National University
The Graduate University
for Advanced Studies [SOKENDAI]

Sensitivity of the ILC to Anomalous Couplings b/w Higgs and Gauge Bosons

ZZH Production Processes

Motivation

>. The key to probe the new physics is to clarify the origin of the EWSB.
(the Higgs mechanism)

1. It is necessary to measure the Higgs boson properties with high precision.
2. It is expected to be sensitive to the physics of SSB which gives mass to the weak bosons.

>. Effective Lagrangian with a Higgs doublet.

1. New physics can be represented by higher dimension operators
2. The lowest operator considered the coupling which couples to only weak boson is dim-5.

relevant term is …

$$\mathcal{L}_{\mathrm{HWW}} = 2M_W^2 \left(\frac{1}{v} + \frac{a}{\Lambda}\right) H\ W_\mu^+ W^{-\mu} + \frac{b}{\Lambda} H\ W_{\mu\nu}^+ W^{-\mu\nu} + \frac{\tilde{b}}{\Lambda} H\ \epsilon^{\mu\nu\sigma\tau} W_{\mu\nu}^+ W_{\sigma\tau}^- \ ,$$

SM (CP-even) Correction [a]

Tensor Couplings CP-even [b]

Tensor Couplings CP-odd [bt]

>. The purpose is to estimate how the ILC is sensitive to these parameters.
If the higgs has small anomalous components, it's not easy to measure with LHC.

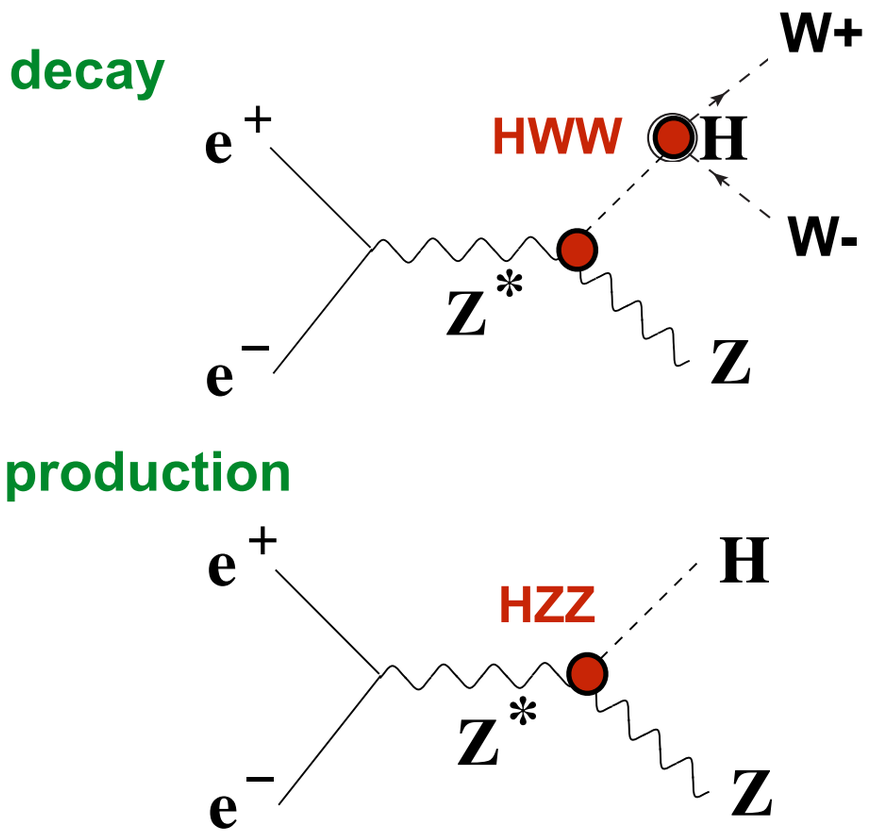
Process

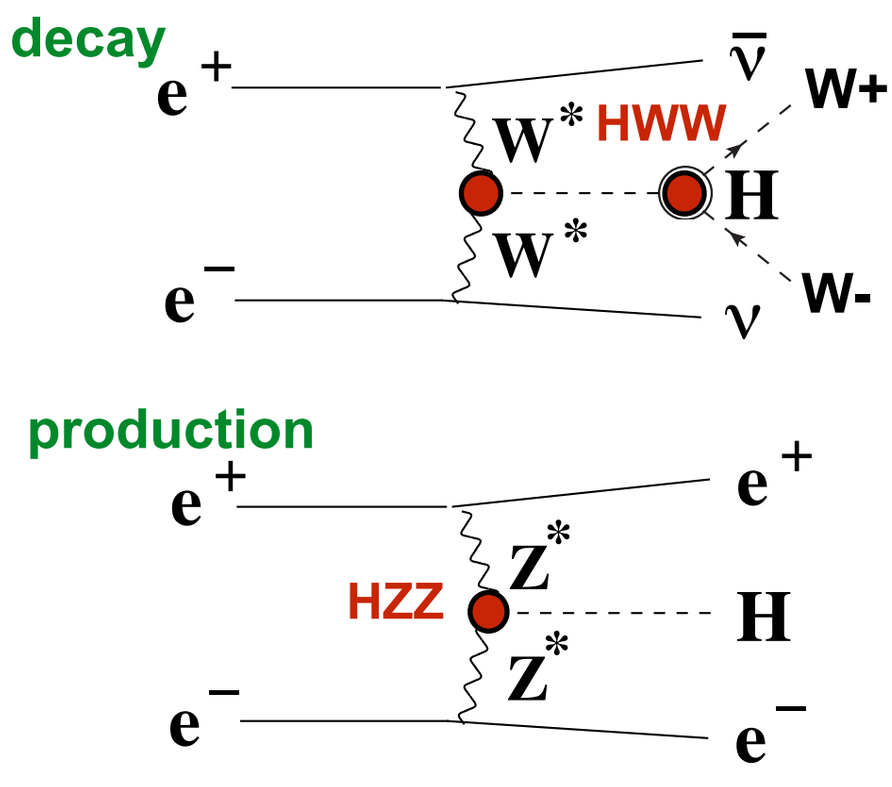
>. Anomalous components (spin-parity) restrict the type of interactions b/w the higgs and other particles.

> . kinematic distributions change for either the decay particles of the higgs and the particles which are associated to the higgs.

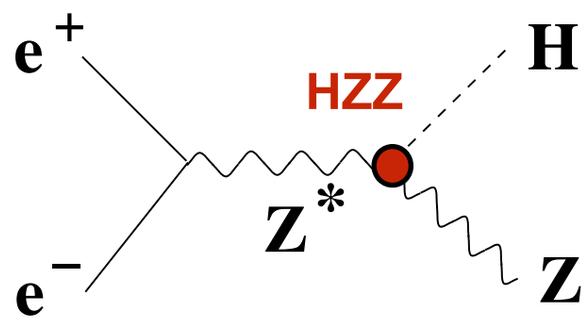
>. In the lepton collider environment,

>. We can use strahlung and fusion processed of the higgs at 250GeV and 500GeV.





Using Production Processes @ 250GeV

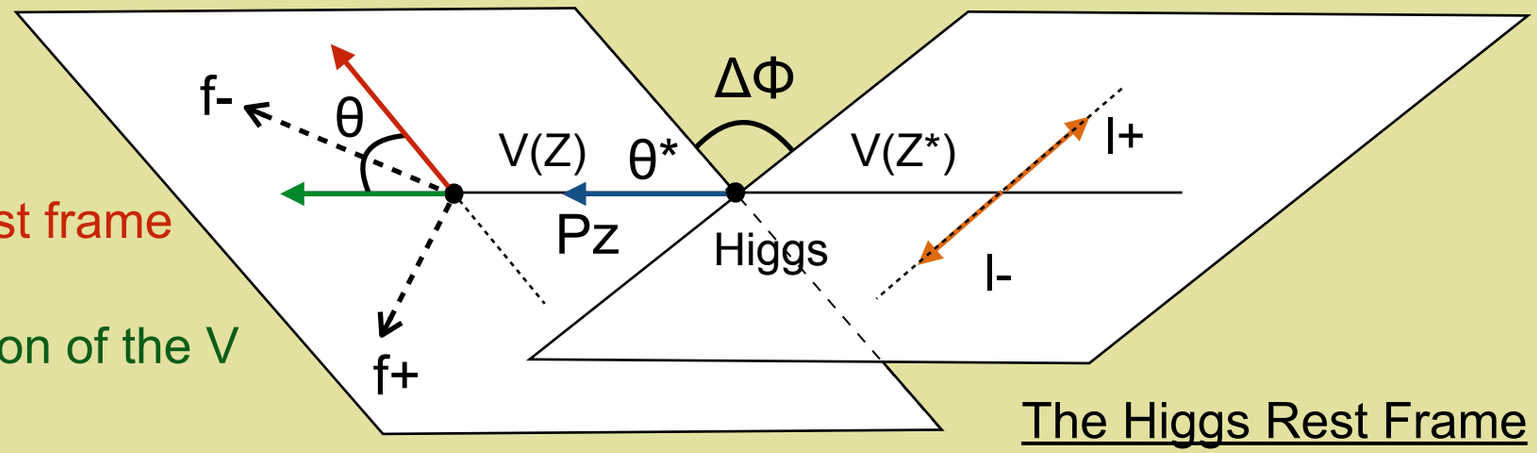


Definition of Sensitive Parameters

>. Definition of parameters which are sensitive to anomalous couplings on the higgs production process.

The direction of motion of the daughter fermion in the H rest frame

The direction of motion of the V in the H rest frame



The Higgs Rest Frame

>. Pz : Z momentum in the Higgs rest frame.

>. θ : The angle between .
the direction of motion of the daughter fermion in the V rest frame and
the direction of motion of the V in the H rest frame .

>. θ* : The production angle of Z in the Higgs rest frame.

>. Φ : The angle between two decay/production planes defined in the Higgs rest frame. (Azimuthal angle)

Definition of Sensitive Parameters

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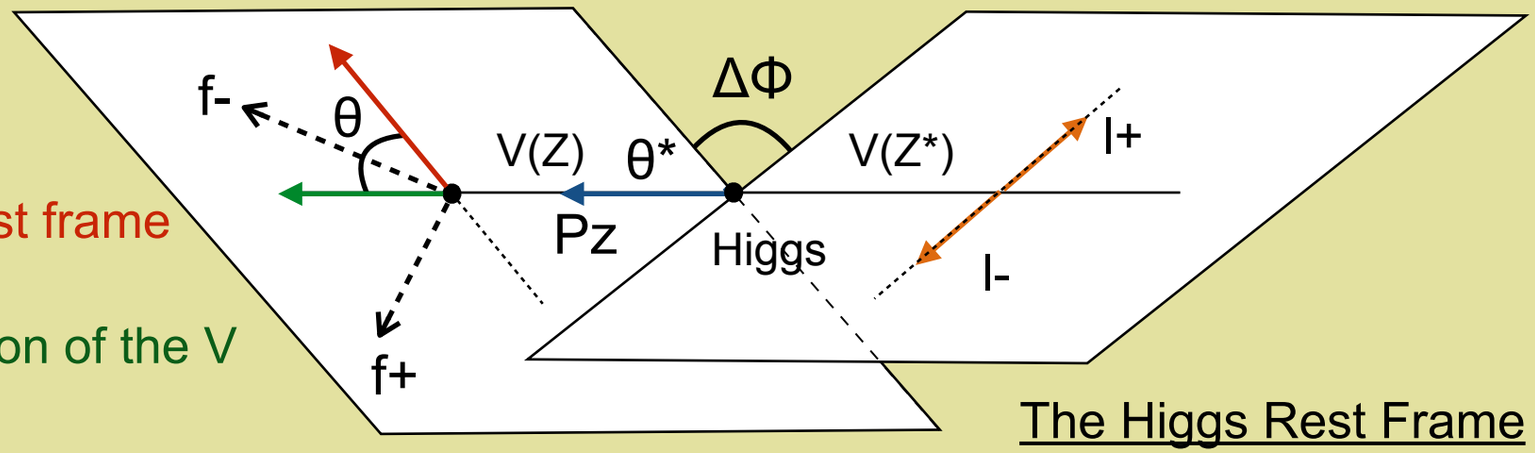
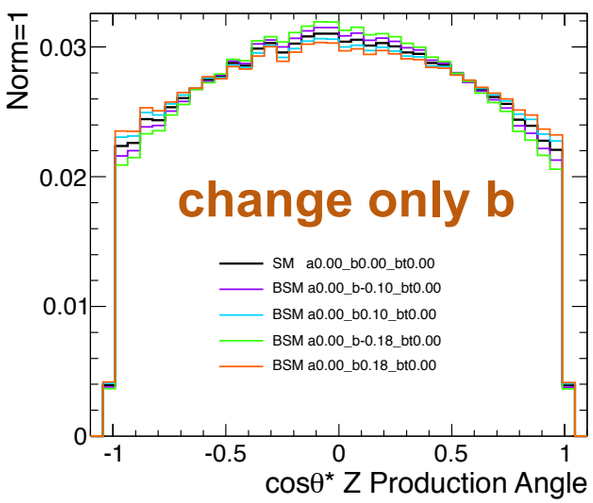


The Higgs Rest Frame

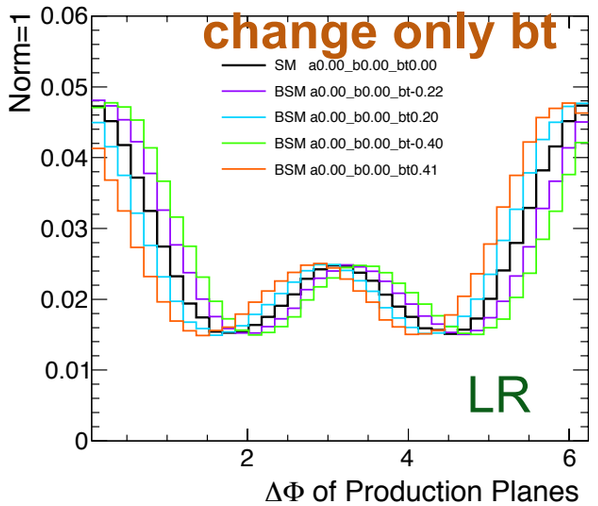
>. Comparison of the Shape itself of each distribution.

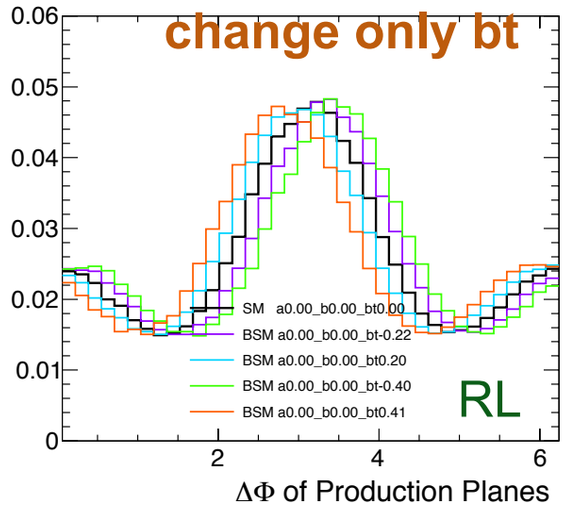
Change parameters slightly.

For small changing, the difference is also small.



difference is not small.



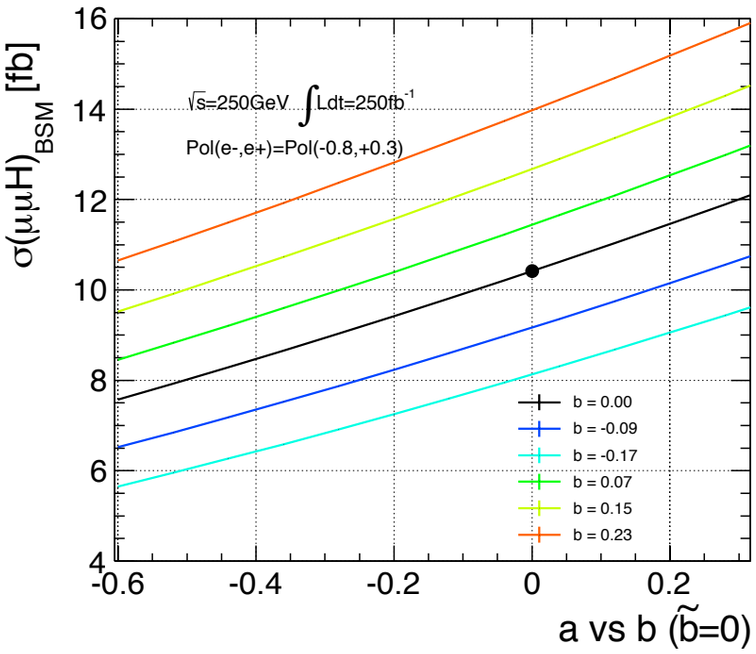


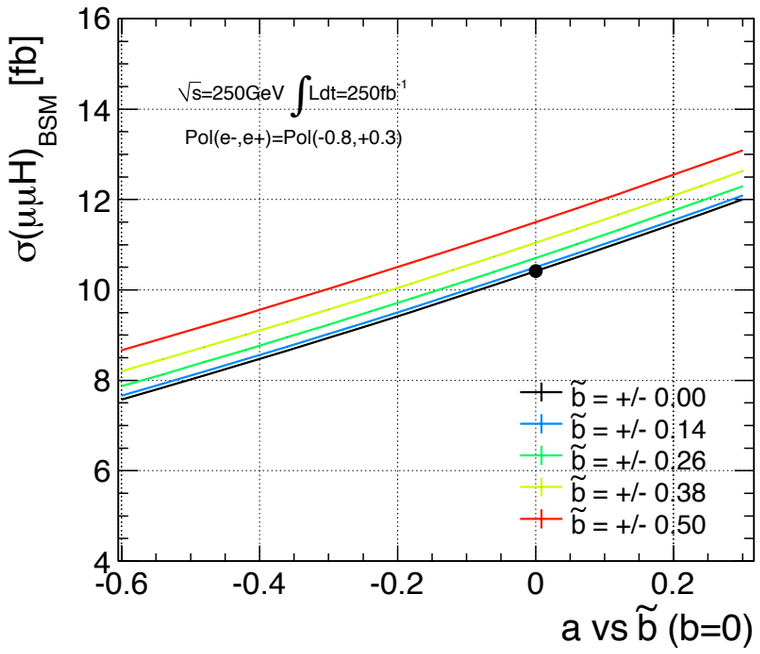
Difference of Cross Section (μμH)

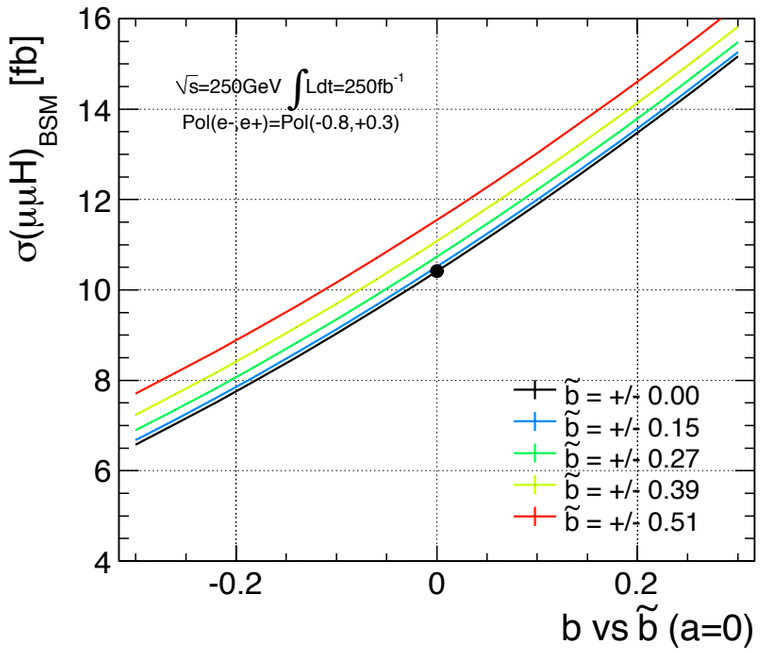
>. Comparison of the cross section with 250GeV, 250fb-1.

>. (a vs b) if parameter a changes to 0.1, the cross section changes ~ 5 %.

>. (b vs bt) if parameter b changes to 0.1, the cross section changes > 10 %.





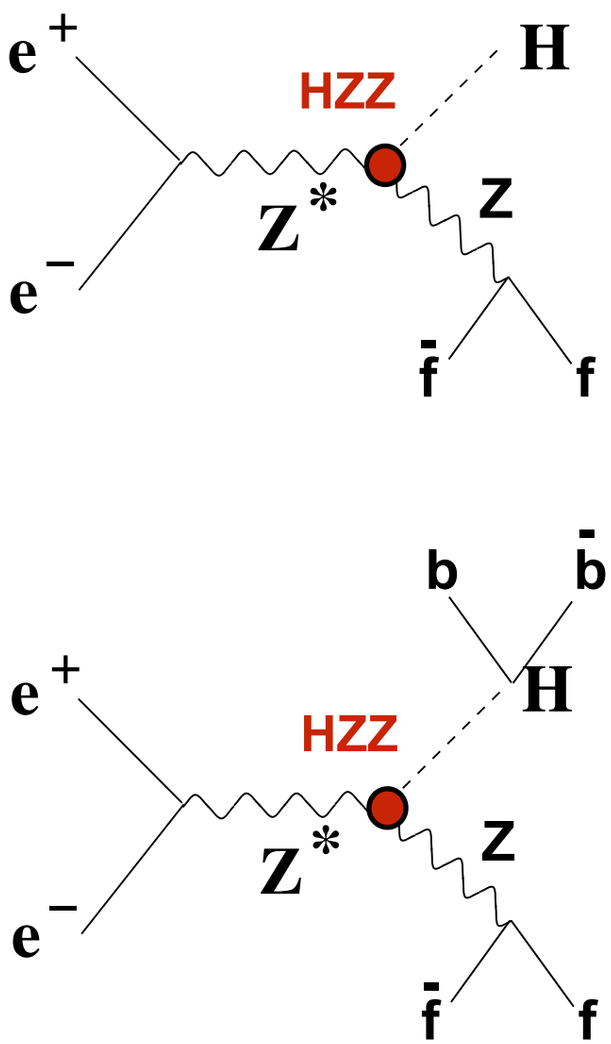


>. We can use angular distribution & absolute value of cross section..

Simulation Processes

>. We can test the effect the anomalous HZZ coupling
by measuring the production cross section, and reconstructed angular distributions.

>. Two opposite strategies.



>. Recoil mass (μμ/ee)

>. Using the recoil mass technique,
without looking at the Higgs decay at all,
we can allow the higgs to decay in any candidates.

>. Use full information of Z and its daughters
to suppress backgrounds.

>. llH ➡ llbb (μμ/ee)

>. The strategy of analysis is opposite to recoil mass.
We pay attention to only the higgs and event topology.

Background Suppression

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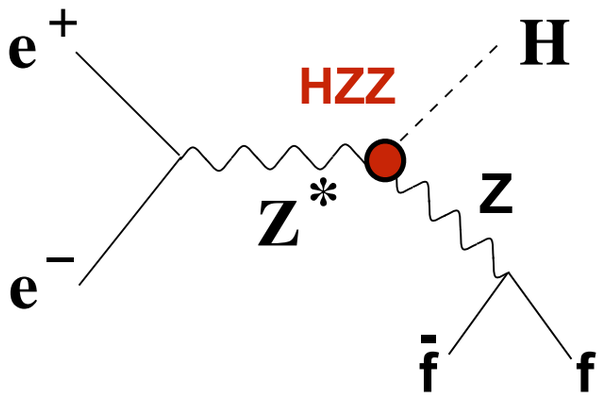
by measuring the production cross section, and reconstructed angular distributions.



>. Recoil mass (μμ/ee)

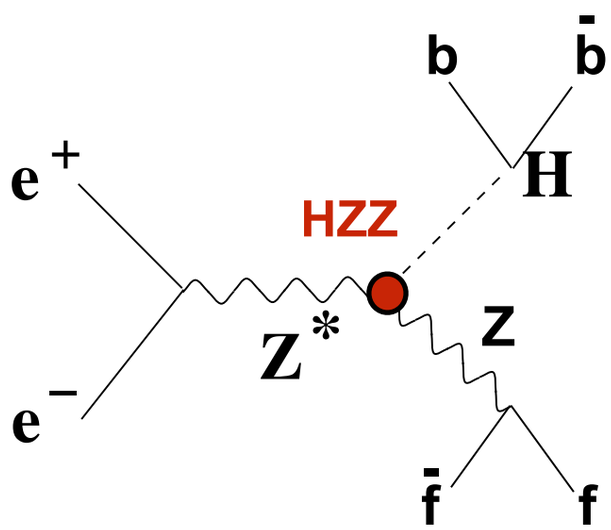
>. Information of Z and Z daughters.

E_z, M_z, Pt_dilepton

Production angle θ of each final state lepton and Z.

Opening angle θ b/w final state leptons.

Pt_balance (including Watanuki-san's correction)



>. llH ➡ llbb (μμ/ee)

>. Information of H and topology.

E_h, M_h, M_z

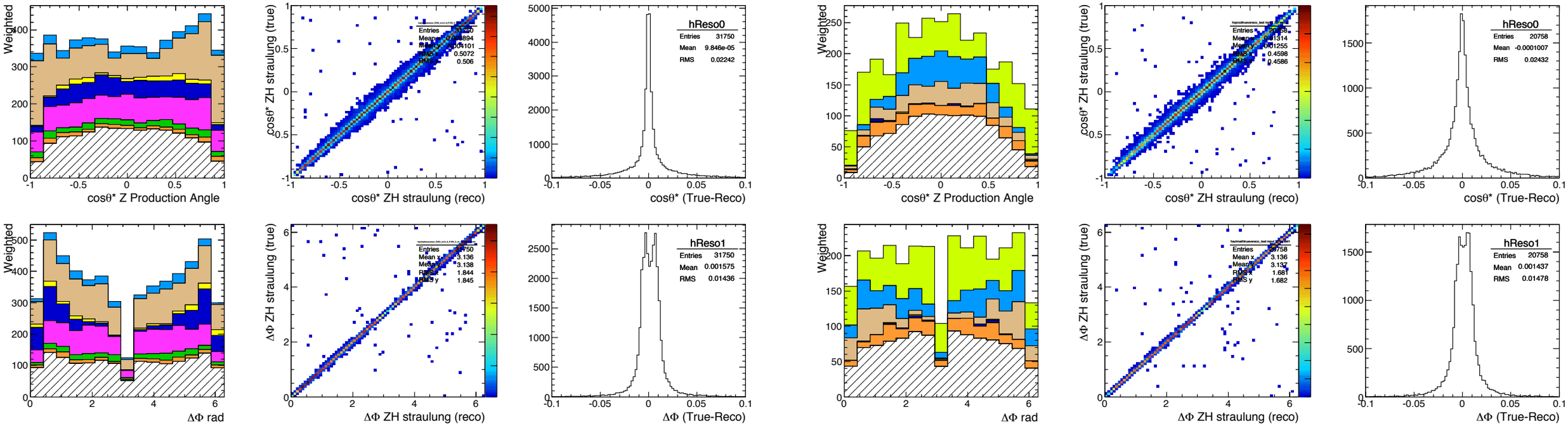
#tracks #bjets (flavor tag)

Reconstructed Angles

>. We can test the effect the anomalous HZZ coupling
by measuring the production cross section, and reconstructed angular distributions.

>. Each parameter is divided into 15 bins .

>. Sensitive parameters are reconstructed almost properly .



Estimation of #Signal Events

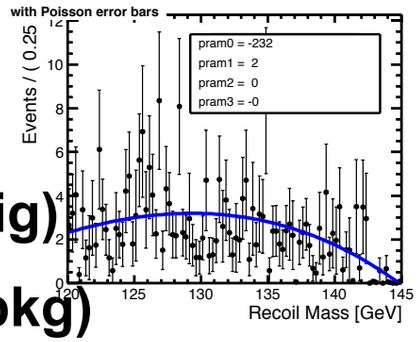
>. Estimation of #Signal events of each bin (15 bins).

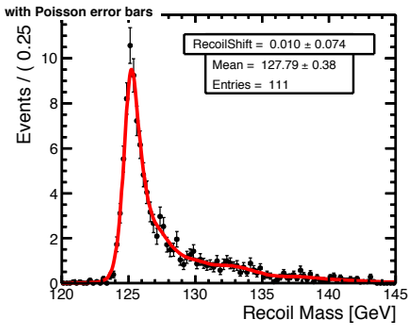
>. Recoil mass

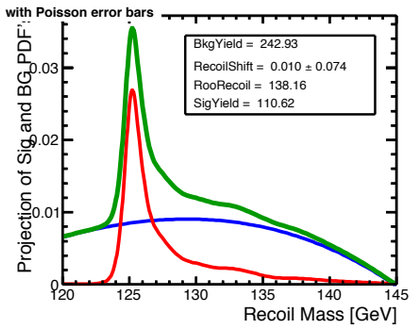
Kernel function (sig)

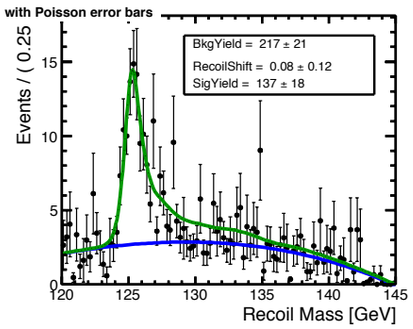
3rd Pol function (bkg)

mmh





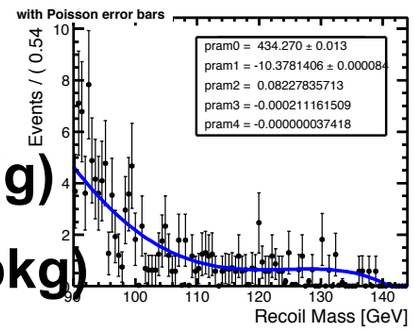


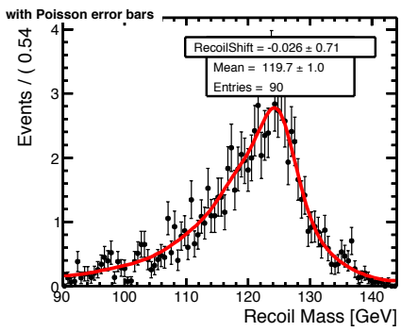


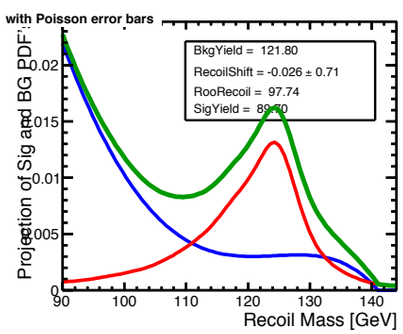
>. llH ➡ llbb

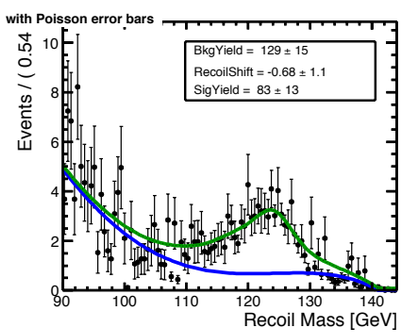
Kernel function (sig)

4rd Pol function (bkg)

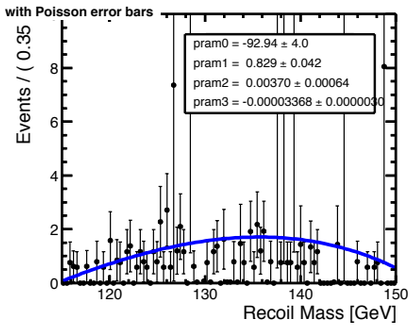


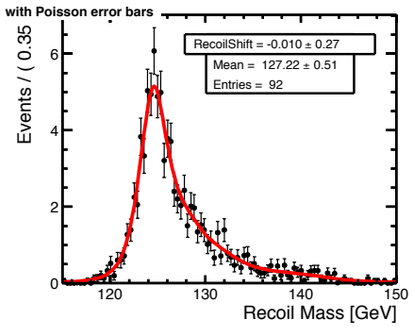


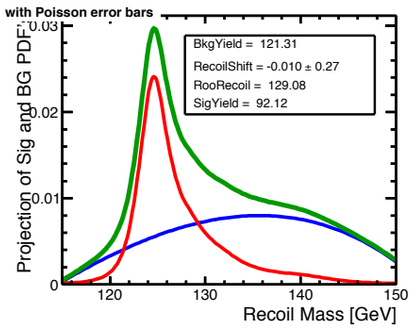


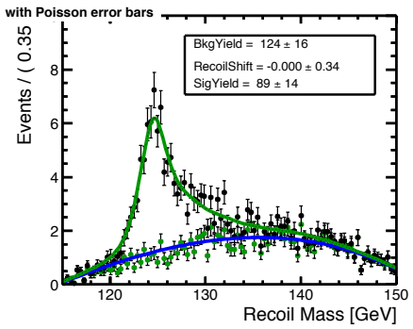


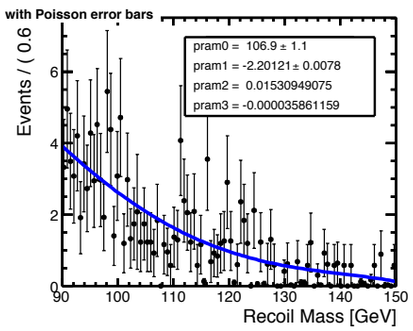
eeh

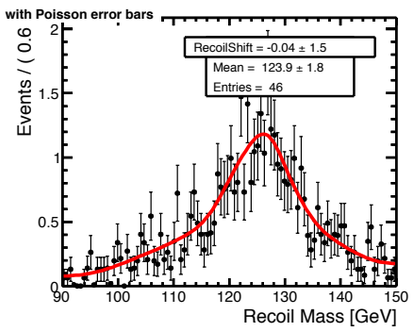


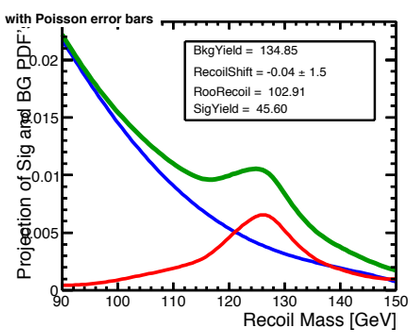


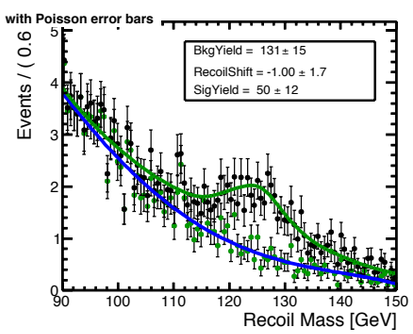












Detector Acceptance (η)

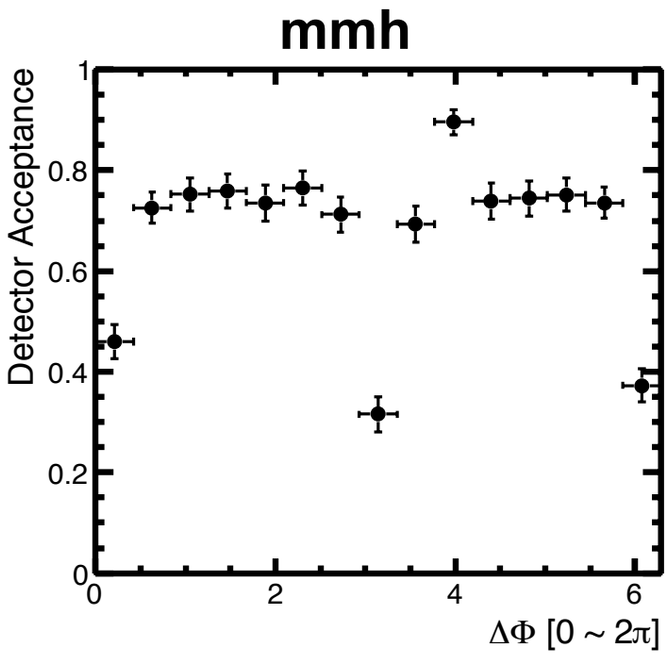
$$\text{Acceptance } \eta_{x_{bin}} = \frac{N^{observed}_{x_{bin}}}{N^{theoretically}_{x_{bin}}},$$

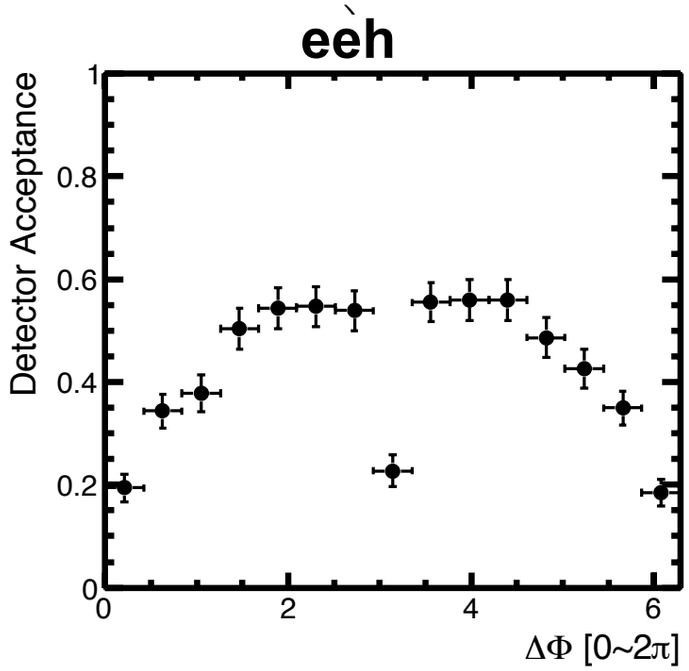
$$\Delta\eta = \frac{\sqrt{\eta_{x_{bin}}(1-\eta_{x_{bin}})}}{\sqrt{N^{generated}_{x_{bin}}}}$$

>. Estimation of #Signal events of each bin (15 bins).

>. Recoil mass

Acceptance drop down due to some angular cut

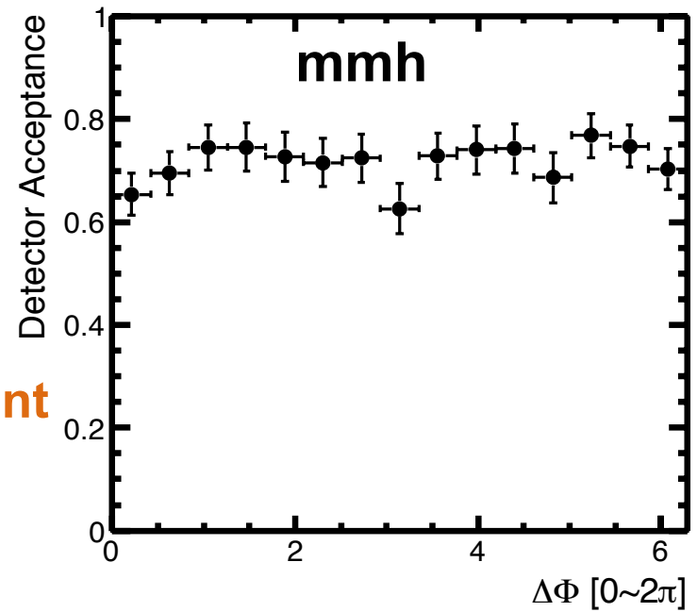


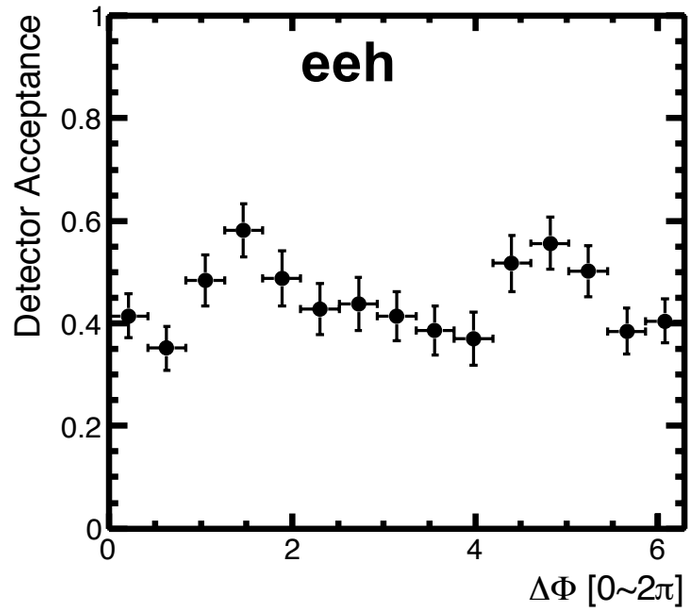


>. llH ➡ llbb

Acceptance is better

in eeh
bag is included for the moment





χ2 Test with Different Models

>. Using detector acceptance gat from analysis up to here,
perform ToyMC with several physics models.

- y_{bin}^{SM-MC}; The observed mean with SM-MC. (fitting result.)
- σ_{bin}^{SM-MC}; The variance related to y_{bin}. (its error if use fitting result.)
- $f^{theory}(x_{bin}; a, b, \tilde{b})$: The predicted model from the theory/model.
- $f^{theory\ w/accep}(x_{bin}; a, b, \tilde{b})$: The predicted model which is applied detector acceptance.

$$f^{theory}(x_{bin}; a, b, \tilde{b}) = \left(\int_{x_{bin}}^{x_{bin+1}} L \cdot \frac{d\sigma}{dx_{bin}} dx_{bin} \right)$$ (contents of each bin)

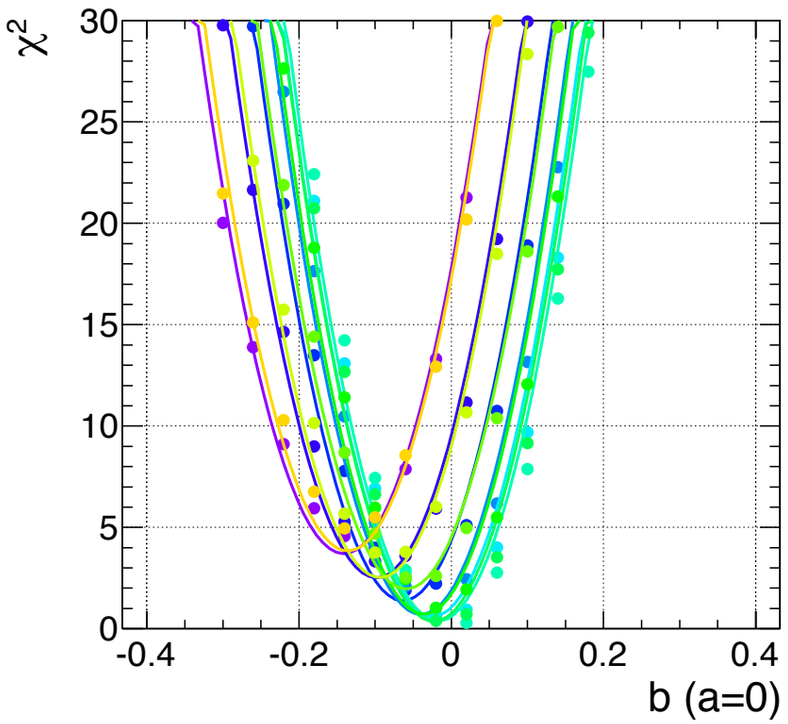
$$\text{Acceptance } \eta_{x_{bin}} = \frac{N_{x_{bin}}^{observed}}{N_{x_{bin}}^{theoretically}}, \qquad \Delta\eta = \frac{\sqrt{\eta_{x_{bin}}(1-\eta_{x_{bin}})}}{\sqrt{N_{x_{bin}}^{generated}}}$$

$$f^{theory\ w/accep}(x_{bin}; a, b, \tilde{b}) = \left(\int_{x_{bin}}^{x_{bin+1}} L \cdot \frac{d\sigma}{dx_{bin}} dx_{bin} \right) \cdot \eta_{x_{bin}}$$

(expected #signals)

$$\chi^2 = \sum_{bin=1}^{15} \left(\frac{y_{bin}^{SM-MC} - f^{theory\ w/accep}(x_{bin}; a, b, \tilde{b})}{\sigma_{bin}^{SM-MC}} \right)^2$$

different color, different bt



Sensitivity to Anomalous Couplings (Recoil mass)

>. (a vs b)
The difference of angular distribution is small for the small changing.
The difference of cross section is almost same in diagonal region.

>. (a vs bt)
The difference of angular distribution is not small for the small changing of bt.
The difference of cross section is almost same with SM in the region where |bt| is large.

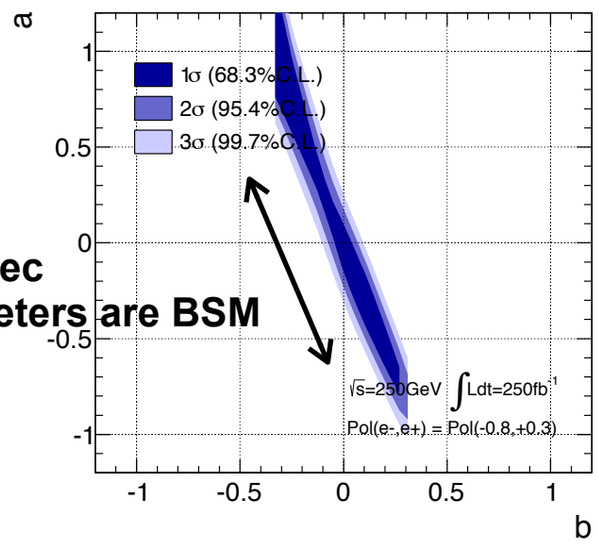
estimation from parameter "cosθ*"

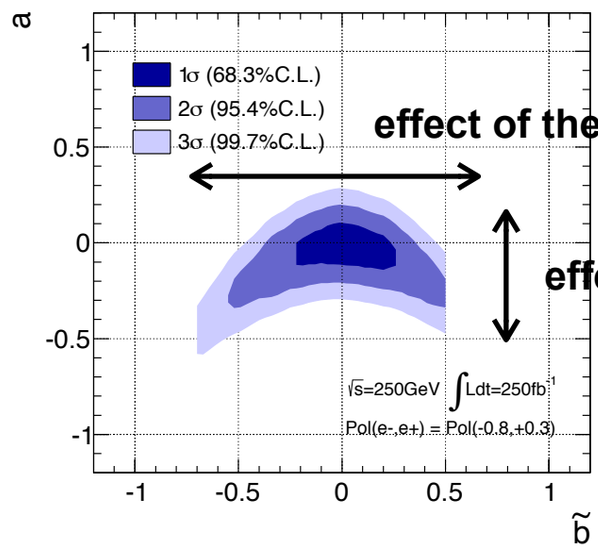
estimation from parameter "ΔΦ"

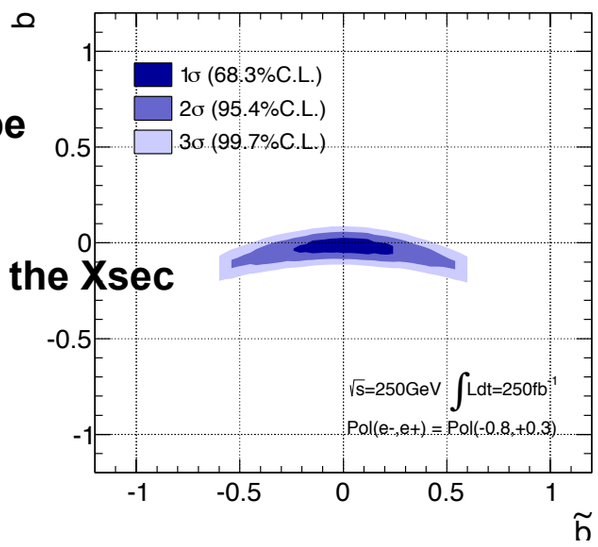
same Xsec
if parameters are BSM

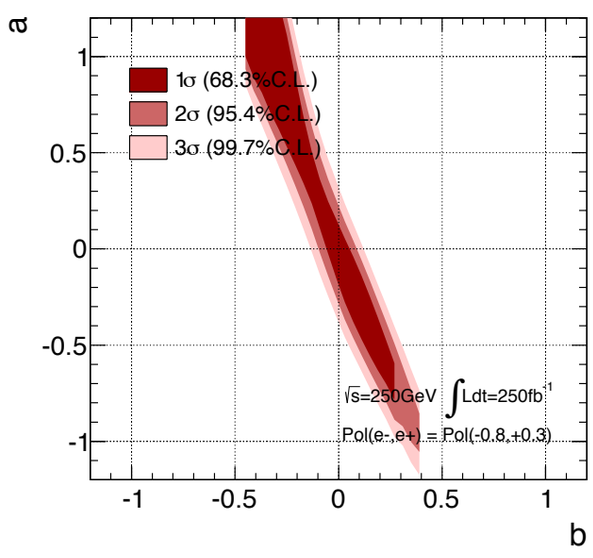
effect of the shape

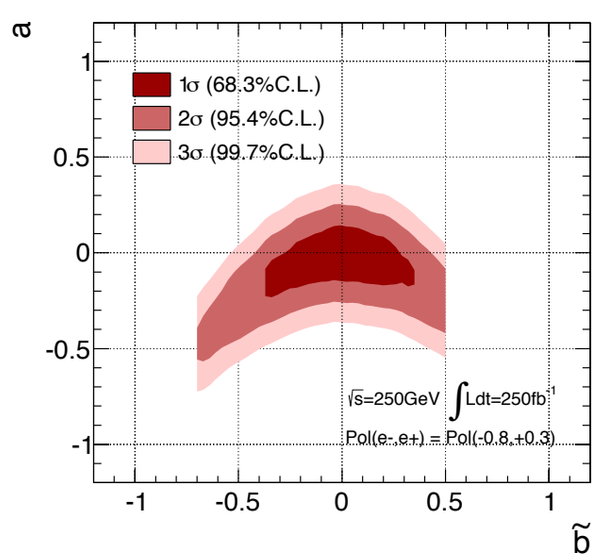
effect of the Xsec

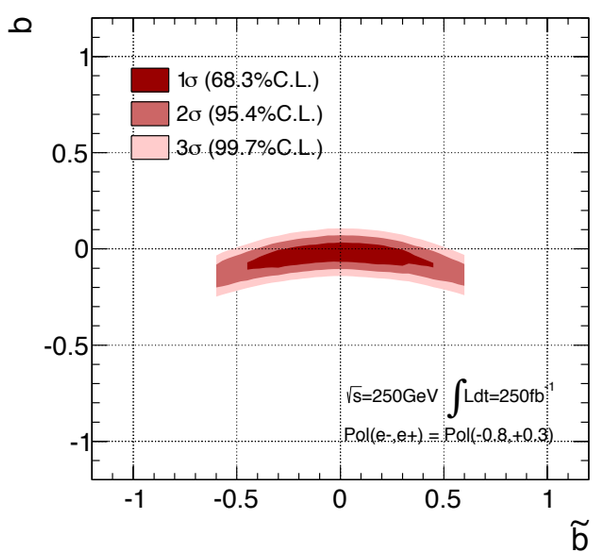












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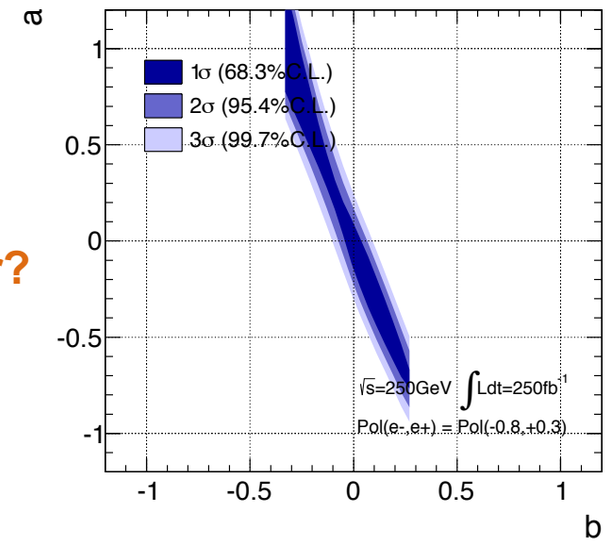
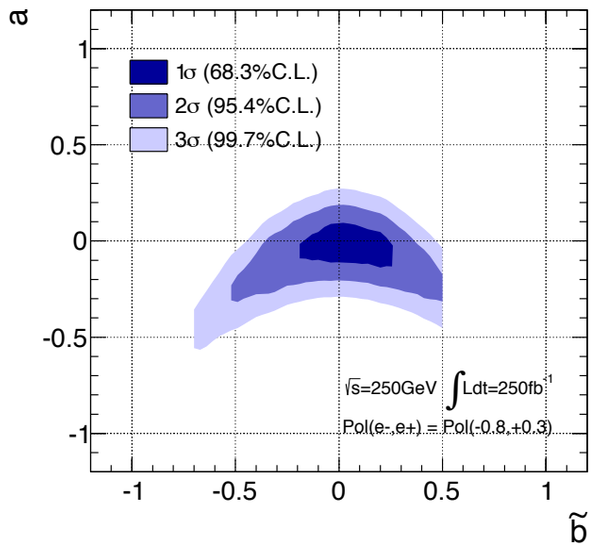
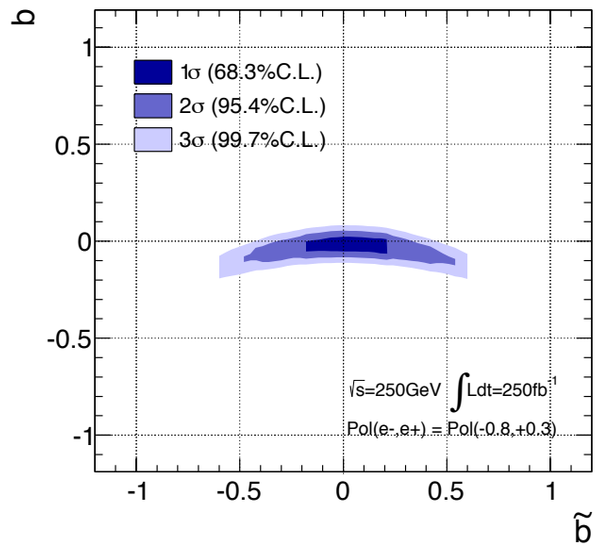
estimation from parameter "ΔΦ"

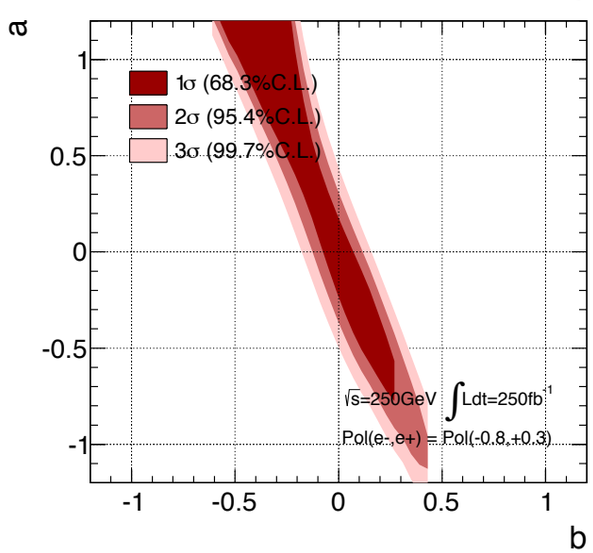
bit better?

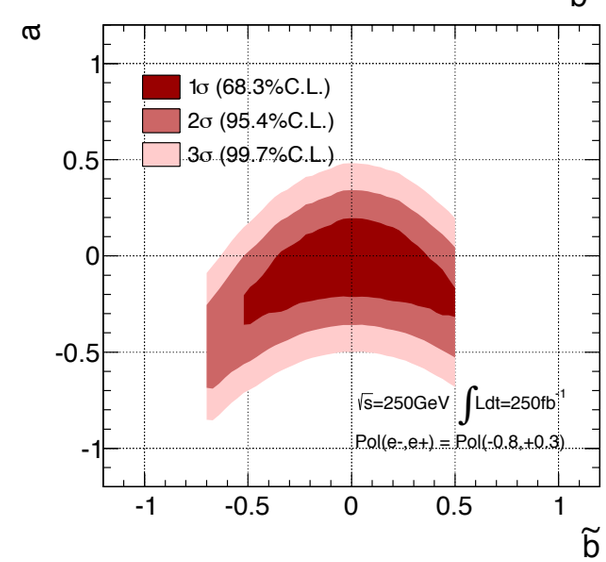


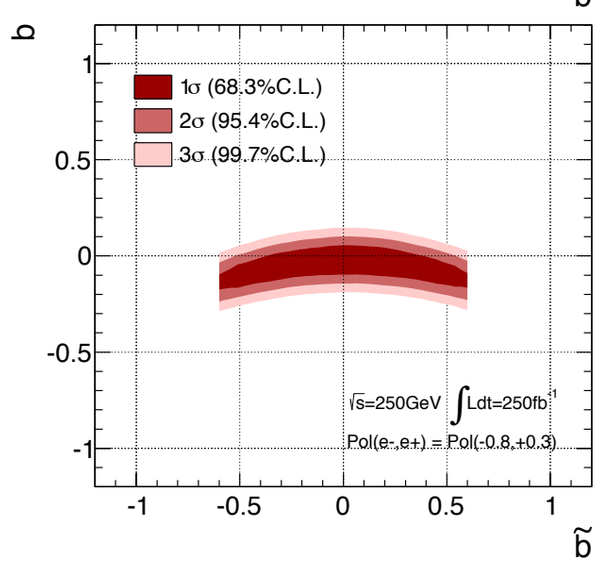




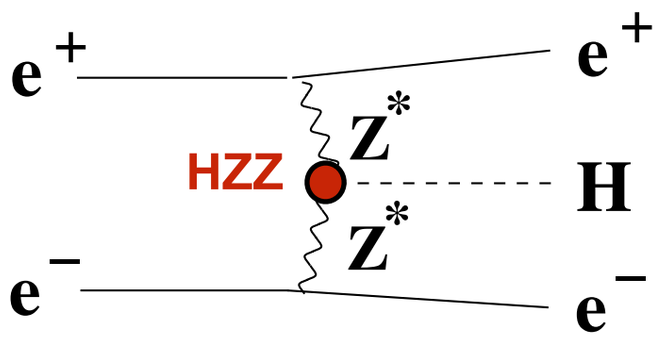
bag is included





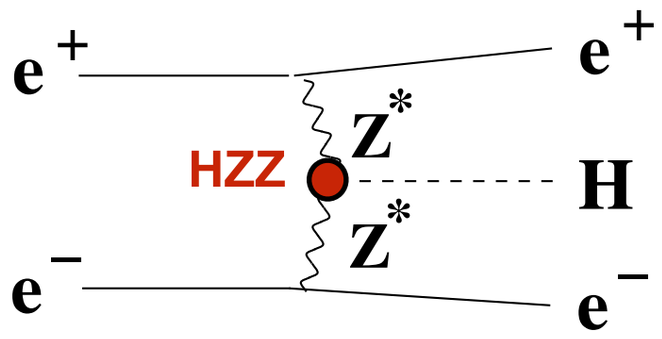


Using Production Processes @ 500GeV



Sensitive Parameters

>. The definition of parameters are same with ZH process.

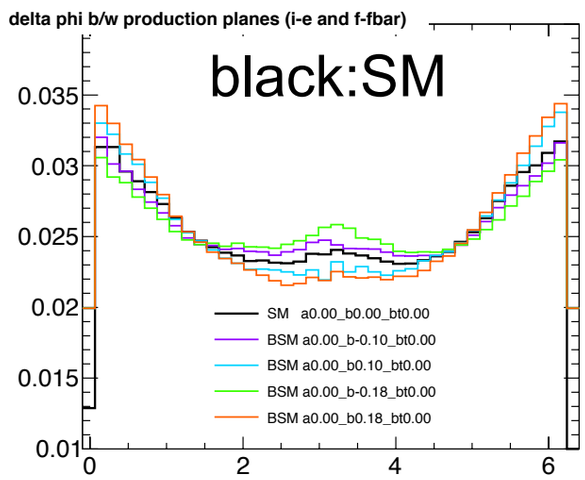


>. The difference of angular distribution is large
for small changing of parameters.

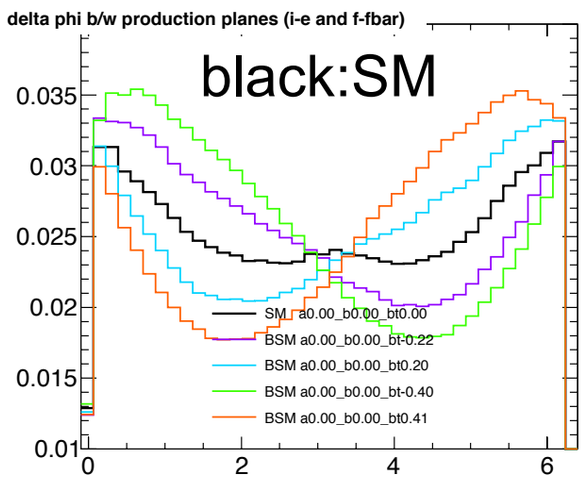
b; change symmetry

bt; change asymmetry

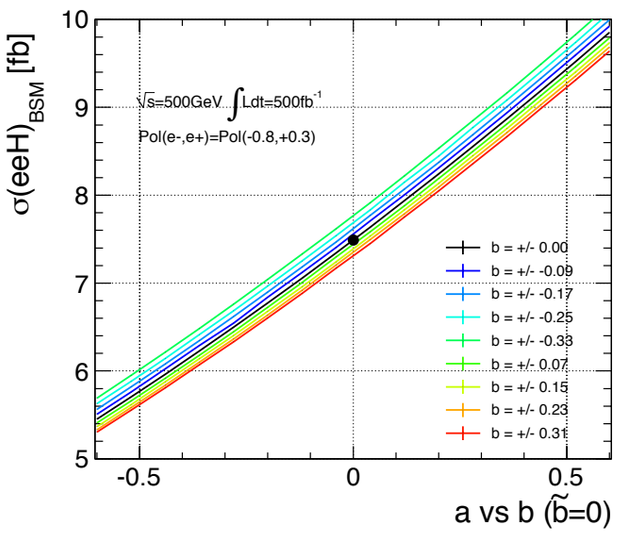
Change only b

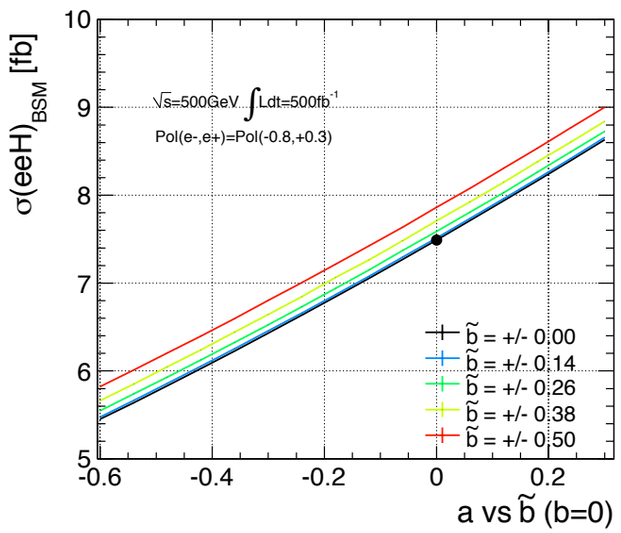


Change only bt

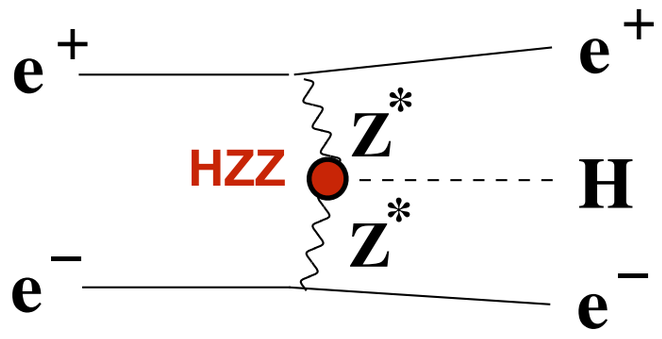


>. The difference of absolute value of cross section is also large
for small changing of parameters.





Analysis Procedure



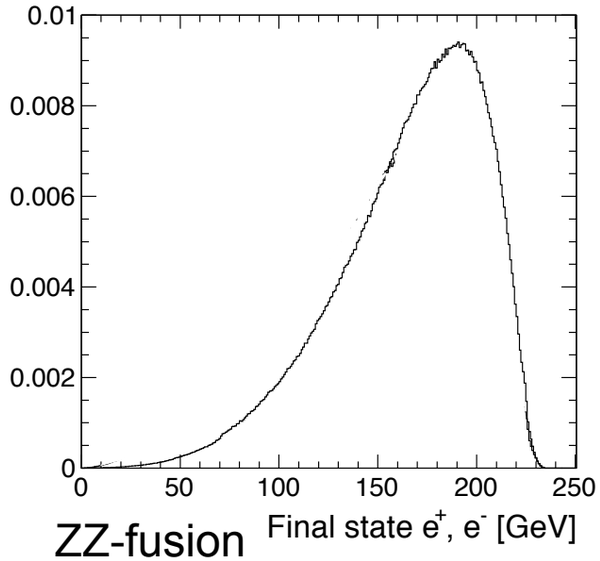
>. Signal is eeH ➡ eebb (Br(H->bb) 57.8%).

>. Reconstruction

>. Require high momentum e- & e+ (>20GeV) to exist in each event.

>. kt algorithm to remove AA background R=1.4 (optimaized)

>. Durlam 2Jet-clustering forcibly.



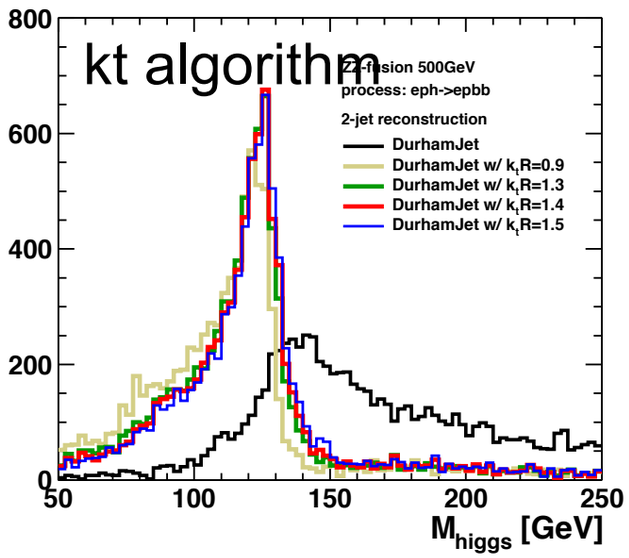
>. Background suppression.

>. Angular variables should not been used.

>. visE, #tracks #bjets (flavor tag)

>. Ejet, E_higgs >. Clustering parameters Y12, Y23.

>. M_dileptons (need to avoid contamination ZH process.)

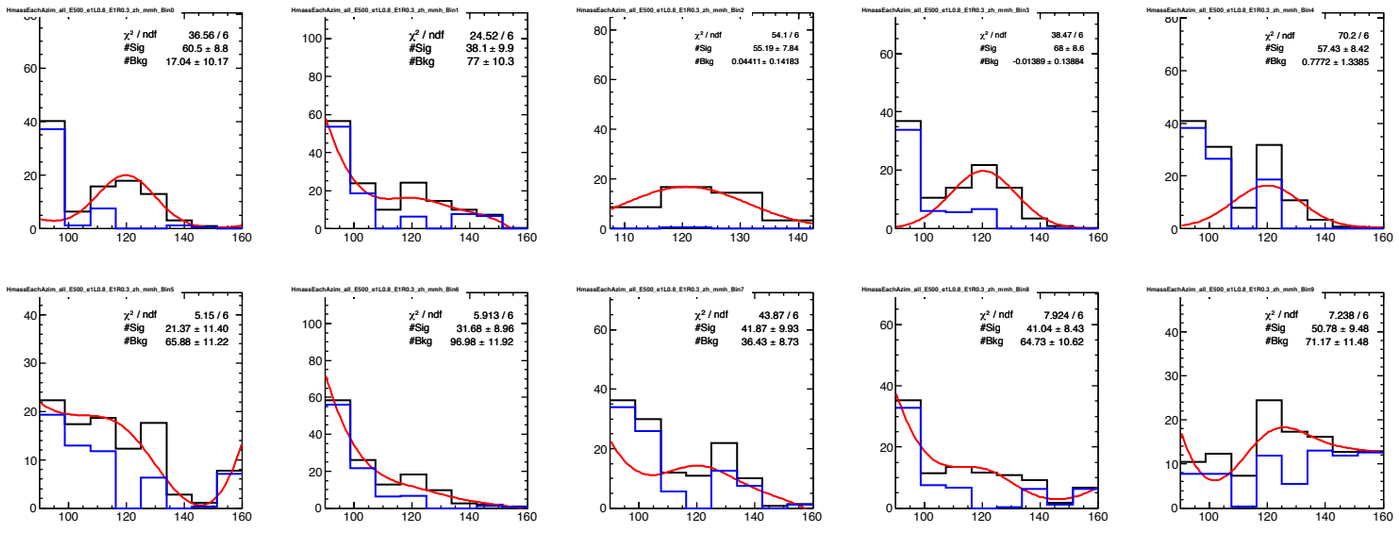


Estimation of #Signal Events & Detector Acceptance

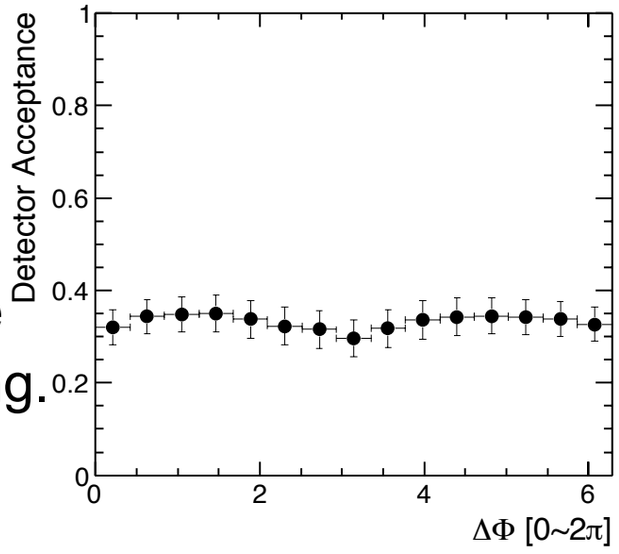
>. For the moment,
estimation of #signals by
using fitting is not easy.

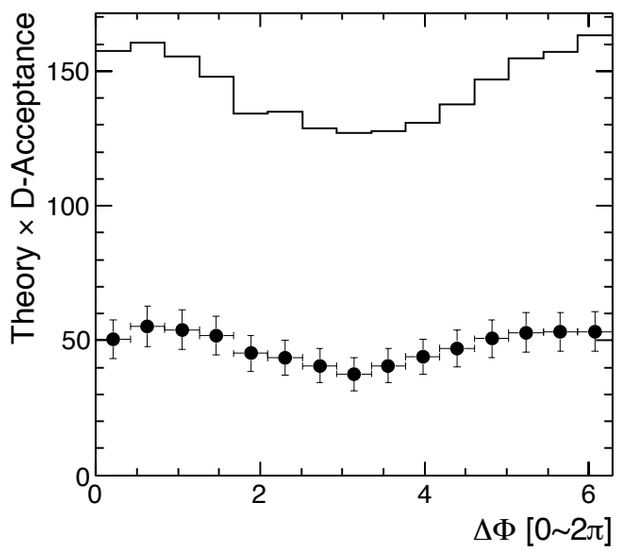
>. Count #events.

>.Distributions of each bin (15bins).



Detector acceptance
estimated by counting.





Theoretical distribution
500GeV 500fb-1

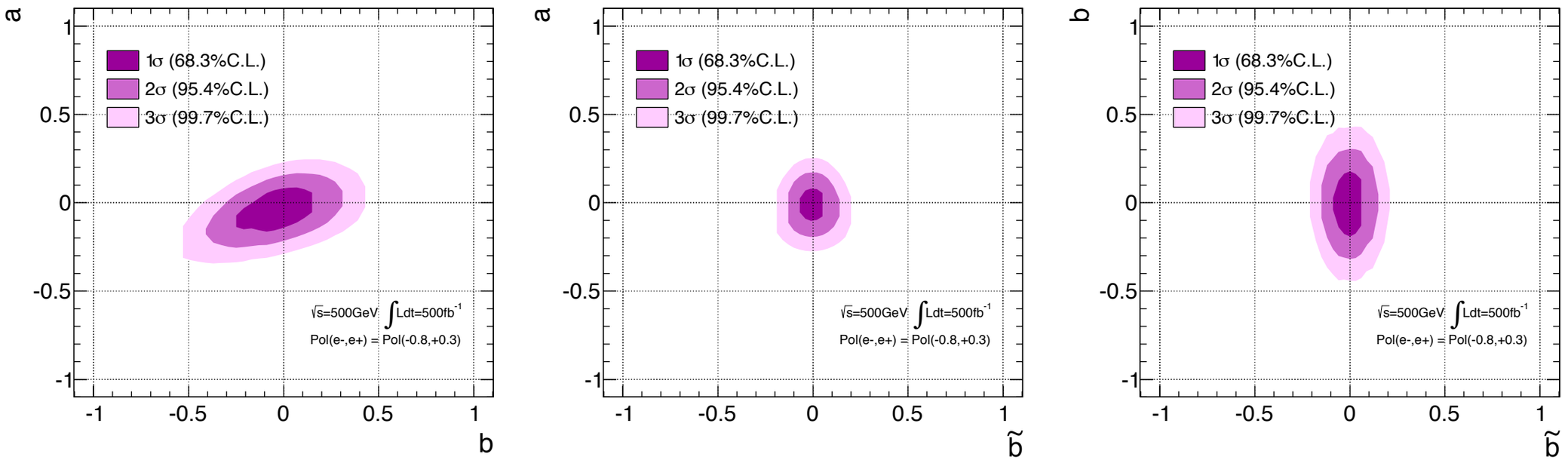
Observer value
with Poisson error

Sensitivity to Anomalous Couplings (eeH➡eebb)

>. (a vs b)
The direction of a is restricted due to changing absolute value of X.
The direction of b is restricted due to changing ΔΦ distribution.

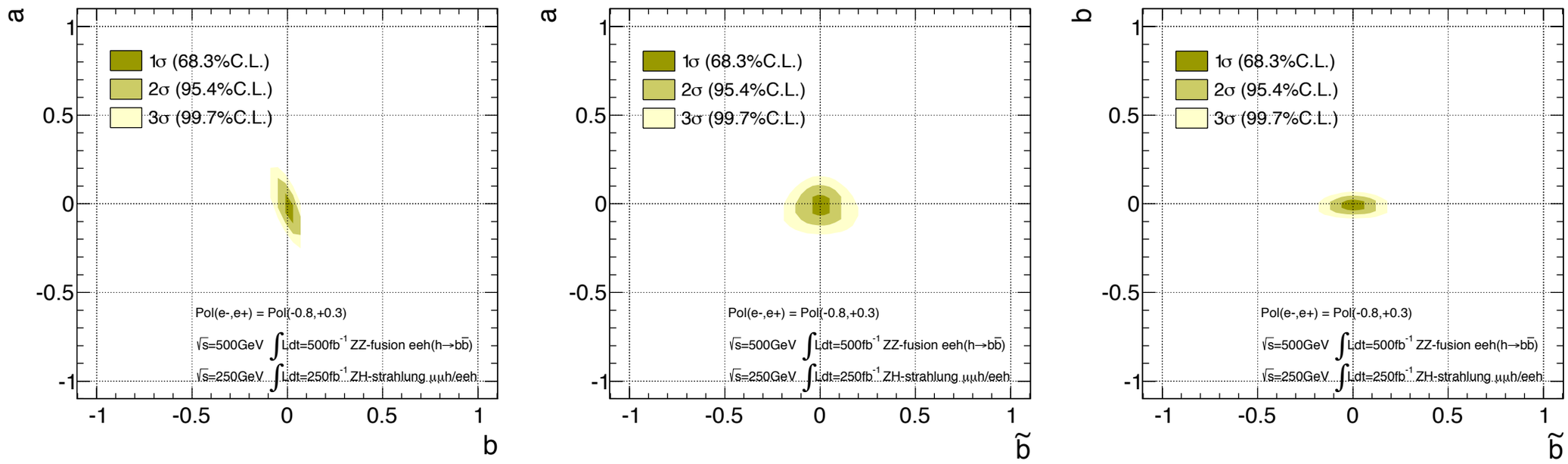
>. (a vs bt)
The direction of a is restricted due to changing absolute value of X.
The direction of bt is restricted due to changing ΔΦ distribution.

estimation from parameter “ΔΦ”



Combined Result & Summary

>. Combined result (mmh, eeh (recoil) and eebb (zz-fusion)).



>. The purpose is to estimate how the ILC is sensitive to anomalous couplings if the higgs has small anomalous components.

>. We studied ZZH case using several production process.

>. We can distinguish such anomalous components ~ 0.1 level on ZZH.

(based on current result)