Search for $H \to \mu\mu$ in SM and MSSM

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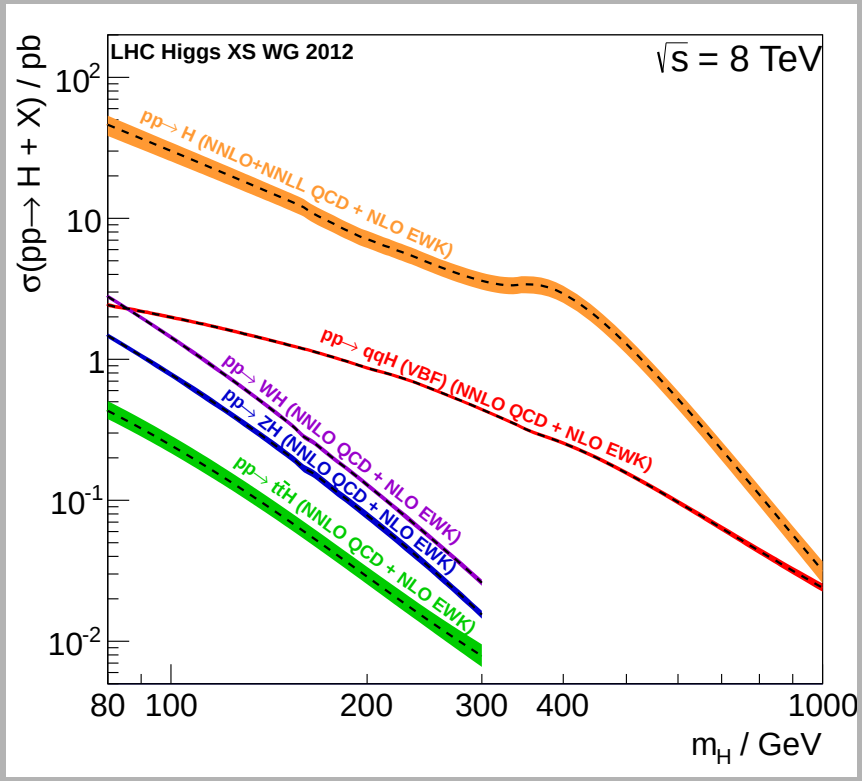
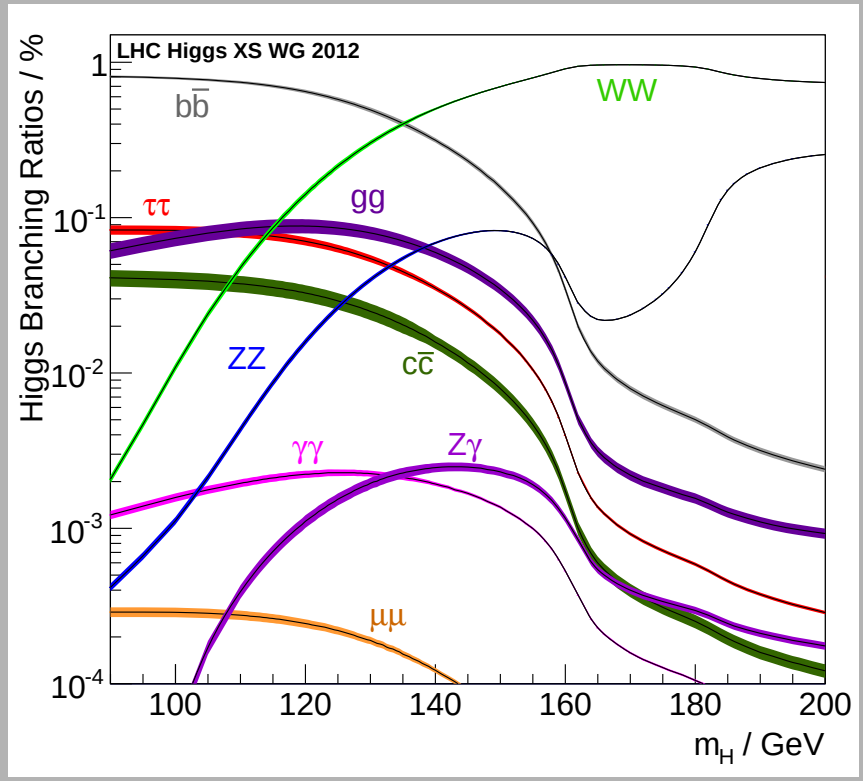
Bundesministerium
für Bildung
und Forschung

SM Higgs $\rightarrow \mu\mu$

cross section and branching ratio

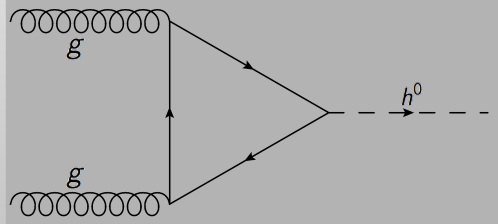




- after discovery of Higgs-like boson, confirmation in as many channels as possible is necessary
- branching ratio into muons is *only* an order of magnitude lower as $H \to \gamma\gamma$
- through exploiting the VBF topology, separation from dominant backgrounds possible

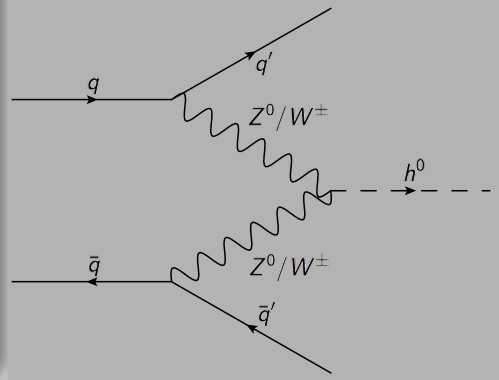
signal topology

Gluon Gluon Fusion



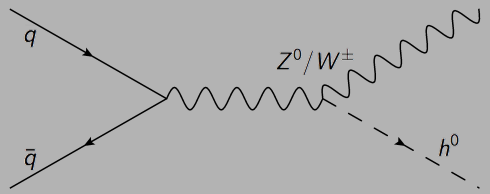
- high cross section
- two isolated muons
- low $\not{E}_T$
- no additional jets

Vector Boson Fusion



- lower cross section
- two isolated muons
- low $\not{E}_T$
- two jets in forward region

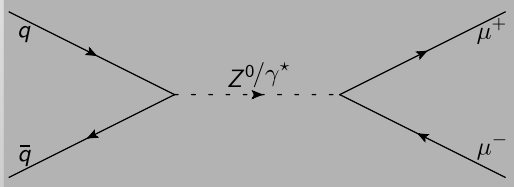
associated production



- very low cross section
- boson in the final state can offer additional leptons for separation
- statistics to low at this point

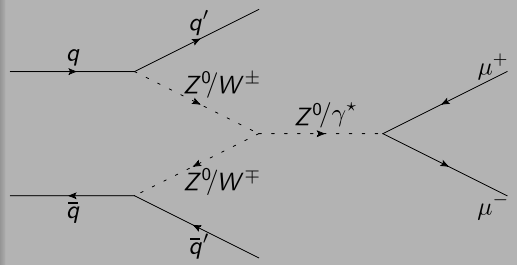
backgrounds

Drell-Yan $Z/\gamma^* \to \mu\mu$



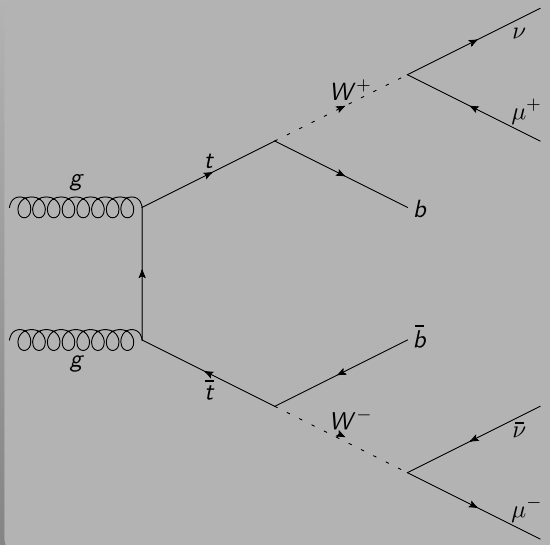
- dominant background in SM selection
- two isolated muons
- low $\not{E}_T$

Drell-Yan VBF contribution



- similar topology to VBF Signal
- two isolated muons
- two well separated forward jets

top quark pairs



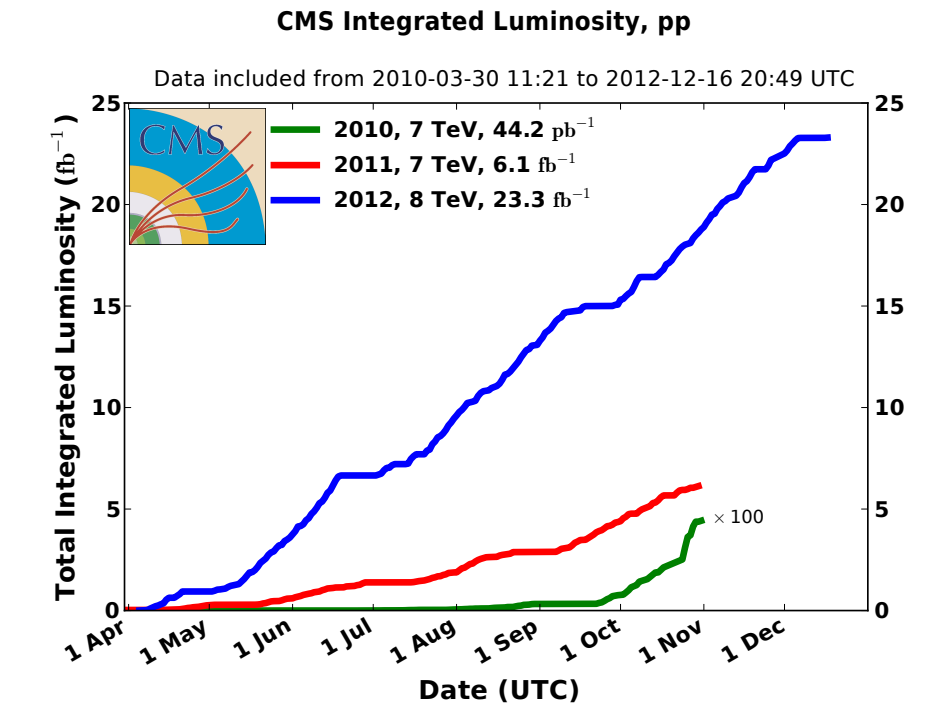
- non-isolated muons with low p_T
- high $\not{E}_T$ due to the neutrinos from the $W^\pm$-decay

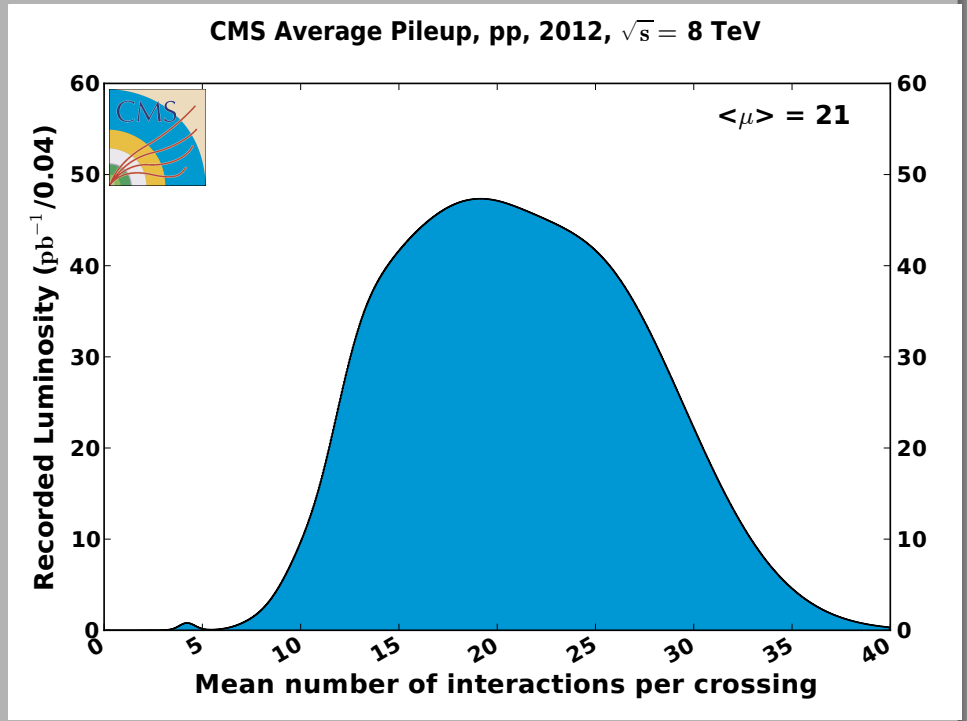
additional backgrounds

- Single top production
- Di-Boson production
- W + Jets
- QCD

LHC data taking

recorded data in LHC phase 1





- MSSM analysis already published with $\approx 5\text{fb}^{-1}$ of 2011 data
- 19.1fb^{-1} of 2012 data @ 8 TeV used for MSSM update
- full 2011 and 2012 data for the SM analysis
- increasing pile-up challenge for trigger rates and details of the SM analysis
- pile-up considered in the simulations by simple 1D re-weighting

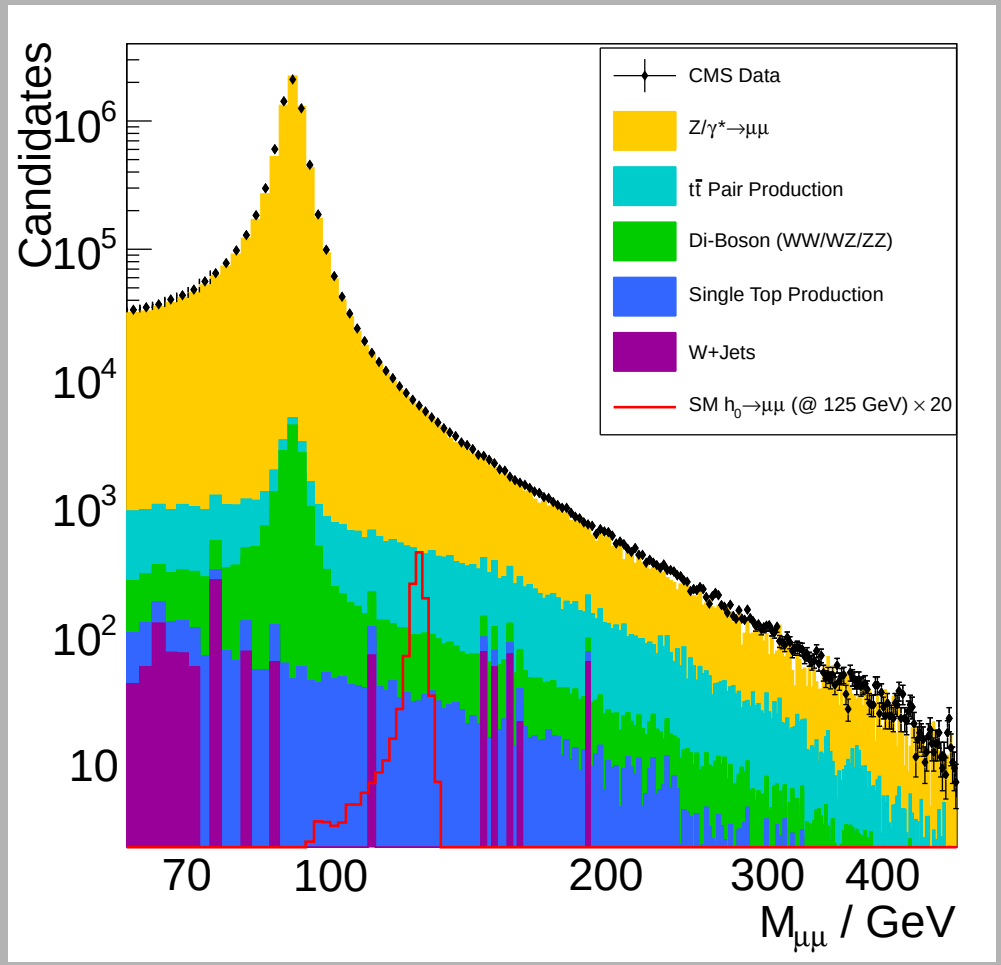
Preselection

basic muon selection

- single muon trigger ($p_{T\mu} > 24$ GeV)
- two well reconstructed muons with:
  - $p_{T\mu} > 25$ GeV
  - $|\eta_\mu| < 2.1$
  - isolation
  - opposite charge

MC corrected for:

- pile-up
- trigger efficiency
- muon reconstruction efficiency
- muon momentum scale



invariant di-muon mass after muon selection

Categorization

di-jet preselection

- two jets with $p_T^{jet} > 40(30)$ GeV
- Pile-Up jets rejected
- $\not{E}_T < 40$ GeV

failing di-jet preselection

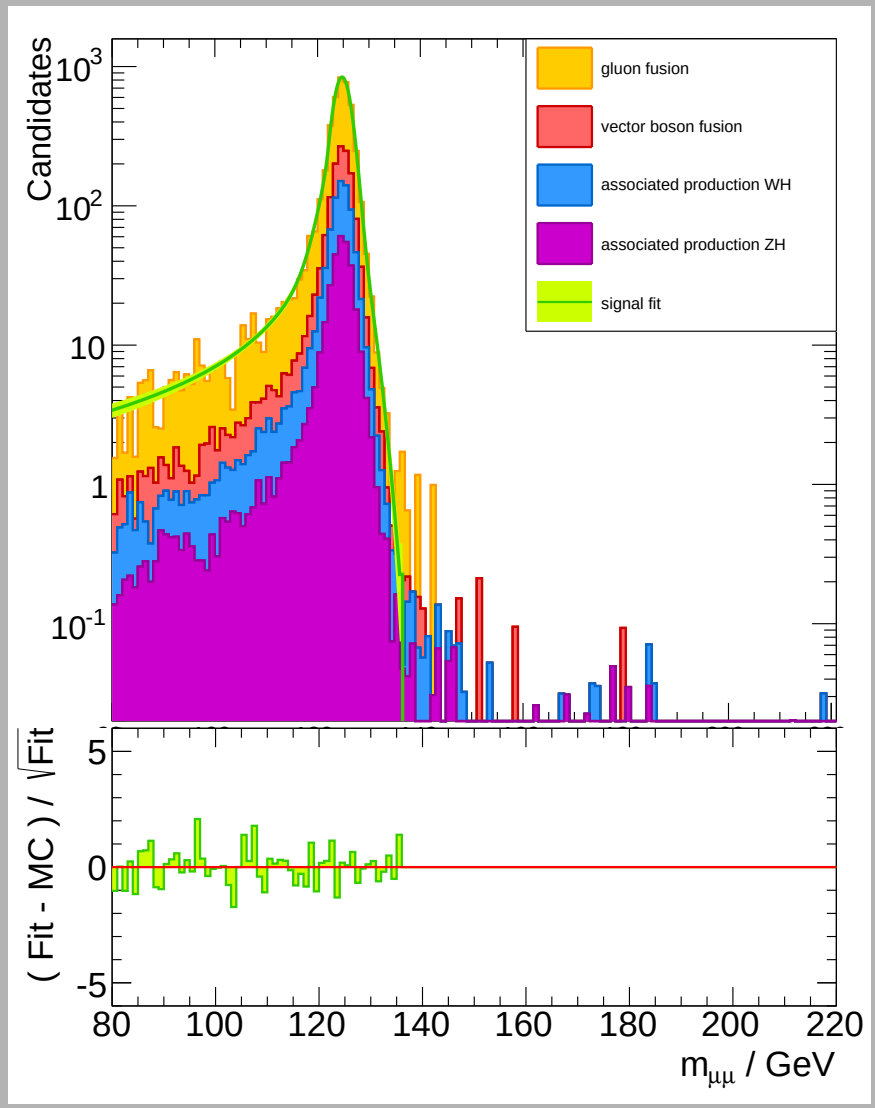
- NonVBF tight
  - $p_T^{\mu\mu} > 10$ GeV
  - split into geometric muon categories
  - (Barrel/Endcap/Overlap)
- NonVBF loose
  - $p_T^{\mu\mu} < 10$ GeV
  - split into geometric muon categories
  - (Barrel/Endcap/Overlap)

passing di-jet preselection

- VBF tight
  - $|\Delta\eta_{jets}| > 3.5$
  - $m_{jj} > 650$ GeV
- GGF tight
  - not in VBF tight
  - $m_{jj} > 250$ GeV
  - $p_T^{\mu\mu} > 50$ GeV
- VBF loose
  - not in VBF tight or GGF tight

Signal Fit

- signal hypothesis consists of linear combination of a Gaussian and a crystal ball shape
- signal hypothesis is fitted to MC Simulation at each point and category
- shape is interpolated between generated mass points
- parameters are fixed for final fit

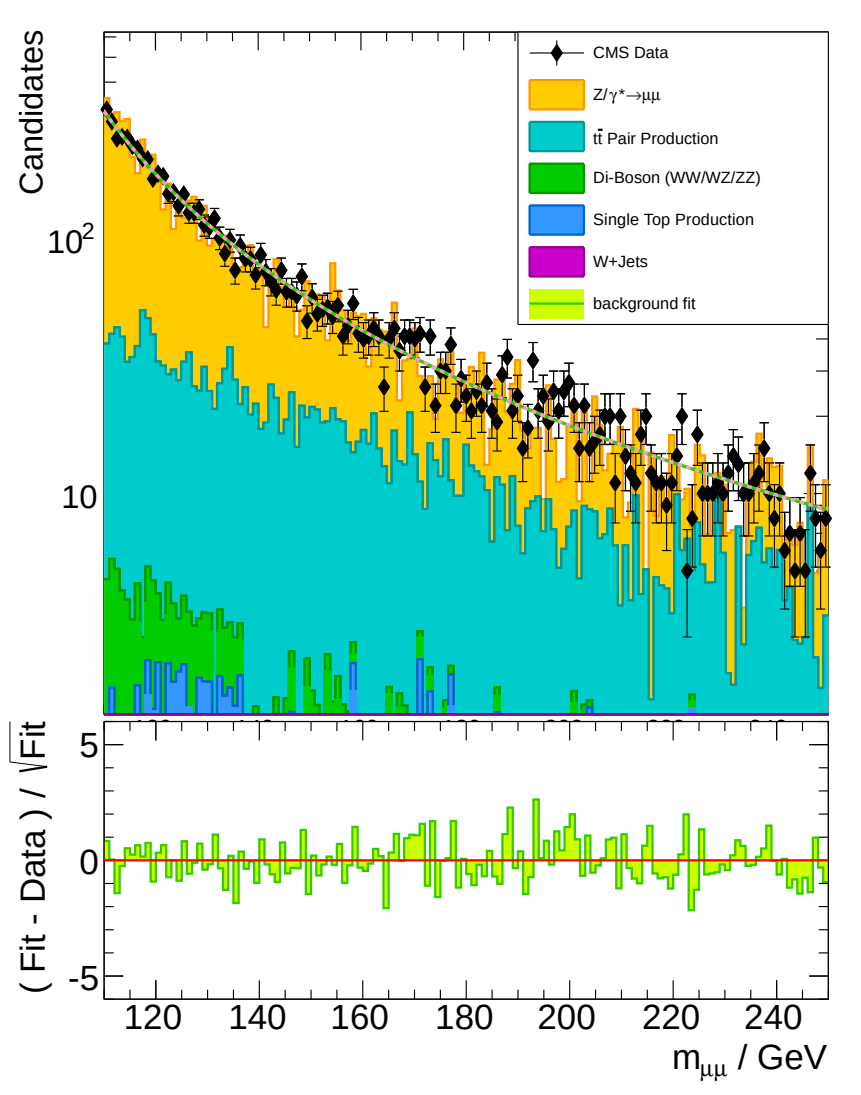


combined fit to data

background hypothesis:

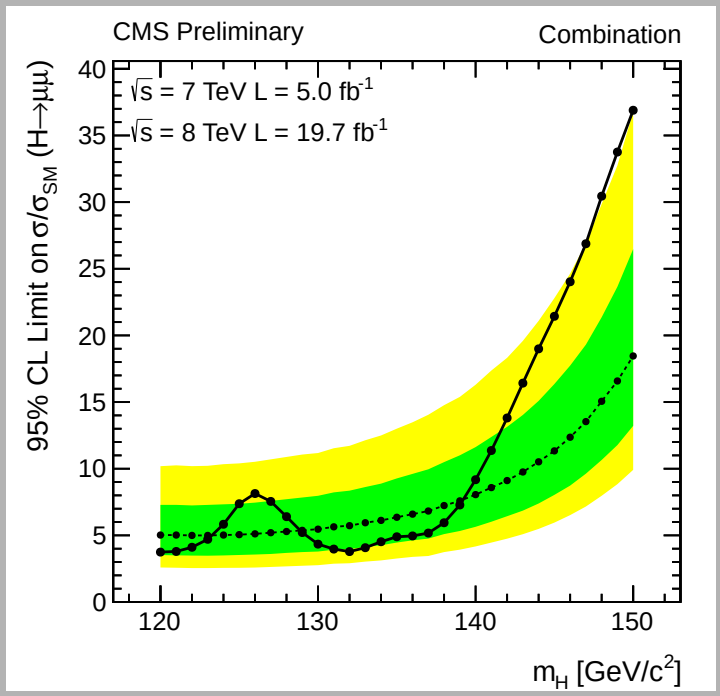
$$f(m) = \frac{e^{-\lambda \cdot m}}{(m - M_Z)^2}$$

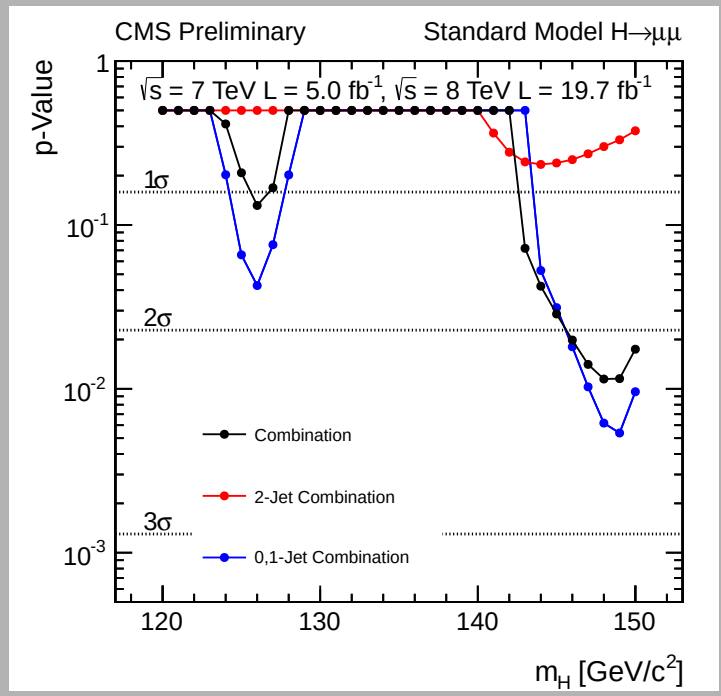
- unbinned likelihood fit of $s + b$ hypothesis to data in each category
- signal strength and background parameters are free
- signal and background shapes used in limit calculation:
- fit systematics and normalization treated as nuisance parameters
- additional systematics on signal simulation considered
- correlation of systematics between categories and data-sets considered



Results

limits and p-values



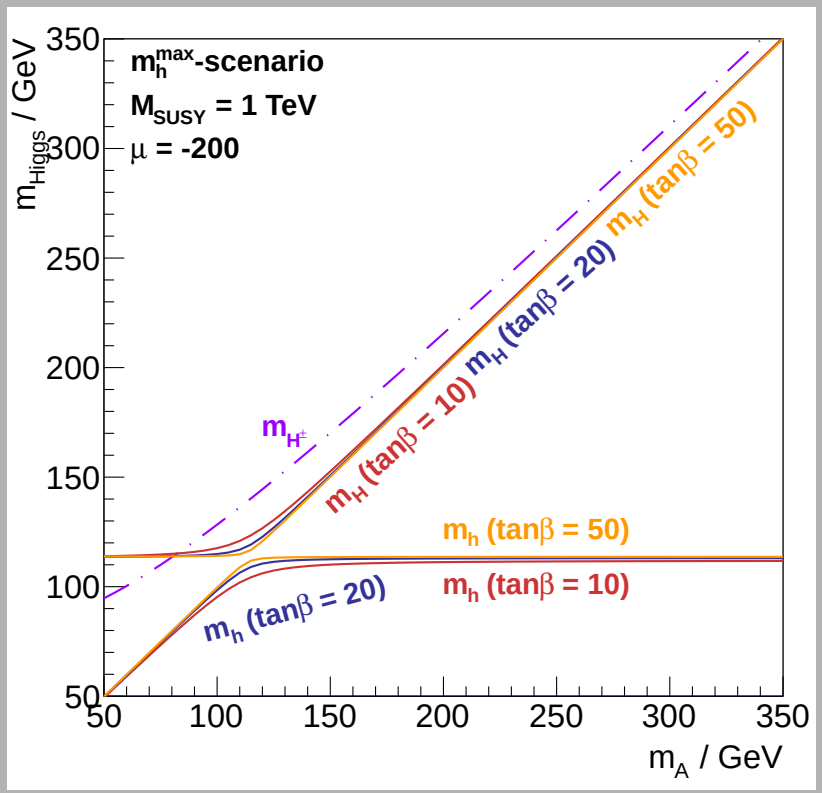


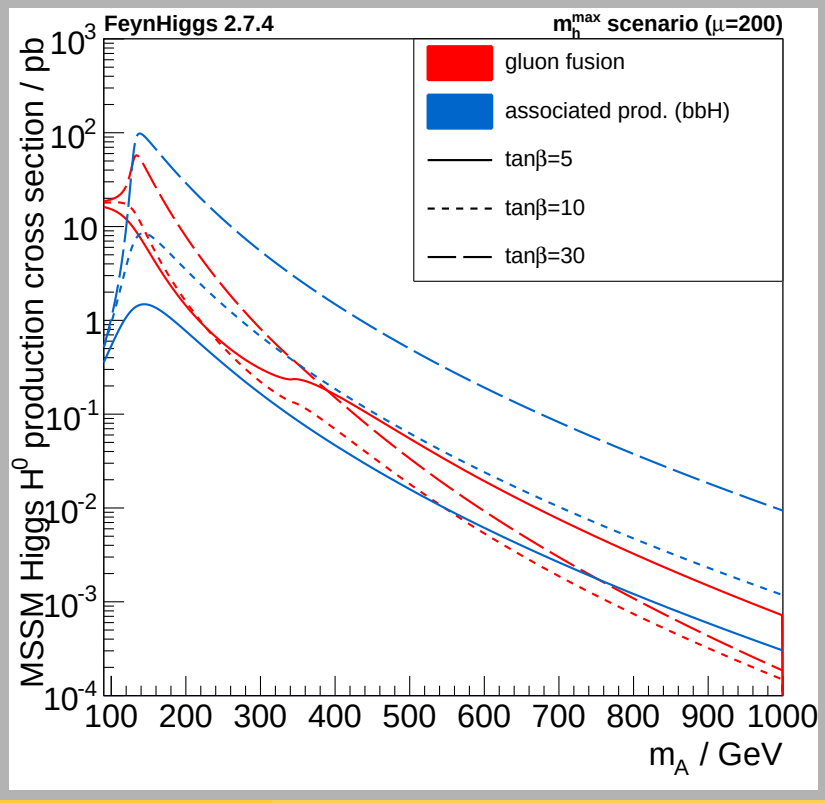
- statistically limited
- expected (observed) limit for a 125 GeV Higgs at $5.5\,^{+2.5}_{-1.7}$ (6.2) for 8 TeV and $12.6\,^{+5.8}_{-3.8}$ (18.5) for 7 TeV
- excess around 144 GeV dominantly from two NonVBF categories resulting in a significance of 0.9 σ considering look-elsewhere effect

MSSM Higgs $\rightarrow \mu\mu$

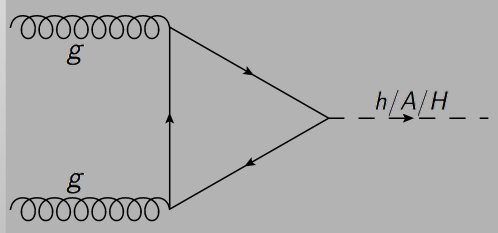
The Higgs in the MSSM

- $\Phi \to \mu^+\mu^- \approx 0.03\%$ is small, but it gives a clean signature in the detector and gives the opportunity to reconstruct m_A and Γ_A and through that $\tan\beta$
- $\Phi \to b\bar{b} \approx 90\%$ dominant for small m_A but hard to reconstruct due to the 4 b-jets in the final state
- $\Phi \to \tau^+\tau^- \approx 9\%$ but the reconstruction of m_A and Γ_A is very difficult



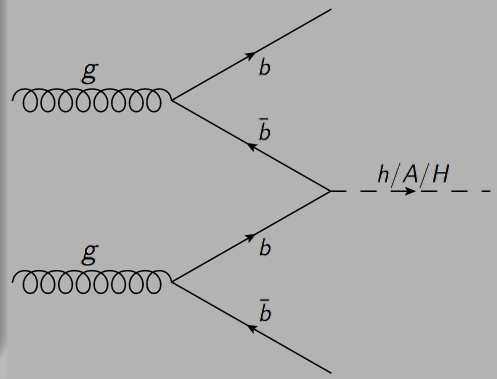


signal and backgrounds in MSSM



- similar to SM GGF
- two isolated muons
- low $\not{E}_T$
- no additional jets

b-associated production



- dominant for higher values of tanβ
- two isolated muons
- low $\not{E}_T$
- two b-jets in forward region

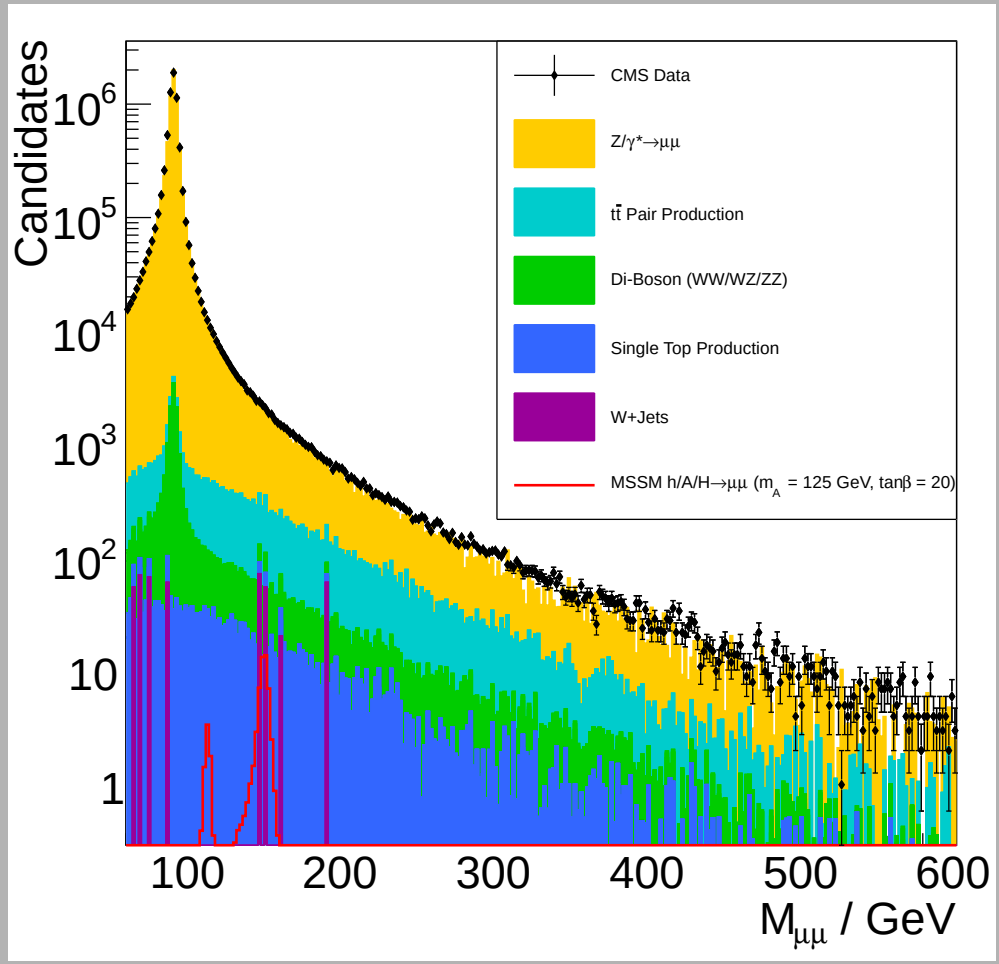
important backgrounds

- similar to SM Analysis
- bbZ production irreducible to bbH
- top pairs more important for bbH

Selection

selection and categorization

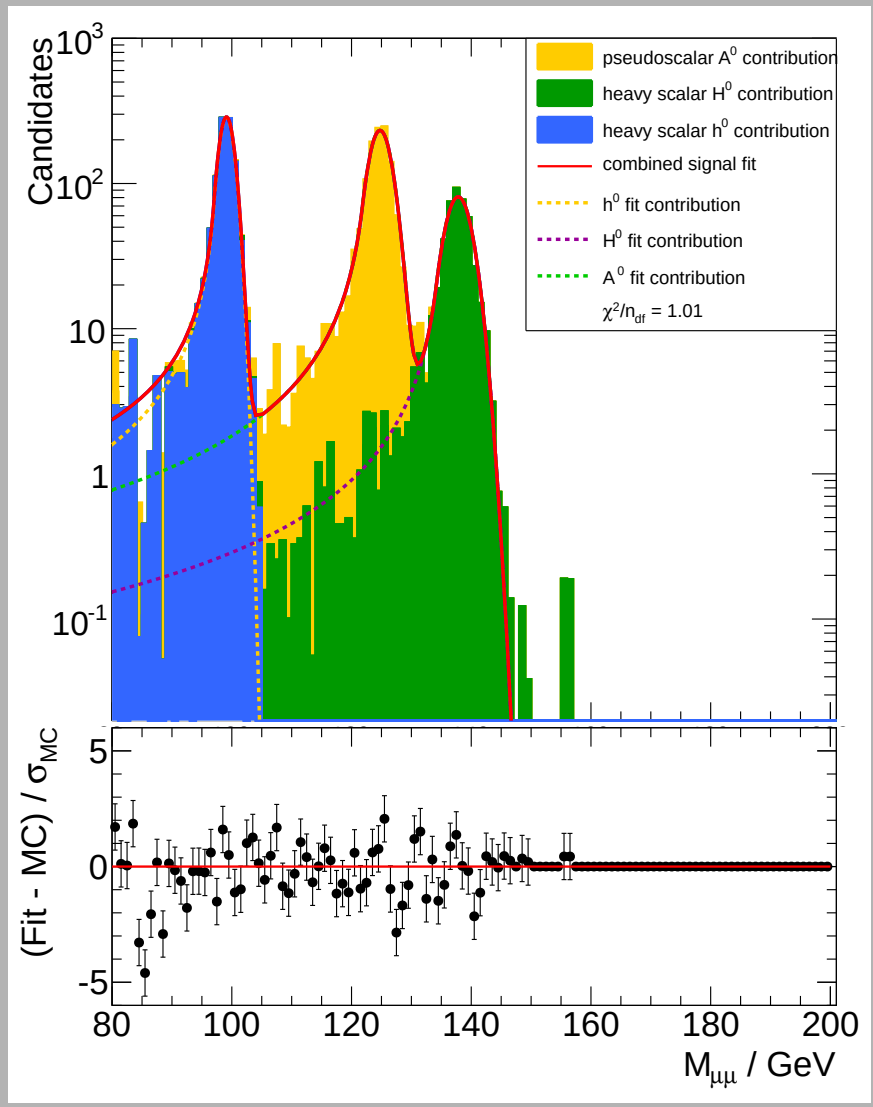
- same trigger and muon selection as SM analysis
- $\not{E}_T < 35$ GeV
- B-tag category: at least one jet with:
  - $p_T > 30$ GeV
  - $|\eta_j| < 2.4$
  - Pile-Up ID passed
  - $\Delta\eta_{j\mu} > 0.5$
  - B-tag ($d_{csv} > 0.679$)
- No-Tag: Everything passing the preselection and not falling into the B-Tag Category



invariant di-muon mass after preselection

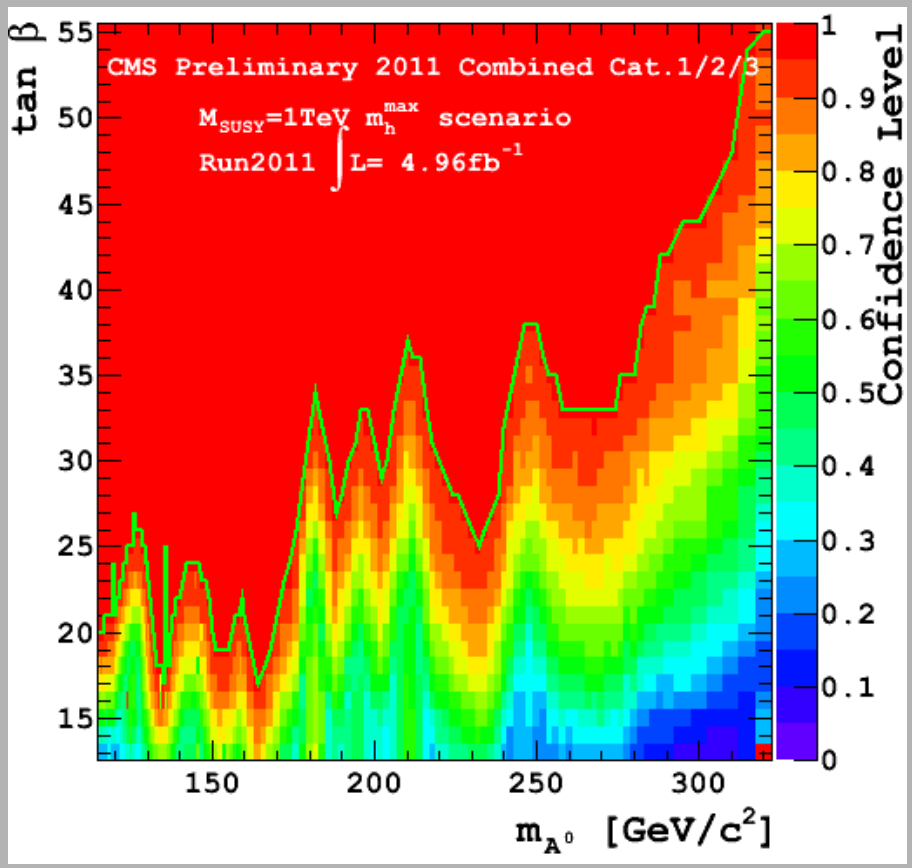
Signal Fit

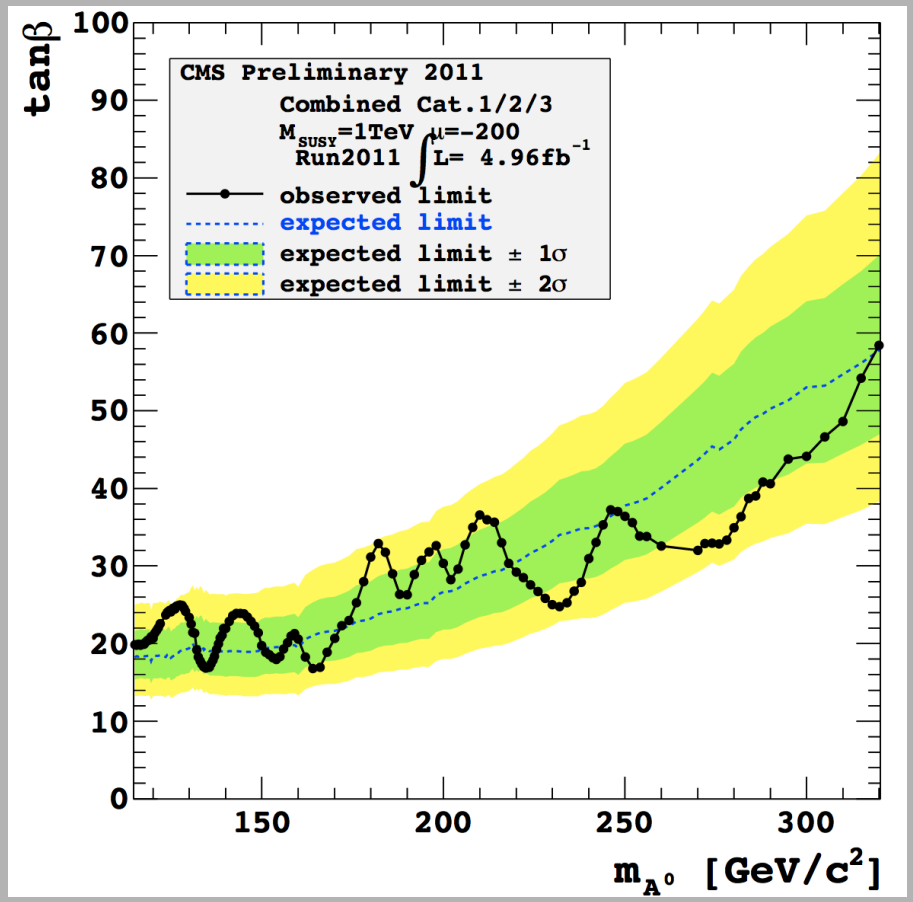
- a single peak consists of linear combination of a Gaussian and a crystal ball shape
- complete signal hypothesis consists of three peaks for each neutral MSSM Higgs
- signal hypothesis is fitted to MC Simulation at each point and category
- shape is interpolated between generated mass points
- parameters are fixed for final fit
- confidence level scanned in m_A – $\tan\beta$ plane
- limits calculated with signal samples closest to 95% C.L. in the scan



MSSM Results

2011 confidence level and limits





2012 in approval process

Summary

SM Higgs

- full luminosity (24.84 fb^{-1}) utilized for analysis
- 15 categories focusing on VBF and GGF
- combined sensitivity of 5.1 times SM is achieved
- fluctuations in two categories lead to a broad excess around 145 GeV
- after look-elsewhere effect they amount to a significance of 0.9σ
- analysis public as CMS PAS HIG-13-007

MSSM Higgs

- 2011 analysis public in CMS PAS HIG-12-011
- update with full data-set in progress
- 2 categories focusing on bbH and ggH respectively
- analysis public soon as CMS PAS HIG-13-024

BACKUP

SM Prospects for 14 TeV

expected sensitivity and significance for 14 TeV