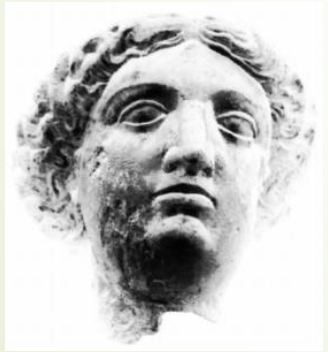
Neutrino-Nucleus Deep Inelastic Scattering Interaction at MINERvA



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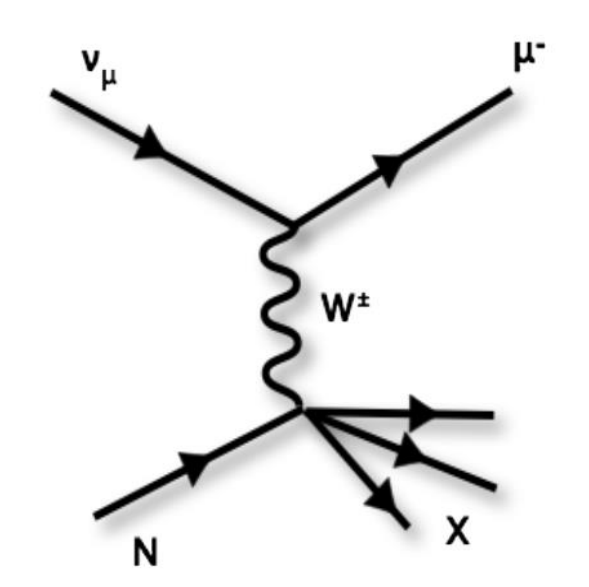
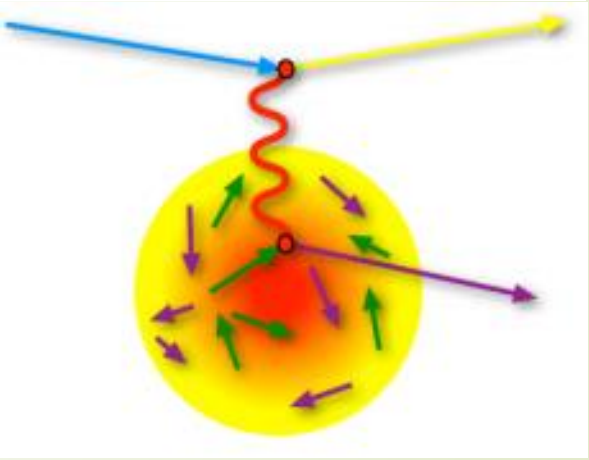
What is Deep Inelastic Scattering?

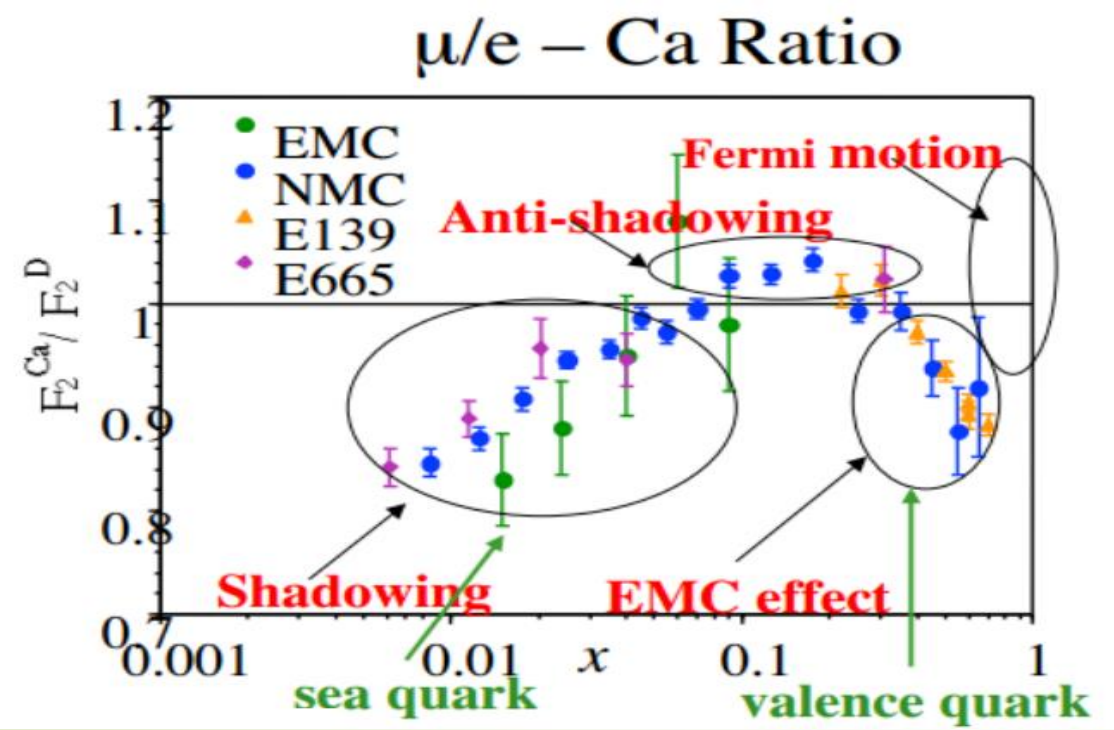
- DIS: scattering of a neutrino with a quark "deep" (high momentum transfer, Q^2) inside a nucleon at high energy which destroy the nucleon (high W).



- Neutrino cross section is very small, need heavy targets.
- **Complication:** correlations between nucleons affect event rate/kinematics of neutrino interaction.
  - Nuclear Effects



Motivation



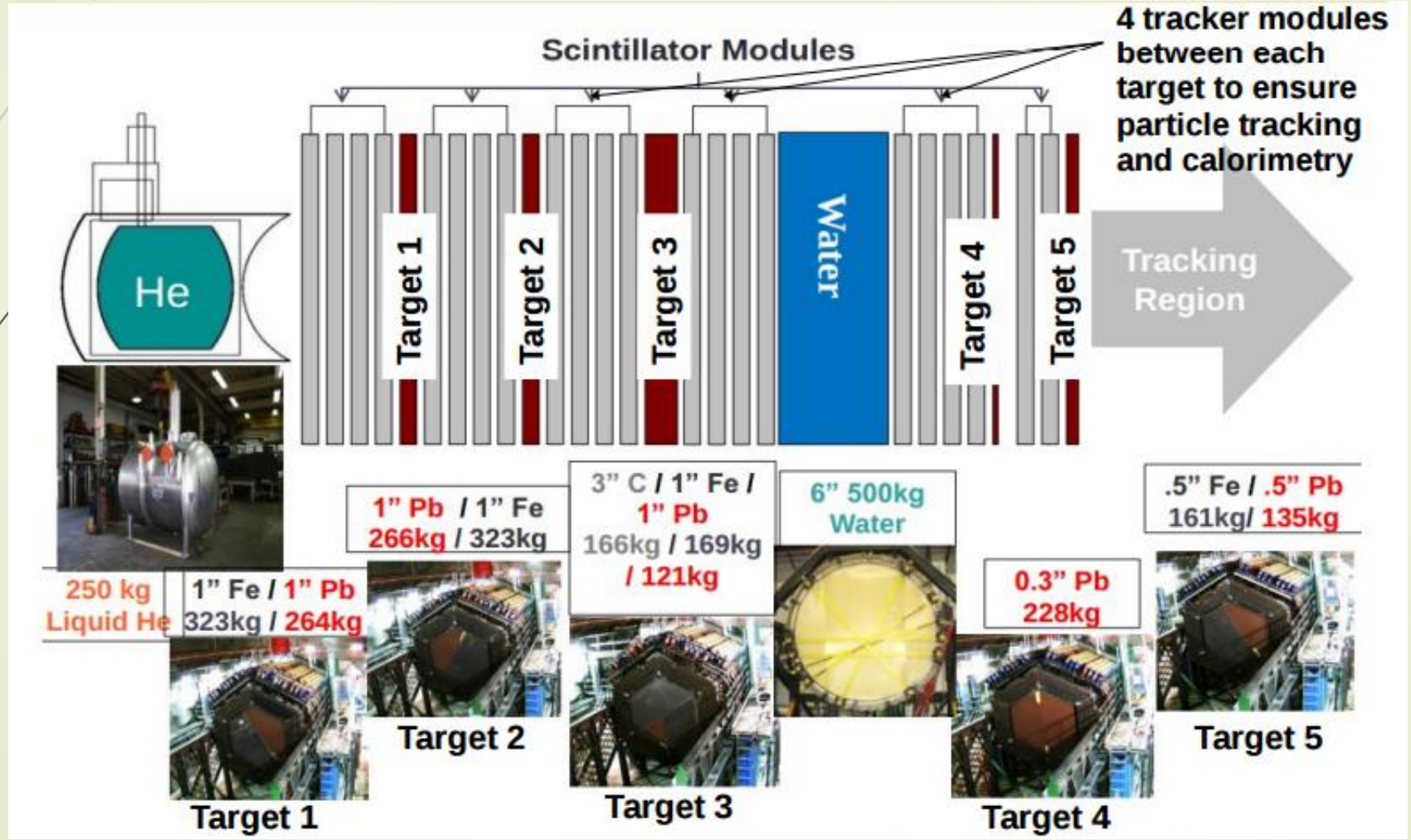
EMC: European Muon Collaboration.
First experiment to discover this effect

$$x = \frac{Q^2}{2M\nu}$$

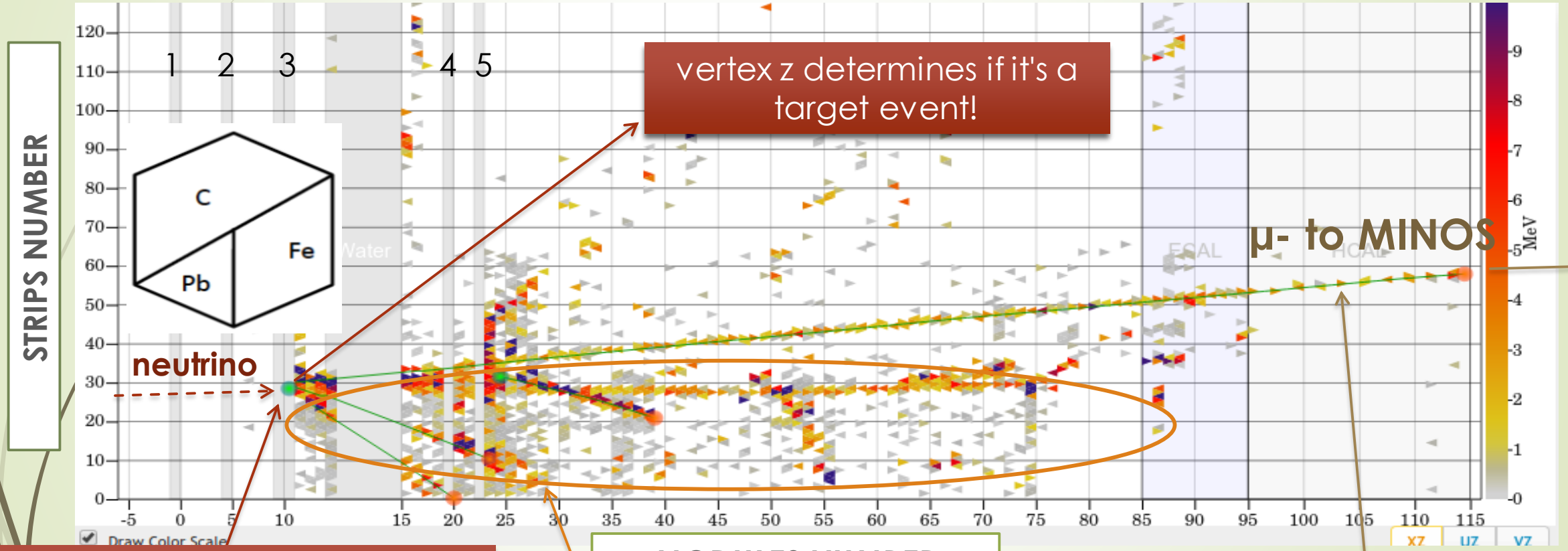
: Bjorken x, scaling of the parton structure

- Nuclear effects still not well understood in neutrino physics.
- We adapt nuclear effects from electron scattering into neutrino scattering.
- Neutrino-nucleus DIS data can tell us:
  - if neutrino nuclear effects is different to charged lepton.
  - if we have modelled the nuclear effects correctly.

MINERvA Takes Data on Many Different Targets, Simultaneously!

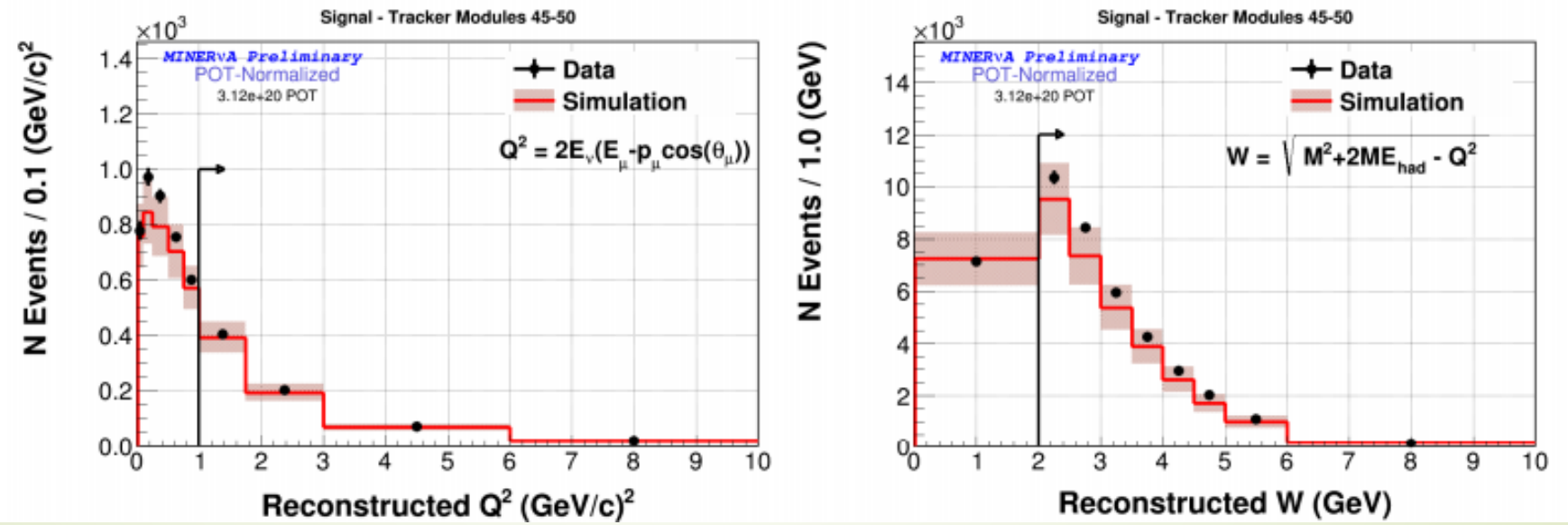


Charged Current (CC) Inclusive Event - Nuclear Target 3



From Inclusive to DIS

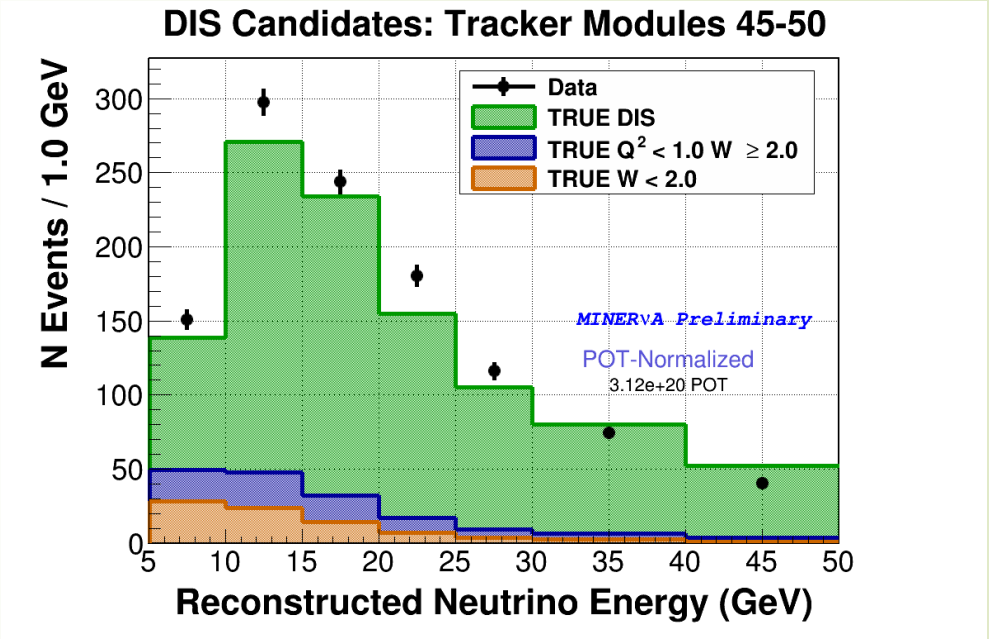
- Select inclusive events with $Q^2 > 1$ GeV/c2 and $W > 2$ GeV to get DIS sample.
- This allows for:
  - Enough momentum transfer (Q^2) to see nucleon structure, with a wavelength or resolving power: $\lambda = \hbar/\sqrt{Q^2}$
  - Enough invariant hadronic mass (W) to get us safely above resonance region.



J. Mousseau, NuInt. November 2015

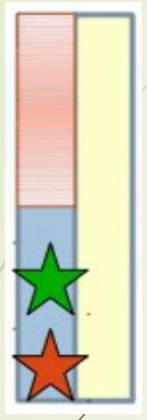
First Background: non-DIS

- **DIS Signal:** true $Q^2 > 1$ and true $W > 2$.
- **DIS Background:** true $Q^2 < 1.0$ (GeV/c)2 and $W < 2.0$ (GeV/c).
- Use background as sideband to predict how many events with low Q^2 and low W are in the data.
- Scale factor are summed per material: C, Fe, Pb, CH.

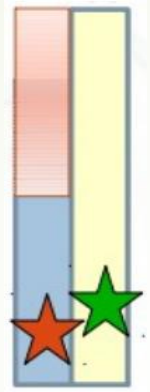


J. Mousseau, NuInt. November 2015

Second Background – Plastic



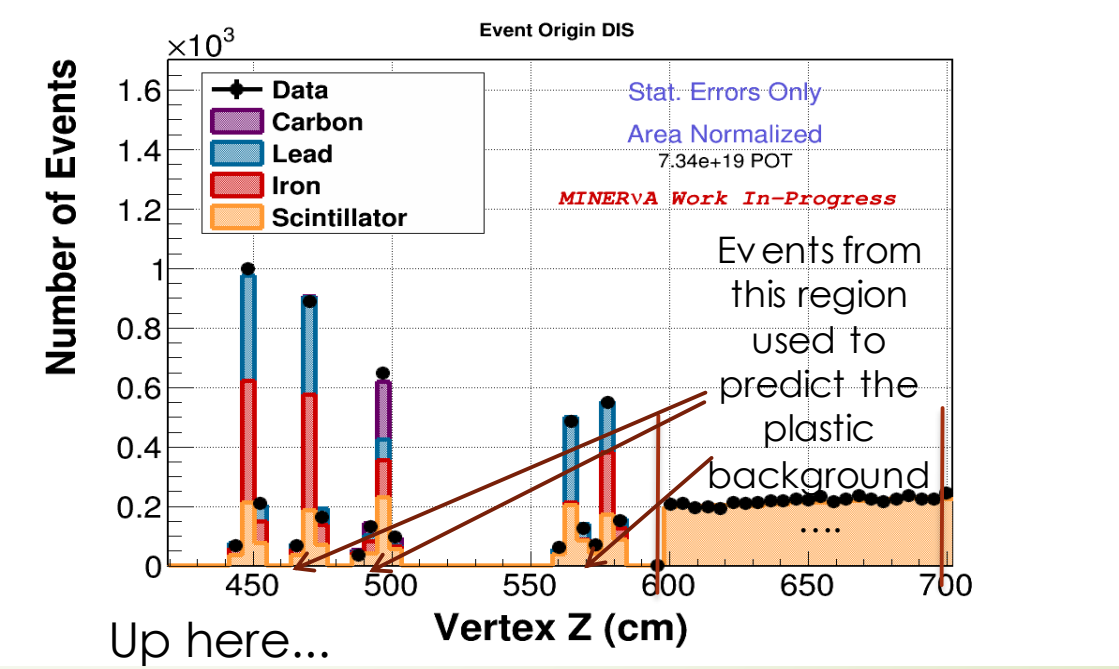
Signal:
True vertex is in iron, AND reconstructed in iron



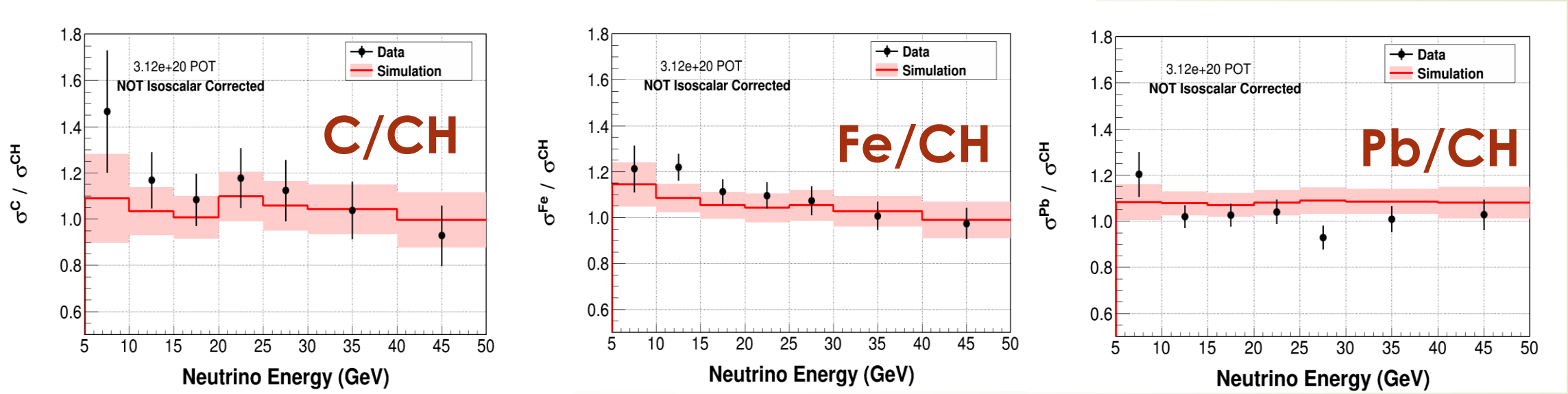
Background:
True vertex is in scintillator, BUT reconstructed in iron

Event selection allows some contamination from plastic surrounding passive targets.

Correct the weight of plastic background based on their geometrical acceptance to MINOS (Eμ, ϴμ)



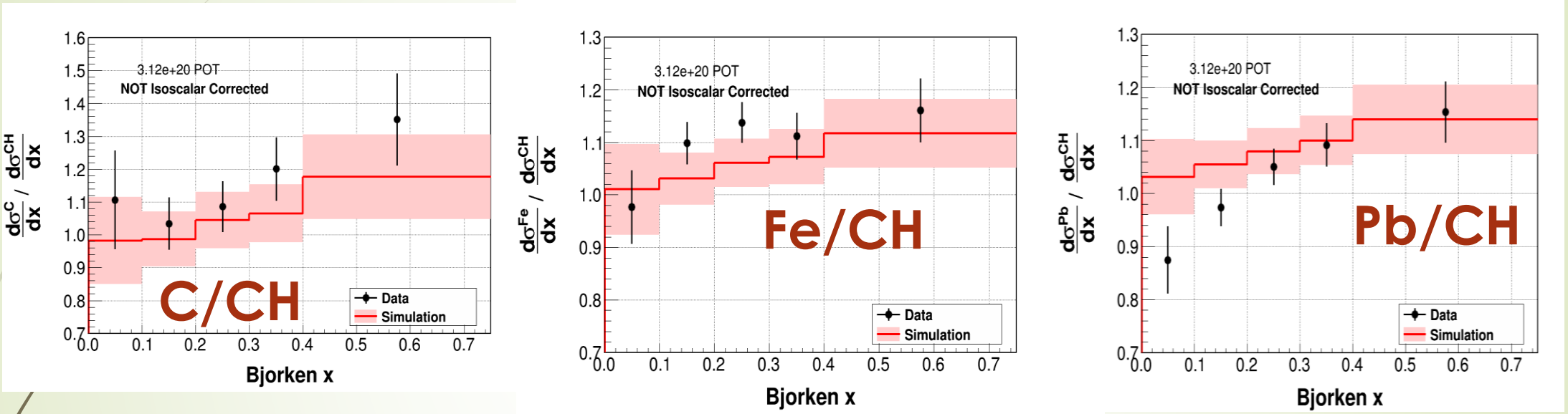
Total Cross Section Ratio Results



- Results are shown for the deeply inelastic events in C, Fe, Pb and CH.
- We measured ratios of cross sections to reduce systematic errors from the neutrino flux calculation.
- Ratios of the C, Fe, Pb to CH gives the evidence for nuclear effect.

Mousseau, Wospakrik, et. al,
Phys. Rev. D 93, 071101 (2016)

Differential Cross Section Ratio Results



- x-dependent ratios translate to x dependent nuclear effects.
- The shape of the data in low x, especially with Pb is consistent with additional nuclear shadowing.

Mousseau, Wospakrik, et. al,
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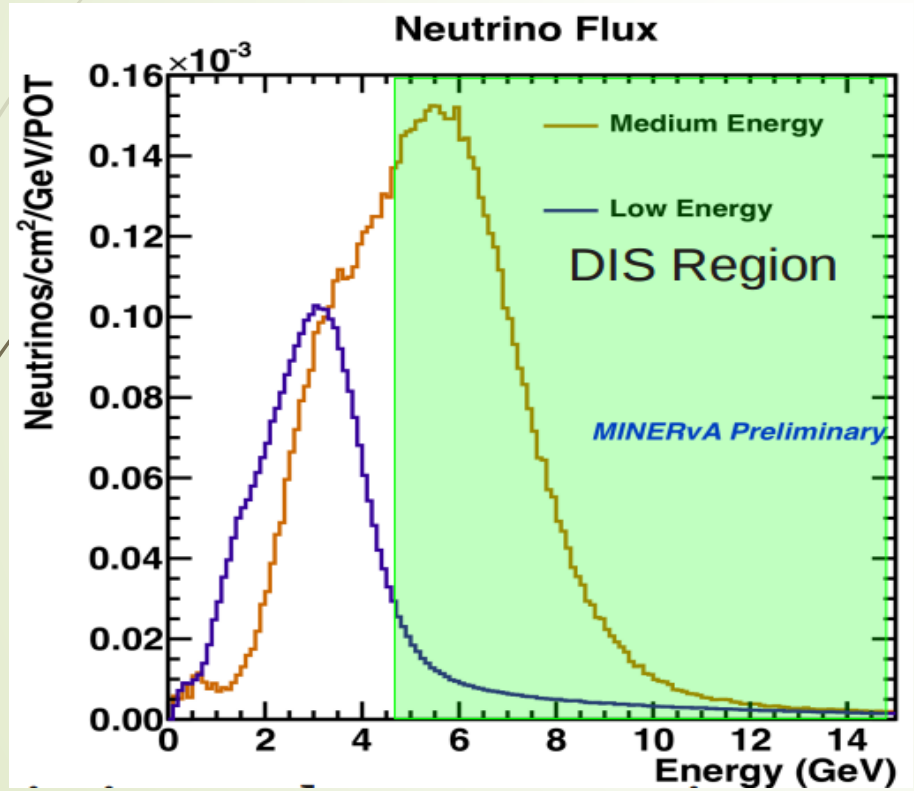
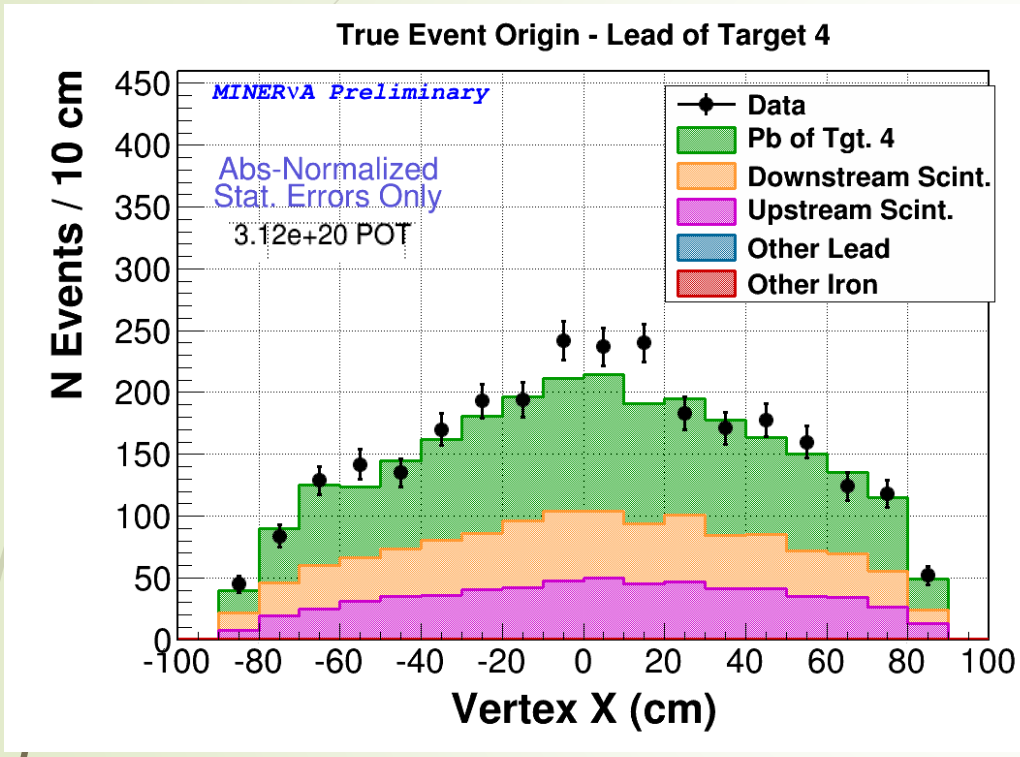
What the Future Holds?

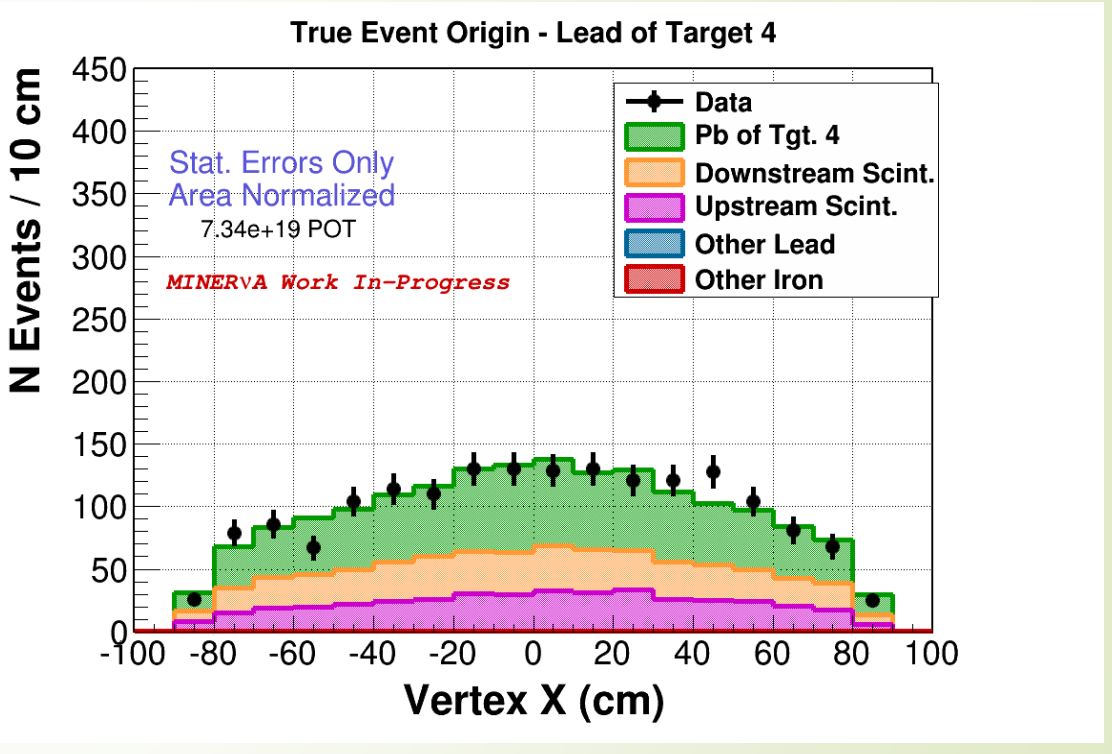


- NuMI beamline currently running with increased beam energy mode which peaks at **~6 GeV**.
- More statistics, especially for DIS interaction. The peak of energy now moves to the DIS kinematic region.
- We have currently taken **~9.8E20 Protons on Target** in this mode.
- Data in this beam energy mode are currently being analyzed.

Preliminary Plots Comparisons



Low Energy



Medium Energy

~half number of LE events at only ~quarter of POT!
Only 10% of the total POT we've collected so far
More background – will be addressed and studied

Conclusion

- MINERvA is the first experiment able to do precision measurements studying neutrino deep inelastic scattering on multiple nuclear targets simultaneously.
- We observed a deficit in our lead to plastic ratio data suggestive of additional nuclear shadowing.
- We are currently taking neutrino scattering data in the increased beam energy mode which gives us higher statistics and will enable to probe this interesting shadowing region and EMC region. We are also continue to work to reduce the systematic uncertainty.
- Stay tuned for more exciting results!

Thank you!

MINERvA Collaboration Meeting, College of William and Mary, June 2016

BACKUP