

# Extracting an Anti Neutrino Charged Current Cross Section Measurement at MINERvA

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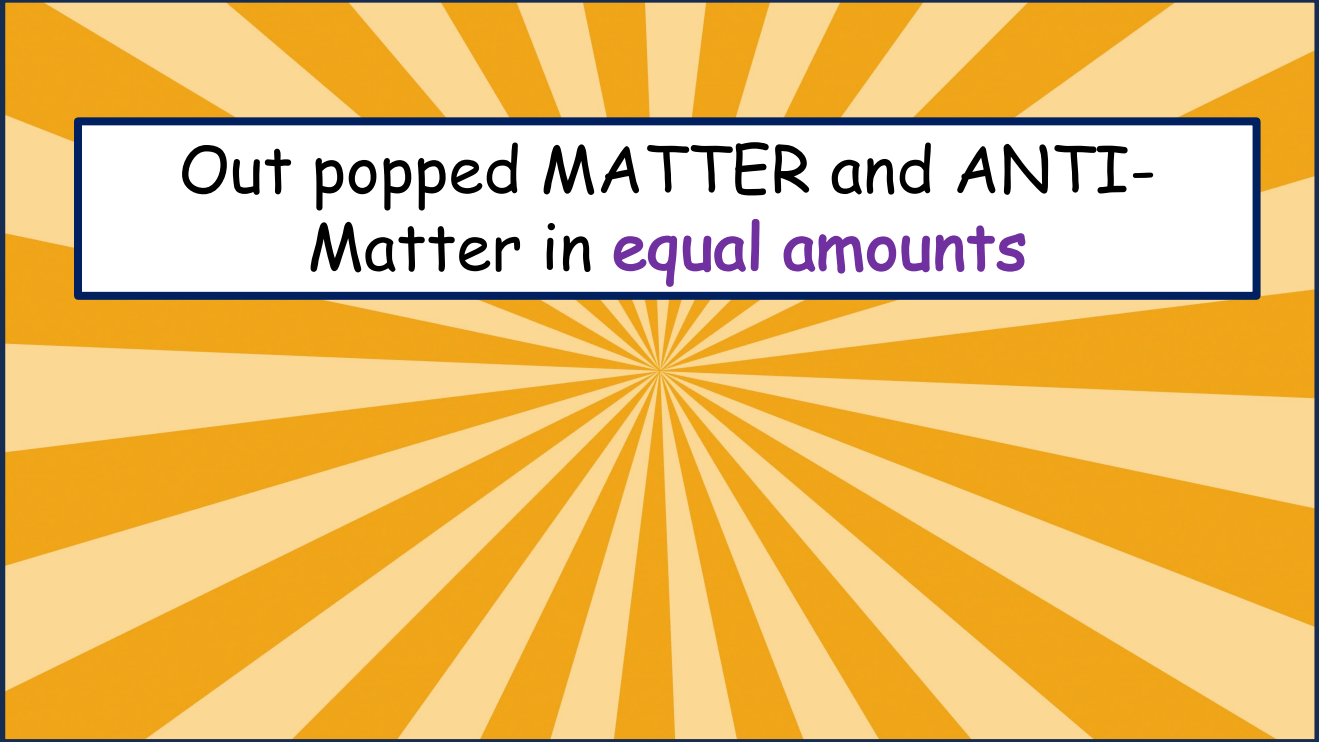


Once upon a time ...

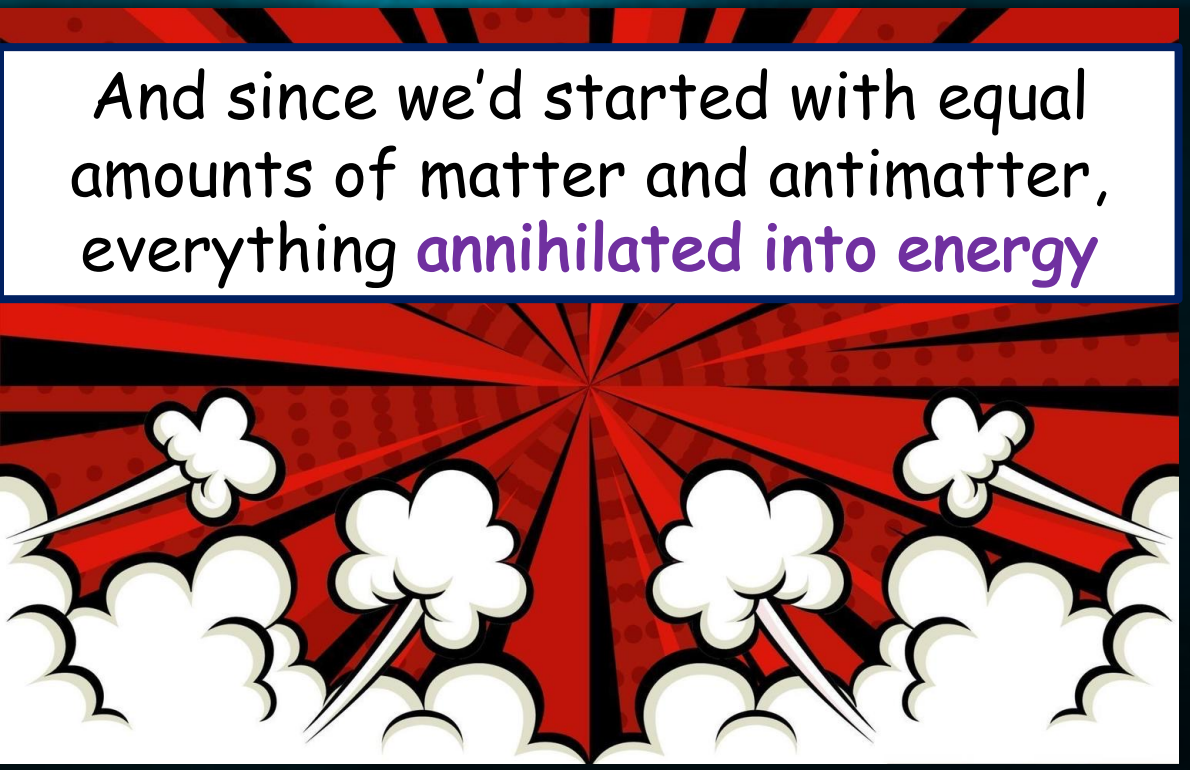
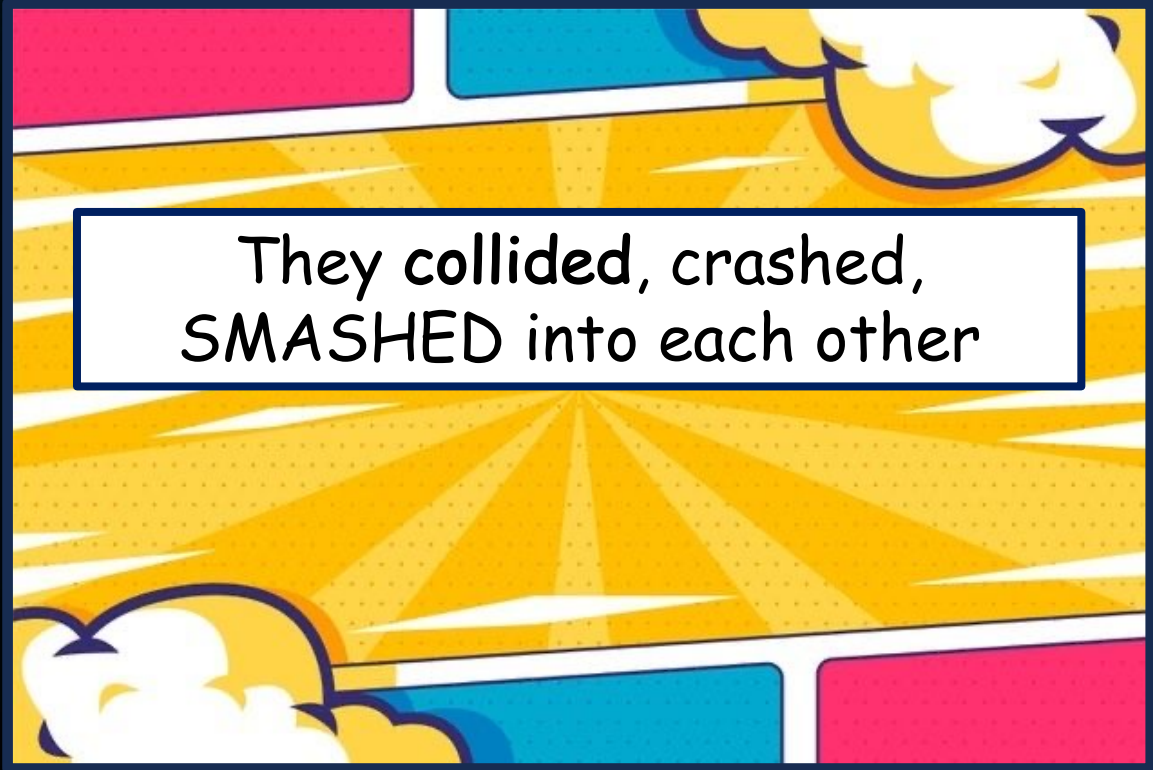
Once upon a time ...



Began the universe



Out popped MATTER and ANTI-Matter in **equal amounts**



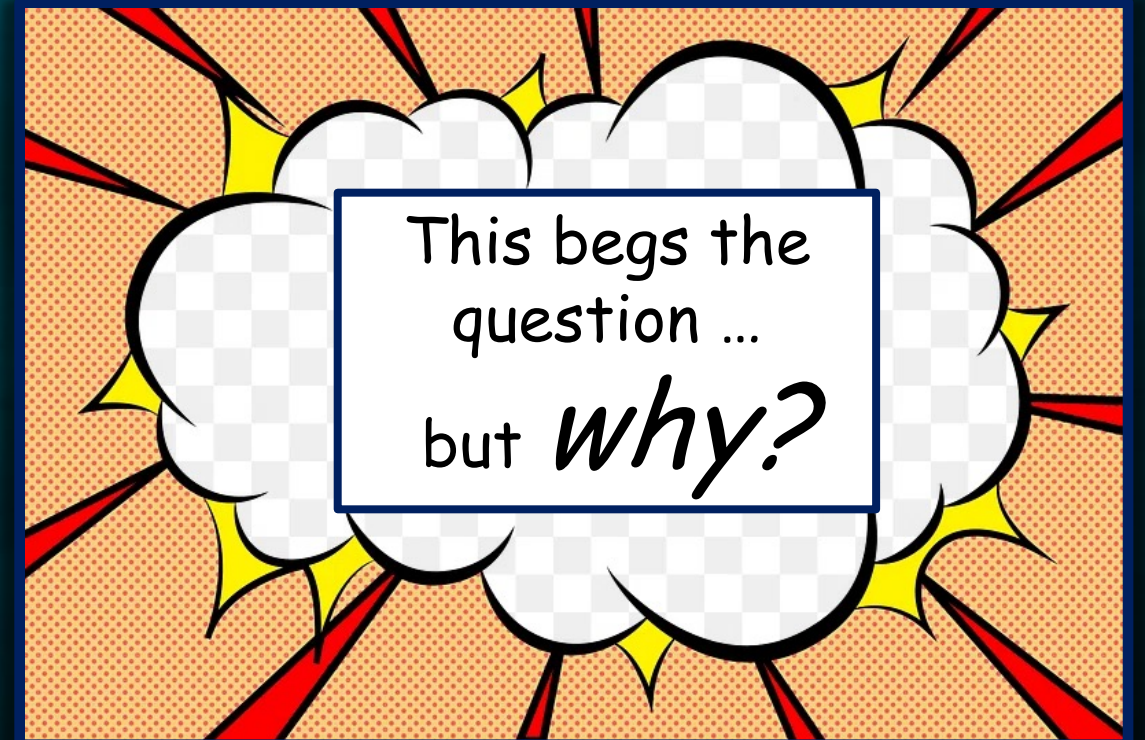
The End.

  
The end.

WRONG!

There is matter in  
the universe

# Picking sides ...



This is a pressing question in particle physics ... And neutrinos could perhaps help answer it.



# The Outline of this Talk



Neutrinos and  
the MINERvA  
Experiment

1.



What this  
analysis is  
about

2.



Steps for a  
cross section  
extraction

3.

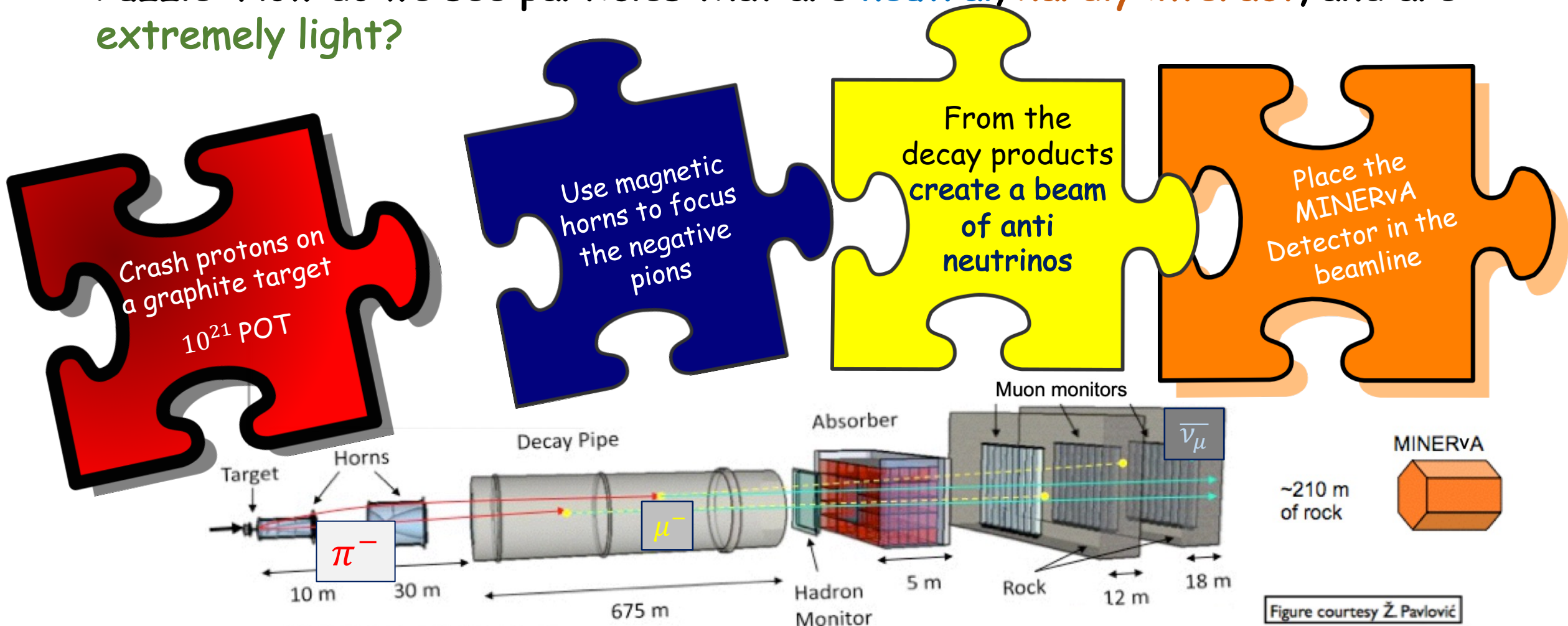


Conclusion

4.

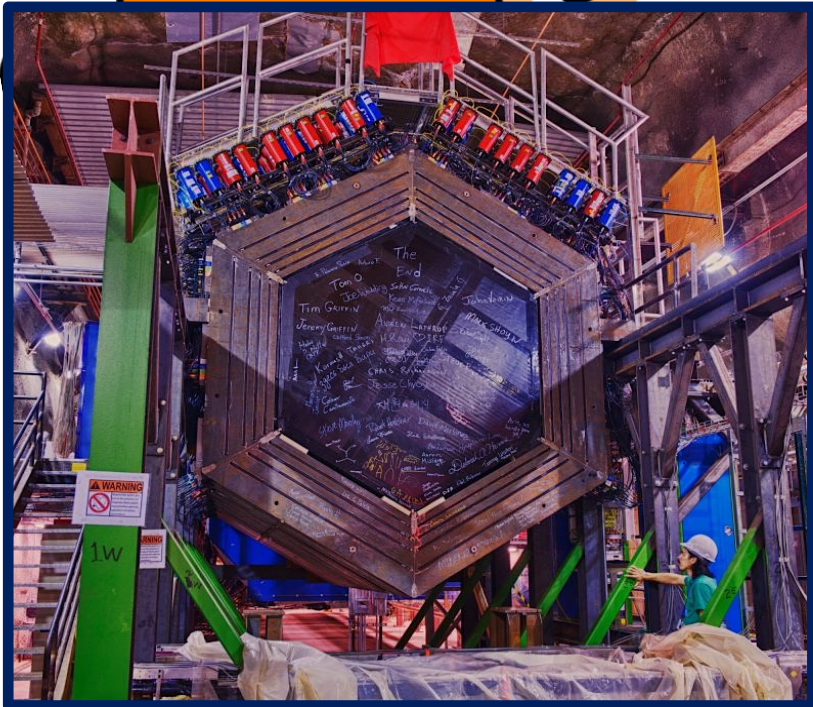
# 1. Neutrinos and the MINERvA Experiment

- Puzzle: How do we see particles that are **neutral**, **hardly interact**, and are **extremely light**?



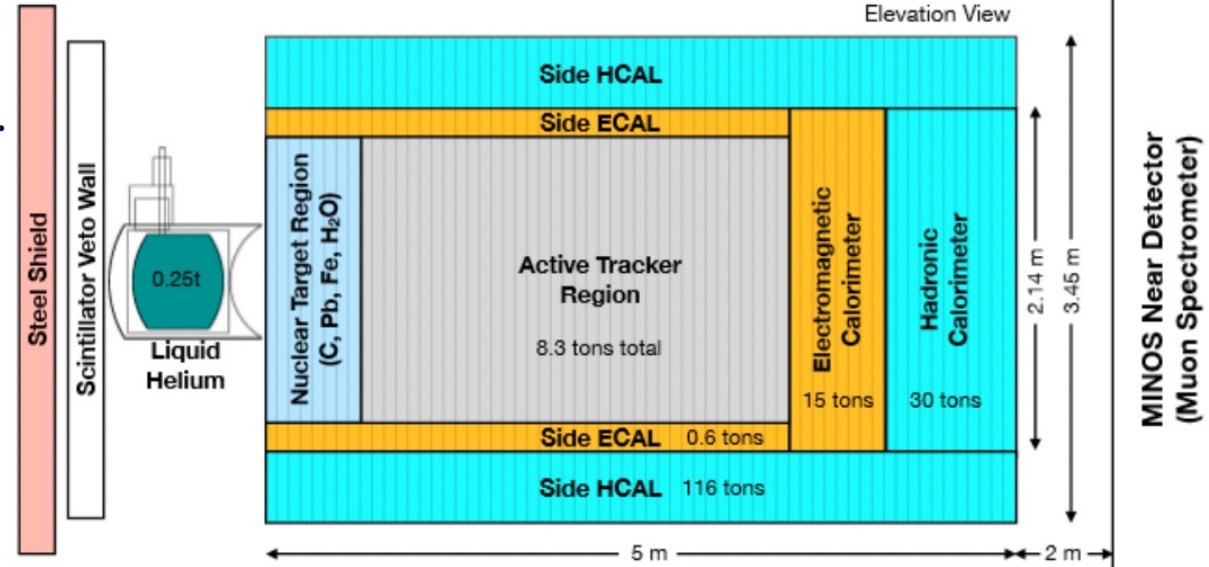
# 1. Anti Neutrinos and the MINERvA Experiment

Place the MINERvA Detector in the beamline

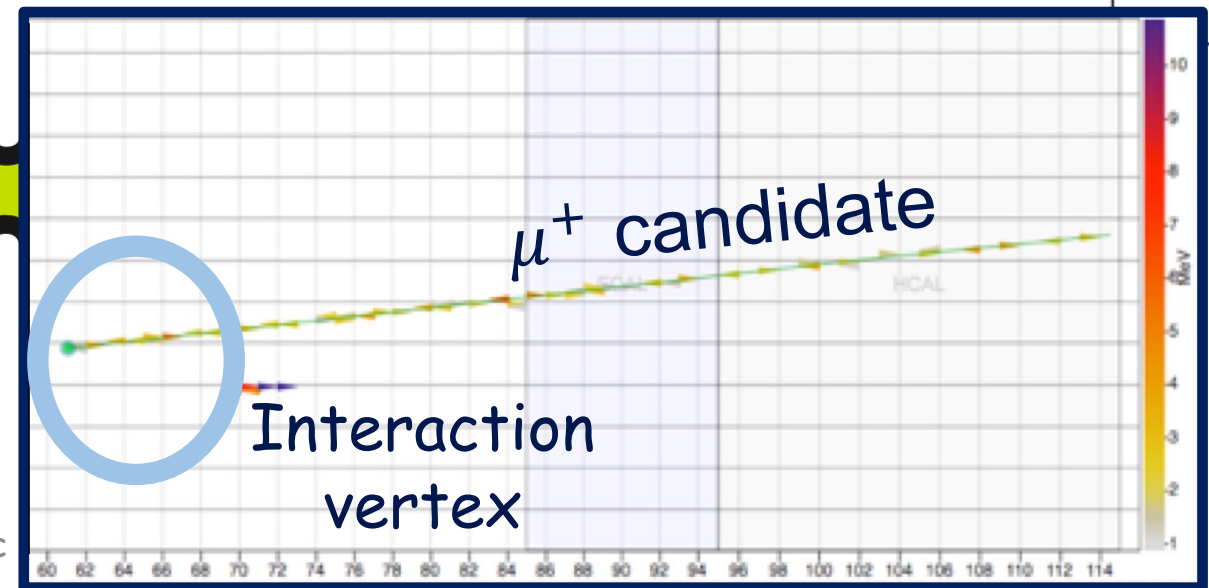


The MINERvA Detector, front face view of module

The MINERvA detector sideview. Segmented with target planes and interspersed with scintillator planes



Use energy deposits in the detector to reconstruct events



# 1. Anti Neutrinos and the MINERvA Experiment

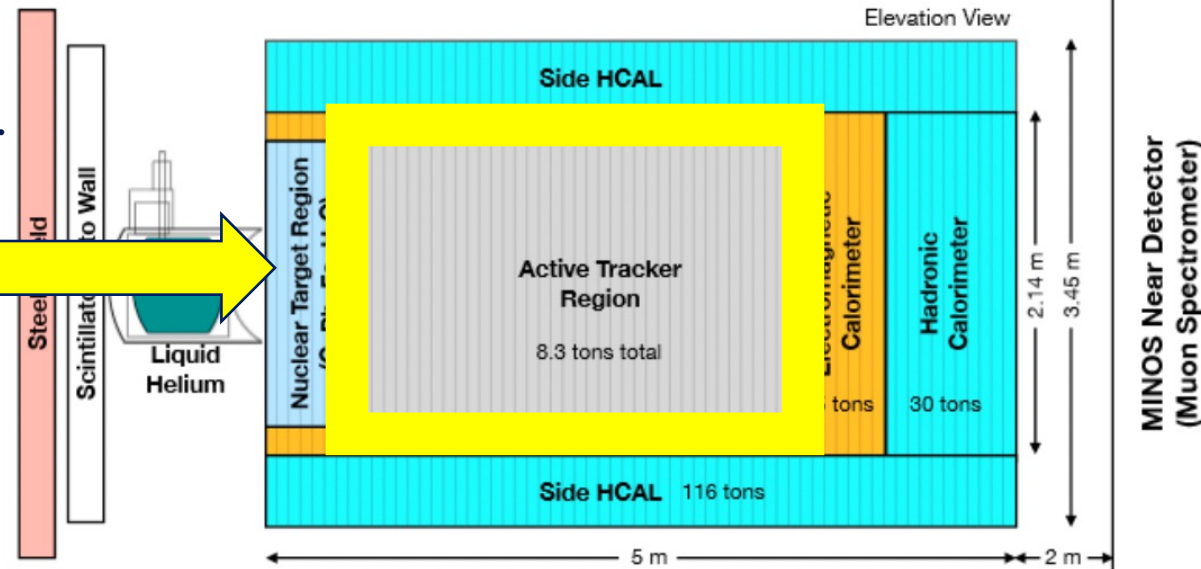
Place the MINERvA Detector on beam

This is the tracker

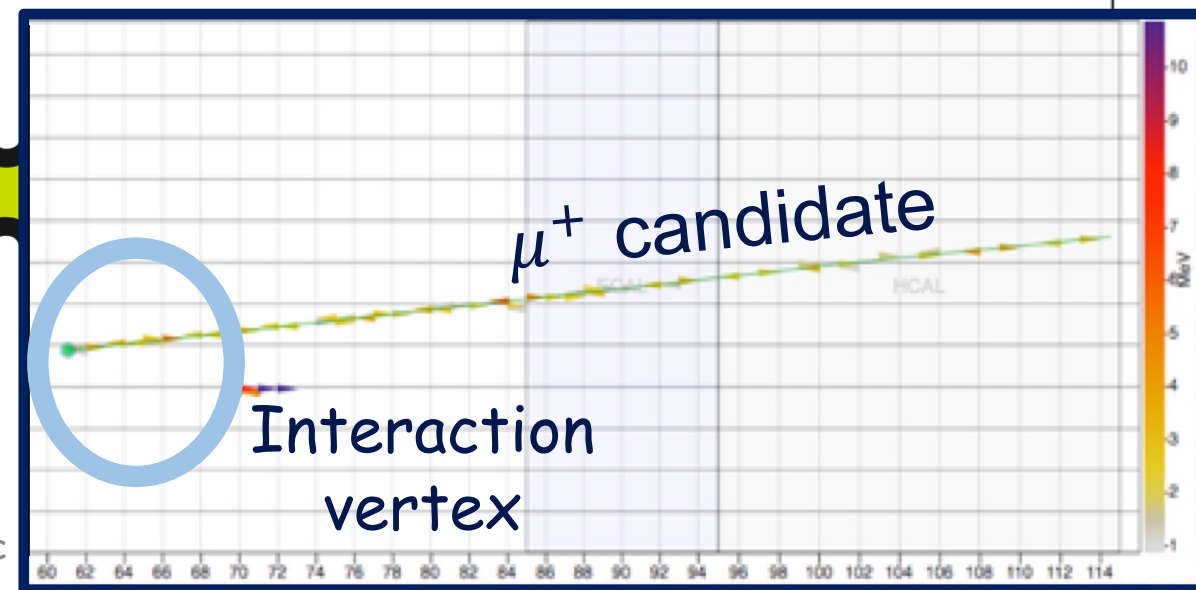


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The MINERvA detector sideview, segmented with target planes and interspersed with scintillator planes



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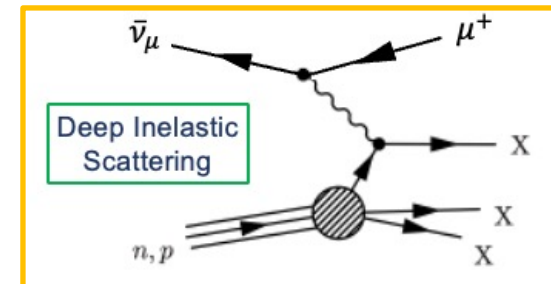
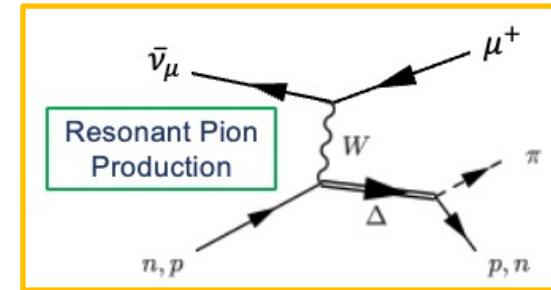
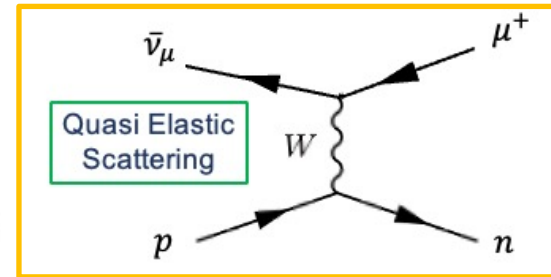
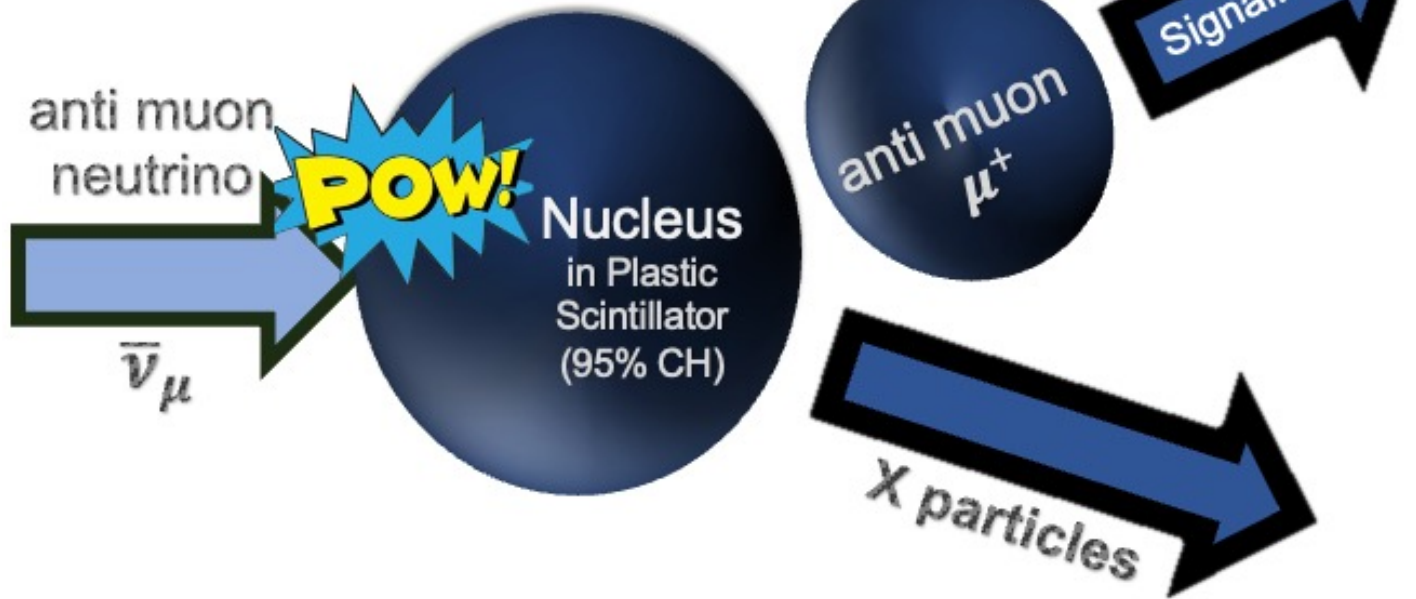
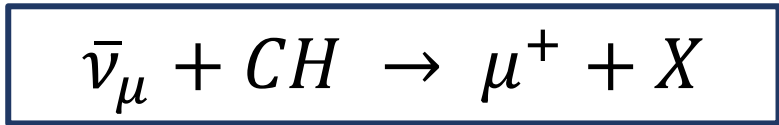
## 2. What is this analysis about?

### Definition

**Cross Section:** A measure of the probability of an interaction occurring

# 2. What is this analysis about?

- Goal: Extract a 2D **cross section** in the tracker in terms of muon transverse and longitudinal momenta

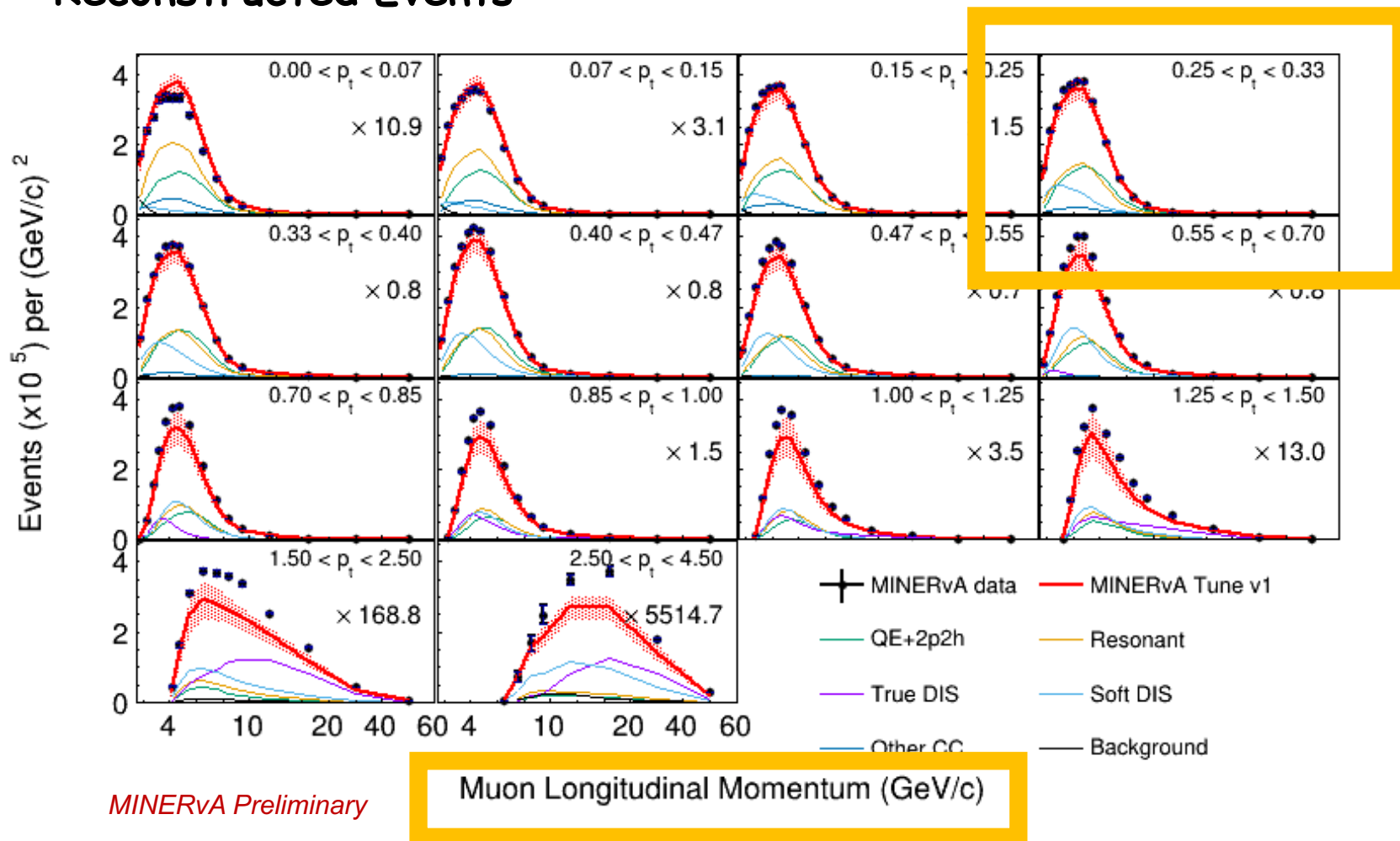


Different amounts of energy and momentum transferred to nucleus.

All interactions that produce an anti muon are considered signal!

# 2. What is this analysis about?

- Reconstructed Events



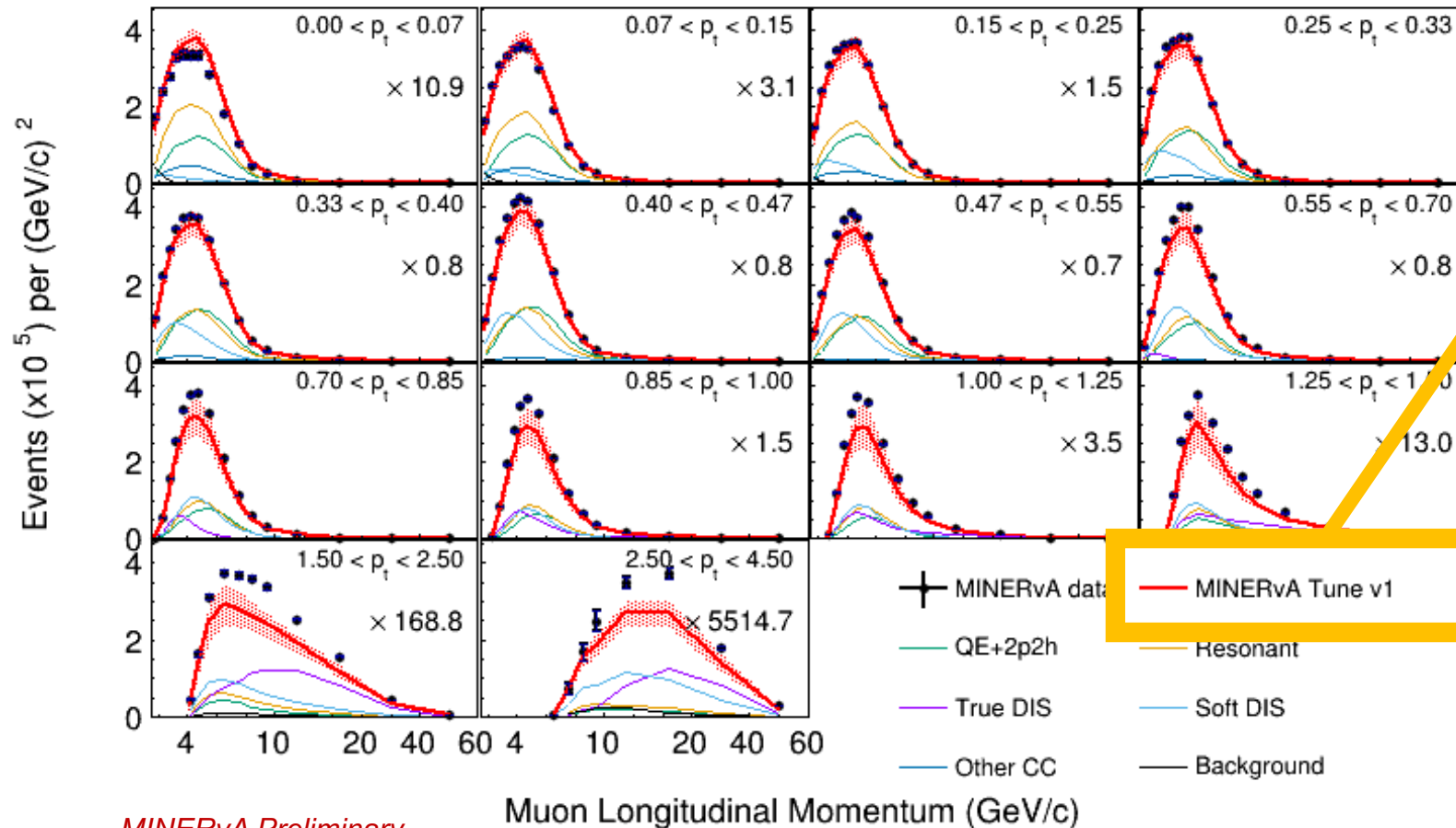
Example of  
 $p_t$  bin on the  
PANEL PLOT!

2D analysis in terms of  
transverse and  
longitudinal muon  
momenta

MINERvA Preliminary

# 2. What is this analysis about?

- Reconstructed Events



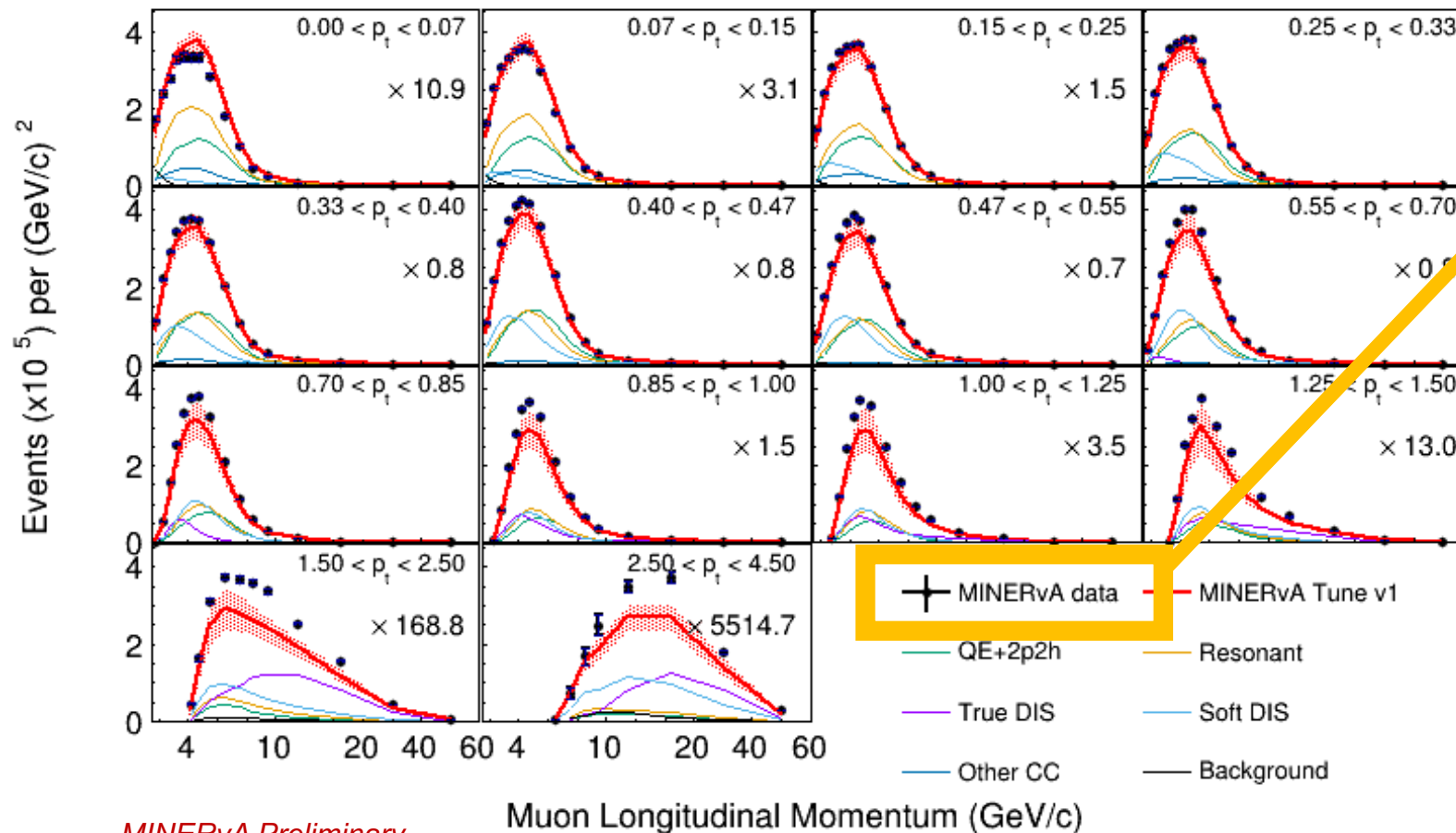
Collection of models used to generate events, same models will be used to predict the xsec

MINERvA Preliminary



# 2. What is this analysis about?

- Reconstructed Events



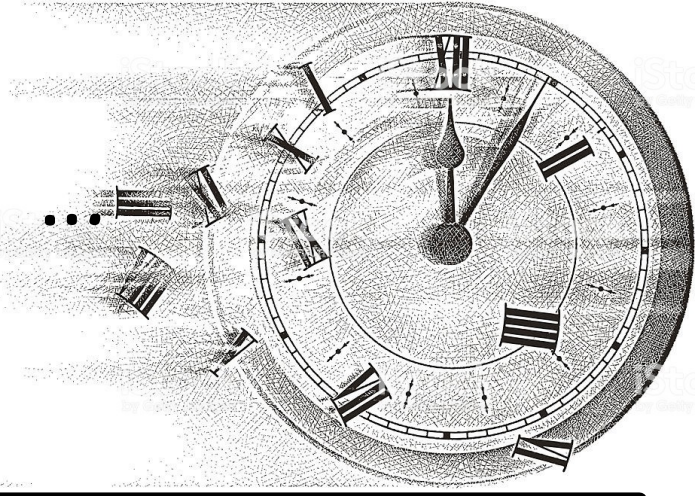
**1.8 million**  
data events  
reconstructed

MINERvA Preliminary

### 3. Steps for a Cross Section Extraction

$$\left(\frac{d^2\sigma}{dx dy}\right)_\alpha = \frac{\sum_j U_{j\alpha}(N_{data,j} - N_{data,j}^{bkgd})}{A_\alpha(\Phi T)(\Delta x)(\Delta y)}$$

Time to take a trip back in time to ...



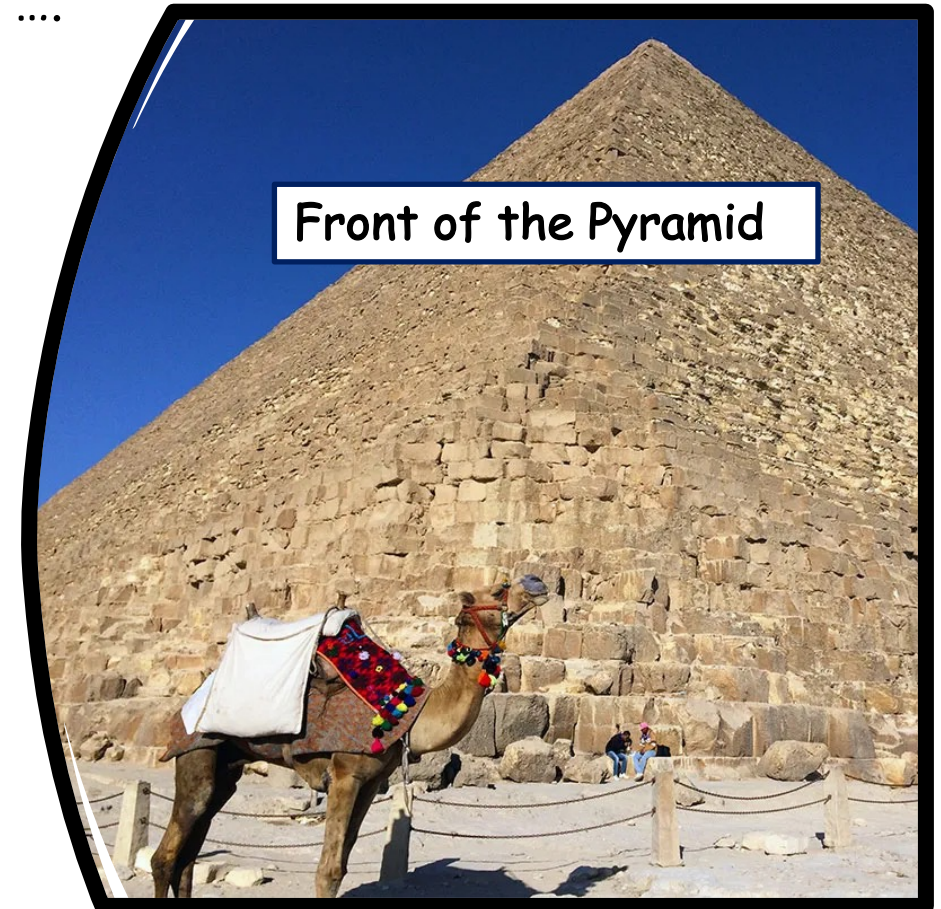
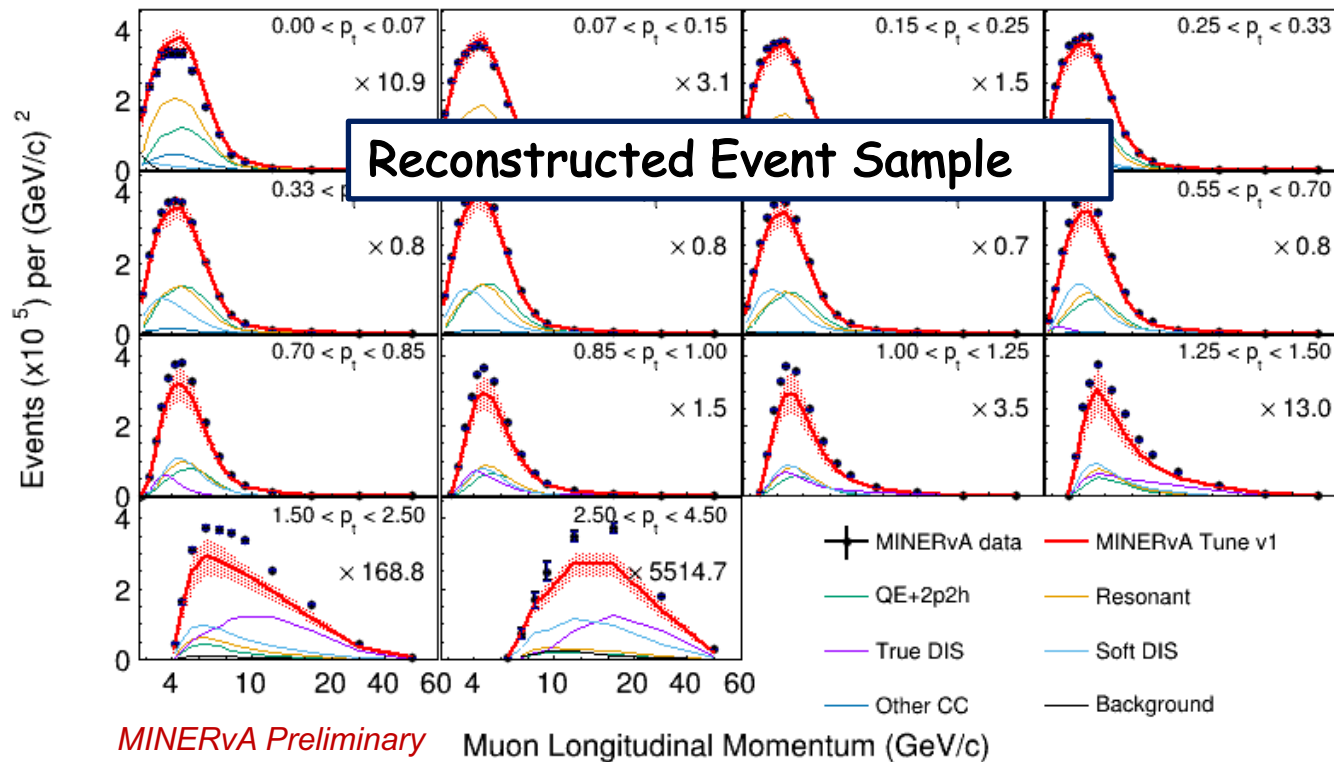
## Ancient Egypt

- Ancient Egyptians built pyramids to house the tombs of pharaohs
- Deep inside the pyramid, there was the Pharaoh's burial chamber which was loaded with riches and treasures
- The pyramid was designed to secure the Pharaoh's chamber



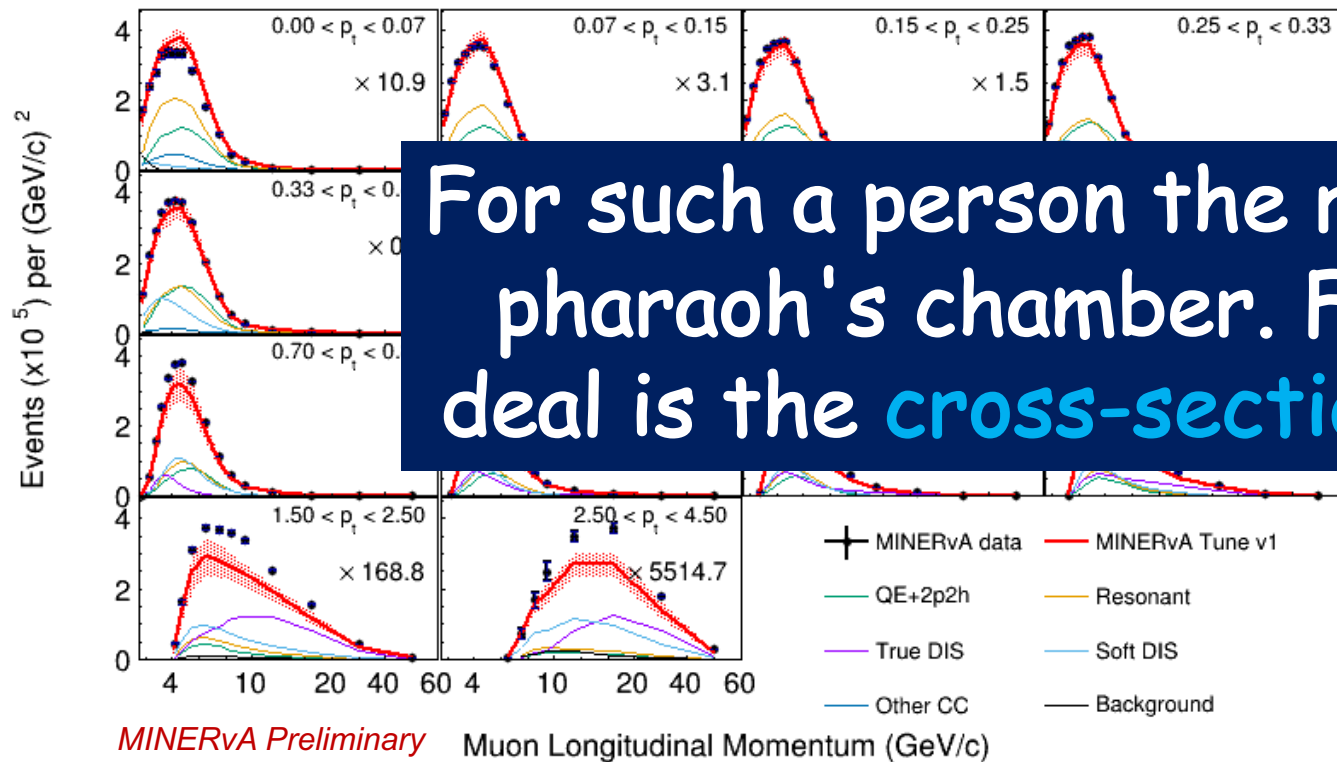
# 3. Cross Section Extraction

For someone who wants to make it to the Pharaoh's chamber, having the reconstructed events distribution is like making it to the front of the pyramid ....



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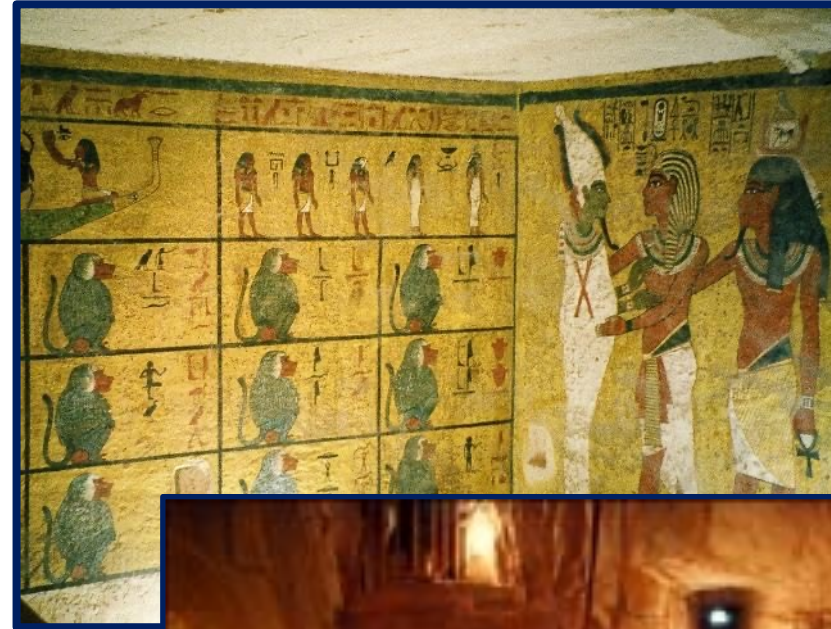
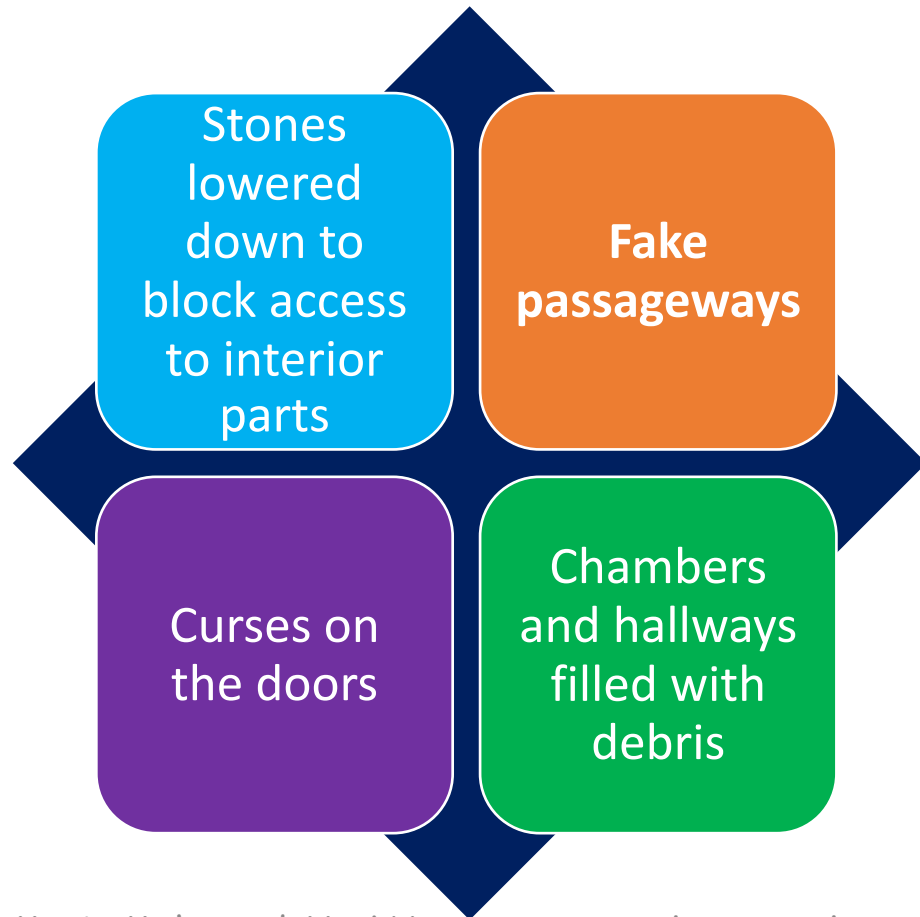


For such a person the real deal was the pharaoh's chamber. For us, the real deal is the **cross-section measurement**



# 3. Cross Section Extraction

To make it to the Pharaoh's chamber:  
needed to overcome **obstacles**



# 3. Cross Section Extraction

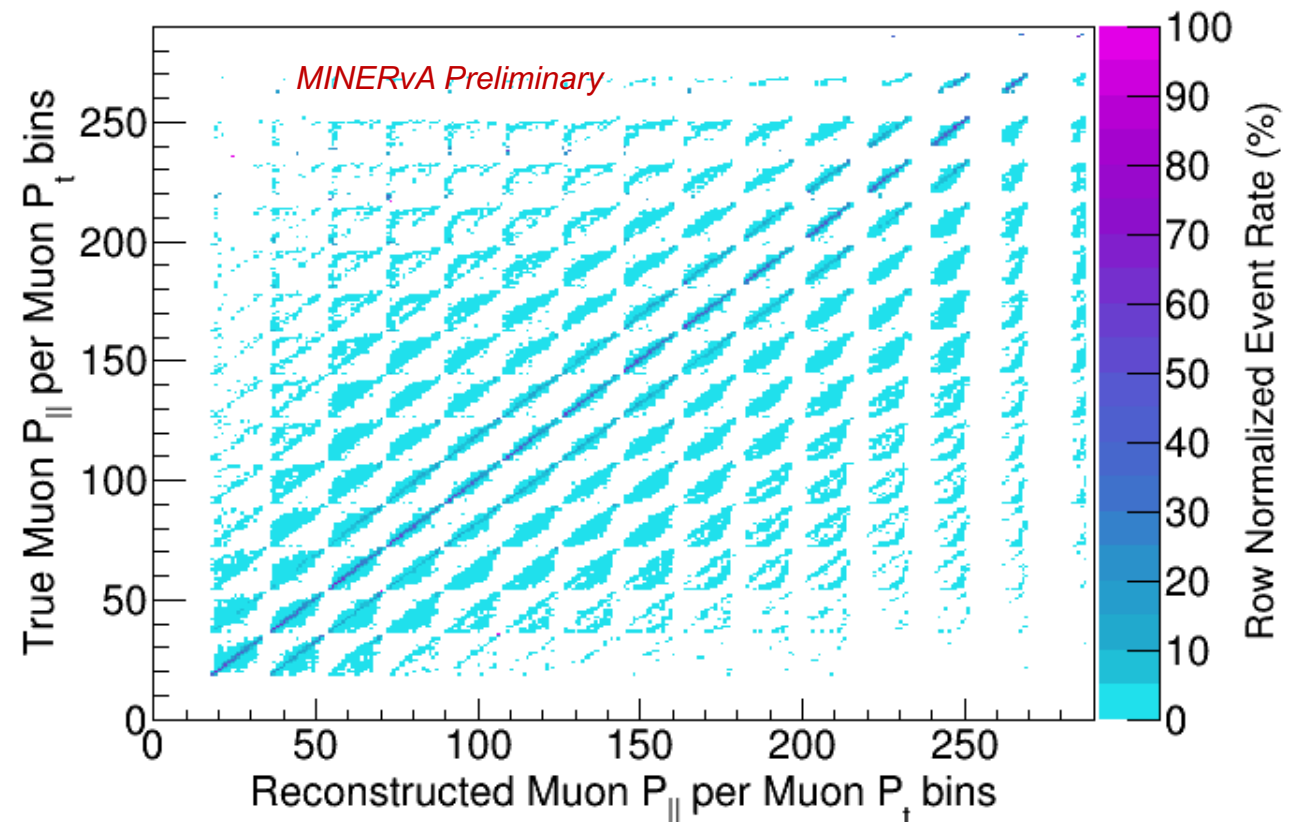
To make a cross section measurement: **need to account for different effects**

## 1. Background Subtract

$$\left(\frac{d^2\sigma}{dxdy}\right)_\alpha = \frac{\sum_j U_{j\alpha}(N_{data,j} - N_{data,j}^{bkgd})}{A_\alpha(\Phi T)(\Delta x)(\Delta y)}$$

## 2. Correct for events that go reconstructed in the wrong bin

$$\left(\frac{d^2\sigma}{dxdy}\right)_\alpha = \frac{\sum_j U_{j\alpha}(N_{data,j} - N_{data,j}^{bkgd})}{A_\alpha(\Phi T)(\Delta x)(\Delta y)}$$



# 3. Cross Section Extraction

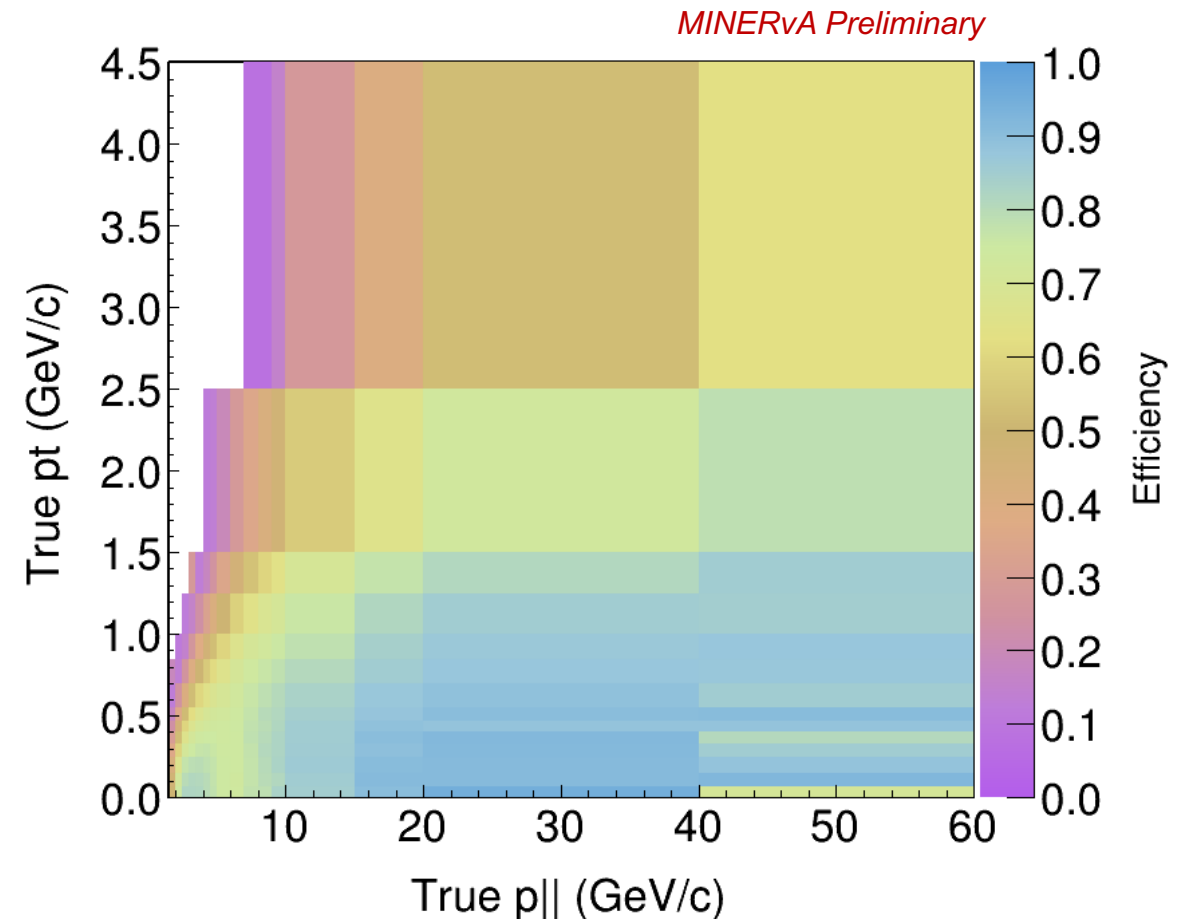
To make a cross section measurement: **need to account for different effects**

3. **Correct for events that didn't get reconstructed at all (Efficiency correct)**

$$\left(\frac{d^2\sigma}{dx dy}\right)_\alpha = \frac{\sum_j U_{j\alpha}(N_{data,j} - N_{data,j}^{bkgd})}{A_\alpha(\Phi T)(\Delta x)(\Delta y)}$$

4. **Normalize by the flux and the # of targets**

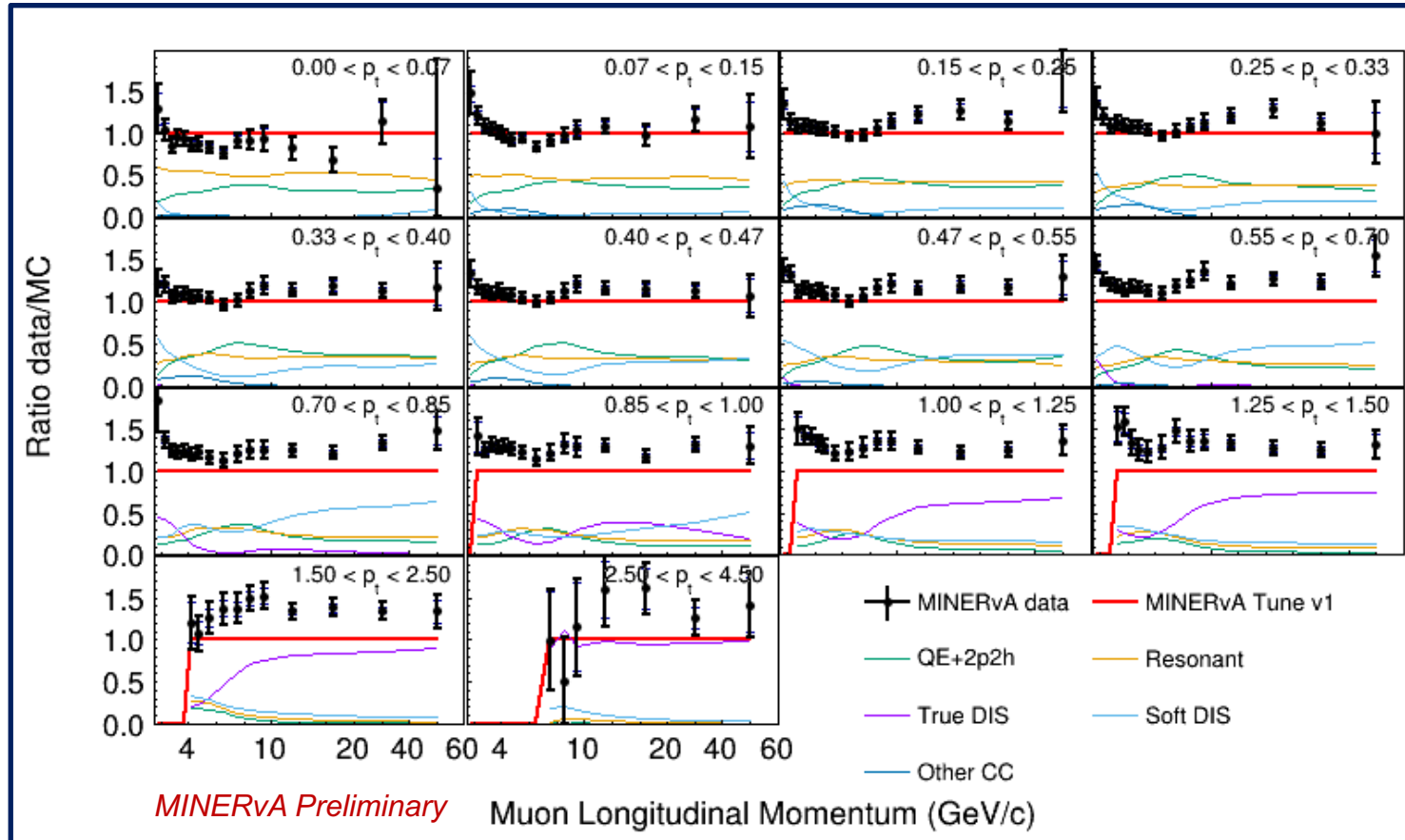
$$\left(\frac{d^2\sigma}{dx dy}\right)_\alpha = \frac{\sum_j U_{j\alpha}(N_{data,j} - N_{data,j}^{bkgd})}{A_\alpha(\Phi T)(\Delta x)(\Delta y)}$$



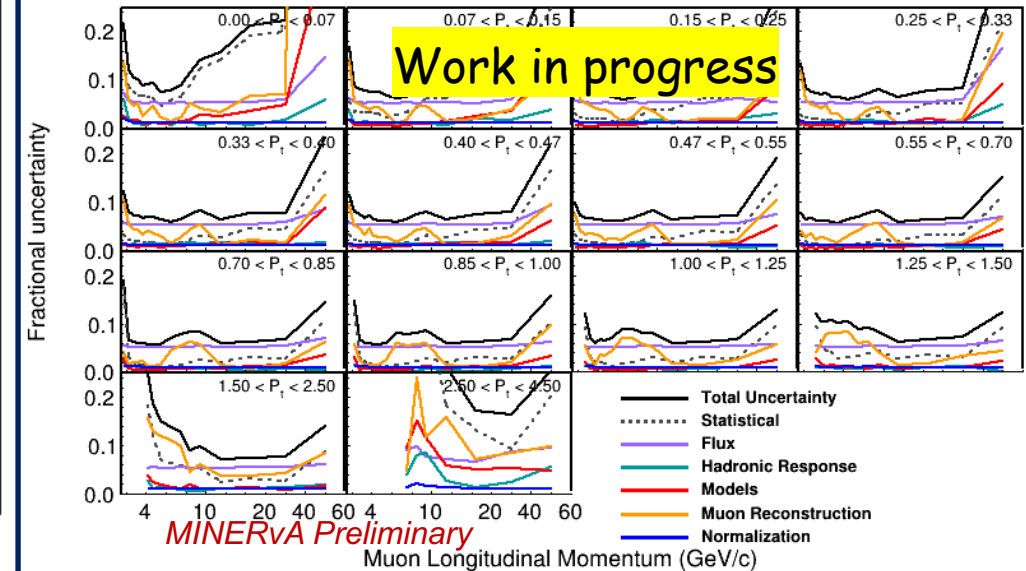


# 3. Cross Section Extraction

- Extracted cross section measurement: Ratio of data/prediction



Breakdown of uncertainty on the data xsec

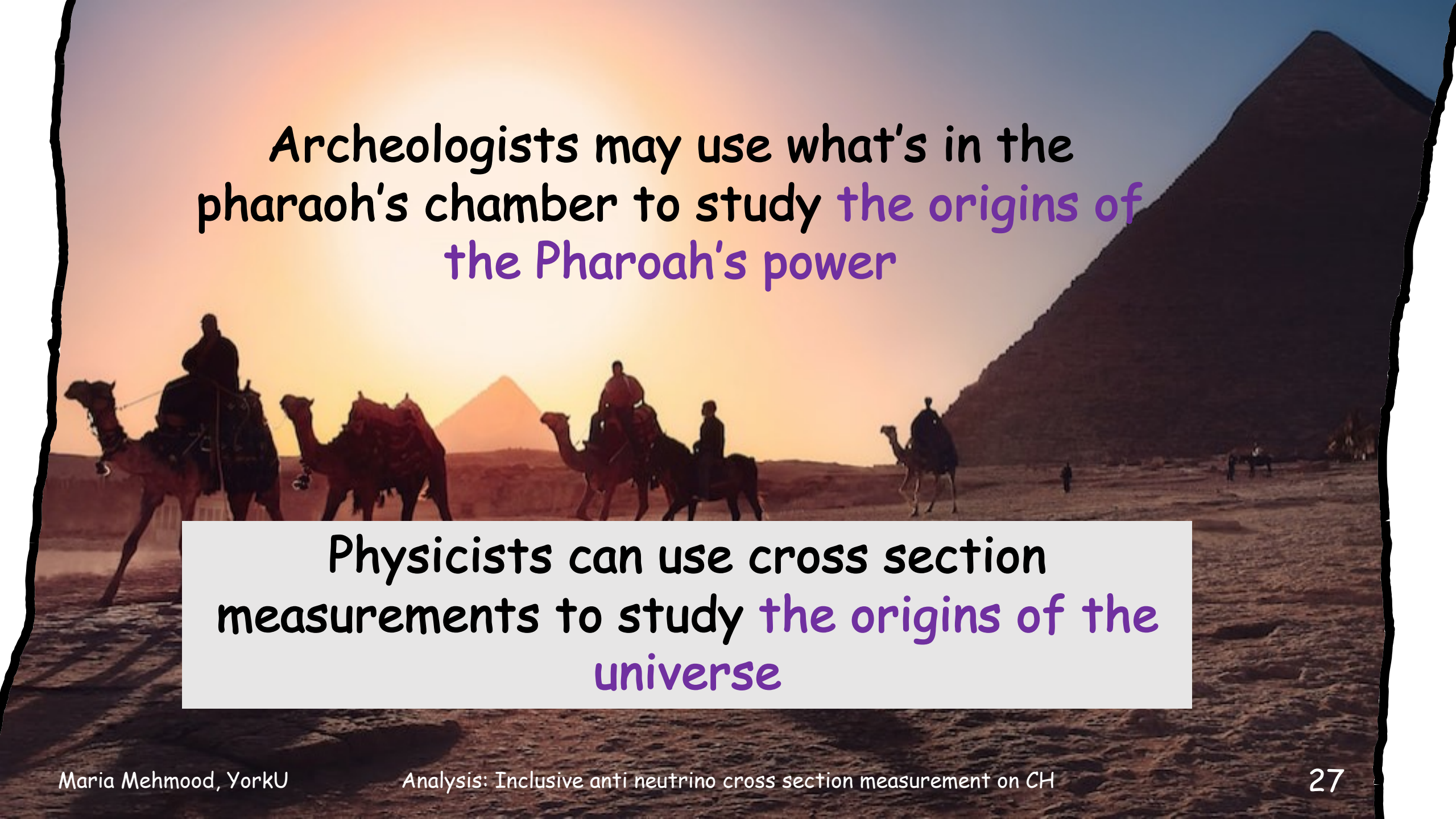


- This is a measurement that has not been made before
- Can be used to improve cross section models where the data/prediction isn't 1

# 4. Conclusion

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- Cross section models can be improved with this measurement
- Models for both anti-neutrino and neutrino cross sections are needed as neutrinos oscillation experiments need to translate the number of events that they see at a far detector to some incoming anti-neutrino (neutrino) flux
- Studying neutrino/antineutrino oscillation differences may help us understand why matter dominates the universe



Archeologists may use what's in the pharaoh's chamber to study the origins of the Pharaoh's power

Physicists can use cross section measurements to study the origins of the universe

Backup