A History of Disasters

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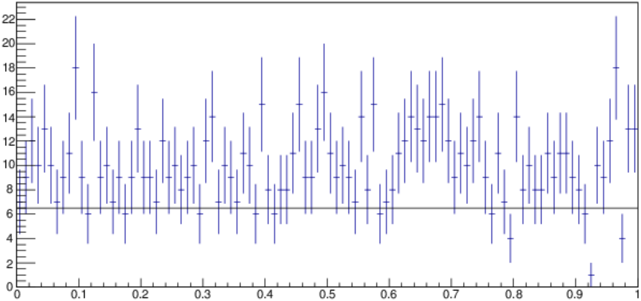
26th February 2025

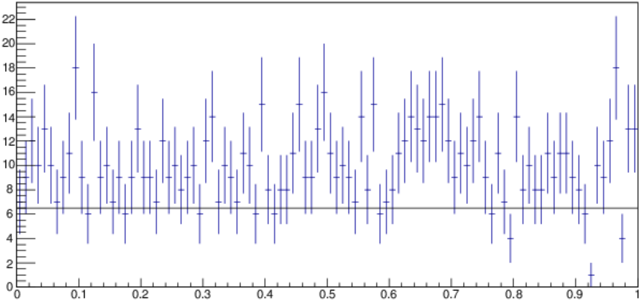
PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Why 5 σ. Isn't that excessive?



How many peaks are there in this plot?

Why 5 σ. Isn't that excessive?



How many peaks are there in this plot?

None

The "Look Elsewhere" Effect

The human eye/brain is very good at seeing features (even when there aren't any)

"I don't see anything in the target region – but there's something interesting elsewhere in the plot"

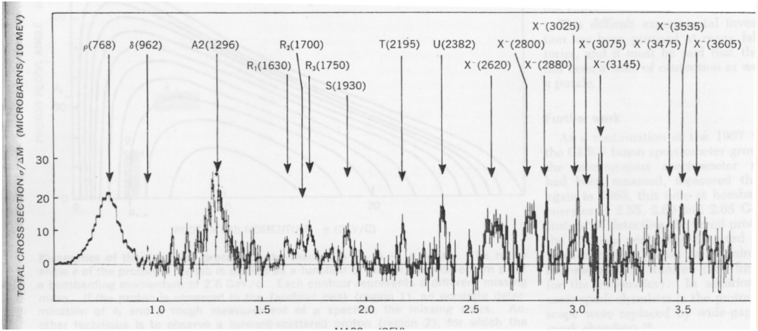
With 100 bins, a $p-$value below 1% is pretty likely

Can be factored in to some extent, using statistics or pseudo-experiments

Does not factor in sheer number of plots being produced by physicists looking for something and trying many different bin sizes, selection criteria, etc.

Now some real data

Data from the CERN Missing Mass Spectometer
Pion beam (few GeV) on hydrogen target $\pi^- + p \to p + X$
Measure energy and momentum of recoil proton to give mass of X^-



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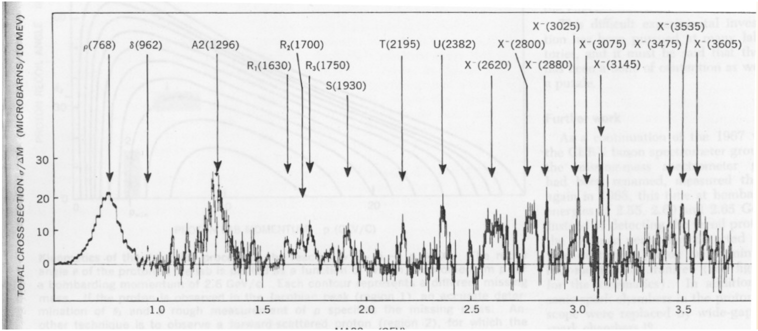


How many of these peaks are real?
And what's going on with the A_2?

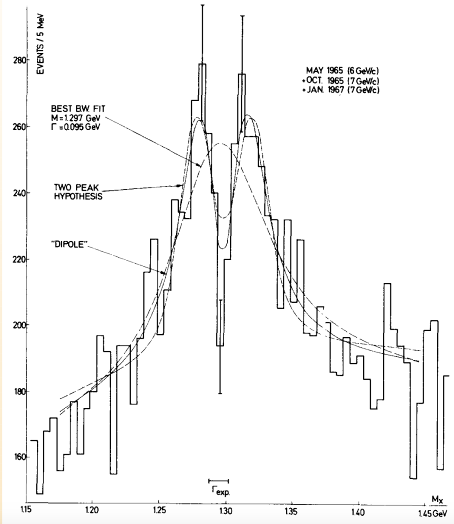
The splitting of the A_2 meson

One of the light quark (u,d) resonances. Now known as the a_2. Mass 1320 MeV, isotriplet, $J^{PC} = 2^{++}$, decays mostly to 3 pions.

First report 1967

$> 6\sigma$ effect

Exciting implications for SU_3 multiplets



Seen by others

Confirmed 1969
went away 1971
Due to
(1) Very creatve analysis cuts
(2) “Bandwagon Effect”.
Experiments wanted to see it. Those that didn’t, didn’t publish.

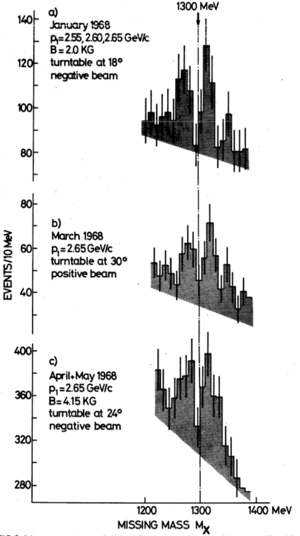


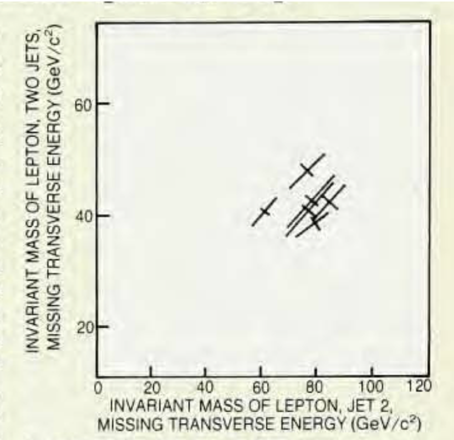
FIG.3 Mass spectra of the A2 region obtained in πp→pX with the CERN Boson Spectrometer (1968) under different experimental conditions

The top quark 'discovery' at UA1

$W \to t\overline{b}$ and $t \to b\ell^{\pm}\nu$

2 b jets, charged lepton, missing energy

Find 6 events. Plot total mass against $b\ell^{\pm}\nu$ mass (ν from missing energy/momentum)
W mass in right place
t mass around 40 GeV

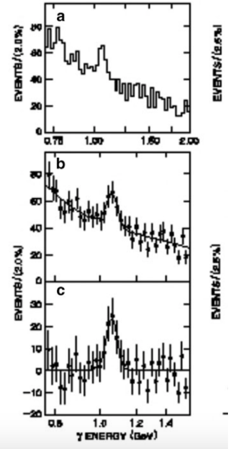


Turned out to be background - and very creative selection cuts

The $\zeta(8.3)$

"Discovered" in 1984 by the Crystal Ball experiment at DESY.

e^+e^- storage ring (DORIS) with energy 9.46 GeV, the mass of the Υ meson (which is a $b\overline{b}$ bound state)



Measure energy of photons

Single energy peak seen!!

Signals $e^+e^- \to \Upsilon \to \zeta\gamma$
4.2 sigma effect
Plots show (a) raw data , (b) fit, and (c) background-subtracted fit

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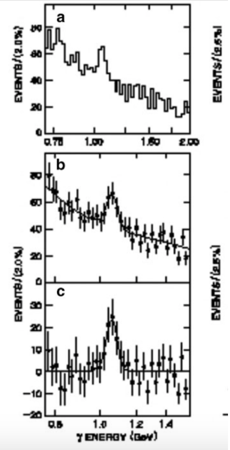

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When more data was taken (in 1985) the peak went away.

Blind Analysis

Pioneered by *BABAR*

"It was easy - I just got a block of marble and chipped away anything that didn't look like David."

Michaelangelo Buonarotti(attrib.)

Maybe good way of creating sculpture - but very bad way of doing physics

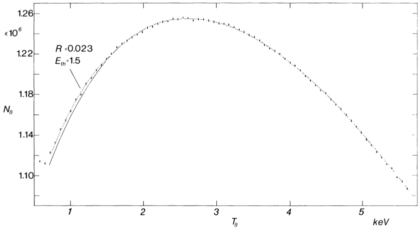
To resist temptation,
For searches, devise cuts *before* looking at the data. Use Monte Carlo simulations, and/or data in 'sidebands'. Only when cuts are optimised do you 'open the box'.
For measurements, apply secret offset until selection frozen.

Some experiments have formal apparatus for doing this.

The 17 keV neutrino

Best way to measure (electron) neutrino mass is through the endpoint of the electron spectrum in tritium decay.

1985: Simpson sees distortion in expected shape, explain by small coupling to new 4th neutrino with mass 17 keV

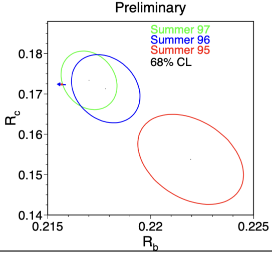


Confirmed by a few experiments but not seen by many others

Eventually declared dead in 1993: effect ascribed to electron energy loss in aluminium foil

The $R_b - R_c$ anomaly

LEP experiments measured the branching fractions of Z to $c\bar{c}$ and $b\bar{b}$
Several different measurements (e.g. lifetimes, event shapes, leptons) and 4 experiments. All in broad agreement.
Combining gave
$R_b = 0.2219 \pm 0.0017$: 3.5 σ above SM prediction 0.21569
$R_c = 0.1543 \pm 0.0074$: 2.5 σ below SM prediction 0.17238
Theorists loved it! Heavy leptophobic Z' from E_6 supersymmetry, and more...
With more data (and analysis improvements) it went away



[1]

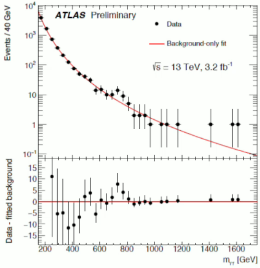
[1] Robert Clare: Acta Physica Polonica B29 266 (1998)

The $\digamma(750)$

"Discovered" in 2015 by the ATLAS and CMS experiments at the LHC.

Invariant mass of pairs of high energy photons from proton proton collisions (Hence the name 'digamma')

3.6 sigma in ATLAS, 2.6 sigma in CMS



The $F(750)$

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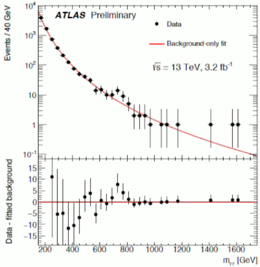

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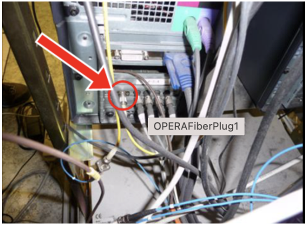
When more data was taken (in 2016) the peak went away

The faster-than-light neutrino

Neutrinos from CERN to OPERA detector in Gran Sasso , 730 km
Pulsed (due to SPS)

September 2011: Neutrinos arrive 60 ns early. Must travel faster than c.
6 sigma effect. Result persisted in next run. But contradicted by ICARUS



March 2012. Retracted.
Timing signal fibre-optic not properly connected. Quite a subtle effect. Badly-connected electrical cables either work or they don't. Optical cables give less light, so photodiode voltage rises more slowly to trigger discriminator.

Conclusions

See also Luc Demortier's talk

Real, False and Missed Discoveries in High Energy Physics
at the Terascale Statistics School, DESY, 2008

For Experimentalists

We use 5 σ to keep ourselves honest - history tells us this is necessary

We use blind analysis for the same reason

These are not a substitute for common sense and healthy scepticism

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For Theorists

Publish quickly!