
cabinetry

cabinetry developers

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CORE CONCEPTS

1.1 Inputs to cabinetry: ntuples or histograms

`cabinetry` supports two types of input files when building a workspace: ntuples containing columnar data and histograms. When using ntuple inputs, `cabinetry` needs to know not only where to find the input files for every template histogram it needs to build, but also what selections to apply, which column to extract and how to weight every event. The configuration schema lists the required options, see [Configuration schema](#) for more information. Less information is required when using histogram inputs: only the path to each histogram needs to be specified in this case.

1.1.1 Input file path specification for ntuples

Paths to ntuple input files for histogram production are specified with the mandatory `InputPath` setting in the `General` config section. If everything is in one file, the value should be the path to this file. It is common to have multiple input files, split across phase space regions or samples. For this purpose, the `InputPath` value can take two placeholders: `{RegionPath}` and `{SamplePath}`.

RegionPath

When building histograms for a specific region, the `{RegionPath}` placeholder takes the value specified in the `RegionPath` setting of the corresponding region. The value of `RegionPath` has to be a string.

SamplePath

The `{SamplePath}` placeholder takes the value given by `SamplePath` of the sample currently processed. This value can either be a string or a list of strings. If it is a list, multiple copies of `InputPath` are created, and in each of them the `{SamplePath}` placeholder takes the value of a different entry in the list. All input files are processed, and their contributions are summed together. The histogram created by `SamplePath: ["a.root", "b.root"]` is equivalent to the histogram created with `SamplePath: "a_plus_b.root"`, where `a_plus_b.root` is produced by merging both files.

Systematics

It is possible to specify overrides for the `RegionPath` and `SamplePath` values in systematic templates. If those settings are specified in the Up or Down template section of a systematic uncertainty, then the corresponding values are used when building the path to the file used to construct the histogram for this specific template.

An example

The following configuration file excerpt shows an example of specifying paths to input files.

```
General:
  InputPath: "inputs/{RegionPath}/{SamplePath}"

Regions:
- Name: "Signal_region"
  RegionPath: "signal_region"

- Name: "Control_region"
  RegionPath: "control_region"

Samples:
- Name: "Data"
  SamplePath: "data.root"

- Name: "Signal"
  SamplePath: ["signal_1.root", "signal_2.root"]

Systematics:
- Name: "Signal_modeling"
  Up:
    SamplePath: "modeling_variation_up.root"
  Down:
    SamplePath: "modeling_variation_down.root"
  Samples: "Signal"
```

The following files will be read to create histograms:

- for *Signal_region*:
 - Data: inputs/signal_region/data.root
 - Signal: inputs/signal_region/signal_1.root, inputs/signal_region/signal_2.root
 - * systematic uncertainty:
 - up: inputs/signal_region/modeling_variation_up.root
 - down: inputs/signal_region/modeling_variation_down.root
- for *Control_region*:
 - Data: inputs/control_region/data.root
 - Signal: inputs/control_region/signal_1.root, inputs/control_region/signal_2.root
 - * systematic uncertainty:
 - up: inputs/control_region/modeling_variation_up.root

· *down*: inputs/control_region/modeling_variation_down.root

1.1.2 Input file path specification for histograms

The specification of paths to histograms works very similarly to the ntuple case. The `InputPath` setting in the `General` config section is still mandatory. It can again take placeholders: `{RegionPath}`, `{SamplePath}`, and `{VariationPath}`. The `VariationPath` setting will default to an empty string if not specified, but it can be set to another value (such as "nominal") in the `General` block.

A major difference to the ntuple path construction is that the histogram path needs to not only include the path to the file containing a given histogram, but also to the histogram within the file. This is achieved by using a colon `:` to distinguish between both parts of the path: `folder/file.root:abc/h1` points to a histogram called `h1` located in a folder called `abc` which itself exists within a file called `file.root` which can be found in a folder called `folder`.

When using histogram inputs, use `cabinetry.templates.collect` instead of `cabinetry.templates.build` (which is used for ntuple inputs).

RegionPath

This works in the same way as it does for ntuples: the `RegionPath` setting in each region sets the value for the `{RegionPath}` placeholder. Note that the value cannot be overridden on a per-systematic basis in the histogram case.

SamplePath

The `SamplePath` setting sets the value for the `{SamplePath}` placeholder. In contrast to the ntuple case, this value cannot be a list of strings.

VariationPath

Each systematic template can set the value for the `{VariationPath}` placeholder via the `VariationPath` setting. The `RegionPath` setting cannot be overridden.

An example

The following shows an example, similar to the ntuple example.

```
General:
  InputPath: "inputs/{RegionPath}.root:{SamplePath}_{VariationPath}"
  VariationPath: "nominal"

Regions:
- Name: "Signal_region"
  RegionPath: "signal_region"

- Name: "Control_region"
  RegionPath: "control_region"

Samples:
- Name: "Data"
  SamplePath: "data"
```

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```
- Name: "Signal"
  SamplePath: "signal"

Systematics:
- Name: "Signal_modeling"
  Up:
    VariationPath: "modeling_variation_up"
  Down:
    VariationPath: "modeling_variation_down"
  Samples: "Signal"
```

The following histograms will be read:

- for *Signal_region*:
 - *Data*: inputs/signal_region.root:data_nominal
 - *Signal*: inputs/signal_region.root:signal_nominal
 - * systematic uncertainty:
 - *up*: inputs/signal_region.root:signal_modeling_variation_up
 - *down*: inputs/signal_region:signal_modeling_variation_down
- for *Control_region*:
 - *Data*: inputs/control_region.root:data_nominal
 - *Signal*: inputs/control_region.root:signal_nominal
 - * systematic uncertainty:
 - *up*: inputs/control_region.root:signal_modeling_variation_up
 - *down*: inputs/control_region:signal_modeling_variation_down

ADVANCED CONCEPTS

2.1 Accessing vector branches

The transverse momentum of the first jet in a vector branch `jet_pT` is obtained via `jet_pT[0]` in ROOT. The uproot backend for ntuple reading treats expressions (such as what is written in `Filter` and `Weight` configuration file options) as Python code. The correct way to access the same information through `cabinetry` is `jet_pT[:,0]`, where the first index runs over events.

2.2 Overrides for template building

2.2.1 Introduction

It is possible to define functions that are called when `cabinetry` tries to construct a template histogram. Such functions need to accept four arguments in the following order:

- a dictionary with information about the region being processed,
- a dictionary with information about the sample being processed,
- a dictionary with information about the systematic being processed,
- the template being considered: a string "Up" / "Down" for variations, or None for the nominal template.

The function needs to return a `boost-histogram Histogram`. This histogram is then further processed in `cabinetry`.

2.2.2 Example

The example below defines a function `build_data_hist`. The decorator specifies that this function should be applied to all histograms for samples with name `ttbar`. It is also possible to specify `region_name`, `systematic_name` and `template` for the names of the region, systematic and template. Not specifying these options means not restricting the applicability of the function. When no user-defined function matches a given histogram that has to be produced, `cabinetry` falls back to use the default histogram creation methods.

```
from typing import Optional

import boost_histogram as bh
import numpy as np
import cabinetry

my_router = cabinetry.route.Router()
```

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```
# define a custom template builder function that is executed for data samples
@my_router.register_template_builder(sample_name="ttbar")
def build_data_hist(
    region: dict, sample: dict, systematic: dict, template: Optional[str]
) -> bh.Histogram:
    hist = bh.Histogram(
        bh.axis.Variable(region["Binning"], underflow=False, overflow=False),
        storage=bh.storage.Weight(),
    )
    yields = np.asarray([17, 12, 25, 20])
    variance = np.asarray([1.5, 1.2, 1.8, 1.6])
    hist[...] = np.stack([yields, variance], axis=-1)
    return hist

cabinetry.templates.build(
    cabinetry_config, method="uproot", router=my_router
)
```

The instance of `cabinetry.route.Router` is handed to `cabinetry.templates.build` to enable the use of `build_data_hist`.

The function `build_data_hist` in this example always returns the same histogram. Given that the dictionaries in the function signature provide additional information, it is for example possible to return different yields per region:

```
if region["Name"] == "Signal_region":
    yields = np.asarray([17, 12, 25, 20])
elif region["Name"] == "Background_region":
    yields = np.asarray([102, 121, 138, 154])
```

2.2.3 Wildcards and multiple requirements

It is also possible to use wildcards to specify which templates a function should be applied to. The implementation currently makes use of `fnmatch`. The following decorator

```
@my_router.register_template_builder(sample_name="ttbar_*")
```

means that the function will for example be applied if the sample name is `ttbar_ljets` or `ttbar_dil`, but not if it is `single_top`. All conditions need to be fulfilled to apply a user-defined function, so

```
@my_router.register_template_builder(
    region_name="signal_region",
    sample_name="signal",
    systematic="alpha_S",
    template="",
)
```

means that for the decorated function to be executed, the region name needs to be `signal_region`, the sample needs to be called `signal`, the systematic needs to be `alpha_S`, but there is no restriction to the template name.

Since `template` can be a string or `None`, its behavior is slightly different:

- `template=""` is the default, and means that any histogram matches (nominal, as well as variations),

- `template=None` matches only nominal histograms,
- `template=string`, where `string` is any string other than `"*"`, can never match the nominal template, but could match the systematic variations called "Up" and "Down".

2.3 Fixed parameters

The `cabinetry` configuration file contains the `Fixed` option (in the `General` group of options), which allows for the creation of a workspace with parameters set to be constant.

```
Fixed:
- Name: par_a
  Value: 2
- Name: par_b
  Value: 1
```

The same can be written in a more compact way:

```
Fixed: [{"Name": "par_a", "Value": 2}, {"Name": "par_b", "Value": 1}]
```

The associated `pyhf` workspace will contain the following:

```
{
  "measurements": [
    {
      "config": {
        "parameters": [
          {"fixed": true, "inits": [2], "name": "par_a"},
          {"fixed": true, "inits": [1], "name": "par_b"}
        ]
      }
    }
  ]
}
```

Fixed parameters are not allowed to vary in fits. Both their pre-fit and post-fit uncertainty are set to zero. This means that the associated nuisance parameters do not contribute to uncertainty bands in data/MC visualizations either. The impact of such parameters on the parameter of interest (for nuisance parameter ranking) is also zero.

2.4 Manually correlating systematics

Systematic uncertainties are correlated if the modifiers defining them in the `pyhf` workspace have the same names. The example below shows a modifier called `correlated_modifier`, correlated between two samples in a workspace.

```
[
  {
    "data": [25.0],
    "modifiers": [
      {
        "data": {"hi": 1.05, "lo": 0.95},
        "name": "correlated_modifier",
```

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```

        "type": "normsys"
      }
    ],
    "name": "Signal"
  },
  {
    "data": [55.0],
    "modifiers": [
      {
        "data": {"hi": 1.05, "lo": 0.95},
        "name": "correlated_modifier",
        "type": "normsys"
      }
    ],
    "name": "Background"
  }
]

```

The names of modifiers written to the workspace are by default picked up from the name of the associated systematic in the `cabinetry` configuration. Names of systematics in the configuration need to be unique, so it is not possible to define multiple systematics with the same name. Instead, the option `ModifierName` can be used to specify the name of the associated modifier(s) used in the workspace:

```

Systematics:
- Name: "first_systematic"
  Up:
    Normalization: 0.05
  Down:
    Normalization: -0.05
  Type: "Normalization"
  Samples: "Signal"
  ModifierName: "correlated_modifier"

- Name: "second_systematic"
  Up:
    Normalization: 0.05
  Down:
    Normalization: -0.05
  Type: "Normalization"
  Samples: "Background"
  ModifierName: "correlated_modifier"

```

This results in a workspace like the example shown above. Without `ModifierName`, the two modifiers would be uncorrelated and called *first_systematic* and *second_systematic*.

In this simple example, the following settings result in the same workspace:

```

Systematics:
- Name: "correlated_modifier"
  Up:
    Normalization: 0.05
  Down:
    Normalization: -0.05

```

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Type: "Normalization"**Samples:** ["Signal", "Background"]

The approach of manually correlating different systematics however allows to define systematics in different ways (e.g. different normalization effect per sample), while still keeping them correlated.

Internally, `cabinetry` refers to systematics by their unique name up until the workspace building stage. For statistical inference, information contained in the workspace is used and thus the original systematics names are replaced by the values set in `ModifierName` (if that option is used).

CONFIGURATION SCHEMA

The configuration schema for `cabinetry` is given below. It is defined via a `json schema` that can be found at <src/cabinetry/schemas/config.json>.

The `General` block holds general settings, followed by blocks that take lists of objects: `regions`, `samples`, `normalization factors`, and `systematics`. The `Regions`, `Samples` and `NormFactors` blocks are required, while `Systematics` is optional. Settings shown in bold are required.

3.1 General

general settings
<i>General settings</i>

3.2 Regions

list of regions	
type	<i>array</i>
items	a region <i>Region</i>
minItems	1
uniqueItems	True

3.3 Samples

list of samples	
type	<i>array</i>
items	a sample <i>Sample</i>
minItems	1
uniqueItems	True

3.4 NormFactors

list of normalization factors	
type	<i>array</i>
items	a normalization factor <i>NormFactor</i>
minItems	1
uniqueItems	True

3.5 Systematics

list of systematics	
type	<i>array</i>
items	a systematic uncertainty <i>Systematic</i>
minItems	0
uniqueItems	True

3.6 Details about the setting blocks:

3.6.1 General settings

general settings	
type	<i>object</i>
properties	
• Measurement	name of measurement
	type <i>string</i>
• POI	name of parameter of interest, defaults to empty string
	type <i>string</i>
• InputPath	path to input files
	type <i>string</i>
• Histogram-Folder	folder to save histograms to and read histograms from
	type <i>string</i>
• Fixed	list of parameters to treat as constant in fits
	type <i>array</i>
	items
	a fixed parameter
	type <i>object</i>
	properties
	• Name
	name of fixed parameter
	type <i>string</i>
	• Value
	value to fix parameter to
	type <i>number</i>
	additionalProperties <i>False</i>
	minItems <i>1</i>
	uniqueItems <i>True</i>
• VariationPath	(part of) path to file containing variation (for histogram inputs), defaults to empty string
	type <i>string</i>
additionalProperties	<i>False</i>

3.6.2 Region

a region of phase space		
required: Name + Variable + Binning (for ntuple inputs), Name (for histogram inputs)		
type	<i>object</i>	
properties		
• Name	name of the region	
	type	<i>string</i>
• Variable	variable to bin in	
	type	<i>string</i>
• Binning	binning to use in histograms	
	type	<i>array</i>
	items	bins
		type <i>number</i>
	minItems	2
	uniqueItems	True
• Filter	selection criteria to apply	
	type	<i>string</i>
• RegionPath	(part of) path to file containing region	
	type	<i>string</i>
additionalProperties	False	

3.6.3 Sample

a sample of a specific process or data		
required: Name + Tree (for ntuple inputs), Name (for histogram inputs)		
type	<i>object</i>	
properties		
• Name	name of the sample	
	type	<i>string</i>
• Tree	name of tree	
	type	<i>string</i>
• Filter	selection criteria to apply (override for region setting)	
	type	<i>string</i>
• Weight	weight to apply to events	
	type	<i>string</i>
• SamplePath	(part of) path(s) to input file(s)	
	SamplePath setting	
• Data	if it is a data sample	
	type	<i>boolean</i>
• DisableStaterror	whether to disable the automatic inclusion of staterror modifiers for this sample, defaults to False	
	type	<i>boolean</i>
• Regions	region(s) that contain the sample, defaults to all regions	
	Regions setting	
additionalProperties	False	

3.6.4 NormFactor

a normalization factor affecting one or more samples		
type	<i>object</i>	
properties		
• Name	name of the normalization factor	
	type	<i>string</i>
• Regions	region(s) that contain the normfactor, defaults to all regions	
	<i>Regions setting</i>	
• Samples	affected sample(s), defaults to all samples	
	<i>Sample setting</i>	
• Nominal	nominal value	
	type	<i>number</i>
• Bounds	lower and upper bound	
	type	<i>array</i>
	items	bounds
		type <i>number</i>
	maxItems	2
	minItems	2
	uniqueItems	True
additionalProperties	False	

3.6.5 Systematic

a systematic uncertainty		
type	<i>object</i>	
properties		
• Name	name of the systematic uncertainty	
	type	<i>string</i>
• Type	type of systematic uncertainty	
	type	<i>string</i>
	enum	Normalization, NormPlusShape
• Up	template for “up” variation	
	<i>Template</i>	
• Down	template for “down” variation	
	<i>Template</i>	
• Regions	region(s) that contain the systematic, defaults to all regions	
	<i>Regions setting</i>	
• Samples	affected sample(s), defaults to all samples	
	<i>Sample setting</i>	
• Smoothing	smoothing to apply	
	<i>Smoothing setting</i>	
• ModifierName	name of modifier in workspace, defaults to value set by Name	
	type	<i>string</i>
additionalProperties	False	

3.7 Common options:

3.7.1 Template

a systematic template (up/down)	
type	<i>object</i>
properties	
• Tree	name of tree (override for nominal setting)
	type <i>string</i>
• Weight	weight to apply (override for nominal setting)
	type <i>string</i>
• Variable	variable to bin in (override for nominal setting)
	type <i>string</i>
• Filter	selection criteria to apply (override for region / sample setting)
	type <i>string</i>
• RegionPath	(part of) path to file containing region (override for nominal setting)
	type <i>string</i>
• SamplePath	(part of) path(s) to input file(s) (override for nominal setting)
	<i>SamplePath setting</i>
• Normalization	normalization uncertainty to apply
	type <i>number</i>
• Symmetrize	whether to apply symmetrization
	type <i>boolean</i>
• VariationPath	(part of) path to file containing variation (for histogram inputs, override for general setting)
	type <i>string</i>
additionalProperties	False

3.7.2 Sample setting

name(s) of affected sample(s)	
oneOf	single affected sample
	type <i>string</i>
	multiple affected samples
	type <i>array</i>
	items
	single affected sample
	type <i>string</i>
	minItems 1
	uniqueItems True

3.7.3 SamplePath setting

path(s) to input file(s) for histogram production		
a list of paths is only supported for ntuple inputs		
oneOf	path to single file	
	type	<i>string</i>
	list of paths	
	type	<i>array</i>
	items	path to single file
		type <i>string</i>
	minItems	1
	uniqueItems	True

3.7.4 Regions setting

name(s) of region(s)		
oneOf	single region	
	type	<i>string</i>
	list of regions	
	type	<i>array</i>
	items	single region
		type <i>string</i>
	minItems	1
	uniqueItems	True

3.7.5 Smoothing setting

smoothing settings for template histograms		
type	<i>object</i>	
properties		
• Algorithm	name of smoothing algorithm to use	
	type	<i>string</i>
	enum	353QH, twice
• Regions	regions to apply smoothing in	
	Regions setting	
• Samples	sample(s) to apply smoothing to, defaults to all samples	
	Sample setting	
additionalProperties	False	

After installing `cabinetry`, a command line interface is available. Below is an example workflow that builds template histograms defined by the config file `config_example.yml`, and applies post-processing to them. A `pyhf` workspace is then constructed and a maximum likelihood fit is performed. The resulting correlation matrix and pull plot are saved to the default output folder `figures/`.

```
cabinetry templates config_example.yml
cabinetry postprocess config_example.yml
cabinetry workspace config_example.yml workspaces/example_workspace.json
cabinetry fit --pulls --corrmat workspaces/example_workspace.json
```

The `--help` flag can be used to obtain more information on the command line:

```
cabinetry --help
```

shows the available commands, while

```
cabinetry fit --help
```

shows what the `fit` command does, and which options it accepts.

It is possible to read the `cabinetry` config and workspaces from `stdin`, and to write workspaces to `stdout`:

```
# read config from stdin
cat config_example.yml | cabinetry workspace - workspaces/example_workspace.json
# read workspace from stdin
cat workspaces/example_workspace.json | cabinetry fit -
# write workspace to stdout
cabinetry workspace config_example.yml -
```

4.1 cabinetry

Entrypoint to the `cabinetry` CLI.

```
cabinetry [OPTIONS] COMMAND [ARGS]...
```

Options

--version

Show the version and exit.

4.1.1 data-mc

Visualizes distributions of fit model and observed data.

WS_SPEC: path to workspace

```
cabinetry data-mc [OPTIONS] WS_SPEC
```

Options

--config <config>

cabinetry configuration file

--postfit

visualize post-fit model (default: pre-fit model)

--figfolder <figfolder>

folder to save figures to (default: “figures”)

Arguments

WS_SPEC

Required argument

4.1.2 fit

Fits a workspace and optionally visualizes the results.

WS_SPEC: path to workspace used in fit

```
cabinetry fit [OPTIONS] WS_SPEC
```

Options

--asimov

fit Asimov dataset (default: False)

--minos <minos>

run MINOS for a parameter (default: disabled)

--goodness_of_fit

calculate goodness-of-fit (default: False)

--pulls

produce pull plot (default: False)

--corrmat
produce correlation matrix (default: False)

--figfolder <figfolder>
folder to save figures to (default: “figures”)

Arguments

WS_SPEC
Required argument

4.1.3 limit

Calculates upper limits and visualizes CLs distribution.

WS_SPEC: path to workspace used in fit

```
cabinetry limit [OPTIONS] WS_SPEC
```

Options

--asimov
fit Asimov dataset (default: False)

--tolerance <tolerance>
tolerance for convergence to CLs=1-confidence_level (default: 0.01)

--confidence_level, --cl <confidence_level>
confidence level for parameter limits (default: 0.95)

--figfolder <figfolder>
folder to save figures to (default: “figures”)

Arguments

WS_SPEC
Required argument

4.1.4 modifier-grid

Visualizes modifier structure of a model.

WS_SPEC: path to workspace

```
cabinetry modifier-grid [OPTIONS] WS_SPEC
```

Options

- split_by_sample**
split grids by sample (default: split by channel)
- figfolder** <figfolder>
folder to save figures to (default: “figures”)

Arguments

- WS_SPEC**
Required argument

4.1.5 postprocess

Post-processes template histograms.

CONFIG: path to cabinetry configuration file

```
cabinetry postprocess [OPTIONS] CONFIG
```

Arguments

- CONFIG**
Required argument

4.1.6 ranking

Ranks nuisance parameters and visualizes the result.

WS_SPEC: path to workspace used in fit

```
cabinetry ranking [OPTIONS] WS_SPEC
```

Options

- asimov**
fit Asimov dataset (default: False)
- max_pars** <max_pars>
maximum amount of parameters in plot (default: 10)
- figfolder** <figfolder>
folder to save figures to (default: “figures”)

Arguments

WS_SPEC

Required argument

4.1.7 scan

Performs and visualizes a likelihood scan over a parameter.

Parameter bounds are determined automatically, unless both the `lower_bound` and `upper_bound` parameters are provided.

WS_SPEC: path to workspace used in fit

PAR_NAME: name of parameter to scan over

```
cabinetry scan [OPTIONS] WS_SPEC PAR_NAME
```

Options

--lower_bound <lower_bound>

lower parameter bound in scan (default: auto)

--upper_bound <upper_bound>

upper parameter bound in scan (default: auto)

--n_steps <n_steps>

number of steps in scan (default: 11)

--asimov

fit Asimov dataset (default: False)

--figfolder <figfolder>

folder to save figures to (default: "figures")

Arguments

WS_SPEC

Required argument

PAR_NAME

Required argument

4.1.8 significance

Calculates observed and expected discovery significance.

WS_SPEC: path to workspace used in fit

```
cabinetry significance [OPTIONS] WS_SPEC
```

Options

--asimov

fit Asimov dataset (default: False)

Arguments

WS_SPEC

Required argument

4.1.9 templates

Produces template histograms.

CONFIG: path to cabinetry configuration file

```
cabinetry templates [OPTIONS] CONFIG
```

Options

--method <method>

backend for histogram production (default: uproot)

Arguments

CONFIG

Required argument

4.1.10 workspace

Produces a pyhf workspace.

CONFIG: path to cabinetry configuration file

WS_SPEC: where to save the workspace containing the fit model

```
cabinetry workspace [OPTIONS] CONFIG WS_SPEC
```

Arguments

CONFIG

Required argument

WS_SPEC

Required argument

4.1.11 yields

Creates yield tables of fit model and observed data.

WS_SPEC: path to workspace

```
cabinetry yields [OPTIONS] WS_SPEC
```

Options

--postfit

show post-fit model (default: pre-fit model)

--tablefolder <tablefolder>

folder to save tables to (default: “tables”)

--tablefmt <tablefmt>

format in which to save the table (default: “simple”)

Arguments

WS_SPEC

Required argument

- *cabinetry.configuration*
- *cabinetry.route*
- *cabinetry.histo*
- *cabinetry.templates*
 - *cabinetry.templates.builder*
 - *cabinetry.templates.collector*
 - *cabinetry.templates.postprocessor*
 - *cabinetry.templates.utils*
- *cabinetry.workspace*
- *cabinetry.fit*
 - *cabinetry.fit.results_containers*
- *cabinetry.visualize*
 - *cabinetry.visualize.plot_model*
 - *cabinetry.visualize.plot_result*
 - *cabinetry.visualize.utils*
- *cabinetry.tabulate*
- *cabinetry.model_utils*
- *cabinetry.smooth*
- *cabinetry.contrib*
 - *cabinetry.contrib.histogram_creator*
 - *cabinetry.contrib.histogram_reader*

5.1 cabinetry.configuration

Provides utilities to handle the cabinetry configuration.

`cabinetry.configuration.histogram_is_needed`(*region*: *Dict*[*str*, *Any*], *sample*: *Dict*[*str*, *Any*], *systematic*: *Dict*[*str*, *Any*], *template*: *Literal*['Up', 'Down'] | *None*) → *bool*

Determines whether a histogram is needed for a specific configuration.

The configuration is defined by the region, sample, systematic and template (“Up” or “Down”, None for nominal).

Parameters

- **region** (*Dict*[*str*, *Any*]) – containing all region information
- **sample** (*Dict*[*str*, *Any*]) – containing all sample information
- **systematic** (*Dict*[*str*, *Any*]) – containing all systematic information
- **template** (*Optional*[*Literal*["Up", "Down"]]) – which template to consider: “Up”, “Down”, None for the nominal case

Raises

NotImplementedError – non-supported systematic variations based on histograms are requested

Returns

whether a histogram is needed

Return type

bool

`cabinetry.configuration.load`(*file_path_string*: *str* | *Path*) → *Dict*[*str*, *Any*]

Loads, validates, and returns a config file from the provided path.

Parameters

file_path_string (*Union*[*str*, *pathlib.Path*]) – path to config file

Returns

cabinetry configuration

Return type

Dict[*str*, *Any*]

`cabinetry.configuration.print_overview`(*config*: *Dict*[*str*, *Any*]) → *None*

Prints a compact summary of a config file.

Parameters

config (*Dict*[*str*, *Any*]) – cabinetry configuration

`cabinetry.configuration.region_contains_modifier`(*region*: *Dict*[*str*, *Any*], *modifier*: *Dict*[*str*, *Any*]) → *bool*

Checks if a region contains a given modifier (Systematic, NormFactor).

A modifier affects all regions by default, and its “Regions” property can be used to specify a single region or list of regions that contain the modifier. This does not check whether the modifier only acts on samples which the region does not contain.

Parameters

- **region** (*Dict*[*str*, *Any*]) – containing all region information

- **modifier** (*Dict[str, Any]*) – containing all modifier information (a Systematic or a NormFactor)

Returns

True if region contains modifier, False otherwise

Return type

bool

`cabinetry.configuration.region_contains_sample(region: Dict[str, Any], sample: Dict[str, Any]) → bool`

Checks if a region contains a given sample.

A sample enters all regions by default, and its “Regions” property can be used to specify a single region or list of regions that contain the sample.

Parameters

- **region** (*Dict[str, Any]*) – containing all region information
- **sample** (*Dict[str, Any]*) – containing all sample information

Returns

True if region contains sample, False otherwise

Return type

bool

`cabinetry.configuration.region_dict(config: Dict[str, Any], region_name: str) → Dict[str, Any]`

Returns the dictionary for a region with the given name.

Parameters

- **config** (*Dict[str, Any]*) – cabinetry configuration file
- **region_name** (*str*) – name of region

Raises

ValueError – when region is not found in config

Returns

dictionary describing region

Return type

Dict[str, Any]

`cabinetry.configuration.sample_contains_modifier(sample: Dict[str, Any], modifier: Dict[str, Any]) → bool`

Checks if a sample is affected by a given modifier (Systematic, NormFactor).

A modifier affects all samples by default, and its “Samples” property can be used to specify a single sample or list of samples on which the modifier acts.

Parameters

- **sample** (*Dict[str, Any]*) – containing all sample information
- **modifier** (*Dict[str, Any]*) – containing all modifier information (a Systematic or a NormFactor)

Returns

True if sample is affected, False otherwise

Return type

bool

`cabinetry.configuration.validate(config: Dict[str, Any]) → bool`

Returns True if the config file is validated, otherwise raises exceptions.

Checks that the config satisfies the json schema, and performs additional checks to validate the config further.

Parameters

config (Dict[str, Any]) – cabinetry configuration

Raises

- **NotImplementedError** – when more than one data sample is found
- **ValueError** – when region / sample / normfactor / systematic names are not unique

Returns

whether the validation was successful

Return type

bool

5.2 cabinetry.route

Provides features to apply functions to template histograms.

class `cabinetry.route.Router`

Holds user-defined processing functions and matches functions to templates.

Provides functions for matching a pattern to apply the right function to each template.

template_builders

user-defined processors for template building

Type

List[Dict[str, Any]]

template_builder_wrapper

wrapper to apply on user- defined template builders

Type

Optional[WrapperFunc]

register_template_builder(* , region_name: str = '*', sample_name: str = '*', systematic_name: str = '*', template: str | None = '*') → Callable[[Callable[[Dict[str, Any], Dict[str, Any], Dict[str, Any], str | None], Histogram]], Callable[[Dict[str, Any], Dict[str, Any], Dict[str, Any], Dict[str, Any], str | None], Histogram]]

Decorator for registering a template builder function.

The function is added to the list stored in the `template_builders` member variable.

Parameters

- **region_name** (str, optional) – name of the region to apply the function to, defaults to "*" (apply to all regions)
- **sample_name** (str, optional) – name of the sample to apply the function to, defaults to "*" (apply to all samples)
- **systematic_name** (str, optional) – name of the systematic to apply the function to, defaults to "*" (apply to all systematics)

- **template** (*Optional[str], optional*) – name of the template to apply the function to (e.g. “Up” or “Down”), or None to apply to nominal only, defaults to “*” (apply to all templates, including nominal)

Returns

the function to register a processor

Return type

Callable[[UserTemplateFunc], UserTemplateFunc]

```
cabinetry.route.apply_to_all_templates(config: Dict[str, Any], default_func: Callable[[Dict[str, Any],
Dict[str, Any], Dict[str, Any], Literal['Up', 'Down'] | None],
None], *, match_func: Callable[[str, str, str, Literal['Up', 'Down']]
| None], Callable[[Dict[str, Any], Dict[str, Any], Dict[str, Any],
Literal['Up', 'Down'] | None], None] | None] | None = None) →
None
```

Applies the supplied function `default_func` to all templates.

The templates are specified by the configuration file. The function takes four arguments in this order:

- the dict specifying region information
- the dict specifying sample information
- the dict specifying systematic information
- the template being considered: “Up”, “Down”, or None for the nominal template

In addition it is possible to specify a function that returns custom overrides. If one is found for a given template, it is used instead of the default.

Parameters

- **config** (*Dict[str, Any]*) – cabinetry configuration
- **default_func** (*ProcessorFunc*) – function to be called for every template by default
- **match_func** – (*Optional[MatchFunc], optional*): function that returns user-defined functions to override the call to `default_func`, defaults to None (then it is not used)

5.3 cabinetry.histo

Provides a histogram class based on boost-histogram.

```
class cabinetry.histo.Histogram(*axes: Axis | CppAxis | Histogram | Any, storage: Storage = Double(),
metadata: Any = None)
```

Holds histogram information, extends `boost_histogram.Histogram`.

property bins: ndarray

Returns the bin edges.

Returns

bin edges

Return type

np.ndarray

classmethod from_arrays(*bins: List[float] | ndarray, yields: List[float] | ndarray, stdev: List[float] | ndarray*) → H

Constructs a histogram from arrays of yields and uncertainties.

The input can be lists of ints or floats, or numpy.ndarrays.

Parameters

- **bins** (*Union[List[float], np.ndarray]*) – edges of histogram bins
- **yields** (*Union[List[float], np.ndarray]*) – yield per histogram bin
- **stdev** (*Union[List[float], np.ndarray]*) – statistical uncertainty of yield per bin

Raises

- **ValueError** – when amount of bins specified via bin edges and bin contents do not match
- **ValueError** – when length of yields and stdev do not match

Returns

the histogram instance

Return type

cabinetry.histo.Histogram

classmethod from_config(*histo_folder: str | Path, region: Dict[str, Any], sample: Dict[str, Any], systematic: Dict[str, Any], *, template: Literal['Up', 'Down'] | None = None, modified: bool = True*) → H

Loads a histogram, using information specified in the configuration file.

To find the histogram, need to provide the folder the histogram is located in and the relevant information from the config: region, sample, systematic, template.

Parameters

- **histo_folder** (*Union[str, pathlib.Path]*) – folder containing all histograms
- **region** (*Dict[str, Any]*) – containing all region information
- **sample** (*Dict[str, Any]*) – containing all sample information
- **systematic** (*Dict[str, Any]*) – containing all systematic information
- **template** (*Optional[Literal["Up", "Down"]], optional*) – which template to consider: “Up”, “Down”, None for the nominal case, defaults to None
- **modified** (*bool, optional*) – whether to load the modified histogram (after post-processing), defaults to True

Returns

the loaded histogram

Return type

cabinetry.histo.Histogram

classmethod from_path(*histo_path: Path, *, modified: bool = True*) → H

Builds a histogram from disk.

Loads the “modified” version of the histogram by default (which received post- processing).

Parameters

- **histo_path** (*pathlib.Path*) – where the histogram is located

- **modified** (*bool, optional*) – whether to load the modified histogram (after post-processing), defaults to True

Returns

the loaded histogram

Return type

cabinetry.histo.Histogram

normalize_to_yield(*reference_histogram: H*) → float

Normalizes a histogram to match the yield of a reference.

Returns the normalization factor used to normalize the histogram.

Parameters

reference_histogram (*cabinetry.histo.Histogram*) – reference histogram to normalize to

Returns

the yield ratio: un-normalized yield / normalized yield

Return type

float

save(*histo_path: Path*) → None

Saves a histogram to disk.

Parameters

histo_path (*pathlib.Path*) – where to save the histogram

property stdev: ndarray

Returns the stat. uncertainty per histogram bin.

Returns

stat. uncertainty per bin

Return type

np.ndarray

validate(*name: str*) → None

Runs consistency checks on a histogram.

Checks for empty bins and ill-defined statistical uncertainties. Logs warnings if issues are founds, but does not raise exceptions.

Parameters

name (*str*) – name of the histogram for logging purposes

property yields: ndarray

Returns the yields per histogram bin.

Returns

yields per bin

Return type

np.ndarray

cabinetry.histo.name(*region: Dict[str, Any], sample: Dict[str, Any], systematic: Dict[str, Any], *, template: Literal['Up', 'Down'] | None = None*) → str

Returns a unique name for each histogram.

If the template is not None, the systematic is required to have a name (guaranteed as long as it follows the config schema).

Parameters

- **region** (*Dict[str, Any]*) – containing all region information
- **sample** (*Dict[str, Any]*) – containing all sample information
- **systematic** (*Dict[str, Any]*) – containing all systematic information
- **template** (*Optional[Literal["Up", "Down"]]*, *optional*) – which template to consider: “Up”, “Down”, None for the nominal case, defaults to None

Returns

unique name for the histogram

Return type

str

5.4 cabinetry.templates

High-level entry point to create, collect and post-process template histograms.

`cabinetry.templates.build(config: Dict[str, Any], *, method: str = 'uproot', router: Router | None = None) → None`

Produces all required histograms specified by the configuration file.

Inputs to the histogram production are ntuples containing columnar data. Uses either a default method specified via `method`, or a custom user-defined override through `router`.

Parameters

- **config** (*Dict[str, Any]*) – cabinetry configuration
- **method** (*str*, *optional*) – backend to use for histogram production, defaults to “uproot”
- **router** (*Optional[Router]*, *optional*) – instance of `cabinetry.route.Router` that contains user-defined overrides, defaults to None

`cabinetry.templates.collect(config: Dict[str, Any], *, method: str = 'uproot') → None`

Collects all required histograms specified by the configuration file.

Histograms must already exist, and this collects and saves them in the format used for further processing. If no default for `VariationPath` is specified in the general settings, it defaults to an empty string.

Parameters

- **config** (*Dict[str, Any]*) – cabinetry configuration
- **method** (*str*, *optional*) – backend to use for histogram production, defaults to “uproot”

`cabinetry.templates.postprocess(config: Dict[str, Any]) → None`

Applies postprocessing to all histograms.

Parameters

config (*Dict[str, Any]*) – cabinetry configuration

5.4.1 `cabinetry.templates.builder`

Creates required template histograms from columnar data.

5.4.2 `cabinetry.templates.collector`

Collects required template histograms provided by user.

5.4.3 `cabinetry.templates.postprocessor`

Applies optional post-processing to template histograms.

`cabinetry.templates.postprocessor.apply_postprocessing`(*histogram*: `Histogram`, *name*: `str`, *,
smoothing_algorithm: `str` | `None` = `None`,
nominal_histogram: `Histogram` | `None` =
`None`) → `Histogram`

Returns a new histogram with post-processing applied.

The histogram handed to the function stays unchanged. A copy of the histogram receives post-processing and is then returned. The postprocessing consists of a fix for NaN statistical uncertainties and optional smoothing.

Parameters

- **histogram** (`cabinetry.histo.Histogram`) – the histogram to postprocess
- **name** (`str`) – histogram name for logging
- **smoothing_algorithm** (`Optional[str]`) – name of smoothing algorithm to apply, defaults to `None` (no smoothing done)
- **nominal_histogram** (`Optional[cabinetry.histo.Histogram]`) – nominal histogram (needed for smoothing), defaults to `None`

Returns

the histogram with post-processing applied

Return type

`cabinetry.histo.Histogram`

5.4.4 `cabinetry.templates.utils`

Provides utilities for template histogram handling.

5.5 `cabinetry.workspace`

Constructs HistFactory workspaces in JSON format.

class `cabinetry.workspace.WorkspaceBuilder`(*config*: `Dict[str, Any]`)

Collects functionality to build a pyhf workspace.

build() → `Dict[str, Any]`

Constructs a *HistFactory* workspace in pyhf format.

Returns

pyhf-compatible *HistFactory* workspace

Return type

Dict[str, Any]

channels() → List[Dict[str, Any]]

Returns the channel information: yields per sample and modifiers.

Returns

channels for pyhf workspace

Return type

List[Dict[str, Any]]

measurements() → List[Dict[str, Any]]

Returns the measurements object for the workspace.

Constructs the measurements, including POI setting and parameter bounds, initial values and whether they are set to constant. Only supports a single measurement so far.

Returns

measurements for pyhf workspace

Return type

List[Dict[str, Any]]

static normalization_modifier(*systematic: Dict[str, Any]*) → Dict[str, Any]Returns a normalization modifier (OverallSys in *HistFactory*).**Parameters****systematic** (*Dict[str, Any]*) – systematic for which modifier is constructed**Returns**single *normsys* modifier for pyhf workspace**Return type**

Dict[str, Any]

normfactor_modifiers(*region: Dict[str, Any]*, *sample: Dict[str, Any]*) → List[Dict[str, Any]]

Returns the list of NormFactor modifiers acting on a sample in a region.

Parameters

- **region** (*Dict[str, Any]*) – specific region to get NormFactor modifiers for
- **sample** (*Dict[str, Any]*) – specific sample to get NormFactor modifiers for

Returns

NormFactor modifiers for sample

Return type

List[Dict[str, Any]]

normplusshape_modifiers(*region: Dict[str, Any]*, *sample: Dict[str, Any]*, *systematic: Dict[str, Any]*) → List[Dict[str, Any]]

Returns modifiers for a correlated shape + normalization effect.

For a variation including a correlated shape + normalization effect, this provides the *histosys* and *normsys* modifiers for pyhf (in *HistFactory* language, this corresponds to a *HistoSys* and an *OverallSys*). Symmetrization could happen either at this stage (this is the case currently), or somewhere earlier, such as during template postprocessing. A *histosys* modifier is not created for single-bin channels, as it has no effect in this case (everything is handled by the *normsys* modifier already).

Parameters

- **region** (*Dict[str, Any]*) – region the systematic variation acts in
- **sample** (*Dict[str, Any]*) – sample the systematic variation acts on
- **systematic** (*Dict[str, Any]*) – the systematic variation under consideration

Raises

ValueError – when both up and down variation specify symmetrization

Returns

a list with a *pyhf norms* modifier and a *histosys* modifier

Return type

List[Dict[str, Any]]

observations() → List[Dict[str, Any]]

Returns the observations object (with data yields) for the workspace.

Returns

observations for pyhf workspace

Return type

List[Dict[str, Any]]

sys_modifiers(*region: Dict[str, Any], sample: Dict[str, Any]*) → List[Dict[str, Any]]

Returns the list of all systematic modifiers acting on a sample in a region.

Parameters

- **region** (*Dict[str, Any]*) – region considered
- **sample** (*Dict[str, Any]*) – specific sample to get modifiers for

Raises

NotImplementedError – when unsupported modifiers act on sample

Returns

modifiers for pyhf workspace

Return type

List[Dict[str, Any]]

cabinetry.workspace.build(*config: Dict[str, Any], *, with_validation: bool = True*) → Dict[str, Any]

Returns a *HistFactory* workspace in pyhf format.

Parameters

- **config** (*Dict[str, Any]*) – cabinetry configuration
- **with_validation** (*bool, optional*) – validate workspace validity with pyhf, defaults to True

Returns

pyhf-compatible *HistFactory* workspace

Return type

Dict[str, Any]

cabinetry.workspace.load(*file_path_string: str | Path*) → Dict[str, Any]

Loads a workspace from a file.

Parameters

file_path_string (*Union[str, pathlib.Path]*) – path to the file to load the workspace from

Returns

pyhf-compatible *HistFactory* workspace

Return type

Dict[str, Any]

`cabinetry.workspace.save(ws: Dict[str, Any], file_path_string: str | Path) → None`

Serializes a workspace to a file.

Parameters

- **ws** (Dict[str, Any]) – pyhf-compatible *HistFactory* workspace
- **file_path_string** (Union[str, pathlib.Path]) – path to the file to save the workspace in

`cabinetry.workspace.validate(ws: Dict[str, Any]) → None`

Validates a workspace with pyhf.

Parameters

ws (Dict[str, Any]) – the workspace to validate

5.6 cabinetry.fit

High-level entry point for statistical inference.

`cabinetry.fit.fit(model: Model, data: List[float], *, minos: str | List[str] | Tuple[str, ...] | None = None, goodness_of_fit: bool = False, init_pars: List[float] | None = None, fix_pars: List[bool] | None = None, par_bounds: List[Tuple[float, float]] | None = None, strategy: Literal[0, 1, 2] | None = None, maxiter: int | None = None, tolerance: float | None = None, custom_fit: bool = False) → FitResults`

Performs a maximum likelihood fit, reports and returns the results.

Depending on the `custom_fit` keyword argument, this uses either the `pyhf.infer` API or `iminuit` directly.

Parameters

- **model** (`pyhf.pdf.Model`) – model to use in fit
- **data** (List[float]) – data (including auxdata) the model is fit to
- **minos** (Optional[Union[str, List[str], Tuple[str, ...]]], optional) – runs the MINOS algorithm for all parameters specified, defaults to None (does not run MINOS)
- **goodness_of_fit** (bool, optional) – calculate goodness of fit with a saturated model (perfectly fits data with shapefactors in all bins), defaults to False
- **init_pars** (Optional[List[float]], optional) – list of initial parameter settings, defaults to None (use pyhf suggested inits)
- **fix_pars** (Optional[List[bool]], optional) – list of booleans specifying which parameters are held constant, defaults to None (use pyhf suggestion)
- **par_bounds** (Optional[List[Tuple[float, float]]], optional) – list of tuples with parameter bounds for fit, defaults to None (use pyhf suggested bounds)
- **strategy** (Optional[Literall[0, 1, 2]], optional) – minimization strategy used by Minuit, can be 0/1/2, defaults to None (then uses pyhf default behavior of strategy 0 with user-provided gradients and 1 otherwise)

- **maxiter** (*Optional[int], optional*) – allowed number of calls for minimization, defaults to None (use pyhf default of 100,000)
- **tolerance** (*Optional[float], optional*) – tolerance for convergence, for details see `iminuit.Minuit.tol` (uses $\text{EDM} < 0.002 \cdot \text{tolerance}$), defaults to None (use `iminuit` default of 0.1)
- **custom_fit** (*bool, optional*) – whether to use the `pyhf.infer` API or `iminuit`, defaults to False (using `pyhf.infer`)

Returns

object storing relevant fit results

Return type

FitResults

`cabinetry.fit.limit(model: Model, data: List[float], *, bracket: List[float] | Tuple[float, float] | None = None, poi_tolerance: float = 0.01, maxsteps: int = 100, confidence_level: float = 0.95, poi_name: str | None = None, init_pars: List[float] | None = None, fix_pars: List[bool] | None = None, par_bounds: List[Tuple[float, float]] | None = None, strategy: Literal[0, 1, 2] | None = None, maxiter: int | None = None, tolerance: float | None = None) → LimitResults`

Calculates observed and expected upper parameter limits.

Limits are calculated for the parameter of interest (POI) defined in the model. Brent's algorithm is used to automatically determine POI values to be tested. The desired confidence level can be configured, and defaults to 95%. In order to support setting the POI directly without model recompilation, this temporarily changes the POI in the model configuration.

Parameters

- **model** (*pyhf.pdf.Model*) – model to use in fits
- **data** (*List[float]*) – data (including auxdata) the model is fit to
- **bracket** (*Optional[Union[List[float], Tuple[float, float]]], optional*) – the two POI values used to start the observed limit determination, the limit must lie between these values and the values must not be the same, defaults to None (then uses 0.1 as default lower value and the upper POI bound specified in the measurement as default upper value)
- **poi_tolerance** (*float, optional*) – tolerance in POI value for convergence to target CLs value ($1 - \text{confidence_level}$), defaults to 0.01
- **maxsteps** (*int, optional*) – maximum number of steps for limit finding, defaults to 100
- **confidence_level** (*float, optional*) – confidence level for calculation, defaults to 0.95 (95%)
- **poi_name** (*Optional[str], optional*) – limit is calculated for this parameter, defaults to None (use POI specified in workspace)
- **init_pars** (*Optional[List[float]], optional*) – list of initial parameter settings, defaults to None (use pyhf suggested inits)
- **fix_pars** (*Optional[List[bool]], optional*) – list of booleans specifying which parameters are held constant, defaults to None (use pyhf suggestion)
- **par_bounds** (*Optional[List[Tuple[float, float]]], optional*) – list of tuples with parameter bounds for fit, defaults to None (use pyhf suggested bounds)
- **strategy** (*Optional[Literall[0, 1, 2]], optional*) – minimization strategy used by Minuit, can be 0/1/2, defaults to None (then uses pyhf default behavior of strategy 0 with user-provided gradients and 1 otherwise)

- **maxiter** (*Optional[int], optional*) – allowed number of calls for minimization, defaults to None (use pyhf default of 100,000)
- **tolerance** (*Optional[float], optional*) – tolerance for convergence, for details see `iminuit.Minuit.tol` (uses $\text{EDM} < 0.002 \times \text{tolerance}$), defaults to None (use `iminuit` default of 0.1)

Raises

- **ValueError** – if no POI is found
- **ValueError** – if lower and upper bracket value are the same
- **ValueError** – if starting brackets do not enclose the limit

Returns

observed and expected limits, CLs values, and scanned points

Return type

LimitResults

`cabinetry.fit.print_results(fit_results: FitResults) → None`

Prints the best-fit parameter results and associated uncertainties.

Parameters with zero uncertainty (those held fixed in the fit) are in addition denoted with “(constant)”.

Parameters

fit_results (*FitResults*) – results of fit to be printed

`cabinetry.fit.ranking(model: Model, data: List[float], *, fit_results: FitResults | None = None, poi_name: str | None = None, init_pars: List[float] | None = None, fix_pars: List[bool] | None = None, par_bounds: List[Tuple[float, float]] | None = None, strategy: Literal[0, 1, 2] | None = None, maxiter: int | None = None, tolerance: float | None = None, custom_fit: bool = False) → RankingResults`

Calculates the impact of nuisance parameters on the parameter of interest (POI).

The impact is given by the difference in the POI between the nominal fit, and a fit where the nuisance parameter is held constant at its nominal value plus/minus its associated uncertainty. The “pre-fit impact” is obtained by varying the nuisance parameters by their uncertainty given by their constraint term.

Parameters

- **model** (*pyhf.pdf.Model*) – model to use in fits
- **data** (*List[float]*) – data (including auxdata) the model is fit to
- **fit_results** (*Optional[FitResults], optional*) – nominal fit results to use for ranking, if not specified will repeat nominal fit, defaults to None
- **poi_name** (*Optional[str], optional*) – impact is calculated with respect to this parameter, defaults to None (use POI specified in workspace)
- **init_pars** (*Optional[List[float]], optional*) – list of initial parameter settings, defaults to None (use pyhf suggested inits)
- **fix_pars** (*Optional[List[bool]], optional*) – list of booleans specifying which parameters are held constant, defaults to None (use pyhf suggestion)
- **par_bounds** (*Optional[List[Tuple[float, float]], optional*) – list of tuples with parameter bounds for fit, defaults to None (use pyhf suggested bounds)
- **strategy** (*Optional[Literall[0, 1, 2]], optional*) – minimization strategy used by Minuit, can be 0/1/2, defaults to None (then uses pyhf default behavior of strategy 0 with user-provided gradients and 1 otherwise)

- **maxiter** (*Optional[int]*, *optional*) – allowed number of calls for minimization, defaults to None (use pyhf default of 100,000)
- **tolerance** (*Optional[float]*), *optional*) – tolerance for convergence, for details see `iminuit.Minuit.tol` (uses $\text{EDM} < 0.002 \cdot \text{tolerance}$), defaults to None (use `iminuit` default of 0.1)
- **custom_fit** (*bool*, *optional*) – whether to use the `pyhf.infer` API or `iminuit`, defaults to False (using `pyhf.infer`)

Raises

ValueError – if no POI is found

Returns

fit results for parameters, and pre- and post-fit impacts

Return type

RankingResults

```
cabinetry.fit.scan(model: Model, data: List[float], par_name: str, *, par_range: Tuple[float, float] | None =
    None, n_steps: int = 11, init_pars: List[float] | None = None, fix_pars: List[bool] | None =
    None, par_bounds: List[Tuple[float, float]] | None = None, strategy: Literal[0, 1, 2] | None
    = None, maxiter: int | None = None, tolerance: float | None = None, custom_fit: bool =
    False) → ScanResults
```

Performs a likelihood scan over the specified parameter.

If no parameter range is specified, center the scan around the best-fit result for the parameter that is being scanned, and scan over twice its uncertainty in each direction. The reported likelihood values are the differences between $-2 \log(L)$ at each point in the scan and the global minimum.

Parameters

- **model** (*pyhf.pdf.Model*) – model to use in fits
- **data** (*List[float]*) – data (including auxdata) the model is fit to
- **par_name** (*str*) – name of parameter to scan over
- **par_range** (*Optional[Tuple[float, float]]*, *optional*) – upper and lower bounds of parameter in scan, defaults to None (automatically determine bounds)
- **n_steps** (*int*, *optional*) – number of steps in scan, defaults to 10
- **init_pars** (*Optional[List[float]]*, *optional*) – list of initial parameter settings, defaults to None (use `pyhf` suggested inits)
- **fix_pars** (*Optional[List[bool]]*, *optional*) – list of booleans specifying which parameters are held constant, defaults to None (use `pyhf` suggestion)
- **par_bounds** (*Optional[List[Tuple[float, float]]]*, *optional*) – list of tuples with parameter bounds for fit, defaults to None (use `pyhf` suggested bounds)
- **strategy** (*Optional[Literal[0, 1, 2]]*, *optional*) – minimization strategy used by Minuit, can be 0/1/2, defaults to None (then uses `pyhf` default behavior of strategy 0 with user-provided gradients and 1 otherwise)
- **maxiter** (*Optional[int]*, *optional*) – allowed number of calls for minimization, defaults to None (use `pyhf` default of 100,000)
- **tolerance** (*Optional[float]*), *optional*) – tolerance for convergence, for details see `iminuit.Minuit.tol` (uses $\text{EDM} < 0.002 \cdot \text{tolerance}$), defaults to None (use `iminuit` default of 0.1)

- **custom_fit** (*bool*, *optional*) – whether to use the `pyhf.infer` API or `iminuit`, defaults to `False` (using `pyhf.infer`)

Raises

ValueError – if parameter is not found in model

Returns

includes parameter name, scanned values and $2 \cdot \log(\text{likelihood})$ offset

Return type

ScanResults

```
cabinetry.fit.significance(model: Model, data: List[float], *, poi_name: str | None = None, init_pars:
    List[float] | None = None, fix_pars: List[bool] | None = None, par_bounds:
    List[Tuple[float, float]] | None = None, strategy: Literal[0, 1, 2] | None = None,
    maxiter: int | None = None, tolerance: float | None = None) →
    SignificanceResults
```

Calculates the discovery significance of a positive signal.

Observed and expected p-values and significances are both calculated and reported.

Parameters

- **model** (*pyhf.pdf.Model*) – model to use in fits
- **data** (*List[float]*) – data (including auxdata) the model is fit to
- **poi_name** (*Optional[str]*, *optional*) – significance is calculated for this parameter, defaults to `None` (use POI specified in workspace)
- **init_pars** (*Optional[List[float]]*, *optional*) – list of initial parameter settings, defaults to `None` (use `pyhf` suggested inits)
- **fix_pars** (*Optional[List[bool]]*, *optional*) – list of booleans specifying which parameters are held constant, defaults to `None` (use `pyhf` suggestion)
- **par_bounds** (*Optional[List[Tuple[float, float]]]*, *optional*) – list of tuples with parameter bounds for fit, defaults to `None` (use `pyhf` suggested bounds)
- **strategy** (*Optional[Literal[0, 1, 2]]*, *optional*) – minimization strategy used by Minuit, can be 0/1/2, defaults to `None` (then uses `pyhf` default behavior of strategy 0 with user-provided gradients and 1 otherwise)
- **maxiter** (*Optional[int]*, *optional*) – allowed number of calls for minimization, defaults to `None` (use `pyhf` default of 100,000)
- **tolerance** (*Optional[float]*, *optional*) – tolerance for convergence, for details see `iminuit.Minuit.tol` (uses $\text{EDM} < 0.002 \cdot \text{tolerance}$), defaults to `None` (use `iminuit` default of 0.1)

Returns

observed and expected p-values and significances

Return type

SignificanceResults

5.6.1 cabinetry.fit.results_containers

Provides containers for inference results.

```
class cabinetry.fit.results_containers.FitResults(bestfit: ndarray, uncertainty: ndarray, labels:  
List[str], corr_mat: ndarray, best_twice_nll: float,  
goodness_of_fit: float = -1, minos_uncertainty:  
Dict[str, Tuple[float, float]] = {})
```

Collects fit results in one object.

Parameters

- **bestfit** (*np.ndarray*) – best-fit results of parameters
- **uncertainty** (*np.ndarray*) – uncertainties of best-fit parameter results, evaluated with Hessian
- **labels** (*List[str]*) – parameter labels
- **corr_mat** (*np.ndarray*) – parameter correlation matrix
- **best_twice_nll** (*float*) – $-2 \log(\text{likelihood})$ at best-fit point
- **goodness_of_fit** (*float, optional*) – goodness-of-fit p-value, defaults to -1
- **minos_uncertainty** (*Dict[str, Tuple[float, float]]*) – uncertainties of best-fit parameter results indexed by parameter name, calculated with MINOS

best_twice_nll: float

Alias for field number 4

bestfit: ndarray

Alias for field number 0

corr_mat: ndarray

Alias for field number 3

goodness_of_fit: float

Alias for field number 5

labels: List[str]

Alias for field number 2

minos_uncertainty: Dict[str, Tuple[float, float]]

Alias for field number 6

uncertainty: ndarray

Alias for field number 1

```
class cabinetry.fit.results_containers.LimitResults(observed_limit: float, expected_limit: ndarray,  
observed_CLs: ndarray, expected_CLs:  
ndarray, poi_values: ndarray, confidence_level:  
float)
```

Collects parameter upper limit results in one object.

Parameters

- **observed_limit** (*float*) – observed limit
- **expected_limit** (*np.ndarray*) – expected limit, including 1 and 2 sigma bands
- **observed_CLs** (*np.ndarray*) – observed CLs values

- **expected_CLs** (*np.ndarray*) – expected CLs values, including 1 and 2 sigma bands
- **poi_values** (*np.ndarray*) – POI values used in scan
- **confidence_level** (*float*) – confidence level used for parameter limits

confidence_level: *float*

Alias for field number 5

expected_CLs: *ndarray*

Alias for field number 3

expected_limit: *ndarray*

Alias for field number 1

observed_CLs: *ndarray*

Alias for field number 2

observed_limit: *float*

Alias for field number 0

poi_values: *ndarray*

Alias for field number 4

class `cabinetry.fit.results_containers.RankingResults`(*bestfit: ndarray, uncertainty: ndarray, labels: List[str], prefit_up: ndarray, prefit_down: ndarray, postfit_up: ndarray, postfit_down: ndarray*)

Collects nuisance parameter ranking results in one object.

The best-fit results per parameter, the uncertainties, and the labels should not include the parameter of interest, since no impact for it is calculated.

Parameters

- **bestfit** (*np.ndarray*) – best-fit results of parameters
- **uncertainty** (*np.ndarray*) – uncertainties of best-fit parameter results
- **labels** (*List[str]*) – parameter labels
- **prefit_up** (*np.ndarray*) – pre-fit impact in “up” direction
- **prefit_down** (*np.ndarray*) – pre-fit impact in “down” direction
- **postfit_up** (*np.ndarray*) – post-fit impact in “up” direction
- **postfit_down** (*np.ndarray*) – post-fit impact in “down” direction

bestfit: *ndarray*

Alias for field number 0

labels: *List[str]*

Alias for field number 2

postfit_down: *ndarray*

Alias for field number 6

postfit_up: *ndarray*

Alias for field number 5

prefit_down: ndarray
Alias for field number 4

prefit_up: ndarray
Alias for field number 3

uncertainty: ndarray
Alias for field number 1

class `cabinetry.fit.results_containers.ScanResults`(*name: str, bestfit: float, uncertainty: float, parameter_values: ndarray, delta_nlls: ndarray*)

Collects likelihood scan results in one object.

Parameters

- **name** (*str*) – name of parameter in scan
- **bestfit** (*float*) – best-fit parameter value from unconstrained fit
- **uncertainty** (*float*) – uncertainty of parameter in unconstrained fit
- **parameter_values** (*np.ndarray*) – parameter values used in scan
- **delta_nlls** (*np.ndarray*) – $-2 \log(L)$ difference at each scanned point

bestfit: float
Alias for field number 1

delta_nlls: ndarray
Alias for field number 4

name: str
Alias for field number 0

parameter_values: ndarray
Alias for field number 3

uncertainty: float
Alias for field number 2

class `cabinetry.fit.results_containers.SignificanceResults`(*observed_p_value: float, observed_significance: float, expected_p_value: float, expected_significance: float*)

Collects results from a discovery significance calculation in one object.

Parameters

- **observed_p_value** (*float*) – observed p-value
- **observed_significance** (*float*) – observed significance
- **expected_p_value** (*float*) – expected/median p-value
- **expected_significance** (*float*) – expected/median significance

expected_p_value: float
Alias for field number 2

expected_significance: float
Alias for field number 3

observed_p_value: float

Alias for field number 0

observed_significance: float

Alias for field number 1

5.7 cabinetry.visualize

High-level entry point for visualizing fit models and inference results.

`cabinetry.visualize.correlation_matrix`(*fit_results*: `FitResults`, *, *figure_folder*: `str` | `Path` = 'figures',
pruning_threshold: `float` = 0.0, *close_figure*: `bool` = `True`,
save_figure: `bool` = `True`) → `Figure`

Draws a correlation matrix.

Parameters

- **fit_results** (*fit.FitResults*) – fit results, including correlation matrix and parameter labels
- **figure_folder** (*Union[str, pathlib.Path]*, *optional*) – path to the folder to save figures in, defaults to “figures”
- **pruning_threshold** (*float*, *optional*) – minimum correlation for a parameter to have with any other parameters to not get pruned, defaults to 0.0
- **close_figure** (*bool*, *optional*) – whether to close figure, defaults to `True`
- **save_figure** (*bool*, *optional*) – whether to save figure, defaults to `True`

Returns

the correlation matrix figure

Return type

`matplotlib.figure.Figure`

`cabinetry.visualize.data_mc`(*model_prediction*: `ModelPrediction`, *data*: `List[float]`, *, *config*: `Dict[str, Any]` | `None` = `None`, *figure_folder*: `str` | `Path` = 'figures', *log_scale*: `bool` | `None` = `None`, *log_scale_x*: `bool` = `False`, *channels*: `str` | `List[str]` | `None` = `None`, *colors*: `Dict[str, str]` | `None` = `None`, *close_figure*: `bool` = `False`, *save_figure*: `bool` = `True`) → `List[Dict[str, Any]]` | `None`

Draws pre- and post-fit data/MC histograms for a pyhf model and data.

The `config` argument is optional, but required to determine correct axis labels and binning. The information is not stored in the model, and default values are used if no `config` is supplied. This allows quickly plotting distributions for models that were not created with `cabinetry`, and for which no `config` exists.

Parameters

- **model_prediction** (`model_utils.ModelPrediction`) – model prediction to show
- **data** (`List[float]`) – data to include in visualization, can either include auxdata (the aux-data is then stripped internally) or only observed yields
- **config** (`Optional[Dict[str, Any]]`, *optional*) – cabinetry configuration needed for binning and axis labels, defaults to `None` (uses a default binning and labels then)
- **figure_folder** (*Union[str, pathlib.Path]*, *optional*) – path to the folder to save figures in, defaults to “figures”

- **log_scale** (*Optional[bool]*, *optional*) – whether to use logarithmic vertical axis, defaults to None (automatically determine whether to use linear/log scale)
- **log_scale_x** (*bool*, *optional*) – whether to use logarithmic horizontal axis, defaults to False
- **channels** (*Optional[Union[str, List[str]]]*, *optional*) – name of channel to show, or list of names to include, defaults to None (uses all channels)
- **colors** (*Optional[Dict[str, str]]*, *optional*) – map of sample names and colors to use in plot, defaults to None (uses default colors)
- **close_figure** (*bool*, *optional*) – whether to close each figure, defaults to False (enable when producing many figures to avoid memory issues, prevents automatic rendering in notebooks)
- **save_figure** (*bool*, *optional*) – whether to save figures, defaults to True

Raises

ValueError – if color specification is incomplete

Returns

list of dictionaries, where each dictionary

contains a figure and the associated region name, or None if no figure was produced

Return type

`Optional[List[Dict[str, Any]]]`

```
cabinetry.visualize.data_mc_from_histograms(config: Dict[str, Any], *, figure_folder: str | Path =
    'figures', log_scale: bool | None = None, log_scale_x: bool =
    False, channels: str | List[str] | None = None, colors: Dict[str, str] | None =
    None, close_figure: bool = False, save_figure: bool = True) → List[Dict[str, Any]]
```

Draws pre-fit data/MC histograms, using histograms created by cabinetry.

The uncertainty band drawn includes only statistical uncertainties.

Parameters

- **config** (*Dict[str, Any]*) – cabinetry configuration
- **figure_folder** (*Union[str, pathlib.Path]*, *optional*) – path to the folder to save figures in, defaults to “figures”
- **log_scale** (*Optional[bool]*, *optional*) – whether to use logarithmic vertical axis, defaults to None (automatically determine whether to use linear/log scale)
- **log_scale_x** (*bool*, *optional*) – whether to use logarithmic horizontal axis, defaults to False
- **channels** (*Optional[Union[str, List[str]]]*, *optional*) – name of channel to show, or list of names to include, defaults to None (uses all channels)
- **colors** (*Optional[Dict[str, str]]*, *optional*) – map of sample names and colors to use in plot, defaults to None (uses default colors)
- **close_figure** (*bool*, *optional*) – whether to close each figure, defaults to False (enable when producing many figures to avoid memory issues, prevents automatic rendering in notebooks)
- **save_figure** (*bool*, *optional*) – whether to save figures, defaults to True

Raises

ValueError – if color specification is incomplete

Returns

list of dictionaries, where each dictionary contains a figure and the associated region name

Return type

List[Dict[str, Any]]

`cabinetry.visualize.limit(limit_results: LimitResults, *, figure_folder: str | Path = 'figures', close_figure: bool = True, save_figure: bool = True) → Figure`

Visualizes observed and expected CLs values as a function of the POI.

Parameters

- **limit_results** (*fit.LimitResults*) – results of upper limit determination
- **figure_folder** (*Union[str, pathlib.Path]*, *optional*) – path to the folder to save figures in, defaults to “figures”
- **close_figure** (*bool*, *optional*) – whether to close figure, defaults to True
- **save_figure** (*bool*, *optional*) – whether to save figure, defaults to True

Returns

the CLs figure

Return type

matplotlib.figure.Figure

`cabinetry.visualize.modifier_grid(model: Model, *, figure_folder: str | Path = 'figures', split_by_sample: bool = False, close_figure: bool = True, save_figure: bool = True) → Figure`

Visualizes the modifier structure of a model in a 2d grid.

Parameters

- **model** (*pyhf.pdf.Model*) – model to visualize
- **figure_folder** (*Union[str, pathlib.Path]*, *optional*) – path to the folder to save figures in, defaults to “figures”
- **split_by_sample** (*bool*, *optional*) – whether to use (channel, parameter) grids for each sample, defaults to False (if enabled, uses (sample, parameter) grids for each channel)
- **close_figure** (*bool*, *optional*) – whether to close figure, defaults to True
- **save_figure** (*bool*, *optional*) – whether to save figure, defaults to True

`cabinetry.visualize.pulls(fit_results: FitResults, *, figure_folder: str | Path = 'figures', exclude: str | List[str] | Tuple[str, ...] | None = None, close_figure: bool = True, save_figure: bool = True) → Figure`

Draws a pull plot of parameter results and uncertainties.

Parameters

- **fit_results** (*fit.FitResults*) – fit results, including correlation matrix and parameter labels
- **figure_folder** (*Union[str, pathlib.Path]*, *optional*) – path to the folder to save figures in, defaults to “figures”

- **exclude** (*Optional[Union[str, List[str], Tuple[str, ...]]], optional*) – parameter or parameters to exclude from plot, defaults to None (nothing excluded)
- **close_figure** (*bool, optional*) – whether to close figure, defaults to True
- **save_figure** (*bool, optional*) – whether to save figure, defaults to True

Returns

the pull figure

Return type

matplotlib.figure.Figure

`cabinetry.visualize.ranking(ranking_results: RankingResults, *, figure_folder: str | Path = 'figures', max_pars: int | None = None, close_figure: bool = True, save_figure: bool = True) → Figure`

Produces a ranking plot showing the impact of parameters on the POI.

The parameters are shown in decreasing order of greatest post-fit impact.

Parameters

- **ranking_results** (*fit.RankingResults*) – fit results, and pre- and post-fit impacts
- **figure_folder** (*Union[str, pathlib.Path], optional*) – path to the folder to save figures in, defaults to “figures”
- **max_pars** (*Optional[int], optional*) – number of parameters to include, defaults to None (which means all parameters are included)
- **close_figure** (*bool, optional*) – whether to close figure, defaults to True
- **save_figure** (*bool, optional*) – whether to save figure, defaults to True

Returns

the ranking figure

Return type

matplotlib.figure.Figure

`cabinetry.visualize.scan(scan_results: ScanResults, *, figure_folder: str | Path = 'figures', close_figure: bool = True, save_figure: bool = True) → Figure`

Visualizes the results of a likelihood scan.

Parameters

- **scan_results** (*fit.ScanResults*) – results of a likelihood scan
- **figure_folder** (*Union[str, pathlib.Path], optional*) – path to the folder to save figures in, defaults to “figures”
- **close_figure** (*bool, optional*) – whether to close figure, defaults to True
- **save_figure** (*bool, optional*) – whether to save figure, defaults to True

Returns

the likelihood scan figure

Return type

matplotlib.figure.Figure

`cabinetry.visualize.templates(config: Dict[str, Any], *, figure_folder: str | Path = 'figures', close_figure: bool = False, save_figure: bool = True) → List[Dict[str, Any]]`

Visualizes template histograms (after post-processing) for systematic variations.

The original template histogram for systematic variations (before post-processing) is also included in the visualization.

Parameters

- **config** (*Dict[str, Any]*) – cabinetry configuration
- **figure_folder** (*Union[str, pathlib.Path], optional*) – path to the folder to save figures in, defaults to “figures”
- **close_figure** (*bool, optional*) – whether to close each figure, defaults to False (enable when producing many figures to avoid memory issues, prevents automatic rendering in notebooks)
- **save_figure** (*bool, optional*) – whether to save figures, defaults to True

Returns

list of dictionaries, where each dictionary contains a figure and the associated region / sample / systematic names

Return type

List[Dict[str, Any]]

5.7.1 cabinetry.visualize.plot_model

Visualizes fit models with matplotlib.

`cabinetry.visualize.plot_model.data_mc` (*histogram_dict_list: List[Dict[str, Any]], total_model_unc: ndarray, bin_edges: ndarray, *, figure_path: Path | None = None, log_scale: bool | None = None, log_scale_x: bool = False, label: str = "", colors: Dict[str, str] | None = None, close_figure: bool = False*) → Figure

Draws a data/MC histogram with uncertainty bands and ratio panel.

Uncertainties for data points are drawn using the “Garwood” frequentist coverage interval as provided by `hist` via `hist.intervals.poisson_interval`.

Parameters

- **histogram_dict_list** (*List[Dict[str, Any]]*) – list of samples (with info stored in one dict per sample)
- **total_model_unc** (*np.ndarray*) – total model uncertainty, if specified this is used instead of calculating it via sum in quadrature, defaults to None
- **bin_edges** (*np.ndarray*) – bin edges of histogram
- **figure_path** (*Optional[pathlib.Path], optional*) – path where figure should be saved, or None to not save it, defaults to None
- **log_scale** (*Optional[bool], optional*) – whether to use a logarithmic vertical axis, defaults to None (automatically determine whether to use linear or log scale)
- **log_scale_x** (*bool, optional*) – whether to use logarithmic horizontal axis, defaults to False
- **label** (*str, optional*) – label written on the figure, defaults to “”

- **colors** (*Optional[Dict[str, str]], optional*) – map of sample names and colors to use in plot, defaults to None (uses default colors)
- **close_figure** (*bool, optional*) – whether to close each figure immediately after saving it, defaults to False (enable when producing many figures to avoid memory issues, prevents rendering in notebooks)

Raises

ValueError – when total model yield is negative in any bin

Returns

the data/MC figure

Return type

matplotlib.figure.Figure

`cabinetry.visualize.plot_model.modifier_grid(grid_list: List[ndarray], axis_labels: List[List[str]], category_map: Dict[int, str], figure_path: Path | None = None, close_figure: bool = False) → Figure`

Draws a grid of modifiers per channel, sample and parameter.

Parameters

- **grid_list** (*List[np.ndarray]*) – list of 2d grids with modifier information
- **axis_labels** (*List[List[str]]*) – list with axis labels for the three axes in order (first axis is grid label, second and third are axes per grid)
- **category_map** (*Dict[int, str]*) – translation of integer values in grid to labels
- **figure_path** (*Optional[pathlib.Path], optional*) – path where figure should be saved, or None to not save it, defaults to None
- **close_figure** (*bool, optional*) – whether to close each figure immediately after saving it, defaults to False (enable when producing many figures to avoid memory issues, prevents rendering in notebooks)

`cabinetry.visualize.plot_model.templates(nominal_histo: Dict[str, ndarray], up_histo_orig: Dict[str, ndarray], down_histo_orig: Dict[str, ndarray], up_histo_mod: Dict[str, ndarray], down_histo_mod: Dict[str, ndarray], bin_edges: ndarray, variable: str, *, figure_path: Path | None = None, label: str = "", close_figure: bool = False) → Figure`

Draws a nominal template and the associated up/down variations.

If a variation template is an empty dict, it is not drawn.

Parameters

- **nominal_histo** (*Dict[str, np.ndarray]*) – the nominal template
- **up_histo_orig** (*Dict[str, np.ndarray]*) – original “up” variation
- **down_histo_orig** (*Dict[str, np.ndarray]*) – original “down” variation
- **up_histo_mod** (*Dict[str, np.ndarray]*) – “up” variation after post-processing
- **down_histo_mod** (*Dict[str, np.ndarray]*) – “down” variation after post-processing
- **bin_edges** (*np.ndarray*) – bin edges of histogram
- **variable** (*str*) – variable name for the horizontal axis
- **figure_path** (*Optional[pathlib.Path], optional*) – path where figure should be saved, or None to not save it, defaults to None

- **label** (*str*, *optional*) – label written on the figure, defaults to “”
- **close_figure** (*bool*, *optional*) – whether to close each figure immediately after saving it, defaults to False (enable when producing many figures to avoid memory issues, prevents rendering in notebooks)

Returns

the template figure

Return type

matplotlib.figure.Figure

5.7.2 cabinetry.visualize.plot_result

Visualizes inference results with matplotlib.

`cabinetry.visualize.plot_result.correlation_matrix`(*corr_mat: ndarray*, *labels: List[str] | ndarray*, *, *figure_path: Path | None = None*, *close_figure: bool = False*) → Figure

Draws a correlation matrix.

Parameters

- **corr_mat** (*np.ndarray*) – the correlation matrix to plot
- **labels** (*Union[List[str], np.ndarray]*) – names of parameters in the correlation matrix
- **figure_path** (*Optional[pathlib.Path]*, *optional*) – path where figure should be saved, or None to not save it, defaults to None
- **close_figure** (*bool*, *optional*) – whether to close each figure immediately after saving it, defaults to False (enable when producing many figures to avoid memory issues, prevents rendering in notebooks)

Returns

the correlation matrix figure

Return type

matplotlib.figure.Figure

`cabinetry.visualize.plot_result.limit`(*observed_CLs: ndarray*, *expected_CLs: ndarray*, *poi_values: ndarray*, *cls_target: float*, *, *figure_path: Path | None = None*, *close_figure: bool = False*) → Figure

Draws observed and expected CLs values as function of the parameter of interest.

Parameters

- **observed_CLs** (*np.ndarray*) – observed CLs values
- **expected_CLs** (*np.ndarray*) – expected CLs values, including 1 and 2 sigma bands
- **poi_values** (*np.ndarray*) – parameter of interest values used in scan
- **cls_target** (*float*) – target CLs value to visualize as horizontal line
- **figure_path** (*Optional[pathlib.Path]*, *optional*) – path where figure should be saved, or None to not save it, defaults to None
- **close_figure** (*bool*, *optional*) – whether to close each figure immediately after saving it, defaults to False (enable when producing many figures to avoid memory issues, prevents rendering in notebooks)

Returns

the CLs figure

Return type

matplotlib.figure.Figure

`cabinetry.visualize.plot_result.pulls`(*bestfit: ndarray, uncertainty: ndarray, labels: List[str] | ndarray, *, figure_path: Path | None = None, close_figure: bool = False*) → Figure

Draws a pull plot.

Parameters

- **bestfit** (*np.ndarray*) – best-fit parameter results
- **uncertainty** (*np.ndarray*) – parameter uncertainties
- **labels** (*Union[List[str], np.ndarray]*) – parameter names
- **figure_path** (*Optional[pathlib.Path]*, *optional*) – path where figure should be saved, or None to not save it, defaults to None
- **close_figure** (*bool*, *optional*) – whether to close each figure immediately after saving it, defaults to False (enable when producing many figures to avoid memory issues, prevents rendering in notebooks)

Returns

the pull figure

Return type

matplotlib.figure.Figure

`cabinetry.visualize.plot_result.ranking`(*bestfit: ndarray, uncertainty: ndarray, labels: List[str] | ndarray, impact_prefit_up: ndarray, impact_prefit_down: ndarray, impact_postfit_up: ndarray, impact_postfit_down: ndarray, *, figure_path: Path | None = None, close_figure: bool = False*) → Figure

Draws a ranking plot.

Parameters

- **bestfit** (*np.ndarray*) – best-fit parameter results
- **uncertainty** (*np.ndarray*) – parameter uncertainties
- **labels** (*Union[List[str], np.ndarray]*) – parameter labels
- **impact_prefit_up** (*np.ndarray*) – pre-fit impact in “up” direction per parameter
- **impact_prefit_down** (*np.ndarray*) – pre-fit impact in “down” direction per parameter
- **impact_postfit_up** (*np.ndarray*) – post-fit impact in “up” direction per parameter
- **impact_postfit_down** (*np.ndarray*) – post-fit impact in “down” direction per parameter
- **figure_path** (*Optional[pathlib.Path]*, *optional*) – path where figure should be saved, or None to not save it, defaults to None
- **close_figure** (*bool*, *optional*) – whether to close each figure immediately after saving it, defaults to False (enable when producing many figures to avoid memory issues, prevents rendering in notebooks)

Returns

the ranking figure

Return type

matplotlib.figure.Figure

`cabinetry.visualize.plot_result.scan`(*par_name*: str, *par_mle*: float, *par_unc*: float, *par_vals*: ndarray, *par_nlls*: ndarray, *, *figure_path*: Path | None = None, *close_figure*: bool = False) → Figure

Draws a figure showing the results of a likelihood scan.

Parameters

- **par_name** (str) – name of parameter used in scan
- **par_mle** (float) – best-fit result for parameter
- **par_unc** (float) – best-fit parameter uncertainty
- **par_vals** (np.ndarray) – values used in scan over parameter
- **par_nlls** (np.ndarray) – $-2 \log(L)$ offset at each scan point
- **figure_path** (Optional[pathlib.Path], optional) – path where figure should be saved, or None to not save it, defaults to None
- **close_figure** (bool, optional) – whether to close each figure immediately after saving it, defaults to False (enable when producing many figures to avoid memory issues, prevents rendering in notebooks)

Returns

the likelihood scan figure

Return type

matplotlib.figure.Figure

5.7.3 cabinetry.visualize.utils

Provides visualization utilities.

5.8 cabinetry.tabulate

Creates yield tables.

`cabinetry.tabulate.yields`(*model_prediction*: ModelPrediction, *data*: List[float], *, *channels*: str | List[str] | None = None, *per_bin*: bool = True, *per_channel*: bool = False, *table_folder*: str | Path = 'tables', *table_format*: str = 'simple', *save_tables*: bool = True) → Dict[str, List[Dict[str, Any]]]

Generates yield tables, showing model prediction and data.

Channels can be filtered via the optional `channels` argument. Either yields per bin, or yields per channel, or both can be shown.

Parameters

- **model_prediction** (model_utils.ModelPrediction) – model prediction to show in table
- **data** (List[float]) – data to include in table, can either include auxdata (the auxdata is then stripped internally) or only observed yields

- **channels** (*Optional[Union[str, List[str]]], optional*) – name of channel to show, or list of names to include, defaults to None (uses all channels)
- **per_bin** (*bool, optional*) – whether to show a table with yields per bin, defaults to True
- **per_channel** (*bool, optional*) – whether to show a table with yields per channel, defaults to False
- **table_folder** (*Union[str, pathlib.Path], optional*) – path to the folder to save tables in, defaults to “tables”
- **table_format** (*str, optional*) – format in which to save the tables, can be any of the formats `tabulate` supports (e.g. html, latex, plain, simple, tsv), defaults to “simple”
- **save_tables** (*bool, optional*) – whether to save tables, defaults to True

Returns

dictionary with yield tables for use with the `tabulate` package

Return type

`Dict[str, List[Dict[str, Any]]]`

5.9 cabinetry.model_utils

Provides utilities for pyhf models.

```
class cabinetry.model_utils.ModelPrediction(model: Model, model_yields: List[List[List[float]]],
                                             total_stdev_model_bins: List[List[List[float]]],
                                             total_stdev_model_channels: List[List[float]], label: str)
```

Model prediction with yields and total uncertainties per bin and channel.

Parameters

- **model** (*pyhf.pdf.Model*) – model to which prediction corresponds to
- **model_yields** (*List[List[List[float]]]*) – yields per channel, sample and bin, indices: channel, sample, bin
- **total_stdev_model_bins** (*List[List[List[float]]]*) – total yield uncertainty per channel, sample and bin, indices: channel, sample, bin (last sample: sum over samples)
- **total_stdev_model_channels** (*List[List[float]]*) – total yield uncertainty per channel and sample, indices: channel, sample (last sample: sum over samples)
- **label** (*str*) – label for the prediction, e.g. “pre-fit” or “post-fit”

label: `str`

Alias for field number 4

model: `Model`

Alias for field number 0

model_yields: `List[List[List[float]]]`

Alias for field number 1

total_stdev_model_bins: `List[List[List[float]]]`

Alias for field number 2

total_stdev_model_channels: `List[List[float]]`

Alias for field number 3

`cabinetry.model_utils.asimov_data(model: Model, *, fit_results: FitResults | None = None, poi_name: str | None = None, poi_value: float | None = None, include_auxdata: bool = True) → List[float]`

Returns the Asimov dataset (optionally with auxdata) for a model.

Initial parameter settings for normalization factors in the workspace are treated as the default settings for that parameter. Fitting the Asimov dataset will recover these initial settings as the maximum likelihood estimate for normalization factors. Initial settings for other modifiers are ignored. If the `fit_results` keyword argument is used, the Asimov dataset is built to recover the fit results given when fitted again.

Parameters

- **model** (*pyhf.Model*) – the model from which to construct the dataset
- **fit_results** (*Optional[FitResults]*, *optional*) – parameter configuration to use when building the Asimov dataset (using the best-fit result), defaults to `None` (then a pre-fit Asimov dataset is built)
- **poi_name** (*Optional[str]*, *optional*) – name of parameter to set to a custom value via `poi_value`, defaults to `None` (use POI specified in workspace)
- **poi_value** (*Optional[float]*, *optional*) – custom value to set POI specified via `poi_name` to, defaults to `None` (no custom value set)
- **include_auxdata** (*bool*, *optional*) – whether to also return auxdata, defaults to `True`

Returns

the Asimov dataset

Return type

`List[float]`

`cabinetry.model_utils.asimov_parameters(model: Model) → ndarray`

Returns a list of Asimov parameter values for a model.

For normfactors and shapfactors, initial parameter settings (specified in the workspace) are treated as nominal settings. This ignores custom auxiliary data set in the measurement configuration in the workspace.

Parameters

model (*pyhf.pdf.Model*) – model for which to extract the parameters

Returns

the Asimov parameters, in the same order as `model.config.suggested_init()`

Return type

`np.ndarray`

`cabinetry.model_utils.match_fit_results(model: Model, fit_results: FitResults) → FitResults`

Matches results from a fit to a model by adding or removing parameters as needed.

If the fit results contain parameters missing in the model, these parameters are not included in the returned fit results. If the fit results do not include parameters used in the model, they are added to the fit results. The best-fit value for such parameters are the Asimov values as returned by `asimov_parameters` (initial parameter settings for unconstrained parameters), and the associated uncertainties as given by `prefit_uncertainties` (zero uncertainty for unconstrained or fixed parameters). These parameters furthermore are assumed to have no correlation with any other parameters. If required, parameters are re-ordered to match the target model.

Parameters

- **model** (*pyhf.pdf.Model*) – model to match fit results to
- **fit_results** (*FitResults*) – fit results to be updated in order to match model

Returns

fit results matching the model

Return type

FitResults

`cabinetry.model_utils.model_and_data(spec: Dict[str, Any], *, asimov: bool = False, include_auxdata: bool = True) → Tuple[Model, List[float]]`

Returns model and data for a pyhf workspace specification.

Parameters

- **spec** (*Dict[str, Any]*) – a pyhf workspace specification
- **asimov** (*bool, optional*) – whether to return the Asimov dataset, defaults to False
- **include_auxdata** (*bool, optional*) – whether to also return auxdata, defaults to True

Returns

- a HistFactory-style model in pyhf format
- the data (plus auxdata if requested) for the model

Return type

`Tuple[pyhf.pdf.Model, List[float]]`

`cabinetry.model_utils.prediction(model: Model, *, fit_results: FitResults | None = None, label: str | None = None) → ModelPrediction`

Returns model prediction, including model yields and uncertainties.

If the optional fit result is not provided, the pre-fit Asimov yields and uncertainties are calculated. If the fit result is provided, the best-fit parameter values, uncertainties, and the parameter correlations are used to obtain the post-fit model and its associated uncertainties.

Parameters

- **model** (*pyhf.pdf.Model*) – model to evaluate yield prediction for
- **fit_results** (*Optional[FitResults], optional*) – parameter configuration to use, includes best-fit settings and uncertainties, as well as correlation matrix, defaults to None (then the pre-fit configuration is used)
- **label** (*Optional[str], optional*) – label to include in model prediction, defaults to None (then will use “pre-fit” if fit results are not included, and “post-fit” otherwise)

Returns

model, yields and uncertainties per channel, sample, bin

Return type

ModelPrediction

`cabinetry.model_utils.prefit_uncertainties(model: Model) → ndarray`

Returns a list of pre-fit parameter uncertainties for a model.

For unconstrained parameters the uncertainty is set to 0. It is also set to 0 for fixed parameters (similarly to how the post-fit uncertainties are defined to be 0).

Parameters

model (*pyhf.pdf.Model*) – model for which to extract the parameters

Returns

pre-fit uncertainties for the parameters, in the same order as `model.config.suggested_init()`

Return type

np.ndarray

cabinetry.model_utils.**unconstrained_parameter_count**(model: Model) → int

Returns the number of unconstrained parameters in a model.

The number is the sum of all independent parameters in a fit. A shapefactor that affects multiple bins enters the count once for each independent bin. Parameters that are set to constant are not included in the count.

Parameters**model** (*pyhf.pdf.Model*) – model to count parameters for**Returns**

number of unconstrained parameters

Return type

int

cabinetry.model_utils.**yield_stdev**(model: Model, parameters: ndarray, uncertainty: ndarray, corr_mat: ndarray) → Tuple[List[List[List[float]]], List[List[float]]]

Calculates symmetrized model yield standard deviation per channel / sample / bin.

Returns both the uncertainties per bin (in a list of channels and samples), and the uncertainty of the total yield per channel (again, for a list of channels and samples). To calculate the uncertainties for the total yield per channel, the function internally treats the sum of yields per channel like another channel with one bin. Similarly, the sum over samples is treated as another sample. The results of this function are cached to speed up subsequent calls with the same arguments.

Parameters

- **model** (*pyhf.pdf.Model*) – the model for which to calculate the standard deviations for all bins
- **parameters** (*np.ndarray*) – central values of model parameters
- **uncertainty** (*np.ndarray*) – uncertainty of model parameters
- **corr_mat** (*np.ndarray*) – correlation matrix

Returns

- list of channels, each channel is a list of samples, and each sample a list of standard deviations per bin (the last sample corresponds to a sum over all samples)
- list of standard deviations per channel, each channel is a list containing the standard deviations per sample (the last sample corresponds to a sum over all samples)

Return type

Tuple[List[List[List[float]]], List[List[float]]]

5.10 cabinetry.smooth

Implements histogram smoothing algorithms.

cabinetry.smooth.**smooth_353qh_twice**(hist: T) → T

Runs the 353QH algorithm twice and returns smooth version of the input.

For documentation see these proceedings <https://cds.cern.ch/record/186223/> on page 292. The algorithm runs twice to avoid over-smoothing peaks and valleys. The algorithm is not aware of statistical uncertainties per entry in the array. See also <https://root.cern.ch/doc/master/classTH1.html#aeb935cae10dbf9cd484bee1b6a549f83> for the ROOT implementation.

Parameters**hist** (*Union[list, np.ndarray]*) – array to smooth**Returns**

smooth version of input

Return type*Union[list, np.ndarray]*

5.11 cabinetry.contrib

Basic implementations of functionality that can be provided by external tools.

5.11.1 cabinetry.contrib.histogram_creator

Creates histograms from ntuples with uproot.

`cabinetry.contrib.histogram_creator.with_uproot`(*ntuple_paths: List[Path], pos_in_file: str, variable: str, bins: ndarray, *, weight: str | None = None, selection_filter: str | None = None*) → Histogram

Reads an ntuple with uproot, fills and returns a histogram with the observable.

The paths may contain wildcards.

Parameters

- **ntuple_paths** (*List[pathlib.Path]*) – list of paths to ntuples
- **pos_in_file** (*str*) – name of tree within ntuple
- **variable** (*str*) – variable to bin histogram in
- **bins** (*np.ndarray*) – bin edges for histogram
- **weight** (*Optional[str], optional*) – event weight to extract, defaults to None (no weights applied)
- **selection_filter** (*Optional[str], optional*) – filter to be applied on events, defaults to None (no filter)

Returns

histogram containing data

Return type*bh.Histogram*

5.11.2 cabinetry.contrib.histogram_reader

Reads histograms with uproot.

`cabinetry.contrib.histogram_reader.with_uproot`(*histo_path: str*) → Histogram

Reads a histogram with uproot and returns it.

Parameters

histo_path (*str*) – path to histogram, use a colon to distinguish between path to file and path to histogram within file (example: `file.root:h1`)

Returns

histogram containing data

Return type

bh.Histogram

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cabinetry is a Python library for building and steering binned template fits. It interfaces many other libraries to make it easy for an analyzer to run their statistical inference pipeline.

This documentation can be viewed [on Read the Docs](#) or locally via

```
sphinx-build docs docs/_build
open docs/_build/index.html
```

See the [README on github](#) for a simple example of using cabinetry, and the [cabinetry-tutorials](#) repository for a more in-depth version.

PRESENTATIONS OF CABINETRY

- vCHEP 2021
 - short talk: <https://indico.cern.ch/event/948465/contributions/4324154/>
 - associated paper: [10.1051/epjconf/202125103067](https://arxiv.org/abs/10.1051/epjconf/202125103067)
- PyHEP 2021
 - notebook talk: <https://indico.cern.ch/event/1019958/contributions/4421868/>

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