

SCALAR LEPTOQUARKS AT LHC^{*○}

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University of Split

Summer School and Workshop on the Standard Model and Beyond

September 10, 2015

^{*}I. Doršner, S. Fajfer, and A. Greljo, JHEP **1410**, 154 (2014), arXiv:1406.4831.

[○]Croatian Science Foundation (HRZZ) project # 7118

OUTLINE

- FRAMEWORK

- LEPTOQUARK PRODUCTION AT LHC
(SINGLE AND PAIR PRODUCTION OF LEPTOQUARKS)

- THE CMS LEPTOQUARK SEARCH RECAST
(SECOND GENERATION LEPTOQUARKS)

- CONCLUSIONS

FRAMEWORK

$SU(3) \times SU(2) \times U(1)$ MULTIPLETS

SCALAR LEPTOQUARKS (LQs):

$$(\bar{\mathbf{3}}, \mathbf{3}, 1/3)$$

$$(\mathbf{3}, \mathbf{2}, 7/6)$$

$$(\mathbf{3}, \mathbf{2}, 1/6)$$

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$$(\bar{\mathbf{3}}, \mathbf{1}, 4/3)$$

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◎

◎W. Büchmuller, R. Rückl, and D. Wyler, Phys. Lett. B 191, 442 (1987).

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• I. Doršner, S. Fajfer, and N. Košnik, Phys. Rev. D 86, 015013 (2012).

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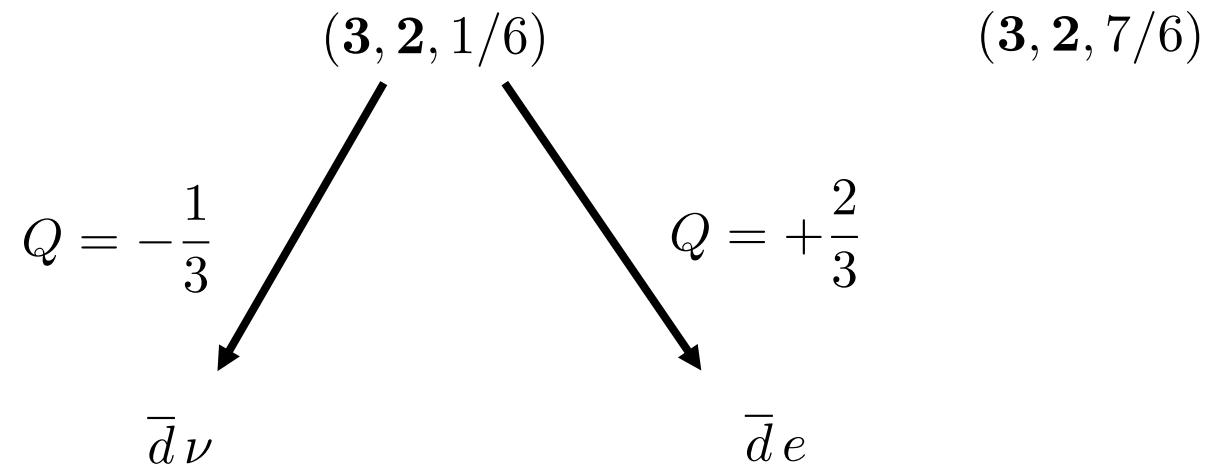
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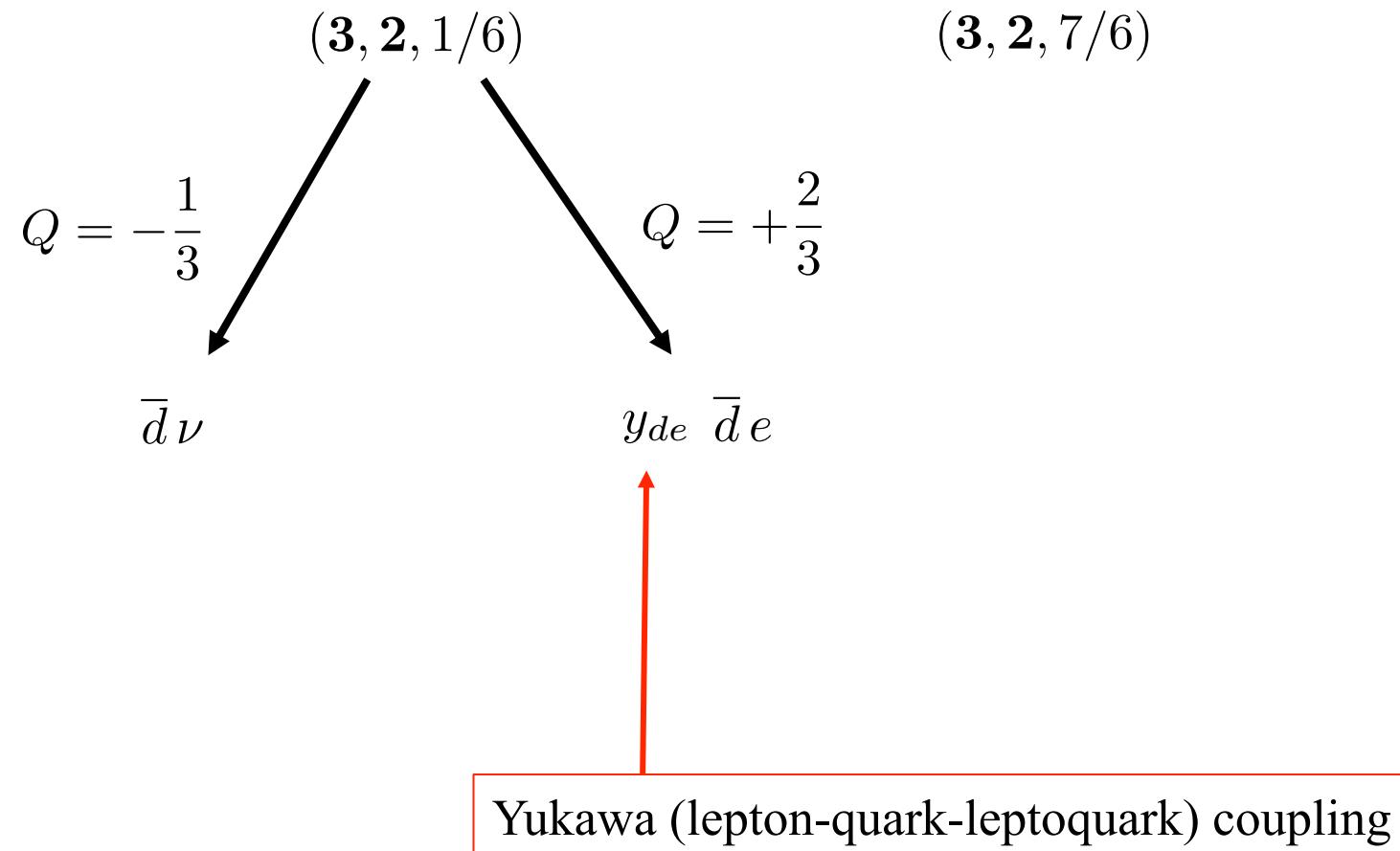
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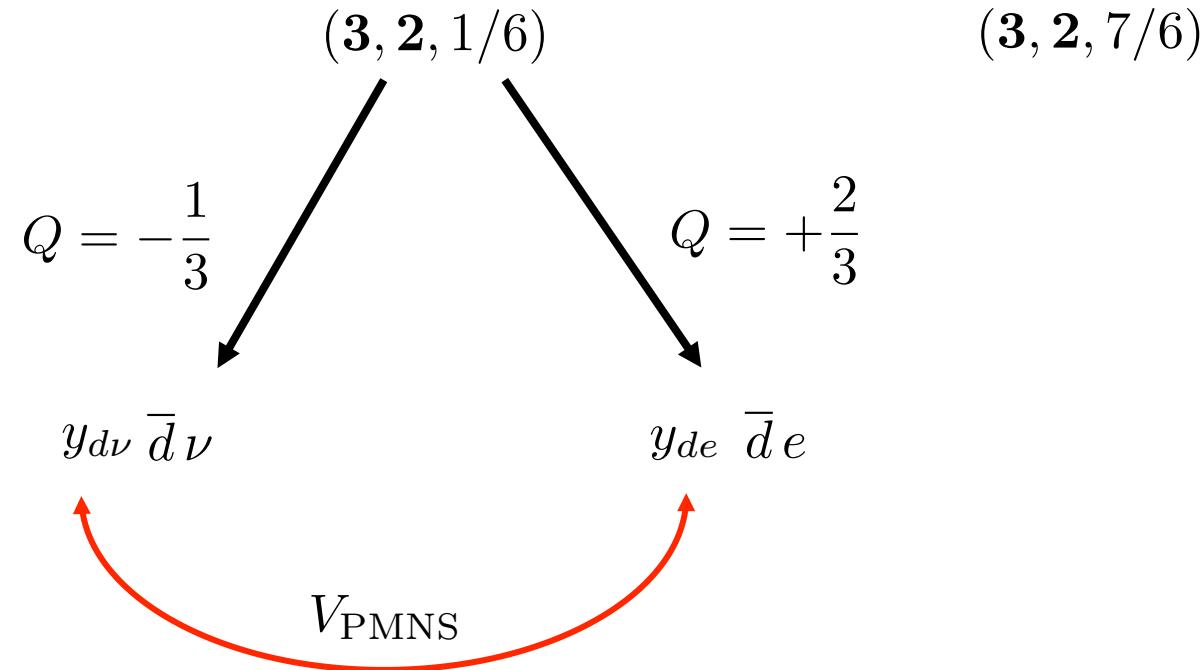
FRAMEWORK



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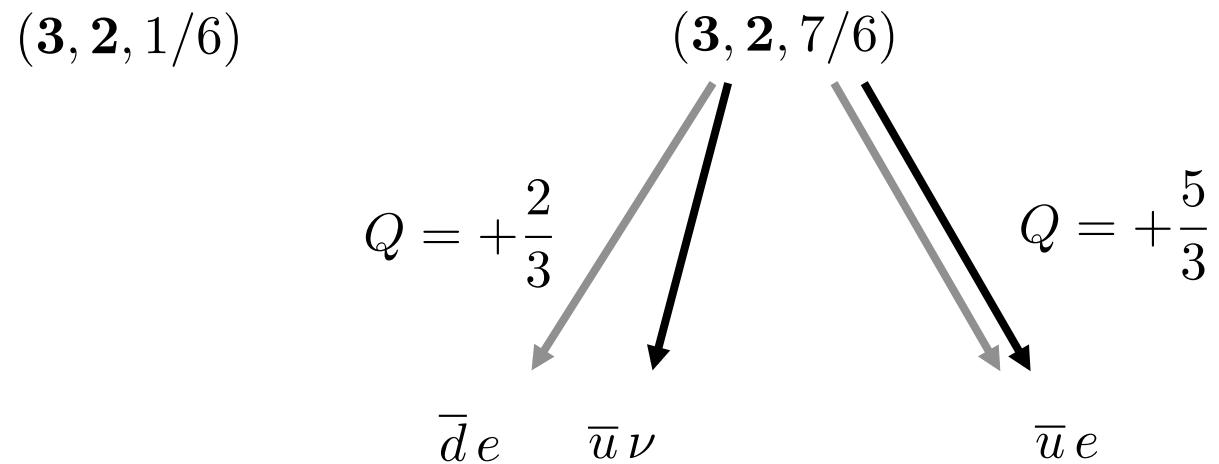


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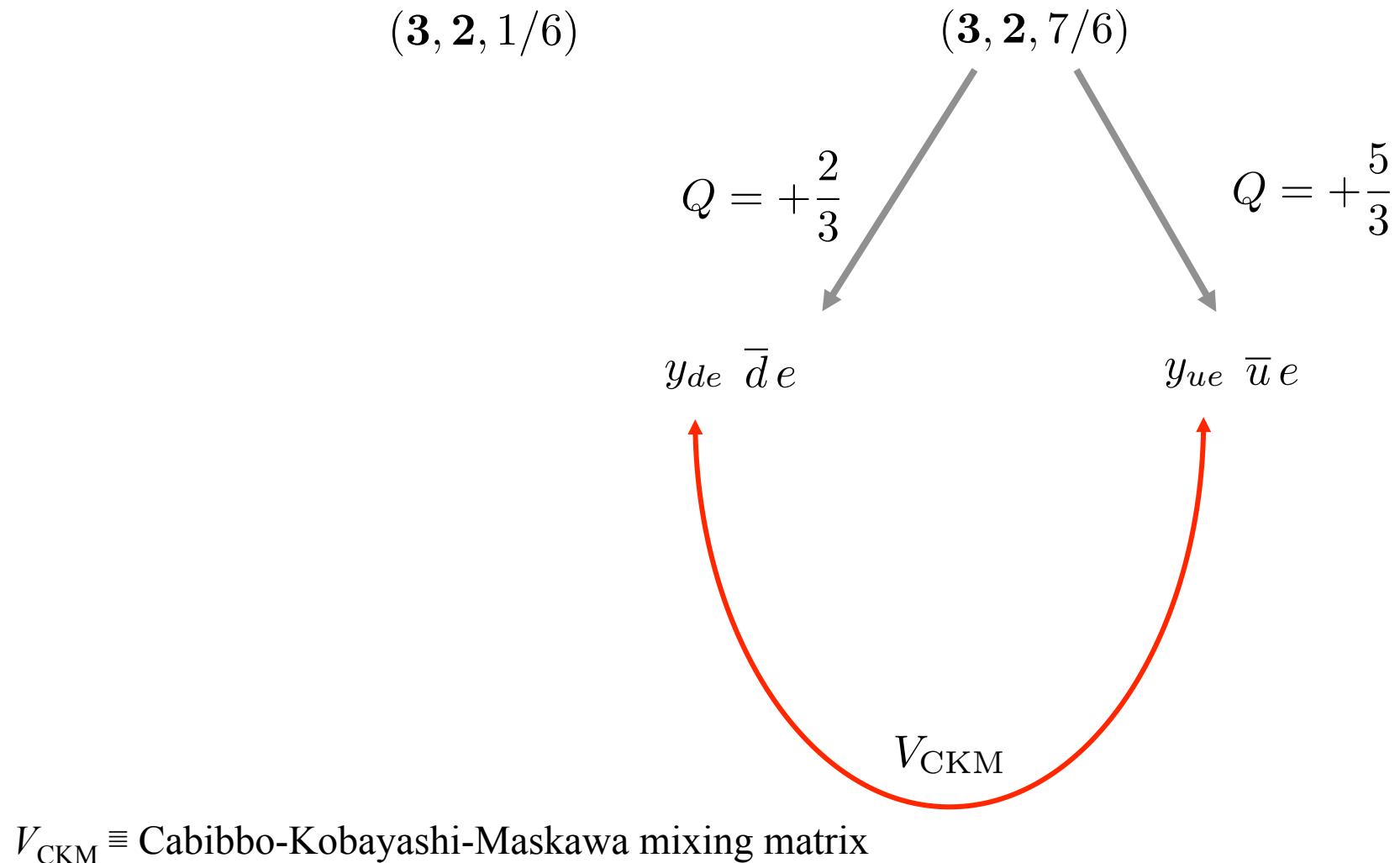


$V_{\text{PMNS}} \equiv$ Pontecorvo-Maki-Nakagawa-Sakata mixing matrix

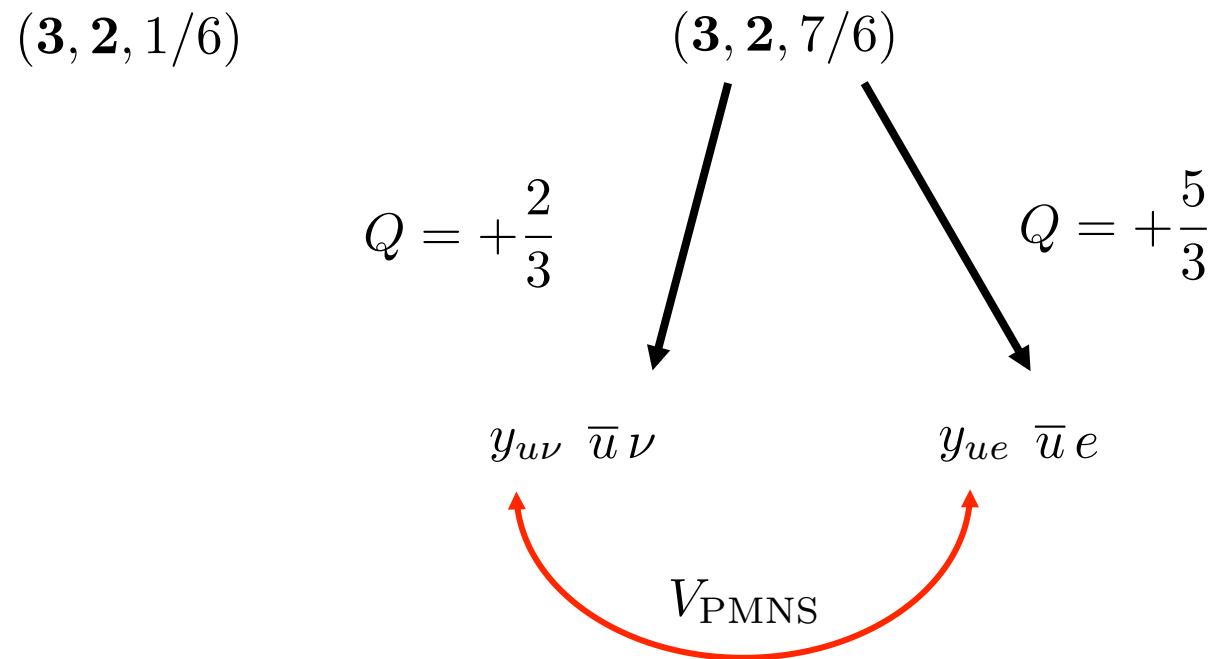
FRAMEWORK



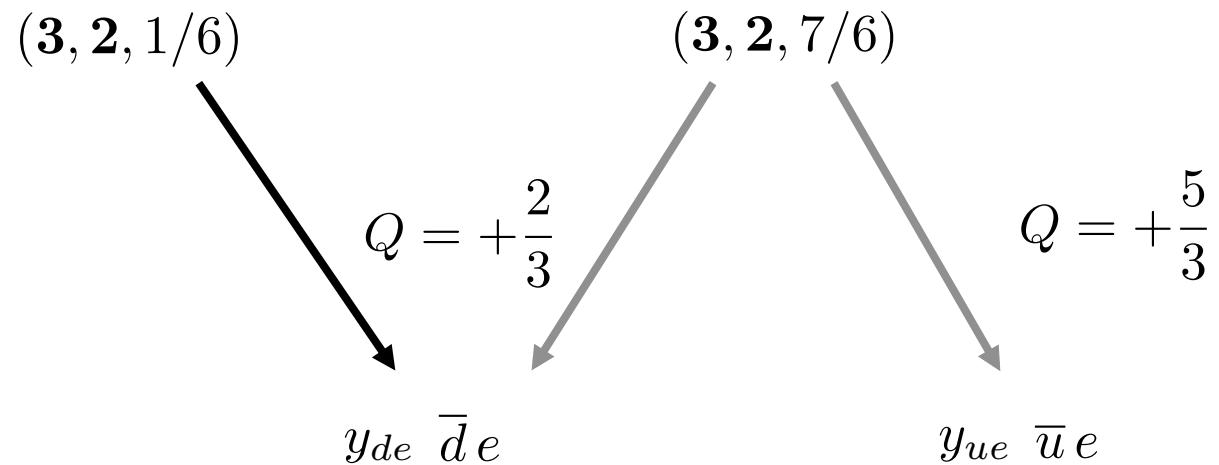
FRAMEWORK



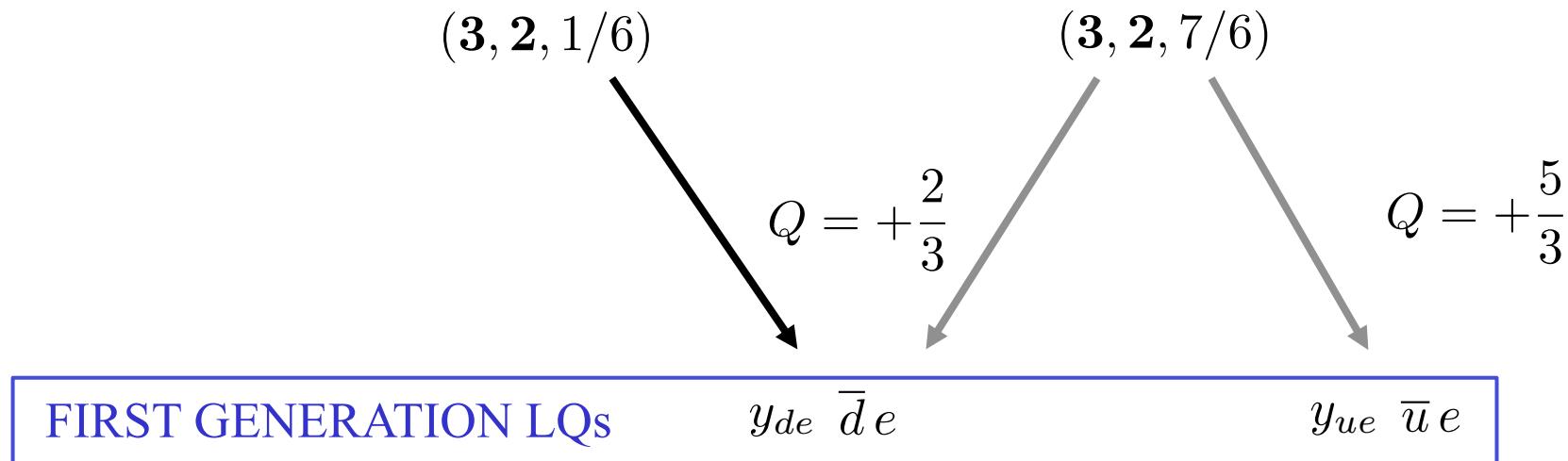
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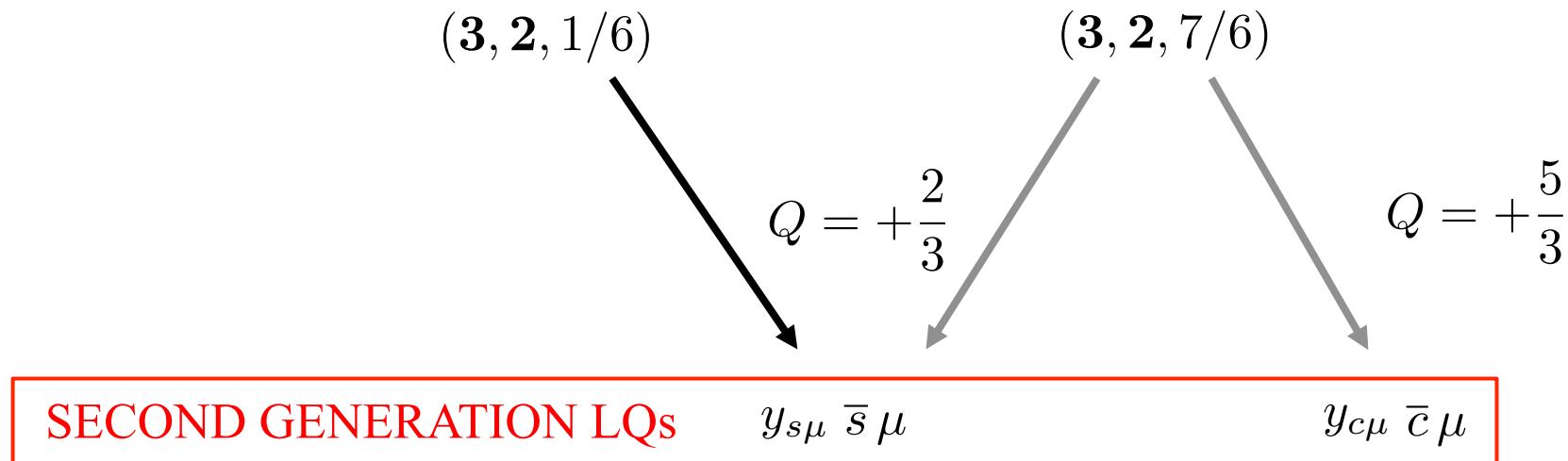
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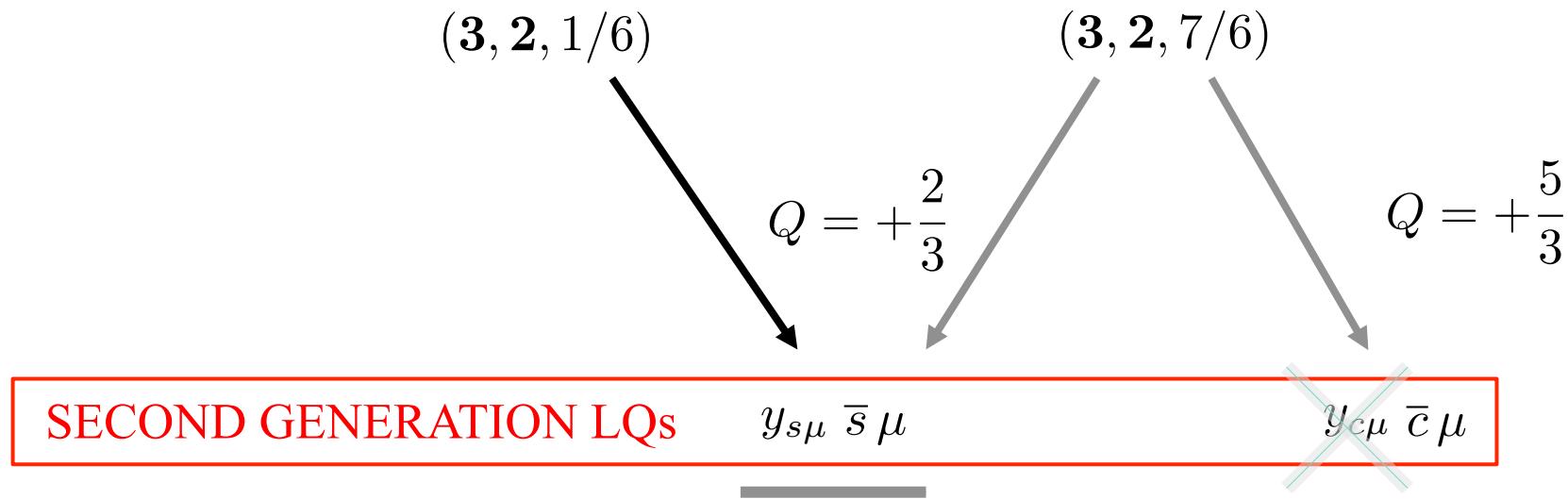
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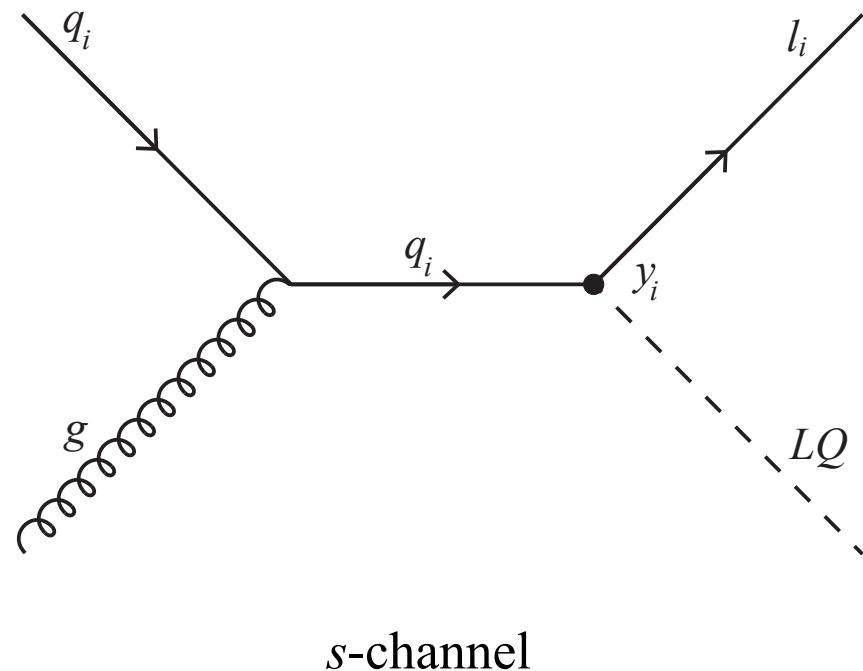


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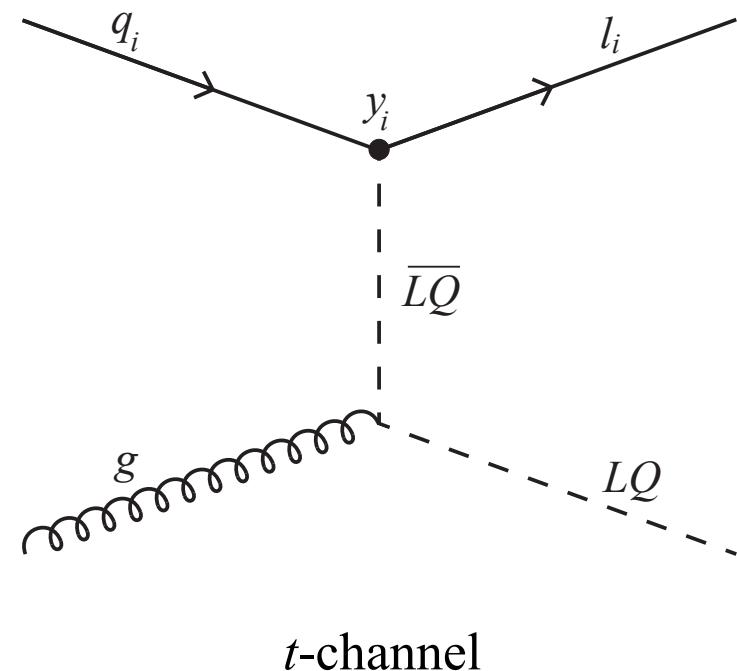


LEPTOQUARK PRODUCTION AT LHC

SINGLE SCALAR LQ PRODUCTION:



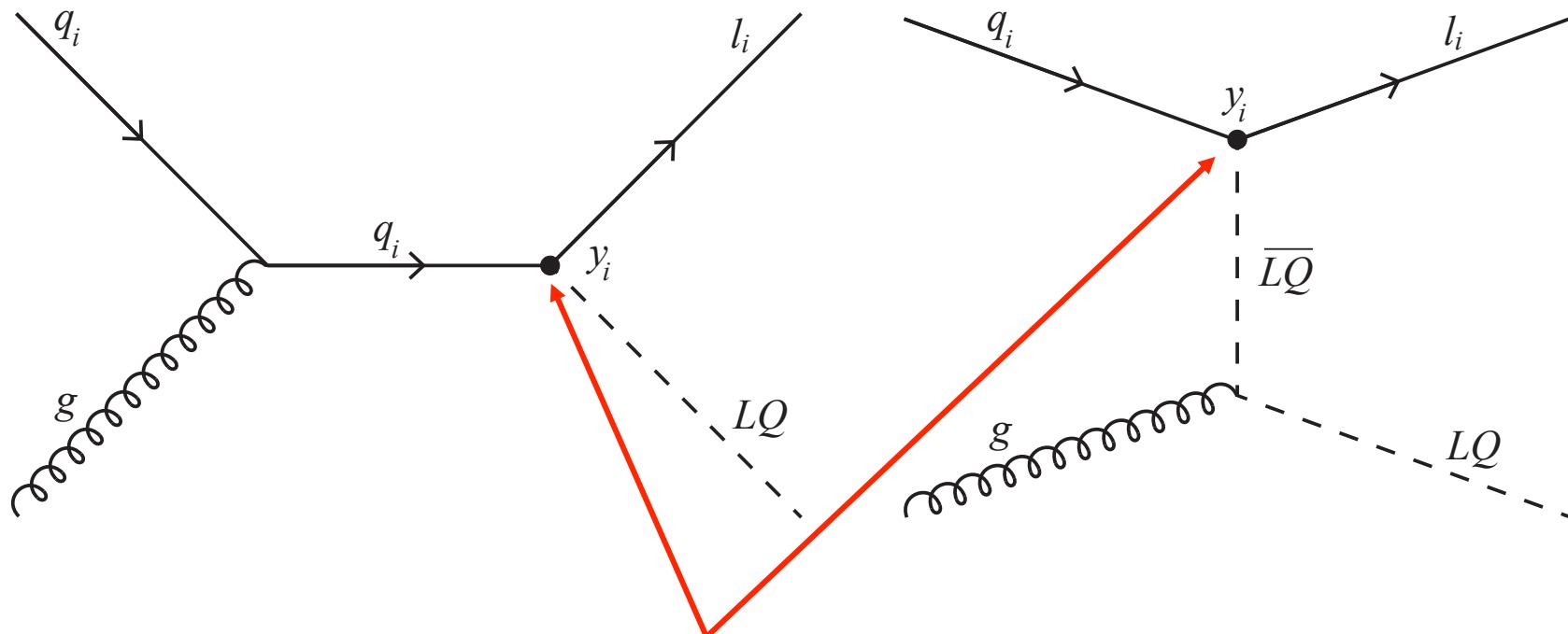
s-channel



t-channel

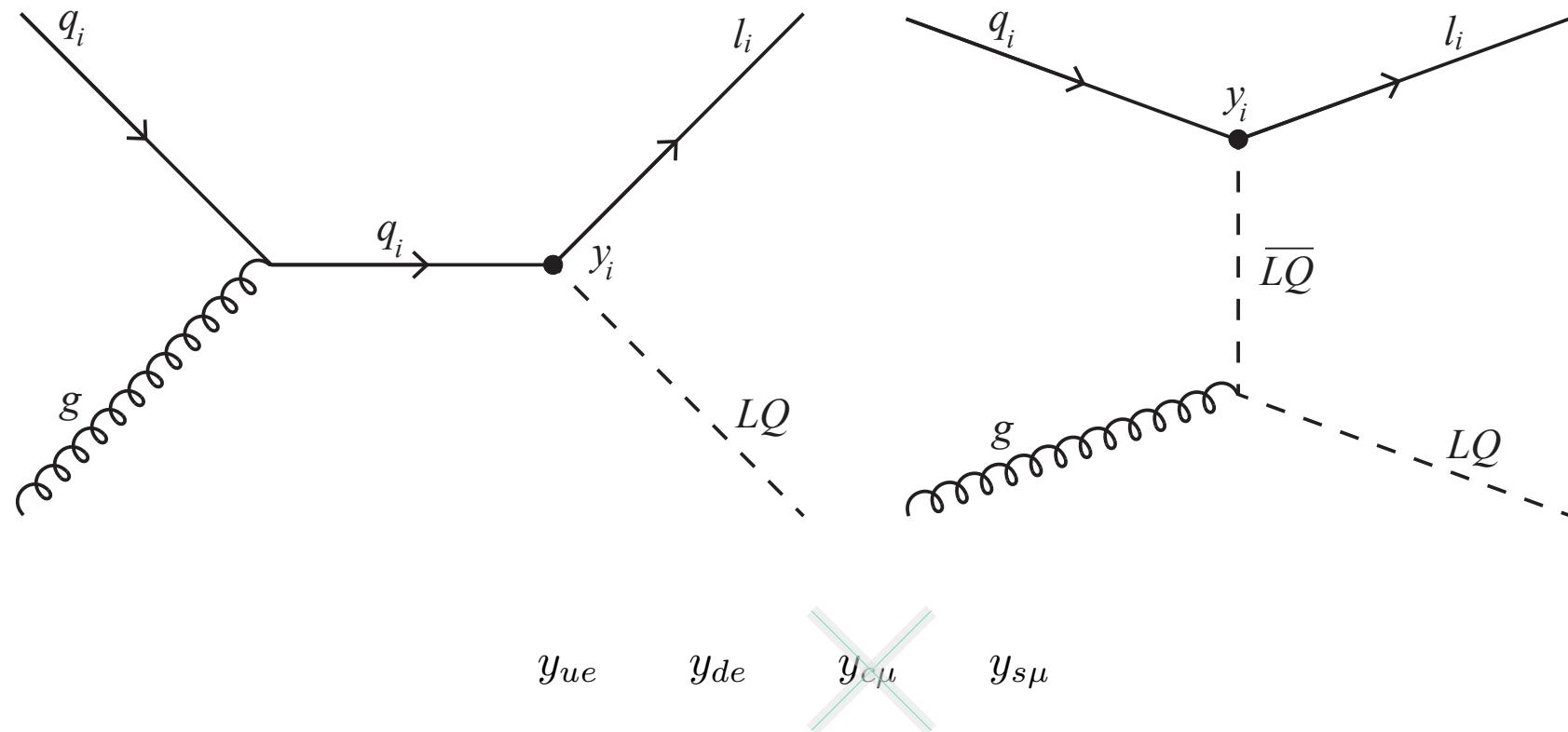
LEPTOQUARK PRODUCTION AT LHC

SINGLE SCALAR LQ PRODUCTION:



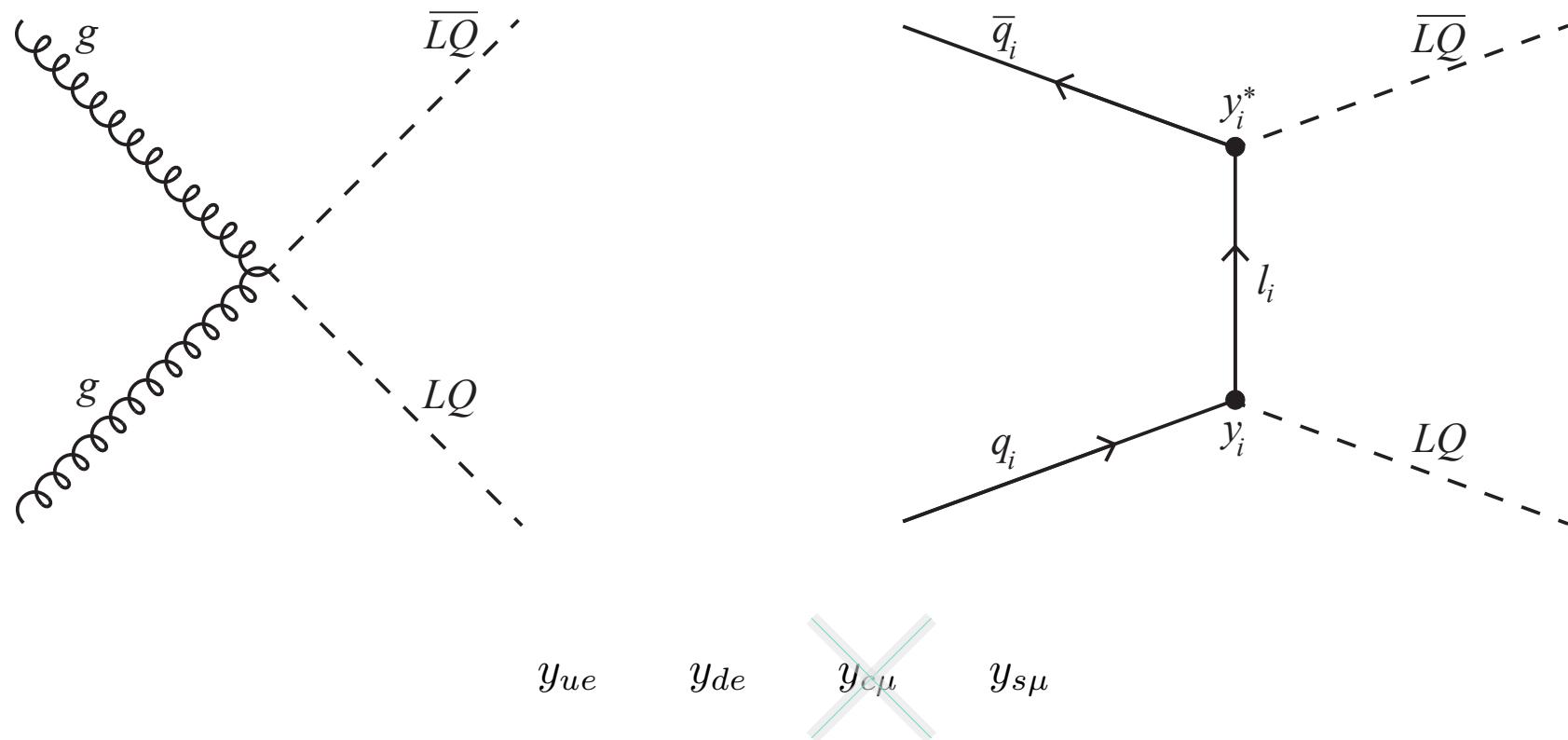
LEPTOQUARK PRODUCTION AT LHC

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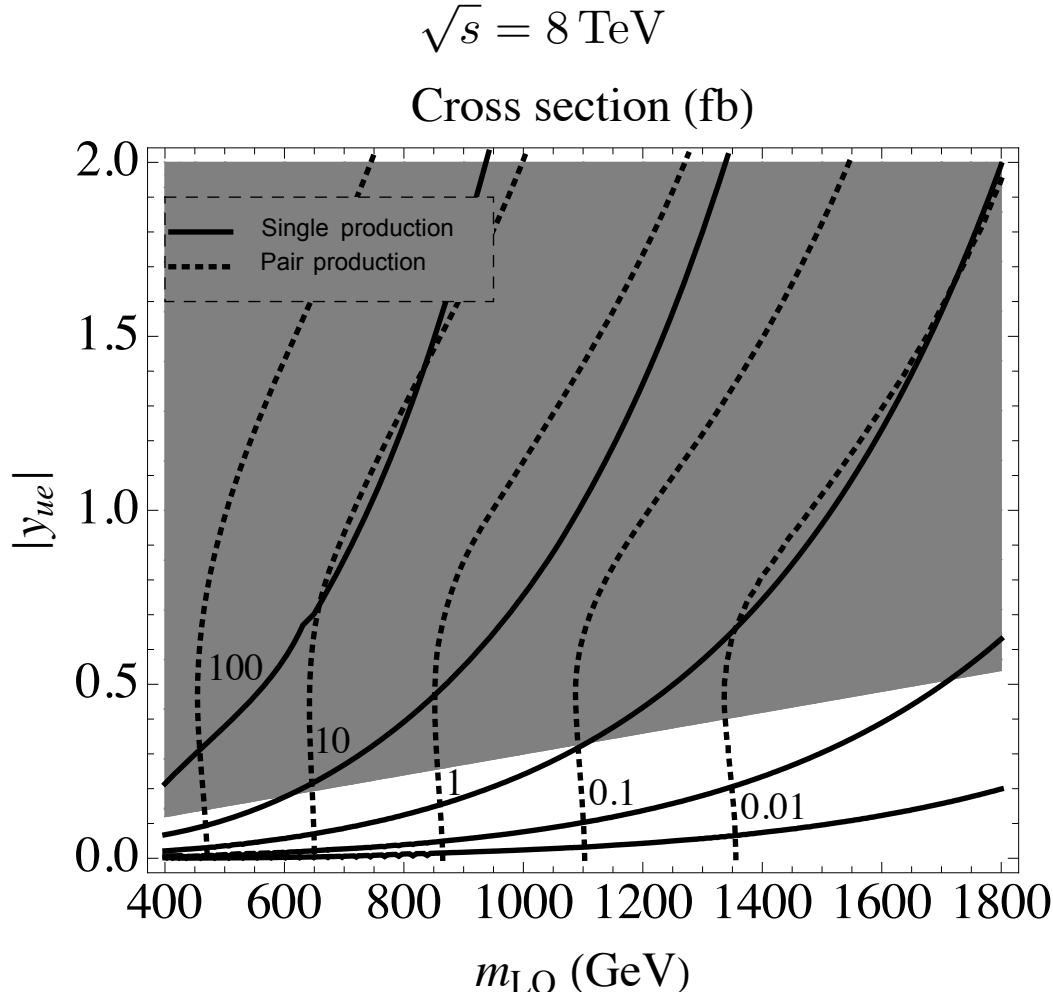


LEPTOQUARK PRODUCTION AT LHC

SCALAR LQ PAIR PRODUCTION:



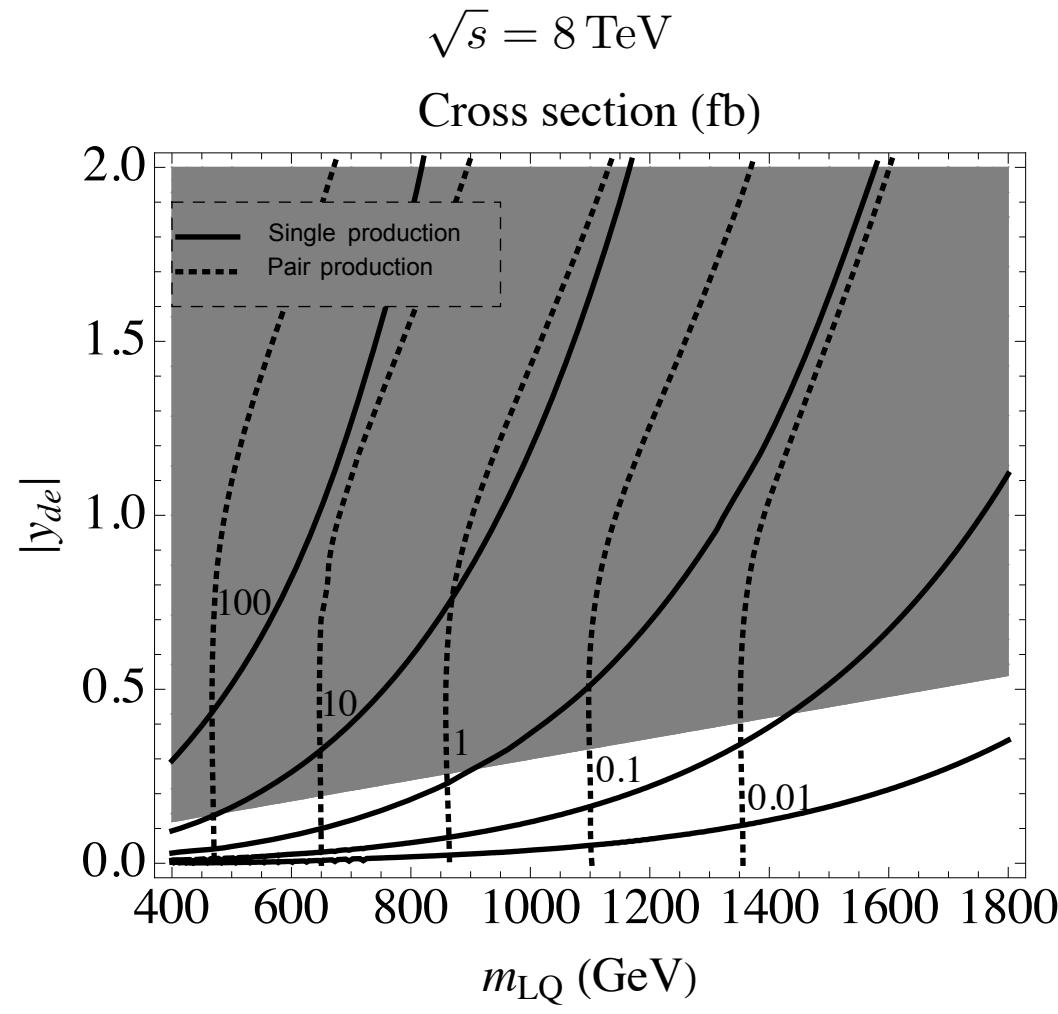
LEPTOQUARK PRODUCTION AT LHC



≡ flavor constraint exclusion region

I. Doršner, S. Fajfer and A. Greljo, JHEP **1410**, 154 (2014).

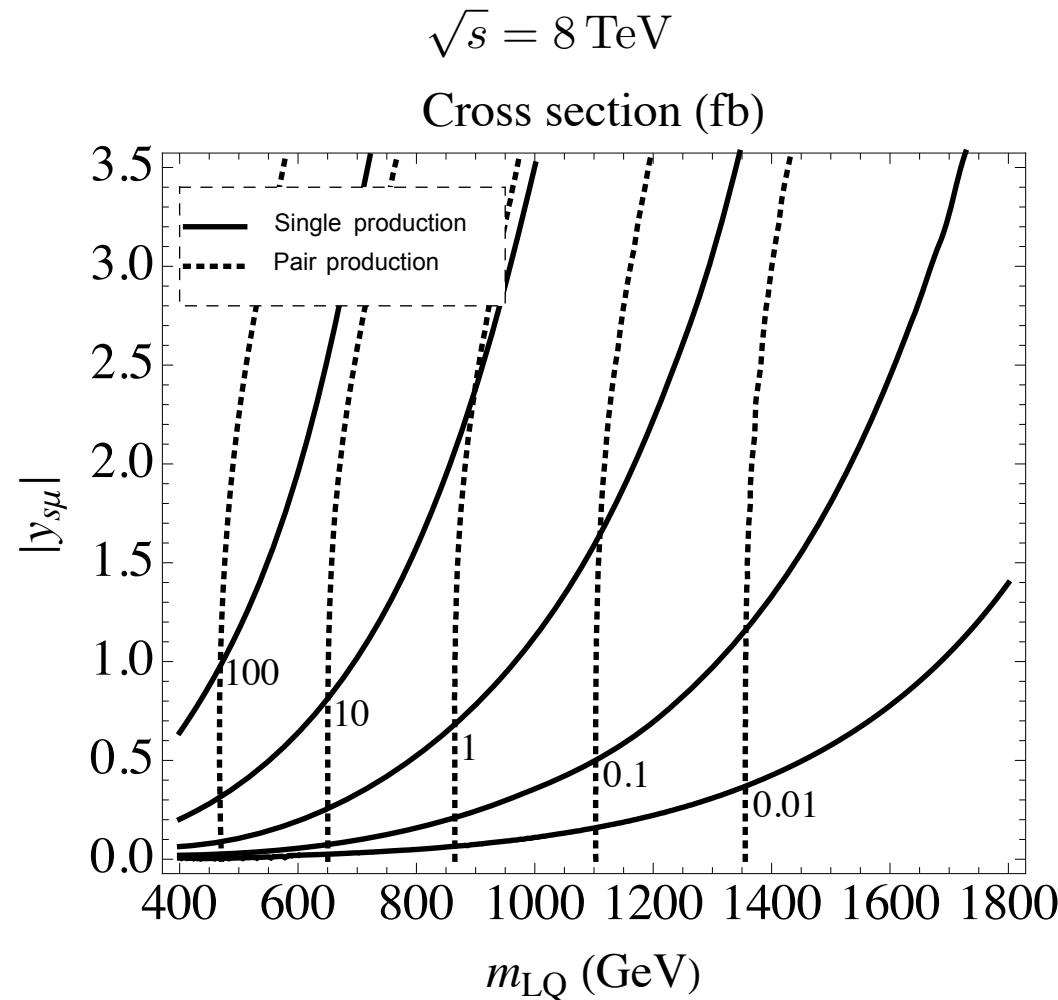
LEPTOQUARK PRODUCTION AT LHC



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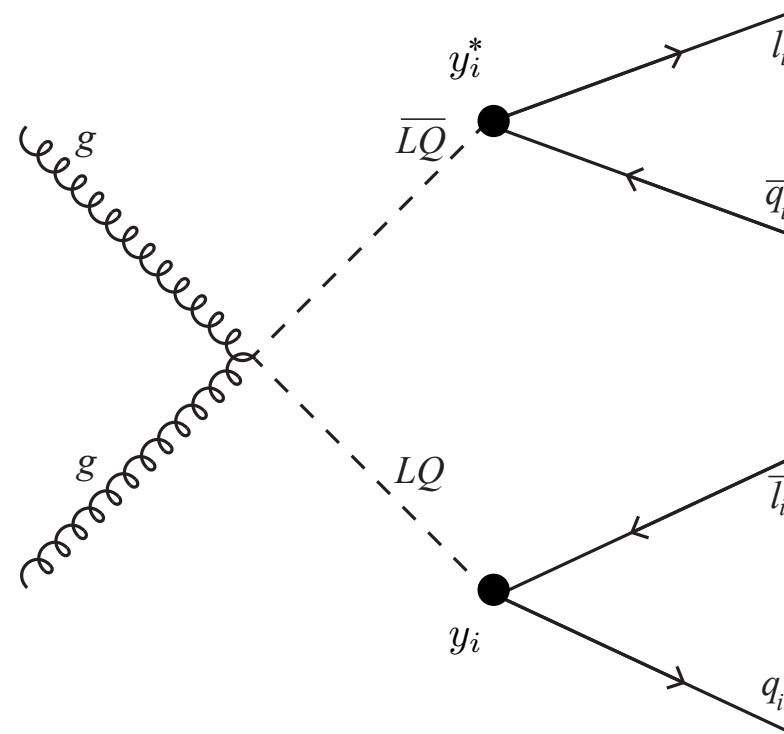
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LEPTOQUARK PRODUCTION AT LHC



THE CMS SEARCH

(FIRST GENERATION LQ SEARCH)*
(SECOND GENERATION LQ SEARCH)^



*CMS PAS EXO-12-041.

$$\Gamma(LQ \rightarrow \bar{q}_i l_i) = \frac{m_{LQ}}{16\pi} |y_i|^2$$

^CMS PAS EXO-12-042.

THE CMS SEARCH

(FIRST GENERATION LQ SEARCH)*
(SECOND GENERATION LQ SEARCH)^

- PAIR PRODUCTION IS QCD DRIVER;
- SINGLE LQ PRODUCTION DOES NOT CONTRIBUTE;

*CMS PAS EXO-12-041.

^CMS PAS EXO-12-042.

THE CMS SEARCH

(FIRST GENERATION LEPTOQUARK)*
(SECOND GENERATION LEPTOQUARK)^

$$S_T = p_T(e_1) + p_T(e_2) + p_T(jet_1) + p_T(jet_2)$$

$$(S_T = p_T(\mu_1) + p_T(\mu_2) + p_T(jet_1) + p_T(jet_2))$$

$$M_{ee} \ (M_{\mu\mu})$$

||||

the invariant mass of the two electrons (muons)

$$M_{\min}(e, jet) \ (M_{\min}(\mu, jet))$$

||||

the smallest of the two electron-jet (muon-jet) invariant masses
which minimizes the $\overline{LQ} - LQ$ invariant mass difference

*CMS PAS EXO-12-041.

^CMS PAS EXO-12-042.

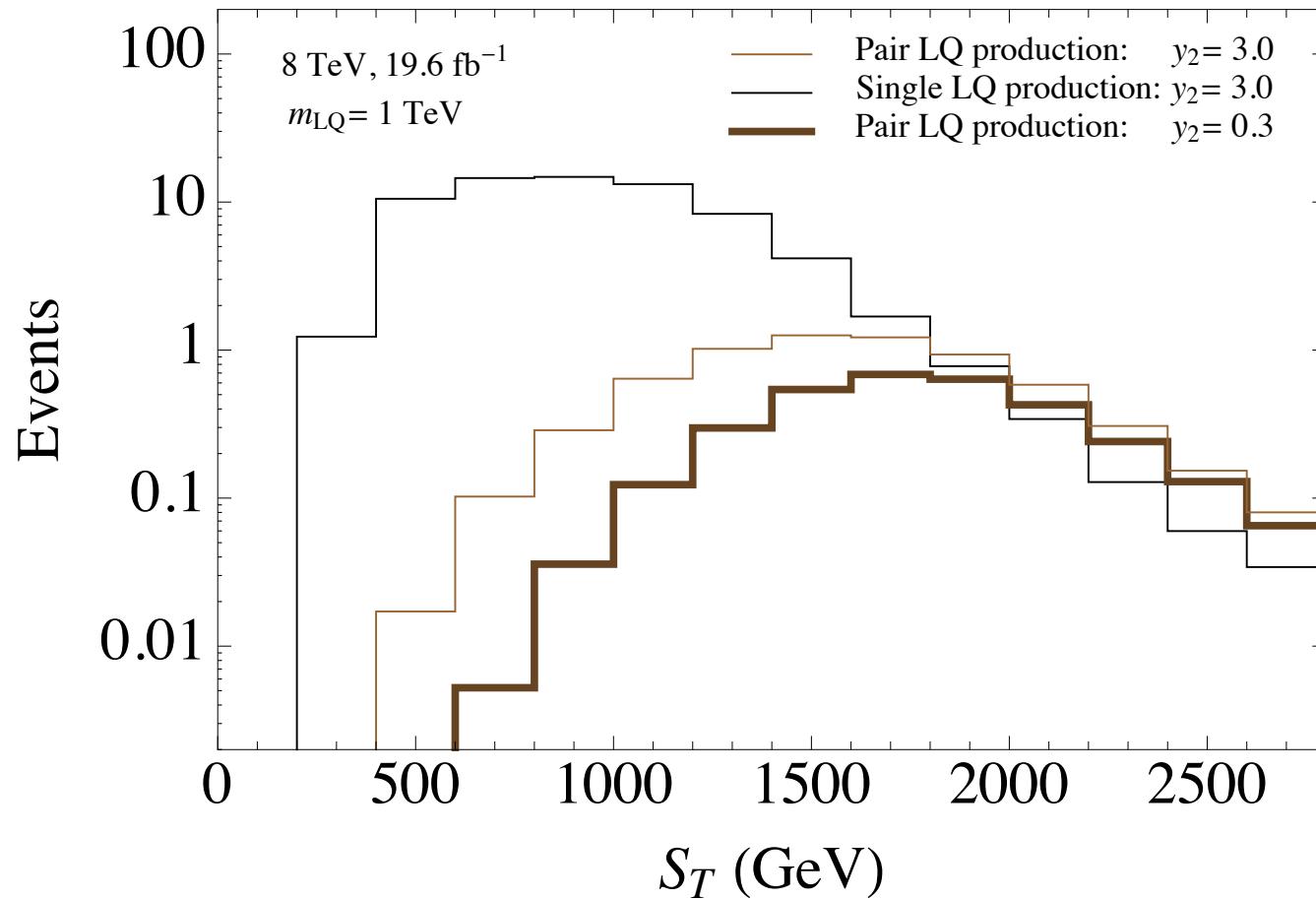
THE CMS SEARCH RECAST

(SECOND GENERATION LQ SEARCH)*

m_{LQ} (GeV)	500	700	900	950	≥ 1000
$S_T >$ (GeV)	685	935	1135	1175	1210
$M_{\mu\mu} >$ (GeV)	150	195	230	235	245
$M_{\min}(\mu, j) >$ (GeV)	155	295	535	610	690
Signal yield < at 95% CL	34	9.8	5.6	3.5	1.8

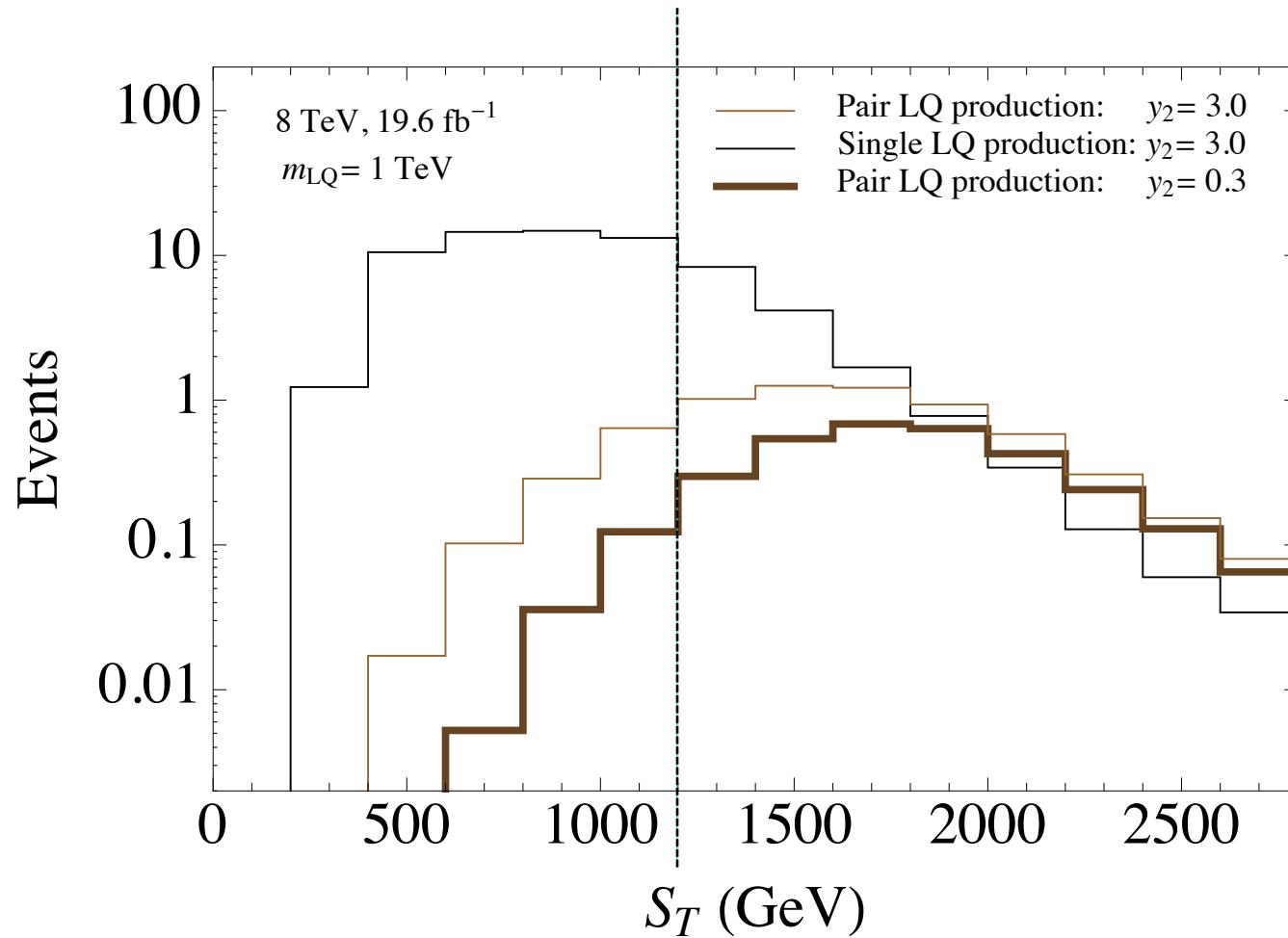
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THE CMS SEARCH RECAST*



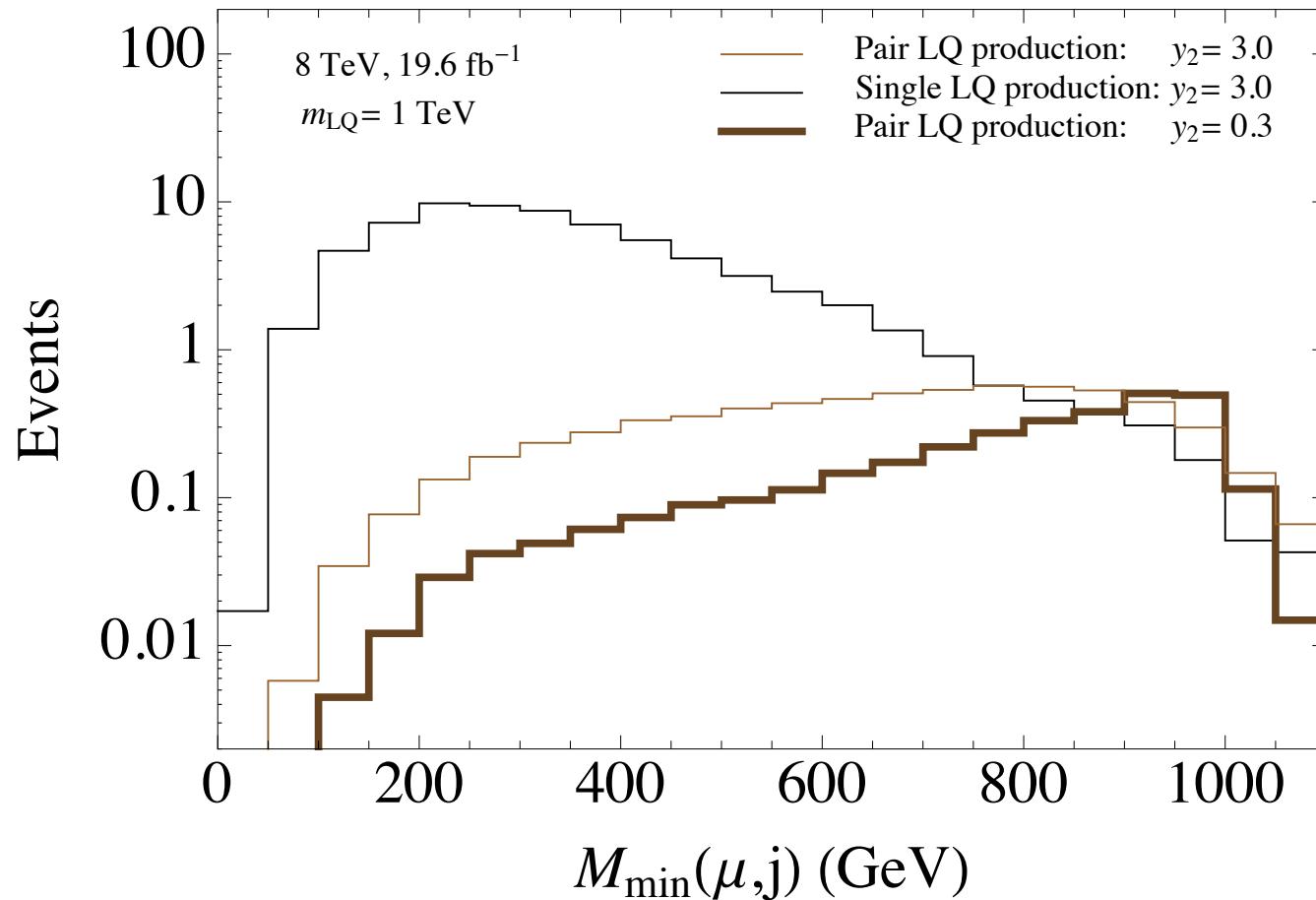
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THE CMS SEARCH RECAST*



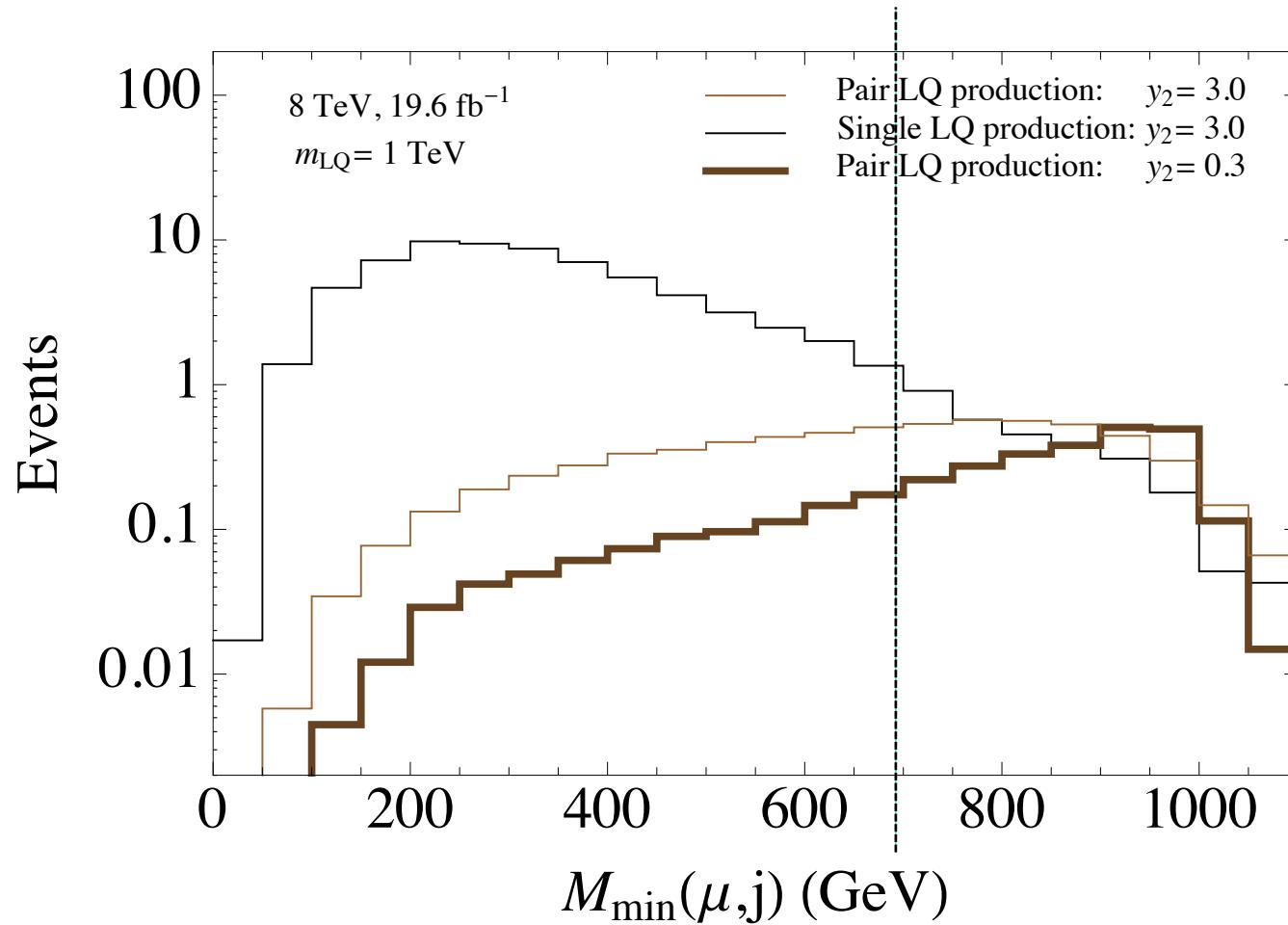
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THE CMS SEARCH RECAST*



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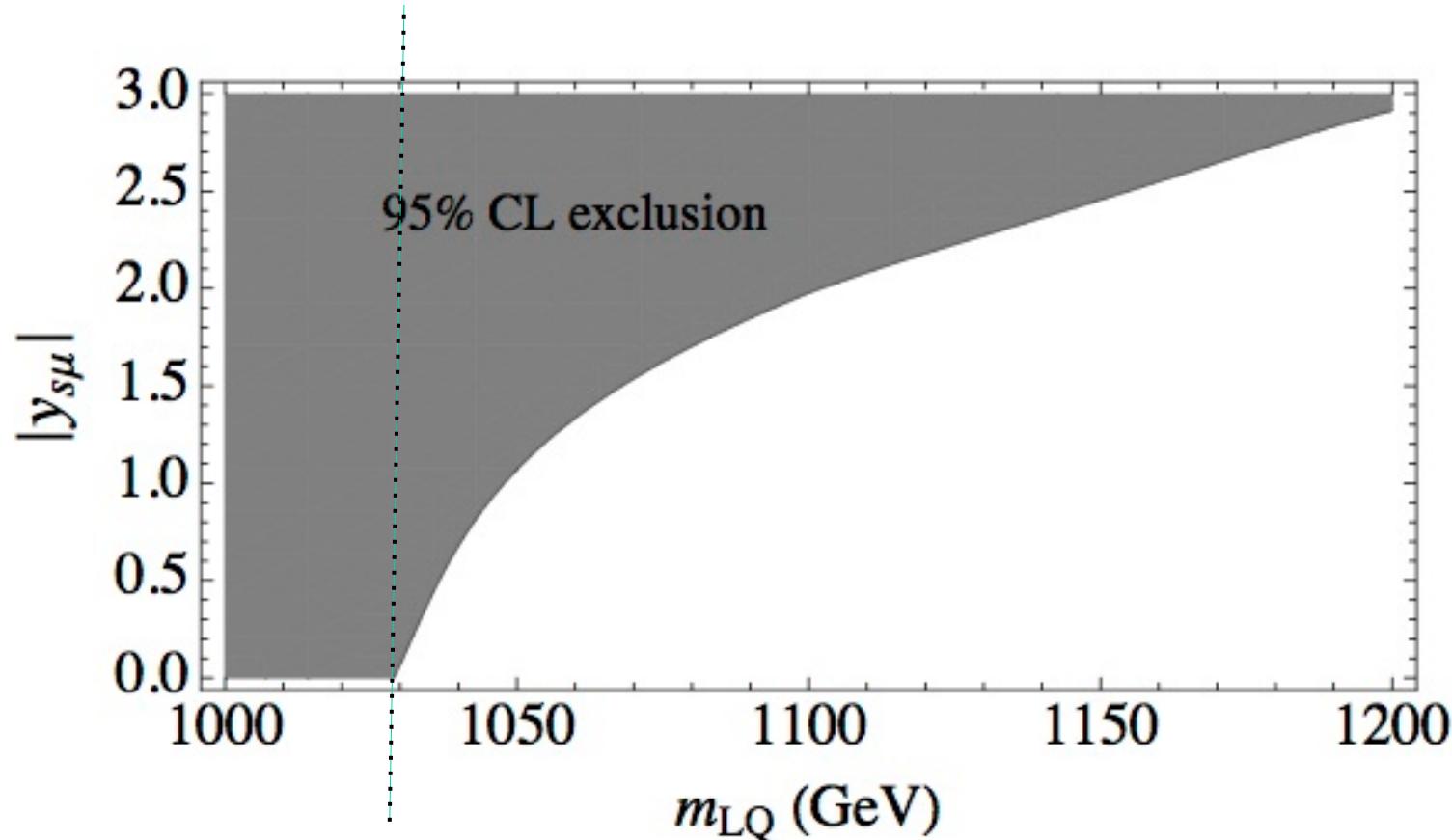
THE CMS SEARCH RECAST* (SECOND GENERATION LEPTOQUARK)

$m_{\text{LQ}}(\text{GeV})$	N_{evs} (Pair production) + N_{evs} (Single production)			
	$y_2 = 0.3$	$y_2 = 1.0$	$y_2 = 2.0$	$y_2 = 3.0$
500	$600 + 8.2$	$600 + 89$	$720 + 330$	$1300 + 700$
700	$55 + 0.98$	$56 + 11$	$64 + 41$	$110 + 81$
900	$6.5 + 0.10$	$6.5 + 1.2$	$7.0 + 4.5$	$11 + 8.4$
1000	$2.2 + 0.03$	$2.2 + 0.33$	$2.3 + 1.1$	$3.1 + 2.3$
1050	$1.5 + 0.02$	$1.5 + 0.27$	$1.5 + 1.0$	$2.1 + 2.1$
1100	$0.96 + 0.02$	$0.96 + 0.21$	$1.0 + 0.82$	$1.4 + 1.6$
1150	$0.62 + 0.02$	$0.62 + 0.17$	$0.66 + 0.75$	$0.92 + 1.4$
1200	$0.41 + 0.01$	$0.41 + 0.14$	$0.44 + 0.55$	$0.60 + 1.3$
1300	$0.17 + 0.01$	$0.17 + 0.09$	$0.19 + 0.37$	$0.26 + 0.74$
1400	$0.07 + 0.00$	$0.07 + 0.06$	$0.08 + 0.24$	$0.12 + 0.52$

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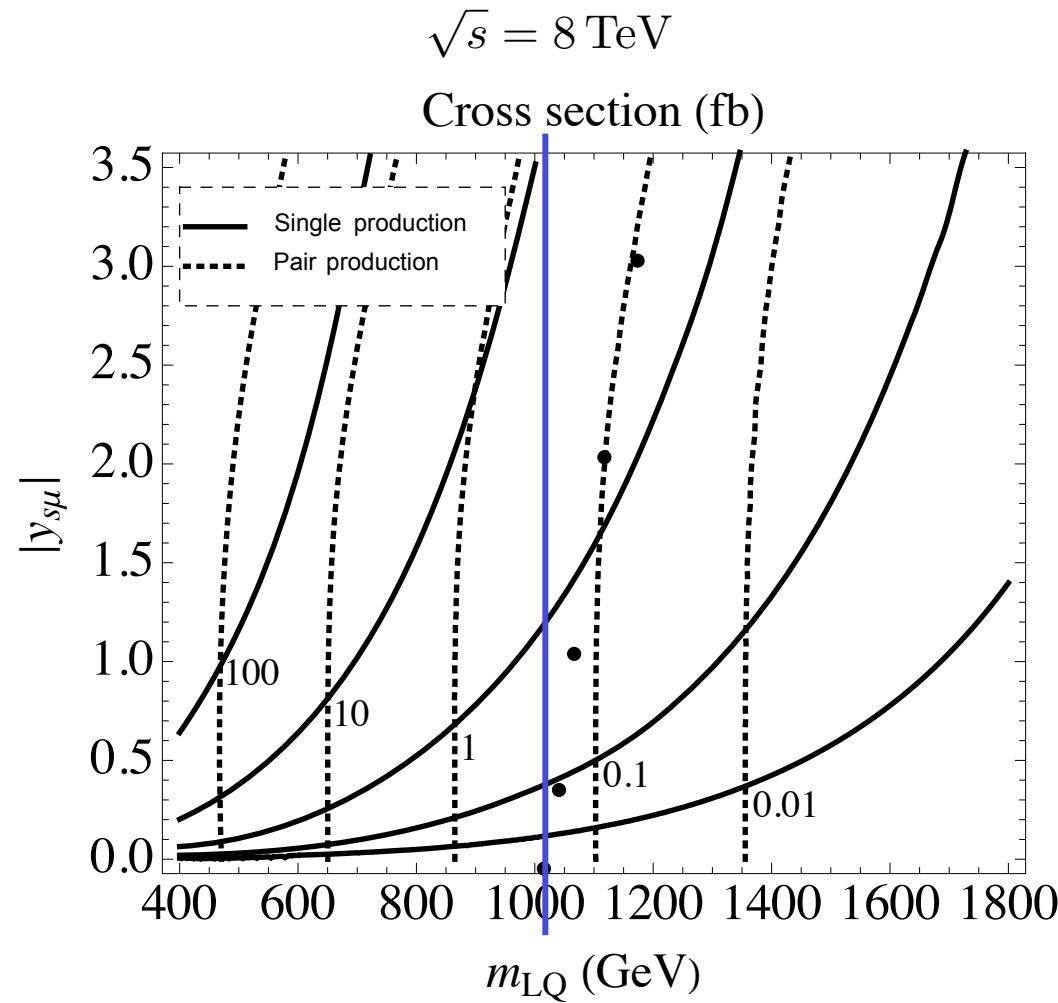
THE CMS SEARCH RECAST

(SECOND GENERATION LEPTOQUARK)*



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LEPTOQUARK PRODUCTION AT LHC



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CONCLUSIONS

Sizeable lepton-quark-leptoquark couplings contribute to leptoquark production at LHC.

A t -channel pair production and a single leptoquark production both need to be taken into consideration if the leptoquark Yukawa coupling cannot be neglected.

A recast of an existing CMS search for the second generation leptoquark yields the best limit on Yukawa coupling between the leptoquark, a muon and a strange quark to date.

THANK YOU

dorsner@fesb.hr

FLAVOR CONSTRAINTS

ATOMIC PARITY VIOLATION



$$|y_{de}| \leq 0.34 \left(\frac{m_{\text{LQ}}}{1 \text{ TeV}} \right)$$

$$|y_{ue}| \leq 0.36 \left(\frac{m_{\text{LQ}}}{1 \text{ TeV}} \right)$$

TO DO LIST

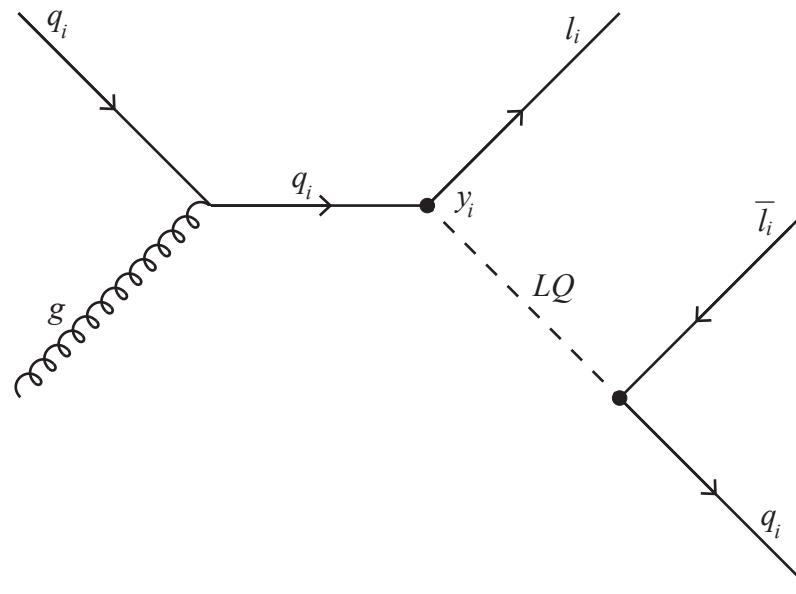
Optimize cuts for the single LQ production scenario...

What happens when one departs from the single generation assumption?

NLO calculation of the single LQ production at the generator level...

THE CMS SINGLE LQ SEARCH

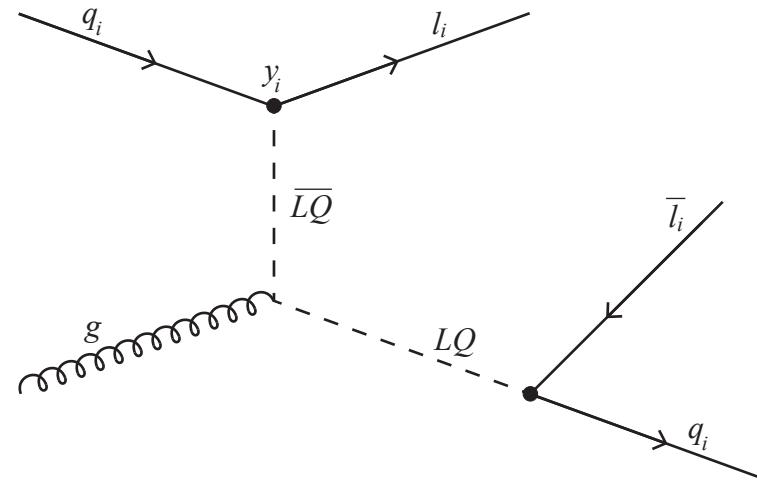
(FIRST GENERATION LEPTOQUARK)*



*EXO-12-043-pas

THE CMS SINGLE LQ SEARCH

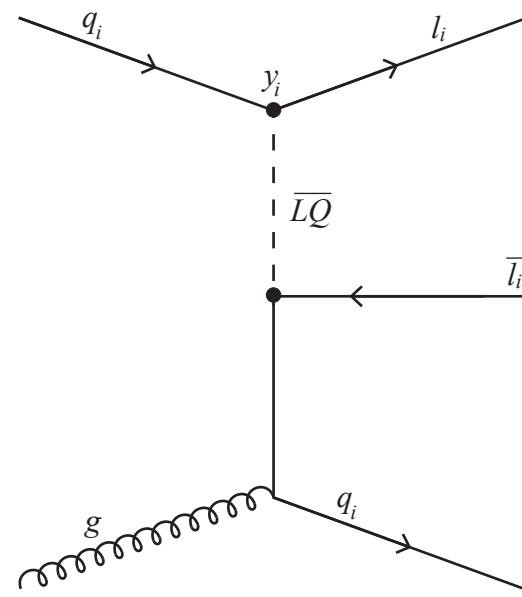
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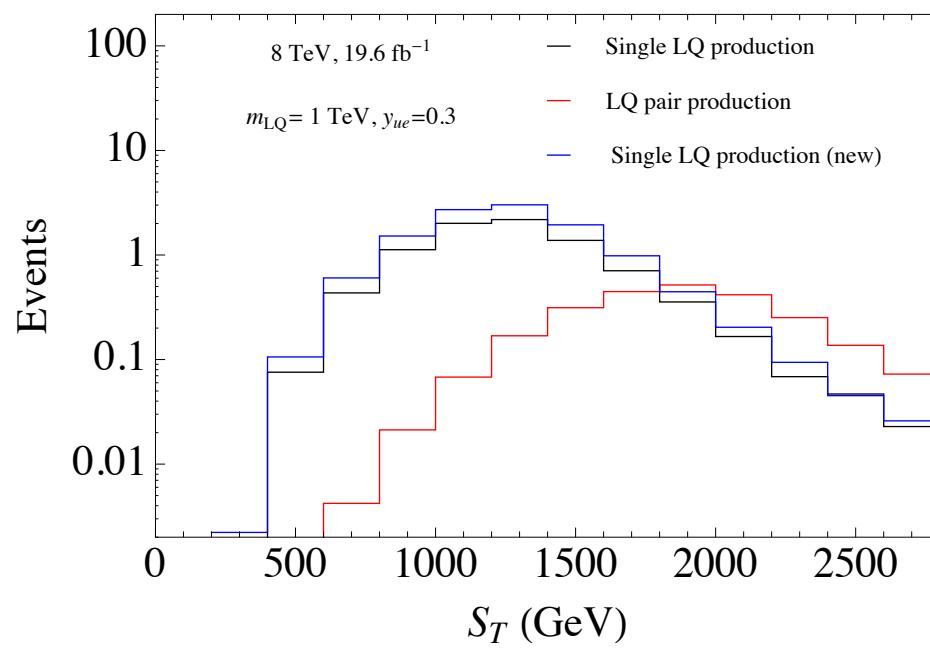
*EXO-12-043-pas

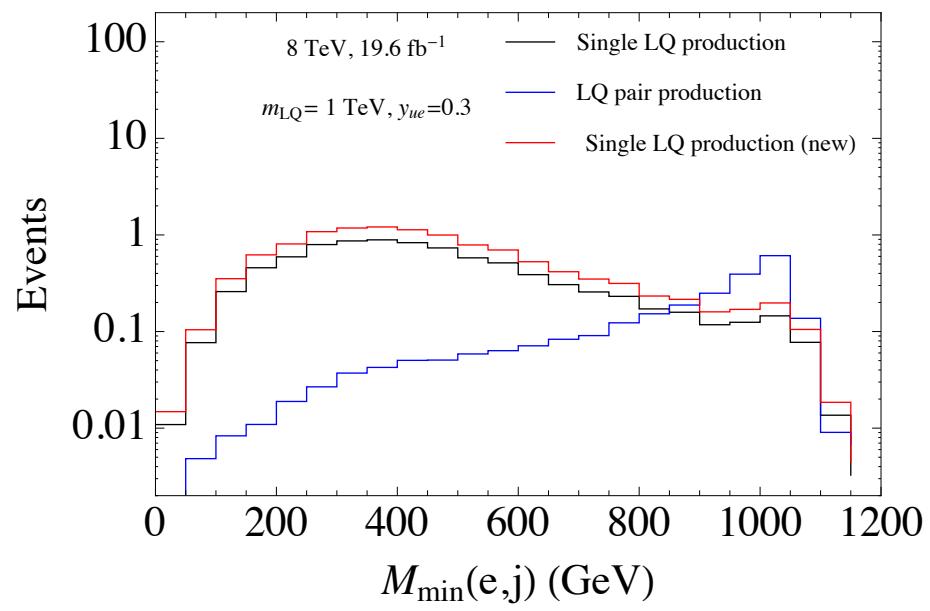
THE CMS SINGLE LQ SEARCH

(FIRST GENERATION LEPTOQUARK)*



*EXO-12-043-pas





FLAVOR CONSTRAINTS

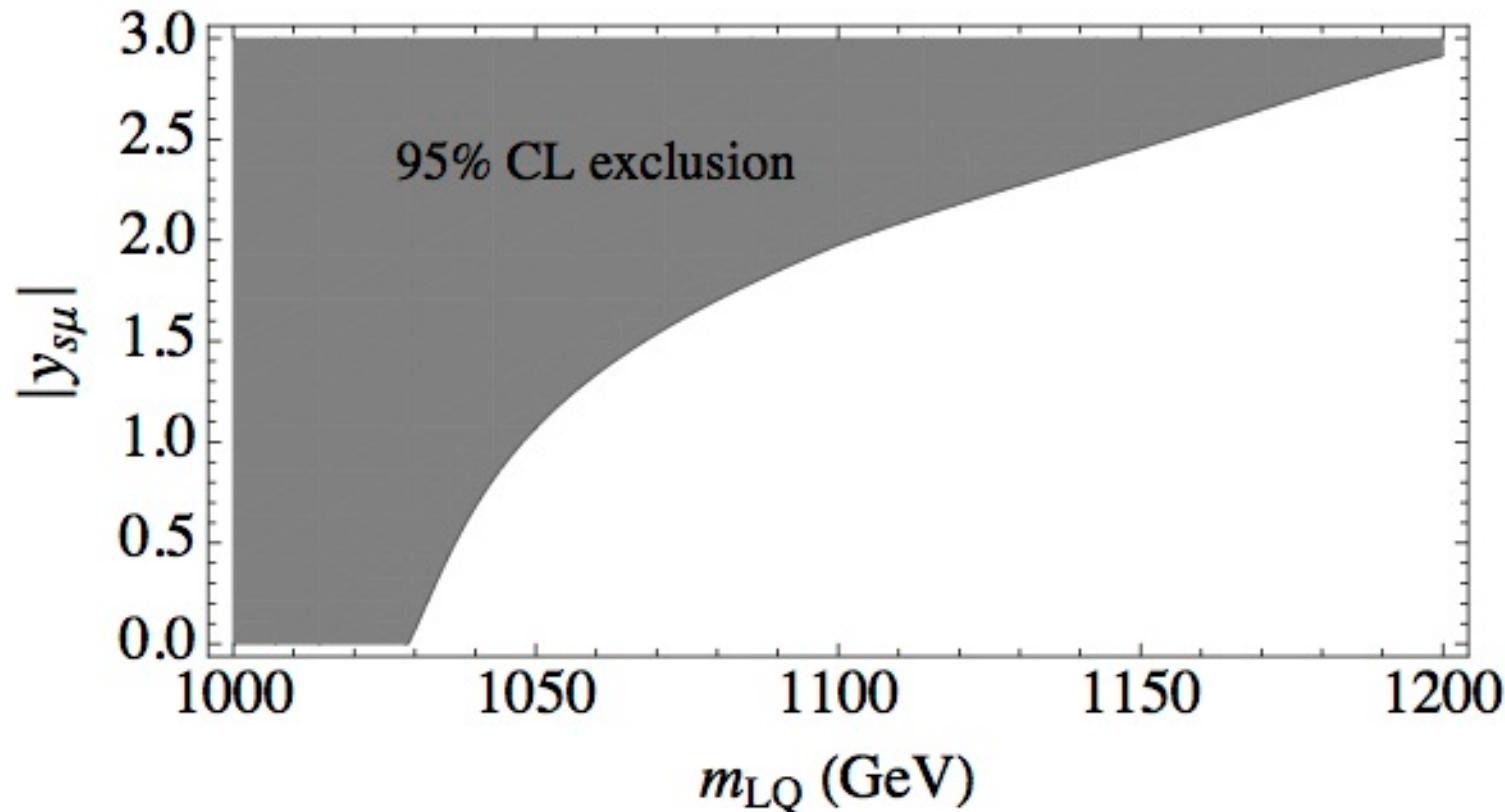
$$K_L \rightarrow \mu^- e^+$$



$$|y_{s\mu} y_{de}^*| < 2.1 \times 10^{-5} \left(\frac{m_{\text{LQ}}}{1 \text{TeV}} \right)^2$$

THE CMS SEARCH RECAST

(SECOND GENERATION LEPTOQUARK)*



*I. Doršner, S. Fajfer and A. Greljo, JHEP **1410**, 154 (2014).