Polarization effects in knock-out reactions

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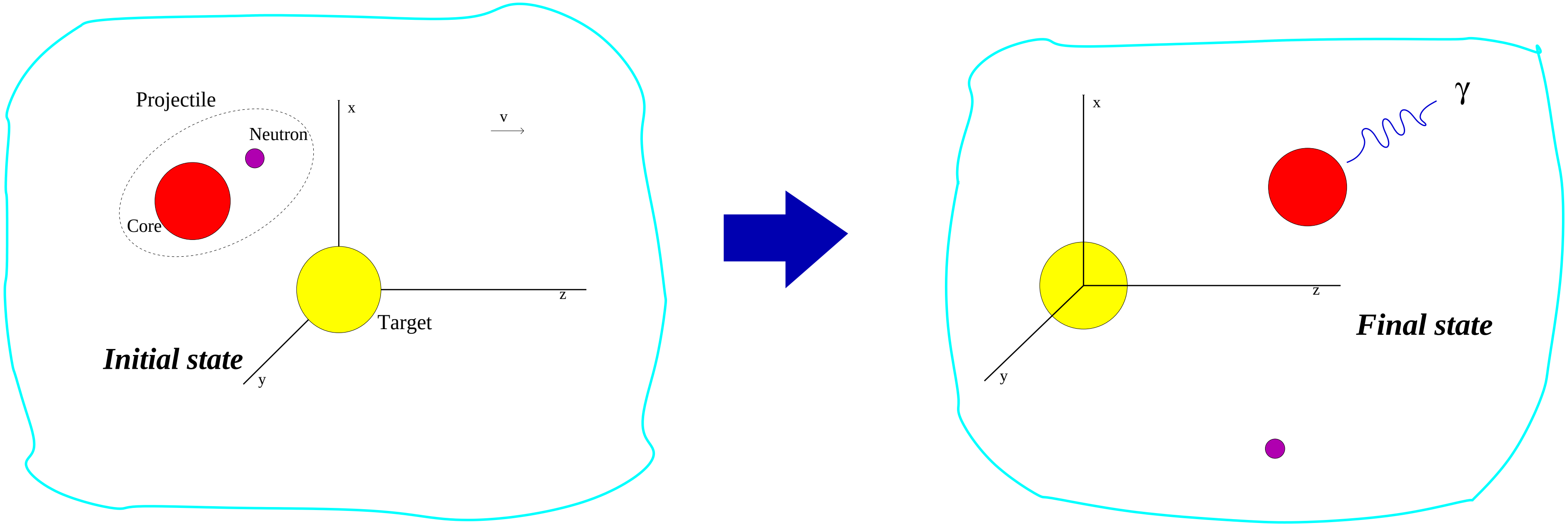
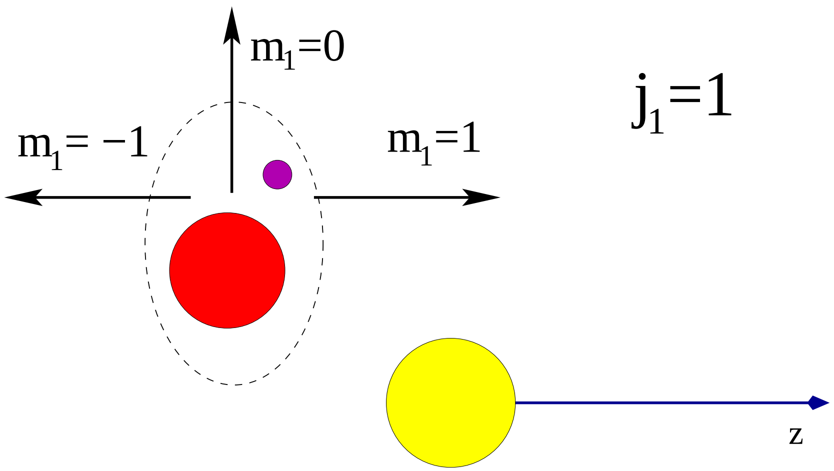
- Reactions
- Polarization
- Reaction model and interactions
- Analysing powers
- γ-ray angular distributions

Knockout reactions



What we mean by polarization



thus instead of

$$\sigma = \frac{1}{2j_1 + 1} \sum_{m_1} \ldots \qquad (1)$$

each of the terms will be considered.

Analysing powers in knockout reactions

$$\frac{\sigma_m}{\sigma} = (1 + \sum_{kq} t^m_{kq} T_{kq})$$

They can be related to the probability amplitude

$$R_{n_1 n'_1} = \int \sum A_{n_1} A^*_{n'_1} \tag{2}$$

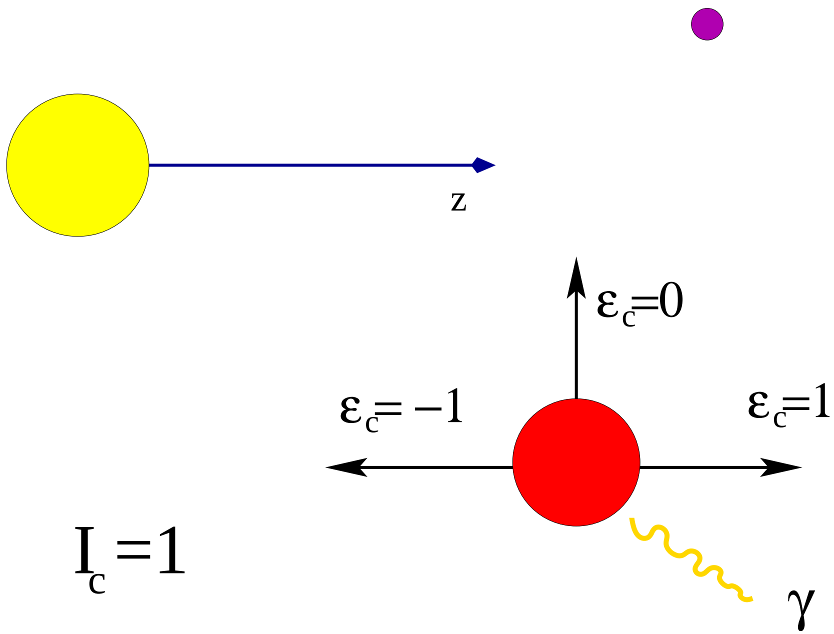
and since

$$N_{kq} = \sum_{n_1, n'_1} \widehat{k}(j_1 \; n_1 \; k \; q | j_1 \; n'_1) R_{n_1 n'_1}$$

and T_{kq} is just $T_{kq} = N_{kq}/N_{00}$.
For a spin-1 particles beam

$$\frac{\sigma_{\pm 1}}{\sigma} = (1 + \frac{T_{20}}{\sqrt{2}}) \; ; \; \frac{\sigma_0}{\sigma} = (1 - \sqrt{2} \; T_{20})$$

What we mean by polarization (II)



different populations of ϵ_c give rise to different γ-ray angular distributions.

Question

How sensitive are these calculations to

- reaction models?
- two-body interactions?

Amplitude in TC (A. Bonaccorso and D. M. Brink, Phys. Rev. **C38** (1988), 1776)

$$
\begin{aligned}
\frac{d\sigma}{dk_1} &= \frac{\hat{j}_1^3}{\hat{l}_1}(16\pi)^2 \frac{\hbar}{mvk_f} W(l_1, j_1, l_1, j_1, s, 0)(-1)^{j_1+l_1-s} \\
&\times \sum_{l_2} \frac{1-|S_{l_2}|^2 + |1-S_{l_2}|^2}{4} \sum_{m_1} |Y_{l_1 m_1}(\beta_1, \pi)|^2 \sum_{m_2} |Y_{l_2 m_2}(\beta_2, 0)|^2 \\
&\times \int |S_{ct}(b)|^2 |K_{m_1-m_2}(\eta b)|^2 \; b \; db \qquad (3)
\end{aligned}
$$

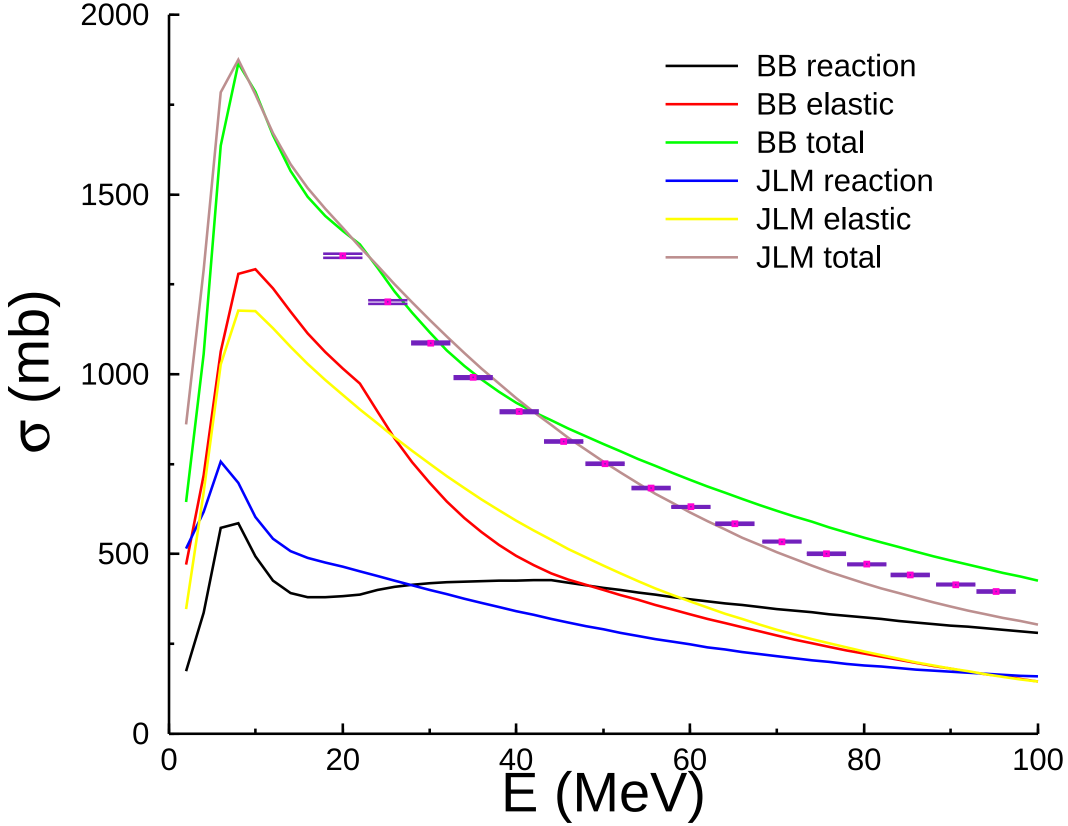
- $\beta_{1,2}$ and η depend on binding energies, beam velocity and masses,
- neutron-target spin-orbit force has been neglected,
- the Bessel function K is usually approximated in literature.

Two-body interactions: n-T

- JLM optical potential (Jeukenne, J.P. and Lejeune, A. and Mahaux, C., Phys. Rev. **C16** (1977), 80)
  - Reid's hard core n-n interaction in infinite nuclear matter
  - Folding by making a local density approximation

- BB parametrisation (A. Bonaccorso and G. Bertsch, Phys. Rev. **C63** (2001),044604)

Two-body interactions: n-T



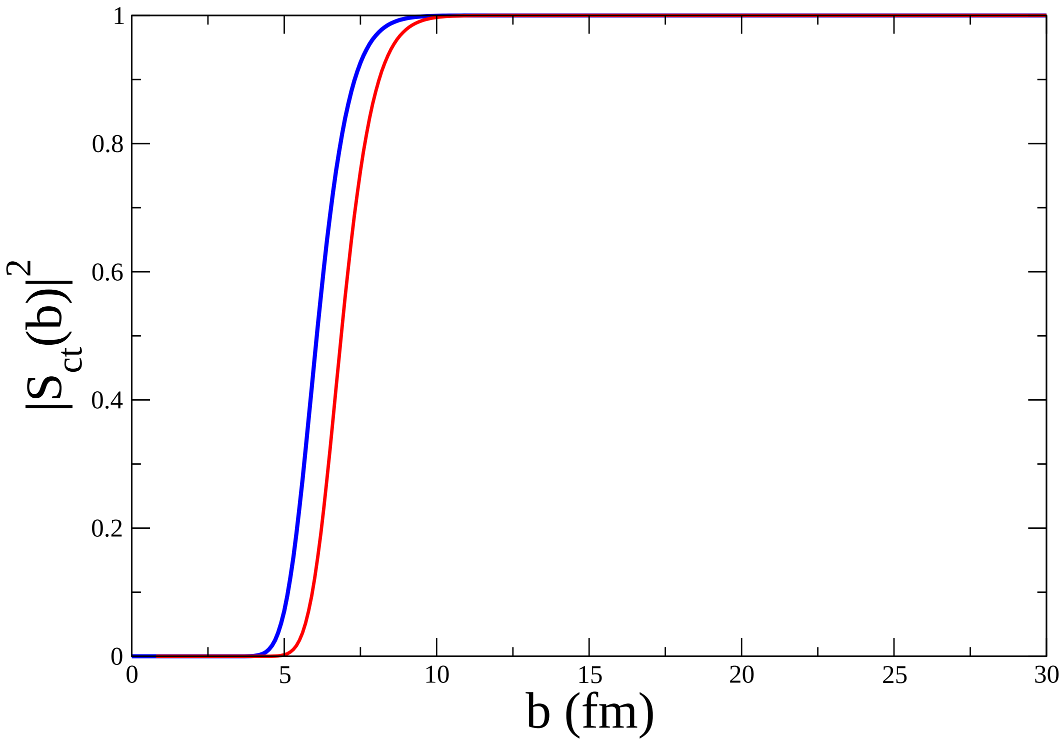
$^{9}Be(n,n)^{9}Be$

Two-body interactions: c-T

- Optical limit of Glauber Theory for $|S_{ct}(b)|^2$

- Parametrisation $|S_{ct}(b)|^2 = \exp\left(-log2 \exp\left(-(R_s - b)/a\right)\right)$ with $R_s = 1.4(A_p^{1/3} + A_t^{1/3})$

Two-body interactions: c-T



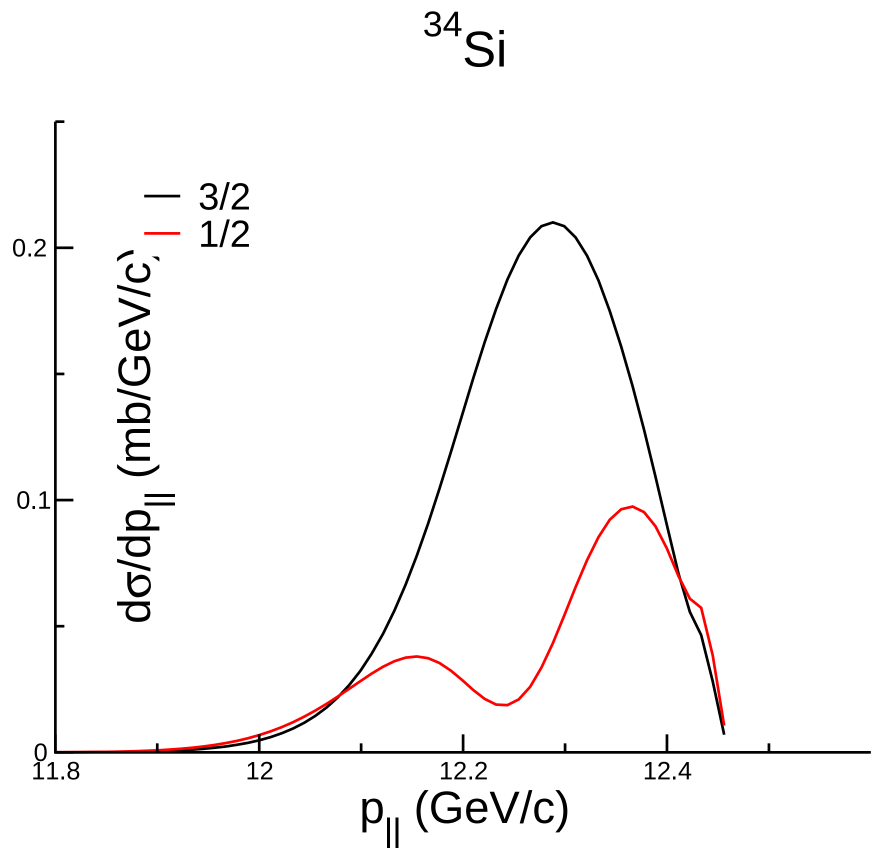
Our results for T_{20}

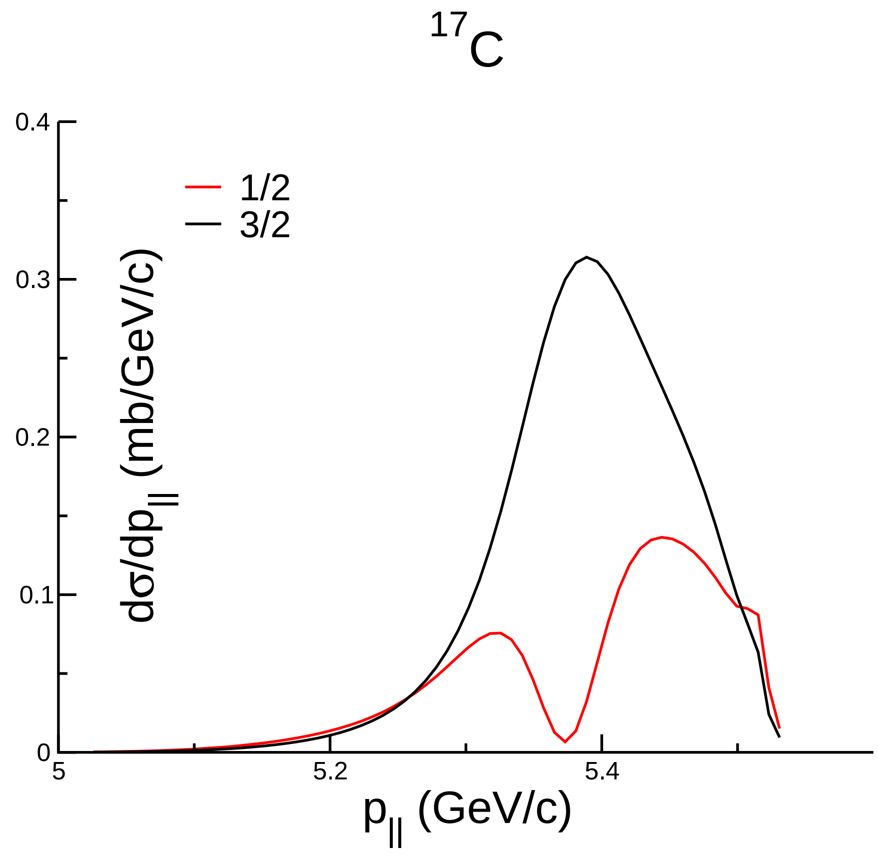
We have calculated some numbers for stripping of ^{17}C at 60 MeV/A, where an eikonal model calculation gives $T_{20} = 0.23$

(R.C. Johnson and J.A. Tostevin, *Analysing power of neutron removal reactions with beams of neutron-rich nuclei*, in: 'Spins in Nuclear and Hadronic Reactions', Proceedings of the RCNP-TMU Symposium (Tokyo, Japan 26 - 28 October 1999), (ed H Yabu, T Suzuki and H Toki, World Scientific (Singapore), October 2000), 155-164)

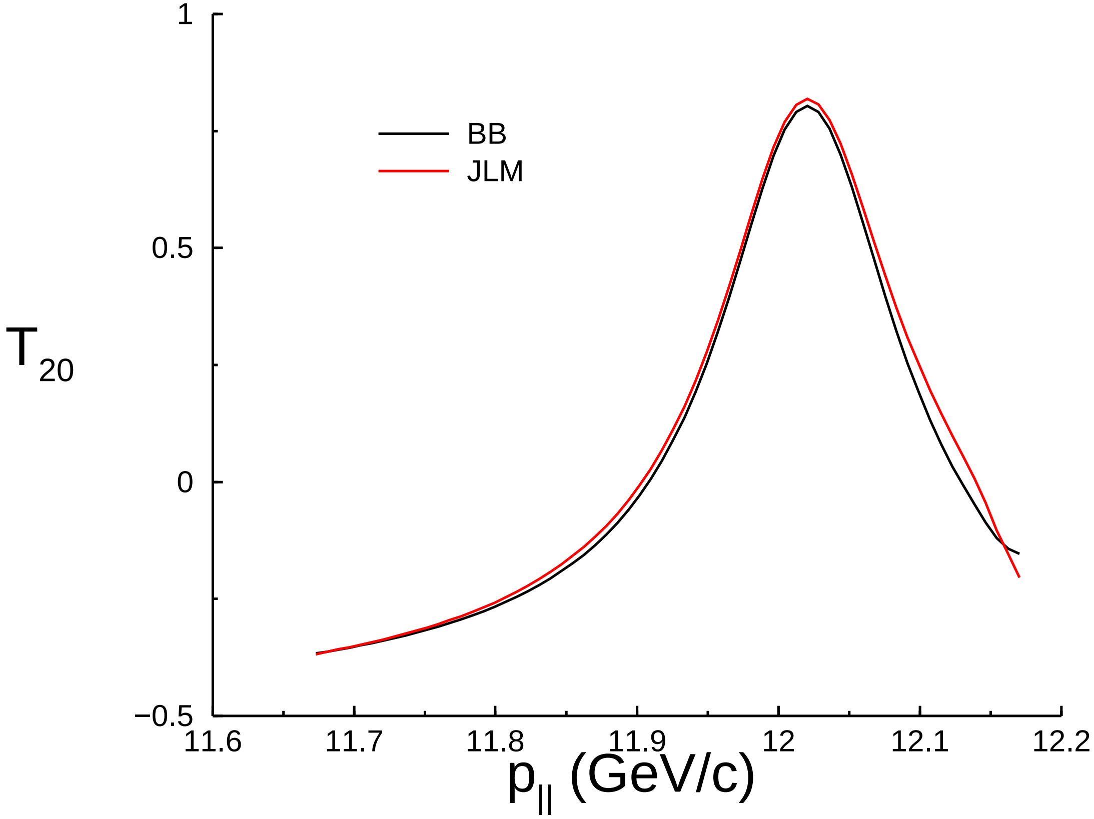
Approx.	T_{20}
0th order	-0.24
1st order	0.10
2nd order	0.24
3rd order	0.28
Bessel function	0.32

Contribution of different orientations





Insensitivity



(^{34}Si case)

Insensitivity

Values of T^i_{20} for ^{17}C for the two values of R_s under examination.

	T^i_{20}	
Approximation	$R_s = 5.95$ fm	$R_s = 6.51$ fm
0th order	-0.37	-0.35
1st	0.03	0.01
2st	0.21	0.22
3st	0.26	0.27
Exact	0.36	0.32

γ-ray angular distribution

$$P^q(\mathbf{k}) = \frac{k}{2\pi\hbar}\sum_K \sum_{L\ L'} \sum_{\pi\ \pi'} B_K(J_1) P_K(\cos\theta)(-1)^{q+J_1-J_2+L'-L-K}\hat{J}_1$$

$$(L\ q\ L'\ \ -q|K\ 0) W(J_1, J_1, L, L'; K, J_2)\ q^{\pi+\pi'} < J_1||T_L^{\pi}||J_2 > < J_1||T_{L'}^{\pi'}||J_2 >^*$$

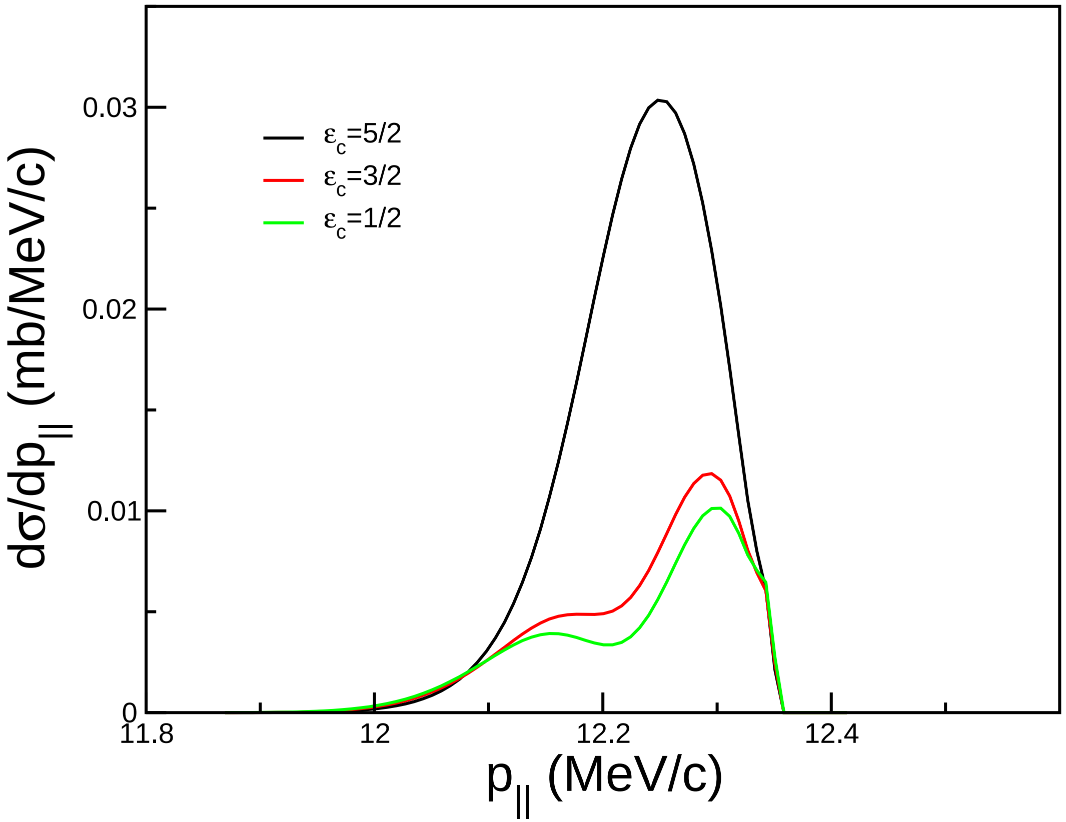
where

$$B_K(J_1) = \sum_{M_1} w(M_1)\widehat{K}(J_1\ M_1\ K\ 0|J_1\ M_1).$$

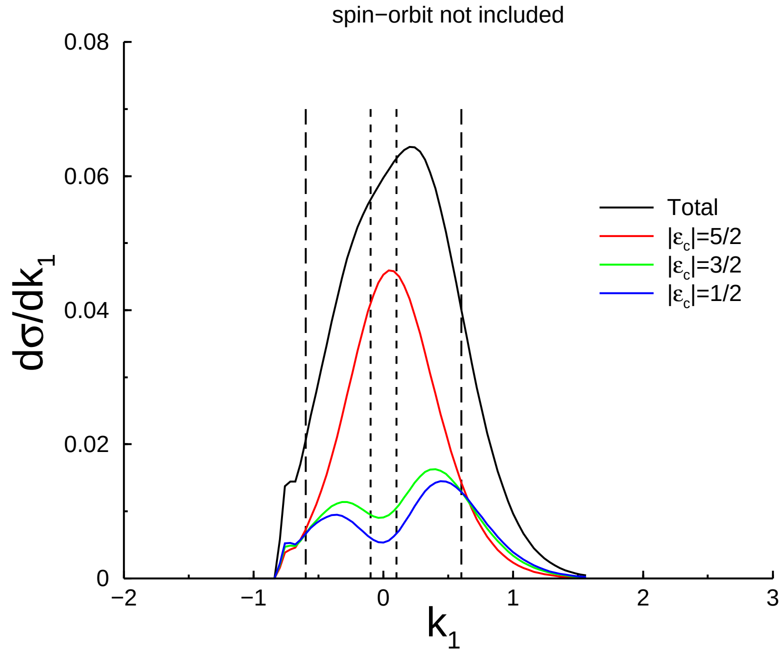
(H. J. Rose and D. M. Brink, Rev. Mod. Phys. **39** (1967),306)

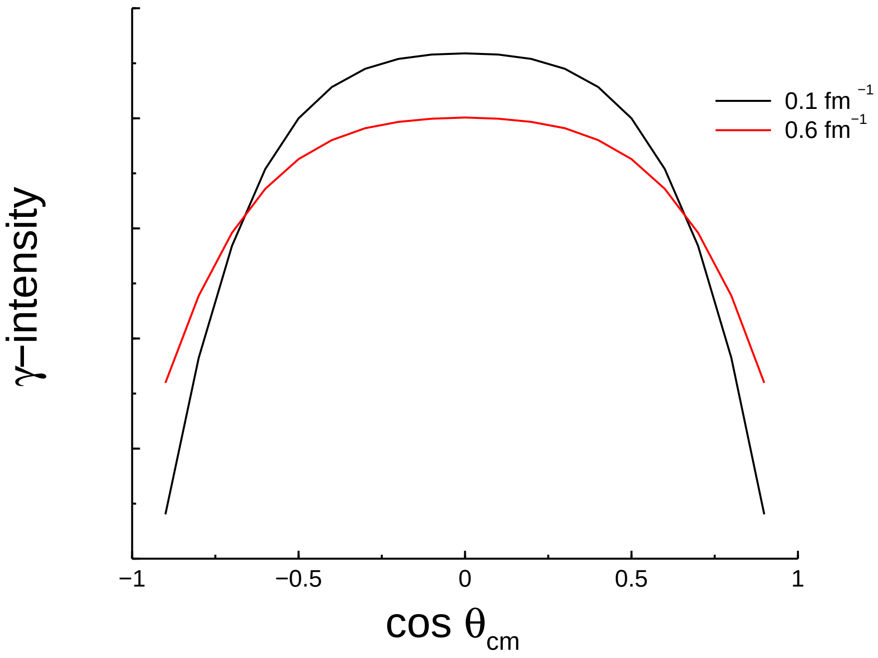
Core substate populations

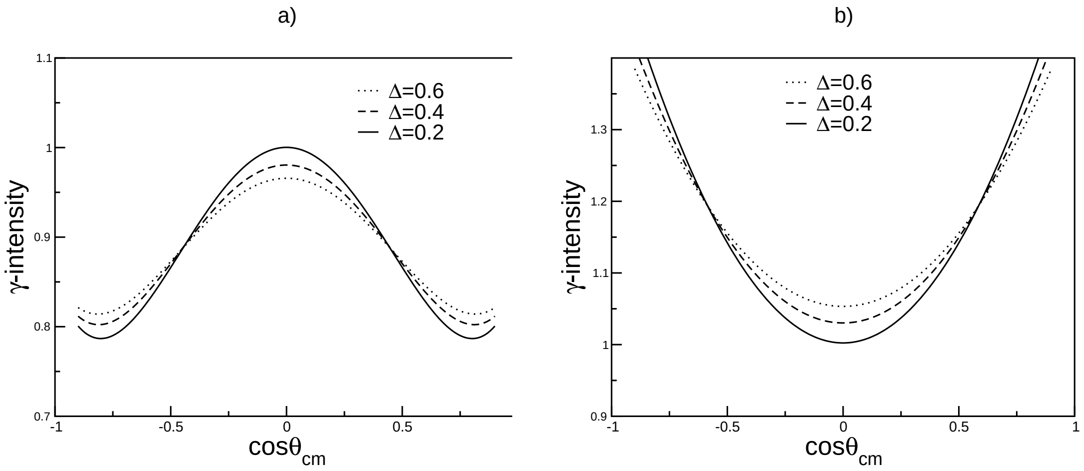
Populating a $d_{5/2}$ state in ^{33}Si



Populations and anisotropy







a) **b)**

γ-ray angular distribution from the ^{33}Si ($5/2^+$,$E_x = 4.32$ MeV) state considering a) E2 and b) M1 transitions. θ_{cm} is the angle of the emitted radiation in the rest frame of the residue. The momentum acceptance Δ is given in fm^{-1} around $k_1 = 0$, $-\Delta \leq k_1 \leq \Delta$. The intensities have been scaled to be 1 at zero angle.

Conclusions

- Analysing powers test the reaction mechanism without requiring too much precision in the interactions, and

- can be used as spectroscopic tools

- γ-ray angular distributions can be calculated