Kick off XXXVIII PhD cycle

Effective Field Theory studies in the context of LHC

TUTORS:

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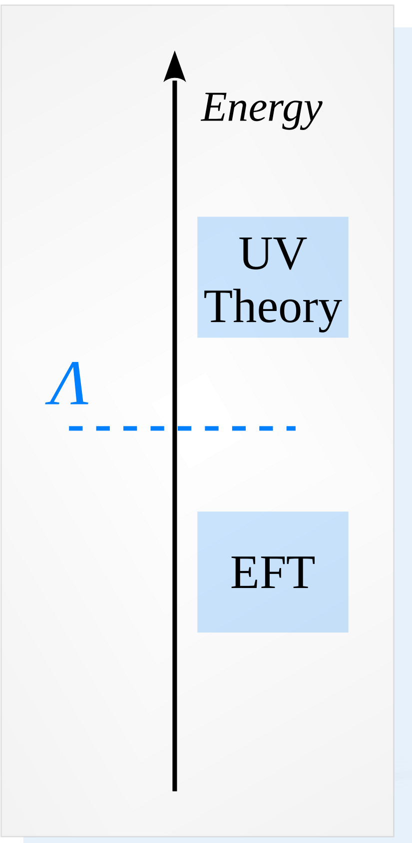
Personal background and studies

- High School diploma at Liceo Classico "Annibale Mariotti" of Perugia in 2014
- Bachelor degree in Physics at University of Perugia in 2018
  Thesis: Nucleosynthesis from neutron captures – the *r* processes in the overview of new frontiers of Astrophysics
- Master degree in Theoretical Physics at University of Perugia in 2022
  Thesis: Study of the impact of unitarity bounds on VBS same-sign W at LHC

Scientific interests:

Phenomenological studies in the context of High Energy Physics and Effective Field Theories

Effective Field Theories (EFT)



- Assumption of the existence of a UV theory whose dynamics is unknown
- Integrating out heavy dof we have EFT with same field content of Standart Model and respecting same symmetries

$$\mathcal{L}_{\text{eft}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{c_i}{\Lambda^{d-4}} \mathcal{Q}_i^{(d)}$$

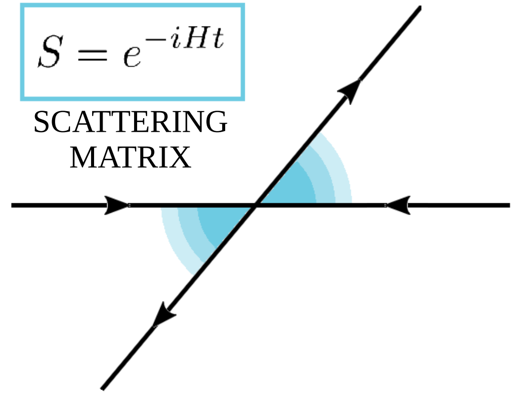
$$\mathcal{L}_{\text{BSM}} \xrightarrow[E \ll M]{} \mathcal{L}_{\text{eft}}$$

- Wilson coefficients
- New Physics scale
- Mass dimension of Q_i

- Free parameters in a model-independent analysis;
- Expressable as a function of parameters of different Beyond SM models.

Unitarity violation in EFTs

SCATTERING MATRIX UNITARITY
=
PROBABILITY CONSERVATION



$S^\dagger S = 1$ → OPTICAL THEOREM → $|\mathcal{M}| < 1$

$$\mathcal{M}_{\text{eft}} = \mathcal{M}_{\text{SM}} + \sum_i \frac{c_i^{(6)}}{\Lambda^2}\mathcal{M}_6^i + \sum_i \frac{c_i^{(8)}}{\Lambda^4}\mathcal{M}_8^i + \ldots$$

In SM unitarity is always preserved

$\mathcal{M}_{\text{eft}} \sim \mathcal{O}(\hat{s})$

$|\mathcal{M}_{\text{eft}}(\hat{s})| > 1$ above a certain value $\hat{s}_u$
(unitarity violation threshold)

- Need to restore unitarity with unitarization procedures

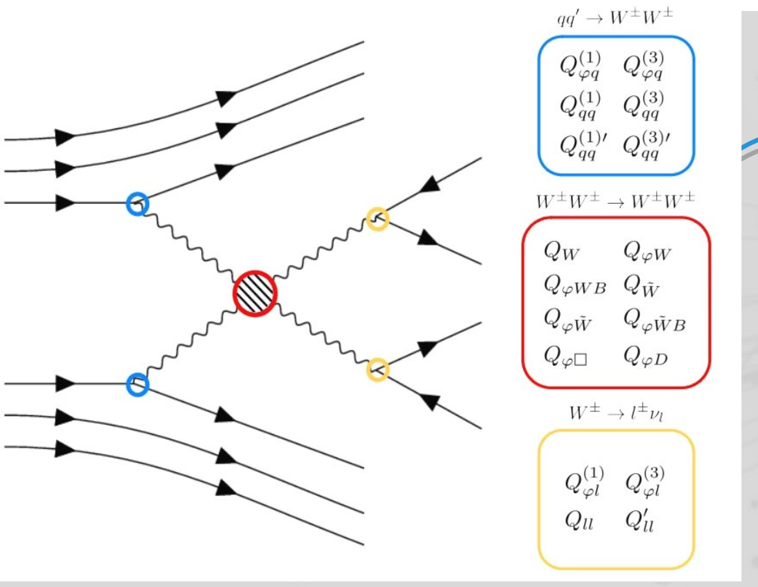
Master Degree Thesis

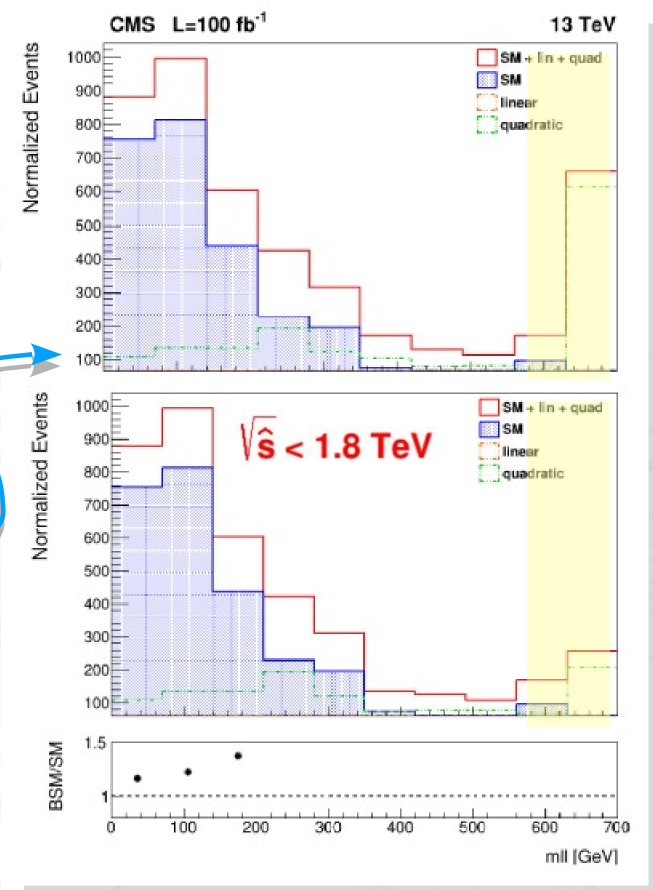
Study of the impact of unitarity bounds on Vector Boson Scattering same-sign W at LHC

- **First result**
  Computation of unitarity bounds as function of Λ and Wilson coefficient

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

$$\mathcal{L}_{\text{EFT}} = \mathcal{L}_5 + \mathcal{L}_6 + \mathcal{L}_7 + \mathcal{L}_8 + \ldots$$





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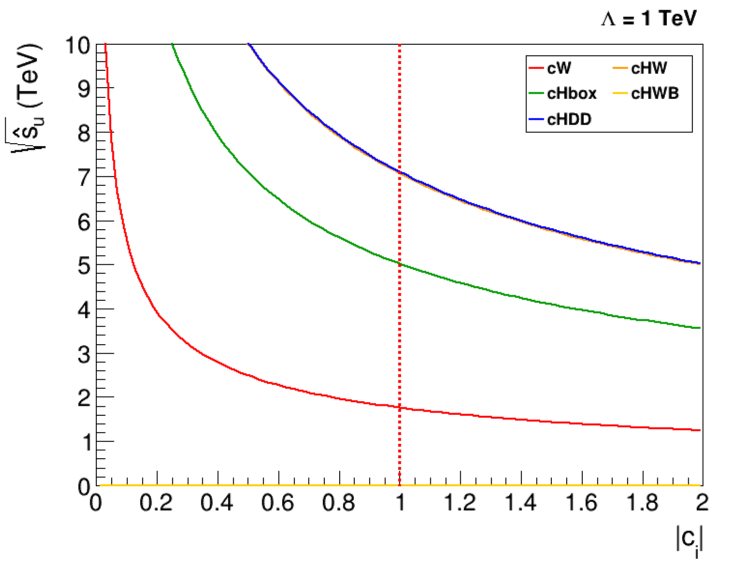
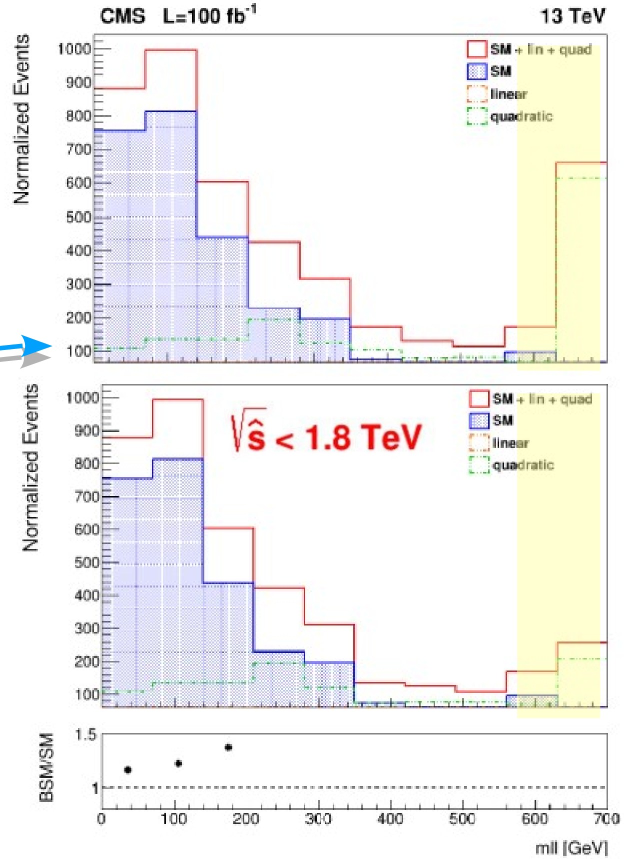
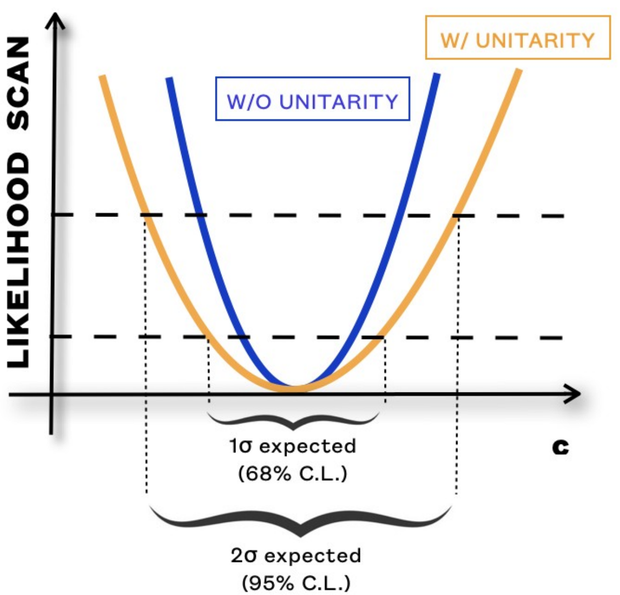


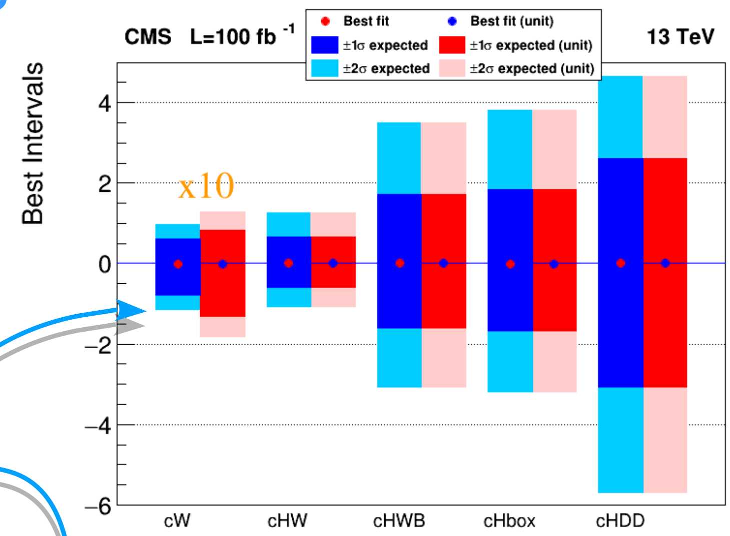


Master Degree Thesis

Study of the impact of unitarity bounds on Vector Boson Scattering same-sign W at LHC

- **Second result**
  Impact of unitarity costraints on theoretical limits on EFT parameters





Bosonic Operators

Coeff.	CL 68%	CL 95%
c_W	[-0.13;0.08]	$[-0.18; 0.13]$
$c_{\varphi W}$	$[-0.60; 0.66]$	$[-1.07; 1.26]$
$c_{\varphi WB}$	$[-1.60; 1.71]$	$[-3.06; 3.50]$
$c_{\varphi\Box}$	$[-1.68; 1.83]$	$[-3.18; 3.81]$
$c_{\varphi DD}$	$[-3.06; 2.62]$	$[-5.69; 4.66]$

47%

Future perspectives

- Very precise measurement lead to higher sensitivity to NP effects
  -- 22 april 2022: Run 3 starts (13.6 TeV, 300 fb^{-1})
  -- 2029: High-Luminosity phase (HL-LHC) (3 ab^{-1})
- Realistic fit should be performed in a physically-consistent EFT framework

PhD project goals:

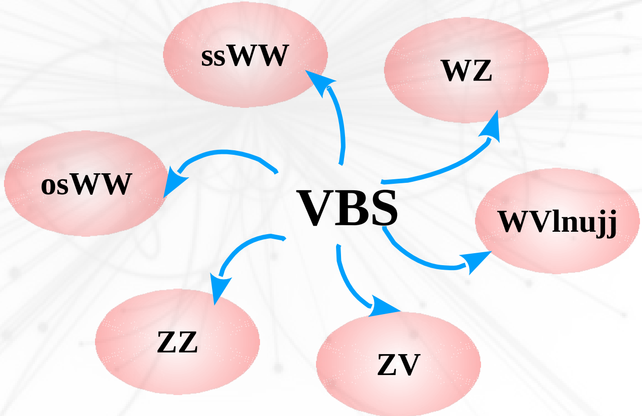
- Study of **interdependence between channels**: how constraints on EFT parameters can be improved including different channels and final states
- General **workflow for EFT validation** (implementation of unitarity bounds, theoretical errors)

PhD Topic: first CMS VBS measurements combination and EFT interpretation

- Developement of tools for combination of existing VBS analysis in CMS (Run II) in **combine** framework
  (LHC EFT Working Group, EFT group of UNIMIB)

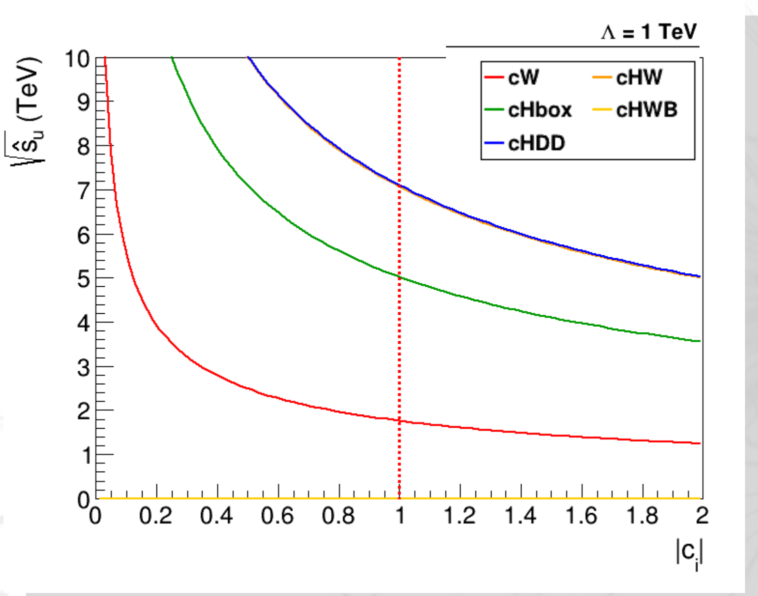
  https://github.com/cms-analysis/HiggsAnalysis-CombinedLimit

- Global fits are key to enhance SM EFT sensitivity



PhD Topic: General method to derive and implement unitarity bounds

- General workflow for unitarity bounds derivation and implementation in a global EFT interpretation framework
  - Method of determination of unitarity violation threshold
  - Study of dependence of unitarity bounds on EFT parameters



PhD Topic: General method to derive and implement unitarity bounds

- Study of theoretical errors due to truncation of EFT expansion

$$\mathcal{L}_{\mathrm{EFT}} = \mathcal{L}_5 + \mathcal{L}_6 + \mathcal{L}_7 + \mathcal{L}_8 + \ldots$$

  - Study of the impact of interference between different dimension operators on observables
  - Innovative approaches already exist (geoSMEFT), study of applicability of results

Conclusions

Providing a framework for the interpretation of LHC data in the context of EFT

- Collaboration with **Bicocca**'s EFT group and **LHC EFT WG** for development of new tools for analysis combination
  → Combination of all analysis of Run II of LHC (CMS)

- EFT approach validation and minimization of dependence on theoretical parameters with **CMS phenomenology group** of Perugia (O. Panella, M. Presilla, S. Ajmal)
  → Unitarity implementation
  → Theoretical error