Search for Z-photon resonances with the ATLAS detector

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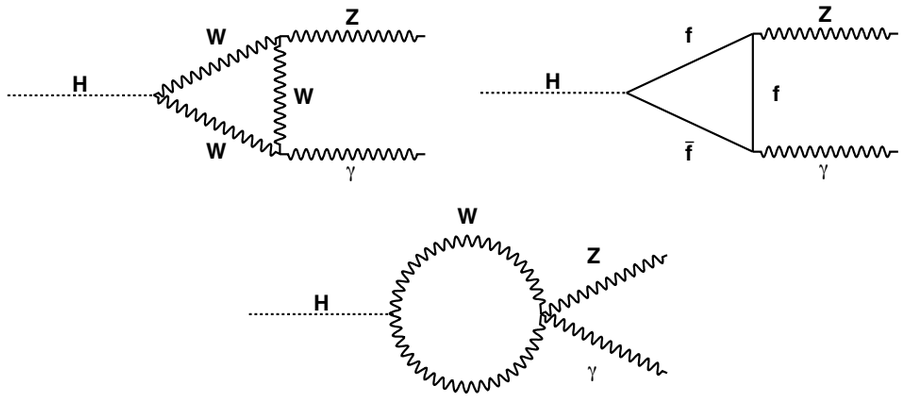
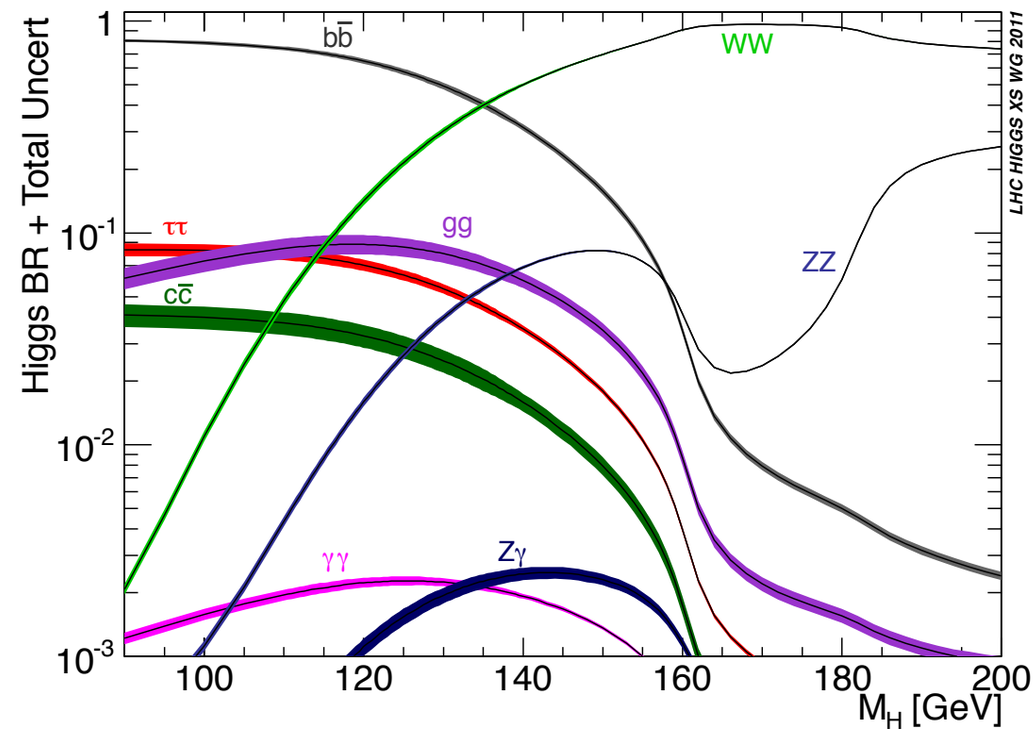
on behalf of the ATLAS Collaboration

Rencontres de Moriond - Electroweak Session - 20/3/17

Search for SM Higgs boson

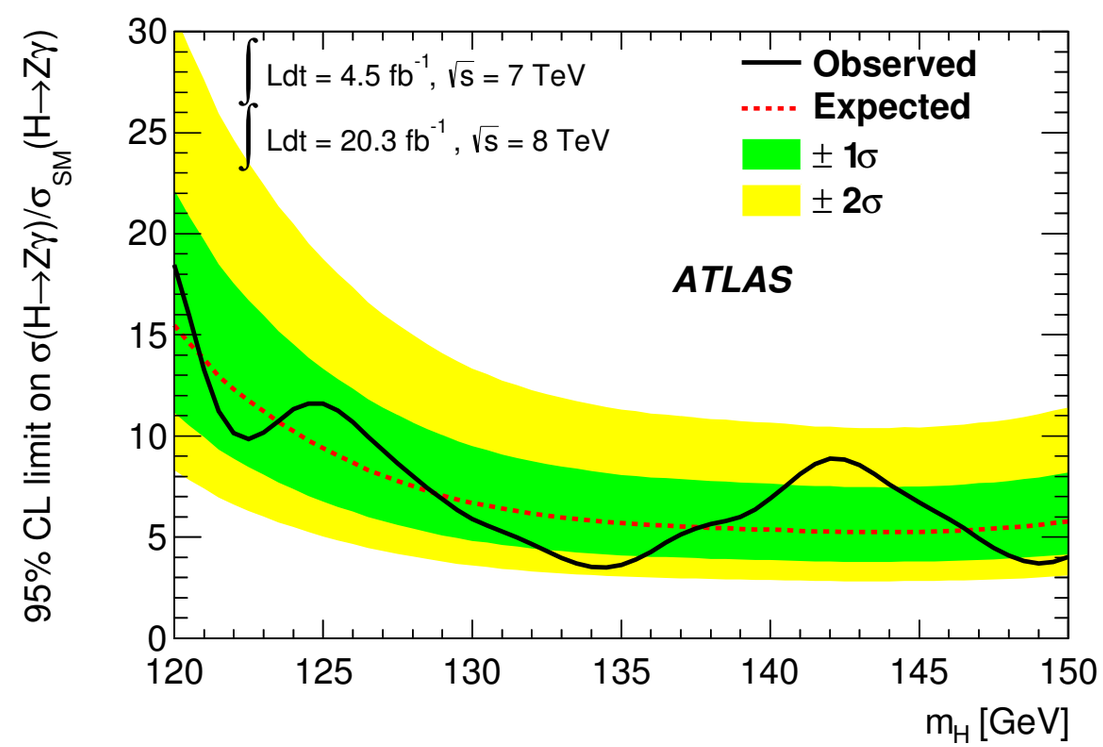




- H→Zγ is very similar to the H→γγ process
  - Comparable branching fraction (H→Zγ = 1.54×10^{-3})
  - Decays share leading-order Feynman diagrams

- Current best results for SM H→Zγ are from Run 1
  - Search used 24.8fb^{-1} of 7 + 8 TeV data
  - Leptonic final states (eeγ, μμγ) analysed
    - Presents relatively clean signal
    - Final state particles may be fully reconstructed
  - Challenging as BR(Z→ℓℓ, ℓ=e,μ) = 6.6%
  - Expected (Observed) limits at m_H = 125 GeV are:
    - 9(11) x SM predictions

- New analysis in progress
  - ATLAS has now recorded 36.1 fb^{-1} of 13 TeV data
  - Limits expected to reduce by at least 40%
  - Low mass analysis being re-optimised
  - Results to be published soon…



Search for new high mass resonances

- Many BSM models add new massive bosons
  - Bosons may decay to final states containing W, Z or γ
  - Useful decay modes for study are γγ, ZZ and Zγ

- Consider decay of narrow-width Higgs-like "X" boson
- Latest public results used 13.3 fb^{-1} of 13 TeV data
  - Published as ATLAS-CONF-2016-044
- Leptonic final states (eeγ, μμγ) analysed
- One event category for each final state
  - Used to exploit different invariant mass resolutions
- Signal resolution varies from:
  - eeγ : 2 GeV (m_X = 200 GeV) to 15 GeV (m_X = 2.5 TeV)
  - μμγ : 2 GeV (m_X = 200 GeV) to 35 GeV (m_X = 2.5 TeV)
  - Loss of precision in high-p_T muon reconstruction

Object Identification and Reconstruction

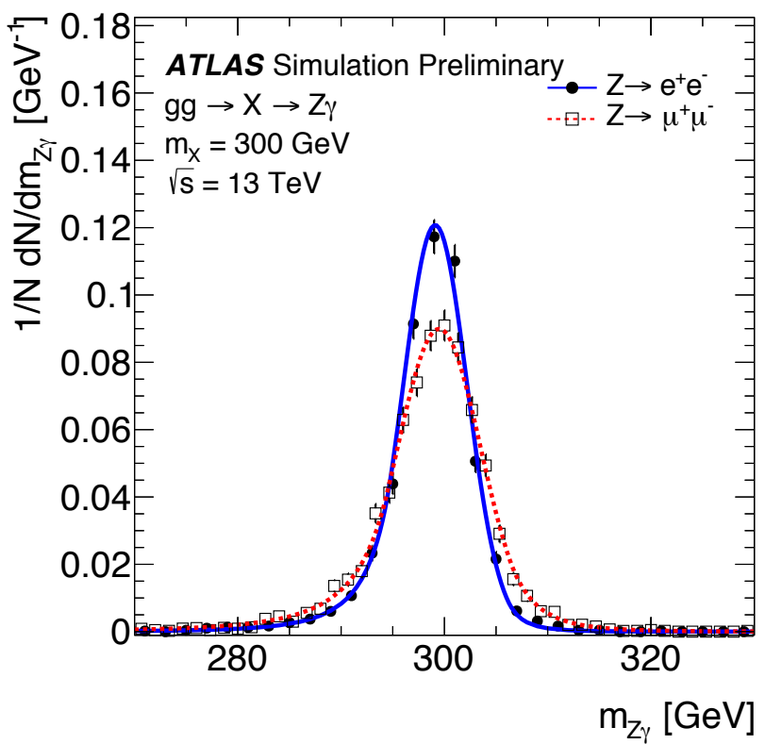
Require good quality, isolated leptons and photons

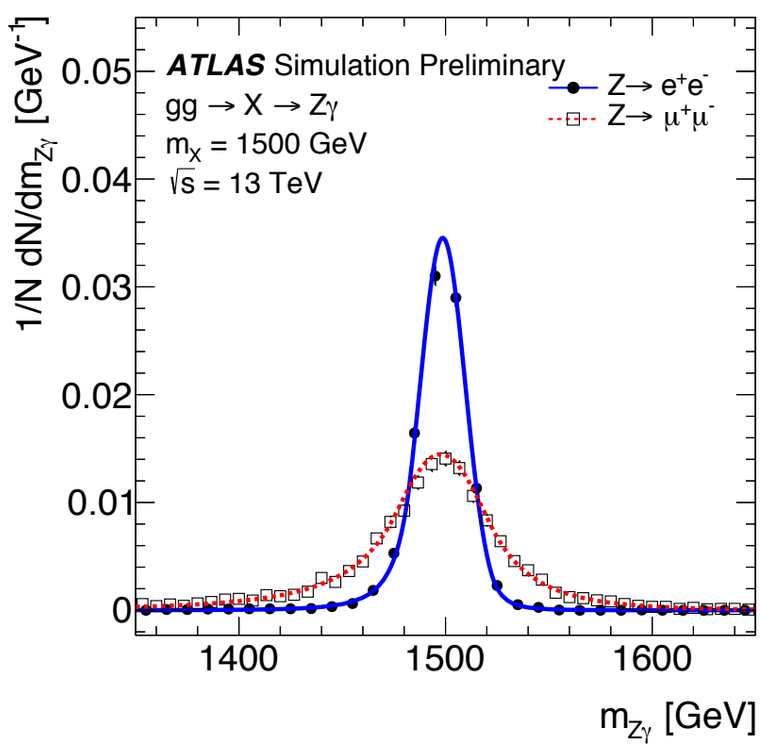
Reconstruct Z from opposite sign, same flavour lepton pairs

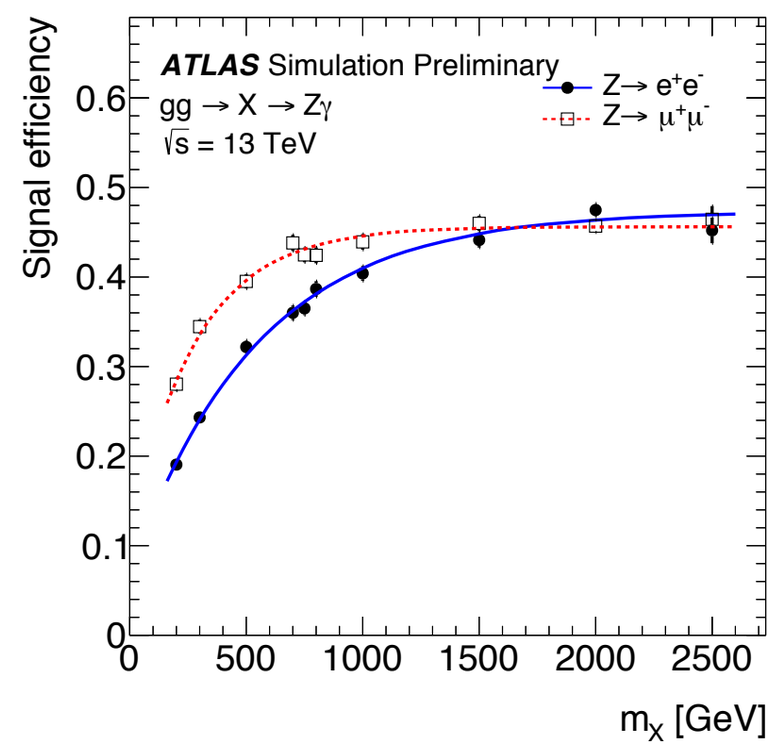
Require $|m_{ll} - m_Z| < 15$ GeV

Merge Z candidate with highest-p_T photon

Require $p_T^{\gamma}/m_{ll\gamma} > 30\%$ of $m_{Z\gamma}$





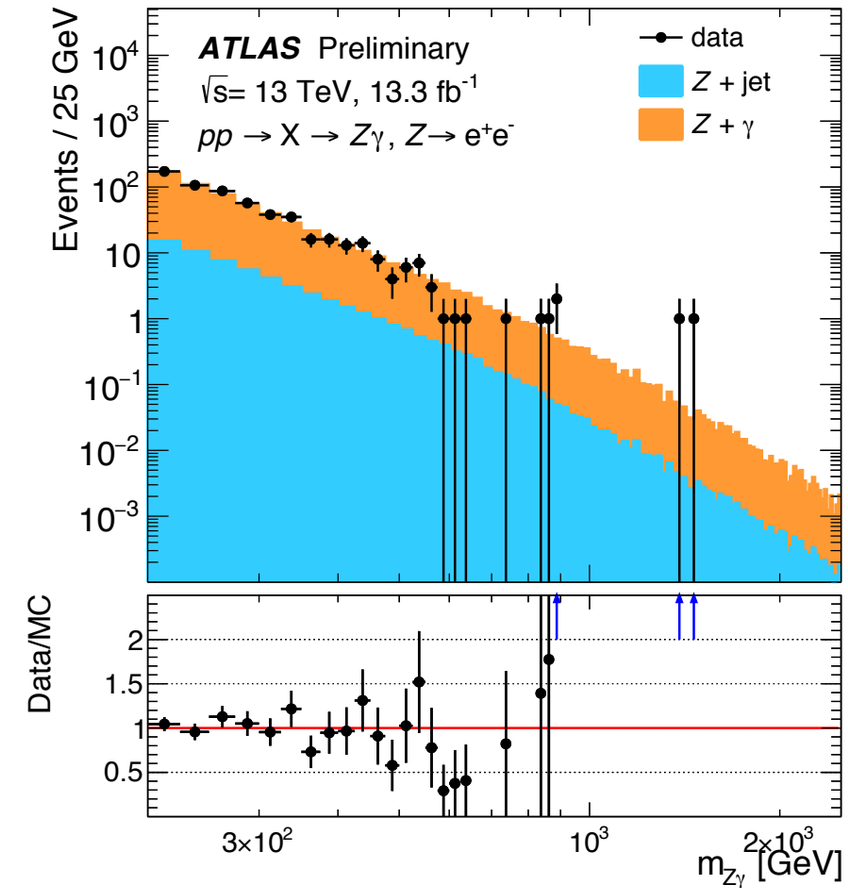


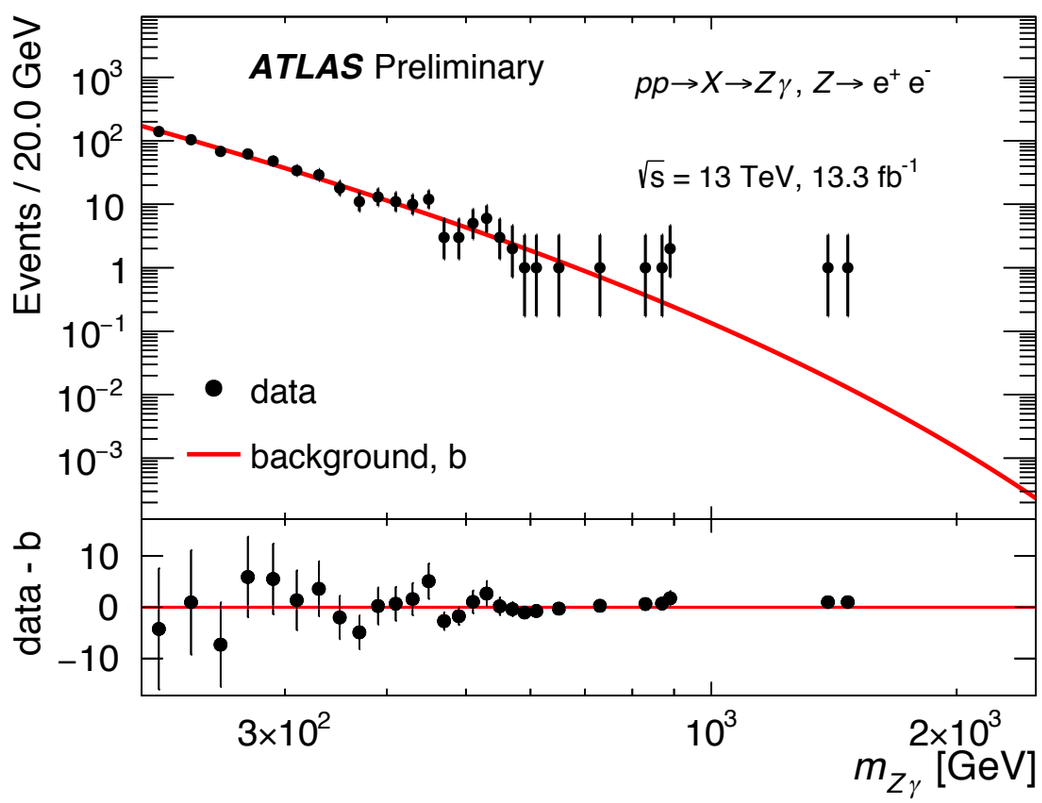
Background description

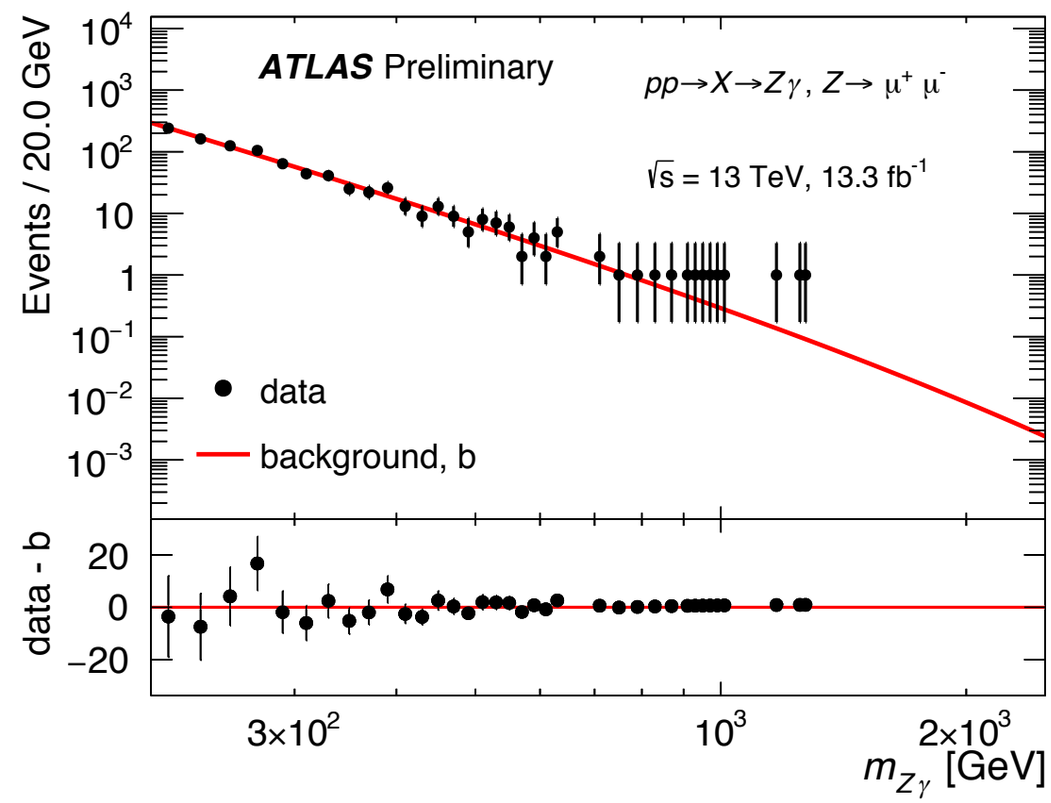
- Background dominated by:
  - Non-resonant Z+γ production (~90%)
  - Z+Jet (~10%)
- Background determined by fitting function directly to data

- F-Test
  - Identify simplest model for which extra parameters do not significantly improve fit quality
- Spurious signal
  - Bias on signal yield from background model choice
  - Ratio of fitted signal yield to its uncertainty must be < 20%
- Chosen function has form:

$$f_{k=0;d=1/3}(x;b,d,\{a_k\}) = (1-x^{1/3})^b x^{a_0} \qquad x = \frac{m_{\ell\ell\gamma}}{\sqrt{s}}$$



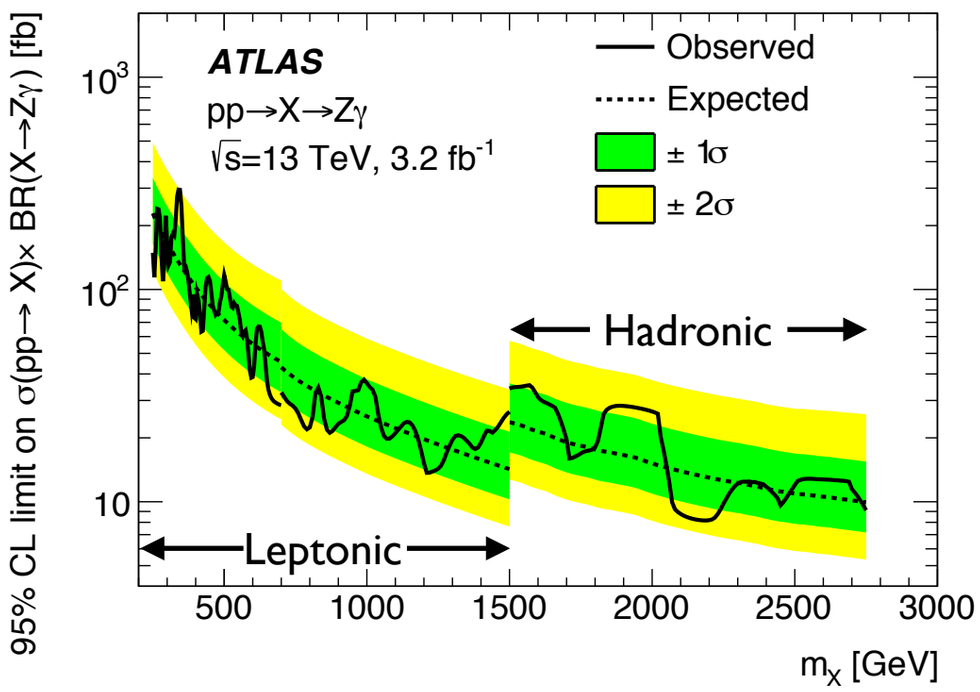




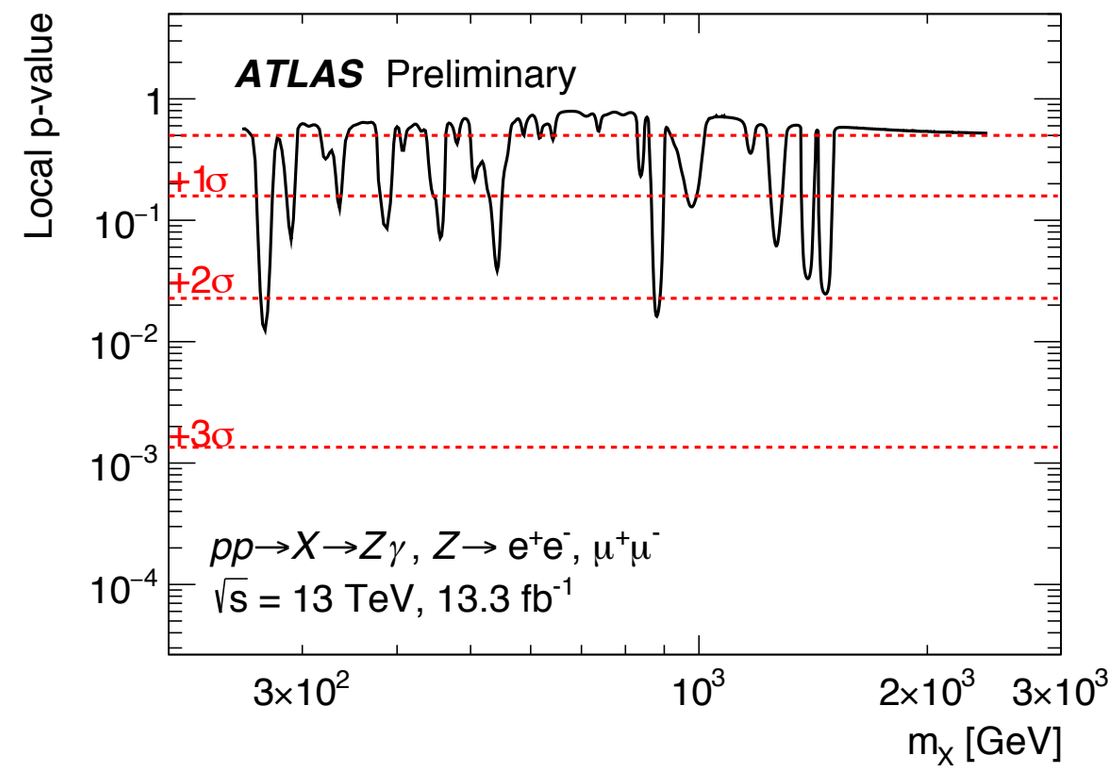
High mass search results

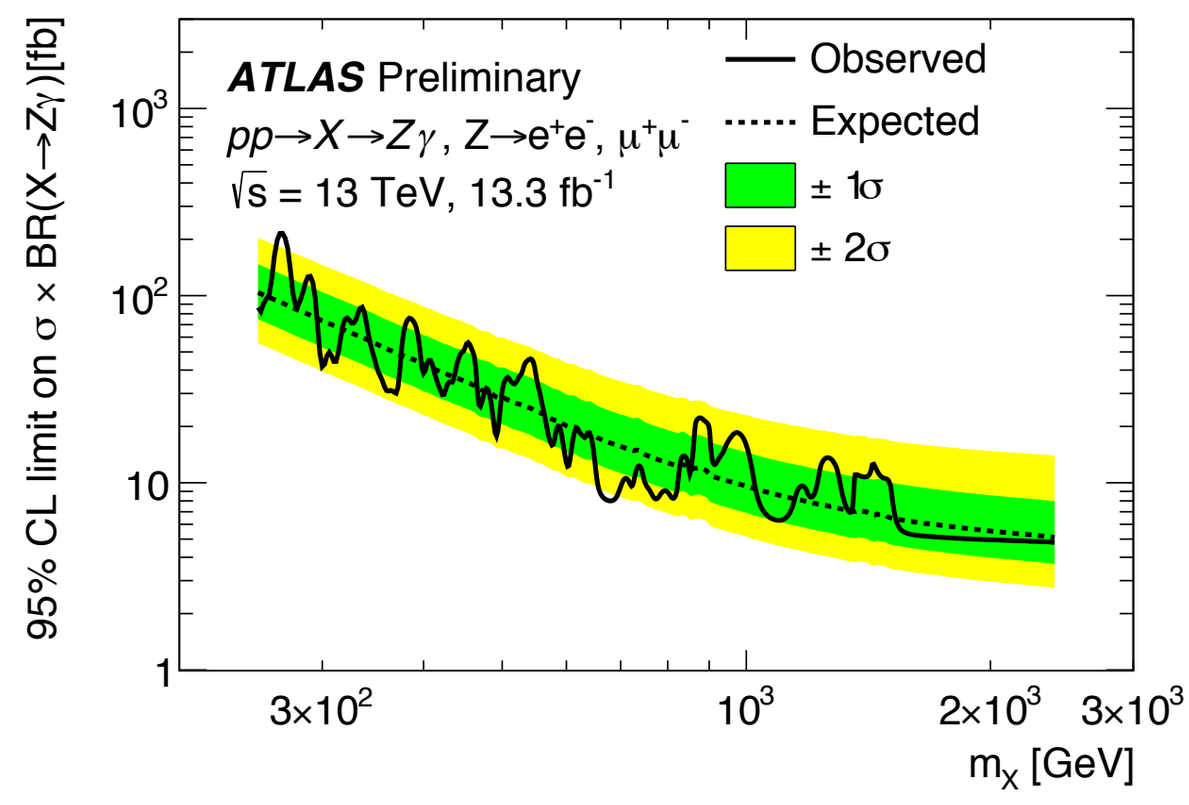
- No significant excesses identified
- Limits set on $\sigma(pp \rightarrow X) \times BR(X \rightarrow Z\gamma)$ at 95% CL
- Expected limits:
  - 103 fb (m_X = 250 GeV) to 5 fb (m_X = 2.4 TeV)
- Observed limits:
  - 215 fb (m_X = 270 GeV) to 5 fb (m_X = 2.4 TeV)

- Similar analysis performed using hadronic Z decays
- Offers improved sensitivity above ~1.5 TeV
  - Boosted jets merge into single large radius jet
  - More statistics in this region



- Revised analysis in progress
  - Search will use 36.1 fb^{-1} of 13 TeV data
  - Results will be public soon…

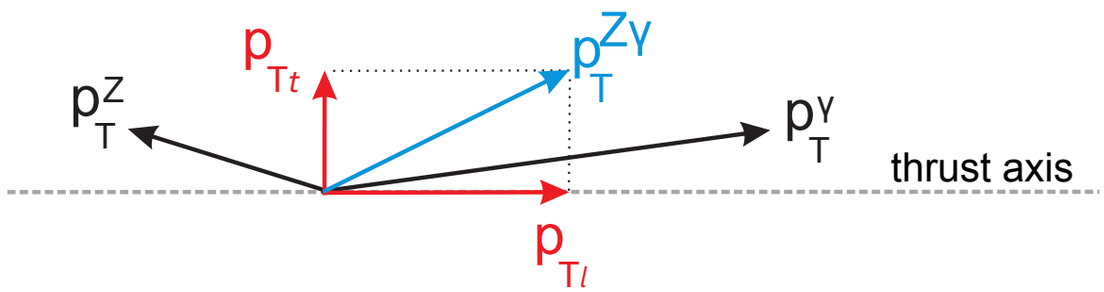




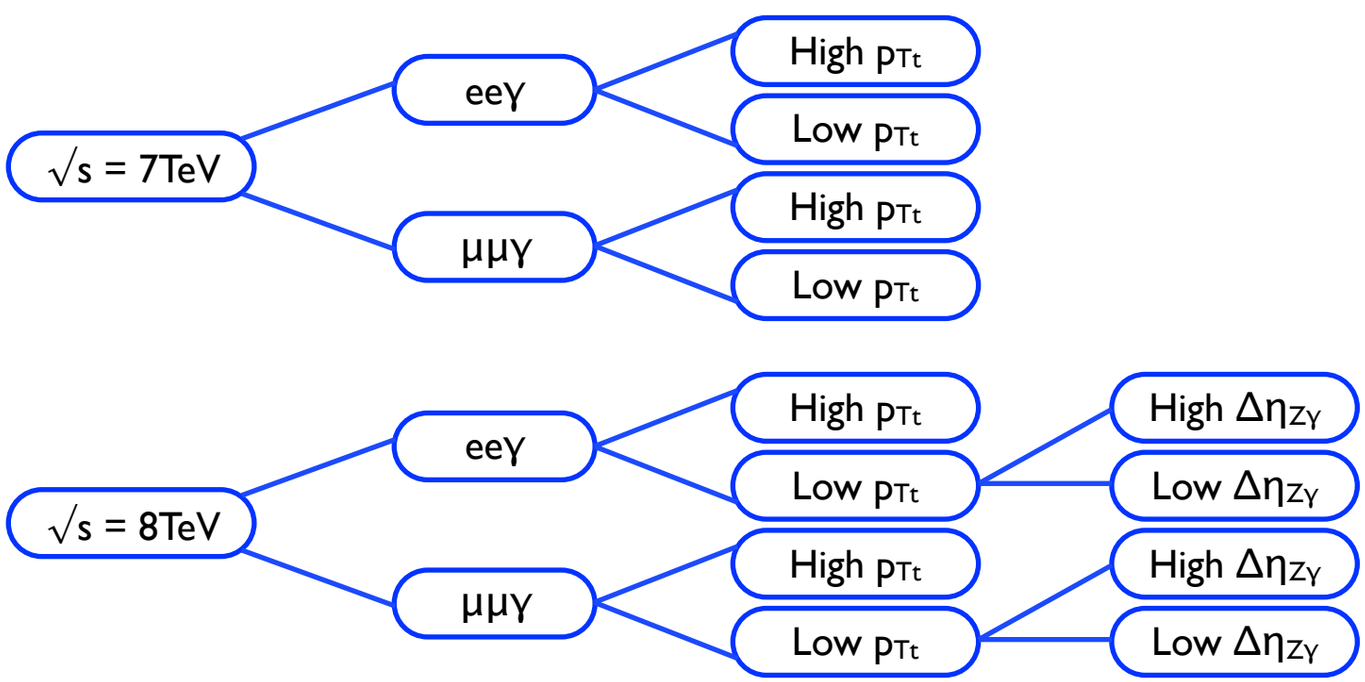
Backup Slides

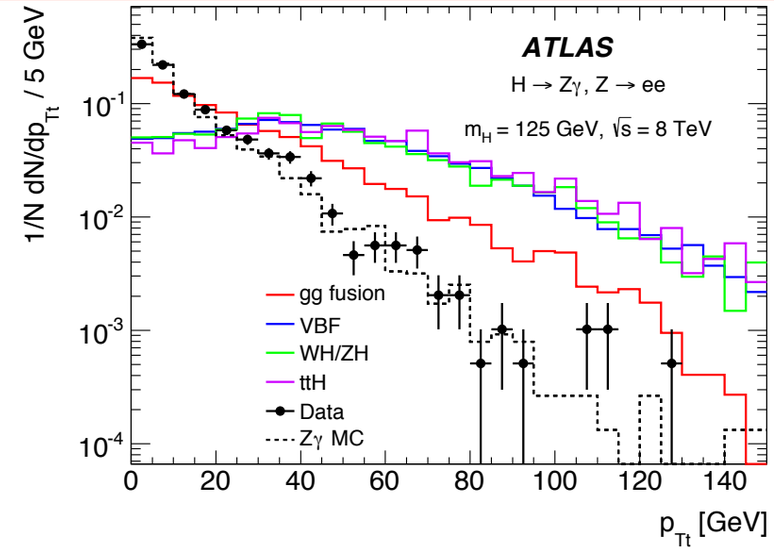
Run 1: Search for SM H→Zγ Decays

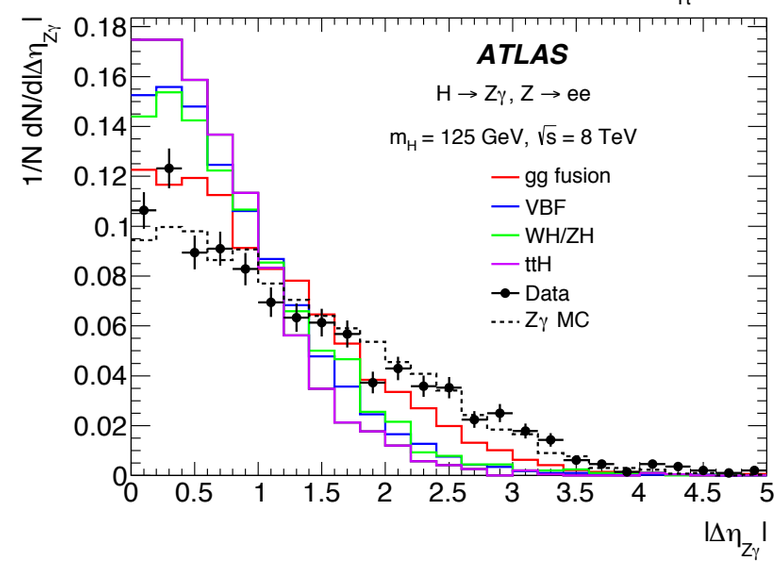
- SM Higgs candidates filtered into ten categories
- Categorisation based on
  - Beam Energy
  - Final state
  - Higgs p_{Tt} (> or < 30GeV)
  - $\Delta\eta_{Z\gamma}$ (> or < 2.0)

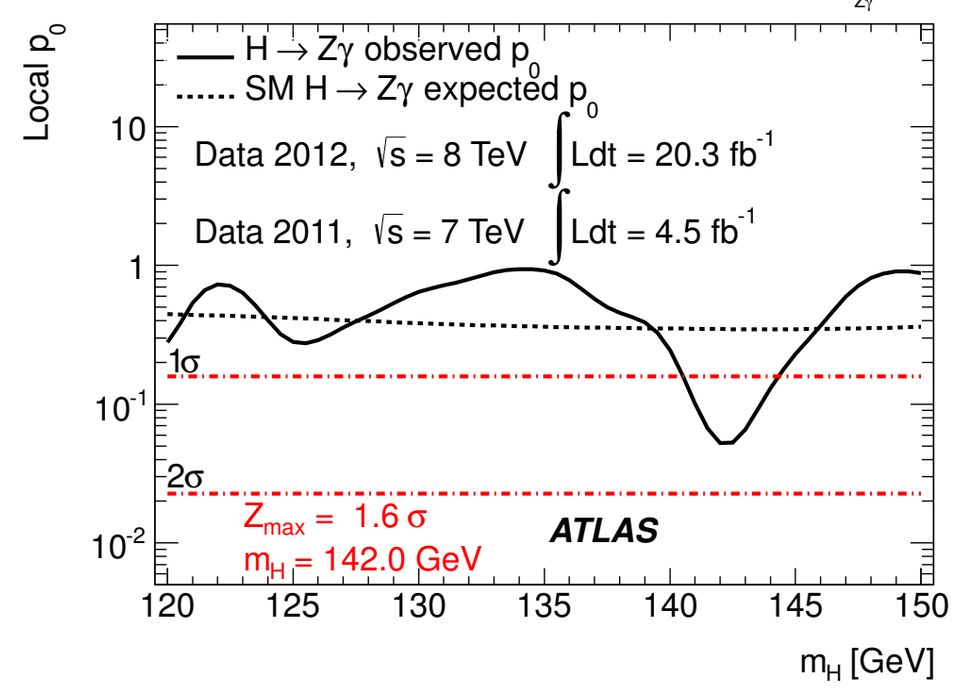


Higgs P_{Tt} is component of Higgs momentum orthogonal to difference between Z and γ momenta





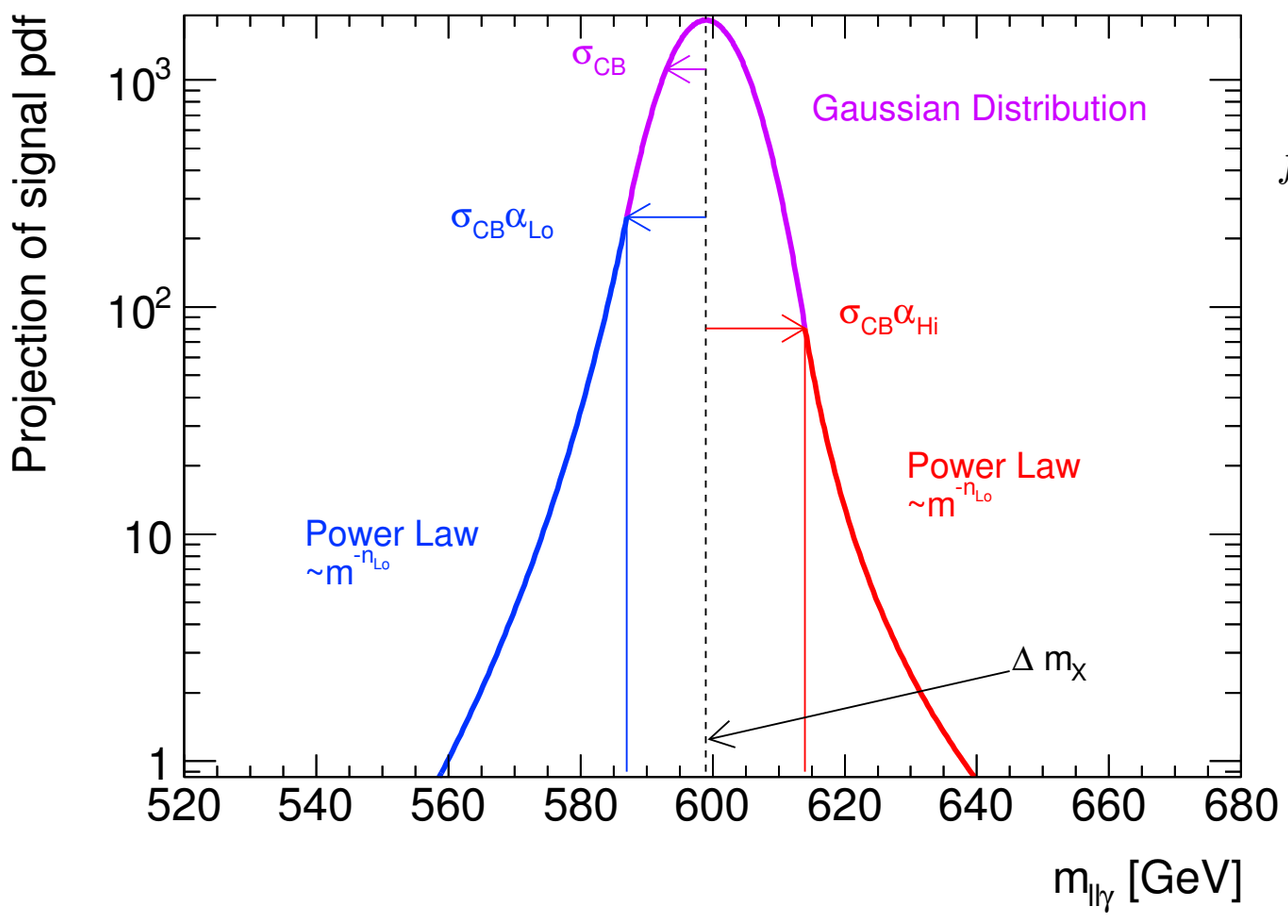




Search for new high mass resonances: Signal Modelling

- All signal samples modelled using double-sided Crystal Ball function
  - Core gaussian distribution
  - Asymmetric power-law tails
  - All mass points fitted simultaneously
  - Shape parameters modelled as polynomials

- Signal efficiency parameterised as second order polynomial



$$f_{sig} = N \cdot \begin{cases} e^{-t^2/2} & \text{if } -\alpha_{\rm Lo} \le t \le \alpha_{\rm Hi} \\ \dfrac{e^{-0.5\alpha_{\rm Lo}^2}}{\left[\frac{\alpha_{\rm Lo}}{n_{\rm Lo}}\left(\frac{n_{\rm Lo}}{\alpha_{\rm Lo}} - \alpha_{\rm Lo} - t\right)\right]^{n_{\rm Lo}}} & \text{if } t < -\alpha_{\rm Lo} \\ \dfrac{e^{-0.5\alpha_{\rm Hi}^2}}{\left[\frac{\alpha_{\rm Hi}}{n_{\rm Hi}}\left(\frac{n_{\rm Hi}}{\alpha_{\rm Hi}} - \alpha_{\rm Hi} + t\right)\right]^{n_{\rm Hi}}} & \text{if } t > \alpha_{\rm Hi}, \end{cases}$$

$$t = \Delta m_X/\sigma_{\rm CB}, \Delta m_X = m_{\ell\ell\gamma} - m_X - \mu_{\rm CB}$$

Parameter	Fitted function
$\mu_{\rm CB}$	$a_\mu + b_\mu \times x + c_\mu \times x^2 + m_X$
$\sigma_{\rm CB}$	$a_\sigma + b_\sigma \times x$
$\alpha_{\rm lo}$	$a_{\alpha_{\rm lo}} + b_{\alpha_{\rm lo}} \times x + c_{\alpha_{\rm lo}} \times x^2$
$\alpha_{\rm hi}$	$a_{\alpha_{\rm hi}} + b_{\alpha_{\rm hi}} \times x + c_{\alpha_{\rm hi}} \times x^2$
x	$(m_X - 100 \ \text{GeV})/100 \ \text{GeV}$

High mass search: Hadronic Z decays

- Search looks for $X \rightarrow Z\gamma$, $Z \rightarrow q\bar{q}$
- Search performed using 3.2fb^{-1} of 13 TeV data
  - Published in PLB
- Boosted quark pair merge into single large radius jet
- Largest excess is 1.8σ for m_X = 1.9 TeV
- Hadronic analysis better than leptonic for m_X>1.5TeV