H → γγ generator level studies for detector upgrade during Phase II

Adolf Bornheim[1], Swagata Mukherjee[2]

(On behalf of Hγγ group)

Future Analyses meeting

May 23, 2013

[1] California Institute of Technology, US
[2] Saha Institute of Nuclear Physics, India

Motivation for this study

CMS detector will go through some upgrade to cope up with high luminosity and high energy of LHC during phase II

Upgrade plans are yet to be finalized

Impact of various Phase II upgrade options on $H \rightarrow \gamma\gamma$ signature for $M_H \sim 125$ GeV is being studied

$H \rightarrow \gamma\gamma$ signature : Narrow peak over a large but smooth background

Need to consider acceptance and efficiency for background and signal as well as resolution for signal.

Datasets Used

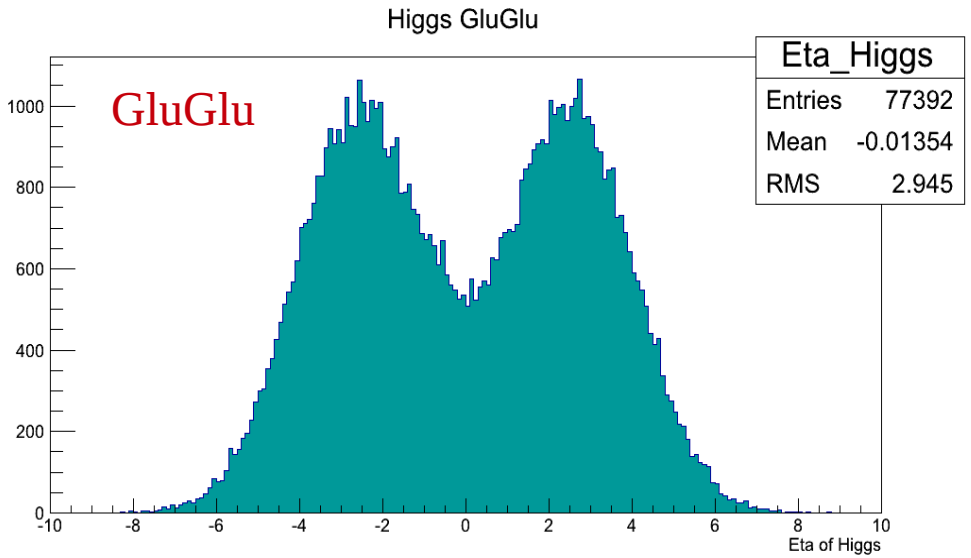
/GluGluToHToGG_M-125_14TeV-powheg-pythia6/Summer12-PU50_POSTLS161_V12-v1/AODSIM
(Number of events: 99990)

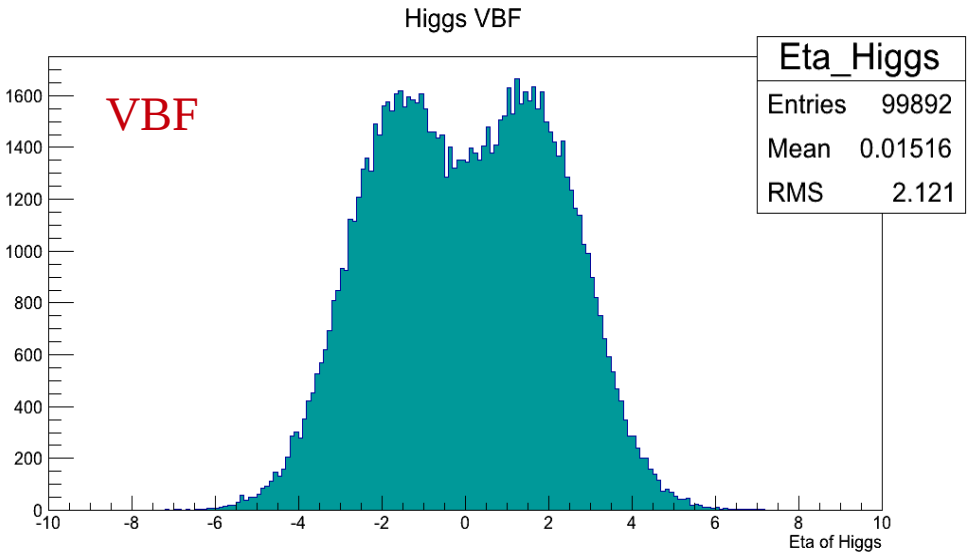
/VBF_HToGG_M-125_14TeV-powheg-pythia6/Summer12-PU50_POSTLS161_V12-v1/AODSIM
(Number of events: 99892)

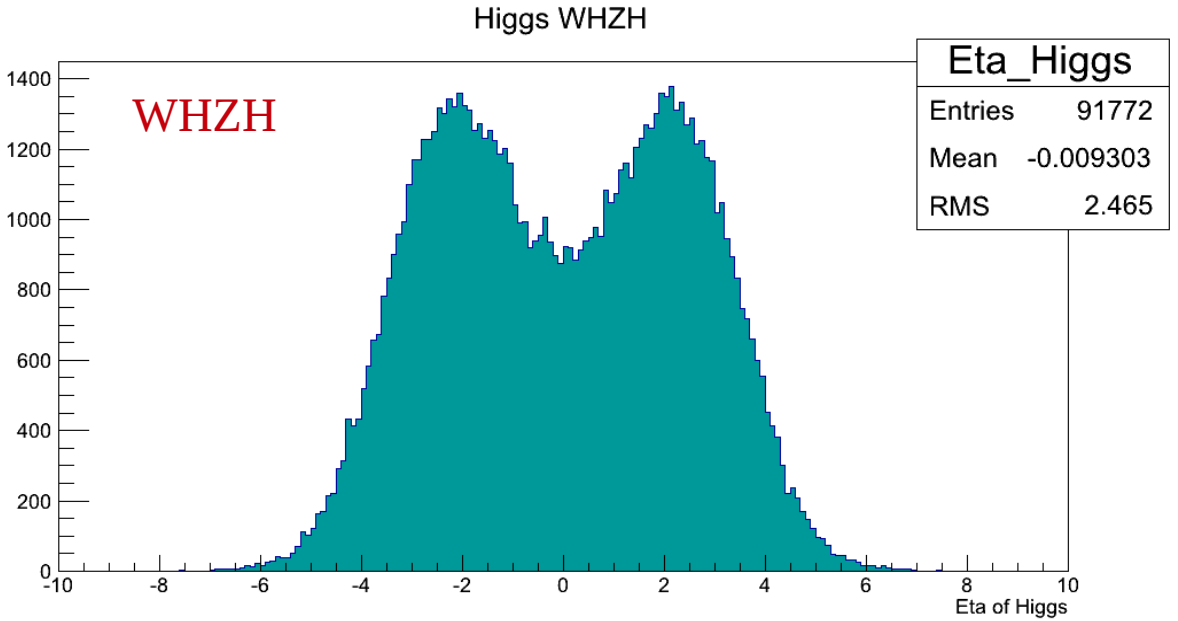
/WH_ZH_HToGG_M-125_14TeV-pythia6/Summer12-PU50_POSTLS161_V12-v1/AODSIM
(Number of events: 100000)

These signal MC samples are produced with CMSSW release 6_0_1_PostLS1v2_patch3

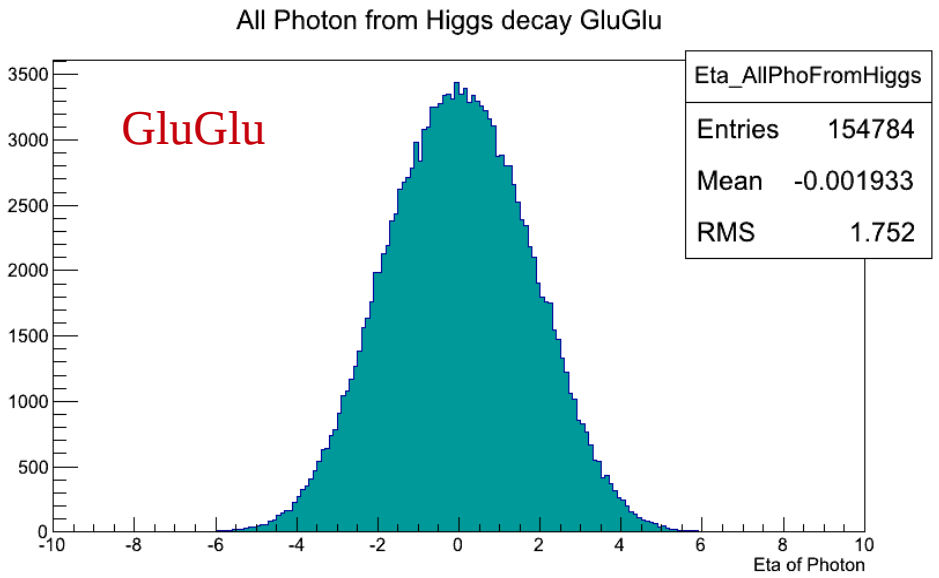
Eta distribution of Higgs

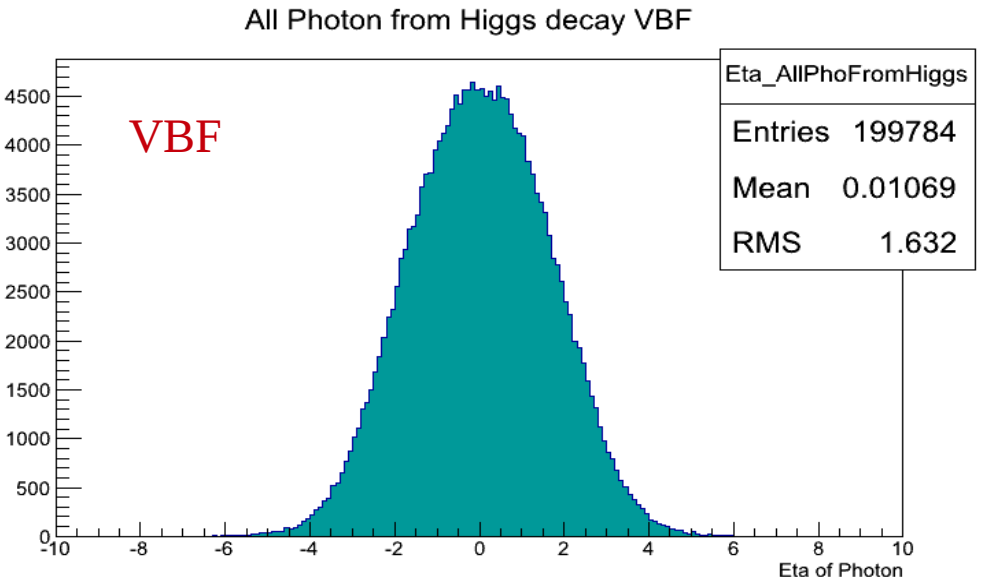


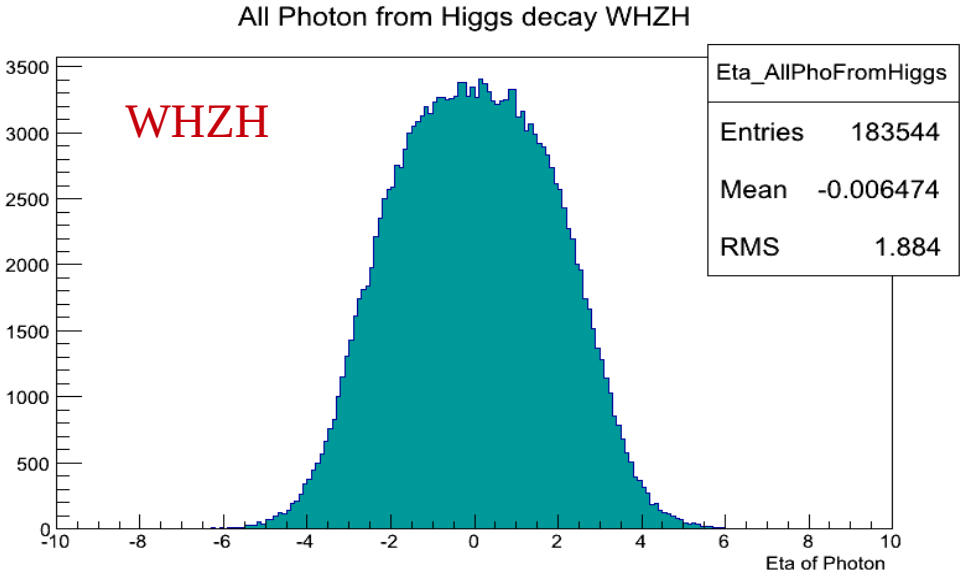




Eta distribution of “all” photons coming from Higgs decay







Current Scenario

Standard p_T Cut + Standard Eta Cut on photons

Standard p_T cut

$\gamma_1 > 41.6$ GeV, $\gamma_2 > 31.3$ GeV

Standard Eta cut

Eta <= 1.4442 or
1.566 <= Eta <= 2.5

Exploring different upgrade scenarios :

Proposed Eta cut

Proposal 1 : Reduction of the EB/EE crack from (1.4442 – 1.566) to (1.4442 – 1.5)
Proposal 2 : Extending the eta coverage upto 3 (Current ECAL, Extended Tracker)
Proposal 3 : Extending the eta coverage upto 4 (Extended ECAL and Tracker)

Proposed p_T cut

Proposal 1 : Loose p_T cut ($\gamma_1 > 35$ GeV, $\gamma_2 > 25$ GeV)
Proposal 2 : Very Loose p_T cut ($\gamma_1 > 30$ GeV, $\gamma_2 > 20$ GeV)
Proposal 3 : Hard p_T cut ($\gamma_1 > 45$ GeV, $\gamma_2 > 35$ GeV)

Current photon p_T cuts are driven by trigger thresholds, not by photon reconstruction. Study impact of p_T cuts to judge possible changes or opportunities of upgraded trigger

Smearing of photon p_T

- To get a feeling of the effect of the detector resolution, p_T of the photons have been smeared and the p_T cut is applied on the smeared p_T
- Gaussian smearing
- "Real" p_T of gen-photon is smeared by p_T resolution. In barrel, p_T resolution is taken as 2.4% and in endcap, it is taken as 3.9%
- These numbers are obtained from a presentation by Francesca Cavallo. She showed that the p_T resolution for electrons (after some corrections) is 2.4% (in barrel) and 3.9% (in endcap)

Detector acceptance in different upgrade scenarios for Gluon Fusion (VBF) [WHZH]

Acceptance cut : |η| <= 1.4442 and 1.566 <= |η| <= 2.5 (Standard Eta Cut)
p_T cut : γ1 > 41.6 GeV, γ2 > 31.3 GeV (Standard p_T Cut)

Fraction of Higgs with both photons in barrel	**0.34**	(0.34)	**[0.27]**
Fraction of Higgs with one photon in barrel and one in endcap	**0.15**	(0.15)	**[0.14]**
Fraction of Higgs with both photons in endcap	**0.05**	(0.05)	**[0.06]**
Fraction of Higgs with at least one photon escaping the ECAL	**0.44**	(0.45)	**[0.52]**

Acceptance cut : |η| <= 1.4442 and 1.50 <= |η| <= 2.5 (EB/EE crack reduced)
p_T cut : γ1 > 41.6 GeV, γ2 > 31.3 GeV (Standard p_T Cut)

Fraction of Higgs with both photons in barrel	**0.34**	(0.34)	**[0.27]**
Fraction of Higgs with one photon in barrel and one in endcap	**0.17**	(0.17)	**[0.15]**
Fraction of Higgs with both photons in endcap	**0.06**	(0.05)	**[0.07]**
Fraction of Higgs with at least one photon escaping the ECAL	**0.41**	(0.42)	**[0.49]**

Acceptance cut : |η| <= 1.4442 and 1.566 <= |η| <= 3.0 (Eta coverage increased upto 3)
p_T cut : γ1 > 41.6 GeV, γ2 > 31.3 GeV (Standard p_T Cut)

Fraction of Higgs with both photons in barrel	**0.34**	(0.34)	**[0.27]**
Fraction of Higgs with one photon in barrel and one in endcap	**0.18**	(0.17)	**[0.16]**
Fraction of Higgs with both photons in endcap	**0.09**	(0.09)	**[0.12]**
Fraction of Higgs with at least one photon escaping the ECAL	**0.37**	(0.39)	**[0.43]**

Detector acceptance in different upgrade scenarios for Gluon Fusion (VBF) [WHZH]

Acceptance cut : |η| <= 1.4442 and 1.566 <= |η| <= 4.0 (Eta coverage increased upto 4)
p_T cut : γ1 > 41.6 GeV, γ2 > 31.3 GeV (Standard p_T Cut)

Fraction of Higgs with both photons in barrel	**0.34**	(0.34)	**[0.27]**
Fraction of Higgs with one photon in barrel and one in endcap	**0.19**	(0.17)	**[0.17]**
Fraction of Higgs with both photons in endcap	**0.15**	(0.12)	**[0.20]**
Fraction of Higgs with at least one photon escaping the ECAL	**0.31**	(0.34)	**[0.34]**

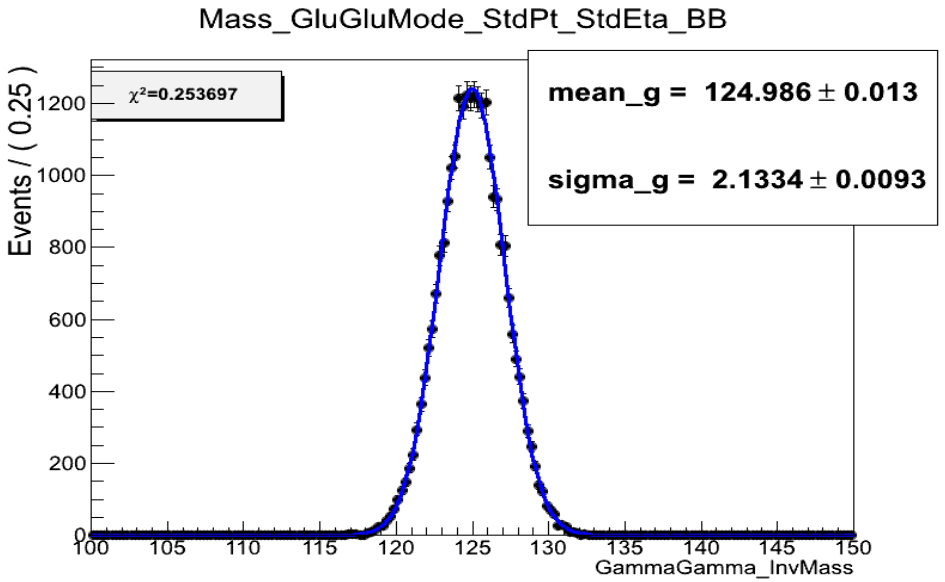
Acceptance cut : |η| <= 1.4442 and 1.566 <= |η| <= 2.5 (Standard Eta Cut)
p_T cut : γ1 > 35 GeV, γ2 > 25 GeV (Loose p_T cut)

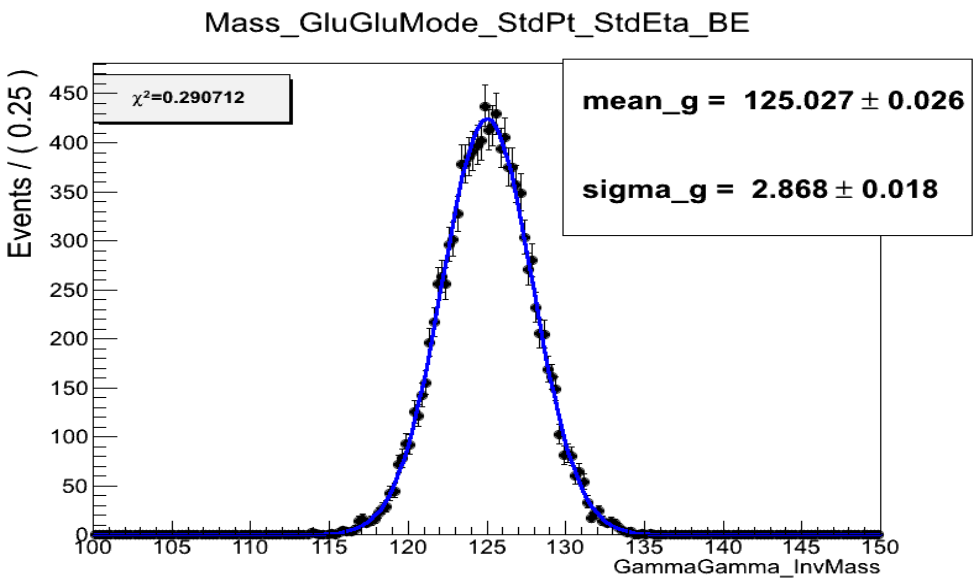
Fraction of Higgs with both photons in barrel	**0.36**	(0.37)	**[0.29]**
Fraction of Higgs with one photon in barrel and one in endcap	**0.18**	(0.18)	**[0.17]**
Fraction of Higgs with both photons in endcap	**0.05**	(0.05)	**[0.06]**
Fraction of Higgs with at least one photon escaping the ECAL	**0.39**	(0.38)	**[0.46]**

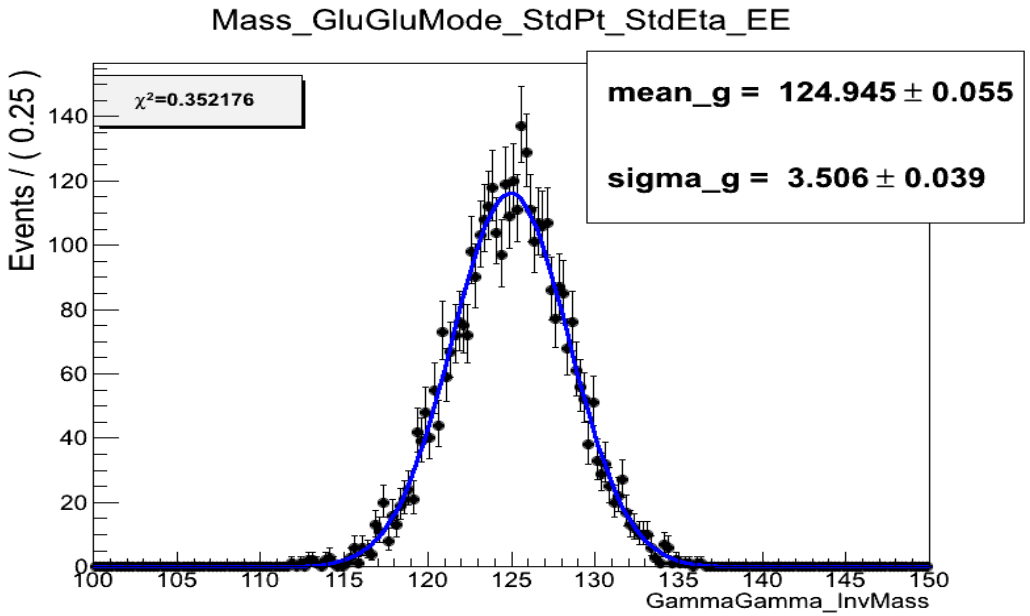
Acceptance cut : |η| <= 1.4442 and 1.566 <= |η| <= 2.5 (Standard Eta Cut)
p_T cut : γ1 > 30 GeV, γ2 > 20 GeV (Very Loose p_T cut)

Fraction of Higgs with both photons in barrel	**0.36**	(0.39)	**[0.30]**
Fraction of Higgs with one photon in barrel and one in endcap	**0.21**	(0.20)	**[0.19]**
Fraction of Higgs with both photons in endcap	**0.05**	(0.05)	**[0.06]**
Fraction of Higgs with at least one photon escaping the ECAL	**0.36**	(0.34)	**[0.43]**

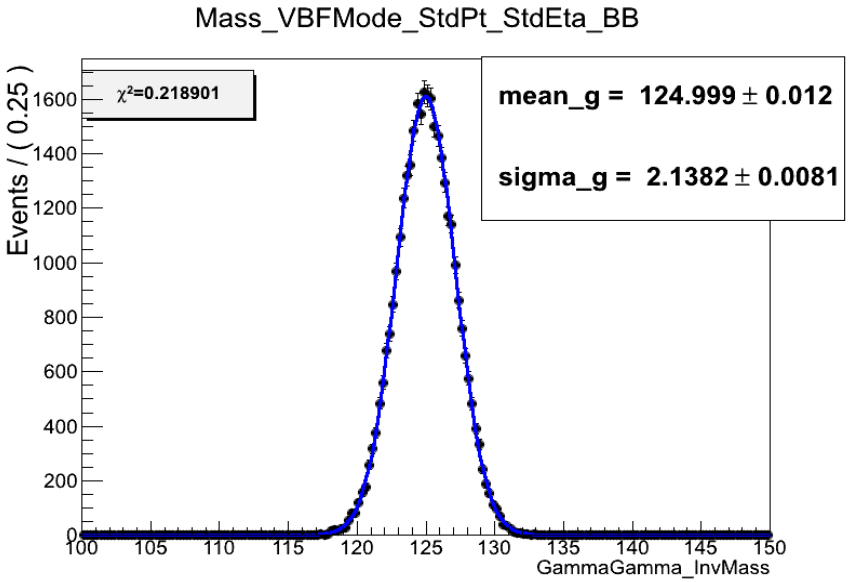
Diphoton mass resolution (Standard p_T cut & Standard Eta cut) in Gluon Fusion production mode

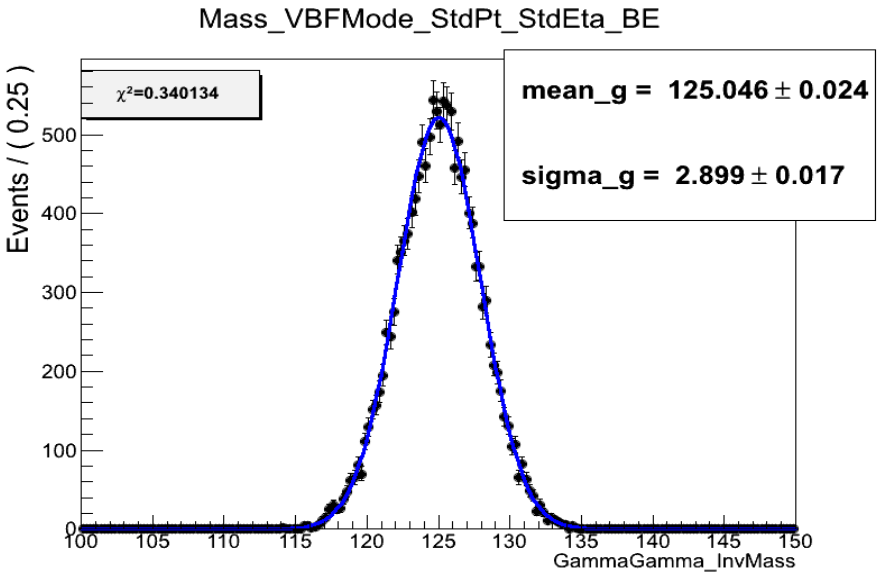


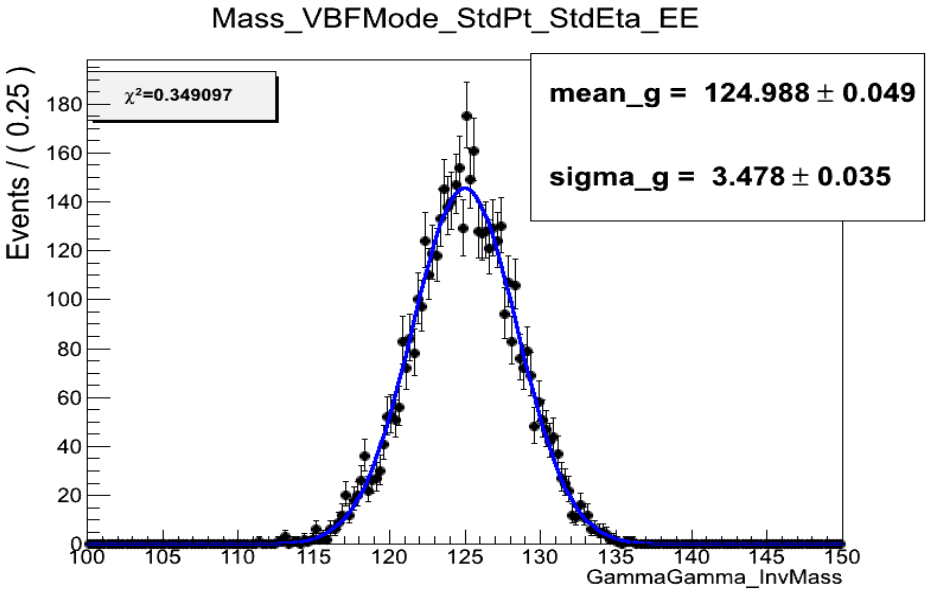




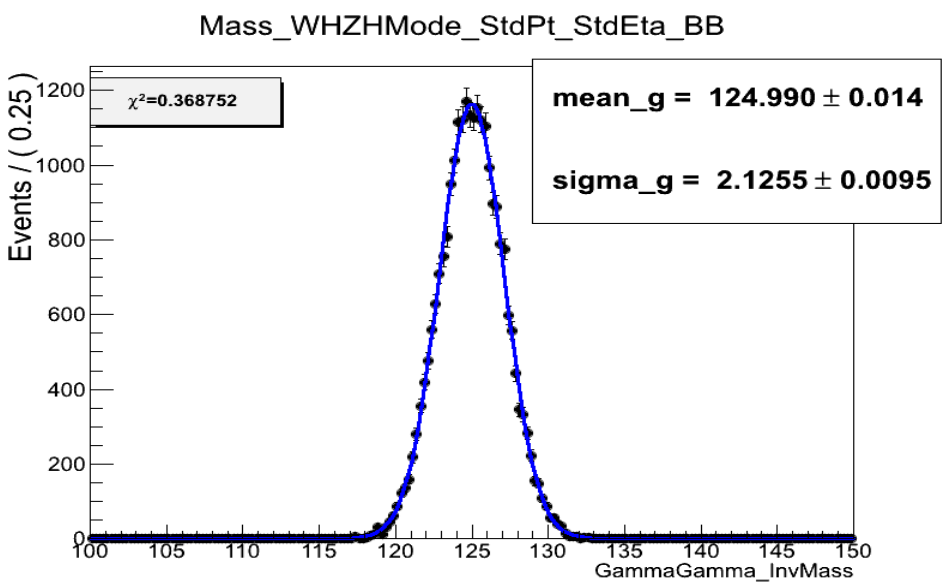
Diphoton mass resolution (Standard p_T cut & Standard Eta cut) in VBF production mode

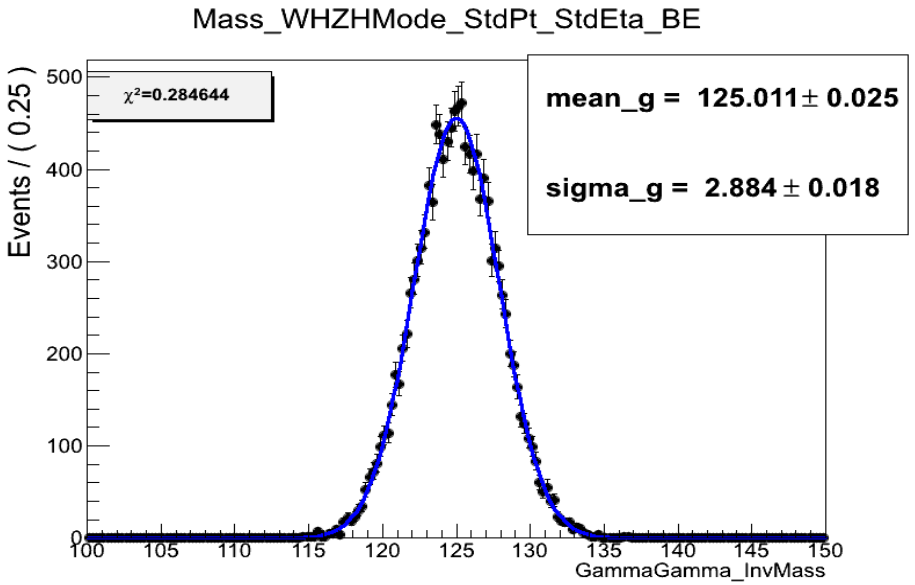


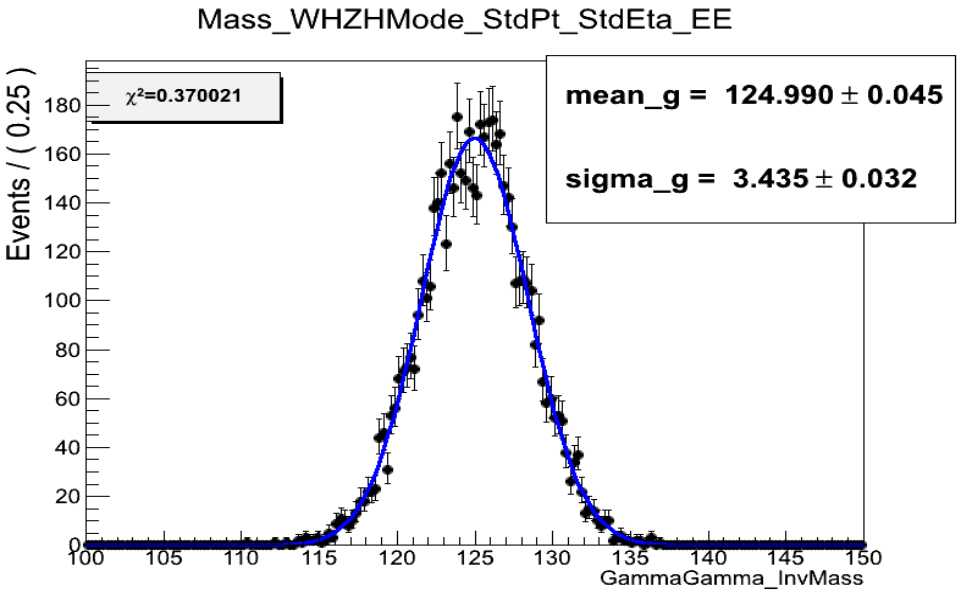




Diphoton mass resolution (Standard p_T cut & Standard Eta cut) in WHZH production mode







Diphoton Mass resolution in different Upgrade Scenarios for Gluon Fusion (VBF) [WHZH]

Acceptance cut : |η| <= 1.4442 and 1.566 <= |η| <= 2.5 (Standard Eta Cut)
p_T cut : γ1 > 41.6 GeV, γ2 > 31.3 GeV (Standard pT Cut)

Barrel-Barrel : Mass Resolution = **2.13 (2.13) [2.12]**
Barrel-Endcap : Mass Resolution = **2.86 (2.89) [2.88]**
Endcap-Endcap : Mass Resolution = **3.50 (3.47) [3.43]**

Acceptance cut : |η| <= 1.4442 and 1.50 <= |η| <= 2.5 (EB/EE crack reduced)
p_T cut : γ1 > 41.6 GeV, γ2 > 31.3 GeV (Standard pT Cut)

Barrel-Barrel : Mass Resolution = **2.13 (2.13) [2.12]**
Barrel-Endcap : Mass Resolution = **2.87 (2.89) [2.88]**
Endcap-Endcap : Mass Resolution = **3.53 (3.48) [3.45]**

Acceptance cut : |η| <= 1.4442 and 1.566 <= |η| <= 2.5 (Standard Eta Cut)
p_T cut : γ1 > 35 GeV, γ2 > 25 GeV (Loose pT cut)

Barrel-Barrel : Mass Resolution = **2.13 (2.13) [2.12]**
Barrel-Endcap : Mass Resolution = **2.88 (2.90) [2.88]**
Endcap-Endcap : Mass Resolution = **3.52 (3.47) [3.42]**

Comparison between different p_T resolution scenarios

Standard pT cut Standard Eta cut **(Gluon Fusion)**	**Photon pT resolution** **Barrel : 4%** **Endcap : 6%**	**Photon pT resolution** **Barrel : 4%** **Endcap : 4%**	**Photon pT resolution** **Barrel : 2.4%** **Endcap : 3.9%**	**Photon pT resolution** **Barrel : 1%** **Endcap : 1.5%** **(Most optimistic scenario : possible after upgrade or replacement)**	**Photon pT resolution** **Barrel : 4%** **Endcap : 10%**
DiPhoton Mass Resolution (Barrel-Barrel)	**3.55226**	**3.55226**	**2.13342**	**0.890177**	**3.55226**
DiPhoton Mass Resolution (Barrel-Endcap)	**4.51403**	**3.54807**	**2.8682**	**1.13337**	**6.66397**
DiPhoton Mass Resolution (Endcap-Endcap)	**5.38807**	**3.59825**	**3.50551**	**1.34963**	**8.9729**

Plans Ahead

1) Use fully simulated data to get an idea about efficiency of cuts.

2) Get some idea about S/B. We do not have background Monte Carlo samples, so what we plan to do is to use the background from the 2012 CiC analysis and scale it up by a factor 2. This seems reasonable from various cross section extrapolations. (Work in Progress)

3) Look at di-Higgs final states

Thanks...

Back Up

Cross section extrapolation from 8 TeV to 14 TeV

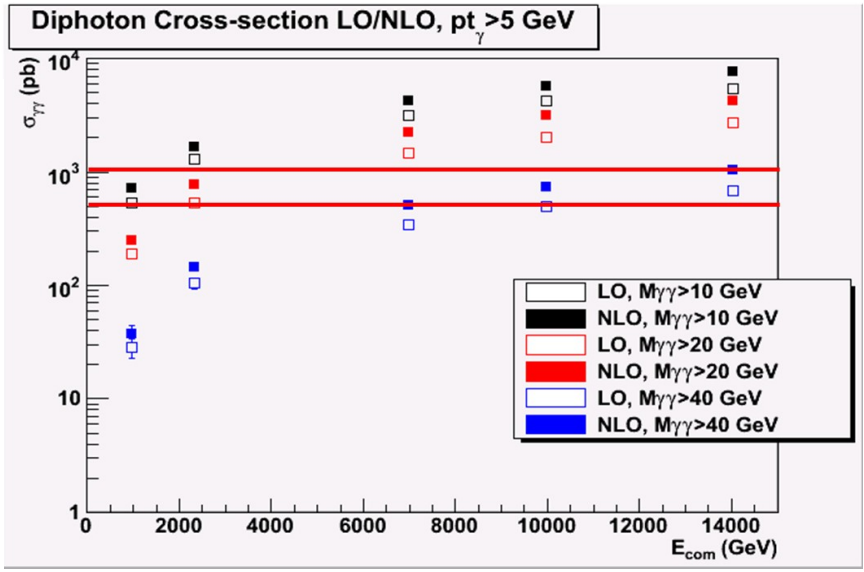
- **gg production cross section @ 125 GeV 7/8/14 TeV : 15.32/19.52/49.85 pb^{-1}**
  https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections#Higgs_cross_sections_at_7_8_and
- **We have not yet studied background samples to evaluate the evolution of the background cross section from 8 TeV to 14 TeV.**
  - **⇒ Scale background from 2012 data.**
- **For now estimate factor 2 increase of background cross section. See eg. slide 22 here (S.Gascon-Shotkin, M. Kado) : https://twiki.cern.ch/twiki/bin/view/LHCPhysics/GammaGamma**
- **Fakes need to be studied on fully simulated events. For 8 TeV H→γγ background dominated by irreducable, not fakes.**

G. Ceballos,

http://ceballos.web.cern.ch/ceballos/hwwlnln/cross_sections_backgrounds.txt

process	ECM=14TeV	ECM=10TeV	ECM=7TeV	comment
W->lnu	3*20283.7	3*14253.7	3*9679.9	MCFM NLO
DY(20-inf)->ll	3*3259.7	3*2323.6	3*1606.6	MCFM NLO
WW	112.5	71.4	42.9	MCFM NLO
WZ	51.0	31.4	18.3	MCFM NLO
ZZ	15.6	9.9	5.9	MCFM NLO
ttbar	918	415	165	MCFM NLO
Wt	56.1	26.0	10.5	MCFM NLO
tq-t_channel	244.6	130.5	62.8	MCFM NLO
tq-s_channel	11.9	7.6	4.6	MSTW 2008 NNLO
W(->lnu)+gamma	54.7*1.8	35.4*1.8	23.2*1.8	NLO k-Factor from Bauer
Z(->ll)+gamma	17.5*1.8	11.3*1.8	7.3*1.8	NLO k-Factor from Bauer

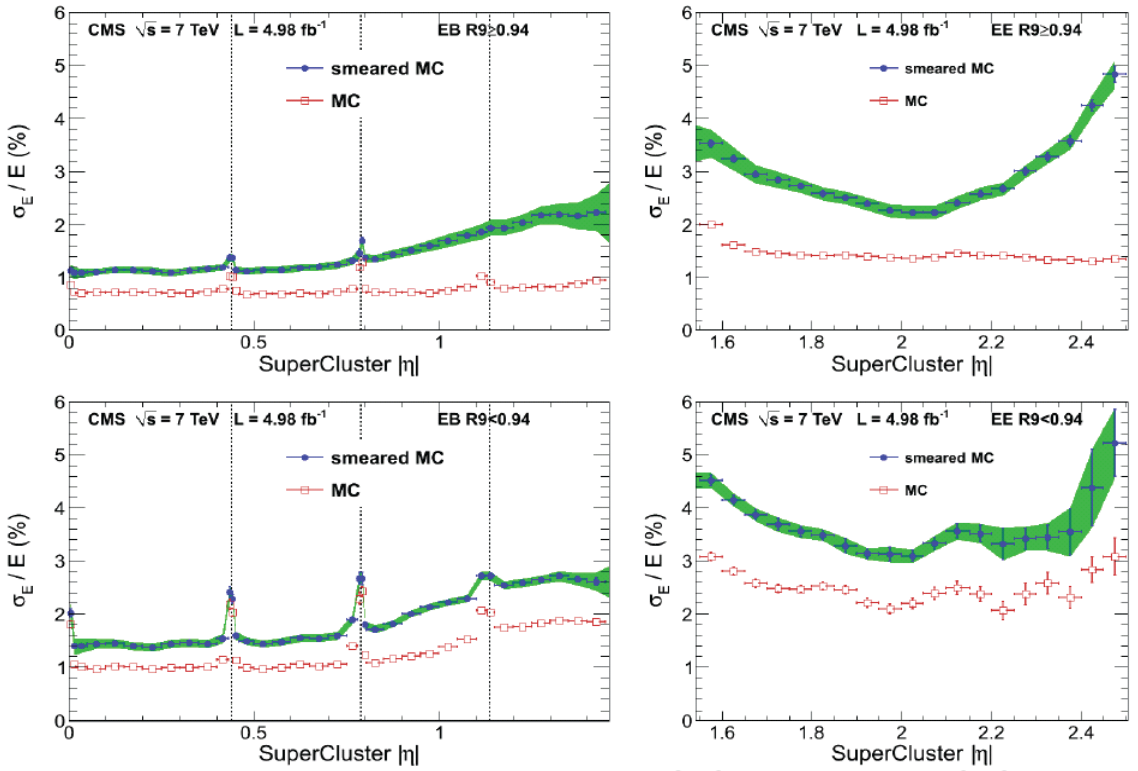
Notice: l includes all lepton flavors
BR(W->lnu)=0.1080
BR(Z->ll)=0.033658



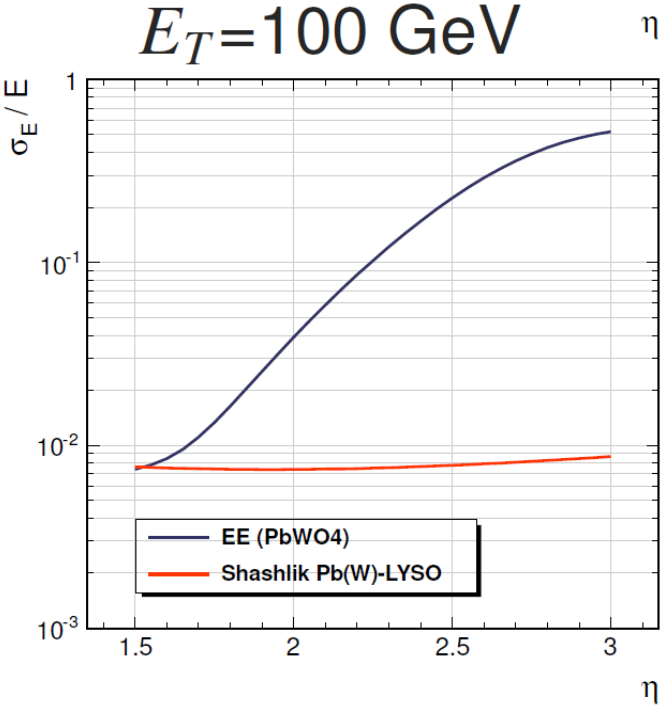
Considerations on Energy Resolution

- Current EE : Energy resolution in MC : 1.5% to 3%, in DATA 3% to 5% (from EGM 11-001).
- Assume 1.5% in EE as most optimistic after the upgrade/replacement
  - 6% (as chosen by F. Cavallo : https://indico.cern.ch/getFile.py/access?contribId=8&sessionId=8&resId=2&materialId=slides&confId=249201
  - ~10% (5%-50%) from aging models after 3 ab^{-1}, see S. Ledovskoy : https://indico.cern.ch/getFile.py/access?contribId=3&resId=0&materialId=slides&confId=249041

Current ECAL, EGM 11-001



Extrapolation with aging, 3 ab^{-1}



⇒ Assume σ_E for EE 1.5%, (4%), 6% 10% as Phase II scenarios

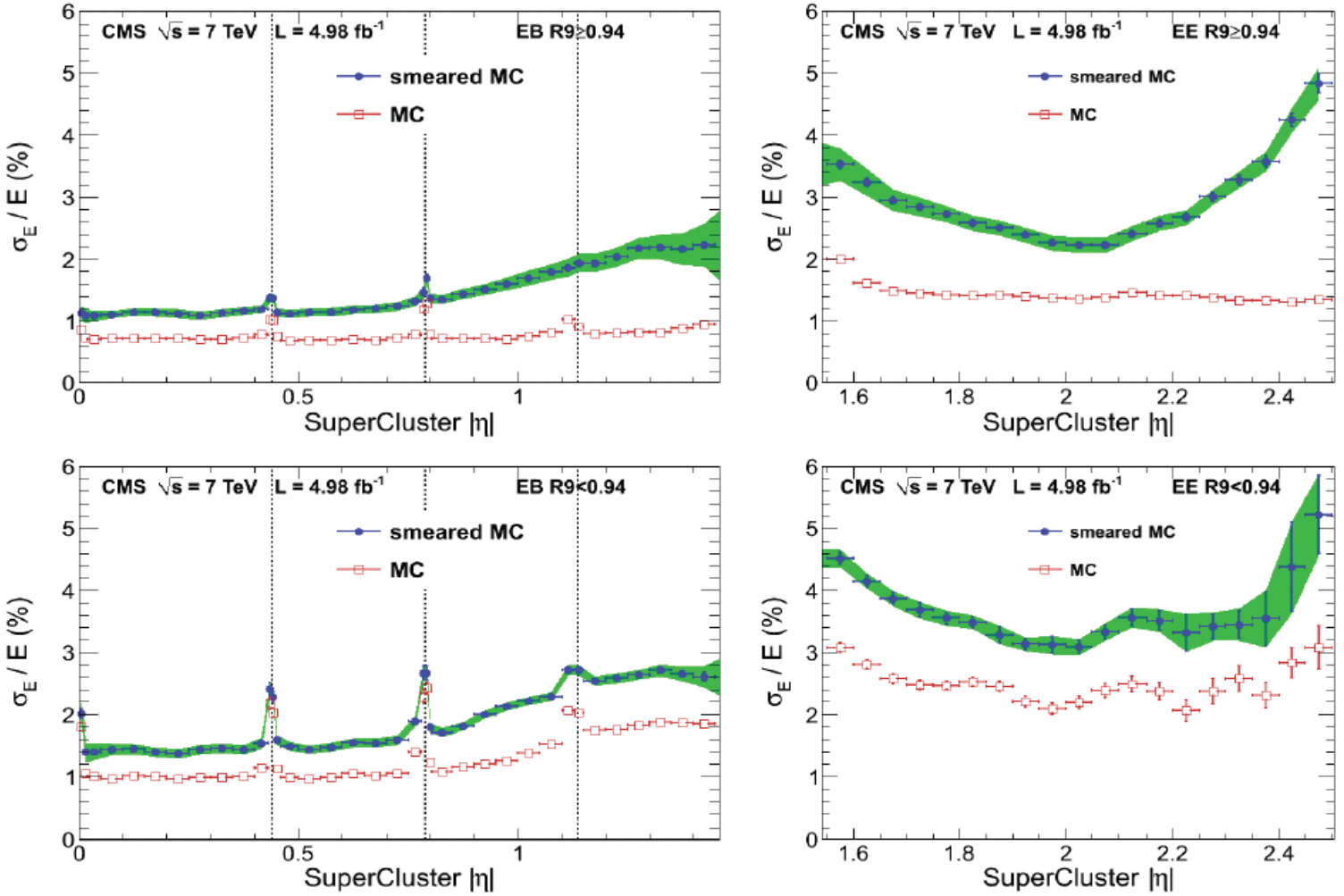
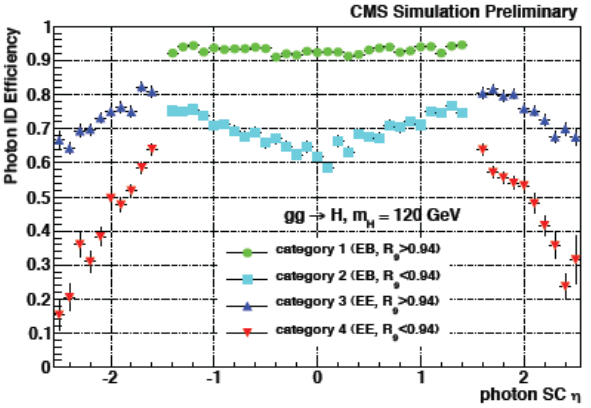
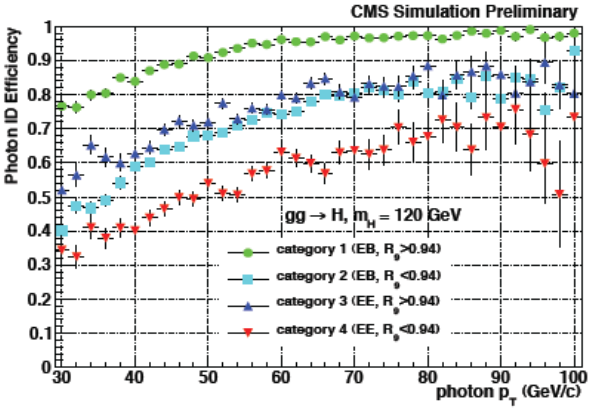


Figure 15: Photon energy resolution in bins of pseudorapidity η for the barrel (left column) and the endcaps (right column). The resolution is shown separately for photons having $R9 \geq 0.94$ (top row) and $R9 < 0.94$ (bottom row). The energy resolution is plotted for the simulated $H \rightarrow \gamma\gamma$ events for the default MC simulation and for MC simulation with the addition of Gaussian smearing. The green band shows the uncertainty on the photon resolution calculated as the quadratic sum of the uncertainty on the additional smearing term derived and the statistical uncertainty in photon resolution (shown by the vertical error bars).

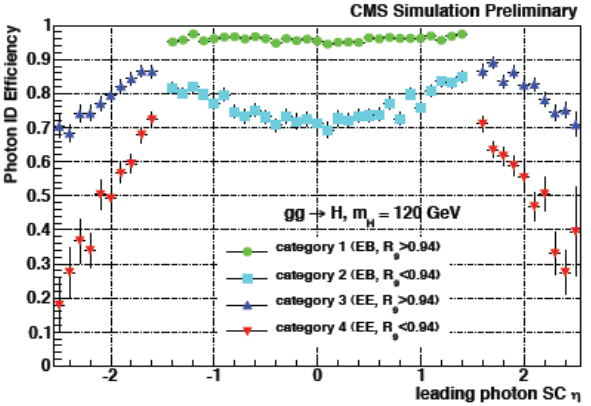
Photon ID efficiency

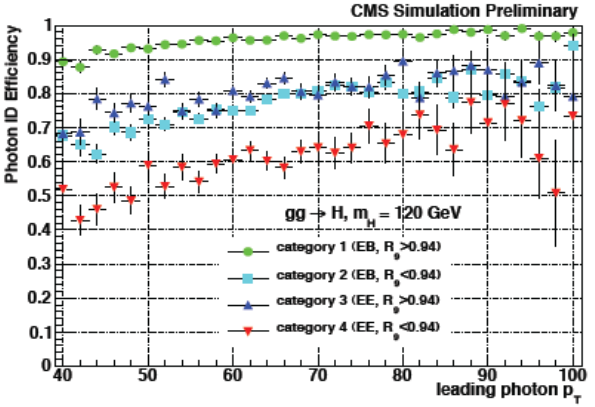
- EE photon ID efficiency in EE depends strongly on eta.
- Needs to be studied with fully simulated events.



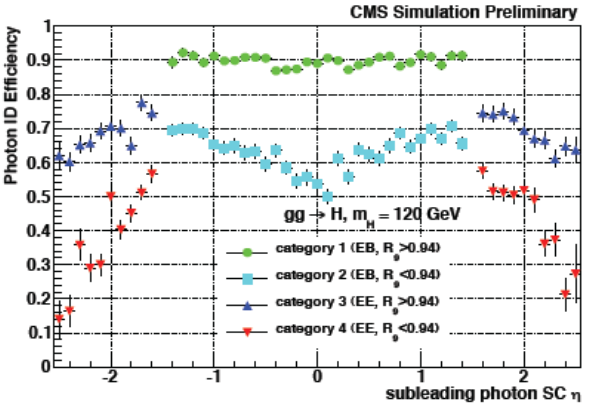


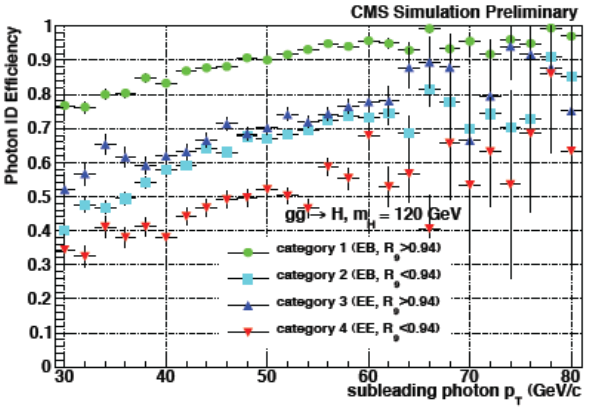
(a) Both photons.

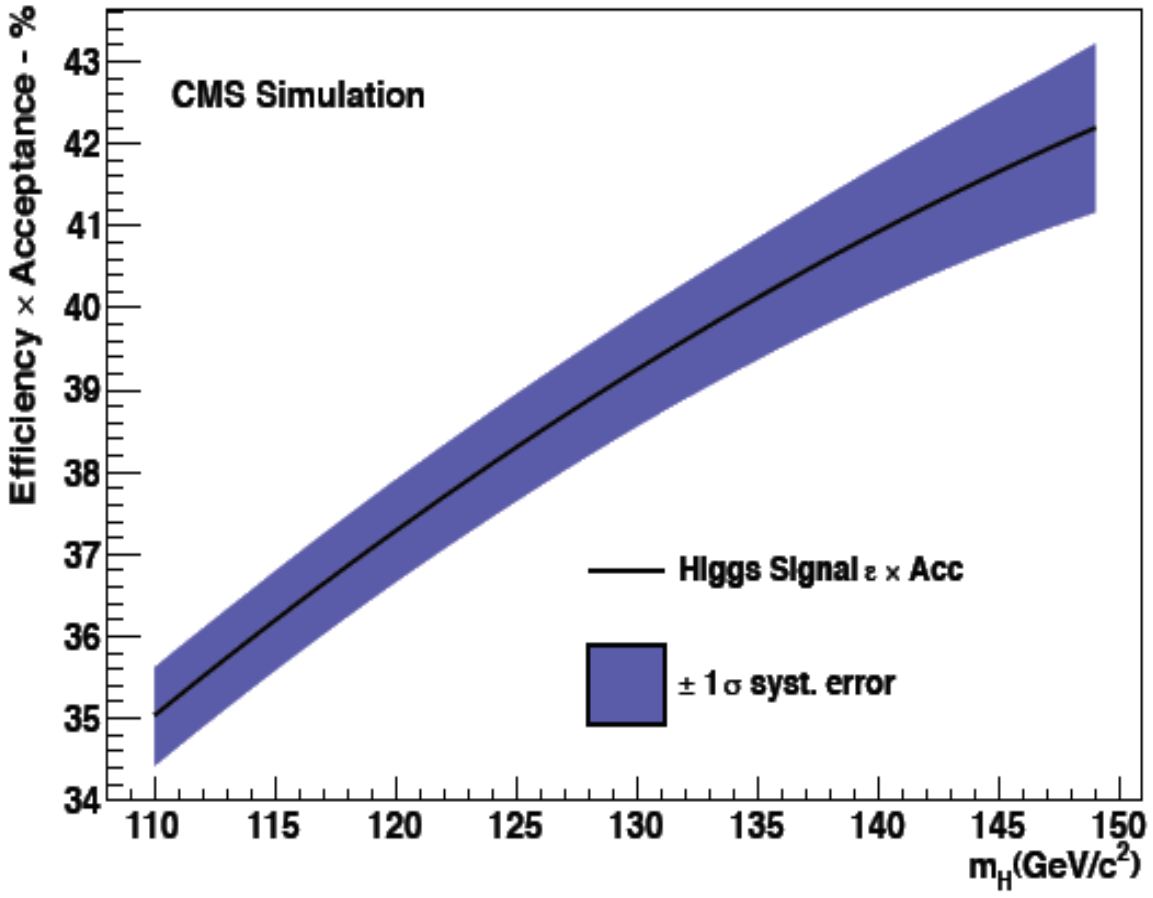




(b) Leading photon.







Acceptance×efficiency as a function of m_{H} Integrated over all event classes.

38% @ 125 GeV