Towards parameter point dependent theory uncertainties

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. . . not a talk

. . . to initiate discussion!

χ^2 calculation:

$\rightarrow$ global χ^2 likelihood function
combines all theoretical predictions with experimental constraints:

$$\chi^2 = \sum_i^N \frac{(C_i - P_i)^2}{\sigma(C_i)^2 + \sigma(P_i)^2} + \sum_i^M \frac{(f_{\mathrm{SM}_i}^{\mathrm{obs}} - f_{\mathrm{SM}_i}^{\mathrm{fit}})^2}{\sigma(f_{\mathrm{SM}_i})^2}$$

N: number of observables studied

M: SM parameters: $\Delta\alpha_{\mathrm{had}}, m_t, M_Z, \alpha_s, \ldots$

C_i: experimentally measured value (constraint)

P_i: MSSM parameter-dependent prediction for the corresponding constraint

errors: $\sigma(C_i)$, $\sigma(P_i)$, $\sigma(f_{\mathrm{SM}_i})$

$\Rightarrow$ as small as possible to yield reliable predictions!

Three different types of errors:

1. Experimental error:
   $\sigma(f_{\mathrm{SM}_i})$: exp. error on SM input parameters
   $\sigma(C_i)$: exp. error on calculated quantity
   parameter dependent?
   $\longrightarrow$ see below

2. Theory error: $\sigma(P_i)$

   $\Rightarrow$ relevant if not much smaller than experimental error!

   (a) Intrinsic error
   $\Rightarrow$ error/uncertainty due to missing higher-order corrections
   only estimates possible
   parameter dependent!

   (b) Parametric error
   $\Rightarrow$ error/uncertainty due to error of (SM) input parameters
   can be calculated
   parameter dependent!
   $\Rightarrow$ automatically included if parameters are fitted . . .

Intrinsic error:

Error/uncertainty due to missing higher-order corrections

Existing calcultion: up to $\mathcal{O}\left(\alpha^n \alpha_s^m\right)$

Missing: $\mathcal{O}\left(\alpha^N \alpha_s^M\right)$ with $N \geq n$, $M \geq m$

QCD:

⇒ scale variation: $\mu/2 \ldots 2\mu$

sufficient?

larger intervals?

⇒ in principle easy to calculate

⇒ but most of our observables are based on EW calculations

Intrinsic error of EW observables:

Examples:

- the lightest Higgs boson mass M_h
- the W boson mass M_W
- the effective weak leptonic mixing angle $\sin^2\theta_{\rm eff}$
- the anomalous magnetic moment of the muon $(g-2)_\mu$
- B physics observables . . .
- . . .

$\Rightarrow$ every calculation/code should contain an evaluation of the intrinsic uncertainties

$\Rightarrow$ but hardly one does . . .

Example: M_h (based on FeynHiggs)

Calculation includes:

– full one-loop

– leading two-loop: $\mathcal{O}(\alpha_t\alpha_s)$, $\mathcal{O}(\alpha_b\alpha_s)$, $\mathcal{O}\left(\alpha_t^2, \alpha_b^2, \alpha_t\alpha_b\right)$

– some very leading three-loop: $\mathcal{O}\left(\alpha_s^2\alpha_t\right)$

Estimate of missing higher-order corrections:

– missing two-loop: scale variation of $\overline{\text{DR}}$ one-loop result

– missing three-loop corrections from $t/\tilde{t}$ sector:
variation of m_t at the two-loop level

– missing three-loop corrections from $b/\tilde{b}$ sector:
variation of Δ_b inclusion (resummed vs. iteratively resummed)

⇒ FeynHiggs output contains intrinsic error for
Higgs masses and mixings

⇒ strong variation from "usual 3 GeV" possible!

Example: M_W

[*J. Haestier, S.H., D. Stöckinger, G. Weiglein '05*]

[*S.H., W. Hollik, D. Stöckinger, A.M. Weber, G. Weiglein '06*]

Estimate missing SUSY corrections order by order:

- $\mathcal{O}\left(\alpha_t^2, \alpha_t\alpha_b, \alpha_b^2\right)$: beyond existing leading contributions
- $\mathcal{O}(\alpha\alpha_s)$: beyond $\Delta\rho$ approx.
- $\mathcal{O}\left(\alpha\alpha_s^2\right)$
- $\mathcal{O}\left(\alpha^2\alpha_s\right)$
- $\mathcal{O}\left(\alpha^3\right)$
- missing phase dependence at two-loop

⇒ evaluate for $M_{\text{SUSY}} = 300, 500, 1000$ GeV

Combine with SM uncertainty: $\delta M_W^{\text{SM,intr.}} = 4$ MeV

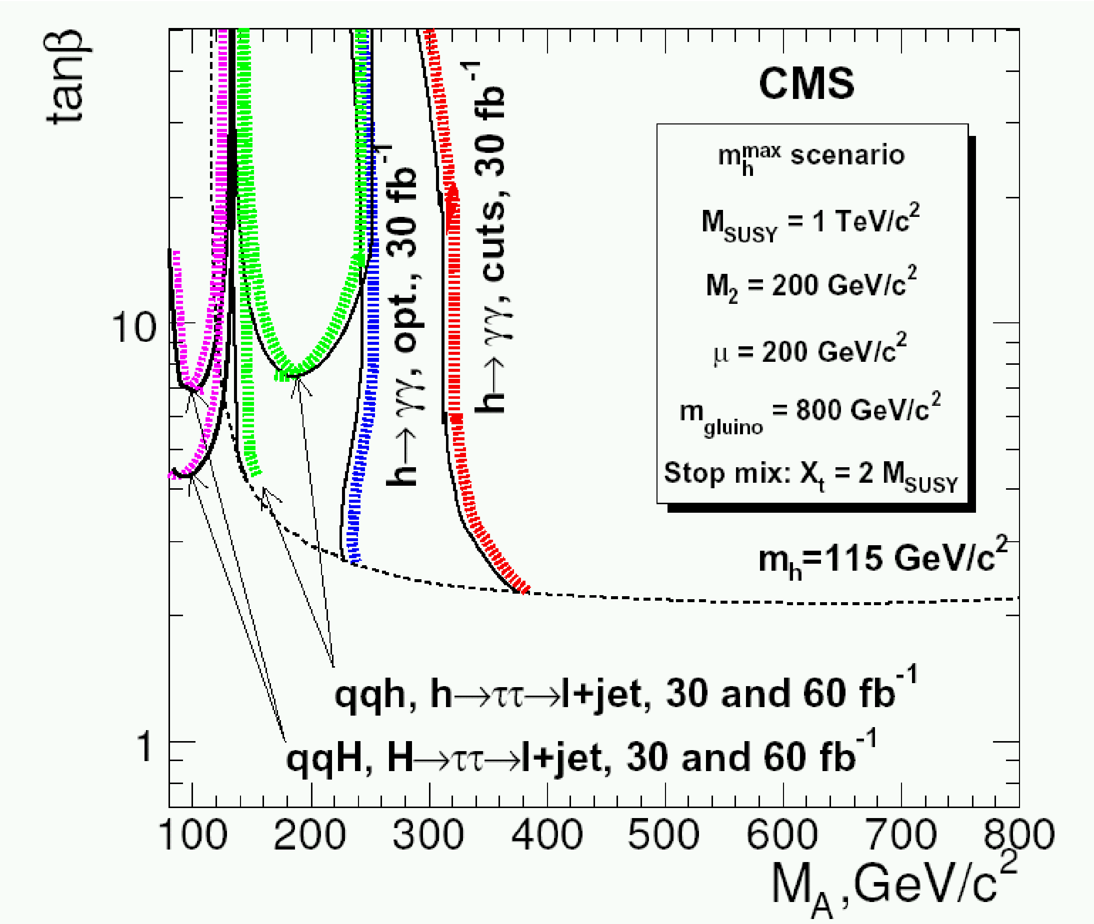
$$\delta M_W^{\text{SUSY,intr.}} = 5 - 11 \text{ MeV} \quad (\text{depending on } M_{\text{SUSY}})$$

⇒ not relevant now, but with future improved exp. precision!

Parameter dependent experimental error?

M_h measurement in the "nice" m_h^{max} scenario:

[*CMS '06*]



Measurement possible only for

$M_A \gtrsim 250$ GeV

$\Rightarrow \delta M_h \approx 200$ MeV

other channels:

$h \to ZZ^* \to 4\mu$ ($M_h \gtrsim 130$ GeV)

otherwise: $\delta M_h \gtrsim 1 - 2$ GeV