# Search of resonant s-channel Higgs production at FCC-ee

## FCC-ee physics workshop

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# Resonant s-channel $e^+e^- \rightarrow H$ production

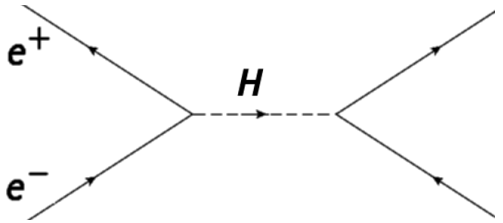
- Resonant Higgs production considered so far only for muon collider:
  $\sigma(\mu\mu \rightarrow H) \sim 70$ pb. Tiny $g_{Hee}$ Yukawa coupling $\Rightarrow$ Tiny $\sigma(ee \rightarrow H)$

$$\frac{g_{H\mu\mu}}{g_{Hee}} \propto \frac{m_\mu^2}{m_e^2} = 4.28 \times 10^4$$

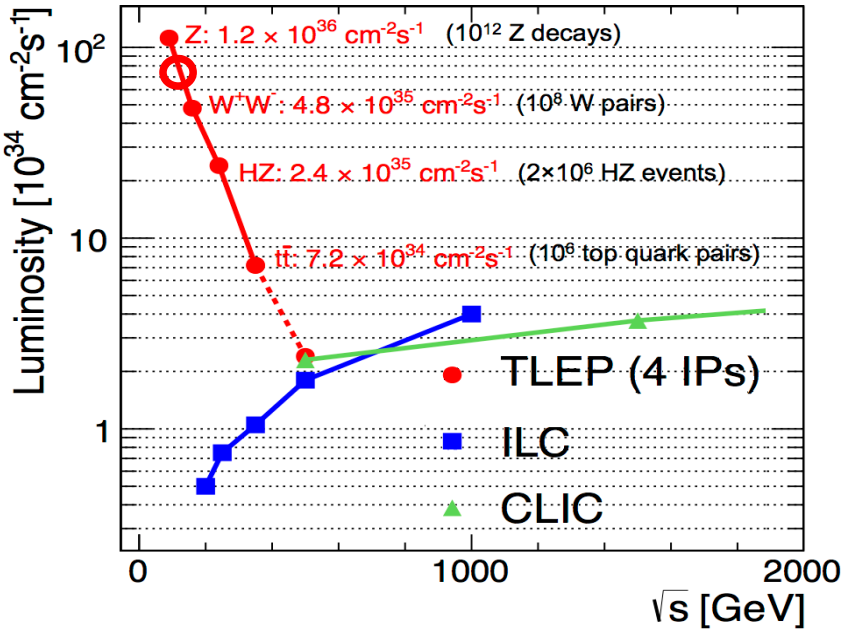
BR($H \rightarrow e^+e^-$)~$5.3 \cdot 10^{-9}$ (decay unobservable)

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

~ 1.64 fb ($m_H$=125 GeV, $\Gamma_H$=4.2 MeV)




- Huge luminosities available at FCC-ee:




In theory, with $L_{int}$~6 $ab^{-1}$ (4 exps./year)

FCC-ee running at H pole mass would produce O(10.000) H bosons.

With reduced beam energy spread & with reduced backgrounds:

→ Electron Yukawa coupling measurable?
→ Higgs width measurable (threshold scan)?
→ Separation of possible nearly-degen. H's?

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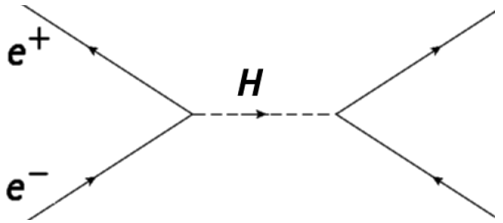


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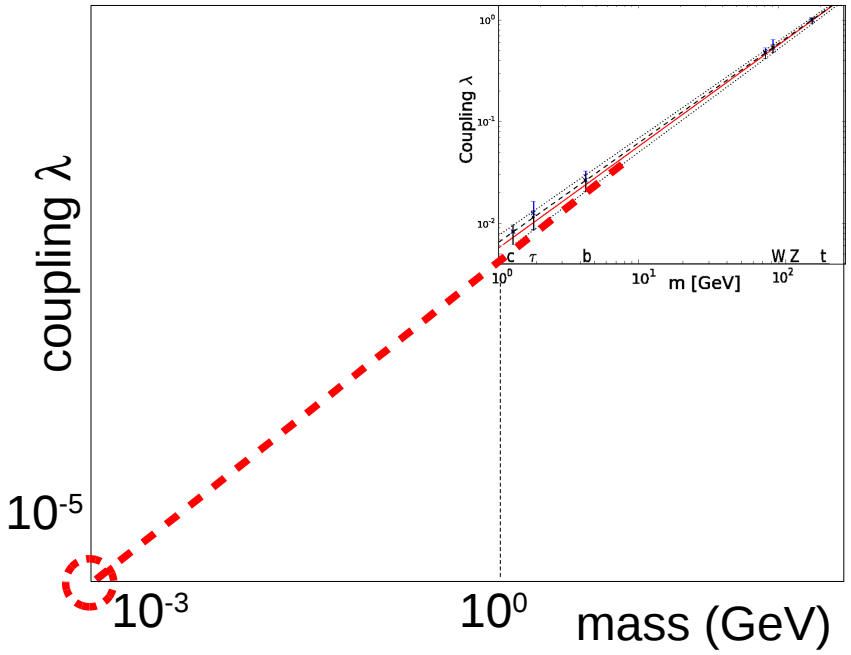


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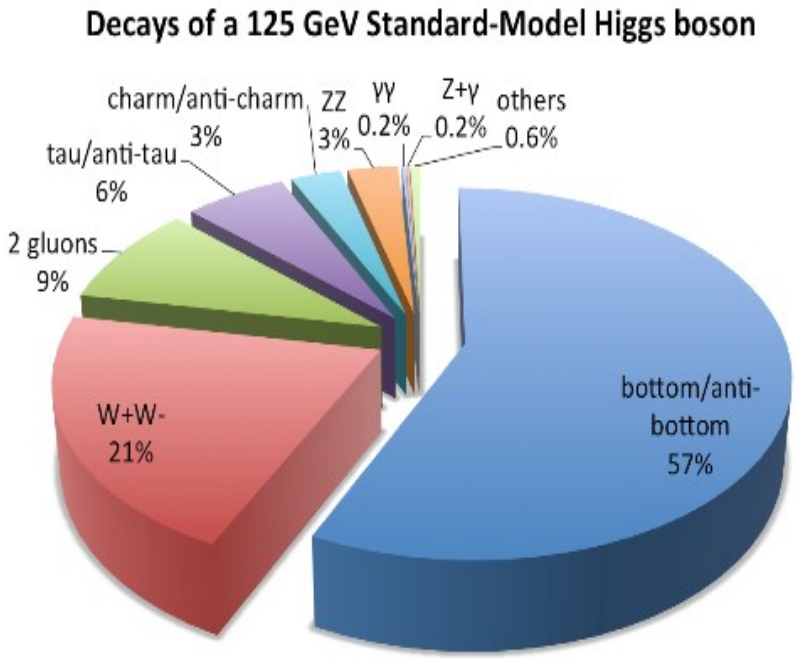
# Visible Higgs decays at FCC-ee(H/2)




- 2-jet final-states (bb,cc,gg) swamped(*) by $e^+e^- \to Z^*,\gamma^* \to q\bar{q}$, $\sigma \sim O(100\,pb)$
- 4-jet final-states (WW*,ZZ*) swamped(*) by $e^+e^- \to Z^*,\gamma^* \to q\bar{q}(gg)$, $\sigma \sim O(1\,pb)$
  $e^+e^- \to WW^*,ZZ^*$, $\sigma \sim O(20\,fb)$
- $\tau$-$\tau$ decays swamped(*) by $e^+e^- \to Z^*,\gamma^* \to \tau\text{-}\tau$, $\sigma \sim O(10\,pb)$
- Rare decays, ZZ(ll),$\gamma\gamma$,$Z\gamma$,.. ~0 counts

*(*) Some cases to be studied in more detail, to be added in combined decays analyses*

- Cleanest channels: WW*(2j,lν), WW*(2l2ν) with σ = 78 ab, 37 ab. dominant continuum background $e^+e^- \to WW^*$ with $\sigma \sim O(5\,fb)$
- In pure leptonic final-state WW*(2l2ν) 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 (more difficult for 2j+lnu: requires jet-charge ...)

# $e^+e^- \rightarrow H(WW^*) \rightarrow 2l2\nu$ (preliminary)

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

  Final state: 2 leptons e,μ,τ(e),τ(μ) + Miss.En. within $|\eta|<5$ (acceptance)

  This retains 60% of the σ(WW*(2l2nu)) = 37 ab.

- Leptons cuts: $p_T(l) > 15$ GeV/c ¬ Kills qqbar

  Isolation ($\Sigma E<0.5$ GeV, $\Delta R<2.5$) ¬ Kills τ-τ

  $m_{l1l2} < 81$ GeV ¬ Reduces ZZ*

  $\cos(\theta_{l1l2})>0$ ¬ Reduces WW* continuum

  Neutrino(s) cuts: ME > 20 GeV ¬ Kills qqbar

- Signal & backgrounds after cuts:

| | | | |
|---|---|---|---|
| H(WW*): | σ = 22 ab | ⇒ | σ(after cuts) ~ 10 ab |
| qqbar: | σ ~ 8 pb | ⇒ | σ(after cuts) ~ 5 ab |
| τ-τ: | σ ~ 1.2 pb | ⇒ | σ(after cuts) ~ 1 ab |
| *WW*:* | *σ = 3.4 fb* | ⇒ | *σ(after cuts) ~ 250 ab* |
| ZZ*: | σ = 1.8 fb | ⇒ | σ(after cuts) ~ 10? ab |

For $L_{int}=1$ ab$^{-1}$

$S/\sqrt{B} \sim 10/\sqrt{270} \sim 0.6$

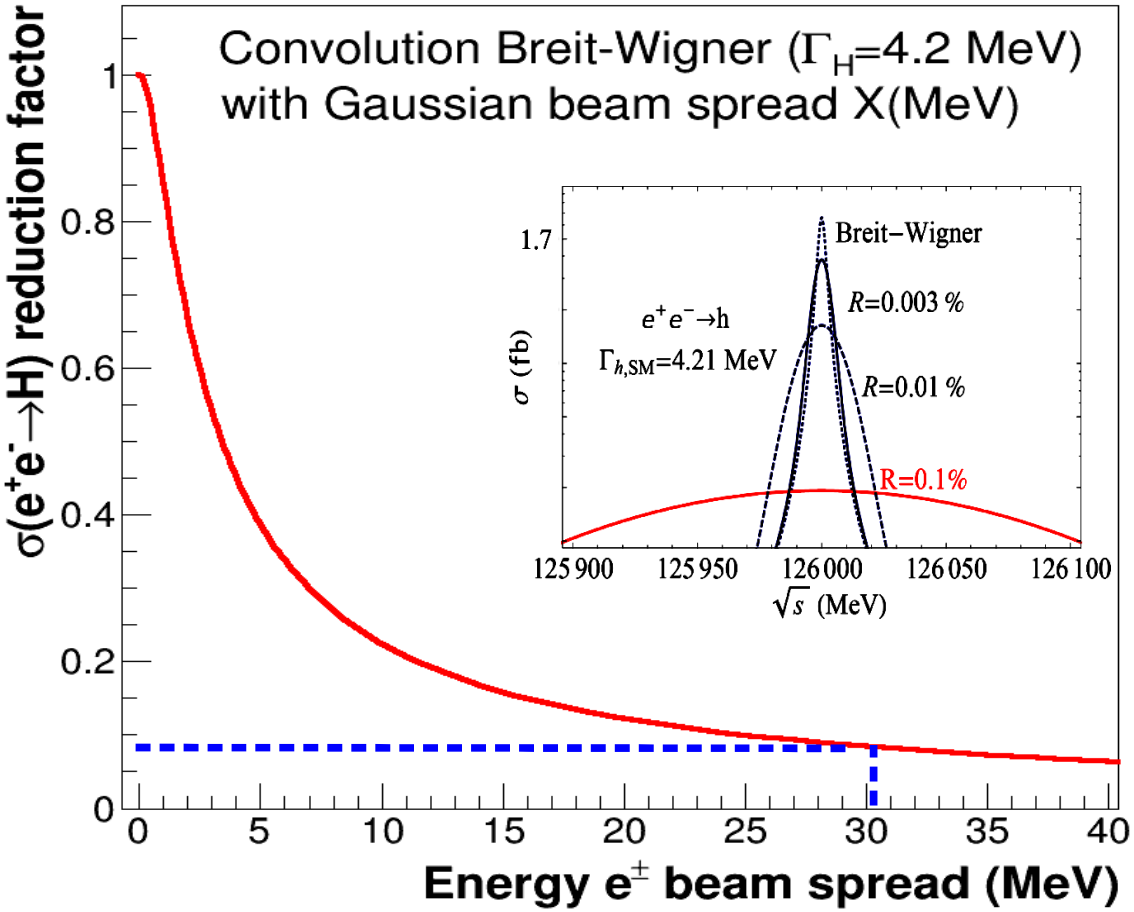
$BR(Hee) < 5 \times BR_{SM}$ (3σ)

$g_{hee} < 2.2 \times g_{Hee,SM}$ (3σ)

Multi-Variate Analysis (in progress) will improve significance.

# $e^+e^- \rightarrow H$ x-section: Beam energy spread

- $\sigma(e^+e^- \rightarrow H)$ considered so far is for B.-W. with natural 4.2 MeV width...
- Convolution of increasing Gaussian energy spread of each $e^{\pm}$ beam with Higgs B.W. results on a (Voigtian) effective cross-section decrease:




$E_{spread} \sim \Gamma_H \sim 4.2$ MeV:

Reduction factor: 45%

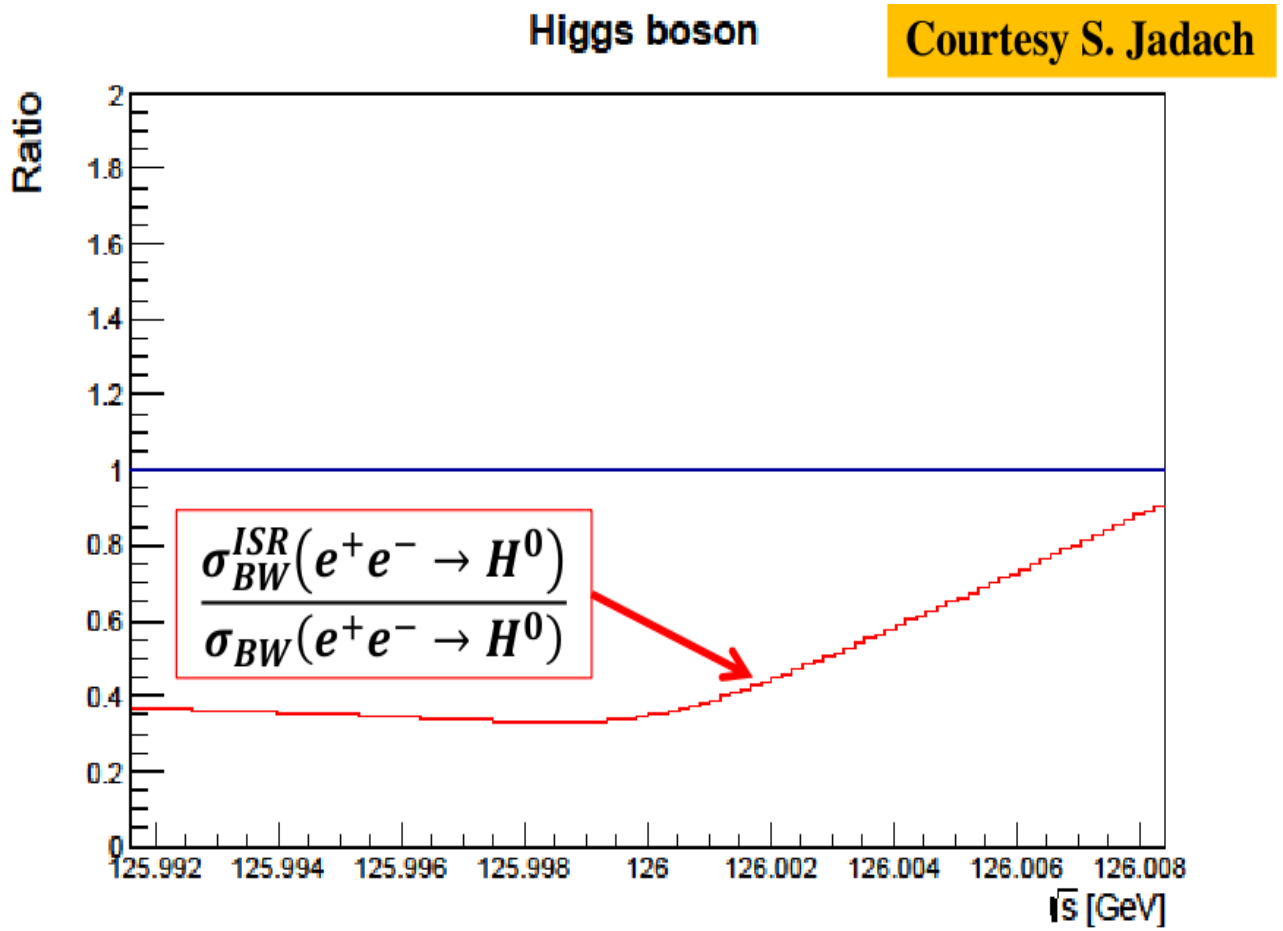
Current FCC-ee nominal ($\Delta E_{beam}/E_{beam} \sim 0.05\%$):

$E_{spread} \sim 30$ MeV:

Reduction factor: 8%

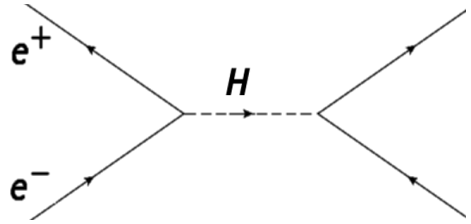
# $e^+e^- \rightarrow H$ x-section: ISR reduction factor

- Extra ~40% reduction in $\sigma(e^+e^- \rightarrow H)$ due to initial state radiation:



# Conclusions

- Resonant s-channel Higgs production at FCC-ee ($\sqrt{s}$ = 125 GeV):




$\sigma(e^+e^- \to H)_{B\text{-}W} \sim 1.64$ fb ($m_H$=125 GeV, $\Gamma_H$=4.2 MeV)
(potentially visible thanks to huge FCC-ee lumi)

- Cleanest channels: WW*(2j,lν), WW*(2l2ν) with σ = 78,37 ab
  Preliminary PYTHIA8 analysis for WW*(2j,lν) for l=e,μ,τ(e),τ(μ):
  Dominant background: WW* continuum (~250 ab, after cuts)
  For $L_{int}$ = 1 $ab^{-1}$, $S/\sqrt{B} \sim 10/\sqrt{270} \sim 0.6$
  $\Rightarrow$ $BR(Hee) < 5 \times BR_{SM}$ (3σ), $g_{hee} < 2.2 \times g_{Hee,SM}$ (3σ)
  (to be improved with: MVA & combination of various channels)
- Significance reduction (×1/20) due to: ISR (0.6), beam $E_{spread}$ (~0.1).
  Crucial to improve current $E_{spread}$ ~ 0.05% by 1 order of magnitude
- Fundamental & unique physics accessible if measurement feasible:
  - → Electron Yukawa coupling
  - → Higgs width measurable ("natural" threshold scan)
  - → Separation of possible nearly-degenarete H's

# Backup slides