Novel Leptoquark Pair Production @LHC*

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University of Split & Jožef Stefan Institute

Corfu Summer Institute: Workshop on the Standard Model and Beyond
Corfu, Greece
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I. D., Svjetlana Fajfer, Ajla Lejlić, and Shaikh Saad, work in progress.

I. D., Svjetlana Fajfer, and Ajla Lejlić, arXiv:2103.11702.

OUTLINE

- **SCALAR LEPTOQUARKS (LQs)**
- **CONVENTINAL LQ PAIR PRODUCTION**
- **NOVEL LQ PRODUCTION MECHANISM @LHC**
  ASYMMETRIC LQ PAIR PRODUCTIONS VIA
  $q_i q_j$ **&** $q_i \bar{q}_j$ **INITIAL STATES, WHERE** $i,j = u,d,s,c,b$
- **A CASE STUDY**
- **CONCLUSIONS**

SCALAR LEPTOQUARKS

$(SU(3), SU(2), U(1))$	LQ SYMBOL	CHIRALITY TYPE (LQ-q-l)	F
$(\overline{\mathbf{3}}, \mathbf{3}, 1/3)$	S_3	LL	-2
$(\mathbf{3}, \mathbf{2}, 7/6)$	R_2	RL, LR	0
$(\mathbf{3}, \mathbf{2}, 1/6)$	$\tilde{R}_2$	RL	0
$(\overline{\mathbf{3}}, \mathbf{1}, 4/3)$	$\tilde{S}_1$	RR	-2
$(\overline{\mathbf{3}}, \mathbf{1}, 1/3)$	S_1	LL, RR	-2

I. D., Svjetlana Fajfer, Admir Greljo, Jernej F. Kamenik, and Nejc Košnik, arXiv:1603.04993.

SCALAR LEPTOQUARKS

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F - fermion number

$$F = 3\,B + L$$

I. D., Svjetlana Fajfer, Admir Greljo, Jernej F. Kamenik, and Nejc Košnik, arXiv:1603.04993.

SCALAR LEPTOQUARKS

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$(\overline{\mathbf{3}}, \mathbf{1}, 1/3)$	S_1	LL, RR	-2

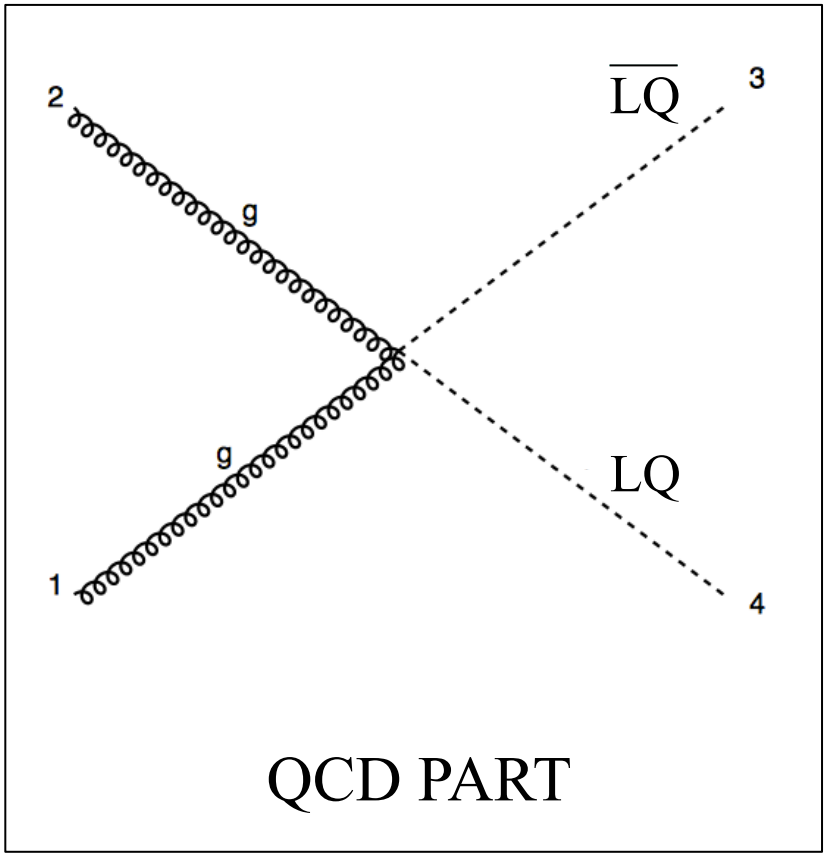
$|F|=2:$ $\quad \mathrm{LQ} \to q\,l \qquad \overline{\mathrm{LQ}} \to \overline{q}\,\overline{l}$

$F=0:$ $\quad \mathrm{LQ} \to q\,\overline{l} \qquad \overline{\mathrm{LQ}} \to \overline{q}\,l$

I. D., Svjetlana Fajfer, Admir Greljo, Jernej F. Kamenik, and Nejc Košnik, arXiv:1603.04993.

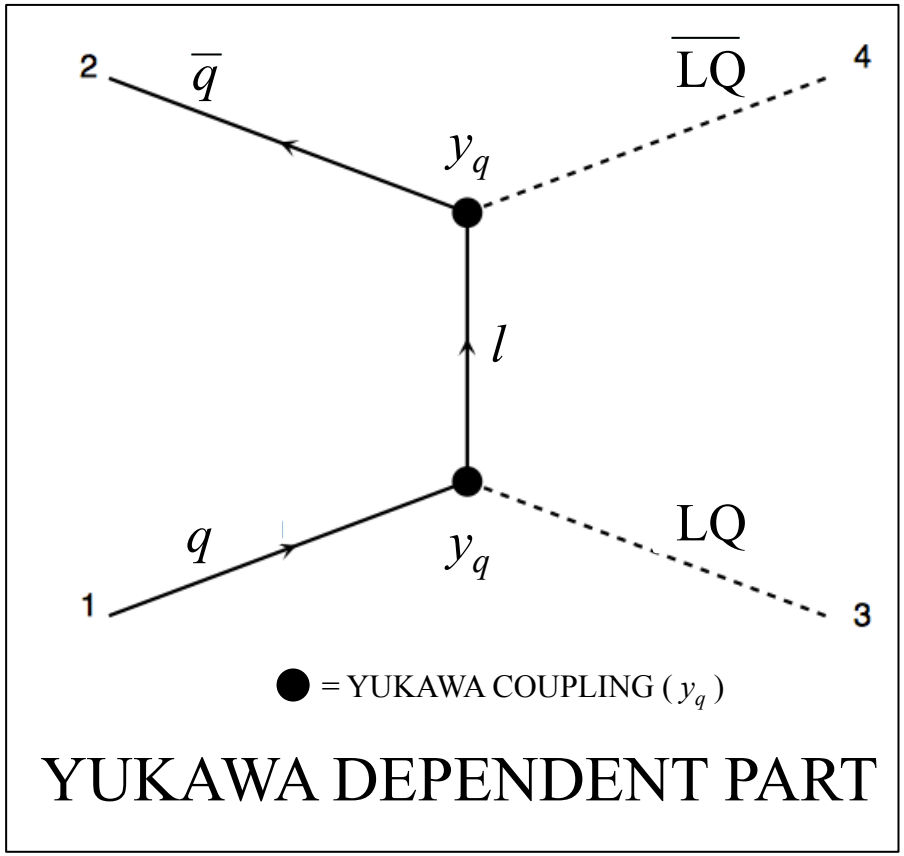
CONVENTIONAL LQ PAIR PRODUCTION @LHC

LQ PAIR PRODUCTION @LHC



QCD PART

+

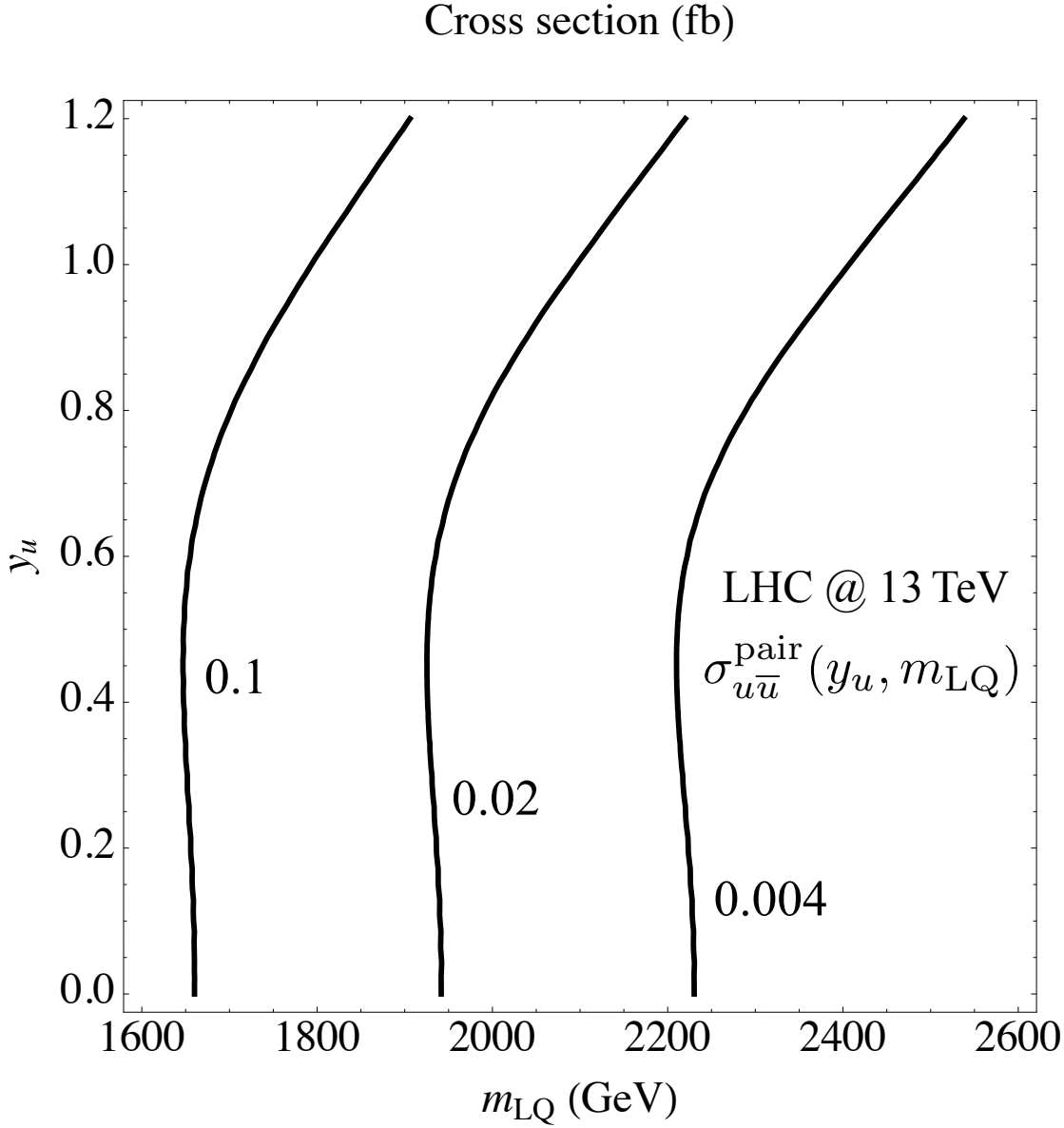


YUKAWA DEPENDENT PART

$$\sigma^{\text{pair}}_{q\bar{q}}(y_q, m_{\text{LQ}}) = \sigma^{\text{pair}}_{\text{QCD}}(m_{\text{LQ}}) + a^{\text{interference}}_{q\bar{q}}(m_{\text{LQ}})y_q^2 + \sigma^{\text{pair}}_{q\bar{q}}(y_q, y_q, m_{\text{LQ}}),$$

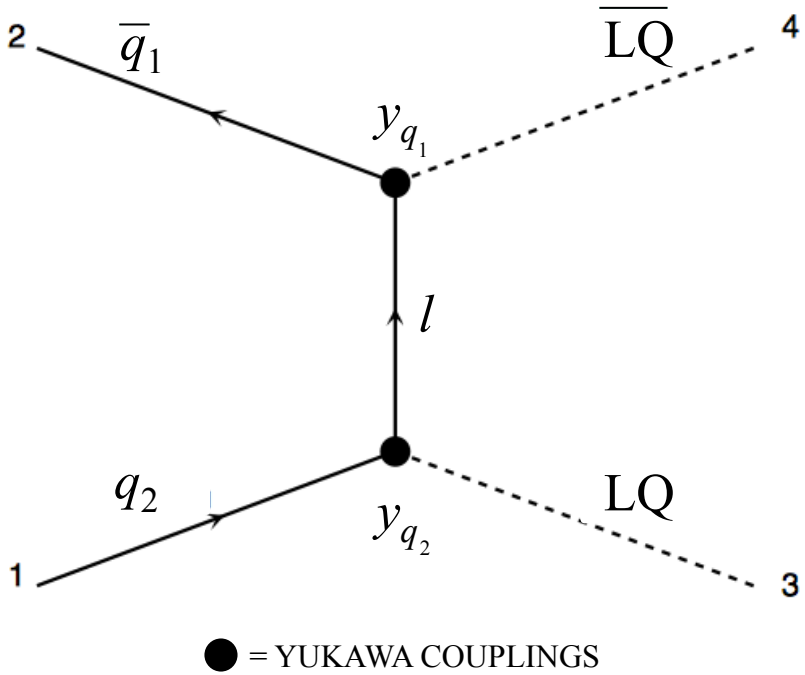
$$q = u, d, s, c, b$$

LQ PAIR PRODUCTION @LHC



I. D., Svjetlana Fajfer, and Admir Greljo, arXiv:1406.4831.

LQ PAIR PRODUCTION @LHC



$a_{q_1\overline{q}_1}^{\mathrm{interference}}(m_{\mathrm{LQ}})y_{q_1}^2$

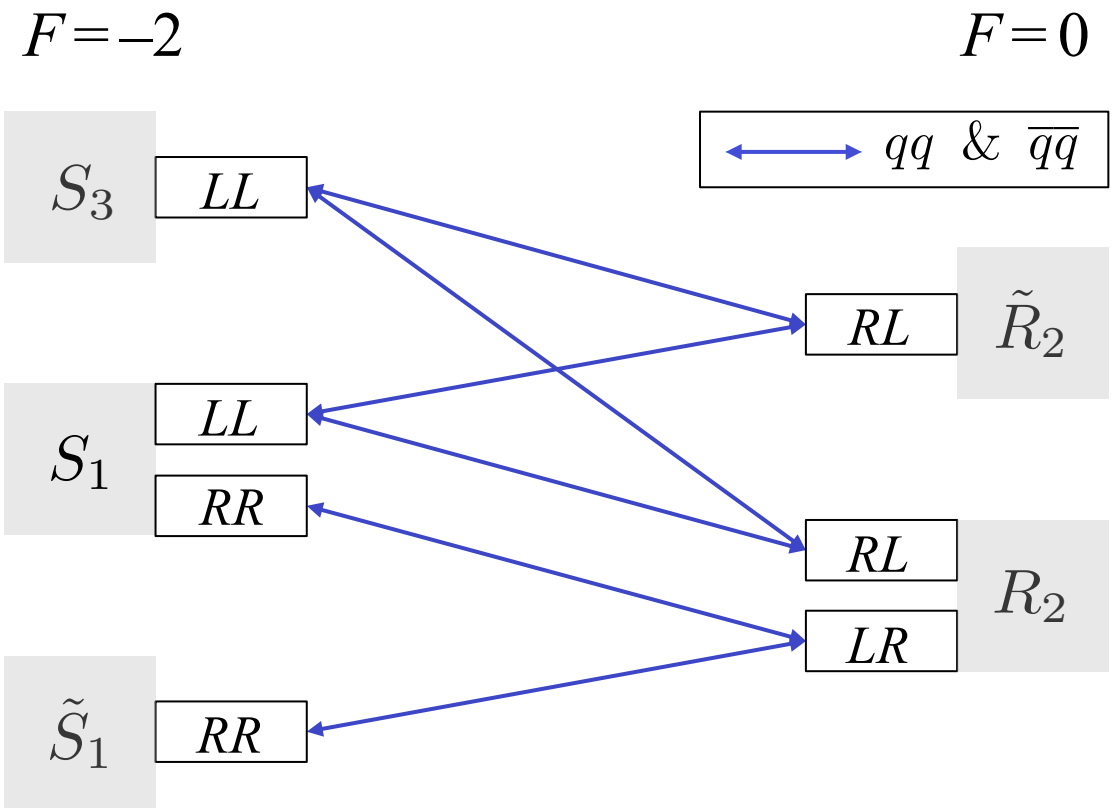
$a_{q_1\overline{q}_2}^{\mathrm{interference}}(m_{\mathrm{LQ}})y_{q_1}y_{q_2}$

$a_{q_2\overline{q}_2}^{\mathrm{interference}}(m_{\mathrm{LQ}})y_{q_2}^2$

$a_{q_2\overline{q}_1}^{\mathrm{interference}}(m_{\mathrm{LQ}})y_{q_1}y_{q_2}$

ASYMMETRIC LQ PAIR PRODUCTION @LHC

NOVEL MECHANISM



I. D., Svjetlana Fajfer, and Ajla Lejlić, arXiv:2103.11702.

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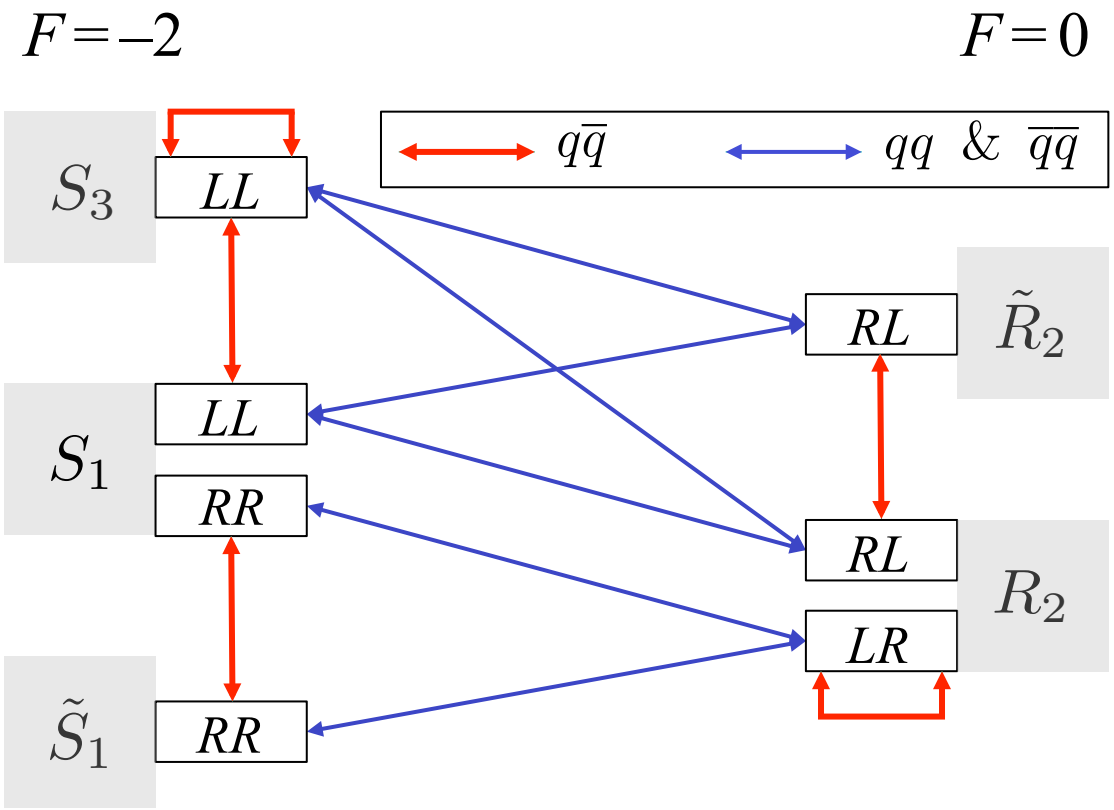
NOVEL MECHANISM



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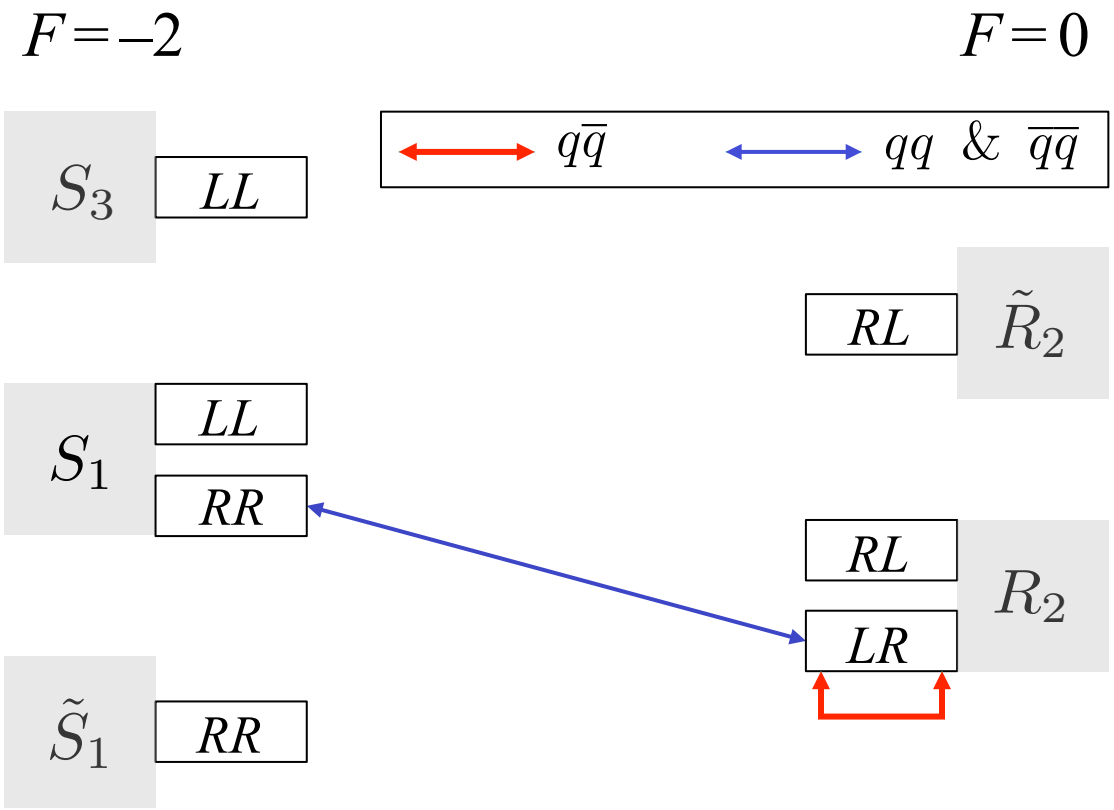
IN THIS TALK…



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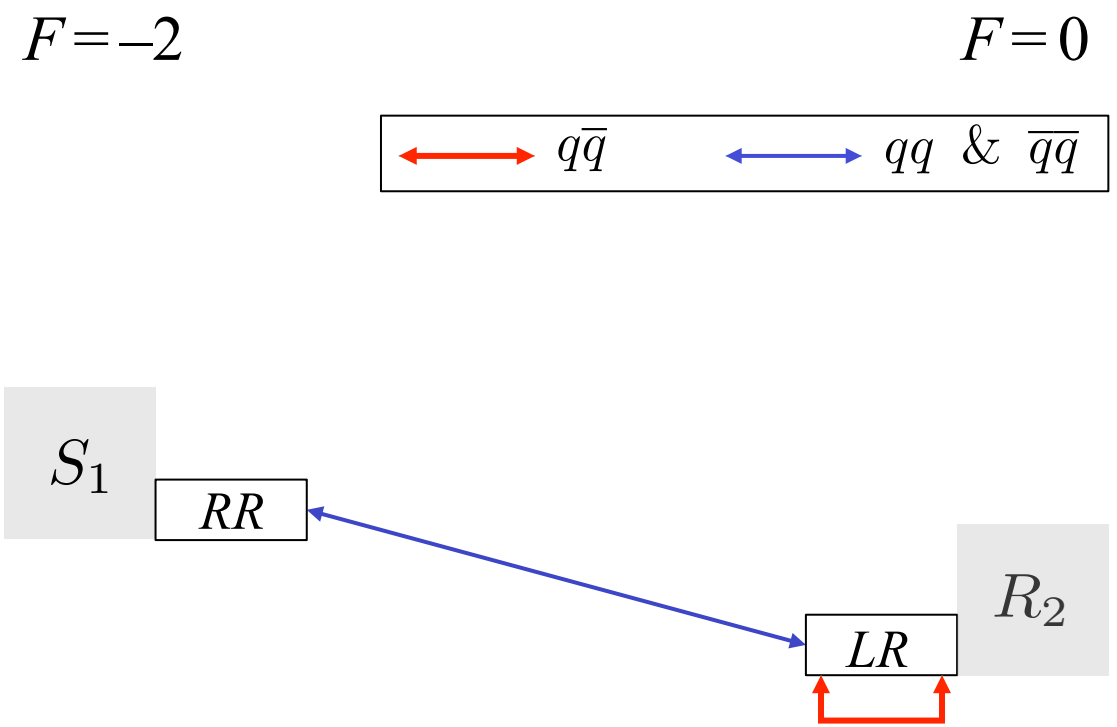

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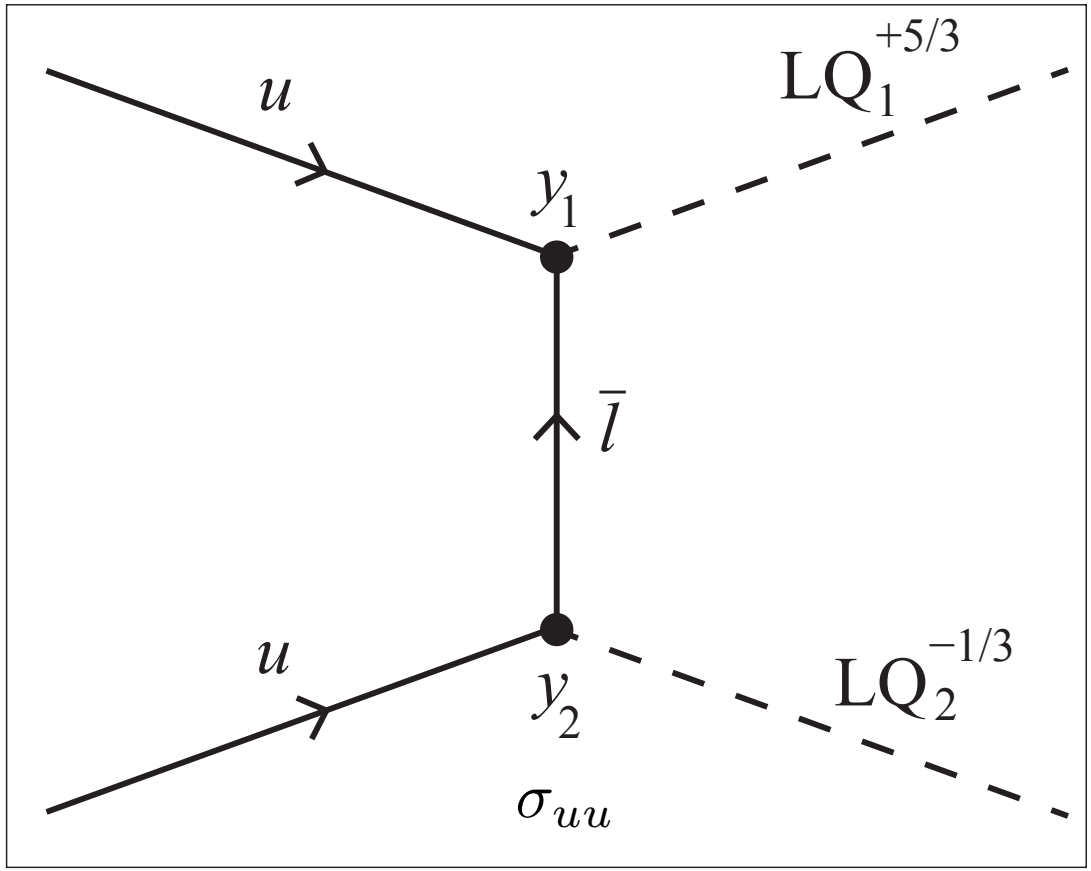
NOVEL PRODUCTION MECHANISM (qq)



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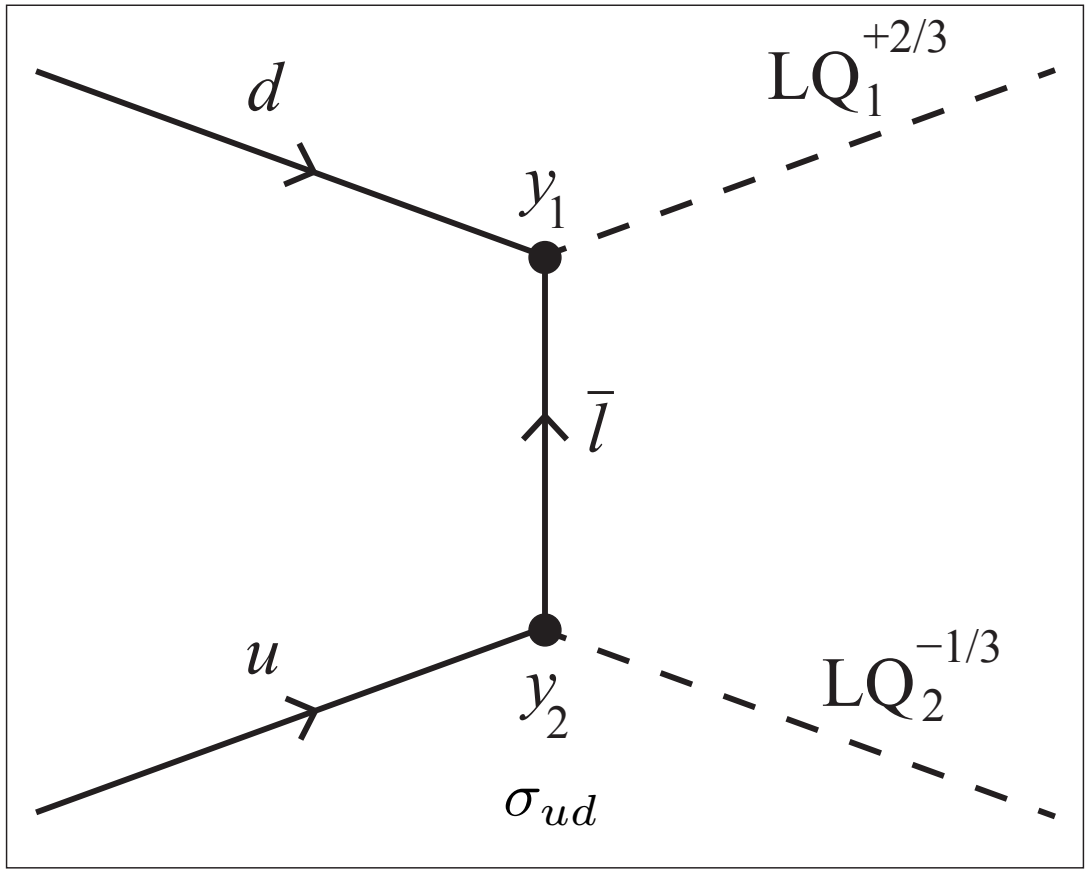

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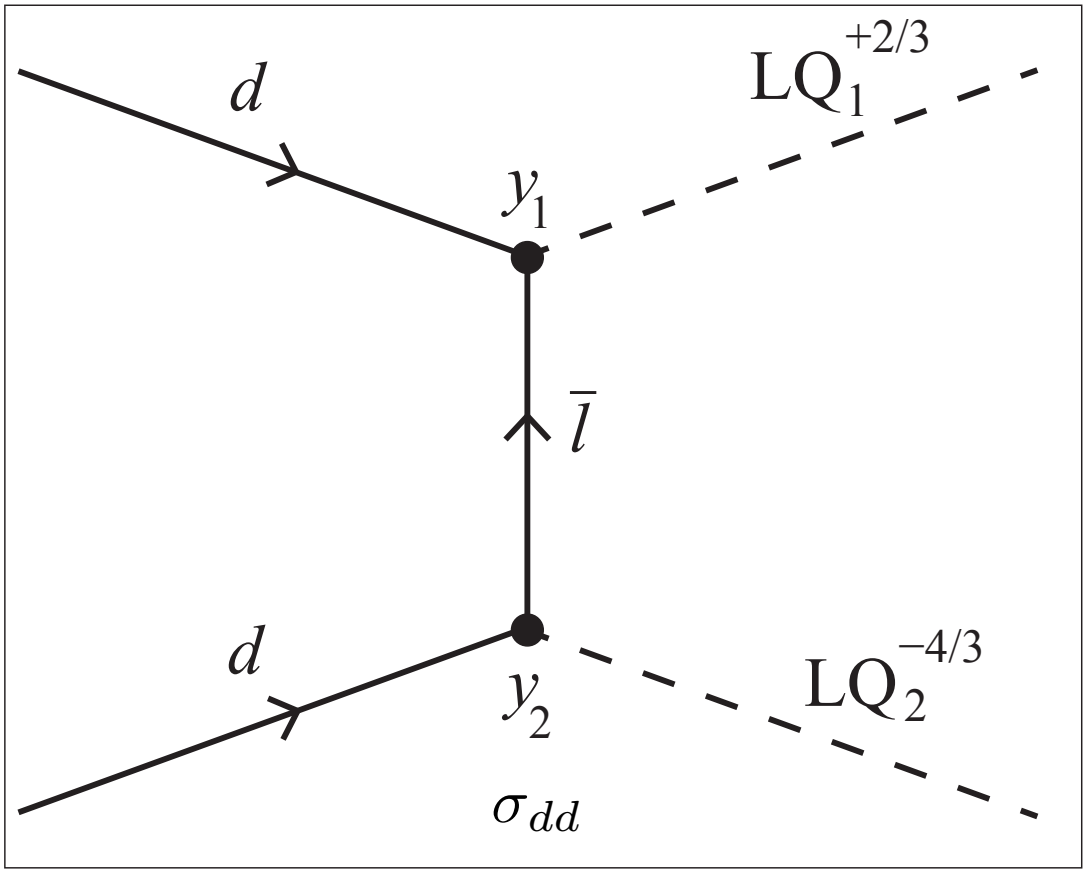

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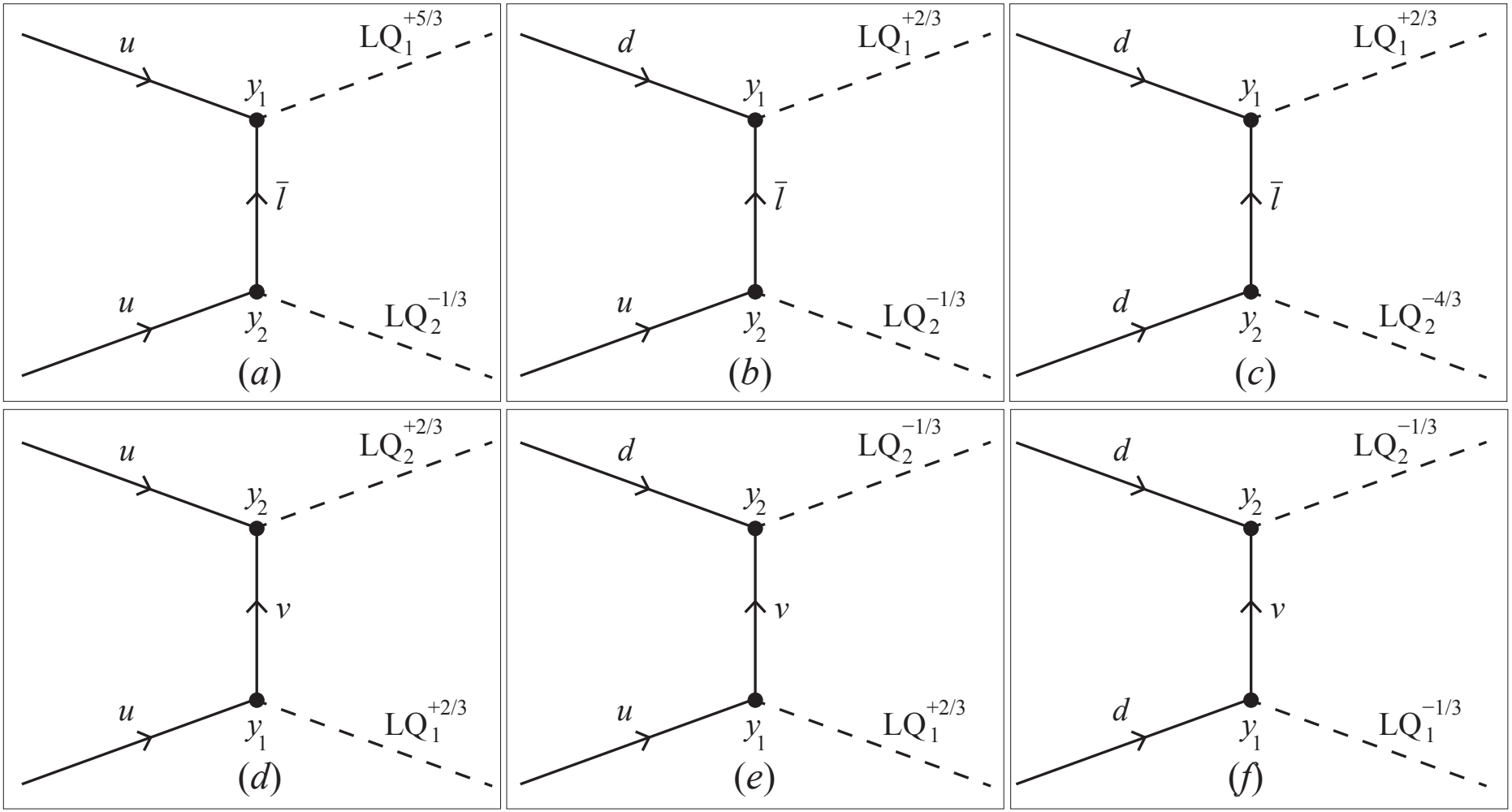

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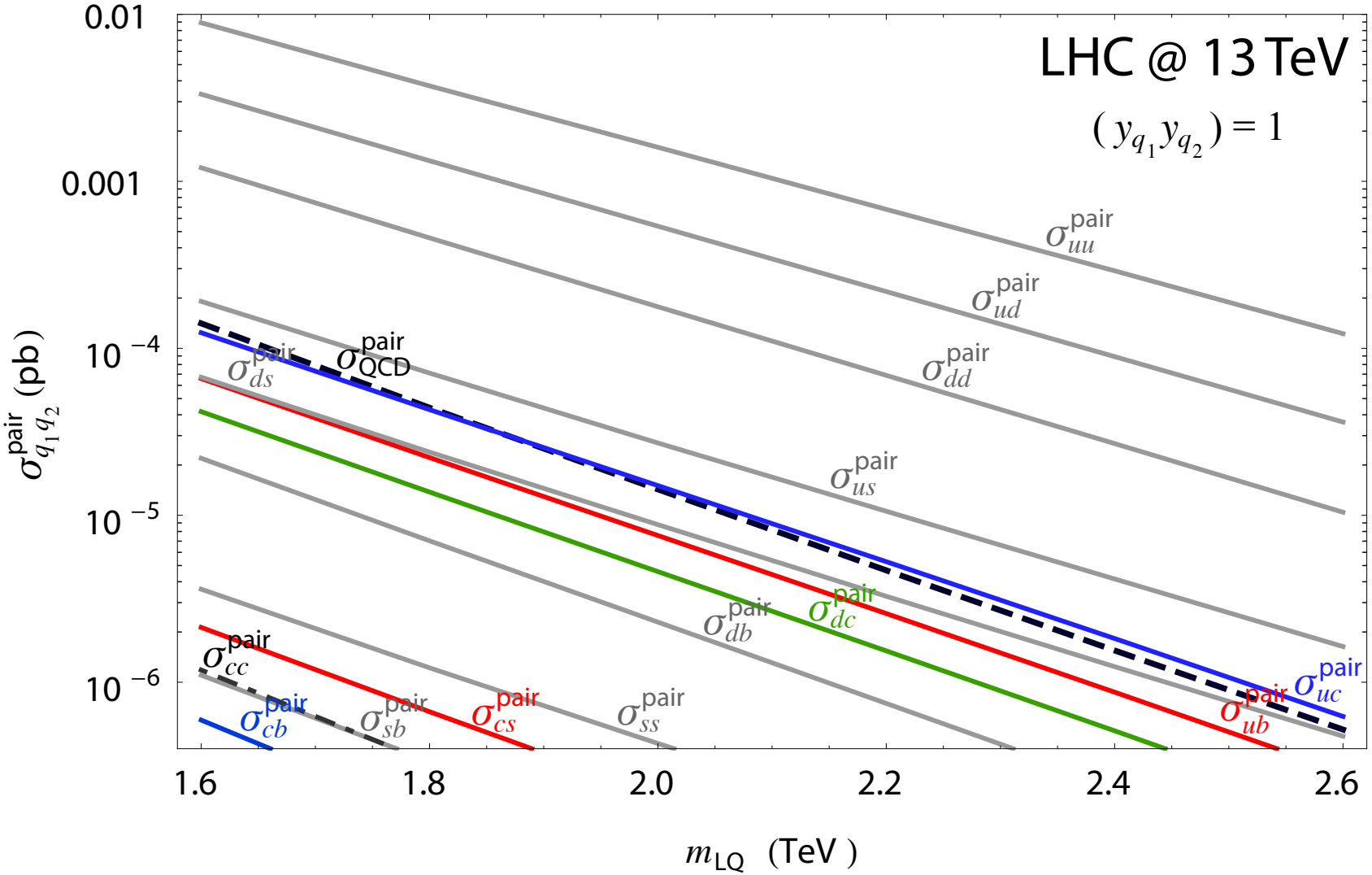

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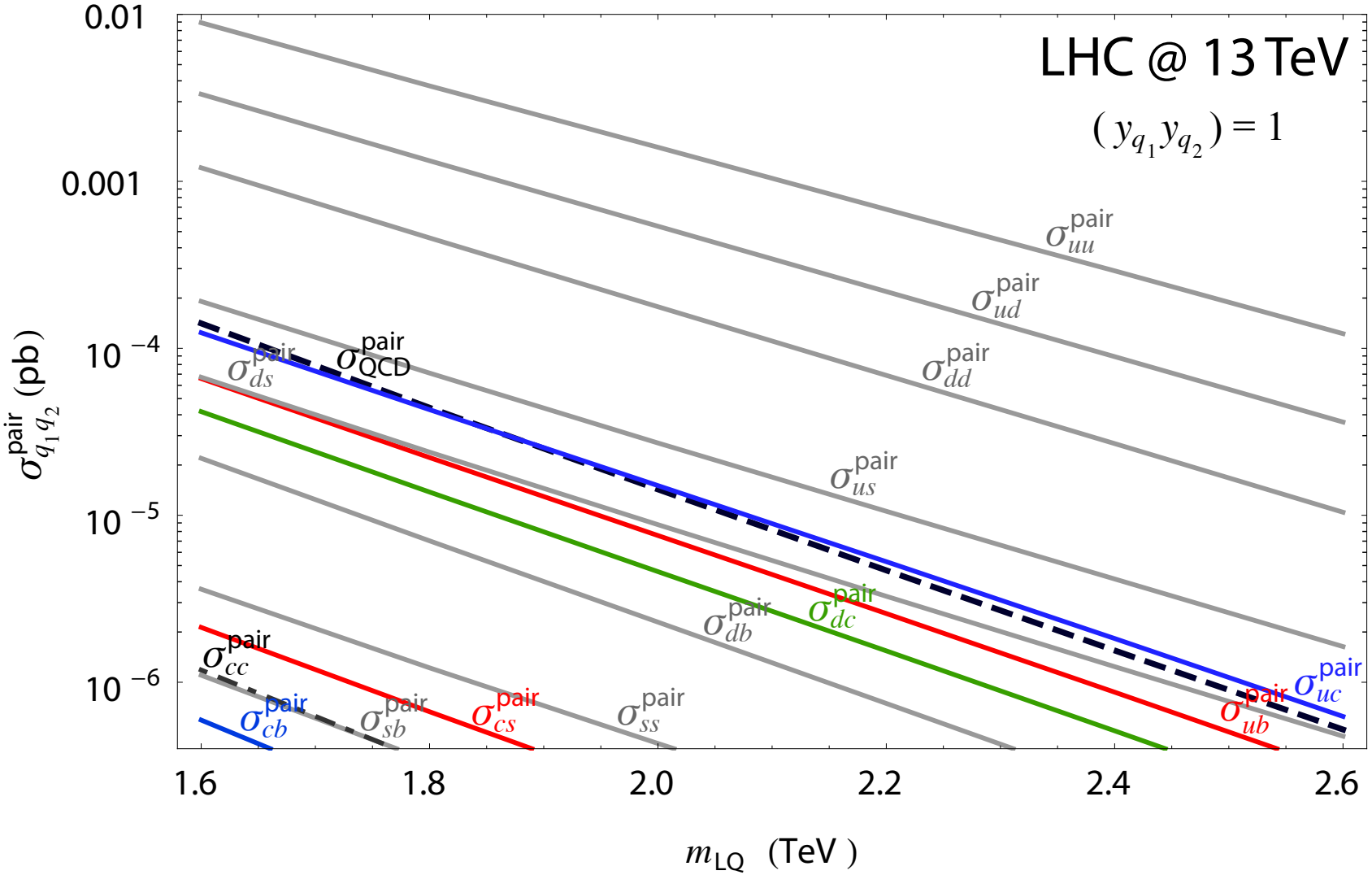
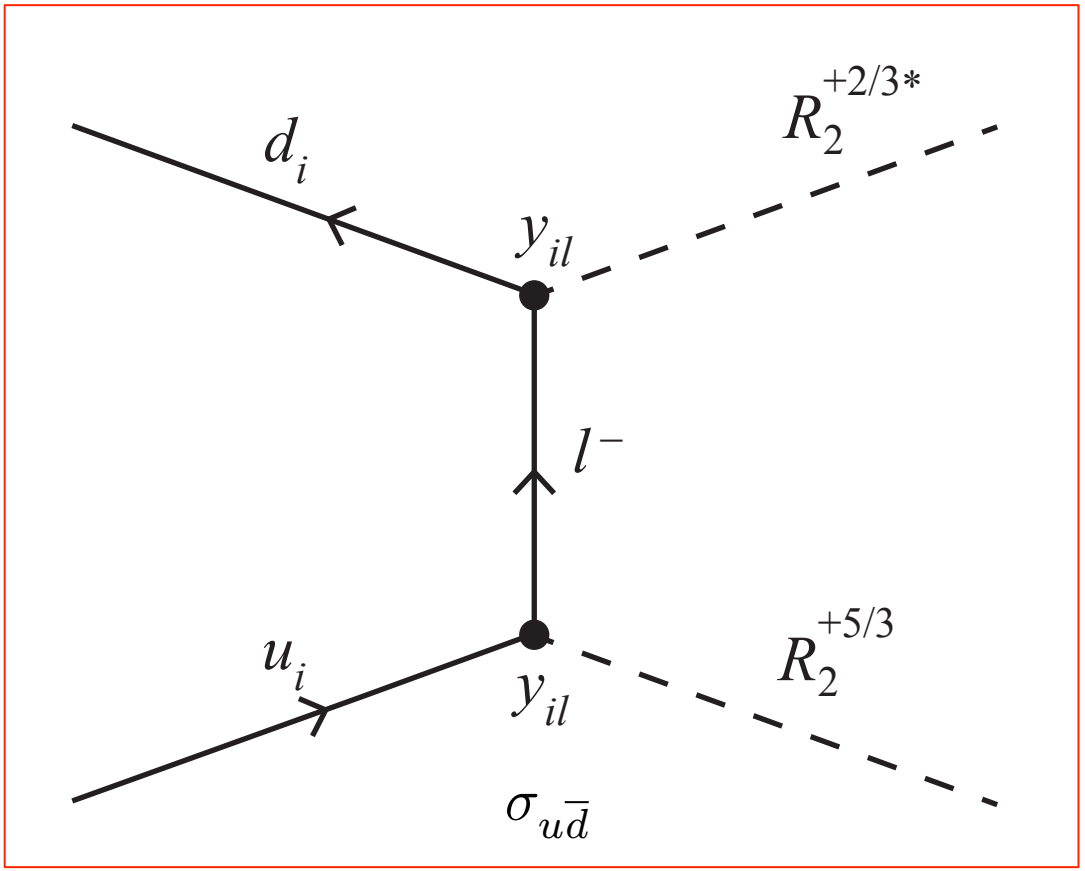
NOVEL PRODUCTION MECHANISM (qq)



Christoph Borschensky, Benjamin Fuks, Adil Jueid, Anna Kulesza, arXiv:2207.02879.

NOVEL PRODUCTION MECHANISM ($q\bar{q}$)



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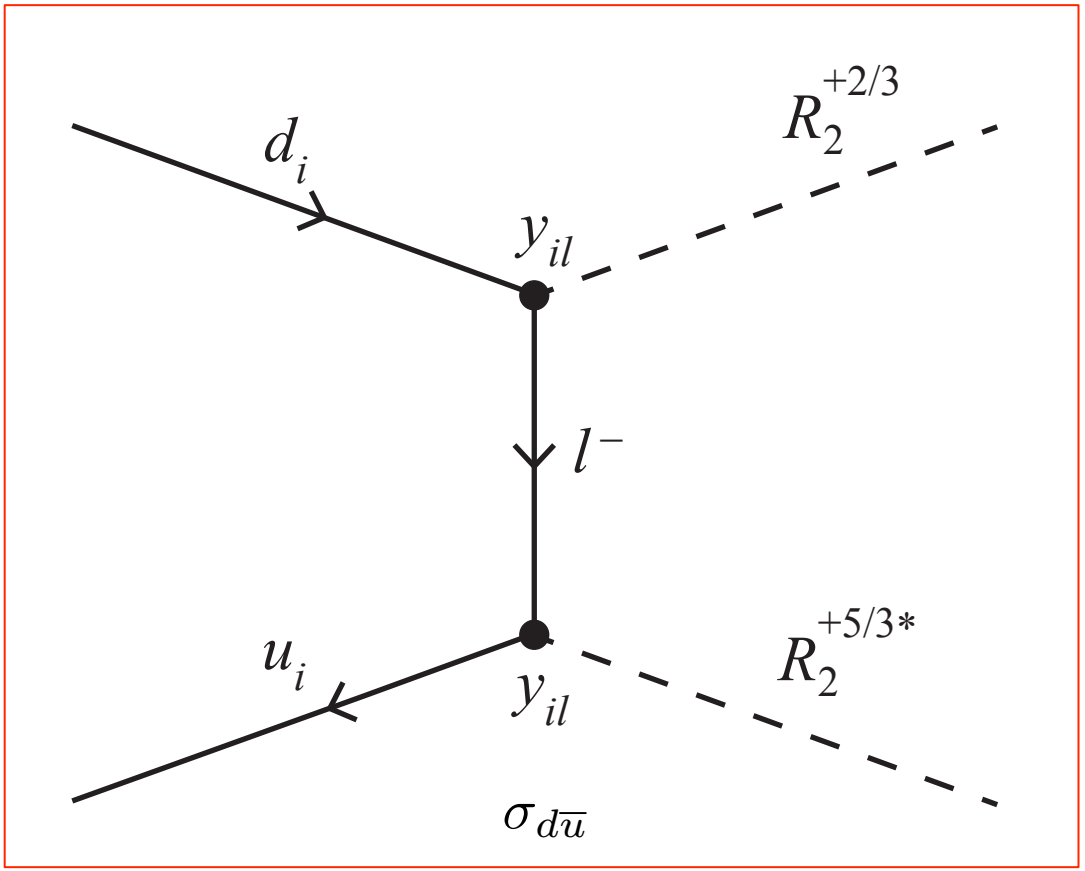

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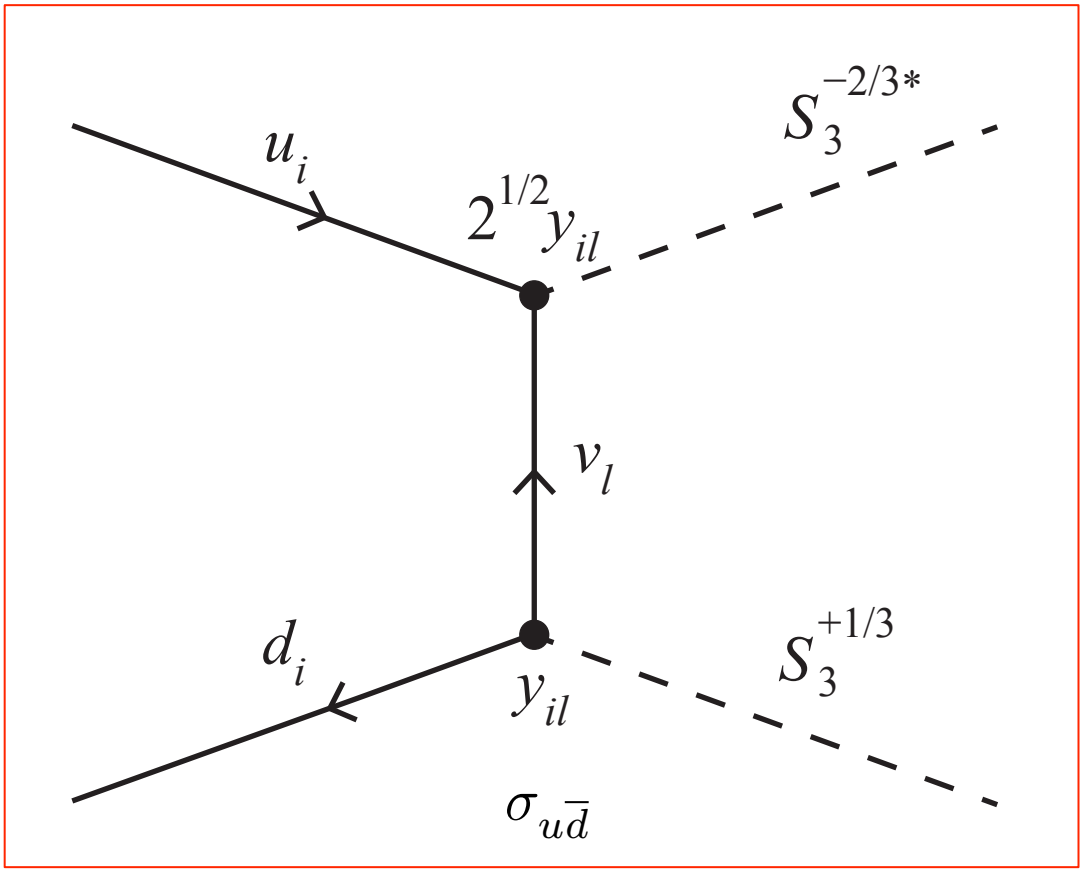

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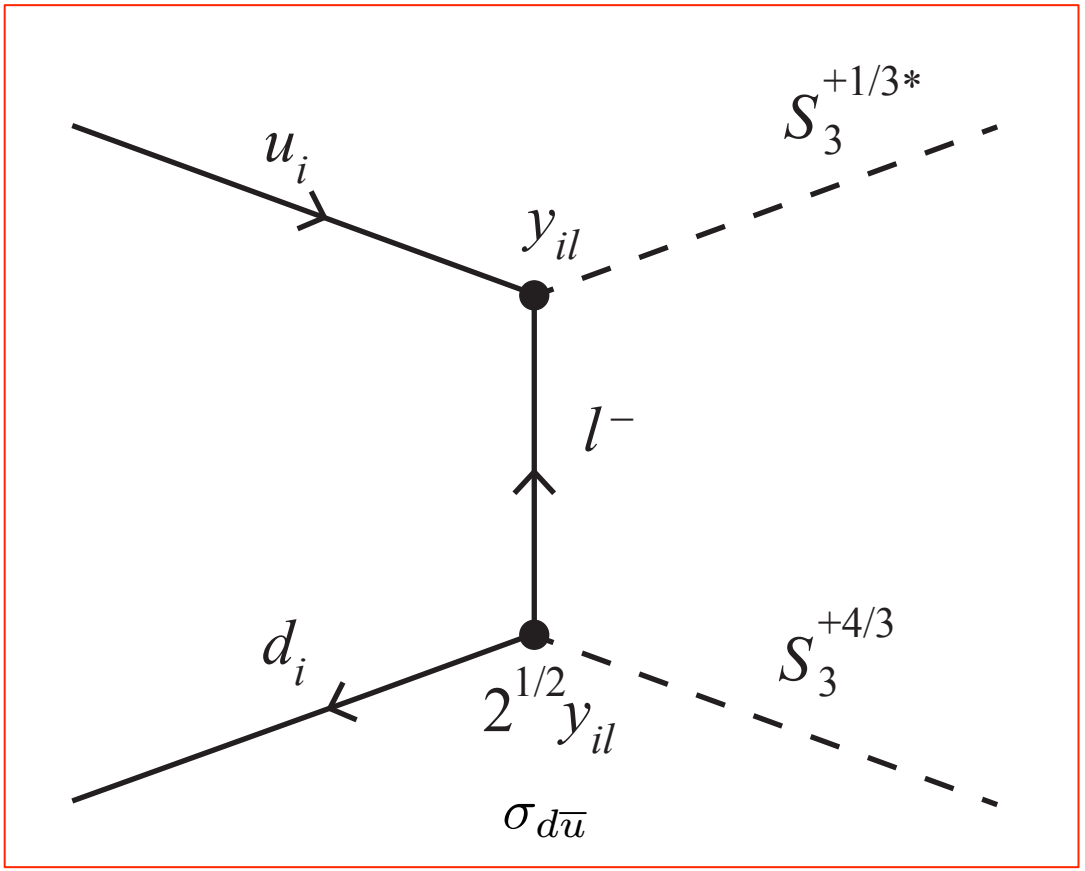

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A CASE STUDY

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$$\mathcal{L} = +y_{1\,ij}\bar{e}^{i}_{R}R^{a\,*}_{2}Q^{j,a}_{L} + y_{2\,ij}\bar{u}^{C\,i}_{R}S_{1}e^{j}_{R} + \text{h.c.}$$

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A CASE STUDY

$$\mathcal{L} = +y_{1\,ij}\bar{e}^i_R R_2^{a\,*} Q_L^{j,a} + y_{2\,ij}\bar{u}_R^{C\,i} S_1 e_R^j + \text{h.c.}$$

$$\mathcal{L} = +(y_1 V^\dagger)_{ij}\bar{e}^i_R u_L^j R_2^{+5/3\,*} + y_{1\,ij}\bar{e}^i_R d_L^j R_2^{+2/3\,*} + y_{2\,ij}\bar{u}_R^{C\,i} e_R^j S_1^{+1/3} + \text{h.c.}$$

V - Cabibbo-Kobayashi-Maskawa matrix

I. D., Svjetlana Fajfer, and Ajla Lejlić, arXiv:2103.11702.

A CASE STUDY

$$\mathcal{L} = +y_{1\,ij}\bar{e}^i_R R_2^{a\,*} Q_L^{j,a} + y_{2\,ij}\bar{u}_R^{C\,i} S_1 e_R^j + \text{h.c.}$$

$$\mathcal{L} = +(y_1 V^\dagger)_{ij}\bar{e}^i_R u_L^j R_2^{+5/3\,*} + y_{1\,ij}\bar{e}^i_R d_L^j R_2^{+2/3\,*} + y_{2\,ij}\bar{u}_R^{C\,i} e_R^j S_1^{+1/3} + \text{h.c.}$$

V - Cabibbo-Kobayashi-Maskawa matrix

$$V_{ij} = \delta_{ij}$$

$$y \equiv y_{1\,11} = y_{2\,11}$$

$$m_{\text{LQ}} \equiv m_{R_2^{+5/3}} = m_{R_2^{+2/3}} = m_{S_1^{+1/3}}$$

I. D., Svjetlana Fajfer, and Ajla Lejlić, arXiv:2103.11702.

A CASE STUDY

$$\mathcal{L} = +y\bar{e}_R u_L R_2^{+5/3\,*} + y\bar{e}_R d_L R_2^{+2/3\,*} + y\bar{u}_R^C e_R S_1^{+1/3} + \text{h.c.}$$

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CONVENTIONAL LQ PAIR PRODUCTION @LHC

$$\mathcal{L} = \boxed{+y\bar{e}_R u_L R_2^{+5/3\,*}} \quad \boxed{+\, y\bar{e}_R d_L R_2^{+2/3\,*}} \quad \boxed{+\, y\bar{u}_R^C e_R S_1^{+1/3}} + \text{h.c.}$$

$$\sigma_{u\bar{u}}^{\text{pair}}(y, m_{\text{LQ}}) \qquad \sigma_{d\bar{d}}^{\text{pair}}(y, m_{\text{LQ}}) \qquad \sigma_{u\bar{u}}^{\text{pair}}(y, m_{\text{LQ}})$$

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NOVEL LQ PAIR PRODUCTION (qq) @LHC

$$\mathcal{L} = +y\bar{e}_R u_L R_2^{+5/3\,*} + y\bar{e}_R d_L R_2^{+2/3\,*} + y\bar{u}_R^C e_R S_1^{+1/3} + \text{h.c.}$$

$$\sigma_{uu}^{\text{pair}} \quad \& \quad \sigma_{\overline{uu}}^{\text{pair}}$$

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NOVEL LQ PAIR PRODUCTION (qq) @LHC

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$$\sigma_{ud}^{\text{pair}} \quad \& \quad \sigma_{\overline{u}\overline{d}}^{\text{pair}}$$

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NOVEL LQ PAIR PRODUCTION (qq) @LHC

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$$\sigma^{\text{pair}}_{u\bar{d}} \quad \& \quad \sigma^{\text{pair}}_{d\bar{u}}$$

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A CASE STUDY

$$pp > S_1^{\frac{1}{3}} S_1^{\frac{1}{3}*}$$

$$pp > R_2^{\frac{5}{3}} R_2^{\frac{5}{3}*}$$

$$pp > R_2^{\frac{2}{3}} R_2^{\frac{2}{3}*}$$

$$pp > R_2^{\frac{5}{3}} R_2^{\frac{2}{3}*}$$

$$pp > R_2^{\frac{2}{3}} R_2^{\frac{5}{3}*}$$

$$pp > S_1^{\frac{1}{3}} S_1^{\frac{1}{3}*}$$

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$$pp > S_1^{\frac{1}{3}} R_2^{\frac{2}{3}}$$

$$pp > R_2^{\frac{5}{3}} R_2^{\frac{2}{3}*}$$

$$pp > R_2^{\frac{2}{3}} R_2^{\frac{5}{3}*}$$

$$pp > S_1^{\frac{1}{3}*} R_2^{\frac{5}{3}*}$$

$$pp > S_1^{\frac{1}{3}*} R_2^{\frac{2}{3}*}$$

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CASE STUDY A

$$pp > S_1^{\frac{1}{3}} S_1^{\frac{1}{3}*}$$

$$pp > R_2^{\frac{5}{3}} R_2^{\frac{5}{3}*}$$

$$pp > R_2^{\frac{2}{3}} R_2^{\frac{2}{3}*}$$

$$pp > R_2^{\frac{5}{3}} R_2^{\frac{2}{3}*}$$

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$$pp > S_1^{\frac{1}{3}} R_2^{\frac{2}{3}}$$

$$pp > R_2^{\frac{5}{3}} R_2^{\frac{2}{3}*}$$

$$pp > R_2^{\frac{2}{3}} R_2^{\frac{5}{3}*}$$

$$pp > S_1^{\frac{1}{3}*} R_2^{\frac{5}{3}*}$$

$$pp > S_1^{\frac{1}{3}*} R_2^{\frac{2}{3}*}$$

$\mu_{\rm LQ}$ - signal strength

$$\mu_{\rm LQ} = \sigma^{\rm pair}(y, m_{\rm LQ}) / \sigma^{\rm pair}_{\rm QCD}(m_{\rm LQ})$$

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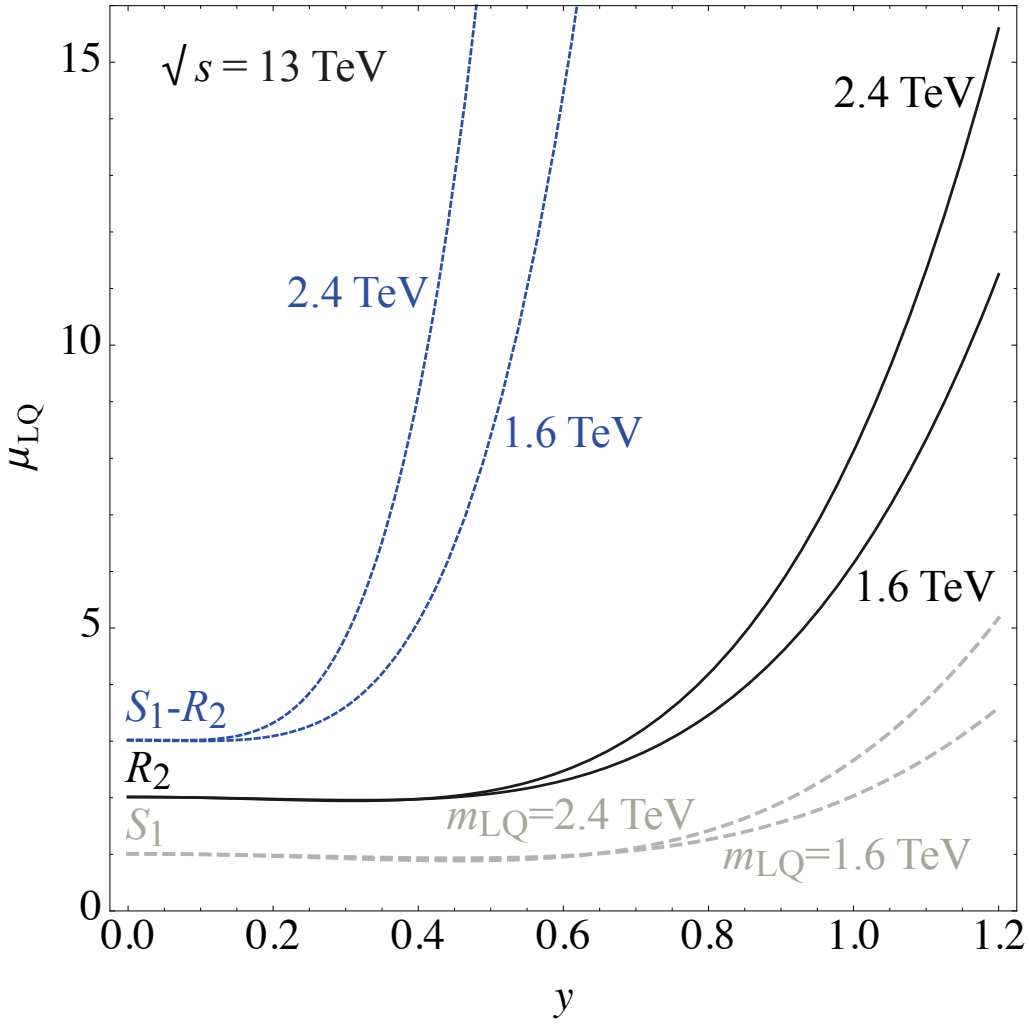
NUMERICAL RESULTS



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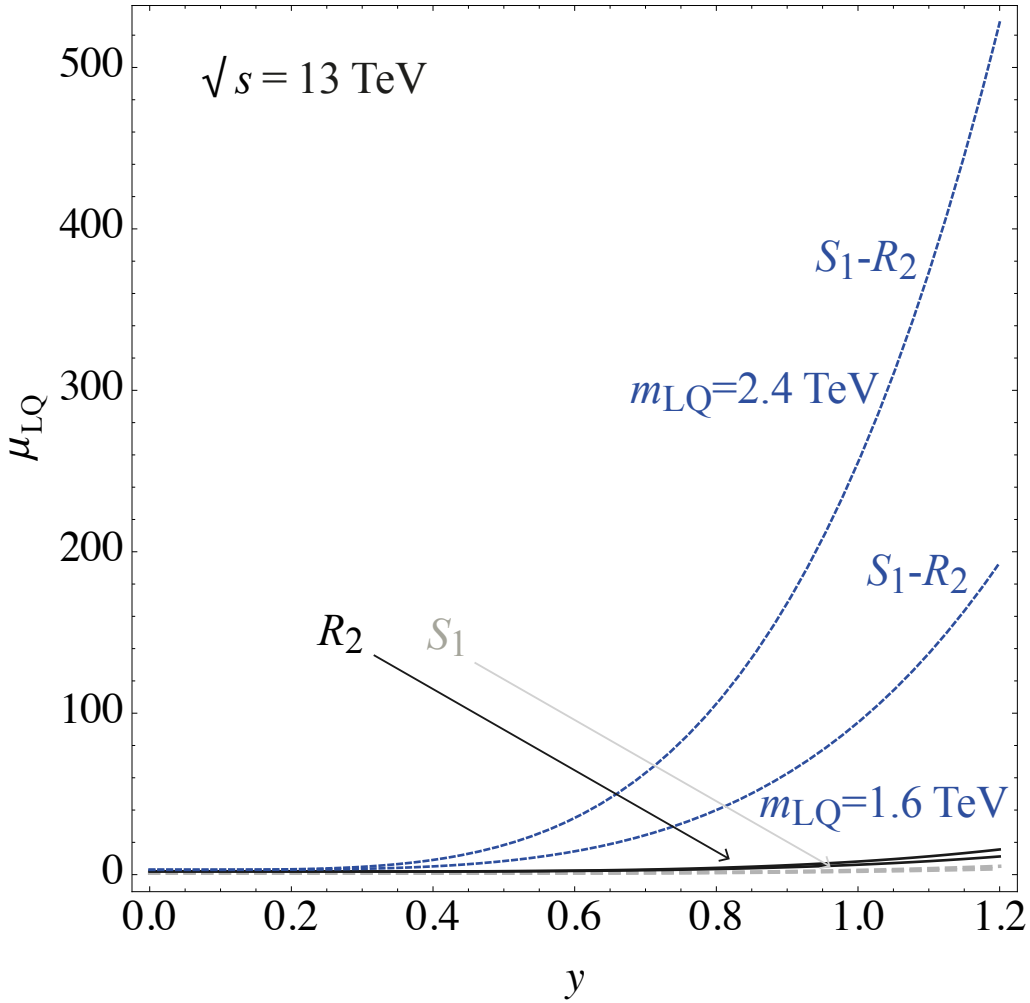

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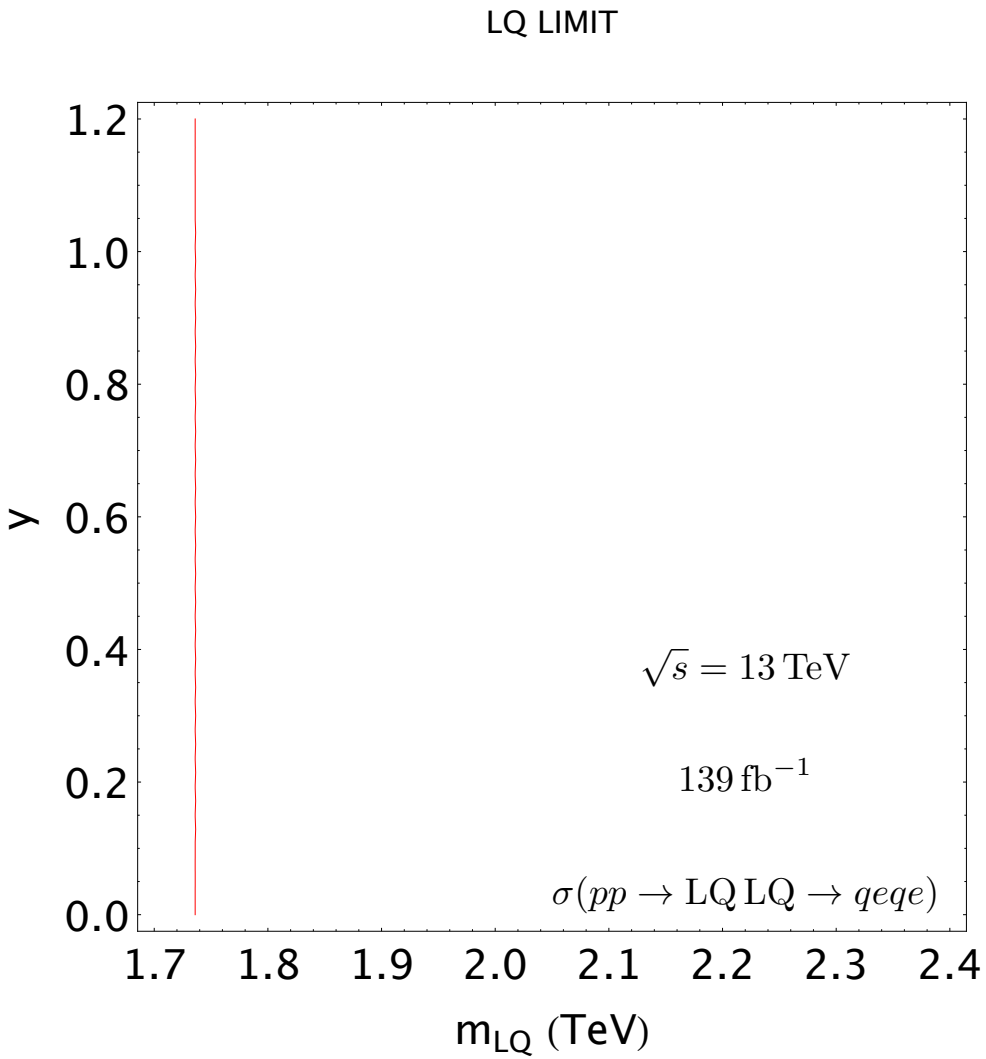
NUMERICAL RESULTS

RECAST OF ATLAS COLLABORATION SEARCH arXiv:2006.05872v2[hep - ex]



one leptoquark - QCD

I. D., Svjetlana Fajfer, Ajla Lejlić, and Shaikh Saad, work in progress.

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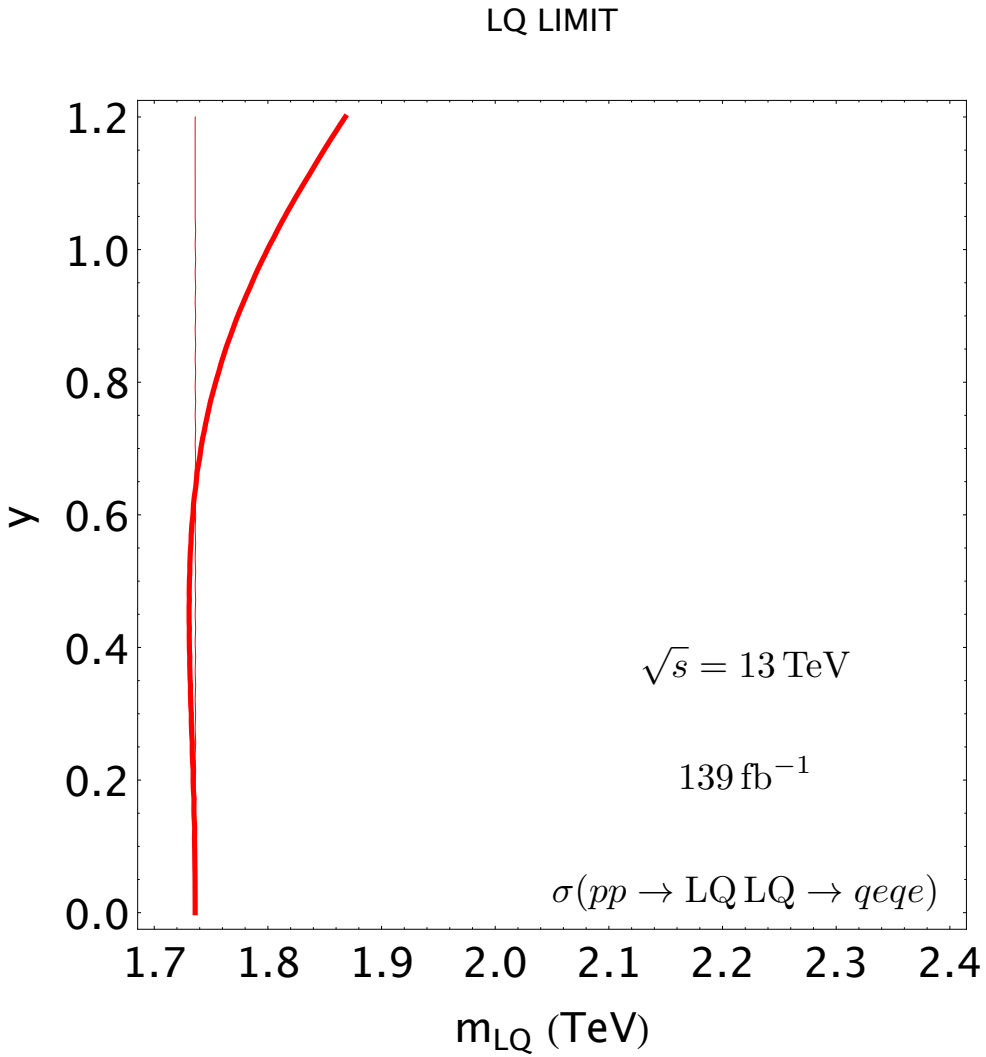

one leptoquark - QCD

one leptoquark - QCD + t-channel $d\bar{d}$

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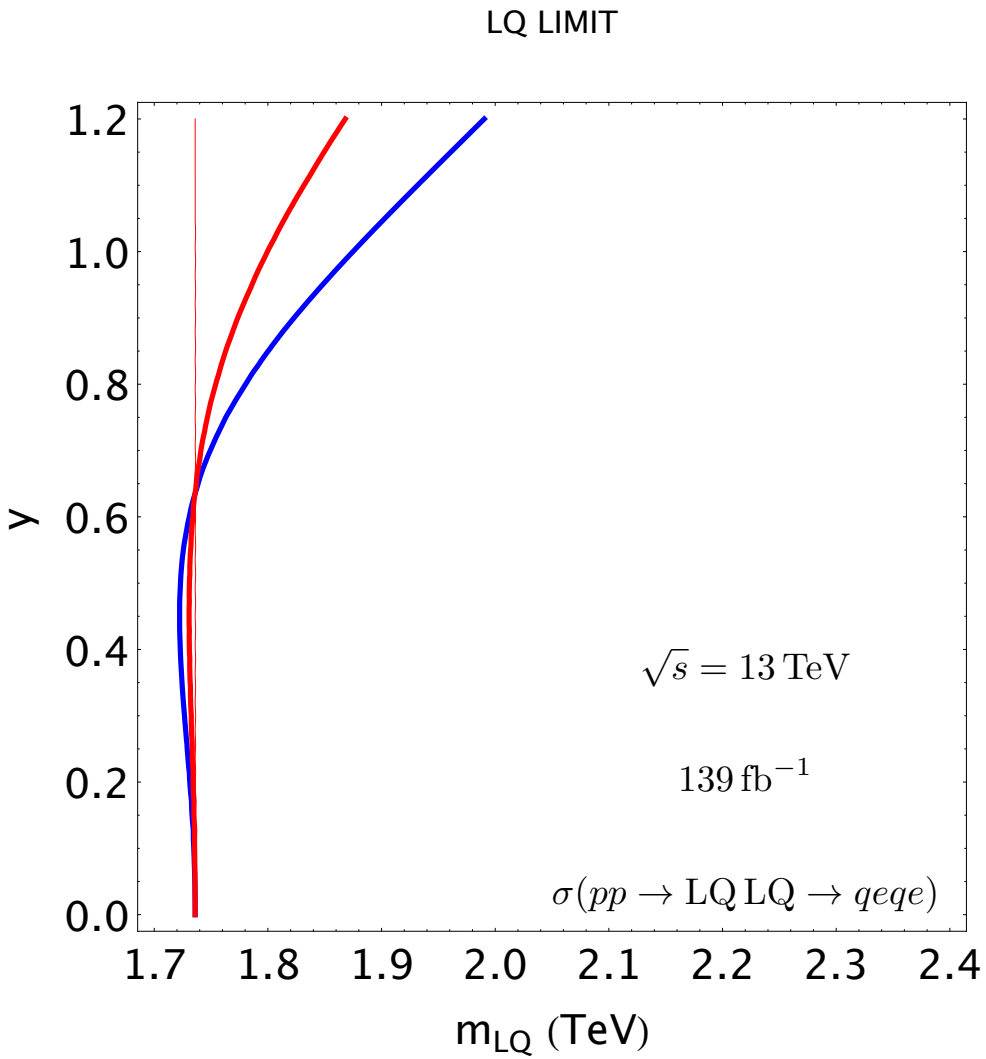

one leptoquark - QCD

one leptoquark - QCD + t-channel $d\bar{d}$

one leptoquark - QCD + t-channel $u\bar{u}$

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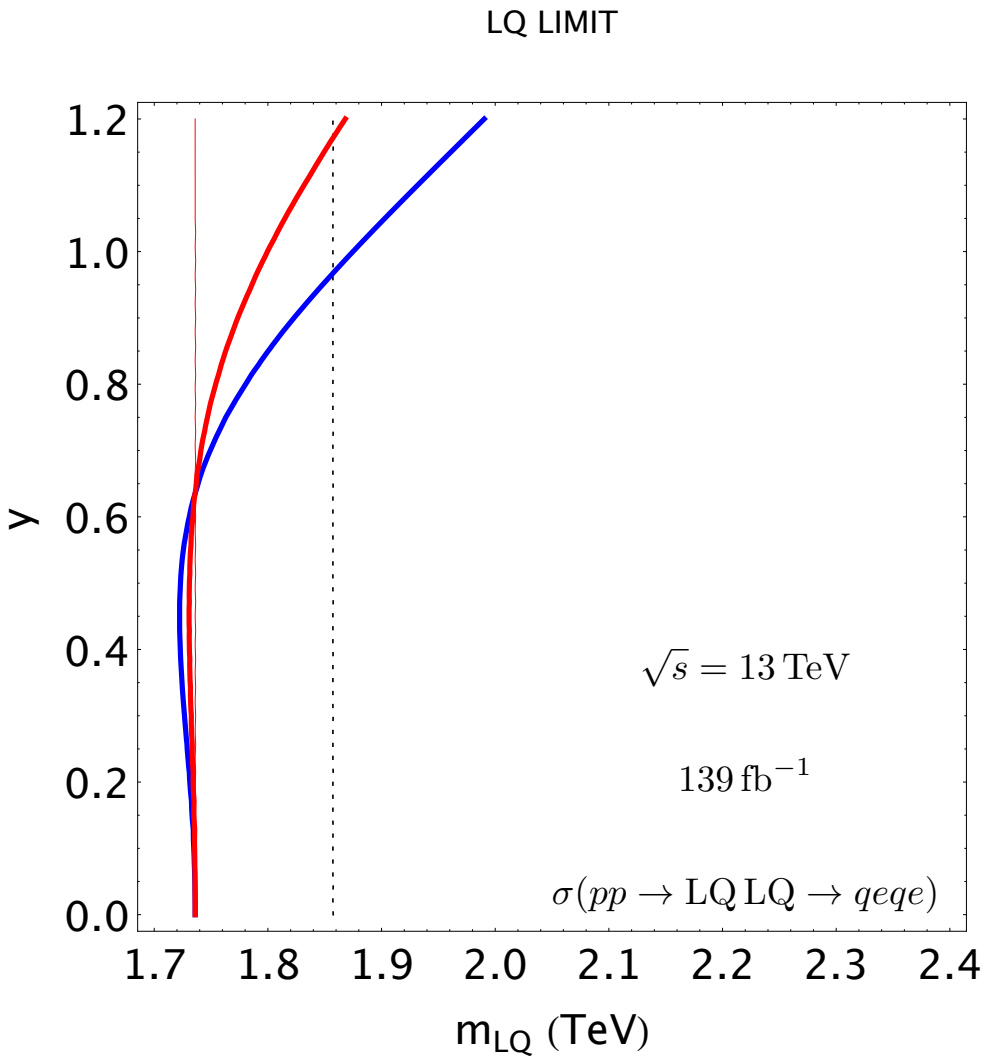


one leptoquark - QCD

one leptoquark - QCD + t-channel $d\bar{d}$

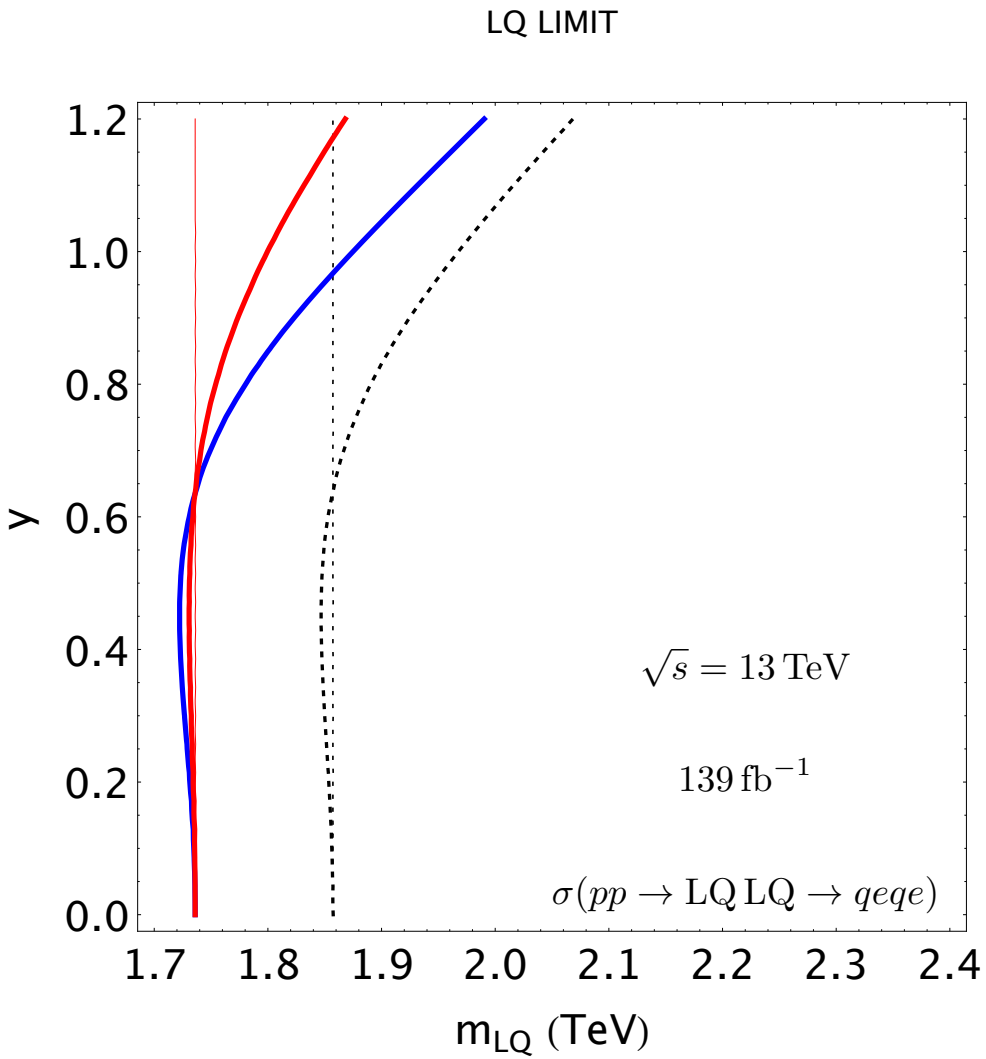
one leptoquark - QCD + t-channel $u\bar{u}$

two leptoquarks - QCD

I. D., Svjetlana Fajfer, Ajla Lejlić, and Shaikh Saad, work in progress.

NUMERICAL RESULTS

RECAST OF ATLAS COLLABORATION SEARCH arXiv:2006.05872v2[hep - ex]



one leptoquark - QCD

one leptoquark - QCD + t-channel $d\bar{d}$

one leptoquark - QCD + t-channel $u\bar{u}$

two leptoquarks - QCD

R_2 - QCD + t-channel

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NUMERICAL RESULTS

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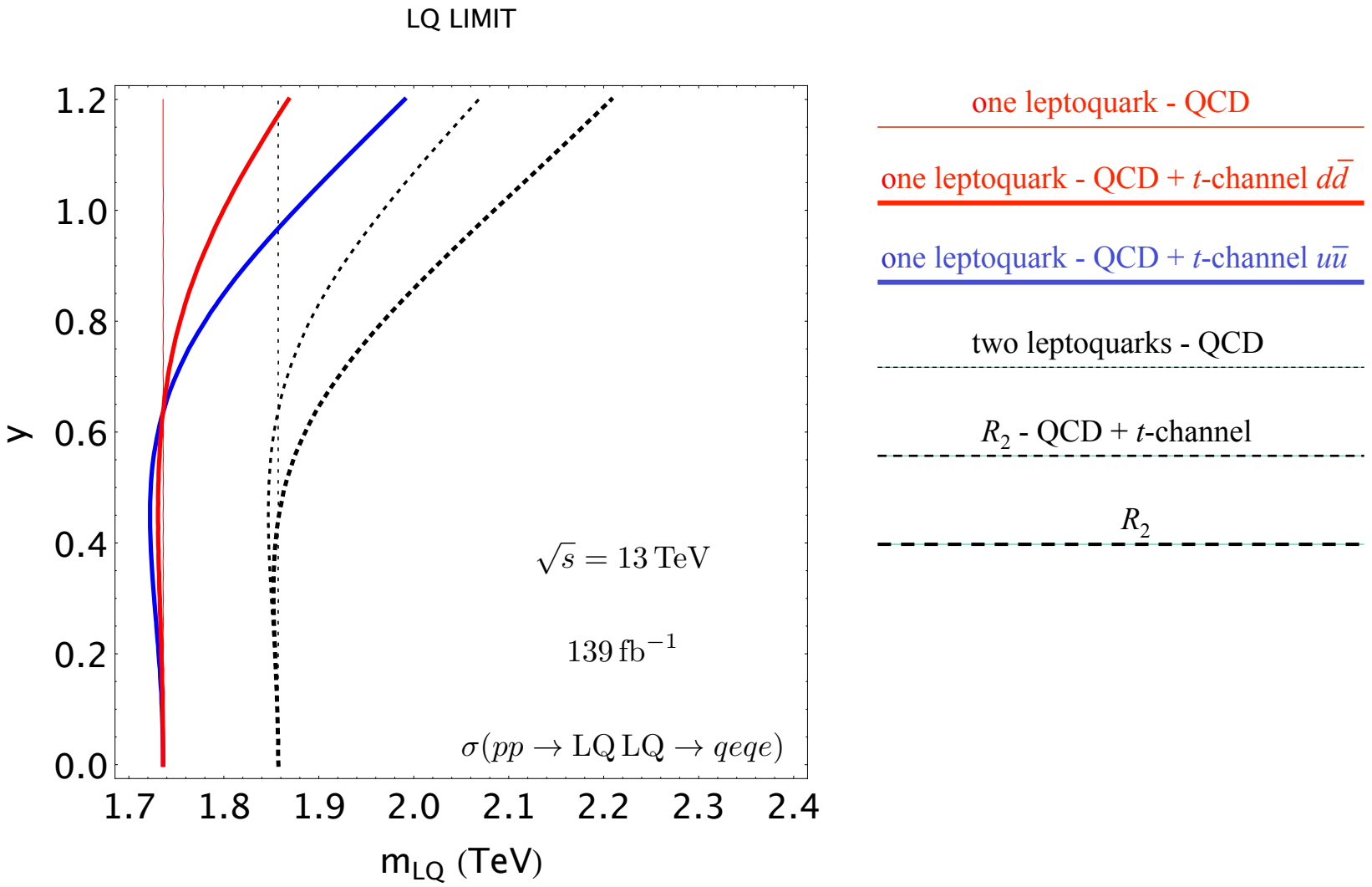

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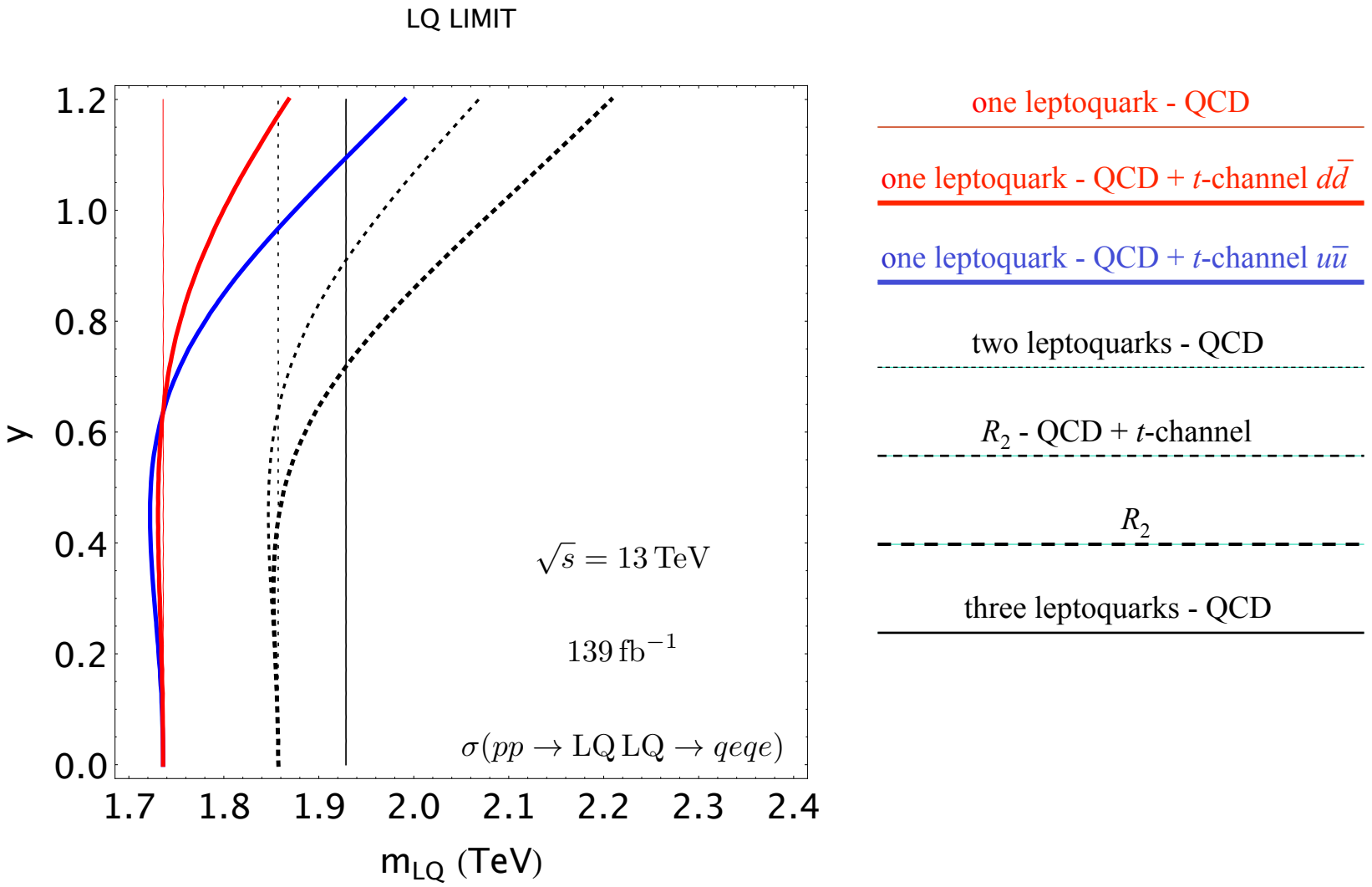

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NUMERICAL RESULTS

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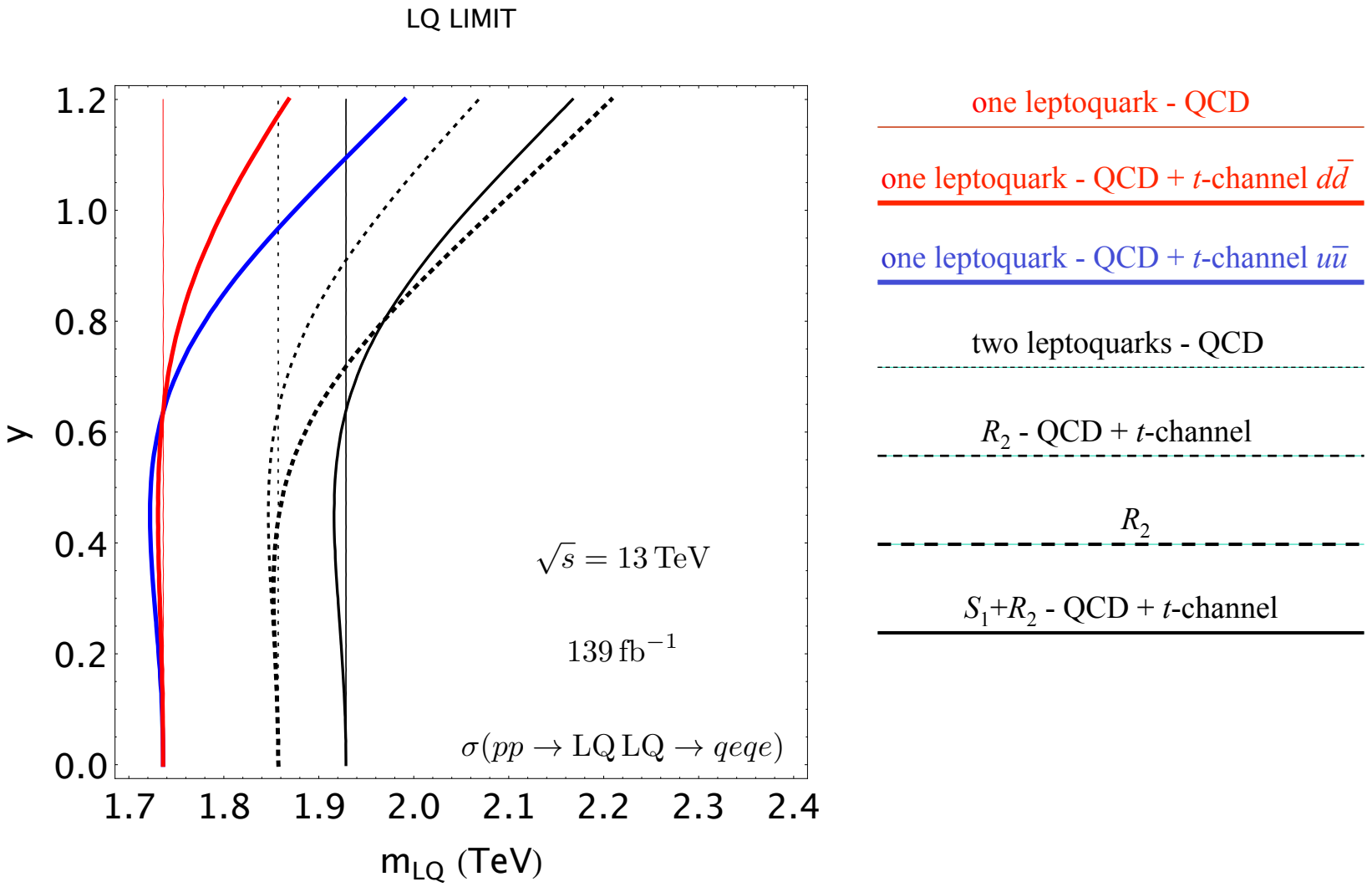

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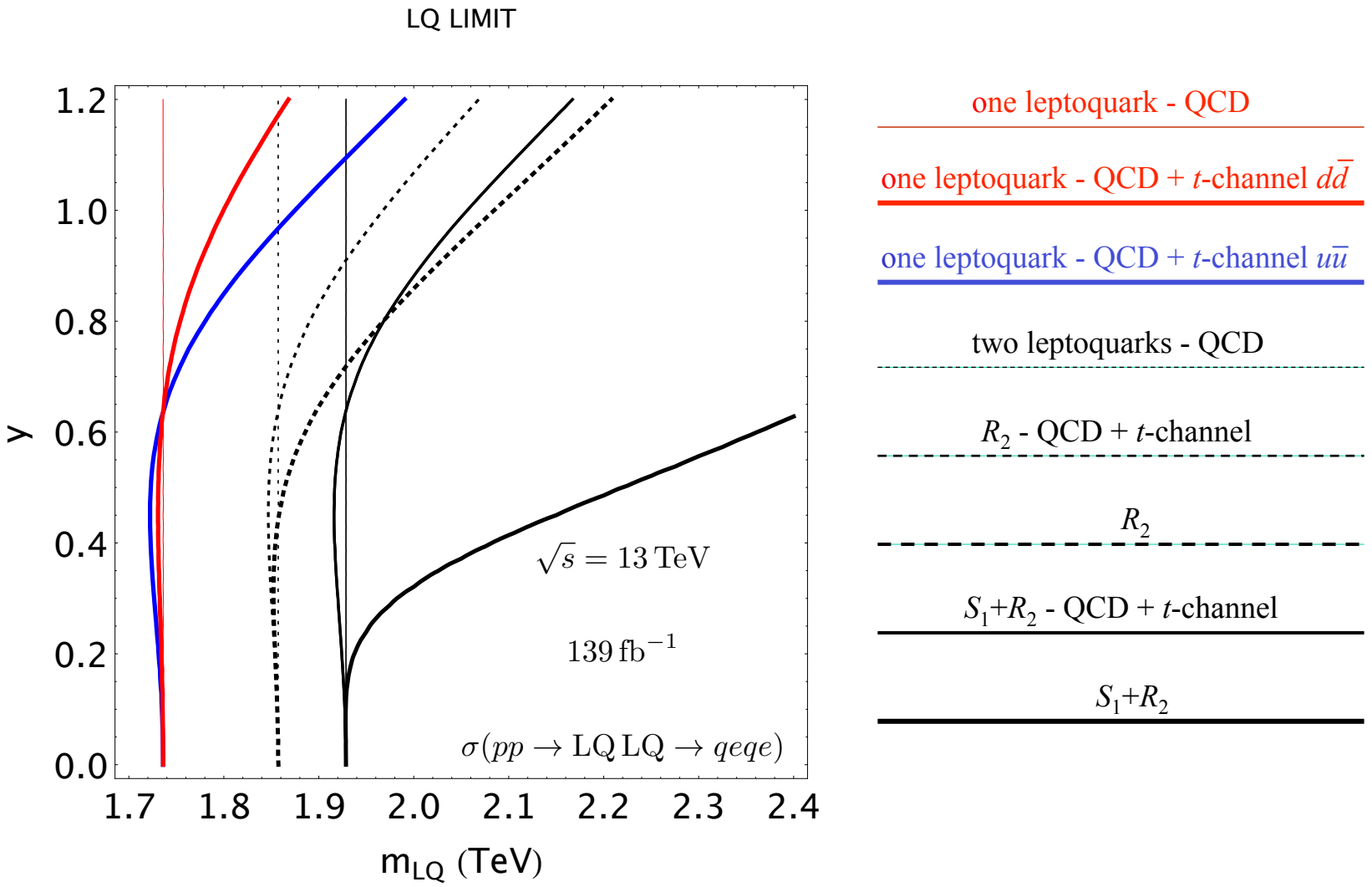

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CONCLUSIONS

I have presented a novel leptoquark production mechanism that yields asymmetric leptoquark pairs @LHC.

The mechanism is ether ($q_i q_j$ & $\overline{q}_i \overline{q}_j$) or $q_i \overline{q}_j$ initiated, where q_i, $q_j = u$, d, s, c, b.

In all instances one has to have two different leptoquarks that couple to a lepton of the same flavour and chirality. The $q_i \overline{q}_j$ ($q_i q_j$ & $\overline{q}_i \overline{q}_j$) initial states correspond to scenarios when the two leptoquarks have the same (deferent) fermion numbers.

THANK YOU

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