D-brane Instantons and Flavour Violation

Lower bounds for the string scale from D-instantons

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Contents

Contents

- Strings at the TeV scale?

Contents

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- Intersecting branes and the MSSM

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- Instantons in string theory

Contents

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  - Bounds on the string mass

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D. Lüst, O. Schlotterer, S. Stieberger, T. Taylor, arXiv:0908.0409

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- String corrections to standard model processes can become visible at the LHC
- Experimental results give bounds on the fundamental parameters, like the string mass

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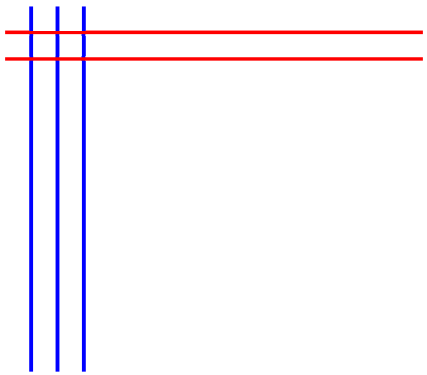

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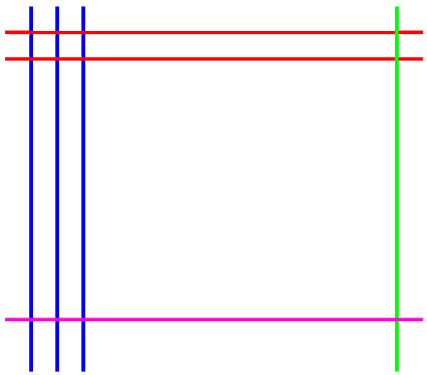

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- additional 1-stacks

Instantons in string theory

Motivation

- Remember: Instantons in field theory as finite-action solutions of the Euclidean Yang-Mills equations.

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- Solution: Connections with selfdual/anti-selfdual field strengths ($F = \pm * F$), first given by Belavin, Polyakov, Schwarz and Tyupkin (BPST)

$$A^a_\mu(x; x_0; \rho) = 2 \frac{\rho^2 \bar{\eta}^a_{\mu\nu} (x - x_0)^\nu}{(x - x_0)^2 [(x - x_0)^2 + \rho^2]} \tag{2}$$

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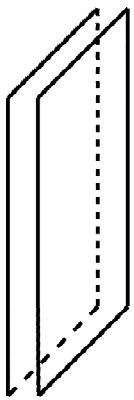
Motivation

This can also be calculated in string theory:
Relevant objects:



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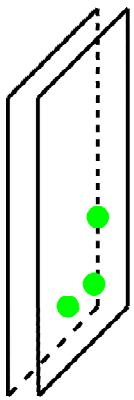

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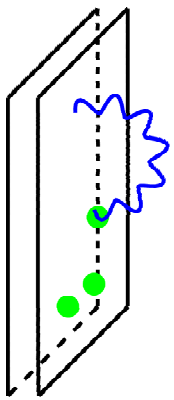

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- D(-1)-branes, i.e. points in spacetime
- Open strings with ends on the different branes

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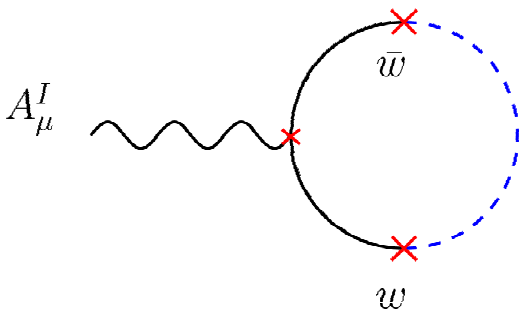

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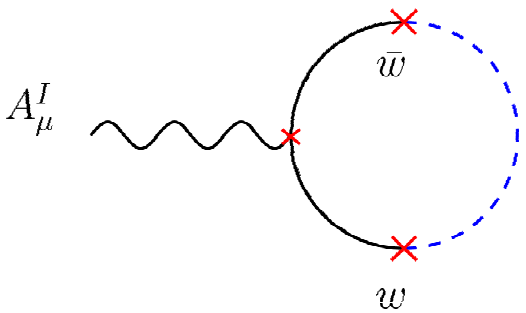

Fouriertransforming the amplitude (in the limit where the string tension vanishes) together with the propagator of the gauge field

$$A^I_\mu(x) = \int \frac{d^4p}{2\pi^2} \mathcal{M}^I_\mu(p, \bar{w}, w) \frac{1}{p^2} e^{ipx}$$

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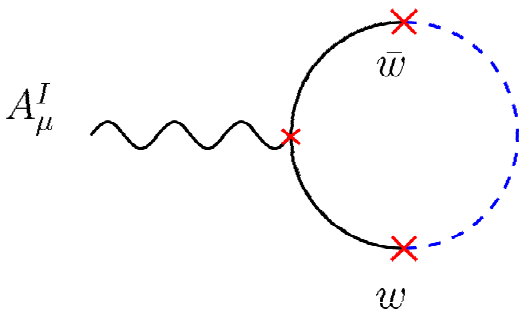

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Pointlike objects in spacetime are the string analogue of field theory instantons

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E2-Instantons

- More general: Objects which are pointlike in the external space and wrap (p+1) dimensional cycles of the internal Calabi-Yau manifold $\longrightarrow$ Euclidean p-instantons.

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- Massless spectrum of open strings with one end on E2 and one end on D6: charged zero modes λ (one Grassmannian degree of freedom)

Instantons in string theory

Instanton calculus

R.Blumenhagen, M.Cvetic, S.Kachru, T.Weigand, arXiv: 0902.3251v2

What is the instanton contribution to the four dimensional effective type II supergravity action?

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$$\int d^4x \; d^2\theta \; d^2\bar{\theta} \; d^n\lambda \dots$$

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$$M_P^{-n} \frac{e^{K/2} \psi_i \psi_j \prod_{k \neq i,j} \phi_k}{\sqrt{K_{ii} K_{jj} \prod_{k \neq i,j} K_{kk}}}$$

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$\longrightarrow$ If we have the right amount of universal and charged zero modes we get a contribution to the superpotential of the (schematic) form

$$\frac{1}{M_s^r M_P^s} \int d^4x \; d^2\theta \; e^{-S_0} \prod_i \Phi_{a_i b_i}$$

Yukawa couplings from D-instantons

M.Cvetic, J. Halverson, R. Richter, arXiv: 0905.3379v2

Take for example a specific MSSM model:

Tabelle: Spectrum of the 5-stack quiver

Sector	Matter	Representation	Multiplicity	Hypercharge
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ab'	$Q_L^{2,3}$	(a, b)	2	$\frac{1}{6}$
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ac'	$U_R^{1,2}$	$(\bar{a}, \bar{c})$	2	$-\frac{2}{3}$
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Yukawa coupling $Q_L^1 H_u U_R^{12}$

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Yukawa coupling $Q_L^1 H_u U_R^{12}$ violates $U(1)$-charge of the b-stack.

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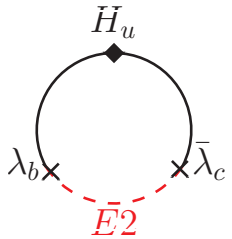
Therefore we have to use an instanton with opposite charge to generate the Yukawa coupling, e.g. via two disc amplitudes:



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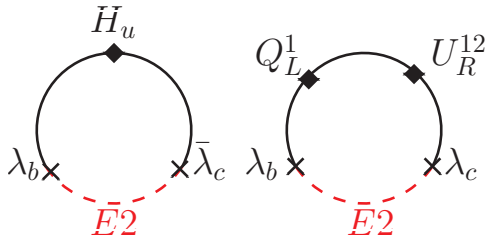

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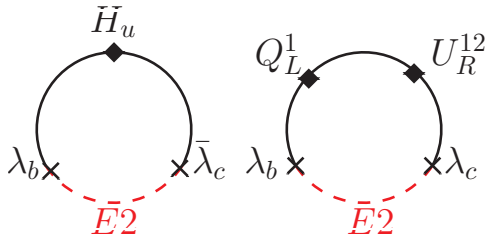

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But we have to sum over all possible discs with matter and charged zero modes inserted.

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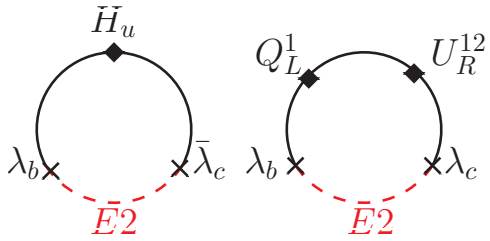


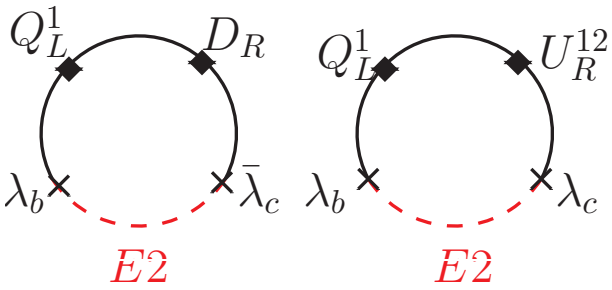
$$\int d^4x d^2\theta d^2\lambda_b d\bar{\lambda}_c d\lambda_c \; e^{-S_0} \langle \lambda_b H_u \bar{\lambda}_c \rangle \langle \lambda_b Q_L^1 U_R^{12} \lambda_c \rangle$$

But we have to sum over all possible discs with matter and charged zero modes inserted.
$\longrightarrow$ additional contributions from the same instanton:

Flavour Violation from D-instantons

Instanton vertices

R. Blumenhagen, A. Deser, D. Lüst, to appear



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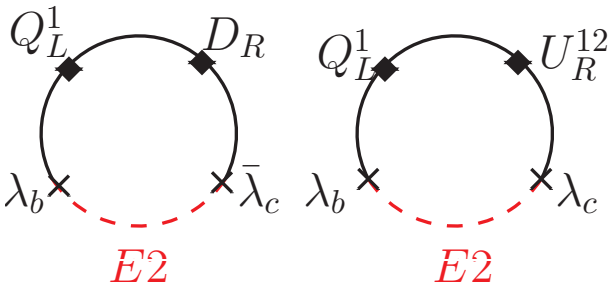

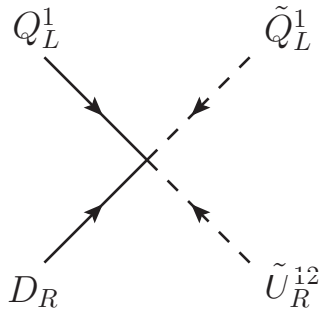

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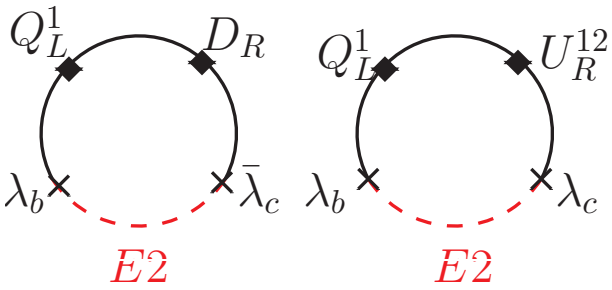

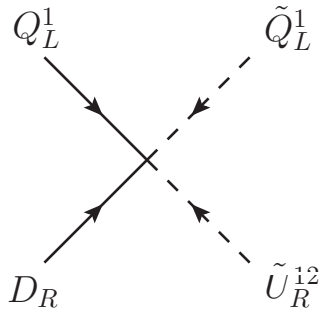

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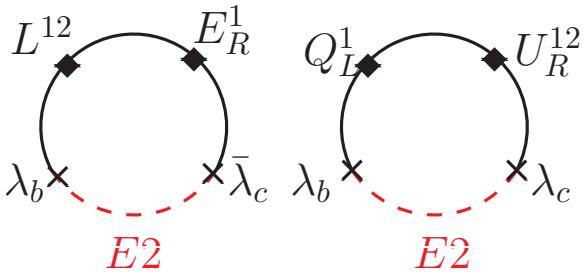

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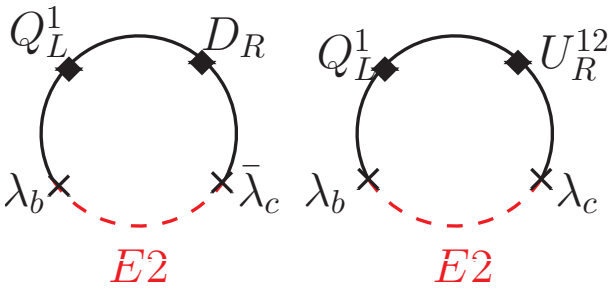

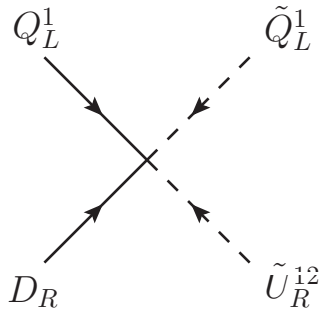

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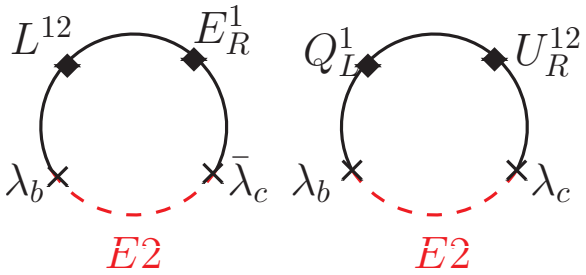

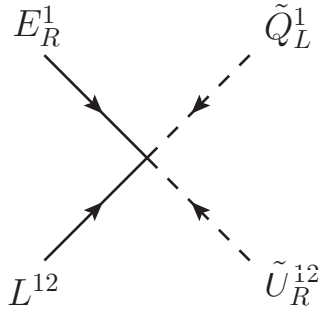

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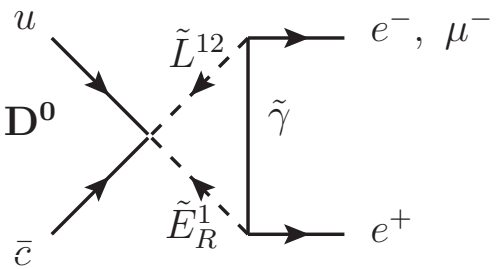

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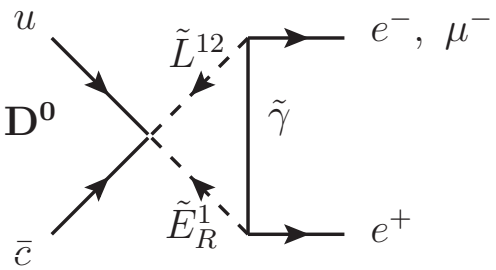

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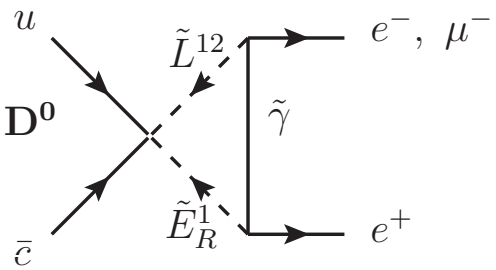

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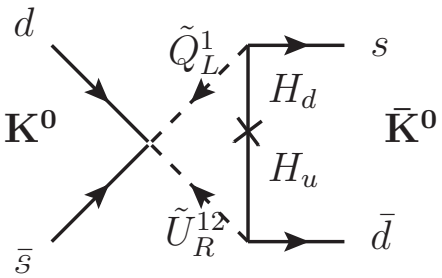

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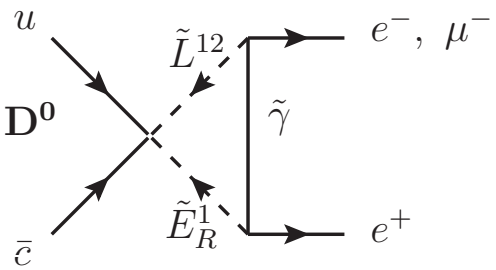

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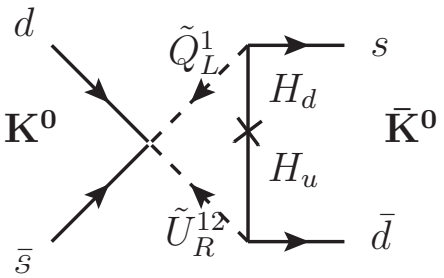

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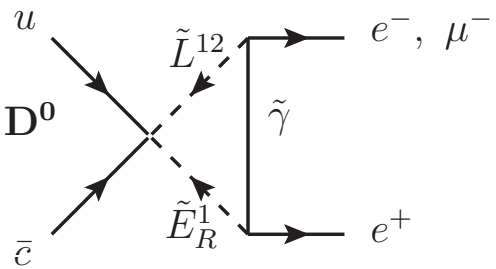

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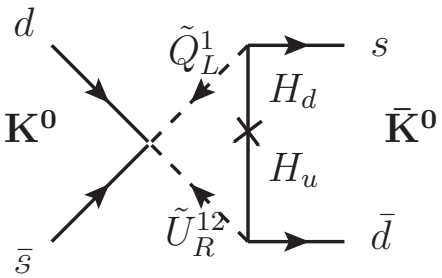

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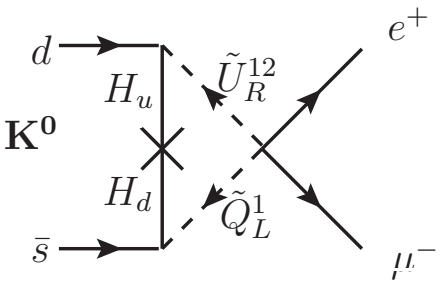

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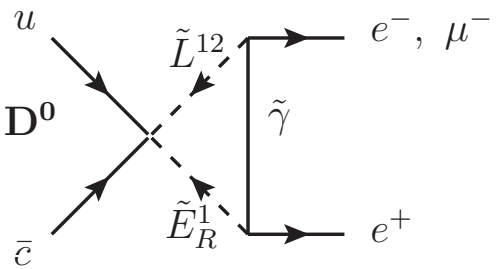

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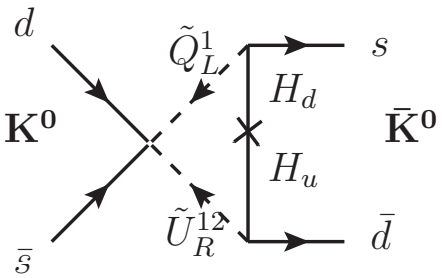

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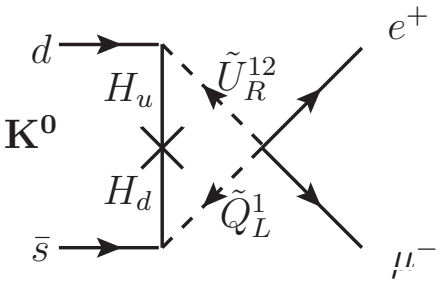

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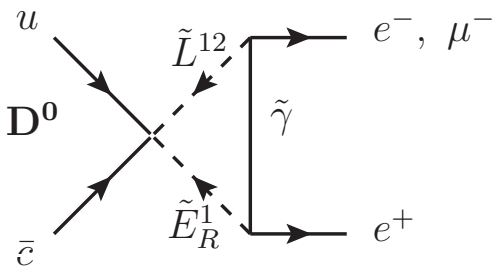

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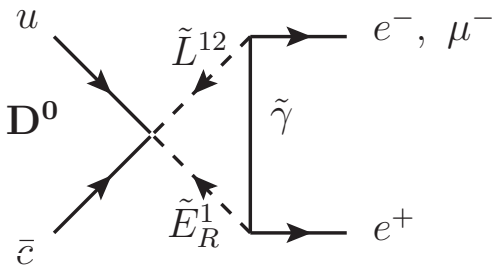

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- $\to$ estimate M_s from below:

$$M_s > 10^{-7}\mathrm{TeV} \quad \text{with norm.} \ \frac{1}{M_s^{\frac{2}{3}} M_P^{\frac{1}{3}}}$$

$$M_s > 2\mathrm{TeV} \quad \text{with norm.} \ \frac{1}{M_s}$$

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- If the order of magnitude of the instanton vertex is fixed (e.g. by an instanton required for Yukawa couplings) we get lower bounds on the string mass.

Thank you!