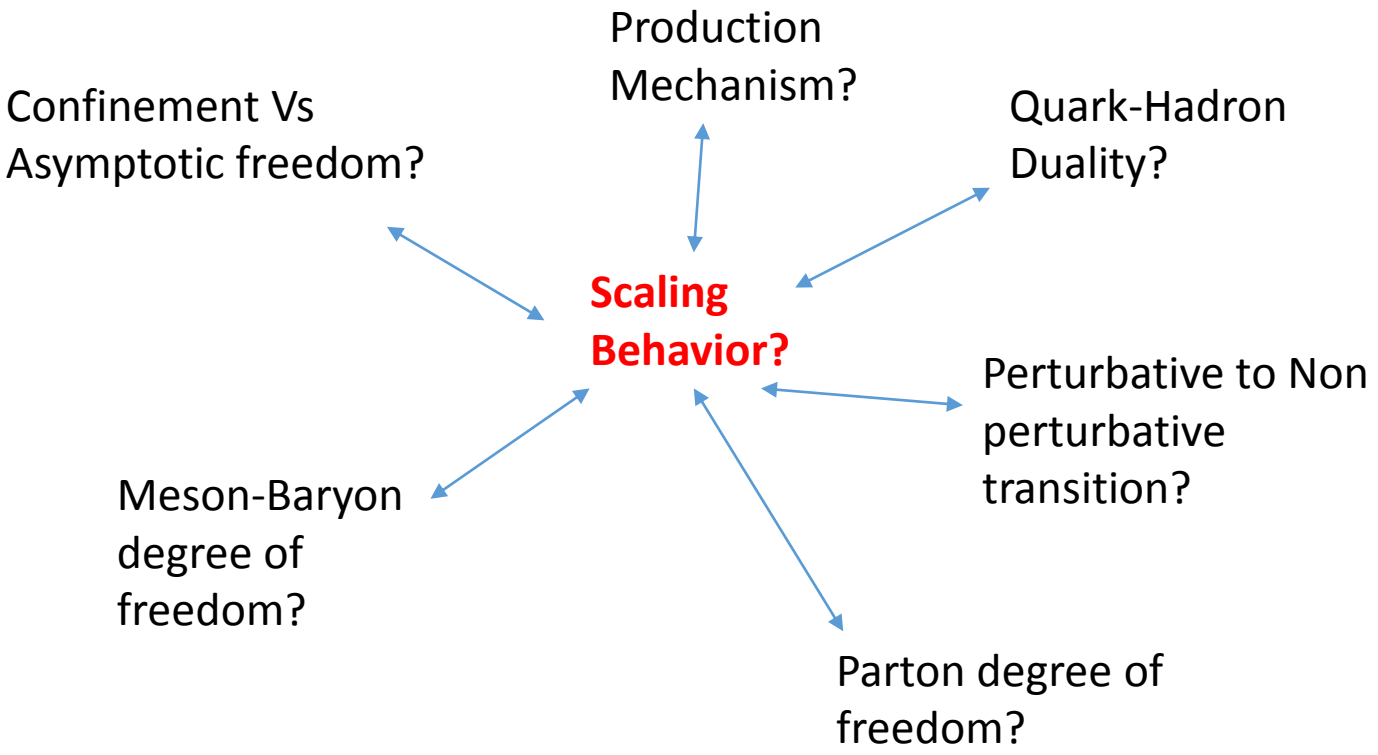
Scaling Behavior

(The study of perturbative to Non-perturbative QCD transition)



The Problem?

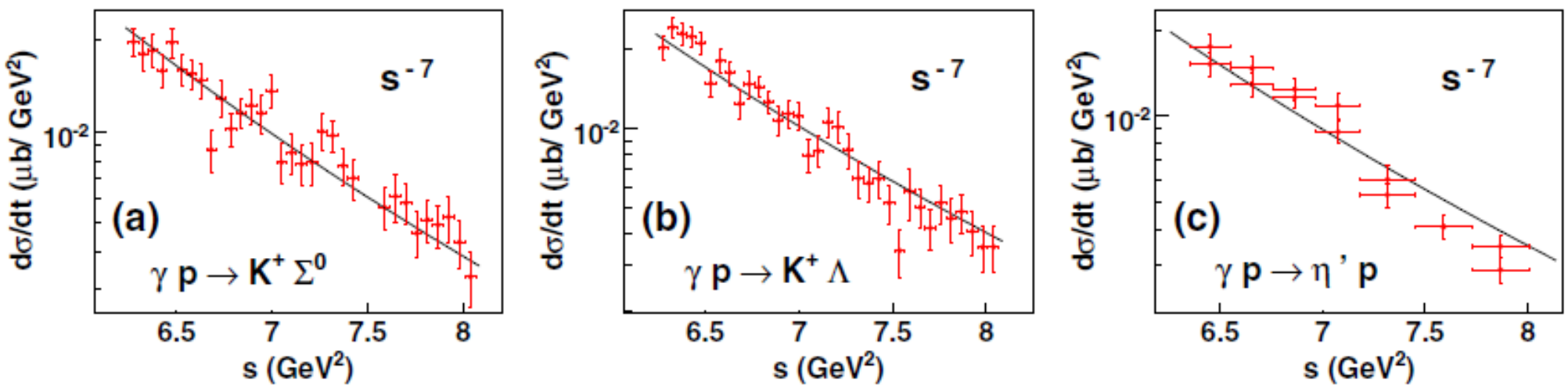
- Understanding How QCD works is one of the great challenge in nuclear physics, especially determining the effective degrees of freedom.
- Asymptotic freedom in which quarks interact weakly in short distance allow us to do calculation perturbatively at high energy or large momentum transfer. This situation makes the efficient description of phenomenon is in term of quark and gluon (parton).
- At low momentum scale, the coupling is large and QCD become highly non-perturbative. Because of the confinement effect, working with the collective degrees of freedom, i.e. physical meson or baryon (hadron) are more effective.
- However, there are regions where the dichotomy between partonic and hadronic degrees of freedom are not clear. This ambiguity is refer as quark-hadron duality.
- Quark-hadron duality reflect the transition from perturbative to non perturbative regimes in QCD.
- Constituent Counting Rule (CCR) and Hadron Helicity Conservation (HHC) phenomenon are widely accepted as the sign of perturbative regime.

Scaling Behavior

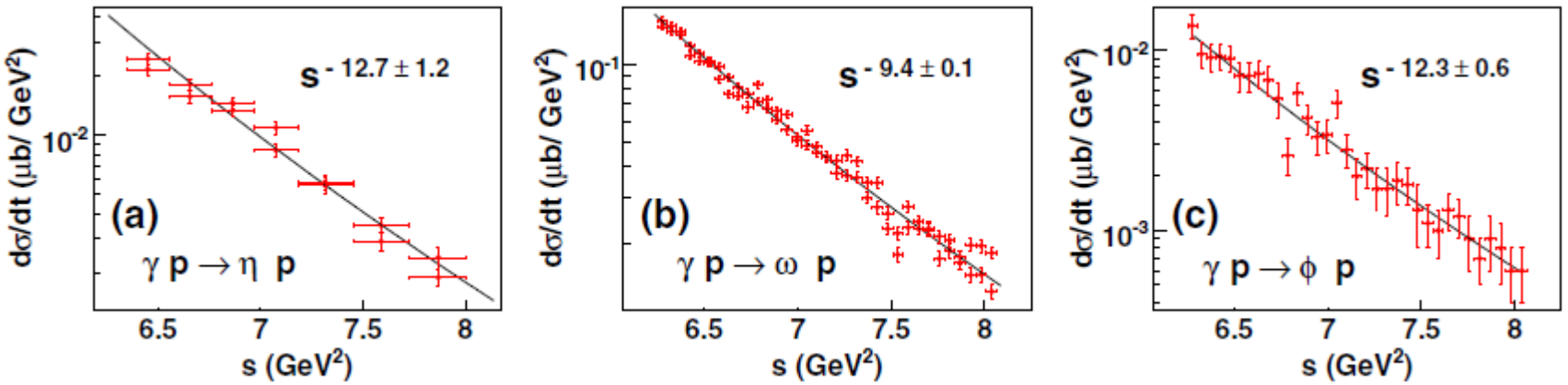
- Constituent Counting Rule (CCR) is reflected on the scaling behavior of the cross section.
- At high energy and large momentum transfer, CCR predict :

$$\frac{d\sigma}{dt}(AB \to CD) \sim s^{2-n} f(\theta_{\text{c.m.}}),$$

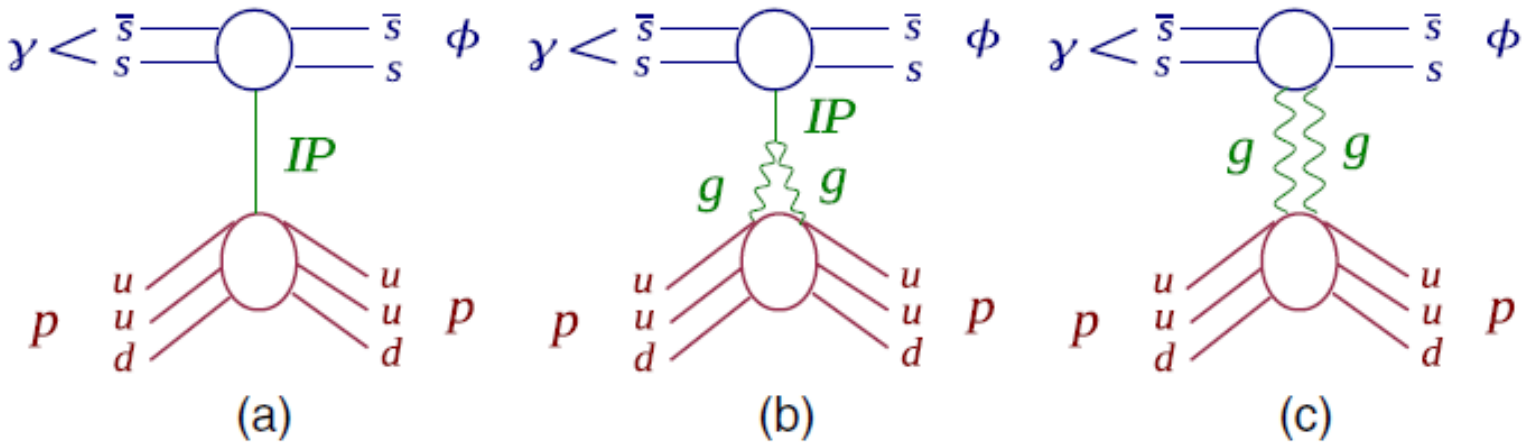
- N is the total number of interacting field in the reaction.
- For γp -> MB ; M = Meson and B = Baryon, with only quark exchange, N = 9 (M=2 , B=3, P=3, γ=1).
- Therefore, for fixed costheta in center of mass system, the cross section will follow a simple scaling fit in the perturbative regime.
- This scaling behavior is seen at some following reaction :


dσ/dt (μb/ GeV²)
10⁻²
s⁻⁷
(a)
γ p → K⁺ Σ⁰
6.5
7
7.5
8
s (GeV²)
dσ/dt (μb/ GeV²)
10⁻²
s⁻⁷
(b)
γ p → K⁺ Λ
6.5
7
7.5
8
s (GeV²)
dσ/dt (μb/ GeV²)
10⁻²
s⁻⁷
(c)
γ p → η ' p
6.5
7
7.5
8
s (GeV²)

- While some reaction does not governed by simple quark exchange :

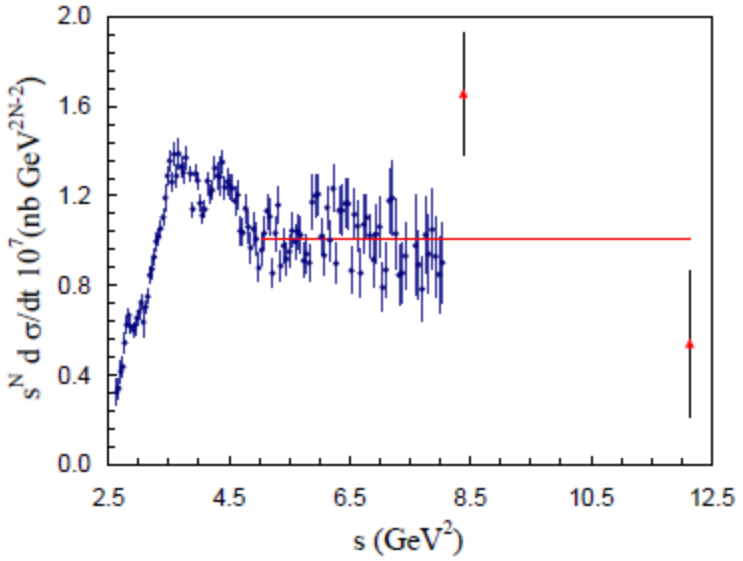


- Those reaction may governed by the mechanism :



Another thing that we can learn?

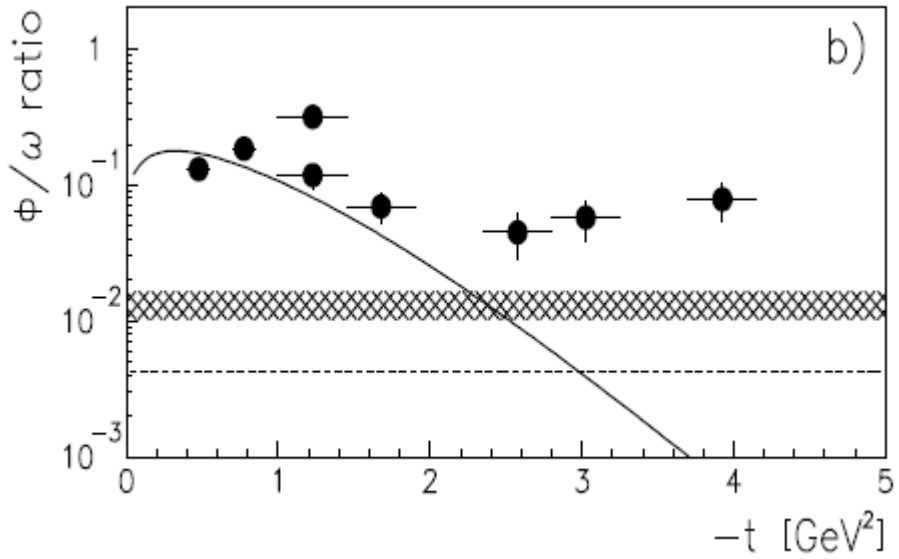
- Recently, scaling behavior can be derived from non-perturbative QCD using ADS/CFT approach. Scaling may still valid in non-perturbative regime without the presence of resonance.



- Oscillatory Behavior?

Insight?

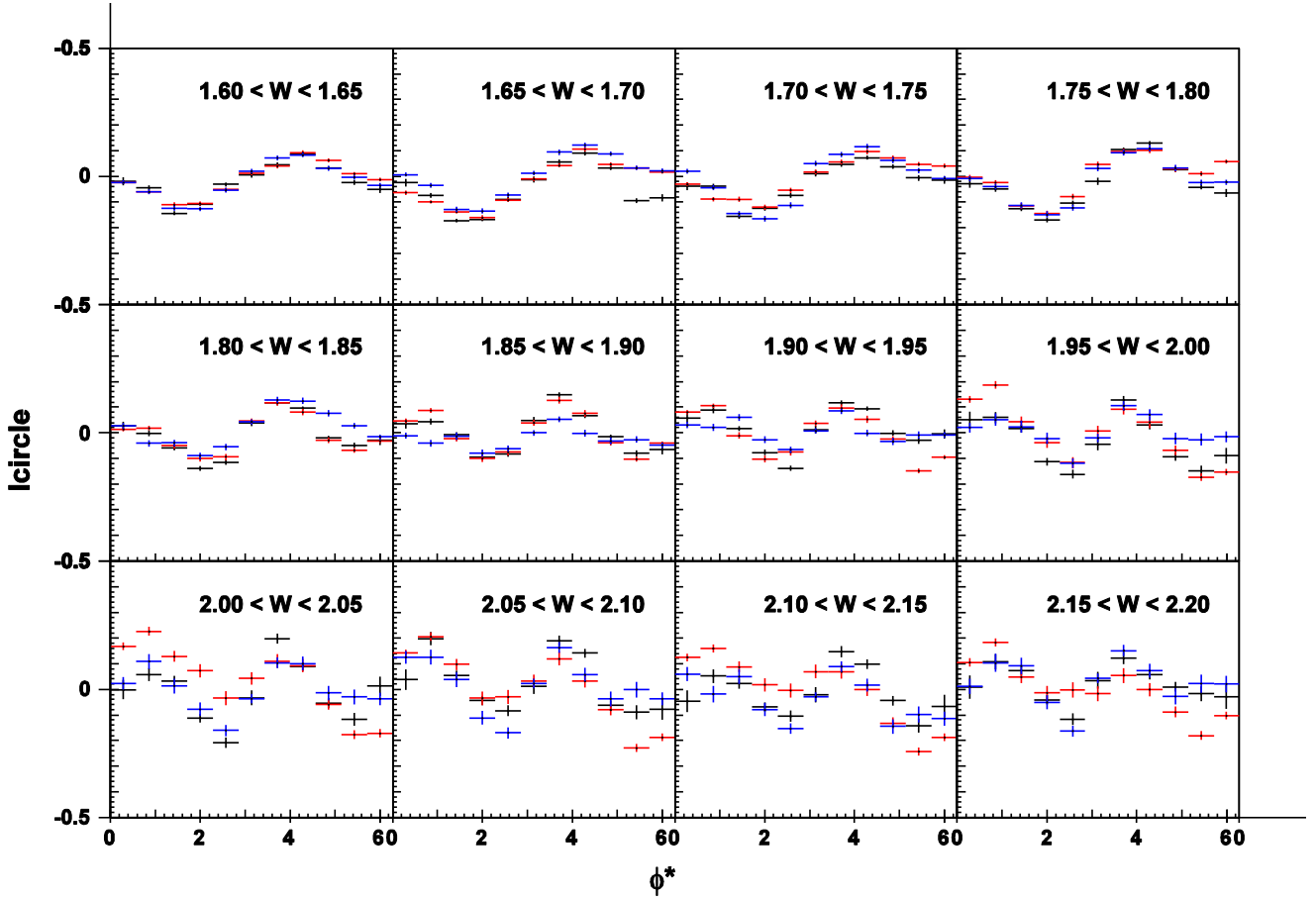
Extend the Ozi violation Rule



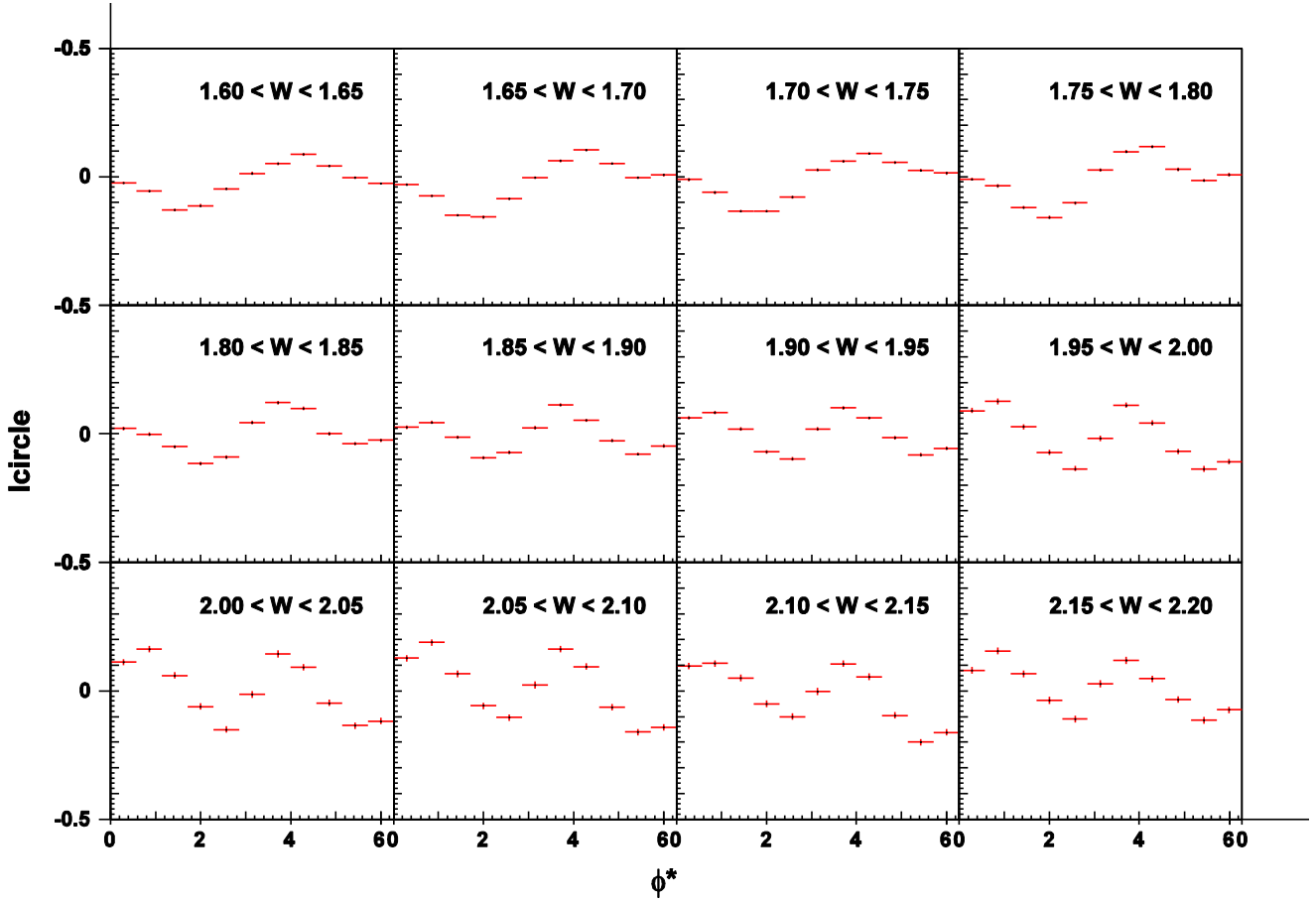
Scaling in two pion? Or rho meson?

- ? ????

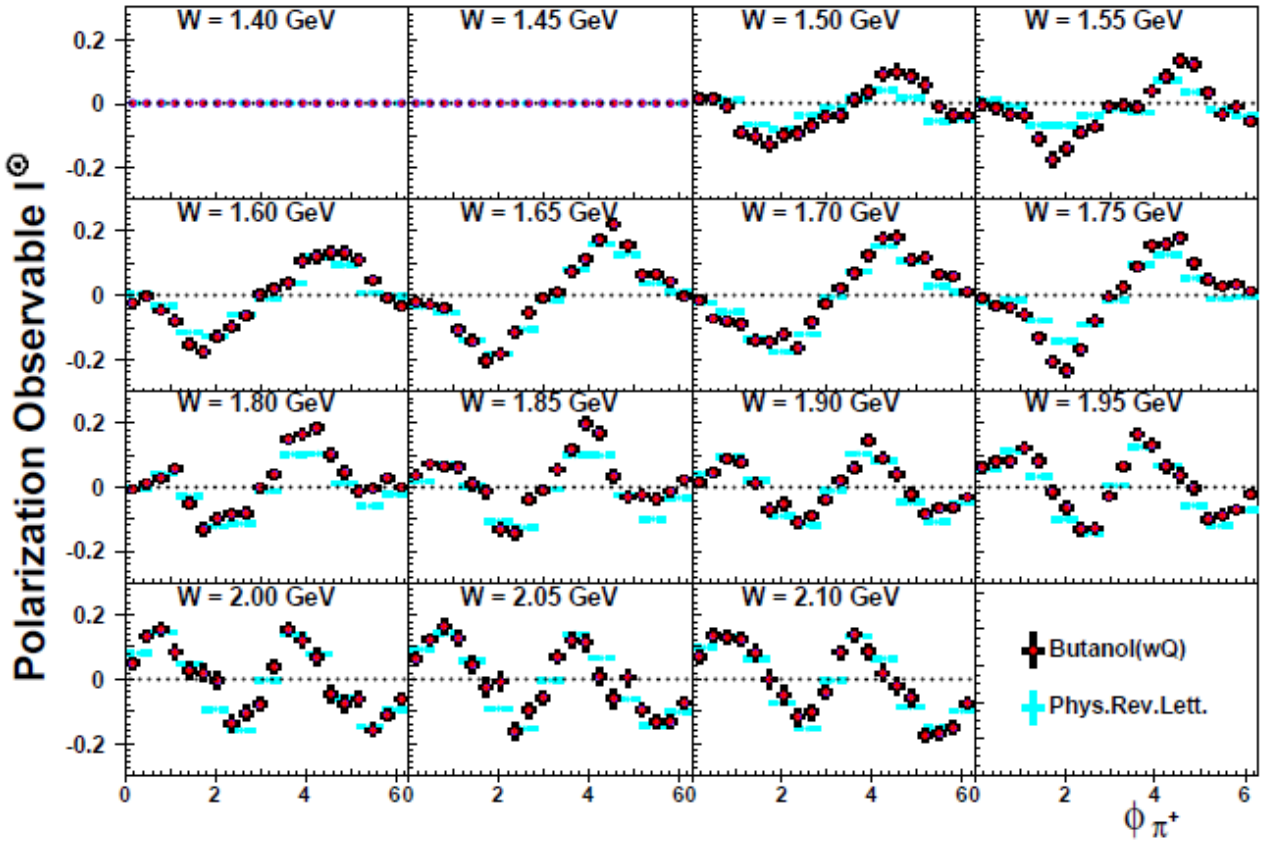
Icircle for three different topology



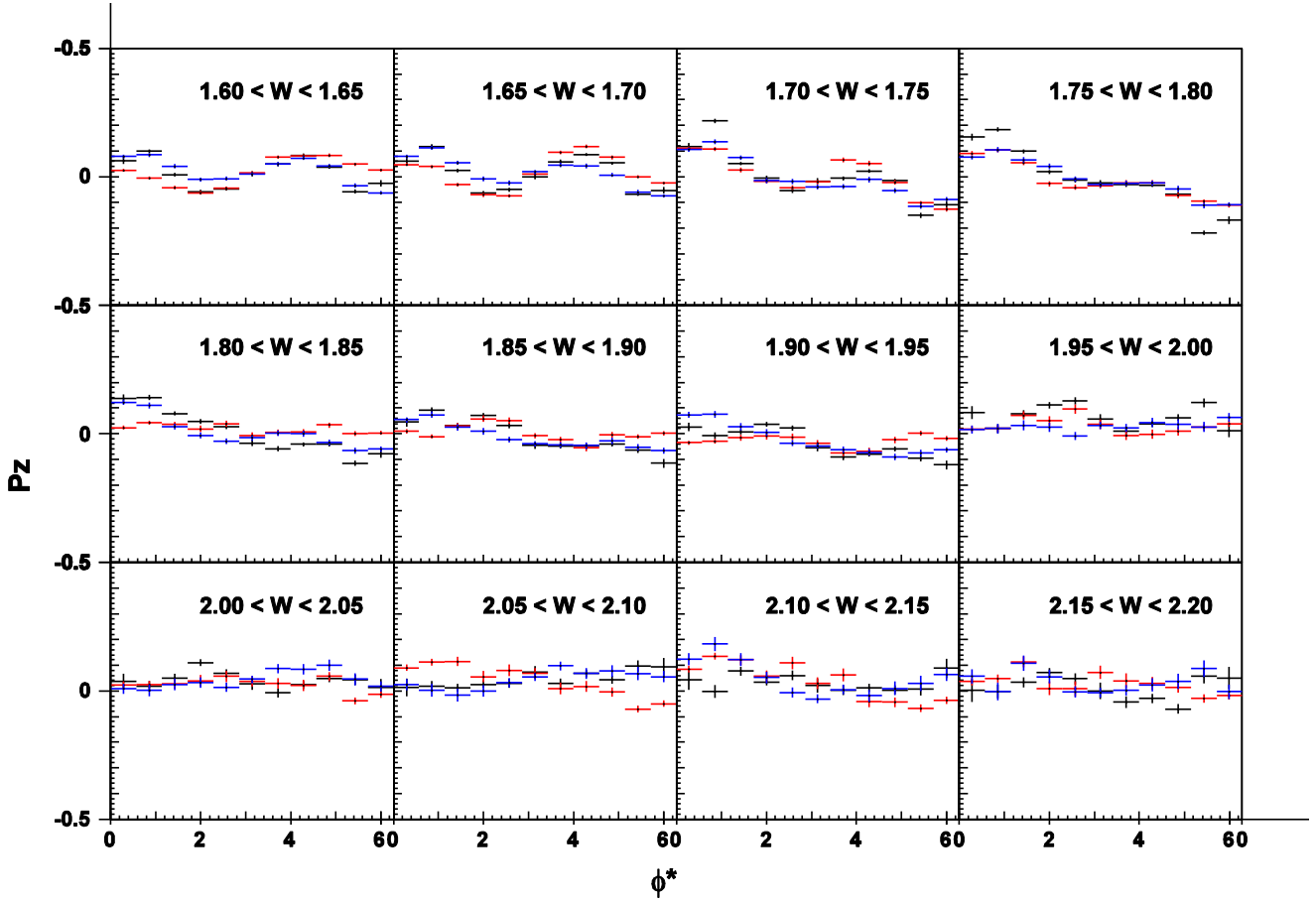
Icircle total



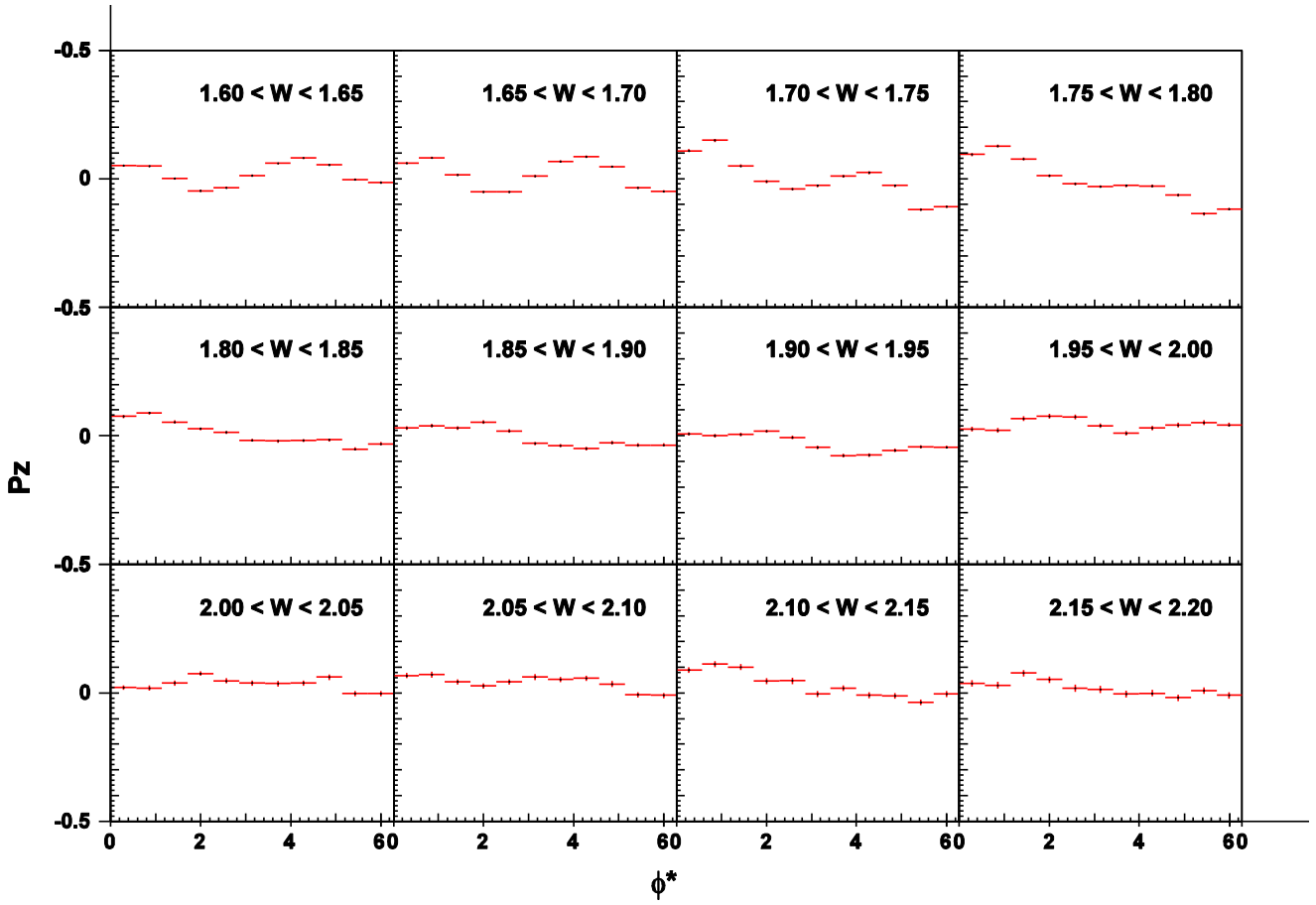
Icircle- sung



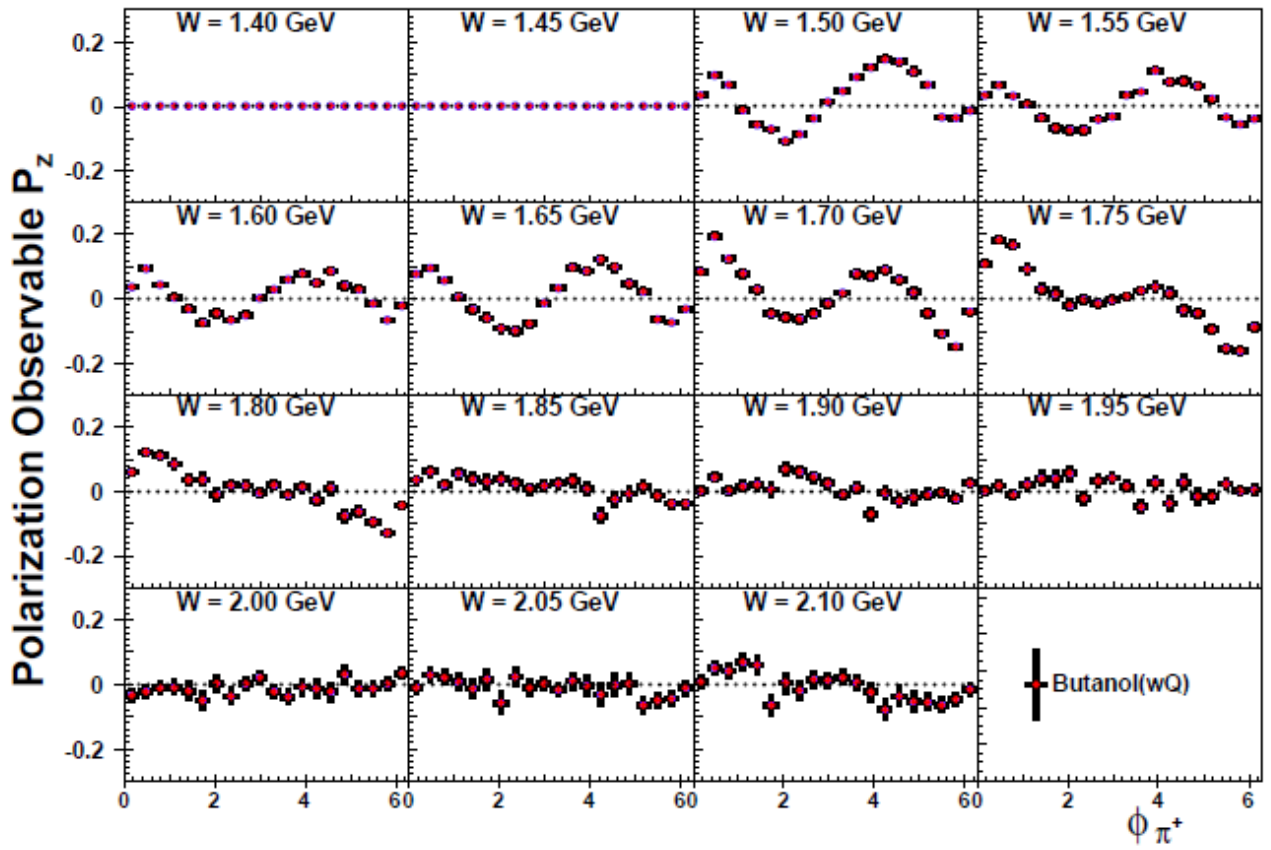
Pz for three different topology



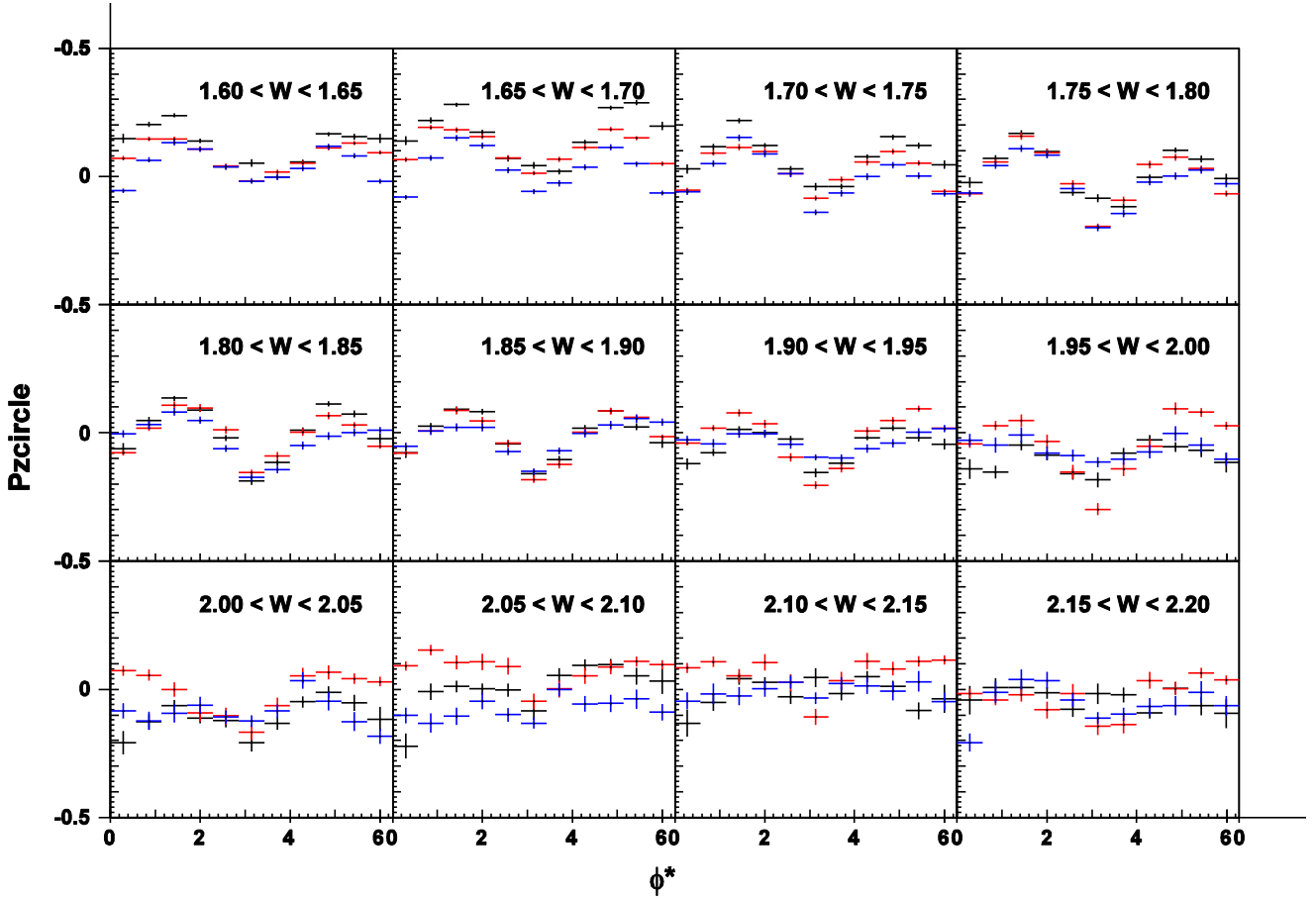
Pz total


1.60 < W < 1.65
1.65 < W < 1.70
1.70 < W < 1.75
1.75 < W < 1.80
1.80 < W < 1.85
1.85 < W < 1.90
1.90 < W < 1.95
1.95 < W < 2.00
2.00 < W < 2.05
2.05 < W < 2.10
2.10 < W < 2.15
2.15 < W < 2.20
Pz
-0.5
0
0
2
4
60
ϕ*

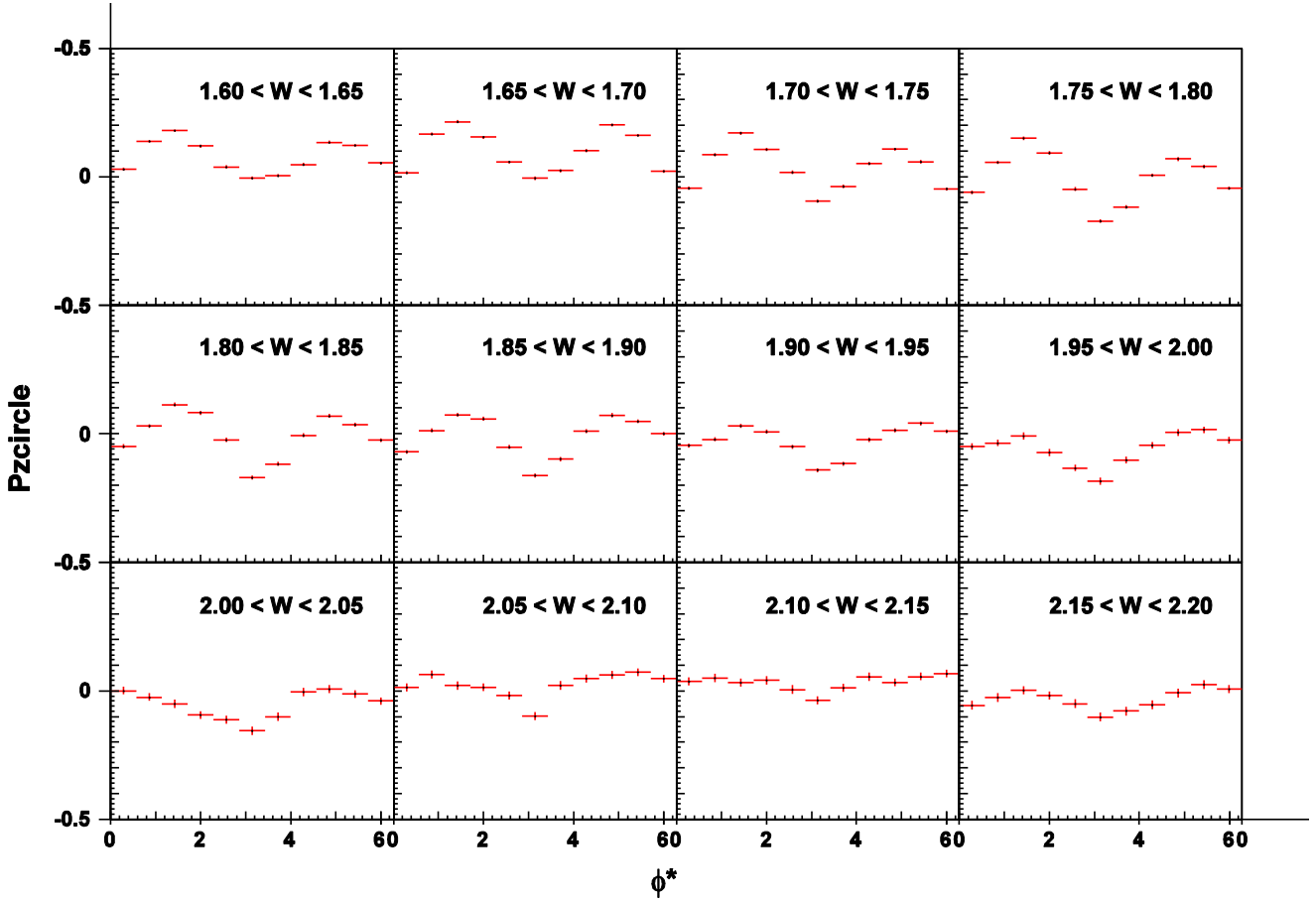
Pz - sung


W = 1.40 GeV
W = 1.45 GeV
W = 1.50 GeV
W = 1.55 GeV
W = 1.60 GeV
W = 1.65 GeV
W = 1.70 GeV
W = 1.75 GeV
W = 1.80 GeV
W = 1.85 GeV
W = 1.90 GeV
W = 1.95 GeV
W = 2.00 GeV
W = 2.05 GeV
W = 2.10 GeV
Butanol(wQ)
Polarization Observable P_z
ϕ_{π^+}

Pzcircle for three different topology



Pzcircle total



Pzcircle - sung