Supersymmetric Corrections to the Top Quark Threshold Production

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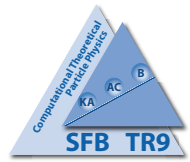
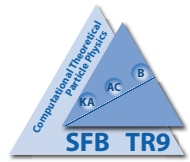
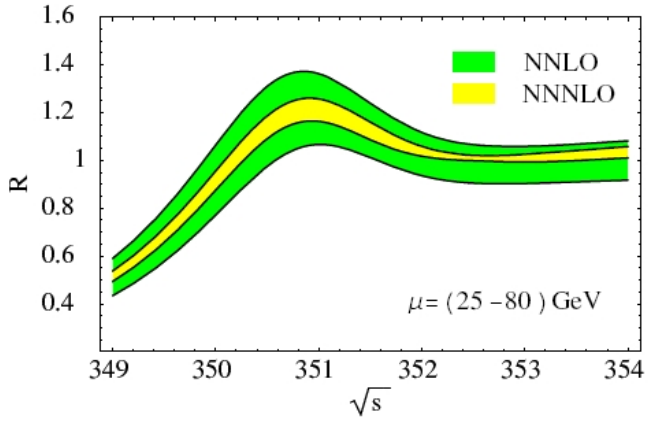
SFB/TR9 Meeting March 24th 2009



Overview



Motivation



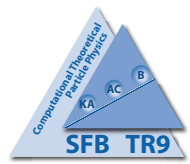
[Beneke,Schuller,Kiyo 08]

- A precise theoretical prediction of $\sigma_{tot}^{t\bar{t}}$ at threshold:
  $\longrightarrow$ accurate measurement α_s, m_t, Γ_t at ILC.
  Future predictions with 3% uncertainty:
  $\longrightarrow \Delta m_t < 100 MeV$!
  Todays predictions (based on SM): [Hoang 06,Pineda,Signer 07]
  $\approx$ 10% uncertainty
  $\longrightarrow$ More work is needed!
- What happens with the total cross section when we use the MSSM as underlying theory?
- How big can the contributions from SUSY particles become?

Cross Section via Optical Theorem

$$\sigma_{tot}(e^+e^- \to t\bar{t}) \propto \frac{1}{s} Im[C^2 G(E + i\Gamma_t)].$$

1. G
   - 2-point Greens function of the Top Quark pair in S_1^3-state.
   - Top quarks are very slow after creation.
     $\to$ Calculated in EFT **N**on **R**elativistic **QCD**.
   - Contains only the soft and ultra soft QCD modes $\sim m_t v, \sim m_t v^2$.
     $v = \sqrt{1 - 4m_t^2/s}$



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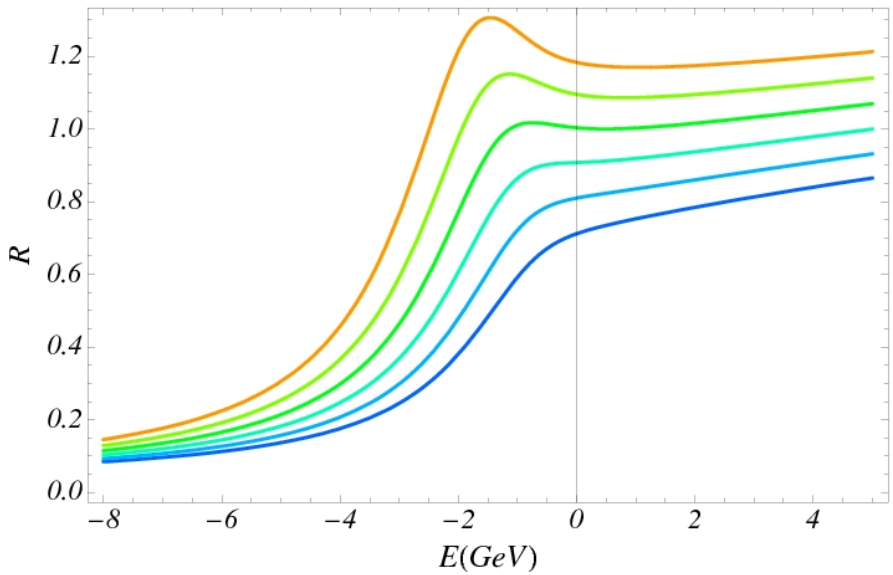

$\alpha_s = 0.10 \leftrightarrow \alpha_s = 0.15$

$$R = \frac{\sigma_{tot}(e^+e^- \to t\bar{t})}{\sigma_{tot}(e^+e^- \to \mu^+\mu^-)}, \; E = \sqrt{s} - 2m_t.$$

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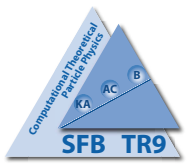
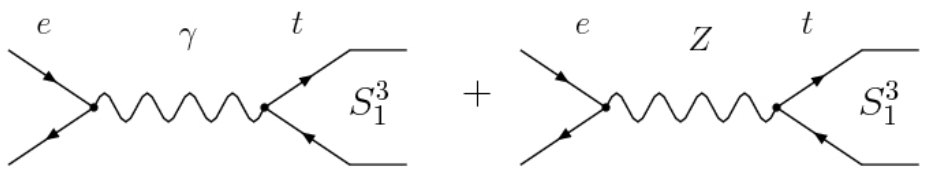
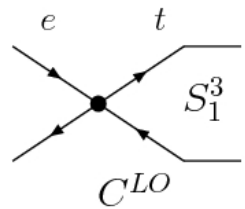
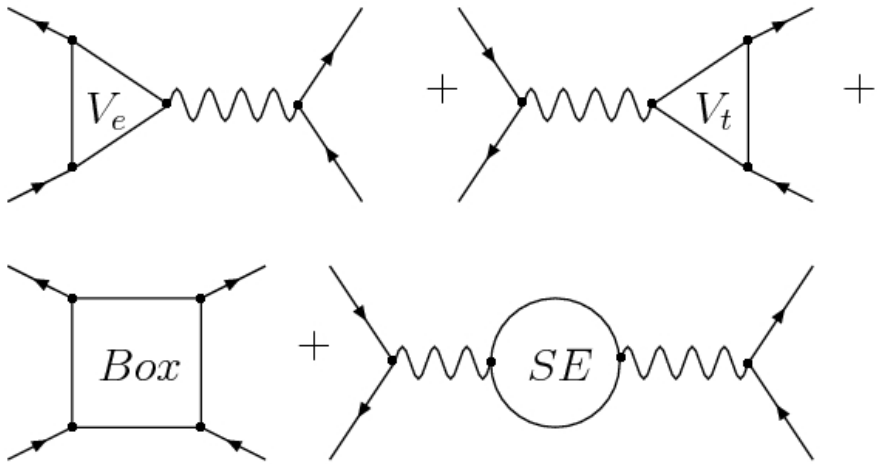
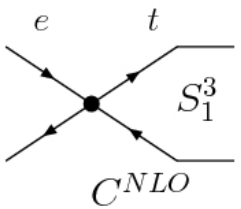
2. C
   - Matching Coefficient of the creation and annihilation operator for S_1^3 Top Quark pairs in NRQCD.
   - Matches the EFT **NRQCD** to the full theory (SM or MSSM).
   - Contains all hard modes $\sim m_t$.
     $\to$ SUSY enters here.

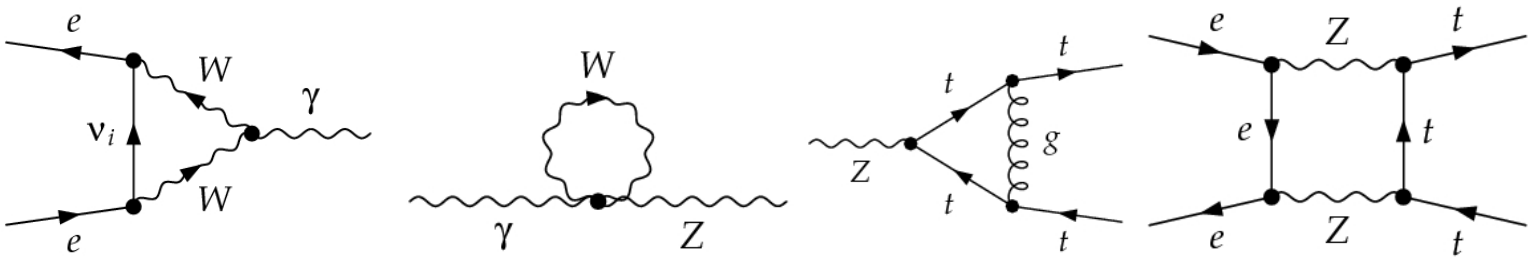


Extracting the Matching Coefficient in Full Theory

Order	Full Theory	NRQCD
LO		
NLO		

- $C_{SM}^{LO} = C_{MSSM}^{LO}$.
- C can be understood as effective charge.

SM

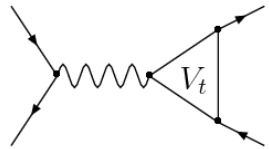


- The EW Contributions to C^{NLO} are known. [Guth,Kühn 92],[Hoang,Reißer 06] We reproduced the results (in t´Hooft Feynman Gauge). ✓
- Divergences are regularized with **D**imensional **REG**ularization (**DREG**) in On-Shell-Scheme.
- The pure QCD contribution is well know and simple for C^{NLO}:

$$C_{\text{QCD}}^{\text{NLO}} = -\frac{8}{3}\frac{\alpha_s}{\pi} \times C^{LO}$$

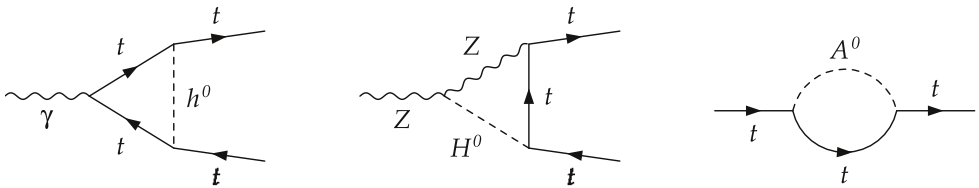
- $C_{\text{QCD}}^{\text{NNNLO}}$ calculation will be discussed today, too $\longrightarrow$ [P. Marquard].

Known Parts of MSSM

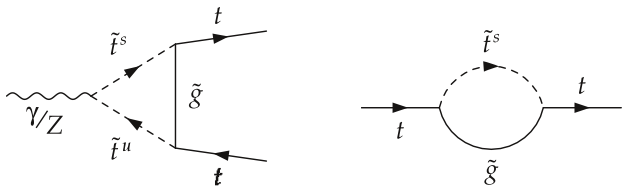


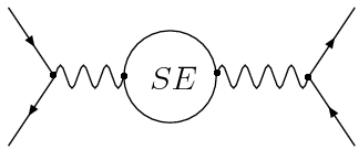
1-Loop contribution to $\gamma t\bar{t}$- and $Zt\bar{t}$-vertex:

- Higgs sector of MSSM $\leftrightarrow$ THDM Type II.
  $\rightarrow$ calculated in **DREG** ($m_b = 0$, CKM $= \mathbb{1}$)[Denner,Guth,Kühn 92]. ✓



- SUSY QCD Contributions are known [Su,Wise 01]. ✓



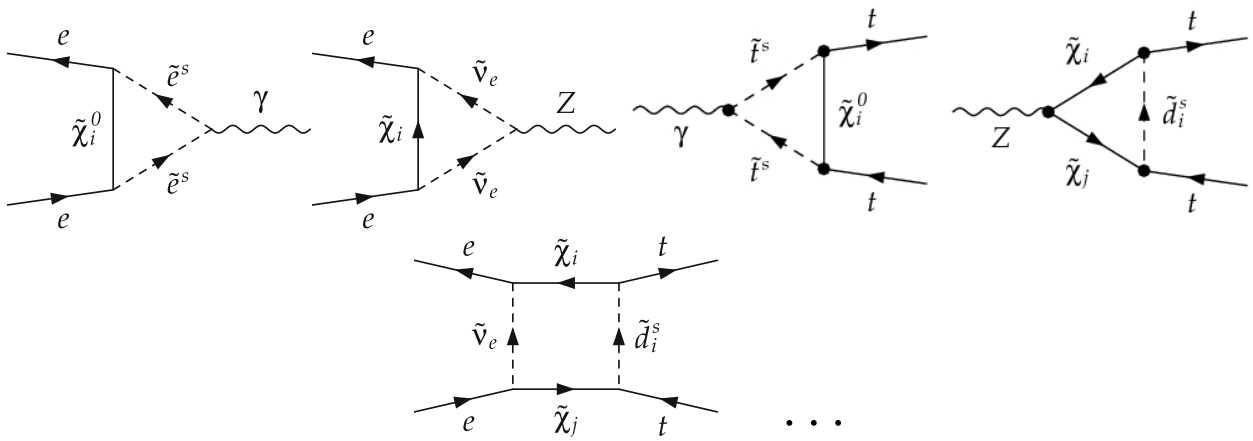


1-Loop Vector Boson SE Corrections:

- Calculated for $\sigma_{\text{tot}}^{\text{NLO}}$ above threshold in **DREG** [Hollik, Schappacher 98]. ✓

New parts of MSSM

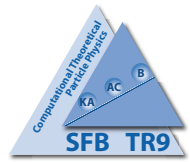
- MSSM: Super symmetric theory.
  $\longrightarrow$ use **D**imensional **RED**uction for regularization!
- Contribution of EW SUSY-particles in $e^- e^+ / t\bar{t}$-vertex and box diagrams:



- Numerical analysis using mSUGRA scenarios.

Technical Details

[Hahn 01] **FeynArts**



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[Hahn 01] **FeynArts** → **Feynman Diagrams**

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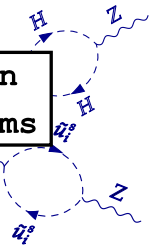

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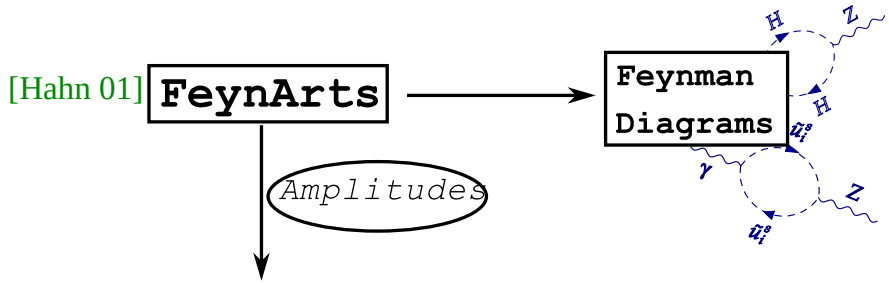

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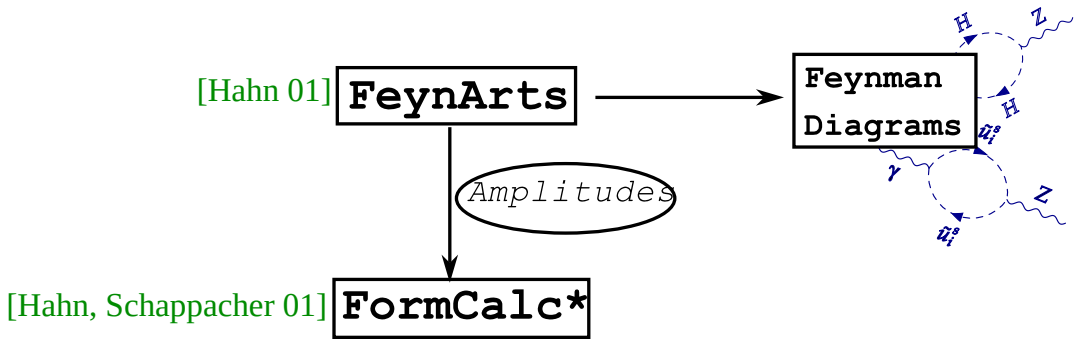

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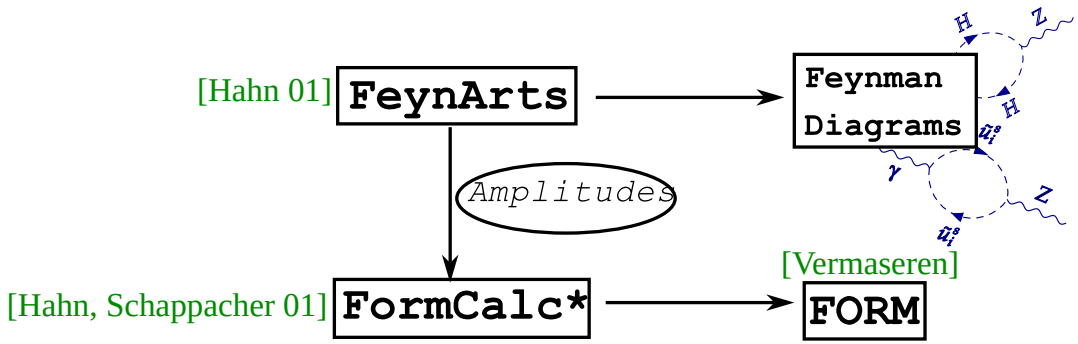

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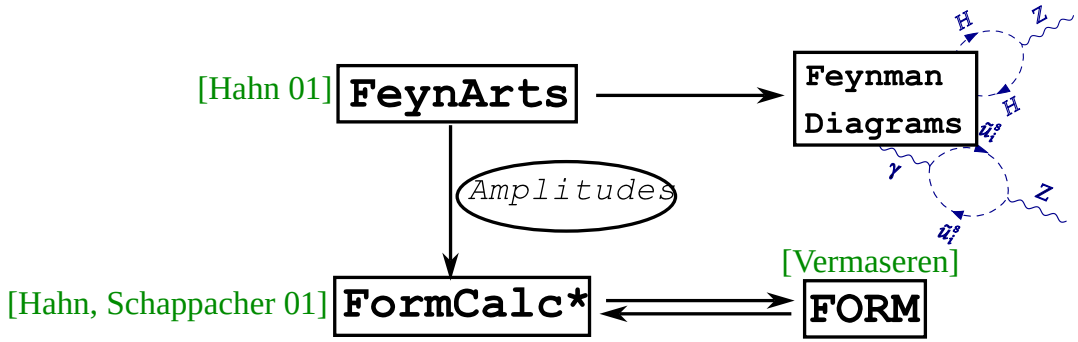

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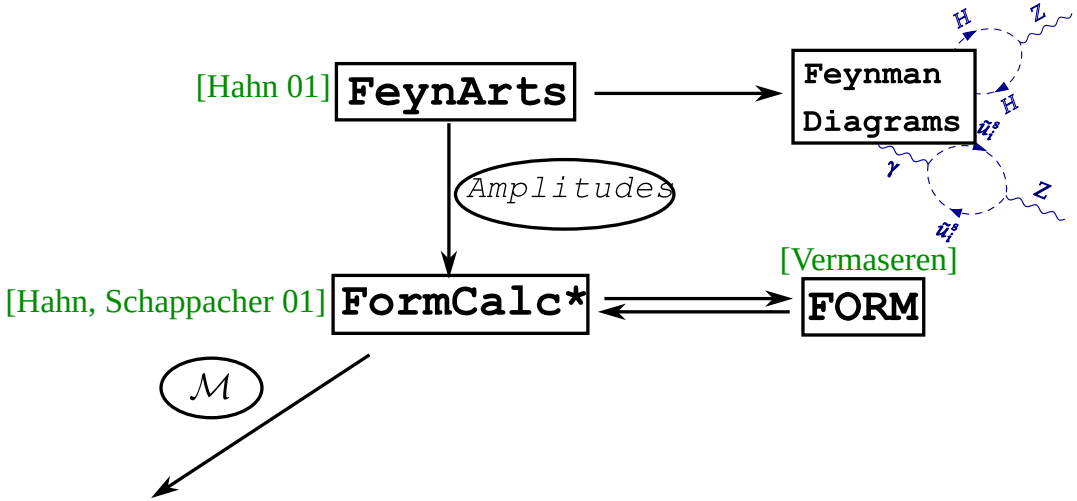

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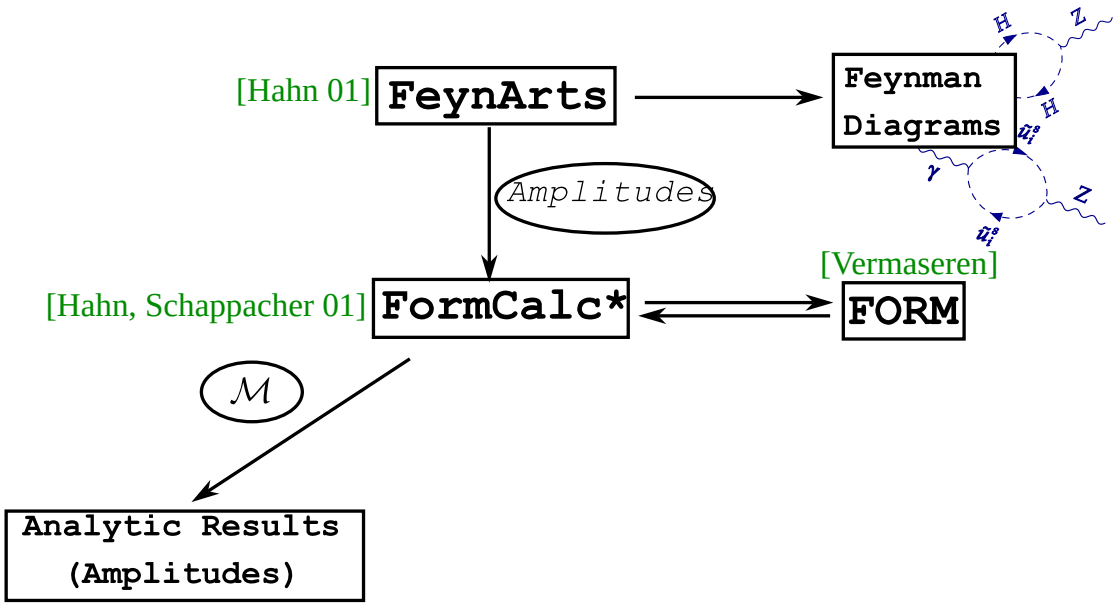

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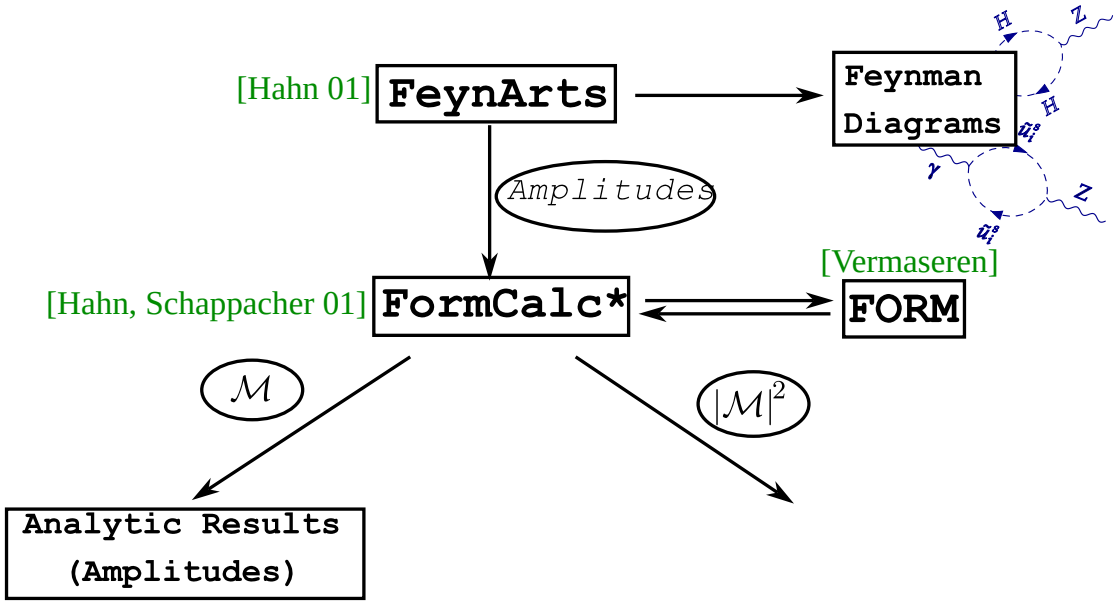

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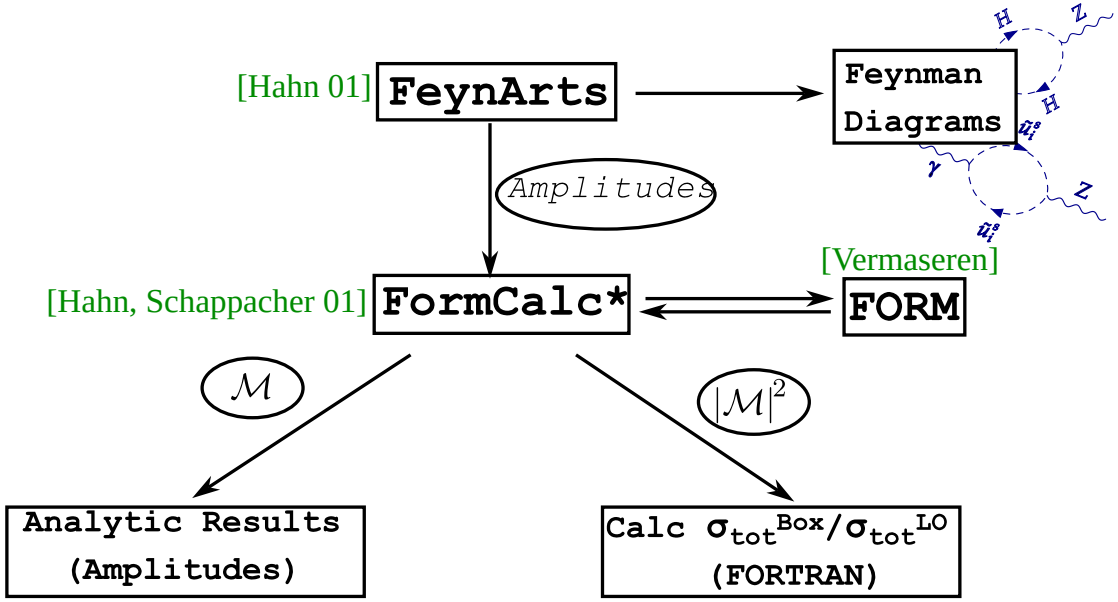

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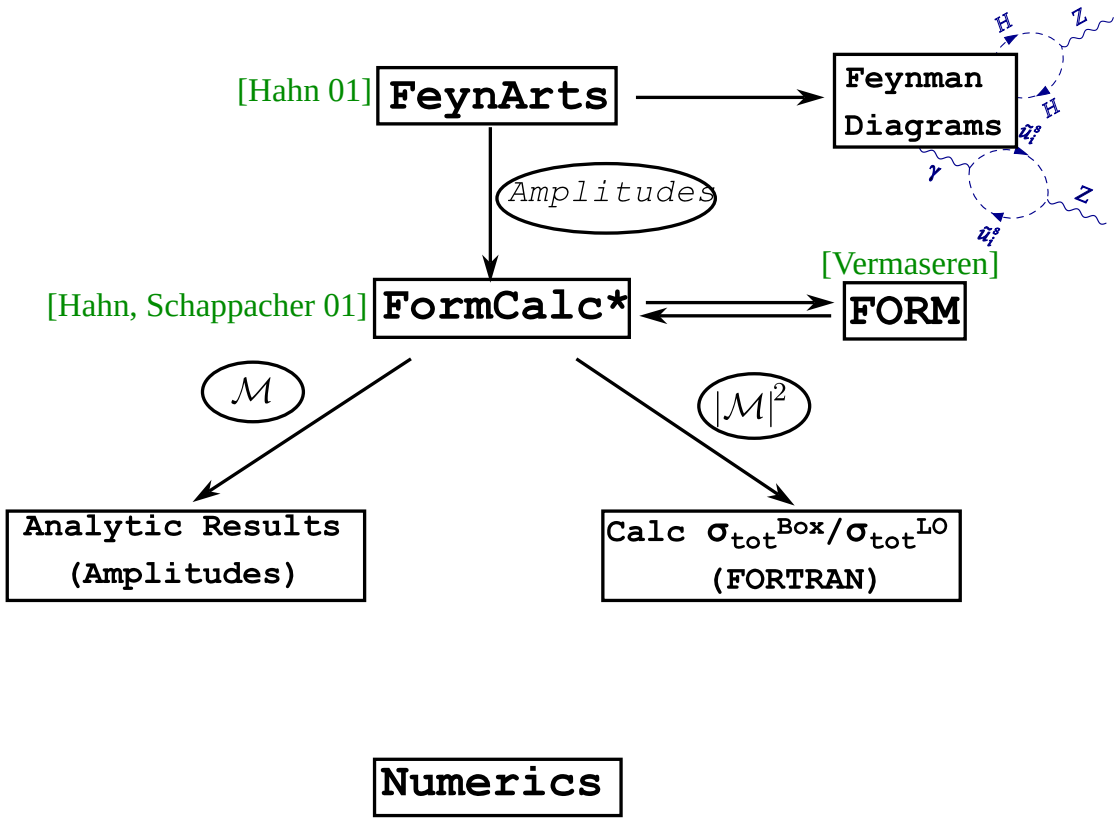

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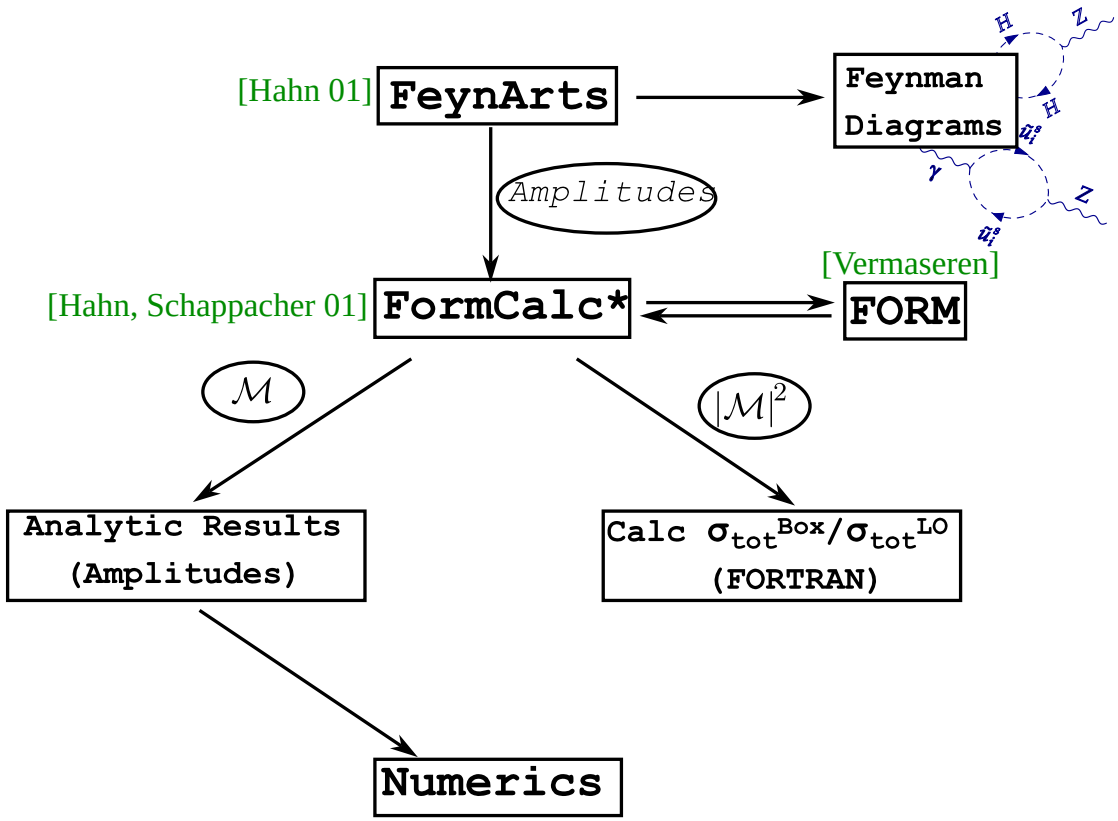

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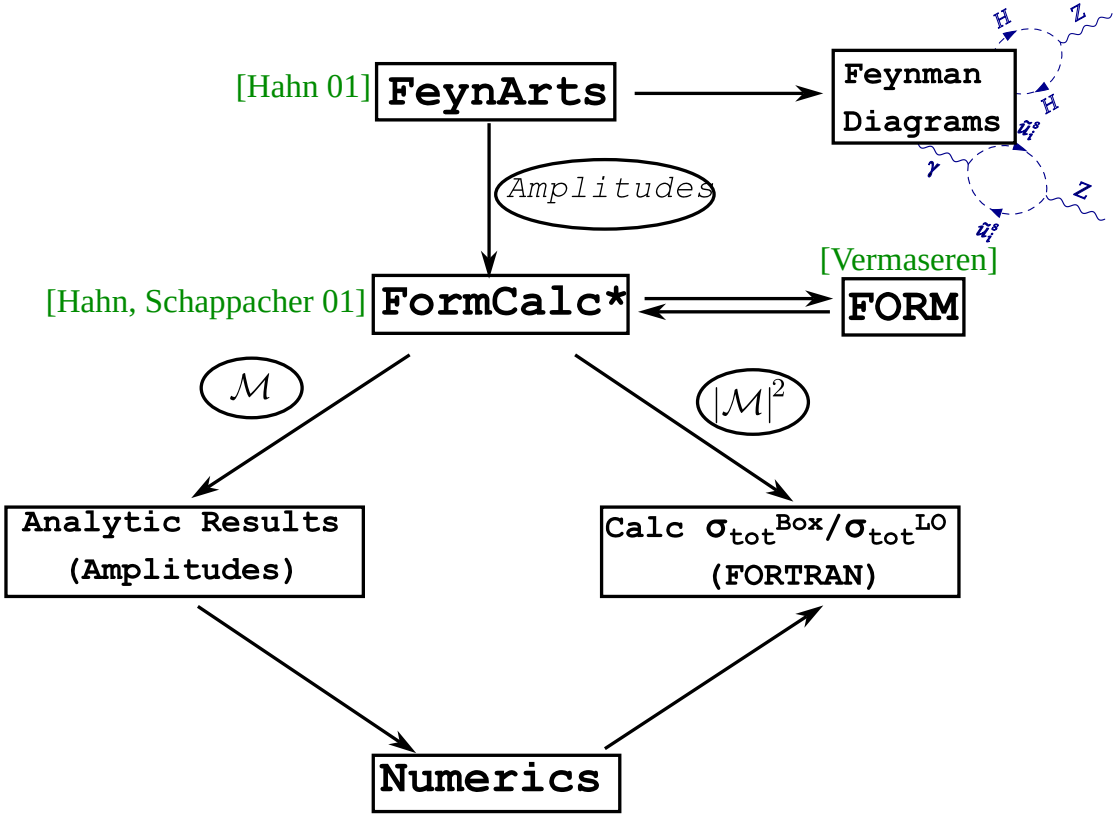

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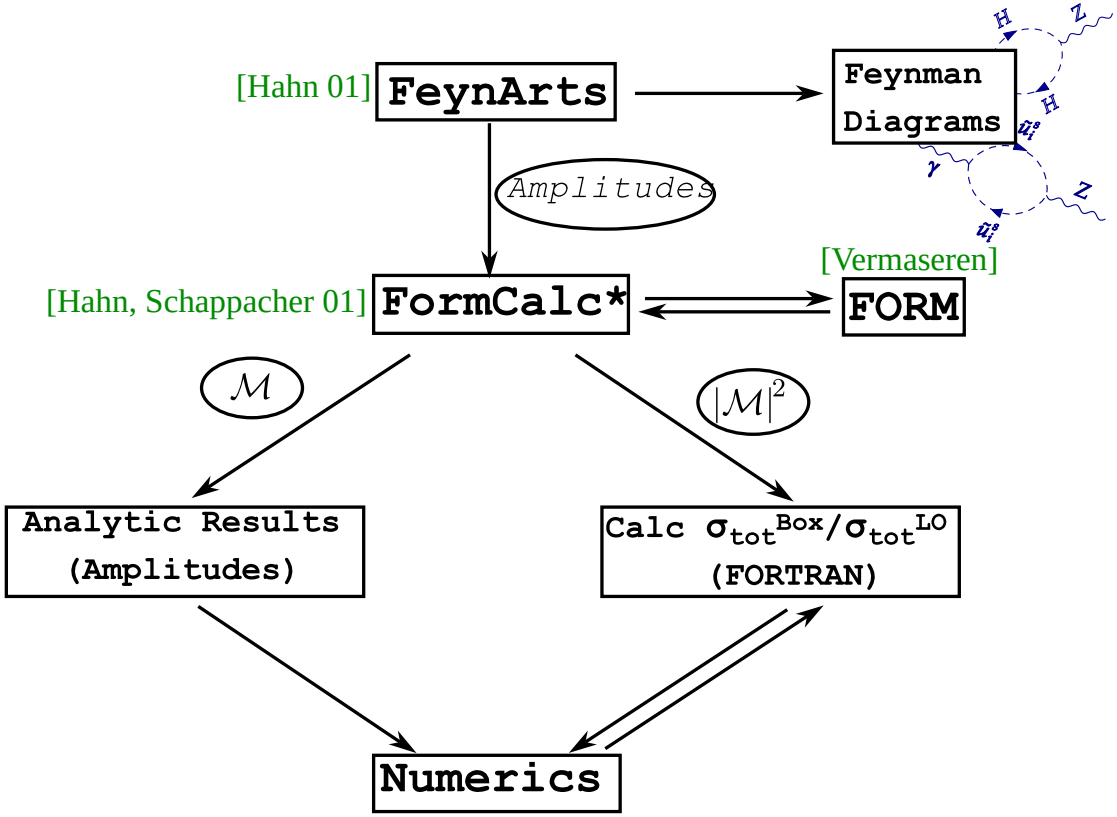

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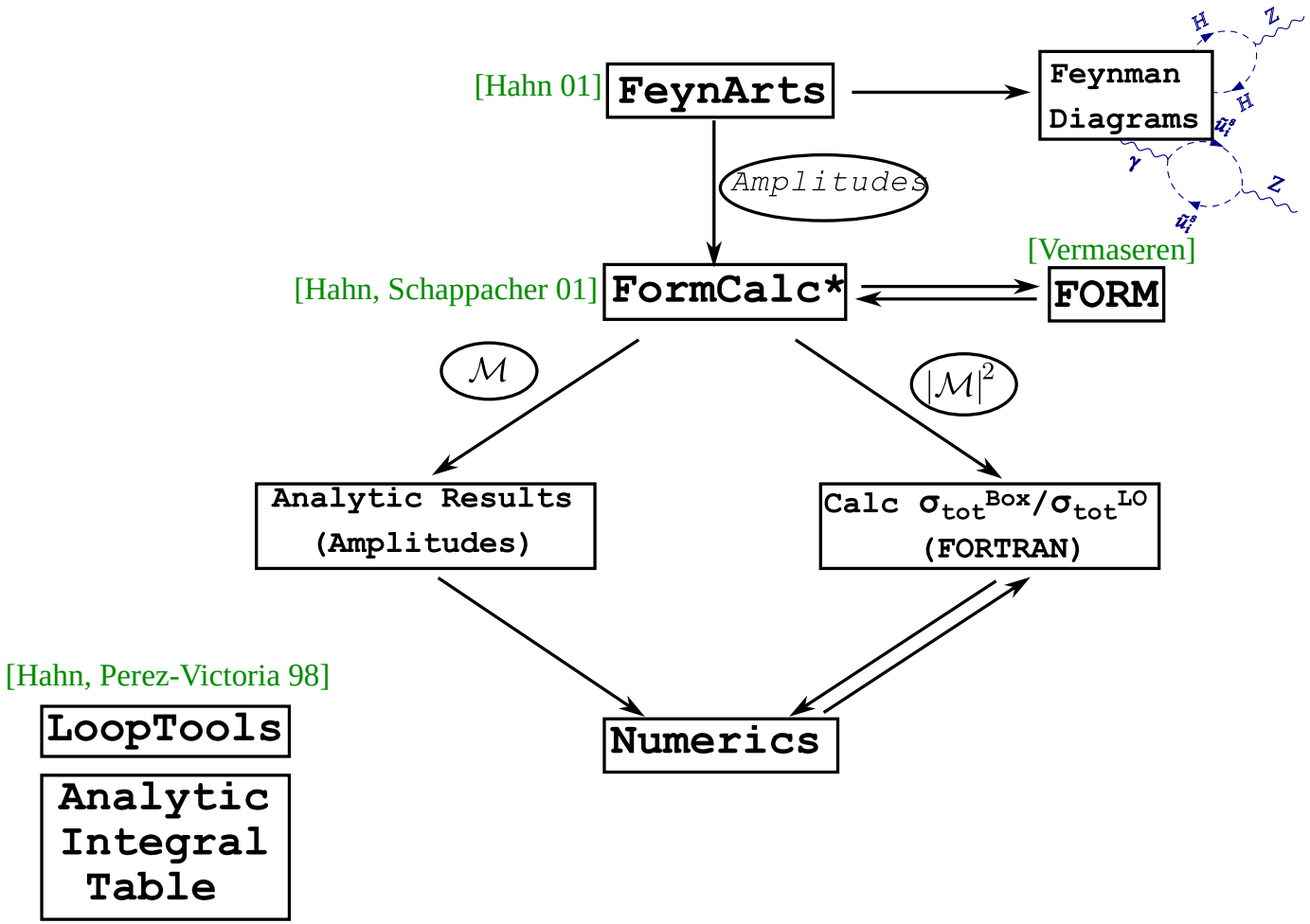

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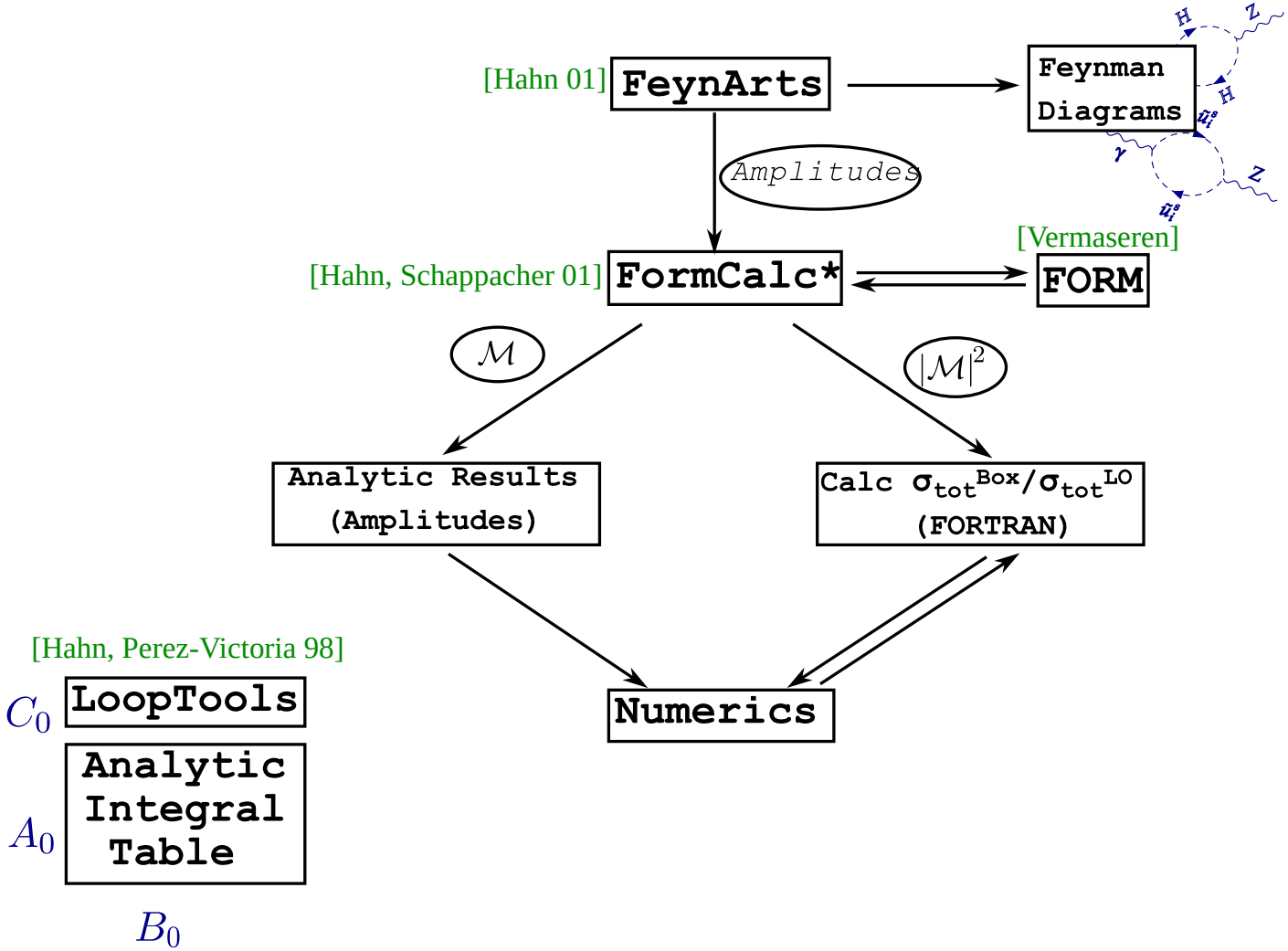

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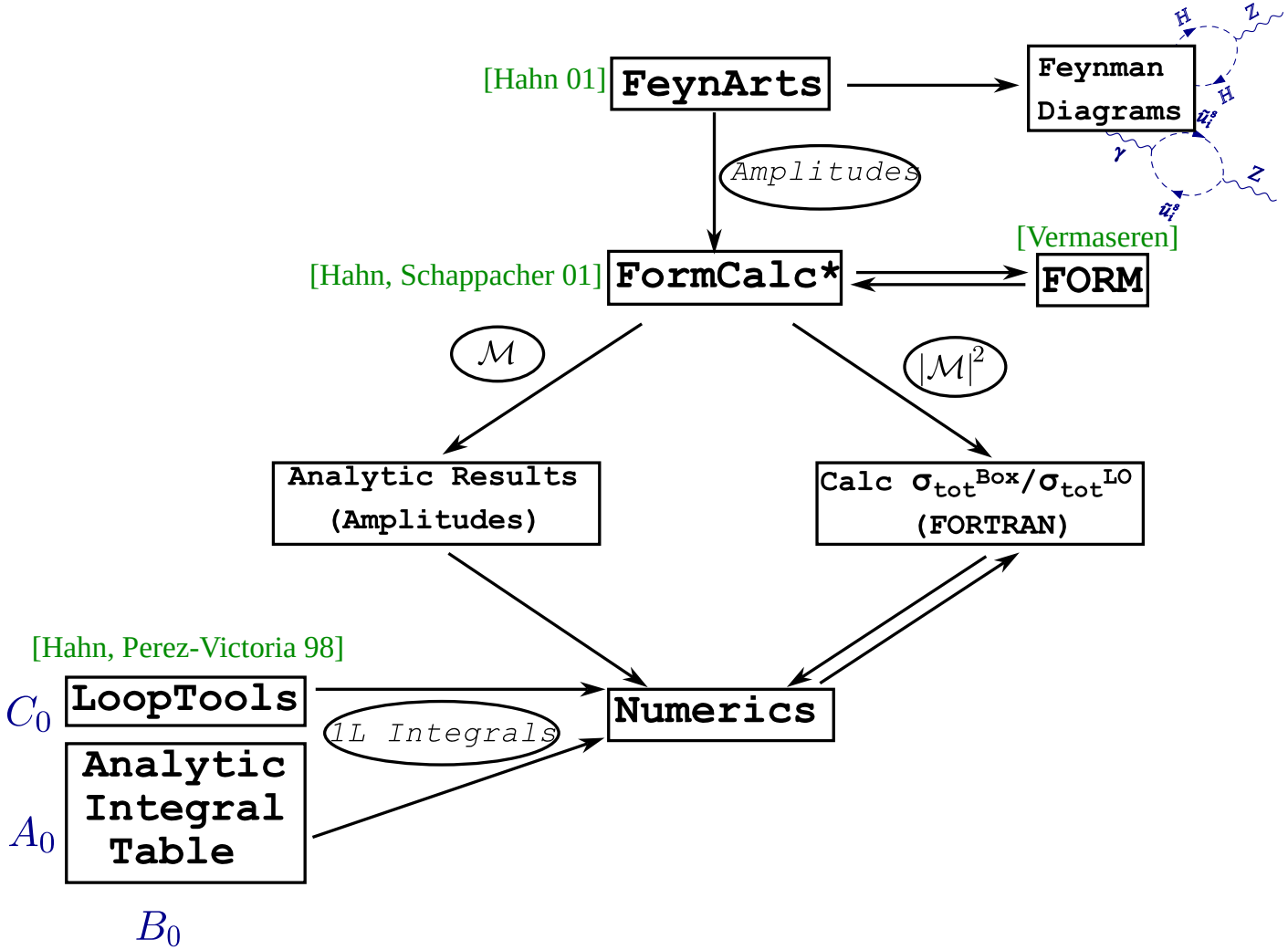

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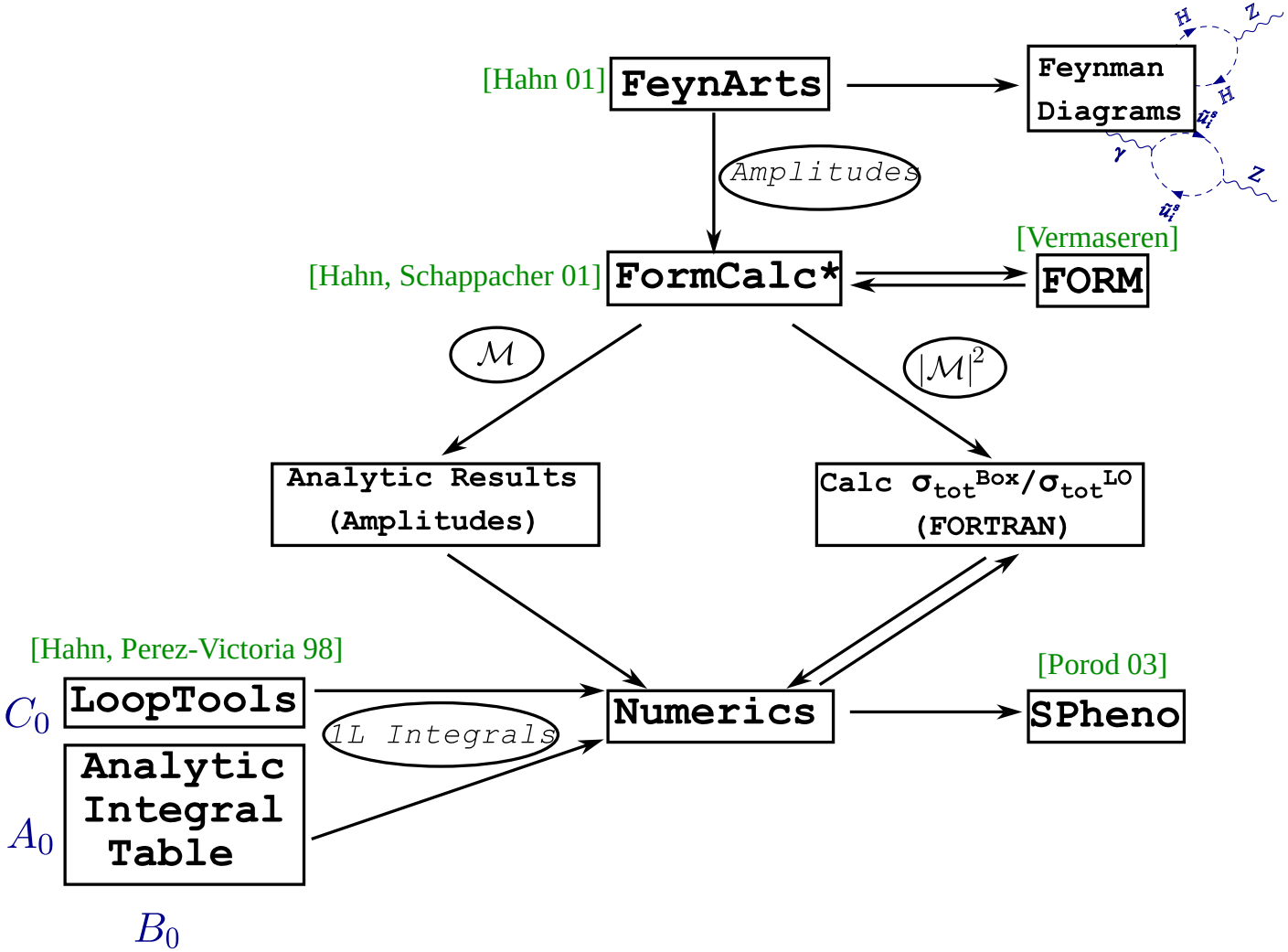

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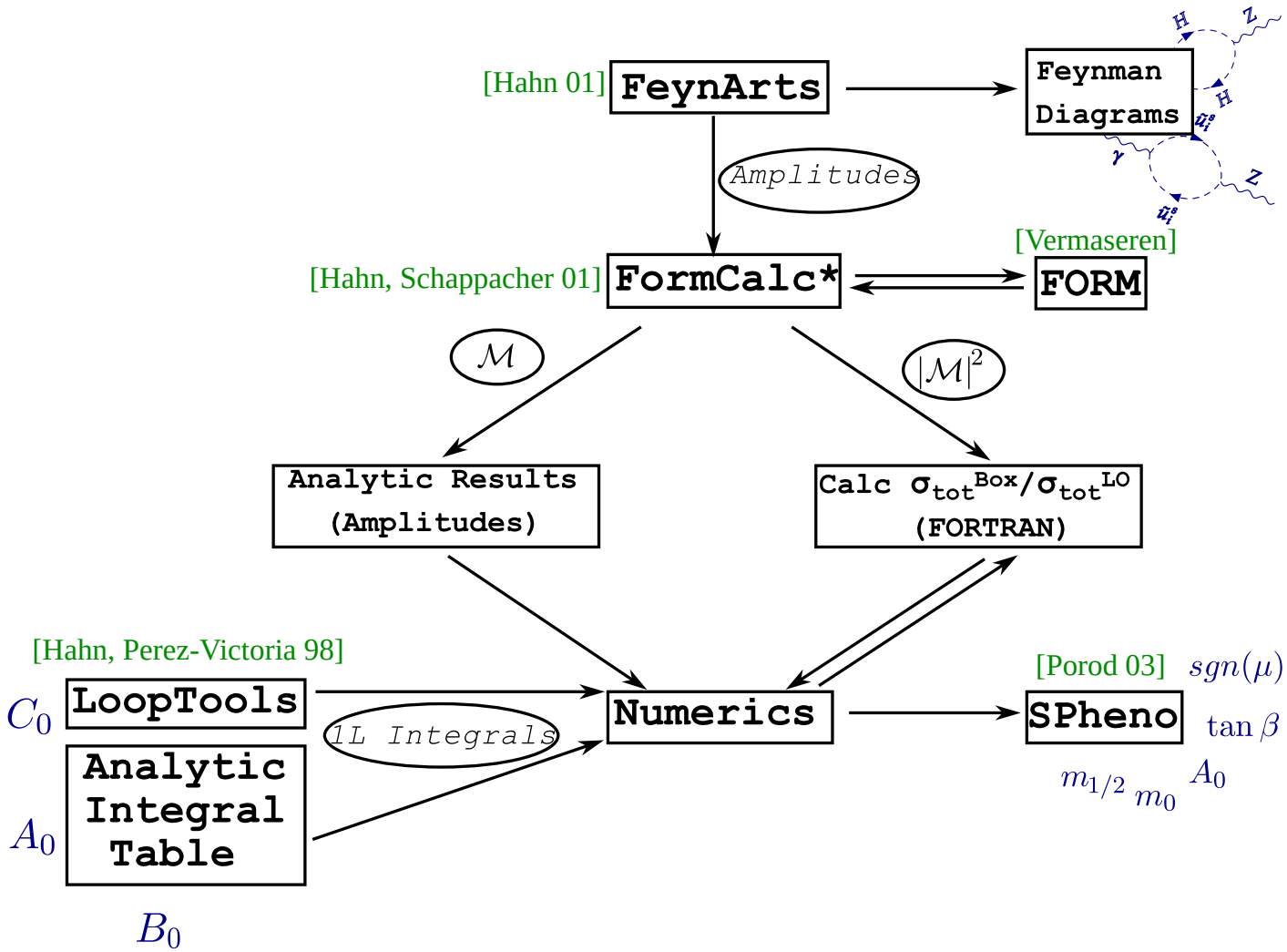

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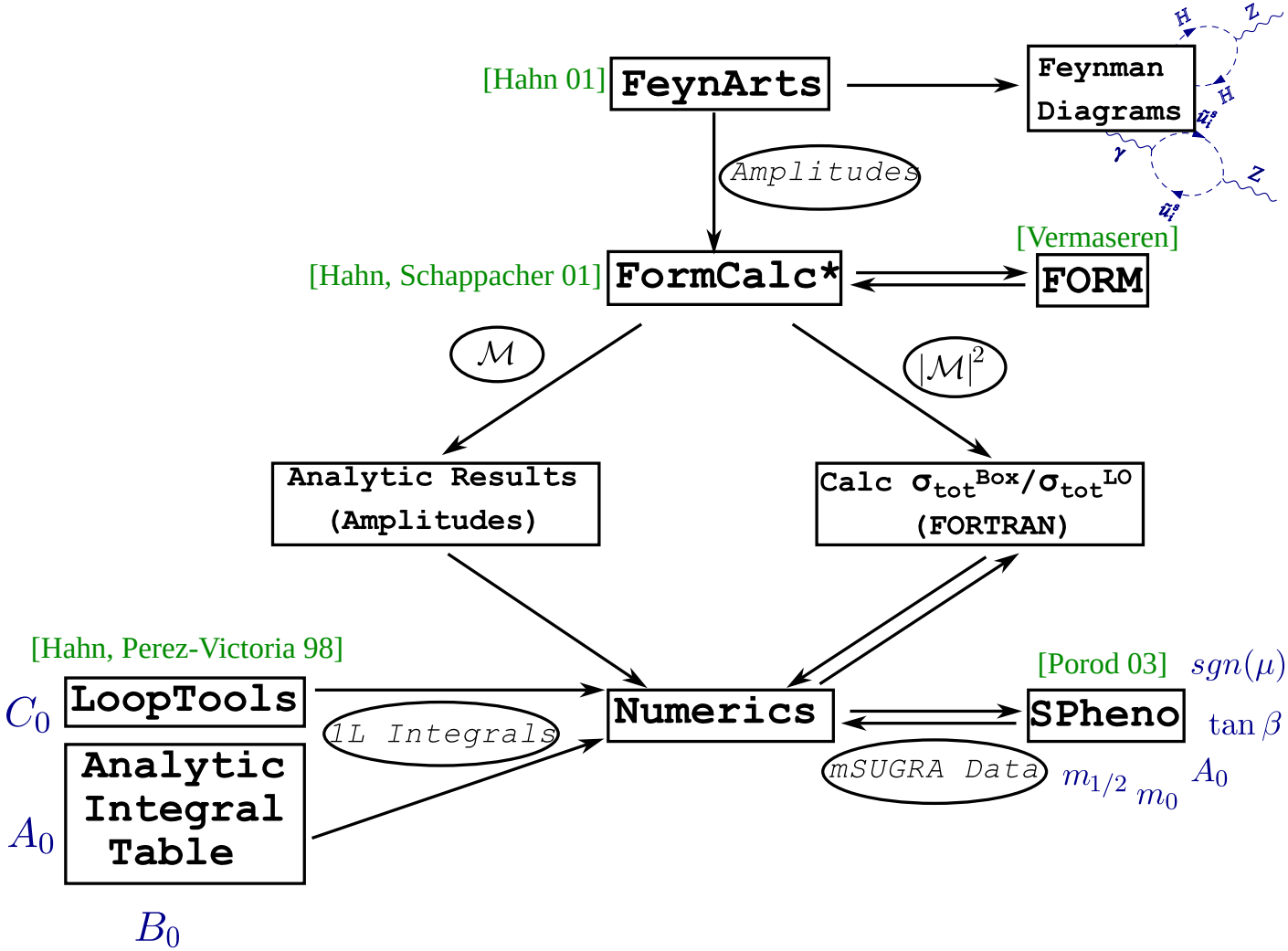

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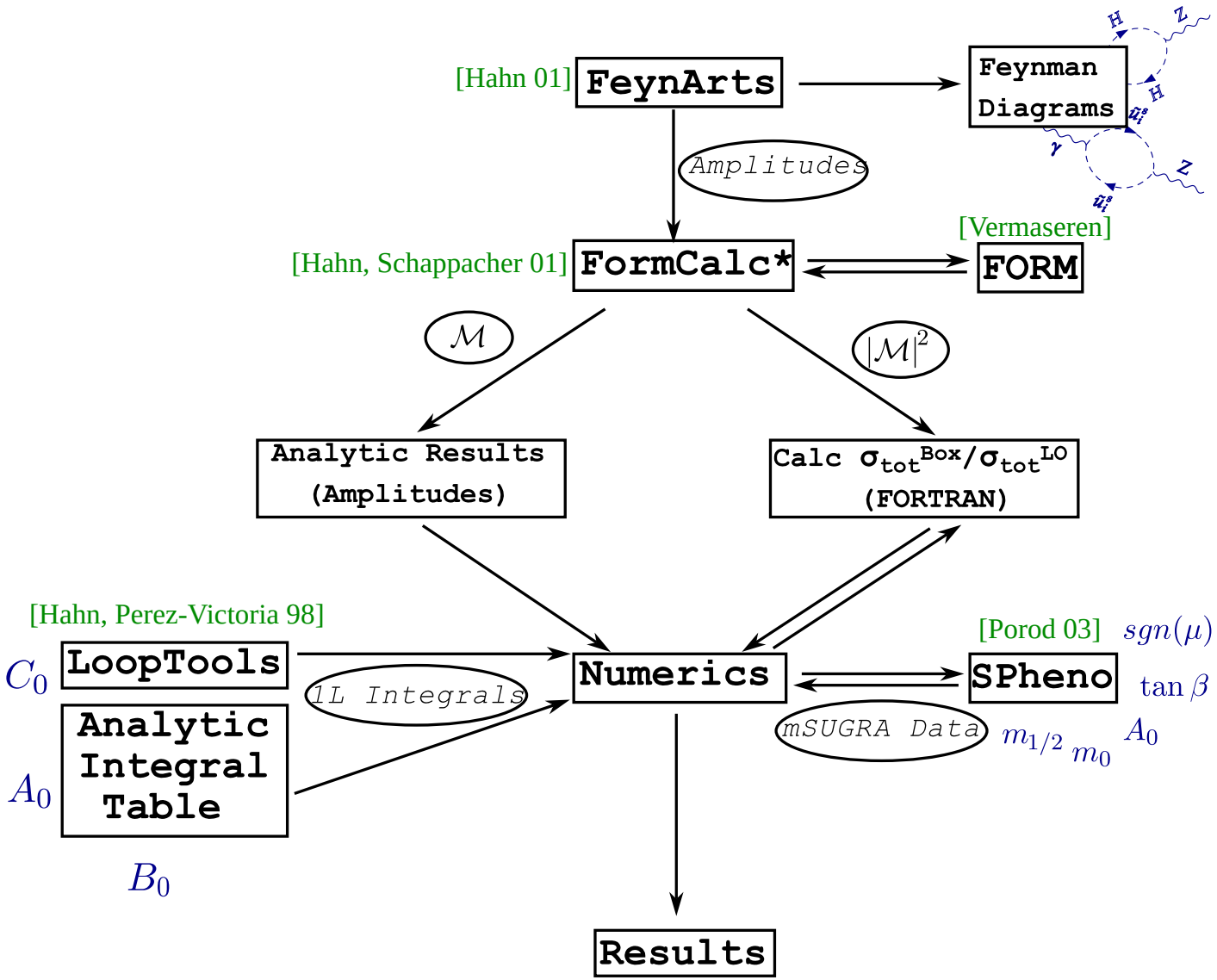

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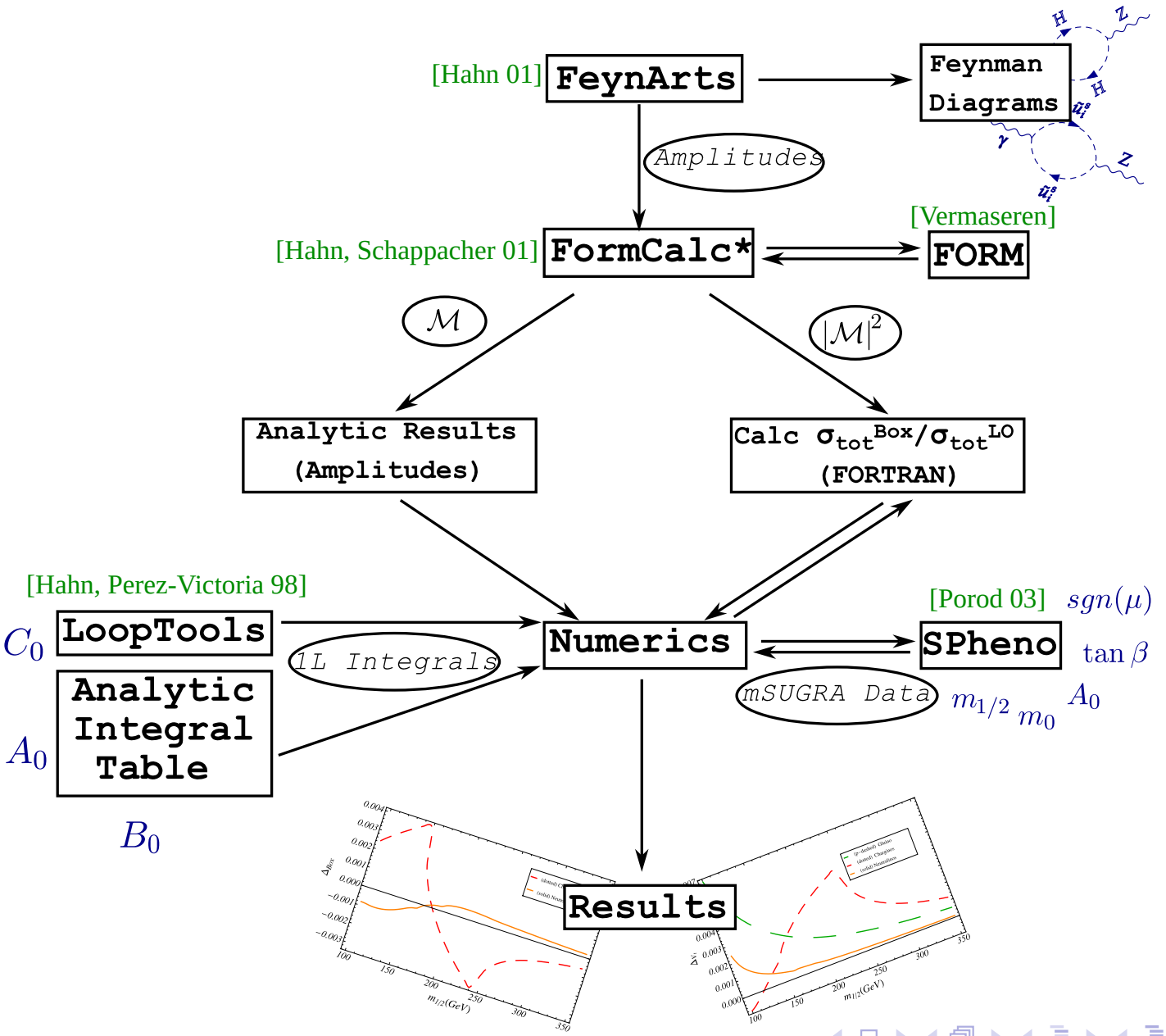
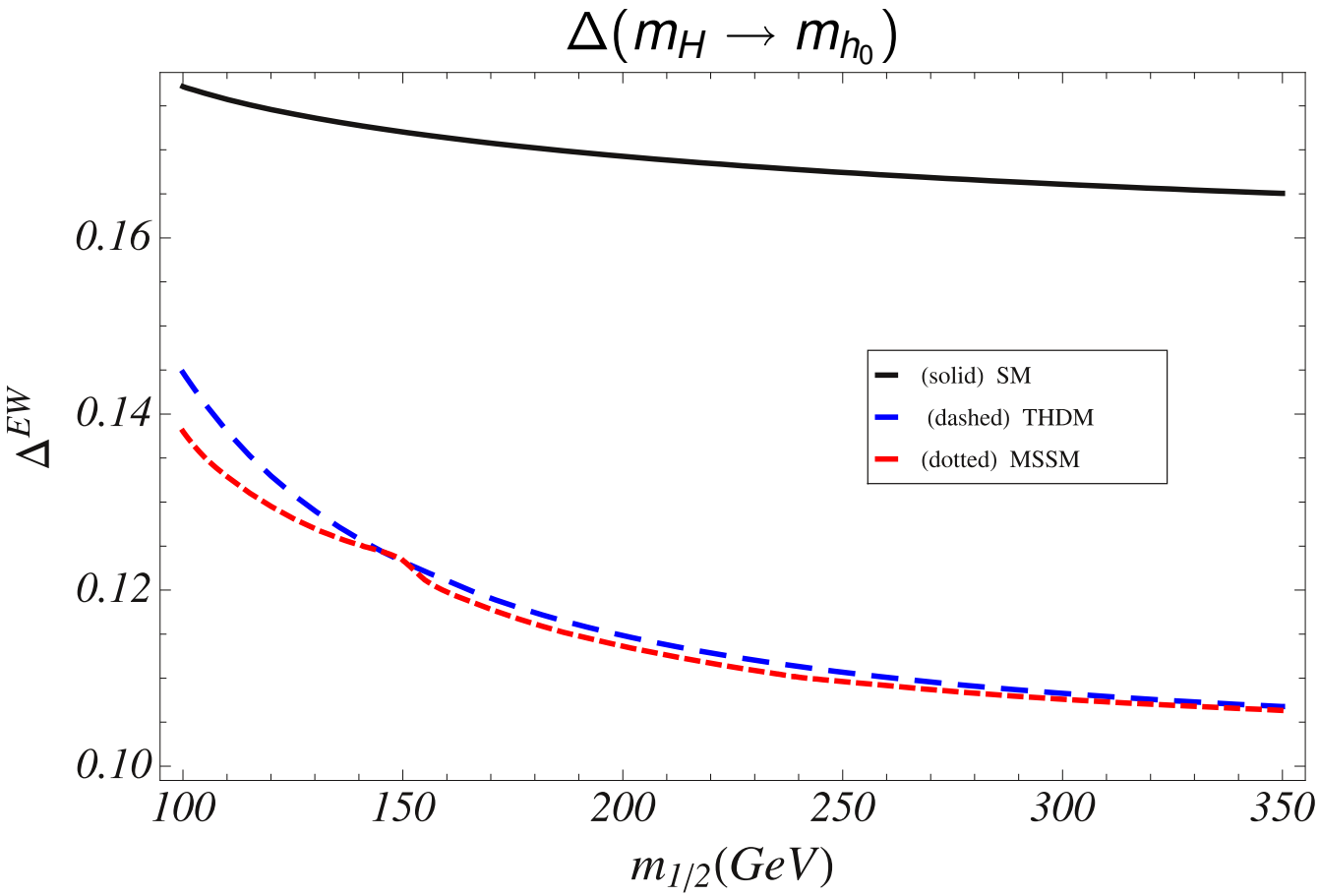


Correction to the Cross Section

$$\Delta = \frac{\sigma_{\text{tot}}^{\text{1L}}}{\sigma_{\text{tot}}^{\text{tree}}}\Big|_{s=4m_t^2} .$$

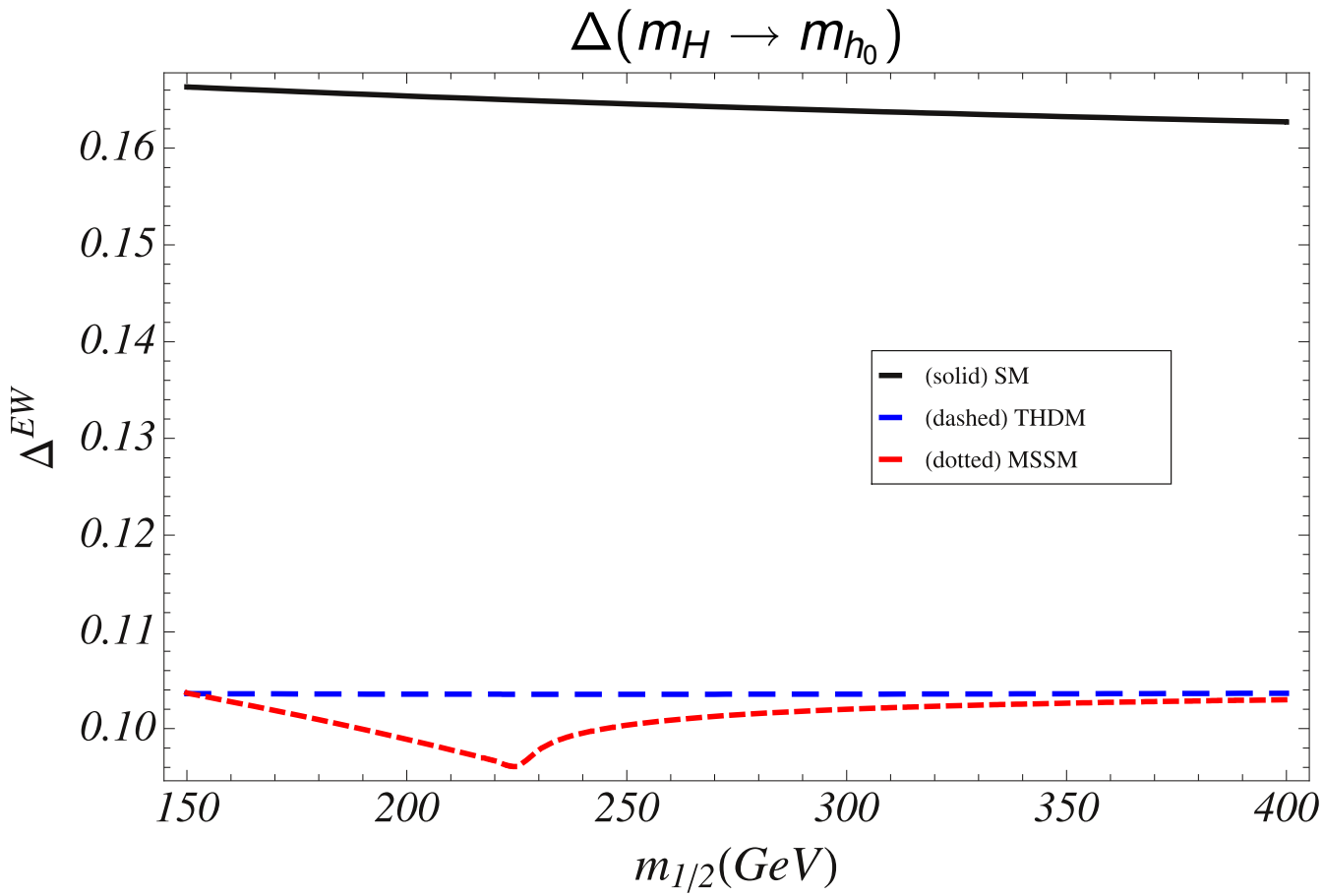
- mSUGRA Scenario SPS1a Slope.
  (**S**nowmass **P**oints and **S**lopes for SUSY Benchmarks [Allanach et al. 02])



Correction to the Cross Section

$$\Delta = \frac{\sigma_{\text{tot}}^{\text{1L}}}{\sigma_{\text{tot}}^{\text{tree}}}\Big|_{s=4m_t^2} .$$

- mSUGRA Scenario SPS2 Slope.



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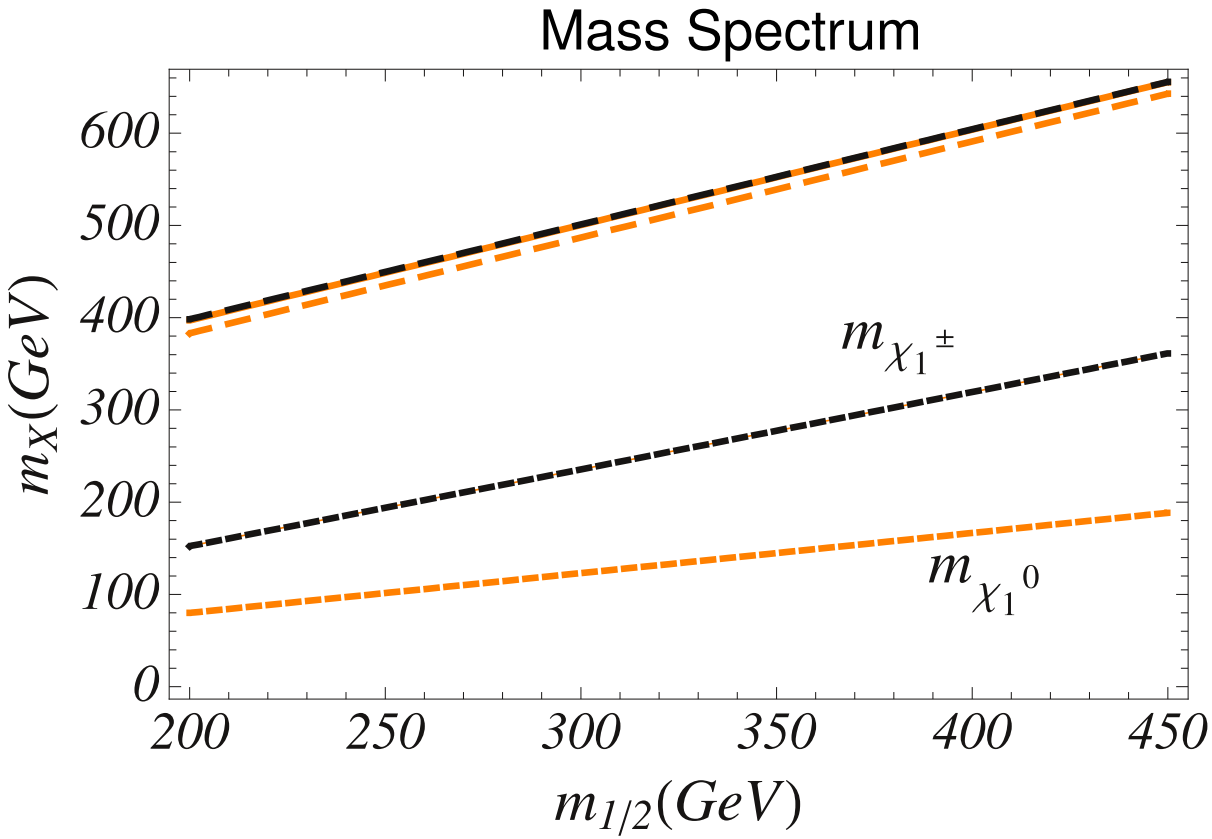

Summary

1. Hard corrections (C^{1L}) to $e^+e^- \to t\bar{t}$-Pair Production at threshold have been calculated in SM, THDM and MSSM.
2. mSUGRA SPSx ($m_H \to m_{h_0}$):

$$\Delta_{\text{EW}}^{\text{SM}} - \Delta_{\text{EW}}^{\text{THDM}} \lesssim 7\% \text{ (suppressed } h_0 t\bar{t}\text{-coupling!)}.$$

$$\Delta_{\text{EW}}^{\text{SM}} \lesssim +16\%, \qquad \Delta_{\text{QCD}}^{\text{SM}} \approx -17\%.$$

$$\Delta_{\text{EW}}^{\text{SUSY}} = \Delta_{\text{EW}}^{\text{MSSM}} - \Delta_{\text{EW}}^{\text{THDM}} \lesssim 1\%.$$

$$\Delta_{\text{QCD}}^{\text{SUSY}} \lesssim 1\%.$$

- Outlook
  - Extended numerical analysis (GMSB-, XMSB-, AMSB-scenarios).
  - Detailed analysis of $m_b \tan\beta$-effects.

$\Rightarrow$ paper in preparation!