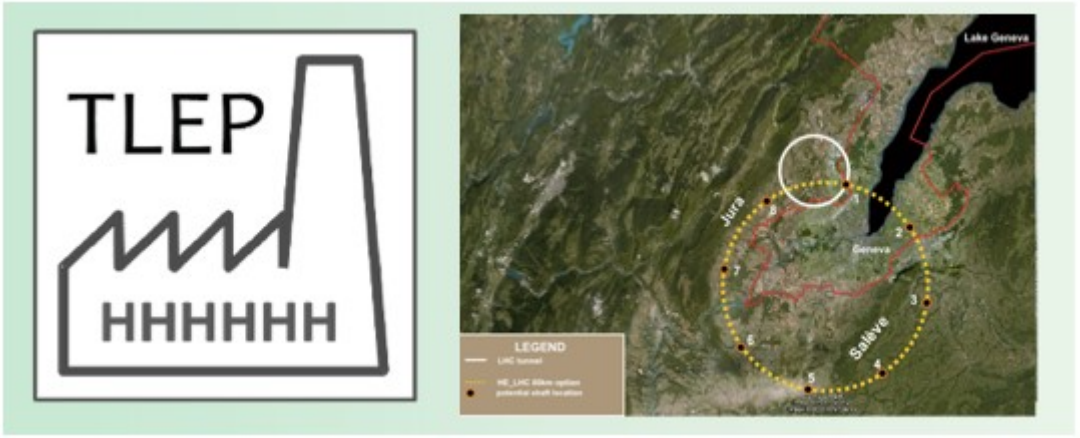

Higgs couplings @ TLEP

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Introduction

- Built a model independent combined fit to estimate the uncertainty on the Higgs couplings for different TLEP measurements and scenarios
- The fit is based on what was performed for ILC by M.Peskin[1]
  - Challenged the LEP3 numbers in 3^{d} TLEP workshop produced in assumption of no exotic decays
- Those are (technically) very simple fits compared to what is done @ the LHC
  - Where all correlations and contaminations are taken into account
  - To do this @TLEP we need to redo all analyses and give as inputs shapes and yields instead of plain numbers
  - This will be done at some point but:
- We are (and were) always doing apples to apples comparison between TLEP and ILC

Fit Procedure

- For each coupling H → XX assume a deviation d_X on the value $g_X/g_{X(SM)}$ from unity
- Each inclusive cross section measurement σ(X → H) has a deviation from unity equal to: $(1+d_X)^2$
- Each σ(X → H) x BR(H → YY) has a deviation equal to:

$$\frac{(1+d_X)^2(1+d_Y)^2}{D\Gamma}$$

- where

$$D\Gamma = \frac{\sum_X BR(H \to XX)(1+d_X)^2}{1-d_{exo}^2}$$

- d_{exo}^2 is the BR to exotic decays

Assumptions in the fit

- Treatment of invisible vs exotic decays
  - Invisible decays can be measured very precisely @ TLEP (~0.2%) and constrain the total width
  - We do **not** use the BR → invisible measurements in the fit but assume we do not know the non SM (exotic) decays
    - Essentially measuring total width in the fit
- Assumptions for g_W,g_Z <SM values
  - Coming from the constraints on W,Z masses and assumptions on CP and presence of double charged Higgs
  - We do **not** use this assumptions in the fit

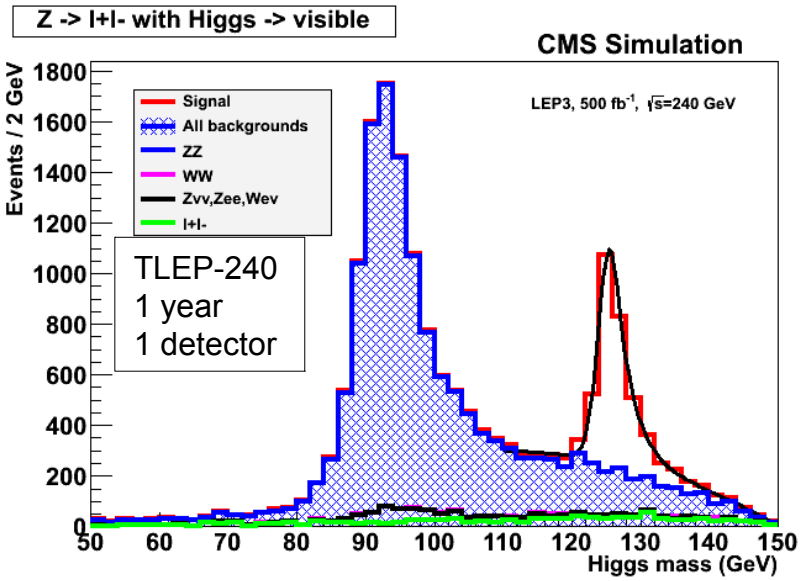
Constrain terms in the PDF

- Each measurement becomes a term in the total pdf product to be maximized
  - Using Gaussians to model the constraints
- For each inclusive cross section measurement σ(X → H) with uncertainty σ, a term is added in the product of the form: $e^{\frac{[1-(1+d_X)^2]^2}{2\sigma^2}}$
- For each σ(X → H) x BR(H → YY) with uncertainty σ, a term is added in the product of the form

$$e^{\frac{[1-\frac{(1+d_X)^2(1+d_Y)^2}{D\Gamma}]^2}{2\sigma^2}}$$

Higgs measurements at 250 GeV

	ILC-250(TDR)	TLEP 240
σ_{HZ}	2.5%	**0.4%**
σ_{HZ} x BR(H → bb)	1.1%	**0.2%**
σ_{HZ} x BR(H → cc)	7.4%	**1.2%**
σ_{HZ} x BR(H → gg)	9.1%	**1.4%**
σ_{HZ} x BR(H → WW)	6.4%	**0.9%**
σ_{HZ} x BR(H → ττ)	4.2%	**0.7%**
σ_{HZ} x BR(H → ZZ)	19%	**3.1%**
σ_{HZ} x BR(H → γγ)	35%	**3.0%**
σ_{HZ} x BR(H → μμ)	100%	**13%**
Γ_{inv}/Γ_H	<1%	**<0.2%**
m_H	40 MeV	**8 MeV**



Inclusive σ_{ZH} measurement from missing mass in Z → ll

- Using the most up to date TLEP analyses/numbers
  - CMS full simulation
  - Except H → gg/cc (extrapolated from ILC)

Higgs measurements at 350 GeV

- Probing Higgs via WW fusion
  - Separating WWH → bbνν from ZH → νν bb by the missing mass
  - Possible at 250 and 350 GeV
- Measurement of the total width constrained in the fit

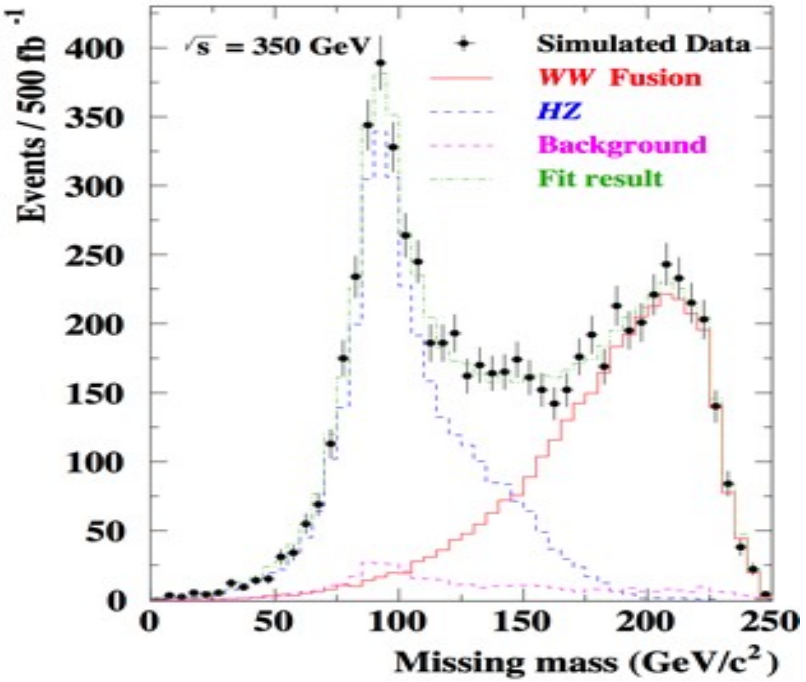
$$\sigma(ZH) \approx g_Z^2$$

$$\sigma(ZH) \cdot BR(H \to ZZ) \approx \frac{g_Z^2 g_Z^2}{\Gamma_T}$$

$$\sigma(ZH) \cdot BR(H \to WW) \approx \frac{g_Z^2 g_W^2}{\Gamma_T}$$

$$\sigma(ZH) \cdot BR(H \to bb) \approx \frac{g_Z^2 g_b^2}{\Gamma_T}$$

$$\sigma(\nu\nu H) \cdot BR(H \to bb) \approx \frac{g_W^2 g_b^2}{\Gamma_T}$$



@TLEP only WWH is improved at 350 GeV
@ILC all measurements improve due to Lumi increasing with energy

	ILC	TLEP
WW → H → bb@ 240	11%	**2%**
WW → H → bb@ 350	1%	**0.4%**

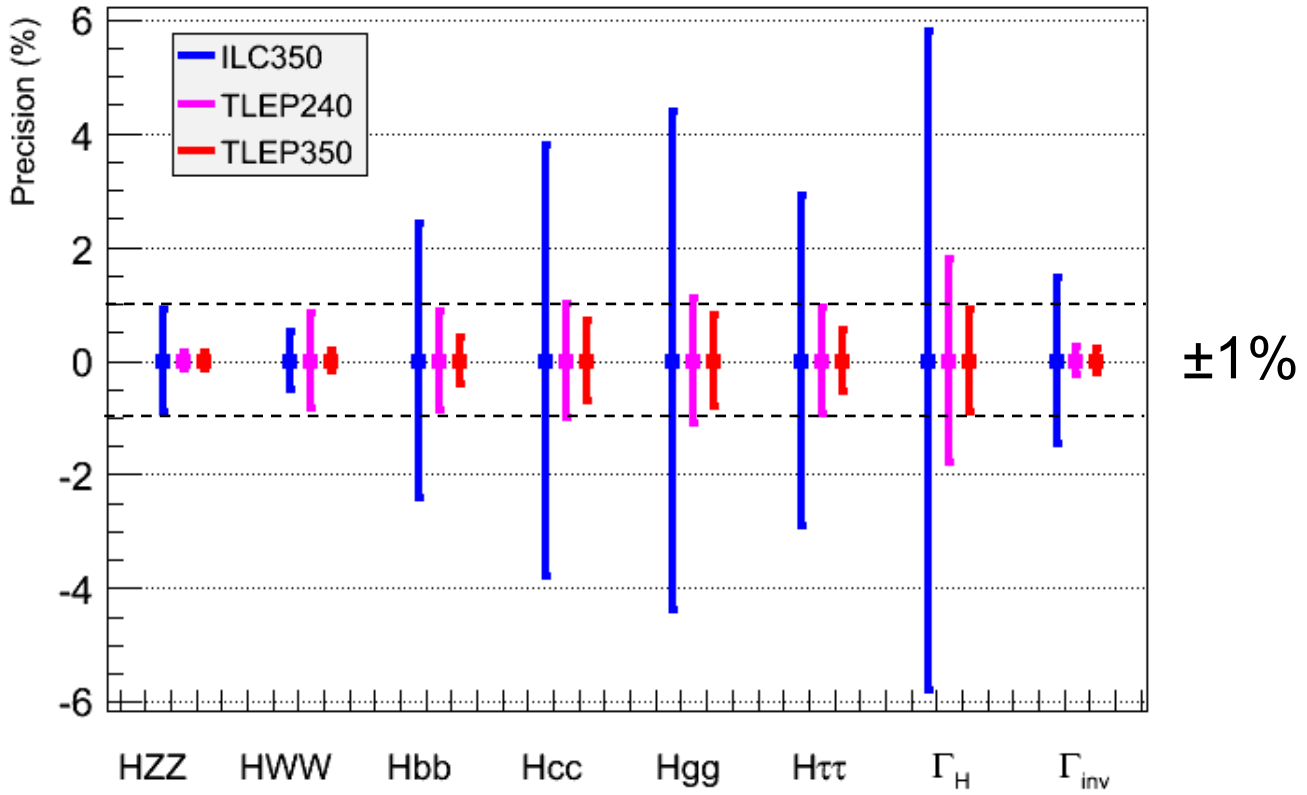
Validation and results

- Started by reproducing the fit by M.Peskin[1]
  - In the beginning diffference due to ILC using HL-LHC inputs
  - After adding HL-LHC inputs got identical results
- Then reproduced all numbers in ILC TDR
- Then run TLEP with latest inputs
- Results:
  - 5-10 times better precision in TLEP wrt ILC up to 350

	g_Z	g_W	g_b	g_c	g_g	g_τ	g_μ	g_γ	BR_{exo}
TLEP-240	0.16%	0.85%	0.88%	1.0%	1.1%	0.94%	6.4%	1.7%	<0.48%
TLEP-350	**0.15%**	**0.19%**	**0.42%**	**0.71%**	**0.80%**	**0.54%**	**6.2%**	**1.5%**	**<0.45%**
ILC 350	0.9%	0.5%	2.4%	3.8%	4.4%	2.9%	45%	14.5%	<2.9%

[1](arXiV:1207.2516v3)

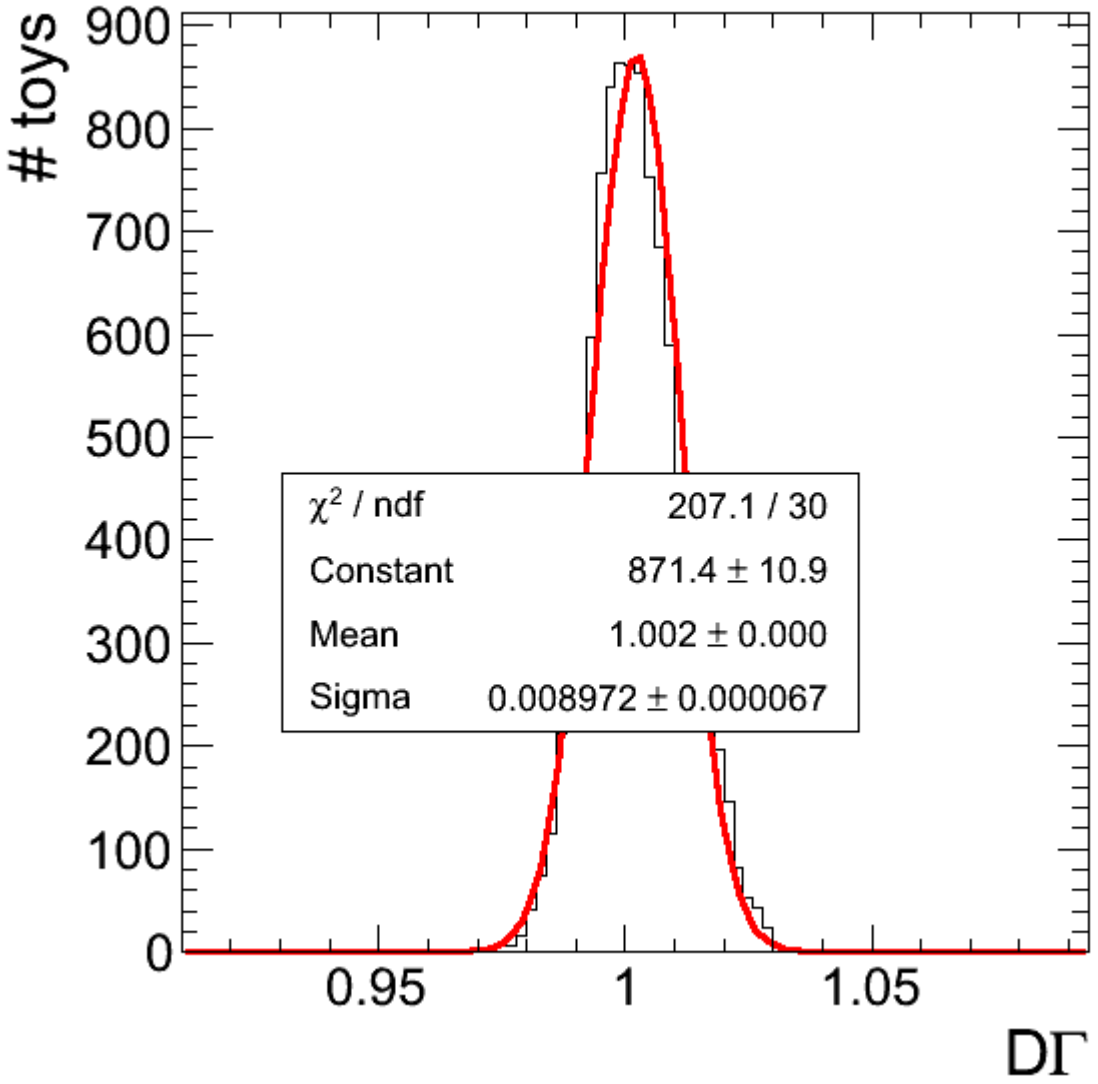
Results@ 250 + 350 GeV



- Only TLEP achieves sub-percent precision in all couplings
- Theoretical systematics can be trivially introduced to the fit when available

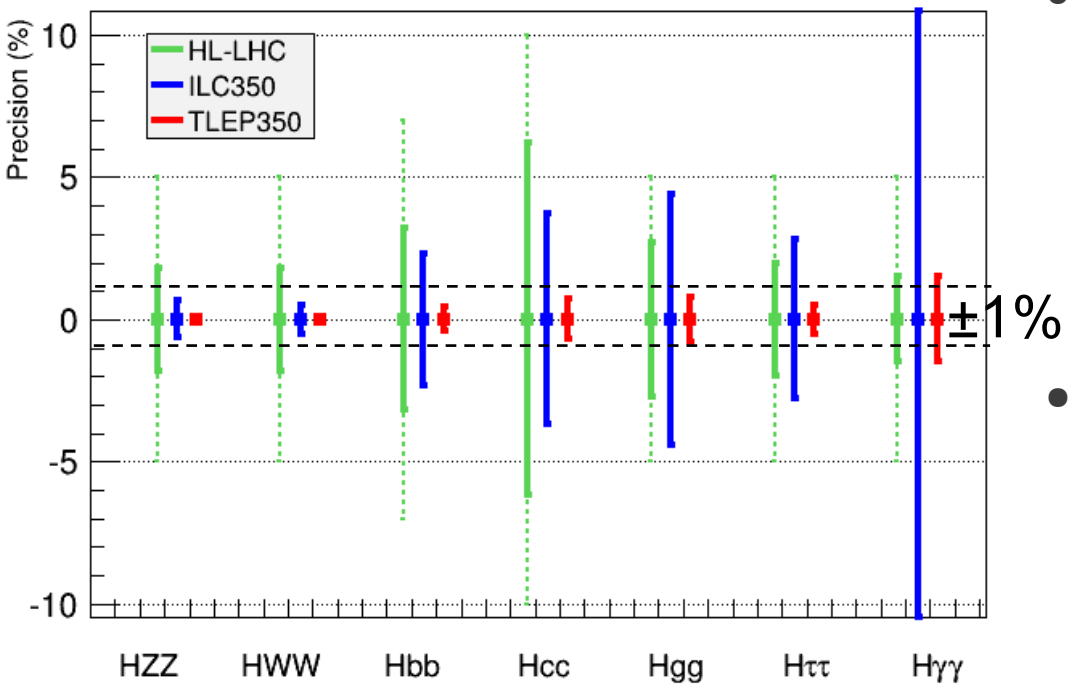
Probing the total width in the fit

- Currently the width results are produced analytically by comparing WWH vs WW and ZH vs ZZ
  - We can take them directly from the fit
  - By sampling the covariance matrix and throwing toys for DΓ
- Result identical to analytical calculation
- @ √s = 250+350:
  - 0.9% for TLEP
  - 5.8% for ILC



Uncertainty on Γ_T ~ 0.9%

Comparison with HL-LHC



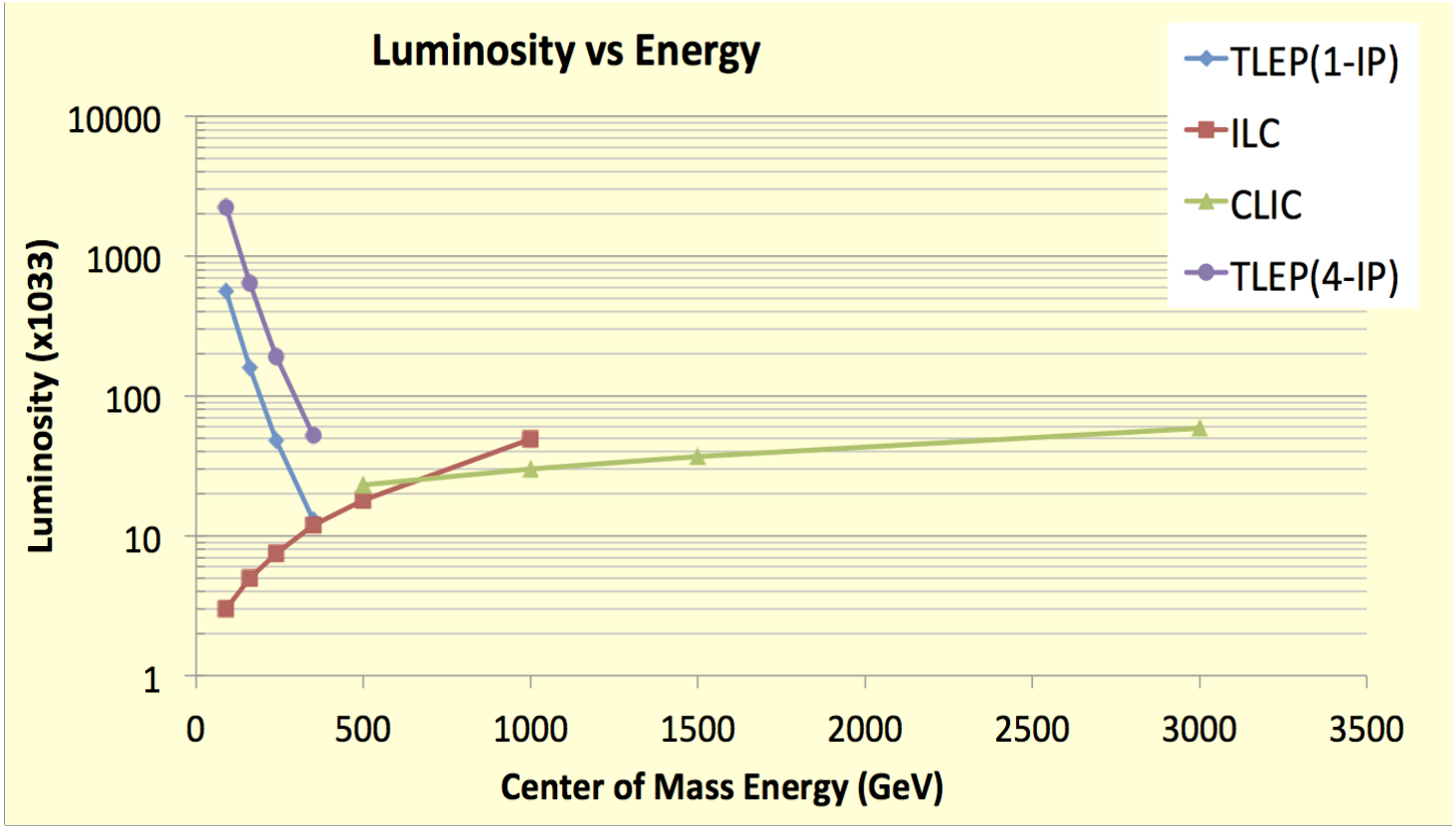
- LHC results with only CMS
  - Scenario I
  - Scenario II
- HL-LHC Assumptions
  - Theory systematics improve by x2
  - Experimental systematics scale with statistics
  - Identical analysis performance as today
- Fit with LHC like assumptions
  - No exotic decays
  - $g_W, g_Z \leq$ SM values
- HL-LHC numbers will improve by $\sqrt{2}$ for ATLAS+CMS and by including new channels (e.g. in ttH)

Conclusions and Plans

- Implemented a fit to perform estimation of the TLEP couplings based on input measurements
- Fit exhaustively validated in ILC inputs
- TLEP can provide ultimate precision in all fermion and vector boson couplings
- Theoretical systematics can be trivially implemented
- Also some evident correlations can be taken into account
  - I.e $H \rightarrow bb$ vs $H \rightarrow cc$ and $H \rightarrow gg$
- Code to become available

Backup

TLEP luminosity

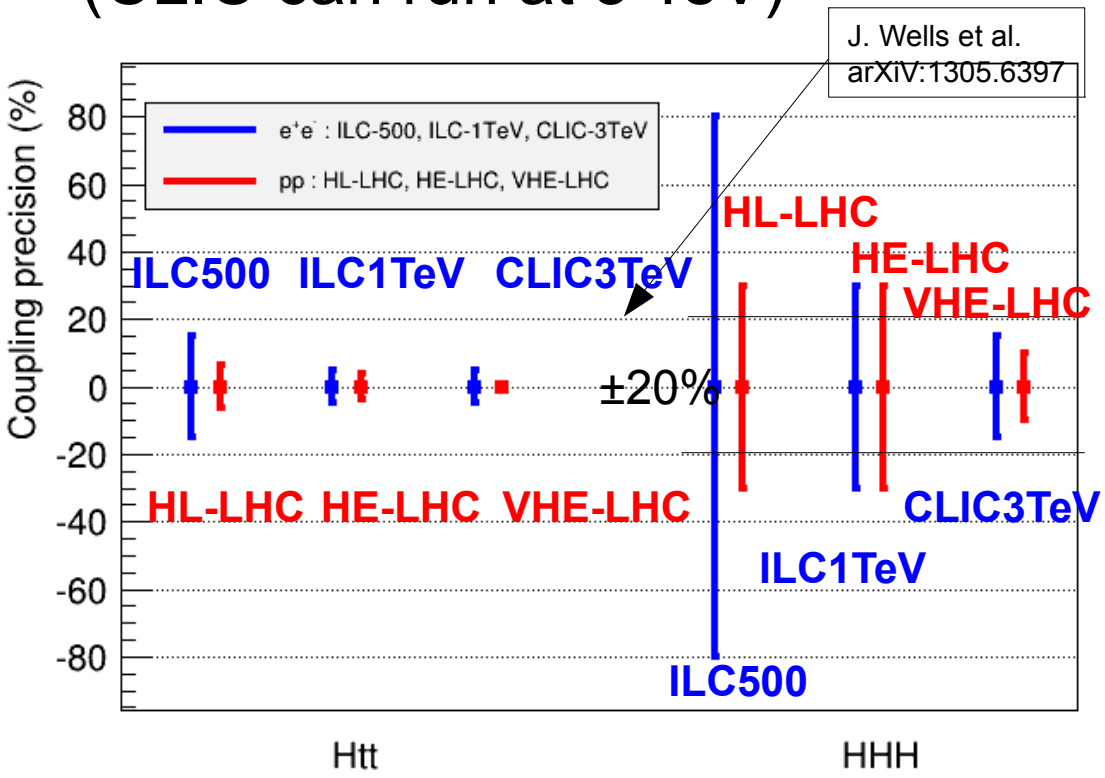


- Much higher repetition rate + multiple interaction points
  - Significantly larger luminosity at ttbar threshold
- RF power is used at lower $\sqrt{s}$ to collide more bunches
- Crossing point with LC at ~ 400 GeV

Note: Luminosity upgrade scenario envisioned @ ILC and TLEP

Towards the energy frontier

- Higgs measurements at higher energy can probe
  - The top coupling (ttH production)
  - The self coupling (HHH)
- ILC proposes upgrade to 1 TeV (CLIC can run at 3 TeV)



- HL-LHC will measure the top coupling by the time the next e+e- collider is foreseen
- Measurement of HHH is difficult
  - Neither HL-LHC, nor ILC can reach a meaningful precision
  - TLEP natural upgrade is VHE-LHC
    - Towards a meaningful measurement of the HHH coupling (<10%) and direct searches for new physics
  - CLIC can also measure HHH @ 3 TeV