Dark Matter from vector-like Technicolor

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Scalar T-diquark states as a possible Dark Matter

$$\tilde{Q} = \begin{pmatrix} U \\ D \end{pmatrix} \qquad Y_{\tilde{Q}} = 0 \qquad SU(2)_W \otimes SU(2)_{TC}$$

$$\tilde{\pi}^+ = U\bar{D},\ \tilde{\pi}^0 = \frac{1}{\sqrt{2}}(U\bar{U} - D\bar{D}),\ \tilde{\pi}^- = \bar{D}U,\ T_{\tilde{\pi}} = 0.$$ **T-pion fields**

$$B^+ = UU\,, \quad B^- = DD\,, \quad B^0 = UD\,, \quad T_B = +1\,,$$
$$\bar{B}^+ = \bar{U}\bar{U}\,, \quad \bar{B}^- = \bar{D}\bar{D}\,, \quad \bar{B}^0 = \bar{U}\bar{D}\,, \quad T_{\bar{B}} = -1\,.$$ **T-baryon fields**

DM candidate

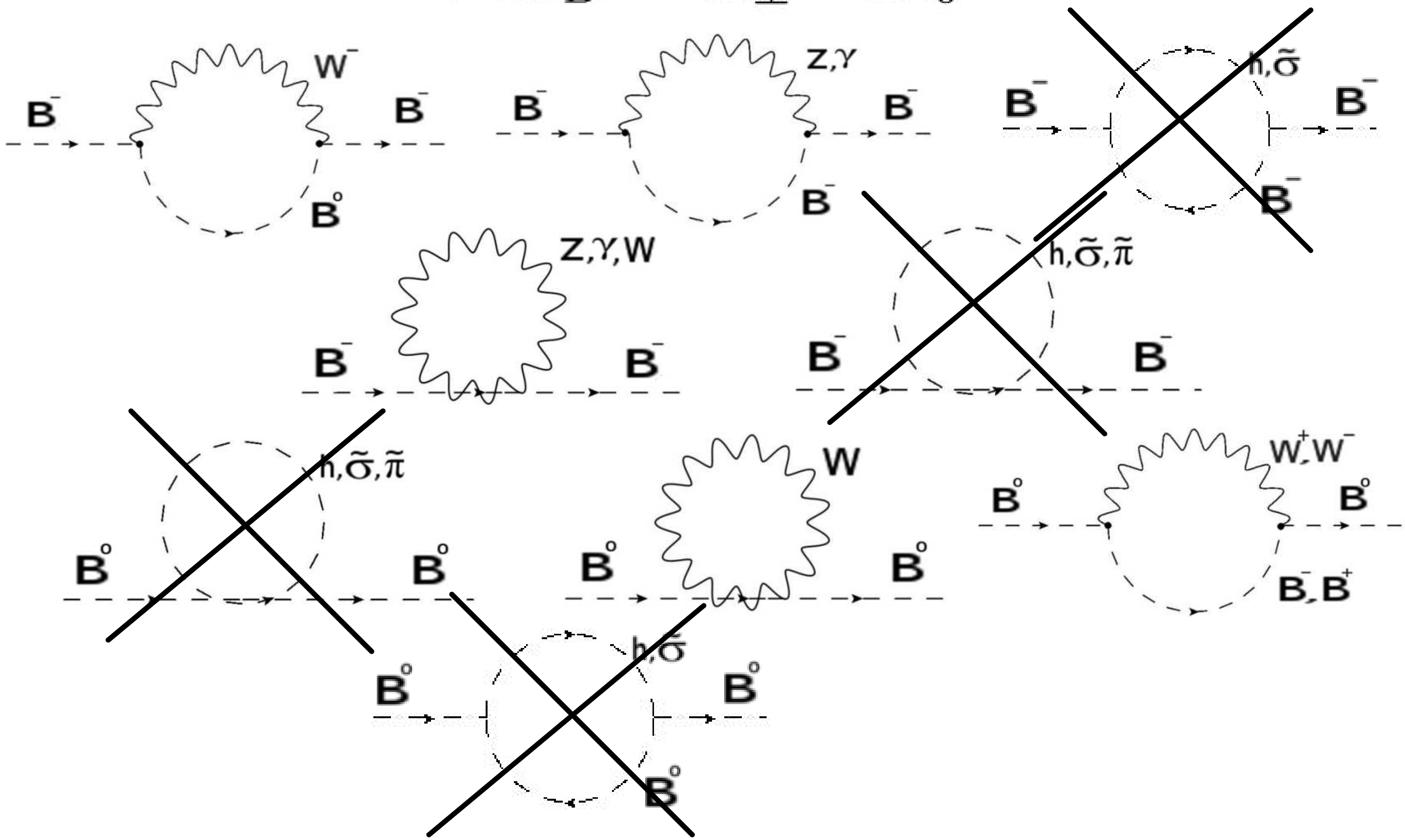
- Stability on cosmological time scales
- Weak participation in the electromagnetic interaction

$M_B \sim 2TeV$

Roman Pasechnik, Vitaly Beylin, Vladimir Kuksa, Grigory Vereshkov. arXiv:1407.2392 (2014)

T-baryon mass splitting

$$\Delta M_B = M_\pm - M_0$$



The T-baryon mass splitting is due to the electroweak interaction

T-baryon mass splitting

$$\Delta M_B^2 = Re\Pi_B^{\pm}(M_B^2) - Re\Pi_B^0(M_B^2)$$

$$\Delta M_B = \frac{G_F M_W^4}{2\sqrt{2}\pi^2 M_B}\left(ln\left(\frac{M_Z^2}{M_W^2}\right) - \beta_Z^2 \ln(\mu_Z) + \beta_W^2 \ln(\mu_W) - \right.$$
$$-\frac{4\beta_Z^3}{\sqrt{\mu_Z}}\left[arctg\left(\frac{2-\mu_Z}{2\sqrt{\mu_Z}\beta_Z}\right) + arctg\left(\frac{\sqrt{\mu_Z}}{2\beta_Z}\right)\right] +$$
$$\left. + \frac{4\beta_W^3}{\sqrt{\mu_W}}\left[arctg\left(\frac{2-\mu_W}{2\sqrt{\mu_W}\beta_W}\right) + arctg\left(\frac{\sqrt{\mu_W}}{2\beta_W}\right)\right]\right) \approx 160 MeV$$

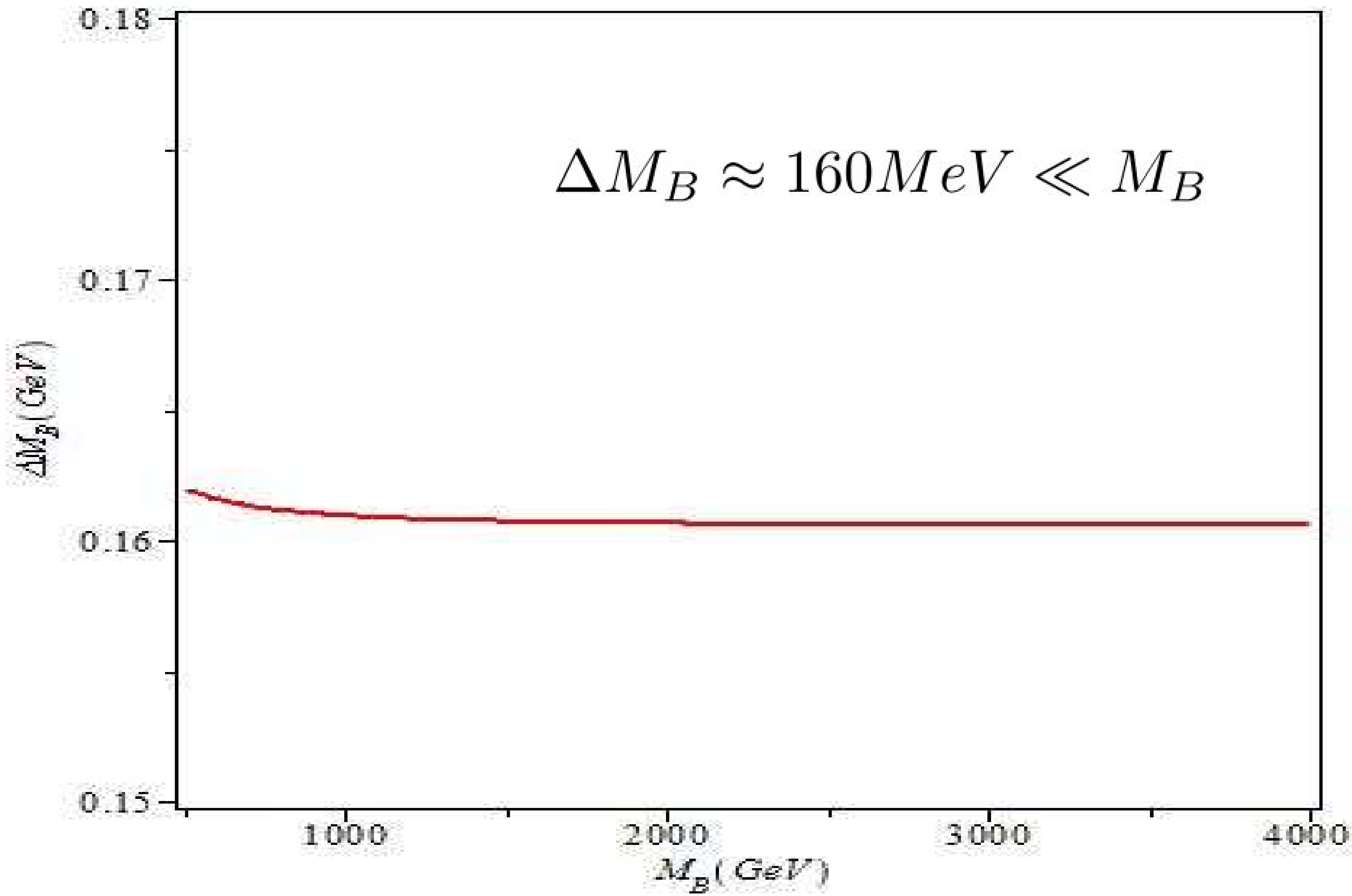
$$\mu_{W,Z} = \frac{M_{W,Z}^2}{M_B^2}, \beta_{W,Z} = \sqrt{1 - \frac{\mu_{W,Z}}{4}}$$

M_W, M_Z -masses of the weak bosons

G_F -Fermi constant

M_B **-mass of the T-baryon**

T-baryon mass splitting



Calculation of relic abundance

High symmetry phase: $T > T_{EV}$

Low symmetry phase: $T < T_{EW}$

$$T_{EV} \simeq 100 GeV$$

Freeze-out temperature:

$$T_f \simeq \frac{M_B}{20}$$

We consider T-baryon abundance formation mainly in low-symmetry phase $M_B \leq 2\ TeV$.

$$\Omega_{TB} \simeq 0.2 \left[\frac{(\sigma v)^{DM}_{ann}}{(\sigma v)_{eff}} \right] \quad (1)$$

$$(\sigma v)^{DM}_{ann} \simeq 2.0 \times 10^{-9} GeV^{-2}$$

G. Steigman, B. Dasgupta and J. F. Beacom, Phis. Rev. D 86 ,023506 (2012)

$(\sigma v)_{eff}$ - effective kinetic T-baryon annihilation cross section

$$\Omega_{CDM} h^2 = 0.1138 \pm 0.0045$$

G. Hinshaw et al. [WMAP Collaboration], Astrophys. J. Suppl. 208, 19 (2013)

T-baryon asymmetry?

Account of coannihilation processes

$$B^{\pm} \rightarrow B^0 + W^{\pm}(\rightarrow l\bar{\nu}_l, q_i\bar{q}_j)$$

$$\tau \approx 4*10^{-9}\, s$$

$$H^{-1}(T_{EW}) = 10^{-9}s$$

$$B^0\bar{B}^0 \rightarrow X$$

$$B^0\bar{B}^{\pm}, \bar{B}^0 B^{\pm} \rightarrow X$$

$$B^{\pm}\bar{B}^{\pm}, B^{\pm}\bar{B}^{\mp} \rightarrow X$$

Coannihilation processes

$$\sigma_{eff} = \sum_{ij}^{N} \sigma_{ij} \frac{g_i g_j}{g_{eff}^2} (1+\Delta_i)^{\frac{3}{2}} (1+\Delta_j)^{\frac{3}{2}} exp\left[\frac{-M_B(\Delta_i + \Delta_j)}{T}\right] \quad (2)$$

$$\Delta_i = \frac{M_i - M_B}{M_B} \quad g_{eff} = \sum_{i=1}^{N} g_i (1+\Delta_i)^{\frac{3}{2}} Exp(\frac{-M_B\Delta_i}{T})$$

Kim Griest, David Seckel, Phis. Rev. D 43 ,3191 (1991)

We shall assume that the initial density of all components of the T-baryon triplet is essentially the same

Table of all the (co)annihilation processes

$$\left.\begin{array}{l} B^+\bar{B}^+ \\ B^-\bar{B}^- \end{array}\right\} \rightarrow \left\{\begin{array}{l} W^+W^-;\gamma\gamma;ZZ;\gamma Z;f\bar{f} \\ \tilde{\pi}^+\tilde{\pi}^-;\tilde{\pi}^0\tilde{\pi}^0;hh;\tilde{\sigma}\tilde{\sigma};h\tilde{\sigma} \end{array}\right.$$

$$\left.\begin{array}{l} \bar{B}^0 B^\pm \\ B^0\bar{B}^\mp \end{array}\right\} \rightarrow \left\{\begin{array}{l} \gamma W^\pm;ZW^\pm;\begin{array}{l}\ell\bar{\nu}_\ell;u\bar{d} \\ \bar{\ell}\nu_\ell;\bar{u}d\end{array} \\ \tilde{\pi}^0\tilde{\pi}^\pm \end{array}\right.$$

$$\bar{B}^\pm B^\mp \rightarrow W^\mp W^\mp;\tilde{\pi}^\mp\tilde{\pi}^\mp$$

$$B^0\bar{B}^0 \rightarrow \left\{\begin{array}{l} W^+W^-;ZZ;f\bar{f} \\ \tilde{\pi}^+\tilde{\pi}^-;\tilde{\pi}^0\tilde{\pi}^0;hh;\tilde{\sigma}\tilde{\sigma};h\tilde{\sigma} \end{array}\right.$$

$s \approx 4M_B^2, \quad M_B \gg M_W$ **-Approximation**

Theoretical parameters

$M_B; \quad M_h; \quad M_{\tilde{\sigma}}; \quad m_{\tilde{\pi}}; \quad \underbrace{g_{BP}; \quad g_{BS}; \quad g_{BH}; \quad g_{TC};}_{\text{Scalar self-couplings}}$

M_B -mass of the T-baryon

$M_{\tilde{\sigma}}$ -mass of the T-sigma

$m_{\tilde{\pi}}$ -mass of the T-pion

$M_h \simeq 125\ GeV$ -mass of the Higgs boson

$$g_{BP} = g_{BS} = g_{BH} = g_{TC}, \quad M_B = 2 g_{TC} U$$

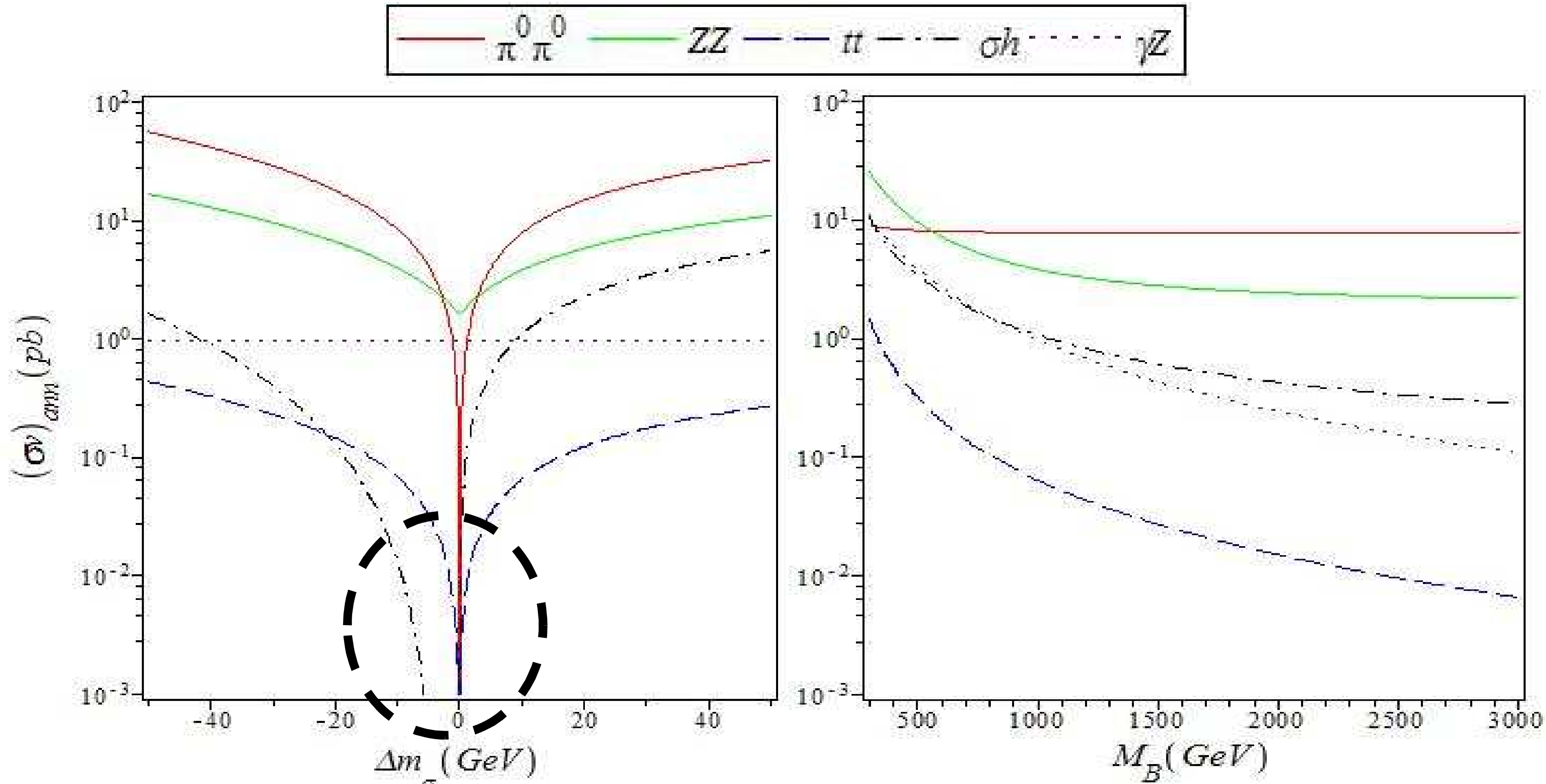
Variable parameters :

$M_B; \quad m_{\tilde{\pi}}; \quad \Delta m_{\tilde{\sigma}} = M_{\tilde{\sigma}} - \sqrt{3} m_{\tilde{\pi}}$

$\Delta m_{\tilde{\sigma}} = M_{\tilde{\sigma}} - \sqrt{3} m_{\tilde{\pi}} \to 0$ -small Higgs-T-sigma mixing limit

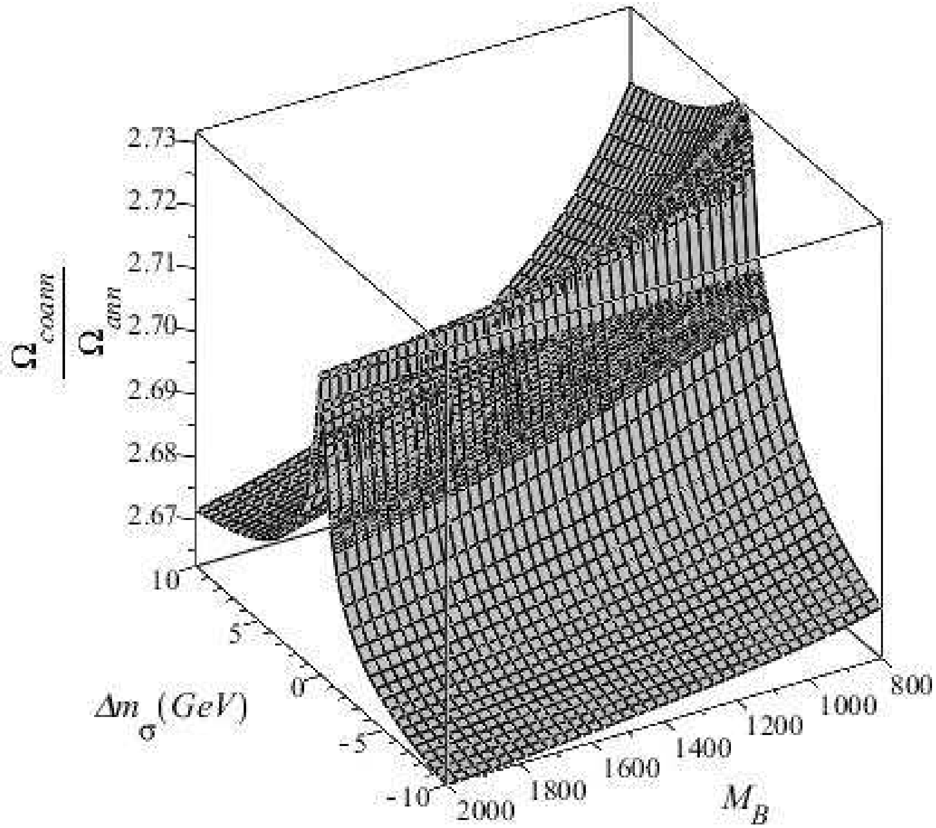
Kinetic T-baryon coannihilation cross section

$$B^+\bar{B}^+ \to \tilde{\pi}^0\tilde{\pi}^0, ZZ, t\bar{t}, \tilde{\sigma}h, \gamma Z$$

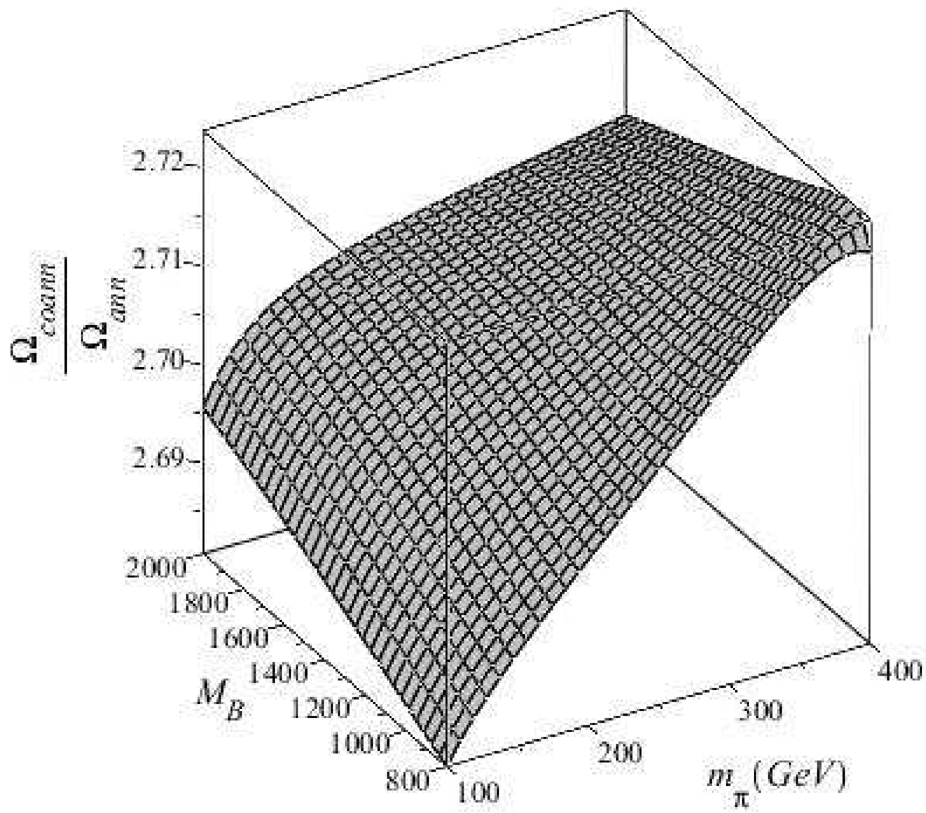


The T-baryon (co)annihilation cross section in the (pseudo)scalar and spinor channels vanishes in the small Higgs-T-sigma mixing limit: $\Delta m_{\tilde{\sigma}} = M_{\tilde{\sigma}} - \sqrt{3}m_{\tilde{\pi}} \to 0$

The ratio of relic abundance calculated with account of coannihilation processes to the one without them as a function of ($\Delta m_{\tilde{\sigma}} = M_{\tilde{\sigma}} - \sqrt{3} m_{\tilde{\pi}}$, M_B) on the left and (M_B, $m_{\tilde{\pi}}$) on the right



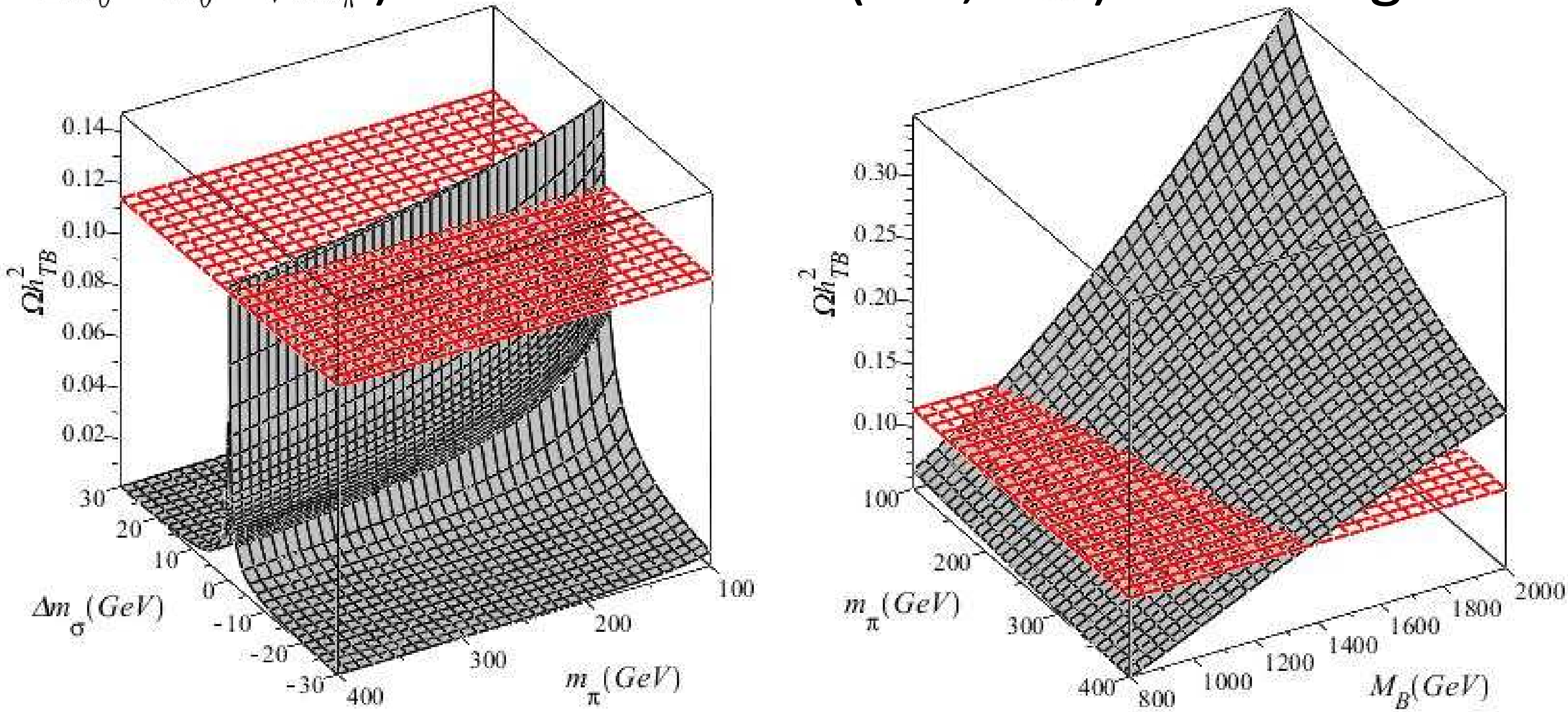
$m_{\tilde{\pi}} = 300\ GeV$



$\Delta m_\sigma = 0.1\ GeV$

$$\frac{\Omega_{coann}}{\Omega_{ann}} \approx 2.7$$

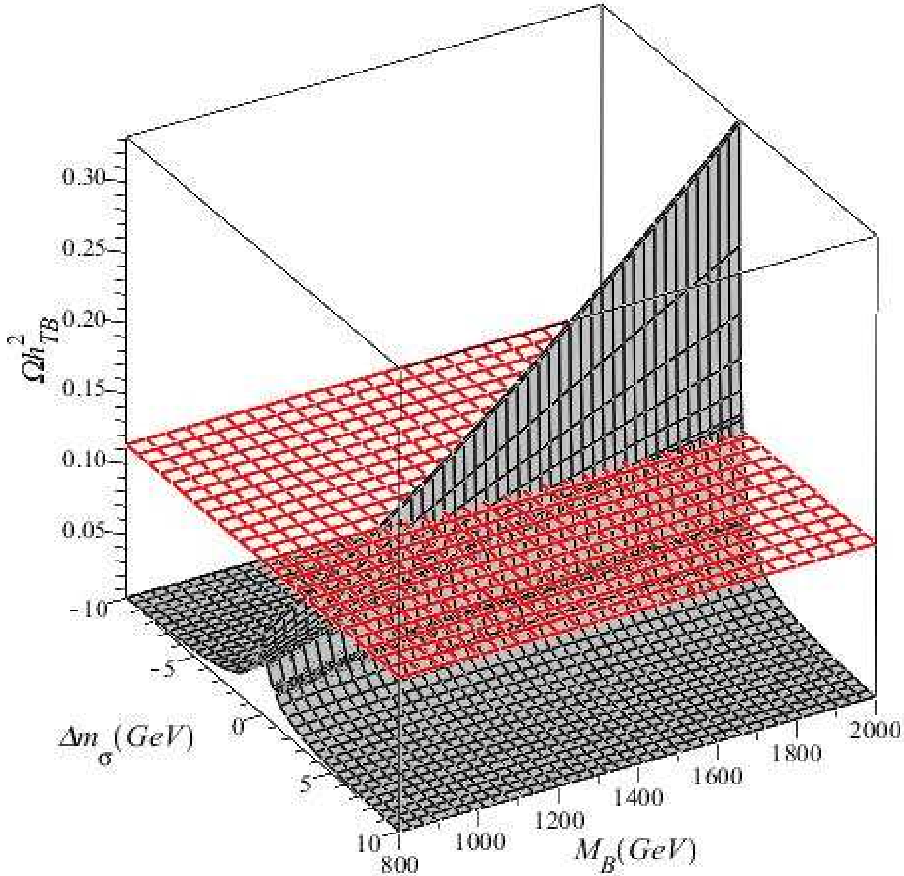
The relic T-baryon abundance as a function of ($m_{\tilde{\pi}}$, $\Delta m_{\tilde{\sigma}} = M_{\tilde{\sigma}} - \sqrt{3} m_{\tilde{\pi}}$) on the left and ($M_B$, $m_{\tilde{\pi}}$) on the right



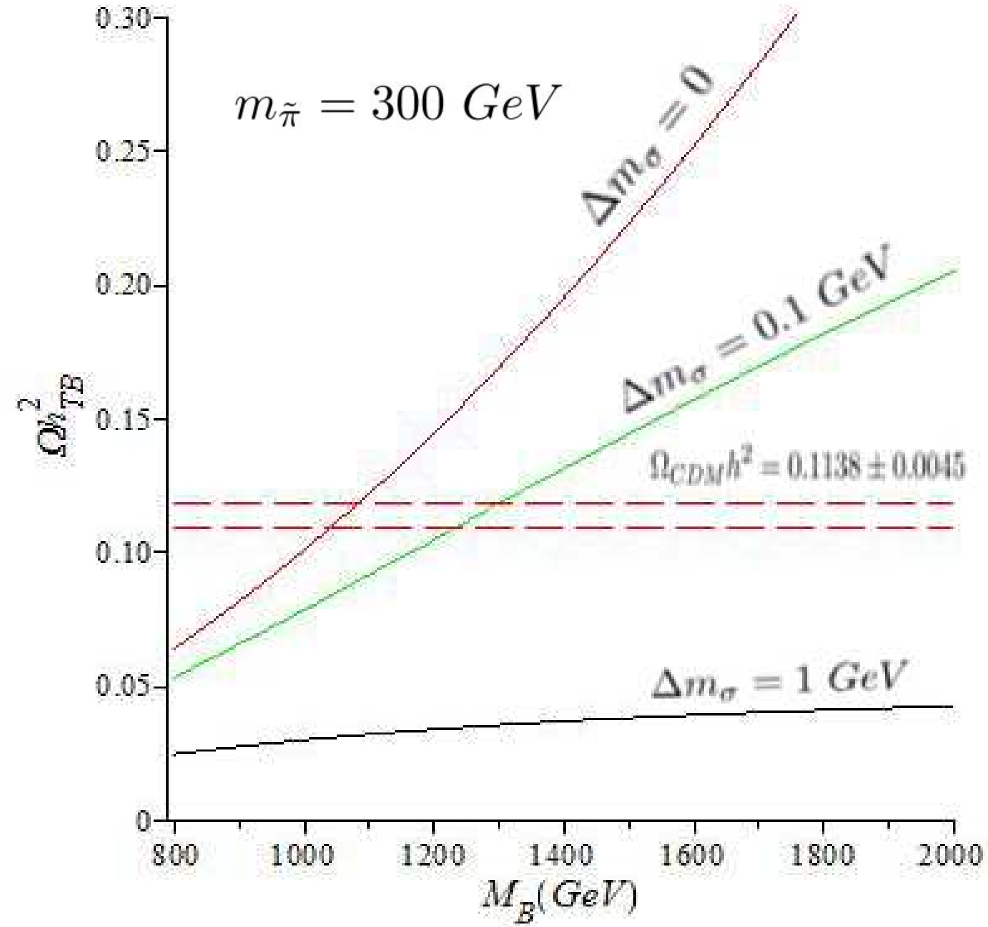
$M_B = 1200\ GeV$ $\Delta m_\sigma = 0.1\ GeV$

We can not say anything definite about the ($m_{\tilde{\pi}}$) in the analysis of the relic T-baryon density .

The relic T-baryon abundance as a function of ($\Delta m_{\tilde{\sigma}} = M_{\tilde{\sigma}} - \sqrt{3} m_{\tilde{\pi}}$, M_B)



$m_{\tilde{\pi}} = 300\ GeV$



Symmetric DM formation is possible only under specific parameter values: $M_B \geq 1 TeV$, $|\Delta m_{\tilde{\sigma}}| = |M_{\tilde{\sigma}} - \sqrt{3} m_{\tilde{\pi}}| \lesssim 0.5 - 1.5\, GeV$

Conclusion and discussions

- T-baryon sector, with respect to its possible important role for DM astrophysics has been considered;

- Mass splitting between charged and uncharged T-baryons appears to be relatively small : $\Delta M_B \approx 160 MeV \ll M_B$;

- Coannihilation processes is wary important for the formation of the relic T-baryon density;

- In the low-symmetry phase symmetric T-baryon DM formation is possible only under specific parameter values:
  $1\ TeV \leq M_B \leq 2\ TeV$, $|\Delta m_{\tilde{\sigma}}| = |M_{\tilde{\sigma}} - \sqrt{3} m_{\tilde{\pi}}| \lesssim 0.5 - 1.5 GeV$;

- The small value of ($\Delta m_{\tilde{\sigma}} = M_{\tilde{\sigma}} - \sqrt{3} m_{\tilde{\pi}}$) is in agreement with the small Higgs-T-sigma mixing ;

- These estimates allow us to specify in what area of energy we can expect the signal of Technicolor Physics;

Thank you for your attention!