Hunting mirror mesons at the LHC

George Triantaphyllou

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Motivation

- After several decades of research,
  we have at last direct evidence of the BEH mechanism
- but: $M_{Planck}/M_{BEH} \sim 10^{17}$
- What preserves such a huge hierarchy?
- If this hierarchy reflects an energy "desert", the LHC is one of our last chances, for many decades to come, to find indirect clues for Planck-energy Physics in particle accelerators

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Outline

1. Motivation
2. Inductive approach
   - Hierarchy stabilization and extrapolation to M_{Planck}
   - Mirror fermions: a promising alternative
3. Katoptron phenomenology
   - General considerations
   - Mirror meson decays at the LHC
4. Conclusions

Some known solutions

- Large extra dimensions
  Stabilizer: **size** of extra dimensions
- Known particles have spin-zero partners (SUSY)
  Stabilizer: **space-time symmetry** - Interaction: weak
- Known particles have mirror partners (Katoptrons)
  Stabilizer:**gauge symmetry** - Interaction: strong

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Previous work

- T.D. Lee and C.N. Yang (1956): Mirror fermions
- J.C. Pati and A. Salam (1973): Coupling unification
- F. Gursey and P. Sikivie (1976): E_7 GUT
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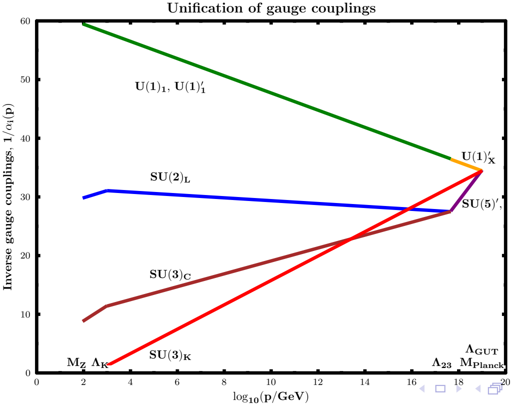
Gauged mirror-family symmetry: strong at 1 TeV $\sim$ $M_{\rm Planck} \exp\left(-1/\alpha_{GUT}\right)$: G.T., *EJTP* **10** (2013) 135.

$$E_8 \times E_8'(M_{Planck}) \to SU(3)_C \times SU(2)_L \times U(1)_1 \times SU(3)_K(1\ \mathrm{TeV}) \to$$

$\to$ Standard Model



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Experimental signatures @ the LHC

- Direct: Bosonic (spin 0,1) bound states of mirror fermions
  QCD analogues: Mirror $\sigma \sim \sigma^K$, Mirror $\rho \sim \rho^K$

  ATLAS and CMS excesses @ 0.125 (σ^K) & 1.9 (ρ^K) TeV

- Indirect: Deviations from SM due to radiative corrections $\rightarrow$

  Importance of heavy fermions:
  - top (and bottom)-quark left-right asymmetries
  - V_{tb} not assuming 3×3 CKM matrix unitarity
  - lepton universality

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The (parity-odd) spectrum

- Color singlets:
  $\pi^{K\ 2\ 0}$ and $\pi^{K\ 2\ \pm}$, "eaten" by Z^0, $W^{\pm}$

  $\pi^{K\ 1\ 0}, \quad \pi^{K\ 1\ \pm}, \quad \pi^{K\ 1\ 0\prime}, \ \eta^K \ \ (\text{spin}-0)$
  $\rho^{K\ 1,2\ 0}, \ \rho^{K\ 1,2\ \pm}, \ \rho^{K\ 0\prime}, \ \ \omega^K \ \ (\text{spin}-1)$

- Color triplets (leptoquarks):
  $\pi_3^{K\ 1,2,2\prime,5}, \ \bar{\pi}_3^{K\ 1,2,2\prime,5} \ (\text{spin}-0)$
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- SM-fermion mass generation from broken $SU(3)_K$ katoptron-family symmetry $\rightarrow$

  Doubling of the mirror-meson spectrum $\rightarrow$ heavy (group "B") and light (group "A") mirror mesons:

  $$r = M_B/M_A \sim \exp\Big(3(C_2(SU(3)_K) - C_2(SU(2)_K))\Big) \sim 5.75$$

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  Offers solution to the S-parameter problem.

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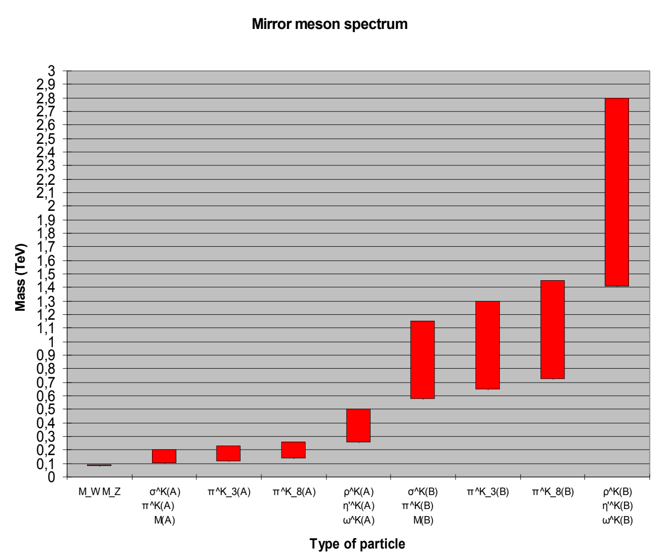
Group A &B mirror-meson mass spectra



Outline

Most promising processes

- $gg \longrightarrow \pi_{8\ (A)B}^{K\ 0\prime} \longrightarrow (\bar{b}b)\ \bar{t}t$
- $gg \longrightarrow \sigma_{(A)B}^{K\ 0} \longrightarrow (\bar{b}b)\ \bar{t}t,\ \gamma\gamma$
- Acollinear $\bar{f}_i f_i$ jets:

$$gg \longrightarrow \text{direct},\ g,\ \rho_{8\ B}^{K\ 0\prime} \longrightarrow \pi_{8\ B}^{K\ +}\ \pi_{8\ B}^{K\ -} \longrightarrow \bar{b}t + \bar{t}b$$
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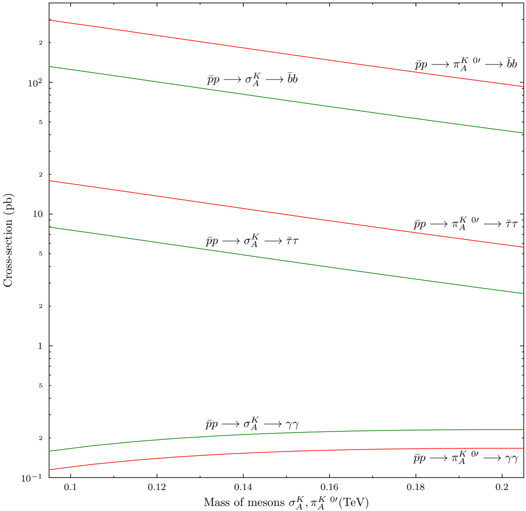
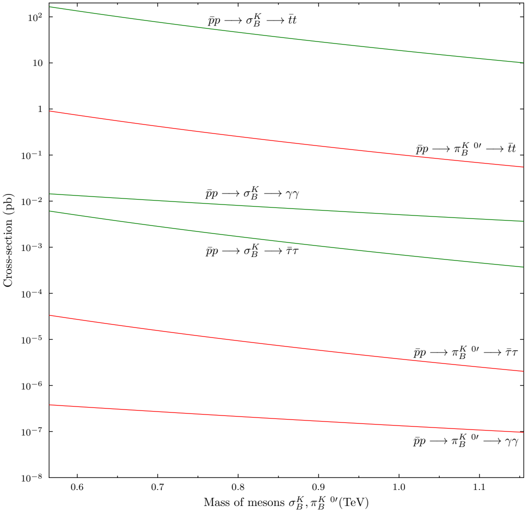
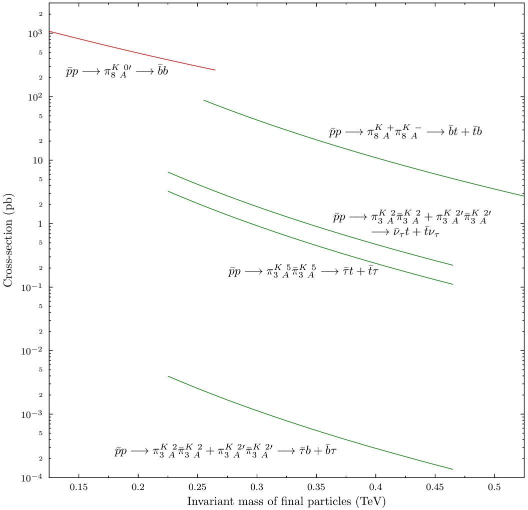
Important A-mirror-meson processes



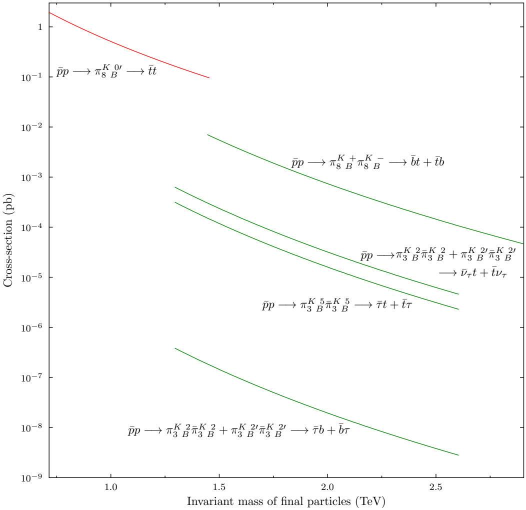
Important B-mirror-meson processes



Color-octet & color-triplet A-mirror mesons



Color-octet & color-triplet B-mirror mesons



Conclusions

- Development of a viable effective BEH mechanism involving strongly-interacting mirror fermions (katoptrons)
- Particularly rich mirror-meson LHC phenomenology $\rightarrow$ Holistic approach in order to differentiate competing models predicting similar signals
- Confirmation of katoptron theory would underline the need for a 3-4 TeV leptonic collider
- Explore quantum-gravity implications related to space-time discreteness and the optimal connectivity principle

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SM fermions and their mirror partners