PHYS 232 Jan. 17, 2025

- Assign. # 1 has been posted on the course website. It is due Friday, Jan. 24 @ 09:00. (Start of class).

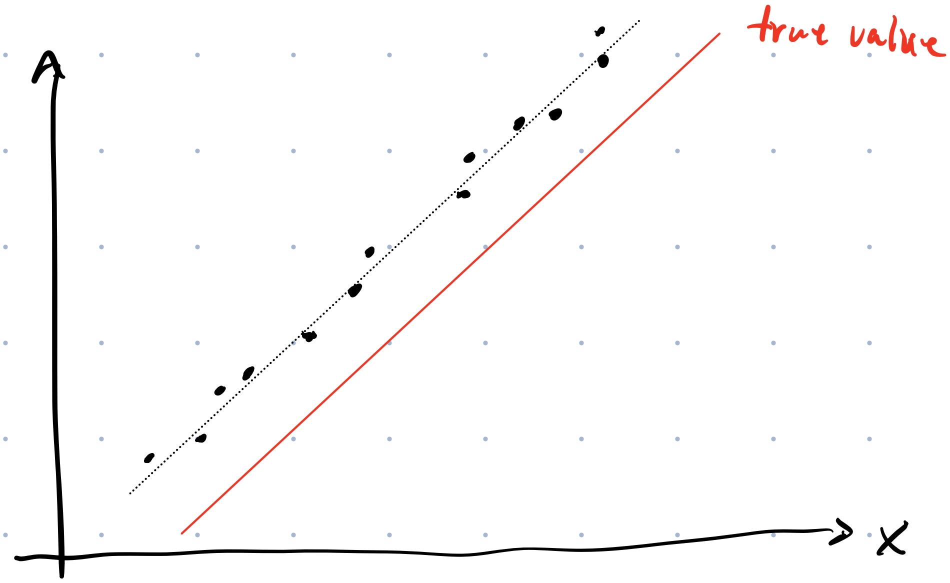
Measurement Uncertainty

In any meas. of a quantity x, must determine from experimental conditions an estimate of our confindence in the measured value.

$\Rightarrow \Delta x$ (uncertainty in meas. value of x).

Accuracy: How close is a meas. to the true value.

Precision: How much fluctuation is there in repeated measurements.



A precise, but inaccurate measurement.

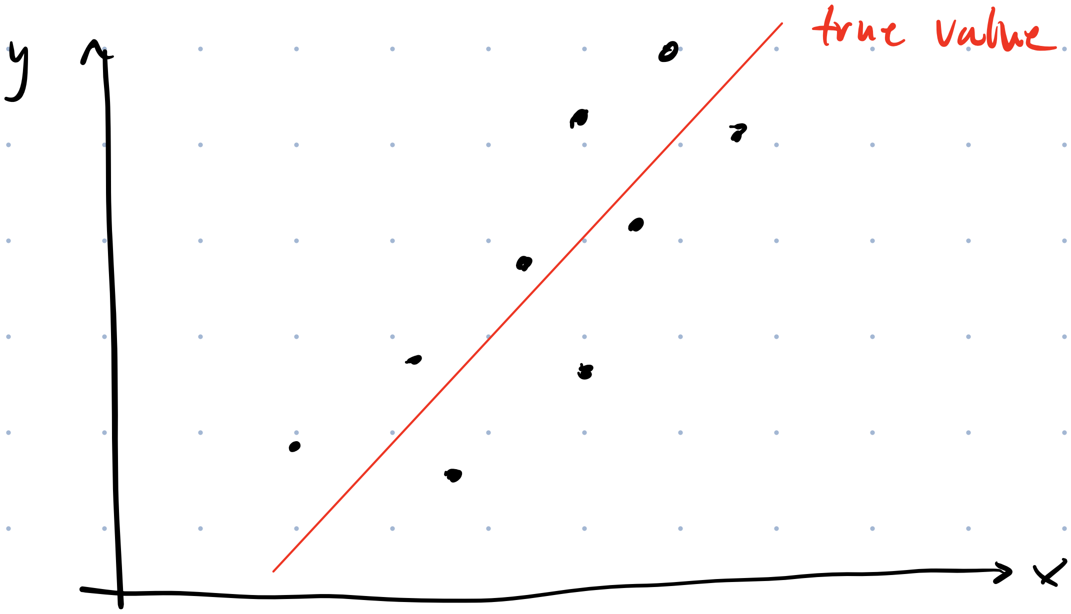
Accuracy of an experiment is largely determined by systematic errors

Errors that make a result reproducibly different than the true value.

→ faulty equipment (improper thermometer calibration, calipers with zero offset, ...)

→ bias in experiment procedure (slow reaction time)

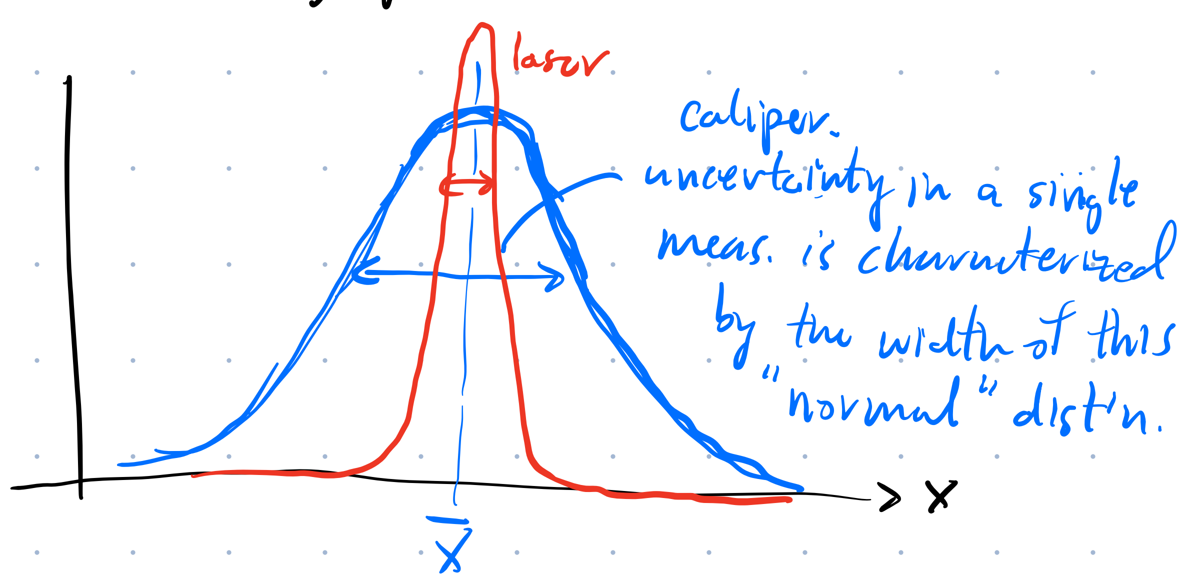
If you are aware of a systematic error, you would correct it.



An imprecise but accurate measurement.

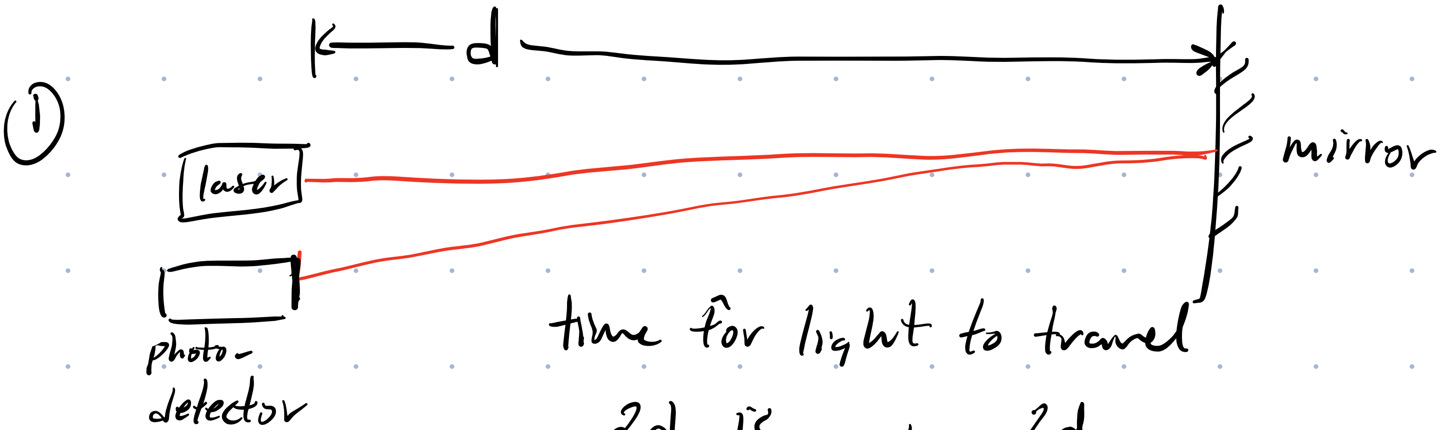
Random errors determine the precision of an experiment.

Eg. Meas. the length of a block of wood w/ calipers. Won't get the same reading each time. Instead, get a dist'n of values.

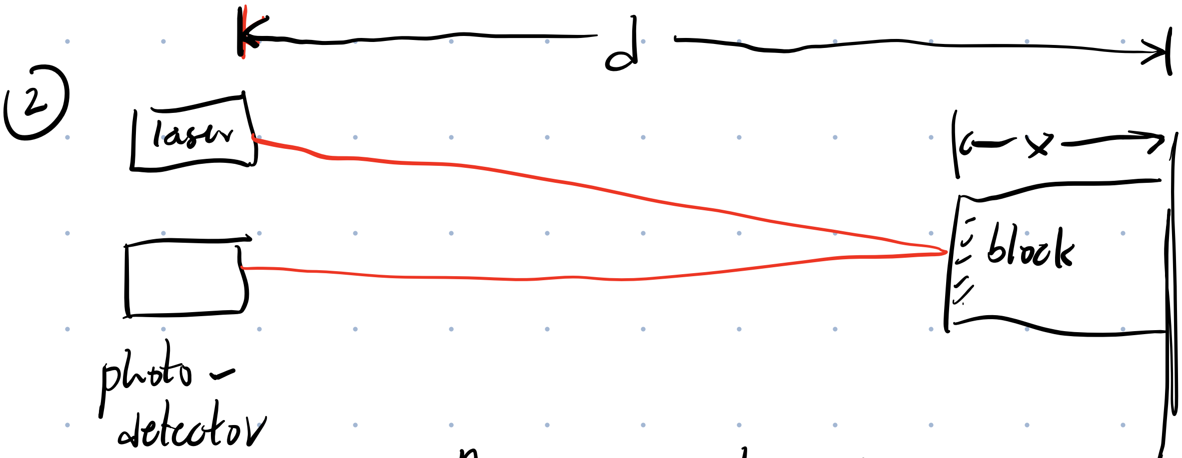


Reducing random errors is acheived through better expermental design or improved equipment.

Eg. Use a laser & photodetector to meas length of block.



time for light to travel 2d is $t_0 = \frac{2d}{c}$



now meas. time is

$$t = \frac{2(d-x)}{c}$$

use meas. of t_0 & t to find x.

Distributions

You have a radioactive sample that emits electrons (Beta decay).

p+n (nucleons)

$$ {}^{A}_{Z}N \longrightarrow {}^{A}_{Z+1}N + e^- + \bar{\nu}_e $$

\# protons

antineutrino

$$ (n \to p + e^- + \bar{\nu}_e) $$

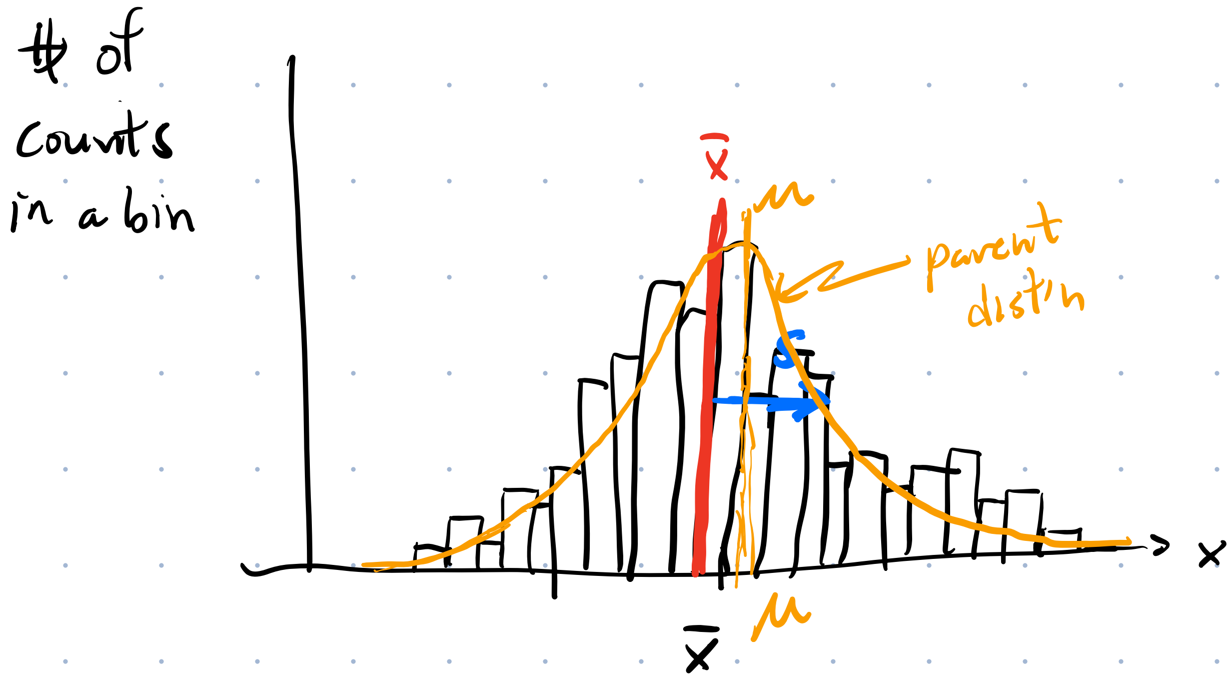
You meas. no. of e^- in a fixed time interval to determine the β decay rate.

trial	counts in Δt
1	12
2	18
3	13
4	17
5	22
⋮	⋮
N	8

Construct a histogram by binning the data and counting the no. of trials that fall within each bin

Eg. bin (12, 13)
(14, 15)
(16, 17)
...

Distribution of meas:



The mean or average of no. of counts is

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i$$

The standard deviation, which characterizes the width of the distribution, is given by:

$$s^2 = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2$$

If we were to take a large no. of meas ($N \to \infty$), then our sample distribution (finite set of N meas) would approach the so-called parent distribution (true dist'n for $N \to \infty$).

mean of parent dist'n is:

$$\mu = \lim_{N\to\infty} \left(\frac{1}{N} \sum_{i=1}^{N} x_i \right)$$

std. dev. of parent dist'n

$$\sigma^2 = \lim_{N\to\infty} \left[\frac{1}{N} \sum_{i=1}^{N} (x_i - \mu)^2 \right]$$

Why does s^2 have a factor of $\frac{1}{N-1}$ instead of $\frac{1}{N}$ like σ?

(see online notes for detailed discussion).

Intutitive argument:

$\sum (x_i - \bar{x})^2$ calculates deviation from $\bar{x}$, but $\bar{x}$ was calculated from x_i data. As a result, $\bar{x}$ is artificially close to the x_i meas.

$\rightarrow \frac{1}{N} \sum (x_i - \bar{x})^2$ would underestimate σ^2. The correction factor turns out to be $\frac{N}{N-1}$.