Measurement of polarization observables in the reaction $\gamma p \to K^+ \Lambda$

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Outline

- Introduction
- Experiment
- Events Selection
- Preliminary results for C_x, C_z and P.
- Conclusion and outlook.

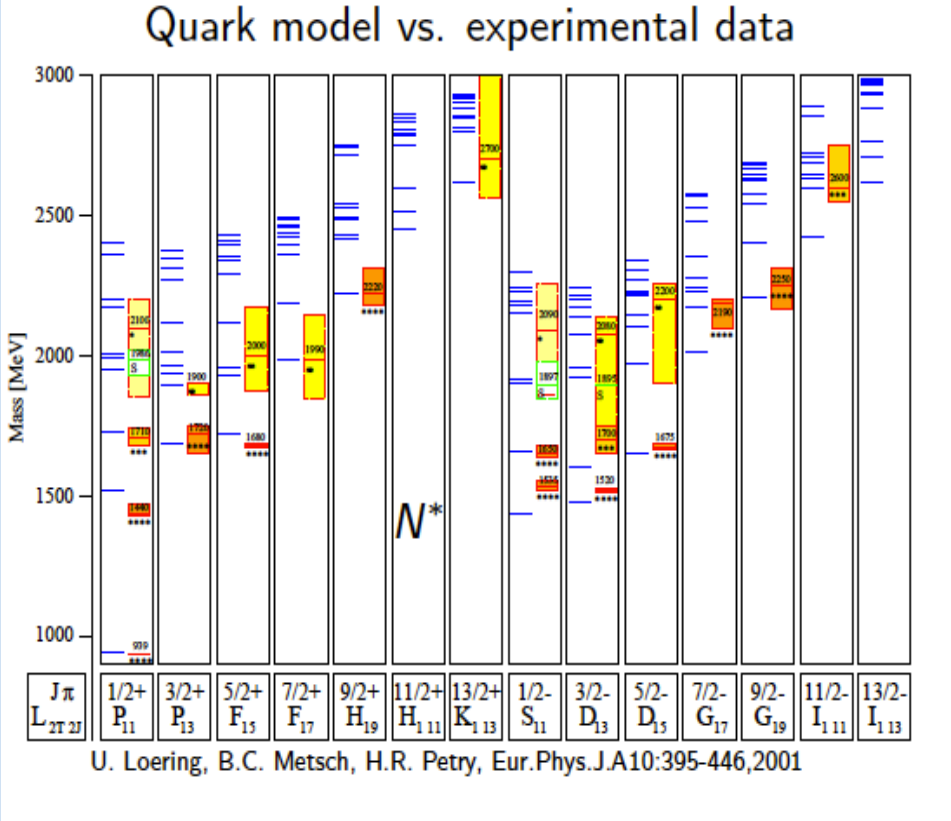
Introduction

- ❖ Study of the baryon resonances are important to understand the fundamental degrees of freedom inside hadrons.
- ❖ Missing Baryon Problem:
  - a lot of predicted resonances from models (Quark, Lattice etc) are not observed yet.

**** Existence is certain
*** Existence is very likely
** Evidence of existence is only fair.
* Evidence of existence is poor.

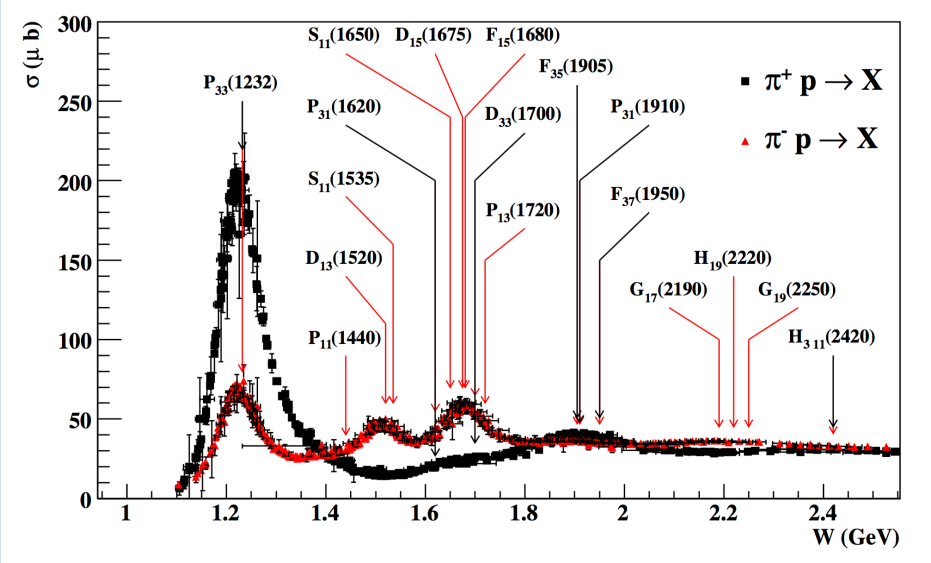
PDG rating for *N**

		overall
N	1/2+	****
N(1440)	1/2+	****
N(1520)	3/2-	****
N(1535)	1/2-	****
N(1650)	1/2-	****
N(1675)	5/2-	****
N(1680)	5/2+	****
N(1700)	3/2-	***
N(1710)	1/2+	*****
N(1720)	3/2+	****
N(1860)	5/2+	**
N(1875)	3/2-	***
N(1880)	1/2+	**
N(1895)	1/2-	**
N(1900)	3/2+	***
N(1990)	7/2+	**
N(2000)	5/2+	**
N(2040)	3/2+	*
N(2060)	5/2-	**
N(2100)	1/2+	*
N(2120)	3/2-	**
N(2190)	7/2-	****
N(2220)	9/2+	****
N(2250)	9/2-	****
N(2300)	1/2+	**
N(2570)	5/2-	**
N(2600)	11/2-	***
N(2700)	13/2+	**



Introduction

- Pion beams was the primary tool to study resonances.



- Not all resonances couple strongly to the Nπ channel.

- Interference of states:
  Possible interference between *N* and *Δ* states.

- $K^+\Lambda$ channel is important that;
  - only contribute to *N** with I = 1/2.
  - Λ -> $p\pi^-$ decay allows to measure recoil polarization.

Observables for photoproduction

- Photoproduction describes by 4 complex amplitudes.
- Total 16 observables.

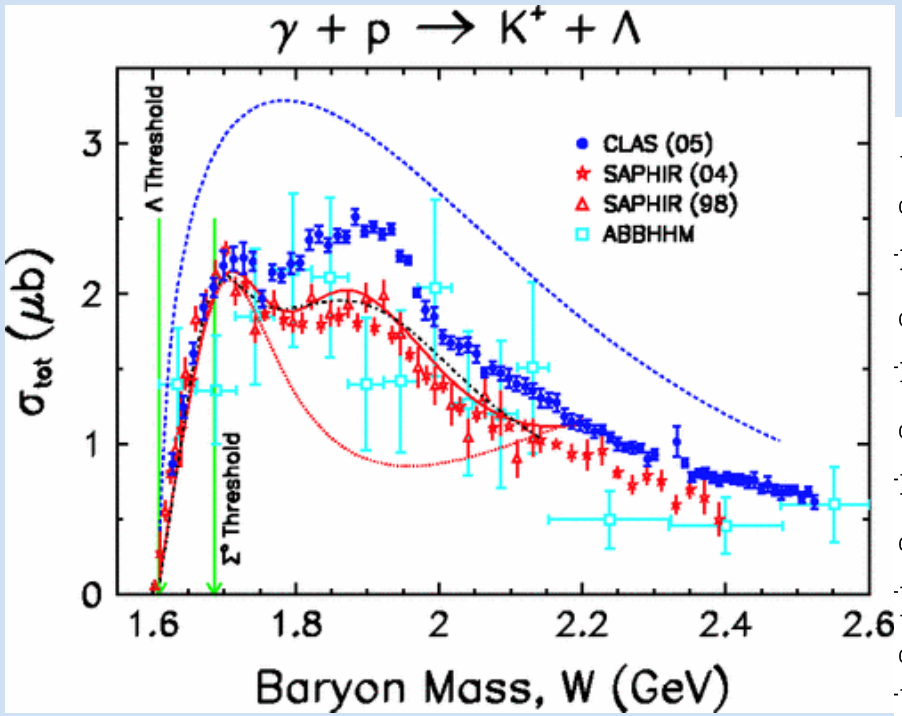
Polarized	Beam	Target	Hyperon
	unpol. linear circular	x y' z	x' y' z'
Unpolar.	σ		
Beam:	Σ		
linear		H G	$O_{x'}$ $O_{z'}$
circular		F E	$C_{x'}$ $C_{z'}$
Target:		T	
x			$T_{x'}$ $T_{z'}$
z			$L_{x'}$ $L_{z'}$
Hyperon:			P

8 observables need to separate amplitude at given *W* along with differential cross section.

- Polarization observables are sensitive to interference from different states and different process.

Previous Measurement $\gamma p \rightarrow K^+\Lambda$

Experiment was in ELSA, JLAB, MAMI

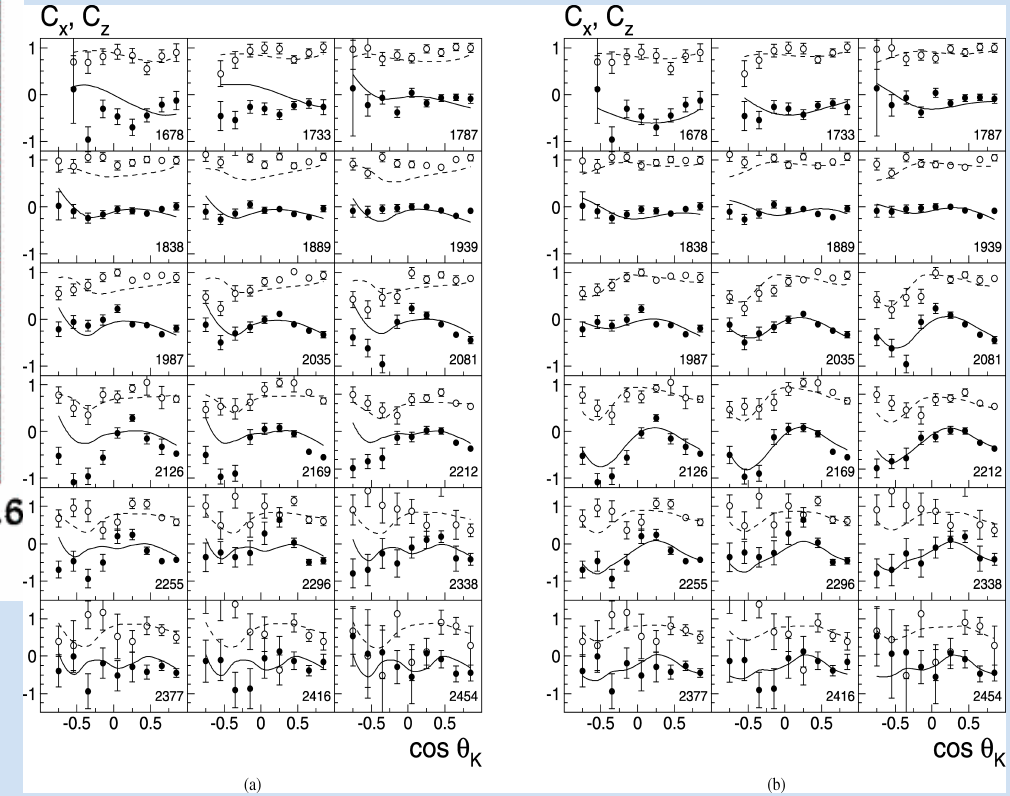


R. Bradford et al., Phys. Rev. C 73, 035202 (2006)

***P* in** $\gamma p \rightarrow K^+\Lambda$

M. McCracken et al., Phys. Rev. C 81, 025201 (2010)

For $N(1900)P_{13}$ pdg rating change from ** to *** .
Disprove quark-diquark model.

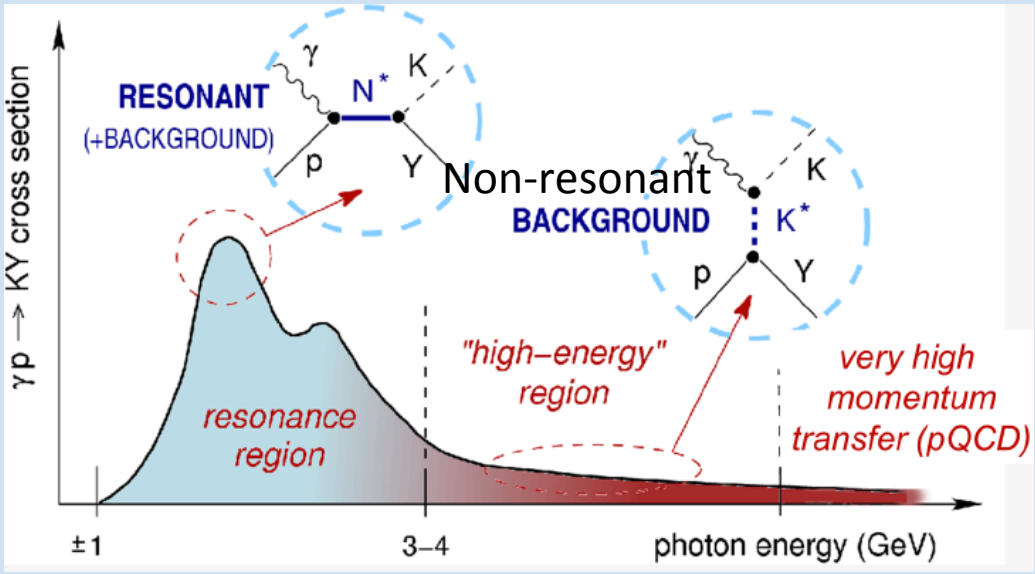


Without 1900 With 1900

Fits: BnGa-Model, V.A. Nikonov et al., Phys. Lett. B 662, 245 (2008)

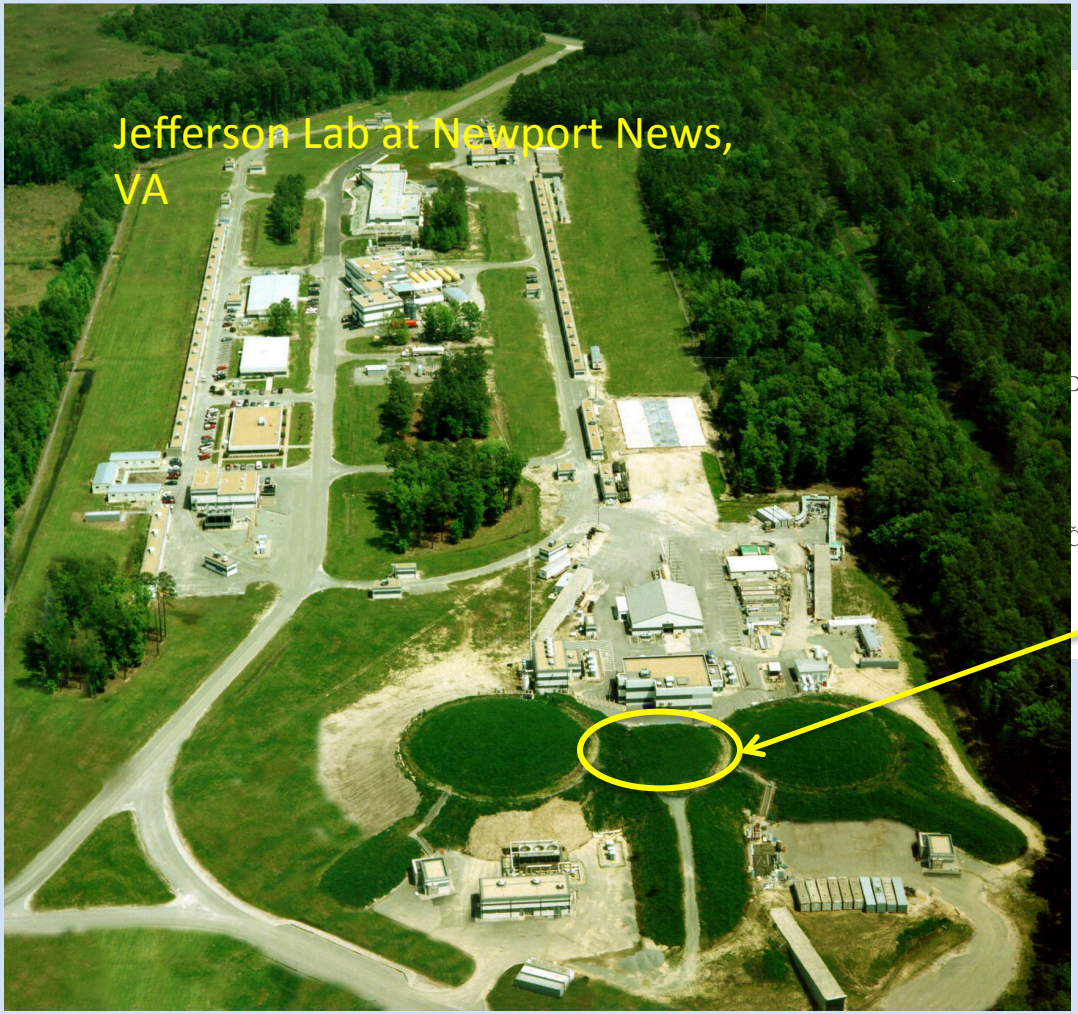
Why this analysis?

- Add more data point on same kinematic range.
- Extend measurement up to 5.45 GeV photon beam energy.
- Suitable to study higher mass states.

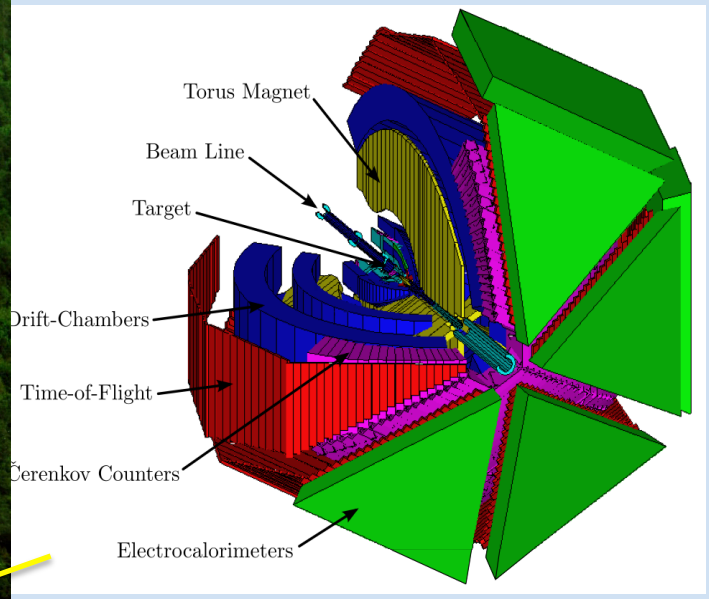


- High energy non-resonant background contributions can be measure.

Experiment



Hall B Detector



G12 experiment

- 60-65 nA electron beam current.
- Photoproduction experiment; beam energy up to 5.5 GeV.
- Circularly polarized photon beam.
- 40 cm long unpolarized hydrogen target.

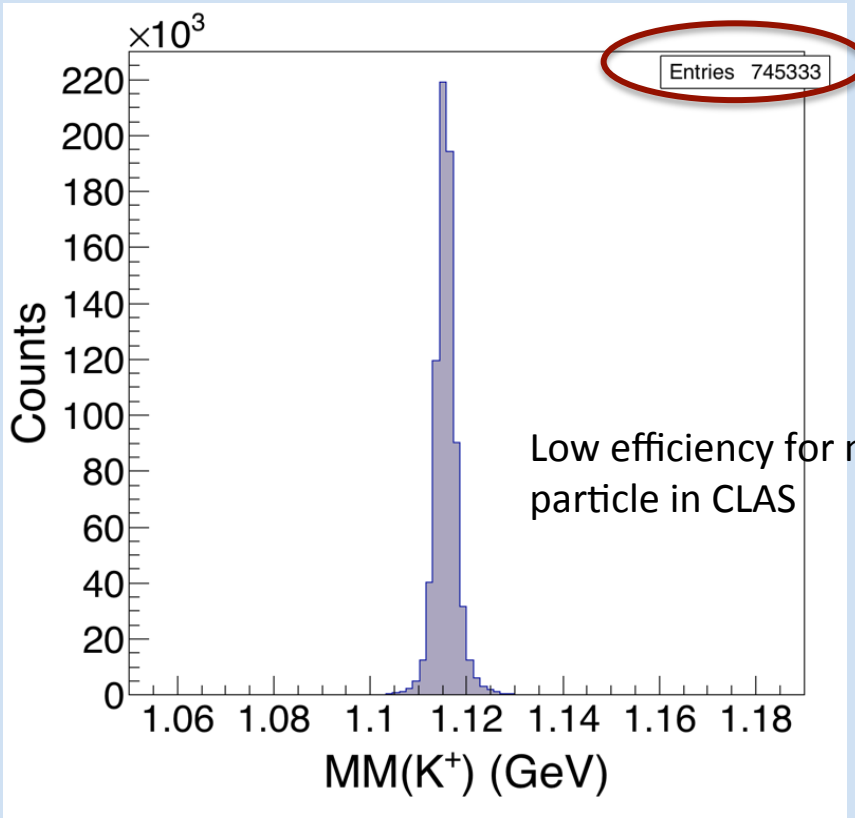
Event Selection

Exclusive (3track)

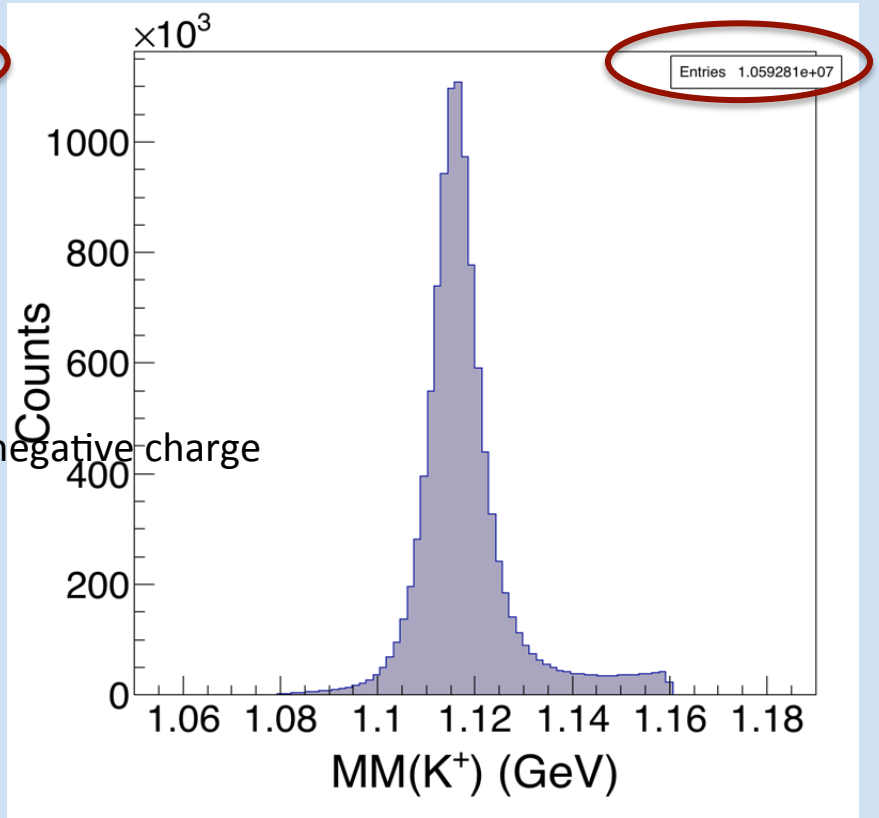
$$\gamma p \to K^+\Lambda \to K^+ p\pi^-$$

Semi-inclusive (2track)

$$\gamma p \to K^+\Lambda \to K^+ p(\pi^-)$$



Low efficiency for negative charge particle in CLAS



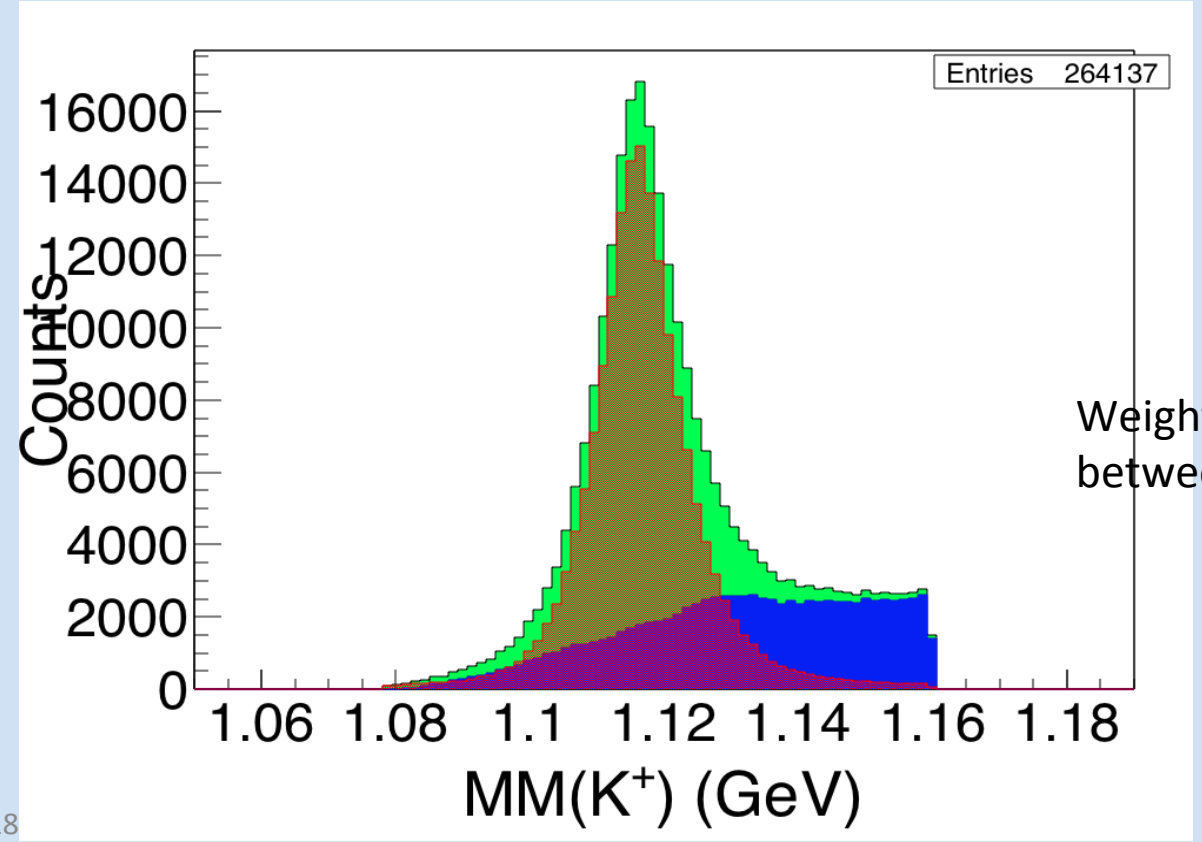
Background Subtraction

For 2Track; energy dependent background appears, binned on energy and applied background subtraction method.

Q Value Method:

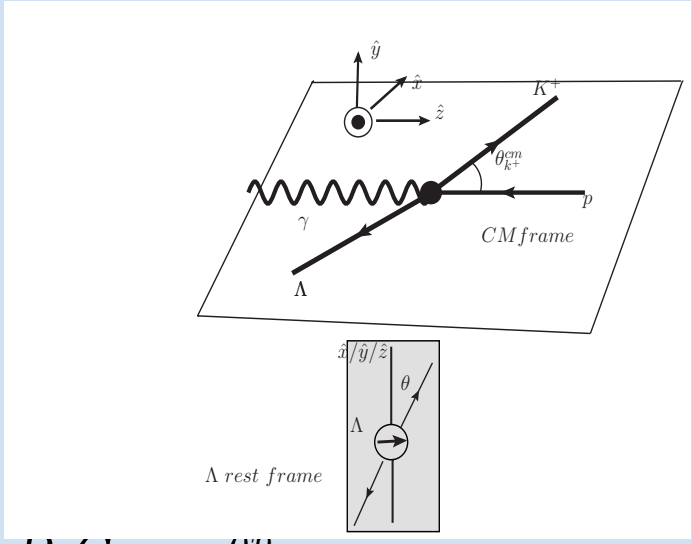
Event-by-event basis method determining the signal event using Q-factor.

M. Williams, M. Bellis, and C. A. Meyer, JINST 4, P10003 (2009).



Weighted by q factor ranges between 0 and 1.

Observables extraction Methods



- 1d fit method

$$A(\cos\theta^p_{x/z}) = \frac{N^+ - N^-}{N^+ + N^-} = \alpha P_\circ C_{x/z}\cos\theta^p_{x/z}$$

α = Weak decay asymmetry 0.642

- 2d fit method

$$A(\cos\theta^p_x, \cos\theta^p_z) = \frac{N^+ - N^-}{N^+ + N^-} = \alpha P_\circ C_x \cos\theta^p_x + \alpha P_\circ C_z \cos\theta^p_z$$

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

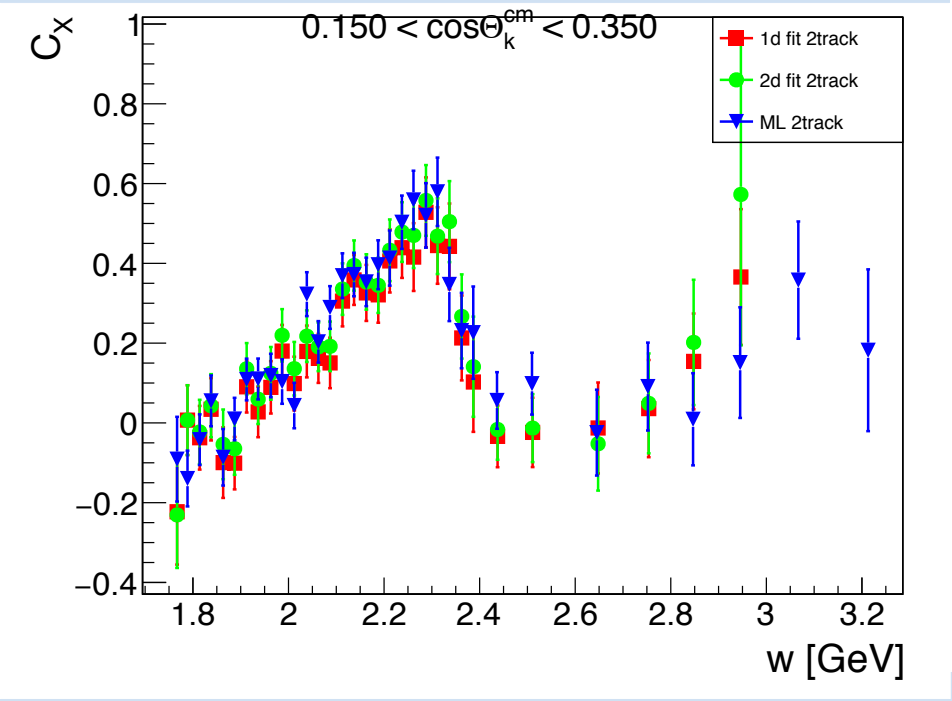
$$f(\cos\theta^p_x, \cos\theta^p_z) = (1 + \alpha P_\circ(C_x \cos\theta^p_x + C_z \cos\theta^p_z))$$

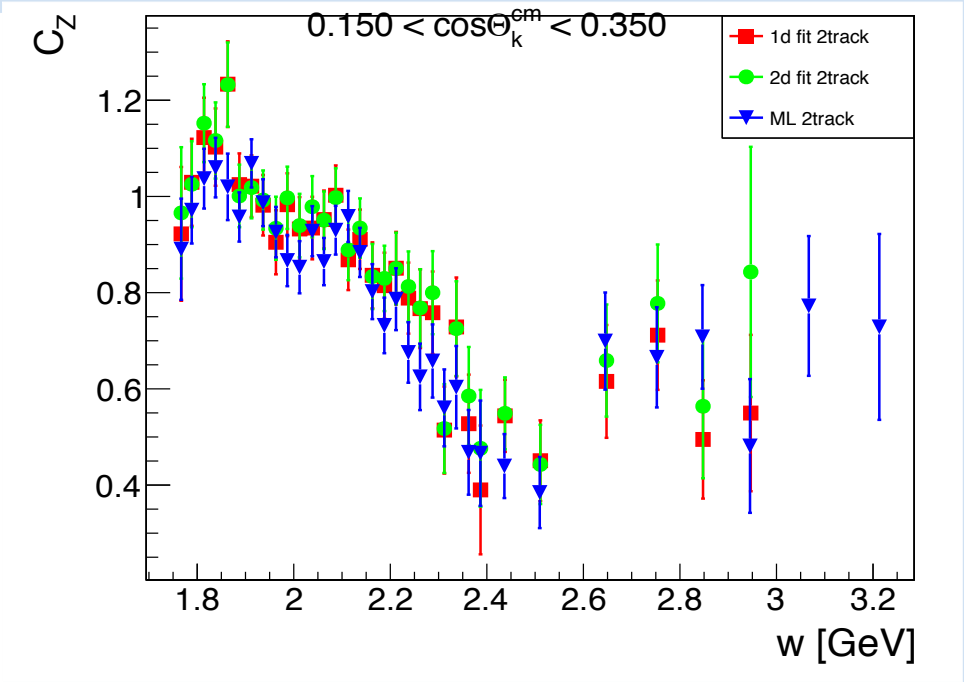
$$L(C_x, C_z) = \prod_{i=1}^n f(\cos\theta^p_x, \cos\theta^p_z)$$

  - Minimize negative log likelihood to fit the data;

$$l = -\sum_{i=1}^n \log f(\cos\theta^p_x, \cos\theta^p_z)$$

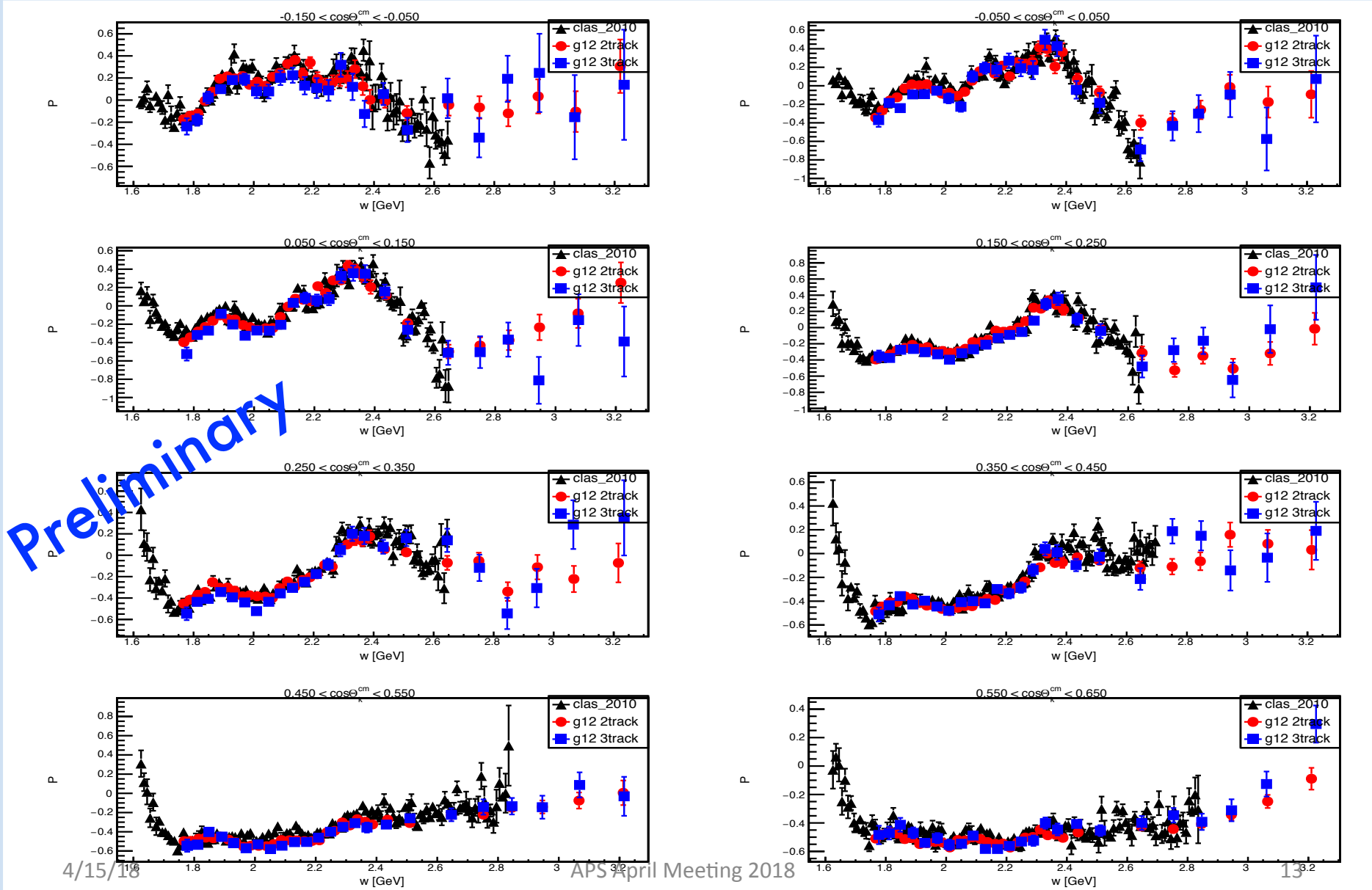
Comparision of 3 methods



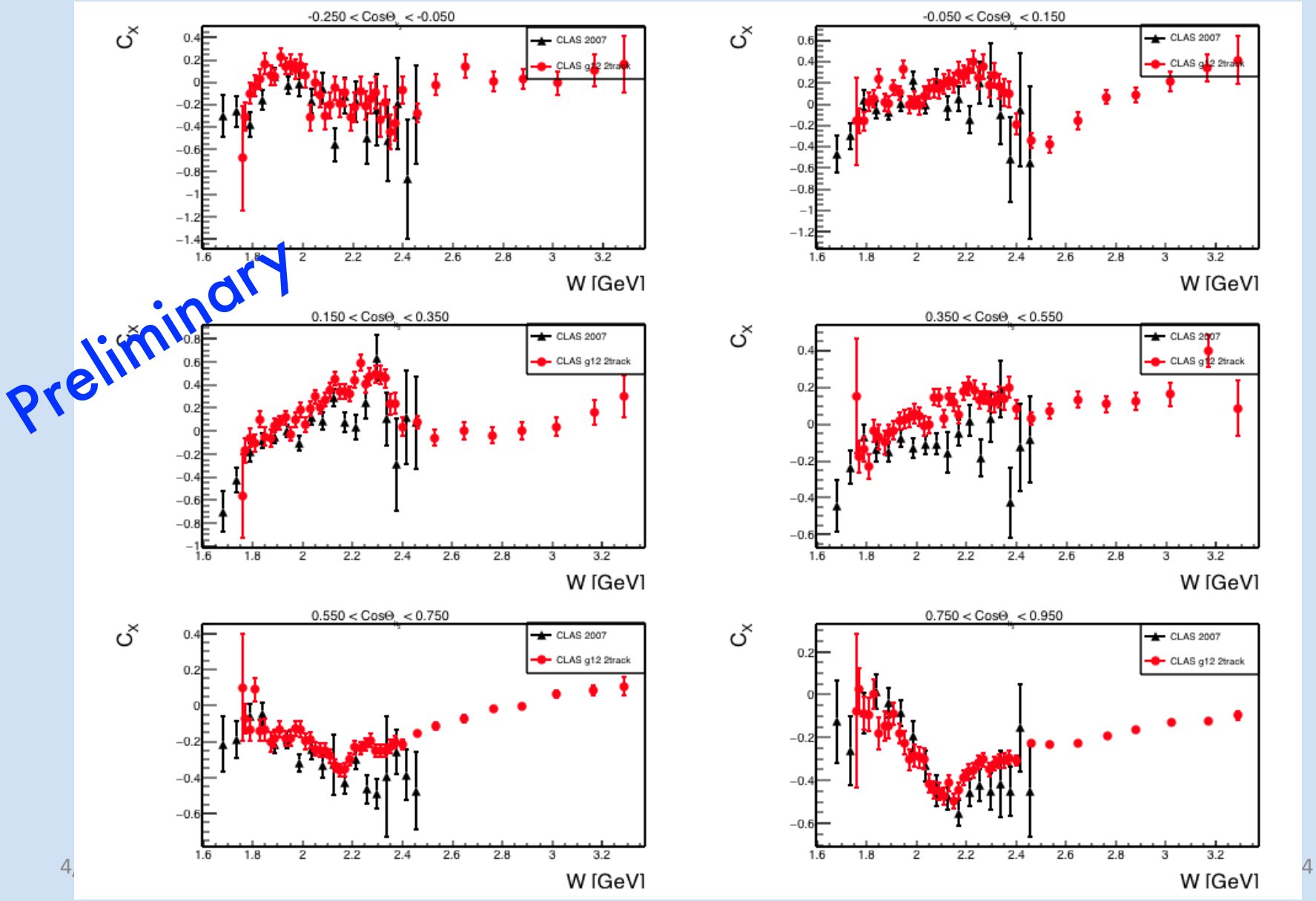


- Shows excellent agreements. Later showing results only for maximum likelihood method.
- Why ML? Applicable even when low statistics per bin.

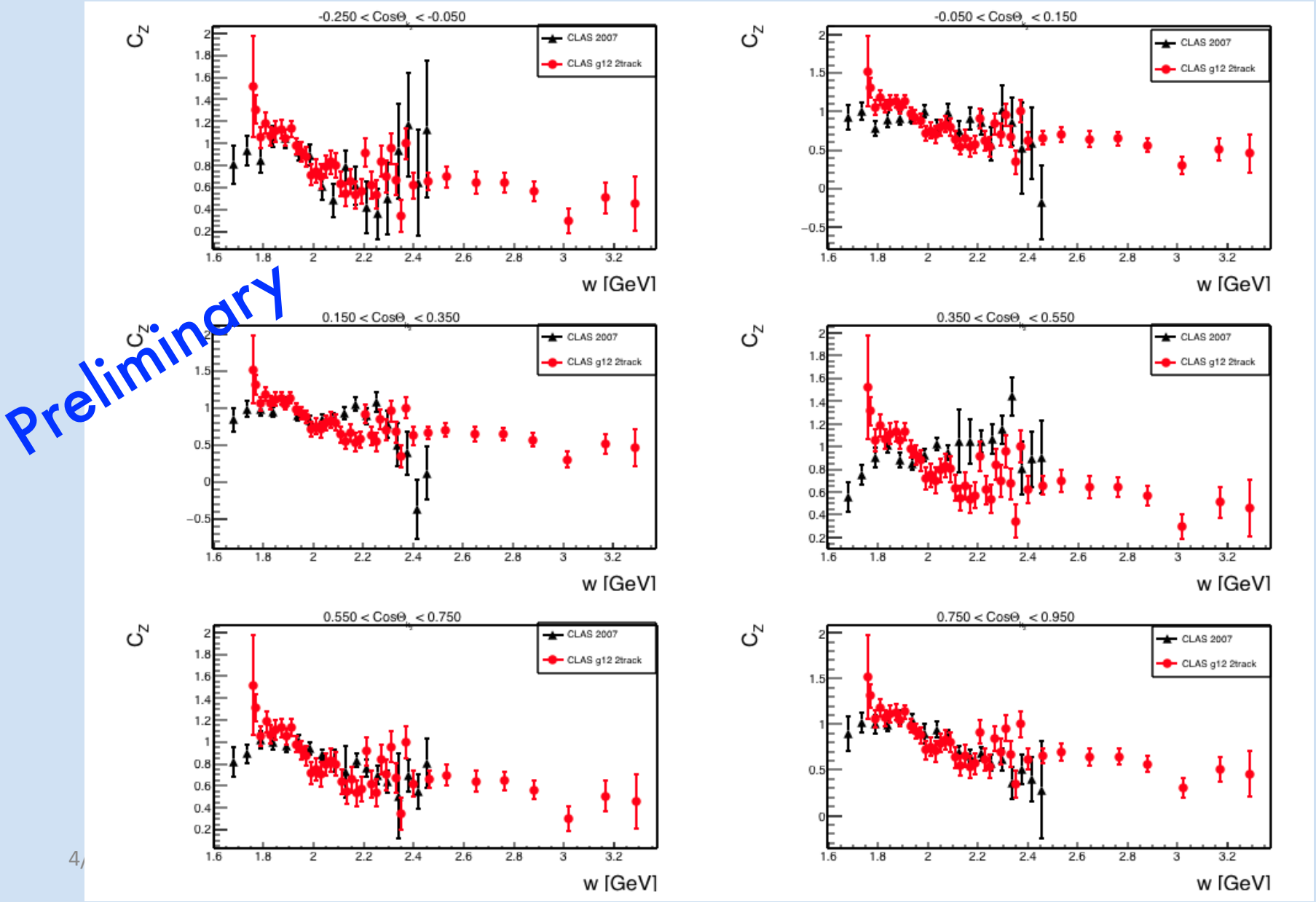
P results and comparision(CLAS 2010)



C_x Results and comparision(CLAS 2007)



C_z Results and comparision(CLAS 2007)



Conclusion and Outlook

- Measured Λ polarization observables C_x, P 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 smaller than previous g1c results for $W < 2.54$ GeV.
  - In the good agreement with earlier CLAS results.
  - First time measurement for $W > 2.54$ GeV.

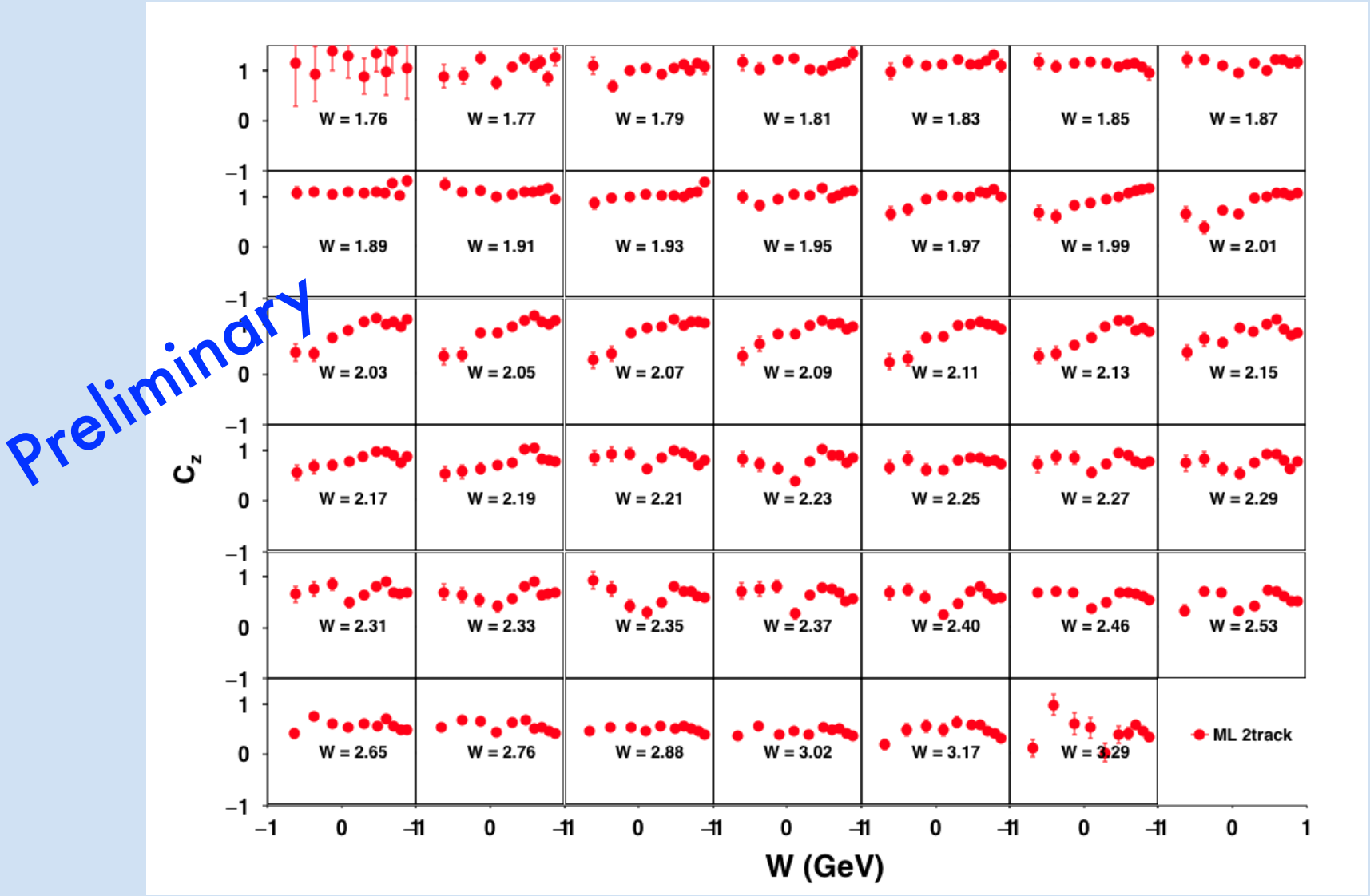
  P results:

  - agree well with CLAS 2010 results.

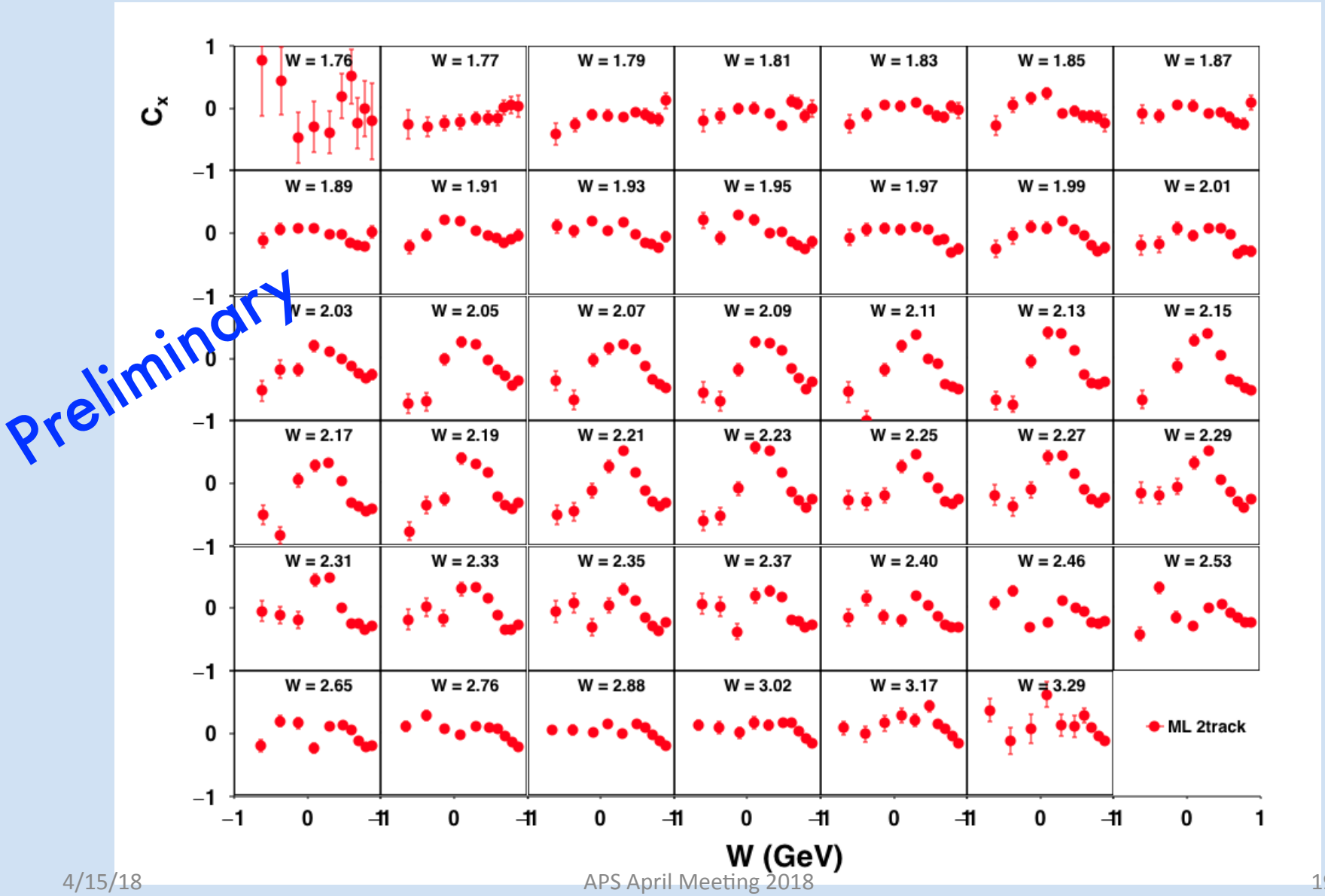
- Can be used to constrain non-resonant (t-channel) contribution.

Thank You!

C_z Results


Preliminary
C_z
W = 1.76
W = 1.77
W = 1.79
W = 1.81
W = 1.83
W = 1.85
W = 1.87
W = 1.89
W = 1.91
W = 1.93
W = 1.95
W = 1.97
W = 1.99
W = 2.01
W = 2.03
W = 2.05
W = 2.07
W = 2.09
W = 2.11
W = 2.13
W = 2.15
W = 2.17
W = 2.19
W = 2.21
W = 2.23
W = 2.25
W = 2.27
W = 2.29
W = 2.31
W = 2.33
W = 2.35
W = 2.37
W = 2.40
W = 2.46
W = 2.53
W = 2.65
W = 2.76
W = 2.88
W = 3.02
W = 3.17
W = 3.29
ML 2track
W (GeV)

C_x Results


Preliminary
C_x
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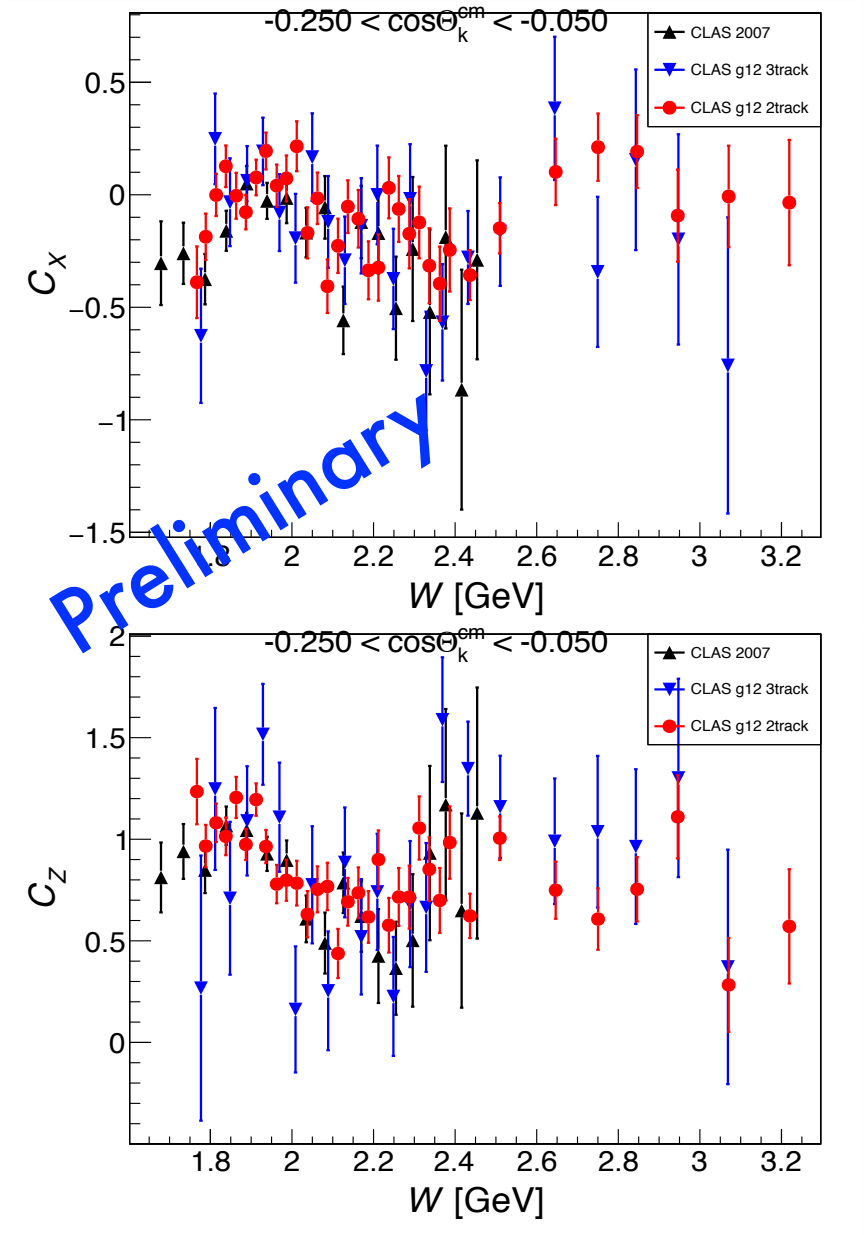
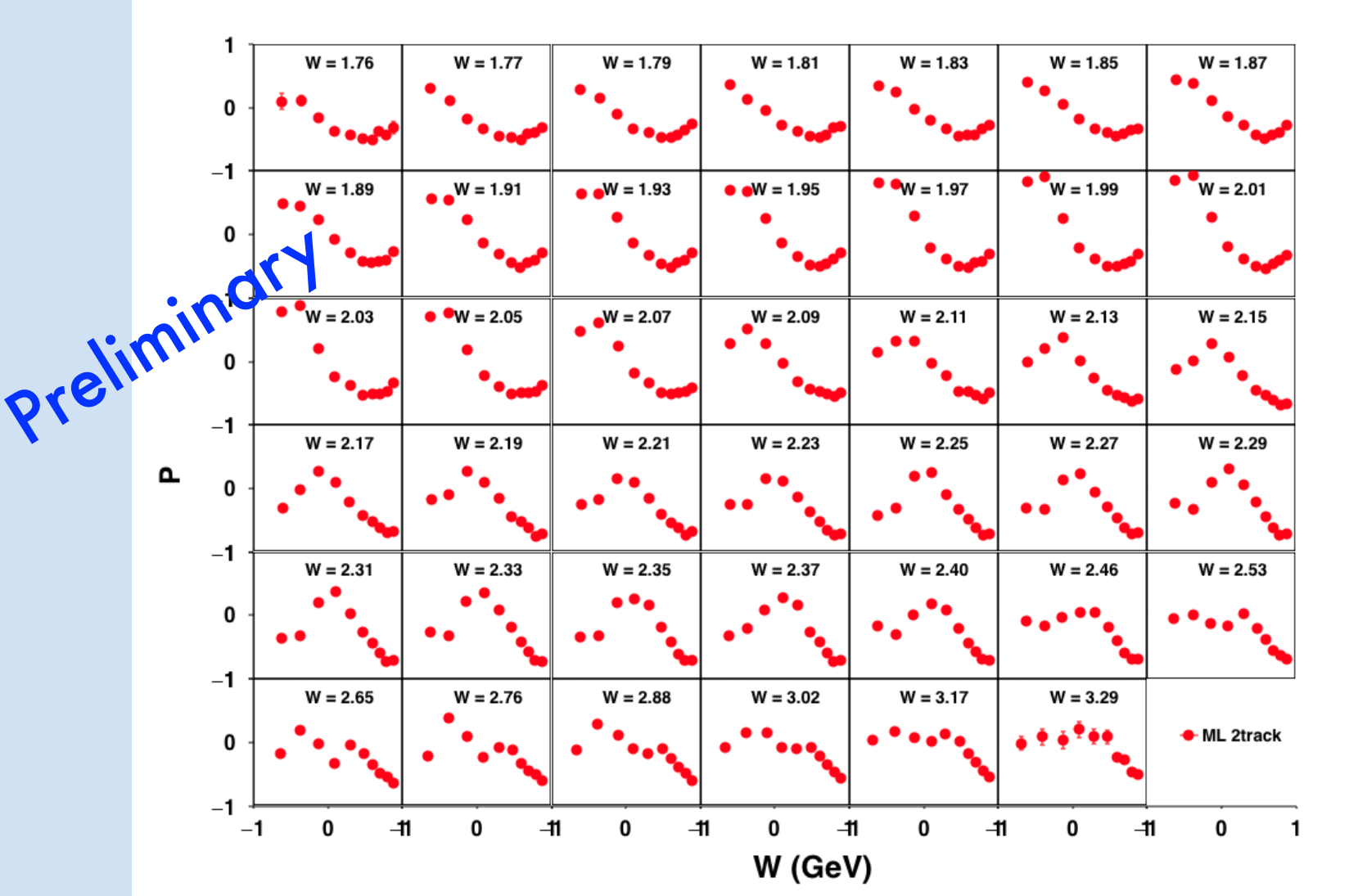
ML 2track
W (GeV)

Comparision with CLAS (2007): C_x,C_z



- Comparing 2 and 3 track:
  - High statistics for 2 track
  - Small statistical uncertainity
- Comparing 2, 3 track with CLAS (2007) results:
  - Much more statistics than previous measurement.
  - 2 track topology has smaller statistical uncertainity.
  - Good agreements.
- Higher kinematic coverage:
  - Include results $W > 2.54$ GeV.

P Results


Preliminary
P
W (GeV)
W = 1.76
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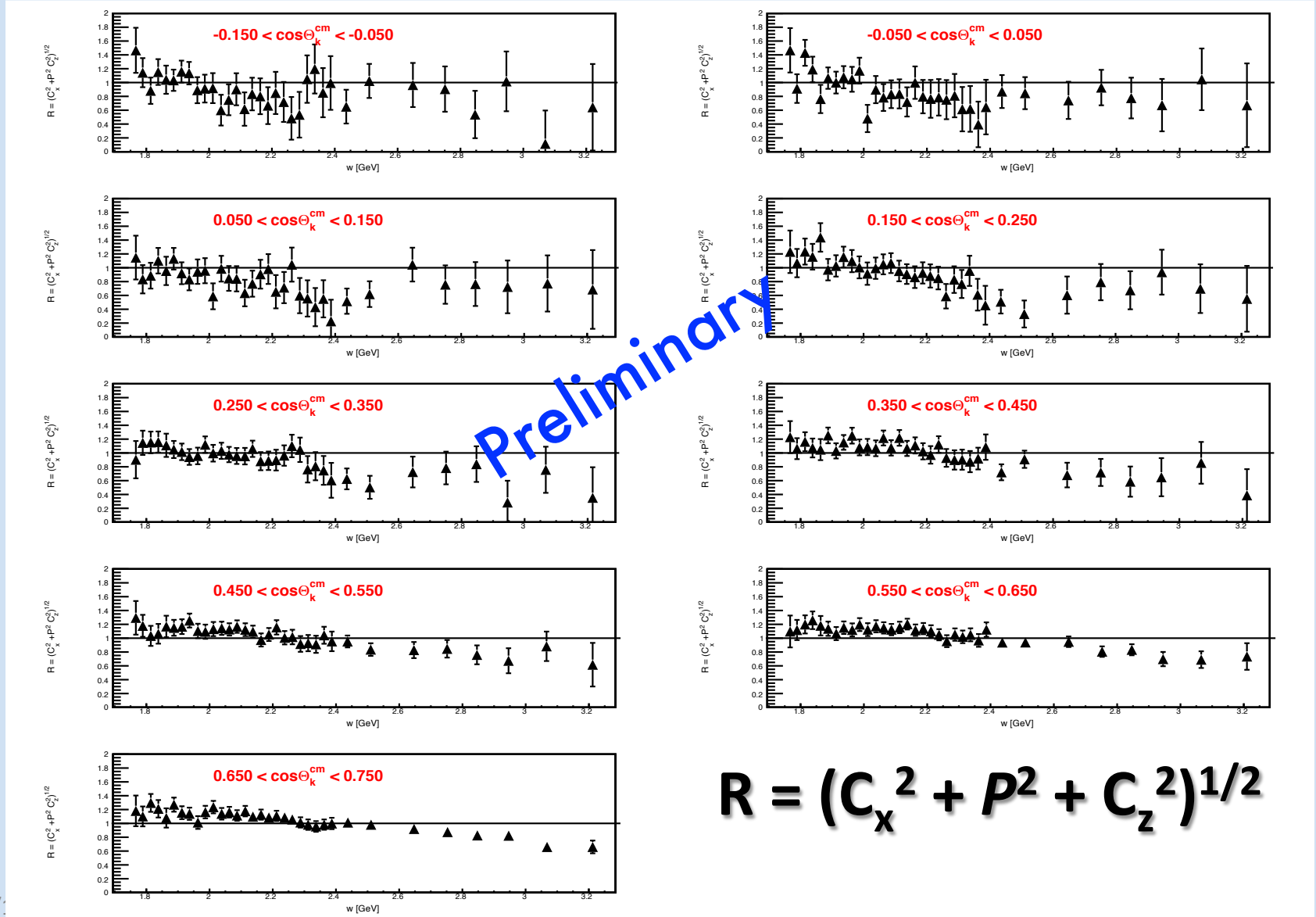
ML 2track

R values for the Λ



$$R = (C_x^2 + P^2 + C_z^2)^{1/2}$$