Color Sextet Scalar Pair Production at the CERN LHC

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W Klemm, V. Rentala, Z. Si and KW, in preparation
C. Chen, W. Klemm, V. Rentala and KW; Phys. Rev. D **79**, 054002 (2009)

SM @ 14 TeV LHC

- total cross section at LHC : 10^{11} pb
- $b\bar{b}$: 10^{7} pb
- $t\bar{t}$: 800 pb
- $W \to e^{\pm}\nu$: 10^{4} pb
- $Z \to e^{+}e^{-}$: 10^{3} pb

Multijet+Same Sign Dilepton+$\not{E}_T$

SM contributes to enomous background as multijet, jets+$W^{\pm}$, jets+Z, jets+$W^+W^-/t\bar{t}$, ... One of the most stricking signals for BSM physics search at the LHC. Same-sign Dilepton as handle

Irreducible SM background

- $t\bar{t}W^{\pm}$ $\mathcal{O}(10)$ fb
- jets+$W^{\pm}W^{\pm}$ $\mathcal{O}(10)$ fb

New Physics with large production $\mathcal{O}$ pb

- SUSY: gluino, same-sign squark pair (gluino in t-channel) $nj\chi_1^{\pm}\chi_1^{\pm}$
- ED: KK-gluon $g'g' \to njW'^{\pm}W'^{\pm}$
- 4-th generation: $b'\bar{b}' \to t\bar{t}W^+W^- \to njW^{\pm}W^{\pm}$
- Color Octet: $88 \to t\bar{t}t\bar{t} \to njW^{\pm}W^{\pm}$

What else?

our example: the same final with different reconstruction at comparable rate

Bottom-up setup

Color Sextet Scalars under $SU(3)_C \times SU(2)_L \times U(1)_Y$: $\overline{\psi^c}\psi\phi$

- $SU(2)_L$ adjoint $\Delta_6 : (6, 3, 1/3)$
- $SU(2)_L$ singlet $\Phi_6 : (6, 1, 4/3)$, $\phi_6 : (6, 1, -2/3)$, $\delta_6 : (6, 1, +1/3)$

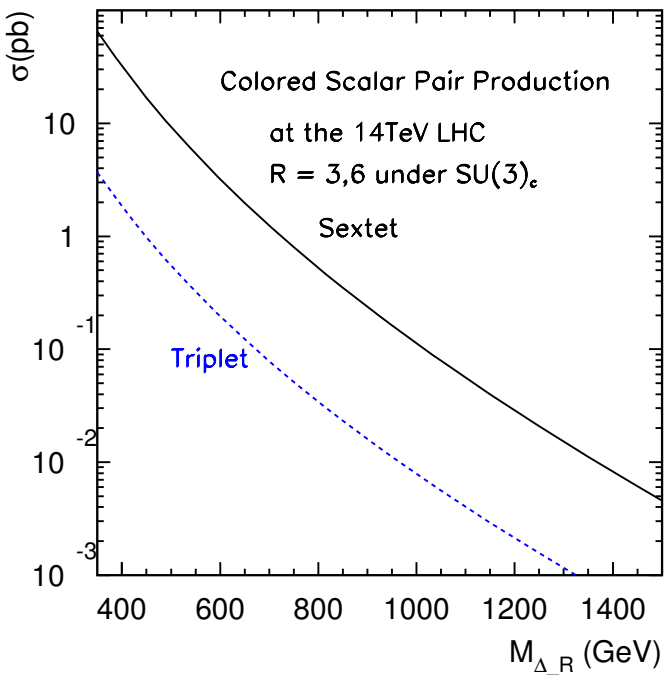
Scalar QCD

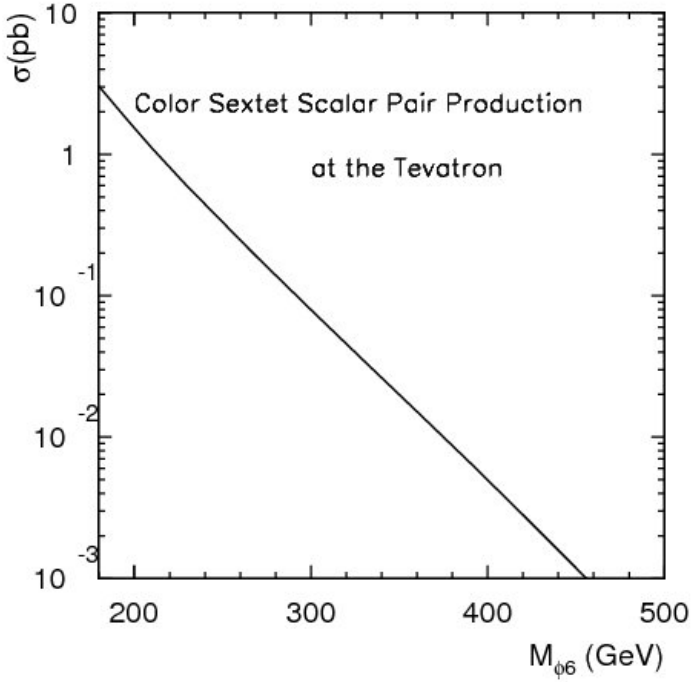
$$
\begin{aligned}
& \mathrm{Tr}[(D_\mu \Delta_6)^\dagger (D^\mu \Delta_6)] - M_\Delta^2 \mathrm{Tr}[\Delta_6^\dagger \Delta_6] + f_\Delta Q_L^T C^{-1} \tau_2 \Delta_6^\dagger Q_L \\
+ \quad & (D_\mu \Phi_6)^\dagger (D^\mu \Phi_6) - M_\Phi^2 \Phi_6^\dagger \Phi_6 + f_\Phi u_R^T C^{-1} u_R \Phi_6^\dagger \\
+ \quad & (D_\mu \phi_6)^\dagger (D^\mu \phi_6) - M_\phi^2 {\phi_6}^\dagger \phi_6 + f_\phi d_R^T C^{-1} d_R \phi_6^\dagger \\
+ \quad & (D_\mu \delta_6)^\dagger (D^\mu \delta_6) - M_{\delta_6}^2 {\delta_6}^\dagger \delta_6 + f_\delta d_R^T C^{-1} u_R \delta_6^\dagger + V
\end{aligned}
$$

$$D_\mu = \partial_\mu - i g_s G_\mu^a T_r^a$$

QCD Production of Color Sextet Scalar Pair

$$g(p_1) + g(p_2) \to \bar{\Phi}_6(k_1) + \Phi_6(k_2) \to \bar{t}\bar{t}tt$$
$$q(p_1) + \bar{q}(p_2) \to \bar{\Phi}_6(k_1) + \Phi_6(k_2) \to \bar{t}\bar{t}tt$$





Production of $\bar{\Phi}_6\Phi_6$ at the LHC and Tevatron $\mu_F = \mu_R = \sqrt{\hat{s}}/2$, CTEQ6L

$$\sigma(q\bar{q} \to \bar{\Phi}_6\Phi_6) = \pi C(3)C(R)\frac{d_8}{d_3^2}\frac{\alpha_s^2}{3s}\beta^3 = \frac{10\pi}{27s}\alpha_s^2\beta^3$$

$$\begin{aligned}
\sigma(gg \to \bar{\Phi}_6\Phi_6) &= d_R C_2(R)\pi\frac{\alpha_s^2}{6s}\frac{1}{d_8^2}[3\beta(3-5\beta^2) - 12C_2(R)\beta(\beta^2-2) \\
&+ \ln|\frac{\beta+1}{\beta-1}|(6C_2(R)(\beta^4-1) - 9(\beta^2-1)^2] \\
&= \frac{5\pi}{96s}\alpha_s^2[\beta(89-55\beta^2) + \ln|\frac{\beta+1}{\beta-1}|(11\beta^4+18\beta^2-29)]
\end{aligned}$$

where $\sqrt{s}$ is the total energy, $\beta = \sqrt{1-4M_{\Phi_6}^2/s}$ and R is 6 with the normalization factor C and Casimir C_2 as

d_R	3	6	8
$C(R)$	$1/2$	$5/2$	3
$C_2(R)$	$4/3$	$10/3$	3

Table: Normalization factor $C(R)$ and quadratic Casimir $C_2(R)$ for $d_R = 3, 6, 8$ under $SU(3)$.

Remarks

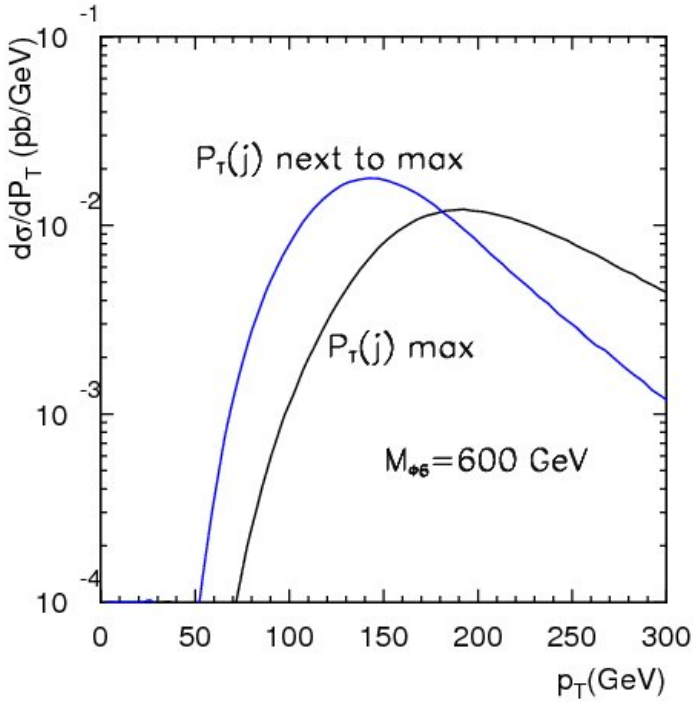
- $qq \to \Phi_6$ from f_{11} or f_{22}
- $\overline{\psi^c}\psi\phi$, the coupling f_{ij} irrelevant to fermion masses
- tree level $D^0 - \overline{D^0}$ mixing from $f_{11}f_{22}$, maybe dominant decaying into top
- GIM violation. But only coupling to righthanded states.
- $$3 \otimes 3 = 6 \oplus \bar{3}$$

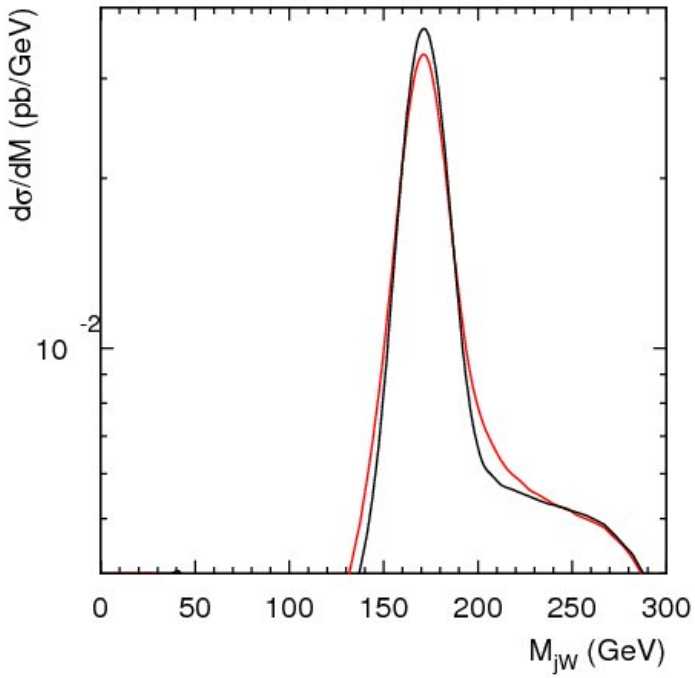
  Squark pair production with R-parity violation decay? only $u^c d^c d^c$
- Sextet Quarks in ETC

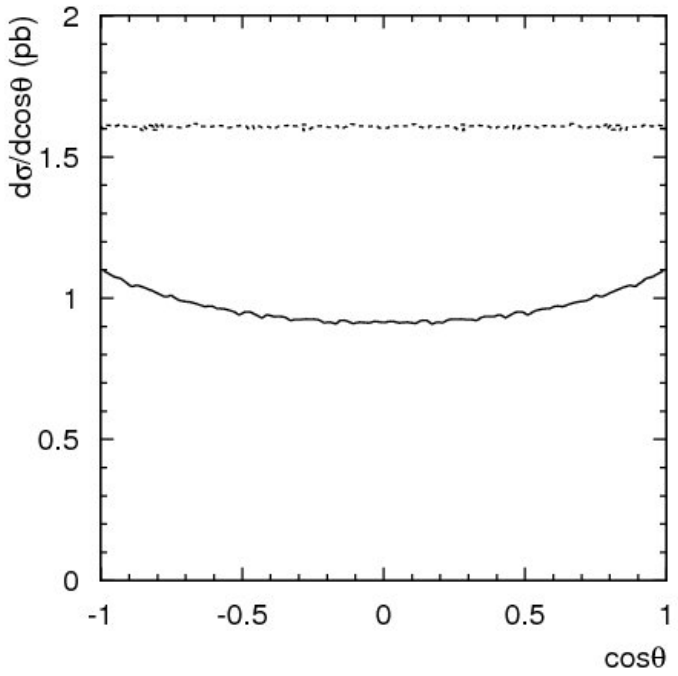
Same Sign Top

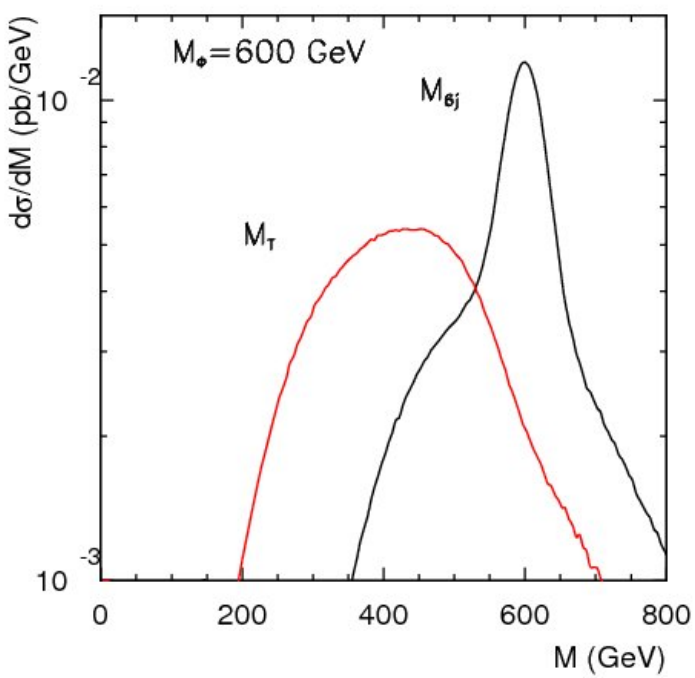
$$pp \to \bar{\Phi}_6 \Phi_6 \to t\bar{t}t\bar{t} \to 4b + \ell^{\pm}\ell^{\pm} + \not{E}_T + Nj,$$

(No radiation included)

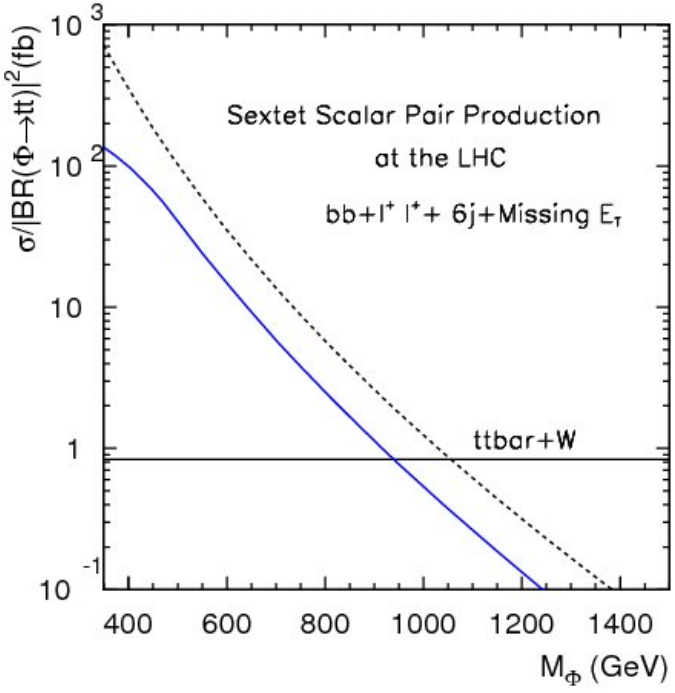


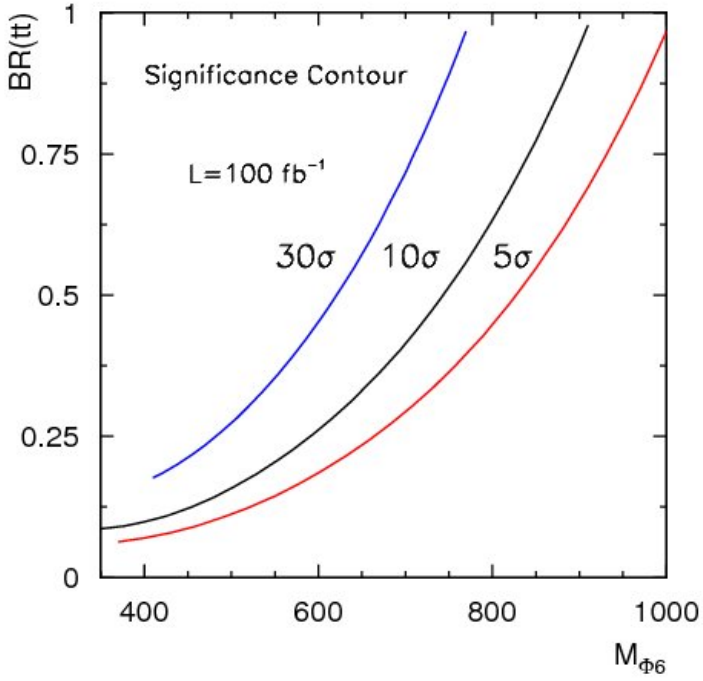






Reconstructed two hadronic Top shows the scalar feature.
Multijet resonance





(background included irreducible only, leading background: $t\bar{t}W^{\pm}$)

Theory Realization

Pati-Salam Model to Left-Right Model

$$SU(2)_L \times SU(2)_R \times SU(4)_C \to SU(2)_L \times SU(2)_R \times U(1)_{B-L} \times SU(3)_C$$

$$(3,1,10) : \{(3,1,-2,1) \oplus (3,1,-2/3,3) \oplus (3,1,2/3,6)\} + L \leftrightarrow R$$

- Neutrino mass:

$$\Delta(3,1,-2,1) : \ell^T C^{-1} i\tau_2 \Delta^\dagger \ell$$

- $\Delta B = 2$ $n - \bar{n}$ neutron anti-neutron oscillation
- why light, SUSY Pati-Salam (Chacko-Mohapatra, 99), Electroweak Baryogenesis(see next talk by Bhupal DEV) and consistent with $n - \bar{n}$ constraints