Reminder on HZ Analysis for LOI (and beyond)

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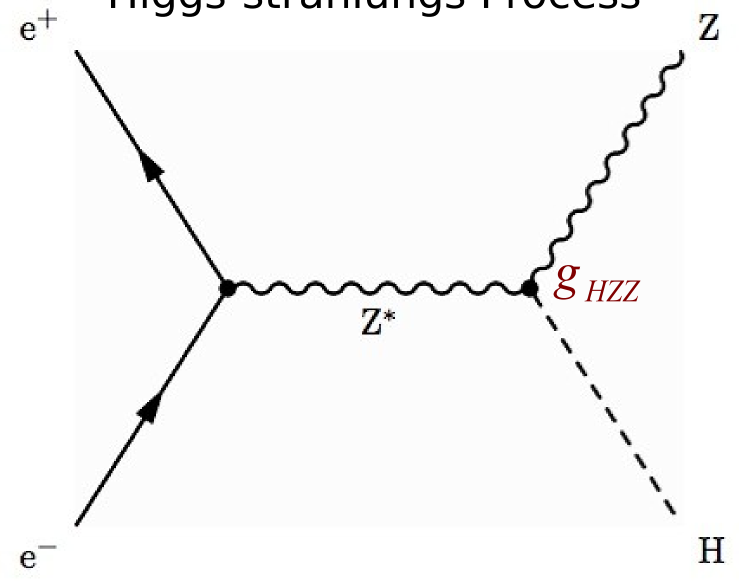
3rd LC Forum
DESY 8/2/2012

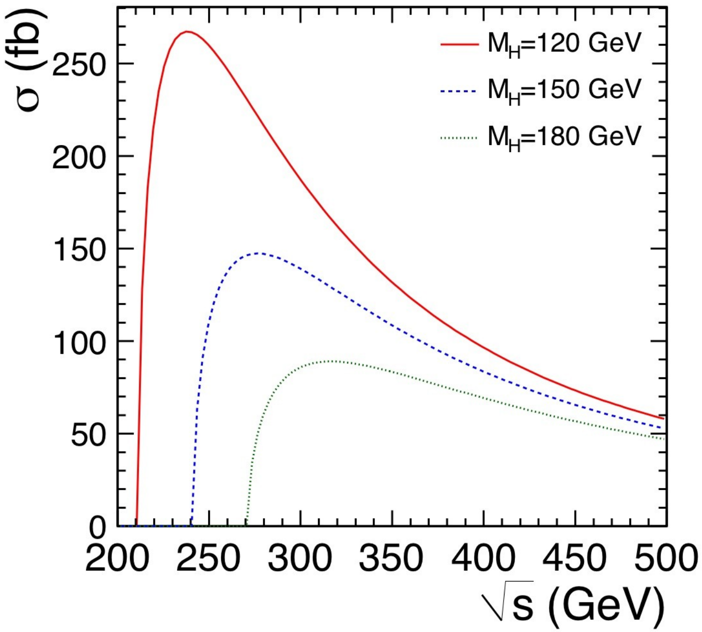
Higgs-strahlung Cross Section and Higgs Mass at the ILC

Higgs-strahlungs Process



Golden Plated Channel at e^+e^- Colliders

Sensitive to coupling at HZZ Vertex



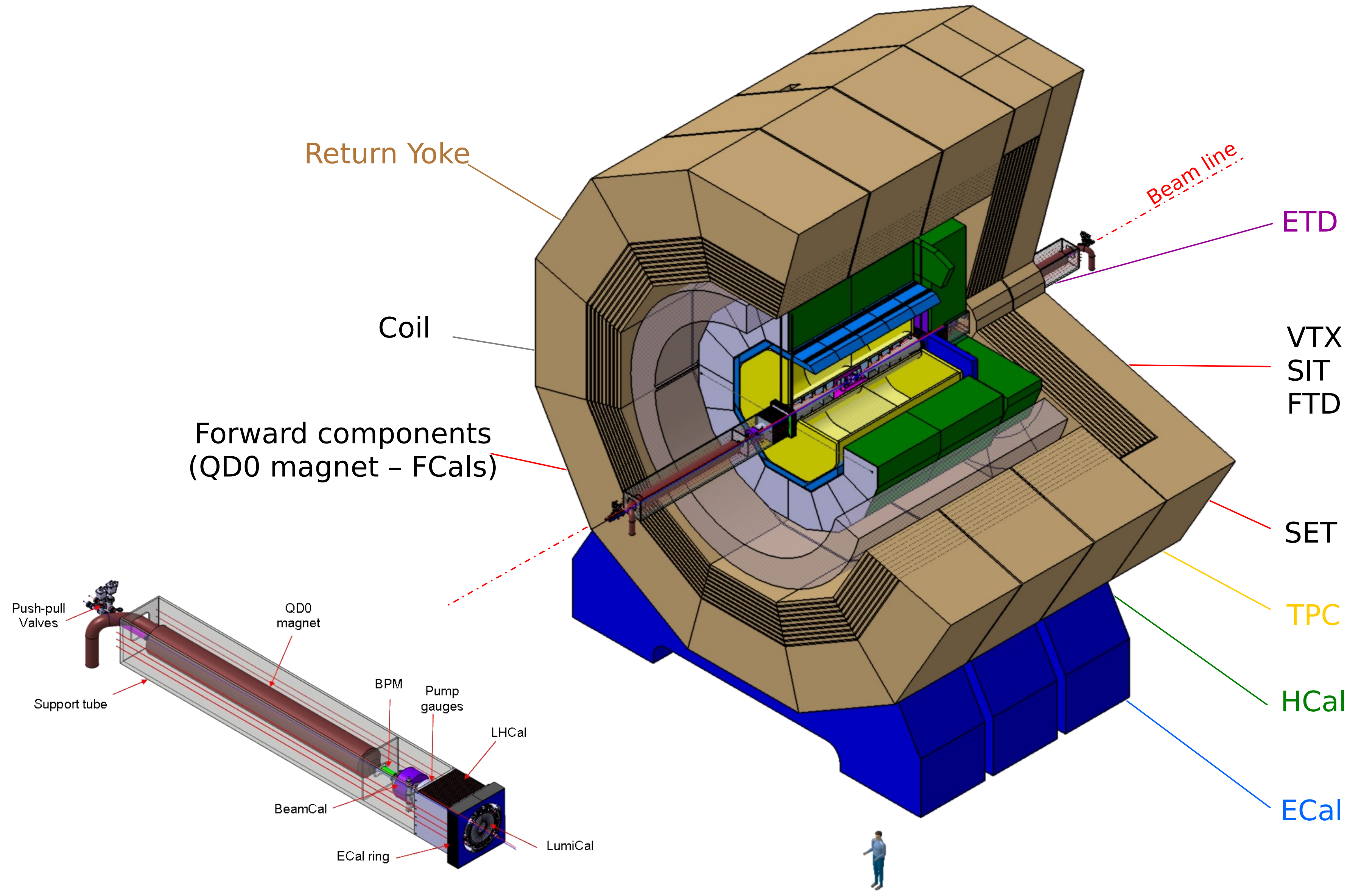
Production Cross Section of SM Higgs Boson

Maximal at HZ production threshold

LOI Benchmark reaction:

Higgs Strahlung at $\sqrt{s}$ = 250 GeV for m_H = 120 GeV

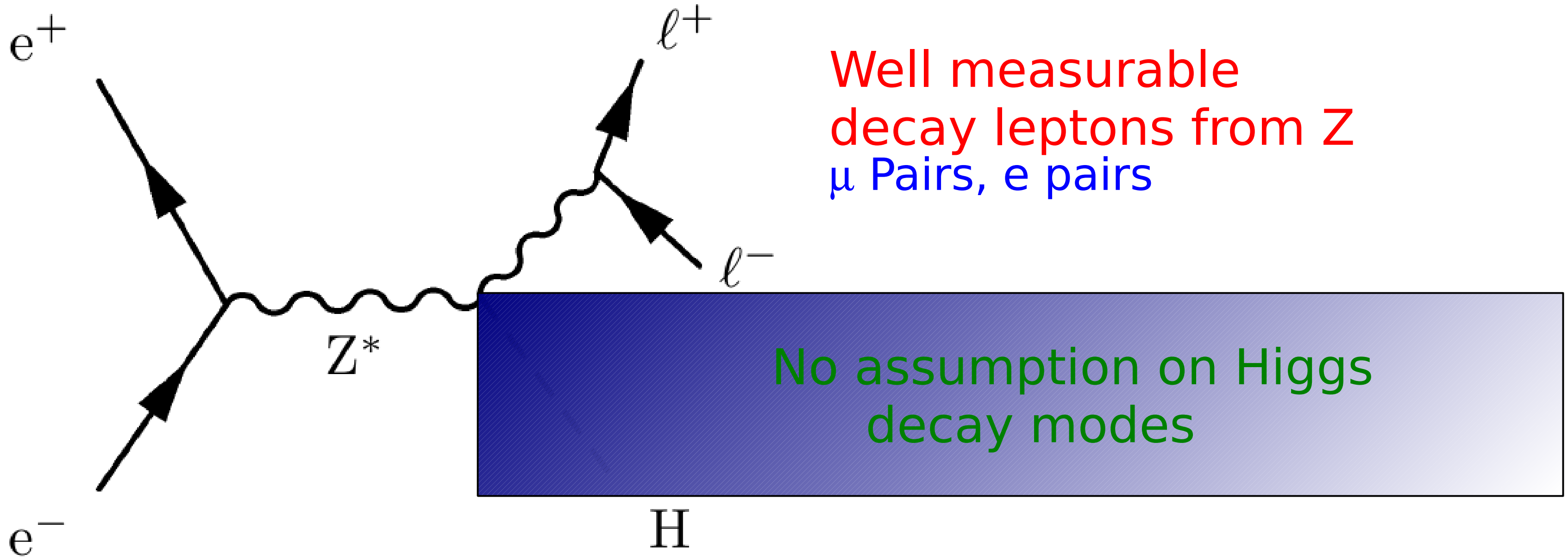
The ILD Detector



Letter of Intent in 2009 – Based on full detector simulation

Why golden plated Channel?

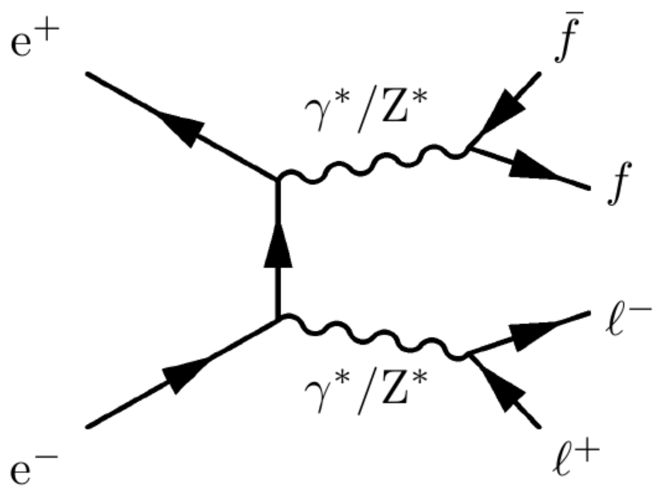
Higgs Mass and ZZH coupling by
Model Independent
measurement

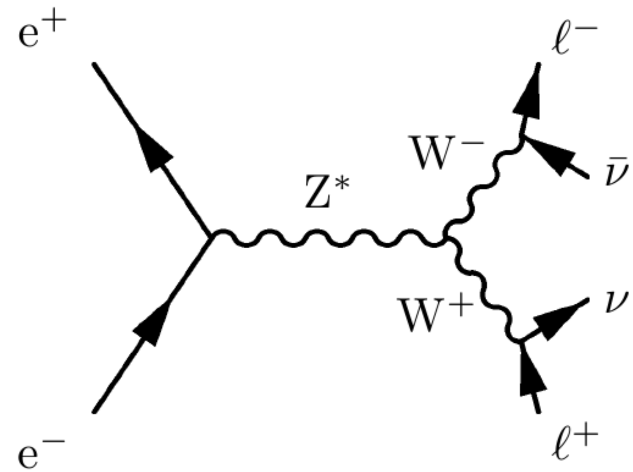


Higgs Recoil Mass: $M_h^2 = M_{recoil}^2 = s + M_Z^2 - 2 E_Z \sqrt{s}$

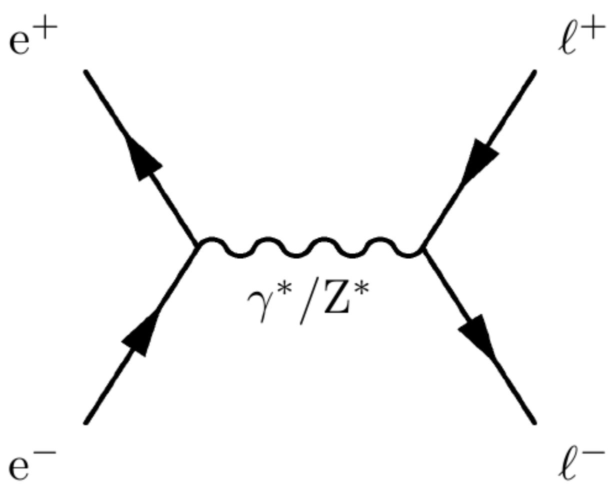
(Main) Background Processes

Boson Pair Production

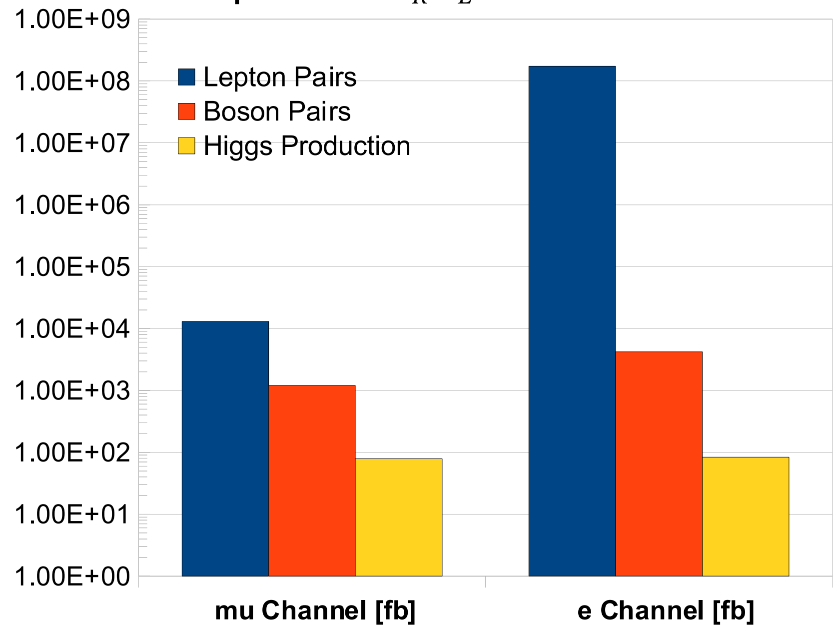




Lepton Pair Production



Example for $e_R^- e_L^+$ Polarisation Mode



Huge Background $\sigma_{signal}/\sigma_{bkgr.}$ ~0

Background Rejection

ILD

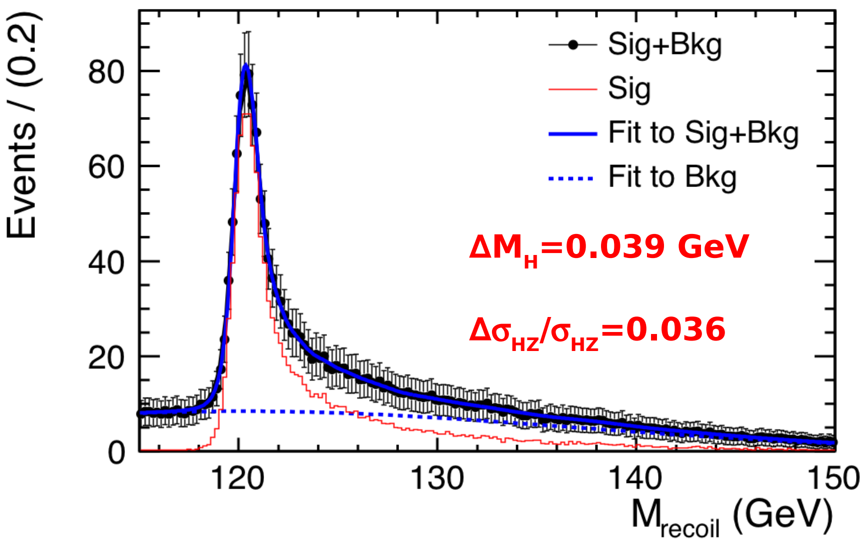
$P_{T,dl} > 20$ GeV
$80 < M_{dl-} < 100$ GeV
$0.2 <$ acop < 3.0
$\Delta P_{Tbal.} > 10$ GeV
$|\cos\theta_{miss.}| < 0.99$
$115 < M_{recoil} < 150$ GeV
Dedicated cuts for radiative events
Multivariate Analysis

- Relaxed constraint on dilepton Mass
- Cuts more closely 'tailored' to background

Signal/Background > 30%

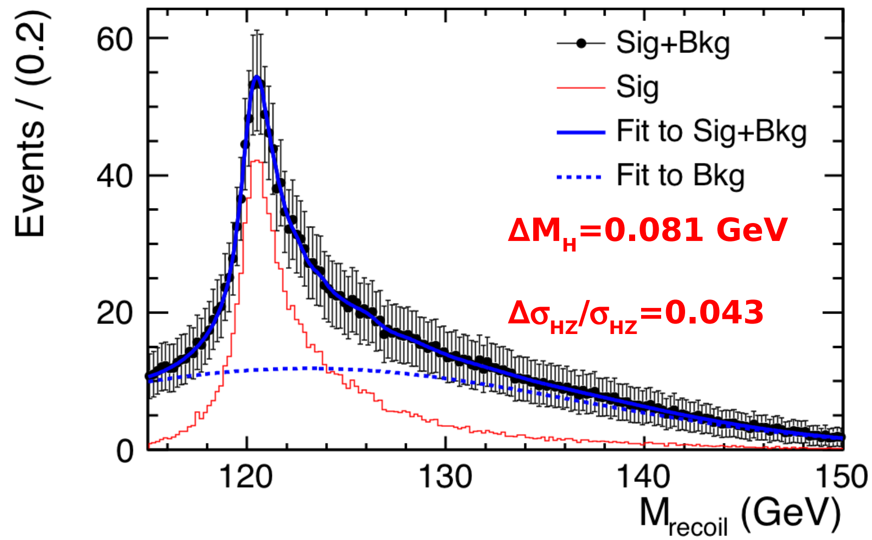
Results (see also LC Note LC_PHSM-2009-006)

Muon Channel



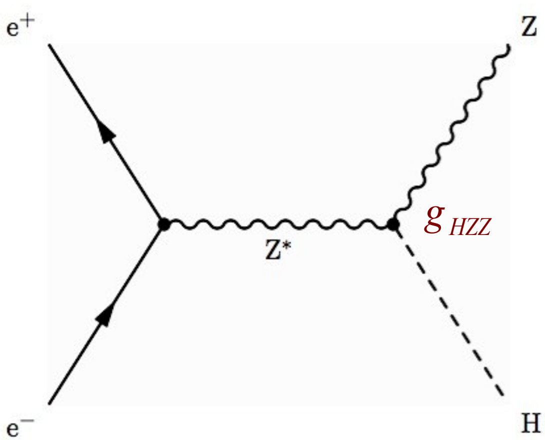
Very Precise Measurement
S/B = 8 in Peak Region

Electron Channel



Less Precise
Bremsstrahlung in detector material

Combined: ΔM_H=0.035 GeV, $\Delta\sigma_{HZ}/\sigma_{HZ}$=0.027

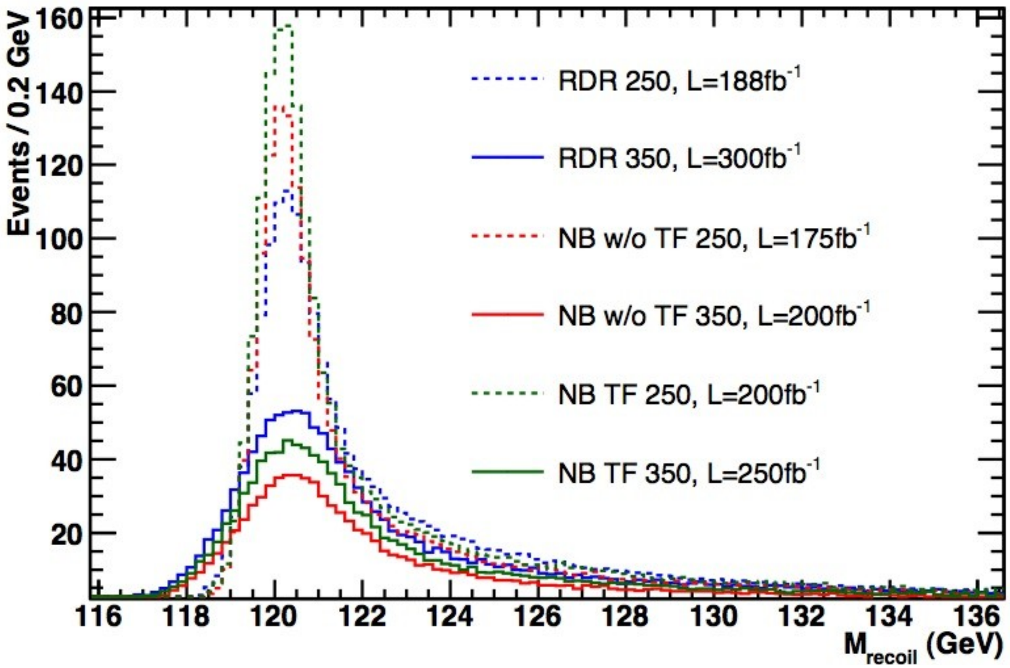


$$\sigma_{HZ} \sim g^2_{HZZ}$$

⇒ Precision in g_{HZZ} coupling 1-2%

Sensitivity to 15% deviations
SM prediction of cross section

Fast Simulation Tool for Higgs-strahlung – Fast reaction to changing beam parameters



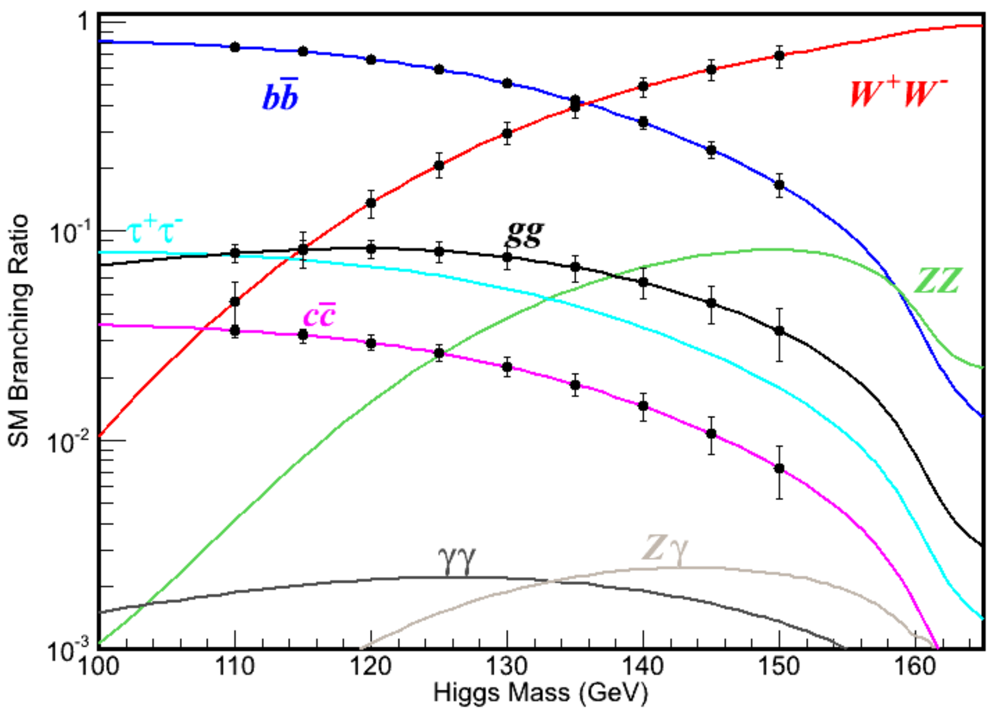
Beam Par	$\mathcal{L}_{\rm int}$ (fb^{-1})	ϵ	S/B	M_H (GeV)	σ (fb) ($\delta\sigma/\sigma$)
RDR 250	188	55%	62%	120.001 ± 0.043	11.63 ± 0.45 (3.9%)
RDR 350	300	51%	92%	120.010 ± 0.087	7.13 ± 0.28 (4.0%)
NB w/o TF 250	175	61%	62%	120.002 ± 0.032	11.67 ± 0.42 (3.6%)
NB w/o TF 350	200	52%	84%	120.003 ± 0.106	7.09 ± 0.35 (4.9%)
NB w/ TF 250	200	63%	59%	120.002 ± 0.029	11.68 ± 0.40 (3.4%)
NB w/ TF 350	250	51%	89%	120.005 ± 0.093	7.09 ± 0.31 (4.4%)

Table 6: Results based on NB beam parameters, assuming a beam polarization of (e^- : -80%, e^+ : $+30\%$), comparing with those of RDR beam parameters.

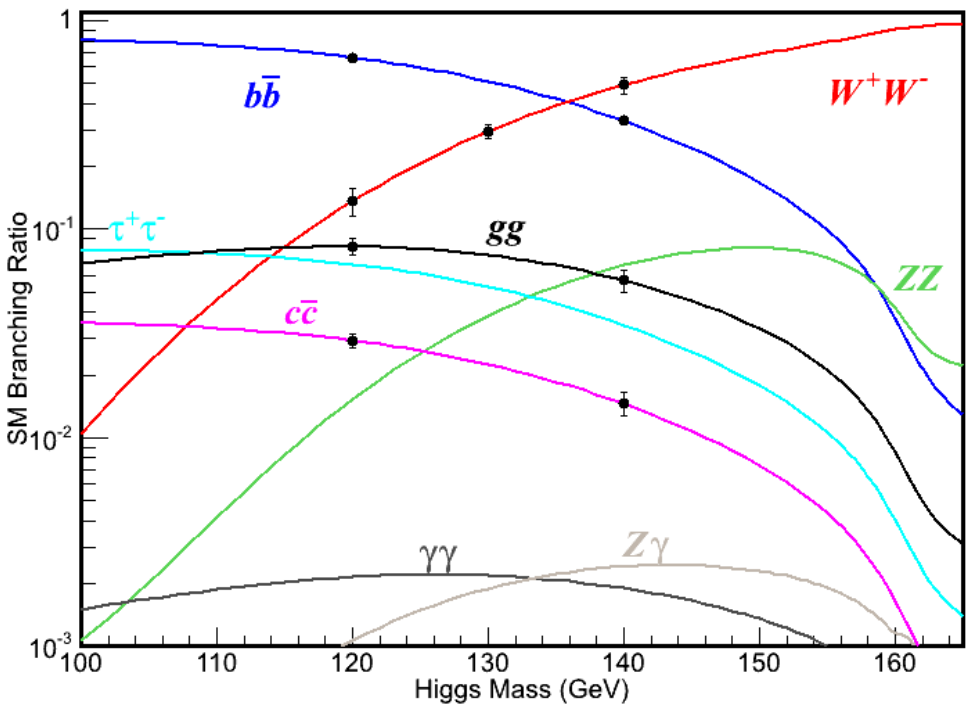
Currently best “fast” reaction tool for ILC studies – Extendable?
Replies to “urgently” needed studies (according to benchmark note)

Higgs BR in light Higgs mass region

Ecm=250 GeV, L=250 fb-1, Pol(e+,e-)=(+30%, -80%) or (-30%, +80%)(ww)



Just extrapolate to the other masses from the accuracies at Mh=120 GeV w/o considering efficiency differences (LCWS11)



Add H→WW*→4j full simulation results
Mh=120 GeV (13.4%)
Mh=130 GeV (6.9%)
Expected to improve including lv+2j

σZH=2.5% uncertainty is also included

Summary of current Higgs study

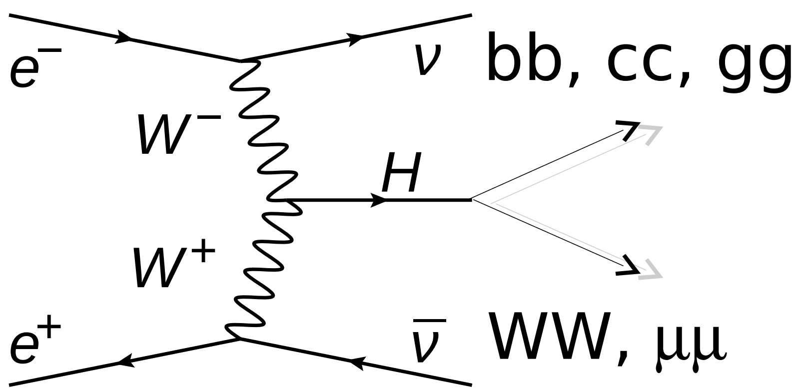
BR precision	Ecm	250 GeV (LOI)	350 GeV	250 GeV	1 TeV (DBD)
H decay	BR	Mh120 GeV	Mh120 GeV	Mh130 GeV	Mh120 GeV
H→bb	66.5%	vvH, qqH, llH	vvH, qqH, llH	To be update	Required vvH
H→cc	2.9%	vvH, qqH, llH	vvH, qqH, llH	To be update	Required vvH
H→gg	8.2%	vvH, qqH, llH	vvH, qqH, llH	To be update	Required vvH
H→WW*	13.6%	vvH, 4j	No	vvH, 4j	Required vvH
H→μμ	0.02%	for DBD	No	No	Required vvH
H→ττ	6.8%	To be done	No	No	No
H→ZZ*	1.5%	start vvH, 4j	No	No	No
H→γγ	0.2%	Constantino	No	No	No
H→Zγ	0.1%	Constantino	No	No	No

Need to do with qqH for WW, ZZ, ττ…
Recoil mass study should also be tested with several masses

vvH @ 1 TeV for DBD

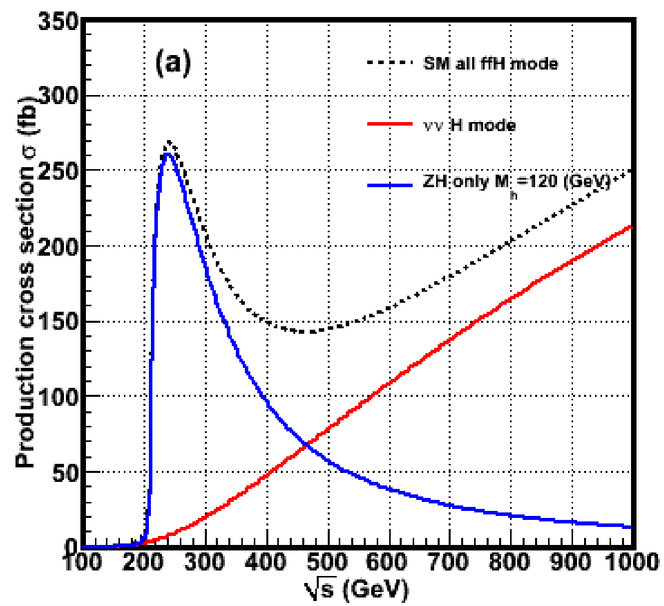
DBD benchmark process: σ*BR for Hμμ, bb, cc, WW, gg

Main produced through W-fusion



H→bb, cc, gg (Hadronic decay)
Di-jet reconstruction
Same strategy as LOI 250 GeV

H→μμ: Muon ID
H→WW*: (4j, lv+2j, 2l+2v)



W-fusion
vvH

ZH

Main backgrounds (WW,ZZ)
ee→ll for H→μμ

Summary and Outlook

- LOI result: Precision of coupling of Higgs Boson to SM Vector Bosons ~1-2%
  High sensitivity to deviations from SM prediction

- HZ Analysis for MH = 120 GeV @ $\sqrt{s}$ = 250 GeV more actual than ever
  Due to increasing interest in low mass Higgs we will publish the
  LC Note to arXiv right after this session

- (Fast simulation) tools at hand to study influence on changing collider parameters
  Proven already to be powerful for process SB2009 -> NB in 2011
  Great work by H. Li

- Higgs BR results
  ΔBR/BR(bb) ~ 3%
  ΔBR/BR(cc) ~ 9%
  ΔBR/BR(gg) ~ 10%
  Error includes $\Delta\sigma_{HZ}$

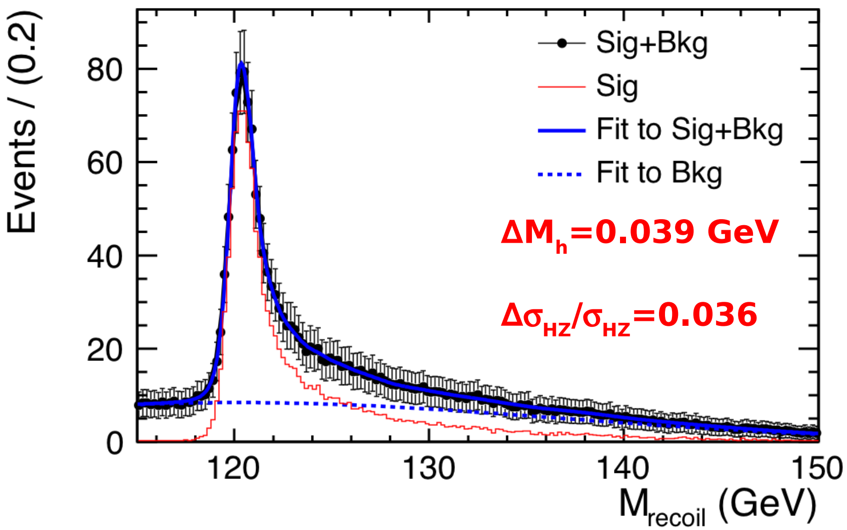
- Higgs BR analysis will be extended to 1 TeV
  ee-> vvH is benchmark process!

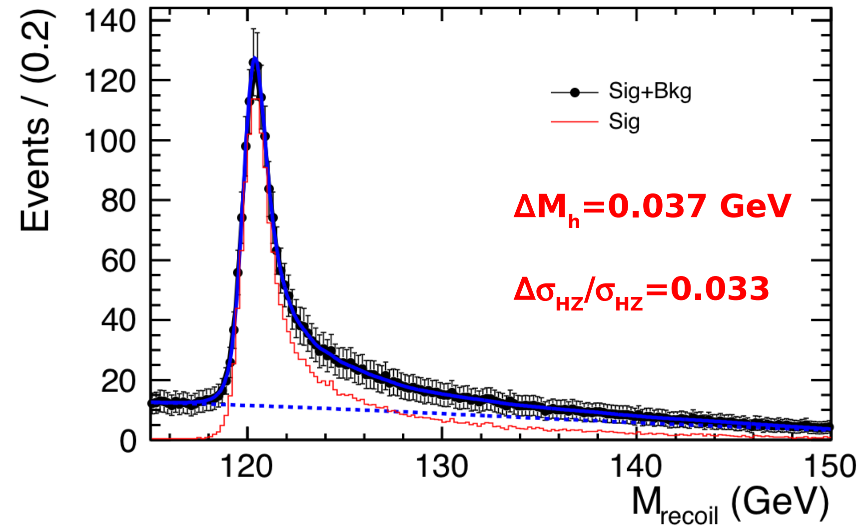
Backup Slides

Model Independent ↔ Model Dependant Analysis

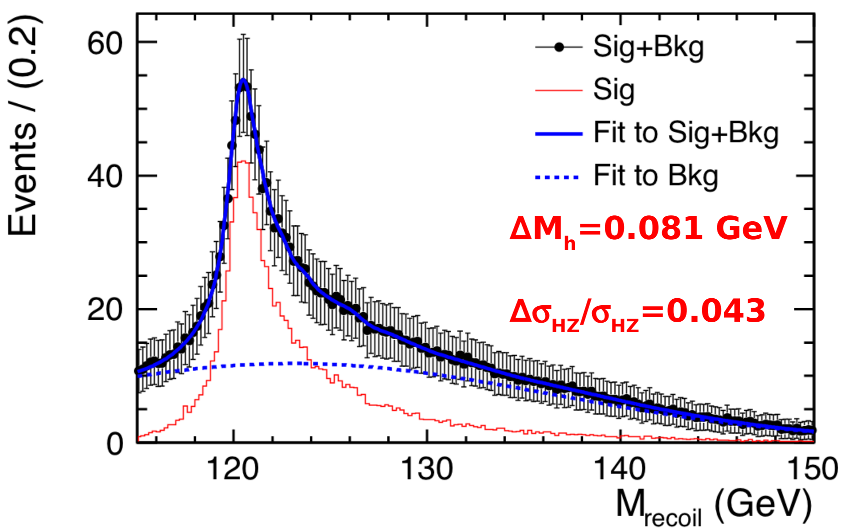
Model dependency by exploiting track activity from SM Higgs decays

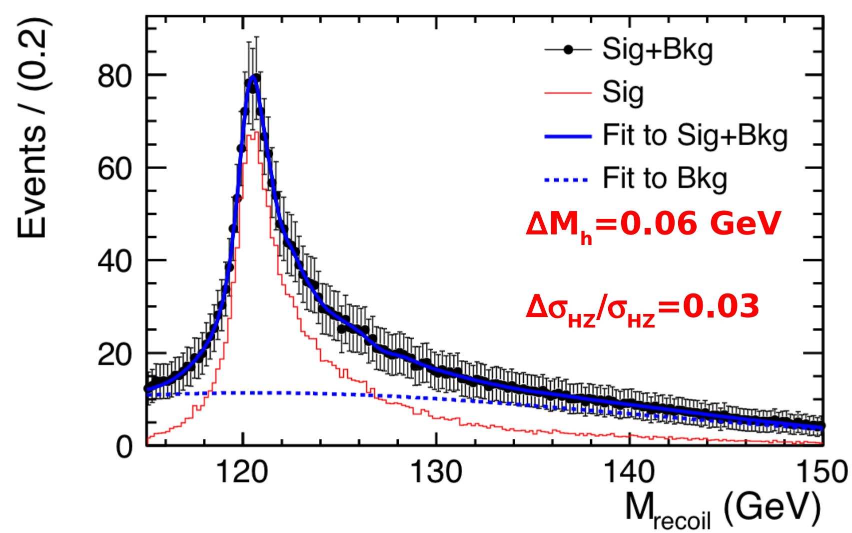
Muon Channel





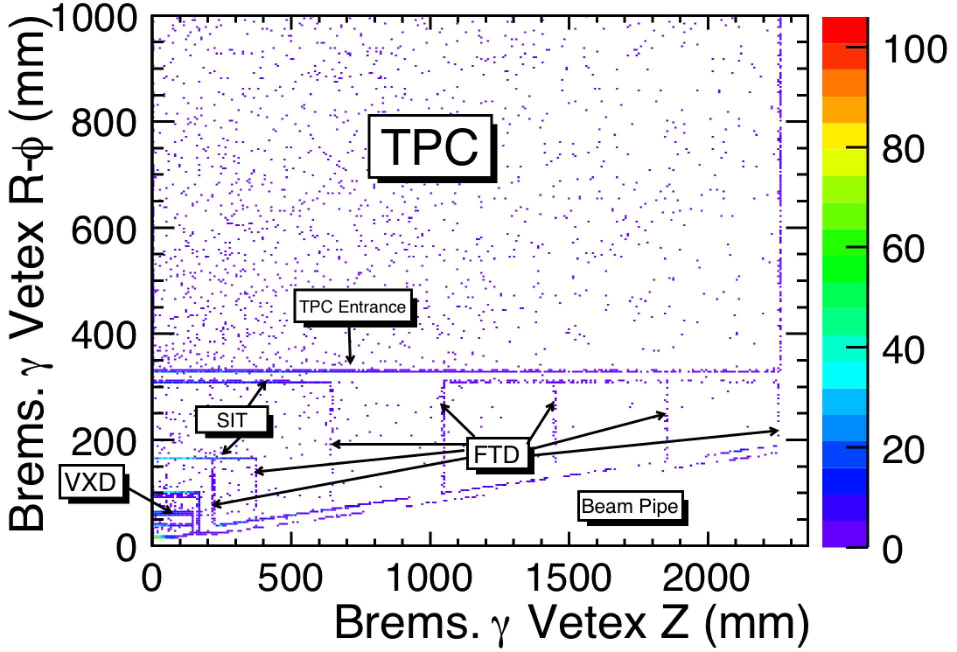
Electron Channel





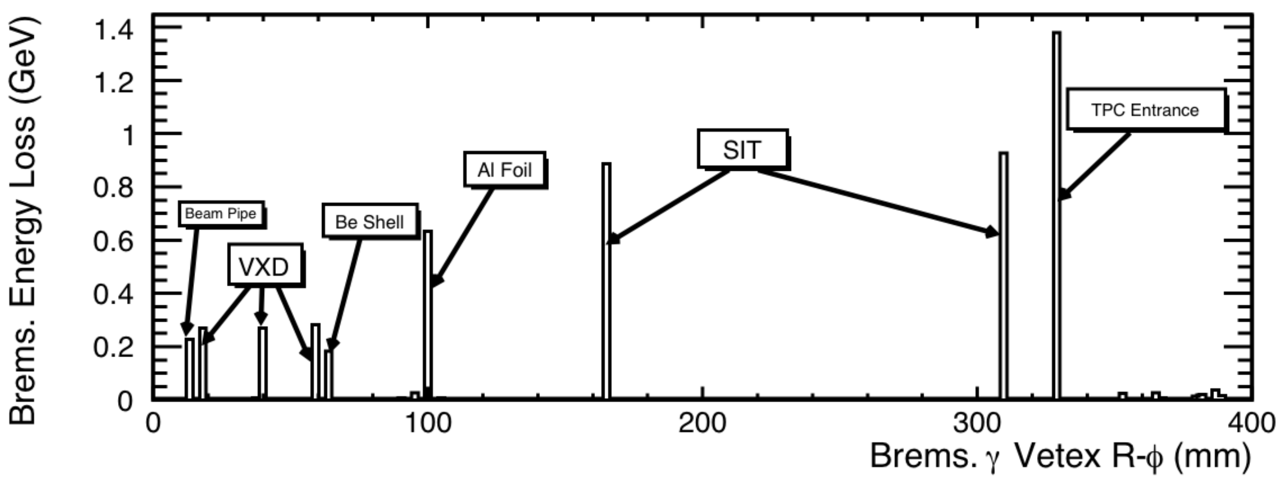
Only little further improvements by introducing Model Dependency

Sources of Bremsstrahlung



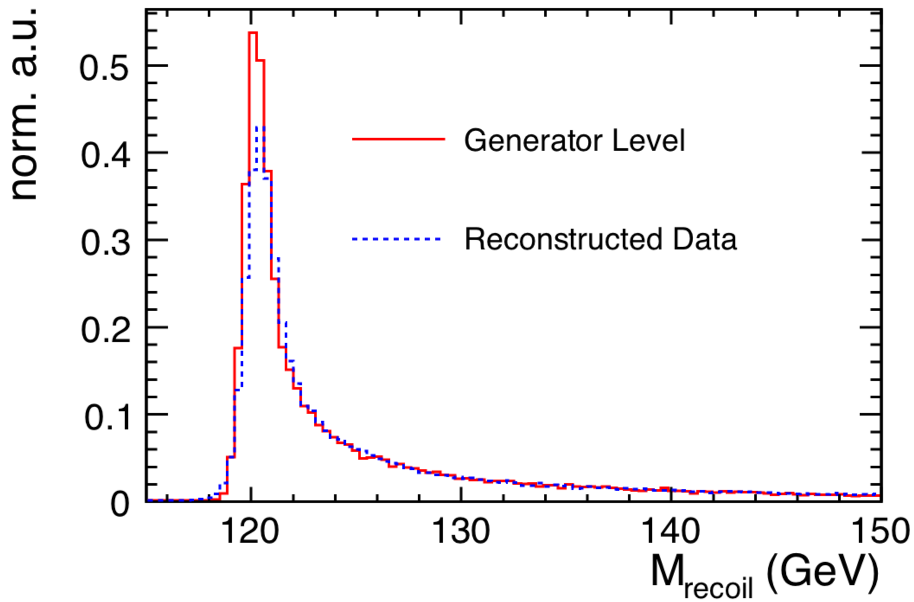
Landscape of ILD Detector
by Bremsstrahlung

Energy loss by Passive Material



Influence of Accelerator Parameters

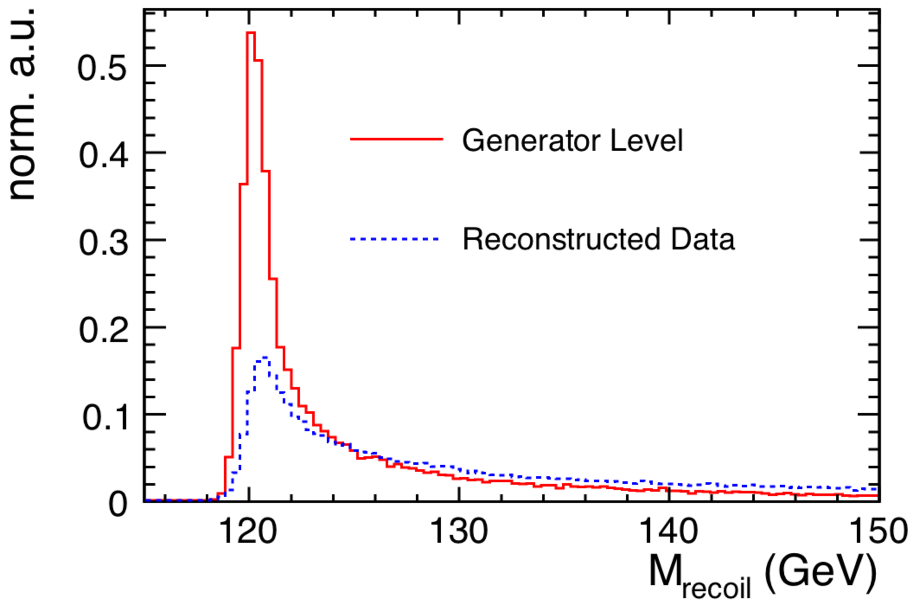
Muon Channel



ΔM_{tot} = 650 MeV

$\Delta M_{mach.}$ = 560 MeV $\Delta M_{det.}$ = 330 MeV

Electron Channel



ΔM_{tot} = 750 MeV

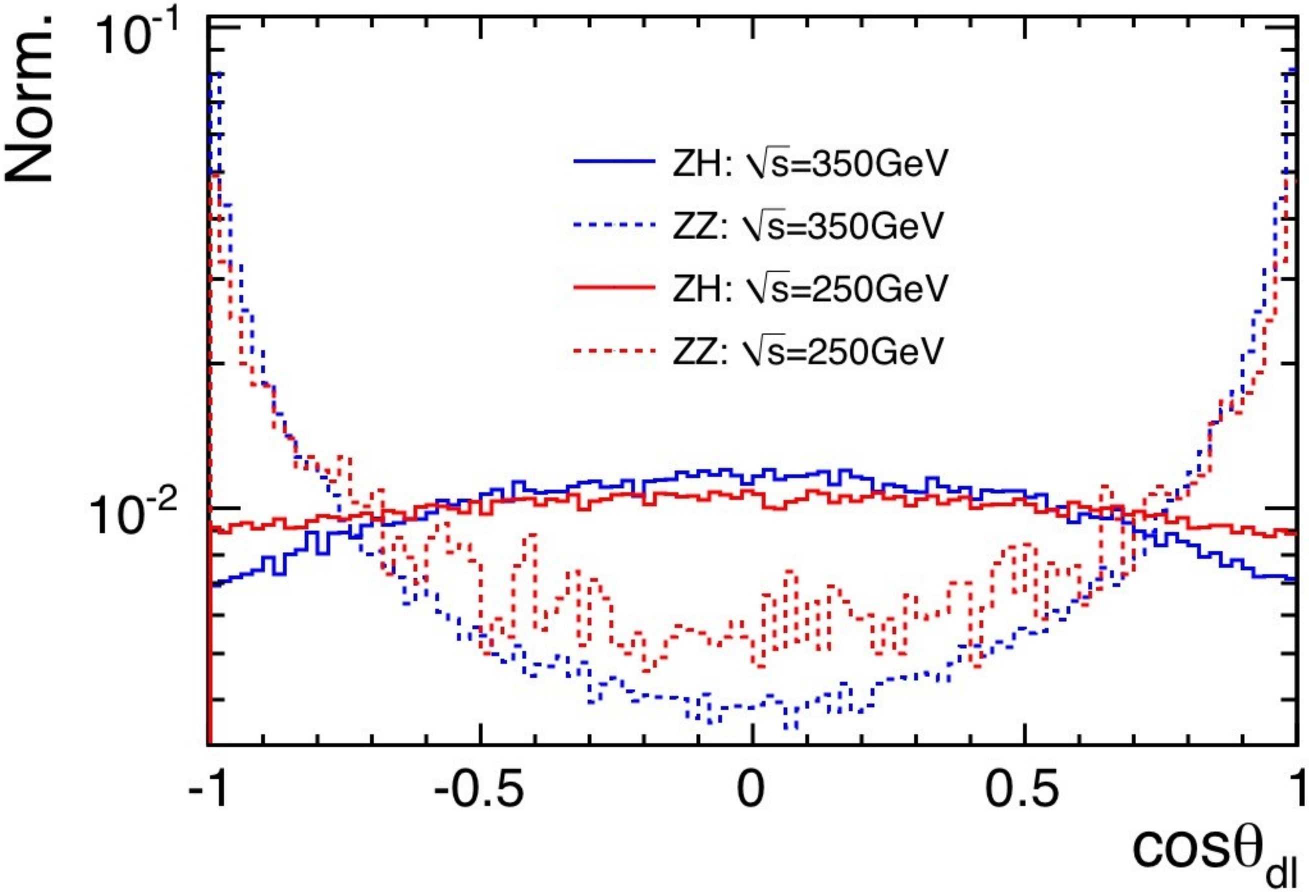
$\Delta M_{mach.}$ = 560 MeV $\Delta M_{det.}$ = 500 MeV

Uncertainties of incoming beams are dominant source
of Statistical Error
(even in Electron Channel)

Higgs-strahlung is key process for optimisation of ILC design

Angular Distributions for 250 and 350 GeV

HZ and ZZ Background



Better Signal/Background Separation at higher Energies

ZH Signal: Z retrieves its Goldstone nature
ZZ Background: Z retrieves its photonic nature

H→WW* study

- ννH, H→WW* at 1 TeV as DBD benchmark process

H→WW* →4j at Ecm=250 GeV , L=250 fb-1, (e+, e-)=(-0.3, +0.8)

1. Forced 4 jets clustering
2. Jet paring with M_{jj} as one on-shell W and M_{4j} as H

$$\chi^2 = \left(\frac{M_W^{\mathrm{Rec}} - M_W}{\sigma_W}\right)^2 + \left(\frac{M_H^{\mathrm{Rec}} - M_H}{\sigma_H}\right)^2$$

Mh=120 and 130 GeV
are studied from LHC results
WW→lν+2j is next target

$$e^+e^- \rightarrow \nu_e \overline{\nu}_e H, H \rightarrow WW^*$$