

PH101 LAB 1

UNCERTAINTY ANALYSIS  
STATISTICS

# Sciencing

- So you have an idea.
- This idea must be *testable* ... or it is not science
- So we test it.
  
- How good is our test? How well did it work?
  - a measure of the result & accuracy
  - does it make any sense? predict something else ...



## SCIENCE IN ACTION

"I'm *Sciencing* as fast as I can!"  
- Professor Farnsworth

# SCIENTIFIC METHOD

### 1. Make an Observation - "What is happening?"

An Observation is when you notice something in the world around you and decide you want to find out more about it.

### 2. Define the Question - "Why is this happening?"

Defining the Question creates an idea that can be tested using a series of Experiments.

### 3. Form a Hypothesis - "I think this happens because..."

A Hypothesis is a statement that uses a few observations, without any experimental evidence, to define why something happens.

### 4. Perform Experiments - "Let's test my Hypothesis..."

An Experiment is a series of tests to see if your Hypothesis is correct or incorrect. For each test, record the data you discover.

### 5. Analyze the Data - "Was my Hypothesis right?"

Analyzing data takes what you found in your experiments and compares it to your Hypothesis. If needed, perform another Experiment to gather better data.

### 6. Conclusion - "Experiments show my hypothesis was..."

Forming a Conclusion presents the Experimental Data and explains how it proves or disproves your Hypothesis. Often, Scientists will take this Conclusion and perform other Experiments on it to discover new things.

# Example

- Does a heavier or lighter object fall faster?
- can't do just one experiment
  - by “chance” one will land first
- do it many times
  - what is the variability?
  - how much is too much?
  - at what point are they basically the same?

# Measurements

- we don't do just one
- make a series of measurements, average them
- this should improve accuracy, right?
- how much? when to stop?
  
- need to quantify degree of uncertainty

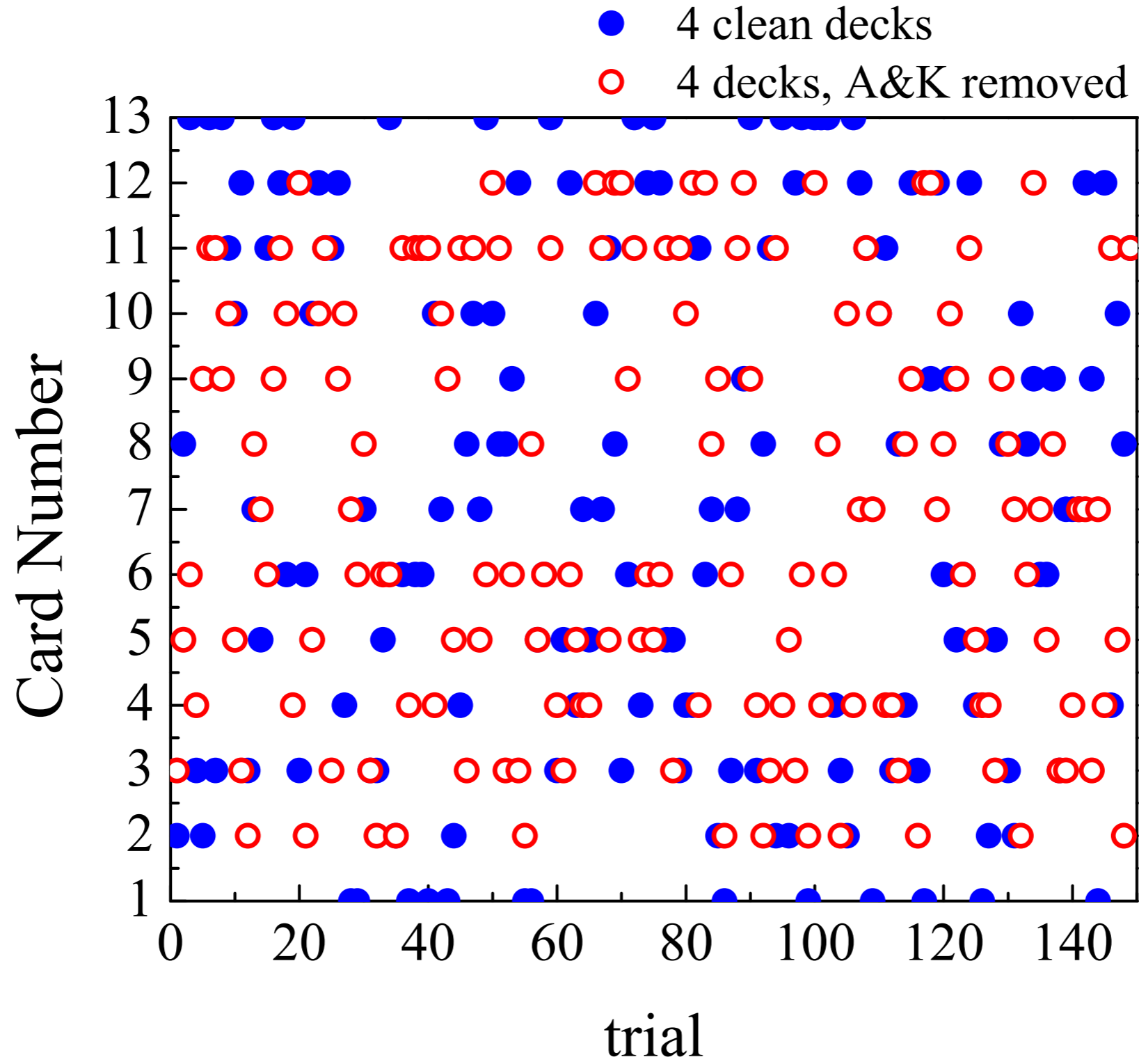
# Today's lab: counting cards

- one measurement vs. many
- how does accuracy improve?
- how to measure accuracy?
- statistical measures of uncertainty & dispersion
  
- if you don't see the whole deck at once, what can you still say?

# The experiment: picking cards

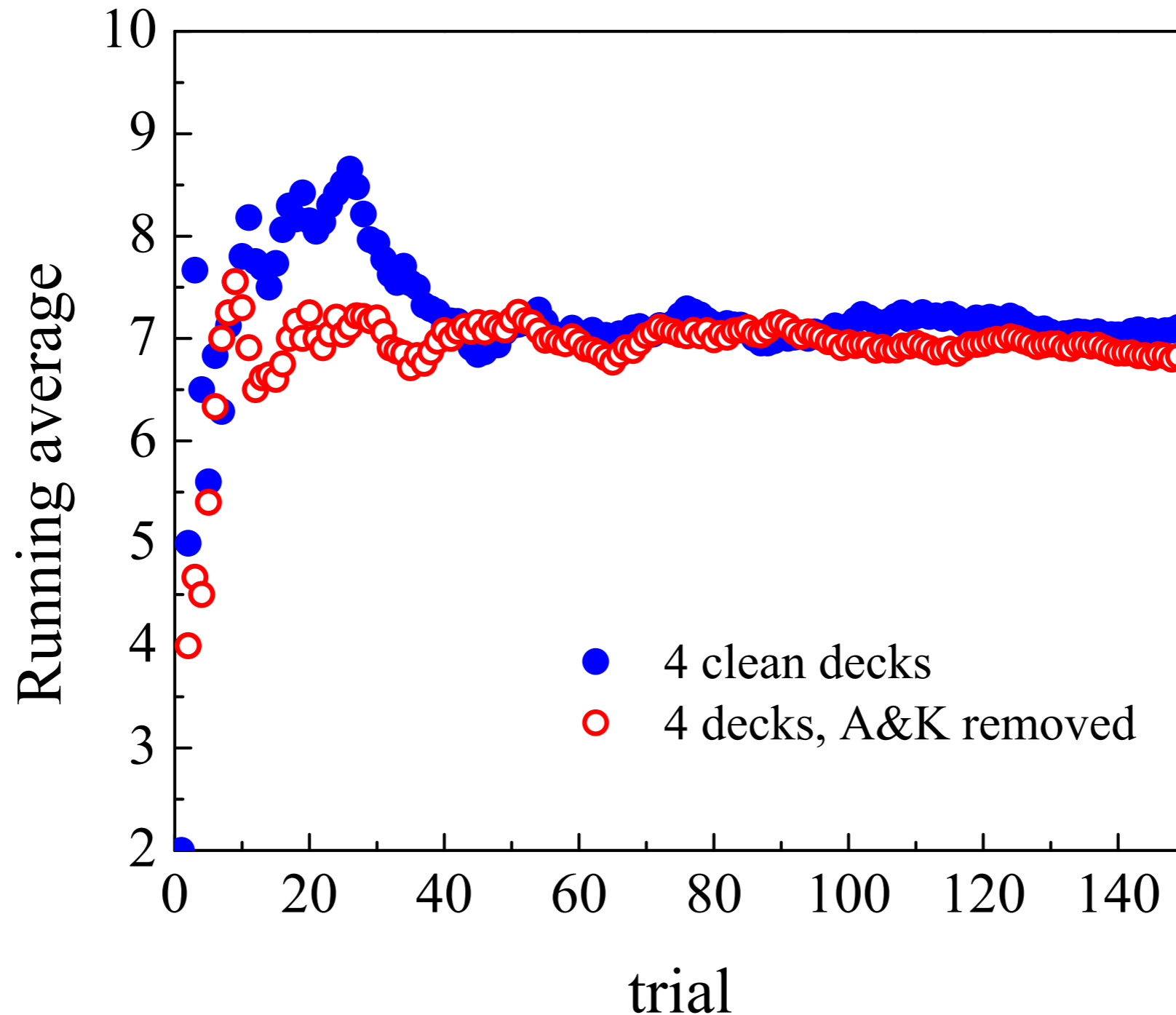
- give each one a number
- Ace = 1, 2 = 2 ... Jack = 11 ... King = 13
- what is the average card?
  - we expect it must be 7 ...
- what is the spread? how to define this?

150 trials ...





draw 1 card, record, shuffle, repeat  
cards have values 1-13, equal number of each  
average must be 7, if one chooses enough cards  
takes ~50 before 'luck' is irrelevant!

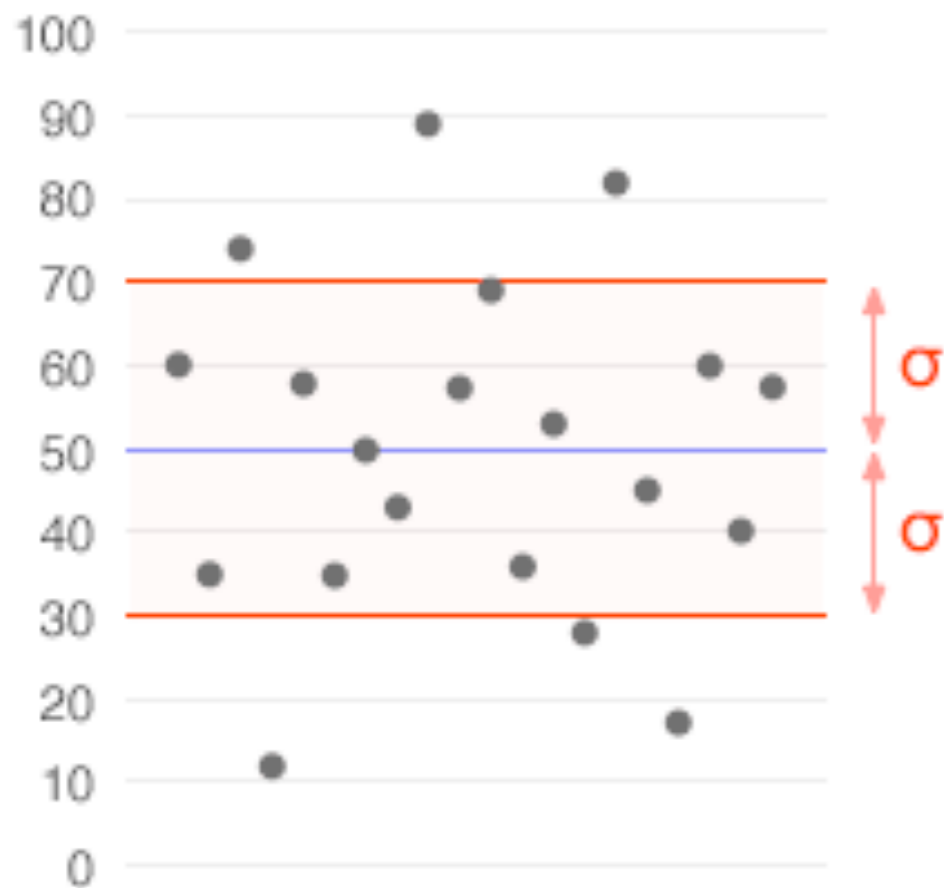


# The mean isn't enough. how about the dispersion?

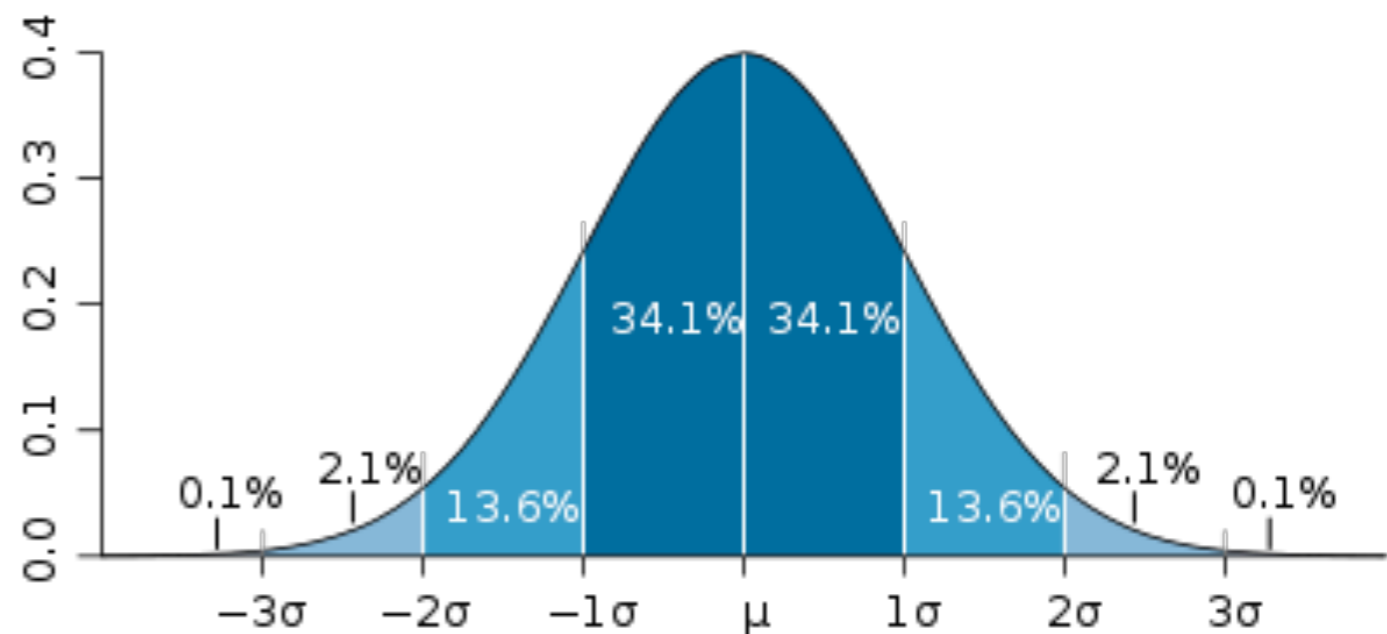
**standard deviation** is a measure of the variability dispersion in a population or data set

low standard deviation: data tends to lie close to the average (mean)

high standard deviation: data spread over a large range



**data set:** data clustered about average



**many trials:** follow a *distribution*

~68% within +/- 1 standard deviation

~95% within +/- 2 standard deviations

~99.7% within +/- 3 ...

# so what?

- knowing the standard deviation tells you
  - if subsequent measurements are outliers
  - what to expect next, on average
  - *accuracy* of a set of data
  - variability in a large batch
- “six sigma” - quality control
  - means one out of 500 million!

# so what?

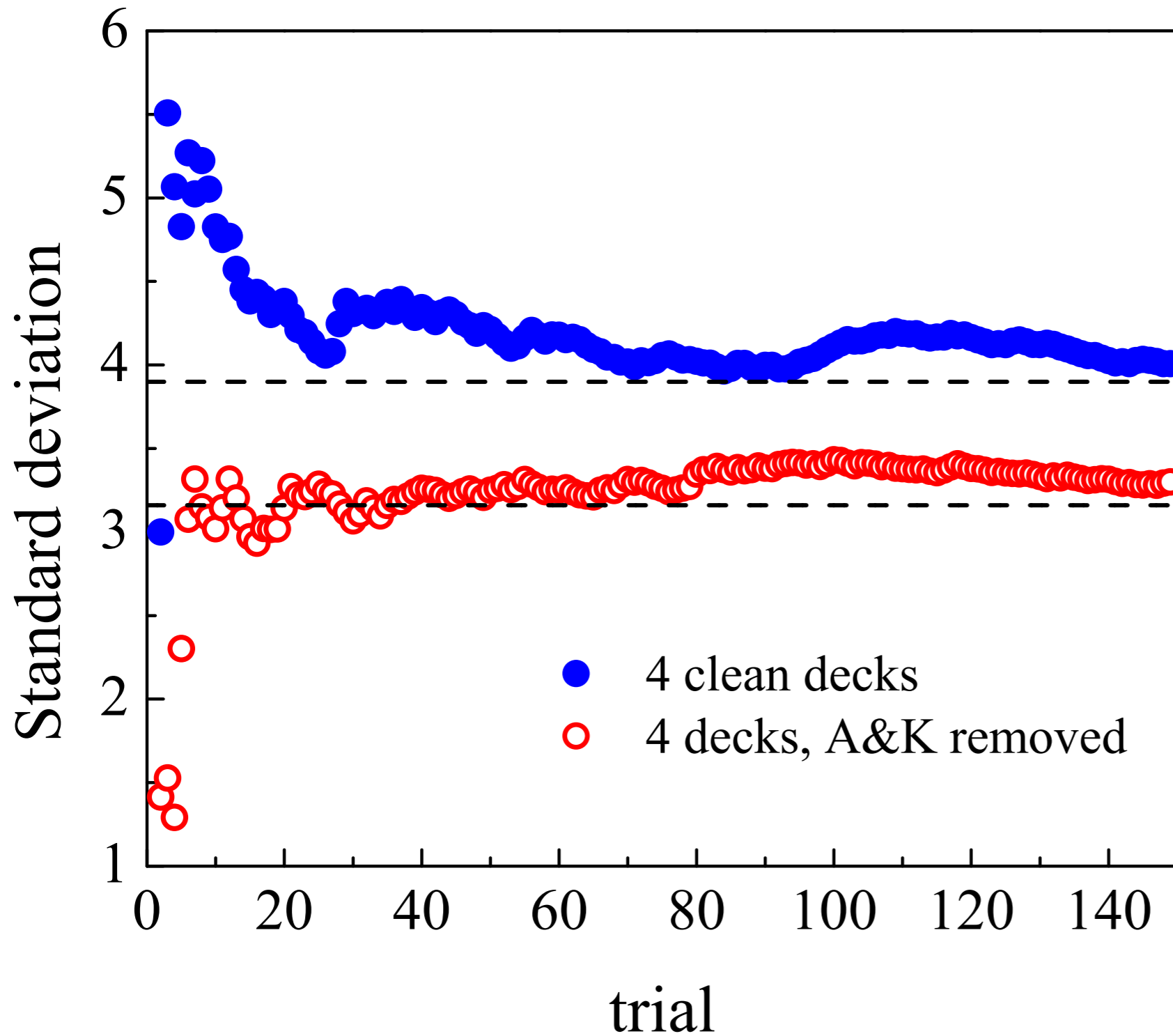
if the mean of the measurements is too far away from the prediction compared to the standard deviation, then the theory being tested probably needs to be revised!

particle physics: 5-sigma standard typical  
1 out of 1.7M chance of false positive

larger signal than that ... probably a new effect!

# for the cards?

take out highest and lowest cards,  
data is more tightly distributed  
lower standard deviation!



# wait, there's more

expect 75% of cards within 2 standard deviations of average

or, 75% are within about 4 cards from the average after 100 trials

or, 75% of cards should be between 3 and Jack (inclusive)

It works!

flip side: we could estimate the distribution of cards without prior knowledge from a run of cards, if long enough, could say what's missing or in excess could take many samples of the deck though (e.g., removing all 7s)

# what else?

- standard deviation gives accuracy of averages
- if you do n measurements, average is more accurate for higher n. makes sense!
- uncertainty of the average is standard deviation over the root of the number of measurements

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

$$(\text{best value of } x) = \bar{x} \pm \sigma_{\bar{x}}$$

detailed explanation & examples in lab procedure  
 ... so read it first. really.  
 excel example included too

draw	card	running average	running standard deviation
1	2	2.00	
2	8	5.00	4.24
3	13	7.67	5.51
4	3	6.50	5.07
5	2	5.60	4.83

	A	B	C	D	E
1	draw	card	running average	running standard deviation	
2	1	2	2.00		
3	2	8	=AVERAGE(\$B\$2:B3)	=STDEV(\$B\$2:B3)	
4	3	13	^ drag down	^ drag down	
5	4	3	6.50	5.07	
6	5	2	5.60	4.83	
7					



