

Elevenes over MadAnalysis 5

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Goal of this tutorial

- How to use Public Analysis Database (PAD) for setting exclusion limits to your new theory
 - ❖ Getting/understanding exclusion limits
 - ❖ Implementing TH uncertainties
 - ❖ HL extrapolations & treating background uncertainties
- Discussion



Prerequisites

- Please download the latest version of MadAnalysis 5 from [this link](#).
- Make sure that following packages are installed;
 - ❖ FastJet (use `install fastjet` command in ma5)
 - ❖ Zlib (use `install zlib` command in ma5)
 - ❖ PADForSFS (use `install PADForSFS` command in ma5)
 - ❖ SciPy (please install via `pip install scipy`)
 - ❖ PAD (**optional**, this requires separate installation of ROOT and Delphes. Use `install PAD` command in ma5.)
 - ❖ Pyhf (**optional**, use `install pyhf` command in ma5)

./bin/ma5

ma5> install zlib

ma5> install fastjet

ma5> install PADForSFS

ma5> install matplotlib

ma5> install numpy

From your terminal:

> pip install numpy

> pip install scipy

```
MA5: Reading user settings ...
MA5: Checking mandatory packages:
MA5:   - Python [OK]
MA5:   - GNU GCC g++ [OK]
MA5:   - GNU Make [OK]
MA5: Checking optional packages devoted to data processing:
MA5:   - Zlib [OK]
MA5:   - FastJet [OK]
MA5-ERROR: command root-config is not found
MA5:   - Root [DISABLED]
MA5:   - Delphes [DISABLED]
MA5:   - Delphes-MA5tune [DISABLED]
MA5: Checking the MadAnalysis 5 core library:
MA5:   => MadAnalysis libraries found.
MA5:   => MadAnalysis test program works.
MA5: Reading user settings ...
MA5: Checking optional packages devoted to reinterperatation:
MA5:   - SciPy [OK]
MA5:   - PAD [DISABLED]
MA5:   - PADForMA5tune [DISABLED]
MA5:   - PADForSFS [OK]
MA5:   - pyhf [DISABLED]
MA5: Checking optional packages devoted to histogramming:
MA5:   - Root [DISABLED]
MA5:   - Matplotlib [OK]
MA5:   - gnuplot [DISABLED]
MA5-WARNING: gnuplot disabled. Plots in anuplot format file will not be produced.
MA5:   - pdflatex [OK]
MA5:   - latex [OK]
MA5: Package used for graphical rendering: Matplotlib
MA5: *****
MA5: Particle labels exported from madanalysis/input/particles_name_default.txt
MA5:   => 87 particles successfully exported.
MA5: Multiparticle labels exported from madanalysis/input/multiparticles_default.txt
MA5:   => Creation of the label 'invisible' (-> missing energy).
MA5:   => Creation of the label 'hadronic' (-> jet energy).
MA5:   => 8 multiparticles successfully exported.
ma5>
```

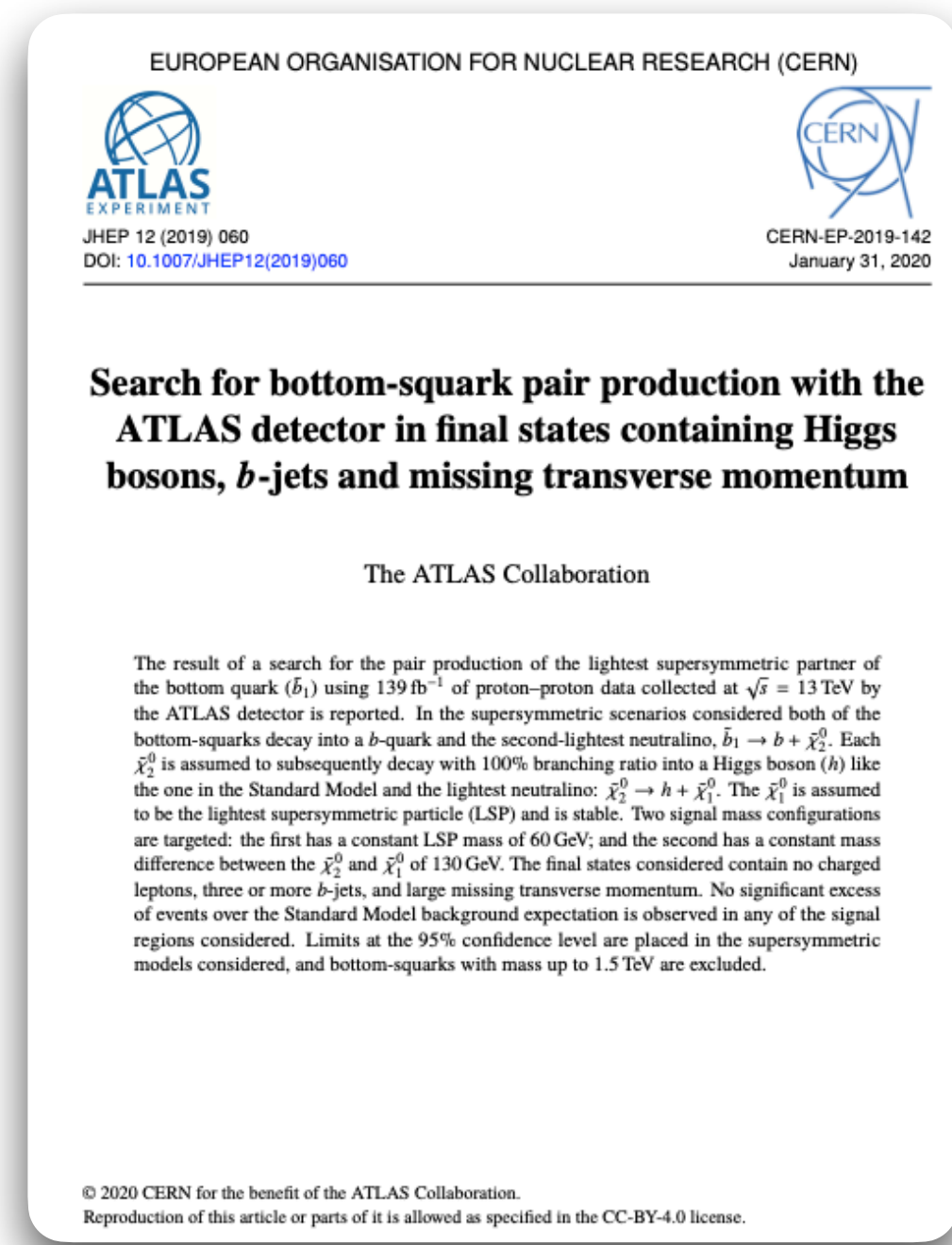
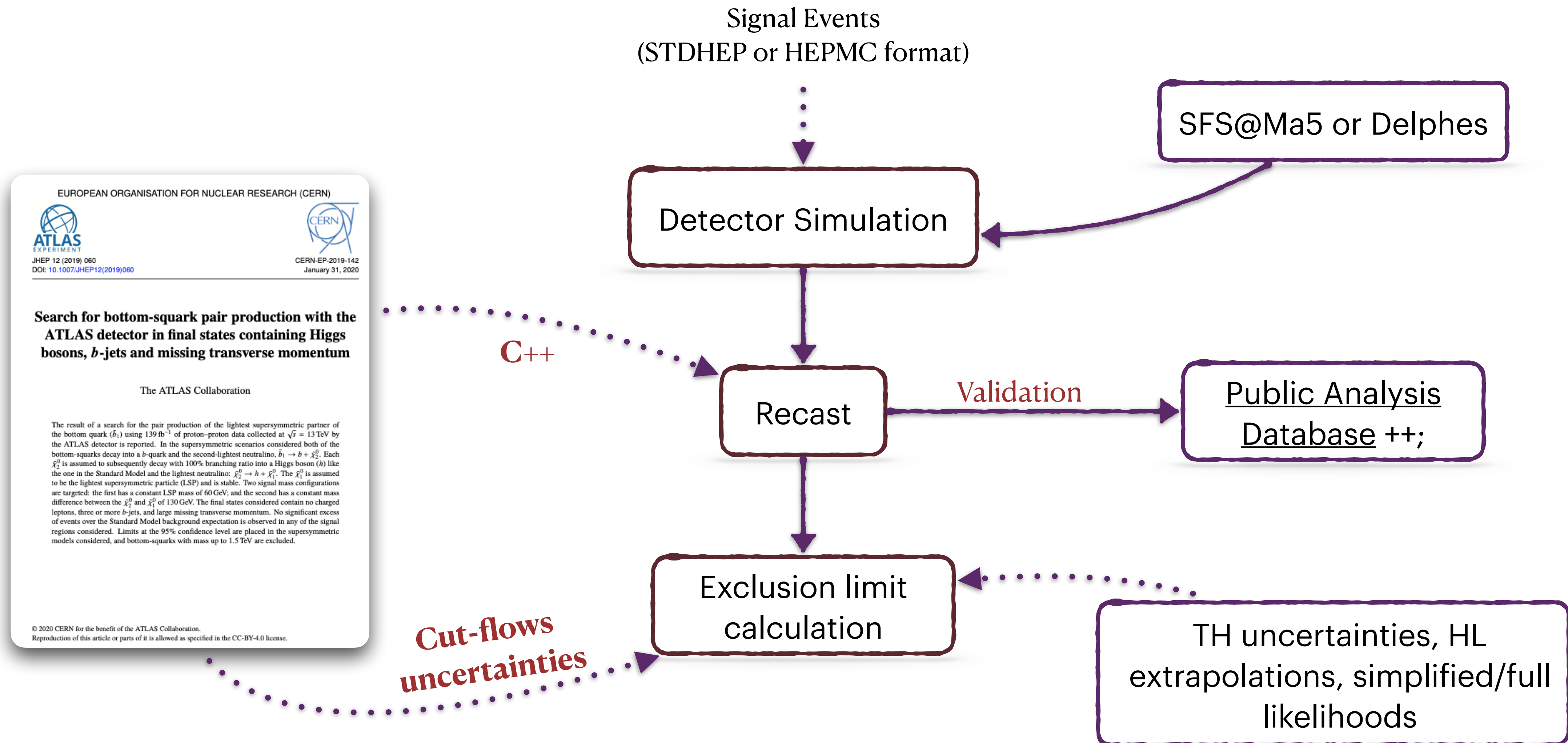
Important for running Ma5

Important for PAD

Important for generating reports in Ma5

Reinterpreting the results of the LHC

Reinterpreting the results of the LHC



Reinterpreting the results of the LHC

JYA, Frank, Fuks [EPJC '20]

- ✓ Theoretical uncertainties & error combination (scale & PDF)
- ✓ Systematic uncertainties
- ✓ HL extrapolation
- ✓ Experimental error extrapolation (systematic or statistical)
- ✓ Experimental error extrapolation assumption

```
ma5>set main.recast.TError_combination = quadratic
```

ma5> set main.recast.TError_combination : How to **combine theoretical uncertainties**, linearly or in quadrature.

ma5> set main.recast.add.systematics : Add desired possible **systematic uncertainty** values on the signal

```
ma5>set main.recast.add.systematics = 0.15
ma5>set main.recast.add.systematics = 0.2
```

ma5> set main.recast.add.extrapolated_luminosity: Add desired luminosity values (in fb^{-1}) for the results to be extrapolated

```
ma5>set main.recast.add.extrapolated_luminosity = 300 3000
```

ma5> set main.recast.error_extrapolation : How to **extrapolate error on the background** to higher luminosity.

- Linear: Uncertainties on the background are assumed to be dominated by systematical error
- Sqrt: Uncertainties on the background are assumed to be dominated by statistical error

- Experimental error assumptions : $\sqrt{\kappa_1^2 + \frac{\kappa_2^2}{n_b}}$ where κ_1 is the estimation of systematic uncertainty and κ_2 is the estimation of statistical uncertainty; e.g.

```
ma5> set main.recast.error_extrapolation = 0.2 0.15
```

```
ma5>set main.recast.error_extrapolation = sqrt
```


**Submit, choose the analysis
that you like to recast.
Get some coffee...**

Reinterpreting the results of the LHC

madanalysis5/MY_ANALYSIS/Output/SAF/CLs_output_summary.dat

dataset name	analysis name	signal region	best?	sig95(exp)	sig95(obs)	1-CLs	efficiency	stat	syst1(15.0%)	syst2(20.0%)
defaultset	sfs_atlas_conf_2019_040	SR2j_1600	1	0.0247549	0.0203238	0.0000	0.0791112	16.0122521	0.0118667	0.0158222
defaultset				Scale var. band:	[0.0000, 0.0051]					
defaultset				TH error band:	[0.0000, 0.0051]					
defaultset				+15.0% -15.0% syst:	[0.0000, 0.0051]					
defaultset				+20.0% -20.0% syst:	[0.0000, 0.0092]					
defaultset	sfs_atlas_conf_2019_040	SR2j_2200	0	0.0435293	0.0412061	0.0029	0.0192484	8.1509288	0.0028873	0.0038497
defaultset				Scale var. band:	[0.0000, 0.0029]					
defaultset				TH error band:	[0.0000, 0.0045]					
defaultset				+15.0% -15.0% syst:	[0.0000, 0.0045]					
defaultset				+20.0% -20.0% syst:	[0.0000, 0.0045]					
defaultset	sfs_atlas_conf_2019_040	SR2j_2800	0	0.0853536	0.0655145	0.0015	0.0021373	2.7396470	0.0003206	0.0004275
defaultset				Scale var. band:	[0.0005, 0.0115]					
defaultset				TH error band:	[0.0000, 0.0115]					
defaultset				+15.0% -15.0% syst:	[0.0000, 0.0115]					
defaultset				+20.0% -20.0% syst:	[0.0000, 0.0115]					
defaultset	sfs_atlas_conf_2019_040	SR4j_1000	0	0.0343839	0.0338904	0.0000	0.0160934	7.4650118	0.0024140	0.0032187
defaultset				Scale var. band:	[0.0000, 0.0022]					
defaultset				TH error band:	[0.0000, 0.0022]					
defaultset				+15.0% -15.0% syst:	[0.0000, 0.0055]					
defaultset				+20.0% -20.0% syst:	[0.0000, 0.0055]					
defaultset	sfs_atlas_conf_2019_040	SR4j_2200	0	0.0368489	0.0368568	0.0000	0.0038189	3.6590500	0.0005728	0.0007638
defaultset				Scale var. band:	[0.0000, 0.0043]					
defaultset				TH error band:	[0.0000, 0.0043]					
defaultset				+15.0% -15.0% syst:	[0.0000, 0.0043]					
defaultset				+20.0% -20.0% syst:	[0.0000, 0.0043]					
defaultset	sfs_atlas_conf_2019_040	SR4j_3400	0	0.1999502	0.1730569	0.0020	0.0002245	0.8887771	0.0000337	0.0000449
defaultset				Scale var. band:	[0.0000, 0.0043]					
defaultset				TH error band:	[0.0000, 0.0045]					
defaultset				+15.0% -15.0% syst:	[0.0000, 0.0106]					
defaultset				+20.0% -20.0% syst:	[0.0000, 0.0106]					
defaultset	sfs_atlas_conf_2019_040	SR5j_1600	0	0.0571895	0.0575745	0.0009	0.0066054	4.8055094	0.0009908	0.0013211
defaultset				Scale var. band:	[0.0009, 0.0024]					
defaultset				TH error band:	[0.0004, 0.0024]					
defaultset				+15.0% -15.0% syst:	[0.0000, 0.0024]					
defaultset				+20.0% -20.0% syst:	[0.0000, 0.0026]					
defaultset	sfs_atlas_conf_2019_040	SR6j_1000	0	0.1359325	0.1762060	0.0000	0.0006458	1.5071000	0.0000969	0.0001292
defaultset				Scale var. band:	[0.0000, 0.0008]					
defaultset				TH error band:	[0.0000, 0.0008]					
defaultset				+15.0% -15.0% syst:	[0.0000, 0.0008]					
defaultset				+20.0% -20.0% syst:	[0.0000, 0.0019]					

Reinterpreting the results of the LHC

madanalysis5/MY_ANALYSIS/Output/SAF/CLs_output_summary.dat

```
dataset name
defaultset
defaultset
defaultset
```

```
ma5>set main.recast = on
MA5-WARNING: Corresponding analyses will be unavailable, please check their requirements : PADForMA5Tune
ma5>import /mnt/.../SqProd/Events/run_01/tag_1_pythia8_events.hepmc.gz
MA5: -> Storing the file 'tag_1_pythia8_events.hepmc.gz' in the dataset 'defaultset'.
```

```
ma5> import my_smp.hepmc.gz as my_fancy_name
```

Tells you which signal region in which analysis

```
analysis name      signal region
sfs_atlas_conf_2019_040  SR2j_1600
```

Final cut efficiency	Statistical error	Systematic error given by the user	
efficiency	stat	syst1(15.0%)	syst2(20.0%)
11 0.0791112	16.0122521	0.0118667	0.0158222

```
ma5>set main.recast.add.systematics = 0.15
ma5>set main.recast.add.systematics = 0.2
```

Reinterpreting the results of the LHC

Best region is the region $\frac{N^{\text{Signal}}}{N^{\text{Expected}}}$ ratio is maximized among all regions

Expected exclusion cross section with 95 % CL [pb]

Observed exclusion cross section with 95 % CL [pb]

Exclusion confidence level

```
best? sig95(exp) sig95(obs) 1-CLs ||
1      0.0247549 0.0203238 0.0000
Scale var. band: [0.0000, 0.0051]
TH error band: [0.0000, 0.0051]
+15.0% -15.0% syst: [0.0000, 0.0051]
+20.0% -20.0% syst: [0.0000, 0.0092]
0      0.0435293 0.0412061 0.0029
Scale var. band: [0.0000, 0.0029]
TH error band: [0.0000, 0.0045]
+15.0% -15.0% syst: [0.0000, 0.0045]
+20.0% -20.0% syst: [0.0000, 0.0045]
0      0.0853536 0.0655145 0.0015
```

Reinterpreting the results of the LHC

Best region is the region $\frac{N^{\text{Signal}}}{N^{\text{Expected}}}$ ratio is maximized among all regions

Expected exclusion cross section with 95 % CL [pb]

Observed exclusion cross section with 95 % CL [pb]

Exclusion confidence level

```

best?      sig95(exp)  sig95(obs)  1-CLs ||
  1         0.0247549  0.0203238  0.0000
Scale var. band: [0.0000, 0.0051]
TH error band:  [0.0000, 0.0051]
+15.0% -15.0% syst: [0.0000, 0.0051]
+20.0% -20.0% syst: [0.0000, 0.0092]
    
```

```

Scale var. band: [0.0000, 0.0051]
TH error band:  [0.0000, 0.0051]
    
```

```

+15.0% -15.0% syst: [0.0000, 0.0051]
+20.0% -20.0% syst: [0.0000, 0.0092]
    
```

Recalculated exclusion CL_s -band for scale and combined scale \oplus PDF uncertainties

Recalculated exclusion CL_s -band for combined TH and systematic uncertainties

Reinterpreting the results of the LHC

```
ma5>set main.recast.add.extrapolated_luminosity = 300 3000
```

```
madanalysis5/MY_ANALYSIS/Output/SAF/defaultset/CLs_output_lumi_300.000.dat
```

Best region is the region $\frac{N^{\text{Signal}}}{N^{\text{Expected}}}$ ratio is maximized among all regions

Expected exclusion cross section with 95 % CL [pb]

Observed exclusion cross section with 95 % CL [pb]. But there is no observed data at HL so its -1.

Exclusion confidence level

```

best?  sig95(exp)  sig95(obs)  1-CLs ||
  1      0.0167612  -1          0.0009 |
Scale var. band: [0.0009, 0.0050]
TH error band:  [0.0000, 0.0050]
+15.0% -15.0% syst: [0.0000, 0.0050]
+20.0% -20.0% syst: [0.0000, 0.0050]
    
```

Recalculated exclusion CL_s -band for scale and combined scale \oplus PDF uncertainties

Recalculated exclusion CL_s -band for combined TH and systematic uncertainties

Time for Questions!