NUFACT 2017

WG2 Summary
Neutrino Scattering Physics

Marco Martini

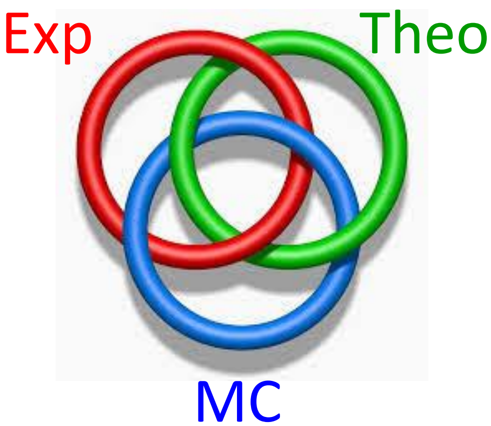
WG2 ν Scattering Physics -- Statistics

Total of 26 presentations

2 Plenary talks

7 Talks in joint WG1+2 sessions

17 Talks in WG2 sessions



18 Experimental talks

6 Theoretical talks

2 MC generators talks

Many thanks to all speakers and participants in WG2

Modern accelerator-based neutrino oscillation experiments

$$\nu_\alpha \rightarrow \nu_\beta$$

Number of events

$$N_\beta \sim \Phi_{\nu_\alpha}(E_\nu)\, \sigma_{\nu_\beta}(E_\nu)\, \varepsilon_{det.}\, P_{\nu_\alpha \rightarrow \nu_\beta}(\{\Theta\}, E_\nu)$$

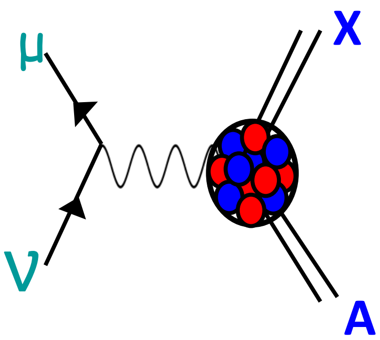
ν flux

ν cross section

Detector efficiency

ν Energy in the oscillation probability

- Nuclear targets (C, O, Ar, Fe…)
- The neutrino energy is reconstructed from the final states



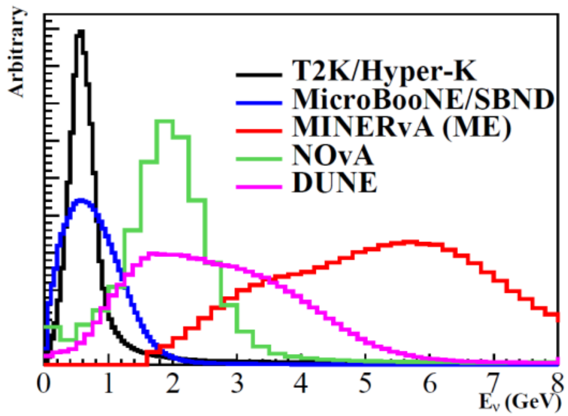
→ The knowledge of the neutrino-nucleus cross section is crucial

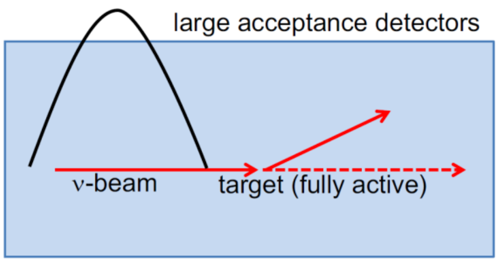
-Today the cross sections are known with a precision not exceeding 20%

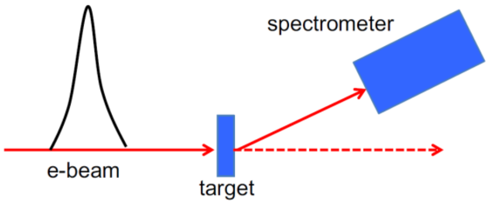
-Today in the oscillation experiments the systematics associated to the cross section uncertainties are ~10% before ND constraints and ~5% after ND constraints

Some crucial points of the accelerator-based ν experiment

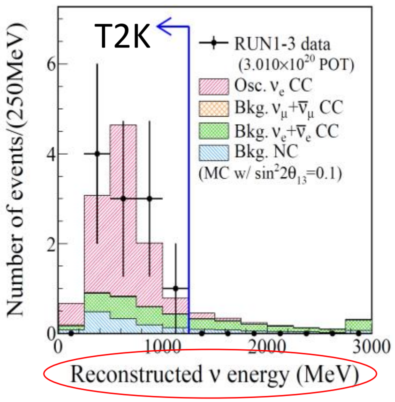
- Neutrino beams are not monochromatic (at difference with respect to electron beams)



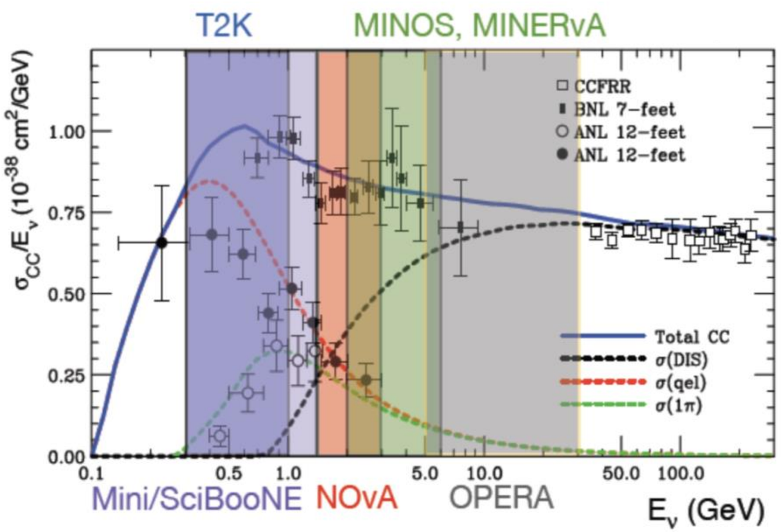




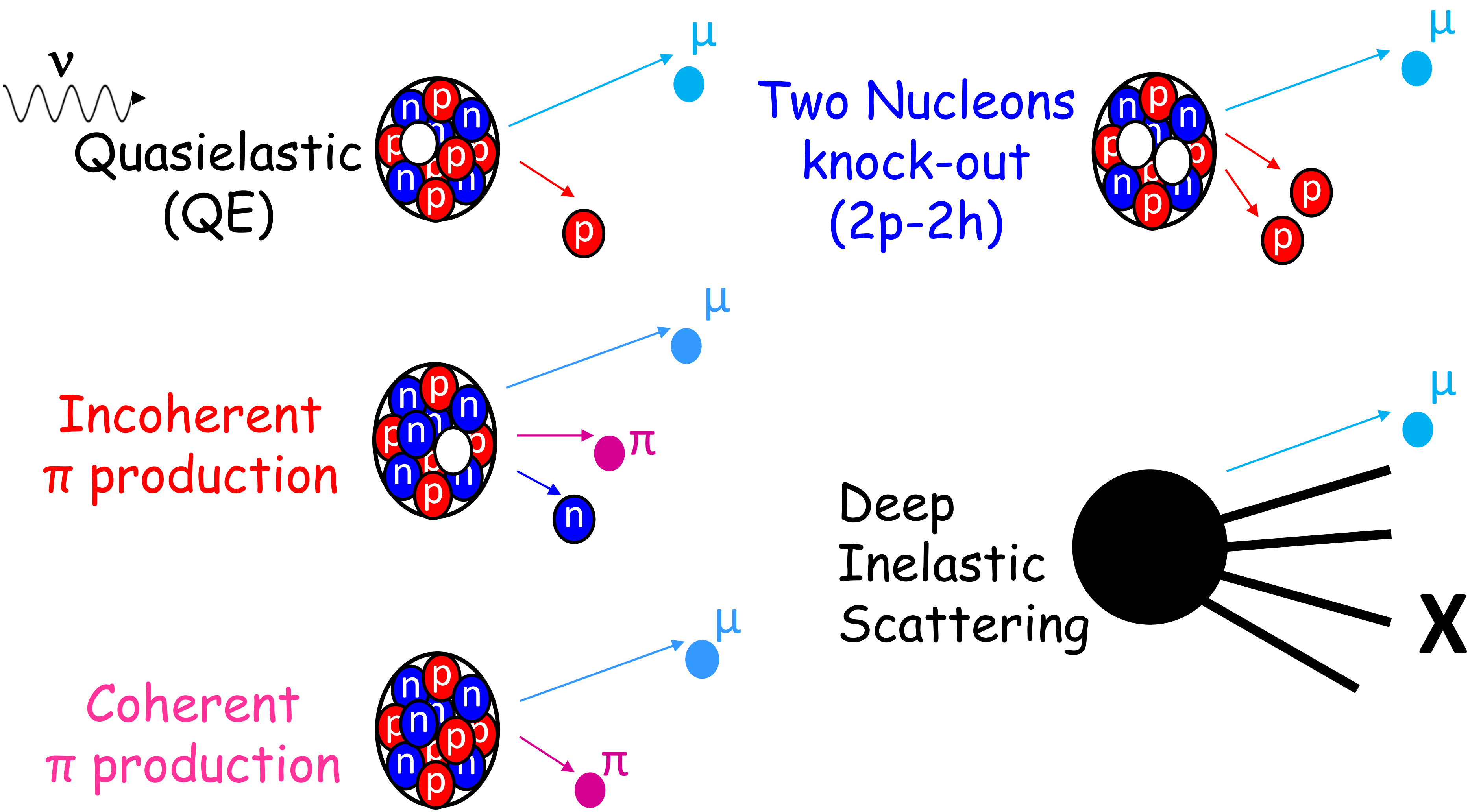
- The neutrino energy is reconstructed from the final states of the reaction (typically from CC Quasielastic events)



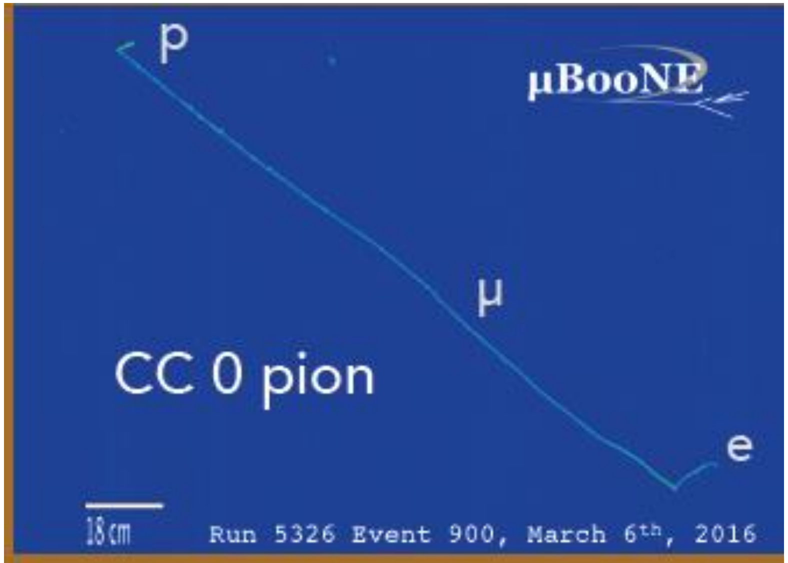
- Different reaction mechanisms contribute to the cross section

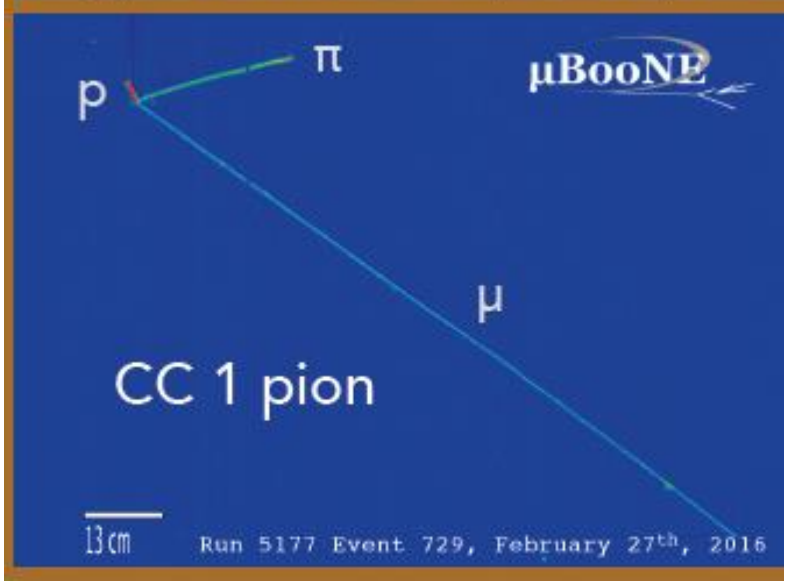


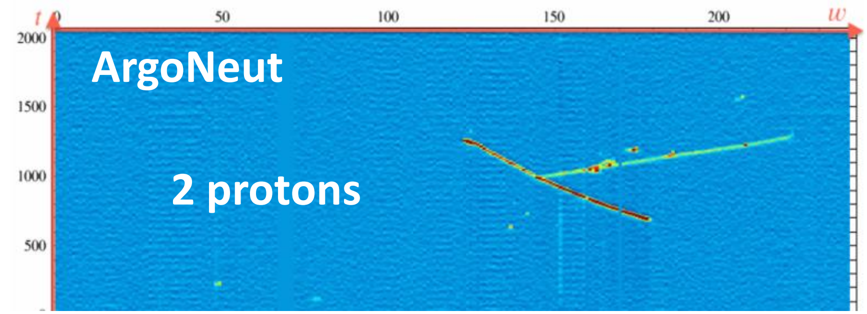
Different reaction mechanisms contribute to the cross section

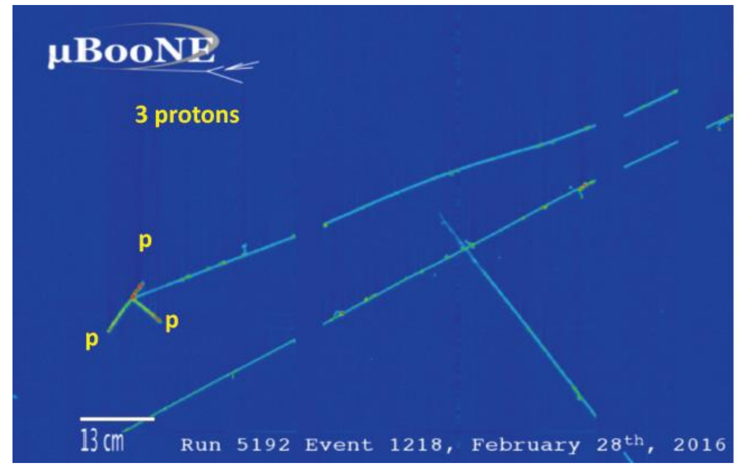


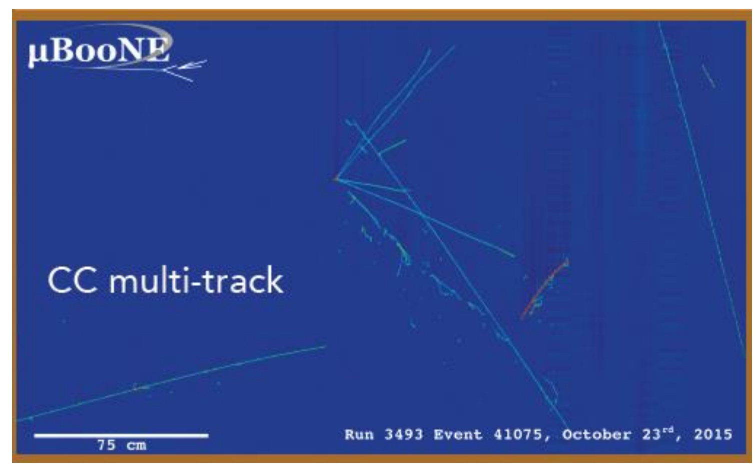
Marco Del Tutto
Xiao Luo







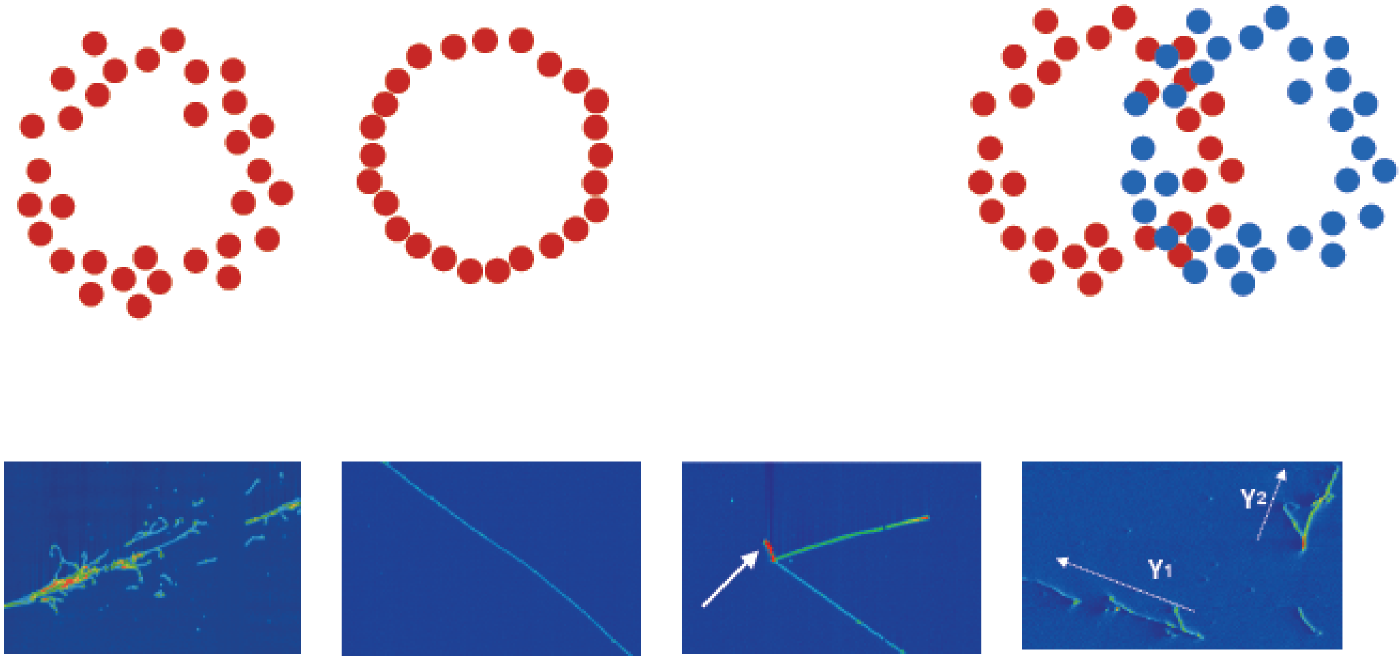




Marco Del Tutto

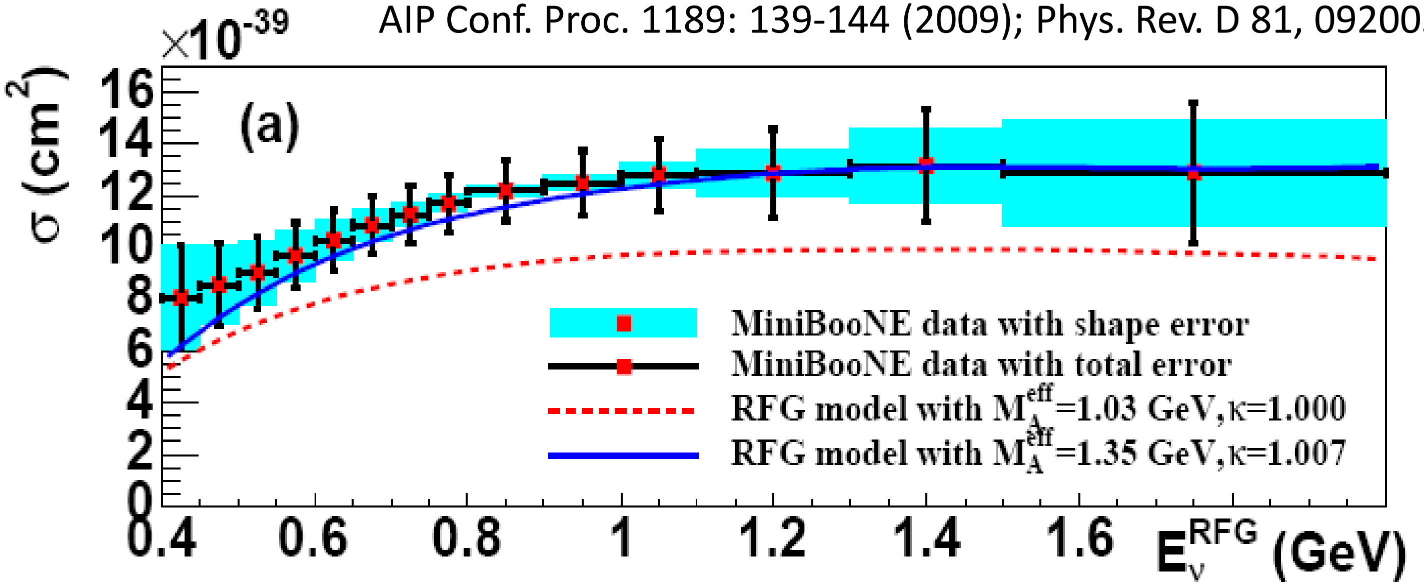
CC0π - Event Topology

	Electron, Photon	Muon	Proton	$\pi^0 \rightarrow \gamma\gamma$
Cherenkov (MiniBooNE)				
LArTPC (MicroBooNE)				



MiniBooNE CC Quasielastic cross section on Carbon and the M_A puzzle

AIP Conf. Proc. 1189: 139-144 (2009); Phys. Rev. D 81, 092005 (2010)



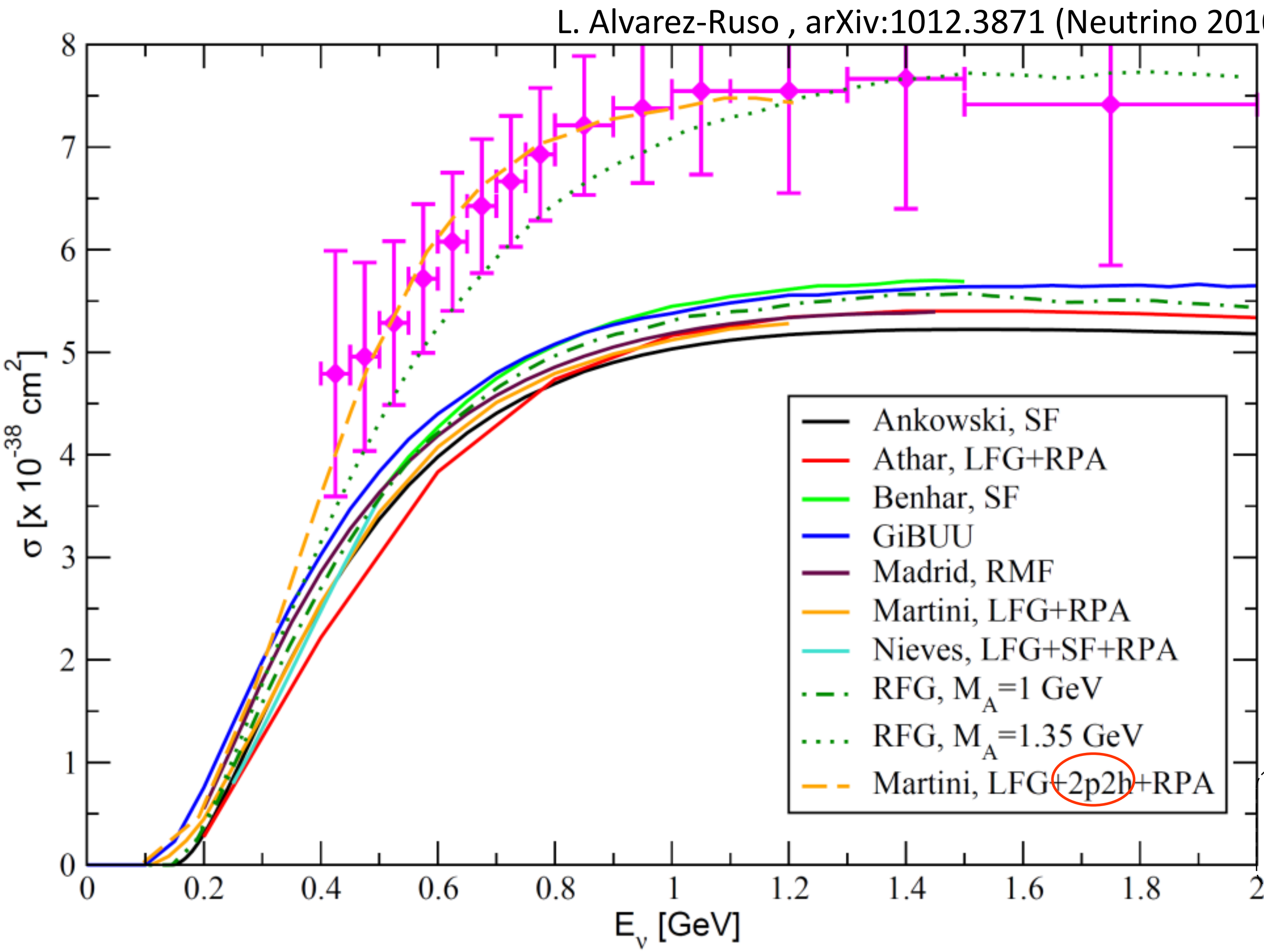
Comparison with a prediction based on RFG using the standard value of M_A=1.03 GeV in the dipole parametrization of the axial form factor (see L. Alvarez-Ruso talk) reveals a discrepancy

In the Relativistic Fermi Gas (RFG) model an axial mass of 1.35 GeV is needed to account for data

p.s. Relativistic Fermi Gas: Nucleus as ensemble of non interacting fermions (nucleons)

puzzle??

Comparison of different theoretical models for Quasielastic



SF: Spectral Function

LFG: Local Fermi Gas

RPA: Random Phase Approximation

RMF: Relativistic Mean Field

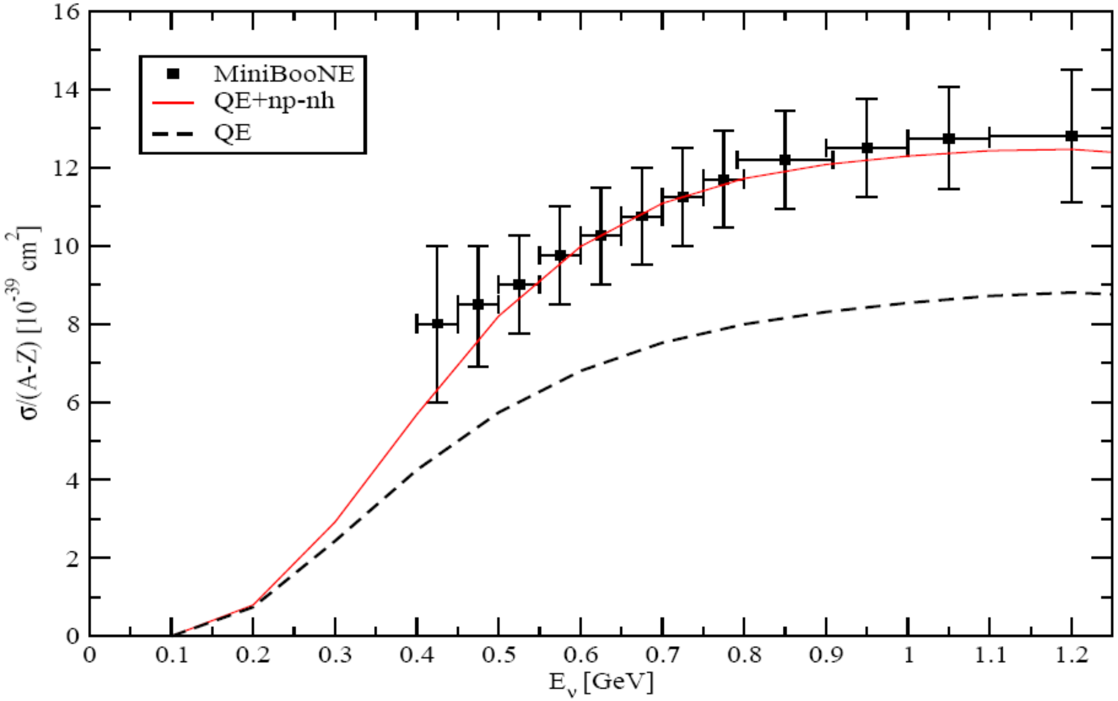
GiBUU: Transport Equation

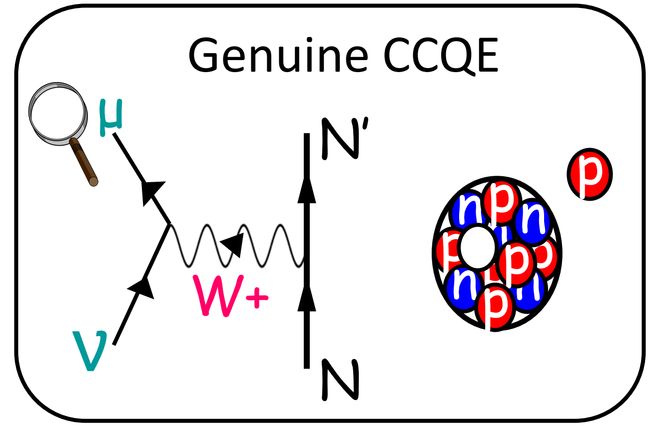
Comparison of models and Monte Carlo: Boyd, Dytman, Hernandez, Sobczyk, Tacik , AIP Conf.Proc. 1189 (2009) 60-73

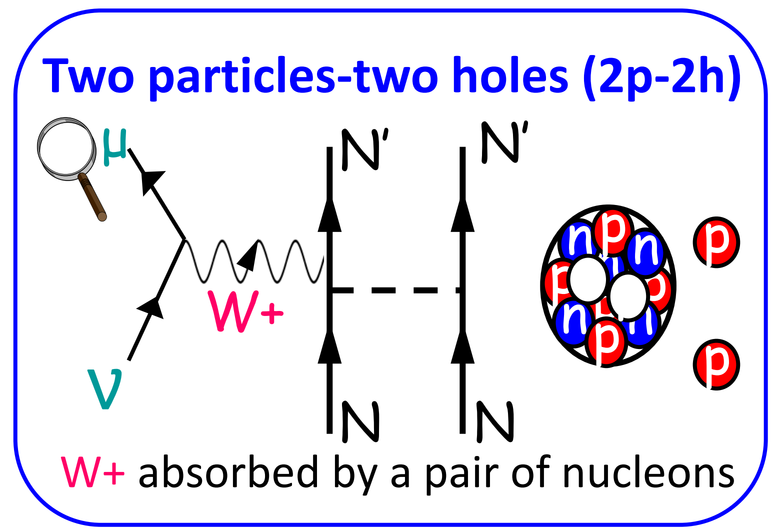
puzzle??

An explanation of this puzzle

Inclusion of the multinucleon emission channel
(np-nh = 2p-2h + 3p-3h)







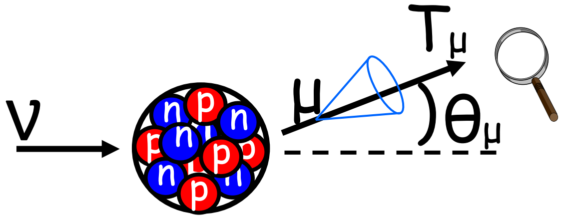
CCQE-like = Genuine CCQE + np-nh

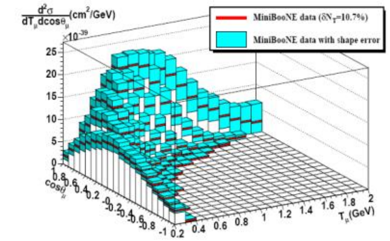
M. Martini, M. Ericson, G. Chanfray, J. Marteau, Phys. Rev. C 80 065501 (2009)

Agreement with MiniBooNE without increasing M_A

CCQE-like flux-integrated double differential cross section

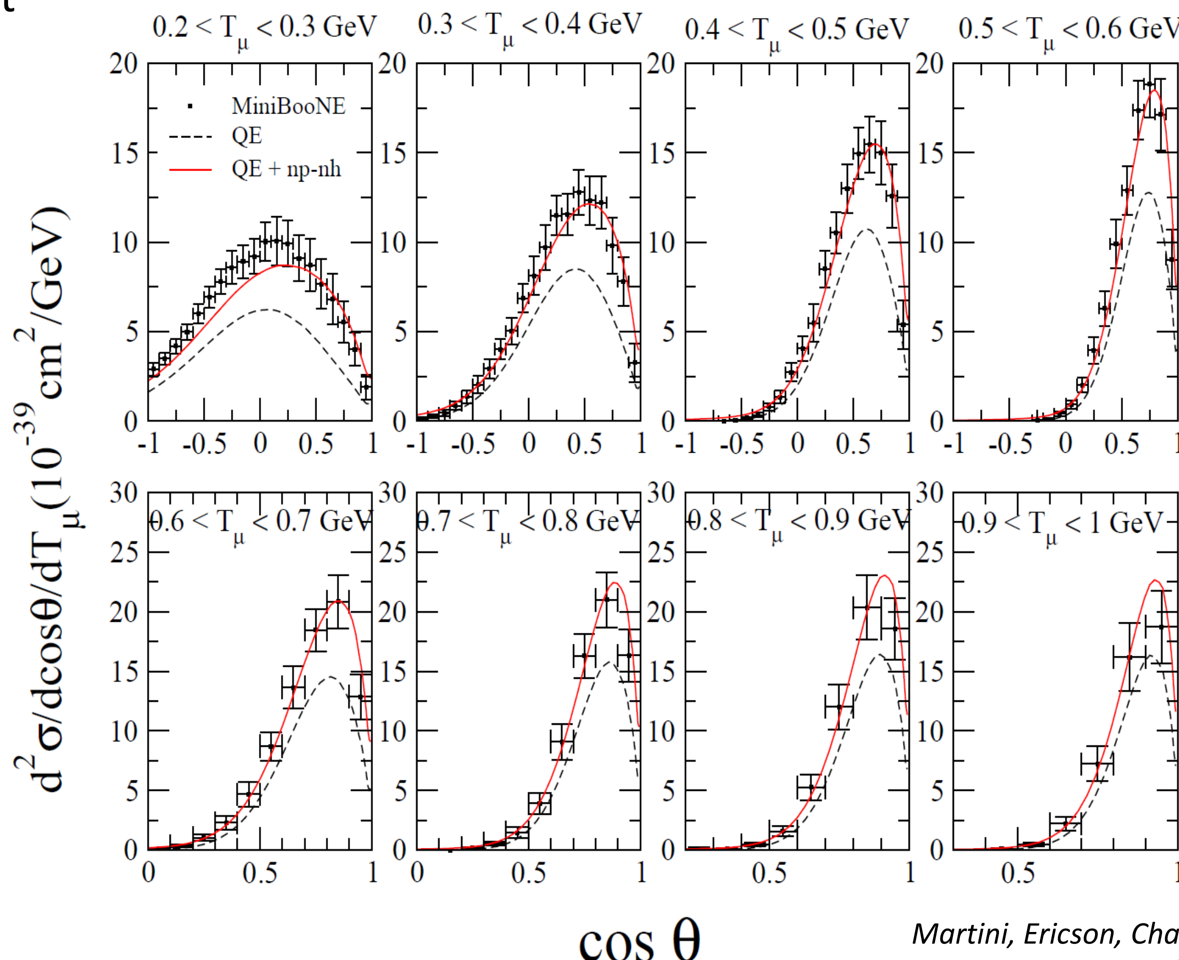
$$\frac{d^2\sigma}{dE_\mu d\cos\theta} = \int dE_\nu \left[\frac{d^2\sigma}{d\omega d\cos\theta}\right]_{\omega=E_\nu - E_\mu} \Phi(E_\nu)$$





MiniBooNE, Phys. Rev. D 81, 092005 (2010)

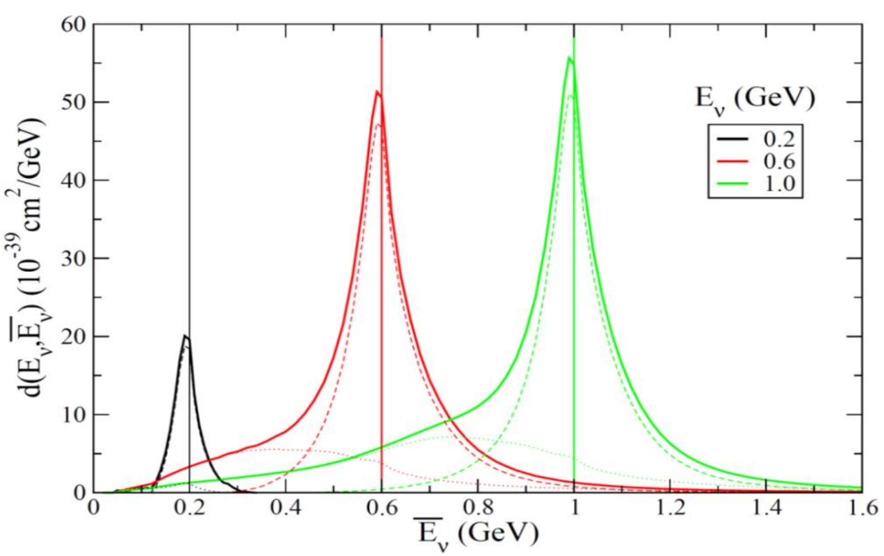
- Less model dependent than $\sigma(E_\nu)$
- Flux dependent



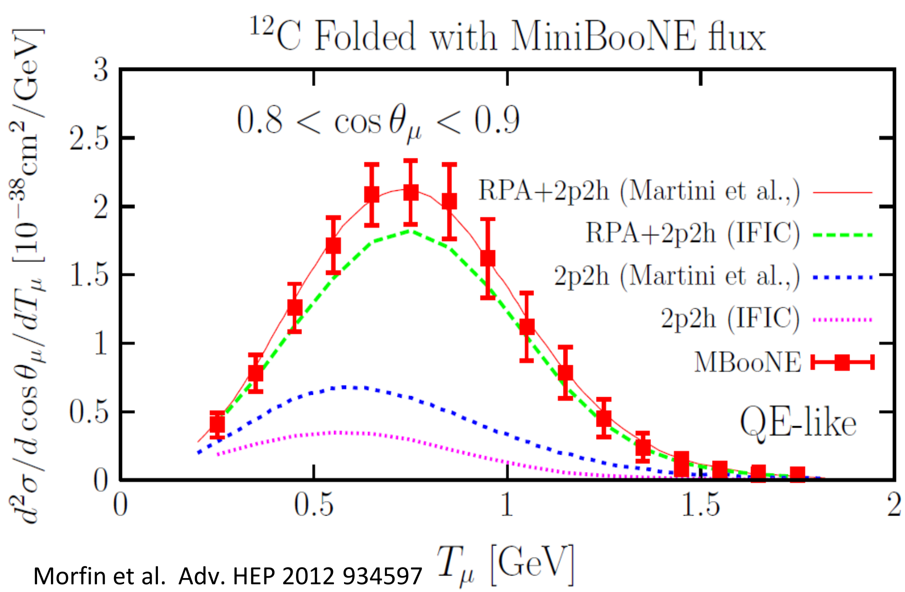
Martini, Ericson, Chanfray, Phys. Rev. C 84 055502 (2011)

The multinucleon emission channel (or np-nh, or 2p-2h)

- A lot of interest in these last years
- Explanation of the axial mass puzzle
- It was not included in the generators used for the analyses of ν experiments
- Today there is an effort to include this np-nh channel in several Monte Carlo (**Hayato talk**)
- One of the most important source of systematic errors in oscillation experiments because it **affects the neutrino energy reconstruction**
- Several theoretical calculations agree on its crucial role but there are some differences on the results obtained for this channel



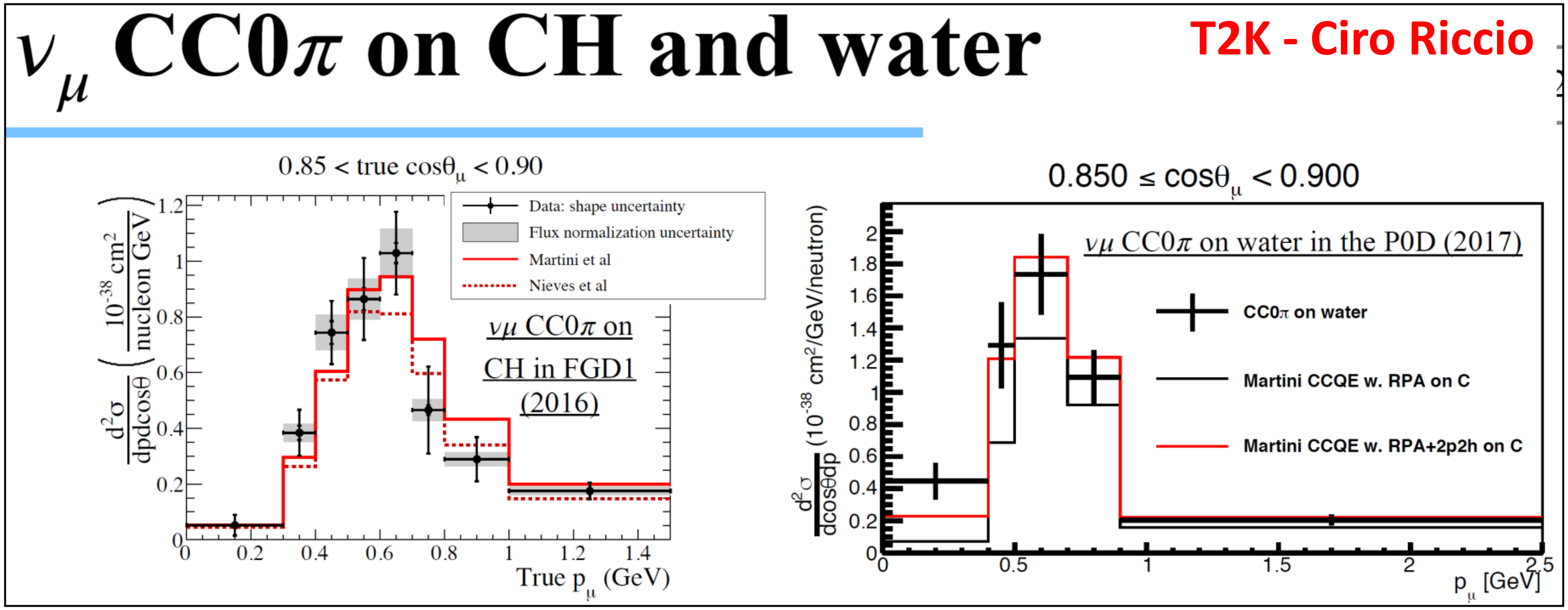
M. Martini, M. Ericson, G. Chanfray, Phys. Rev. D 87 013009 (2013)

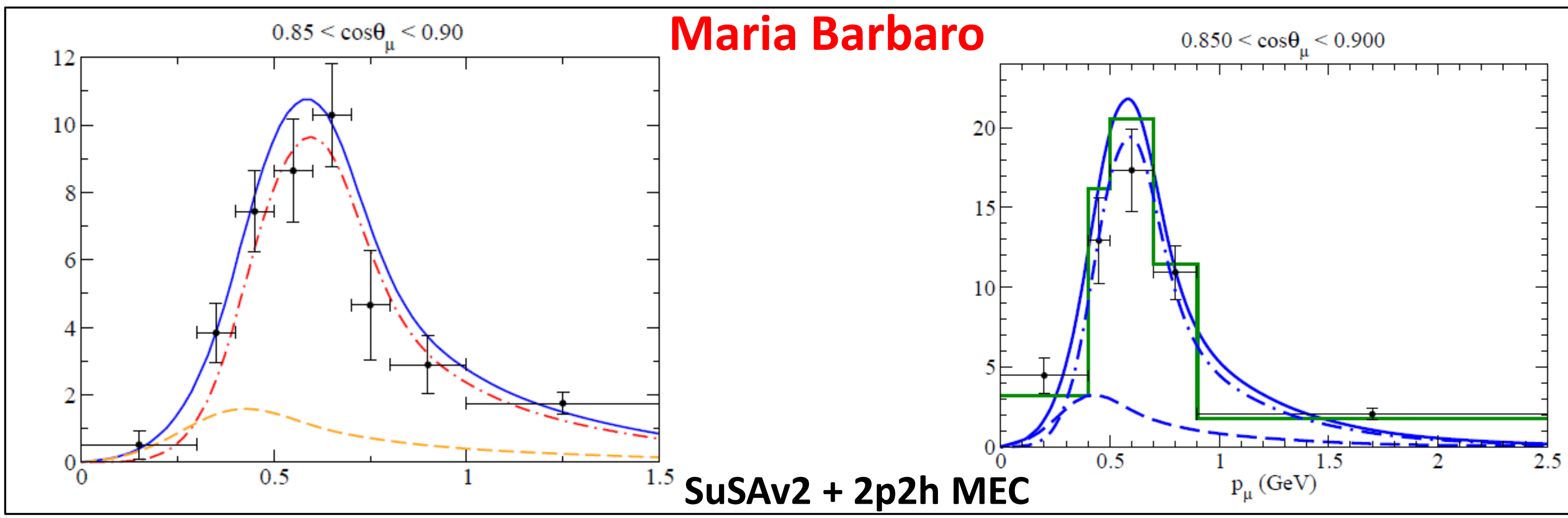


Morfin et al. Adv. HEP 2012 934597

CC0π = CCQE-like without subtraction of π absorption background

It is increasingly more popular to present the data in terms of final state particles (e.g. 1μ, 0π, any p)





Yoshinari Hayato

Introduction

There are many theoretical attempts to explain the data:

Spectral function, Local Fermi-gas model, Super Scaling, Random phase approximation, Multi-nucleon interactions, ab-initio calculations etc...

New models are introduced in the course of the developments of the neutrino – nucleus interaction simulation programs (generators).

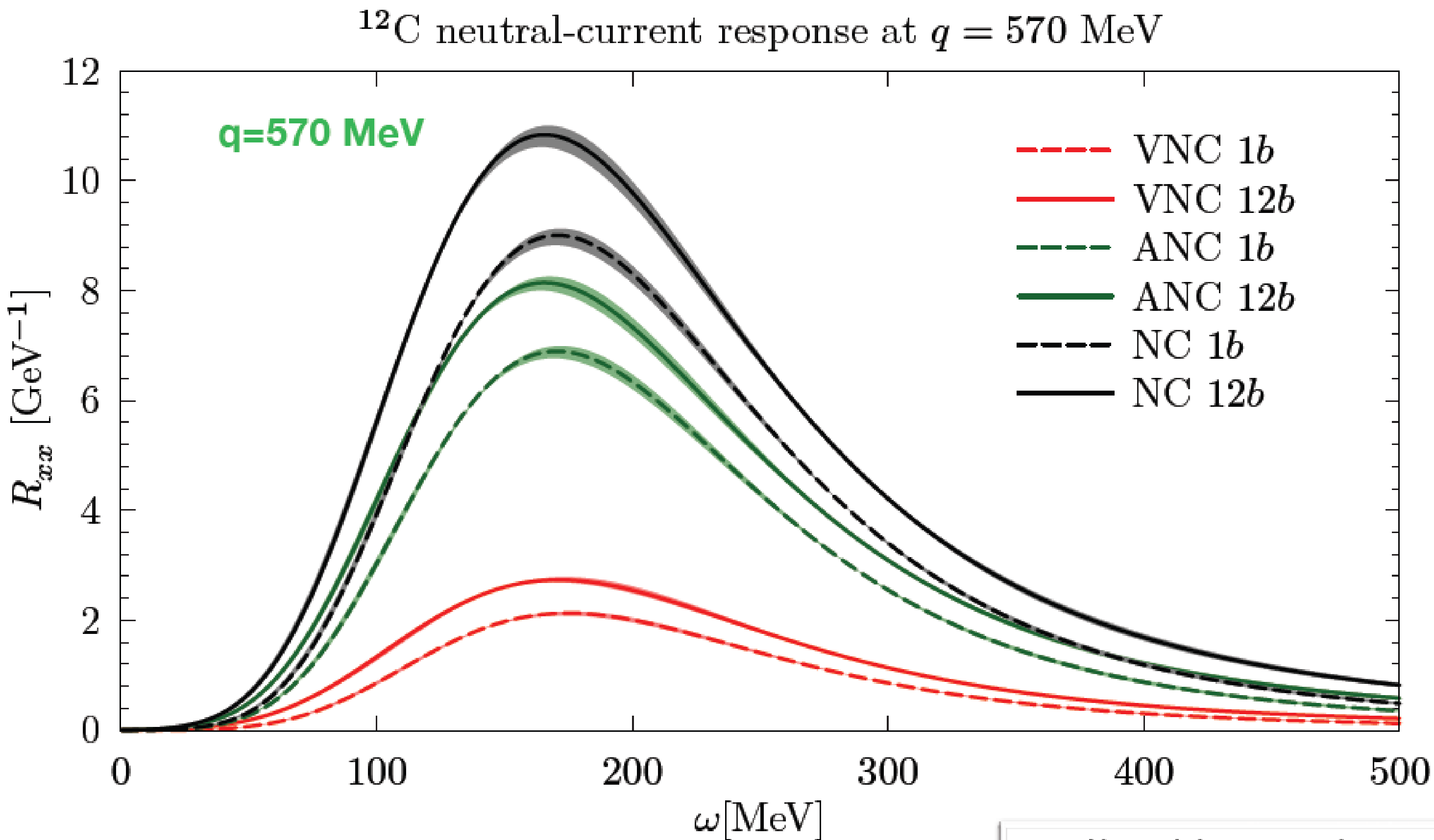
GENIE	Be universal and comprehensive
GIBUU	Framework to encode "best possible" theory
Neut	Mainly for specific experiments (SK, T2K etc.)
NuWro	Provide the latest model useful for the community

GFMC: an *ab-initio* microscopic approach

Alessandro Lovato

^{12}C neutral-current response

- We were recently able to invert the neutral-current Euclidean responses of ^{12}C

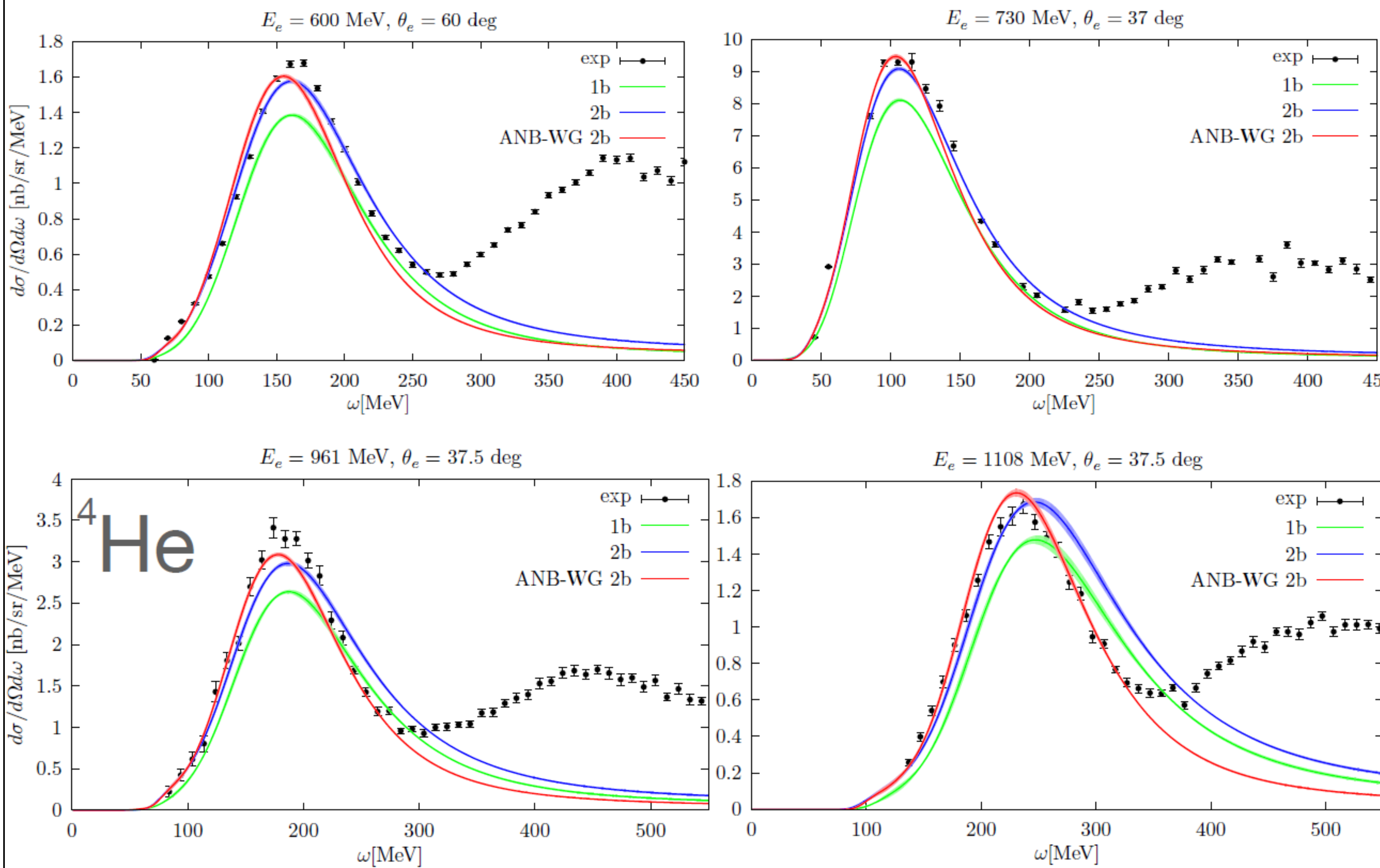


AL et al. in preparation

From scaling to cross sections within GFMC

Noemi Rocco

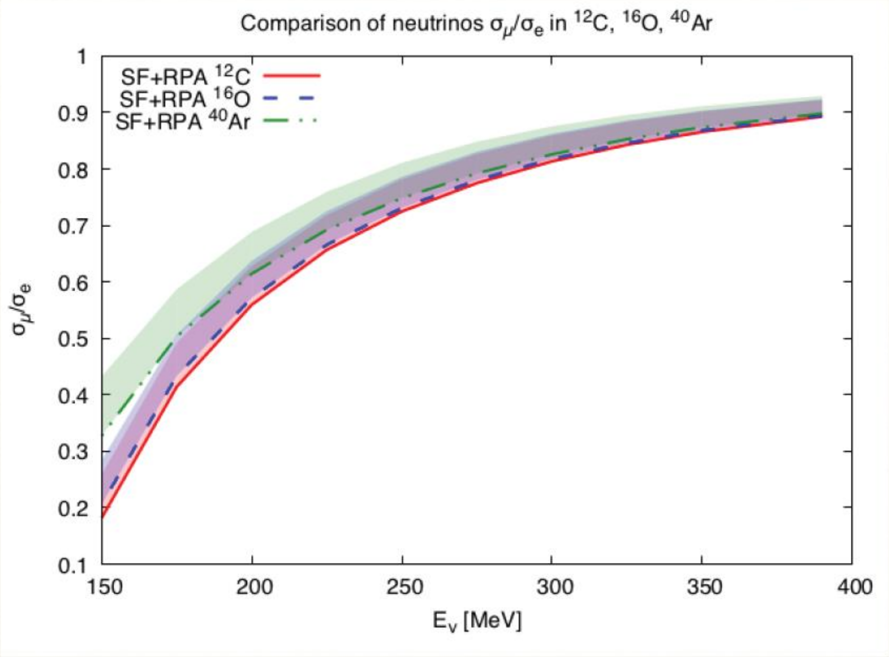
We use the interpolation to obtain cross sections

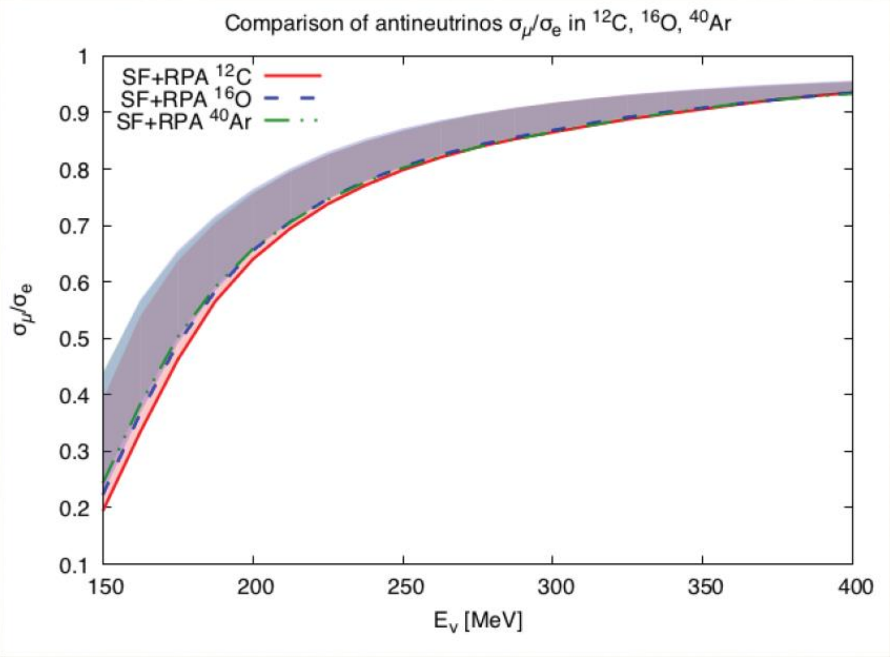


Joanna Sobczyk

Ratio σ(μ)/σ(e)

Spectral function + RPA



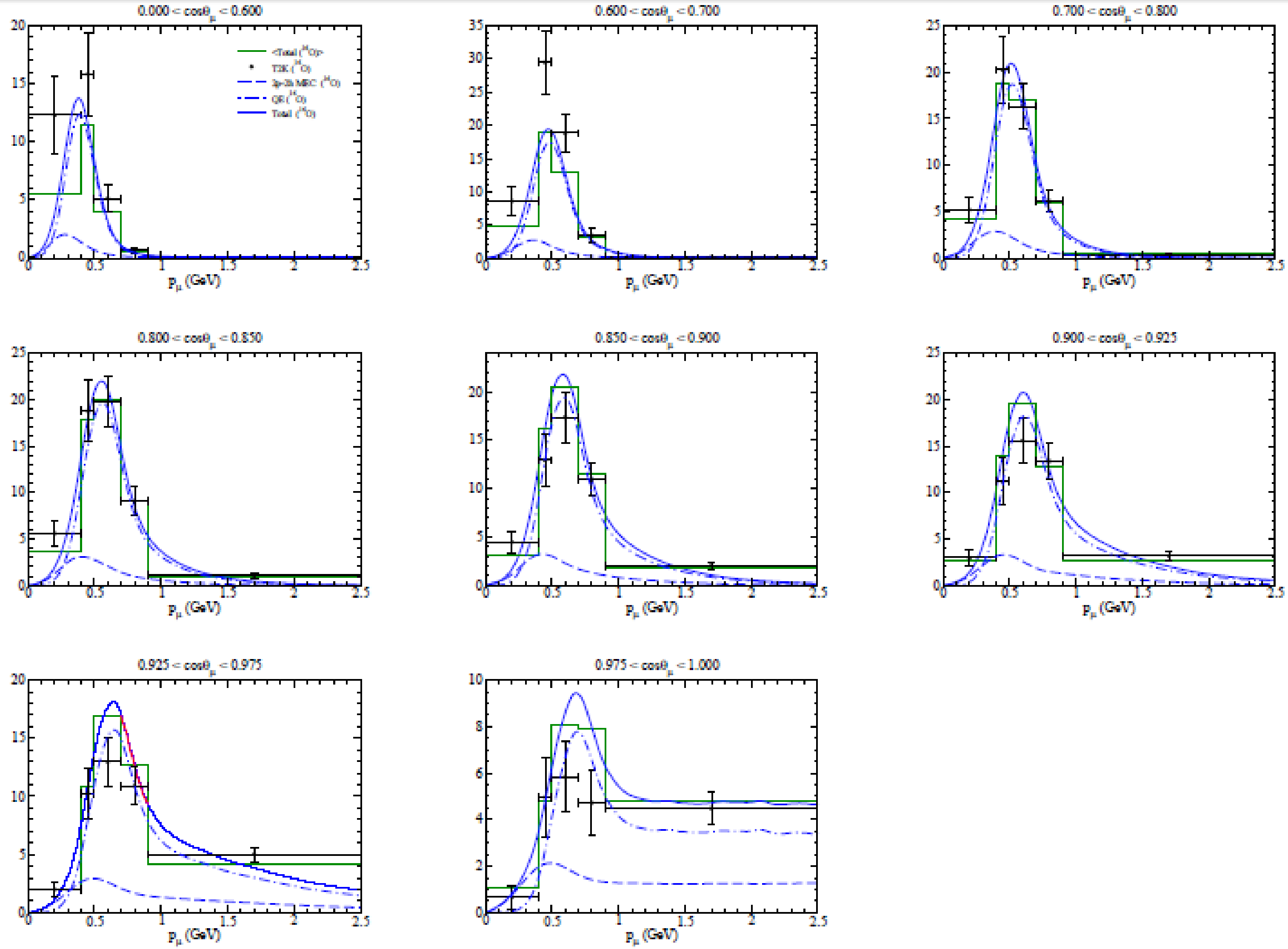


Nuclear effects **do not cancel out** when we take the ratio σ(μ)/σ(e)

$\equiv \sigma(\nu_\mu + {}^AZ \to \mu^- + X)/\sigma(\nu_e + {}^AZ \to e^- + X)$

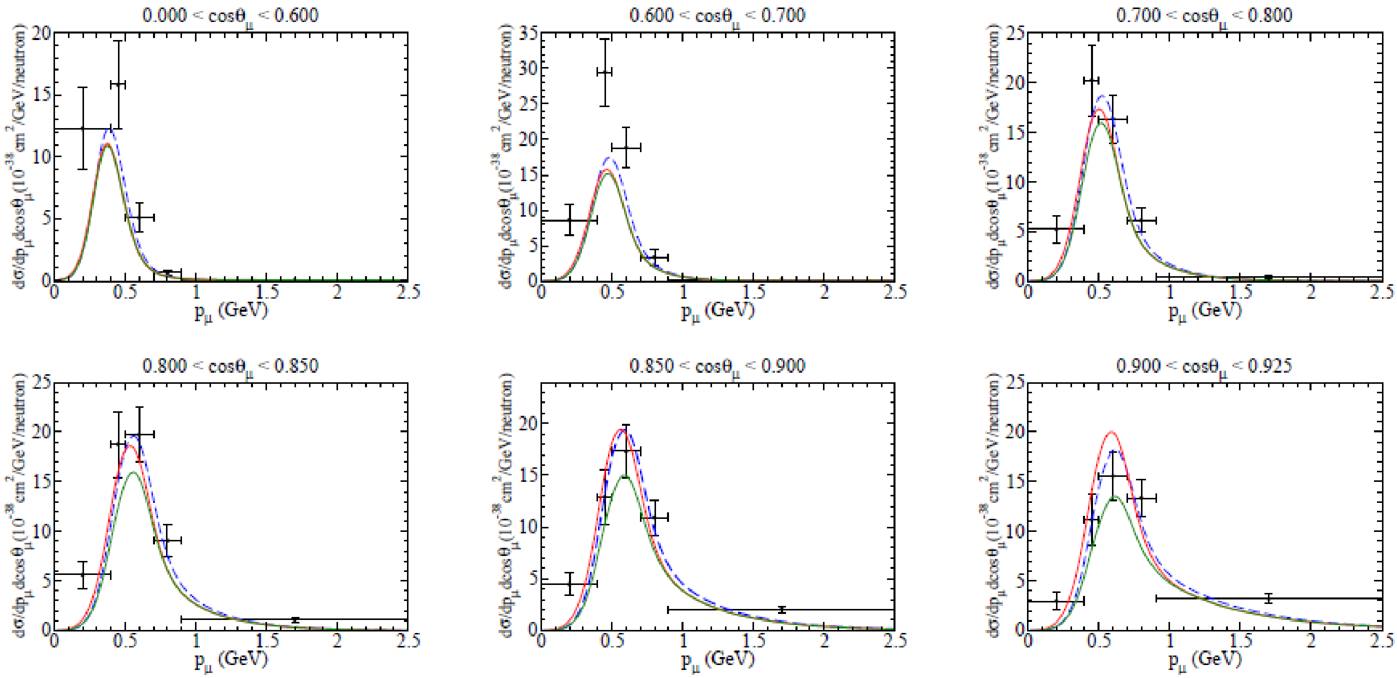
Maria Barbaro

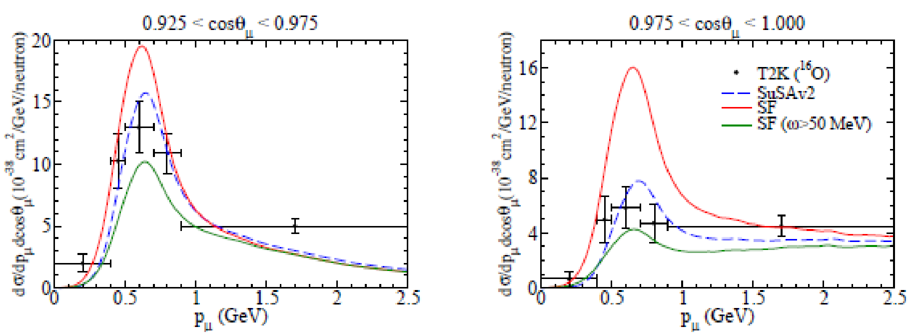
T2K CC0π ν_μ-O in the SuSAv2-MEC model



Maria Barbaro

T2K CCQE ν_μ-O in the Spectral Function PWIA approximation





Oxygen SF from O. Benhar

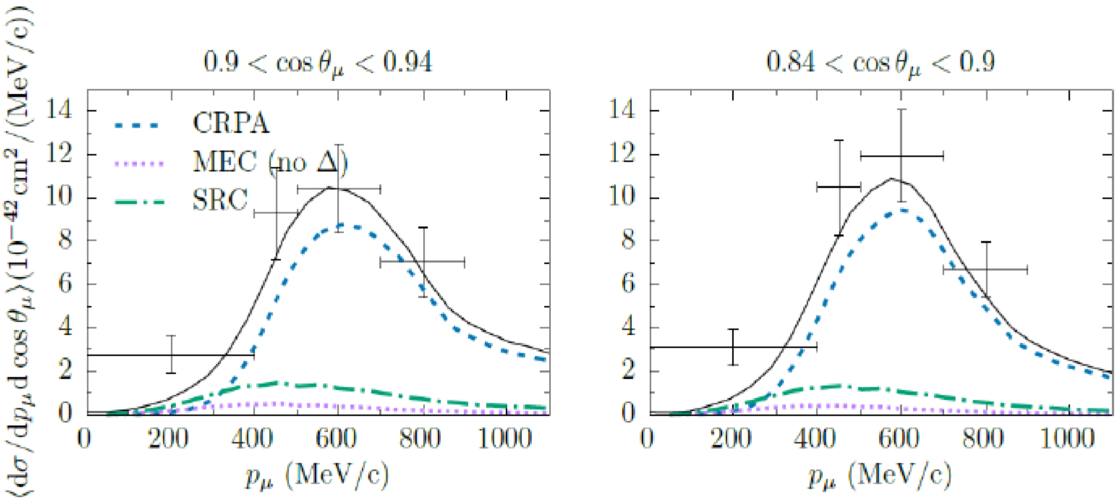
SuSAv2 and SF + PWIA give similar results at $\cos\theta < 0.9$

Large differences at forward angles, where SF+PWIA overestimates the data

Low energy transfers dominate at small angles

Raul Gonzalez Jiménez

Flux folded xs: MiniBooNE & T2K



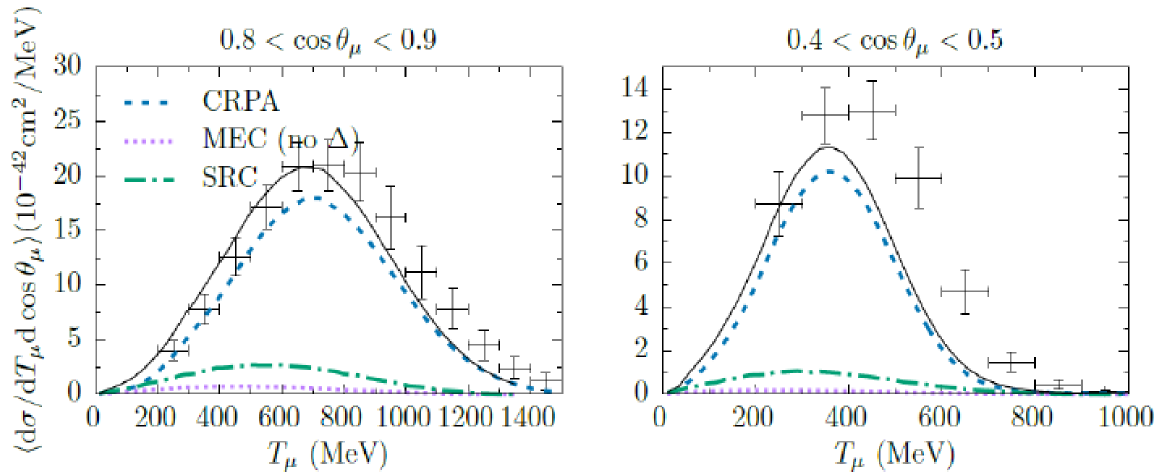
T2K

(inclusive: QE, 2p2h, pions, DIS)

Ghent group

MiniBooNE

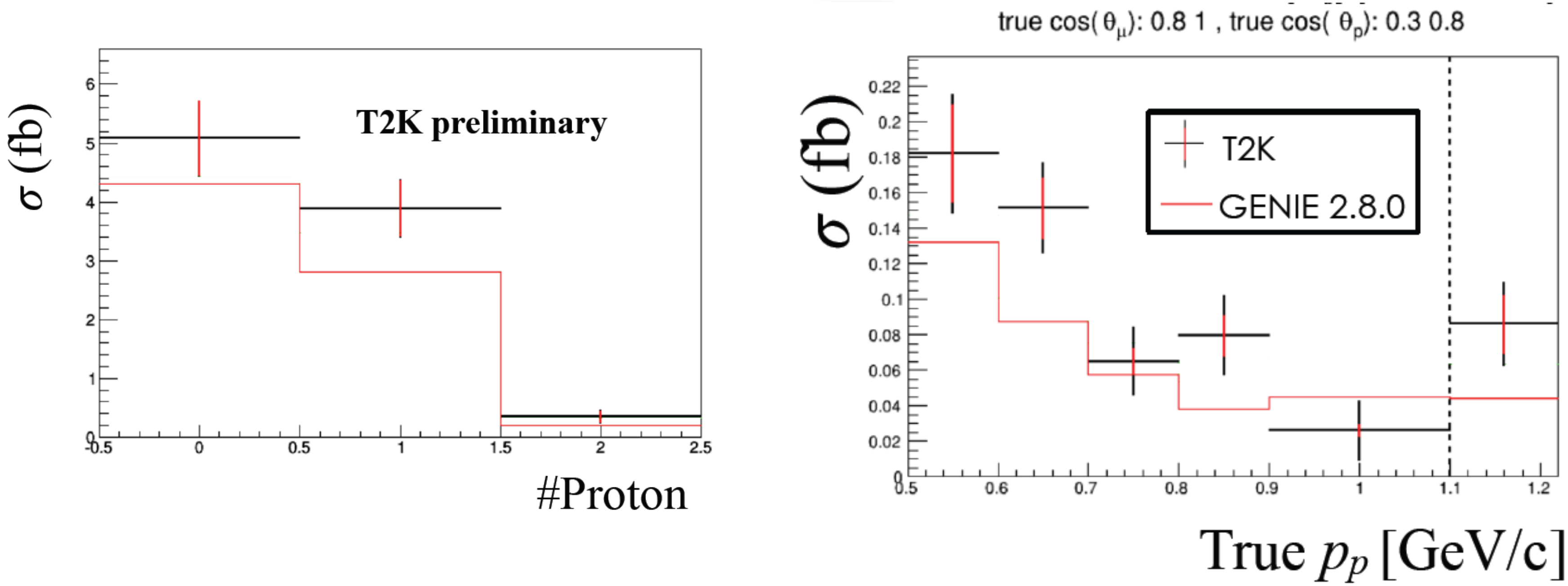
(QE-like: QE+2p2h)



- In order to understand the CCQE and multi-nucleon excitations, further detailed information on hadrons are necessary
- There is a growing interest to use hadron information

Ciro Riccio

ν_μ CC0π using μ+p kinematics

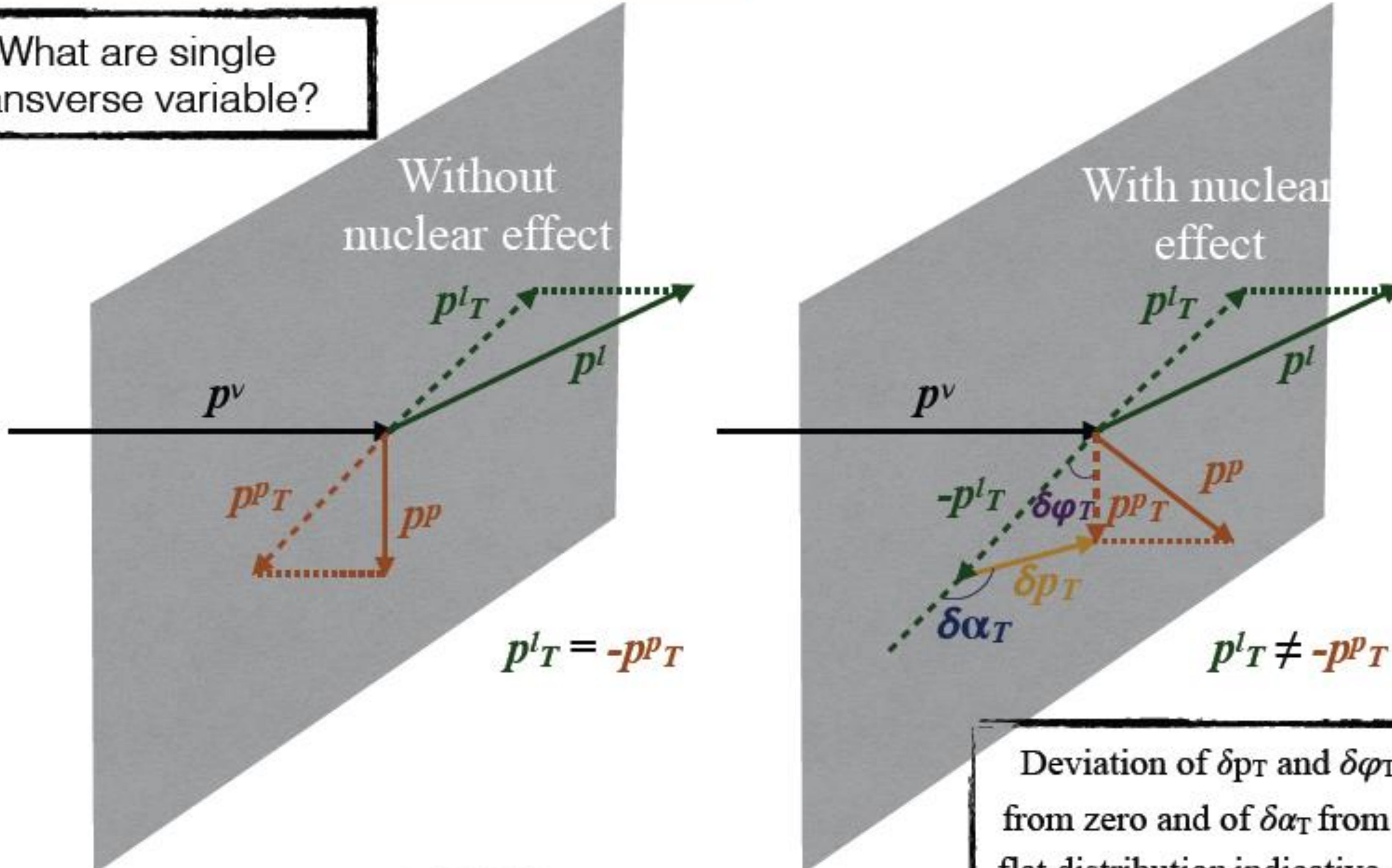


Observed interesting excess over GENIE (w/o 2p2h)

Ciro Riccio

ν_μ CC0π using single transverse variables

What are single transverse variable?



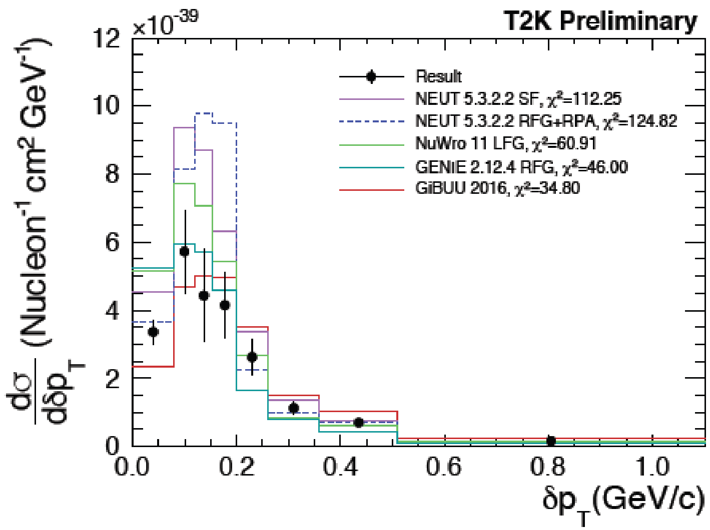
Deviation of δp_T and $\delta\varphi_T$ from zero and of $\delta\alpha_T$ from a flat distribution indicative of nuclear effects

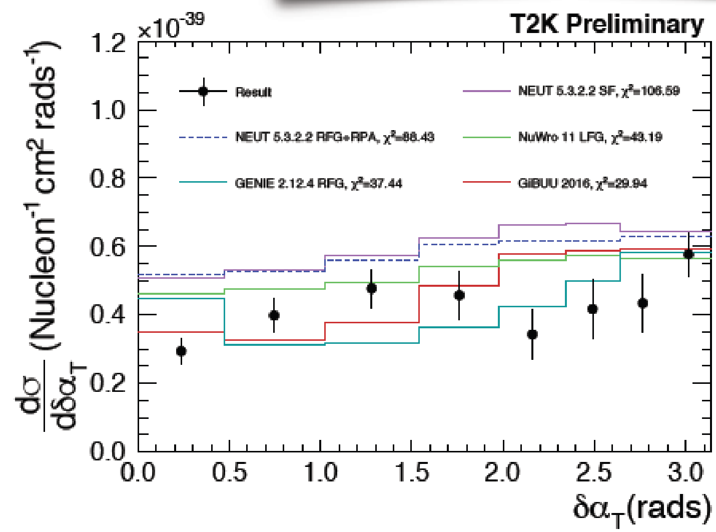
X.-G. Lu et al. Phys. Rev. C 94, 015503 (2016)

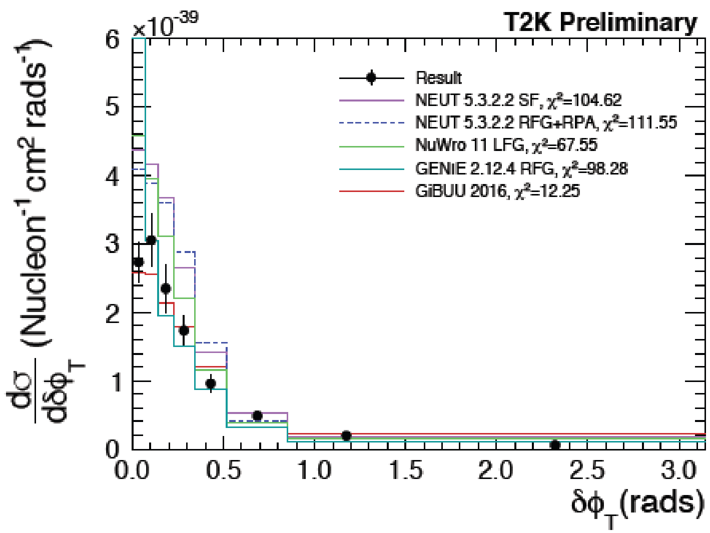
Ciro Riccio

ν_μ CC0π with single transverse variables

Publication in preparation!







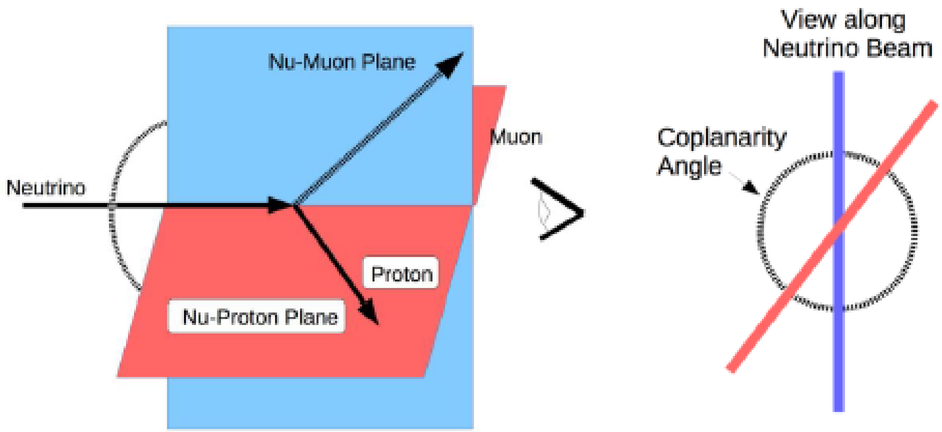
Data strongly disfavor RFG in favor of LFG and Spectral Function

GIBUU with very different FSI seems close to data

GENIE shape in first bin of each STV related to FSI model ("hA")

Sandro Bravar, Patrick Cheryl

CCQE Event Coplanarity on C, Fe, Pb

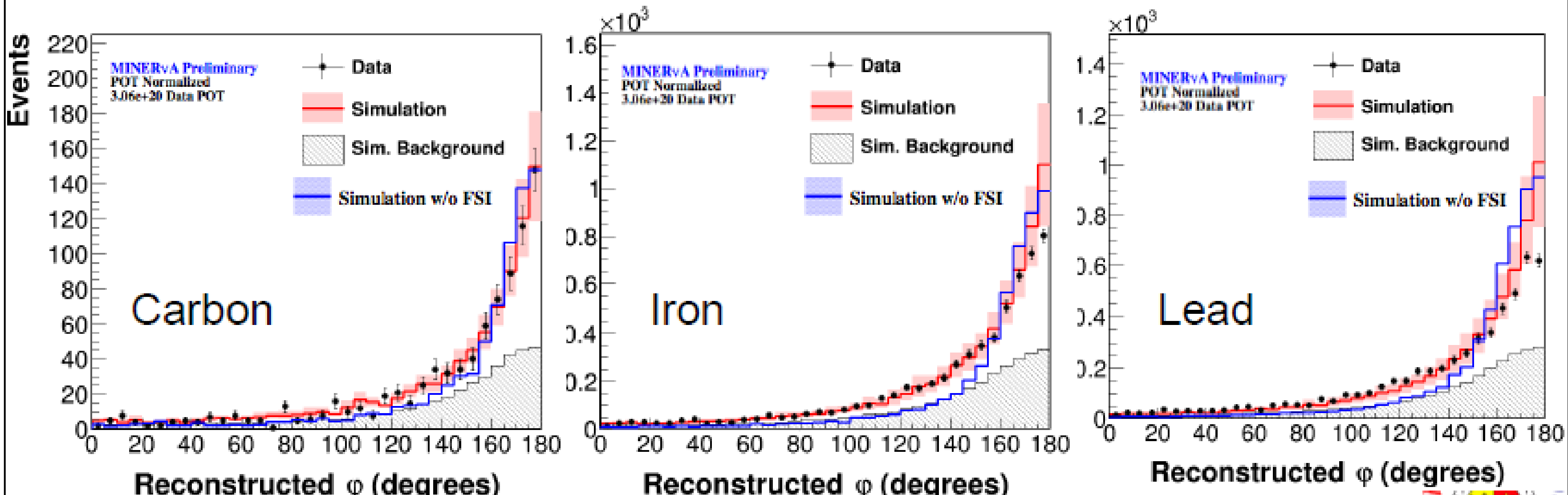


MINERvA

ϕ: Coplanarity

180° for proton at rest
and 2-body interaction
and no final state interactions

Betancourt et al., PRL119 (2017) 082001

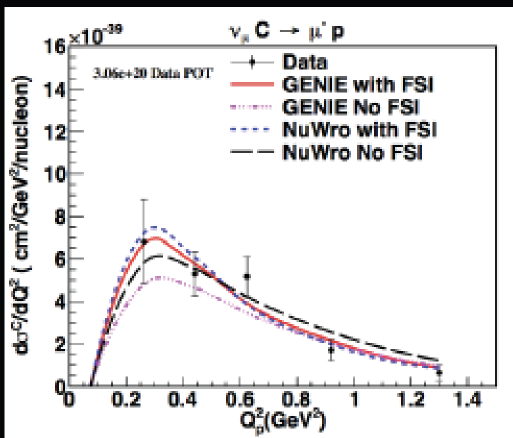


Data/MC discrepancy increases with A

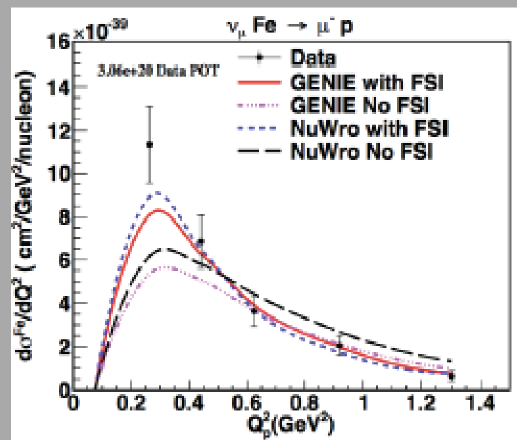
Patrick Cheryl, Sandro Bravar

Cross sections

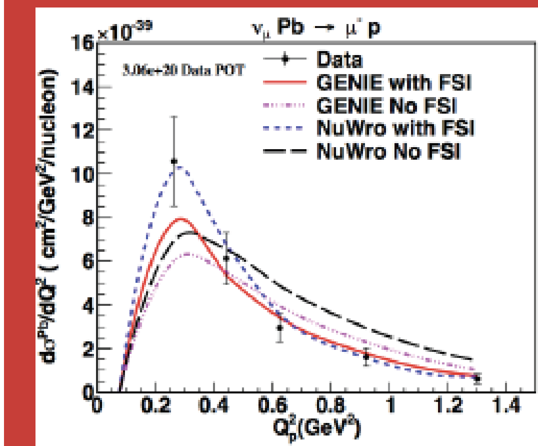
Carbon



Iron



Lead



Both GENIE and NuWro include similar 2p2h and RPA effects

Model	Carbon	Iron	Lead
GENIE RFG	11.0	63.8	41.1
GENIE RFG + 2p2h	5.9	18.9	16.3
GENIE RFG + 2p2h + RPA	5.9	19.9	17.5
NuWro RFG + 2p2h + RPA	6.0	14.6	11.0

χ^2 for 5 degrees of freedom

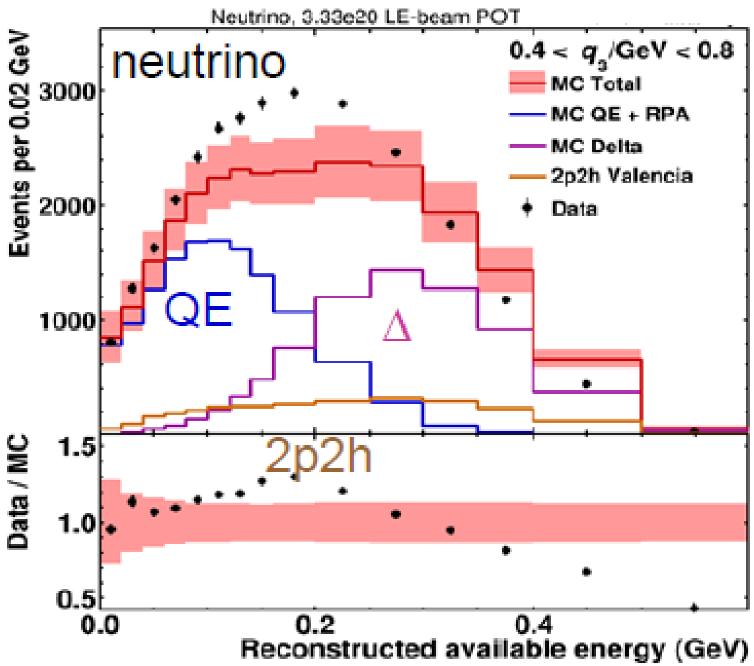
NuWro has an A-dependent pion absorption FSI model that is not included in GENIE

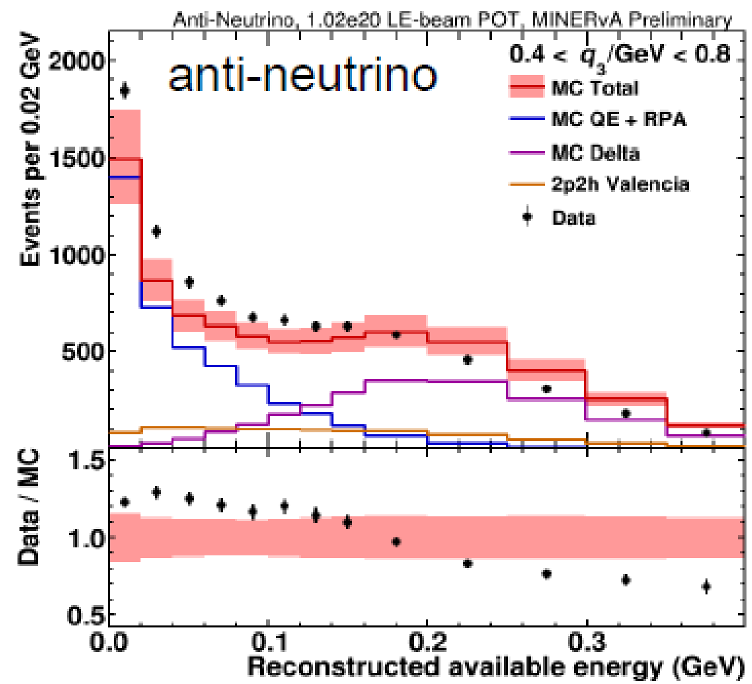
Patrick Cheryl, Sandro Bravar

ν_μ CCQE Data in the $(q_0 - q_3)$ Plane

Rodrigues et al., PRL116 (2016) 071802

Gran, NuINT17





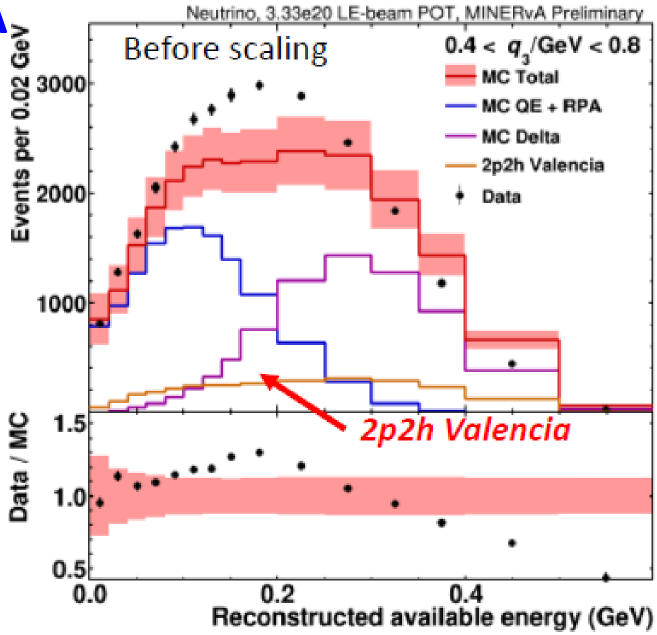
$$E_{\mathrm{avail}} = \sum \mathrm{p\ and\ } \pi^{\pm}\ \mathrm{K.E.} + \mathrm{total\ energy\ of\ all\ other\ particles\ except\ n}$$

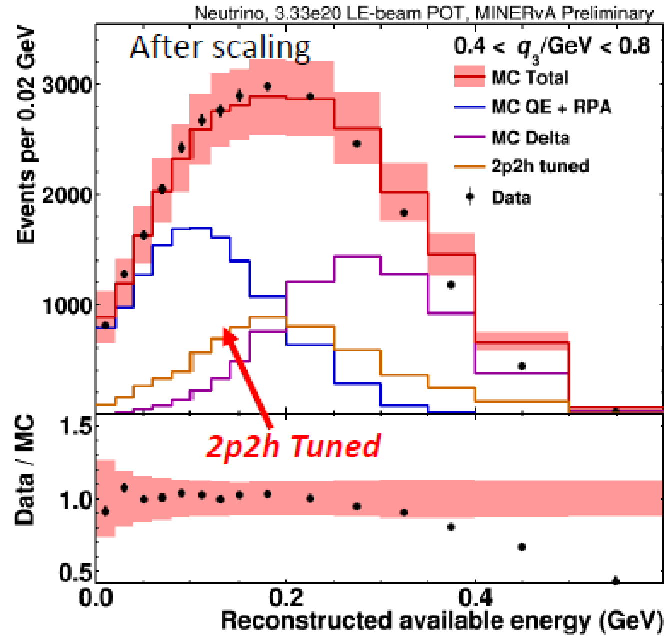
Adding in RPA (a charge screening nuclear effect) and 2p2h (correlations) processes improves agreement in some regions

The 2p2h contribution in the Valencia model is not quite enough

Excess observed in similar kinematic region as in antineutrino CCQE

MINERvA

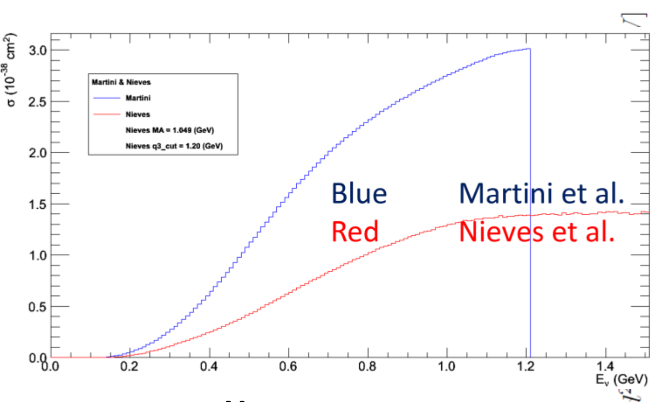




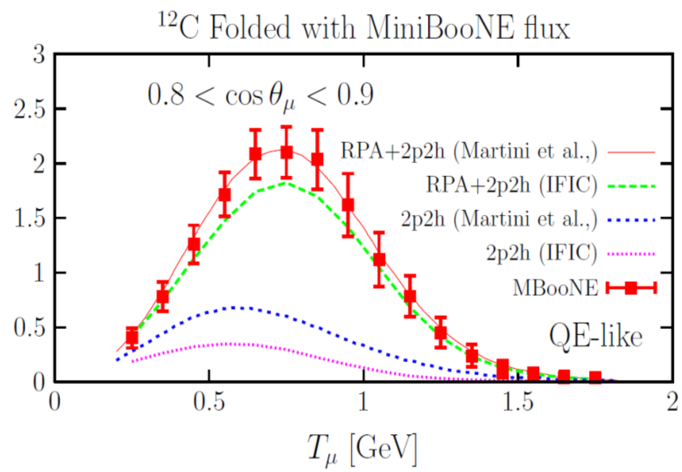
Cheryl, Bravar, Hayato, McFarland

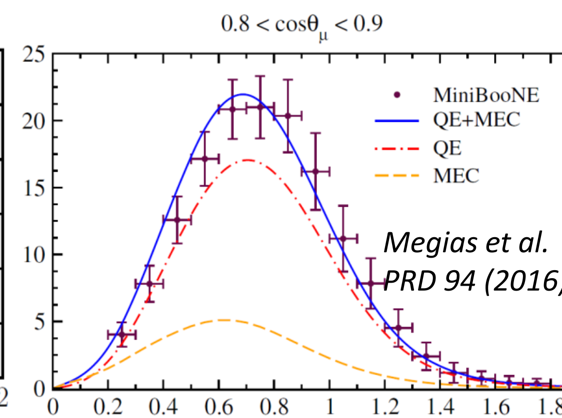
Rather large scaling (~ 50 % overall, x2 in dip region) is necessary

Remind: other microscopic calculations have 2p-2h contributions larger than the Valencia ones



Hayato



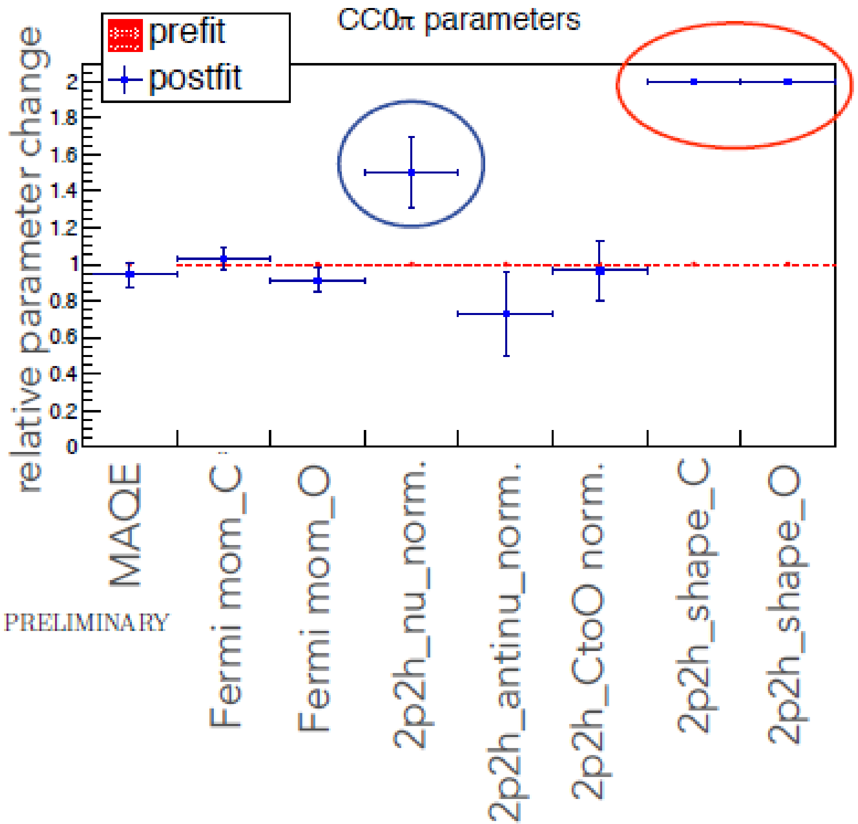


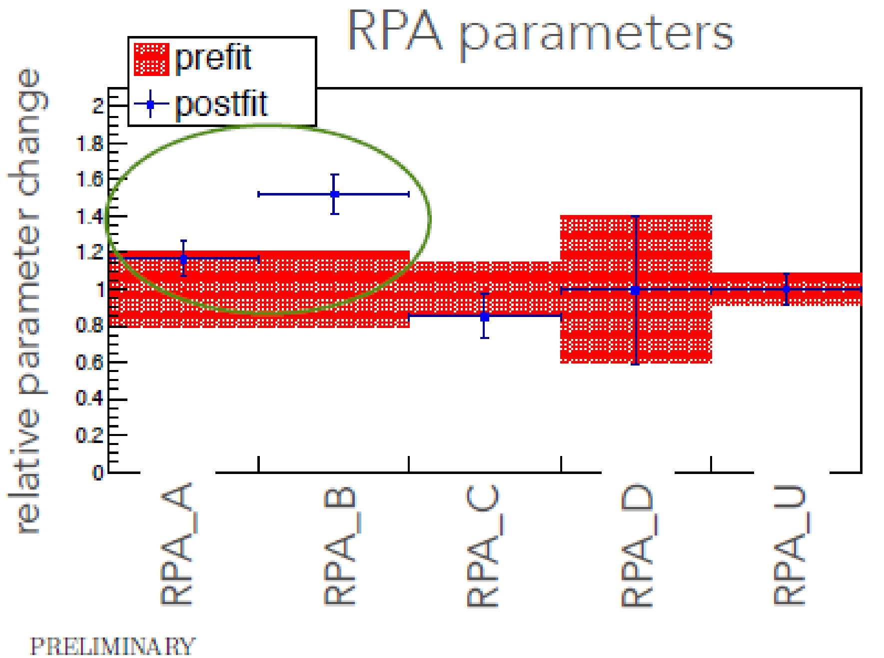
Barbaro: SuSAv2+MEC

Keigo Nakamura

Near detector fit results

T2K





These results should not be taken as the cross section results, but effective parameters which effectively describe the data and propagate the uncertainty to the oscillation analysis.

GENIE Tuning against CC0π datasets (MiniBooNE, T2K, MINERvA)

Sheer results

G16_01b - Default + MEC

Parameter	Best fit	Nominal
M_A (GeV/c^2)	1.17 ± 0.03	0.99 ± 0.01
QEL-CC-XSecScale	0.92 ± 0.02	1
RES-CC-XSecScale	1.02 ± 0.07	1
MEC-FracCCQE	0.55 ± 0.06	0.45
FSI-PionMFP-Scale	0.86 ± 0.04	1.0 ± 0.2
FSI-PionAbs-Scale	0.76 ± 0.09	1.0 ± 0.3

G16_02a - Full Nieves Model

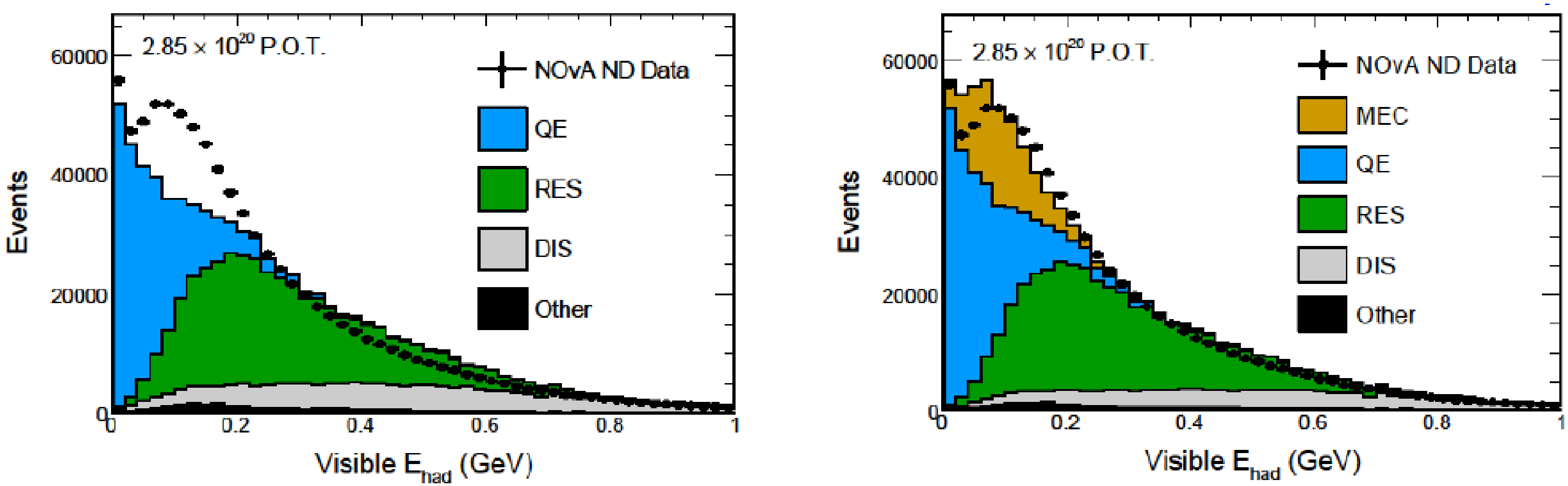
Parameter	Best fit	Nominal
M_A (GeV/c^2)	1.00 ± 0.03	0.99 ± 0.01
QEL-CC-XSecScale	0.91 ± 0.02	1
RES-CC-XSecScale	1.01 ± 0.04	1
MEC-CC-XSecScale	1.18 ± 0.02	1
FSI-PionMFP-Scale	1.17 ± 0.04	1.0 ± 0.2
FSI-PionAbs-Scale	1.02 ± 0.09	1.0 ± 0.3

- M_A is reasonably low
  - Nieve's model is compatible with free nucleons fit
  - Precision of M_A reduced
  - $\Rightarrow$ Our choice not to add a strong prior
- QEL reduced by $\sim$ 10%
- MEC increased by $\sim$ 20%
- FSI parameters strongly correlated
  - They are better constrained than the GENIE prior

Marco Roda

Kirk Bays

Tuning NOvA simulation

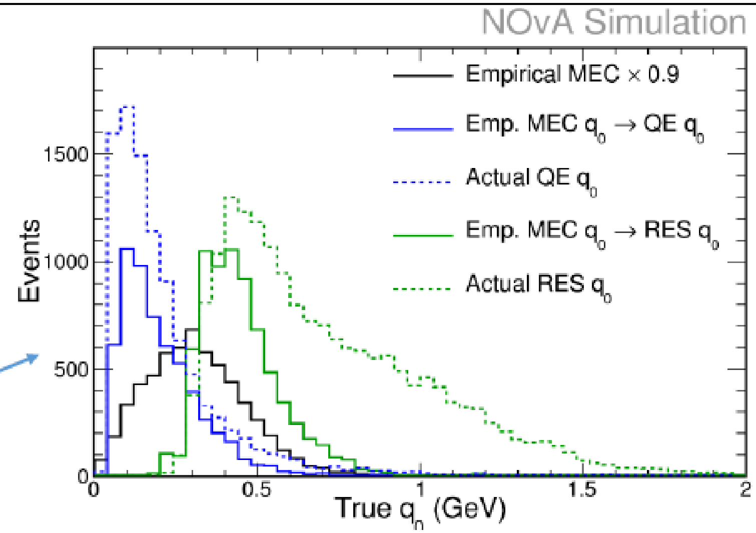


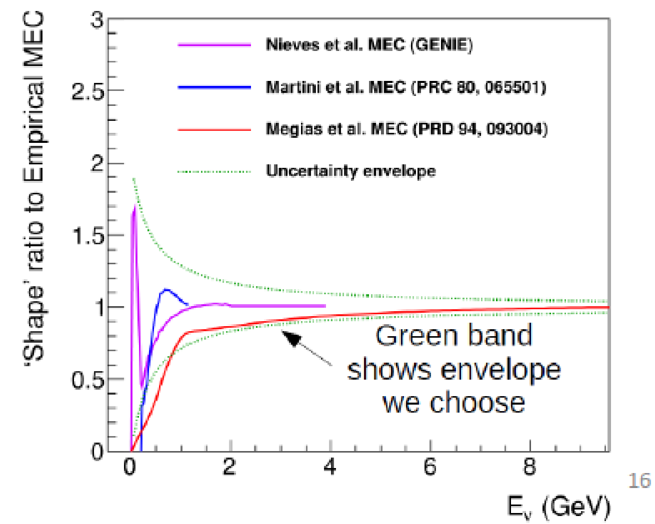
- Early on we discovered a significant anomaly in our ND data. Including 2p2h/MEC significantly improved this discrepancy.
- We're currently wrapping up our third iteration of oscillation analyses and gearing up for our fourth. Each time our treatment of 2p2h has grown more sophisticated.

Kirk Bays

Third analysis x-sec tune

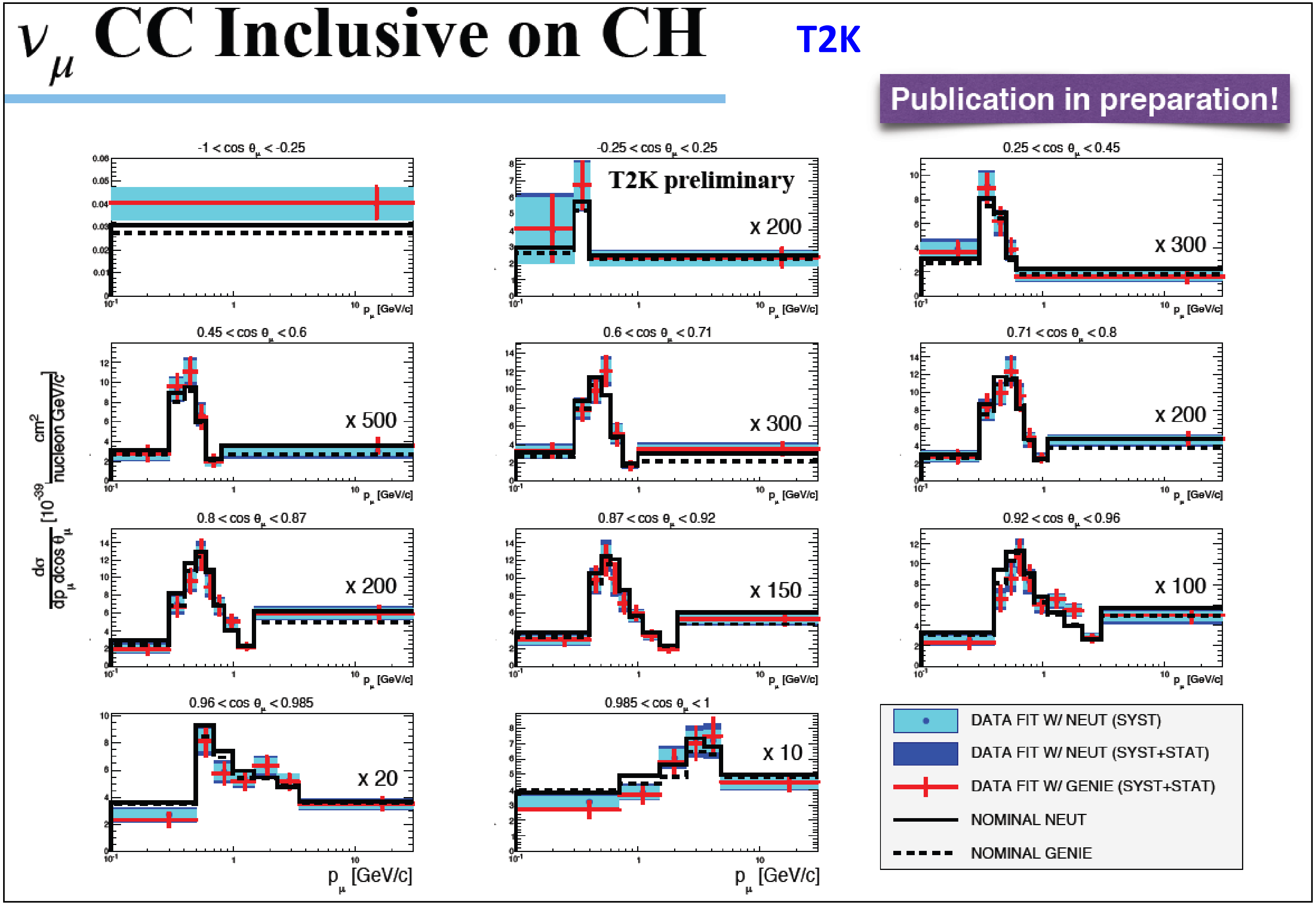
- Will be used for upcoming analyses
- 2p2h:
  - Empirical MEC scaled up 20%, same result as fitting |q| to ND data
  - New systematics: energy transfer shape, np/nn ratio, x-sec normalization
- DIS:
  - Additional systematics for 'transition region' DIS, with W>1.7 GeV, and for >2 pion events, to cover anomalies in GENIE
- RPA applied
- Non-res single π fix (arXiv:1601.01888v3)
- Tuned simulation agrees within uncertainties





- **Precise inclusive cross section measurements are very important**

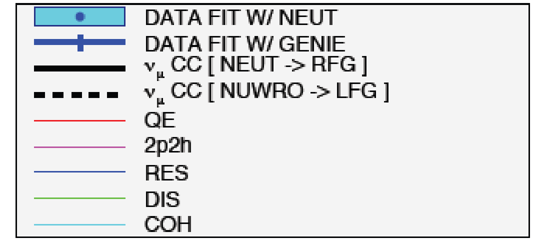
Ciro Riccio

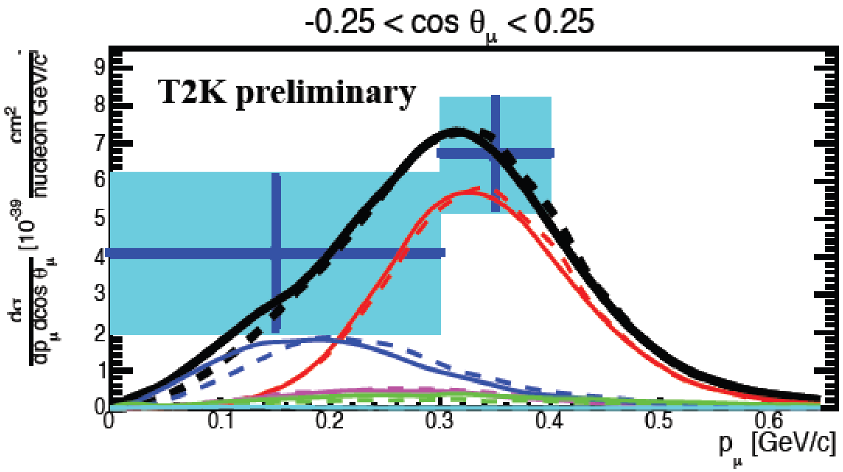


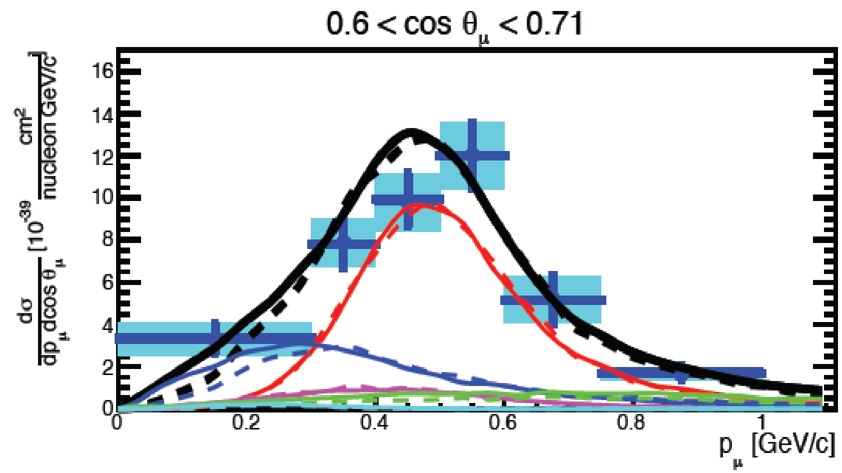
Ciro Riccio

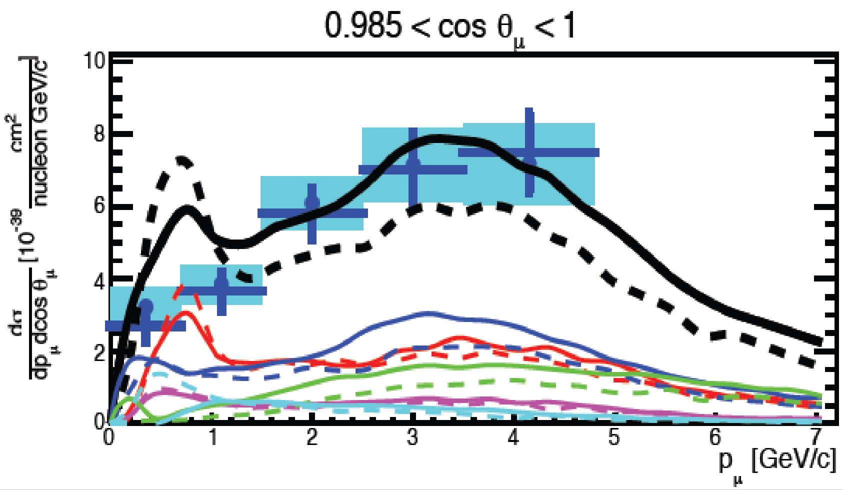
ν_μ CC Inclusive on CH

T2K





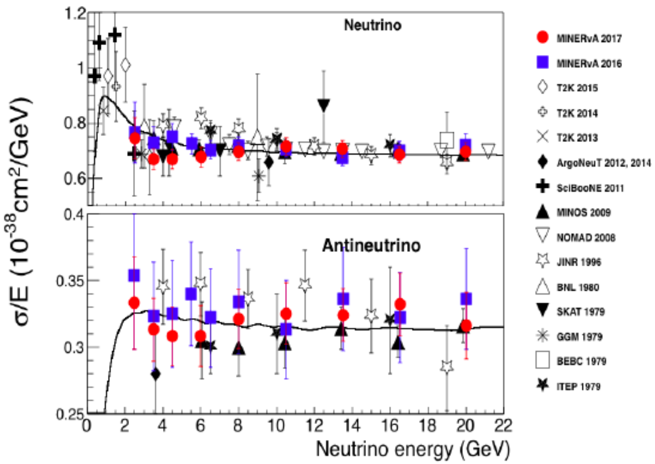




NEUT using Relativistic Fermi Gas (RFG) as nuclear model and NuWro using Local Fermi Gas (LFG) overestimate the cross section in low momentum bins

MINERvA

Inclusive CC Scattering
Phys. Rev. D 95, 072009 (2017)



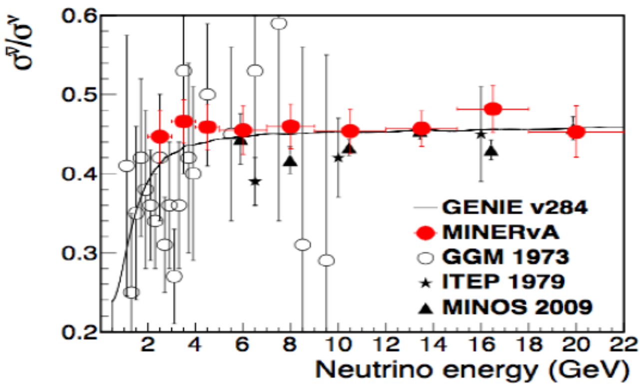
Edgar Valencia, Sandro Bravar

- Antineutrino cross section result is the most precise to date below 6 GeV (errors dominated by statistical precision)
- Shows that the technique is applicable to future neutrino experiments operating at multi-GeV energies

- Long-Baseline oscillation experiments will measure a ratio of oscillation probabilities to constraint CP violation.

$$\mathcal{A}_{CP} = \frac{P(\nu_\mu \to \nu_e) - P(\overline{\nu}_\mu \to \overline{\nu}_e)}{P(\nu_\mu \to \nu_e) + P(\overline{\nu}_\mu \to \overline{\nu}_e)}$$

- New precise $\sigma_\nu/\sigma_{\bar{\nu}}$ ratio relevant to δ_{CP} measurement using the Low Nu Method.



NOvA

ν_μ CC inclusive ν_e CC inclusive ν_μ CC π^0

To be released this year

Linda Cremonesi

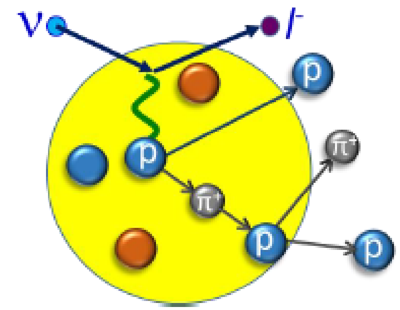
Yoshinari Hayato

Single pion production

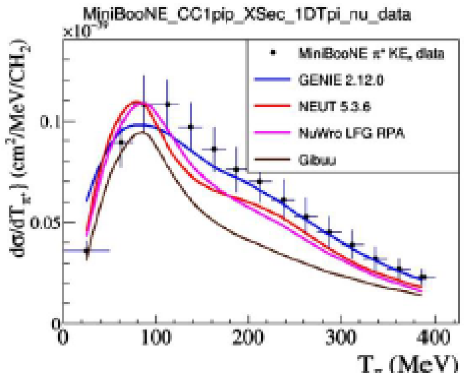
Measurements of π kinematics

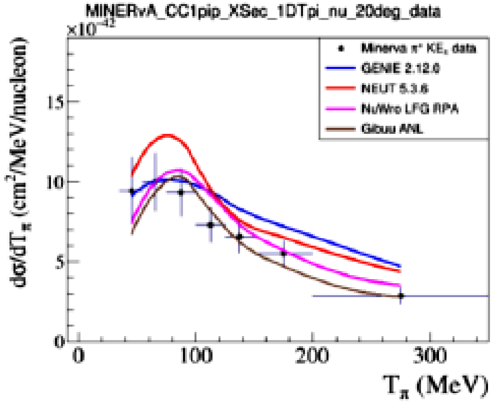
Various new results are coming

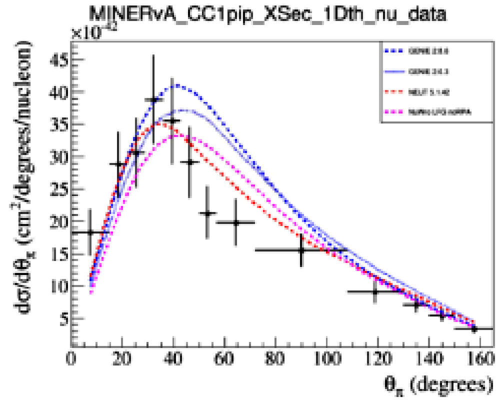
~ MINERνA, NOνA, T2K and MicroBooNE ....

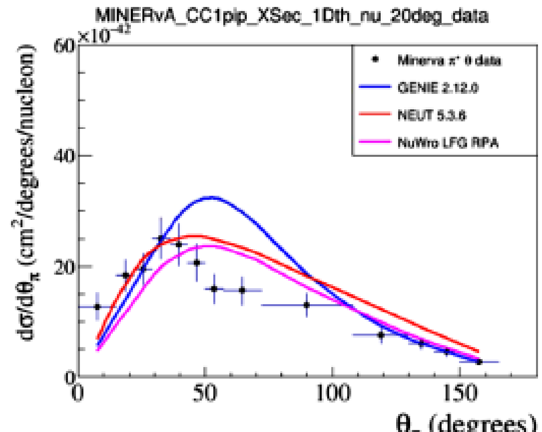


Further improvements on both ν π production
and
final state interactions of π are necessary.



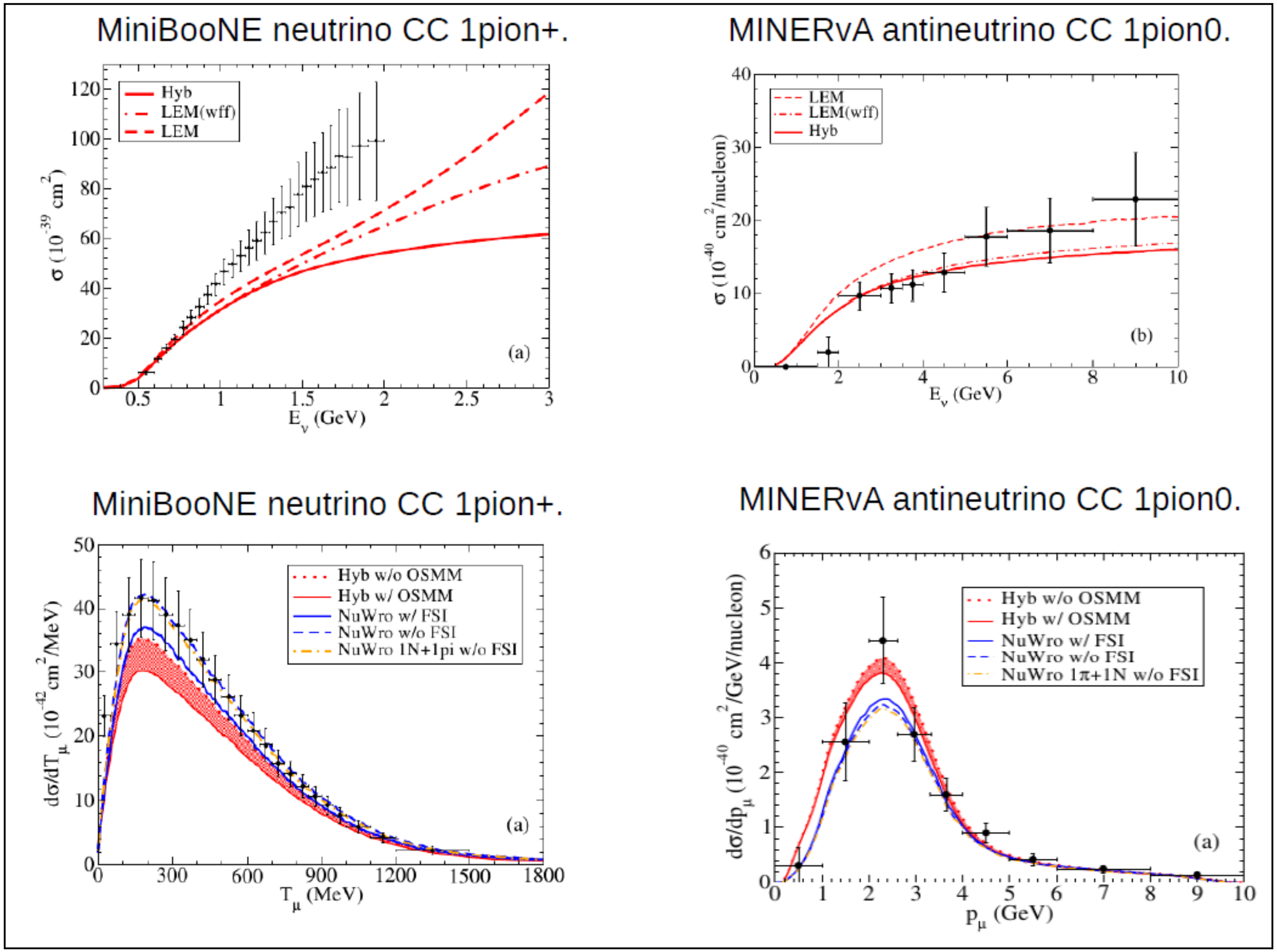






S. Dytman @ NuINT17

Raul Gonzalez Jiménez



✔ **Single-pion production**: Danger! Low-energy models should not be used in high W regions. Take a look to our **Hybrid model**. Distortion effects may improve the current situation.

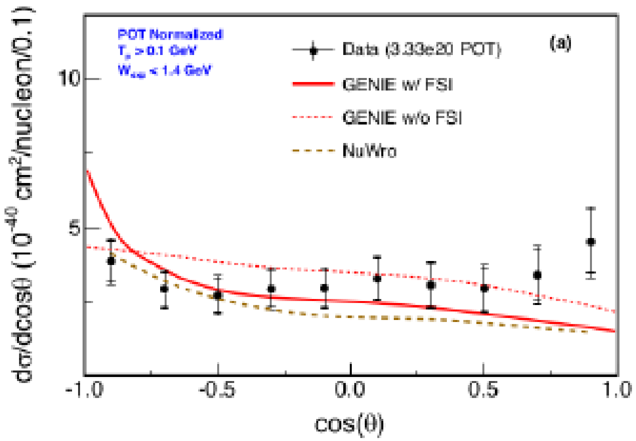
MINERvA

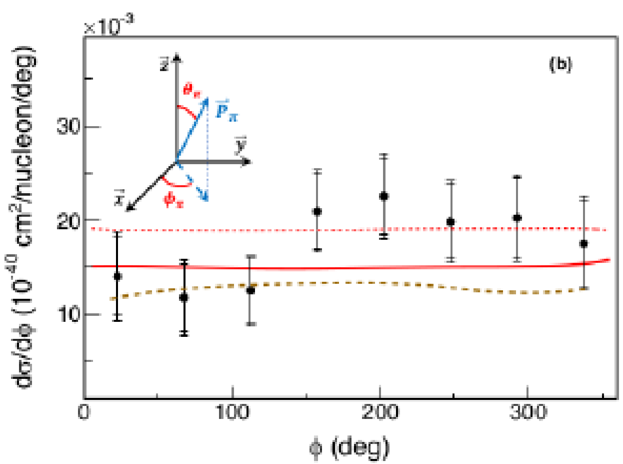
ν_μ CC Single π^0 Production

Hadronic System

Edgar Valencia

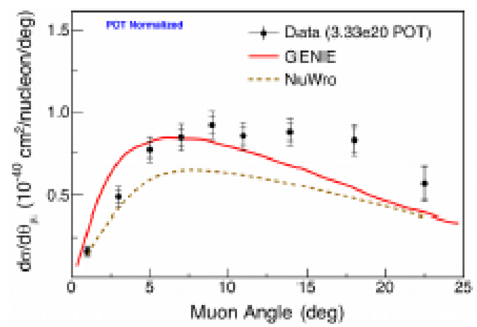
- **Δ^+ (1232) decay angles are measured for the first time!**



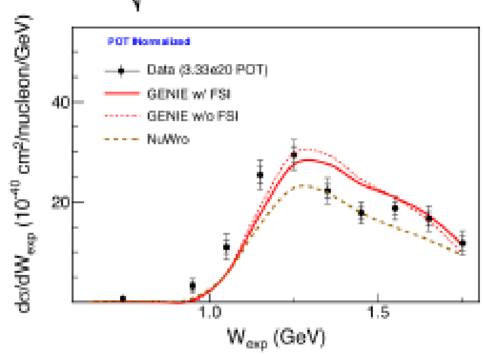


- **GENIE and NuWro assume isotropic Δ^+ (1232) decay**

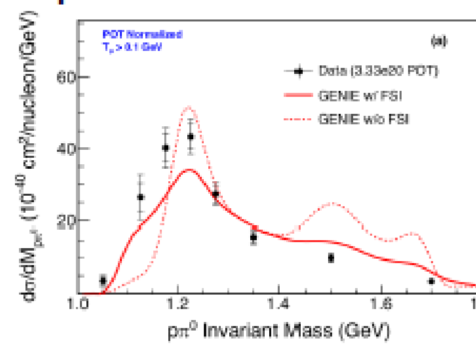
- **These disagreements identify areas in need of improvement.**



$$W_{exp} = \sqrt{m_n^2 + 2m_n(E_\nu - E_\mu) - Q^2}$$



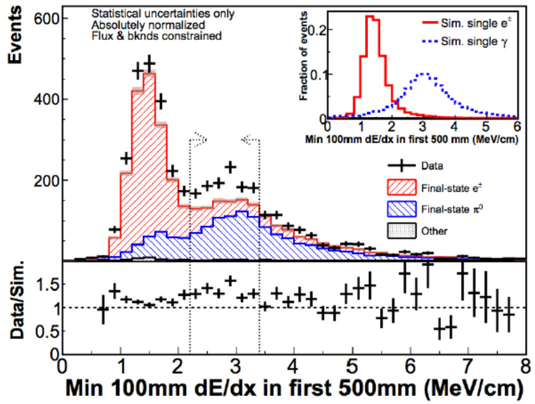
Invariant Mass calculated with proton and π^0 4-momentums



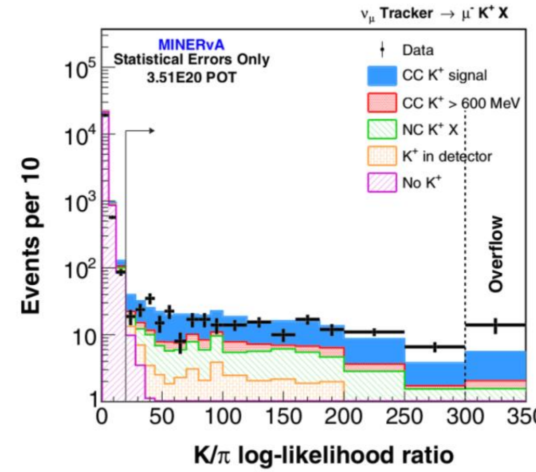
Other recent MINERvA results

Edgar Valencia

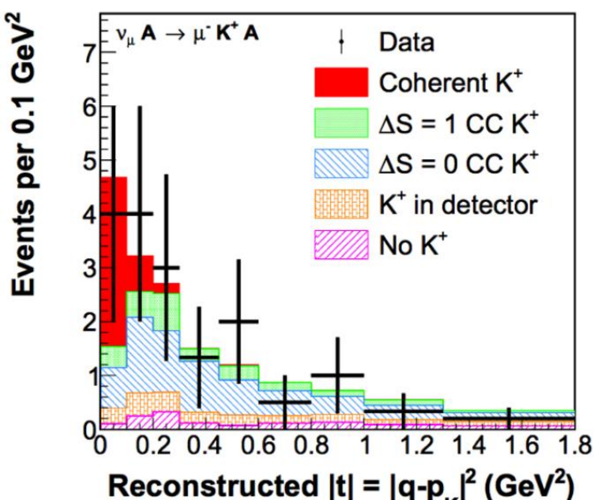
Diffractive Neutral Pion Production
Phys. Rev. Lett. 117, 111801 (2016)



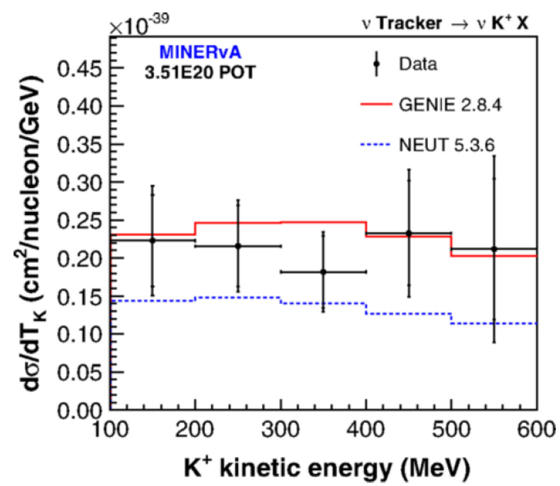
Charge Current K⁺ Production
Phys. Rev. D 94 012002 (2016)



Coherent K⁺ Production
Phys. Rev. Lett. 117, 061802 (2016)



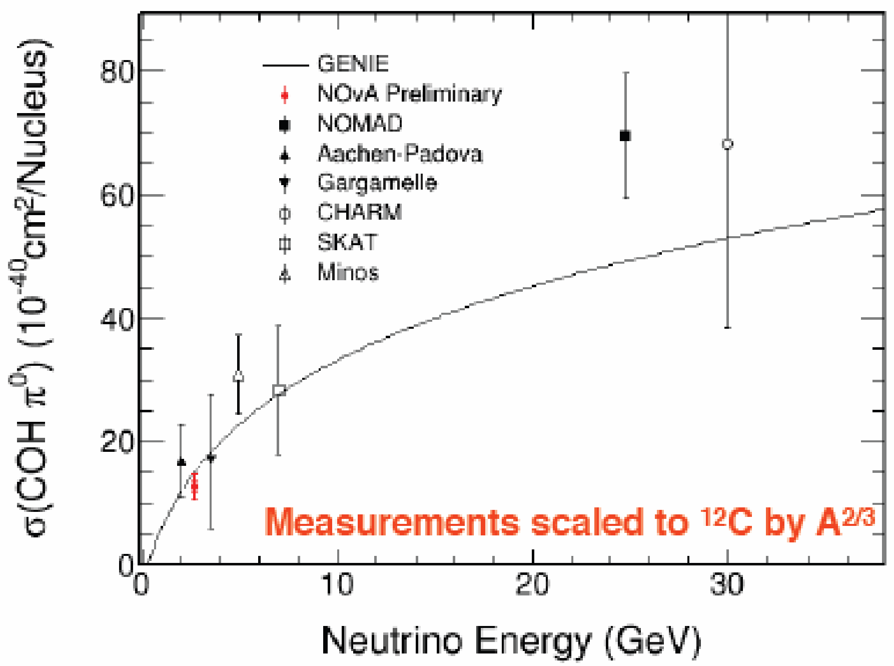
Neutral Current K⁺ Production
Phys. Rev. Lett. 199, 0011802 (2017)



Linda Cremonesi

NC Coherent π^0

NOvA Preliminary



Source	$\delta(\%)$
Calorimetric Energy Scale	3.4
Background Modeling	10.0
Control Sample Selection	2.9
EM Shower Modeling	1.1
Coherent Modeling	3.7
Rock Event	2.4
Alignment	2.0
Flux	9.4
Total Systematics	15.3
Signal Sample Statistics	5.3
Control Sample Statistics	4.1
Total Uncertainty	16.7

- Renormalised background using energy and angle 2D space.
- Measured flux-averaged cross-section using background subtraction:

$\sigma = 14.0 \pm 0.9(\text{stat.}) \pm 2.1(\text{syst.}) \times 10^{-40} \text{cm}^2/\text{nucleus}$

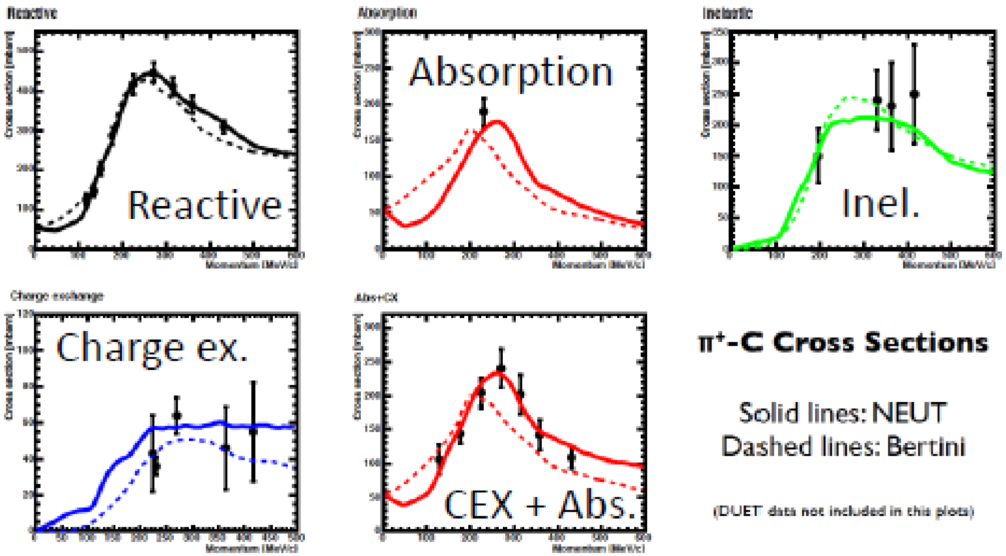
- Total uncertainty 16.7%, systematic dominant

Nuclear effects ~ pion interaction in nucleus

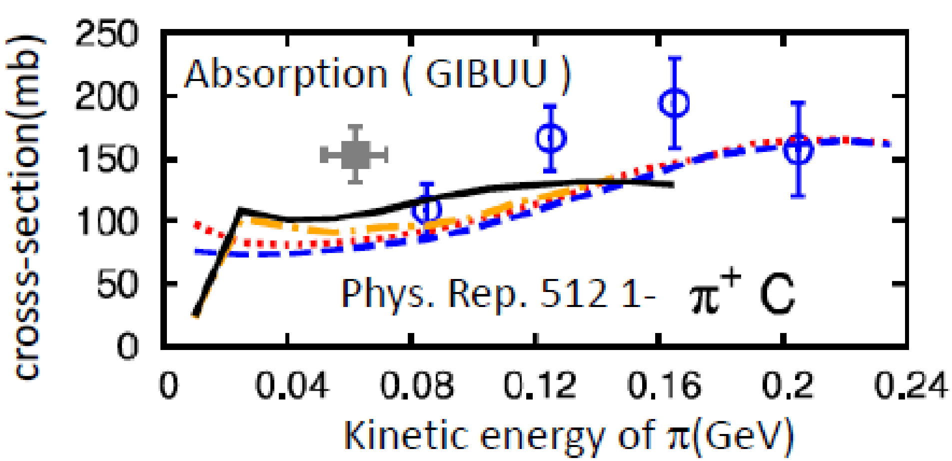
Yoshinari Hayato

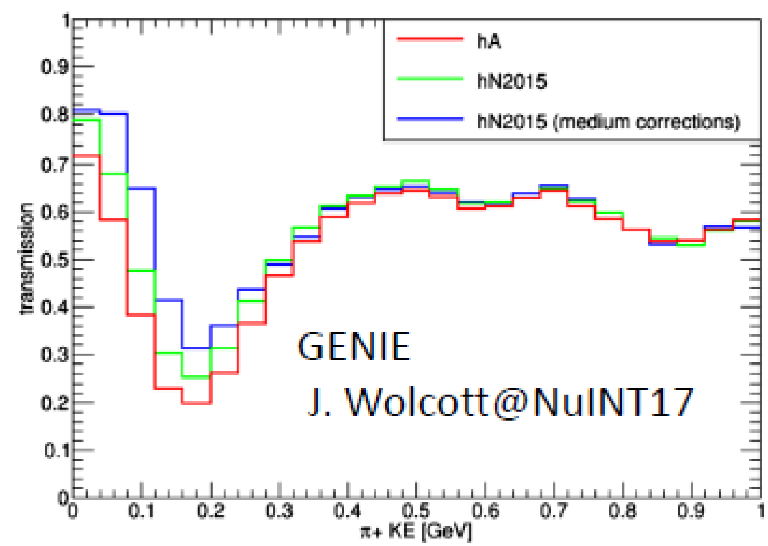
Various tuning of pion interactions are on-going.

Some of the works are also used to improve detector simulations.



Neut cascade with GEANT4
E. Pinzon & M. Yu (@ NuINT17)





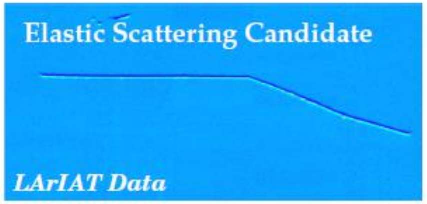
Pion Cross-Section

- **The total π^-–Argon Cross-Section includes**

$$\sigma_{Total} = \sigma_{elastic} + \sigma_{inelastic} + \sigma_{ch\text{-}exch} + \sigma_{absorp.} + \sigma_{\pi\text{-}production}$$

Justin Hugon

LArIAT



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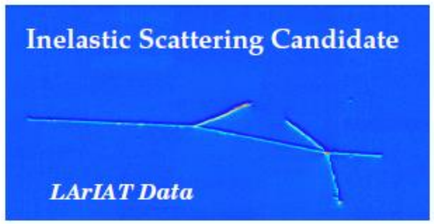

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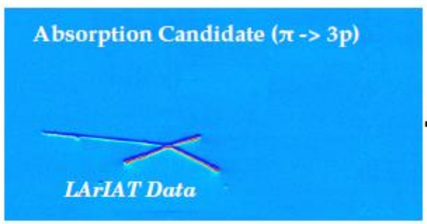

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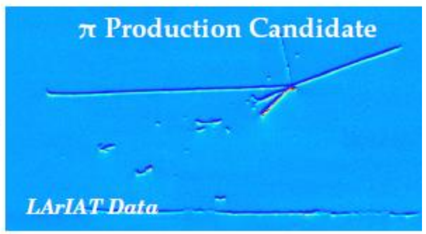
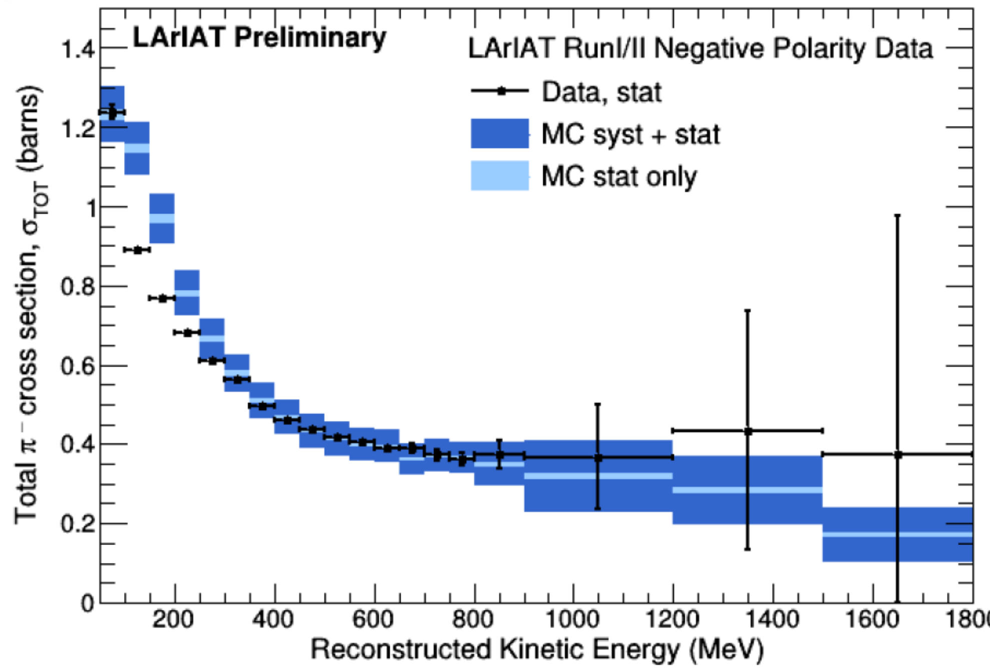
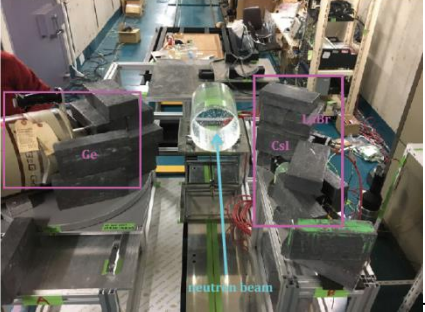






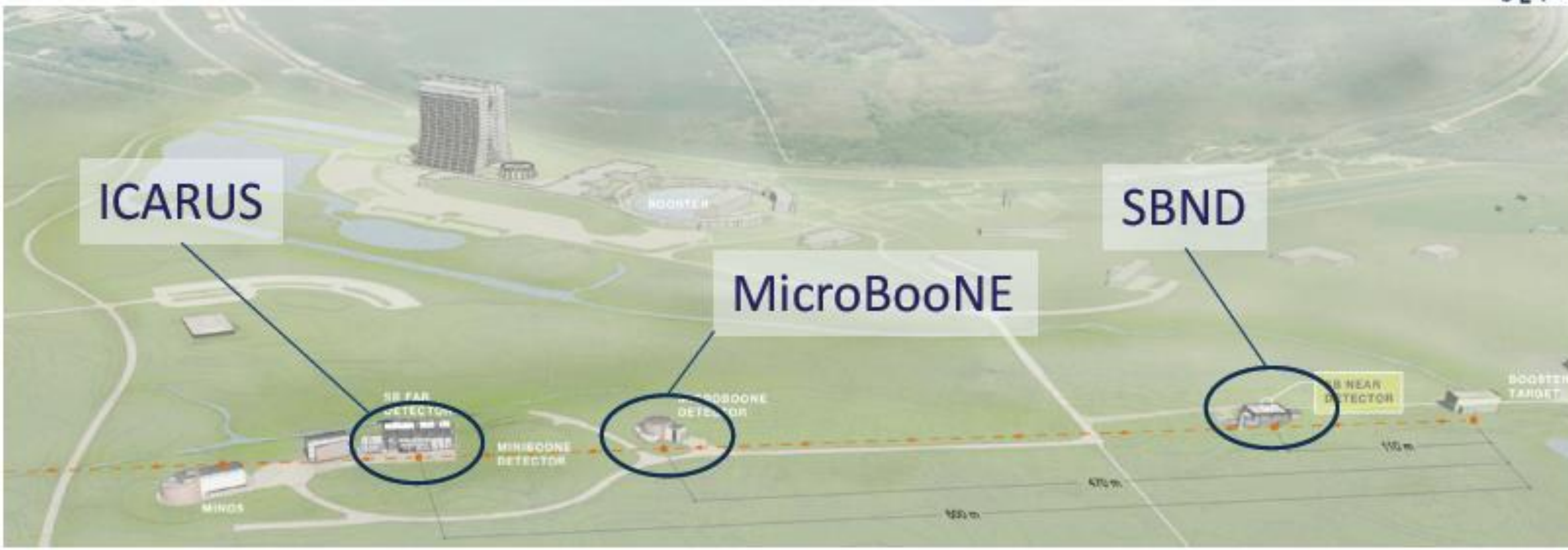
Measurement of gamma-rays from neutron-oxygen reaction for neutrino-nucleus interaction

Yosuke Ashida

- Precise knowledge of neutrino NCQE interaction is important for several physics searches at T2K and SK.
- Largest source of systematics comes from poor nuclear physics model.
- We study the nuclear process with measurement and aim to improve the model.
- At RCNP, we made a gamma-ray measurement with 80 MeV neutron;
  - **Observed gamma-rays from neutron-oxygen reactions**
  - Measured items necessary to obtain neutron flux
  - Measured scattered neutron backgrounds
  - Estimated very preliminary cross section (analysis is on-going.)
- Physics processes behind the E487 results seem to be consistent with T2K data.

Nicola McConkey, Marco Del Tutto, Xiao Luo

Short Baseline Neutrino Program

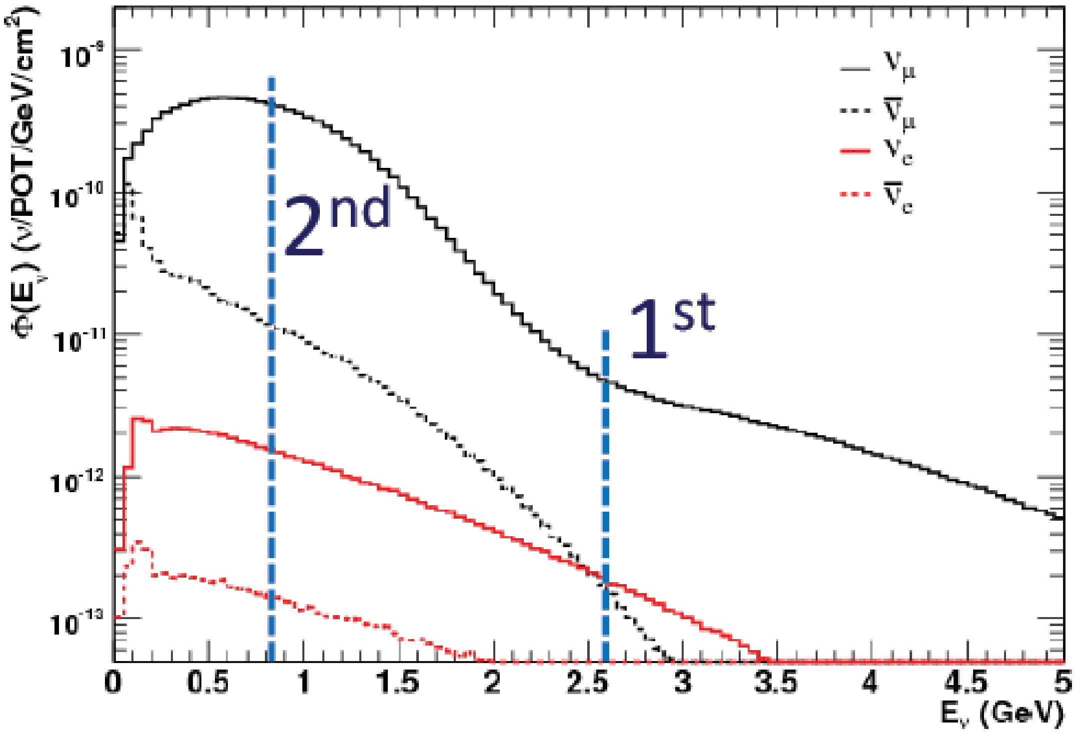


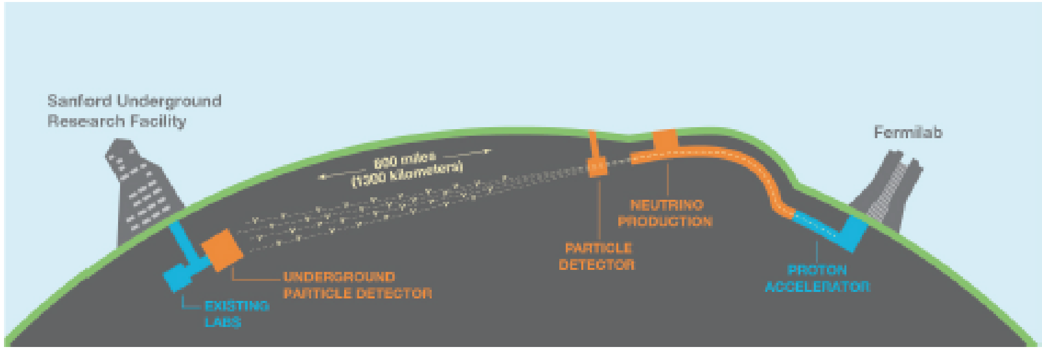
Detector	Baseline (m)	Active LAr mass (tonnes)
SBND	110	112
MicroBooNE	470	87
ICARUS T-600	600	476

- Three detector measurement program in the Fermilab Booster Neutrino Beam (BNB)
- LAr TPC detectors
  - Same nuclear target and detector technology
  - Reducing effect of systematic uncertainties

Nicola McConkey

Relevance to DUNE





- BNB flux covers neutrino energy at both 1st and 2nd oscillation peak for Deep Underground Neutrino Experiment
- High statistics measurement of neutrino interactions at 2nd oscillation peak energy

Nicola McConkey

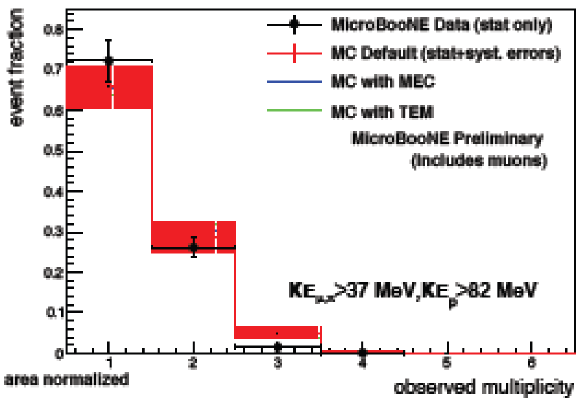
Summary

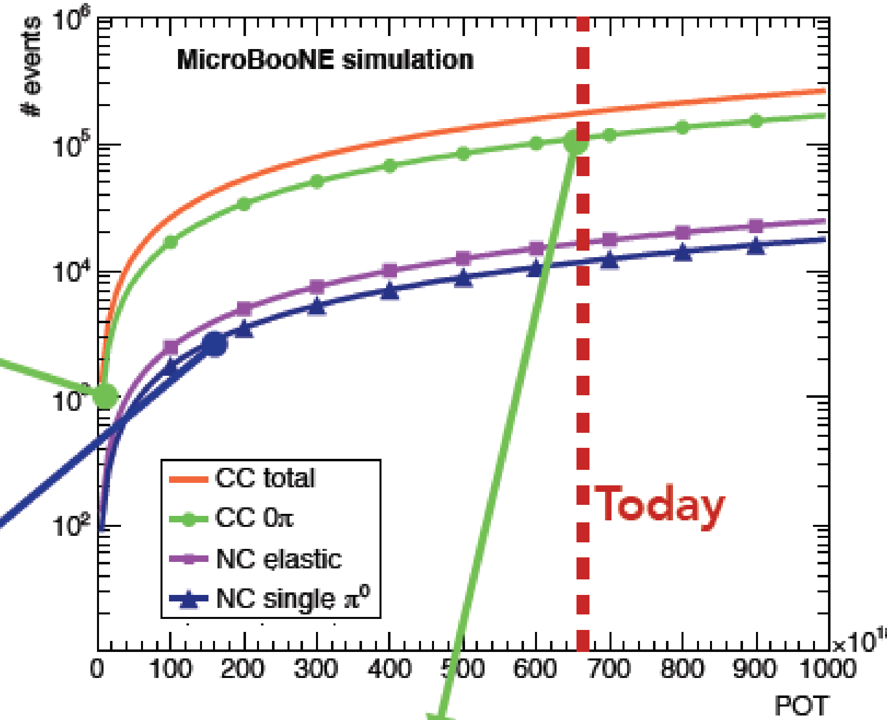
- SBND is the near detector for the Short Baseline Neutrino program at Fermilab
  - It will measure the unoscillated BNB flux
  - Significant contribution to systematic error reduction for the SBN sterile neutrino searches
- SBND will measure ν-Ar interactions with unprecedented precision due to excellent detector characteristics and high event rates
  - Transform our understanding of ν-Ar interactions in the low energy range
    - Exclusive topologies
    - Rare channels
    - Input to nuclear modelling
- SBND is currently under construction, and will begin taking neutrino data in 2019!
  - Exciting times ahead!

MicroBooNE in the Future

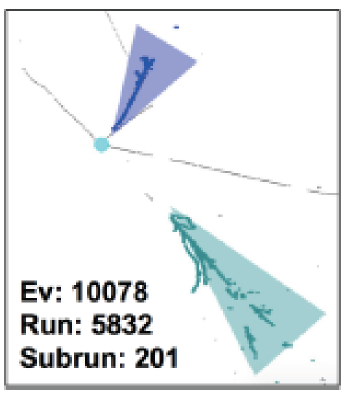
Marco Del Tutto
Xiao Luo

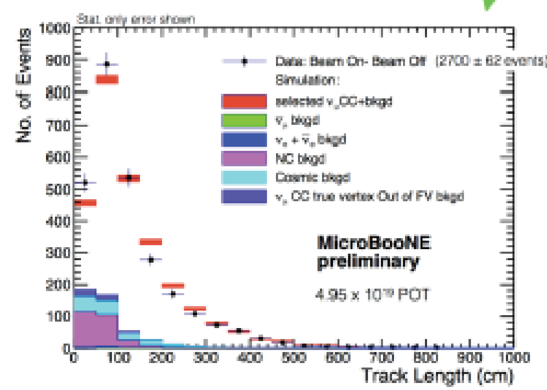
MicroBooNE
Particle Multiplicity





MicroBooNE
Towards a π^0 Mass Peak





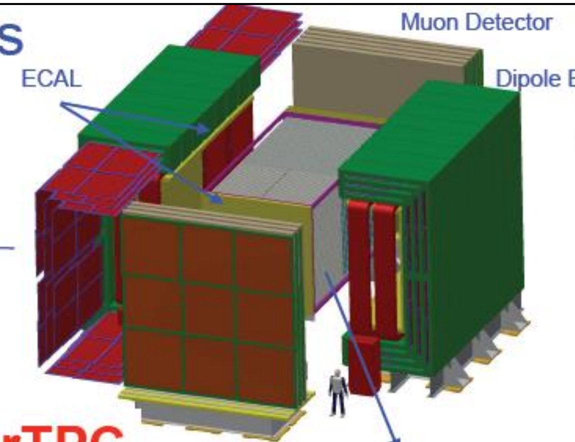
MicroBooNE
Event Distribution
towards a Cross
Section
Measurement

DUNE ND

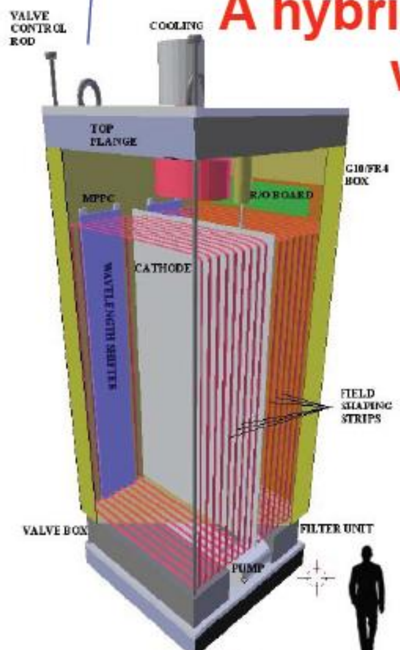
Hongyue Duyang

Near Detector Options

- Currently we have several ND options under study:
  - LAr TPC
  - Straw Tube Tracker (STT, CDR reference design)
  - High-Pressure Ar Gas TPC
  - Scintillating plastic tracker



A hybrid detector combining a LArTPC with a low-density tracker



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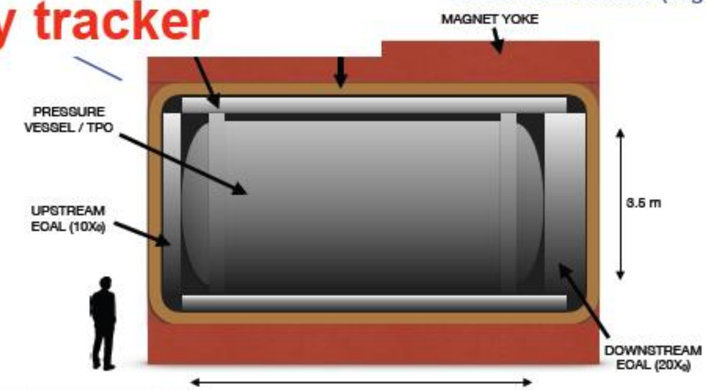
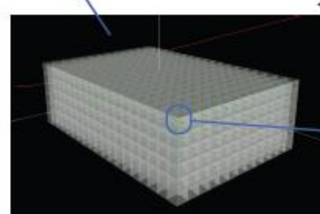
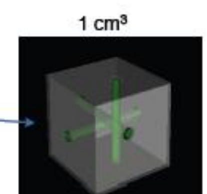






Upgrade of the T2K near detector ND280

Mathieu Lamoureux

- T2K proposes to keep taking data up to $\sim$ 2026 and near-detector upgrade seems a necessary step to improve oscillation results.
- An upgrade configuration is proposed:
  - keep current tracker
  - add one *new target* (R&D ongoing) surrounded by additional TPCs and *Time-of-Flight detectors*
- Studies have shown that it is able to cover better *high-angle and backward tracks* $\Rightarrow 4\pi$ acceptance.
- This would allow us to:
  - *better constrain flux and Q^2-dependent parameters* in current model parametrization
  - study and test different models (such as 2p2h Martini VS Nieves)

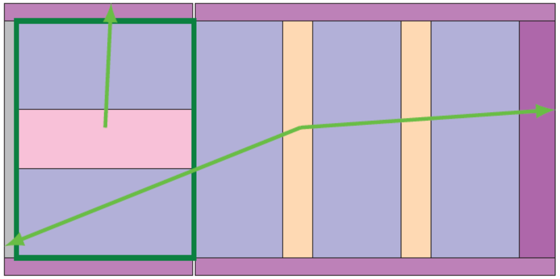
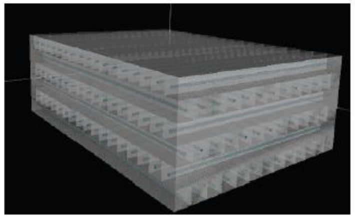
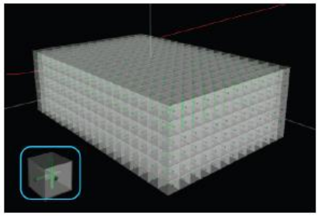


Figure: Schematics of upgrade detector central region, colors: New target, FGD, TPC, ECal, ToF counters

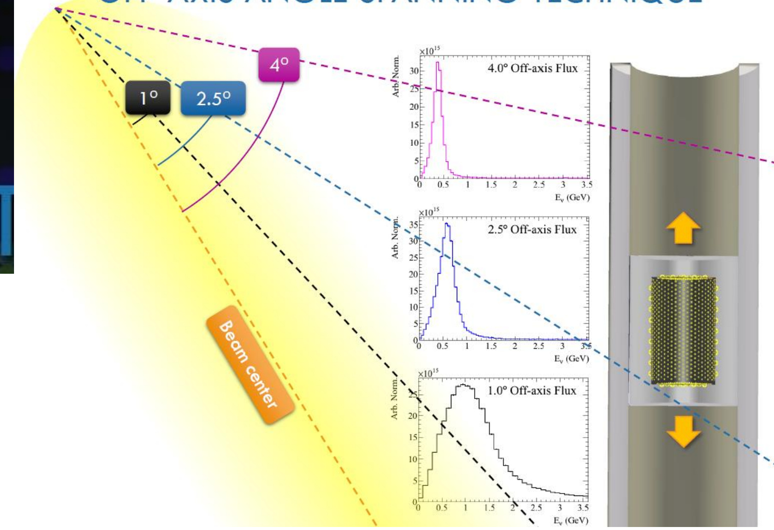
FGD XZ



SuperFGD



OFF-AXIS ANGLE SPANNING TECHNIQUE



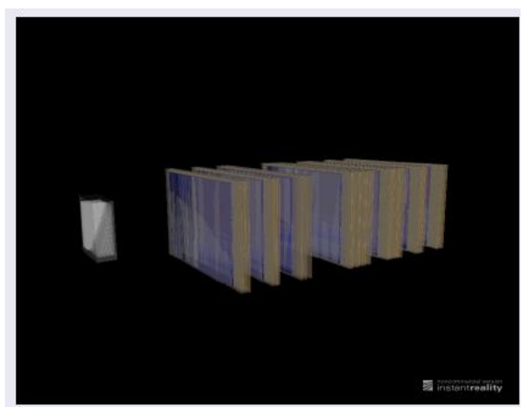
Cristovao Vilela

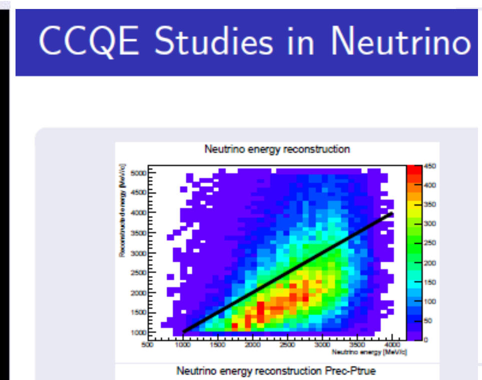
- The E61 off-axis angle spanning technique gives a data-driven method to convert E_{rec} to E_{true}, decoupling the flux shape from interaction models.
- Significant effort has led to a mature project, with sophisticated analyses being developed using realistic simulation and reconstruction tools.
- An extensive R&D programme for multi-PMTs is in place, with initial prototypes currently in production.
- The construction of an initial phase of the detector has been proposed.
  - Either a full-sized detector at J-PARC or a reduced detector on a test beam.
- An aggressive time scale is being pursued, aiming at collecting a significant amount of Phase 1 data concurrently with T2K-II.

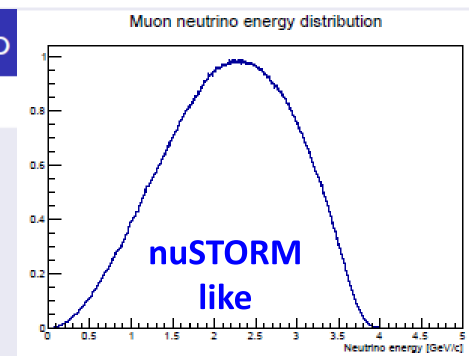
Baby MIND

Sven-Patrik Hallsjo

- Installation of the Baby MIND detector at the J-PARC ND280 pit early 2018.
- Magnet modules: novel design, innovative magnetization scheme with optimal flux return, enables far greater flexibility in detector layout compared with previous designs for this type of detector.
- Scintillator modules: All 18 modules extensively tested and qualified with testbeam.
- Previously MINDs not considered for lower than 1 GeV/c.
- MINDs both as standalone muon spectrometer or neutrino detector.
- Baby MIND can go down to lower momentum, $\approx$ 200 MeV/c $\rightarrow$ 10 GeV/c
- Possible for near or far detector.
- Modular so it can be wrapped around any target, LAr, TPC etc...
- More data analysis in the works.
- Muon charge efficiency above 80% with additional position information full range, above 95% at 800 MeV/c for both layouts.

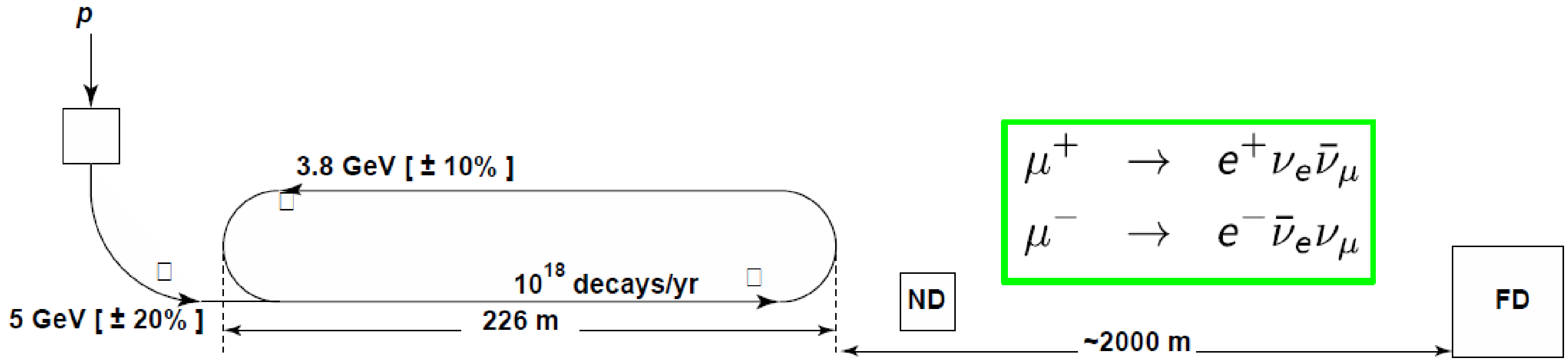






Kenneth Long

Neutrinos from stored muons



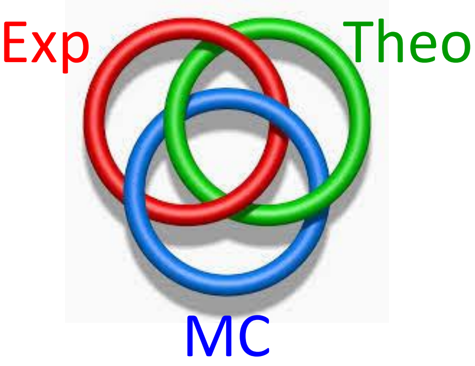
$$\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$$
$$\mu^- \rightarrow e^- \bar{\nu}_e \nu_\mu$$

- nuSTORM can deliver:
  - *n**N*** scattering measurements with precision required to:
    - Serve the long- and short-baseline neutrino programmes
    - Provide a valuable probe for nuclear physics

- CERN PBC study:
  opportunity to define innovative programme:
    - nuSTORM:
      - Delivers critical measurement: ν_e/ν_μ *N* scattering;
      - Has discovery potential: sterile neutrinos;
      - Potential for 6D ionization-cooling programme to follow MICE

WG2: Neutrino cross sections - Summary

- Many new experimental, theoretical and Monte Carlo results have been presented
- Experiment : high precision data sets; hadron information
- Theory: interesting and promising new developments
- Monte Carlo: effort going into implementation of new models/idea



Collaboration between experiments, theorists and generators is crucial

- 2p-2h remains an hot topic: discussed in 13/26 talks, mentioned in 22/26 (and in many plenaries)
- The one pion production puzzle is still open
- New ND idea for current and future LBL experiments

Thanks again to all speakers and participants in WG2
and thank you for your attention