

# CheckMATE Tutorial

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# Installation

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- Virtual Disk available for download with CheckMATE preinstalled.
  - <http://www.th.physik.uni-bonn.de/people/jsk/index.html>
  - After downloading the virtual disk, the Virtual Machine settings are as follow:
    - Name: "CheckMATEVM", OS "Linux Ubuntu 32 bit", Memory  $\geq$  1024 MB
    - "Use existing hard disk" and select the downloaded, unzipped .vdi file
    - Password for screen lock: checkmate
- For Linux/MacOS machines, detailed step-by-step installation instructions at
  - <https://checkmate.hepforge.org/tutorial/ver2/start.php>

# Testing if CheckMATE works

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- `cd /home/checkmate/tools/checkmate2-master/bin`
- `./CheckMATE testparam.dat`

## Output

```
Evaluating Results
Test: Calculation of  $r = \text{signal}/(95\%CL \text{ limit on signal})$ 
Result: Allowed
Result for r: 0
Analysis: cms_sus_13_016
SR: SR1
checkmate@CheckMATE-VM:~/tools/checkmate2-master/bin$ █
```

This is because the included testfile.hep contains very few events.

# Generating signal events with MG5

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- `cd /home/checkmate/tools/mg5_amc/bin`
- `./bin/mg5_aMC`

In MadGraph, we generate events in a toy model with  $pp \rightarrow U\bar{U}$ , with  $U \rightarrow u \varphi_1$  and  $\bar{U} \rightarrow u \varphi_2$ , with  $\varphi_2 \rightarrow e^+ E$ ,  $E \rightarrow e^- \varphi_1$ , where  $U, \bar{U}, E, \bar{E}$  are Dirac fields,  $\varphi_1$  and  $\varphi_2$  are scalars, and  $M_U > M_{\varphi_2} > M_E > M_{\varphi_1}$ .

- `import model MC4BSM_2012_UFO`
- `define l = e+ e-`
- `define lv = ev ev~`
- `generate p p > uv uv~, uv > u p1, (uv~ > u~ p2, (p2 > l lv, lv > l p1))`
- `output /home/checkmate/tutorial/MC4BSM/mc4bsm`

# Generating signal events with MG5

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- `cd /home/checkmate/tutorial/MC4BSM/mc4bsm`

In the Cards directory, modify `param_card.dat` and `run_card.dat` (`vi/leafpad` in the VM).

- In `param_card.dat`, you can change the BSM particle masses/decay widths according to the model you're testing. Here, let's change decay width of BSM particles to `auto`.

Back in `/home/checkmate/tutorial/MC4BSM/mc4bsm`

- `./bin/madevent launch`

Press `1` (enables Pythia), then `Enter`, then again `Enter`. Note down cross section.

- `cd Events/run_01`
- `gunzip -k tag_1_pythia_events.hep.gz`

# Reinterpreting in CheckMATE

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- `cd /home/checkmate/tools/checkmate2-master/bin`

Copy `testparam_with_analysis.dat` as `mc4bsm.dat`, open the latter and make the following changes:

- [Parameters]
- Name: `New_Run`
- Analyses: `atlas_2101_01629`
  
- [myprocess]
- XSect: `0.452 PB`
- XSectErr: `10 %`
- Events: `/home/checkmate/tutorial/MC4BSM/mc4bsm/Events/run_01/tag_1_pythia_events.hep`

This is the analysis described [here](#). Table 3 lists the signal regions, and event selection.

# Reinterpreting in CheckMATE

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- ./CheckMATE mc4bsm.dat

At the prompt, type y then Enter.

## Results

```
Evaluating Results
Test: Calculation of  $r = \text{signal}/(95\%CL \text{ limit on signal})$ 
Warning: Error is dominated by Monte Carlo Statistics!
Result: Excluded
Result for r: 2.02910580473
Analysis: atlas_2101_01629
SR: 4J lx bveto 1000
```

Details and more information in `/home/checkmate/tools/checkmate2-master/results/New_Run`

# Details

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Cutflows and events passing region selection in folder: analysis

- Number of events in selection regions normalized by cross section and luminosity.

More details in folder: evaluation

- total\_results.txt shows number of signal events, expected signal and observed background, as well as upper 95% CL. for all selection regions.
- The metric to choose best signal region is rexpcns, defined as  $\frac{\text{signal events} - 1.64 \times \text{signal error}}{s_{95exp}}$ .
- robscons is output, and the model is excluded if the value is >1.

**For more options in the CheckMATE run card, see**

- `/home/checkmate/tools/checkmate2-master/bin/example_run_cards/all_parameters_explained.dat`

# Analysis Manager

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- `cd /home/checkmate/tools/checkmate2-master/bin`
- `./AnalysisManager`

This executable allows you to list all implemented analyses, add new analysis, edit analysis information, remove analysis, or update observed events, background estimates, uncertainties and s95 values for an analysis.

# Further information

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1. CheckMATE homepage: <https://checkmate.hepforge.org/>
2. Email for contact: [checkmate@projects.hepforge.org](mailto:checkmate@projects.hepforge.org)
3. Toy Model – MC4BSM-2012 tutorial Section 2 [[arxiv: 1209.0297](https://arxiv.org/abs/1209.0297)]
4. Search for squarks and gluinos in final states with one isolated lepton, jets, and missing transverse momentum at  $\sqrt{s} = 13$  TeV with the ATLAS detector [[arxiv: 2101.01629](https://arxiv.org/abs/2101.01629)]