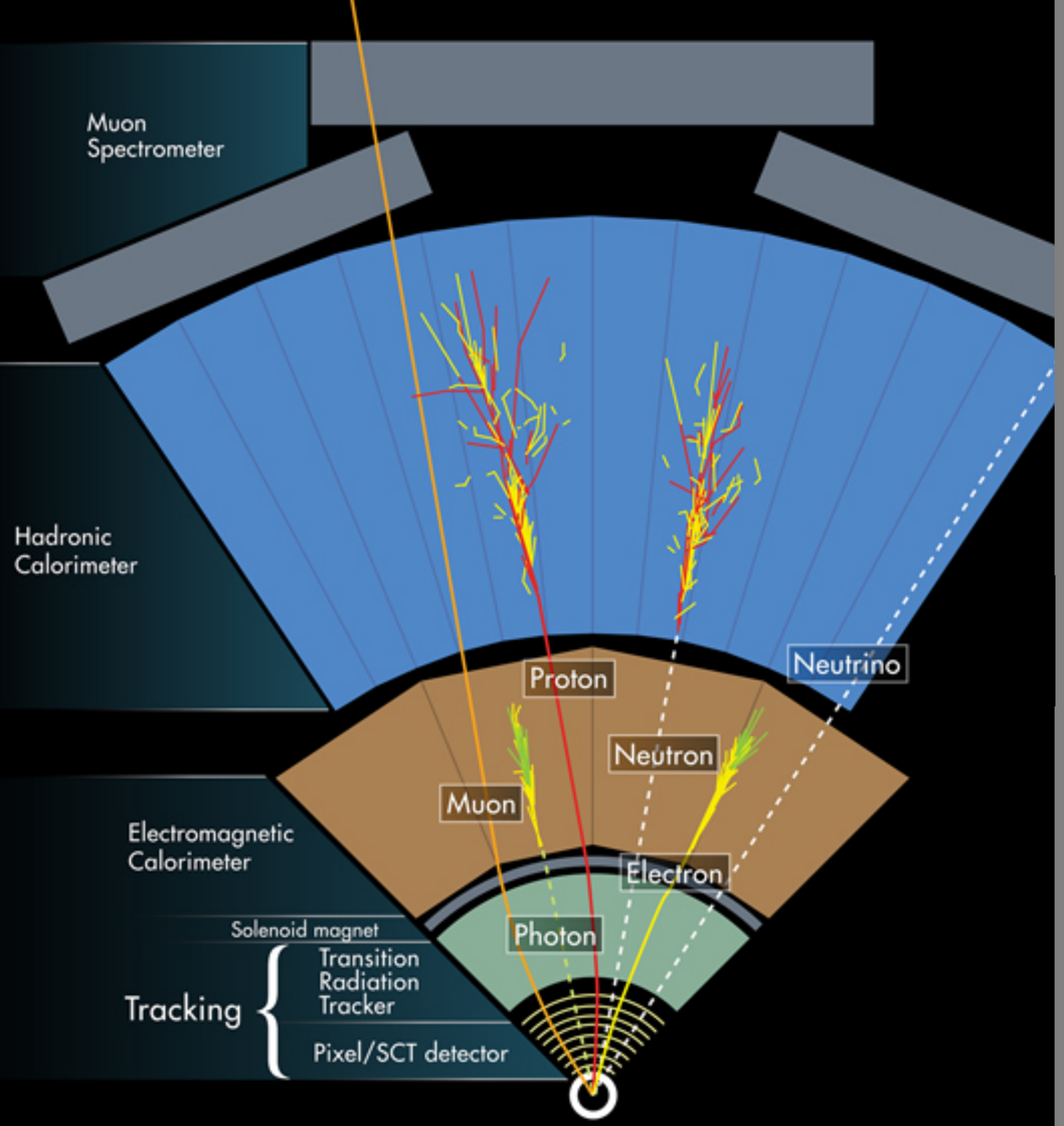

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MadAnalysis 5

from beginner to expert

TOOLS 2020

Nov. 3rd, 2020

Durham University

Science & Technology Facilities Council

MCnet

IP3

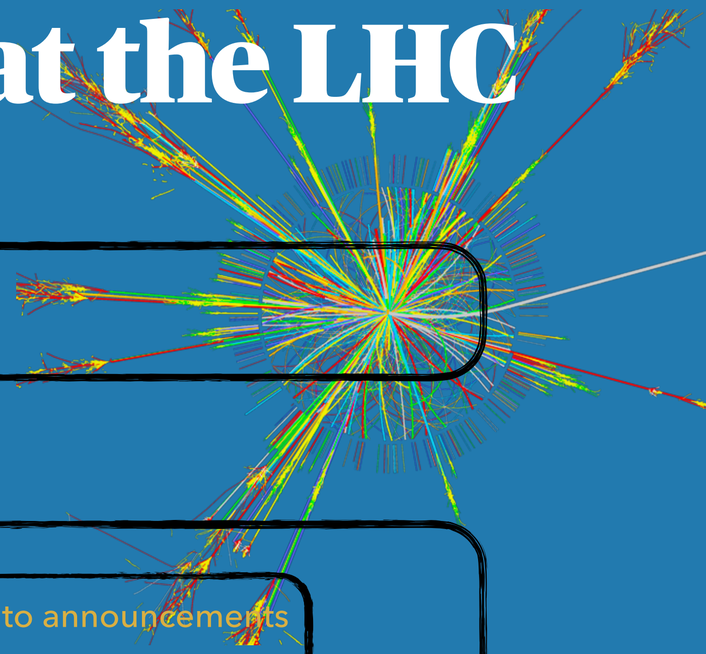
Goals of this tutorial...

- “Hello World!” in MadAnalysis 5: the normal mode (very brief introduction)
  - Matrix element level event analysis, plotting various distributions, simple cut-based analysis.
- How to use Public Analysis Database (PAD) for setting exclusion limits to your new theory
  - Getting confidence level exclusions, implementing theoretical and systematic uncertainties, extrapolating your results to higher luminosities, understanding the importance of the background uncertainties.
- How to use the SFS module for detector simulations
  - Reconstructing showered events with FastJet, Using the default detector cards, writing your own detector simulation, plotting the distributions in the normal mode
- Becoming the expert of MadAnalysis 5
  - Writing your own analysis with or without a detector simulation, using multi-region option, writing an analysis for PAD and how to validate your code to be included in PAD for HEP community.

Prerequisites

- Latest version of MadAnalysis 5 can be downloaded from this link.
- Python 2.7 or higher but not 3 & C++ compiler on your machine. Python 2.7 will need to include scipy and your machine needs to have pdflatex and latex. Please make sure that these are detected when you run MadAnalysis 5 (check this slide to see how it should look like).
  - Familiarity with C++ will be useful for the very last portion of the tutorial but up to that part you don't need to know any programming language.
- We will need two event samples prepared in advance:
  - Squark production: $pp \to \tilde{u}_1\bar{\tilde{u}}_1 \to jj\tilde{\chi}_1^0\tilde{\chi}_1^0$ (for PAD section at least 50,000 MC events)
  - Drell-Yan: $pp \to ll$ and $l\nu$ (for SFS section)

MonteCarlo tools & discoveries at the LHC



Exploration

We still need to uncover the veil of the new physics!

Hitchhiker's guide to new physics

✦ Apriori preparation
- Theoretical model building
- Phenomenological studies
- Collider analyses

✦ A posteriori reactions to announcements
- Theoretical model building
- Recasting experimental analyses
- Precision measurements

✦ MonteCarlo tools are essential

✦ How to analyze the MC output easily?

MadAnalysis 5 in a nutshell

[Conte, BF, Serret (CPC '13); Conte, Dumont, BF, Wymant (EPJC '14)]

★ Normal Mode

- Intuitive commands typed in the Python interface
- Analysis performed behind the scenes (black box)
- Human readable output: Html and LaTeX

★ Expert Mode

- C++ programming within the SampleAnalyzer framework
- Support for multiple sub-analyses, an efficient way for handling cuts and histograms, etc.

MadAnalysis 5 in a nutshell

[Conte, BF, Serret (CPC '13); Conte, Dumont, BF, Wymant (EPJC '14)]

★ What is MadAnalysis 5?

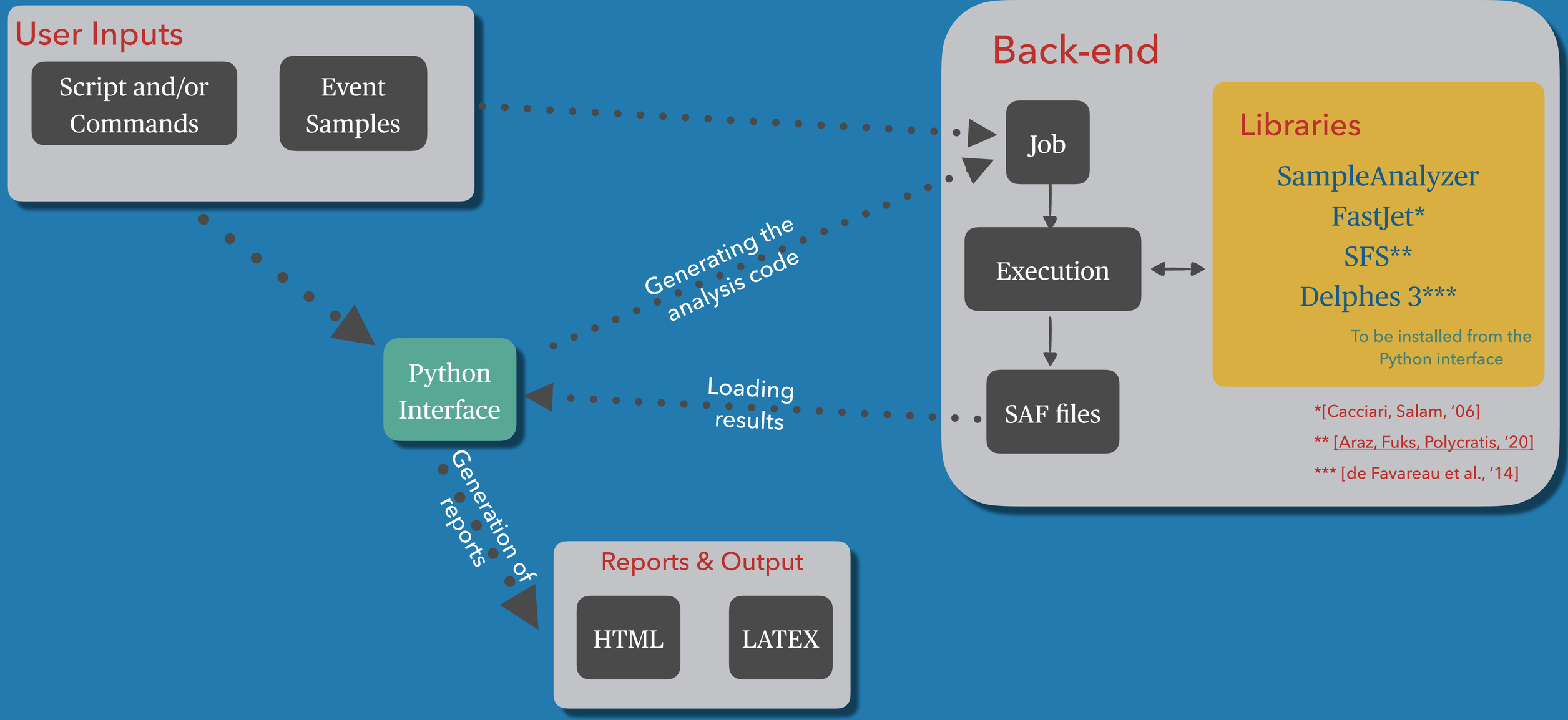
- A Python and C++ based framework for *phenomenological analyses*
- *Any level of sophistication:* partonic, hadronic, detector, reconstructed
- *Several input* format: STDHEP, HEPMC, LHE, LHEO, ROOT (from Delphes)
- *User-friendly, flexible and fast*
- Interfaces to other HEP packages (fast detector simulation, jet clustering etc.)

★ Two modules

- A Python command line interface (interactive)
- A C++ core module, SampleAnalyzer

MadAnalysis 5: Normal mode

MadAnalysis 5: Normal Mode



> ./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 reinterpretation:
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 gnuplot 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

MadAnalysis 5: Normal Mode

Let's get some samples to work with!

Now we have 5 different samples to work with

- TTbar: semileptonic, leptonic, full hadronic
- Z to dilepton
- DiBoson ZZ production

```
ma5>!ls samples
MA5:    Running the shell command: ls samples.
mg5_ttbar2l.lhco  ttbar_fh.lhe.gz   ttbar_sl_1.lhe.gz ttbar_sl_2.lhe.gz zz.lhe.gz
mg5_zll.lhco      ttbar_sl_1.lhe    ttbar_sl_2.lhe    wget.log
ma5>
```

ma5> install samples

```
ma5>install samples
MA5:
MA5:    ************************************************************
MA5:                        Installing samples
MA5:    ************************************************************
MA5:    Detecting a previous installation ...
MA5:    => not found. OK
MA5:    Creating a devoted folder ...
MA5:    Downloading the package ...
MA5:     - 1/8 http://madanalysis.irmp.ucl.ac.be/raw-attachment/wiki/samples/ttbar_sl_1.lhe.gz ...
              --> Download 391.24K of 391.24K (100.0%)
MA5:     - 2/8 http://madanalysis.irmp.ucl.ac.be/raw-attachment/wiki/samples/zz.lhe.gz ...
              --> Download 240.34K of 240.34K (100.0%)
MA5:     - 3/8 http://madanalysis.irmp.ucl.ac.be/raw-attachment/wiki/samples/ttbar_sl_1.lhe ...
              --> Download 1.67M of 1.67M (100.0%)
MA5:     - 4/8 http://madanalysis.irmp.ucl.ac.be/raw-attachment/wiki/samples/ttbar_fh.lhe.gz ...
              --> Download 389.05K of 389.05K (100.0%)
MA5:     - 5/8 http://madanalysis.irmp.ucl.ac.be/raw-attachment/wiki/samples/ttbar_sl_2.lhe.gz ...
              --> Download 391.26K of 391.26K (100.0%)
MA5:     - 6/8 http://madanalysis.irmp.ucl.ac.be/raw-attachment/wiki/samples/mg5_zll.lhco ...
              --> Download 68.41K of 68.41K (100.0%)
MA5:     - 7/8 http://madanalysis.irmp.ucl.ac.be/raw-attachment/wiki/samples/mg5_ttbar2l.lhco ...
              --> Download 87.34K of 87.34K (100.0%)
MA5:     - 8/8 http://madanalysis.irmp.ucl.ac.be/raw-attachment/wiki/samples/ttbar_sl_2.lhe ...
              --> Download 1.67M of 1.67M (100.0%)
MA5:    Checking the installation ...
MA5:    Installation complete.
MA5:    Elapsed time = 6.92 seconds
MA5:    => Status: [OK]
MA5:    ************************************************************
```

MadAnalysis 5: Normal Mode

1. Import TTbar samples

```
ma5>import samples/ttbar*lhe* as ttbar
MA5:     -> Storing the file 'ttbar_fh.lhe.gz' in the dataset 'ttbar'.
MA5:     -> Storing the file 'ttbar_sl_1.lhe' in the dataset 'ttbar'.
MA5:     -> Storing the file 'ttbar_sl_2.lhe' in the dataset 'ttbar'.
MA5:     -> Storing the file 'ttbar_sl_1.lhe.gz' in the dataset 'ttbar'.
MA5:     -> Storing the file 'ttbar_sl_2.lhe.gz' in the dataset 'ttbar'.
```

2. ma5> plot # press tab : all possible plotting options

ABSETA	N	dABSETA	dTHETA	dsR	dvPY	rPX	sPT	sdPHI	vN	vdMT
ALPHAT	NAPID	dBETA	dY	dsTHETA	dvPZ	rPY	sPX	sdPT	vP	vdMT_MET
ALPHA_QCD	NPID	dDELTAR	dsABSETA	dsY	dvR	rPZ	sPY	sdPX	vPHI	vdN
ALPHA_QED	P	dE	dsBETA	dvABSETA	dvTHETA	rR	sPZ	sdPY	vPT	vdP
BETA	PHI	dET	dsE	dvBETA	dvY	rTHETA	sR	sdPZ	vPX	vdPHI
DELTAR	PT	dETA	dsET	dvDELTAR	rABSETA	rY	sTHETA	sdR	vPY	vdPT
DPHI_0_2PI	PX	dGAMMA	dsETA	dvE	rBETA	sABSETA	sY	sdTHETA	vPZ	vdPX
DPHI_0_PI	PY	dM	dsGAMMA	dvET	rE	sBETA	sdABSETA	sdY	vR	vdPY
E	PZ	dMT	dsM	dvETA	rET	sE	sdBETA	vABSETA	vTHETA	vdPZ
ET	R	dMT_MET	dsMT	dvGAMMA	rETA	sET	sdE	vBETA	vY	vdR
ETA	RECOIL	dN	dsMT_MET	dvM	rGAMMA	sETA	sdET	vDELTAR	vdABSETA	vdTHETA
GAMMA	SCALE	dP	dsN	dvMT	rM	sGAMMA	sdETA	vE	vdBETA	vdY
M	SQRTS	dPHI	dsP	dvMT_MET	rMT	sM	sdGAMMA	vET	vdDELTAR	
MEFF	TET	dPT	dsPHI	dvN	rMT_MET	sMT	sdM	vETA	vdE	
MET	THETA	dPX	dsPT	dvP	rN	sMT_MET	sdMT	vGAMMA	vdET	
MHT	THT	dPY	dsPX	dvPHI	rP	sN	sdMT_MET	vM	vdETA	
MT	WEIGHTS	dPZ	dsPY	dvPT	rPHI	sP	sdN	vMT	vdGAMMA	
MT_MET	Y	dR	dsPZ	dvPX	rPT	sPHI	sdP	vMT_MET	vdM	

3. ma5> define l = l+ l-

   Define multi-particles

4. ma5> plot PT (l[1]) 10 0 500 [logY]

   Plot transverse momentum of the leading lepton with 25 GeV bins

5. ma5> select (l) PT > 10

   Define quality criteria on leptons

6. ma5> select (j) DELTAR (l) > 0.4

   Define jet cleaning: only choose jets if they are separated from leptons with $\Delta R(j, l) > 0.4$

7. ma5> reject PT (j) < 20

   Define cuts with reject or select options

8. ma5> display selection

   Display the selections that have been made and use “remove” and “swap” options to change them them

9. ma5> set selection[n]. #press tab

   Modify your selections as you like.

MadAnalysis 5: Normal Mode

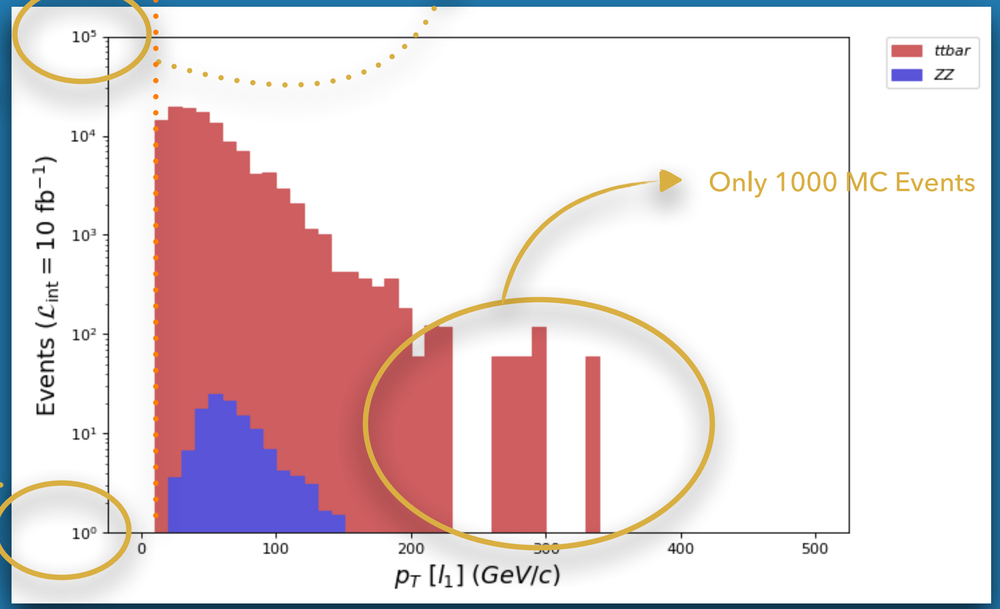
```
ma5>set ttbar.
ttbar.backcolor              ttbar.linewidth              ttbar.scale_down_variation  ttbar.type
ttbar.backstyle              ttbar.pdf_down_variation     ttbar.scale_up_variation    ttbar.weight
ttbar.linecolor              ttbar.pdf_up_variation       ttbar.scale_variation       ttbar.weighted_events
ttbar.linestyle              ttbar.pdf_variation          ttbar.title                 ttbar.xsection
```

```
ma5>import samples/zz.lhe.gz as ZZ
MA5:     -> Storing the file 'zz.lhe.gz' in the dataset 'ZZ'.
ma5>import samples/ttbar*lhe* as ttbar
MA5:     -> Storing the file 'ttbar_fh.lhe.gz' in the dataset 'ttbar'.
MA5:     -> Storing the file 'ttbar_sl_1.lhe' in the dataset 'ttbar'.
MA5:     -> Storing the file 'ttbar_sl_2.lhe' in the dataset 'ttbar'.
MA5:     -> Storing the file 'ttbar_sl_1.lhe.gz' in the dataset 'ttbar'.
MA5:     -> Storing the file 'ttbar_sl_2.lhe.gz' in the dataset 'ttbar'.
ma5>define l = l+ l-
ma5>select (l) PT > 10
ma5>select (j) PT > 20
ma5>select (j) DELTAR (l) > 0.4
ma5>plot PT (l[1]) 50 0 500 [logY]
ma5>set selection[4].ymin = 1
ma5>set selection[4].ymax = 1e5
```

What does it mean?

- select PT (l) > 20: selects those for which at least one lepton has a $p_T > 20$ GeV
- reject PT(l) < 20: rejects those events for which $p_T < 20$ GeV is found.
- select (l) PT > 20: keep in each event only the leptons with $p_T > 20$ GeV and ignore any other lepton

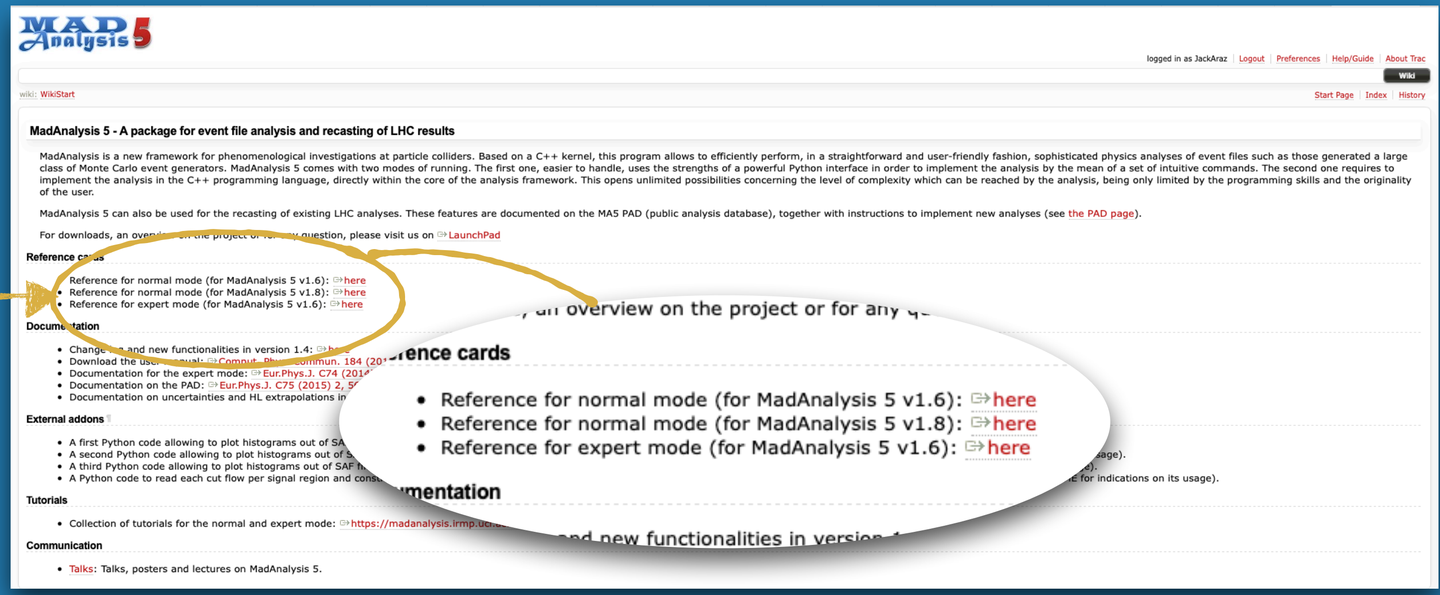
```
ma5> submit FunWithMa5
```

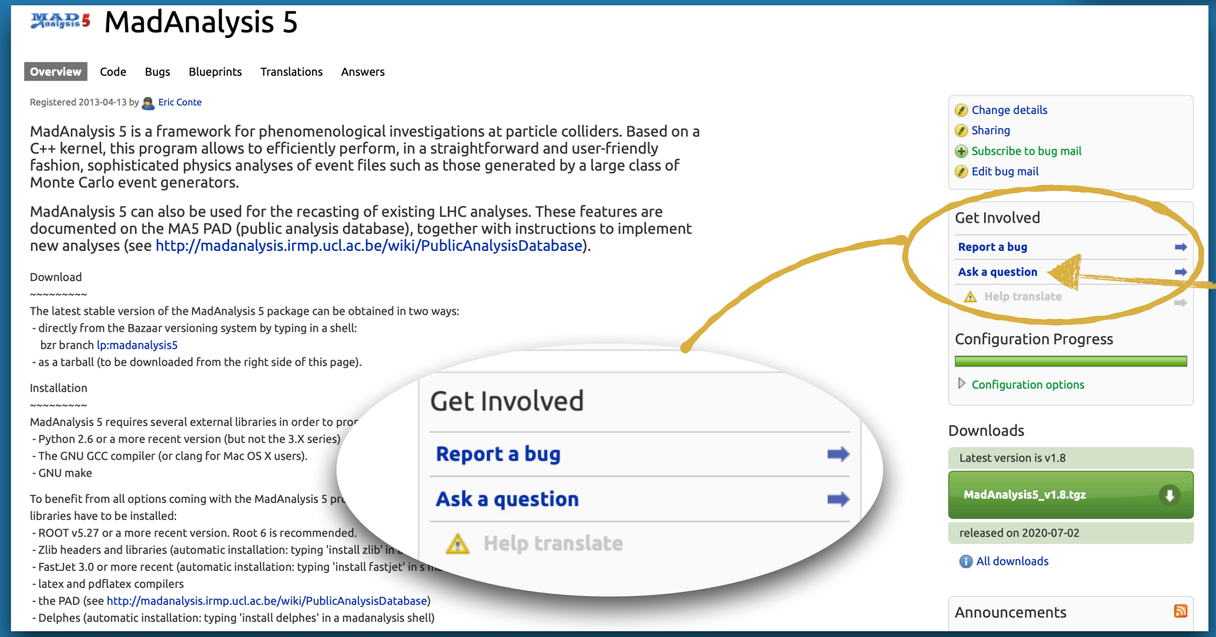


MadAnalysis 5: Normal Mode

Where can I find more information for normal mode functionalities?

- Visit MadAnalysis 5 home page, there you can find a reference card for normal mode.





Where can I find more information?

- Ask questions in Launchpad

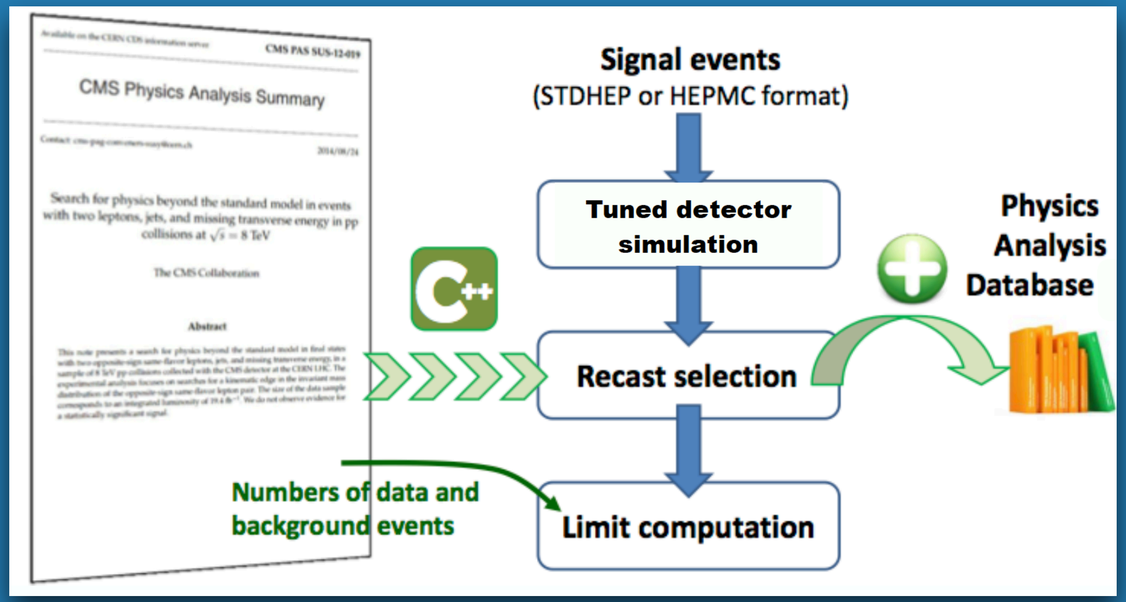
Reinterpreting the results of LHC

[Conte, Dumont, BF, Wymant (EPJC ’14); Dumont, BF, Kraml et al. (EPJC ’15); Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

✦ We have a ton of new physics realizations that deserve to be studied
- Theory relies on a public detector simulator mimicking the ATLAS/CMS simulations
- We need a public framework where LHC analyses can be implemented

★The recasting strategy in MadAnalysis 5



✦Two options available for detector effects
- Delphes 3
- SFS (transfer functions)

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

./bin/ma5 -R

```
ma5>set main.recast = on
MA5-WARNING:  Corresponding analyses will be unavailable, please check their requirements : PADForMA5Tune
ma5>import /[illegible]/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>set defaultset.xsection = 1.8524788535e-06
ma5>set defaultset.scale_up_variation = 0.388
ma5>set defaultset.scale_down_variation = 0.262
ma5>set defaultset.pdf_up_variation = 0.131
ma5>set defaultset.pdf_down_variation = 0.131
```

Coming from MadGraph

```
#*********************************************************************
#
# original cross-section: 1.8524788535e-06
#      scale variation: +38.8% -26.2%
#      central scheme variation: +9.65% -28.2%
# PDF variation: +13.1% -13.1%
#
# dynamical scheme # 1 : 1.4971e-06 +36.5% -25.1% # \sum ET
# dynamical scheme # 2 : 1.48846e-06 +36.5% -25.1% # \sum\sqrt{m^2+pt^2}
# dynamical scheme # 3 : 2.03123e-06 +39.9% -26.7% # 0.5 \sum\sqrt{m^2+pt^2}
# dynamical scheme # 4 : 1.33005e-06 +35.2% -24.5% # \sqrt{\hat s}
#*********************************************************************
```

ma5> set defaultset.scale_XX_variation : declaration of the unphysical scale uncertainties on the system

ma5> set defaultset.pdf_XX_variation : declaration of the PDF uncertainties on the system

ma5> set defaultset.pdf_variation : symmetric uncertainty envelops for PDF

ma5> set defaultset.scale_variation : symmetric uncertainty envelops for scale uncertainties

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

```
ma5>set main.recast.add.extrapolated_luminosity = 300 3000
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.systematics : Add desired possible systematic uncertainty values on the signal

ma5> set main.recast.add.systematics : If you provide two values they will be treated as upper and lower bound of asymmetric systematic uncertainty

ma5> submit

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

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

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

  ma5> set main.recast.error_extrapolation = 0.2 0.15

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

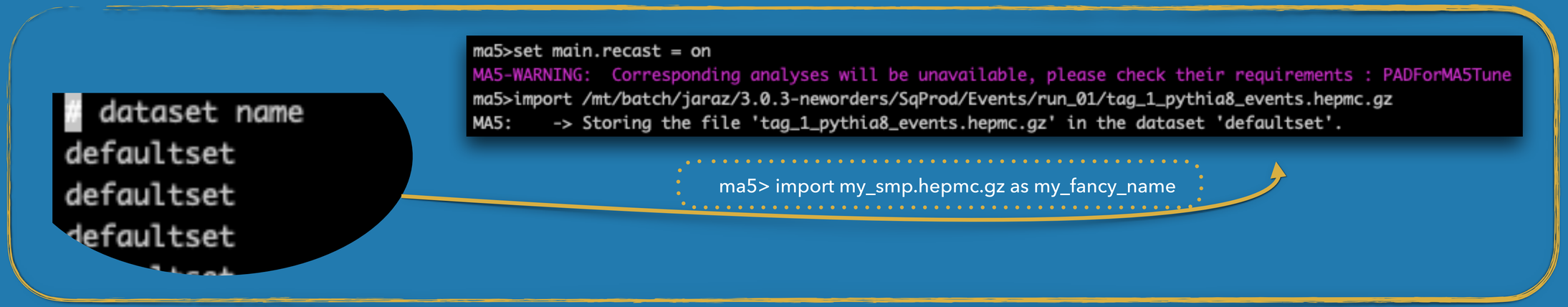
madanalysis5/MY_ANALYSIS/Output/SAF/CLs_output_summary.dat

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]							

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

madanalysis5/MY_ANALYSIS/Output/SAF/CLs_output_summary.dat



[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of 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 /mt/batch/jaraz/3.0.3-neworders/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

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of 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 /mt/batch/jaraz/3.0.3-neworders/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%)
||    0.0791112       16.0122521      0.0118667       0.0158222
```

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

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

madanalysis5/MY_ANALYSIS/Output/SAF/CLs_output_summary.dat

```
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
```

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

madanalysis5/MY_ANALYSIS/Output/SAF/CLs_output_summary.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]

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
```

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

madanalysis5/MY_ANALYSIS/Output/SAF/CLs_output_summary.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]

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]
```

Recalculated exclusion CL_s-band for scale and combined scale ⊕ PDF uncertainties

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

Recalculated exclusion CL_s-band for combined TH and systematic uncertainties

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

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

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

analysis name	signal region	best?	sig95(exp)	sig95(obs)	1-CLs		efficiency	stat	syst1(15.0%)	syst2(20.0%)
sfs_atlas_conf_2019_040	SR2j_1600	1	0.0167612	-1	0.0009	||	0.0791112	10.8993147	0.0118667	0.0158222
		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]						
sfs_atlas_conf_2019_040	SR2j_2200	0	0.0295522	-1	0.0000	||	0.0192484	5.5482225	0.0028873	0.0038497
		Scale var. band:		[0.0000, 0.0026]						
		TH error band:		[0.0000, 0.0026]						
		+15.0% -15.0% syst:		[0.0000, 0.0026]						
		+20.0% -20.0% syst:		[0.0000, 0.0026]						
sfs_atlas_conf_2019_040	SR2j_2800	0	0.0566007	-1	0.0026	||	0.0021373	1.8648392	0.0003206	0.0004275
		Scale var. band:		[0.0014, 0.0041]						
		TH error band:		[0.0008, 0.0046]						

[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of 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]

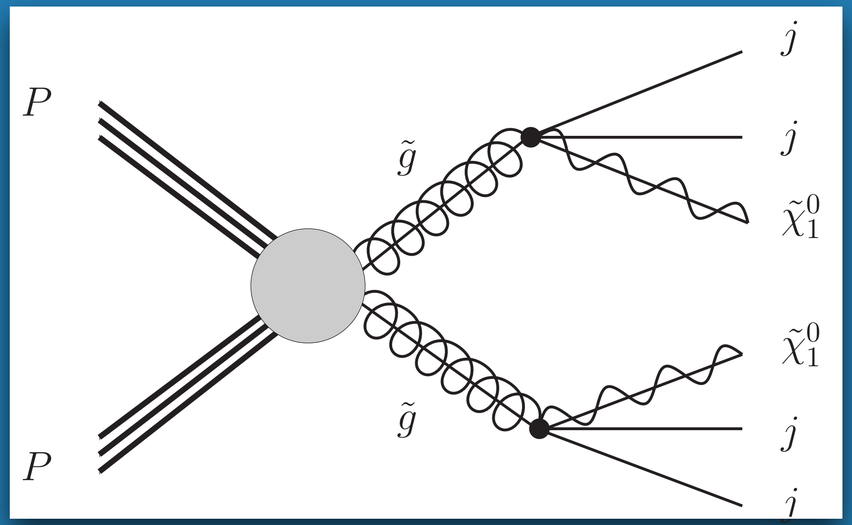
Recalculated exclusion CL_s-band for scale and combined scale $\oplus$ PDF uncertainties

Recalculated exclusion CL_s-band for combined TH and systematic uncertainties

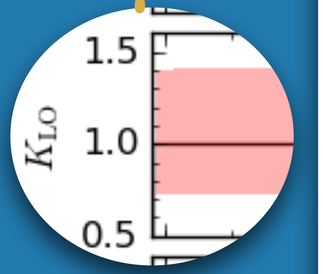
[Araz, Frank, Fuks, (EPJC '20)]

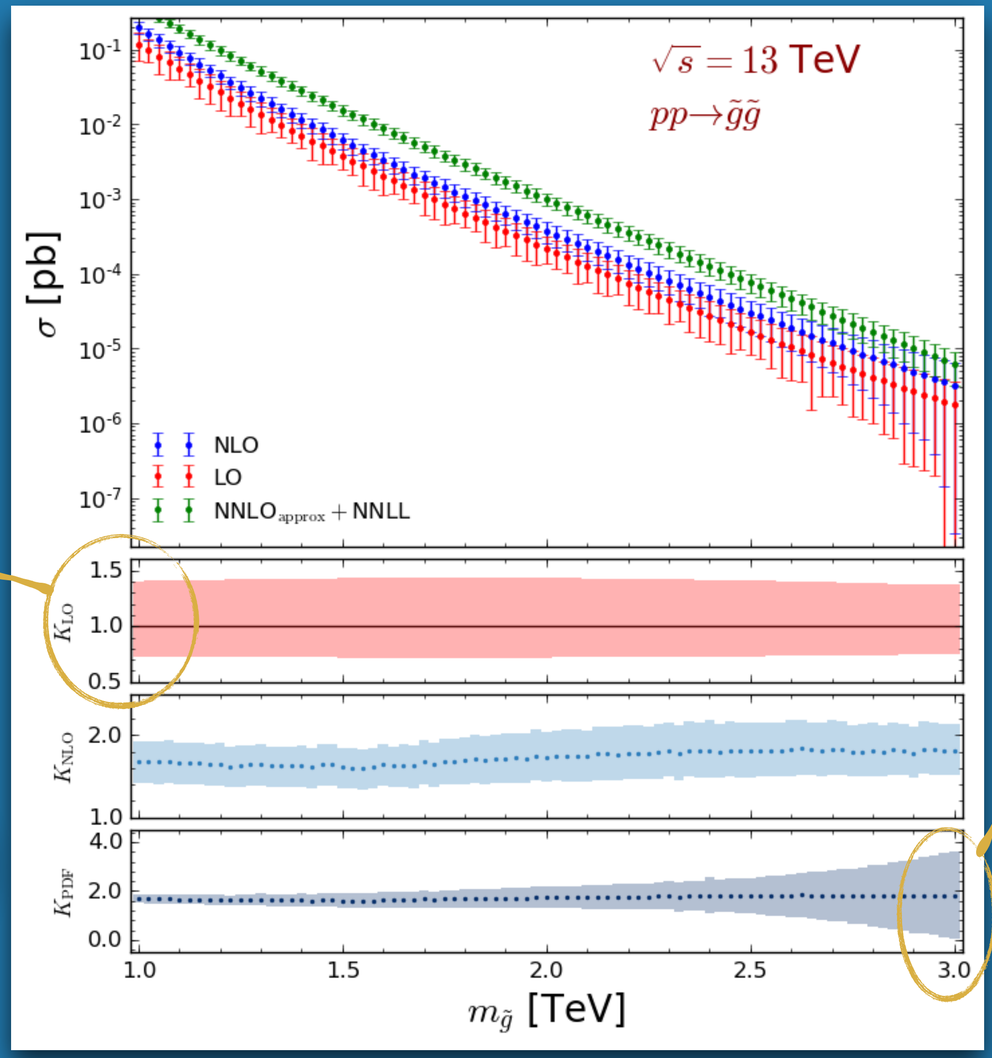
Reinterpreting the results of LHC

Why theoretical uncertainties are so important?
They seem to be quite low.

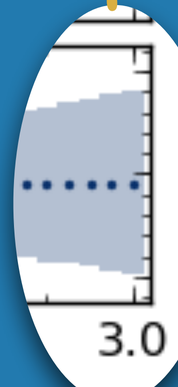


Scale uncertainties are reaching up to $\sim 50\,\%$ at LO





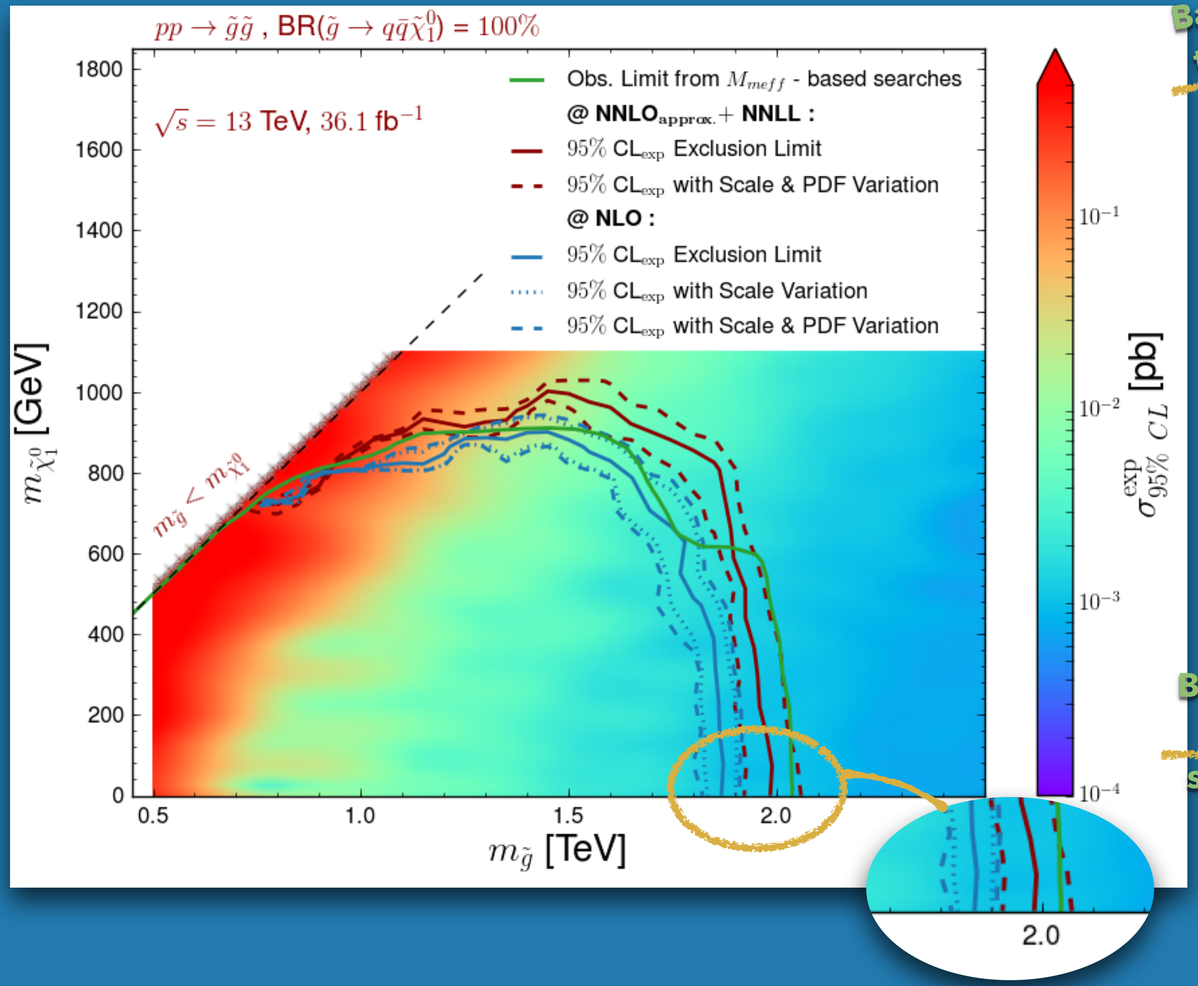
$\sim 100\,\%$



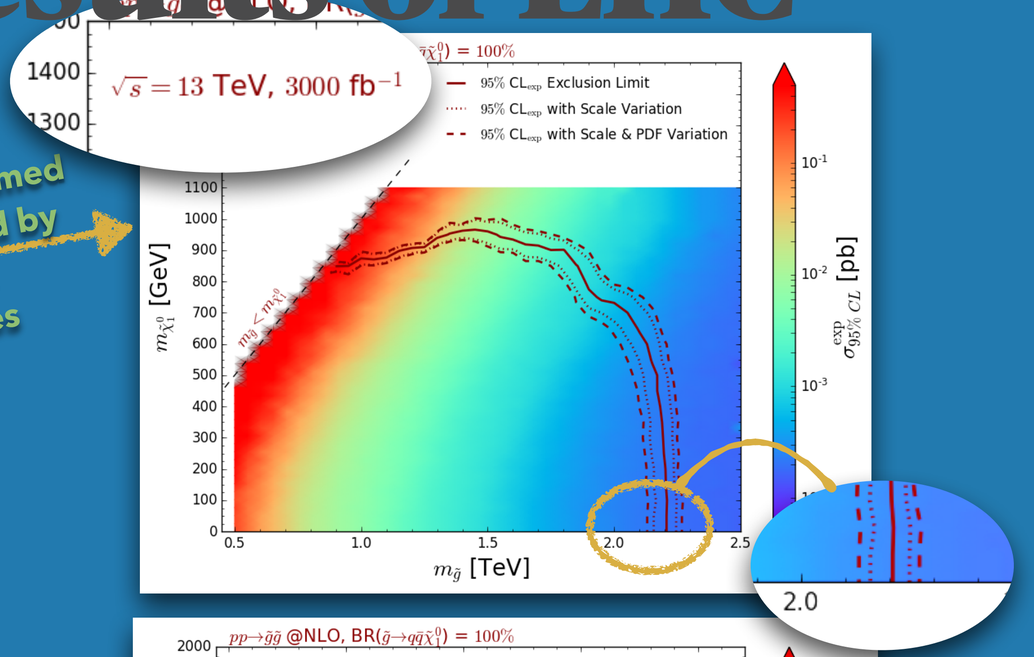
[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC

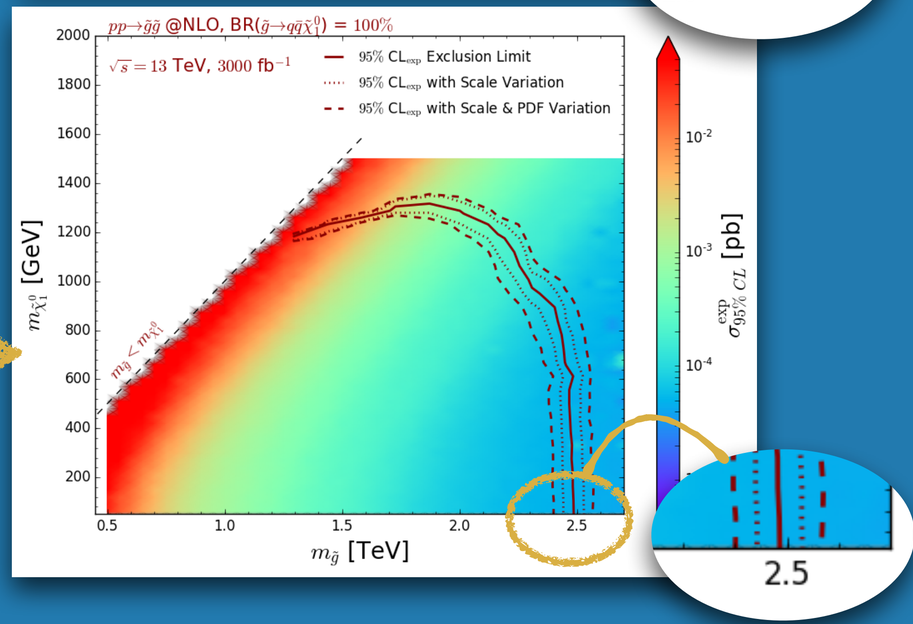
ATLAS-SUSY-2016-07



Background assumed to be dominated by systematic uncertainties

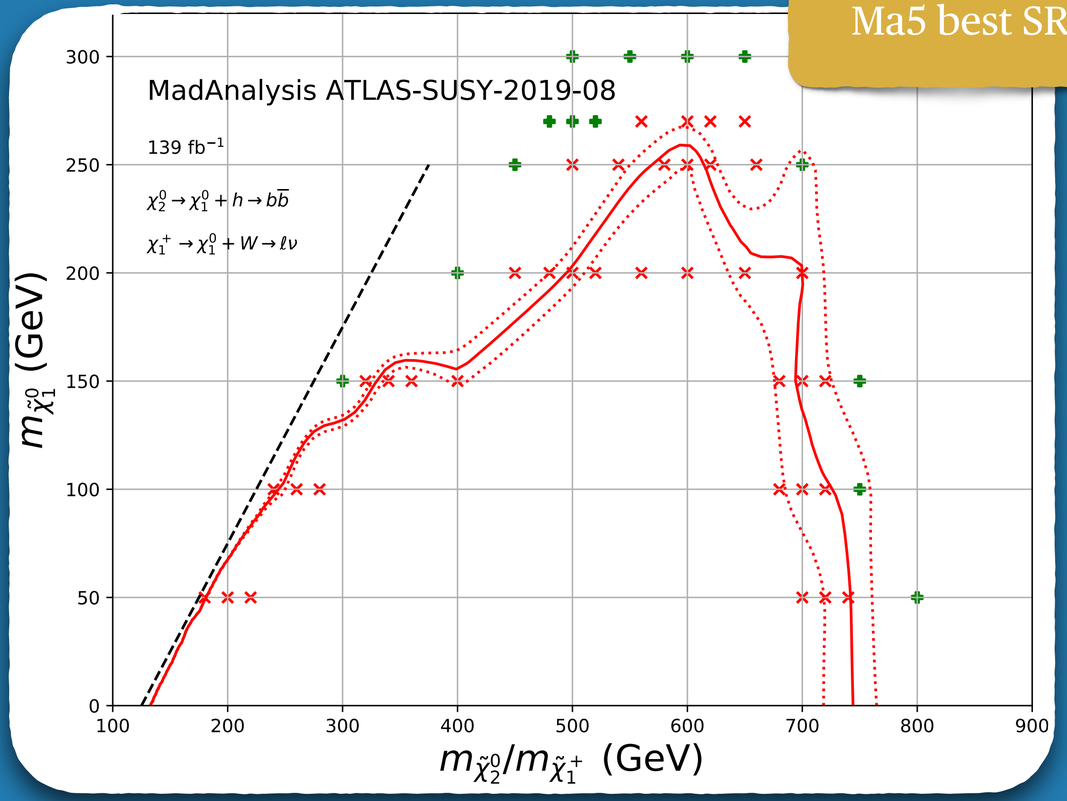


Background assumed to be dominated by statistical uncertainties

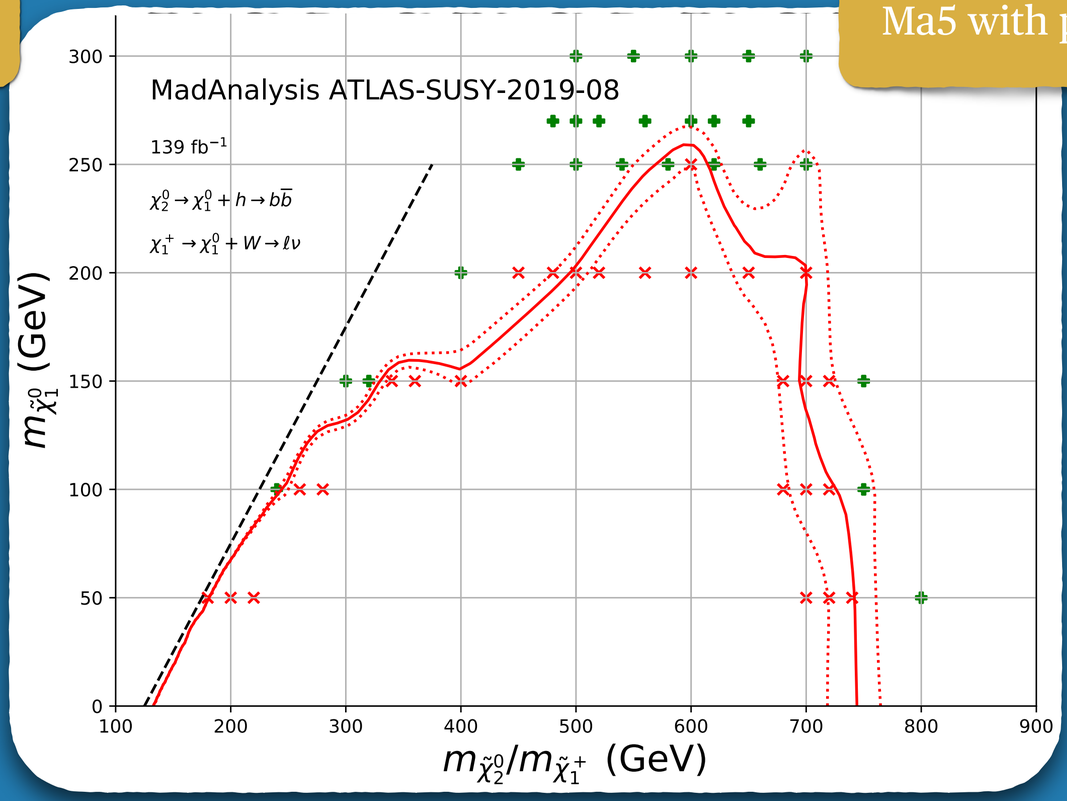


Reinterpreting the results of LHC

Ma5 best SR



Ma5 with pyhf

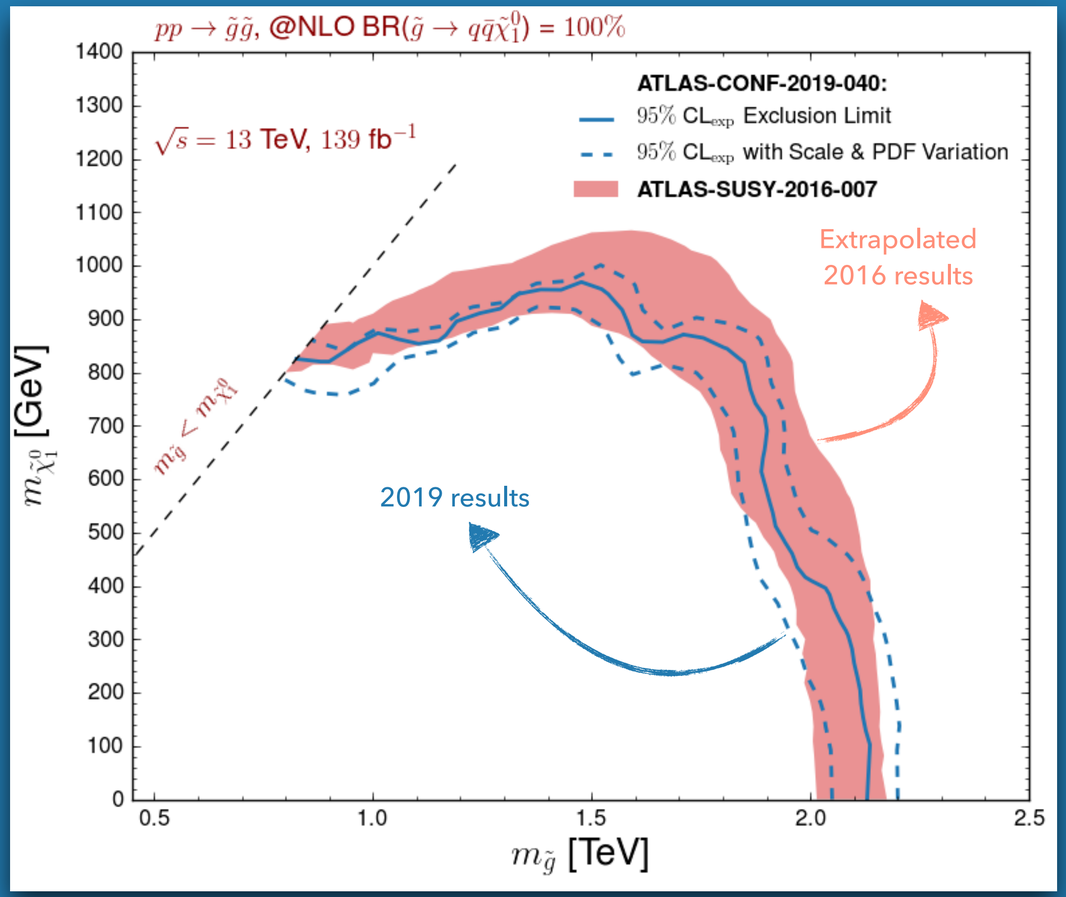


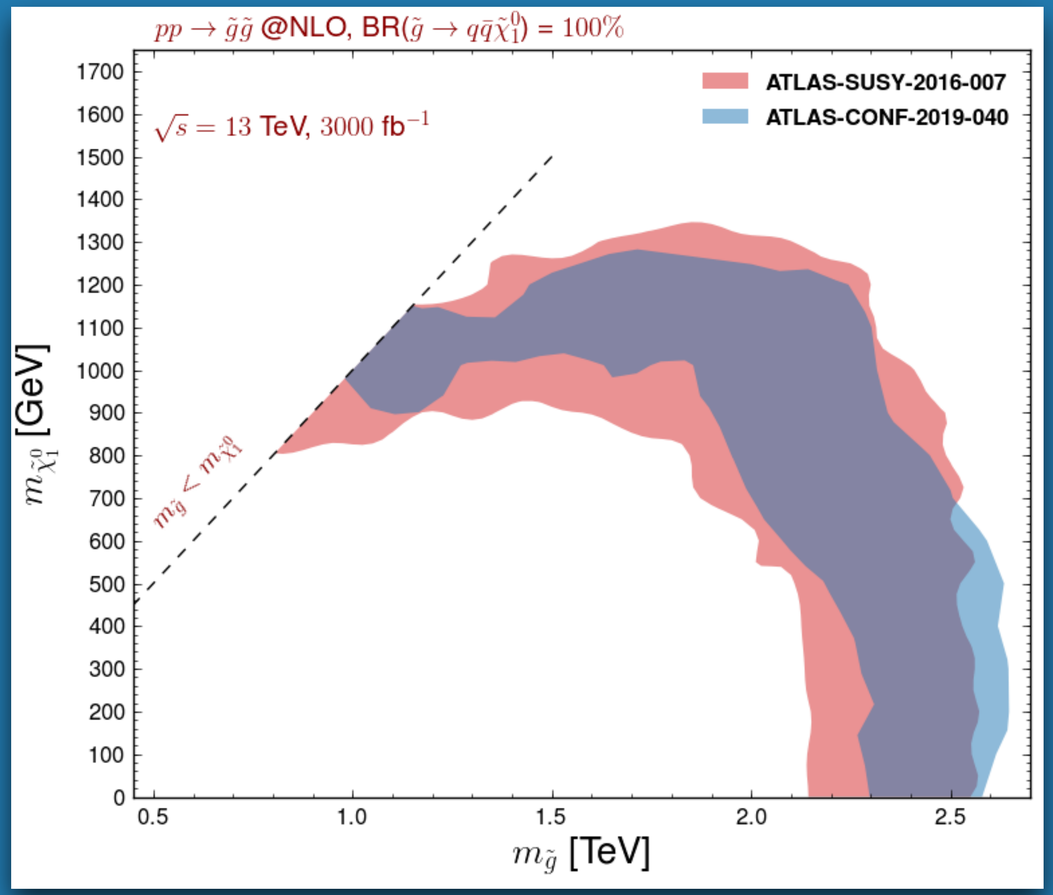
Les Houches 2019

Plot credit: Mark Goodsell.

[Araz, Frank, Fuks, (EPJC '20)]

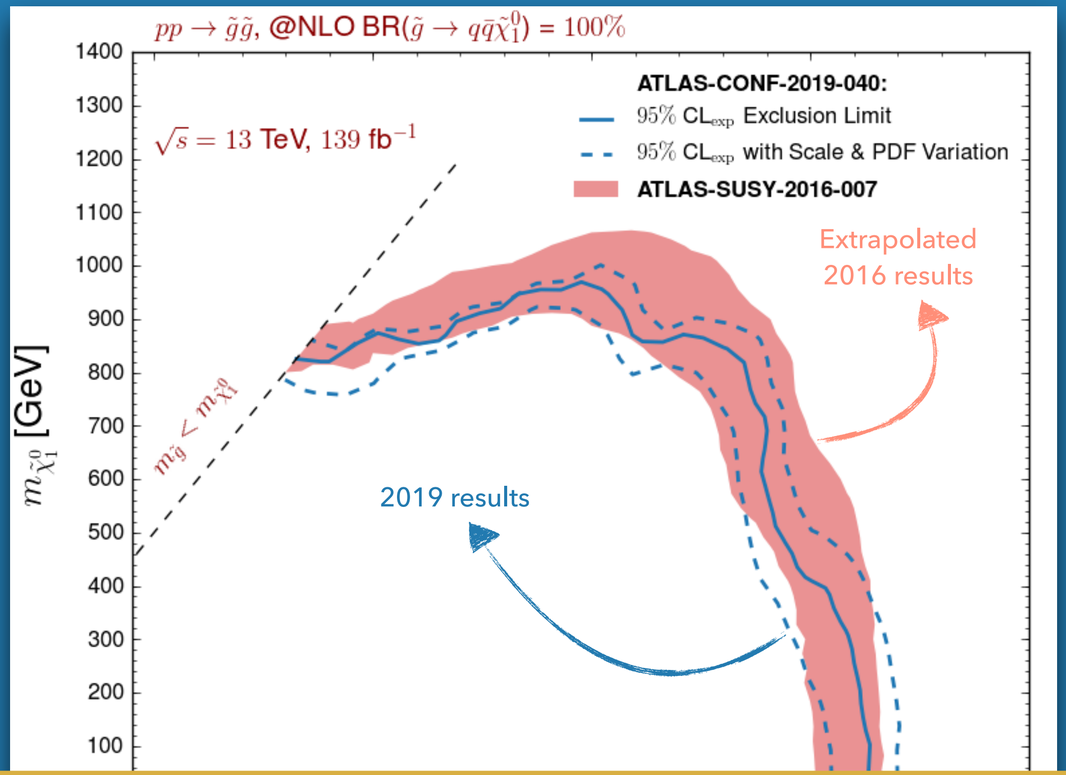
Reinterpreting the results of LHC

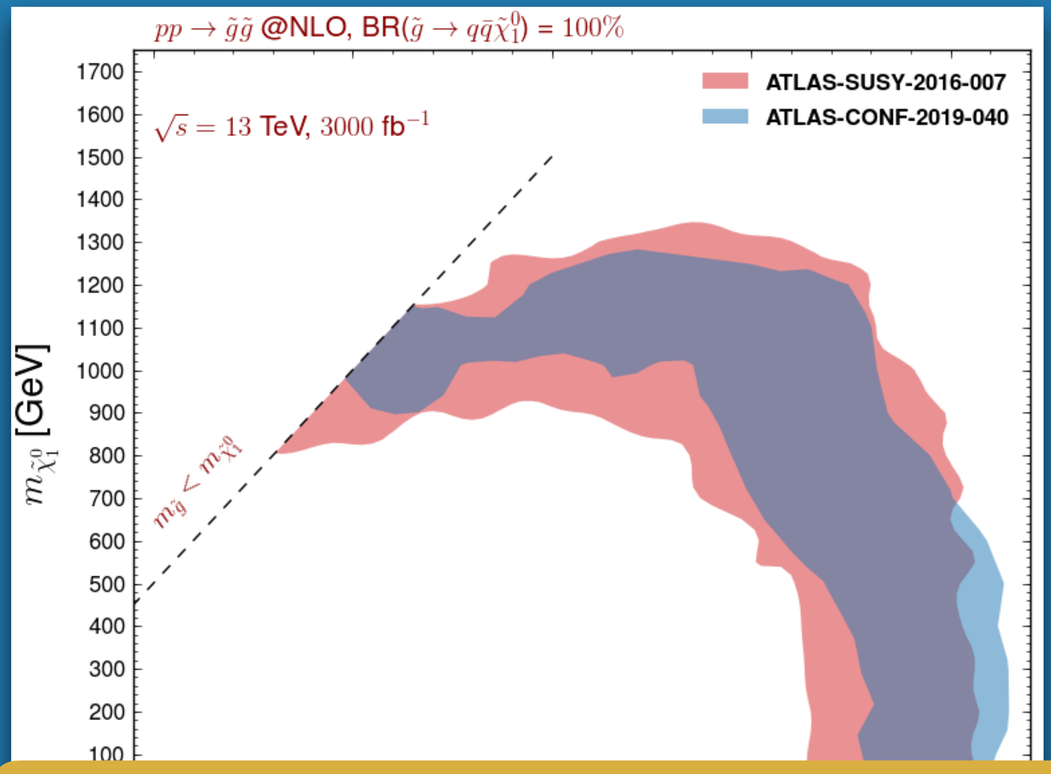




[Araz, Frank, Fuks, (EPJC '20)]

Reinterpreting the results of LHC





Are there other recasted analyses?

- Yes, when you install PAD or PADForSFS module you are installing all the available analyses. Visit Ma5 webpage for details on PAD and PADForSFS.

What is the difference between PAD and PADForSFS?

- PAD uses Delphes 3 detector simulation module, PADForSFS, as the name suggests, uses SFS module

Simplified-Fast Detector Simulation

[Araz, Fuks, Polykratis; '20]

How to define a jet clustering algorithm?

FastJet basics

1.> set main.fastsim.package = fastjet

2.> set main.fastsim.algorithm = XXX

3.> set main.fastsim.radius = XXX

4.> set main.fastsim.ptmin = XXX

1. Initialize FastJet
2. Set clustering algorithm e.g. antikt
3. Set clustering radius
4. Set minimum minimum transvers momentum for reconstructed jet

Set reconstruction mode for SFS:

> set main.fastsim.jetrecomode = XXX

jets

apply smearing to the reconstructed jet object

constituents

apply smearing before reconstructing jet objects

Which constituents one jets should I use?

Jet smearing is designed to act on reconstructed jet objects after clustering. Most of the experimental fitting has been done using relatively stable jet objects. Thus you can use the “jets” option for most of the cases. Constituent smearing is applied to hadrons which will go into the clustered jet. This method is essential for jet-substructure studies.

How to define reconstruction efficiencies?

Reconstruction Efficiencies

> define reco_efficiency <object> <function> [<domain>]

- Jets (j)
- Hadronic taus (ta)
- Electrons (e)
- Muons (mu)
- Photons (a)

Any function in LaTeX or Python format. It can depend on PT, E, ETA, PX, PY, PZ, PHI of your object and it can include any functional form.

Where does this function live?

Use AND/OR to separate multi- domain input!

Reconstruction Efficiencies

> define reco_efficiency e 0.0 [PT < 10 or ABSETA>2.5]

> define reco_efficiency e 0.85 [ABSETA < 1.5 and PT >= 10 and PT < 100]

> define reco_efficiency e 0.95 [ABSETA >= 1.5 and ABSETA <= 2.5 and PT >= 100]

Probability to reconstruct each electron

$$\varepsilon_e(p_T,\eta) = \begin{cases} 0\,\% & p_T < 10 \text{ GeV or } |\eta| > 2.5 \\ 85\,\% & |\eta| < 1.5 \;\&\; 10 \le p_T < 100 \text{ GeV} \\ 95\,\% & 1.5 \le |\eta| \le 2.5 \;\&\; p_T \ge 100 \text{ GeV} \end{cases}$$

What is happening in the background?

- Your input is going to be parsed into a C++ code to construct a piecewise function.
- The value calculated in the function per domain is the probability to accept the given particle.
- The particle of your choosing will be either reconstructed or thrown away according to this probability calculated via given function per domain.

How to define a smearing function?

Particle Smearing

> define smearer <object> with <obs> <function> [<domain>]

- Jets (j)
- Hadronic taus (ta)
- Electrons (e)
- Muons (mu)
- Photons (a)

Observable to be smeared, such as E, PT, PX, PY, PZ, ETA, PHI.

Any function in LaTeX or Python format. It can depend on PT, E, ETA, PX, PY, PZ, PHI of your object and it can include any functional form.

Where does this function live? Use AND/OR to separate multi-domain input!

Smearer

> define smearer j with E sqrt(E^2*0.05^2 + E*1.5^2) [ABSETA <= 3]

> define smearer j with E sqrt(E^2*0.13^2 + E*2.7^2) [ABSETA > 3 and ABSETA <= 5]

Standard deviation for jet energy smearing

$$\sigma_j(E) = \begin{cases} 0.05 \oplus 1.5\sqrt{E} & \text{for } |\eta| \leq 3 \text{ ,} \\ 0.13 \oplus 2.7\sqrt{E} & \text{for } 3 < |\eta| \leq 5 \end{cases}$$

arXiv: 1405.6569

What is happening in the background?

- Your input is going to be parsed into a C++ code to construct a piecewise function as standard deviation of a Gaussian centred around the given energy value.
- The jet energy will be smeared within that Gaussian.
- The p_T and energy of the jet will be modified accordingly.

How to define (mis)tagging functions?

Particle Tagging

> define tagger <true> as <reco> <function> [<domain>]

- Jets (j)
- B-jets (b)
- C-jets (c)
- Hadronic taus (ta)
- Electrons (e)
- Muons (mu)
- Photons (a)

What would you like your true particle to be reconstructed as.

Any function in LaTeX or Python format. It can depend on PT, E, ETA, PX, PY, PZ, PHI of your object and it can include any functional form.

Where does this function live? Use AND/OR to separate multi-domain input!

Tagging options

Truth level		Reco level
• Jets (j)		➡ b/c/ta/e/a
• B-jets (b)		➡ j/b/c
• C-jets (c)		➡ j/b/c
• Hadronic taus (ta)	as	➡ j/ta
• Electrons (e)		➡ j/mu/a
• Muons (mu)		➡ j/e/a
• Photons (a)		➡ j/e/mu

What is happening in the background?

- Your input is going to be parsed into a C++ code to construct a piecewise function.
- The value calculated in the function per domain is the probability to (mis)tag the given particle.
- The particle of your choice will be either reconstructed as it is or reconstructed as the particle that its appointed according to this probability calculated via given function per domain.

What's next?

To get a LHE-type output of the detector simulation, simly type

> set main.outputfile = "my_sample.lhe.gz"

> submit MY_FIRST_FASTSIM

Hands on!

Here we will use a Drell-Yan process and try to apply some detector effects.
Then we will plot the corresponding distributions to see its effects.

SFS setup in MadAnalysis 5

```
set main.fastsim.package = fastjet
set main.fastsim.algorithm = antikt
set main.fastsim.radius = 0.5
```

FastJet setup

```
define smearer mu with PT sqrt(0.01^2  + pt^2*1.0e-4^2) [abseta <= 0.5 and pt > 0.1]
define smearer mu with PT sqrt(0.015^2 + pt^2*1.5e-4^2) [abseta > 0.5 and abseta <= 1.5 and pt > 0.1]
define smearer mu with PT sqrt(0.025^2 + pt^2*3.5e-4^2) [abseta > 1.5 and abseta <= 2.5 and pt > 0.1]
```

p_T smearing for muon tracking

```
define reco_efficiency mu 0.0  [pt <= 10.0 or abseta > 2.4]
define reco_efficiency mu 0.891 [abseta <= 1.5 and pt > 10.0 and pt <= 1000.]
define reco_efficiency mu 0.891*exp(0.5 - pt*5.0e-4) [abseta <= 1.5 and pt > 1000.]
define reco_efficiency mu 0.882 [abseta > 1.5 and abseta <= 2.4 and pt > 10.0 and pt <= 1000.]
define reco_efficiency mu 0.882*exp(0.5 - pt*5.0e-4) [abseta > 1.5 and abseta <= 2.4 and pt > 1000.]
```

Reconstruction efficiencies for muon

Let's plot the results!

import /PATH/my_sample.hepmc.gz

reject (l) PT < 10
reject M (l+ l-) < 50.0
reject (hadronic) PT < 20
reject (hadronic) DELTAR (l) < 0.4

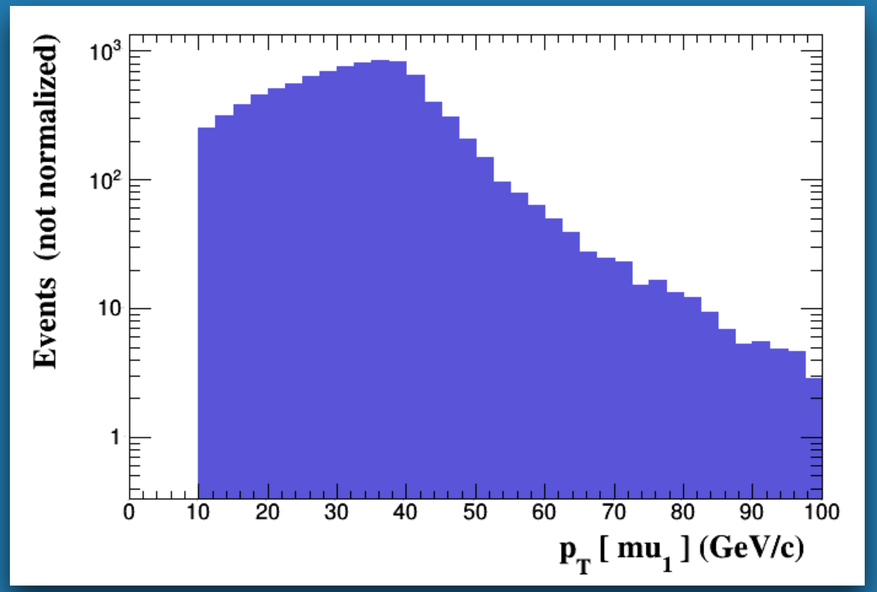
Some important cuts

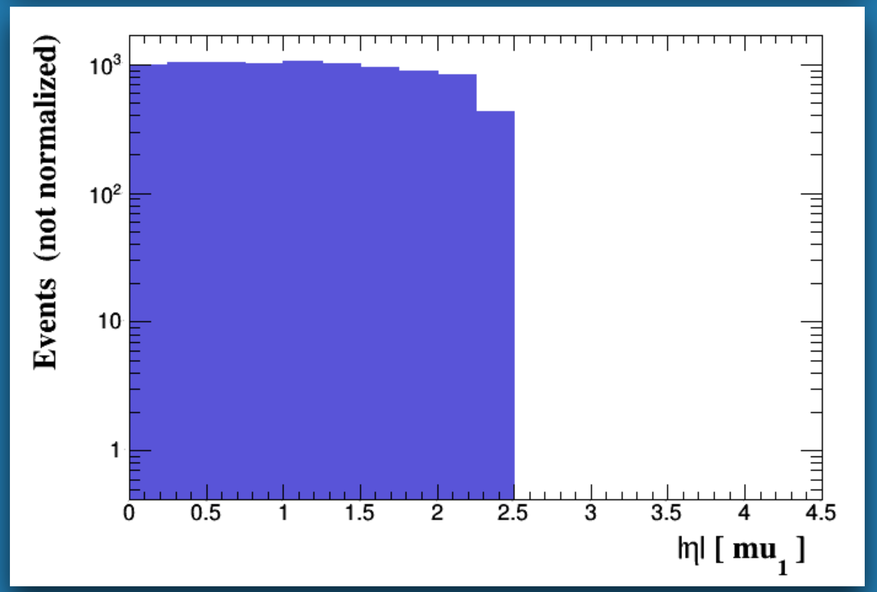
plot PT (mu[1]) 40 0 100 [logY]
plot ABSETA (mu[1]) 18 0 4.5 [logY]

Here are the plots for p_T and $|\eta|$ for the leading muon

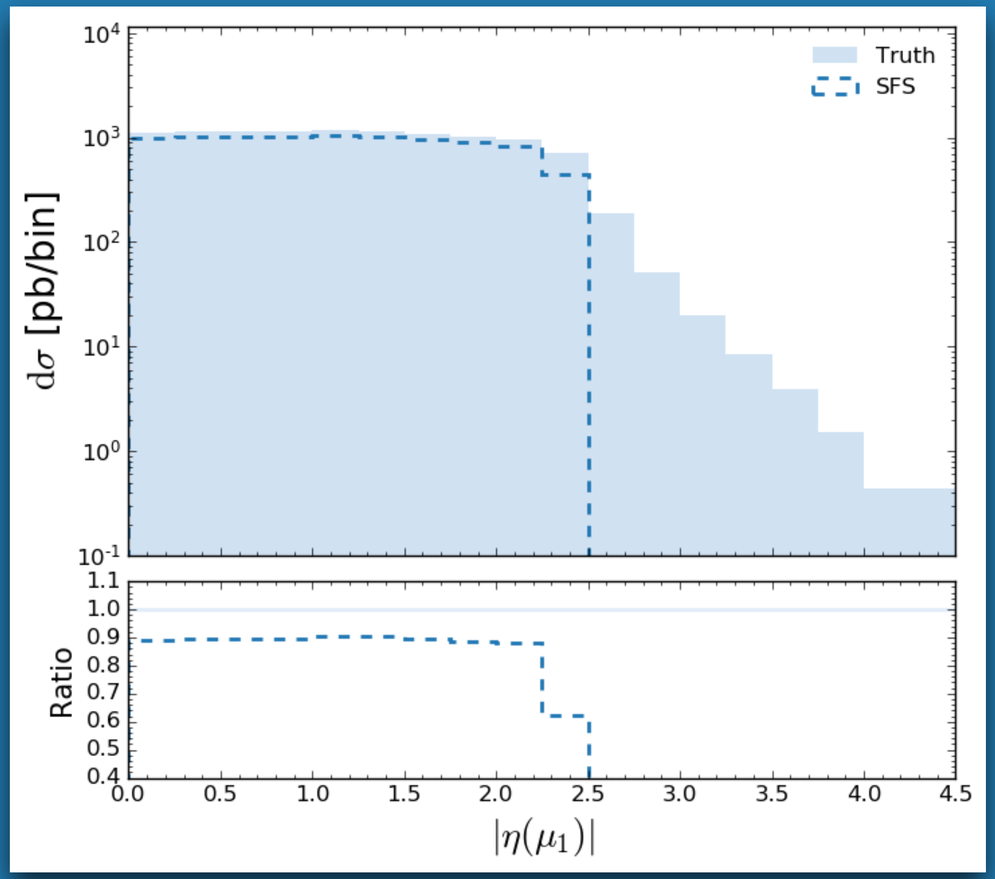
submit tutorial

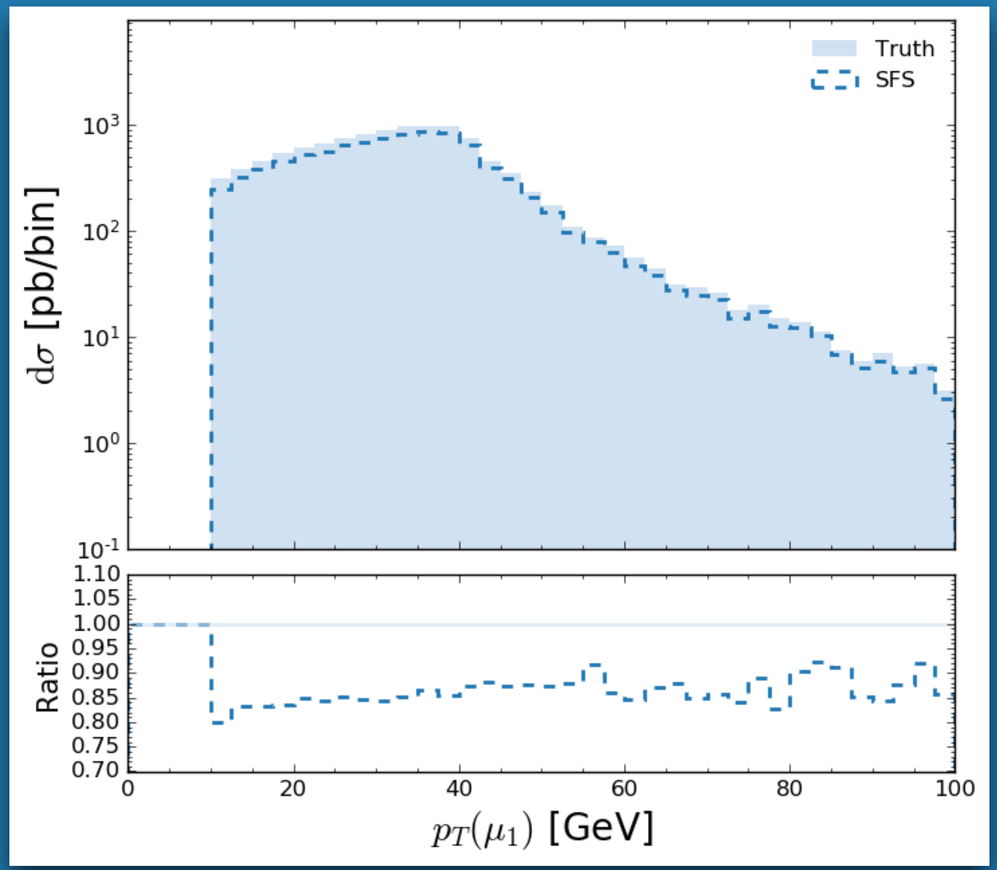
Voilà!





What's the difference?





I'm too lazy to write my own detector simulation! Are there any ready-to-use ones?

Yes! Run MadAnalysis 5 with the following command!

> ./bin/ma5 -R madanalysis/input/CMS_default.ma5

For CMS construction

OR

> ./bin/ma5 -R madanalysis/input/ATLAS_default.ma5

For ATLAS construction

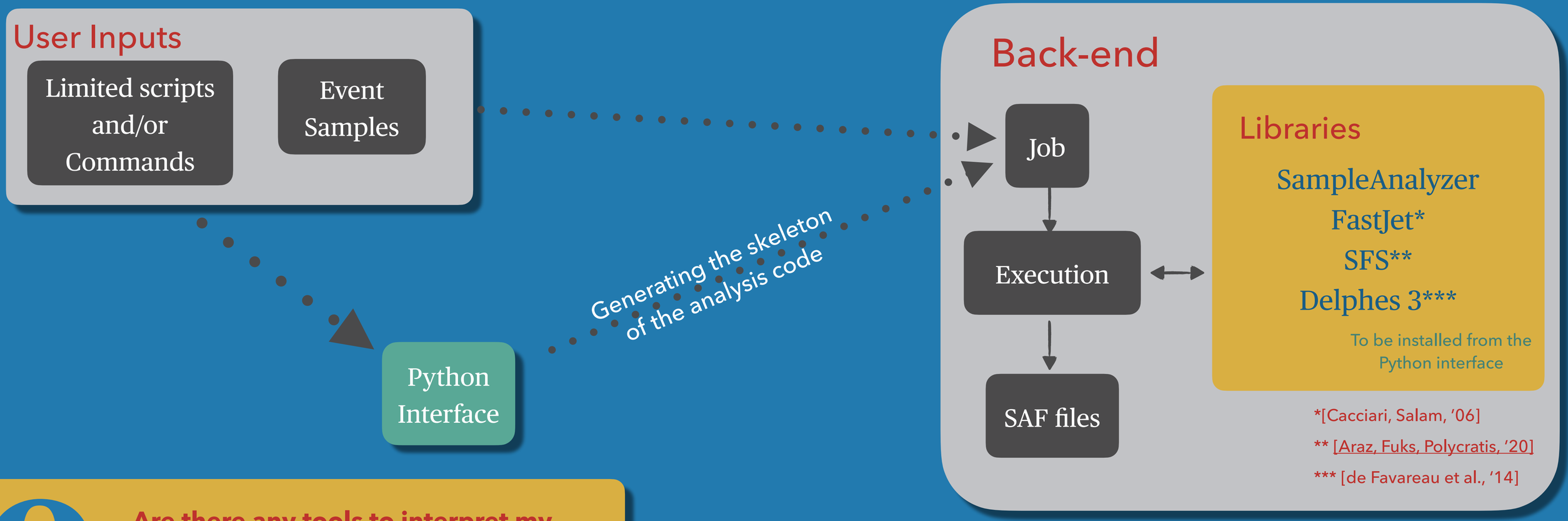
I'm an expert, I want to write my own analysis embedded in a detector simulation. Is that possible?

Yes! Write your own SFS card or use a default one and then simply type

> ./bin/ma5 -Re my_folder my_analysis my_sfs.ma5

MadAnalysis 5: Expert mode

MadAnalysis 5: Expert Mode



Are there any tools to interpret my expert-mode results?

- effofex/ma5-histo : Github repository for plotting
- jackaraz/ma5_expert : Github repository for preparing the cut-flows as LaTeX tables

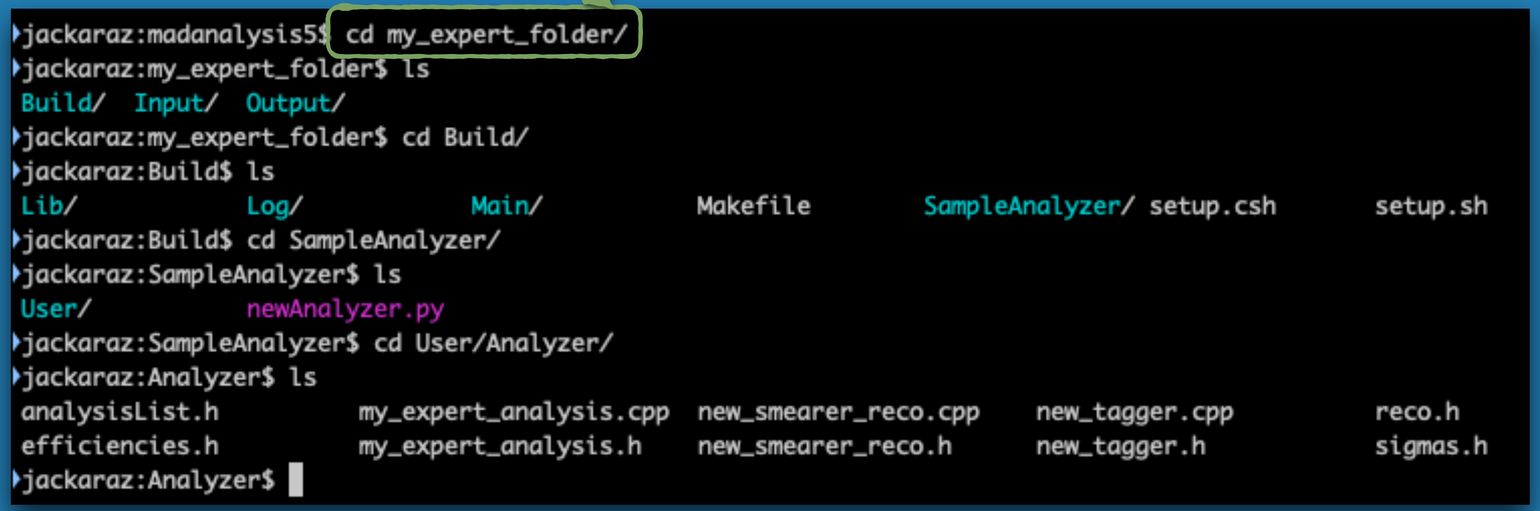
The Structure of the Expert mode

./bin/ma5 -Re my_expert_folder my_expert_analysis madanalysis/input/CMS_default.ma5

```
jackaraz:madanalysis5$ cd my_expert_folder/
jackaraz:my_expert_folder$ ls
Build/  Input/  Output/
jackaraz:my_expert_folder$ cd Build/
jackaraz:Build$ ls
Lib/            Log/            Main/           Makefile        SampleAnalyzer/ setup.csh       setup.sh
jackaraz:Build$ cd SampleAnalyzer/
jackaraz:SampleAnalyzer$ ls
User/           newAnalyzer.py
jackaraz:SampleAnalyzer$ cd User/Analyzer/
jackaraz:Analyzer$ ls
analysisList.h          my_expert_analysis.cpp  new_smearer_reco.cpp    new_tagger.cpp          reco.h
efficiencies.h          my_expert_analysis.h    new_smearer_reco.h      new_tagger.h            sigmas.h
jackaraz:Analyzer$
```

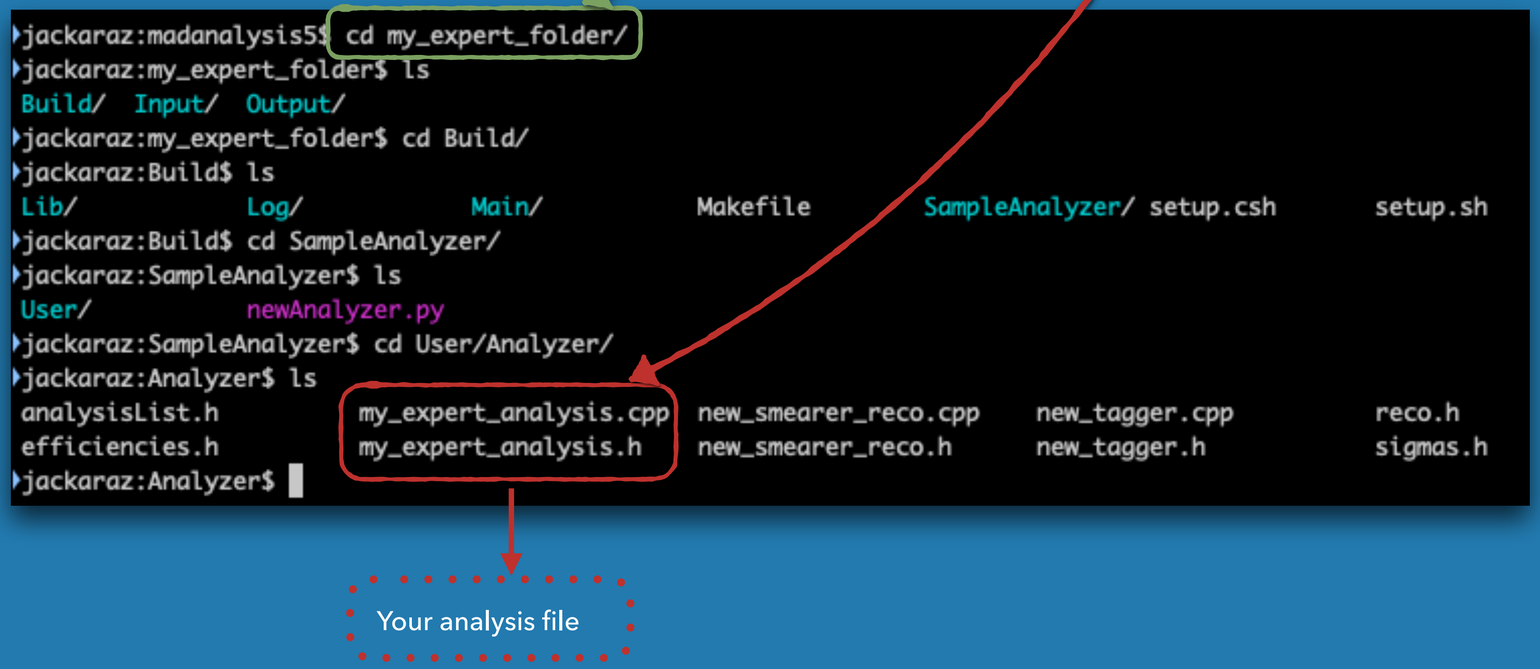
The Structure of the Expert mode

./bin/ma5 -Re my_expert_folder my_expert_analysis madanalysis/input/CMS_default.ma5



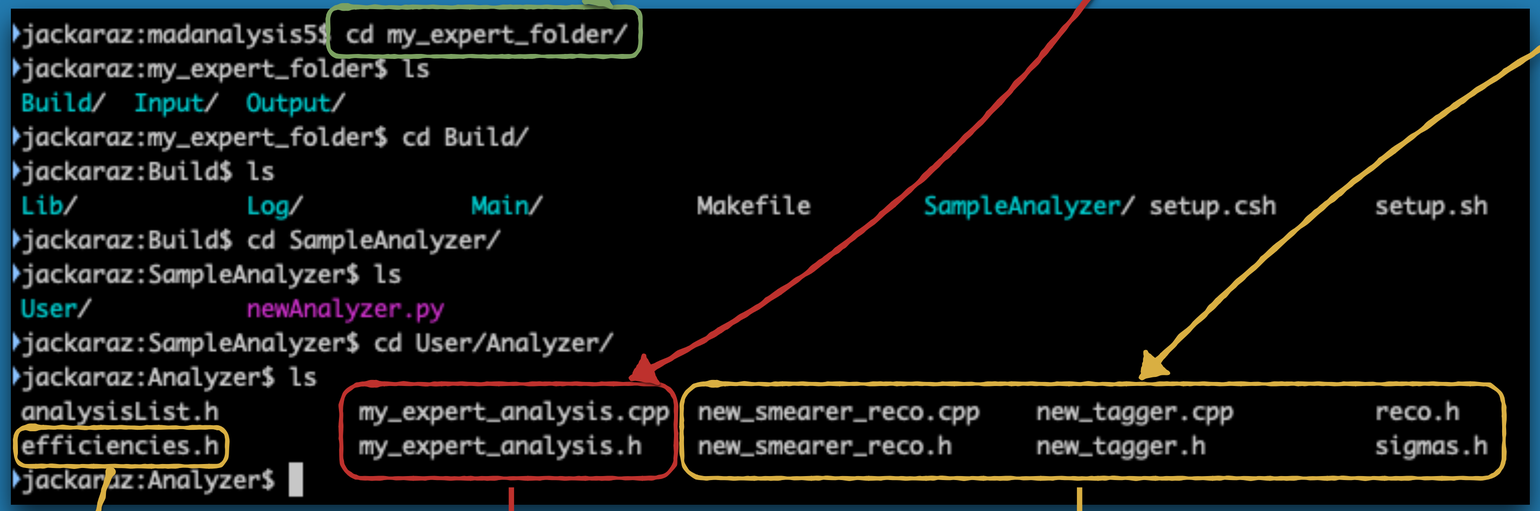
The Structure of the Expert mode

./bin/ma5 -Re my_expert_folder my_expert_analysis madanalysis/input/CMS_default.ma5



The Structure of the Expert mode

./bin/ma5 -Re my_expert_folder my_expert_analysis madanalysis/input/CMS_default.ma5

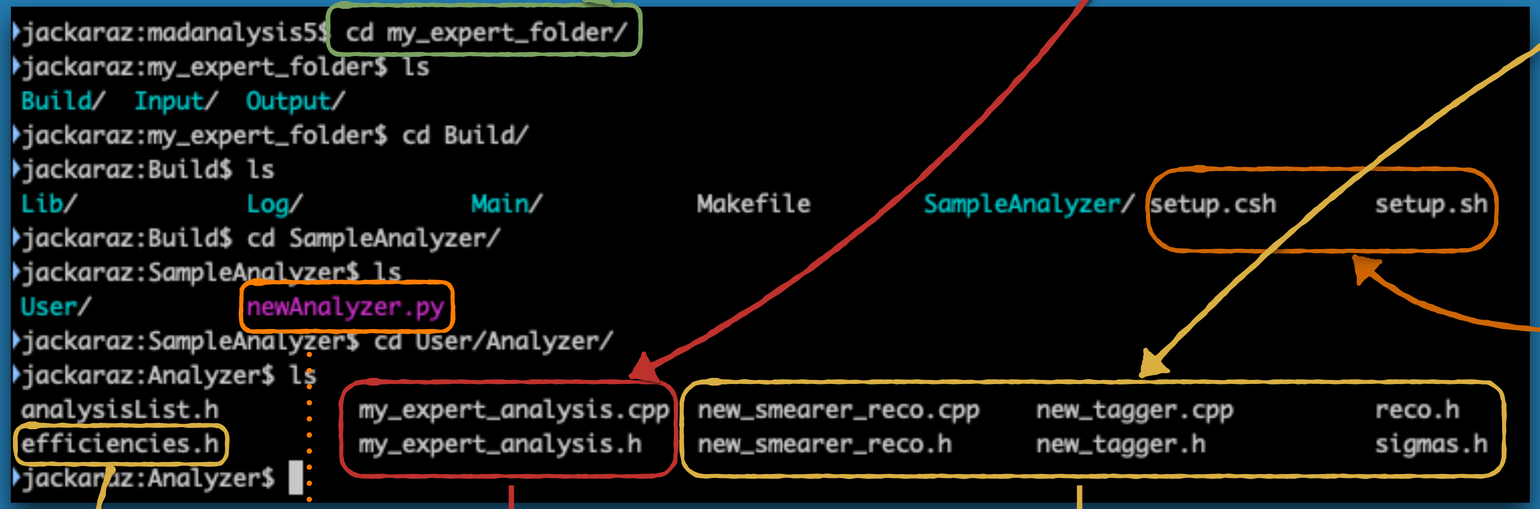


Your analysis file

SFS functions: It will apply detector effects on the fly.

The Structure of the Expert mode

./bin/ma5 -Re my_expert_folder my_expert_analysis madanalysis/input/CMS_default.ma5



How to compile & run?

> cd my_expert_folder/Build
> source setup.sh
> make clean all
> ./MadAnalysis5job ../Input/my_samples.list

> my_editor ../Input/my_samples.list
/path/to/my/sample/my_sample.hepmc.gz
Save & exit

Your analysis file

SFS functions: It will apply detector effects on the fly.

Python script to automatically add a new analysis

> python newAnalyzer.py my_new_analysis

The Structure of the Expert mode

my_expert_analysis.cpp

```
// -----------------------------------------------------------------------------
// Initialize
// function called one time at the beginning of the analysis
// -----------------------------------------------------------------------------
bool my_expert_analysis::Initialize(const MA5::Configuration& cfg, const std::map<std::string,std::string>& parameters)
{
  cout << "BEGIN Initialization" << endl;
  // initialize variables, histos
  cout << "END   Initialization" << endl;
  return true;
}
```

```
// -----------------------------------------------------------------------------
// Execute
// function called each time one event is read
// -----------------------------------------------------------------------------
bool my_expert_analysis::Execute(SampleFormat& sample, const EventFormat& event)
{
```

Initialize

- ✦ Declaration of the regions.
- ✦ Declaration of the cut-flows per region
- ✦ Declaration of the histograms per region

Execute

- ✦ Preselection
- ✦ Apply the cut-flow
- ✦ Fill the histograms

The Structure of the Expert mode

Initialize

Identifying particles

- ✦ If you are running SFS or simply FastJet, MadAnalysis needs to know what is hadronic and what is invisible.
- ✦ Declaration of hadrons: PHYSICS->mcConfig().AddHadronicId(PDGID);
- ✦ Declaration of invisible particles: PHYSICS->mcConfig().AddInvisibleId(PDGID);
- ✦ For the full list see this link.

The Structure of the Expert mode

Initialize

Identifying particles

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- Declaration of hadrons: `PHYSICS->mcConfig().AddHadronicId(PDGID);`
- Declaration of invisible particles: `PHYSICS->mcConfig().AddInvisibleId(PDGID);`
- For the full list see this link.

Regions

- A region can be defined by

  `Manager()->AddRegionSelection("my_region");`
- Cut-flows for each region will be saved in separate SAF files

The Structure of the Expert mode

Initialize

Identifying particles

- If you are running SFS or simply FastJet, MadAnalysis needs to know what is hadronic and what is invisible.
- Declaration of hadrons: PHYSICS->mcConfig().AddHadronicId(PDGID);
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- For the full list see this link.

Regions

- A region can be defined by

  Manager()->AddRegionSelection("my_region");
- Cut-flows for each region will be saved in separate SAF files

Cuts

- A cut can be defined by

  Manager()->AddCut("my_cut", "my_region");
- A cut without a specific region will be applied to all regions.
- Region input can be given as a list of strings

  std::string MultiRegion[] = {"Region1", "Region2"};

The Structure of the Expert mode

Initialize

Identifying particles

- If you are running SFS or simply FastJet, MadAnalysis needs to know what is hadronic and what is invisible.
- Declaration of hadrons: `PHYSICS->mcConfig().AddHadronicId(PDGID);`
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Regions

- A region can be defined as

  `Manager()->AddRegionSelection("my_region");`
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Cuts

- A cut can be defined as

  `Manager()->AddCut("my_cut", "my_region");`
- A cut without a specific region will be applied to all regions.
- Region input can be given as a list of strings

  ```
  std::string MultiRegion[] = {"Region1", "Region2"};
  Manager()->AddCut("my_cut", MultiRegion);
  ```

Histograms

- A histogram can be defined as

  `Manager()->AddHisto("myHist", Nbin,Xmin,Xmax, "myRegion");`
- A histogram without a specific region will be applied to all regions.
- Region input can be given as a list of strings as before.

  `Manager()->AddHisto("myHist", Nbin,Xmin,Xmax, MultiRegion);`

The Structure of the Expert mode

Execute

```
// Event weight
MAdouble64 EvWeight;
if(Configuration().IsNoEventWeight()) EvWeight=1.;
else if(event.mc()->weight()!=0.) EvWeight=event.mc()->weight();
else { return false;}
Manager()->InitializeForNewEvent(EvWeight);
// Empty event
if (event.rec()==0) {return true;}
```

Initialize the event weight. If event weight does not exits do not execute

event.rec() is the reconstructed object collection. If its empty do not execute

jets()

event.rec()->...

RecJetFormat : Contains vector of jets where
one can access to all their kinematic properties.

The Structure of the Expert mode

Execute

```
// Event weight
MAdouble64 EvWeight;
if(Configuration().IsNoEventWeight()) EvWeight=1.;
else if(event.mc()->weight()!=0.) EvWeight=event.mc()->weight();
else { return false;}
Manager()->InitializeForNewEvent(EvWeight);
// Empty event
if (event.rec()==0) {return true;}
```

Initialize the event weight. If event weight does not exits do not execute

event.rec() is the reconstructed object collection. If its empty do not execute

taus()

event.rec()->...

RecTauFormat : Contains vector of hadronic taus
where one can access to all their kinematic properties.

The Structure of the Expert mode

Execute

```
// Event weight
MAdouble64 EvWeight;
if(Configuration().IsNoEventWeight()) EvWeight=1.;
else if(event.mc()->weight()!=0.) EvWeight=event.mc()->weight();
else { return false;}
Manager()->InitializeForNewEvent(EvWeight);
// Empty event
if (event.rec()==0) {return true;}
```

Initialize the event weight. If event weight does not exits do not execute

event.rec() is the reconstructed object collection. If its empty do not execute

muons()

event.rec()->...

RecLeptonFormat : Contains vector of muons where one can access to all their kinematic properties.

The Structure of the Expert mode

Execute

```
// Event weight
MAdouble64 EvWeight;
if(Configuration().IsNoEventWeight()) EvWeight=1.;
else if(event.mc()->weight()!=0.) EvWeight=event.mc()->weight();
else { return false;}
Manager()->InitializeForNewEvent(EvWeight);
// Empty event
if (event.rec()==0) {return true;}
```

Initialize the event weight. If event weight does not exits do not execute

event.rec() is the reconstructed object collection. If its empty do not execute

electrons()

event.rec()->...

RecLeptonFormat : Contains vector of electrons
where one can access to all their kinematic properties.

The Structure of the Expert mode

Execute

```
// Event weight
MAdouble64 EvWeight;
if(Configuration().IsNoEventWeight()) EvWeight=1.;
else if(event.mc()->weight()!=0.) EvWeight=event.mc()->weight();
else { return false;}
Manager()->InitializeForNewEvent(EvWeight);
// Empty event
if (event.rec()==0) {return true;}
```

Initialize the event weight. If event weight does not exits do not execute

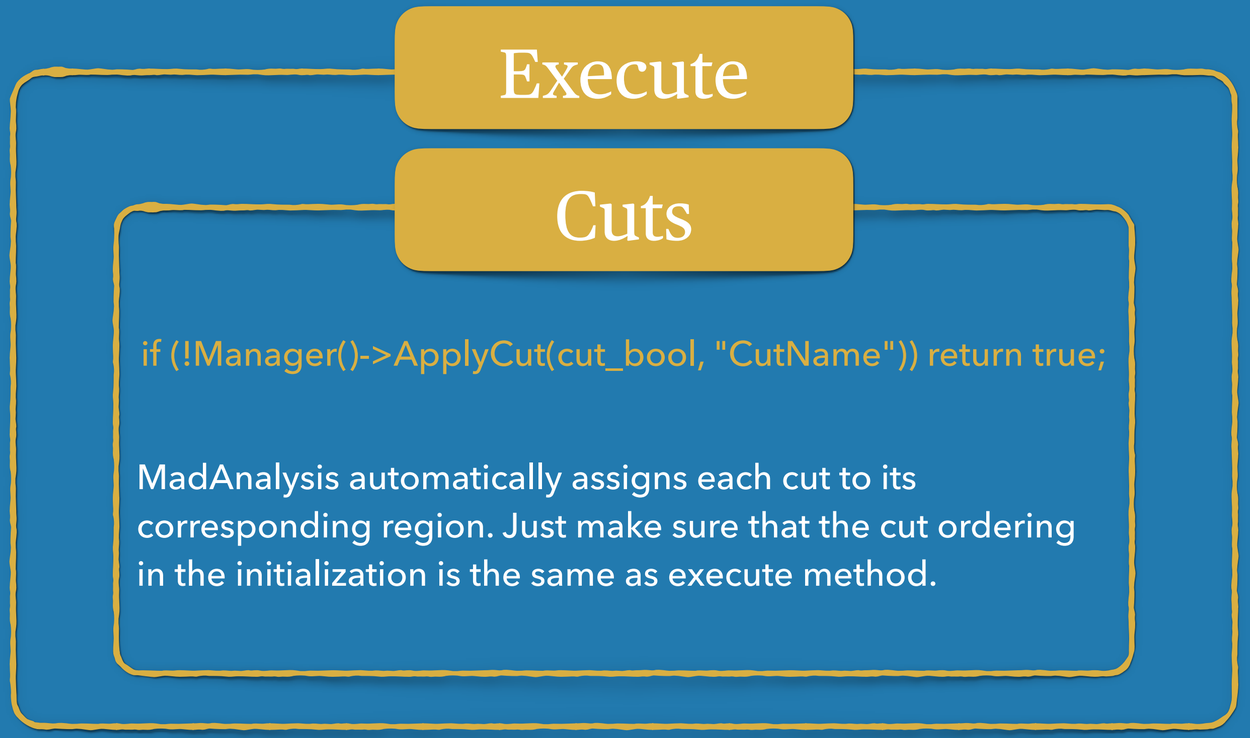
event.rec() is the reconstructed object collection. If its empty do not execute

photons()

event.rec()->...

RecPhotonFormat : Contains vector of photons where one can access to all their kinematic properties.

The Structure of the Expert mode



The Structure of the Expert mode

Execute

Cuts

```
if (!Manager()->ApplyCut(cut_bool, "CutName")) return true;
```

MadAnalysis automatically assigns each cut to its corresponding region. Just make sure that the cut ordering in the initialization is the same as execute method.

Histograms

```
Manager()->FillHisto("HistoName",   Value);
```

MadAnalysis automatically assigns each histogram to its corresponding region. If you are plotting a histogram in region A non of the cuts that are applied to region B will be effective on this histogram.

The Structure of the Expert mode

Execute

Cuts

```
if (!Manager()->ApplyCut(cut_bool, "CutName")) return true;
```

MadAnalysis automatically assigns each cut to its corresponding region. Just make sure that the cut ordering in the initialization is the same as execute method.

Histograms

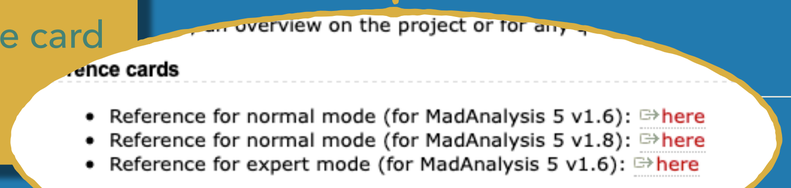
```
Manager()->FillHisto("HistoName",   Value);
```

MadAnalysis automatically assigns each histogram to its corresponding region. If you are plotting a histogram in region A non of the cuts that are applied to region B will be effective on this histogram.

Q

Is there any reference card for all the properties of the accessors?

- Of course, just check the MadAnalysis 5 webpage and you will find a reference card for the expert-mode.



Hands on!

My Expert Analysis

Initialize

```
// ========================= //
// ===== Signal region ===== //
// ========================= //

Manager()->AddRegionSelection("SR_Zmass");
Manager()->AddRegionSelection("SR_noZmass");

std::string SR[]   = {"SR_Zmass","SR_noZmass"};

// ======================= //
// ===== Selections ===== //
// ======================= //

Manager()->AddCut("$OS Dilepton$",       SR);
Manager()->AddCut("$m_{ll} > 50$ [GeV]", SR);

Manager()->AddCut("Z veto",              "SR_noZmass");

// ======================= //
// ===== Histograms ===== //
// ======================= //

Manager()->AddHisto("DileptonMass",      20,0.0,200., "SR_Zmass");
Manager()->AddHisto("DileptonMass_Zveto", 20,0.0,200., "SR_noZmass");
```

We define two signal regions one with s-channel Z vetoed and one without.

We define three cut;

1. Choose opposite sign dileptons
2. Reject events with if the dilepton mass is less than 50 GeV.
3. Veto s-channel Z.

Define histograms for dilepton mass for both regions.

My Expert Analysis

Execute

```
// Define Lepton container
std::vector<const RecLeptonFormat*> SignalLeptons;

// ========================================= //
// == Electron with pT > 4.5 GeV & eta < 2.47 == //
// ========================================= //
for(MAuint32 ie=0; ie<event.rec()->electrons().size(); ie++)
{
  const RecLeptonFormat *CurrentElectron = &(event.rec()->electrons()[ie]);
  if( CurrentElectron->pt()>4.5 && CurrentElectron->abseta() < 2.47)
    SignalLeptons.push_back(CurrentElectron);
}
// ========================================= //
// == Muons with pT > 4 GeV & eta < 2.5 == //
// ========================================= //
for(MAuint32 im=0; im<event.rec()->muons().size(); im++)
{
  const RecLeptonFormat *CurrentMuon = &(event.rec()->muons()[im]);
  if( CurrentMuon->pt()>4. && CurrentMuon->abseta() < 2.5)
    SignalLeptons.push_back(CurrentMuon);
}
```

Set lepton container

Select electrons with
$p_T > 4.5$ GeV & $|\eta| < 2.47$

Select muons with
$p_T > 4$ GeV & $|\eta| < 2.5$

My Expert Analysis

Execute

```
MAbool hasOS = false;
MAbool hasZ  = false;
if (SignalLeptons.size() >= 2)
{
    hasOS = SignalLeptons[0]->charge() != SignalLeptons[1]->charge();
    hasZ  = std::fabs((SignalLeptons[0]->momentum()+SignalLeptons[1]->momentum()).M() - 91.) < 15.;
}
```

```
if(!Manager()->ApplyCut(SignalLeptons.size() == 2 && hasOS, "$OS Dilepton$")) return true;

MAdouble64 DiLeptonMass = (SignalLeptons[0]->momentum()+SignalLeptons[1]->momentum()).M();
if(!Manager()->ApplyCut(DiLeptonMass>50., "$m_{ll} > 50$ [GeV]")) return true;

if(!Manager()->ApplyCut(!hasZ, "Z veto")) return true;
```

```
Manager()->FillHisto("DileptonMass",        DiLeptonMass);
Manager()->FillHisto("DileptonMass_Zveto",  DiLeptonMass);
```

```
Manager()->AddHisto("DileptonMass",        20,0.0,200., "SR_Zmass");
Manager()->AddHisto("DileptonMass_Zveto",  20,0.0,200., "SR_noZmass");
```

```
Manager()->AddCut("$OS Dilepton$",      SR);
Manager()->AddCut("$m_{ll} > 50$ [GeV]", SR);

Manager()->AddCut("Z veto",             "SR_noZmass");
```

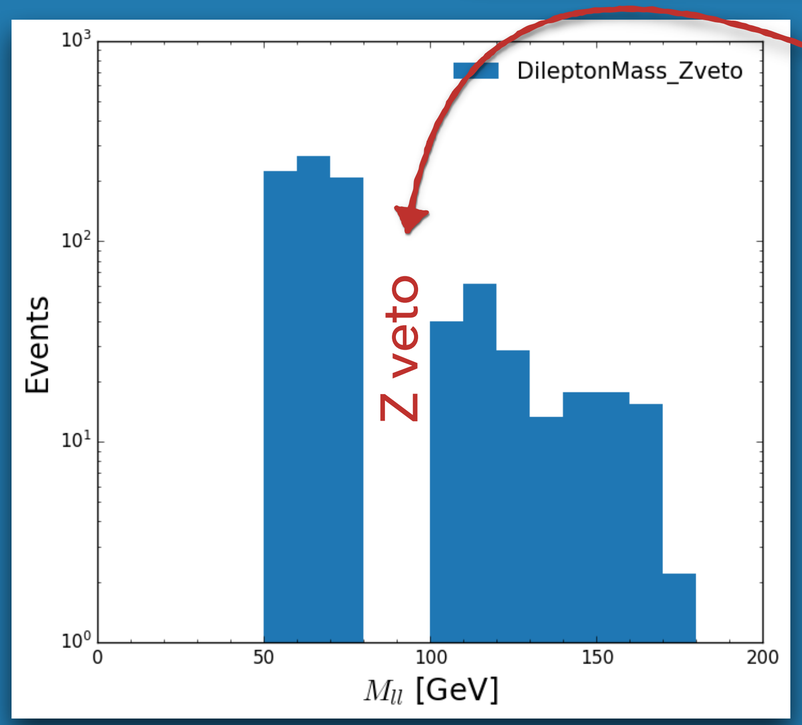
Select opposite signed leptons that might be originating from Z

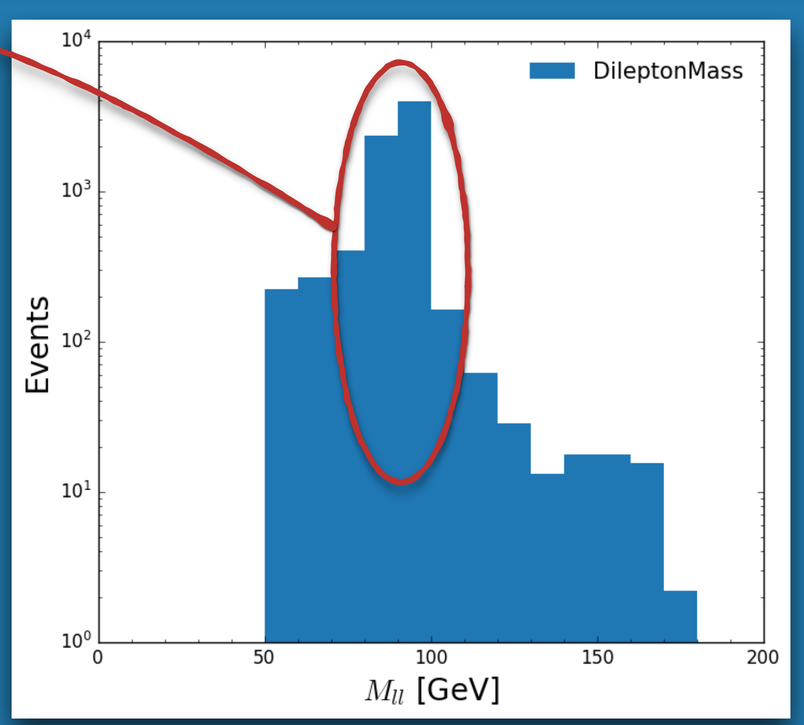
$m_{ll} = 91 \pm 15$ GeV

My Expert Analysis

Results

```
jackaraz:madanalysis5$ cd my_expert_folder/Output/SAF/_drell_yan/my_expert_analysis_0
jackaraz:my_expert_analysis_0$ ls
Cutflows/                Histograms/              my_expert_analysis.saf
```






```
if(!Manager()->ApplyCut(!hasZ, "Z veto")) return true;

Manager()->FillHisto("DileptonMass",        DiLeptonMass);
Manager()->FillHisto("DileptonMass_Zveto",  DiLeptonMass);
```

Both histograms are plotted after the same cut: MadAnalysis takes care all the regions for you!

How to add analysis to PAD?

One last step!

atlas_susy_2018_32.info

```
<analysis id="atlas_susy_2018_32">
  <lumi>139.0</lumi> <!-- in fb^-1 -->

  <region type="signal" id="SR_DF_0J_MT2_100_inf">
    <nobs>95</nobs>
    <nb>96</nb>
    <deltanb>15</deltanb>
  </region>
```

With this file, MadAnalysis 5 can calculate exclusion limits for any given event sample

Analysis name (same the name of the code) and luminosity value

For each signal region that is declared in the code, give the number of observed events (nobs), number of expected events (nb), and expected uncertainty (deltanb)

How to add analysis to PAD?

One last step!

With this file, MadAnalysis 5 can calculate exclusion limits for any given event sample

atlas_susy_2018_32.info

```
<analysis id="atlas_susy_2018_32">
  <lumi>139.0</lumi> <!-- in fb^-1 -->

  <region type="signal" id="SR_DF_0J_MT2_100_inf">
    <nobs>95</nobs>
    <nb>96</nb>
    <deltanb_syst>5</deltanb_syst>
    <deltanb_stat>8</deltanb_stat>
  </region>
```

Analysis name (same the name of the code) and luminosity value

If provided!!! For each signal region that is declared in the code, give the number of observed events (nobs), number of expected events (nb), expected systematic uncertainty (deltanb_syst) and expected statistical uncertainty (deltanb_stat)

This will allow more precise HL extrapolation!!!

How to add analysis to PAD?

One last step!

- ✦ Code is ready.
- ✦ Detector card (Delphes or SFS) is ready.
- ✦ Info file is ready.
- ✦ Validation : We require around 20%-30% agreement throughout the available cut-flow.
- ✦ Done? Send us an email with your validation note and code so that we can include your recast in PAD.

WANTED!!!

New recasts are always welcomed and appreciated in our ever growing database!!!

Stay safe!