Probing the electron coupling to the H^0

(…trying the impossible!)

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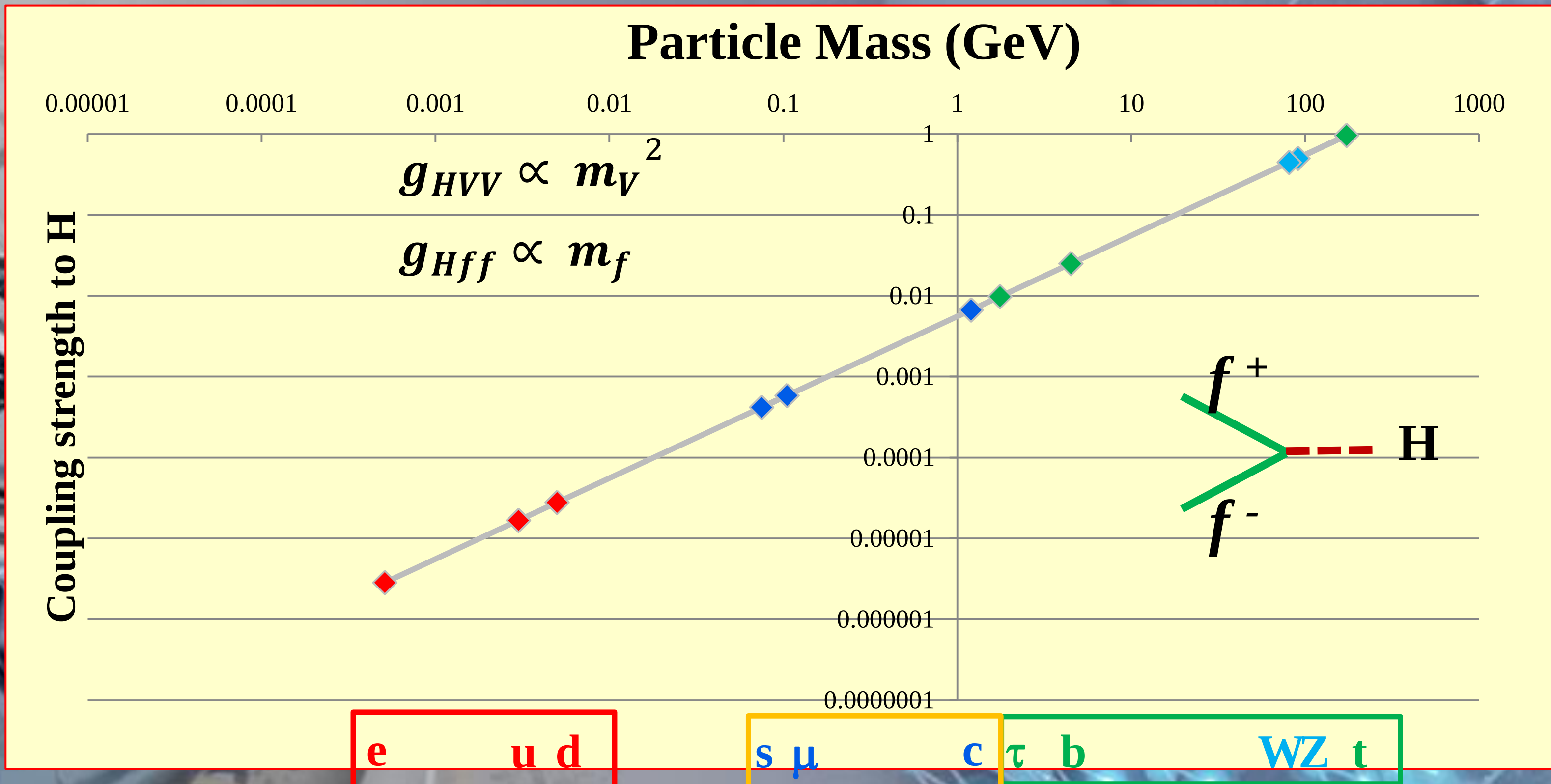
- Introduction
- Direct H production at TLEP
- Next steps

Very preliminary … many pending issues

Measuring the particle coupling to H^0



1^{st} generation

?

2^{nd} generation

HL-LHC
TLEP/LC

3^{rd} generation +VB

LHC

…yet the electron mass is one of the most fundamental quantity in physics

Measuring the H^0 -electron coupling is challenging!

Particle type	$Br(H \to ff)$
WW^*	0.22
ZZ^*	2.6 10^{-2}
$b\bar{b}$	0.57
$c\bar{c}$	2.8 10^{-2}
$\tau^+\tau^-$	6.4 10^{-2}
$\mu^+\mu^-$	2.2 10^{-4}
e^+e^-	5.3 10^{-9}

Extremely difficult to observe H^0 decays to a such tiny BR

Note: Even the observation of H decays to muon pair is tough (e-pair is 5 order of smaller and suffers from higher background)

e.g. HL-LHC (3ab^{-1}, i.e. 10 years) ⇨ ~1 $H^0 \rightarrow e^+e^-$ expected!
and TLEP (10ab^{-1}, i.e. 5 years, 4 IP) ⇨ ~10^{-2} $H^0 \rightarrow e^+e^-$ expected!!!

What about direct H^0 production at e^+e^- colliders ?

It has been proposed to build a Higgs factory based on a muon collider

- **Cross section is ~20 pb ($\delta E/E=10^{-4}$)**
- **Several thousand H produced per year with L ~0.6 10^{32} cm^{-2} s^{-1}**
- **S/B ratio is OK, i.e. ~1/4**

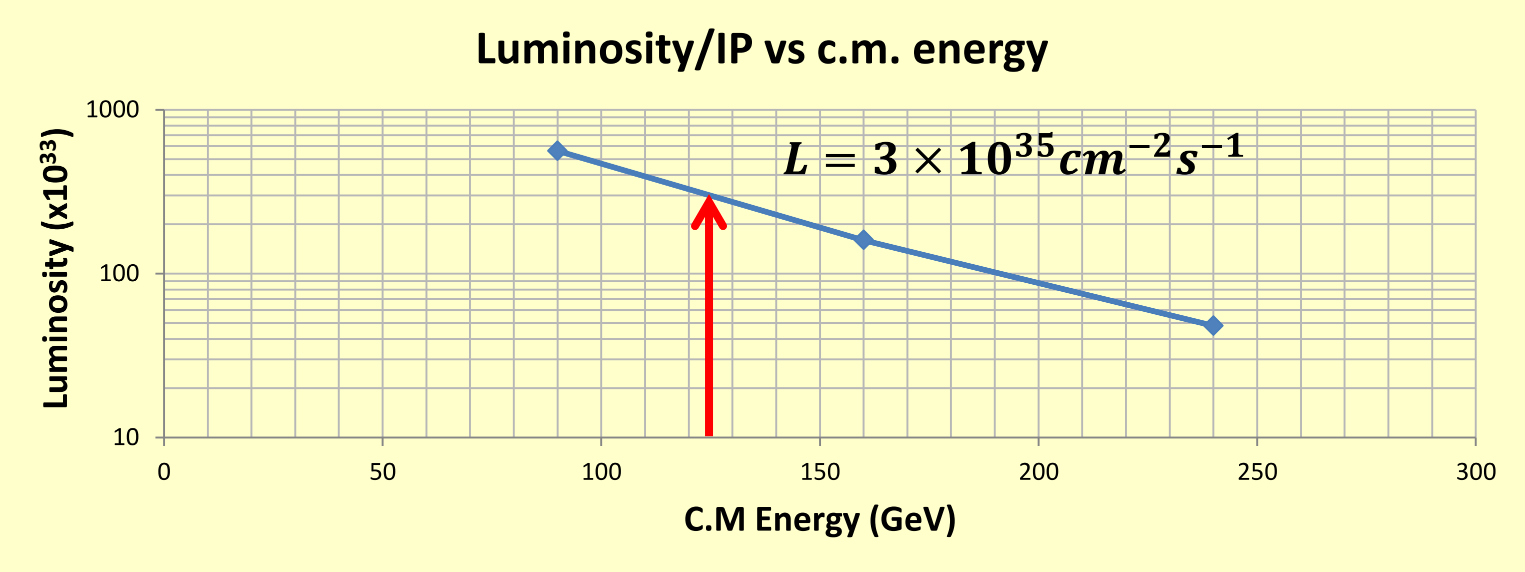
- **But still a lot of R&D necessary before building a muon collider?**
- **Is a ~10^{32} luminosity feasible?**
- **Even so, an e^+e^- collider such as TLEP would produce >10 times more H per year at 240 GeV and has a much broader physics programme**
- **… and in any case, a muon collider cannot address the H coupling to electrons**

If one decides to build an e^+e^- collider, let us investigate whether Higgs particles can be produced directly?

What about direct H^0 production at e^+e^- colliders ?

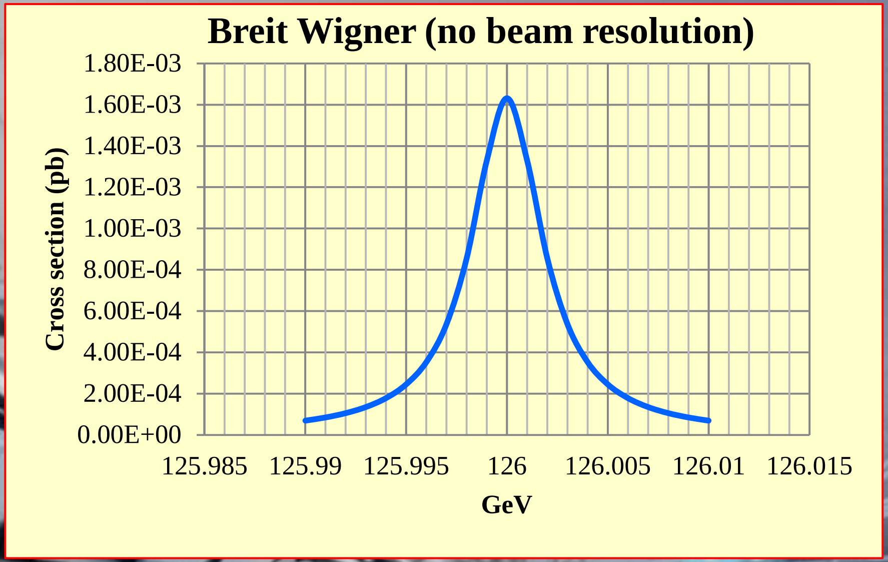
Advantages at a circular e^+e^- collider:

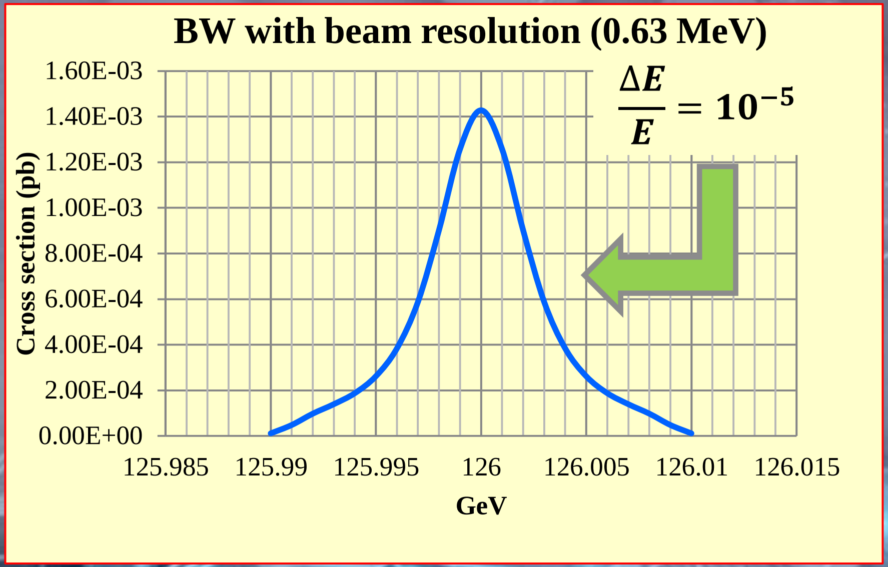
- **Excellent beam energy resolution ($\Delta E/E=10^{-5}$)**
- **Very high luminosity @ 126 GeV (> 10^{35} cm^{-2} s^{-1})**

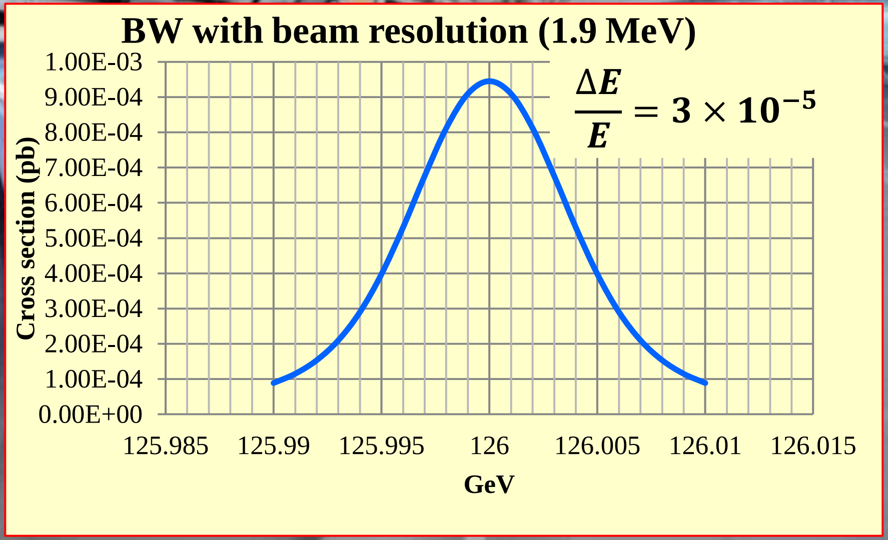


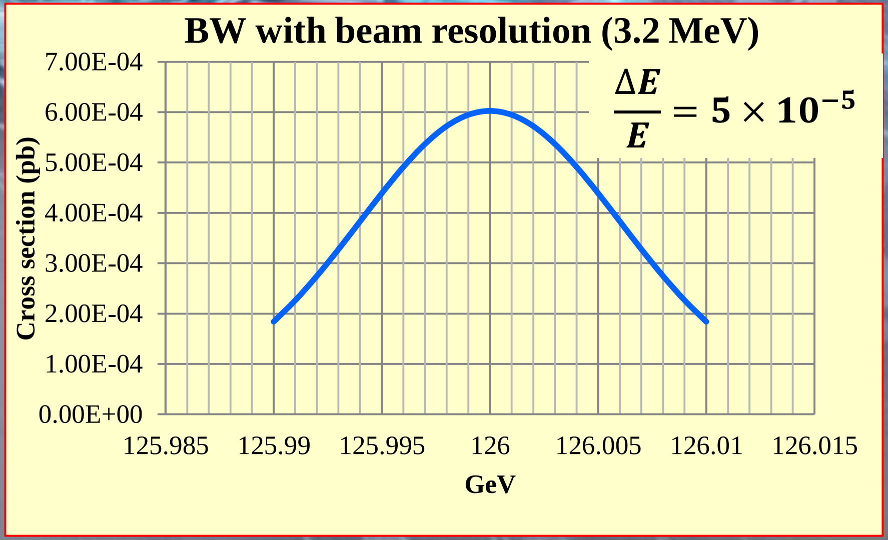
- **But what is the cross section (i.e. do we produce Higgs at all)?**
- **What is the background and can it be overcome?**
- **… if not, what sensitivity of the electron coupling to H can we get?**

Higgs cross section in e^+e^- collisions









$$\sigma(e^+e^- \rightarrow H^0) \approx 1.4 fb$$

Higgs cross section in e^+e^- collisions

$\sigma(e^+e^- \rightarrow H^0) \approx 1.4 fb$

L= 1.5-3 10^{35} cm^{-2} s^{-1}

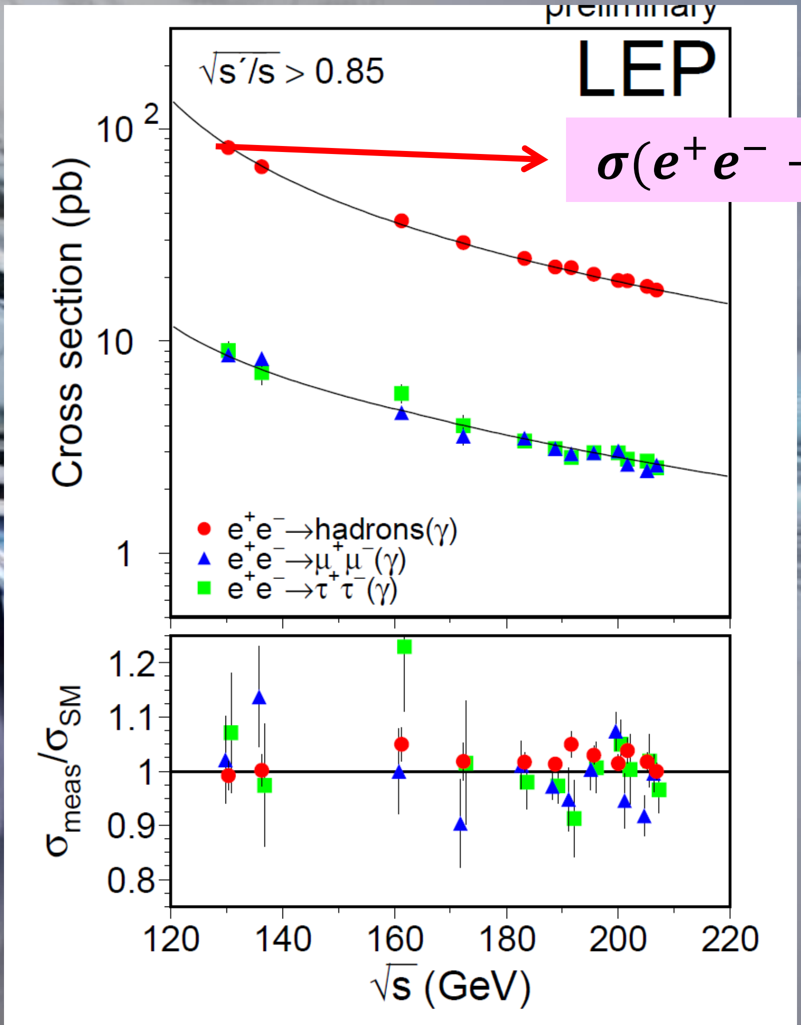
Full day operation = 8.6 10^4 s

18-36 events/day/IP!!!

About 90% of H decays are 2 jets or more

Higgs Decay	Branching Fraction (%)	Main topology	Total
bb	58	2 jets	~69
cc	2.8	2 Jets	
gg	8.2	2 jets	
WW->4j	10	4 jets	18
WW->2j+l	8	2jets+1lept.	
ZZ_>4j	1.3	4 jets	1.56
ZZ->2j+2l	0.26	4j+2lept.	

Background @ e^+e^- collisions



$\boldsymbol{\sigma(e^+e^- \rightarrow Hadrons) \approx 90pb}$

Huge background to be overcome!!!
Signal/Background =1 / (6 x 10^4)!!!

Clearly this makes the observation of the BW very difficult (understatement!)

But it should not prevent us to set a limit on g_{Hee}

Sensitivity to g_{Hee}

For illustration, let us assume that

- **the Higgs mass is precisely known**
- **L = 1.5 x 10^{35} cm^{-2} s^{-1}**
- **One takes the equivalent of 10 full days (8.6 10^{5} s) per IP at the peak**

$$\frac{S}{\sqrt{B}} = 0.054$$

$$Br_{H\to ee} < 54 \times Br_{H\to ee}^{SM} \text{ at the } 3\sigma \text{ level}$$

$$Br_{H\to ee} < 30 \times Br_{H\to ee}^{SM} \text{ at } 95\% \; CL$$

If one assumes $\Gamma_H \equiv \Gamma_H^{SM}$

$$g_{Hee} < 5.5 \; g_{Hee}^{SM} @95\% \; CL$$

$$g_{Hee} < 7.5 \; g_{Hee}^{SM} @ \; 3\sigma \text{ level}$$

Alternatively, if a signal is observed with 5σ significance

$$Br_{H\to ee} = 90 \times Br_{H\to ee}^{SM} \; (5\sigma) \text{ and } g_{Hee} = 9.5 \times g_{Hee}^{SM} \; (5\sigma)$$

Words of caution

This is an oversimplified study and several caveats apply

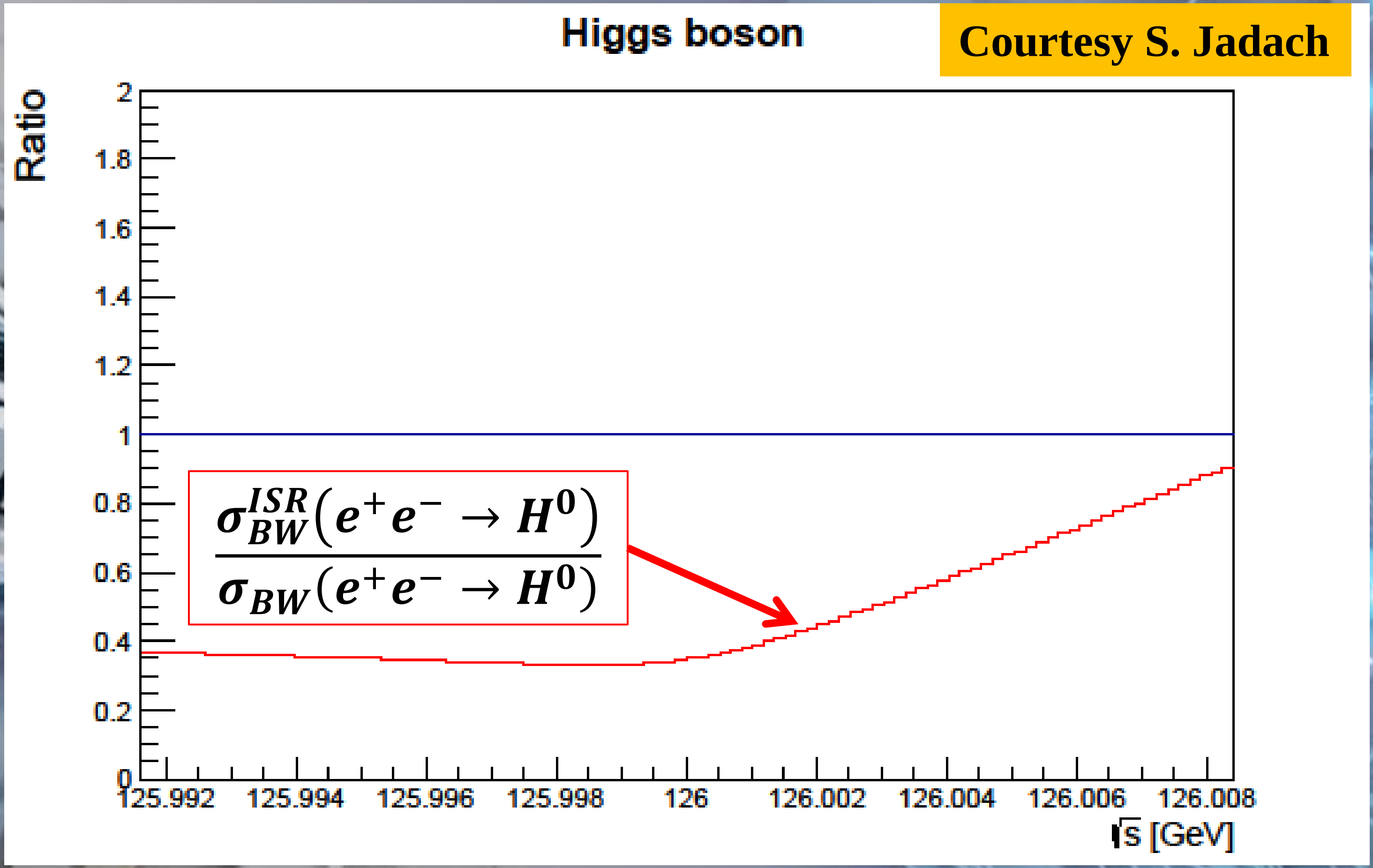
- How precisely will the Higgs mass be measured (7 MeV @ TLEP)
  - Can one do a better mass measurement ?
    - ➢ **Essential to have the simulation tools in place**
  - If not, an energy scan would be required (say 10 points with 1 MeV intervals, i.e. 100 full day equivalent); note however that running at ~126 is useful for other physic topics, e.g. neutrino species counting with Zγ events)

What is the beam resolution (including beamstrahlung) ?

A convolution of the signal with ISR is required

- ➢ **initial estimate leads to a reduction of σ by factor ~3**

Words of caution



$g_{Hee} < 9.2\, g_{Hee}^{SM} @ 95\%\, CL$

$g_{Hee} < 12.5\, g_{Hee}^{SM} @\, 3\sigma\ level$

… but there is also room for improvement

S/B can be improved when using final state characteristics (b-tagging, 3(4) jet events, angular distribution…)

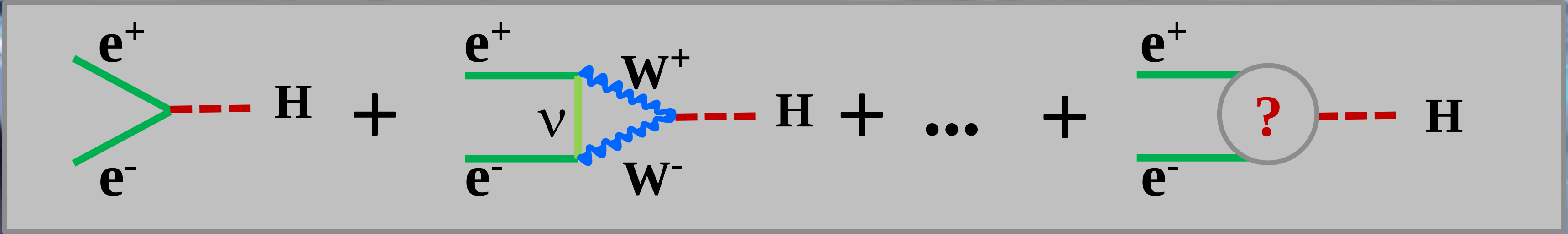
- **Essential to have the simulation tools in place**

… and any new ideas!!!

Physics Case

Is there a theoretical motivation to carry out such a search?

- **How important is it to set a limit on g_{Hee} at the level deemed feasible (i.e. < 10 times SM)?**
- **Alternatively, is there realistic models, which would predicts g_{Hee} to be significantly higher by a factor of ~10 than the SM while not affecting the other couplings?**



- **A different complementary way to address the issue of H coupling to electron may be the search of FCNC, in particular $H \rightarrow \tau e$ ... decays?**

➡ **Here TLEP should be enable significant improvements**

Conclusions

Difficult to observe resonant Higgs production @TLEP if g_{Hee} is the SM value

If deemed important, possible to set limits at TLEP for each IP at the level of:

$g_{Hee} < 9.2\ g_{Hee}^{SM} @95\%\ CL$ $g_{Hee} < 12.5\ g_{Hee}^{SM} @\ 3\sigma\ level$

This is an order of magnitude estimate. Further work is needed to assess these numbers as there are pending issues (some of which can even leads to improvements)

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