Diquark Higgs at LHC

Hai-Bo Yu

University of California, Irvine

with Mohapatra and Okada,Phys.Rev.D77:011701,2008
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New Physics, New Particles

- New physics associated with electroweak symmetry breaking(EWSB) and hierarchy problem.
- A class of new physics models with U_{B-L} gauge symmetry is suggested by the small neutrino mass. There are many new particles that carry baryon number.
- TeV scale diquark exists in a class of Pati-Salam model as NG boson although the natural scale of the model is $10^{10} - 10^{11}\mathrm{GeV}$ [Chacko and Mohapatra PRD 1999].

Diquark Higgs $\Delta_{u^c u^c}$

- $\Delta_{u^c u^c}$ has quantum number $(6, 1, 4/3)$ under $SU(3) \times SU(2) \times U(1)$.
- It couples to up-type quark by $\Delta_{u^c u^c} u^c u^c$ (or $\overline{\Delta}_{u^c u^c} uu$). The coupling only involve right-handed up-type quark.
- It carries baryon number $2/3$.

Consequences of TeV scale diquark:

- No grand unification.
- No proton decay.
- Neutrino-anti-neutrino oscillation [Dutta,Mimura,Mohapatra PRL(2006)].

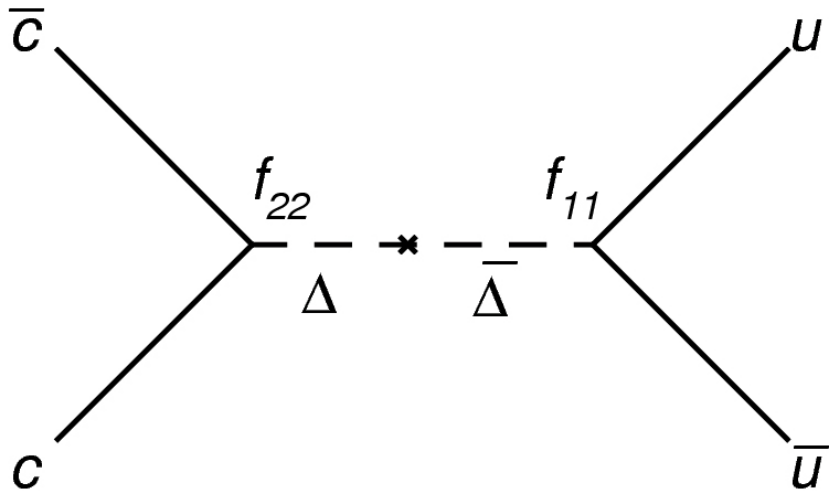
Light diquark indicates different high scale physics.

Phenomenological Constraints on f_{ij}

$f_{ij}\overline{\Delta}_{u^c u^c} u^i u^j + h.c.$, where i, j are family indices, and f_{ij} is a matrix

$$f_{ij} = \begin{bmatrix} f_{11} & f_{12} & f_{13} \\ f_{12} & f_{22} & f_{23} \\ f_{13} & f_{23} & f_{33} \end{bmatrix} = \begin{bmatrix} 0.3 & 0 & 0.3 \\ 0 & 0 & 0 \\ 0.3 & 0 & 0.3 \end{bmatrix}.$$

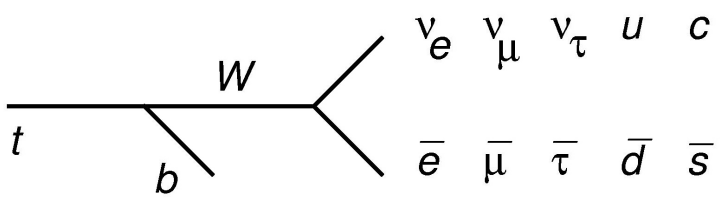
We take



$D^0 - \overline{D^0}$ 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 $m_\Delta \sim 1\mathrm{TeV}$.

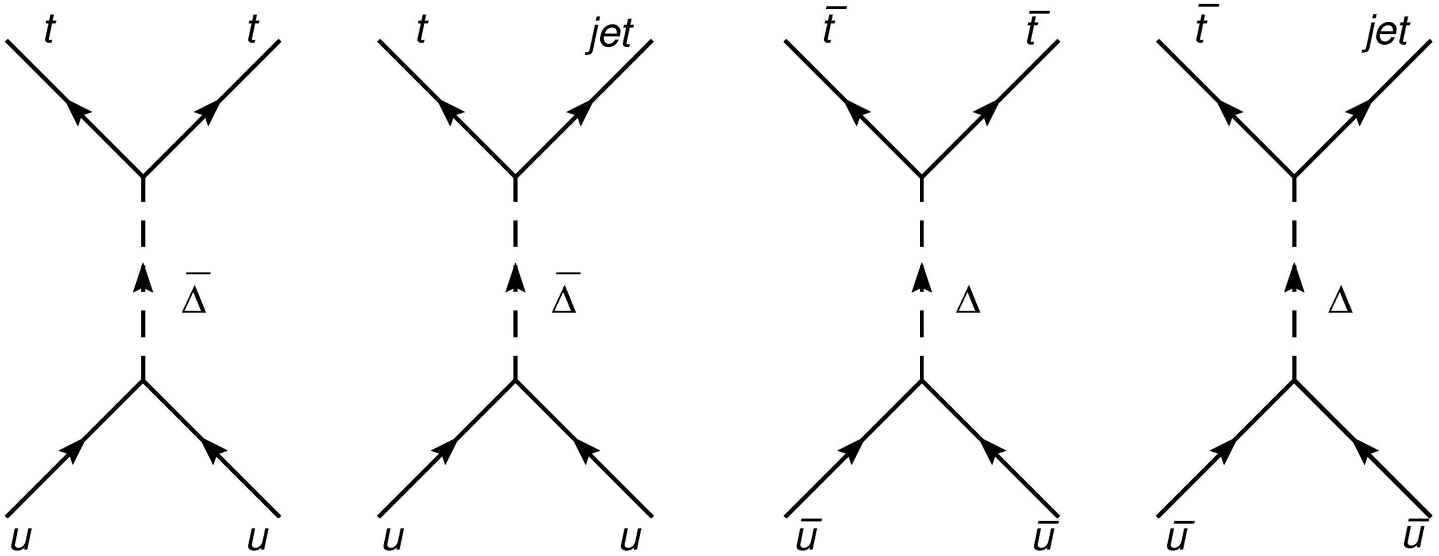
How Can We See $\Delta_{u^c u^c}$ at LHC?

- The resonant production of diquark at LHC $uu \to \overline{\Delta}_{u^c u^c}$. It is different at Tevatron.
- There are three main decay channels of $\overline{\Delta}_{u^c u^c}$: jet+jet,jet+t,t+t.
- Top quark is a good window for new physics. $t \to bW^+ \to bl^+\nu_l, bu\overline{d}, bc\overline{s}.l = e, \mu, \tau.$



- We focus on $\mathbf{uu \to \overline{\Delta}_{u^c u^c} \to tt}$ and $\mathbf{jet + t;\overline{uu} \to \Delta_{u^c u^c} \to \overline{tt}}$ and $\mathbf{jet + \bar{t}}$.

Diquark Resonance



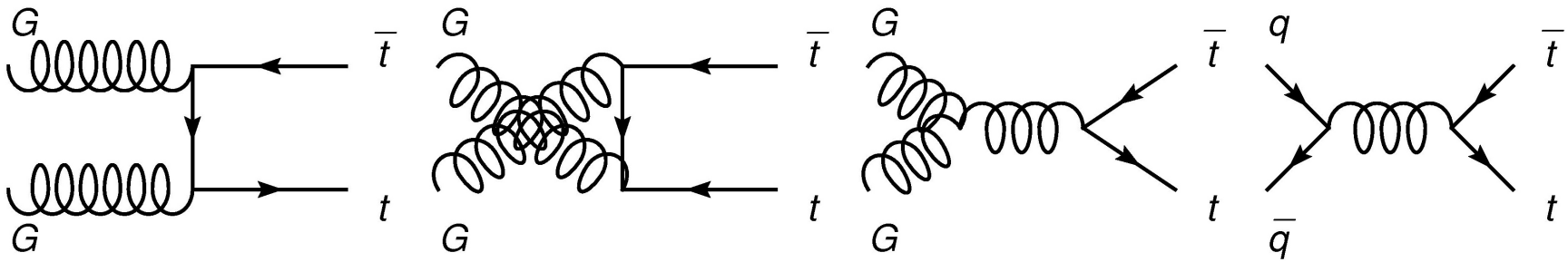
Signals

- S-channel resonance peak.
- No dependence on the angle θ.
- $\overline{\Delta}_{u^c u^c}$ carries baryon number $-2/3$. It can cause the number asymmetry of t and $\bar{t}$ in the final state at LHC.
- It can cause the number asymmetry of left-handed top quark and right-handed top quark.

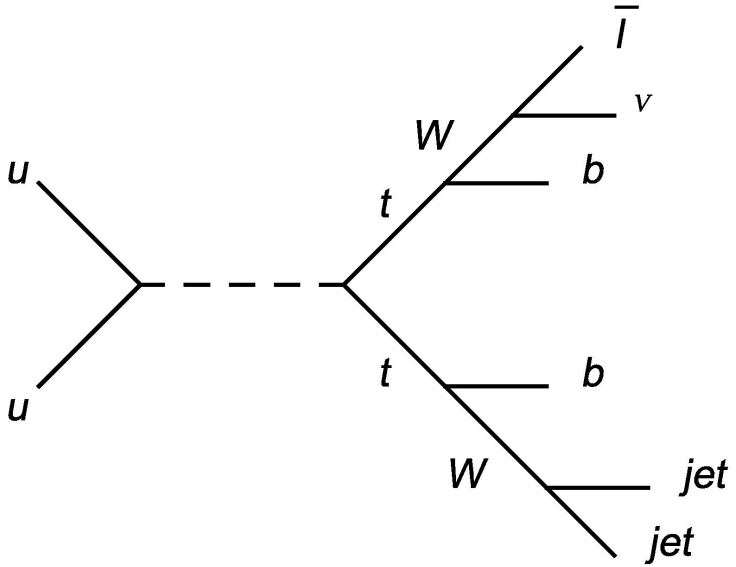
The last two features can be used to distinguish diquark from other new physics.

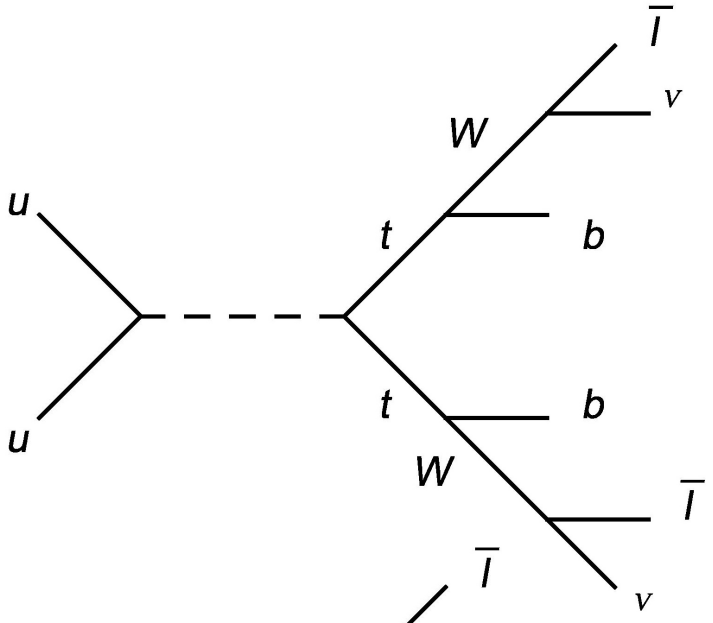
Standard Model Background

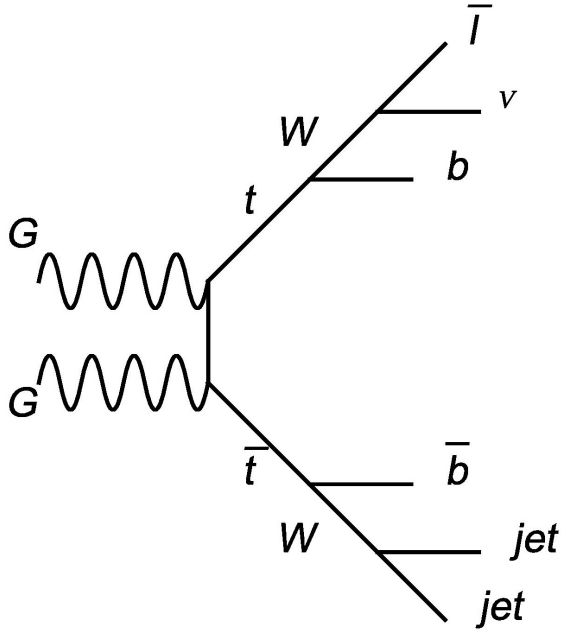
- We shall focus on the semi-leptonic decay mode.
- The signal is an isolated charged lepton plus the missing energy, 2 b-jets and 2 light jets.
- In the SM, $t\bar{t}$ production is from $q\bar{q} \longrightarrow t\bar{t}$ and $gg \longrightarrow t\bar{t}$

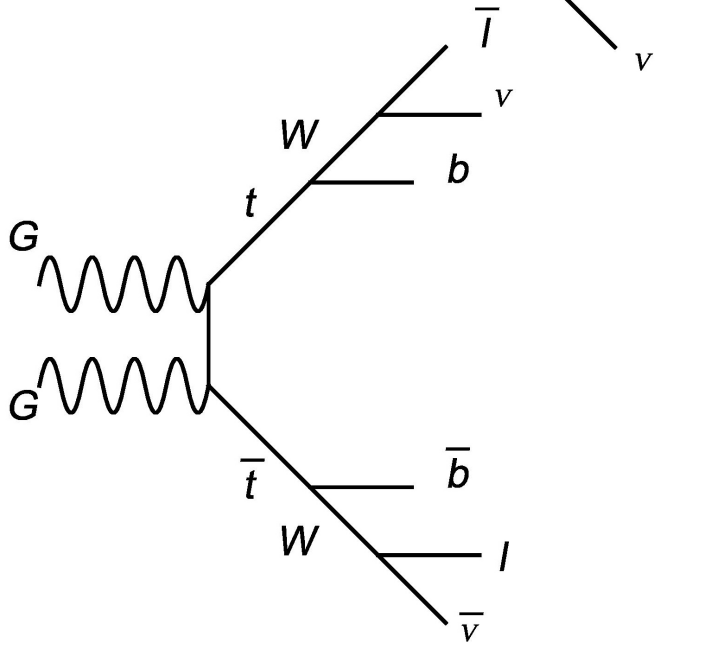


Top Production









Tevatron Bound on Diquark Mass

Top pair production cross section measured at Tevatron

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

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

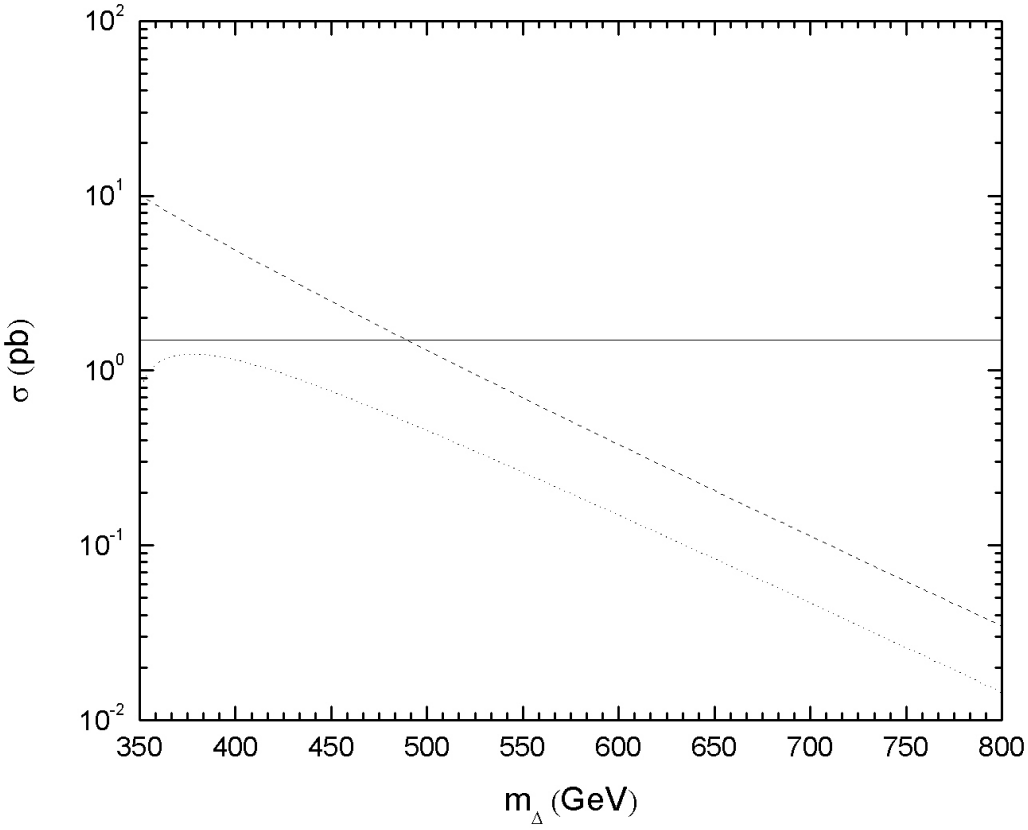
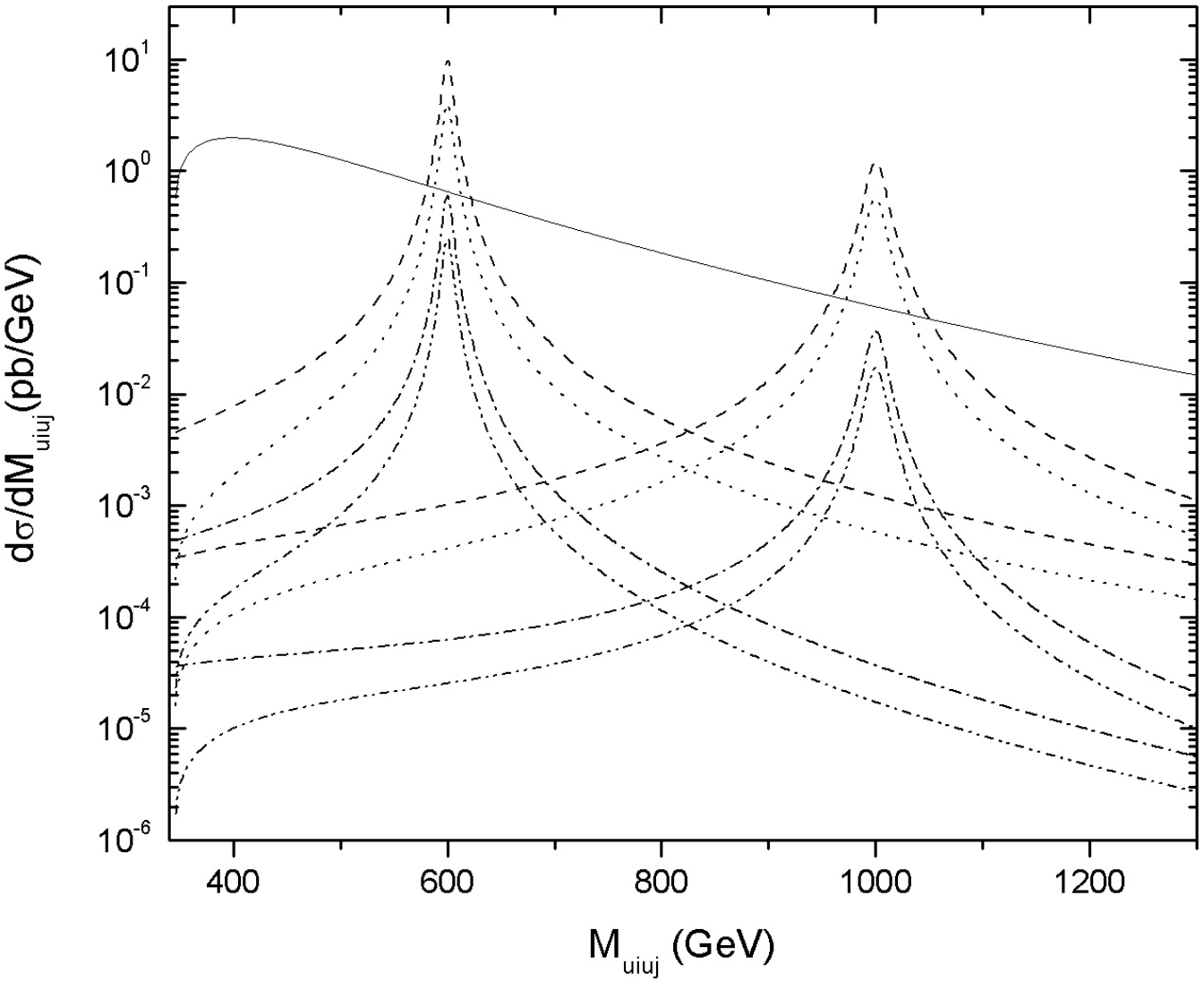


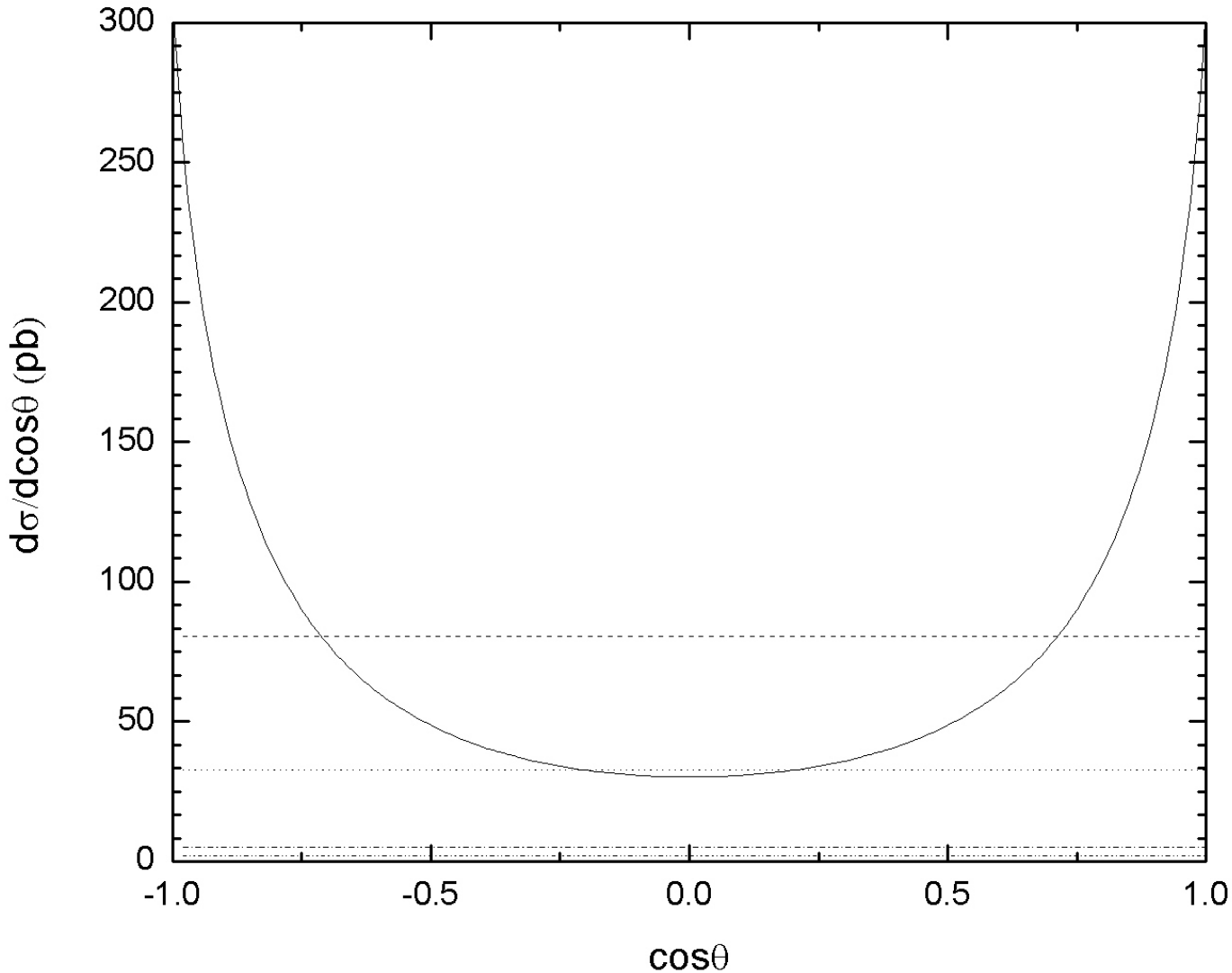
Figure: The cross sections of tt (dotted line) and tj (dashed line)

Resonant Production at LHC



Angular Distribution

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



Conclusion

- The existence of diquark is well motivated in physics beyond SM.
- In this talk, we focus on the color sextet $\overline{\Delta}_{u^c u^c}$ with the mass around TeV. It carries color quantum number 6 and only couples to right-handed quarks.
- 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.
  - no angular distribution.