Higgs physics overview

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29th October 2014,

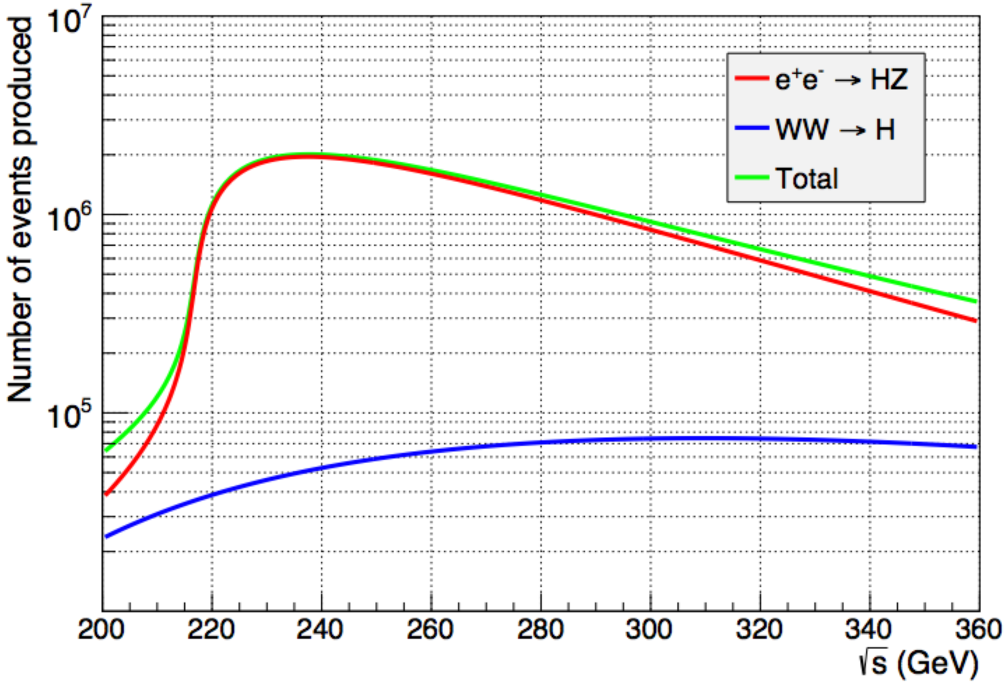
FCC-ee physics workshop

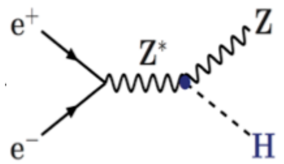
Higgs physics overview

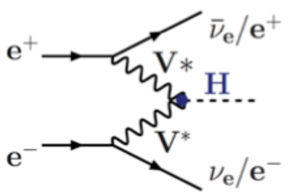
- Latest studies
- Proposed work packages

FCC-ee: ultimate Higgs factory

5 years, 4 IP



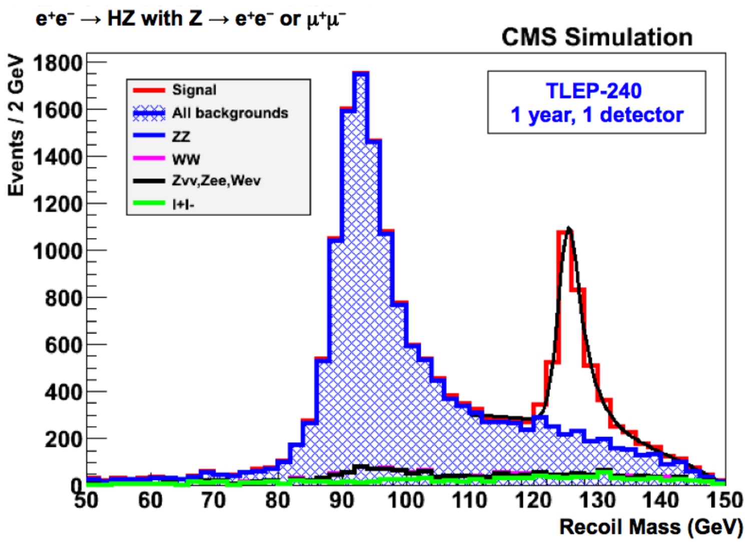




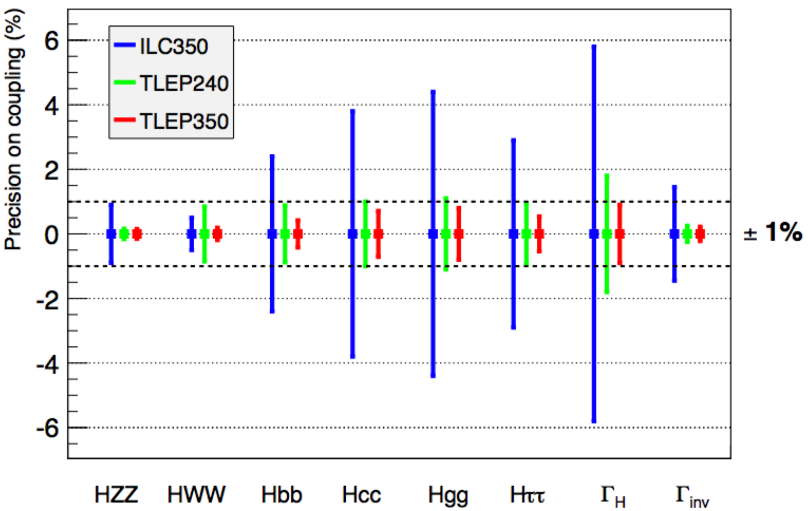
	TLEP 240
Total Integrated Luminosity (ab^{-1})	**10**
Number of Higgs bosons from $e^+e^- \to HZ$	**2,000,000**
Number of Higgs bosons from boson fusion	**50,000**

TLEP case study

Study based on CMS detector parameters (with a vertex detector similar to ILD)



arXiv:1308.6176

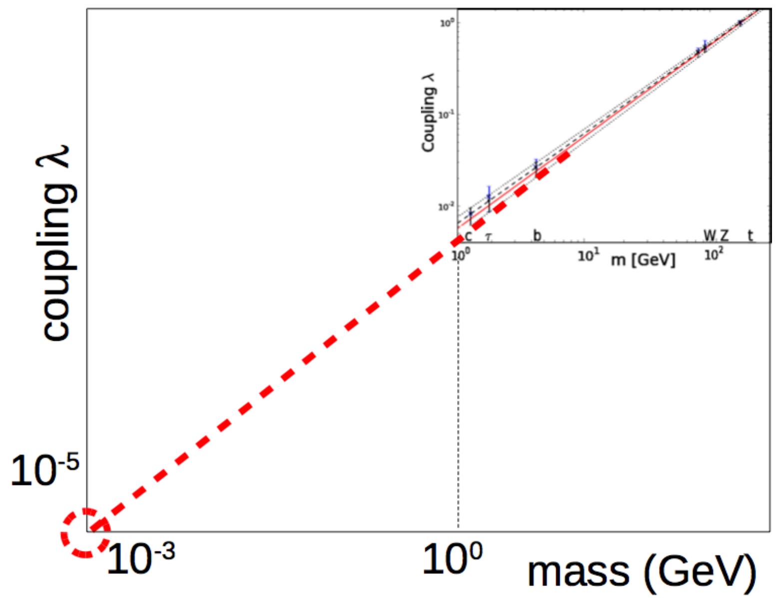


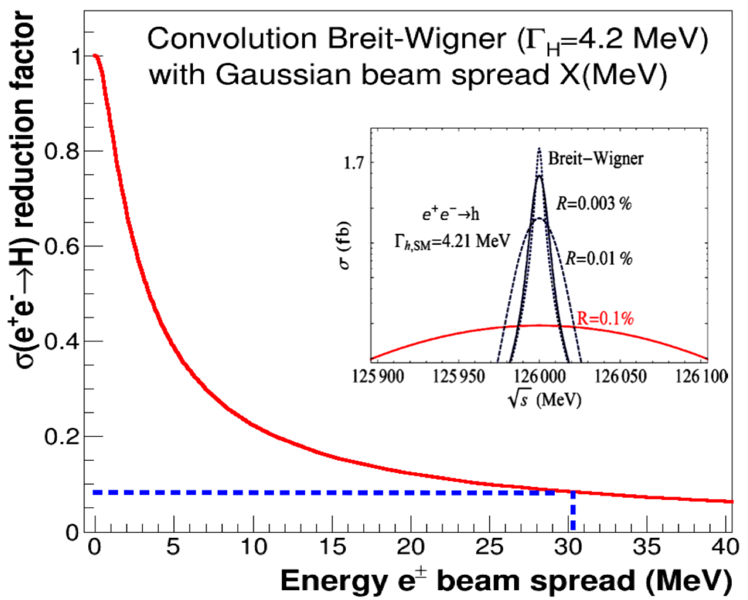
Model independent coupling measurements with sub-percent level experimental uncertainties

s-channel Higgs production

(d'Enterria, Wojcik, Aleksan)

Unique opportunity to measure electron-Yukawa coupling





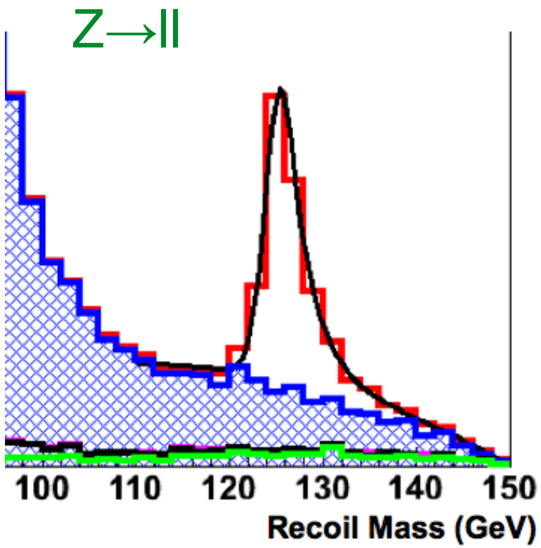
Estimated significance reduction (x1/20) due to ISR (0.6) and beam E_{spread} (~0.1). Highly challenging, expect <1% S/B

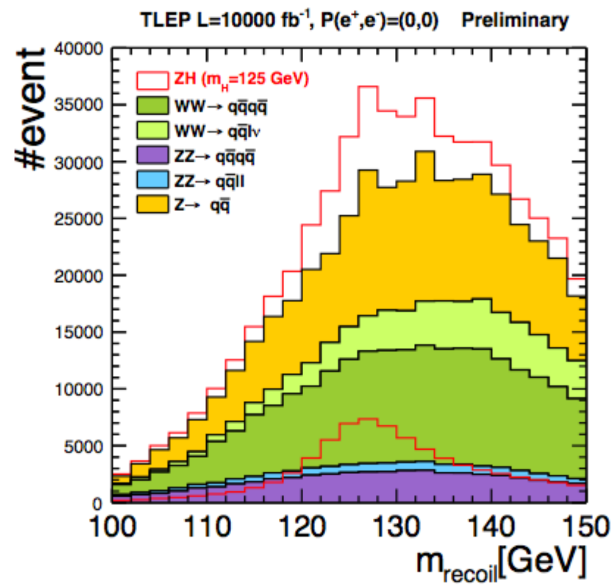
→ David's talk today

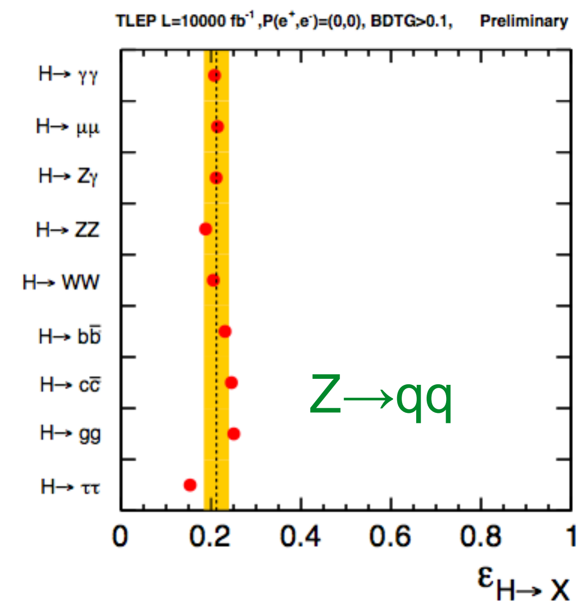
Inclusive measurement with hadronic Z decays

Increase precision with large BR(Z→qq)

(Haddad)







$$\Delta(\sigma_{ZH})/\sigma_{ZH} \sim 1.1\%$$

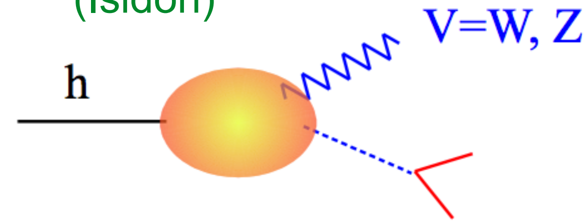
Main challenges

- Large diboson backgrounds
- Selection efficiency biases due to combinatorics need to be well understood

Rare/forbidden Higgs decays

Many examples… FCC-ee sensitivities need to be worked out

(Isidori)



Three (almost) unexplored directions:

Kinematical studies
in $h \to 4l$ & in $V+h$ associated production

$$A(h \to 4l) \neq \text{“}A(h \to VV)\text{”} \neq A(pp \to Vh)$$

GI, Manohar, Trott, '13; Ellis, Sanz, You, '13
Grinstein *et al.* '13, GI, Trott, '13
Pomarol & Riva, '13; Buchalla *et al.*' 13,
Beneke *et al.*' 14, ...

Rare SM modes
[including *exclusive semi-hadronic* decays]

E.g.:
$h \to \Upsilon Z$ [$BR_{SM} \sim 1.6 \times 10^{-5}$]
$h \to \psi\gamma$ [$BR_{SM} \sim 2.5 \times 10^{-6}$]
...

GI, Manohar, Trott, '13
Bodwin *et al.* '13, Kagan *et al.* '14

Exotic/forbidden decay modes
[e.g. *LFV* modes, *h → invisible*, *h → new light states*, ...]

E.g.:
$h \to \mu\tau$
$h \to Z+A$
...

Blankenburg, Ellis, GI, '12
Harnik *et al.* '12; Curtin *et al.* '13
Gonzales-Alonso, GI, '14
Falkowski, Vega-Morales, '14, ...

See also talk on Tuesday by Yotam on $H \to \rho\gamma$

Experimental studies

Large number of channels to be studied…

1. Higgs-strahlung production (ee -> HZ)
    - Inclusive Z -> ll measurements
        - Measurement of the ZH cross section
    - Exclusive Z -> ll measurements
        - Hadronic Higgs decays (H -> bb, cc, gg, WW, ZZ)
        - Higgs to ZZ (Essential for the total width determination at $\sqrt{s}$ = 240 GeV)
        - Higgs to WW (with lepton decays)
        - Higgs to tau tau
    - Inclusive Z -> qq measurements
        - Measurement of the ZH cross section
    - Exclusive Z -> qq measurements
        - Four jet final state (H -> bb, cc, gg, WW, ZZ)
        - Six jet final state (H -> WW, ZZ, bb, cc, gg)
        - Jets plus leptons final states (H -> WW,ZZ,mumu)
        - Higgs to tau tau
    - Exclusive Z -> νν measurements
        - Higgs to bb
    - Invisible Higgs decays
    - Exotic Higgs decays (e.g. flavour changing decays)
2. Vector boson fusion production
3. Exclusive H-> γγ or H -> μμ (ee) production
4. Exclusive H -> Zγ production
5. ee -> Hγ production
6. ee -> H direct production
7. Other production processes
    - SM Higgs: bbH production, tau tau H production
    - 2HDM: hA production, bbH, tau tau production (enhanced with tan beta), and specific decays h -> AA, etc.

Work packages

Main goal of experimental studies

- Assess performance of Higgs measurements @ FCC-ee
- Qualify the detector design

Next steps with a first version of the FCC software framework

- Move existing studies to new framework for testing and feed back to developers
- Use a first detector implementation inside DELPHES. This could be well an ILC detector, also useful for cross checks with ILC studies
- Repeat TLEP case study with FCC framework
- Start detector qualification with well defined benchmark studies and deliverables (work packages)
- Focus first on signal reconstruction

Detector acceptance

CMS detector parameters already close to optimal for Higgs coupling measurements

Study signal selection efficiency as a function of the detector theta coverage

- E.g. $H\rightarrow 4l$
- Limit on BR($H\rightarrow$invisible)
- …

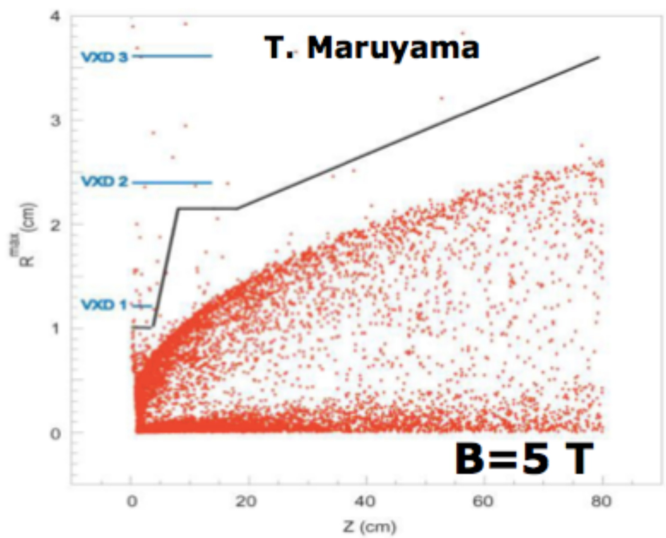
Forward electron tagging for eeH production?

Heavy flavour tagging

H→bb,cc,gg discrimination crucial for the FCC-ee physics programme. HF tagging performance is one of the key questions for detector qualification

Flavour tagging (b vs. c)

- Decay length (IP parameter resolution)
- Mass
- Number of lepton tracks
- …



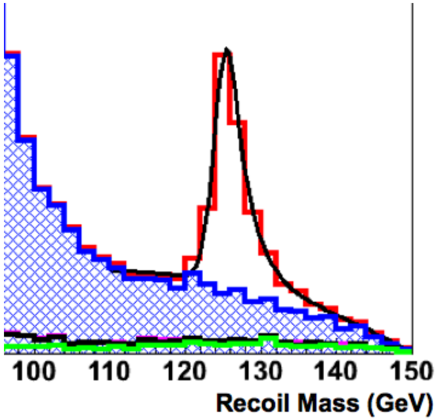
Need to study both algorithm and detector design. The ILC detectors are a good starting point

→ See presentation by Aidan

Tracking momentum resolution

Recoil mass measurement in Z(ll)H is a key aspect of the FCC-ee Higgs physics programme

- Gives common normalisation in H coupling measurements
- Most sensitive channel is Z→ μμ



Limiting aspects for measurement accuracy

- Track momentum resolution
- Beam energy spread / initial state radiation
- Z decay width

1. Study Z(μμ)H cross section and mH measurements as a function of the muon momentum resolution (start with perfect resolution and apply smearing)

2. Similar study for BR(H→μμ) measurement

Jet energy determination

Distinguish two cases: events without or with significant missing mass

- Use jet directions and momentum conservation for jet energy determination
- Use Calo/PFlow

1. Study hadronic Higgs decay (H→bb, ZZ,…) measurements in Z(ll)H as a function of the jet angular resolution (CAL granularity)

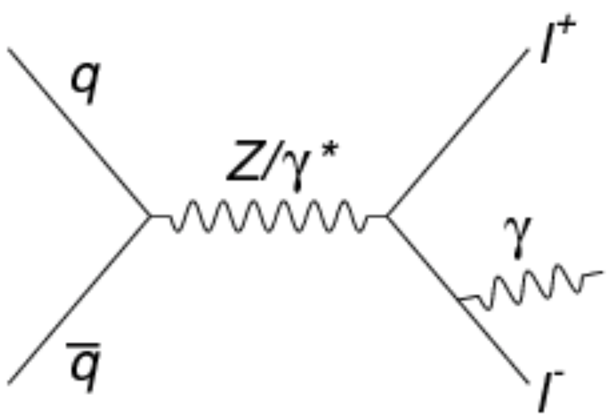
2. Study cross section (or Γ_H) measurement accuracy of vvH(→bb) as function of jet energy resolution (calo)

EM resolution

Intrinsic calo resolution not the only aspect, bremsstrahlung (~ ID material) and its measurement very important too

1. Quantify Z(ee)H cross section and BR($H \rightarrow \gamma\gamma$) measurement dependence on Ecal resolution and ID material budget

2. Study brem recovery algorithms



Conclusions

Started to define benchmark processes for detector qualification

- Your feedback is highly welcome! Let us know if you would like to propose further work packages

The FCC software framework is a crucial help towards detector qualification

- Repeat Higgs coupling measurements of TLEP study
- Compare to existing studies with ILC parameters
- Studies can then easily be repeated for different detector configurations and resolution/efficiency studies