Karlsruher Institut für Technologie

Medusa: A tale of two Loops

by Christoph Wiegand
GK Workshop Freudenstadt
27.9.2016

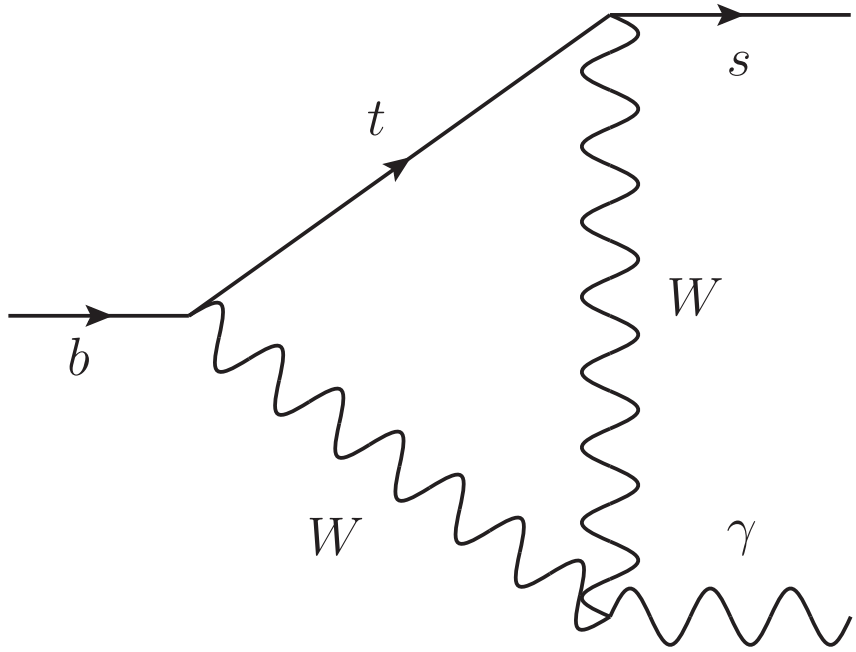
KARLSRUHE INSTITUTE OF TECHNOLOGY (KIT)

Motivation

- SM obviously not complete (DM, ν-Masses, Inflaton?)+conceptual problems
- No direct evidence of the extension
- Turn to indirect measurements
- If something turns up: need precise predictions in a number of possible SM extensions

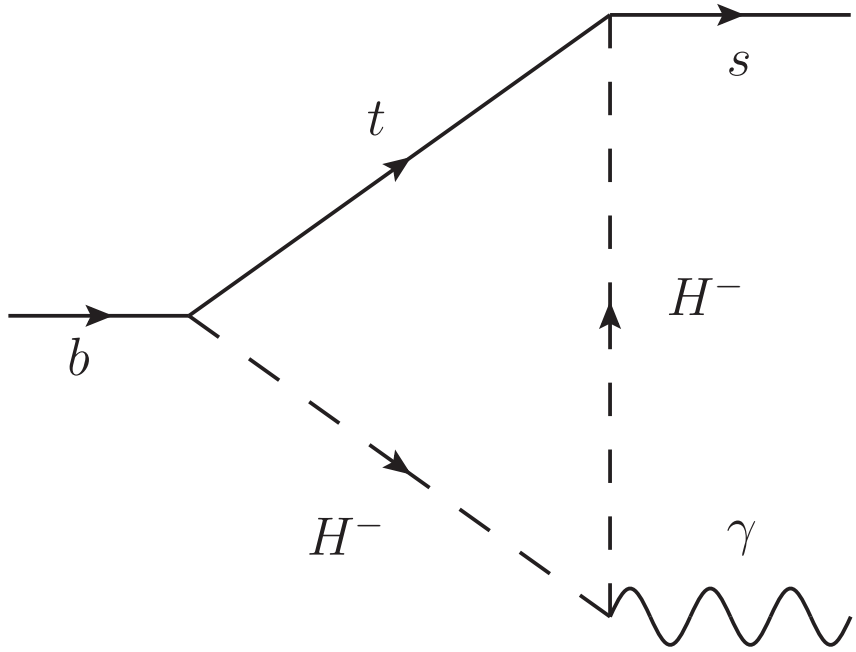
On the necessity of being loopy

- Indirect searches look at processes that are loop induced in the SM



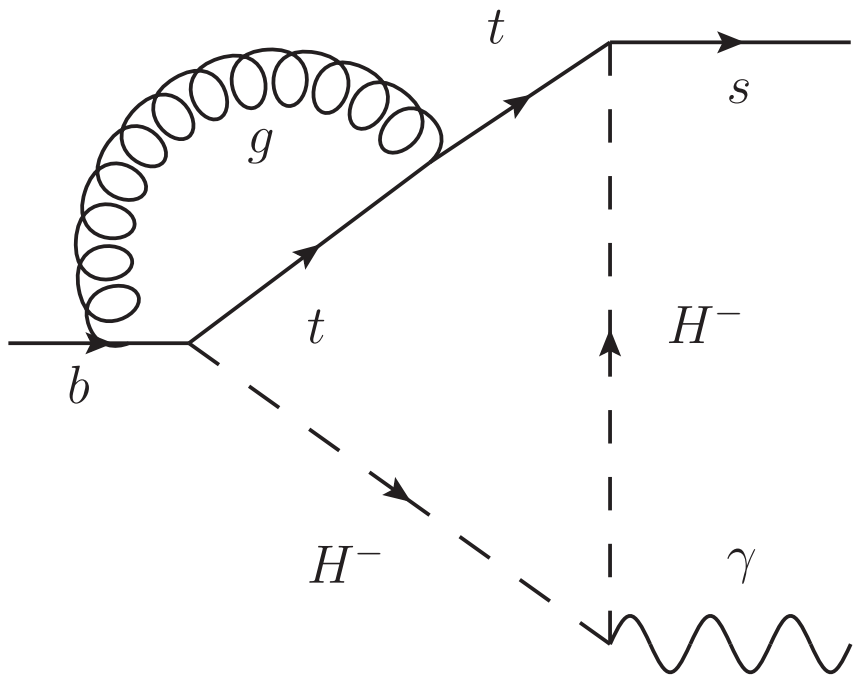
On the necessity of being loopy

- Indirect searches look at processes that are loop induced in the SM
- NP contribution either tree level or at least on the same loop order than SM



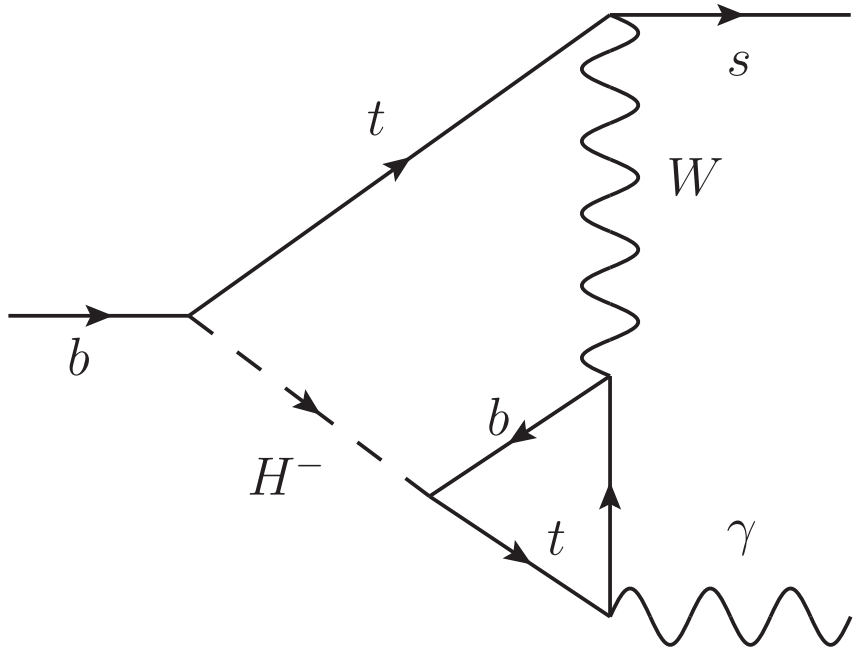
On the necessity of being two-loopy

- Either: Coupling is large i.e. α_s



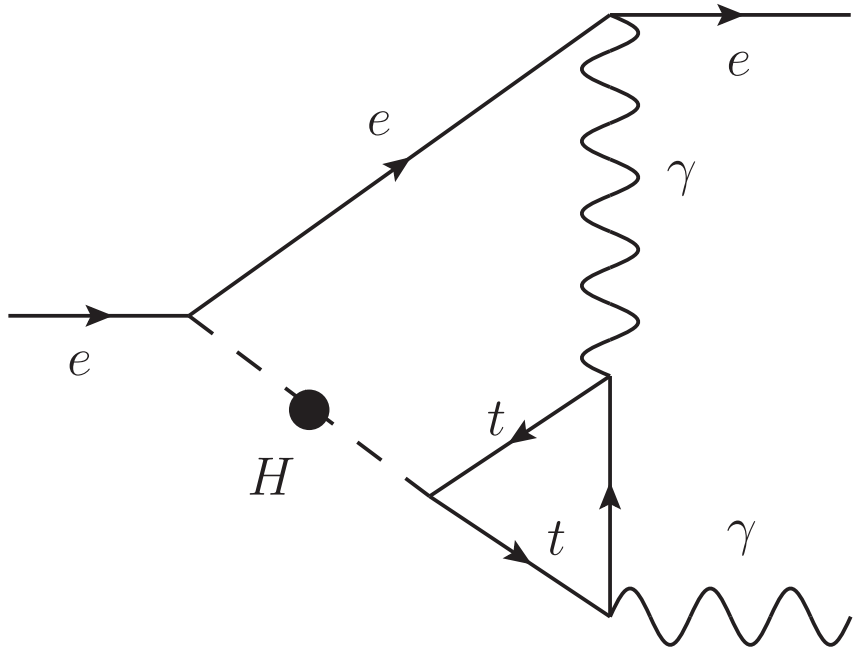
On the necessity of being two-loopy

- Either: Coupling is large i.e. α_s
- Next loop order is enhanced: ditch $1/\tan(\beta)$
- $\tan^2(\beta)$ Term can be important for large $\tan(\beta)$



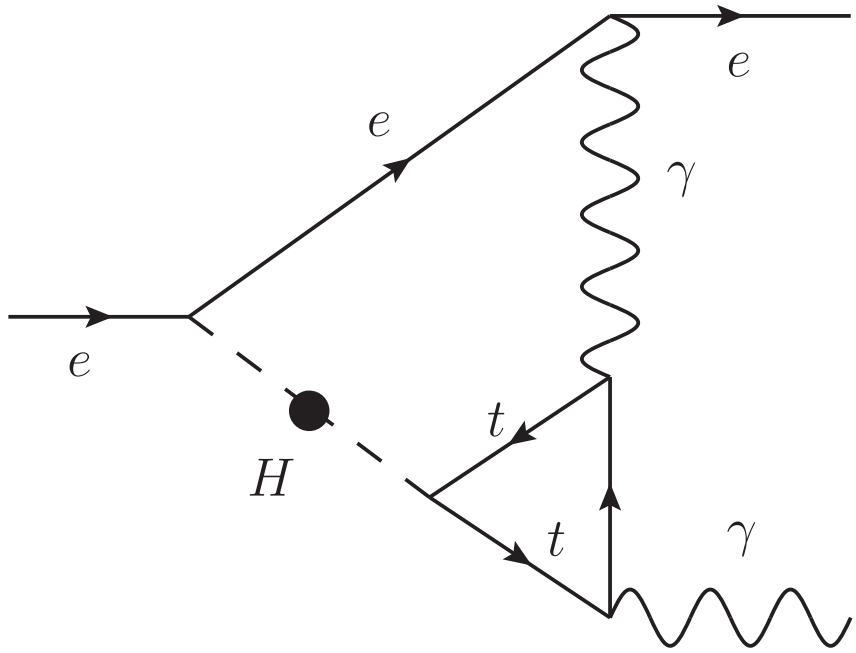
On the necessity of being twoloopy

- Either: Coupling is large i.e. α_s
- Next loop order is enhanced: ditch $1/\tan(\beta)$
- $\tan^2(\beta)$ Term can be important for large $\tan(\beta)$
- Even bigger effect for leptonic case: for example eEDM
- exchange m_e for m_t: 2 loop can be larger than one loop



On the necessity of being twoloopy

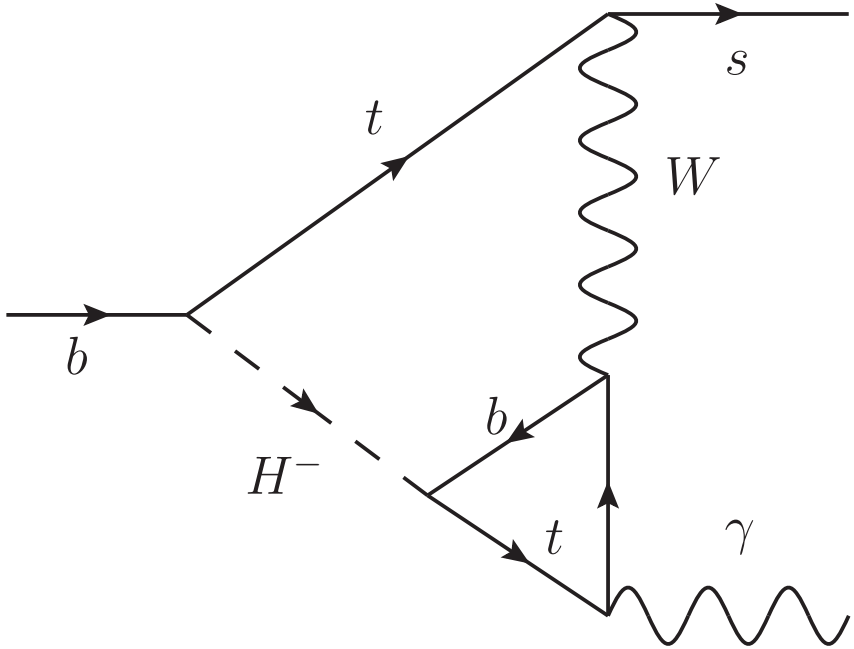
- Either: Coupling is large i.e. α_s
- Next loop order is enhanced: ditch $1/\tan(\beta)$
- $\tan^2(\beta)$ Term can be important for large $\tan(\beta)$
- Even bigger effect for leptonic case: for example eEDM
- exchange m_e for m_t: 2 loop can be larger than one loop



$\Longrightarrow$ Two loop contributions can be very important in predictions. If you want to disentangle several possible extensions: Need precise prediction in a number of models.

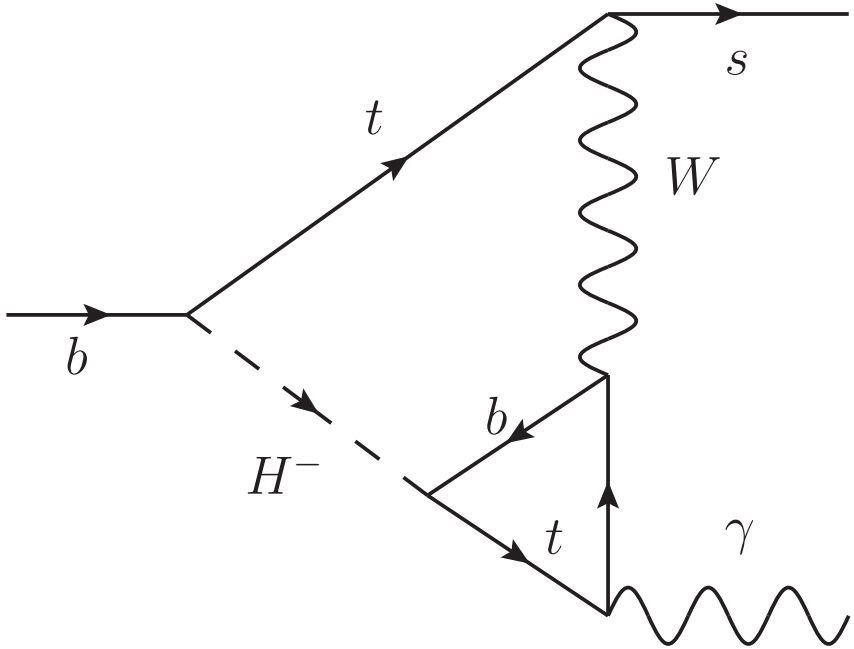
Medusa

- FeynArts interface
- Traces handled with Tracer
  ('t Hooft Veltman scheme for γ_5)
- Spinor chains treated in NDR



Medusa

- FeynArts interface
- Traces handled with Tracer
  ('t Hooft Veltman scheme for γ_5)
- Spinor chains treated in NDR

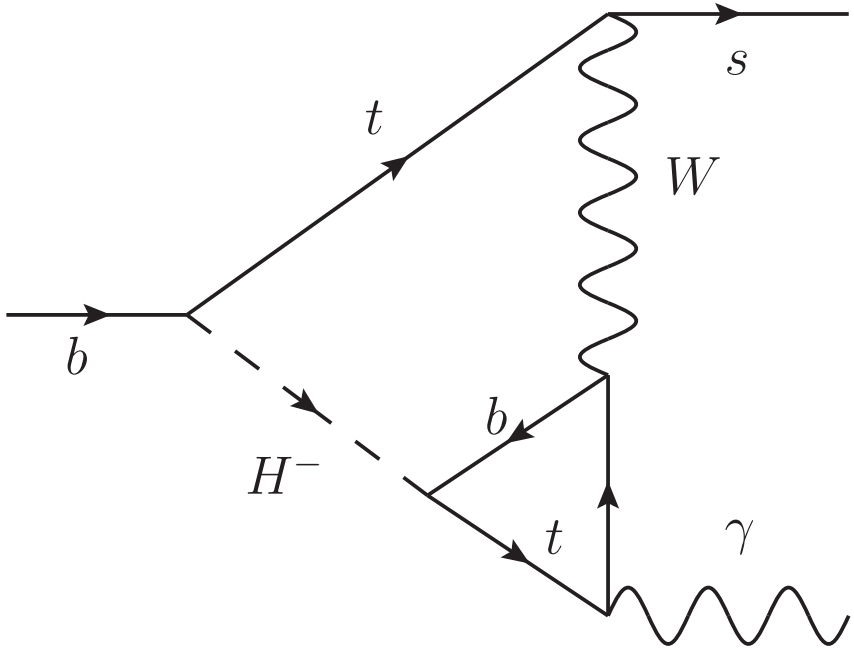


$$T^{\nu_1\dots\nu_s;\mu_1\dots\mu_r}_{lnjab}(p,k,M_i) = \frac{\mu^{4\epsilon}e^{2\gamma_E\epsilon}}{[i\pi^{\frac{D}{2}}]^2}\iint d^Dq_1\,d^Dq_2\,\frac{q_1^{\nu_1}\cdots q_1^{\nu_s}\cdot q_2^{\mu_1}\cdots q_2^{\mu_r}}{(M_1^2-q_1^2)^l\cdot(M_2^2-q_2^2)^n}$$

$$\frac{1}{(M_3^2-(q_1+q_2)^2)^j}\sum_{\lambda=1}^{2}\frac{1}{(M_{4,\lambda}^2-(q_\lambda+k)^2)^{a_\lambda}}\sum_{\kappa=1}^{2}\frac{1}{(M_{5,\kappa}^2-(q_\kappa+p)^2)^{b_\kappa}}$$

Medusa

- FeynArts interface
- Traces handled with Tracer ('t Hooft Veltman scheme for γ_5)
- Spinor chains treated in NDR
- Asymptotic expansion in external momenta ($p, k \sim m_b$ in this example)
- Implemented algorithm: expansion by subgraphs

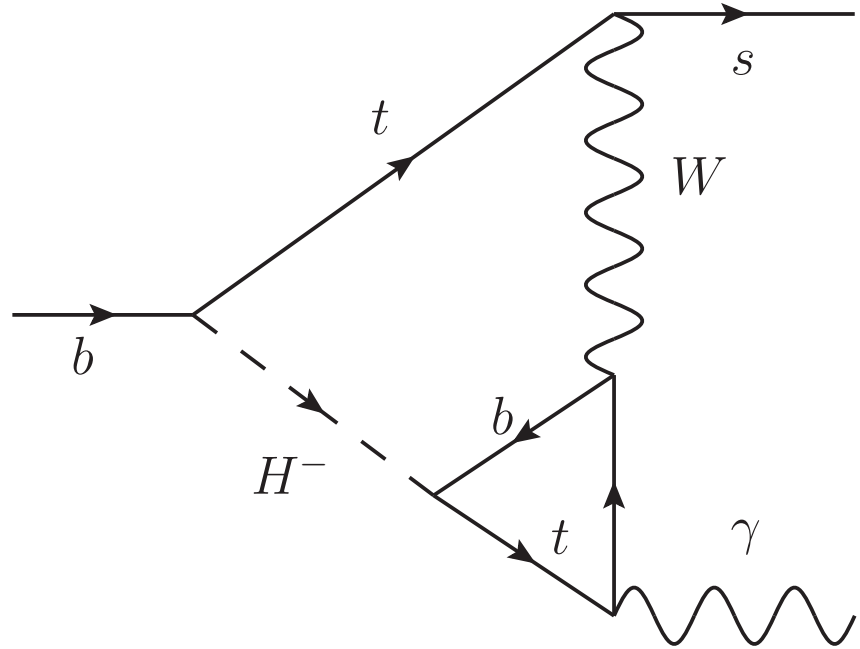


$$T_{lnj}^{\nu_1 \ldots \nu_s;\mu_1 \ldots \mu_r}(M_1, M_2, M_3) =$$

$$\frac{\mu^{4\epsilon} e^{2\gamma_E \epsilon}}{[i\pi^{\frac{D}{2}}]^2} \iint d^D q_1 \, d^D q_2 \, \frac{q_1^{\nu_1} \cdots q_1^{\nu_s} \cdot q_2^{\mu_1} \cdots q_2^{\mu_r}}{(M_1^2 - q_1^2)^l \cdot (M_2^2 - q_2^2)^n} \, \frac{1}{(M_3^2 - (q_1 + q_2)^2)^j}$$

Medusa

- FeynArts interface
- Traces handled with Tracer ('t Hooft Veltman scheme for γ_5)
- Spinor chains treated in NDR
- Asymptotic expansion in external momenta ($p, k \sim m_b$ in this example)
- Implemented algorithm: expansion by subgraphs
- no recursive reduction: calculation does not blow up in intermediate steps
- Solution given in terms of hypergeometric functions. Expanded by HypExp.



Medusa

Specialist to easily do two loop calculations for rare decays. Only requirement: Expansion in external momenta needs to be possible
Features:

- Analytic results
- no recursive algorithms
- compact results (and intermediate results)
- Mathematica: easy interface to customize calculation
- FeynArts interface