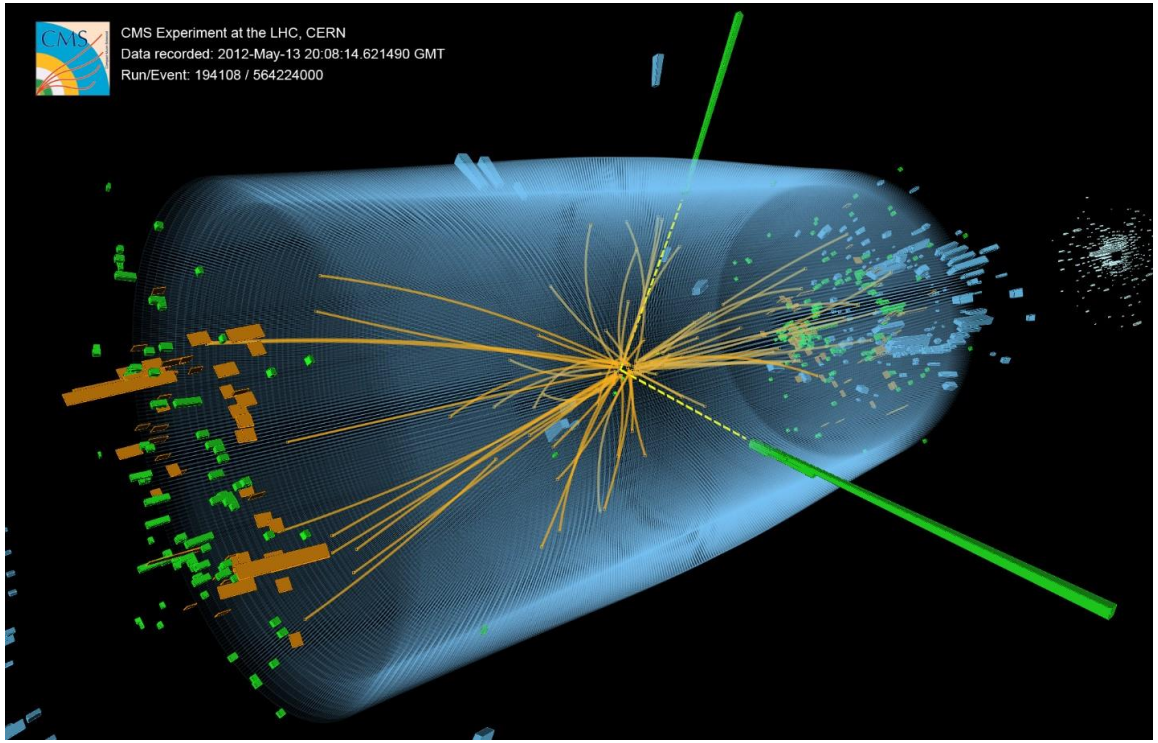
The Epistemology of Experiment: The Higgs Boson and Gravity Waves.

Department of Physics
University of Colorado



CERN
February 1, 2018

Roles for experiment, other than theory testing

1. Exploratory—designed to investigate a subject for which a theory doesn't exist, so that a theory can be formulated
2. Articulation of theory
3. Call for a new theory—show existing theory is incorrect, exhibit new phenomena that call for a theory.
4. Demonstrate that entities involved in our accepted theories exist.
5. Measure a quantity of physical interest—guided by theory.
6. Correct previous or misinterpreted results
7. Enabling-more often theory, but can be experiment.
8. Life of its own—independent of theory
9. Pursuit
10. Introduce a new experimental method.

1) Experimental checks and calibration, in which the experimental apparatus reproduces known phenomena.
2) Reproducing artifacts that are known in advance to be present.
3) Elimination of plausible sources of error and alternative explanations. As Holmes remarked to Watson, “How often have I told you that when you have eliminated the impossible, whatever remains, however improbable, must be the truth (Conan Doyle 1967)." (the Sherlock Holmes strategy)
4) Using the results themselves to argue for their validity. In this case one argues that there is no plausible malfunction of the apparatus, or background effect, that would explain the observations.
5) Using an independently well-corroborated theory of the phenomena to explain the results;

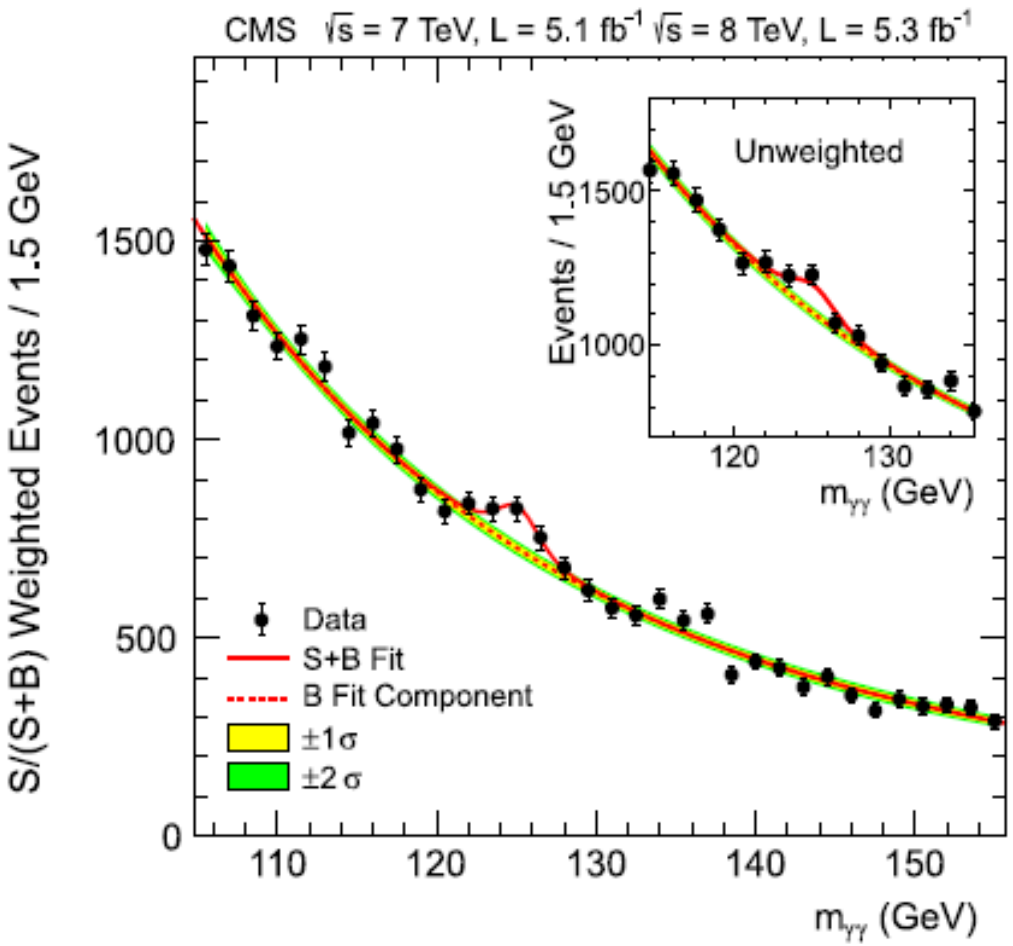
6) Using an apparatus based on a well-corroborated theory.

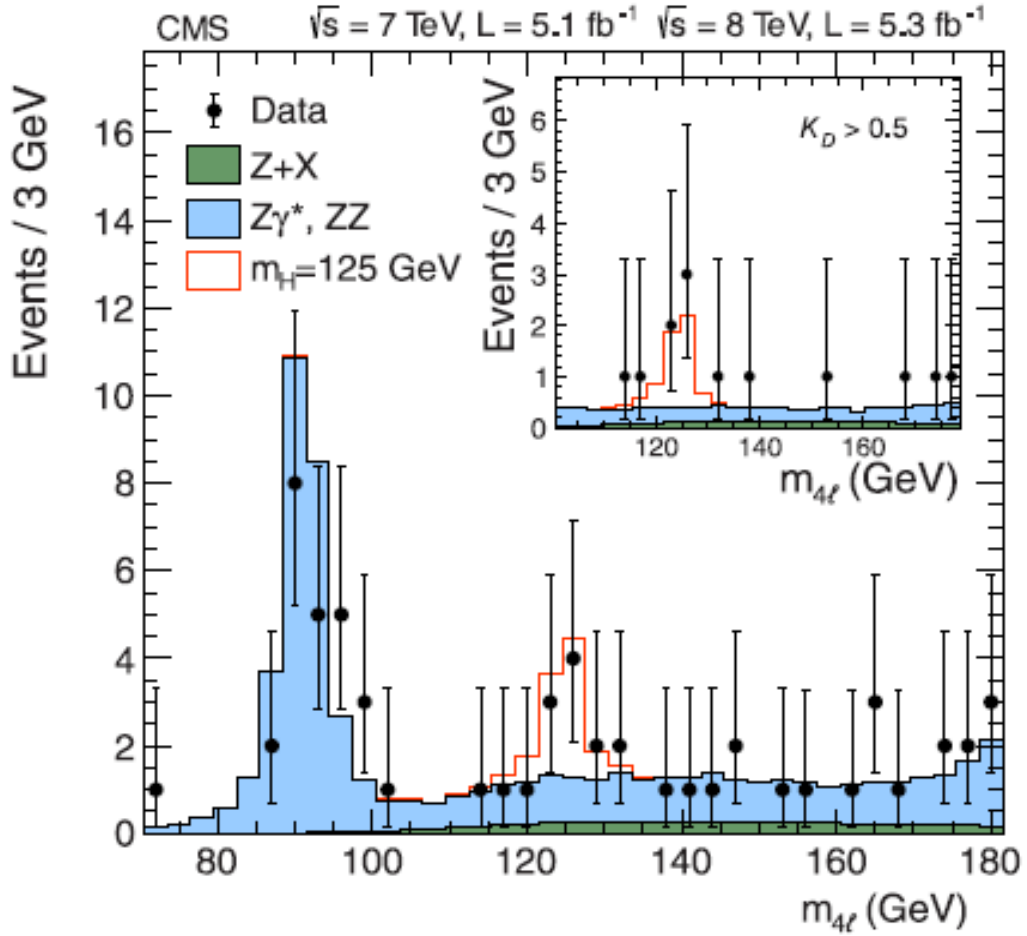
7) Using statistical arguments.

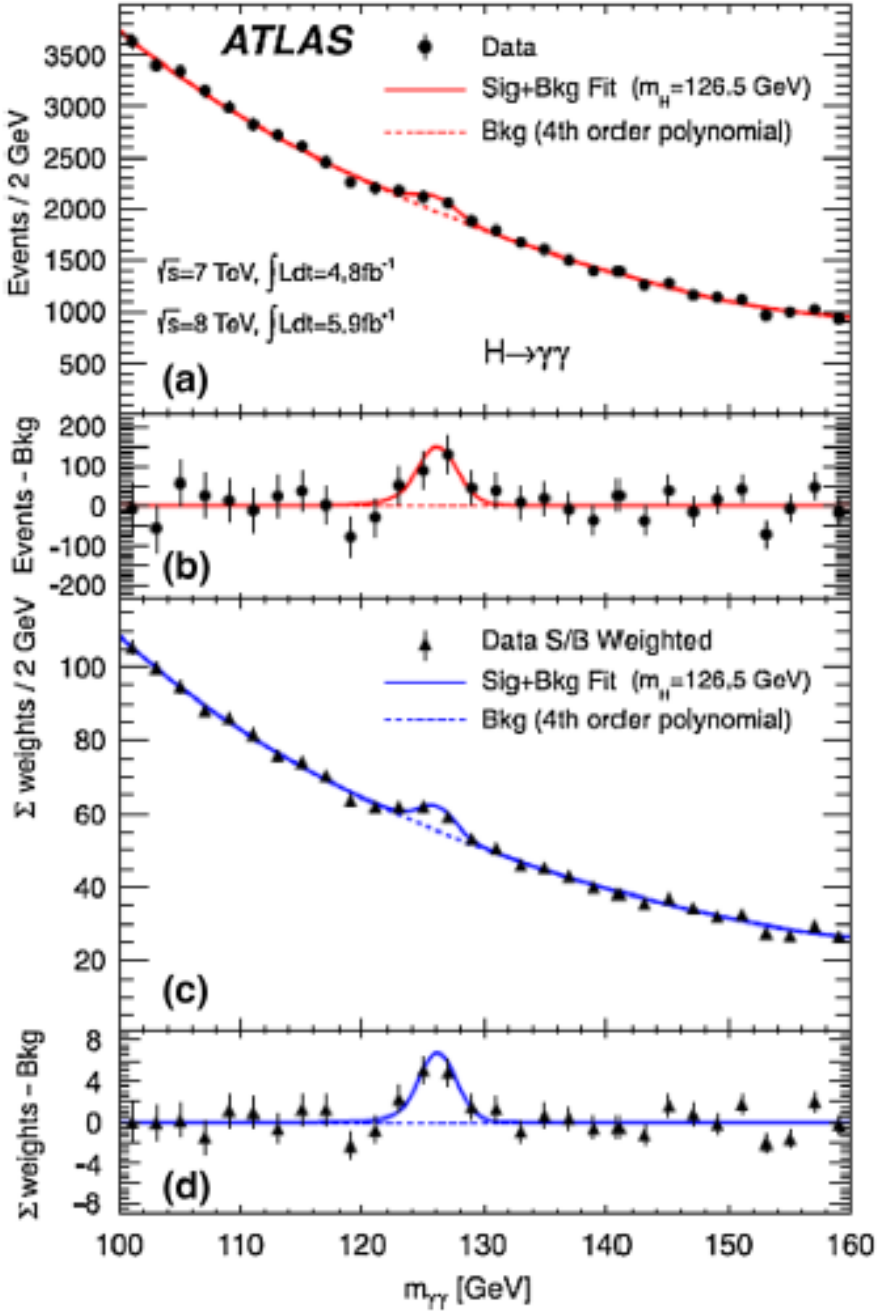
8) Manipulation, in which the experimenter manipulates the object under observation and predicts what they would observe if the apparatus was working properly. Observing the predicted effect strengthens belief in both the proper operation of the experimental apparatus and in the correctness of the observation.

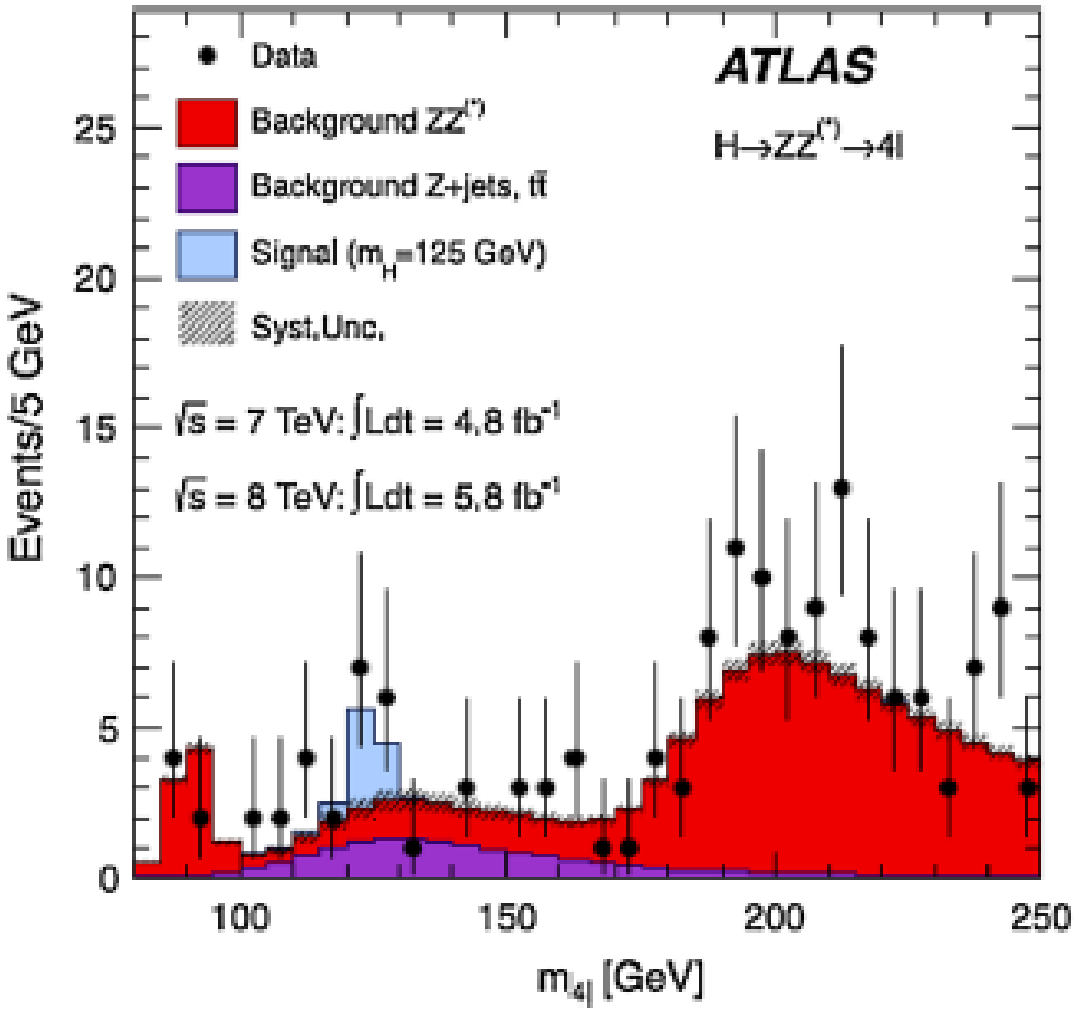
9) The strengthening of one's belief in an observation by independent confirmation.

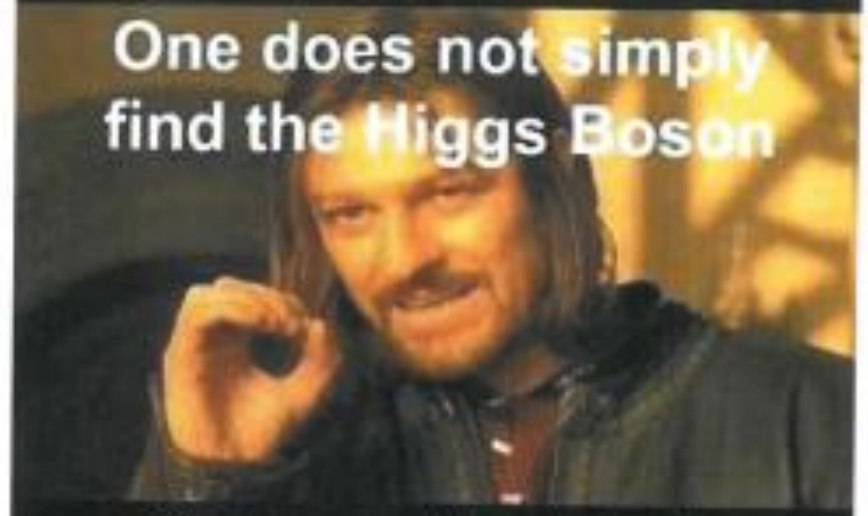
10) Using “blind” analysis, a strategy for avoiding possible experimenter bias.


CMS √s = 7 TeV, L = 5.1 fb⁻¹ √s = 8 TeV, L = 5.3 fb⁻¹
S/(S+B) Weighted Events / 1.5 GeV
m_γγ (GeV)
Data
S+B Fit
B Fit Component
±1σ
±2σ
Unweighted
Events / 1.5 GeV
m_γγ (GeV)


CMS
√s = 7 TeV, L = 5.1 fb⁻¹ √s = 8 TeV, L = 5.3 fb⁻¹
Data
Z+X
Zγ*, ZZ
m_H=125 GeV
Events / 3 GeV
m_4ℓ (GeV)
K_D > 0.5


ATLAS
Data
Sig+Bkg Fit (m_H=126.5 GeV)
Bkg (4th order polynomial)
$\sqrt{s}$=7 TeV, $\int Ldt$=4.8fb^{-1}
$\sqrt{s}$=8 TeV, $\int Ldt$=5.9fb^{-1}
H→γγ
(a)
Events / 2 GeV
Events - Bkg
(b)
Data S/B Weighted
Sig+Bkg Fit (m_H=126.5 GeV)
Bkg (4th order polynomial)
(c)
Σ weights / 2 GeV
Σ weights - Bkg
(d)
$m_{\gamma\gamma}$ [GeV]


Data
Background ZZ(*)
Background Z+jets, tt̄
Signal (m_H=125 GeV)
Syst.Unc.
√s = 7 TeV: ∫Ldt = 4.8 fb⁻¹
√s = 8 TeV: ∫Ldt = 5.8 fb⁻¹
ATLAS
H→ZZ(*)→4l
Events/5 GeV
m_4l [GeV]
0
5
10
15
20
25
100
150
200
250



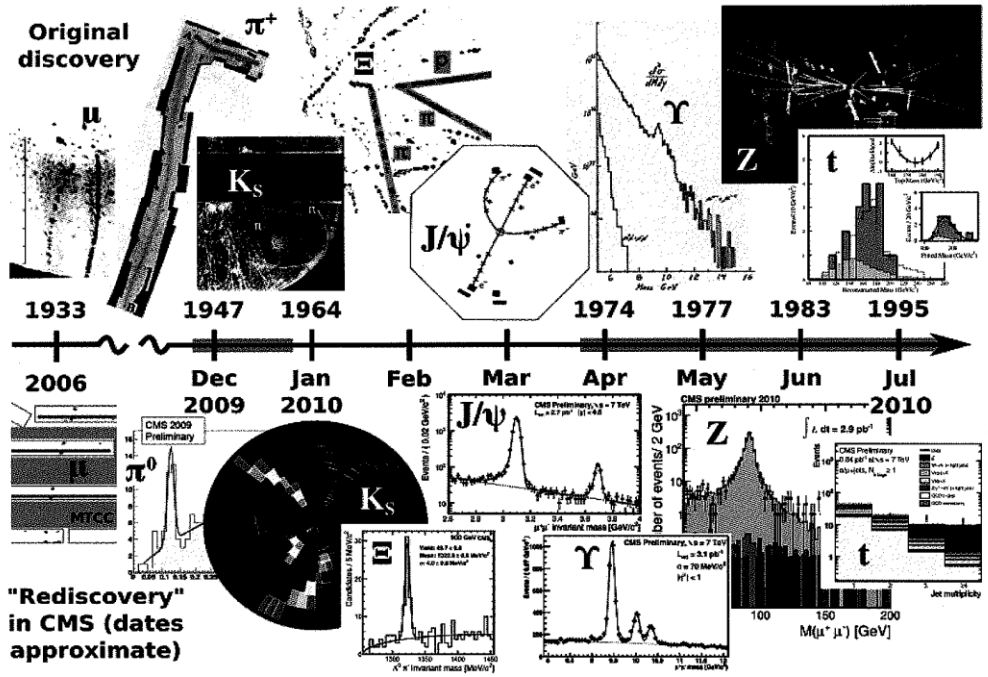
One sees something that might
have been the Higgs Boson

And then one counts the number of times
one has seen something that might
have been the Higgs Boson.

And one compares that number to how many
times one would have seen something
that might have been the Higgs Boson
if, in fact, there was no Higgs Boson

And, if the difference is large enough,
then one has probably found it.

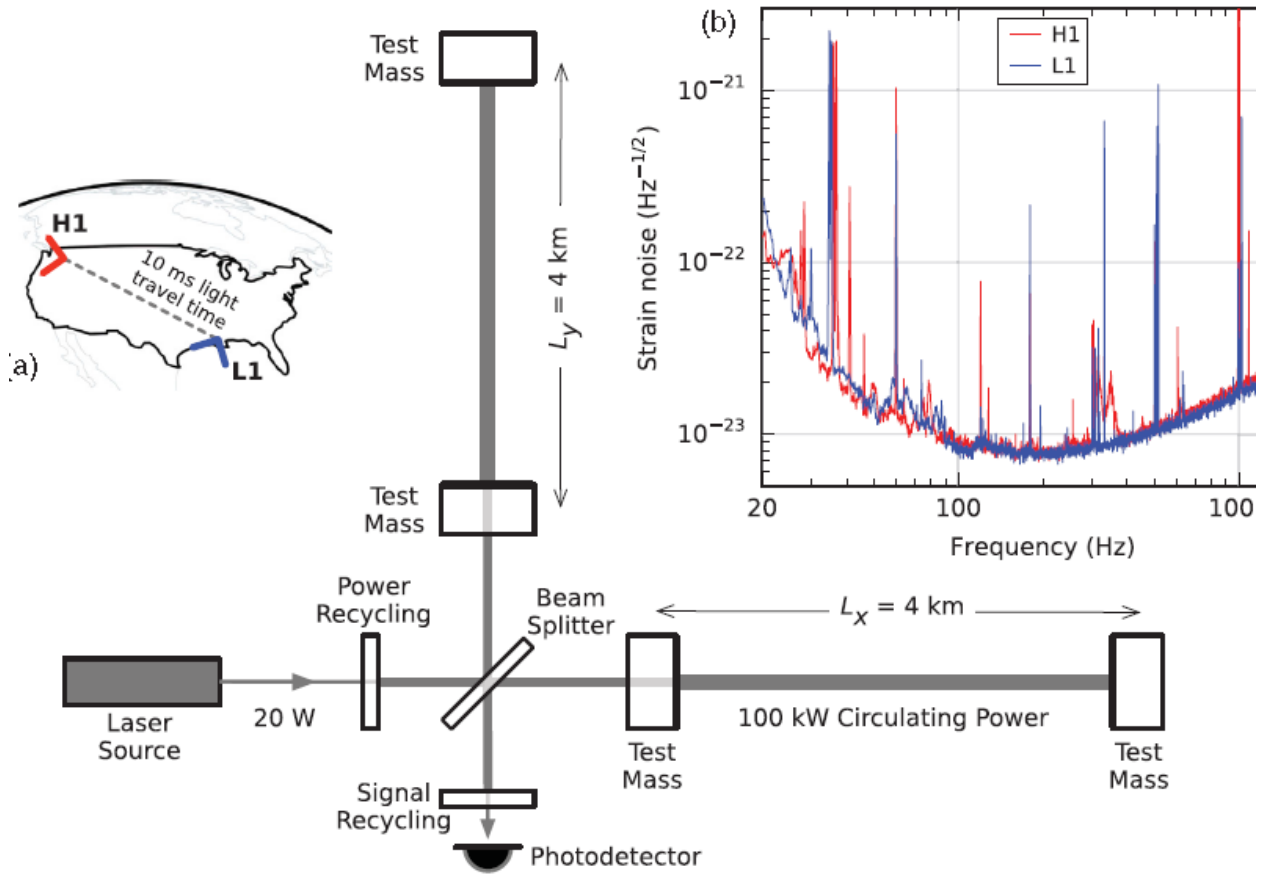
Re-discovering the Standard Model at 7TeV

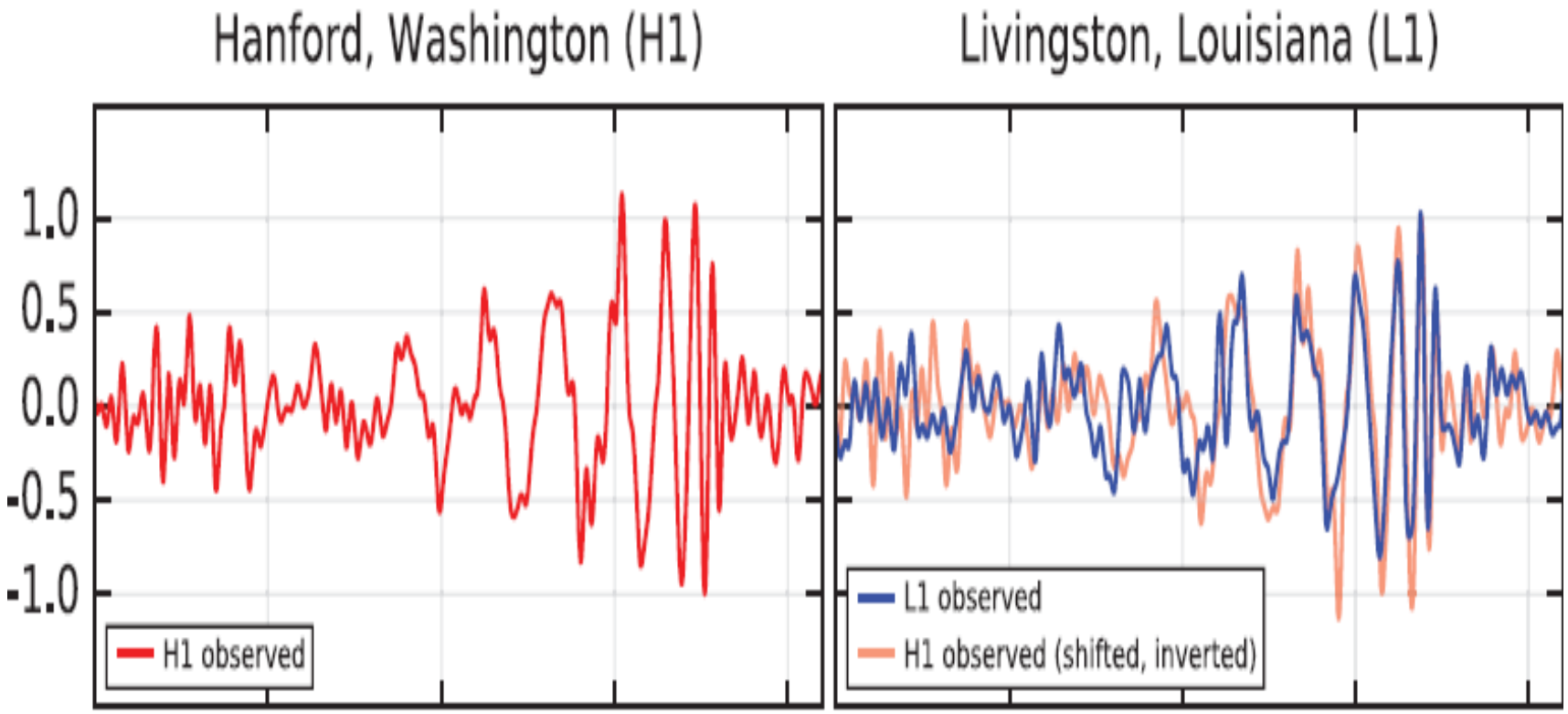


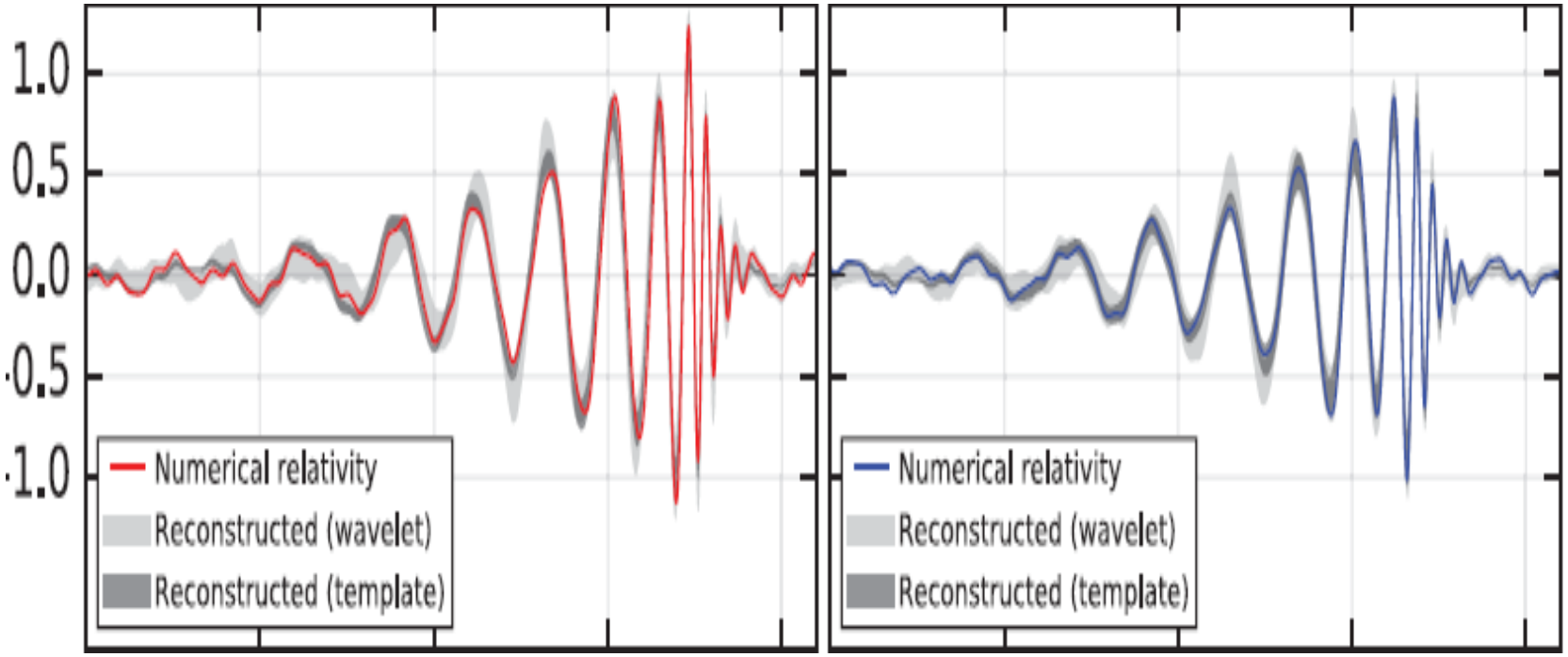
Standard Sources—Publications—papers, conference proceedings, letters

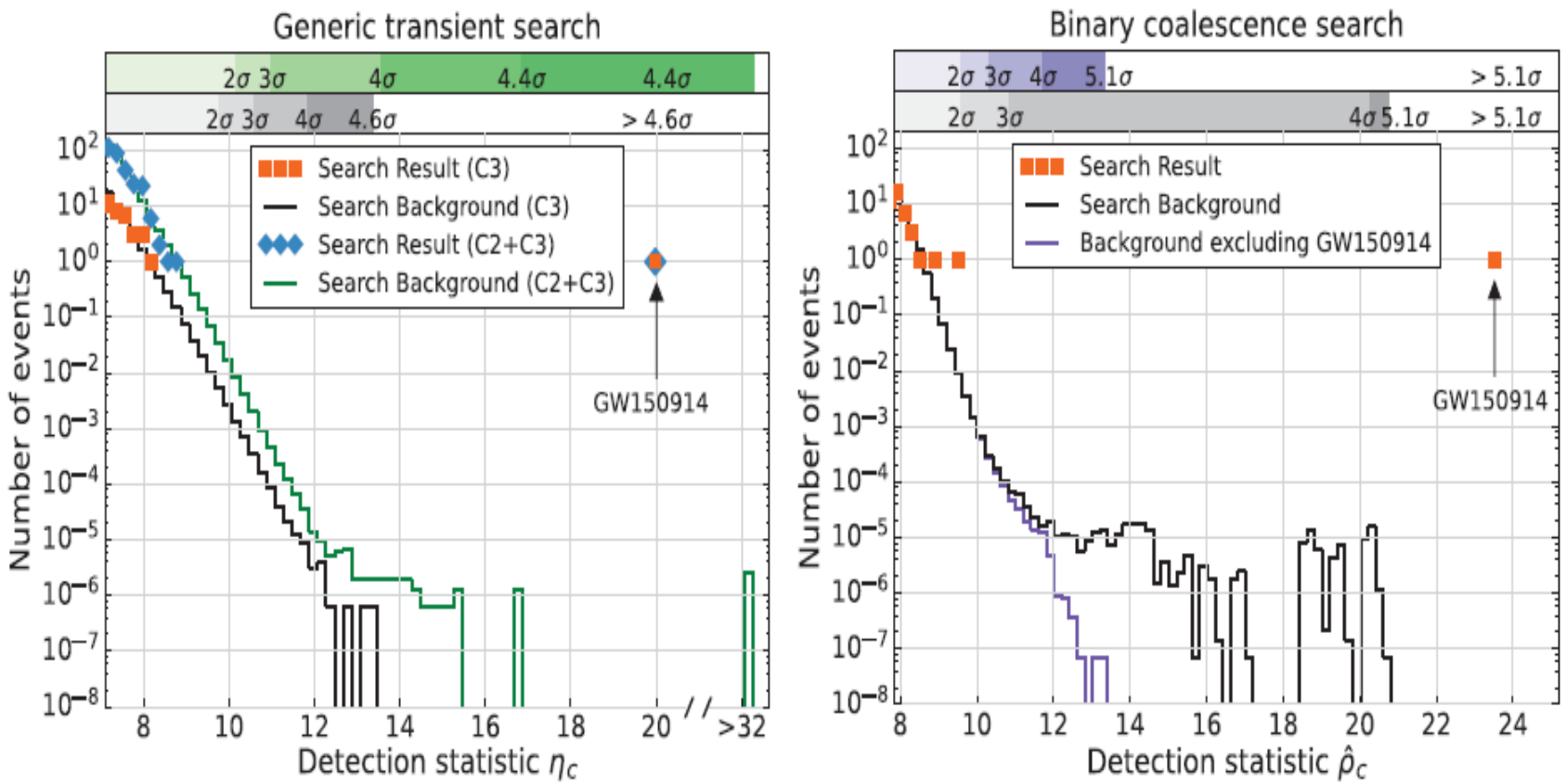
Others—e-mails, interviews, first person accounts

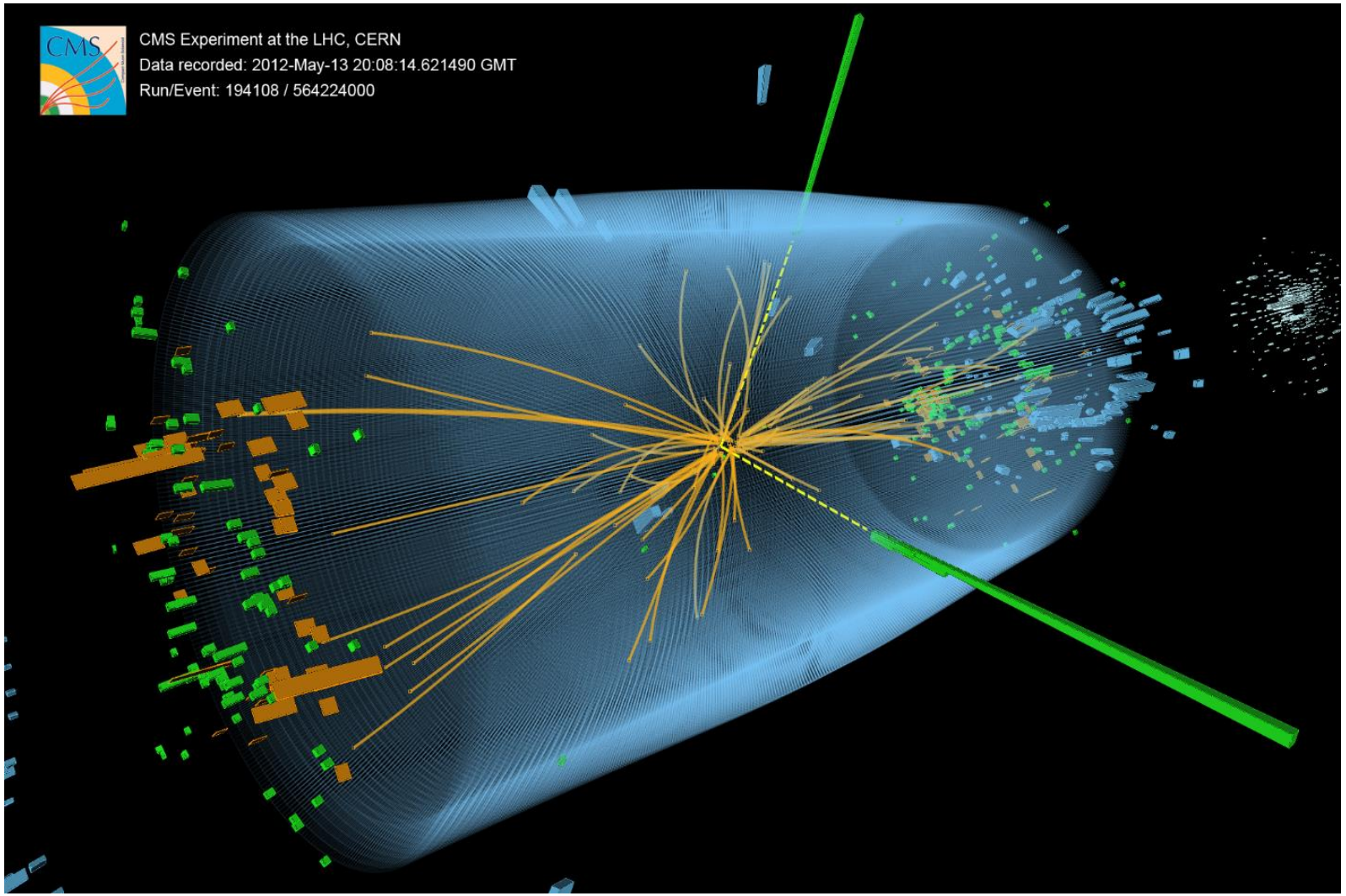
New sources -- arXiv– several versions of a paper--, PowerPoints of talks, Embedding


(a)
H1
L1
10 ms light travel time
Test Mass
Test Mass
L_y = 4 km
Power Recycling
Beam Splitter
L_x = 4 km
Laser Source
20 W
100 kW Circulating Power
Test Mass
Test Mass
Signal Recycling
Photodetector
(b)
H1
L1
Strain noise (Hz$^{-1/2}$)
10^{-21}
10^{-22}
10^{-23}
20
100
100
Frequency (Hz)


Hanford, Washington (H1)
Livingston, Louisiana (L1)
1.0
0.5
0.0
-0.5
-1.0
H1 observed
L1 observed
H1 observed (shifted, inverted)


1.0
0.5
0.0
-0.5
-1.0
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)
Numerical relativity
Reconstructed (wavelet)
Reconstructed (template)


Generic transient search
2σ 3σ 4σ 4.4σ 4.4σ
2σ 3σ 4σ 4.6σ > 4.6σ
Search Result (C3)
Search Background (C3)
Search Result (C2+C3)
Search Background (C2+C3)
GW150914
Number of events
Detection statistic η_c
Binary coalescence search
2σ 3σ 4σ 5.1σ > 5.1σ
2σ 3σ 4σ 5.1σ > 5.1σ
Search Result
Search Background
Background excluding GW150914
GW150914
Number of events
Detection statistic $\hat{\rho}_c$


CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000

Event recorded with the CMS detector in 2012 at a proton-proton centre-of-mass energy of 8 TeV. The event shows characteristics expected from the decay of the SM Higgs boson to a pair of photons (dashed yellow lines and green towers). ***The event could also be due to known standard model background processes***