

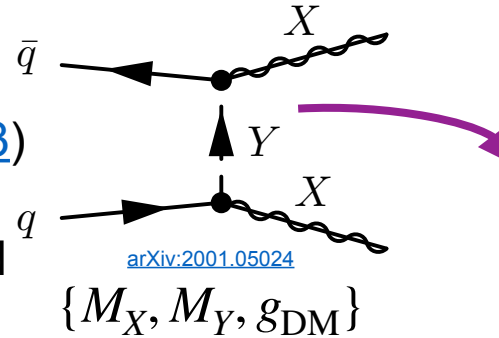
# CONTUR: recent updates and ongoing developments

**(Re)interpretation of the LHC results for new physics**  
Durham University

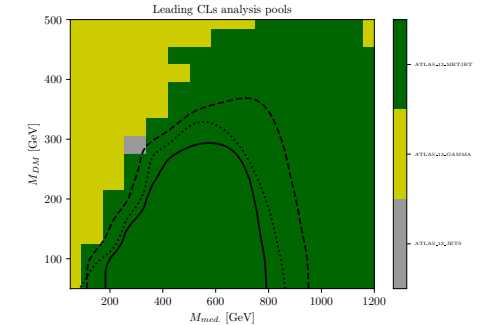
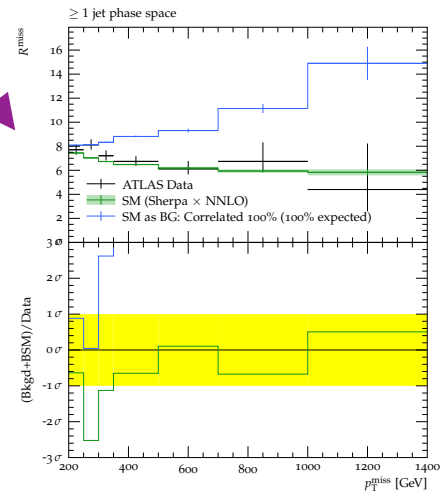
**Yoran Yeh on behalf of the CONTUR team**  
29 August 2023

# Introduction

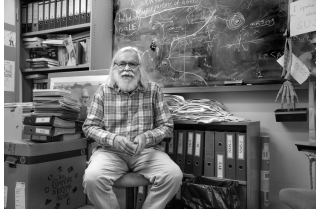
- Constraints on new theories using Rivet ([SciPost Phys.Core 4 \(2021\) 013](https://arxiv.org/abs/2011.013))
- “How excluded is a new beyond the SM (BSM) theory already by published LHC measurements?”
- Rivet analyses divided into orthogonal pools (experiment, beam energy, final state)
- Very quick and computationally light because only particle-level measurements are considered



Vary model parameters



# CONTUR workflow



$\mathcal{L}_{\text{BSM}}$

FeynRules

UFO directory

Event generator

YODA (BSM yields)

Rivet

HepMC (particle-level events)

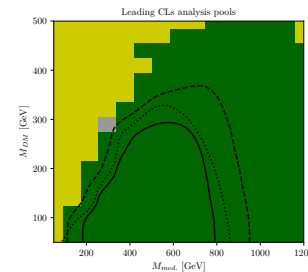
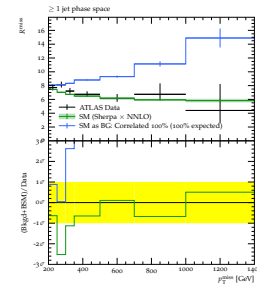
contur

CONTUR outputs

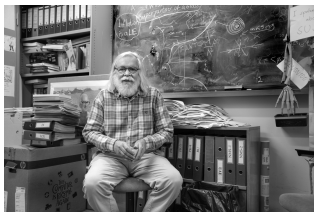
ANALYSIS folder

1D histograms

2D exclusions



# CONTUR workflow



$\mathcal{L}_{\text{BSM}}$

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UFO directory

YODA (BSM yields)

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CONTUR outputs

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1D histograms

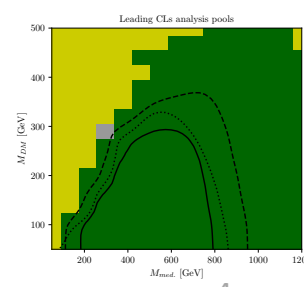
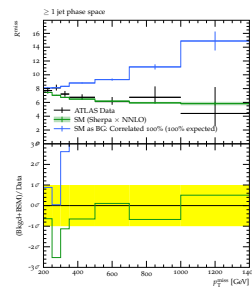
2D exclusions

contur-batch

$\mathcal{O}(\text{hours})$  to test 2D grid in BSM parameter space to thousands of individual histograms!

Event generator

particle-level events



- Counting experiment

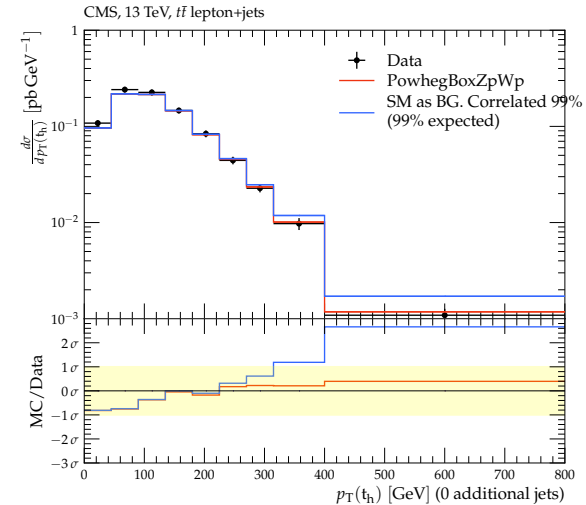
$$\mathcal{L}(\vec{x} | \mu \vec{s} + \vec{b}) = \prod_{i=1}^n \frac{(\mu s_i + b_i)^{x_i}}{x_i!} e^{-(\mu s_i + b_i)}$$

- Profile likelihood ratio as test statistic
- To be conservative, use the CLs method

$$\text{CL}_s = \frac{P_{s+b}}{1 - p_b}$$

- Statistical and systematic uncertainties treated in covariance matrix

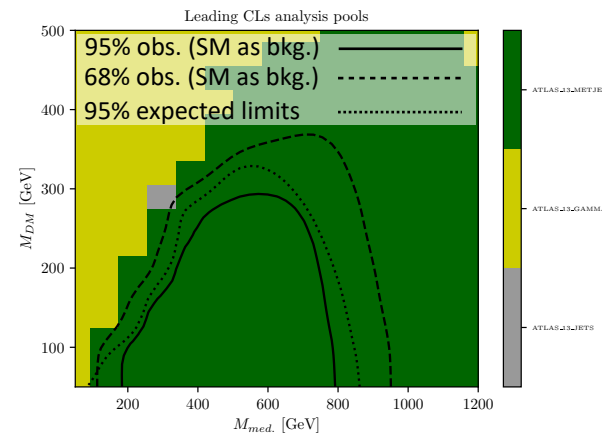
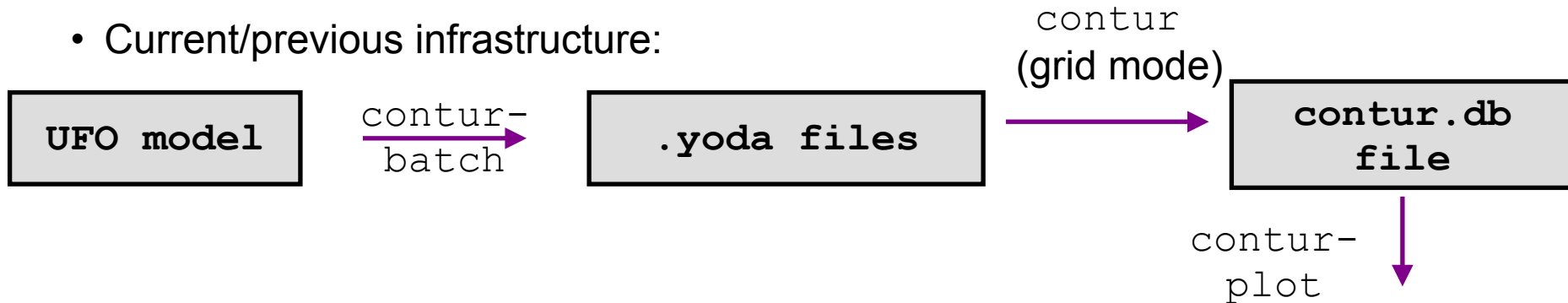
$$t_{\mu}^{\text{obs}} \approx \chi_{\mu, \text{obs}}^2 = (\vec{x} - \mu \vec{s} - \vec{b})^T \text{Cov.}^{-1} (\vec{x} - \mu \vec{s} - \vec{b})$$





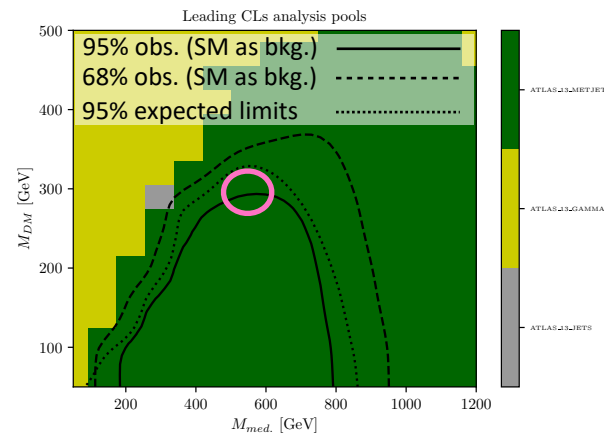
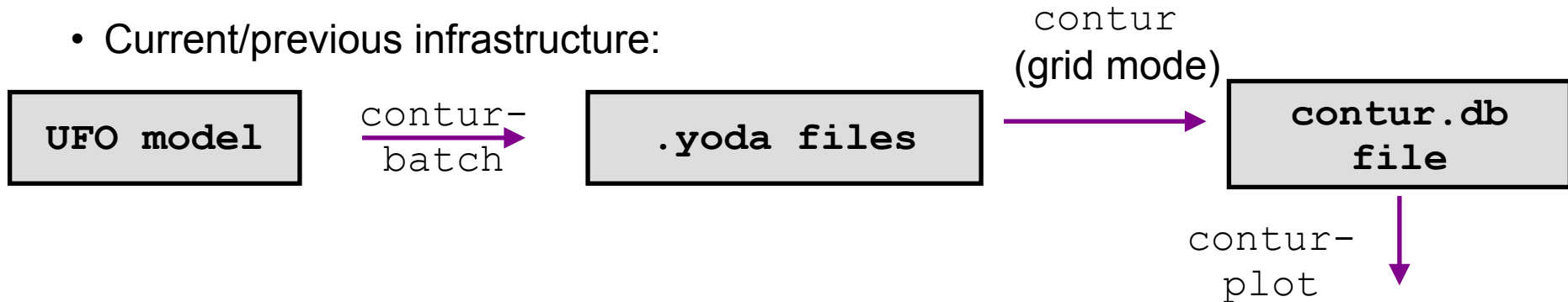
# Updated 1D plotting infrastructure

- Current/previous infrastructure:



# Updated 1D plotting infrastructure

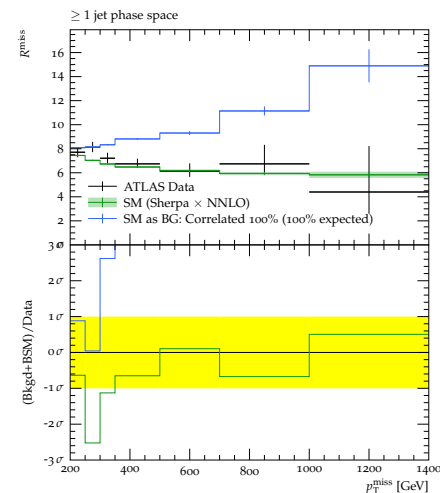
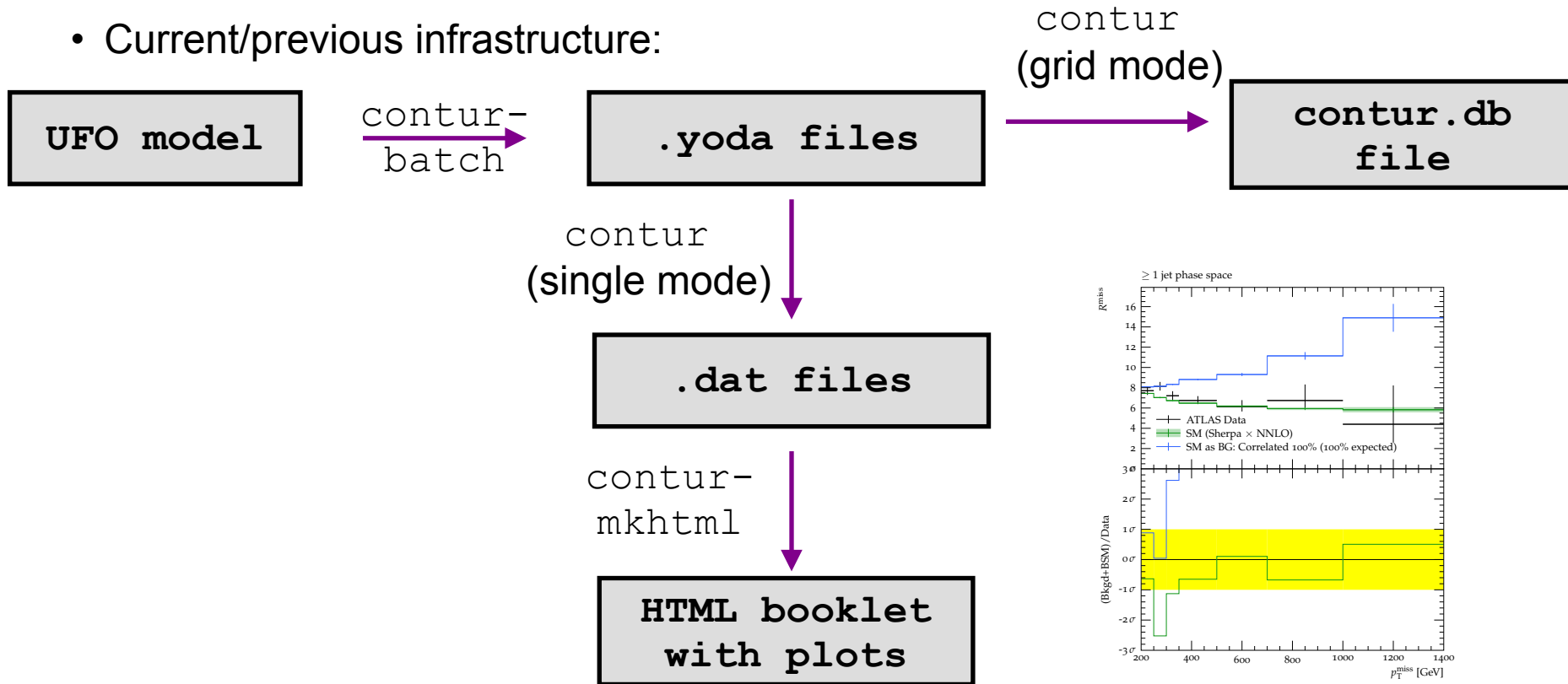
- Current/previous infrastructure:





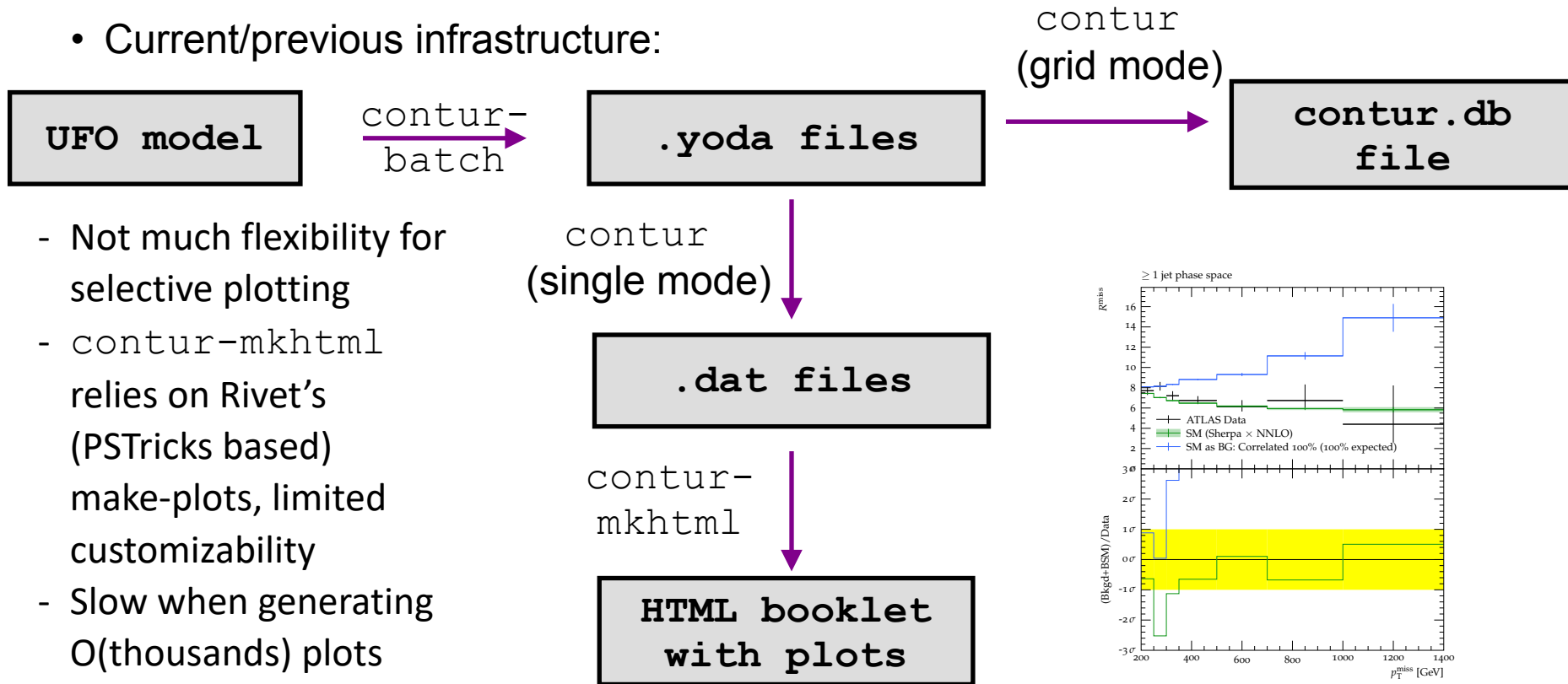
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- Current/previous infrastructure:

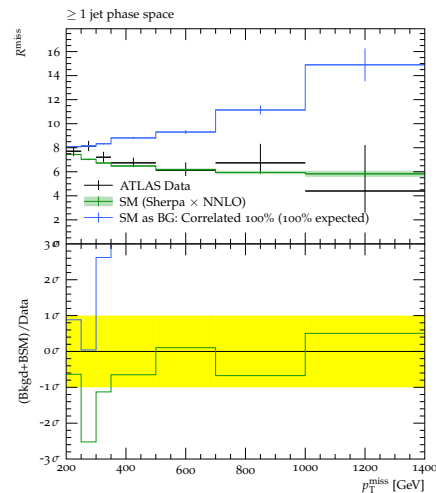


# Updated 1D plotting infrastructure

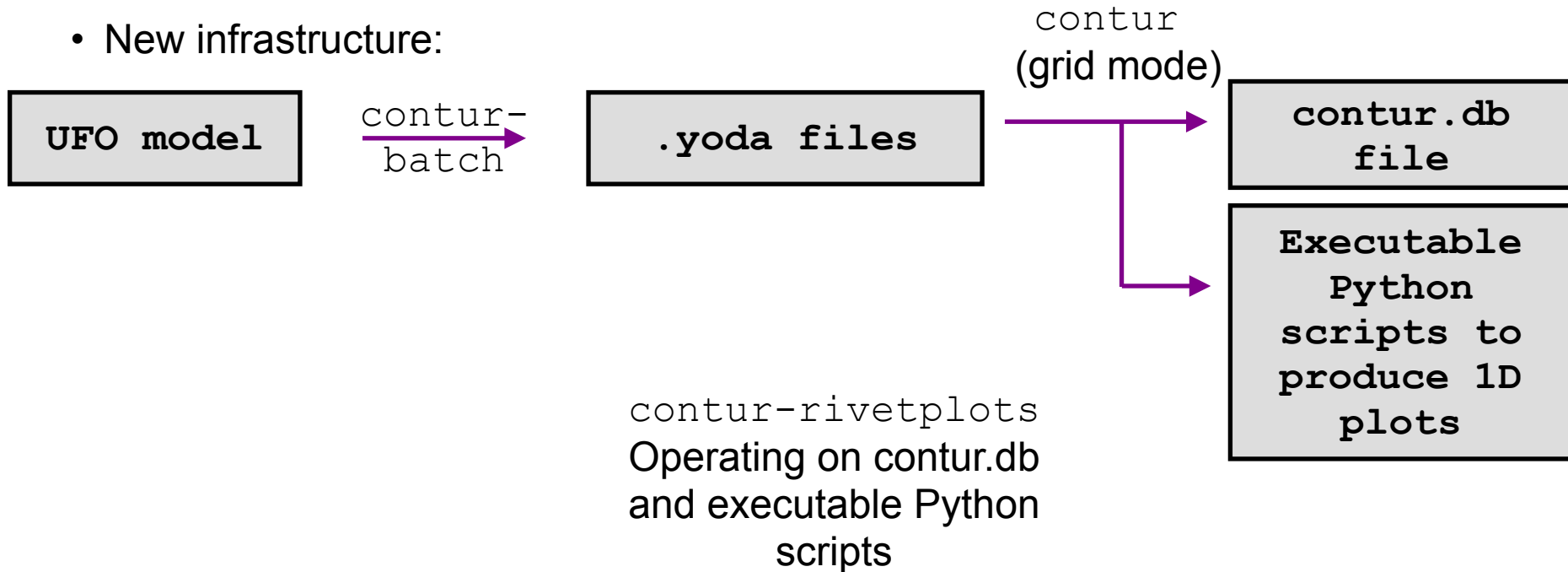
- Current/previous infrastructure:



- Not much flexibility for selective plotting
- `contur-mkhtml` relies on Rivet's (PSTricks based) `make-plots`, limited customizability
- Slow when generating  $O(\text{thousands})$  plots



- New infrastructure:



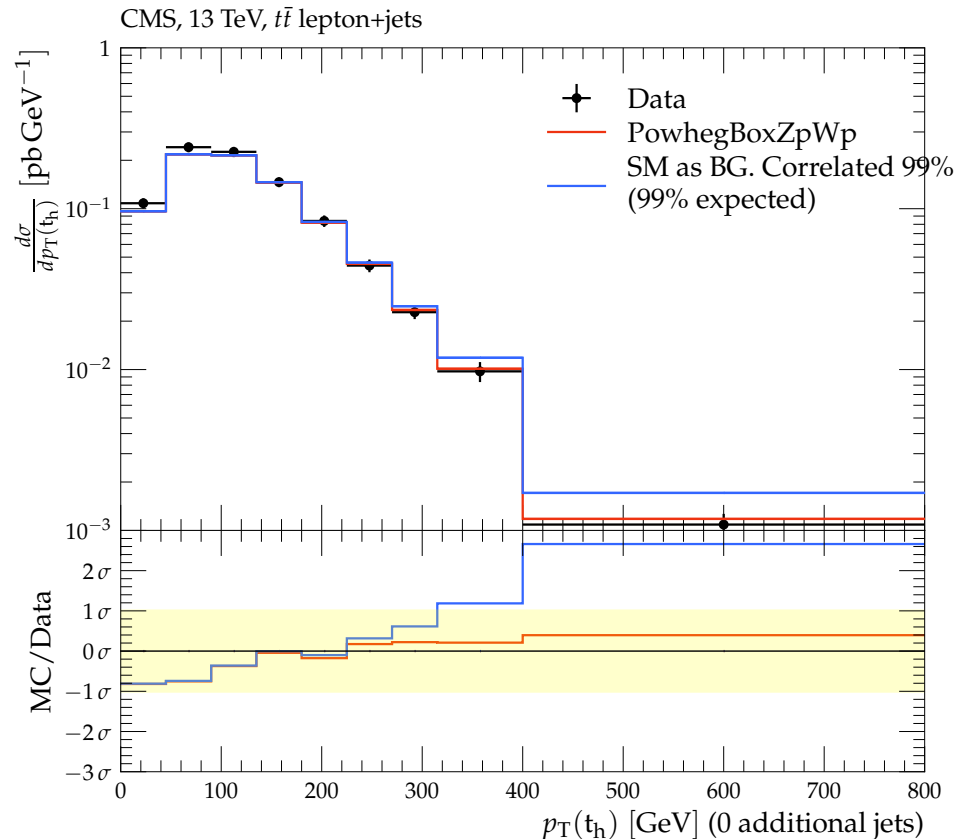
- -p flag gives quick overview of which analyses and histograms contribute to exclusion by how much

```
(rivetvenv) yoranyeh@Yorans-MacBook-Pro-4 0000 % contur-rivetplots -p
INFO - Contur version 2.5.x
INFO - See https://hepcedar.gitlab.io/contur-webpage/
Writing log to contur.log
INFO - Read DB file ANALYSISISTEST/contur_run.db
CMS_13_EEJET
- CMS_2019_I1753680:LMODE=EL
-- d28-x01-y02 : 0.01(DATABG) 0.00(SMBG) 0.00(EXP)
-- d27-x01-y02 : 0.00(DATABG) 0.00(SMBG) 0.00(EXP)
-- d26-x01-y02 : 0.00(DATABG) 0.00(SMBG) 0.00(EXP)
- CMS_2018_I1667854:LMODE=EL
-- d05-x01-y01 : 0.11(DATABG) 0.00(SMBG) 0.00(EXP)
-- d08-x01-y01 : 0.04(DATABG) 0.00(SMBG) 0.00(EXP)
-- d14-x01-y01 : 0.39(DATABG) 0.00(SMBG) 0.00(EXP)
-- d11-x01-y01 : 0.19(DATABG) 0.00(SMBG) 0.00(EXP)
-- d07-x01-y01 : 0.02(DATABG) 0.00(SMBG) 0.00(EXP)
-- d16-x01-y01 : 0.10(DATABG) 0.00(SMBG) 0.00(EXP)
-- d13-x01-y01 : 0.28(DATABG) 0.00(SMBG) 0.00(EXP)
-- d02-x01-y01 : 0.21(DATABG) 0.00(SMBG) 0.00(EXP)
-- d10-x01-y01 : 0.18(DATABG) 0.00(SMBG) 0.00(EXP)
-- d01-x01-y01 : 0.19(DATABG) 0.00(SMBG) 0.00(EXP)
-- d04-x01-y01 : 0.12(DATABG) 0.00(SMBG) 0.00(EXP)
-- d18-x01-y01 : 0.09(DATABG) 0.00(SMBG) 0.00(EXP)
-- d09-x01-y01 : 0.08(DATABG) 0.00(SMBG) 0.00(EXP)
-- d15-x01-y01 : 0.46(DATABG) 0.00(SMBG) 0.00(EXP)
-- d12-x01-y01 : 0.20(DATABG) 0.00(SMBG) 0.00(EXP)
-- d03-x01-y01 : 0.07(DATABG) 0.00(SMBG) 0.00(EXP)
-- d06-x01-y01 : 0.21(DATABG) 0.00(SMBG) 0.00(EXP)
-- d17-x01-y01 : 0.09(DATABG) 0.00(SMBG) 0.00(EXP)
ATLAS_13_METJET
- ATLAS_2017_I1609448
-- d02-x01-y01 : 0.00(DATABG) 0.00(SMBG) 0.15(EXP)
-- d01-x01-y01 : 0.00(DATABG) 0.00(SMBG) 0.36(EXP)
-- d04-x01-y01 : 0.00(DATABG) 0.00(SMBG) 0.17(EXP)
-- d03-x01-y01 : 0.00(DATABG) 0.00(SMBG) 0.16(EXP)
```

- -p flag gives quick overview of which analyses and histograms contribute to exclusion by how much
- Filter by name of the analysis or pool and CLs exclusion  
`contur-rivetplots -p`  
`--ana-match CMS --cls 0.5`

```
(rivetvenv) yoranyeh@Yorans-MacBook-Pro-4 0000 % contur-rivetplots -p \  
--ana-match CMS --cls 0.5 -i ANALYSISTEST | head -n 35  
INFO - Contur version 2.5.x  
INFO - See https://hepcedar.gitlab.io/contur-webpage/  
Writing log to contur.log  
INFO - Read DB file ANALYSISTEST/contur_run.db  
CMS_13_MMJET  
- CMS_2021_I1866118  
-- d05-x01-y01 : 1.00(DATABG) 0.99(SMBG) 0.99(EXP)  
-- d02-x01-y01 : 1.00(DATABG) 0.99(SMBG) 1.00(EXP)  
-- d01-x01-y01 : 1.00(DATABG) 0.97(SMBG) 0.99(EXP)  
-- d04-x01-y01 : 1.00(DATABG) 0.94(SMBG) 1.00(EXP)  
-- d03-x01-y01 : 1.00(DATABG) 0.86(SMBG) 0.99(EXP)  
CMS_13_LLJET  
- CMS_2022_I2079374  
-- d05-x01-y01 : 0.56(DATABG) 0.00(SMBG) 0.00(EXP)  
-- d07-x01-y01 : 0.97(DATABG) 0.00(SMBG) 0.00(EXP)  
-- d27-x01-y01 : 0.99(DATABG) 0.00(SMBG) 0.00(EXP)  
-- d09-x01-y01 : 0.95(DATABG) 0.00(SMBG) 0.00(EXP)  
-- d25-x01-y01 : 0.84(DATABG) 0.00(SMBG) 0.00(EXP)  
-- d17-x01-y01 : 0.93(DATABG) 0.00(SMBG) 0.00(EXP)  
CMS_13_LMETJET  
- CMS_2018_I1662081  
-- d11-x01-y01 : 0.97(DATABG) 0.42(SMBG) 0.86(EXP)  
-- d13-x01-y01 : 1.00(DATABG) 0.80(SMBG) 0.99(EXP)  
-- d10-x01-y01 : 1.00(DATABG) 0.00(SMBG) 0.92(EXP)  
-- d09-x01-y01 : 0.98(DATABG) 0.00(SMBG) 0.81(EXP)  
-- d12-x01-y01 : 1.00(DATABG) 0.90(SMBG) 0.93(EXP)  
- CMS_2018_I1663958  
-- d32-x01-y01 : 1.00(DATABG) 0.86(SMBG) 1.00(EXP)  
-- d05-x01-y01 : 1.00(DATABG) 0.99(SMBG) 1.00(EXP)  
-- d50-x01-y01 : 0.89(DATABG) 0.00(SMBG) 0.50(EXP)  
-- d67-x01-y01 : 0.93(DATABG) 0.00(SMBG) 0.54(EXP)  
-- d19-x01-y01 : 0.99(DATABG) 0.21(SMBG) 0.76(EXP)  
-- d76-x01-y01 : 0.75(DATABG) 0.00(SMBG) 0.35(EXP)
```

- -p flag gives quick overview of which analyses and histograms contribute to exclusion by how much
- Filter by name of the analysis or pool and CLs exclusion  
`contur-rivetplots -p`  
`--ana-match CMS --cls 0.5`
- Remove -p option to execute the (already produced) Python scripts and provide you with HTML booklet of plots



# Further improvements

- Rivet + CONTUR interface in MG5 and vice versa
  - Very successful tutorial in the recent MCnet school at Durham!
- Interfaced to GAMBIT
  - Publication on constraining the electroweakino in MSSM ([talk at RiF 2022, 2303.09082](#))
- Ongoing work to run CONTUR on MC production runs in ATLAS
- `contur_run.db` file, small and more readable
- Deal with different integrated luminosities within the same measurement

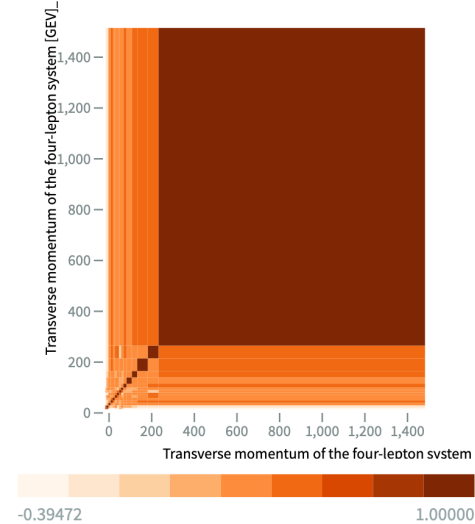


# Further improvements

- Support for PyPI: `pip install contur`
- Covariance matrices used from HEPdata (in >20 analyses)
  - Alternatively, build covariance matrix from error breakdown (correlating errors), or if this is not available assume matrix is diagonal
- Many, many more new analyses and SM predictions!
  - When publishing results, include:
    - ❖ HEPData record for measured data (with a breakdown of the systematics, correlations matrices)
    - ❖ Rivet routine
    - ❖ Best-available SM predictions (plus total cross-section if normalised!)

[Matous' talk at RiF @ CERN](#)

<https://www.hepdata.net/record/ins1625109>





# How to get involved?

- To get started: [link to code repository and tutorial](#)
  - Local installation using PyPI or build manually
  - MG5 interface
  - For CERN users: Rivet + CONTUR installation on LXPLUS
  - Docker container
  - [Mattermost channel](#)
- Sky is the limit, any BSM theory can be tested in principle
  - Results webpage: <https://hepcedar.gitlab.io/contur-webpage/index.html>
  - Combined constraints on dark photons [[JHEP 03 \(2023\) 182](#)]
  - Testing the scalar triplet solution to CDF's heavy W problem at the LHC [[Phys.Rev.D 107 \(2023\) 7, 075020](#)]



- Developing CONTUR into a tool that is more widely used and usable! Recent updates in:
  - Making the interface more user-friendly
  - More analyses (and theory predictions) available to improve limit-setting
- Thank you for your attention!