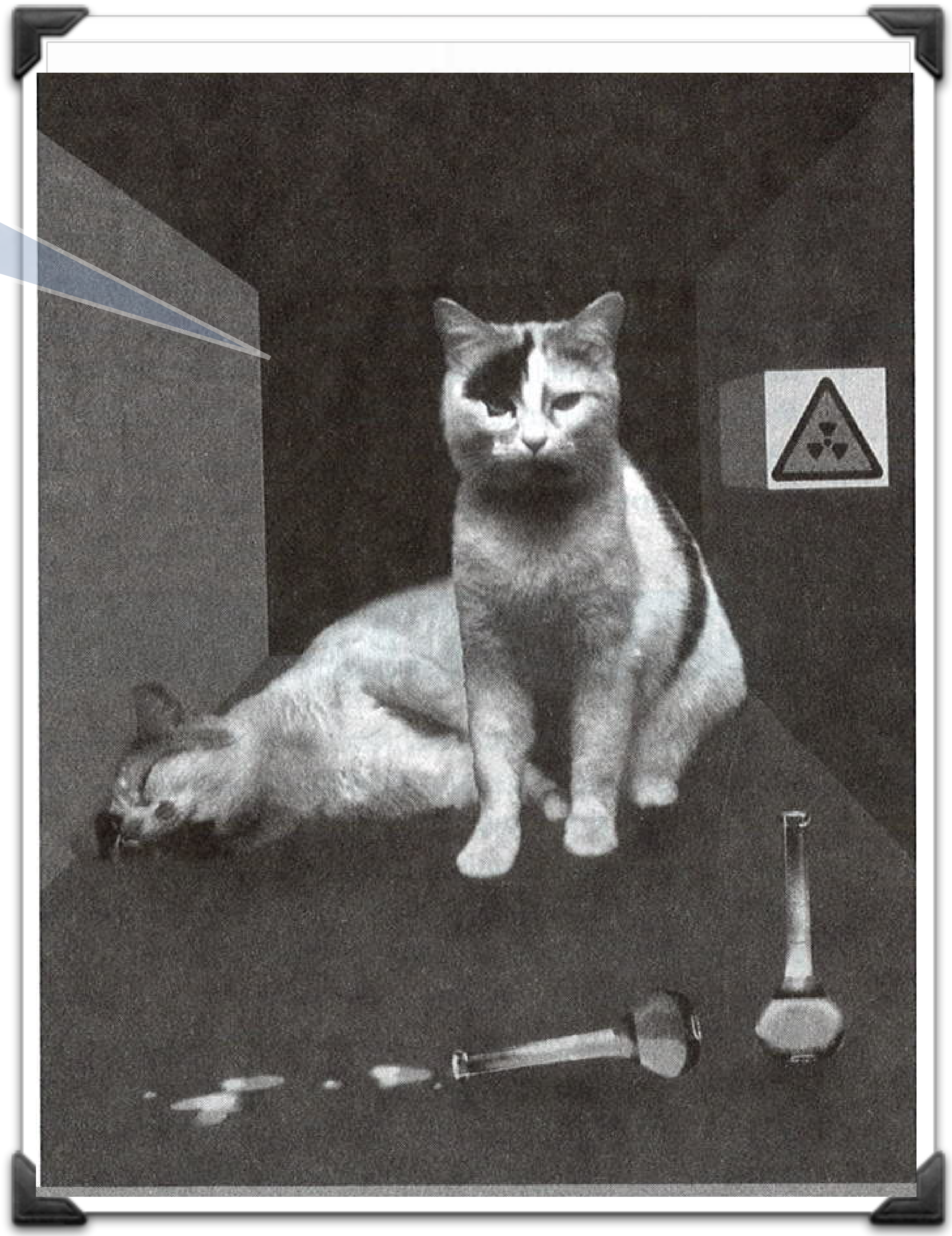
Welcome back to PHY 3305



Today's Lecture:

Even More Schoedinger Equation!

Schrödinger's Cat
Alive or Dead?

ANNOUNCEMENTS

- Reading Assignment for Thursday, Oct 26: Chapter 5.8.
- Problem set 10 is due Tuesday, Oct 31 at 12:30 pm.
- Regrade for problem set 9 is due Tues Oct 31 at 12:30 pm.
- Next week, first drafts of your presentations are due. They should be emailed to Dr. Cooley <cooley@physics.smu.edu> in pdf format before 12:30 pm on Tuesday, Oct 31.
- Dark Matter Days at SMU: Series of events — stay up-to-date: https://www.physics.smu.edu/web/events/darkmatterday/

Oct. 29 at 4pm in McCord Auditorium:

DARK MATTER DAY

Marusa Bradac, Associate Professor at UC Davis, will give a public lecture on Dark Matter. Reception to follow lecture from 5-6 pm in the Dallas Hall Rotunda with beverages and light snacks.

Free and open to the public.

smu.edu/physics

Please RSVP by October 27.
smudarkmatterlecture.eventbrite.com

https://www.physics.smu.edu/web/events/darkmatterday/

What is good and what is bad about the following slides?

In this talk, we will consider a new framework for dark-matter physics which takes advantage of this possibility.

- *Multi-component framework*: dark matter comprises a vast ensemble of interacting fields with varying masses, mixings, and abundances.
- Rather than impose stability for each field individually (or even for the collection of fields as a whole), we ensure the phenomenological viability of this scenario by requiring that states with larger masses and SM decay widths have correspondingly smaller abundances, and vice versa.
- *In other words, stability is not an absolute requirement in such a scenario: stability is balanced against abundance!*
- As we shall see, this leads to a highly dynamical scenario in which cosmological quantities such as Ω_{CDM} experience non-trivial time-dependences beyond those associated with the expansion of the universe.

"Dynamical Dark Matter" (DDM)

ASTROPHYSICAL OBSERVABLES

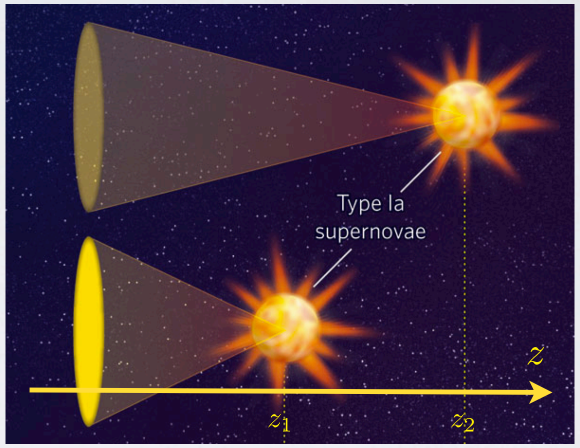
redshift & scale factor

$$a = \frac{1}{1+z}$$

$$z = \Delta\lambda/\lambda$$

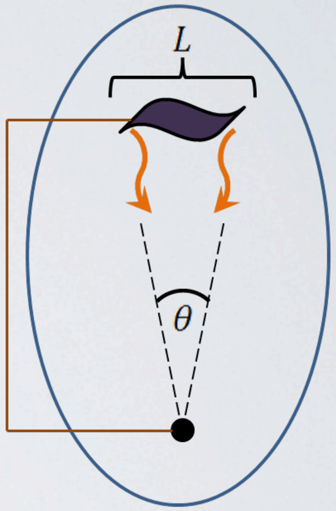
$D_L(z)$ Luminosity distance: **standard candle**

1. supernovae (SNe)



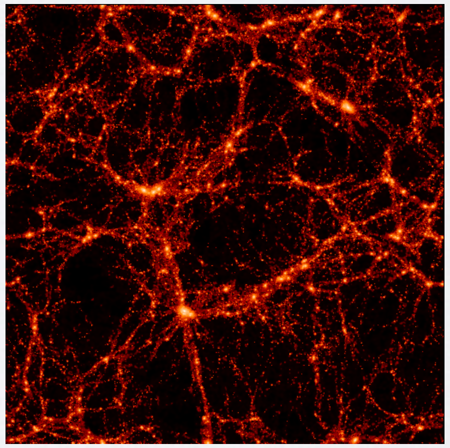
$D_A(z)$ Angular diameter distance: **standard ruler**

2. baryon acoustic oscillations (BAO) , cosmic microwave background (CMB)



$G(\rho, z)$ Growth of structure: **galaxy clustering**

3. weak gravitational lensing (WL)
4. galaxy cluster abundance (Clusters)

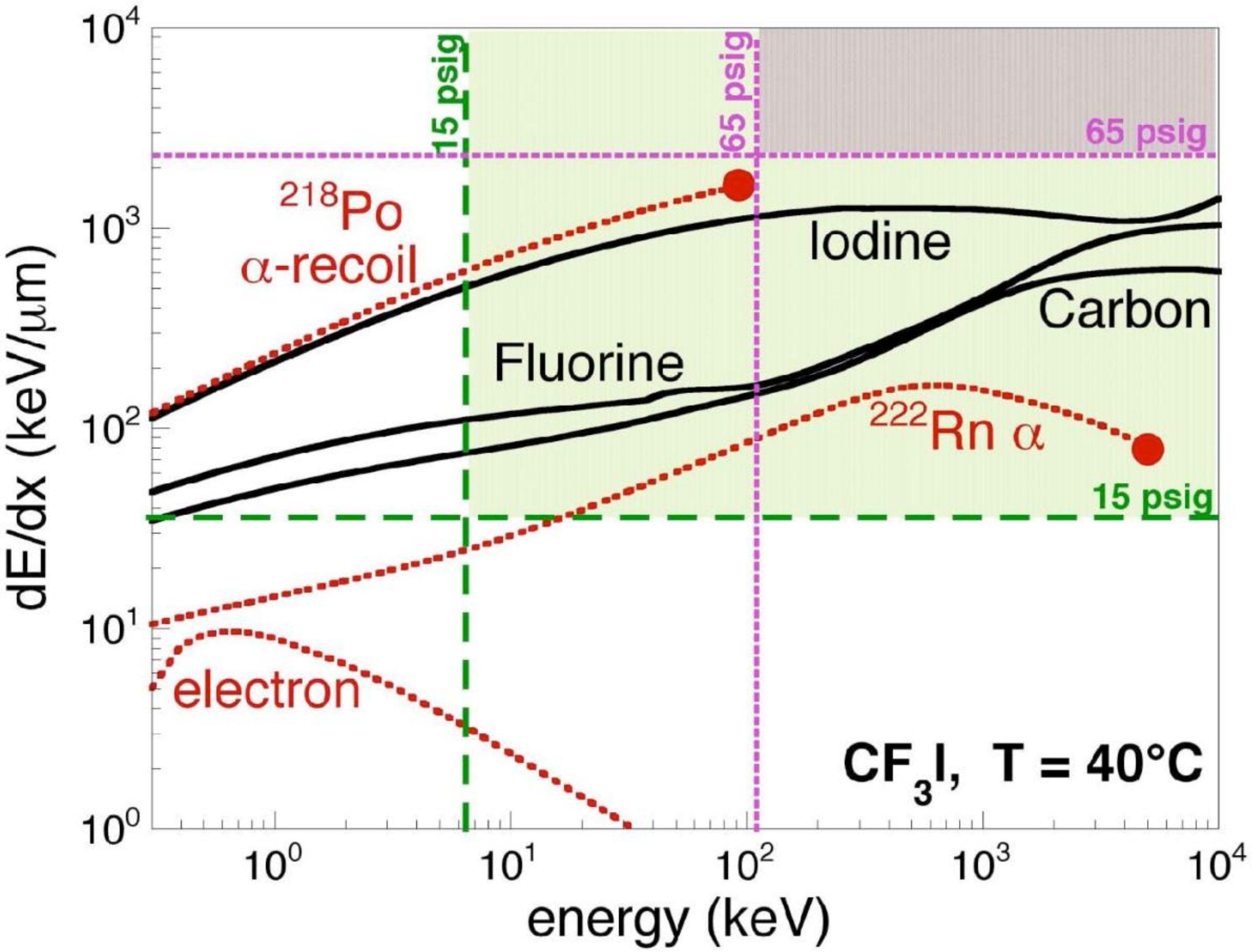


DES is sensitive to Dark Energy via 4 probes.

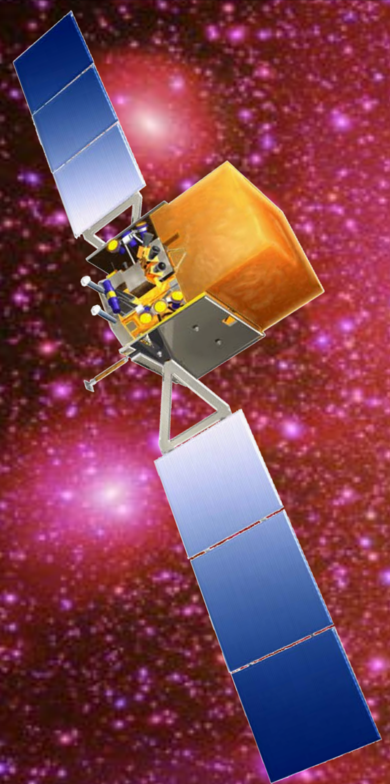
Planck results will be used in DES analyses.

Why bubble chambers?

- Only proto-bubbles with $r > r_{crit}$ grow to be macroscopic
- Better than 10^{-10} rejection of electron recoils (betas, gammas).
- Alphas are (were) a concern because bubble chambers are threshold detectors.



Search for Dark Matter with the Fermi Large Area Telescope



Aldo Morselli

INFN Roma Tor Vergata

on behalf of the Fermi-Lat Collaboration

ICHEP2012 Melbourne

36th International Conference on High Energy Physics

ICHEP2012

Melbourne 7 Jul 2012

Summary

CDMS has been a long-time leader in the field of direct searches for dark matter

iZIP design vastly improves background rejection, paving the way for < 10^{-46} cm^2 sensitivity to spin-independent WIMP-nucleon scattering *with full control over backgrounds*

10-kg SuperCDMS Soudan has begun and is now collecting data

R&D for the SNOLAB phase is actively underway, aiming for construction in 2014

Stay tuned!

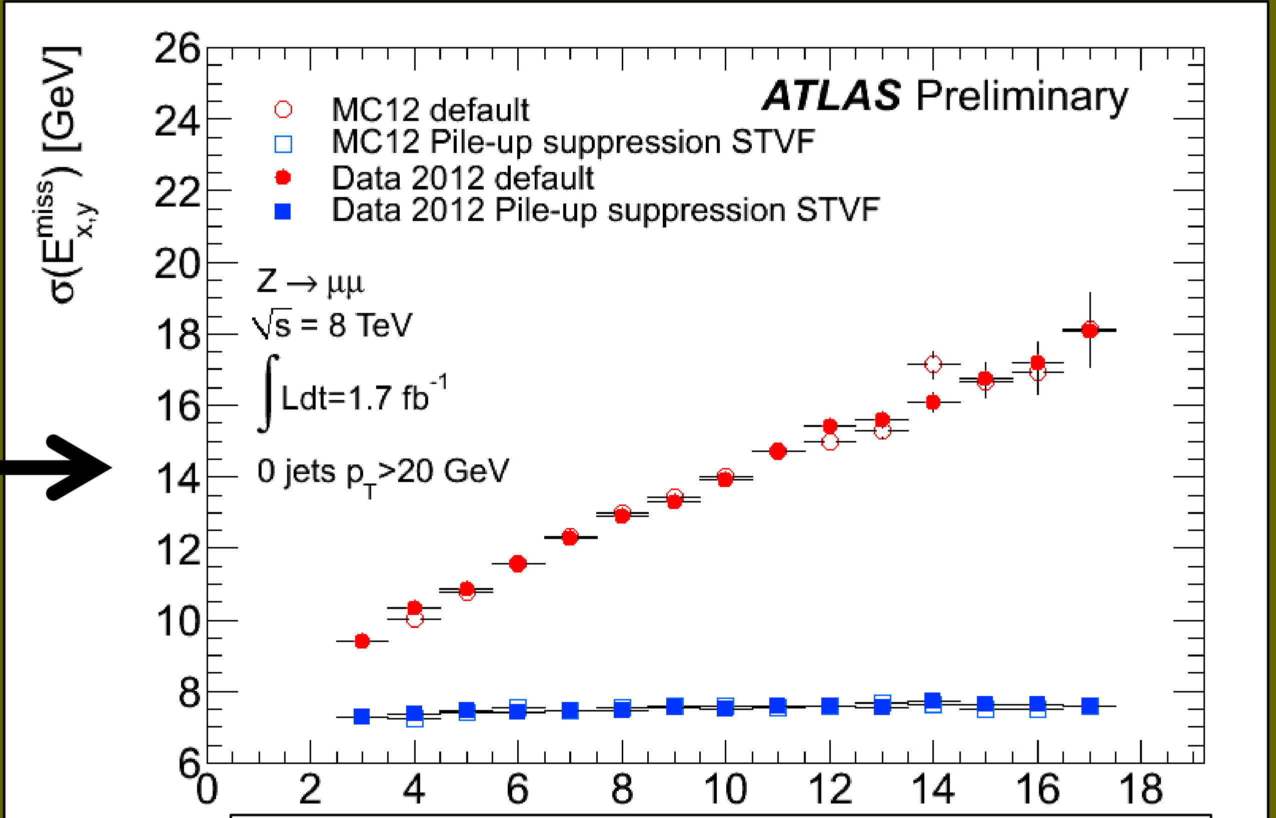
Huge efforts over last months to prepare for 2012 conditions and mitigate impact of pile-up on trigger, reconstruction of physics objects (in particular E_T^{miss}, soft jets, ..), computing resources (CPU, event size)

- Pile-up robust, fast trigger and offline algorithms developed
- Reconstruction and identification of physics objects (e, γ, μ, τ, jet, E_T^{miss}) optimised to be ~independent of pile-up → similar (better in some cases!) performance as with 2011 data
- Precise modeling of in-time and out-of-time pile-up in simulation
- Flexible computing model to accommodate x2 higher trigger rates and event size as well as physics and analysis demands

Understanding of E_T^{miss} (most sensitive to pile-up) is crucial for H→ WW(*) → lνlν , W/ZH→W/Zbb, H→ττ

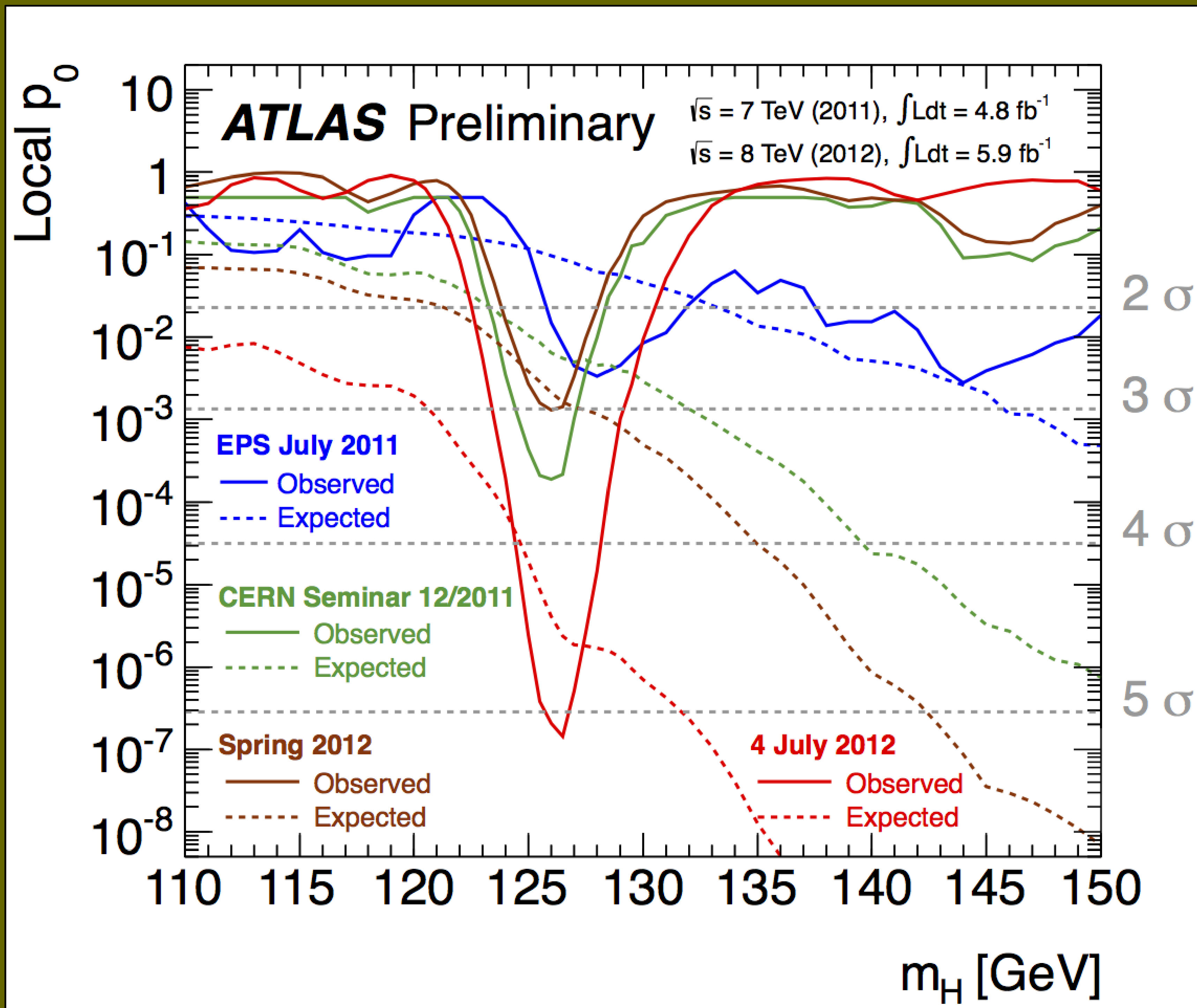
E_T^{miss} resolution vs pile-up in Z→ μμ events **before** and ***after*** pile-up suppression using tracking information

Note: number of reconstructed primary vertices is ~ 60% number of interactions per crossings



Number of reconstructed primary vertices

Evolution of the excess with time



Energy-scale systematics not included

WHAT ARE THE COMPONENTS OF A PRESENTATION?

A presentation is a story.

1. Title Slide (1 slide):
   a) Title of your presentation
   b) Name, date, venue
   c) Affiliation
2. Outline (1 slide):
   a) Tell your audience what you are going to tell them
3. Body (~ 6 - 12 slides)
   a) Contains all the details including introductory material and is the main focus of the talk.
4. Conclusion(1 slide):
   a) Tell your audience what you told them.
5. Sources (1 slide):

NUTS AND BOLTS

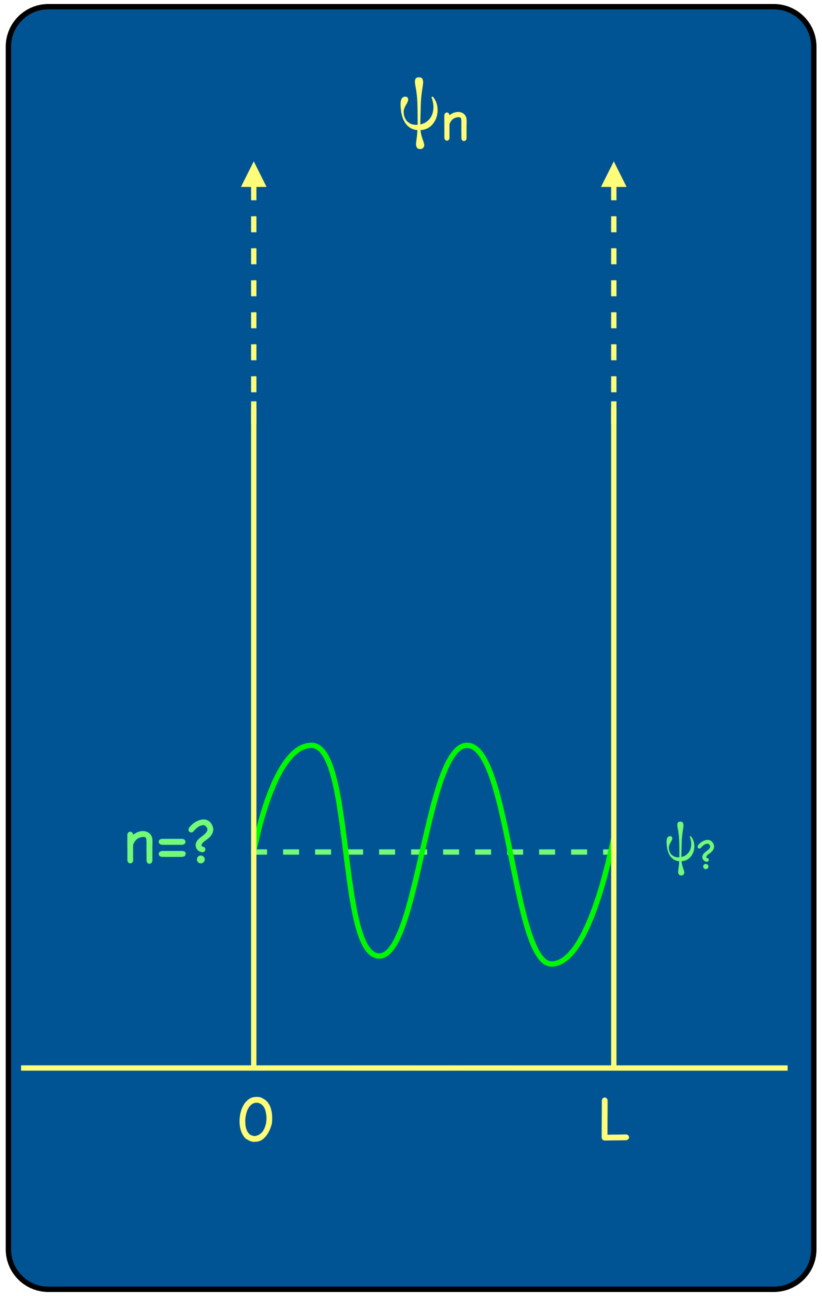
- Visual Aides: can help illustrate your point
- Plots: Make sure to describe them and tell the audience what they mean
- Textual Points -- NOT paragraphs
- Mathematical Expressions -- explain in words what they mean

WHAT ARE ASPECTS OF GOOD SLIDES?

- Use a clear title and outline your points
- Do not put too much on a slide. Don't use too small of font and pick a font that is readable.
- Think about what colors you are using. Slides need to be readable.
- Number your slides.
- Put your name, the date and the venue at the footer of each slide.
- Spend a proper amount of time on each slide (1-2 minutes is typically good)

REVIEW QUESTION 1

An electron is in a one-dimensional infinite square well potential. A graph of its wave function ψ(x) versus x is shown in the figure. What is the value of the quantum number n ?



A) 0

B) 1

C) 2

D) 3

E) 4

F) 5

Review from Video Lecture:

The SWE for a harmonic Oscillator:

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2} + \frac{1}{2}\kappa x^2\psi(x) = E\psi(x)$$

Form of the general solution:

$$\psi(x) = Ae^{-ax^2}$$

Solving for energy gives:

$$E = (n + \frac{1}{2})\hbar\omega_0$$

where

$$\omega_0 = \sqrt{\frac{\kappa}{m}}$$

Review from Video Lecture:

2. Their is a unique wave function for each energy.

   - The wave functions are the product of normalization factors, gaussian factors and Hermite polynomials.

   - The simple Gaussian we computed is the GROUND STATE of the system

TABLE 5.1 Harmonic oscillator solutions

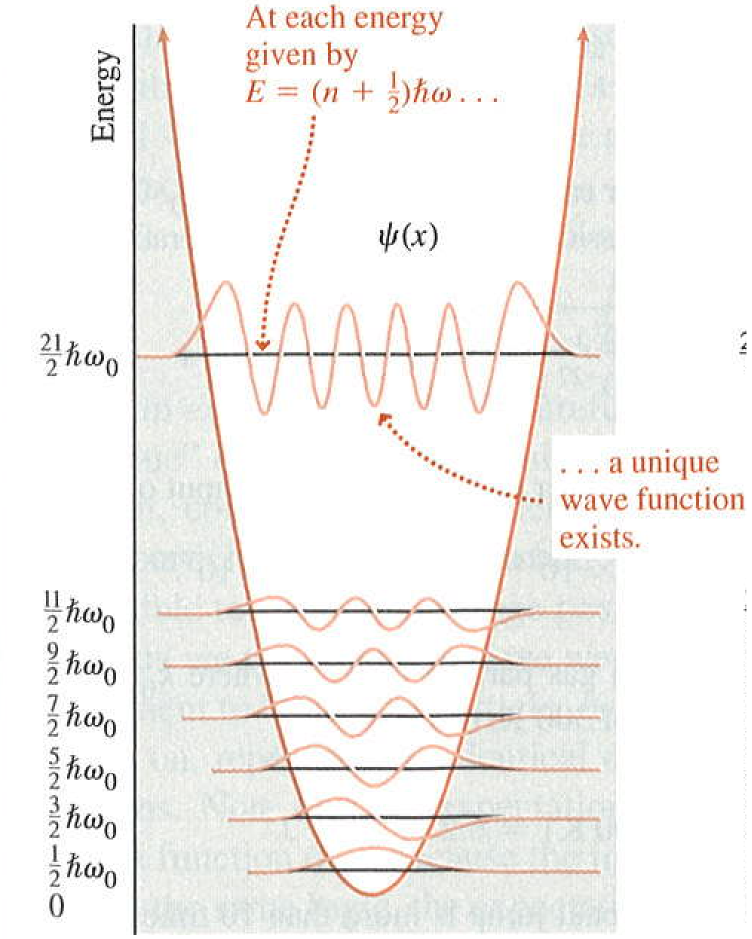
n	$\psi_n(x)$
0	$\left(\frac{b}{\sqrt{\pi}}\right)^{1/2} e^{-\frac{1}{2}b^2x^2}$
1	$\left(\frac{b}{2\sqrt{\pi}}\right)^{1/2} (2bx)e^{-\frac{1}{2}b^2x^2}$
2	$\left(\frac{b}{8\sqrt{\pi}}\right)^{1/2} (4b^2x^2 - 2)e^{-\frac{1}{2}b^2x^2}$
3	$\left(\frac{b}{48\sqrt{\pi}}\right)^{1/2} (8b^3x^3 - 12bx)e^{-\frac{1}{2}b^2x^2}$
n	$\left(\frac{b}{2^n n!\sqrt{\pi}}\right)^{1/2} H_n(bx)e^{-\frac{1}{2}b^2x^2}$

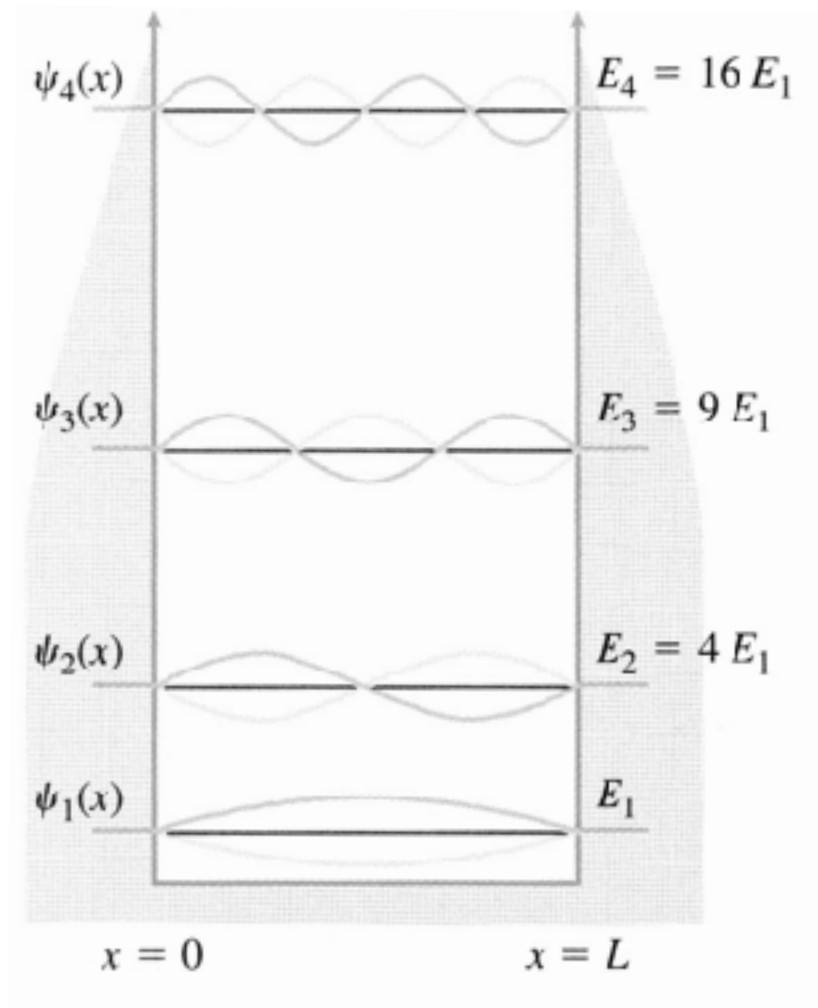
Note: $b \equiv (m\kappa/\hbar^2)^{1/4}$

FOOD FOR THOUGHT

The quantized energy levels in an infinite well get further apart as n increased, but in the harmonic oscillator they are equally spaced. Why?

Consider the distance between the potential "walls" and what happens to the wavelength, momentum and energy.

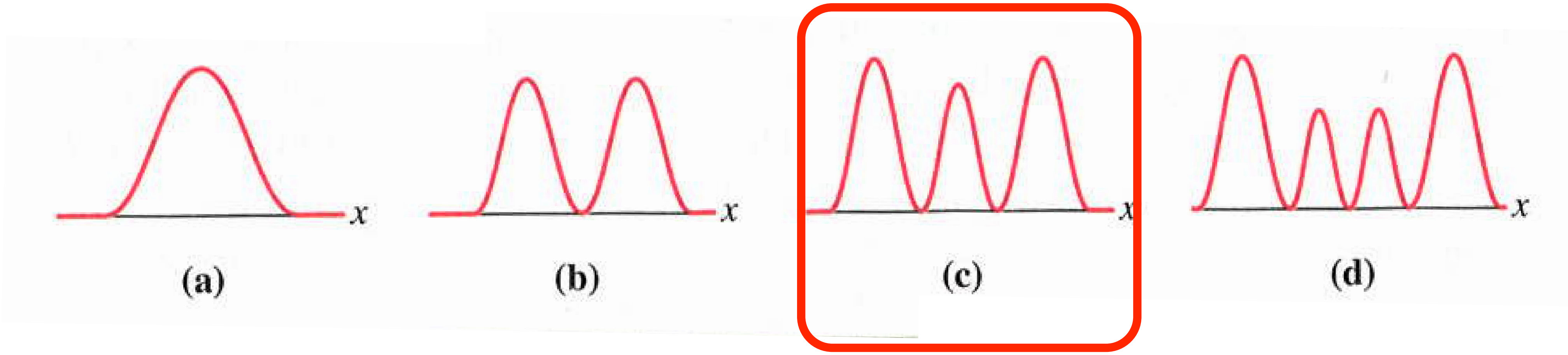


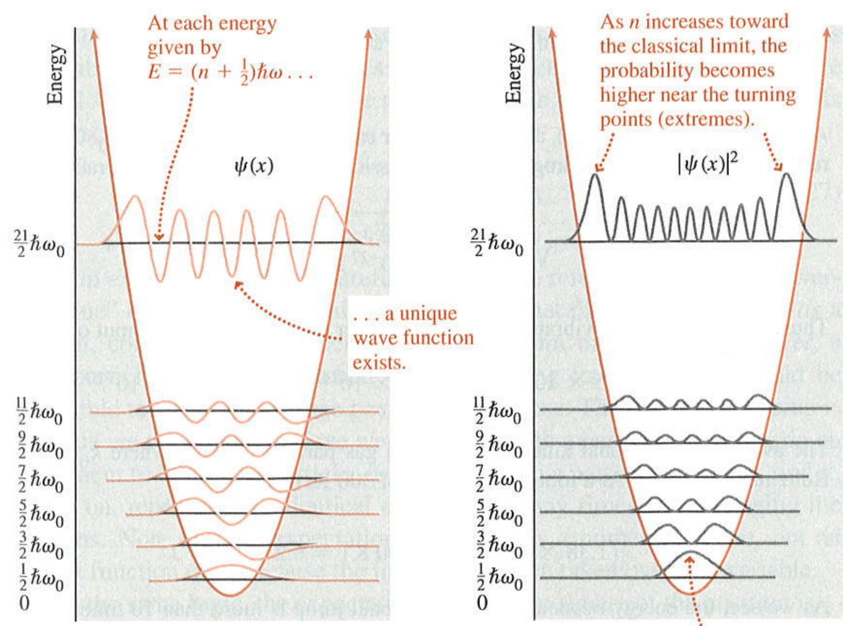


The potential "walls" get further apart as total energy increases for the harmonic oscillator. This results in evenly spaced energy levels. The higher levels of the infinite well are more closely confined. Compared to the oscillator, they would have a shorter wavelength, higher momentum and thus would have higher energy for a given energy state.

Which probability density represents a quantum harmonic oscillator with

$$E = \frac{5}{2}\hbar\omega$$





$$E = (n + \frac{1}{2})\hbar\omega_0$$

The ground state energy of an oscillating electron is 1.24 eV. How much energy must be added to the electron to move to the second excited state?

Energy levels are given by

$$E = (n + \frac{1}{2})\hbar\omega_0$$

Thus, the difference between neighboring energy level is

$$\Delta E = \hbar\omega$$

We are given the ground state energy. Thus,

$$E_0 = \frac{1}{2}\hbar\omega_0 \longrightarrow \hbar\omega_0 = 2E_0$$

Putting it together:

$$E_{0\rightarrow 2} = 2\hbar\omega_0 = 2(2E_0) = 4(1.24\ eV)$$

$$\boxed{E_{0\rightarrow 2} = 4.96\ eV}$$

The period of a macroscopic pendulum made with a mass of 10 g suspended from a massless cord 50 cm long is 1.42 s.

a) Compute the ground-state (zero-point) energy.

$$E_0 = (0 + \frac{1}{2})\hbar\omega_0$$

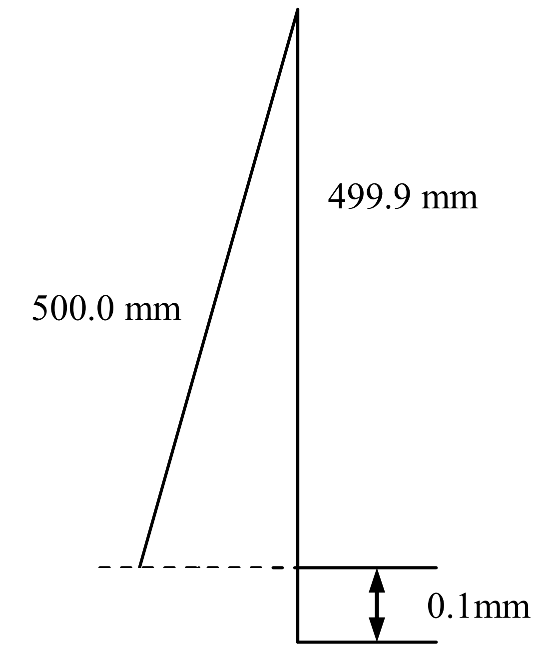
$$= \frac{1}{2}\hbar(\frac{2\pi}{T})$$

$$= \frac{1}{2}(1.055 \times 10^{-34}\ J \cdot s)(\frac{2\pi}{1.42s})$$

$$E_0 = 2.3 \times 10^{-34}\ J$$

The period of a macroscopic pendulum made with a mass of 10 g suspended from a massless cord 50 cm long is 1.42 s.

b) If the pendulum is set into motion so that the mass raises 0.1 mm above its equilibrium position, what will be the quantum number of the state?



Use conservation of energy. At the max height:

$$E = U$$

$$(n + \frac{1}{2})\hbar\omega_0 = mgy$$

$$n = \frac{mgy}{\hbar\omega_0} - \frac{1}{2} = \frac{mgy}{2E_0} - \frac{1}{2} = \frac{(0.01\ kg)(9.8\ m/s^2)(0.1 \times 10^{-3}\ m)}{2(2.3 \times 10^{-34}\ J)} - \frac{1}{2}$$

$$n = 2.1 \times 10^{28}$$

THE END
(FOR TODAY)