Benchmarks for FCC-ee detector qualification

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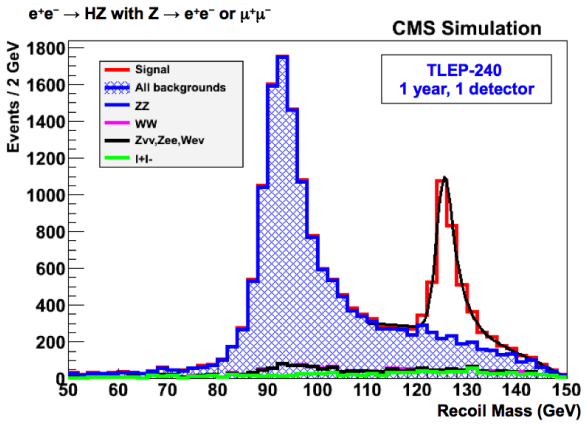
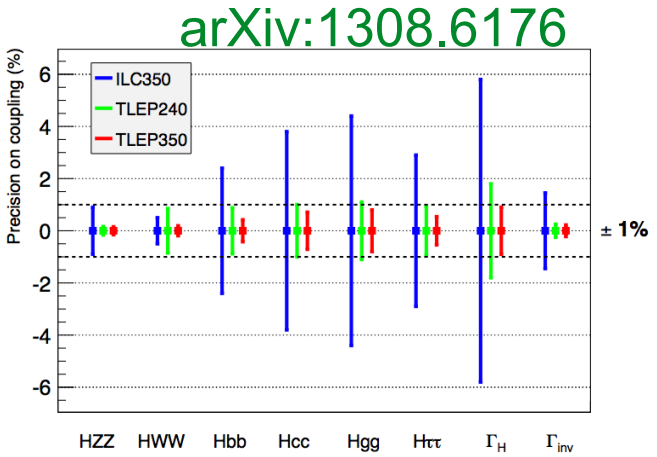
First FCC-ee workshop on Higgs Physics

TLEP case study

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





Model independent coupling measurements with sub-percent level experimental uncertainties

Main goal of experimental studies

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

Experimental studies

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 -> vv 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.

Detector qualification

Large number of channels to be studied… Where to begin?

Possible roadmap for the work

- Move existing studies to FCC software framework for testing and feed back to developers
- Repeat TLEP case study with CMS like and an ILC detector (also useful for cross checks with ILC studies)
- Start detector qualification with well defined benchmark studies and deliverables
- Can be a very complex problem. Optimise detector to control experimental uncertainties, redundancy, calibration, alignment, etc.
- Focus first on signal reconstruction, increase complexity thereafter

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)
- …

Hermetic detectors important for recoil mass measurement

Heavy flavour tagging

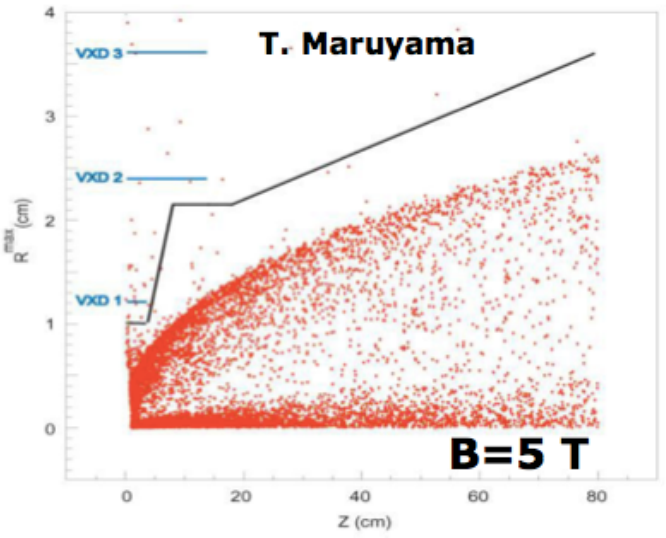
H→bb,cc,gg discrimination crucial for the FCC-ee physics programme. HF tagging performance is one of the key questions for detector qualification

Flavour tagging (b vs. c)

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

Need to study both algorithm and detector (and accelerator) design

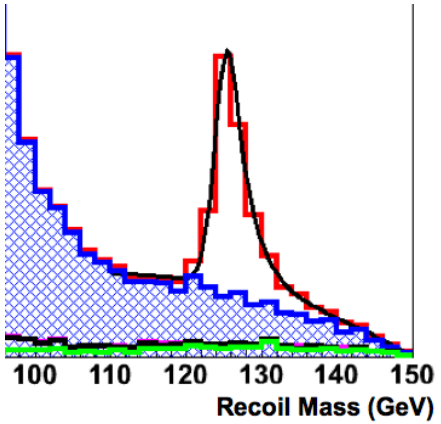
The ILC detectors are a good starting point (though important differences in detectors and machine)



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 ($H \rightarrow bb$, ZZ,…) measurements in ZH as a function of the jet angular resolution (CAL granularity)

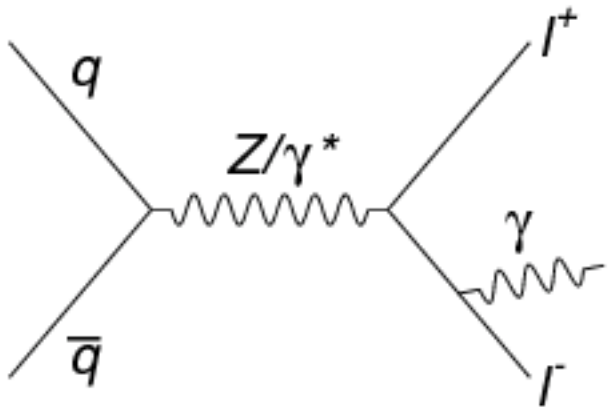
2. Study cross section (or Γ_H) measurement accuracy of $\nu\nu H(\rightarrow bb)$ as function of jet energy resolution (calo)

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 → γγ) 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!

If you are interested in contributing to the FCC-ee Higgs studies, these benchmark processes are an excellent starting point

Possible roadmap for the work

- 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
- FCC software framework in place to carry out these studies in a coherent way (see presentation from Colin)