Contur Update

Jon Butterworth
CERN, 14 May 2018

Initial idea: arXiv:1606.05296 (JHEP 2017 078)
JMB, D. Grellscheid, M. Krämer, B. Sarrazin, D. Yallup
Reminder: Precision ‘Standard Model’ Measurements

- They should not (and mostly do not) assume the SM
- They agree with the SM
- Thus they can potentially exclude extensions
Reminder: Precision ‘Standard Model’ Measurements

• They should not (and mostly do not) assume the SM
• They agree with the SM
• Thus they can potentially exclude extensions
Key tools:

• BSM Model in FeynRules
• New processes in Herwig7
• Rivet, and data from HepData
Key tools: Constraints On New Theories Using Rivet

- BSM Model in FeynRules
- UFO interface
- New processes in Herwig7
- Rivet, and data from HepData

Final State Particles

Exclusion
Key tools:  Constraints On New Theories Using Rivet

- BSM Model in FeynRules
- UFO interface
- New processes in Herwig7
- Rivet, and data from HepData

https://contur.hepforge.org/
Strategy

• Use measurements shown to agree with the Standard Model
  – (Mostly) assume the data = the background, as in a typical search control region. Although see later.

• Excellent for quick sensitivity/limit scans of new models

• Key for constraining new models if there is a signal (unintended consequences)

• Key for constraining scale of new physics if there is no signal
Dynamic data selection

• SM measurements of fiducial, particle-level differential cross sections, with existing Rivet routines

• Classify according to data set (7, 8, 13 TeV) and into non-overlapping signatures

• Use only one plot from each given statistically correlated sample
  – Jets, Drell-Yan, W+jets, Z+jets, $\gamma$ (+jets), $\gamma\gamma$, ZZ, etc …

• “Most sensitive measurement” will vary with model and model parameters
Updates

• Alternative statistical tools
  – Can generally use $\chi^2$ test – simpler, easier to adapt to ratios, theory comparisons etc
  – Retain LL Poisson as a cross check.

• New data sets
• First implementation of inclusion of SM theory predictions
• New models
New data sets

• Lots of 8 TeV now, some 13 TeV too. Some highlights:
  – Measurements of four-lepton production in pp collisions at $s\sqrt{s}=8$ TeV with the ATLAS detector arXiv:1509.07844
  – Several particle-level/differential/fiducial top and Higgs measurements from CMS and ATLAS, e.g. CMS boosted top arXiv:1605.00116
  – $V+\gamma$ measurements e.g. ATLAS arXiv:1604.05232
  – High mass Drell-Yan arXiv:1606.01736
  – Can now use the Jets + missing $E_T$ ratio analysis
  – And more...
SM Theory

• Existence proof:
  – Easy to include SM predictions, e.g. Herwig7/Matchbox (this run courtesy J.Huang)
Some new models...
Simplified DM model coupling to all flavours

Heatmaps for $g_q = 0.25$, $g_{DM} = 1$

Heatmap and contour for all available data (measurements from 7, 8 and 13 TeV runs in Rivet/Contrib as of 2018/03/24)
Simplified DM model coupling to all flavours
A muon-rich 2 Higgs Doublet Model

- Killed by muon combinatorial in the 4-lepton line shape

**Figure 6:** Projection of the contribution of our model, for $M_{h^\pm} = 100$ GeV, on to the ATLAS four-lepton differential cross-section mass measurement (left) and transverse momentum of the four-lepton system (right). Black points indicate the data, the red upper histogram is the data+BSM. The lower sections of the plots show the ratio of (data+BSM)/data. The uncertainty in the measurement is suppressed by the axis scale. The numbers in the legend show the bin number of the most powerful bin, and the exclusion from that bin expressed as a probability.

**Figure 7:** As in Fig.6, but for $M_{h^\pm} = 200$ GeV. The yellow error band indicates the uncertainty on the measurement.
Light scalars

- Effective couplings to gauge bosons. Dominant decay to photons → sensitivity in inclusive, diphoton and V+photon measurements (model from S. Fichet, G. Moreau)

![Graphs showing diphoton mass and differential cross-section measurements](image)

**Figure 1:** Projection of the contribution of the CP-odd model, (left) for $M_\phi = 10$ GeV and $\Lambda = 3500$ TeV, on to the 8 TeV ATLAS $\gamma + E_T^{\text{miss}}$ differential $E_T^{\gamma}$ cross-section measurement and (right) on the diphoton mass measurement, now with $M_\phi = 20$ GeV – which brings the mass peak from the $\phi$ within the range of the measurement. Black points indicate the data, the red upper histogram is the data-BSM. The lower sections of the plots show the ratio of (data+BSM)/data, with the yellow band indicating the uncertainty in the measurement. The numbers in the legend show the bin number of the most powerful bin, and the exclusion from that bin expressed as a probability.
Heatmaps for CP-odd Light Scalar Model

Heatmap and contour for all available data (measurements from 7, 8 and 13 TeV runs in Rivet as of 21/9/2017)

Heatmaps for CP-even Scalar Model

Heatmap and contour for all available data (measurements from 7, 8 and 13 TeV runs in Rivet as of 21/9/2017)
Next steps

• More data (and catch up with some key publications – experiments please keep helping!)
• More models (some preliminary results already on hepforge)
• More SM theory
• Better usability
• Treat correlations better, where available
• *We want your UFO files (and, more recently, your SM theory predictions!)*