Higgs Session at IWLC2010

- Facts and Trends -

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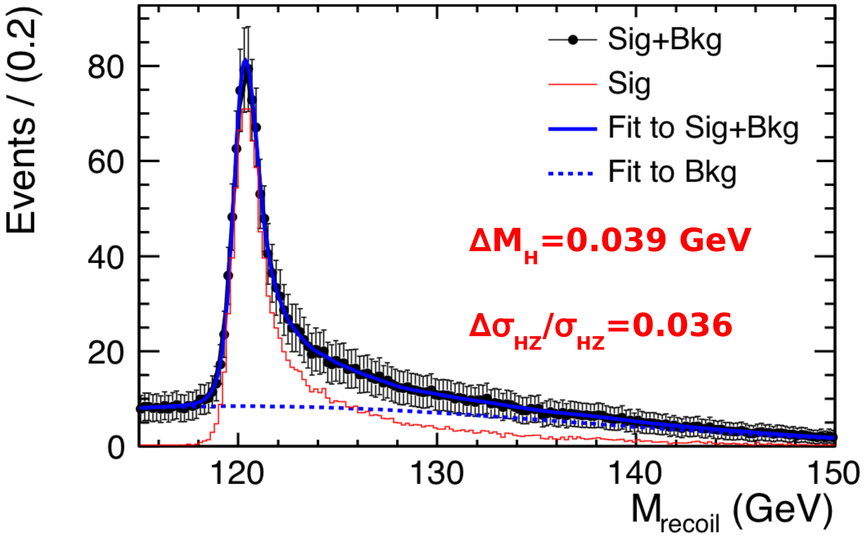
Disclaimer

- **This is** an attempt to point out tendencies which I think could figure out during the presentations of discussions on Higgs related issues during IWLC2010

- **This is not** a compilation of these presentations which can be looked up in their full glory on the web

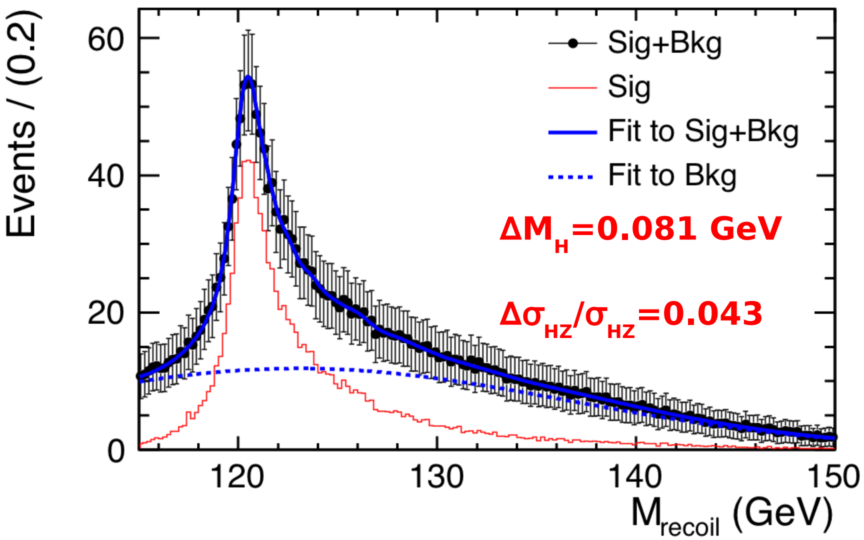
Reminder - Results LOI 2009

Muon Channel



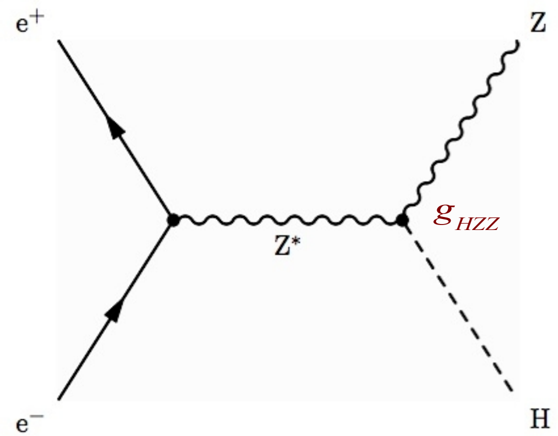
Very Precise Measurement
S/B = 8 in Peak Region

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

Theoretical Issues

- Observation: See little up to no feedback to the results published in the detector LOIs

- Still: The community strives to cope with the precision promised by ILC

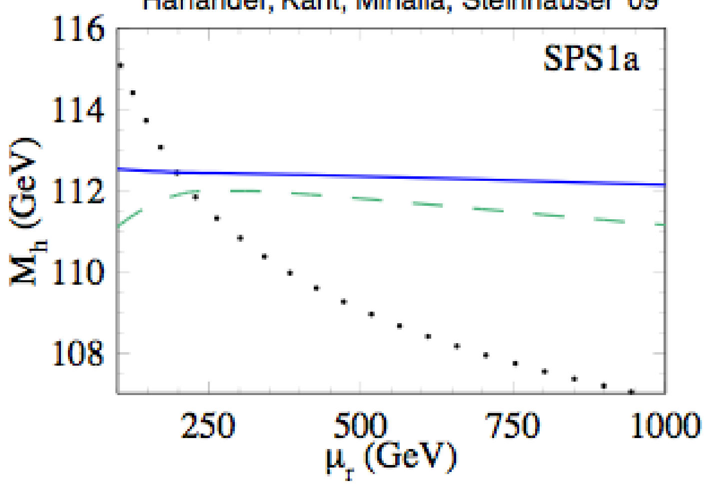
Example: MSSM m_{h0} at 3-Loop

remaining uncertainty

- scale uncertainty reduced to $\mathcal{O}(100\,\text{MeV})$
- theory uncertainty conservative estimate 50% of Δm_{h_0}(3-loop) $\rightarrow \delta m_{h_0} = 0.1 - 1$ GeV for $m_{1/2} = 100\,\text{GeV} - 1\,\text{TeV}$
- parametric uncertainty $\alpha_s, m_t, \ldots$ about $\mathcal{O}(500\,\text{MeV})$

scale dependence

Harlander, Kant, Mihaila, Steinhauser '09



(Complicated) Final States of the Higgs Boson I

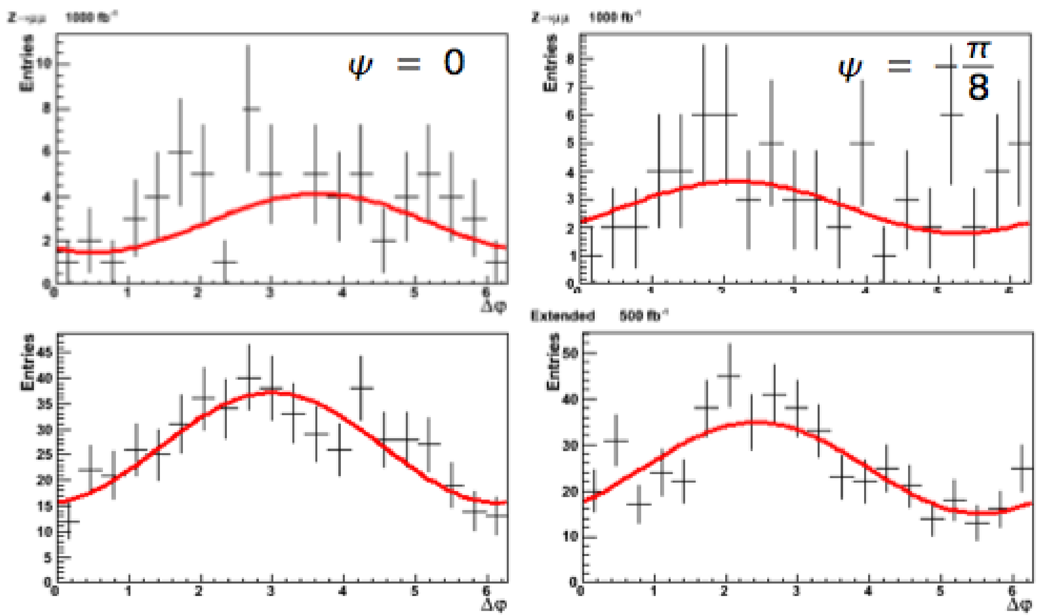
Higgs properties via ee → ZH → ff ττ e.g. CP violating Higgs: $g\bar{\tau}(\cos\psi + i\sin\psi\,\gamma_5)\tau$

Look at hadronic decays of the τ lepton: $\tau^{\pm}\rightarrow\nu_{\tau}\pi^{\pm}$ $\tau^{\pm}\rightarrow\nu_{\tau}\rho^{\pm}\rightarrow\nu_{\tau}\pi^{\pm}\pi^{0}$

Information on CP violating phase can be extracted via (azimuthal) angles between decay mesons in tau restframe and flight direction of τ
(nice exercise on kinematics and frame transformation)

PID based on photon counting in SiW electromagnetic calorimeter (of ILD)

m_H = 120 GeV
√s = 250 GeV
L=300/fb



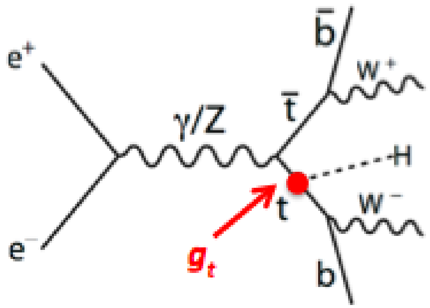
$Z \rightarrow \mu^+\mu^-$

$Z \rightarrow \mu^+\mu^-$, e^+e^-, $q\bar{q}$ q=u,d,s

χ² fit with the function $W_{fit}(\Delta\phi) = a(1 - b\cos(\Delta\phi - 2c))$

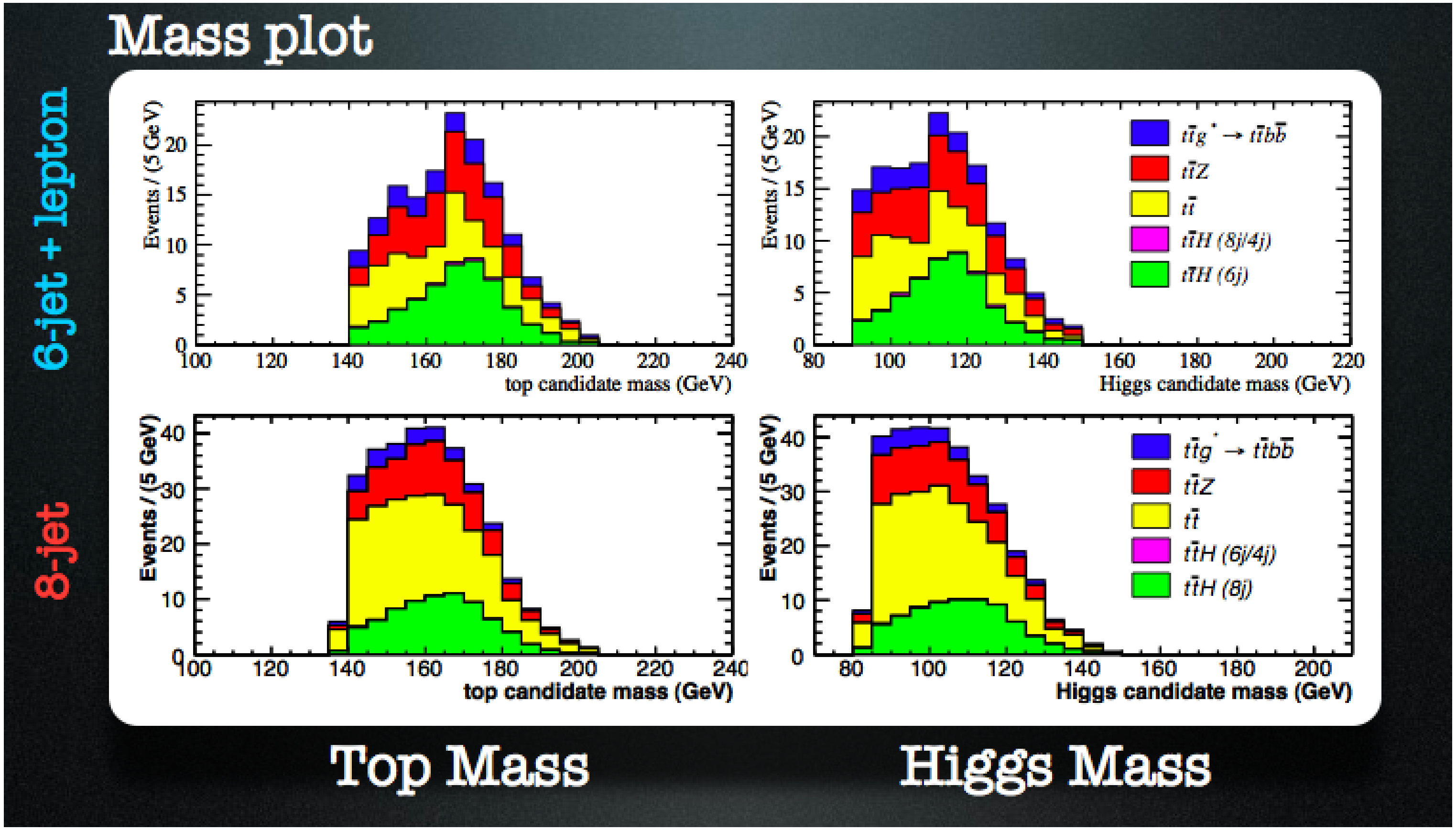
Net result: CP violating phase larger than pi/8 can be excluded at 4.5 sigma level

(Complicated) Final States of the Higgs Boson II



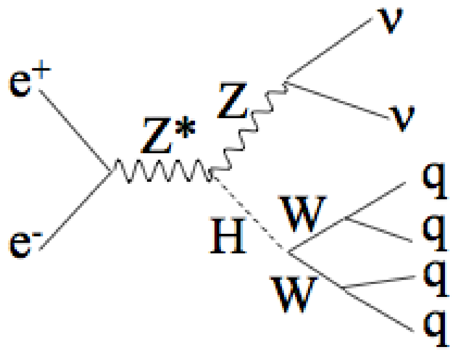
Top Yukawa Coupling

Benchmark scenario √s @ = 1 TeV
Here preliminary study at √s=500 GeV with fast simulation



Beam Polarisation: (Pe-, Pe+) = (-0.8, +0.3)

Main Conclusion: Top Yukawa Coupling can be measured to 10% accuracy
Needs, however confirmation in full simulation!!!

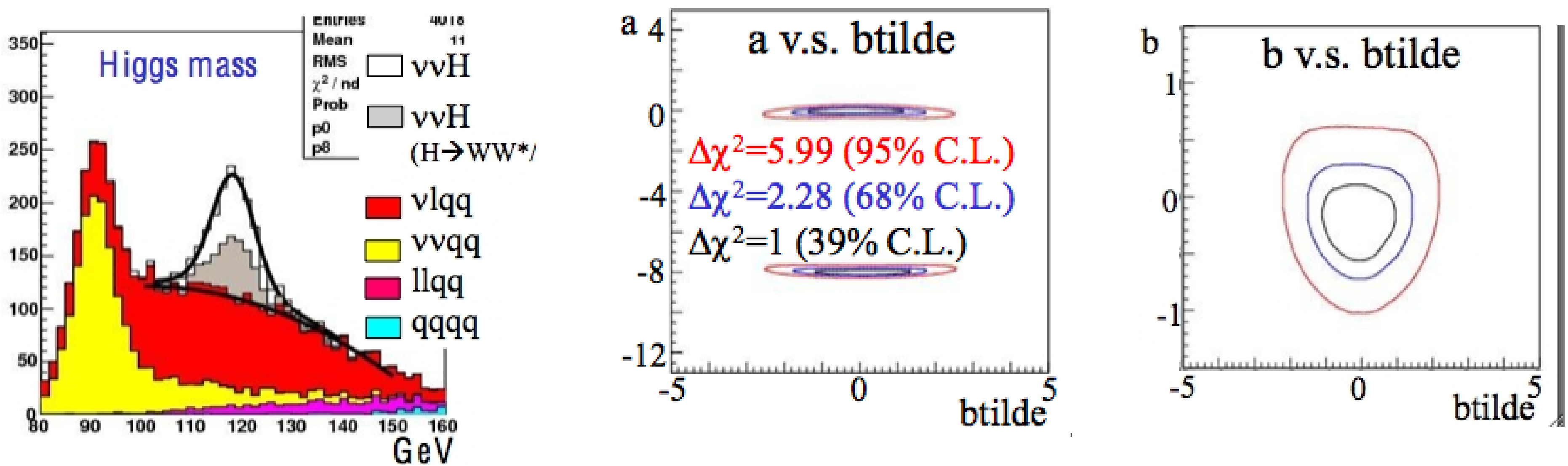


(Anomalous) couplings: H → W*W

CP even CP odd

$$\mathcal{L} = 2m_W^2 \left(\frac{1}{v} + \frac{a}{\Lambda}\right) H W_\mu^+ W^{-\mu} + \frac{b}{\Lambda} H W_{\mu\nu}^+ W^{-\mu\nu} + \frac{\tilde{b}}{\Lambda} H \varepsilon^{\alpha\beta\mu\nu} W_{\mu\nu}^+ W_{\alpha\beta}^-$$

Study @ √s = 250 GeV for m_H=120 GeV
Likelihood analysis to cope with considerable background



Anomalous Couplings by Strongly Interaction Light Higgs?

Light Higgs which couples weakly in the SM
is associated with strong dynamics at a higher scale f
Strong dynamics can be e.g. Technicolor

Parameter which interpolates between SM and strong sector

$$\xi = \frac{v^2}{f^2}$$ where $v^2 = (246\ \text{GeV})^2$

Couplings of e.g. (composite) Higgs to SM gauge bosons are modified according to the actual value of this parameter

E.g. Coupling H → WW

Sensitivity (Assuming a Higgs mass of m_H = 120 GeV):

$\xi \approx 0.01$ for ILC

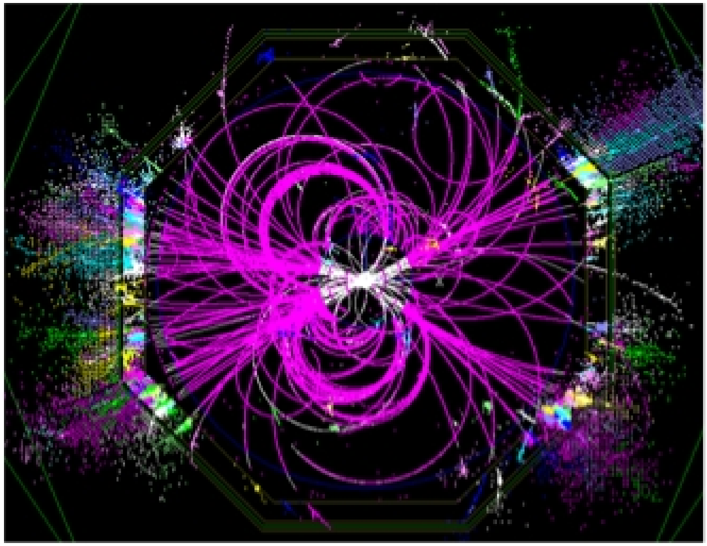
$\xi \approx 0.002$ for CLIC

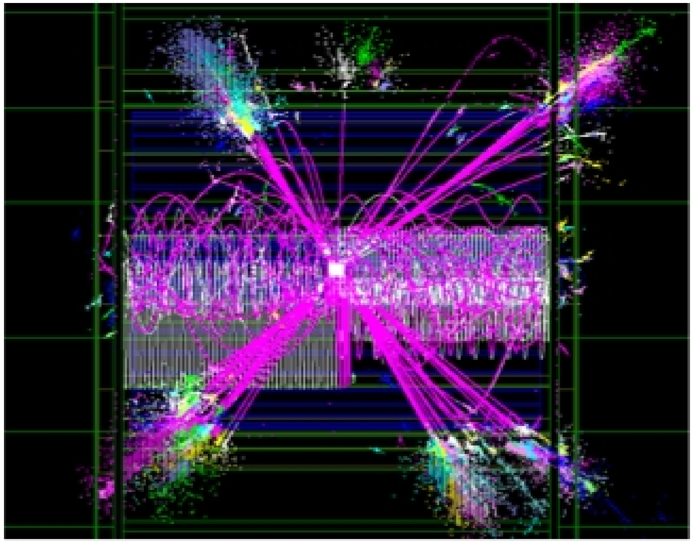
CLIC Study at 3 TeV of Heavy Higgs Bosons

e+e- → H0A0 → bbbb in Dark Matter motivated SUSY

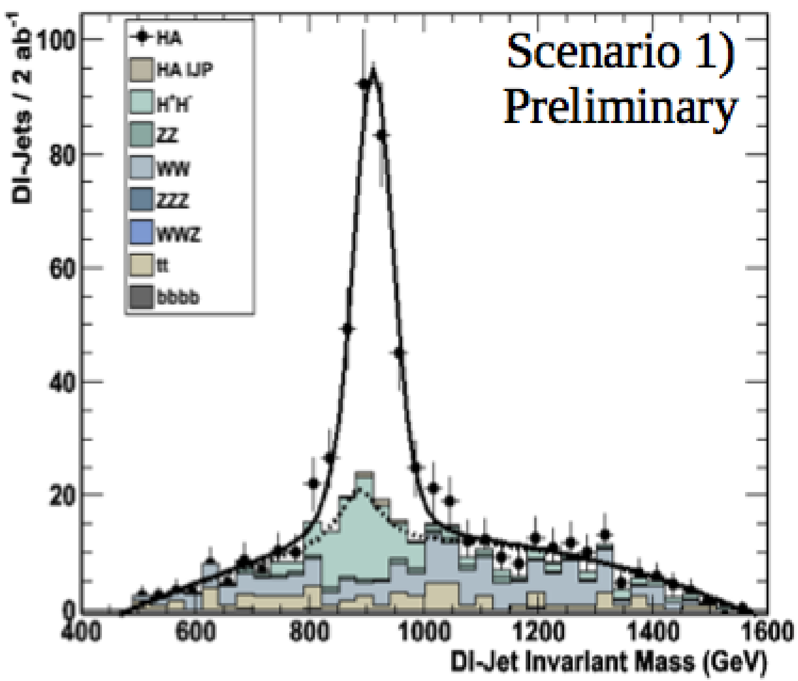
Scenario 1) (S Martin, CLIC Study Group)	Scenario 2) (Point K' of MB et al, Eur. Phys. J. C33 (2004))
MSSM model with non-unified gaugino masses	cMSSM model
M_1=780 GeV, M_2=940 GeV, M_3=540 GeV m_0 = 303 GeV, A_0 = -750 GeV, tan β = 24, μ>0	m1/2=1300 GeV, m_0 = 1001 GeV, A_0 = 0, tan β = 46, μ<0
M_A = 902.6 GeV M_H = 902.4 GeV	M_A = 1139.2 GeV M_H = 1143.8 GeV

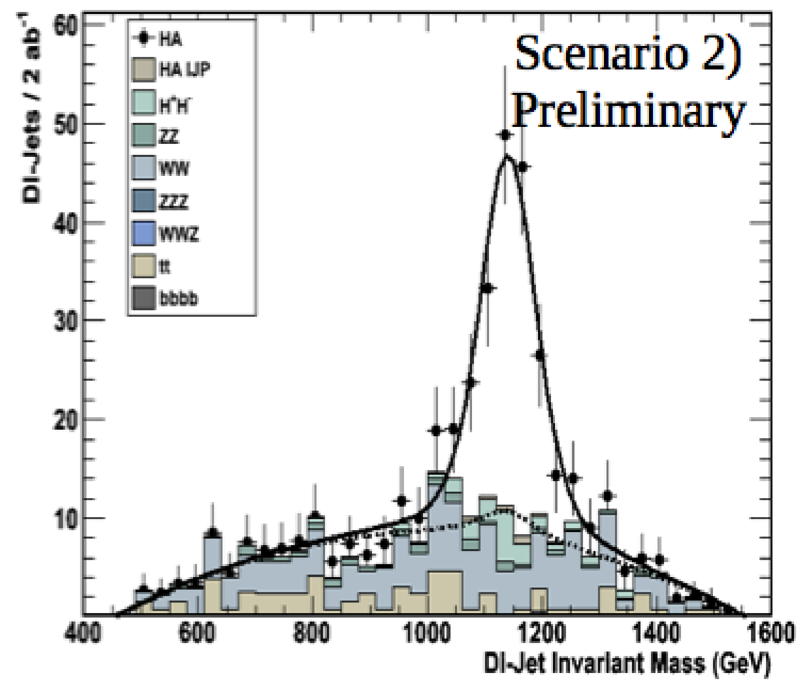
Study employing full detector simulation and reconstruction





Higgs Mass Reconstruction
(3 TeV, 2 ab^{-1})





7-par Fit (M_A, Γ, N_{sig}, Bkg shape)
M_A = (906.2+/-3.3 (stat)) GeV

7-par Fit
M_A = (1141.0+/-6.0 (stat)) GeV

Precision measurement
Robust against $\gamma\gamma$ background

The Holy Grail – ee → ZHH

- LOI Result: Resolution on x-section ~95%
  assuming an optimal b-tagging, otherwise 180% !!

- Analysis depends crucially on b-tagging and thus in turn on correct jet finding, i.e. particle association to jet

  Analyses use "good old" Durham algorithms
  Study of different jet algorithms is needed
  Good for clean and "innocent" LEP environment

- Challenging analysis?

- Analysis might require the establishment of a "jet working group" in which experiences from multi-jet final states at LHC need to be exploited

  Optimising of jet algorithms concerns a number of studies at an LC
  (particular for energies >~ 1 TeV)

Difficult analysis: How to address this issue ?

Conclusion

- Linear Collider is (still) the ideal machine to study the properties of the Higgs boson

- Most analyses start from a light Higgs with m_H~120 GeV

- Most of the properties of the Higgs can be measured or determined in current energy range of the ILC
  - e.g. here CP violatiing Higgs or not
  - (anomalous) couplings to Fermions and gauge bosons

  (I think) turn towards 1 TeV starts after IWLC10

- A machine operated at higher energies need to prove that these Higgs properties can be determined with the same precision

  - CLIC would have a “final” word on Higgs compositeness
  - CLIC would see directly heavy Higgs states as suggested/required by/in SUSY scenarios

- Most of the analyses look directly into the Higgs decay
  Little use of the advantages of Model Independent determination of Higgs properties

- Question to community: What to do with ee → HZZ?