PHYS 142/242

Lecture 01: Introduction

Javier Duarte — January 6, 2025

Welcome to PHYS 142/242

- Fill out the pre-course survey: https://forms.gle/7n7L81ptCvqWX7pVA
- Let's review the syllabus
- Instructor: Javier Duarte (jduarte@ucsd.edu), Office hours after lecture M or by appt.
- TA: Anthony Aportela (aaportel@ucsd.edu), Office hours during/after lab TuTh
- Learning outcomes:
  - Design computer programs to numerically solve physics problems, like the harmonic oscillator using the Feynman path integral approach
  - Consider multiple approaches and compare their computational performance, accuracy, and fidelity to physical laws
  - Find and choose the best tool or programming language for the task
  - Visualize the solutions
  - Collaborate with peers to tackle complex, realistic problems
  - Present findings

Assignment breakdown

- 30% Homework
- 15% Quizzes
- 10% Participation and attendance
- 20% Midterm project
- 25% Final project

Attendance

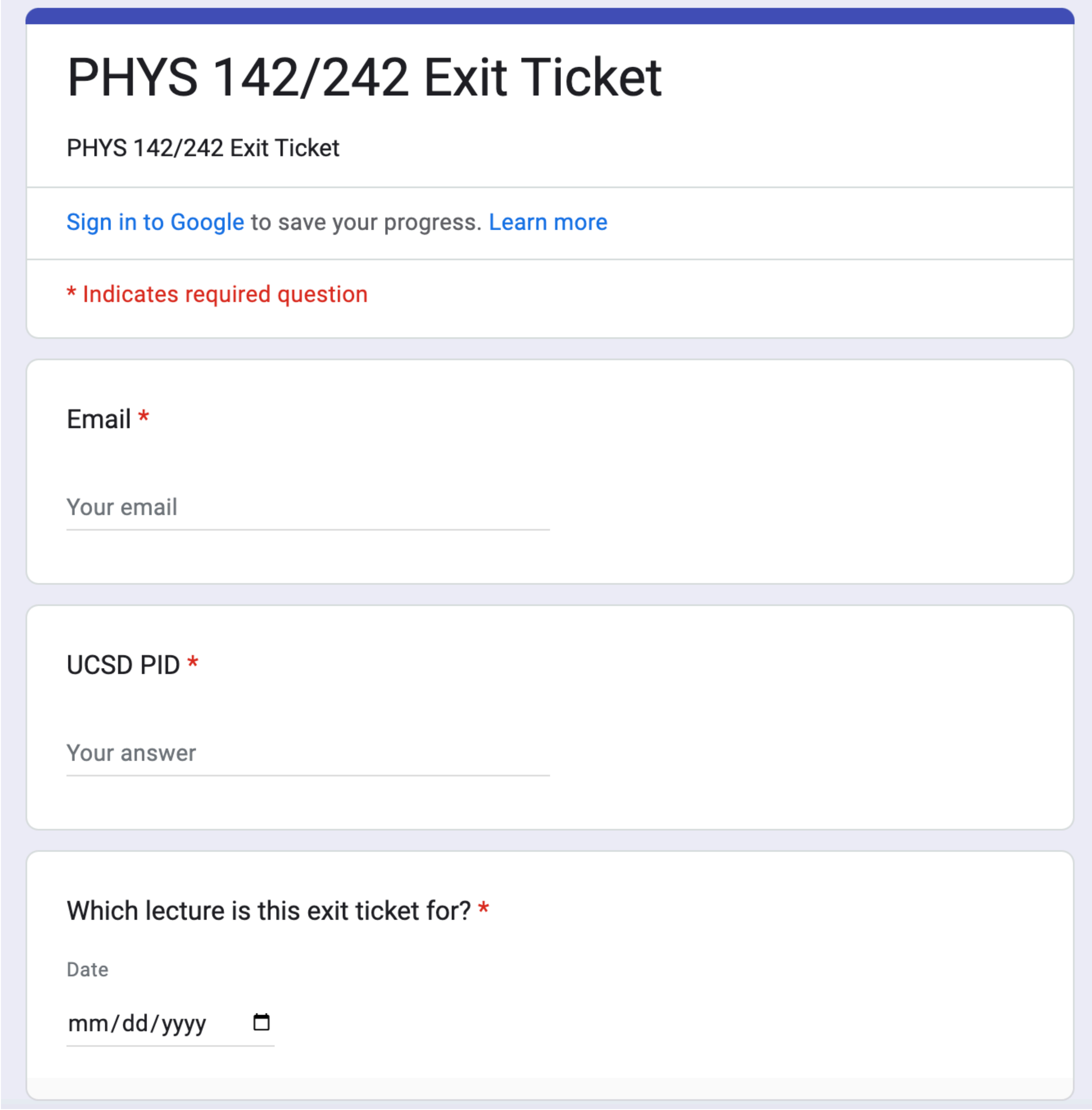
- Lecture attendance (5%)
    - To record your attendance, write your name on the whiteboard or chalkboard either at the beginning or end of lecture.
    - The full 5% will be awarded for attending 80% of the lectures.
- Lab attendance (5%)
    - Similar to lecture, write your name on the whiteboard or chalkboard either at the beginning or end of lab.
    - The full 5% will be awarded for attending 80% of the labs.

Homework

- Half of grade will be from turning in first “draft”
  - Graded on effort and completeness (for all problems)
  - Solution released shortly afterward
- Half of grade will be from turning in corrected solution
  - Graded on effort and correctness (for all problems)
  - ***Note: DO NOT just turn in solutions; CORRECT your own first attempt***
- Report (pdf file) uploaded to Gradescope
- Code (zip file) uploaded to Gradescope
- First homework will be released later this week (due in Week 3)

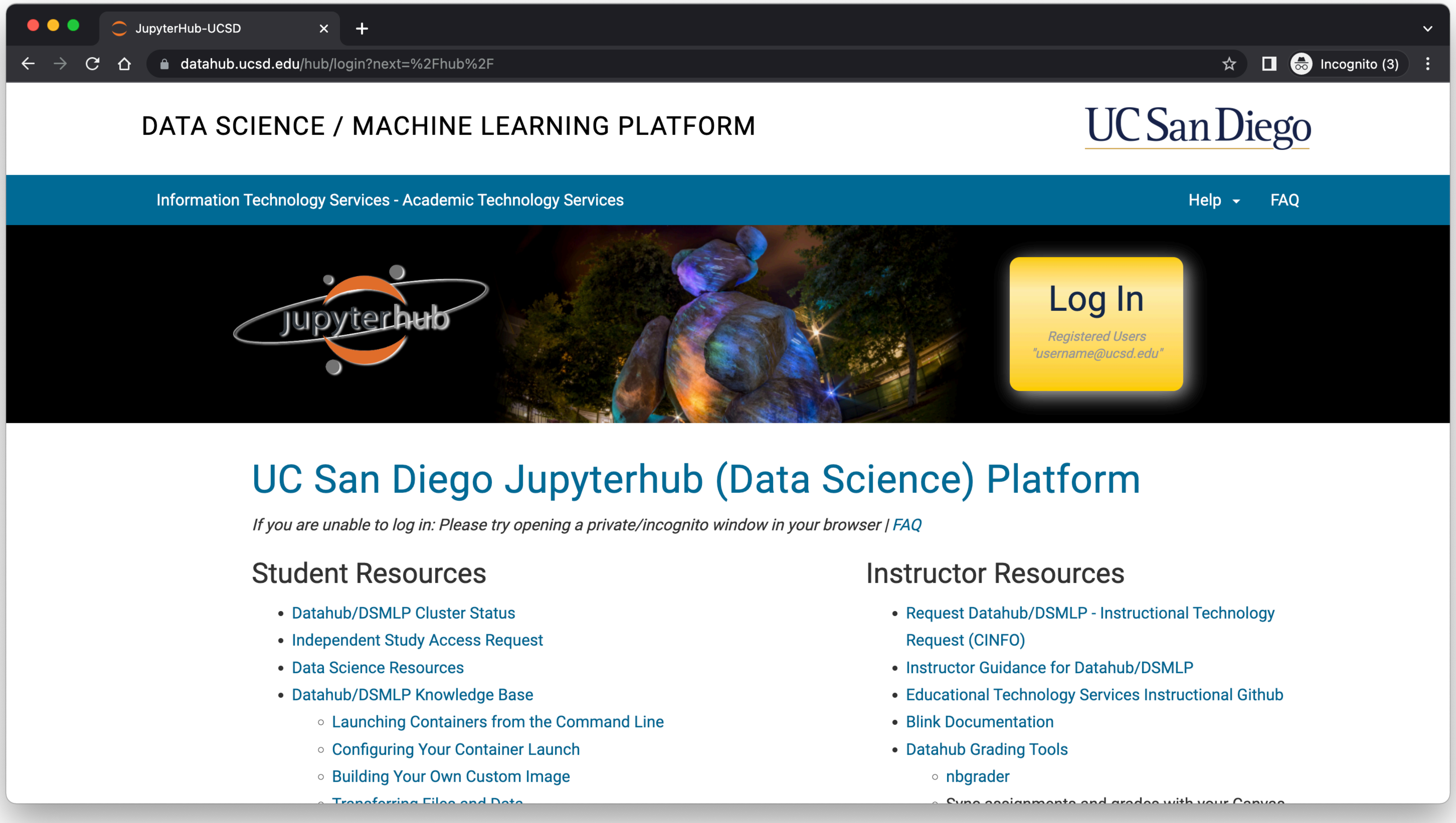
Exit tickets

- Exit tickets: https://forms.gle/opY7EFZJiRBgkMsAA
  - Designed to see how you felt about the lecture, what you took away, whether you have any further questions or feedback
  - Filling it out will go toward the 5% participation score



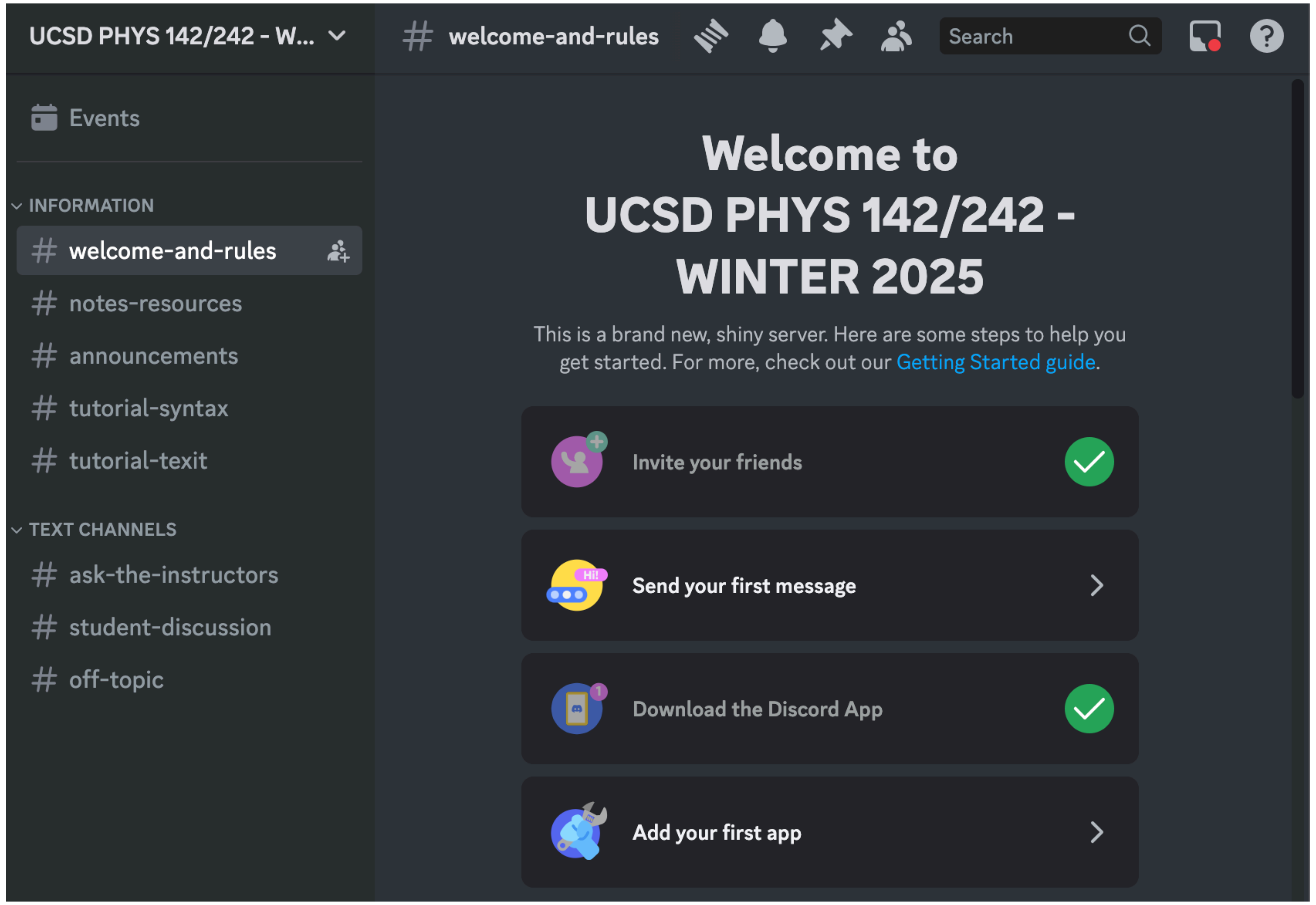
DataHub

- We will use DataHub for in-class hands-on portions
  - Recommend to use it for homework, final project, etc.
- Address: datahub.ucsd.edu
- Similar to public, free services Google Colab, but with access to better CPUs and GPUs and run by UCSD
- Provides a “Jupyter notebook” interface (Python-based but interactive coding like MATLAB/Mathematica)



Discord

- Join the Discord for the course: https://discord.gg/WnDCU6xsGk
- Beginner's Guide to Discord: https://support.discord.com/hc/en-us/articles/360045138571-Beginner-s-Guide-to-Discord
- Feel free to create channels to collaborate with others, etc.

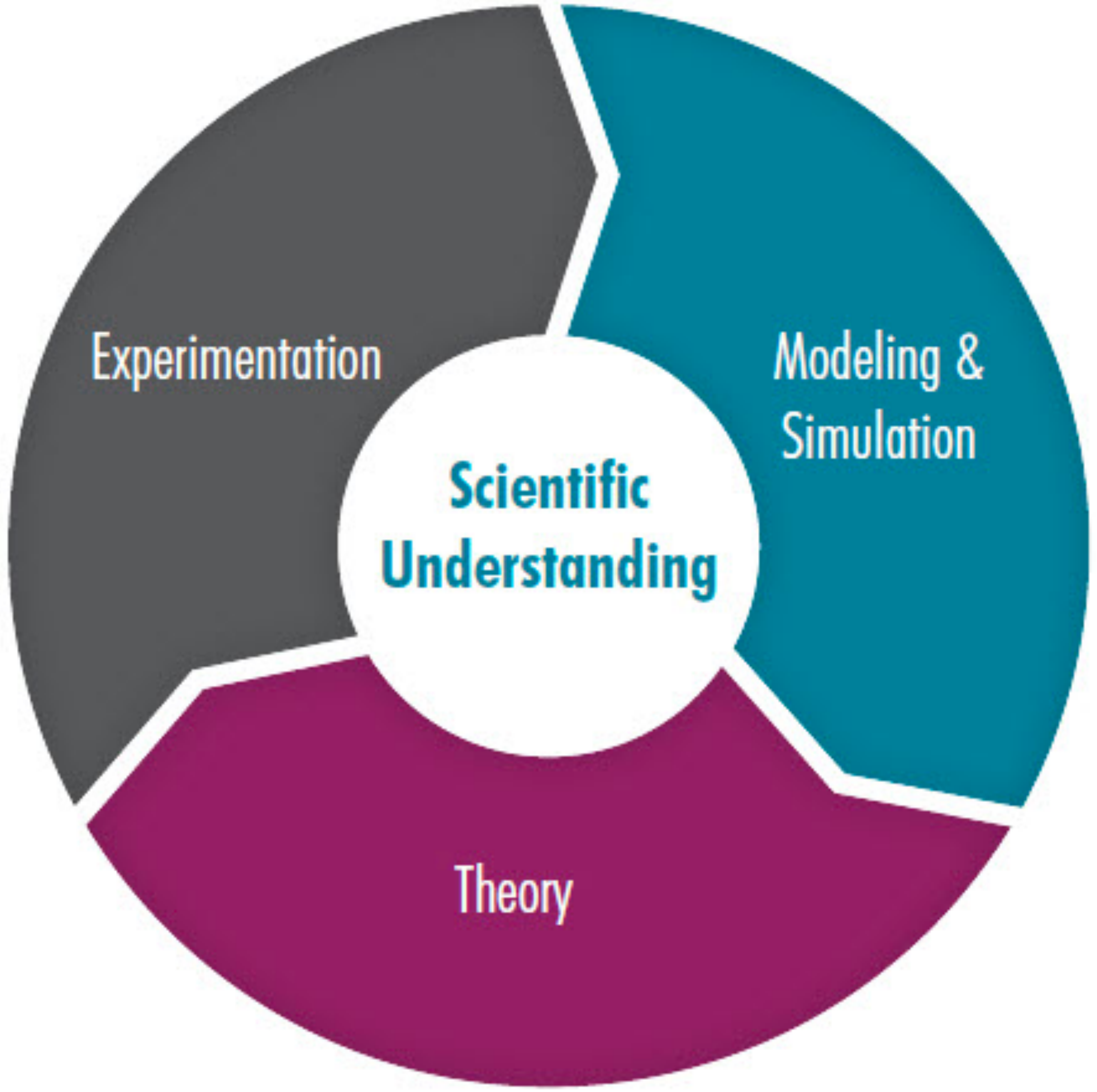


Course overview

- Course overview, preview of double-slit experiments
- Lagrangian mechanics, principle of least action
- Recap of quantum mechanics
- Feynman path integral
- Free particle
- Harmonic oscillator
- Schrodinger equation
- Double well potential
- Recap of statistical mecahnics
- Markov chain Monte Carlo, Metropolis algorithm
- 2D Ising model
- MCMC for Feynman path integral
- VEGAS algorithm
- MC in particle physics; Compton scattering

Computer modeling

- Computer modeling plays a very important role in science today
- Physical sciences are characterized by an interplay between experiment and theory
    - Experiment: a system is subjected to measurements, and results, expressed in numeric form, are obtained
    - Theory: a model of the system is constructed, usually in the form of a set of mathematical equations
- Modeling and simulation live at the intersection between (and supplement) theory and experiment
    - But are not a substitute for real-world experimentation



Three components to modeling

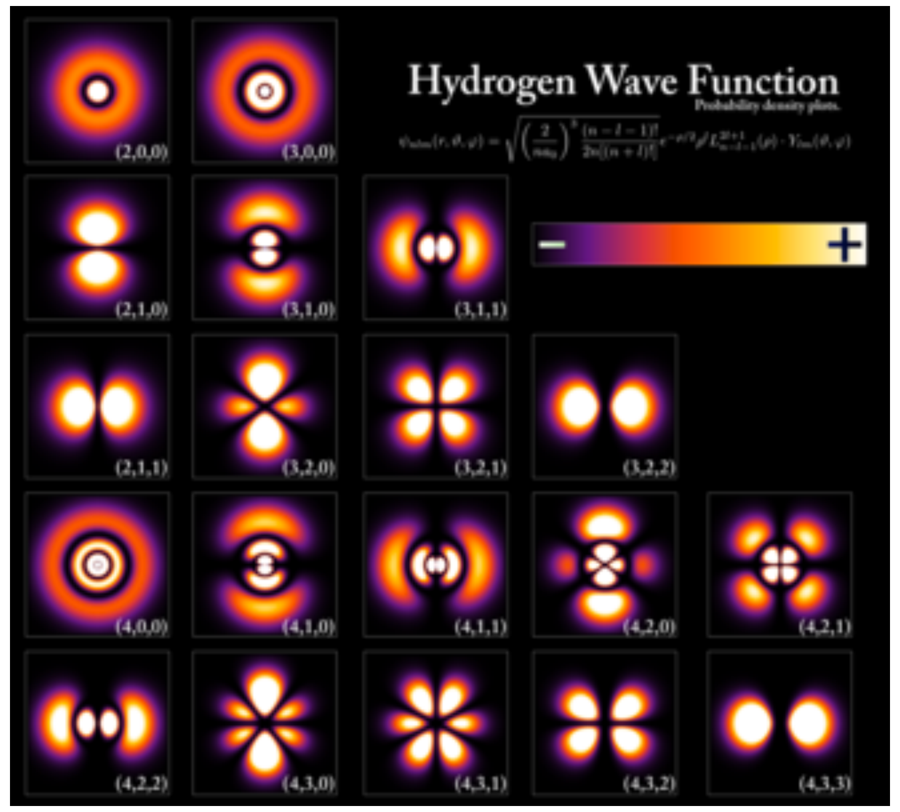
1. The physical problem and its theoretical model

    - Necessary to understand the underlying physics of the problem

    - Only ask the computer to do the things which cannot be done otherwise (e.g. analytically).

    - Development of computer experiments has altered substantially the relationship between theory and experiment, allowing “thought experiments” and more realistic, complex models

    - Creativity is an important component!



Three components to modeling

2. Algorithm and software implementation

    - The advent of high speed computers and “high-level” programming languages, starting with Fortran (1957), C (1972), C++ (1980), Python (1990), Rust (2010), Julia (2012), … made modeling & simulation much more accessible to scientists

Three components to modeling

3. Analysis and visualization

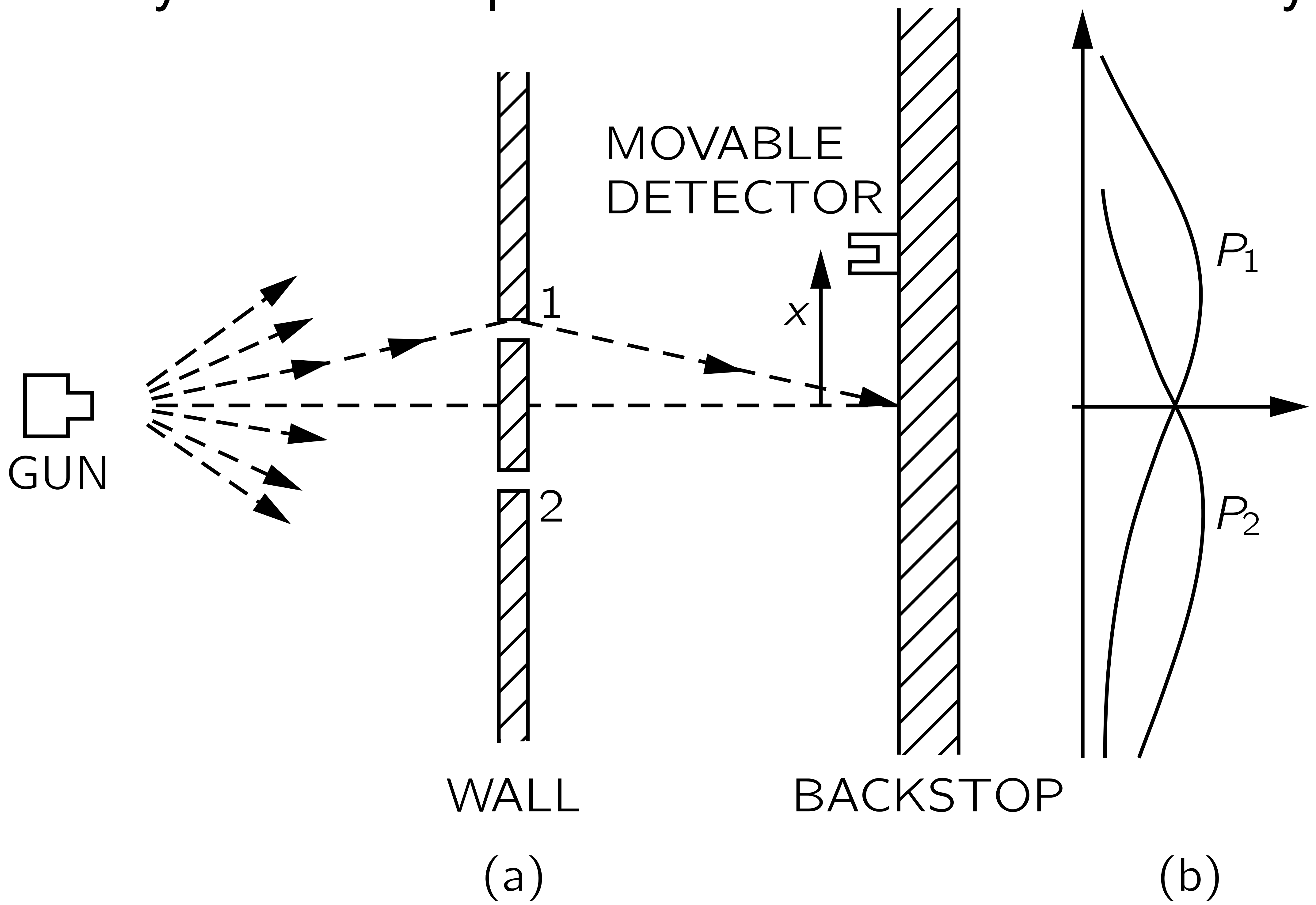
    - Analysis: physical interpretation of the data generated by the computer simulation

    - Visualization tools are indispensable in the interpretation of the results

- For illustration we will discuss solving quantum mechanical and statistical mechanical problems using a variety of approaches, including Feynman Path Integral with Markov chain MC, numerical solutions of Schrödinger Equation, etc.

Double slit: darts

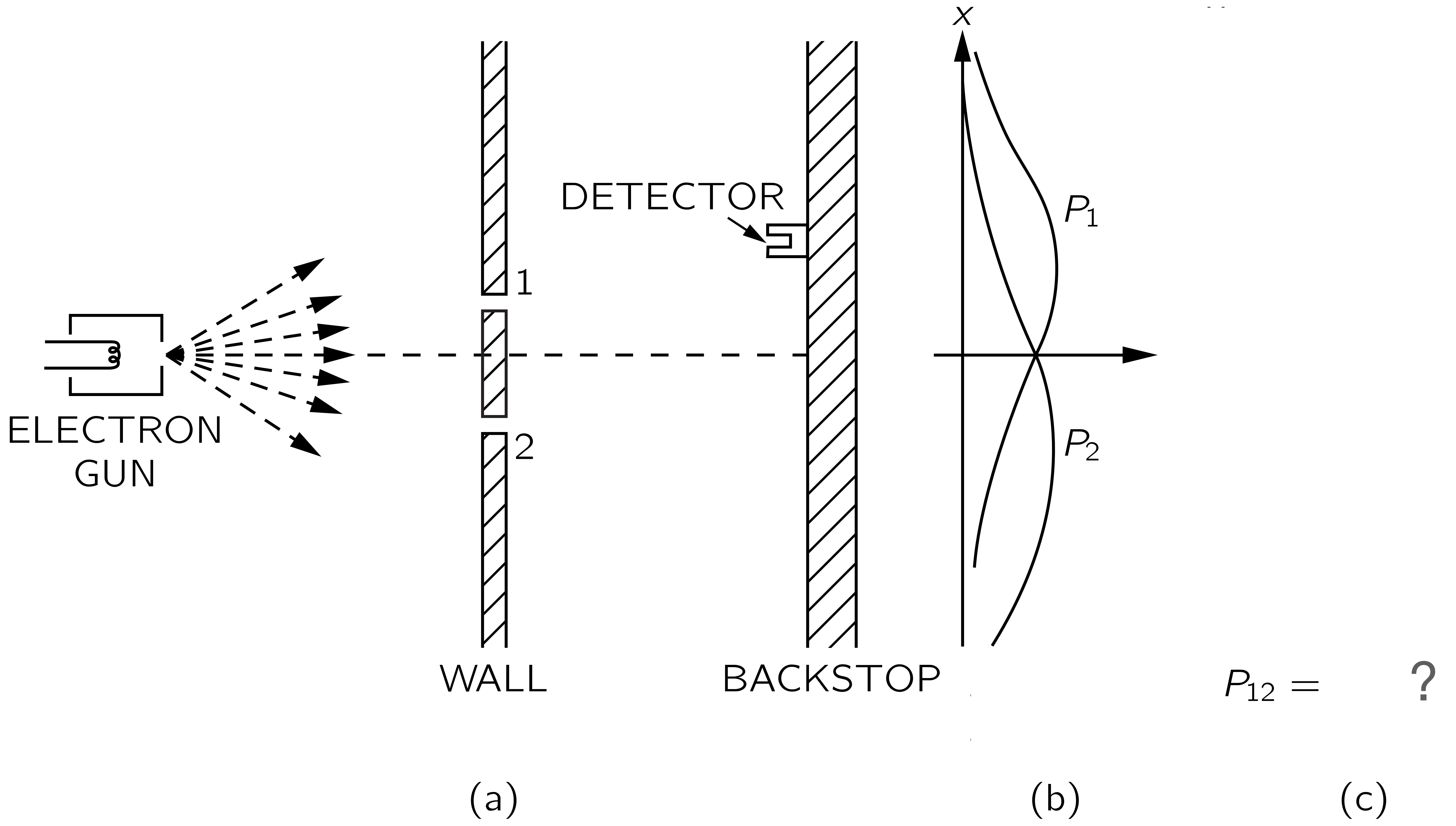
- Classical (macroscopic) behavior, e.g. a Nerf gun
- $P_i(x)$ is the probability a dart hits position x on the screen if only hole i is open



- What is the probability distribution $P_{12}(x)$ if both holes are open?
- Each dart that travels from the Nerf gun to the backstop must go through either hole 1 or 2
- The probability of arrival at x is the sum of two parts: $P_1(x)$ the probability of arrival passing through hole 1, plus $P_2(x)$, the probability of arrival passing through hole 2

Double slit: electrons

- How do individual electrons behave?



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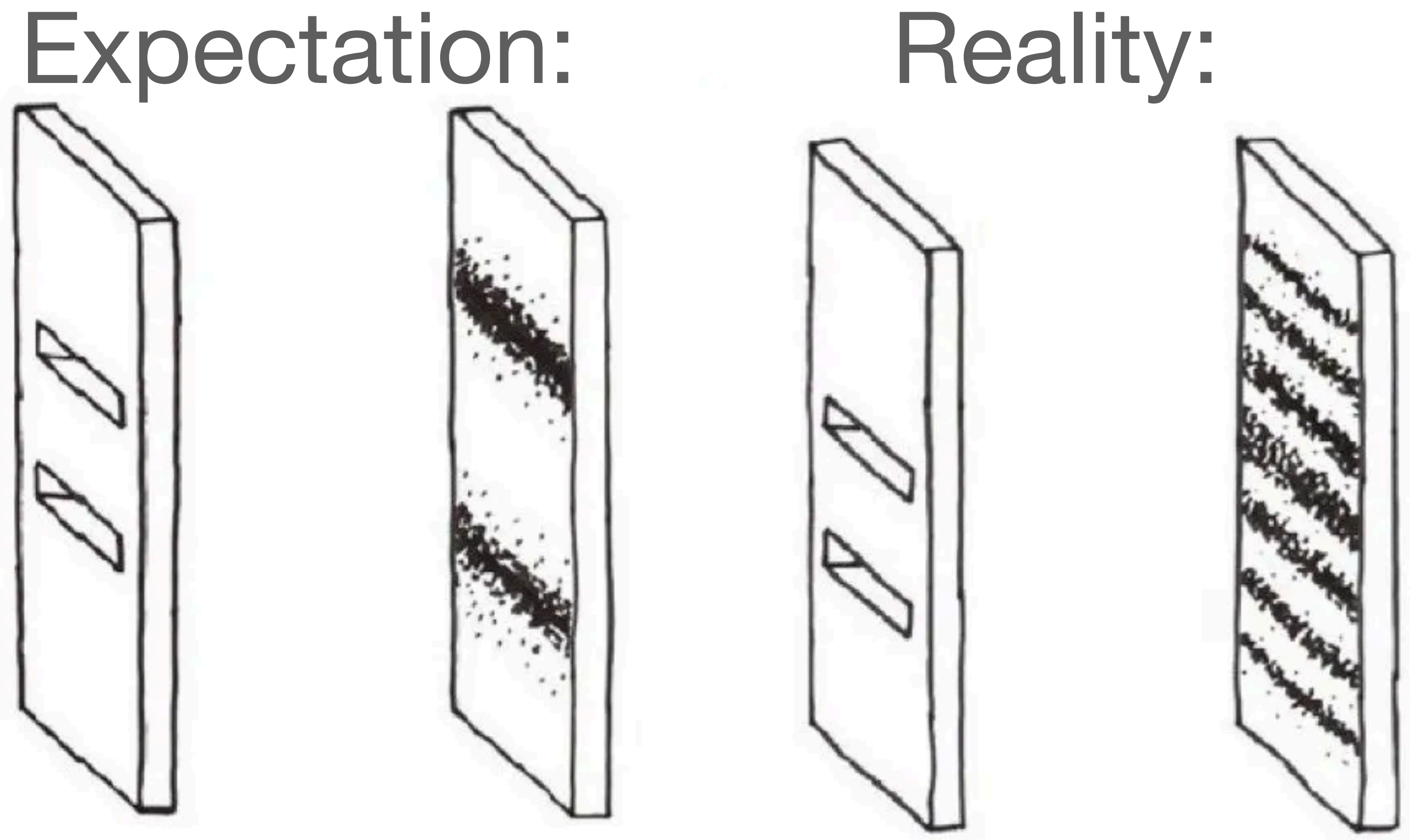
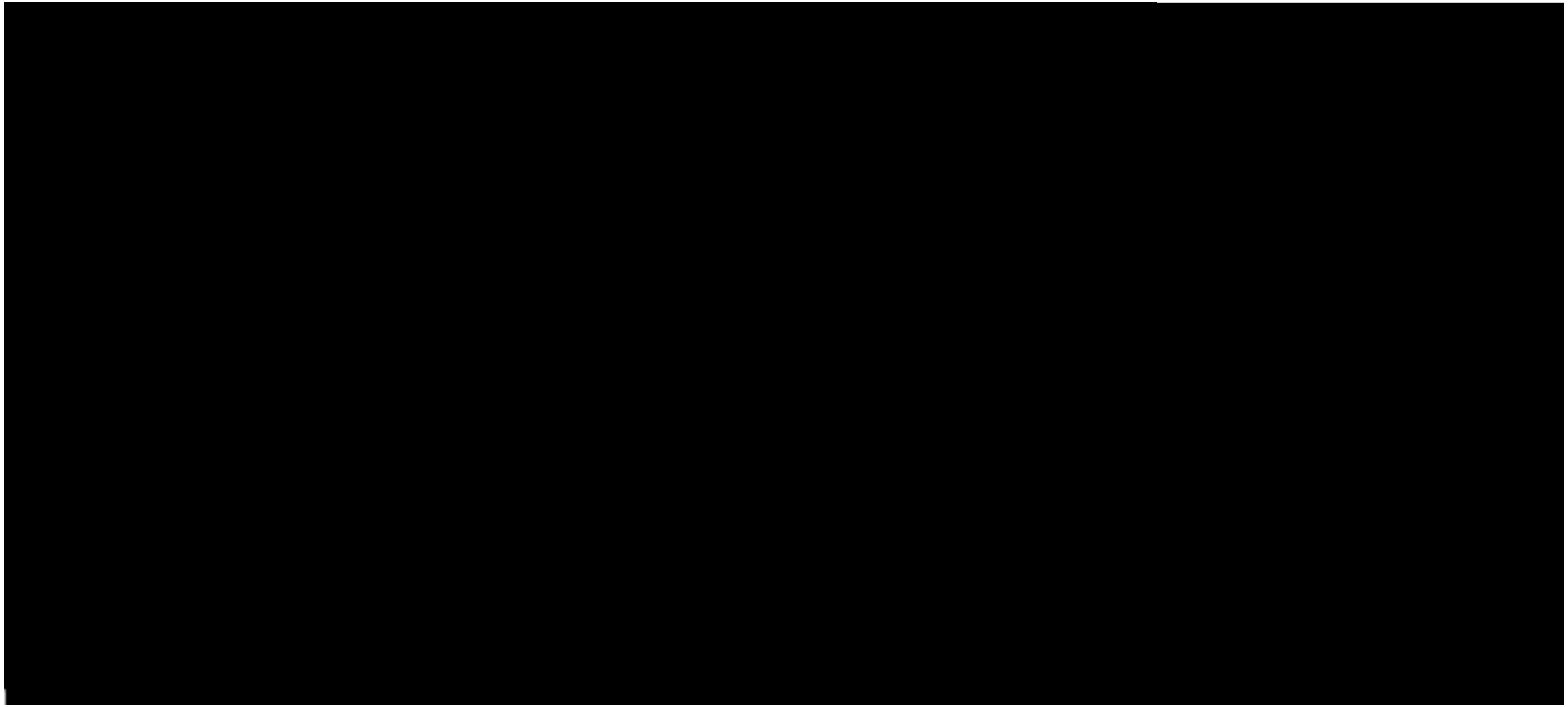
Double slit: 1 electron at a time

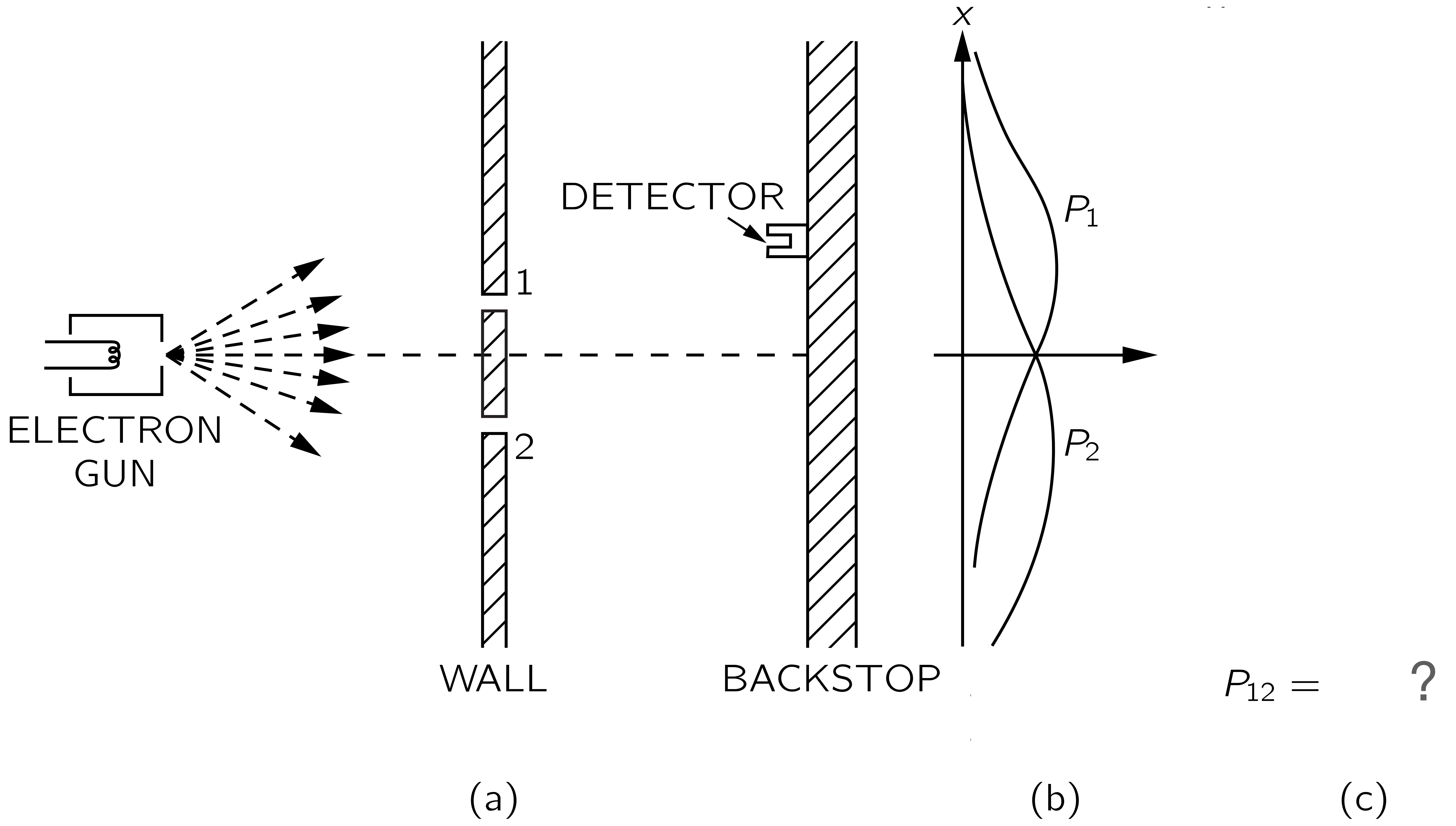


- [Roger Bach et al., "Controlled double-slit electron diffraction", New J. Phys. 15 033018 (2013)]



Double slit: electrons

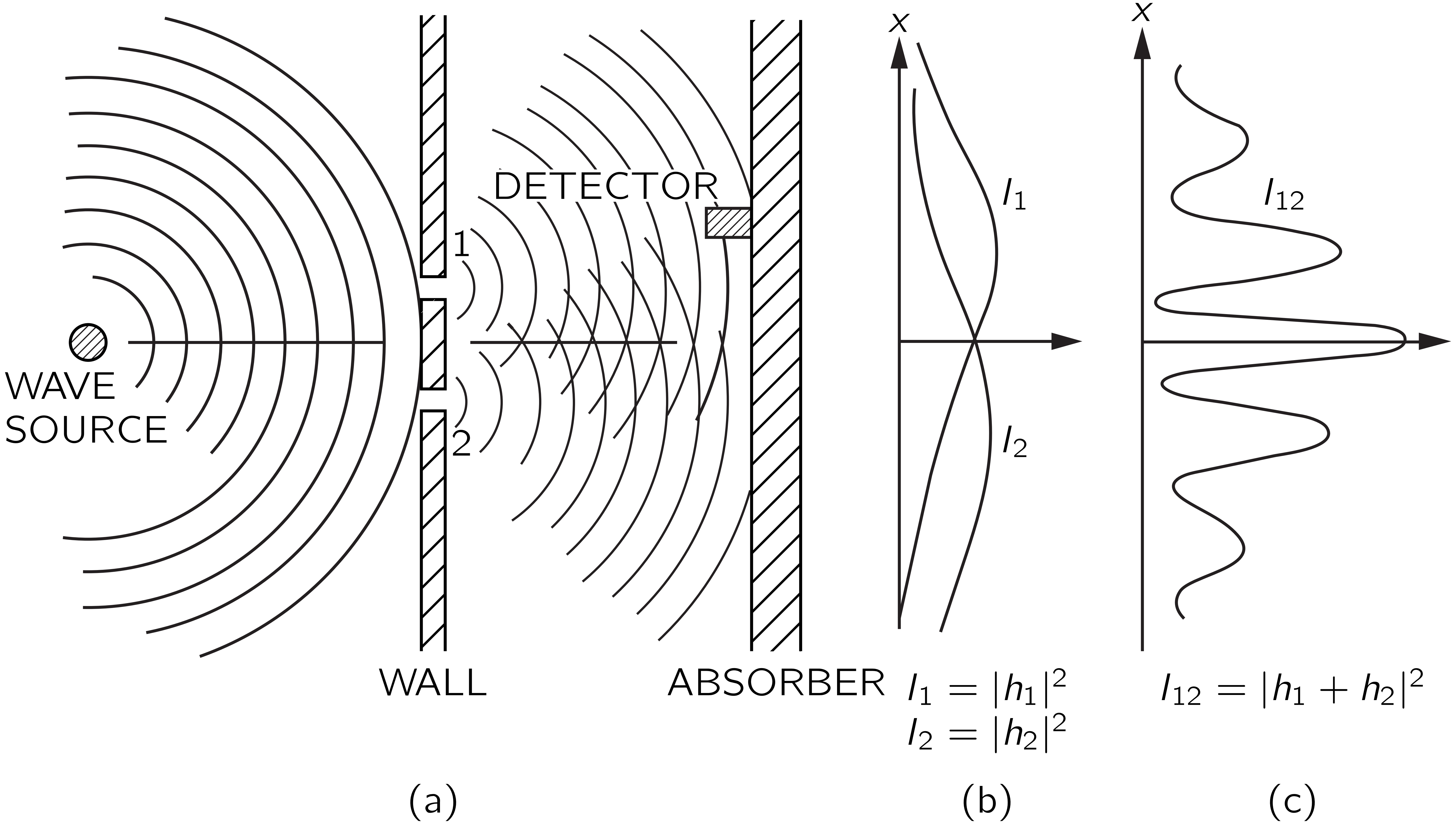
- How do individual electrons behave?



- If we perform the experiment, we observe the following pattern
- Probability amplitude $\phi_i(x)$ for each hole i, and the probability amplitudes sum $\phi_{12}(x) = \phi_1(x) + \phi_2(x)$; interpret ***intensity*** as probability $P_{12}(x) = |\phi_{12}(x)|^2$

Double slit: waves

- This is a familiar phenomenon! Electrons behave like waves



Double slit: meaning

- What does this mean?
  - When both holes are open, ***it is not true that the electron goes through either one hole or the other***
  - ***Instead the two alternatives “interfere”***

Double slit: effect of observation

- What if we put some kind of detector to tell for sure which hole the electron passes through?
- It destroys the interference pattern! Left with the classical behavior
- Just by watching the electrons, we change the probability that they arrive at x
- How is this possible?
  - Detection implies interaction with the electron, e.g. scattering with a photon, which alters its motion and its probability of arrival at x