Detection of mirror-meson decays at CERN

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Motivation

- What hides behind the BEH mechanism?
- What causes the $M_{Planck}/M_{BEH} \sim 10^{17}$ hierarchy?
- The LHC has started producing interesting results

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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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- T.D. Lee and C.N. Yang (1956): Mirror fermions
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- S. Weinberg (1976), L. Susskind (1979):
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The Katoptron Lagrangian

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\begin{aligned}
\mathscr{L} &= \mathscr{L}_{YM} + \mathscr{L}_{int} \\
\mathscr{L}_{YM} &= -\frac{1}{4} B_{\mu\nu} B^{\mu\nu} - \frac{1}{4} W^a_{\mu\nu} W^{a\ \mu\nu} - \frac{1}{4} G^e_{\mu\nu} G^{e\ \mu\nu} - \frac{1}{4} G^{K\ e}_{\mu\nu} G^{K\ e\ \mu\nu} \\
\mathscr{L}_{int} &= i \sum_{j,k} \left[(\bar{\psi}_u^{j|k}, \bar{\psi}_d^{j|k}) \gamma_\mu \mathscr{D}_k^\mu \begin{pmatrix} \psi_u^{j|k} \\ \psi_d^{j|k} \end{pmatrix} + (\bar{\hat{\psi}}_u^{j|k}, \bar{\hat{\psi}}_d^{j|k}) \gamma_\mu \hat{\mathscr{D}}_k^\mu \begin{pmatrix} \hat{\psi}_u^{j|k} \\ \hat{\psi}_d^{j|k} \end{pmatrix} \right]
\end{aligned}
$$

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\begin{aligned}
\psi_u^{j|k} &= (N_L^j, U_L^j, N_R^K \delta^{3j}, U_R^K \delta^{3j}) \\
\psi_d^{j|k} &= (E_L^j, D_L^j, E_R^K \delta^{3j}, D_R^K \delta^{3j}) \\
\hat{\psi}_u^{j|k} &= (N_R^j, U_R^j, N_L^K \delta^{3j}, U_L^K \delta^{3j}) \\
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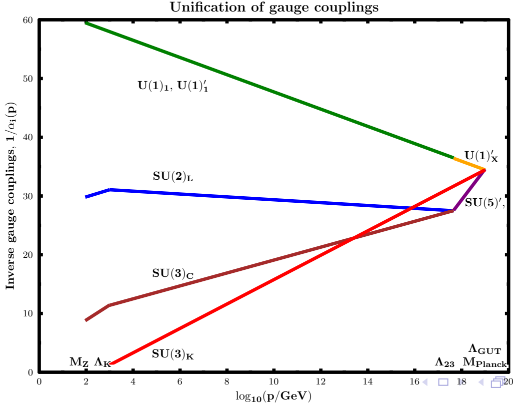
Gauged mirror-family symmetry: strong at 1 TeV $\sim M_{\rm Planck} \exp\left(-1/\alpha_{GUT}\right)$: G.T., *EJTP* **10** (2013) 135.

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

$\to$ Standard Model



The (parity-odd) spectrum

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

  $\pi^{K\ 1\ 0}$, $\pi^{K\ 1\ \pm}$, $\pi^{K\ 1\ 0\prime}$, η^K (spin − 0)
  $\rho^{K\ 1,2\ 0}$, $\rho^{K\ 1,2\ \pm}$, $\rho^{K\ 0\prime}$, ω^K (spin − 1)
- Color triplets (leptoquarks):
  $\pi_3^{K\ 1,2,2\prime,5}$, $\bar{\pi}_3^{K\ 1,2,2\prime,5}$ (spin − 0)
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- Katoptron-family group self breaks:
  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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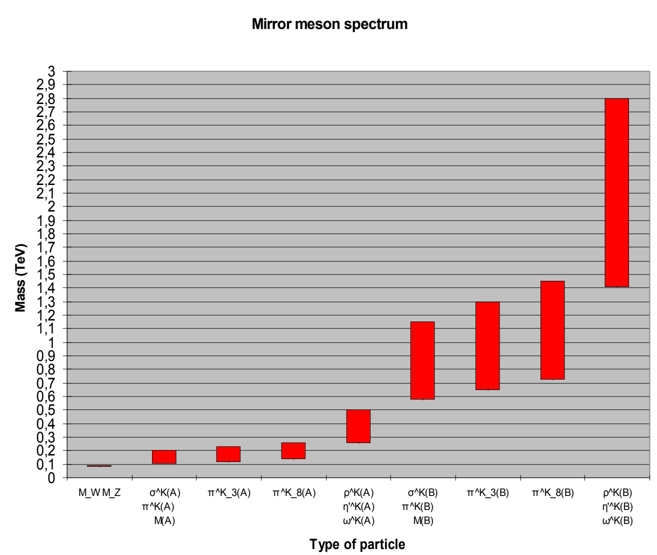
Group A &B mirror-meson mass spectra



Dynamical Masses and the S parameter

$$< \bar{\psi}^{3|3,4}_{u,d} \hat{\psi}^{3|3,4}_{u,d} + \text{h.c.} > \approx -\frac{N_i}{4\pi^2} \int dp^2 M_i(p^2)$$

$$m_f = \begin{pmatrix} m_{SM} & m \\ m & M \end{pmatrix}, \text{with } M \equiv \begin{pmatrix} M_A & 0 \\ 0 & M_B \end{pmatrix} \text{ and } m \equiv \begin{pmatrix} m_{AA} & m_{AB} \\ m_{AB} & m_{BB} \end{pmatrix}$$

$$S = S_A + S_B = 4\pi \sum_A \left(\frac{F^2_{\rho^K_A}}{M^2_{\rho^K_A}} - \frac{F^2_{a^K_A}}{M^2_{a^K_A}} \right) + 4\pi \sum_B \left(\frac{F^2_{\rho^K_B}}{M^2_{\rho^K_B}} - \frac{F^2_{a^K_B}}{M^2_{a^K_B}} \right)$$

$$S_B \approx 4\pi (v/M_{\rho^K_B})^2 \lesssim 0.122 \text{ for } M_{\rho^K_B} > 2.5 \text{ TeV}$$

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Deviations from SM due to radiative corrections

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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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:

$$gg \longrightarrow \text{direct},\ g,\ \rho_{8\ B}^{K\ 0\prime} \longrightarrow \pi_{8\ B}^{K\ +}\ \pi_{8\ B}^{K\ -} \longrightarrow \bar{b}t + \bar{t}b$$
$$gg \longrightarrow \text{direct},\ g,\ \rho_{8\ B}^{K\ 0\prime} \longrightarrow \pi_{3\ B}^{K\ 5}\ \bar{\pi}_{3\ B}^{K\ 5} \longrightarrow \bar{\tau}\ t + \bar{t}\ \tau$$
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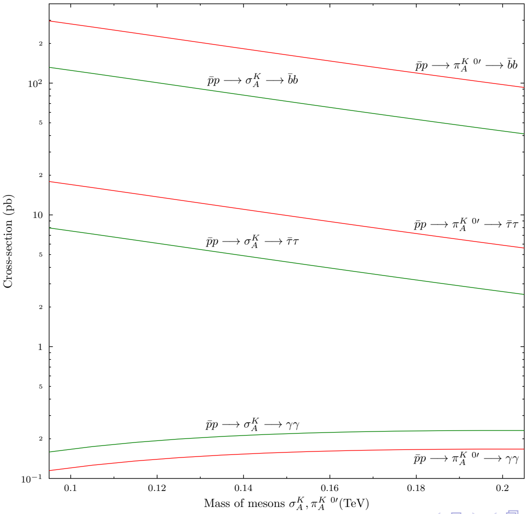
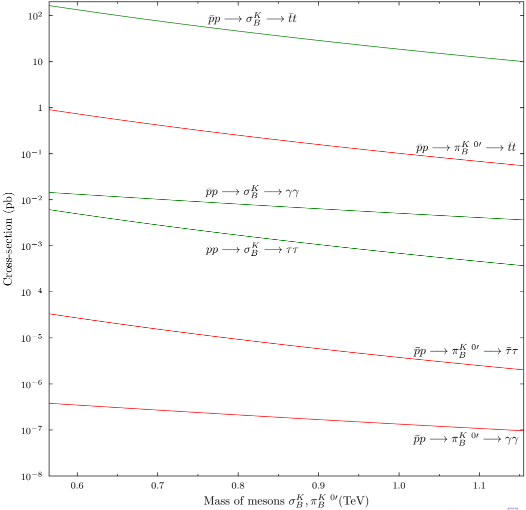
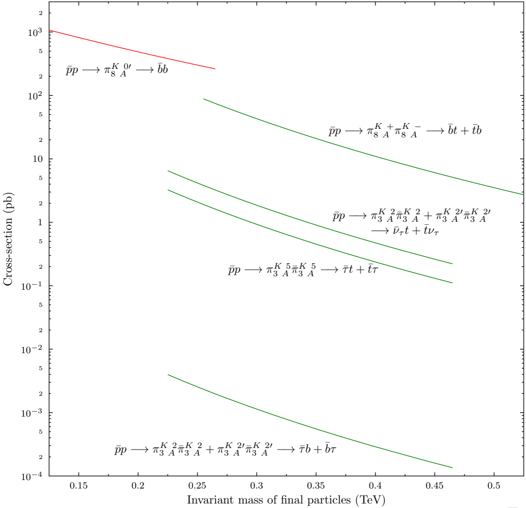
Important A-mirror-meson processes



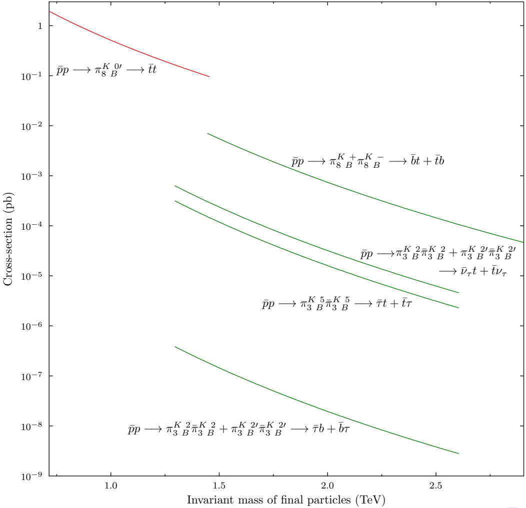
Important B-mirror-meson processes



Color-octet & color-triplet A-mirror mesons



Color-octet & color-triplet B-mirror mesons



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