

# High Statistics Inclusive Cross Section Measurements from MINERvA

**Amy Filkins**  
William & Mary

**For the MINERvA Collaboration**

**NDNN**

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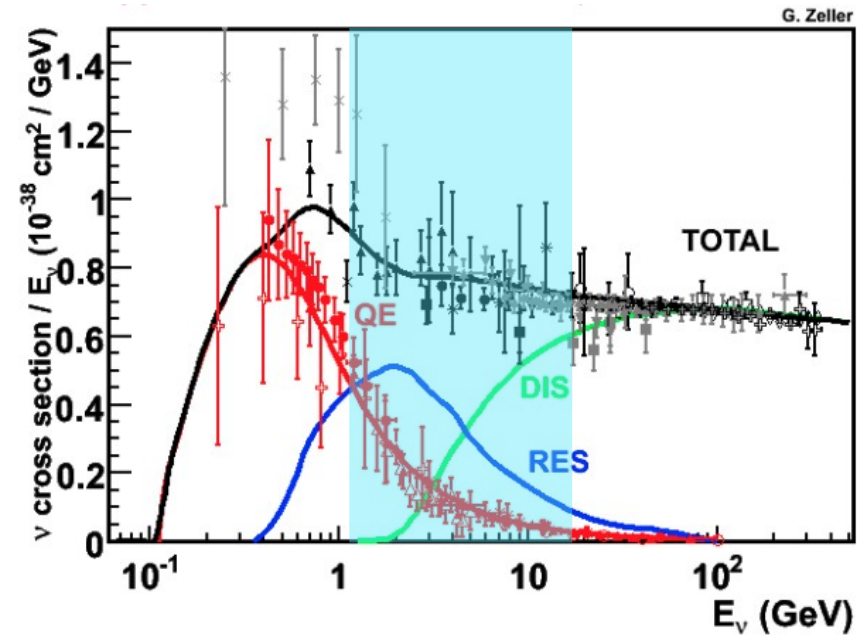


**WILLIAM  
& MARY**

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# Motivation

- Many processes contribute to the cross section at a few GeV
- Inclusive measurements provide stringent test of generators
- High statistics, small backgrounds
- Double differential cross sections in muon  $p_{||}$ ,  $p_T$
- $p_{||}$  correlated with  $E_\nu$   
 $p_T$  correlated with  $Q^2$ 
  - Provides nice process separation without the model dependence that comes with using hard to reconstruct variables



# Analysis

- **Two parallel analyses done with different beam energies**

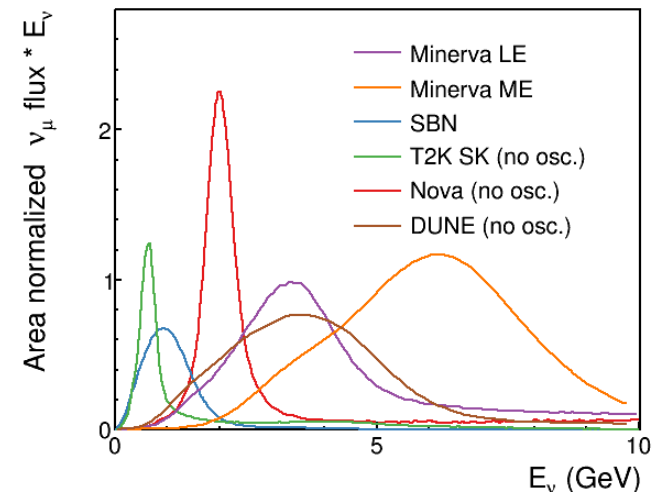
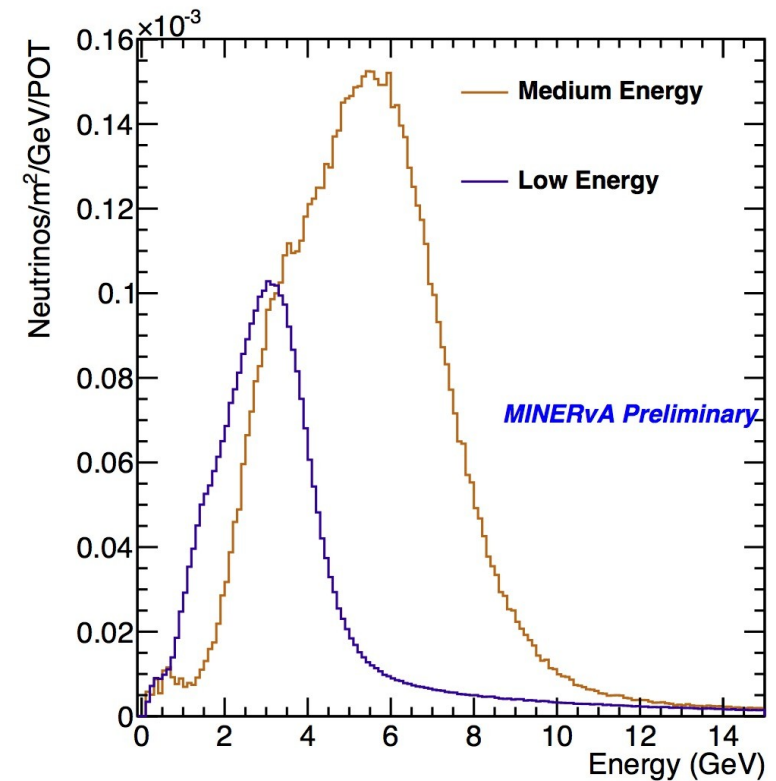
- Low energy beam  $\langle E_\nu \rangle \sim 3.5$  GeV
- Medium energy beam  $\langle E_\nu \rangle \sim 6$  GeV

- **Signal definition:**

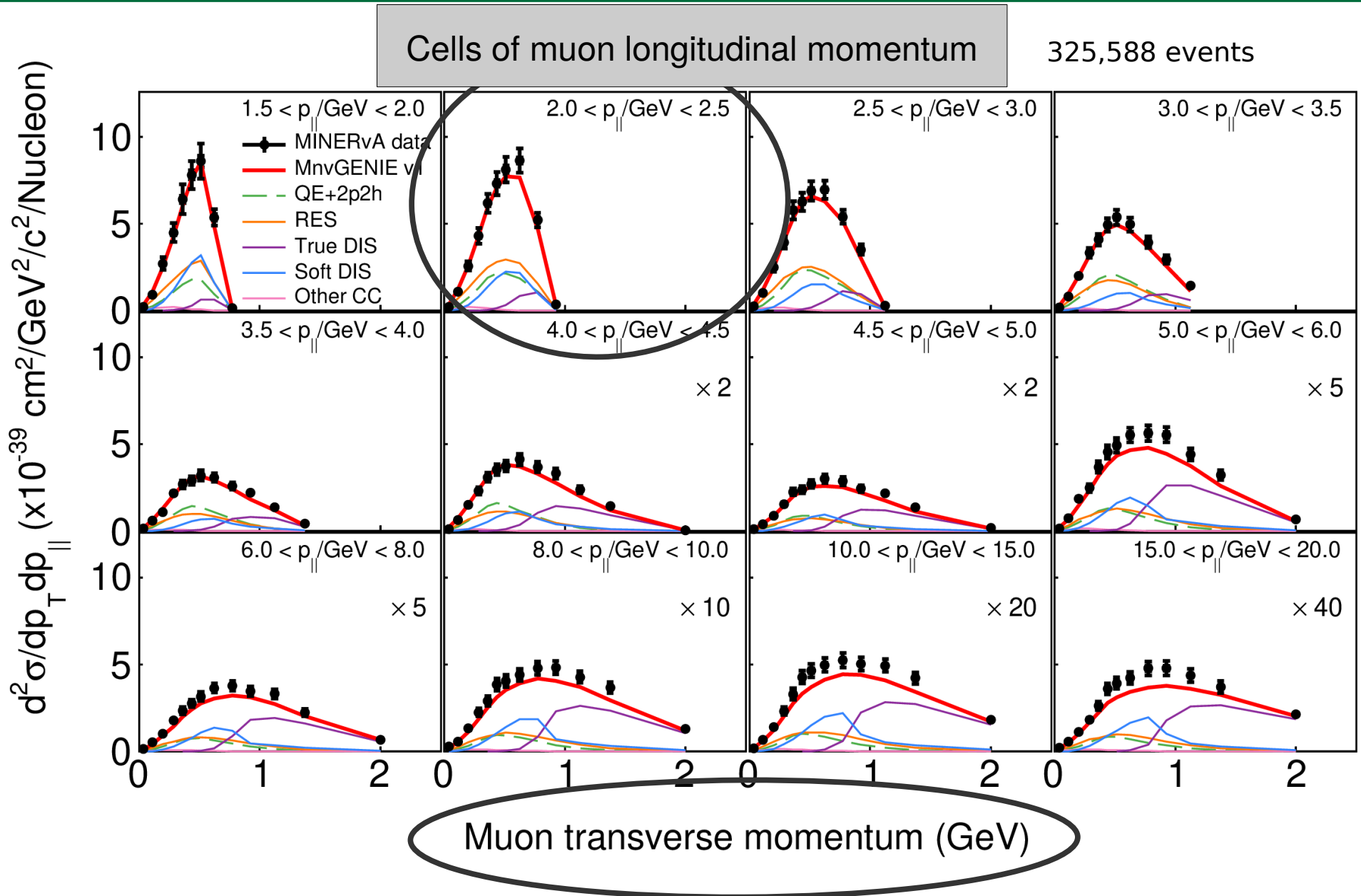
- $\nu_\mu$  CC
- Muon angle  $< 20^\circ$  wrt beam
- $p_\mu > 1.5$  GeV

- **Minerva Tune v1**

- RPA, enhanced Valencia 2p2h, non-resonant pion tune
- GENIE 2.8.4 (LE), GENIE 2.12.6 (ME)

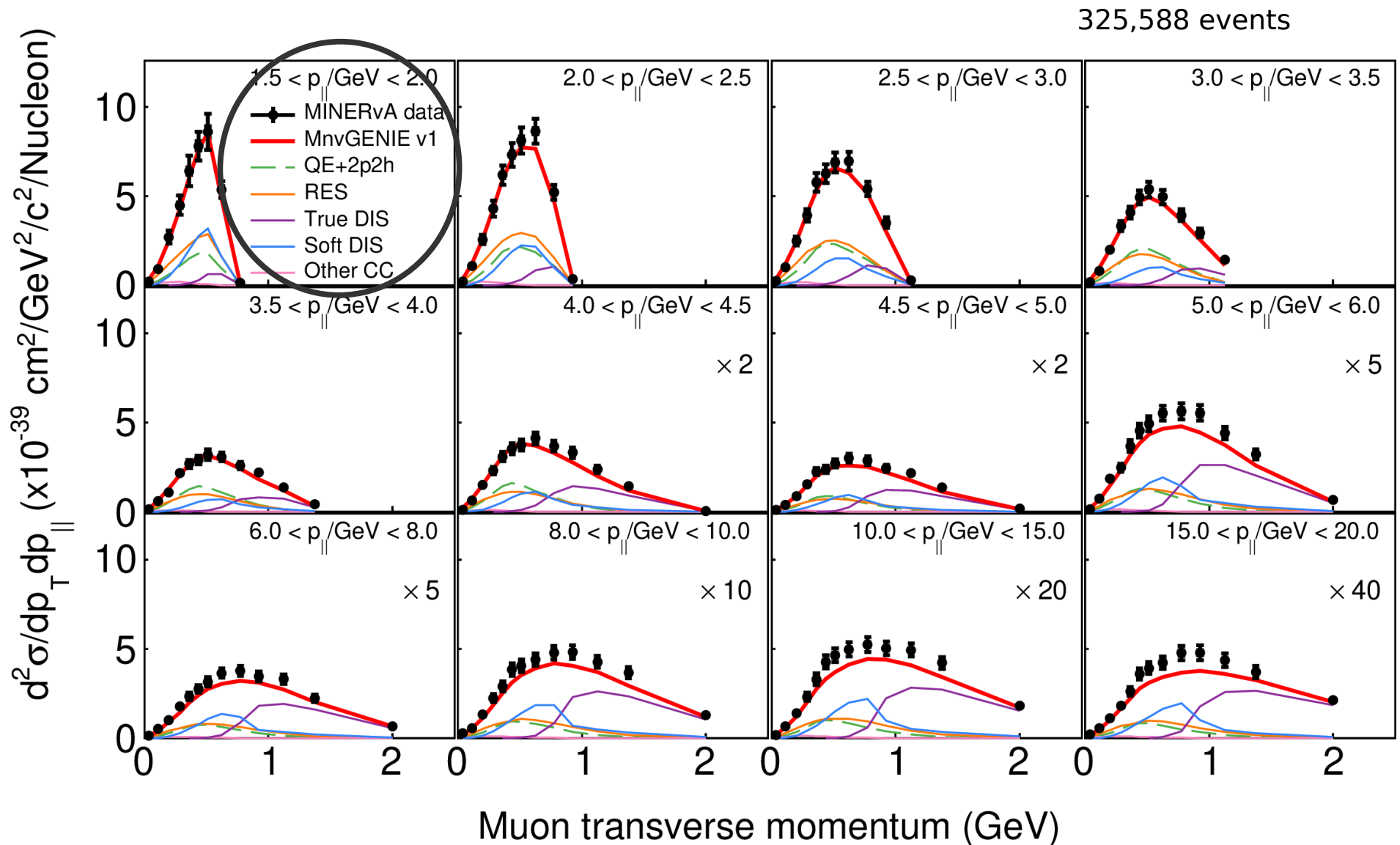


# Low Energy Double Differential Cross Section



<https://doi.org/10.1103/PhysRevD.101.112007>

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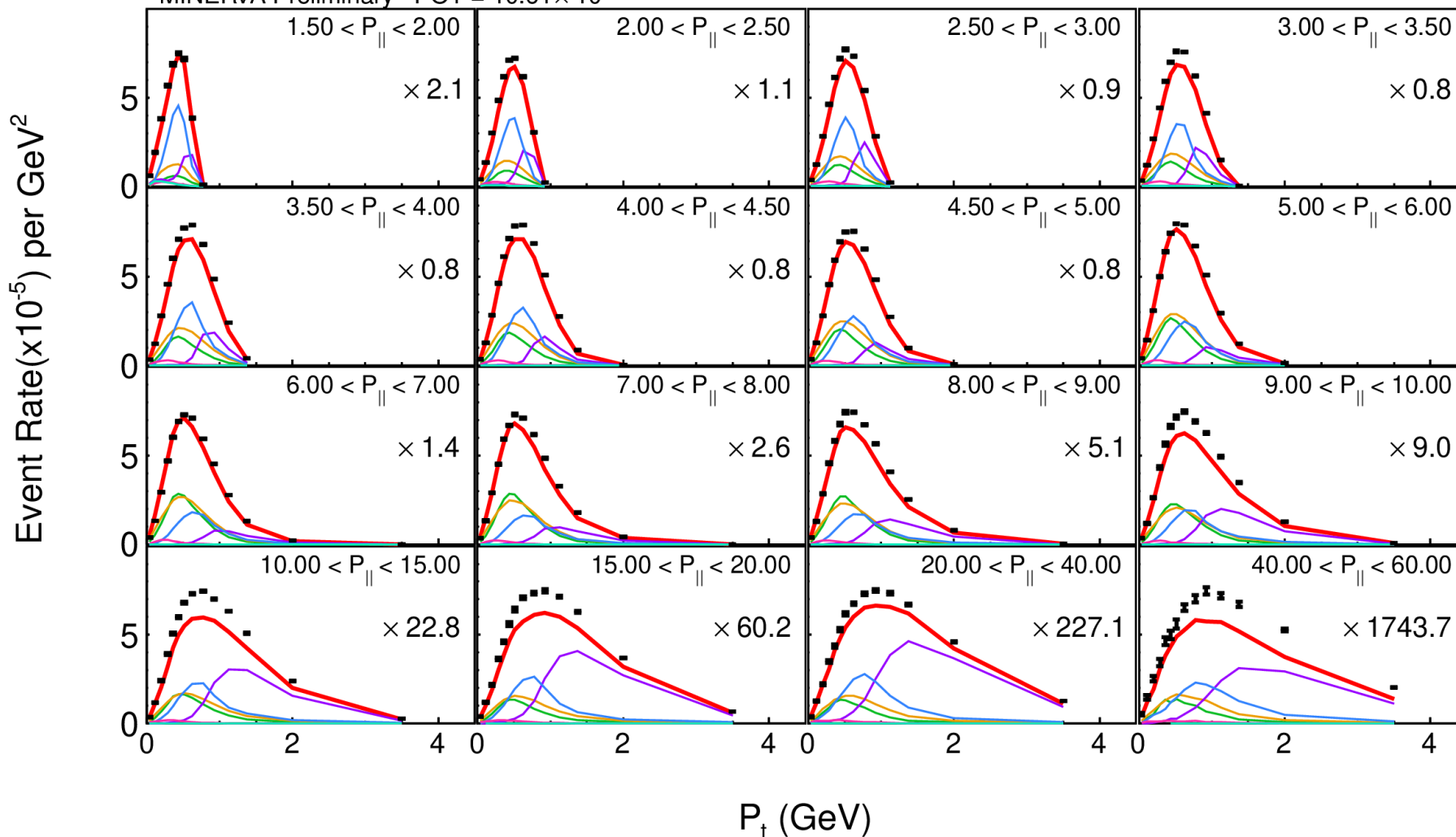
# Medium Energy Event rate

- + MINERvA data
- MINERvA Tune
- QE+2p2h
- Resonant
- True DIS
- Soft DIS
- Other CC
- Background

Stat errors only

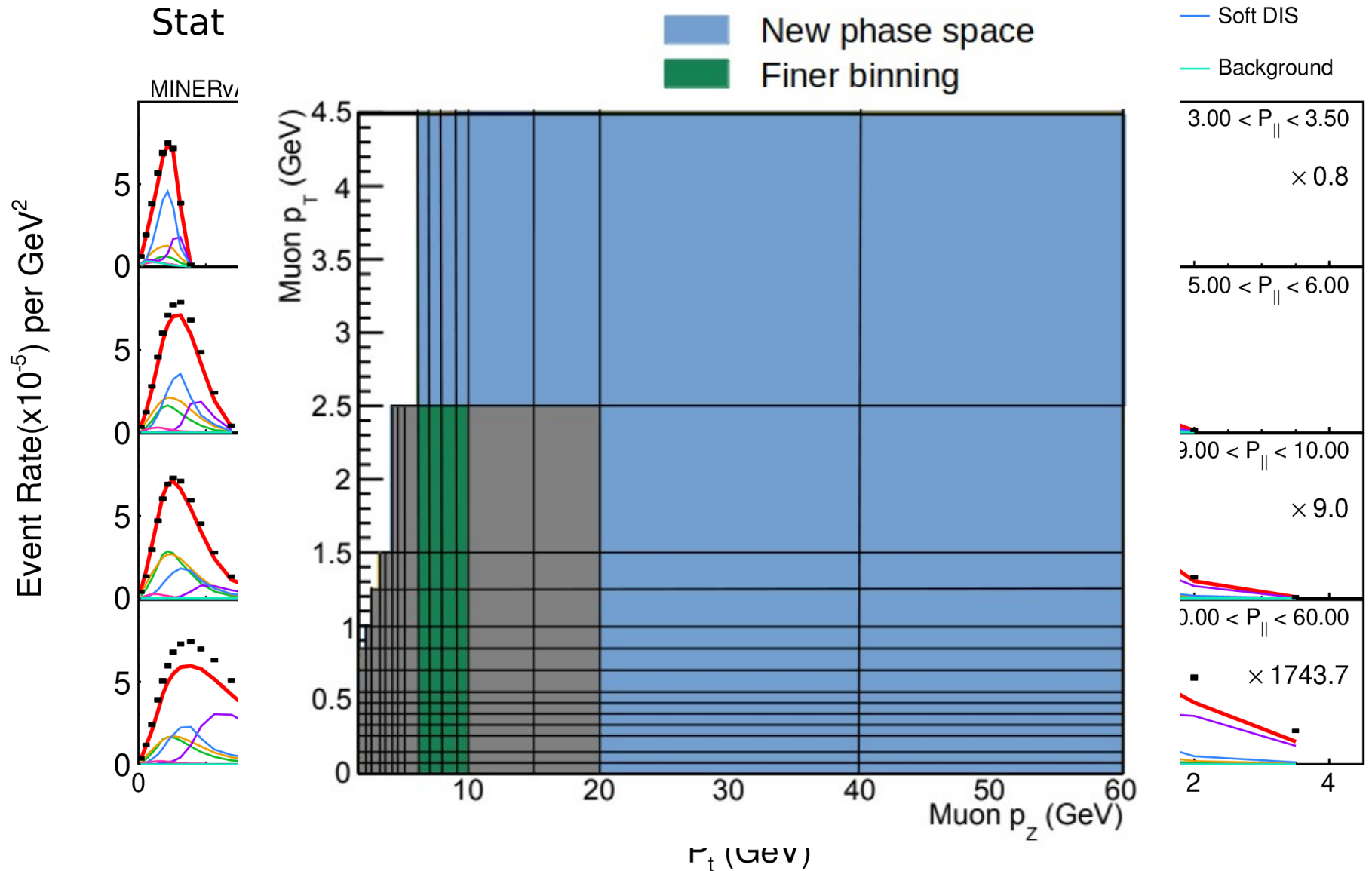
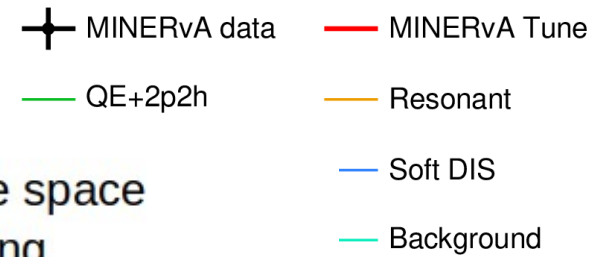
4,108,942 events

MINERvA Preliminary POT =  $10.61 \times 10^{20}$



Expanded phase space: 4 more  $p_{||}$  bins, 1 more  $p_T$  bin

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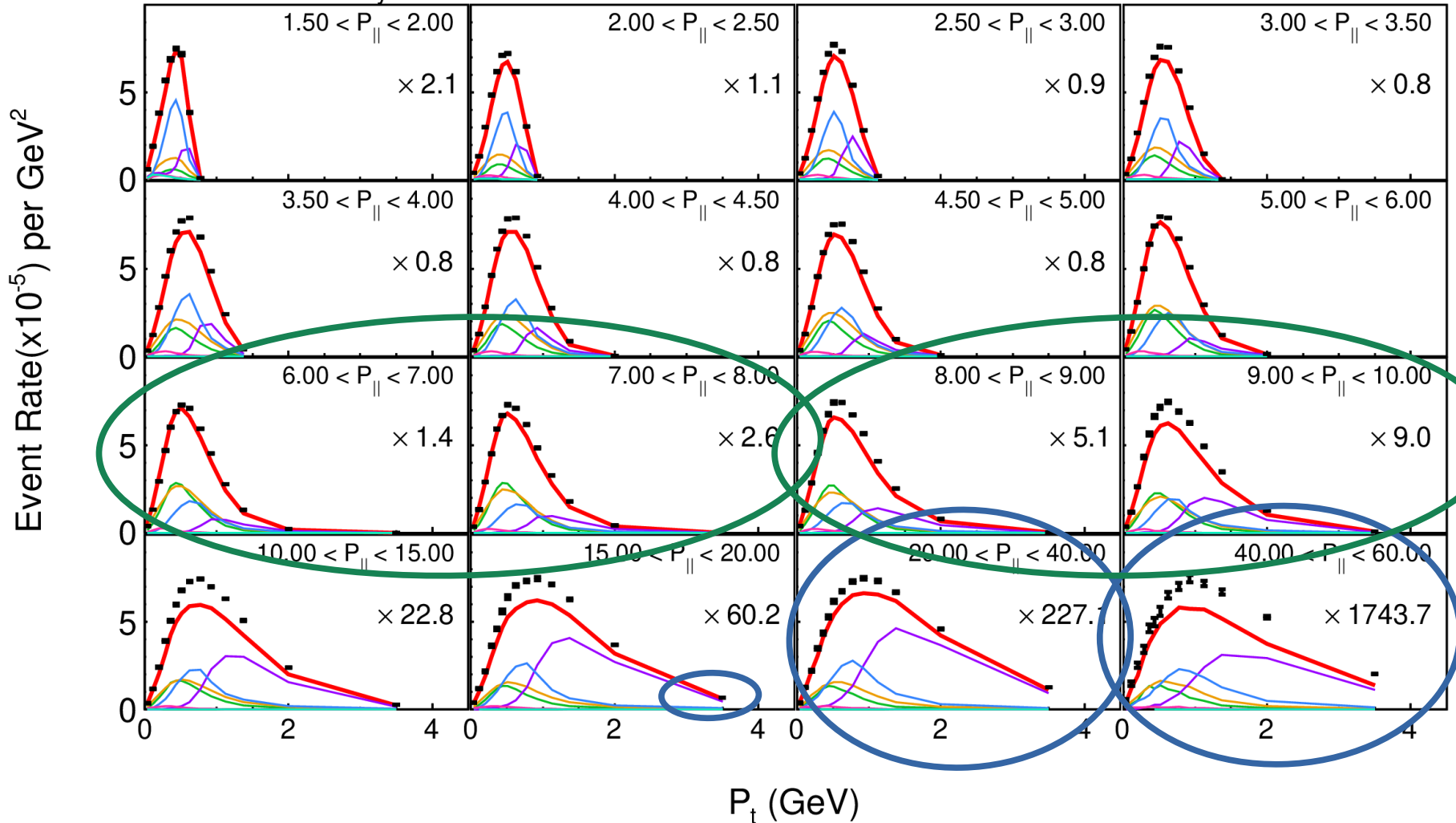
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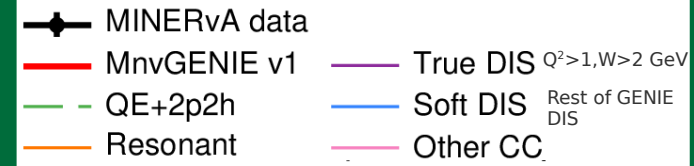
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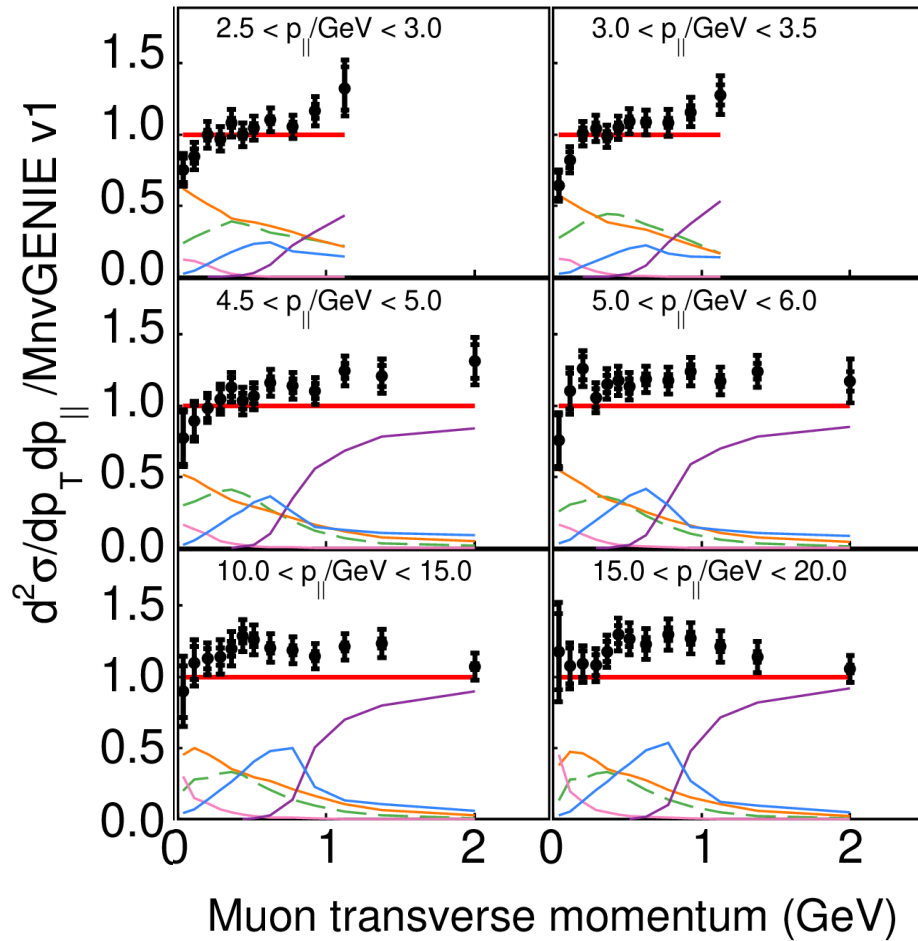
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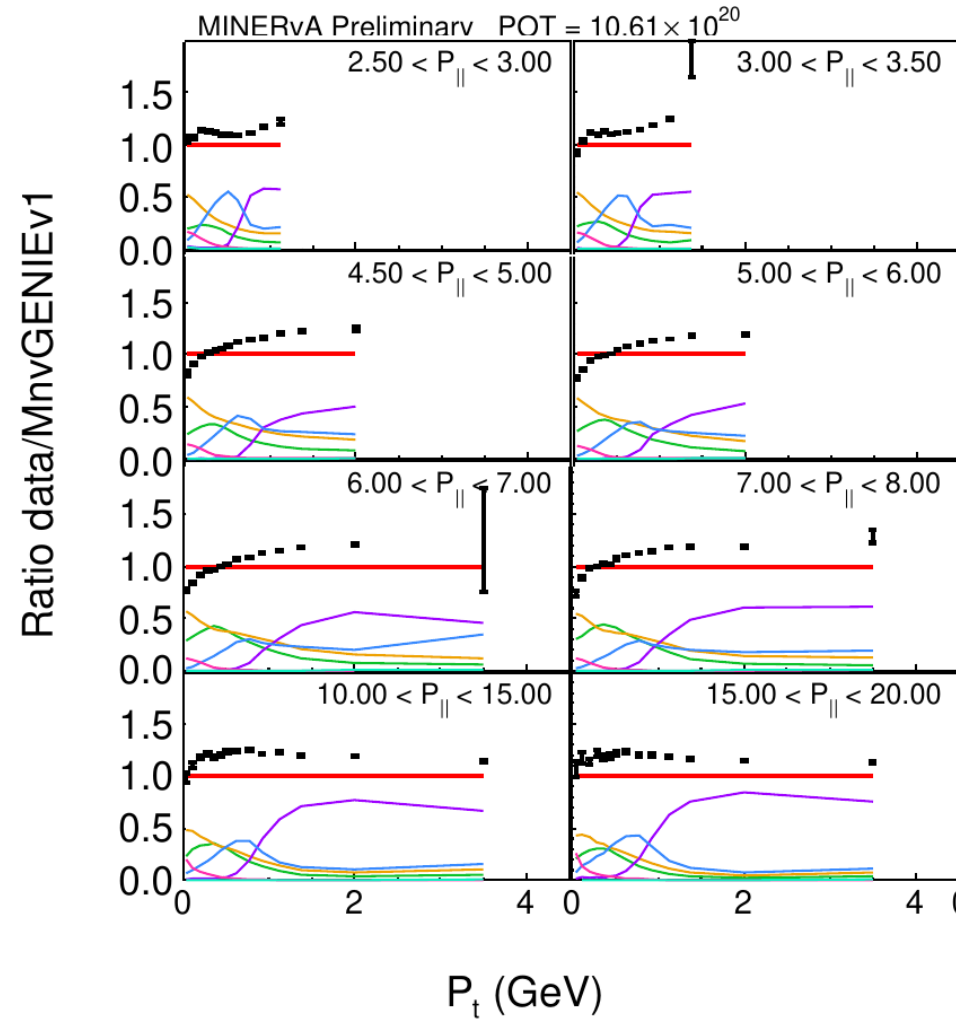
# Ratios to MnvGENIE



## Low Energy

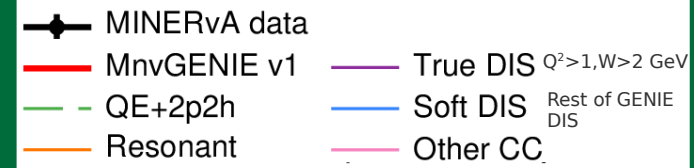


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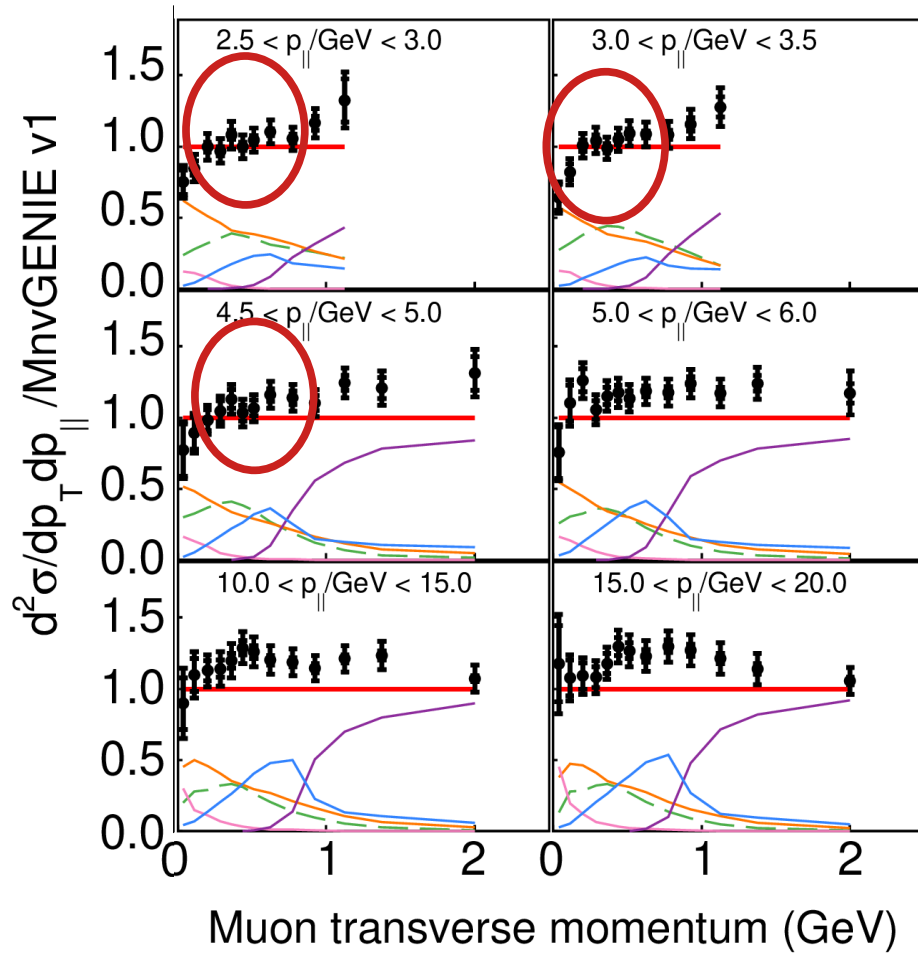


Ratio to MnvGENIE v1  
 Half of the  $p_{\parallel}$  bins from each data set

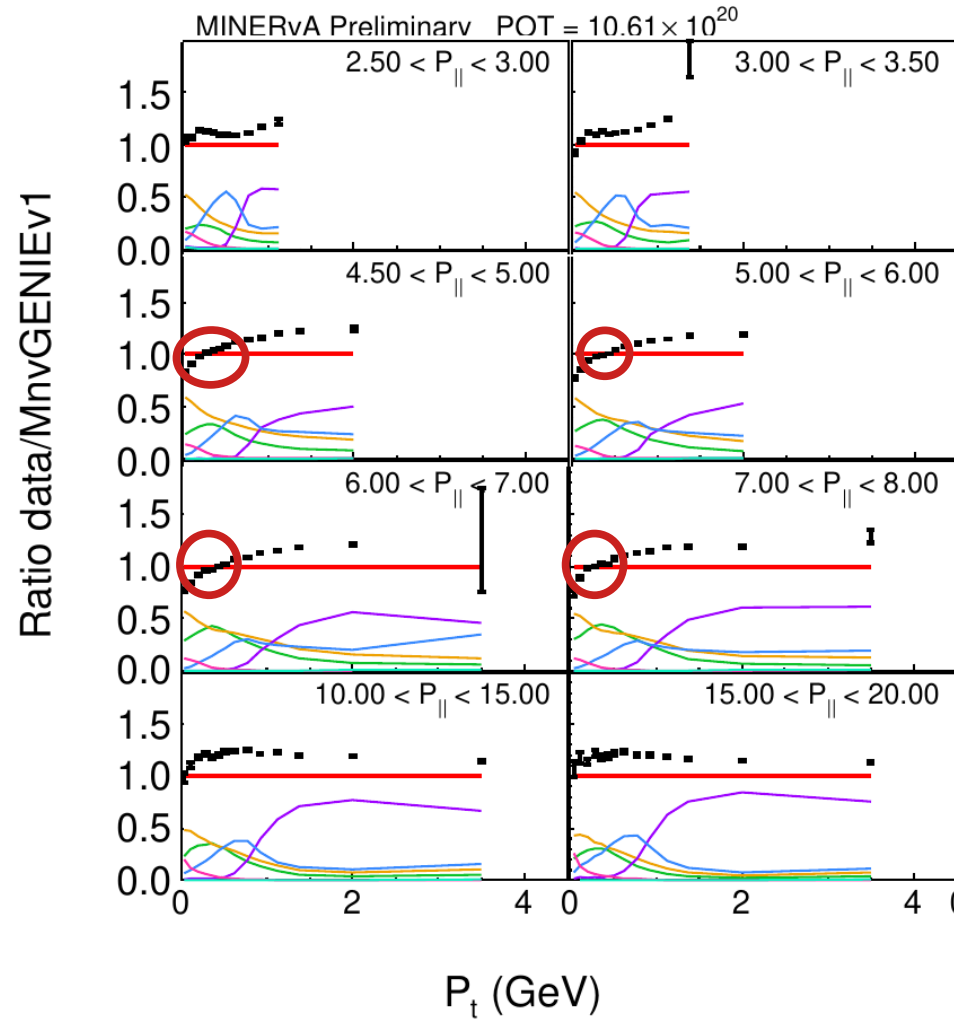
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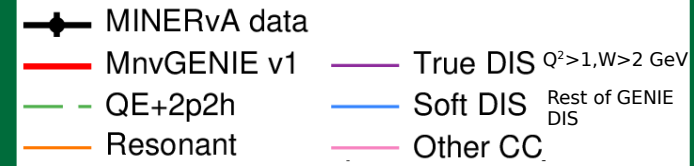


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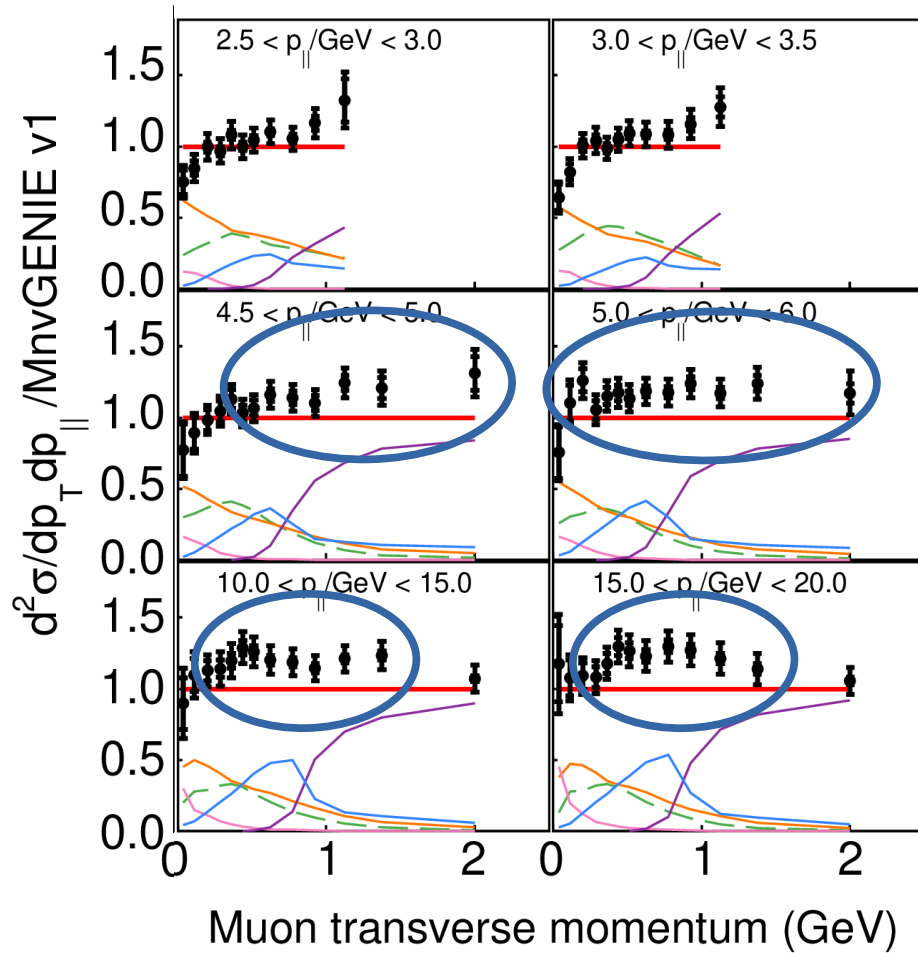


Around flux peak – area of agreement centered around  $p_T \sim 0.5 \text{ GeV}$

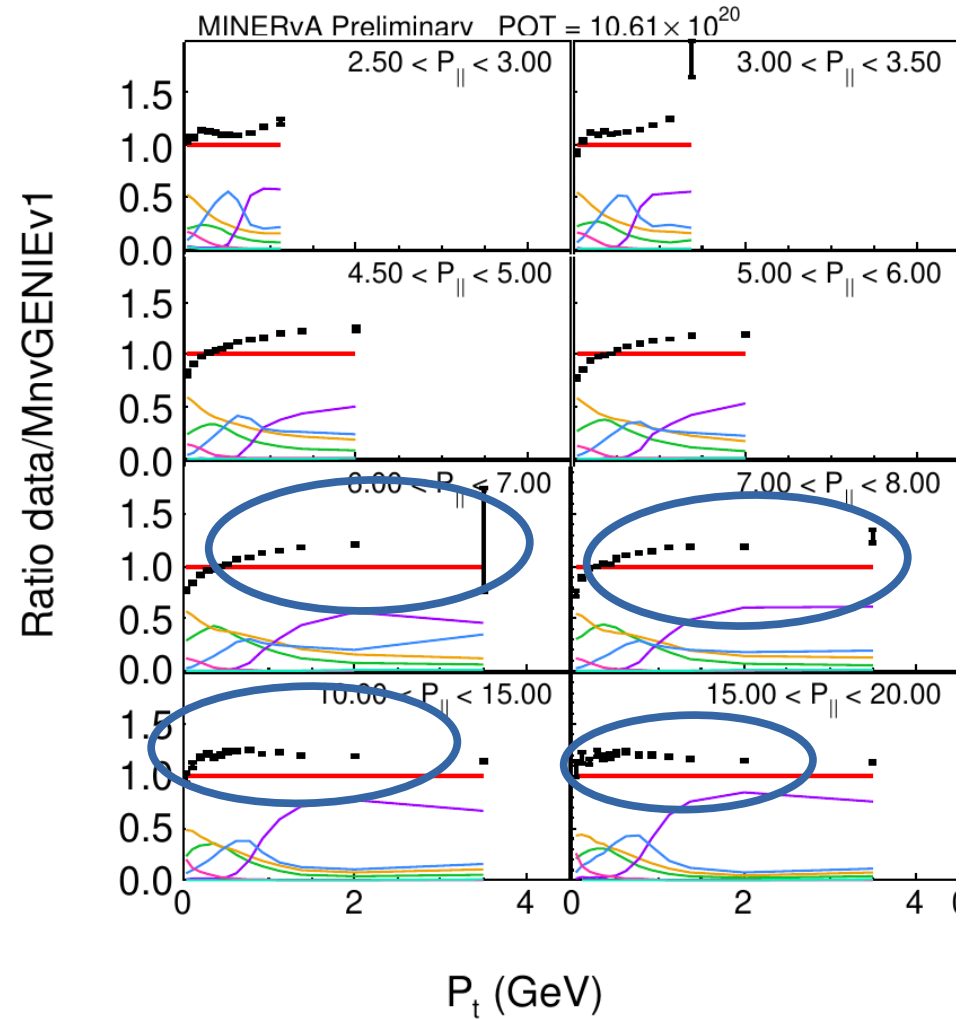
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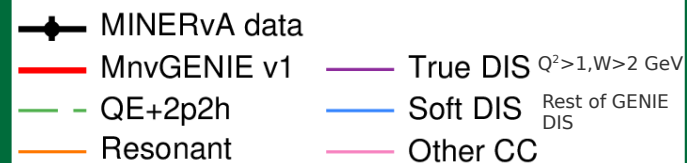


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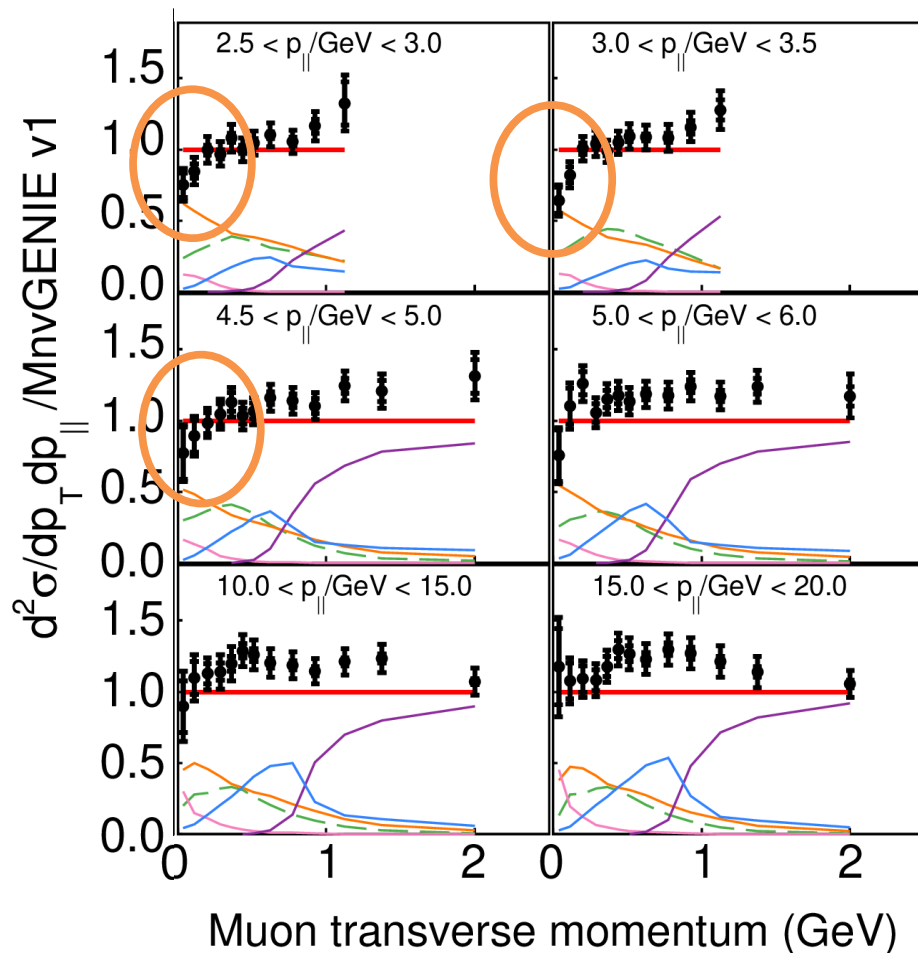


At high  $p_{\parallel}$  underpredictions, except for highest  $p_T$  bin

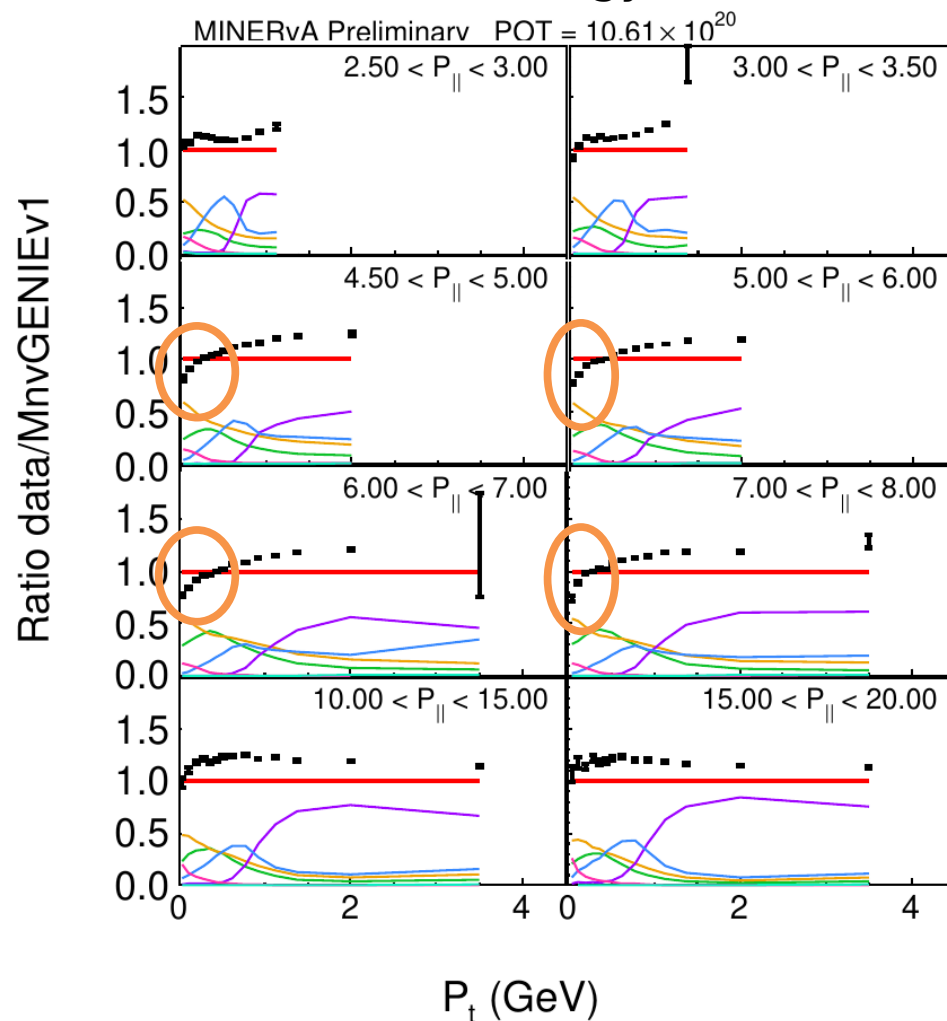
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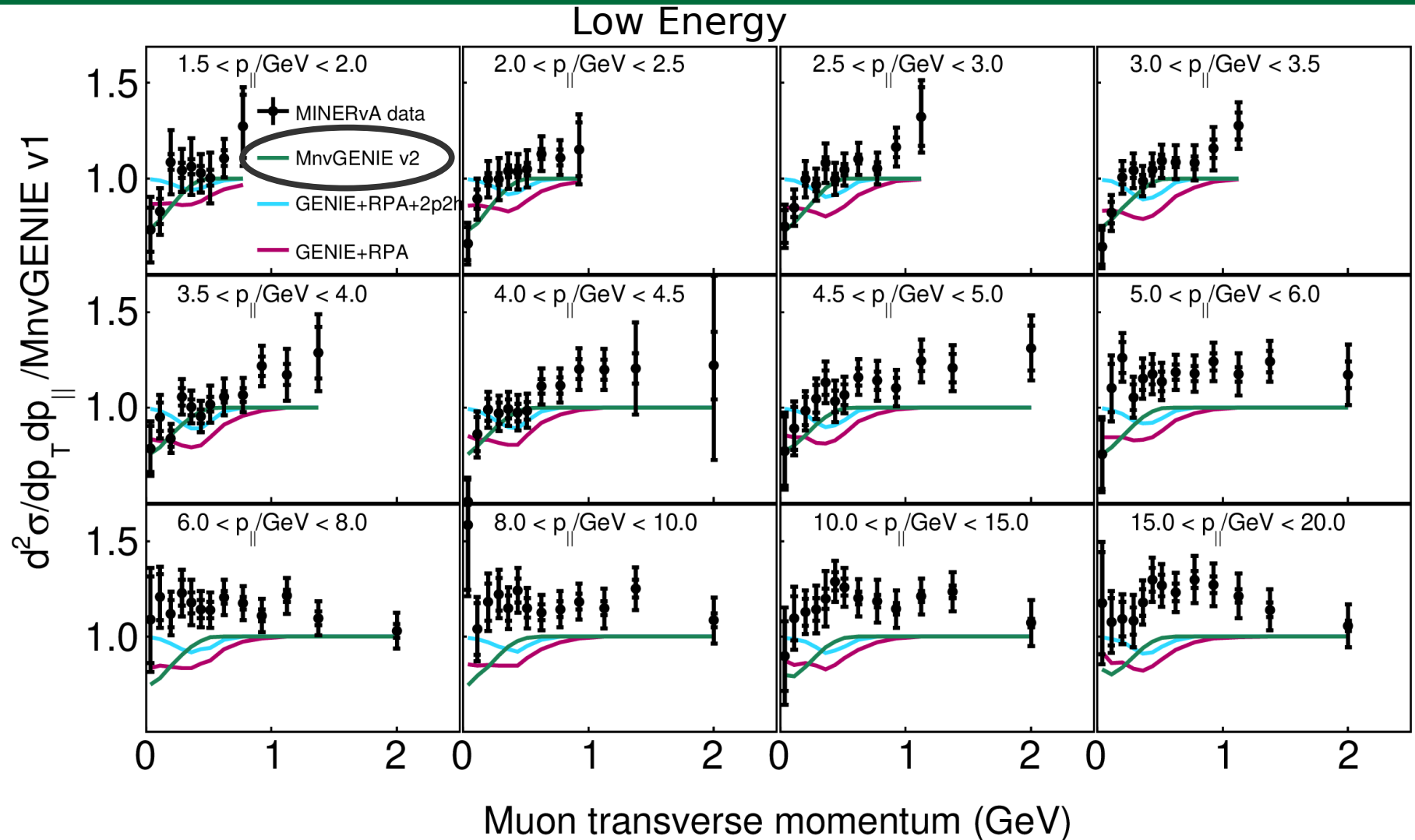


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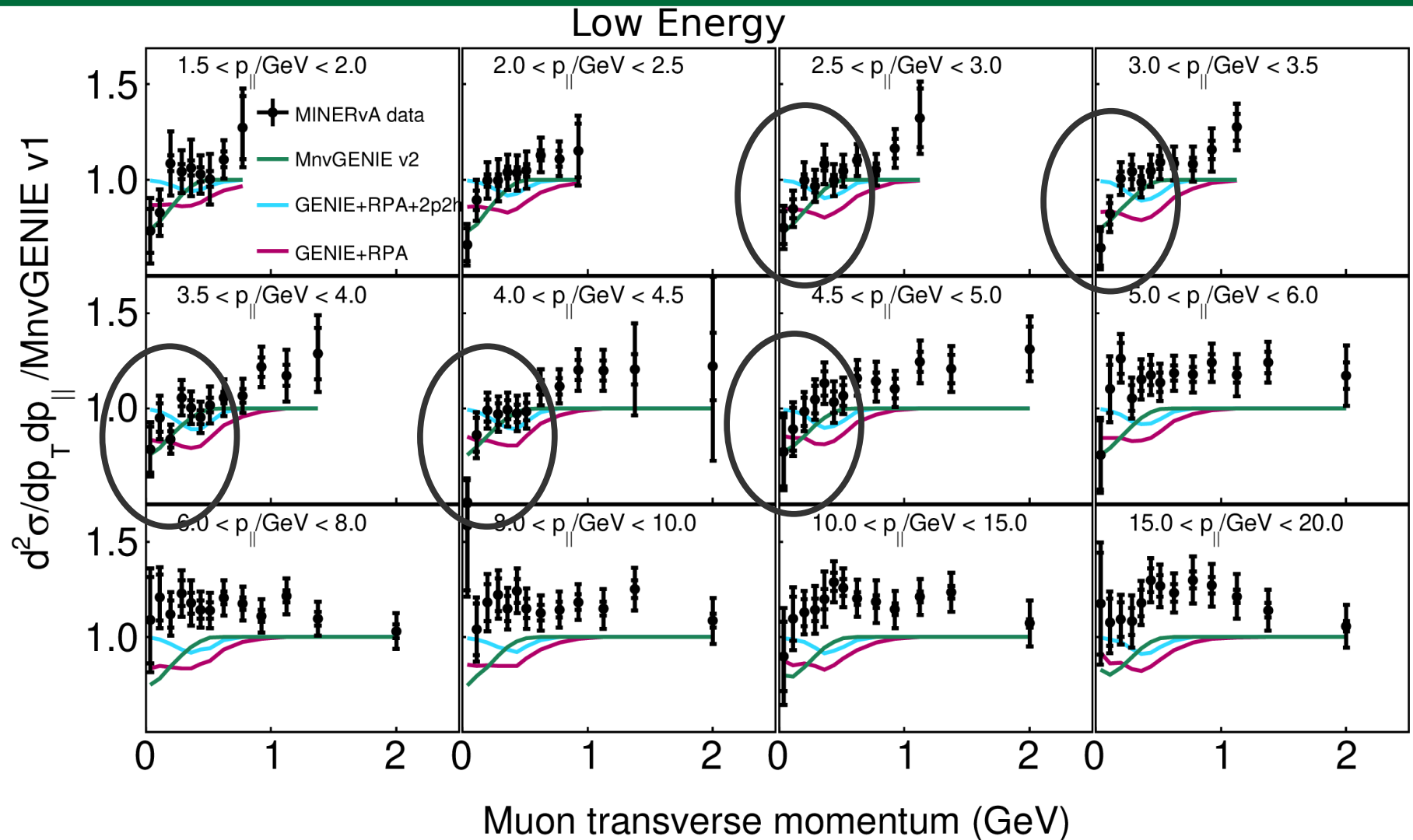
Around flux peak – overprediction at low  $p_T$   
 Low  $Q^2$  resonant suppression needed?

# Low $Q^2$ ResonantSuppressions



Addition of a low  $Q^2$  resonant suppression better matches data in some regions (especially around flux peak)

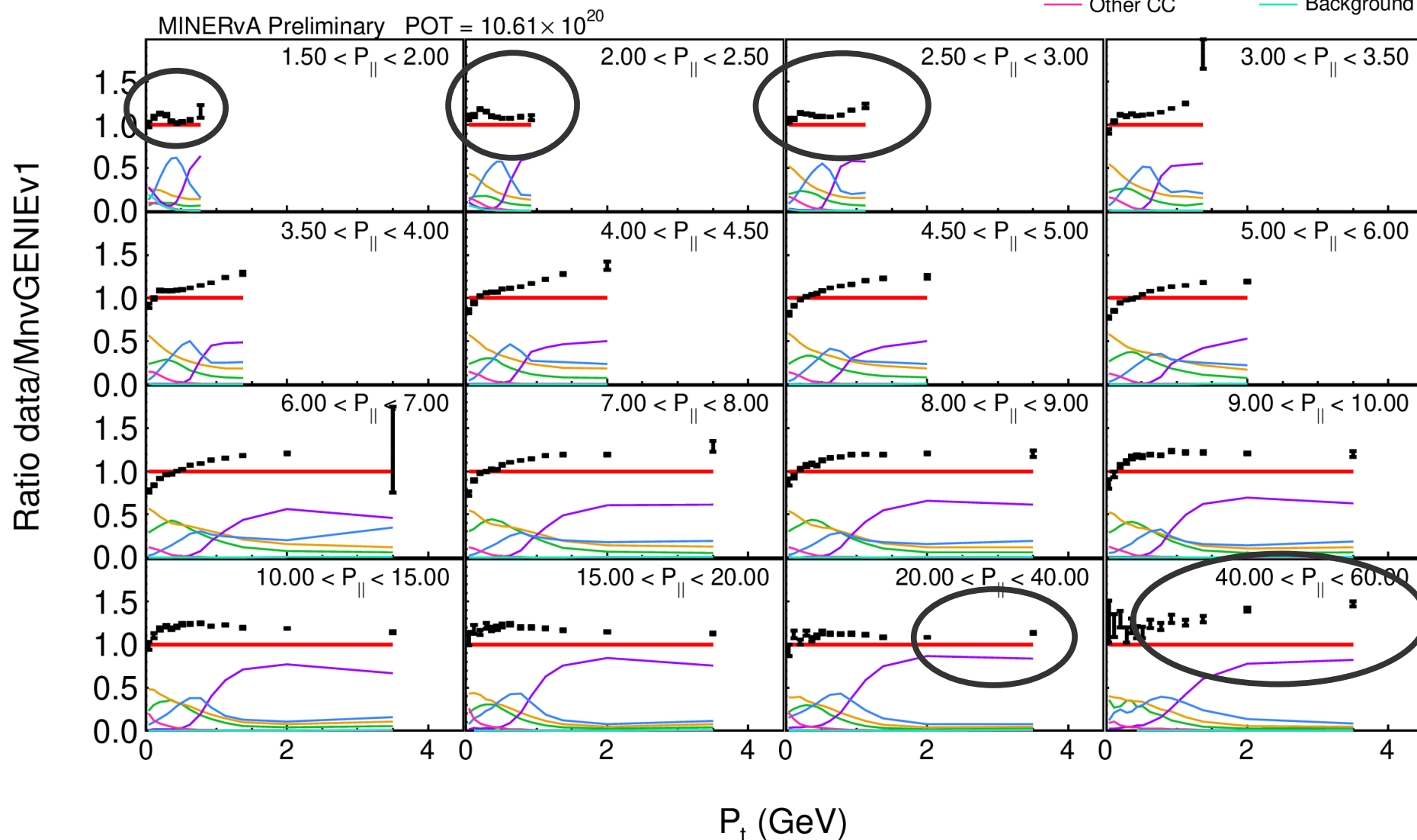
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# Medium Energy Event Ratios

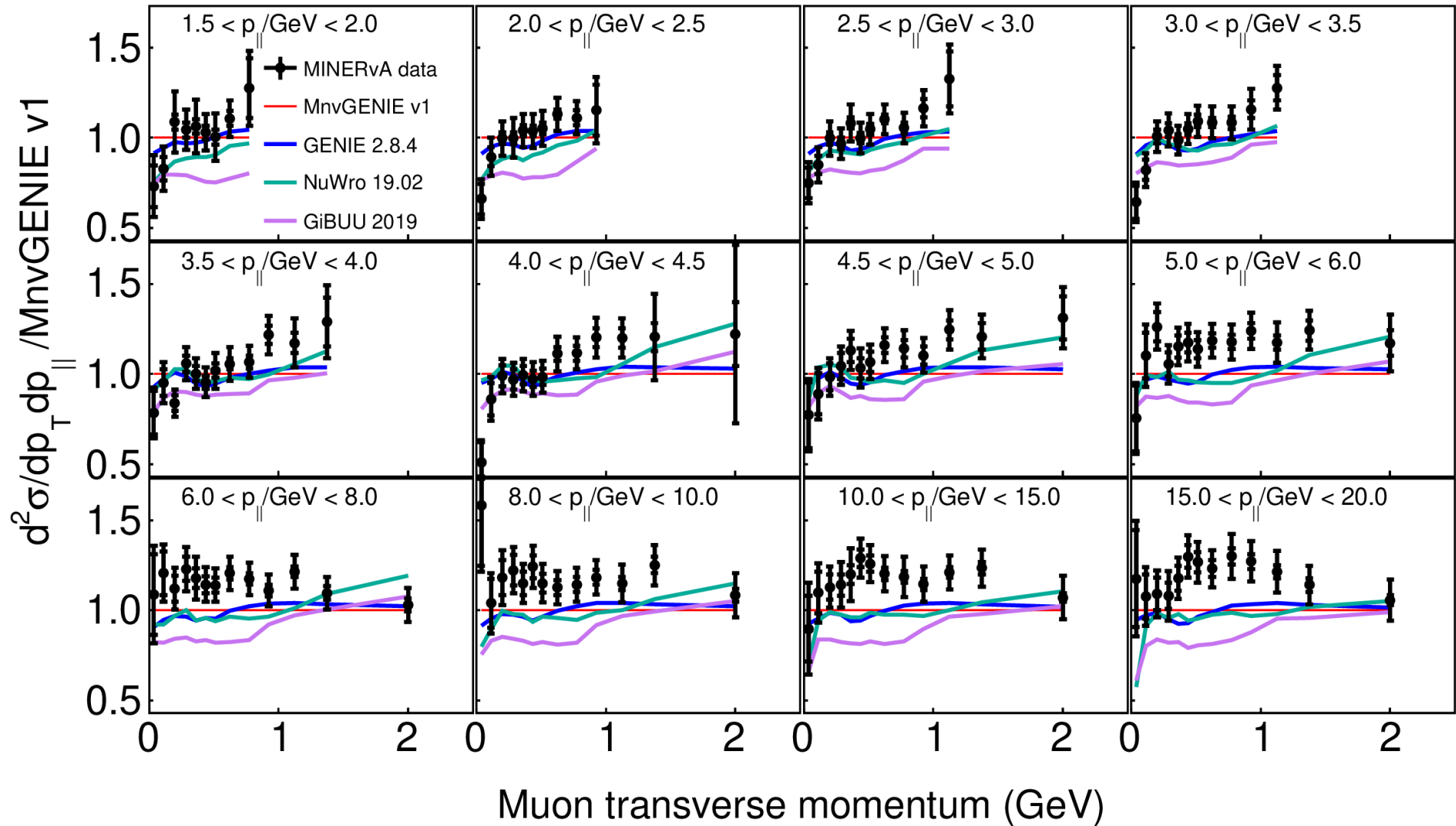
- ✦ MINERvA data
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Unique to ME: area with fairly flat ratio at low  $p_{||}$ , under predictions at highest  $p_{||}$ ,  $p_T$



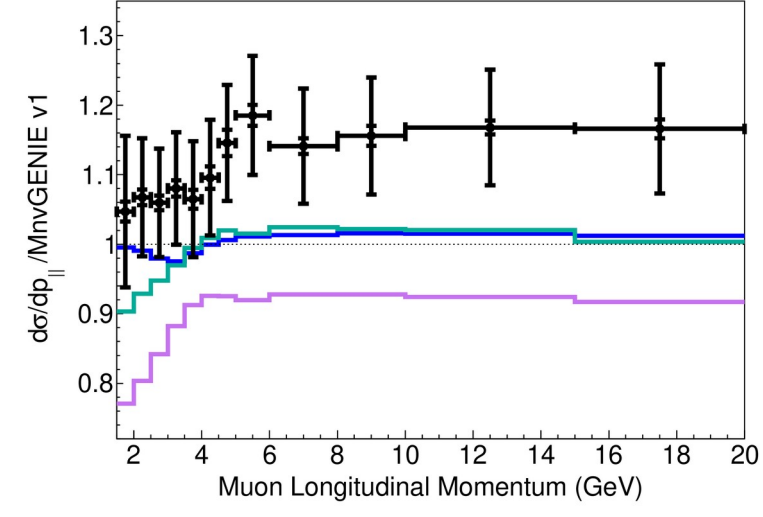
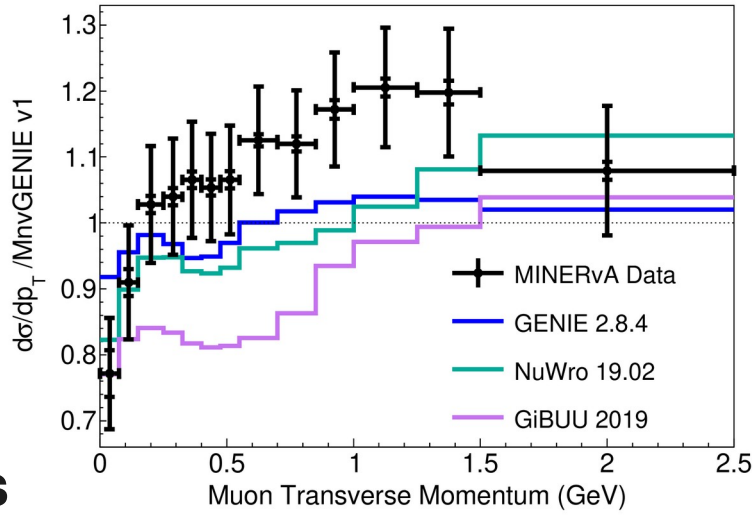
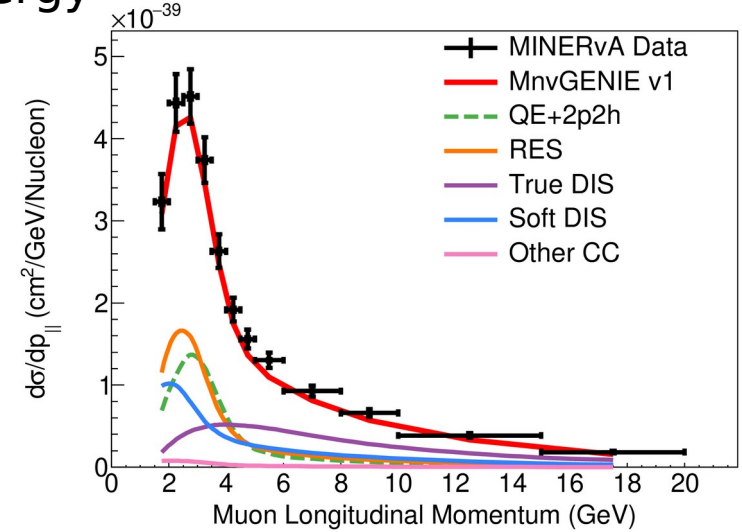
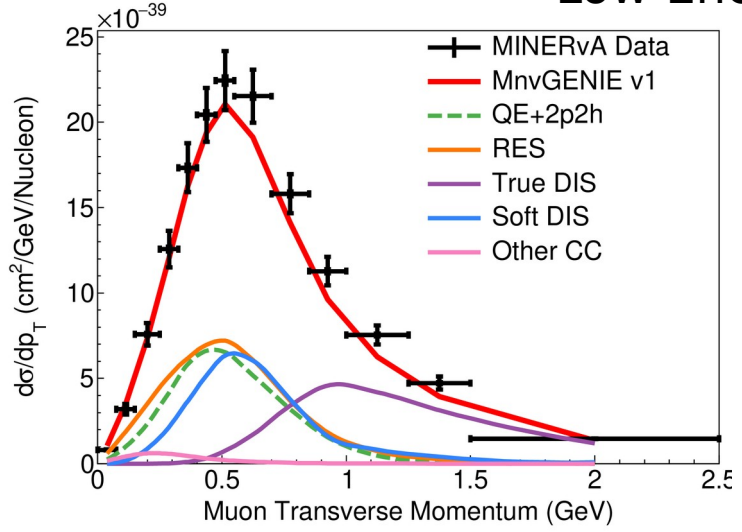
# Low Energy – Model comparisons



# Single Differential Cross Sections - $p_T$

- **MnvGENIE cross section overpredicts at low  $p_T$**
- **Underpredicts at higher  $p_T$**
- **$P_{||}$  dependence isn't being accurately predicted**
- **General underpredictions**

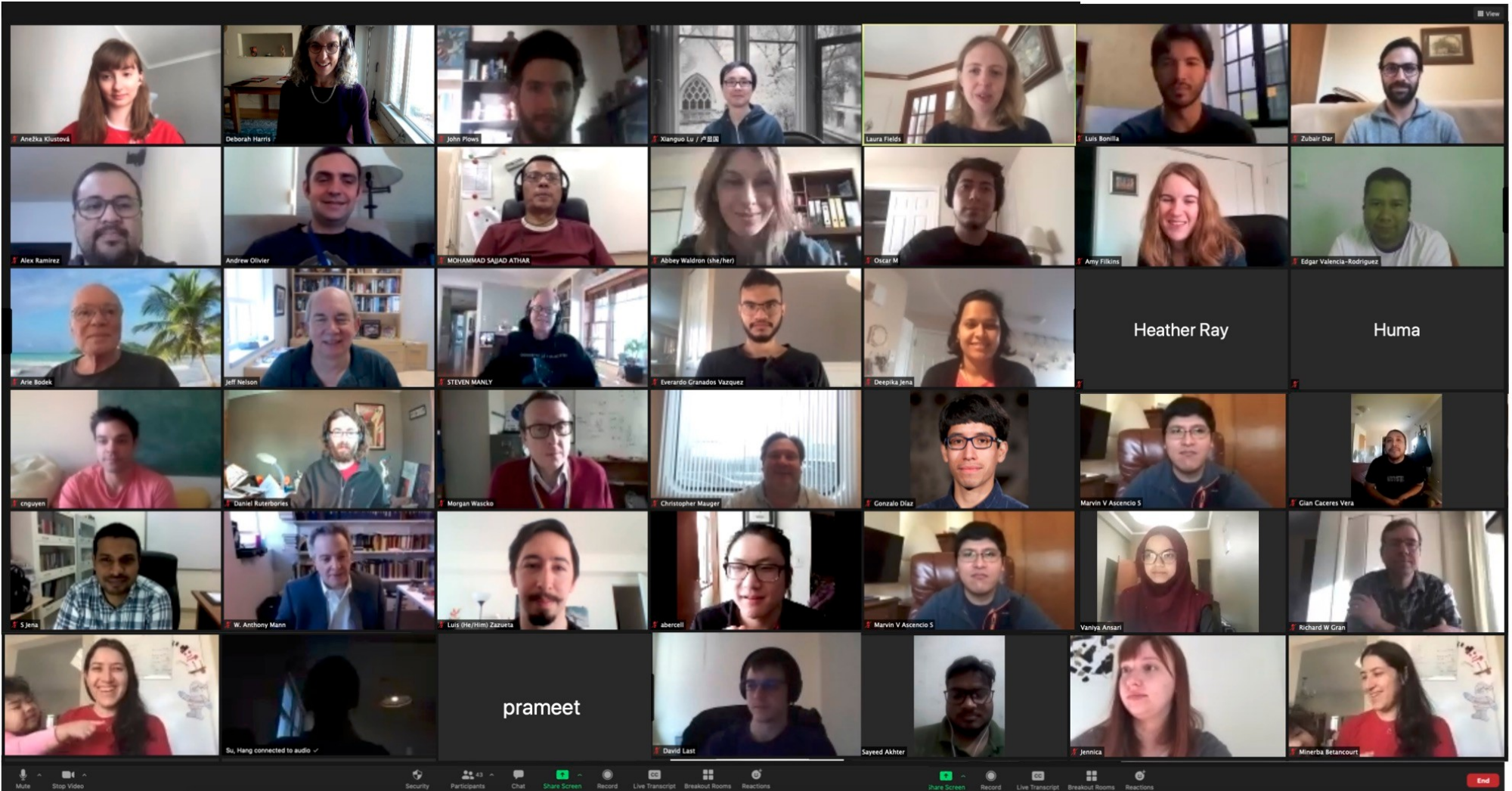
Low Energy



# Summary

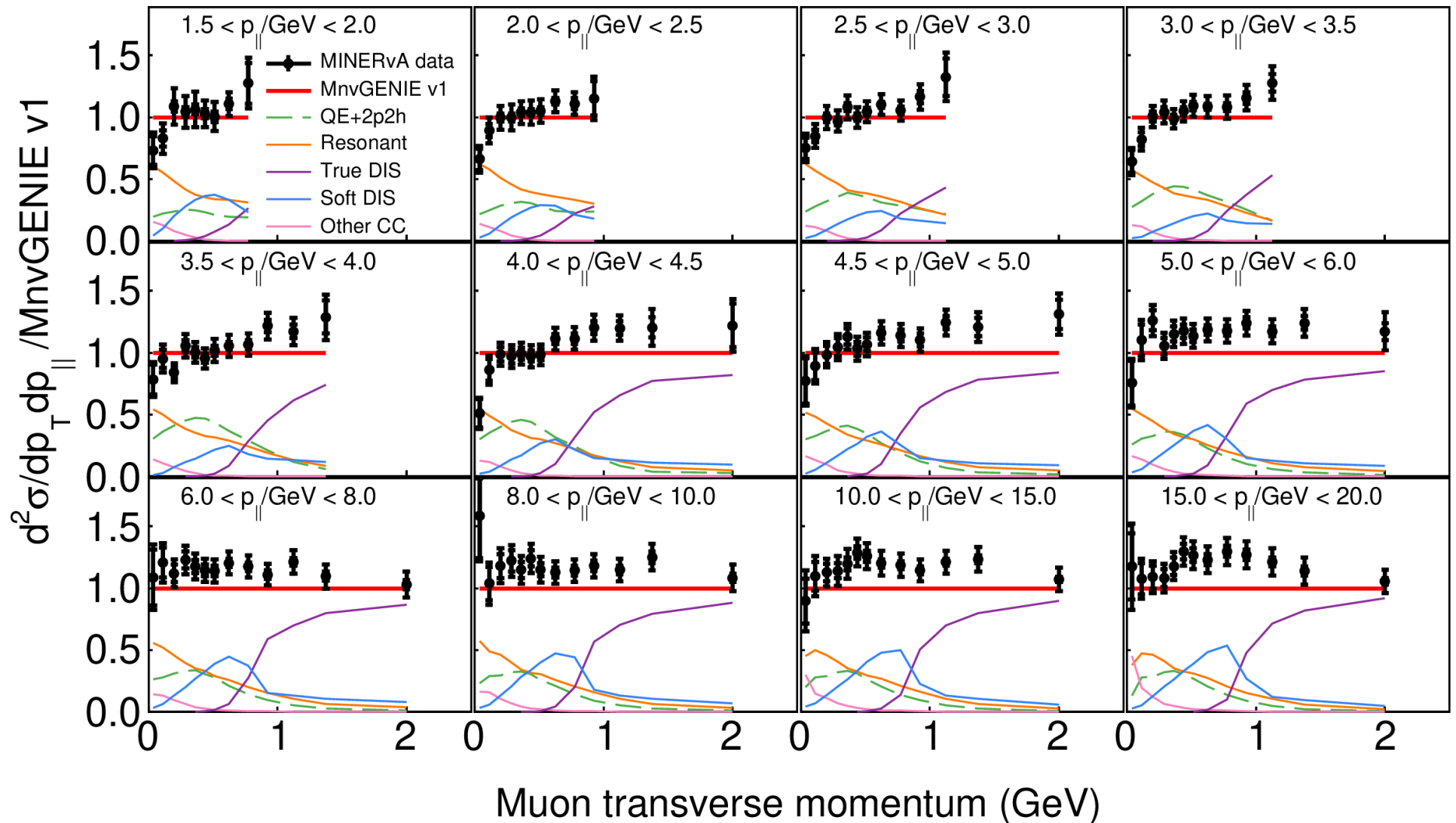
- **Measured cross sections aren't consistently reproduced by any model throughout phase space**
- **See similar trends with both data sets**
- **Indication that low  $Q^2$  resonant suppression called for**
- **ME inclusive cross sections coming soon**
- **Many more ME analyses are underway**
- **Exclusive results can help differentiate between possible sources of mismodeling seen in inclusive results**

# Thank you!



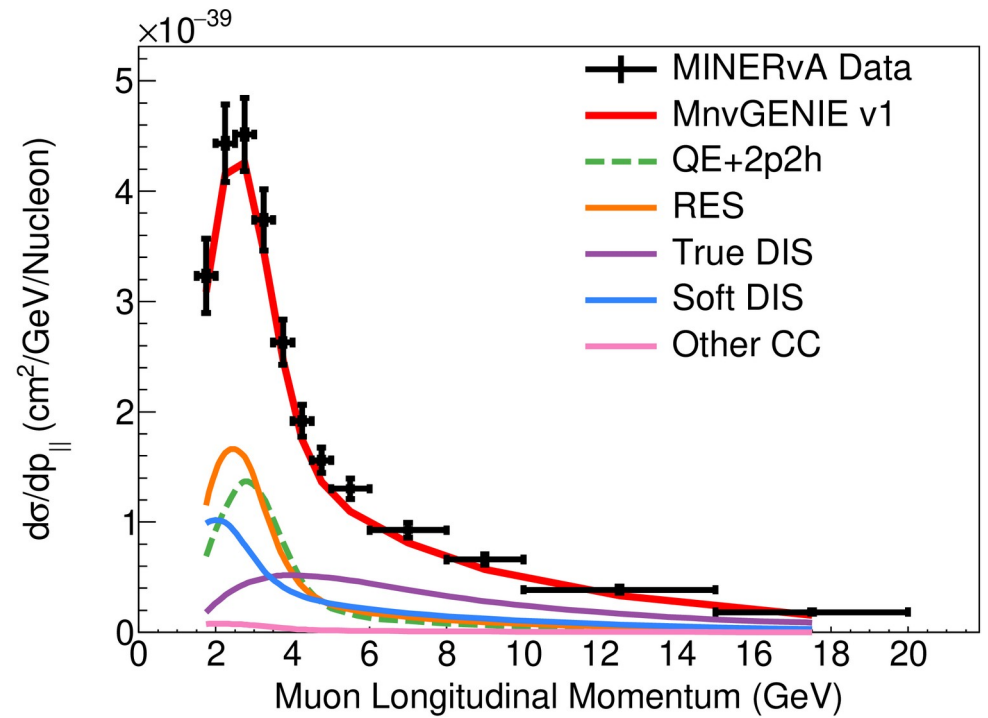
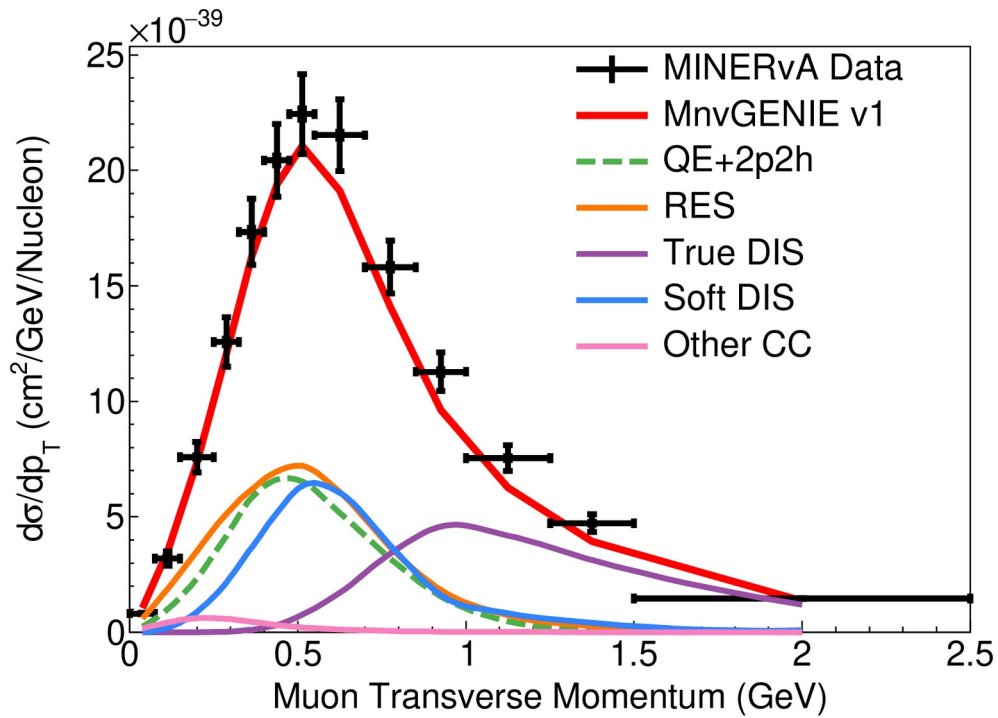
# Backup

# Low Energy cross section ratio



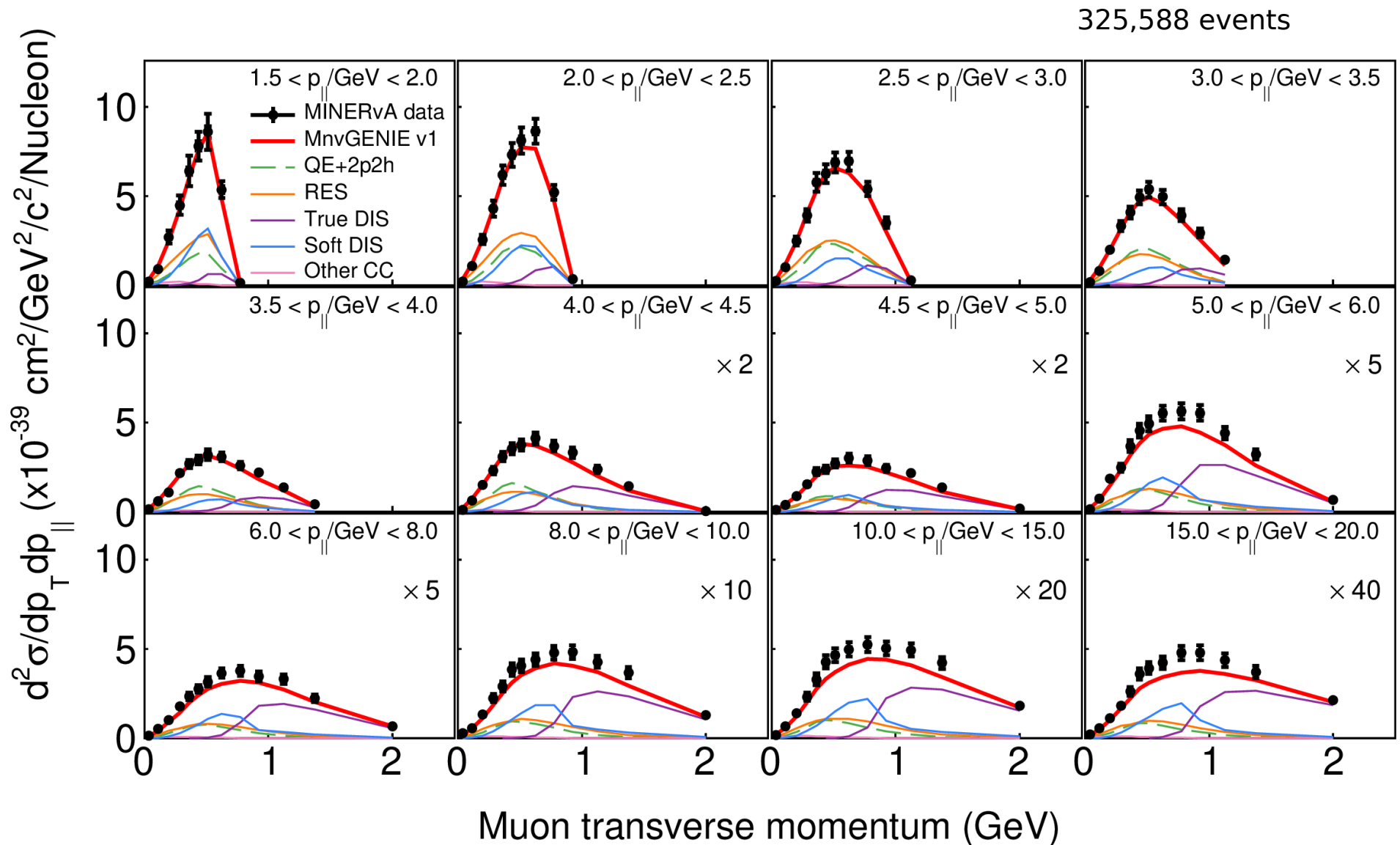


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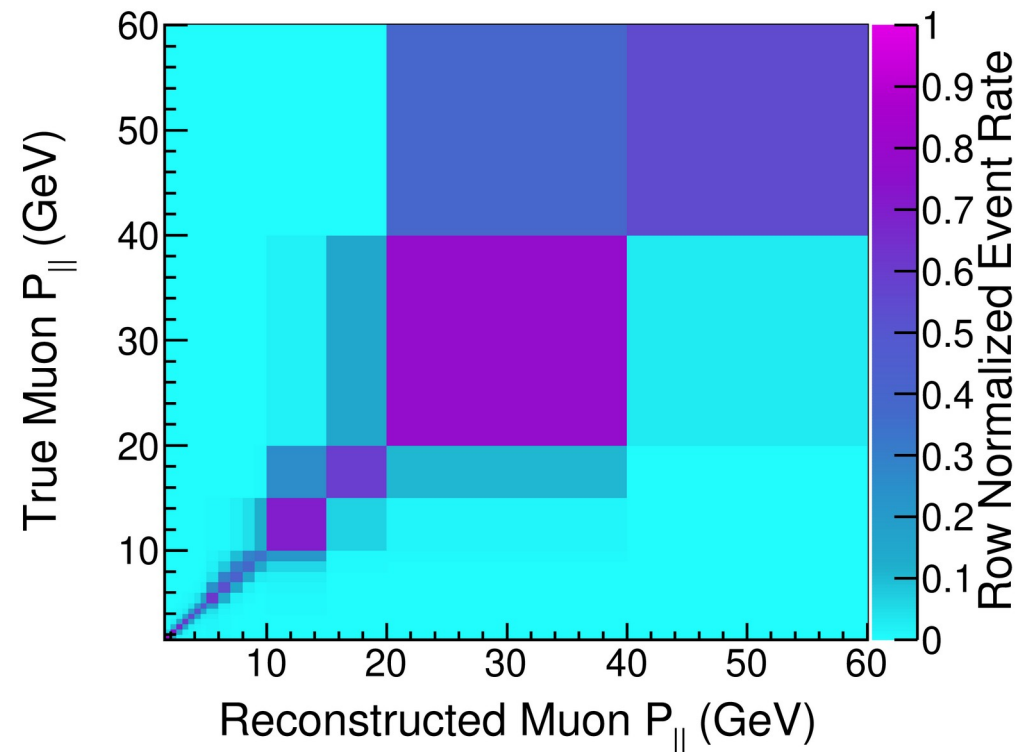
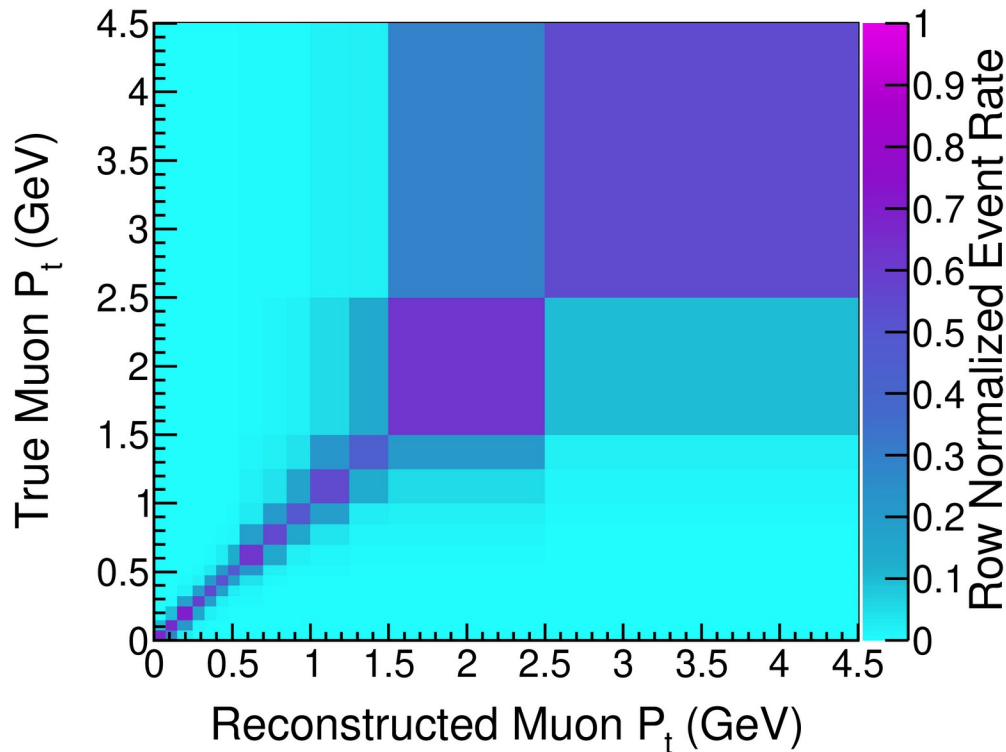




# Low Energy Double Differential Cross Section



# Preliminary ME Migration



- **Mostly diagonal**
- **There is more migration in the higher  $p_T$  and  $p_{||}$  bins**