Color Sextet Higgs at LHC

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Based on Mohapatra, Okada and Yu PRD (2008) arXiv:0709.1486

Outline

- Some motivations and backgrounds
- Phenomenological constraints
- Signals at LHC
- Summary

LHC Era

- New physics related to electroweak symmetry breaking (EWSB) and hierarchy problem: Higgs, SUSY, Extra-Dim, Little Higgs, Twin Higgs...
- New physics related to dark matter. See Jonathan, Randy and Graham`s talk.
- New physics models with U(1)_(B-L) gauge symmetry are suggested by the small neutrino mass. There are many new particles that carry baryon number.
- But in general, their masses are around 10^(10)-10^(13) GeV.

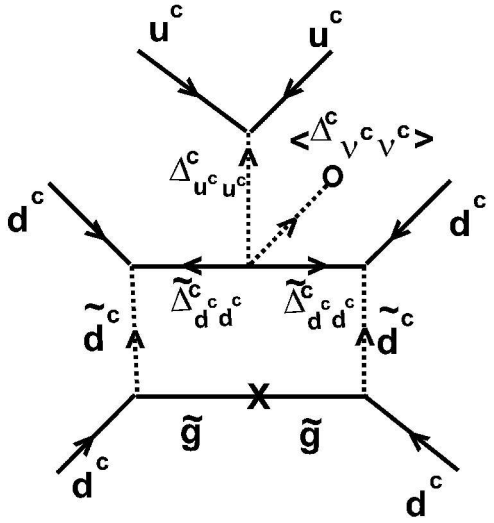
Light Color Sextet-Diquark Higgs

- TeV scale color sextet exists in a class of Pati-Salam model as a NG boson, and its mass is ~v_(B-L)^2/Mpl. SU(4) × SU(2) ×SU(2) .
- Color sextet Δ has quantum number (6,1,4/3) under SM gauge group SU(3)×SU(2) ×U (1).
- It couples to right-handed up-type quarks through Yukawa .
- It carries baryon number 2/3.

•No grand unification, only partial unification.

•No proton decay.

•Induce neutron-anti-neutron oscillation. Prediction 10^(10) seconds. Current lower limit is 10^ (8) secon

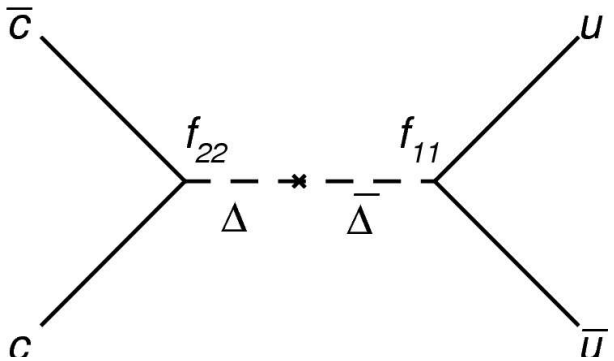


Chacko and Mohapatran PRD (1999), Dutta, Mimura and Mohaptara PRL (2006)]

Phenomenological Constraints

- D-Dbar mixing

$$f_{ij}\overline{\Delta}_{u^c u^c} u^i u^j + h.c.$$

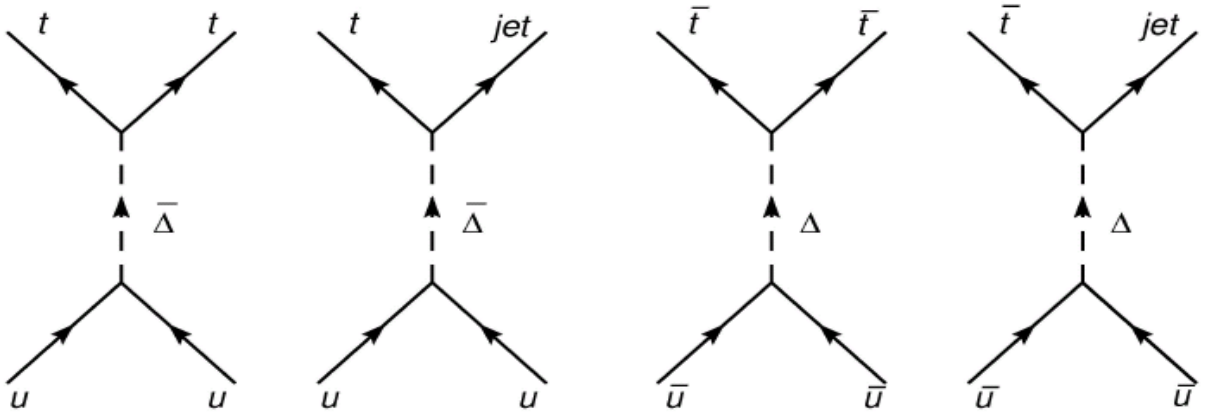


$D^0 - \overline{D^0}$ transition implies $8.5 \times 10^{-15} \leq \Delta M_D \leq 1.9 \times 10^{-14}\mathrm{GeV}$, which gives bound $f_{11} f_{22} \leq 4 \times 10^{-6}$ with $m_\Delta \sim 1\mathrm{TeV}$.

We take $f_{ij} = \begin{bmatrix} 0.3 & 0 & 0.3 \\ 0 & 0 & 0 \\ 0.3 & 0 & 0.3 \end{bmatrix}$

Production of Color Sextet

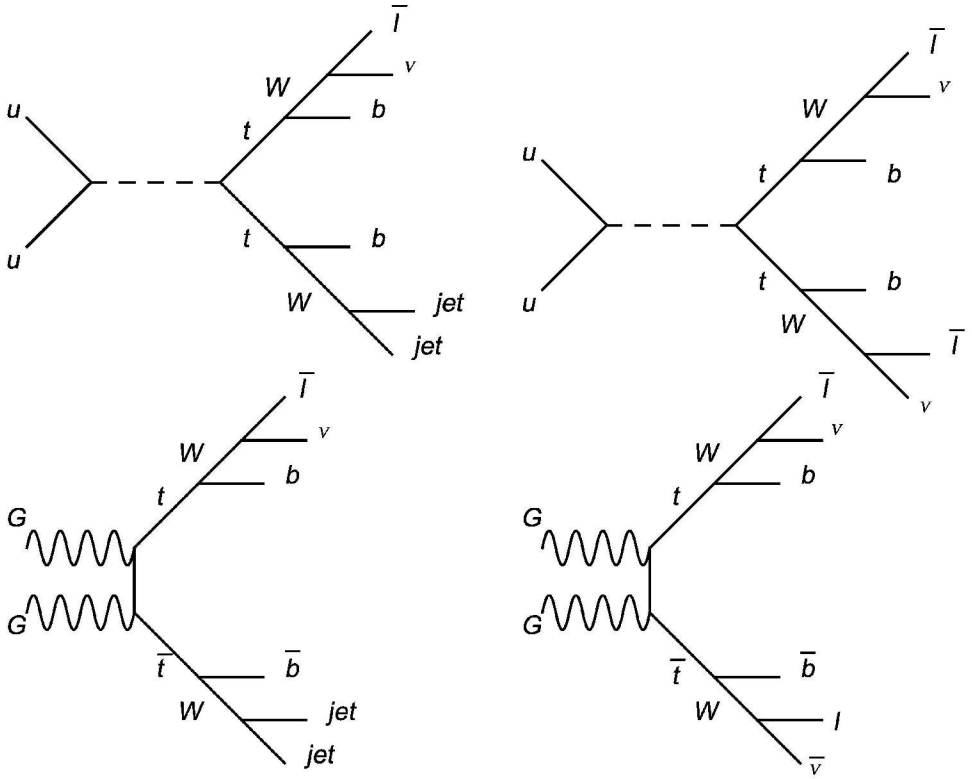
- Resonance production.
- Gluon-gluon fusion. Chen, Klemm, Rentala and Wang (2008)
- LHC is more favorable for production of diquark compared to Tevatron.
- Decay channels: jet+jet, jet+top, top+top
- Top quark is a good window for new physics.



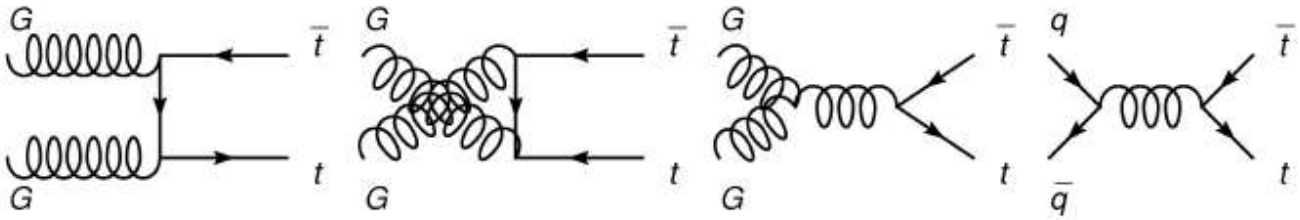
Signals

- S-channel resonance peak.
- The differential cross section has no angular dependence: it is scalar.
- The same sign di-lepton events.
- At LHC, the production rate of diquark and anti-diquark is different.
  - It carries baryon number. Counting the number of top events and anti-top events from their leptonic decay modes would reveal a nozero baryon number of color sextet Higgs.
- It only couples to the right-handed up-type quarks.

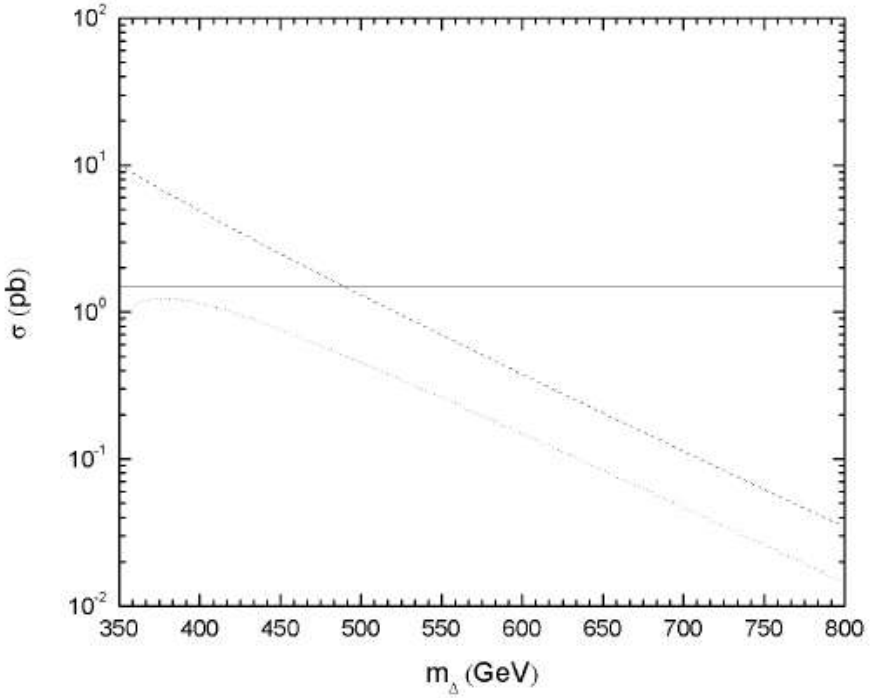
Semi-leptonic decay mode



- To reconstruct kinematics. We focus on the semi-leptonic decay mode.
- The signal is an isolated charged lepton+missing energy+2 b-jets and 2 light-jets.
- SM background.



Tevatron Bound



Cross sections of tt (dotted line) and tj (dashed line) at Tevatron

- For Tevatron, it is a proton-anti-proton collidder. The production rate of color sextet is suppressed.
- If we assume all top events can be understood by SM production, the lower mass bound from Tevatron is about 470 GeV.

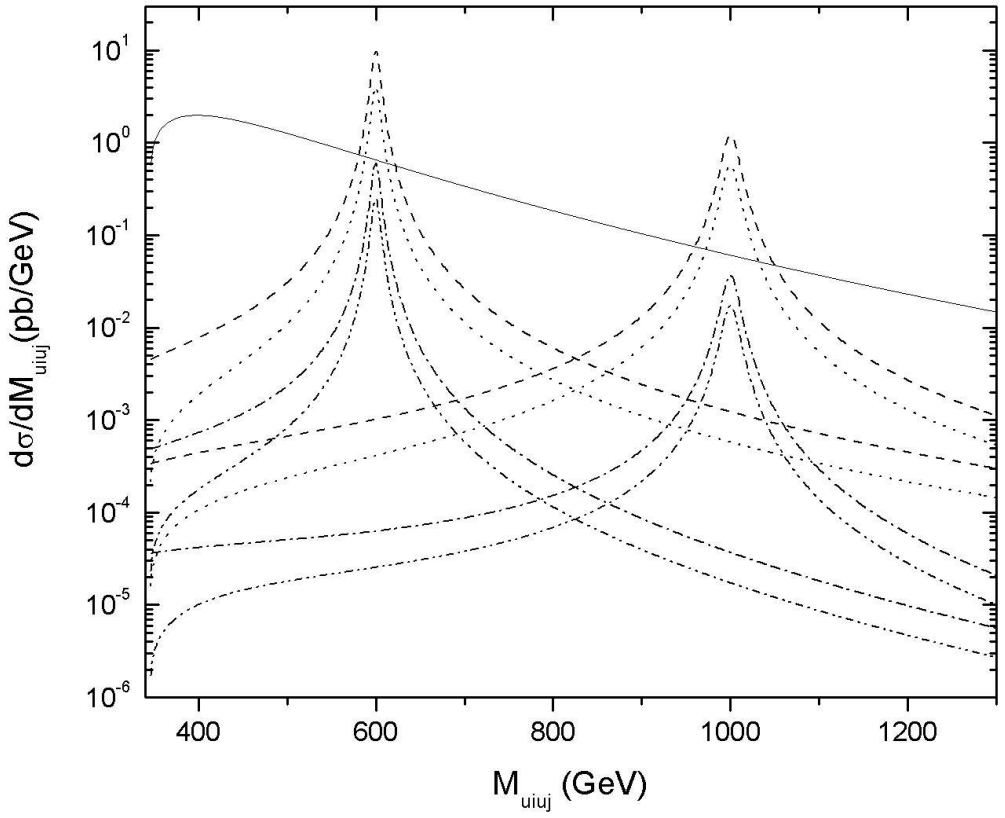
I

$$\sigma(t\bar{t}) = 7.3 \pm 0.5(\text{stat}) \pm 0.6(\text{syst}) \pm 0.4(\text{lum})\ \text{pb}.$$

S. Cabrera [CDF and D0 Collaboration] FERMILAB-CONF-06-228-E, Jul 2006

$$\sigma(p\bar{p} \to \Delta_{u^c u^c} \to tt, ut) \lesssim 1.5\text{pb} \Rightarrow m_\Delta \gtrsim 470\ \text{GeV}$$

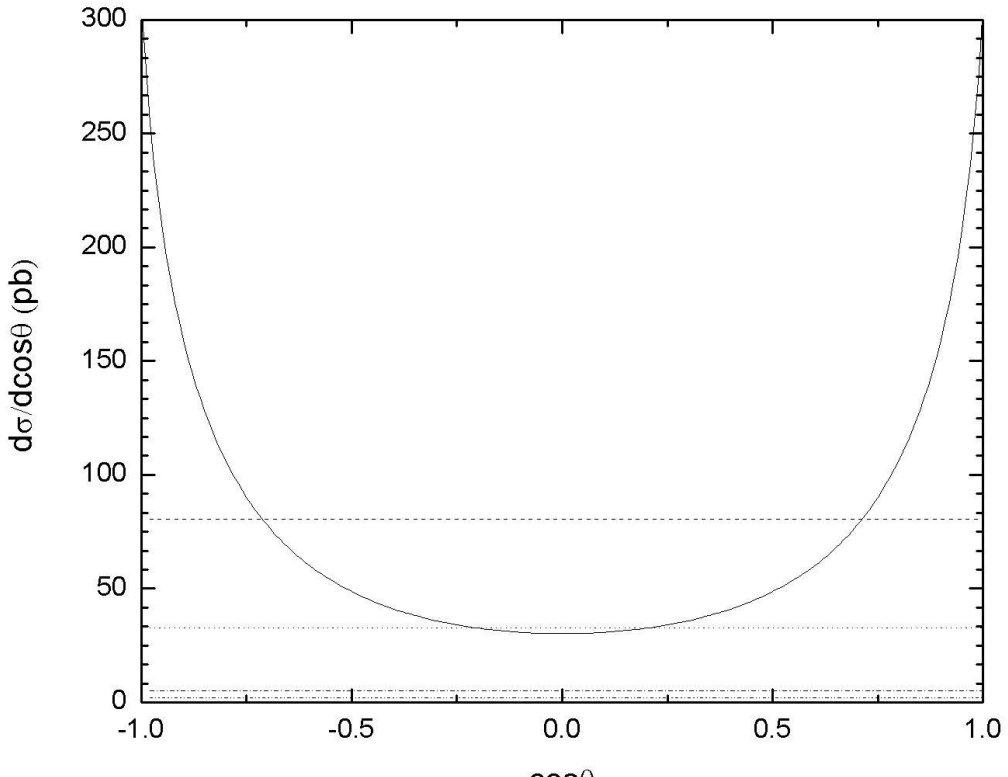
Resonance



Cross sections as invariant mass.

- The solid line is the SM top and anti-top production.
- Left peak corresponds to 600 GeV and the right one to 1TeV.
- The rate of top+jet is higher than anti-top+jet
- The rate of top+top is higher than anti-top+anti-top.

Angular Distribution



$m_\Delta = 600\mathrm{GeV}$ and $M_{cut} = 550\mathrm{GeV}$

- For the SM background, the differential cross section shows peaks in the forward and backward region.
- The signal of the sextet production is enhanced at the large scattering angle.
- We can impose a lower cut on the invariant mass to reduce the SM background

Summary

- LHC is coming. We expect new physics at the TeV scale.
- TeV scale color sextet is well motivated in the new physics beyond SM. Existence of such fields will indicate a new direction for unification than the conventional grand unification.
- We have studied the resonant production at the hadron collider.
  - sizable deviations from SM background.
  - asymmetry for top and anti-top production.
  - asymmetry for left-handed up-quark and right-handed up-quark production.
  - Special angular distribution.