MIT-FCC-25 PROJECTS

Overview of projects

MIT [E. Smith]

- Lambda-b polarisation and flavour-changing neutral currents
- Particle identification through timing

MIT [C. Paus]

- Higgs → WW couplings and cross-section
- Beam background studies on
  - Vertexing and occupancy
  - Tracking performance
- W boson mass measurement at the threshold

Maryland [C. Palmer]

- Higgs → b/c couplings and cross-section

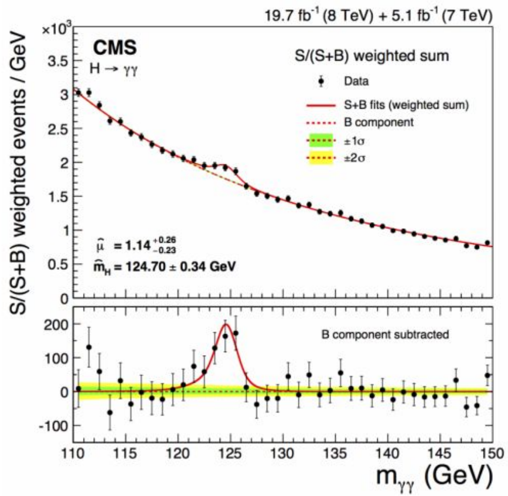
Other institutions will join dedicated projects in line with the group’s interests

Higgs Physics

The Higgs boson is discovered at the LHC in 2012

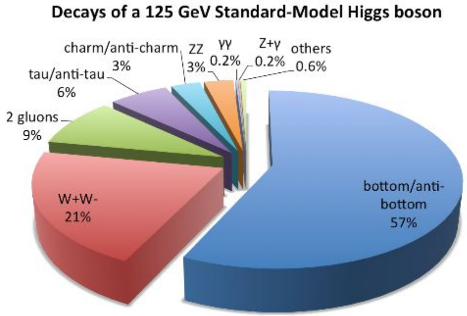
Need to study the Higgs precisely in a e^+e^- collider

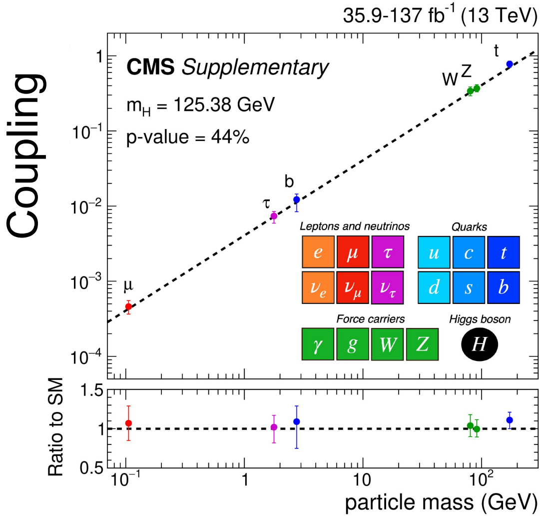
- Mass (~ 125 GeV) and width (~ 4 MeV)
- Couplings to particles it decays into (quarks, leptons, bosons)
- Self-coupling



The coupling is proportional to the mass of the particle

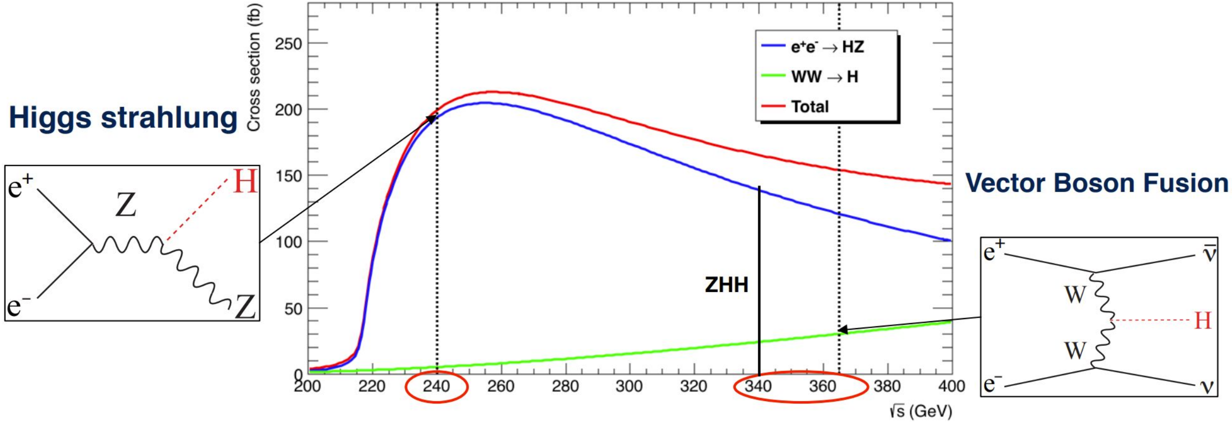
- The higher the particles mass, the higher probability the Higgs will decay into it (= branching fraction)
- In particular b/top-quarks, W/Z (heavy particles)
- More challenging to measure the lighter ones (c/s,μ,τ)





Higgs Physics at FCC-ee

Dedicated lecture on Higgs Physics at FCC-ee next week

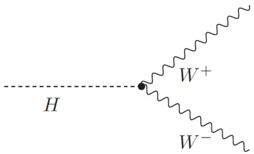


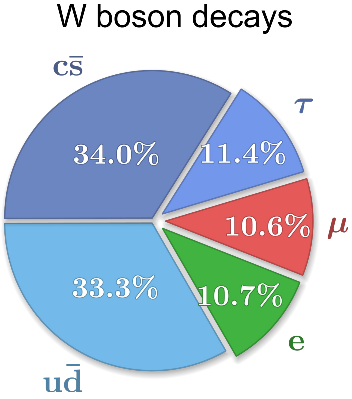
In a nutshell, the FCC-ee will run at center-of-mass energies of

- 240 GeV → L_{int} = 10.8 ab^{-1} → 2M Higgs bosons (ZH)
- 365 GeV → L_{int} = 3.0 ab^{-1} → 0.5 M Higgs bosons (ZH and VBF)

Enough Higgs bosons to study it precisely

Higgs Physics at FCC-ee

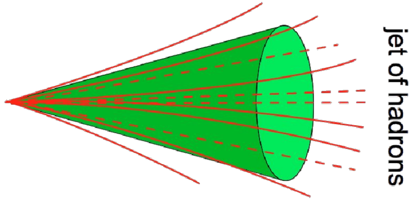


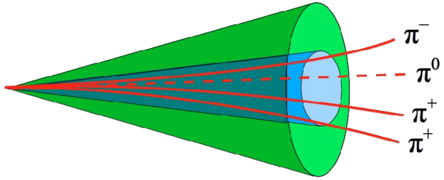


We have 2 main projects for Higgs physics at FCC-ee

1) [MIT] Measuring the Higgs → WW at center-of-mass energies of 240 and 365 GeV
    - We have ZH → ZWW in the intermediate state
    - Many possible final states, depending on the Z and W decays
    - Most interesting ones
        - Z→vv, WW→ lvlv, qqqq (2 students)
        - Z→ee/$\mu\mu$, WW→ lvlv, lvqq (2 students)

2) [Maryland] Measuring Higgs → b/c quarks at 240 GeV
    - Quarks hadronize to hadronic jets (“spray of particles”)
    - We need to cluster all the particles into jets → jet clustering
    - Then we need to identity the “flavor” of each jet based on their properties (with flavor we mean what is the original quark flavor for this jet, e.g. b/c/s/gluon)

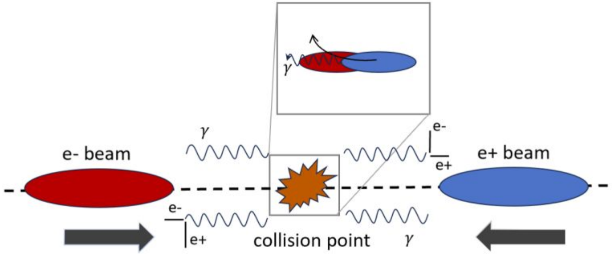




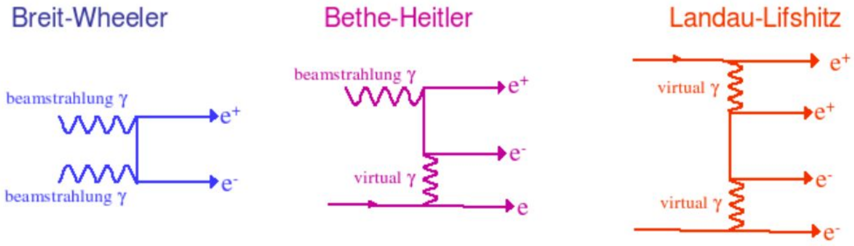
Beam background studies

Need to assess the impact of the beam background on the detector performance

- Beam backgrounds originate from (unwanted) interaction of the highly dense electron-positron beams when they cross each other



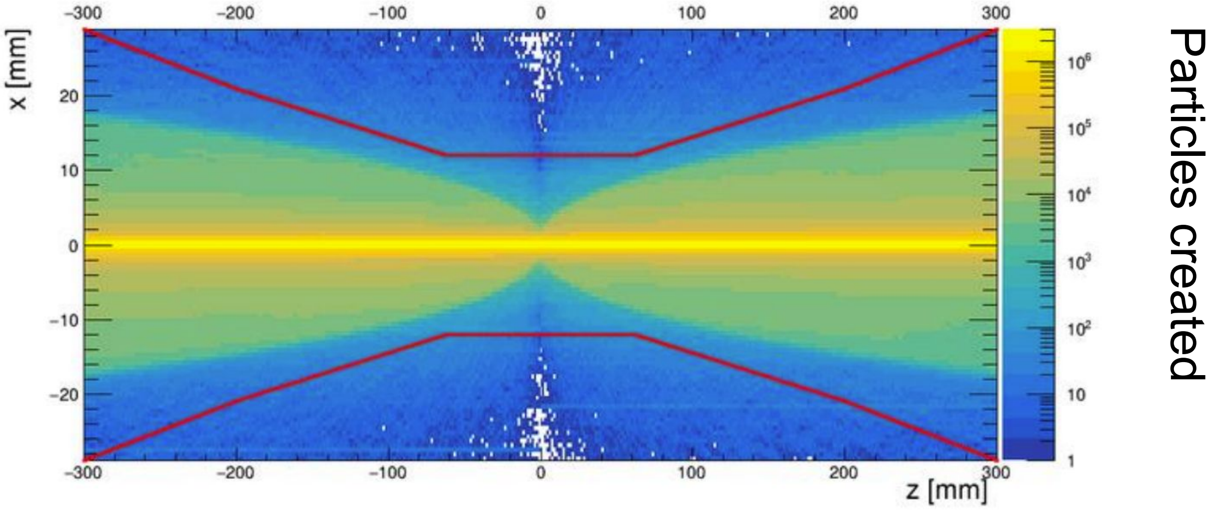
- Different processes can occur, mostly generating extra electron-positron pairs (so called incoherent pair production)



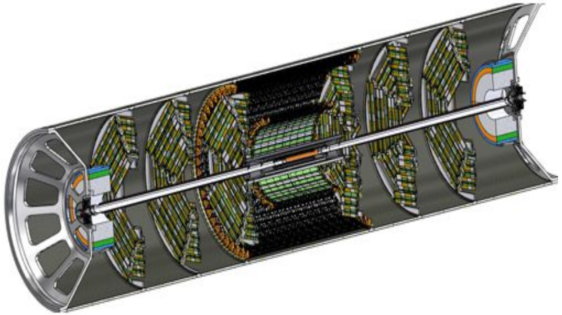
Beam background studies

The particles from the beam background interact with the detectors and can weaken it's performance

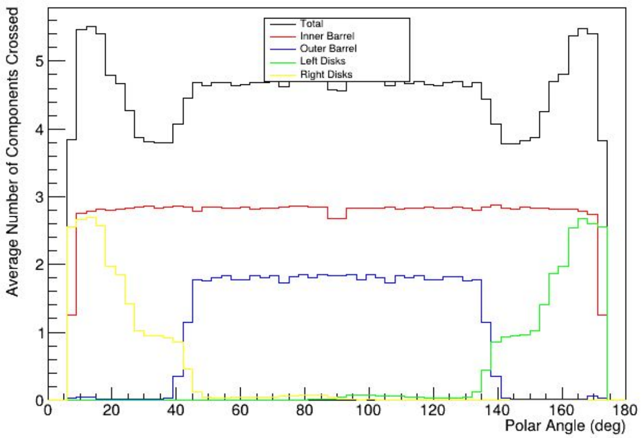
- We need to optimize our detectors and minimize the performance degradation
- Based on simulation of beam backgrounds with a dedicated program
- Overlap beam backgrounds with our known physics events (e.g. Z→$\mu\mu$)

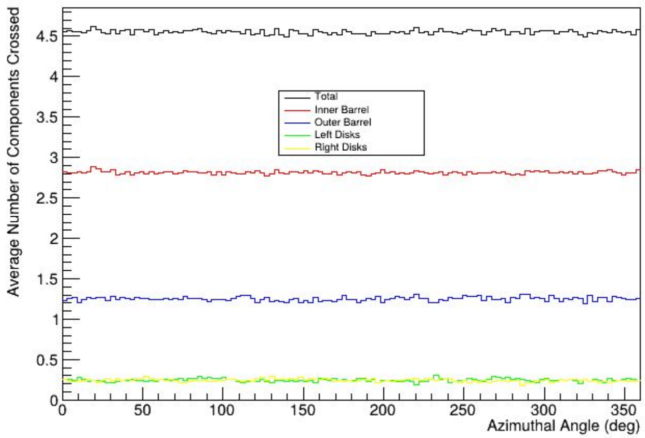


Beam background studies



Layer #	Radius [mm]	No staves	No modules /stave	Total Length [mm]	Active Area [cm^2]	Power [W]
1	13.7	15	6	217.40	241.92	12
2	23.7	24	10	346.20	645.12	32
3	34 & 35.60	36	16	539.40	1548.29	77





Beam background studies

2 main projects

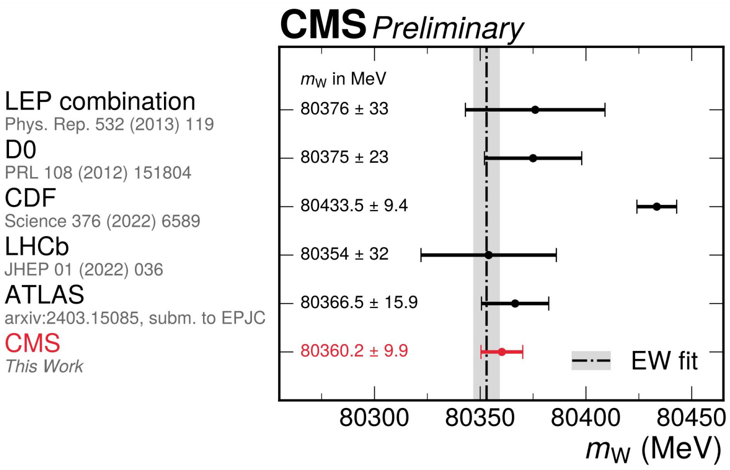
- Impact on vertex detector and validation of beam background (1–2 students)
  - Continue ongoing work
  - Characterization of the beam backgrounds
  - Assess impact on vertex detector layers

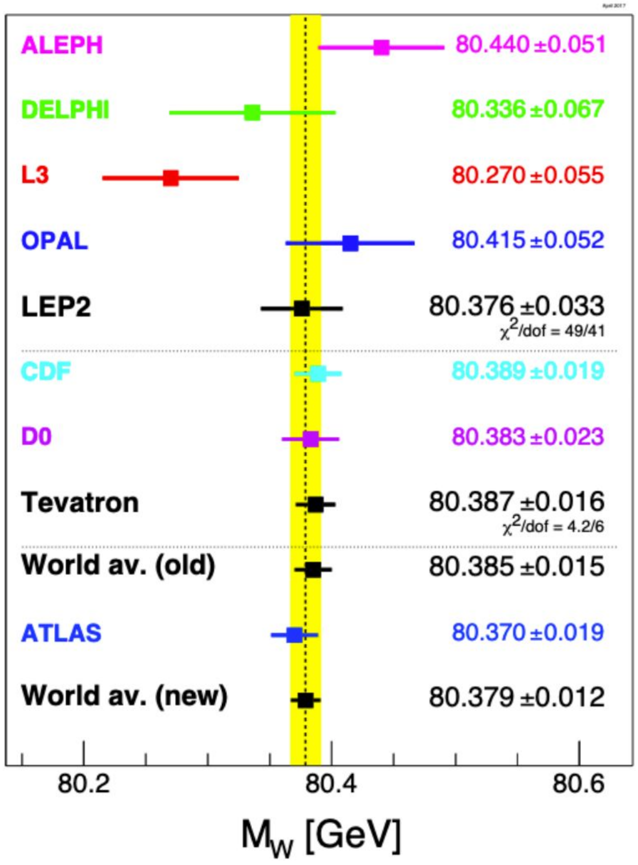
- Impact on tracking in silicon and drift chamber (1-2 students)
  - Assess impact on the tracking system (drift/silicon)
  - Improve tracking algorithms
  - Ultimately usage of Machine Learning to suppress the impact on beam backgrounds

W boson mass

The W boson is the “twin particle” of the Z boson, but ~ 10 GeV lighter and charged (W+ and W–)

- Measuring its mass is difficult, many experiments performed the measurement with increasing precision
- Currently uncertainty on W boson mass is about 10 MeV (Z mass 2 MeV)
- At FCC we aim to bring it down to 500 keV or lower

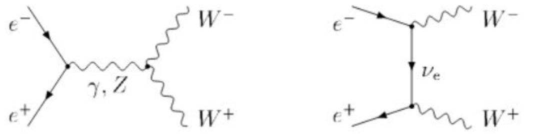




W boson mass at FCC-ee

W bosons are produced in pairs, to conserve the charge

- We therefore need sufficient energy to produce them
- At least around 2*m_W ~ 160 GeV

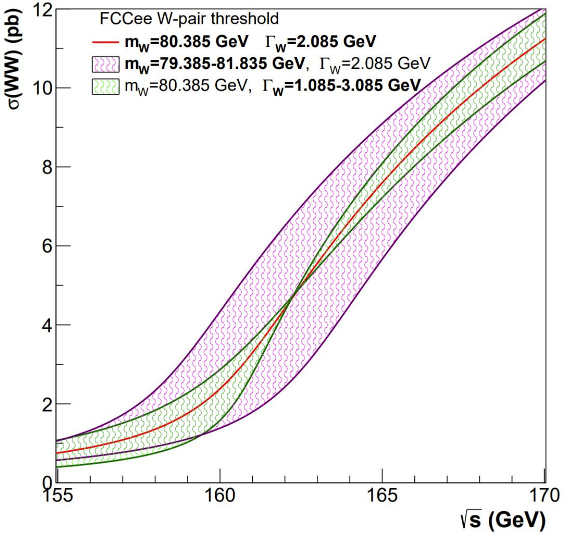


a) Z or photon exchange in the s-channel

b) neutrino exchange in the t-channel

The cross-section around the kinematic threshold (2*m_W) is very sensitive to the W boson mass

- The idea is to measure precisely the cross-section around 155-170 GeV center-of-mass energy
- Measuring this “lineshape” will enable us to extract the W boson mass with a precision of 500 keV



Analyses challenges

- Many final states → need to combine all of them
- Suppress the Z and ZZ backgrounds (cut-and-count)
- Machine learning to further optimize

Λ_b polarisation and flavour-changing neutral currents

Flavour-changing neutral currents are rare in the Standard Model
=> challenging experimentally but useful theoretically

Advantages at the FCC:

- much lower background compared to the LHC
- Λ_b baryons are polarized (more measurable quantities)

Project a) measure the angular observables in $\Lambda_b \rightarrow \Lambda\mu\mu$

Project b) measure the Λ_b polarisation in $\Lambda_b \rightarrow \Lambda J/\psi$

Particle identification through timing

In flavour physics it is very important to correctly identify charged hadrons.

Possible by measuring their time-of-flight from one point in the detector to another
=> hadrons differ in their mass, m = p/velocity = p/(distance/time)

Project: Is it possible to distinguish charged hadrons by measuring their time-of-flight with the tracking detectors?