

# Fermilab and Particle Physics

- Questions in Elementary Particle Physics
- What is the nature of the fundamental interactions? How do they connected? Why are their strengths so different?
- What is the nature of the elementary particles? Are quarks and leptons indivisible? What is the reason for the mass scale? What is the dark matter? Do neutrinos have mass?

# Fermilab and Particle Physics

- What do asymmetries exist in the universe?
- Why do we perceive only three dimensions?

# Tour Itinerary

- MINOS prototype
- LINAC
- HyperCP
- KTeV
- D0

# Expectation Values

- How do you get information out of a wave function
- Function itself tells you probability of particle being in any location
- Can use probability distribution to get “expectation” i.e. mean values

# Expectation Values

$$\langle f(x) \rangle = \frac{\int f(x) \varphi^* \varphi dx}{\int \varphi^* \varphi dx}$$

$$\varphi_0(x) = \left( \frac{m\omega}{\hbar\pi} \right)^{1/4} e^{-m\omega x^2 / (2\hbar)}$$

$$\varphi_1(x) = \sqrt{2} \left( \frac{m\omega}{\hbar\pi} \right)^{1/4} \left( \frac{m\omega}{\hbar} \right) x e^{-m\omega x^2 / (2\hbar)}$$

$$\varphi_2(x) = \frac{1}{\sqrt{2}} \left( \frac{m\omega}{\hbar\pi} \right)^{1/4} \left( 2 \frac{m\omega}{\hbar} x^2 - 1 \right) e^{-m\omega x^2 / (2\hbar)}$$

# Expectation Values

- Even functions times odd functions are odd
- Integrals of odd functions between symmetric limits are zero
- Easy to show that  $\psi_0, \psi_1$  are orthogonal.  
Harder to show that  $\psi_0, \psi_2$  are orthogonal;  
requires integration by parts

# Three Dimensions

- SE becomes

$$-\frac{\hbar^2}{2m}\nabla^2\varphi + U(\mathbf{x})\varphi = E\varphi$$

$$\varphi = A(x)B(y)C(z)$$

$$\varphi = R(r)\Phi(\phi)L(\theta)$$

Degeneracy means different wave functions have the same energy