Plans of Higgs self-coupling analysis towards DBD

task force for the Higgs self-coupling analysis

Goal

- full investigation of the feasibility of Higgs self-coupling measurement at the ILC
  - ⋆ different energies: 500 GeV, 1 TeV
  - ⋆ different search modes: ZHH, vvHH
  - ⋆ different polarization: left, right
  - ⋆ different Higgs masses: 120, 130, 140 GeV

results based on current analysis technology

Polarization: (e-,e+)=(-0.8,0.3) $e^+ + e^- \to ZHH$ $M(H) = 120\text{GeV}$ $\int Ldt = 2\text{ab}^{-1}$

Energy (GeV)	Modes	signal	background	significance	
				excess (I)	measurement (II)
500	$ZHH \to (l\bar{l})(b\bar{b})(b\bar{b})$	6.4	6.7	2.1σ	1.7σ
500	$ZHH \to (\nu\bar{\nu})(b\bar{b})(b\bar{b})$	5.2	7.0	1.7σ	1.4σ
500	$ZHH \to (q\bar{q})(b\bar{b})(b\bar{b})$	8.5	11.7	2.2σ	1.9σ
		16.6	129	1.4σ	1.3σ

combined significance of ZHH excess: **3.9σ**

$$\sigma_{ZHH} = 0.22 \pm 0.07 \quad \text{fb}$$

precision of cross section: **32%**

precision of Higgs self-coupling: **57%**

remained backgrounds (llHH)

full simulation @ 500GeV

Polarization: (e-,e+)=(-0.8,0.3) $\int Ldt = 2\mathrm{ab}^{-1}$

with statistical errors on the expected numbers of events

	llHH	vvHH	qqHH (i)	qqHH (ii)
Signal	6.4	5.2	8.5	16.6
BG	6.7	7.0	11.7	129
ZZZ	1.2	0.6	2.1	6.7
ZZH	4.3	1.5	2.7	7.6
tt, ttqq	-	3.3	5.2	105
llbb, bbbb	1.2	1.6	1.3	9.1

we need better analysis technology

future improvements

- jet clustering

  vertex-based, optimized for b-tagging

- b-tagging

  based on new jet-clustering

  neural-net tuning

- jet pairing

  kinematical, kinematic fitting

  dynamical? charge?

- lepton ID

tt-bar suppression

ZZZ, ZZH suppression

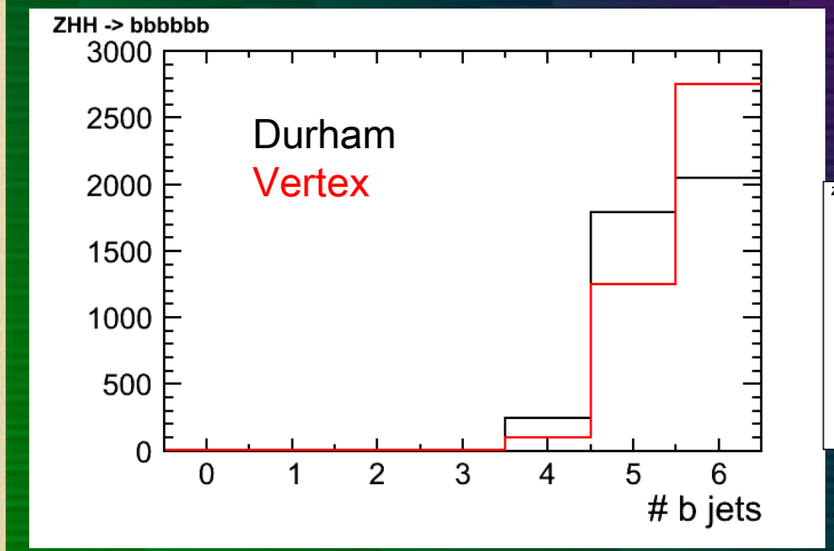
llbb, bbbb suppression

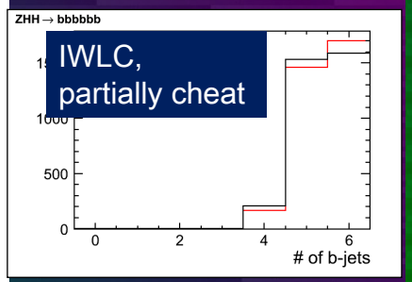
jet clustering

(T. Suehara)

- Vertex Finder --> Jet Cluster --> Flavor Tagger.
- tracks from one B-hadron will not be clustered to different jets

Number of b jets in bbbbbb

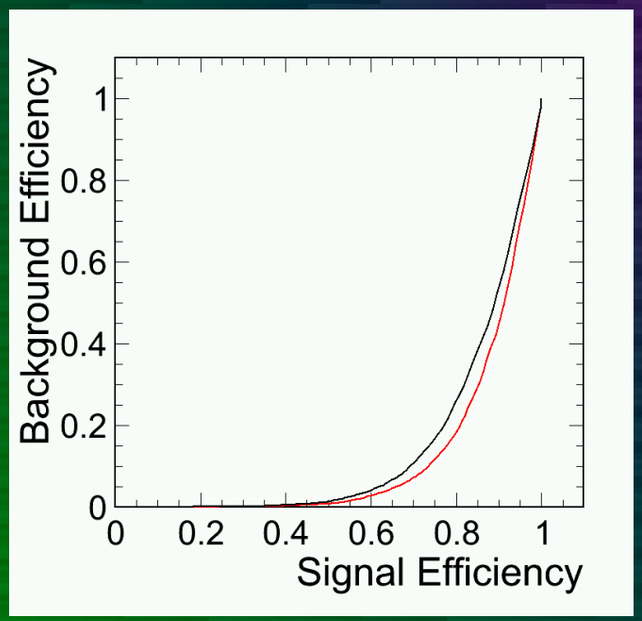




significant improvement seen!
All jets including b – 52% -> 66%

Results (4-b required)

Obtained by changing b-likeness threshold



Clear improvement!

qqhh

applied to tt-bar suppression

ongoing

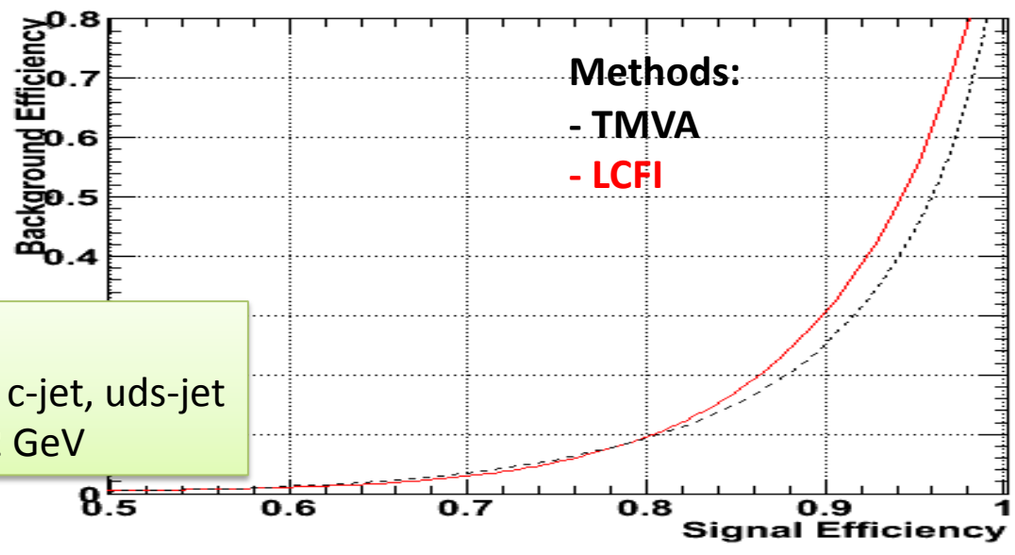
flavor tagging (LCFIVetex)

(T. Tanabe)

- new framework with TMVA, easier to modify
- optimization of input variables.

improvements

- improvements attempts have already begun by incorporating new variables
  - currently incorporate the vertex ordering information (vertex distance and vertex momentum direction)
  - already see improvement in the high signal efficiency region
- will incorporate other variables & optimize at higher energies



signal = b-jet
background = c-jet, uds-jet
Z-> qq @ 91.2 GeV

ongoing

jet pairing

(J. Tian)

- likelihood pairing algorithm.
- kernel function can well estimate the shape of the invariant mass spectrum

jet pairing using Kernel Function

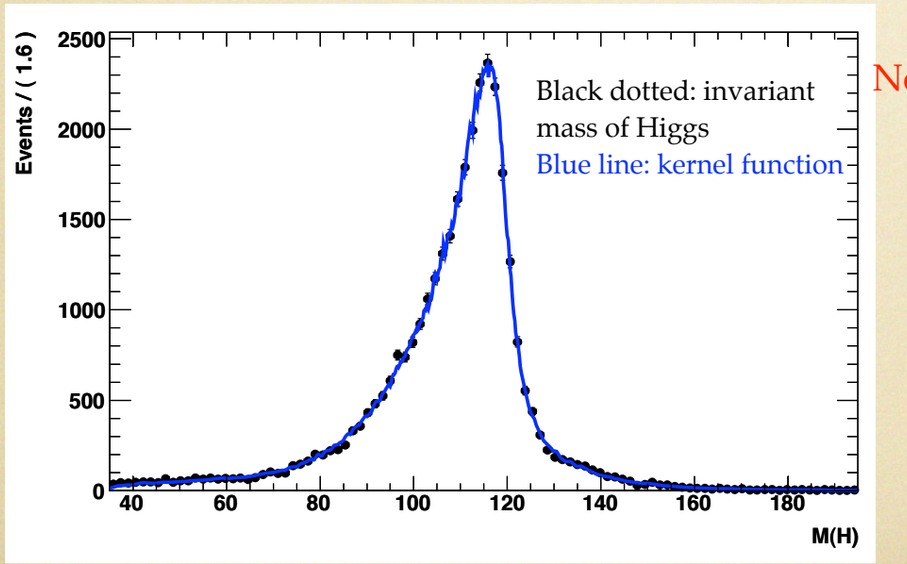
not gaussian!

traditionally: $\chi^2 = \frac{(M(b,\bar{b}) - M_H)^2}{\sigma^2_{H_1}} + \frac{(M(b,\bar{b}) - M_H)^2}{\sigma^2_{H_2}} + \frac{(M(l,\bar{l}) - M_Z)^2}{\sigma^2_Z}$

define: $L = f(M_{12})f(M_{34}) \quad \chi^2 = -\ln L = -\ln f(M_{12}) - \ln f(M_{34})$

f: the real probability density function (from MC)

distribution of invariant mass and estimated kernel function



Non-parametric Kernel Estimation

$$F(x) = \frac{1}{N}\sum_{j=1}^{m} n_j G(x; t_j, h_j)$$

$$h_j = \left(\frac{4}{3}\right)^{1/5} N^{-1/5} \triangle x \sqrt{\frac{N}{n_j}}$$

efficiency of correct pairing improved: 80% ----> 85%

kinematic fitting?
charge information?
color singlet information?

ongoing

lepton identification

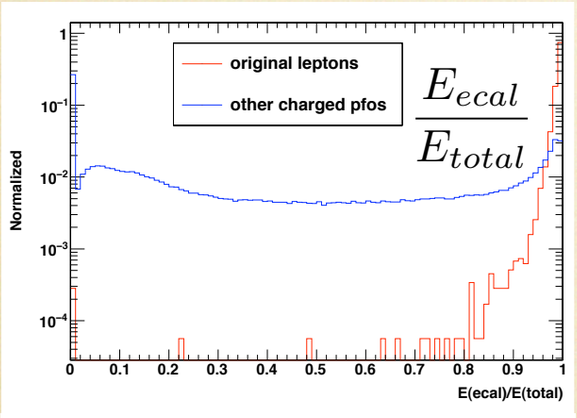
(J. Tian & K. Fujii)

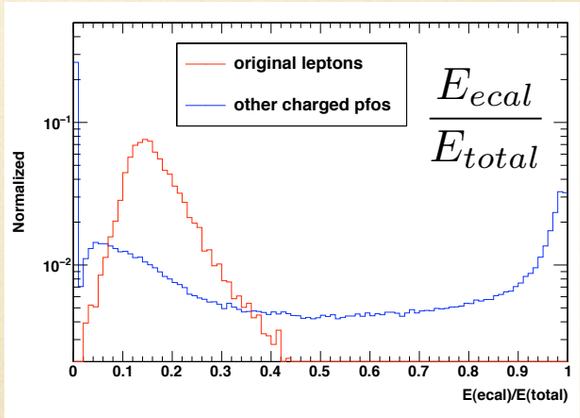
- previously only P, E(Ecal), E(Hcal) and E(cone) used. more information (dE/dx? shower profile?)
- Fisher Classification used for isolation requirement.

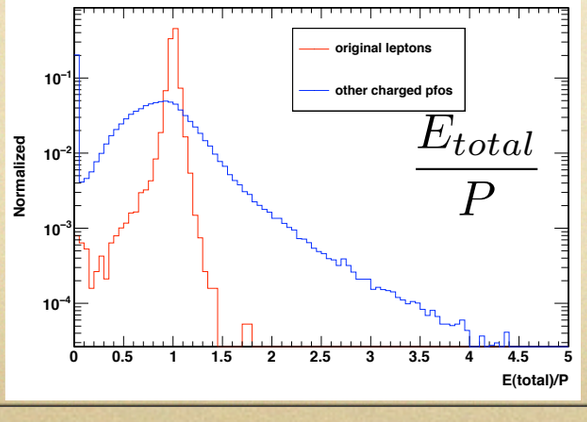
lepton identification

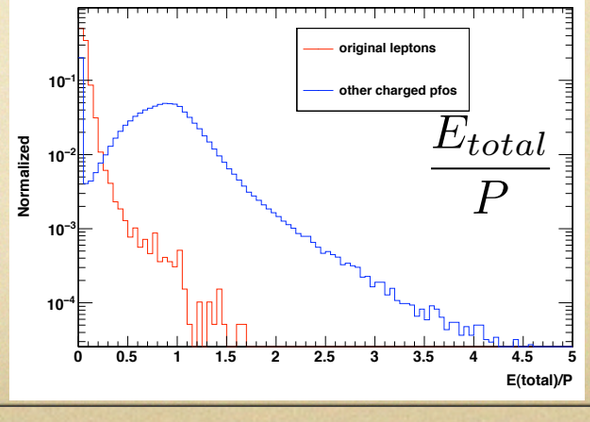
- **electron almost deposits all the energy in the ECAL.**
- **muon deposits small part of the energy in both ECAL and HCAL, but more in the HCAL than ECAL.**

$$e: \begin{cases} \frac{E_{ecal}}{E_{total}} > 0.9 \\ 0.8 < \frac{E_{total}}{P} < 1.2 \end{cases} \qquad \mu: \begin{cases} \frac{E_{ecal}}{E_{total}} < 0.5 \\ \frac{E_{total}}{P} < 0.3 \end{cases}$$









samples:
eeHH & μμHH

red:
prompt leptons

blue:
other charged pfos

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leptons in a jet:

- used for flavor tagging
- calibrate the missing neutrino pt

not started yet

further analyses

ZHH and vvHH analyses @ 1 TeV

- previously, only WW fusion at 1 TeV based on fast simulation

preliminary

reduction table (vvHH)

no beam polarization $E_{\rm cm} = 1000{\rm GeV}, M_H = 120{\rm GeV}$ $\int Ldt = 2{\rm ab}^{-1}$

	υυHH(υυbbbb)	tt-bar	WWZ	ZZZ	ZZH	νvZZ	νvWW	ttH	υυZH
MC	500K	500K	500K	500K	500K	500K	50K	50K	500K
expected	142.6(63.4)	377600	123400	1664	700	12100	30200	4960	2500
pre-selection	115.8(61.1)	160971	27772	609.2	239.7	6112	14048	184.3	1620
Evis<600	110.8(58.3)	32326	11512	330.2	134.8	5932	13626	89.2	1548
mlp_tt>0.8	33.0(20.7)	376.8	57.5	1.95	2.42	140.0	171.5	2.38	159.8
mlp_zzzh>0.6	20.6(12.8)	182.8	17.0	0.45	0.60	6.32	4.83	1.78	22.0
noff4>0 noff3>2	6.17(5.8)	3.78	0	0.02	0.05	0.36	0	0.40	2.16
mjet4>2 econe>0.1	5.95(5.62)	1.51	0	0.02	0.04	0.36	0	0.20	2.04

excess significance: 2.4σ

precision on the cross-section: 52%

precision on the Higgs self-coupling: 44%

recalling $\frac{\Delta\lambda}{\lambda} = 0.85\frac{\Delta\sigma}{\sigma}$

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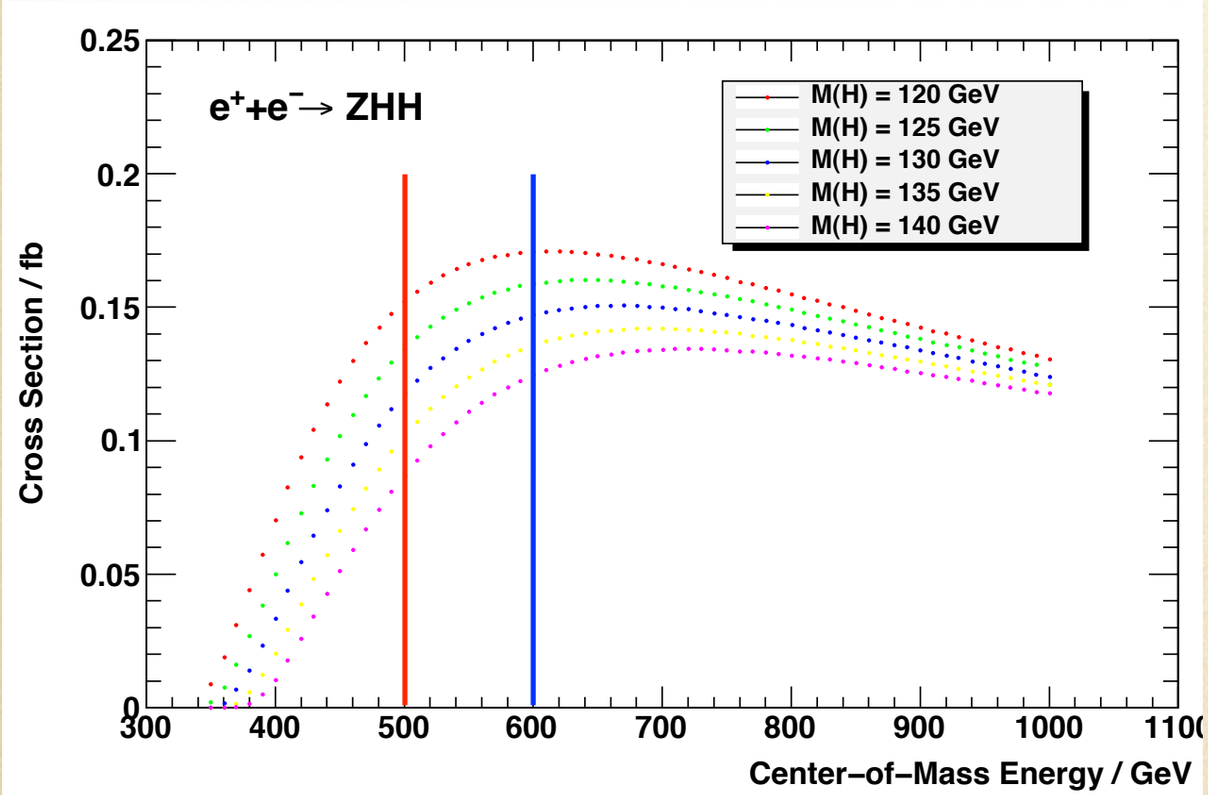
we need full simulation

not started yet

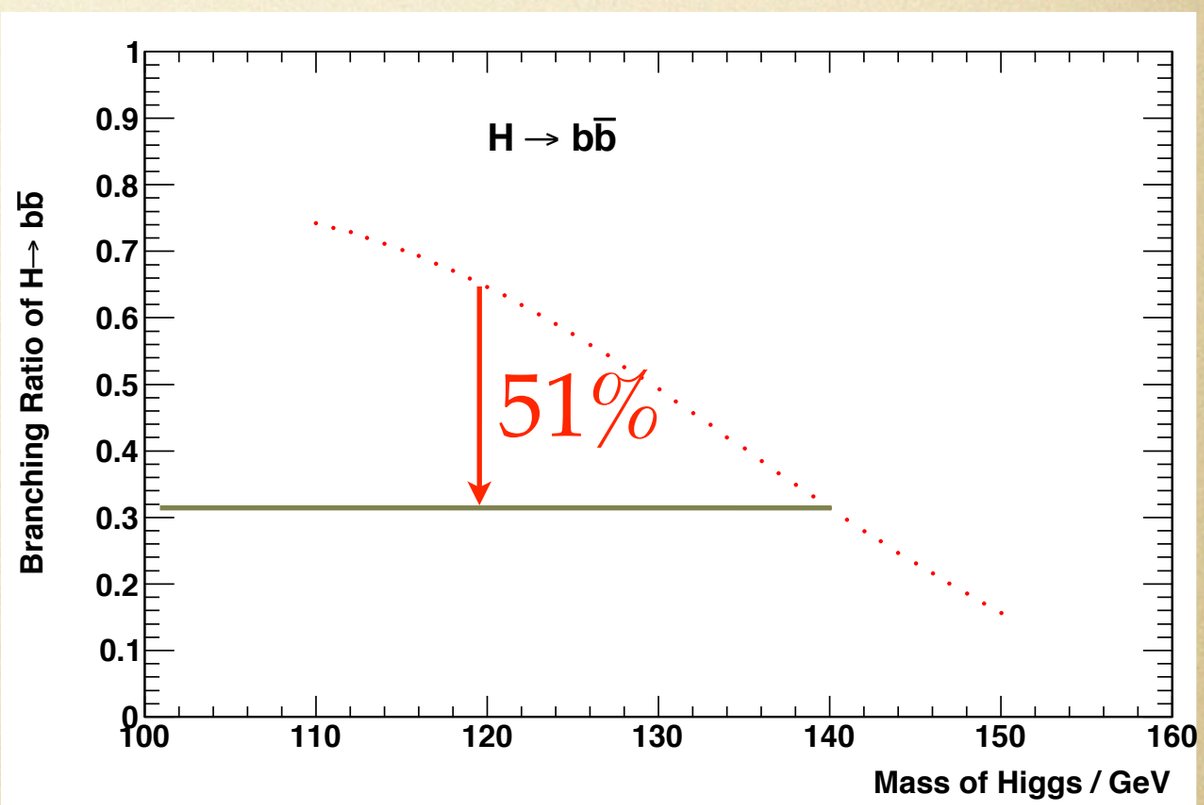
analysis with different Higgs masses

- now, only 120 GeV tested

cross section drops quickly



Br(H-->bb) drops quickly



For 140 GeV Higgs, σ(ZHH-->Zbbbb) will be only 13% of that for 120 GeV

we need more efficient selection and consider H--> WW* mode

not started yet

Call for the Task Force

- very important study, lots of work to do
- currently 4 members: T. Suehara, T. Tanabe, J. Tian and K. Fujii
- chaired by T. Suehara, supervised by K. Fujii
- biweekly meeting
- start from an investigation of cheated jet clustering

anyone interested is invited!

backup

Hypothesis Test (Combined)

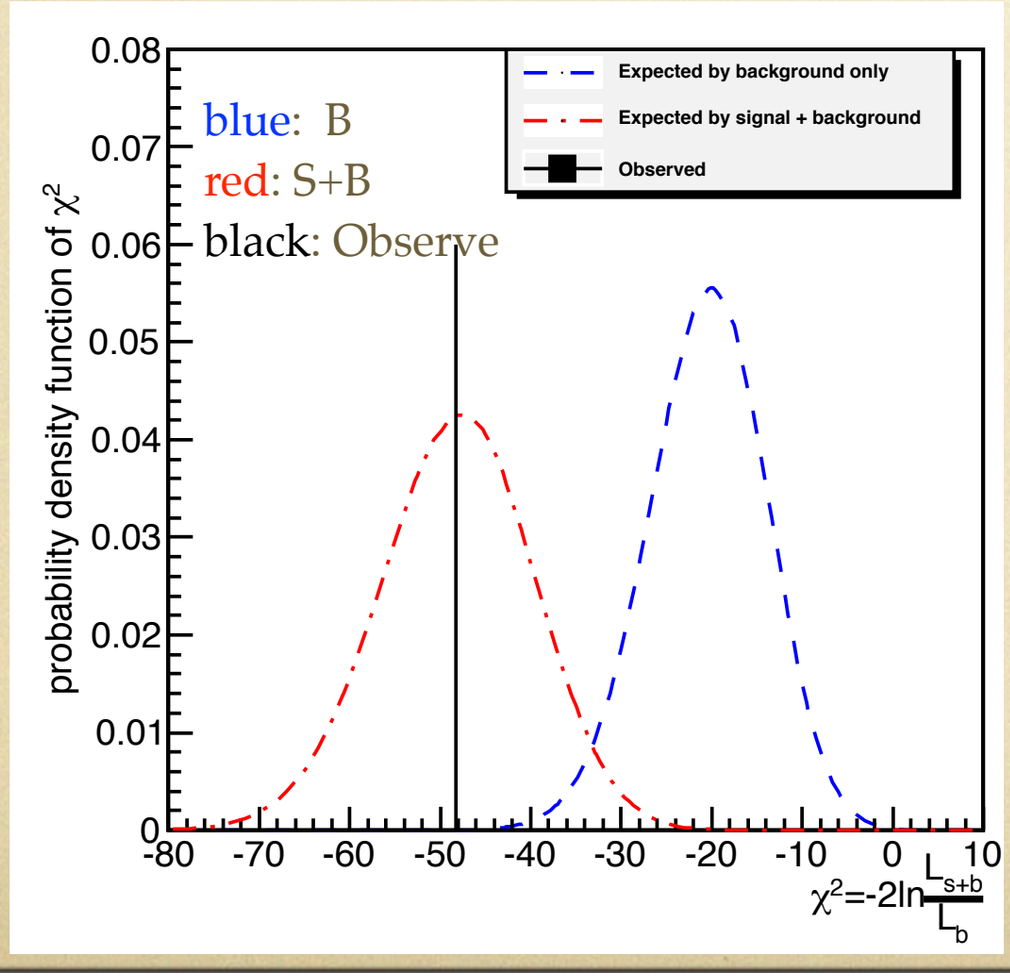
H0: background only H1: ZHH events exist

test: $\chi^2 = -2\ln\frac{L_{s+b}}{L_b}$

$$L_{s+b} = \Pi_i \frac{e^{-(s_i+b_i)}(s_i+b_i)^{n_i}}{n_i!} \qquad L_b = \Pi_i \frac{e^{-b_i} b_i^{n_i}}{n_i!}$$

s_i: the expected number of signal events
b_i: the expected number of background events
n_i: the observed number of events

Distributions of the test



$$p = \int_{-\infty}^{\chi^2_{obv}} f(\chi^2)\, d\chi^2$$

$$= 4.6 \times 10^{-5}$$

combined significance of ZHH excess: **3.9σ**

extracting the cross section of ZHH

$$L_{s+b} = \Pi_i \frac{e^{-(s_i+b_i)}(s_i+b_i)^{n_i}}{n_i!}$$

b_i: expected background number (known from MC)

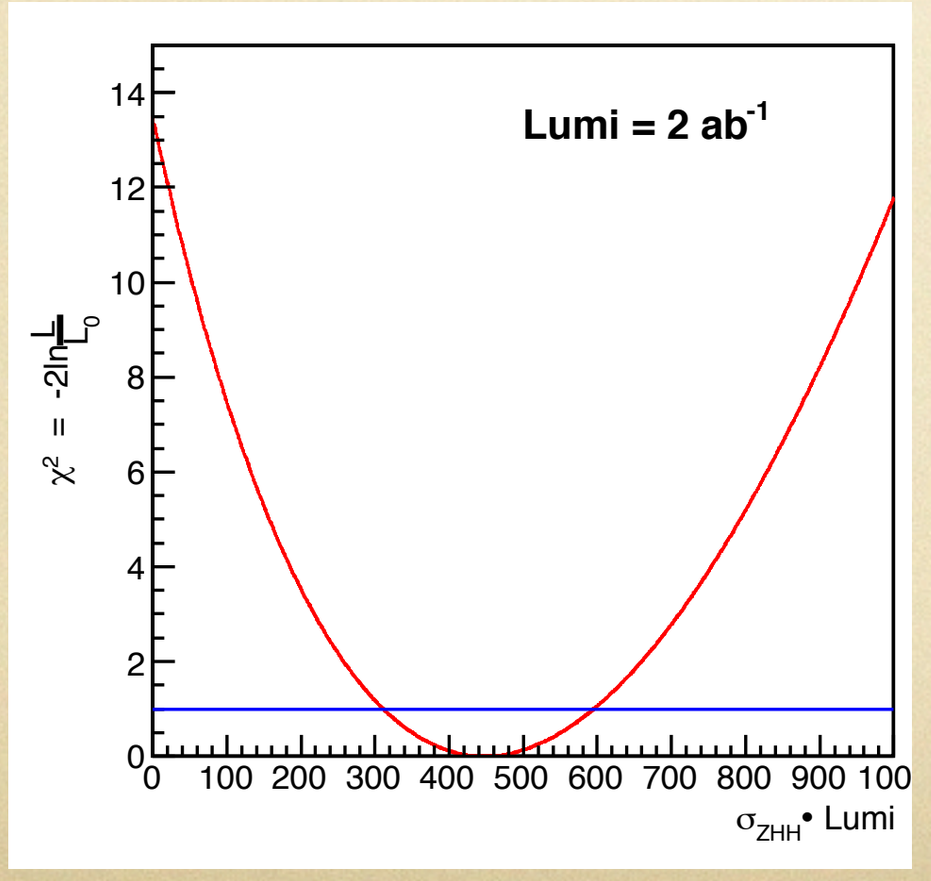
n_i: number of observed events (known from Experiment)

s_i: parameter related with the cross section

$$s_i = (\sigma_{ZHH} + \sigma_i) \cdot \mathrm{Lumi} \cdot \mathrm{Br}_i \cdot \mathrm{Eff}_i$$

$$\chi^2 = -2ln\frac{L}{L_{max}}$$

σi: fusion contribution (negligible at 500 GeV)



$$\sigma_{ZHH} \cdot \mathrm{Lumi} = 448^{+145}_{-137}$$

$$\sigma_{ZHH} = 0.22 \pm 0.07 \ \ \mathrm{fb}$$

precision of cross section: **32%**

precision of Higgs self-coupling: **57%**

recalling $\frac{\Delta\lambda}{\lambda} = 1.8\frac{\Delta\sigma}{\sigma}$