JOHANNES GUTENBERG
UNIVERSITÄT MAINZ

JG|U

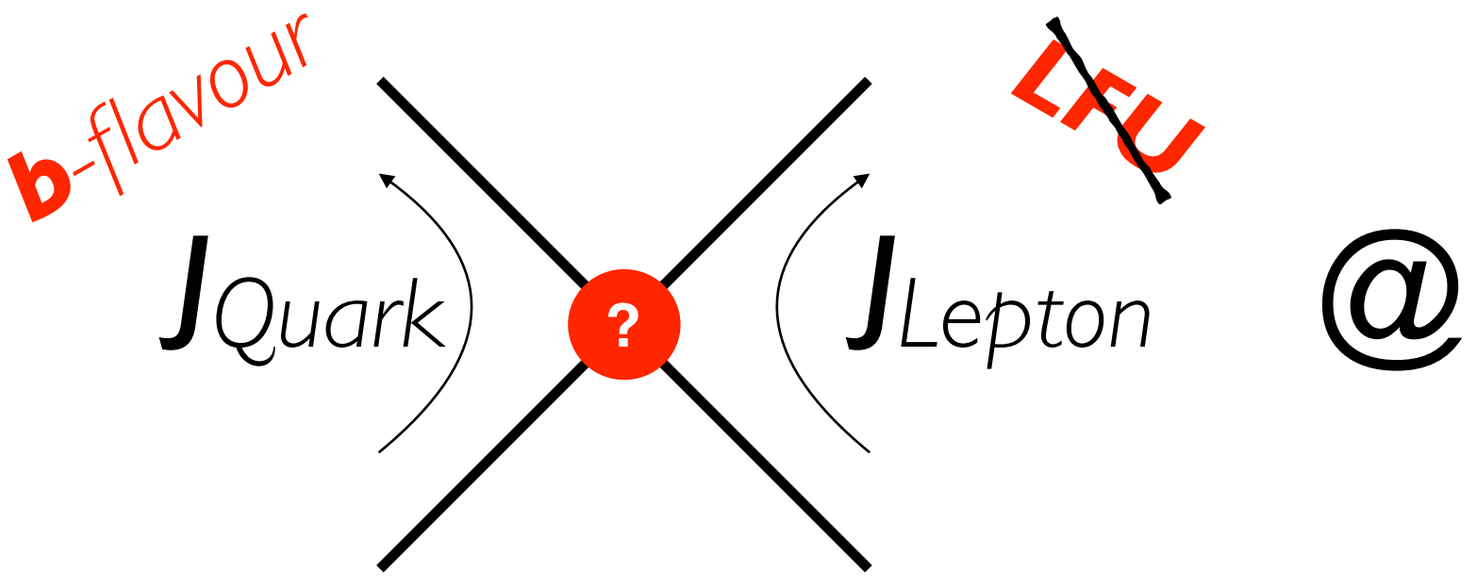
WG6 summary - Part II

Admir Greljo

21 September 2018, CKM

WG6 Part II Leitmotif

Imagine, for a moment, NP in



@

LHCb

Belle II

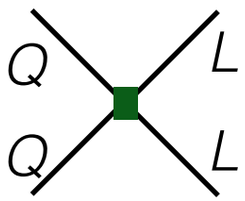
What is the physics case

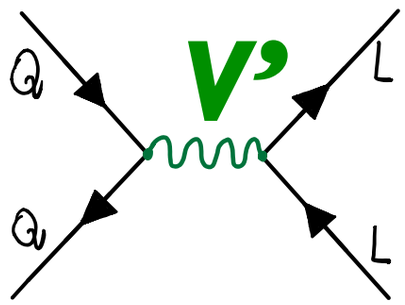
@ high-p_T

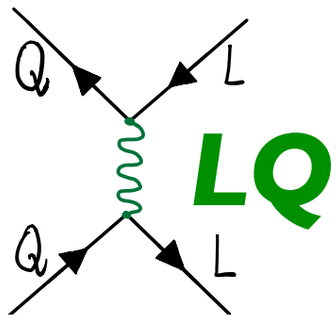
ATLAS EXPERIMENT

CMS Compact Muon Solenoid

?







WEDNESDAY, 19 SEPTEMBER

EFT & Z'

[Theory]

- **Marco Nardecchia**
  "New mass scale behind the B-anomalies"
- **David Marzocca**
  "Rare B-decays and High-pT dilepton tails"
- **Darius Faroughy**
  "Semi-Tauonic B-decays and Di-Tau at high-pT"
- **Benjamin Allanach**
  "B-anomalies: The physics case for future colliders"

[Experiment]

- **Etienne Dreyer**
  "Z' & Contact interactions searches at the LHC: Experiment overview"

THURSDAY, 20 SEPTEMBER

Leptoquarks

[Theory]

- **Yi-Ming Zhong**
  "The leptoquark Hunter's guide: Pair production"
- **Ilja Doršner**
  "Leptoquark toolbox for precision collider studies"
- **Ivan Nišandžić**
  "Flavorful leptoquarks at hadron colliders"
- **Arvind Rajaraman**
  "LQ at the LHC: Beyond the Lepton-Quark Final State"

[Experiment]

- **David Michael Morse**
  "Leptoquark searches at the LHC: Experiment overview"

Lessons from the past

- Unitarity arguments often served as a guide in HEP

1) Beta decay: perturbative unitarity breaks down at ~ 900 GeV [Fermi (1934)]

2) ππ scattering in χPT [Weinberg (1966), …]

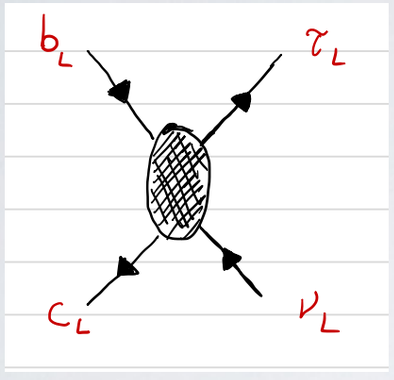
- the scale of unitarity violation ~ 500 MeV signals the onset of new resonances

3) LHC "no lose theorem" → $\Lambda \lesssim 1$ TeV [Lee, Quigg, Thacker (1977), …]

- upper bound either on Higgs mass or on the scale of NP unitarizing WW scattering

If B-anomalies are true…

- *What do we expect?* (Worst case scenario)



$$\mathcal{A}(\psi\psi \to \psi\psi) \propto s$$

Tree-Level Pertubative Unitarity criterium

$$|\mathcal{A}_{J=0}| < 1/2$$

[Di Luzio, Nardecchia, 1706.01868]

$$\begin{cases} \sqrt{s}_{max} \equiv \Lambda_U = 9 \text{ TeV} & b \to c\tau\nu \\ \sqrt{s}_{max} \equiv \Lambda_U = 80 \text{ TeV} & b \to s\mu\mu \end{cases}$$

An old lesson: VV scattering…
$\Lambda_U = 2$ TeV, $m_h = 125$ GeV

Exciting

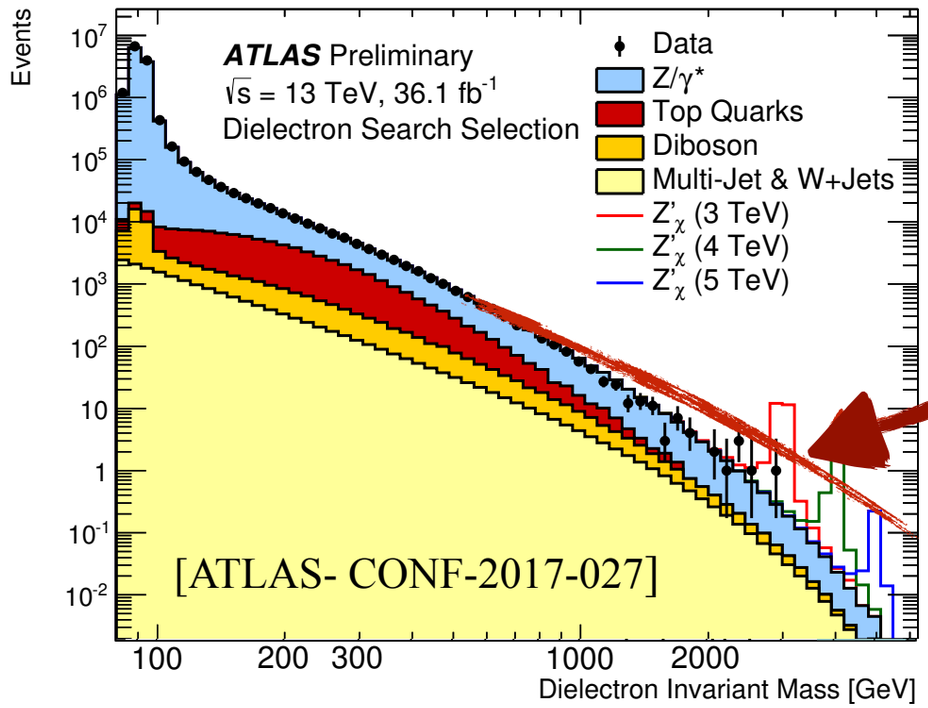
- **Marco Nardecchia**
  "New mass scale behind the B-anomalies"

$$R_{K(*)}$$

Best New Physics interpretation:

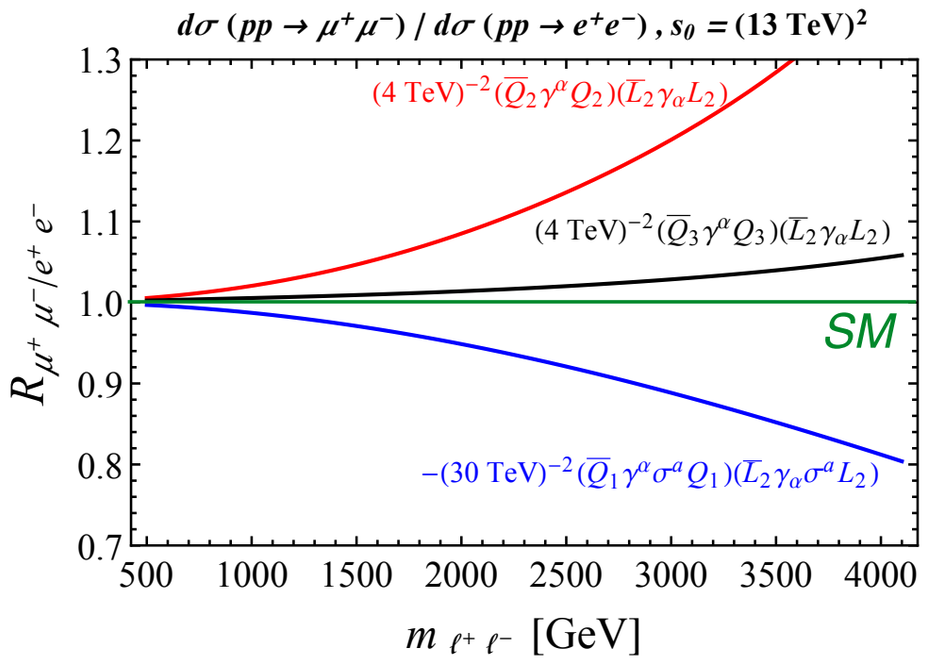
$$\frac{1}{\Lambda^2_{bs\mu}}(\bar{s}_L\gamma_\mu b_L)(\bar{\mu}_L\gamma^\mu\mu_L)$$

$\Lambda_{bs\mu} \sim 32$ TeV

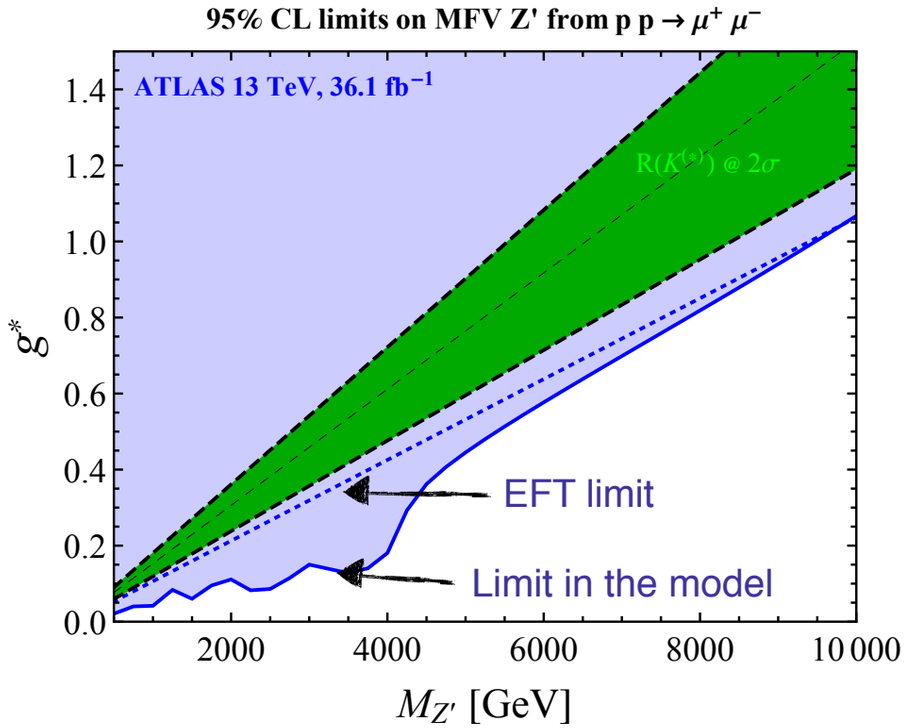


Deviations in the dilepton tails if NP is heavy!

LFU ratios @ High-p_T

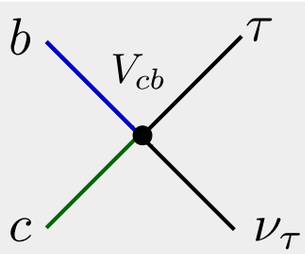


Model with a **spin-1 singlet MFV Z'**

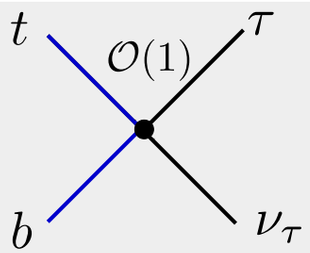


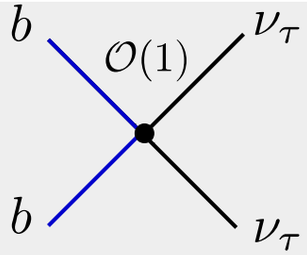
- **David Marzocca**
  "Rare B-decays and High-pT dilepton tails"

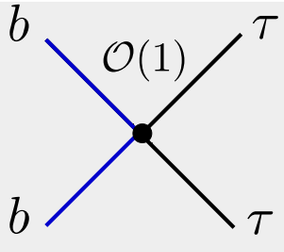
SU(2) invariance & Flavor structure



b → c



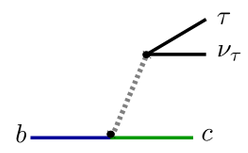
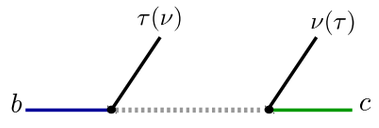
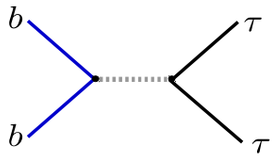
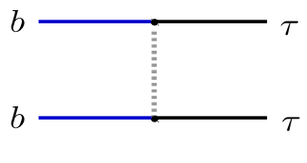




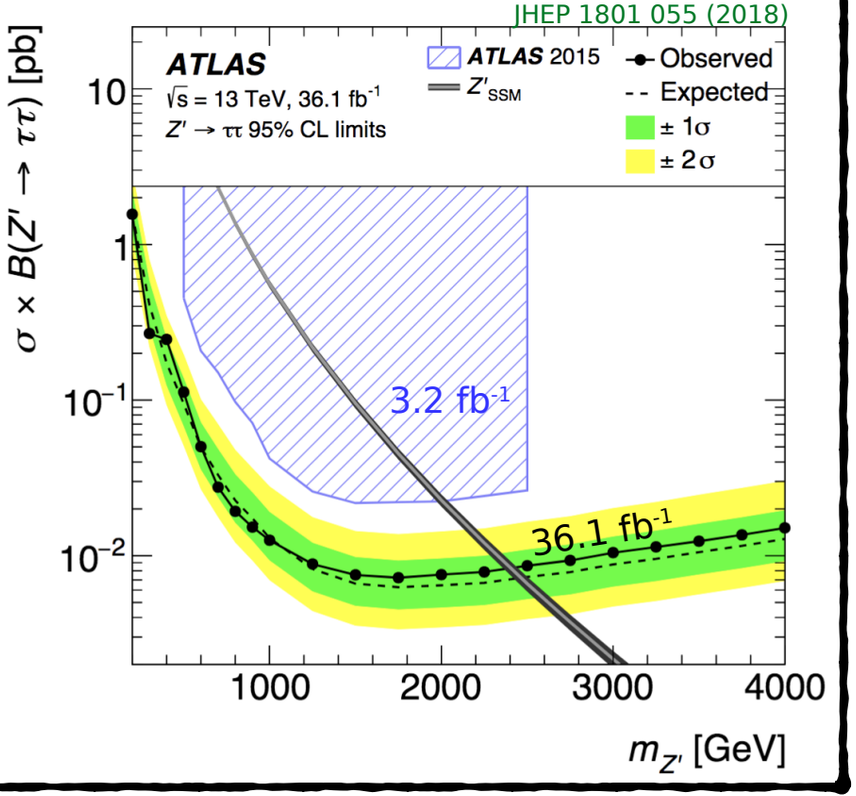
$\mathbf{V_{cb}^{-1}}$ enhancement with respect to b → c transitions

Observation!

$$pp \to \tau^+\tau^- + X$$

	V'	**LQ**
b → c		
LHC $b\bar{b} \to \tau^+\tau^-$		
Signature	di-Tau Resonance	Non-resonant excess in di-Tau tails

JHEP 1801 055 (2018)



- **Darius Faroughy**
  "Semi-Tauonic B-decays and Di-Tau at high-pT"

Low-p_T & High-p_T complementarity!

$\tau \to \mu\phi$

$$\begin{pmatrix} 0 & 0 & 0 \\ 0 & x_L^{s\mu} & x_L^{s\tau} \\ 0 & x_L^{b\mu} & x_L^{b\tau} \end{pmatrix}$$

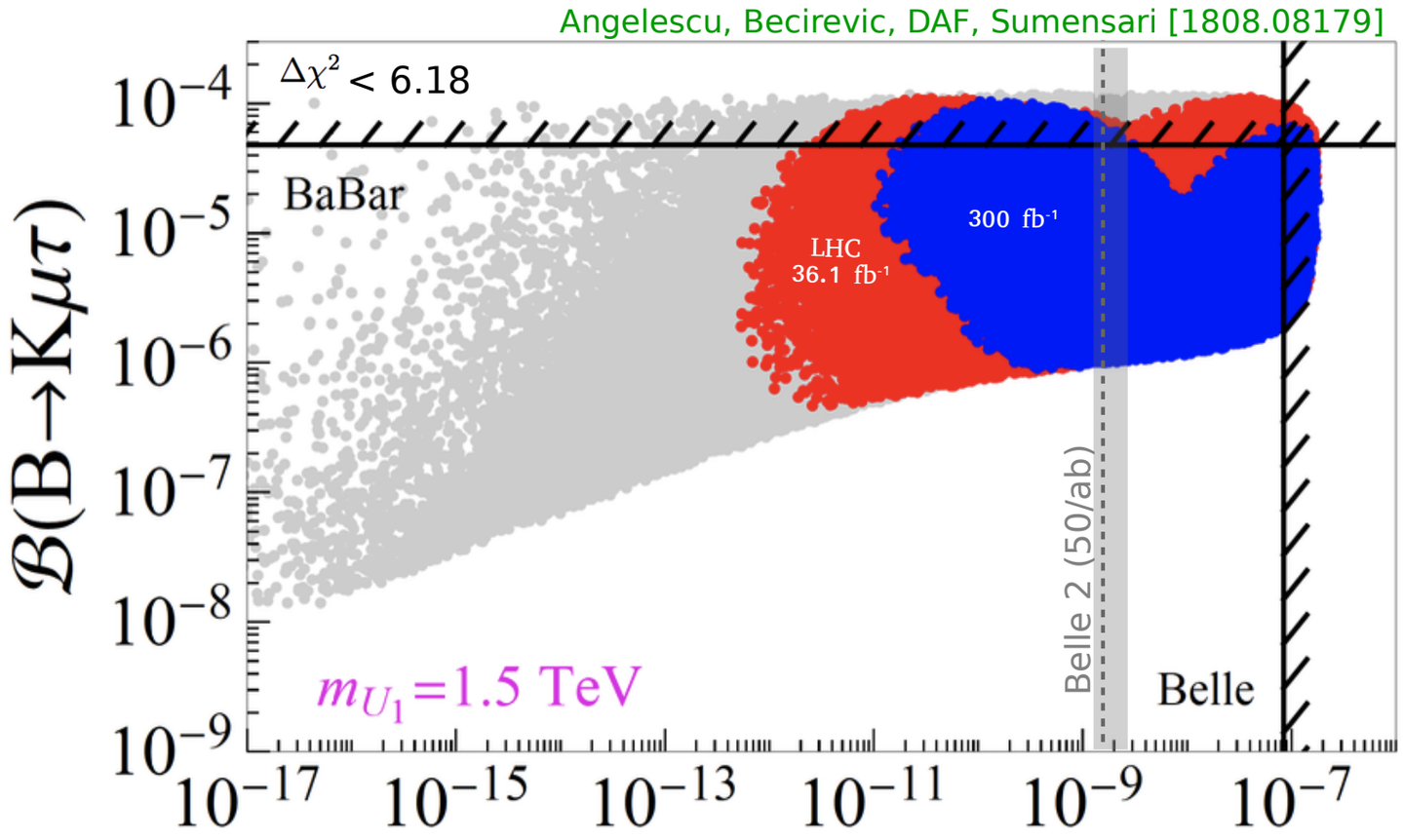
$B \to K\mu\tau$

$$\begin{pmatrix} 0 & 0 & 0 \\ 0 & x_L^{s\mu} & x_L^{s\tau} \\ 0 & x_L^{b\mu} & x_L^{b\tau} \end{pmatrix}$$

$pp \to \tau^+\tau^- + X$

$$\begin{pmatrix} 0 & 0 & 0 \\ 0 & x_L^{s\mu} & x_L^{s\tau} \\ 0 & x_L^{b\mu} & x_L^{b\tau} \end{pmatrix}$$

Angelescu, Becirevic, DAF, Sumensari [1808.08179]



$U_1 = (\mathbf{3}, \mathbf{1})_{2/3}$

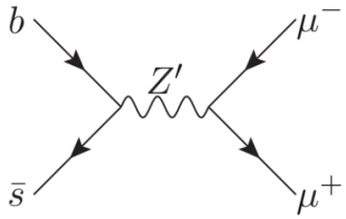
- **Darius Faroughy**

"Semi-Tauonic B-decays and Di-Tau at high-pT"

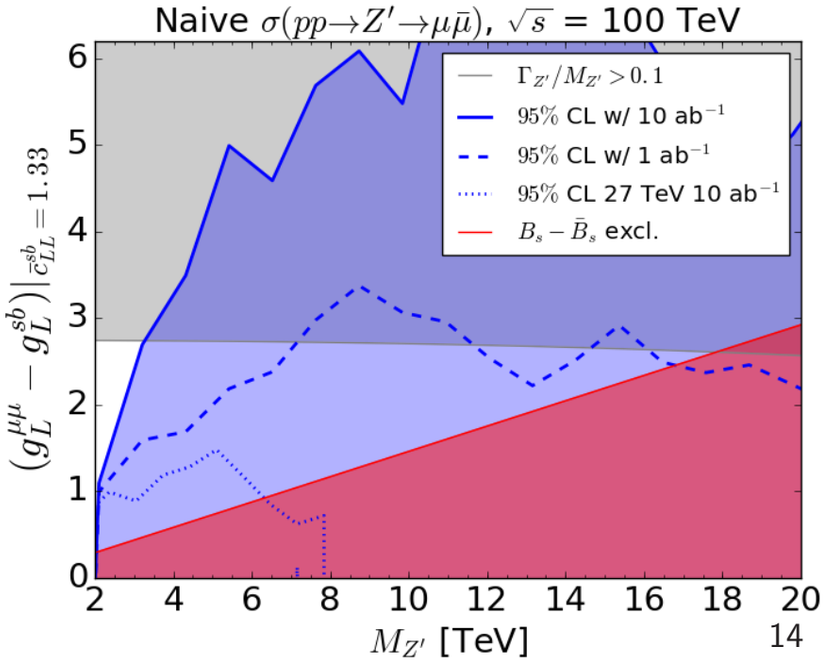
If $R_{K(*)}$ anomalies true, when will we see a new resonance?

Principle of Maximal Pessimism

[minimal ingredients needed to fit…]

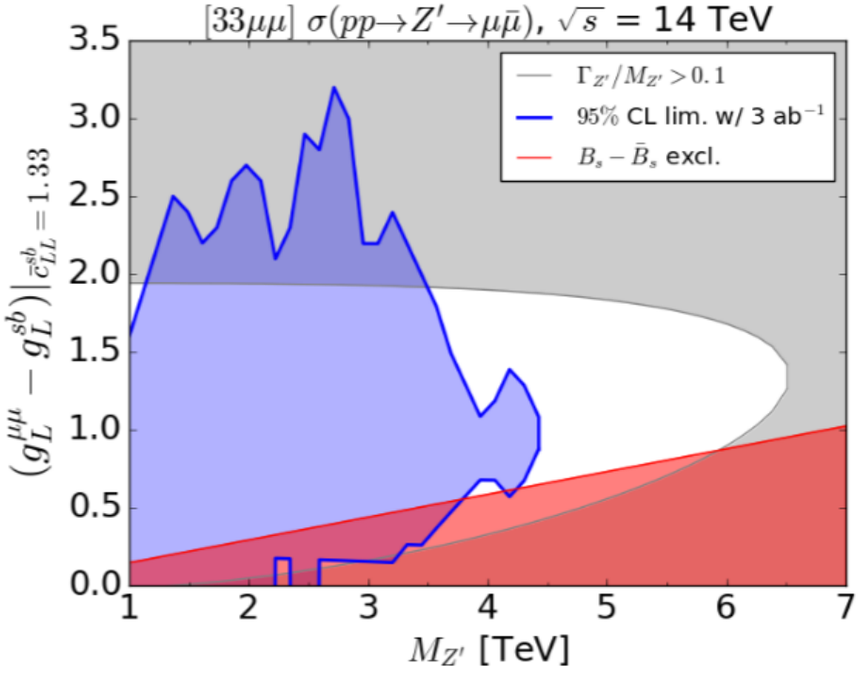


- ***Difficult!***



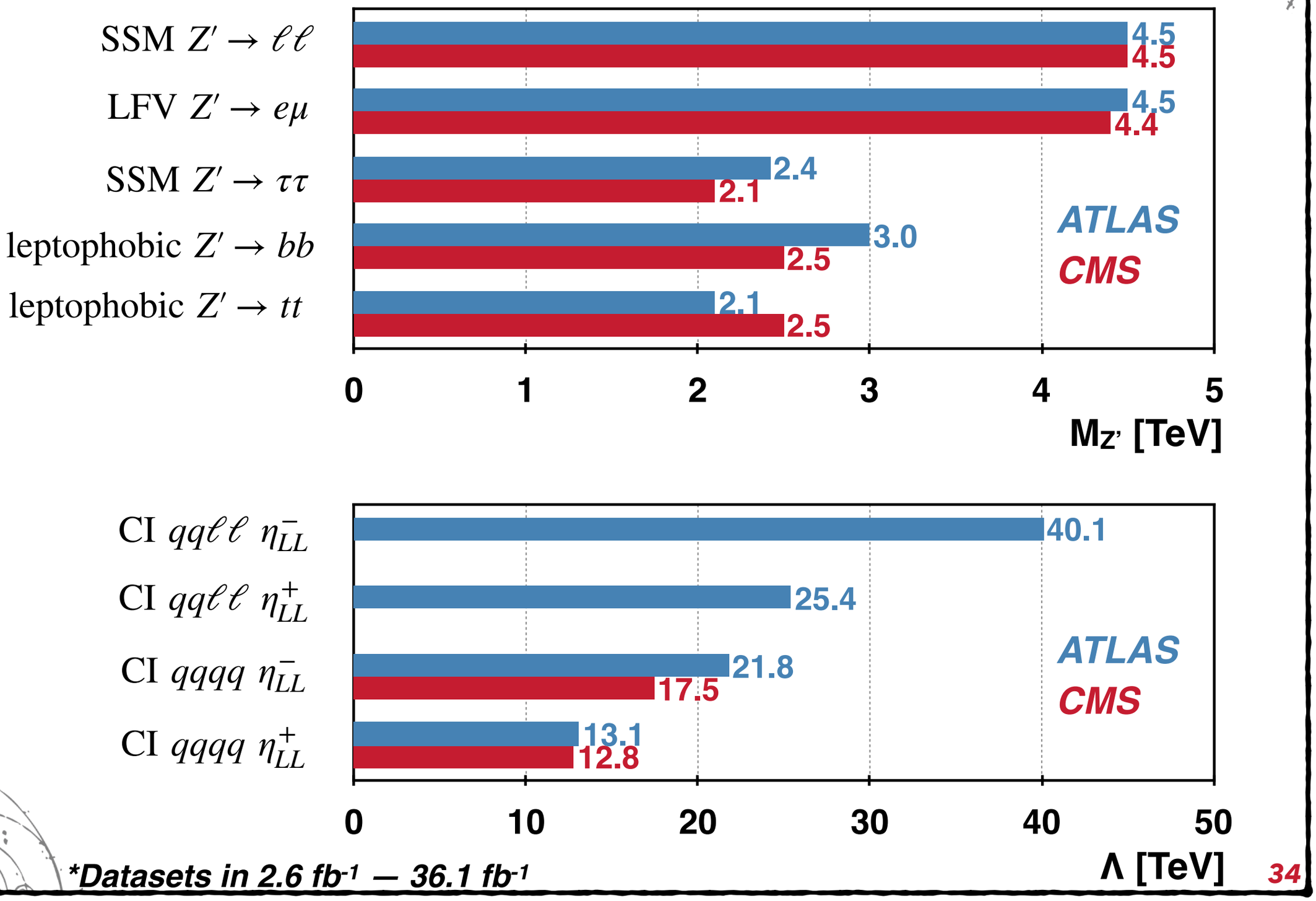
Third Family Hypercharge Model

- ***Realistic Z' model, Good prospects!***



- **Benjamin Allanach**
  "B-anomalies: The physics case for future colliders"

Summary: Run II benchmark observed limits*



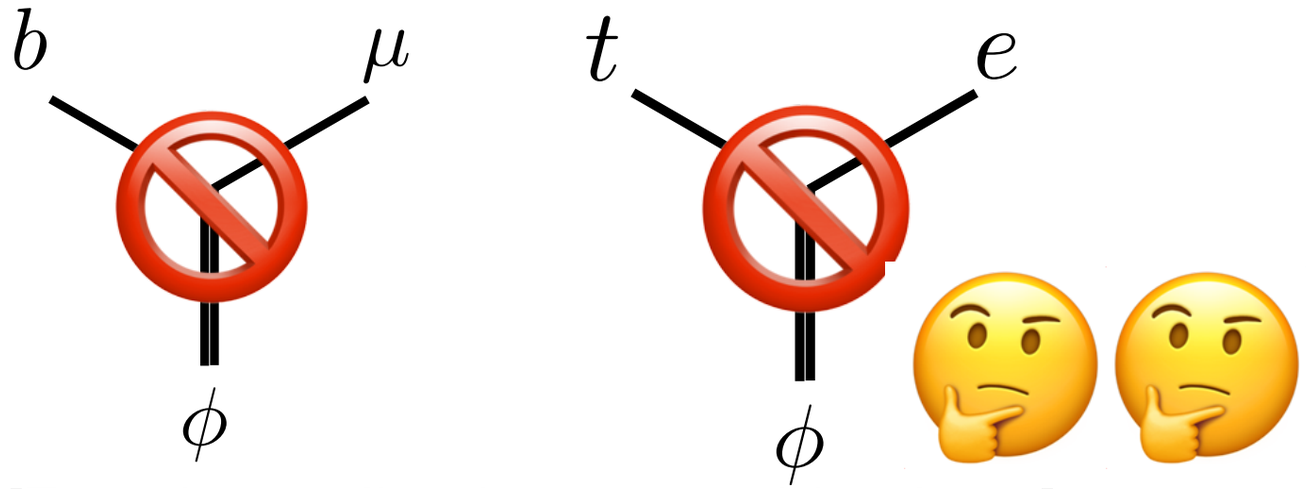
*Datasets in 2.6 fb^{-1} — 36.1 fb^{-1}

34

- **Etienne Dreyer**
  "Z' & Contact interactions searches at the LHC: Experiment overview"

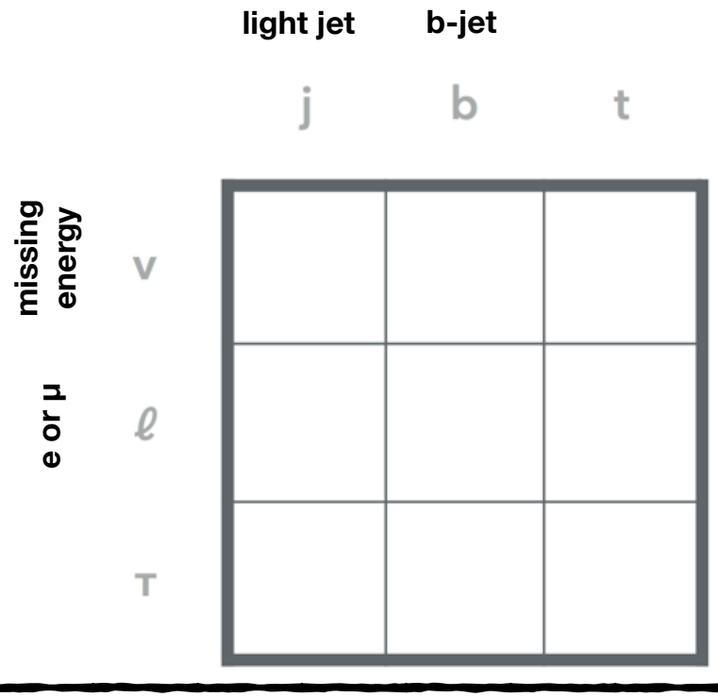
The leptoquark hunter's guide

A complaint to experimentalists from theorists

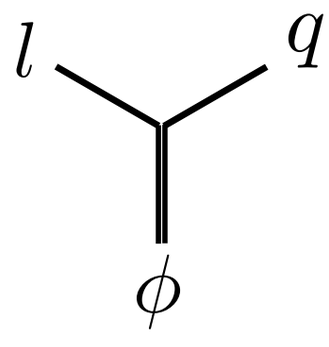


[Experimentalist do not consider these]

The leptoquark matrix



108 MLQ's



- *To cover general LQ parameter space, his proposal is to look for all LQ decay modes shown in the LQ matrix!*

- **Yi-Ming Zhong**
  "The leptoquark Hunter's guide: Pair production"

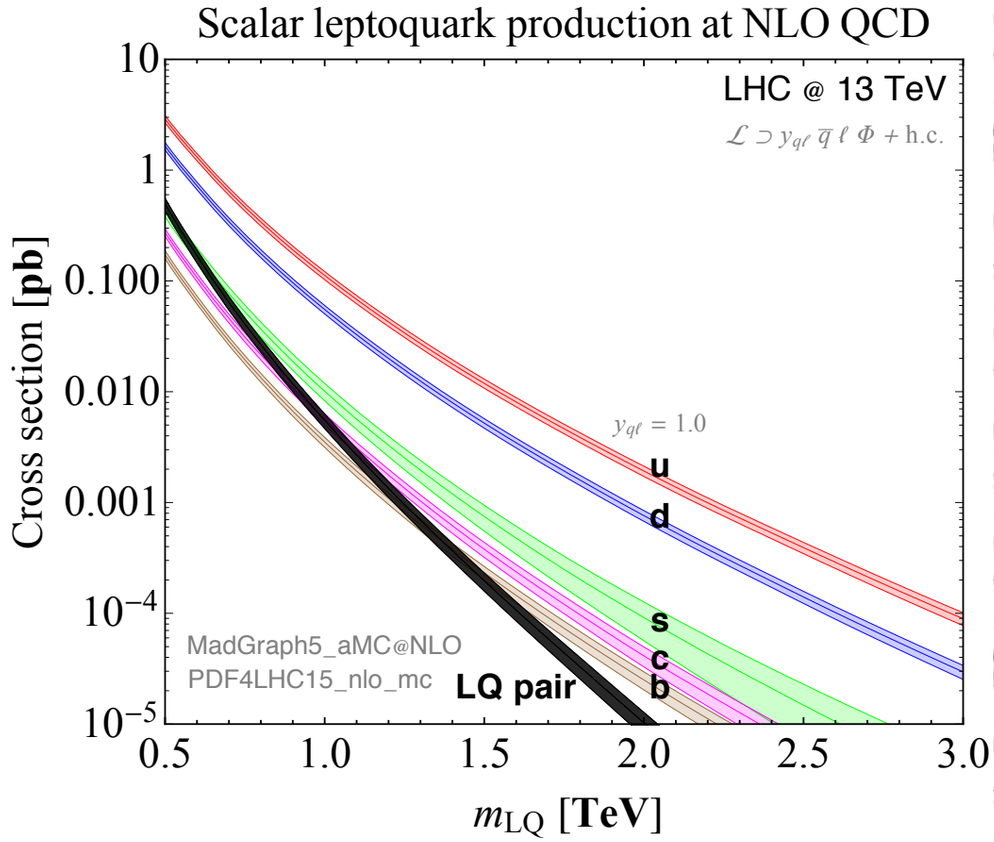
LEPTOQUARK TOOLBOX

An up-to-date Monte Carlo toolbox for precision collider studies

NLO QCD

- *LQ pair production*
- *Single LQ + lepton production*

PHYSICS RESULTS



LQ_NLO TOOLBOX @ HepForge

https://lqnlo.hepforge.org

- Home
- Downloads
- Contact

LQ_NLO

LQ_NLO is a leptoquark toolbox for precision collider studies. It contains Universal FeynRules Output (UFO) model file directories for all scalar leptoquarks and one vector leptoquark to be used with MADGRAPH5_AMC@NLO. It also contains original FeynRules model files to allow for reusability and customisation. The main features of these UFO models and associated physics results are summarised in **arXiv:1801.07641**.

Please acknowledge **arXiv:1801.07641** if you use the LQ_NLO material.

- **Ilja Doršner**

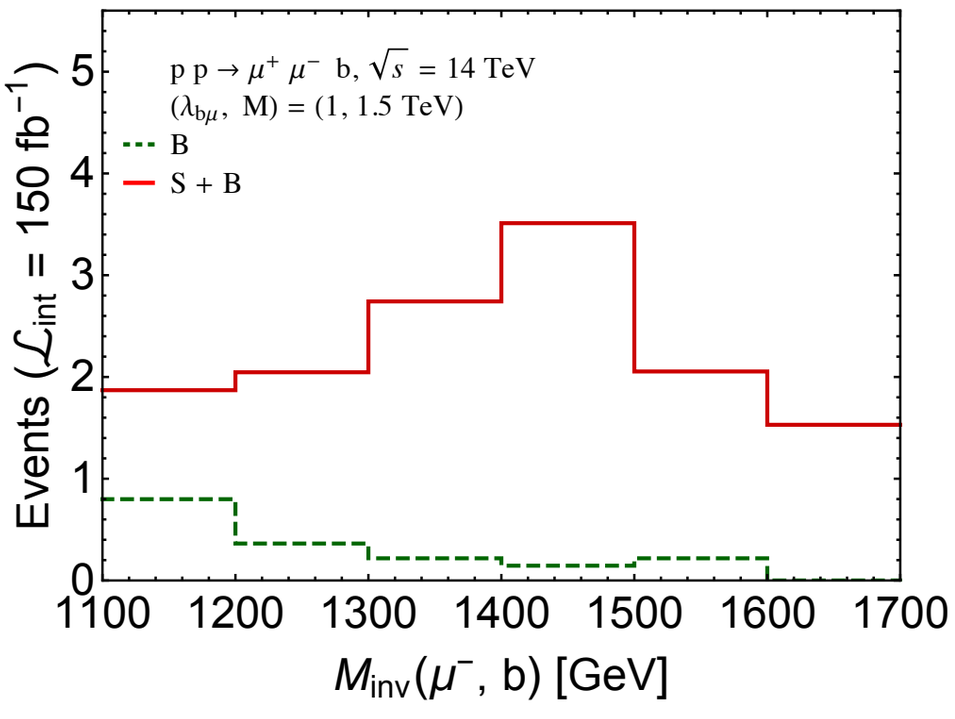
 "Leptoquark toolbox for precision collider studies"

- ***Flavour model to explain the SM Yukawas***
- ***Focus on the S_3 LQ solution to $b > s\,\mu\mu$***
  - Looking at scalars:

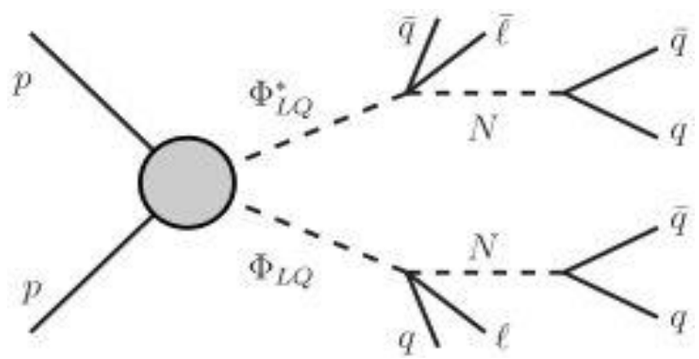
	representation	C_{AB}	Relation	$R_{K^{(*)}}$
$\tilde{S}_2$	$(3,2,1/6)$	C_{RL}	$C_9' = -C_{10}'$	$R_K < 1,\ R_{K^*} > 1$
S_3	$(\bar{3},3,1/3)$	$C_{LL}^{\rm NP}$	$C_9 = -C_{10}$	$R_K \simeq R_{K^*} < 1$
S_2	$(3,2,7/6)$	C_{LR}	$C_9 = C_{10}$	$R_K \simeq R_{K^*} \simeq 1$
$\tilde{S}_1$	$(\bar{3},1,4/3)$	C_{RR}	$C_9' = C_{10}'$	$R_K \simeq R_{K^*} \simeq 1$

- ***Single LQ + muon production at the LHC is important!***

$$pp \to \phi\mu \to b\mu\mu$$

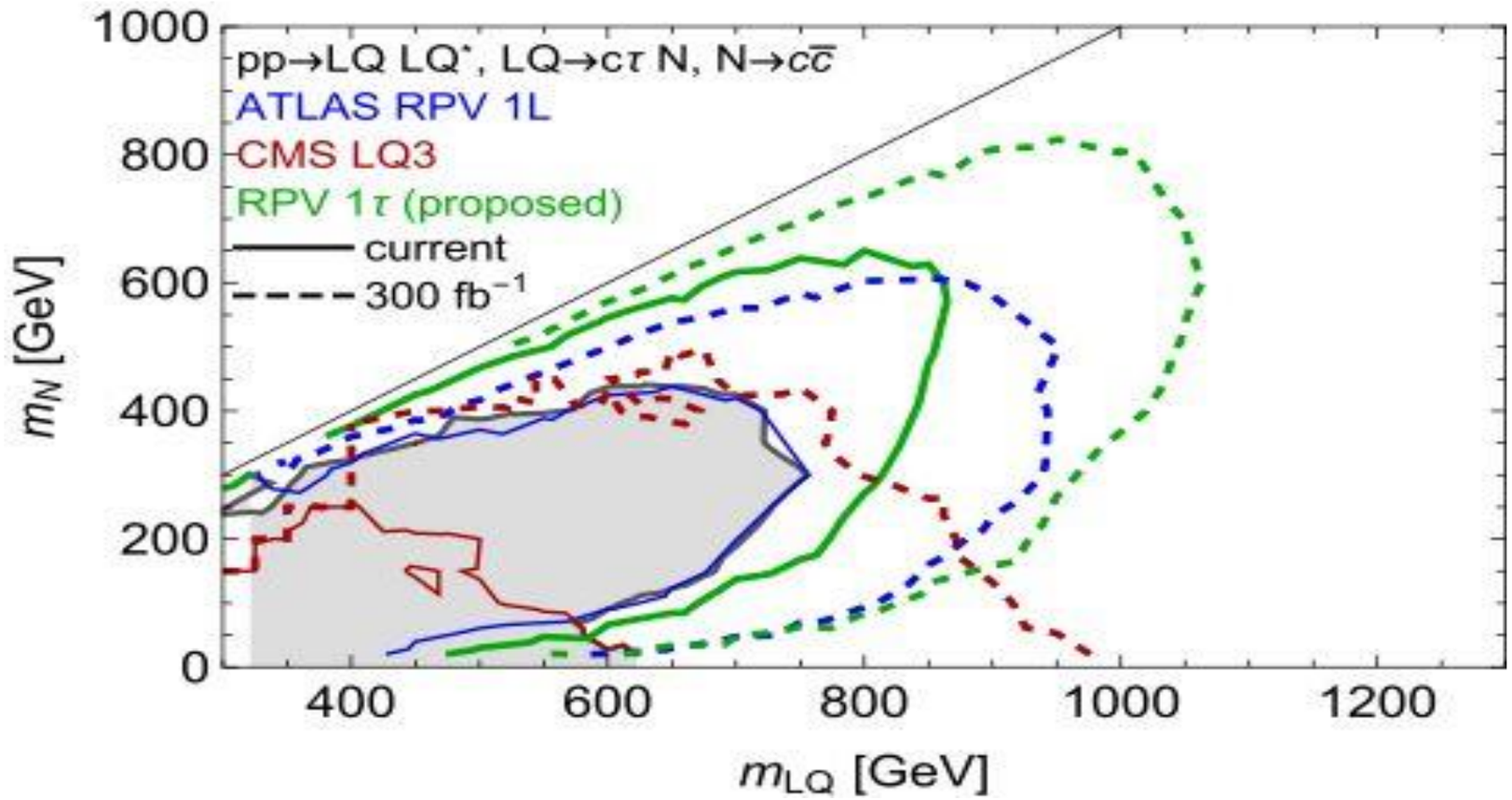


- **Ivan Nišandžić**
  "Flavorful leptoquarks at hadron colliders"



[in some composite LQ models]

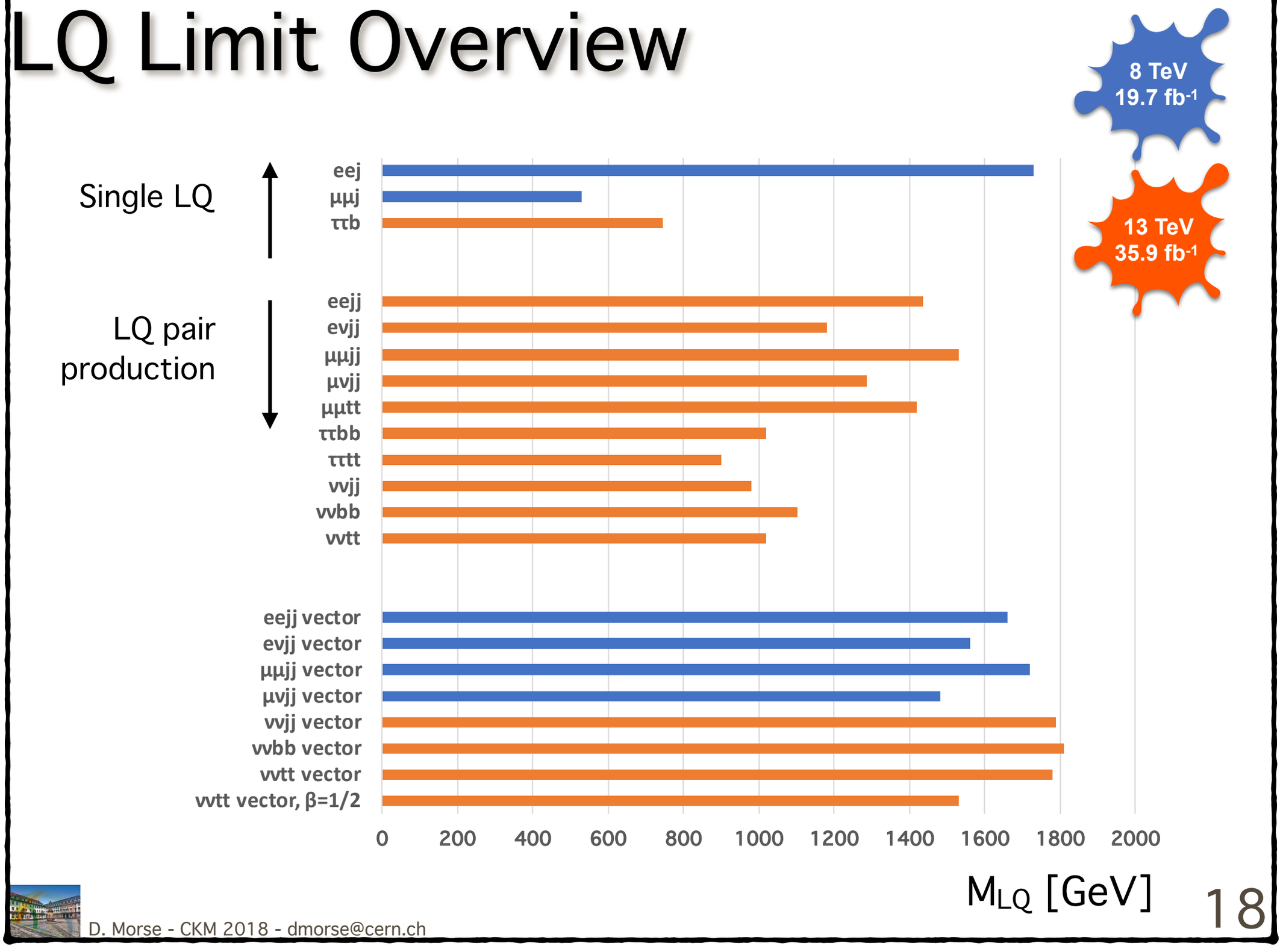
Exotic LQ decays to 3 jets + 1 lepton



- *Novel RPV-like signatures, Good prospects!*

- **Arvind Rajaraman**
  "LQ at the LHC: Beyond the Lepton-Quark Final State"

LQ Limit Overview



- **David Michael Morse**
  "Leptoquark searches at the LHC: Experiment overview"