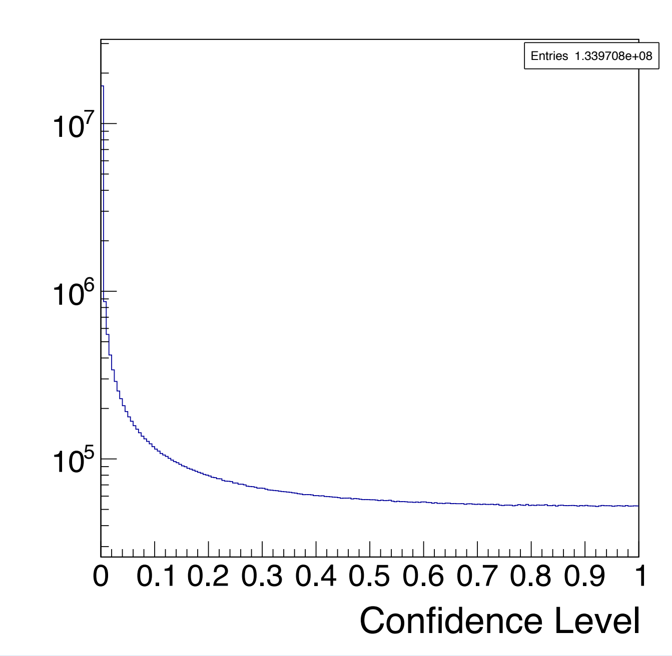


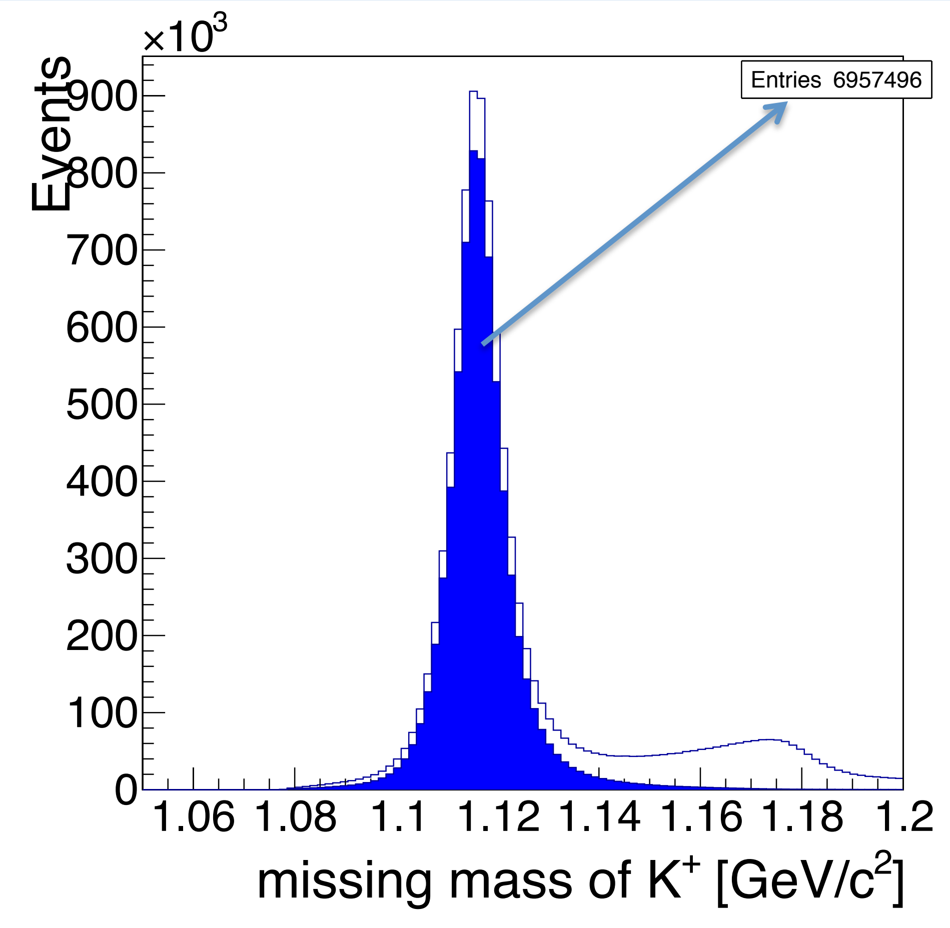
➔ Use 1% confidence level cut.

➔ **Total lambda events 745391**

Event Selection: $K^+p(\pi^-)$ (2track) Topology

➔ **Cuts**: Basic cuts defined on the previous slide.



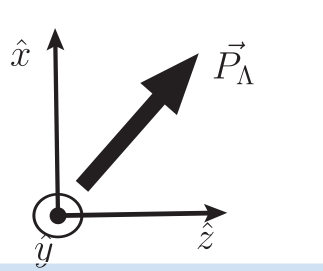


➔ **CL > 5%**

Defining C_x, C_z and P

$$\rho_\Lambda \frac{d\sigma}{d\Omega_{K+}} = \frac{d\sigma}{d\Omega_{K+}}\Big|_{unpol}\{1+\sigma_y P + P_{beam}(C_x\sigma_x + C_x\sigma_x)\}$$

$$\rho_\Lambda = \left(1 + \vec{\sigma}.\vec{P_\Lambda}\right)$$ Density matrix.



Defining C_X, C_Z and P

$P_{\Lambda_X} = P_{beam} C_X$; transferred polarization along x.

$P_{\Lambda_Y} = P$; induced polarization along y.

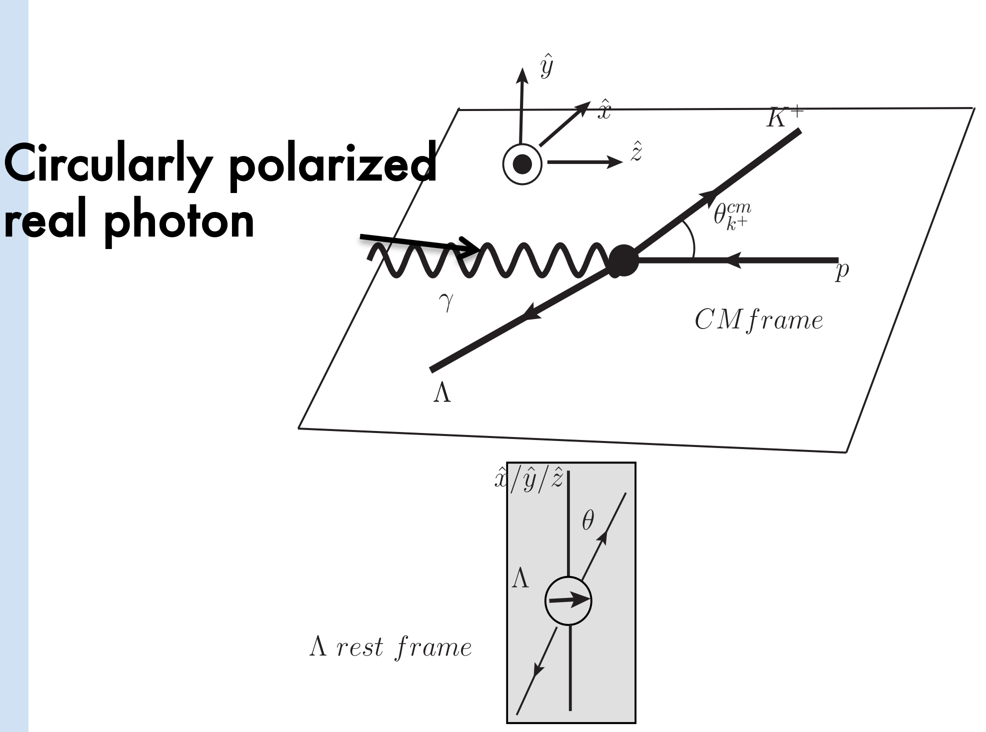
$P_{\Lambda_Z} = P_{beam} C_Z$; transferred polarization along z.

Measurement of Polarization

- If the produced particle is polarized then, we can extract polarization observables from its decay particles.

- It is possible when there is weak decay of polarized particle such as Lambda.

$$\gamma p \to K^+ \Lambda$$



$$\hat{z} = \hat{p}_\gamma$$
$$\hat{y} = \frac{\hat{p}_\gamma \times \hat{p}_K}{|\hat{p}_\gamma \times \hat{p}_K|}$$
$$\hat{x} = \hat{y} \times \hat{z}$$

➔ Analysis focus on measurement of C_x and C_z.

Observables extraction Methods

- 1d fit method

$$Asymm = \frac{N^+ - N^-}{N^+ + N^-} = \alpha P_\circ C_{x/z} cos\Theta_{x/z}$$

- 2d fit method

$$Asymm = \frac{N^+ - N^-}{N^+ + N^-} = \alpha P_\circ C_x cos\Theta_x + \alpha P_\circ C_z cos\Theta_z$$

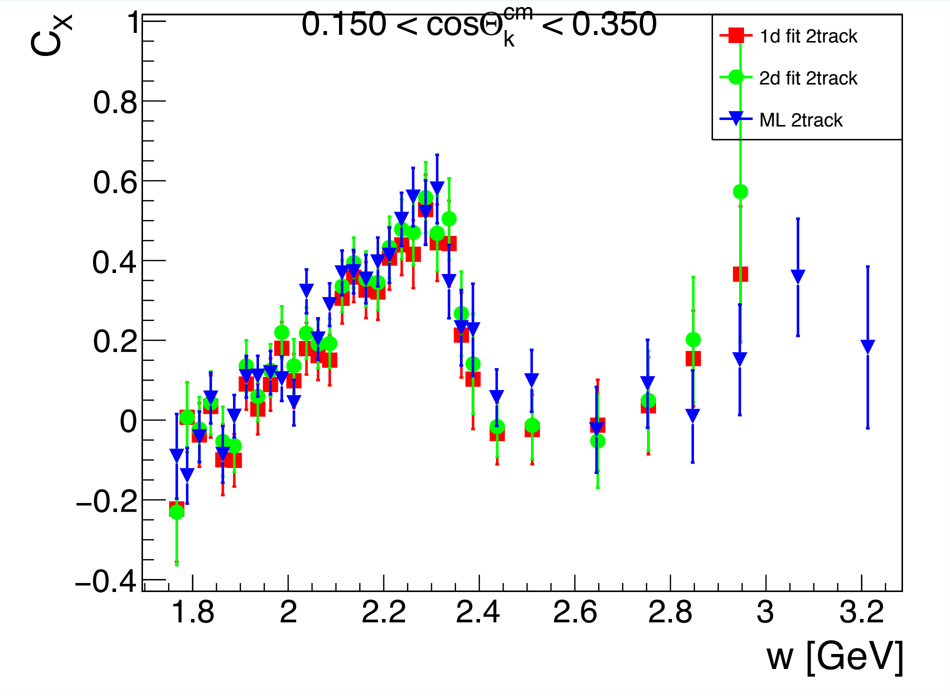
- Maximum likelihood method
  - Event by event basis.
  - Reduce the bias comes from acceptance because of event wise analysis.

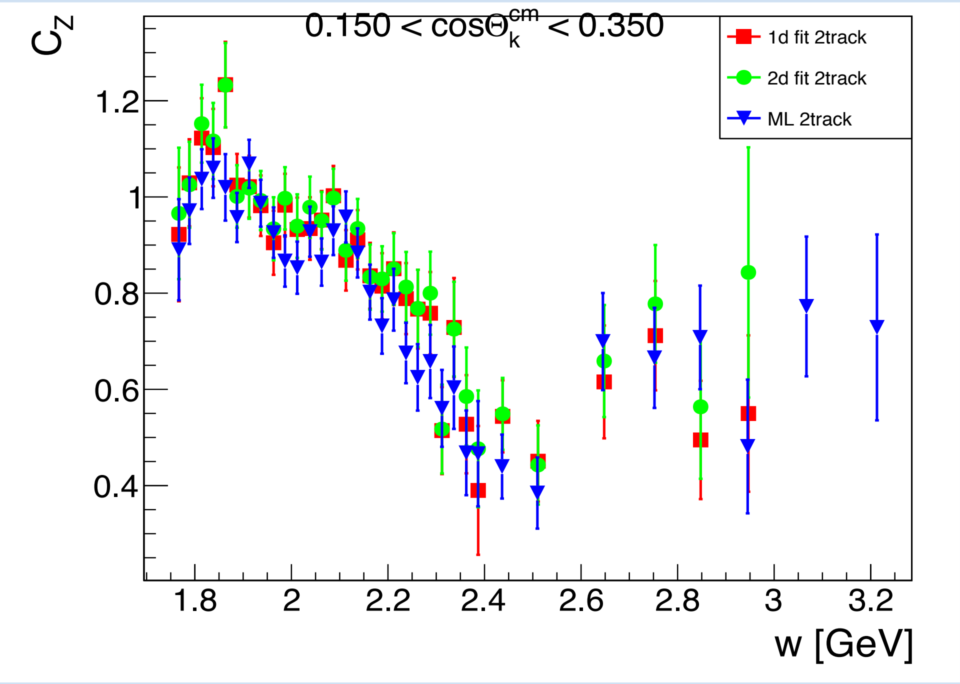
$$L(C_i) = \prod_{i=1}^{n} f(Cos\Theta_i, C_i)$$

  - Minimize negative log likelihood to fit the data;

$$\ell = -\sum_{i=1}^{n} \log f(Cos\Theta_i, C_i)$$

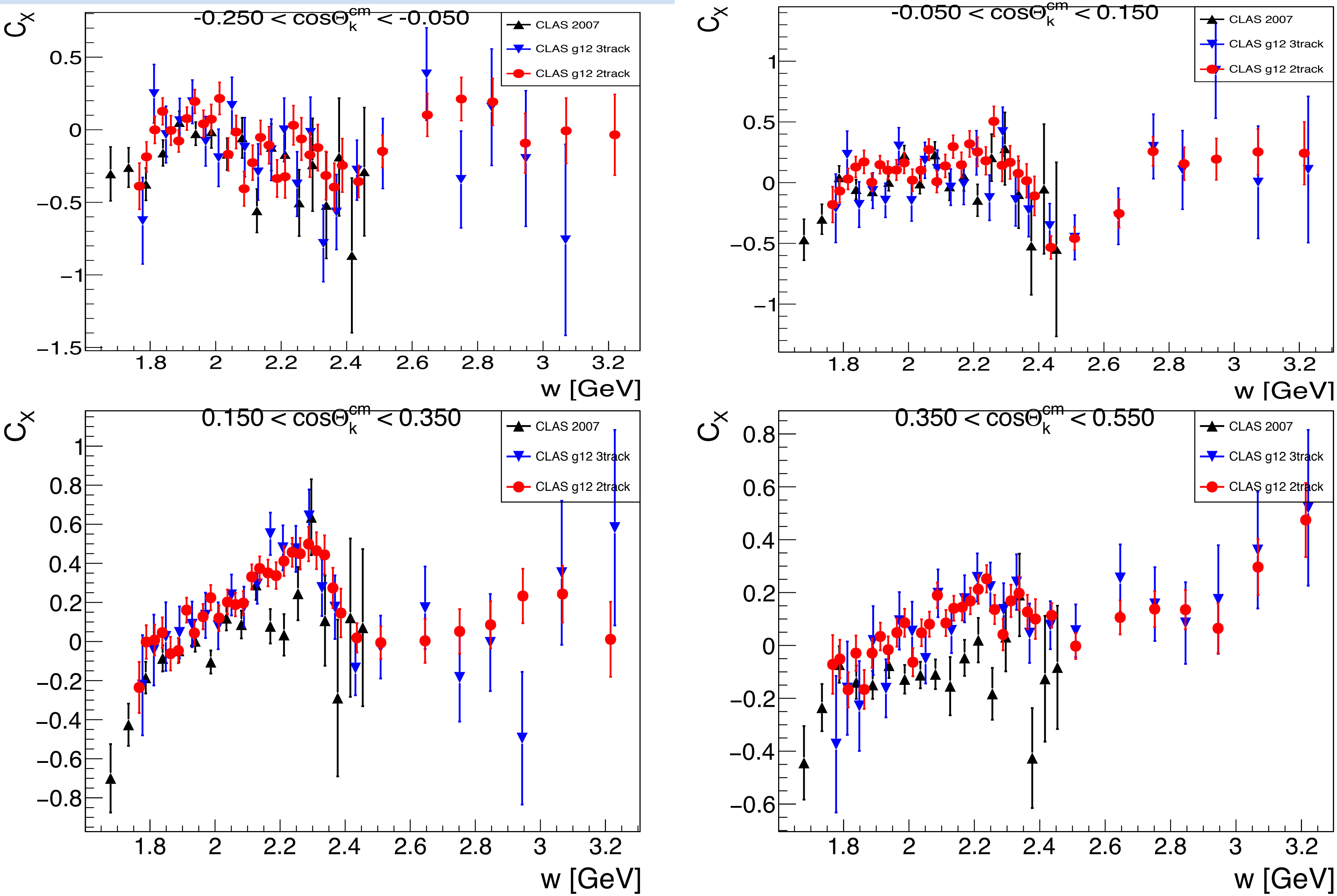
Comparision between different methods



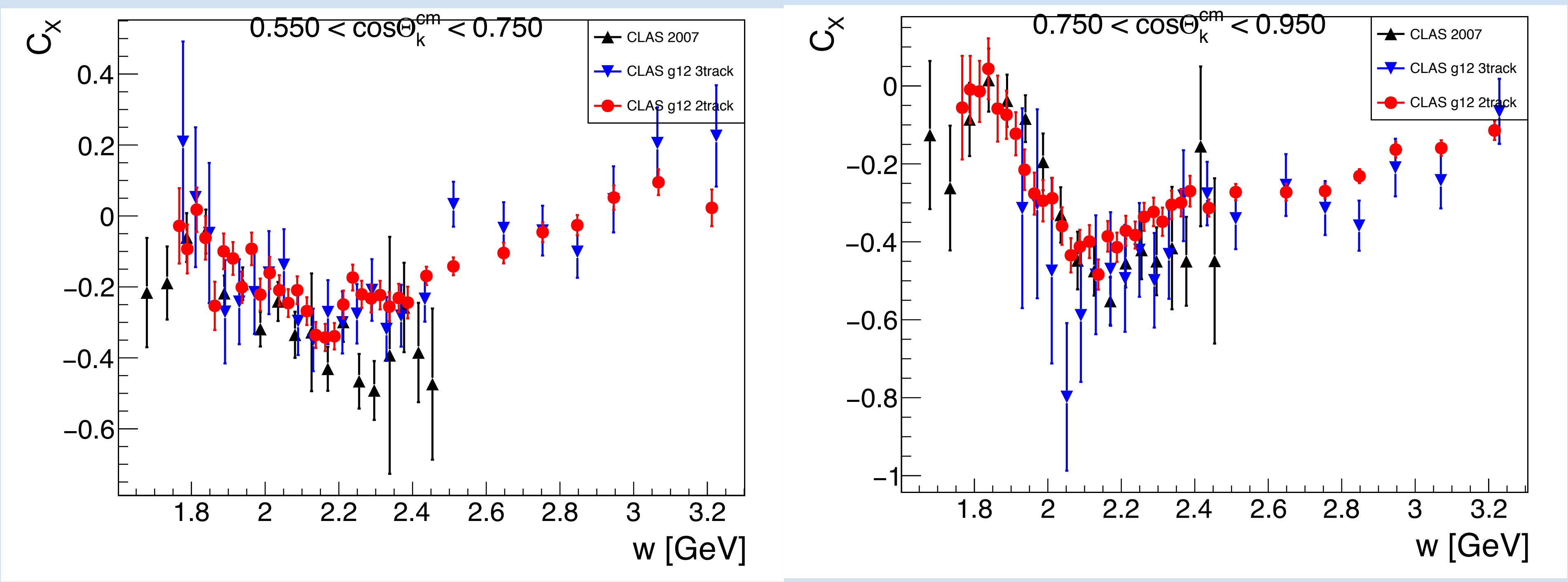


➔ Show good agreement. Later showing results only for Maximum likelihood method.

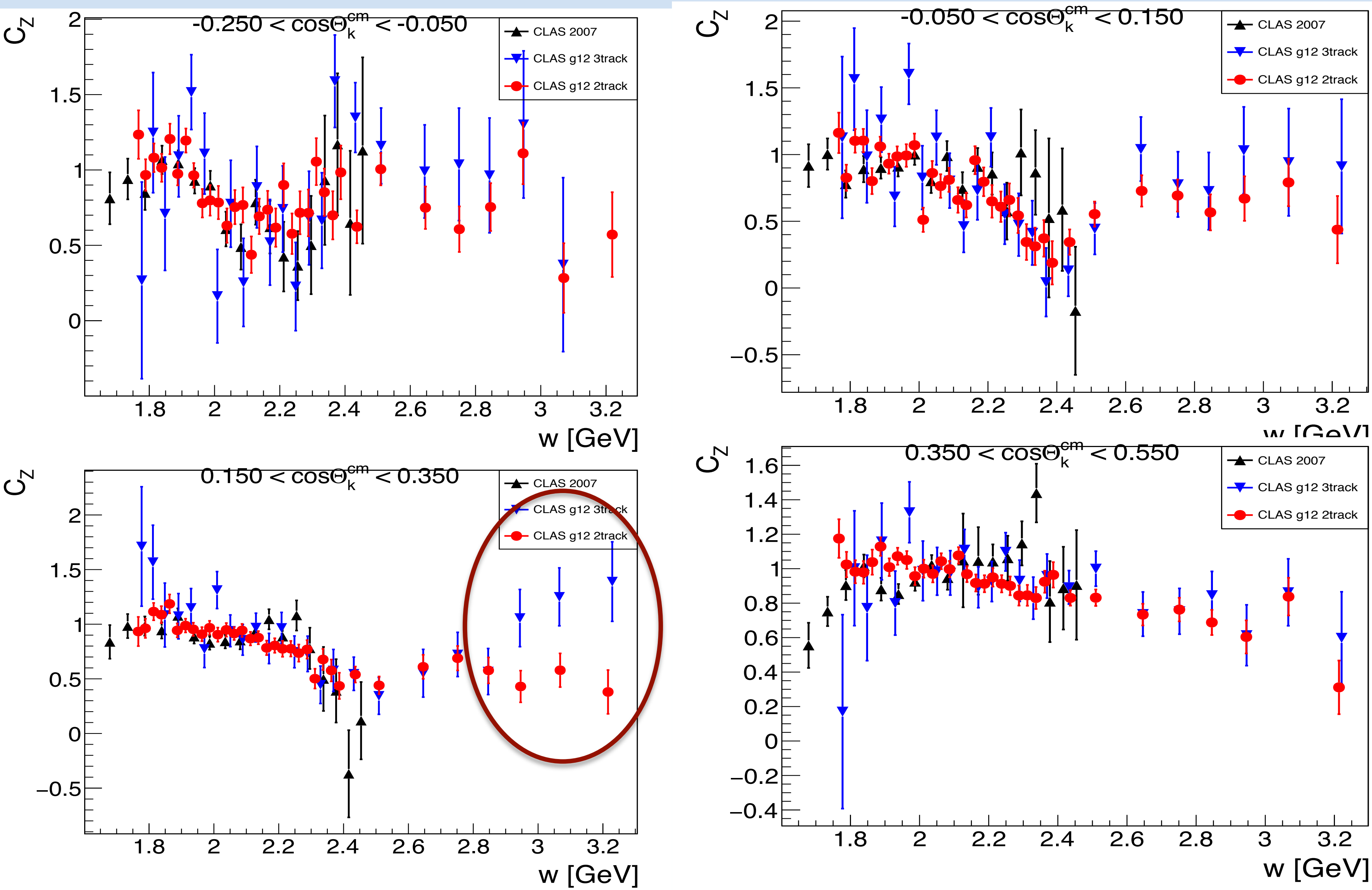
Comparision with g1c: C_x



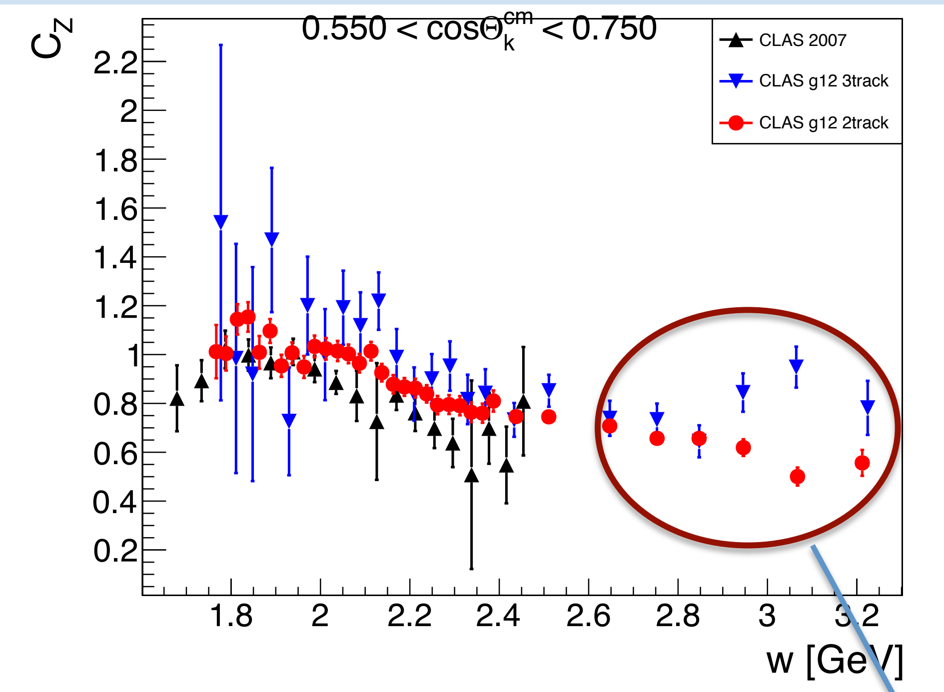
Comparision with g1c: C_x

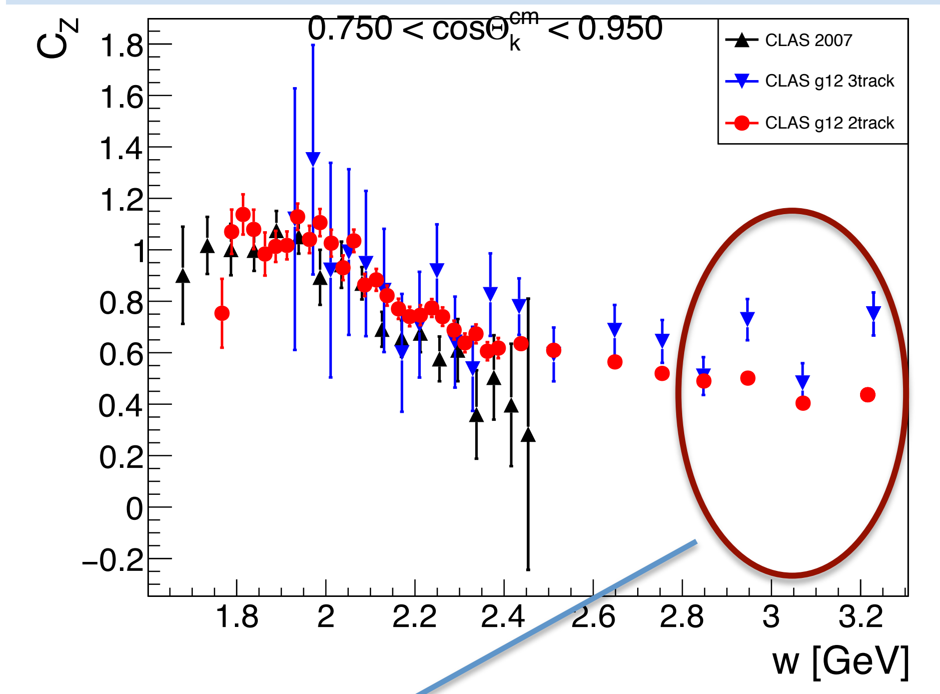


Comparision with g1c: C_z



Comparision with g1c: C_z





Further investigation:
Mass distribution

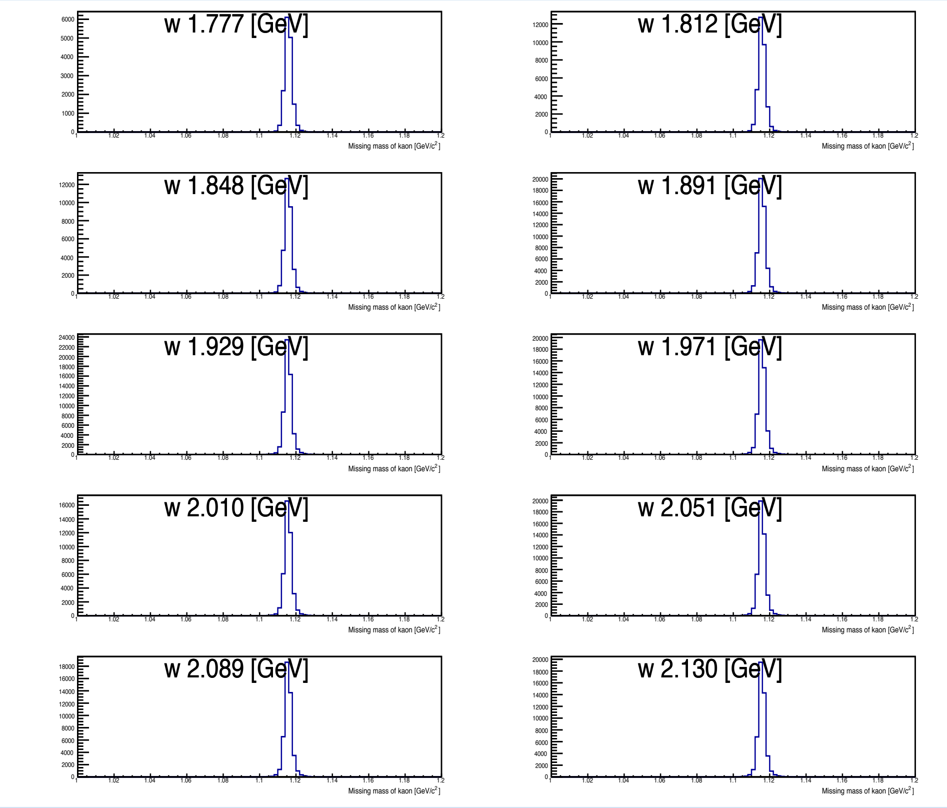
Energy dependent mass distribution for $K^+p\pi^-$ vs $K^+p(\pi^-)$

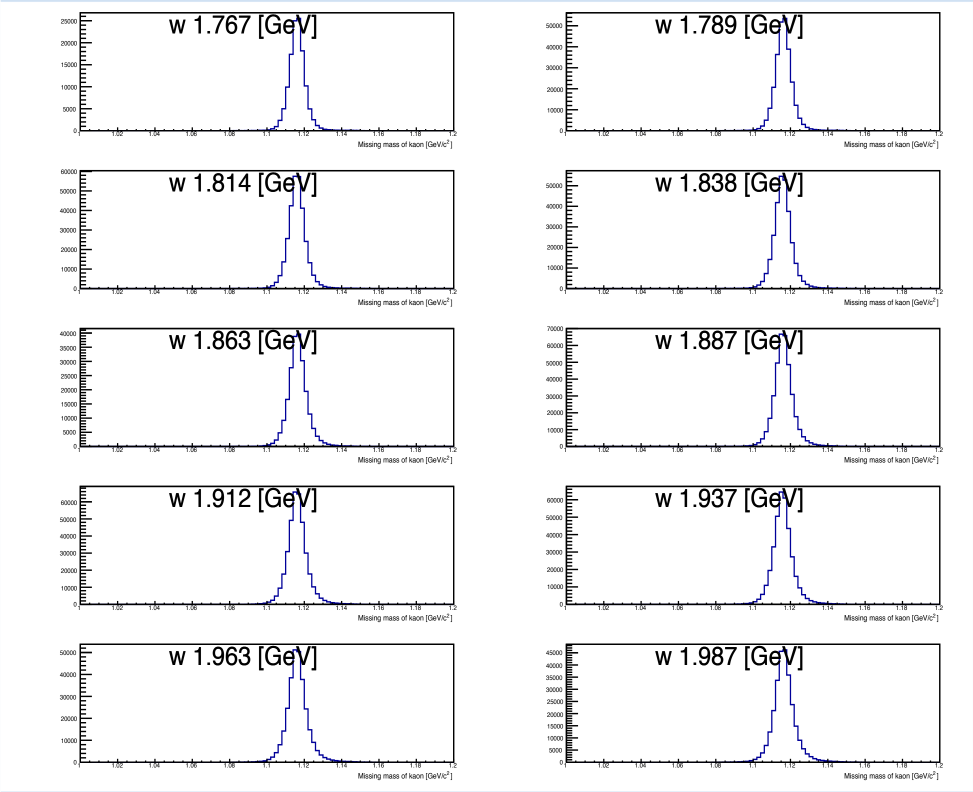
Binning: $K^+p\pi^-$ | $K^+p(\pi^-)$

w[1.75, 2.4) = 16 | **w[1.75, 2.4) = 26**

w[2.4,3.3] = 8 | **w[2.4,3.3] = 8**

Missing mass of kaon.





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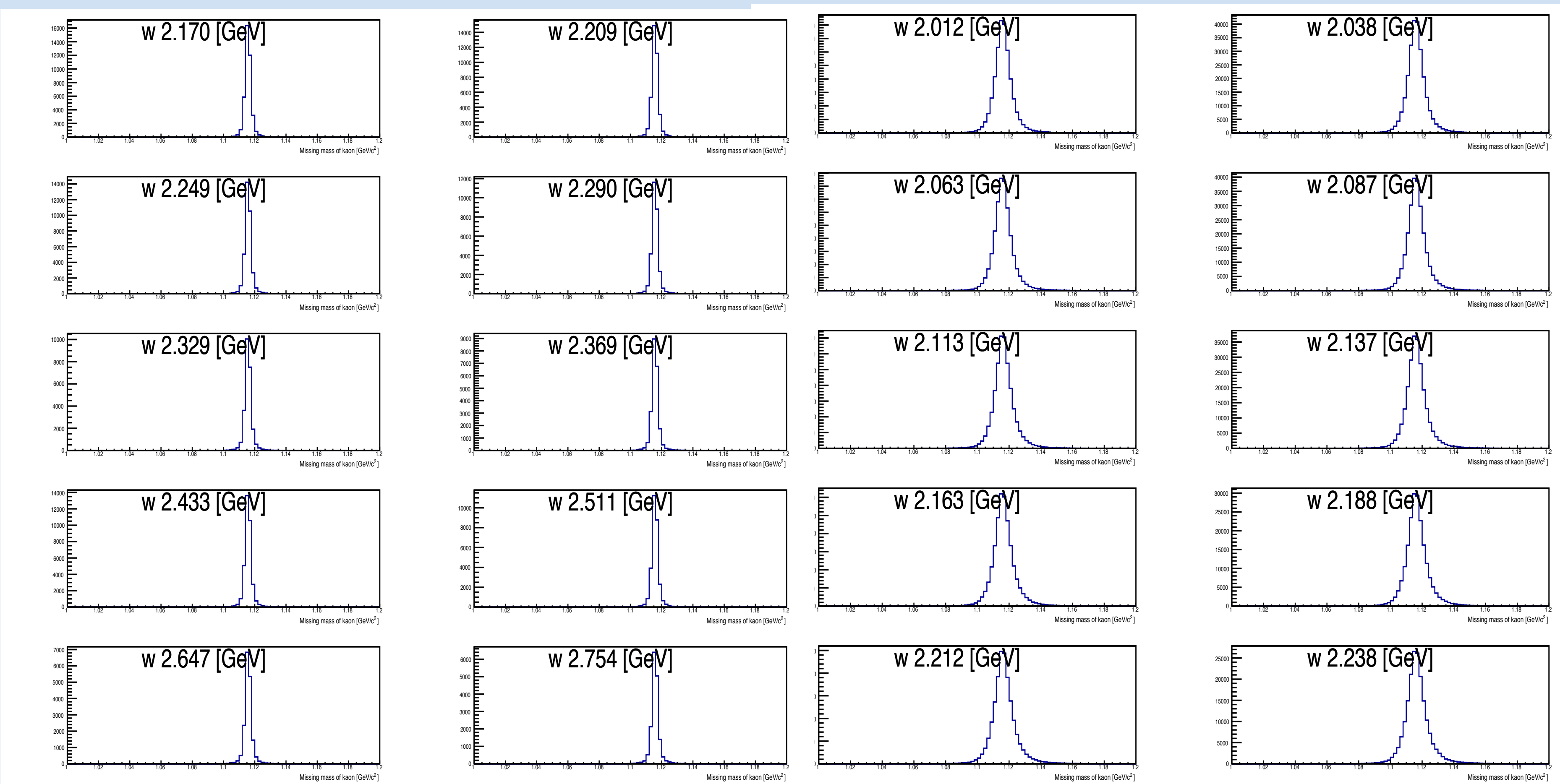
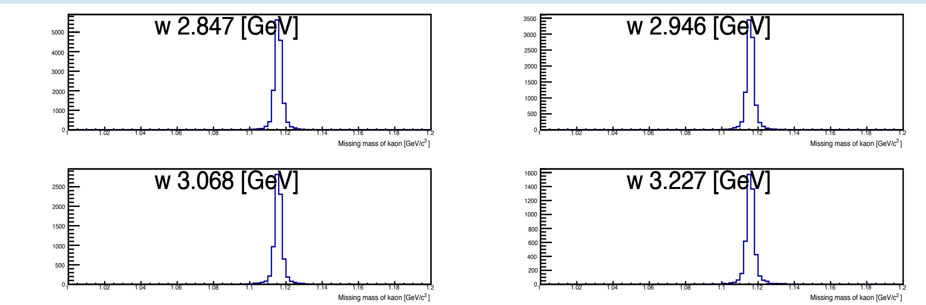
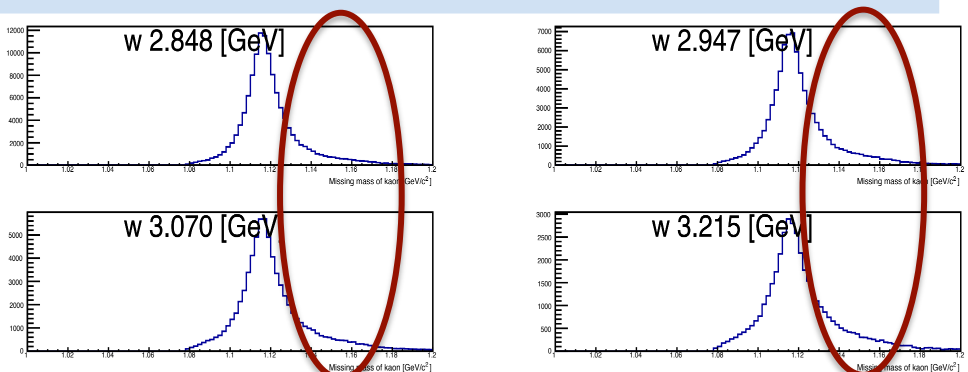
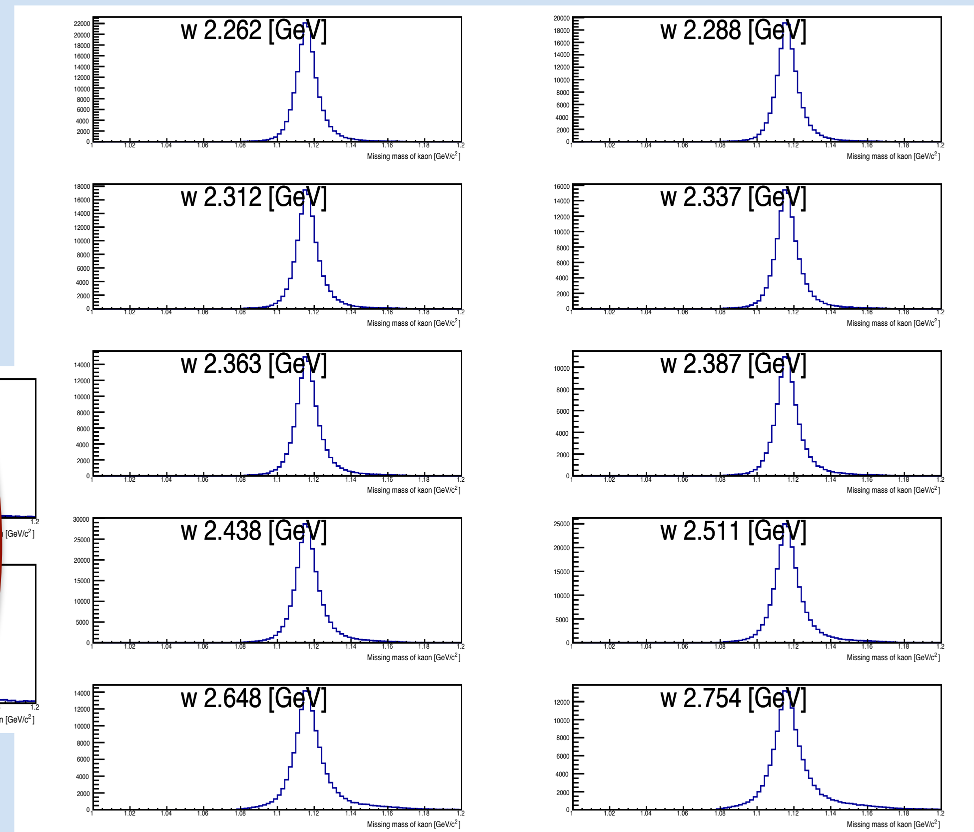


Energy dependent mass distribution for $K^+p\pi^-$ vs $K^+p(\pi^-)$



High energy mass distribution
top; 3track, bottom; 2track





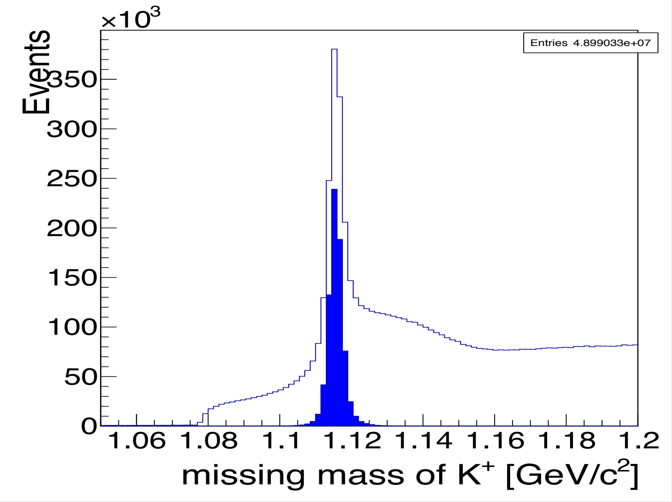
Future work: Background substraction

Conclusion and Outlook

- Measured Lamba polarization observables C_x and C_z using g12 dataset for 1.75 < w < 3.3 GeV.
  - 3 method: 1d/2d/ML methods, all showing consistent results.
  - 2 topologies analyzed: results are mostly self-consistent.
- Preliminary C_x/C_z results:
  - Statistical uncertainty are much smaller than previous g1c results for w < 2.6 GeV.
  - In the good agreement with earlier CLAS results.
  - First time measurement for w > 2.6 GeV.
  - Can be used to constrain non-resonant(t-channel) contribution.
- Future work:
  - Induced polarization measurement.
  - Background contamination and systematic uncertainties.

Thank You!

Comparision: g12 with g1c



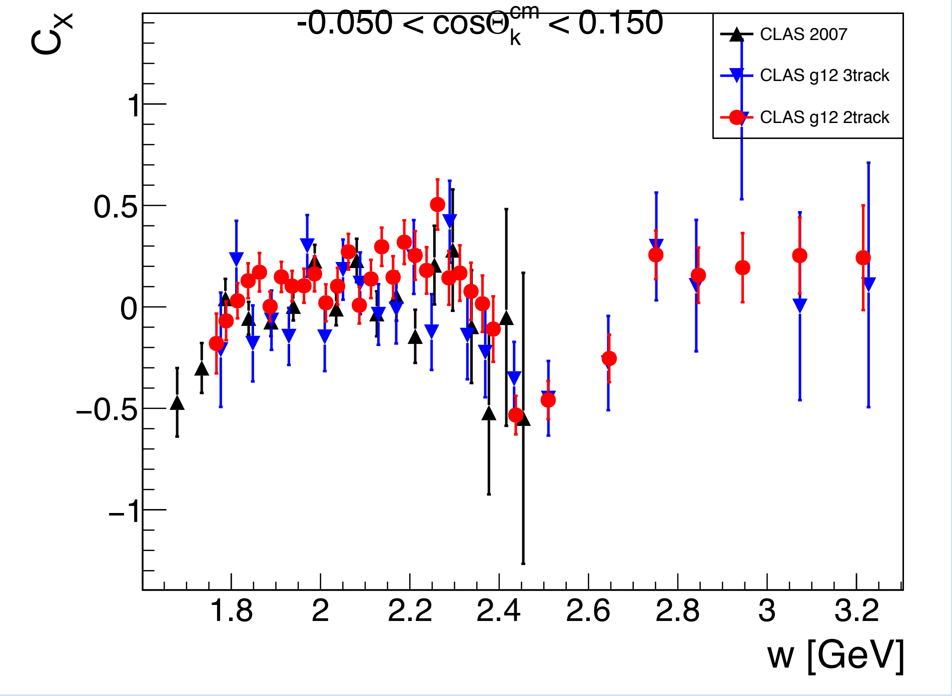
Analysis 2 topology:

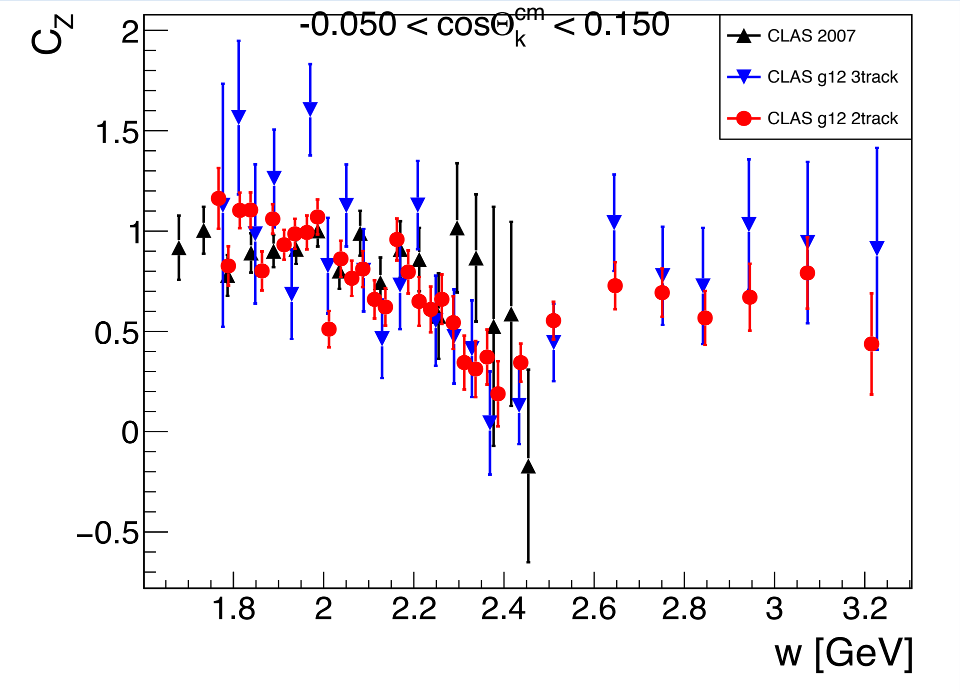
$K^+p\pi^-$ (3track)

$K^+p(\pi^-)$ (2track)

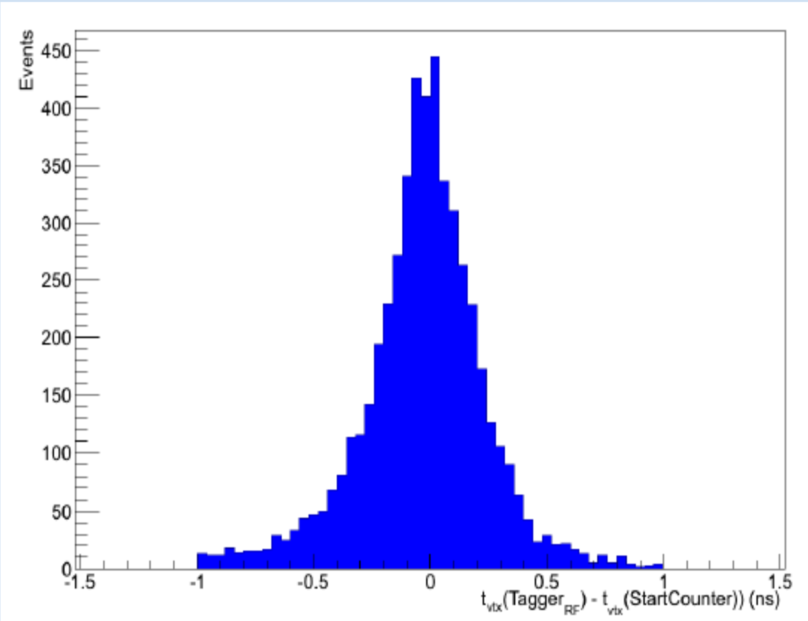
Kinematic coverage:

1.75 < w < 3.3 GeV.

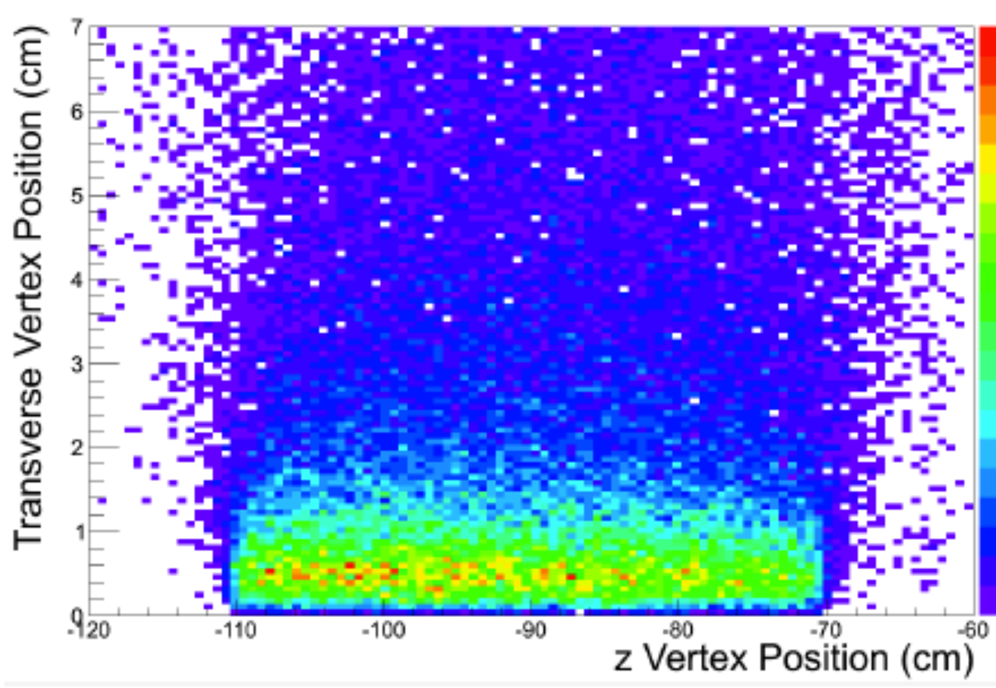




Timing and Vertex Cuts



• 1 ns agreement between time measured by RF corrected - tagger and start counter.



• Vertex selection occupied cylindrical volume around target with -120 to -60 cm along beam and 7 cm radius.

Fiducial cut

Fiducial meaning *Trustworthy*

- Based on CLAS detector geometry.

- Removing the events those lie on non-uniform region; such as between the sector.