CONTUR: new results and technical developments

MCnet Meeting 2022, Universität Graz
Yoran Yeh on behalf of the CONTUR team
23 September 2022
• Constraints on new theories using Rivet (SciPost Phys.Core 4 (2021) 013)
• Aims to answer: “How excluded is a new beyond the SM (BSM) theory already by published LHC measurements?”
• Very quick and computationally light because only particle-level measurements are considered
• Rivet analyses divided into orthogonal pools (experiment, beam energy, final state)
• Results webpage: https://hepcedar.gitlab.io/contur-webpage/index.html
Dirac DM, vector (V) mediator

- DM model mediated in s-channel diagrams, benchmarked to ATLAS search summary plots
- Right plot: coloured squares indicate measurement pool with largest exclusion
- ttbar production at $M_{Z'} > 350$ GeV
- Slightly lower sensitivity in CONTUR at high $M_{Z'}$

ATL-PHYS-PUB-2022-036

C. Velasquez, J. Butterworth

Dijet and missing energy+jets at 3.2 fb$^{-1}$
ttbar(had) at 36.1 fb$^{-1}$
Dirac DM, V (low-mass)

- Extend plot down to $M_{Z'} = 4$ GeV on a logarithmic axis
- Sensitive for data as bkg. (white line), from $\gamma + \text{jets}$ and $W, Z + \text{jets}$ measurements
- SM predictions for some analyses not yet available in CONTUR, hence sensitivity of solid black line is not as stringent
Dirac DM, V, non-zero lepton coupling

- Shape of excluded region similar, ATLAS searches with 139 fb$^{-1}$ of data benefit from better statistics (vs. 3.2 fb$^{-1}$ for the analyses used in CONTUR)

ATL-PHYS-PUB-2022-036
Dirac DM, axial-vector (A) mediator

- Similar to vector DM case: comparable shape but slightly different sensitivity
- Full Run-2 dijet measurement (and missing energy+jets measurement) expected to improve limits significantly

ATL-PHYS-PUB-2022-036

C. Velasquez, J. Butterworth
Dirac DM, A, non-zero lepton coupling

- Lepton signatures dominate the exclusion plot
- Eventual full Run-2 measurements of dileptons + ditau would increase CONTUR sensitivity
- Of course CONTUR is not limited to these common benchmark models!
Simplified t-channel DM model

- Characterised by quark/DM/mediator coupling
- Various configurations with different DM spins, Majorana/Dirac DM or quark contributions
- Great CONTUR candidate due to the number of different configurations and large parameter space
Light scalars with EFT couplings

- Light scalar particles (CP odd or even) $\phi$ coupling to electroweak gauge bosons
- Parameters: $M_\phi$ and coupling to SM particles, i.e. effective couplings governed by $\Lambda_i$ for SM particle $i$
- CP-odd: set all scales very high, except $W, B$ which are set equal CP. CP-even: include Higgs coupling
- Measurements of interest with an isolated photon or photon pairs in the final state (both inclusively and with jets, W or Z)

139 fb$^{-1}$ ATLAS diphoton
(arXiv:2107.09330)
Gildner-Weinberg 2HDM

- Two-Higgs-doublet model with additional mass constraint \( (\sum_{\mathcal{H}} M_{\mathcal{H}}^4)^{1/4} = 540 \text{ GeV} \) on extra Higgs-bosons \( \mathcal{H} = \{ H, H_A, H^\pm \} \) (see e.g. Les Houches 2019 New Physics Working Group report arXiv:2002.12220)
- “Data as background” more stringent; not all measurements have SM predictions in CONTUR + SM uncertainties are included

\[ \sum_{\mathcal{H}} M_{\mathcal{H}}^4 = 540 \text{ GeV} \]

\( \mathcal{H} = \{ H, H_A, H^\pm \} \)

Sept. 2022
New data, use SM predictions
(Rivet 3.1.6, Contur 2.4 candidate)

\[ \tan \beta = 0.5 \]
• New photon measurements (ATLAS_13_GAMMA) and four lepton (ATLAS_13_4L) analyses
• SM predictions for few dilepton+jets measurements not available in CONTUR
Updates to **CONTUR** package

• **Contur 2.4.0 release notes** (aiming for release end of this month!)
  ‣ Support pip/PyPI: `pip install contur` (M. Liu)
  ‣ Emphasis on SM theory as background in contur-plot and uses YODA 1.9.6 with correlation bugfix (J. Butterworth)
  ‣ Include covariance matrices from HEPData where possible (E. Butterworth)
  ‣ Increase speed for plotting with results database (S. Mao)
  ‣ Improved Madgraph5_aMC@NLO interface (S. Jeon)
  ‣ Updated outputs to work with yodastream output for GAMBIT interface (T. Procter)
Other developments

- **CONTUR ORACLE**: machine-learning assisted parameter scans (J. Rocamonde, L. Corpe, G. Zilgalvis, M. Avramidou & J. Butterworth)
  - Not viable to probe entire parameters space of BSM model in multidimensional scans
  - Most interested in the contour lines of 68% and 95% exclusion
  - Main idea: iterative training with partial CONTUR scans to predict exclusion status in parameter space, sample new points according to the outcome, repeat
  - >90% precision and <10% computing resources!
  - Details in *SciPost Phys. 13, 002 (2022)*

- To get started:
  - Local installation with `pip install` - instructions on the [Contur Gitlab page](https://gitlab.com/contur)
  - For CERN users; Rivet + CONTUR installation on LXPLUS
  - Docker container
  - Mattermost channel
Summary

- Updated and new limits on a wide range of BSM theories
  - Comparison with benchmark models from dedicated searches show added virtue of CONTUR!
- Ongoing technical developments to improve performance and user-friendliness
- There is always room for more!
  - Adding new measurements, SM predictions and correlations to library
  - Scrutinise new regions of parameter space