Measurability of Anomalous ttH Couplings at the ILC 1.

Analysis procedure is similar with our VVH analysis.

KEK/SOKENDAI

Motivation.

>. The top quark is the heaviest particle in the SM.

>. Its Yukawa coupling to the Higgs is also the strongest and has a important role.

>. Some deviations might appear in this ttH coupling.

>. Direct measurement using ttH vertex with ILC.

>. The ttH coupling with CP-mixed Higgs CP phase are parametrized;

$$g_{\Phi tt} = -i\frac{e}{s_W}\frac{m_t}{2M_W}\left((1+a)+ib\gamma_5\right) \qquad \phi_{CP} \equiv \arctan(b/a+1)$$

>. a and b are independent.

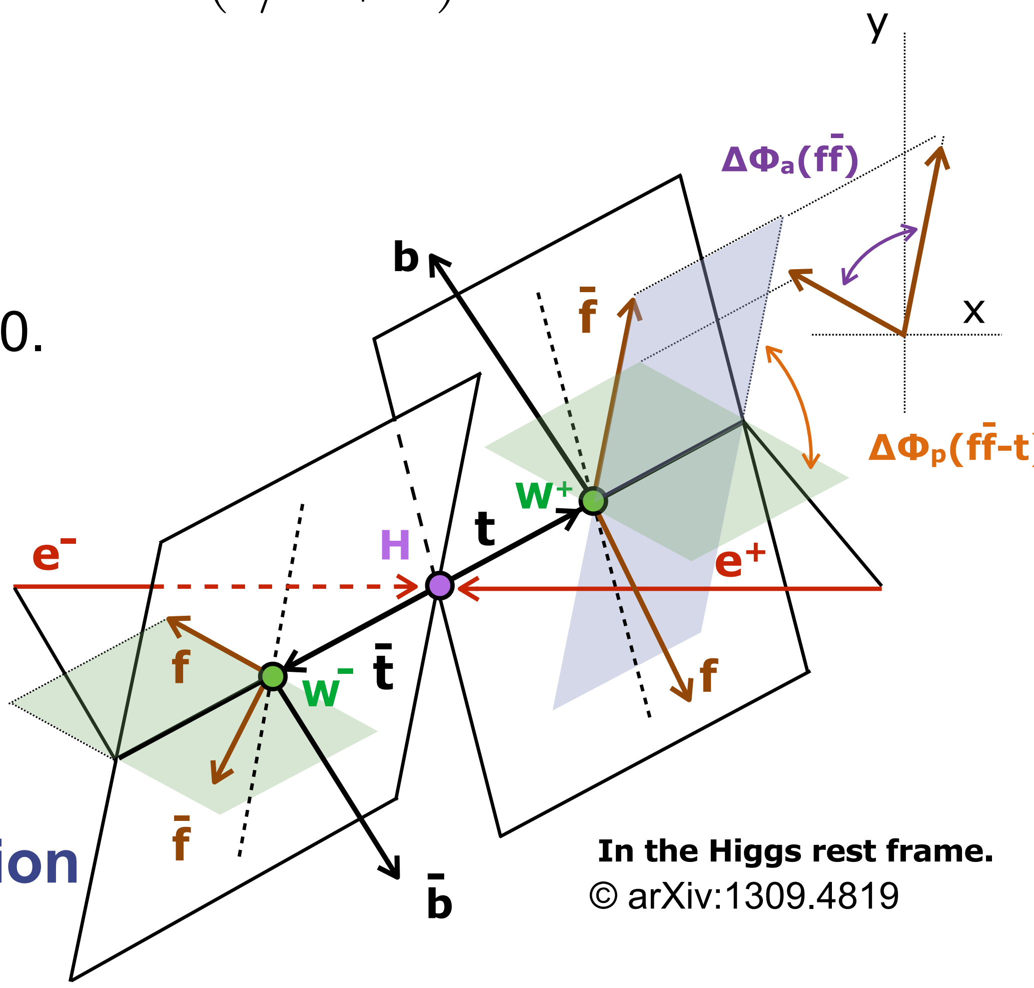
>. In the SM coefficients are given by a=0, b=0.

>. A pure pseudo-scalar coupling is given by a=-1, b≠0.

>. A mixed state of a Higgs is given by a≠-1, b≠0.

>. Angular observables exhibit a clear difference between the scalar and pseudo-scalar processes.

>. Exploiting angular/spin correlation and polarization of a top pair is useful to extract CP information.



In the Higgs rest frame.

© arXiv:1309.4819

Momentum/Angular Distributions.

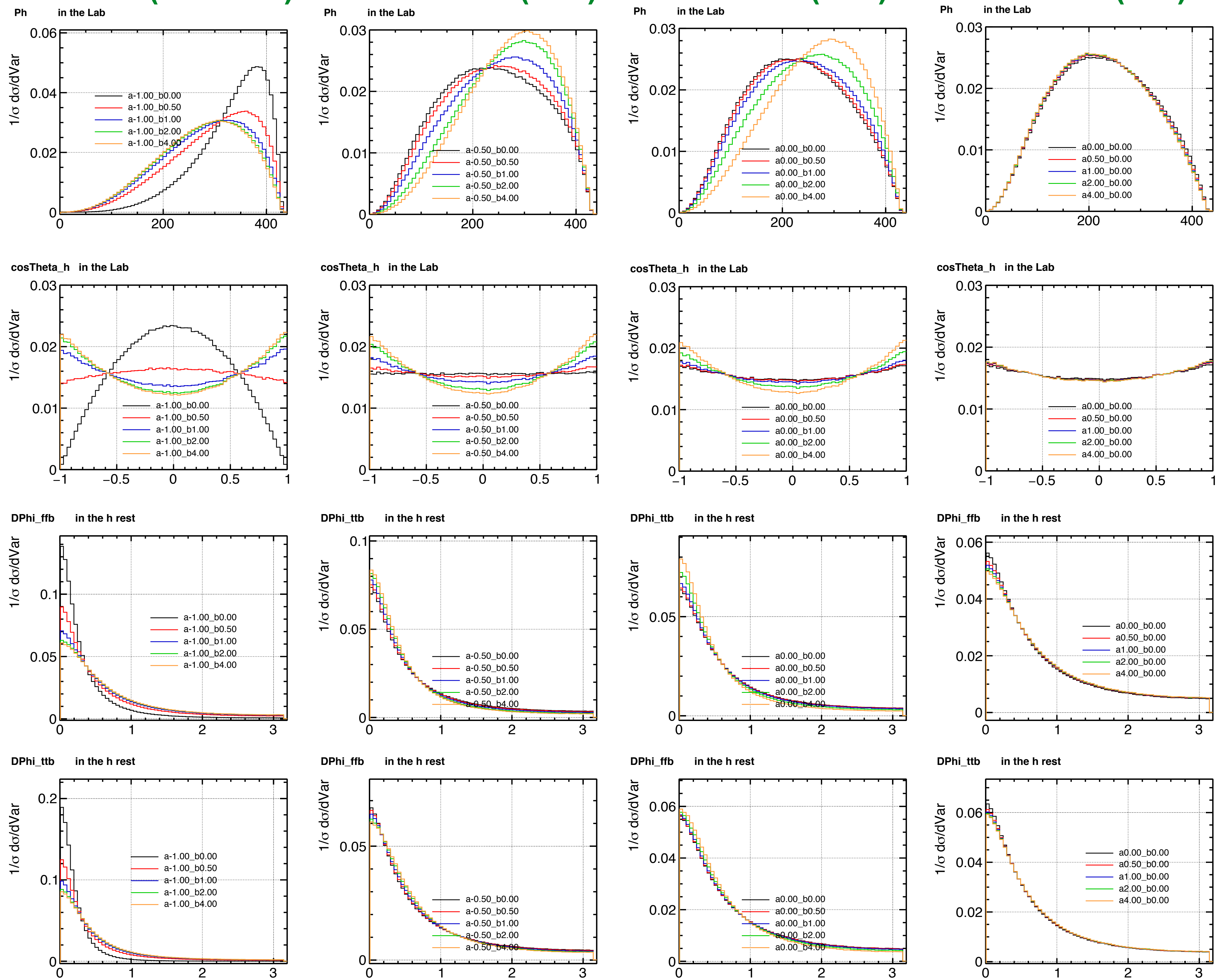
a=-1 b=X (Pseudo) | a=-0.5 b=X(Mix) | a=0 b=X(Mix) | a=X b=0 (SM)

Hmom in Lab.

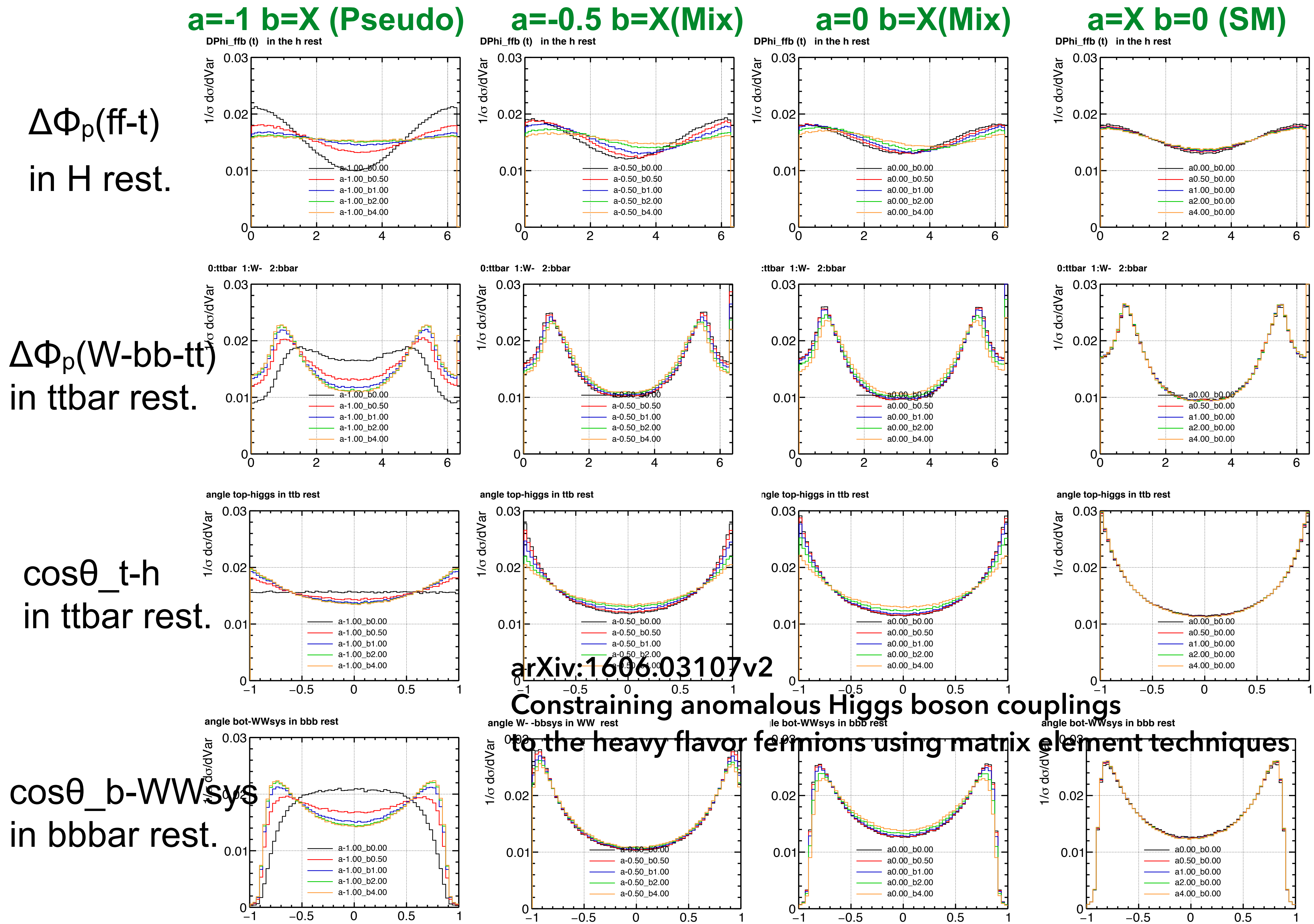
cosθh in Lab.

ΔΦa_ff in H rest.

ΔΦa_tt in H rest.



Momentum/Angular Distributions.



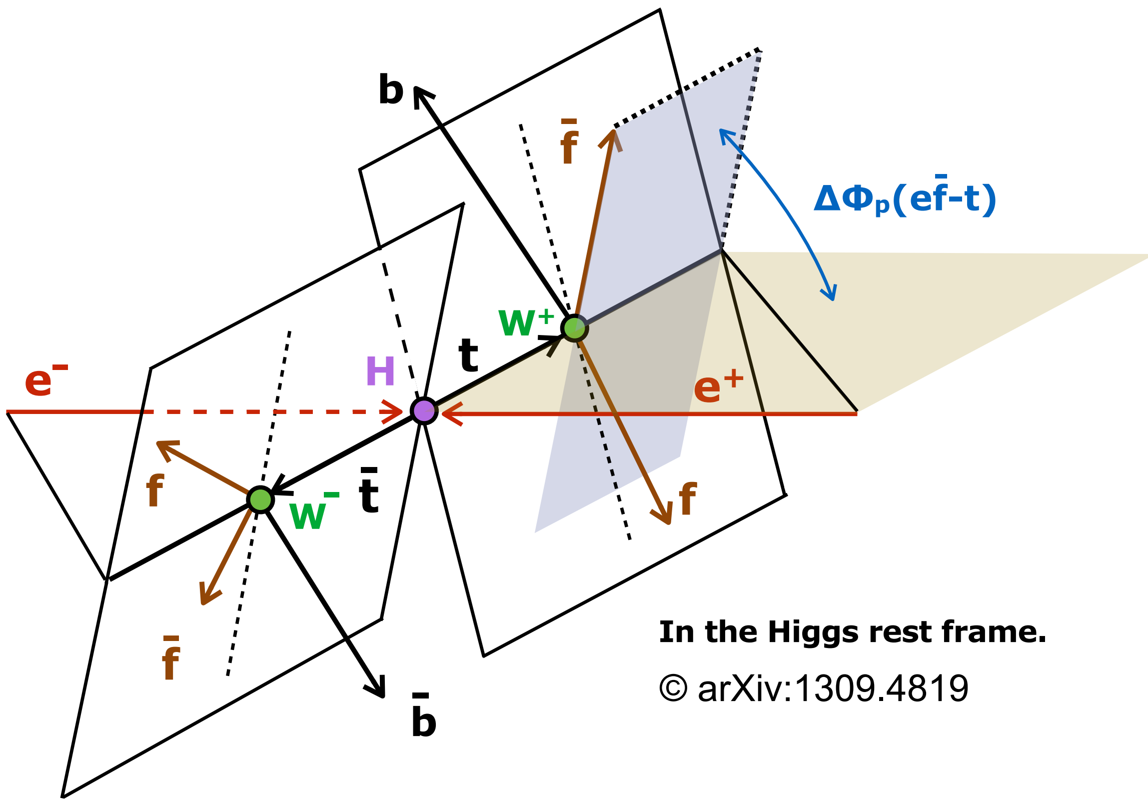
arXiv:1606.03107v2

Constraining anomalous Higgs boson couplings to the heavy flavor fermions using matrix element techniques

Angular Distributions: ttH→4qlν+bb.

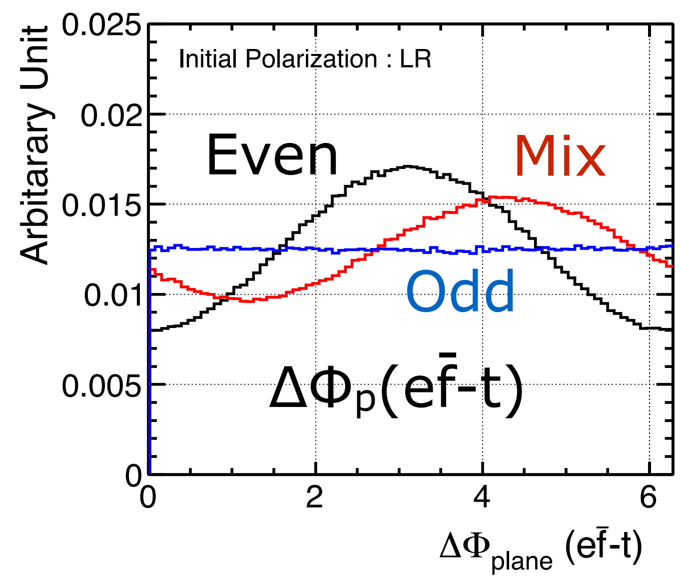
>. The top spin info. is translated to the dists. of the decay products and it is not polluted by the effects of strong interaction.

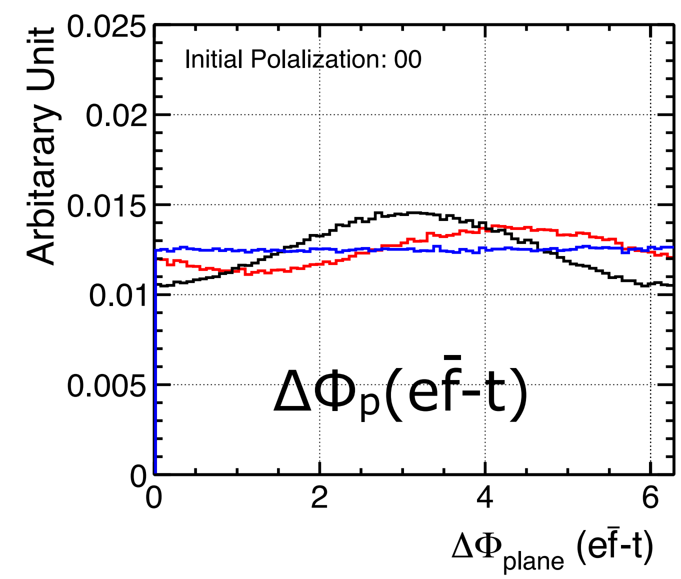
>. Lepton angular dists. in the decay of top is not affected by any non-SM effects in the decay vertex.



In the Higgs rest frame.

© arXiv:1309.4819





$$\Delta\Phi_p(f\bar{f};t)\ [-\pi \le \Delta\Phi_p \le \pi]$$

$$= \begin{cases} (\cos\xi \le 0), & \arctan(\frac{\sin\xi}{\cos\xi}) \\ (\cos\xi \ge 0), & \arctan(\frac{\sin\xi}{\cos\xi}) + \pi\cdot\mathrm{sgn}(\sin\xi) \end{cases}$$

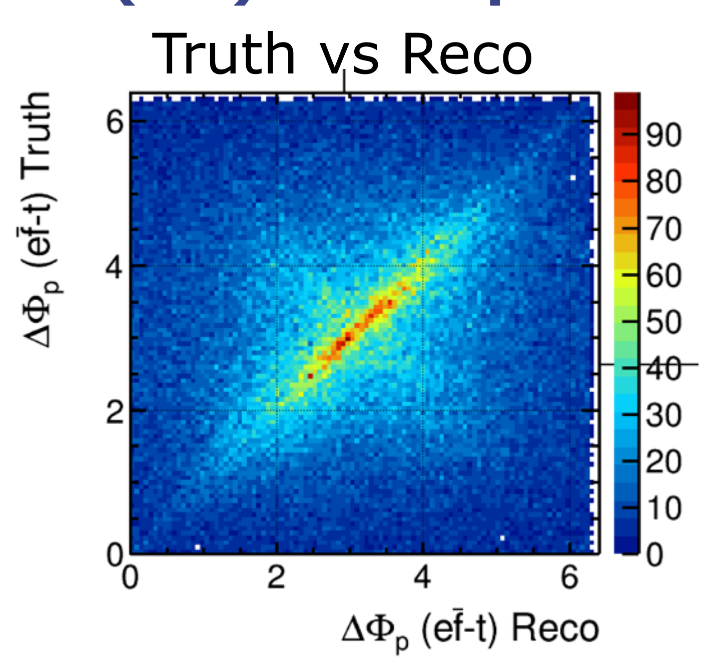
$$\sin\xi = \hat{\boldsymbol{P}}_t \cdot [(\hat{\boldsymbol{P}}_t \times \hat{\boldsymbol{P}}_f) \times (\hat{\boldsymbol{P}}_t \times \hat{\boldsymbol{P}}_{\bar{f}})]$$

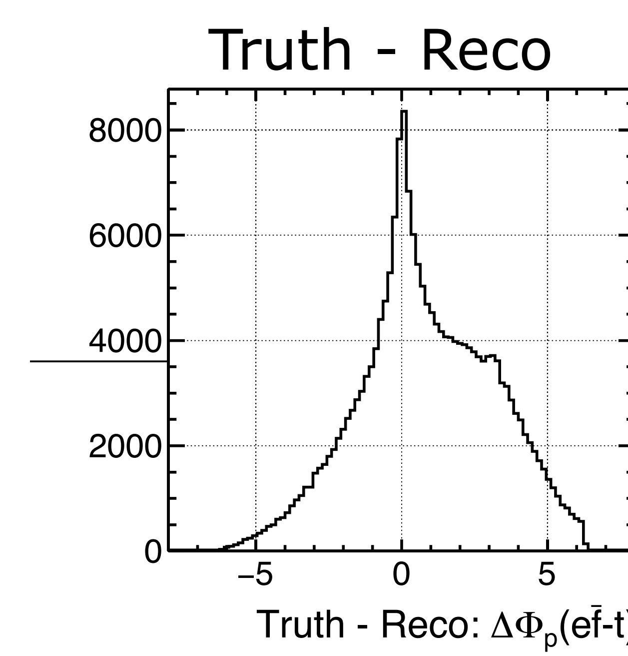
$$\cos\xi = (\hat{\boldsymbol{P}}_t \times \hat{\boldsymbol{P}}_f) \times (\hat{\boldsymbol{P}}_t \times \hat{\boldsymbol{P}}_{\bar{f}})$$

Axis:top l^-: $l^- \to e^+$

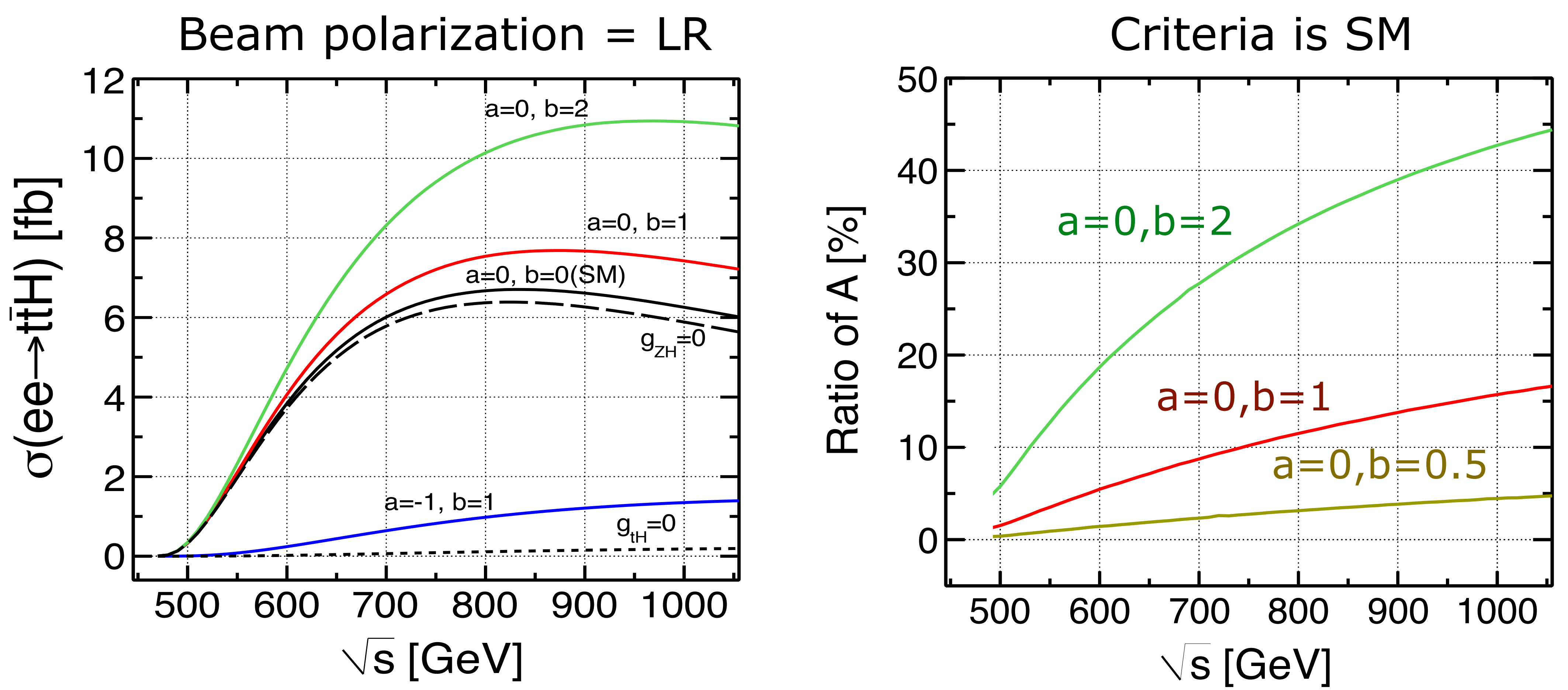
l^+: $e^- \to l^+$

>. (ex.) ttH→4qlν+bb at 500GeV.





Pseudo-scalar: ECM vs Total σ(ee→ttH)



> Power of kinematical information for anomalous couplings.

>. Construct momentum/angular distributions.

	X(physsim)	selection effi	ratio of A	
@500GeV: σtth	~ 0.4(SM) *1000(L)	* 20% = 80	* 1.5%(b=1) ~ 1	→ useless
@550GeV: σtth	~ 2.0(SM) *1000(L)	* 20% = 400	* 4 %(b=1) ~ 16	
@600GeV: σtth	~ 4.0(SM) *1000(L)	* 20% = 800	* 6 %(b=1) ~ 48	→ possible?
@ 1 TeV: σtth	~ 6.0(SM) *1000(L)	* 20% = 1200	* 15 %(b=1) ~ 180	→ possible

* @500GeV nominal σ (whizard) LR ~ 0.809

Rough Estimation At 500GeV.

CP-violating interaction contributes to the electric dipole moment (EDM).
Any EDM constraints are not imposed here.

>. No information on momentum/angular distributions.

>. Distributions can not be available due to lack of events & low contamination of A.

>. Information we can rely on is only Xsec probably.

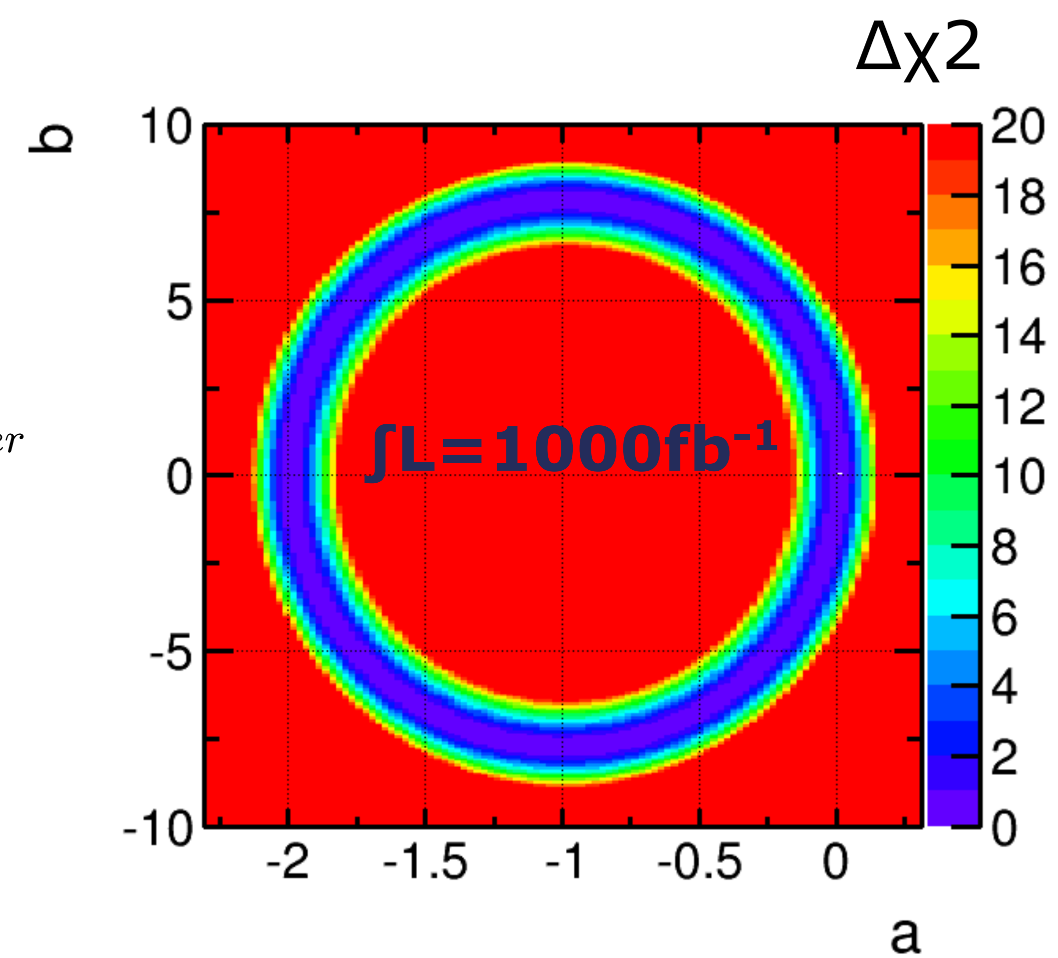
>. Estimate sensitivity roughly for anomalous parameters in the a–b plane.

$$\Delta\chi^2 = \left[\frac{N^{SM}\cdot\epsilon - N^{BSM}\cdot\epsilon}{\delta\sigma\cdot N^{SM}\cdot\epsilon}\right]^2$$

>. σ_{tth} (LR/RL) = 0.809. / 0.340.
>. N^{SM}, N^{BSM} is calculated analytically.

$$\sigma_{tth} = (1+a)^2\cdot\sigma_{tth}^{SM} + b^2\cdot\sigma_{tth}^{Pseudo} + (1+a)b\cdot\sigma_{tth}^{Inter}$$

>. $\delta\sigma_{tth}$ ~ 10% (with 500fb-1)
>. ε ~ 20% (selection efficiency)



Rough Estimation At 600GeV.

>. My interest 600GeV. But no official samples.

>. What I can do is to assume reasonably and estimate it roughly.

>. At 600 GeV pseudo-scalar component could be relatively large.

>. Angular dist. will be observed because remaining events will be much.

>. σ_{tth} (LR/RL) = 3.84./1.51 (Physsim), (which are 5 times better than that of 500.)

>. $\delta\sigma_{tth}$ ~ 10% (@500GeVwith 500fb-1) / **Sqrt(5)** .

>. ε ~ 20% (selection efficiency for N).

$N_{remainng}$ = $\sigma_{tth\ (h\text{->}bb)}$ 2.30 (eL0.8pR0.3) * 1000(L) * 0.2 (ε)
~ 450 (180+180+90)

>. Angular dist. is divided into 8 bins. (3*3 for 2d)

>. Acceptance for angular info. is 20% for each bin.

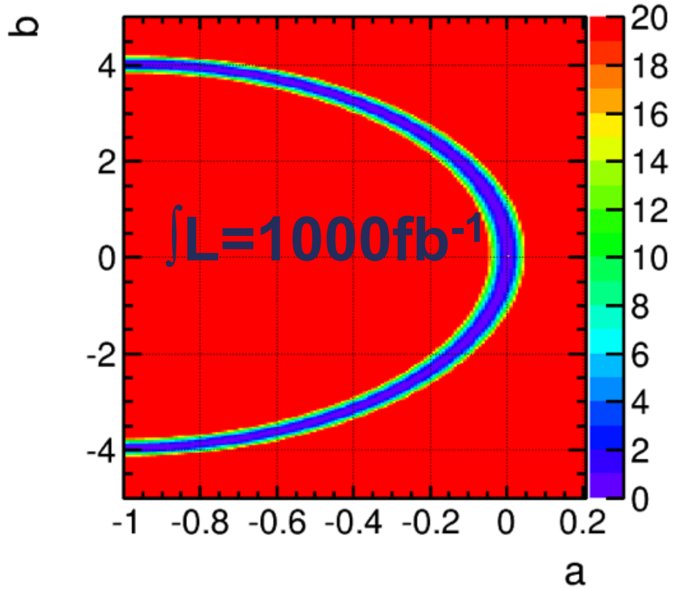
>. Bkgs on each bin are asuumed to be 10 time more.

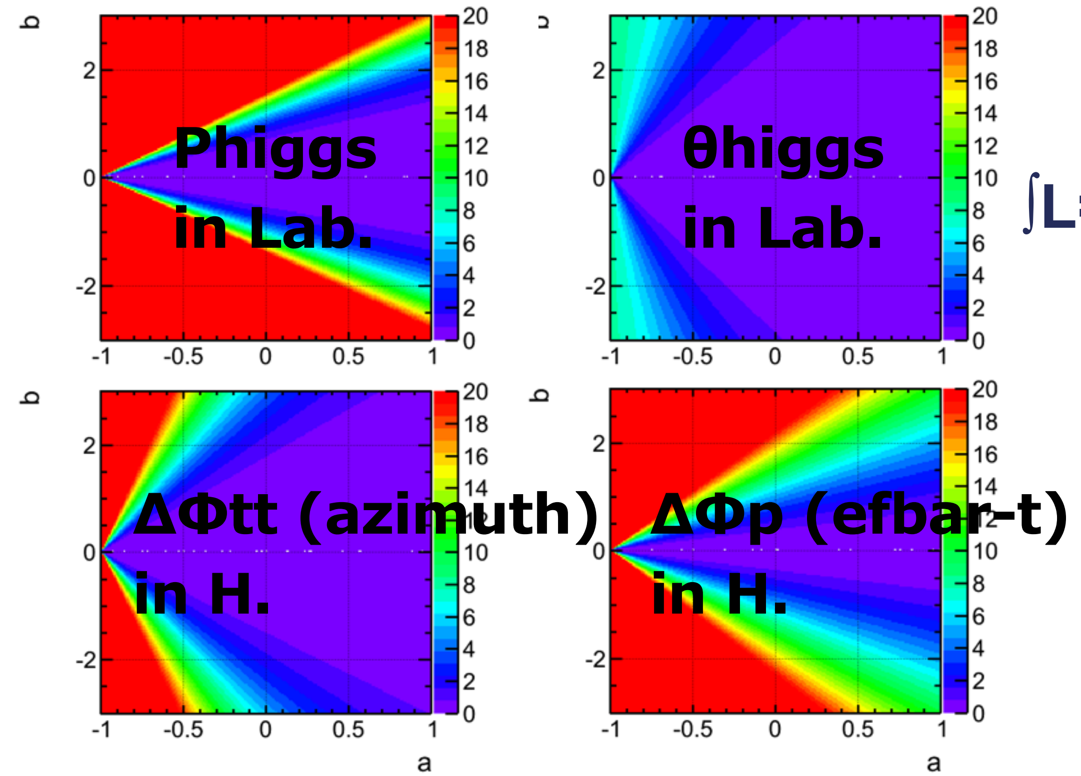
>. NErr on each bin is estimated by √(S+B).

$$\chi^2 = \sum_{i=1}^{n}\sum_{j=1}^{n}\left[\frac{N^{SM}(x_{ij})\cdot f_{ij} - N^{BSM}(x_{ij};a,b)\cdot f_{ij}}{\delta N^{SM}(x_{ij})}\right]^2 + \left[\frac{N^{SM}\cdot\epsilon - N^{BSM}\cdot\epsilon}{\delta\sigma\cdot N^{SM}\cdot\epsilon}\right]^2$$

Rough Estimation At 600GeV.

>. Only Xsec info.





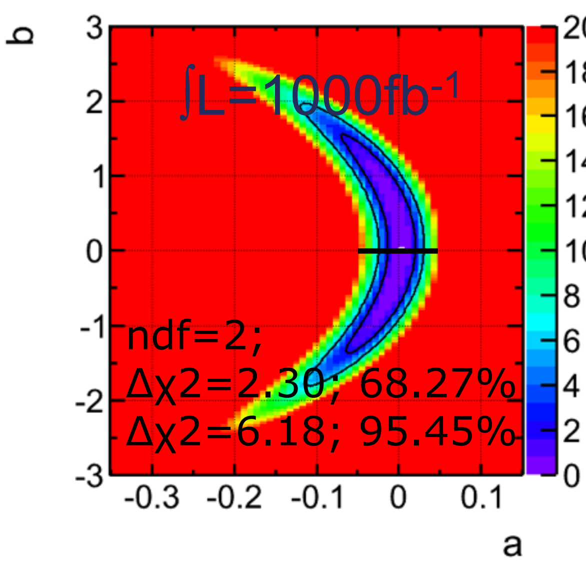
$\int L=1000fb^{-1}$

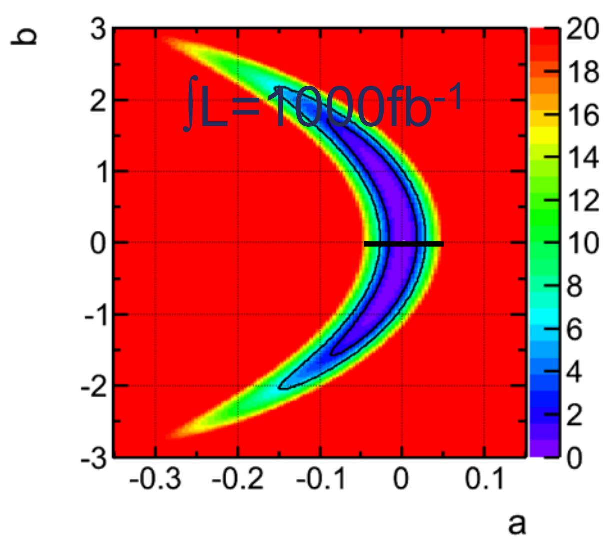
$\Delta\chi 2$

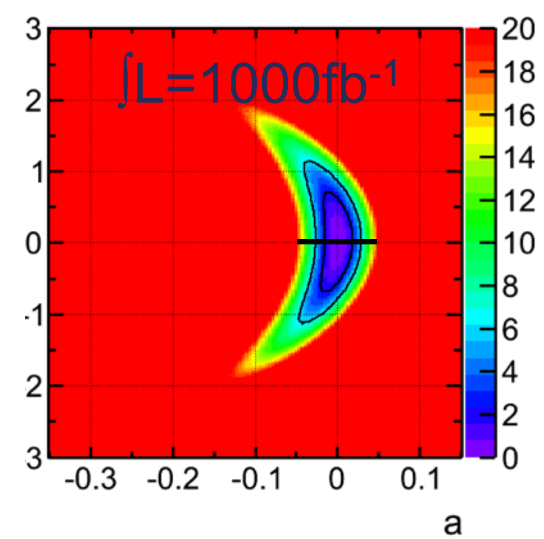
>. Only 1 angular info. is used (Ph).

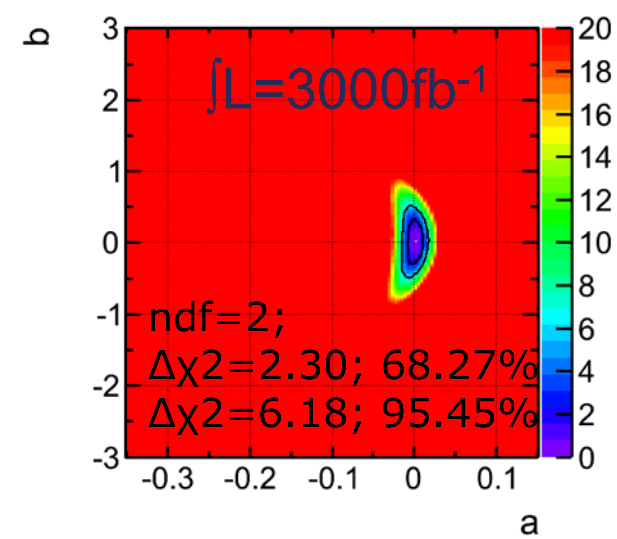
>. 2d info. is used.

(Ph,cosθ). (Ph,ΔΦ).









a=1-0.12, b=2.0
ArcTan(2.0/0.88) ~ 1.16
CP-phase Φcp: ~ 0.37π

a=1-0.05, b=1.2
ArcTan(1.2/0.95) ~ 0.90
CP-phase Φcp: ~ 0.29π

a=1-0.015, b=0.5
ArcTan(0.5/0.985) ~ 0.47
CP-phase Φcp: ~ 0.15π

Move on 1TeV.

Ecm = 1TeV.

>. Sigs.

>. ttH→4qlv+bb / 6q+bb / 2q2l2v+bb

>. σ_{tth} (LR/RL) = 5.89697. / 2.65115.

>. Beam (Pe^-,Pe^+)=(-0.8,+0.3).

>. L=1000fb^{-1}

@ 1 TeV information

http://www-jlc.kek.jp/~miyamoto/CDS/mc-dbd.log/generated/1000-B1b_ws/tth/

>. Bkgs.

>. Interfering BGs (same final state: ttbb).

- EW : ttZ -> ttbb
- QCD: ttg -> ttbb (g->bb: dominant)

>. Non-interfering BGs (but, huge cross sections).

- ttbar

(Hard gluon emission from bottom quarks.)

(Fraction of mis-reconstruction and/or failure of b-tag lead to significant BGs)

Ecm = 1TeV.

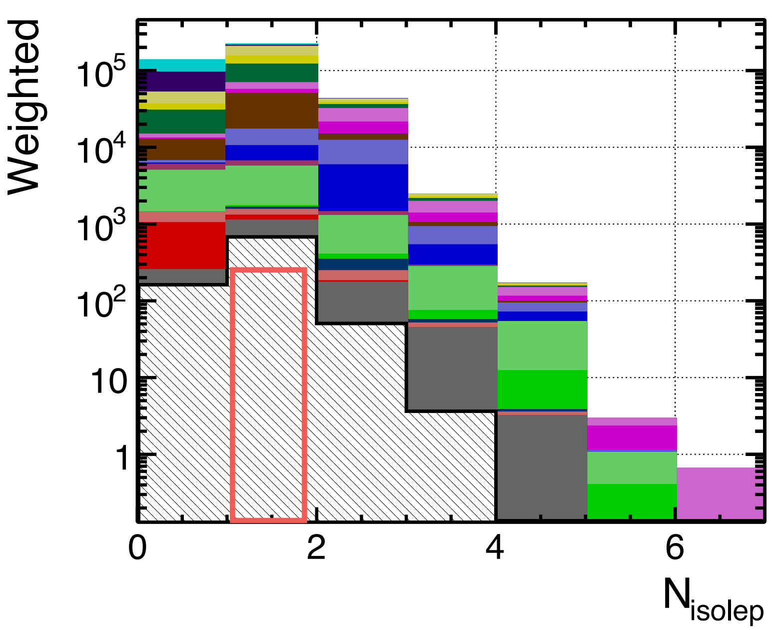
>. Reconstruction chain.

```
<processor name="myRootFileProcessor"/>
<processor name="myTauJetFinder"/>          (suehara's tau finding)
<processor name="myIsoLepExtractor"/>       (old method with measured E)
<processor name="MyFastJetProcessor"/>      (for removal of γγ overlay)
<processor name="MyUndoJetProcessor"/>

<processor name="MyVertexFinder"/>
     <processor name="MyJetClusteringAndFlavorTag_6Jets"/> or
     <processor name="MyJetClusteringAndFlavorTag_8Jets"/> or
     <processor name="MyJetClusteringAndFlavorTag_4Jets"/>
<processor name="MyThrustReconstruction"/>
<processor name="MySphericityProcessor"/>
<processor name="myTTHAnalyzer"/>
```

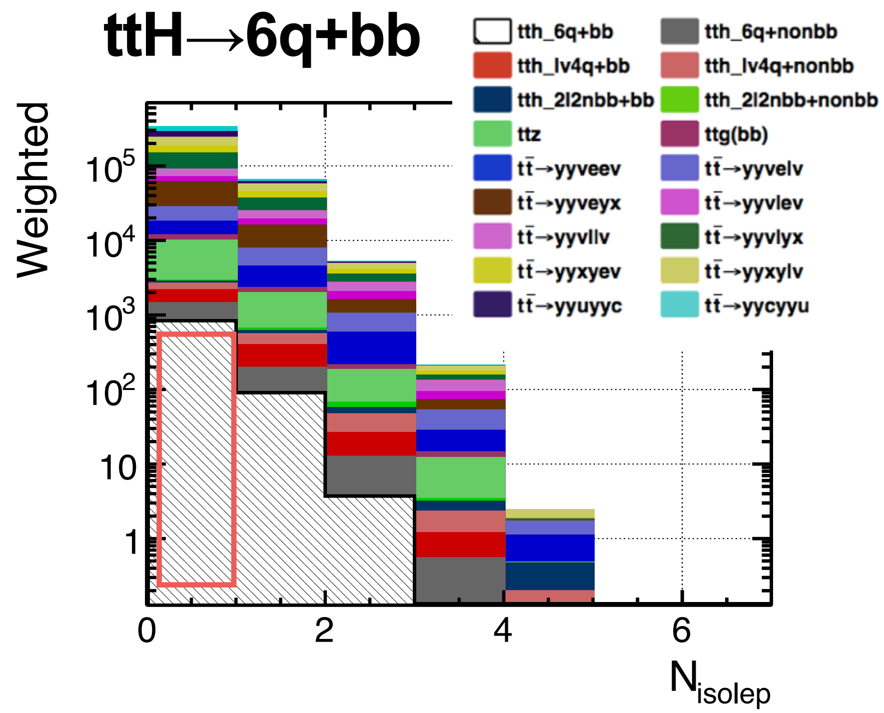
>. #IsoLeptons.

ttH→4qlν+bb



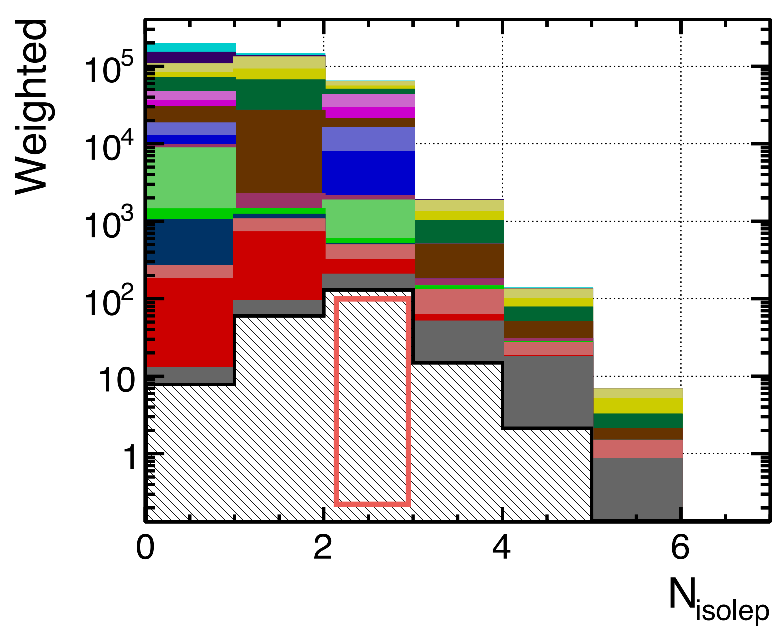
Evnts with 1 IsoLep ~ 76.0%

ttH→6q+bb



Evnts with 0 IsoLep ~ 90.6%

ttH→2q2l2ν+bb

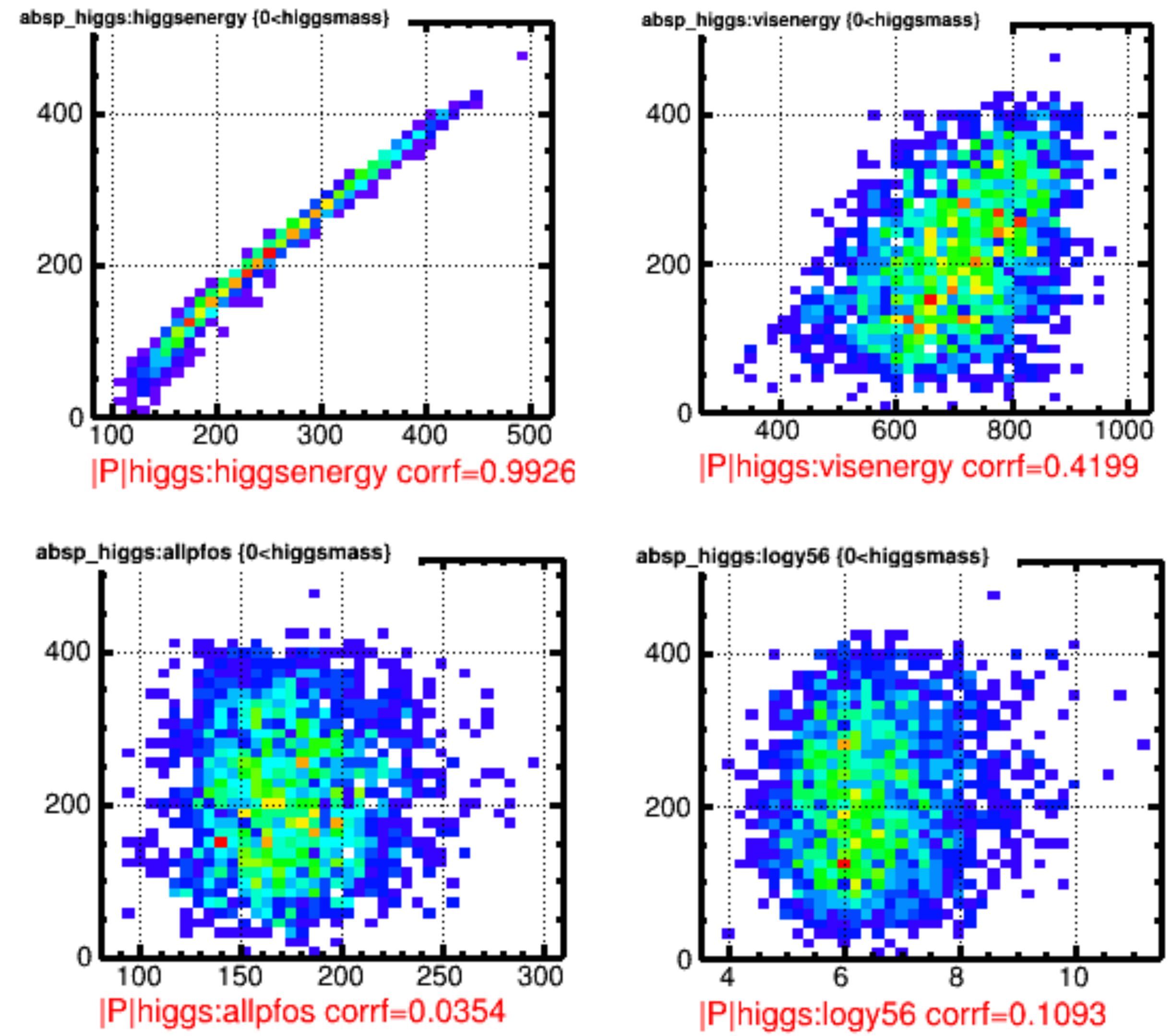


Evnts with 2 IsoLep ~ 60.9%

>. I did not optimize carefully this time, there is still room for improvement of results.

Event Selection.

Correlation between Phiggs vs observables.



>. Strong information to distinguish anomalous couplings is angular dists.
→ No angular cut.

>. Momentum is also useful info. to distinguish it
→ Correlated observables with it should not be used.

>. What we can use is event topology.

>. Cut region is determined by a scan so as to maximize signal significance.

>. Significance (ttH→4qlv+bb) : $S/\sqrt{(S + B)}$ = 4.84 effi: 19.84
>. Significance (ttH→6q +bb) : $S/\sqrt{(S + B)}$ = 5.79 effi: 22.21
>. Significance (ttH→2q2l2v+bb) : $S/\sqrt{(S + B)}$ = 2.71 effi: 17.59

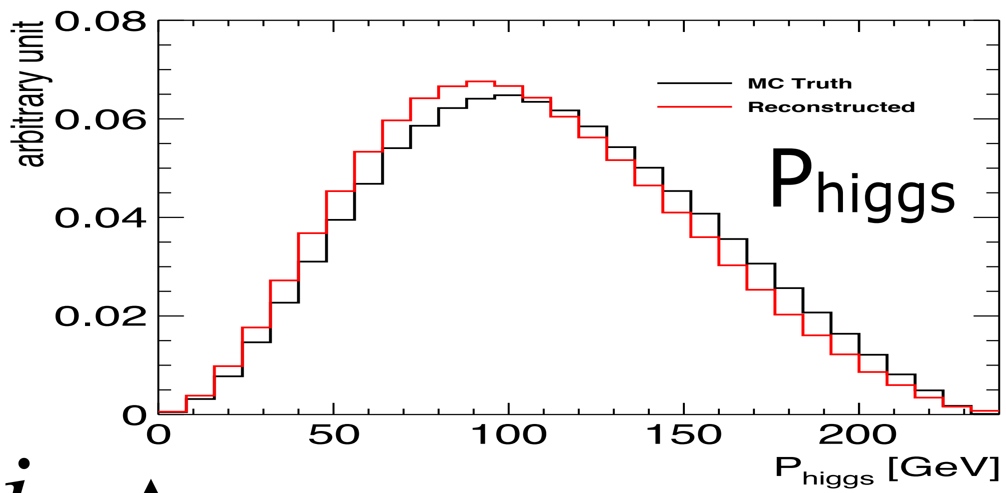
arXiv:1409.7157v4
T. Price[a,1], P. Roloff[b,2], J. Strube[c,3,5], T. Tanabe[d,4]

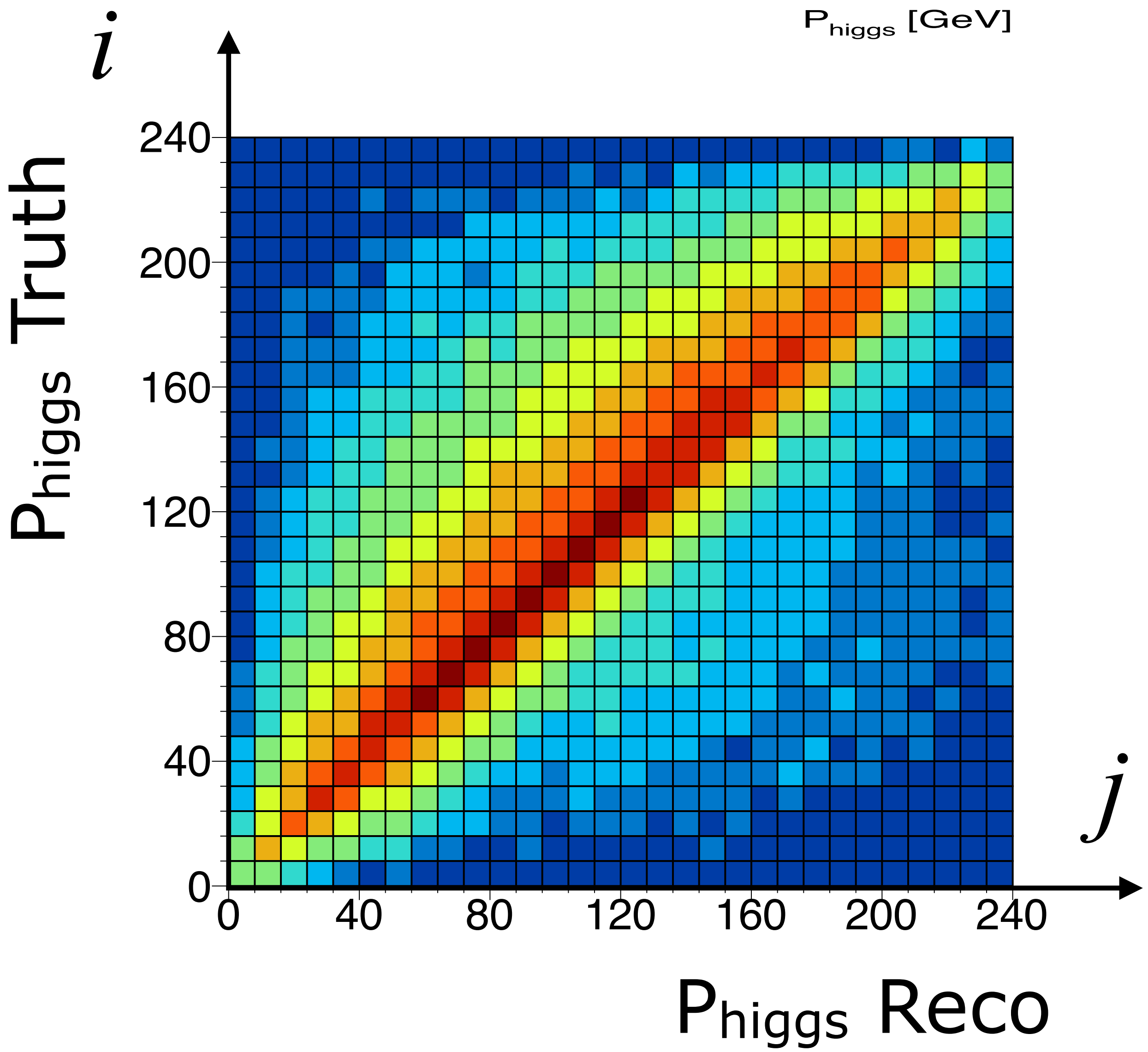
The selection efficiencies for signal events are 33.1% (6jets) and 56.0% (8jets)

Overall Acceptance: f .

>. Need to get acceptance.

$$\chi^2 = \sum_{i=1}^{n} \left[\frac{N^{SM}(x_i) \cdot f_i - N^{BSM}(x_i; a, b) \cdot f_i}{\delta N^{SM}(x_i)} \right]^2$$





1d

$$N^{Reco}(x_j^{Reco}) = \sum_i f(x_j^{Reco}, x_i^{Gene}) \cdot N^{Gene}(x_i^{Gene})$$

$$= \sum_i f_{ji} \cdot N_i^{Gene}$$

$$= \sum_i \bar{f}_{ji} \cdot \eta_i \cdot N_i^{Gene}$$

$$\eta_i \equiv \frac{N_i^{Accept}}{N_i^{Gene}} \quad \text{(Event acceptance.)}$$

$$\bar{f}_{ji} \equiv \frac{N_{ji}^{Accept}}{N_i^{Accept}} \quad \text{(Detector responce function.)}$$

2d

$$N^{Reco}(x_{j\beta}^{Reco}) = \sum_i \sum_\alpha \bar{f}_{j\beta i\alpha} \cdot \eta_{i\alpha} \cdot N_{i\alpha}^{Gene}$$

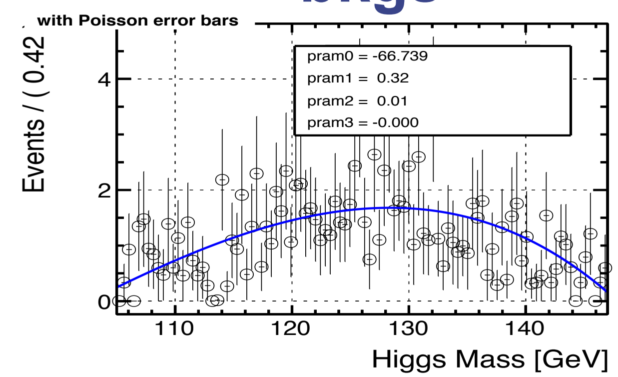
$$\eta_{i\alpha} \equiv \frac{N_{i\alpha}^{Accept}}{N_{i\alpha}^{Gene}} \quad \text{(Event acceptance.)}$$

$$\bar{f}_{j\beta i\alpha} \equiv \frac{N_{j\beta i\alpha}^{Accept}}{N_{i\alpha}^{Accept}} \quad \text{(Detector responce function.)}$$

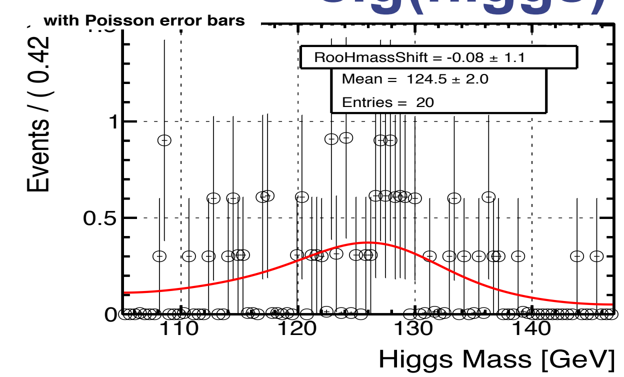
Error of #N on Each Bin: δN.

>. 3rd order polynomial.
>. KEST1,2
>. Combine .

bkgs

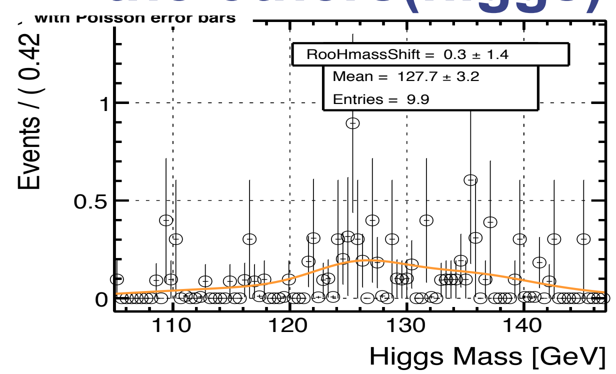


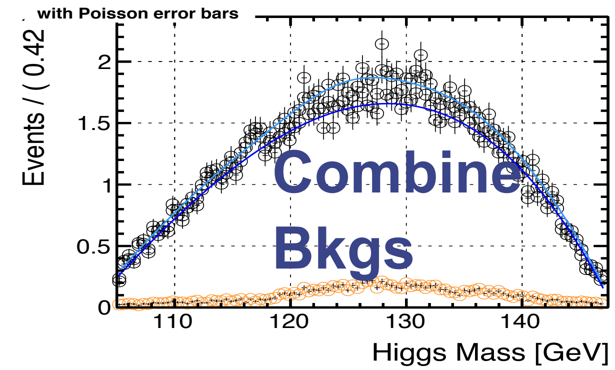
sig(higgs)

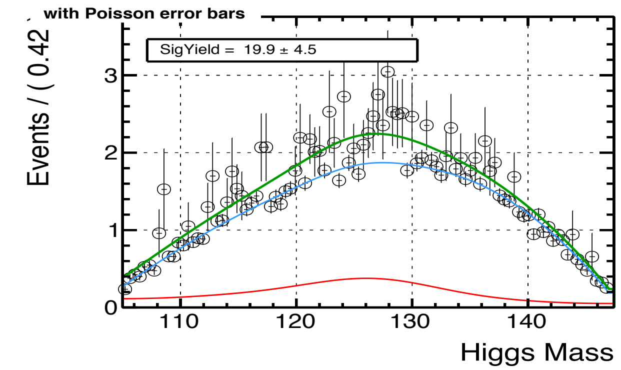


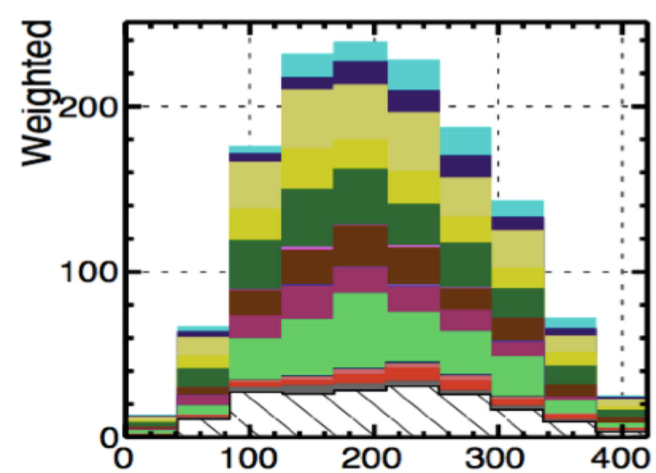
>. ttH→4qlv+bb
>. bin by bin (10).

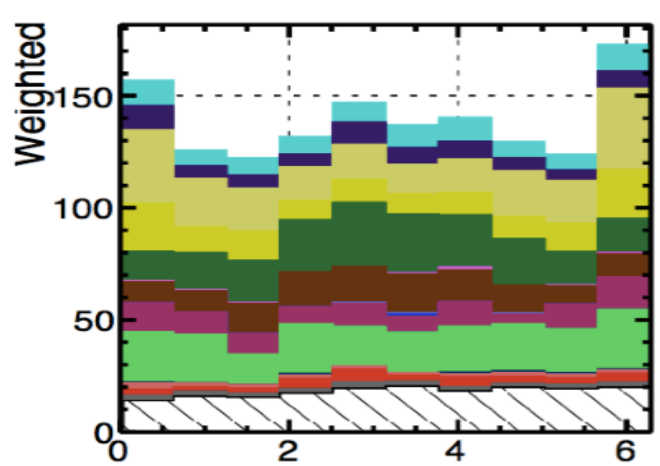
the others(higgs)

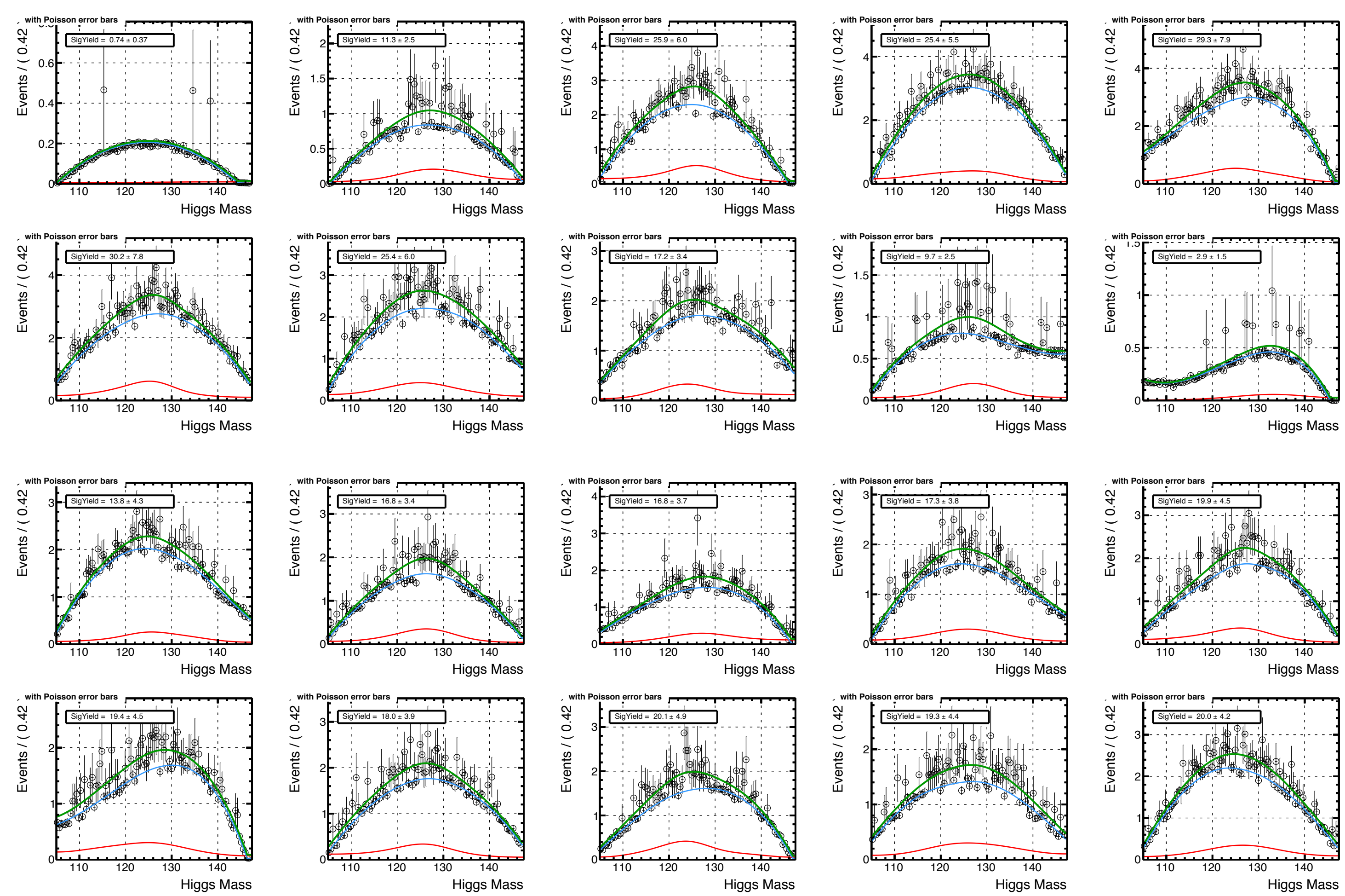












Dists. on Bkgs, Sig, Event/Overall Acceptance.

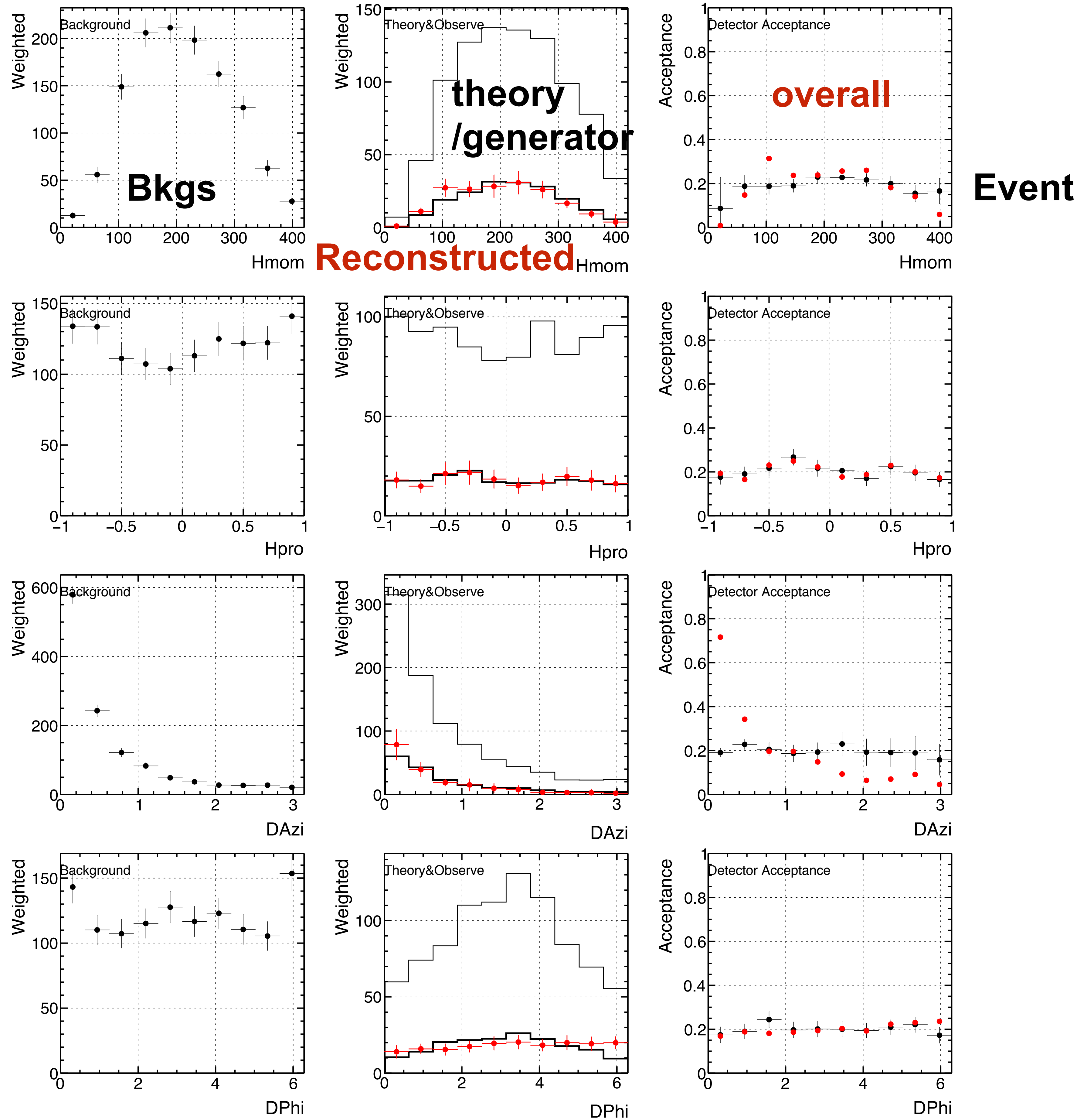
>. ttH→4qlv+bb

Hmom
in Lab.

cosθh
in Lab.

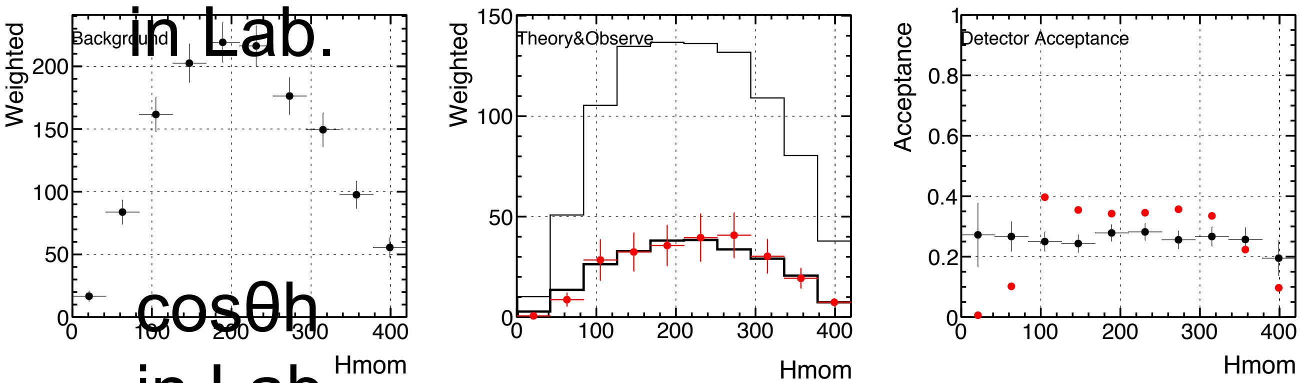
ΔΦa_ff
in H rest.

$\Delta\Phi_p$(ef-t)
in H rest.

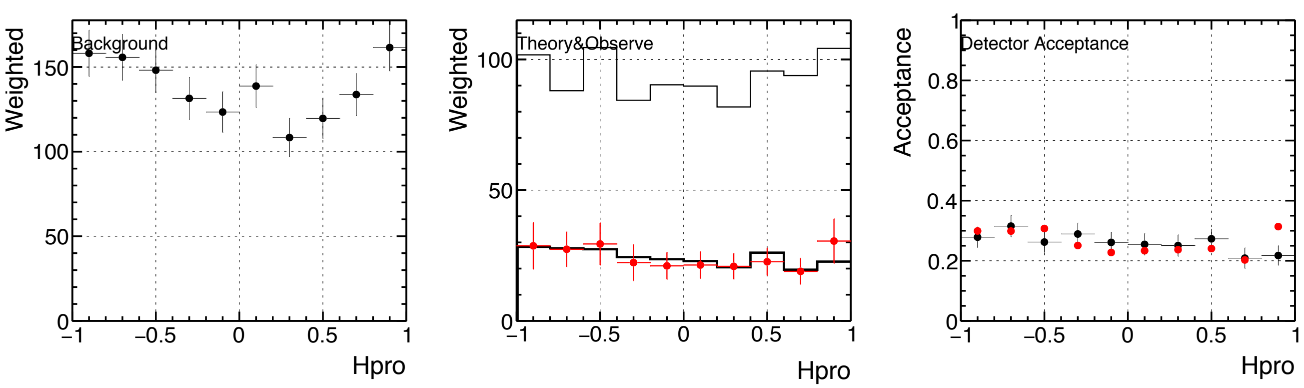


>. ttH→6q+bb

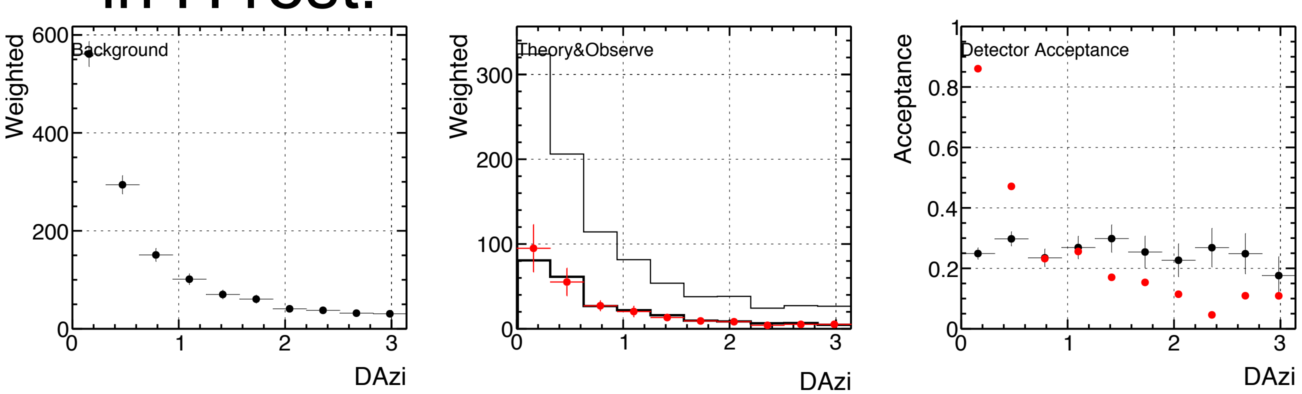
Hmom in Lab.



cosθh in Lab.

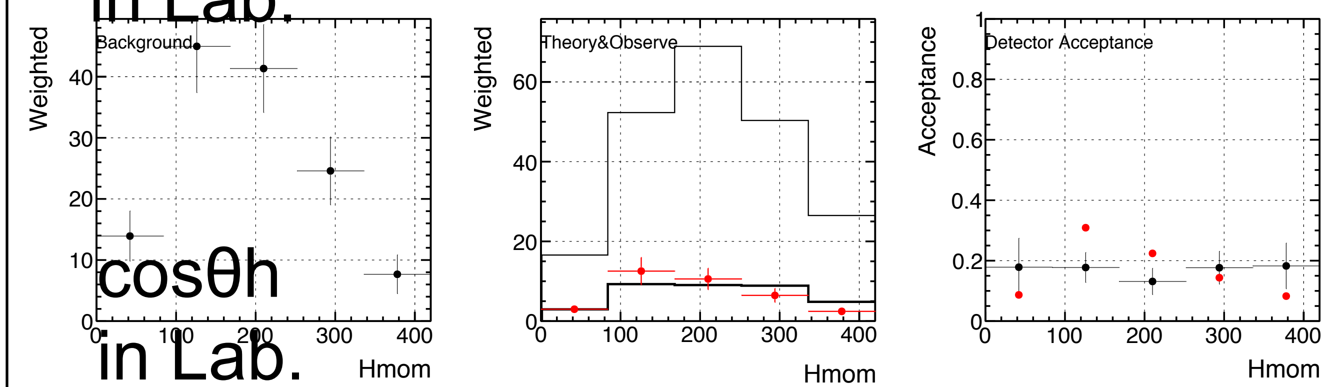


ΔΦa_tt in H rest.

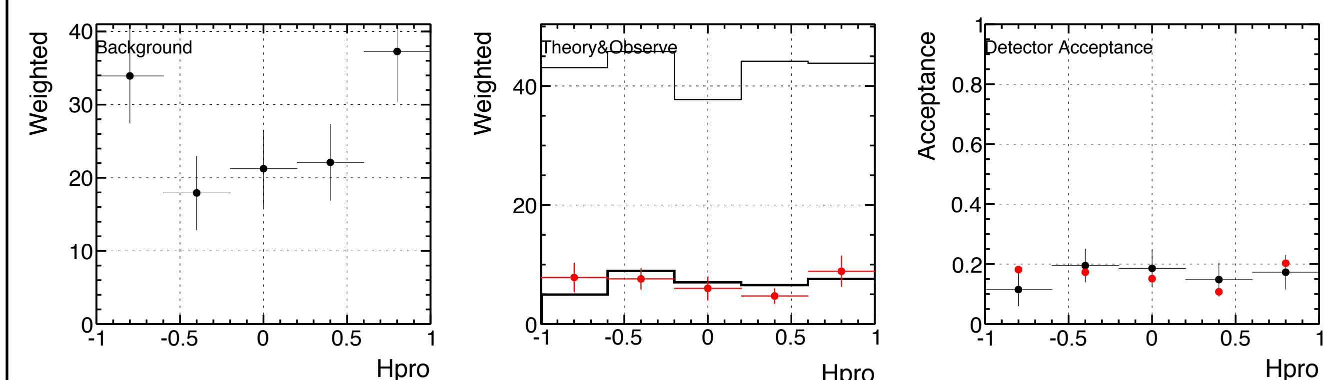


>. ttH→2q2l2v+bb

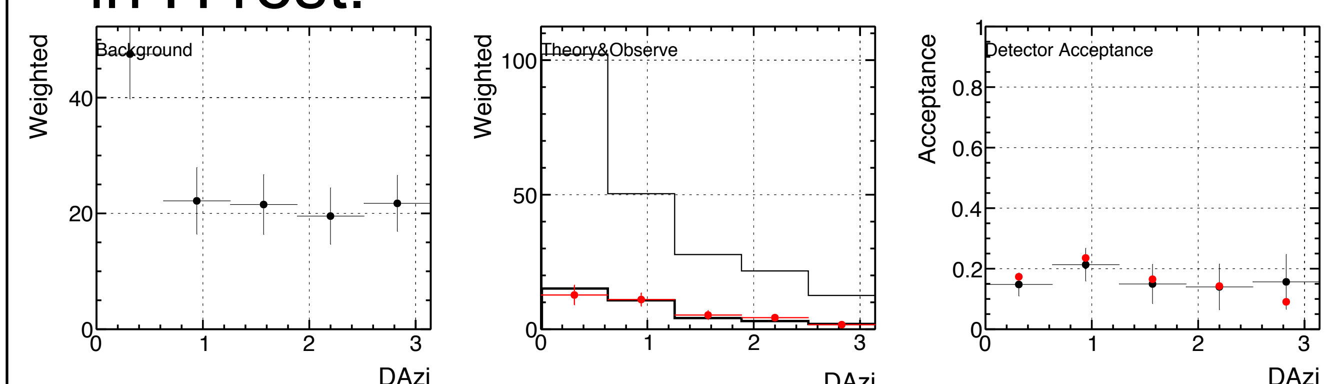
Hmom in Lab.



cosθh in Lab.



ΔΦa_ff in H rest.



Sensitivity to Anomalous Parameters.

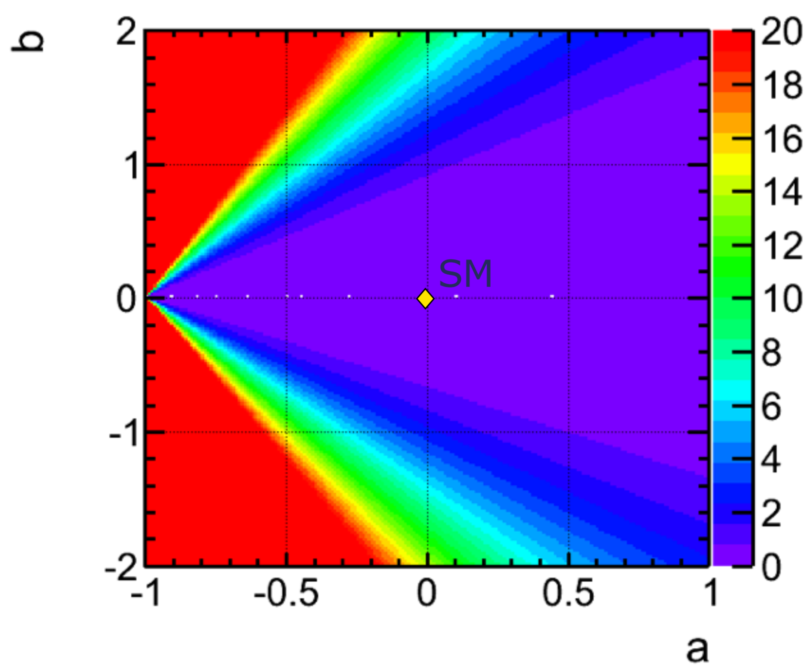
>. Contour plots on sensitivity for anomalous parameters in the a–b plane.

>. Process is **ttH→4qlv+bb** and assumed L is 1000fb-1.

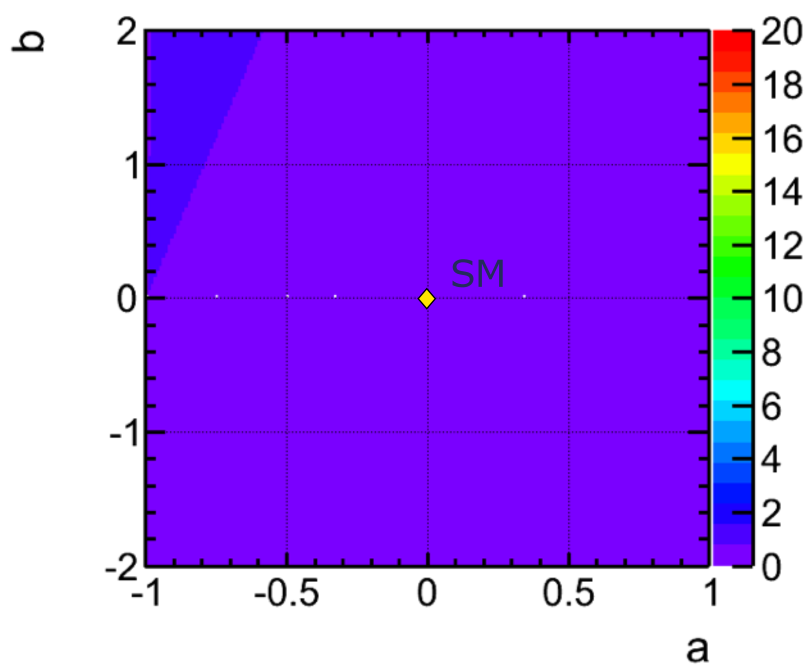
>. Use only momentum/angular distributions.

$$\chi^2 = \sum_{i=1}^{n}\left[\frac{N^{SM}(x_i)\cdot f_i - N^{BSM}(x_i;a,b)\cdot f_i}{\delta N^{SM}(x_i)}\right]^2$$

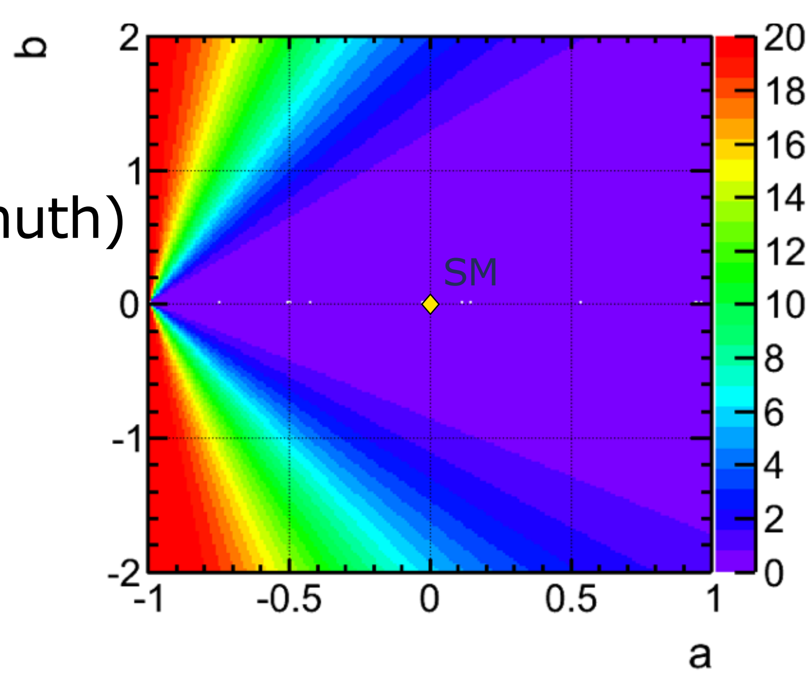
Phiggs in Lab.



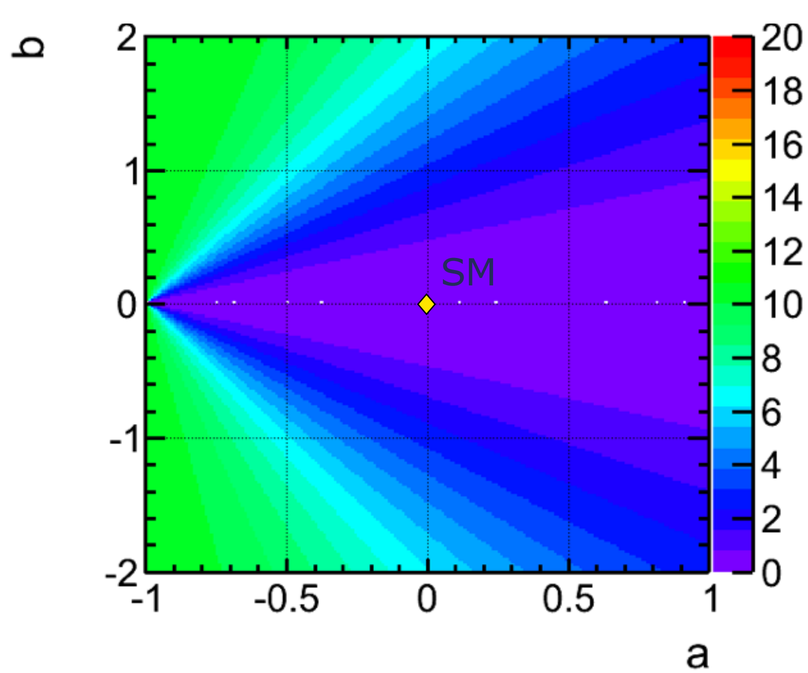
θhiggs in Lab.



ΔΦtt (azimuth) in H.



ΔΦp (efbar-t) in H.



Sensitivity to Anomalous Parameters.

>. **Contour plots on sensitivity for anomalous parameters in the a–b plane.**

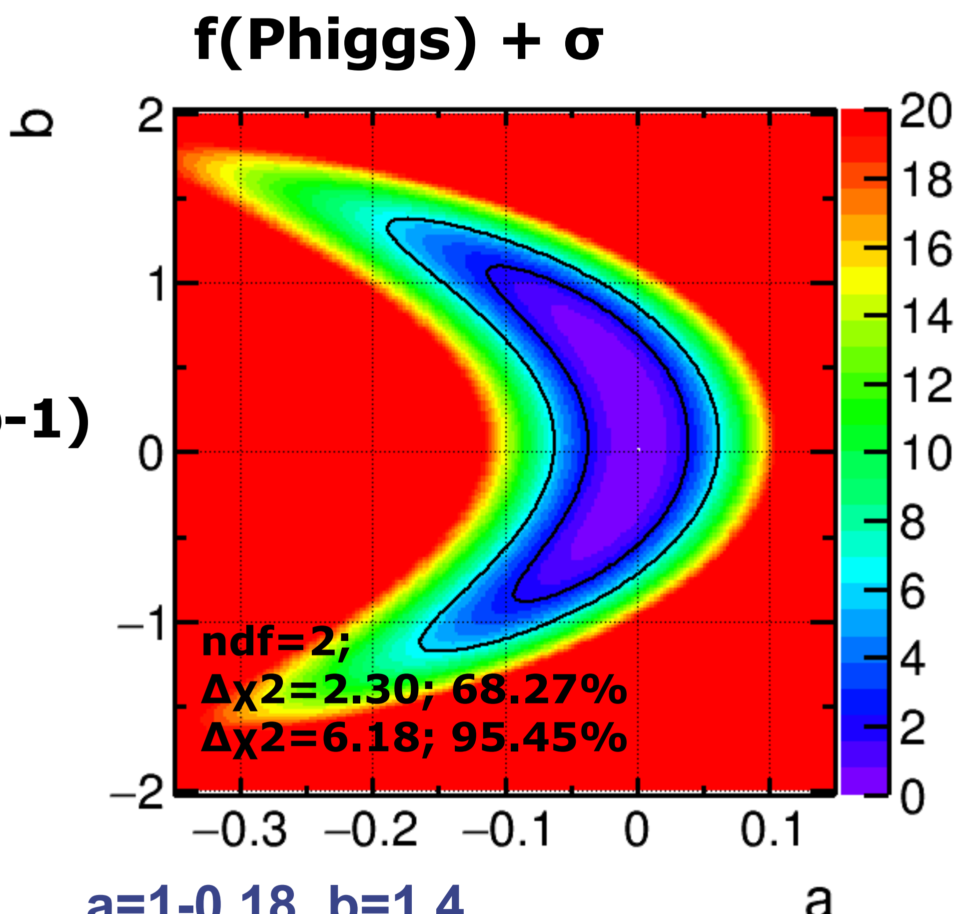
>. Process is **ttH→4qlv+bb** and assumed L is 1000fb-1.

>. Use only momentum/angular distributions. **+ Cross section effect.**

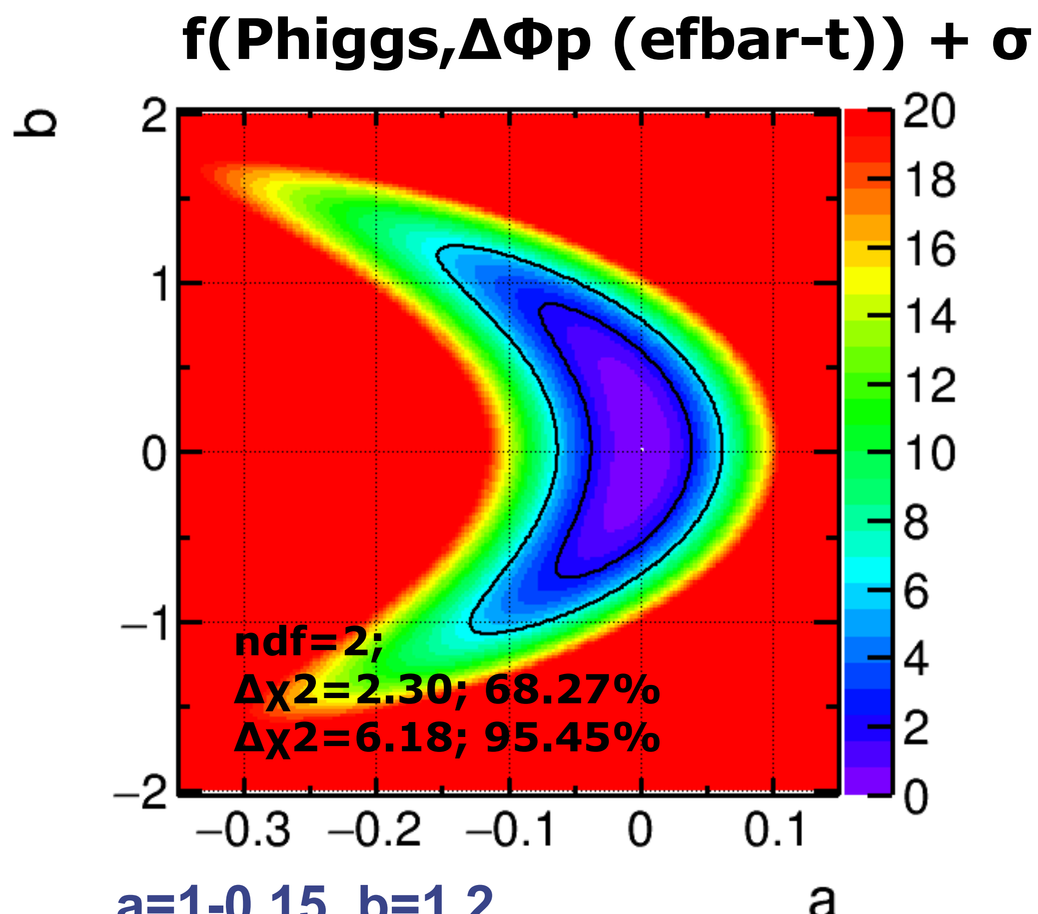
>. **Excluded Region on Φ_{cp}** $\phi_{CP} \equiv \arctan(b/a+1)$

$\int L=1000fb^{-1}$

$\delta\sigma_{tth}$~5% (with 1000fb-1)



a=1-0.18, b=1.4
ArcTan(1.4/0.82) ~ 1.04
CP-phase Φcp: ~ 0.33π (95%C.L.)



a=1-0.15, b=1.2
ArcTan(1.2/0.85) ~ 0.95
CP-phase Φcp: ~ 0.30π (95%C.L.)

Excluded Region on Φ_{cp}

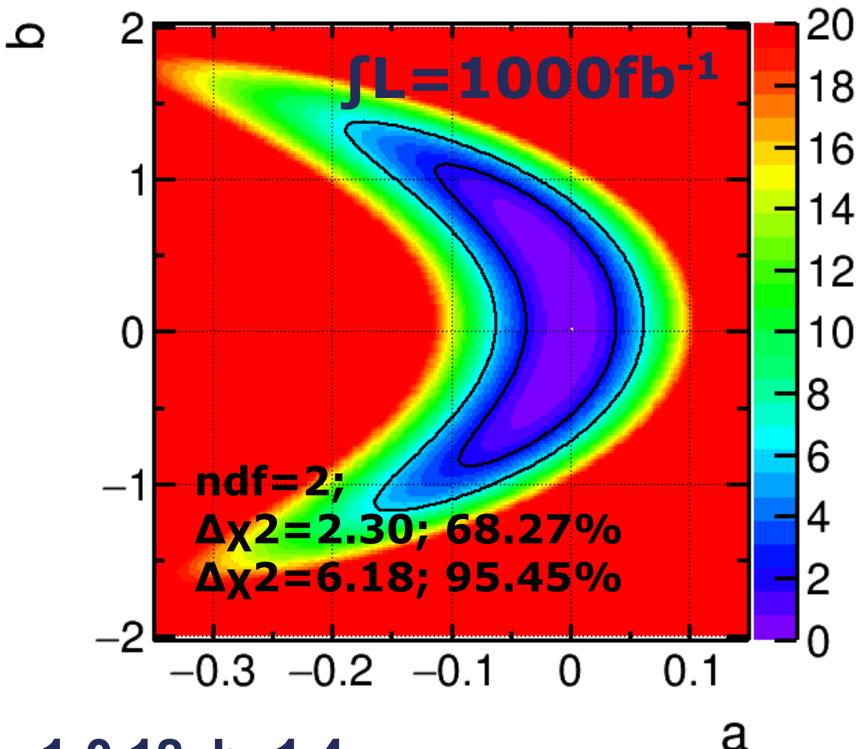
>. Contour plots on sensitivity for anomalous parameters in the a–b plane.

>. Each process on **ttH** and assumed L is 1000fb-1.

>. **Use the only higgs momentum distribution. + Cross section effect.**

ttH→4qlv+bb

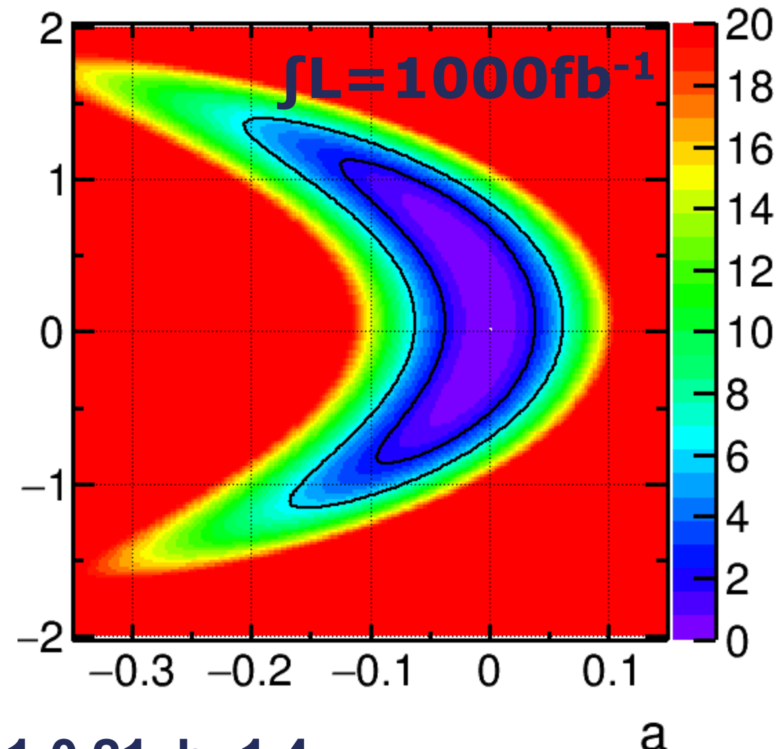
Nsig integral : 180.2
Nbck integral : x
Significance : 4.84
Bins of hist ; 10



a=1-0.18, b=1.4
ArcTan(1.4/0.82) ~ 1.04
CP-phase Φcp: ~ 0.33π (95%C.L.)

ttH→6q+bb

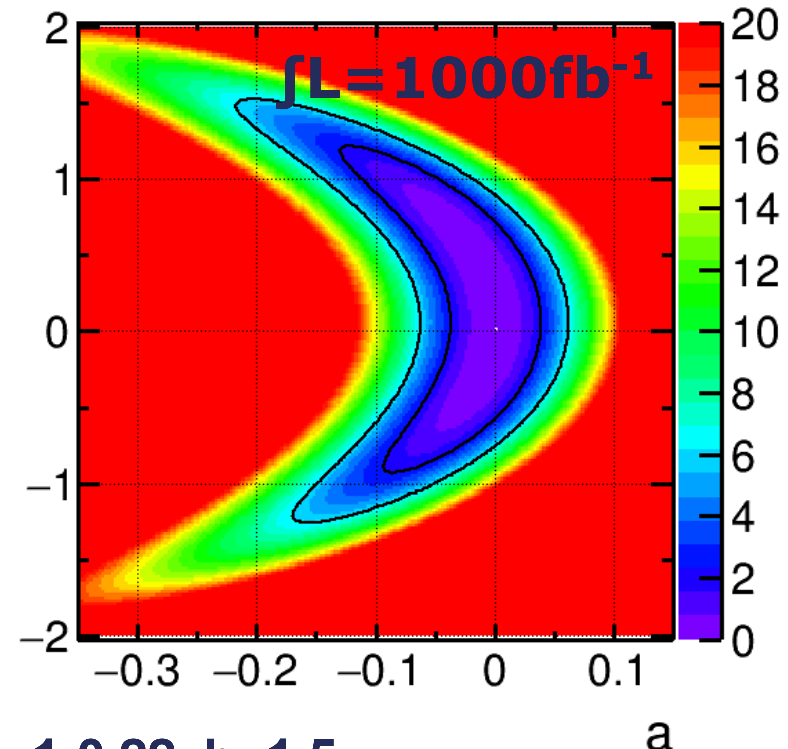
Nsig integral : 217.6
Nbck integral : x
Significance : 5.79
Bins of hist ; 10



a=1-0.21, b=1.4
ArcTan(1.4/0.79) ~ 1.06
CP-phase Φcp: ~ 0.34π (95%C.L.)

ttH→2q2l2v+bb

Nsig integral : 35.0
Nbck integral : 132.4
Significance : 2.71
Bins of hist ; 5



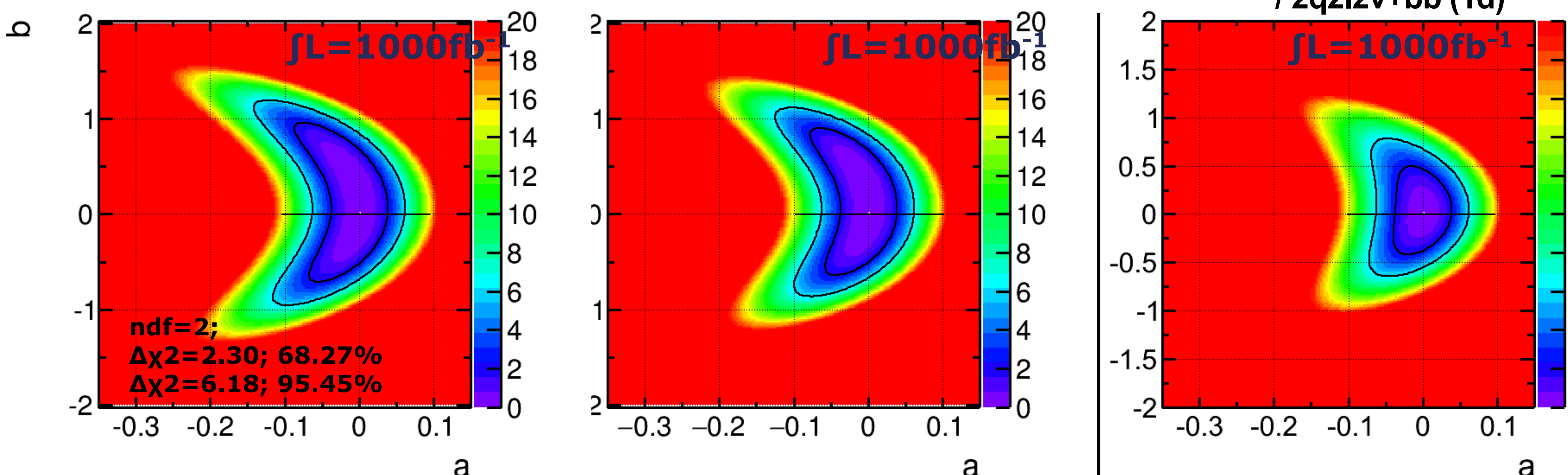
a=1-0.22, b=1.5
ArcTan(1.5/0.78) ~ 1.09
CP-phase Φcp: ~ 0.35π (95%C.L.)

Excluded Region on Φ_{cp}: Combined

>. Contour plots on sensitivity for anomalous parameters in the a–b plane.

>. Each process on **ttH** and assumed L is 1000fb-1.

>. **Use the only higgs momentum distribution. + Cross section effect.**



ttH→4qlv+bb / 6q+bb	ttH→4qlv+bb / 6q+bb / 2q2l2v+bb	ttH→4qlv+bb (2d) / 6q+bb (2d) / 2q2l2v+bb (1d)
a=1-0.14, b=1.2	a=1-0.13, b=1.1	a=1-0.07, b=0.6
ArcTan(1.2/0.86) ~ 0.95	ArcTan(1.1/0.87) ~ 0.94	ArcTan(0.6/0.93) ~ 0.57
CP-phase Φcp: ~ 0.30π (95%C.L.)	CP-phase Φcp: ~ 0.29π (95%C.L.)	CP-phase Φcp: ~0.18π?

>. Φcp > 0.29π is excluded using the only one distribution.

>. If MELA is applied, sensitivity will much better because all dist. is calculated based on mom.

>. 600GeV might has similar sensitivity.

ATLAS Studies on Anomalous ttH.

>. arXiv:1406.1961v2

$$\mathcal{L} \supset -\frac{y_t}{\sqrt{2}}\bar{t}(\cos\xi + i\gamma^5 \sin\xi)th,$$

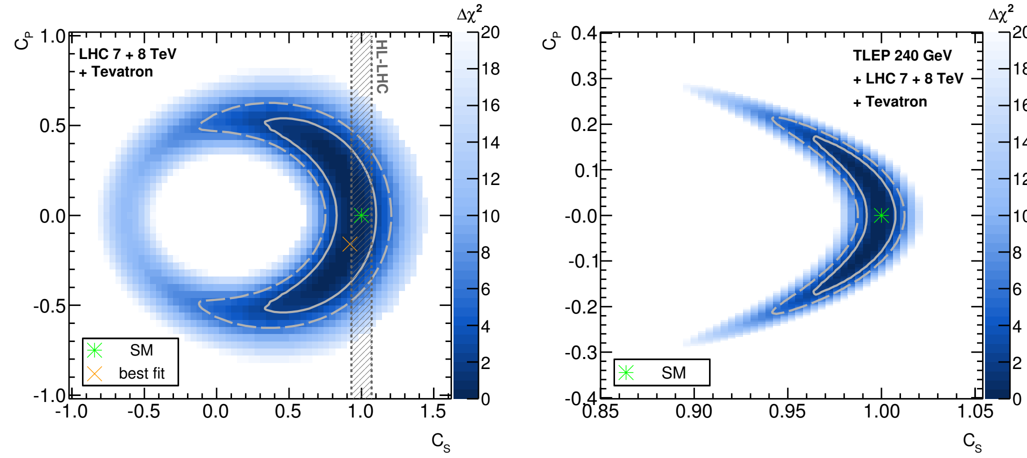


Figure 2. The Higgs data constraints on the anomalous couplings C_S and C_P at the LHC and the expected sensitivity of these couplings at 240 GeV TLEP. The solid and dashed lines correspond to 68% and 95% C.L. respectively. The shadowed region represents the expected measurement uncertainty at HL-LHC.

4 Conclusion

In this paper, we have obtained constraints on the $\mathcal{CP}$-violating top-Higgs couplings using the current Higgs data and found that values of $\mathcal{CP}$-violating phase $|\xi| > 0.6\pi$ are already excluded at 95% C.L.. We expected TLEP to improve this exclusion region to $|\xi| > 0.07\pi$.

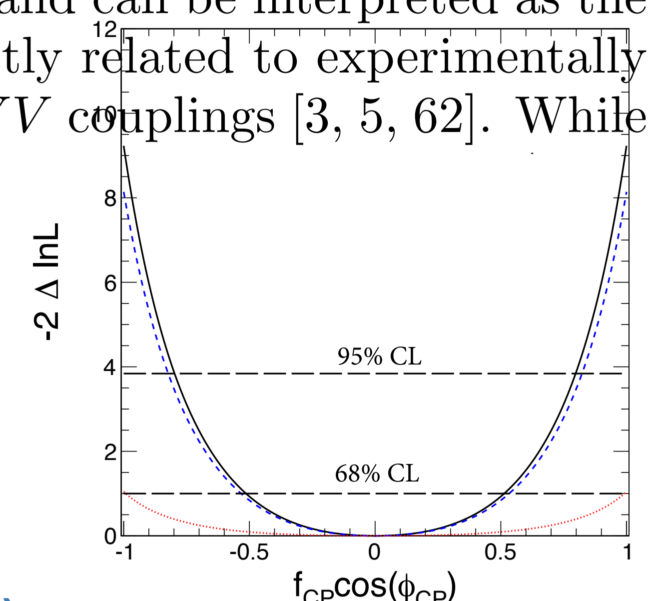
>. arXiv:1606.03107v2 (MELA)

Φcp > ~0.18π(my case)

where the f_{CP} parameter is conveniently bounded between 0 and 1, is uniquely defined, and can be interpreted as the cross section fraction corresponding to the pseudoscalar coupling, and therefore is directly related to experimentally observable effects. It is a convenient counterpart of the f_{a3} parameter defined for the HVV couplings [3, 5, 62]. While

independent

$$\mathcal{L}(Hf\bar{f}) = -\frac{m_f}{v}\bar{\psi}_f\left(\kappa_f + \mathrm{i}\,\tilde{\kappa}_f\gamma_5\right)\psi_f\,H, \qquad f_{CP} = \frac{|\tilde{\kappa}_f|^2}{|\kappa_f|^2 + |\tilde{\kappa}_f|^2}, \quad \phi_{CP} = \arg(\tilde{\kappa}_f/\kappa_f),$$



Scenarios with a sizable CP mixture, $|f_{CP}\cos\phi_{CP}| \gtrsim 0.8$, are excluded at 2σ.

300 fb^{-1} of proton-proton collision data collected at 13 TeV

direct: fcpcos(Φcp) > 0.25. (my case)

Summary.

>. Based on classical method, anom couplings on ttH was studied.

>. Any angular distribution can not be constructed @500GeV because of …

>. Angular/Momentum dists. @1TeV are very useful.

and $\Phi cp > \sim 0.18\pi$ is excluded if we use 2d/1d dimensional dists for all modes.

>. However #N are not many, 2d/1d are limits.

>. MELA(multi dimensional analysis) is the best way for CP of ttH.

>. 600GeV might have similar power with 1TeV.

Plan.

>. IsoLep finding should be improved.

>. Go back to VVH analysis. We decided a plan of analysis for MELA.

>. Come back later.

ttH→4qlv+bb

cut	variable	min		max
cut: 1	nisoleptons	0.500	-	1.500
cut: 2	nvtx2nds	3.500	-	9999.000
cut: 3	visenergy	580.000	-	900.000
cut: 4	maxbtag_higgs	0.505	-	1.100
cut: 5	maxbtag_bbar	0.638	-	1.100
cut: 6	allpfos	153.500	-	256.500
cut: 7	logy45	3.500	-	5.610
cut: 8	logy56	4.060	-	8.320
cut: 9	printhrust	0.566	-	0.866
cut: 10	btagsum_higgs	0.980	-	1000.000
cut: 11	higgsmass	105.000	-	147.000

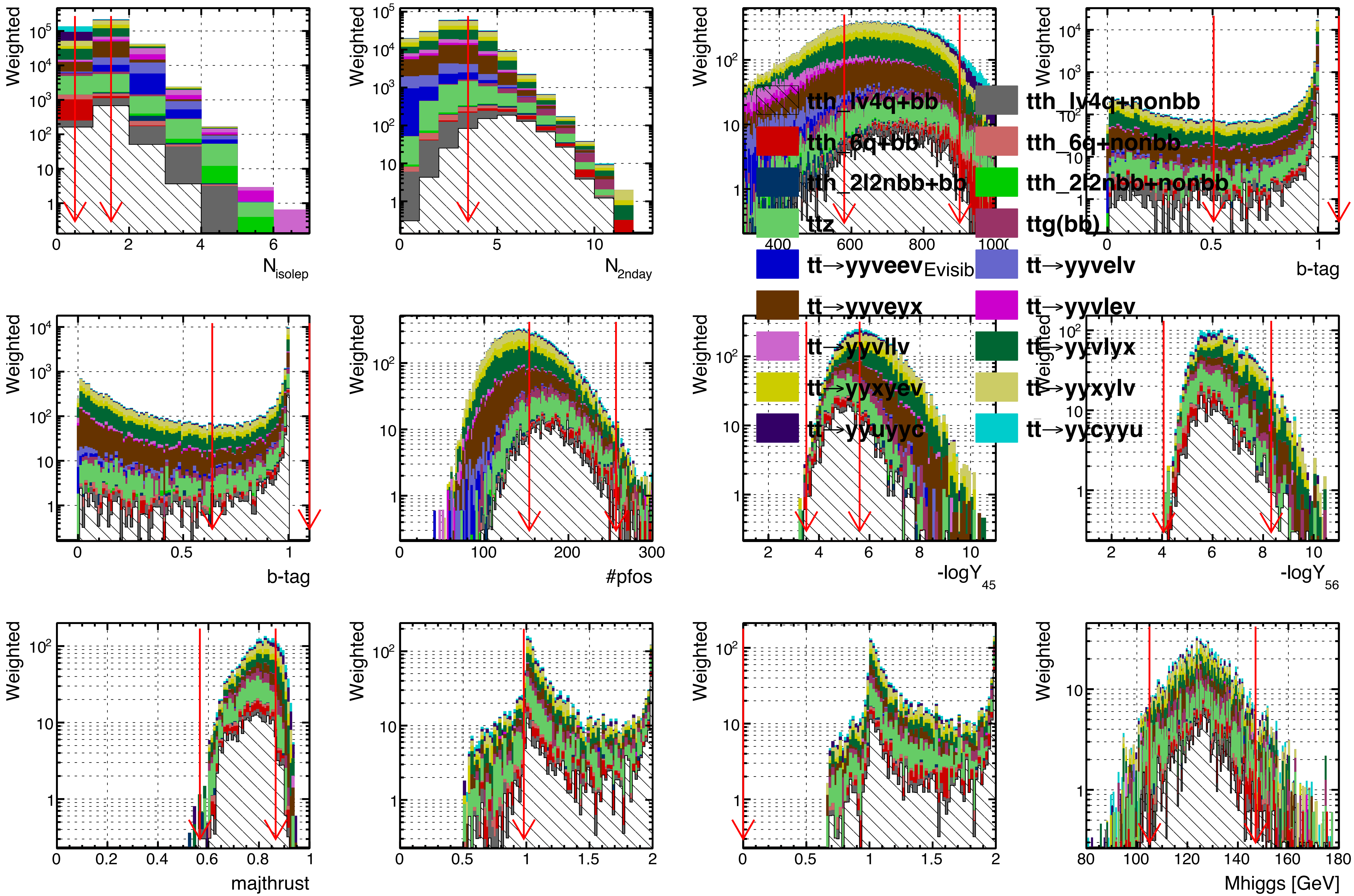
Cut Table Summary

# cut&process	lv4qbb	lv4qnonbb	6qbb	6qnonbb	2l2nbbbb	2l2nbbnonbb	ttz	ttbb	yyveev	yyvelv	yyveyx	yyvlev	yyvllv	yyvlyx	yyxyev	yyxylv	yyuyyc	yycyyu
# raw data	6481	9992	6592	11478	1194	996	26899	7164	24141	32711	188053	32710	52336	207966	188052	207952	188050	188048
# used data	6481	9992	6592	11478	1194	996	26899	7164	24141	32711	188053	32710	52336	207966	188052	207952	188050	188048
# passed data	1286	336	228	246	24	0	617	330	2	5	649	4	10	659	670	711	262	338
# passed/used	19.843	3.363	3.459	2.143	2.010	0.000	2.294	4.606	0.008	0.015	0.345	0.012	0.019	0.317	0.356	0.342	0.139	0.180
# xsection	0.895	0.656	0.934	0.685	0.215	0.157	8.355	2.059	8.742	14.054	41.458	13.694	24.587	69.153	40.997	69.416	50.443	50.351
# xsection*L	895	656	934	685	215	157	8355	2059	8742	14054	41458	13694	24587	69153	40997	69416	50443	50351
+nisoleptons==1	76.04	63.18	16.63	34.58	49.58	46.49	45.14	46.02	43.29	47.78	80.50	47.58	49.94	72.82	80.41	72.73	16.04	16.13 =
+nvtx2nds	63.45	21.95	13.73	12.83	40.79	12.85	16.16	35.52	4.65	6.75	16.07	6.56	7.90	15.49	16.17	15.30	3.82	3.84 =
+visenergy	54.36	17.48	9.38	9.98	17.42	5.12	11.73	25.40	1.10	1.66	11.09	1.48	2.05	10.80	11.15	10.62	2.35	2.39 =
+maxbtag_higgs	50.29	12.26	7.96	7.58	15.91	4.62	9.57	22.60	0.91	1.38	9.12	1.20	1.72	8.88	9.20	8.71	1.85	1.88 =
+maxbtag_bbar	45.29	9.21	6.90	5.14	13.57	3.21	7.47	18.90	0.41	0.62	5.29	0.55	0.77	5.02	5.32	5.00	1.12	1.18 =
+allpfos	34.47	7.14	6.22	4.09	6.78	1.00	5.18	13.09	0.10	0.13	2.06	0.14	0.21	1.92	2.10	1.88	0.70	0.76 =
+logy45	25.01	5.07	5.40	3.44	2.68	0.20	3.54	7.20	0.01	0.03	0.65	0.03	0.04	0.60	0.65	0.60	0.37	0.40 =
+logy56	24.47	5.07	5.39	3.44	2.43	0.20	3.46	6.95	0.01	0.03	0.59	0.03	0.04	0.55	0.60	0.55	0.35	0.39 =
+printhrust	22.96	4.71	5.19	3.29	2.18	0.20	3.19	6.18	0.01	0.02	0.46	0.02	0.03	0.42	0.46	0.44	0.21	0.25 =
+btagsum_higgs	21.51	3.73	4.63	2.65	2.09	0.20	2.70	5.44	0.01	0.02	0.40	0.02	0.03	0.35	0.39	0.38	0.17	0.21 =
+higgsmass	19.84	3.36	3.46	2.14	2.01	0.00	2.29	4.61	0.01	0.02	0.35	0.01	0.02	0.32	0.36	0.34	0.14	0.18 =
# Evts(Remain)	180.2	20.6	34.6	15.4	4.6	0.0	203.5	96.5	1.2	1.8	126.7	1.2	3.8	200.1	127.5	208.9	71.3	90.0

>. Significance: $S/\sqrt{(S + B)} = 4.84$

. The selection efficiencies (purities) for signal events are 33.1% (27.7%) and 56.0% (25.2%) for the six- and eight- jets analyses in ILD, respectively,

ttH→4qlv+bb


Weighted
N_isolep
N_2nday
Evisib
b-tag
#pfos
-logY_45
-logY_56
majthrust
Mhiggs [GeV]
tth_lv4q+bb
tth_lv4q+nonbb
tth_6q+bb
tth_6q+nonbb
tth_2l2nbb+bb
tth_2l2nbb+nonbb
ttz
ttg(bb)
tt→yyveev
tt→yyvelv
tt→yyveyx
tt→yyvlev
tt→yyvllv
tt→yyvlyx
tt→yyxyev
tt→yyxylv
tt→yyuyyc
tt→yycyyu

ttH→6q+bb


```
cut: 1        nisoleptons     -0.500 -    0.500
cut: 2        nvtx2nds         3.500 - 9999.000
cut: 3        visenergy      560.000 - 1100.000
cut: 4        maxbtag_higgs    0.528 -    1.100
cut: 5        maxbtag_bbar     0.670 -    1.100
cut: 6        allpfos        189.000 -  336.000
cut: 7        minpfoinjets     0.000 -   28.000
cut: 8        maxpfoinjets    29.700 -   84.167
cut: 9        logy45           3.135 -    5.205
cut: 10       logy56           3.800 -    6.816
cut: 11       logy67           4.862 -    8.086
cut: 12       logy78           5.000 -    9.830
cut: 13       logy89           6.261 -    9.830
cut: 14       btagsum_higgs    0.800 -  500.000
cut: 15       higgsmass      105.000 -  150.000
```

Cut Table Summary

# cut&process	6qbb	6qnonbb	lv4qbb	lv4qnonbb	2l2nbbbb	2l2nbbnonbb	ttz	ttbb	yyveev	yyvelv	yyveyx	yyvlev	yyvllv	yyvlyx	yyxyev	yyxylv	yyuyyc	yycyyu
# raw data	6592	11478	6481	9992	1194	996	26899	7164	24141	32711	150244	32710	52336	170153	150243	170142	150242	150240
# used data	6592	11478	6481	9992	1194	996	26899	7164	24141	32711	150244	32710	52336	170153	150243	170142	150242	150240
# passed data	1464	595	291	110	3	2	753	469	0	0	69	1	5	119	82	115	882	967
# passed/used	22.209	5.184	4.490	1.101	0.251	0.201	2.799	6.547	0.000	0.000	0.046	0.003	0.010	0.070	0.055	0.068	0.587	0.644
# xsection	0.934	0.685	0.895	0.656	0.215	0.157	8.355	2.059	8.742	14.054	41.458	13.694	24.587	69.153	40.997	69.416	50.443	50.351
# xsection*L	934	685	895	656	215	157	8355	2059	8742	14054	41458	13694	24587	69153	40997	69416	50443	50351
sucsess:	99.97	99.92	99.89	99.95	100.00	100.00	99.95	99.93	99.98	99.96	99.97	99.98	99.99	99.98	99.98	99.99	99.99	99.99
+nisoleptons	90.61	84.27	77.49	73.28	67.09	63.15	83.20	82.66	67.63	71.06	78.57	71.38	74.12	81.67	78.63	81.69	91.52	91.53
+nvtx2nds	78.14	35.61	64.87	25.20	54.02	16.47	32.53	64.78	7.67	9.76	15.33	9.40	11.10	18.50	15.51	18.44	27.12	27.23
+visenergy	77.73	34.73	59.27	20.54	25.63	7.03	28.64	57.69	1.65	2.27	11.61	2.15	3.02	14.57	11.74	14.50	26.58	26.70
+maxbtag_higgs	67.64	23.11	51.86	14.39	23.03	5.42	21.02	48.60	1.12	1.55	8.96	1.49	2.11	11.10	8.97	10.95	18.33	18.45
+maxbtag_bbar	51.93	12.45	33.61	6.14	8.63	1.51	11.05	31.30	0.12	0.24	1.69	0.23	0.33	2.25	1.69	2.20	7.51	7.61
+allpfos	40.22	9.30	12.27	3.01	1.76	0.60	6.23	16.90	0.01	0.03	0.33	0.02	0.05	0.45	0.34	0.44	3.02	3.17
+minpfoinjets	40.20	9.30	12.27	3.01	1.76	0.60	6.23	16.89	0.01	0.03	0.33	0.02	0.05	0.45	0.34	0.44	3.02	3.17
+maxpfoinjets	40.02	9.24	12.24	3.01	1.76	0.60	6.21	16.83	0.01	0.03	0.33	0.02	0.05	0.45	0.34	0.44	3.01	3.15
+logy45	29.40	6.85	7.34	1.72	0.84	0.30	4.04	9.07	0.00	0.00	0.09	0.01	0.01	0.14	0.10	0.13	0.99	1.09
+logy56	28.23	6.70	6.45	1.58	0.25	0.20	3.82	8.57	0.00	0.00	0.07	0.00	0.01	0.10	0.08	0.10	0.86	0.95
+logy67	27.20	6.56	5.60	1.42	0.25	0.20	3.63	7.91	0.00	0.00	0.06	0.00	0.01	0.09	0.07	0.09	0.76	0.83
+logy78	27.03	6.53	5.49	1.39	0.25	0.20	3.60	7.82	0.00	0.00	0.06	0.00	0.01	0.08	0.07	0.09	0.75	0.82
+logy89	25.02	6.32	4.97	1.36	0.25	0.20	3.35	7.43	0.00	0.00	0.05	0.00	0.01	0.08	0.06	0.08	0.70	0.75
+btagsum_higgs	24.09	5.73	4.71	1.20	0.25	0.20	3.10	7.16	0.00	0.00	0.05	0.00	0.01	0.07	0.06	0.07	0.65	0.70
+higgsmass	22.21	5.18	4.49	1.10	0.25	0.20	2.80	6.55	0.00	0.00	0.05	0.00	0.01	0.07	0.05	0.07	0.59	0.64
# Evts(Remain)	217.6	35.8	37.8	7.0	0.5	0.3	234.9	128.0	0.0	0.0	18.1	0.6	1.9	49.6	20.4	46.7	293.3	319.9

>. Significance: $S/\sqrt{(S+B)} = 5.79$

. The selection efficiencies (purities) for signal events are 33.1% (27.7%) and 56.0% (25.2%) for the six- and eight- jets analyses in ILD, respectively,

ttH→2q2l2v+bb

Cut Table Summary

# cut&process	2l2nbbbb	2l2nbbnonbb	lv4qbb	lv4qnonbb	6qbb	6qnonbb	ttz	ttbb	yyveev	yyvelv	yyveyx	yyvlev	yyvllv	yyvlyx	yyxyev	yyxylv	yyuyyc	yycy
# raw data	1194	996	6481	9992	6592	11478	26899	7164	24141	32711	150244	32710	52336	170153	150243	170142	150242	150240
# used data	1194	996	6481	9992	6592	11478	26899	7164	24141	32711	150244	32710	52336	170153	150243	170142	150242	150240
# passed data	210	3	61	11	1	2	82	50	28	29	30	25	50	20	16	20	1	0
# passed/used	17.588	0.301	0.941	0.110	0.015	0.017	0.305	0.698	0.116	0.089	0.020	0.076	0.096	0.012	0.011	0.012	0.001	0.000
# xsection	0.215	0.157	0.895	0.656	0.934	0.685	8.355	2.059	8.742	14.054	41.458	13.694	24.587	69.153	40.997	69.416	50.443	50.351
# xsection*L	215	157	895	656	934	685	8355	2059	8742	14054	41458	13694	24587	69153	40997	69416	50443	50351
sucsess:	60.89	44.78	11.93	25.27	1.53	12.44	14.90	12.23	69.48	61.02	11.50	61.21	54.34	10.22	11.49	10.34	1.51	1.44
+nisoleptons	60.89	44.78	11.93	25.27	1.53	12.44	14.90	12.23	69.48	61.02	11.50	61.21	54.34	10.22	11.49	10.34	1.51	1.44
+nvtx2nds	50.59	12.65	9.09	7.45	1.24	4.06	4.44	8.58	8.41	7.98	1.71	7.91	7.11	1.62	1.69	1.62	0.29	0.31
+visenergy	50.59	12.65	8.69	7.21	0.90	3.62	4.16	7.98	7.28	6.96	1.64	6.97	6.36	1.56	1.62	1.56	0.17	0.18
+maxbtag_higgs	49.50	9.14	7.95	5.79	0.77	2.88	3.57	7.34	6.75	6.47	1.38	6.45	5.86	1.28	1.34	1.30	0.14	0.14
+maxbtag_bbar	49.08	8.03	7.75	5.22	0.71	2.60	3.27	7.10	6.08	5.74	1.22	5.85	5.26	1.12	1.20	1.16	0.12	0.13
+allpfos	44.97	7.33	7.41	4.83	0.59	2.42	2.96	6.18	3.23	2.94	1.01	3.11	2.72	0.96	1.03	0.98	0.11	0.12
+minpfoinjets	41.96	6.43	7.02	4.26	0.52	2.30	2.68	5.40	2.46	2.23	0.87	2.35	2.07	0.82	0.87	0.84	0.11	0.11
+logy23	37.19	5.02	6.54	3.91	0.52	2.12	2.32	4.29	1.33	1.18	0.57	1.25	1.16	0.55	0.56	0.56	0.07	0.07
+logy34	36.93	5.02	6.53	3.90	0.50	2.12	2.31	4.15	1.17	1.01	0.55	1.15	1.04	0.54	0.54	0.54	0.07	0.07
+logy45	36.93	5.02	6.51	3.90	0.50	2.11	2.31	4.15	1.17	1.01	0.55	1.15	1.04	0.54	0.54	0.54	0.07	0.07
+logy56	36.93	5.02	6.16	3.77	0.44	1.91	2.21	4.08	1.17	1.01	0.55	1.14	1.04	0.53	0.53	0.53	0.07	0.07
+btagsum_higgs	25.54	0.70	2.96	0.66	0.09	0.34	0.82	2.00	0.38	0.28	0.10	0.33	0.32	0.08	0.08	0.10	0.01	0.01
+btagsum_bbar	19.60	0.30	1.53	0.16	0.05	0.04	0.42	1.01	0.15	0.10	0.03	0.11	0.13	0.02	0.02	0.02	0.00	0.00
+higgsmass	17.59	0.30	0.94	0.11	0.02	0.02	0.30	0.70	0.12	0.09	0.02	0.08	0.10	0.01	0.01	0.01	0.00	0.00
# Evts(Remain)	35.0	0.5	8.9	0.9	0.0	0.1	26.1	15.5	7.8	10.8	8.6	10.2	22.9	9.0	4.1	6.6	0.4	0.0

Nsig integral(restricted range) : 35.0
Nbck integral(restricted range) : 132.4
Significance : 2.71