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HIGGS-BOSON
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HM

EW theory needs for Higgs Physics at FCC-ee

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Paris/virtual, 05/2020

1. Motivation
2. SM parameter determination
3. SM Higgs (the "easy" case)
4. BSM Higgs(es) (the "difficult" case)
5. Conclusions

1. Introduction

Experimental situation:

(HL-)LHC/ILC/CLIC/FCC-ee/CEPC/...
will provide (high!) accuracy measurements!

Theory situation:

– Measurements are performed using theory predictions

– measured observables have to be compared with theoretical predictions (in various models: SM, THDM, (N)MSSM, ...)

Full uncertainty is given by the (linear) sum of experimental and theoretical uncertainties!

$\Rightarrow$ Experimetal precision can only fully be exploited with theory uncertainties at the same level of accurady!

Many results shown here based on: [*arXiv:1906.05379*]

Write-up for FCC-ee physics WG2 – Precision EW Calculations

Theoretical uncertainties for electroweak and Higgs-boson precision measurements at FCC-ee

A. Freitas[*1], S. Heinemeyer[*2], M. Beneke[3], A. Blondel[4], S. Dittmaier[5], J. Gluza[6,7], A. Hoang[8], S. Jadach[9], P. Janot[10], J. Reuter[11], T. Riemann[6,12], C. Schwinn[13], M. Skrzypek[8], and S. Weinzierl[14]

⇒ Here: focus on Higgs precision

⇒ should be taken into account by "exp groups"!

⇒ Here: current status and future of Higgs TH calculations
what may/should be achievable in TH calculations "in time"

Where we need theory prediction:

1. Prediction of the measured quantity
   Example: $\Gamma(H \to b\bar{b})$
   $\to$ at the same level or better as the experimental precision

2. Prediction of the measured process to extract the quantity
   Example: $e^+e^- \to ZH$
   $\to$ better than then "pure" experimental precision

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Two types of theory uncertainties:

1. intrinsic: missing higher orders

2. parametric: uncertainty due to exp. uncertainty in SM input parameters
   Example: m_t, m_b, α_s, $\Delta\alpha_{\text{had}}$, ...

Options for the evaluation of intrinsic uncertainties:

1. Determine all prefactors of a certain diagram class (couplings, group factors, multiplicities, mass ratios) and assume the loop is $\mathcal{O}(1)$

2. Take the known contribution at n-loop and $(n-1)$-loop and thus estimate the $n+1$-loop contribution:

$$\frac{(n+1)^{(\text{estimated})}}{n^{(\text{known})}} \approx \frac{n^{(\text{known})}}{(n-1)^{(\text{known})}}$$

   $\Rightarrow$ simplified example! Has to be done
   "coupling constant by coupling constant"

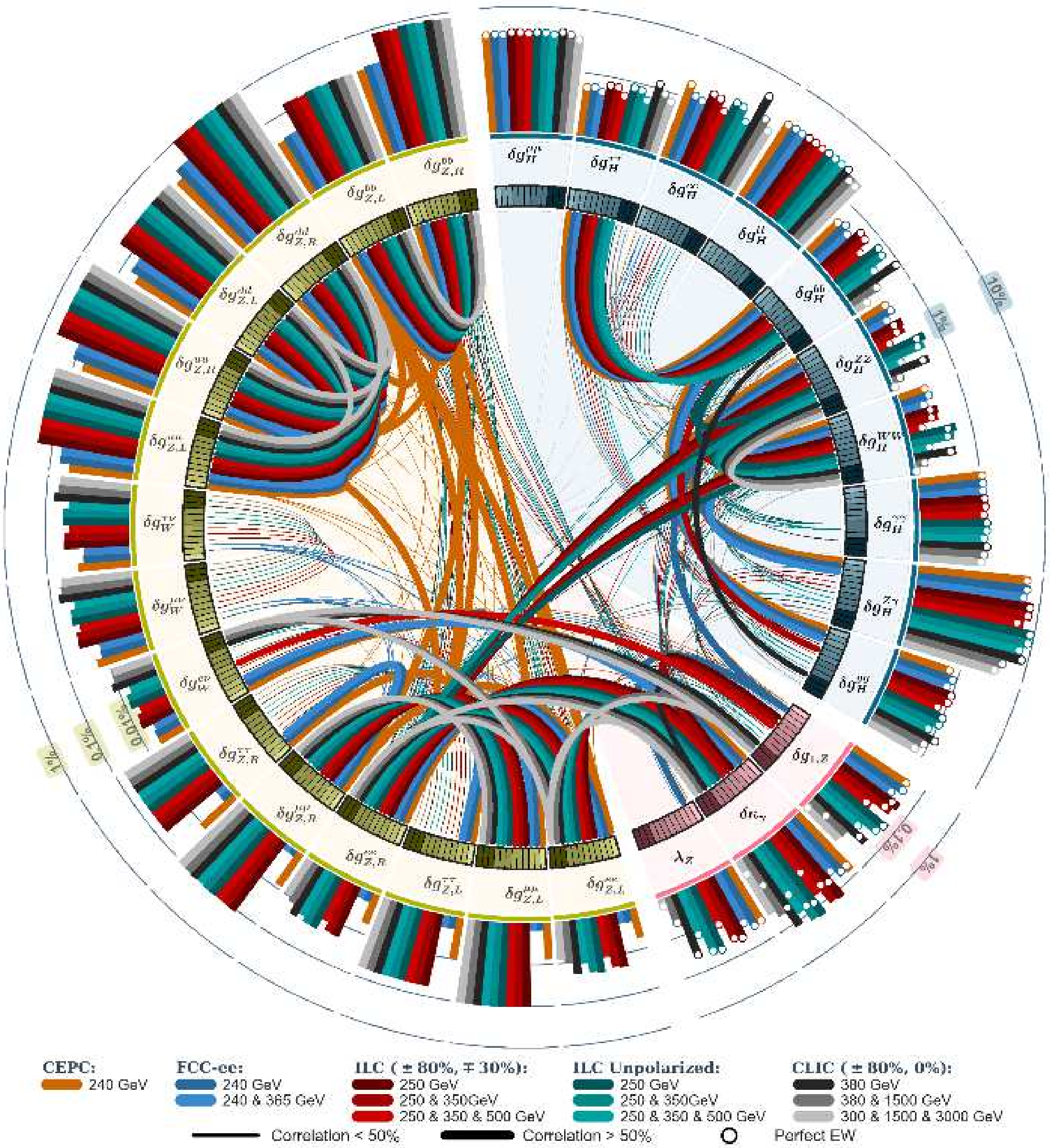
3. Variation of $\mu^{\overline{\text{MS}}}$ (QCD!, EW?)

4. Compare different renormalizations

$\Rightarrow$ Mostly used here: 1 & 2

Correlatoins with EWPO:

[*J. de Blas et al. '19*]



Based on EFT approach

⇒ relevant correlations
between Higgs and EWPO

2. SM parameter determination

$\Rightarrow$ intrinsic uncertainties $\Rightarrow$ more details in back-up

1. M_H: better than 20 MeV $\Rightarrow$ negligible
2. M_Z: $\sim$ 0.1 MeV with negligible theory uncertainties $\Rightarrow$ negligible
3. $\alpha_s(M_Z)$: from (mainly) R_ℓ
   $\delta\alpha_s^{\text{exp}} \sim 10^{-4}$, $\delta\alpha_s^{\text{theo}} \sim 1.5 \times 10^{-4}$
4. m_t: from threshold scan
   $\delta m_t^{\text{exp/theo}} \lesssim 50$ MeV
5. m_b: from lattice calculations
   $\delta m_b \sim 10$ MeV
6. $\Delta\alpha_{\text{had}}$: BES III and Belle II: $\delta(\Delta\alpha_{\text{had}}) \sim 5 \times 10^{-5}$
   better from measurements "around the Z pole? $\sim 3 \times 10^{-5}$?

3. SM Higgs (the "easy" case)

Initial measurement: $\sigma \times$ BR

recoil method: $e^+e^- \to ZH$, $Z \to e^+e^-$, $\mu^+\mu^-$

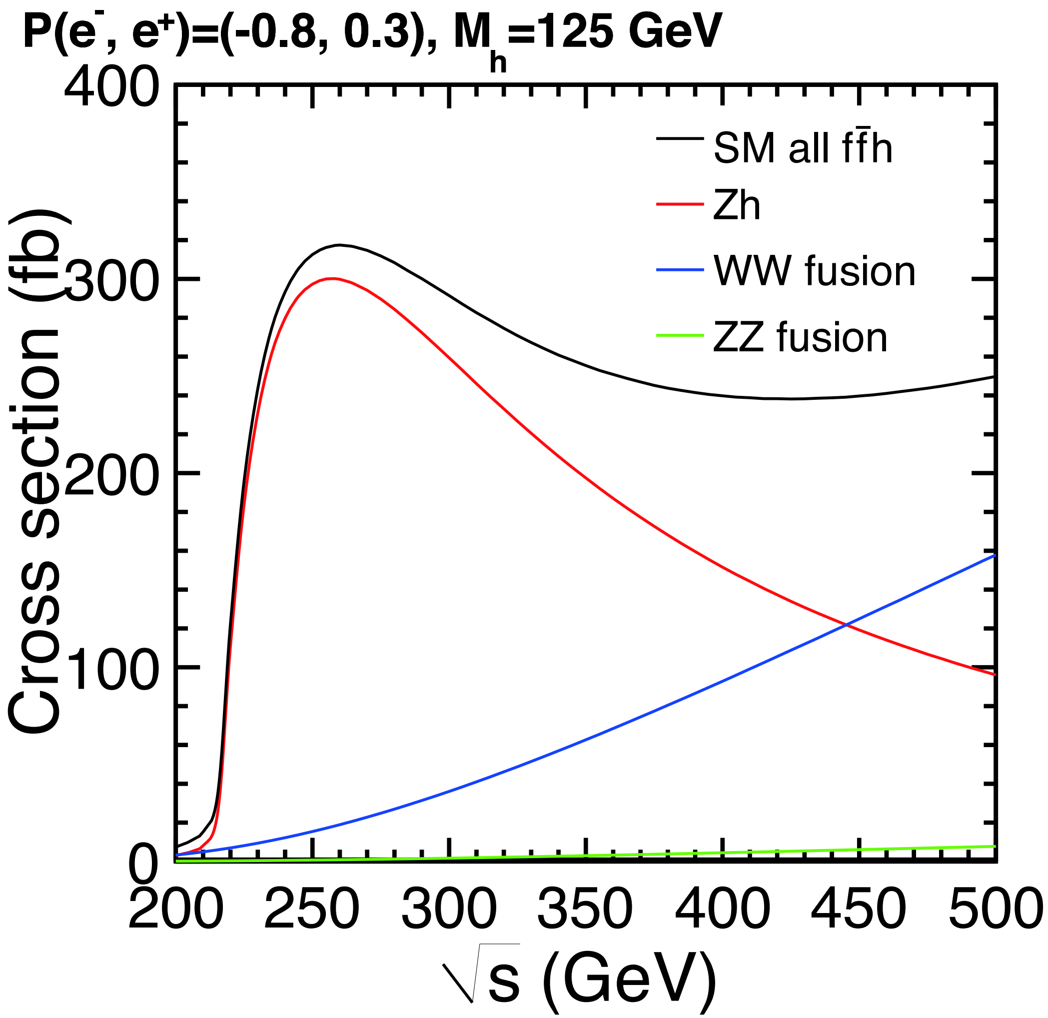
$\Rightarrow$ measurement of the Higgs production cross section

$\Rightarrow$ NO additional theoretical assumptions needed for absolute determination of partial widths

$\Rightarrow$ indirect measurement of total width

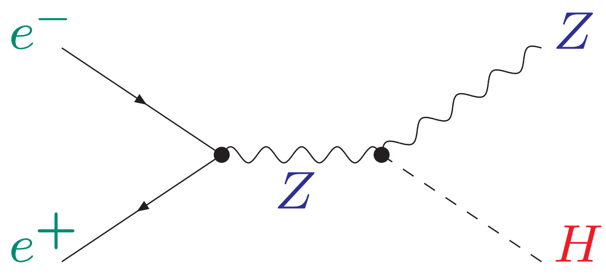
$\Rightarrow$ direct extraction of partial widths (couplings)

Higgs production cross sections:



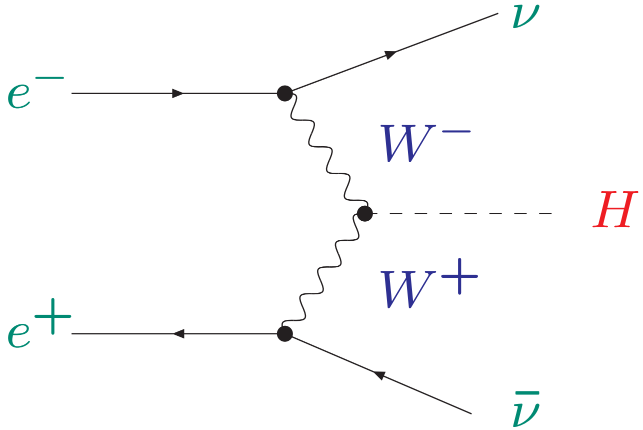
Higgs-strahlung:

$e^+e^- \to Z^* \to ZH$



weak boson fusion (WBF):

$e+e- \to \nu\bar{\nu}H$



$\sqrt{s} \sim$ 250 GeV, Higgs-strahlung dominated

Short overview: $\Rightarrow$ more details in the back-up

Higgs-Strahlung: $\Delta_{\text{th}} \sim \mathcal{O}(1\%)$
With full 2-loop corrections: $\Delta_{\text{th}} \lesssim \mathcal{O}(0.3\%)$

Weak-boson fusion: $\Delta_{\text{th}} \sim \mathcal{O}(1\%)$
$\mathcal{O}\left(\alpha^2\right)$ for $2 \to 3$ very challenging, closed fermion loops?!
Backgrounds: $\mathcal{O}(\alpha)$ needed for $2 \to 4$, technology exists ...

$h \to b\bar{b}$: $\Delta_{\text{th}} < 0.4\%$, full 2-loop: $\sim 0.2\%$
δm_b, $\delta\alpha_s$: $\Delta_{\text{par}} \sim 0.8\%$, future: $\sim 0.3\%$

$h \to \tau^+\tau^-$: full 2-loop: $\Delta_{\text{th}} < 0.1\%$

$h \to WW^*, ZZ^*$: $\Delta_{\text{th}}^{\text{EW}} < 0.3\%$, $\Delta_{\text{th}}^{\text{QCD}} < 0.5\%$
with NNLO final state QCD: $\Delta_{\text{th}}^{\text{QCD}} < 0.1\%$
δM_H: $\Delta_{\text{par}} \sim 0.1\%$

$h \to gg$: $\Delta_{\text{th}} \sim 3\% \to \Delta_{\text{th}} \sim 1\%$
$\delta\alpha_s$: $\Delta_{\text{par}} \sim 3\% \to \Delta_{\text{par}} \sim 0.3\%$

$h \to \gamma\gamma$: $\Delta_{\text{th}} < 1\%$

Intrinsic uncertainties for decay widths: [arXiv:1905.03764]

"ILC/CEPC/FCC-ee" = expected precision on g^2_{Hxx} (incl. HL-LHC meas.)

Partial width	QCD	electroweak	total	future	ILC/CEPC/FCC-ee
$H \to WW \to$ 4f	$<$ 0.5%	$<$ 0.3%	$\sim$ 0.5%	$\lesssim$ 0.4%	0.6/1.9/0.8%
$H \to ZZ \to$ 4f	$<$ 0.5%	$<$ 0.3%	$\sim$ 0.5%	$\lesssim$ 0.3%	0.4/0.4/0.3%
$H \to gg$	$\sim$ 3%	$\sim$ 1%	$\sim$ 3.2%	$\sim$ 1%	1.7/2.2/1.8%
$H \to \gamma\gamma$	$<$ 0.1%	$<$ 1%	$<$1%	$<$ 1%	2.4/2.4/2.4%
$H \to Z\gamma$	$\lesssim$ 0.1%	$\sim$ 5%	$\sim$ 5%	$\sim$ 1%	22/13/20%
$H \to b\bar{b}$	$\sim$ 0.2%	$<$ 0.3%	$<$ 0.4%	$\sim$ 0.2%	1.2/1.8/1.3%
$H \to c\bar{c}$	$\sim$ 0.2%	$<$ 0.3%	$<$ 0.4%	$\sim$ 0.2%	2.4/4.0/2.6%
$H \to \tau^+\tau^-$	–	$<$ 0.3%	$<$ 0.3%	$<$ 0.1%	1.3/1.9/1.3%
$H \to \mu^+\mu^-$	–	$<$ 0.3%	$<$ 0.3%	$<$ 0.1%	7.8/7.8/7.8%
$\Gamma_{\rm tot}$				$\sim$ 0.3%	1.1/1.8/1.2%

$\Rightarrow$ non-negligible for $H \to WW/ZZ \to$ 4f

Future parametric uncertainties for decay widths:

decay	fut. intr.	fut. para. m_q	para. α_s	para. M_H	ILC/CEPC/FCC-ee
$H \to WW$	$\lesssim 0.4\%$	–	–	$\sim 0.1\%$	0.6/1.9/0.8%
$H \to ZZ$	$\lesssim 0.3\%$	–	–	$\sim 0.1\%$	0.4/0.4/0.3%
$H \to gg$	$\sim 1\%$		0.5%	–	1.7/2.2/1.8%
$H \to \gamma\gamma$	$< 1\%$	–	–	–	2.4/2.4/2.4%
$H \to Z\gamma$	$\sim 1\%$	–	–	$\sim 0.1\%$	22/13/20%
$H \to b\bar{b}$	$\sim 0.2\%$	$\sim 0.6\%$	$< 0.1\%$	–	1.3/1.8/1.3%
$H \to c\bar{c}$	$\sim 0.2\%$	$\sim 1\%$	$< 0.1\%$	–	2.4/4.0/2.6%
$H \to \tau^+\tau^-$	$< 0.1\%$	–	–	–	1.3/1.0/1.3%
$H \to \mu^+\mu^-$	$< 0.1\%$	–	–	–	7.8/7.8/7.8%
Γ_{tot}	$\sim 0.3\%$	$\sim 0.4\%$	$< 0.1\%$	$< 0.1\%$	1.1/1.8/1.2%

Γ_{tot} applies "to all" (partial cancelations . . .)
$\Rightarrow$ possible impact particular on ZZ, WW

One word of caution:

The above numbers have all been obtained assuming the SM as calculational framework.

The SM constitutes the model in which highest theoretical precision for the predictions of Higgs observables can be obtained.

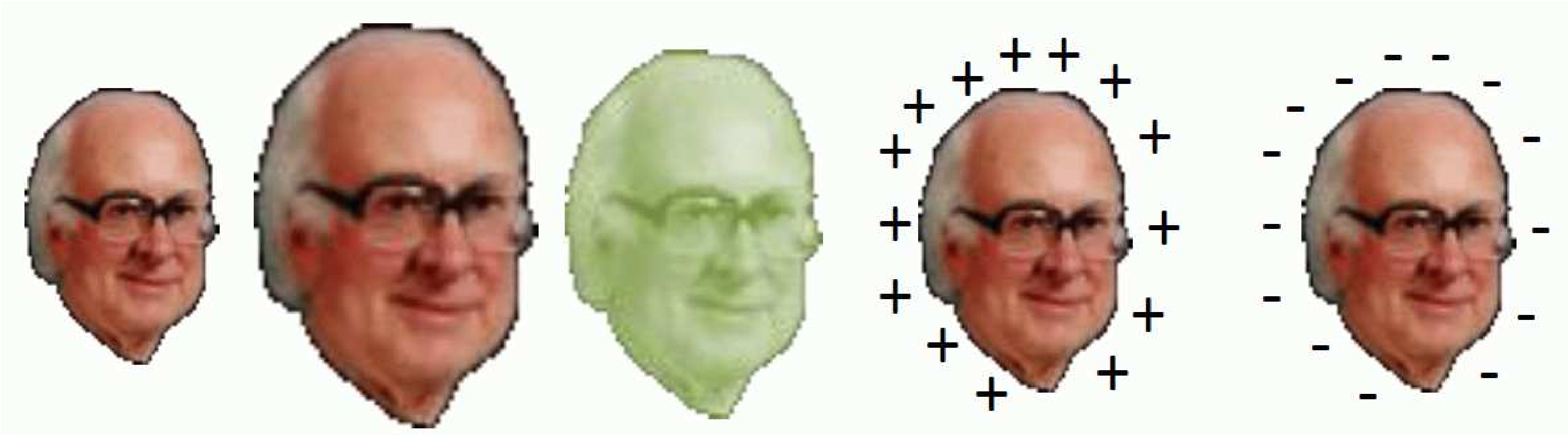
We know that BSM physics must exist! (DM, gravity, . . .)

As soon as BSM physics will be discovered, an evaluation of the Higgs predictions in any preferred BSM model will be necessary.

The corresponding theory uncertainties, both intrinsic and parametric, can then be larger (as known for the MSSM).

A dedicated theory effort (beyond the SM) would be needed in this case.

4. BSM Higgs(es) (the difficult case)



– new opportunities

– new challenges

– often (N)MSSM still best worked out models

⇒ please repeat in your favorite model!

Required precision for Higgs couplings?

MSSM example:

$$\kappa_V \approx 1 - 0.5\% \left(\frac{400\ \text{GeV}}{M_A}\right)^4$$

$$\kappa_t = \kappa_c \approx 1 - \mathcal{O}(10\%) \left(\frac{400\ \text{GeV}}{M_A}\right)^2 \cot^2\beta$$

$$\kappa_b = \kappa_\tau \approx 1 + \mathcal{O}(10\%) \left(\frac{400\ \text{GeV}}{M_A}\right)^2$$

Composite Higgs example:

$$\kappa_V \approx 1 - 3\% \left(\frac{1\ \text{TeV}}{f}\right)^2$$

$$\kappa_F \approx 1 - (3-9)\% \left(\frac{1\ \text{TeV}}{f}\right)^2$$

⇒ couplings to bosons in the per mille range

⇒ couplings to fermions in the per cent range

⇒ theory/experimental match?

New opportunity in BSM physics – new challenge

SUSY and other models predict M_h

$\Rightarrow$ new precision observable

How does the theory uncertainty match the experimental error?

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The Higgs mass accuracy: experimental combination:

Experiment:

ATLAS:	$M_h^{\text{exp}} = 125.36 \pm 0.37 \pm 0.18$ GeV
CMS:	$M_h^{\text{exp}} = 125.03 \pm 0.27 \pm 0.15$ GeV
combined:	$M_h^{\text{exp}} = 125.09 \pm 0.21 \pm 0.11$ GeV

. . . and going down with new data!

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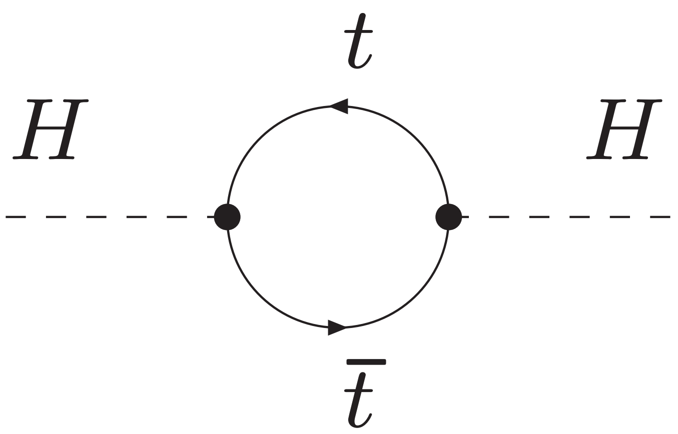
The Higgs mass accuracy: MSSM theory precision:

FeynHiggs:	$\delta M_h^{\text{theo}} \sim 0.5 - 1.5$ GeV

$\rightarrow$ full 1L, sub/leading 2L (but no full 2L!), leading 3L, log resum . . .

This is not a SUSY specific feature! All models in which M_h is predicted!

Nearly any model: large coupling of the Higgs to the top quark:



$\Rightarrow$ one-loop corrections $\Delta M_H^2 \sim G_\mu m_t^4$

$\Rightarrow$ M_H depends sensitively on m_t in all models where M_H can be predicted (SM: M_H is free parameter)

SUSY as an example: $\Delta m_t \approx \pm 1$ GeV $\Rightarrow$ $\Delta M_h \approx \pm 1$ GeV

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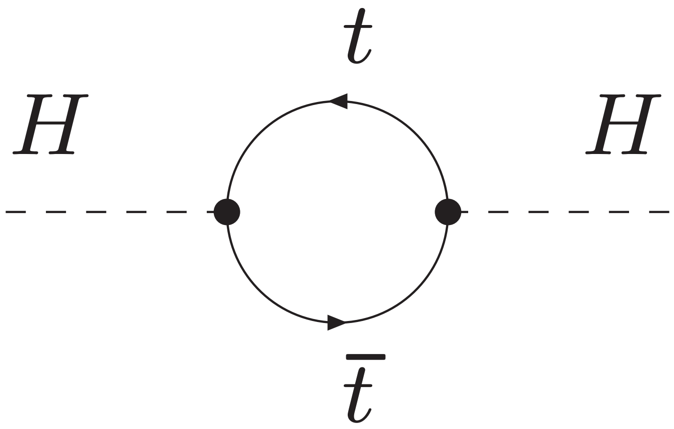

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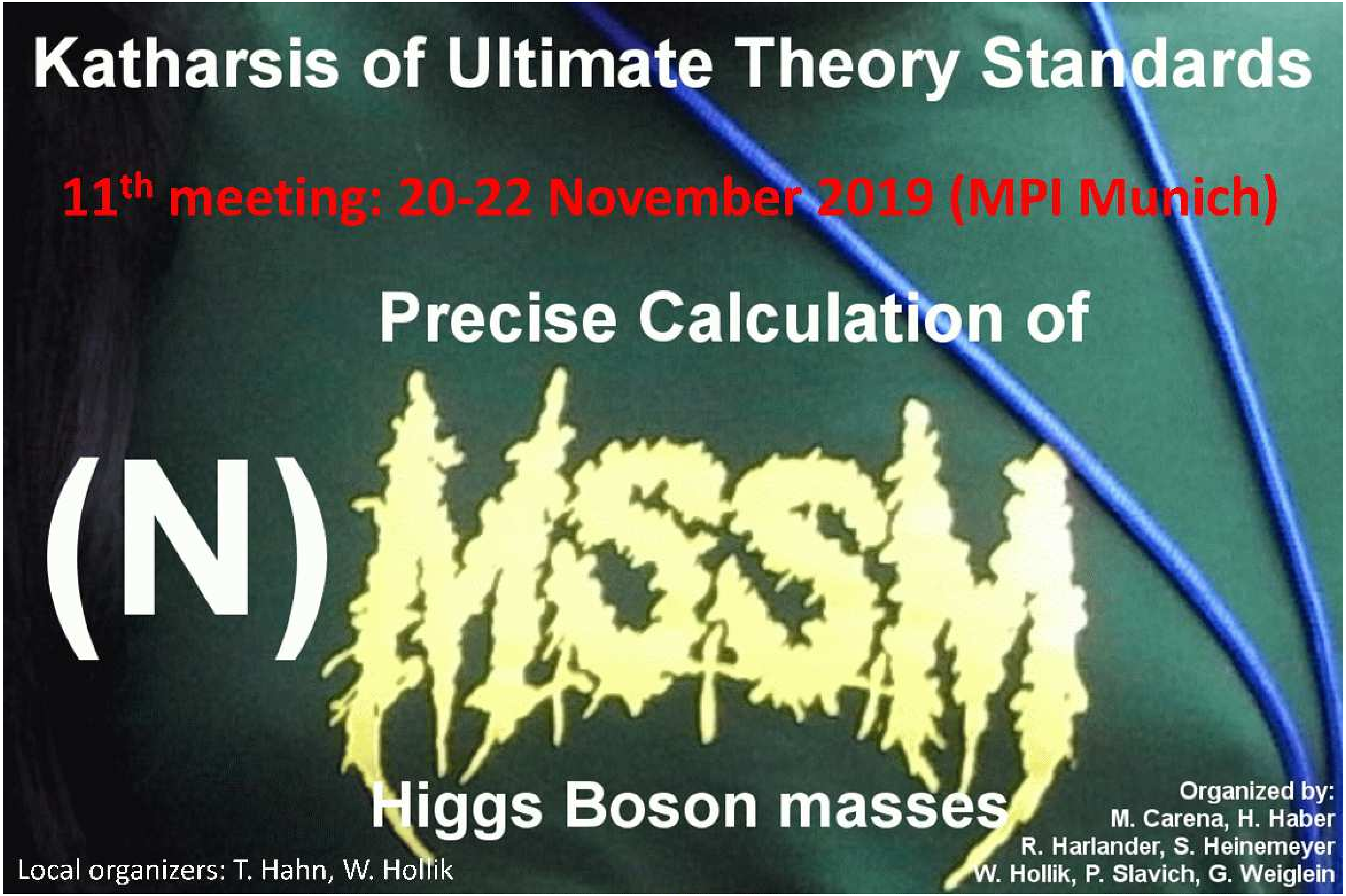
SUSY as an example: $\Delta m_t \approx \pm 1$ GeV $\Rightarrow$ $\Delta M_h \approx \pm 1$ GeV

$\Rightarrow$ Precision Higgs physics needs e^+e^- precision of $\mathcal{O}(50$ MeV$)$ in m_t!

Working group on M_h predictions: sites.google.com/site/kutsmh



⇒ next meeting: 01/2021 at ???

Neutral BSM Higgs production:

$$e^+e^- \to h_iZ,\ h_i\gamma,\ h_ih_j,\ h_i\nu\bar{\nu},\ h_ie^+e^-,\ h_it\bar{t},\ h_ib\bar{b},\ \ldots \qquad (i,j = 1,2,3)\,.$$

Now available in the cMSSM at the full one-loop level:
[S.H., C. Schappacher '15] *[F. Arco, S.H., C. Schappacher '18]*

$$\sigma(e^+e^- \to h_ih_j)$$
$$\sigma(e^+e^- \to h_iZ)$$
$$\sigma(e^+e^- \to h_i\gamma)$$

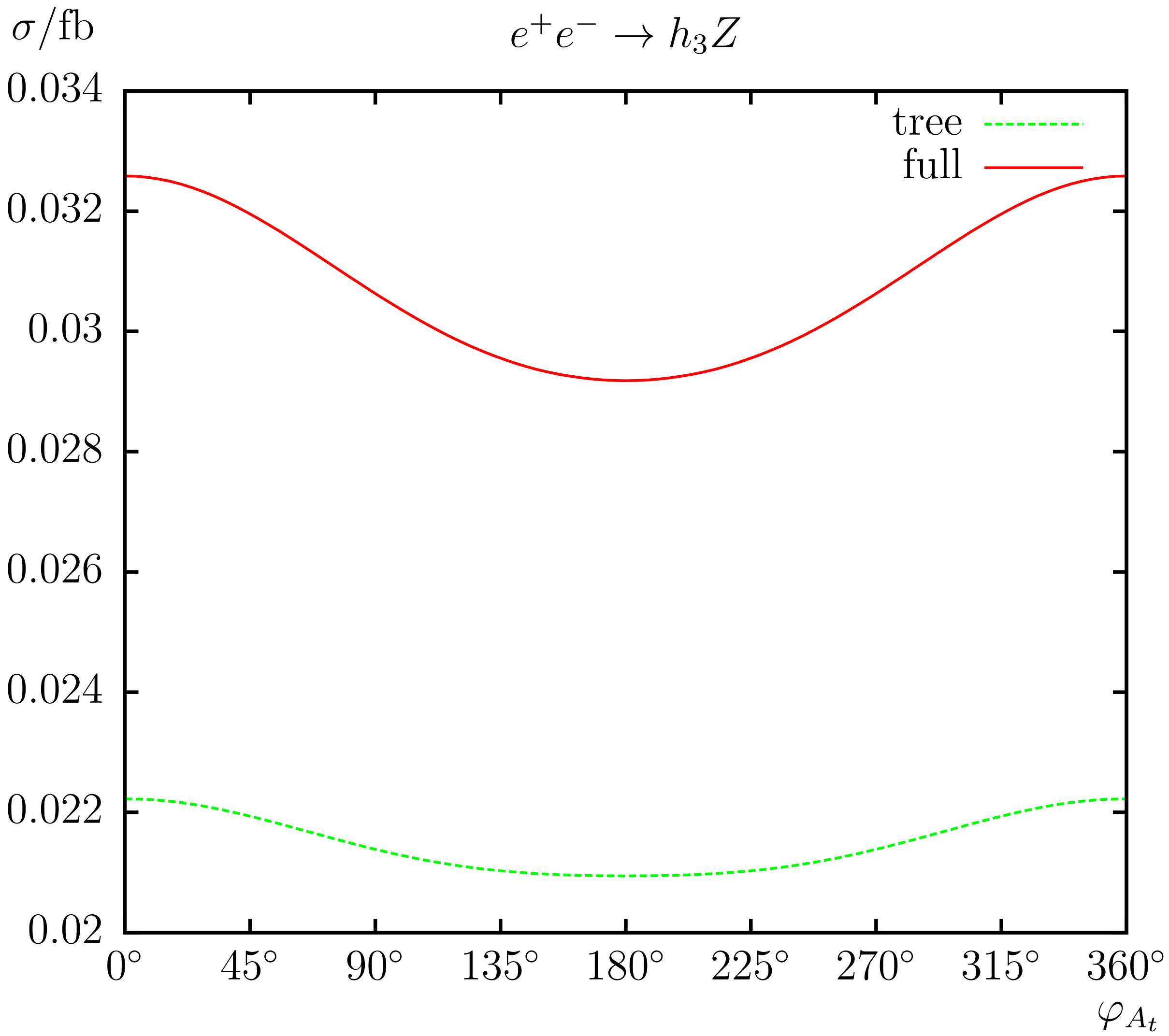
Precision required as in the SM:

– full 1L
– at least leading 2L, at best full 2L (depending on BSM scale)
  note: not even for masses full 2L is available yet
– renormazlization is more involved, more (complex) parameters, . . .

⇒ please repeat in your favorite model!

Example: $e^+e^- \to h_3 Z$:

[S.H., C. Schappacher '16]



$\Rightarrow$ pronounced phase dependence at the loop level

Neutral BSM Higgs decay:

[F. Domingo, S.H., S. Passehr, G. Weiglein '18]

Overall (N)MSSM Higgs decay uncertainty estimates

- $h_i \to q\bar{q}$: SM-like: SM NNLO QCD, EW NNLO, SUSY 2L: $\sim 5\%$
  heavy: as SM-like, Sudakov logs: $\sim 5 - 10\%$
- $h_i \to \ell\bar{\ell}$: SM-like: $\lesssim 1\%$
  heavy: Sudakov logs for very heavy Higgses $\lesssim 10\%$
- $h_i \to WW^{(*)}, ZZ^{(*)}$: SM-like: $\lesssim 1\%$
  heavy: missing 2L (very small width): $\lesssim 50\%$
- $h_i \to \gamma\gamma, gg, \gamma Z$: $\gamma\gamma$: NNLO QCD, EW: $\lesssim 4\%$
  gg: NNLO QCD, EW: $\lesssim 4\%$
  γZ: NLO: $\sim 5\%$
- $h_i \to$ SUSY SUSY: [S.H., C. Schappacher '14-'16]
  1L effects $10 - 20\%$, 2L?
- all decays: $\mathbf{U}_{ij}$, $\mathbf{Z}_{ij}$: few %, effects close to threshold?

⇒ approaching e^+e^- prec. for SM-like Higgs (not for heavy Higgses yet)

⇒ please repeat in your favorite model!

5. Conclusions

- High anticipated experimental precision for Higgs/EWPO at future e^+e^- colliders
- Crucial: theory uncertainties: intrinsic and parametric

$$\text{total} = \sqrt{\text{experimental}^2 + \text{parametric}^2} + \text{intrinsic}$$

- We give (realistic/optimistic) estimates for future intrinsic and parametric uncertainties
- SM Higgs: cross section can be under control with full $2 \to 2$ calc.
  $\Rightarrow$ intrinsic unc. can be relevant for $H \to WW/ZZ \to$ 4f
  $\Rightarrow$ parametric unc. will probably be under control
- Uncertainties should be taken into account by experimental analyses!
- BSM Higgs: deviations in per-cent range $\Rightarrow$ What can we learn?
  $\Rightarrow$ intrinsic unc. larger than in the SM
  $\Rightarrow$ additional theory effor necessary

  $\Rightarrow$ Compare e^+e^- precision with concrete BSM expectations
  $\Rightarrow$ possible distinction between (B)SM models!


Further Questions?

Following slides: with material from Ayres Freitas

Uncertainty budget for m_t:

From $e^+e^- \to t\bar{t}$ at $\sqrt{s} \sim 350$ GeV

today:	**future:**
$\delta m_t^{\overline{\rm MS}} = [\quad]_{\rm exp}$	$[20 \text{ MeV}]_{\rm exp}$
$\oplus\ [50 \text{ MeV}]_{\rm QCD}$	$\oplus\ [30 \text{ MeV}]_{\rm QCD}$ (h.o. resummation)
$\oplus\ [10 \text{ MeV}]_{\text{mass def.}}$	$\oplus\ [10 \text{ MeV}]_{\text{mass def.}}$
$\oplus\ [70 \text{ MeV}]_{\alpha_s}$	$\oplus\ [15 \text{ MeV}]_{\alpha_s}$ ($\delta\alpha_s \lesssim 0.0002$)
> 100 MeV	$\lesssim 50$ MeV

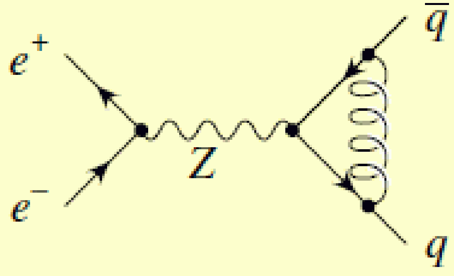
$\Rightarrow$ improvement in α_s crucial

Without improvement: $\delta m_t^{\alpha_s} \sim 10 \text{ MeV} \quad \to \quad 70 \text{ MeV}$

Uncertainty in α_s:

- α_s: d'Enterria, Skands, et al. '15
  - Electroweak precision ($R_\ell = \Gamma_Z^{\text{had}}/\Gamma_Z^\ell$):

    $\alpha_s = 0.120 \pm 0.003$ PDG '18

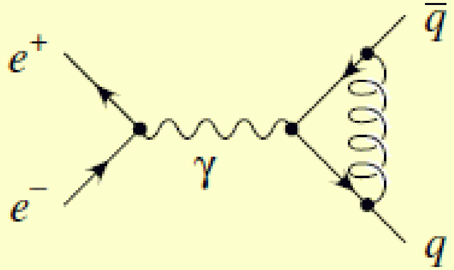
    $\longrightarrow$ No (negligible) non-perturbative QCD effects

    FCC: $\delta R_\ell \sim 0.001$

    $\Rightarrow$ $\delta\alpha_s < 0.0002$ (subj. to theory error)

    Caviat: R_ℓ could be affected by new physics

  - $R = \frac{\sigma[ee \to \text{had.}]}{\sigma[ee \to \mu\mu]}$ at lower $\sqrt{s}$

    e.g. CLEO ($\sqrt{s} \sim 9$ GeV): $\alpha_s = 0.110 \pm 0.015$

    Kühn, Steinhauser, Teubner '07

    $\longrightarrow$ dominated by s-channel photon, less room for new physics

    $\longrightarrow$ QCD still perturbative

    naive scaling to 50 ab^{-1} (BELLE-II): $\delta\alpha_s \sim 0.0001$

Higgs-Strahlung uncertainty:

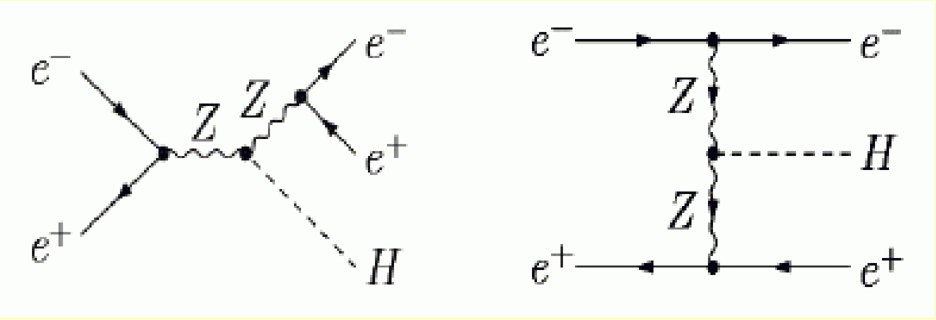
hZ production:

- $\mathcal{O}(\alpha)$ corr. to hZ production and Z decay — Kniehl '92; Denner, Küblbeck, Mertig, Böhm '92; Consoli, Lo Presti, Maiani '83; Jegerlehner '86; Akhundov, Bardin, Riemann '86
- Technology for $\mathcal{O}(\alpha)$ with off-shell Z-boson available — Boudjema et al. '04
- Can be combined with h.o. ISR QED radiation — Greco et al. '17
- $\mathcal{O}(\alpha\alpha_s)$ corrections — Gong et al. '16; Chen, Feng, Jia, Sang '18

Theory error: $\Delta_{th} \sim O(1\%)$

With full 2-loop corrections for $ee \to HZ$:

$\Delta_{th} \lesssim O(0.3\%)$



Parametric error: negligible if $\delta M_H < 100$ MeV

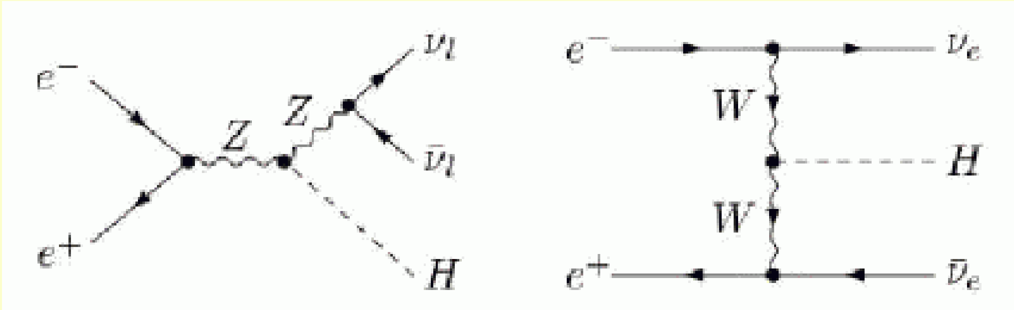
Weak-Boson Fusion:

WW fusion:

- $\mathcal{O}(\alpha)$ corrections with h.o. ISR — Belanger et al. '02; Denner, Dittmaier, Roth, Weber '03

Theory error: $\Delta_{\text{th}} \sim O(1\%)$?

Parametric error: negligible



Full $\mathcal{O}(\alpha^2)$ calculation for 2→3 process is very challenging
→ Contributions with closed fermion loops maybe feasible

Backgrounds:

- Also need $O(\alpha)$ (or better?) corrections for backgrounds: $e^+e^-b\bar{b}$, $\nu\bar{\nu}b\bar{b}$, etc.
  → Technology exists, but work needed — Denner, Dittmaier, Roth, Wieders '05

Higgs decay to fermions:

hbb:

- $\mathcal{O}(\alpha_s^4)$ QCD corrections — Baikov, Chetyrkin, Kühn '05
- $\mathcal{O}(\alpha)$ QED+EW — Dabelstein, Hollik '92; Kniehl '92
- leading $\mathcal{O}(\alpha^2)$ and $\mathcal{O}(\alpha\alpha_s)$ for large m_t — Kwiatkowski, Steinhauser '94; Butenschoen, Fugel, Kniehl '07
  $\longrightarrow$ Use for error estimate

Current theory error: $\Delta_{th} < 0.4\%$

With full 2-loop: $\Delta_{th} \sim 0.2\%$

Parametric error:

$$\left.\begin{array}{l}\delta m_b = 0.030 \text{ GeV} \\ \delta\alpha_s = 0.001\end{array}\right\} \rightarrow \Delta_{par} \approx 0.8\%$$

$$\left.\begin{array}{l}\delta m_b = 0.005 \text{ GeV} \\ \delta\alpha_s = 0.0001\end{array}\right\} \rightarrow \Delta_{par} \approx 0.3\%$$

h$\tau\tau$:

With full 2-loop (no QCD): $\Delta_{th} < 0.1\%$

Parametric error negligible

Higgs decay to massive gauge bosons:

hWW*/hZZ*:

- complete $\mathcal{O}(\alpha) + \mathcal{O}(\alpha_s)$ for $h \to 4f$ — Bredenstein, Denner, Dittmaier, Weber '06
- leading $\mathcal{O}(\alpha^2)$, $\mathcal{O}(\alpha\alpha_s)$ and $\mathcal{O}(\alpha\alpha_s^2)$ for large m_t — Djouadi, Gambino, Kniehl '97; Kniehl, Spira '95; Kniehl, Steinhauser '95

  $\to$ Small (0.2%) effect — Kniehl, Veretin '12

Theory error: $\Delta_{\text{th,EW}} < 0.3\%$, $\Delta_{\text{th,QCD}} < 0.5\%$

With NNLO final-state QCD corrections: $\Delta_{\text{th,QCD}} < 0.1\%$

Parametric error:

$\delta M_H \sim 10$ MeV $\to \Delta_{\text{par}} \approx 0.1\%$

Note: Distributions affected by corrections $\to$ implementation into MC tools

Higgs decay to massless gauge bosons:

hgg:

- $\mathcal{O}(\alpha_s^2)$ and $\mathcal{O}(\alpha_s^3)$ (in large m_t-limit) QCD corrections — Baikov, Chetyrkin '06; Schreck, Steinhauser '07
- $\mathcal{O}(\alpha)$ EW — Aglietti, Bonciani, Degrassi, Vicini '04; Degrassi, Maltoni '04

Theory error (dominated by QCD): $\Delta_{th} \approx 3\%$

With $\mathcal{O}(\alpha_s^4)$ in large m_t-limit (4-loop massless QCD diags.): $\Delta_{th} \approx 1\%$

Parametric error: $\delta\alpha_s = 0.001 \rightarrow \Delta_{par} \approx 3\%$

$\delta\alpha_s = 0.0001 \rightarrow \Delta_{par} \approx 0.3\%$

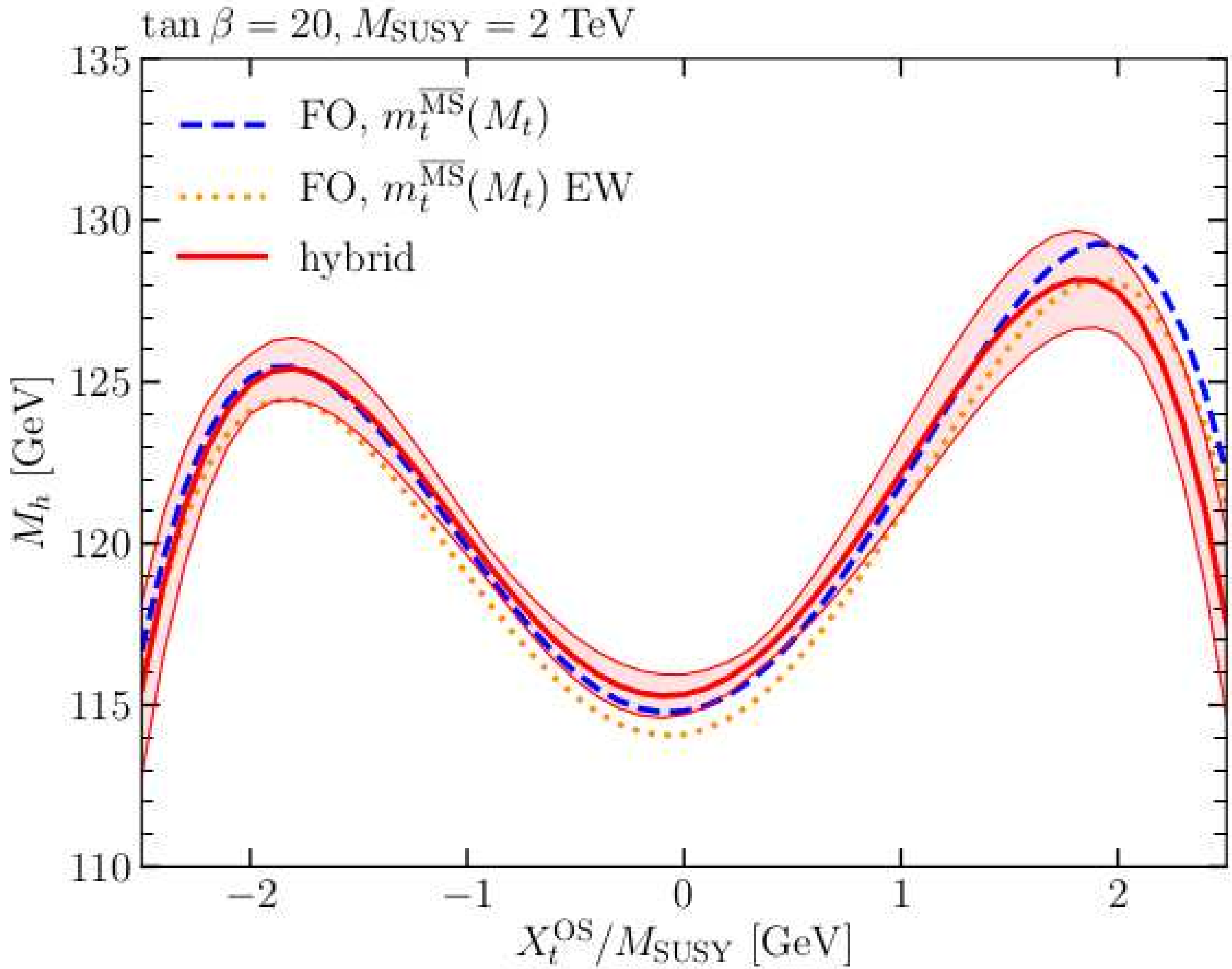
h$\gamma\gamma$:

- $\mathcal{O}(\alpha_s^2)$ QCD corrections — Zheng, Wu '90; Djouadi, Spira, v.d.Bij, Zerwas '91; Dawson, Kauffman '93; Maierhöfer, Marquard '12
- $\mathcal{O}(\alpha)$ EW — Aglietti, Bonciani, Degrassi, Vicini '04; Degrassi, Maltoni '04; Actis, Passarino, Sturm, Uccirati '08

Theory error: $\Delta_{th} < 1\%$

Parametric error negligible

New uncertainty estimate: [FeynHiggs 2.15.0, H. Bahl, S.H., W. Hollik, G. Weiglein '19]



Note: simple single scale scenario!

Let us assume that we do see a deviation

What do we learn from that?
How do we learn something from that?

⇒ We have to compare the observed deviation with predicted deviations

⇒ Preferrably with the predicted deviations in a concrete models
(A comparison with an EFT result subsequently requires the mapping to concrete models anyway . . .)

⇒ Needed: sufficiently precise predictions in BSM model
close to ready: MSSM, NMSSM
(I am not aware of uncertainty estimates in other models)

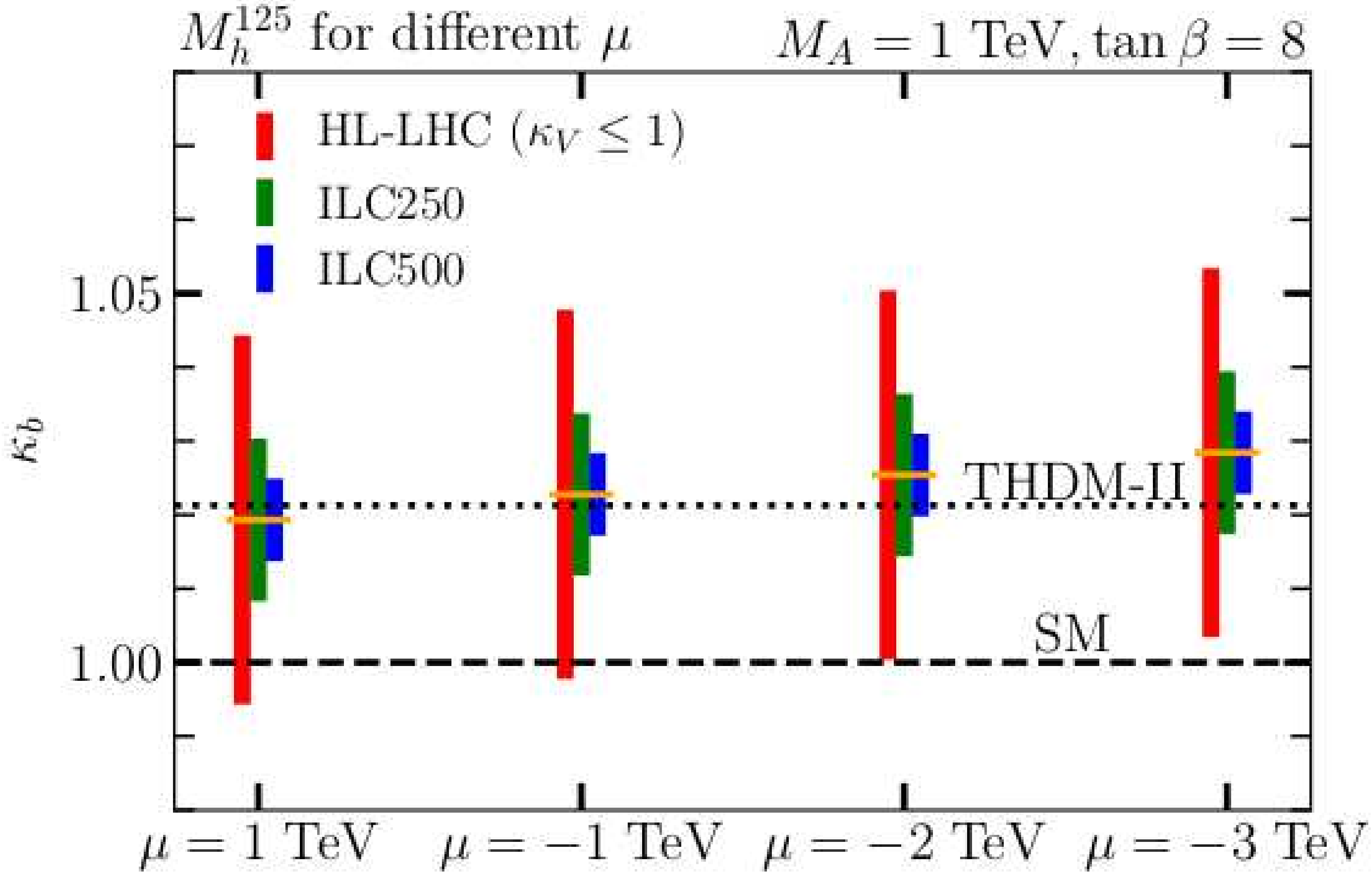
⇒ in the following:

model prediction (w/o TH unc.) ⇔ e^+e^- precision

⇒ “Wäscheleinen-Plots” (concrete: ILC500 – FCC-ee similar!)

MSSM Wäscheleine: e^+e^- vs. M_h^{125} ($M_A = 1000$ GeV, $\tan\beta = 8$)

[*H. Bahl et al – PRELIMINARY*]



⇒ SM vs. BSM: "easy"

⇒ MSSM vs. 2HDM: very challenging!