Internal report to E89-003 collaboration

Comparison between `WIZARD` and `LEA` Calculations for Quasifree $^{16}\mathbf{O}(e,e'p)$

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Table I compares the input used by Wally van Orden in his `WIZARD` code with the input that I usually choose for `LEA`, although most parameters can take many more choices. I also performed a calculation with `LEA` intended to imitate `WIZARD` as closely as possible. I believe that only two important differences remain.

- **recoil correction** — I went to a lot of trouble to employ consistent kinematics for direct knockout throughout `LEA`, including recoil of the residual nucleus in both initial and final states. `WIZARD`, on the other hand, does not account for recoil, effectively assuming that the residual nucleus is infinitely massive. Some experimentation with my code suggests that this can be an important effect at large p_m and that removal of the recoil correction would bring my results for A_{LT} closer to those of `WIZARD`, but unfortunately it would be quite difficult to implement an infinitely massive target as an option in `LEA` and not worth the effort because such targets don't exist.

- **EMA in current operator** — `WIZARD` performs a momentum-space integral that accounts for the momentum spread in the ejectile wave function, whereas `LEA` evaluates the current matrix element in coordinate space using the asymptotic momentum of the ejectile. This approximation is consistent with the off-shell prescription of de Forest, which is not used by `WIZARD`. Furthermore, given that Gordon and gauge ambiguities are inevitable in a single-nucleon current operator, I believe that the effective momentum approximation (EMA) is adequate for direct knockout.

Differential cross sections and left-right asymmetries are compared in Figs. 1-2 for three models: `LEA` (solid black), `WIZARD` (green dash-dot), and `WIZARD`-like `LEA` (red dashed). All models use normalization factors of 0.65 for $1p_{1/2}$ or 0.75 for $1p_{3/2}$ adjusted by eye. The cross sections for modest p_m are all quite similar — actually, I find the fact that the normalization factors for the EDAD1 and LF optical potentials are consistent to be rather surprising because the LF potential is rather poor for proton scattering. The most important difference between the two LEA models is the choice of optical model, with differences in current operator, electron distortion, and other ingredients being fairly small. The LF optical model produces more structure in A_{LT} at large p_m that is qualitatively consistent with `WIZARD`, but signficant differences in cross section remain. I cannot determine whether these differences are primarily due to the ejectile momentum distribution or the absence of recoil in `WIZARD`. Furthermore, there may still be differences in optical model arising from the PTTH (Pickelsimer, Tandy, Thaler, Hynes) prescription for converting a nonrelativistic to a Dirac

TABLE I. Comparison between model inputs

ingredient	WIZARD	standard LEA
representation	momentum space	coordinate space
density	3pF	Fourier-Bessel
bound state	Dirac-Hartree	Dirac-Hartree
wave equation	Dirac	relativized Schrödinger
spinor distortion	automatic	EMA
optical model	Love-Franey	EDAD1
recoil correction	no	yes
current operator	Γ_2	$\bar{\Gamma}_2$ with EMA
form factors	Höhler 8.2	MMD
gauge	Coulomb	Coulomb
electron distortion	none	EMA

optical model. Finally, one could debate endlessly whether relatively small differences for large p_m are actually meaningful where small differences in any of the many approximations required by any DWIA model can produce substantial variations.

It would be much easier using WIZARD for van Orden to investigate the relative importance of the ejectile momentum distribution versus the remaining differences in optical model than it would be for me using LEA. We both would probably find it difficult to investigate the importance of the recoil correction. Nevertheless, although I still cannot reproduce the WIZARD model completely, there appears to be no indication that either code is failing to compute its own model faithfully; there are no obvious mistakes in either.

I regard the apparent success of the WIZARD calculation in reproducing A_{LT} so well to be somewhat fortuitous because in most respects the LEA calculation is technically superior.

- The LF interaction does not reproduce proton elastic scattering, proton absorption, or neutron total cross sections particularly well — the EEI or EDAD1 potentials fit these quantities much better.

- The three-parameter Fermi distribution is not very good for oxygen, and WIZARD used a density and optical potential for ^{16}O rather than for the residual nucleus ^{15}N. The Fourier-Bessel expansion fitted to electron scattering is much better than 3pF.

- LEA handles the kinematics and recoil corrections better.

- Electron distortion is included in LEA but omitted in WIZARD.

- LEA provides more flexibility in the current operator, which is useful for assessing importance of ambiguities in the model. The coordinate-space approach also permits density-dependent form factors.

Conversely, the momentum-space approach of WIZARD is useful for testing the reliability of the effective momentum approximation (EMA).

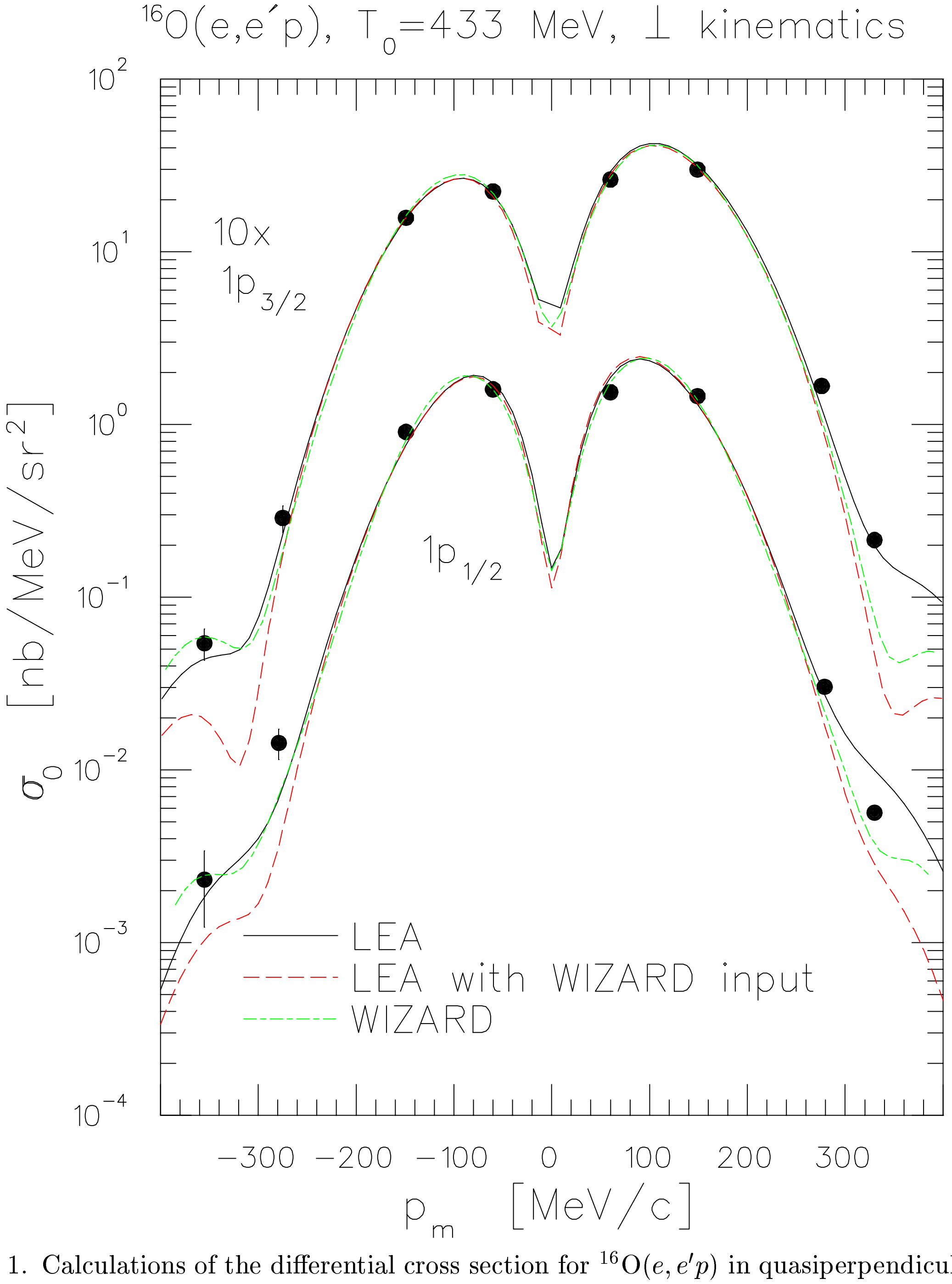

FIG. 1. Calculations of the differential cross section for $^{16}\mathrm{O}(e,e'p)$ in quasiperpendicular kinematics with $Q^2 = 0.8$ (GeV/c)^2. Solid black curves use the **LEA** model, green dash-dotted curves are based upon **WIZARD** output, and red dashed curves use **WIZARD**-like input in **LEA**.

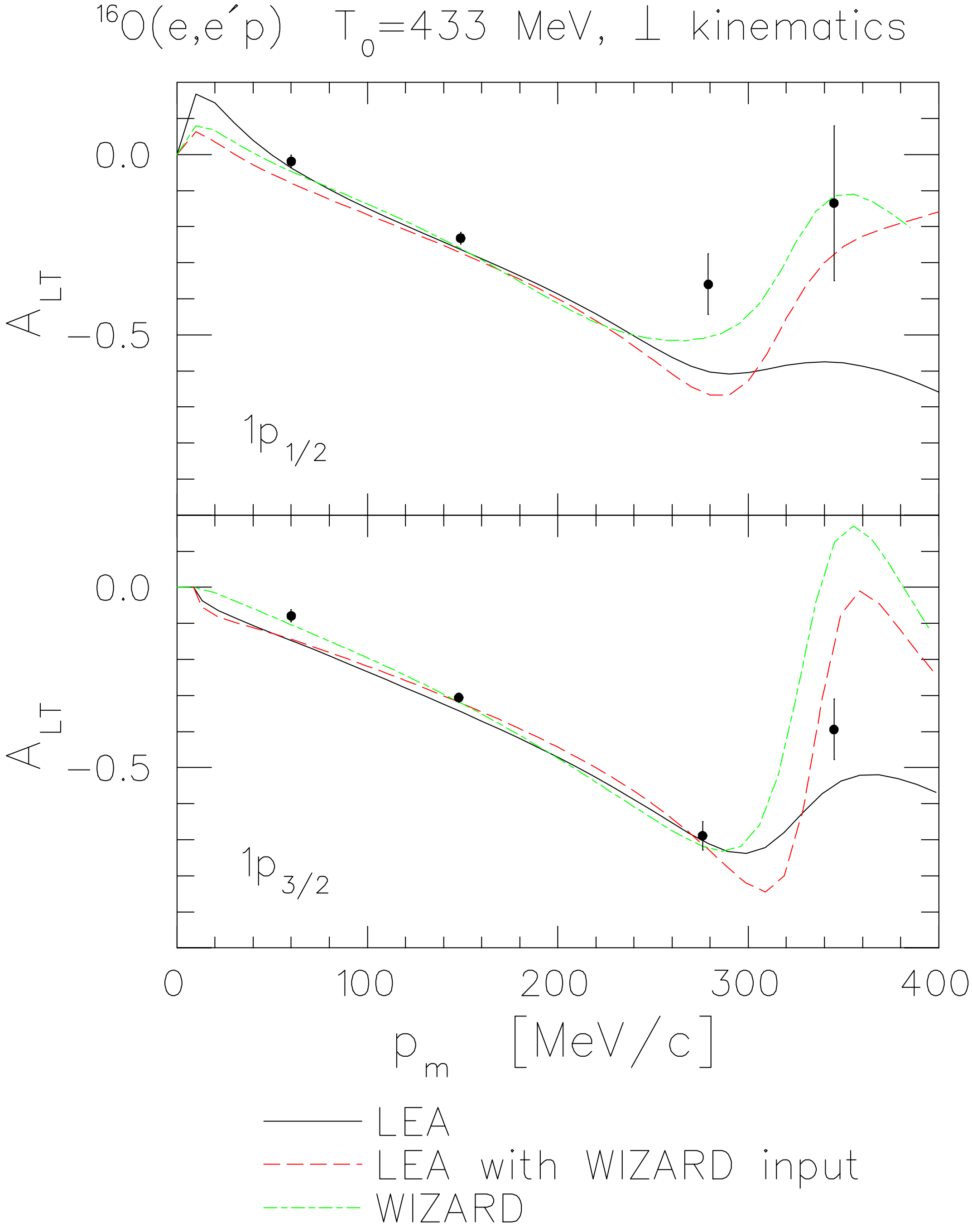

FIG. 2. Calculations of the left-right asymmetry for $^{16}\mathrm{O}(e,e'p)$ in quasiperpendicular kinematics with $Q^2 = 0.8$ $(\mathrm{GeV}/c)^2$. Solid black curves use the `LEA` model, green dash-dotted curves are based upon `WIZARD` output, and red dashed curves use `WIZARD`-like input in `LEA`.