Search for the Standard Model Higgs Boson in the two photon decay mode

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QM IOP - April 4, 2012

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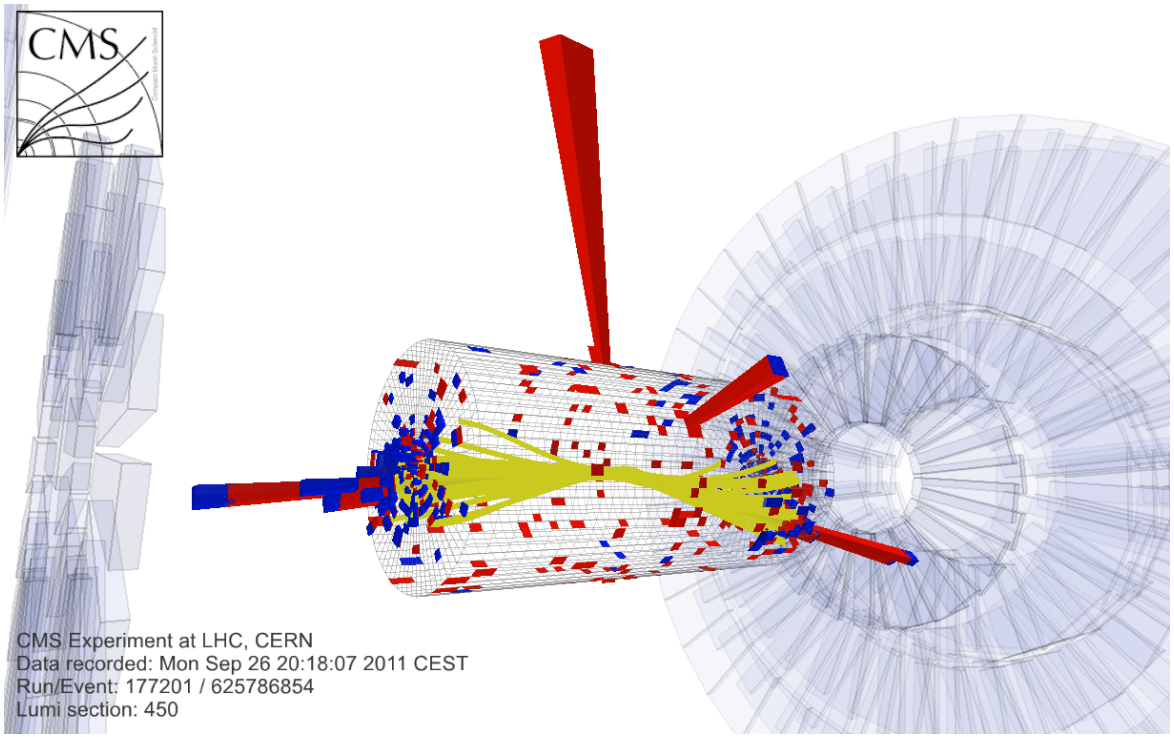
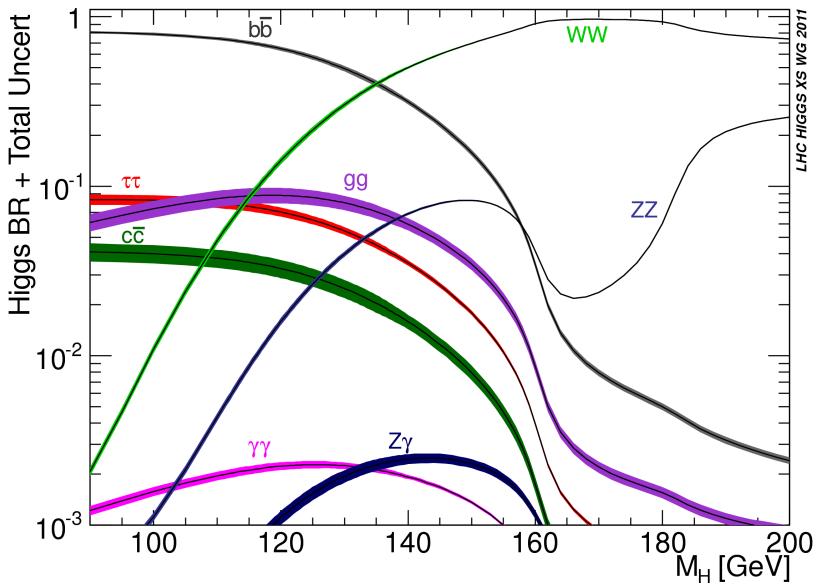
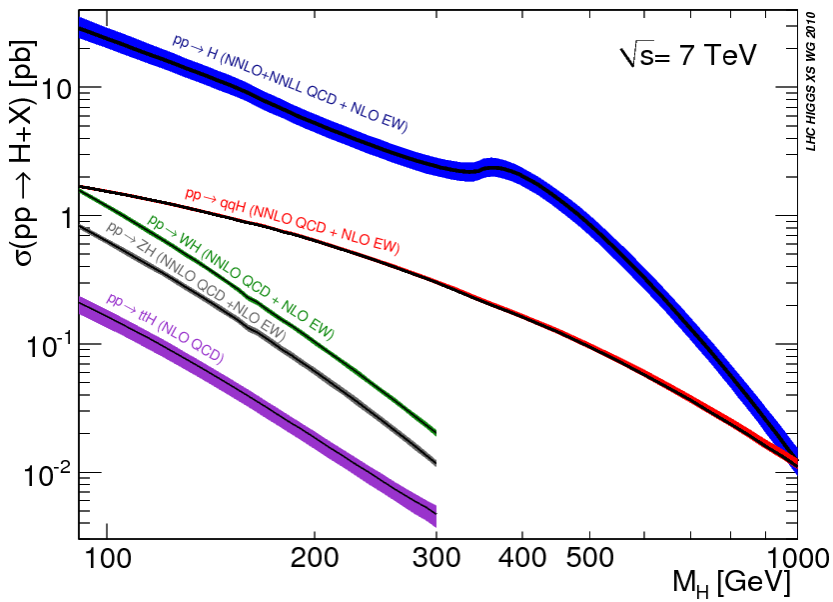


Introduction

Search performed at CMS on $4.8 fb^{-1}$ pp dataset at $\sqrt{s} = 7 TeV$

Update from recent paper.

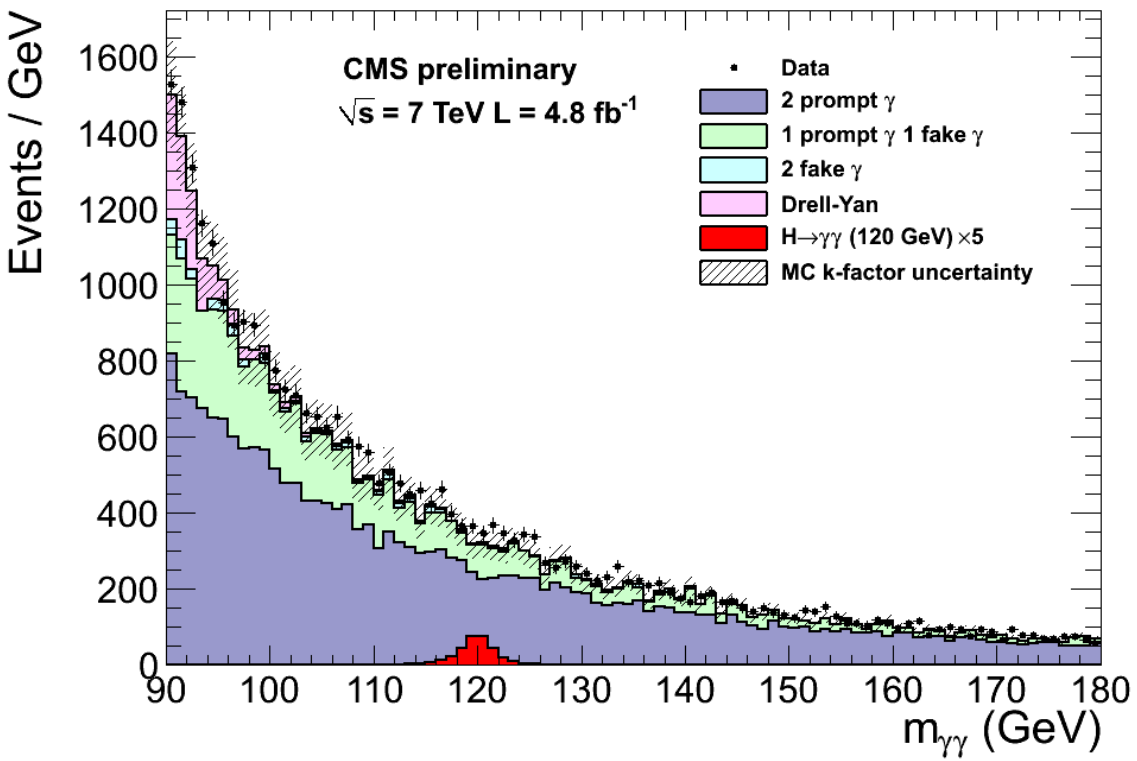




Event Selection

- Two high p_T photons
- MVA ID quality cut to reject fakes.
  - isolation variables to reject jets
  - shower shape variables for π^0
- Vertex from track information.
  - Correct vertex found 85% of the time.

$$\frac{p_T}{m_{\gamma\gamma}} > \frac{1}{3}, \frac{1}{4}$$

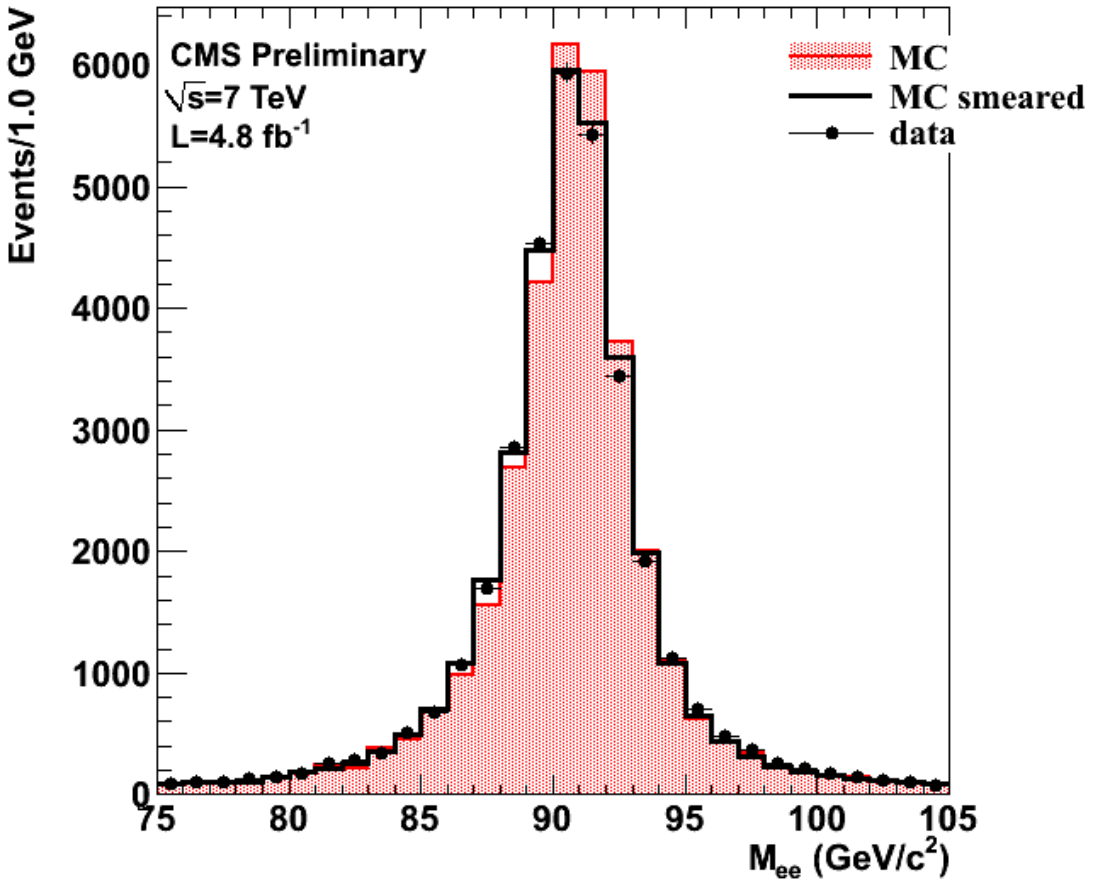


Search Strategy

Sensitivity dominated by $H \to \gamma\gamma$ peak

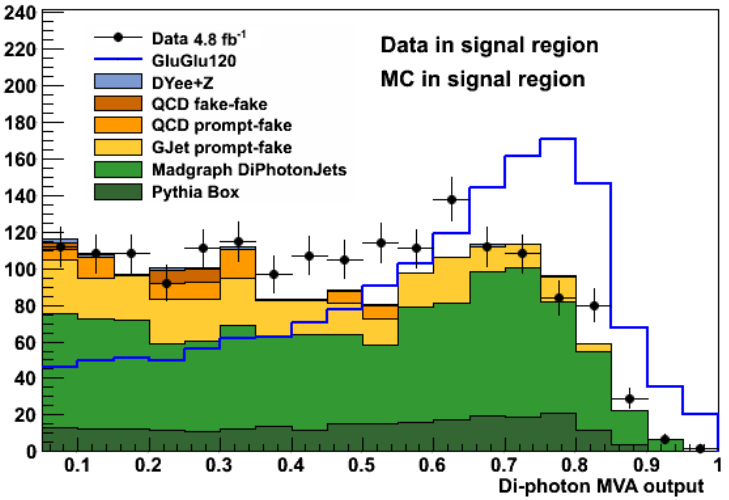
Width of the peak is driven by the experimental resolution

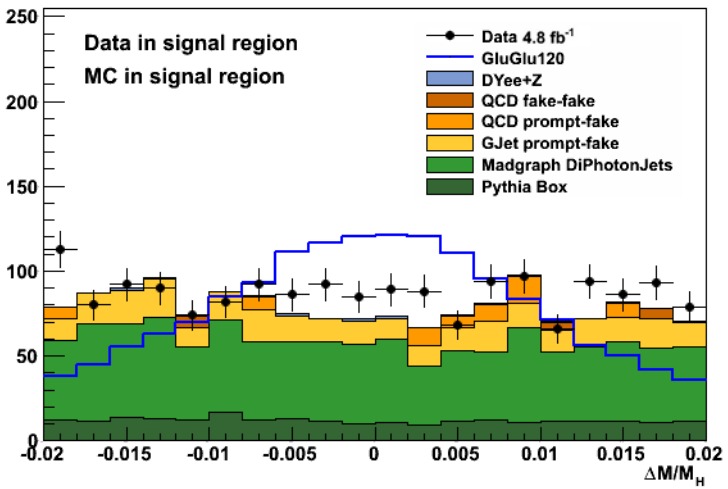
Search is performed in a $\pm 2\%$ window around the peak



Event Classification

- **Photon Kinematics**
  - $p_T^{\gamma 1}/m_{\gamma\gamma}$, $p_T^{\gamma 2}/m_{\gamma\gamma}$
  - $\eta^{\gamma 1}$, $\eta^{\gamma 2}$, $\cos(\Delta\phi)$
- **Photon Discriminator**
  - $IDMVA^{\gamma 1}$, $IDMVA^{\gamma 2}$
- **Event Resolution**
  - $\sigma(correct)/m_{\gamma\gamma}$, $\sigma(wrong)/m_{\gamma\gamma}$
  - $vtxprob$

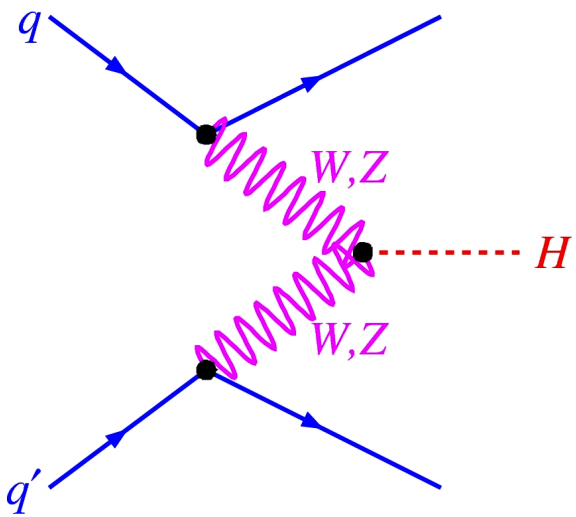




Combine with (Δ_M/M_H) using a second BDT

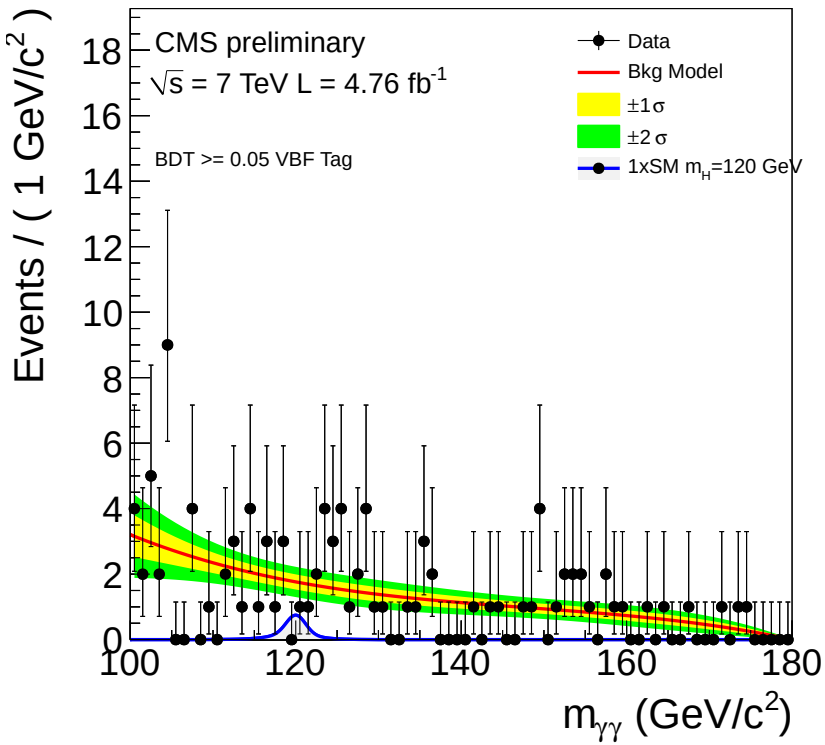
Inputs invariant with m_H

Di-jet Category



Look for two high E_T forward Jets.

Jets back to back with di-photon system.

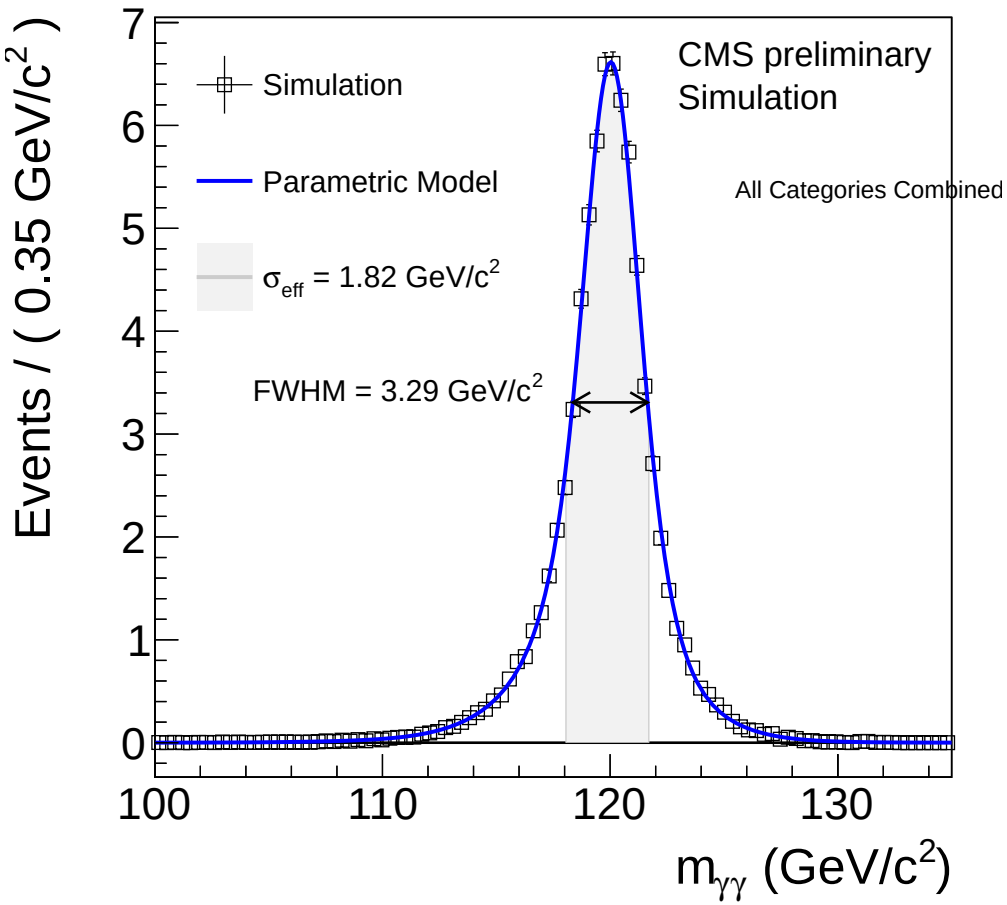


Signal Model

Signal model derived from MC simulation.

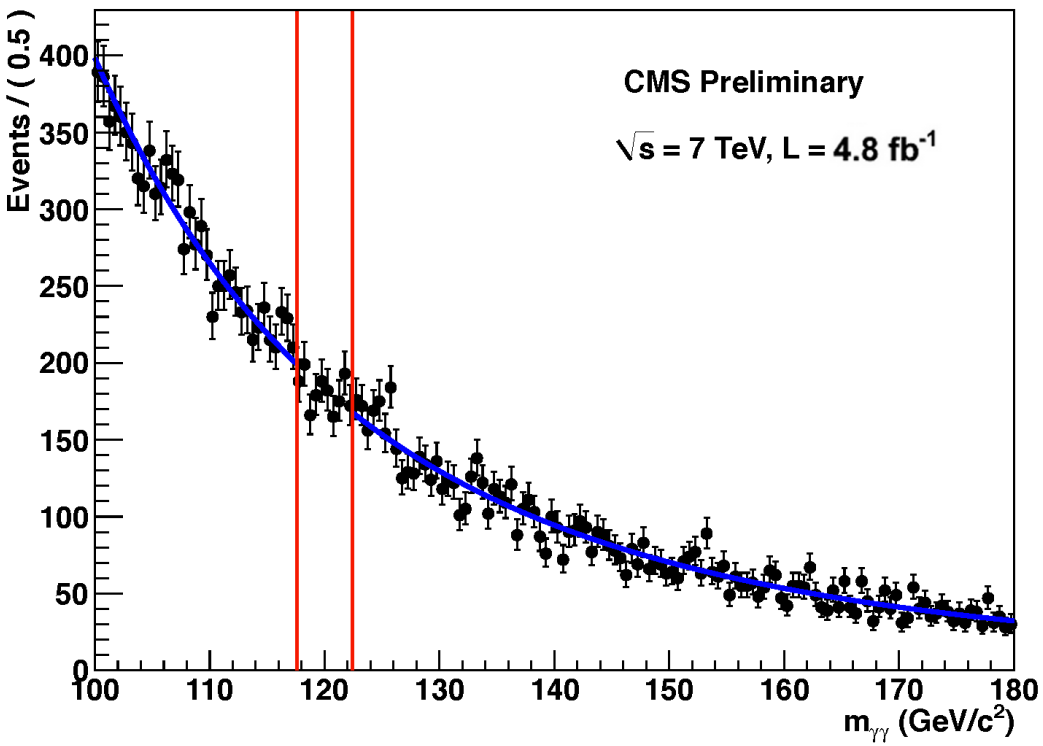
MC corrected for detector effects (data-driven measurements in $Z \to ee$ and $Z \to \mu\mu\gamma$)

Dominant systematics are energy scale and resolution



Background Model - Normalization

$$f_{bkg}(m_{\gamma\gamma}) = N(m_{\gamma\gamma}^{-a} + bm_{\gamma\gamma}^{-c})$$



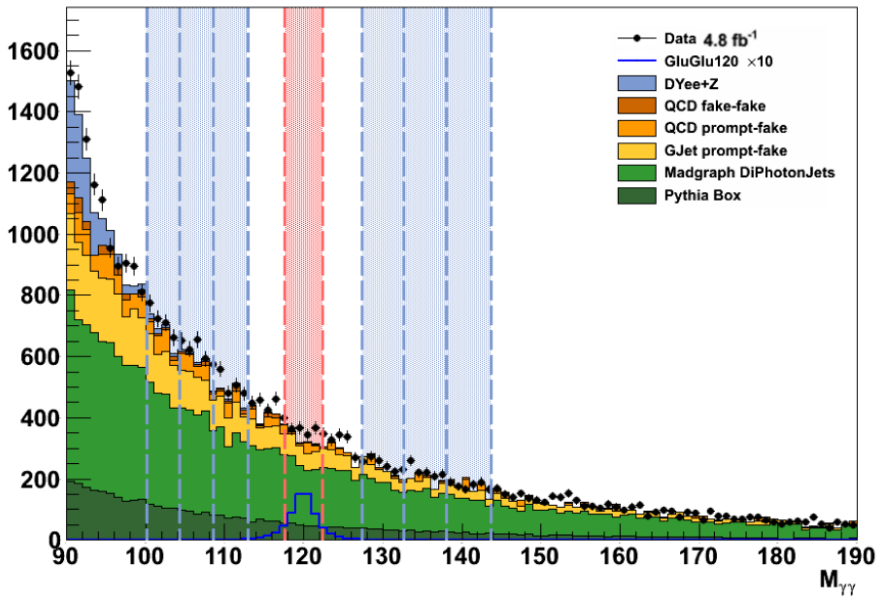
Total background normalization taken from fit to sidebands.

Systematic included for remaining potential bias from wrong function choice.

Single parameter in the Likelihood

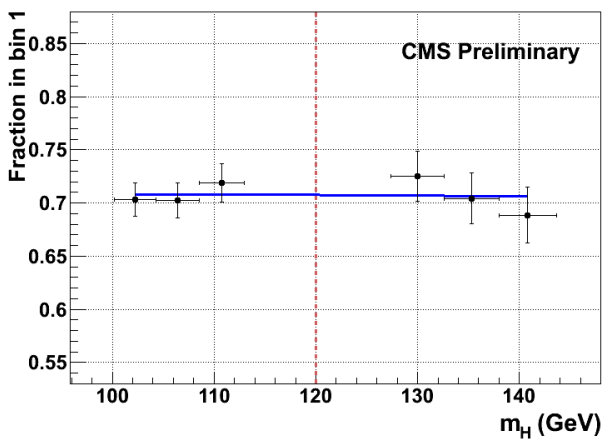
Background Model - Shape

Define sidebands outside the signal region

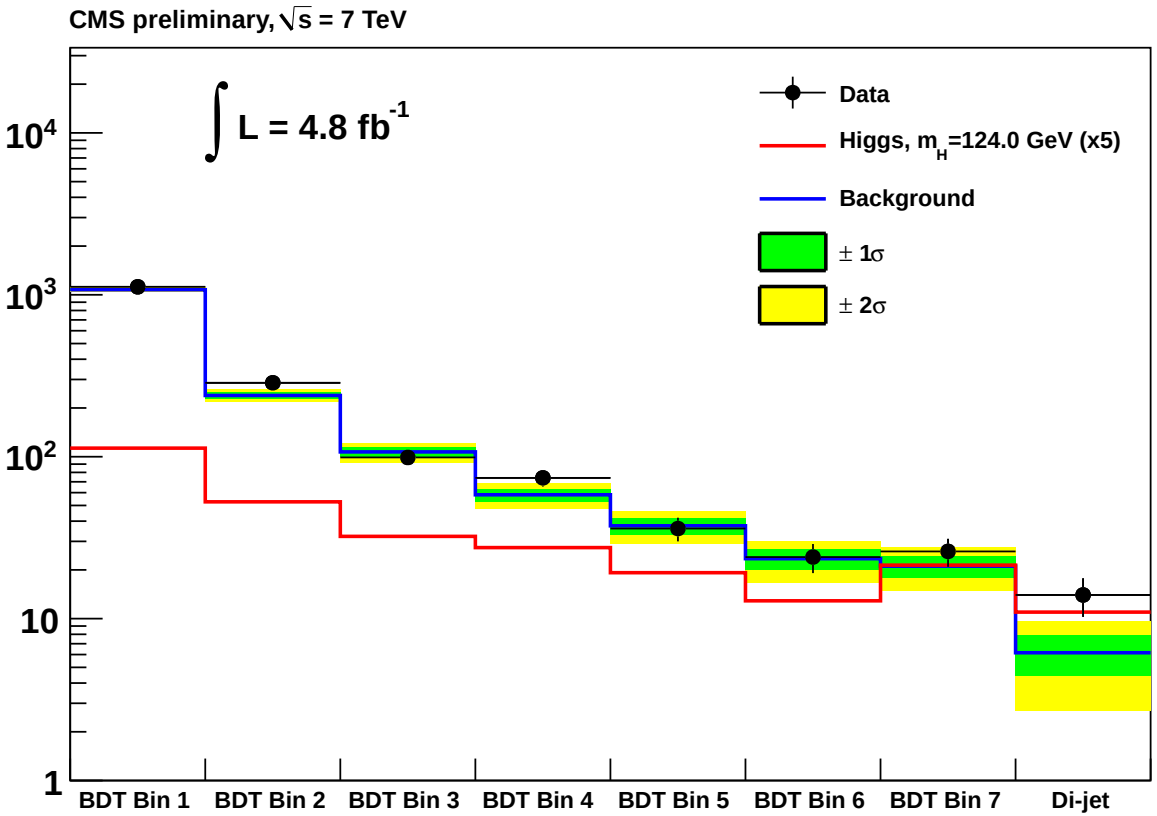


Shape in BDT extracted from linear fits in m_H

- Only assumption is variation as a function of mass is linear
- Systematic included to account for potential higher order terms



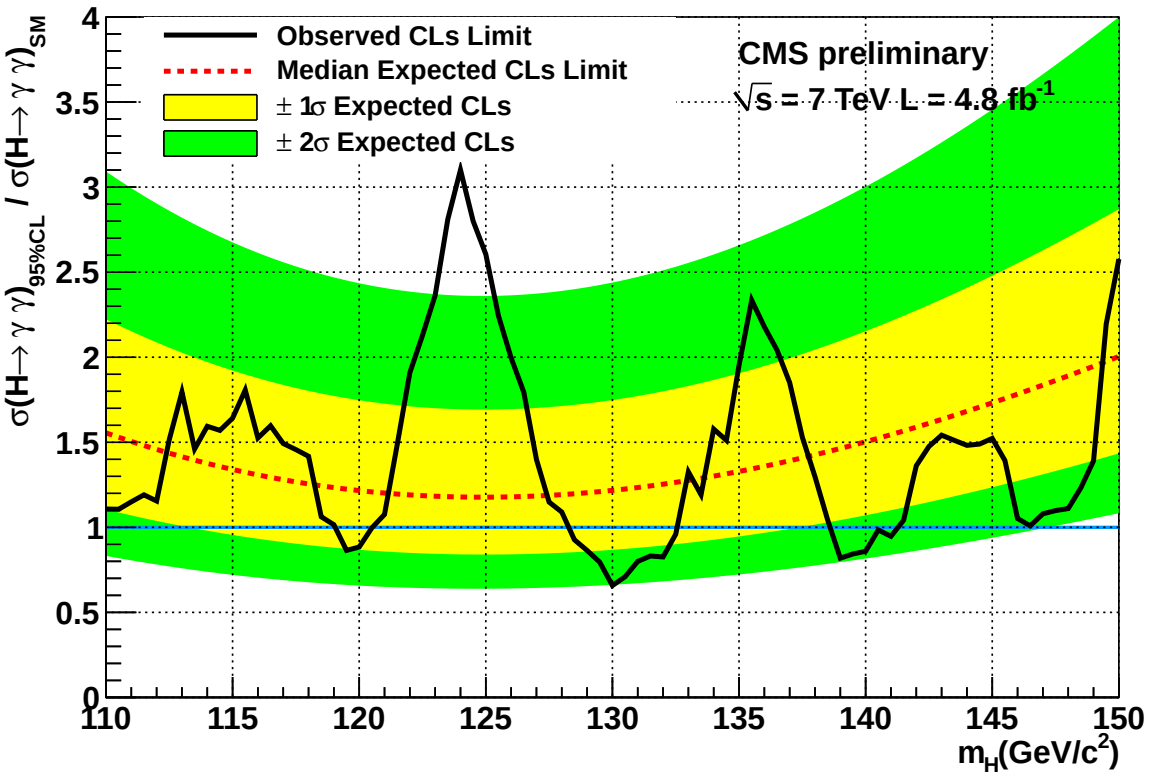
Results



Categories optimized so as to achieve the best sensitivity to signal.

Likelihood constructed as a combination of counting experiments.

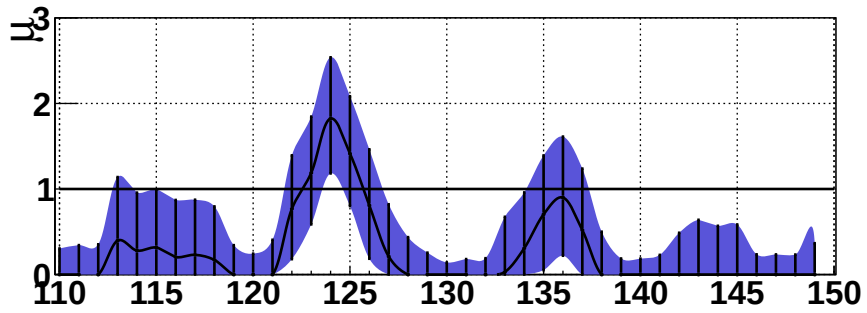
Exclusion Limits

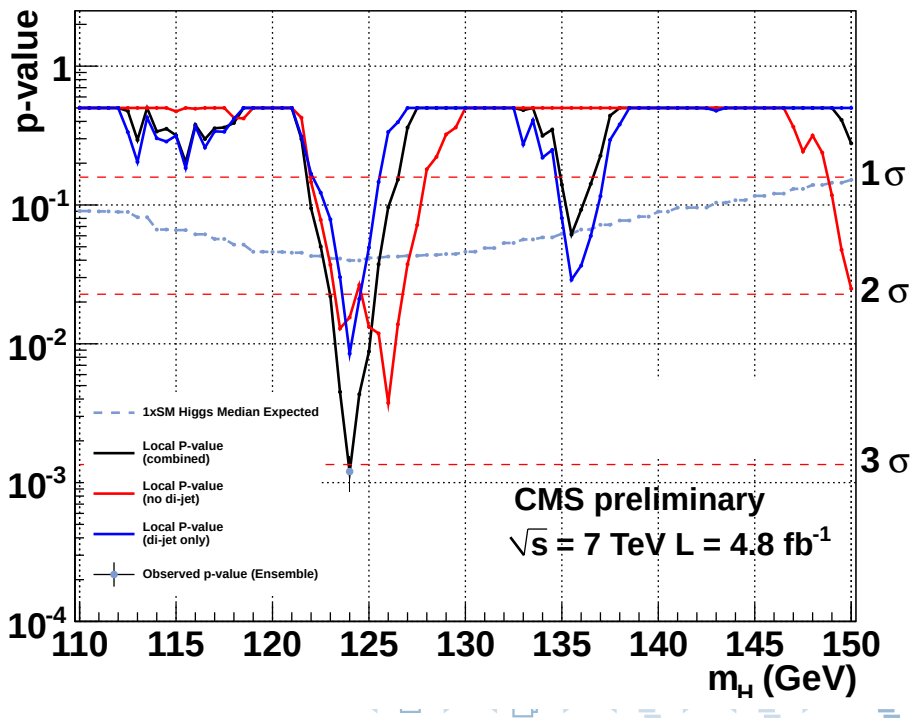


- Exclusion limits extracted in the range $110 < m_H < 150$
- Expected exclusion limit less than 1.5xSM in $110 < m_H < 140$
- Several ranges excluded at 95% confidence level (CL).

Significance Scan

- Significance and best-fit signal strength are extracted in the range $110 < m_H < 150$
- Largest local significance around 3σ
- Look elsewhere effect reduces this to 1.9σ



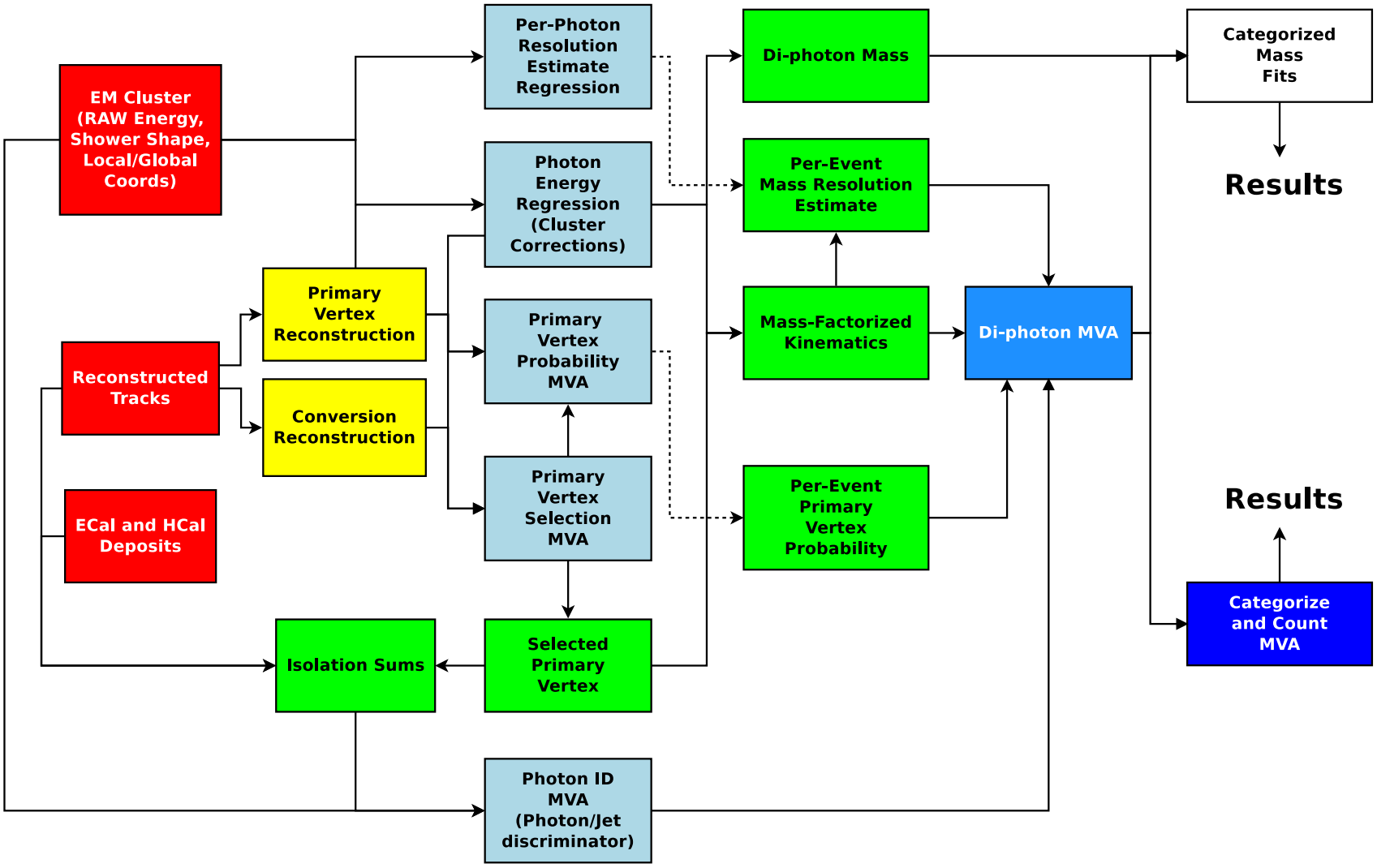


Conclusions

- A search for the SM Higgs has been performed on $4.8 fb^{-1}$ of pp collisions at CMS
- Exclusions placed on the SM Higgs at several ranges of mass hypotheses.
- No significant excess is observed in the search range.
- Can expect to become sensitive to SM Higgs by summer with twice the current dataset.
- The analysis is described in CMS public document HIG-12-001.

Backup

Analysis Workflow

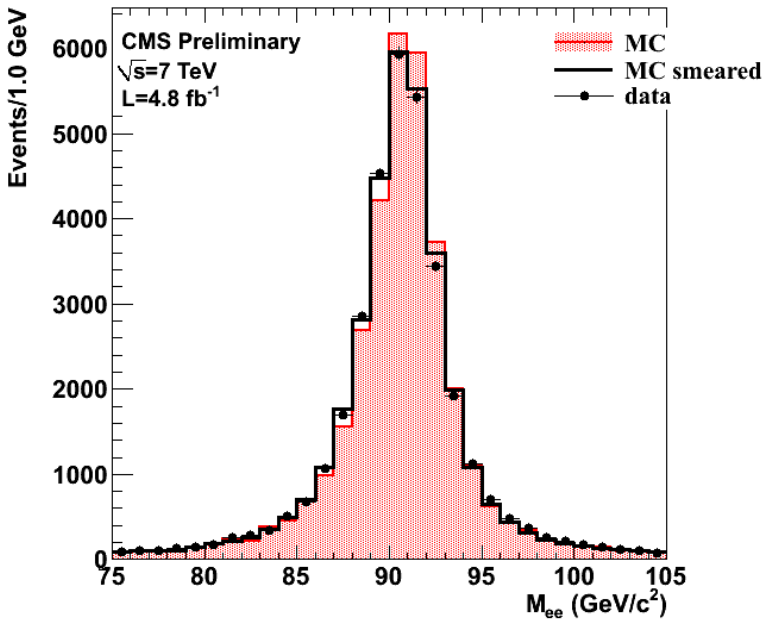


VBF Selection

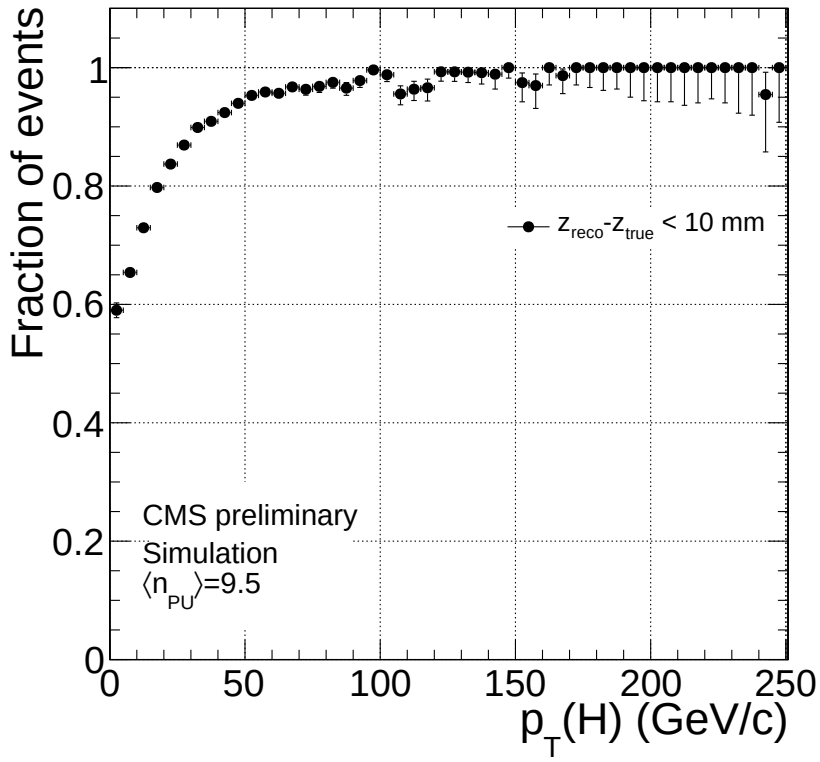
Jet Tag

$$E_T > 30/20 GeV$$
$$m_{jj} > 350 GeV$$
$$|\eta_1^j - \eta_2^j > 3.5|$$
$$|\phi_{jj} - \phi_{\gamma\gamma} > 2.6|$$
$$|0.5(\eta_1^j - \eta_2^j) - \eta_{\gamma\gamma}| < 2.5$$

Signal MC Corrections



MC additional smearing measured using $Z \rightarrow ee$ MC-data likelihood fit in categories.



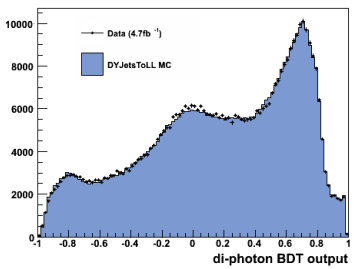
Vtx Probabilities measured in $Z \rightarrow \mu\mu\gamma$ as a function of boson p_T, MC reweighted.

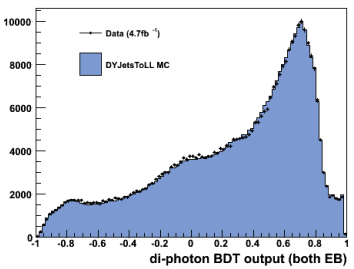
Signal Systematics

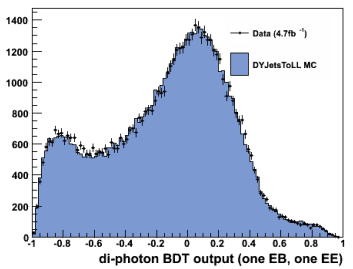
Sources of systematic uncertainty		Uncertainty	
Per photon		Barrel	Endcap
Photon identification efficiency		1.0%	2.6%
Energy resolution ($\Delta\sigma/E_{MC}$)	$R_9 > 0.94$ (low η, high η)	0.22%, 0.61%	0.91%, 0.34%
	$R_9 < 0.94$ (low η, high η)	0.24%, 0.59%	0.30%, 0.53%
Energy scale ($(E_{data} - E_{MC})/E_{MC}$)	$R_9 > 0.94$ (low η, high η)	0.19%, 0.71%	0.88%, 0.19%
	$R_9 < 0.94$ (low η, high η)	0.13%, 0.51%	0.18%, 0.28%
Photon identification MVA (Effect of up to 11% event class migration.)		$\pm$0.025 (shape shift)	
Photon energy resolution MVA (Effect of up to 8% event class migration.)		$\pm$10% (shape scaling)	
Per event			
Integrated luminosity		4.5%	
Vertex finding efficiency		0.4%	
Trigger efficiency	One or both photons $R_9 < 0.94$ in endcap	0.4%	
	Other events	0.1%	
Dijet selection			
Dijet-tagging efficiency	VBF process	10%	
	Gluon-gluon fusion process	70%	
Production cross sections		Scale	PDF
Gluon-gluon fusion		+12.5% -8.2%	+7.9% -7.7%
Vector boson fusion		+0.5% -0.3%	+2.7% -2.1%
Associated production with W/Z		1.8%	4.2%
Associated production with $t\bar{t}$		+3.6% -9.5%	8.5%
Scale and PDF uncertainties (Effect of up to 16% event class migration.)		(y, p_T)-differential	

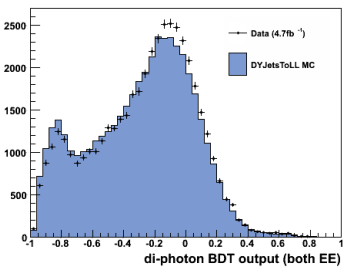
MVA Validation using $Z \rightarrow ee$

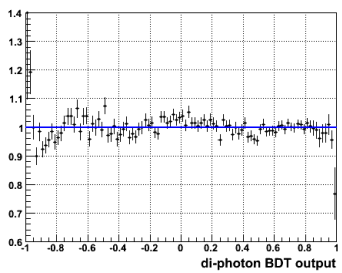
MC simulation is validated using $Z \rightarrow ee$ MC-data comparisons.

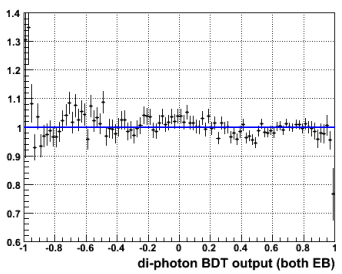


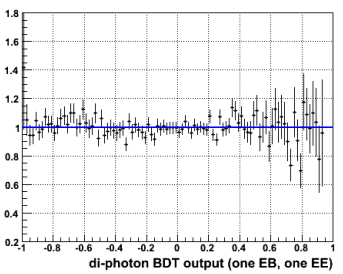


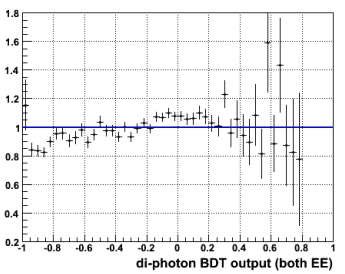












CLs

Limit setting with the CLs procedure:

- Fit toy data, once conditionally with a fixed μ and once with μ floating.
- Systematics are incorporated into Likelihood, constraints randomized in the fits (nuisance parameters).
- Ratio of Likelihoods is the Profile Likelihood, we use the test statistic - $$q_\mu = -2 \ln \frac{L(\mu, \hat{\theta})}{L(\hat{\mu}, \hat{\hat{\theta}})}$$
- Throw toys from model fit to data to generate the distribution of under signal+background and background only hypotheses
- Exclude at 95% confidence when ratio of p-values $CL_s = CL_{s+b}/CL_b$ is 0.05.