Flavour Changing Neutral Currents in Models with Intersecting D-branes

Exotic Signals at Hadron Colliders
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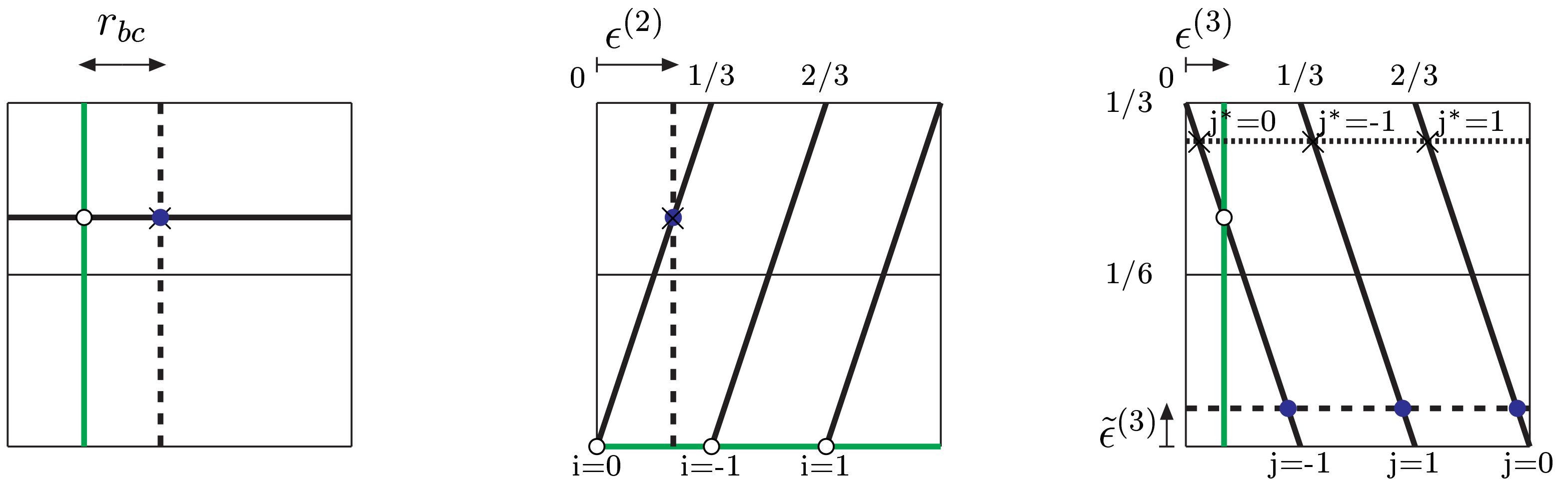
Outline

- Introduction: models with intersecting D-branes
  - Low energy spectrum
  - Yukawa couplings
- Flavour Changing Neutral Currents
  - Kaluza-Klein origin
  - String origin
- Phenomenological discussion: bounds on the string scale
- Conclusions

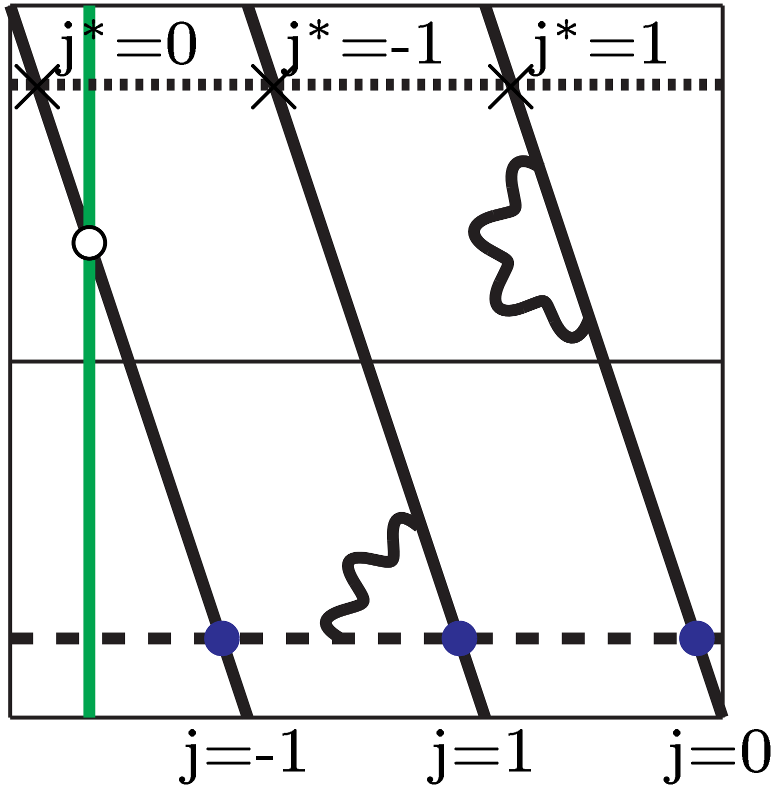
Models with intersecting D6-branes

- Type II string theory in 10-dim space-time with 6 dimensions compactified on $T^6 = T^2 \times T^2 \times T^2$ with four stacks of D6-branes wrapping 3-cycles on the tori (one per tori) with non-trivial angles between them



- Possible wrapping numbers (*i.e.* spectrum) are determined by consistency conditions (absence of RR tadpoles).

- Gauge bosons of $U(N)$ (or $SO(N), Sp(2N)$) live in the world-volume of the branes: 7-dim fields ⇒have KK excitations
- Massless chiral fermions, transforming as bifundamentals, plus (generally massive) scalars live at the intersections of different stacks of branes (spectrum generically non-supersymmetric). Multiple wrappings ⇒family replication
- Yukawa couplings are proportional to (minus the exponential of) the area of the triangle among the intersections of the two fermions and the Higgs


j* =0
j* =-1
j* =1
j=-1
j=1
j=0

FCNC: KK origin

- Family replication through multiple wrappings: split fermions

$$\mathcal{L}_5 = -\frac{1}{4}F^{MN}F_{MN} + \mathrm{i}\,\bar{f}_i\gamma^\mu D_\mu f_i\;\delta(y - y_i)$$

- KK reduction

$$A_\mu(x,y) = \frac{A_\mu^{(0)}(x)}{\sqrt{L}} + \sqrt{\frac{2}{L}}\sum_{n=1}^{\infty}\left(A_\mu^{(n)}(x)\,\cos\frac{2\pi n y}{L} + A_\mu^{\prime(n)}(x)\,\sin\frac{2\pi n y}{L}\right)$$

- Non-universal couplings to KK gauge bosons

$$\mathcal{L} = -\frac{1}{4}\mathcal{K} + \frac{1}{2}\sum_{n=1}^{\infty}\left(\frac{2\pi n}{L}\right)^2\left(A_\mu^{(n)2} + A_\mu^{\prime(n)2}\right)$$
$$+\,\mathrm{i}\,\bar{f}_i\gamma^\mu\left[\partial_\mu + \mathrm{i}gA_\mu^{(0)} + \mathrm{i}g\sqrt{2}\sum_{n=1}^{\infty}\left(c_n^{(i)}A_\mu^{(n)} + s_n^{(i)}A_\mu^{\prime(n)}\right)\right]f_i$$

- In the physical basis

$$\underset{\text{current}}{f_i} = U_{ia} \underset{\text{mass}}{f_a} ,$$

non-universal couplings induce FCNC

$$\mathcal{L} \sim \sum_n \left[A_\mu^{(n)} \bar{f}_a \gamma^\mu \boxed{U^\dagger_{ai} g_i^n U_{ib}} f_b + A'^{(n)}_\mu \bar{f}_a \gamma^\mu \boxed{U^\dagger_{ai} g'^{\,n}_i U_{ib}} f_b \right] + \ldots$$

- At low energies four-fermion interactions are generated

$$\mathcal{L} = c_{abcd} \, (\bar{f}_a \gamma^\mu f_b)(\bar{f}_c \gamma_\mu f_d)$$

with coefficients

$$\boxed{c_{abcd} = -g^2 \sum_{ij} U^\dagger_{ai} U_{ib} U^\dagger_{cj} U_{jd} \sum_n \frac{\cos[M_n(y_i - y_j)]}{M_n^2}}$$

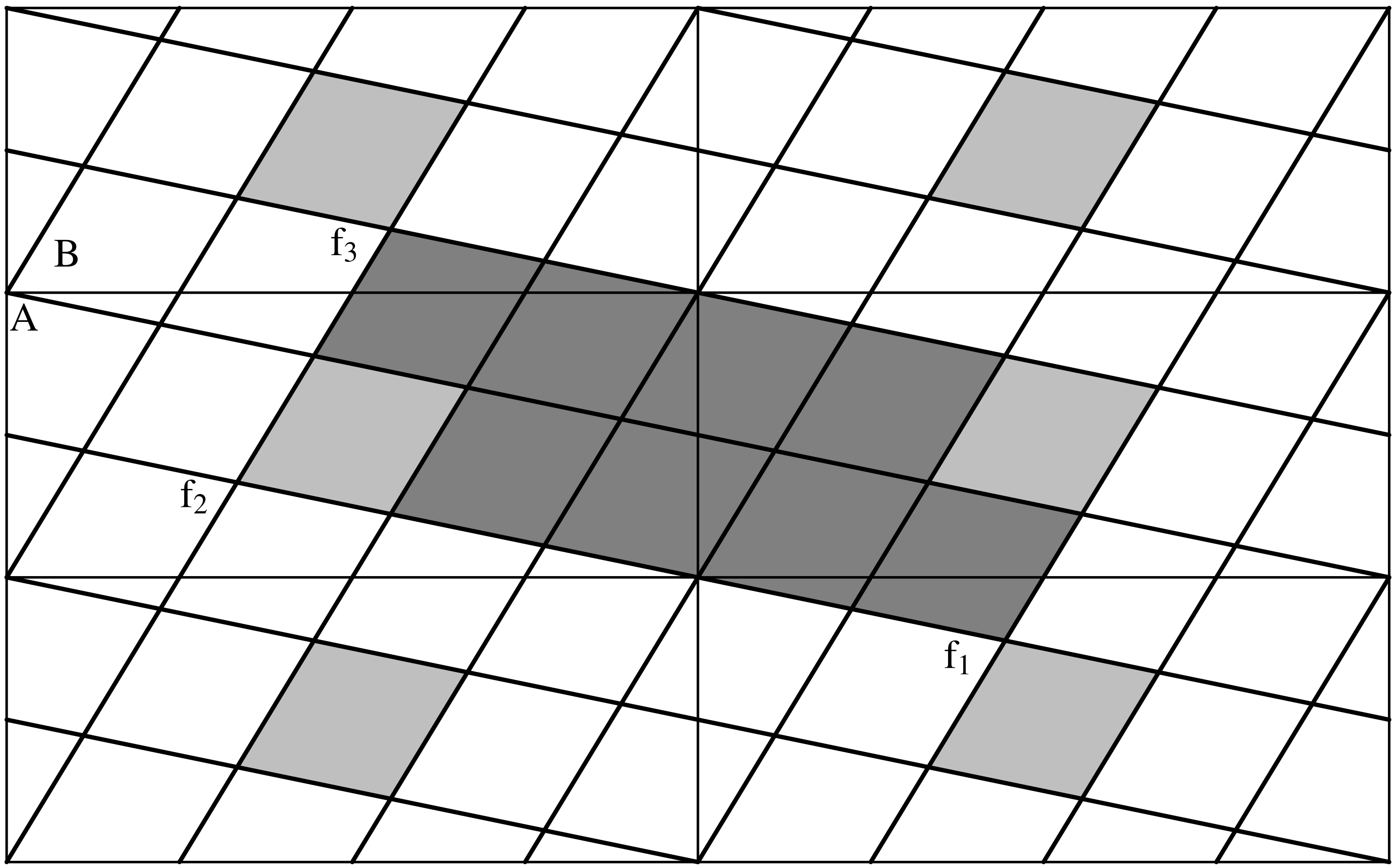
FCNC: String origin

- It is possible to perform the tree level string calculation of four-fermion interactions with branes at angles Abel and Owen; Cvetic and Papadimitriou
- Technology similar to closed string twisted states
- Classical part can be worked out

$$\mathcal{A}(1,2,3,4) \sim \sum \mathrm{e}^{-S_{\mathrm{cl}}}$$

with $S_{\mathrm{cl}} \sim$ area of the world-sheet

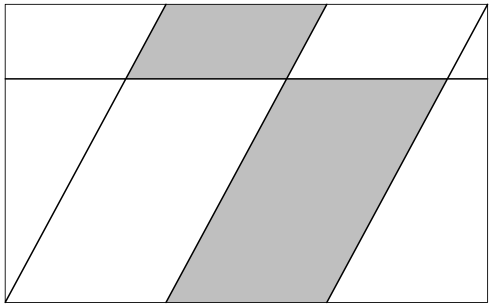
FCNC in D-brane models



FCNC in D-brane models

Two cases

- $\Delta f_A, \Delta f_B \neq 0 \Rightarrow$ New stringy source of FCNC ($\tau \to e e \mu$)



$$\boxed{\mathcal{A}(\tau \to e e \mu) \sim \left(\frac{l_s}{L}\right)^2 \frac{1}{M_s^2} \mathrm{e}^{-A/(2\pi l_s^2)}}$$

- $\Delta f_A = 0$ (equiv Δf_B) $\Rightarrow$ we recover the KK contribution

$$\mathcal{L} \sim [\bar{u}^{(i)} \gamma^\mu u^{(i)} \bar{u}^{(j)} \gamma_\mu u^{(j)}] \Big(\frac{1}{s} + 2 \sum_n \frac{\cos[M_n(y_i - y_j)] \delta^{-l_s^2 M_n^2}}{s - M_n^2} \Big)$$

Phenomenological discussion

We have found two different sources of FCNC with different $\boxed{l_s/L}$ dependence

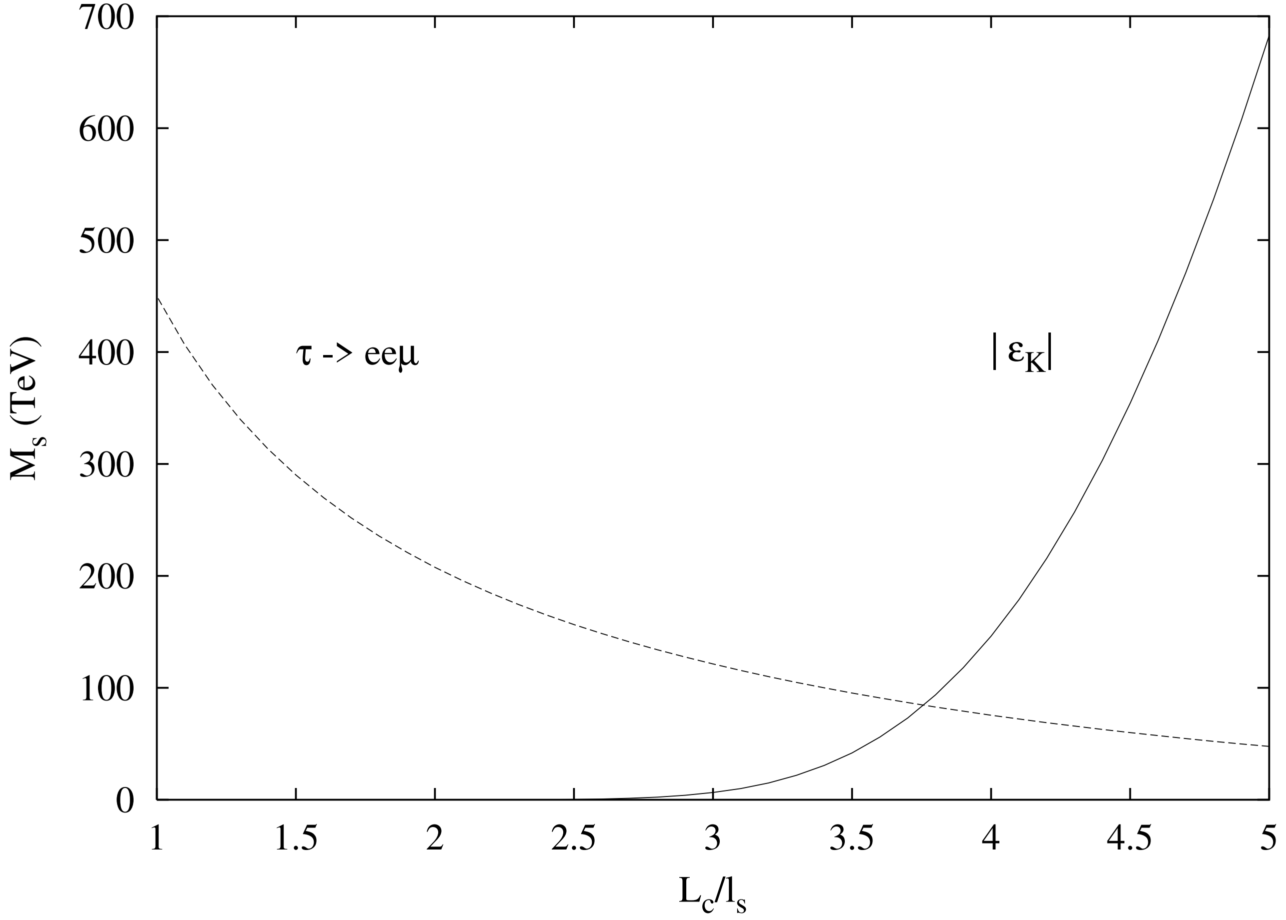
- Gauge boson KK modes

$$c_{\mathrm{KK}}^{\mathrm{reg}} \sim \sum_n \left(\frac{L}{2\pi n}\right)^2 \delta^{-(2\pi n l_s/L)^2}$$

- Excited string states

$$c_{\mathrm{Str}} \sim \left(\frac{l_s}{L}\right)^2 \frac{1}{M_s^2} \mathrm{e}^{-A/(2\pi l_s^2)}$$

FCNC in D-brane models



Conclusions

- Models with intersecting D-branes give rise to realistic models: chiral fermions, SM spectrum, family replication
- FCNC are generated not only at M_s (string source) but also at M_c (KK source)
- They can be computed through a full string calculation (recovers and complements the field theory calculation)
- Different contributions impose a tight bound on the string scale

$$\boxed{M_s \gtrsim 100 \text{ TeV}}$$

- Processes relevant for hadron colliders can be computed in low scale string theory