MAD Analysis 5

Developments and functionalities (v 1.5-1.6)

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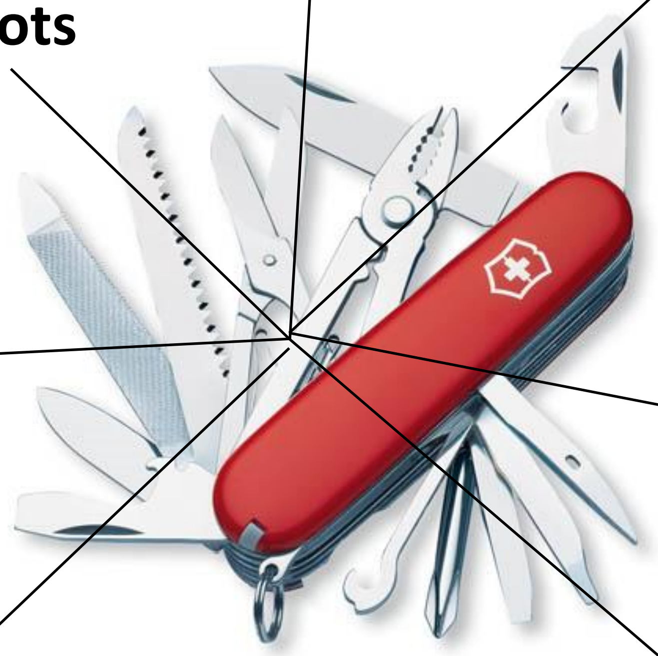
MadAnalysis5 : Functionalities

MadAnalysis 5: a multi-purpose tool

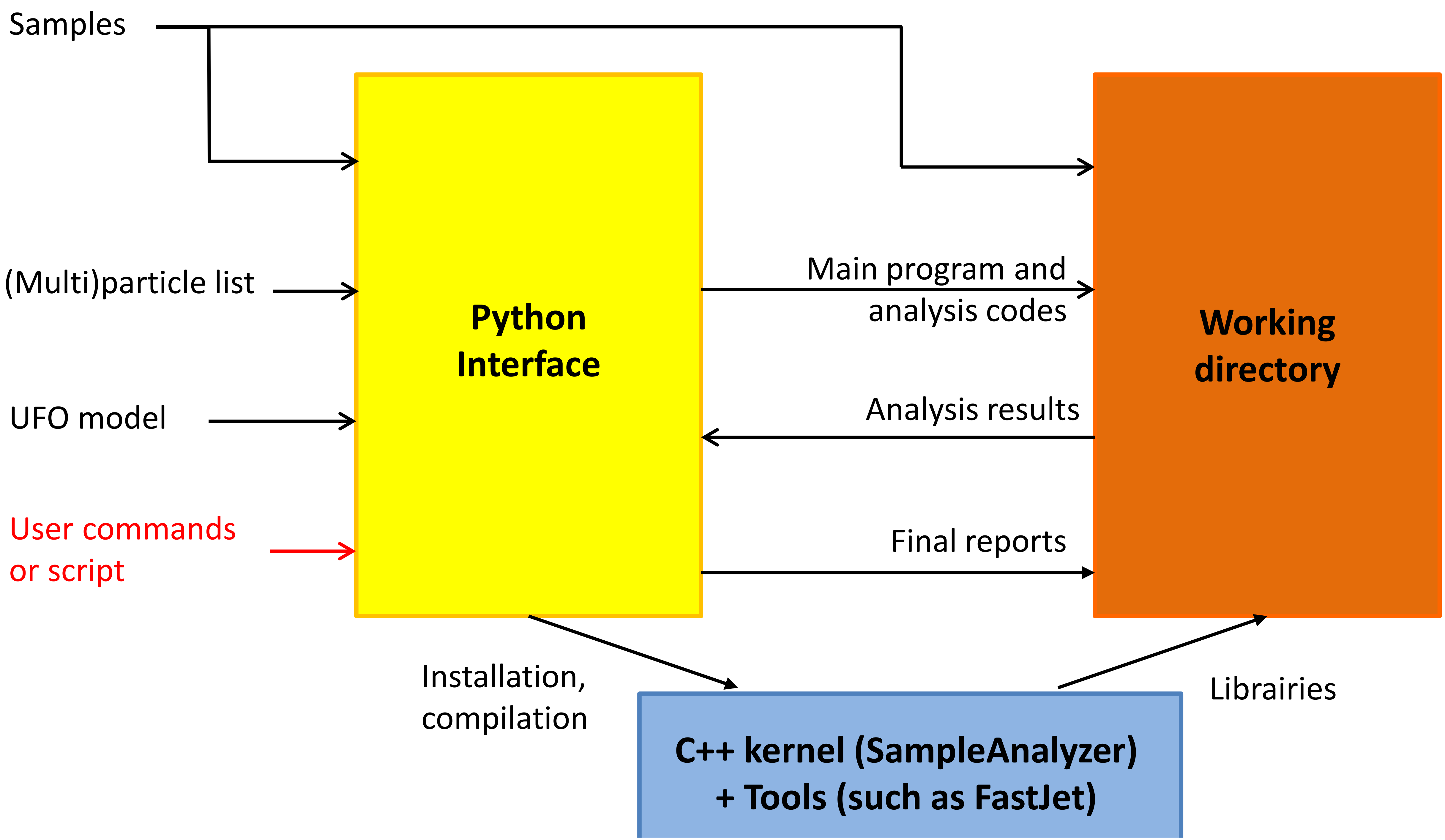
- **Histogramming and selection** in the normal mode
- **Writing** the events in another data format.
- Producing special plots such as **ME/PS merging validation plots**



- Designing a sophisticated analysis in the **expert mode**
- Applying **a jet-clustering algorithm** to your hadronic events
- **Recasting an existed analysis** and **computing a limit** to a BSM signal
- Applying a **fast-simulation detector (Delphes)** to your hadronic events

MadAnalysis5 : Functionalities

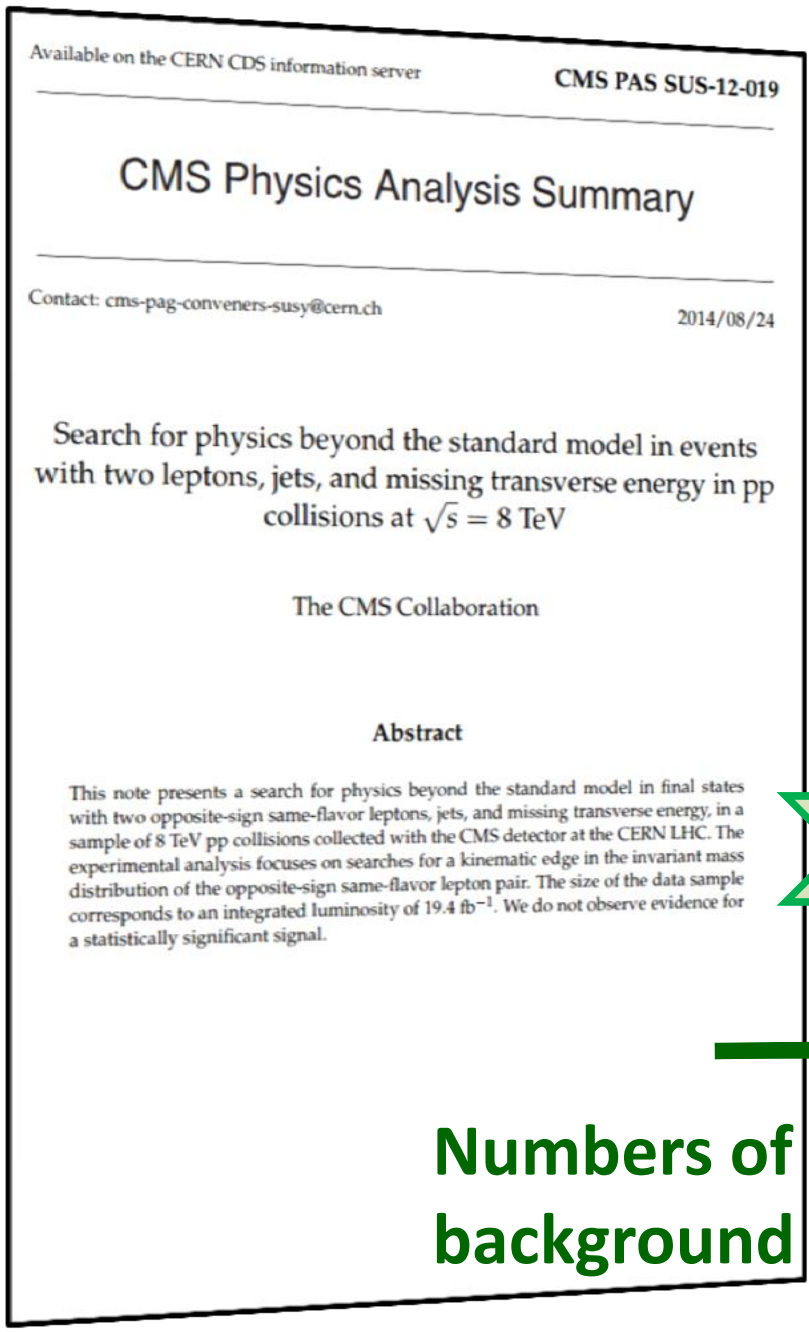
Software architecture



A Human Readable HTML/PDF is generated

MadAnalysis5 : Functionalities

MadAnalysis recasting way


Available on the CERN CDS information server

CMS PAS SUS-12-019

CMS Physics Analysis Summary

Contact: cms-pag-conveners-susy@cern.ch

2014/08/24

Search for physics beyond the standard model in events with two leptons, jets, and missing transverse energy in pp collisions at $\sqrt{s} = 8$ TeV

The CMS Collaboration

Abstract

This note presents a search for physics beyond the standard model in final states with two opposite-sign same-flavor leptons, jets, and missing transverse energy, in a sample of 8 TeV pp collisions collected with the CMS detector at the CERN LHC. The experimental analysis focuses on searches for a kinematic edge in the invariant mass distribution of the opposite-sign same-flavor lepton pair. The size of the data sample corresponds to an integrated luminosity of 19.4 fb^{-1}. We do not observe evidence for a statistically significant signal.

Signal events

(STDHEP or HEPMC format)

Analysis Specific Tunes : New

DELPHES / DELPHESMA5TUNE

Recast selection
(Expert Mode)

Physics Analysis Database

Numbers of data and background events

Limit computation

Eur.Phys.J. C74 (2014) 3103

MadAnalysis5 : Functionalities

Installation card

- More options in the configuration file: **madanalysis/input/installation_options.dat**

```
# ----GENERAL----
# tmp_dir = /tmp/toto/
# download_dir = /Users/fuks/Desktop/tmp
# webaccess_veto = 0 # 0=No, 1=Yes

# -----ROOT-----
# root_veto     = 0 # 0=No, 1=Yes
# root_bin_path = /home/toto/root/bin

# -----MATPLOTLIB-----
#matplotlib_veto = 0 # 0=No, 1=Yes

# -----DELPHES-----
# delphes_veto     = 0 # 0=No, 1=Yes
# delphes_includes = /Users/fuks/Work/tools/madanalysis/bzr/v1.3beta/tools/RE_delphes/
# delphes_libs     = /Users/fuks/Work/tools/madanalysis/bzr/v1.3beta/tools/RE_delphes/

# -----DELPHESMA5TUNE-----
# delphesMA5tune_veto     = 0 # 0=No, 1=Yes
# delphesMA5tune_includes = /home/toto/delphesMA5tune/include
# delphesMA5tune_libs     = /home/toto/delphesMA5tune/lib

# -----ZLIB-----
# zlib_veto     = 0 # 0=No, 1=Yes
# zlib_includes = /usr/include
# zlib_libs = /usr/lib

# -----FASTJET-----
```

Madanalysis 5: New methods

- Signal regions can be defined as in the normal mode
- Refactorized Code: compilation/linking improved
- Automated Recasting.
- Delphes interface modified to include both “narrow” and “fat”jets
- New module for treating long lived particles.
- A fresh new interface with MG5.

MadAnalysis5 : Functionalities

Graphical driver

- **For histogramming, there are 3 possibilities:**
  - ROOT (version > 5.27)
  - MatPlotlib (version > 1.0.1)
  - None

MadAnalysis 5 chooses at the beginning of the session the best program

- **Command for changing the graphical renderer:**

```
ma5>set main.graphic_render = <program name>
```

<program name> = root, matplotlib or none

- **When you launch an analysis, MadAnalysis 5 will save the histograms in scripts:**
  - A C++ script for ROOT
  - A Python script for Matplotlib

→ Easy to tune your figures before publishing

This script can be found in the folder: <analysis folder>/Histos/selection_*

Madanalysis 5: New Functionalities

Collaboration work between MadGraph and MadAnalysis authors
Special thank to Olivier & Valentin!

MadAnalysis 5 ➤➤➤➤ MG_aMC@NLO
arXiv:1405.0301 [hep-ph]

- **Installing MadAnalysis 5 from MG_aMC@NLO console**

```
MG_aMC@NLO> install zlib
MG_aMC@NLO> install MadAnalysis
```

→ strongly advised

- **Defining the physics process and launching the generation**

```
The following switches determine which programs are run:
/------------------------------------------------------------------------------------\
|  1. Choose the shower/hadronization program:                  shower = Not installed    |
|  2. Choose the detector simulation program:                 detector = Not installed    |
|  3. Run an analysis package on the events generated:        analysis = MADANALYSIS_5    |
|  4. Decay particles with the MadSpin module:                 madspin = OFF              |
|  5. Add weights to events for different model hypothesis:   reweight = OFF              |
\------------------------------------------------------------------------------------/
```

Madanalysis 5: Public Analysis Database

A database with MadAnalysis 5 implementations of LHC analyses
https://madanalysis.irmp.ucl.ac.be/wiki/PublicAnalysisDatabase

B. Dumont et al, Eur. Phys. J. C75 (2015) 56

ATLAS analyses, 13 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Version
ATLAS-SUSY-2015-06	Multijet + missing transverse momentum	S. Banerjee, B. Fuks, B. Zaldivar	Inspire	PDF	v1.3/Delphes3
ATLAS-EXOT-2015-03	Monojet (3.2 fb-1)	D. Sengupta	Inspire	PDF	v1.3/Delphes3
ATLAS-EXOT-2016-27	Monojet (36.1 fb-1)	D. Sengupta	To appear	To appear	v1.6/Delphes3
ATLAS-EXOT-2016-32	Monophoton (36.1 fb-1)	S. Baek, T.H. Jung	Inspire	PDF	v1.6/Delphes3
ATLAS-CONF-2016-086	b-pair + missing transverse momentum	B. Fuks & M. Zumbihl	Inspire	PDF	v1.6/Delphes3

Delphes card for ATLAS-CONF-2016-086
Delphes card for ATLAS-EXOT-2015-03 and ATLAS-SUSY-2015-06
Delphes card for ATLAS-EXOT-2016-27
Delphes card for ATLAS-EXOT-2016-32

CMS analyses, 13 TeV

Analysis	Short Description	Implemented by	Code	Validation note	Version
CMS-SUS-16-052	SUSY in the 1l + jets channel (36 fb-1)	D. Sengupta	To appear	PDF	v1.6/Delphes3
CMS-EXO-16-037	Monojets (12.9 fb-1)	B. Fuks & M. Zumbihl	To appear	To appear	v1.6/Delphes3
CMS-EXO-16-010	Mono-Z-boson (2.3 fb-1)	B. Fuks	Inspire	To appear	v1.6/Delphes3

Madanalysis 5: Workshops

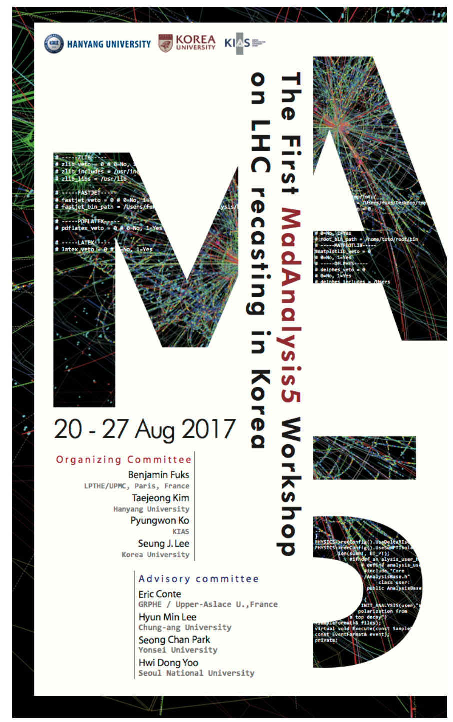
The first MadAnalysis 5 workshop on LHC recasting @ Korea

20-27 August 2017
Asia/Seoul timezone

Search...

- Overview
- Timetable
- Registration
- Participant List
- Practical information
- Pre-workshop requirements

The first MadAnalysis 5 workshop on LHC recasting @ Korea



This workshop is intended to PhD students, postdocs, junior and more senior researchers who have interests in the development of publicly available tools and methods for reinterpreting the results of the LHC. On top of general featured lectures on new physics theories and experimental collider physics aspects, the program includes both lectures and practical hands-on sessions on the reimplementation of an LHC analysis in the MadAnalysis 5 framework. Moreover, a particular attention is to be paid to the usage of such reimplementations for constraining any model of physics beyond the Standard Model.

The workshop format aims to form working groups of 5-6 people that will work together, both during the workshop and in the following months, on a specific LHC analysis. The tasks that are assigned to each working group will range from the reimplementation, in the MadAnalysis 5 framework, of the analysis at stake, to its validation, submission to our public analysis database and usage for a concrete physics project.

School-cum-workshop on "Collider Physics: Events, Analysis and QCD"

Department of Physics, IIT Guwahati

27th – 31st March, 2017

Home | Accomodation | Venue | How to reach IIT Guwahati | About Guwahati | Programme | Contact | Poster

The workshop is partially funded by

Regional Centre for Accelerator based Particle Physics (RECAPP) at the Harish Chandra Research Institute (HRI), Allahabad	Department of Science and Technology (DST-SERB), Govt. of India	Institute of Mathematica[l] Sciences (IM[Sc]) Chennai

...

The school cum workshop is intended to the PhD students, and postdoctoral fellows wor[king in] collider physics (particles) phenomenology. The workshop will include discussion and h[ands-on] sessions event generation (mostly WHIZARD), detector level analysis (mostly MadAna[lysis]) Importance of QCD at hadron colliders, and how to handle it, as well as radiative correc[tions] relevant to both hadronic as well as leptonic colliders will be discussed.

Topics	Speakers	Special Talks by
• Parton Distribution Functions • Radiative Corrections • NLO QCD • Collider Physics • WHIZARD event generator • Detector level analysis with MadAlanysis.	• Benjamin Fuks, *LTPHE, UPMC, Paris* • Prakash Mathews, *SINP, Kolkata* • V. Ravindran, *IMSc, Chennai* • Juergen Reuter, *DESY, Hamburg* • Dipan Sengupta, *Michigan State University* • Anurag Tripathi, *IIT*	• Biplob Bhattacher[jee], *IISc, Bangalore* • Partha Konar, *PRL, Ahmedabad* • Biswarup Mukhopadhyaya, *Allahabad* • Ritesh K. Singh, II[SER] Kolkata

MadAnalysis5 : Functionalities

Normal mode with the PYTHON console

- **Installing the required framework within MadAnalysis 5.**
  - → All available analyses are automatically downloaded from the PAD.
  - → 3 options: only Delphes-based analyses, only DelphesMA5tune-based analyses, or both.

```
ma5>install PADForMA5tune
```

and/or

```
ma5>install PAD
```

- **Importing your signal samples**

- **Activating the recasting mode**

```
ma5>set main.recast = on
```

- **Launching the processing**

```
ma5>submit
MA5: Would you like to edit the recasting Card ? (Y/N)
```

MadAnalysis5 : Functionalities

Recasting card: only 'ON' / 'OFF' to be changed

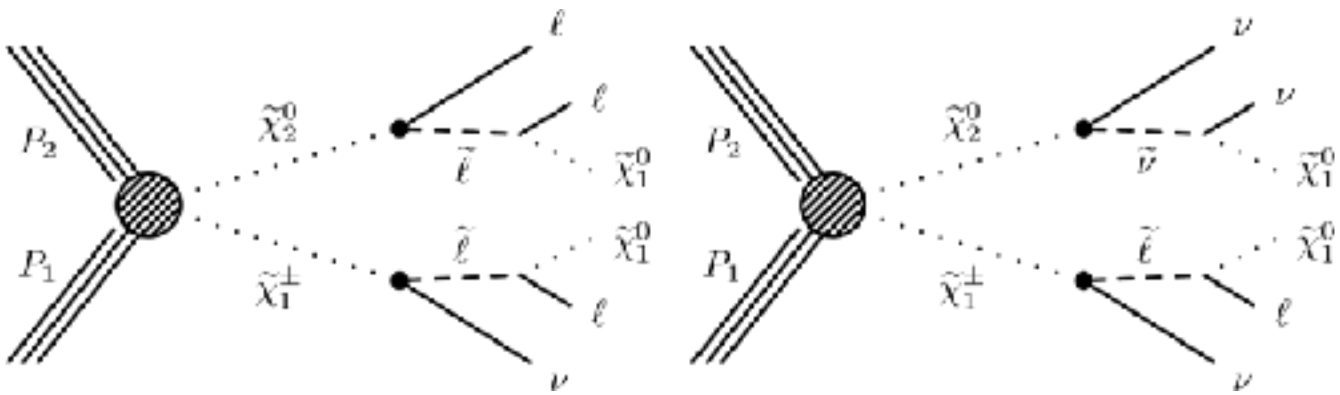
```
# AnalysisName           PADType   Switch   DelphesCard
atlas_susy_2013_04        v1.1      off     delphes_card_atlas_sus_2013_04.tcl          # ATLAS - multijet + met
atlas_sus_13_05           v1.1      on      delphes_card_atlas_sus_2013_05.tcl          # ATLAS - stop/sbottom - 0 lepton + 2 bjets + met
atlas_susy_2013_11        v1.1      off     delphes_card_atlas_sus_2013_11.tcl          # ATLAS - ewkinos - 2 leptons + met
atlas_susy_2013_21        v1.1      off     delphes_card_atlas_sus_2013_05.tcl          # ATLAS - monojet
atlas_susy_2014_10        v1.1      off     delphes_card_atlas_sus_2014_10.tcl          # ATLAS - squark-gluino - 2 leptons + jets + met
atlas_1405_7875           v1.1      off     delphes_card_atlas_sus_2013_11.tcl          # ATLAS - squark-gluino - 0 leptons + 2-6 jets + met
atlas_higg_2013_03        v1.1      off     delphes_card_atlas_sus_2013_11.tcl          # ATLAS - ZH to invisible + 2 leptons
cms_sus_13_012            v1.1      off     delphes_card_cms_standard.tcl               # CMS   - squark-gluino - MET/MHT
cms_sus_13_016            v1.1      off     delphes_card_cms_standard.tcl               # CMS   - gluinos - 2 leptons + bjets + met
cms_sus_14_001_TopTag     v1.1      on      delphes_card_cms_sus14004.tcl               # CMS   - stop - the top tagging channel
cms_sus_14_001_monojet    v1.1      off     delphes_card_cms_standard.tcl               # CMS   - stop - the monojet channel
cms_sus_13_011            v1.1      on      delphes_card_cms_standard.tcl               # CMS   - stop - 1 lepton + bjets + met
ATLAS_EXOT_2014_06        v1.2      off     delphes_card_atlas_sus_2013_05_pad.tcl      # ATLAS - monophoton
cms_exo_12_047            v1.2      off     delphes_card_cms_b2g_12_012.tcl             # CMS   - monophoton
cms_exo_12_048            v1.2      off     delphes_card_cms_b2g_12_012.tcl             # CMS   - monojet
cms_b2g_14_004            v1.2      off     delphes_card_cms_b2g_14_004.tcl             # CMS   - Dark matter production with a ttbar pair
cms_b2g_12_022            v1.2      off     delphes_card_cms_b2g_14_004.tcl             # CMS   - Monotop search
CMS_B2G_12_012            v1.2      off     delphes_card_cms_b2g_12_012.tcl             # CMS   - T5/3 partners in the SSDL channel
```

Illustrative output (beware of low statistics for the example)

```
# analysis name     signal region                                sig95(exp)   sig95(obs)   ||   efficiency   stat. unc
cms_sus_13_011      Stop->T+neutralino, LowDeltaM, MET>200       0.3301365    0.2651069    ||   0.0070623    0.0083740
cms_sus_13_011      Stop->T+neutralino, LowDeltaM, MET>250       -1           -1           ||   0.0000000    0.0000000
cms_sus_13_011      Stop->T+neutralino, LowDeltaM, MET>300       -1           -1           ||   0.0000000    0.0000000
cms_sus_13_011      Stop->T+neutralino, HighDeltaM, MET>150      -1           -1           ||   0.0000000    0.0000000
cms_sus_13_011      Stop->T+neutralino, HighDeltaM, MET>200      -1           -1           ||   0.0000000    0.0000000
cms_sus_13_011      Stop->T+neutralino, HighDeltaM, MET>250      -1           -1           ||   0.0000000    0.0000000
cms_sus_13_011      Stop->T+neutralino, HighDeltaM, MET>300      -1           -1           ||   0.0000000    0.0000000
cms_sus_13_011      Stop->b+chargino, LowDeltaM, MET>100         2.9531986    2.7750373    ||   0.0070623    0.0083740
cms_sus_13_011      Stop->b+chargino, LowDeltaM, MET>150         1.1270604    0.8966912    ||   0.0070623    0.0083740
cms_sus_13_011      Stop->b+chargino, LowDeltaM, MET>200         0.4476290    0.3246151    ||   0.0070623    0.0083740
cms_sus_13_011      Stop->b+chargino, LowDeltaM, MET>250         -1           -1           ||   0.0000000    0.0000000
```

HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

CMS-SUS-16-039

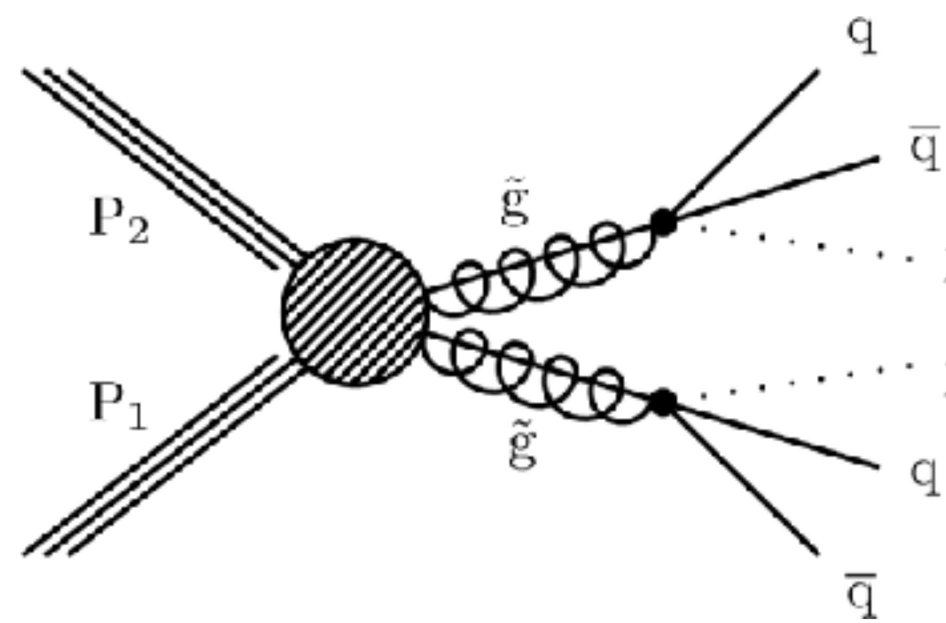


Look at all the signal regions

M_T (GeV)	E_T^{miss} (GeV)	$M_{\ell\ell} < 75$ GeV	$75 \leq M_{\ell\ell} < 105$ GeV	$M_{\ell\ell} \geq 105$ GeV
0 – 100	50 – 100	SR A01	3SR A15*	SR A32
	100 – 150	SR A02	SR A16	SR A33
	150 – 200	SR A03	SR A17	SR A34
	200 – 250	SR A04	SR A18	SR A35
	250 – 400	SR A05	SR A19	SR A36
	400 – 550		SR A20	
	≥ 550		SR A21	
100 – 160	50 – 100	SR A06	SR A22	SR A37
	100 – 150	SR A07	SR A23	SR A38
	150 – 200	SR A08	SR A24	SR A39
	≥ 200	SR A09	SR A25	SR A40
≥ 160	50 – 100	SR A10	SR A26	SR A41
	100 – 150	SR A11	SR A27	SR A42
	150 – 200	SR A12	SR A28	SR A43
	200 – 250	SR A13	SR A29	SR A44
	250 – 400	SR A14	SR A30	
	≥ 400		SR A31	

Multiple Signal regions with overlapping cuts

CMS-SUS-16-036

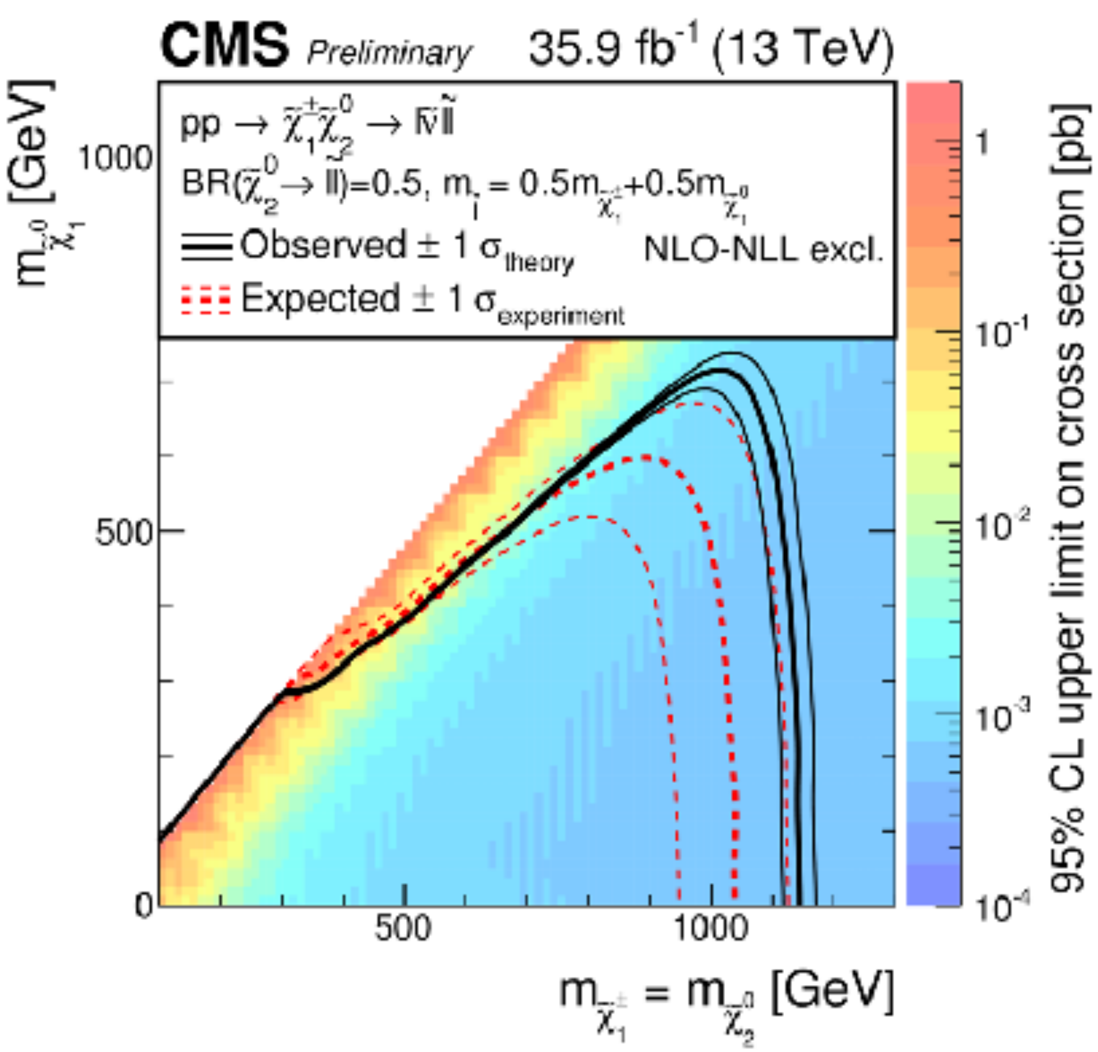


Region	N_j	N_b	H_T [GeV]	M_{T2} [GeV]	Prediction	Data	N_{95}^{obs}
2j loose	≥ 2	—	>1000	>1200	38.9 ± 11.2	42	26.6–27.8
2j tight	≥ 2	—	>1500	>1400	2.9 ± 1.3	4	6.5–6.7
4j loose	≥ 4	—	>1000	>1000	19.4 ± 5.8	21	15.8–16.4
4j tight	≥ 4	—	>1500	>1400	2.1 ± 0.9	2	4.4–4.6
7j loose	≥ 7	—	>1000	>600	$23.5^{+5.9}_{-5.6}$	27	18.0–18.7
7j tight	≥ 7	—	>1500	>800	$3.1^{+1.7}_{-1.4}$	5	7.6–7.9
2b loose	≥ 2	≥ 2	>1000	>600	$12.9^{+2.9}_{-2.6}$	16	12.5–13.0
2b tight	≥ 2	≥ 2	>1500	>600	$5.1^{+2.7}_{-2.1}$	4	5.8–6.0
3b loose	≥ 2	≥ 3	>1000	>400	8.4 ± 1.8	10	9.3–9.7
3b tight	≥ 2	≥ 3	>1500	>400	2.0 ± 0.6	4	6.6–6.9
7j3b loose	≥ 7	≥ 3	>1000	>400	5.1 ± 1.5	5	6.4–6.6
7j3b tight	≥ 7	≥ 3	>1500	>400	0.9 ± 0.5	1	3.6–3.7

Available Information

Exclusion Curves

Representative cutflows



Selection	(200/100) GeV events	(200/100) GeV efficiency	(500/150) GeV events	(500/150) GeV efficiency
all events	3630	-	115.79	-
3 tight e, μ or τ_h	482.20	13.3%	18.06	15.6%
4^{th} lepton veto	481.49	99.9%	18.03	99.8%
conversions and low-mass veto	463.71	96.3%	17.79	98.6%
b-jet veto	456.68	98.5%	17.47	98.2%
$p_T^{miss} > 50$ GeV	317.00	69.4%	16.98	97.2%
$M_T > 100$ GeV	111.97	35.3%	12.74	75.1%
$M_{\ell\ell} > 75$ GeV	103.49	92.4%	11.71	91.9%

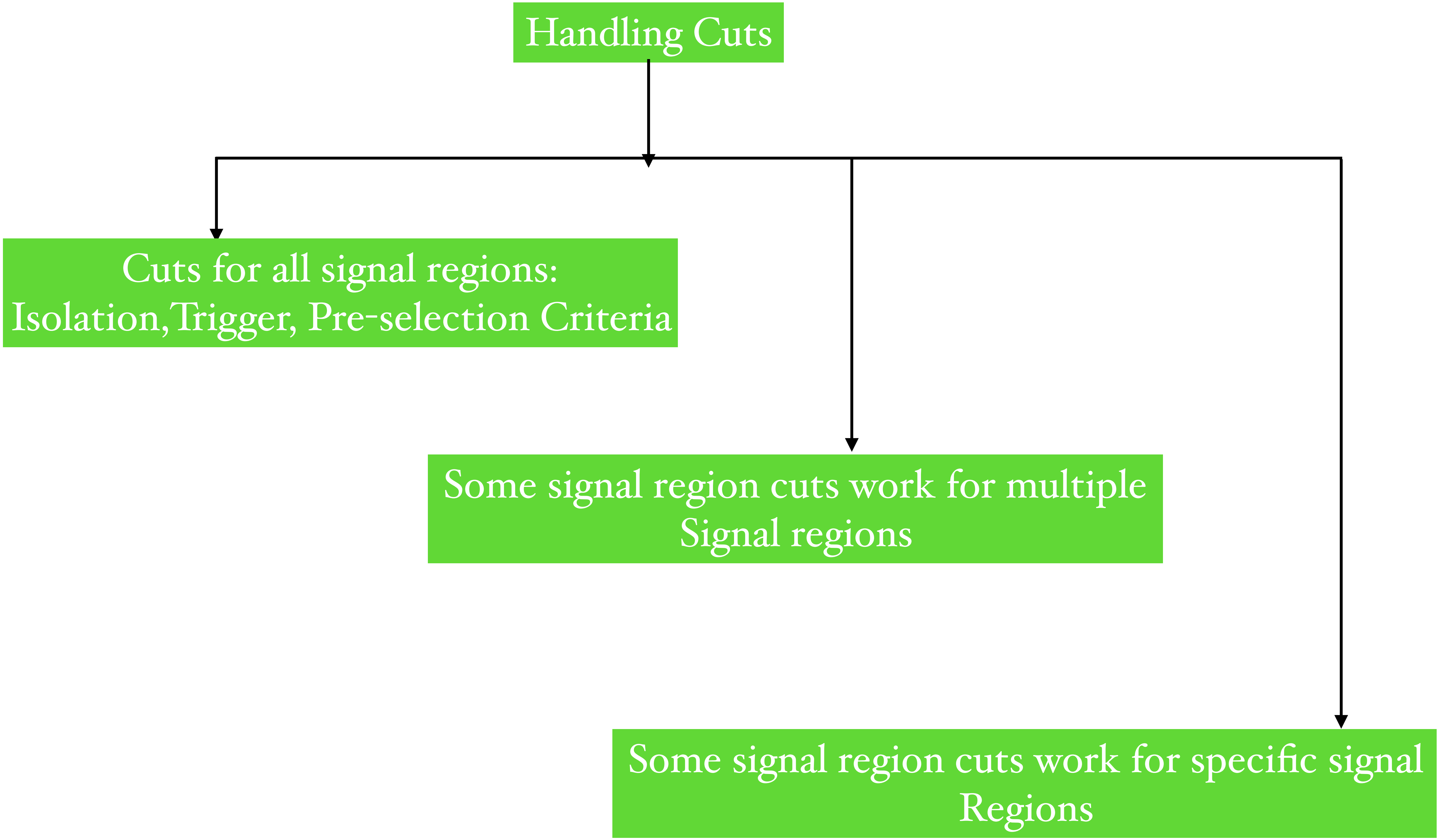
How to implement histos and cuts : expert mode

Structure of the Analyzer

```
#ifndef analysis_cms_sus_13_011_h
#define analysis_cms_sus_13_011_h

#include "SampleAnalyzer/Process/Analyzer/AnalyzerBase.h"

namespace MA5
{
class cms_sus_13_011 : public AnalyzerBase
{
  INIT_ANALYSIS(cms_sus_13_011,"cms_sus_13_011")

 public:
  virtual bool Initialize(const MA5::Configuration& cfg, const std::map<std::string,std::string>& parameters);
  virtual void Finalize(const SampleFormat& summary, const std::vector<SampleFormat>& files);
  virtual bool Execute(SampleFormat& sample, const EventFormat& event);

 private:
};
}

#endif
```

- The analyzer code in MA5 expert mode consists of the basic functions :
- Initialize : Initialization of signal regions, declaration of cuts, histograms and user defined functions.
- Execute : Containing the analysis cuts and weights applied to each event.
- Finalize : Production of the results, histograms and cut flows.

HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

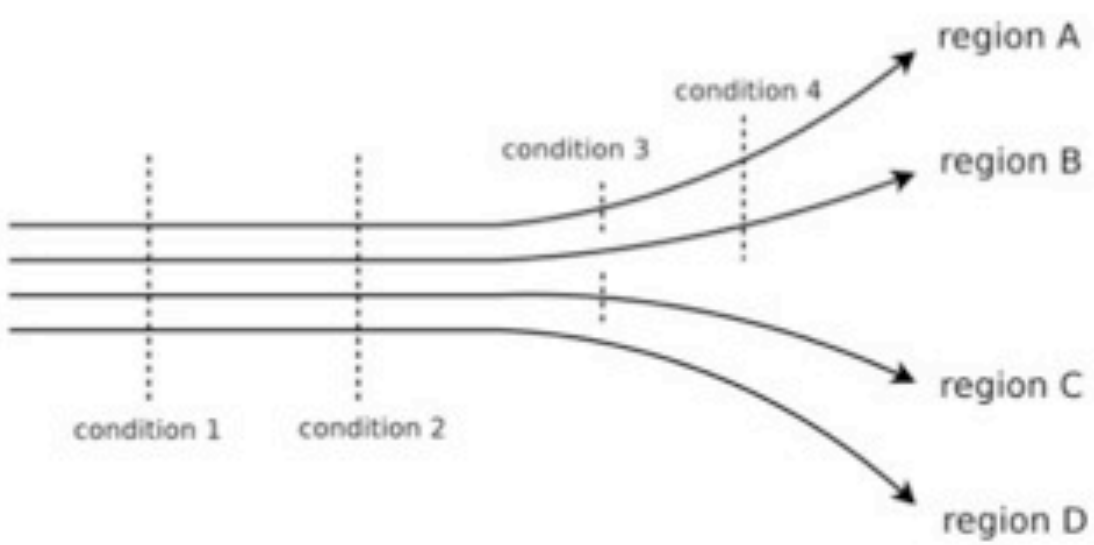


HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

Handling cuts and histograms

- Naive approach not efficient (see cut #4 for instance)

```
count the event in region D
if (condition 3)
{
  count the event in region C
  if (condition 4)
  {
    count the event in region A
  }
}
if (condition 4)
{
  count the event in region B
}
```



- A more efficient algorithm has been implemented
  - ★ Each cut condition is only evaluated once
  - ★ It is applied to all surviving regions simultaneously

HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

Step 1: Declare all the signal regions in the analysis

```
// =====Declare the signal regions in this analysis=====
  Manager()->AddRegionSelection("2jloose");
  Manager()->AddRegionSelection("4jloose");
  Manager()->AddRegionSelection("7jloose");
  Manager()->AddRegionSelection("2bloose");
  Manager()->AddRegionSelection("3bloose");
  Manager()->AddRegionSelection("7j3bloose");
  //Manager()->AddRegionSelection("EM7");
//=================================//
  Manager()->AddRegionSelection("2jtight");
  Manager()->AddRegionSelection("4jtight");
```

Step 2: Declare all cuts that are not region specific

```
// Declare all the cuts used in the analysis.
// Note that the order in which you declare cuts defines the order in which
// they appear in the cut flow table. What you want this order to be is the
// order in which the cuts are applied. It's therefore on you to declare cuts
// in the order that they are applied, so as to have a sensible cut flow at
// the end.
// Cuts are declared with RSManager's AddCut method. A cut needs a (string)
// name, and a set of signal regions which it applies to; if the latter is not
// specified, i.e. AddCut is called with only a name as its argument, the cut
// is taken to apply to *all* signal regions, i.e. it's a common cut, not a
// region-specific cut. We do this here:
```

```
//=============General Cuts=================//
Manager()->AddCut("MET > 30 GeV");
Manager()->AddCut("HT > 1000 GeV");
Manager()->AddCut("N(j) >= 1");
Manager()->AddCut("MT2 > 200 GeV");
Manager()->AddCut("dphij1met > 0.3");
Manager()->AddCut("dphij2met > 0.3");
Manager()->AddCut("dphij3met > 0.3");
Manager()->AddCut("dphij4met > 0.3");
Manager()->AddCut("ratio < 0.5");
Manager()->AddCut("ElectronVeto");
Manager()->AddCut("MuonVeto");


 Manager()->AddCut("Leading jet pT > 250 GeV");
```

HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

Step 3: Declare all cuts that are region specific

```
// Some cuts, on the other hand, apply only to some of the regions and not all
// of them. To declare such cuts, call the method AddCut with a second
// argument - an array of strings - with each string corresponding to the name
// of a signal region. This is what we do next.
// (Note that we have declared all common cuts first, then all region-specific
// cuts afterwards; we clarify that it doesn't need to be done like this -
// that's just the order of the cuts in the experimental analysis we're
// implementing here.)
```

```
//======Signal Region Cuts====RegionEMs==========
  Manager()->AddCut("HT > 1000 GeV", HT1000);
Manager()->AddCut("HT > 1500 GeV", HT1500);
Manager()->AddCut("MT2 > 400 GeV", MT2400);
Manager()->AddCut("MT2 > 600 GeV", MT2600);
Manager()->AddCut("MT2> 800 GeV", "7jtight");
Manager()->AddCut("MT2 > 1000 GeV", "4jloose");
Manager()->AddCut("MT2 > 1200 GeV", "2jloose");
Manager()->AddCut("MT2 > 1400 GeV", MT21400);
Manager()->AddCut("N(j) >= 2", nj2);
Manager()->AddCut("N(j) >= 4", nj4);
Manager()->AddCut("N(j) >= 7", nj7);
Manager()->AddCut("N(b) >= 2", nb2);
Manager()->AddCut("N(b) >= 3", nb3);
```

How to implement histos and cuts : expert mode

Some cuts could be part of multiple signal regions

```
std::string HT1000[] = {"2jloose", "4jloose", "7jloose","2bloose", "3bloose",
    "7j3bloose","new"};
std::string HT1500[] = {"2jtight", "4jtight", "7jtight","2btight", "3btight",
    "7j3btight"};
std::string MT2400[] = { "3bloose", "7j3bloose","3btight", "7j3btight"};
std::string MT2600[] = { "7jloose","2bloose","2btight"};
std::string MT21400[] = { "2jtight","4jtight"};
std::string nj2[] =
    { "2jloose","2jtight","2bloose","2btight","3bloose","3btight"};
std::string nj4[] = { "4jloose","4jtight","new"};
std::string nj7[] = { "7jloose","7jtight","7j3bloose","7j3btight"};
std::string nb2[] = { "2bloose","2btight","new"};
std::string nb3[] = { "3bloose","3btight","7j3bloose","7j3btight"};
```

HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

Declare all the Histograms in the analysis
Follows the same logic as cuts

```
Manager()->AddHisto("MT",10,0,300); // Fig. 2a
Manager()->AddHisto("MET",10,100,350); // Fig. 2b
Manager()->AddHisto("MT2W",17,75,500); // Fig. 2c
Manager()->AddHisto("chi2",20,0,20); // Fig. 2d
Manager()->AddHisto("HTratio",25,0,1); // Fig. 2e
Manager()->AddHisto("pT(leading b-jet)",9,30,300); // Fig. 2g
Manager()->AddHisto("pT(l)",8,20,100); // Fig. 2i
Manager()->AddHisto("JetMETMindeltaPhi",15,0,PI); // Fig. 2f
Manager()->AddHisto("deltaR(l, leading b-jet)",15,0,5); // Fig. 2h
Manager()->AddHisto("MT2W after MT>120",17,75,500); // Fig. add 12
Manager()->AddHisto("chi2 after MT>120",20,0,20); // Fig. add 14
Manager()->AddHisto("HTratio after MT>120",25,0,1); // Fig. add 16
Manager()->AddHisto("JetMETMindeltaPhi after MT>120",25,0,PI); // Fig. add 17
Manager()->AddHisto("pT(leading b-jet) after MT>120",20,0,500); // Fig. add 13
Manager()->AddHisto("deltaR(l, leading b-jet) after MT>120",20,0,5); // Fig.
                                                                      // add 15
```

HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

Define Objects

```
//Defining the containers
  vector<const RecJetFormat*> SignalJets, myjet, pseudojets ;
  vector<const RecLeptonFormat*>SignalMuons,SignalElectrons;
  vector<const RecTauFormat*>SignalTaus;
```

```
//electron with pt>20
       for(unsigned int ie=0; ie<event.rec()->electrons().size(); ie++)
        {
        const RecLeptonFormat * CurrentElectron = &(event.rec()->electrons()[ie
            ]);
        double pt = CurrentElectron->pt();
        double abseta = fabs(CurrentElectron->eta());
        if(pt > 20. && abseta < 2.47)
        SignalElectrons.push_back(CurrentElectron);
        }
```

Basic cuts on Electrons

```
    for(unsigned int ij=0; ij<event.rec()->jets().size(); ij++)
     {
      const RecJetFormat * CurrentJet = &(event.rec()->jets()[ij]);
      if ( CurrentJet->pt() > 30.0 && abs(CurrentJet->eta())<2.8){
      SignalJets.push_back(CurrentJet);
      HT = HT + CurrentJet->pt();
      px = px + CurrentJet->px();
      py = py + CurrentJet->py();
      pz = pz + CurrentJet->pz();
  nj = nj + 1;
      if (CurrentJet->btag()) nbjets = nbjets+1;
```

Basic cuts on Jets

B-tag

Isolation + Overlap removal

```
for(int im=SignalMuons.size()-1;im>=0;im--)
{
  const RecLeptonFormat * myMuon = &(event.rec()->muons()[im]);
  double mympt=myMuon->pt();
  double chargeptm=PHYSICS->Isol->eflow->sumIsolation(myMuon,event.rec(),0.4,
      0.,IsolationEFlow::TRACK_COMPONENT);
  double neutralptm=PHYSICS->Isol->eflow->sumIsolation(myMuon,event.rec(),0.4
      ,0.,IsolationEFlow::NEUTRAL_COMPONENT);
  double photonptm=PHYSICS->Isol->eflow->sumIsolation(myMuon,event.rec(),0.4,
      0.,IsolationEFlow::PHOTON_COMPONENT);
 double ttptm=chargeptm + neutralptm + photonptm;
  if(ttptm > 0.2*mympt)
     SignalMuons.erase(SignalMuons.begin()+im);
}


//=====Overlap removal of jets==================//
   SignalJets = PHYSICS->Isol->JetCleaning(SignalJets, SignalElectrons, 0.4);
   SignalJets = PHYSICS->Isol->JetCleaning(SignalJets, SignalMuons,     0.4);
```

HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

Define Missing Energy

```
MALorentzVector MET=event.rec()->MET().momentum();
double METval=MET.Pt();
```

Mass of a four vector created out of two four vectors

```
MALorentzVector Pll=Pos_el_loose[ii]->momentum()+Neg_el_loose[jj]->
    momentum();
if(Pll.Mag()<105.0 && Pll.Mag()>75.0)mllossf=false;
if(Pll.Mag()<12.0)mlllow=false;
```

Define Transverse Mass

```
mtmiss=pl3.mt_met(MET)
```

Define MT2

```
double mt2_ll=0.0;
double m_trial=0.0;
if(TightElectrons.size()>=2){mt2_ll=PHYSICS->Transverse->MT2(&(TightElectrons
    [0]->momentum()),&(TightElectrons[1]->momentum()),MET,m_trial);}
else if(TightMuons.size()>=2){mt2_ll=PHYSICS->Transverse->MT2(&(TightMuons[0]
    ->momentum()),&(TightMuons[1]->momentum()),MET,m_trial);}
```

HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

Angular Cuts between objects

```
DeltaPhiJet1= SignalJets[0]->dphi_0_pi(pTmiss);
```

Execute cuts corresponding to pre-defined cut names

```
//General cuts//===========

//======Missing Et cut=====//

 if(!Manager()->ApplyCut(MET > 30,"MET > 30 GeV"))
   return true;


//======HT cut=====//

 if(!Manager()->ApplyCut(HT > 1000,"HT > 1000 GeV"))
   return true;

//======Number of jets cut=====//

 if(!Manager()->ApplyCut(nj > 1,"N(j) >= 1"))
   return true;
```

→ Cut associated with all the signal regions

HOW TO IMPLEMENT HISTOS AND CUTS : EXPERT MODE

Execute cuts corresponding to cuts associated with signal regions

```
//=======Signal Region Specific Cuts=============//

if(!Manager()->ApplyCut((mt2 > 400),"MT2 > 400"))
return true;
if(!Manager()->ApplyCut((mt2 > 600),"MT2 > 600"))

return true;
if(!Manager()->ApplyCut((mt2 > 800),"MT2 > 800"))
return true;
if(!Manager()->ApplyCut((mt2 > 1000),"MT2 > 1000"))
return true;
if(!Manager()->ApplyCut((mt2 > 1200),"MT2 > 1200"))
return true;
if(!Manager()->ApplyCut((mt2 > 1400),"MT2 > 1400"))
return true;
```

How to implement histos and cuts : expert mode

```
// Some histos which are defined only after the previous cut:
Manager()->FillHisto("MT2W after MT>120", mt2w);
Manager()->FillHisto("chi2 after MT>120", chi2);
Manager()->FillHisto("HTratio after MT>120", HTratio);
Manager()->FillHisto("JetMETMindeltaPhi after MT>120", MinDeltaPhiJetMET);
Manager()->FillHisto("pT(leading b-jet) after MT>120",LeadingBjetpT);
Manager()->FillHisto("deltaR(l, leading b-jet) after MT>120",deltaRb1l);
```

Looking at the Output , present in the Output folder in xml format : Cutflows

```
-bash-4.1$ ls
Build  exclusion_CLs.py  Input  Output
-bash-4.1$ cd Output/
-bash-4.1$ ls
test.txt
-bash-4.1$ cd test.txt/
-bash-4.1$ ls
ATLAS_1604_07773_0  ATLAS_1604_07773_0.out  test.txt.saf
-bash-4.1$ cd ATLAS_1604_07773_0
-bash-4.1$ ls
ATLAS_1604_07773.saf  Cutflows  Histograms
-bash-4.1$ cd Cutflows/
-bash-4.1$ ls
EM1.saf  EM2.saf  EM3.saf  EM4.saf  EM5.saf  EM6.saf  EM7.saf  IM1.saf  IM2.saf  IM3.saf  IM4.saf  IM5.saf  IM6.saf
-bash-4.1$
```

How to implement Histos and Cuts : Expert Mode

Looking at the Output , present in the Output folder in xml format : Cutflows

```
<SAFheader>
</SAFheader>

<InitialCounter>
"Initial number of events"      #
19114          0               # nentries
1.911400e+04   0.000000e+00    # sum of weights
1.911400e+04   0.000000e+00    # sum of weights^2
</InitialCounter>

<Counter>
"at least 2 leptons"            # 1st cut
1671           0               # nentries
1.671000e+03   0.000000e+00    # sum of weights
1.671000e+03   0.000000e+00    # sum of weights^2
</Counter>

<Counter>
"at least 2 OS leptons"         # 2st cut
157            0               # nentries
1.570000e+02   0.000000e+00    # sum of weights
1.570000e+02   0.000000e+00    # sum of weights^2
</Counter>
```

f IM6.saf

HOW TO TEST CUTFLOWS

For every signal region : after every cut

n_s = Acceptance x efficiency x cross section x luminosity

$\tilde{q} \to q\tilde{\chi}_1^0$ (650/645) cutflow				
cut	# events (Official)	relative change	# events MA5	relative change
Initial number of events	4544	-	4544	-
$E_T^{\text{miss}} > 100$ GeV	1917	58 %	2031	55 %
Trigger	1604	16 %	-	-
Event cleaning	1592	1 %	-	-
Lepton veto	1591	0.01 %	2022	0.4 %
$N_{\text{jets}} \leq 4$	1492	6 %	1883	7 %
$\Delta\phi(E_T^{\text{miss}}, \text{jets}) > 0.4$	1409	5 %	1798	5 %
Jet Quality	1343	4 %	-	-
$p_T^{\text{j1}} > 250$ GeV	435	67 %	426	76 %
$E_T^{\text{miss}} > 250$ GeV	404	7 %	402	6 %
M1 : $\text{E}_{\text{T}}^{\text{miss}} = [250 - 300]$ GeV	58	86 %	57	86 %
M2 : $\text{E}_{\text{T}}^{\text{miss}} = [300 - 350]$ GeV	65	84 %	69	83 %
M3 : $\text{E}_{\text{T}}^{\text{miss}} = [350 - 400]$ GeV	59	86 %	57	86 %
M4 : $\text{E}_{\text{T}}^{\text{miss}} = [400 - 500]$ GeV	85	79 %	81	80 %
M5 : $\text{E}_{\text{T}}^{\text{miss}} = [500 - 600]$ GeV	53	87 %	57	86 %
M6 : $\text{E}_{\text{T}}^{\text{miss}} = [600 - 700]$ GeV	34	91 %	36	91 %
M7 : $\text{E}_{\text{T}}^{\text{miss}} > 700$ GeV	49	89 %	46	90 %

GOING FROM CUTFLOWS TO EXCLUSION

In order to test a new physics signal (corresponding to a Monte Carlo sample mysample.hep.gz or mysample.hepmc.gz), it is sufficient to start MadAnalysis 5 in the reco mode (./bin/ma5 -R) and type

```
set main.recast = on
set main.recast.store_root = False
import <path-to-the-event-sample>
submit
```

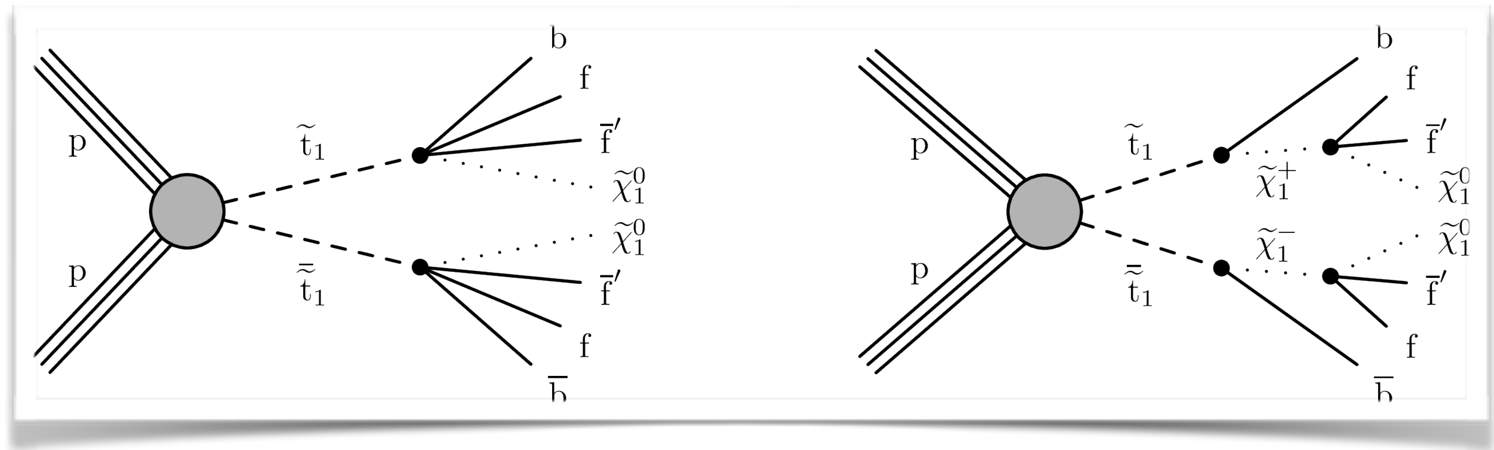
The interpreter then asks to edit the recasting card where one can tick/untick the analyses that need to be recasted. One can also use the command

```
set main.recast.card_path = <path-to-a-recasting-card>
```

to provide the recasting card directly. The output directory contains the events of the store_root option has been set to True, as well as the CLs an efficiency information for each signal region of each of the selected analyses. The cross section excluded at the 95% CL by each region is also provided as additional information.

Validation of CMS_16_052

Signal of Interest



Cuts

Table 1: Definition of signal regions and their corresponding control regions. The subregions of signal regions are denoted by tags in parentheses described in the text. For jets, the attributes "soft" and "hard" refer to the p_T ranges 30–60 GeV and $>$ 60 GeV, respectively.

Variable	common to all SRs					
Number of hard jets	≤ 2					
$\Delta\phi$(hard jets) (rad)	< 2.5					
p_T^{miss} (GeV)	> 300					
Lepton rejection	no τ, or additional ℓ with $p_T > 20$ GeV					
	SR1			SR2		
H_T (GeV)	> 400			> 300		
p_T(ISR jet) (GeV)	> 100			> 325		
Number of b jets	0			$\geq$1 soft, 0 hard		
$\lvert\eta(\ell)\rvert$	< 1.5			< 2.4		
	SR1a	SR1b	SR1c	SR2a	SR2b	SR2c
m_T (GeV)	< 60	60–95	> 95	< 60	60–95	> 95
$Q(\ell)$	-1	-1	any	any	any	any
$p_T(\mu)$ (GeV)	3.5–5 (VL)	3.5–5 (VL)	-	3.5–5 (VL)	3.5–5 (VL)	-
$p_T(e, \mu)$ (GeV)	5–12 (L)	5–12 (L)	5–12 (L)	5–12 (L)	5–12 (L)	5–12 (L)
	12–20 (M)	12–20 (M)	12–20 (M)	12–20 (M)	12–20 (M)	12–20 (M)
	20–30 (H)	20–30 (H)	20–30 (H)	20–30 (H)	20–30 (H)	20–30 (H)
	> 30 (CR)	> 30 (CR)	> 30 (CR)	> 30 (CR)	> 30 (CR)	> 30 (CR)
C_T (GeV)	$300 < C_{T1} < 400$ (X)			$300 < C_{T2} < 400$ (X)		
	$C_{T1} > 400$ (Y)			$C_{T2} > 400$ (Y)		

Validation of CMS_16_052

Unspecified details :

Decay channels, all fermions or only leptons.

Are there chagrinos in the intermediate stage.

What cross sections are the numbers normalized too

Selection	T2tt-500-470	T2tt-375-365
common to all SRs		
$\|p_T^{miss}\| > 200$ GeV &		
$p_T(ISR) > 100$ GeV &		
H_T >300 GeV	656.25±5.04	933.68±6.32
$\Delta\phi$(j1, j2) < 2.5	606.41±4.86	872.78±6.13
N($hard\ jet$) ≤ 2	454.33±4.31	662.53±5.47
N(τ)==0	447.02±4.27	654.13±5.44
N(l) ≥ 1	328.26±3.59	371.63±4.0
N($l\ with\ p_T > 20$) ≤ 2	327.27±3.59	371.59±4.0
$p_T(l) < 30$GeV	313.73±3.51	368.62±3.99
common to SR1s		
$N(bjet) == 0$	274.9±3.14	333.59±3.66
$C_{T1} > 300$ GeV	154.18±2.32	191.96±2.75
$\|\eta(l)\| < 1.5$	138.03±2.2	174.01±2.63
SR1aX	16.55±0.76	32.18±1.13
SR1aY	16.25±0.75	38.78±1.25
SR1bX	9.26±0.57	5.68±0.47
SR1bY	8.37±0.54	6.61±0.5
SR1cX	14.73±0.72	2.01±0.28
SR1cY	19.71±0.82	3.58±0.36
common to SR2s		
N($soft\ bjet$)==1 & N($hard\ bjet$) $== 0$	19.7±0.49	13.87±0.39
$C_{T2} > 300$GeV	10.72±0.37	7.36±0.29
SR2aX	1.09±0.11	1.1±0.11
SR2aY	1.37±0.14	1.15±0.11
SR2bX	0.68±0.09	0.39±0.07
SR2bY	0.54±0.08	0.56±0.09
SR2cX	1.32±0.13	0.18±0.05
SR2cY	1.82±0.15	0.45±0.08

Validation of CMS_16_052

With a lot of guesswork, Validation looks good.

Table 1: Summary of yields for the $\tilde{t}_1 \to b f f' \tilde{\chi}_1^0$ model for two benchmark points with $m_{\tilde{t}_1} = 500, 375$ GeV, as compared to official CMS results given on http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/SUS-16-052/index.html. The uncertainties given for the CMS event numbers are statistical only.

	$m_{\tilde{t}_1, \tilde{\chi}_1^0} = 500, 470$ GeV		$m_{\tilde{t}_1, \tilde{\chi}_1^0} = 375, 365$ GeV	
cut	CMS result	MA 5 result	CMS result	MA 5 resul
All signal Regions				
$H_T + p_T(ISR) > 100 + E_T^{\text{miss}} > 200$ GeV	656.3	678.3	933.7	945.9
$+ \Delta\phi(j_1, j_2)$	606.4	592.1	872.8	881.4
$+ N(hard\ jet) \leq 2$	454.3	461.8	662.5	678.8
$+$ N$(\tau = 0)$ $+$ N$(l \geq 1)$ $+$ N $(l\ with\ p_T > 20\ ) \leq 2$	327.3	352.4	371.6	382.4
$+ p_T(l) < 30$	313.7	332.8	368.6	374.2
Common to SR1				
$+ N_b = 0$	274.9	268.4	333.6	348.8
$+ C_{T1} > 300$	154.2	148.8	192	196.2
$+ \eta_l \leq 1.5$	138	141.4	174	178.4
SR1ax	16.5	19.8	32.2	37.4
SR1aY	16.3	19.2	38.8	43.6
SR1bX	9.3	13.2	5.7	7.4
SR1bY	8.4	10.1	6.6	8.0
SR1cX	14.7	16.2	2.0	2.8
SR1cX	19.7	22.8	3.6	4.2
Common to SR2				
$+ N_b(hard) = 0 + N_b(soft) = 1$	19.7	22.6	13.9	16.2
$+ C_{T2} > 300$	10.7	13.2	7.4	8.9
SR2aX	1.1	1.8	1.1	1.6
SR2aY	1.4	1.8	1.2	1.5
SR2bX	0.7	1.1	0.4	0.6
SR2bY	0.5	0.7	0.6	0.8
SR2cX	1.3	1.7	0.2	0.5
SR2cY	1.8	2.2	0.5	0.7

Madanalysis 5: Conclusion

- **MadAnalysis5 is a code to re-interpret new physics searches**

- separate, validated implementations of the analyses are necessary to fully exploit the power of the LHC BSM searches
- it also gives useful feedback to the experiments:
  - alternative models being probed by their analysis
  - blind spots motiving the design of a new search
  - quality of the presentation of the analysis (see the Les Houches Recommendations for the Presentation of LHC Results [S. Kraml, B.C. Allanach, M. Mangano, H.B. Prosper, S. Sekmen, et al., arXiv:1203.2489])
- analysis reimplementation and validation a tedious task; we thank the ATLAS and CMS collaborations for their help! many more analyses are currently being implemented and validated using MadAnalysis 5
- you're welcome to use and/or contribute to the public database!