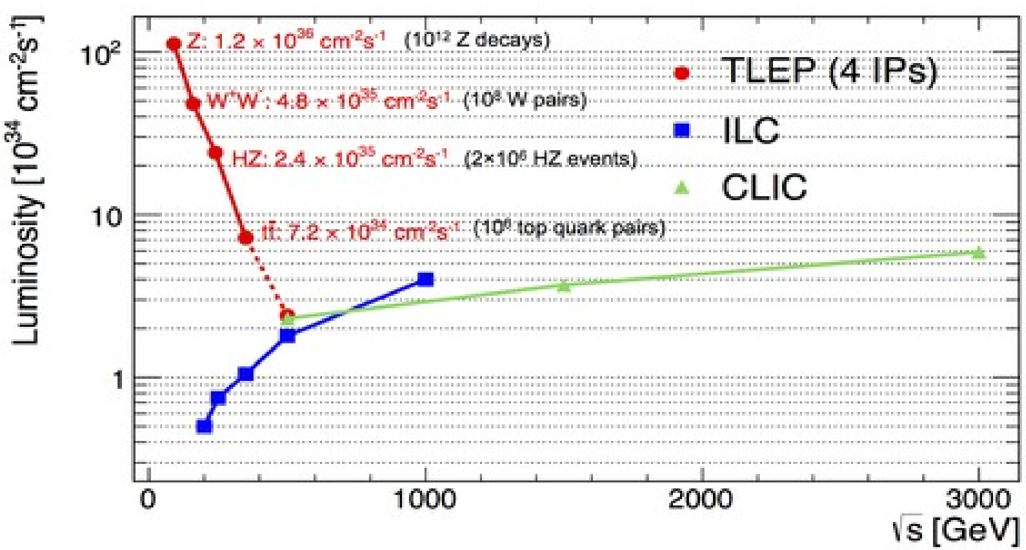
Search for Resonant s-channel Higgs Production at FCC-ee

George Wojcik
Supervisor: Dr. David d'Enterria

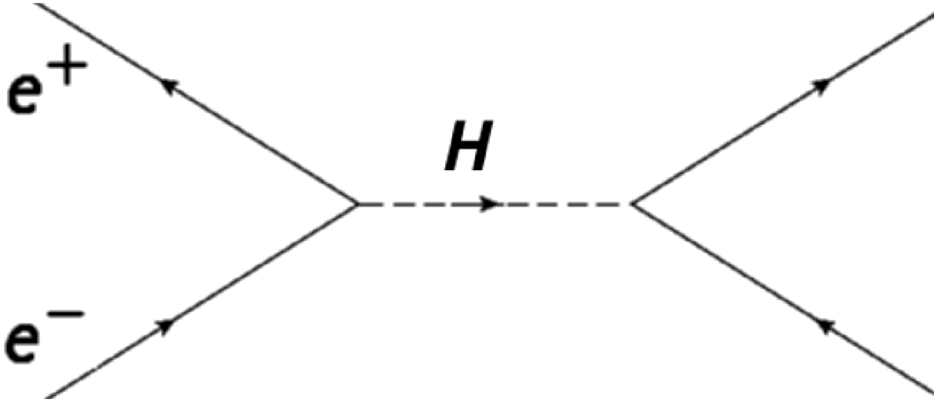
FCC- Future Circular Colliders

- What's next for accelerators?
- Future colliders – One potential machine is the FCC-ee, a high-precision, high-luminosity e^+e^- machine
- Able to probe rare events with high precision due to extreme luminosities



Resonant Higgs Production

- Higgs coupling is proportional to the square of the electron's mass, so it's tiny!!!

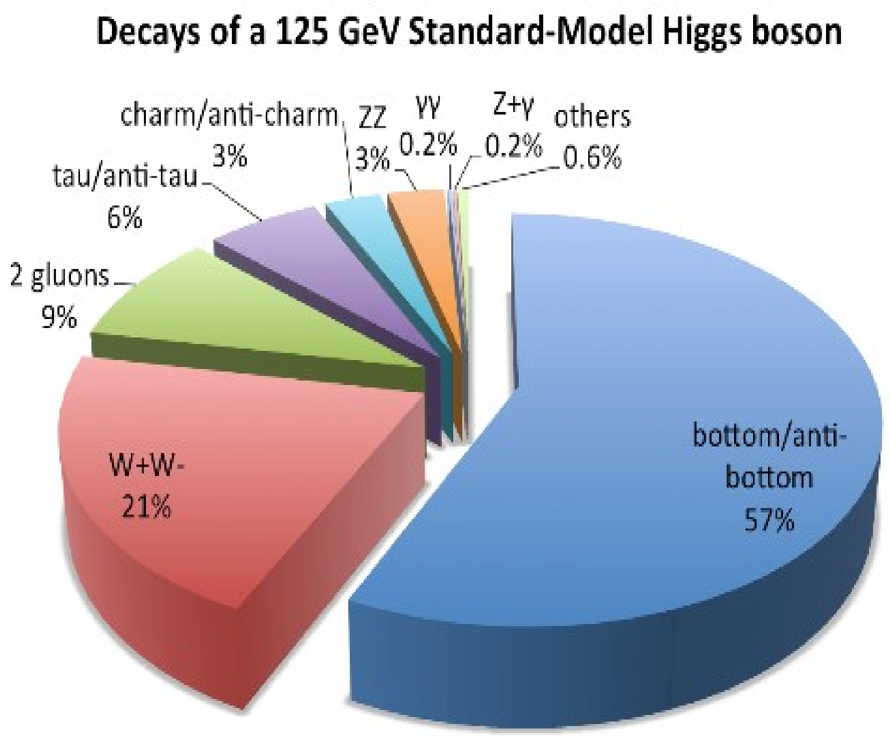


BR($H \rightarrow e^+e^-$)~$5.3 \cdot 10^{-9}$, m_H=125 GeV, Γ_H=4.2 MeV

$$\sigma(e^+ e^- \rightarrow H) = \frac{4\pi\Gamma_H^2 Br(H \rightarrow e^+ e^-)}{(\hat{s} - M_H^2)^2 + \Gamma_H^2 M_H^2}$$ ~ 1.64 fb

- Compare to muon Higgs coupling (~70 pb)
- At any other machine, this cross-section would be unobservable... But we're working with L_{int} as high as 10 ab^{-1}!
- Measure Electron Yukawa coupling!

How do we see this process?



- My job – simulating different decay pathways to determine event yields, significance
- Using PYTHIA8 and ROOT, I simulate events for signal and background, and find cuts and analysis that maximize significance of the Higgs signal

- What channels are visible?
- So far, 7 channels are considered:
  - WW*(2j,lν) (σ = 166 ab), continuum background σ~O(20 fb)
  - WW*(2l2ν) (σ = 39 ab), continuum background σ~O(5 fb)
  - WW*(4j) (σ = 173 ab), qqbar background σ~O(100 pb)
  - ZZ*(2j2ν) (σ = 14 ab), continuum background σ~O(270 ab)
  - ZZ*(2l2j) (σ = 6.7 ab), continuum background σ~O(134 ab)
  - bb(2j) (σ = 922 ab) continuum background σ~O(20 pb)
  - gg(2j) (σ = 139 ab) continuum background σ~O(100 pb)

Example Channel: $e^+e^- \to H(WW^*) \to 2l2\nu$

- PYTHIA8 for signal & backgrounds at $\sqrt{s} = m_H = 125$ GeV.

  Final state: 2 isolated ($\Sigma E < 1$ GeV, $\Delta R<0.25$) leptons $e,\mu,\tau(e),\tau(\mu)$ +Miss.En.
  no unisolated leptons or final state hadrons, within $|\eta|<5$ (acceptance). This retains 60% of the $\sigma(WW^*(2l2nu)) = 39$ ab.
- Kinematic Cuts: Sphericity > 0.03 ¬ Kills tautau
  $\Delta R(l,ME) > 1.5$ ¬ Kills tautau
  $\cos(\theta_{l1l2})>-0.6$ ¬ Kills tautau
- We can exploit different lepton angular correlations from spin-0 decays into $W^-(l_L\nu_L)W^+(l_R\nu_L)$ and continuum to reduce the latter. MVA across kinematic and angular variables reduces WW* continuum.

- Signal & backgrounds before kinematics/MVA (left) and after (right):

H(WW*):	$\sigma = 23$ ab	⇒	σ(after cuts) ~ 13 ab
qqbar:	$\sigma \sim 0^*$ pb	⇒	σ(after cuts) ~ 0 ab
τ-τ:	$\sigma \sim 1.3$ pb	⇒	σ(after cuts) ~ 1 ab
WW:*	*$\sigma = 3.4$ fb*	⇒	*σ(after cuts) ~ 705 ab*
ZZ*:	$\sigma = 29$ ab	⇒	σ(after cuts) ~ 2.03 ab

*preselection kills this channel entirely

For $L_{int}=1\ ab^{-1}$
$S/\sqrt{B}\sim13/\sqrt{708}\sim0.5$
Significance~0.5

$BR(Hee) < 6\times BR_{SM}$ (3σ)
$g_{hee} < 2.6 \times g_{Hee,SM}$ (3σ)

Results

- Combining the statistics of different channels, we can see the combined statistical significance for all of our channels!

Channel	Significance (1 ab^{-1})	Significance (6 ab^{-1})	Significance (10 ab^{-1})
WW->lvjj	0.75	1.85	2.38
WW->2l2v	0.49	1.20	1.55
ZZ->2j2v	0.60	1.47	1.89
bb	0.15	0.36	0.46
WW->4j	0.18	0.45	0.58
ZZ->2l2j	0.24	0.60	0.77
gg	0.09	0.23	0.30
Combined	1.14	2.78	3.60

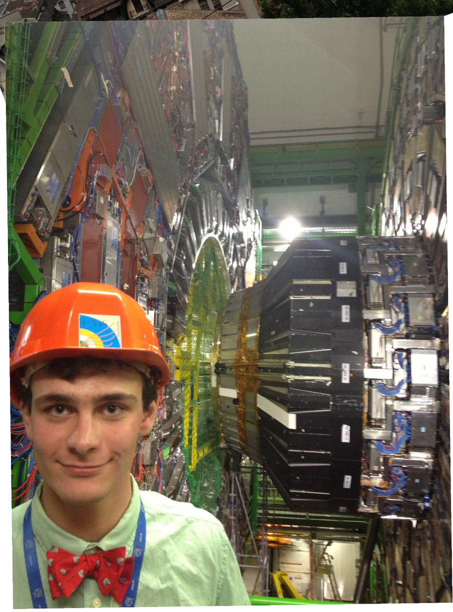
Conclusions

- While a 5σ signal is out of reach, observations (3σ) seem feasible, and our preliminary analysis indicates that (under admittedly ideal conditions), a reasonable upper limit could be detected!
- At L_{int}=10 ab^{-1}, our significance gives...

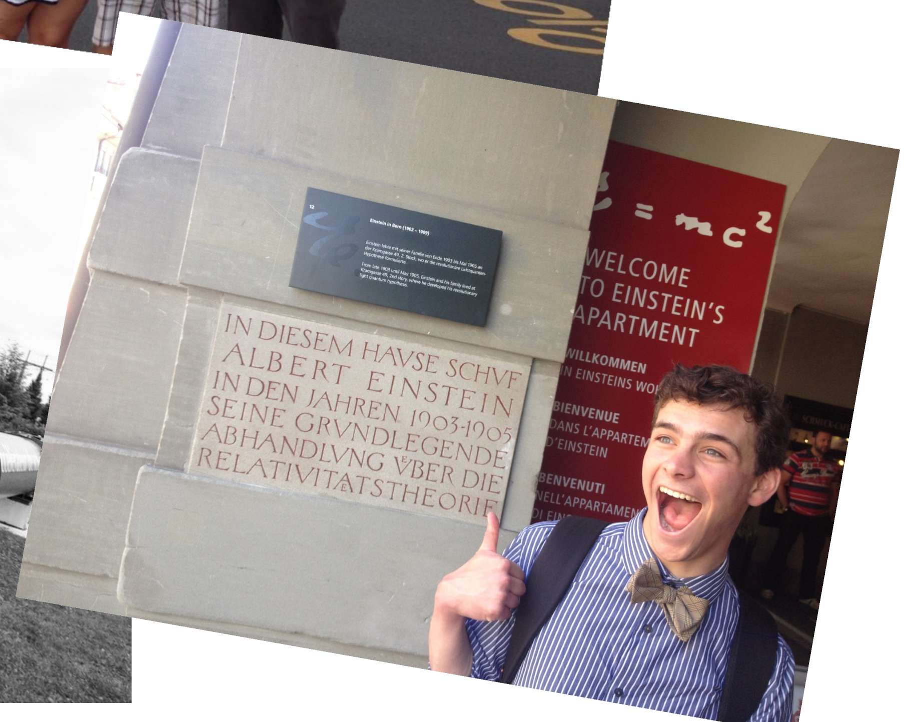
  $3.6\sigma \rightarrow BR(Hee)<1.39*BR_{SM}(5\sigma) \rightarrow g_{hee}<1.18*g_{Hee,SM}(5\sigma)$

- Complication: ISR and beam energy spread provide extreme reductions in the signal (~1/4)... Continuing work being done to work around this issue – what limits can we set in a real experiment?
  - Beam polarization
  - Determining ISR effect on background

Fun Stuff!




CERN


IN DIESEM HAVSE SCHVF
ALBERT EINSTEIN
IN DEN JAHREN 1903-1905
SEINE GRVNDLEGENDE
ABHANDLVNG VBER DIE
RELATIVITÄTSTHEORIE
WELCOME
TO EINSTEIN'S
APARTMENT