Superscaling in neutrino/antineutrino CCQE scattering from MiniBooNE to NOMAD energies

G. D. Megias[1], J. E. Amaro[2], M. B. Barbaro[3],
J. A. Caballero[1], T. W. Donnelly[4]

[1]Dpto. de FAMN, Universidad de Sevilla, Sevilla, Spain.
[2]Dpto. de FAMN and Instituto Carlos I, Universidad de Granada, Granada, Spain.
[3]Dpto. di FT, Università di Torino and INFN, Torino, Italy
[4]Center for Theoretical Physics, M.I.T., Cambridge, Massachusetts, USA.

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Quasielastic Regime

CCQE scattering

$$\nu_\mu(\bar{\nu}_\mu)+A \rightarrow \mu^-(\mu^+)+p(n)+(A-1)$$

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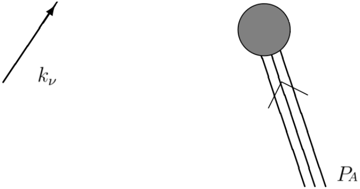

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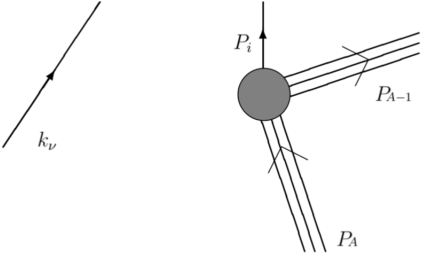

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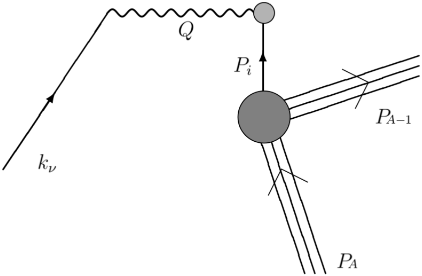

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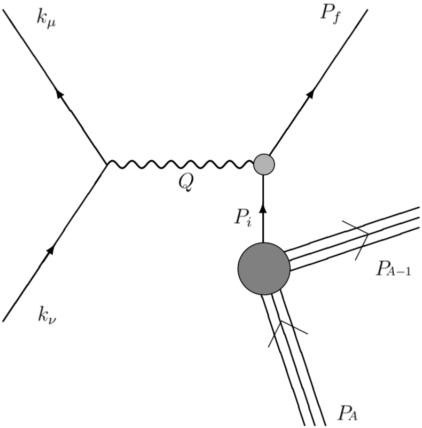

Motivation

Two main related objectives:

1. Complete theoretical description of the CCQE neutrino-nucleus interaction and the weak structure of the nucleon.
2. Full analysis of the experimental data in all range of energies from intermediate $E_\nu \sim 1\ GeV$ (MiniBooNE) to high values $E_\nu \sim 10$ - $100\ GeV$ (NOMAD).

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Relevance of this investigation:

- To know better the hadronic structure of the nucleon and other nuclear properties such as correlations or 2p-2h MEC contributions.
- To analyze better neutrino oscillations experiments.

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MiniBooNE

MiniBooNE (Fermilab)

- Measurement of CCQE ν_μ ($\bar{\nu}_\mu$) cross sections on a ^{12}C target in the 1 GeV region.
- Discrepancy between the data and traditional nuclear models.

MiniBooNE

MiniBooNE (Fermilab)

➲ Measurement of CCQE ν_μ ($\bar{\nu}_\mu$) cross sections on a ^{12}C target in the 1 GeV region.

➲ Discrepancy between the data and traditional nuclear models.

Two options to solve this puzzle:

1. MiniBooNE proposed a higher nucleon axial mass value: $M_A = 1{,}35$ GeV/c^2 $\Longrightarrow$ It does not work at high energy data (NOMAD).
2. Microscopic explanations based on multi-nucleon excitations, such as the evaluation of the Meson Exchange Currents (MEC) within the 2p-2h approach $\Longrightarrow$ Do not give a full account for the discrepancy.

➥ A consistent evaluation of MEC is hard to achieve.

NOMAD

NOMAD (CERN)

➲ CCQE $\nu_\mu(\bar{\nu}_\mu)-{}^{12}$C cross sections measurements go from 3 to 100 GeV.

➲ Results do not call for a large axial-vector mass (M_A) and do not seem to match with the MiniBooNE results.

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$\Downarrow$

Main goal

➥ To perform a consistent theoretical analysis of the CCQE neutrino-nucleus interaction in the entire 0-100 GeV region.

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Theoretical descriptions: Nuclear model dependence

➠ For this purpose we need to employ a nuclear model which can be applied up to very high energies.

➠ Two basic requirements: it has to be relativistic and it must describe QE electron scattering data from intermediate up to high energies.

SuperScaling Approach (SuSA)

- Based on the superscaling function extracted from QE electron scattering data.
- This model does not account for the ∼10 % scaling violations of the transverse channel, which are associated with 2p-2h MEC. This should therefore be added.
- An evaluation of MEC is very hard to achieve. Our present MEC parametrization does not work well for $E_\nu \gtrsim 2\,\mathrm{GeV}$ (work in progress).

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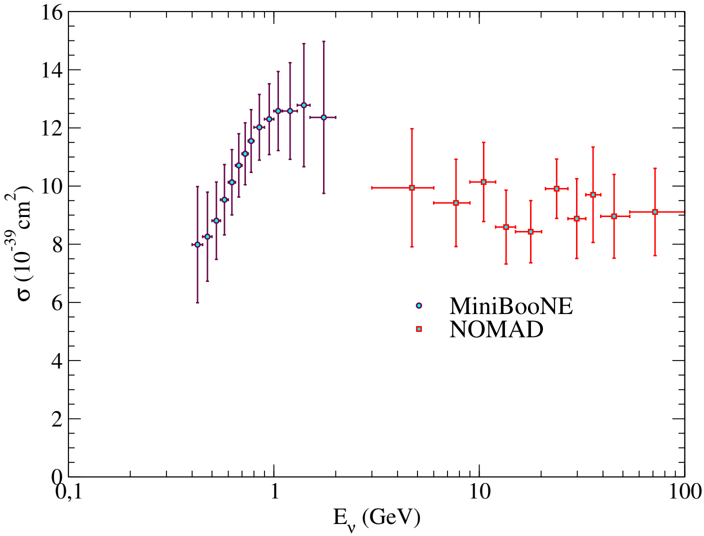

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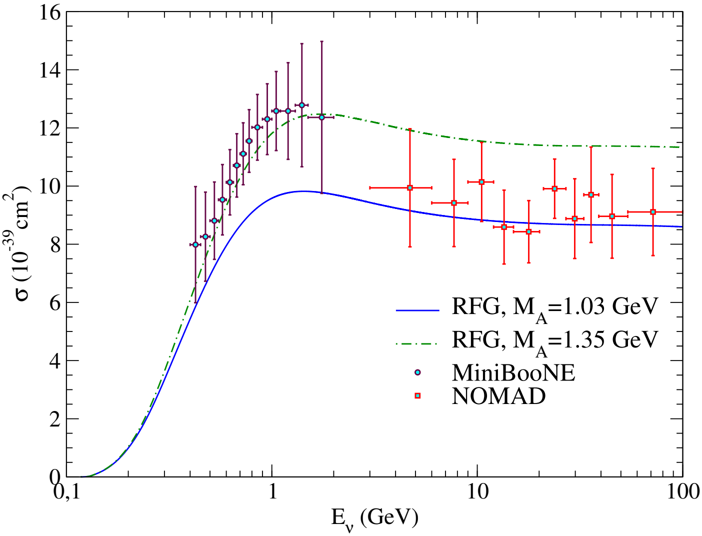

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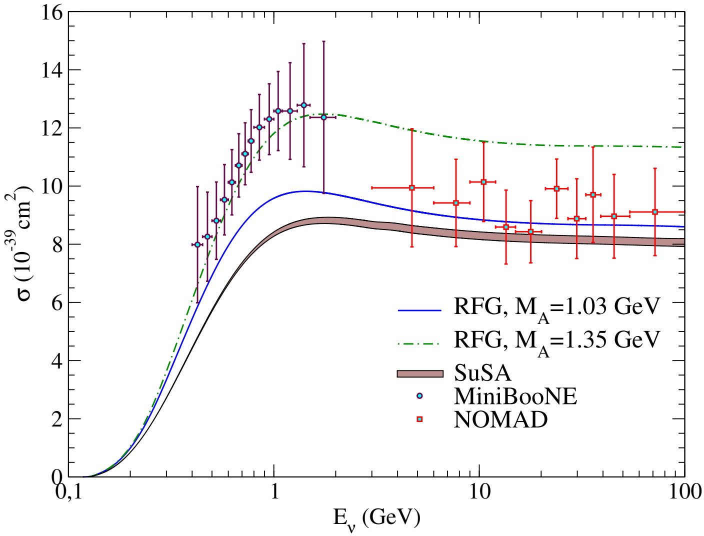

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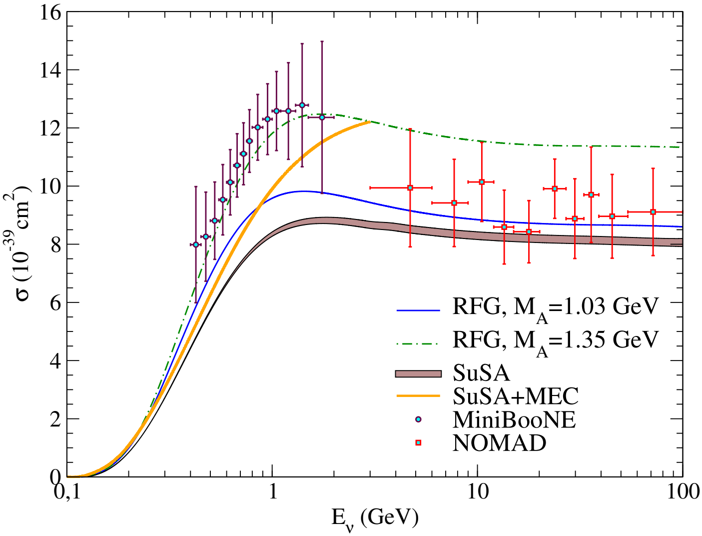
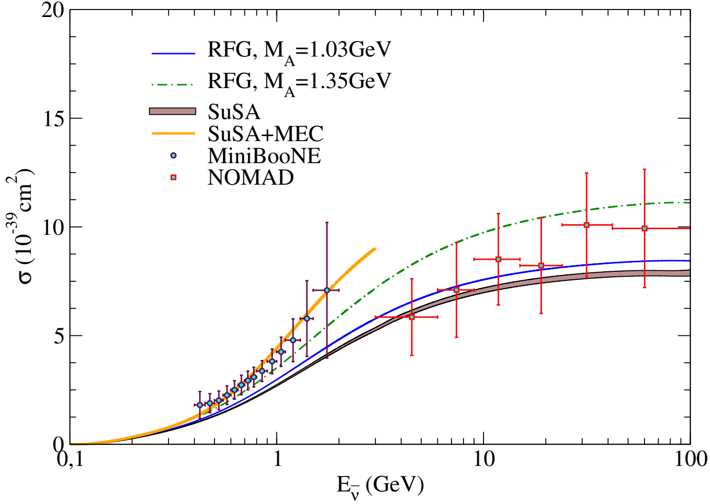
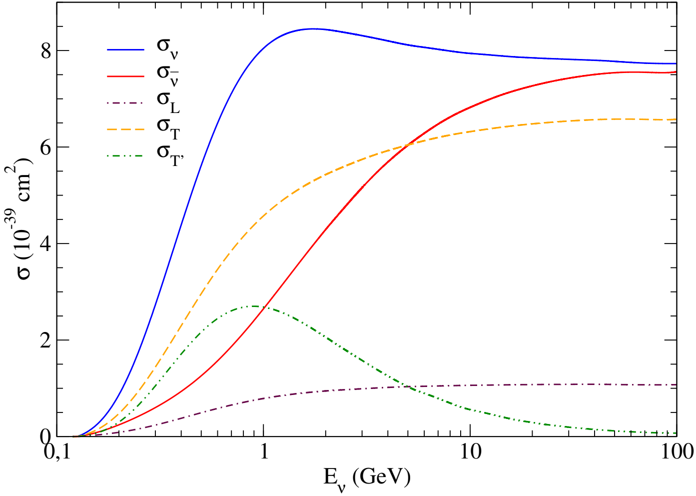


$\bar{\nu}_\mu$-^{12}C CCQE scattering



Separated Contributions in the SuSA Model



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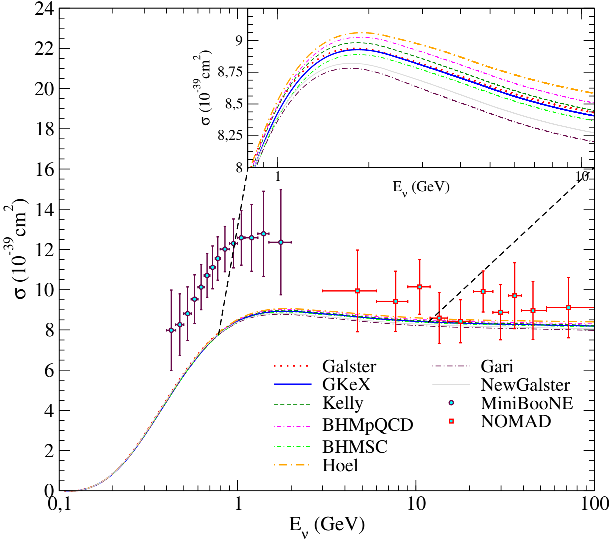
Parametrization of the nucleon EM form factors



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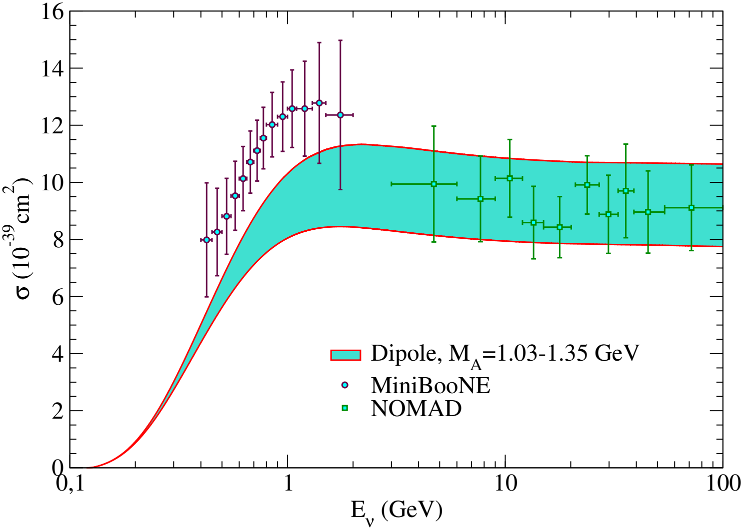
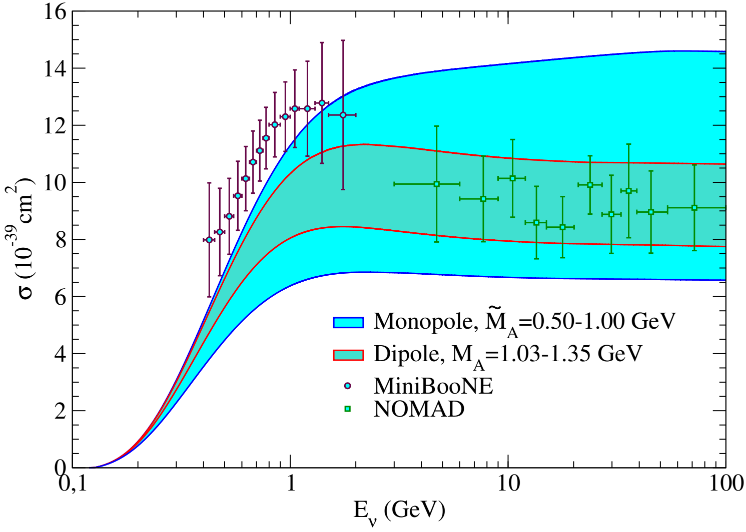
Dipolar axial form factor



Monopolar axial form factor



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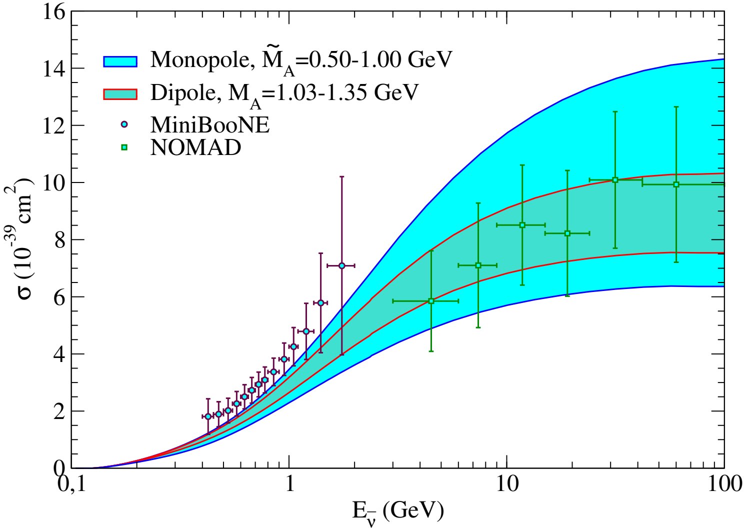

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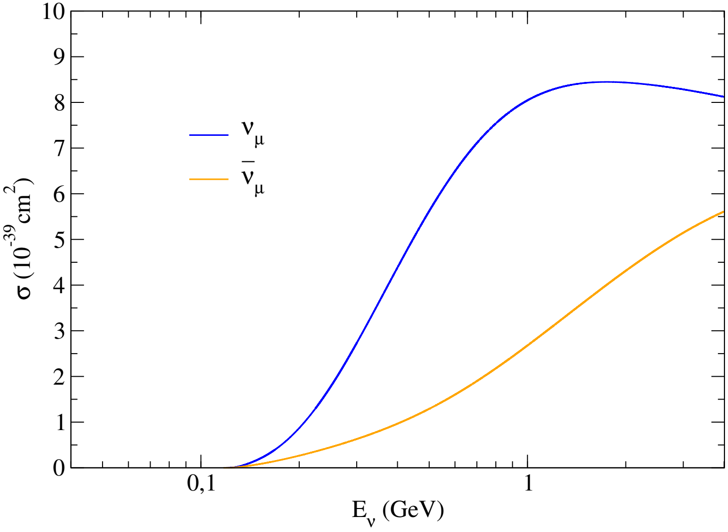
ν_μ vs. ν_e CCQE Cross Section



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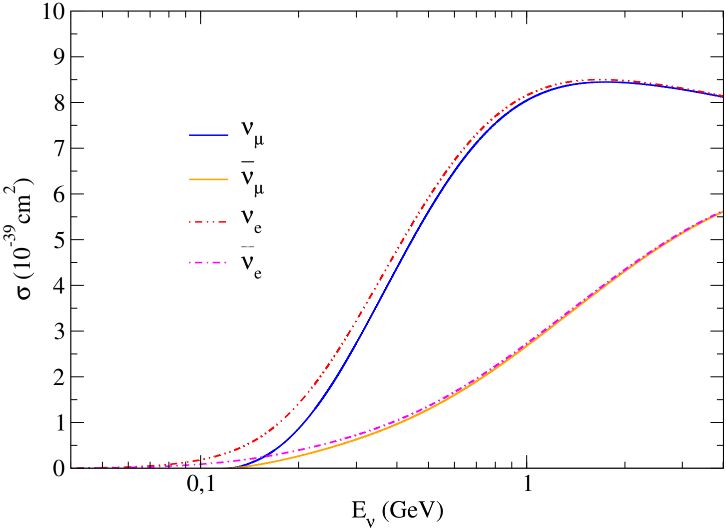

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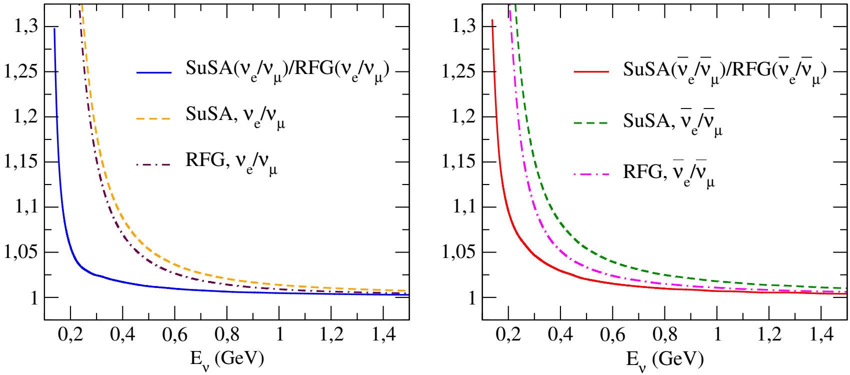

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Summary and Main Conclusions

arXiv:1305.6884 [nucl-th]

➲ First SuSA results from intermediate to high energies. In spite of similar results between RFG and SuSA, RFG fails to reproduce (e, e') data whereas SuSA agrees with them by construction.

➲ SuSA model has to be completed with effects that go beyond the Impulse Approximation (correlations, MEC) $\Rightarrow$ increase of the cross sections at low energies (10-15 %) $\Rightarrow$ better data explanation without increasing M_A.

➲ Moreover, our predictions corresponding to νSTORM kinematics can be useful to get information about the electroweak nuclear matrix elements and the dipole or monopole nature of the axial-vector form factor.

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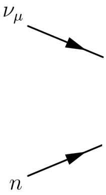

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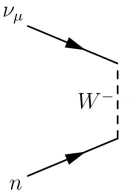

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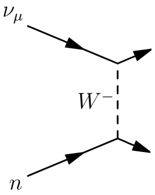

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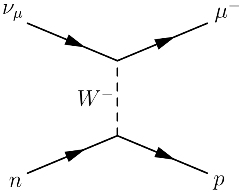
- Study of future νSTORM, Minerνa and T2K results.

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