QUANTUM MECHANICAL STUDY OF THE FLEISCHMANN-PONS EFFECT

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Oct 8, 2009

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LA-UR 09-06126

Introduction

- The Fleischmann-Pons Effect (FPE) was swiftly rejected when first published in 1989, yet many researchers have since reported energy gains in similar experiments; e.g., see Storms review.
  - The body of evidence suggests that the energy gains are real, even though the heat production powers are small and often difficult to replicate.
- Fleischmann and Pons suggested that these gains are the result of "cold fusion" or Low Energy Nuclear Reactions (LENR) where energy is released from a deuterium-deuterium (d-d) fusion.
- However, the probability of a d-d fusion under the conditions within a FPE cell, as we understand it, is vanishingly small.
- As stated by Pons et al., "it is necessary to reconsider the quantum mechanics of electrons and deuterons in such host lattices."
  - We would add that other less exotic mechanisms of heat production within these lattices should also be investigated.

Study overview

- To predict changes in the probability of d-d fusion, caused by:
  - perturbations to the energy barriers;
  - or positive interference caused by the effects of adjacent atoms in a lattice.
  - Work is in its infancy, so here we report early results.
- First model: effect of adjacent lattice atoms on fusion examined in 1½ D model.
  - Quantum barrier model is formulated using the transfer matrix approach.
  - Then additional barriers are introduced in the form of adjacent atoms.
  - Initial results show **resonance** structure for the transmission of incoming deuterons through deuterium atom nuclei
  - This implies an **increase** in fusion probabilities at particular deuteron energies.
  - We will also discuss the possible effects of quantized deuteron energies.
- It is noted that the energy gains observed in FPE experiments often occur in highly dislocated metal lattices. The possible role of these dislocations in facilitating the d-d fusion process will also be examined.

One-Dimensional Transfer Matrices

The time-independent Schrödinger equation in 1-D has the solution

$$\psi(x) = Ae^{ikx} + Be^{-ikx}$$

or in matrix notation,

$$\psi(x) = \begin{pmatrix} e^{ikx} & e^{-ikx} \end{pmatrix} \cdot \begin{pmatrix} A \\ B \end{pmatrix}$$

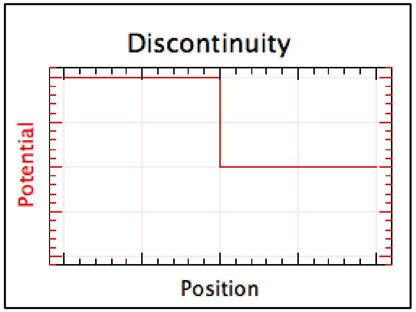
Where k is the particle wave number, $k = \rho\sqrt{\varepsilon - v}$, $\rho = \sqrt{2mV_0}/\hbar$, m is the particle mass, V_0 is a potential energy used for non-dimensionalizing, and ε and v are the non-dimensionalized particle energy and potential felt by the particle.

The coordinate system can be translated to the left or right by a distance a, or **propagated** via straightforward multiplication, for example:

$$\begin{pmatrix} A \\ B \end{pmatrix}_{x=a} = \begin{pmatrix} e^{ika} & 0 \\ 0 & e^{-ika} \end{pmatrix} \cdot \begin{pmatrix} A \\ B \end{pmatrix}_{x=0} \equiv \mathbf{p} \cdot \begin{pmatrix} A \\ B \end{pmatrix}_{x=0}$$

One-Dimensional Transfer Matrices, continued

In the same manner the potential, *v*, felt by a particle can be changed using a **discontinuity matrix** at $x = 0$, such as



$$\begin{pmatrix} A \\ B \end{pmatrix}_{x-} = \frac{1}{2}\begin{pmatrix} 1+k^+/k^- & 1-k^+/k^- \\ 1-k^+/k^- & 1+k^+/k^- \end{pmatrix} \cdot \begin{pmatrix} A \\ B \end{pmatrix}_{x+} \equiv \mathbf{t} \cdot \begin{pmatrix} A \\ B \end{pmatrix}_{x+}$$

or at $x = a$ by using a combination of propagation and discontinuity,

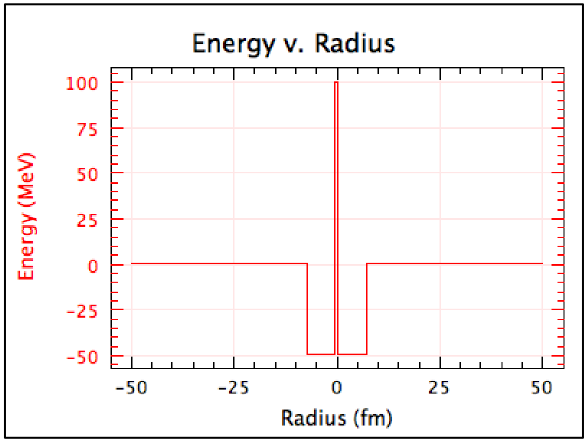
$$\begin{aligned} \begin{pmatrix} A \\ B \end{pmatrix}_{x-} &= \begin{pmatrix} e^{-ika} & 0 \\ 0 & e^{ika} \end{pmatrix} \cdot \frac{1}{2}\begin{pmatrix} 1+k^+/k^- & 1-k^+/k^- \\ 1-k^+/k^- & 1+k^+/k^- \end{pmatrix} \cdot \begin{pmatrix} e^{ika} & 0 \\ 0 & e^{-ika} \end{pmatrix} \cdot \begin{pmatrix} A \\ B \end{pmatrix}_{x+} \\ &= \mathbf{p}_{-a} \cdot \mathbf{t} \cdot \mathbf{p}_{+a} \cdot \begin{pmatrix} A \\ B \end{pmatrix}_{x+} \equiv \mathbf{t}_{total} \cdot \begin{pmatrix} A \\ B \end{pmatrix}_{x+} \end{aligned}$$

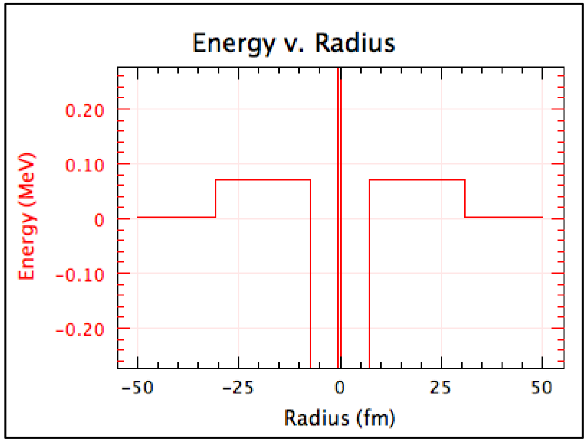
Finally, **transmission** through a system can be calculated using the formula

$$T = 1 - \frac{\left|\mathbf{t}_{total,21}\right|^2}{\left|\mathbf{t}_{total,11}\right|^2}$$

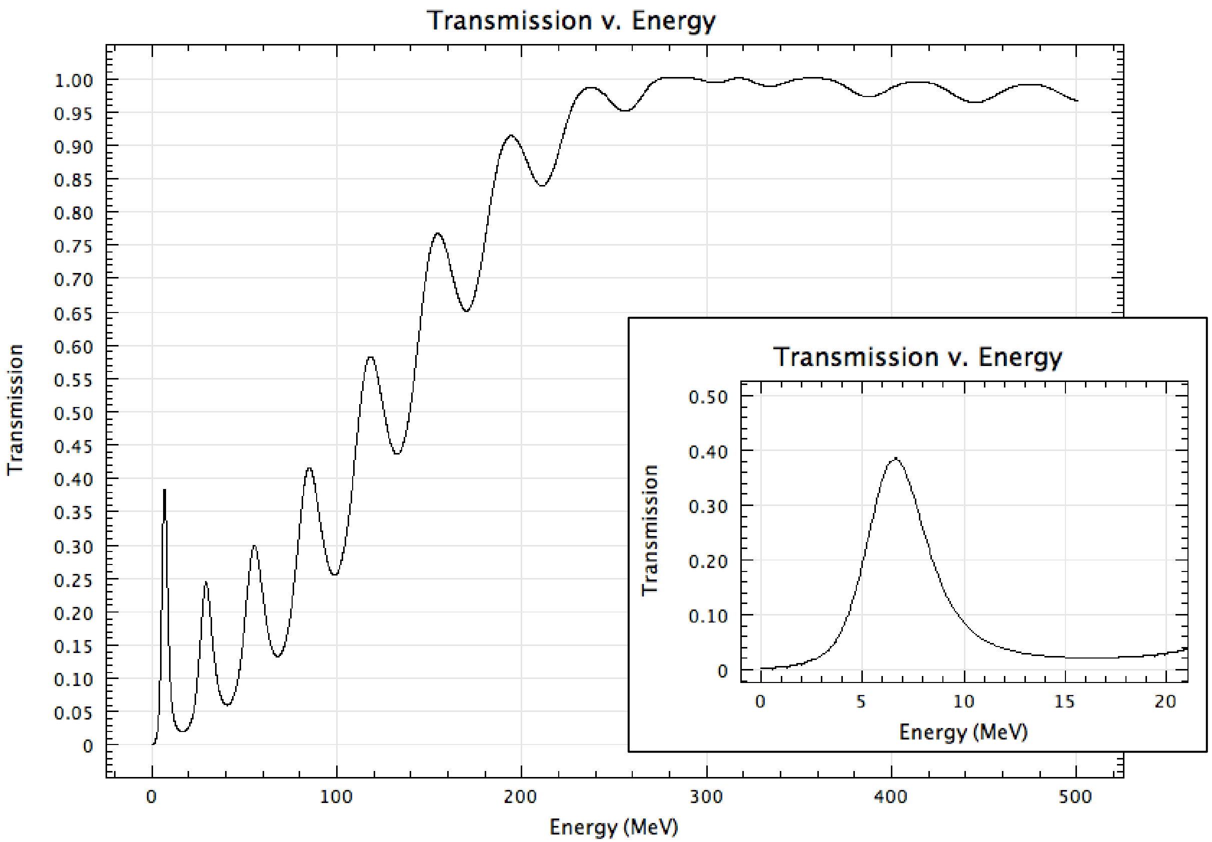
Simplistic Deuterium Atoms

- Used the femtometer and the electron volt as characteristic scales.
  - Recognizable scales make results clear.
- Basic atom constructed from idealized deuterium with a 1s electron
  - 100 MeV repulsive hard core from the origin to a radius of 0.34 fm
  - -50 MeV symmetric (attractive) well from HC to radius of 7.24 fm
  - Optionally, a 70 keV coulomb repulsion from well to radius of 30.6 fm
  - A second coulomb repulsion section was sometimes added, but was found to be negligible.
  - This is a **rough** model, not an accurate model; hence the neglect of bonding effects or nearby Pd electron clouds.

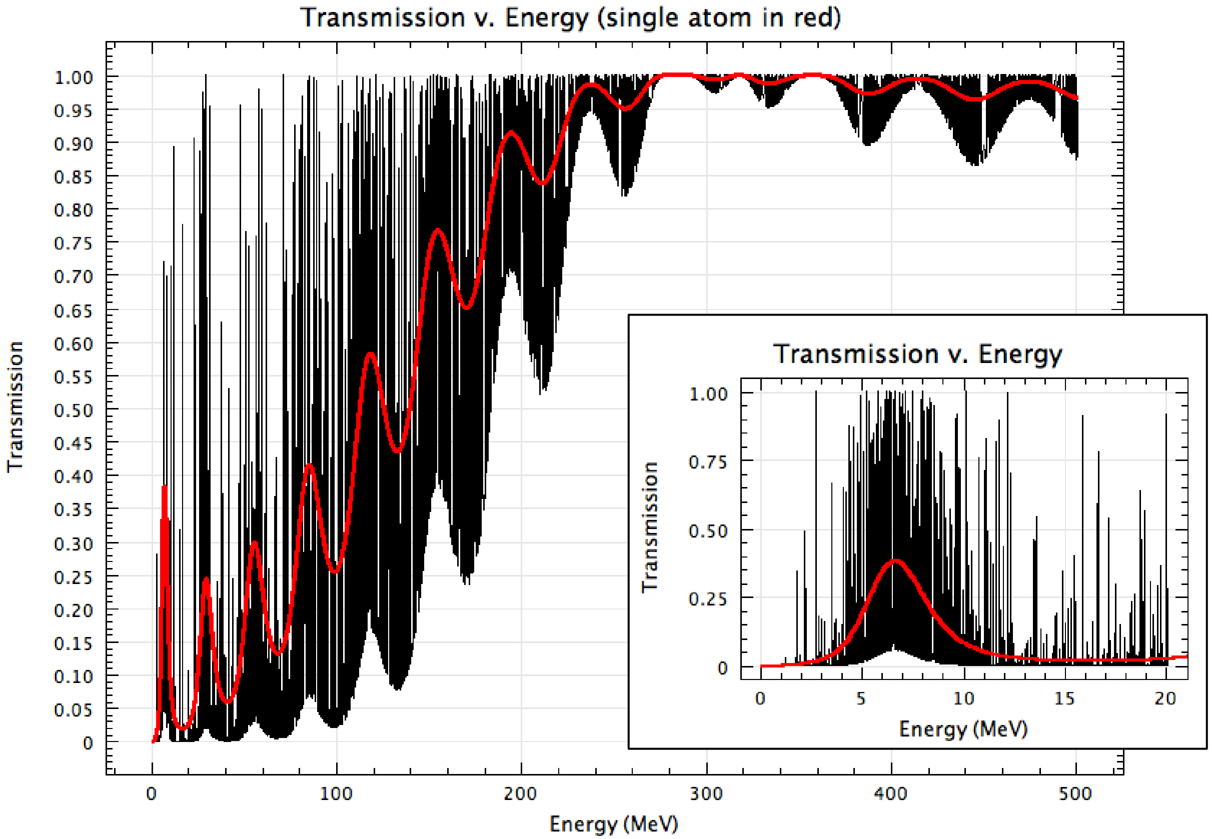




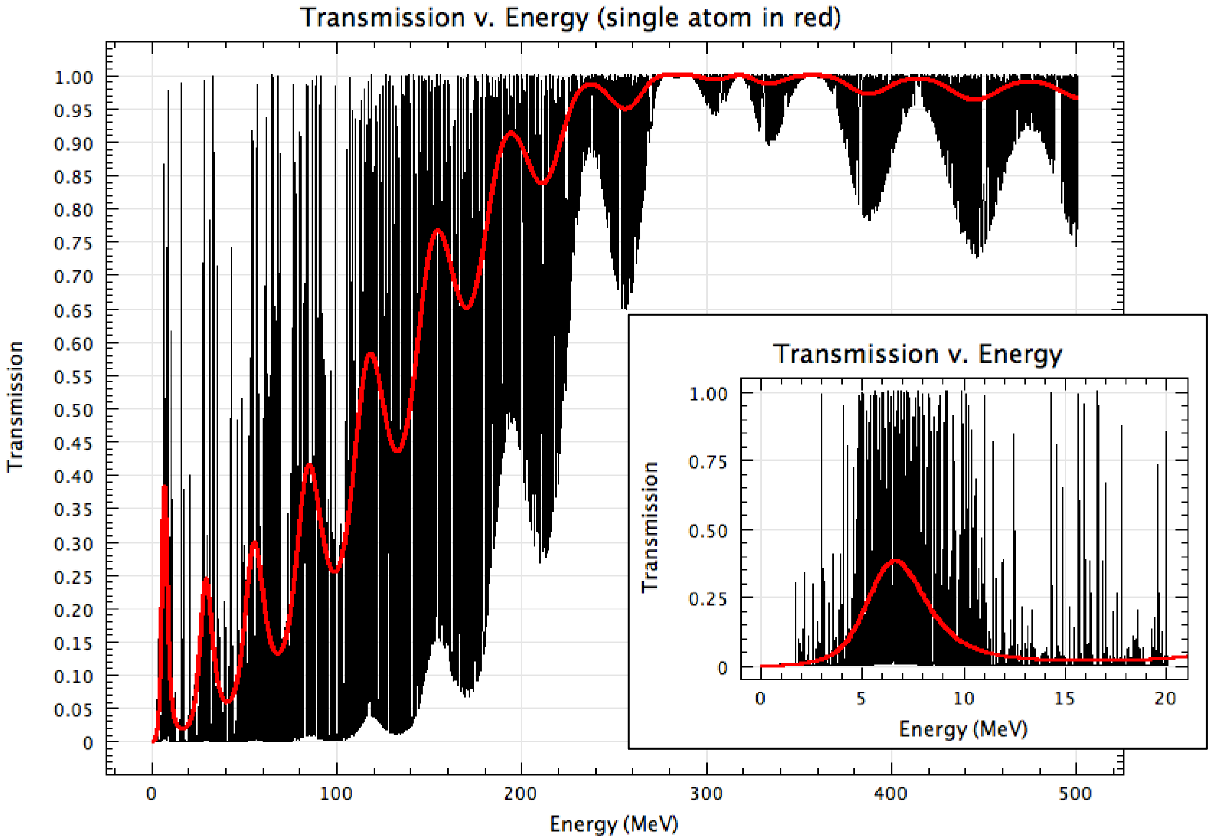
Single Atom Transmission



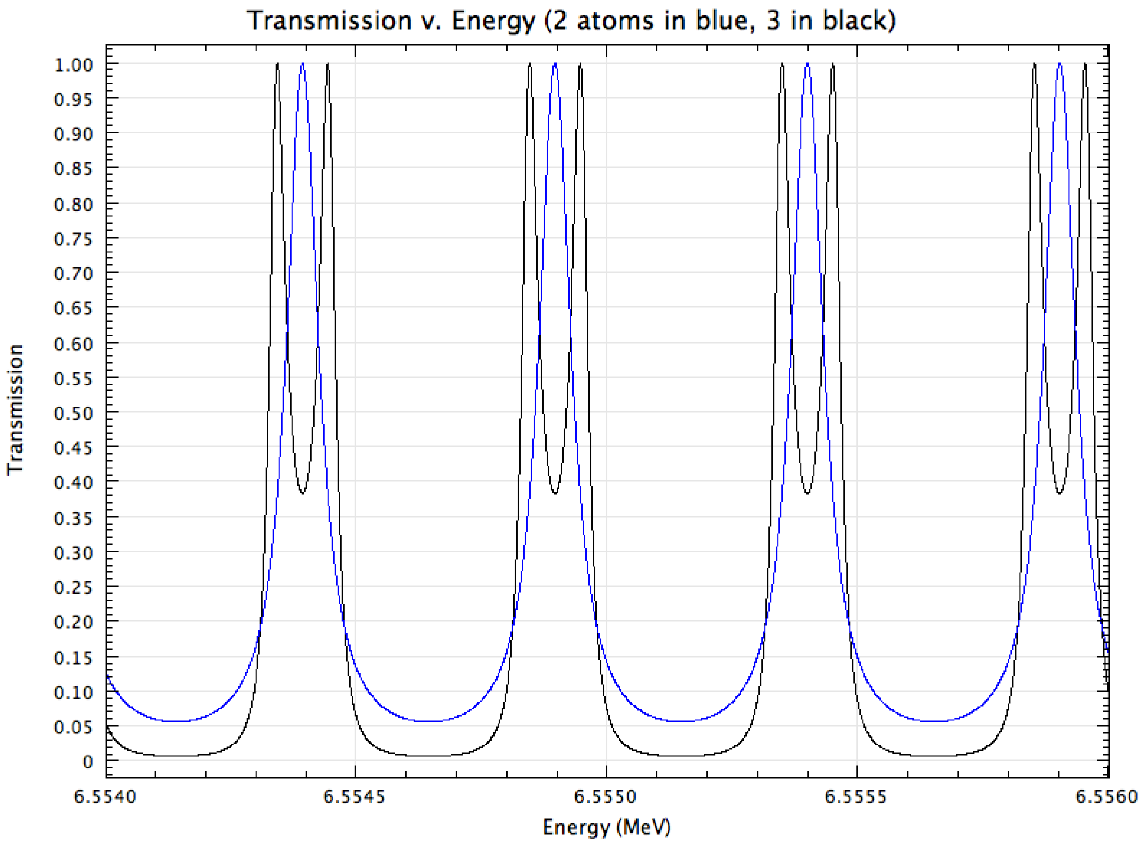
Two Atom Transmission (1-Å separation)



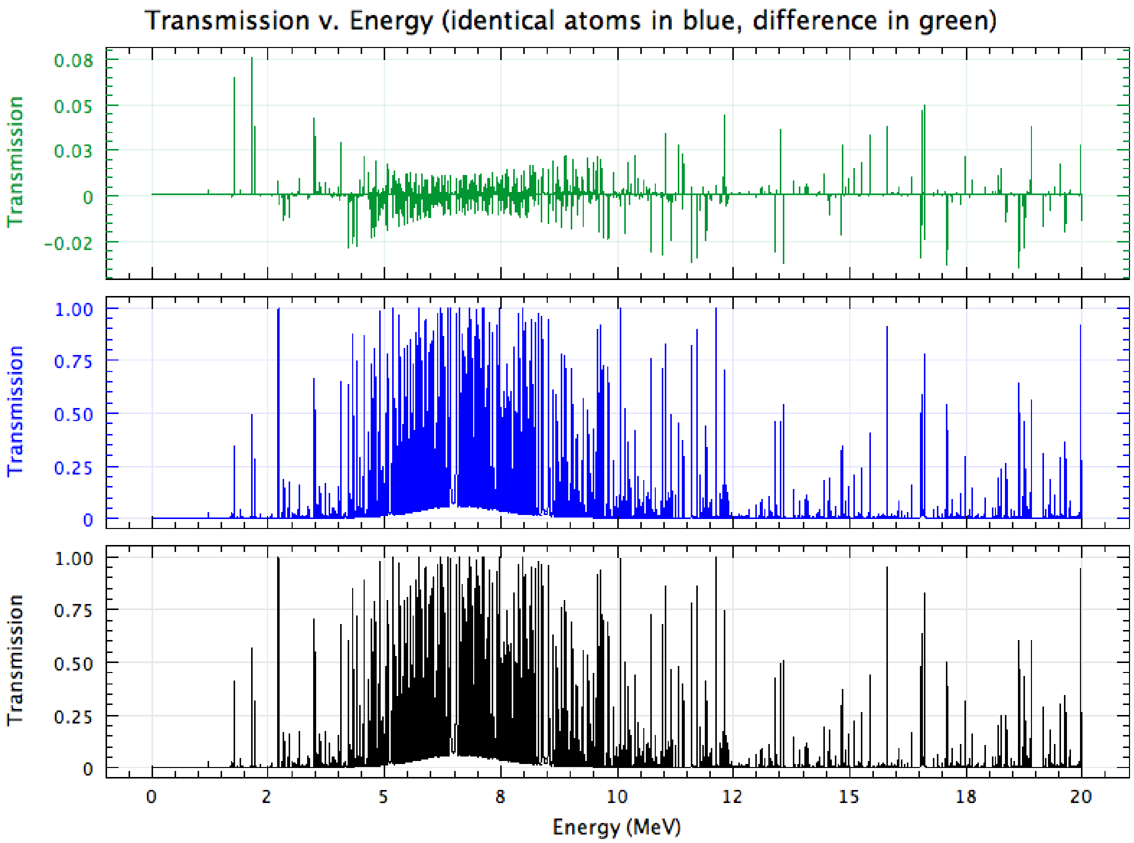
Three Atom Transmission (1-Å separation)



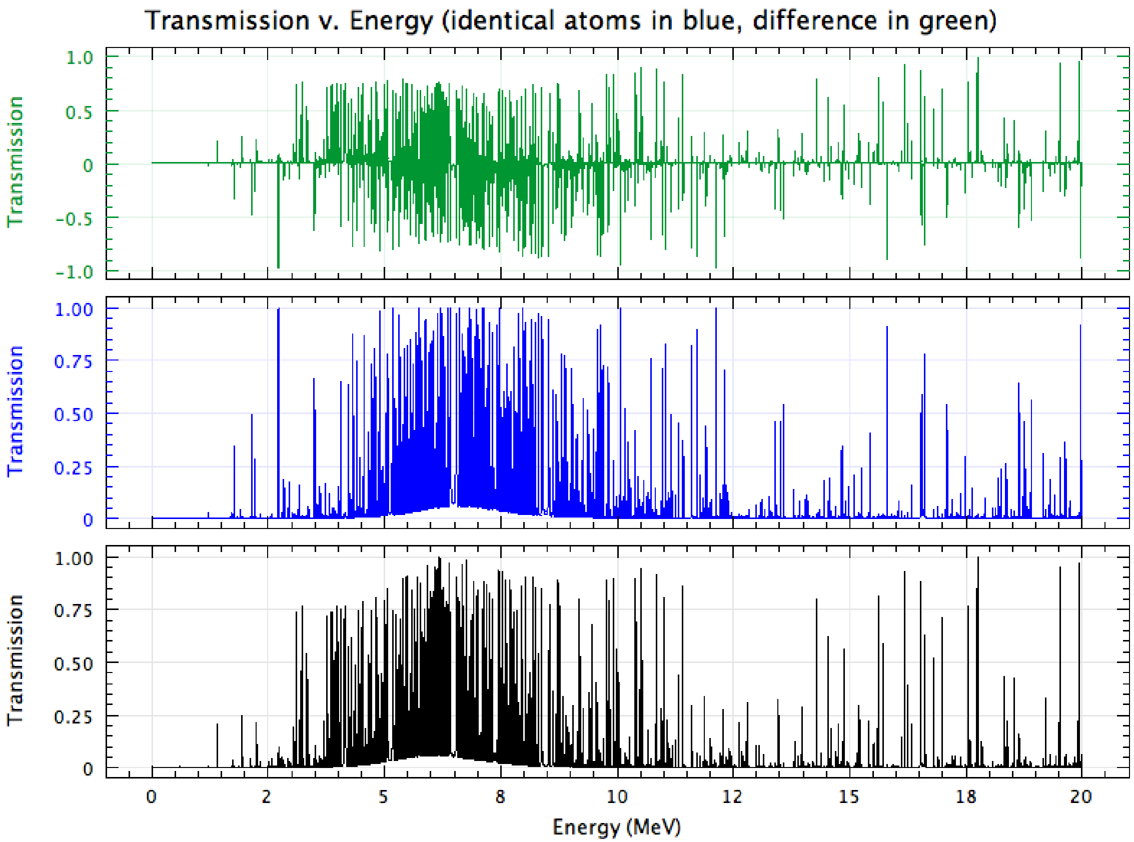
Peak Splitting (1-Å separation)



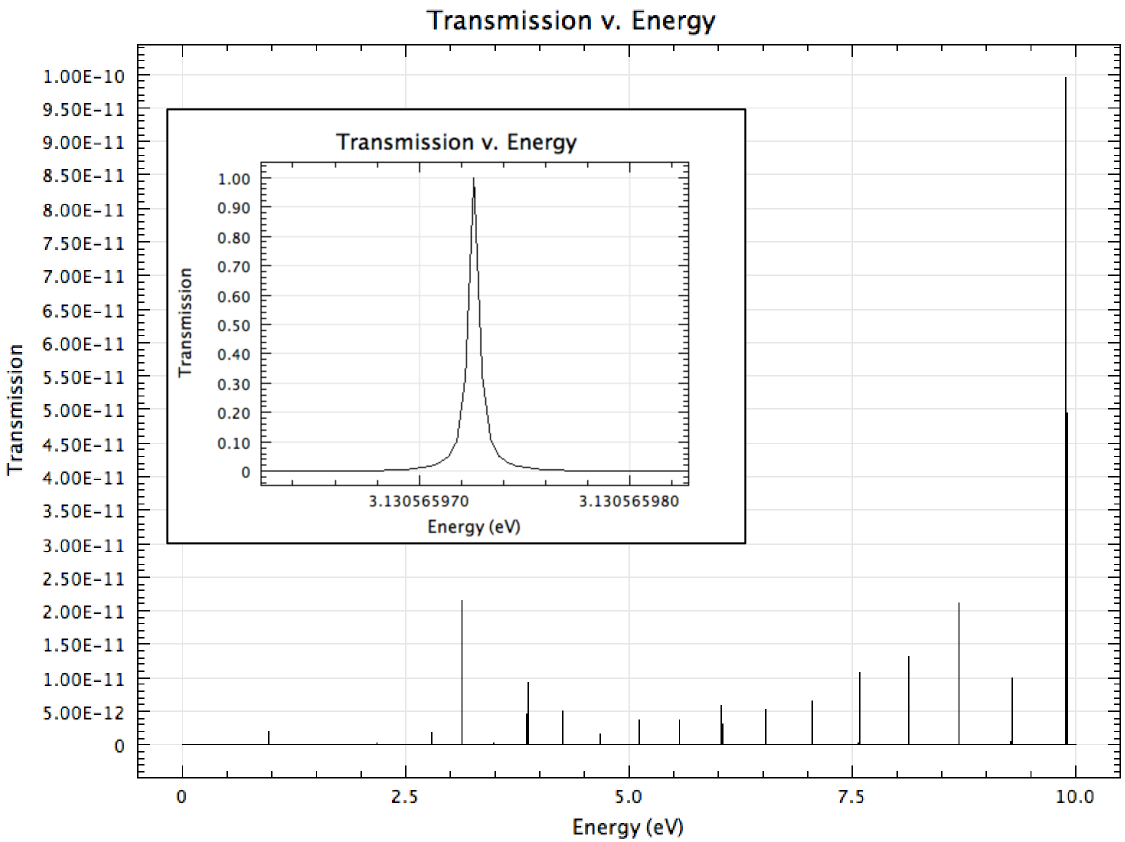
Large Energy Perturbation of +10 keV (2 atoms)



Extreme Energy Perturbation of +1 MeV (2 atoms)



Some Unit Transmission Even at a Few eV (2 atoms)



Conclusions

- Transmission has been estimated for a deuteron through one or more deuterium atoms.
  - Estimate is rough, but representative
  - Transmission through entire atoms is closely related to fusion with one of the atoms.
- Complicated resonance structure exists for even 2 atom transmission
  - Resonance peaks are regularly spaced
  - Resonance peaks are extremely narrow (but with unit transmission)
- Large (10 keV) perturbations in deuterium-deuteron attractive or repulsive potential have very little effect on transmission resonances.

Discussion of Probabilities

- Narrow resonance peaks would imply that transmission is extremely improbable when waves encounter particles in free space.
  - This is due to the broad, continuous energy distribution of particles in free space.
- However, deuterium atoms trapped in a lattice structure would behave as “particles in a box”, and hence have **quantized** energy levels.
- **Overlaps** between quantized energy levels and narrow resonance peaks may drastically **increase the transmission probability**.
  - Requires further study: energy levels of deuterium within a particular lattice should be fully understood before drawing any further conclusions.

Future work

- Perform calculations to understand the effect that quantized deuterium energies may have on transmission probabilities – as just discussed
- Another planned approach is to examine possible non-linear oscillation effects.
- Examine the role of a highly dislocated lattice on the d-d fusion process.
- To our knowledge, all previous Q-M studies of the FPE have been based on the time *independent* solution to the Schrödinger equation
- We propose formulating a time *dependent* solution for an oscillator problem
  - (Quasi) 3-D d-d particles are constrained to interact along a 1-D axis.
  - Non-linear excursions from stationary electronic configurations are investigated.
  - We will seek possible enhancement of quantum barrier effects and enhanced probability of electron capture by protons.

Acknowledgements

- The project was funded in part by the United States Defense Threat Reduction Agency, Dr. William H. Wilson.
- The authors are grateful to Dr. E. Storms for invaluable background information.