

Results for different current operators (exercise). Show that for free positive energy spinors they are equivalent

$$\Gamma_1^\mu(\mathbf{p}_f, \mathbf{p}_i) = \gamma^\mu G_M(Q^2) - \frac{P^\mu}{2m} F_2(Q^2)$$

$$\Gamma_2^\mu(\mathbf{p}_f, \mathbf{p}_i) = \gamma^\mu F_1(Q^2) + i\sigma^{\mu\nu} \frac{q_\nu}{2m} F_2(Q^2)$$

$$\Gamma_3^\mu(\mathbf{p}_f, \mathbf{p}_i) = \frac{P^\mu}{2m} F_1(Q^2) + i\sigma^{\mu\nu} \frac{q_\nu}{2m} G_M(Q^2)$$

On shell nucleons

- We can put artificially 'on shell' the initial and final nucleon by forcing their wave functions to fulfill 'half' the *free* Dirac equation
- Gordon transformation will be valid for these EMA spinors, and matrix element should factorize into the ones for free nucleons
- Show that the previous current operators are equivalent for EMA (on-shell) positive energy spinors. Show that they verify free Dirac equation

$$\bullet \psi_{RDWIA}(\vec{p}) = \left(\begin{array}{c} \psi_{up}(\vec{p}) \\ \frac{\vec{\sigma} \cdot \vec{p}}{E+M+S-V} \psi_{up}(\vec{p}) \end{array} \right) \rightarrow$$

$$\psi_{EMA}(\vec{p}) = \left(\begin{array}{c} \psi_{up}(\vec{p}) \\ \frac{\vec{\sigma} \cdot \vec{p}_{as}}{E_{as}+M} \psi_{up}(\vec{p}) \end{array} \right)$$



Superscaling QE (e, e') predictions (SUSAE)

Codes sigsusa.linux, sigsusa.cygwin.exe, sigsusa.win.exe

Input file sigsusa.in:

```
1 target nucleus (1: 12C, 2: 16O, 3: 40CA, 4: 56FE)
680. -36. ebeam (MeV) and q (if <0, assume it is the scattering angle in_degrees)
1. 300. 10. win wfin wstep (energy transfer range)
```

Output file sigsusa.out:

```
w(GeV) sigma(nbarn/sr/GeV) psi' f(psi') q (MeV/c) theta
```

References:

Phys.Rev.Lett.95:252502,2005, Phys.Rev. C68 (2003) 048501, Phys.Rev.Lett.100:052502,2008, Phys.Lett.B653:366-372,2007, PRC60,065502



RFG (e,e') predictions

Codes rfgee.f, rfgee.cygwin.exe, rfgee.linux, rfg.win.exe

Input file rfg.in:

(see next slide)

Output file sigma.out:

w(GeV) sigma(nbarn/sr/GeV) psi' f(psi') q (MeV/c) theta

References:

Many references for RFG. This version is my own RFG that is somewhat described in my internal report (inclusiv.pdf notes) and in Nucl.Phys.A602:263-307,1996 and I've employed in Phys. Rev. Lett. 74 (1995) 4993, Phys.Rev.C52:3399-3415,1995



CC Comienzo del caso....

output file

pwdwia.out

CC

Zinc, Amass, Zfin, Amass fin.

6. 12. 5. 11.008503

XXXXXXXXXXXXXXXXXXXXX Iff ireac (0 for EM) not used neut(1.) or antineut (-1.)

0 0 0 0.0 1 0 0 1.

win, wfin wstep q or thet Pmfermi, Pauli Blocking Energy (MeV)

0.01 300. 1. -36 225.5 27.

ekin, Binding Energy (MeV) XXXX

680. 27.0 0.0

XXXXXXXXXXXXXXXXXXXXX

0

CC Opciones del programa

XXXXXX N_points cosmin cosmax print

0. 0. 100 -0.9999999999 0.9999999999 0

nuc. intermediate files (nuc00,nucll)

emuwork:nuc00.dat

emuwork:nucll.dat

radial integrals interm. files (rad00,ll1,ll2)

emuwork:rad00.dat

emuwork:radll1.dat

emuwork:radll2.dat

output file for pm-cross-section

pwcrs.out

CC Opciones del calculo

XXXXXXX, lcc (1-cc1, 2-cc2 < 0, impose cc) F2s G1s

0 0 -1 0 -0. -0.0

CC Fin del caso....



RMF calculations for nucleonic response

RMF-CC0-60-680, RMF-CC0-60-620, RMF-CC0-36-680, RMF-CC0-36-560
RMF-CC0-36-480, RMF-CC0-60-560, RMF-CC0-60-519, RMF-CC0-60-440,
RMF-CC0-13.54-1500

Files: protons.crs, neutrons.crs, total.crs and others

Format of the files:

w(MeV) sig1 sig2 sig3 sig_noFSI

USE ONLY sig2 or sig3 or sig_noFSI

Look out UNITS: $d\sigma/d\omega$ (nb/MeV/sr²)

Described in my talk, also Phys.Rev. C68 (2003) 048501,
Phys.Rev.Lett.95:252502,2005



Inclusive (e,e') data

File 12C-data.dat contains most data for ^{12}C in (e,e')

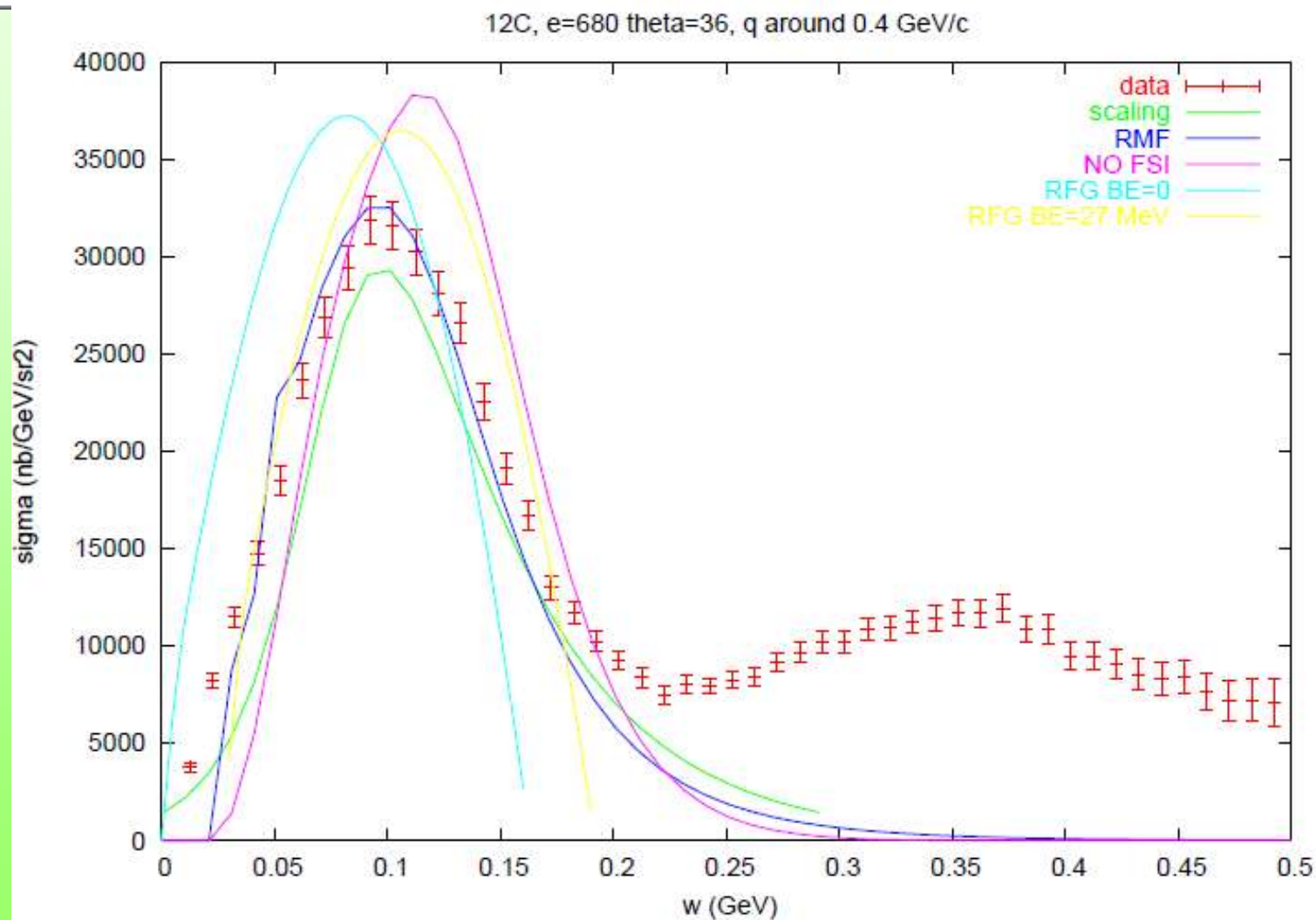
Format of file:

Z A beam-energy (GeV) angle w (GeV) $d\sigma/d\omega$ err ref.

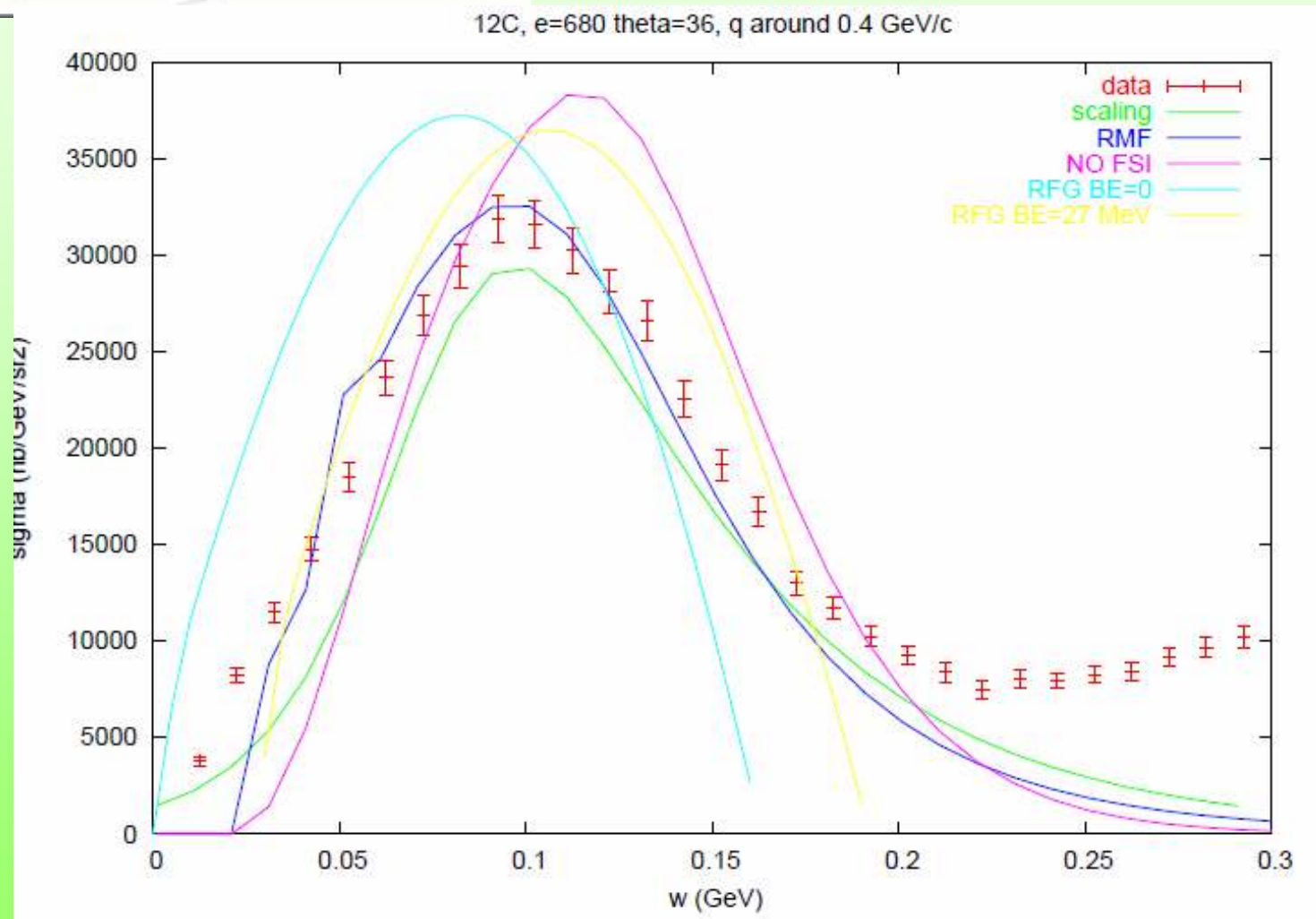
Easy to get from the Virginia Welcome to Quasielastic Electron
Nucleus Scattering Archive (thanks to D. Day and many others):

<http://faculty.virginia.edu/qes-archive/C12/C12-index.php>

Comparison to experiment

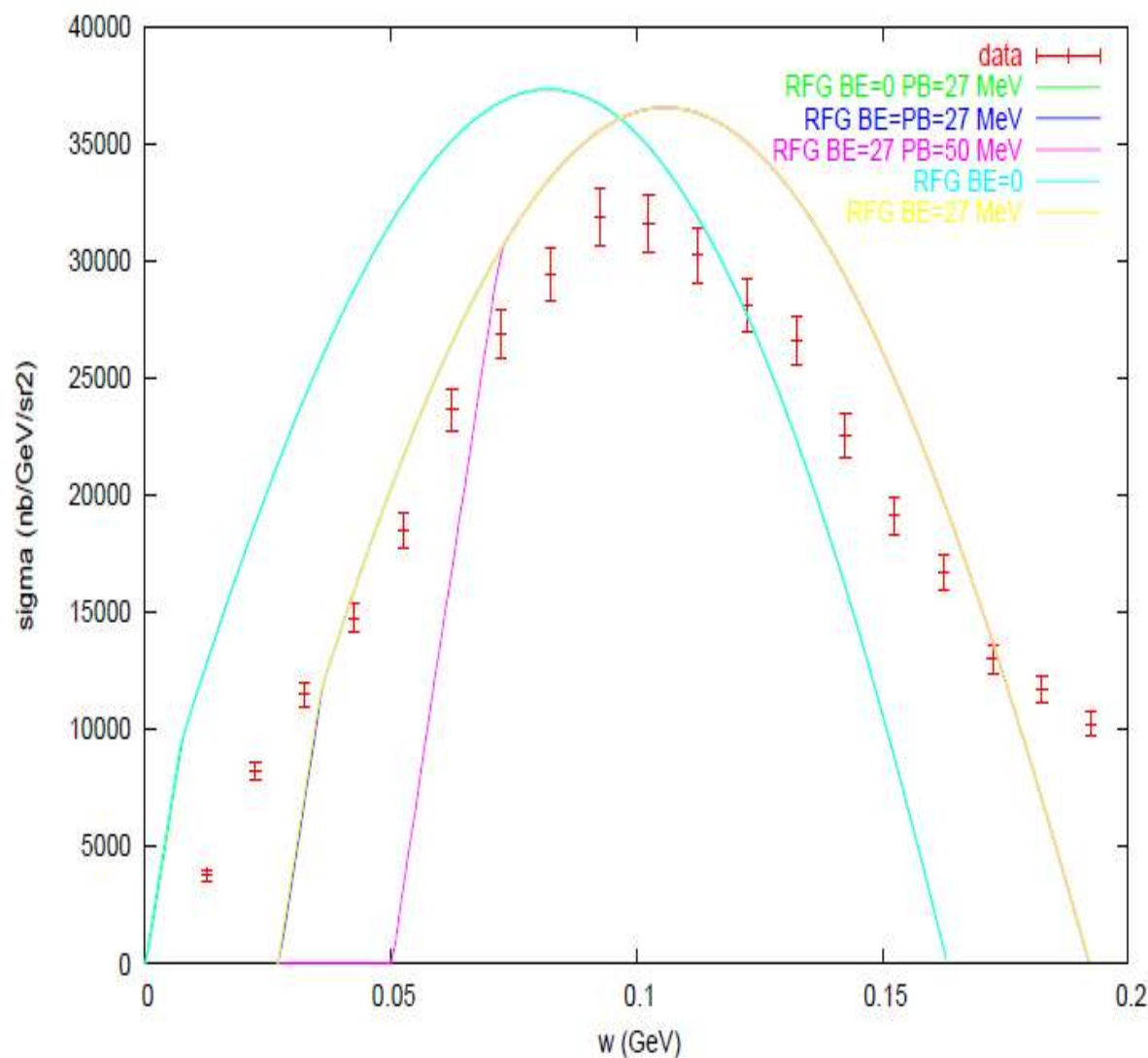


Zoom into the nucleonic peak



Effect of RFG parameters

^{12}C , $e=680$ $\theta=36^\circ$, q around $0.4 \text{ GeV}/c$



PB is negligible except for very small q
Or unrealistical values of PB

BE puts the peak in the right position and breaks Gauge invariance and puts the nucleons off-shell

RFG parameters give some handle to tune the nuclear model, but not a very good one!

RMF calculations: Nuclear effects have a noticeable impact for 1 GeV neutrino energy. I'll prepare codes for the CC case

