LEP II constraints on brane models with bulk leptons

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Extra Dimensions and Constraints from Electroweak Physics

- Two popular scenarios
  - All fermions on the brane, only gauge bosons and/or Higgs in the bulk

    Pomarol & Quiros, 1998, Nath & Yamaguchi, 1999, Masip & Pomarol, 1999

  - Everything in the bulk, Universal Extra dimensions (UED)

    Appelquist, Cheng & Dobrescu, 2000

Electroweak Constraints

- Brane fermions scenario: Strict constraints on the size of the extra dimension
- For 1 extra dimension:
  - Gauge bosons in the bulk: M_c~4.5 TeV (EWPT), M_c~6.3 TeV (LEP-II) at 95% CL
  - Gauge bosons + Higgs in the bulk: M_c~3.8 TeV (EWPT), M_c~6.3 TeV (LEP-II) at 95% CL

  Barbieri, Pomarol, Rattazzi & Strumia, 2004
- Universal extra dimensions: Less severe constraints
  - For 1 extra dimension, M_c~300-600 GeV (Heavier Higgs alows for lower values)

  Gogoladge & Macesanu, 2004

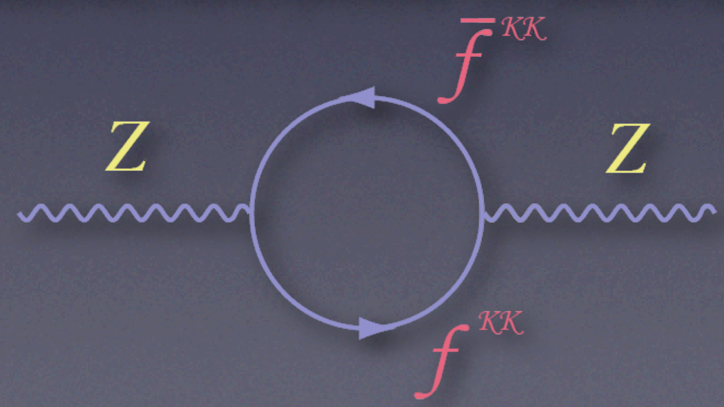
Electroweak Constraints

Bulk Gauge Boson Theories

- Corrections from KK modes appear in tree level processes ⇒ severe constraints on M_c

UED

- KK number conservation only allows processes with pairs of KK particles ⇒ less constrained



Alternative Scenarios

- 600 GeV - 6.3 TeV is rather larger domain. The two models lie on the two ends of the spectrum.
- 600 GeV is at the limits of Tevatron. 6.3 TeV is even beyond LHC territory.

Macesanu, McMullen & Nandi, 2002

- Are there possible models in the middle ground?

Bulk Lepton Model

- Well motivated from string theory.
- UED not a natural choice in the context of strings - weak and strong interaction branes extend in different directions inside the compactified space.
- Weak/strong coupling ratio can be retrieved if we assume an additional dimension for the weak brane. Lepton and Higgs sector propagate in this extra dimension.

Possible Electroweak Constraints

- No tree level KK processes present (same as UED) ⇒ Automatically less constrained compared to the bulk gauge boson models.

- Oblique corrections? Can we get constraints from there?

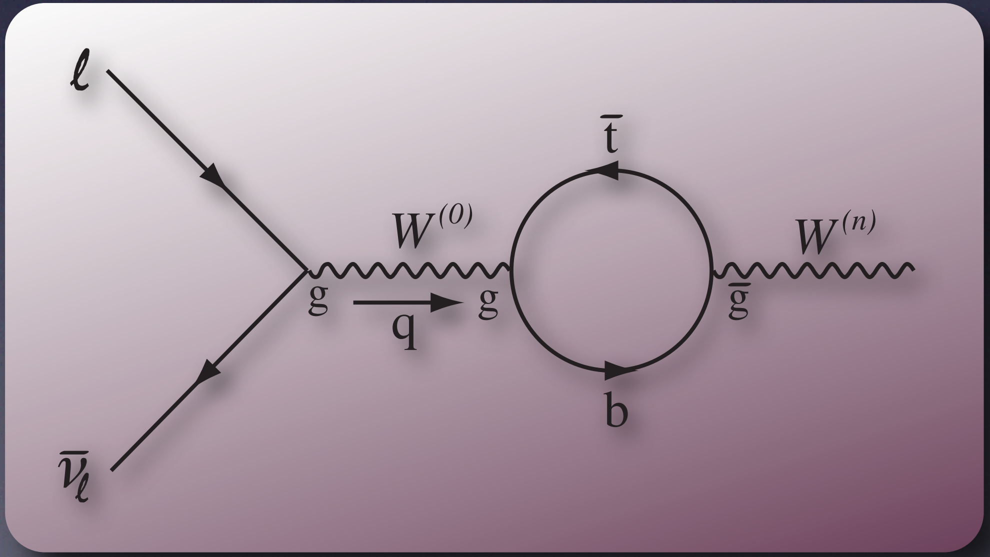
- Answer: Probably not good. In the case of UED, the strongest bound comes from

$$T \sim \frac{1}{\alpha}\frac{3m_t^2}{8\pi^2 v^2}\frac{2}{3}\frac{m_t^2}{M_c^2}$$

for a top quark with KK modes. But now the top has no KK states, only leptons of very small mass do. We expect the correction to be negligible.

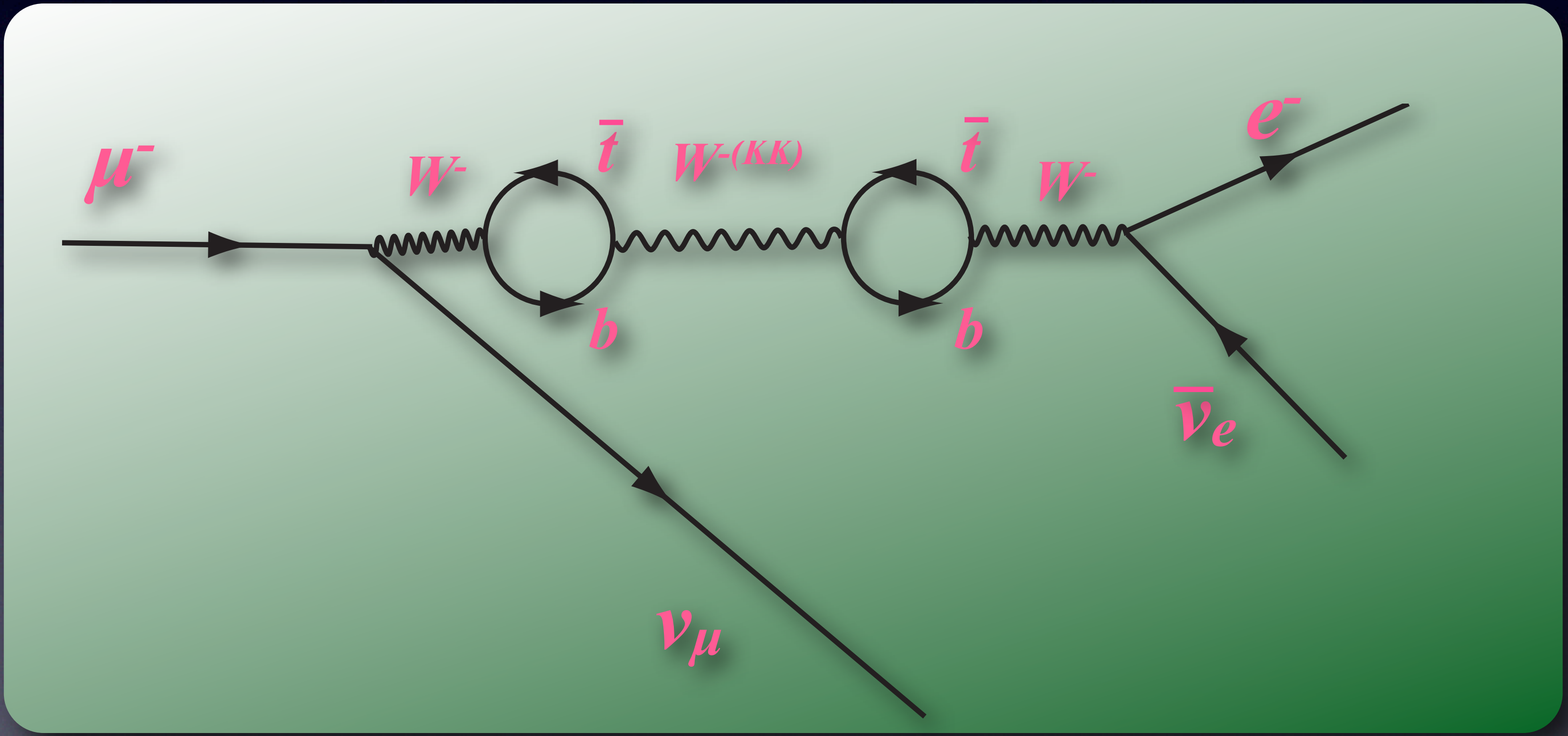
Possible Electroweak Constraints

- Only quark vertices can break KK number conservation. KK vector bosons can be emitted in this case.
- We are interested in diagram containing a quark bubble with a KK vector boson propagator attached to it.



Relevant Processes

- Easiest to examine: Fermi constant
- In this case, it receives KK corrections only from 2-loop quark diagrams



Estimated bound from Fermi Constant: $M_c \geq 320$ GeV

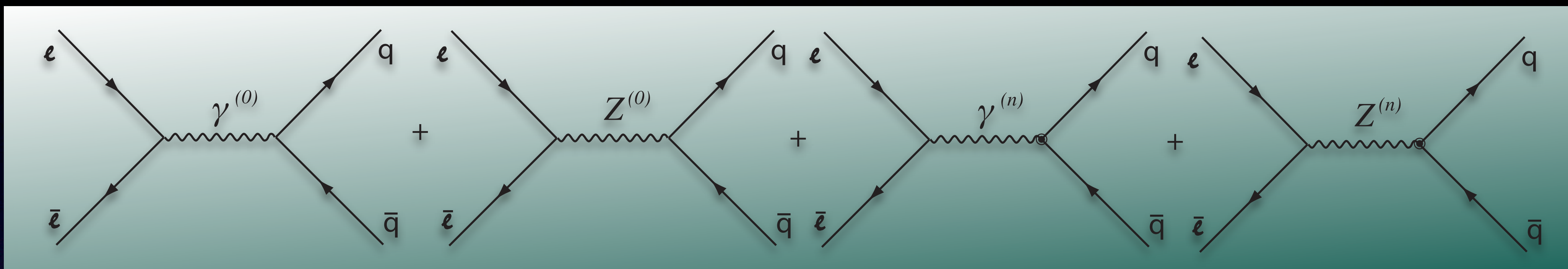
Relevant Processes

- Best constraints from processes with only one intermediate quark loop.
- Suitable electroweak observables:
  - ✓ σ_h
  - ✓ R_b
  - ✓ R_c
  - ✓ Forward-Backward Asymmetry
- Fit Using LEP-II data (up to 207 GeV)

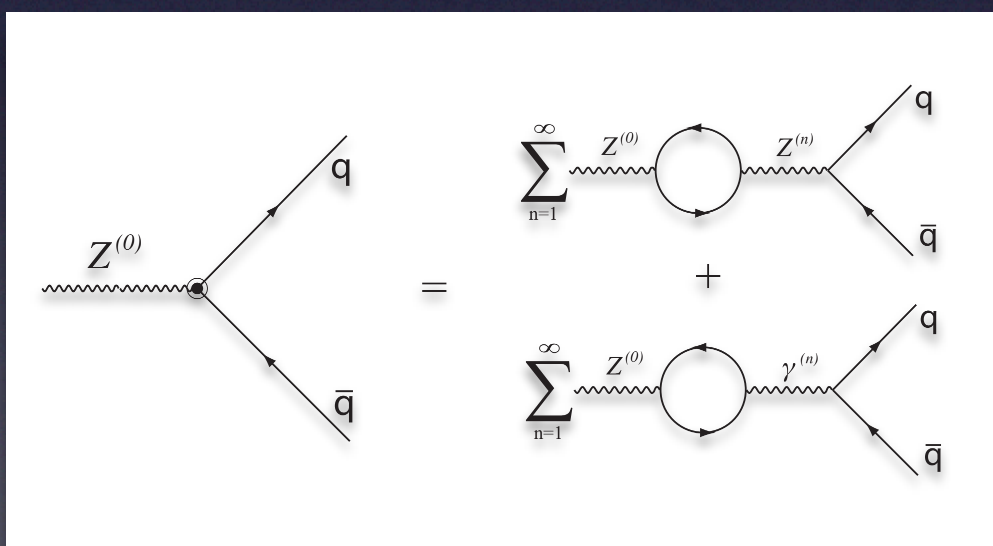
Total Hadronic Cross-Section

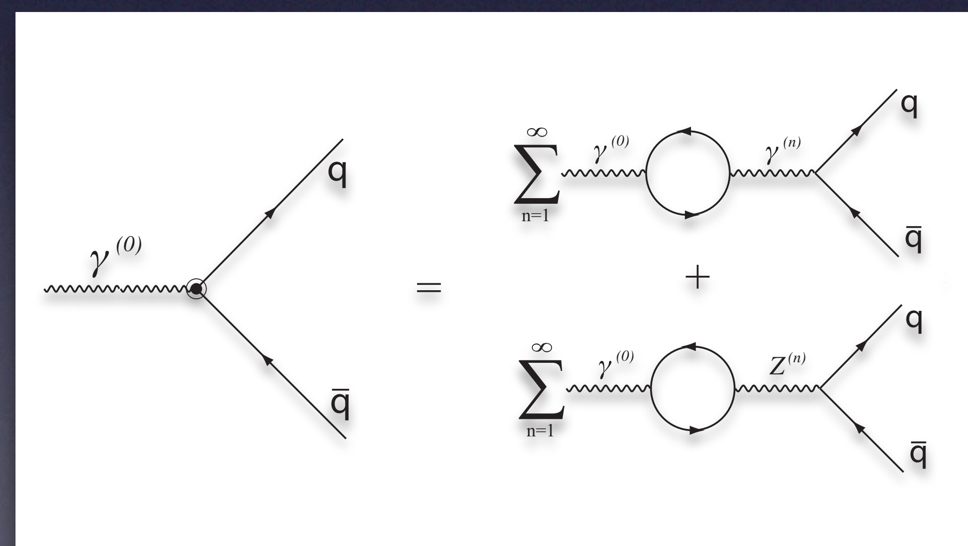
- We need to define form factors for the diagram involving 1-loop corrections and KK vector boson propagators
- 2 ways to do this:
  - Define effective ee vertices (suitable for calculating corrections to Fermi Constant)
  - Define effective qq vertices (suitable for total hadronic cross-section)

Relevant Diagrams



Form Factor Diagrams





Total Hadronic Cross-Section

- Results depend logarithmically on the cutoff Λ of the theory
- For LEP-II data, M_c ~ 750 - 1100 GeV depending on Λ (assume 2 - 10 TeV)
- R_b and R_c seem at this point unable to provide a better constraint

Further Developments

- Include contributions from quark vertex corrections
- Check forward-backward asymmetry
- Find and compare similar constraints from LEP-I
- Verify that oblique corrections from KK leptons are negligible
- Include the mass of the Higgs as a parameter of the fit