Possible misunderstandings of the LHC H→γγ search in the presence of signal
My own opinons – not ATLAS

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Thanks to V. Sharma, E. Gross,
M. Kado, A. Read

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- Mass accuracy
- Signal rate
- Signal width

How is the search done?

- Pick an m_H hypothesis
- Fit for signal strength at that m_H
  - Compare with expectations for a signal at that mass
- Plot the results as a function of m_H

- So what is wrong?

How is the search done?

- Pick an m_H hypothesis
- Fit for signal strength at that m_H
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- So what is wrong?
  - Nothing.
  - Unless you then use the results to pick out one mass

- The above procedure assumes

$$m_H^{tested} \equiv m_H^{true}$$

- So lets start with that....

Dummy experiment

- ## Like ATLAS search
  - 22K background and 55 signal
  - Two categories
    - 90% signal, 99% bkd.
    - 10% signal, 1% bkd.
  - Mass resolution 1.7GeV

- ## A bit like the ATLAS γγ search
  - but just a dummy designed following their papers
  - Parameters designed to have 1.4σ expected sensitivity
- ## Make toy MC investigations *with a signal*
  - Inject signal
  - Constrain μ to be non-negative
  - Fit with mass fixed or floating to compare results
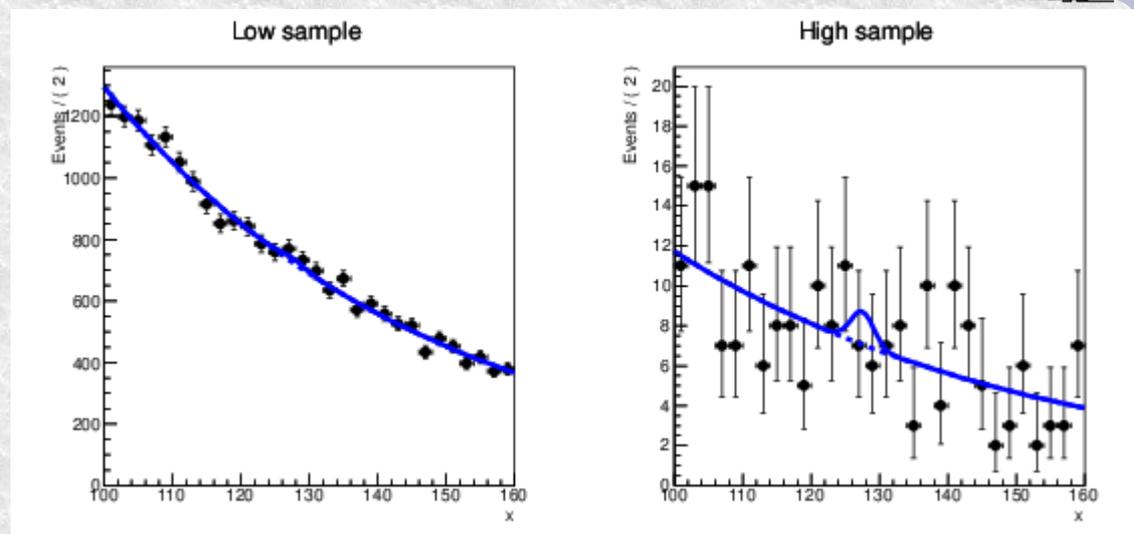
Fitted Mass distribution

- ML fit in minuit
  - Fit 2 background slopes and rates and 1 signal rate
  - Scan 115-135 first
- Quite often the best fit has NOTHING to do with the signal
  - RMS 3.7 (in this window!)
- RED selects 'lucky' experiments with 2.5-3σ observed excess
  - 2xexpected, as ATLAS/CMS
  - Cluster around the signal
  - But RMS still 2.6GeV
- ATLAS+CMS compatible!

mass

RMS= 3.67

Cut RMS = 2.64

m_{fit} [GeV]
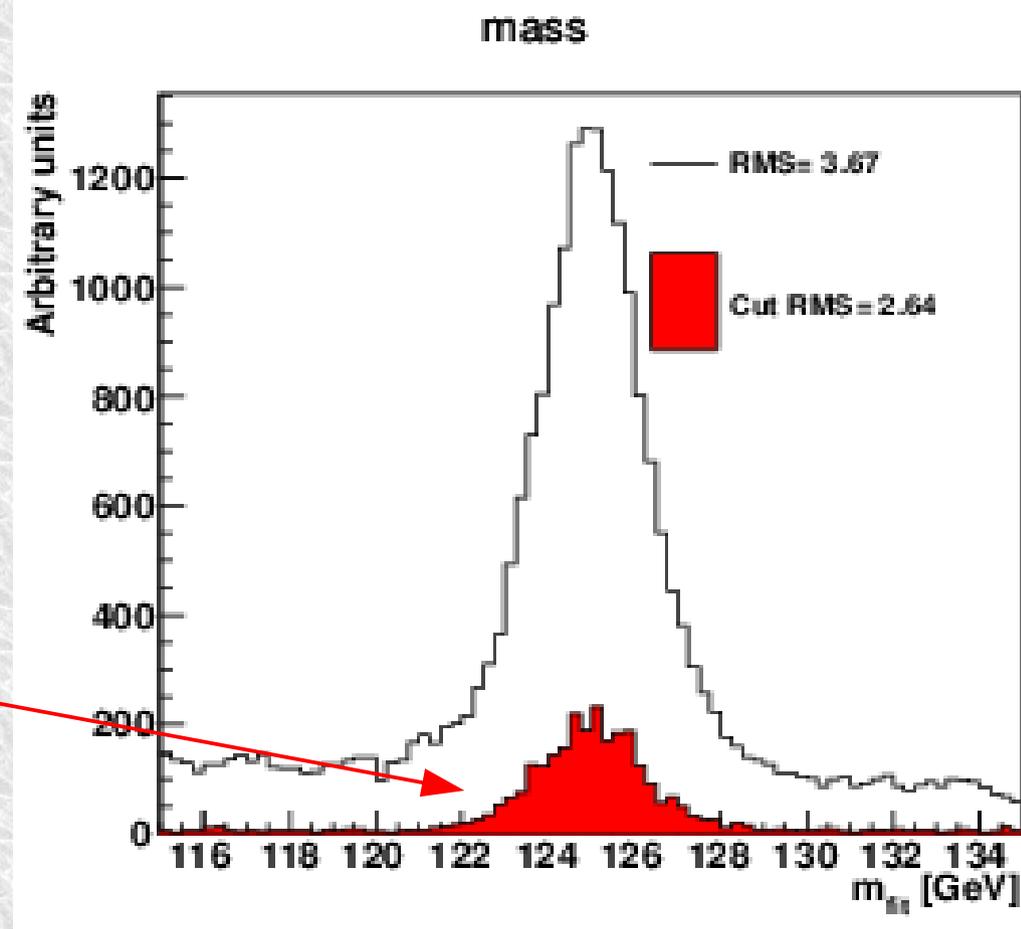
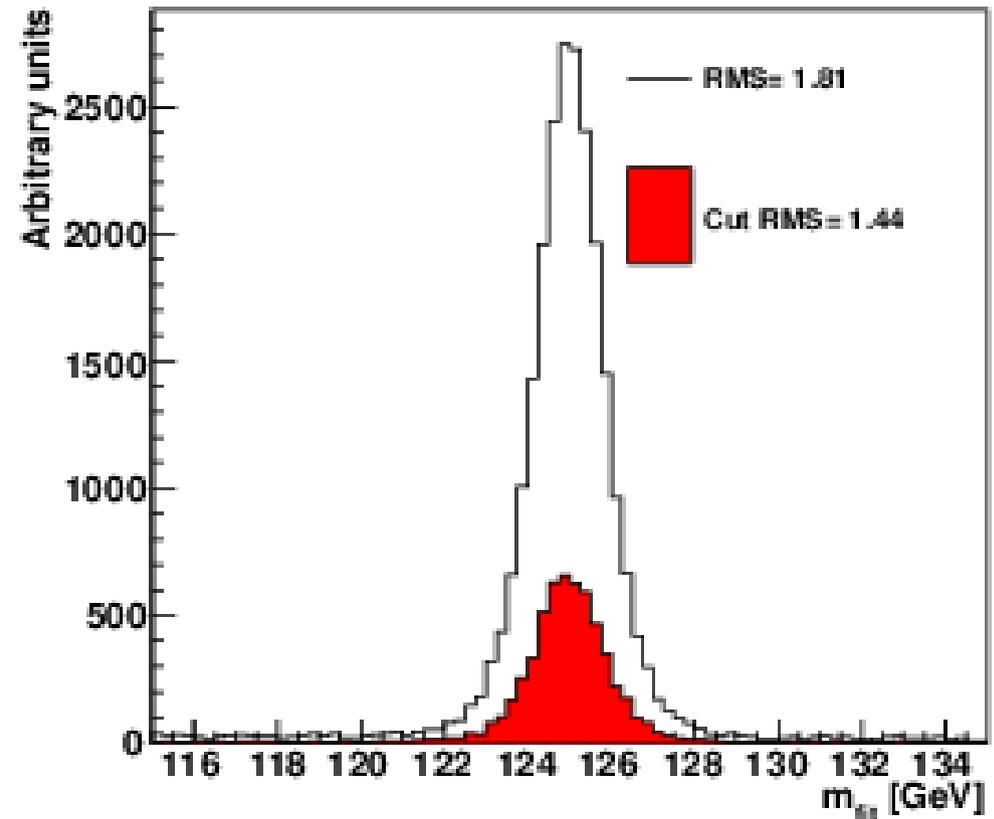# Dependence on TRUE signal

Signal 55 expected
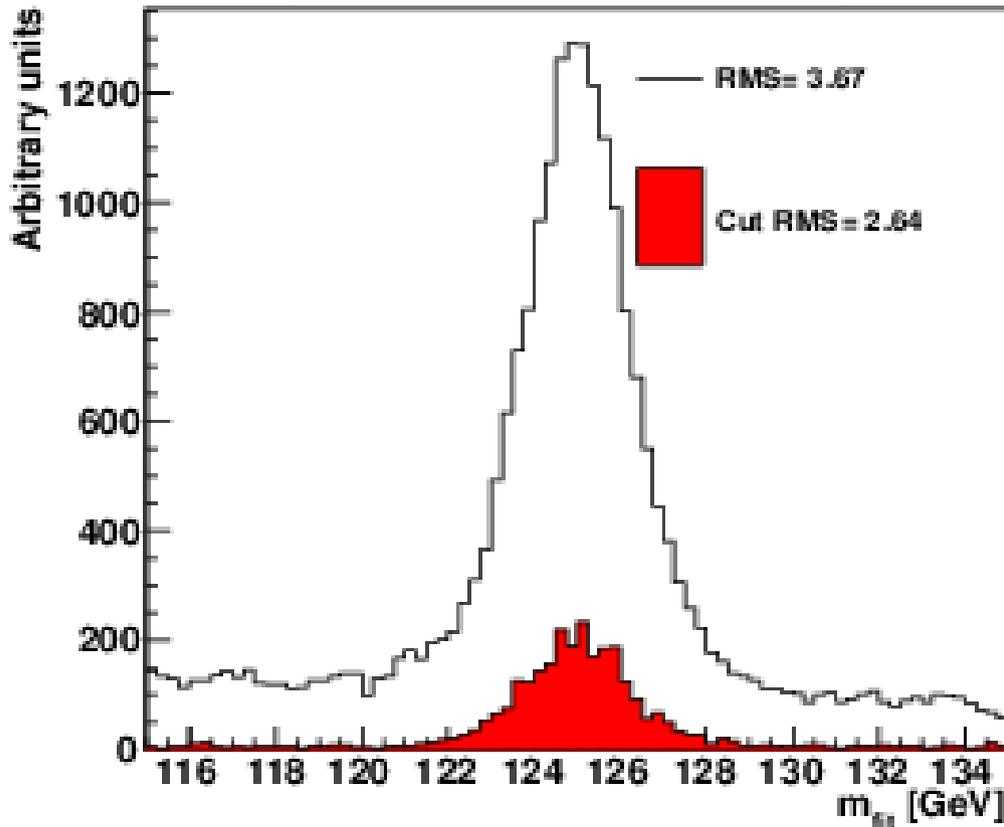
Signal 110 expected

- Injecting 2xSM ≠ observing 2xSM.
- Even with 2.5-3σ observed, RMS depends on *true* signal

OK, so $m_H^{fitted} \neq m_H^{true}$

- The resolution on m_H is worse than the per-event resolution!
  – The statistics is dominated by background fluctuations

- Imagine a 'perfect' (Asimov) signal
- Add a fluctuating background under it
  – Just above and just below peak gives 2 chances to fluctuate
  – Odds are one of them fluctuates up
  – The signal gets pulled to that point
  – And grows in size!
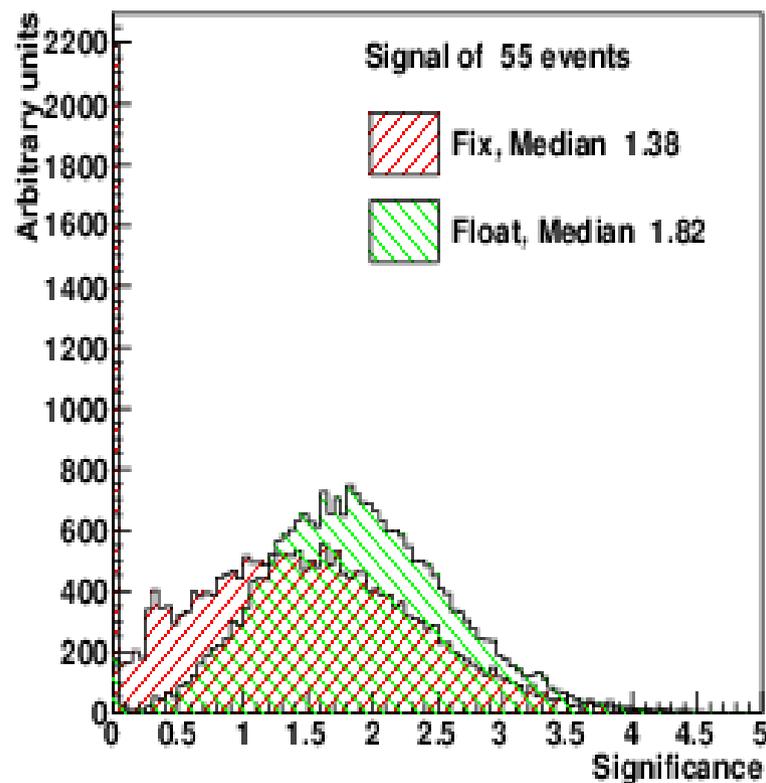- This is not included in the ATLAS/CMS 'expected p-values for signal' because they assume $m_H^{fitted} = m_H^{true}$
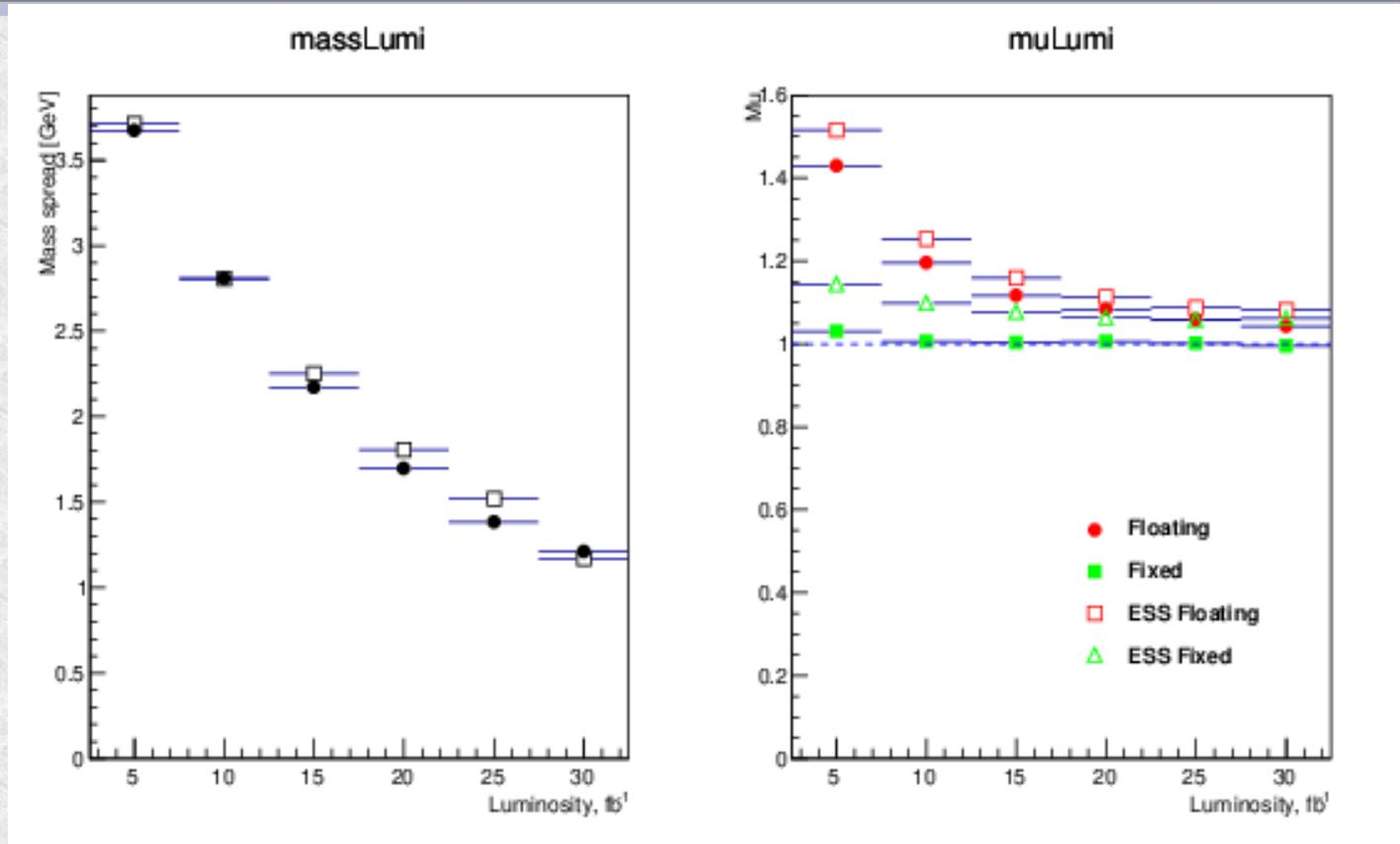
How large is effect on μ?
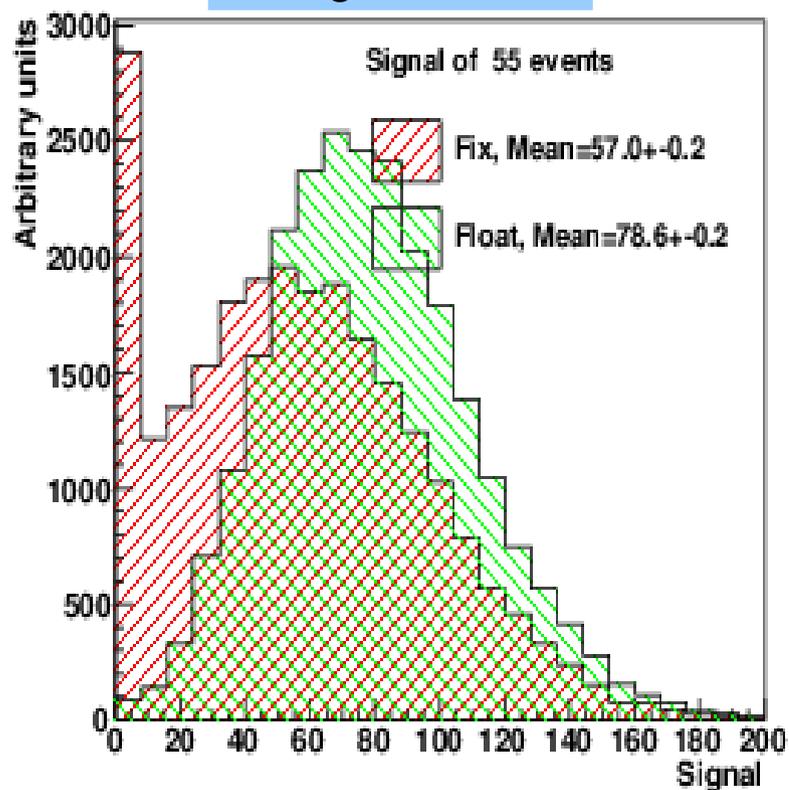
Signal size

Signal significance

- Red injects at 125 and tests at 125 – as expts. Do
  - 4% bias, coming from μ≥0
- Green injects at 125 and fits with m_H free
  - **43% bias!**

Evolution with data?

massLumi / muLumi plots. Legend: Floating, Fixed, ESS Floating, ESS Fixed. Axes: Mass spread [GeV] and Mu vs Luminosity, fb⁻¹
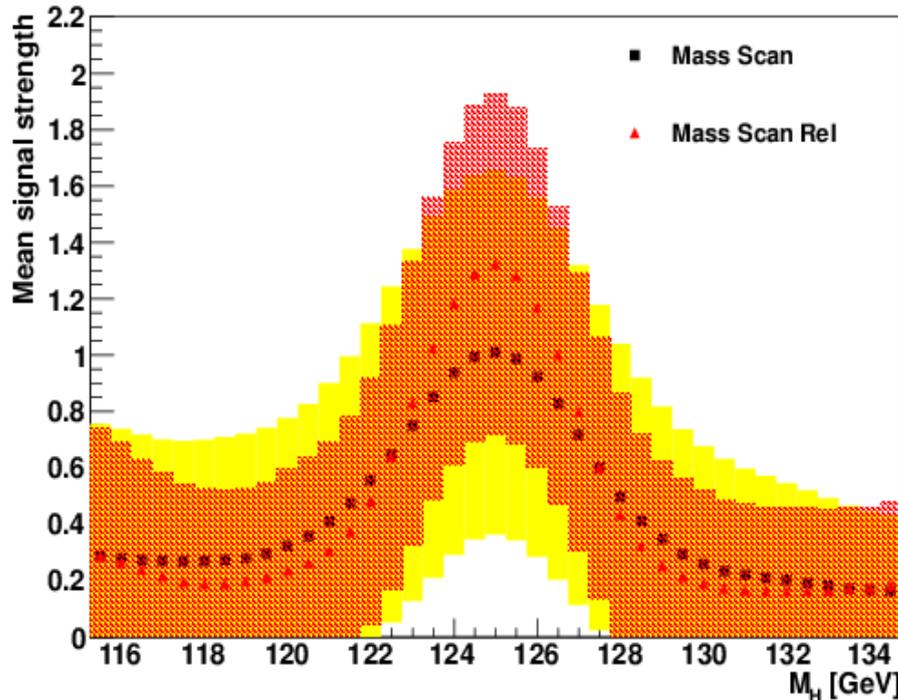
- Mass accuracy improves a little faster than $\sqrt{\mathscr{L}}$

- Bias in signal rate drops like $1/\mathscr{L}$
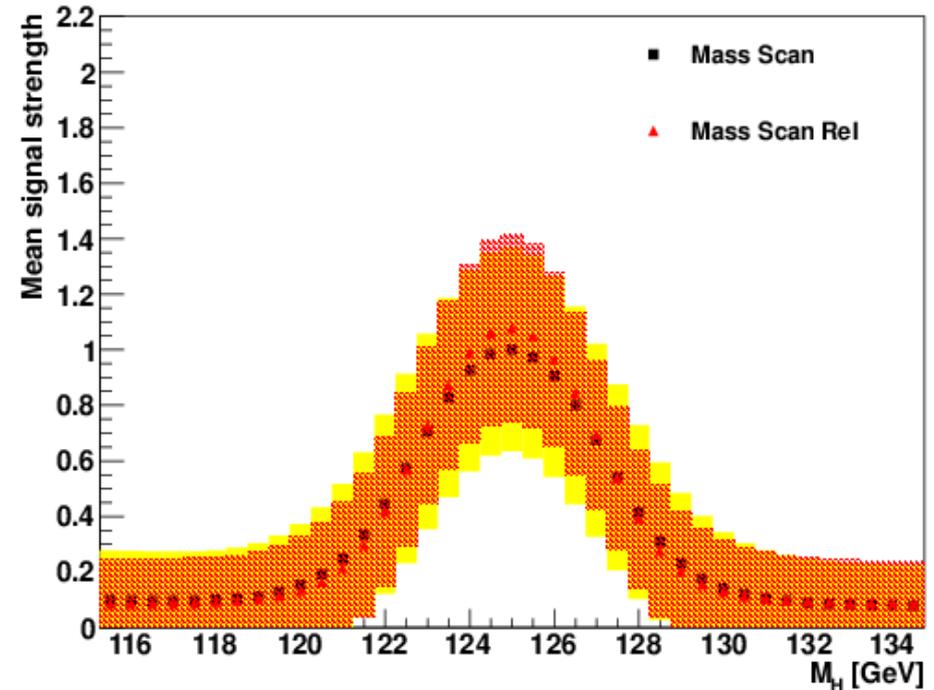 – Note ESS (0.7% between channels) makes µ bias even bigger

Signal apparent width

- The mean (and spread) μ v m_H with signal injected
- Black injected at 125, test all over, as experiments do
- Red when each scan is re-centred by largest p-value
  - Peaks at higher rate – as discussed
  - But narrower than the experiments injection plots suggest

Conclusions

- None of the numbers presented in this talk should be believed
  - This is an indicative toy study
- The best-fit m_H gives the true m_H by worse than $\sigma_m^{\gamma\gamma}$
  - The results of ATLAS and CMS are perfectly compatible
- There is an upward bias coming from background fluctuations
  - IFF you select the most extreme point
  - Signal could be overestimated by of order 50%
- The width of a signal will be less than injection plots show
- The statistics honed for discovery/exclusion have not (yet) been tweaked for interpretation of signal – Caveat Emptor
- This is my personal conclusion, not that of ATLAS