Using a nonlocal dispersive-optical-model to generate ingredients for ν-A cross sections

Mack C. Atkinson

Washington University in St. Louis

ECT* 2019

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Bob Charity
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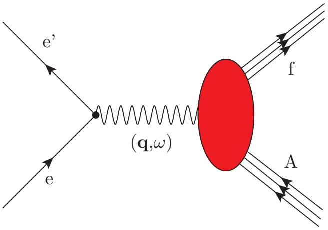
- Experimental data is used to constrain the DOM
- The $(e, e'p)$ reaction can be described using the DOM
- This can be extended to different leptonic probes
- In particular, a DOM analysis of ^{40}Ar (relevant for DUNE) is underway

Electron-Nucleus Scattering



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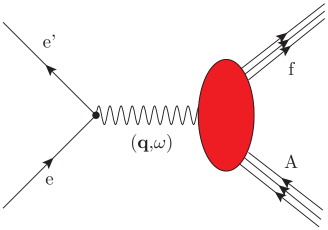

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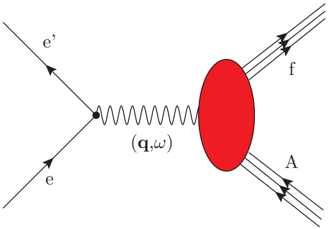

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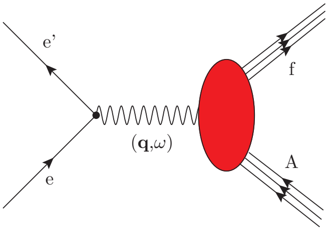

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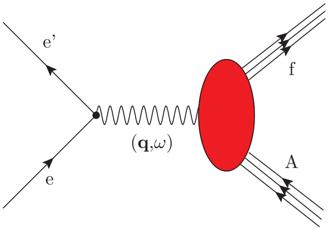

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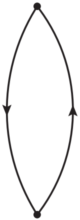

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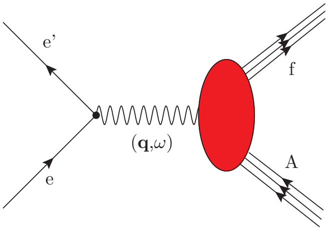

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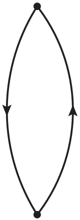
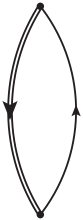


PWIA



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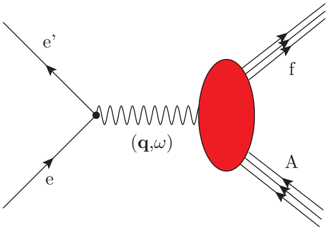

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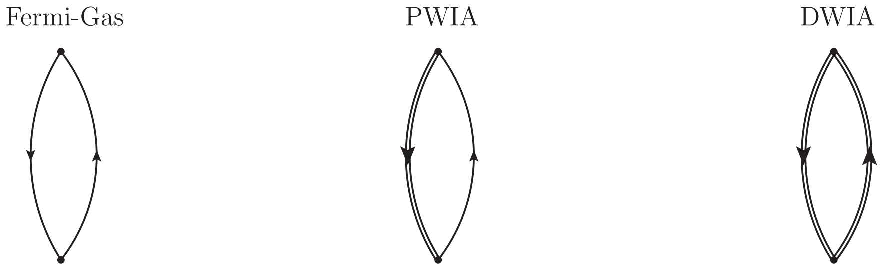

Single-Particle Propagator and the Dyson Equation

$$G_{\ell j}(r,r';E) = \sum_m \frac{\langle \Psi_0^A | a_{r\ell j} | \Psi_m^{A+1} \rangle \langle \Psi_m^{A+1} | a_{r'\ell j}^\dagger | \Psi_0^A \rangle}{E - (E_m^{A+1} - E_0^A) + i\eta} + \sum_n \frac{\langle \Psi_0^A | a_{r'\ell j}^\dagger | \Psi_n^{A-1} \rangle \langle \Psi_n^{A-1} | a_{r\ell j} | \Psi_0^A \rangle}{E - (E_0^A - E_n^{A-1}) - i\eta}$$

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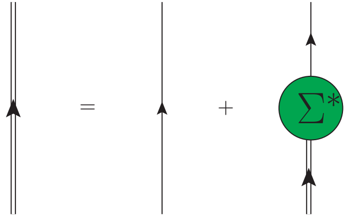

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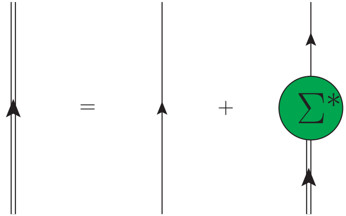
- Numerator like a transition probability to given excitation
- Close connection with experimental observables
- Perturbation expansion of G leads to the Dyson equation
- If the irreducible self-energy (Σ^*) is known, then so is G



Spectral function

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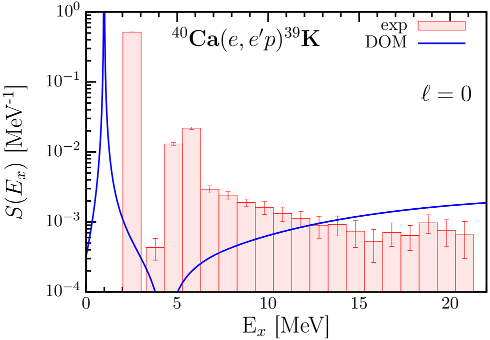

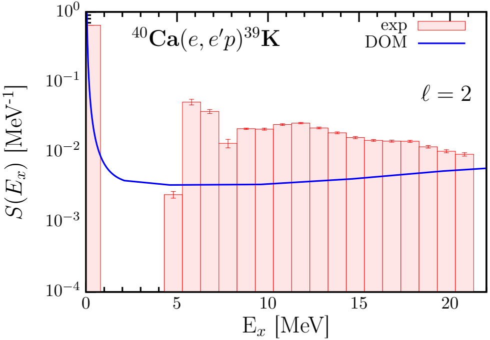

M. Atkinson *et al.*, PRC **98**, 044627 (2018)

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Dispersive Correction

$$Re\Sigma_{\ell j}(r, r'; E) = Re\Sigma_{\ell j}(r, r'; \epsilon_F) - \frac{1}{\pi}(\epsilon_F - E)\mathcal{P}\int_{\epsilon_T^+}^{\infty} dE' Im\Sigma_{\ell j}(r, r'; E')[\frac{1}{E - E'} - \frac{1}{\epsilon_F - E'}]$$
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- This constraint ensures bound and scattering quantities are simultaneously described

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- Parameters of self-energy varied to minimize χ^2

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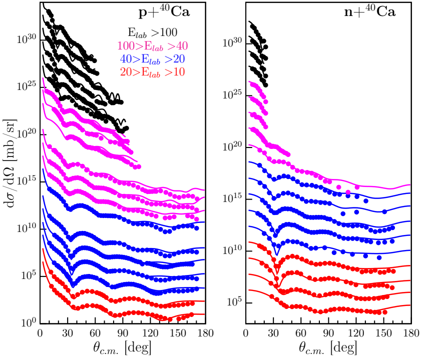

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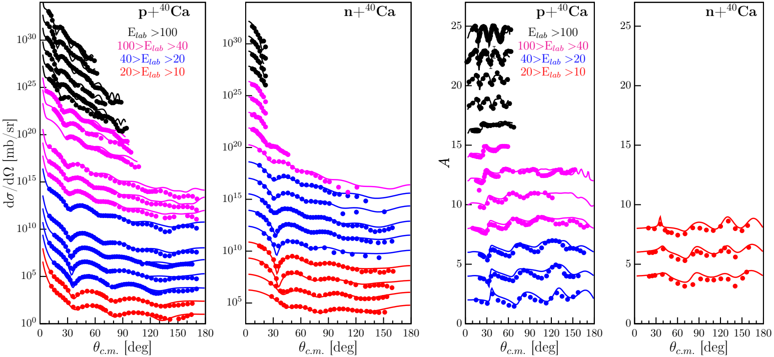

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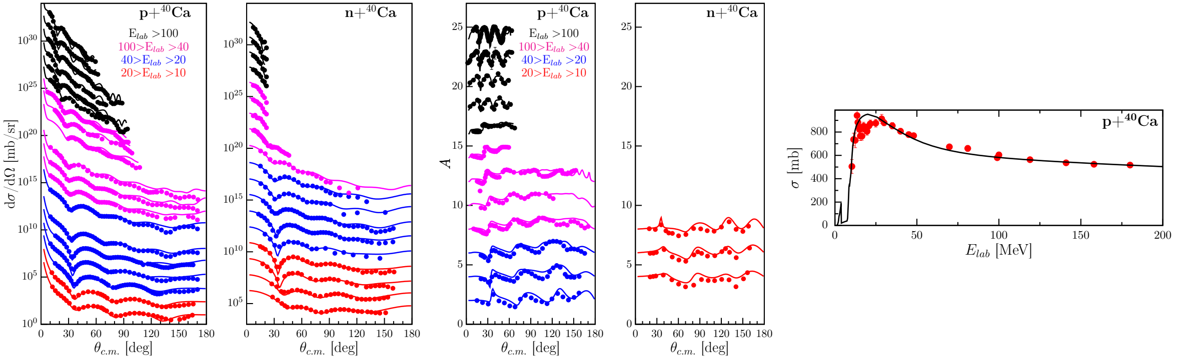

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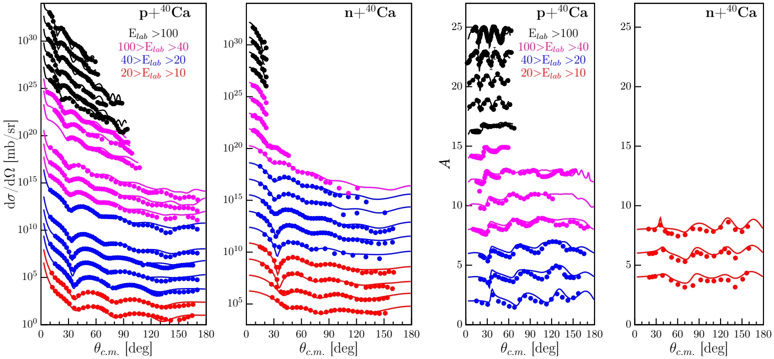

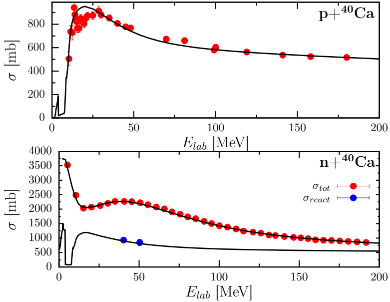

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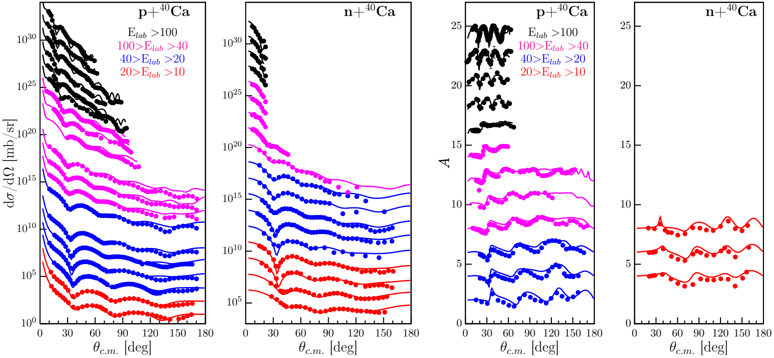

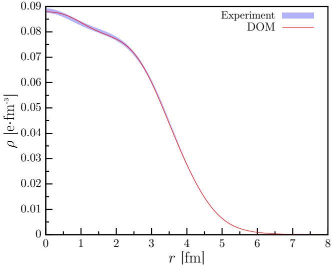

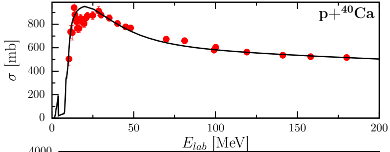

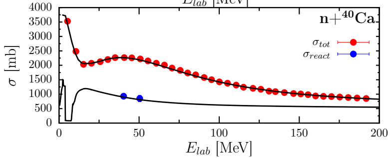

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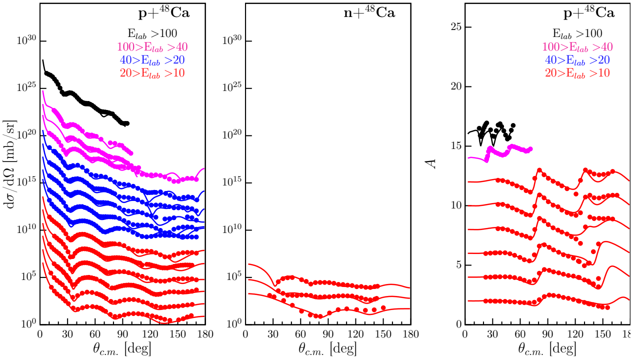

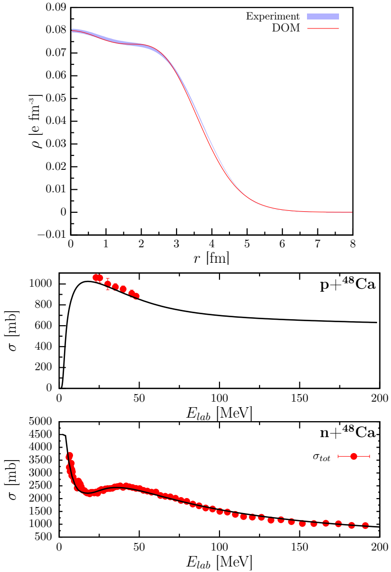

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Momentum Distributions

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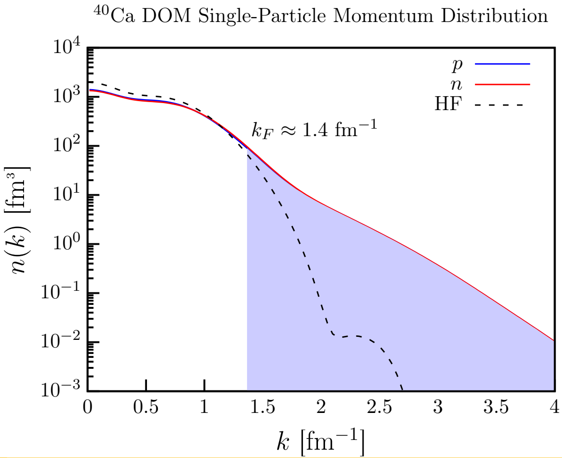

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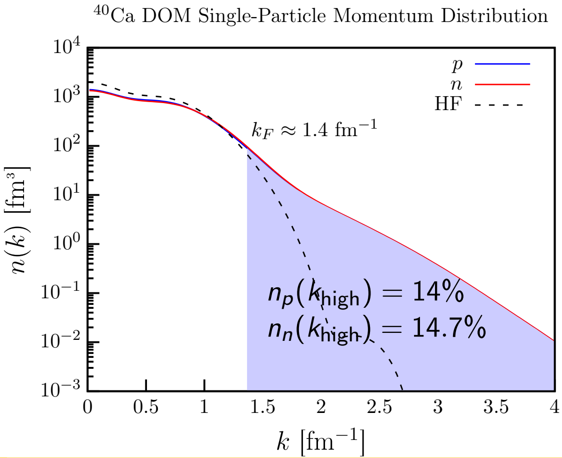

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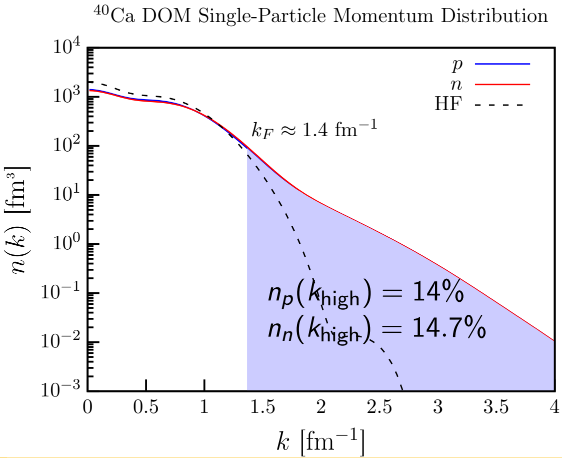

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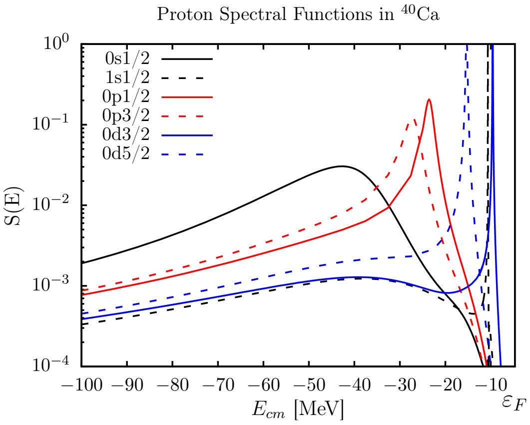

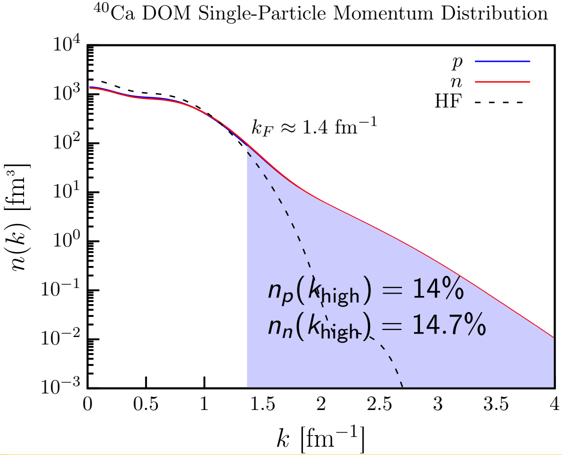

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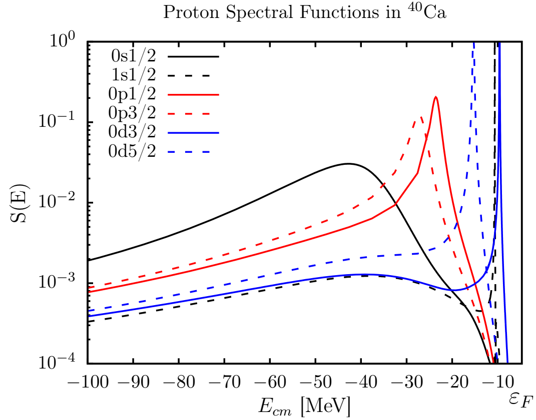

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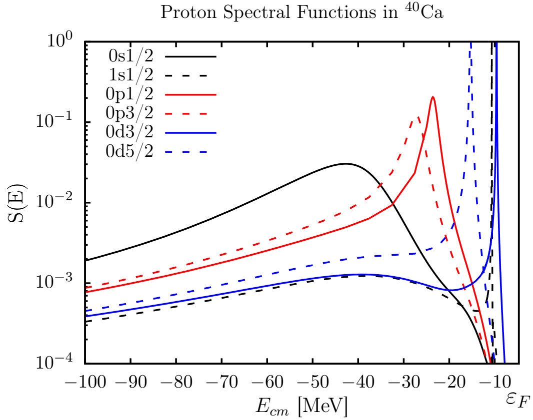

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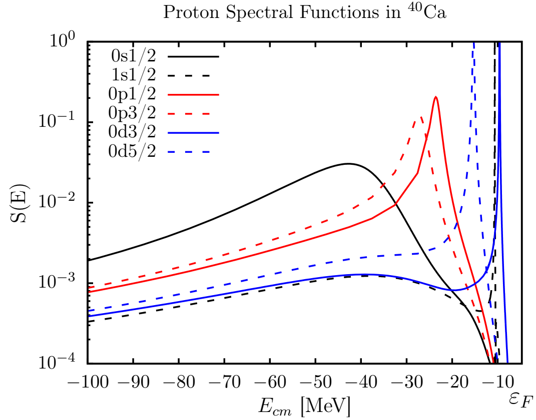

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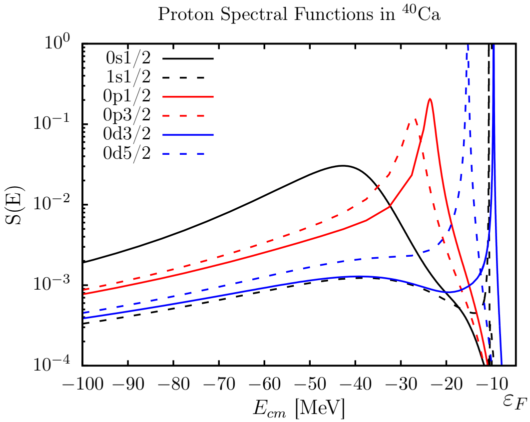
$$E_0^A = \frac{1}{2} \sum_{\alpha\beta} \left[T_{\beta\alpha}\rho_{\alpha\beta} + \delta_{\alpha\beta} \int_{-\infty}^{\epsilon_f^-} dEES_h(\alpha; E) \right]$$



Constraints for Spectral Function

$$S^h(\alpha,\beta;E) = \frac{1}{\pi} Im\{G(\alpha,\beta;E)\} \qquad S^h(E) = \sum_\alpha S(\alpha,\alpha;E)$$

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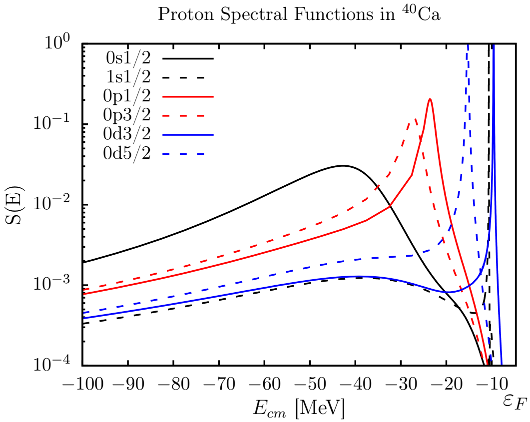
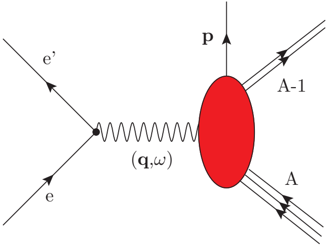
	N	Z	DOM E_0^A/A	Exp. E_0^A/A
^{40}Ca	19.9	19.8	-8.49	-8.55
^{48}Ca	27.9	19.9	-8.7	-8.66



DWIA for exclusive ^{40}Ca$(e, e'p)^{39}$K reaction



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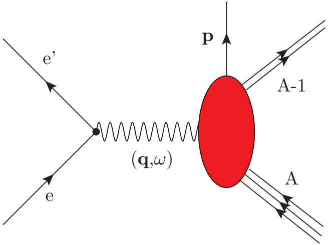

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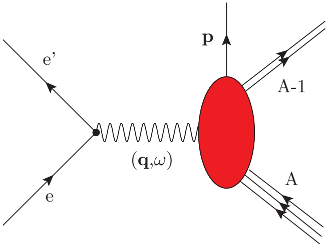

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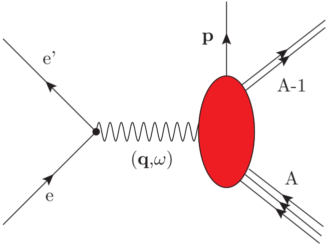

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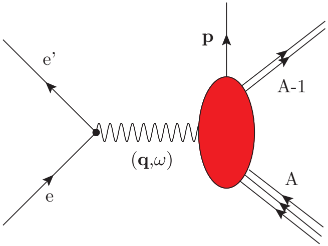

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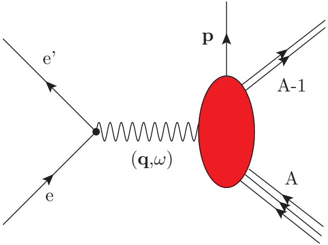

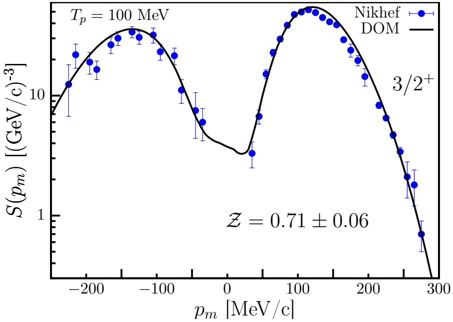

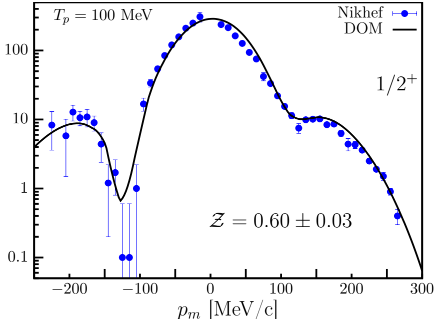

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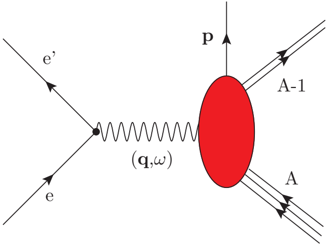

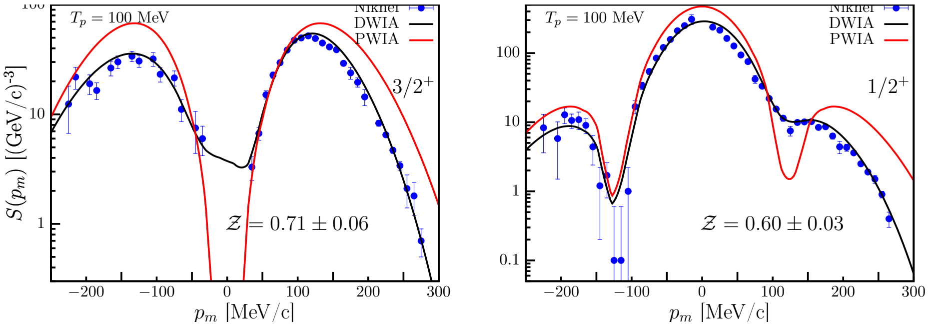

Spectroscopic factor, Occupation, and Depletion

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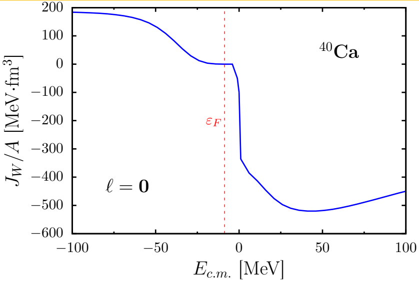

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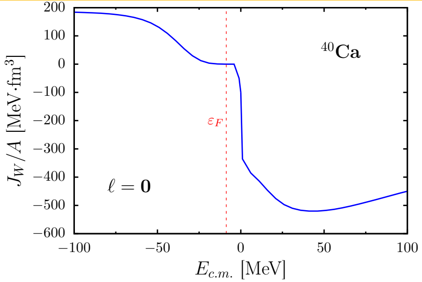

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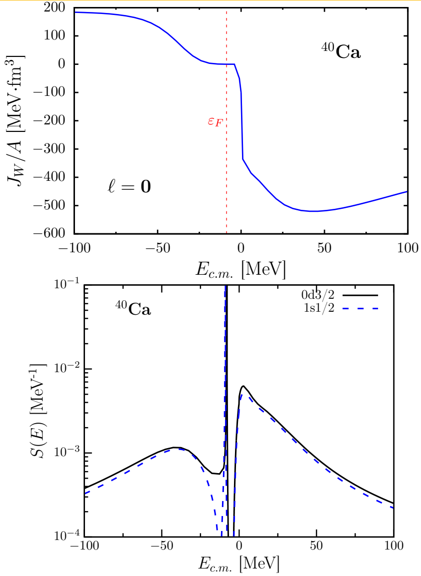

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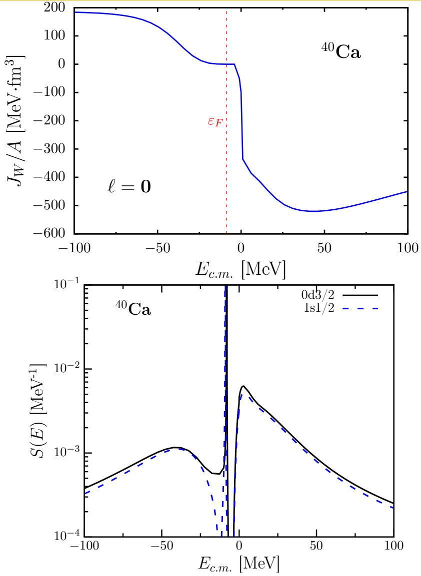

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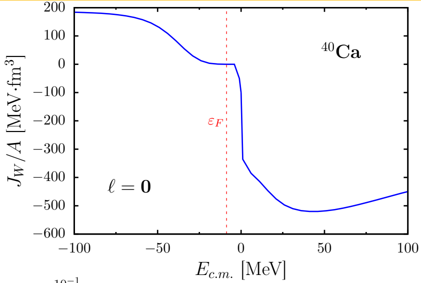
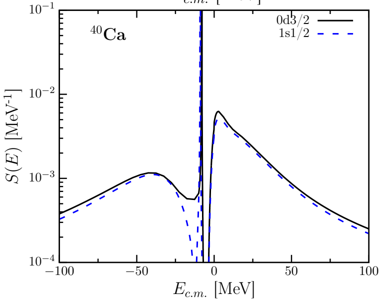
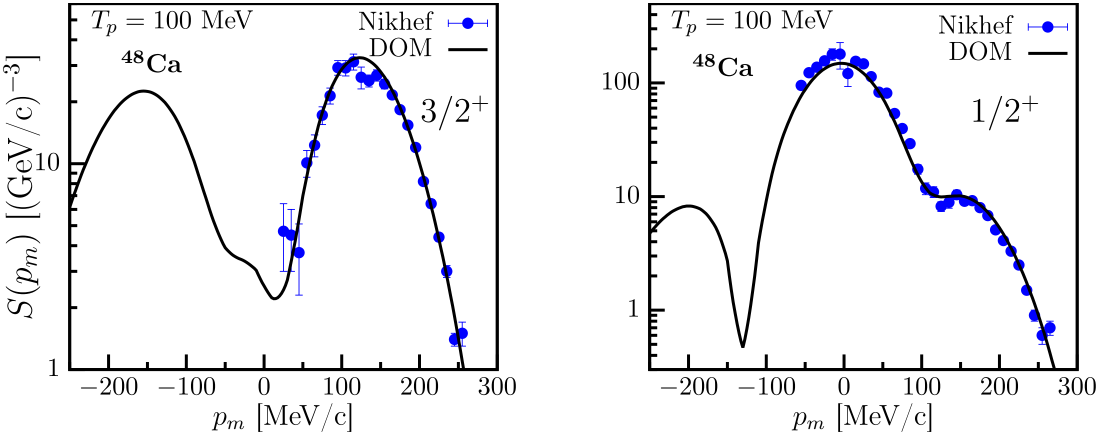
Orbital	$\mathcal{Z}$	$n_{n\ell j}$	$d_{n\ell j}$
$0d\frac{3}{2}$	0.71	0.80	0.17
$1s\frac{1}{2}$	0.60	0.82	0.15





^{48}Ca(e,e'p)^{47}K Momentum Distribution



Data: G. J. Kramer *et. al*, Nucl. Phys. A, **679**, 267 (2001)

Extending to inclusive cross section

- First implement PWIA
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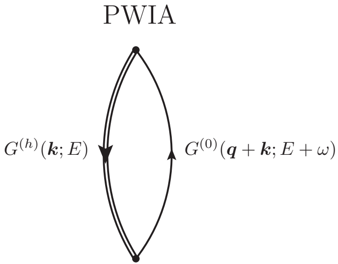

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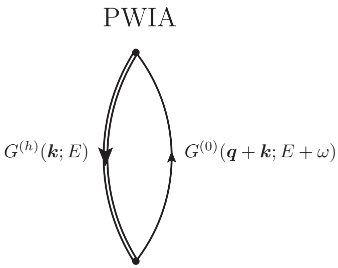
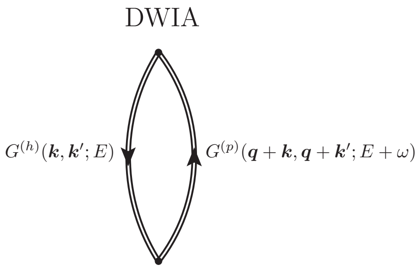
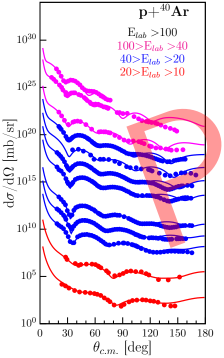




Preliminary Fit of ^{40}Ar



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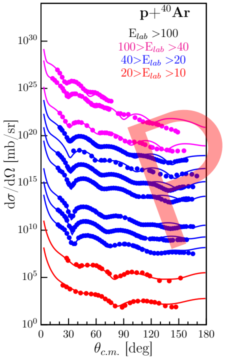

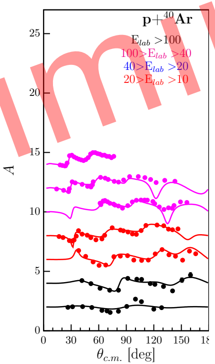

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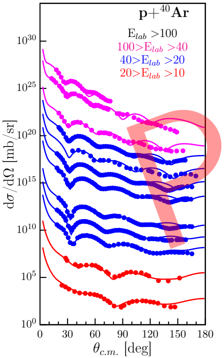

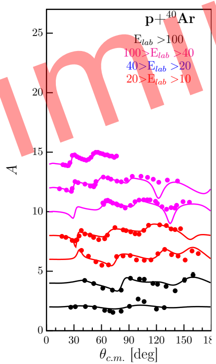

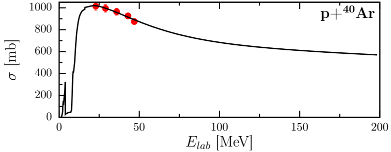

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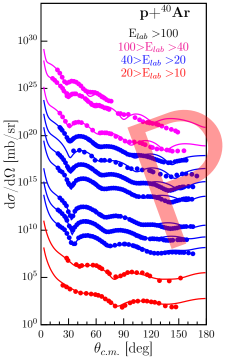
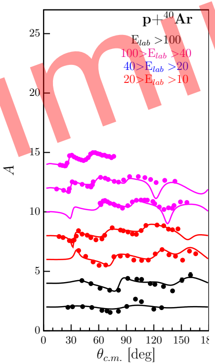
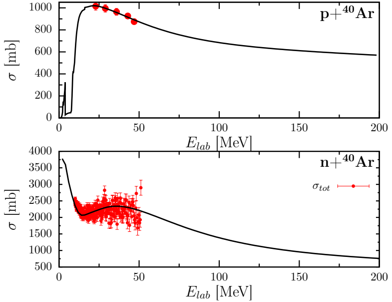
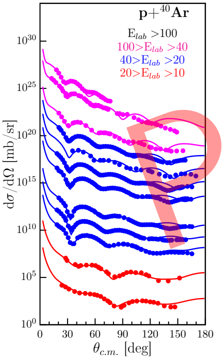
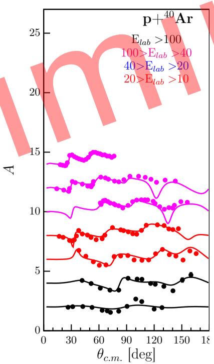








p+^{40}Ar
E$_{lab}$ >100
100>E$_{lab}$ >40
40>E$_{lab}$ >20
20>E$_{lab}$ >10
dσ/dΩ [mb/sr]
θ$_{c.m.}$ [deg]



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A
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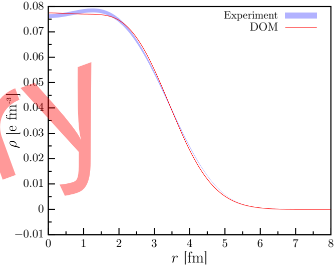
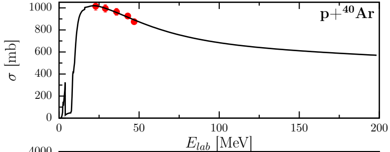
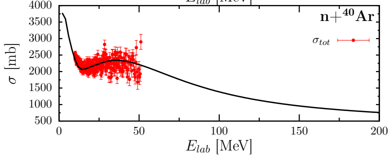


Experiment
DOM
ρ [e fm^{-3}]
r [fm]



p+^{40}Ar
σ [mb]
E$_{lab}$ [MeV]



n+^{40}Ar
σ$_{tot}$
σ [mb]
E$_{lab}$ [MeV]

Conclusions and Outlook

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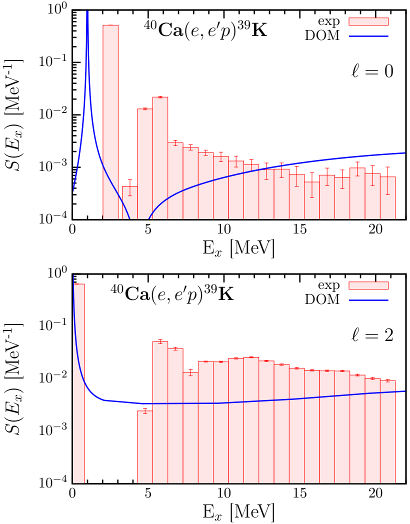
- Since this works for electrons, it should work for neutrinos
- DOM analysis of ^{40}Ar is underway

Thanks

- Willem Dickhoff - Advisor
- Robert Charity - DOM and data for DOM
- Henk Blok - $(e, e'p)$ data at Nikhef
- Louk Lapikás - $(e, e'p)$ data at Nikhef
- Carlotta Giusti - DWEEPY Code
- Hossein Mahzoon - DOM
- Lee Sobotka - Data for DOM

- "Smearing" of self-energy poles inflates $\mathcal{Z}$
- Renormalize with experimental excitation energy spectrum

$$\frac{\mathcal{Z}_F^{\text{DOM}}}{\int dE\ S^{\text{DOM}}(E)} = \frac{\mathcal{Z}_F^{\text{exp}}}{\int dE\ S^{\text{exp}}(E)}$$



M. Atkinson *et al.*, PRC **98**, 044627 (2018)