H→$\mu\mu$

Lydia Brenner on behalf of ATLAS and CMS

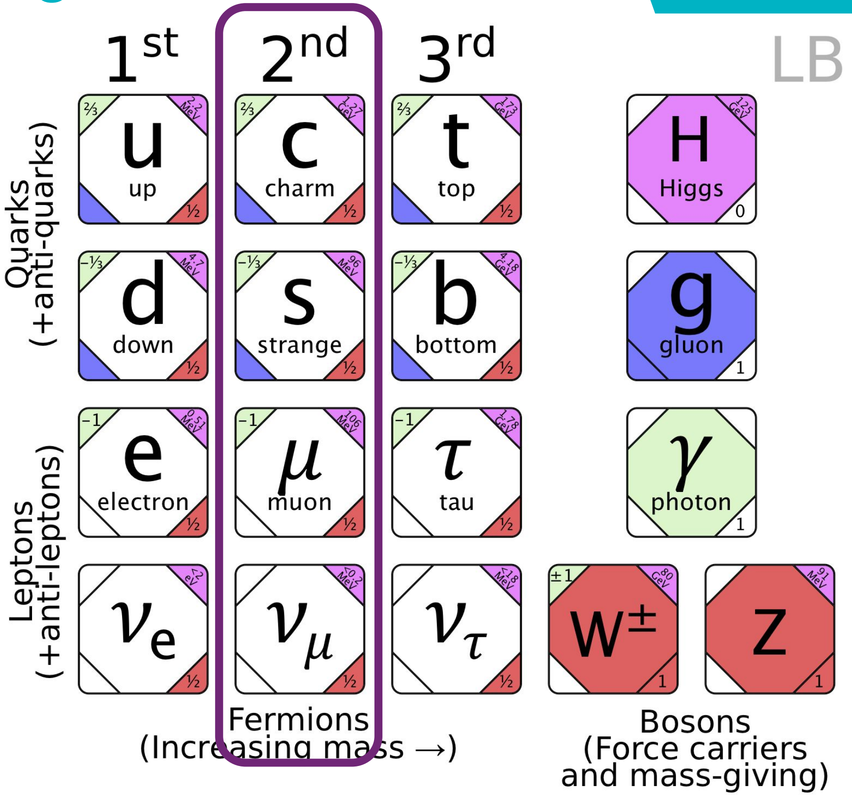
Talking about Run 2

Why not talk about Run 1? Or 2012 in particular?

The Standard Model: Second generation

Higgs coupling to fermions is proportional to the fermion mass

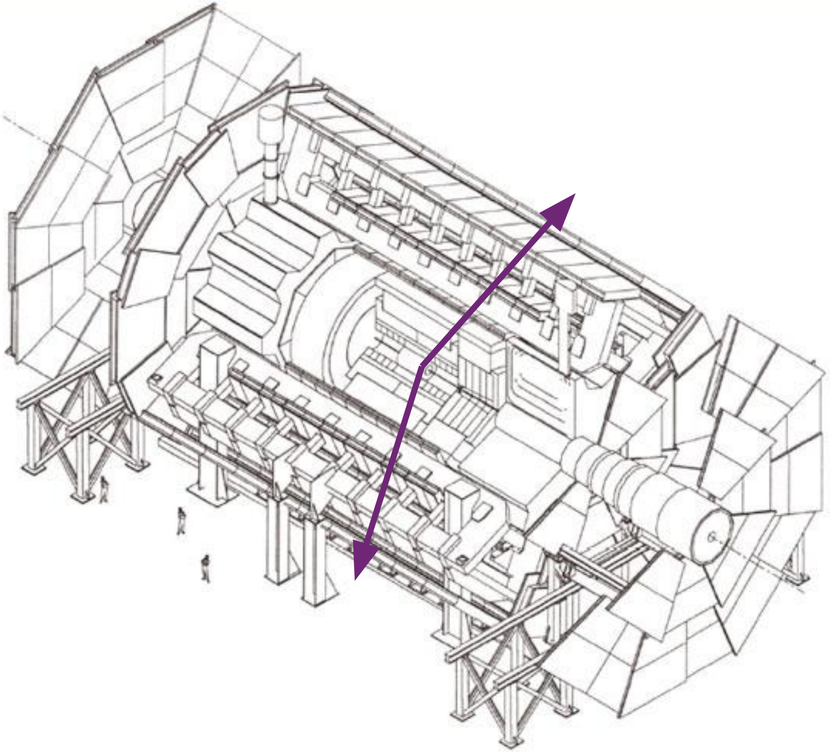
- ➔ Seen talks on third generation and the difficulties of H→cc
- ➔ H→$\mu\mu$ good candidate to test Higgs coupling to second generation
  - ◆ Relatively heavy
  - ◆ Detectors have relatively good muon resolution



Detector signal

Search for events with two muons

➔ Coming from the same vertex

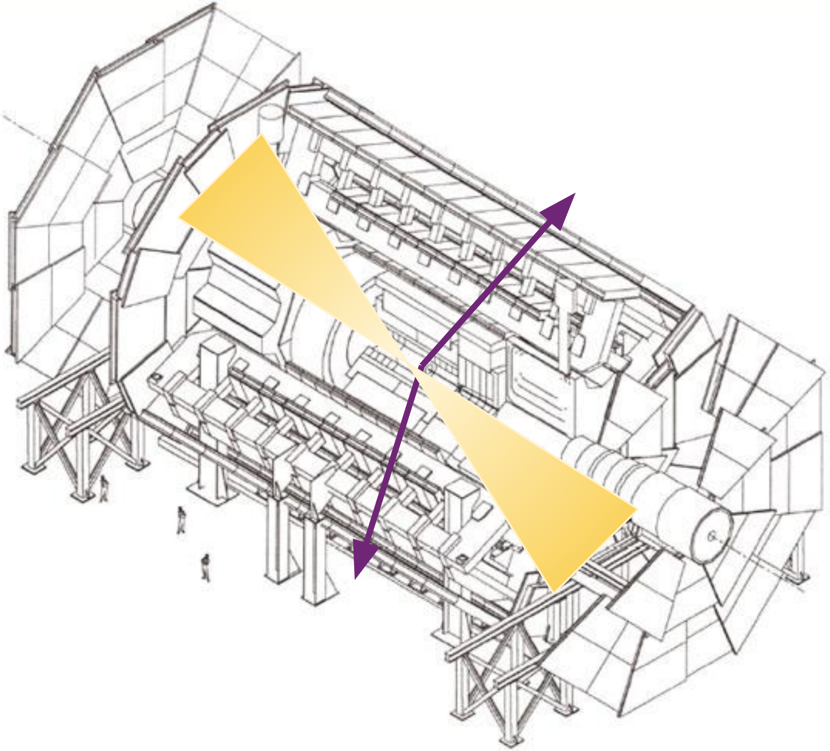


Detector signal

Search for events with two muons

➔ Coming from the same vertex

➔ Possibly with two jets

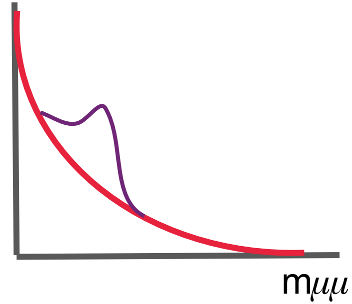


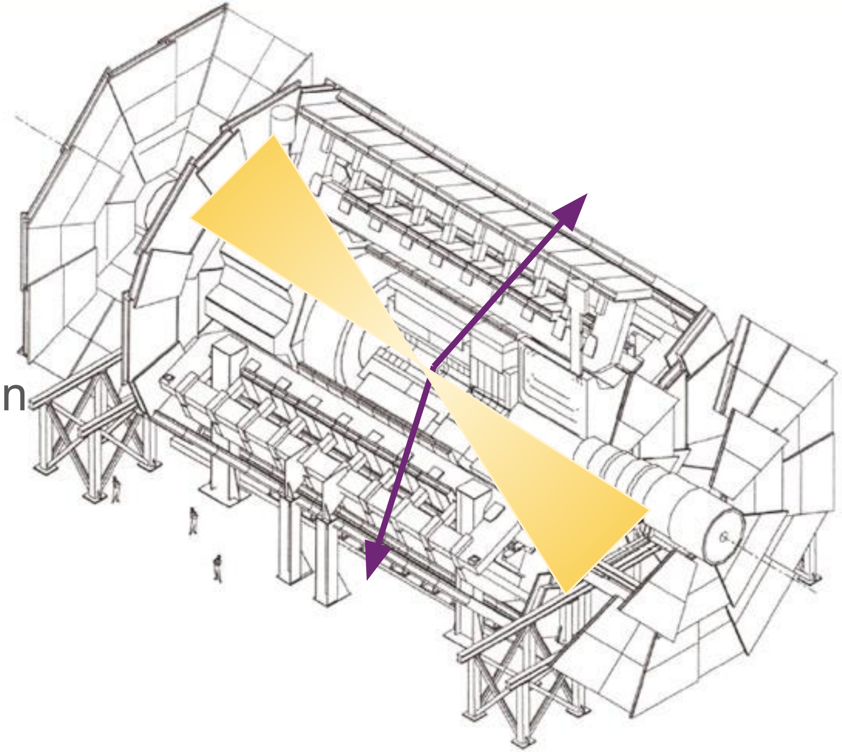
Detector signal

Search for events with two muons

- ➔ Coming from the same vertex
- ➔ Possibly with two jets

Look for a peak in the distribution of the invariant mass of the di-muon system



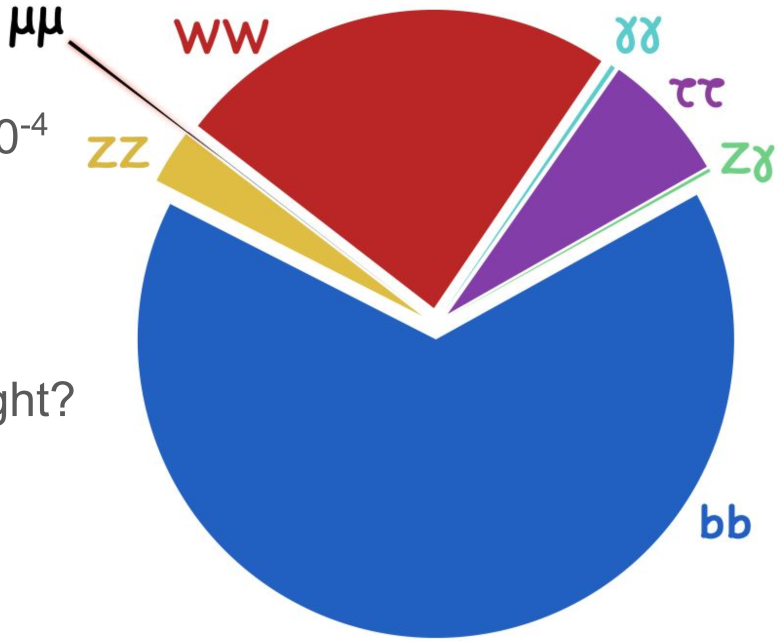


That sounds easy!

Not really…

- Small Branching Ratio of 2.17×10^{-4}

But since the muon reconstruction is advanced this should be still doable right?

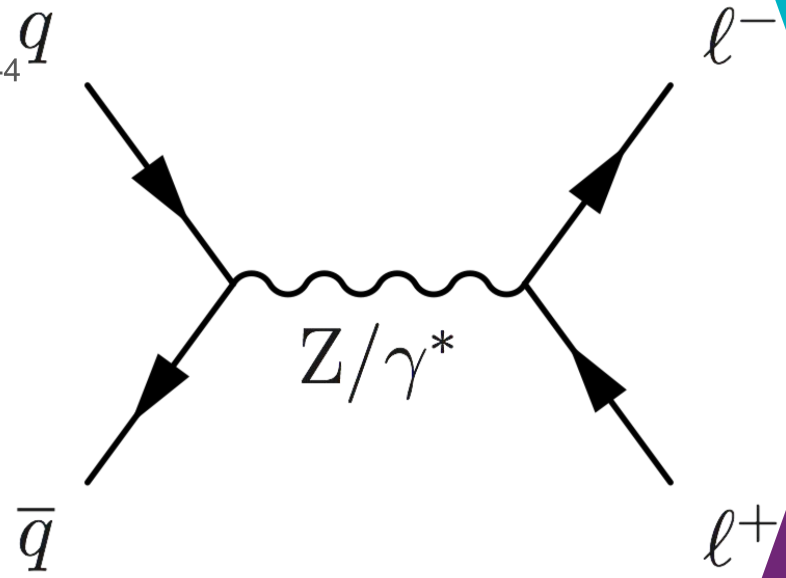


That sounds easy!

Not really…

- Small Branching Ratio of 2.17×10^{-4}
- Indistinguishable Drell-Yan background with same final state $\sim 10^3$ times larger than signal

Signal/Background ratio ~1/1000



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We are going too slow!

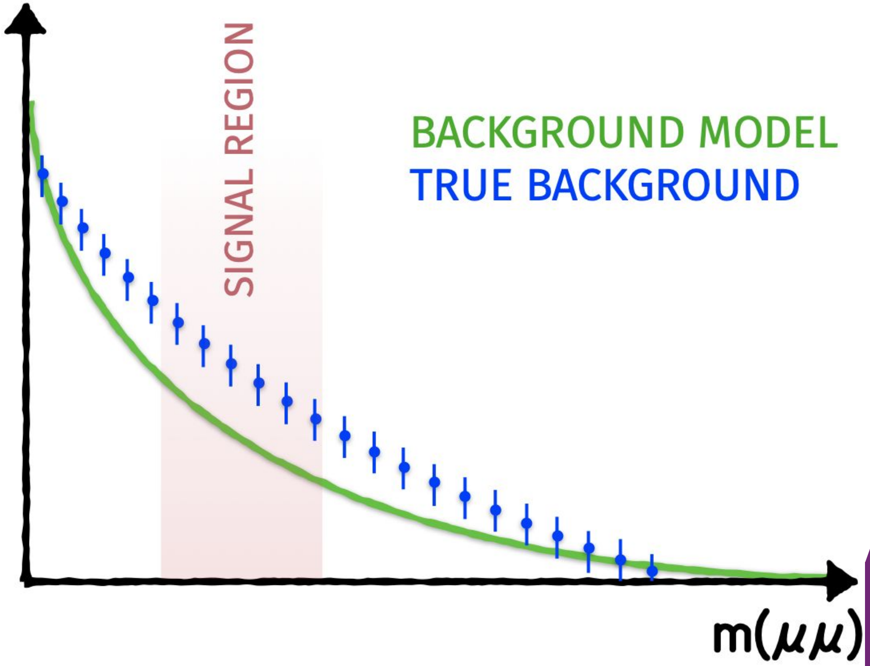
Enough excuses… let's just do this!

- Problems are very similar to H$\gamma\gamma$

Dealing with backgrounds

Very precise background models are needed

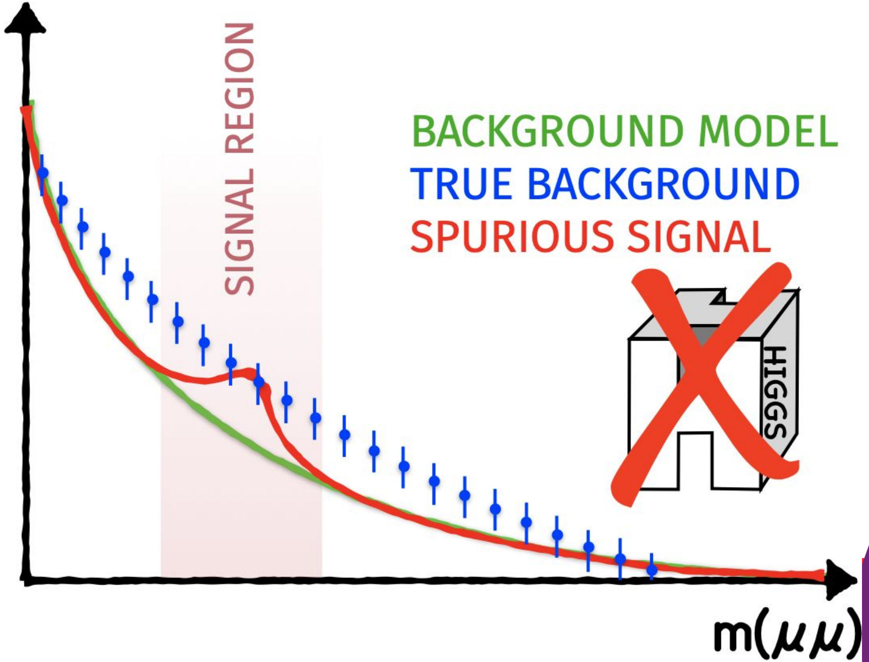
- What if the background model is not accurate?



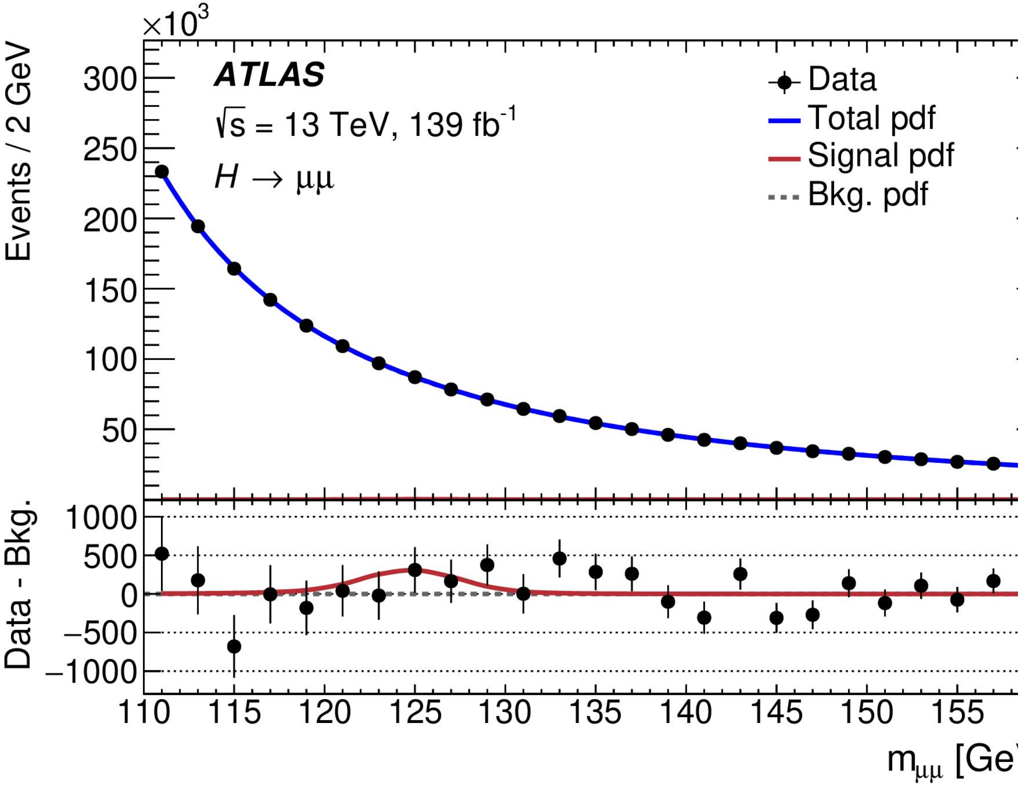
Dealing with backgrounds

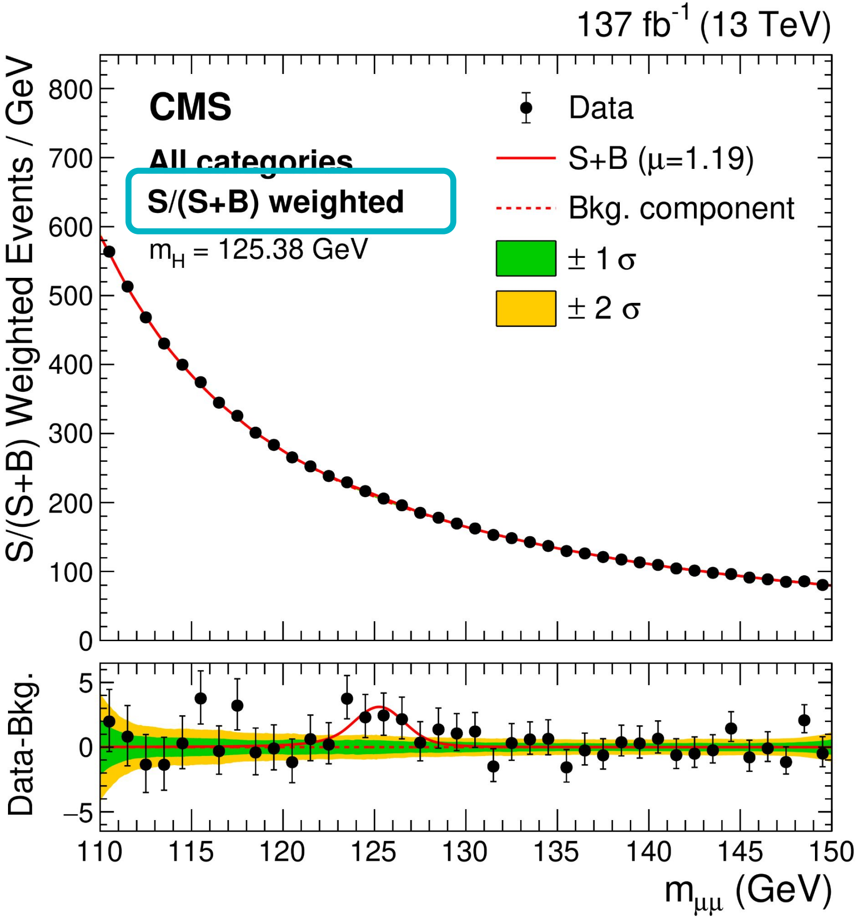
Very precise background models are needed

- What if the background model is not accurate?
- Let's assume we have no signal
  - Fitting the background-only spectrum can give a signal ≠ 0, due to the inaccuracy of the background model: spurious signal



The size of the background

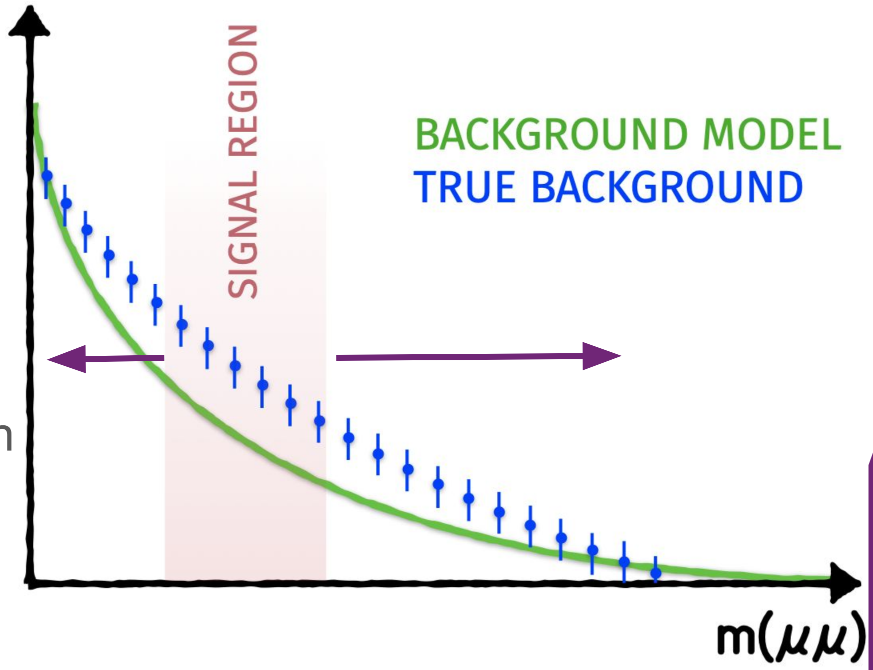




Background modelling

Using an empirical function for the background model

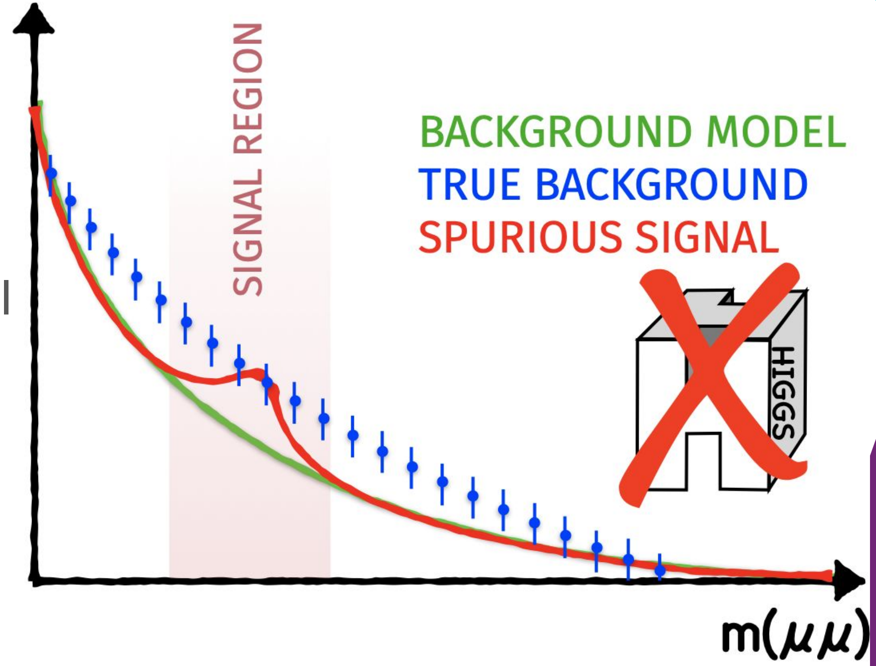
- Require good match between model and data in sidebands
- Reweigh high statistics MC sample to have good match between data and MC in the sidebands
- Require good match in between MC and model in signal region



Background modelling

Is this enough to not be bothered by spurious signal? No

- Use separate high statistics MC sample to estimate size of spurious signal in the signal region
- Require that the spurious signal <20% dN_{sig} to select function



Background composition

Different production modes have different dominant background contributions

ggH

- ➔ 87% of total H cross section
- ➔ Low signal purity : 0.2-2%
- ➔ Large DY background

VH

- ➔ 4% of total H cross section
- ➔ Additional e, μ in the event from leptonic decays of W, Z
- ➔ Main backgrounds : ZZ, WZ

VBF

- ➔ 7% of total H cross section
- ➔ Two jets with large η-gap, mjj
- ➔ Main backgrounds : DY, EWK Z+jj

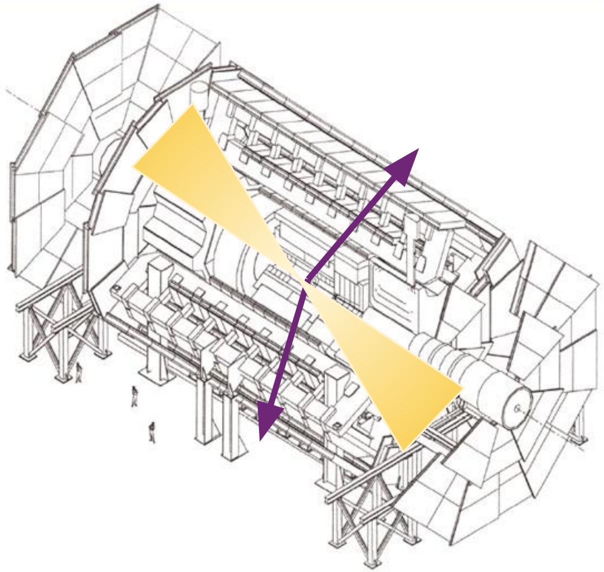
ttH

- ➔ 1% of total H cross section
- ➔ Additional jets, b-jets, leptons in the event from top decays
- ➔ Main backgrounds : tt, ttZ

Optimising the signal

In order to improve S/B and the total significance even further we split into several distinct signal regions optimised depending on production signature

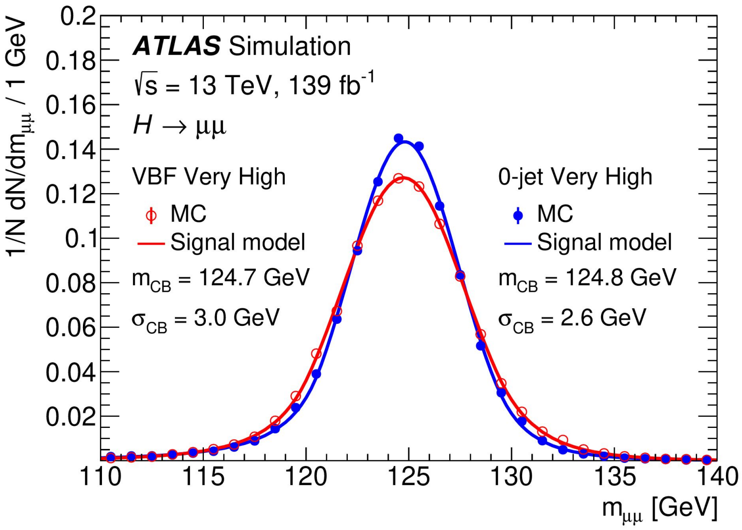
- Defined 19 (CMS) and 20 (ATLAS) orthogonal signal regions
  - Each signal region has different background contributions
  - Optimise background model for each signal region separately

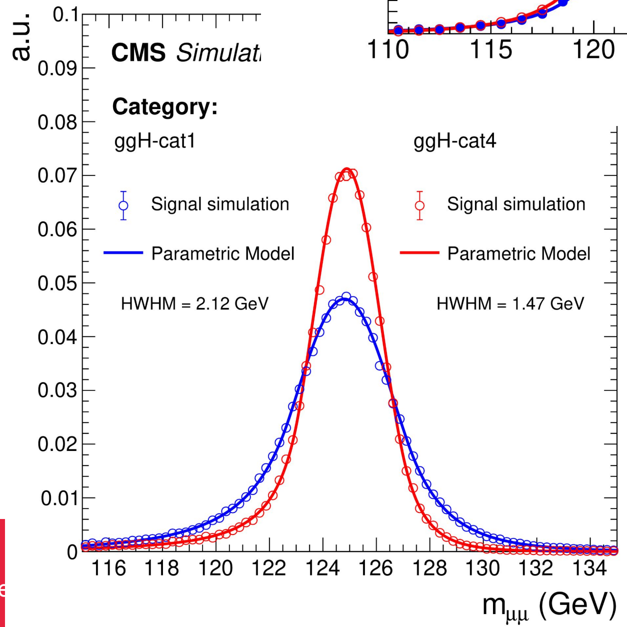


The Signal model

Signal shape is dominated by detector resolution

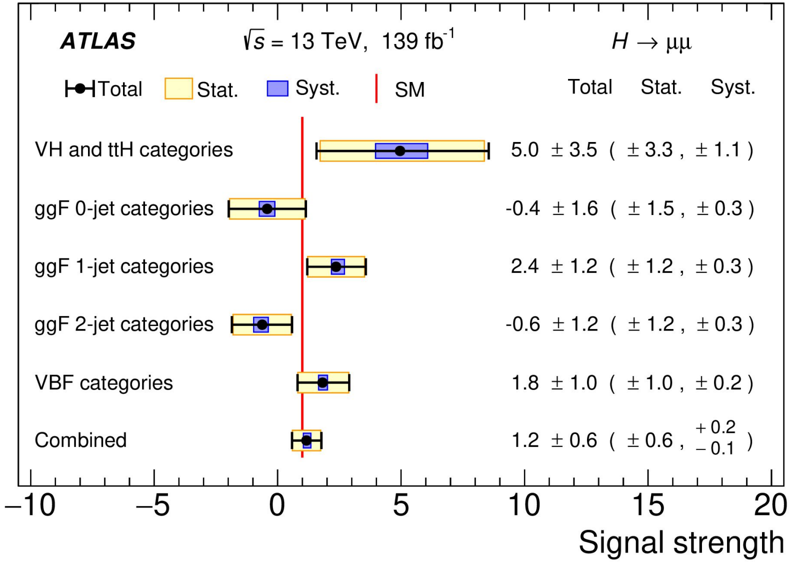
- Using double-sided Crystal Ball (CB) as analytic parameterisation for the signal
  - Gaussian core + power-law tails on each side

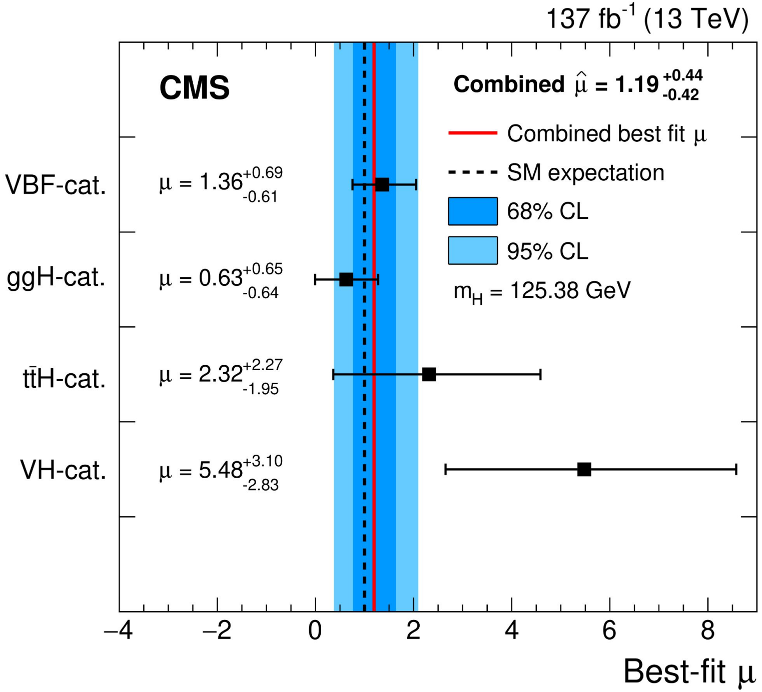




The results

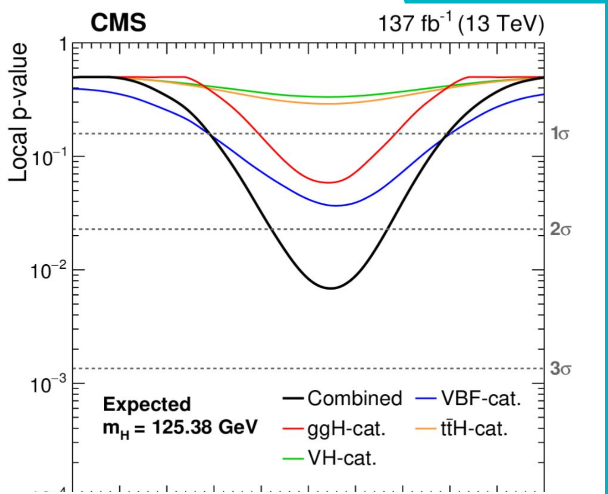
- Signal strength;
  - 1.2±0.6 (ATLAS) and 1.19±0.44 (CMS)

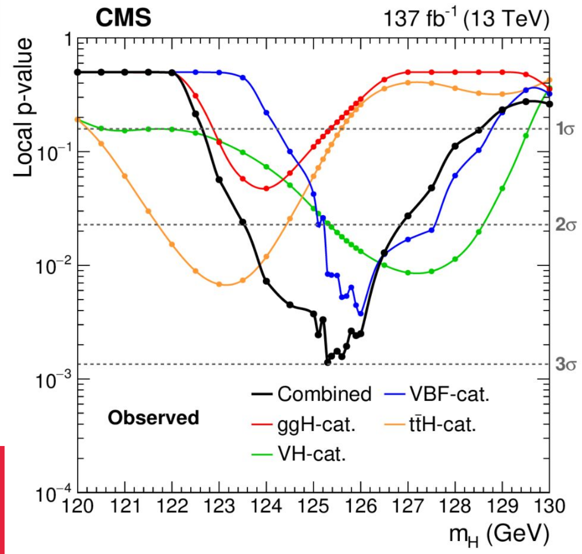




The results

- Signal strength;
  - 1.2±0.6 (ATLAS) and 1.19±0.44 (CMS)
- Significance
  - Expected: 1.7σ (ATLAS) and 2.5σ (CMS)
  - Observed: 2.0σ (ATLAS) and 3.0σ (CMS) ⭐





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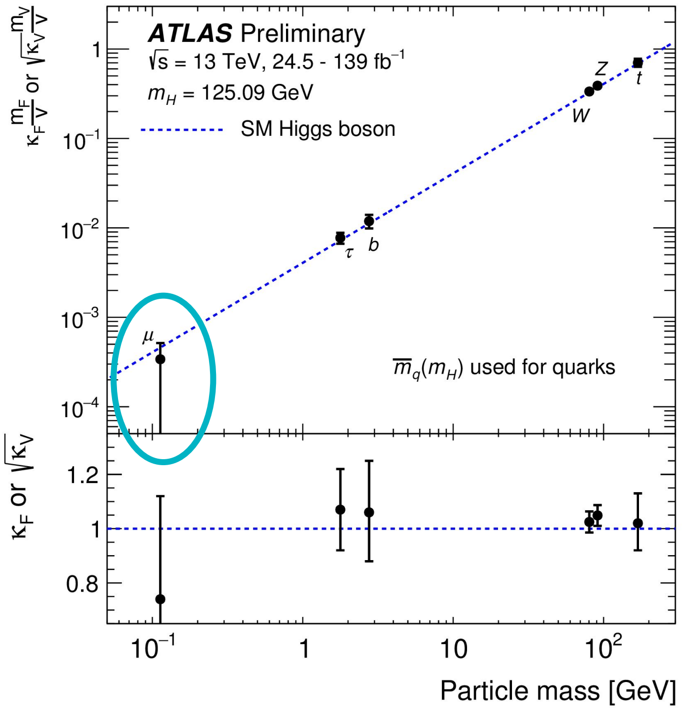
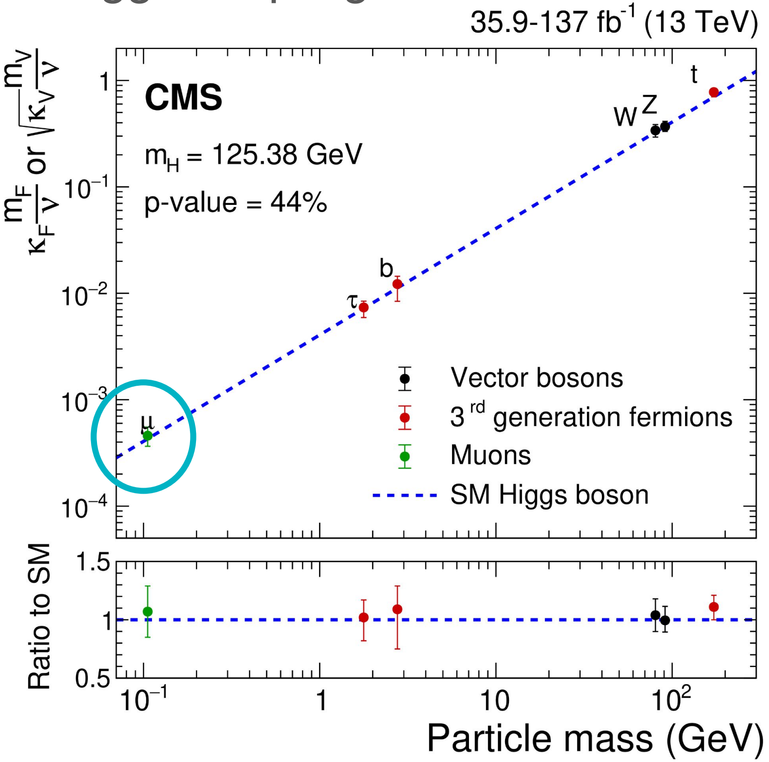
- Significance
  - Expected: 1.7σ (ATLAS) and 2.5σ (CMS)
  - Observed: 2.0σ (ATLAS) and 3.0σ (CMS)⭐
- BR limit at 95% CL
  - 4.7 x 10^{-4}
- Main uncertainties in order of size
  - Statistics (data) ⇒ Stay tuned for Run 3!
  - Theory predictions of the signal
  - Background modelling

The big picture

Coupling modifiers compared to other Higgs couplings





Nikhef

Summary and conclusion

- Full run 2 measurement done for $H\rightarrow\mu\mu$ in ATLAS and CMS
- Shown first Higgs boson coupling to second generation (CMS)
  - 3.0σ observed
- Measured signal strength compatible with the Standard Model
  - ~1.2 ±0.6(ATLAS) ±0.44(CMS)

Exciting Run 3 ahead for $H\rightarrow\mu\mu$

➔ In the style of a Run 1 discovery search
  - ◆ Only this time we are unsurprised to find it