

# Composite Higgs models at the High Energy Muon Collider

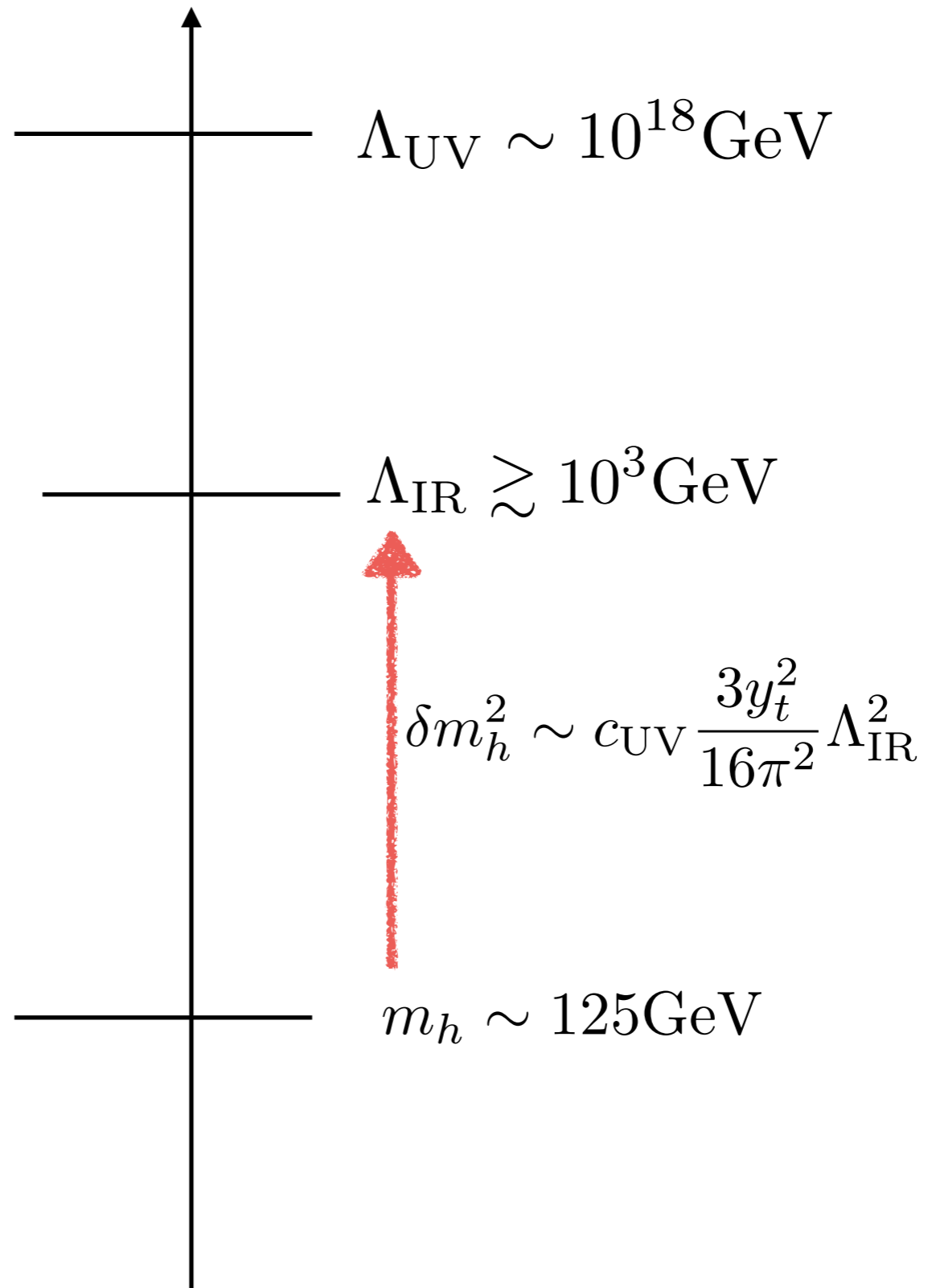
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UC, Davis

With L.T. Wang and K.P. Xie  
To appear soon

# Hierarchy problem

Need engineering the UV parameter



# Naturalness as Guideline

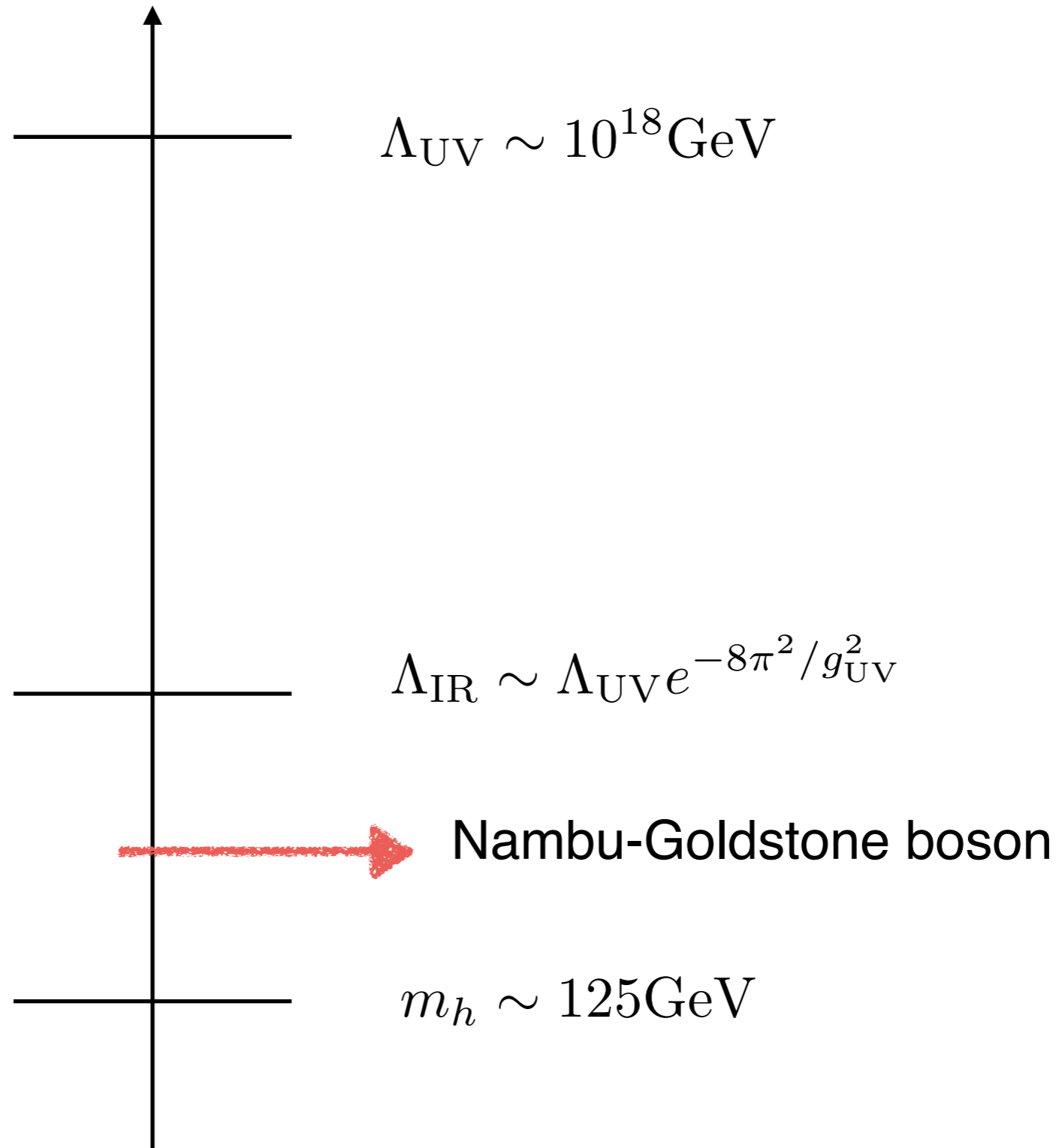
- Compositeness

$$\Lambda_{\text{IR}} \sim \Lambda_{\text{UV}} e^{-8\pi^2/g_{\text{UV}}^2} \longrightarrow \text{Dimensional Transmutation}$$

- Supersymmetry

$$Q|\phi\rangle = |\psi\rangle \longrightarrow \text{Enhanced chiral symmetry}$$

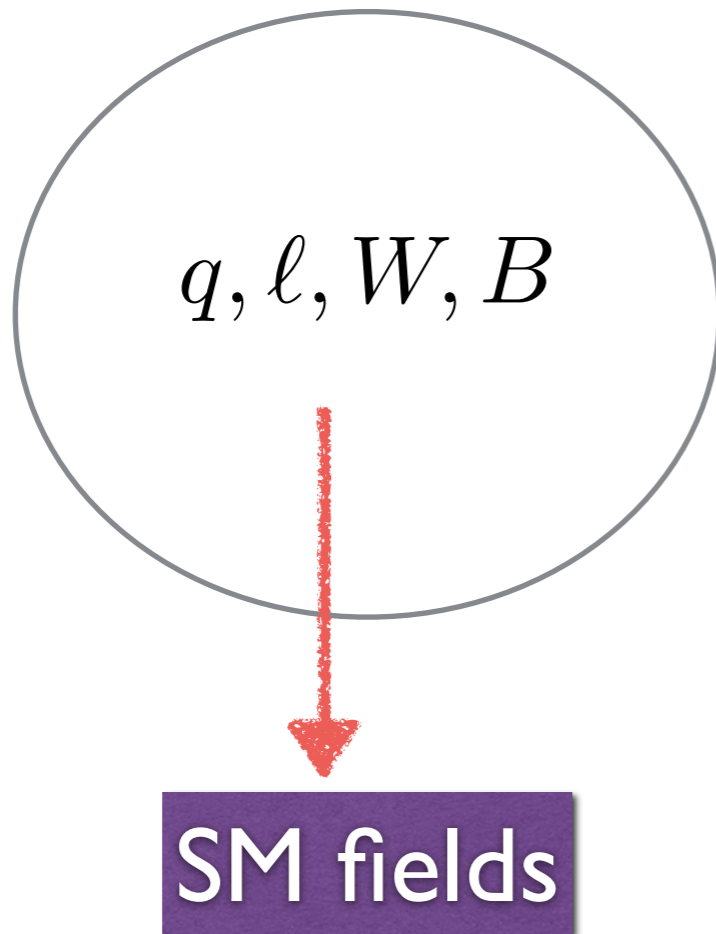
# Compositeness



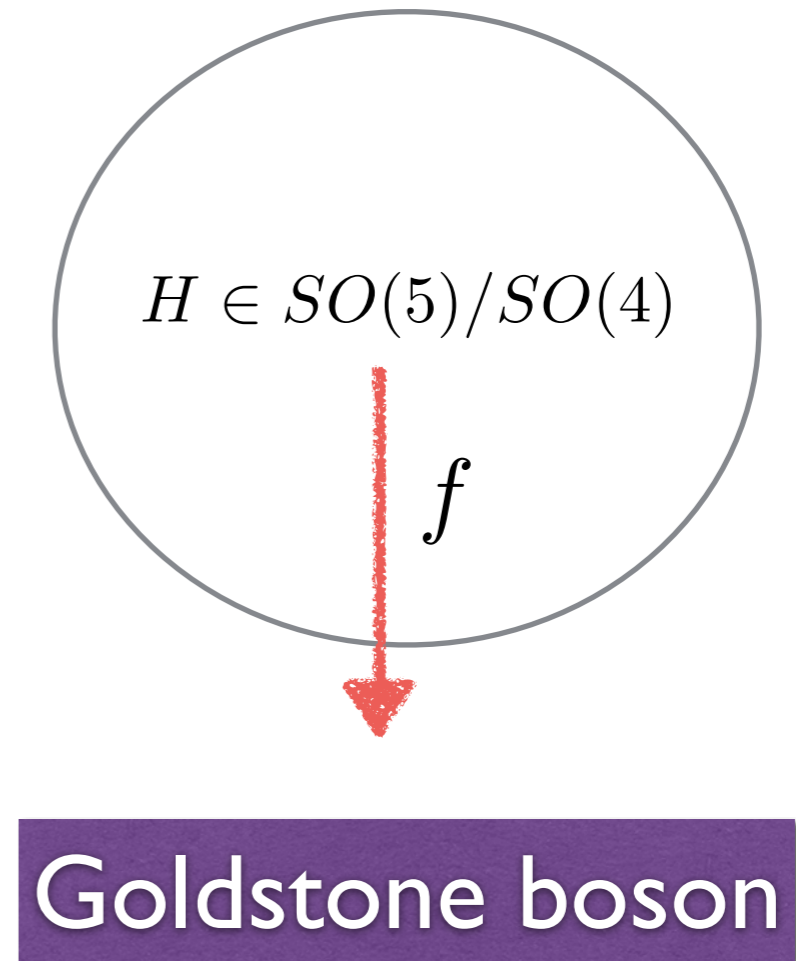
Enhanced shift symmetry!

# Composite Higgs models: Assumption I

Elementary

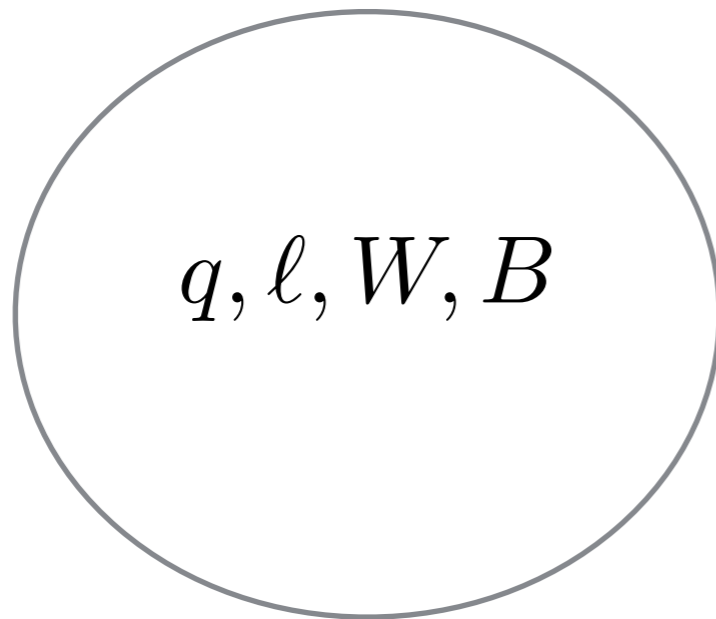


Strong

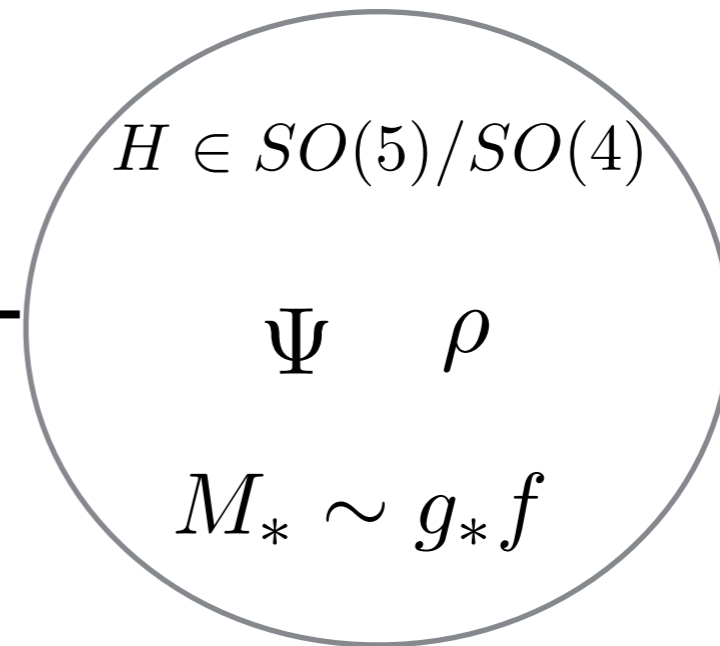


# Composite Higgs models: Assumption II

Elementary



Strong



$y_f, g, g'$

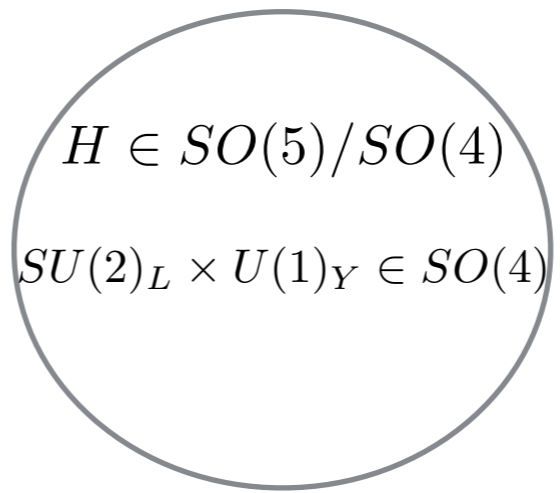


Partial Compositeness

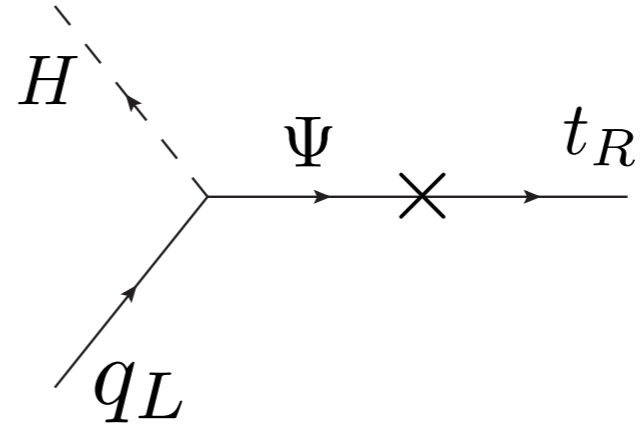
$$\xi = \frac{v^2}{f^2}$$

# Partial compositeness: top quark mass

$$y_L \bar{q}_L^{I_L} \mathcal{O}_{I_L} + y_R \bar{t}_R^{I_R} \mathcal{O}_{I_R}$$



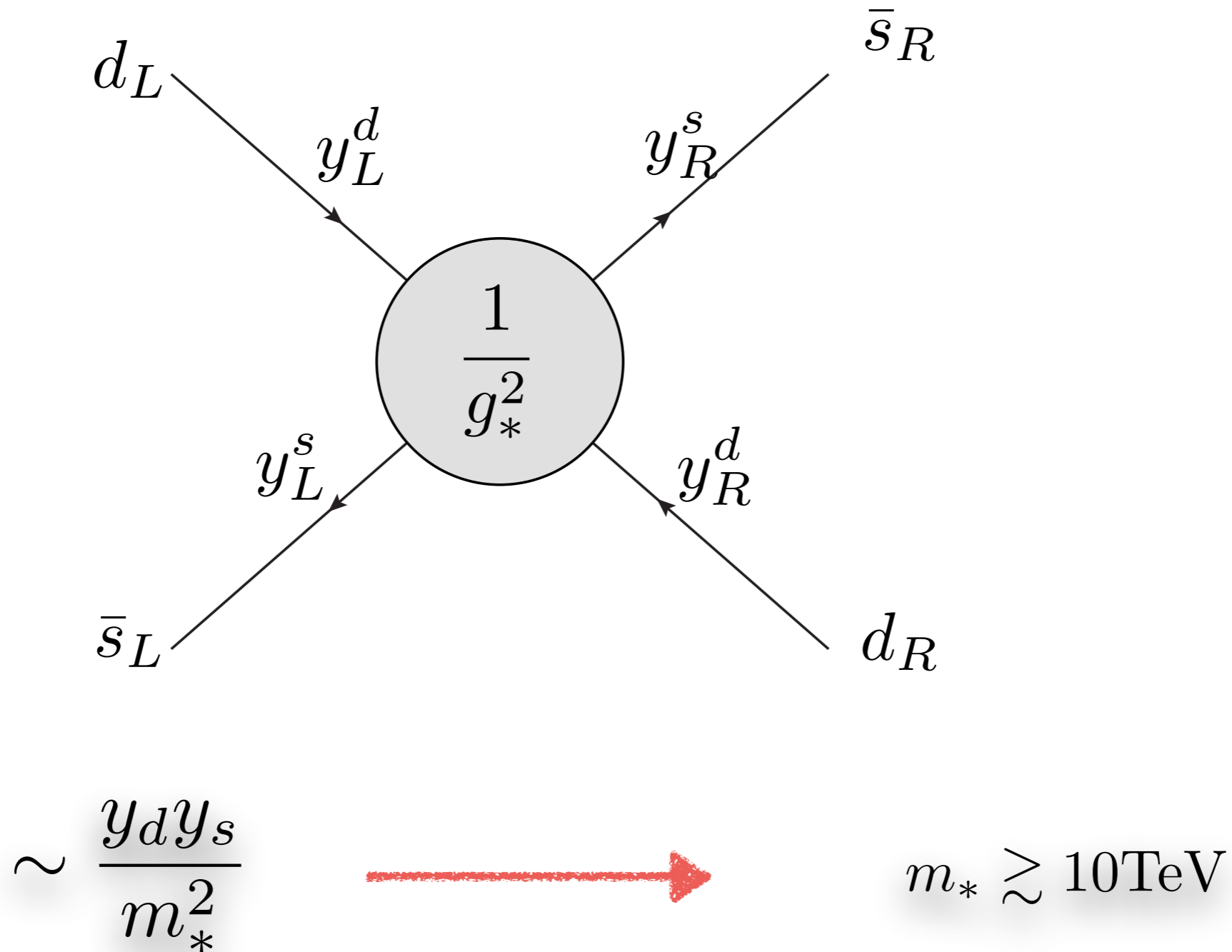
$$y_L \bar{q}_L H \Psi_R + y_R f \bar{t}_R \Psi_L$$



$$\frac{y_L y_R f}{M_\Psi} \bar{q}_L \tilde{H} t_R$$

$$y_t \sim \frac{y_L y_R}{g_*}$$

# Partial compositeness: Flavor





# Targets at the Muon Collider

- Probe the on-shell resonances up to kinematical limits
- Measure the couplings as precise as possible

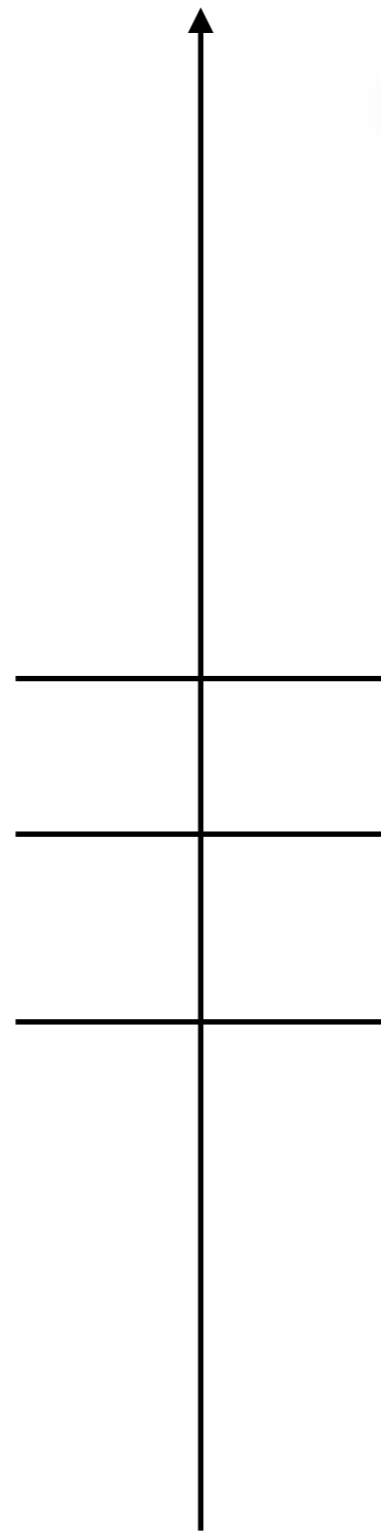
# Direct Resonance searches

$$\rho_L = (3, 1)$$

$$Q_X = \left( \begin{array}{c} X_{5/3} \\ X_{2/3} \end{array} \right)_{\frac{7}{6}}$$

$$Q = \left( \begin{array}{c} T \\ B \end{array} \right)_{\frac{1}{6}}$$

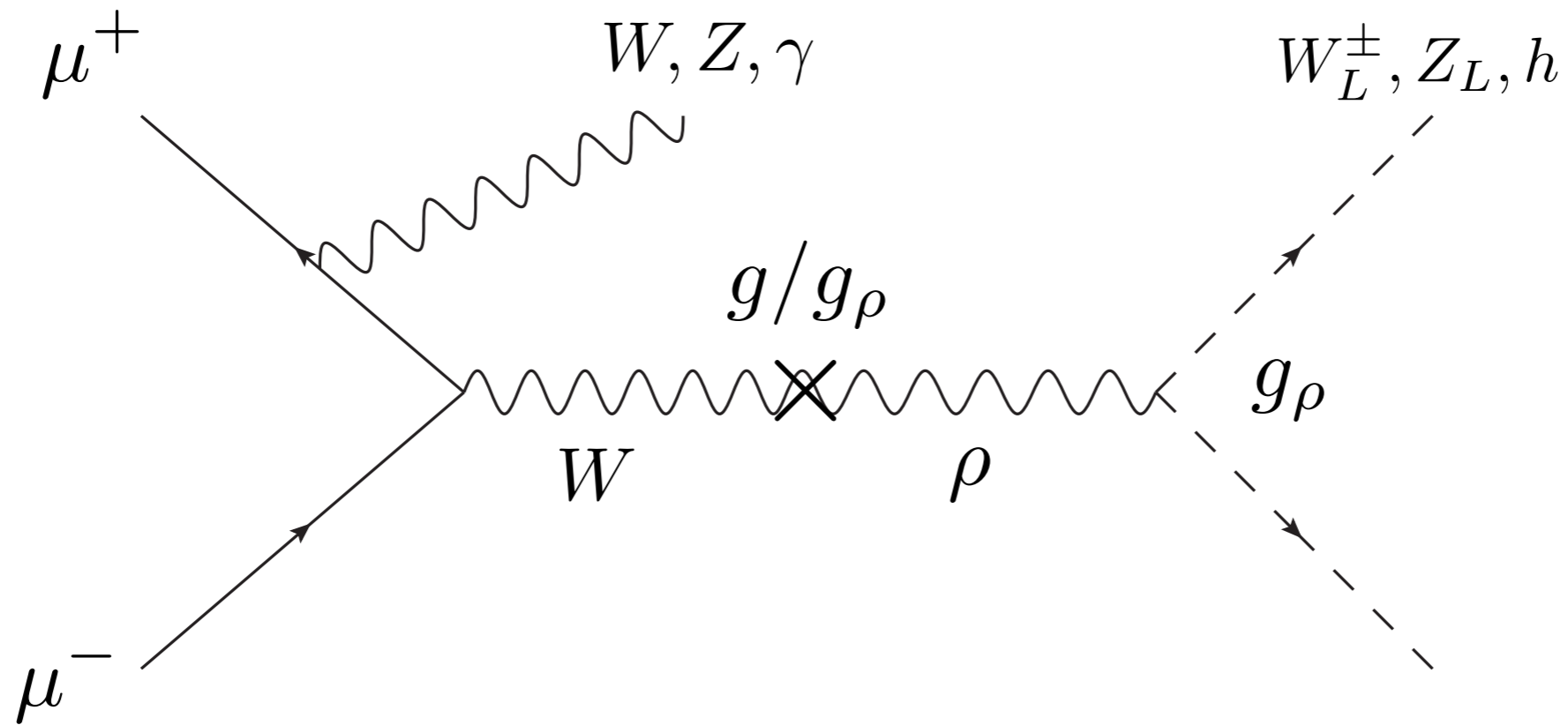
$$m_\rho = a_\rho g_\rho f$$



$$M_T = \sqrt{M_\Psi^2 + y_L^2 f^2}$$

$$M_{X_{5/3}} = M_\Psi$$

# Spin-1 resonances: DY-like

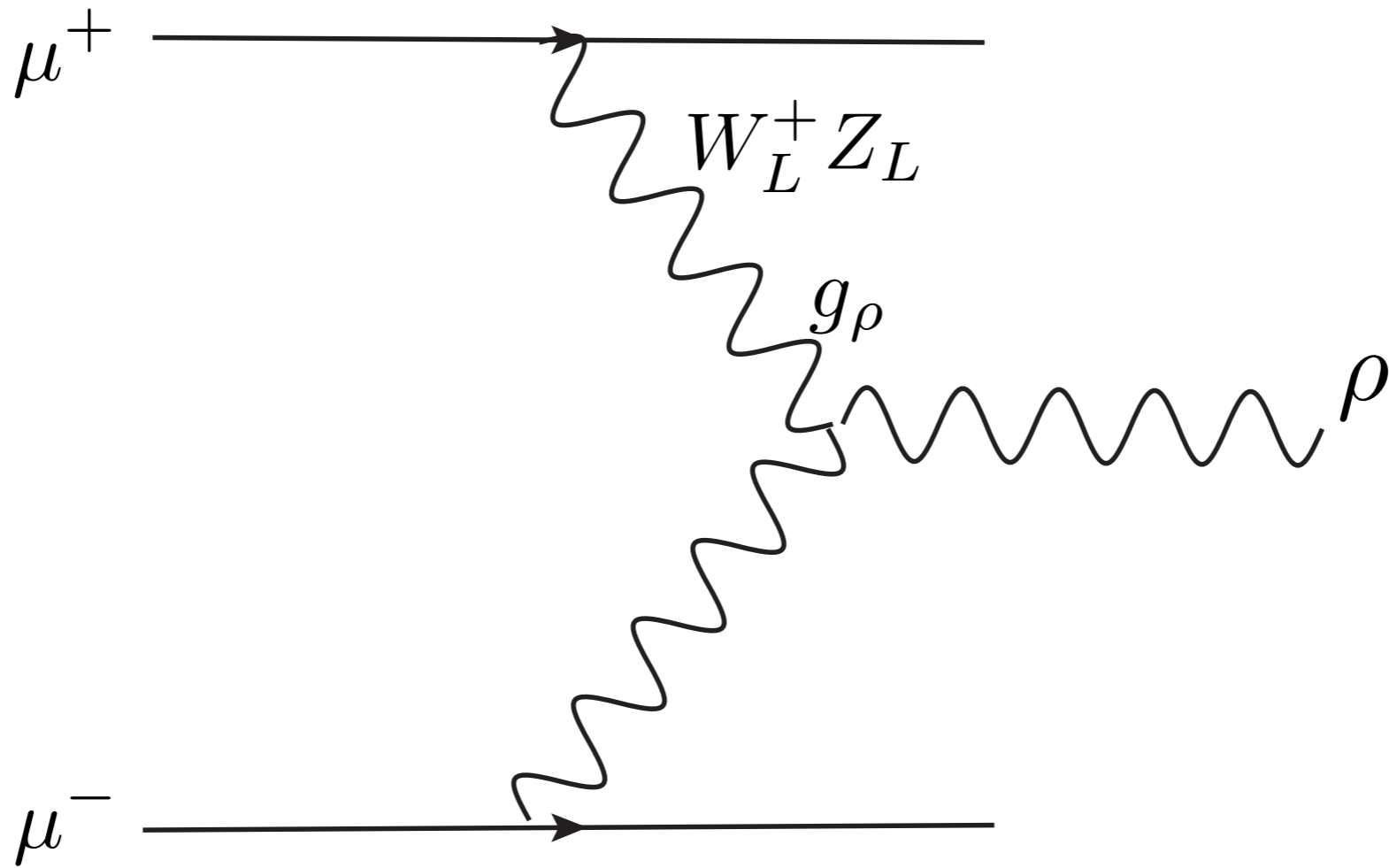


$$\sigma \sim \frac{1}{E_\gamma} \sim \frac{1}{s - M_\rho^2}$$

$$\text{BR}_{VV+Vh} \gtrsim 80\%, \quad \text{for } g_\rho > 3$$

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Working in progress

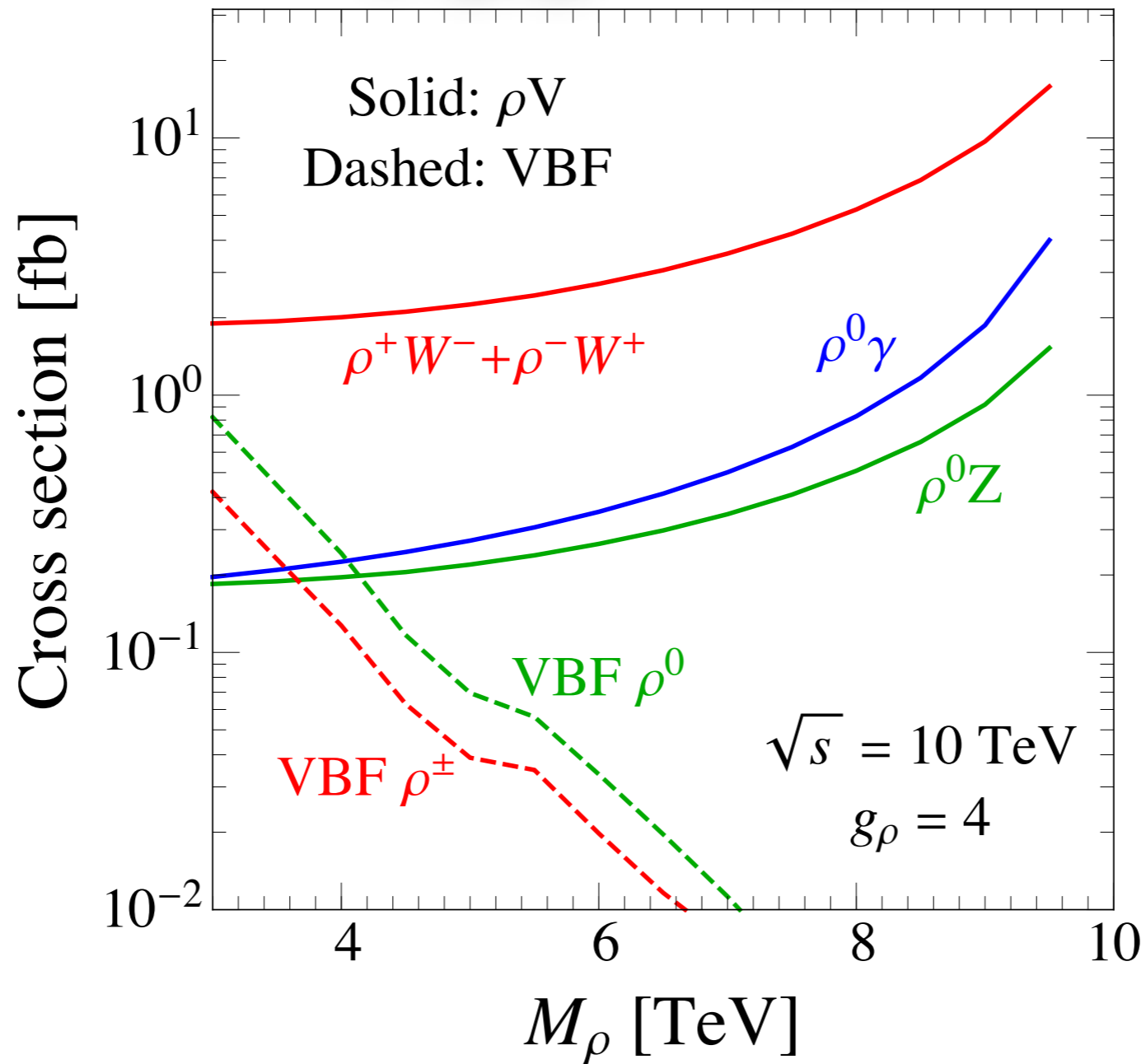
# Spin-1 resonances: VBF



# Spin-1 resonances: XS

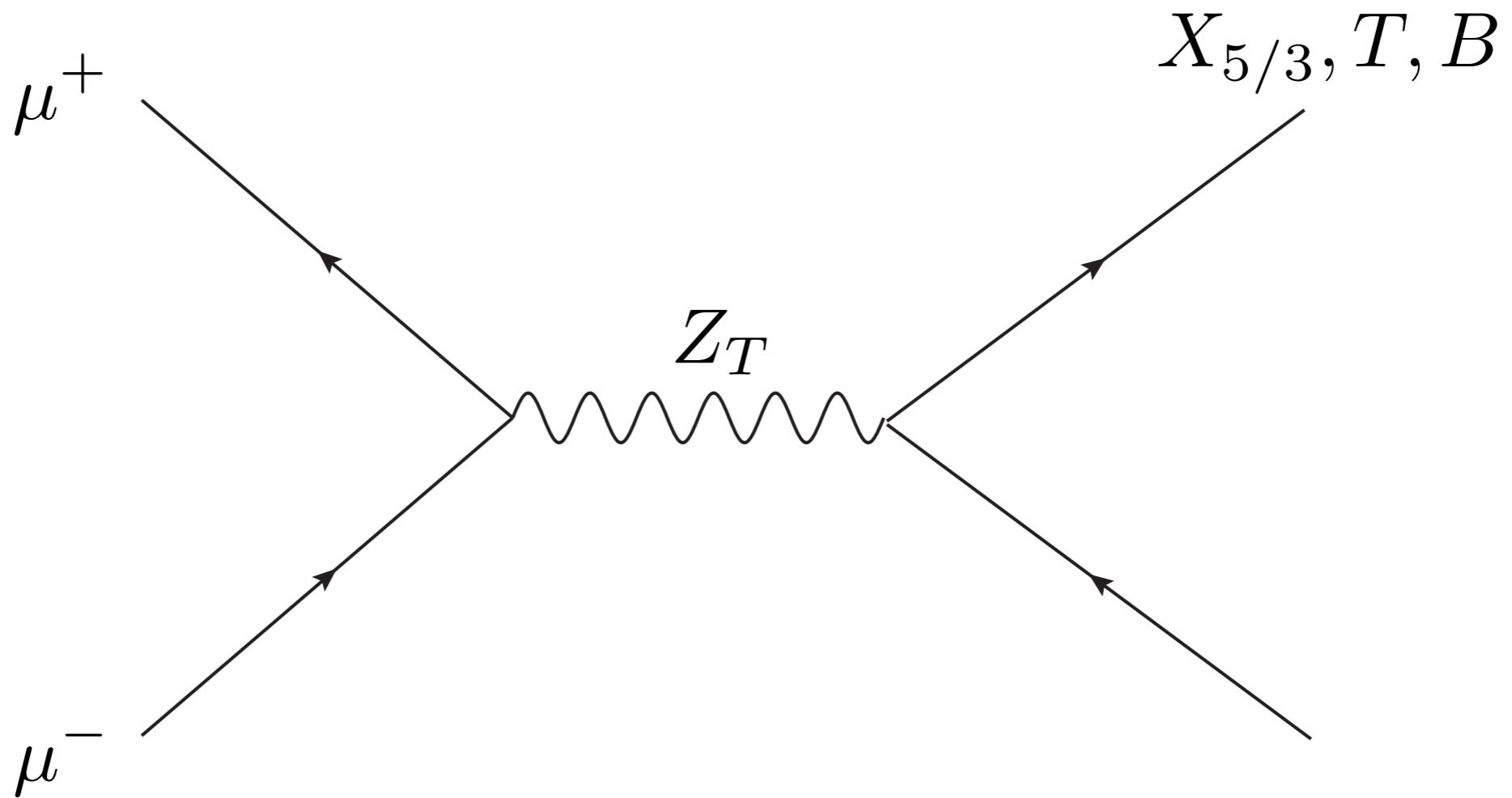
$$\sqrt{s}_{\mu^+\mu^-} = 10\text{TeV}$$

$$L = 10\text{ab}^{-1}$$



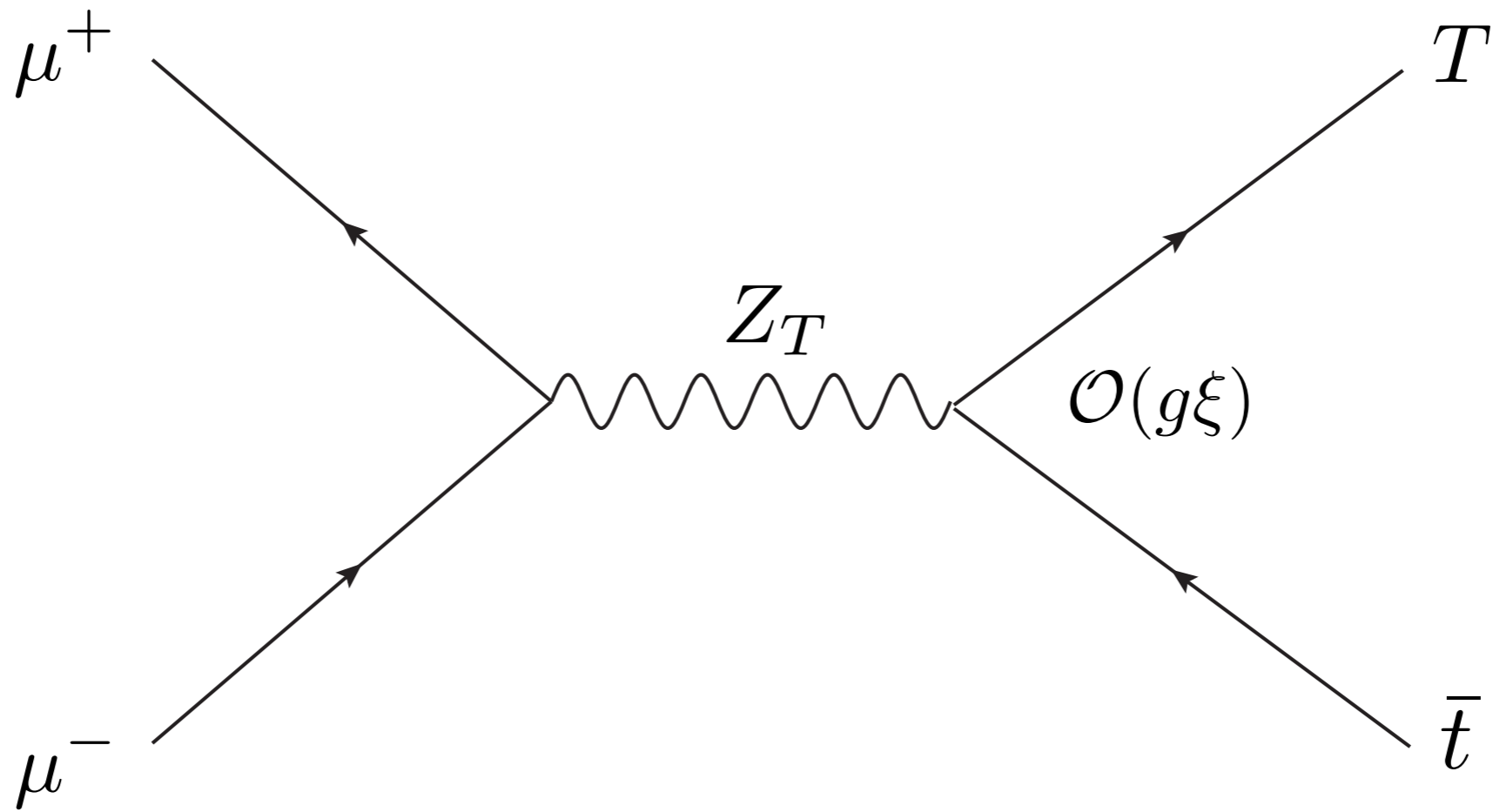
$$N \sim \mathcal{O}(100)$$

# Top partners: DY Pair

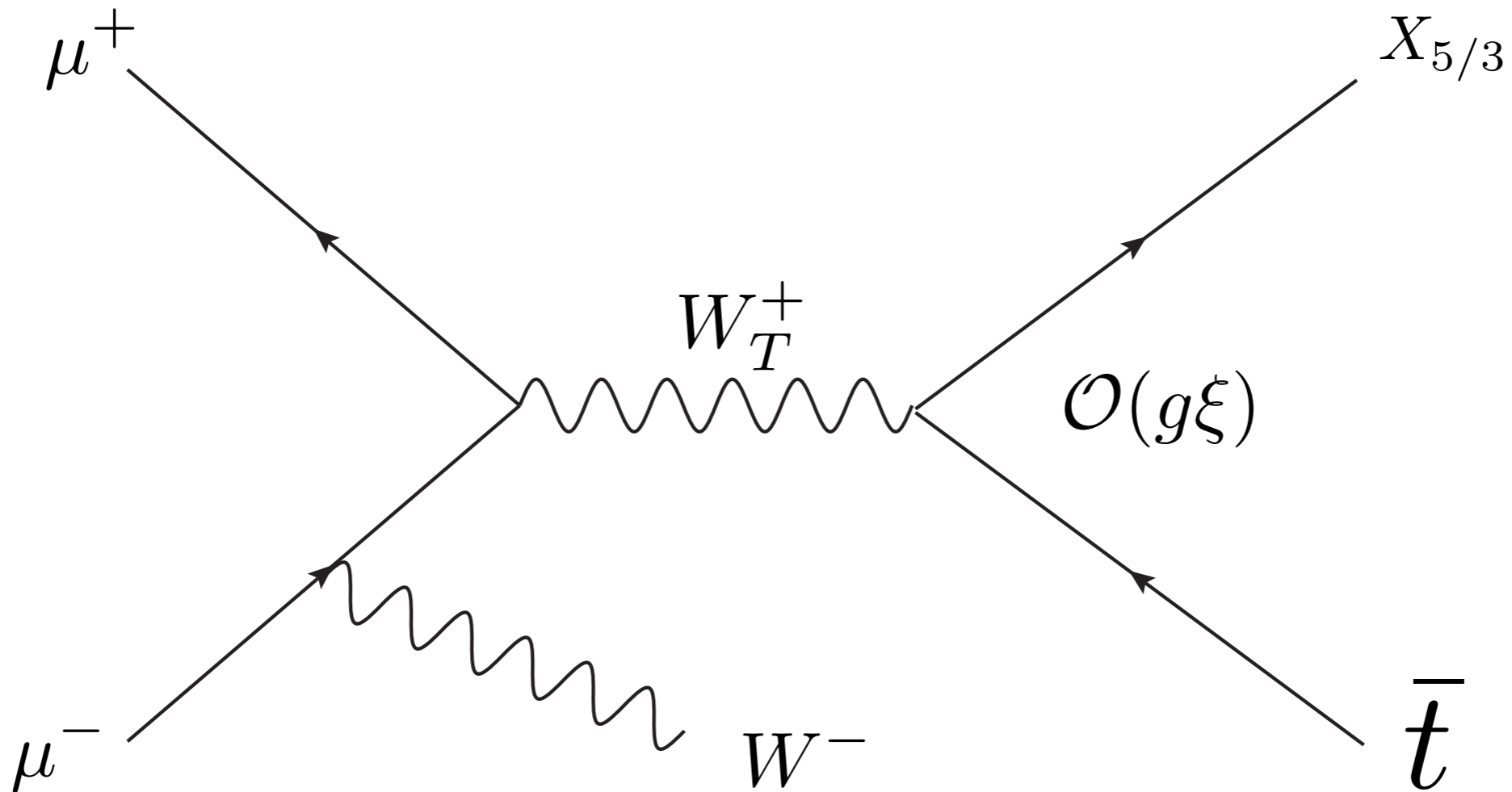


DL, L.T.Wang and K. P. Xie  
Working in progress

# Top partners: DY Single

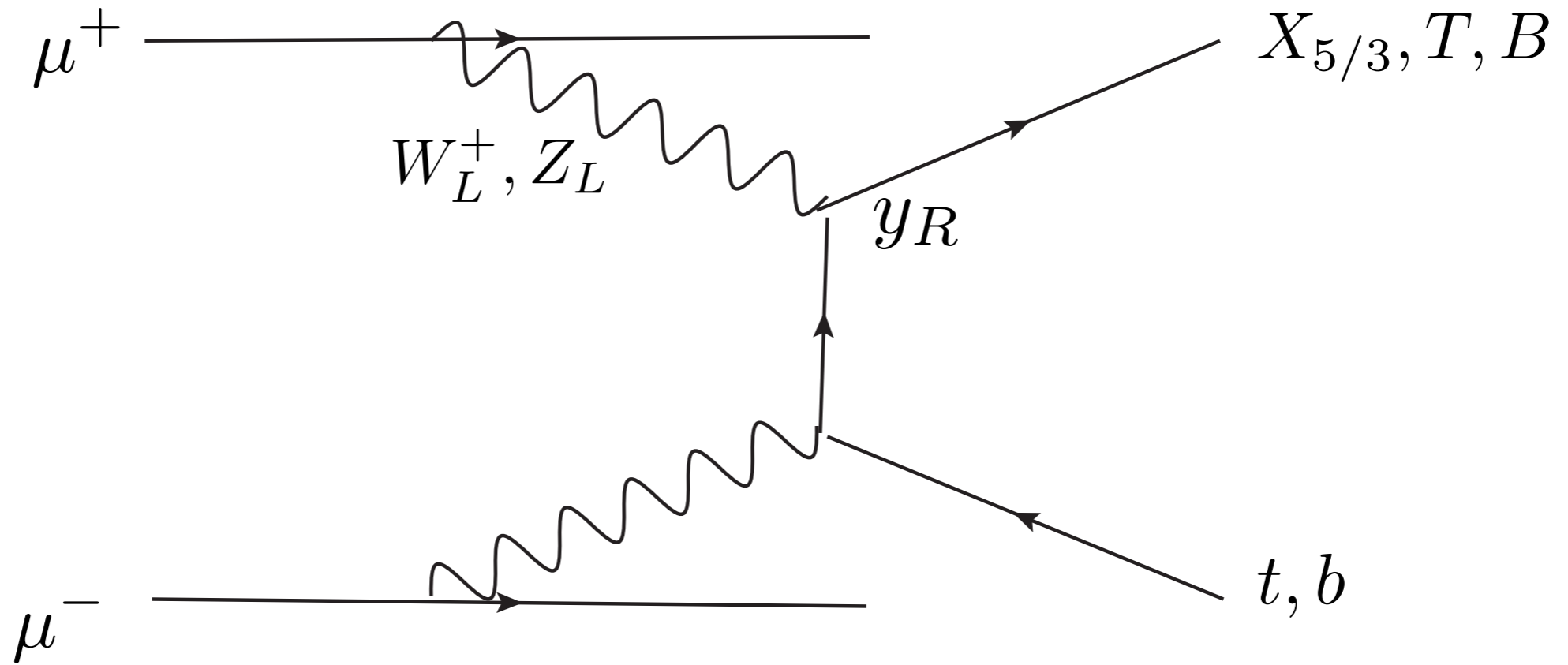


# Top partners: DY-like Single



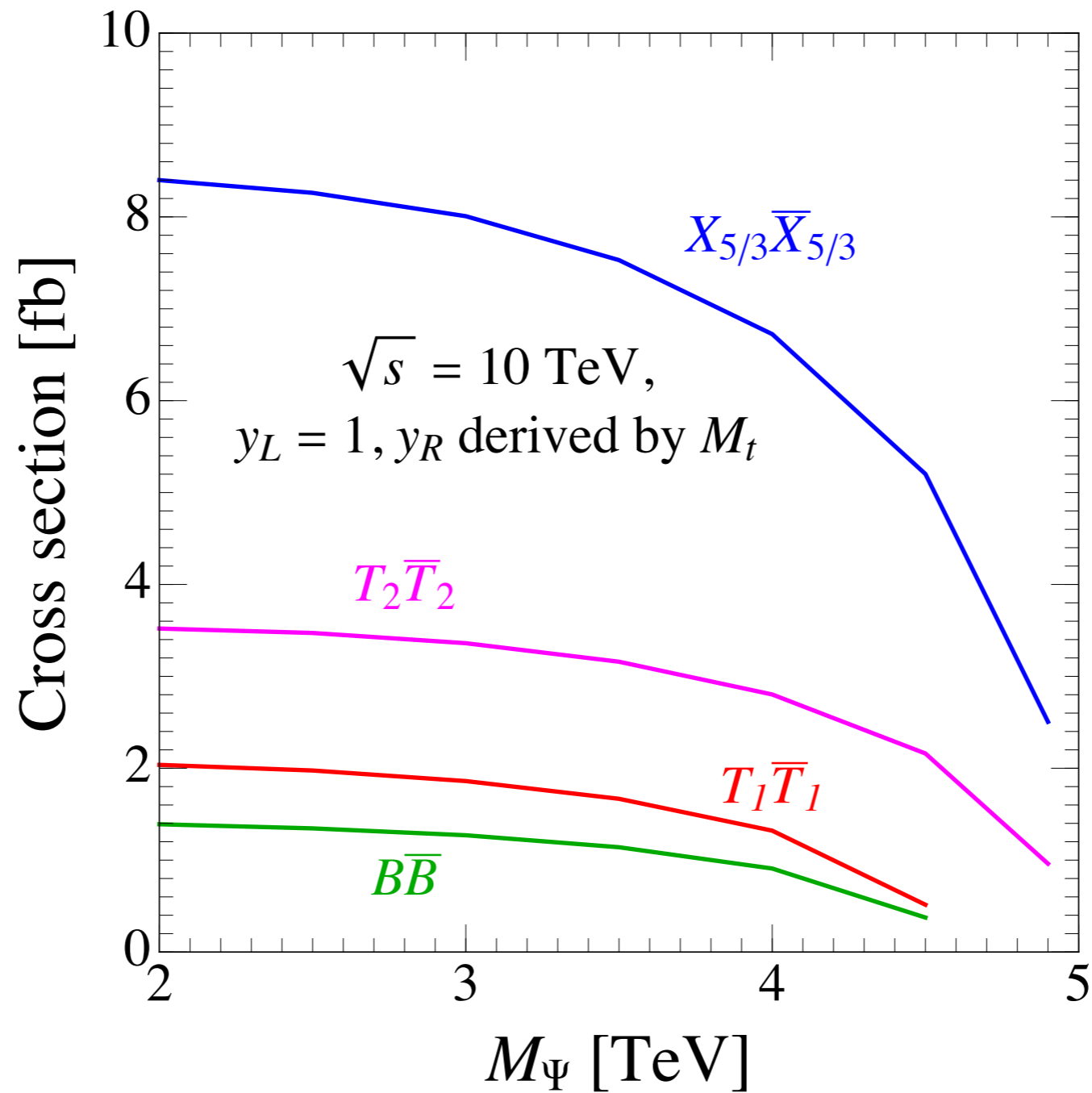


# Top partners: VBF



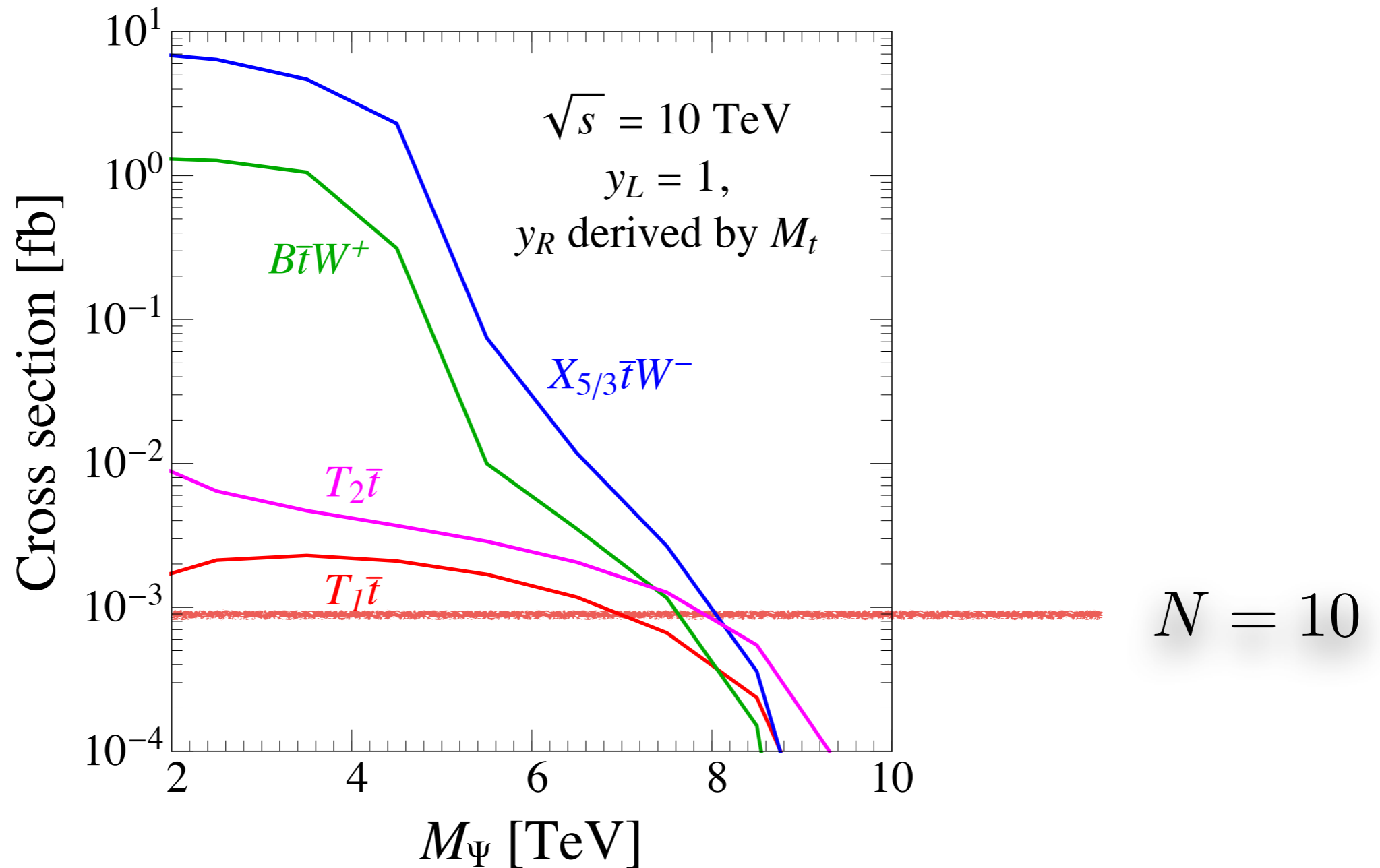
Relevant for large  $y_R$

# Top partners: Pair production XS



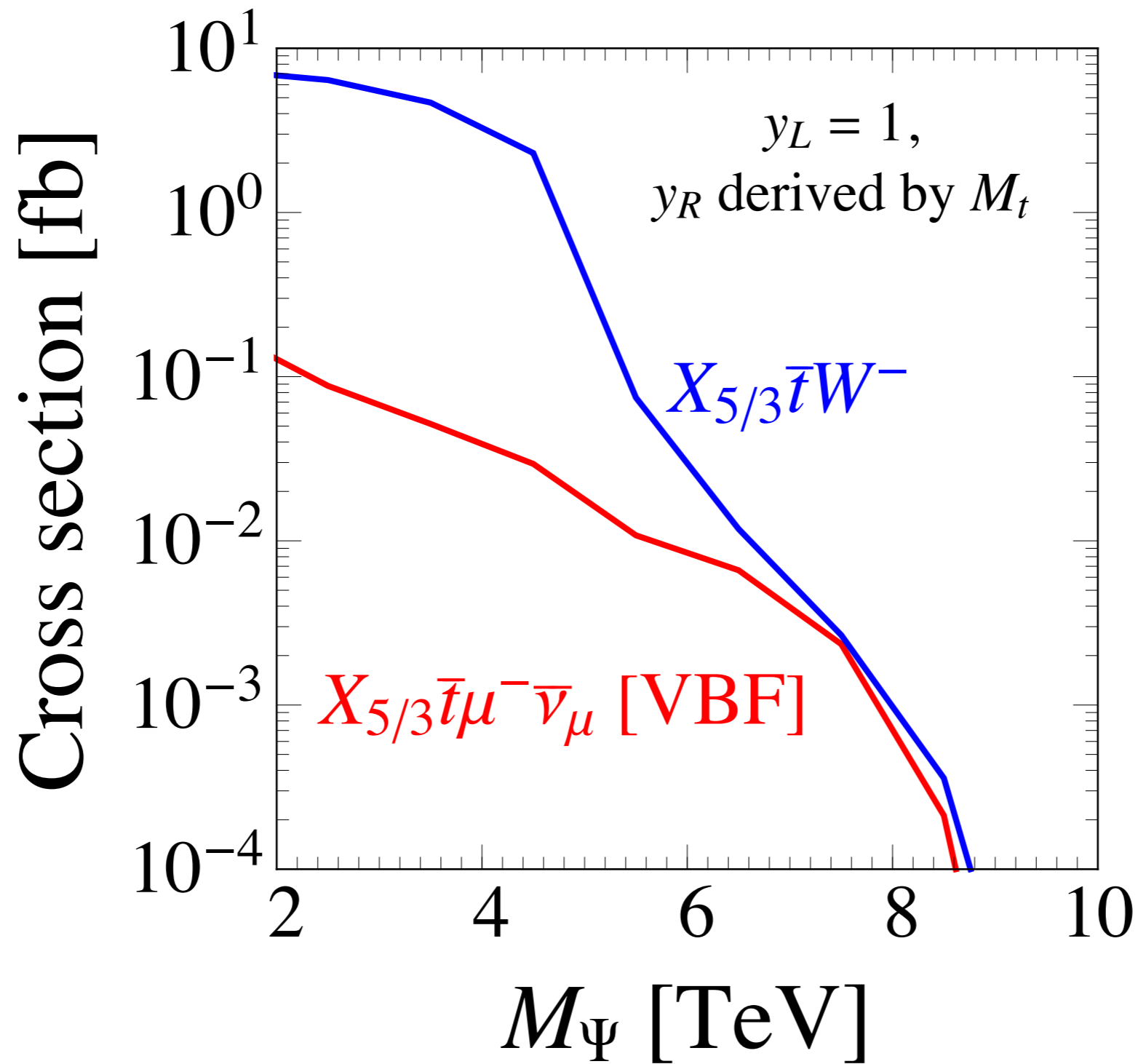
# Top partners: Single production

$$\xi = 0.015, f = 2 \text{ TeV}$$



Pair production is included when possible

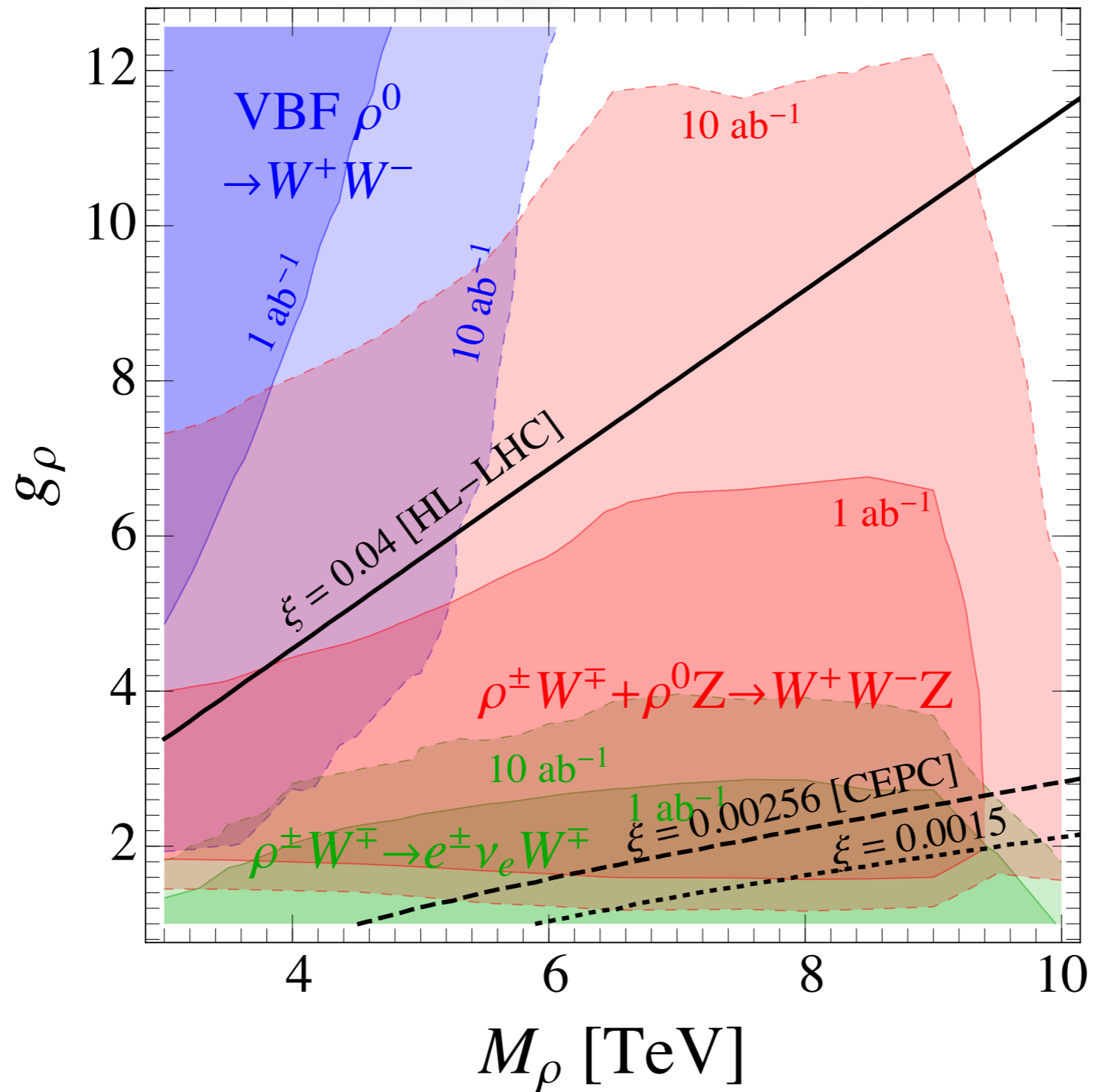
# Top partners: VBF Production XS



$\xi = 0.015, f = 2 \text{ TeV}$

# Projection: Spin-1

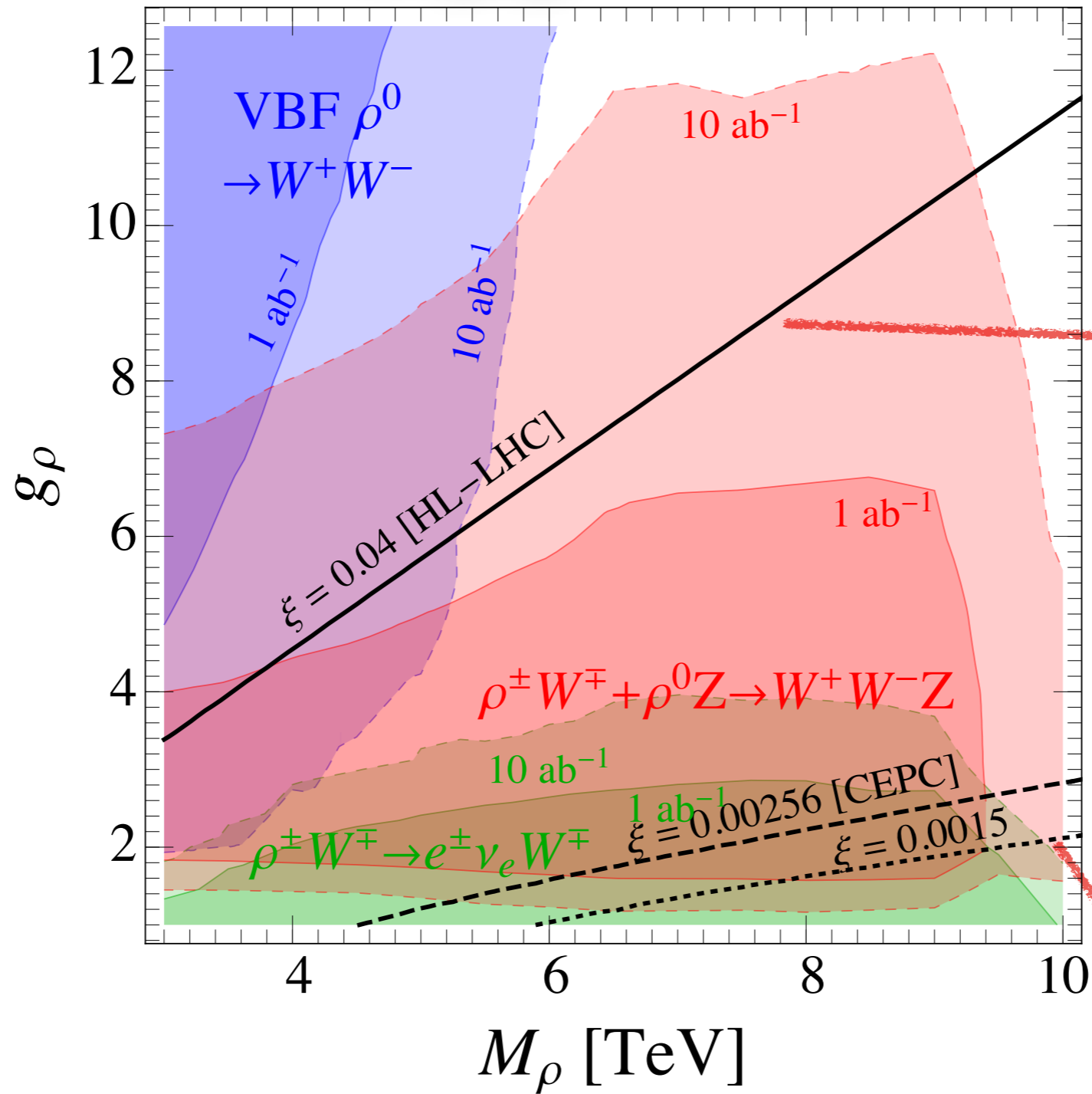
$$\sqrt{s}_{\mu^+\mu^-} = 10\text{TeV}$$



Hadronically decaying

# Projection: Spin-1

$$\sqrt{s}_{\mu^+\mu^-} = 10\text{TeV}$$

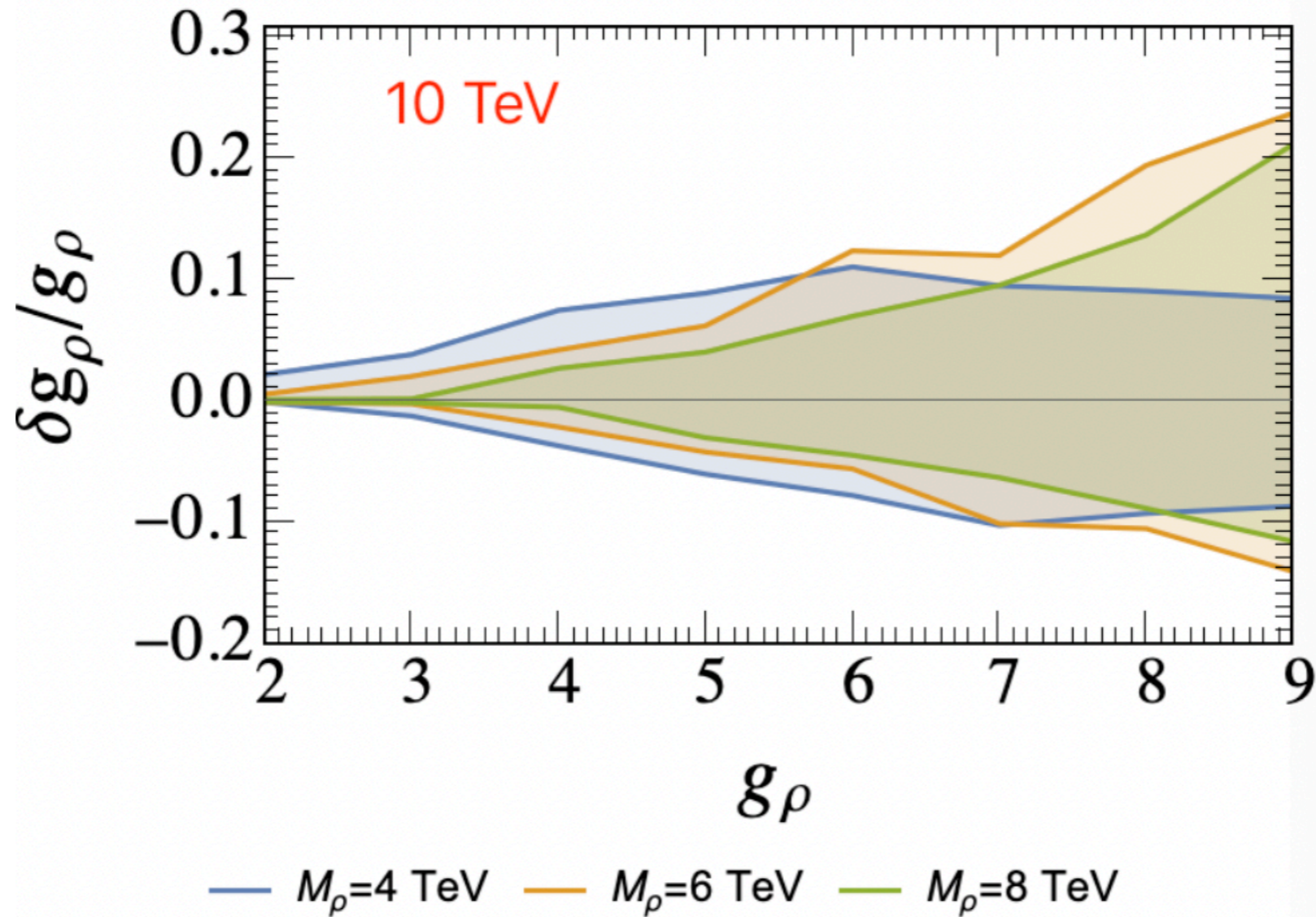


$$M_\rho = \frac{1}{\sqrt{2}} g_\rho f$$

10 TeV Muon Collider  
see T. Han, DL, I. Low and X. Wang

# Coupling Measurement

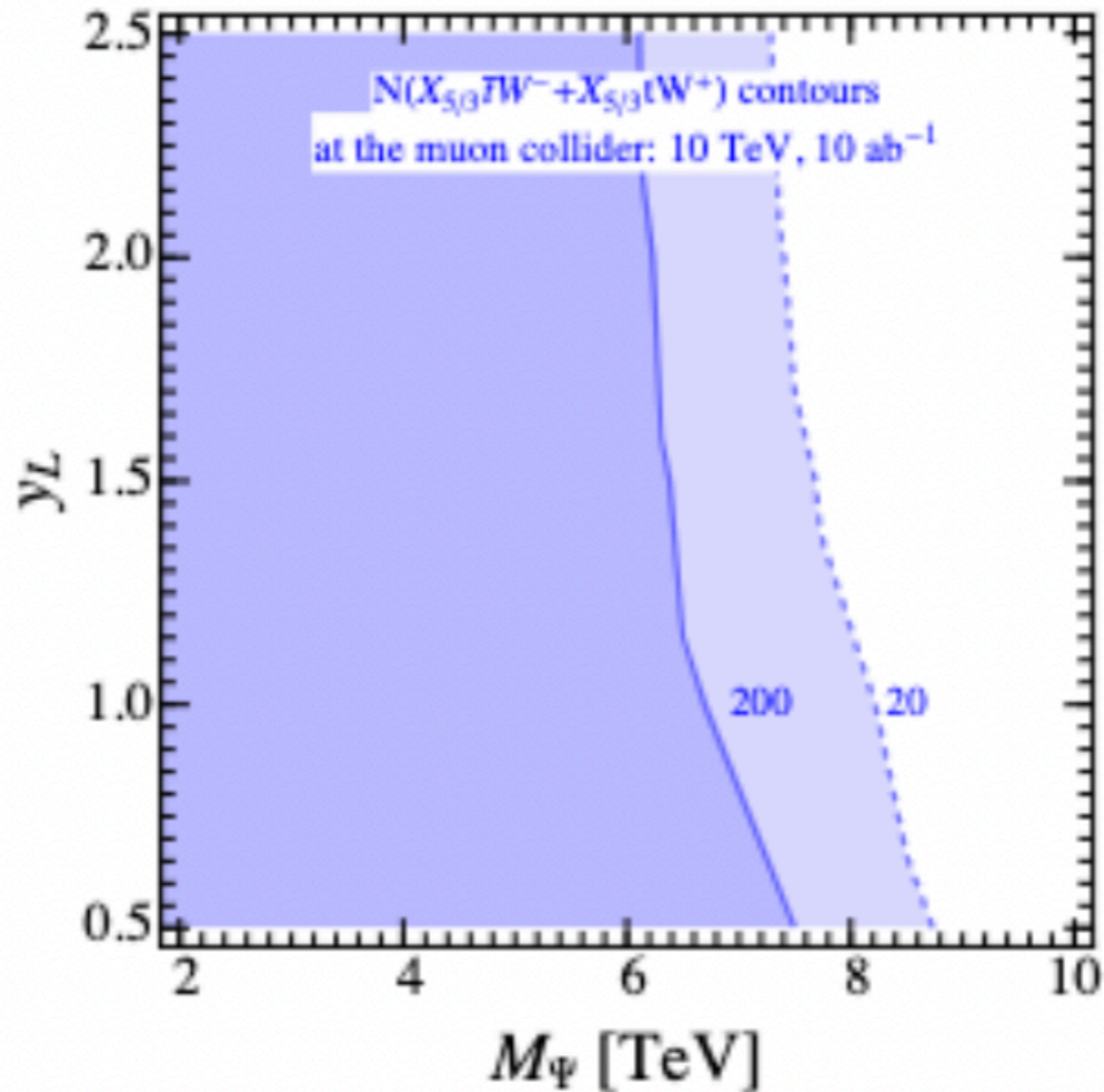
$$\sqrt{s}_{\mu^+\mu^-} = 10\text{TeV}$$





# Projection: top partner

$$\sqrt{s}_{\mu^+\mu^-} = 10\text{TeV}$$





# Conclusion

- Compositeness is an elegant way to address the hierarchy problem.
- Prospects at high energy muon collider are under careful scrutiny

**Back-up slides**

