

# SIDIS Simulation – Update

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6 September 2017

# Introduction

- Project: Nuclear modification of quarks from ratio

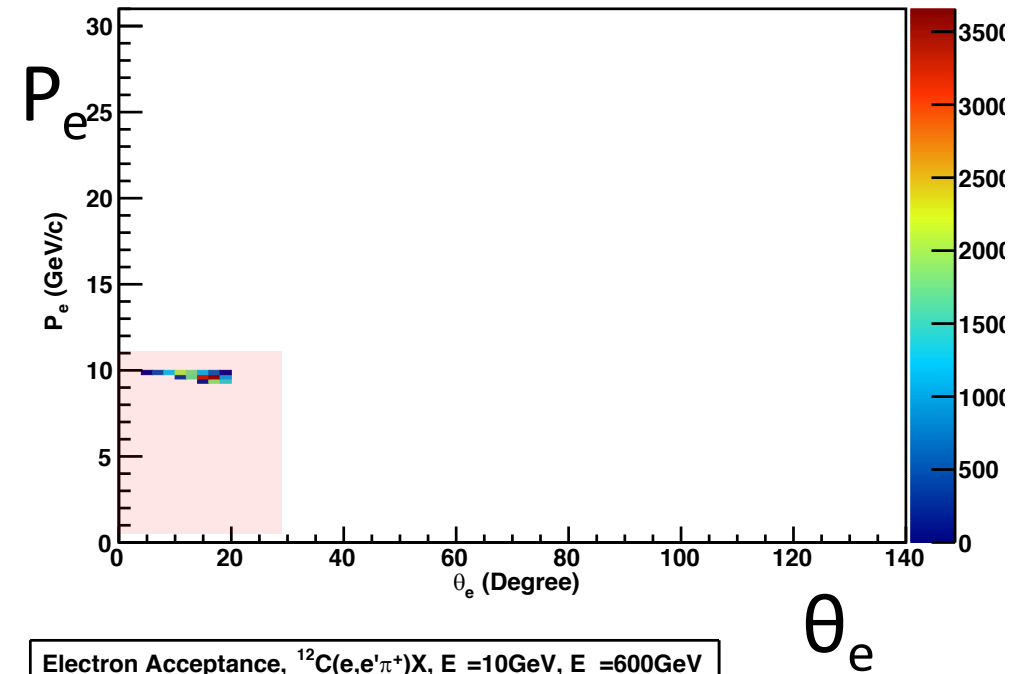
$$R(Q^2, z, x) = \frac{N_c(\pi^+) - NC(\pi^-)}{N_d(\pi^+) - Nd(\pi^-)}$$

- Wanted: Error of the ratio = 1%
- Study with SIDIS simulation necessary statistics and systematic effects
- First step: MC sampling / integration error

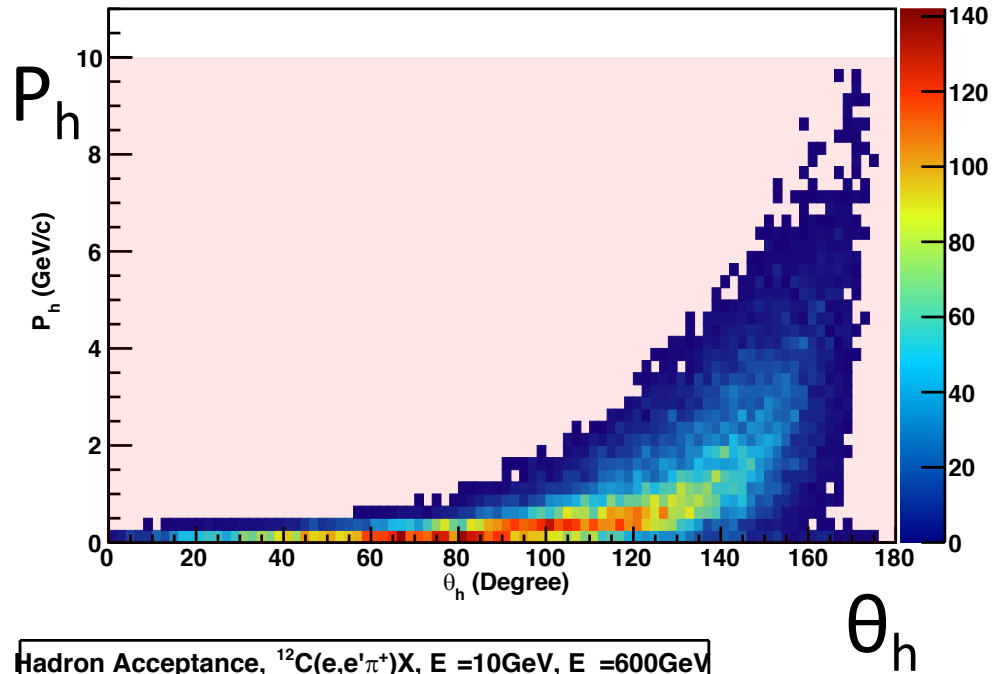
# Simulation parameter

- $^{12}\text{C}$  with  $E_e = 10 \text{ GeV}$  and  $E_A = 600 \text{ GeV}$ , d with  $E_A = 100 \text{ GeV}$
- 500 Million events (already generated) for CTEQ  $^{12}\text{C}$  and d
- LO PDF set and s-, sbar-, gluon-pdf = 0
- Event generation within:
  - $8.5 \text{ GeV}/c < p_e' < 10.5 \text{ GeV}/c$
  - $0 \text{ GeV}/c < p_h < 10 \text{ GeV}/c$
  - $0^\circ < \theta_e < 25^\circ$  but generation itself in  $\cos(\theta)$
  - $0^\circ < \theta_h < 180^\circ$  but generation itself in  $\cos(\theta)$
  - $0^\circ < \phi_{e/h} < 360^\circ$
- Cuts in event generation:
  - $0.03 < x < 0.15$  ( $0.05 < x < 0.1$  cut applied later)
  - $Q^2 > 1$
  - $W > 2$

Electron Acceptance,  $^{12}\text{C}(e,e'\pi^+)X$ ,  $E_e=10\text{GeV}$ ,  $E_A=600\text{GeV}$

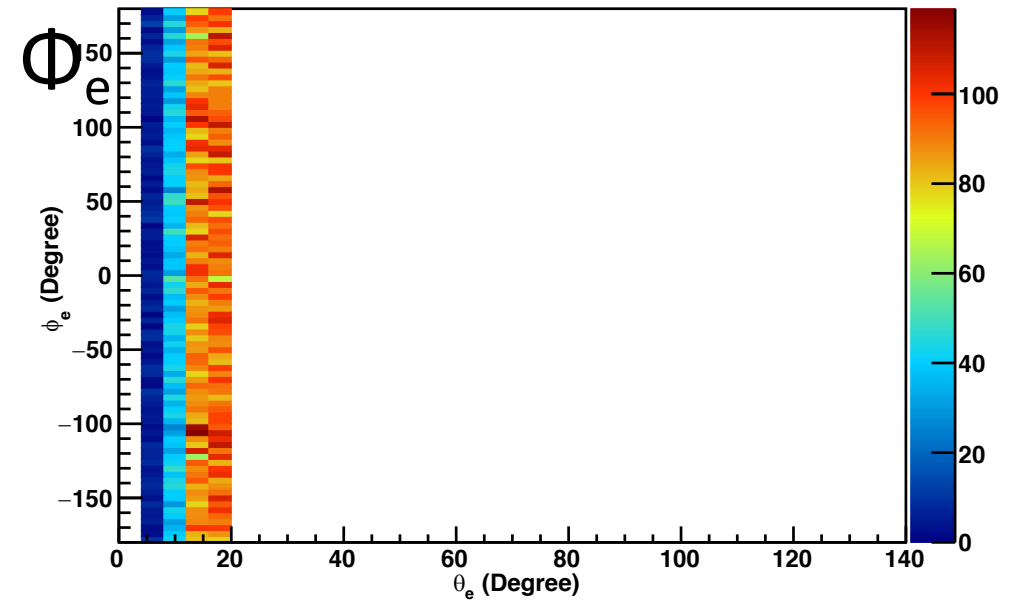


Hadron Acceptance,  $^{12}\text{C}(e,e'\pi^+)X$ ,  $E_e=10\text{GeV}$ ,  $E_A=600\text{GeV}$

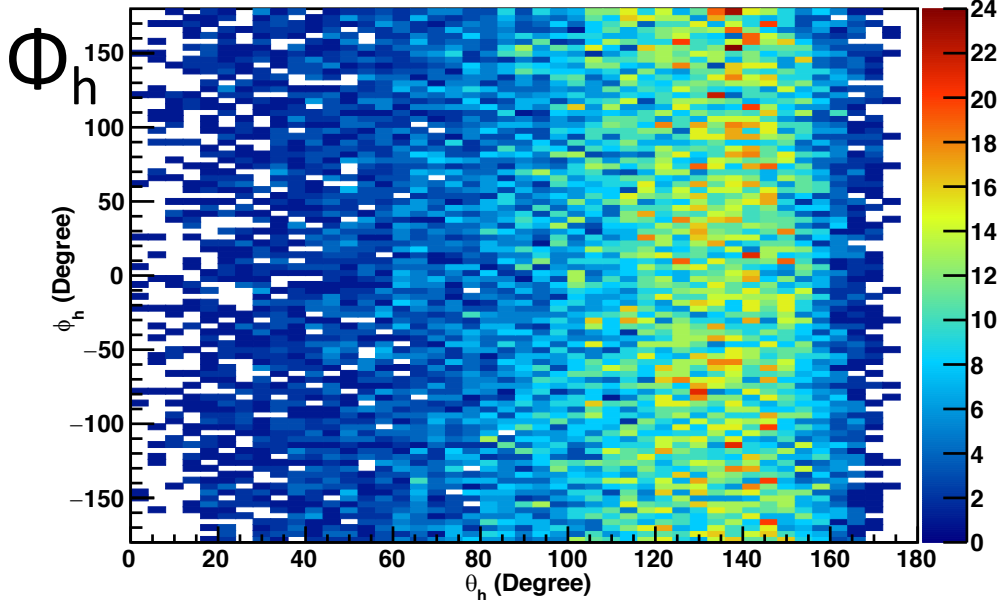


- $Q^2 < 10$
- $p_t < 1 \text{ GeV/c}$
- $0.05 < x_B < 0.1$
- xs weighted
- 1M events

Electron Acceptance,  $^{12}\text{C}(e,e'\pi^+)X$ ,  $E_e=10\text{GeV}$ ,  $E_A=600\text{GeV}$



Hadron Acceptance,  $^{12}\text{C}(e,e'\pi^+)X$ ,  $E_e=10\text{GeV}$ ,  $E_A=600\text{GeV}$

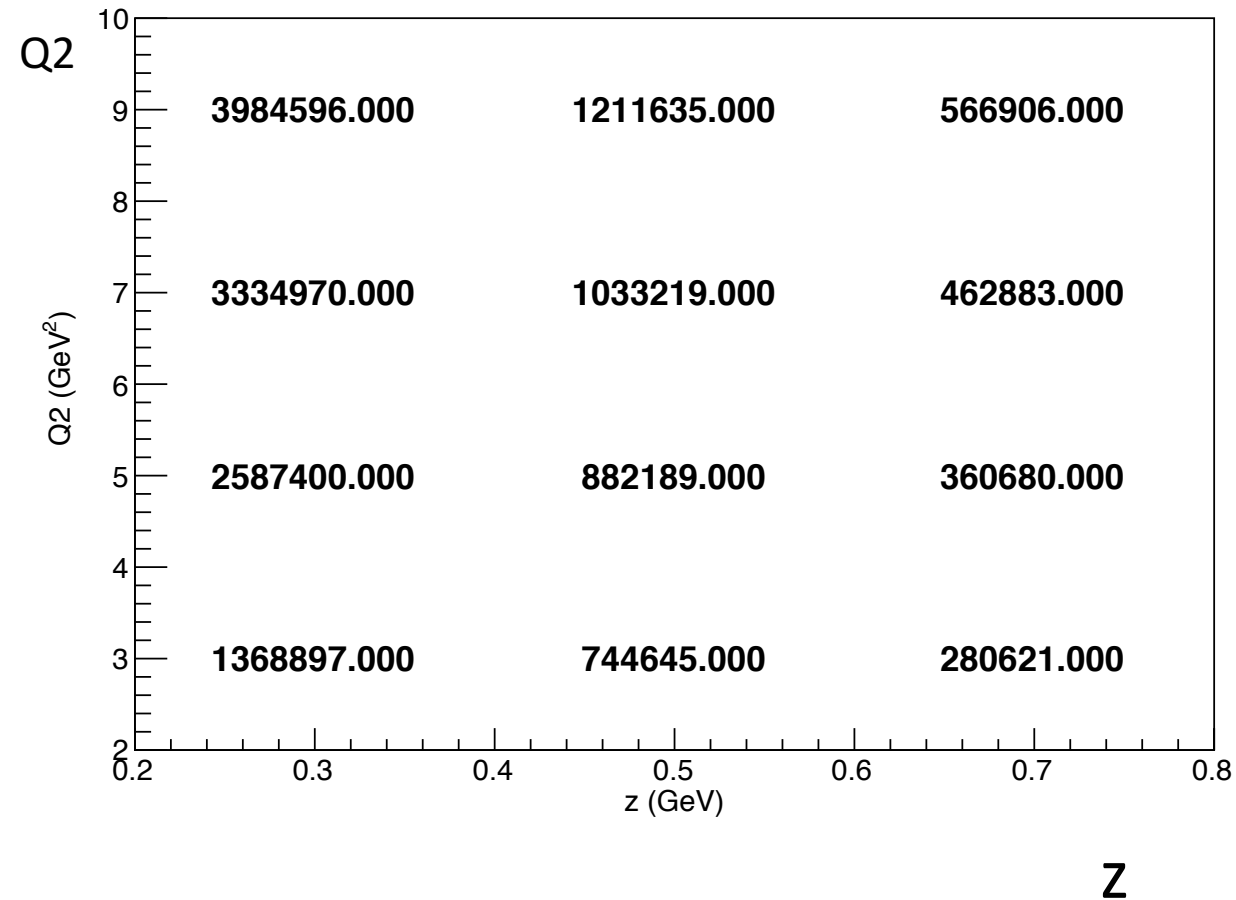


# $Q^2$ and $z$ Bins for SIDIS Ratio

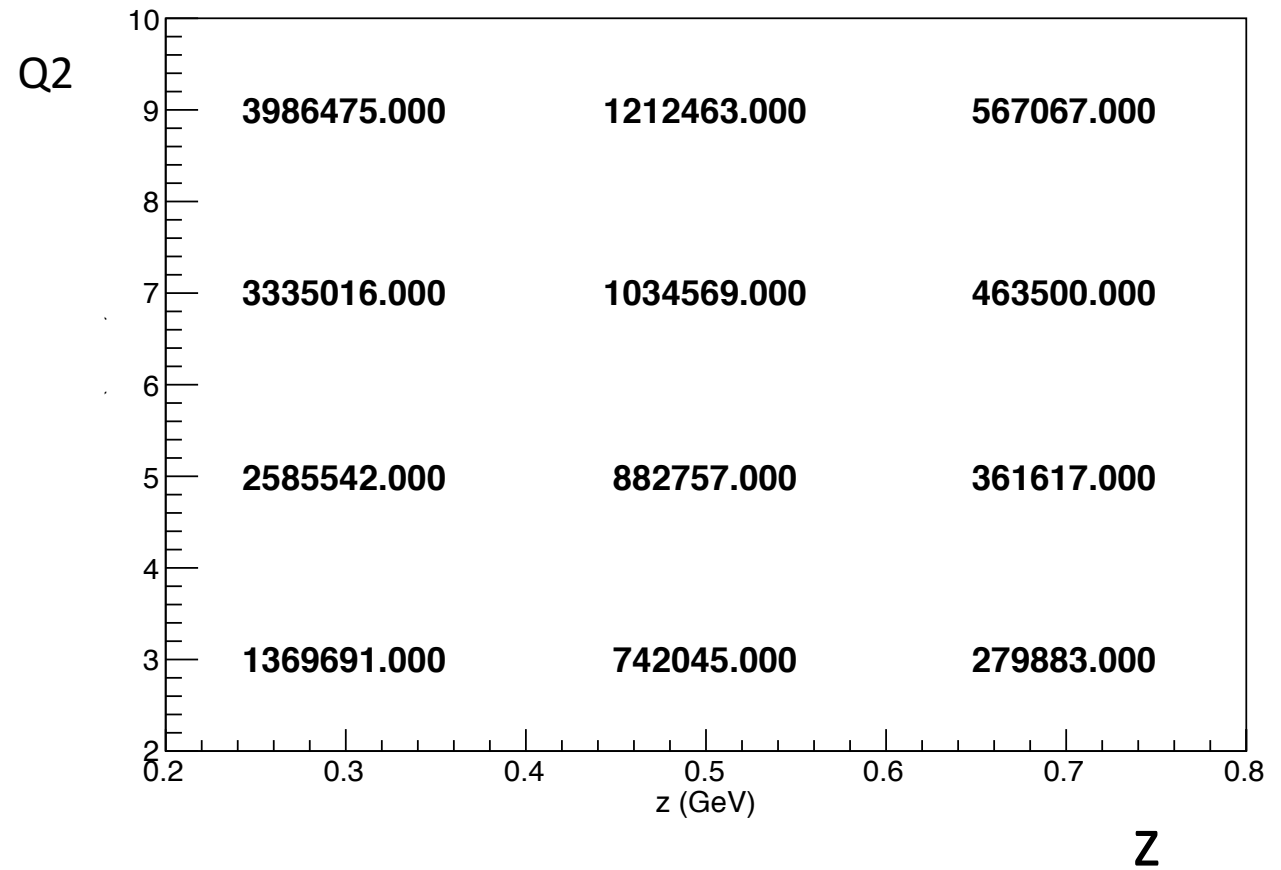
- $Q^2$  cut limits:
  - $Q2\_cut [5] = \{2.0, 4.0, 6.0, 8.0, 10.\}$
- $z$  cut limits:
  - $z\_cut[4] = \{0.2, 0.4, 0.6, 0.8\}$
- $x$  cut:
  - $0.05 \leq x_B \leq 0.1$
- $p_t < 1 \text{ GeV}/c$

# Number of Events for 50M generated events

Counts per z and Q2 bin for  $^{12}\text{C}(\text{e},\text{e}'\pi^+)\text{X}$



Counts per z and Q2 bin for  $\text{d}(\text{e},\text{e}'\pi^+)\text{X}$

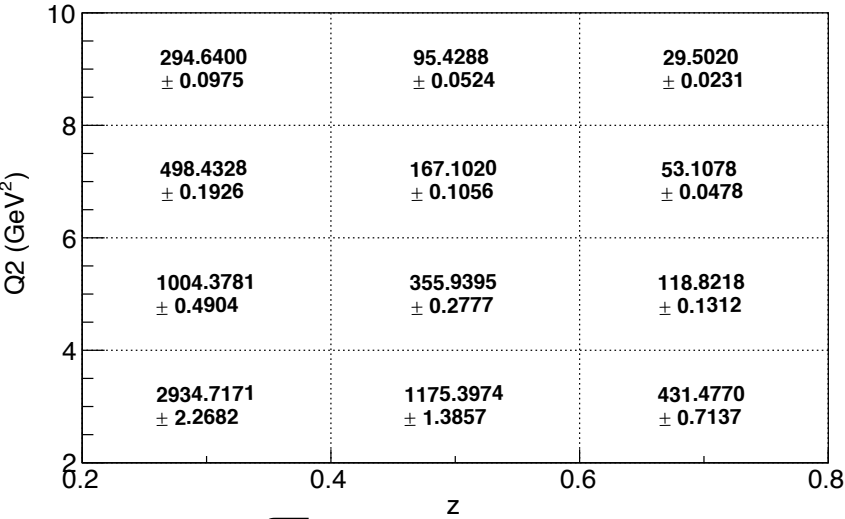


# Calculation of MC Sampling / Integration Error

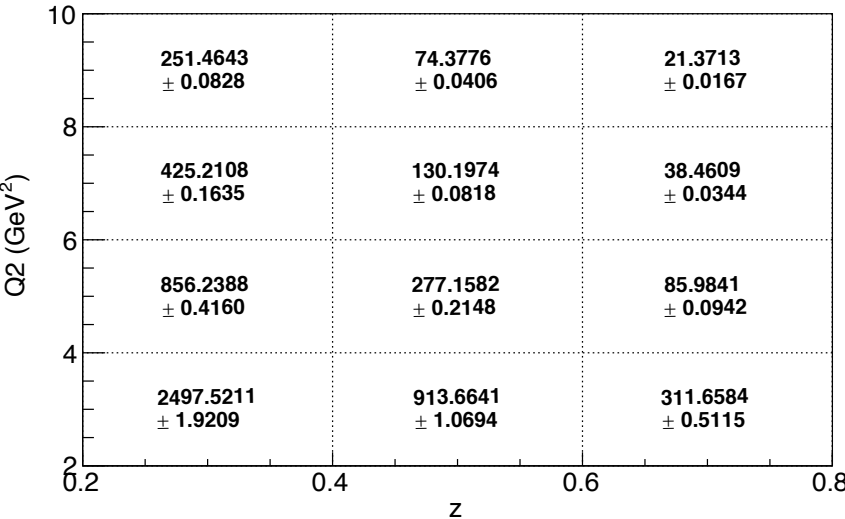
- Method 1 adapted from Numerical Recipes (Charles)
    - N events generated in phase space V with weights. Integral of function  $f$  (cross section) is
    - $$\frac{V}{N} \sum_i f(x_i) \pm \frac{V}{\sqrt{N}} \sqrt{\left[ \frac{1}{N} \sum_i f^2(x_i) \right] - \left[ \frac{1}{N} \sum_i f(x_i) \right]^2}$$
  - Method 2 (adapted from Zhihongs Code):
    - Plot weighted Q2 distribution
    - Value = histo->GetSum() [ROOT]
    - Error = sqrt( sum (variance) ) [done via ROOT]
- Both calculations gave the same error

# Deuterium Results on Weighted Cross Section/Count Rates from 500M Events

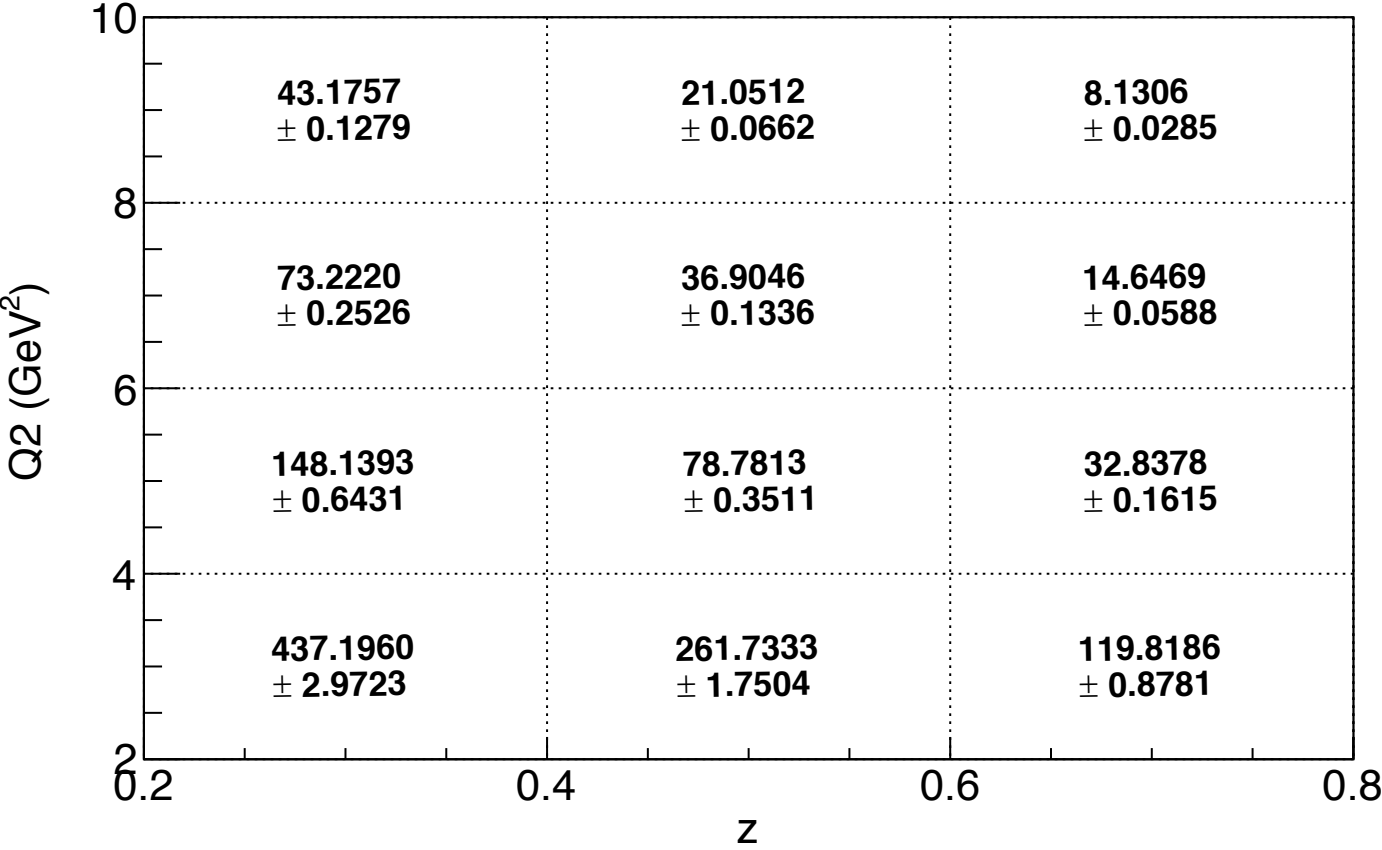
$\pi^+$



$\pi^-$

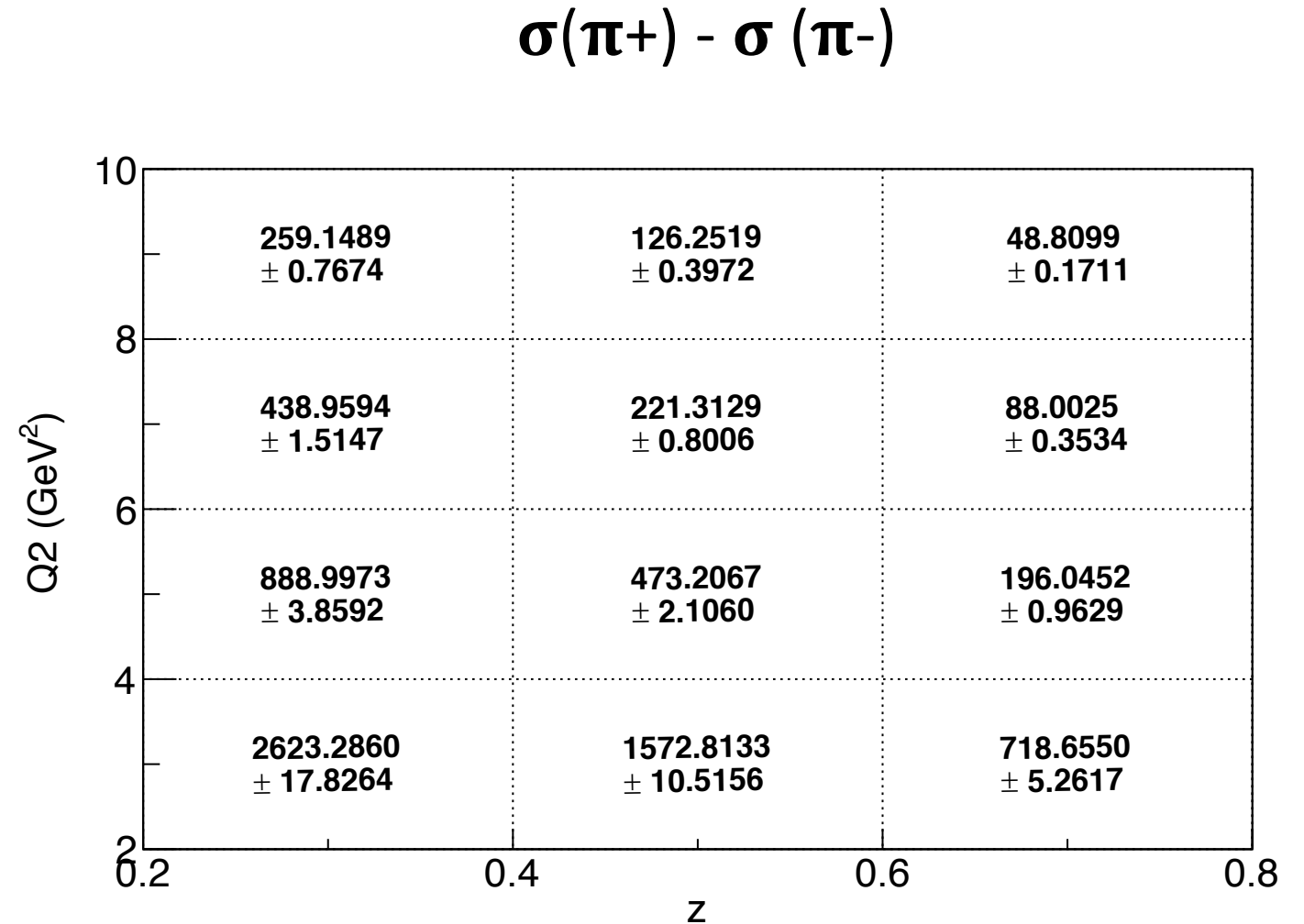
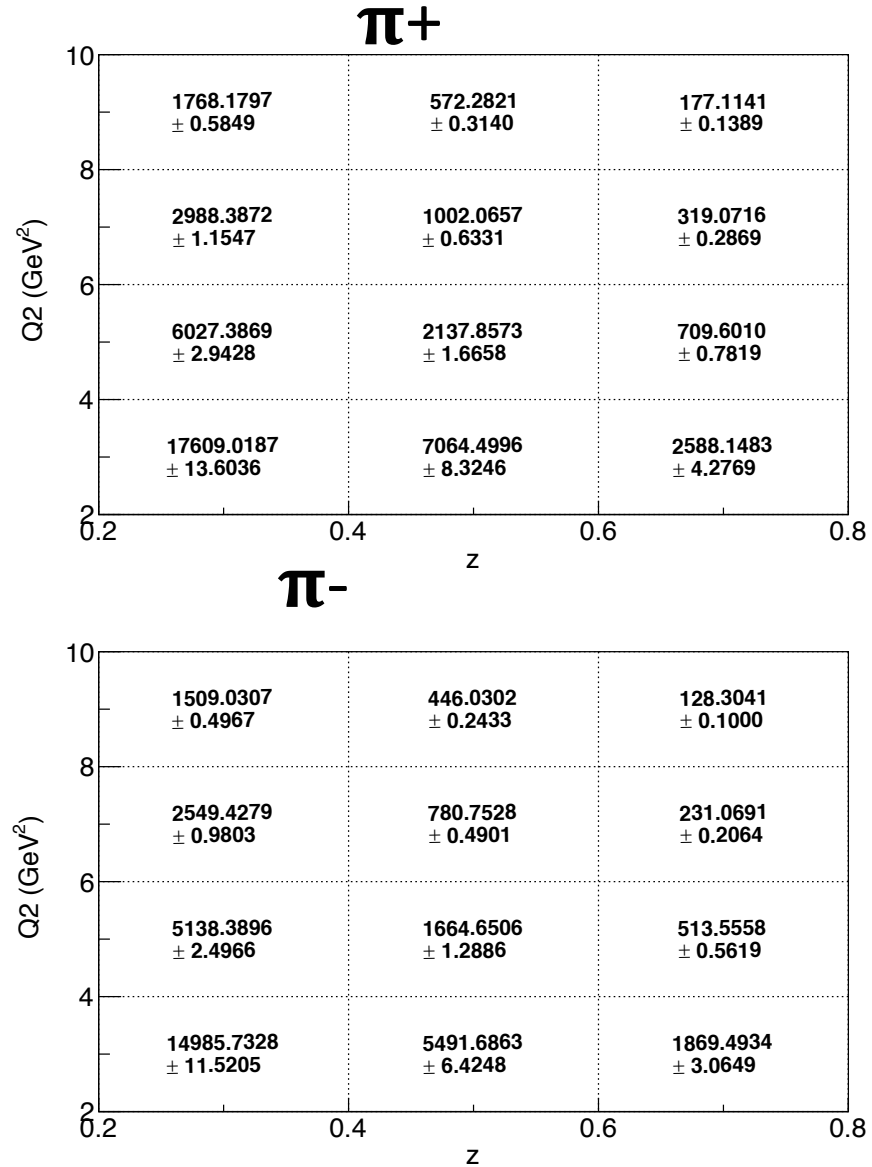


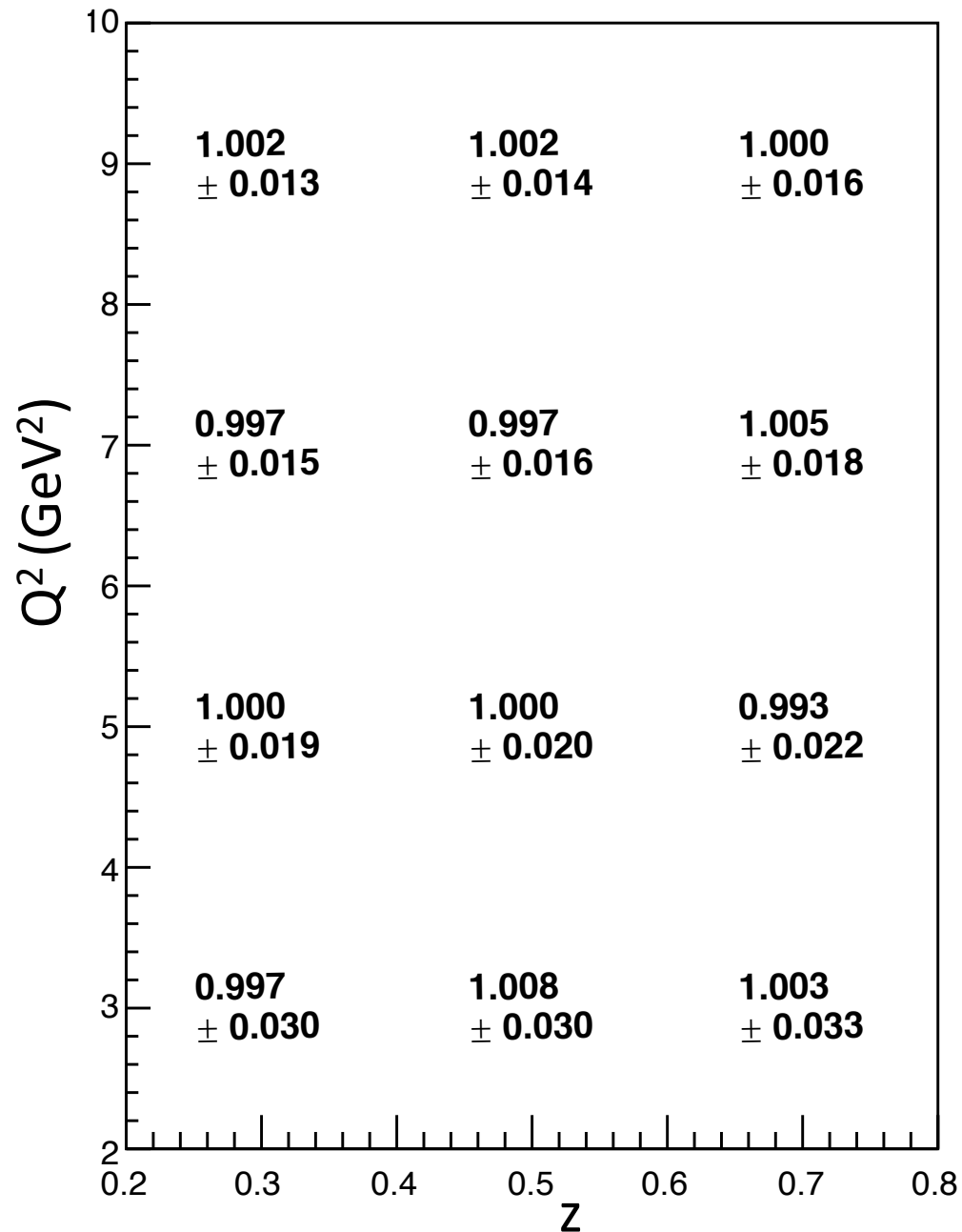
$\sigma(\pi^+) - \sigma(\pi^-)$





# $^{12}\text{C}$ Results on Weighted Cross Section/Count Rates from 500M Events





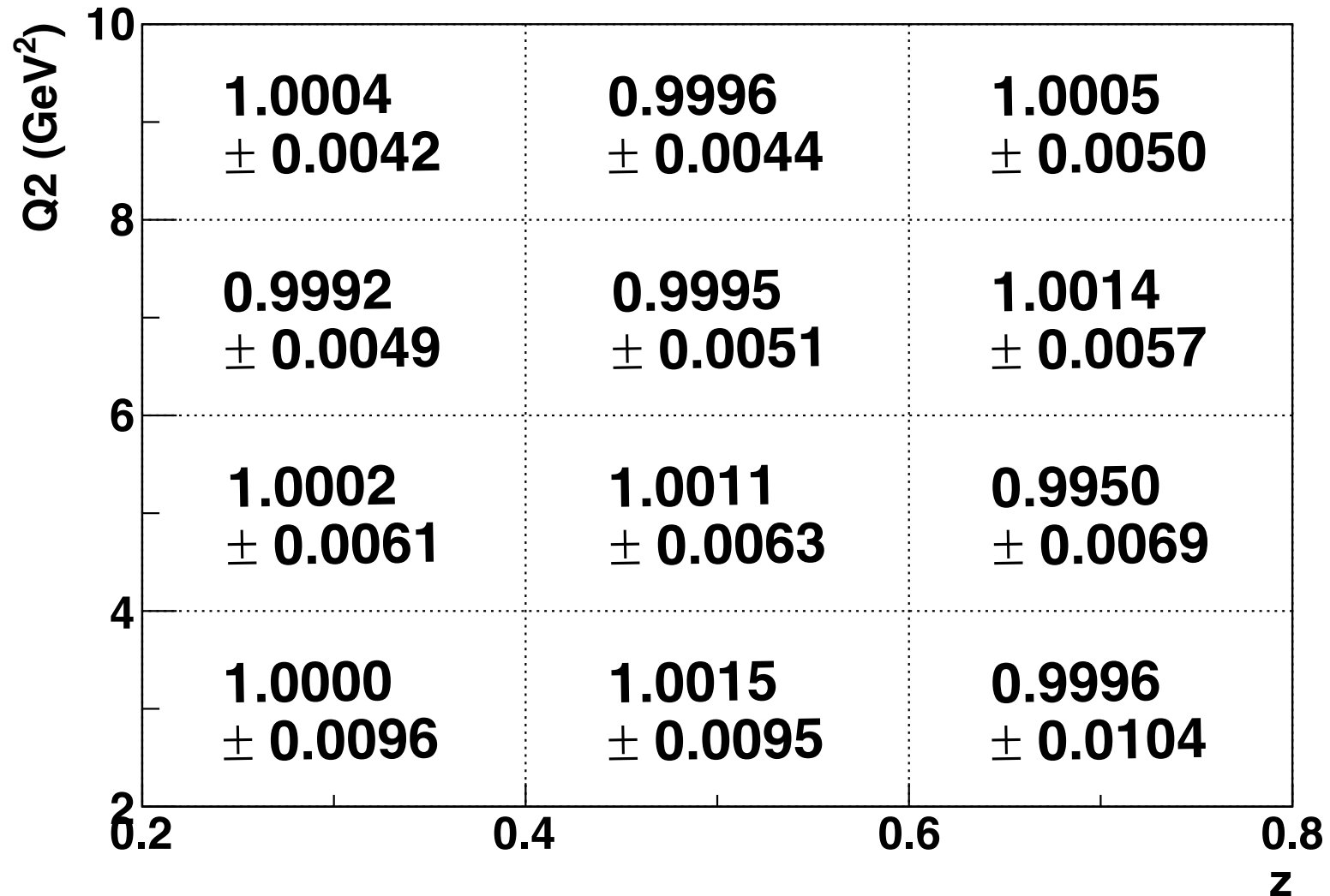
## Previous Result for SIDIS Ratio - 50M Events

$$R(Q^2, z, x) = \frac{\sigma_c(\pi^+) - \sigma_c(\pi^-)}{6 * \sigma_d(\pi^+) - \sigma_d(\pi^-)}$$

Error from standard error  
propagation of individual  
weighted count rates

-> not sufficient statistic  
in each bin for error < 1%

# Result for SIDIS Ratio with 500M Events



$$R(Q^2, z, x) = \frac{\sigma_c(\pi^+) - \sigma_c(\pi^-)}{6 * \sigma_d(\pi^+) - \sigma_d(\pi^-)}$$

-> sufficient statistic for  
all bins that MC sampling  
error is < 1%

# Next steps

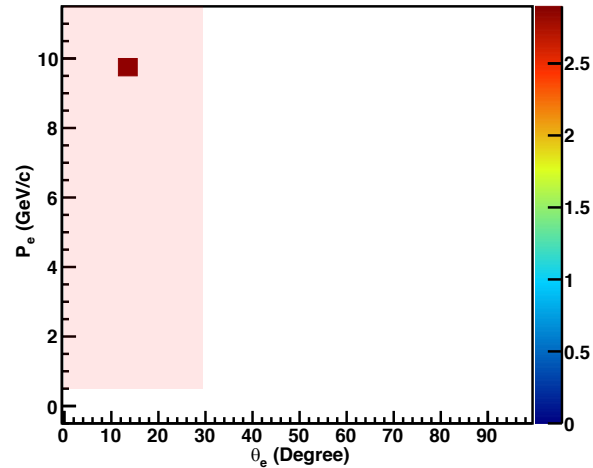
- Implement smearing ( $\Delta p/p_e = 1\%$ ,  $\Delta p/p_h = 2\%$ ,  $\Delta\theta_{e/h} = 2$  or  $10\text{mrad}$ )  
-> Study systematics from bin migration
- More simulations with nuclear modification (EPS09) for C12
- Check results with half the events for  $\text{Pi}^+$  and the other half for  $\text{Pi}^-$

Smearing Plots for  $\Delta p/p_e = 1\%$ ,  $\Delta p/p_h = 2\%$ ,  
 $\Delta\theta_{e/h} = 2\text{mrad}$ )

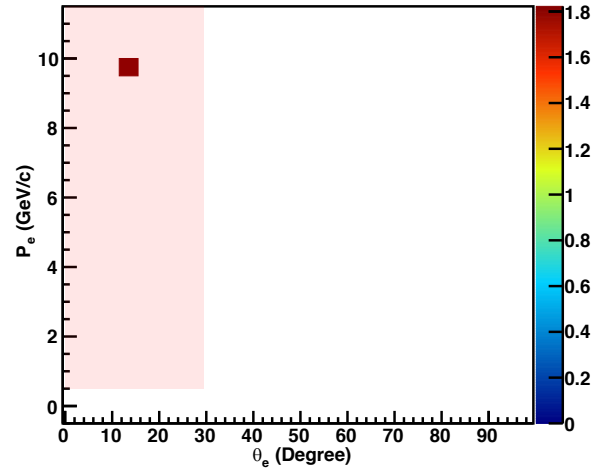
Extra Slides

# Generated Values for fix $Q^2$ and variable $z$ ( $0.05 < x_B < 0.1$ )

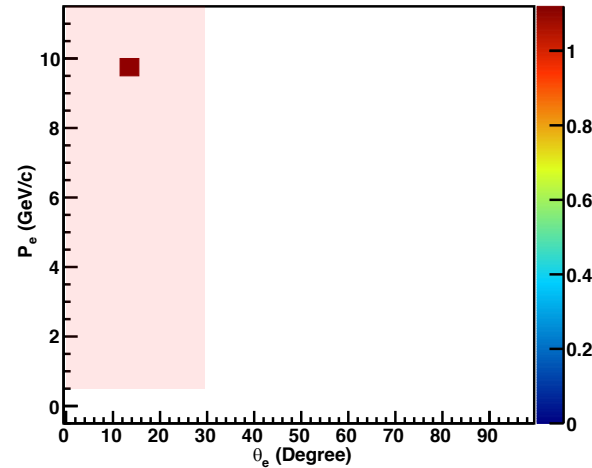
$5.0 \leq Q^2 < 6.0$  and  $0.2 \leq z < 0.3$



$5.0 \leq Q^2 < 6.0$  and  $0.3 \leq z < 0.4$



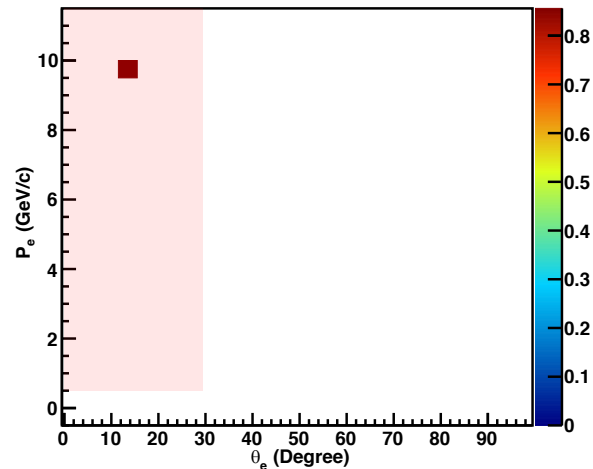
$5.0 \leq Q^2 < 6.0$  and  $0.4 \leq z < 0.5$



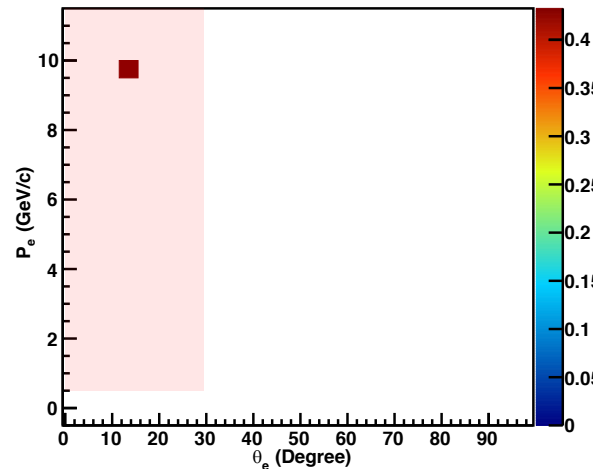
Electrons  
weighting  
only positive hadrons

$5.0 \leq Q^2 < 6.0$

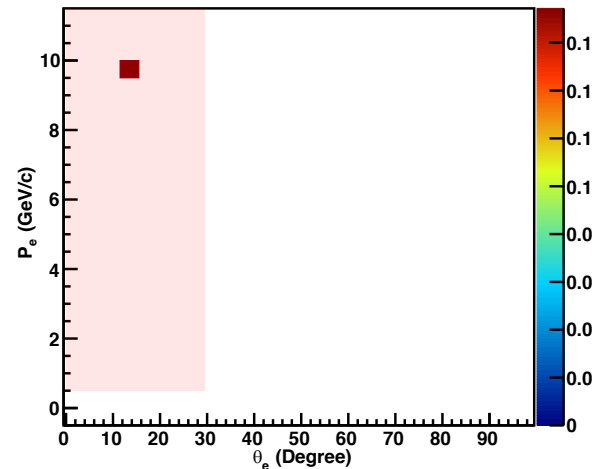
$5.0 \leq Q^2 < 6.0$  and  $0.5 \leq z < 0.6$



$5.0 \leq Q^2 < 6.0$  and  $0.6 \leq z < 0.7$



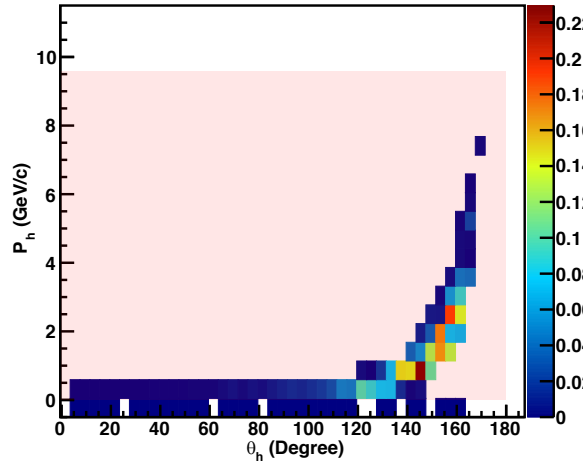
$5.0 \leq Q^2 < 6.0$  and  $0.7 \leq z < 0.8$



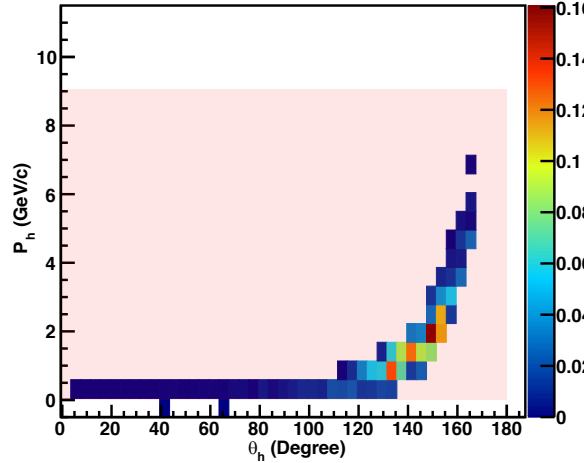
Very small  
phase space  
In generated  
values

# Generated Values for fix $Q^2$ and variable $z$ ( $0.05 < x_B < 0.1$ )

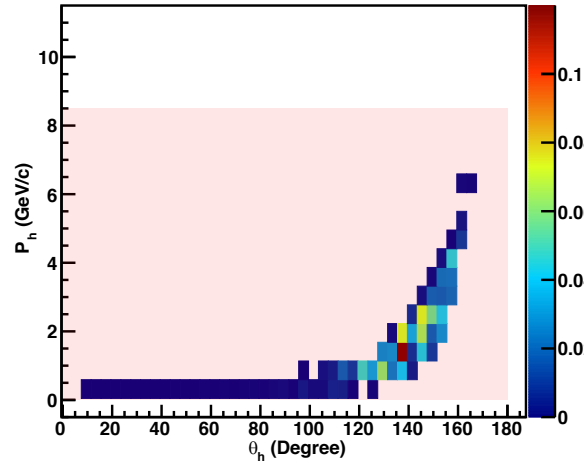
$5.0 \leq Q^2 < 6.0$  and  $0.2 \leq z < 0.3$



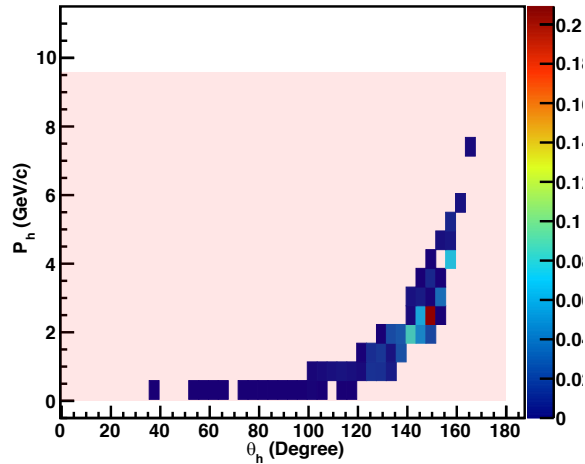
$5.0 \leq Q^2 < 6.0$  and  $0.3 \leq z < 0.4$



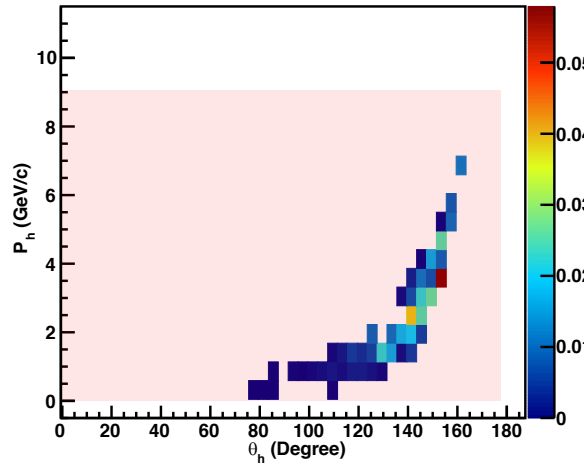
$5.0 \leq Q^2 < 6.0$  and  $0.4 \leq z < 0.5$



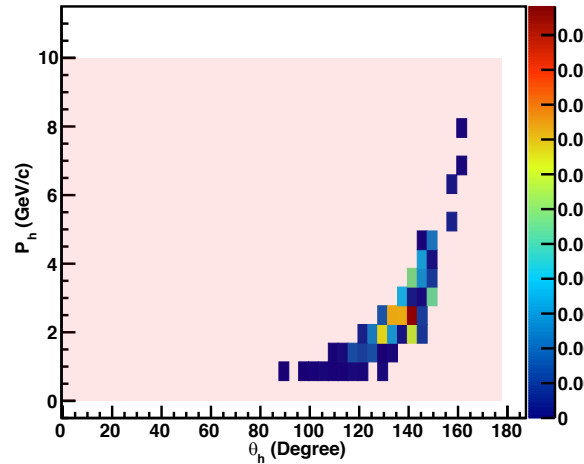
$5.0 \leq Q^2 < 6.0$  and  $0.5 \leq z < 0.6$



$5.0 \leq Q^2 < 6.0$  and  $0.6 \leq z < 0.7$



$5.0 \leq Q^2 < 6.0$  and  $0.7 \leq z < 0.8$



Hadrons  
weighting  
only positive hadrons

$5.0 \leq Q^2 < 6.0$