S, T and U parameters

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19/04/2013, Crete

Motivation

- For light external fermions we only need loop corrections to the gauge propagators (oblique corrections) [1].

[1] D. C. Kennedy, ``Renormalization of electroweak gauge interactions,'' FERMILAB-CONF-91-271-T

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Motivation

- For light external fermions we only need loop corrections to the gauge propagators (oblique corrections) [1].
- The effect of the oblique corrections to the EW observables can be written in terms of some finite parameters.
- We can use these finite parameters for precision measurements at low energies.

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Oblique corrections

Assumptions-Approximations

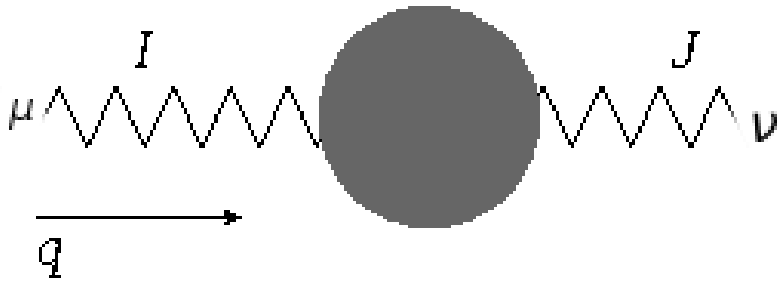
1. Electroweak gauge symmetry: $SU(2) \bigotimes U_Y(1)$.

2. Negligible external fermion masses.

3. The scale of new physics is much greater than the Electroweak scale.

1PI Diagrams

We need to calculate only 1PI diagrams (2nd assumption)



The general form of this diagram is

$$\Pi_{IJ}^{\mu\nu} = ig^{\mu\nu}\Pi_{IJ}(q^2) + iq^\mu q^\nu F_{IJ}(q^2).$$

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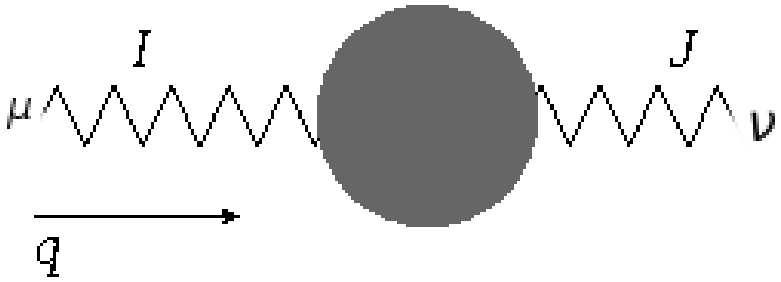

The general form of this diagram is

$$\Pi_{IJ}^{\mu\nu} = ig^{\mu\nu}\Pi_{IJ}(q^2) + iq^\mu q^\nu F_{IJ}(q^2).$$

The term $F_{IJ}(q^2)$ does not contribute.

Definitions

EW Noether currents in the Isospin and electric charge basis:

$$J^{\mu}_{W} = \frac{e}{s_W} J^{\mu}_{1}$$
$$J^{\mu}_{\gamma} = e J^{\mu}_{Q}$$
$$J^{\mu}_{Z} = \frac{e}{s_W c_W} \left(J^{\mu}_{3} - s^2 J^{\mu}_{Q} \right)$$

Definitions

1PI corrections in the Isospin and electric charge basis

$$\Pi_{WW}(q^2) = \frac{e^2}{s_W^2}\Pi_{11}(q^2)$$
$$\Pi_{\gamma\gamma}(q^2) = e^2\Pi_{QQ}(q^2)$$
$$\Pi_{Z\gamma}(q^2) = \frac{e^2}{s_W c_W}\left(\Pi_{3Q}(q^2) - s^2\Pi_{QQ}(q^2)\right)$$
$$\Pi_{ZZ}(q^2) = \frac{e^2}{s_W^2 c_W^2}\left(\Pi_{33}(q^2) - 2s^2\Pi_{3Q}(q^2) + s^4\Pi_{QQ}(q^2)\right)$$

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Because of $U_Q(1)$

$$\Pi_{\gamma\gamma}(0) = \Pi_{\gamma Z}(0) = 0.$$

S, T and U parameters

Taylor expansion of Π's at $q^2 = 0$

$$\Pi_{11}(q^2) \approx \Pi_{11}(0) + q^2 \frac{d}{dq^2}\Pi_{11}(q^2)|_{q^2=0},$$

$$\Pi_{33}(q^2) \approx \Pi_{33}(0) + q^2 \frac{d}{dq^2}\Pi_{33}(q^2)|_{q^2=0},$$

$$\Pi_{QQ}(q^2) \approx q^2 \frac{d}{dq^2}\Pi_{QQ}(q^2)|_{q^2=0},$$

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S, T and U parameters

Observations:

- Six Taylor coefficients.

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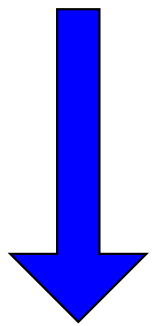

Three finite linear combinations!

S, *T* and *U* parameters

These three finite combination are known as *S*, *T* and *U* parameters [2]

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S, T and U parameters

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- $S = 16\pi \left(\Pi'_{33}(0) - \Pi'_{3Q}(0)\right)$
- $T = \dfrac{4\pi}{s^2 c^2 m_Z^2} \left(\Pi_{11}(0) - \Pi_{33}(0)\right)$
- $U = 16\pi \left(\Pi'_{11}(0) - \Pi'_{33}(0)\right)$

where $\Pi'_{IJ}(0) \equiv \dfrac{d}{dq^2}\Pi_{IJ}(q^2)|_{q^2=0}$

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S, *T* and *U* parameters

Are these parameters finite?

The infinite parts of the *Pi*'s are of the form

- $\Pi_{11}^{(\infty)}(q^2)=\Pi_{33}^{(\infty)}(q^2) \sim \left(A + q^2 B\right) log(\Lambda)$

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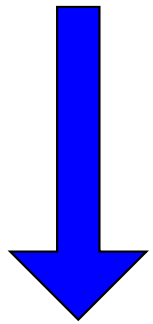
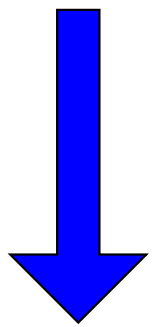


***S*, *T* and *U* are finite!**

S, T and U parameters

Estimation of S, T and U for almost degenerate masses of fermions

- $S \sim \sum_{\text{new fermions}} (T_{3L} - T_{3R})^2$
- $T \sim \dfrac{\Delta m^2}{M_Z^2}$
- $U \sim \dfrac{Dm^2}{M_N^2}$

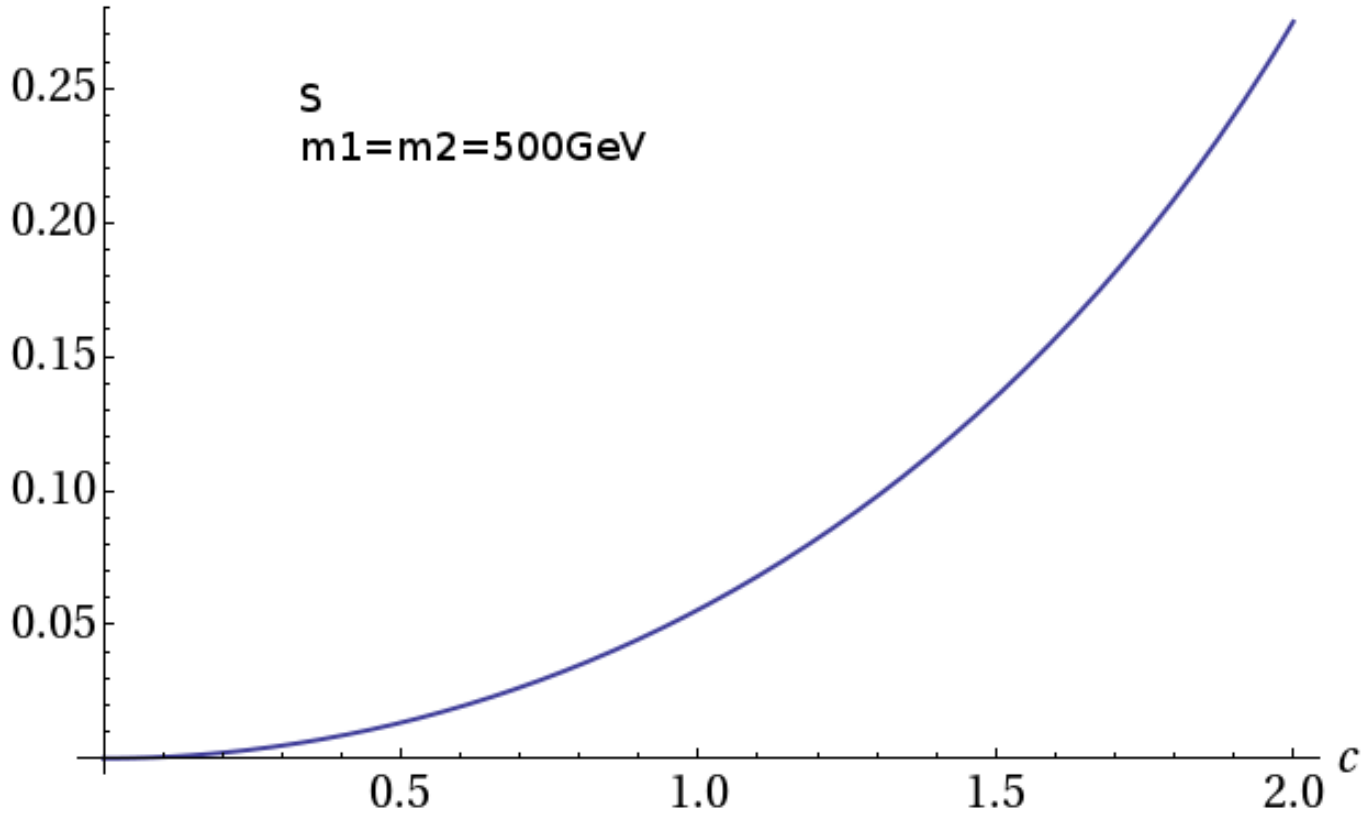


Limited space for chiral fermions!
non-decoupling effect

Examples

- Example I: $\psi_{L,R} \equiv \begin{pmatrix} \psi_u \\ \psi_d \end{pmatrix}^{Y}_{L,R}, \quad \chi^{Y-1}_{L,R},$
- Example II: $Q^{Y}_{L} \equiv \begin{pmatrix} q_u \\ q_d \end{pmatrix}^{Y}_{L}, q_R{}^{Y+1}{}_1, q_R{}^{Y-1}{}_2.$

Example I



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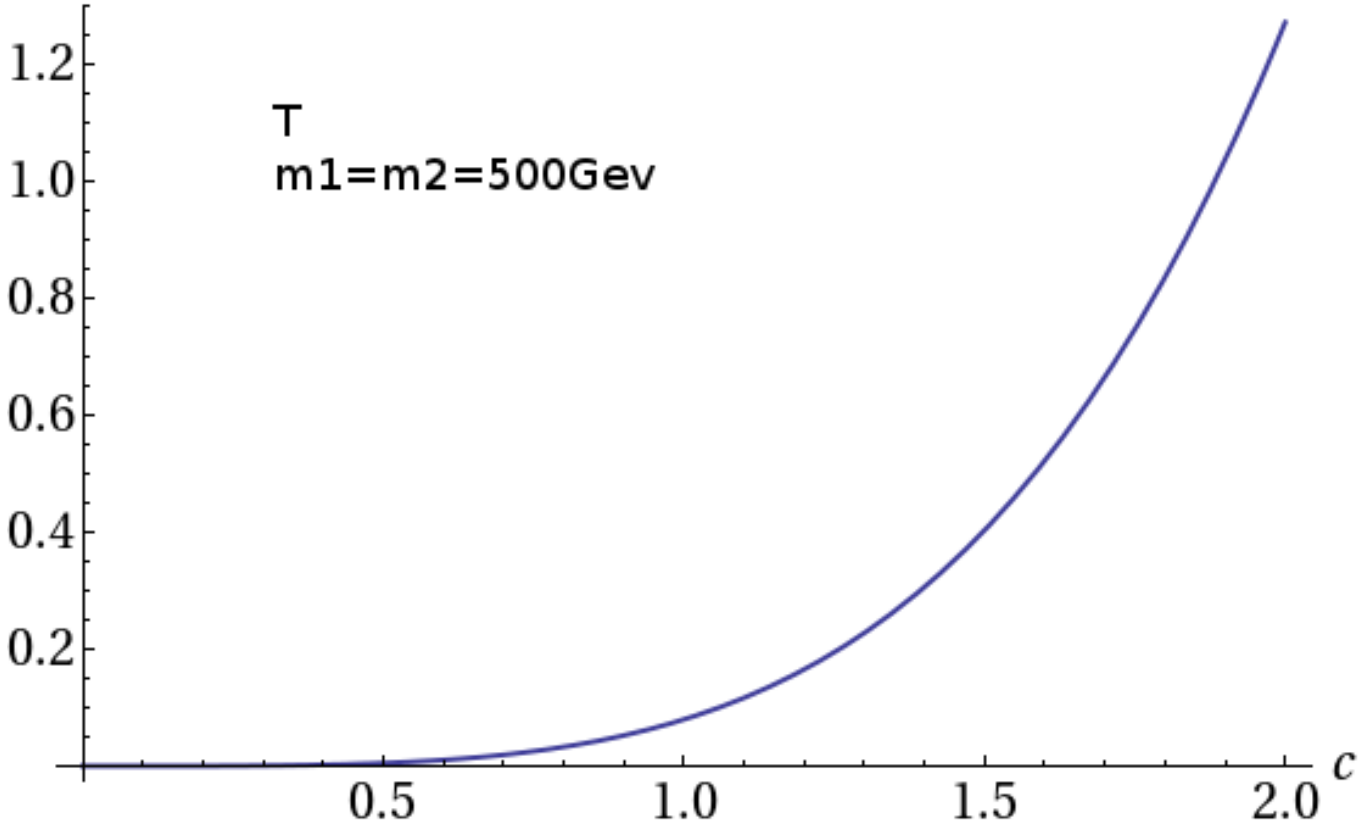

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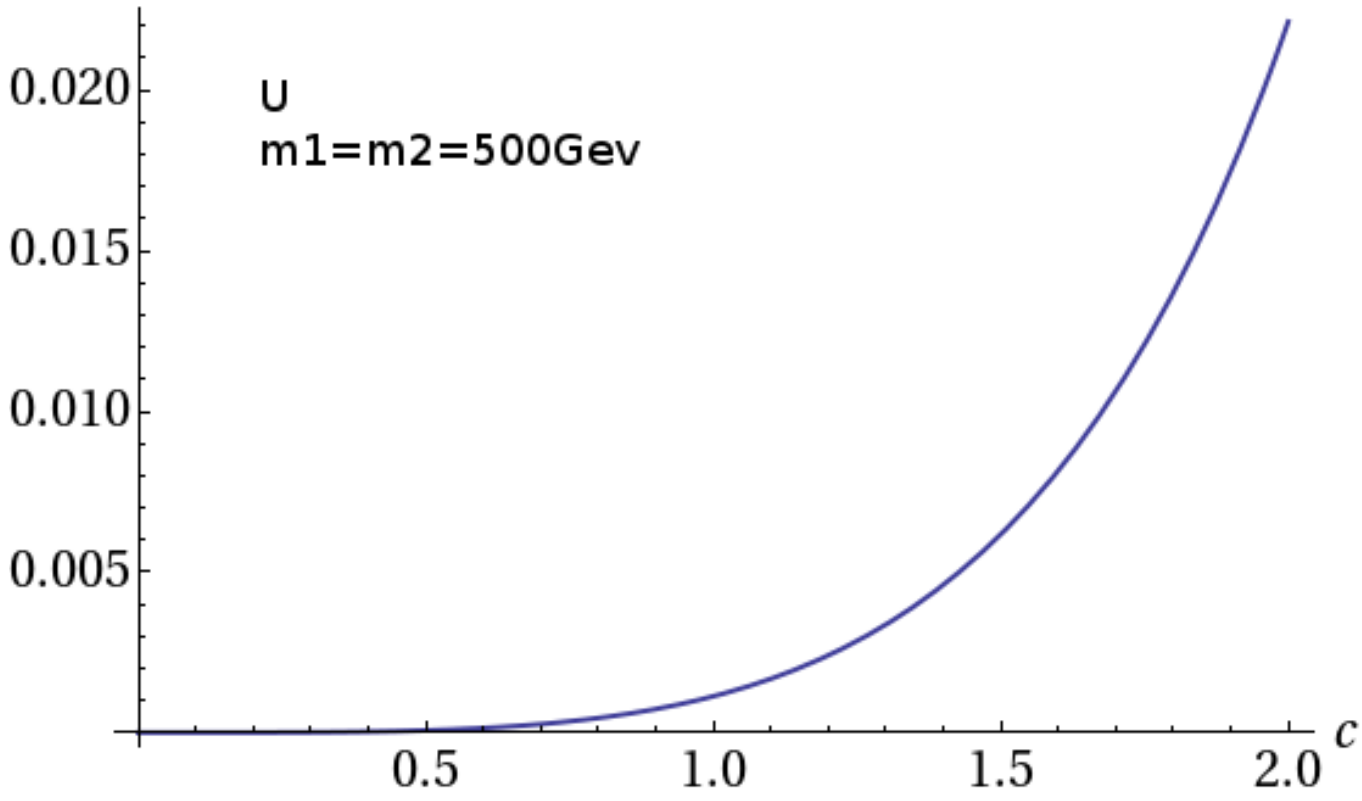
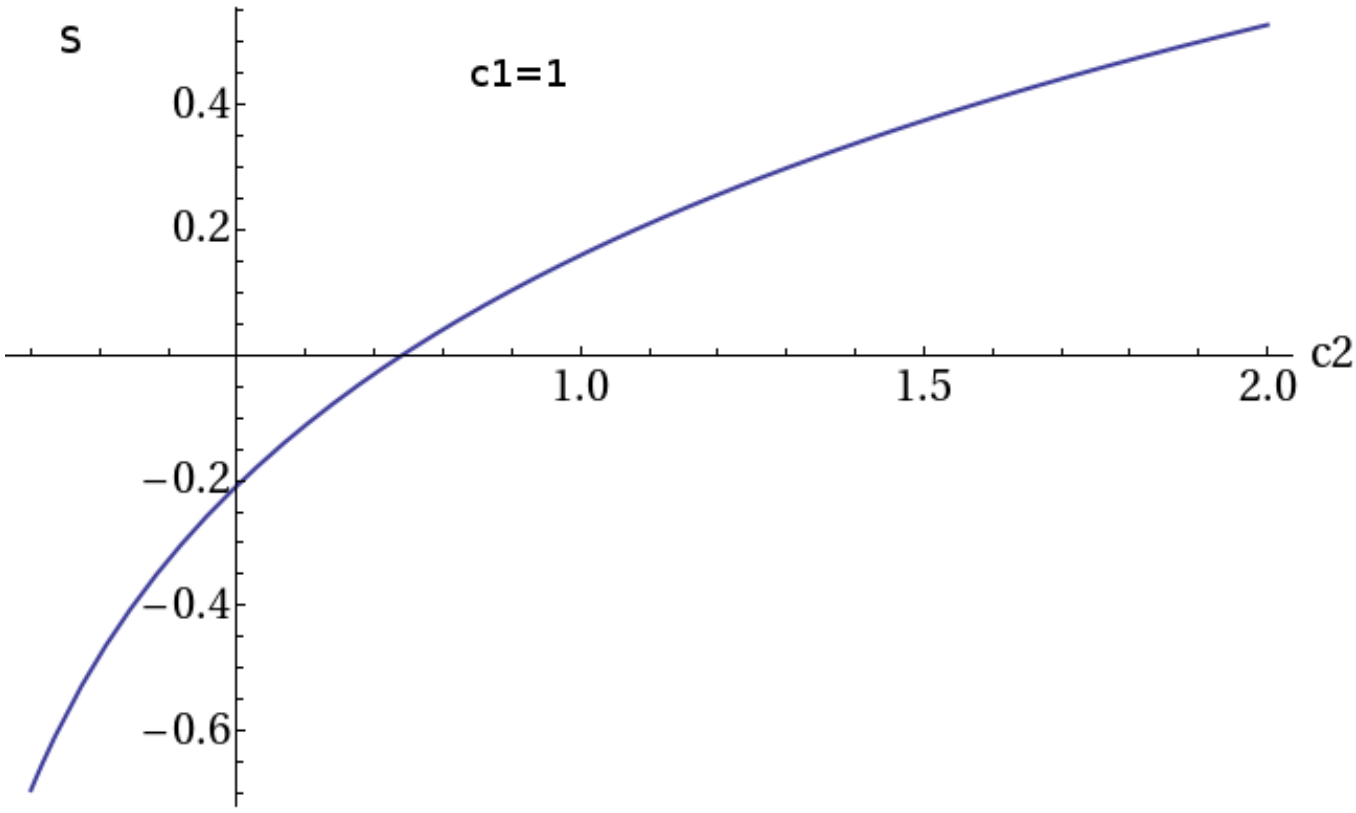


Example II



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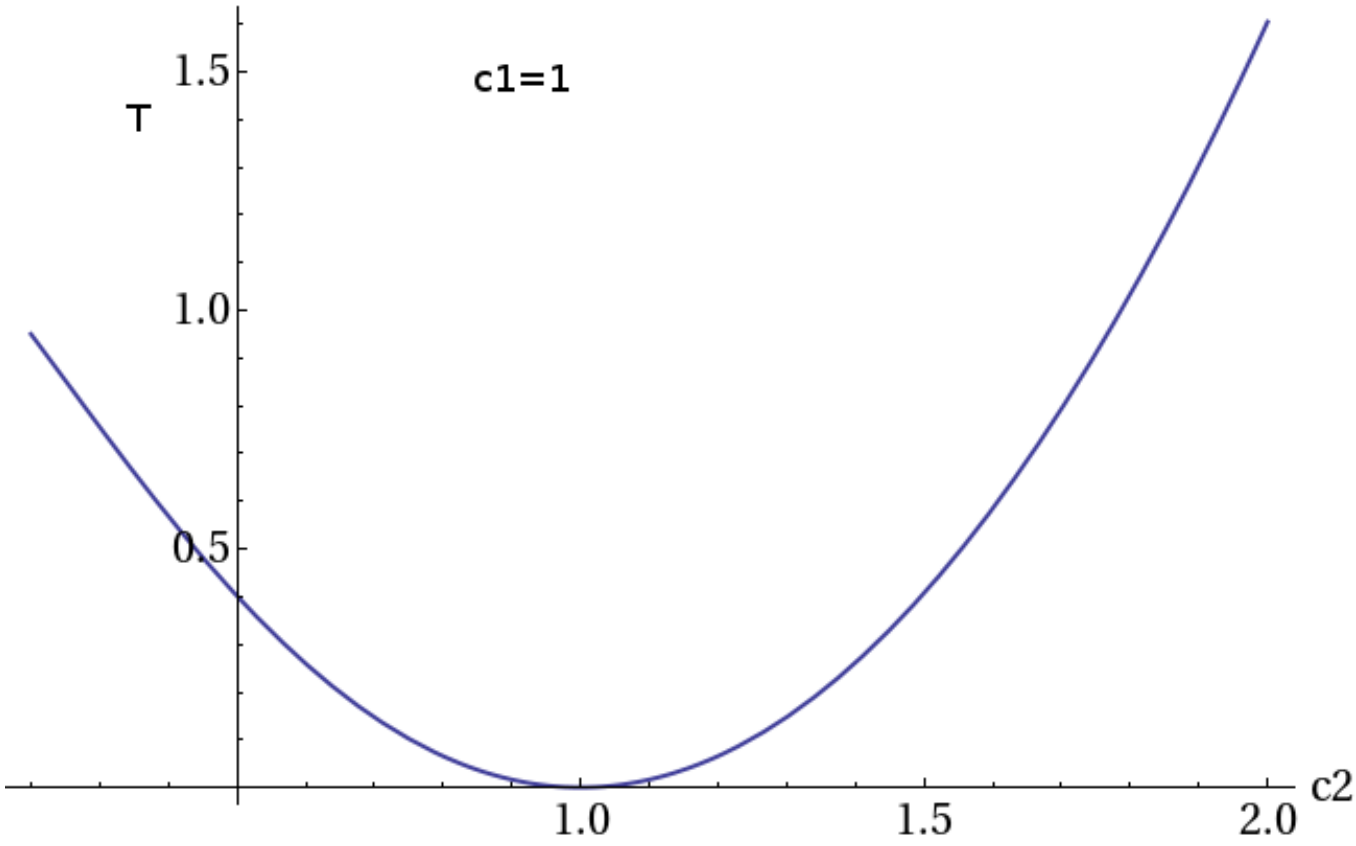

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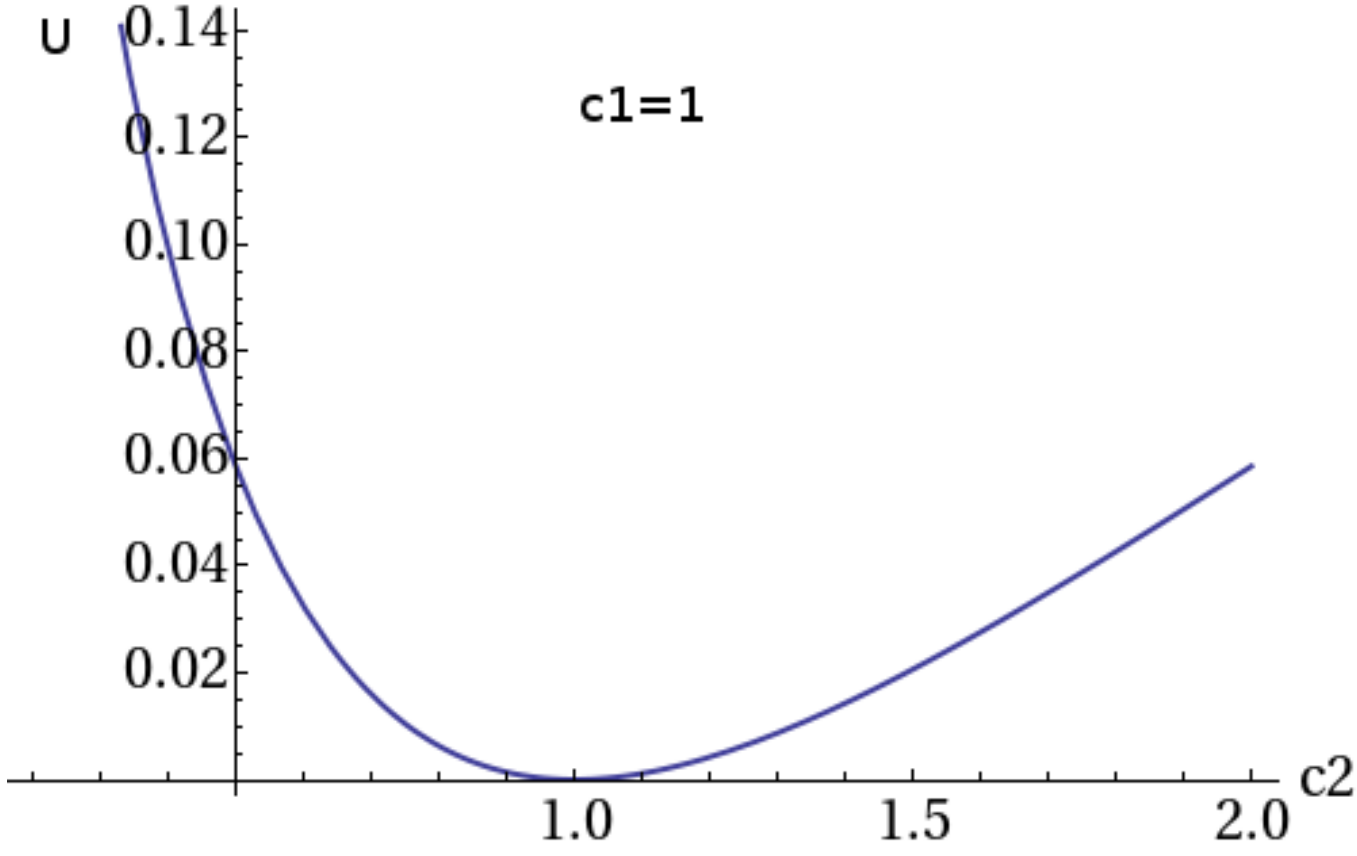

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- Easy to calculate diagrams (only oblique corrections and no counterterms)!
- High energy physics contributions that affect low energy experiments!