UNIVERSITÀ DEGLI STUDI DI PERUGIA

Summary of Second Year Activity

By: Sehar Ajmal
Doctoral Student Cycle XXXVI

Thesis Topic:

New Physics in Direct and Indirect Searches at the LHC and Future Colliders.

Tutors:

- Dr. Orlando Panella (U. and INFN Perugia)
- Dr. Matteo Presilla (U. and INFN Perugia)

Contents

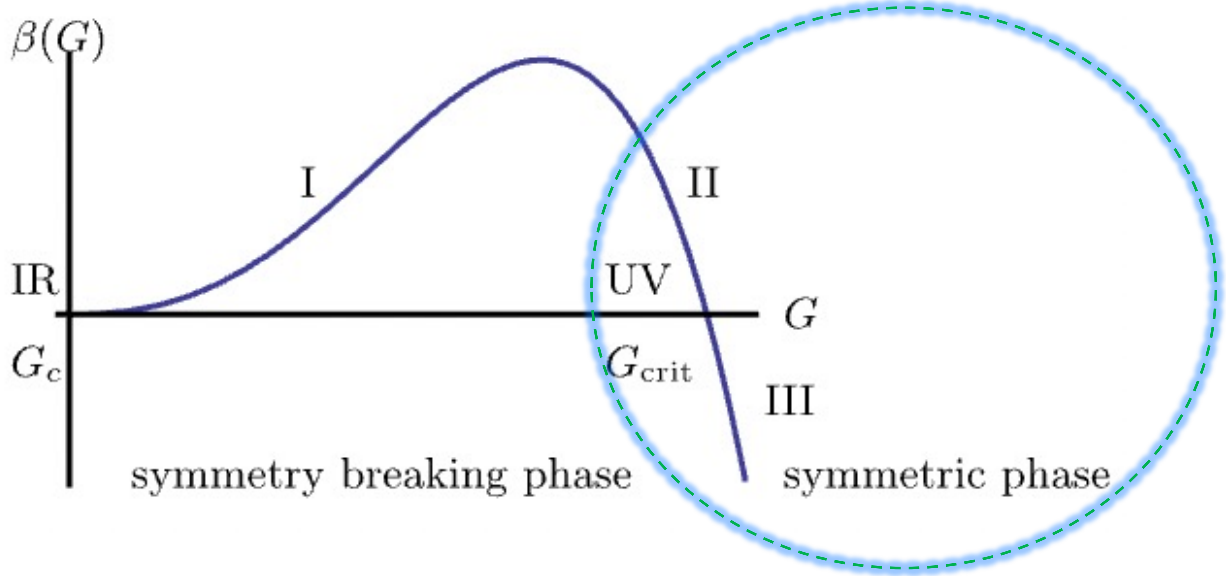
Research Activities

1. **Composite Model Phenomenology at LHC**
   - Extension of the work "**Phenomenology at the LHC of composite particles from strongly interacting Standard Model fermions via four-fermion operators of NJL type**" [*Eur. Phys. J. C* 80, 309 (2020).]
   - In Collaboration with
     - **S. S. XUE** (ICRANet, Sapienza University Rome)
     - **O. Panella, R. Leonardi & M. Presilla** (INFN sezione di Perugia)
     - **F. Romeo, J. T. Gaglione & A. Gurrola** (Department of Physics and Astronomy, Vanderbilt University, Nashville, USA)
     - **H. Sun** (Institute of Theoretical Physics, School of Physics, Dalian University of Technology, People's Republic of China)

2. **Study of the Impact of Unitarity Bounds on VBS Ssww at LHC**
   - In Collaboration with
     - **C. Carrivale**, **O. Panella, & M. Presilla** (U. & INFN sezione di Perugia)

Composite Model

Nambu-Jona-Lasinio (NJL) Four Fermion Interactions



- The Effective Four Fermion operators

$$\sum_{f=1,2,3} G[\overline{\psi_L}^f \psi_R{}^f \, \overline{\psi_R}^f \psi_L{}^f]_{Q_i=0,-1,\frac{2}{3},-\frac{1}{3}}. \quad where \quad G \propto \Lambda^{-2}$$

- By Analyzing the behavior of the β-function in terms of the four-fermion coupling G (in figure)
- IR-domain of weak-coupling four-fermion operators in the SSB phase where the low-energy SM is realized.
- We find a scaling region (UV-domain) of the ultraviolet (UV) stable fixed point of strong-coupling four-fermion operators in the gauge-symmetric phase.
- In this UV domain at high energies, it realizes an effective theory of composite bosons and fermions composed by SM elementary fermions, also preserves SM symmetries.

Model Building (Composite Bosons)

- There are 3 type of composite bosons, their CI Lagrangians are given.
- Table Below Contains the list of Composite Bosons and their respective Quantum numbers.
- Composite bosons are gauge invariant under the Electroweak part of SM. So, gauge interactions are calculated for the gauge group $SU(2)_L \times U(1)_Y$
- Gauge Interaction Lagrangian for Composite Bosons

$$\mathcal{L}_{\rm CI}^{\Pi^\pm} = g_{\rm Y}(\bar{d}^a_R u_{La})\Pi^- + {\rm h.c.},$$
$$\mathcal{L}_{\rm CI}^{\Pi^0_{\rm d}} = g_{\rm Y}(\bar{d}^a_R d_{La})\Pi^0_d + {\rm h.c.},$$
$$\mathcal{L}_{\rm CI}^{\Pi^0_{\rm u}} = g_{\rm Y}(\bar{u}^a_R u_{La})\Pi^0_u + {\rm h.c.},$$

where $g_{\rm Y} = (F_\Pi/\Lambda)^2$.

Composite bosons Π	constituents	charge $Q_i = Y + t^i_{3L}$	$SU_L(2)$ 3-isospin t^i_{3L}	$U_Y(1)$-hypercharge Y
Π^+	$(\bar{d}^a_R u_{La})$	$+1$	$1/2$	$1/2$
Π^-	$(\bar{u}^a_R d_{La})$	-1	$-1/2$	$-1/2$
Π^0_u	$(\bar{u}^a_R u_{La})$	0	$1/2$	$-1/2$
Π^0_d	$(\bar{d}^a_R d_{La})$	0	$-1/2$	$1/2$

Contact Interaction of Composite Boson and Gauge Bosons

❖ In UV domain Composite bosons can decay into gauge bosons via contact interaction

$$\mathcal{L} = \frac{gg' N_c}{4\pi^2 F_\Pi} \epsilon_{\mu\nu\rho\sigma} \frac{1}{4} (F^{\rho\mu})(F'^{\sigma\nu})\Pi$$

❖ This Effective contact interaction is an axial anomaly vertex, as a result of a triangular quark loop and standard renormalization procedure in SM.

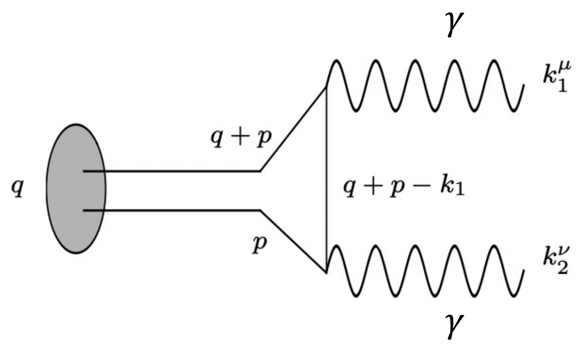
❖ Possible Decay channels

$$\Pi^0_{u,d} \to \gamma\gamma, \gamma Z^0, Z^0 Z^0, W^+ W^-$$

$$\Pi^\pm \to \gamma W^\pm, Z^0 W^\pm$$

❖ E.G for $\Pi^0_u \to \gamma\gamma$

$$\Gamma = \left(\frac{4}{9}\right)^2 \left(\frac{\alpha N_c}{\pi F_\Pi}\right)^2 \frac{M^3_\Pi}{64\pi}$$



Parameters

- g, g' is the standard coupling of SM particles with gauge bosons
- $N_c = 3$ color factor
- F_Π is the decay constant of composite bosons
- M_Π is the mass of composite bosons

Model Building (Leptoquarks)

- Leptoquarks (LQs) are hypothetical beyond the Standard Model (BSM) particles that feature tree level quark-lepton couplings.
- There are four type of Leptoquarks, their CI Lagrangians are given.
- Table Below Contains the list of Composite Bosons LQ and their respective Quantum numbers.
- Leptoquarks obeys the symmetries of SM. Gauge interactions for the SM group $SU(3)_c \times SU(2)_L \times U(1)_Y$ are calculated.
- Gauge Interaction Lagrangian for LQ

$$\mathcal{L}_{\rm CI}^{\Pi_{\rm a}^{-5/3}} = g_{\rm Y}(\bar{e}_R u_{La})\Pi_a^{-5/3} + \text{h.c.},$$
$$\mathcal{L}_{\rm CI}^{\Pi_{\rm a}^{1/3}} = g_{\rm Y}(\bar{\nu}_R^e d_{La})\Pi_a^{1/3} + \text{h.c.},$$
$$\mathcal{L}_{\rm CI}^{\Pi_{\rm ua}^{-2/3}} = g_{\rm Y}(\bar{\nu}_R^e u_{La})\Pi_{ua}^{-2/3} + \text{h.c.},$$
$$\mathcal{L}_{\rm CI}^{\Pi_{\rm da}^{-2/3}} = g_{\rm Y}(\bar{e}_R d_{La})\Pi_{d_a}^{-2/3} + \text{h.c.},$$

LQ Composite bosons Π_a^Q	constituents	charge $Q_i = Y + t_{3L}^i$	$SU_L(2)$ 3-isospin t_{3L}^i	$U_Y(1)$-hypercharge Y
$\Pi_a^{+5/3}$	$(\bar{e}_R u_{La})$	$+5/3$	$1/2$	$7/6$
$\Pi_a^{-1/3}$	$(\bar{\nu}_R^e d_{La})$	$-1/3$	$-1/2$	$1/6$
$\Pi_{u_a}^{2/3}$	$(\bar{\nu}_R^e u_{La})$	$2/3$	$1/2$	$1/6$
$\Pi_{d_a}^{2/3}$	$(\bar{e}_R d_{La})$	$2/3$	$-1/2$	$7/6$

Implementation in Feynrules

- FeynRules is Mathematica Package[Ref]
- Composite Fermions Interactions were implemented before.
- Extended the Implementation to
  - Composite Boson
  - Leptoquarks
- Contact Interactions and Gauge interactions are implemented for both. Next to leading order Interactions are there for Composite bosons
- 5 Flavour scheme is implemented.
- Universal Feynrules output (UFO) for the use Monte Carlo generator: MadGraph

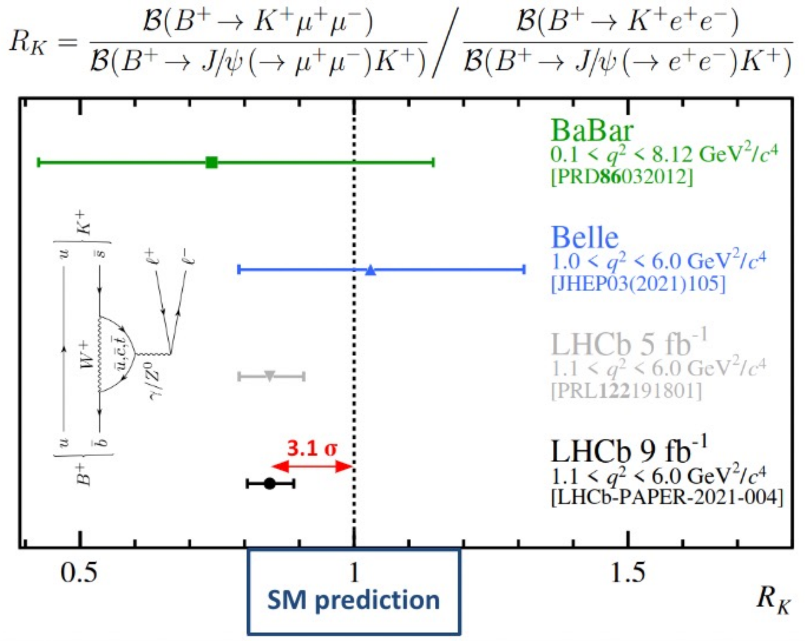
```
Lcf := Lstarkin + HC[Llepqua + Llepqua1 + Llepqua2 + Llepqua3] + Llepqua + Llepqua1 + Llepqua2 + Llepqua3;
CheckHermiticity[Lcf, FlavorExpand → True];
vertices = FeynmanRules[Lcf];
FeynmanGauge = False;
GetKineticTerms[Lstarkin]
GetMassTerms[Lstarkin]
GetInteractionTerms[Lstarkin]
GetInteractionTerms[Llepqua + Llepqua1 + Llepqua2 + Llepqua3]
WriteUFO[LGauge, LFermions, LHiggs, LYukawa, LGhost, Lcf, FlavorExpand → True];
```

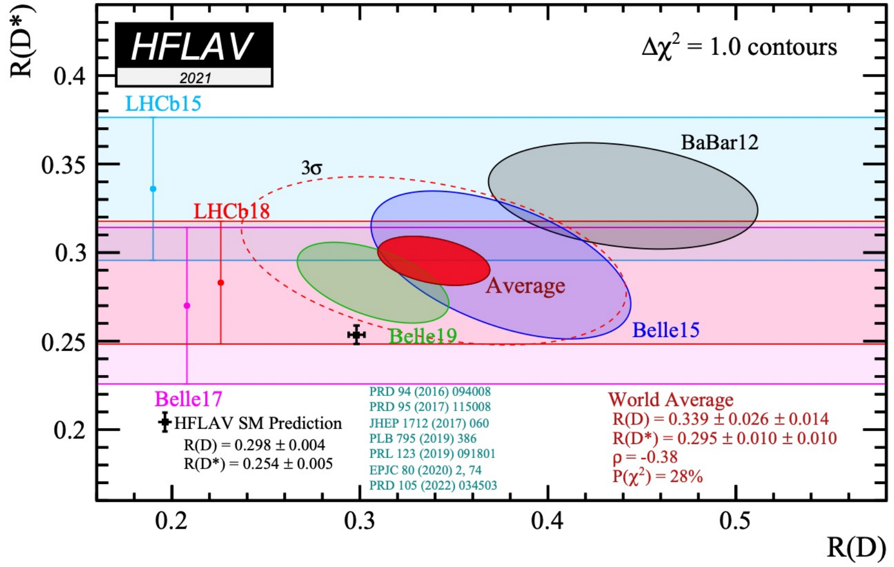
Data_Cards_LQ_Prodcution	coupling_update	last month
FR_NJL_3.2	version3.2	6 months ago
FR_NJL_3.3	update_of_July	3 months ago
FR_NJL_3.3LQ	update_september2022	last month
HN_FeynRules_model	update	9 months ago
NJL-Model_version_3.1	update_feb2022	8 months ago
Old version of model	updates	4 months ago
.DS_Store	..	4 months ago
README.md	september_update	last month

https://github.com/mpresill/compositeNJL

Planning to upload the model on Feynrules website for public use.

Phenomenology of the Leptoquarks





Theoretical/Experimental Motivation

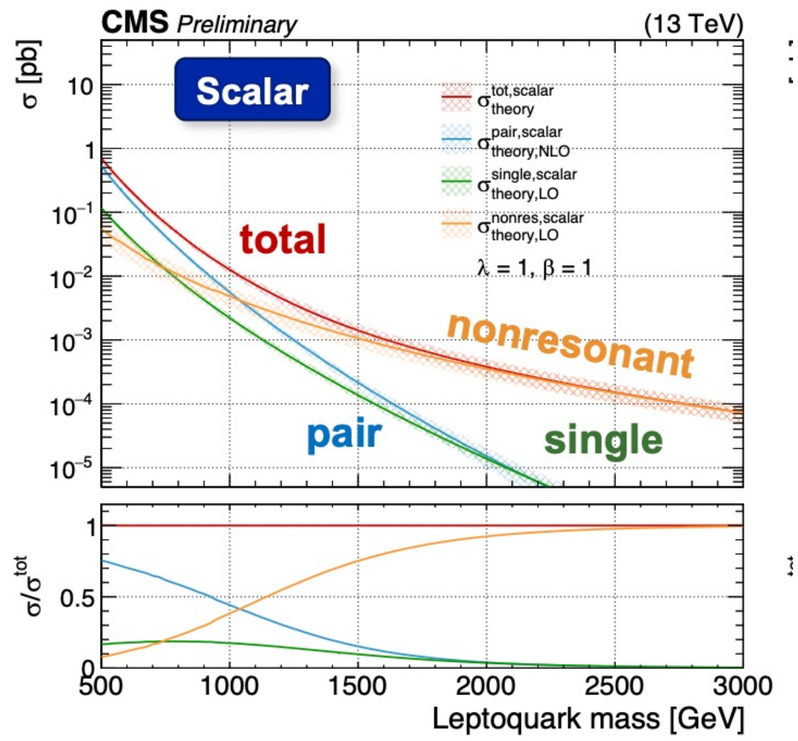
- UV completion of the theory
- At low energy anomalies e.g., in B meson decays.
- Measurements of the decay rates reported by the BaBar Belle , and LHCb Collaborations collectively deviate from the SM predictions by about four standard deviations [Ref].

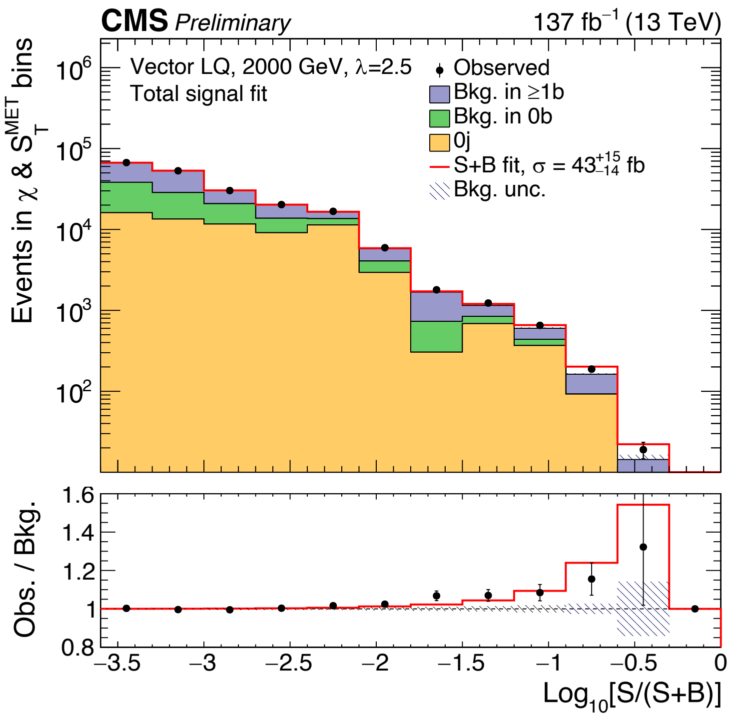
$$R_{K^{(*)}} = \frac{\Gamma\left(B \to K^{(*)}\mu\mu\right)}{\Gamma\left(B \to K^{(*)}ee\right)} \overset{\text{SM}}{<1} \qquad R_{D^{(*)}} = \frac{\Gamma\left(B \to D^{(*)}\tau\bar{\nu}\right)}{\Gamma\left(B \to D^{(*)}\ell\bar{\nu}\right)} \overset{\text{SM}}{>} 0.25$$

Anomalies involve leptons and quarks. ⟹ Favored BSM: Leptoquark models

Leptoquarks at High Energies

- ATLAS and CMS collaborations also explore Lepton flavor universality violation at the LHC.
- Recently, CMS observed excess with a significance of 3.4 standard deviations above the standard model expectation in the data in the Search for a third-generation leptoquark coupling to a τ lepton and a b quark
CMS-PAS-EXO-19-016





CMS-PAS-EXO-19-016

Phenomenology of the Leptoquarks

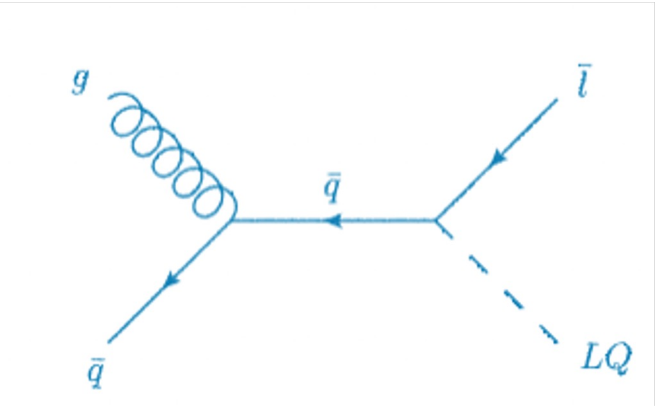
- There are 2 categories of channels which are considered in this work.

- First one, proton proton (pp) collider.
- Second, photon Proton (γp) collider, we can choose these options in the tool.

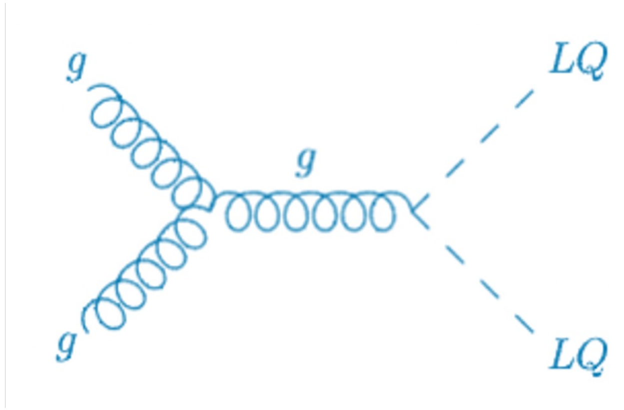
- MadGraph5_aMC@NLO is used for the phenomenological studies.

- Partonic Distribution Functions (PDF) are being chosen according to the requirement of initial state.

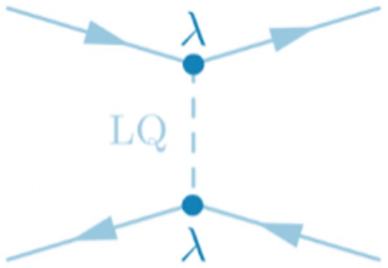
- Parameter space → $(F_{\Pi}, \Lambda, M_{\pi})$



Single LQ Production



Pair Production



Non-Resonant Production

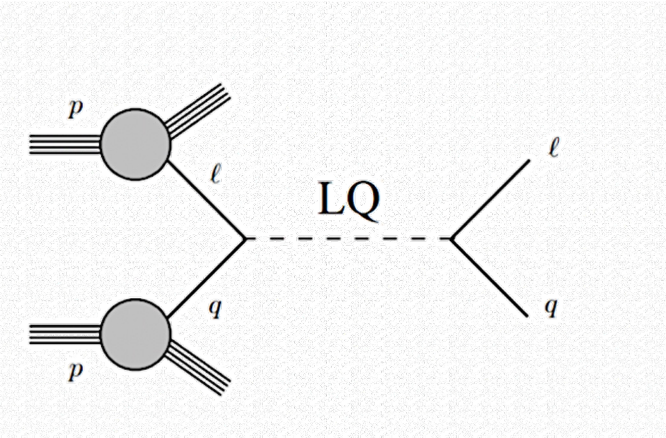
Phenomenology of the Leptoquarks

- There is version of LUXQED NNPDF which contains leptons in the proton name as: NNPDF (LUXlep-NNPDF31_nlo_as_0118_luxqed)

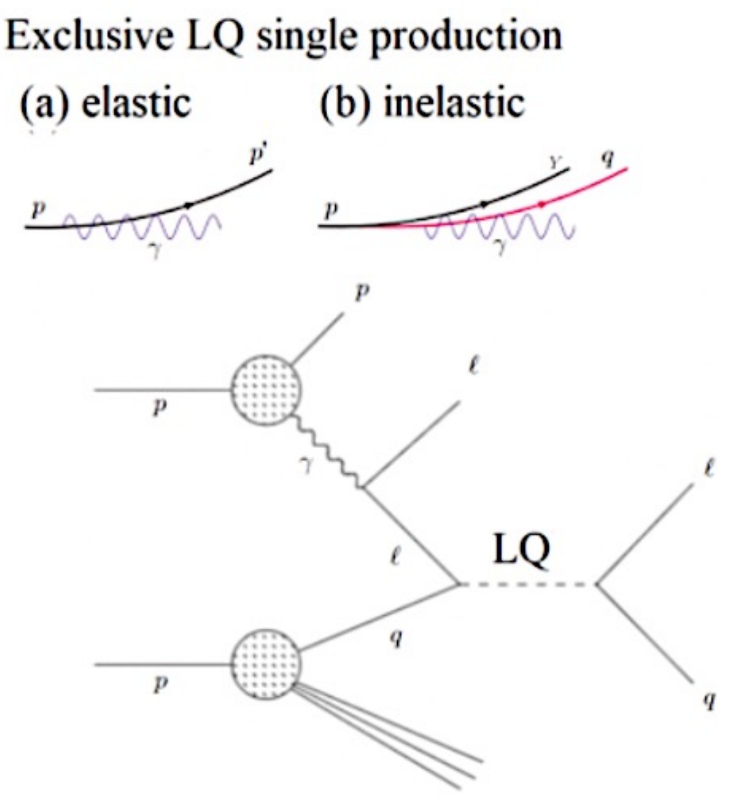
- Idea is based on the fact that leptons are coming from photon i.e., radiated by proton, can be possible in two ways Elastic and InElastic.

- Ideally, two diagrams mentioned here should be equivalent.

- So, there are two Processes
  1. $p\,p > \ell\ q$, with luxlep PDF
  2. $\gamma\ p > \ell\ell q$, with luxqed PDF



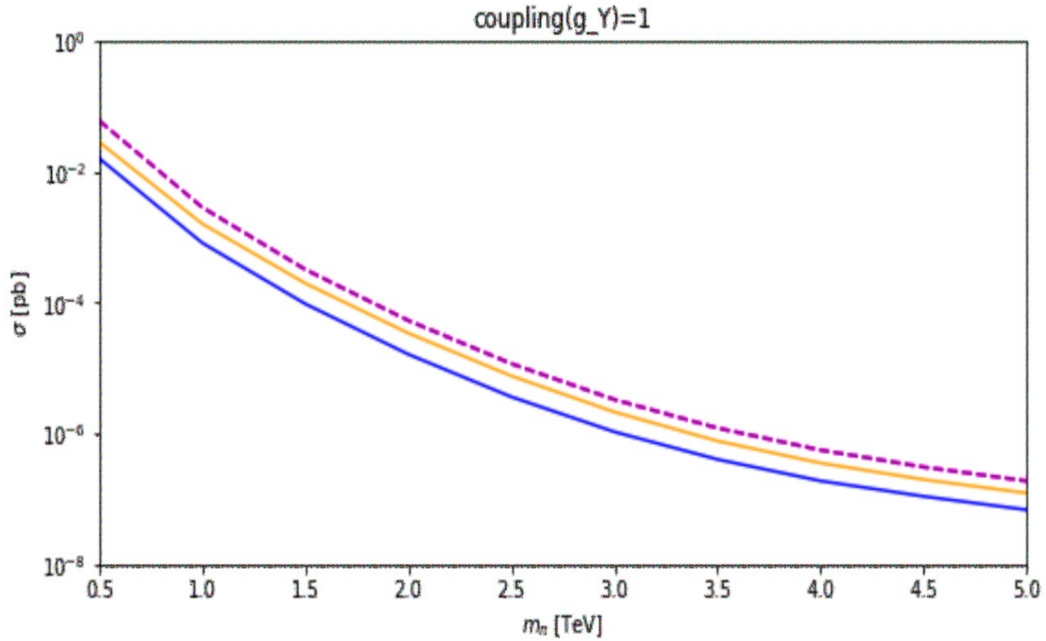
Single Production
Leptons coming from Proton
Leptons in the Proton



Phenomenology of the Leptoquarks

- We tried to separate elastic and inelastic part for the process with photons in initial state and add them to compare with one with leptons in initial state (expecting equal contribution).
- Got higher contribution for leptonic one.
- Later we noticed that LUXPDF is not good choice to separate elastic and inelastic part because it already contains both contributions (Madgraph team also confirms this)
- Chose different partonic distribution function i.e., MRST2004qed_proton with ID 20463
- Redone the comparison as the selected PDF only contains inelastic contribution and with Madgraph it is possible to set collider beams in such a way that we can get separate contribution.

Implementation in Madgraph



- ----- $p\,p > \tau^+ b$ with leptonic PDF
- —— $\gamma\,p > \tau^+\tau^- b$ (elastic+inelastic) process with MRST2004qed_proton pdf
- —— $\gamma\,p > \tau^+\tau^- b$ but with LUX pdf

Coupling g_Y=1 and mass range is 0-5 TeV

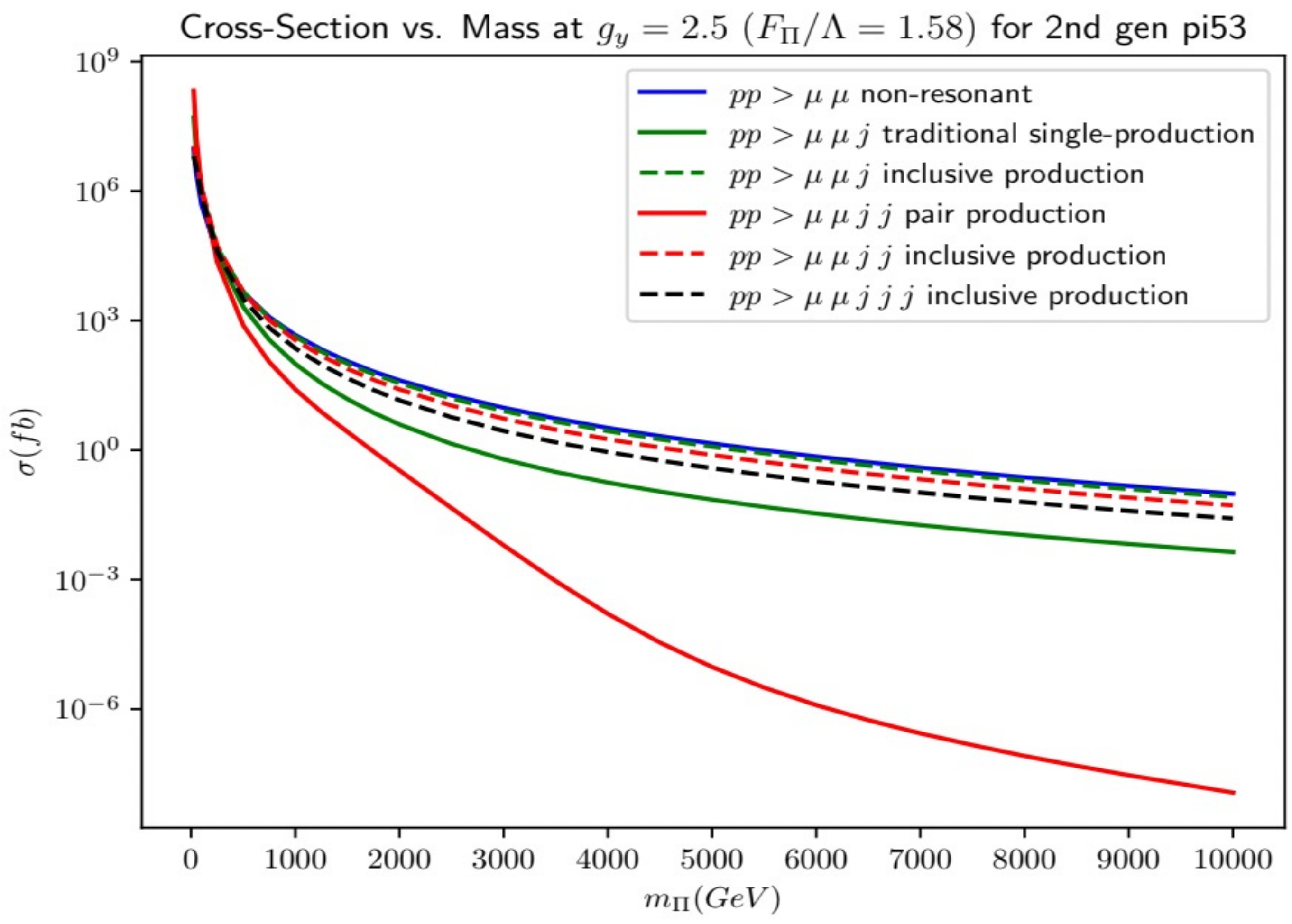
Phenomenology of the Leptoquarks

- For Monte Carlo Signal Production
  - $p\,p > e^+e^-(0-3\ jets)$
  - $p\,p > \mu^+\mu^-(0-3\ jets)$
  - $p\,p > \tau^+\tau^-(0-3\ jets)$
  - $\gamma\,p > e^+e^-(1-3\ jets)$
  - $\gamma\,p > \mu^+\mu^-(1-3\ jets)$
  - $\gamma\,p > \tau^+\tau^-(1-3\ jets)$

- Preliminary xsec studies shows:

Xsec $(p\,p > \mu^+\mu^-(0-3\ jets)$ is higher than traditional LQ searches (green and red solid line)

CROSS-SECTION STUDIES, $g_y = 2.5$



Phenomenology of the Leptoquarks

Main idea is to understand realistic statistical significance at LHC Run3 13.6 TeV as well as for future colliders HL-LHC.

Samples Production

- Backgrounds are selected: Single and pair top production, Wj, Zj, VV and Drell-Yan.
- Parameter choice
  - 25, 50, 100, 250 GeV
  - 250 to 2000 GeV in steps of 250 GeV
  - 2000 to 10000 GeV in steps of 500 GeV

  } Mass points
  - $g_y = \left(\frac{F_\Pi}{\Lambda}\right)^2$ = 0.5, 1.0, 2.0, 2.5
- Once LHE files are produce, then Pythia is used for Parton Showering.
- Fast simulations of CMS like detector via software Delphes.

Next Steps

- Half of the samples (p p collider) are already ready for 1st two generations.
- Remaining samples and background production.
- Framework to be setup in order to read Root Files (already in progress)
- Analyze the results (Kinematics Studies and Statistical Significance).
- Compile the Paper Draft (Already in progress)

Study of the Impact of Unitarity Bounds on VBS ssWW at LHC

Motivation & Background

- For understanding EWK symmetry breaking quartic gauge couplings are important —> **Vector Boson Scattering**
- Vector Boson Scattering (VBS) allows indirect search of New Physics, usually parametrizing deviations from SM as Effective Field Theory (EFT) expansion
- EFT being a model-independent approach, is a powerful tool to study Physics Beyond Standard Model

$$\mathcal{L}_{EFT} = \sum_i \frac{C_i}{\Lambda^{\delta_i - 4}} O_i$$

- By introducing EFT contributions one can see an unphysical growth

of scattering amplitudes and the unitarity of scattering matrix is violated.

- For validation of the EFT approach, it is needed to implement unitarity constraints.

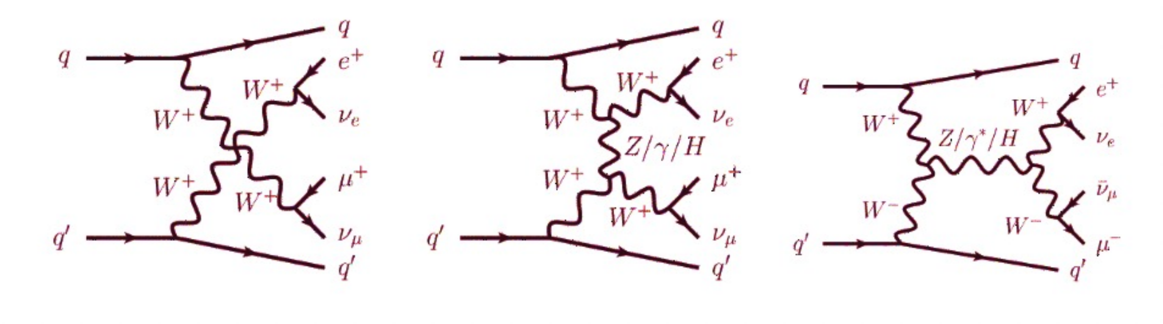
- C_i is the Wilson coefficient
- O_i is and the Effective operator.
- Λ is the Cut-off scale below which the EFT is effective and δ_i is the dimension.

Vector Boson Scattering(ssWW)

❖ Process in consideration

$$qq' \to W^{\pm}W^{\pm}jj \to l\nu_l l'\nu_{l'}jj$$

Feynman Diagrams



❖ Set of dimension 6 operators given by the Warsaw basis. Here for the inclusion of these operators, we are using the model called SMEFTsim_U35_MwScheme (arXiv:2012.11343)

- ❖ $U(3)^5$ *symmetry* $\xrightarrow{for\ kinetic\ terms} U(3)_q \times U(3)_u \times U(3)_d \times U(3)_l \times U(3)_e$
- ❖ Input parameters $\to \{M_W, M_Z, G_F\}$
- ❖ Unitary Gauge

❖ **Operators**

Mainly there are Bosonic and Fermionic operators, Bosonic ones are considered for calculation of unitarity bounds for gauge bosons interaction.

	X^3	$\varphi^4 D^2$	$X^2\varphi^2$
CPC	$Q_W = \epsilon^{ijk} W_\mu^{\nu i} W_\nu^{\rho j} W_\rho^{\mu k}$	$Q_{\varphi\Box} = (\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$ $Q_{\varphi D} = (\varphi^\dagger D^\mu\varphi)^*(\varphi^\dagger D_\mu\varphi)$	$Q_{\varphi W} = \varphi^\dagger\varphi W_{\mu\nu}^i W^{\mu\nu i}$ $Q_{\varphi WB} = \varphi^\dagger\tau^i\varphi W_{\mu\nu}^i B^{\mu\nu}$
CPV	$Q_{\tilde{W}} = \epsilon^{ijk} \tilde{W}_\mu^{\nu i} W_\nu^{\rho j} W_\rho^{\mu k}$		$Q_{\varphi\tilde{W}} = \varphi^\dagger\varphi \tilde{W}_{\mu\nu}^i W^{\mu\nu i}$ $Q_{\varphi\tilde{W}B} = \varphi^\dagger\tau^i\varphi \tilde{W}_{\mu\nu}^i B^{\mu\nu}$

Table 1. Bosonic operators in Warsaw basis which affect VBS ssWW processes.

Analysis Scheme

Amplitude Calculation

$$W^{\pm}(p_1,\lambda_1)W^{\pm}(p_2,\lambda_2) \rightarrow W^{\pm}(p_3,\lambda_3)W^{\pm}(p_4,\lambda_4)$$

Amplitudes for the process is calculated via Mathematica Packages: **Feynarts, FormCalc and Vecset**

For all the operators there are codes written and available on github repo

Calculation of Unitarity Bounds

Partial wave expansion has been carried out for each independent amplitude associated to relevant operators: by using these equations and results from the amplitude calculation.

$$\mathcal{M}_{\lambda_1\lambda_2\lambda_3\lambda_4} = 16\,\pi \sum_{j=0}^{\infty} a^{j}_{\lambda_1\lambda_2\lambda_3\lambda_4}\,(2j+1)P_j(cos\theta)$$

$\left|a^{j}_{\lambda_1\lambda_2\lambda_3\lambda_4}\right| \leq 1$ puts limit on COM energy $\hat{s}$

Analysis at LHE level

Event Generation via MadGraph _aMC@NLO v.2.7 for both $W^{\pm}$ processes.

Different EFT contributions are obtained via reweighting method.

Histogram Production and Confidence Intervals Calculation.

Results

	$\mathcal{M}_{\mp\mp\mp\pm} = \mathcal{M}_{\mp\mp\pm\mp} = \mathcal{M}_{\mp\pm\mp\mp} = \mathcal{M}_{\pm\mp\mp\mp}$	$\mathcal{M}_{\pm\pm\mp\mp}$	$\mathcal{M}_{0\pm0\mp} = \mathcal{M}_{\pm0\mp0}$	$\mathcal{M}_{0\pm\mp0} = \mathcal{M}_{\pm00\mp}$	$\mathcal{M}_{0000}$
Q_W	$-6\bar{g}\frac{c_W}{\Lambda^2}s$	$12\bar{g}\frac{c_W}{\Lambda^2}s$	$-\frac{3}{4}\bar{g}\frac{c_W}{\Lambda^2}s(3+\cos\theta)$	$\frac{3}{4}\bar{g}\frac{c_W}{\Lambda^2}s(3-\cos\theta)$	0
$Q_{\varphi W}$	0	0	$\bar{g}\frac{c_{\varphi W}}{\Lambda^2}s(1-\cos\theta)$	$-\bar{g}\frac{c_{\varphi W}}{\Lambda^2}s(1+\cos\theta)$	0
$Q_{\varphi WB}$	0	0	0	0	0
$Q_{\varphi\Box}$	0	0	0	0	$2\frac{c_{\varphi\Box}}{\Lambda^2}s$
$Q_{\varphi D}$	0	0	0	0	$\frac{c_{\varphi D}}{\Lambda^2}s$

Contributions to the helicity amplitudes of CPC bosonic operators

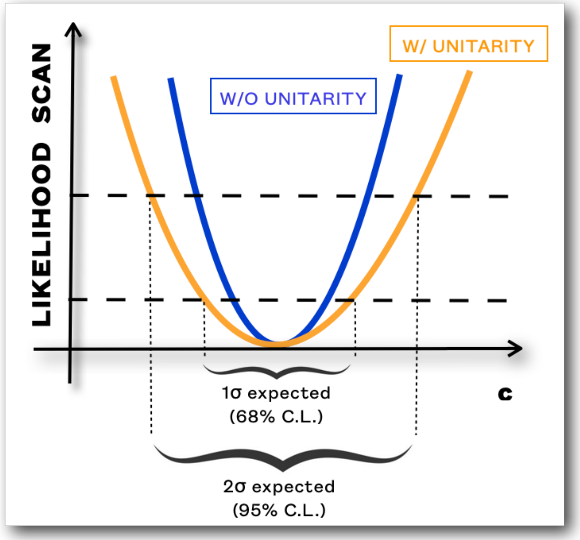
	$\mathcal{M}_{+++-} = -\mathcal{M}_{---+} = \mathcal{M}_{++-+} = -\mathcal{M}_{--+-} = \mathcal{M}_{-+--} = -\mathcal{M}_{+-++} = \mathcal{M}_{+---} = -\mathcal{M}_{-+++}$	$\mathcal{M}_{++--} = -\mathcal{M}_{--++}$	$\mathcal{M}_{0+0-} = -\mathcal{M}_{0-0+} = \mathcal{M}_{+0-0} = -\mathcal{M}_{-0+0}$	$\mathcal{M}_{0+-0} = -\mathcal{M}_{0-+0} = \mathcal{M}_{+00-} = -\mathcal{M}_{-00+}$
$Q_{\tilde{W}}$	$-6\bar{g}\frac{c_{\tilde{W}}}{\Lambda^2}s$	$12\bar{g}\frac{c_{\tilde{W}}}{\Lambda^2}s$	$-\frac{3}{4}\bar{g}\frac{c_{\tilde{W}}}{\Lambda^2}s(3+\cos\theta)$	$\frac{3}{4}\bar{g}\frac{c_{\tilde{W}}}{\Lambda^2}s(3-\cos\theta)$
$Q_{\varphi\tilde{W}}$	0	0	$\bar{g}\frac{c_{\varphi\tilde{W}}}{\Lambda^2}s(1-\cos\theta)$	$-\bar{g}\frac{c_{\varphi\tilde{W}}}{\Lambda^2}s(1+\cos\theta)$
$Q_{\varphi\tilde{W}B}$	0	0	0	0

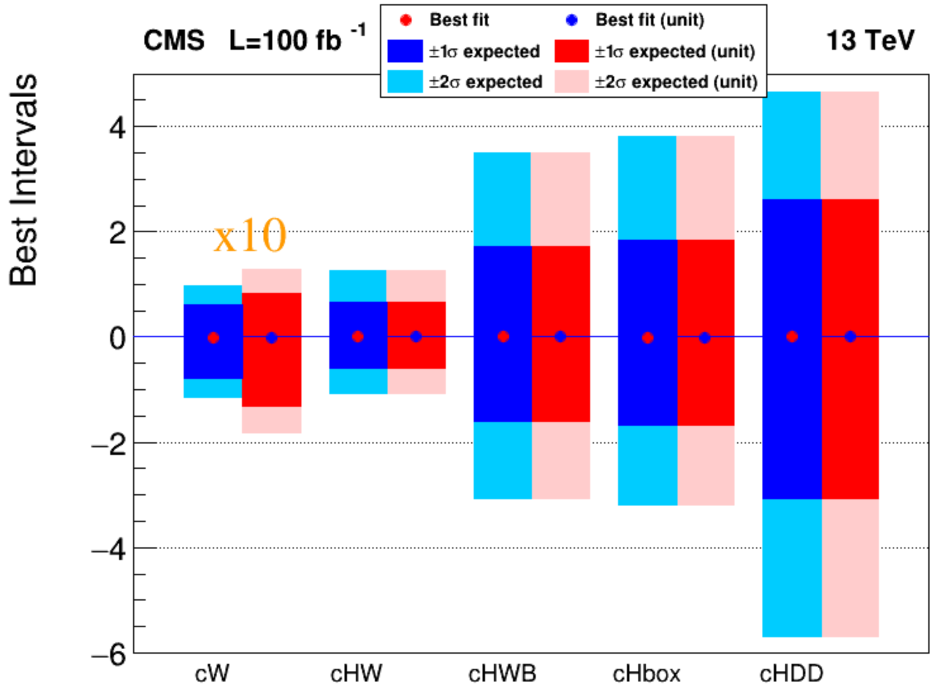
Contributions to the helicity amplitudes of CPV bosonic operators

For each EFT operator under examination, analytical expression of $\sqrt{\hat{s}_u}$ as a function of Λ and associated Wilson coefficient and relative unitarity bounds obtained with the conditions Λ = 1 and $|c_i|$ = 1.

Operator	$\sqrt{\hat{s}_u}(\lvert c_i\rvert)$	Bound on $\sqrt{\hat{s}}$
Q_W	$2\left(\frac{\Lambda^2\pi}{3\bar{g}}\right)^{1/2}\frac{1}{\lvert c_W\rvert^{1/2}}$	$\sqrt{\hat{s}} \leq 1.8$ TeV
$Q_{\varphi W}$	$4(\Lambda^2\pi)^{1/2}\frac{1}{\lvert c_{\varphi W}\rvert^{1/2}}$	$\sqrt{\hat{s}} \leq 7.1$ TeV
$Q_{\varphi WB}$	-	-
$Q_{\varphi\Box}$	$2(2\Lambda^2\pi)^{1/2}\frac{1}{\lvert c_{\varphi\Box}\rvert^{1/2}}$	$\sqrt{\hat{s}} \leq 5.0$ TeV
$Q_{\varphi D}$	$4(\Lambda^2\pi)^{1/2}\frac{1}{\lvert c_{\varphi D}\rvert^{1/2}}$	$\sqrt{\hat{s}} \leq 7.1$ TeV
$Q_{\tilde{W}}$	$2\left(\frac{\Lambda^2\pi}{3\bar{g}}\right)^{1/2}\frac{1}{\lvert c_{\tilde{W}}\rvert^{1/2}}$	$\sqrt{\hat{s}} \leq 1.8$ TeV
$Q_{\varphi\tilde{W}}$	$4(\Lambda^2\pi)^{1/2}\frac{1}{\lvert c_{\varphi\tilde{W}}\rvert^{1/2}}$	$\sqrt{\hat{s}} \leq 7.1$ TeV
$Q_{\varphi\tilde{W}B}$	-	-

Impact of unitarity constraints on theoretical limits on EFT parameters





Bosonic Operators

Next/Last Step

Paper Draft in preparation (soon it will be ready).
This will also have impact on the ongoing analysis within CMS Perugia group

Study of the impact of unitarity bounds on VBS ssWW at LHC

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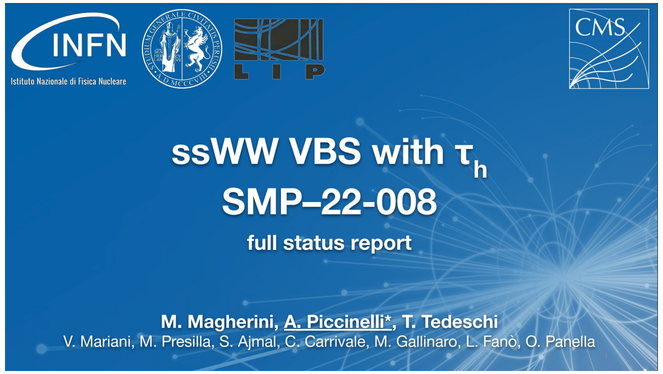
[2] *INFN, Sezione di Perugia, I-06123 Perugia, Italy*
(Dated: October 24, 2022)



Educational Activities

- **Courses**
  - Advance Python course **(Corso avanzato di Python per uso scientifico)** (Responsabile: Daniele Spiga) Perugia, 27-29 Ottobre 2021
  - Ph.D. course Introduction to Space Physics [8h | 1.5 CFU]
  - Teaching and Learning Physics By Organtini [4 CFU]
- **In person Activities**
  - **XXXIII INTERNATIONAL SEMINAR of NUCLEAR and SUBNUCLEAR PHYSICS "Francesco Romano" , Otranto, Jun 3 – 10, 2022**
  - **CMS week at CERN in September**
- **Tutorship**
  - Course name= LABORATORY I (2021/22) - 21_205472, degree course= [L-30] PHYSICS
  - 5 lessons (10 hours), each lesson contain exercises for the theoretical part of the course.

Educational Activities

- **Seminars/Workshops (Online)**
  - The Bright Side of the Universe by Prof. Yogendra Narain Srivastava, Dipartimento di Fisica e Geologia - Università degli Studi di Perugia
  - GGI talks: Steven Weinberg and his legacy

  "The effort to understand the universe is one of the very few things that lifts human life a little above the level of farce and gives it some of the grace of tragedy."
  - “Challenges and Opportunities of a Muon Collider” by LianTao Wang (Chicago U.), Daniel Schulte (CERN)
  - “High-precision measurement of the W boson mass with the CDF II detector”by Prof. Ashutosh Kotwal (Duke University, US)
  - First CMS EFT workshop by Alexander Josef Grohsjean (Deutsches Elektronen-Synchrotron (DE)), Kirill Skovpen (Ghent University (BE)), Matteo Presilla (INFN), Predrag Milenovic (University of Belgrade (RS))
  - CMS Physics Days: Review of Run 2 interesting excesses (14-15 September 2022)

CMS Service Work

Production Of Monte Carlo Simulated Samples For The Vector Boson Scattering

- Working as Monte Carlo (MC) Contact for SMP-VV subgroup since December 2021.
- In 2022, we have prepared requests from different Analyzers, for Standard Model and EFT (VBS) Processes.
- Gain experience with Madgraph especially with Les Houches Event (LHE) files.
- Interaction with different people from all over the world.

1. Gathering information / Requests Preparation /Local Validation
2. Global Validation and Ticket Preparation
3. Presentation in Weekly Mcm Meeting
4. Approval and Submission

Conclusion and Future Plans

❖ **Up till now**

- Learned many new things by interacting with the Professors, Collaborators and colleagues.
- Gained knowledge specific for research field and hoping to enhance it more in future.
- Gaining experiences in conferences' world.

❖ **Looking Forward**

- Complete the Paper Drafts mentioned in the research activities.
    - Composite Model Phenomenology
    - Study of the impact of unitarity bounds on VBS ssWW at LHC
- Carry on the research work for the PhD thesis for Last year.

Thank You for your attention!

Backup slides!

Phenomenology of the Leptoquarks

- All the datacards (for signal production in Madgraph) is created and stored in the Github repo
- https://github.com/mpresill/compositeNJL/tree/main/Data_Cards_LQ_Prodcution
- Diagrams and datacards for one set of coupling and mass point are available for all 3 generations.

	process	PDF set	Flavor scheme	MG version	MG card git folder
3rd Generation	p p > ta+ ta- b/b~ (QCD)	324900	5F	MG5_aMC_v3_1_0	https://github.com/mpresill/composite
	p p > ta+ ta-	324900	5F	MG5_aMC_v3_1_0	https://github.com/mpresill/composite
	p p > pid23tre pid23tre~	324900	5F	MG5_aMC_v3_1_0	https://github.com/mpresill/composite
	p p > pid23tre ta- , pid23tre> ta+ b + b~ contribution	324900	5F	MG5_aMC_v3_1_0	https://github.com/mpresill/composite
	p p > ta+ ta- b/b~ (QED) inelastic	20463	5F	MG5_aMC_v3_1_0	https://github.com/mpresill/composite
	p p > ta+ ta- b/b~ (QED) Elastic	20463	5F	MG5_aMC_v3_1_0	https://github.com/mpresill/composite
	p p > ta+ b	82400	5F	VERSION 3.1.0 BZR (3.2.0_leptonfromproton)	https://github.com/mpresill/composite
	p p > ta- b~	82400	5F	VERSION 3.1.0 BZR (3.2.0_leptonfromproton)	https://github.com/mpresill/composite

Motivation for BSM Physics

- SM does not incorporate neutrino masses and mixing, also there are too many parameters.
- No Dark Matter (DM) candidate present in the SM, does not accommodate gravity.
- Higgs mass Hierarchy problem. $\delta M_H^2(f) = -\frac{|\lambda_f|^2}{8\pi^2}[\Lambda^2 + \cdots]$
- Generation puzzle and pattern with-in one generation
- Different Models can be used to solve these problems e.g., Supersymmetry,

Left right symmetric Model, **Compositeness,** 331 Model, …etc.

- Effective Lagrangian approach-> At lower energies we may have an Effective Lagrangian which, in principle, can be derived from the fundamental high-energy Lagrangian. Effective Lagrangian contain higher-dimension operators (dimension 5, 6 and higher).