# Weak Triplet, Color Octet Scalars, and the CDF Bump

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# Overview

- Minimal Octo-triplet Model
- Heavy Vectorlike Quark
- CDF Wjj Excess
- B-Meson Mixing

# “Octo-triplet” $\Theta^{a\alpha}$

SU(3)xSU(2)xU(1) : (8,3,0)

$$\mathcal{L} \supset \frac{1}{2} D^{\mu}\Theta^{a\alpha} D_{\mu}\Theta^{a\alpha} - \frac{1}{2} M_{\Theta}^{2} \Theta^{a\alpha}\Theta^{a\alpha} - \mu_{\Theta} f^{abc} \epsilon^{\alpha\beta\gamma} \Theta^{a\alpha}\Theta^{b\beta}\Theta^{c\gamma}$$

Charge Eigenstates

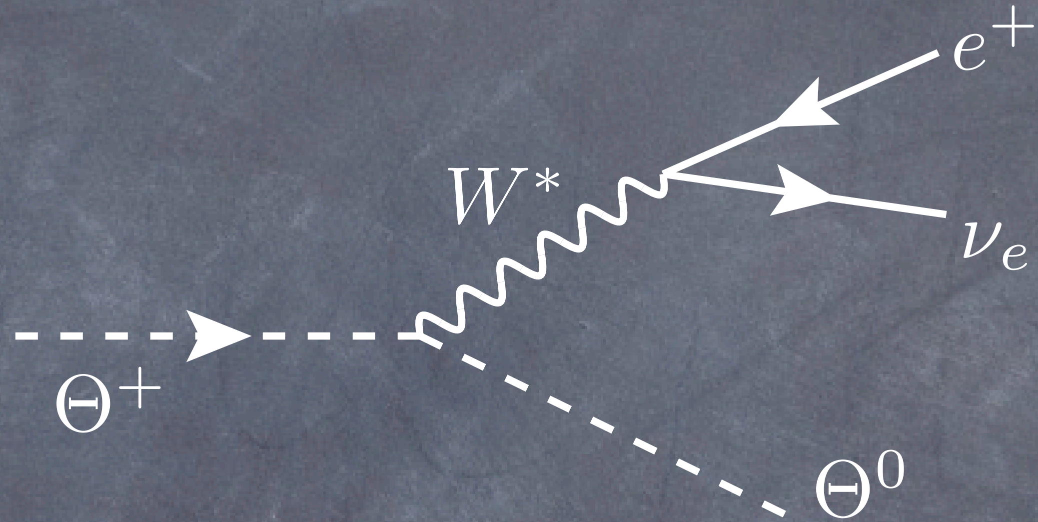
$$\Theta^{a\pm} \equiv \frac{1}{\sqrt{2}} (\Theta^{a1} \pm i\Theta^{a2}) \quad , \quad \Theta^{a0} \equiv \Theta^{a3}$$

* No tree level quark couplings *

*No VEV -> suppressed single production*

# Tree Level $\Theta^{a\pm}$ Decay

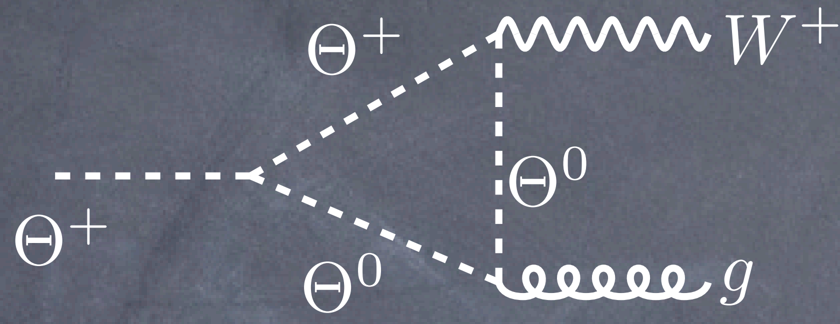
Tiny mass splitting gives

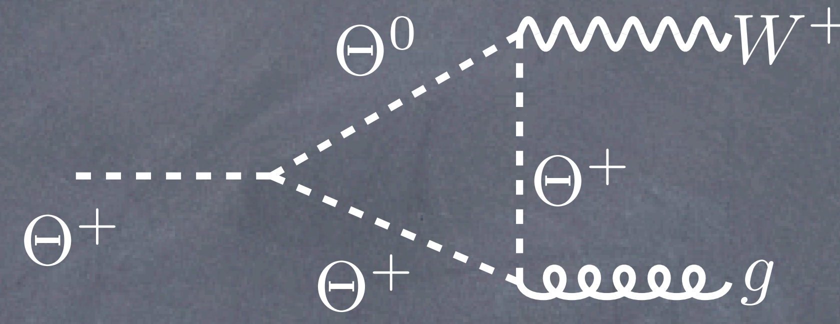


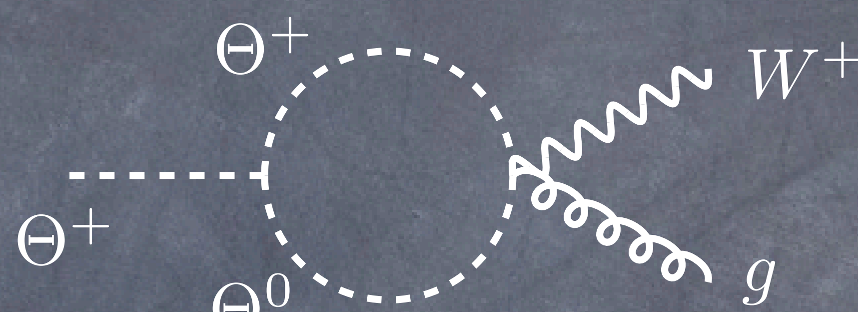

Tiny width:

$$\Gamma\left(\Theta^\pm \to \Theta^0 e^\pm \nu\right) \simeq \frac{\alpha^2}{15\pi \sin^4\theta_W} \frac{(\delta M)^5}{M_W^4} = 1.6 \times 10^{-16}\,\mathrm{GeV}$$

# Loop Decays Easily Win ...



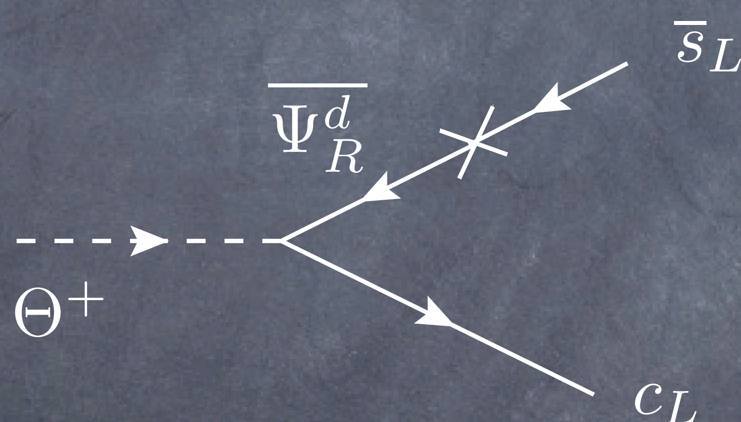

$$\Gamma\left(\Theta^{\pm} \to W^{\pm} g\right) \simeq \frac{\alpha \alpha_s \mu_\Theta^2}{\pi^3 \sin^2\theta_W M_\Theta} f(M_W/M_\Theta) \sim 10^{-7} \frac{\mu_\Theta^2}{M_\Theta}$$

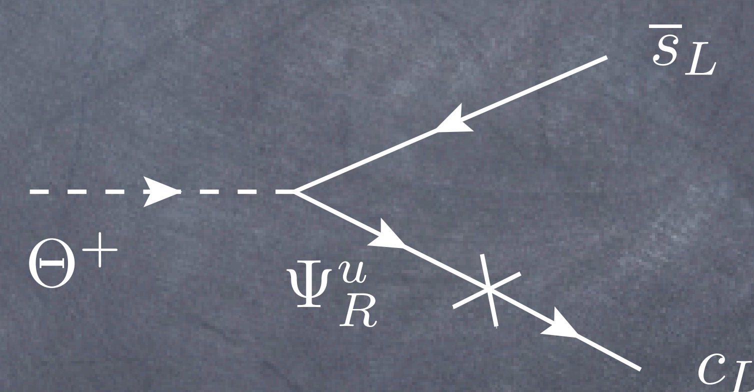
... but the width is still tiny. Can other operators dominate?

# Add vectorlike quark doublet

$$\mathcal{L}_{\Theta\Psi} = \Theta^{a\alpha}\,\overline{\Psi}_R\,T^a\frac{\sigma^\alpha}{2}\left(\eta_i Q_L^i + \eta_\psi \Psi_L\right) + \mathrm{H.c.}$$

$$\mathcal{L}_\Psi = -m_\psi \overline{\Psi}_L \Psi_R - \mu_i \overline{Q}_L^i \Psi_R + \mathrm{H.c.}$$




Integrate out to obtain H.D.O.s

$$-\frac{i\,c_{ij}}{\sqrt{2}\,m_\psi}\left(m_{d_j}\Theta^{a+}\,\overline{u}_L^i T^a d_R^j + \; m_{u_j}\Theta^{a-}\,\overline{d}_L^i T^a u_R^j\right) + \mathrm{H.c.}\,,$$

# Decays Through HDOs

Dijet:

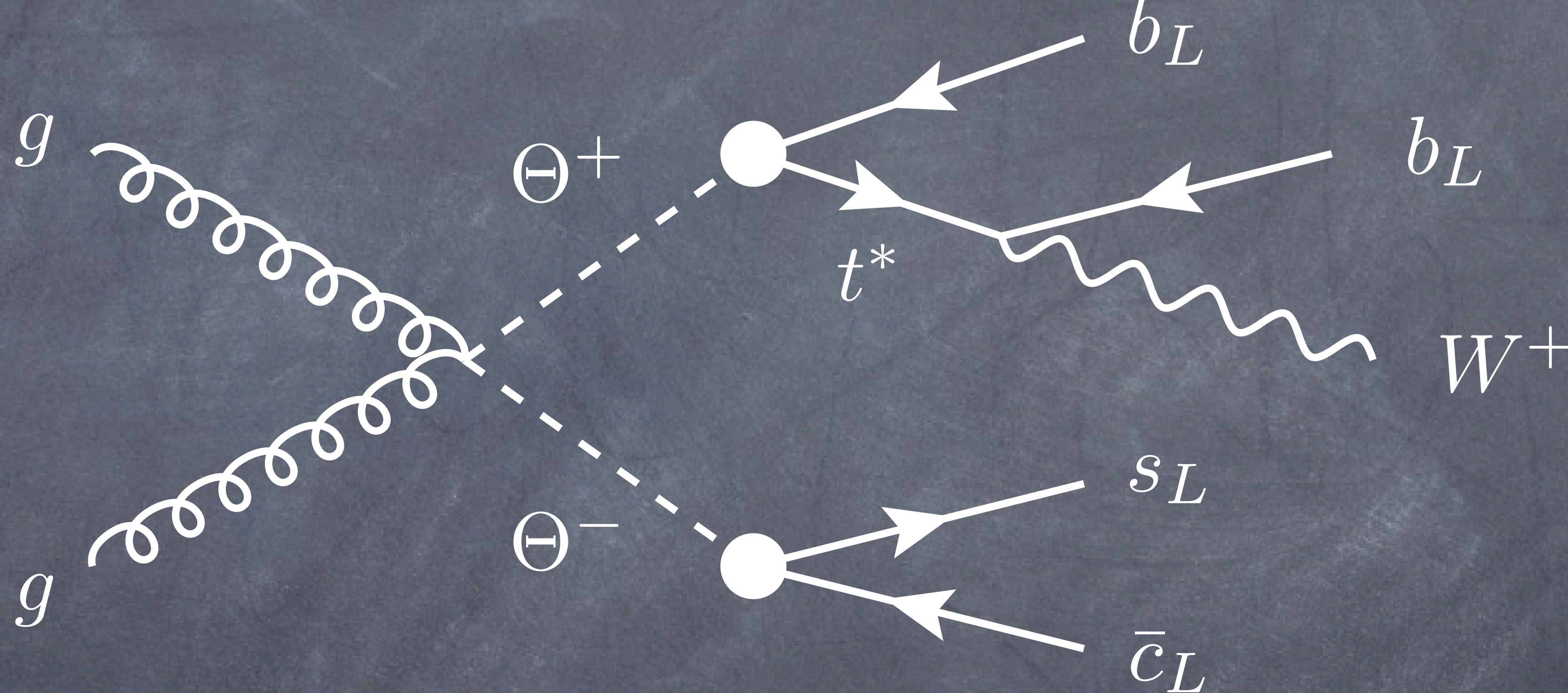
$$\Gamma(\Theta^+ \to c\,\bar{s}) \simeq 10^{-6}\ \mathrm{GeV}\,\frac{|\,\eta_2\mu_2\,|^2}{m_\psi^2}\,\frac{M_\Theta}{150\,\mathrm{GeV}}\left(\frac{1\,\mathrm{TeV}}{m_\psi}\right)^2$$

3-Body virtual top:

$$\Gamma(\Theta^+ \to W^+ b\bar{b}) \simeq 3\times 10^{-6}\,\mathrm{GeV}\,\frac{|\eta_3\mu_3|^2}{m_\psi^2}\,\frac{\mathcal{F}(M_\Theta)}{\mathcal{F}(150\ \mathrm{GeV})}\left(\frac{1\,\mathrm{TeV}}{m_\psi}\right)^2$$

Generically $\mathcal{B}(\Theta \to W^+ b\bar{b}) \sim \mathcal{B}(\Theta \to jj)$

# Competition -> W + dijet signal for $M_\Theta < m_t$




Soft b-jets often fall below cuts

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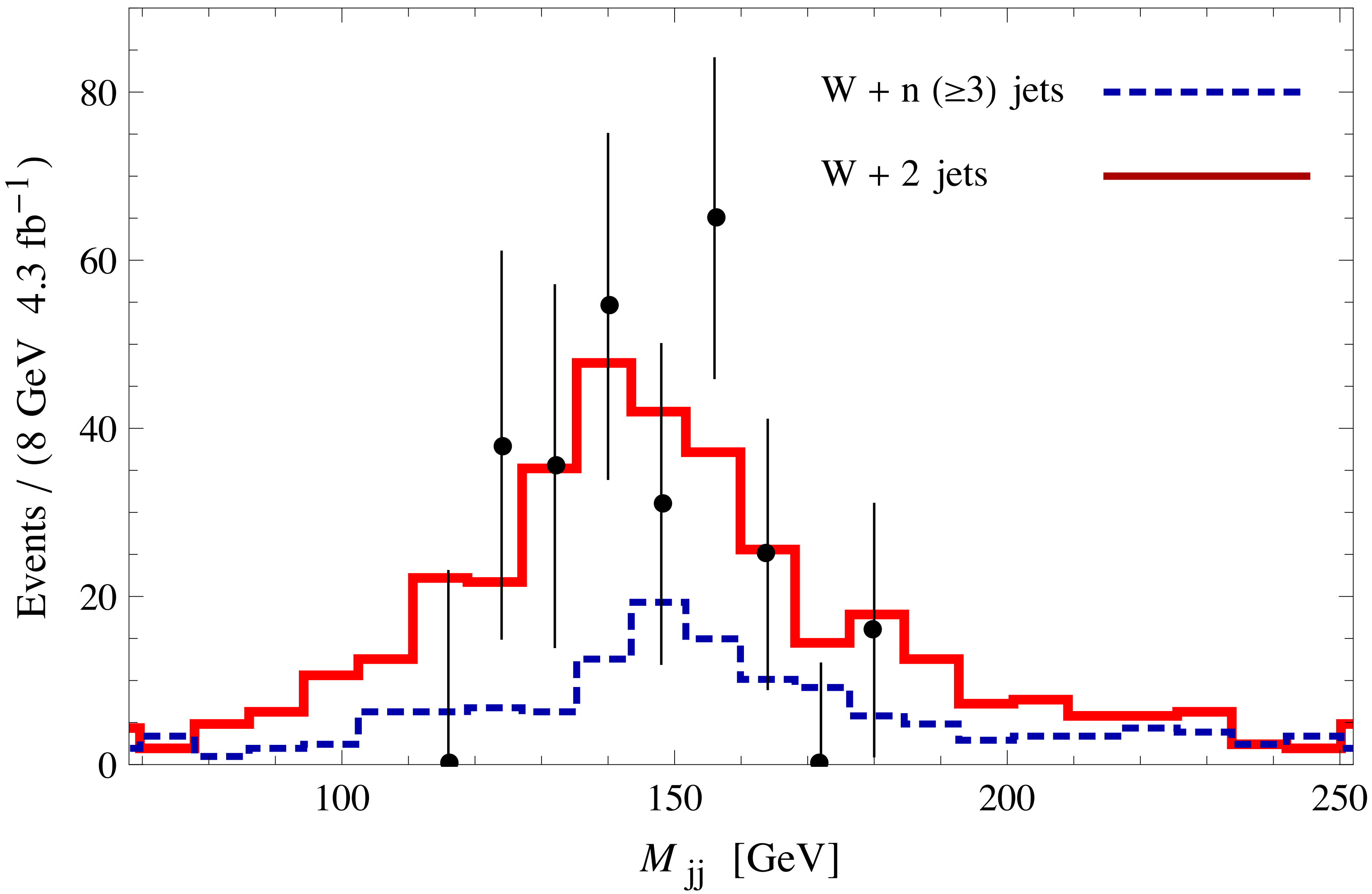
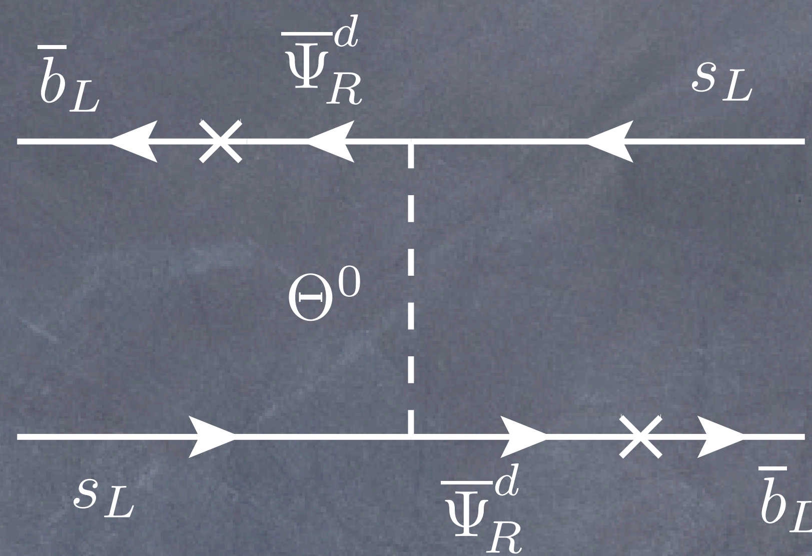
# CDF Wjj Excess




Generated w/ MadGraph / MadEvent / Pythia / PGS

$$M_\Theta = 155\,\mathrm{GeV},\ \mathcal{B}(\Theta^+ \to W^+ b\bar{b}) = 40\%$$

# B-Meson Mixing




Complex parameters -> CPV

Integrate out octo-triplet and heavy quark:

$$\mathcal{L}_{B_s - \overline{B}_s} = \left( \frac{\eta_2 \mu_3 \, m_b}{2 M_\Theta m_\psi^2} \right)^2 \left( \bar{b}_R \, T^a s_L \right)^2 + \mathrm{H.c.}$$

# May Explain DØ Dimuon Excess

Parametrize NP matrix element:

$$\frac{\langle \overline{B}_s | \mathcal{H}_{\rm SM} + \mathcal{H}_\Theta | B_s \rangle}{\langle \overline{B}_s | \mathcal{H}_{\rm SM} | B_s \rangle} \equiv C_{B_s} e^{-i\phi_s} \quad ,$$

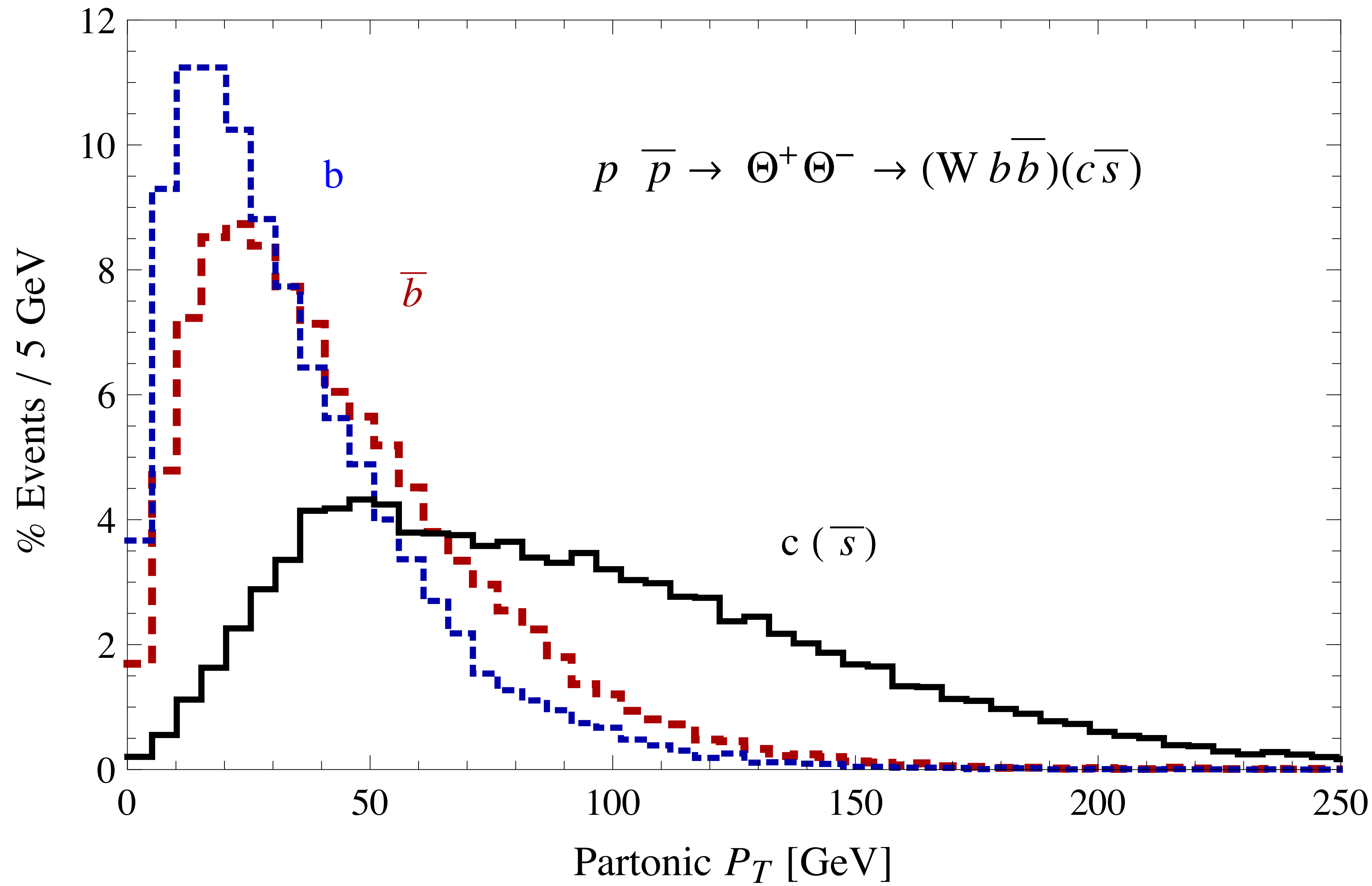
Predicts relation between inputs :

$$m_\psi = 1.1\,\mathrm{TeV}\,|\eta_2|\,\frac{|\mu_3|}{m_\psi}\,\frac{150\,\mathrm{GeV}}{M_\Theta}$$

# Conclusion

- Octo-triplet -> (8,3,0) simple model, small widths
- HDOs can generate dominant decays
- May explain CDF Wjj excess w/ (Wbj)(jj) final state
- Inclusive bump growth (preliminary CDF result)
- Predicts dual resonances (pair production)
- CPV in B-meson system
- Copious LHC production

# PT distributions




$$M_\Theta = 155$$