H->bb/cc/gg Analysis

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Outlook

- Current analysis take systematic uncertainty into account, and reduce as much systematic uncertainty source as possible
- Changes from previous analysis:
  - 2D template fit -> 3D fit(1 D mumu-recoil mass + 2D template)
    - Model independent estimation on dominant backgrounds
  - Estimate relative number of H->bb/cc/gg to H->inclusive
    - Part of systematic uncertainty in H->inclusive canceled

Analysis Strategy

Br(H->bb/cc/gg)= N(H->bb/cc/gg)/N(H->inclusive)

N^{obs}(H->inclusive) = N(H->inclusive)*ε

N^{obs}(H->bb/cc/gg) = N(H->bb/cc/gg)*ε' $\varepsilon' = \varepsilon * \varepsilon_{jets}$

ε is the efficiency on inclusive Higgs cut, only applied to muons
The systematic uncertainty canceled in this part (an exception is the isolation lepton efficiency for H->bb/cc/gg is slightly different from H inclusive decay), including:

- **Luminosity uncertainty**
- **Z->ll prediction**
- **muon selection(approximation), muon pair invariant mass and recoil mass**
- **ISR correction**

Only need to consider systematic uncertainty from jets cuts and extraction of H->bb/cc/gg

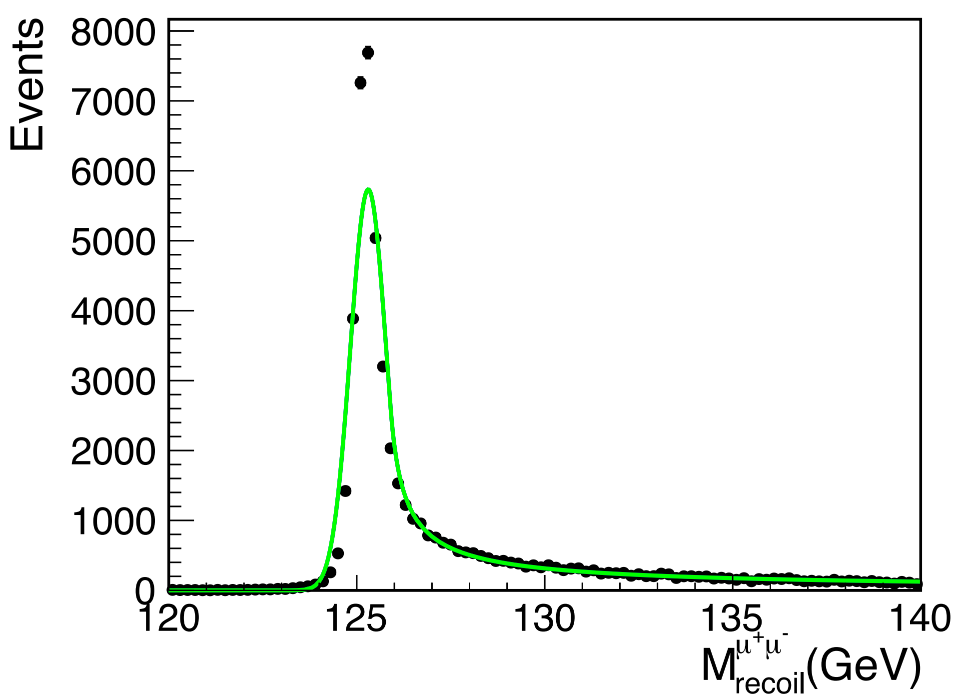
Remaining Systematic Uncertainty

- Uncertainty from extraction of H->bb/cc/gg
    - 3D fit method
        - Imperfect modeling
        - Uncertainty from the fixed parameters in the fit
    - Flavor tagging
- Systematic uncertainty from jet cuts
    - Lepton veto, Jet cos theta cuts, nPFO cut, y-th value cut
- Systematic uncertainty of non-uniformity of isolation lepton cuts

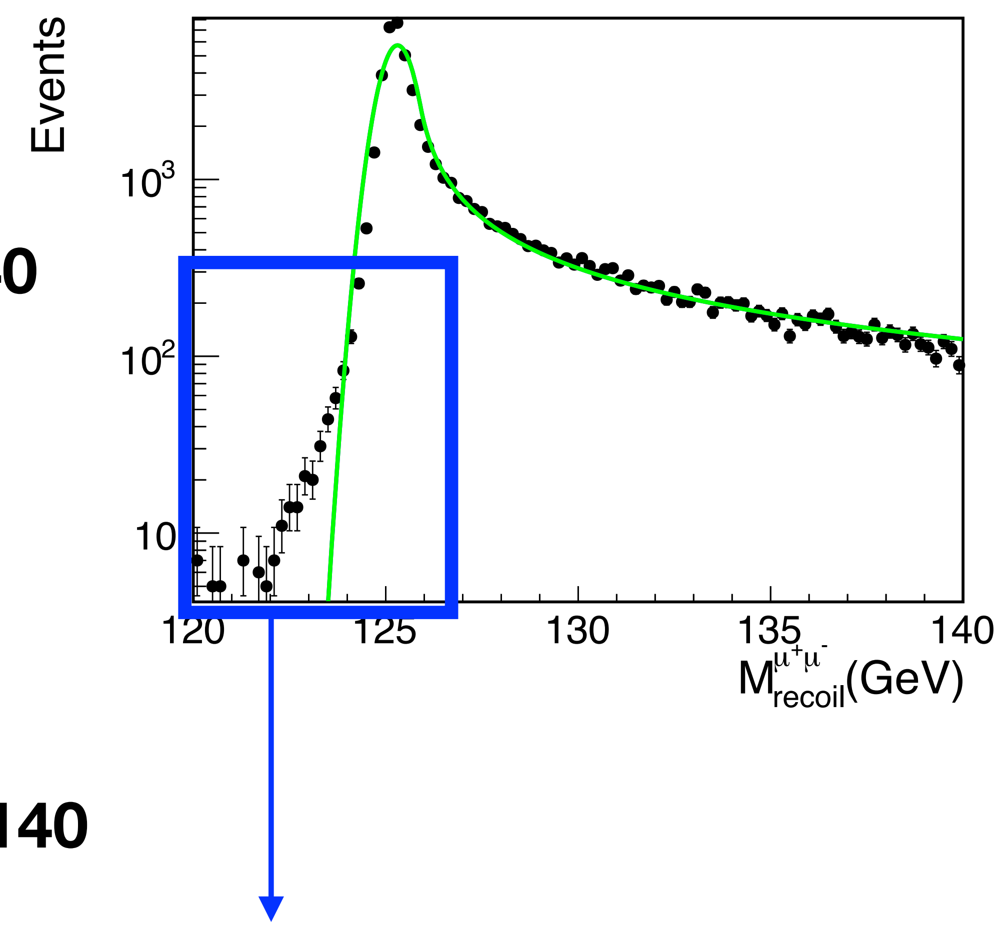
3D fit

- PDFs:
  - 3D PDF = mumu_recoil_mass PDF × 2D flavor template PDF
    - Background recoil mass using 2 order Chebychev polynomial function
    - Signal recoil mass using Crystal ball function + 2 side exponential function
- Fit applied without mumu-recoil mass cuts, events in signal region is estimated from fitted results
- Mumu recoil mass Fit range for background set from 120 GeV to 140 GeV
- Jet's invariant mass cut loosen, to reduce the impact from jet energy resolution uncertainty

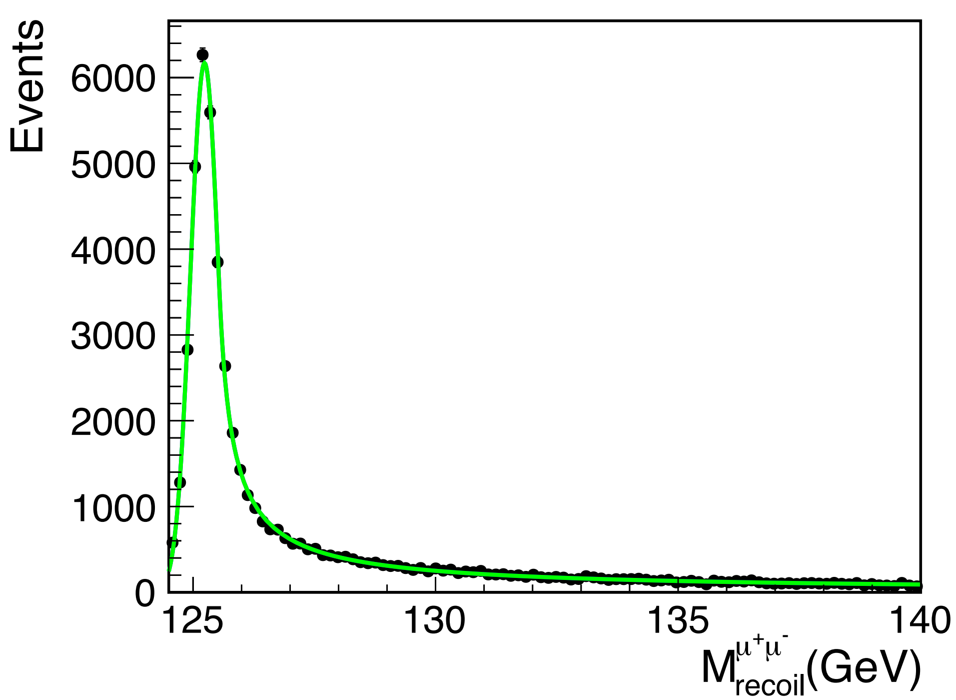
Signal-only fit on Recoil Mass



120-140



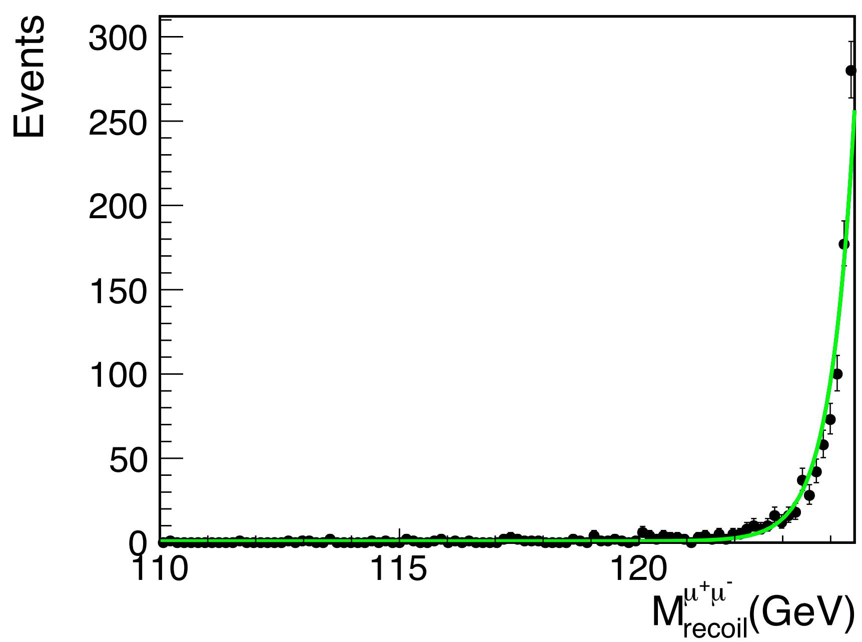
a tail hard to described by CB function

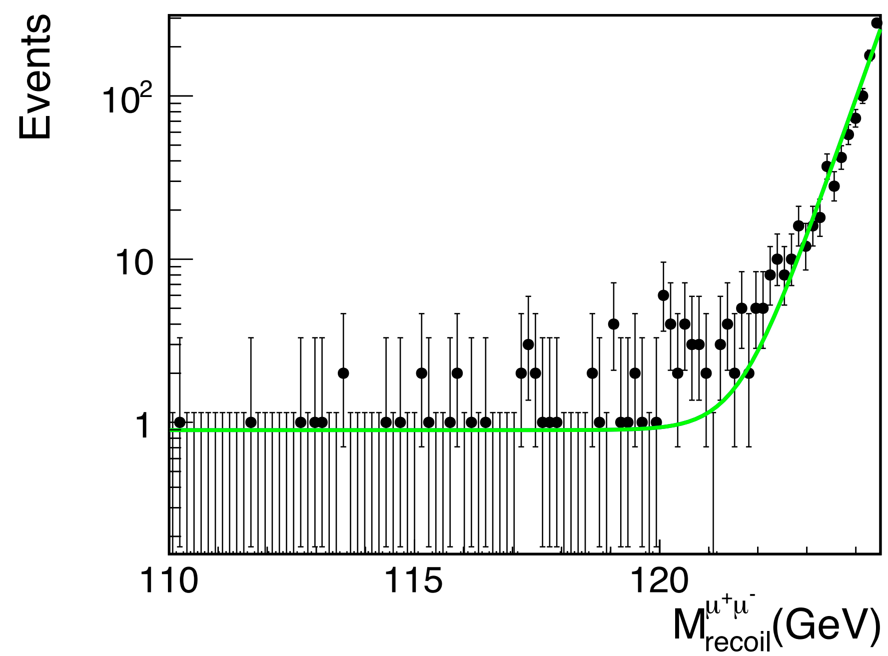


124.5-140

CB function can describe signal shape well above 124.5 GeV

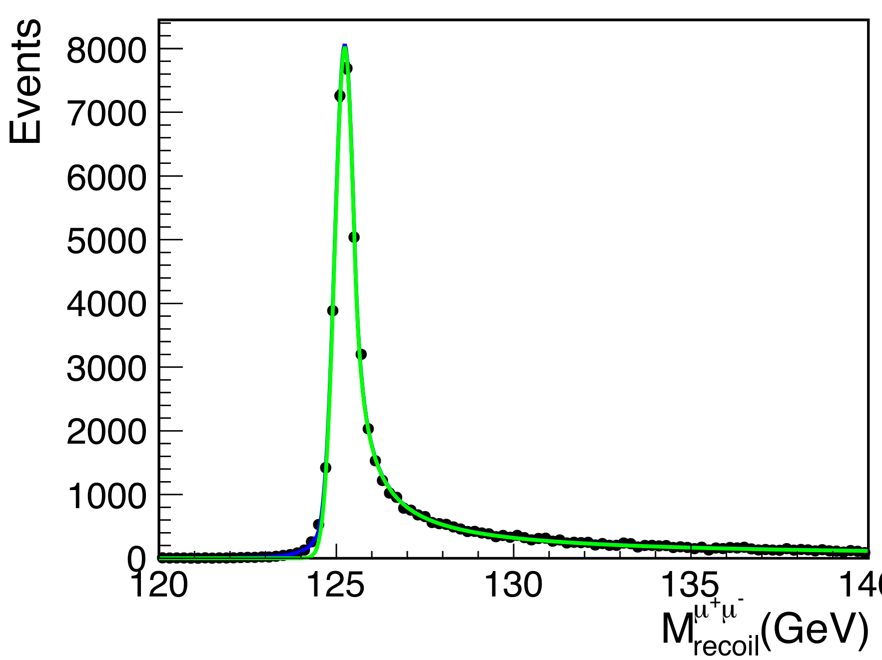
fitting on the tail: 2 side exponential + constant

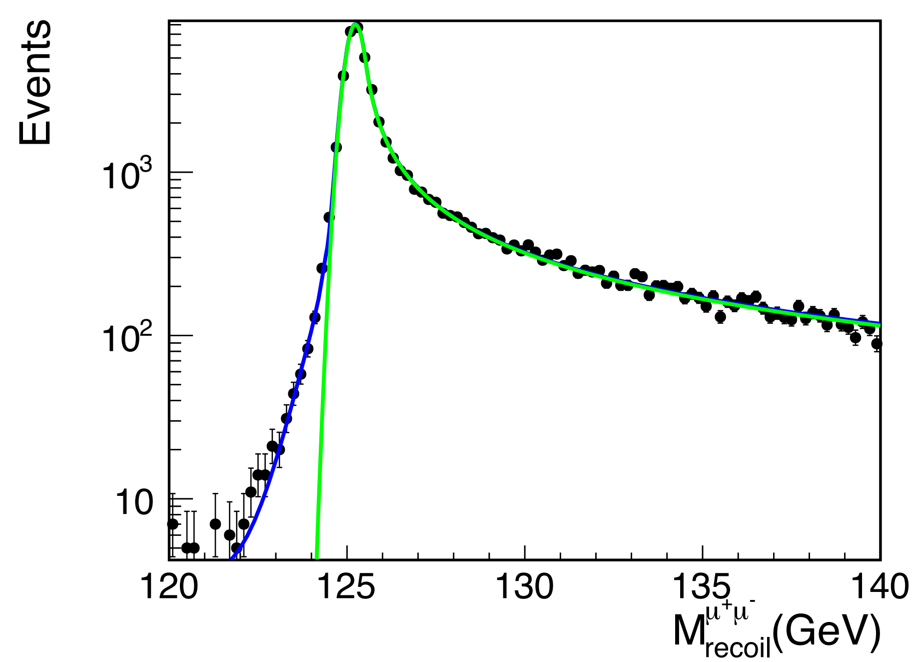




fitting on signal with tail

Significantly improved





Unbinned fit result

```
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-263621 FROM HESSE     STATUS=OK          186 CALLS        1151 TOTAL
                     EDM=0.000344761    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   INTERNAL      INTERNAL
 NO.   NAME        VALUE            ERROR        STEP SIZE       VALUE
  1  C            8.15598e-02   4.74701e-02   2.38007e-03  -1.38993e+00
  2  a           -8.55628e-01   1.93877e-02   3.59477e-04  -8.56675e-02
  3  a1          -2.90441e-01   2.27928e-02   2.85182e-03  -2.90441e-01
  4  a2          -8.85864e-03   2.26059e-02   7.12198e-03  -8.85864e-03
  5  mean         1.25197e+02   3.77741e-03   1.39799e-03   1.08257e-01
  6  n            1.08893e+00   3.21412e-02   5.48546e-04  -8.98210e-01
  7  nHbb         1.21616e+04   3.02035e+02   1.72857e-03   2.17841e-01
  8  nHcc         5.57433e+02   6.59704e+01   3.32443e-03  -1.09451e+00
  9  nHgg         1.62898e+03   1.09281e+02   1.18455e-02  -3.56160e-01
 10  nbkg         2.51605e+02   3.59676e+01   9.60252e-03  -9.98050e-01
 11  nsig         9.38479e-01   2.36299e-02   1.53474e-02  -2.32500e-01
 12  nzzsl_mu_bb   1.89757e+03   2.95530e+02   3.50975e-03  -4.75795e-01
 13  nzzsl_mu_cc   1.82726e+03   7.26050e+01   2.78164e-03  -4.98532e-01
 14  nzzsl_mu_uds   5.53577e+03   1.11082e+02   1.37959e-03  -4.62345e-01
 15  sigma        2.61527e-01   3.53294e-03   1.36772e-03  -6.38737e-01
                               ERR DEF= 0.5
EXTERNAL ERROR MATRIX.    NDIM=  40    NPAR= 15    ERR DEF=0.5
ELEMENTS ABOVE DIAGONAL ARE NOT PRINTED.
```

Fitted Result in Signal Region

	N_Hbb	N_Hcc	N_Hgg
Fitted	12161.6	557.4	1629.0
MC	12179.5	571.1	1639.8
difference	-0.15%	-2.4%	-0.66%

Fitted free parameters

	signal			l^+l^-H background		ZZ semi-leptonic			other background
	$b\bar{b}$	$c\bar{c}$	gg	WW^*	ZZ^*	$l^+l^- + b\bar{b}$	$l^+l^- + b\bar{b}$	$l^+l^- + q\bar{q}$	
Recoil mass shape	Released					Released			Fixed
Normalization	R	R	R	F	F	R	R	R	F

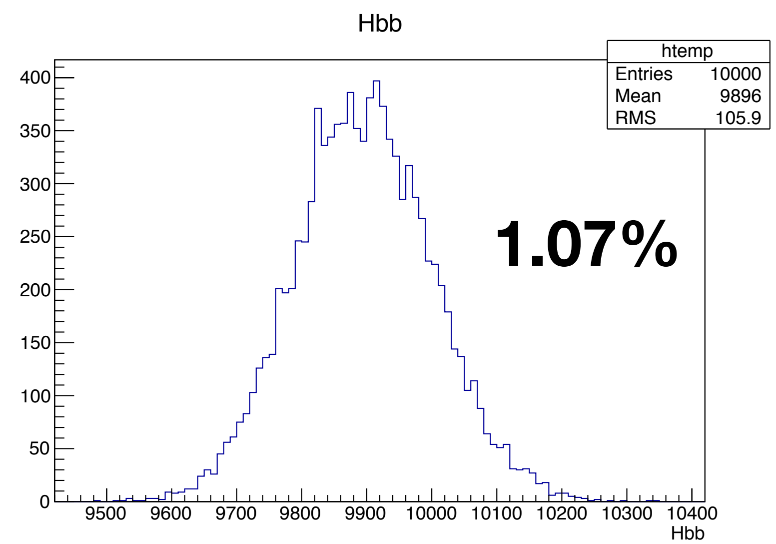
Table 3: Parameters setting in the 3D-fit. The signal and l^+l^-H backgrounds share the same recoil mass shape; the ZZ semi-leptonic background share the same recoil mass shape. Other background's shape and normalization are fixed according to a 3-dimension histogram distribution. The 'R' and 'F' in last row stands for 'Released' and 'Fixed' respectively.

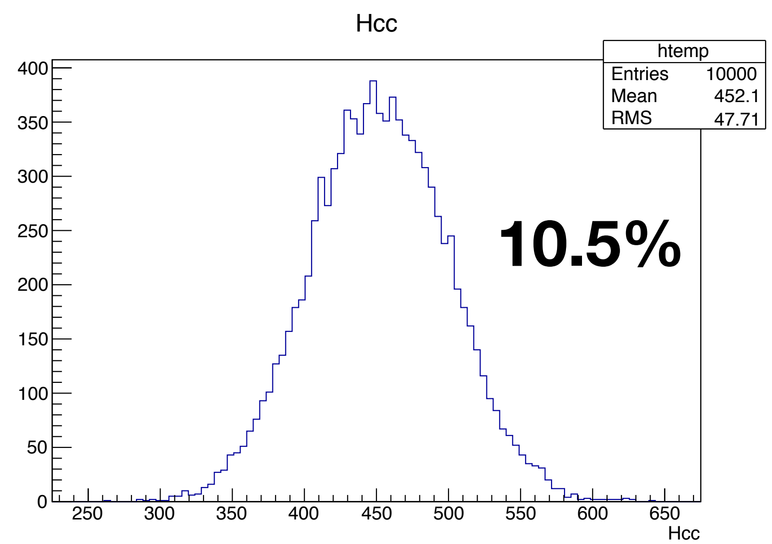
Fitted Result in Signal Region

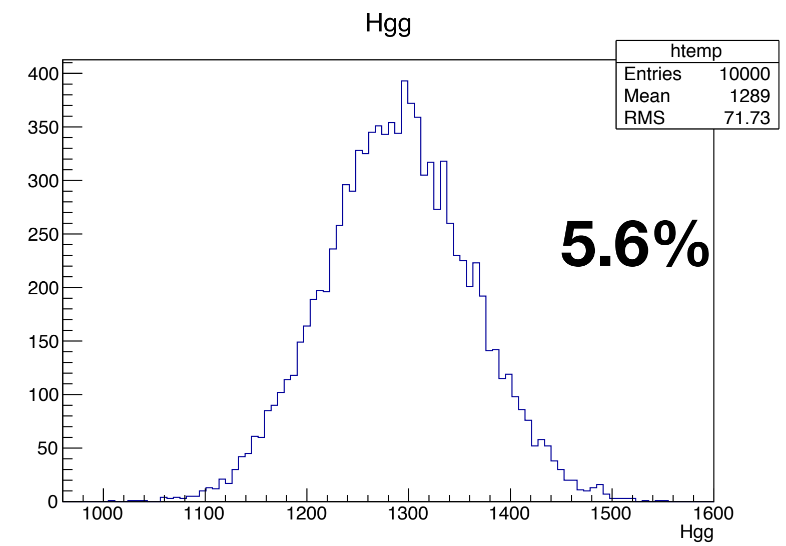
	N_Hbb	N_Hcc	N_Hgg
Fitted	10026.1	459.55	1342.94
MC	10022.2	469.2	1350
difference	0.038%	-2.1%	-0.52%

ToyMC Study with Binned Data

Statistic Uncertainty:



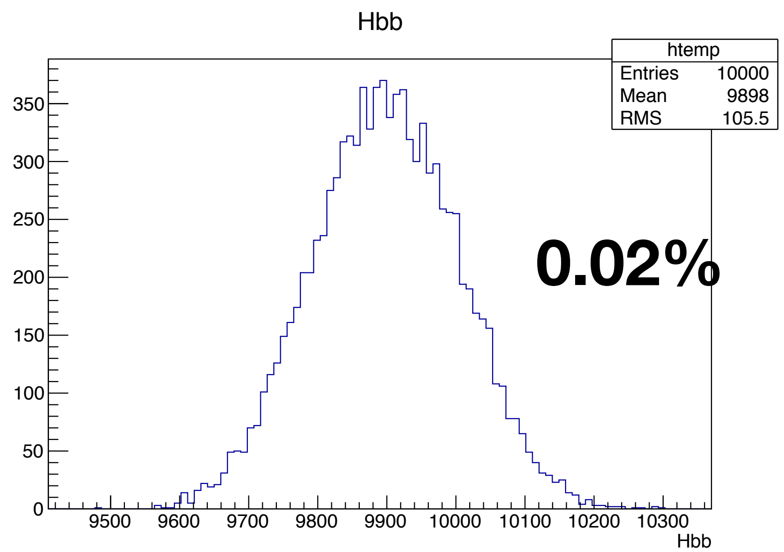


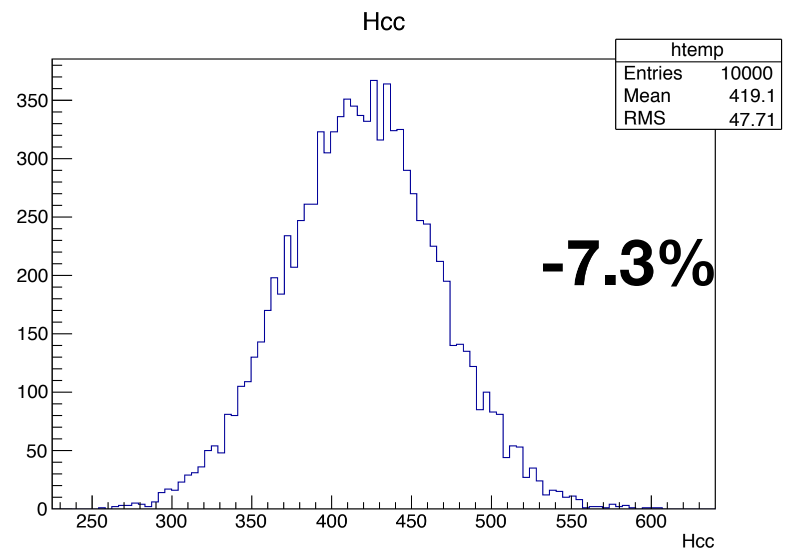


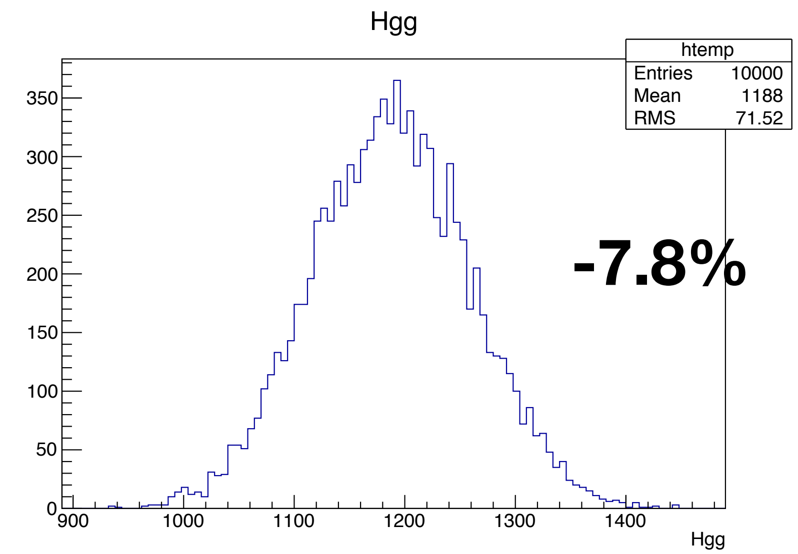
3D histogram of ToyMC

Hww Systematic

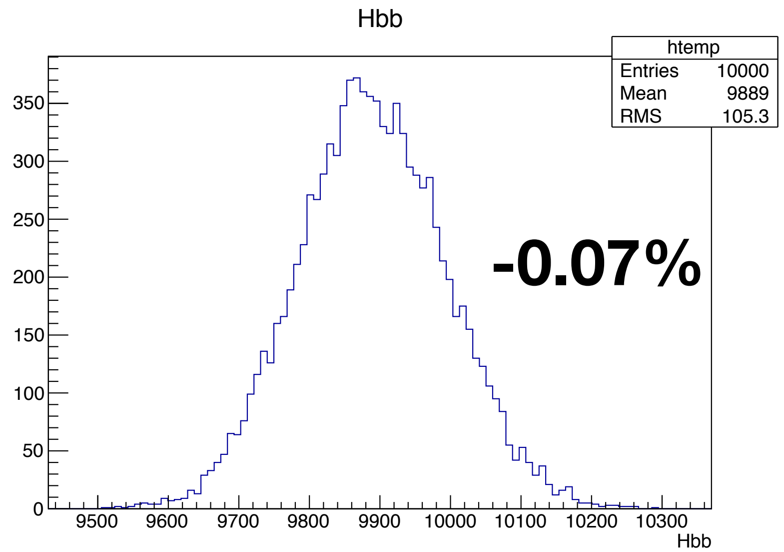
Over estimate by 10%

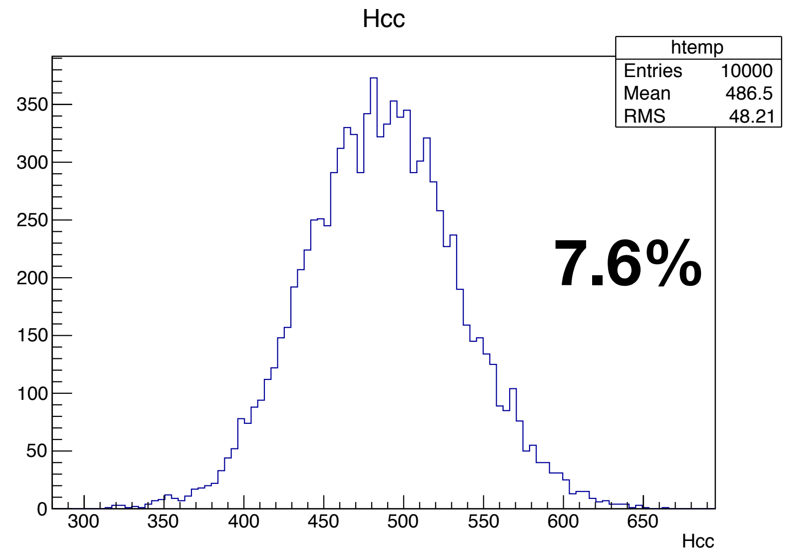


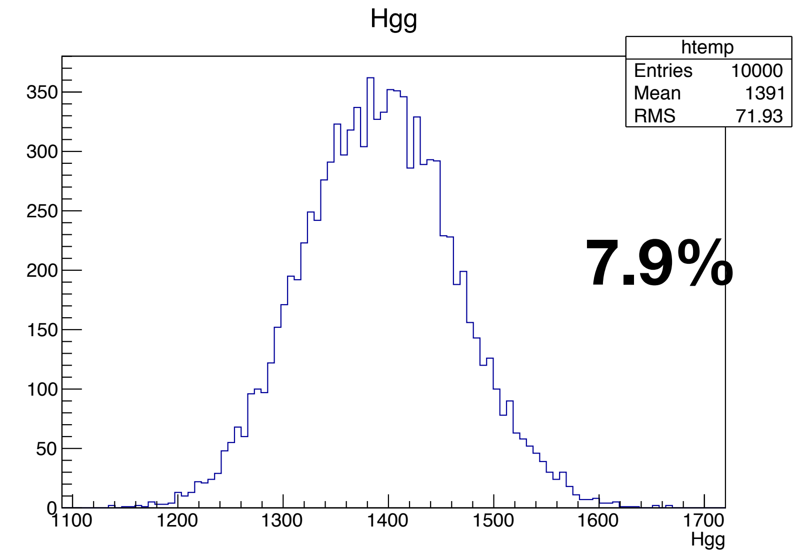




Under estimate by 10%

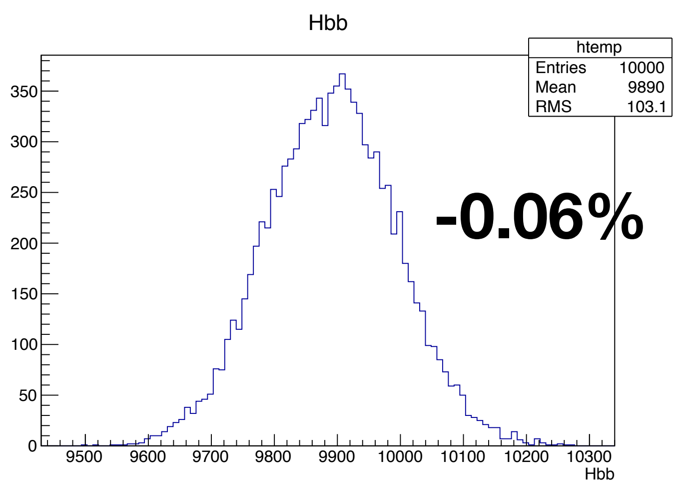


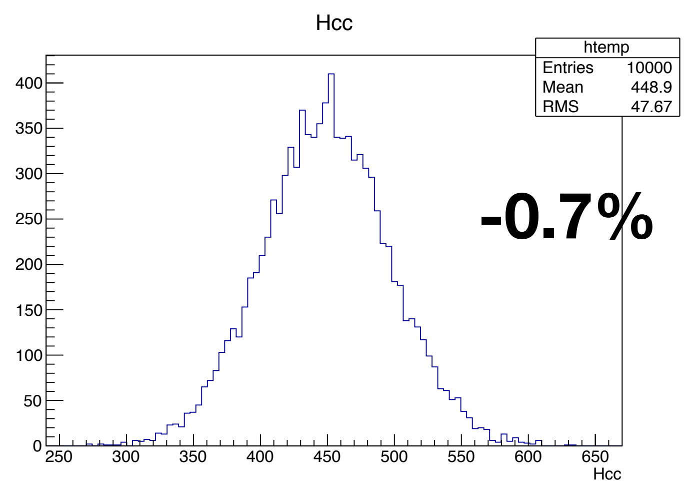


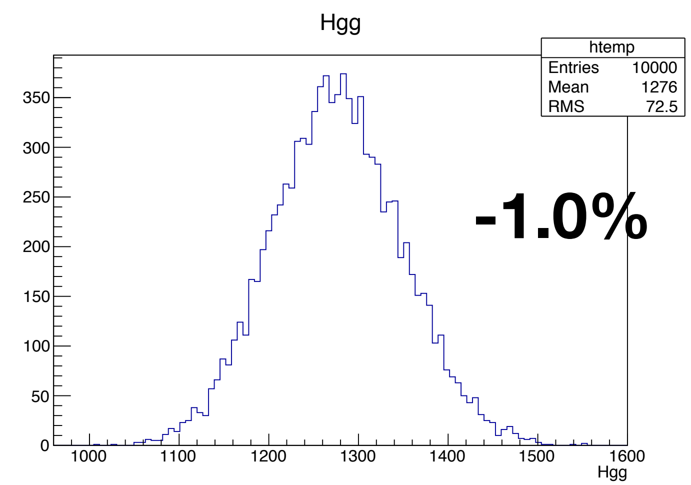


Hzz Systematic

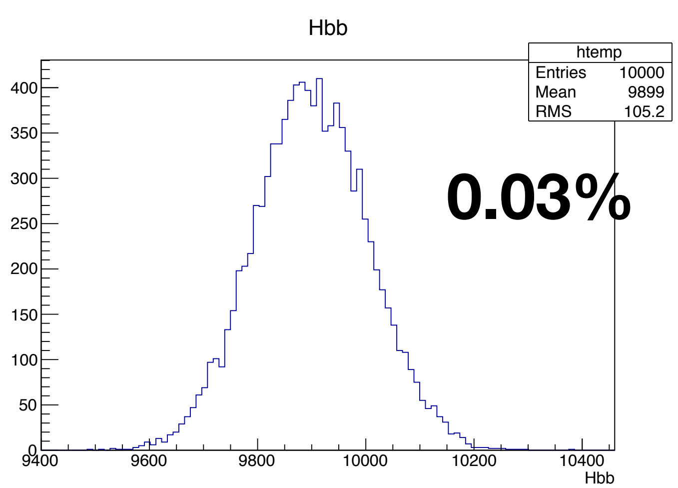
Over estimate by 10%

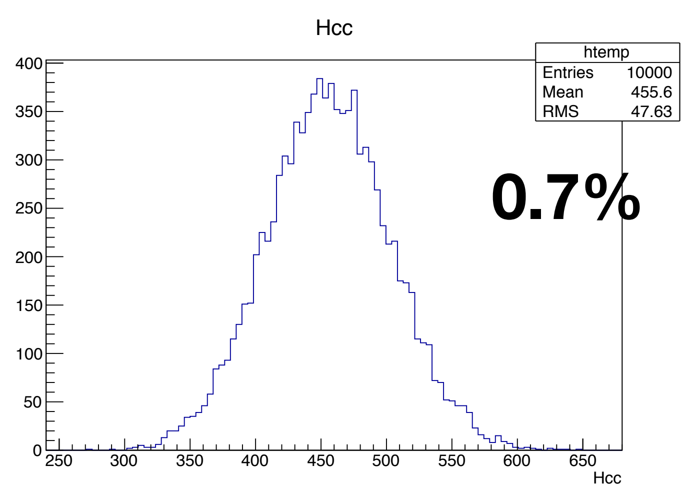


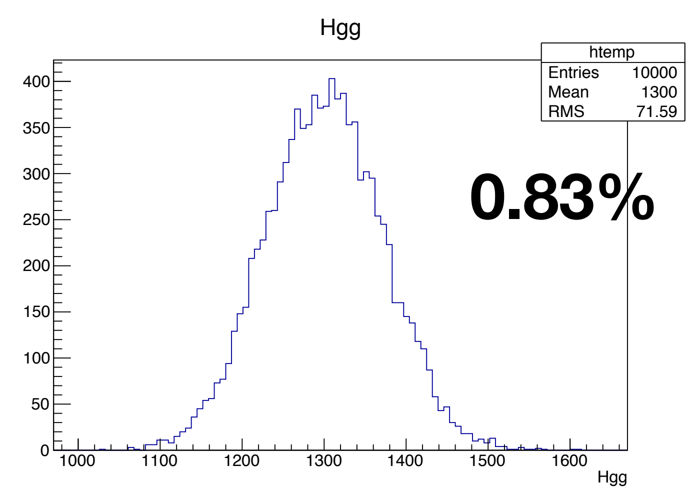




Under estimate by 10%

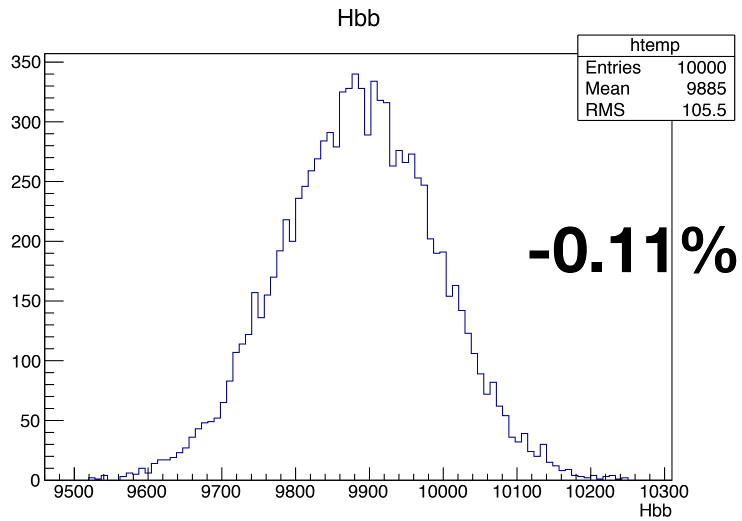


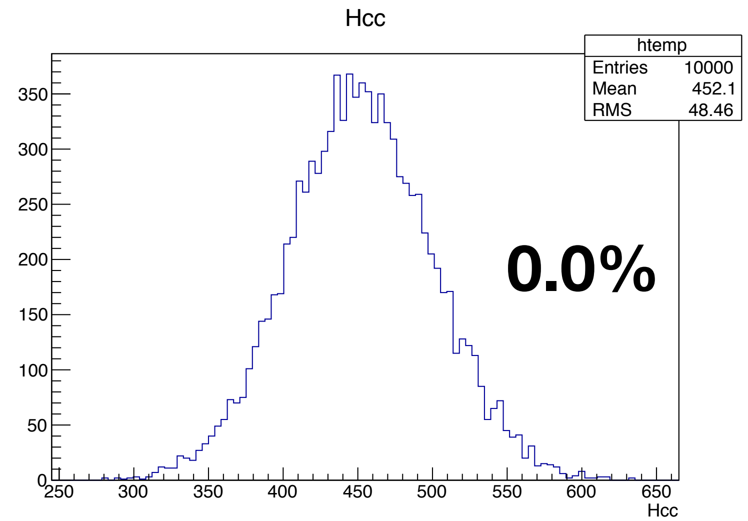


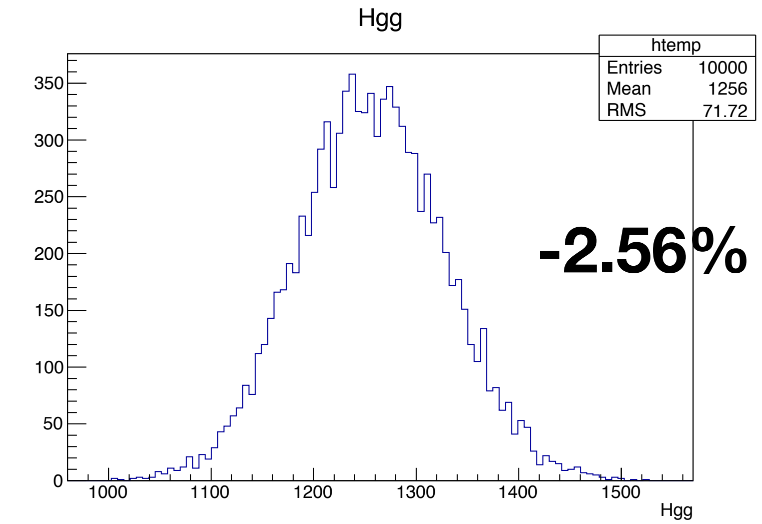


Other SM background

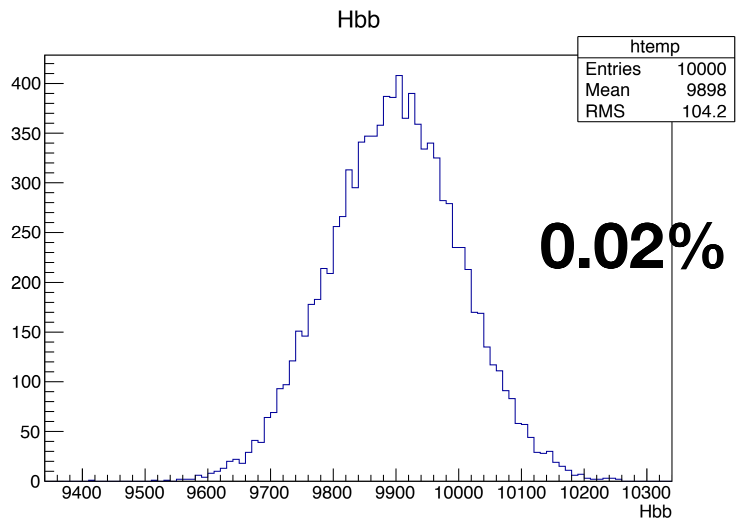
Over estimate by 100%

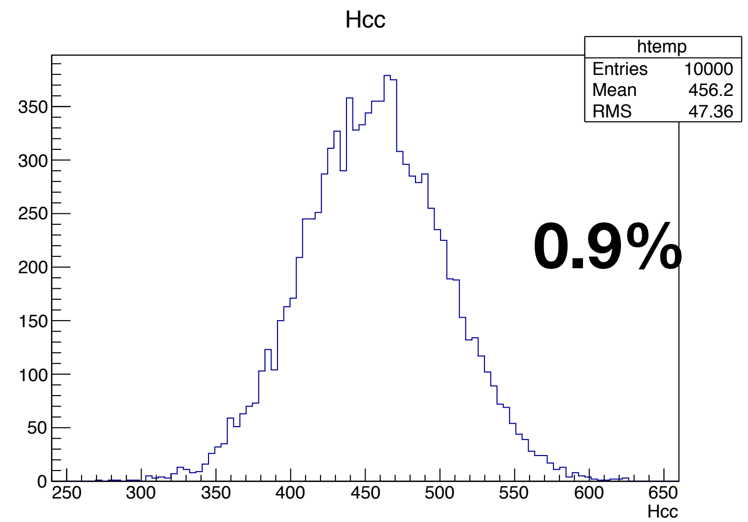


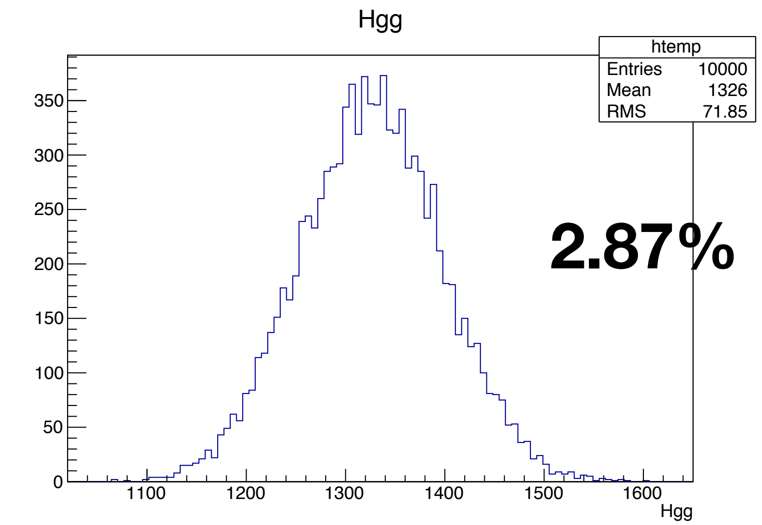




Under estimate by 10%







Systematic Uncertainty from Flavor tagging

- For H->bb/cc, we assume we can calibrate the flavor template using Z-pole data
- Fluctuation of template from Z-pole data take as uncertainty
- Results coming soon

Systematic Uncertainty ofJet Cuts

Lepton Veto

- **For bb events, fake isolation lepton from b-hadrons can be studied with precision N(Z->bb)*fake rate ~ 1/sqrt(2 billions * 0.4%) = 0.03%. We take 0.03% as the uncertainty of inefficiency of bb lep cut**

Jet nPFO cut and cos theta cut

- **Can we just assume a number?**

Jet Invariant Mass

- **Directly assume a number or take 3% or 4% as mass resolution and assume we under-estimate or over estimate mass by 3% or 4%**
  - **Hbb, -0.68%, 0.20%**
  - **Hcc, -1.08%, 0.43%**
  - **Hgg, -1.68%, 0.71%**

non uniformity of lepton cuts

Hbb	Hcc	Hgg	Hww
(87.22±0.14)%	(86.92±0.65)%	(86.86±0.37)%	(85.86±0.23)%
Hzz	Htautau	Hpp	All
(90.68±0.57)%	(88.28±0.41)%	(87.92±2.26)%	(86.69±0.11)%

Semi-lepton Hww/Hzz have more muons-> higher efficiency in isolep selection

Assuming 10% more/less Hww/Hzz -> tiny effect

Summary

	Hbb	Hcc	Hgg
Imperfect modeling	0.04%	2%	0.52%
Hww	-0.07%,0.02%	7,3%,-7.6%	7.8%-7.9%
Hzz	-0.06%,0.03%	-07%,0.7%	-1.0%,0.83%
Lepton Veto	0.03%	tiny	tiny
Jet nPFO and Jet costheta, yth-value	To be set		
Jet pair mass	-0.01%,0.02%	0, 0.9%	-2.56,2.97%
Flavor Template	coming soon		
Isolation cut(non-uniformity)	tiy		