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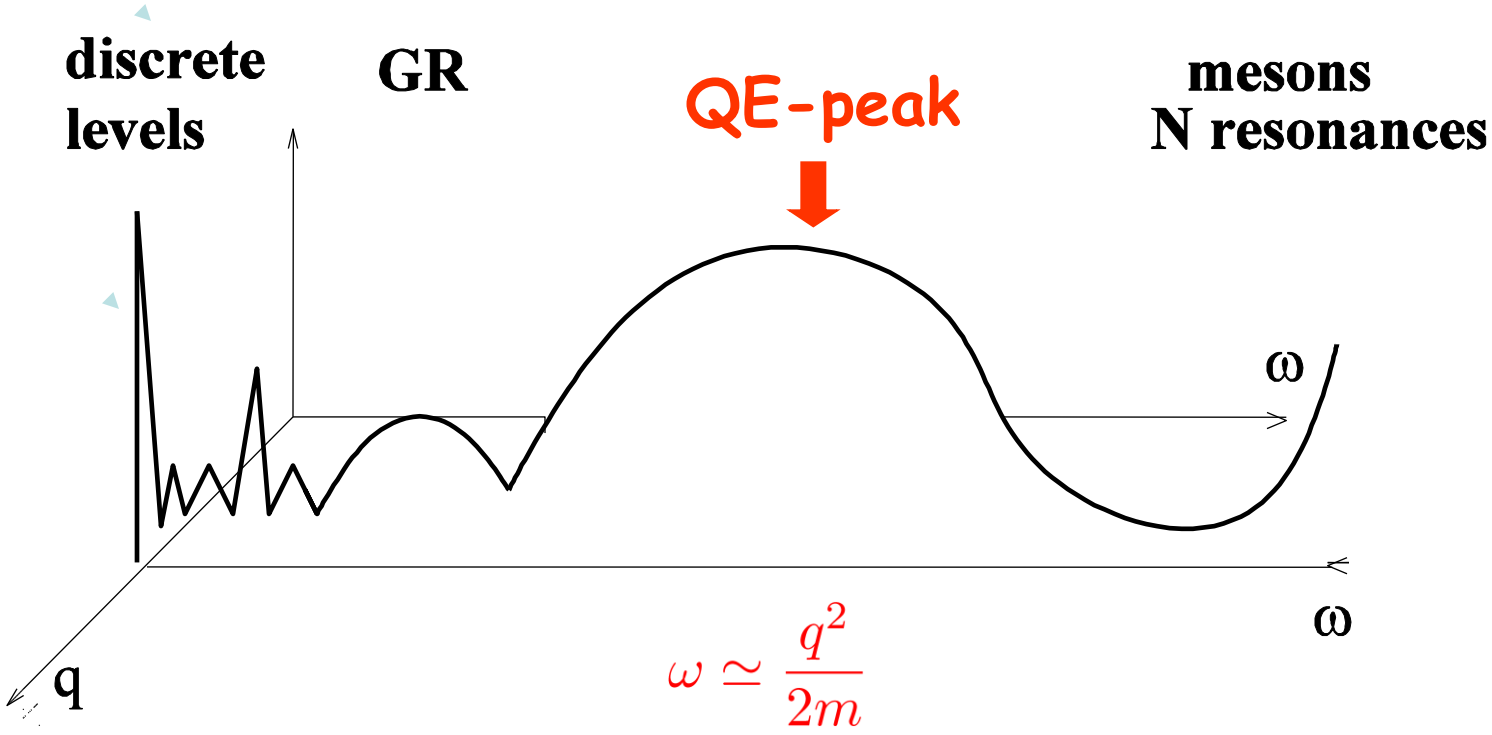
NUCLEAR REACTIONS WITH ELECTROWEAK PROBES: QUASIELASTIC ELECTRON AND NEUTRINO-NUCLEUS SCATTERING

QUASIELASTIC ELECTRON AND NEUTRINO-NUCLEUS SCATTERING

- electron scattering: electron is a probe to investigate nuclear properties
- neutrino experiments aimed to determine neutrino properties
- nuclei used as neutrino detectors
- nuclear effects must be well under control
- models developed for electron scattering and tested in comparison with electron scattering data have been applied to neutrino scattering

nuclear response to the electroweak probe



QE-peak dominated by one-nucleon knockout

QE e-nucleus scattering

$$e + A \Longrightarrow e' + N + (A-1)$$

- both e′ and N detected one-nucleon knockout (e,e′p)
- (A-1) is a discrete eigenstate n exclusive (e,e′p)
- only e′ detected inclusive (e,e′)

QE ν-nucleus scattering

$$\nu_l(\bar{\nu}_l) + A \Longrightarrow \nu_l(\bar{\nu}_l) + N + (A-1) \qquad \text{NC}$$

$$\nu_l(\bar{\nu}_l) + A \Longrightarrow l^-(l^+) + N + (A-1) \qquad \text{CC}$$

- only N detected semi-inclusive NC and CC
- only final lepton detected inclusive CC

QUASIELASTIC ELECTRON AND NEUTRINO-NUCLEUS SCATTERING

- consistent models developed for different exclusive, semi-inclusive and inclusive process
- non relativistic and relativistic models
- comparison of different models
- comparison of the models with experimental data

COMPARISON OF DIFFERENT MODELS

collaboration with J.A. Caballero (Sevilla)

J.M. Udias (Madrid)

M.B. Barbaro (Torino)

RELATIVISTIC MODELS

COMPARISON OF RELATIVISTIC MODELS

- consistency of numerical results for inclusive scattering
- comparison of different descriptions of FSI

COMPARISON OF DIFFERENT RELATIVISTIC MODELS

(e,e')

A. Meucci, J.A. Caballero, C. Giusti, F.D. Pacati, J.M. Udias PRC (2009) 80 024605

CCQE

A. Meucci, J.A Caballero, C. Giusti, J.M. Udias PRC (2011) 83 064614

comparison with MiniBooNE data

A. Meucci, M.B. Barbaro, J.A. Caballero, C. Giusti, J.M. Udias PRL (2011) 107 172501

B. Meucci, C. Giusti, F.D. Pacati PRD (2011) 84 113003

C. C. Giusti, A. Meucci J. of Phys. (2011) 336 012025

A. Meucci, C. Giusti PRD (2012) 85 093002

INCLUSIVE SCATTERING

- only final lepton detected: different treatment of FSI
- RDWIA — sum of 1NKO where FSI are described by a complex OP with an imaginary absorptive part does not conserve the flux
- REAL POTENTIAL
- RPWIA — FSI neglected
- rROP — only the real part of the OP: conserves the flux but it is conceptually wrong
- RMF — RELATIVISTIC MEAN FIELD: same real energy-independent potential of bound states

  Orthogonalization, fulfills dispersion relations and maintains the continuity equation
- RGF — GREEN'S FUNCTION: same COMPLEX OP of the exclusive scattering, but here the imaginary part redistributes the strength in all the channels and the flux is conserved

Comparison with MiniBooNe data

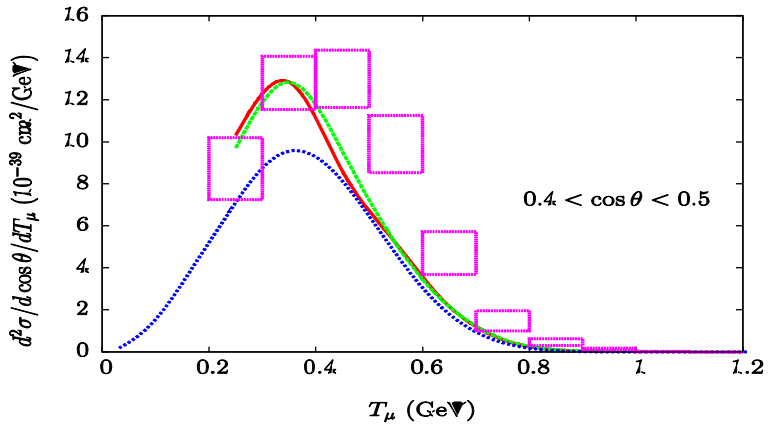
First Measurement of the Muon Neutrino Charged Current Quasielastic Double Differential Cross Section, PRD 81 (2010) 092005

$$\nu_\mu + {}^{12}\mathrm{C} \longrightarrow \mu^- + \mathrm{X}$$

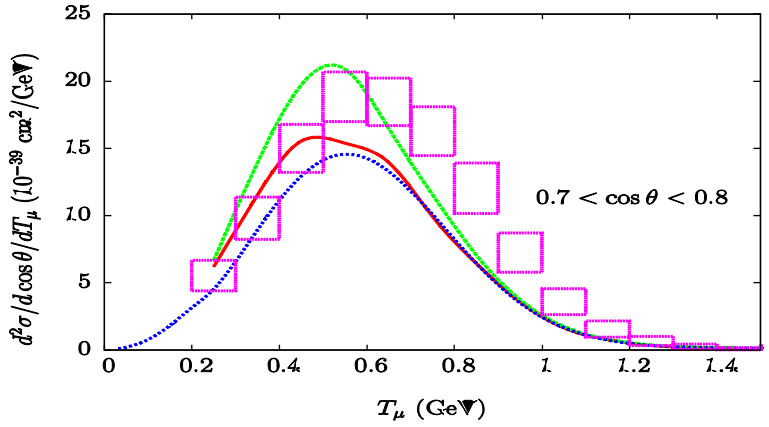
Measured cross sections larger than the predictions of the RFG model and of other more sophisticated models.

Unusually larger values of the nucleon axial mass must be used to reproduce the data (about 30% larger)

Comparison with MiniBooNe CCQE data



$0.4 < cos\theta_\mu < 0.5$

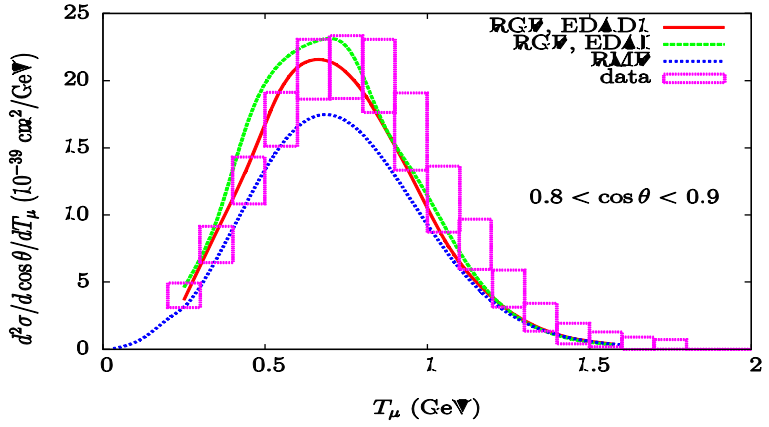


$0.7 < cos\theta_\mu < 0.8$

RGF-EDAI

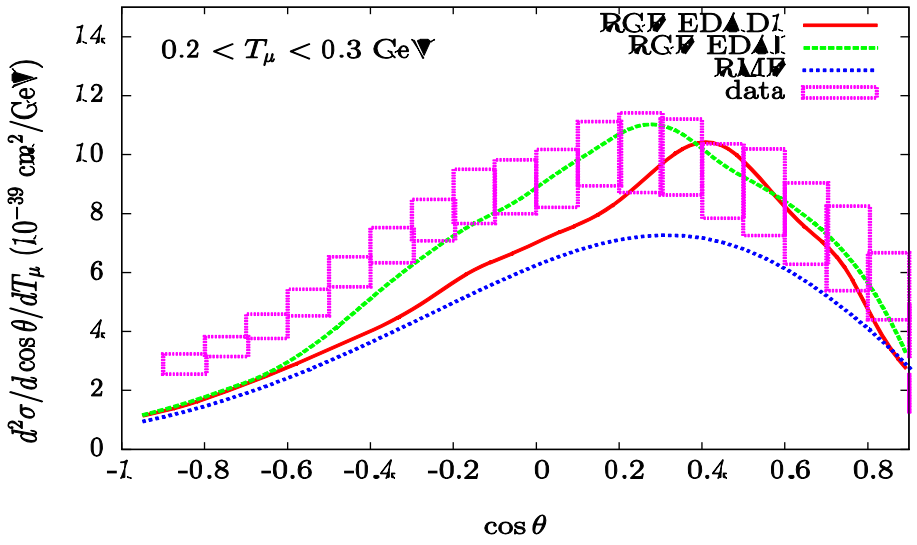
RGF-EDAD1

RMF



$0.8 < cos\theta_\mu < 0.9$

Comparison with MiniBooNe CCQE data

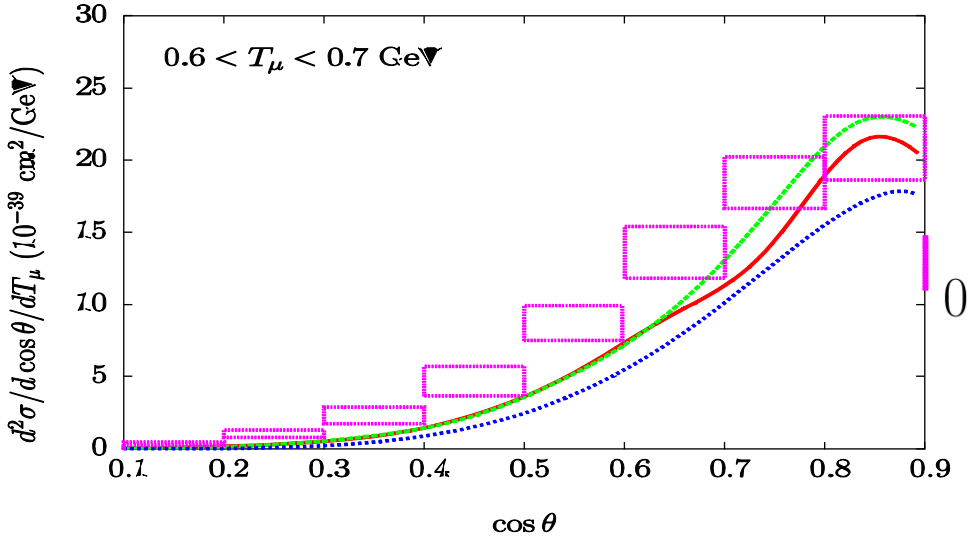


$0.2 < T_\mu < 0.3$ GeV

RGF-EDAI

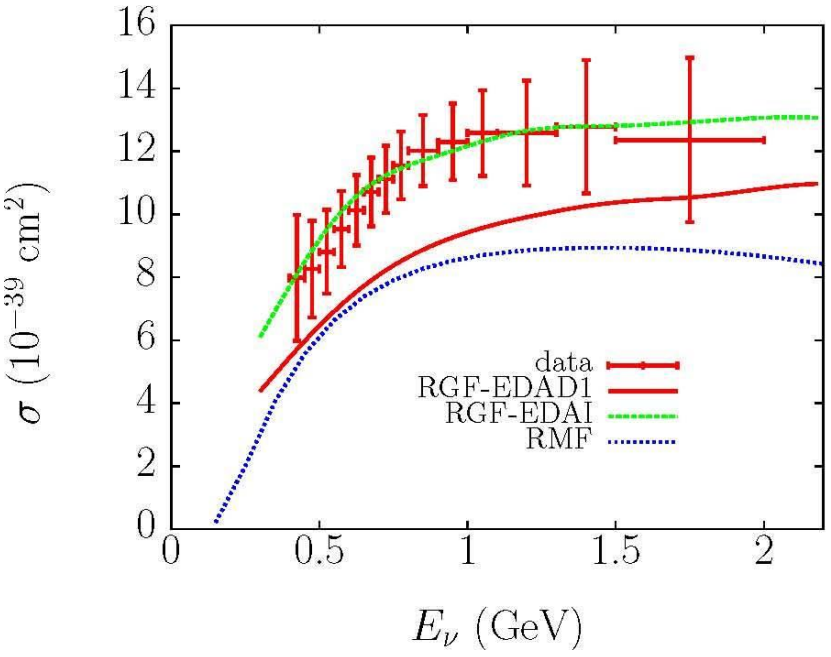
RGF-EDAD1

RMF



$0.6 < T_\mu < 0.7$ GeV

Comparison with MiniBooNe CCQE data

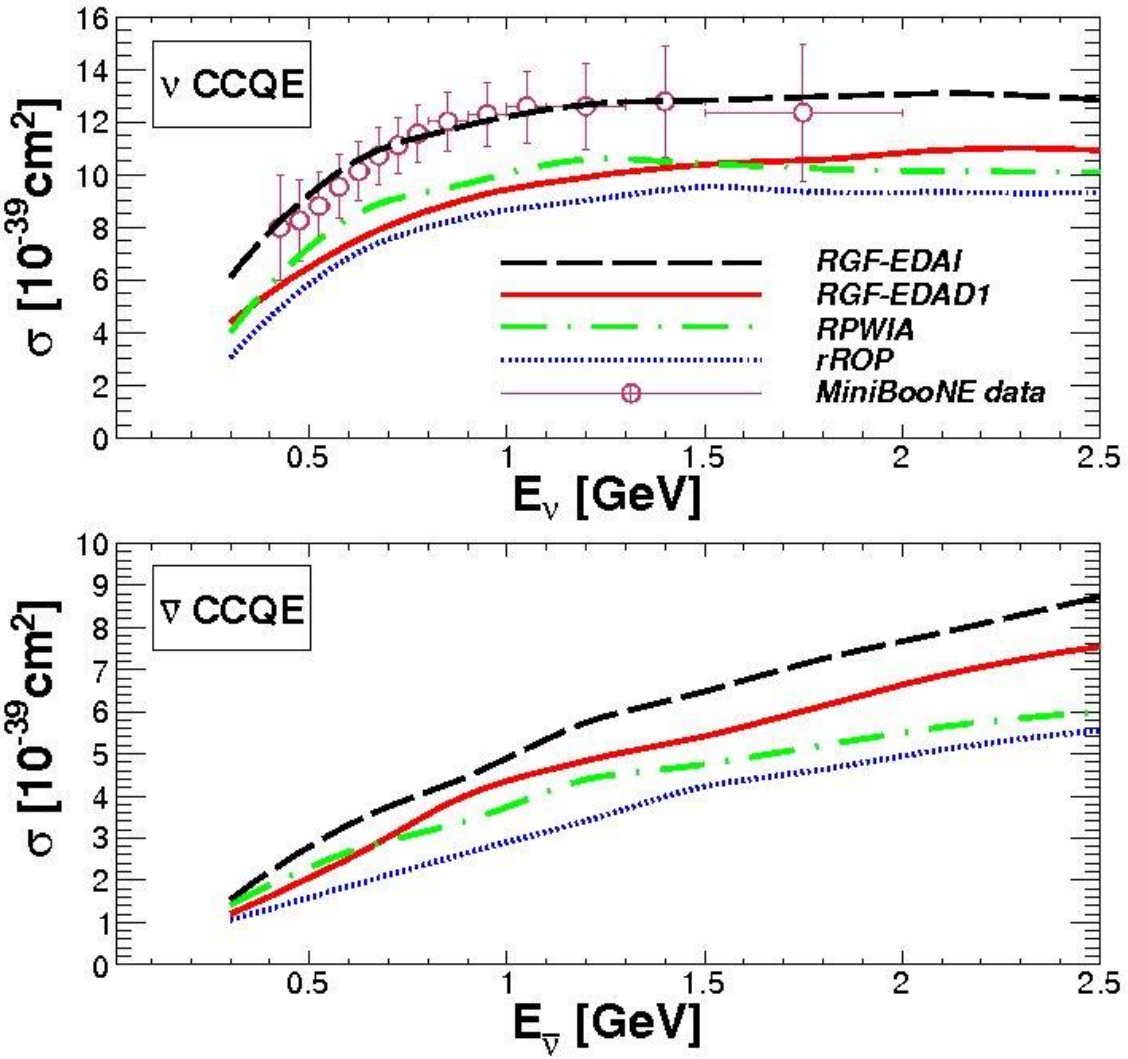


RGF-EDAI

RGF-EDAD1

RMF

Comparison CCQE neutrino-antineutrino scattering



Comparison with MiniBooNE NCE data

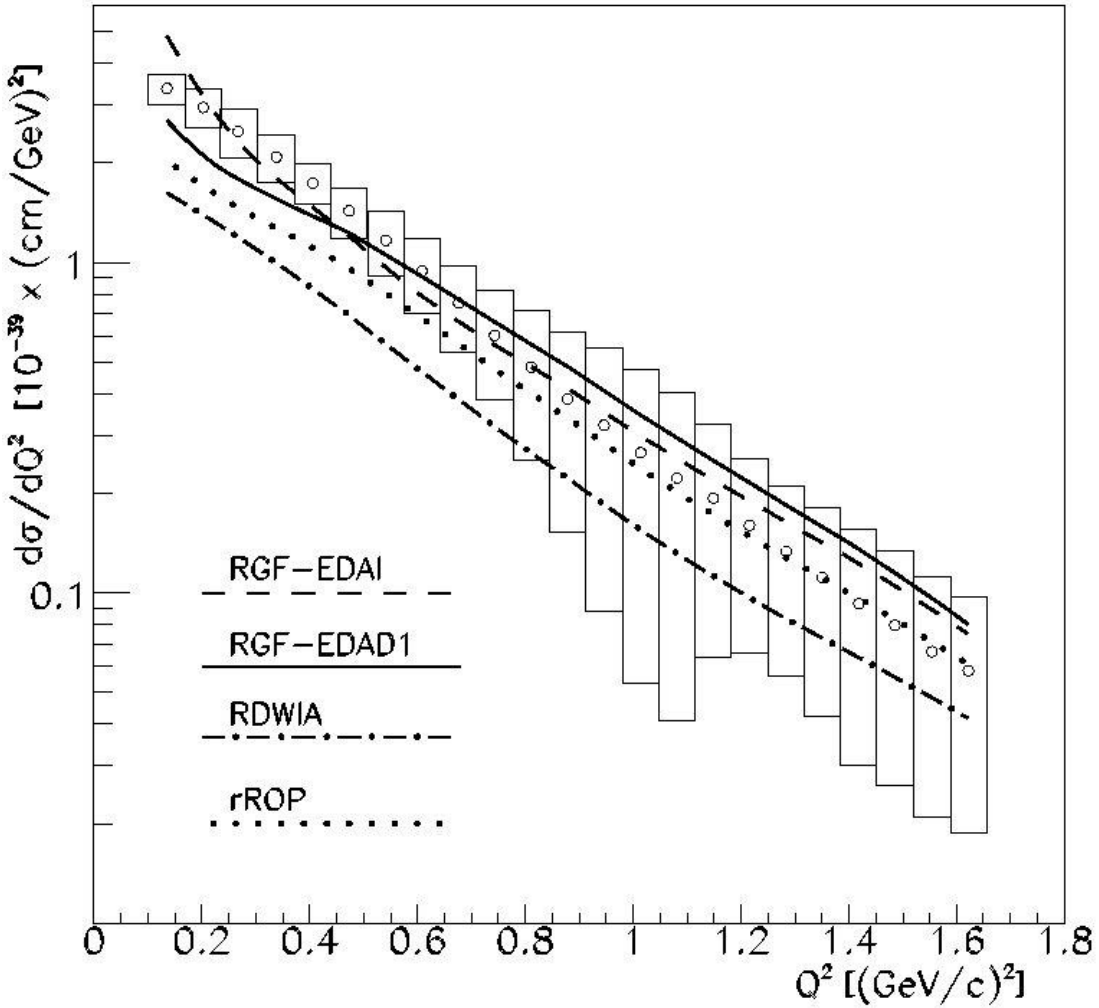
Measurement of the flux averaged neutral-current elastic (NCE) differential cross section on CH_2 as a function of Q^2 PRD 82 092005 (2010)

The NCE cross section presented as scattering from individual nucleons and consists of 3 different processes: scattering of free protons in H, bound protons and neutrons in C

NC ν-nucleus scattering

- only the outgoing nucleon is detected: semi-inclusive scattering
- FSI ?
- RDWIA : sum of all integrated exclusive 1NKO channels with absorptive imaginary part of the ROP. The imaginary part accounts for the flux lost in each channel towards other inelastic channels. Some of these reaction channels are not included in the experimental cross section when one nucleon is detected. For these channels RDWIA is correct, but there are channels excluded by the RDWIA and included in the experimental c.s.
- RGF recovers the flux lost to these channels but can include also contributions of channels not included in the semi-inclusive cross section
- we can expect RDWIA smaller and RGF larger than the experimental cross sections
- relevance of contributions neglected in RDWIA and added in RGF depends on kinematics

Comparison with MiniBooNE NCE data



EXOTIC NUCLEI

collaboration with G. Co' (Lecce)

V. De Donno (Lecce)

P. Finelli (Bologna)

M. Grasso (Orsay)

M. Anguiano (Granada)

A. Lallena (Granada)

Quasifree (e,e'p) Reactions on Nuclei with Neutron Excess

Carlotta Giusti

Andrea Meucci

Franco Pacati

Giampaolo Co'

Viviana De Donno

PRC 84 024615 (2011)

J. Phys: Conf. Ser. 366 012019 (2012)

MOTIVATION

- understanding the evolution of nuclear properties as a function of N/Z
- nuclear reactions main source of information on nuclear properties
- direct reactions give insight into the s.p. properties
- advantages of the elm probe: (e,e'p) preferential tool to study proton-hole states, bound protons, validity and limits of IPSM
- large amount of (e,e'p) data, accurate information on s.p. properties of stable nuclei
- advent of RIB facilities will provide data on unstable nuclei
- electron RIB colliders that use storage rings under construction (GSI, RIKEN) will offer unprecedented opportunities to study exotic nuclei with electron scattering (ELISe at FAIR, SCRIT at RIKEN)
- exclusive (e,e'p) knockout experiments (ELISe at FAIR, SCRIT at RIKEN)

(e,e'p) on neutron-rich nuclei

- NIKHEF data ^{40}Ca ^{48}Ca
- original analysis DWIA with phen. WS bound state w.f.
- DWIA (WS and HF w.f.) and RDWIA equivalently good description of data
- calculations performed for Ca isotopes: 40, 48, 52, 60
- evolution of nuclear properties with models of proven reliability in stable isotopes will test the ability of the established nuclear theory in the domain of exotic nuclei
- reference for future experiments

Mean Field Calculations of Exotic Nuclei Ground States

G. Co' , V. De Donno

P. Finelli

M. Grasso

M. Anguiano, A.M. Lallena

C. Giusti, A. Meucci, F.D. Pacati

PRC 85 024322 (2012)

Mean Field Calculations of Exotic Nuclei Ground States

Predictions of three mean field theoretical approaches (non relativistic HF with both zero and finite-range interactions, relativistic Hartree) in the description of the ground state properties of some spherical nuclei far from the stability line (O, Ca Ni, Sn isotopes) . Binding energies, s.p. particle spectra, density distributions, charge and neutron radii are compared. The agreement between the results of the different models indicates that the results are more related to the basic hypothesis of the mean-field approach rather than to its implementation in actual calculations