Spectral function at small missing energies.

(Faddeev results for ^{16}O)

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References:

W. H. Dickhoff and C.B., nucl-th/0402034

ECT, Workshop on spectroscopic factors*

Wednesday, March 10, 2004

Information on single-particle motion

- “wave function” and energy of a nucleon inside the system

$$\psi^{(h)}(k) = \langle \Psi_n^{A-1} | c_{\vec{k}} | \Psi_0^A \rangle$$ one-body overlap

$$E_m = E_0^A - E_n^{A-1}$$ missing energy

- Spectroscopic factor

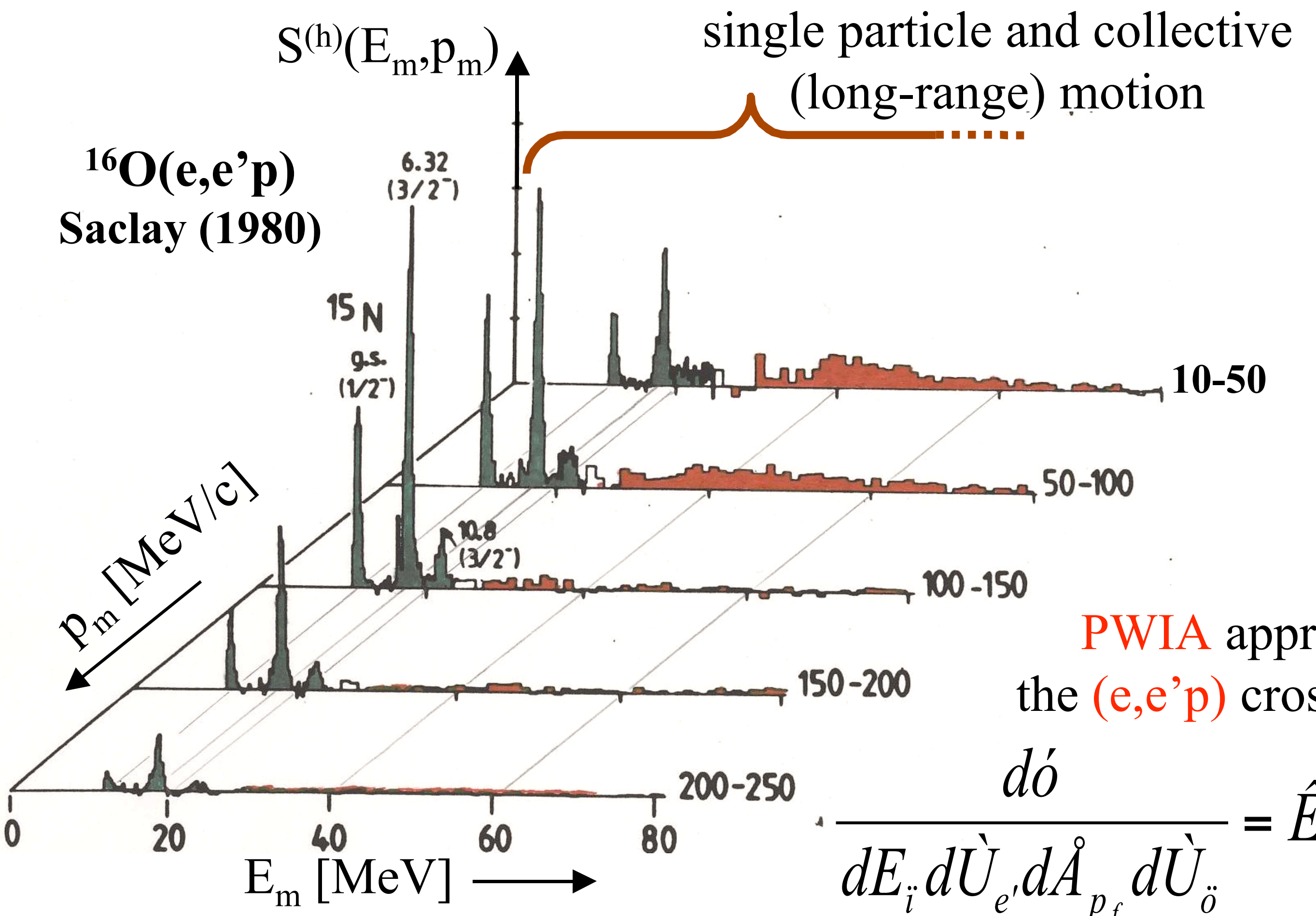
$$Z_n \equiv \int d^3k \, |\psi_n^{(h)}(k)|^2$$

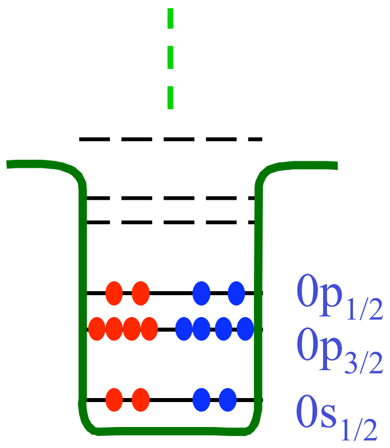
- One-hole spectral function

$$S^{(h)}(k,\omega) = \sum_n \left| \langle \Psi_n^{A-1} | c_{\vec{k}} | \Psi_0^A \rangle \right|^2 \delta(\omega - (E_0^A - E_n^{A-1}))$$

→ Distribution of particles in momentum *and* energy

Example of one-hole spectral function (mean field region)

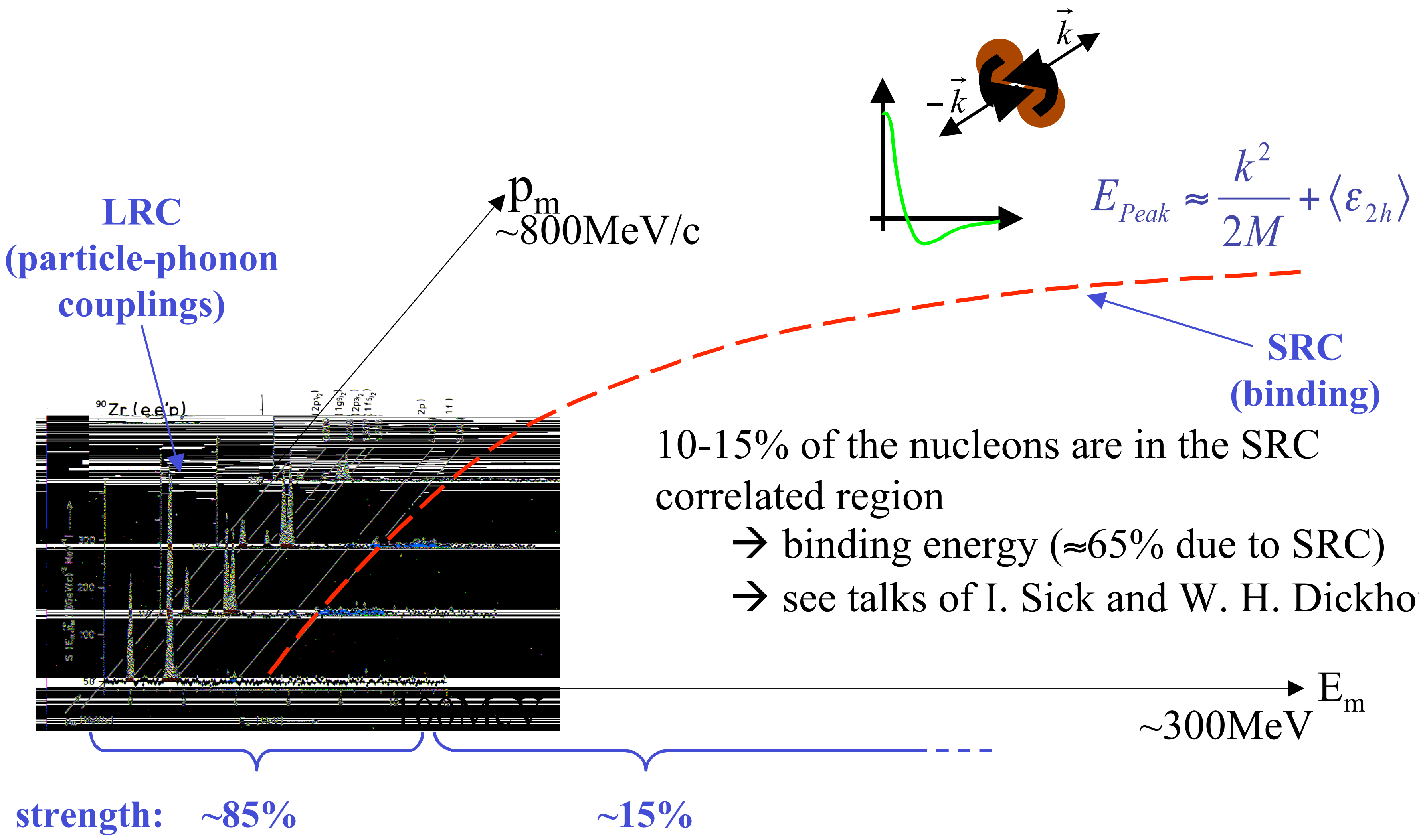




PWIA approximation of the (e,e'p) cross section:

$$\frac{d\sigma}{dE_{\nu}\, d\Omega_{e'}\, dE_{p_f}\, d\Omega_{\varphi}} = K\sigma_{ep}^{cc}\, S^{(h)}(p_m, E_m)\, T_{p_f}$$

Location of single-particle strength

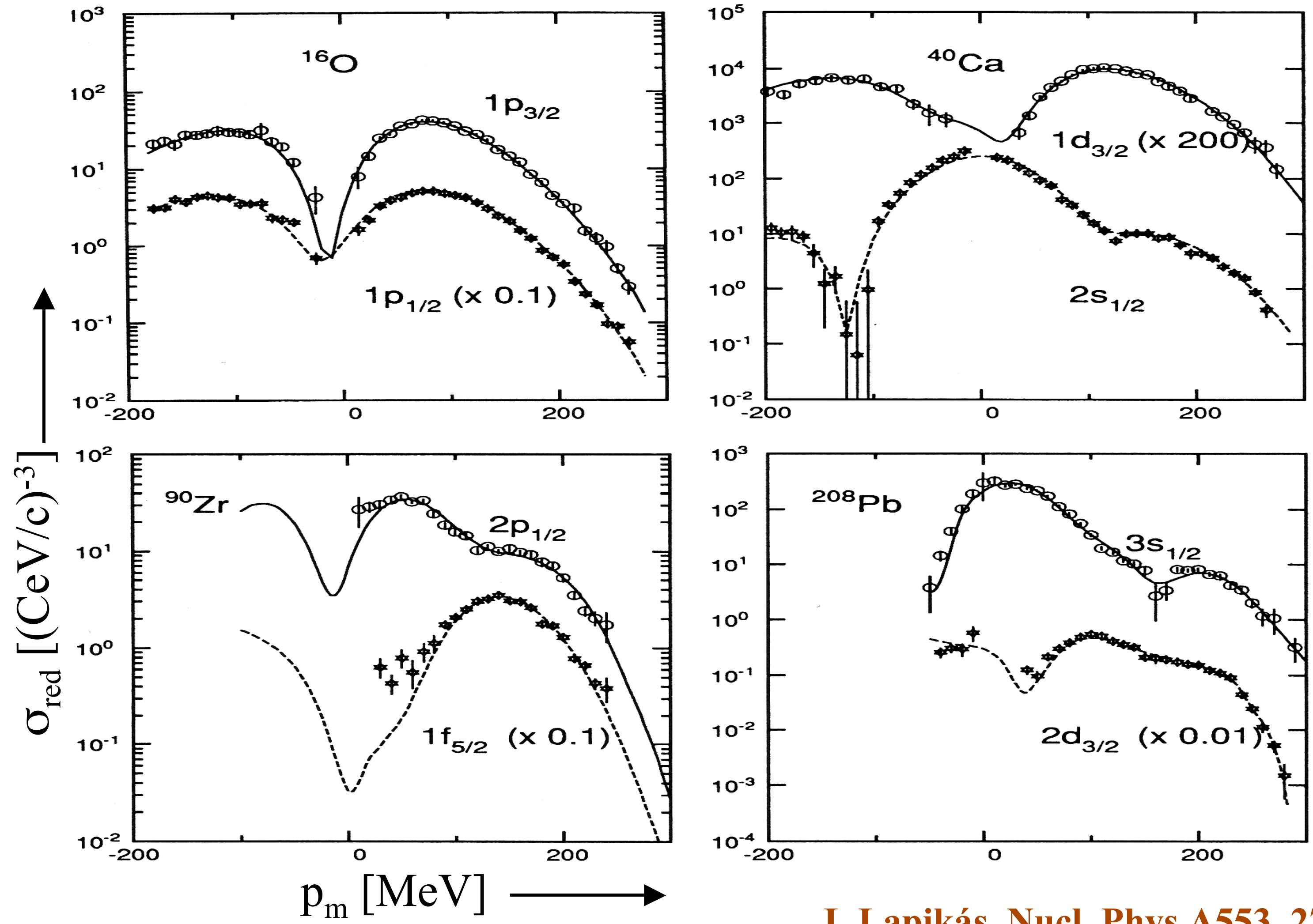


10-15% of the nucleons are in the SRC correlated region

→ binding energy (≈65% due to SRC)

→ see talks of I. Sick and W. H. Dickhoff

Single particle orbitals in nuclei (from (e,e'p) data)



L.Lapikás, Nucl. Phys A553, 273c (1993)

Spectroscopic factors near the Fermi energy

- Independent. part. Model (IMP):

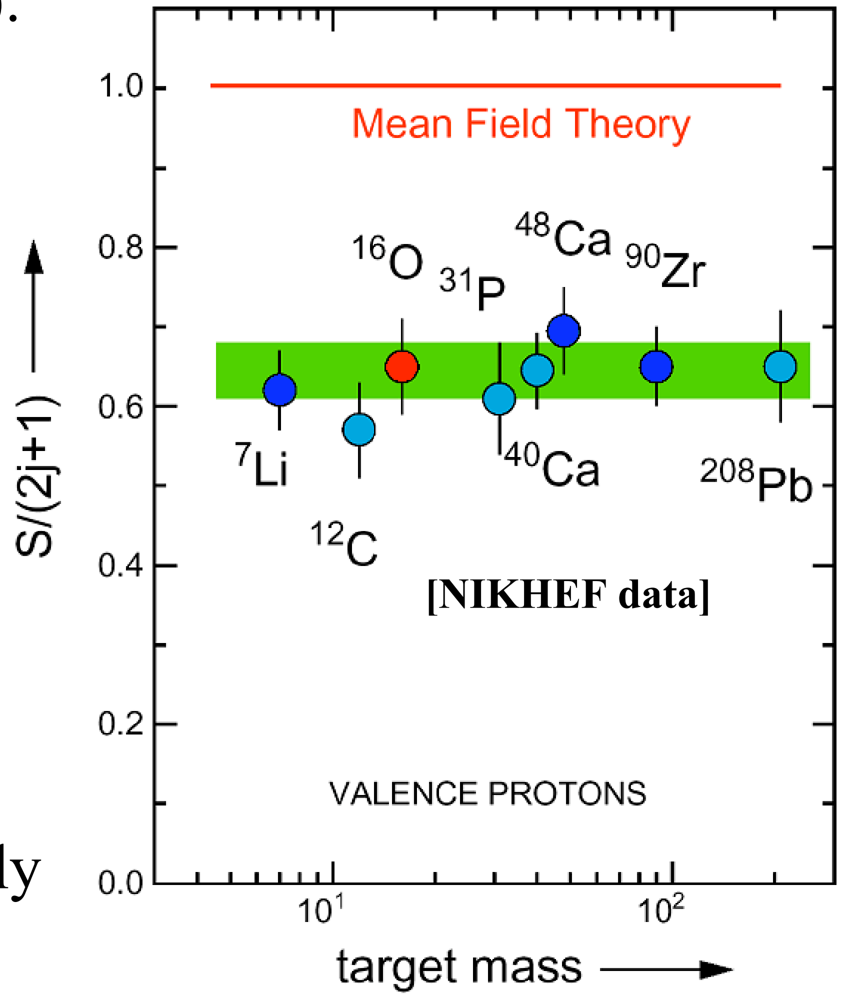
$$Z_n = 0 \ , \ 1$$

- Experiment:

$$Z_n \approx 0.65$$

→ both short- and long-range correlations!

- Theory (VMC, shell model, SCGF…) can explain some of these results BUT ^{16}O is not fully understood.



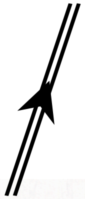
One-body Green's function

- $$g_{\alpha\beta}(\omega) = \sum_n \frac{\langle \Psi_0^A | c_\alpha | \Psi_n^{A+1} \rangle \langle \Psi_n^{A+1} | c_\beta^+ | \Psi_0^A \rangle}{\omega - (E_n^{A+1} - E_0^A) + i\eta}$$
$$+ \sum_k \frac{\langle \Psi_0^A | c_\beta^+ | \Psi_k^{A-1} \rangle \langle \Psi_k^{A-1} | c_\alpha | \Psi_0^A \rangle}{\omega - (E_0^A - E_k^{A-1}) - i\eta}$$

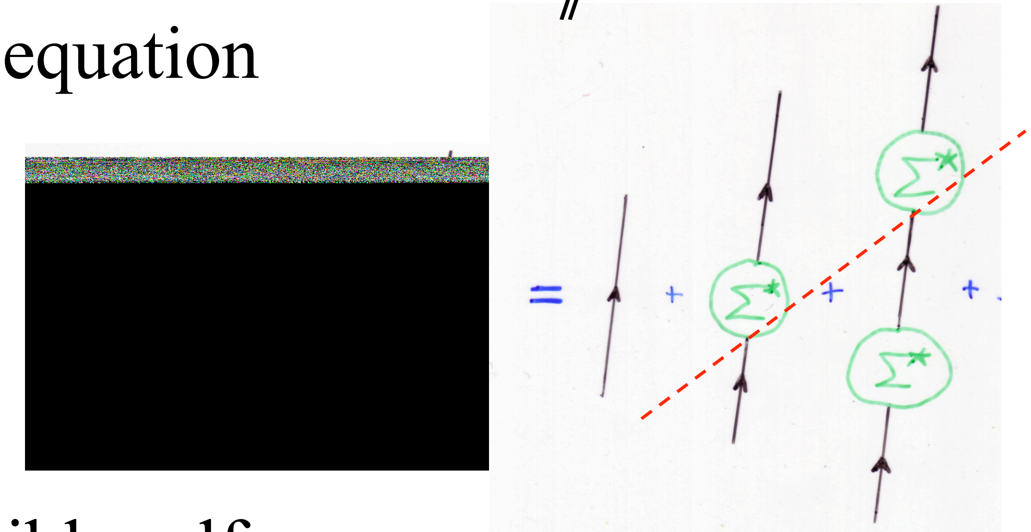
  forwardgoing part (A+1 nucleons): quasiparticles

  backwardgoing part(A-1nucleons): quasiholes

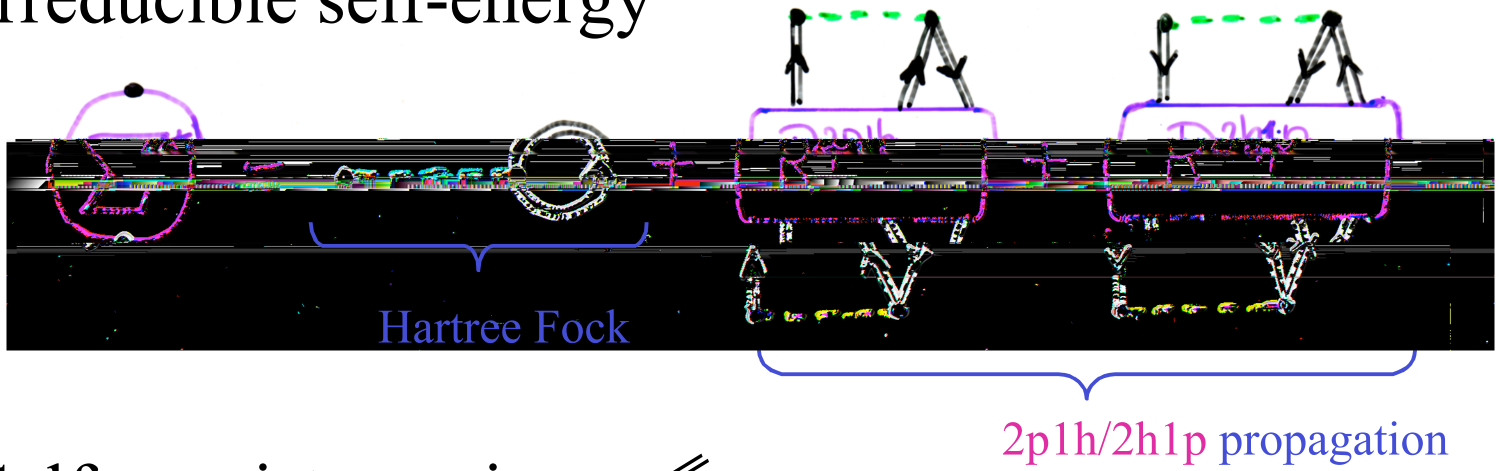
- Spectral function $$S_\alpha(\omega) = \frac{1}{\pi} \operatorname{Im} g_{\alpha\alpha}(\omega)$$

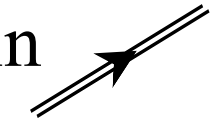
Evaluation of $g(\omega)=$ 

- Dyson equation



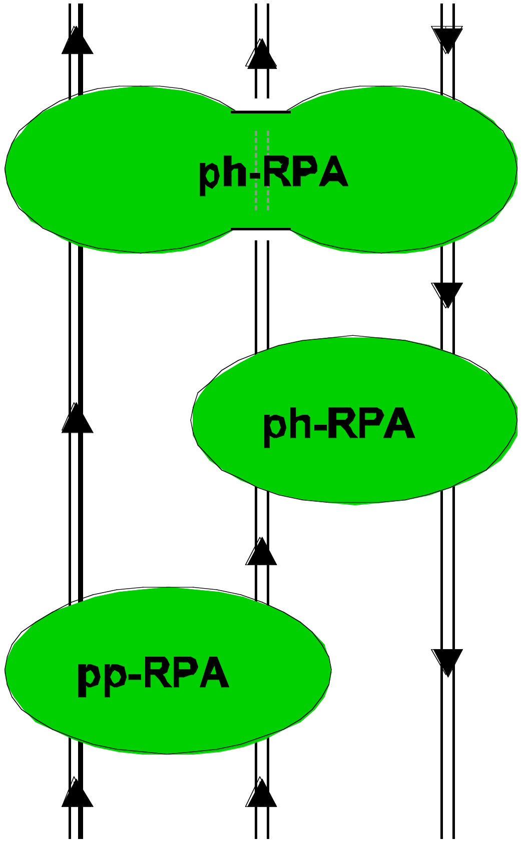
- Irreducible self-energy



- Self-consistency in 

Coupling of single-particle to collective ph and 2p(2h) phonons

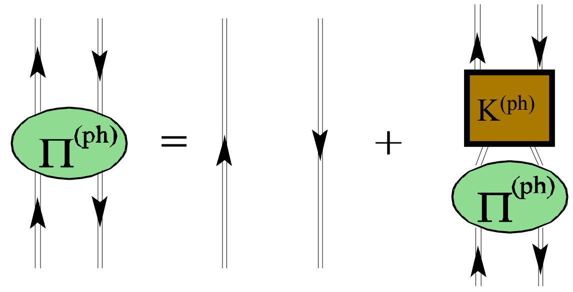
[Barbieri, Dickhoff, PRC63, 034313 (2001)]



- Need of an all order summation in terms of Faddeev equations
- Phonon in RPA approx. (and beyond: BSE)
- Pauli contributions (up to 2p1h/h1p)

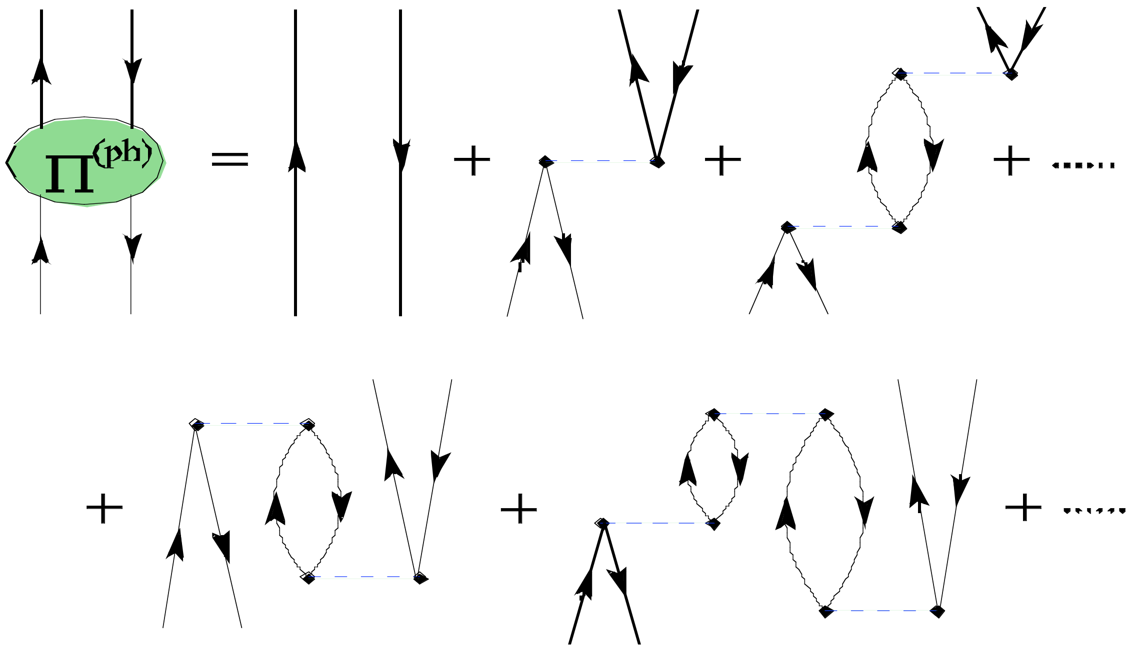
Collective phonons

- ph propagator:

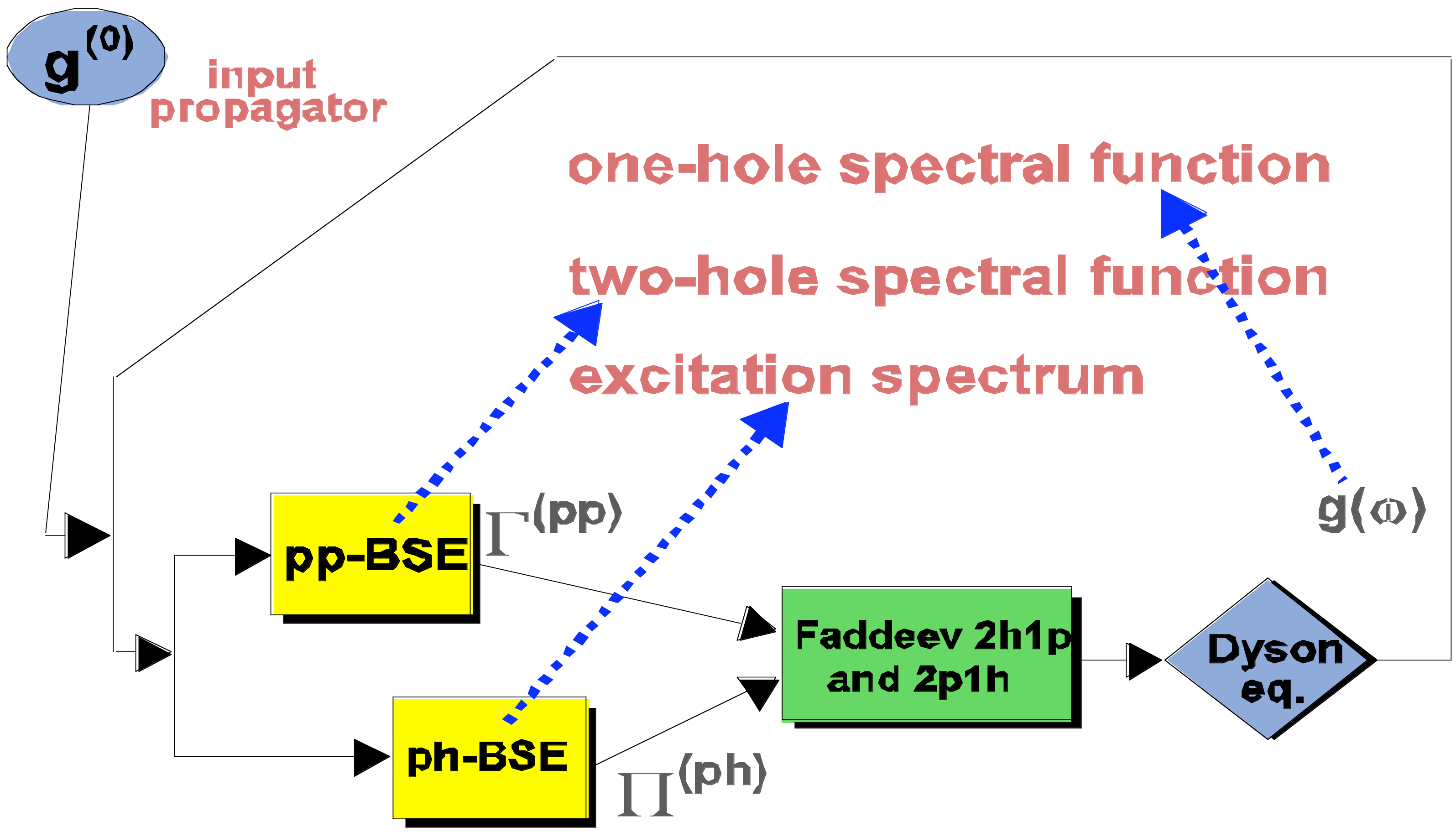


(Bethe-Salpeter Equation)

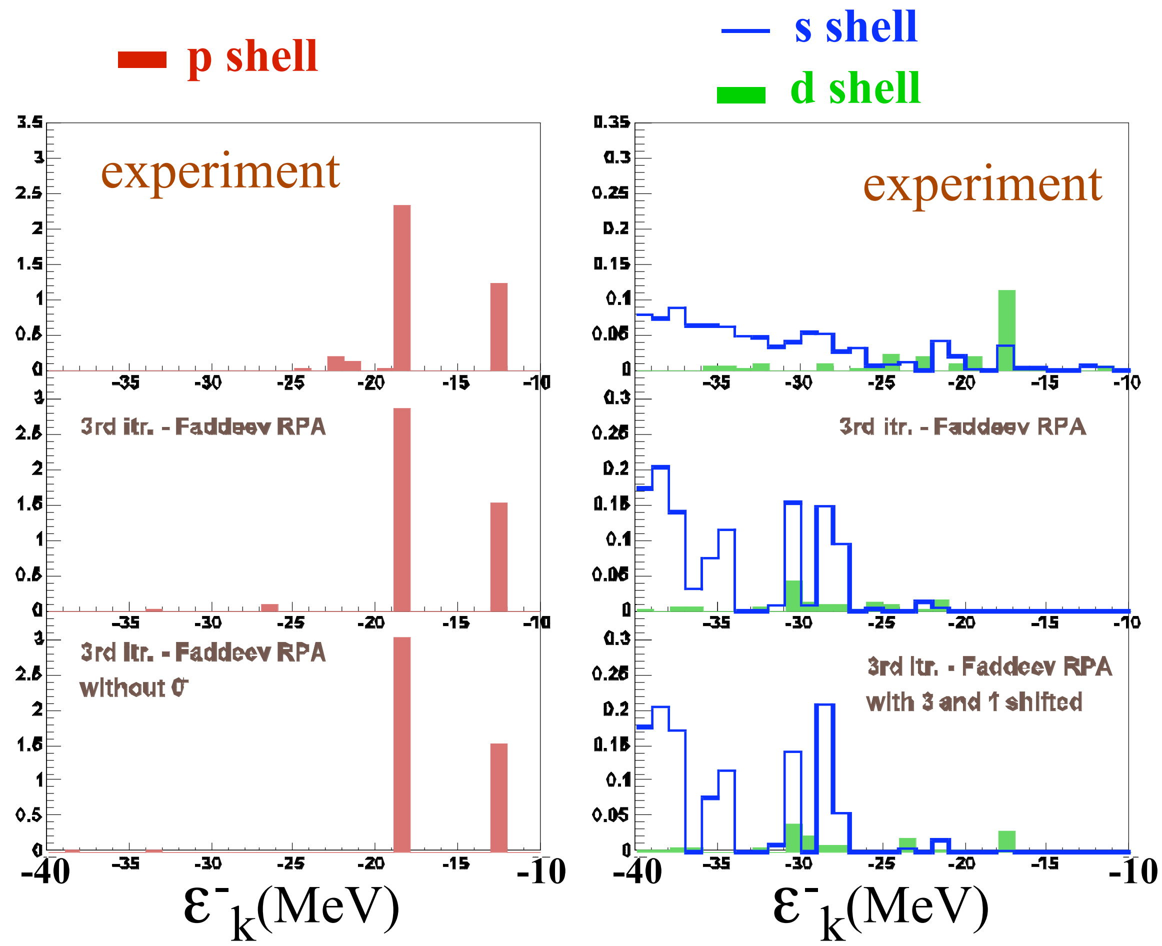
- RPA approximation



Self-consistent Green's function approach (SCGF)



One-hole spectral function for ^{16}O

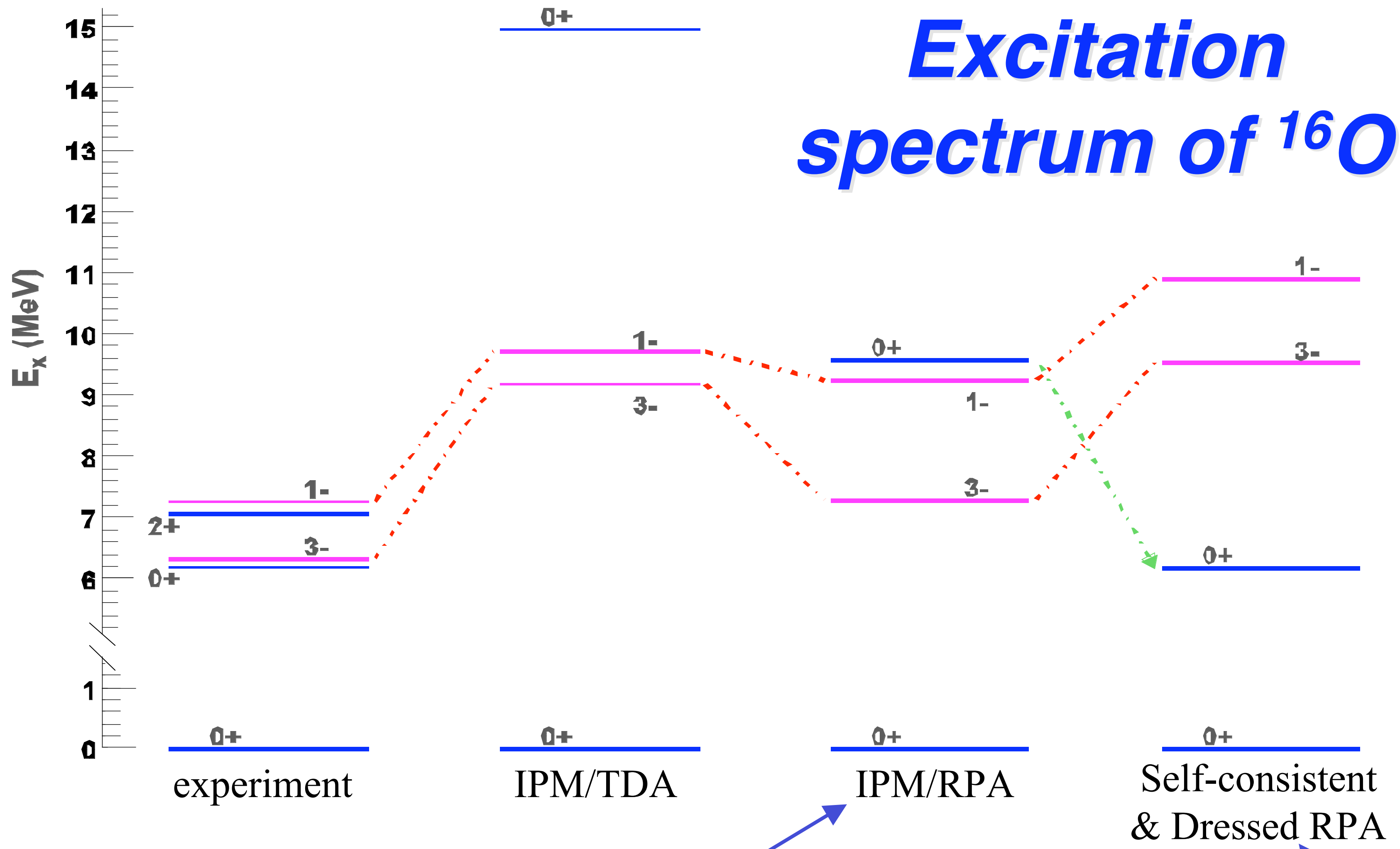


Experiment from NIKHEF, Leuschner et. al., PRC59, 655 (94)

- Results from Faddeev expansion and SCGF

Barbieri et. al., PRC65, 064313 (2002)

Excitation spectrum of ^{16}O



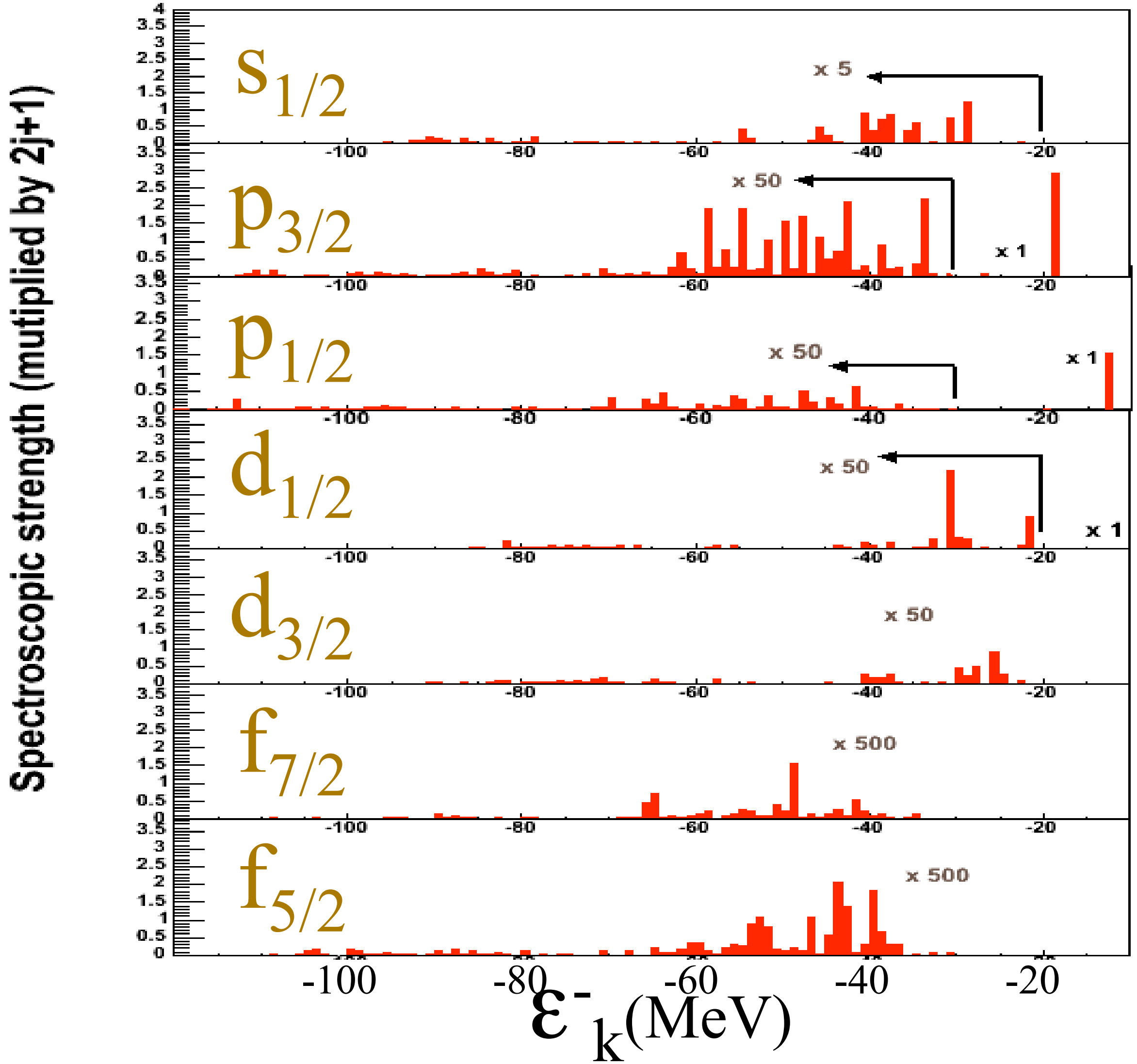
$d_{5/2}$ and $s_{1/2}$ fragments at E_m~15MeV

$(3^-) - (p_{1/2}) \rightarrow (d_{5/2})^{-1}$

break up of $p_{3/2}$ hole fragment

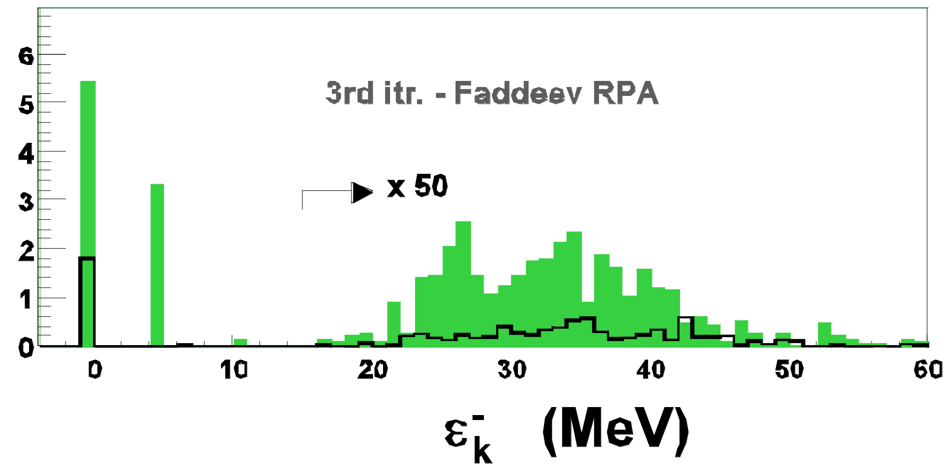
$(0_2^+) - (p_{3/2}) \rightarrow (p_{3/2})^{-1}$

Hole spectral function for ^{16}O (at high E_m)



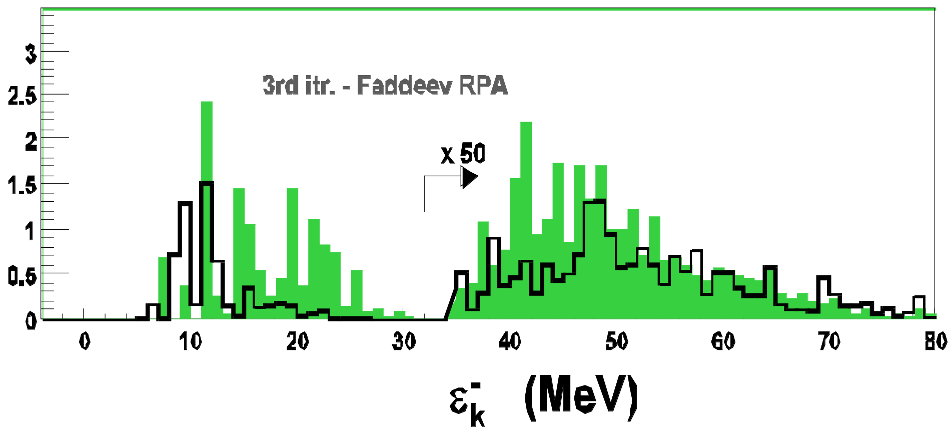
Barbieri, Dickhoff, PRC65, 064313 (2002)

One-particle spectral function for ^{16}O



$S_d(\varepsilon^-_k)$

$S_{s1/2}(\varepsilon^-_k)$



$S_f(\varepsilon^-_k)$

$S_p(\varepsilon^-_k)$

Barbieri, Ph.D. thesis, 2002

Quasihole fragments in ^{16}O
(spectroscopic factors)

	$Z_{p1/2}$	$Z_{p3/2}$	
• Experiment	**0.63**	**0.67**	**±0.05** exp. uncertainty
• Short-range oriented methods			
VMC [Argonne, '94]	**0.90**		
GF(SRC) [St.Louis-Tübingen '95]	**0.91**	**0.89**	
FHNC/SOC [Pisa '00]	**0.90**		
• Including particle-phonon couplings			
GF(Faddeev) [St.Louis '01]	**0.77**	**0.72**	

• → relevance of collective motion

Center of mass correction to the spectroscopic factors

$$\psi^{(h)}(\vec{r}) = \langle \Psi_n^{A-1} \,|\, \delta(\vec{r} - \vec{r}_A) \,|\, \Psi_0^A \rangle$$

- Spurious motion of the c.o.m.

$$\psi^{(\mathrm{exp.})}(\vec{r}) = \langle \Psi_n^{A-1} \,|\, \delta[\vec{r} - (\vec{r}_A - \vec{R}_{A-1})] \,|\, \Psi_0^A \rangle$$

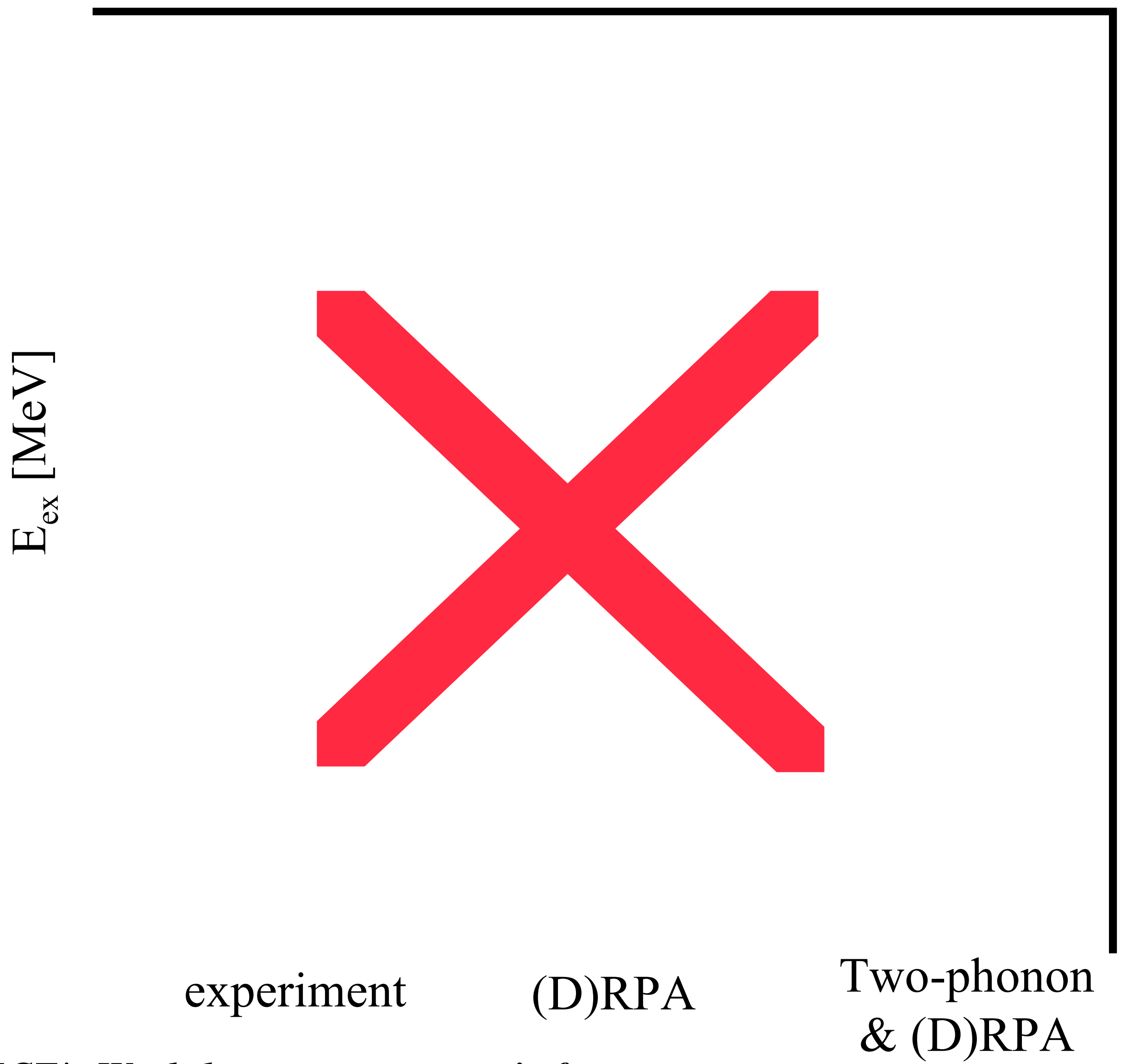
- For the p-shell orbitals:

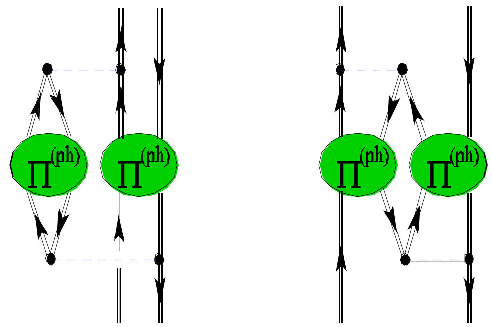
$$Z^{(\mathrm{exp.})} = \frac{A}{A-1} Z^{(h)}$$

Still unexplained!

- For ^{16}O : $1.0 \; + \; \underset{\text{c.o.m}}{0.08} \; - \; \underset{\text{SRC}}{0.10} \; - \; \underset{\text{2p1h/2h1p}}{0.15} \; - \; 0.18 \; \approx \; \underset{\text{experiment}}{0.65}$

Coupling of two-phonons in ^{16}O





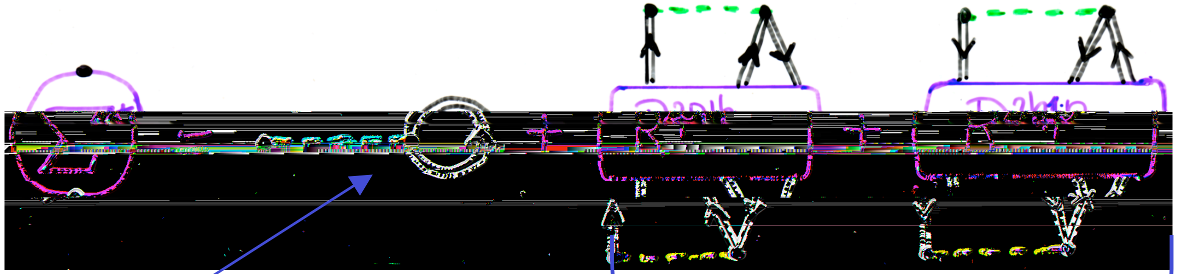
Barbieri, Dickhoff, PRC68, 014311 (2003)

Need to do better:

- pp(hh) interactions
- 4-phonon states
  [Feshbach & Iachello ('73)]

N-A scattering at low energies

•The irreducible self-energy is a nucleon-nucleus optical potential [see eg. Mahaux and Sartor, Adv. Nucl. Phys. 20, (1991)]



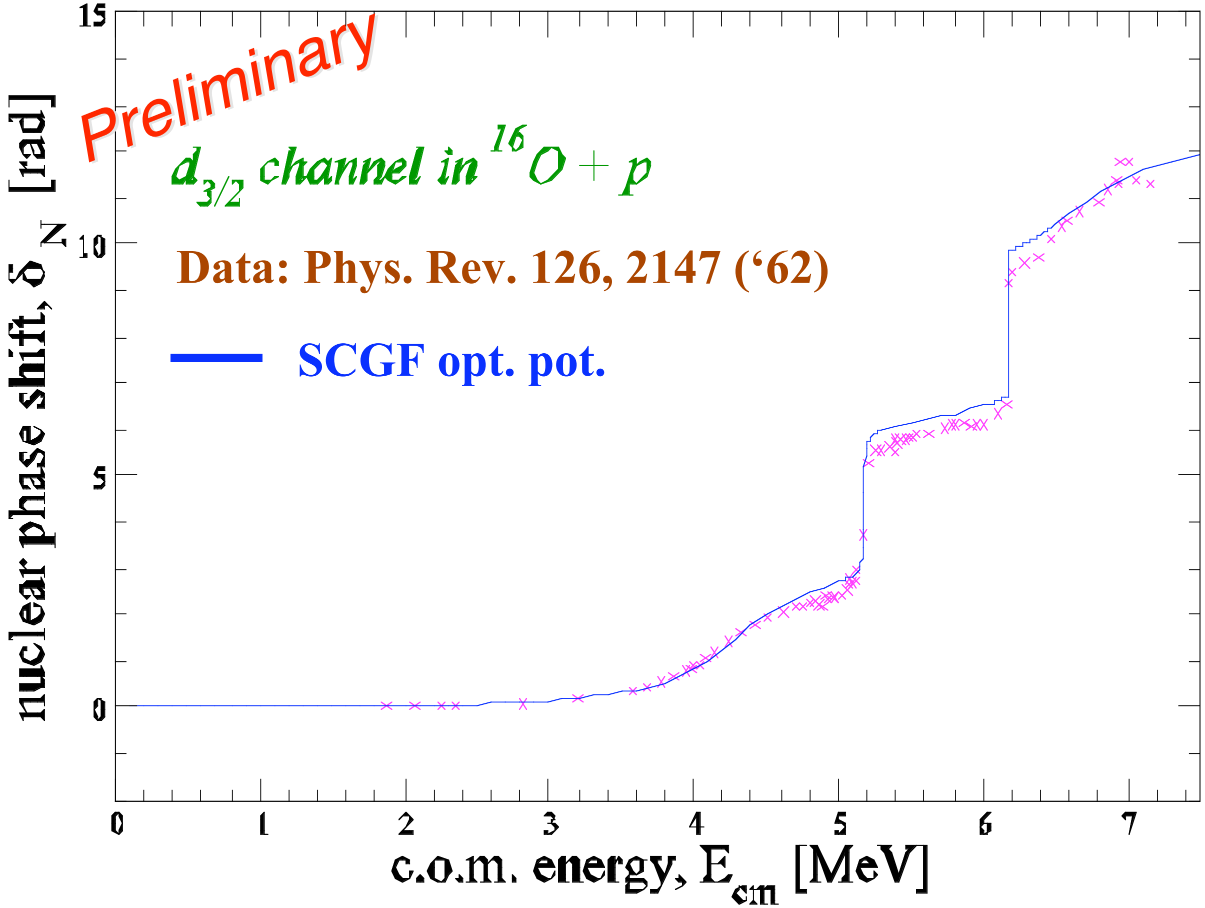
mean field

core polarization, ect.

•Scattering problem (Dyson eq.)

$$-\frac{\hbar^2\nabla^2}{2m} z^{k-}_{\mathbf{r}m} + \sum_{m_1}\int d^3r_1\; \Sigma'^{*}_{\mathbf{r}m\;\mathbf{r}_1m_1}(\varepsilon_k)\, z^{k-}_{\mathbf{r}_1m_1} = \varepsilon_k^-\, z^{k-}_{\mathbf{r}m},$$

N-A phase shifts at low energy (on going work)

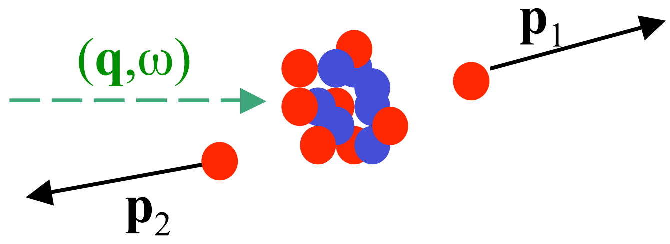


- Encouraging results for the $d_{3/2}$ channel
- More work needed for other phase shifts
- Possible study of ANC (in the future…)

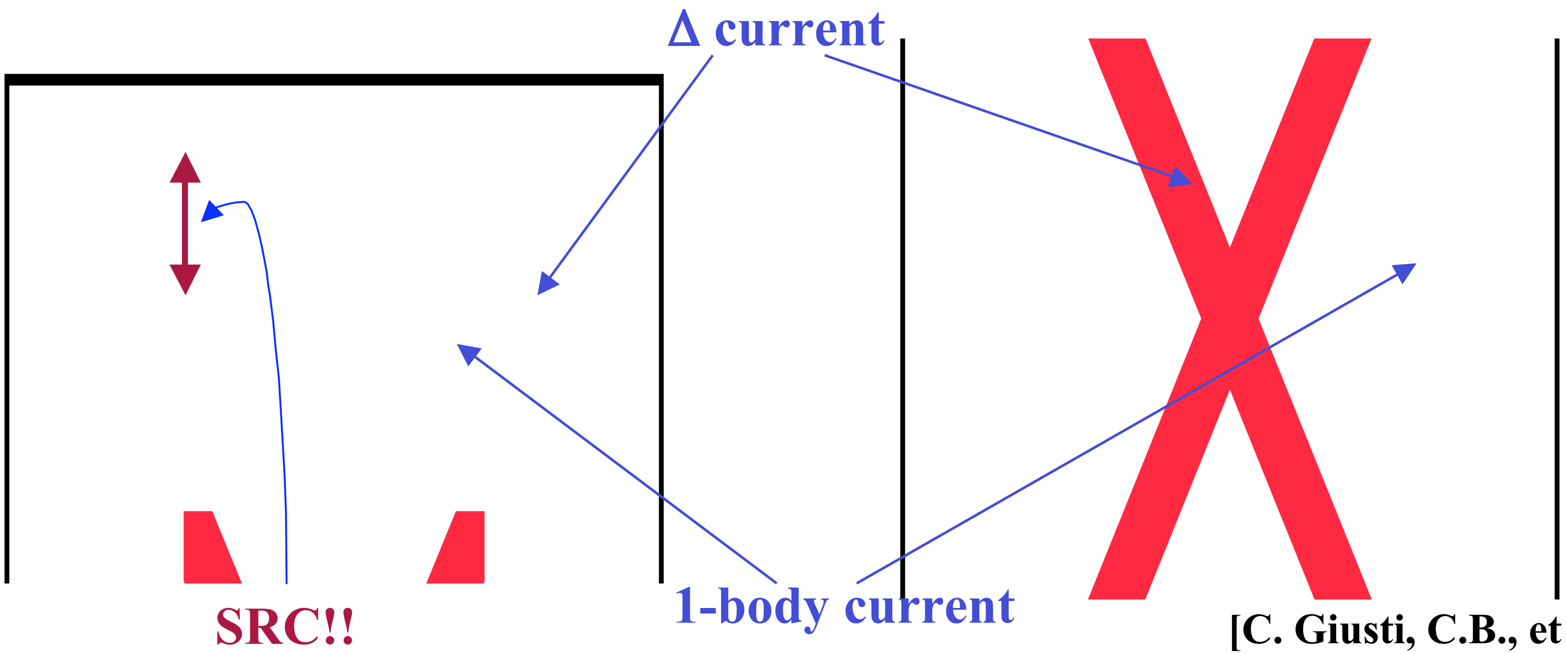
Correlations form two-proton knock out

- ***$^{16}O(e,e'pN)^{14}C$***

- Pavia model for FSI and spectral function from SCGF

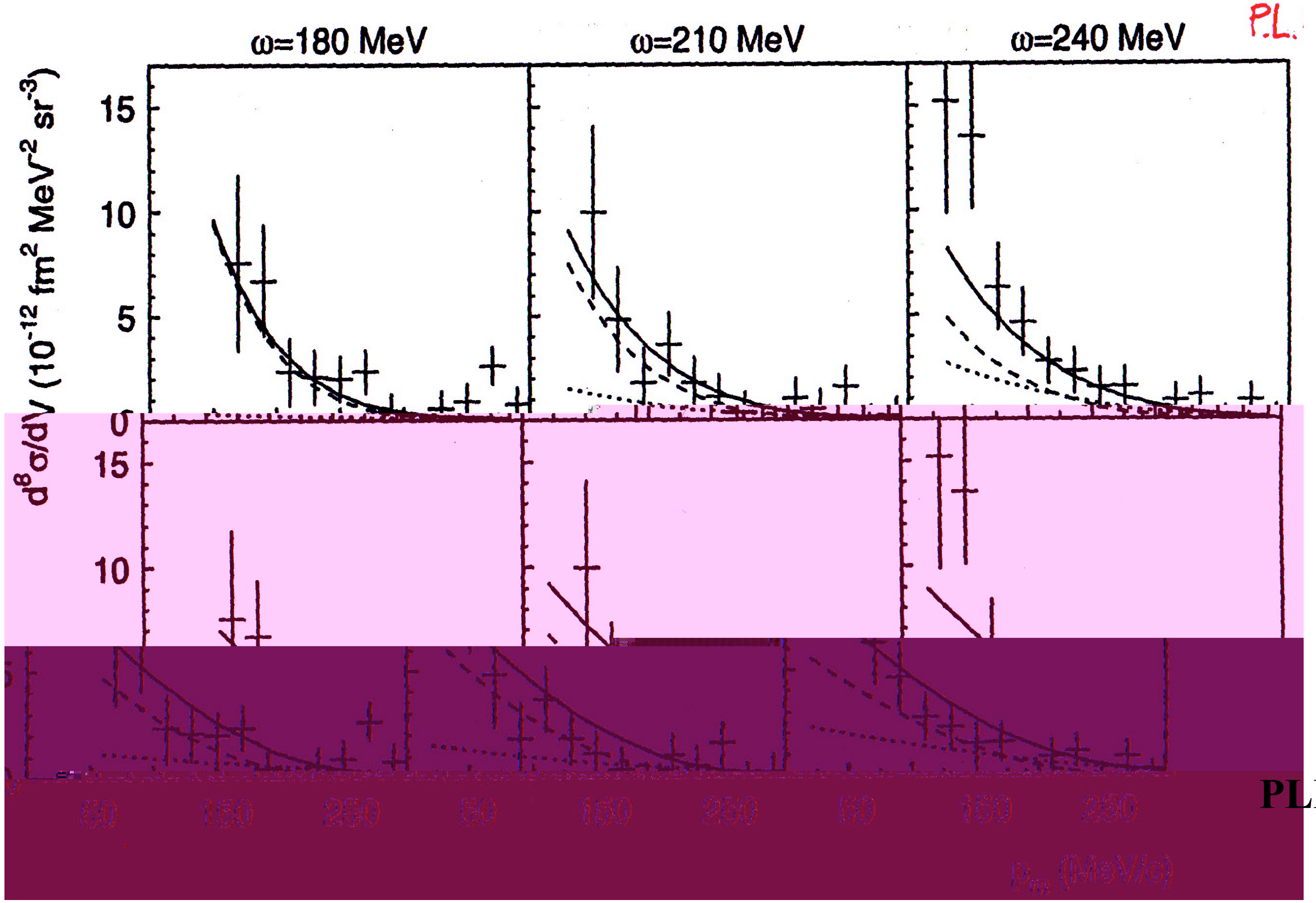


- $\mathbf{p}_B \equiv \mathbf{q} - \mathbf{p}_1 - \mathbf{p}_2$



[C. Giusti, C.B., et al., nucl-th/0402081]

Comparison to ^{16}O (e,e´pp)^{14}C experiment – *signatures of SRC*



PAVIA

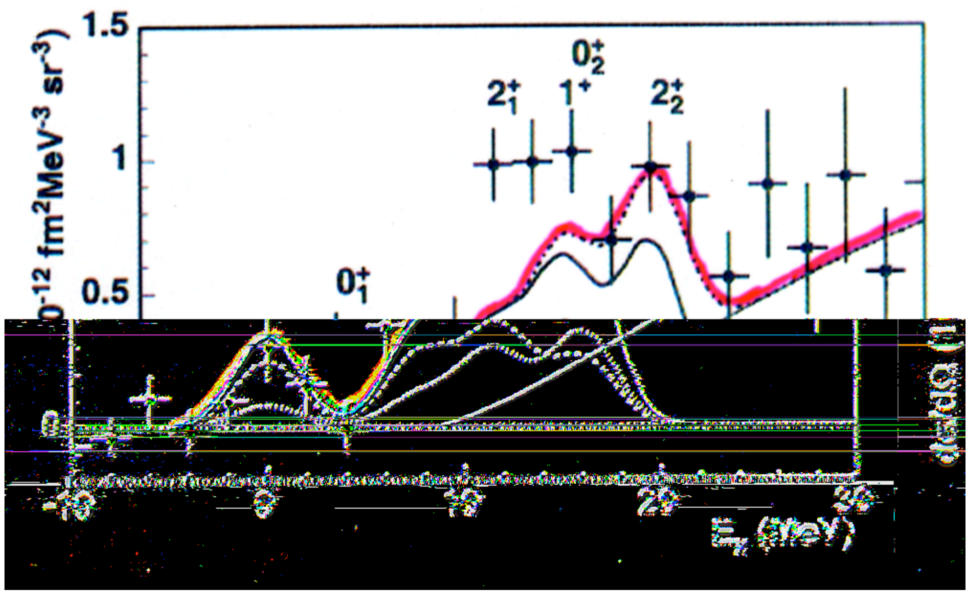
GENT

PLB474,33(2000)

Ambiguity: more to be done

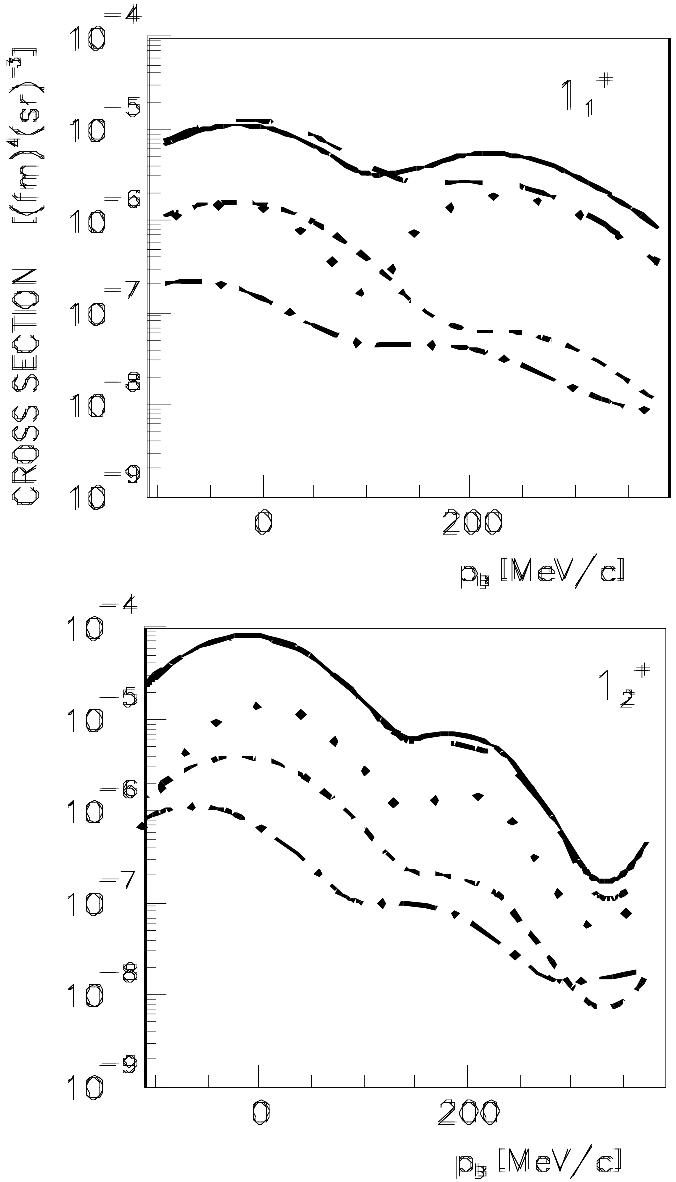
Comparison to ^{16}O (e,e´pp)^{14}C experiment – *signatures of SRC*

- Pavia model + NIKHEF data



PRL 81, 2213 ('98)

Emission of a proton-neutron pair [$^{16}O(e,e'pn)^{14}N$]



- Role of **Δ** is predominant

  → tensor correlations

- Measurement from MAMI

[C. Giusti, C.B., et al., nucl-th/0402081]

Overview

- Short-range correlations explain only a 10% quenching of the spectroscopic factors close to the Fermi energy

- Further substantial reduction comes from coupling of single-particle motion to collective states
  - → importance of collective (long-range) correlations
  - → Faddeev approach to particle-phonon couplings
  - → multi-phonon contributions

- Application to nucleon-nucleus scattering at low energy

- Two-nucleon knock out

- More work need to be done for ^{16}O !!!

- Extension to other systems (future work)