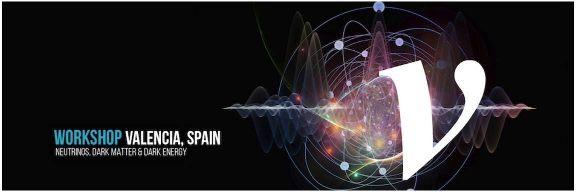

# Light-Quark Dipole Operators at LHC

**Nuno Rosa**

Based on **arXiv:1905.05187**
In collaboration with E. Almeida, O. Eboli and M.C. Gonzalez-Garcia

UNIVERSITAT DE BARCELONA

elusives
neutrinos, dark matter & dark energy physics

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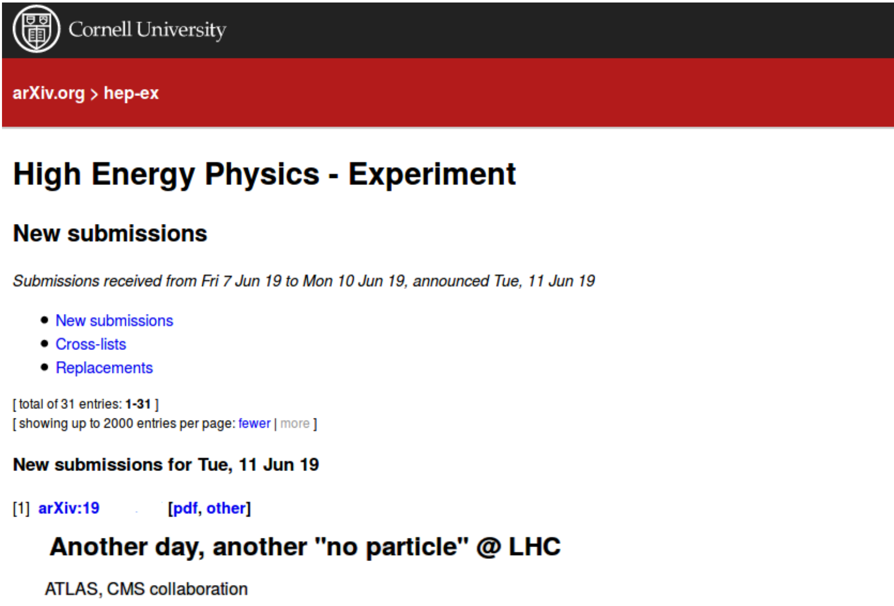

Cornell University

arXiv.org > hep-ex

# High Energy Physics - Experiment

## New submissions

*Submissions received from Fri 7 Jun 19 to Mon 10 Jun 19, announced Tue, 11 Jun 19*

- New submissions
- Cross-lists
- Replacements

[ total of 31 entries: **1-31** ]
[ showing up to 2000 entries per page: fewer | more ]

### New submissions for Tue, 11 Jun 19

[1] **arXiv:19** **[pdf, other]**

**Another day, another "no particle" @ LHC**

ATLAS, CMS collaboration

We continue to not find new particles at the LHC. Should we start to hate the Standard Model?

# Where are we standing?

- The search for direct NP did not show any new state.
- Probably they are heavy and there might exist a gap between them and the SM states.

**The remarkable success of the SM and the lack of unexpected particles motivates to use a different approach to study NP.**

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Two different conceptual routes to aproach the NP problem:

Build a Model
**Make true predictions!!!!**

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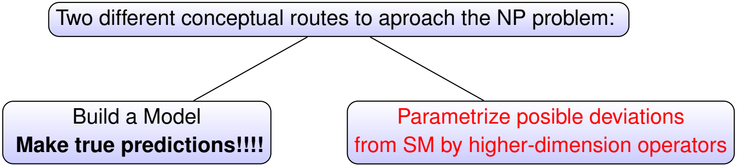

Two different conceptual routes to aproach the NP problem:

Build a Model
**Make true predictions!!!!**

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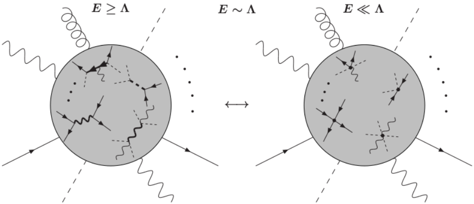
# Effective Lagrangian: Linear realization

- We parametrize new physics in terms of a linear effective Lagrangian, with a light Higgs:

$$\mathcal{L}_{\rm eff} = \mathcal{L}_{\rm SM} + \sum_{n>4,j} \frac{f_{n,j}}{\Lambda^{n-4}} \mathcal{O}_{n,j}$$



**Particle content:** Same as the SM. No undiscovered particle at low energy.
**Symmetries:** The SM gauge symmetry $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$ is linearly realized. The lepton and baryon numbers are conserved.

- There exist **59 Dimension-6 operators**.

[Grzadkowski et al. arXiv: 1008.4884]

# of relevant operators can be reduced by several considerations

Data-driven:
**TGC, EWPD, Higgs**

**Operator basis HISZ**
(EOM to eliminate redudant ones)

NP conserves
**C and P symmetries**

# Light-Quark Dipole Operator @ LHC

- Study the operators which include dipole-like couplings for the quarks.

$$\mathcal{O}_{uW,ij} = i\bar{Q}_i\sigma^{\mu\nu}u_{R,j}\hat{W}_{\mu\nu}\tilde{\Phi}\ , \qquad \mathcal{O}_{uB,ij} = i\bar{Q}_i\sigma^{\mu\nu}u_{R,j}\hat{B}_{\mu\nu}\tilde{\Phi}\ ,$$

$$\mathcal{O}_{dW,ij} = i\bar{Q}_i\sigma^{\mu\nu}d_{R,j}\hat{W}_{\mu\nu}\Phi\ , \qquad \mathcal{O}_{dB,ij} = i\bar{Q}_i\sigma^{\mu\nu}d_{R,j}\hat{B}_{\mu\nu}\Phi$$

$$\boxed{\mathcal{L} = -\frac{ev}{\sqrt{2}\Lambda^2}\left[F_{f\gamma}\bar{f}\gamma^{\mu\nu}f\partial_\mu A_\nu + F_{fZ}\bar{f}\gamma^{\mu\nu}f\partial_\mu Z_\nu + \left(\bar{f}\sigma^{\mu\nu}\left(F^L_{ff'W}L + F^R_{ff'W}R\right)f'\partial_\mu W^+_\nu + h.c.\right)\right]}$$

$$\boxed{F_{u\gamma} = f_{uW} + f_{uB}\ ,\ F_{d\gamma} = f_{dW} - f_{dB}} \quad \Rightarrow \textbf{Anomalous magnetic moment}$$

$$\boxed{F^R_{udW} = \frac{1}{s_W}f_{uW}\ ,\ F^L_{udW} = \frac{1}{s_W}f_{dW}} \quad \Rightarrow \textbf{W boson width decay}$$

$$\boxed{F_{uZ} = \frac{c_W}{s_W}f_{uW} - \frac{s_W}{c_W}f_{uB}\ ,\ F_{dZ} = \frac{c_W}{s_W}f_{dW} - \frac{s_W}{c_W}f_{dB}} \quad \Rightarrow \textbf{Z boson width decay}$$

- Can be constrainted by the fit to the LEP observables.
- They also take part in electroweak diboson production $pp \to W^+W^-$ and $pp \to ZW^\pm$.

**Have these operators any impact on the TGV analysis?**

# TGV analysis

$$\mathcal{O}_{WWW} = \mathrm{Tr}[\widehat{W}_{\mu}^{\nu}\widehat{W}_{\nu}^{\rho}\widehat{W}_{\rho}^{\mu}]$$

$$\mathcal{O}_{W} = (D_\mu\Phi)^\dagger\widehat{W}^{\mu\nu}(D_\nu\Phi)$$

$$\mathcal{O}_{B} = (D_\mu\Phi)^\dagger\widehat{B}^{\mu\nu}(D_\nu\Phi)$$

**The tradicional operators of TGC couplings**

# TGV analysis

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**The ”omnipresent” operators.**

$$\mathcal{O}_{LLLL} = (\bar{L}\gamma^{\mu}L)(\bar{L}\gamma^{\mu}L)$$

**Gives a finite contribuition to the Fermi constant.**

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**The ”omnipresent” operators.**

$$\mathcal{O}_{LLLL} = (\overline{L}\gamma^\mu L)(\overline{L}\gamma^\mu L)$$

**Gives a finite contribuition to the Fermi constant.**

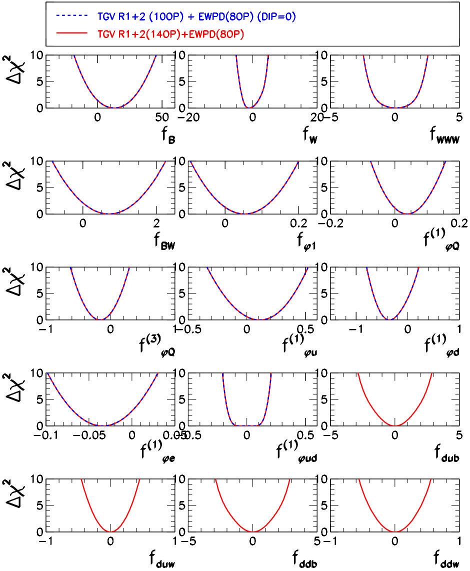
$$\mathcal{O}^{(1)}_{\Phi Q,ij} = \Phi^\dagger (i\overset{\leftrightarrow}{D}_\mu \Phi)(\overline{Q}_i \gamma^\mu Q_j) \quad , \quad \mathcal{O}^{(3)}_{\Phi Q,ij} = \Phi^\dagger (i\overset{\leftrightarrow}{D}{}^a_\mu \Phi)(\overline{Q}_i \gamma^\mu T_a Q_j)$$

$$\mathcal{O}^{(1)}_{\Phi u,ij} = \Phi^\dagger (i\overset{\leftrightarrow}{D}_\mu \Phi)(\overline{u}_{R_i} \gamma^\mu u_{R_j}) \quad , \quad \mathcal{O}^{(1)}_{\Phi d,ij} = \Phi^\dagger (i\overset{\leftrightarrow}{D}_\mu \Phi)(\overline{d}_{R_i} \gamma^\mu d_{R_j})$$

$$\mathcal{O}^{(1)}_{\Phi e,ij} = \Phi^\dagger (i\overset{\leftrightarrow}{D}_\mu \Phi)(\overline{e}_{R_i} \gamma^\mu e_{R_j}) \quad , \quad \mathcal{O}^{(1)}_{\Phi ud} = \tilde{\Phi}^\dagger (i\overset{\leftrightarrow}{D}_\mu \Phi)(\overline{u}_R \gamma^\mu d_R + \mathrm{h.c.})$$

**The fermionic operators**

# Impact of the dipole operators on the TGV



- The impact of the dipoles is **minimum**.

- Neverthless the TGV can impose **strong bounds** on the dipole operators! How strong????

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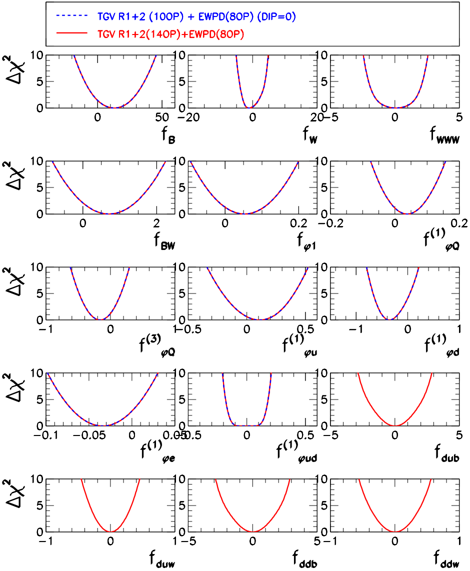

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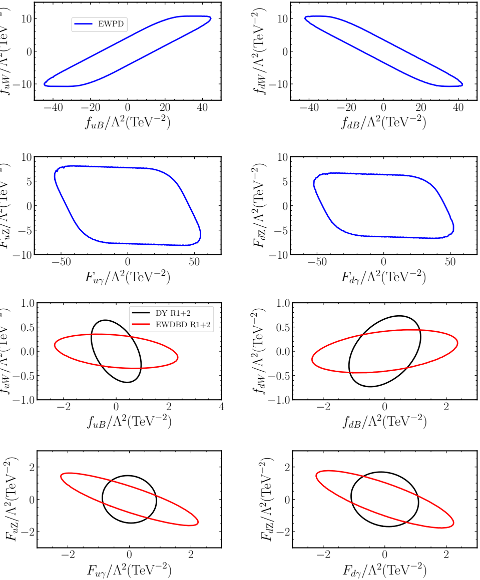
**How these bounds are comparable with other data set?**

# LHC vs EWPD



- The bounds from EWPD are **weaker** than those from LHC EWDBD.
- The contributions from dipole operators to EWDBD **grow as *s***.
- DY results totally resolve the light-quark dipole couplings.

$\Downarrow$

**stronger constrains**

# Summary

- Constraints derived on all the Wilson coefficients of those non-dipole operators **is robust under the inclusion of the light-quark dipole operators**.
- Analyses of **LHC data improves over EWPD**.
- The improvements driven both by the growth of the dipole contribution with energy.
- LHC also ”sees” $\boldsymbol{Z}$ and $\gamma$ couplings with similar weight.

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**LHC as a precision machine!!!**

We should never forget that energy can provide a new discovery...

# Thank you very much!!!