CLAS collaboration, Summer 2012
Hadron Spectroscopy PWG

Update on the Polarization Observables Extraction in Double-Pion Production from g9a

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Outline

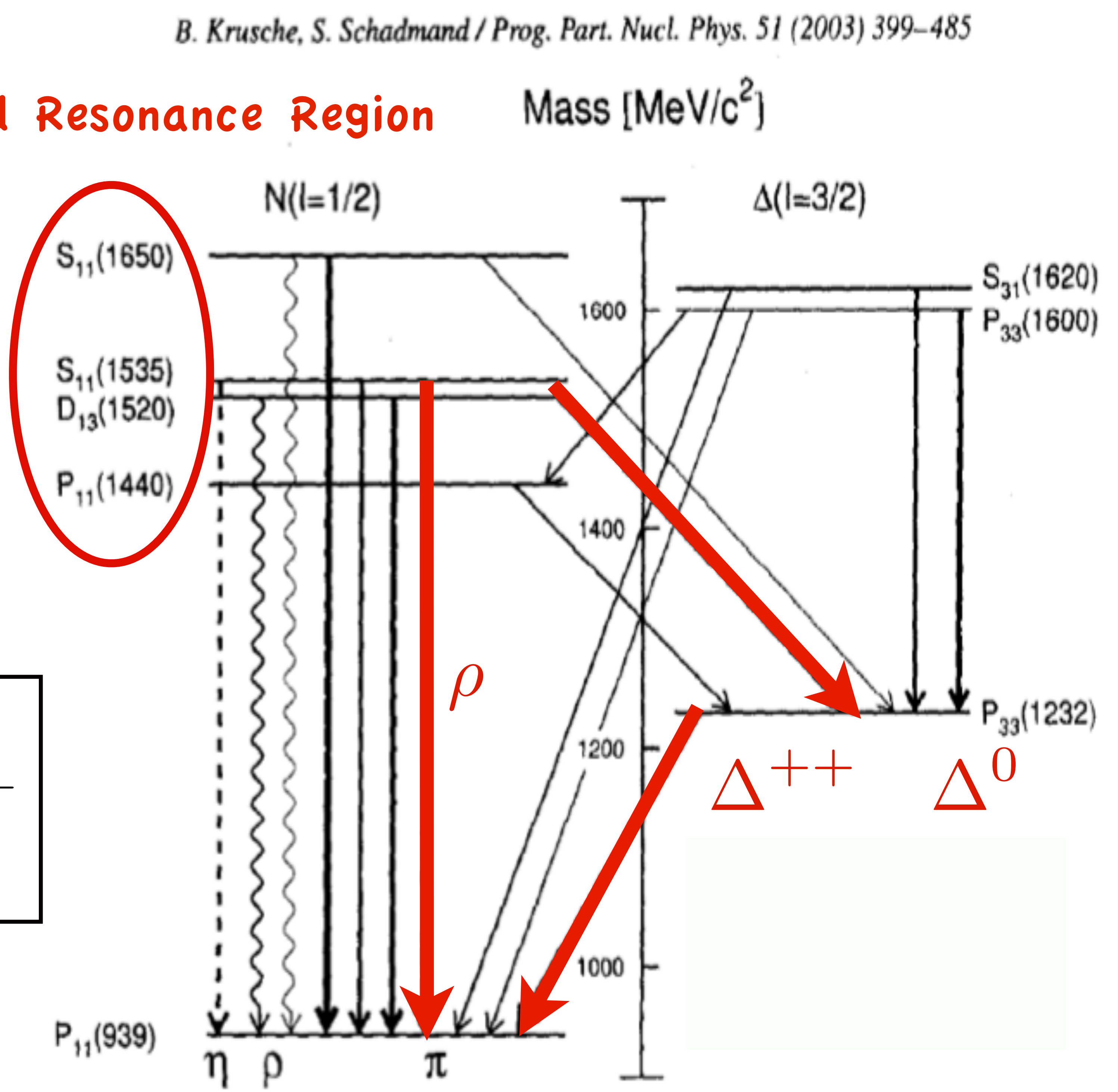
- Introduction
- Analysis
    - Identification of the Double-Pion Reaction
    - Bound Nucleon Background
    - Asymmetry from Target Polarization Flip
    - Polarization Observables: P_z P_z^s P_z^c
    - Further Study on Observables
    - Comparison with Circularly Polarized data
- Conclusion and Future

Intro - Reaction

- Research interest -- second resonance region
- Three main independent reaction channels

Three main channels

$$\gamma p \rightarrow \begin{pmatrix} p\rho \\ \Delta^{++}\pi^{-} \\ \Delta^{0}\pi^{+} \end{pmatrix} \rightarrow p\pi^{+}\pi^{-}$$



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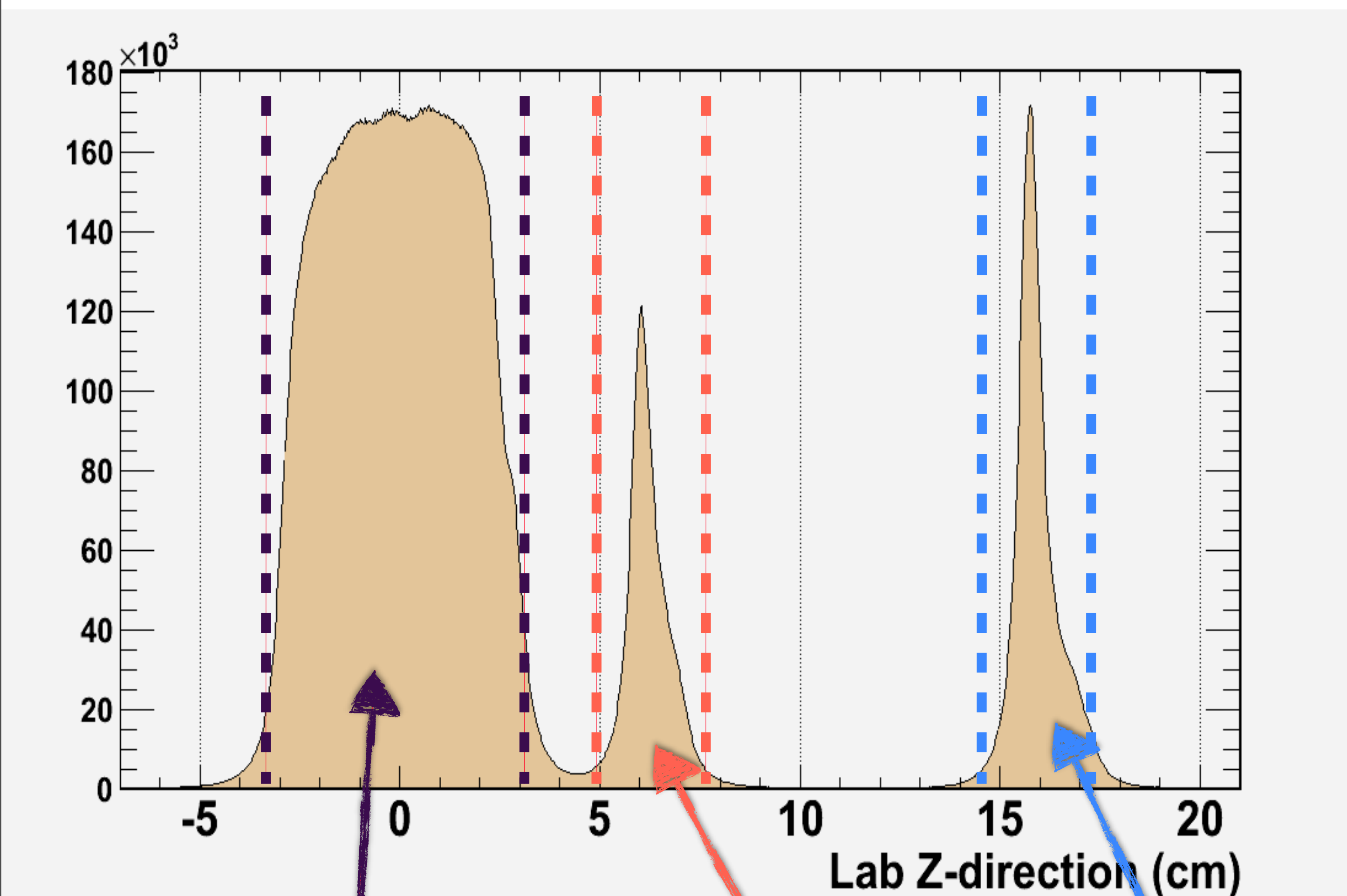
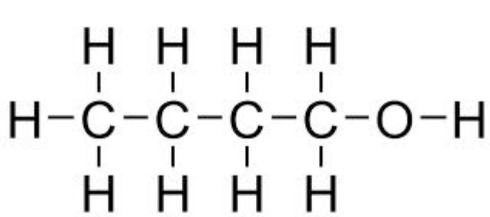
Intro - Experiment

Target



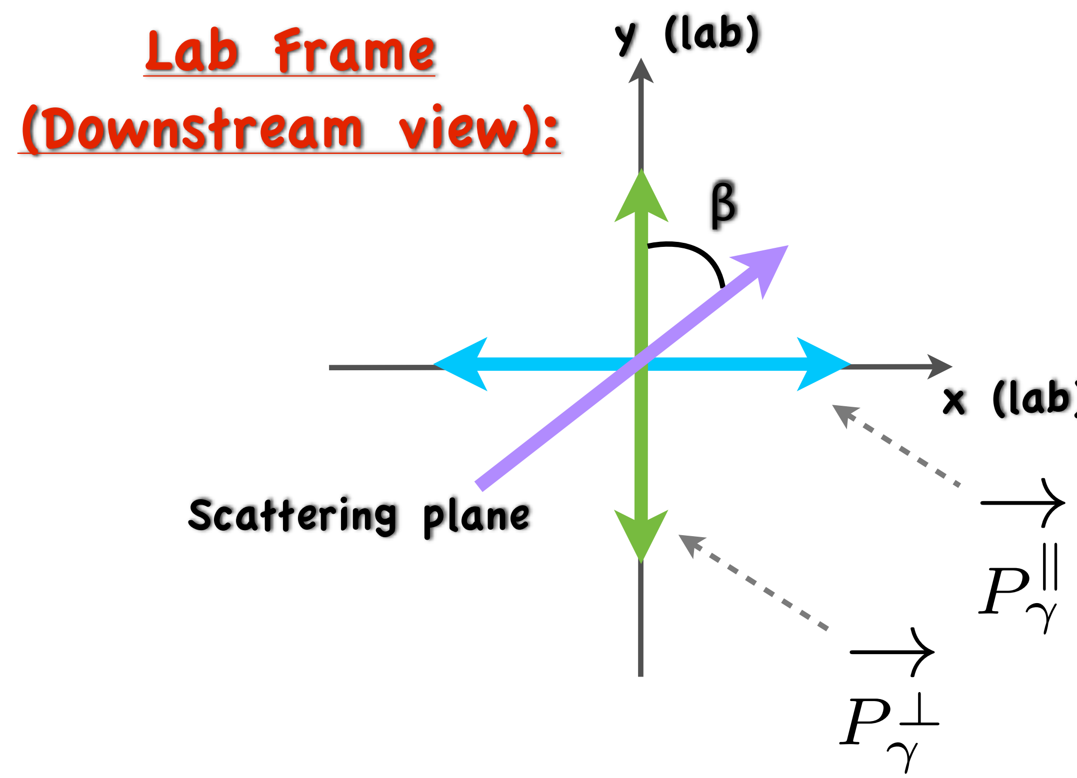
Polarized Target



Unpolarized C^{12}

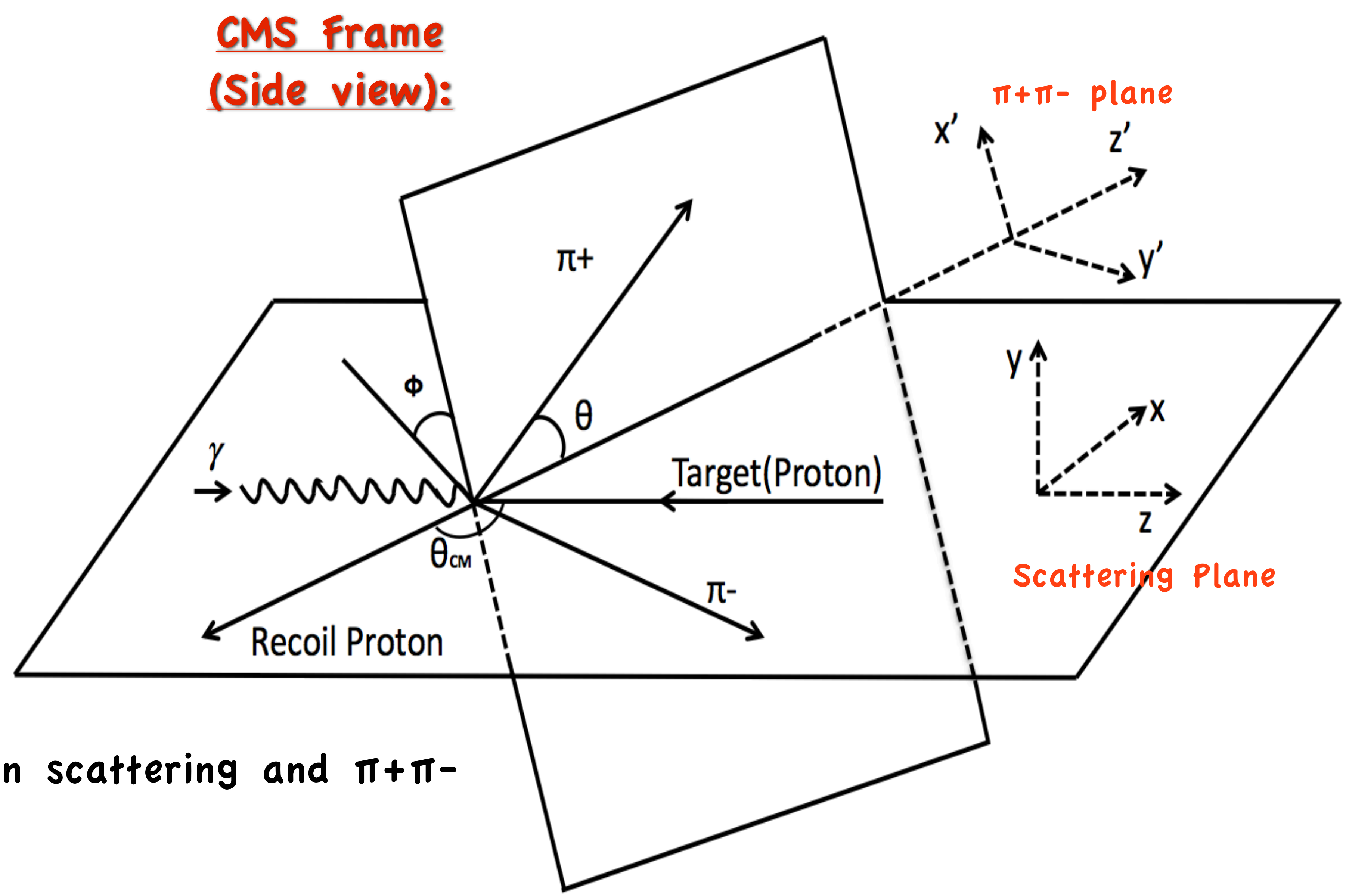
Unpolarized CH_2

Photon Beam



- To extract observables, free protons in butanol are longitudinally polarized (positive and negative)
- Carbon target is necessary for extraction of unpolarized background
- Photon beam is linearly polarized

Intro - Reaction Plane



- Scattering plane - by incident photon and recoiling proton

- π+π- plane - by two π mesons

- ϕ - Azimuthal angle (between scattering and π+π- plane)

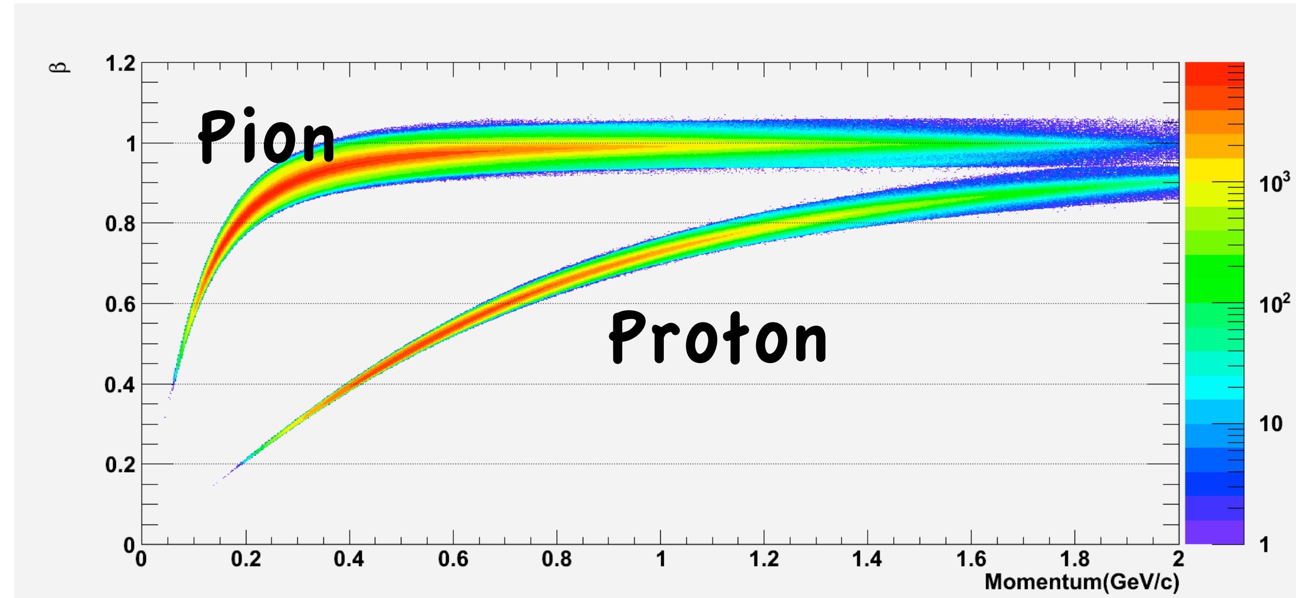
- θ - Polar angle (between π+ vector and z' axis)

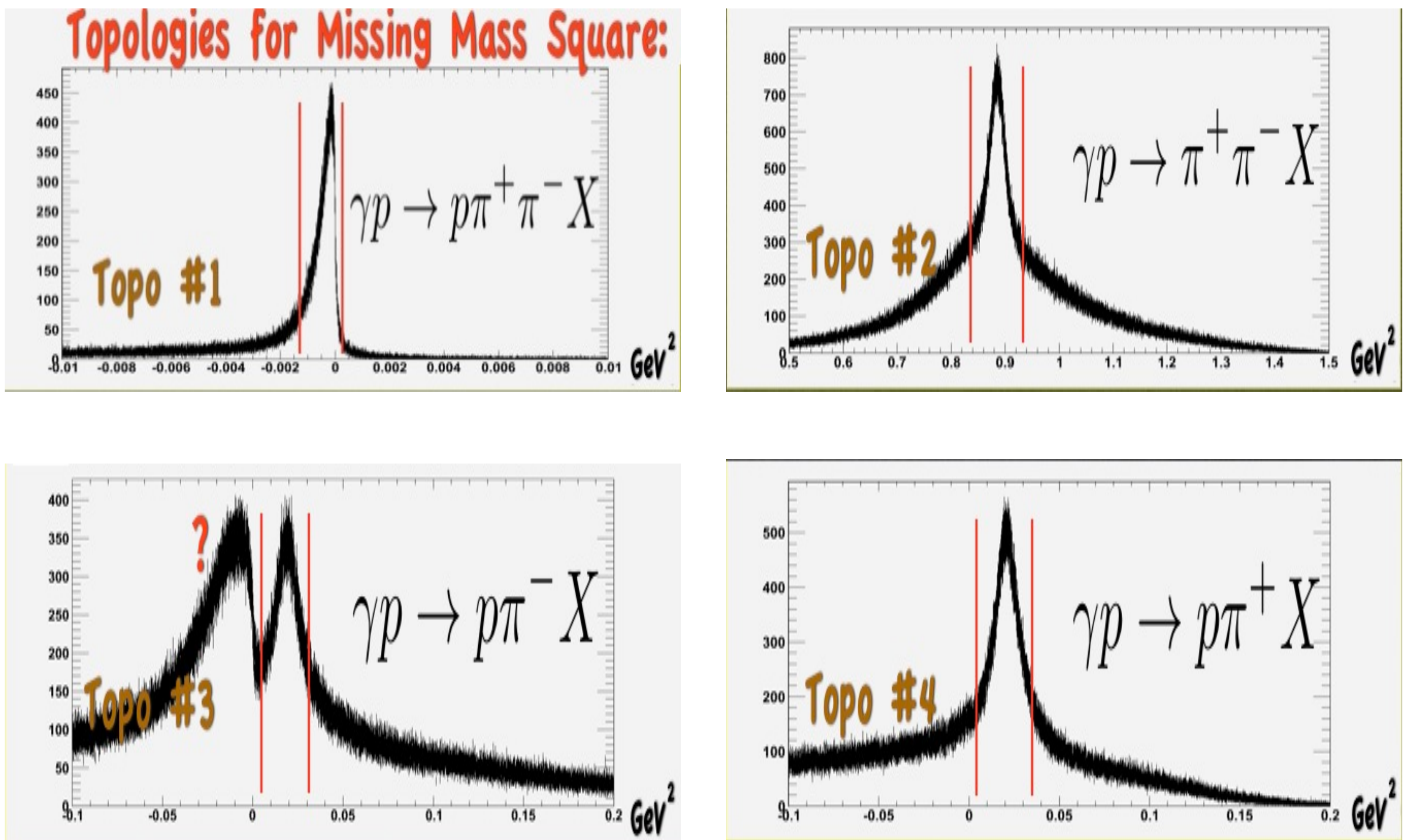
- θ_{CM} - CM Polar angle (between E_γ and recoiling proton)

Reaction Reconstruction

Particle ID:

- Time-difference cut (assumed and calculated time) for proton and pion meson
- Photon selection (1ns time difference cut)





Channel ID:

- Reconstruct the reaction channel by detected particles and incident photon
- 4 topologies with various missing mass distributions
- Cut on missing mass to make channel ID

1: None missing	2: Proton missing
3: π+ missing	4: π- missing

All Units:(GeV^2/c^4)

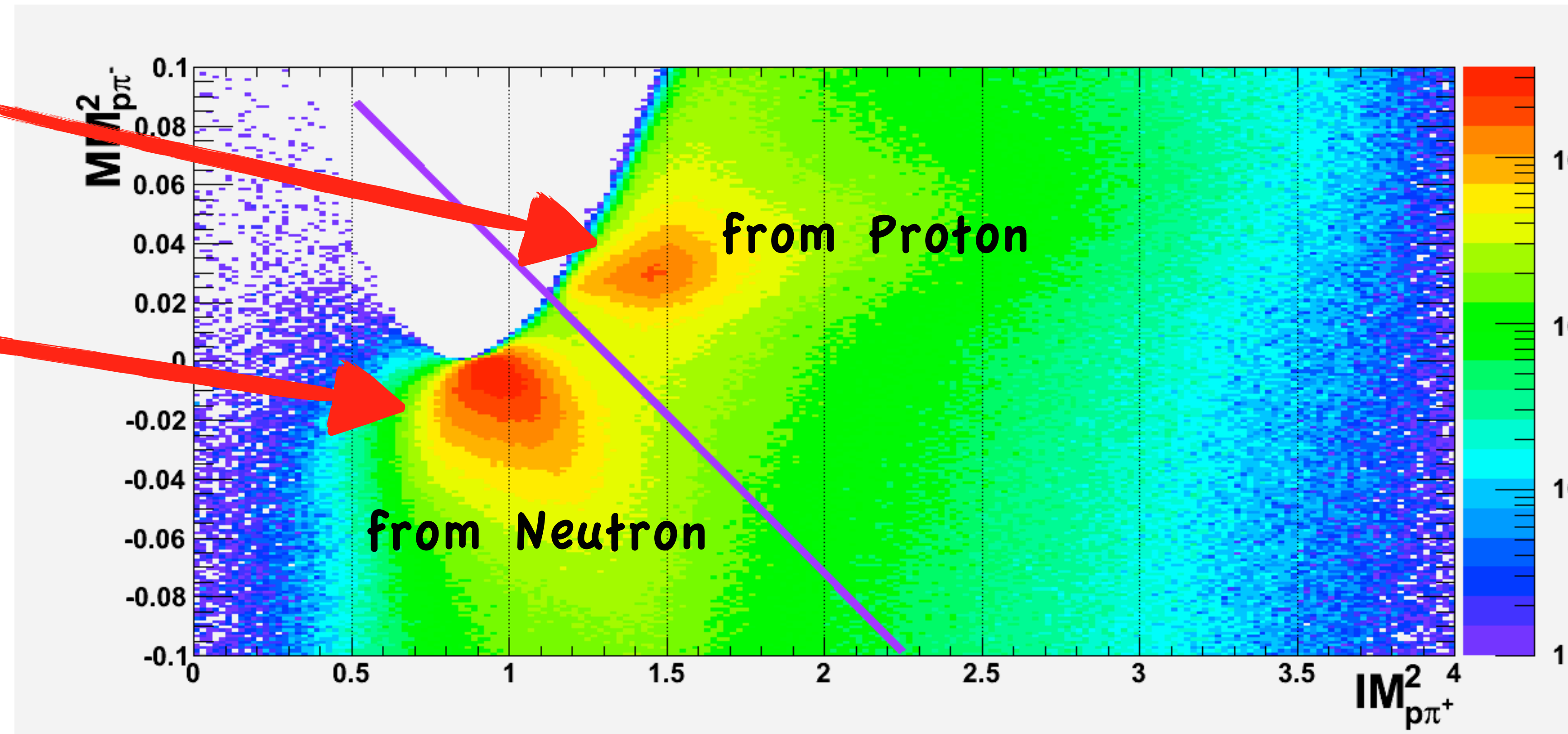
Reaction Reconstruction

$\gamma p \rightarrow p\pi^-(\pi^+)$

(Channel Interested)

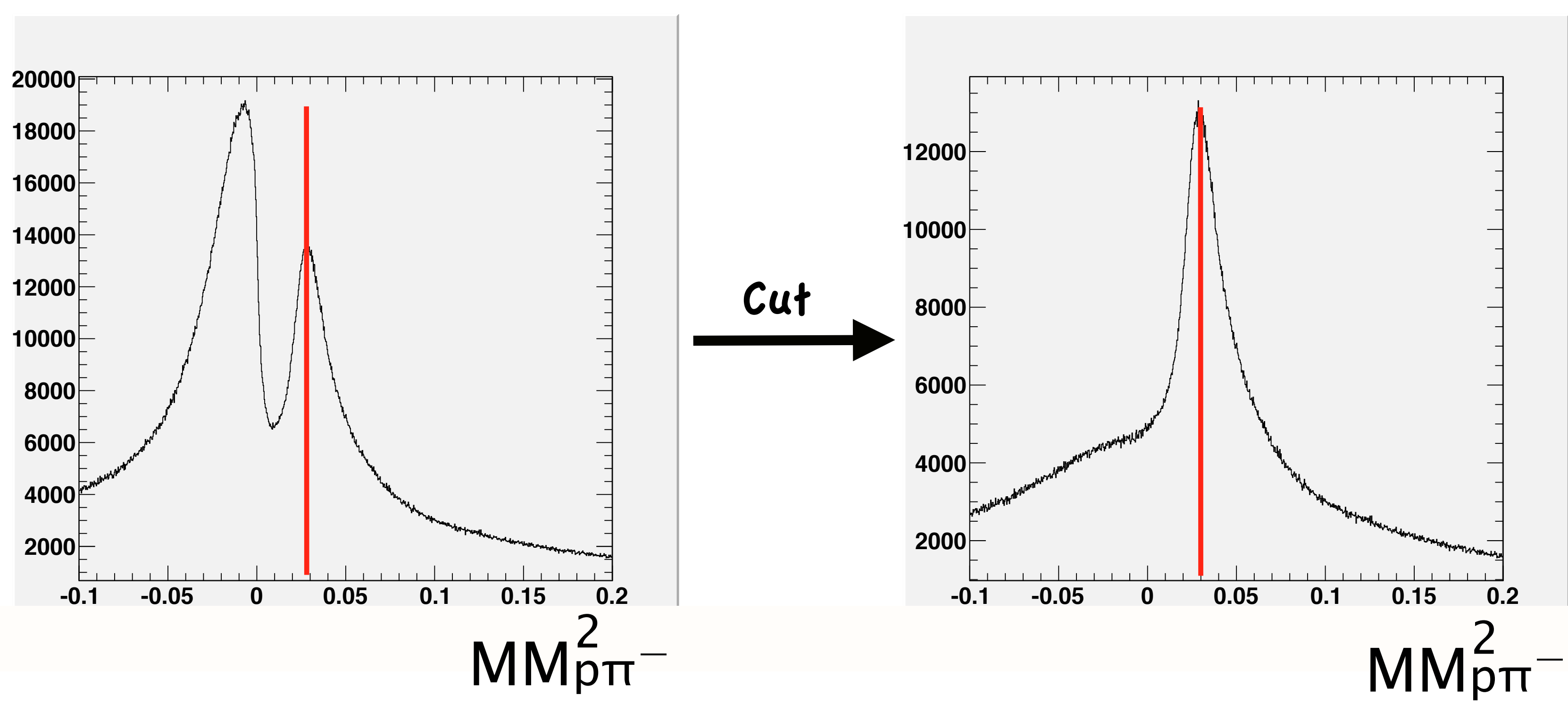
$\gamma n \rightarrow p\pi^-$

(Background)

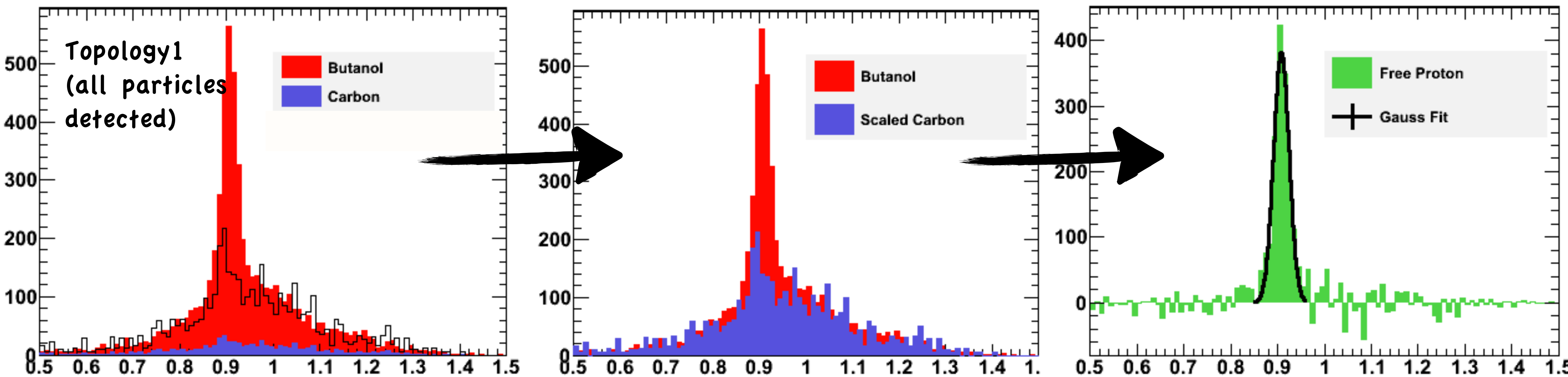


All Units:(GeV^2/c^4)

- Neutron reaction in butanol target
- Larger mass of neutron caused the MM peak shifted to left
- Background peak is removed by cut on the 2D histogram
- 97% of the events from proton passed the cut
- The other 3 topologies have π+ detected. Thus only in the topology 3, events off the neutron can enter the missing mass distribution.



Bound Nucleon Background



All Units:(GeV^2/c^4)

● **Scale Factor:**

The ratio of bound-proton yields between butanol and carbon targets

● **Procedure:**

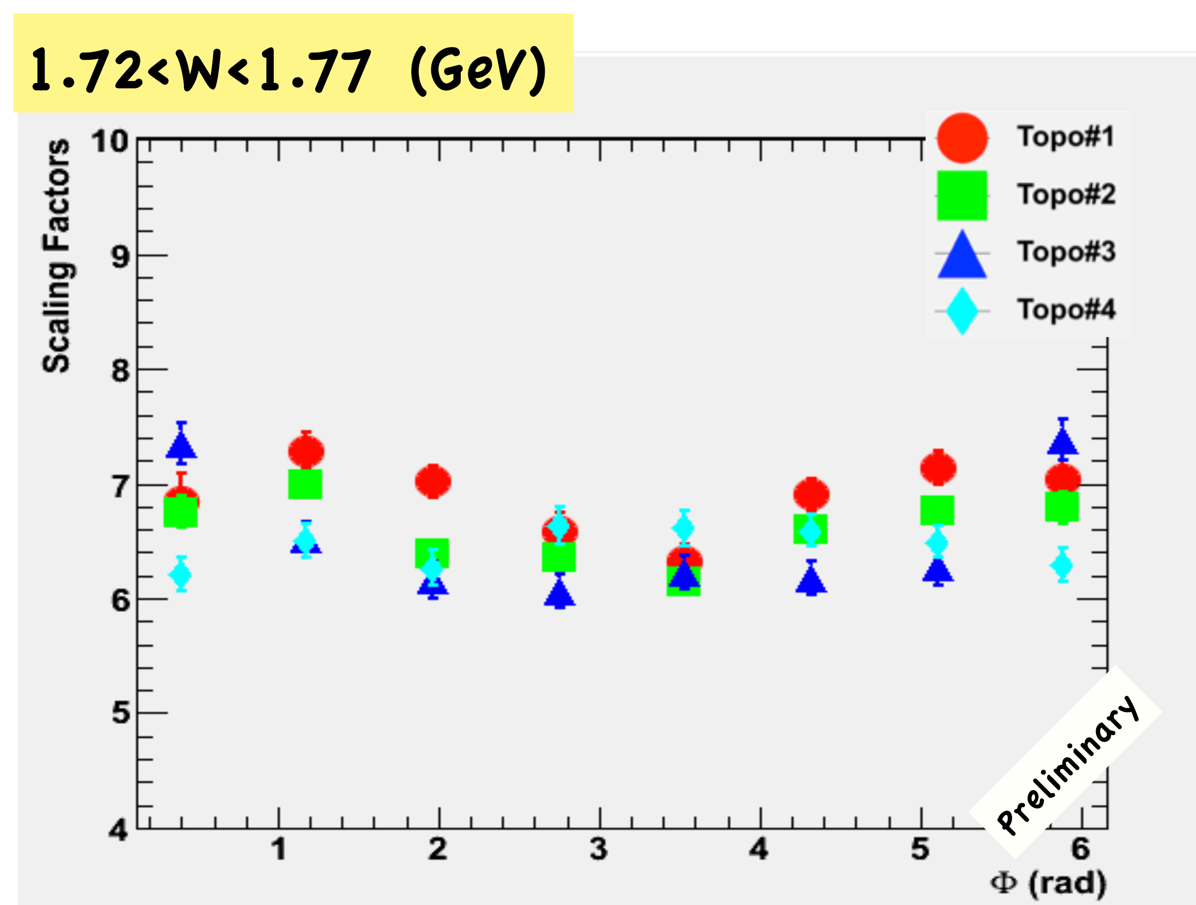
Fit butanol missing mass distribution with scaled carbon and gaussian peak, where scale factor is the fit parameter

● **Free Proton:**

Subtract the scaled carbon distribution from that of butanol

● **Problem:**

Low statistics of carbon target influenced the fit quality in some kinematic bins



Asymmetry from Target Polarization Flip

Yields: Y+ and Y- from positively and negatively polarized target cannot be applied for asymmetry calculation directly, NORMALIZATION is necessary!

Definition of asymmetry:

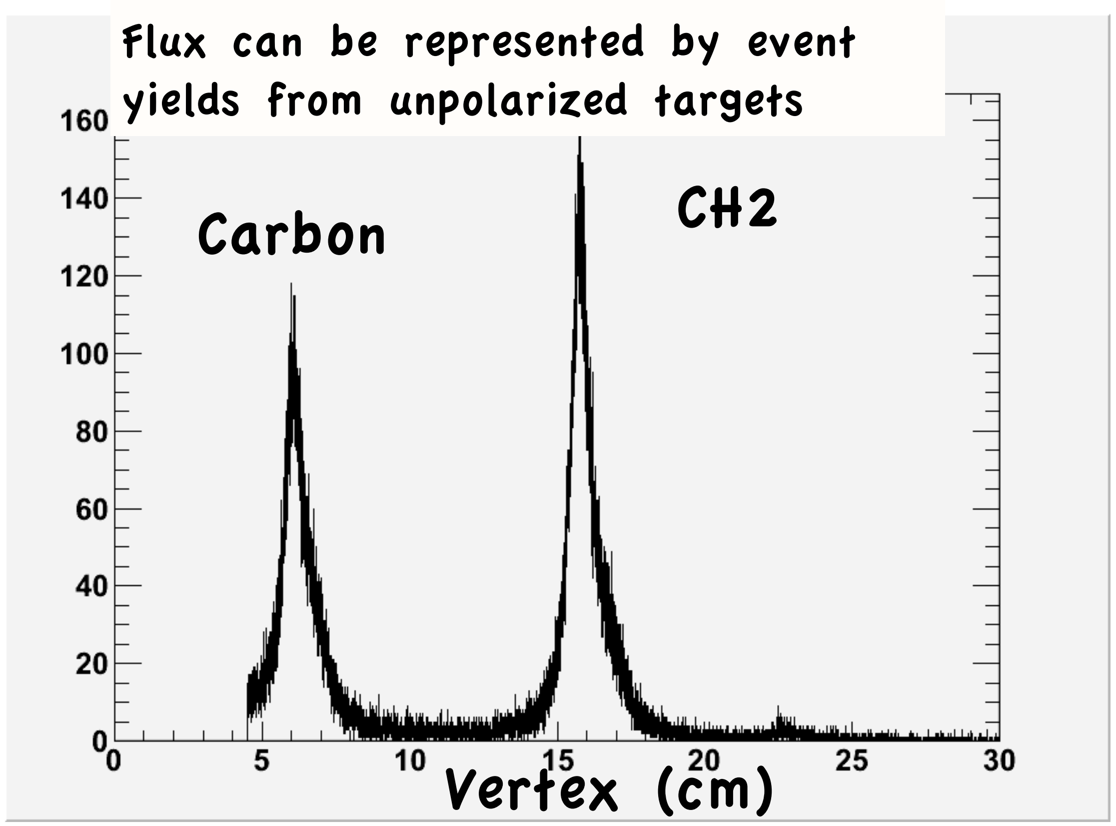
$$Asy = \frac{I^+ - I^-}{I^+ + I^-}$$

Normalized yield with target positively polarized

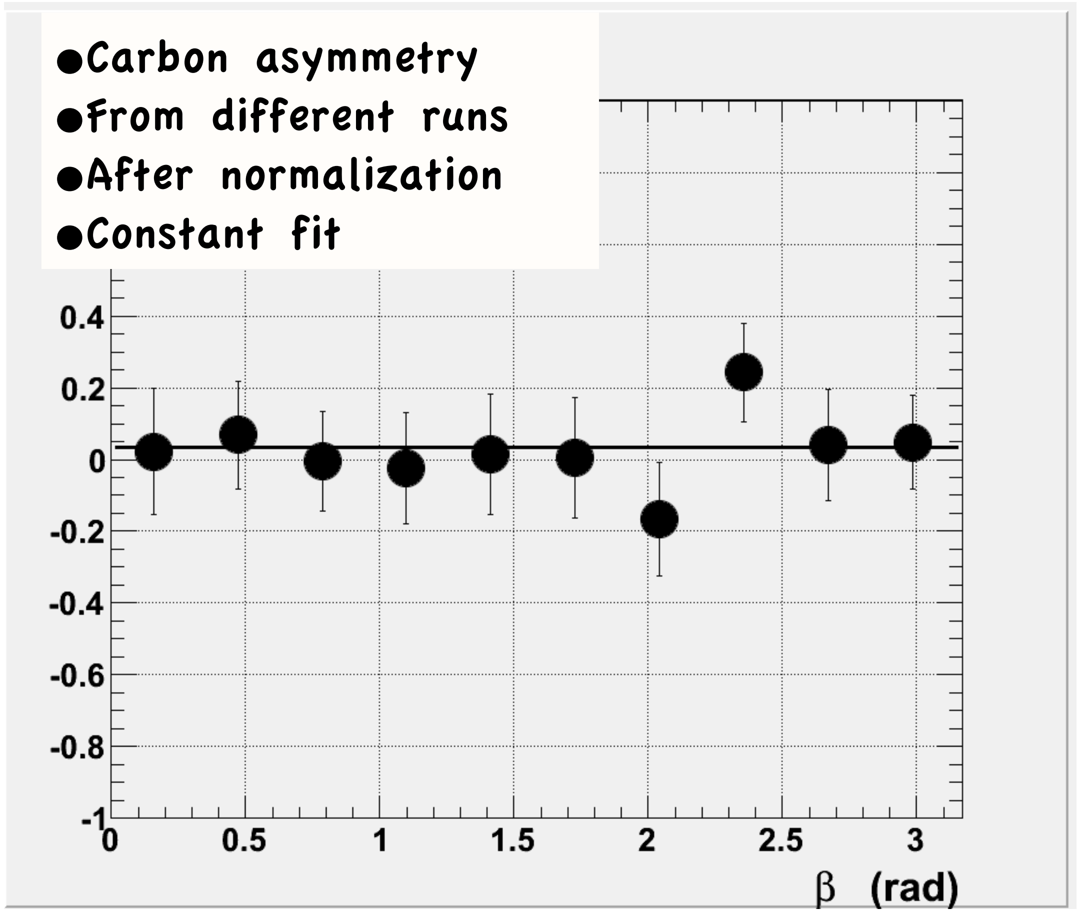
$$I^+ = I_0 \left\{ (1 + \Lambda^+ \cdot P_z) + \delta^+ [\sin 2\beta (I_s + \Lambda^+ \cdot P_z^s) + cos2\beta (I_c + \Lambda^+ \cdot P_z^c)] \right\}$$

Normalized yield with target negatively polarized

$$I^- = I_0 \left\{ (1 - \Lambda^- \cdot P_z) + \delta^- [\sin 2\beta (I_s - \Lambda^- \cdot P_z^s) + cos2\beta (I_c - \Lambda^- \cdot P_z^c)] \right\}$$



Check the Normalization quality

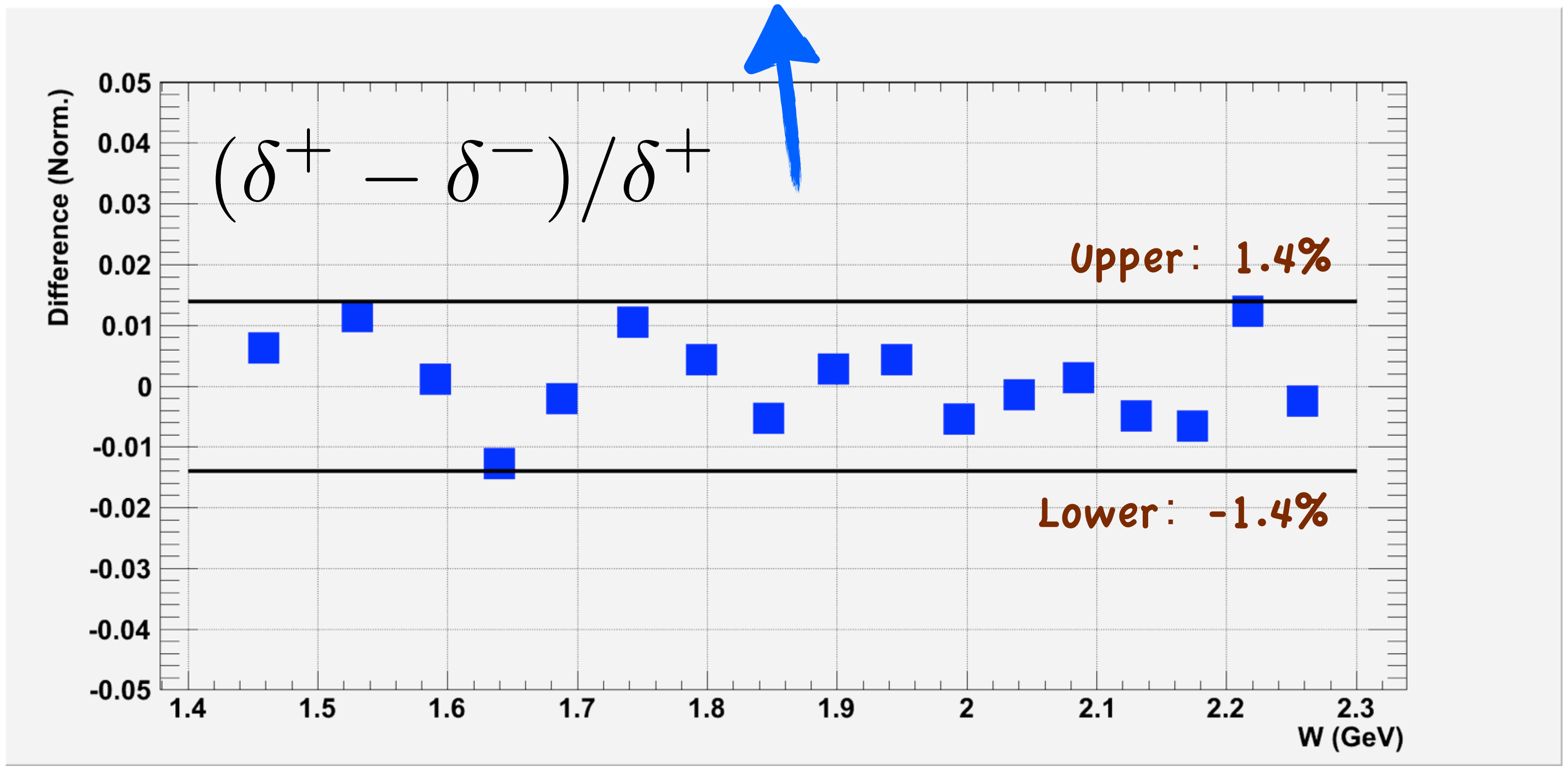


Asymmetry from Target Polarization Flip

After the normalization, make the subtraction: →

$$\begin{aligned}\Delta I &= I_0(\Lambda^+ + \Lambda^-)P_z \\ &+ I_0(\delta^+\Lambda^+ + \delta^-\Lambda^-)(\sin 2\beta \cdot P_z^s + \cos 2\beta \cdot P_z^c) \\ &+ I_0(\delta^+ - \delta^-)(\sin 2\beta \cdot I^s + \cos 2\beta \cdot I^c)\end{aligned}$$

- The Blue term contains two other observables
- Blue term could appear if beam polarizations are unequal for target positively and negatively polarized
- Right plot: check the equality
- Equality ranges from 0.986 - 1.014



How can we extract the observables? →

$$\frac{\Delta I}{2I_0} = \Lambda_z(P_z + \delta(\sin 2\beta \cdot P_z^s + \cos 2\beta \cdot P_z^c))$$

Asymmetry — Polarization Observables

where: $\Lambda_z = \dfrac{|\Lambda^+| + |\Lambda^-|}{2}$

Asymmetry from Target Polarization Flip

Asymmetry calculated:

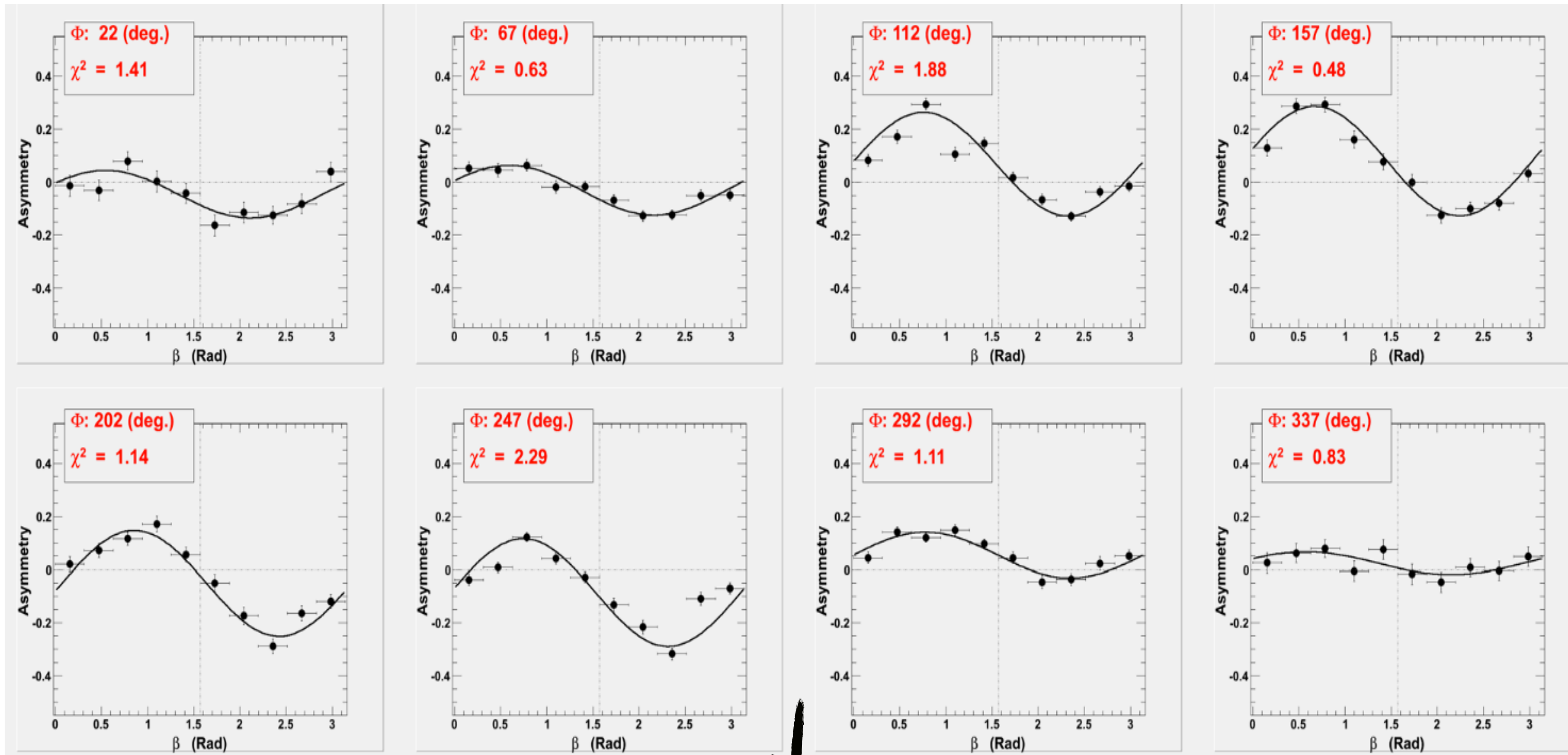
$$\frac{\Delta I}{2I_0} = \frac{N_B^+ - N_B^-}{N_B^+ + N_B^- - S.F \cdot N_C}$$

N_B^+ -- Yields from positively polarized, butanol target

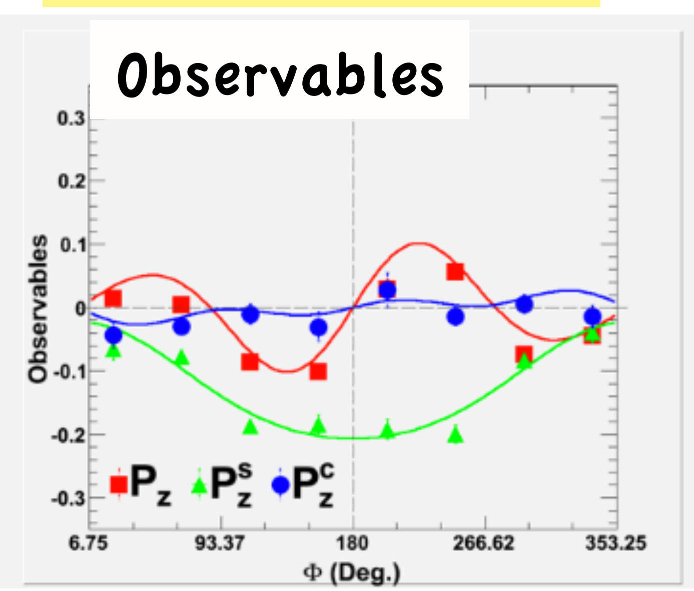
N_B^- -- Yields from negatively polarized, butanol target

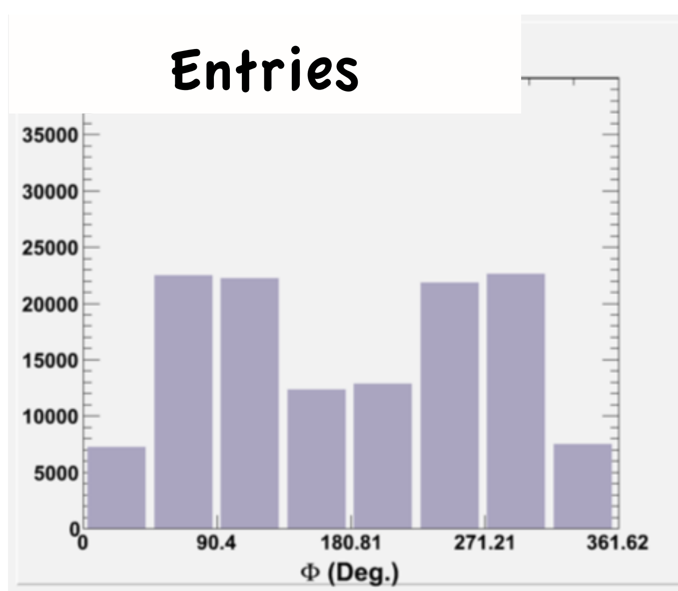
N_C -- Yields from carbon target

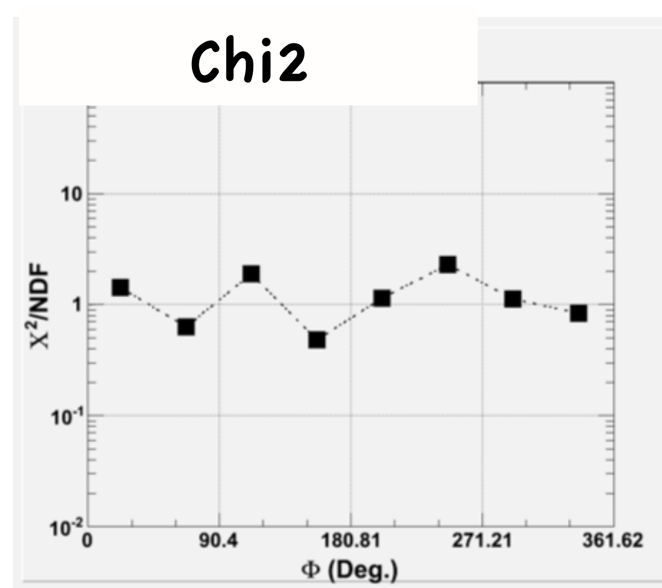
$S.F$ -- Scale Factor



1.56<W<1.62 (GeV)

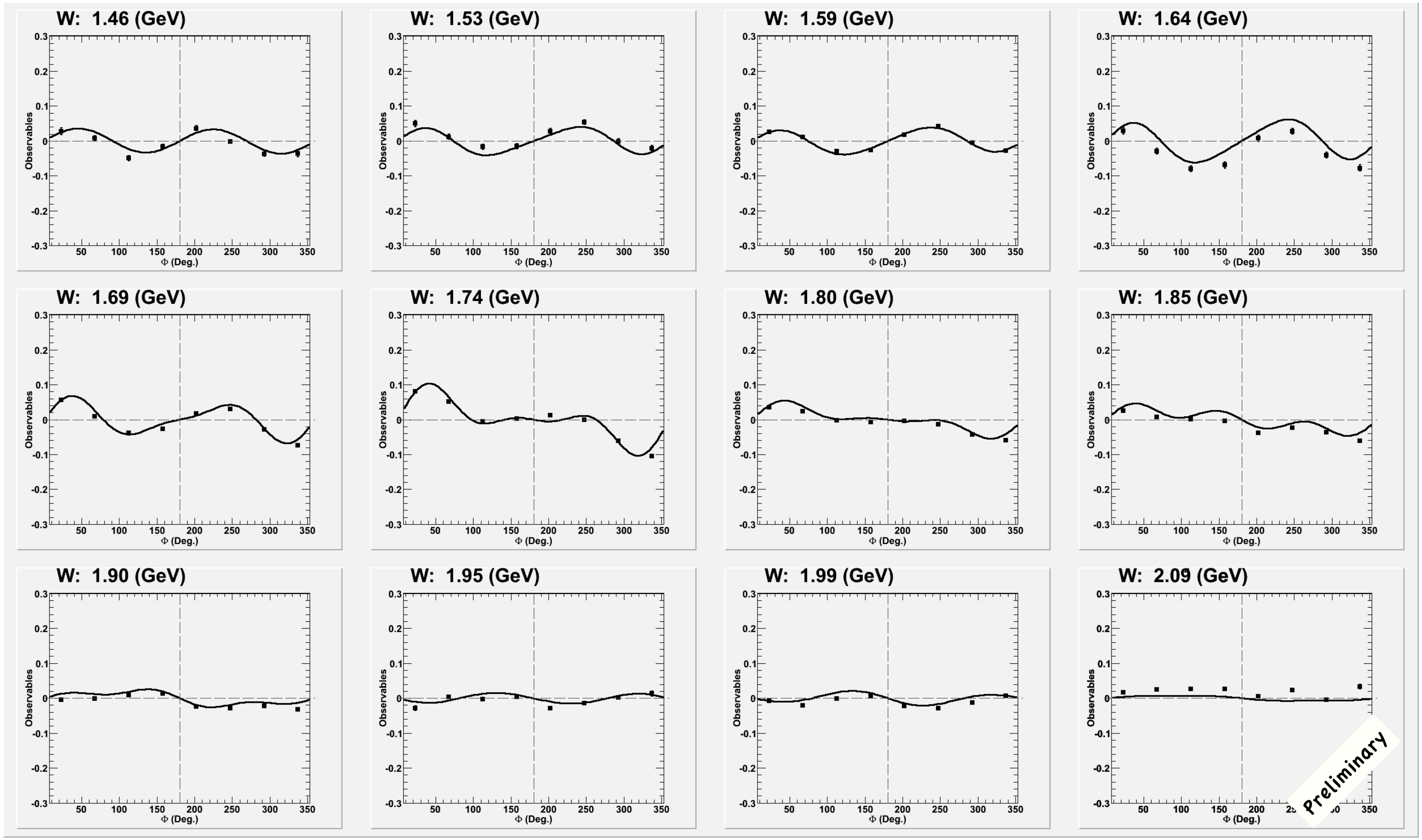






- Bin: W(17) and ϕ(8)
- Entries: 1000 - 35000 for each kinematic bin
- Chi2: Close to 1

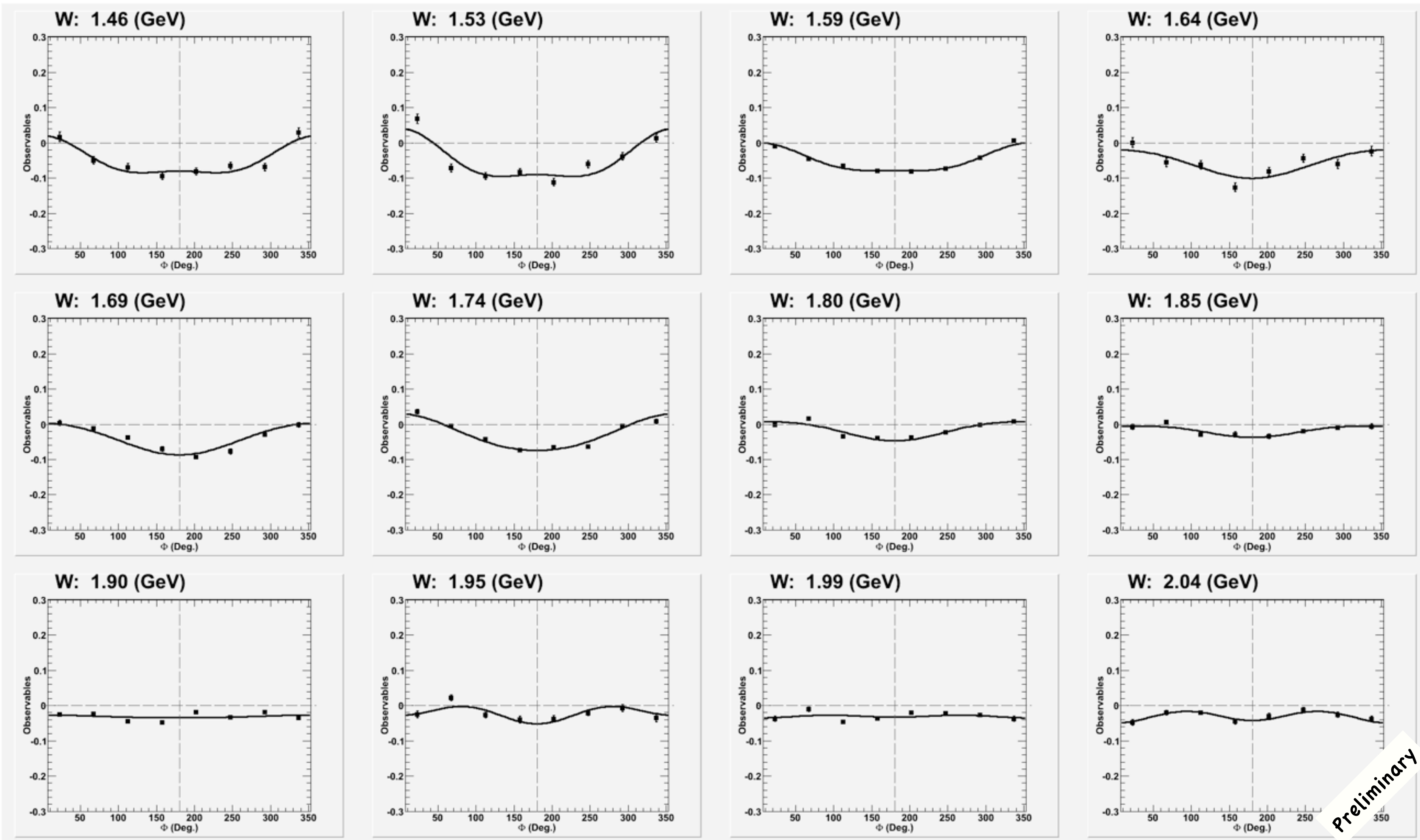
Observable: P_z



- Fit the observables by Fourier series
- Amplitudes of observables decrease as W increases

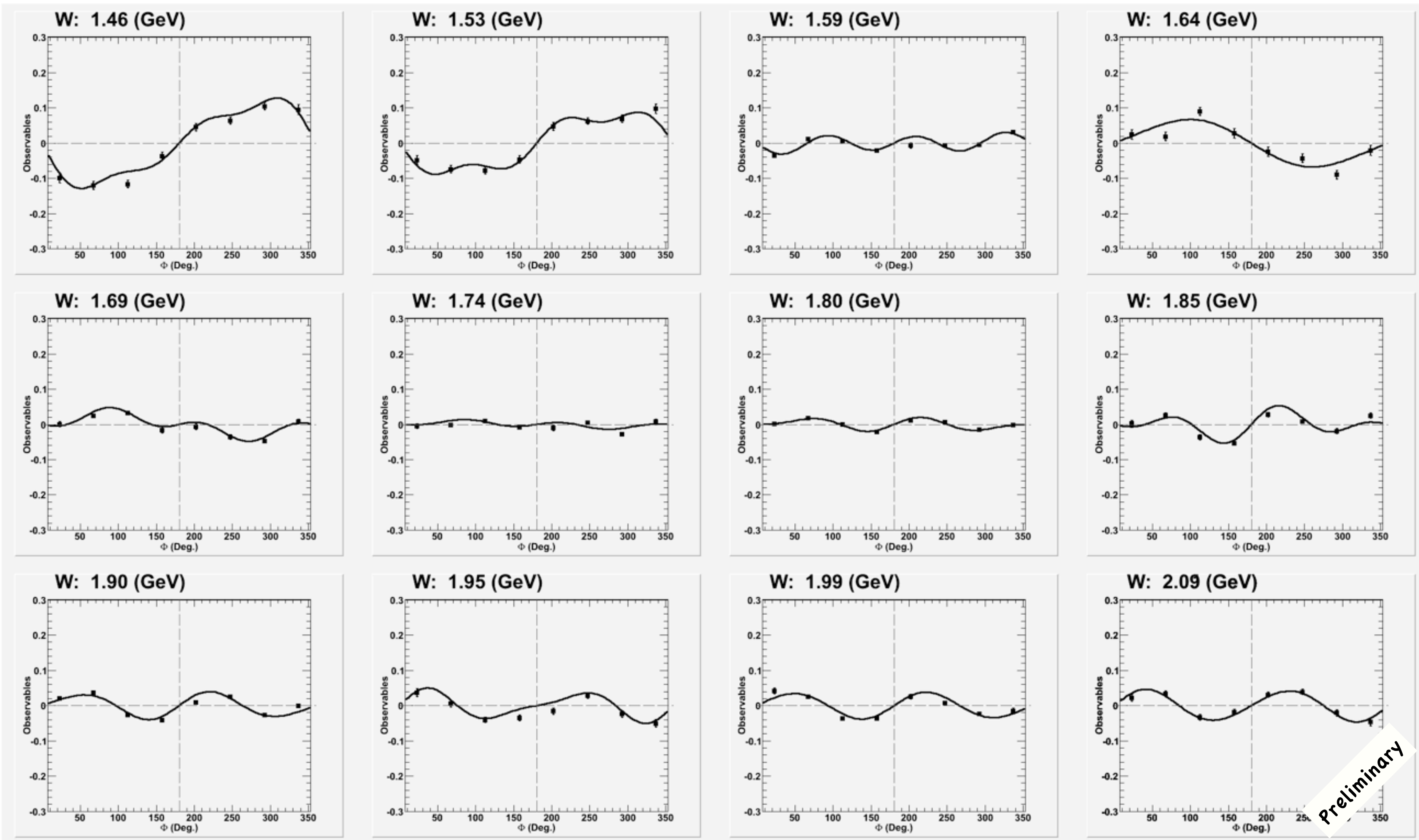
$$P_z = a \cdot \sin(\phi) + b \cdot \sin(2\phi) + c \cdot \sin(3\phi)$$

Observable: P_z^s



$$P_z^s = a \cdot \cos(\phi) + b \cdot \cos(2\phi) + c \cdot \cos(3\phi)$$

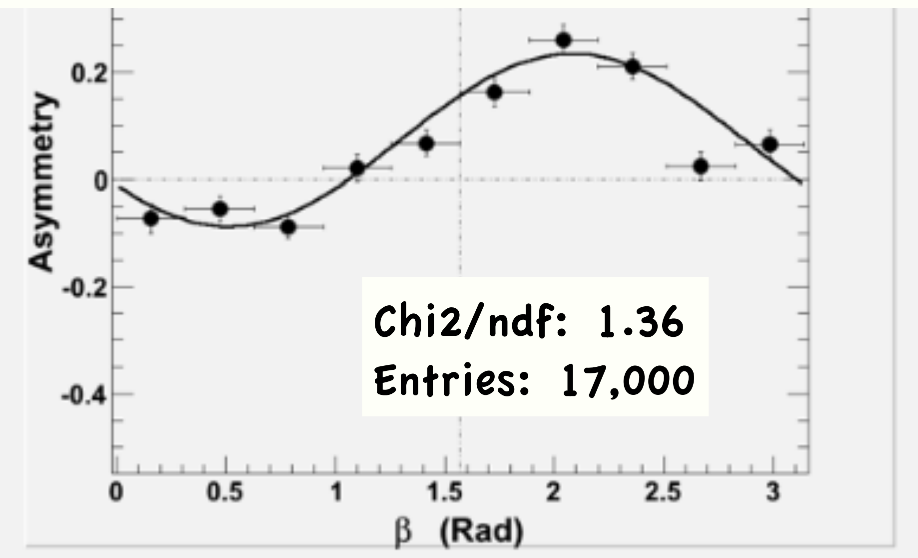
Observable: P_z^c



$$P_z^c = a \cdot \sin(\phi) + b \cdot \sin(2\phi) + c \cdot \sin(3\phi)$$

Observables - Further Study

Asymmetry of a certain kinematic bin:
W: 1.69 GeV
ϕ: 247 deg.

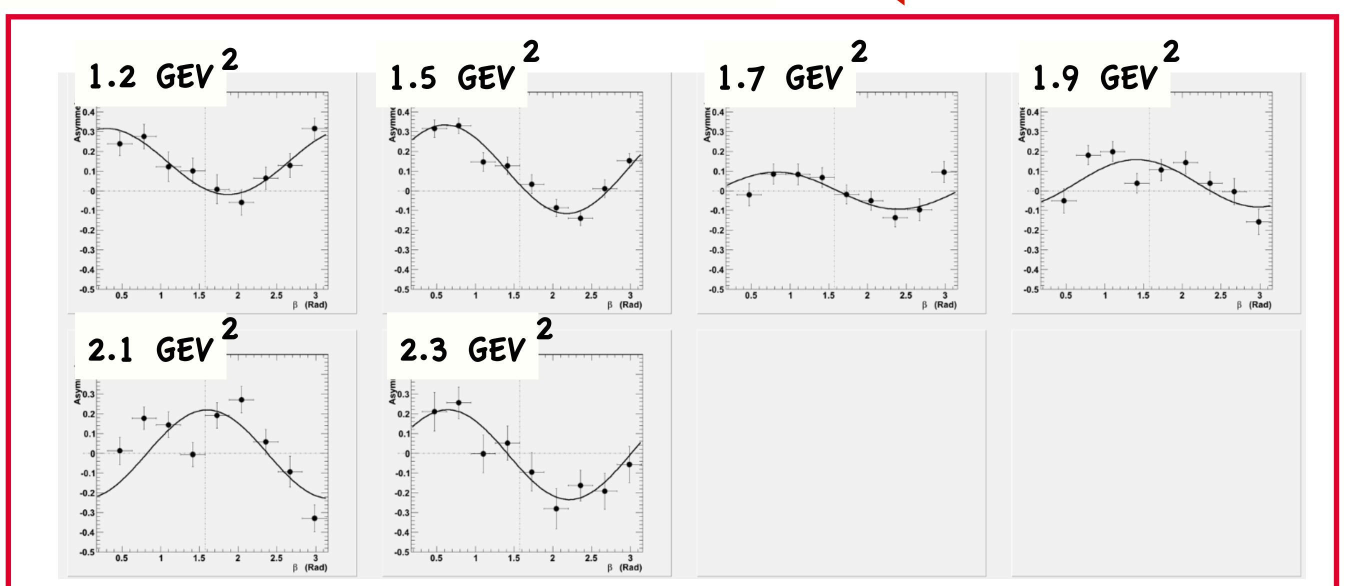


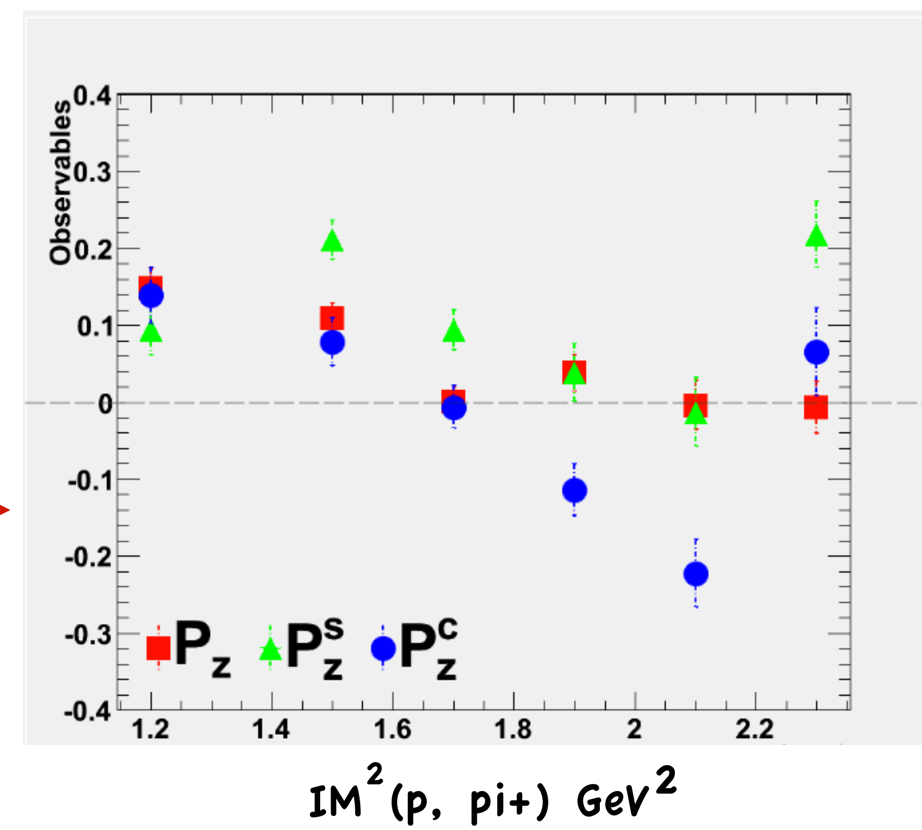
Bin on the 3rd variable -- Invariant mass of pπ+
(1st - W, 2nd - ϕ angle)

- In one W bin
- In one azimuthal angle bin
- Bin the Invariant Mass (6 bins, 1.1-2.4 GeV)
- Clear distinct asymmetries and observables for third level kinematic bins

Bin Further

Asymmetries of sub-kinematic bins with various Invariant mass of pπ+





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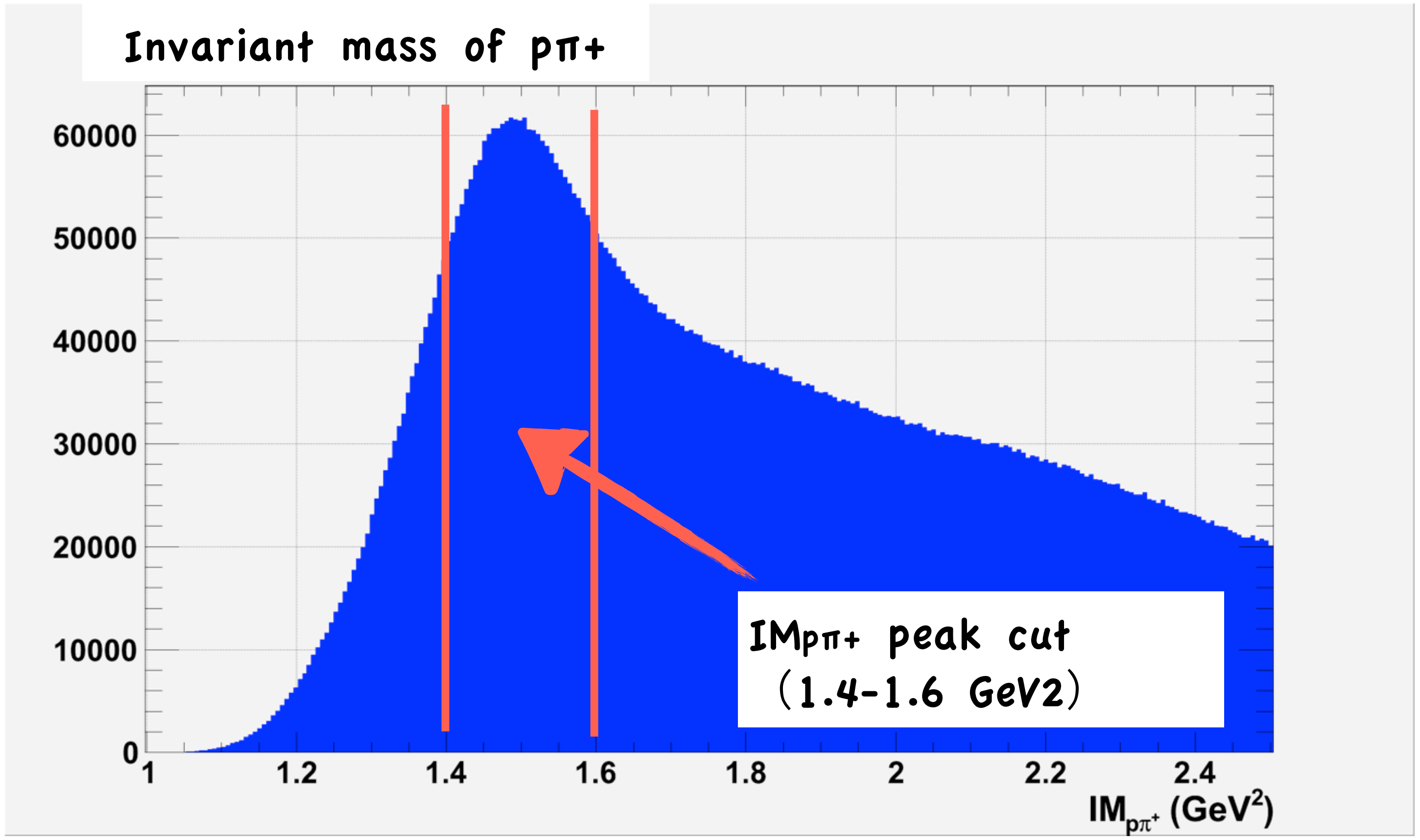
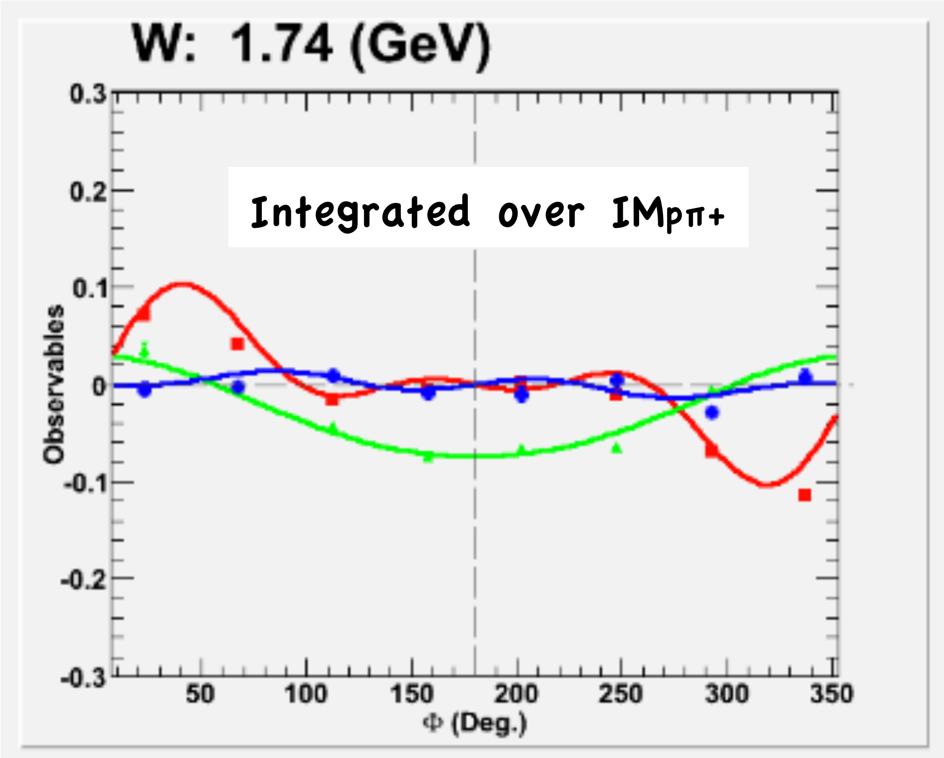
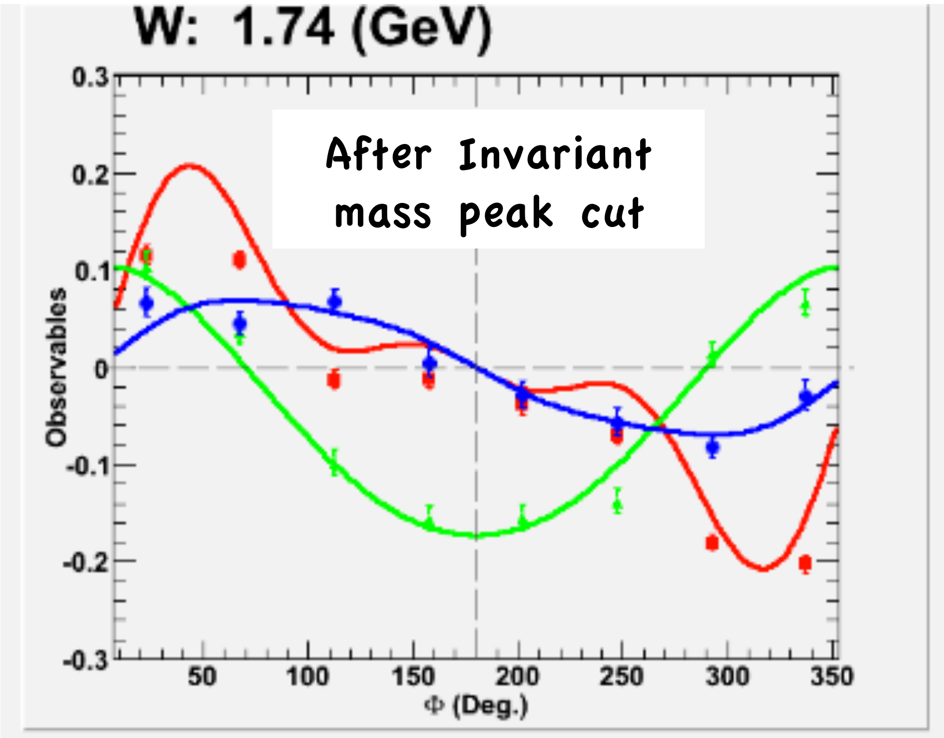
Observables - Further Study







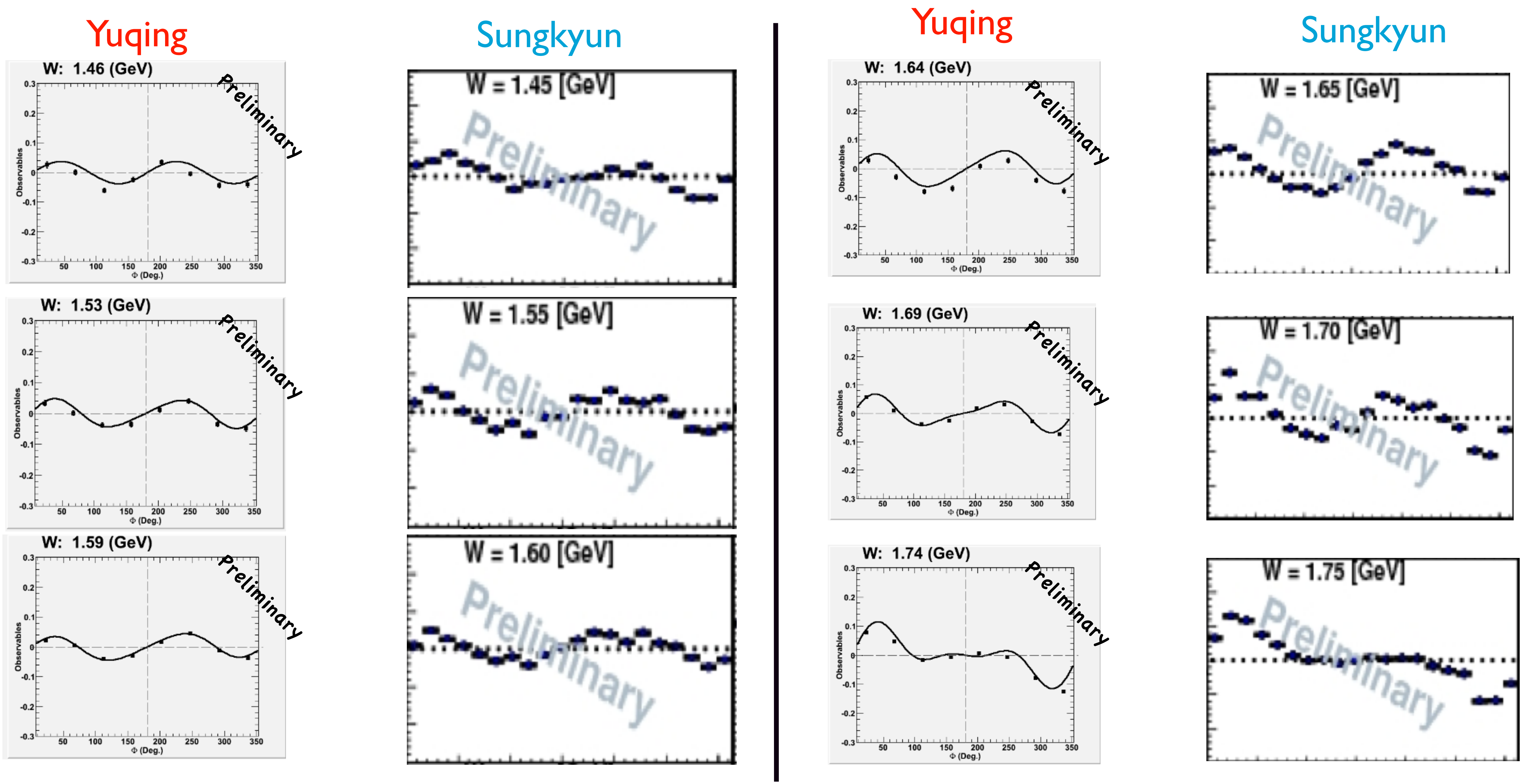
Observable-Sensibility on IMpπ+ peak cut

- In one W bin (1.74 GeV)
- In one Invariant Mass bin of pπ+ (1.4-1.6 GeV)
- Bin the Azimuthal angle

What we can find?

- Much larger amplitudes for all the 3 polarization observables

Comparison of the Pz



Yuqing (South Carolina): Linearly-Polarized beam of g9a

Sungkyun (Florida State): Circularly-Polarized beam of g9a

- Different runs
- Similar distribution
- Similar amplitudes

Conclusion & Future

Conclusion:

- Asymmetries are calculated by using normalized data
- Observables have symmetric behavior for azimuthal angle bin
- In addition to W and Phi bins, further kinematic bins showed more different asymmetries and observables
- Yuqing vs. Sungkyun -- Qualitatively comparable observable Pz

Future:

- Systematic uncertainty analysis