MadAnalysis 5 v1.6
Normal-Mode reference card

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website: http://madanalysis.irmp.ucl.ac.be/

references: arXiv:1206.1599[hep-ph], arXiv:1405.3982[hep-ph], arXiv:1407.3278[hep-ph]

1 Starting the MadAnalysis 5 interpreter

The MadAnalysis 5 command line interface can be started by typing in a shell

```
bin/ma5 [options] [script]
```

where the potential options (`[options]`) are given in the table below.

Short	Full	Description
`-P`	`--partonlevel`	Parton-level mode.
`-H`	`--hadronlevel`	Hadron-level mode.
`-R`	`--recolevel`	Reconstructed-level mode.
`-E`	`--expert`	Expert mode.
`-v`	`--version`	Displays the current MadAnalysis 5 version number.
	`--release`	
`-b`	`--build`	Builds of the SampleAnalyzer library.
`-f`	`--forced`	Skips MadAnalysis 5 confirmation messages.
`-s`	`--script`	Executes a script containing all analysis commands and exits the program. The file containing the script has to be provided as `[script]`. Removing the `-s` option prevents MadAnalysis 5 from exiting.
`-h`	`--help`	Print all the available commands.
`-i`	`--installcard`	Generates a file with information on the MadAnalysis 5 dependencies, `installation_card.dat`, that is located in the `madanalysis/input` folder.
`-d`	`--debug`	Debug mode.

In case of installation issues, the usage of the dependencies can be tuned by editing the file: `madanalysis/input/installation_options.dat`
More information can be found in the original MadAnalysis 5 manual [6].

2 Installation of optional packages

MadAnalysis 5 is interfaced to several high-energy physics packages and can be linked to a variety of external plugins. Any of those can be installed by typing in the MadAnalysis 5 interpreter,

```
install [package]
```

where the different choices for `[package]` are given in the table below.

Package	Description
`PAD`	The MadAnalysis 5 Public Analysis Database of recasted LHC analyses relying on Delphes 3 for the simulation of the detector effects.
`PADforMA5tune`	The MadAnalysis 5 Public Analysis Database of recasted LHC analyses relying on the old tuned version of Delphes 3 for the simulation of the detector effects.
`delphes`	The current release of Delphes 3.
`delphesMA5tune`	The old tuned version of Delphes 3.
`fastjet`	The FastJet and FastJetContrib packages.
`samples`	Some test Monte Carlo samples.
`zlib`	The ZLib library allowing to handle gzipped compressed files.

3 Commands available from the MadAnalysis 5 interpreter

A small set of commands, to be typed from the MadAnalysis 5 interpreter, are related to console actions.

Command	Description
`quit` `EOF`	Exits MadAnalysis 5.
`help`	Displays the list of available commands.
`help [command]`	Displays details about a specific command.
`history`	Displays the history of all commands that have been typed by the user.
`reset`	Clears the MadAnalysis 5 memory as when the program is started.
`restart`	Restarts MadAnalysis 5.
`shell [command]` `![command]`	Executes a Unix command from the interpreter.
`#[text]`	Indicates a comment.

In order to design an analysis in the MadAnalysis 5 framework, the user can rely on the following commands.

Command	Description
`define [(multi)particle label] = [ID1] [ID2] ...`	
	Creates a new (multi)particle label attached to the provided PDG codes `[ID1]`, `[ID2]`, ...
`define_region [label1] [label2] ...`	
	Creates one or more signal regions named `[label1]`, `[label2]`, ...
`import [label]`	Imports a sample or a UFO model.
`open [folder]`	Opens a report from the folder `[folder]`. If the folder is unspecified, the last created report is open.
`plot [obs]([part1] [part2] ...) nbins min max [ [opts] ] { [regs] }`	
	Defines a histogram with the distribution in the observable `[obs]`. Its computation may require to combine the momenta of several objects `[part1]`, `[part2]`, ... Any other parameter is optional. The `nbins`, `min` and `max` quantities respectively correspond to the number of bins, and the upper and lower bound of the x-axis of the histogram. The options `[opts]` (see below) allow the user to tune the display of the histogram, and `[regs]` indicates to which signal region one needs to attach this histogram.
`reject [criterion]` `select [criterion]`	Defines a selection cut that leads to the rejection (or selection) of an event if the `[criterion]` condition is satisfied.
`reject ([part]) [criterion]`	
`select ([part]) [criterion]`	
	Defines a selection cut that leads to the rejection (or selection) of an object candidate if the `[criterion]` condition is satisfied.
`remove [object]`	Deletes an object (a (multi)particle label, a region, a histogram or a cut).
`resubmit`	Adjusts the last generated C++ code relatively to the commands issued after the last `submit` command, and executes it.
`set [obj] = [val]`	Sets an attribute of a specific object to a given value.
`submit [folder]`	Generates, compiles and executes the C++ code corresponding to the current analysis either in a folder named `[folder]`, if specified, or in an arbitrary folder otherwise.
`swap main.selection[n1] main.selection[n2]`	
	Swaps the analysis steps number `[n1]` and `[n2]`.

Throughout the analysis, information can be printed to the screen by means of the following commands.

Command	Description
`display [object]`	Displays the properties of a specific object.
`display_datasets`	Displays the list of all defined datasets.
`display_multiparticles`	Displays the list of all defined multiparticle labels.
`display_particles`	Displays the list of all defined particle labels.
`display_regions`	Displays the list of all defined signal regions.

4 Properties of the main object

The `main` object of MadAnalysis 5 allows to setup varied options (see the table below) to impact the code on run time. They can be modified and displayed by using the `set` and `display` commands introduced above.

Command	Description
`main.currentdir`	Folder containing MadAnalysis 5.
`main.fastsim.package`	The package used for the fast-simulation of the detector response. The available choices are `fastjet`, `delphes`, `delphesMA5tune` and `none`.
`main.fom.formula`	Formula to be used to calculate the figure of merit in the cutflow charts. Denoting by S and B the number of signal and background events, the available choices are 1 (S/B), 2 ($S/\sqrt{B}$), 3 ($S/\sqrt{B}$), 4 ($S/\sqrt{S+B}$) and 5 ($S/\sqrt{S+B+x_B^2}$). For this last formula, the x_B parameter is specified via `main.fom.x`.
`main.graphic_render`	Package to use for figure generation. The available choices are `root`, `matplotlib` and `none`.
`main.isolation.algorithm`	Algorithm to be used for particle isolation. The available choices are `cone` (no activity in a cone of radius specified by `main.isolation.radius`) and `sumpt` (the scalar sum of the transverse momenta of all particles lying in a given cone around the candidate must be smaller than `main.isolation.sumPT` and the ratio of the transverse energy of all particles in this cone to the transverse momentum of the candidate must be smaller than `main.isolation.ET_PT`).
`main.lumi`	Integrated luminosity, in fb^{-1}, to use for histogram and cutflow normalization.
`main.normalize`	Way in which histograms have to be normalized. The available choices are `none` (each event counts for 1), `lumi` (normalization to the integrated luminosity without taking into account the event weights), `lumi_weight` (as `lumi` but with the event weights).
`main.outputfile`	Name of the output file to write events onto.
`main.recast`	Switching the recasting mode `on` and `off`.
`main.stacking_method`	Way in which the contributions of the different datasets to a histogram are displayed. The available choices are `normalize2one` (the integral of each contribution equals 1), `stack` (each contribution is stacked) and `superimpose` (each contribution is superimposed).

5 Observables to be used for histograms and cuts

As shown in the tables above, the definition of a histogram or of a cut condition necessitates to provide an observable that could depend on the momentum of one or more particles or objects. We list in the tables below all observables supported by MadAnalysis 5, and begin with those that do not depend on the momenta of any object. They are therefore called without any argument.

Symbol	Description
`ALPHA_QCD`	Value of the QCD coupling constant.
`ALPHA_QED`	Value of the electromagnetic coupling constant.
`ALPHA_T`	The α_T variable [9].
`MEFF`	Effective mass being defined as the sum of the transverse momentum of all final-state objects and the missing transverse energy.
`MET`	Missing transverse energy.
`MHT`	Missing transverse energy defined from the jet activity only.
`NPID`	Particle content (PDG code distribution).
`NAPID`	Particle content (PDG code distribution in absolute value).
`SQRTS`	Partonic center-of-mass energy.
`SCALE`	Energy scale of the event.
`TET`	Scalar sum of the transverse energy of all final-state objects.
`THT`	Scalar sum of the transverse energy of all final-state jets.
`WEIGHTS`	Event weights.

The set of observables provided in the following table can be used to study the properties of a given object or particle, and thus requires to provide one four-momentum or one combination of four-momenta as an argument of the observable function.

Symbol	Description
ABSETA	Absolute value of the pseudorapidity.
BETA	Velocity $\beta = v/c$ (relatively to the speed of light).
E	Energy.
EE_HE	Ratio of the electromagnetic energy to the hadronic energy (for a jet).
ET	Transverse energy.
ETA	Pseudorapidity.
GAMMA	Lorentz-factor.
HE_EE	Ratio of the hadronic energy to the electromagnetic energy (for a jet).
M	Invariant mass.
MT	Transverse mass.
MT_MET	Transverse mass of the system comprised of the object and the missing momentum.
NTRACKS	Number of tracks (inside a jet).
P	Magnitude of the three-momentum.
PHI	Azimuthal angle.
PT	Transverse momentum.
PX	x-component of the momentum.
PY	y-component of the momentum.
PZ	z-component of the momentum.
R	Position in the (η, ϕ) plane.
Y	Rapidity.

Three additional observables involving two objects are also available, the methods given in the table below taking thus two arguments separated by a comma.

Symbol	Description
DELTAR	Angular distance, in the transverse plane, between the objects.
DPHI_0_PI	Angular distance in azimuth between the objects. The bounds for the angle are $[0, \pi]$.
DPHI_0_2PI	Angular distance in azimuth between the objects. The bounds for the angle are $[0, 2\pi]$.

For all arguments of any of the above observable, any sequence of momenta separated with spaces will lead to a sum of these momenta before computing the observable. For instance,

```
plot M(e+ e-)
```

allows for the computation of the invariant of an electron-positron system.

6 Options for histograms

The command `plot` accept varied options `[opts]`,
`plot [obs]([part1] [part2] ...) nbins min max [ [opts] ] { [regs] }`

to be provided between squared brackets. The list of all available choices is given in the table below.

Symbol	Description
Eordering	Sorts the objects in increasing energy.
ETordering	Sorts the objects in increasing transverse energy.
ETAordering	Sorts the objects in increasing pseudorapidity.
Pordering	Sorts the objects in increasing three-momentum magnitude.
PTordering	Sorts the objects in increasing transverse momentum.
PXordering	Sorts the objects in increasing momentum x-component.
PYordering	Sorts the objects in increasing momentum y-component.
PZordering	Sorts the objects in increasing momentum z-component.
allstate	Considers all (initial-state, final-state and intermediate-state) objects in the events.
finalstate	Considers only final-state objects (default).
initialstate	Considers only initial-state objects.
interstate	Considers only objects that are neither initial-state nor final-state objects.
logX	Logarithmic scale for the x-axis.
logY	Logarithmic scale for the y-axis.
normalize2one	Normalizes the histogram to 1.
stack	Stacks the contributions of different datasets in the histogram.
superimpose	Superimposes the contributions of different datasets in the histogram.

7 Options for datasets

Once one or more samples have been imported as a dataset, properties that will impact the display of the subsequent contribution in histograms can be modified by using the `set` command. For instance, a dataset named `defaultset` can be imported as

```
import <path-to-sample> as defaultset
```

and its properties can be modified by typing in

```
set defaulset.<property> = <value>
```

The list of available properties is given in the table below, together with the allowed values.

Symbol	Description
backcolor	Background color in a histogram. The available colors are `auto`, `black`, `blue`, `cyan`, `green`, `grey`, `none` (transparent), `orange`, `purple`, `red`, `white` and `yellow`. The color can be made lighter or darker by adding an explicit ± 1, ± 2 or ± 3.
backstyle	Background texture in a histogram. The available values are `dline` (diagonal-lines), `dotted` (dots), `hline` (horizontal lines), `solid` (uniform color) and `vline` (vertical lines).
linecolor	Color of the histogram lines. The available colors are the same as for the `backcolor` attribute.
linestyle	Style of the histogram lines. The available values are `dash-dotted`, `dashed`, `dotted` and `solid`.
linewidth	Width of the histogram lines, given as an integer smaller than 10.
title	Name of the dataset (for histogram legends).
type	`background` or `signal` nature of a given sample (for figure-of-merit calculations).
weight	Reweights each histogram entry with a constant factor. The value has to be a floating-point number.
weighted_events	Allows MadAnalysis 5 to ignore the weights of the events (property to be set to `true` or `false`).
xsection	This overwrites the event sample cross section. The value has to be given in pb.

8 Using FastJet through MadAnalysis 5

In order to activate the usage of FastJet through MadAnalysis 5, the program has to be started in the reconstructed mode and the first command to be typed in the interpreter has to be

```
set main.fastsim.package = fastjet
```

This allows for various option of the `main.fastsim` object, tuning the properties of the jet algorithm that has to be employed. Those options are set by typing in

```
set main.fastsim.<property> = <value>
```

the list of all available properties being presented, together with the allowed values, in the following table.

Symbol	Description
`algorithm`	Sets up the jet algorithm to use. The allowed values are `antikt` [3], `Cambridge` [7,11], `cdfjetclu` [1], `cdfmidpoint` [2], `genkt` [4], `gridjet` [4], `kt` [5,8], `none` and `siscone` [10].
`areafraction`	Controls the size of the cones in the CDF midpoint algorithm.
`exclusive_id`	Exclusive mode for jet reconstruction. If set to `false`, electrons muons and photons issued from hadron decays are included into the electron, muon and photon collections respectively.
`input_ptmin`	Soft protojet threshold in the siscone algorithm.
`iratch`	Switching on ratcheting for the CDF jet clustering algorithm.
`npassmax`	Number of iterations in the siscone algorithm.
`overlap`	Fraction of overlapping momentum used to combine protojets in the siscone and CDF reconstruction algorithms.
`p`	p parameter of the generalized k_T algorithm.
`ptmin`	Threshold for the transverse momentum of the reconstructed jets.
`radius`	Radius parameter relevant for most jet clustering algorithms.
`seed`	Threshold parameter used in the constituent merging procedure of the CDF reconstruction algorithms.
`spacing`	Grid spacing in the grid jet algorithm.
`ymax`	Maximum rapidity value in the grid jet algorithm.

In addition, basic detector simulation effects can be mimicked through setting up the parameters included in the table below.

Symbol	Description
`bjet_id.efficiency`	b-tagging efficiency, as a float.
`bjet_id.exclusive`	Allows several b-jets to be issued from a single B-hadron.
`bjet_id.matching_dr`	Angular distance parameter matching a b-jet with a B-hadron.
`bjet_id.misid_cjet`	Mistagging rate of a c-jet as a b-jet, as a float.
`bjet_id.misid_ljet`	Mistagging rate of a light jet as a b-jet, as a float.
`tau_id.efficiency`	Tau-tagging efficiency, as a float.
`tau_id.misid_ljet`	Mistagging rate of a light jet as a hadronic tau, as a float.

9 Using Delphes through MadAnalysis 5

In order to activate the usage of Delphes through MadAnalysis 5, the program has to be started in the reconstructed mode and the first command to be typed in the interpreter has to be

```
set main.fastsim.package = delphes
```

The properties of the simulation of the detector can then be adjusted through

```
set main.fastsim.<property> = <value>
```

the allowed choices being given in the table below.

Symbol	Description
detector	Determines which detector card to use. The card can be further modified on run time).
output	Saves the output ROOT file (true or false).
rootfile	Name of the output file.
pileup	Specifies the path to the input pile-up event file.
skim_genparticles	If set to true, the generator-level particles are not stored in the output file.
skim_tracks	If set to true, the track collection is not stored in the output file.
skim_towers	If set to true, the collection of calorimetric towers is not stored in the output file.
skim_eflow	If set to true, the collection of particle-flow towers is not stored in the output file.

10 Multipartonic matrix element merging

MADANALYSIS 5 can be used to double check the merging procedure of event samples related to a given hard process but with matrix elements featuring a different final-state jet multiplicity. MADANALYSIS 5 has to be started in the hadronic mode, and the check is then performed by typing in

```
set main.merging.check = true
```

Two extra options are available,

```
set main.merging.ma5_mode = <true or false>
set main.merging.njets = <integer>
```

the first one indicating to extract the number of extra hard jets from the process identifier, and the second one setting up the maximum number of extra jets to consider.

References

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