Bundesministerium
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RWTH AACHEN UNIVERSITY

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

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Physics at the Terascale
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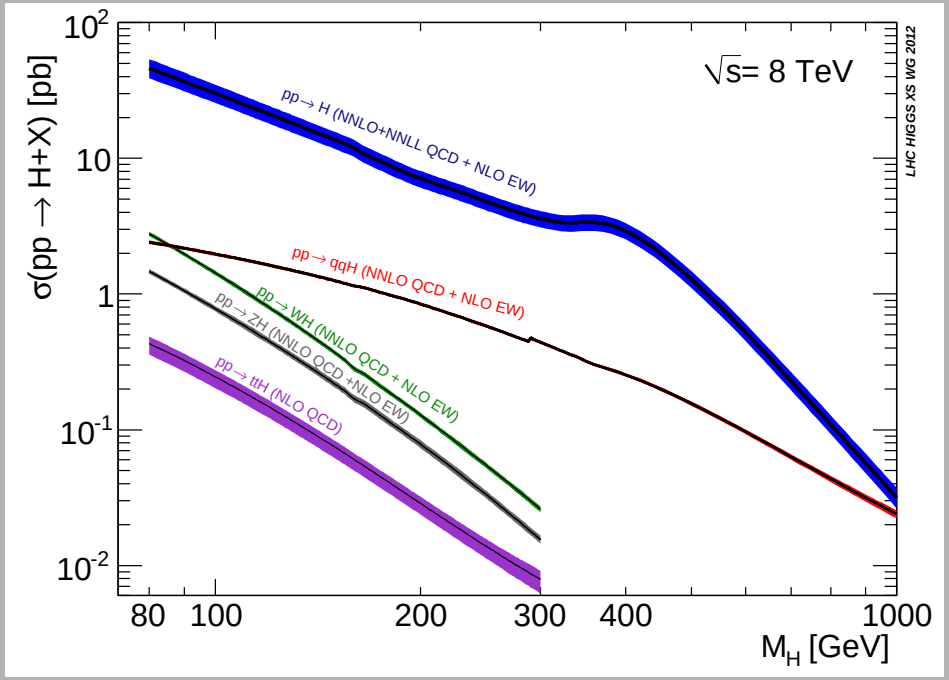
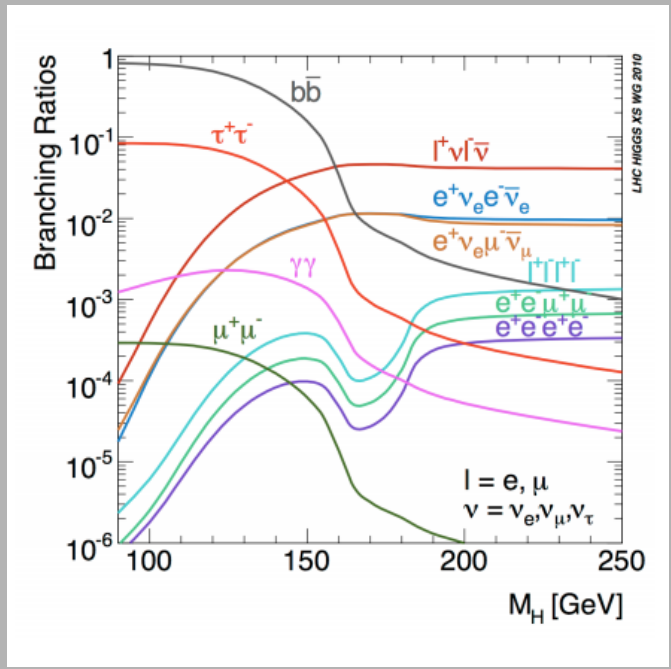
the Standard Model Higgs

cross section and branching ratio

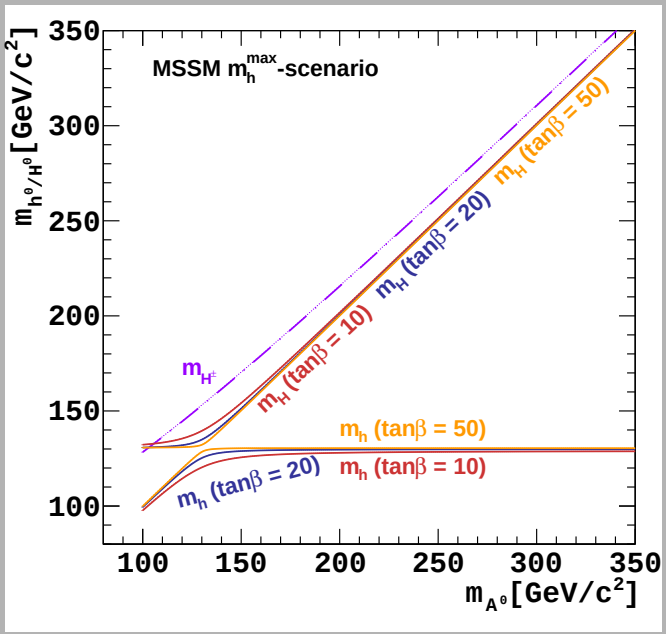


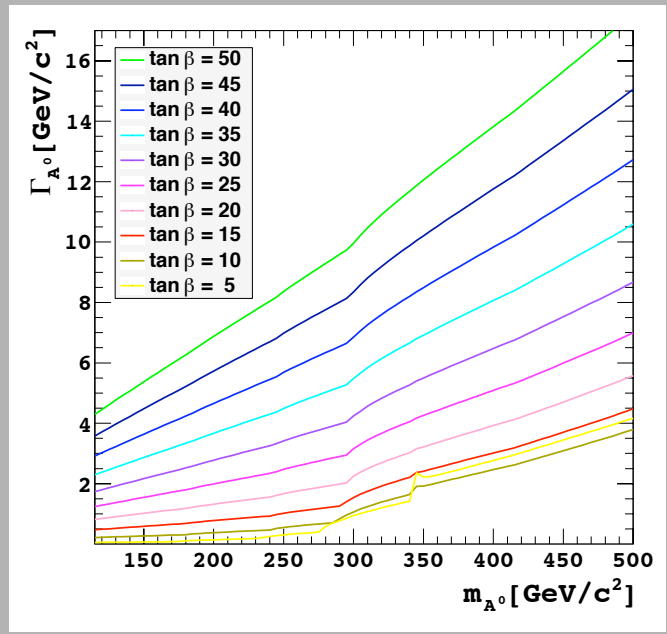


- after discovery of Higgs-like boson, confirmation in as many channels as possible is necessary
- branching ratio into muons is *only* an order of magnitude lower as $H \to \gamma\gamma$
- exploiting the VBF topology separation from dominant backgrounds possible
- smooth background and simple signal shape make background estimation from data easy

The Higgs in the MSSM

- $\varphi \to b\bar{b} \approx 90\%$ dominant for small m_A but hard to reconstruct due to the 4 b-jets in the final state
- $\varphi \to \tau^+\tau- \approx 9\%$ but the recontruction of m_A and Γ_A is very difficult
- $\varphi \to \mu^+\mu^- \approx 0.03\%$ 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 $\tan\beta$



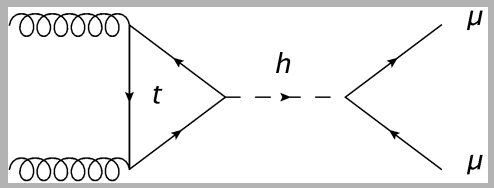


- the masses of two neutral Higgs bosons are always degenerated
- Higgs sector completely defined by m_A and $\tan\beta$

signal topology

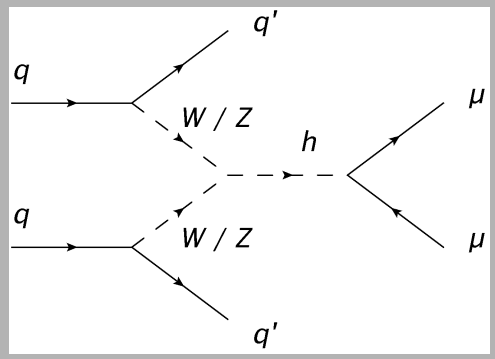
Standard Model

gluon-gluon fusion



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

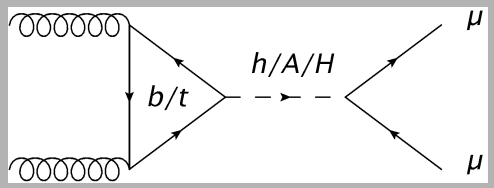
Vector Boson Fusion



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

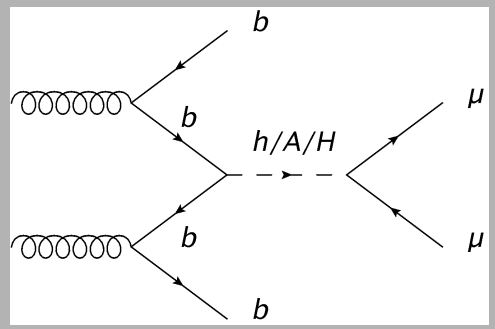
MSSM

gluon-gluon fusion



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

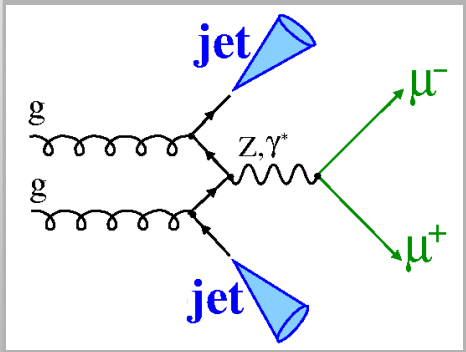
b-associated production



- dominant for high $\tan\beta$
- two isolated muons
- two b-jets
- low $\not{E}_T$

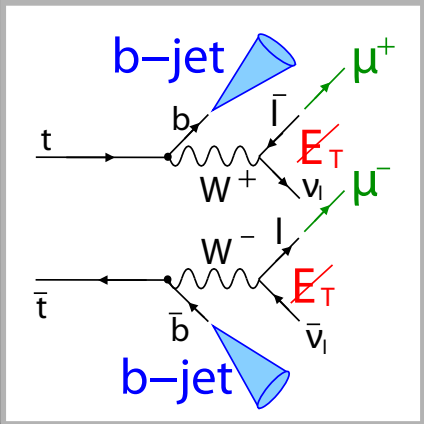
backgrounds

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



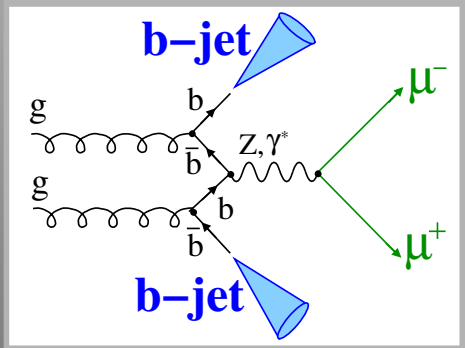
- dominant background in SM selection
- two isolated muons
- low $\not\!\!E_T$

top quark pairs



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

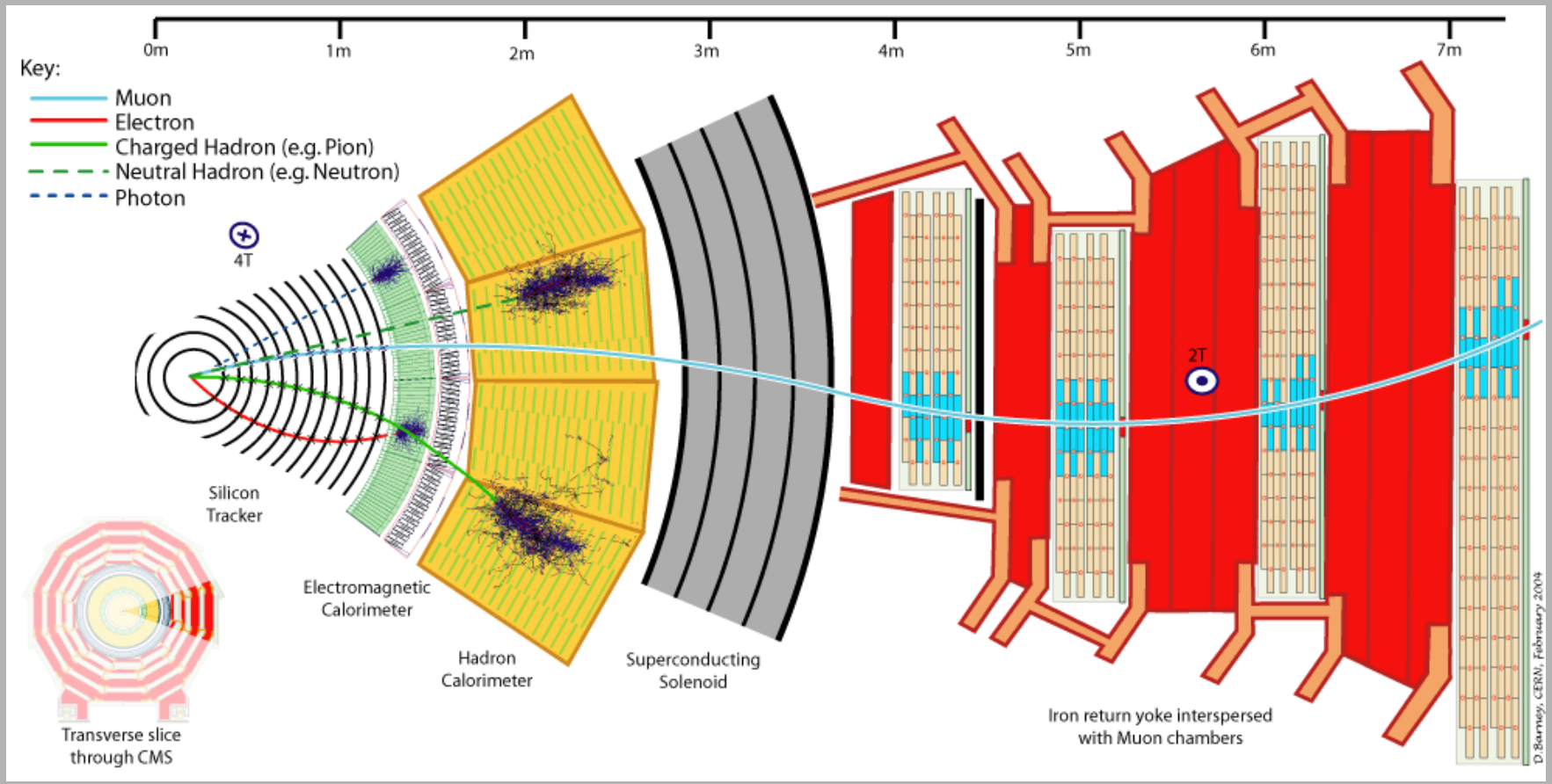
$bbZ/\gamma^* \to \mu\mu$



- same event topology as MSSM signal
- two isolated muons
- two b-jets
- low $\not\!\!E_T$

additional backgrounds considered: W+Jets, WW, WZ, ZZ, Single top

Compact Muon Solenoid



MSSM analysis

as published in CMS PAS HIG-12-011

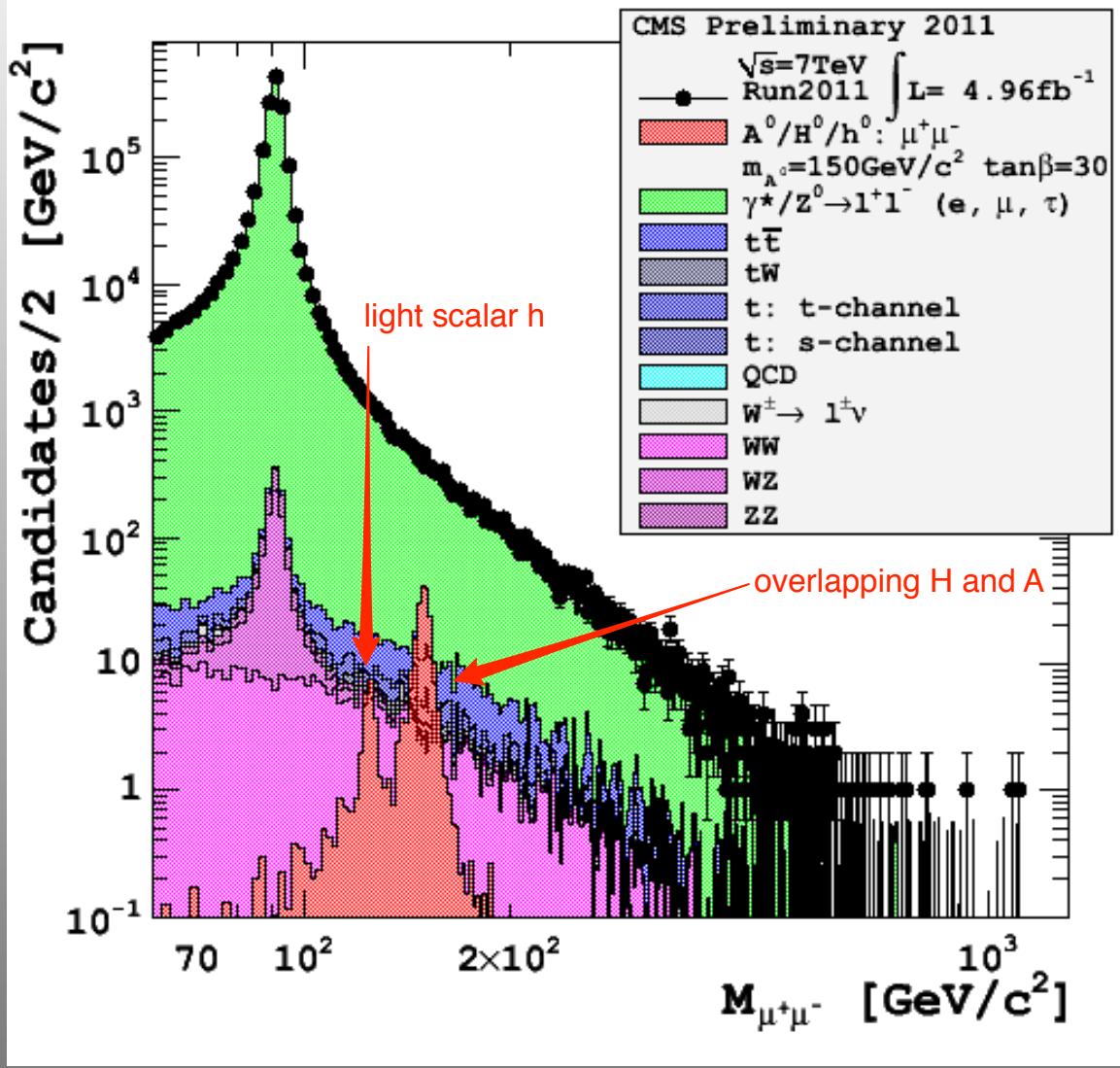
event selection

pre-selection:

- basic muon selection
  - $p_{T\mu 1} > 30\ GeV$ & $p_{T\mu 2} > 20\ GeV$
    (asymmetric due to trigger thresholds)
  - $|\eta_\mu| < 2.1$
  - isolation
- $\not{E}_T < 30\ GeV$

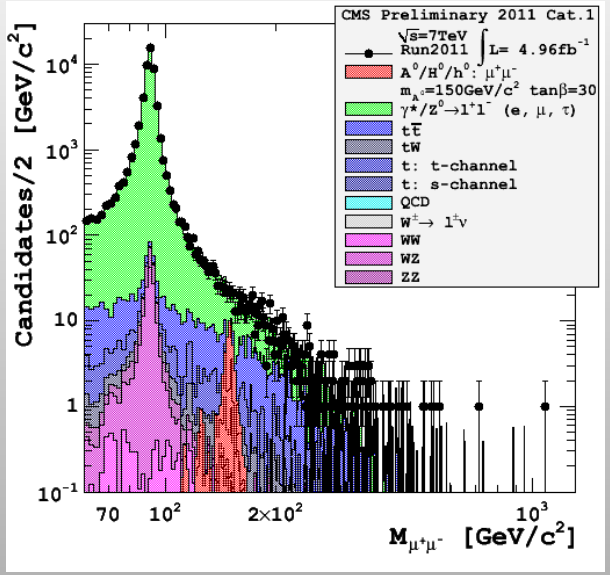
event categories:

- 1 tagged b-jet
  - $p_T^{Jet} > 20\ GeV$
  - $|\eta_{Jet}| < 2.4$
  - loose b-tag ID
- 1 additional muon
  - $p_T^{\mu} > 3\ GeV$
  - $|\eta_\mu| < 2.4$
  - separation to other muons
- everything else

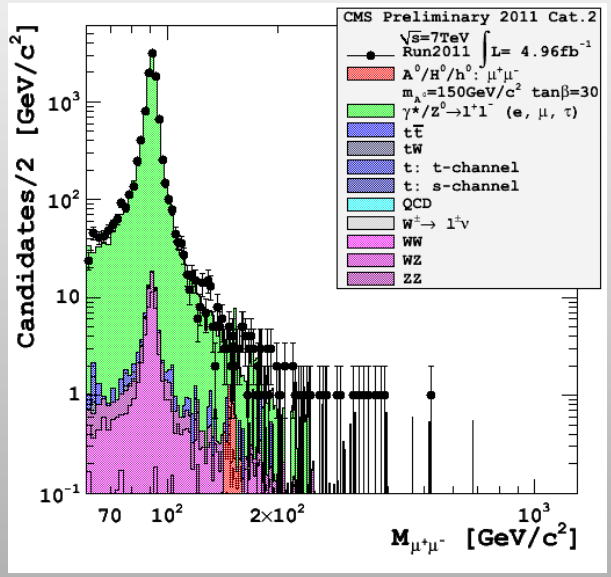


invariant di-muon mass
after pre-selection

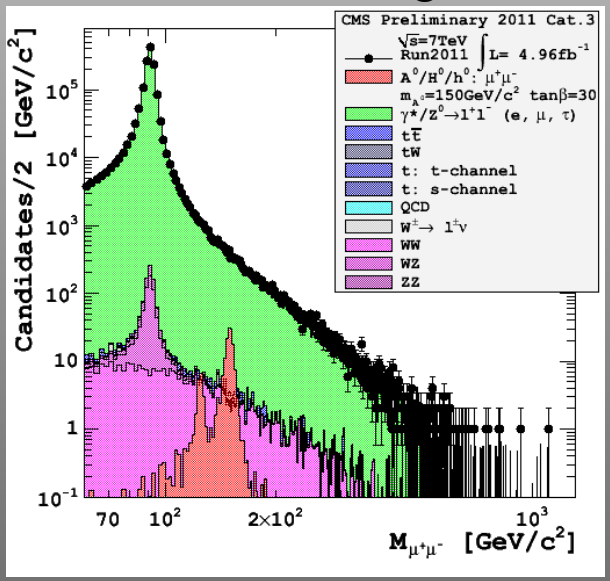
categories



Cat. 1: b-tag



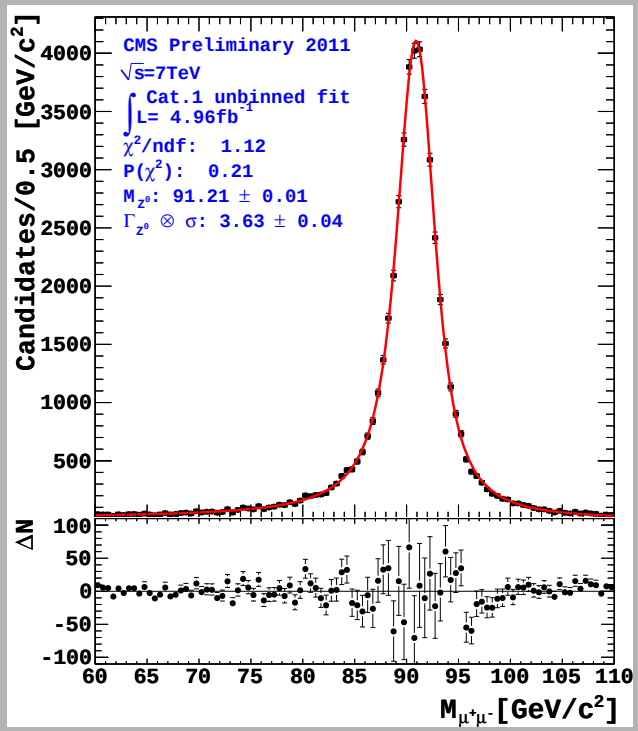
Cat. 2: add. muon

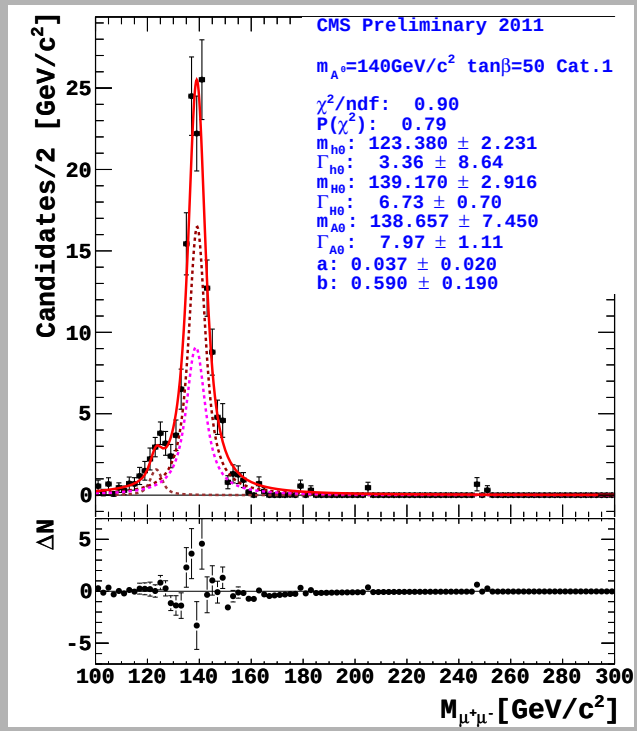


Cat. 3: rest

- category 1 has best signal to background ratio
- category 3 has highest statistics
- category 1 and 3 have highest sensitivity
- category 2 has low sensitivity, but serves as verification if a signal appears in category 1 or 3

background estimation from data

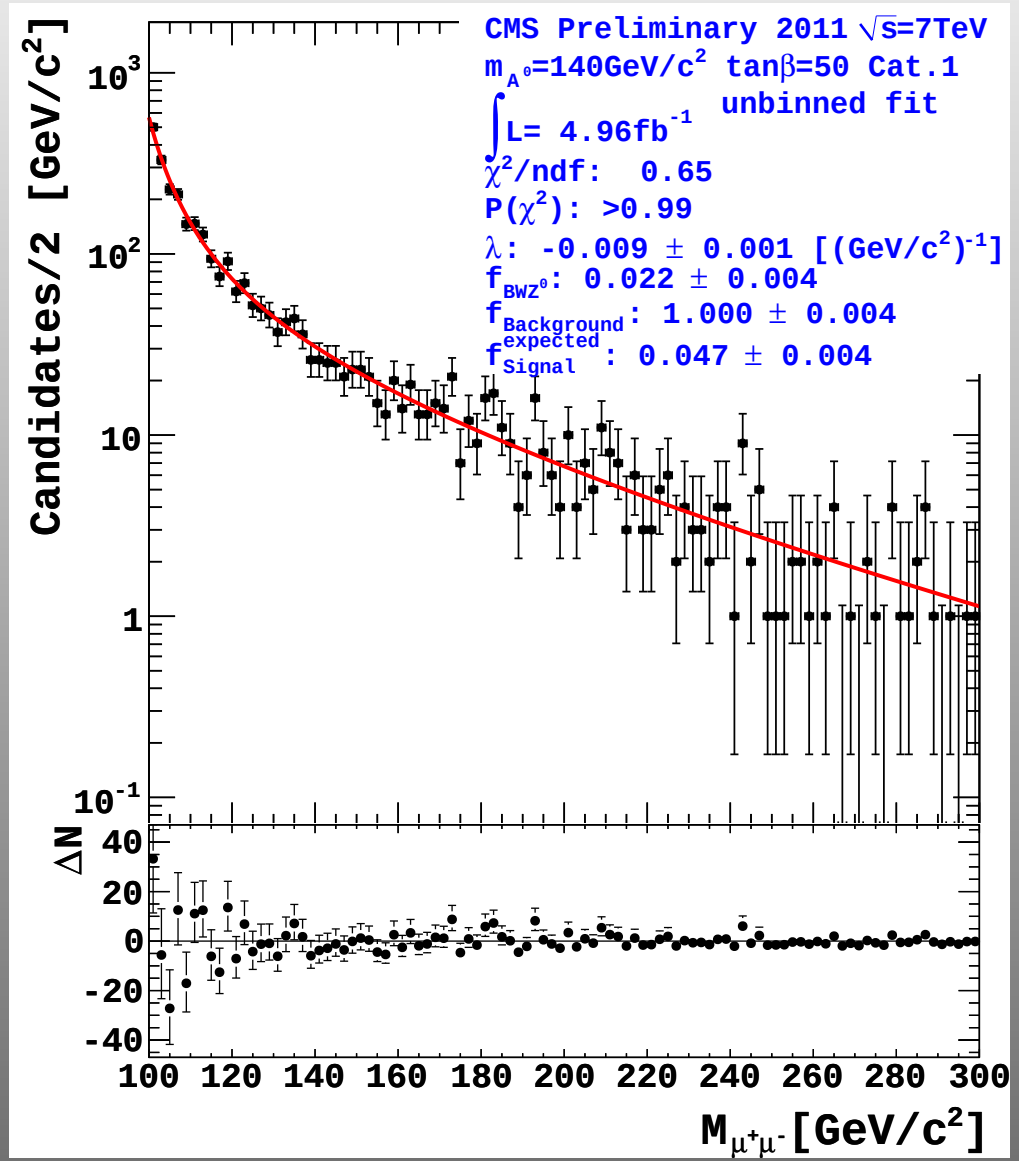




- background model: linear combination of
  - Breit-Wigner at the Z peak
  - photon propagator contribution
  - both multiplied with a falling exponential for the pdf contribution
  - Z parameters fixed from fit to data with crystal ball (outside of signal region)
- signal model:
  - linear combination of three Breit-Wigner peaks, convoluted with a common detector resolution
  - signal parameters fixed by a fit to simulation

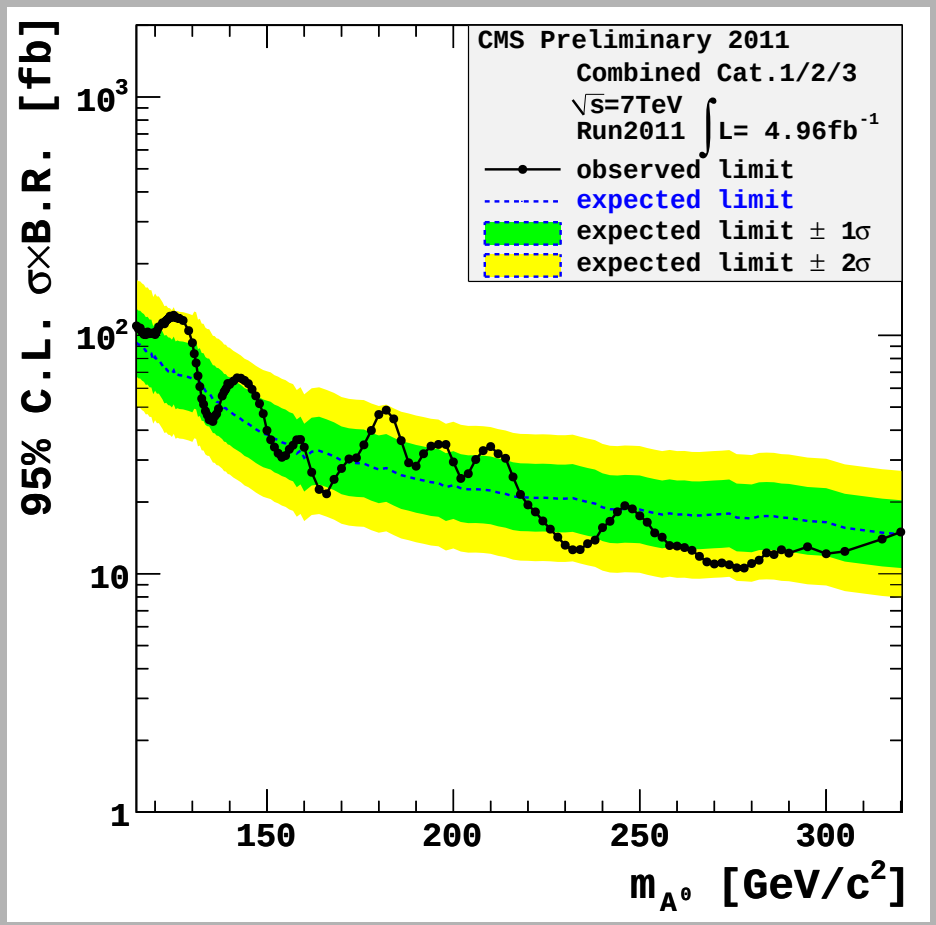
background estimation from data

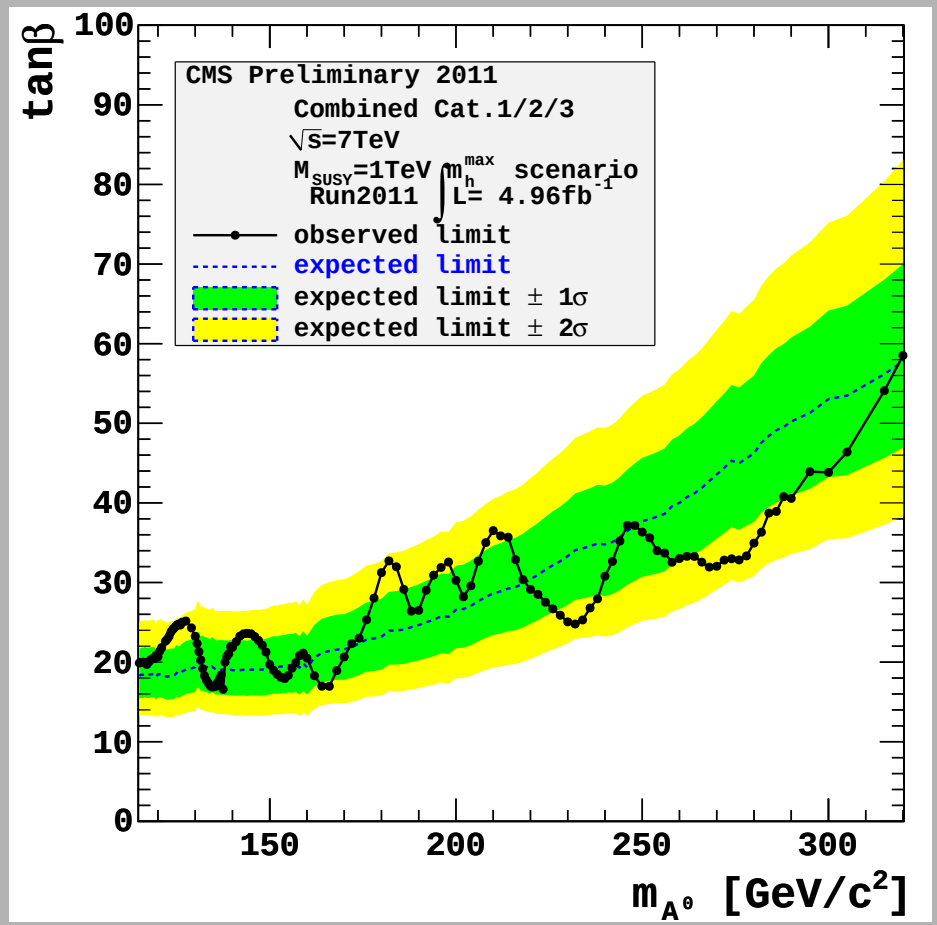
- unbinned likelihood fit of $s + b$ hypothesis to data
- signal strength as free parameter
- signal and background shapes used in limit calculation:
  - signal shape from fit to simulation
  - background shape from fit to data
- confidence level scanned in $m_A - \tan\beta$ plane
- limits calculated with signal samples closest to 95% C.L. in the scan
- shape uncertainties considered as systematic uncertainty
- more details can be found in CMS PAS HIG-12-011



limit calculation (2011)

Combination





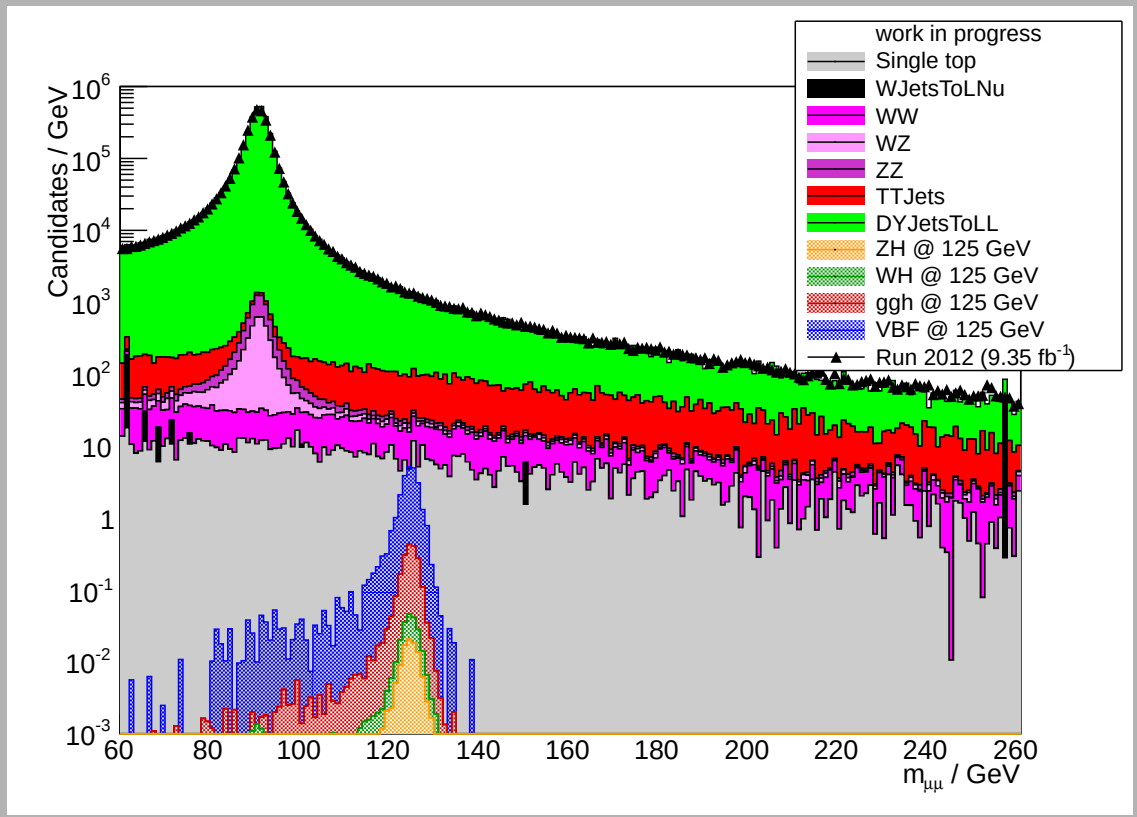
biggest contribution to the combination from categories 1 & 3
updated analysis with 2012 dataset in preparation

SM Higgs analysis

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



event categorization

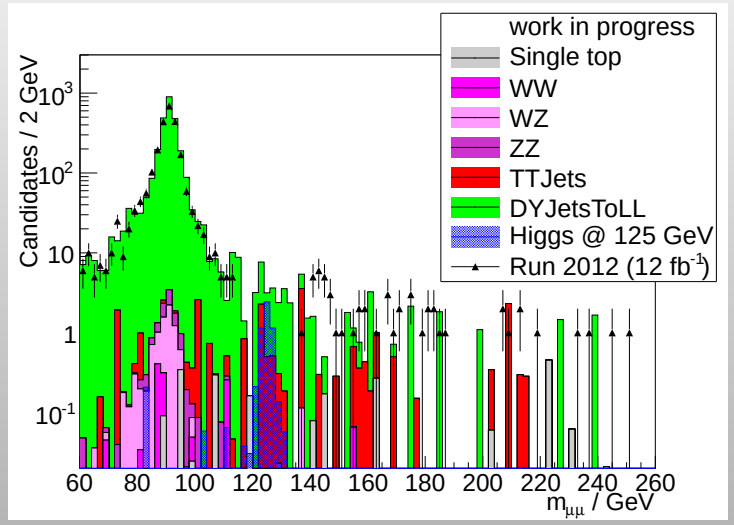
VBF categories

- two jets with
- $p_T^{jet} > 30$ GeV
- $|\eta_{jet}| < 5$
- no additional jets in the rapidity gap
- **VBF Tight**
  - $|\Delta\eta_{j,j}| > 5$
  - $m_{j,j} > 400$ GeV
- **VBF Medium**
  - not in VBF Tight
  - $|\Delta\eta_{j,j}| > 4$
  - $m_{j,j} > 400$ GeV
- **VBF Loose**
  - not in VBF Tight or Medium
  - $|\Delta\eta_{j,j}| > 3$
  - $m_{j,j} > 300$ GeV

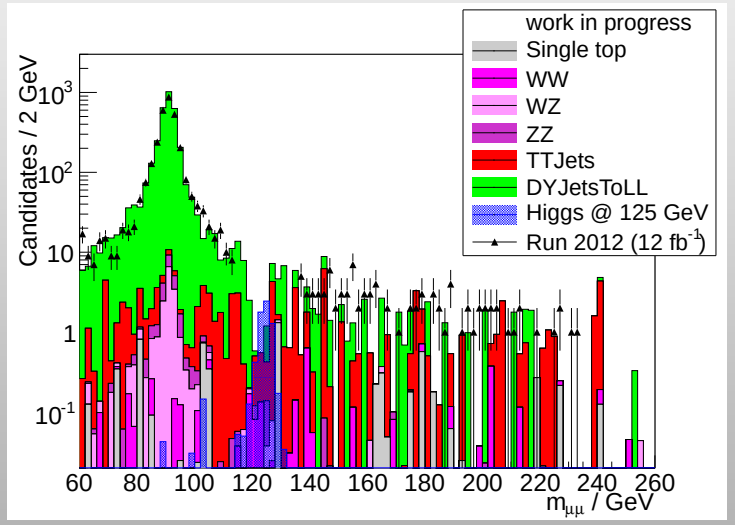
Non-VBF categories

- events which fail the VBF Preselection are split up further:
- **DiMuonPt Very Low**
  - $p_T^{\mu\mu} < 30$ GeV
- **DiMuonPt Low**
  - 30 Gev $p_T^{\mu\mu} < 50$ GeV
- **DiMuonPt Medium**
  - 50 Gev $p_T^{\mu\mu} < 75$ GeV
- **DiMuonPt High**
  - 75 Gev $p_T^{\mu\mu} < 125$ GeV
- **DiMuonPt Very High**
  - $p_T^{\mu\mu} > 125$ GeV

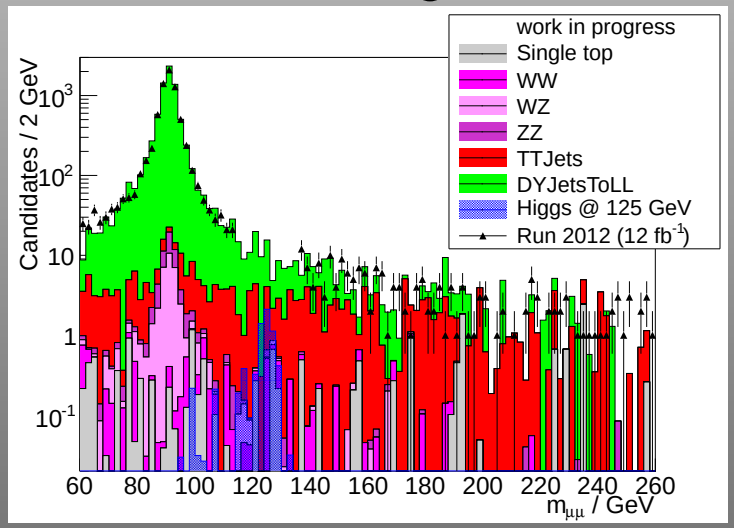
VBF categories



VBF Tight



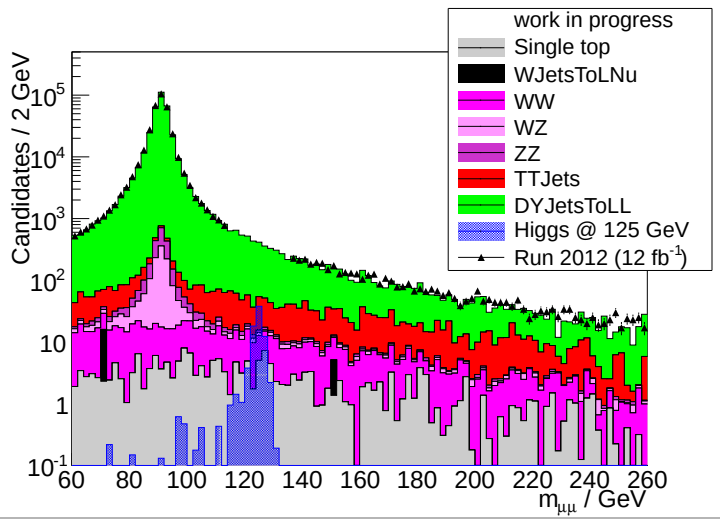
VBF Medium



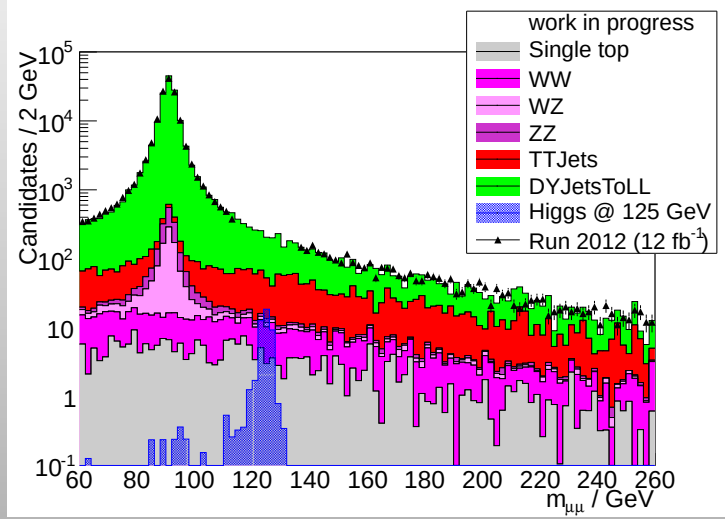
VBF Loose

- contributions by gluon fusion and VBF production
- good signal to background ratio in all three categories
- low statistics

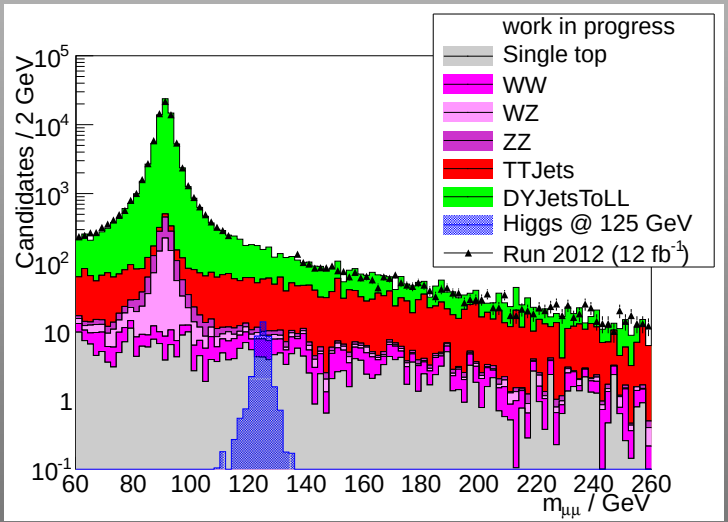
VBF categories



Pt Low



Pt Medium

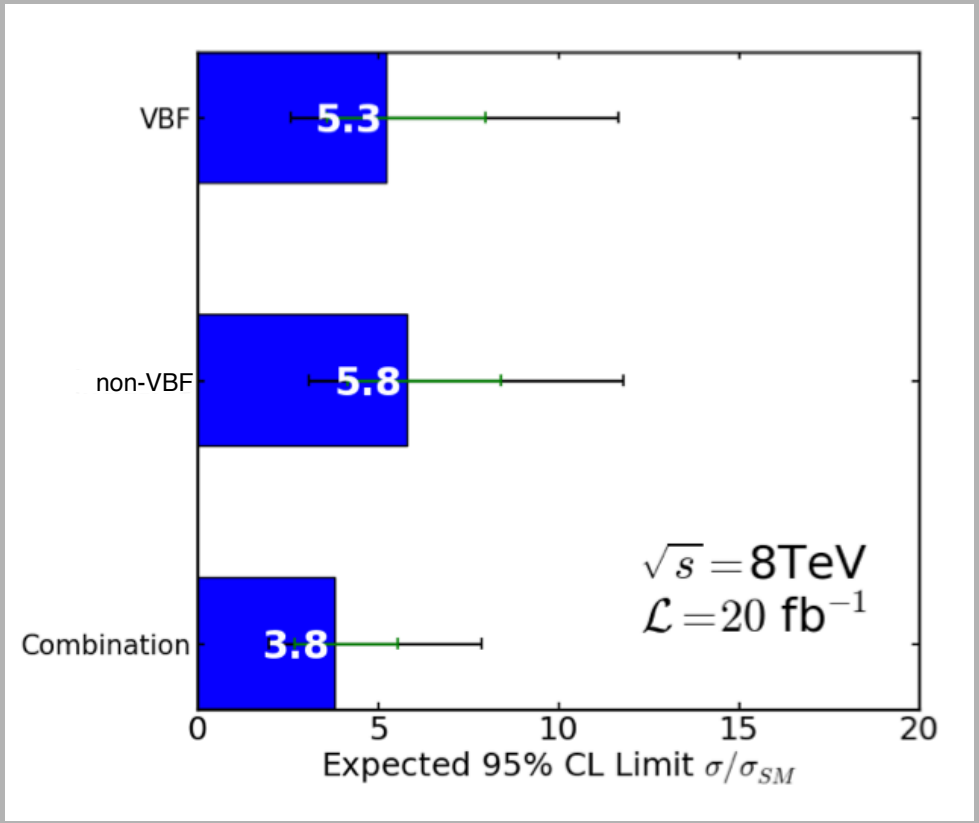


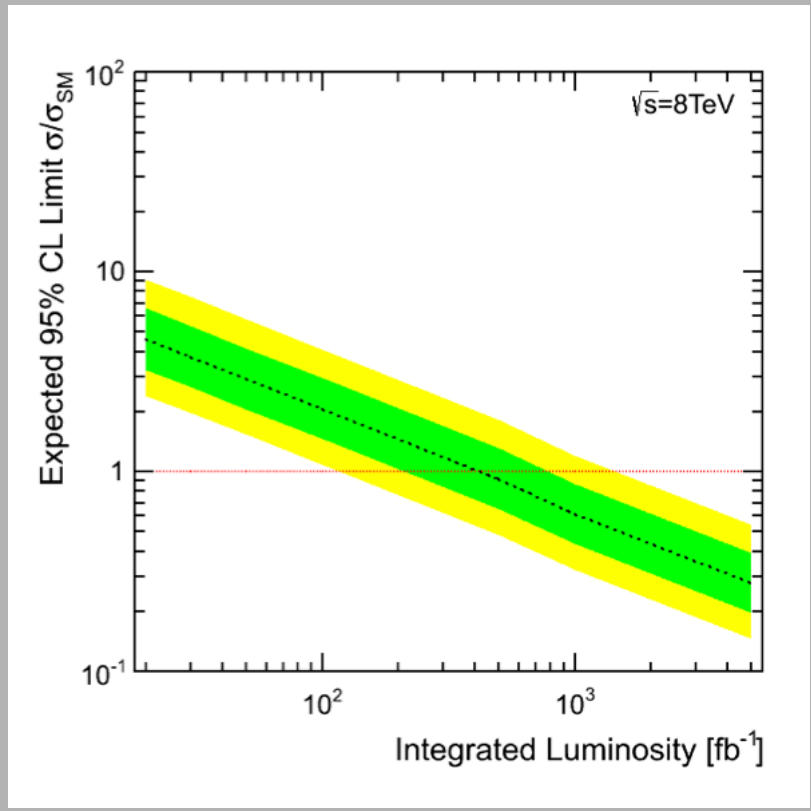
Pt High

- main contribution by gluon fusion
- signal to background ratio not as good as in VBF
- high statistics
- smooth background in sideband
- additional MVA's intended on all SM categories

SM Higgs limit prospects

first limit predictions from MC





Considering further improvement in pile-up veto and higher cross sections for 13 (14) TeV the sensitivity of this channel should be sufficient to see a SM Higgs before LS2.

conclusions and outlook

conclusions

- MSSM analysis already published with 2011 data
- updated prospects for 8 TeV already done this summer
- SM analysis gains momentum
- selection and event categories established
- first estimations for sensitivity suggest $\approx$ 4x SM cross section

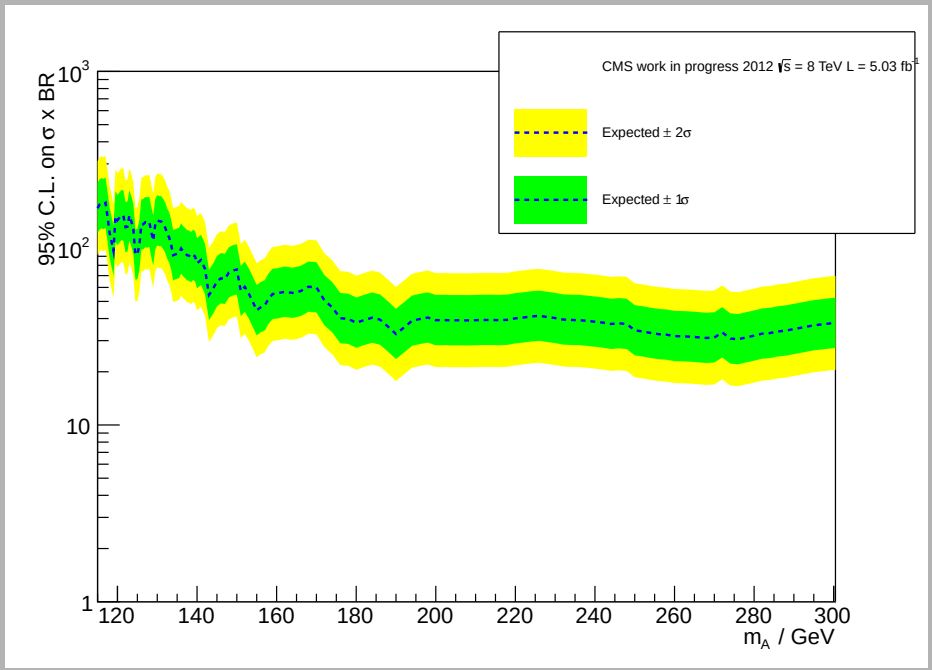
outlook

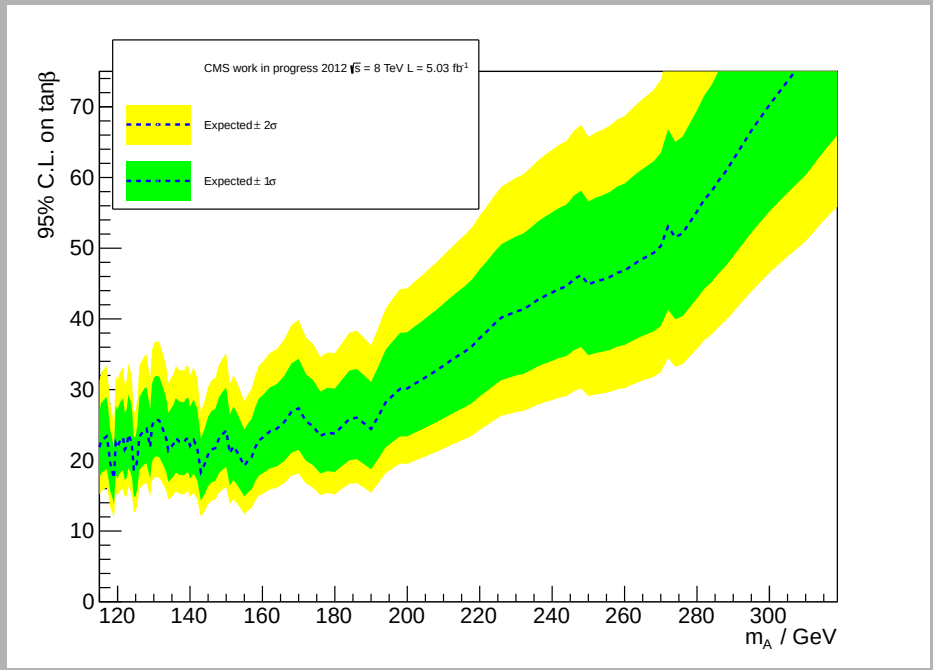
- detailed update of MSSM analysis with full 2012 dataset
- proper SM Higgs limit estimation including
  - background estimation (similar to MSSM analysis)
  - signal modelling
  - category optimization
  - study of systematic uncertainties

BACK UP

limit calculation (2012) first prospects

Combination





biggest contribution to the combination from categories 1 & 3

signal injection study

signal injection