WG2 Summary

Kendall Mahn, MSU
Marco Martini, Ghent U.
Hide-Kazu Tanaka, ICRR, U. Tokyo

Thank you! to the speakers and active participants for a successful workshop

Question:

are the modern models able to describe the recent ad new experimental results? What puzzles remain?

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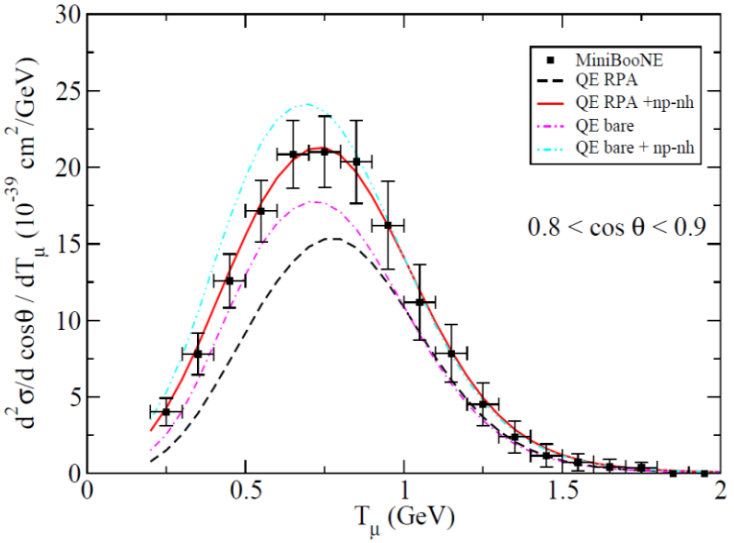
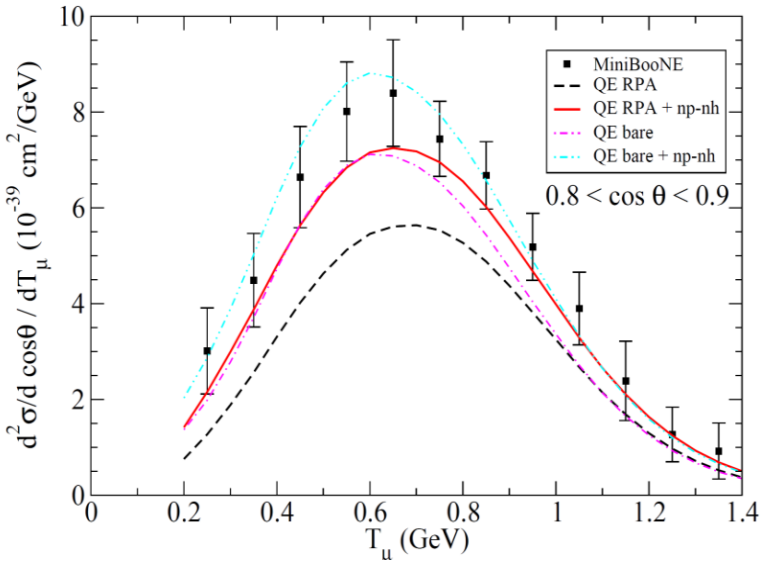
Martini et al.





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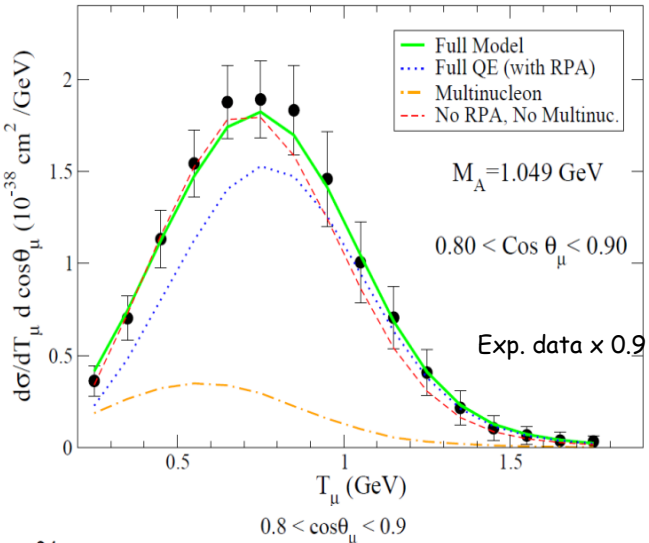
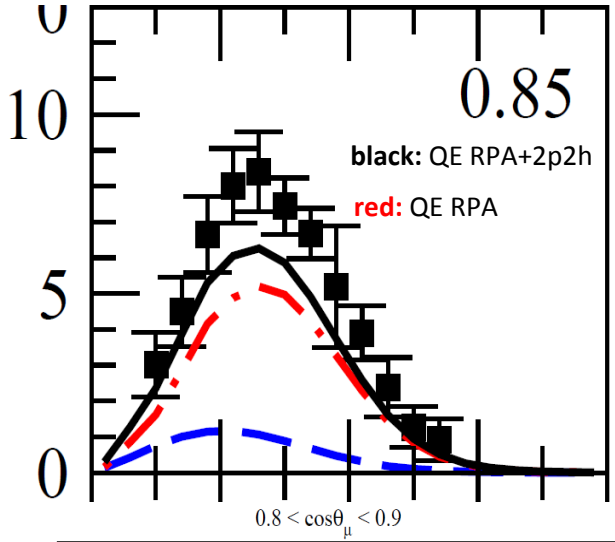
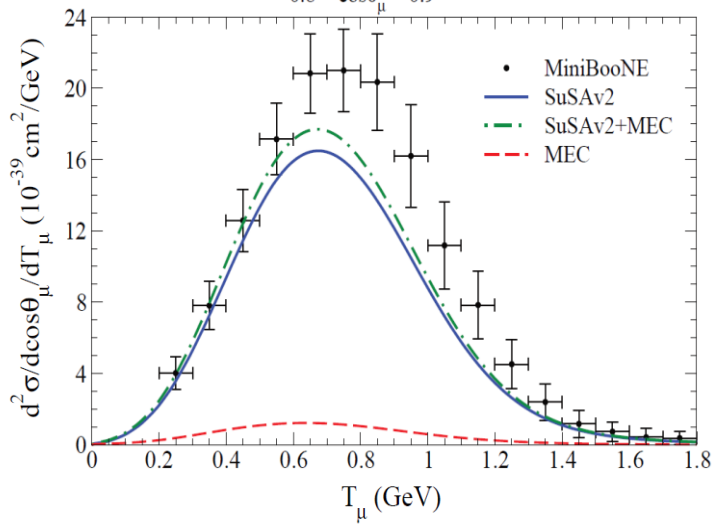
Nieves et al.

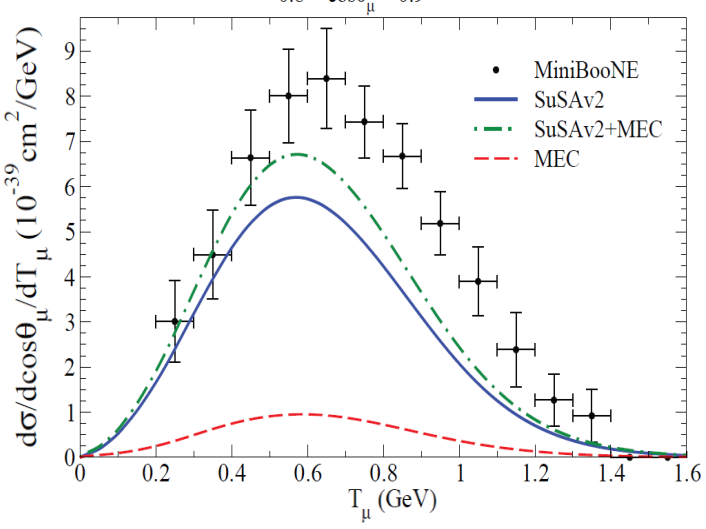




Amaro et al.

[Megias talk]





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M. Martini; Monday plenary talk

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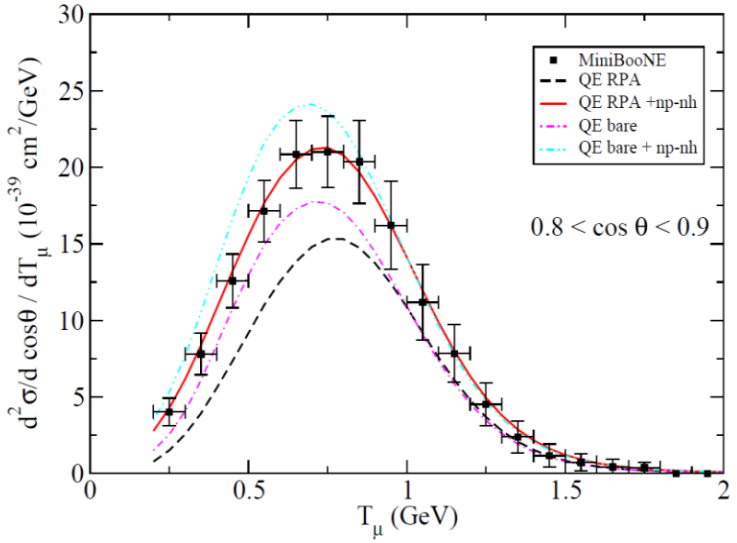
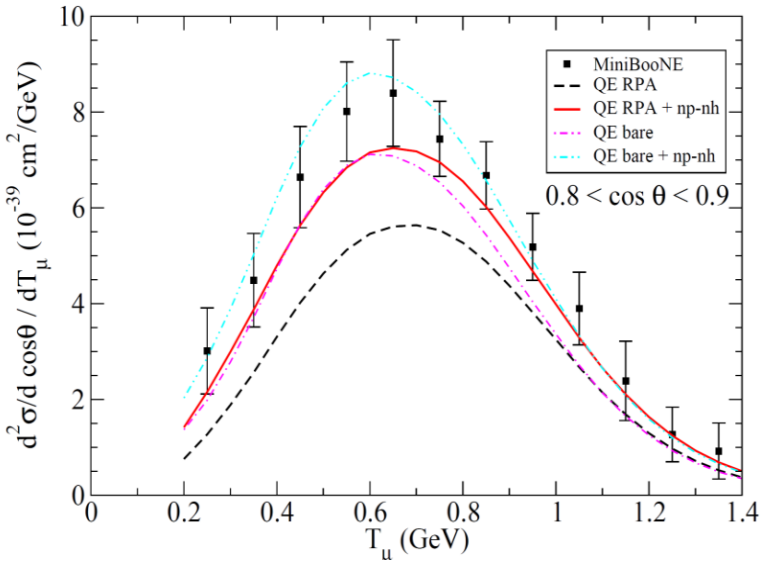
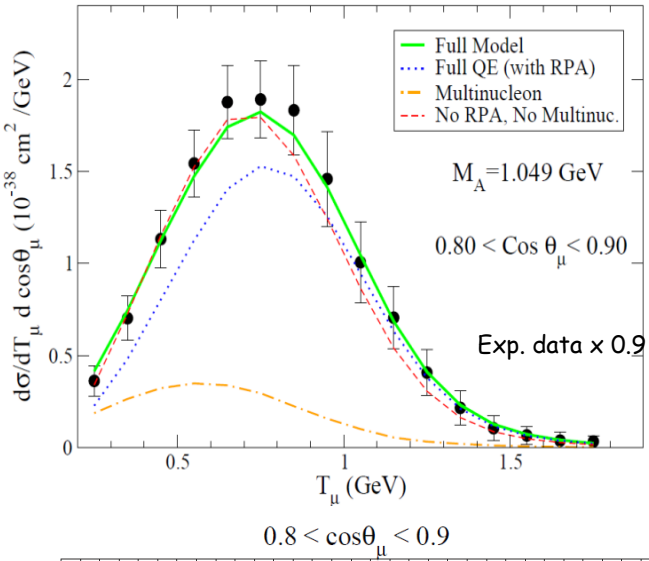
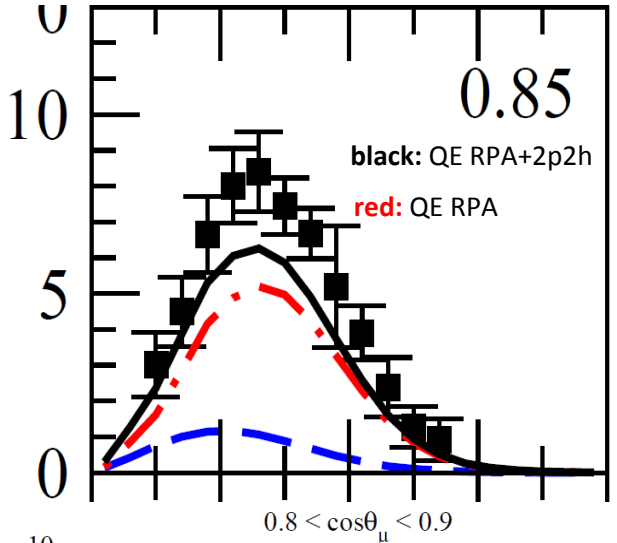
Martini et al.





Nieves et al.





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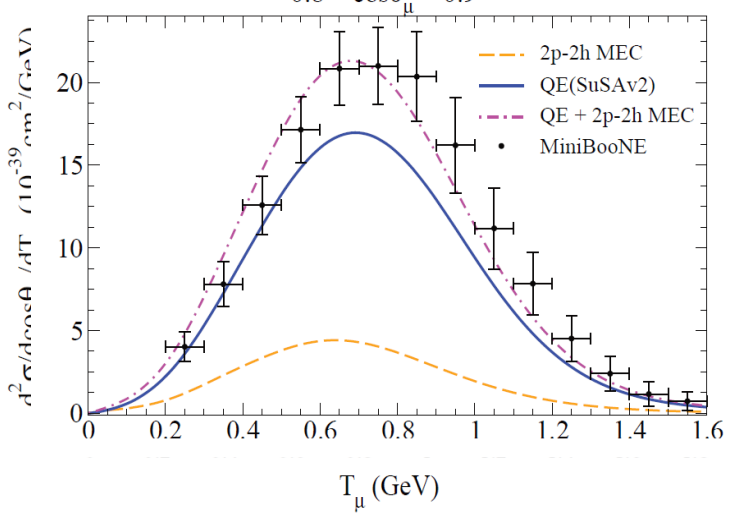
Megias talk



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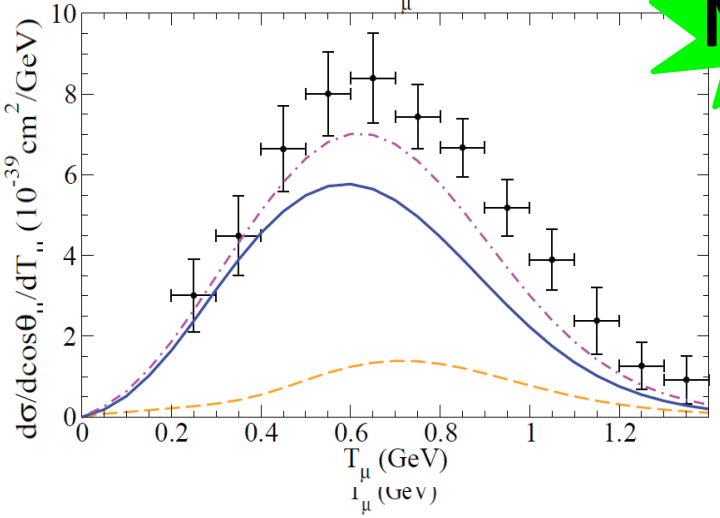


Megias talk: SuSA approach

Inclusion of the MEC contribution also in the axial sector, like in the case of Martini et al. and Nieves et al.

The qualitative agreement between the different approaches is improved

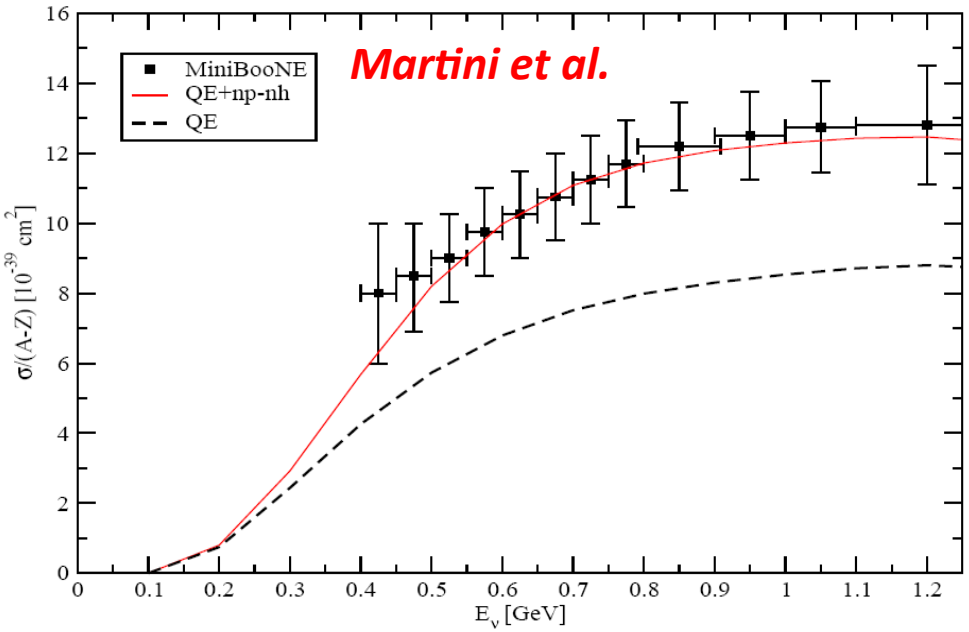
Differences remain due to the different approximations for the 2p-2h calculations

Approach	Vector	Axial	NN correlations	MEC	NN-MEC interference	Relativistic	Direct-Exchange Interference
Martini et al. (Martini Talk)	Yes	Yes	Yes	Yes	Yes	Some ingredients	No
Nieves et al.	Yes	Yes	Yes	Yes	Yes	Approximations in the WNNπ vertex	No
Supercaling (Megias Talk)	Yes	Yes **New!** Preliminary	No (work in progress)	Yes	No (work in progress)	Fully Relativistic	Yes
Van Cuyck et al. (Van Cuyck Talk)	Yes	Yes	Yes	No (work in progress)	No (work in progress)	Some ingredients	No

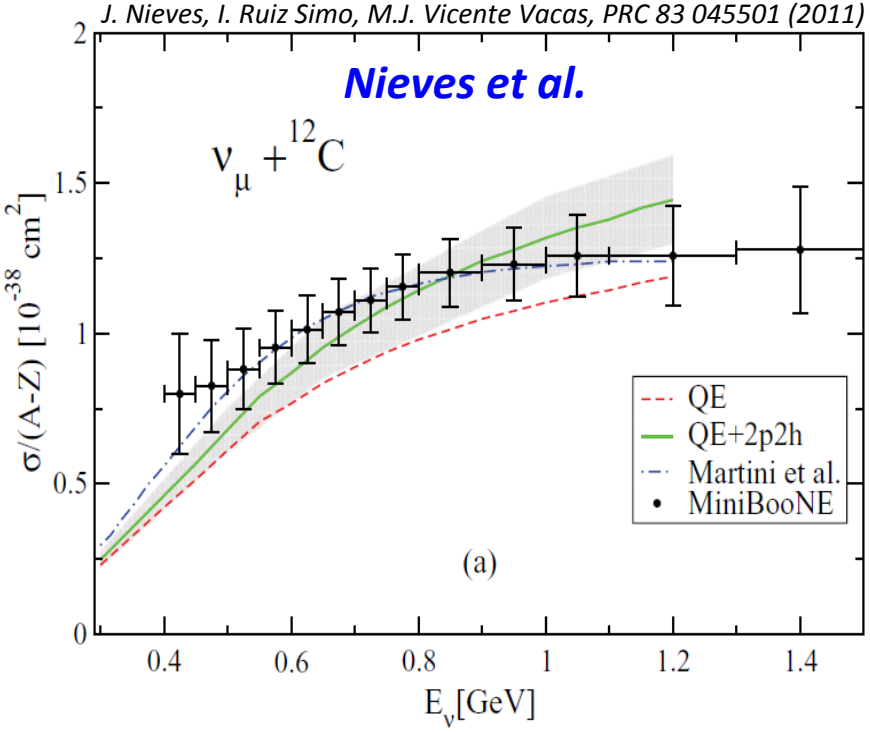
(see also Martini and Megias talks)

CCQE-like σ comparisons

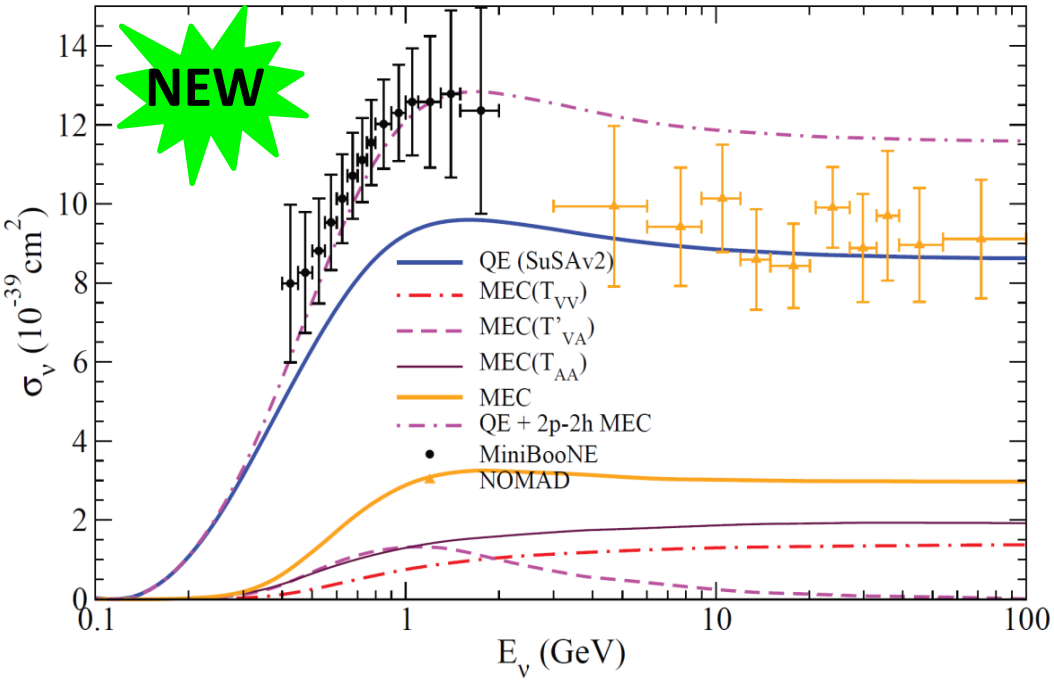
M. Martini, M. Ericson, G. Chanfray, J. Marteau, PRC 80 065501 (2009)



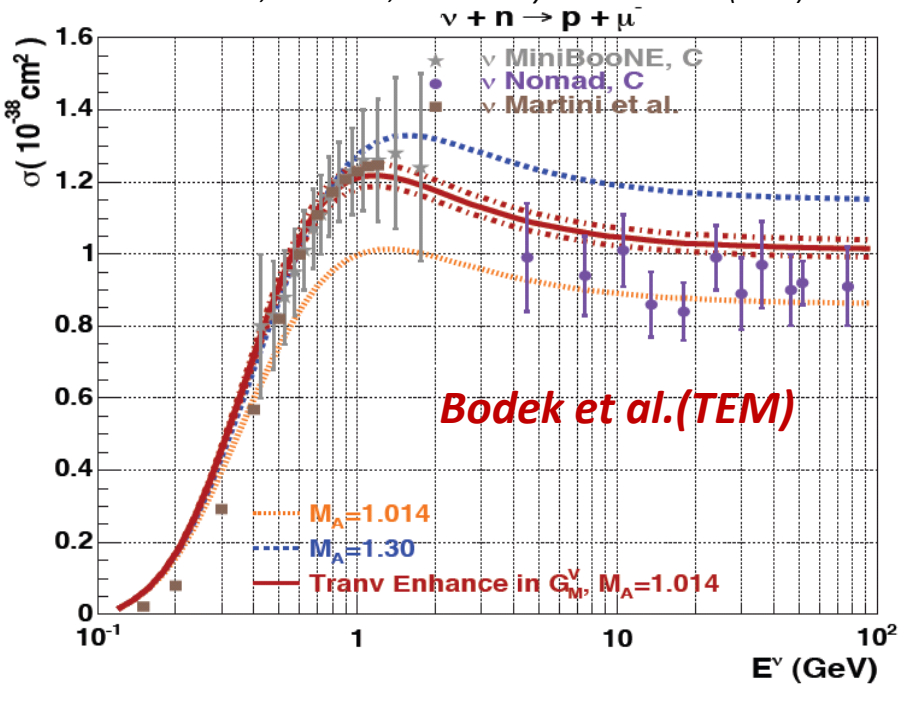
J. Nieves, I. Ruiz Simo, M.J. Vicente Vacas, PRC 83 045501 (2011)



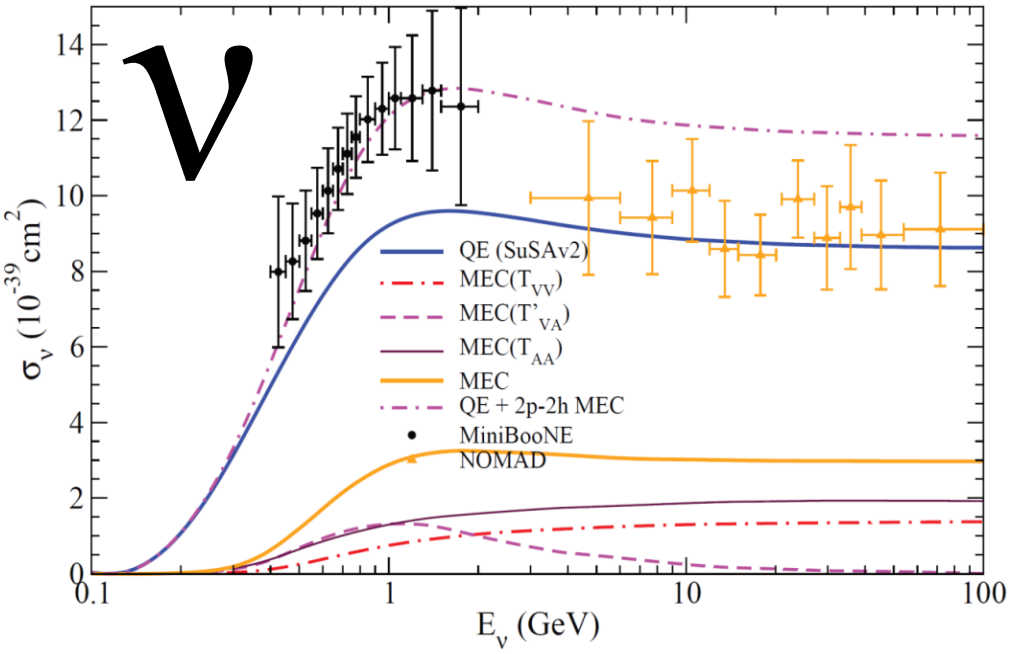
Superscaling, Megias talk



A. Bodek, H.S. Budd, M.E. Christy EPJ C 71 1726 (2011)



Simultaneous comparison with MiniBooNE and NOMAD



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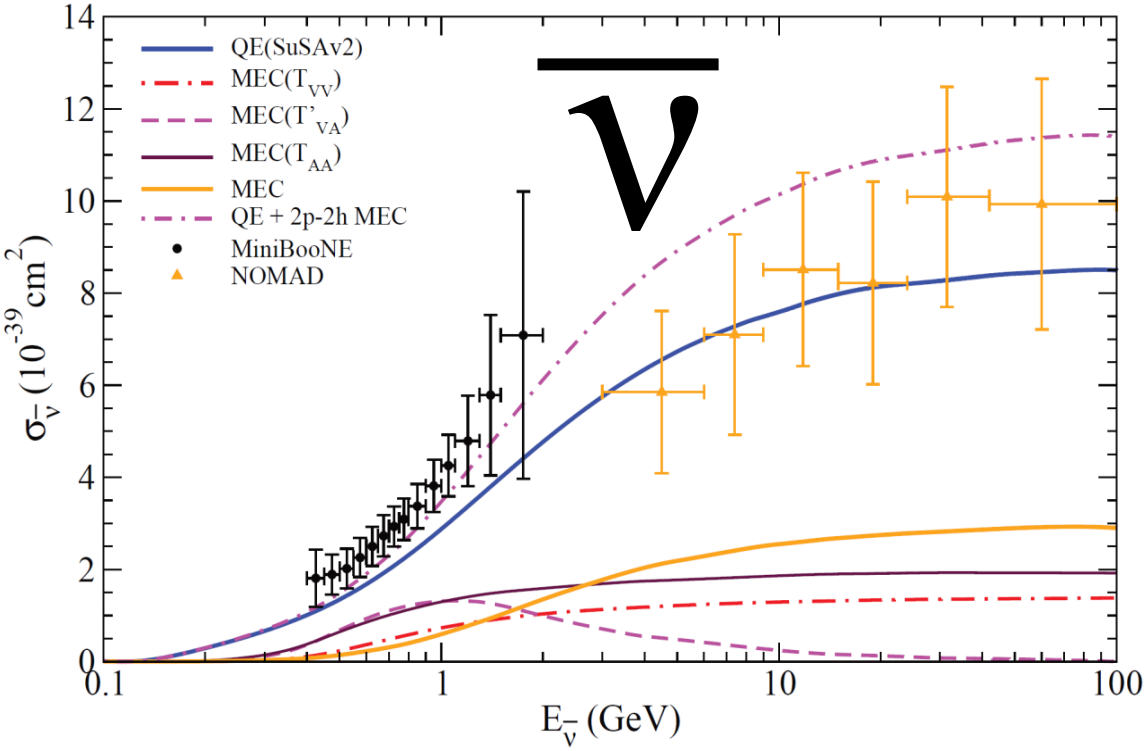
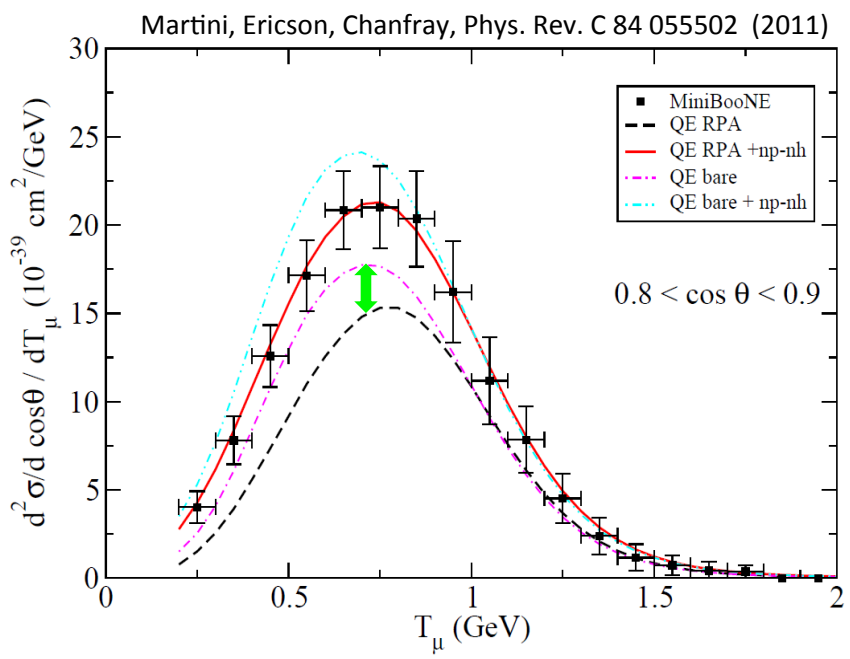
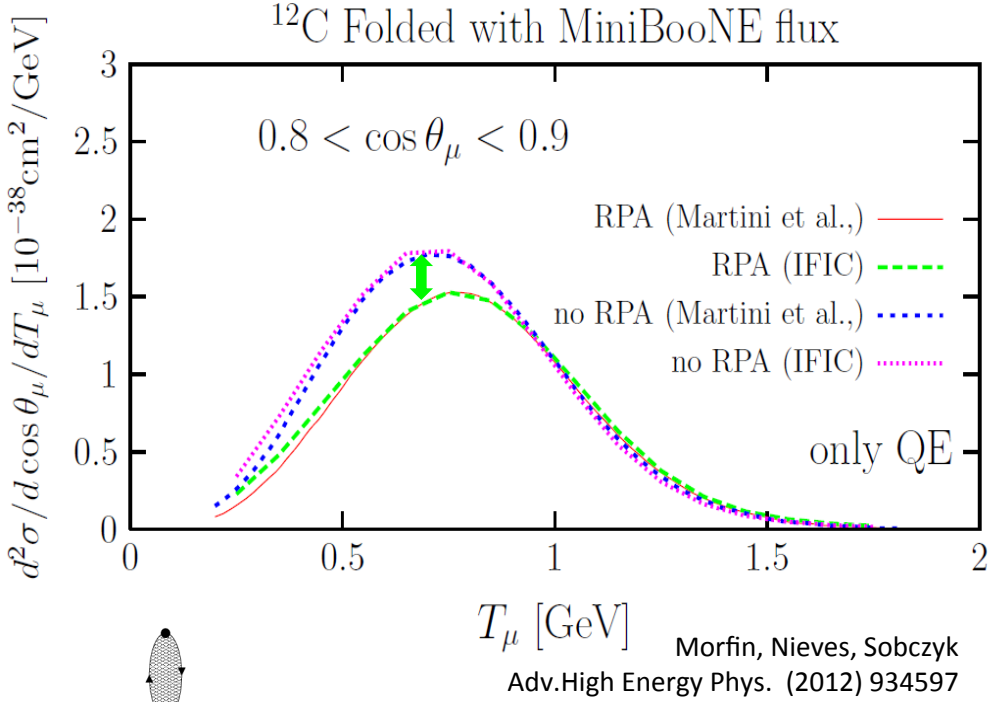
G. Megias talk



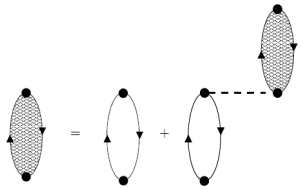
RPA effects



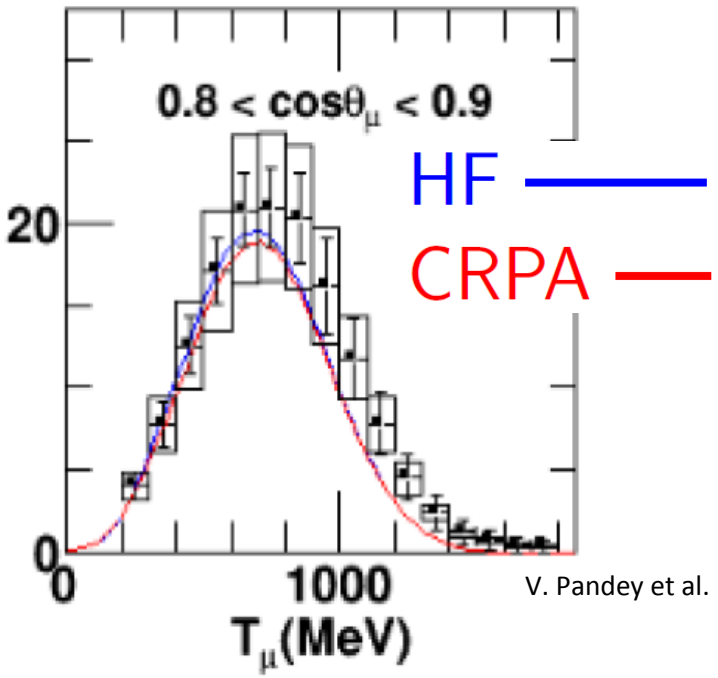


Morfin, Nieves, Sobczyk
Adv.High Energy Phys. (2012) 934597

- Martini et al. and Nieves et al. : similar and important RPA quenching



- T. Van Cuyck talk (Pandey et al.): small RPA quenching

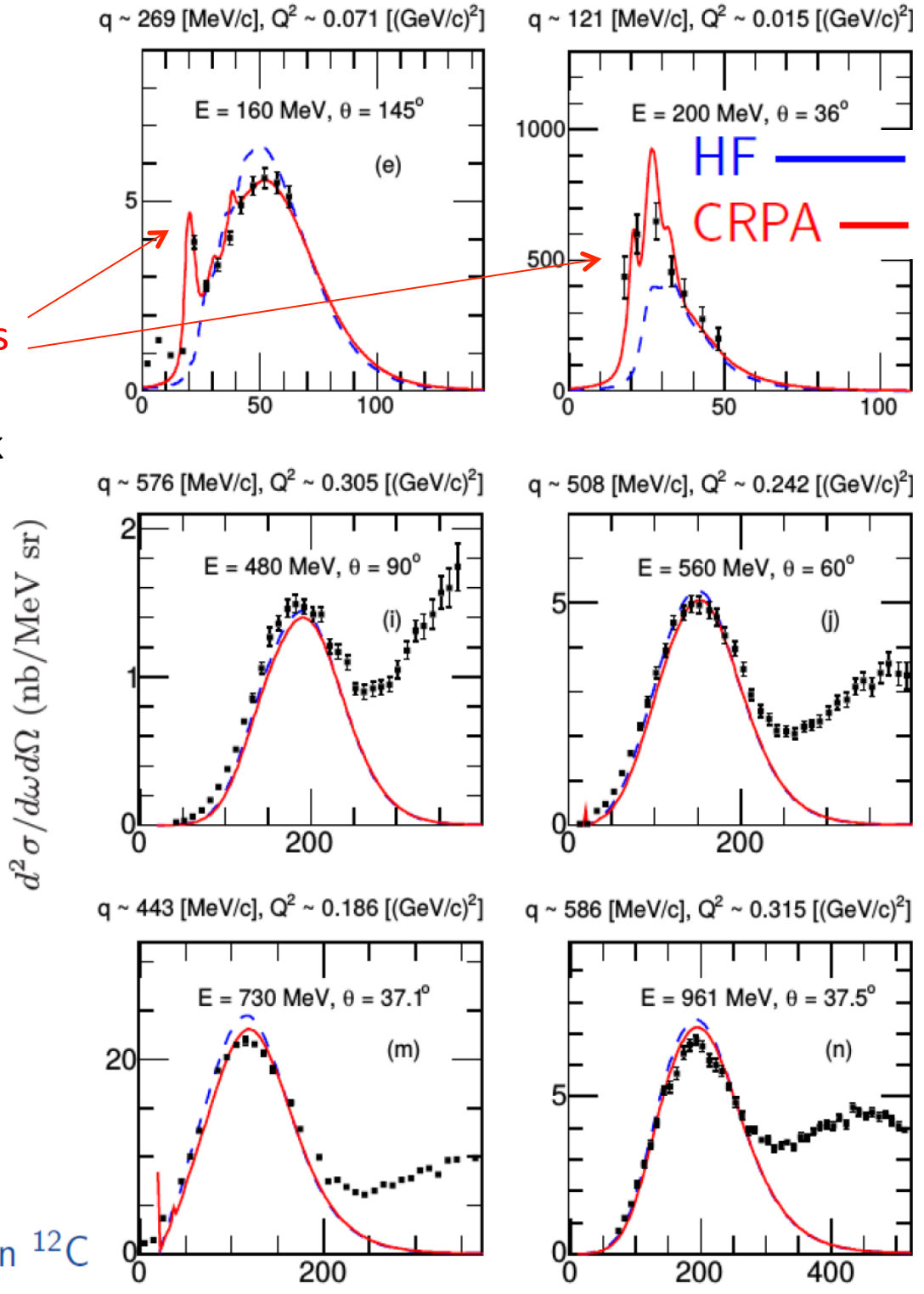


V. Pandey et al.

T. Van Cuyck talk

CRPA results:

- description of low-lying giant resonances
- small quenching of the quasielastic peak



(e, e') scattering on ^{12}C

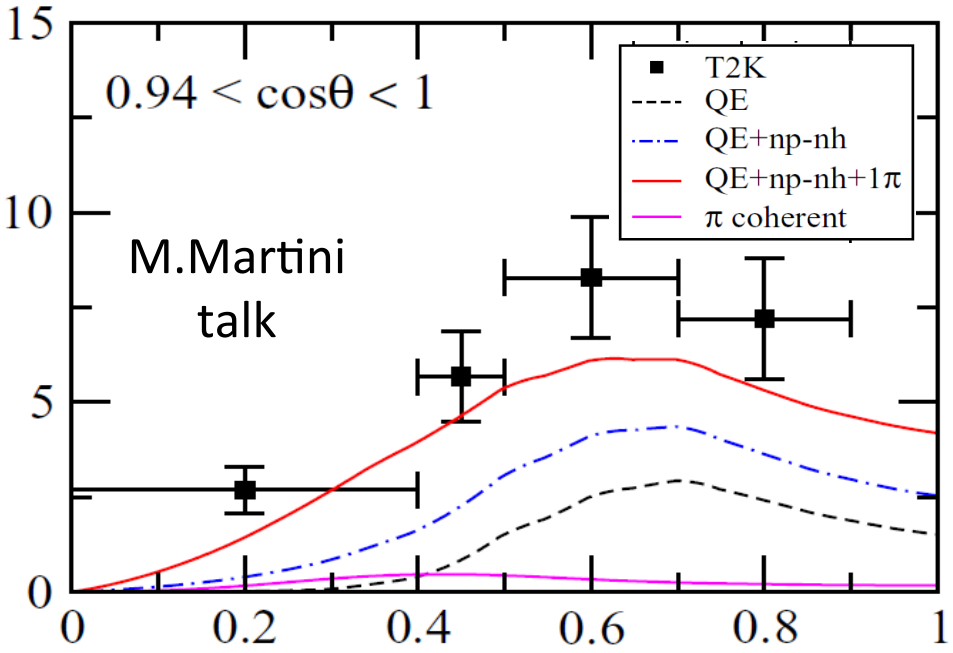
V. Pandey, *et al.*, Phys.Rev. C92, 024606 (2015)

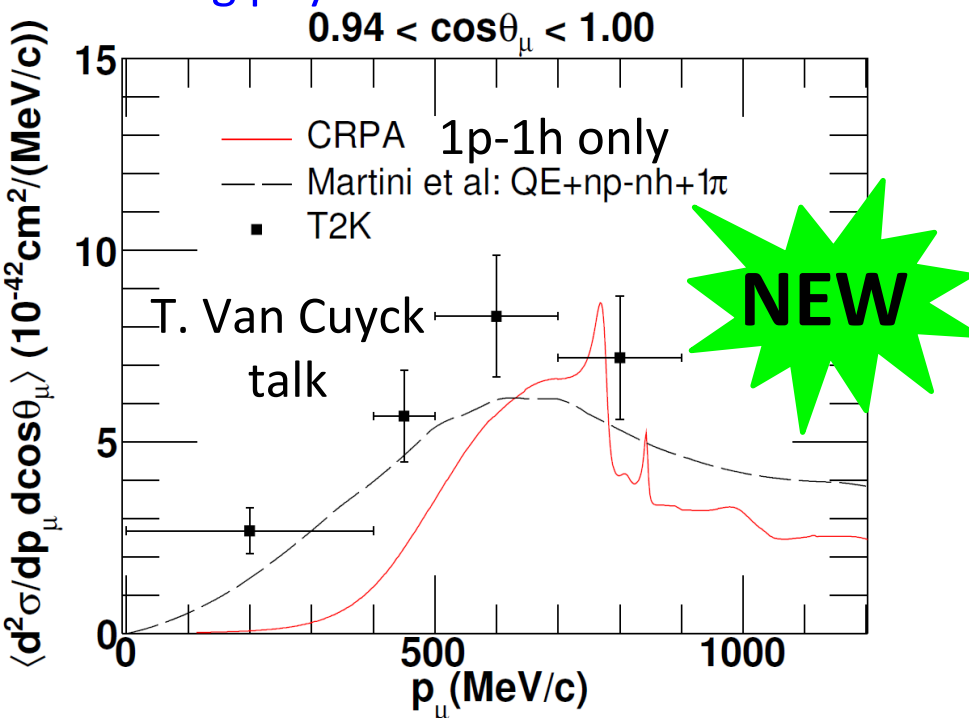
Analogies and differences of RPA based approaches

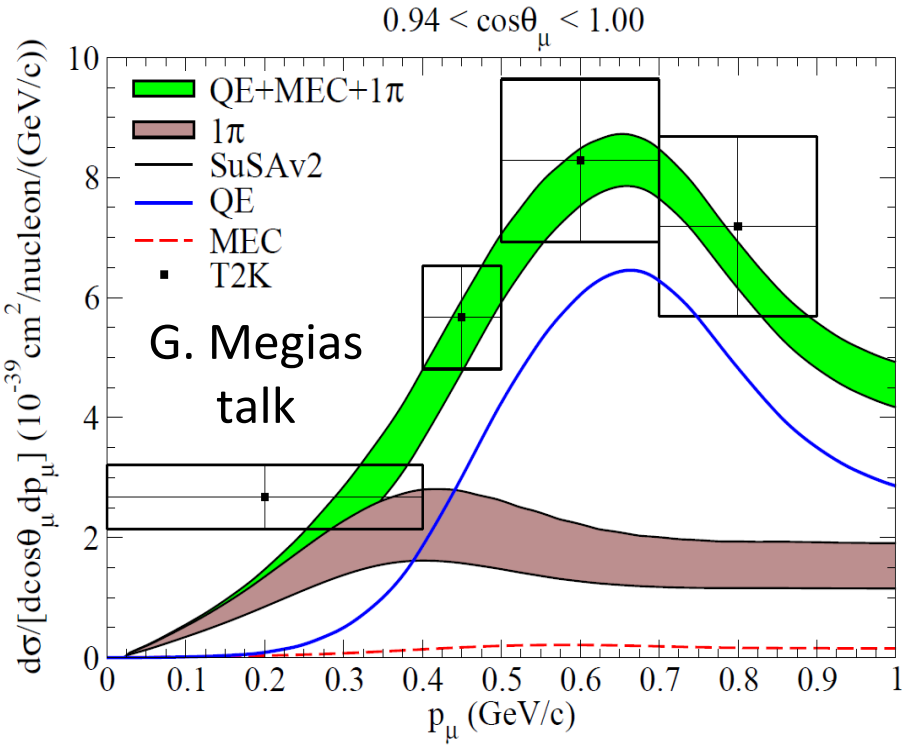
Approach	Shell effects	Low-lying Giant Resonances	Inclusion of Δ excitations (LLEE effect)	Starting point (Independent particle system)	Nuclear force
RPA (Martini et al. and Nieves et al.)	No	No	Yes	Local Fermi Gas	Meson exchange (π,ρ,g')
CRPA (V. Pandey et al.) T. Van Cuyck Talk	Yes	Yes	No	Hartree-Fock	Skyrme
QRPA/PQRPA A. Samana Talk	Yes	Yes	No	Hartree-Fock-Bogoliubov	Simplified Skyrme

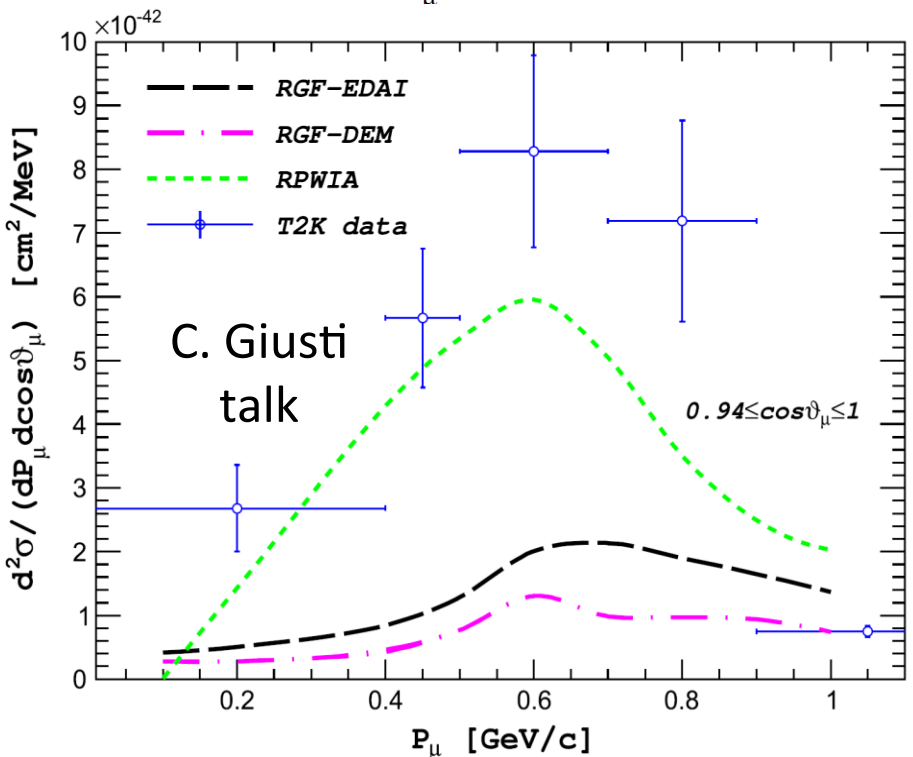
$d^2\sigma$ in the forward direction (T2K flux integrated)

Analogies, differences and interesting physics



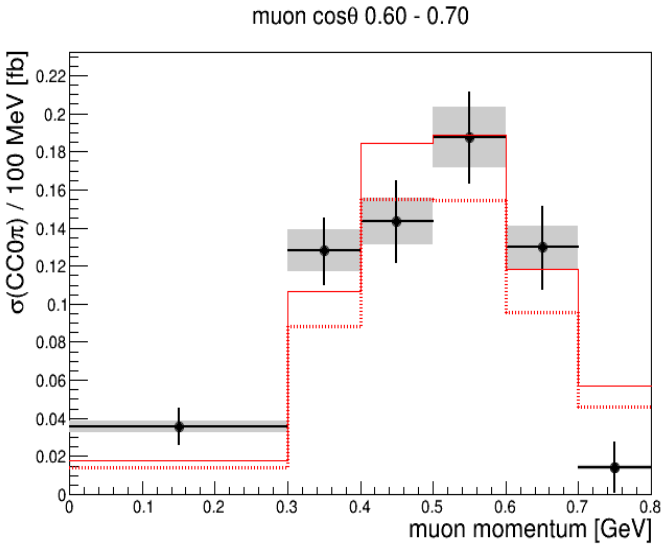


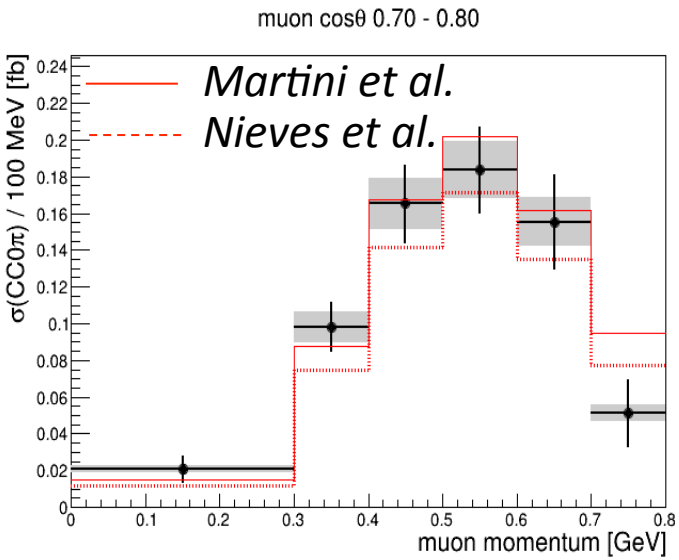


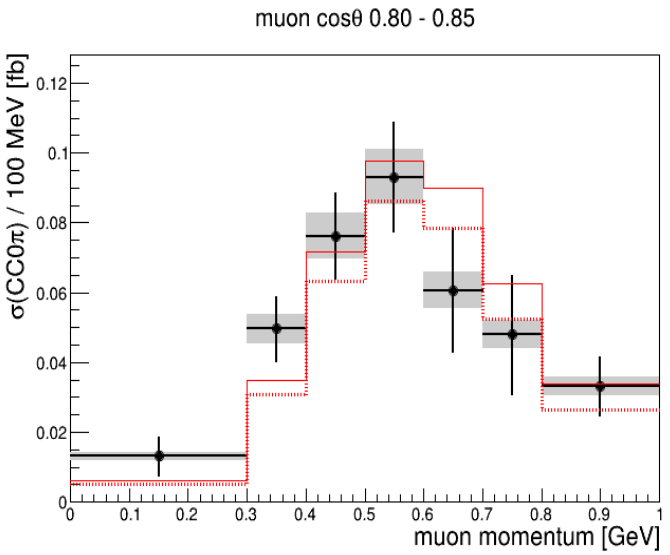


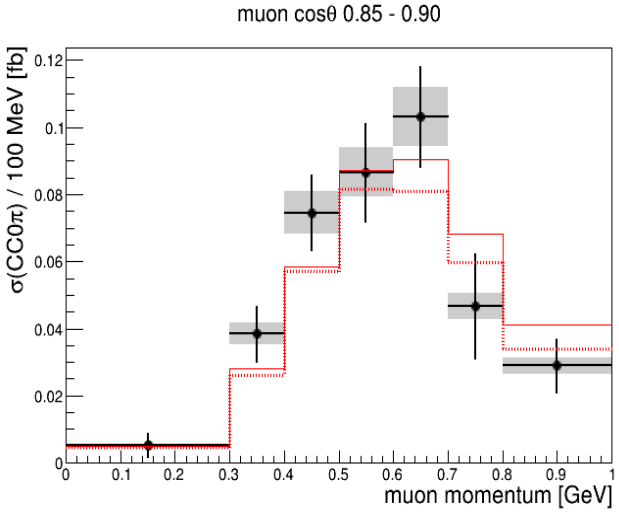
T2K flux-integrated **CC0π** measurement *vs* **CCQE+np-nh** calculations

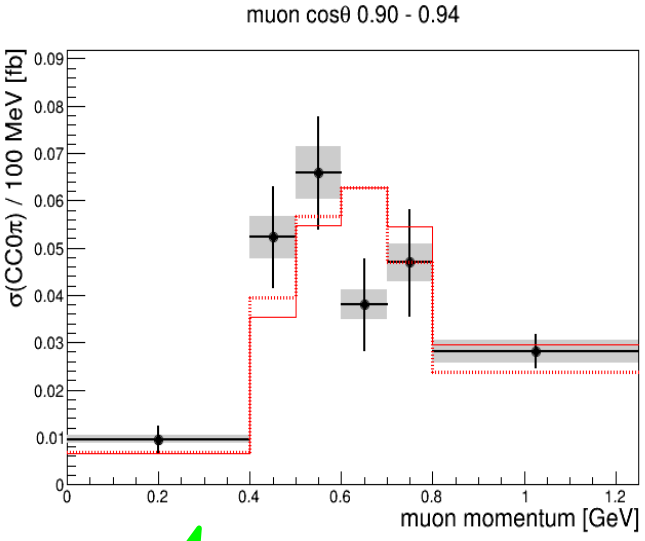
[S. Bolognesi and A. Furmanski talks]

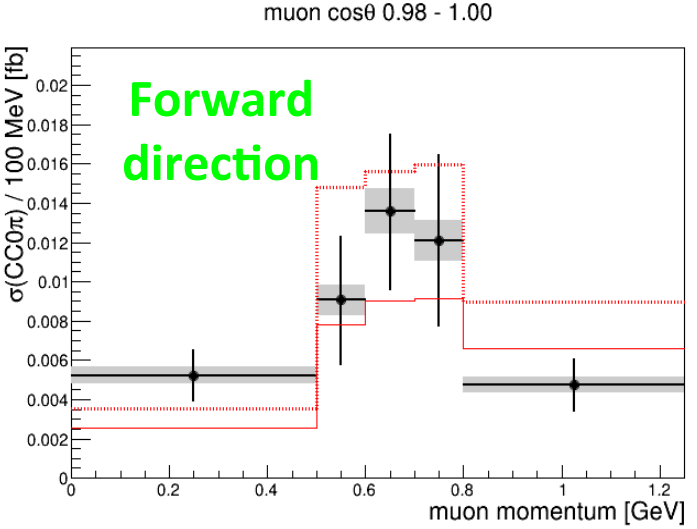








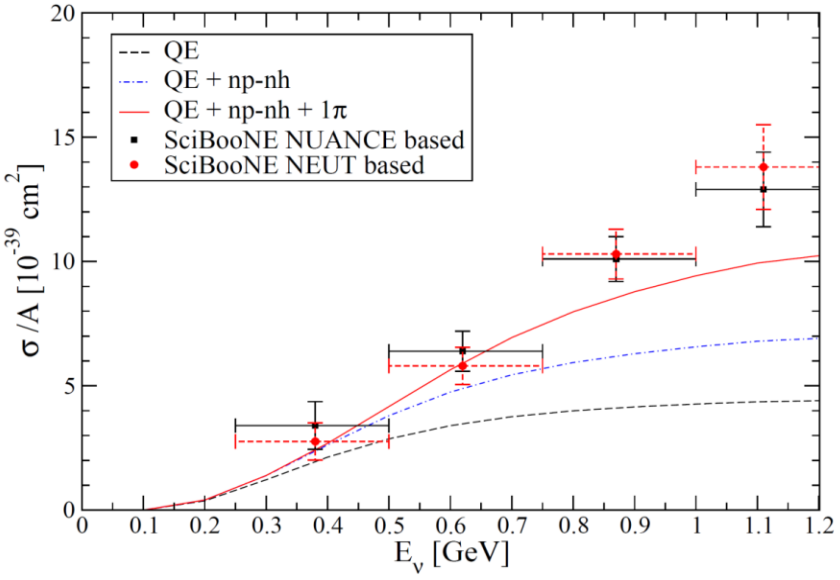


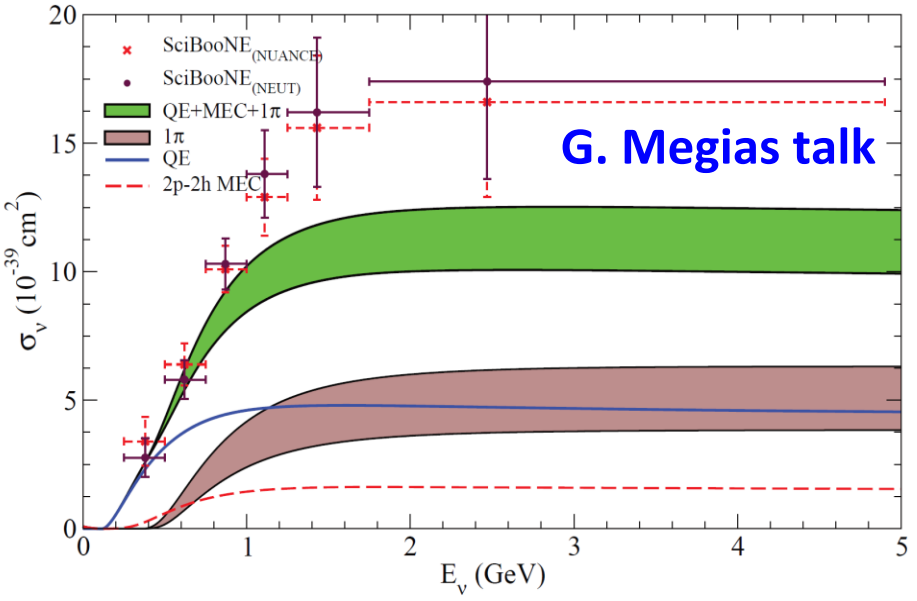


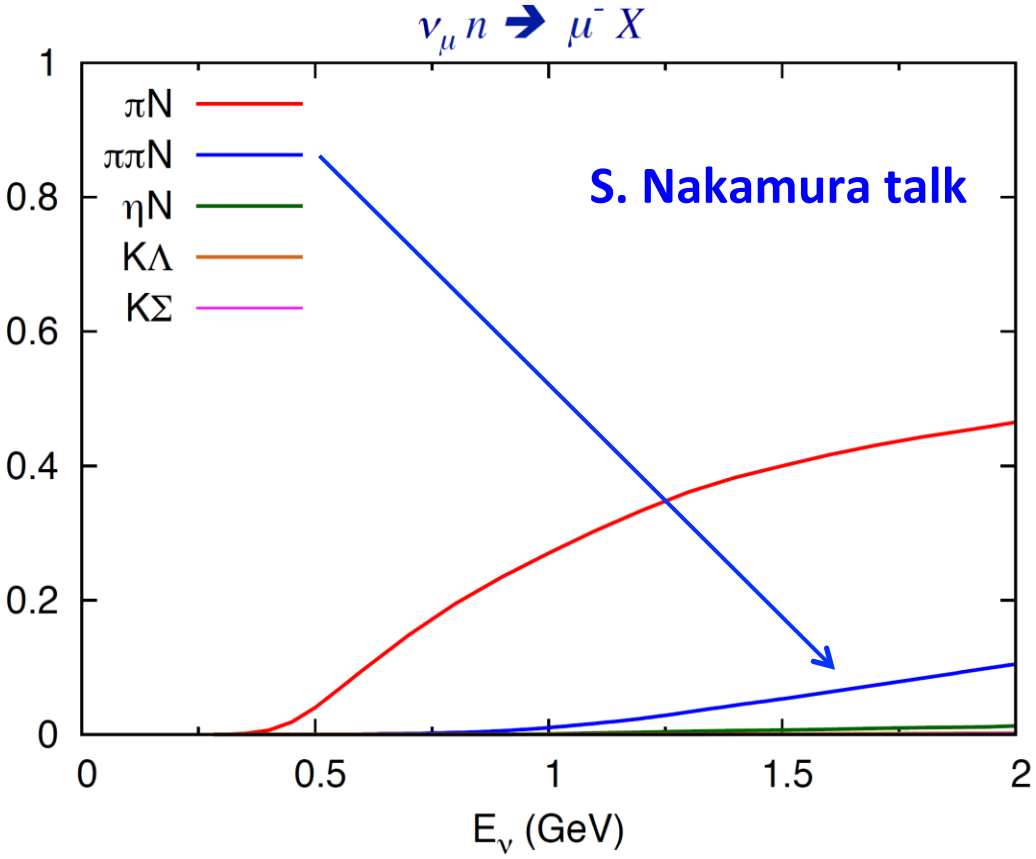
NEW

Different channels contributions to the neutrino cross sections

M. Martini, M. Ericson, Phys. Rev. C 90 025501 (2014)



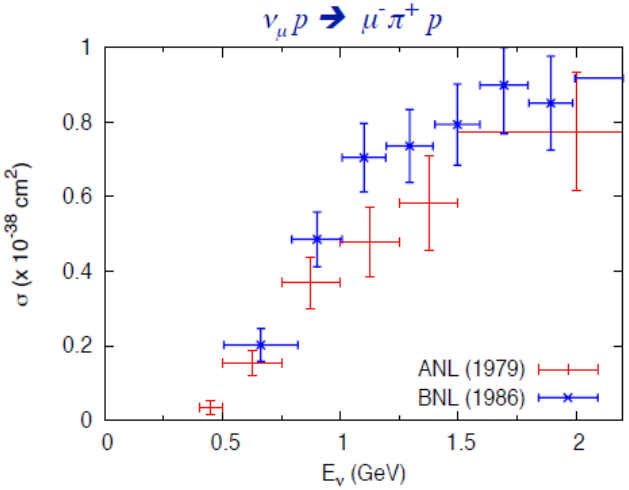




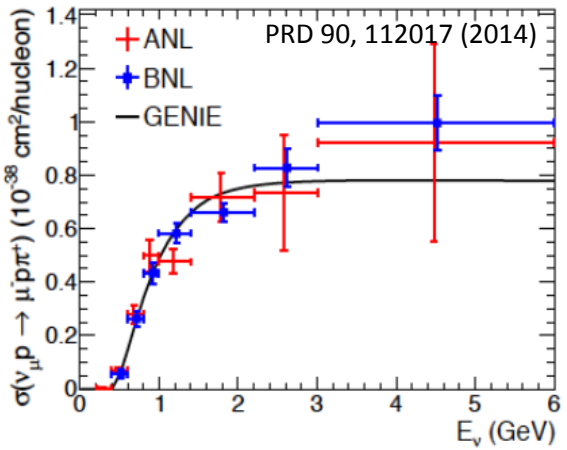
For E_ν > 1 GeV
$\pi\pi$ is important

Here is where Martini and Ericson and Megias et al. underestimate the inclusive cross section

Neutrino-induced meson production in the resonance region

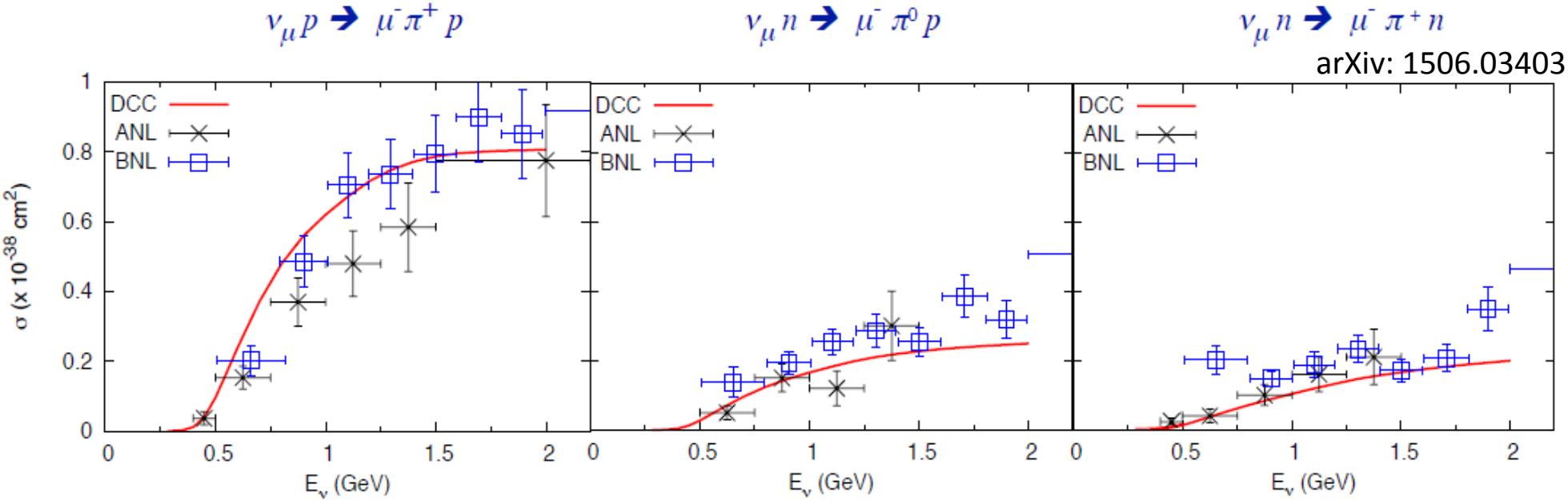


Discrepancy between BNL and ANL data



Recent reanalysis of original data
-> discrepancy resolved (!?)

S. Nakamura talk: Dynamical coupled channel (DCC) model

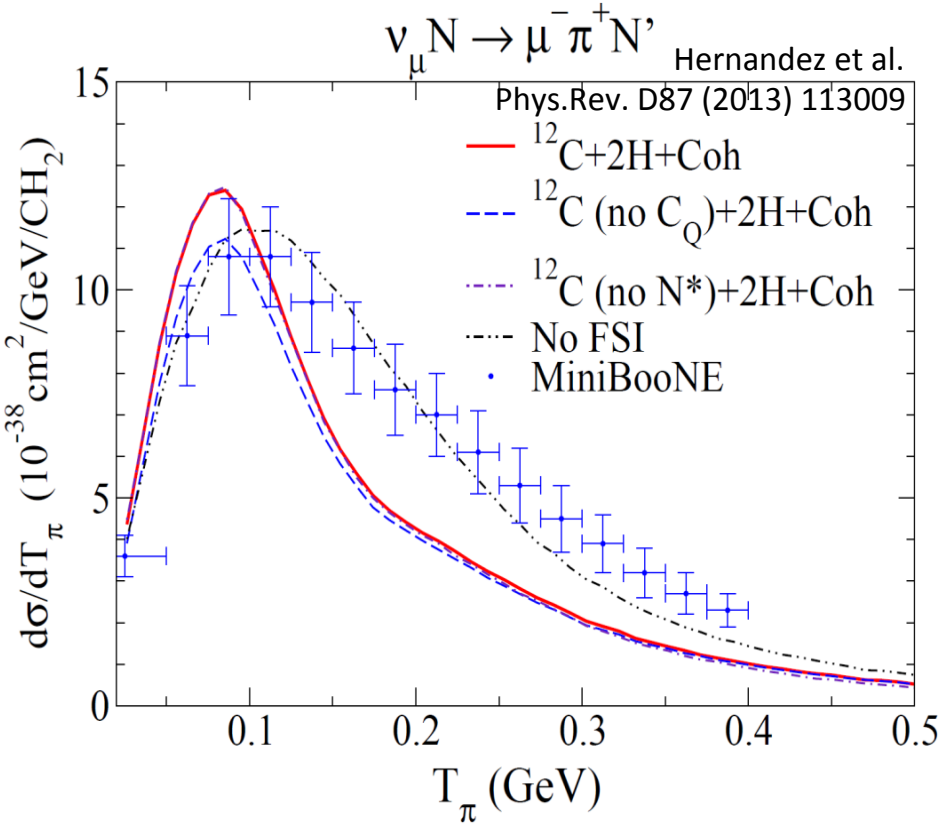


- DCC model prediction is consistent with 1π data
- Fairly good DCC prediction of 2π production (first dynamical model)

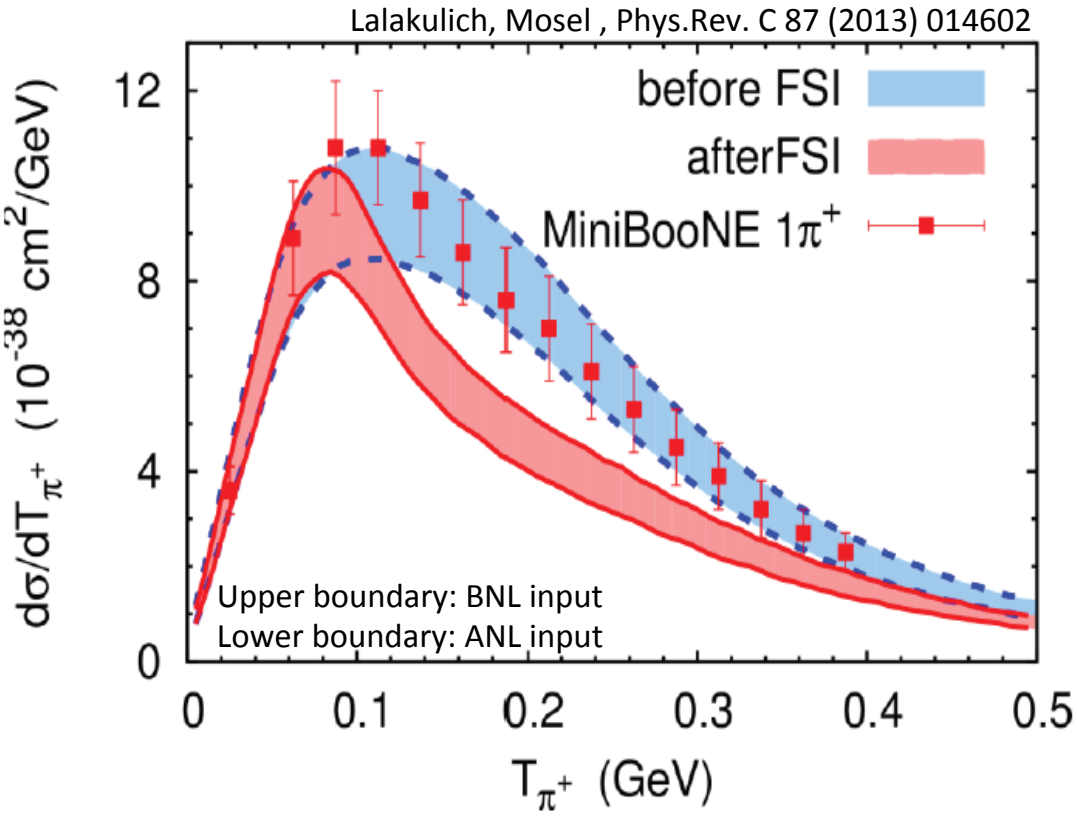
MiniBooNE flux-integrated CC1π+ differential cross section

MiniBooNE Phys. Rev. D 83 052007 (2011)

function of T_π



Valencia

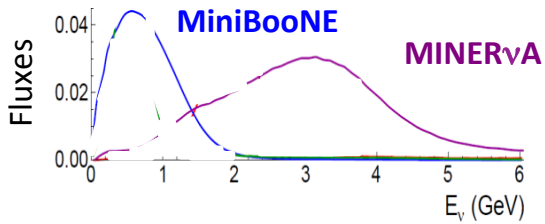


GiBUU

controversy

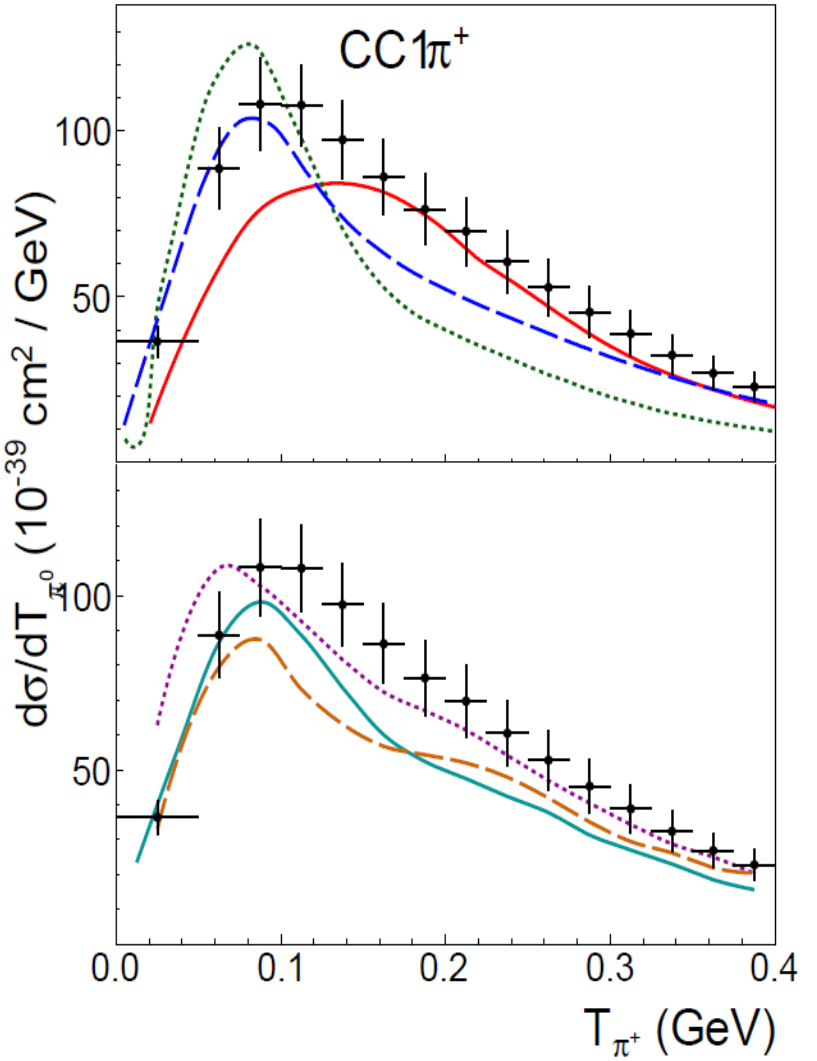
- Theories (with Δ medium effects and pion rescattering) do not agree with pion KE spectrum

MiniBooNE *vs* MINERνA CC1π+ production



MiniBooNE

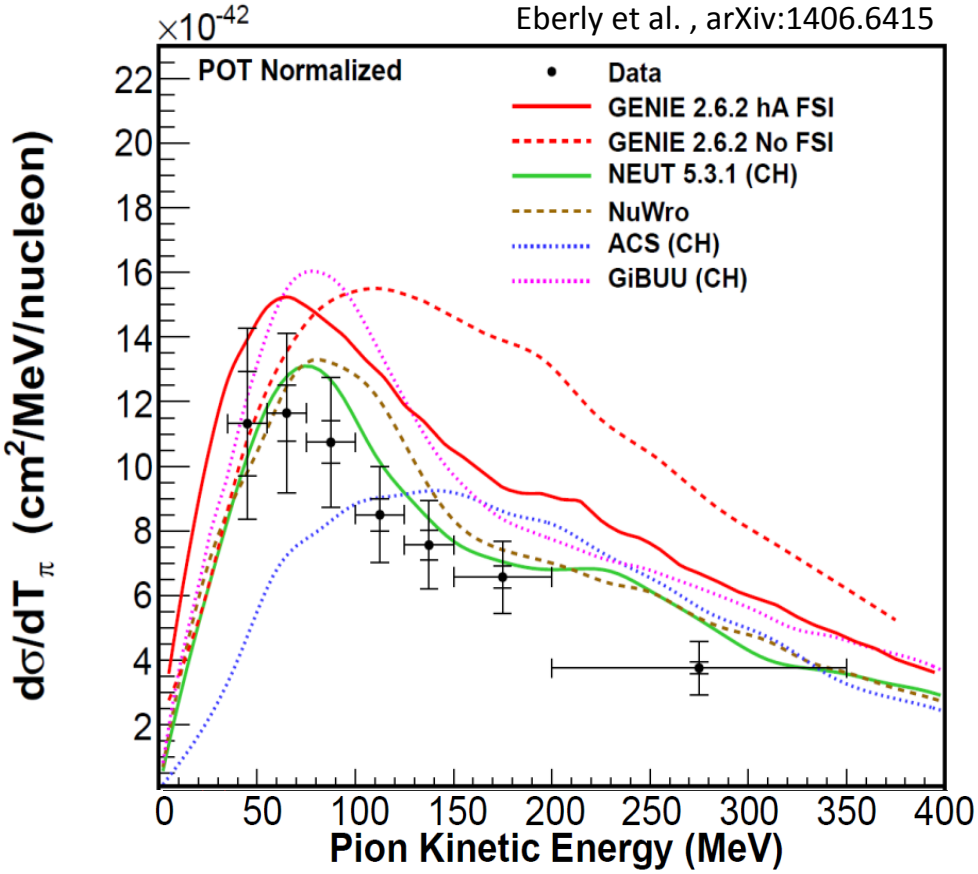
Rodrigues, arXiv:1402.4709



Athar *et al.* Nieves *et al.* GiBUU NuWro
GENIE NEUT MB data

MINERνA

Eberly et al. , arXiv:1406.6415



Some tension

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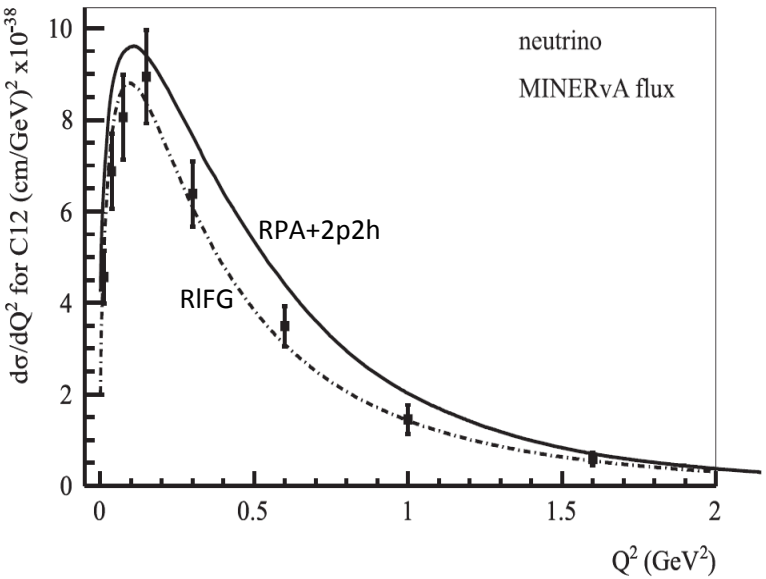
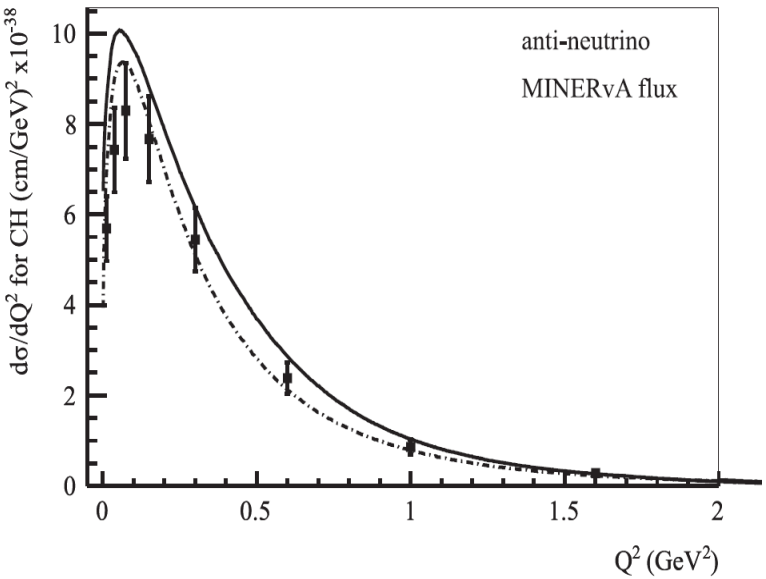
Gran, Nieves et al.
PRD 88 (2013)





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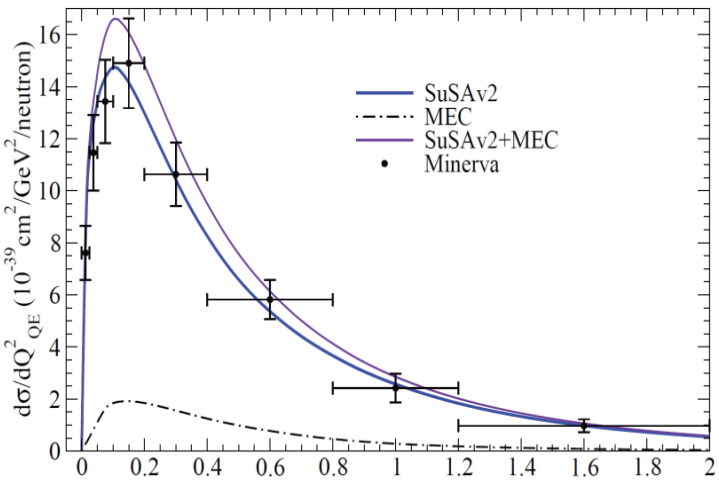
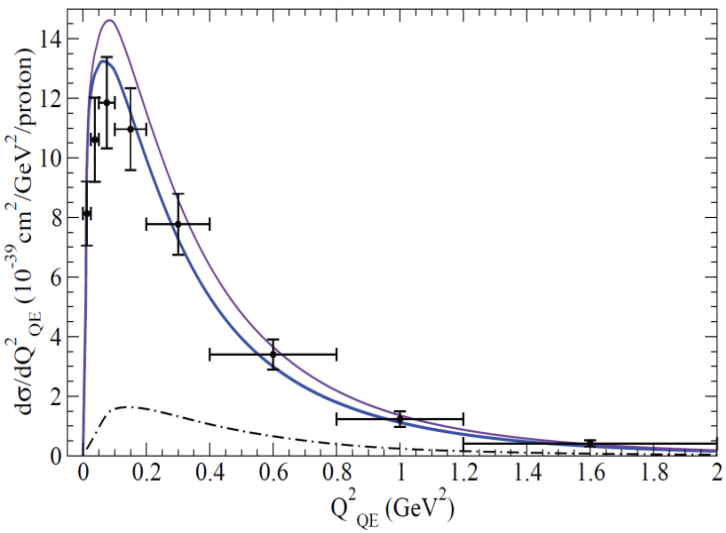
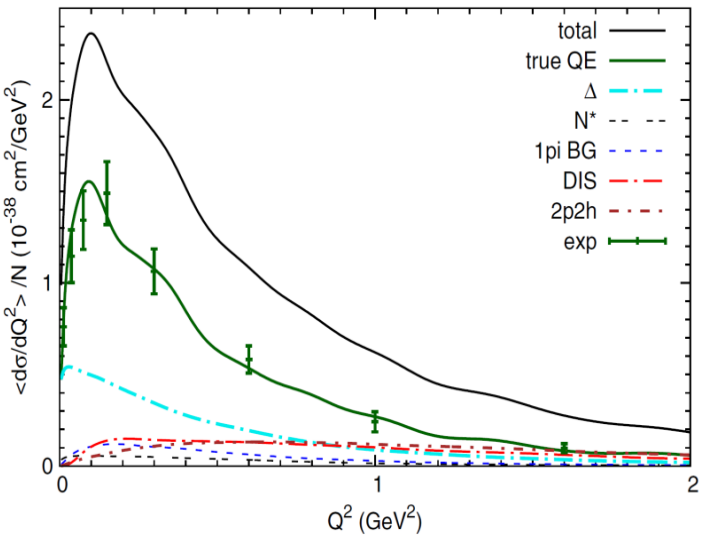
Megias, Amaro et al.
PRD 91 (2015)



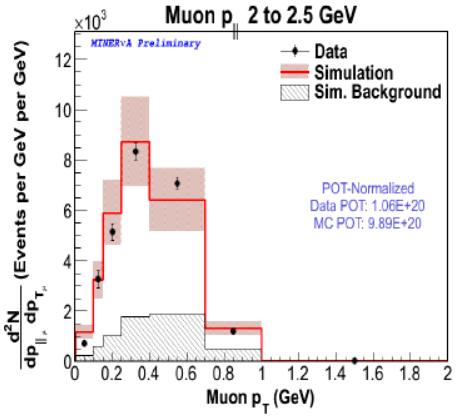


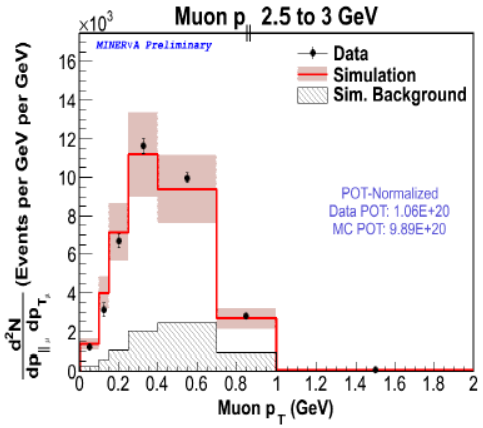
Mosel et al.
PRD 89 (2014)

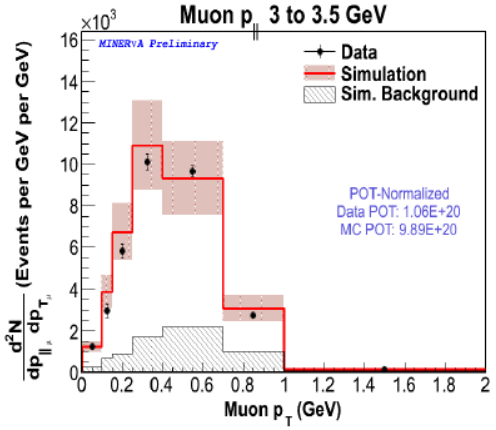


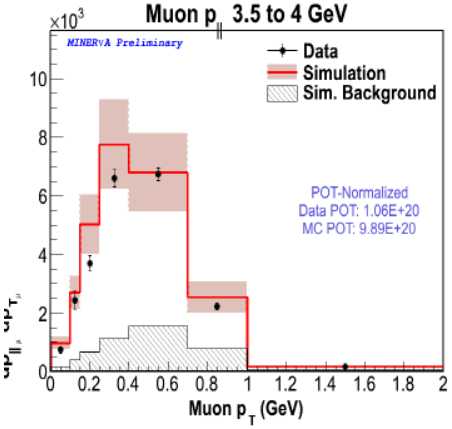
- **MINERνA CCQE Q^2 distributions can be reproduced also without the inclusion of np-nh**
- **This is not the case of the MiniBooNE Q^2 distributions and $d^2\sigma$**

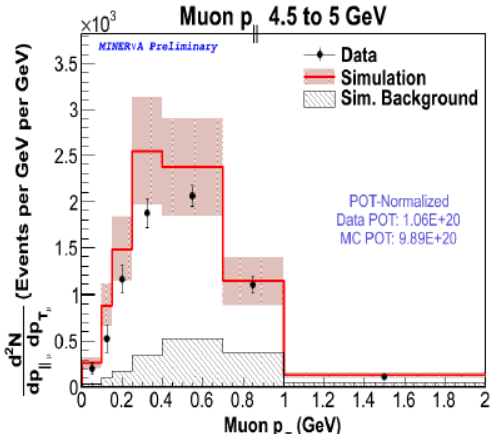
Question: Where is there agreement/disagreement between new experimental results at different beam energies?

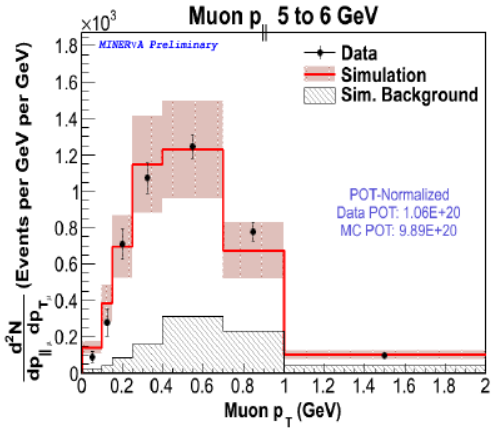






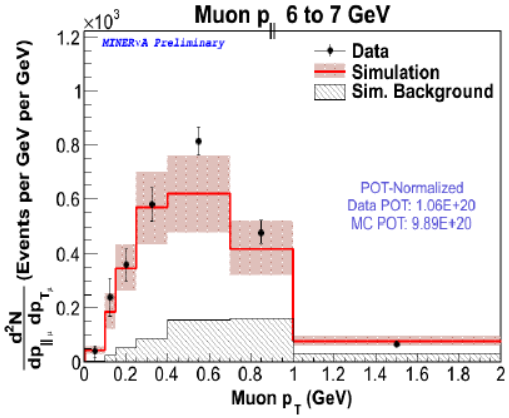






- Double-differential cross sections in measurable variables will provide extra information to help distinguish between models.

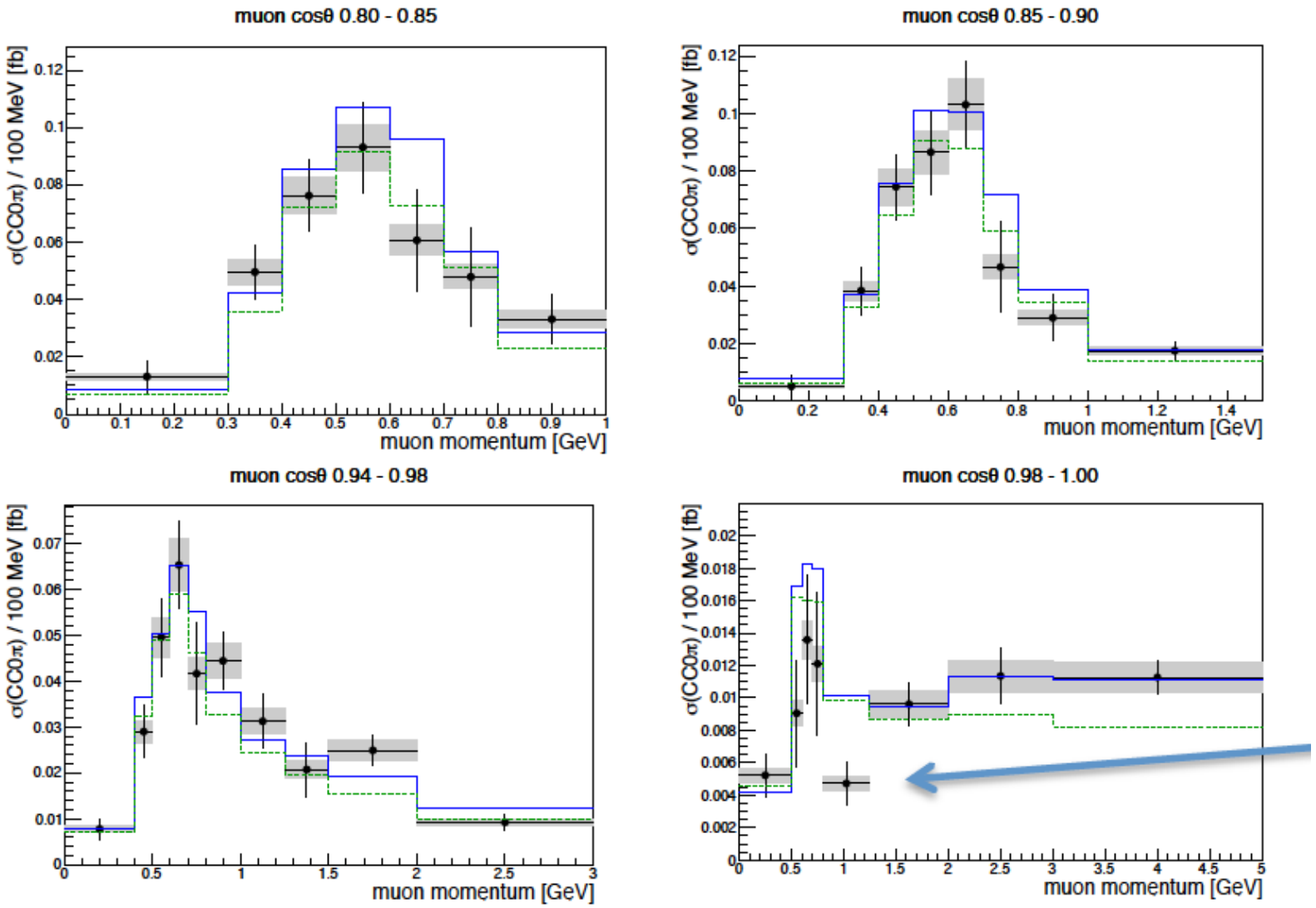
- The plots to the left are for the antineutrino CCQE sample.



New! MINERvA double differential QE-like (CH) results (A. Ghosh talk)

- Significant uncertainties in last interation of analysis from neutrino interactions and FSI
- New Question: What are the systematic uncertainties which limit current determinations of the cross section?

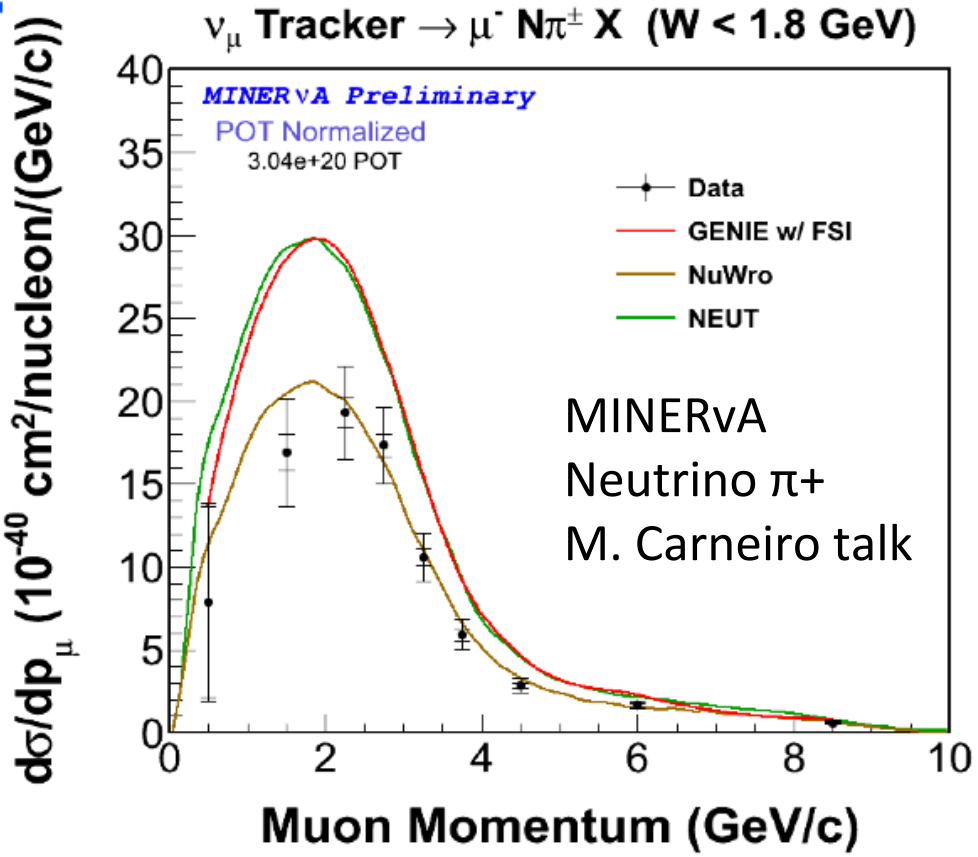
Question: Where is there agreement/disagreement between new experimental results at different beam energies?

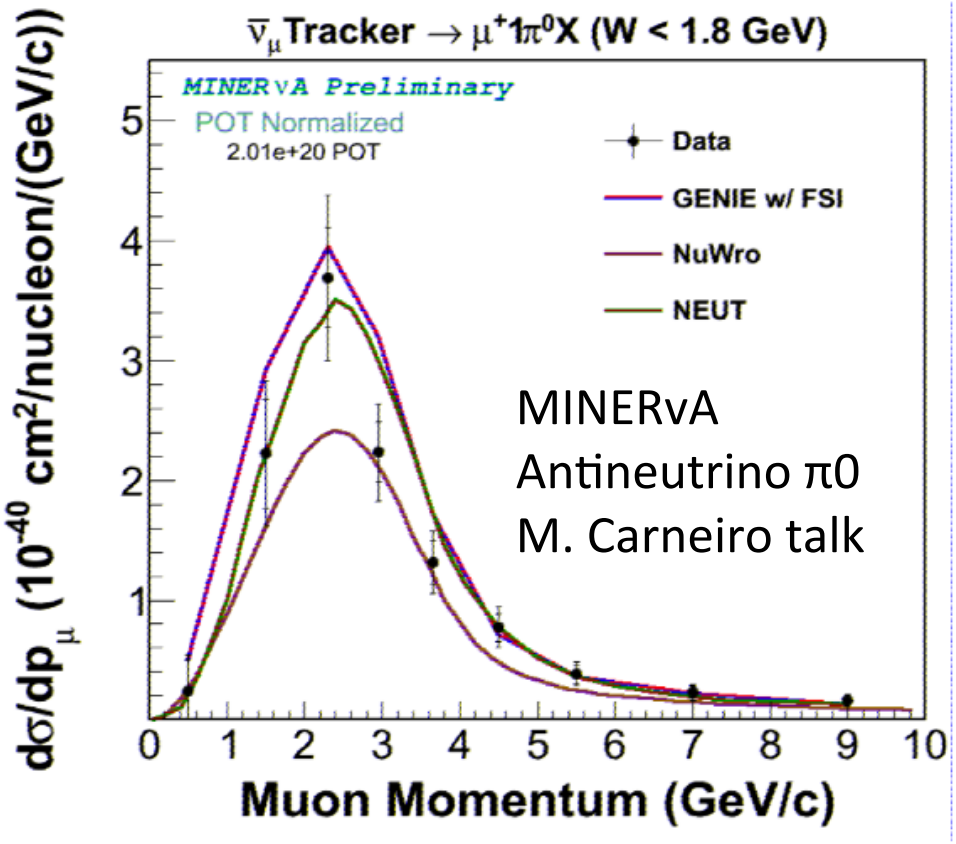


New! T2K double differential QE-like (CH) results (A. Furmanski talk)

- Agreement qualitatively with Nieves et al, Martini et al
- NEUT model disagrees in some regions
- Interesting dip seen in two different analyses in forward bin

Question: Where is there agreement/disagreement between new experimental results at different beam energies?





New! MINERvA single pion production (CH) results vs lepton kinematics

- Inconsistent normalization as compared to MiniBooNE for neutrinos
- GENIE/NEUT ~50% larger than MINERvA neutrino measurement, agrees for antineutrino measurement

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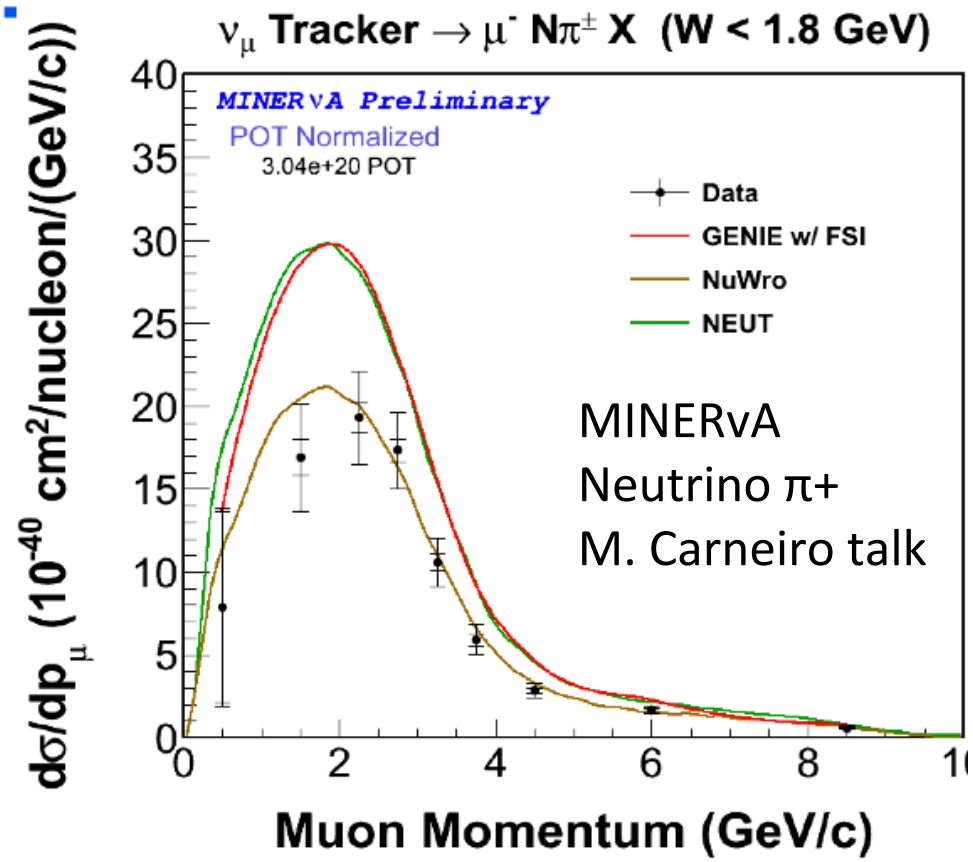

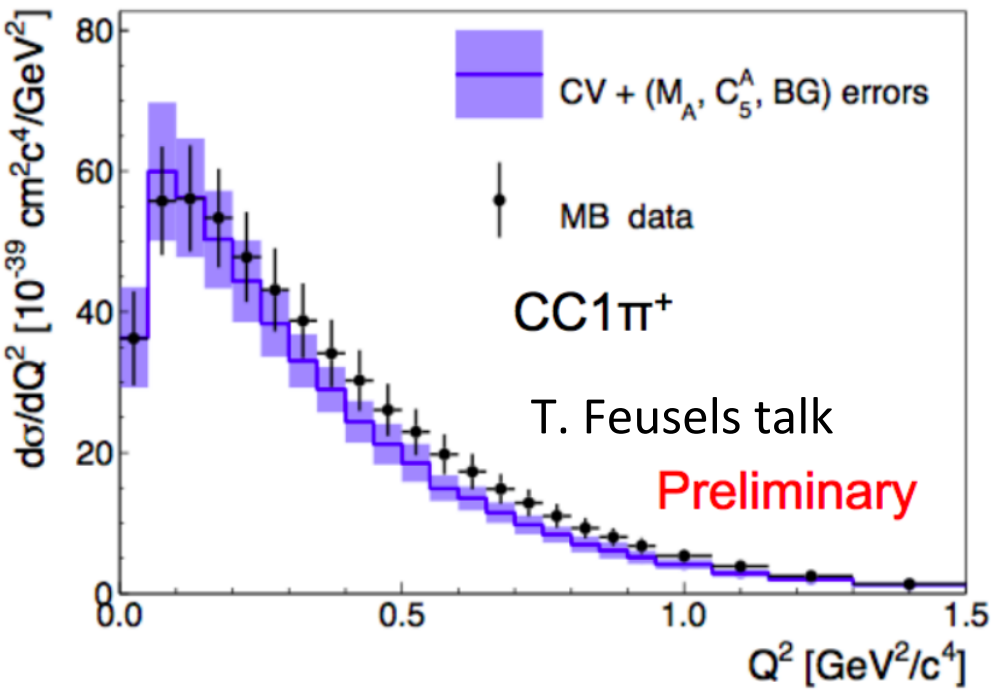

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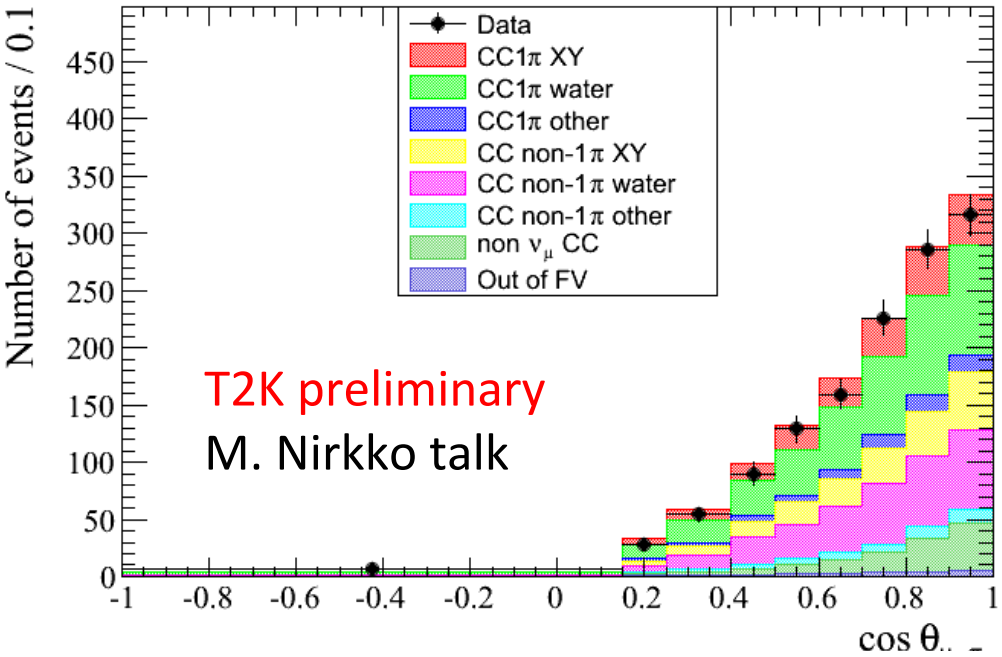
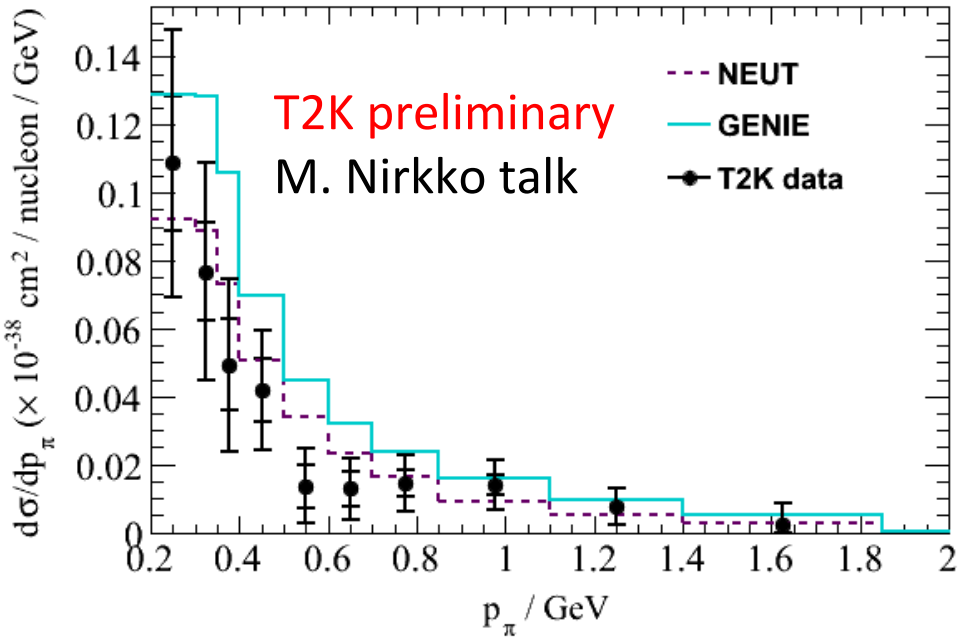


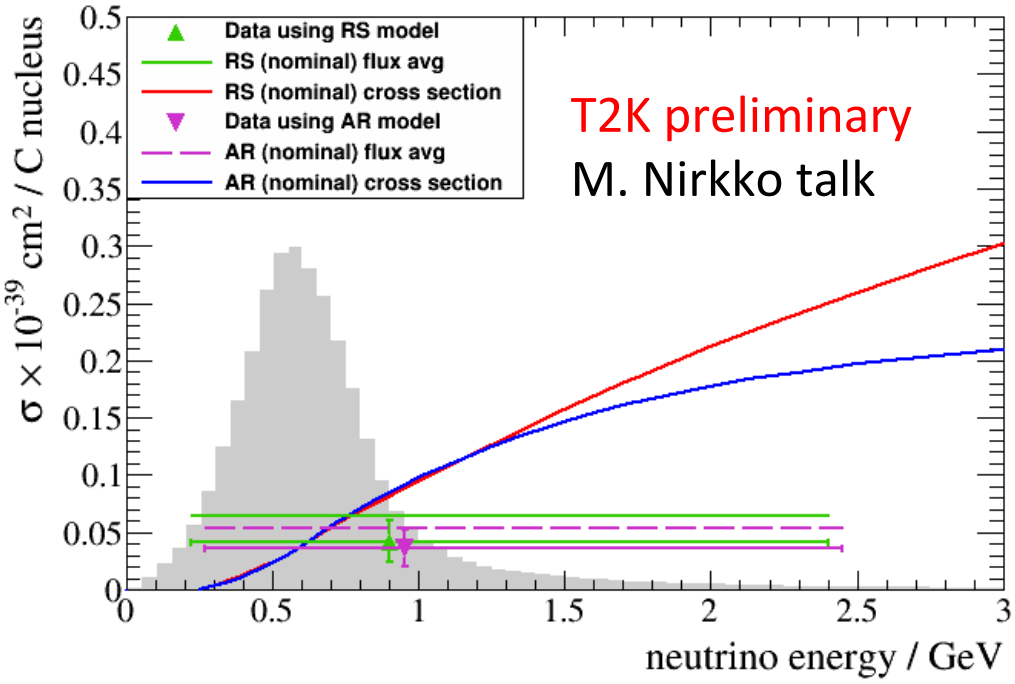
New T2K single pion production (H2O)

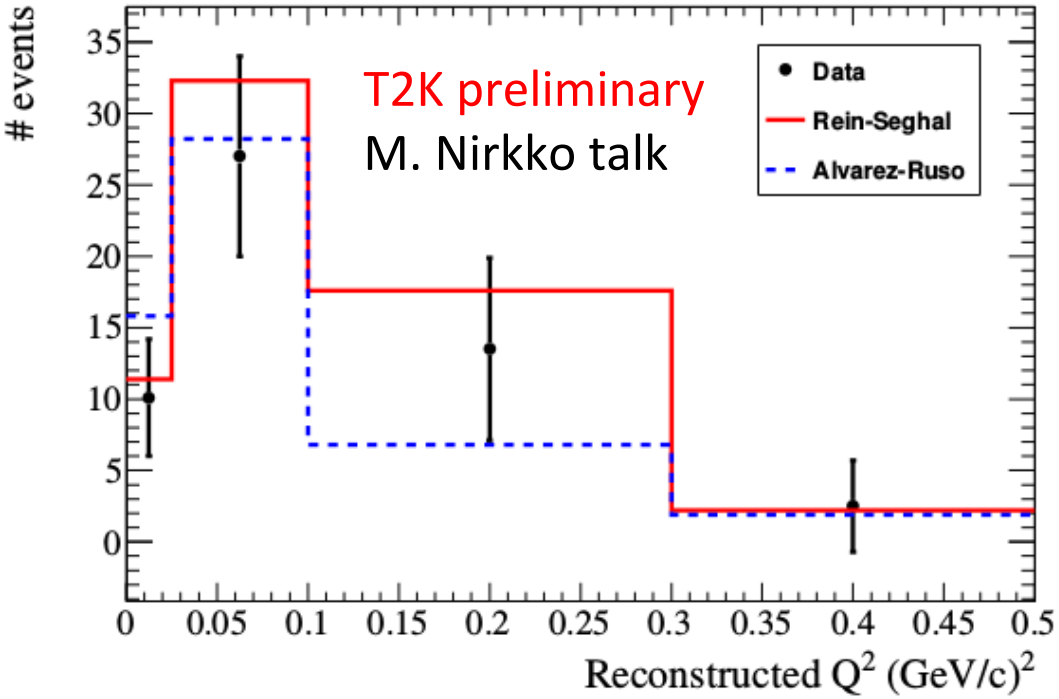
- GENIE ~30% too high, but not NEUT

New Question: What is the role of limited acceptance, and background subtractions on T2K, MINERvA measurements?



Questions: Are modern models able to describe the new results? MAYBE YES?





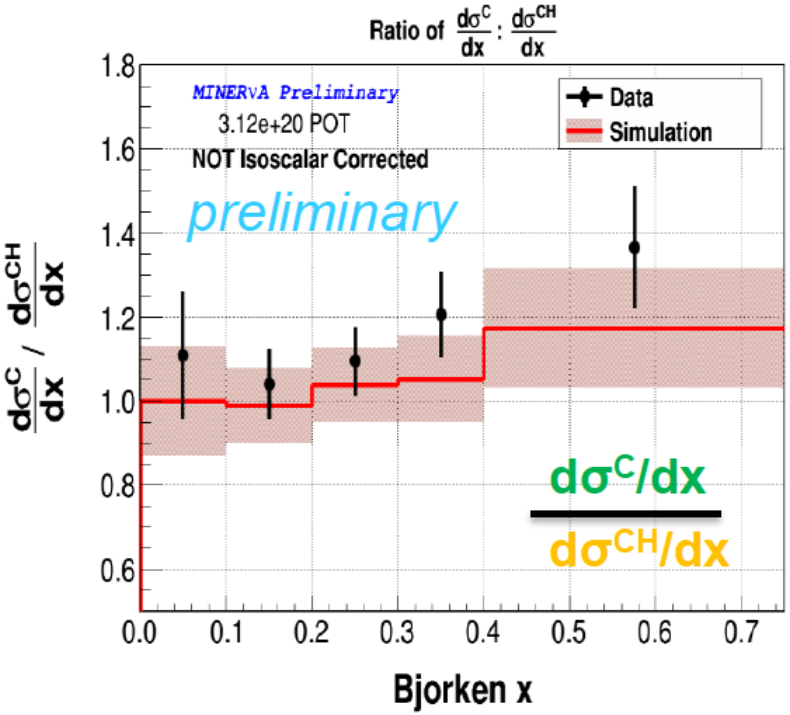
New T2K CC coherent measurement

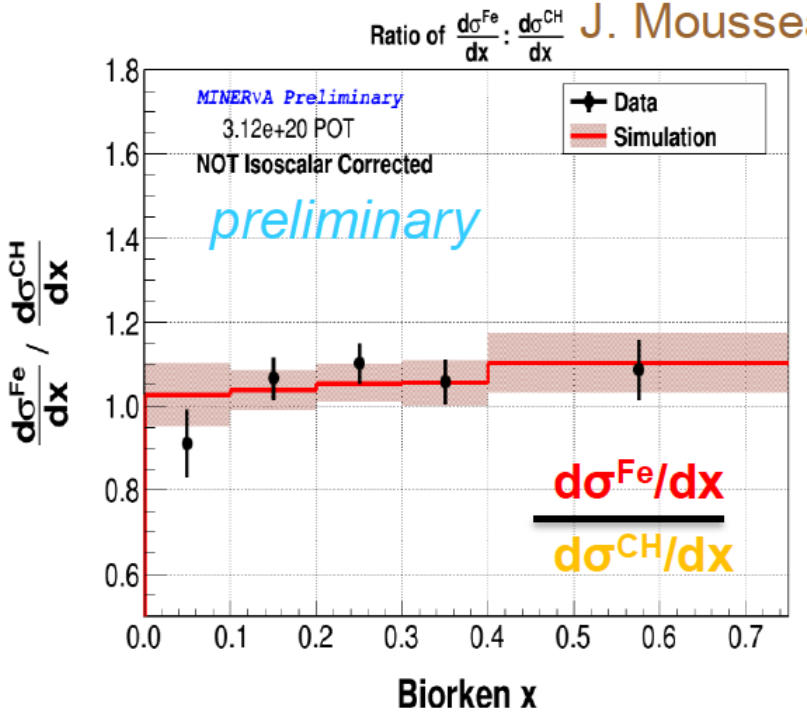
- Excess of 55 +/-20 events
- Can't distinguish between R-S and Alvarez-Russo models
- Complementary to MINERvA result

Additional investigation into negative cross section bins (MINERvA CC coherent result)

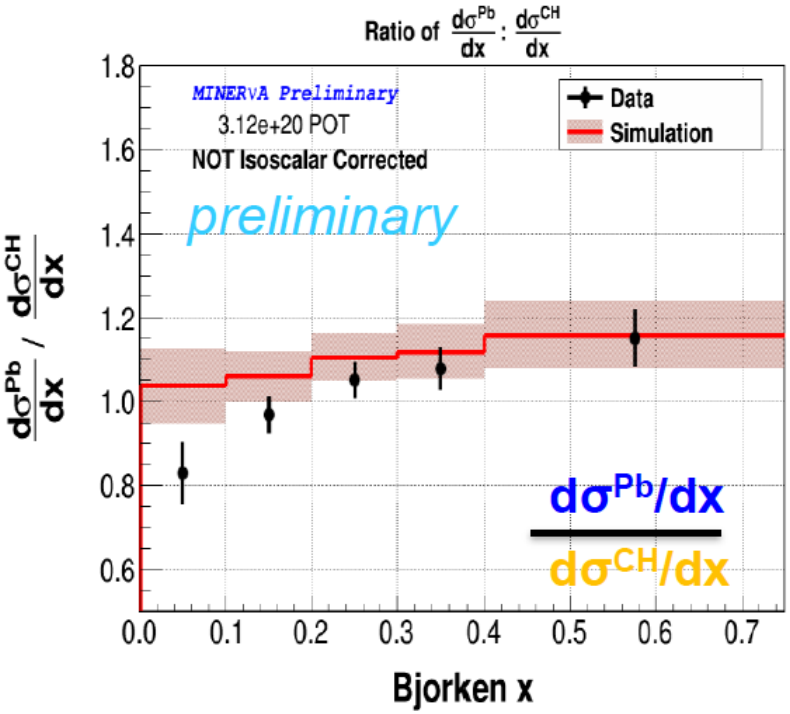
- Background subtraction also critical for these analyses

Questions: Are modern models able to describe the new results?





J. Mousseau, PhD



Unfolded x (detector smearing)

$$x_{Bj} = \frac{Q^2}{2ME_h}$$

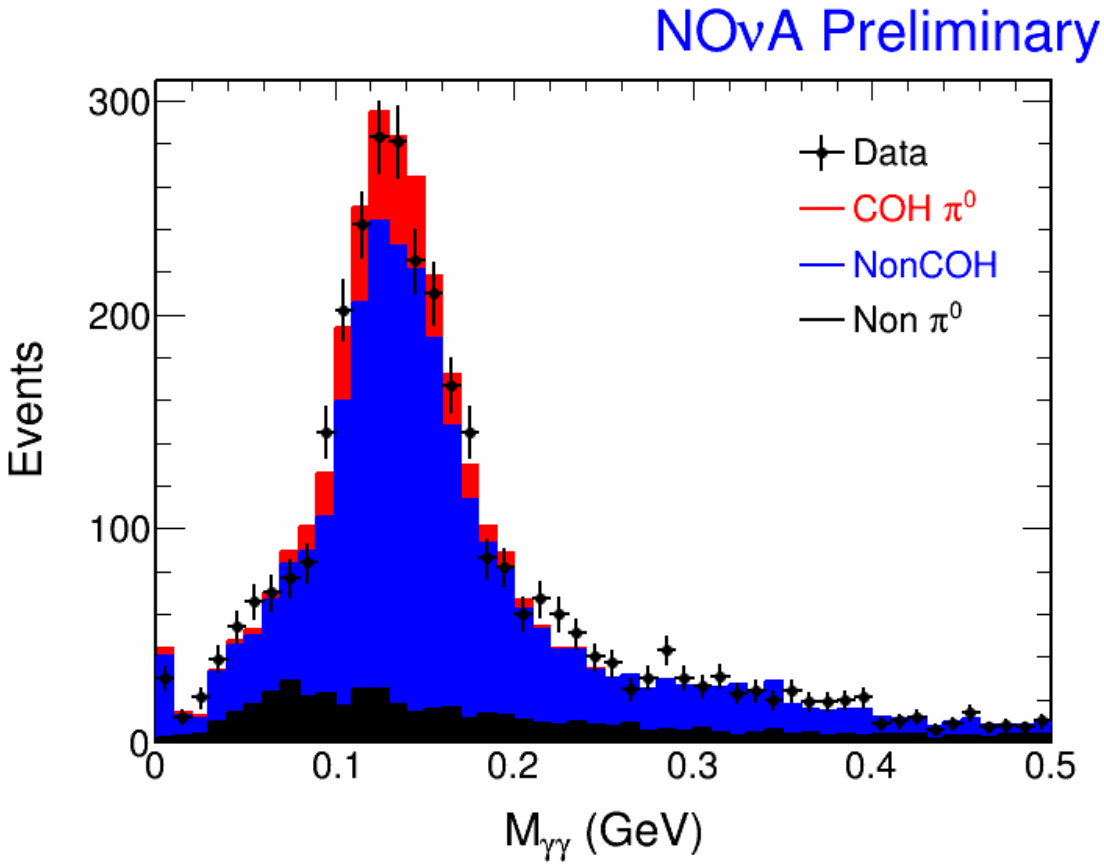
New! MINERvA DIS results (A. Bravar talk)

- Overall agreement between data and MC, except
- Hints of additional nuclear shadowing in at lowest x
- More to come with medium energy data

Question: What are the prospects for new measurements?

- NC K+ (MINERvA) and CC K+ (T2K) measurements for proton decay (M. Nirrko, M. Carneiro talks)
- Search for low energy (~50 MeV) coherent neutrino scattering
  - CONNIE experiment with ANGRA reactor and CCD detectors (C. Bonifazi talk)
  - COHERENT experiment at SNS with CsI, Ge and Xe detectors (B. Scholz talk)
- CAPTAIN-MINERvA: LAr detector in NuMI beamline (A. Higuera talk)
- Additional measurements from T2K, MINERvA, MicroBooNE (D. Harris talk)

- NOvA: (J. Paley talk)
- Millions of events!
- Will contribute to CC π^+ coherent vs. NC π^0 coherent production puzzle



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Impressive domestic and international effort (with MINERvA) on Brazilian science:

***** Neutrino agreement for Joe Biden and Dilma Rousseff**
The Brazil Minister of Science, Technology & Innovation Rebelo signed a statement of intent that promotes collaborative R&D in neutrino physics with the US DOE. It took place during lunch hosted by VP Joe Biden in honor of President Dilma Rousseff during her official visit to the U.S. The document recalls that Brazil and the US have many decades of collaboration in HEP. Brazil has several working groups studying neutrinos and the US DOE considers this field a priority for its future particle physics program.
http://www.mcti.gov.br/ and search "neutrino"

CAPTAIN-MINERνA

- CAPTAIN-MINERvA would study neutrino-argon interactions in the medium-energy NuMI beam
  - Ideally 6x10^{20} POT in both neutrino and antineutrino mode
- The proposal is signed by members of both collaborations
- Unique and complementary to existing LAr R&D
- We are requesting resources so that the engineering work can begin as soon as possible
  - Allows us to be ready for the earliest possible run date (2016)
- **We welcome additional Brazilian collaborators desiring to understand ν LAr interactions in advance of the DUNE experiment**

Questions: How have near detectors been used so far? What are the tactics used by future near detectors (or dedicated service experiments) to address deficiencies?

Near detectors currently reduce the uncertainties to 5~10% level (K. Mahn talk)

Wide variety of service experiments coming online or running now:

- ANNIE: Neutron tagging in H2O with Gd (M. Sanchez talk)
- CAPTAIN: Neutron tagging in LAr (J. St. John, A. Higuera talks)
- LArIAT: pion, proton interactions in LAr (J. St. John talk)

Impressive host of future measurements possible for Hyper-K, DUNE ND and current program (A. Minamino, K. McDonald, D. Cherdak, M. Hartz, D. Harris talks).

- Flux measurement with neutrino-electron scattering (done in MINERvA)
- Use of mono-chromatic beams as a better probe of nuclear interactions (nuPRISM)

"Do we want one ~1% measurement, or do we want ~10 10% measurements?"
– D. Harris

Personal view: Challenge to interpret differences between MiniBooNE, MINERvA and T2K ND – needed those measurements to see issues! Need a combined effort with new approaches, clarification of existing systematics, background treatment of above tactics, and theory-experimental discussion

Larger question of theory-experiment, experiment-experiment connections:

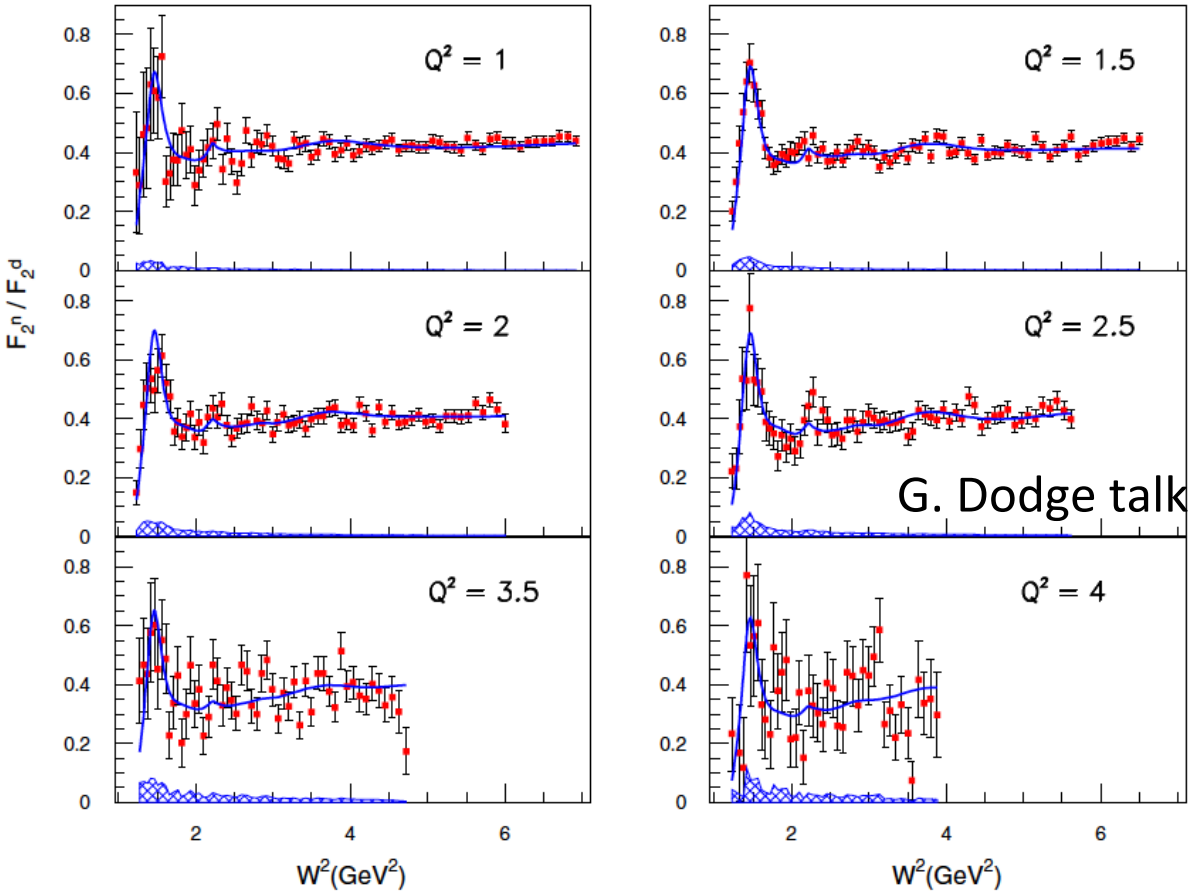
- NuSTEC theory-experimental initiative (J. Morfin talk)

◆ The main goal is to improve our understanding of neutrino interactions with nucleons and nuclei and, practically, get that understanding in our event generators.

▼ The impact of our main goal will be widespread in both hadron and nuclear physics and directly effect oscillation physics.

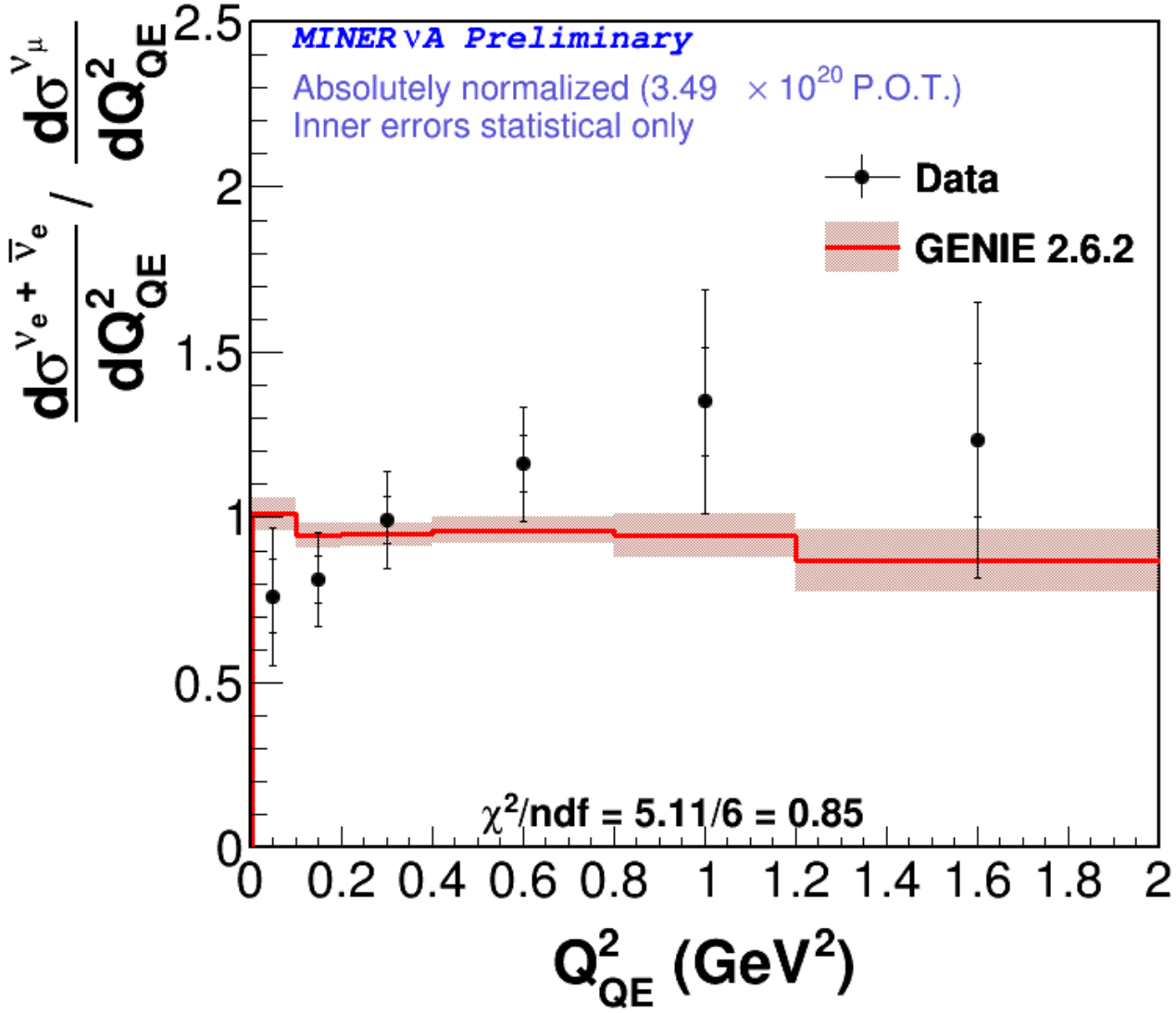
- Formation of a new J-PARC-KEK theory initiative (S. Nakamura talk)

- BoNuS electron experiment: measurements of neutron structure using spectator tagging
- Neutron duality holds except for Delta region down to Q2~1
  - May provide information about FSI in deuterium system?



Questions: What are the most significant neutrino interaction systematic uncertainties which need confronting for osc experiments?

Understanding of the electron neutrino (and antineutrino) cross section is important for the Hyper-Kamiokande CP violation search (M. Hartz talk)



First steps toward such measurements shown by MINERvA (A. Ghosh talk)

- 10% uncertainties, predominantly statistical

Possible ~1% measurement using identification of K+ and special beamline (F. Terranova talk)

nuSTORM, nuPRISM (or combination) also a possibility

Summary:

Multiple exciting new developments from theory and experiment shown for the first time at this workshop

But, still many outstanding issues which need more work

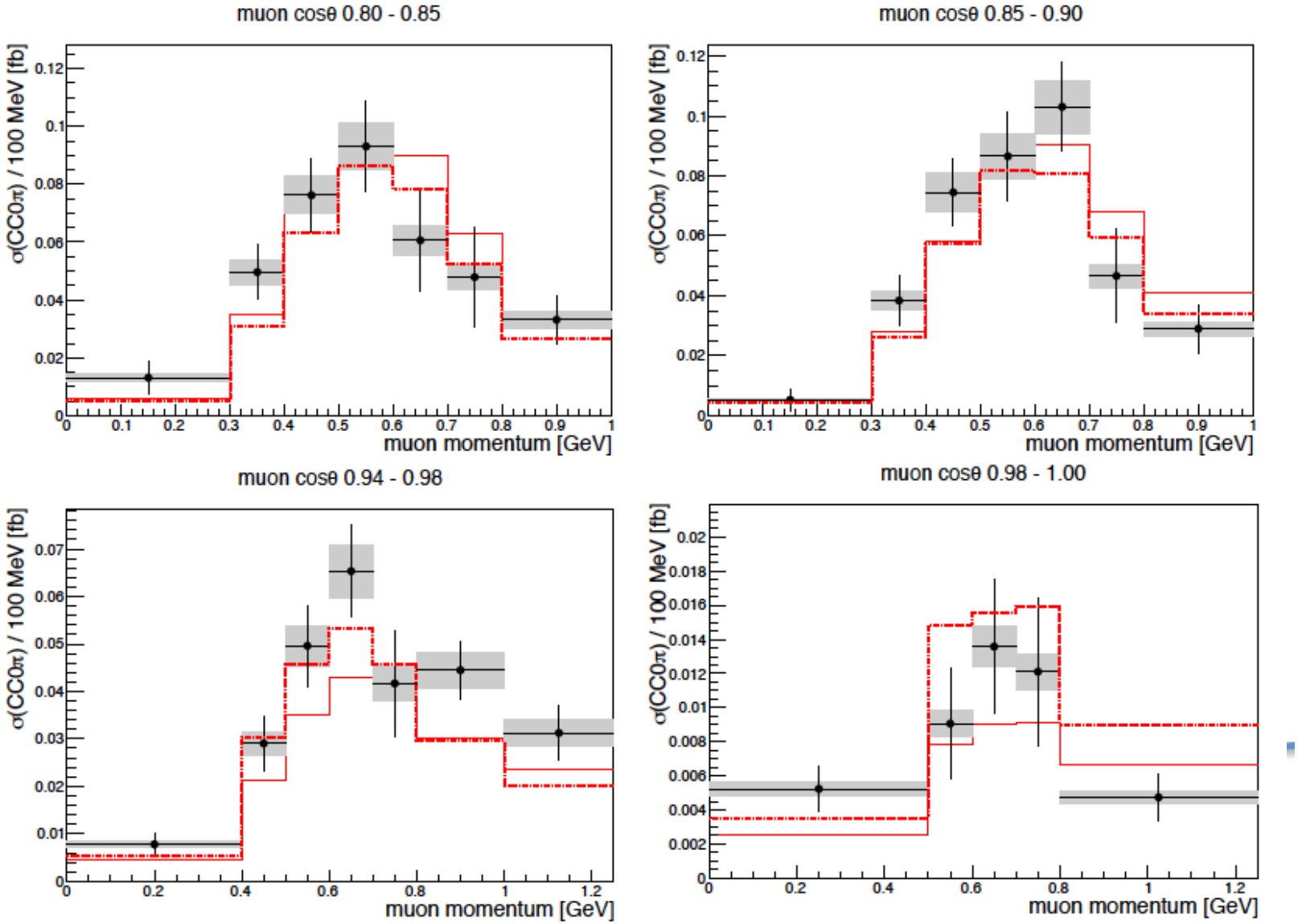
- Suggestion of fake data challenge by H. Gallagher: clarify the effect of ongoing physics issues for the current and future experiments

The future physics lies ahead of us

Photo from: http://gadling.com/2009/11/27/coconuts-banned-on-rio-de-janeiro-beaches/

Backups

Question: Where is there agreement/disagreement between new experimental results at different beam energies?



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