Higgs search in the H→ττ→μμ channel

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DPG Frühjahrstagung

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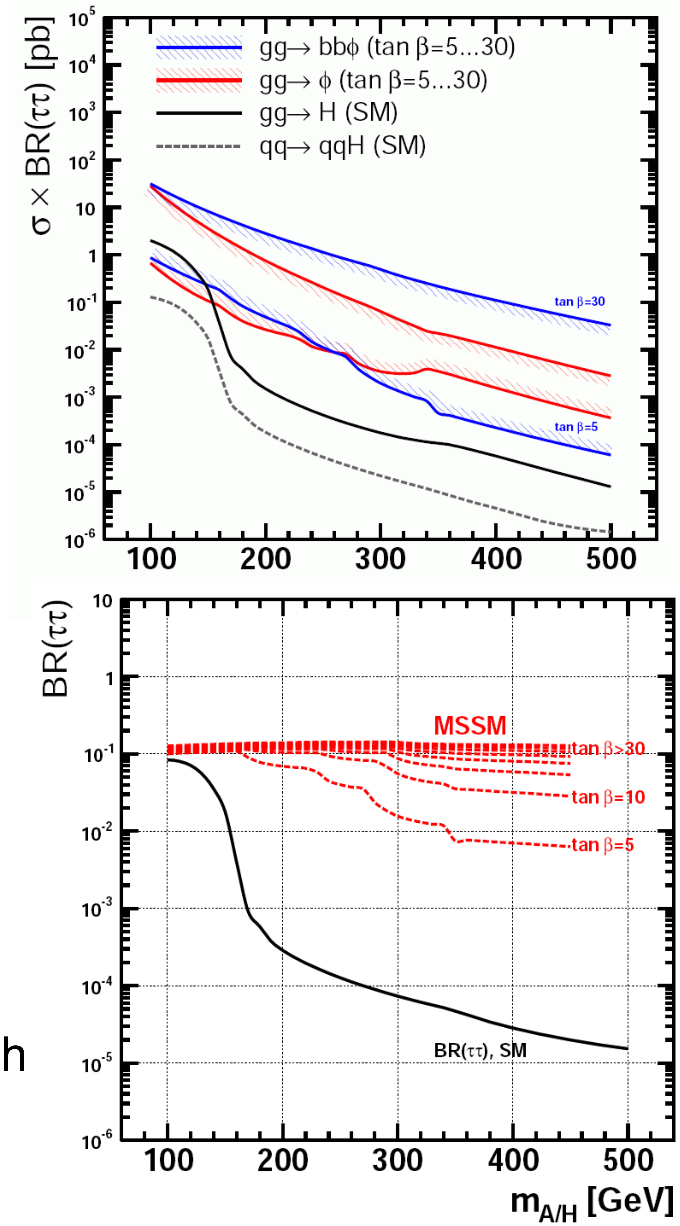
H→ττ at the LHC

- Standard Model
  - promising channel at $M_H \leq 130$ GeV
  - $\sigma(pp \rightarrow H) \times Br(H \rightarrow \tau\tau) = 1.2 - 1.5$ pb
- MSSM
  - 5 scalar states
    - 2 CP-even : h , H
    - 1 CP-odd : A
    - 2 charged : $H^{\pm}$
  - two key parameters defining Higgs phenomenology in MSSM
    - m_A and $\tan\beta$
  - production cross sections enhanced at high $\tan\beta$: $\sigma \sim \tan^2\beta$
  - $Br(H/A \rightarrow \tau\tau) \geq 8\%$ at $\tan\beta \geq 20$



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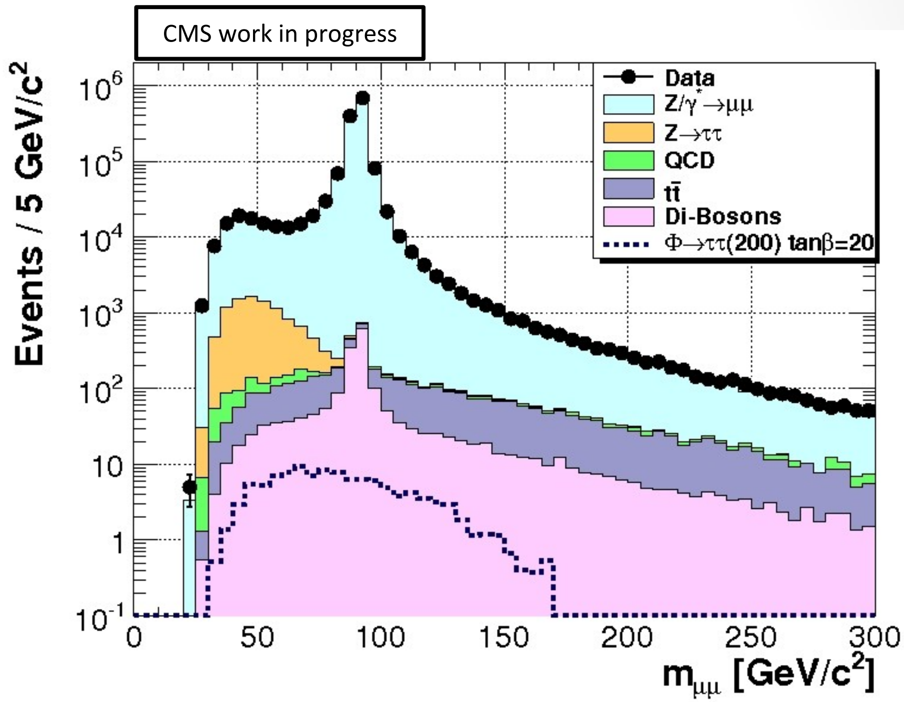
Analysis Strategy

Analysis performed in 2011 CMS data, $L=4.5\ pb^{-1}$

- Challenging channel
  - Small BR $\tau\tau\rightarrow\mu\mu$ 3%
  - Direct DY$\rightarrow\mu\mu$ background
- Preselection
  - Opposite sign muons (using double or single muon triggers)
  - p_T >20 (10) GeV for the leading (sub-leading) muon
  - Isolated muons



- Event categorisation
  - SM (3 categories) & MSSM (2 categories)
- Likelihood selection

After preselection the sample is still dominated by the DY background

Further selection needed!!

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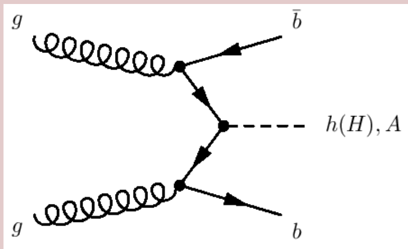
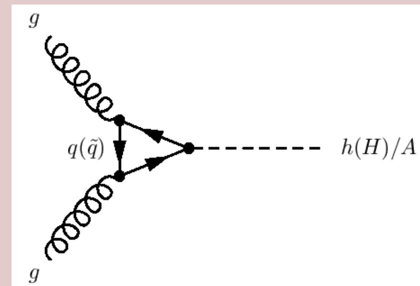
Event Categories

MSSM

b-tag (at least one b-jet present)

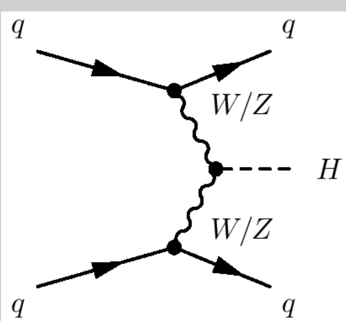


No b-tag

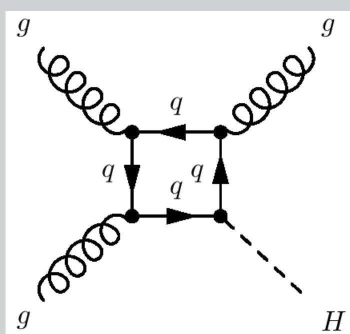


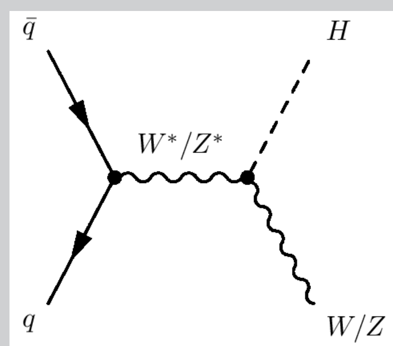
SM

Vector Boson Fusion (VBF) (2 jets with big η gap)

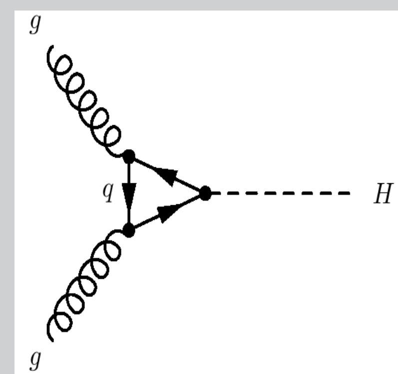


Boosted Higgs (one high p_T jet, p_T>150 GeV/c²)





1/0 jets (gluon fusion)

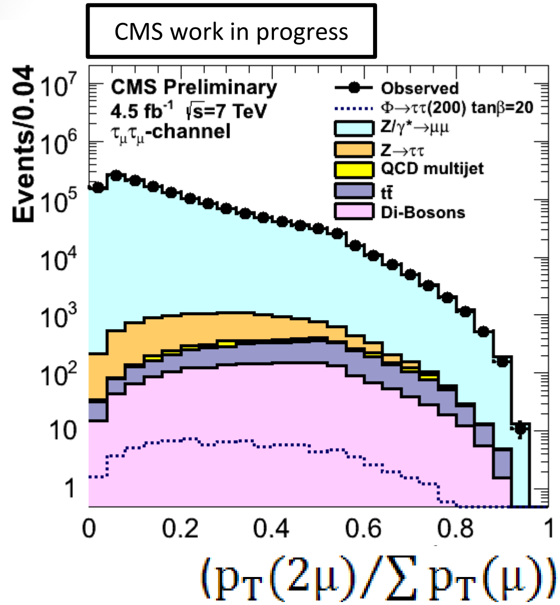


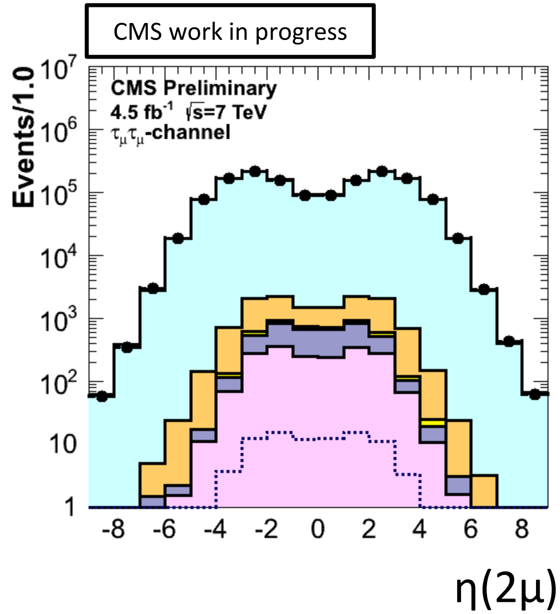
Likelihood selection

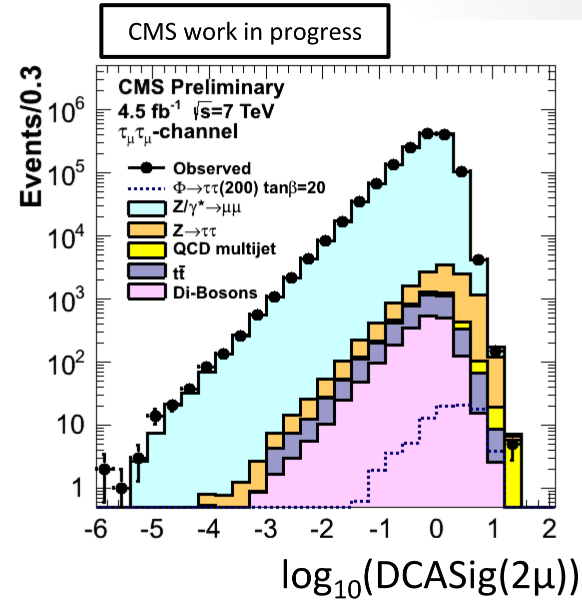
- Preselected dimuon event sample is dominated by DY background
- Likelihood method (MVA technique)
  - $Prob(j) = \prod_{i=1}^{m} f(j, x_i)$
  - $L(j) = \frac{Prob(j)}{\sum_{k=1}^{3} Prob(k)}$
- 3 event classes (j)
  - $Z/\gamma^* \rightarrow \mu\mu$
  - $Z \rightarrow \tau\tau \rightarrow \mu\mu$
  - $\Phi \rightarrow \tau\tau \rightarrow \mu\mu$ signal
- Discriminating variables (x_i)

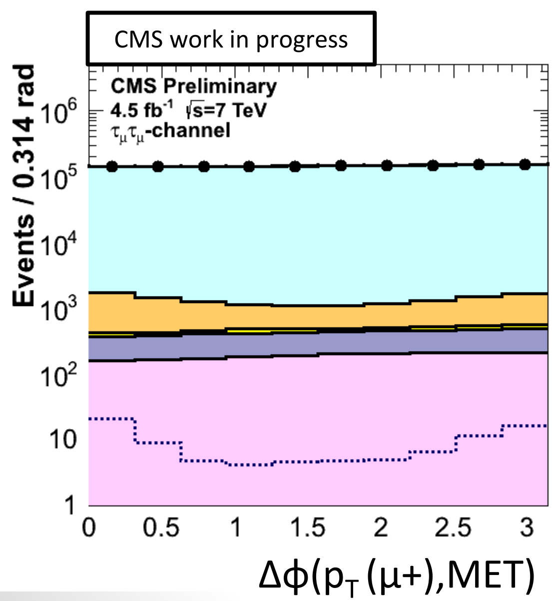
Discriminating variables	MSSM inclusive & SM 0/1 jets category	SM VBF & SM Boosted categories
$p_T(2\mu)/\Sigma p_T(\mu_i)$	y	n
$\eta(2\mu)$	y	n
$\log_{10}$(DCASign(2μ))	y	y
$\Delta\Phi(p_T(\mu^+)$,MET)	y	y
MET	n	y
Validity of Collinear approximation	y	y

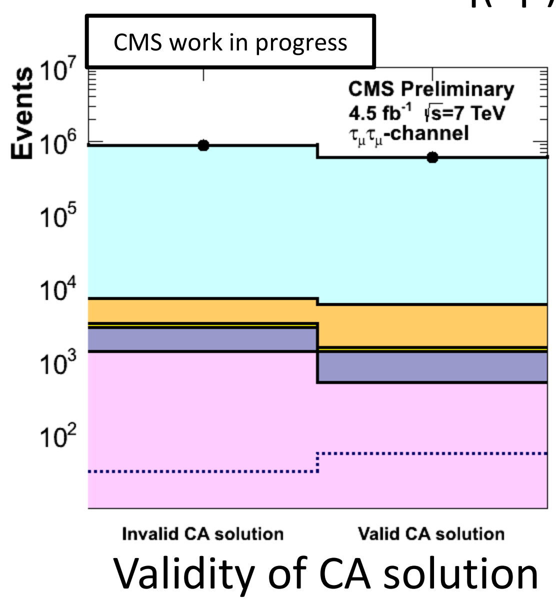
MSSM likelihood variables

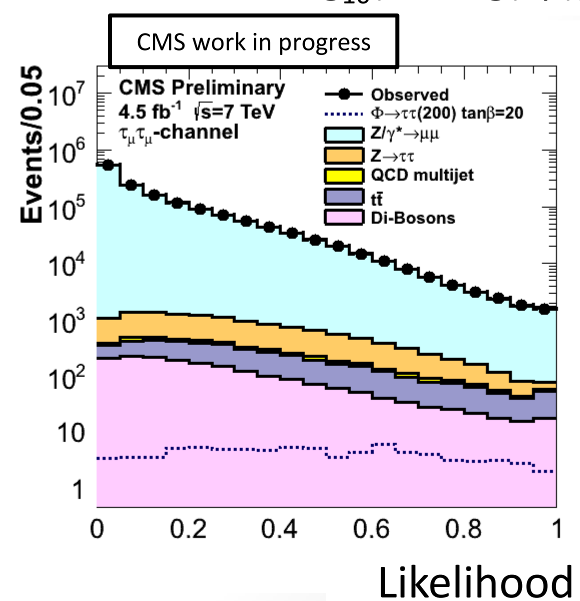










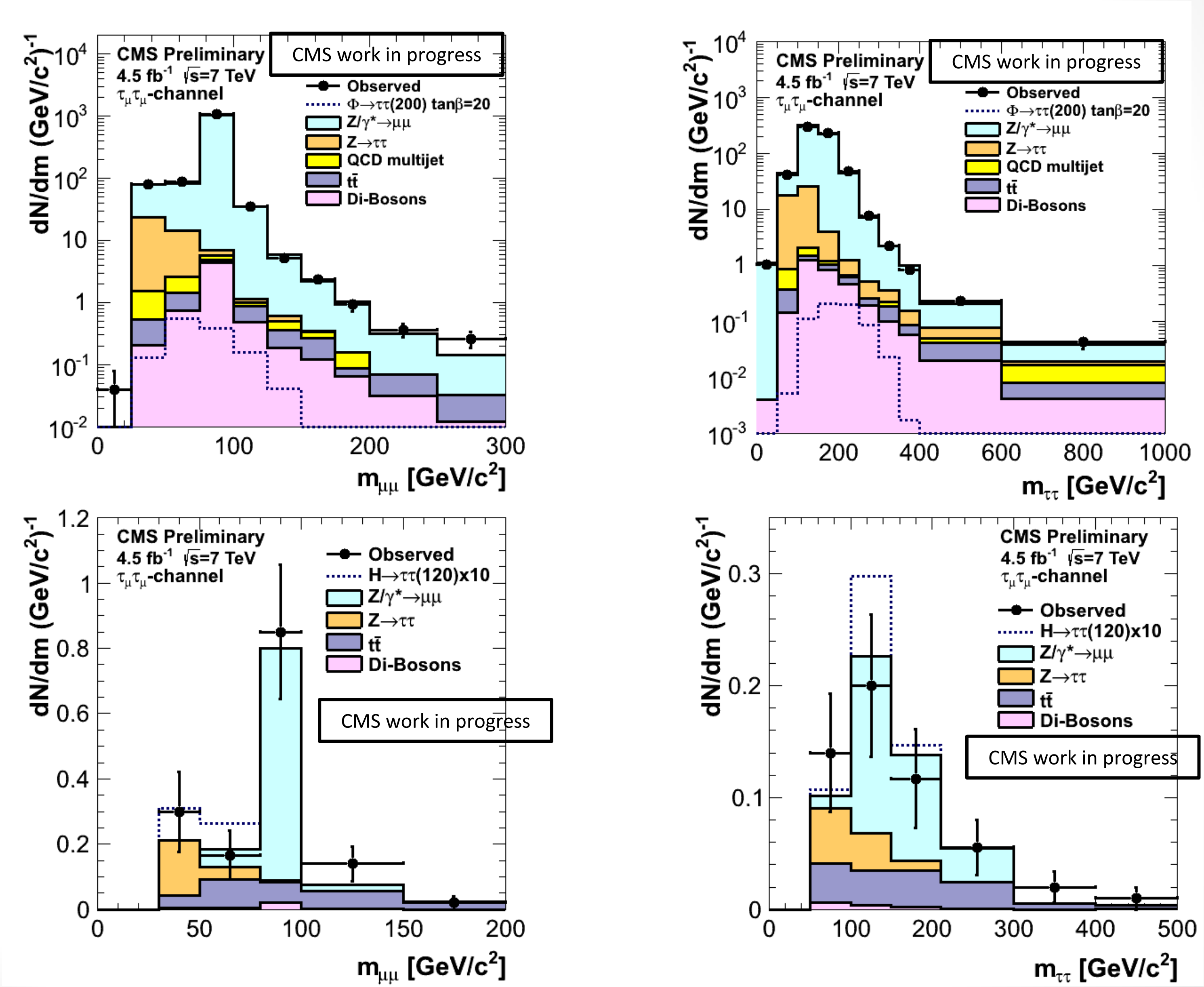


Mass distributions

Note: in the bottom two histograms the signal is on top of the other MC samples.

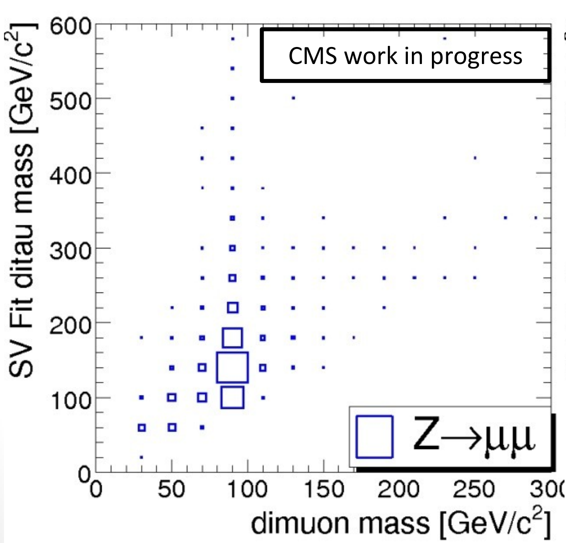
MSSM No b-tag Cat.

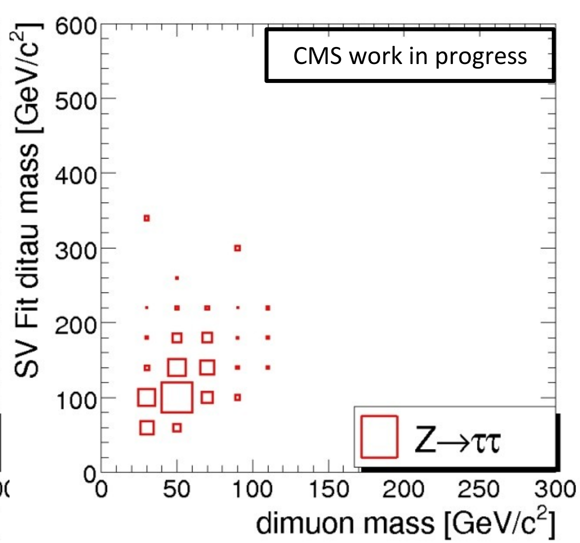
SM VBF Cat.

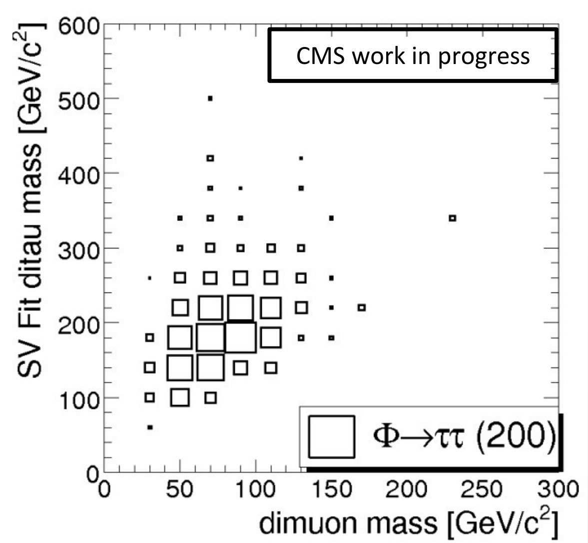


2D distributions

- Final discriminating object : 2D distributions
  - dimuon vs ditau mass OR
  - MET vs ditau mass for high Higgs mass hypotheses in the MSSM search.
- Improvement by a factor 1.5-2.5 in the limit setting, compared with the 1D approach.





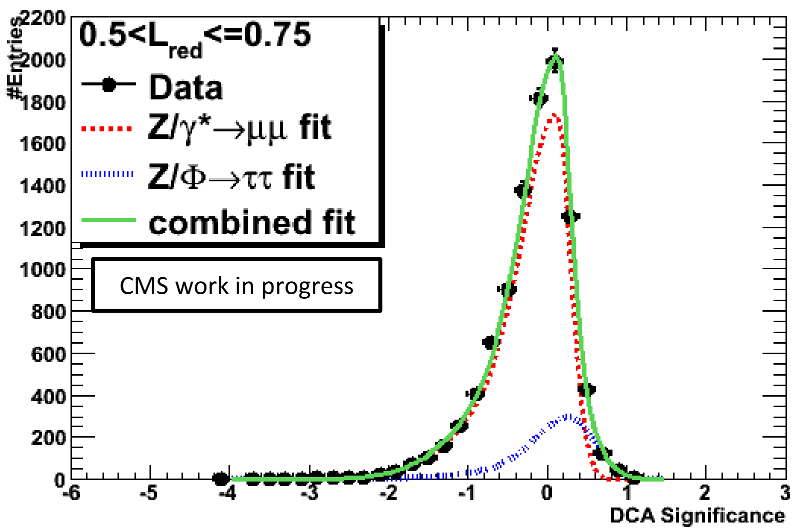


DY background evaluation

- By exploiting the difference in the shapes of the intermuon DCA significance between:
  - $Z/\gamma^* \to \mu\mu$
  - $Z \to \tau\tau$ and $\Phi \to \tau\tau \to \mu\mu$ signal
- The DY background is estimated in 5 dimuon mass regions

The method:

- A new "reduced" likelihood (L_{red}) is constructed including the same variables except the DCA significance
  - 4 Bins of L_{red} are considered, in the range (0,1)-step 0.25
- DCA significance distributions are fitted in bins of L_{red} for every dimuon mass region.
  - templates for $Z/\gamma^* \to \mu\mu$ and $Z/\Phi \to \tau\tau \to \mu\mu$
- Then the data are fitted as a superposition of the 2 templates



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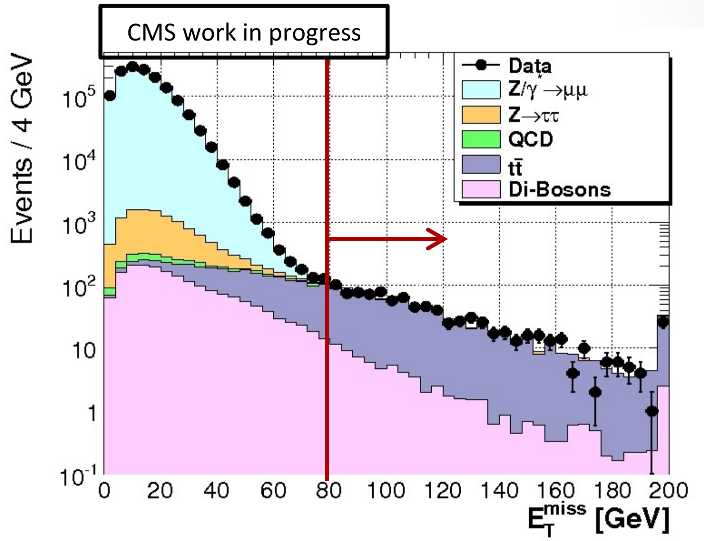
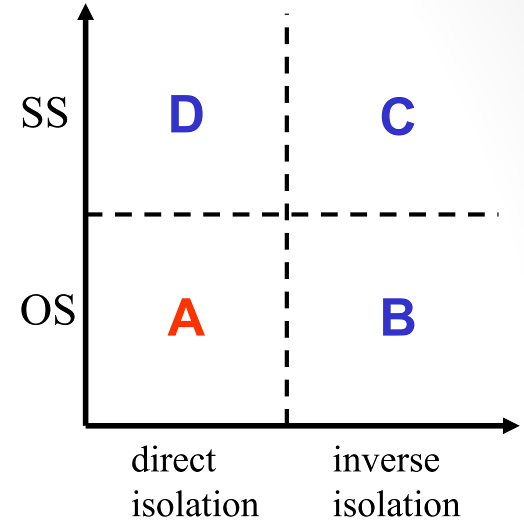
TTBar background evaluation

- TTBar is extrapolated from control region
  - MET> 80 GeV, after preselection
  - Purity > 97%
  - Fits of DCASig(2μ) for TTBar and heavy resonance decays
  - Templates derived from MC
  - Normalisation for the TTBar contribution extracted from the fit of the top contribution to the control region
  - Good agreement with MC prediction



QCD Background evaluation

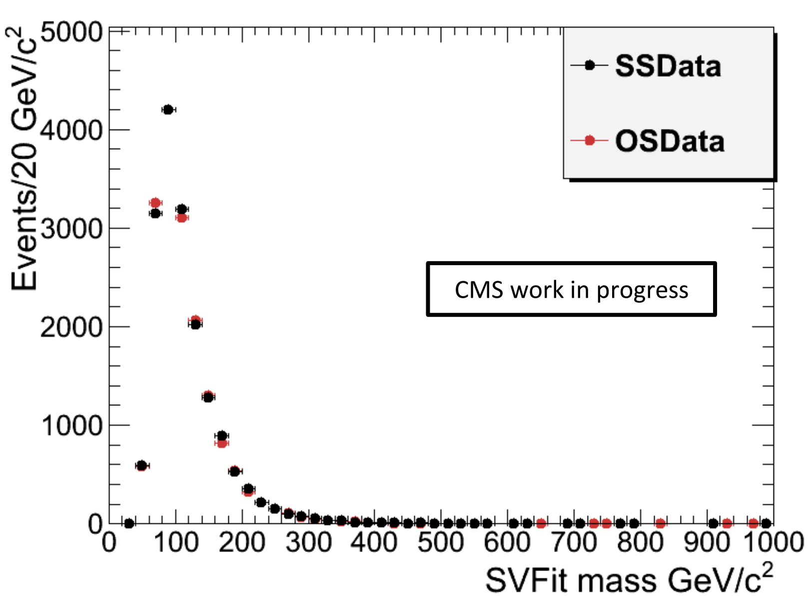
- The A,B,C,D method:
  - A: signal region
  - If after selection opposite sign and same sign have same properties: A=B·D/C
  - Direct Isolation <0.1 (0.15) for muons with p_T >(<)15GeV/c
  - Inverse Isolation > 0.5



Lhd > 0.5	OS/SS Data	OS/SS MC
InvIso	1.819 +/-0.014	1.846+/-0.035
DirIso	-	1.101+/-0.842

- For the 0/1 jet and non-b categories.
- No entries for the low statistics categories

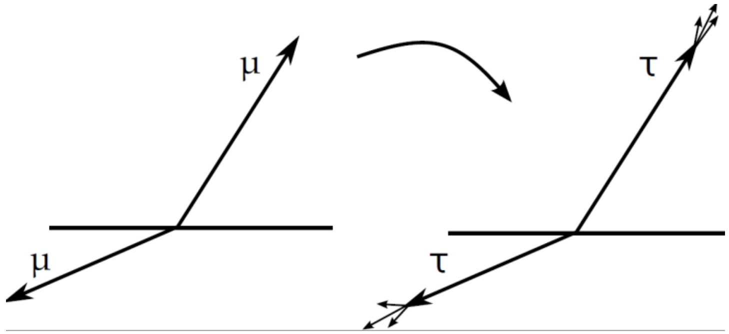
QCD events in the final sample:
120+/-16



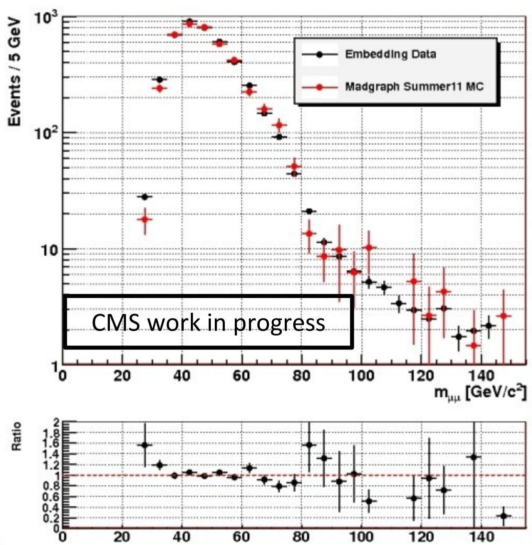
Embedding method

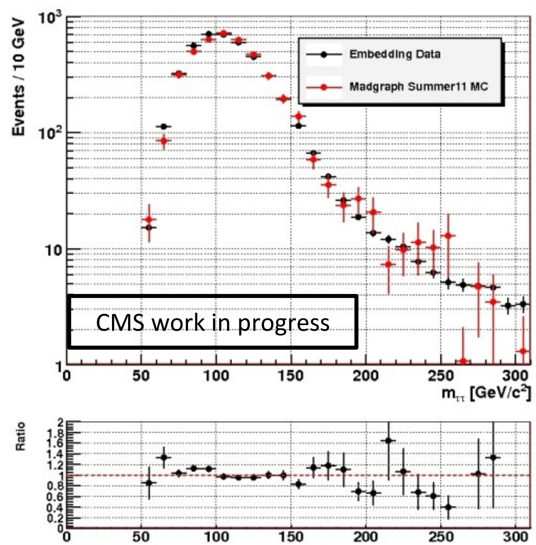
More details in the presentation by Armin Burgmeier

- In a Z→μμ data the two muons are replaced with simulated taus.



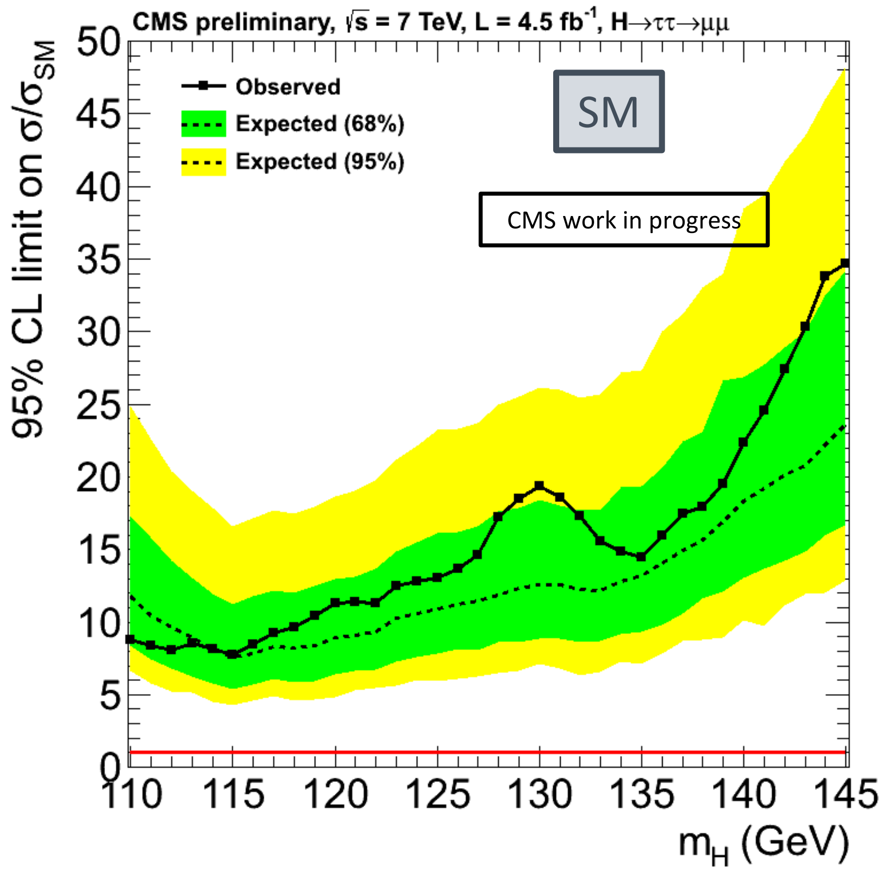
- Z→$\tau_\mu\tau_\mu$ embedded sample is used to model mass shapes
- The normalisation is taken from the regular MC sample
- Embedded data and regular MC samples consistent.

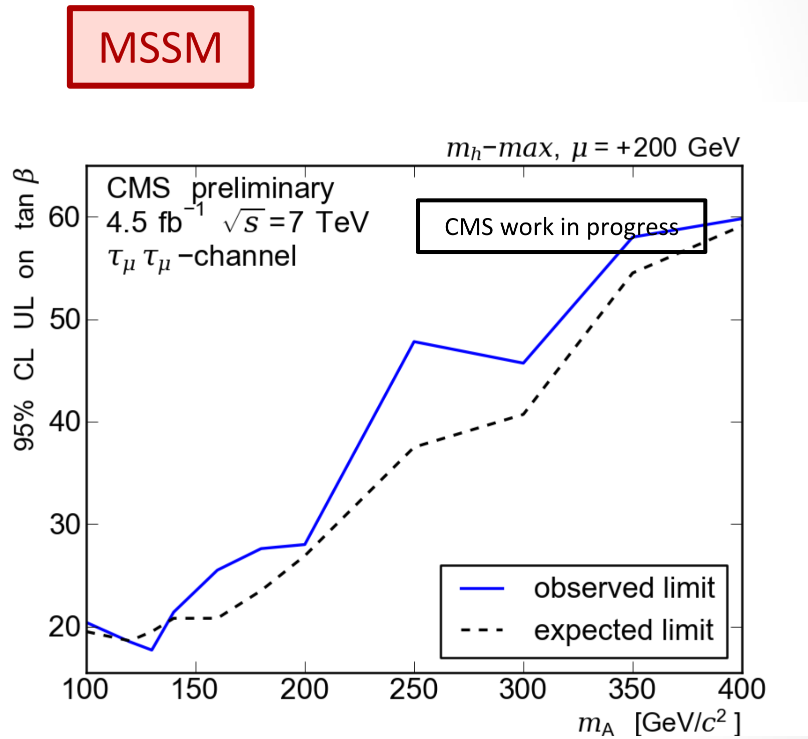




Limit setting

- All systematic uncertainties taken into account
- No evidence for signal in the mass distributions
- Statistical interpretation of the data is done by using the **CLs** limit setting technique





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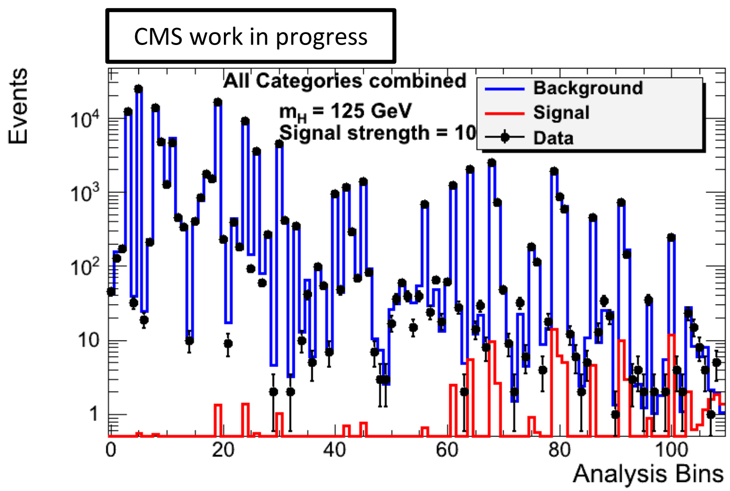
Summary

- Search for neutral Higgs bosons is performed in the $H \rightarrow \tau\tau \rightarrow \mu\mu$ channel, in the context of SM and MSSM
  - Exploiting different production mechanisms (e.g. $bb \rightarrow \Phi$ for MSSM and VFB for SM)
- Background contributions are evaluated in data driven ways
- No evidence for signal
- Exclusion limits for the Higgs boson production are set

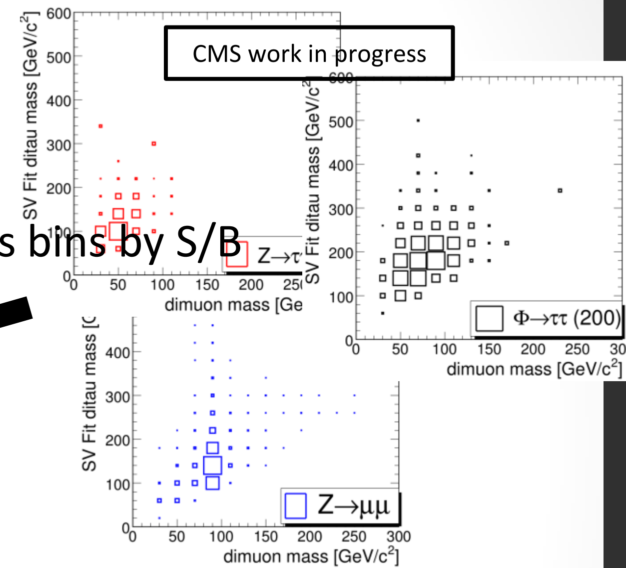
Thank you for your attention

Backup

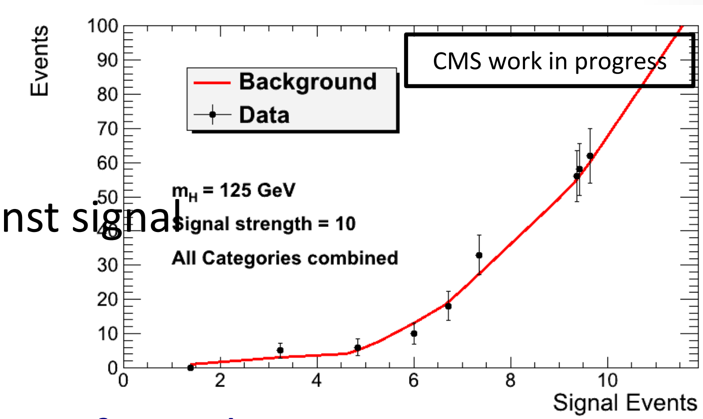
Mass Plots vs. Limits (2)



Order **all** analysis bins by S/B



Integrate from the right, plot against signal



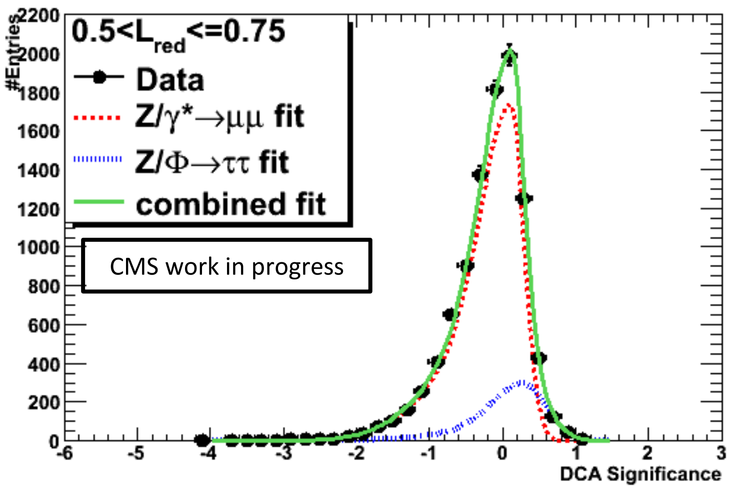
Limit is driven by the first few most significant bins

DY background evaluation

- By exploiting the difference in the shapes of the intermuon DCA significance between:
  - $Z/\gamma^* \rightarrow \mu\mu$
  - $Z \rightarrow \tau\tau$ and $\Phi \rightarrow \tau\tau \rightarrow \mu\mu$ signal
- The DY background is estimated in 4 dimuon mass regions
  - m<70GeV/c^2 ($Z \rightarrow \tau\tau$ contribution)
  - 70 GeV/c^2 < m < 91 GeV/c^2 (radiative tail of the Z peak)
  - 91 GeV/c^2 < m < 110 GeV/c^2 (falling side of theZ peak)
  - 110 GeV/c2 < m < 140 GeV/c^2 , with significant contribution from top pair events
  - and very high dimuon mass region, m > 140 GeV/c^2

A new "reduced" likelihood is constructed including the same variables except the DCA significance

- 4 Bins of L_{red} are considered
  - In the range (0,1)-step 0.25
- DCA significance distributions are fitted in bins of [L_{red} , $M_{\mu\mu}$]
  - templates for $Z/\gamma^* \rightarrow \mu\mu$ and $Z/\Phi \rightarrow \tau\tau \rightarrow \mu\mu$
- Then the data are fitted as a superposition of the 2 templates



Systematic uncertainties

Experimental Uncertainties		Propagated to Limit Calculation				
Uncertainty	Estimate	*0/1-Jet*	*Boost*	*VBF*	*Non B-Tag*	*B-Tag*
Muon ID & Trigger	±2%	±4%	±4%	±4%	±4%	±4%
JES	±2 – 5%	∓1%	±7%	±10%	∓2%	±5%
b-Tag Efficiency	±10%	–	–	–	∓1%	±5%
Mis-Tagging	±30%	–	–	–	±4%	∓1%
Norm. $Z \to \tau\tau$	±3.3%	±3.3%	±3.3%	±3.3%	±3.3%	±3.3%
Statistics of the $Z \to \tau\tau$ embedded sample		$< 1\%$	±3.5%	±8%	$< 1\%$	±2 – 3.5%
Norm. $Z \to \mu\mu$	±4 – 6%	±4 – 6%	±4 – 6%	±4 – 6%	±4 – 6%	±4 – 6%
SF for event categories (Rel. stat. uncert.) $Z \to \mu\mu$		–	±3%	±5%	–	±3%
Norm. $t\bar{t}$	±8%	±8%	±8%	±8%	±8%	±8%
Norm. (di-bosons)	±30%	±30%	±30%	±30%	±30%	±30%
Lumi (Di-bosons, W + *Jets*, Signal)	±4.5%	±4.5%	±4.5%	±4.5%	±4.5%	±4.5%
MC statistics						
VBF signal		±8 – 10%	±20 – 23%	±8 – 10%	–	–
$gg \to H$ signal		±6 – 8%	±20 – 30%	±50 – 100%	–	–
$b\bar{b}\Phi$ signal		–	–	–	±3 – 7%	±7 – 18%
$gg \to \Phi$ signal		–	–	–	±3 – 7%	±22 – 100%
$Z \to \mu\mu$		$< 1\%$	±20%	±22%	$< 1\%$	±1 – 2.5%
$t\bar{t}$		±4%	±17%	±19%	±5 – 9%	±4 – 7%
MET scale	±1 – 5%	shape altering uncertainty				

Theory Uncertainties (SM)		Propagated to Limit Calculation				
Uncertainty	Estimate	*0/1-Jet*	*Boost*	*VBF*	*Non B-Tag*	*B-Tag*
PDF	-	±8%	±8%	±8%	-	-
$\mu_r/\mu_f(gg \to H)$	-	±12%	±25%	±12%	-	-
$\mu_r/\mu_f(qq \to H)$	-	±3.5%	±4%	±4%	-	-
Underlying event & PS	-	∓4%	±4%	±4%	-	-

Embedding method