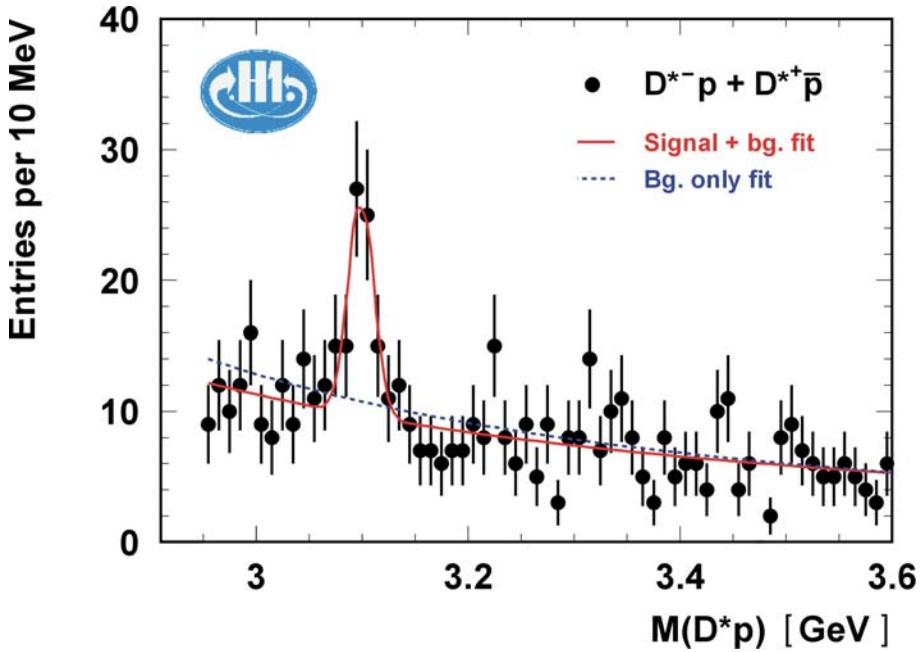
# Significance Significance and Discoveries

Last time:
- $\chi^2$ Fitting
- $\chi^2$ Tests

Today:
- (Null) Hypothesis testing
- Signal Significance




'… *lies, damned lies and statistics* …' (Disraeli)

# Null Hypothesis Example

- Toss a coin 15 times, get heads 12 times … is the coin biased?

- Null hypothesis is that P(H) = $\frac{1}{2}$

- If P(H)=1/2, then P(at least 12 H from 15 throws)
  = P(12) + P(13) + P(14) + P(15)
  = 1.4% + 0.3% + 0.05% + 0.003% = 1.8%

- But the question was `is the coin biased?', not `is the coin biased in favour of heads?'

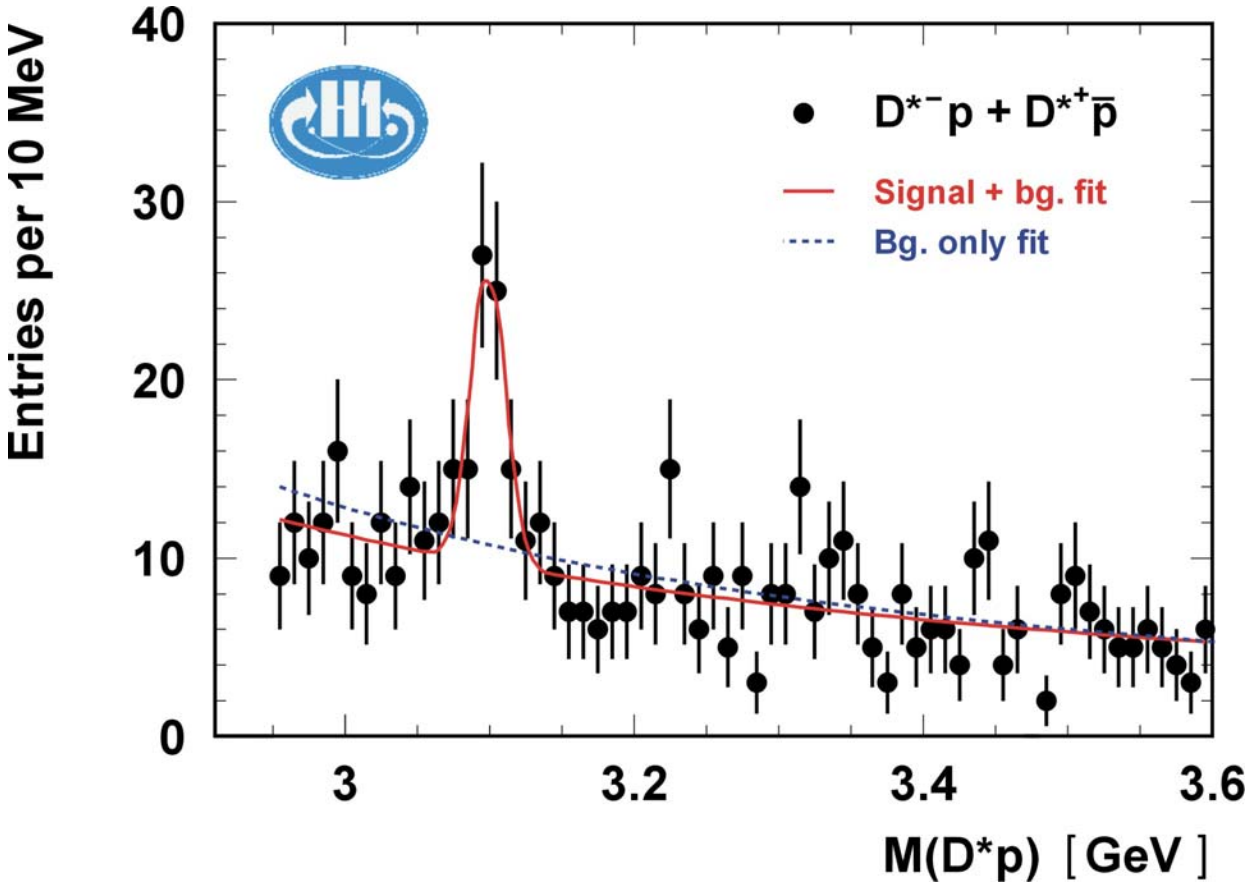
- Also need to consider P(at least 12 T) = 1.8%

- So P(at least 12 identical results) = 3.6%
- A clear statement is: "Coin shows bias at 96.4% CL (2 tailed)"

- Result depended on the exact hypothesis tested!

# Hypotheses and Signals for New Physics

- Example from the H1 paper Phys. Lett. B588 (2004) 17.
- Combining D*- mesons (d+cbar) with protons (u+u+d)
- Signal in this mass distribution can only be explained by `charmed pentaquark' (u+u+d+d+cbar)

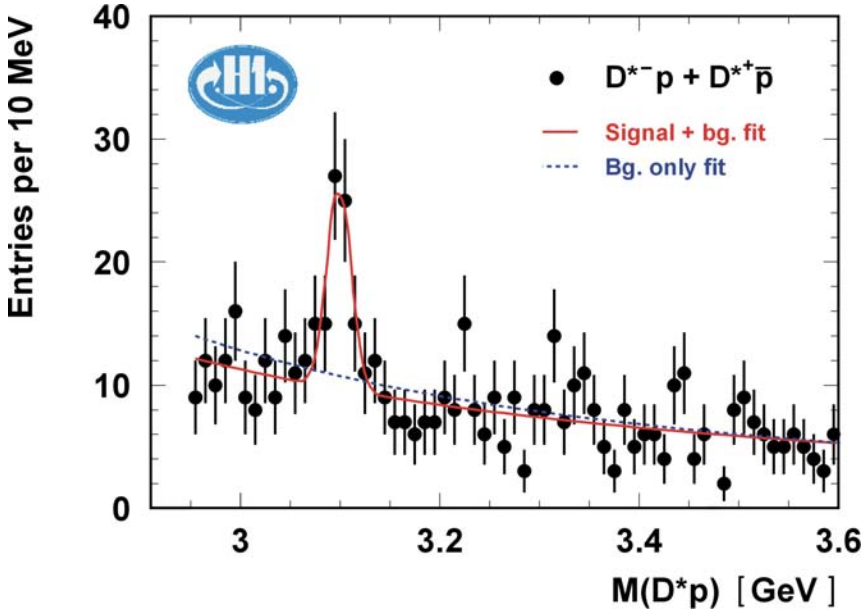



- But how significant is this signal?

- Test null hypothesis that the signal is produced by a statistical fluctuation of the background.

# Significance of Pentaquark Signal?

- Perform max log likelihood fit (signal + smooth background) … red curve
- Reasonable statistics … Gaussian approx to Poisson OK for quick signal assessment




**Within 2σ of peak …**
**Total 95 events, of which 51.7 +/- 2.7 (sys) background**

- Signal is estimated to be S = 95.0 - 51.7 = 43.3 events
- Stat error on background sqrt(B) = sqrt(51.7) = 7.2 events
- Total error on background σ(B) = sqrt(7.2+2.7) = 7.7 evts
- Null hypothesis rejected at
  level of S/σ(B)=43.3 / 7.7 = 5.6 Gaussian σ
  i.e probability of ~$10^{-8}$ to get a bigger fluctuation!

# Quantifying Signal Significance

- General statement of the significance of a signal:

"the number of (Gaussian) standard deviations of the background distribution to which the signal corresponds"

Significance = $S/\sigma(B)$

… so if the background is tiny, only a small number of events is needed …

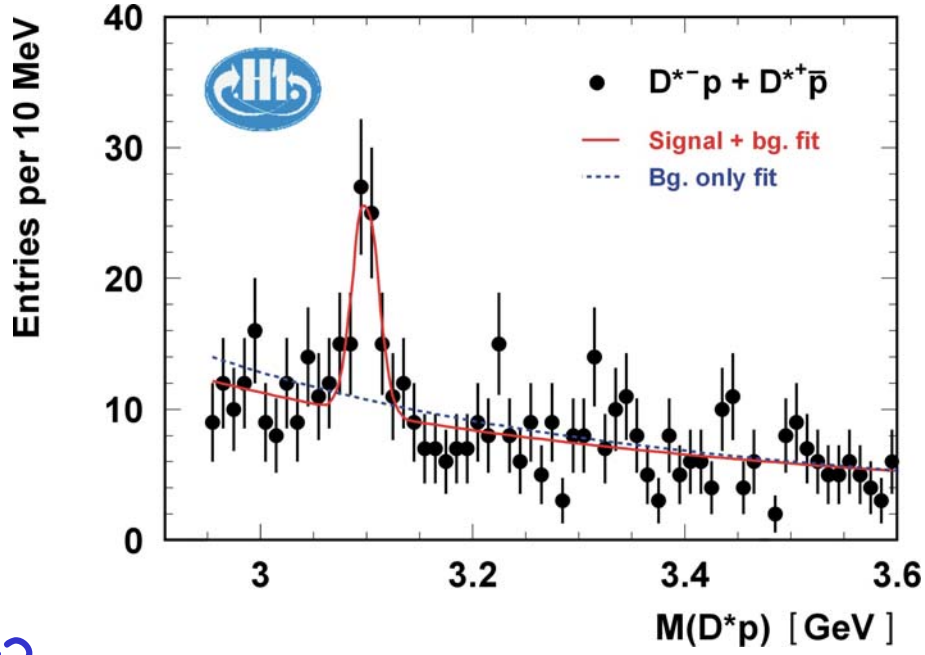
- If the systematic uncertainty on the background distribution can be neglected:

Significance = S / sqrt(B)

- If the systematic uncertainty on the background distribution is $\delta_{syst}$:

Significance = S / sqrt($B + \delta_{syst}^2$)

# So H1 gets Nobel Prize?




- Signal unlikely to be real
  - unconfirmed by any other experiment……
- Yet it remains unexplained by known systematic effects!
- What happened????

Many factors diluting probability?…

- Systematic uncertainty on background
- The peak could have appeared in any position in plot
- The H1 experiment probably looked at 100 such plots
- Several other experiments looked for the same thing
- Null results often unpublished, just the one in the tail!

c.f. UA1 'discovered' W and Z bosons with 3 events of each type & non-negligible background!… $<<5\sigma$!… but they knew what to expect and where!… **Common sense is your best friend!**

# Last Points for Course: Accelerators

Something we did not cover …how accelerators work …
Some information provided for interest on course web page …

## Accelerators

- The following are extracts from a lecture course at Nikhef (Amsterdam).
- You are not required to know this information for this course, but you will find it interesting as background information
- There are, of course, many other good resources for this subject on the web!




… will not feature in exam!