Universal Extra Dimensions Search at SPRACE

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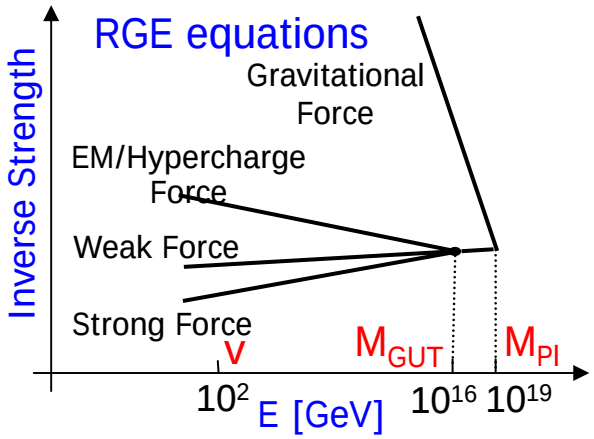
DOSAR Workshop at U.T. Arlington

Physics Analysis at SPRACE

- We are starting our first physics analysis at SPRACE in close collaboration with Greg Landsberg from Brown University
- We intend to explore the signatures of Universal Extra Dimensions at D0
- We started with an initial warmup doing some analysis exercises (e.g. Z peak cross section evaluation) in order to get used with the D0 analysis tools;
- Greg Landsberg will make his second visit to São Paulo in the next week in order to discuss the first steps of the UED analysis.

Physics Beyond SM



- If SM is the ultimate theory up to GUT scale, an extremely precise fine-tuning is required

- We may conclude that SM is an effective theory, i.e. a low energy approximation of a more complete model that explains things only postulated in the SM
- Extra Dimension Models can solve the hierarchy problem
- In this case, new physics effects should appear in a scale comparable to the mass of the Higgs boson (~ 1 Tev)

Examples of Extra Dimensions Models

- ADD Model (Arkani-Hamed, Dimopoulos, and Dvali): hides the hierarchy problem by making gravity as strong as other gauge forces in (4+n)-dimensions. Only graviton can access the extra dimensions (n>1)

- RS Model (Randall and Sundrum): provides a solution for the hierarchy problem using metric of curved anti-deSitter space. Only graviton can access the extra dimension (n=1)

- Universal Extra Dimensions (Appelquist, Cheng, and Dobrescu): in this model the extra dimensions can be accessed by all SM fields (n=1,2,...). Gravity is not included in the model

Experimental Constraints on Extra Dimensions Models

- All these models result in rich low energy phenomenology
- Constraints for the ADD Model could be obtained from Gravity experiments, Astrophysical and Cosmological data, and Collider experiments
- For RS and UED Models only Collider experiments could provide interesting limits, dominated by precision electroweak measurements at LEP

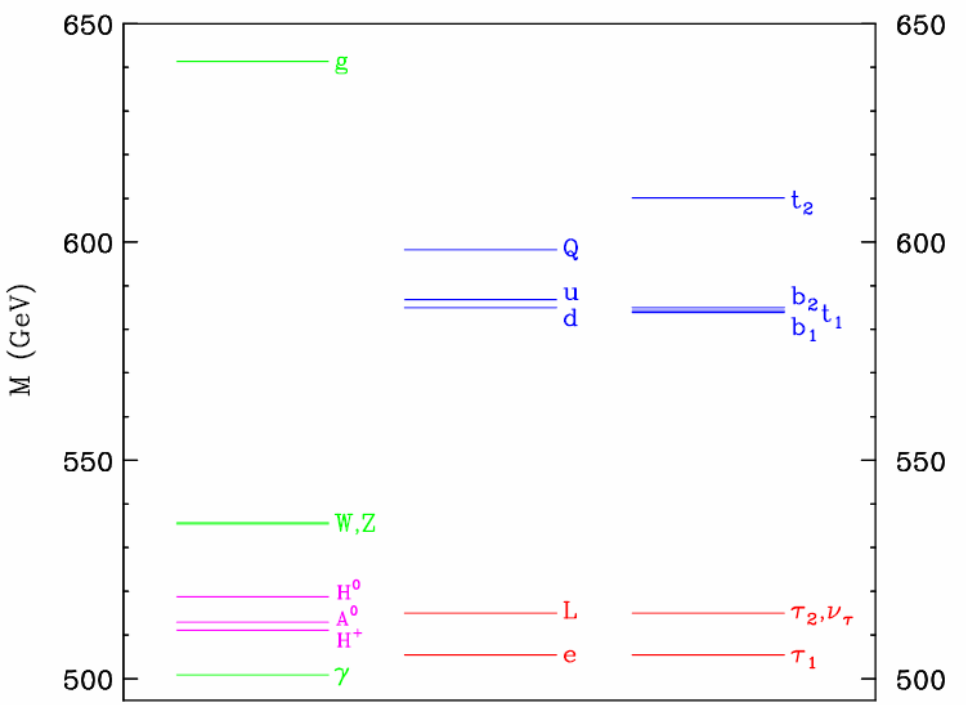
UED Models

- Many theoretical reasons for studying UEDs (electroweak symmetry breaking, proton decay, the number of generations, neutrino masses, etc.)
- All SM fields are free to propagate in EDs with the size $R_c = 1/M_c \sim 1\ TeV^{-1}$
- Instead of chiral doublets and singlets, model contains vector-like quarks and leptons
- The Gravitational force is not included
- The number of ED is not fixed
- All particles acquire Kaluza-Klein (KK) modes with masses $M_n^2 = M_0^2 + n^2/R_c^2$, n = 0, 1, 2, …
- If KK number (n) is conserved at tree level, KK-excitations are produced in pairs, similar to SUSY particles
- Current limits dominated by precision electroweak measurements are low ($M_c = 1/R_c \sim 300$ GeV)

MUED Phenomenology

- Simplest scenario, all SM fields propagating in a single extra dimension
- One would expect large clusters of nearly degenerate states with mass around $1/R_C$, $2/R_C$, ….
- However, as radiative corrections tend to be large, the KK excitation mass spectrum resembles that of SUSY! (Cheng, Feng, Matchev, Schmaltz)
- The pair production of 1-level (KK) modes of quarks and leptons could be tested at Tevatron

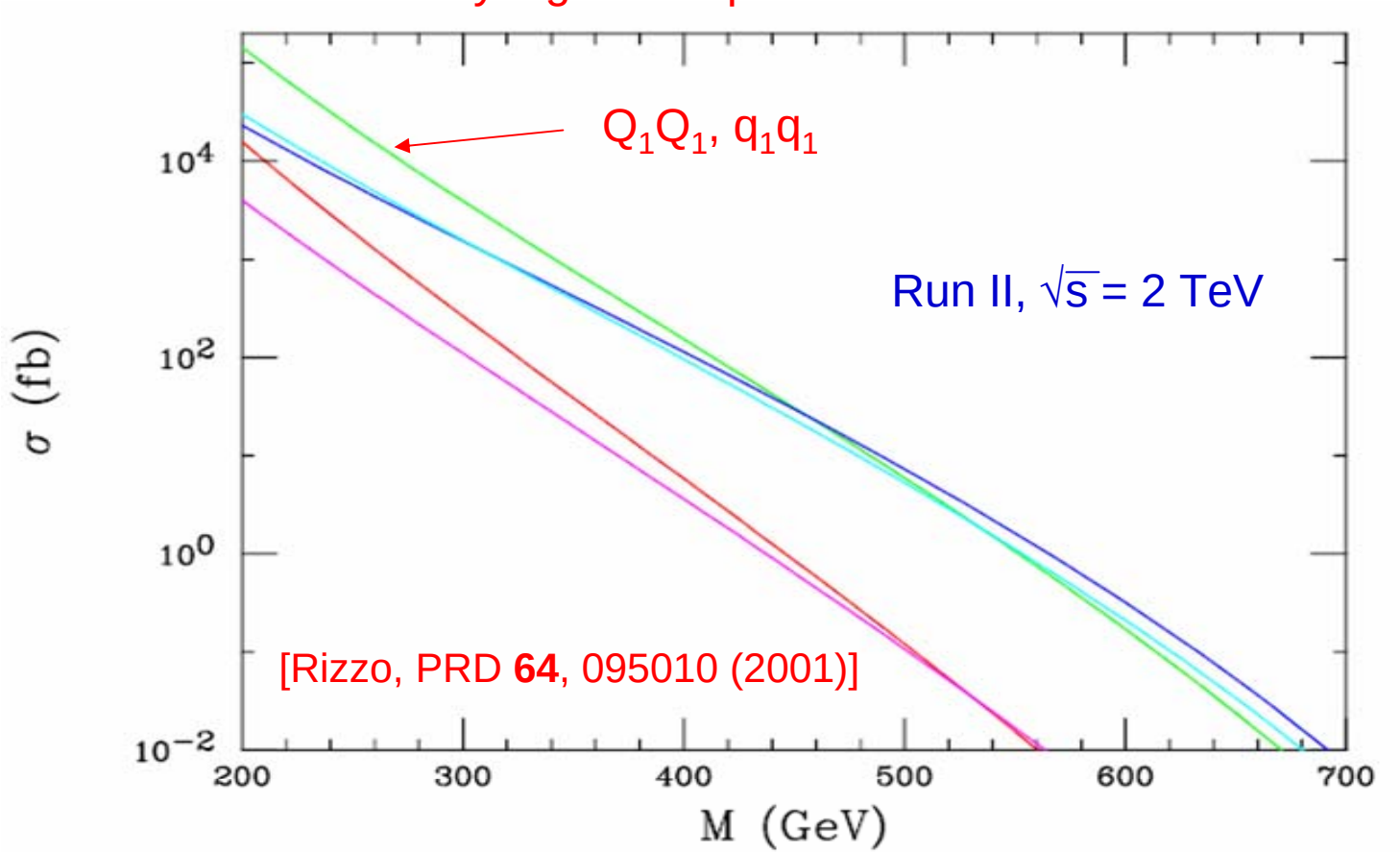
[Cheng, Matchev, Schmaltz, PRD **66**, 056006 (2002)]



- One-loop corrected mass of 1-level (kk) modes: Q, L (q, l) are SU(2) doublets (singlets) and contain both chiralities

Production Cross Section

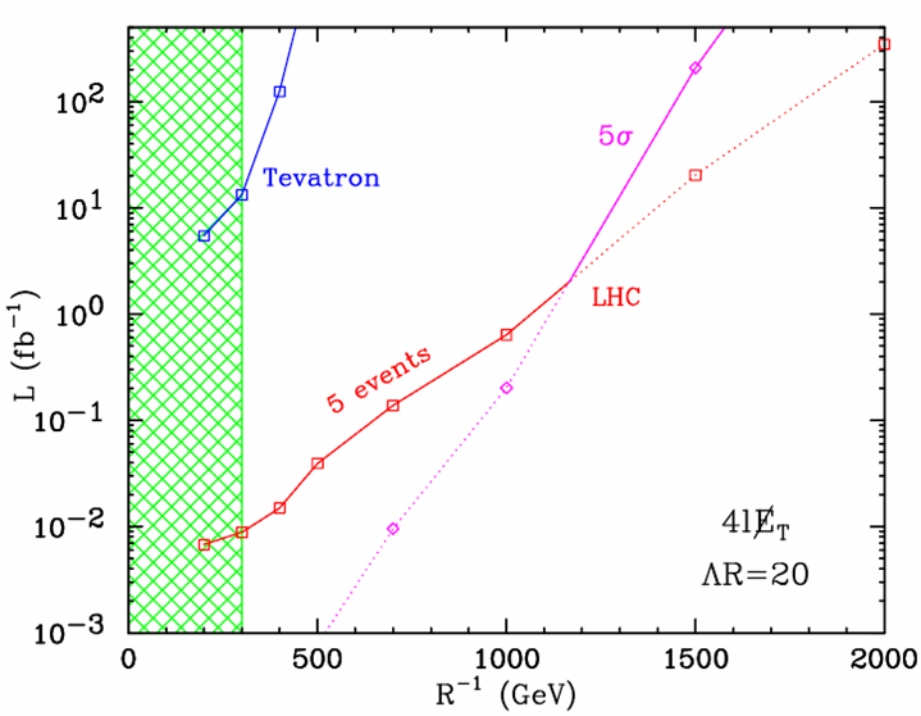
Reasonably high rate up to M ~ 500 GeV



MUED Signatures at Tevatron

- Consider Q_1Q_1 Production ($\sim\sigma^{had}/4$)
  $Q_1Q_1 \rightarrow W_1W_1, W_1Z_1, Z_1Z_1$ + jets
  $\rightarrow$ 2-4 leptons + ME_T
- Only the gold-plated 4-leptons + ME_T mode has been considered in the original paper
- Sensitivity in Run IIb can exceed current limits
- Much more promising channels:
  - dileptons + jets + ME_T + X
  - trileptons + jets + ME_T + X
- Detailed simulations is required
- One could use SUSY production with adjusted masses and branching fractions as a quick fix

[Cheng, Matchev, Schmaltz, PRD **66**, 056006 (2002)]



Discovery reach for MUEDs

2UED Phenomenology

- The case of two ED is theoretically attractive, as it breaks down to the chiral SM and has additional nice features (proton stability, etc.)
- Level-2 (KK) Modes of the gauge bosons can be tested at Tevatron
- Considering kk-number violating interactions, a level-2 KK mode can be produced in the s-channel
- These level-2 modes decay mainly into a pair of SM particles giving rise to a high transverse momentum signal

[Burdman, Dobrescu, Pontón, hep-ph/0601186]

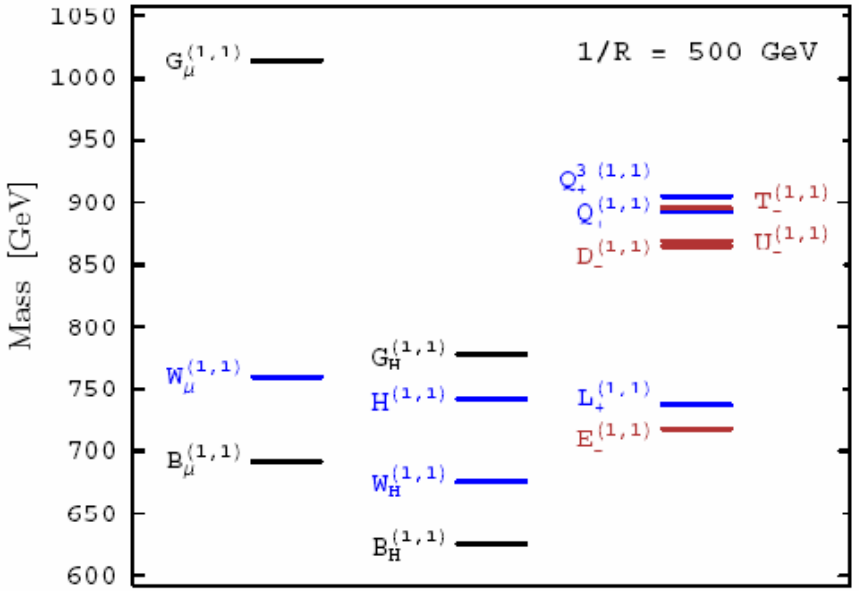


FIG. 1: Mass spectrum of the (1,1) level for $1/R = 500$ GeV. Electroweak symmetry breaking effects are small, and have not been included.

Production Cross Section

[Burdman, Dobrescu, Pontón, hep-ph/0601186]

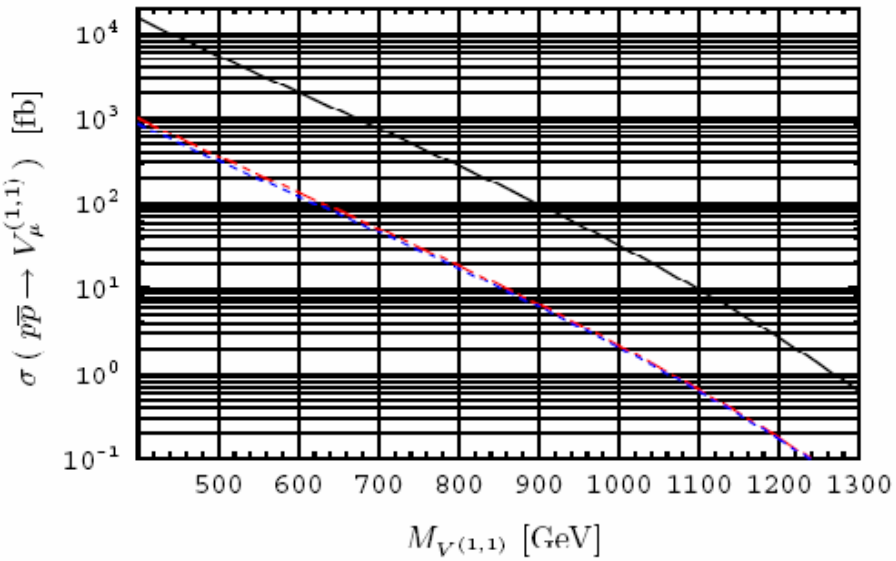


FIG. 3: Production cross sections for $(1,1)$ vector modes in the s channel at the Tevatron, as a function of their mass. The solid line is for $G_\mu^{(1,1)}$, while the dashed and dotted (lowest) lines are for $W_\mu^{(1,1)3}$ and $B_\mu^{(1,1)}$, respectively (accidentally, the cross sections for these two are close to each other such that they might not be distinguishable).

2UED Signatures at Tevatron

[Burdman, Dobrescu, Pontón, hep-ph/0601186]

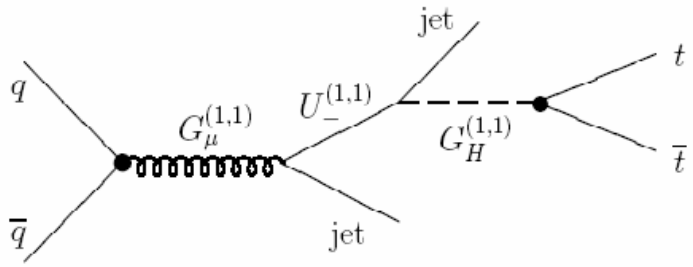


FIG. 4: Production of the vector (1,1) gluon followed by a cascade decay. The • stands for a KK number-violating coupling. Other diagrams having the same topology exist: the $U_-^{(1,1)}$ quark KK mode may be replaced by $D_-^{(1,1)}$, $Q_+^{(1,1)}$, or the corresponding antiquarks; in addition the spinless gluon $G_H^{(1,1)}$ may be replaced by $B_\mu^{(1,1)}$ or $B_H^{(1,1)}$, and in the case where the quark KK mode is an $SU(2)_W$ doublet, by $W_\mu^{(1,1)3}$ or $W_H^{(1,1)3}$.

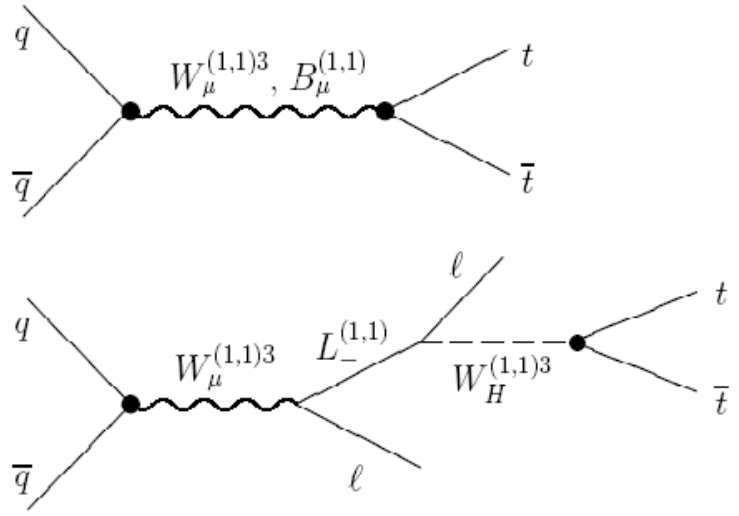


FIG. 5: Production of W_μ^3 and B_μ (1,1) modes, followed by representative decays.

- t tbar resonances could be observed taking into account realistic t tbar pair mass resolution
- A limit on 1/R in the 320-450 GeV range may be imposed with 4 fb^{-1}

Summary

- Mininal UED Model promising channels:
  - 4-leptons + ME_T
  - dileptons + jets + ME_T + X
  - trileptons + jets + ME_T + X
  - Run II will increase the Run I limit (1/R ~ 280 GeV) and precision electroweak measurements (1/R ~ 300 GeV)

- 2 UED Model promising channels:
  - t tbar, t tbar + 2jets, t tbar + 2 leptons
  - t tbar resonances could be observed taking into account realistic t tbar pair mass resolution
  - A limit on 1/R in the 320-450 GeV range may be imposed with 4 fb^{-1}

- Discuss with Greg Landsberg in the next weeks the first steps of the UED analysis