Searching for Massive New Particles Decaying to Jets at ATLAS

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Physics | Lancaster University

Massive new particles

- Excited quarks - q^*
- Quantum black holes - QBH
- W' bosons

Excited quarks

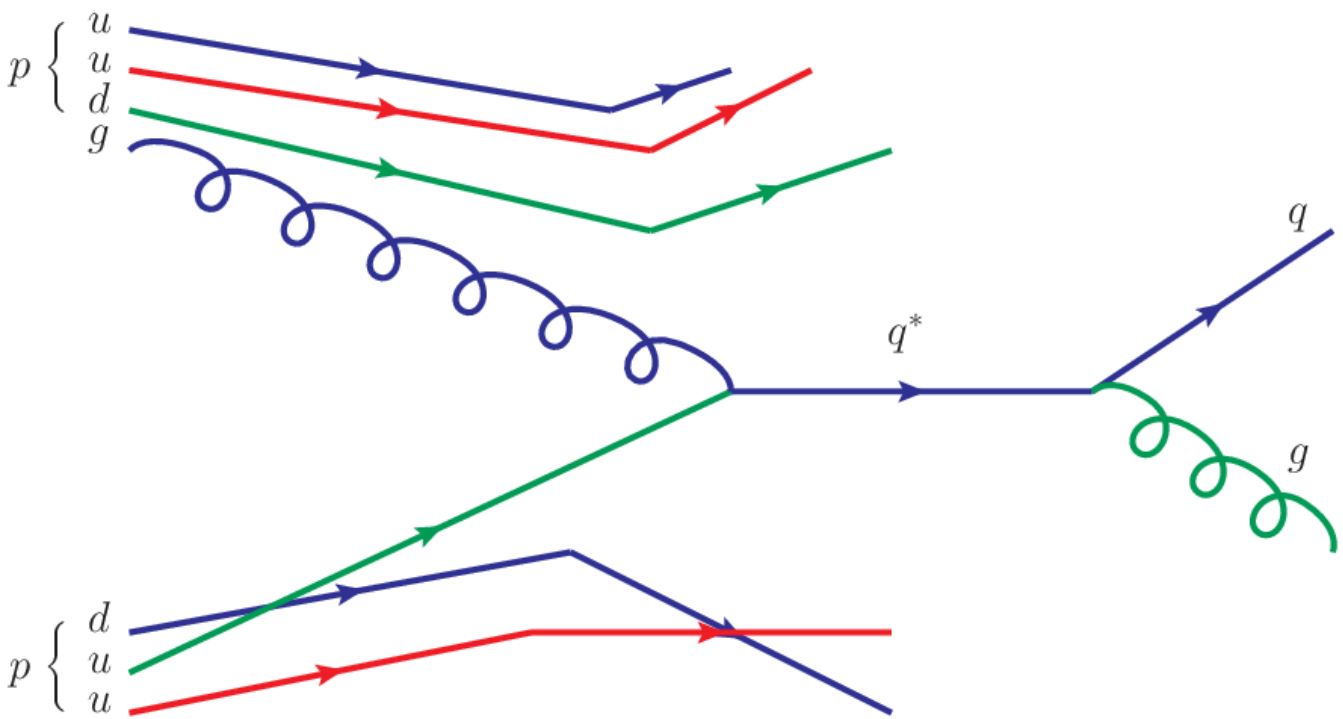


Figure 1: Excited quark formation in a proton-proton collision[1].

[1] Image: http://www.quantumdiaries.org/2015/02/04/lhc-run-ii-excited-quarks/

Jets

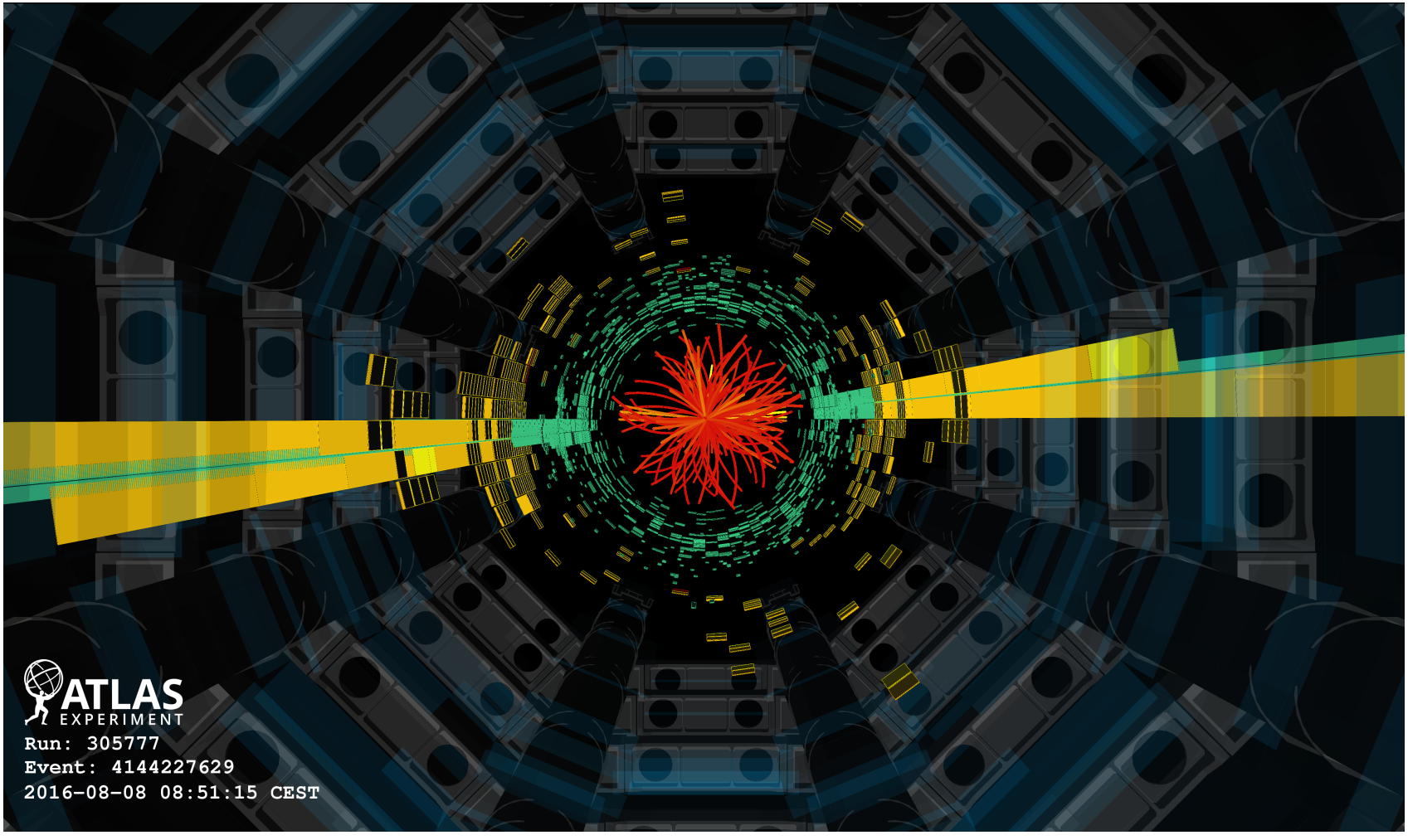


Figure 2: Example dijet event at the ATLAS detector[2].

[2] M. Aaboud et al. Search for new phenomena in dijet events using 37 fb^{-1} of pp collision data collected at $\sqrt{s} = 13\,\mathrm{TeV}$ with the ATLAS detector. *Phys. Rev.*, D96(5):052004, 2017.

Dijet invariant mass

- With the total energies E and momenta p of jets 1 and 2

$$m_{jj} = \sqrt{(E_1 + E_2)^2 - (p_1 + p_2)^2}$$

- m_{jj} is the rest mass of the massive particle

m_{jj} distribution

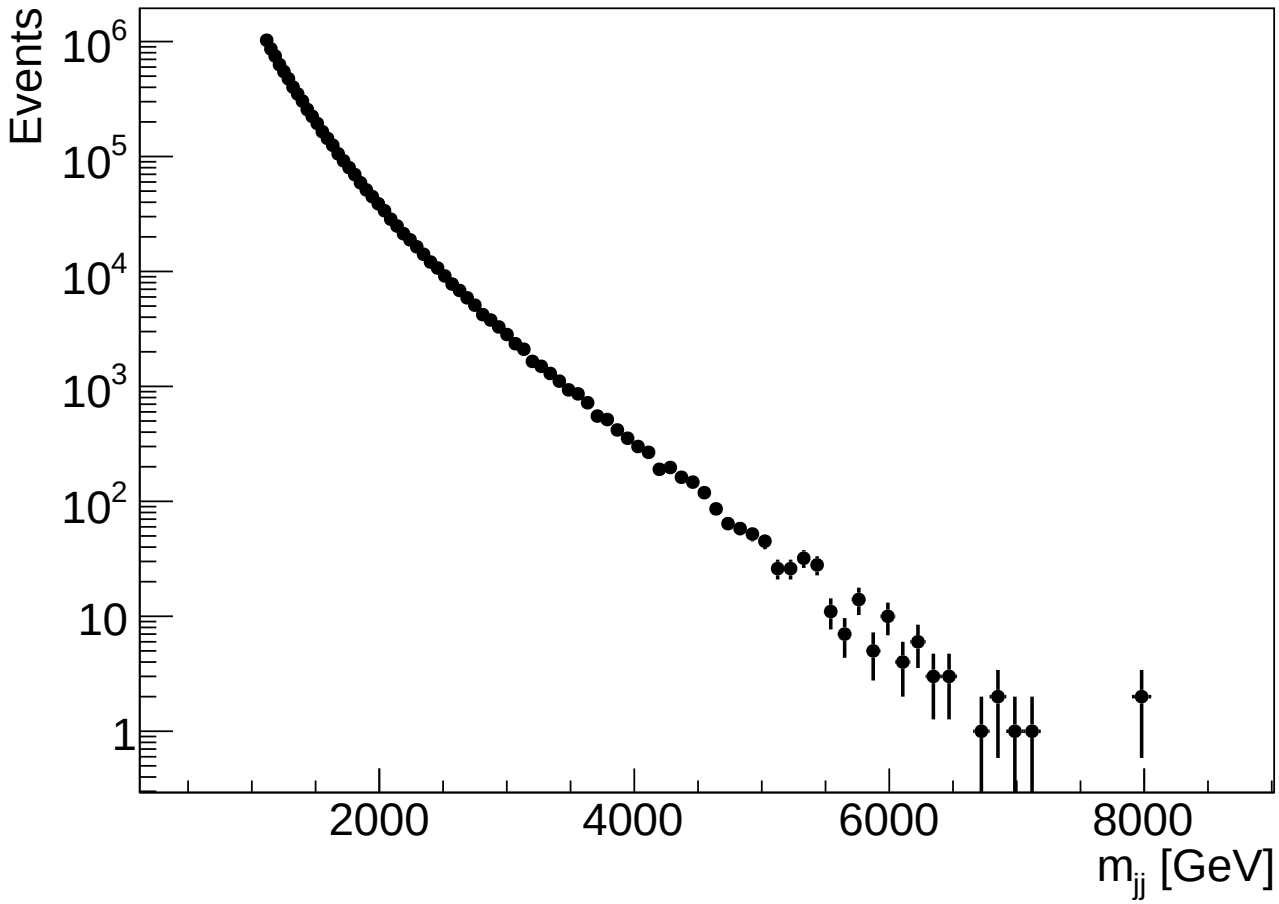


Figure 3: Binned m_{jj} distribution of dijet events from 2015-16 ATLAS measurements in 37 fb^{-1} p-p collisions.

Equivalent Higgs

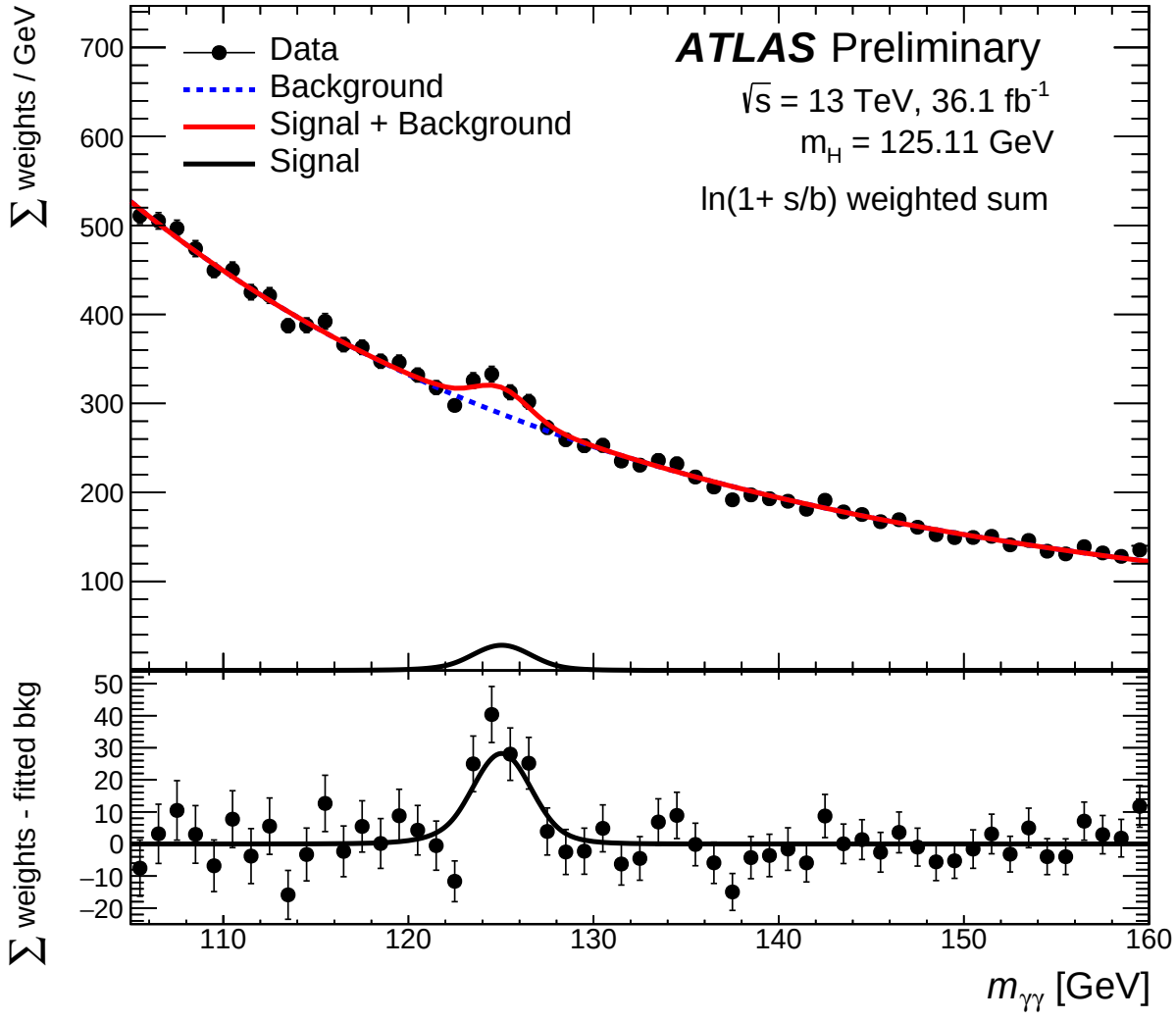


Figure 4: The Higgs was discovered in the photon-photon distribution.

Excited quark simulated signal peak

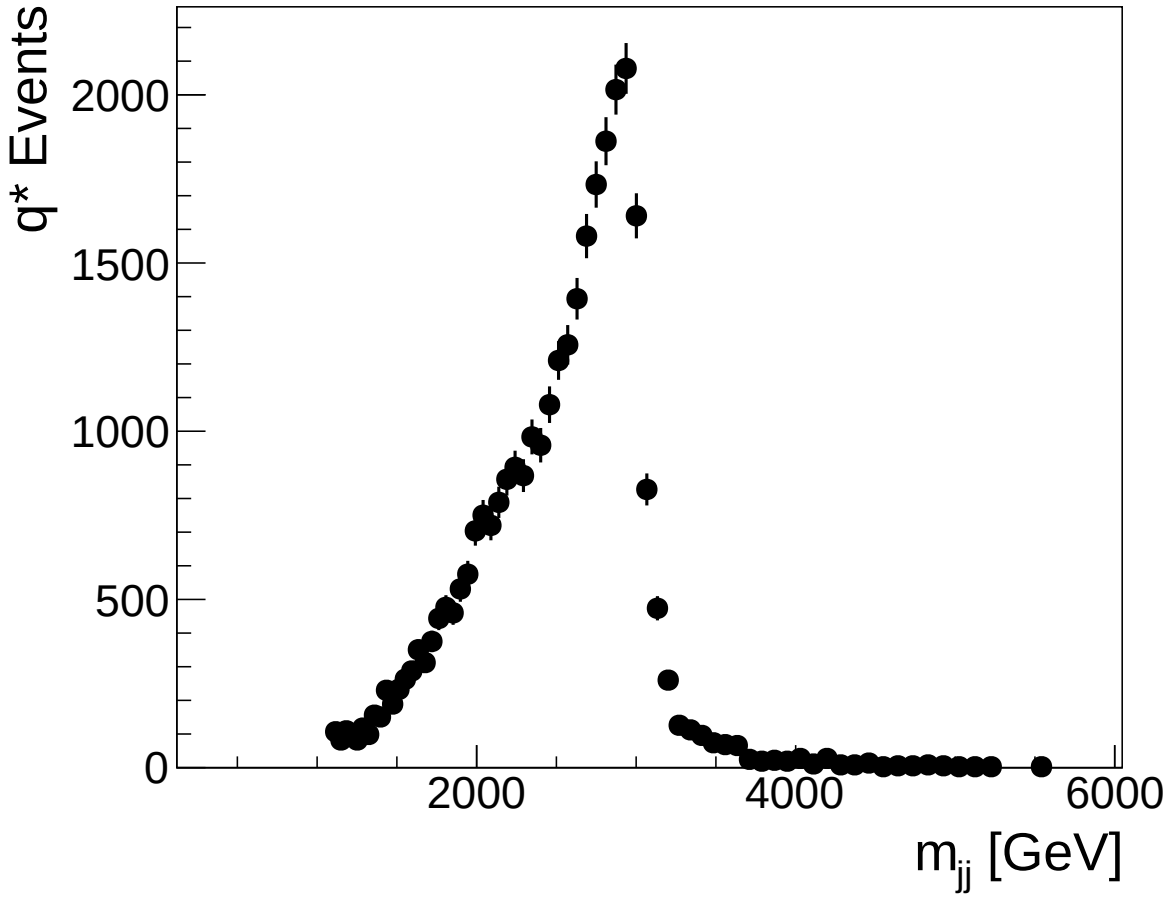


Figure 5: Example excited quark peak at $m_{q^*} = 3\,\mathrm{TeV}$.

Quantum black hole simulated signal peak

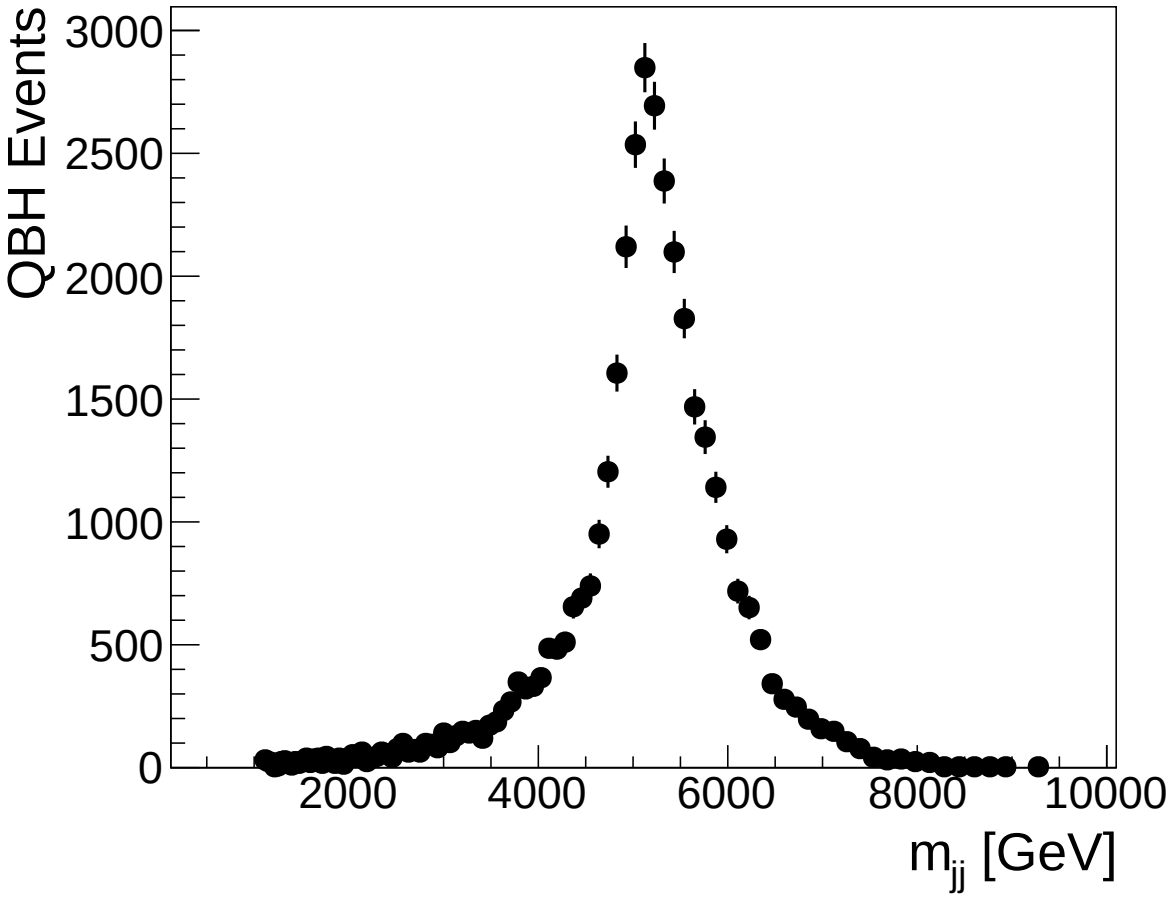


Figure 6: Example QBH peak at $m_{QBH} = 5\,\mathrm{TeV}$.

W' simulated signal peak

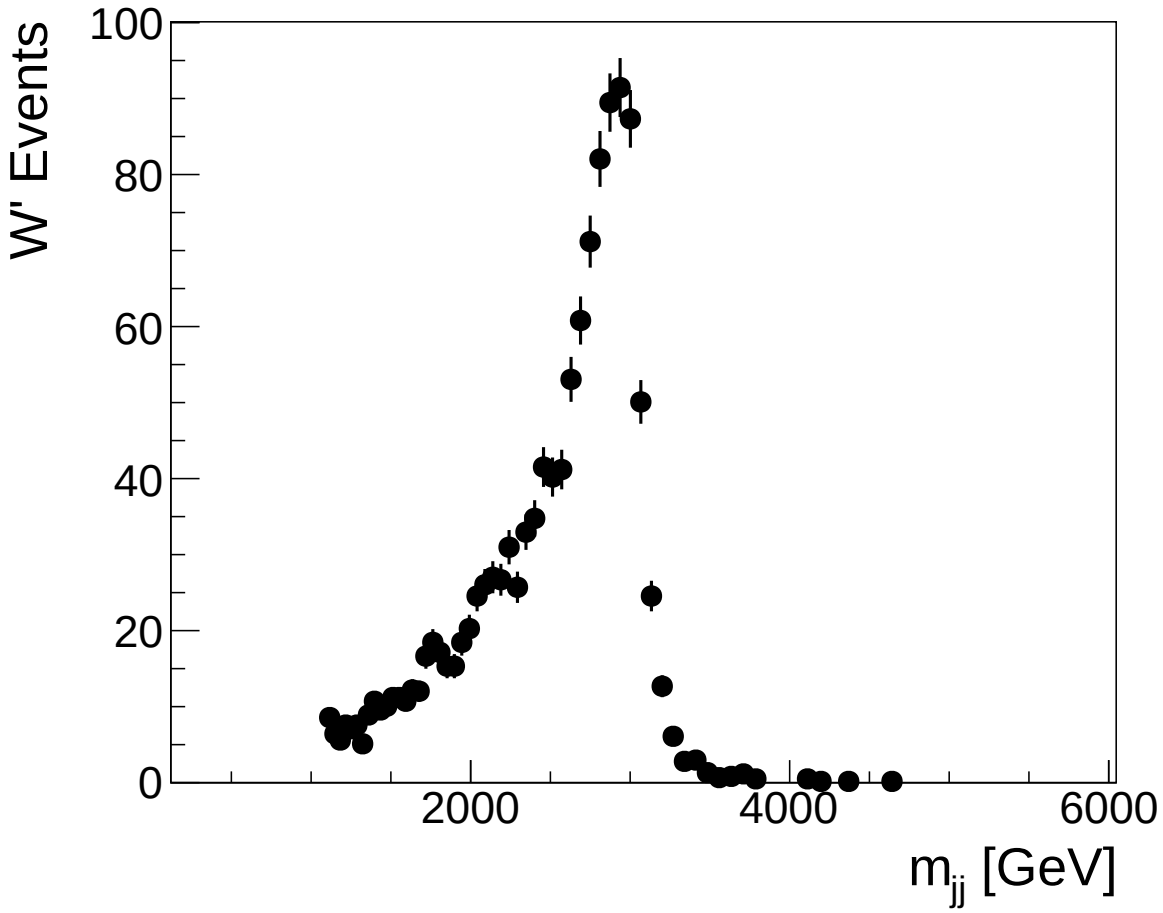


Figure 7: Example W' peak at $m_{W'} = 3\,\mathrm{TeV}$.

Likelihood

- The binned log likelihood for a given background b, fitted background f, and peak p scaled to N events:

$$\mathrm{L(N)} = -\sum_i \ln(\mathrm{Poisson}(b_i,\ f_i + p_{i,N}))$$

Using likelihood testing

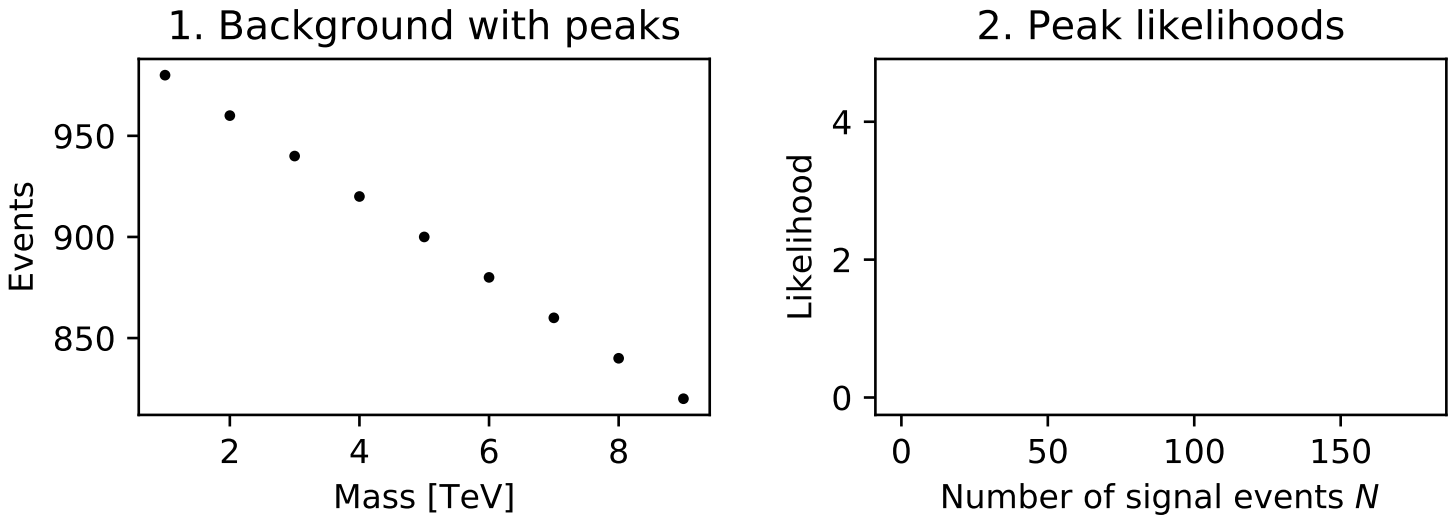
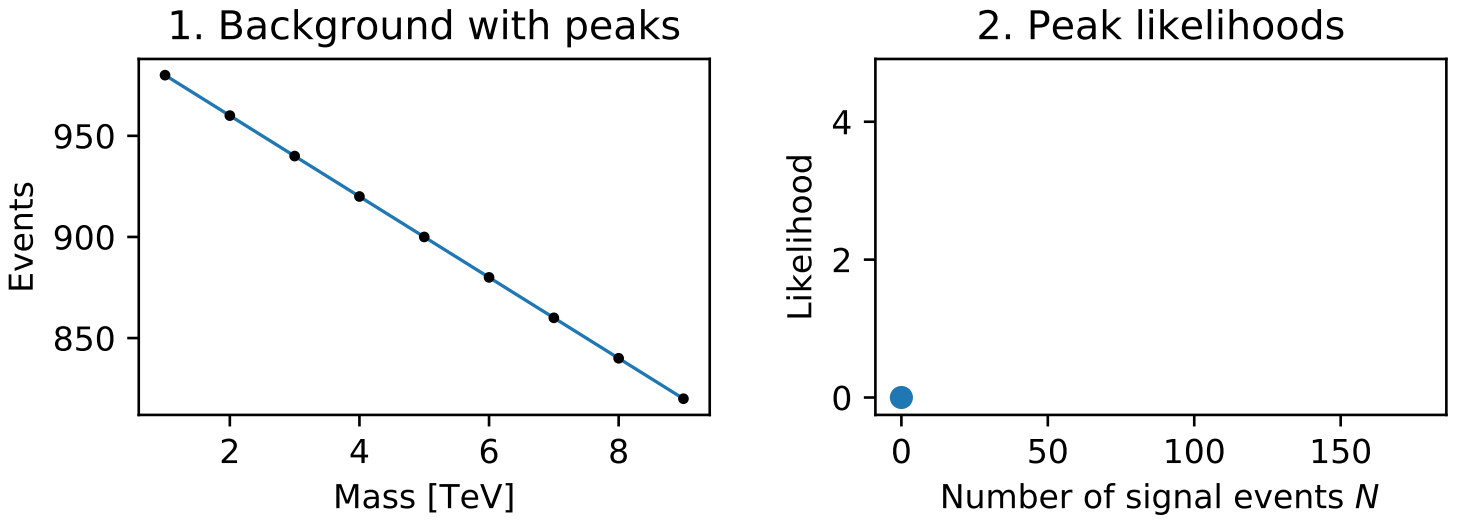


Figure 8: Illustration of likelihood testing process.

Using likelihood testing



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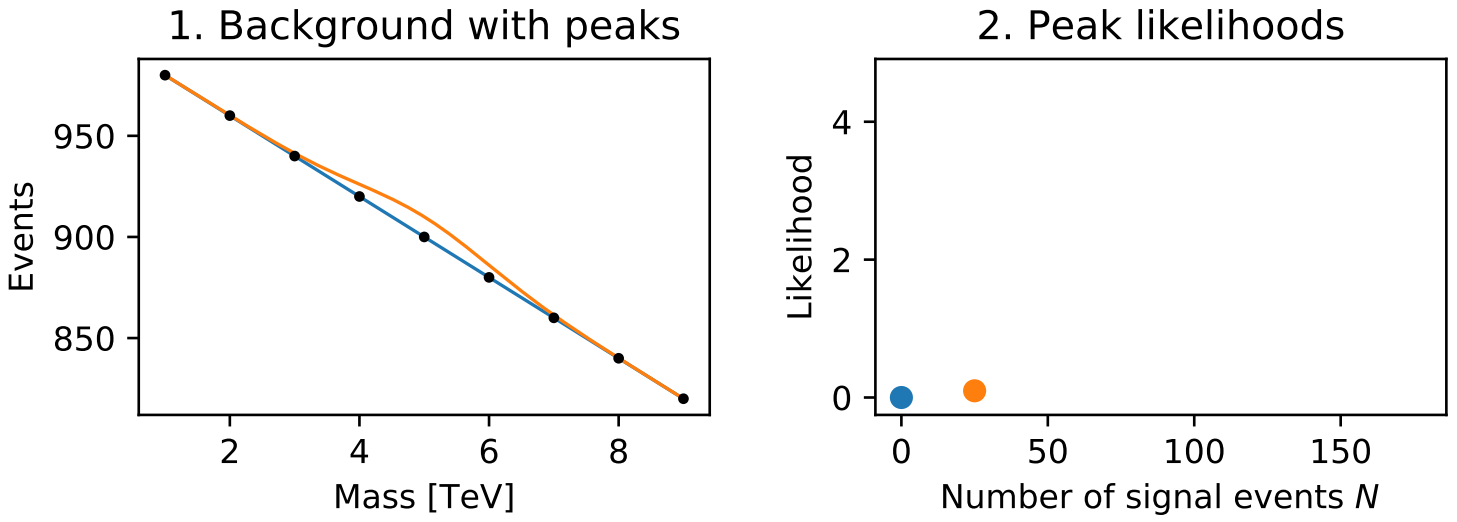

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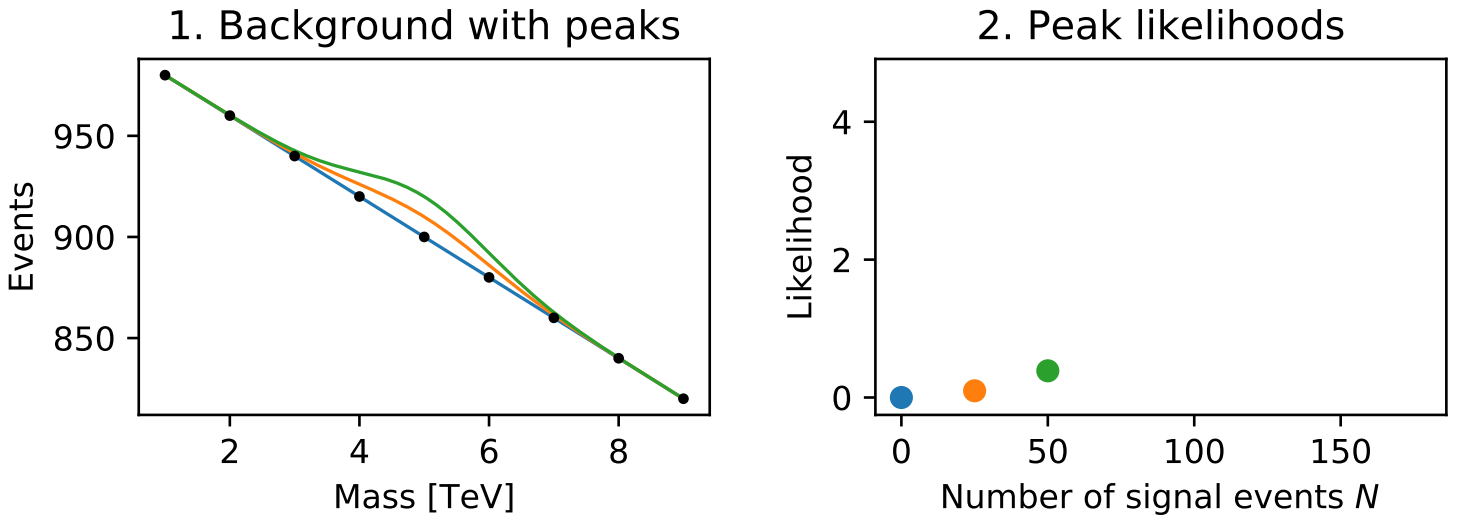

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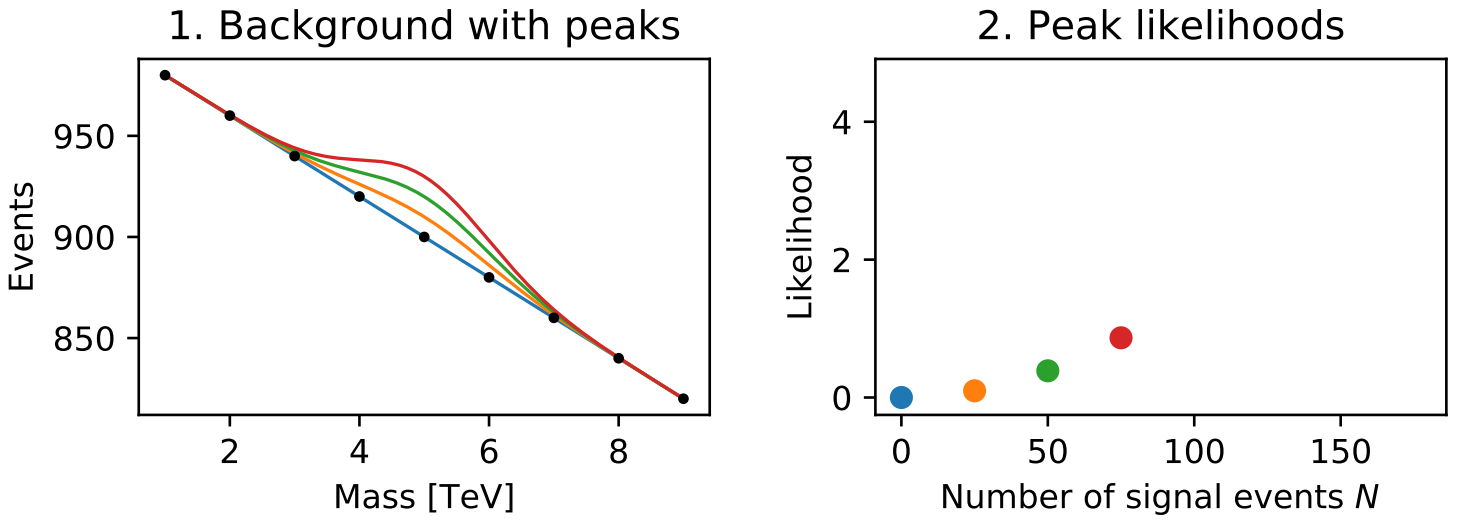

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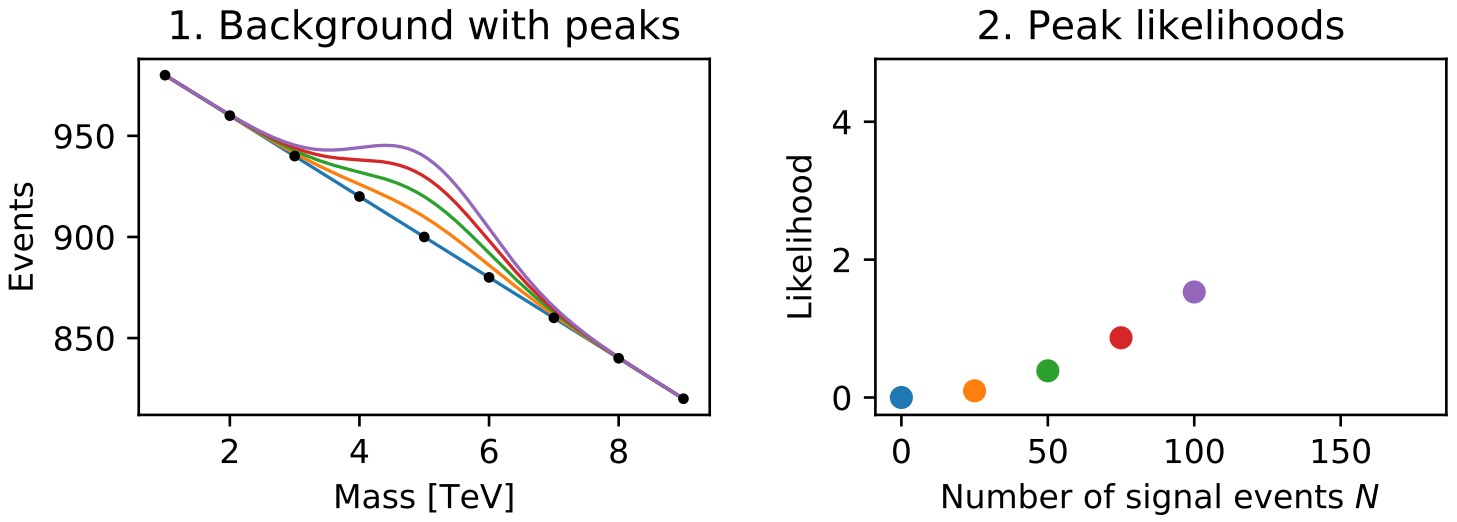

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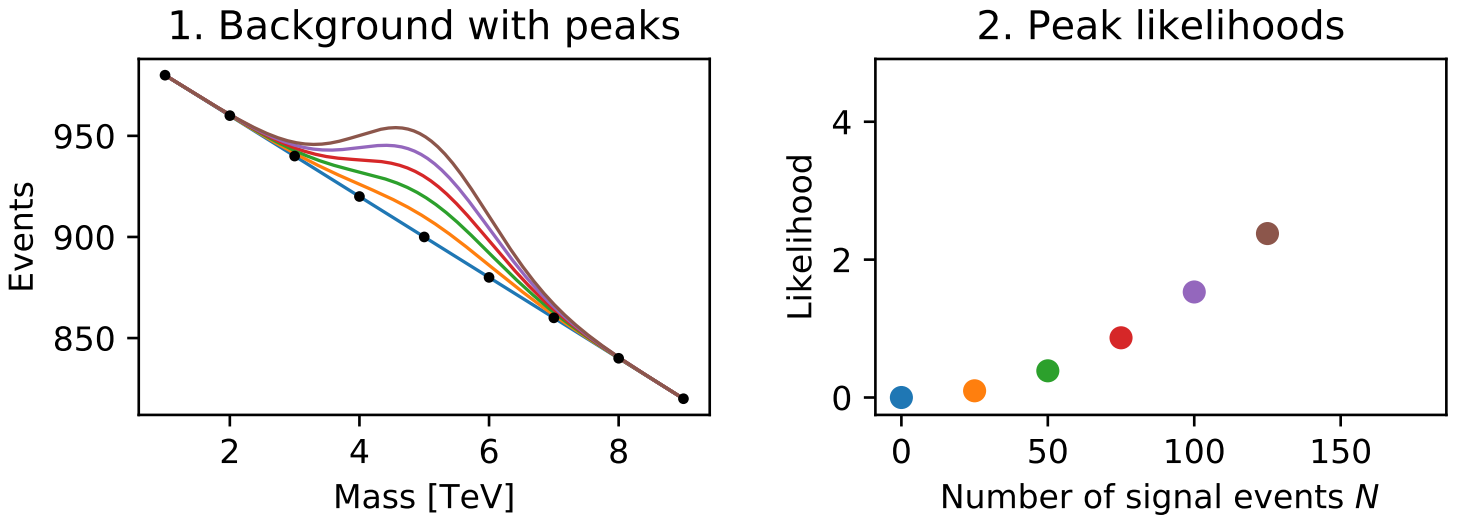

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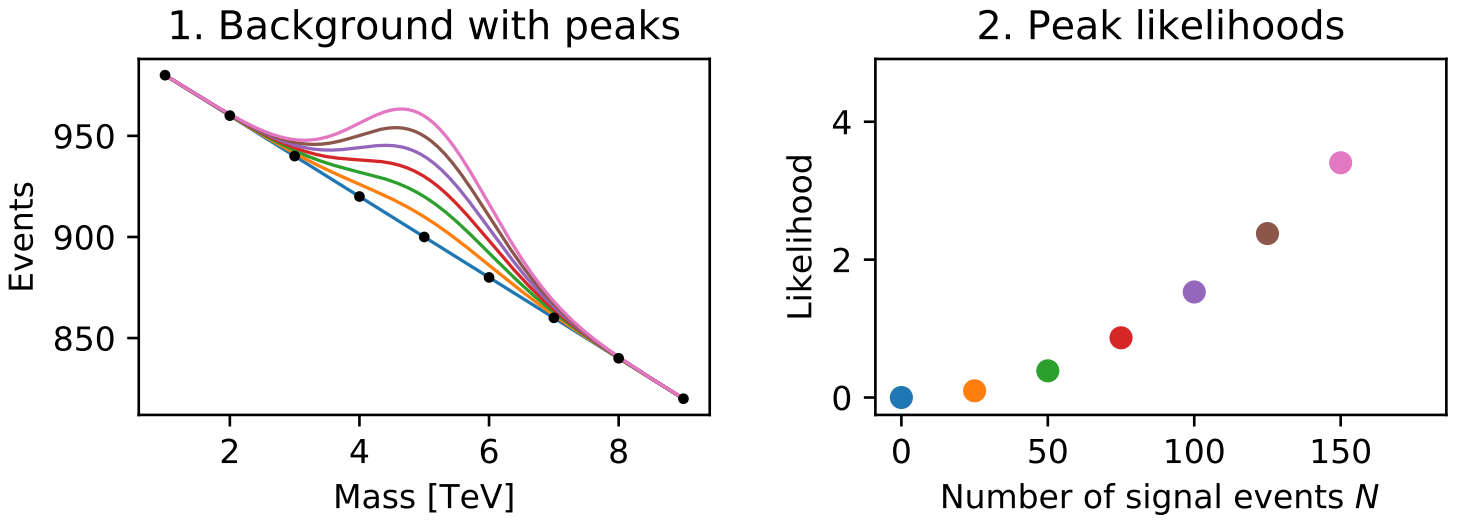

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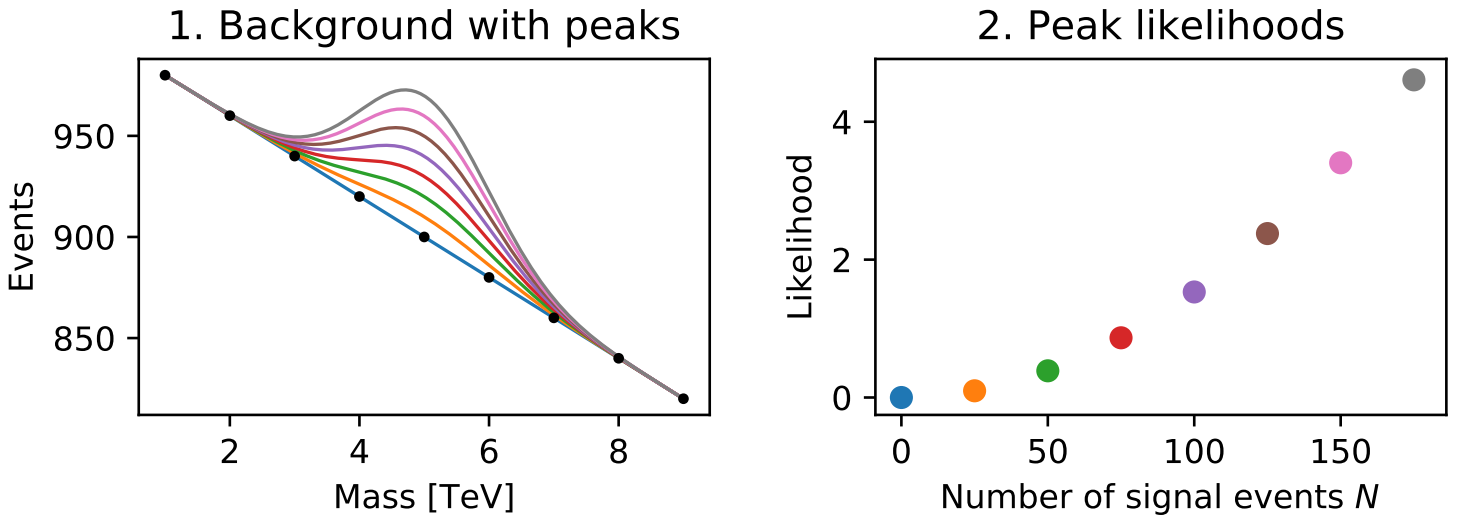

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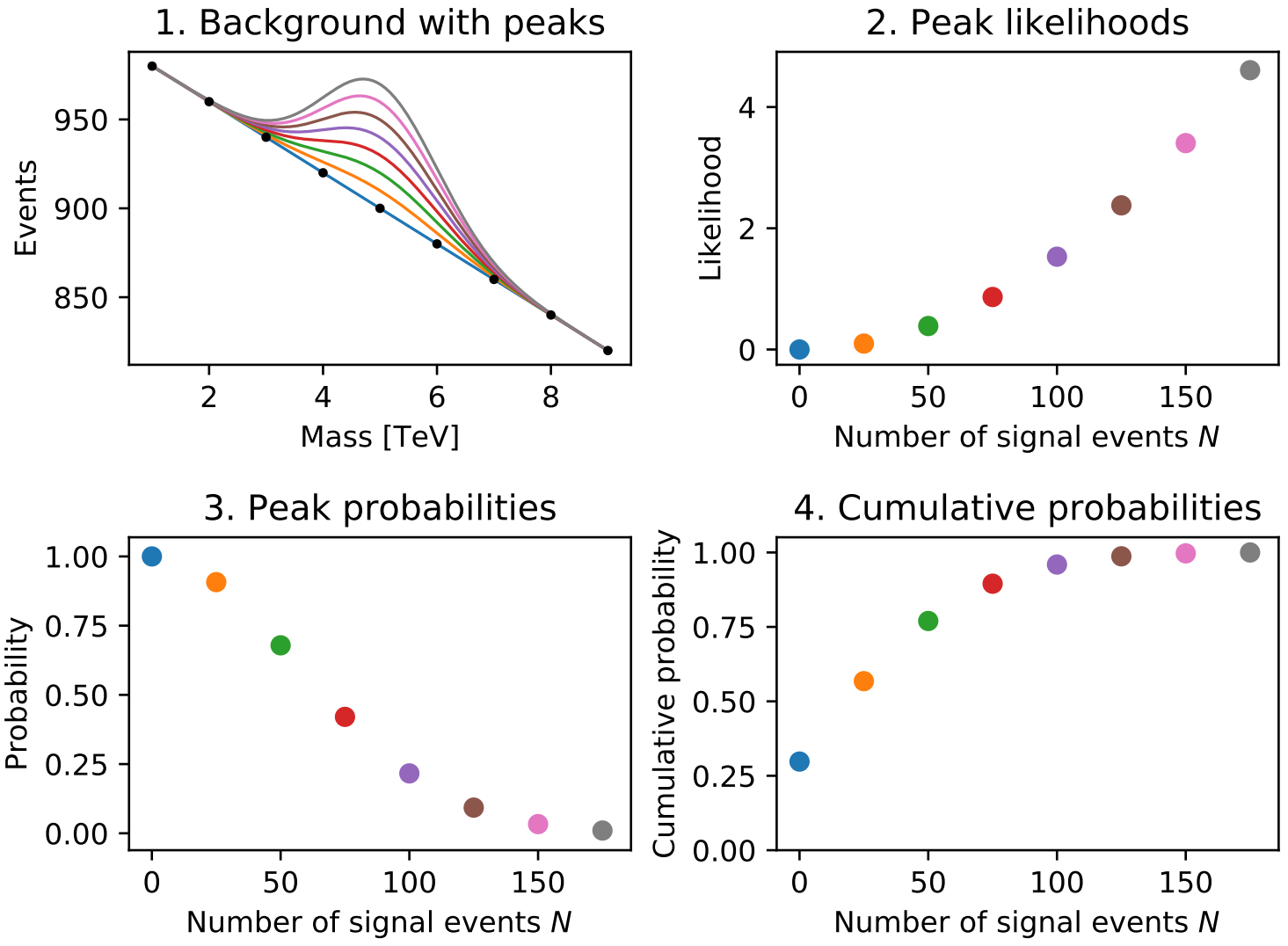

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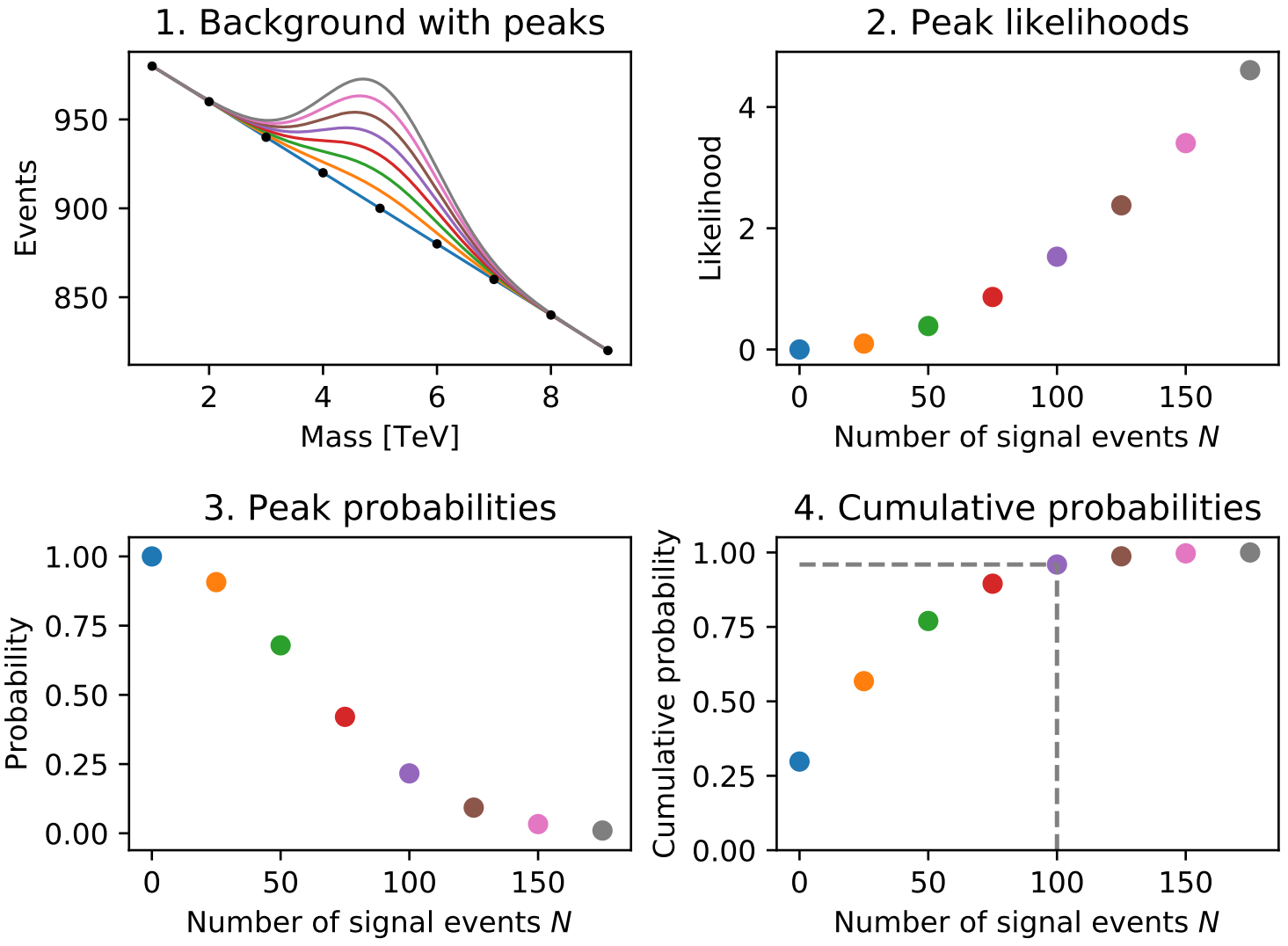

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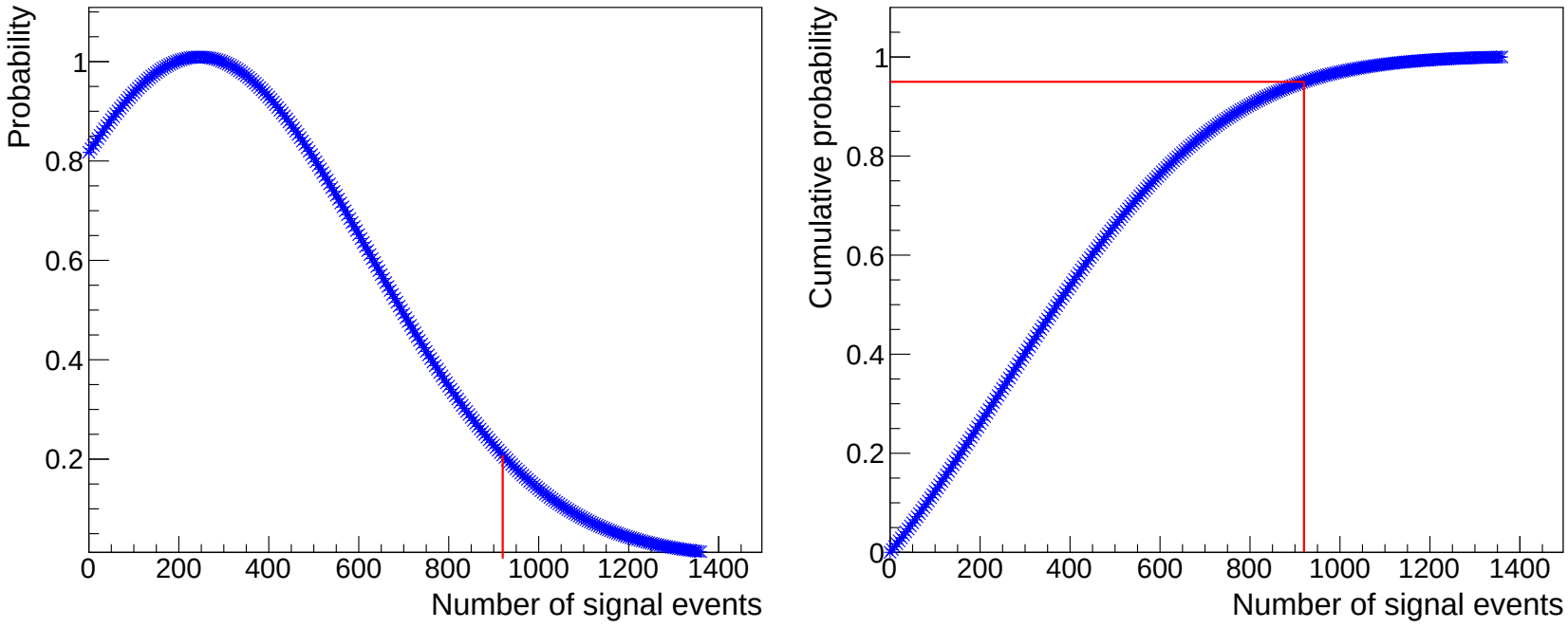
In practice



(a) Distribution

(b) Cumulative distribution

Figure 9: Example probability distribution for a single randomly generated background with a q^* peak at 3 TeV containing a varying number of events.

Simulated QCD background

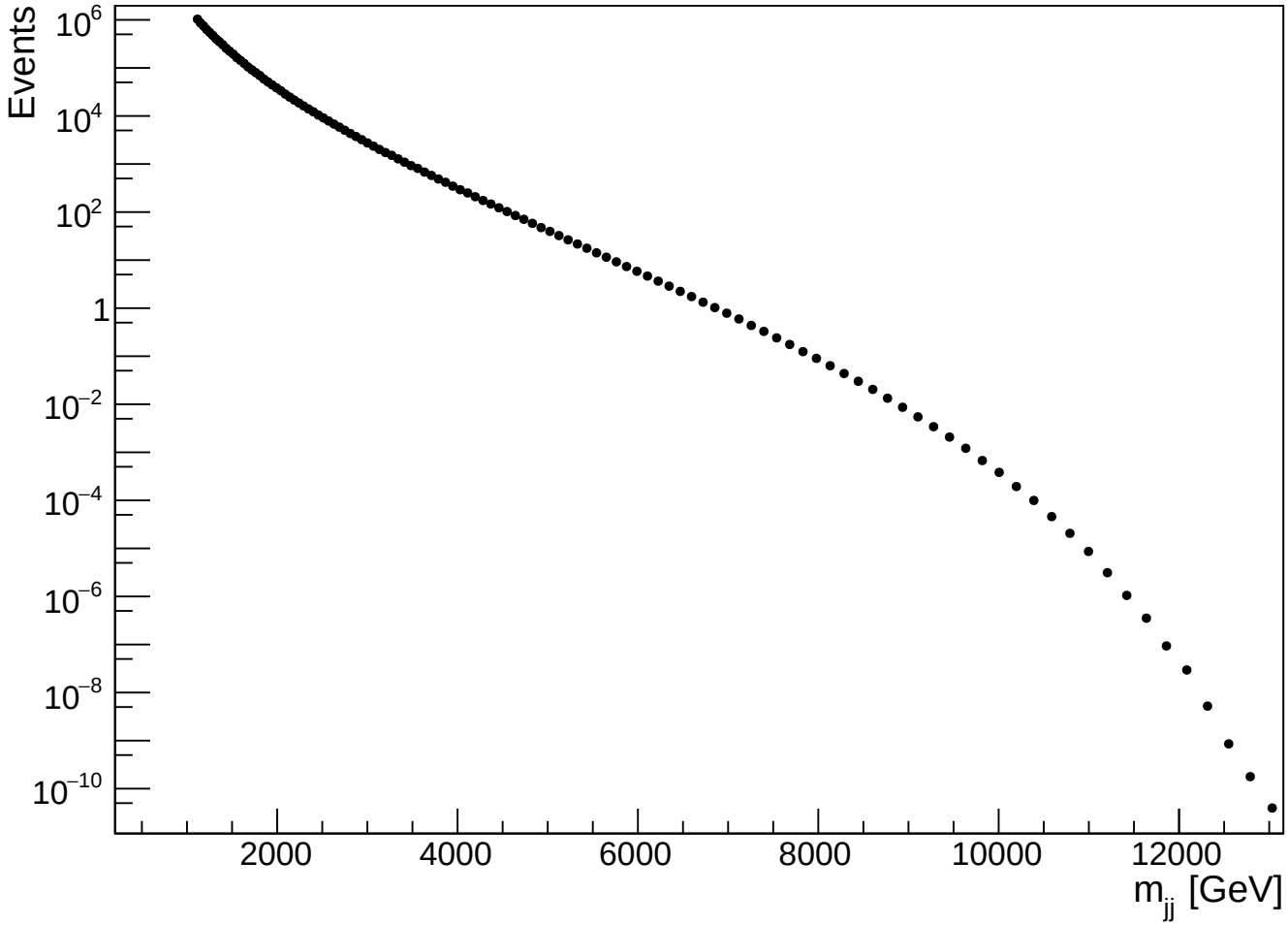


Figure 10: Simulated smooth background for expected number of dijet events with no massive particles considered. Randomly sampled to generate many data-like backgrounds.

Distribution of expected limits

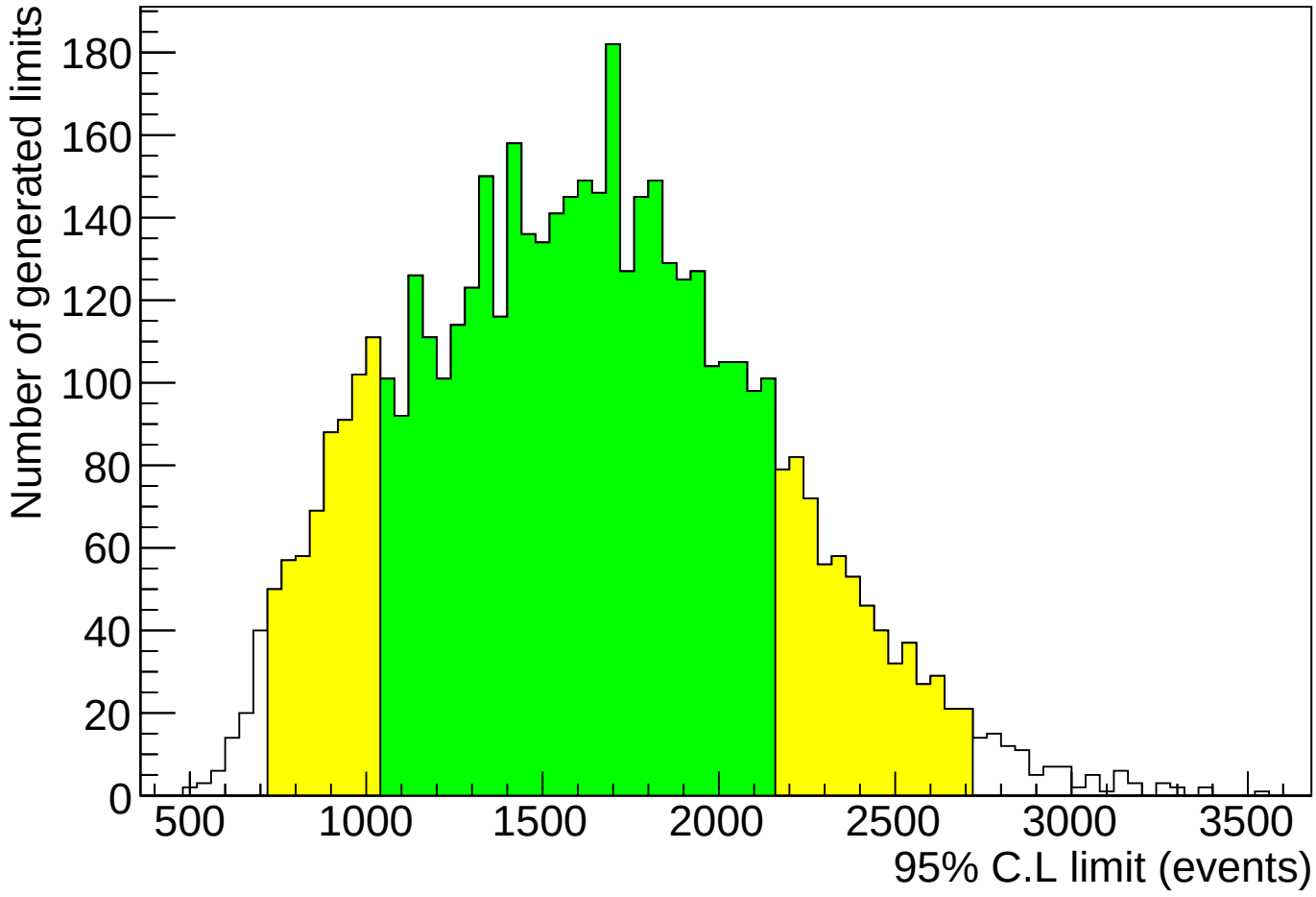


Figure 11: Distribution of 5000 expected limits for a q^* at 3 TeV, based on randomly generated backgrounds.

Excited quark Brazil plot

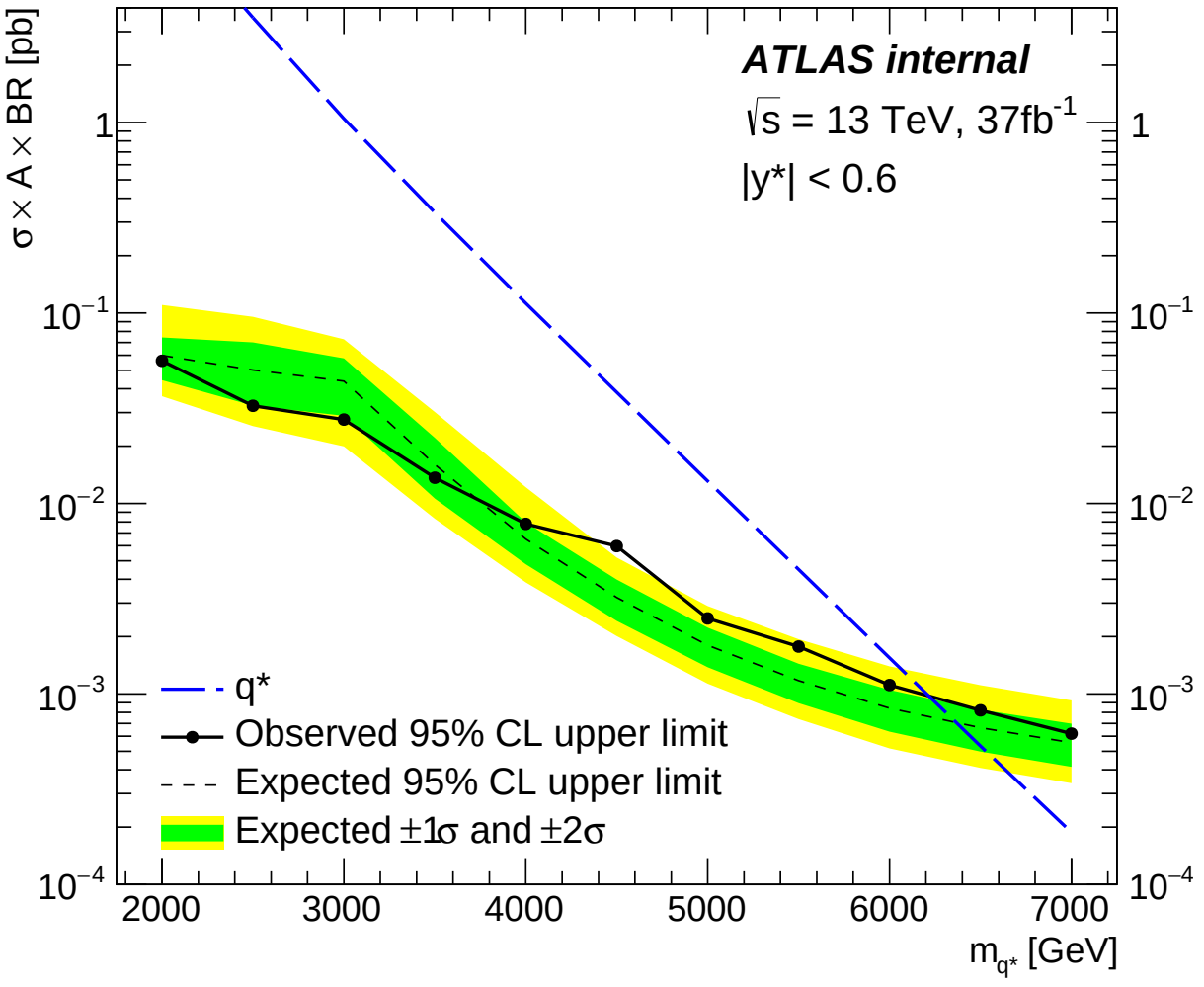


Figure 12: Brazil plot for observed and expected q^* cross sections.

QBH Brazil plot

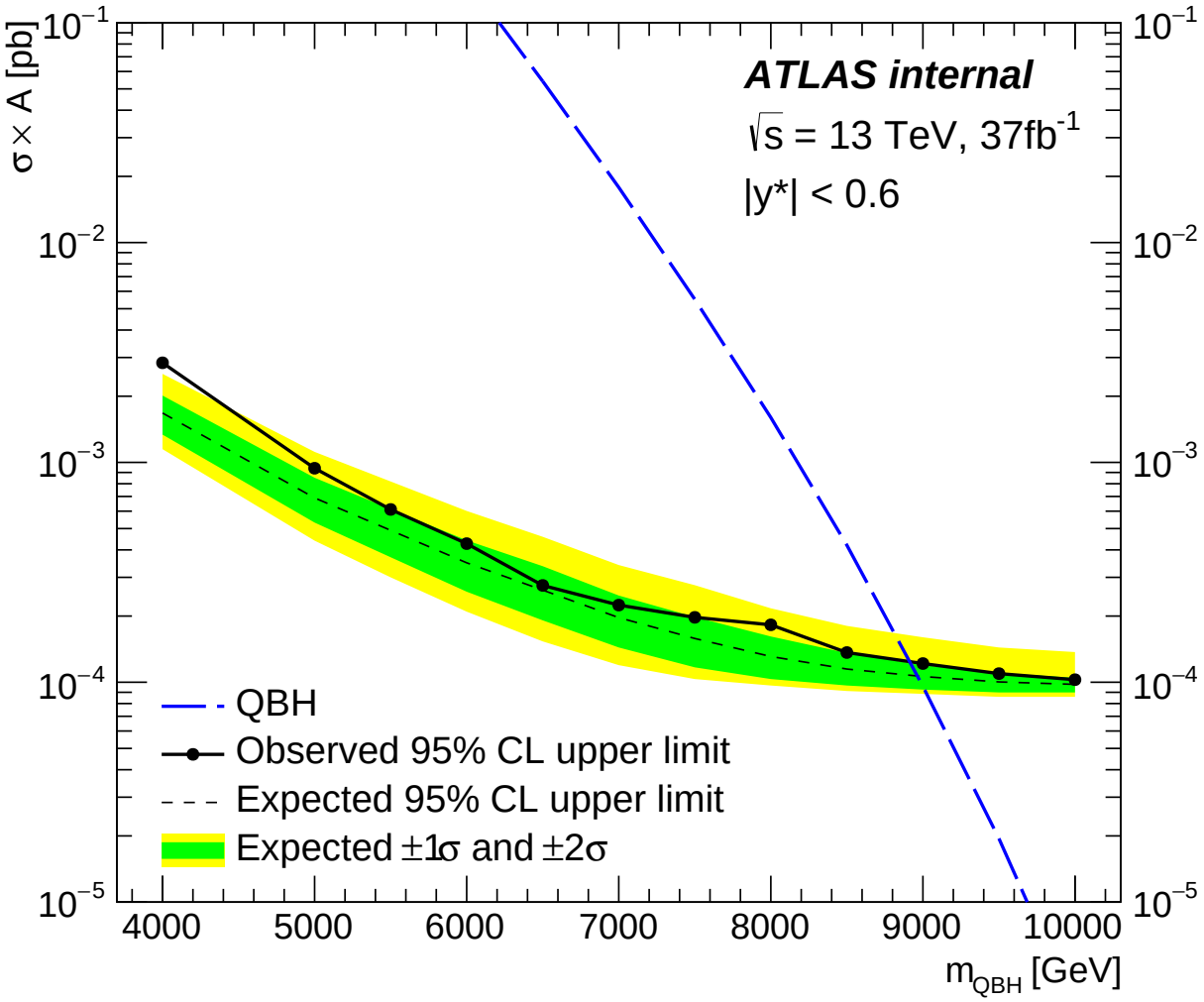


Figure 13: Brazil plot for observed and expected QBH cross sections.

W' Brazil plot

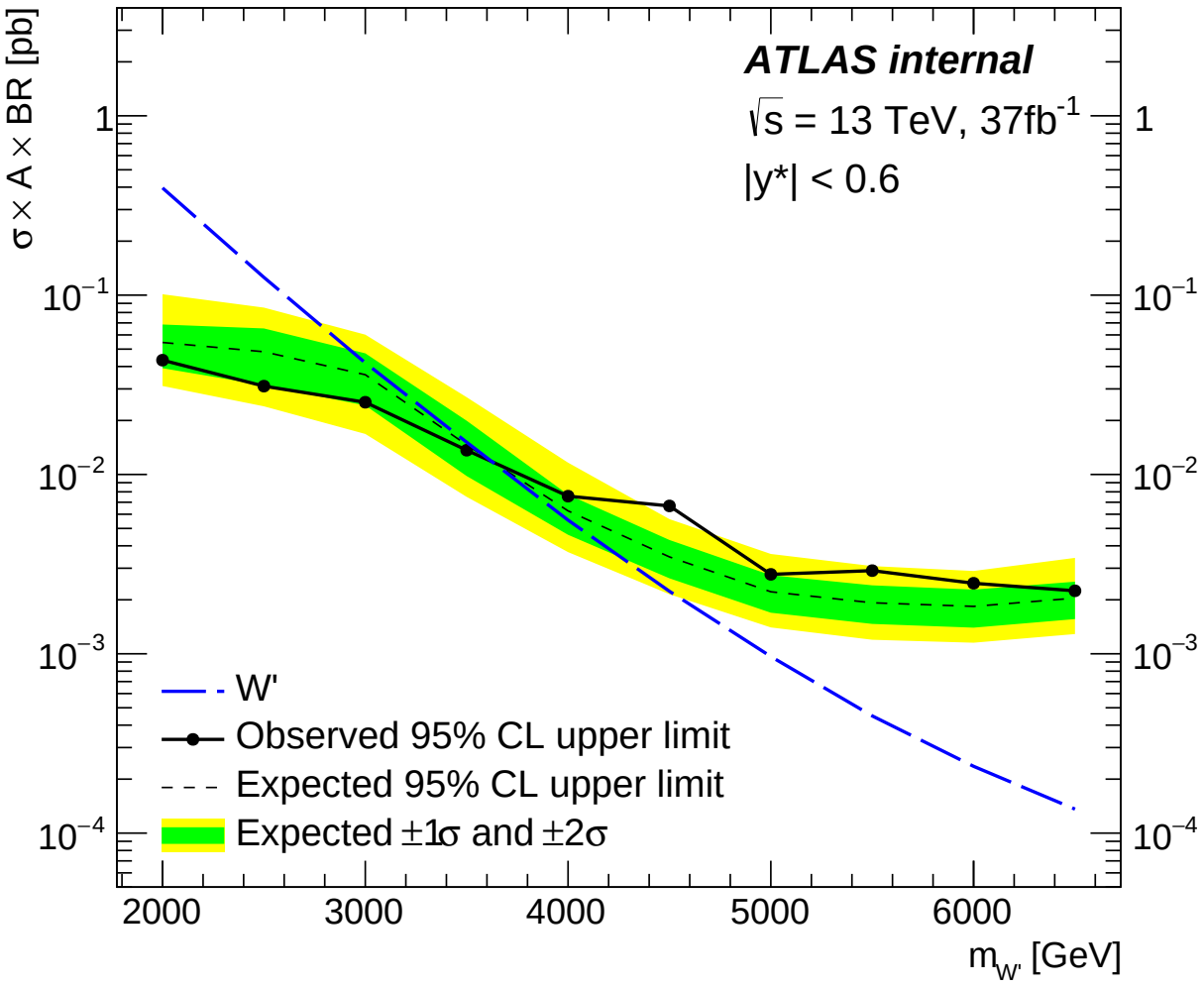


Figure 14: Brazil plot for observed and expected W' cross sections.

95% C.L lower mass limits

- Regions where the 95% C.L upper cross section limit is lower than the simulated cross section are excluded.

	95% C.L lower mass limit	
Model	Expected	Observed
q^*	6.4 TeV	6.2 TeV
QBH	9.0 TeV	8.9 TeV
W'	3.6 TeV	3.6 TeV

Table 1: Summary of expected and observed 95% confidence level lower mass limits based on the intersections of the cross section upper limits with the simulated cross section.

The End

Questions?