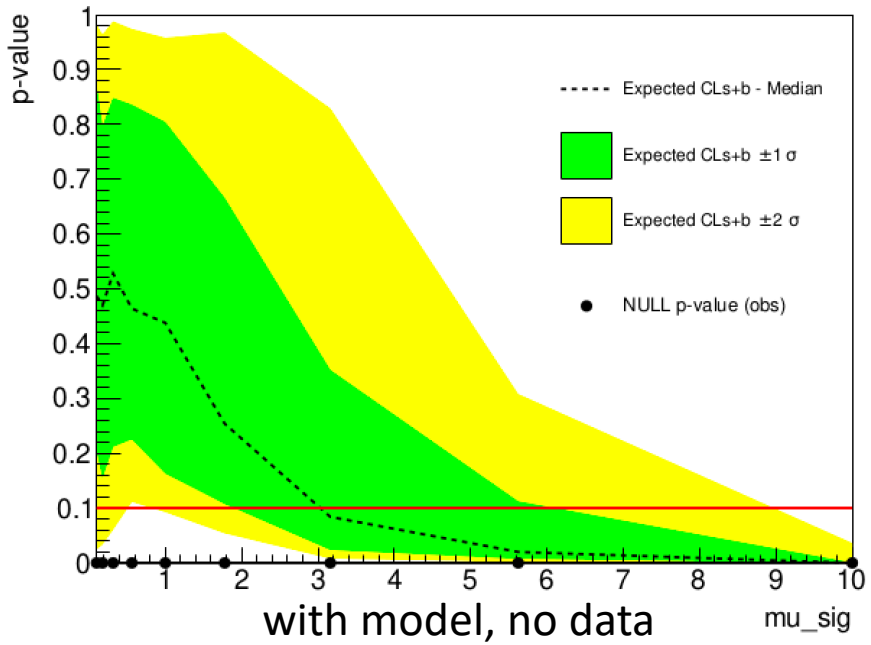
LZStats

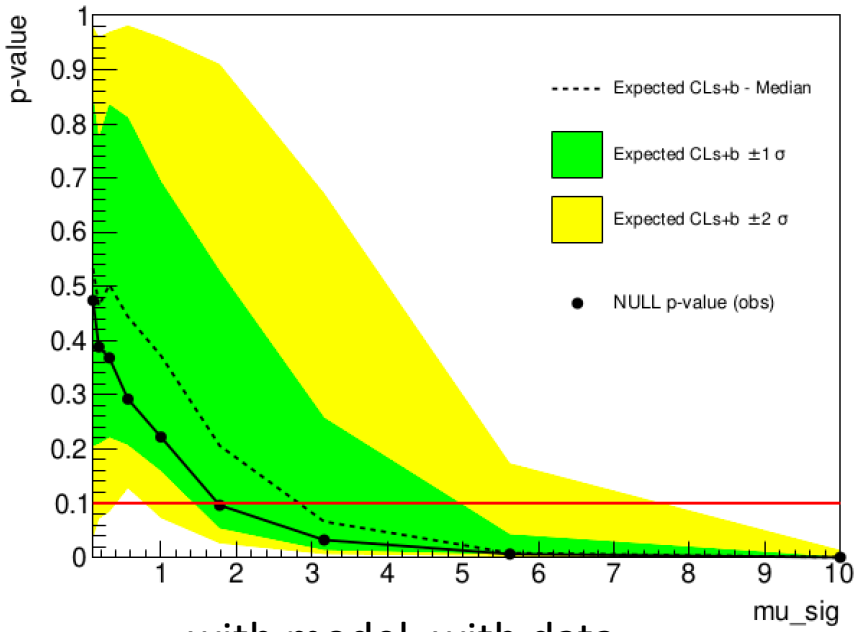
Yitong Liu

Update

- Add constraint function to wall model
  - Run model + data, model+no data case for 60d
  - Run LZStats with calculator type 1, with 500 toys caused a crash in the middle
  - Compare the result of calculator type = 1 and 0 (Toy = 100)
- Run no data, with model case with other background source (vvBB) --> how it affects the mu_sig value

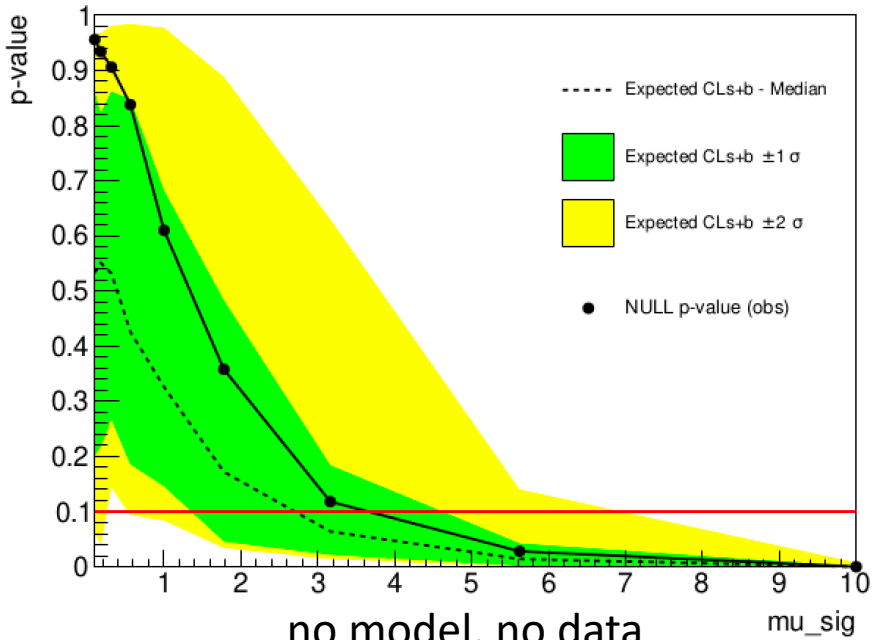


with model, no data
(0, 3.032)

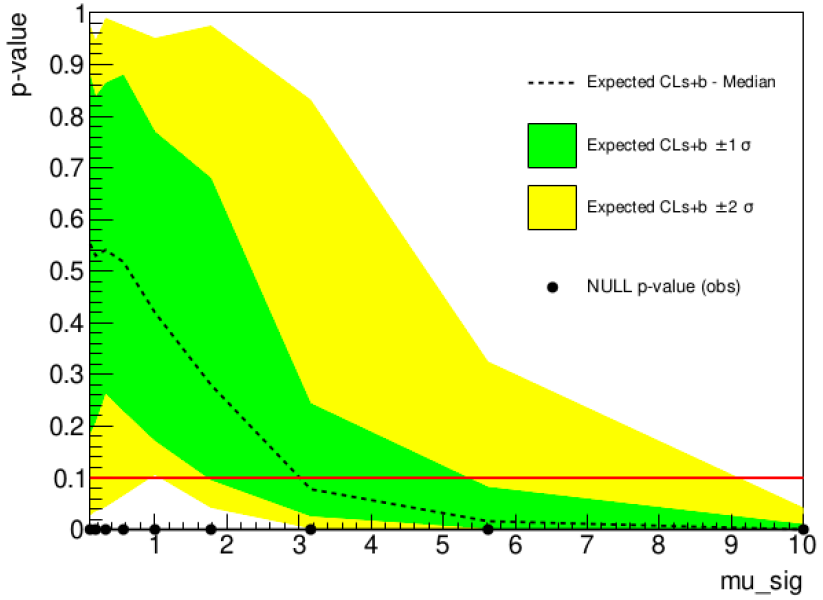


with model, with data
(1.7536, 2.8262)

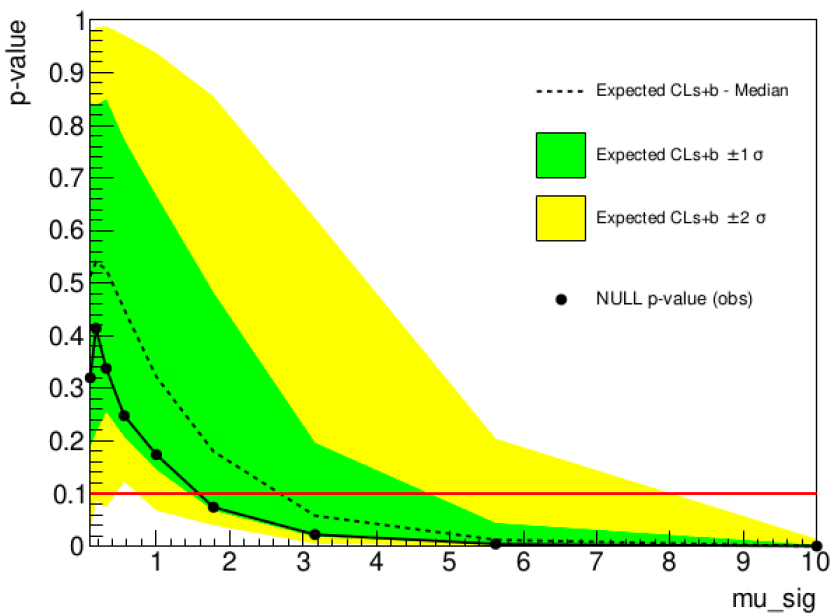
60 livedays
500Toys
40GeV
With wall constraint
Calculator Type = 0



no model, no data
(2.7009, 3.6545)

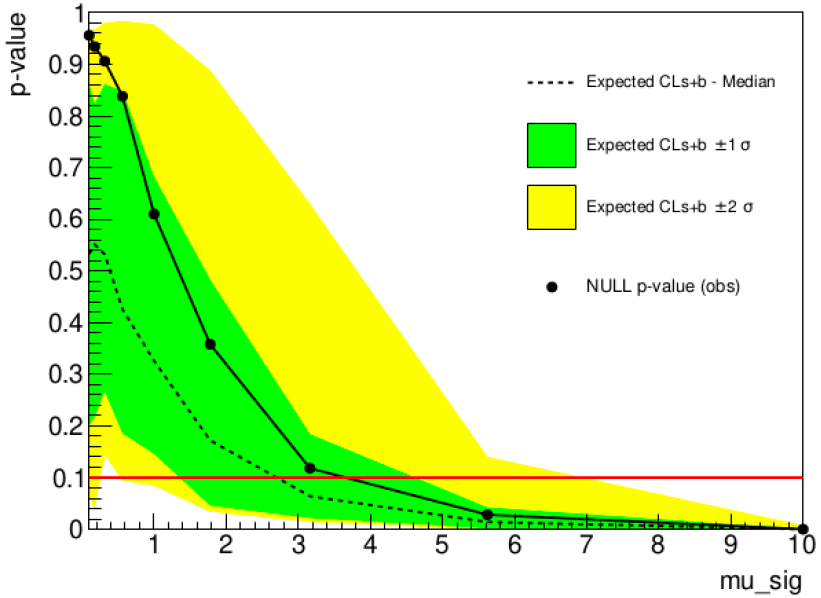


with model, no data
(0, 3.0115)



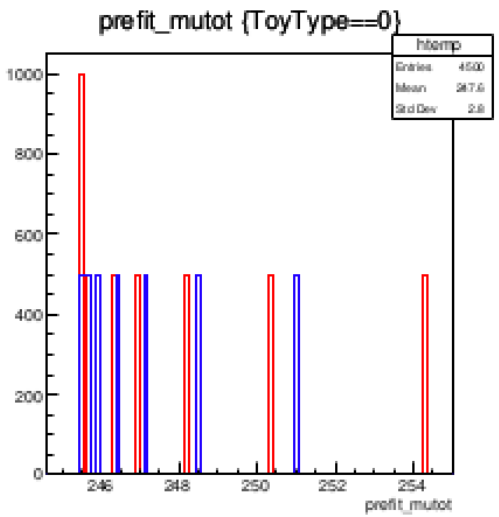
with model, with data
(1.5759, 2.6897)

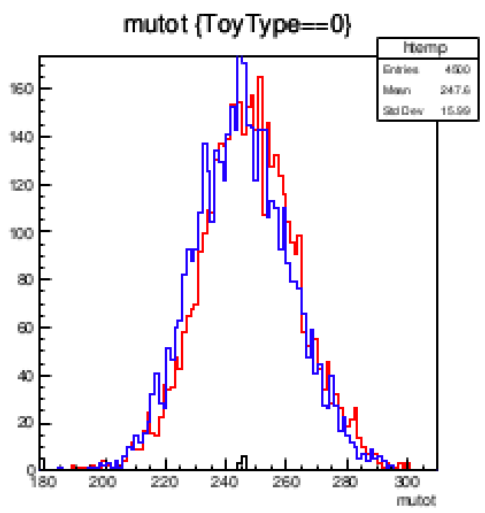
60 livedays
500Toys
40GeV
No wall constraint
Calculator Type = 0

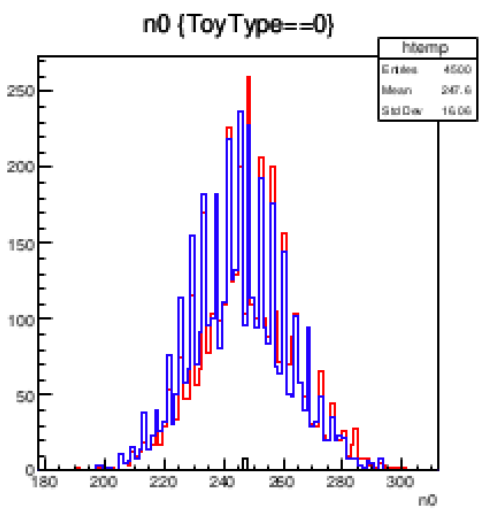


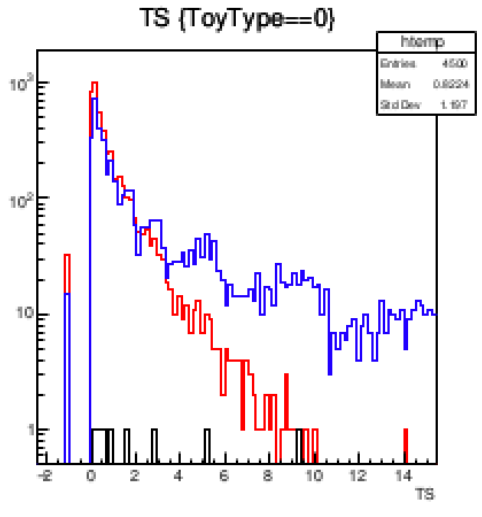
no model, no data
(2.7009, 3.6545)

60 d
Data+model
No wall constraint

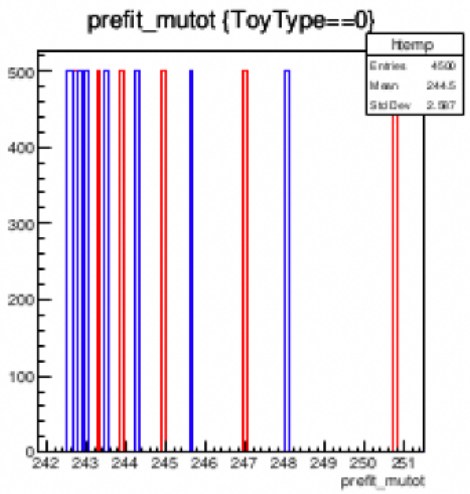


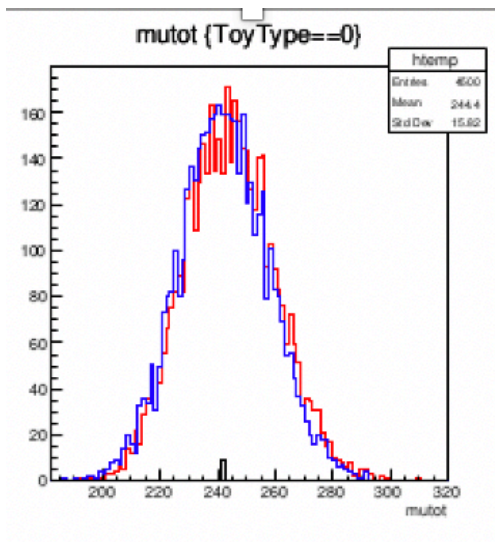


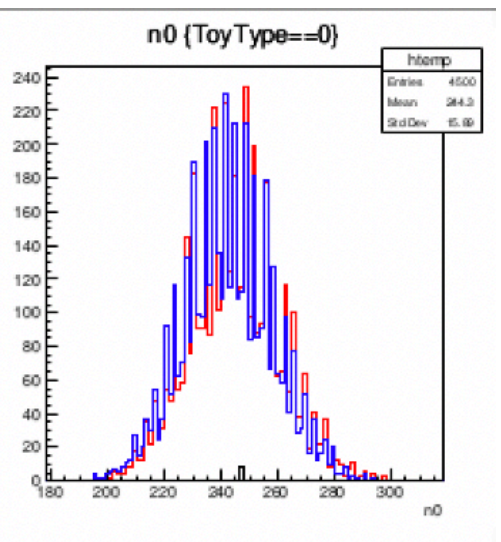


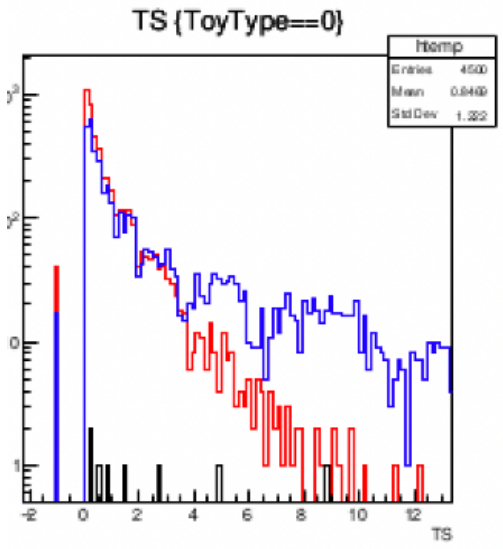


60 d
Data+model
With wall constraint

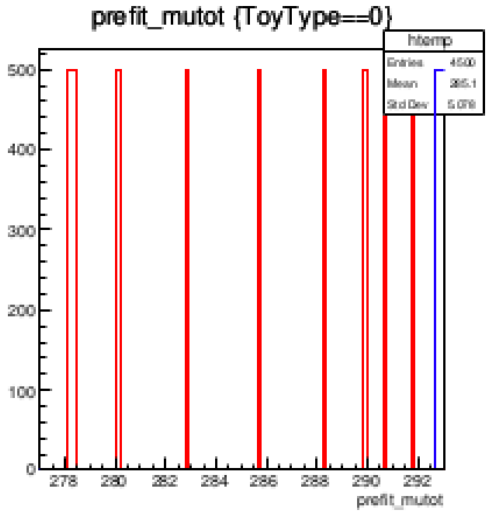


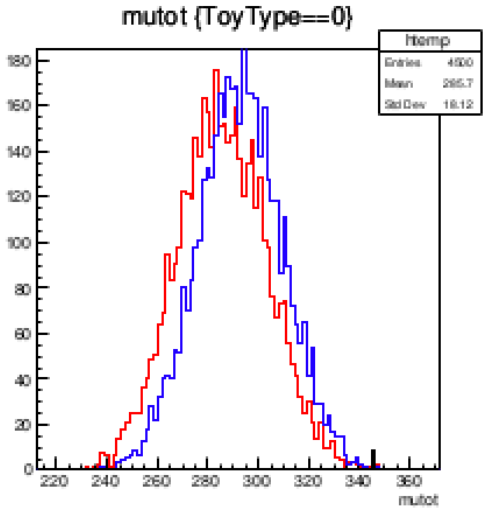


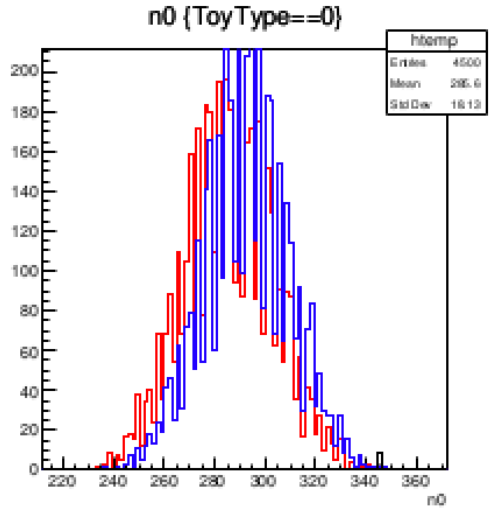


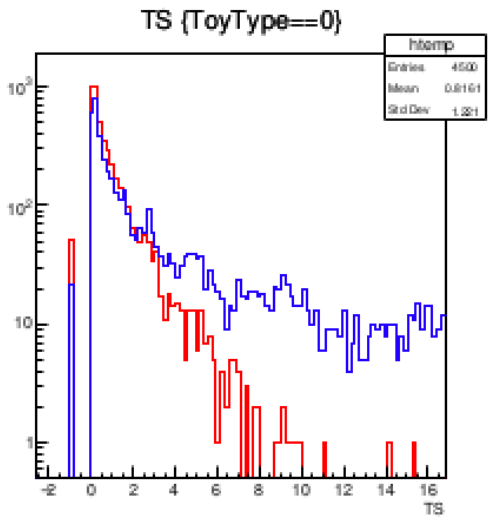


60 d
No Data+model
No wall constrair

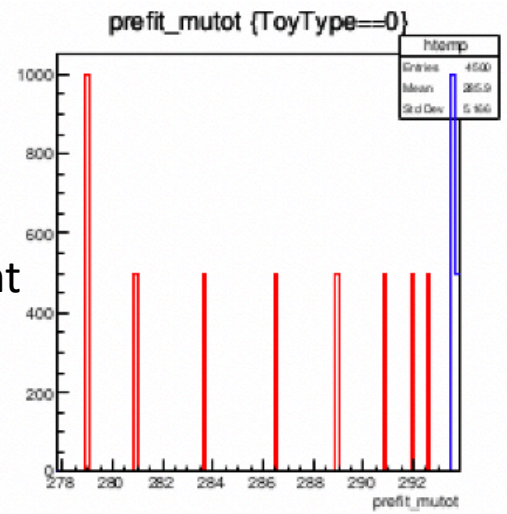


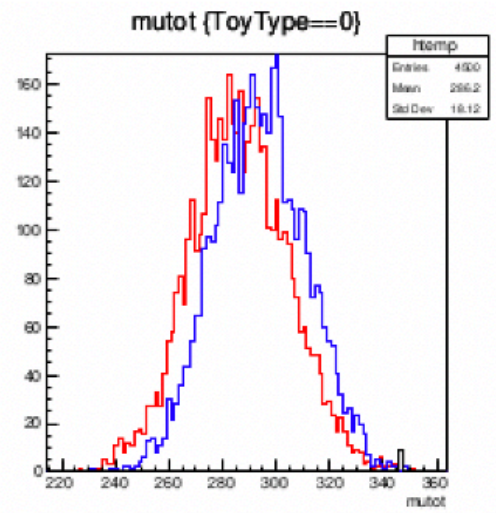


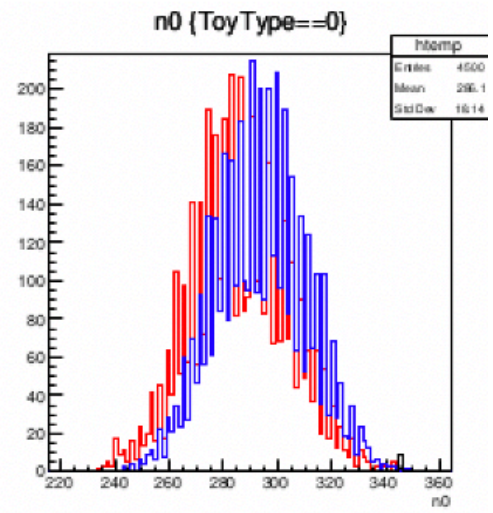


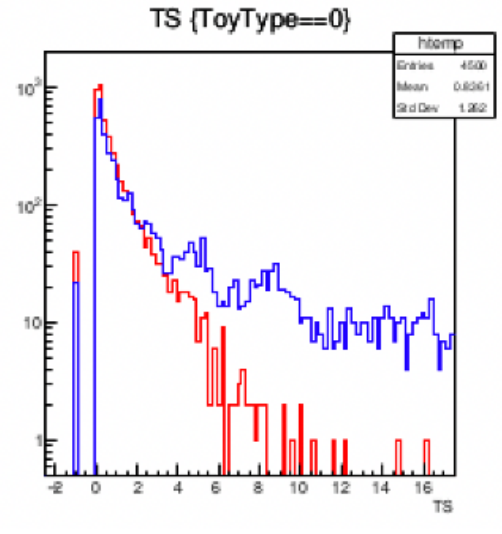


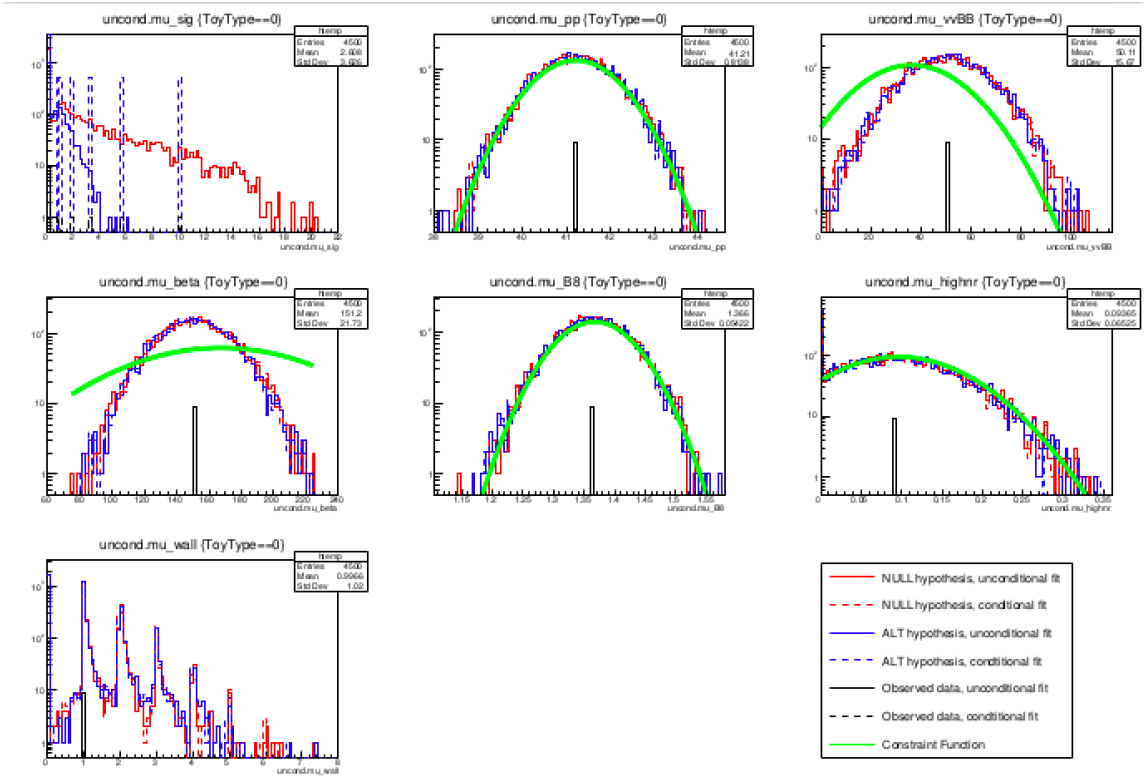
60 d
No Data+model
With wall constraint



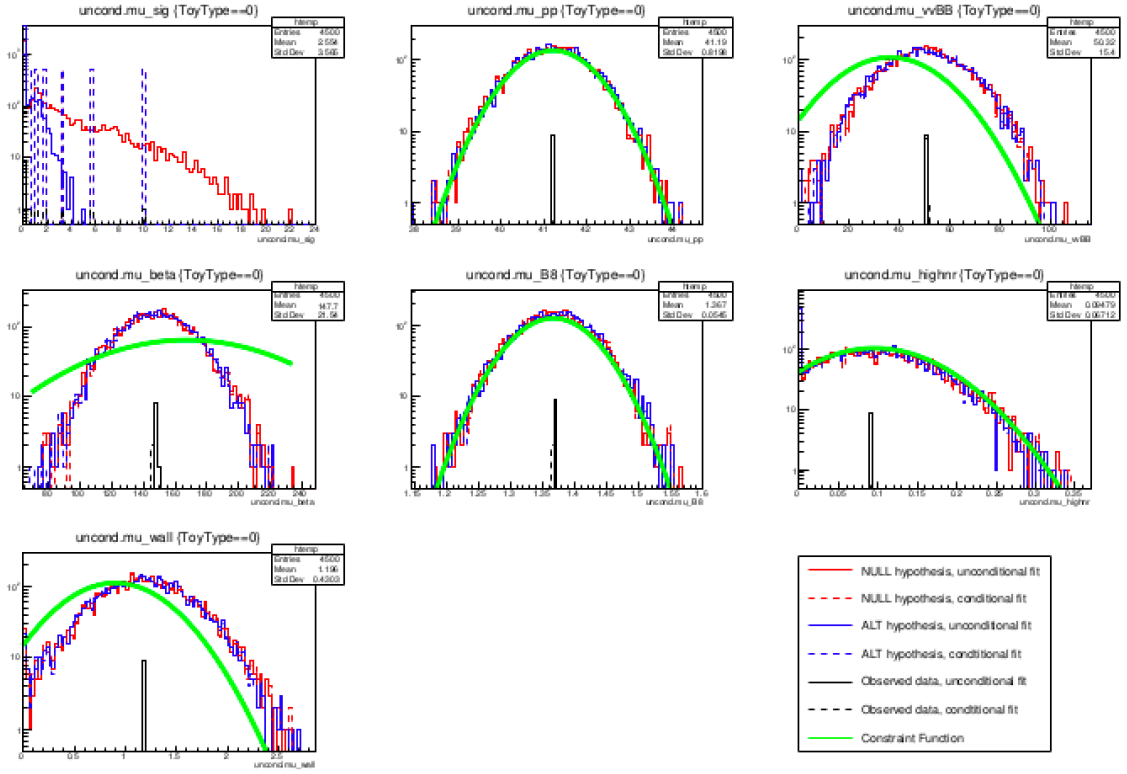




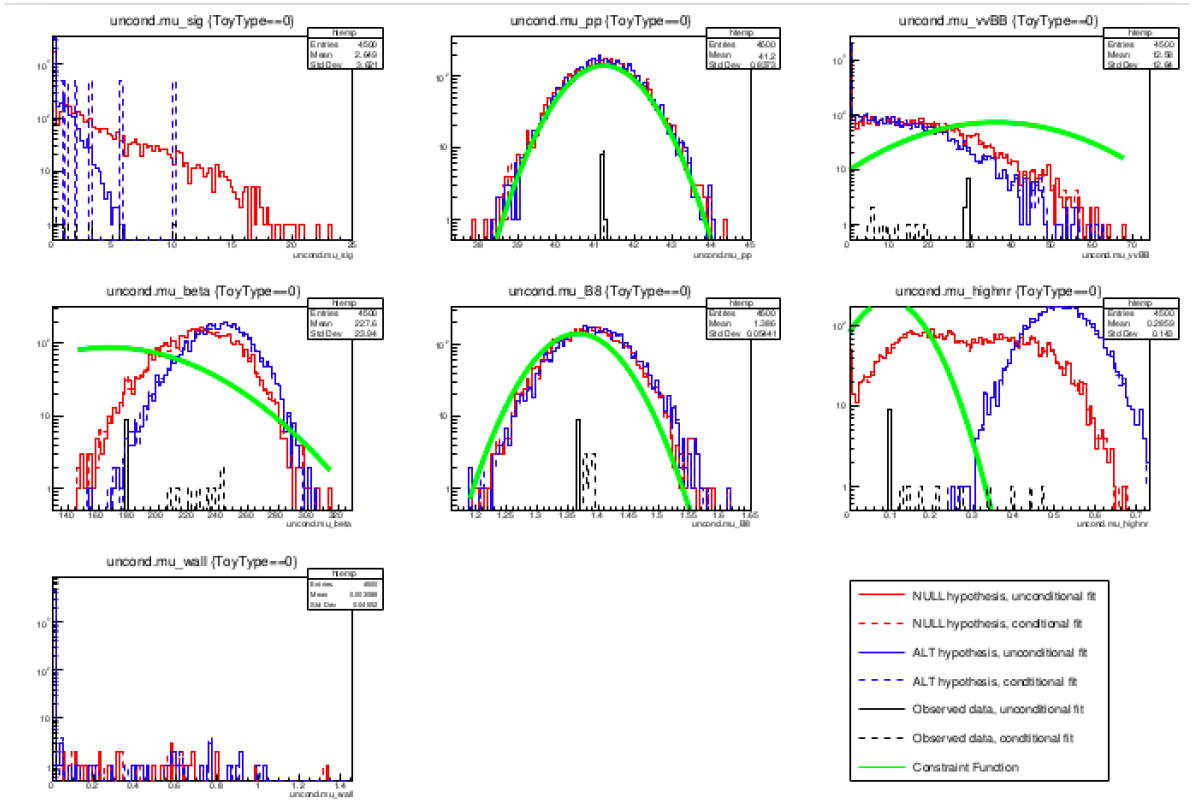




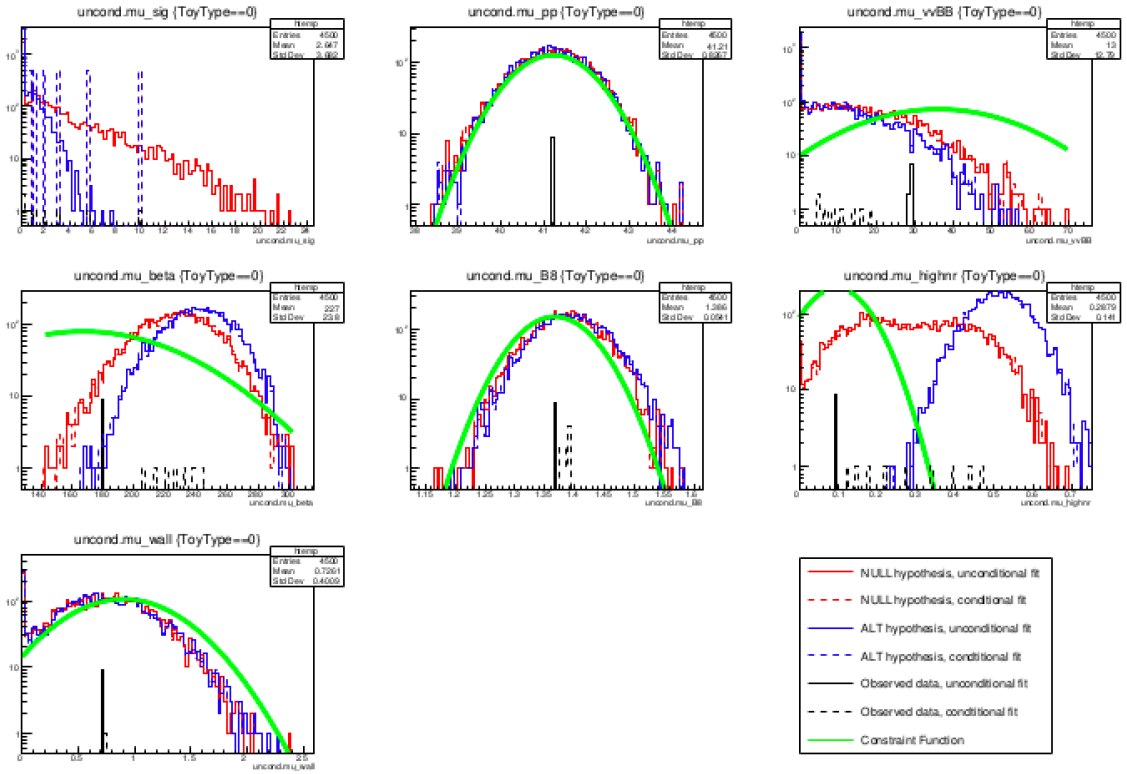
60 d
Data+model
No wall constraint



60 d
Data+model
With wall constraint



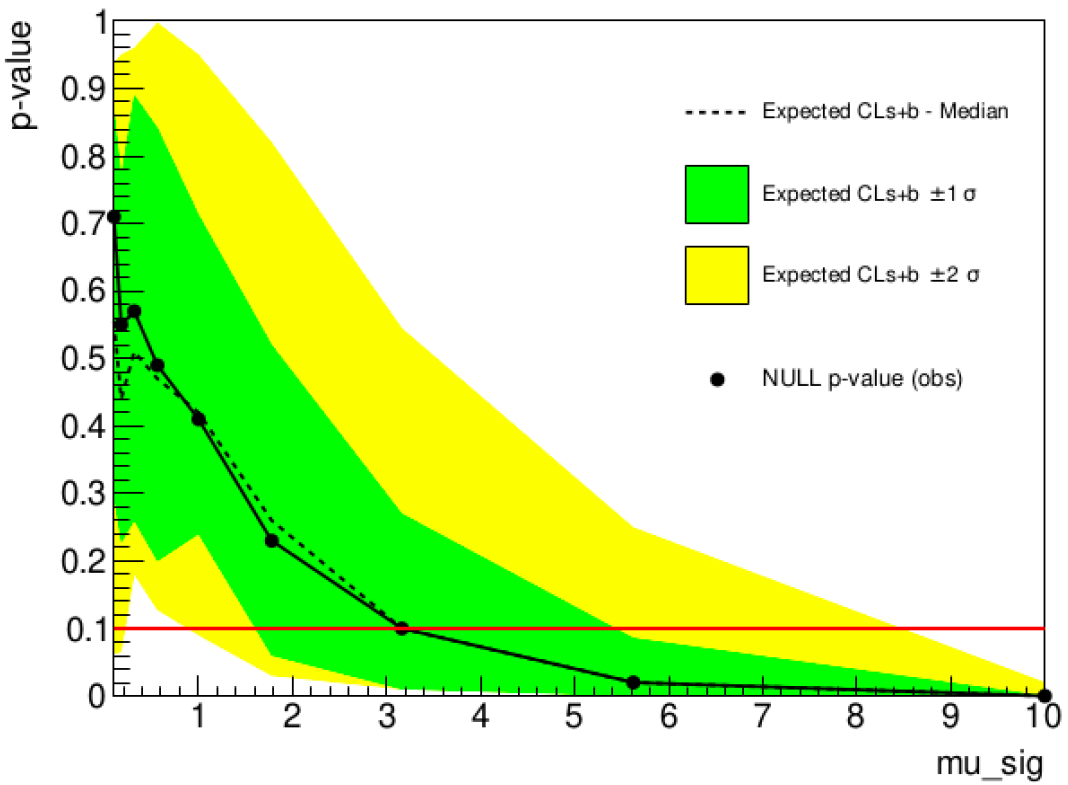
60 d
No Data+model
No wall constraint



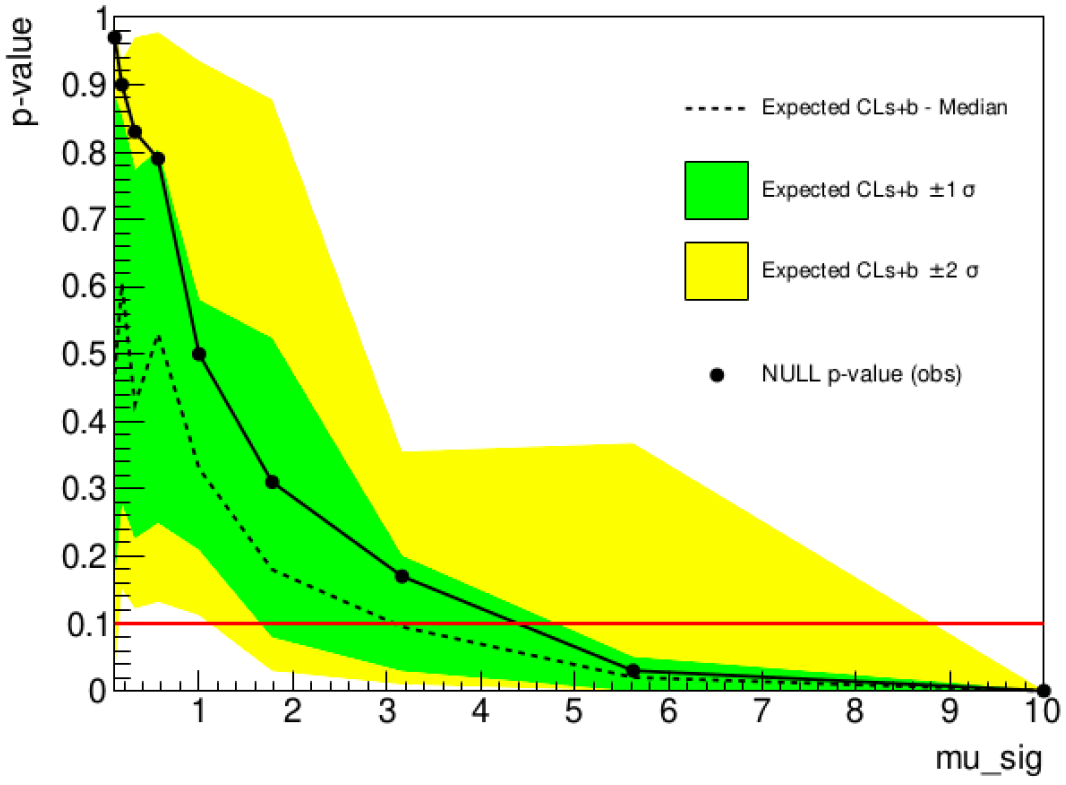
60 d
No Data+model
With wall constraint

Calculator type

60 livedays
100Toys
40GeV
With wall constraint



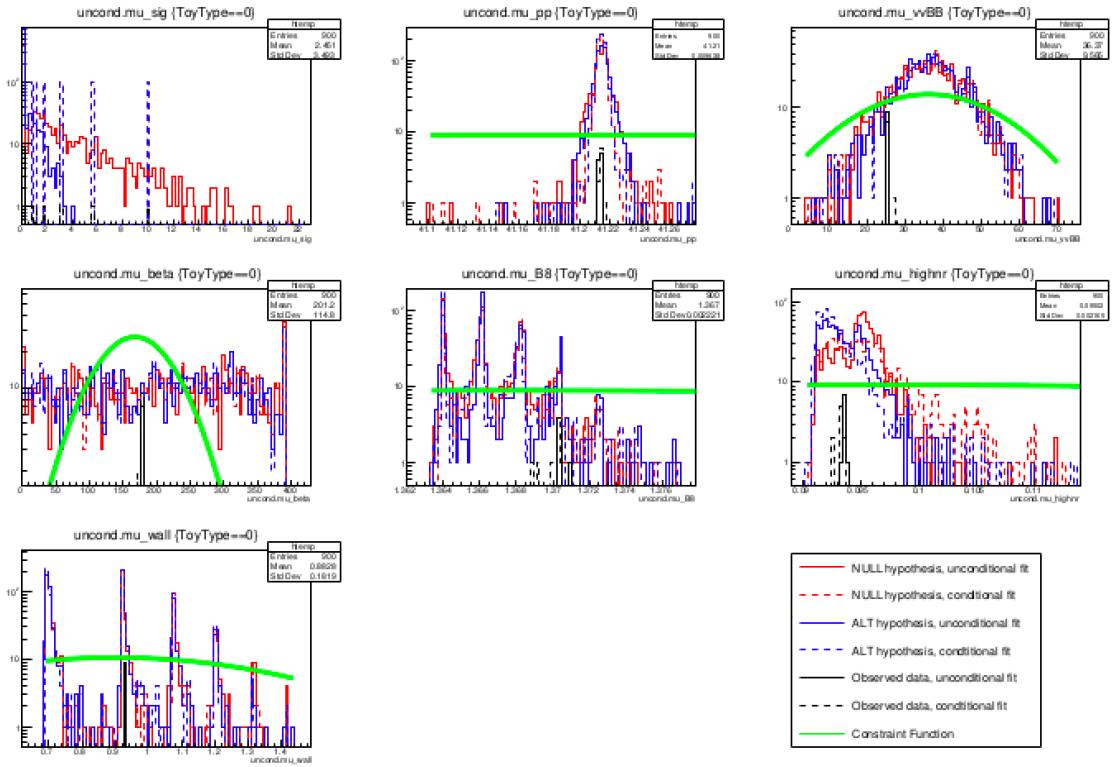
With Model, with data
Calculator Type = 1
(3.1623, 3.1623)



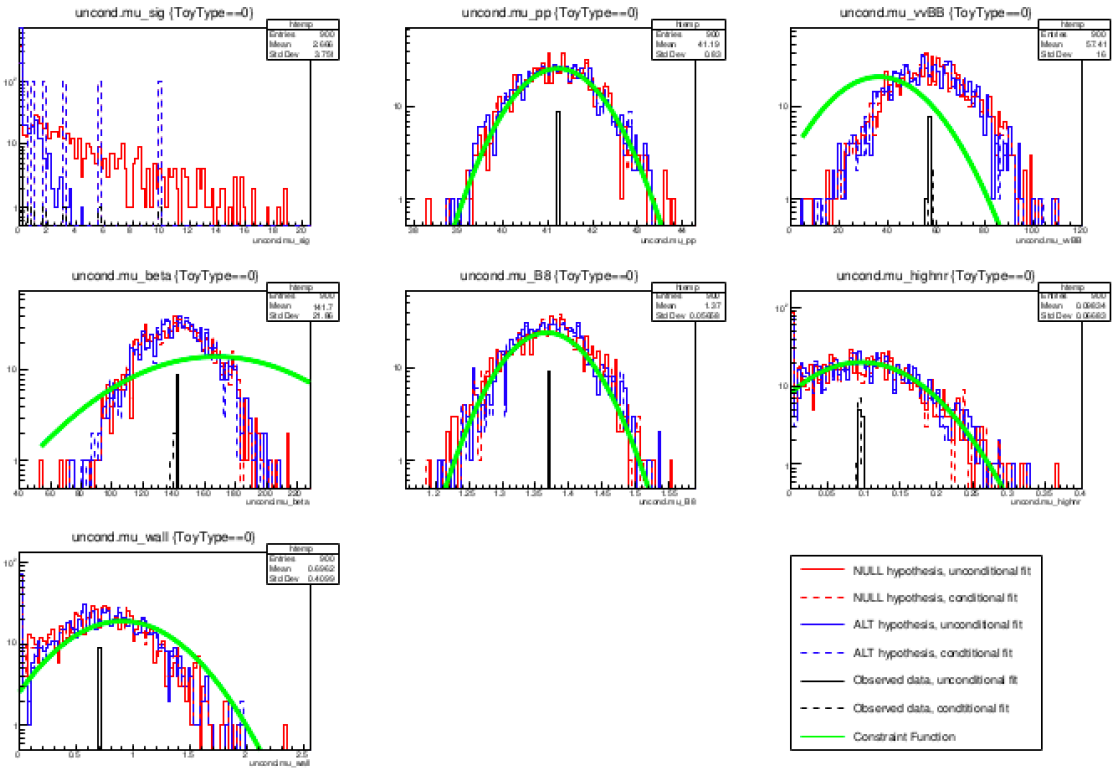
With model, with data
Calculator Type = 0
(4.3928, 3.0854)

Calculator type

60 livedays
100Toys
40GeV
With wall constraint



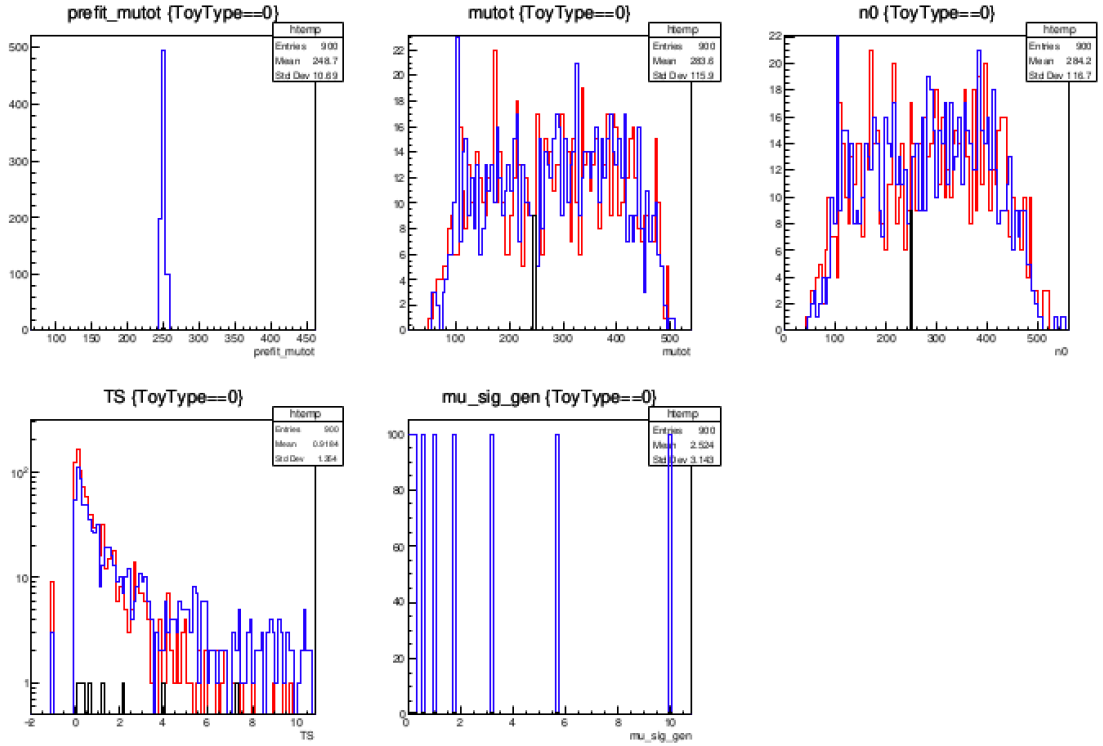
With Model, with data
Calculator Type = 1



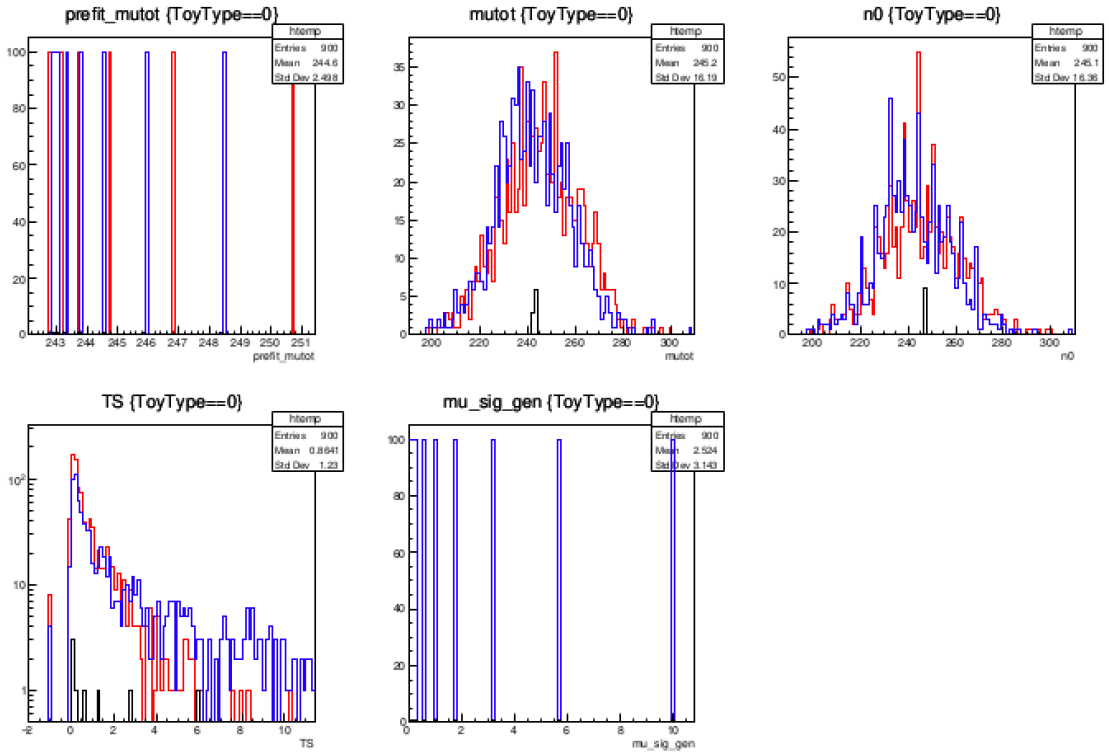
With model, with data
Calculator Type = 0

Calculator type

60 livedays
100Toys
40GeV
With wall constraint

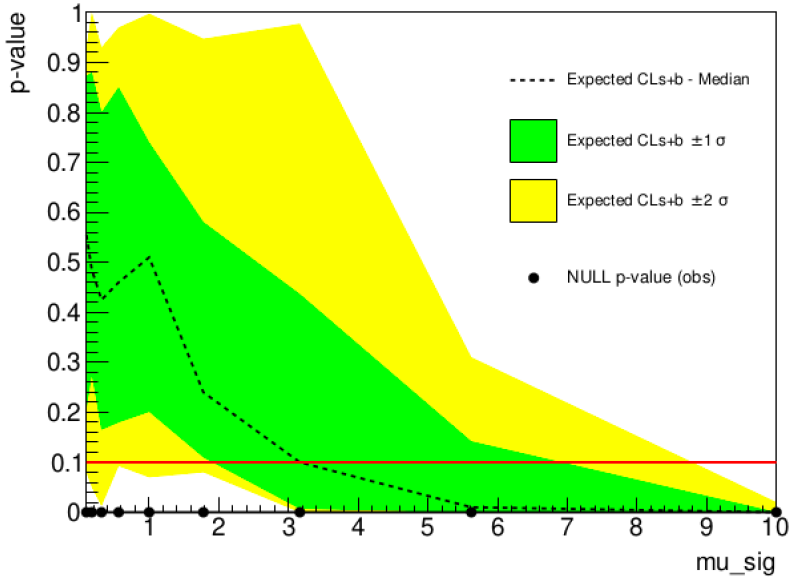


With Model, with data
Calculator Type = 1



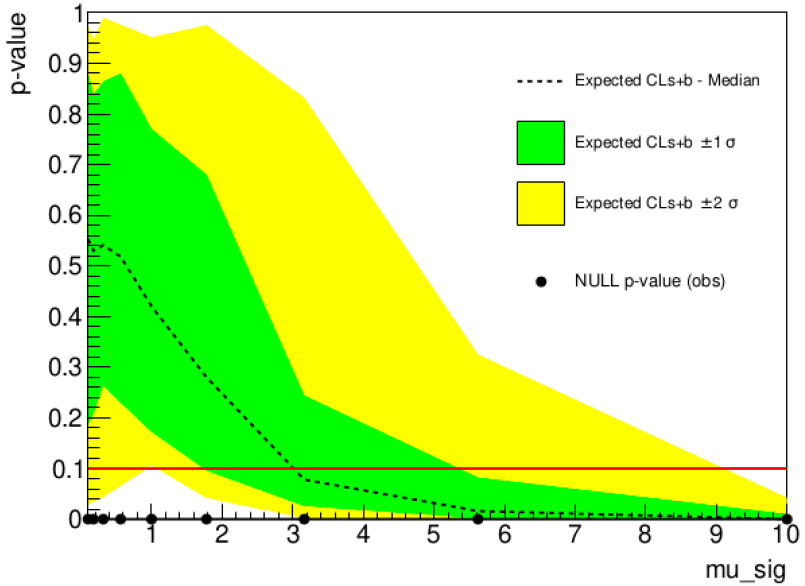
With model, with data
Calculator Type = 0

vvBB 60 d



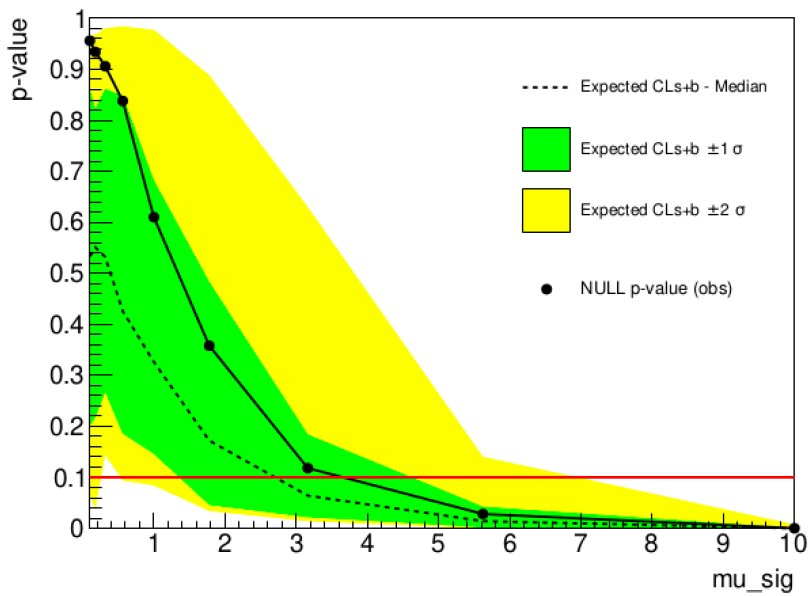
no vvBBdata + model
(0, 3.1623)

```
mu_B8      = 1.37045      +/-  0.0546247 (limited)
mu_beta    = 124.442      +/-  25.0879   (limited)
mu_highnr          = 29.9959      +/-  21.4604   (l
mu_pp      = 0.00842288   +/-  0.000168457      (l
mu_sig     = 97.6774      +/-  10.1734   (limited)
mu_vvBB    = 43.095       +/-  20.5078   (limited)
```



no wall data + model
(0, 3.0115)

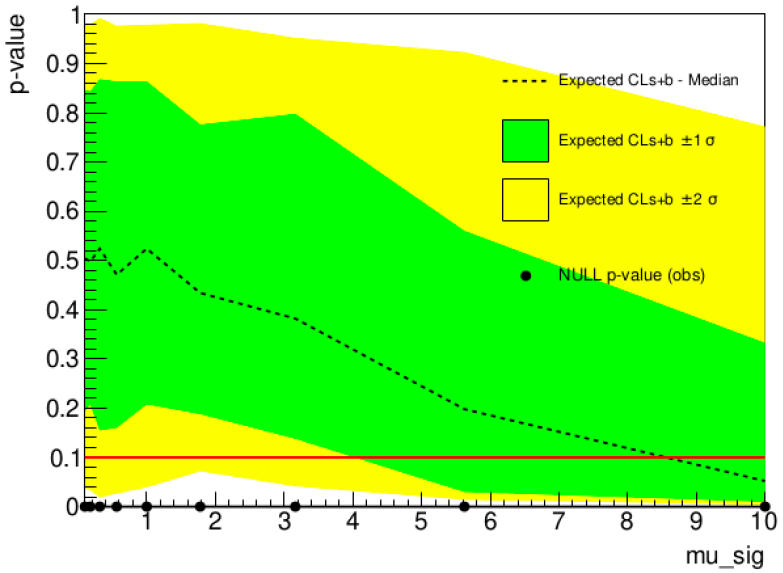
```
mu_B8      = 1.36838      +/-  0.0546394 (limited)
mu_beta    = 179.293      +/-  22.1503   (limited)
mu_highnr          = 0.0961636    +/-  0.0718755 (limit
mu_pp      = 41.2129      +/-  0.824277  (limited)
mu_sig     = 95.0326      +/-  10.2029   (limited)
mu_vvBB    = 29.0058      +/-  15.7028   (limited)
mu_wall    = 0.717923     +/-  0.449614  (limited)
```



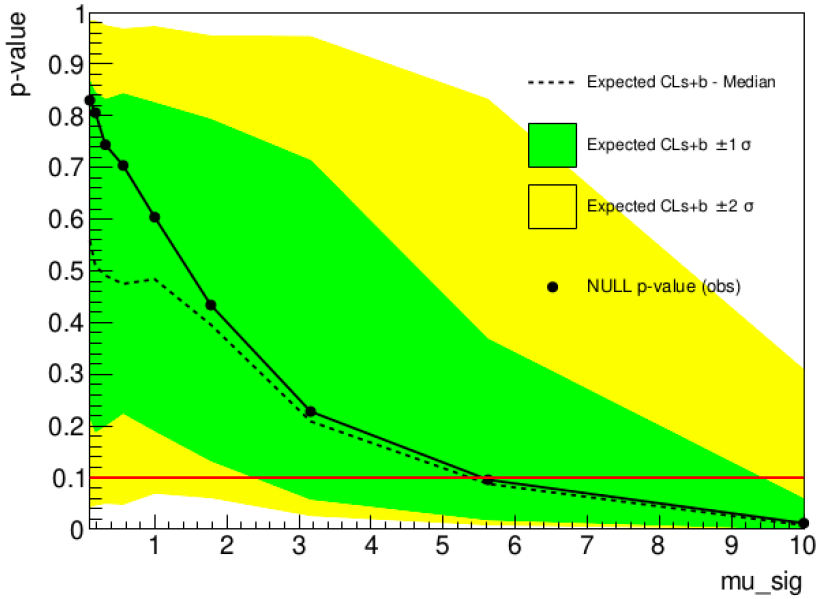
with vvBB data + model
(2.7009, 3.6545)

```
mu_B8      = 1.3685       +/-  0.0545922 (limited)
mu_beta    = 148.658      +/-  21.7967   (limited)
mu_highnr          = 0.0920129    +/-  0.0719094 (limited)
mu_pp      = 41.2149      +/-  0.824283  (limited)
mu_sig     = 3.76949e-06  +/-  0.656966  (limited)
mu_vvBB    = 49.9272      +/-  15.5211   (limited)
mu_wall    = 1.19545      +/-  0.379159  (limited)
```

Previous Slides

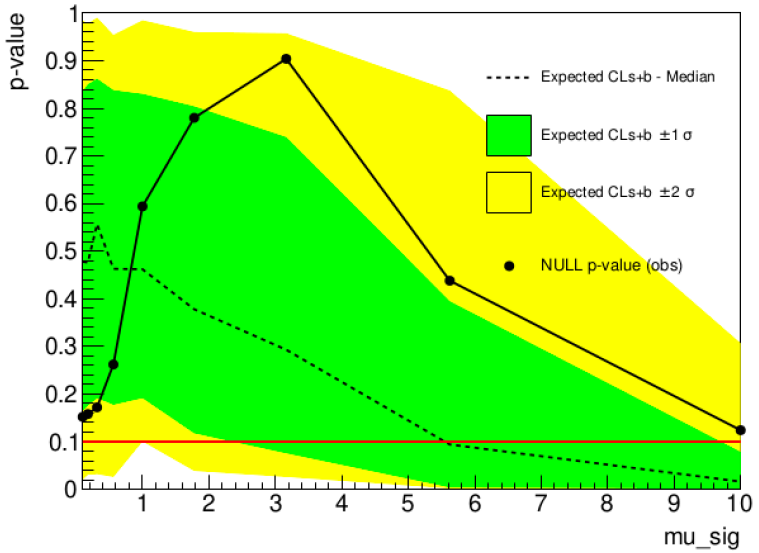


with model, no data
(0, 8.5611)



with model, with data
(5.5488, 5.3783)

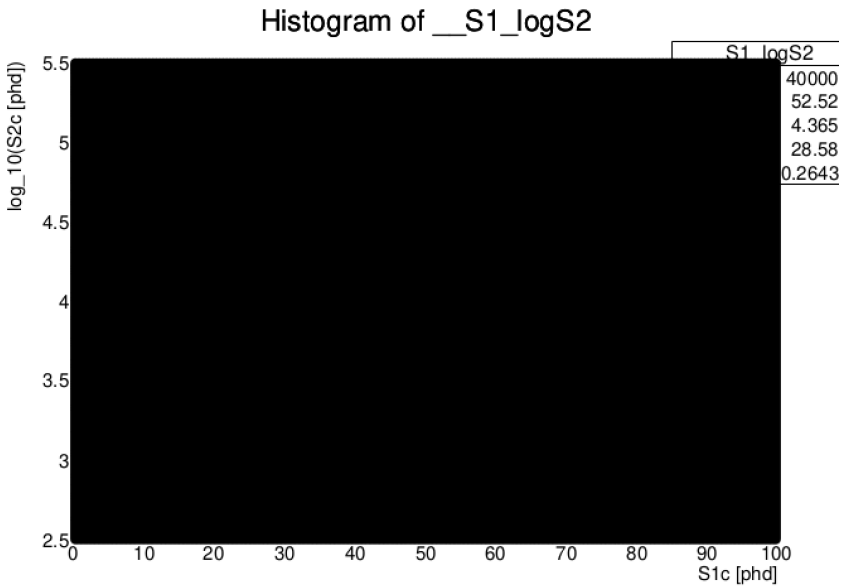
1000livedays
500Toys
40GeV
S1 = 16



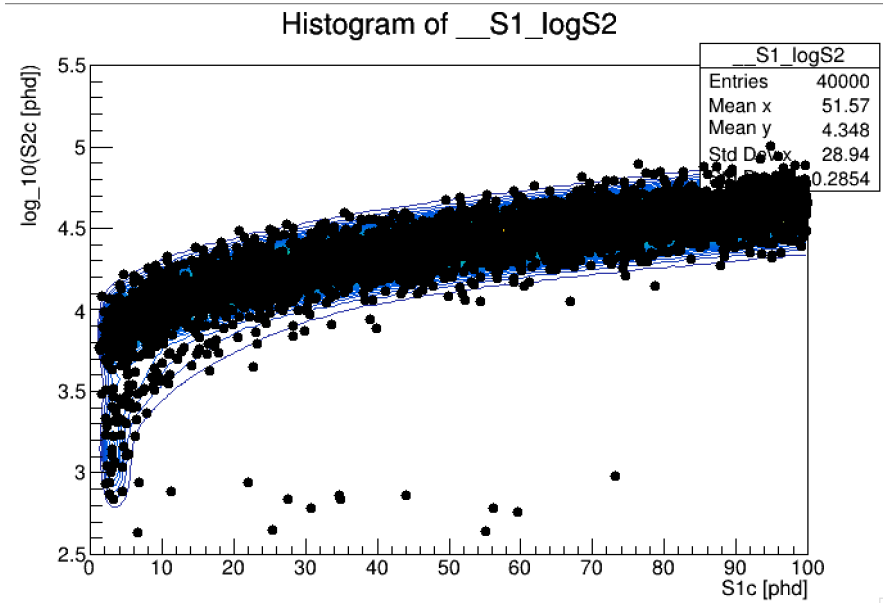
no model, no data
(0, 5.5492)

New update

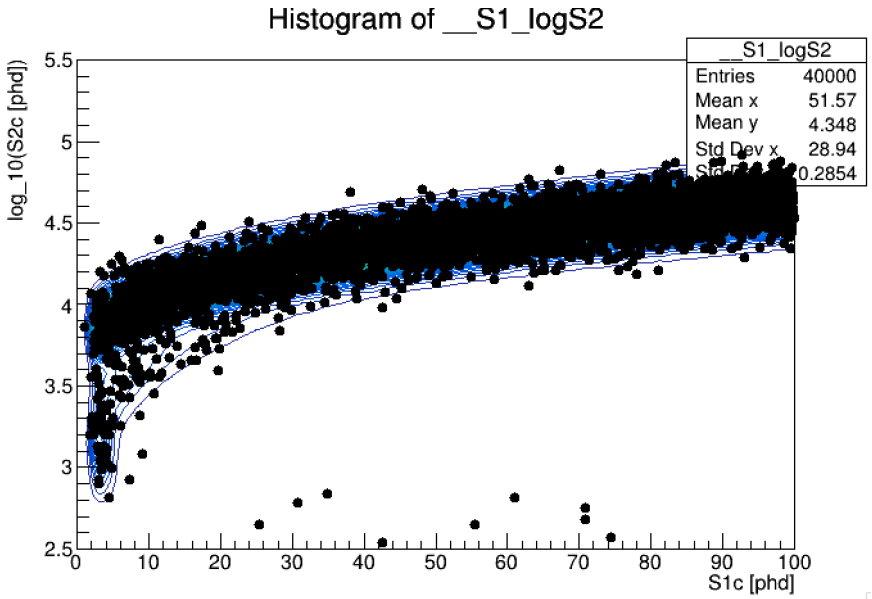
- Create wall data
- Finished four cases of the wall model and the data for 1000d, 1500~1700min to run
- Change 1000d -> 60d, 80~100min to run
- Change S1 value (80) of the wall model ->1/5 S1 (16)



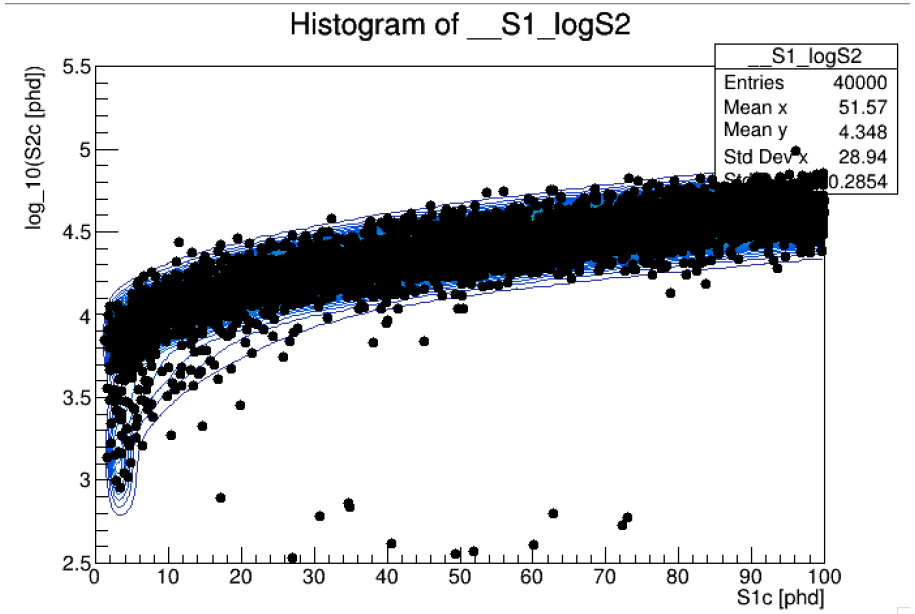
Interpolation order = 0



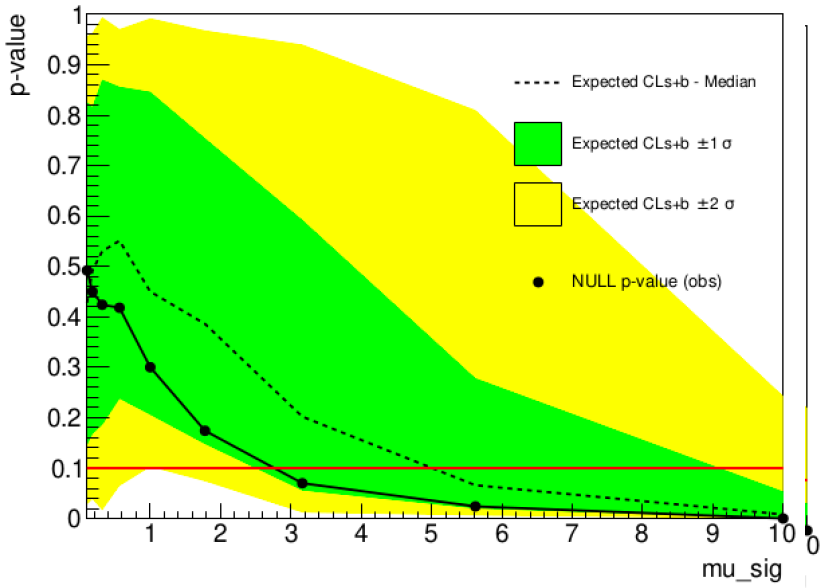
Interpolation order = 1



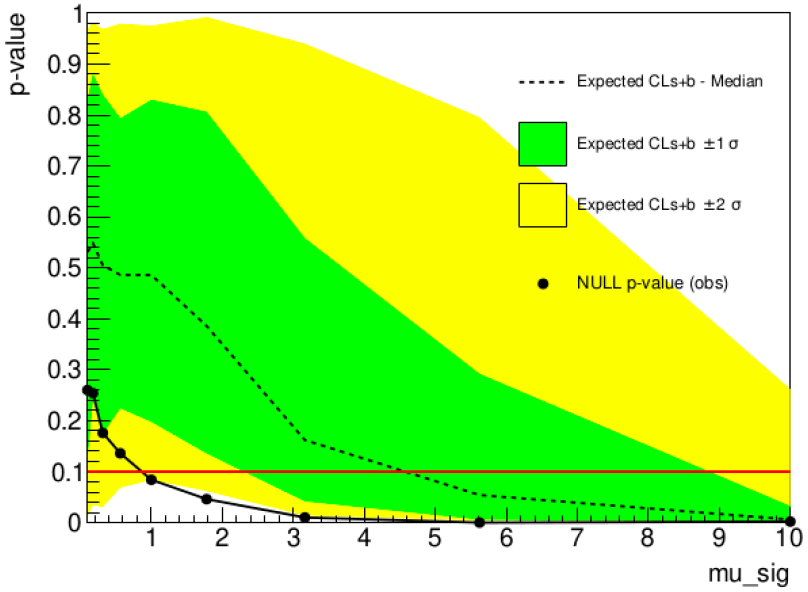
Interpolation order = 2



Interpolation order = 3



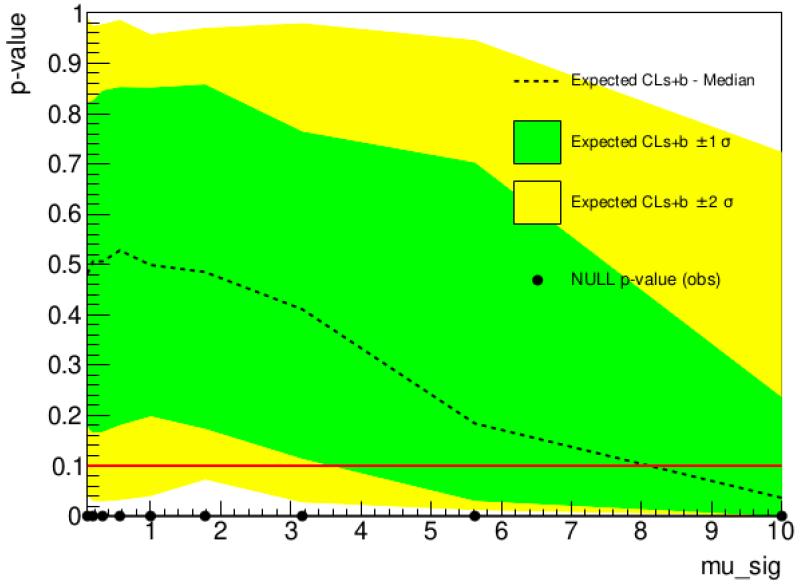
With model, with data
(2.763, 5.0081)



No model, no data
(0.8653, 4.5748)

1000 livedays
500 Toys
40GeV

Fluctuation on 500 toys
10 runs, non-log: 5.6%
5 runs, log: 9.7%

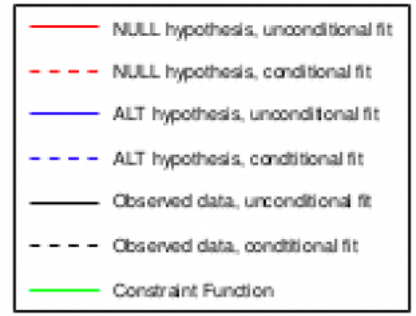


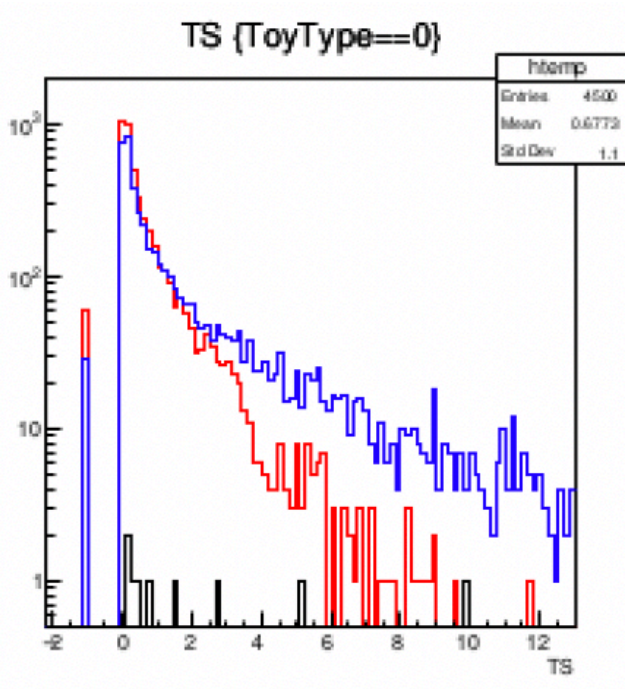
With model, no data
(0, 8.1071)

Error Log

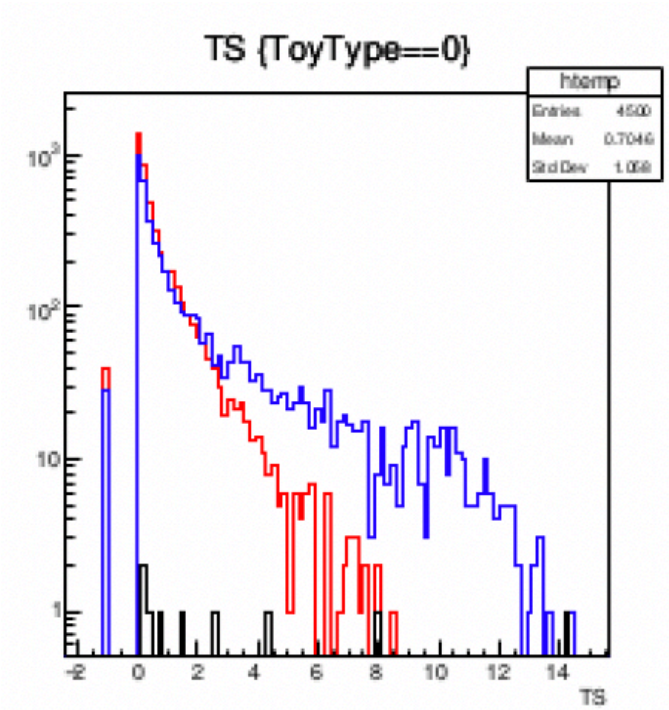
```
MnSeedGenerator: for initial parameters FCN = -1e+30
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
Returning maximum FCN so far (-1e+30) to force MIGRAD to back out of this region. Error log follows
Parameter values: mu_B8=33.7589, mu_beta=2788.13, mu_highnr=1.59861, mu_pp=685.575, mu_sig=2, mu_vvBB=6
03.82
```

No model, with data

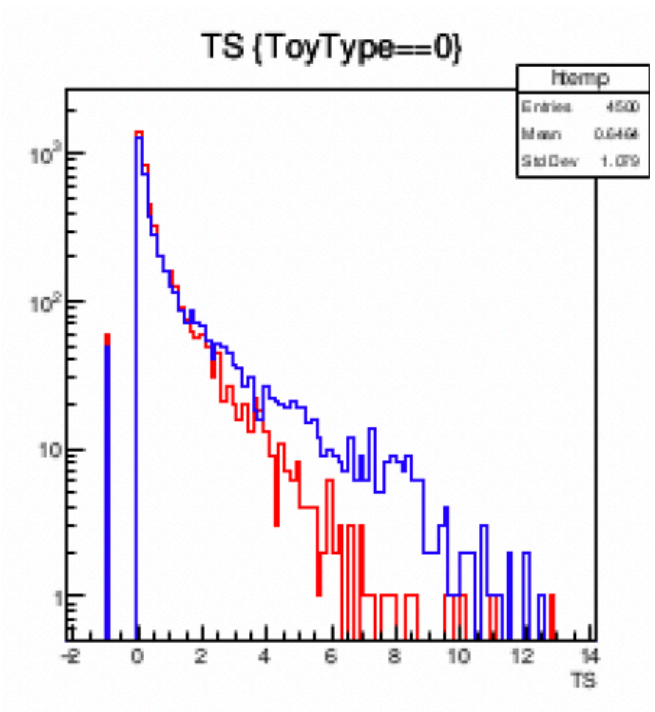




With model, with data

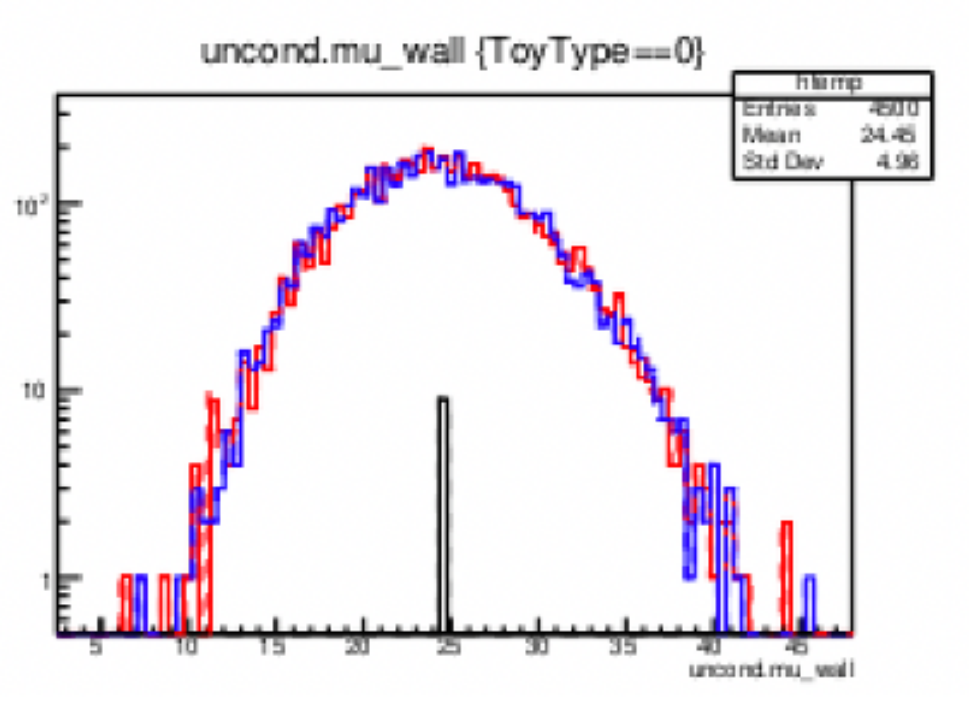


No model, no data

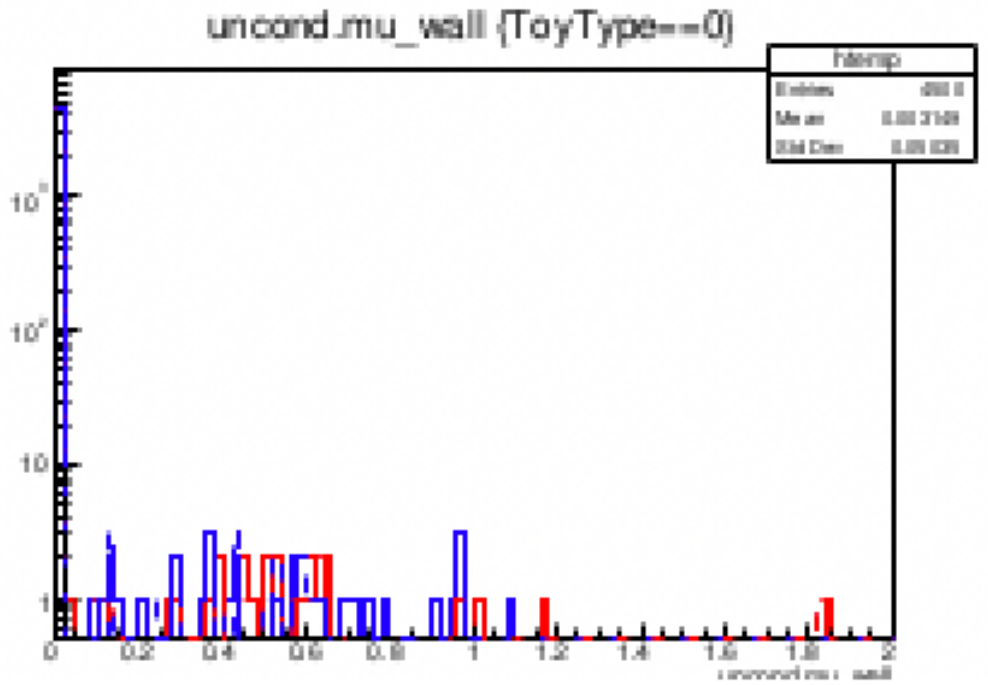


With model, no data

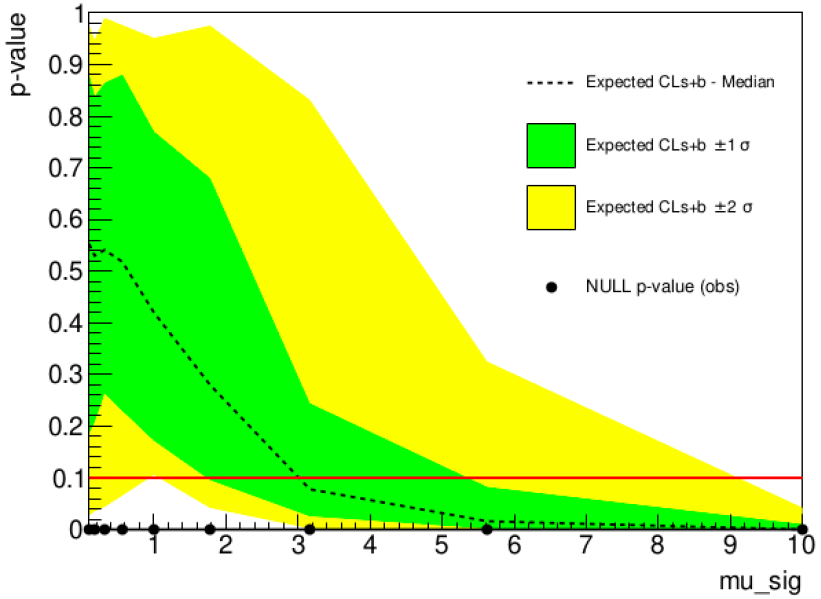
Mu_wall



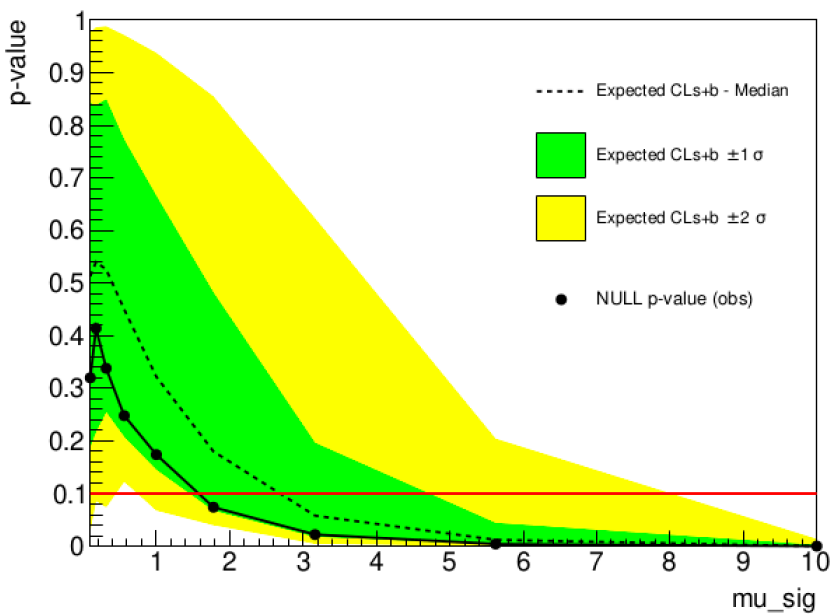
With model, with data



With model, no data

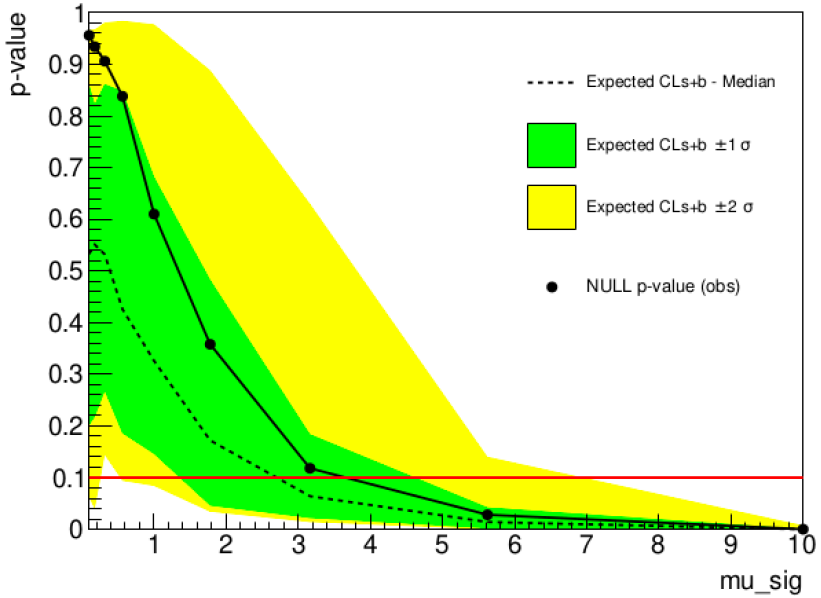


with model, no data
(0, 3.0115)



with model, with data
(1.5759, 2.6897)

60 livedays
500Toys
40GeV



no model, no data
(2.7009, 3.6545)

1000d S1 = 80

NMND

```
mu_B8      = 22.6238       +/-   0.900904   (limited)
mu_beta    = 2601.55       +/-   125.835    (limited)
mu_highnr          = 1.91342       +/-   1.1663    (limit
mu_pp      = 685.552       +/-   13.7085    (limited)
mu_sig     = 2.52418       +/-   3.53167    (limited)
mu_vvBB    = 790.199       +/-   111.955    (limited)
Minuit2Minimizer::Hesse using max-calls 3000
```

WMND

```
mu_B8      = 22.8801       +/-   0.899772   (limited)
mu_beta    = 2790.25       +/-   128.957    (limited)
mu_highnr          = 1.66107       +/-   1.18804    (limi
mu_pp      = 685.734       +/-   13.7083    (limited)
mu_sig     = 99.7426       +/-   11.7455    (limited)
mu_vvBB    = 599.906       +/-   113.991    (limited)
mu_wall    = 0.00020556    +/-   0.515219   (limited)
Minuit2Minimizer::Hesse using max-calls 3500
```

WMWD

```
mu_B8      = 22.7223       +/-   0.898862   (limited)
mu_beta    = 2721.68       +/-   126.416    (limited)
mu_highnr          = 1.19898       +/-   1.16059    (limited)
mu_pp      = 685.503       +/-   13.7088    (limited)
mu_sig     = 0.000179582   +/-   1.85019    (limited)
mu_vvBB    = 672.398       +/-   112.31     (limited)
mu_wall    = 15.3528       +/-   3.95649    (limited)
```

1000d S1 = 16

```
mu_B8      = 22.9834       +/-   0.893984   (limited)
mu_beta    = 2849.35       +/-   126.579    (limited)
mu_highnr          = 1.71022       +/-   1.1814    (lim
mu_pp      = 685.588       +/-   13.7087    (limited)
mu_sig     = 2.61366       +/-   3.32041    (limited)
mu_vvBB    = 534.428       +/-   111.676    (limited)
```

```
mu_B8      = 22.8725       +/-   0.899812   (limited)
mu_beta    = 2789.93       +/-   128.964    (limited)
mu_highnr          = 1.64896       +/-   1.19026    (lim
mu_pp      = 685.74        +/-   13.7083    (limited)
mu_sig     = 99.6011       +/-   11.7303    (limited)
mu_vvBB    = 600.23        +/-   114.003    (limited)
mu_wall    = 4.31981e-06   +/-   0.591311   (limited)
```

```
mu_B8      = 22.6987       +/-   0.89895    (limited)
mu_beta    = 2742.21       +/-   125.106    (limited)
mu_highnr          = 1.35402       +/-   1.15881    (limited)
mu_pp      = 685.633       +/-   13.7084    (limited)
mu_sig     = 9.18943e-06   +/-   3.24849    (limited)
mu_vvBB    = 648.585       +/-   110.768    (limited)
mu_wall    = 6.22466       +/-   2.53271    (limited)
```

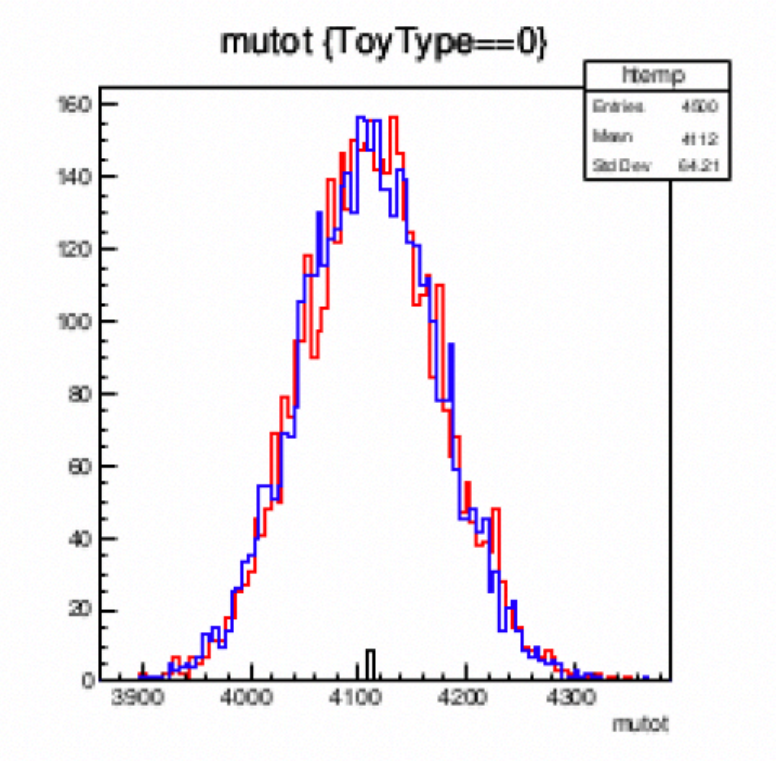
60d S1 = 80

```
mu_B8      = 1.36768       +/-   0.0546333 (limited)
mu_beta    = 168.331       +/-   21.494    (limited)
mu_highnr          = 0.0948004     +/-   0.0719291 (li
mu_pp      = 41.2164       +/-   0.824267   (limited)
mu_sig     = 0.339844      +/-   1.10286    (limited)
mu_vvBB    = 34.6605       +/-   15.4484    (limited)
```

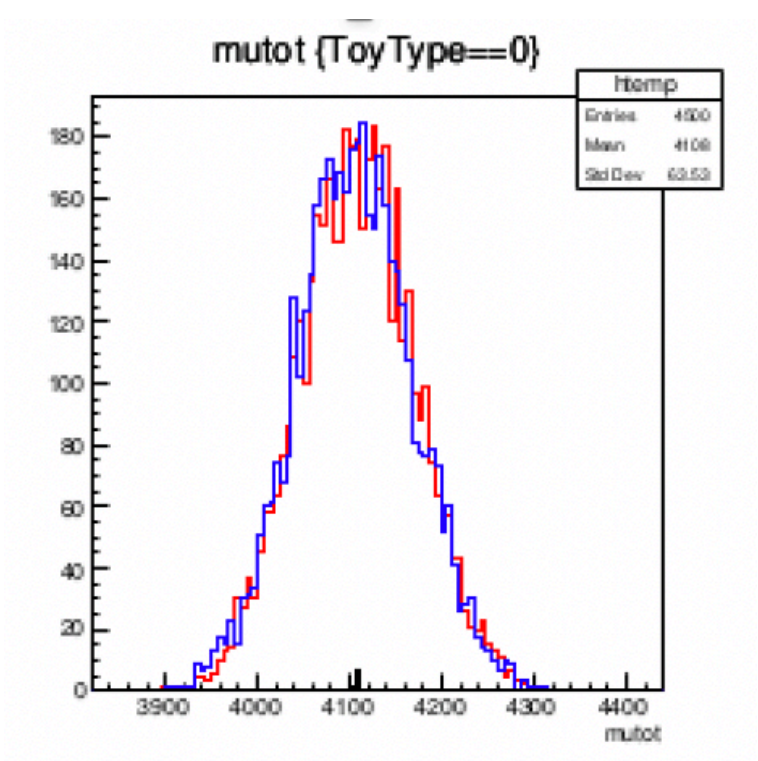
```
mu_B8      = 1.36835       +/-   0.0546378 (limited)
mu_beta    = 179.012       +/-   22.1341    (limited)
mu_highnr          = 0.0960529     +/-   0.0718966 (li
mu_pp      = 41.2192       +/-   0.824248   (limited)
mu_sig     = 95.0126       +/-   10.1997    (limited)
mu_vvBB    = 29.2128       +/-   15.6858    (limited)
mu_wall    = 0.000137438   +/-   0.559187   (limited)
```

```
mu_B8      = 1.36836       +/-   0.054593   (limited)
mu_beta    = 156.383       +/-   21.5197    (limited)
mu_highnr          = 0.0951341     +/-   0.0718702 (limited)
mu_pp      = 41.2111       +/-   0.824279   (limited)
mu_sig     = 2.46738e-05   +/-   0.755975   (limited)
mu_vvBB    = 44.4113       +/-   15.3156    (limited)
mu_wall    = 2.01062       +/-   1.41745    (limited)
```

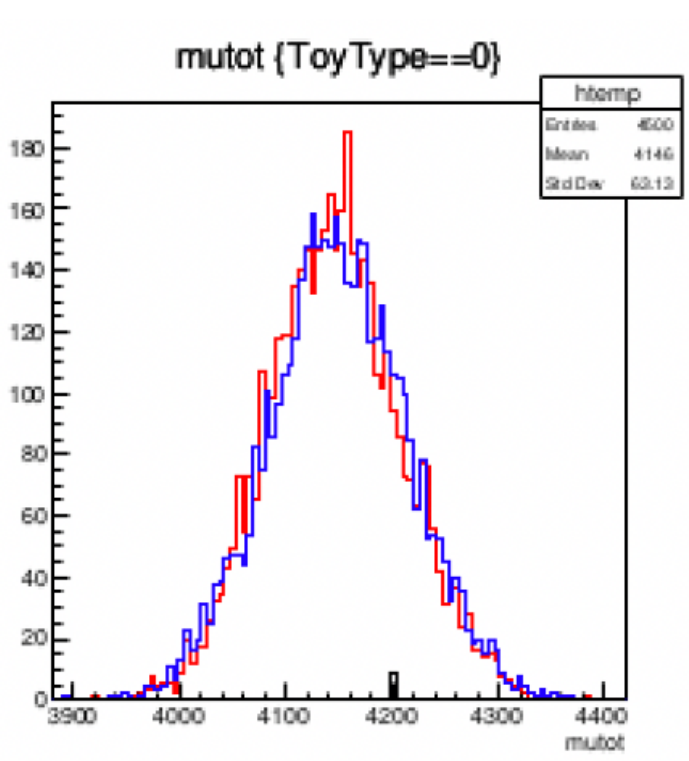
With model, with data



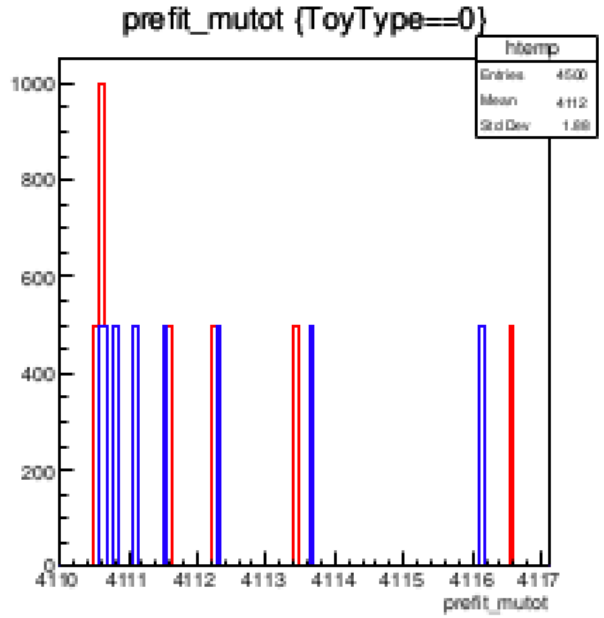
No model, no data

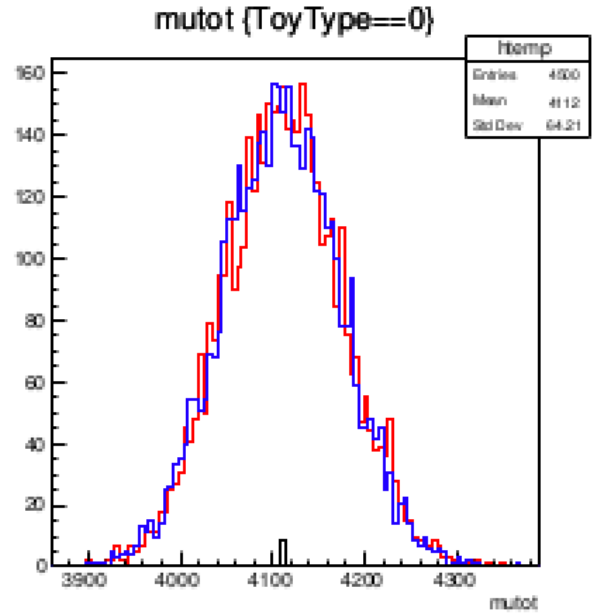


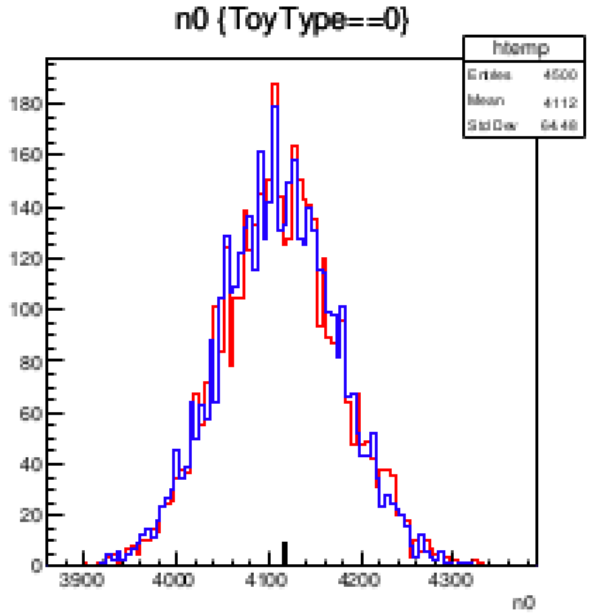
With model, no data

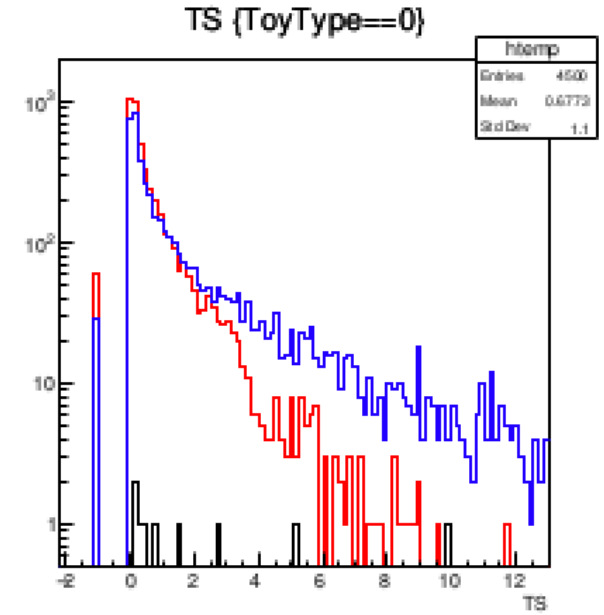


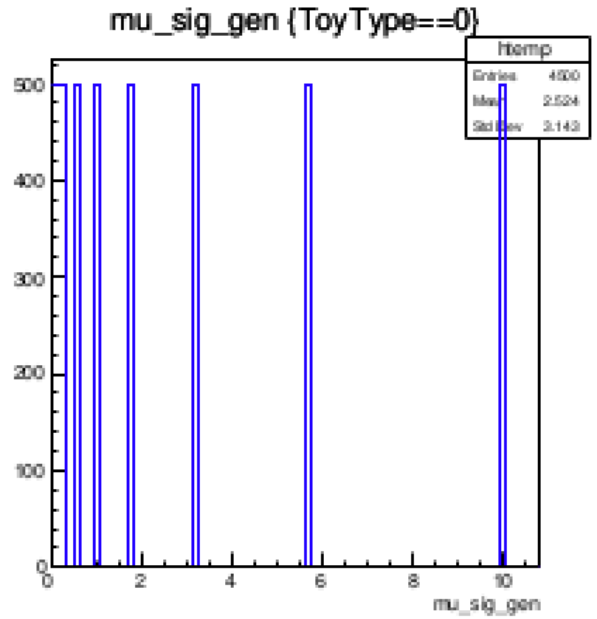
WM, WD

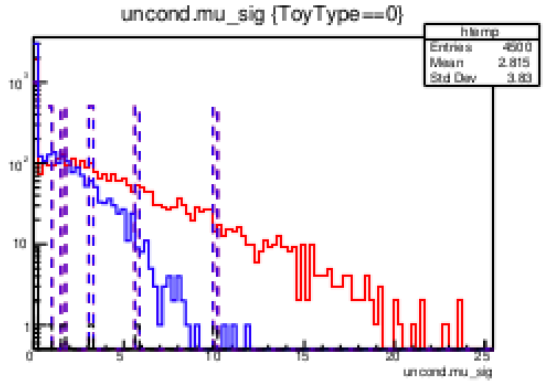

prefit_mutot {ToyType==0}
htemp
Entries 4500
Mean 4112
Std Dev 1.69
prefit_mutot

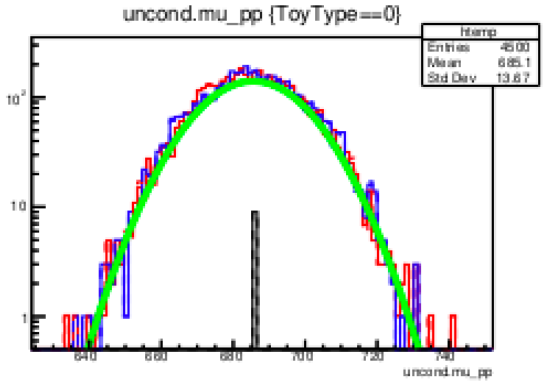

mutot {ToyType==0}
htemp
Entries 4500
Mean 4112
Std Dev 64.21
mutot

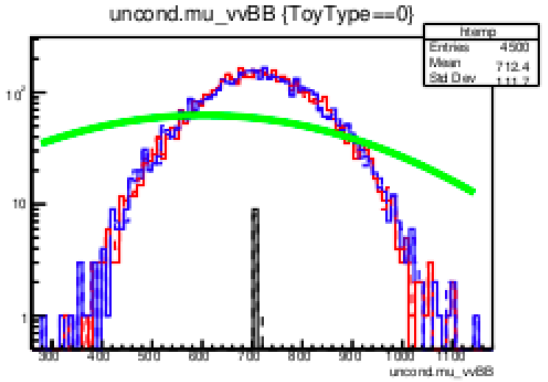

n0 {ToyType==0}
htemp
Entries 4500
Mean 4112
Std Dev 64.48
n0

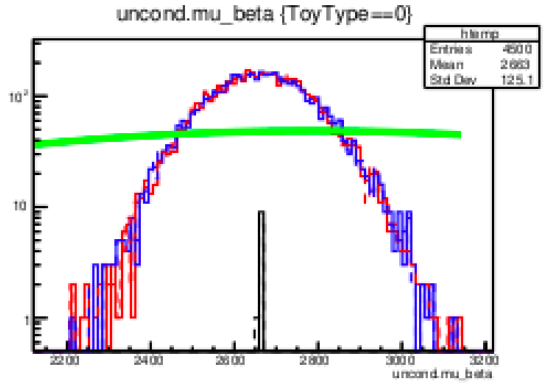

TS {ToyType==0}
htemp
Entries 4500
Mean 0.6773
Std Dev 1.1
TS

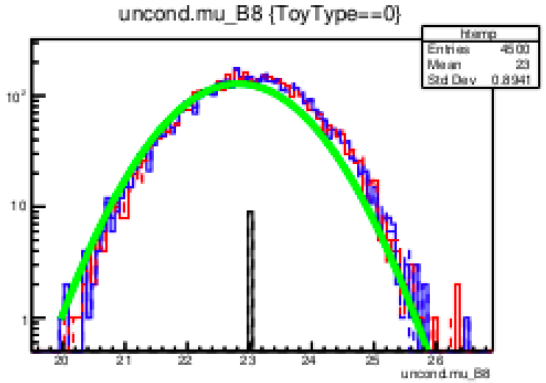

mu_sig_gen {ToyType==0}
htemp
Entries 4500
Mean 2.524
Std Dev 3.143
mu_sig_gen

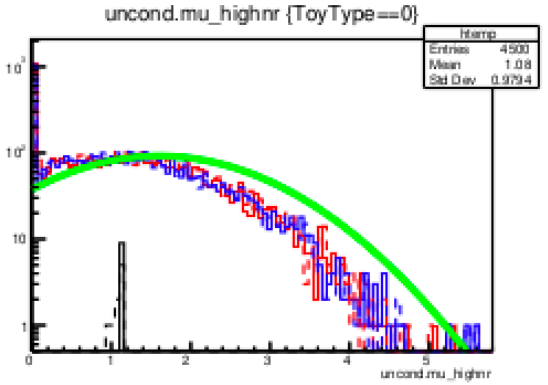

uncond.mu_sig {ToyType==0}
htemp
Entries 4500
Mean 2.815
Std Dev 3.83
uncond.mu_sig

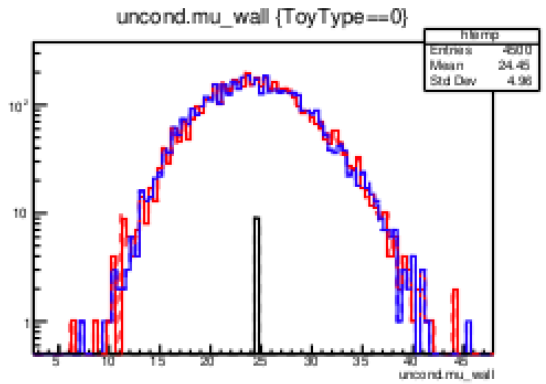

uncond.mu_pp {ToyType==0}
htemp
Entries 4500
Mean 685.1
Std Dev 13.67
uncond.mu_pp

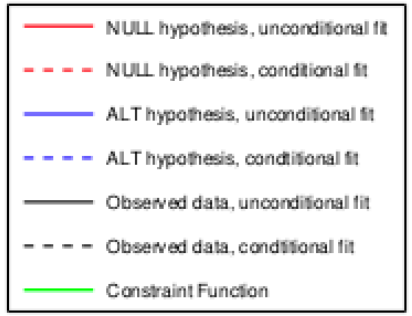

uncond.mu_vvBB {ToyType==0}
htemp
Entries 4500
Mean 712.4
Std Dev 111.7
uncond.mu_vvBB


uncond.mu_beta {ToyType==0}
htemp
Entries 4500
Mean 2693
Std Dev 125.1
uncond.mu_beta

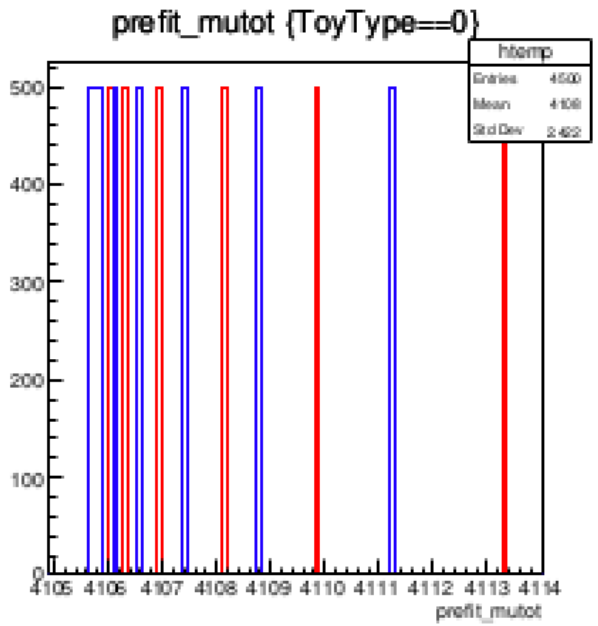

uncond.mu_B8 {ToyType==0}
htemp
Entries 4500
Mean 23
Std Dev 0.8941
uncond.mu_B8

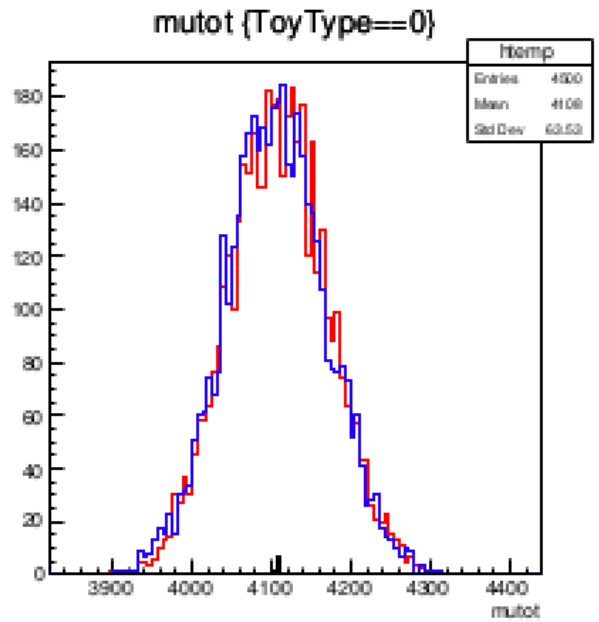

uncond.mu_highnr {ToyType==0}
htemp
Entries 4500
Mean 1.08
Std Dev 0.9794
uncond.mu_highnr

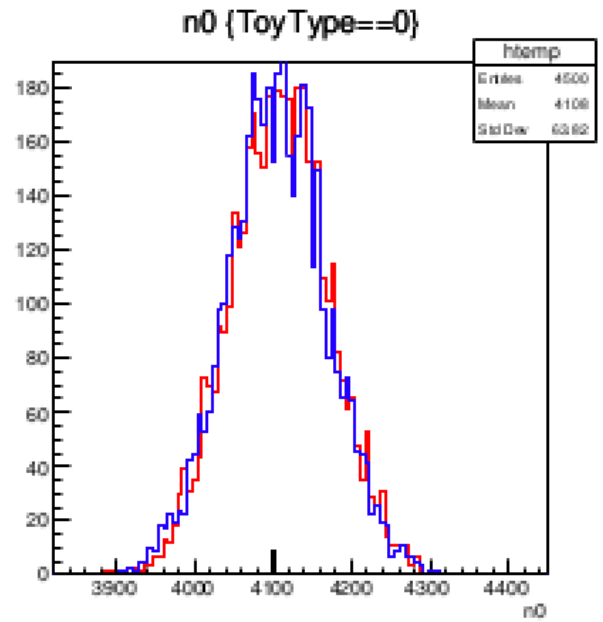

uncond.mu_wall {ToyType==0}
htemp
Entries 4500
Mean 24.45
Std Dev 4.98
uncond.mu_wall

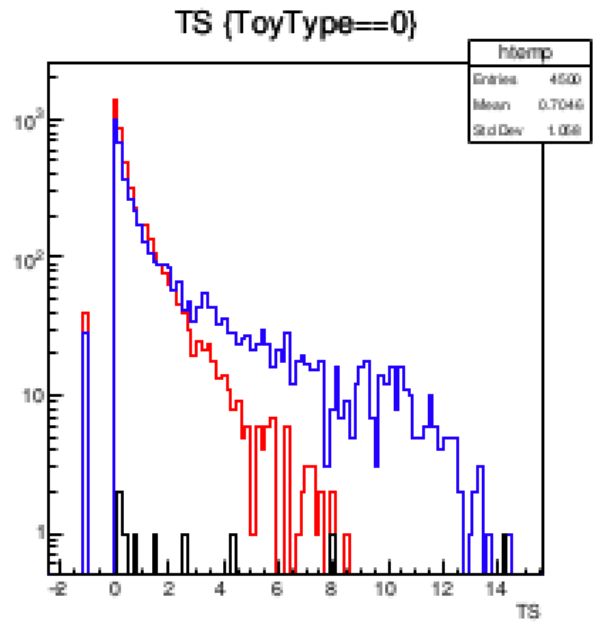

NULL hypothesis, unconditional fit
NULL hypothesis, conditional fit
ALT hypothesis, unconditional fit
ALT hypothesis, conditional fit
Observed data, unconditional fit
Observed data, conditional fit
Constraint Function

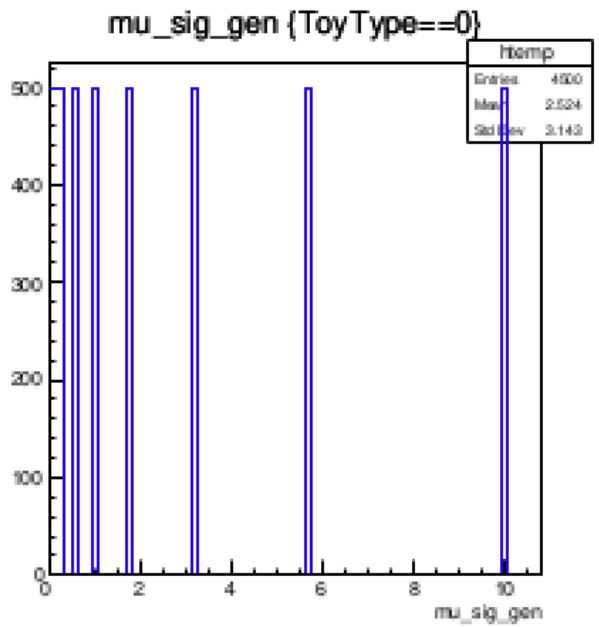
NW,ND


prefit_mutot {ToyType==0}
htemp
Entries 4500
Mean 4108
Std Dev 2.492
prefit_mutot

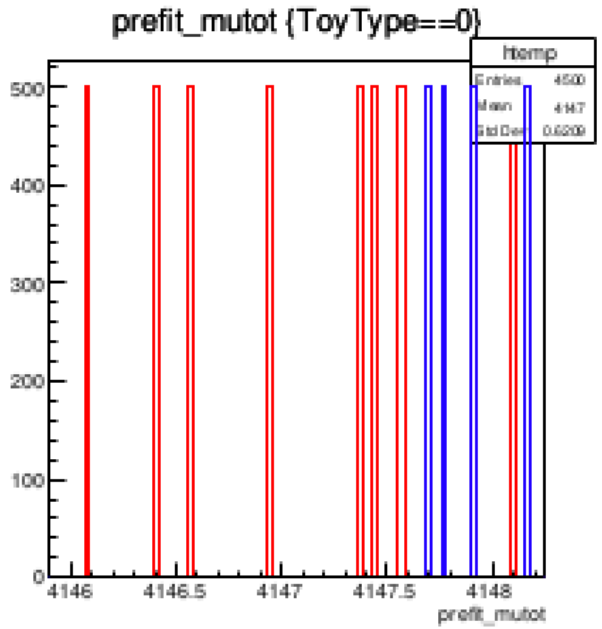

mutot {ToyType==0}
htemp
Entries 4500
Mean 4108
Std Dev 63.53
mutot

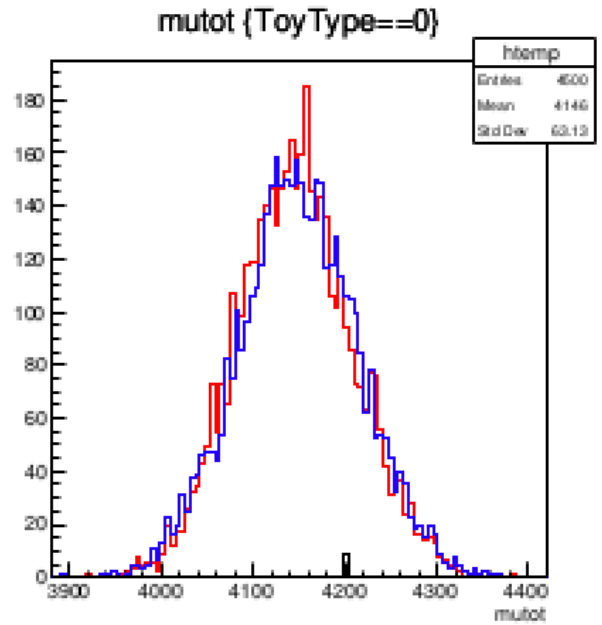

n0 {ToyType==0}
htemp
Entries 4500
Mean 4108
Std Dev 63.62
n0

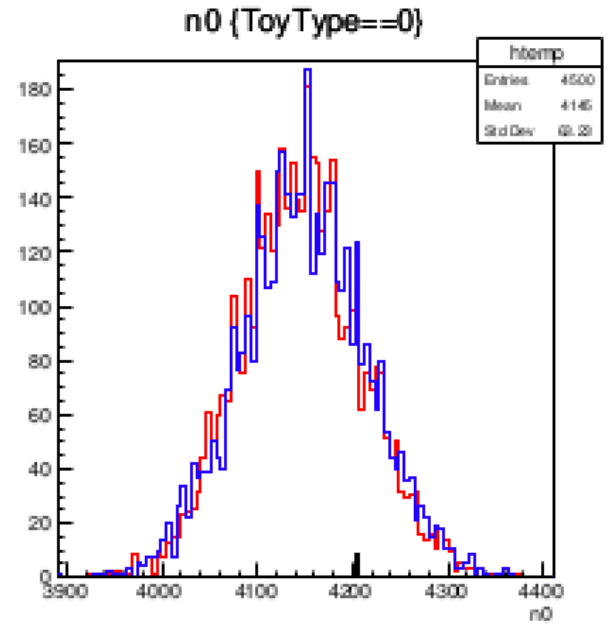

TS {ToyType==0}
htemp
Entries 4500
Mean 0.7046
Std Dev 1.058
TS

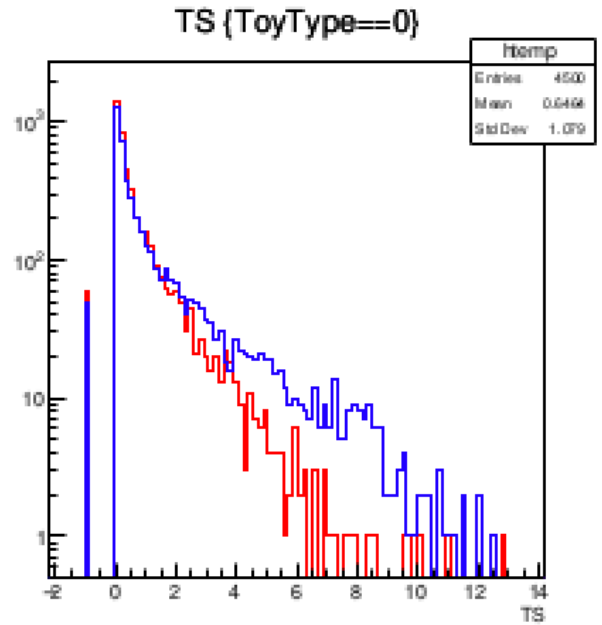

mu_sig_gen {ToyType==0}
htemp
Entries 4500
Mean 2.524
Std Dev 3.143
mu_sig_gen

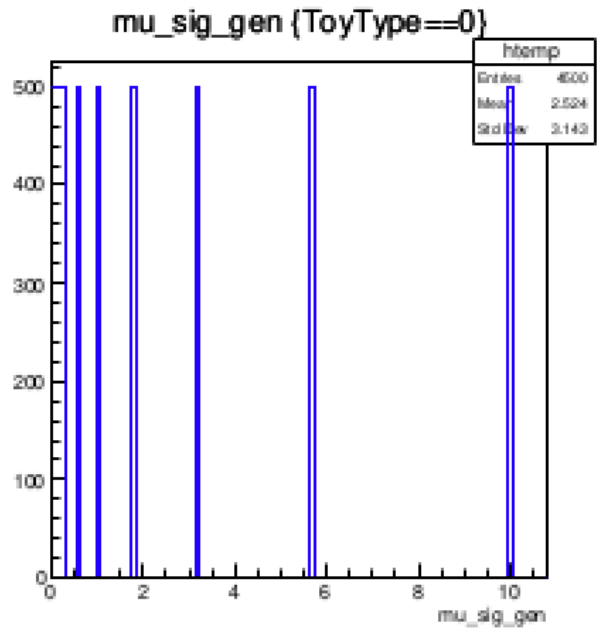
ND,WM

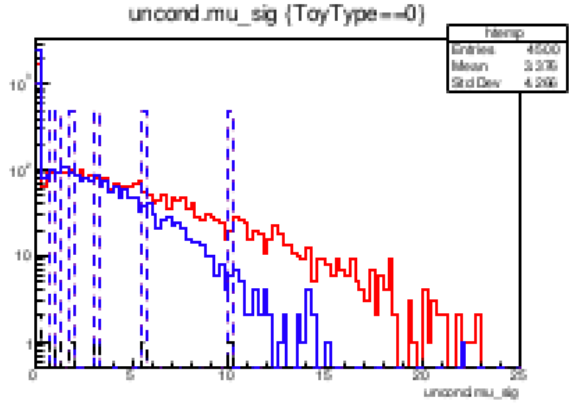

prefit_mutot {ToyType==0}
htemp
Entries 4500
Mean 4147
Std Dev 0.6209
prefit_mutot

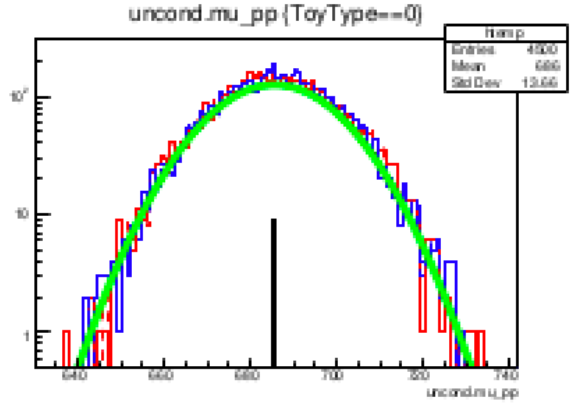

mutot {ToyType==0}
htemp
Entries 4500
Mean 4146
Std Dev 63.13
mutot

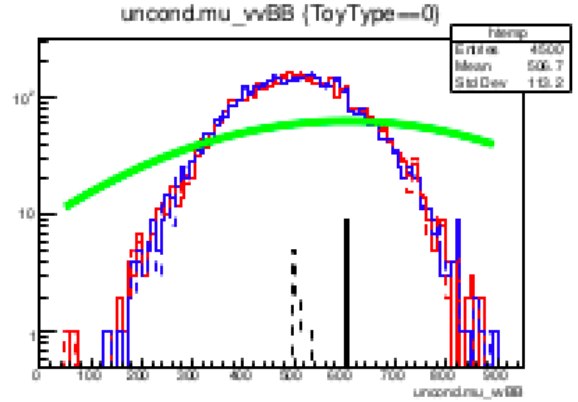

n0 {ToyType==0}
htemp
Entries 4500
Mean 4146
Std Dev 63.29
n0

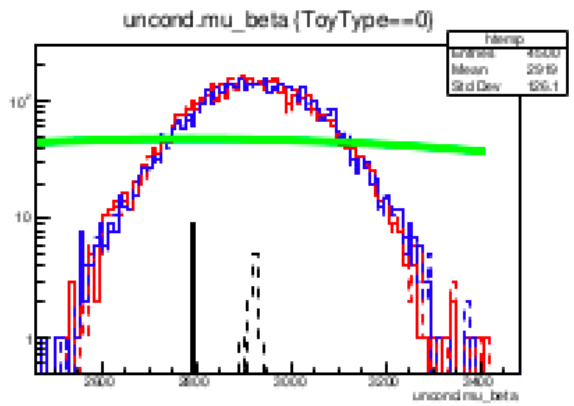

TS {ToyType==0}
htemp
Entries 4500
Mean 0.6468
Std Dev 1.079
TS

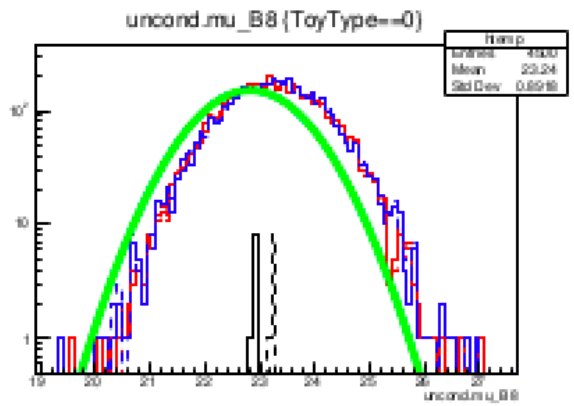

mu_sig_gen {ToyType==0}
htemp
Entries 4500
Mean 2.524
Std Dev 3.143
mu_sig_gen

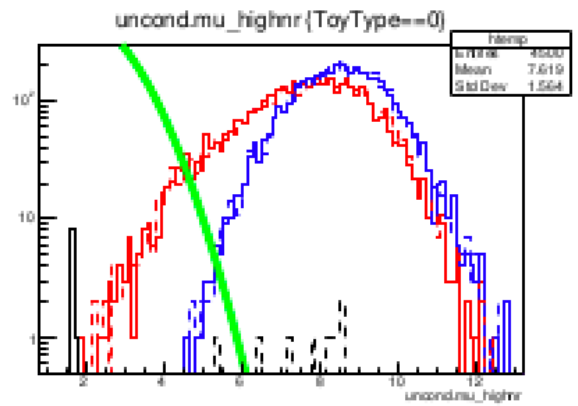

uncond.mu_sig {ToyType==0}
htemp
Entries 45000
Mean 3.276
Std Dev 4.299
uncond.mu_sig

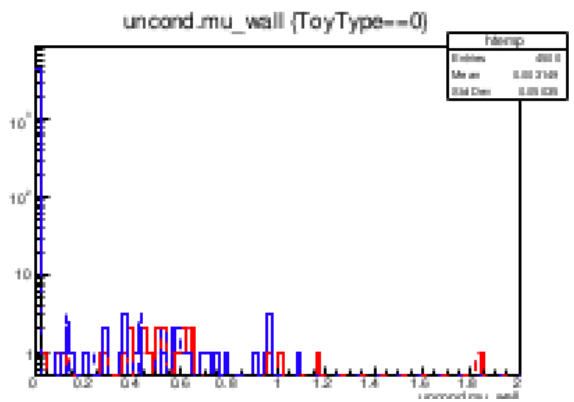

uncond.mu_pp {ToyType==0}
htemp
Entries 45000
Mean 699
Std Dev 13.66
uncond.mu_pp

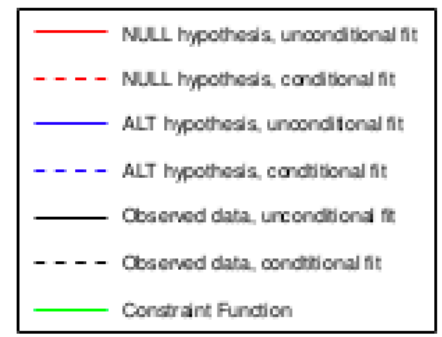

uncond.mu_vvBB {ToyType==0}
htemp
Entries 45000
Mean 506.7
Std Dev 110.2
uncond.mu_vvBB


uncond.mu_beta {ToyType==0}
htemp
Entries 45000
Mean 2919
Std Dev 120.1
uncond.mu_beta


uncond.mu_B8 {ToyType==0}
htemp
Entries 45000
Mean 23.24
Std Dev 0.8918
uncond.mu_B8


uncond.mu_highnr {ToyType==0}
htemp
Entries 45000
Mean 7.619
Std Dev 1.564
uncond.mu_highnr


uncond.mu_wall {ToyType==0}
htemp


NULL hypothesis, unconditional fit
NULL hypothesis, conditional fit
ALT hypothesis, unconditional fit
ALT hypothesis, conditional fit
Observed data, unconditional fit
Observed data, conditional fit
Constraint Function

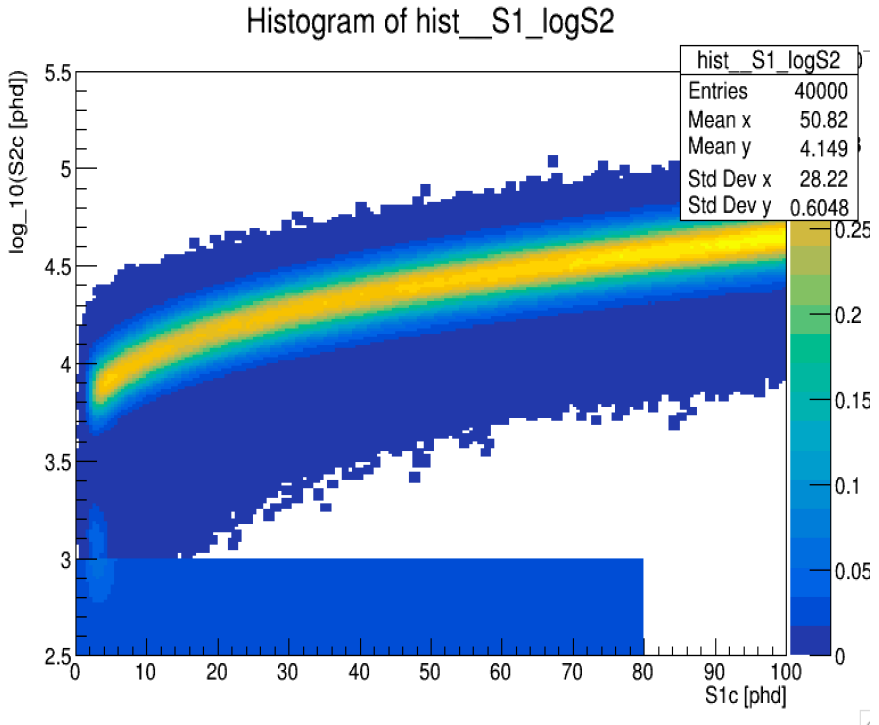
Update

- How the wall model affects the limit
- Learnt a lot about RooFit
- With Jonathan's great help, able to create the wall model and add it to the workspace.
- 4 cases

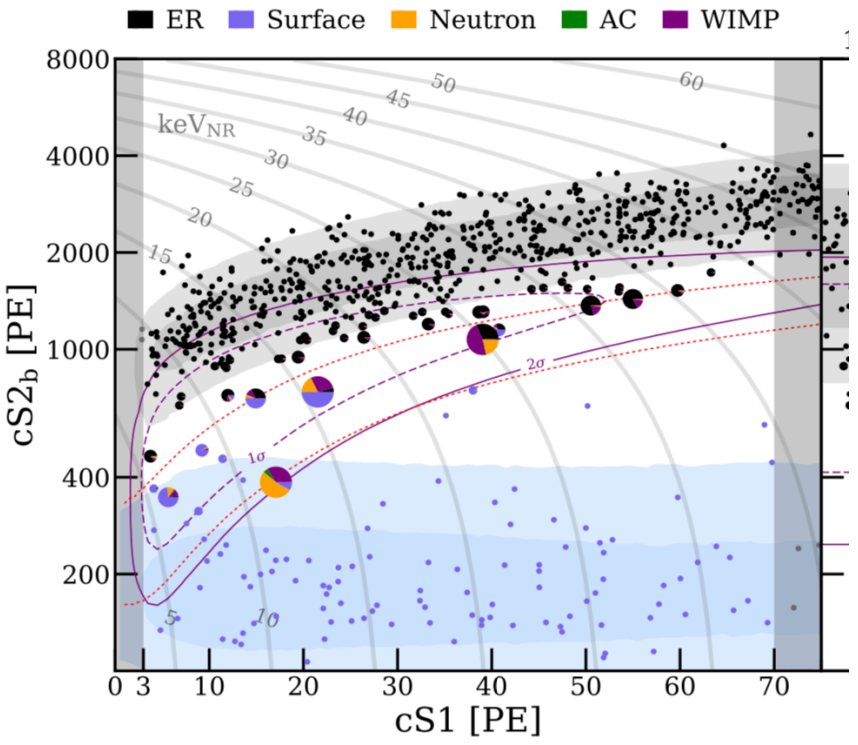
With wall model	No wall data
With wall model	With wall data
No wall model	No wall data
No wall model	With wall data

Wall model

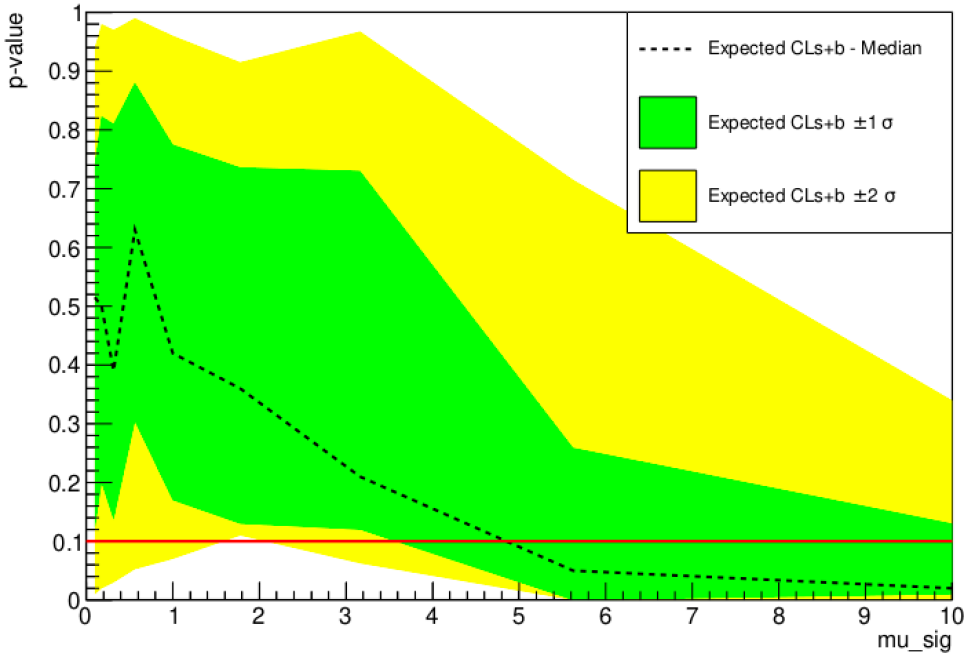
- Create workspace:
  - Wall model: create 2 step functions, S1, and logS2, and take their product and add it to the EventModel
  - Can control the expected event of wall model: w->var("mu_wall")->setVal();
  - Set the mu_wall to be 15, for 1000 livedays



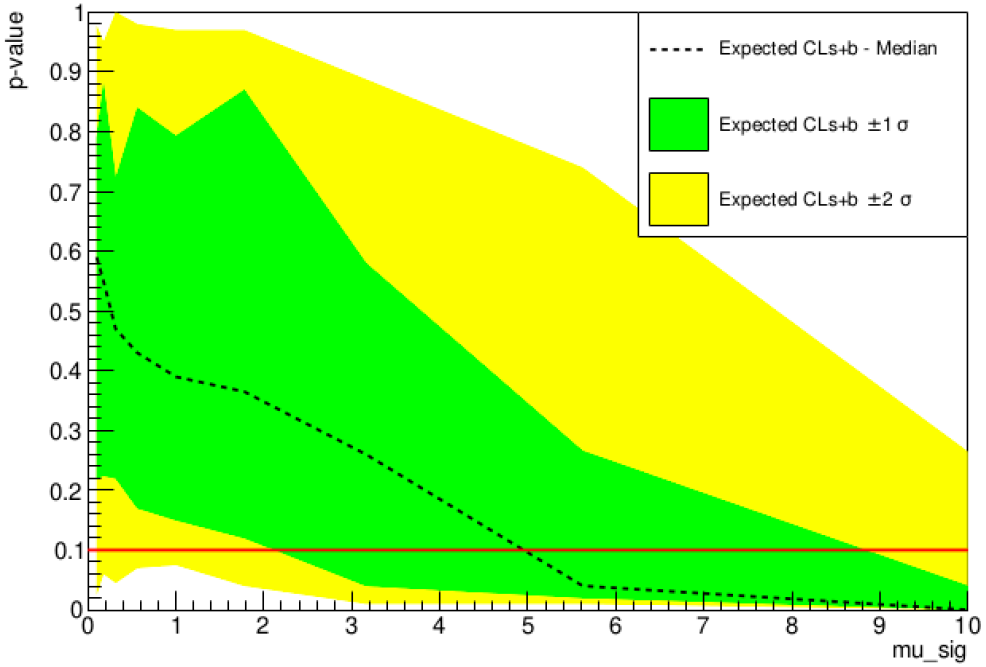
S1: 0~80
logS2: 0~3



Setting:
Min_POI = 0.1
Max_POI = 10
#POI_SCAN = 9
LogScan
#TOY = 100
Livedays = 1000
WIMP_mass = 40GeV
Interpolation = 3



No wall model, no wall data
mu_sig = 4.8543



With wall model, with wall data
mu_sig = 4.9522

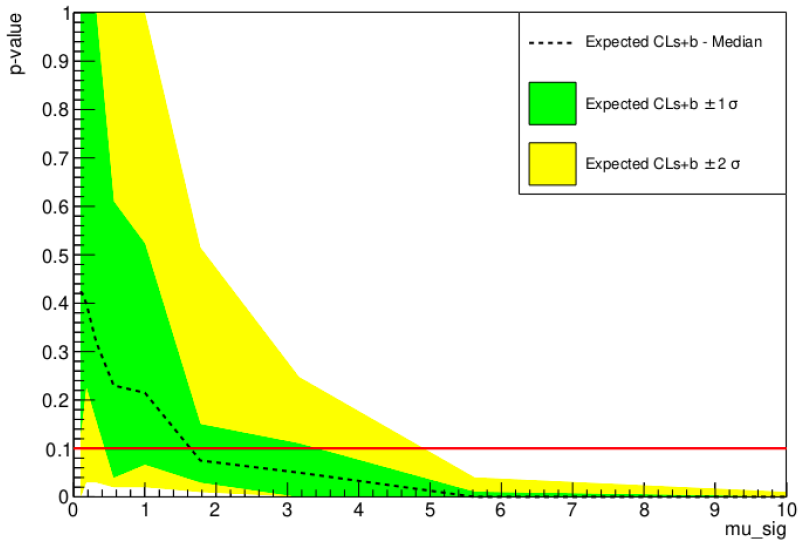
To Do

- Finish the other two cases
- Increase the toy number, decrease the interpolation order

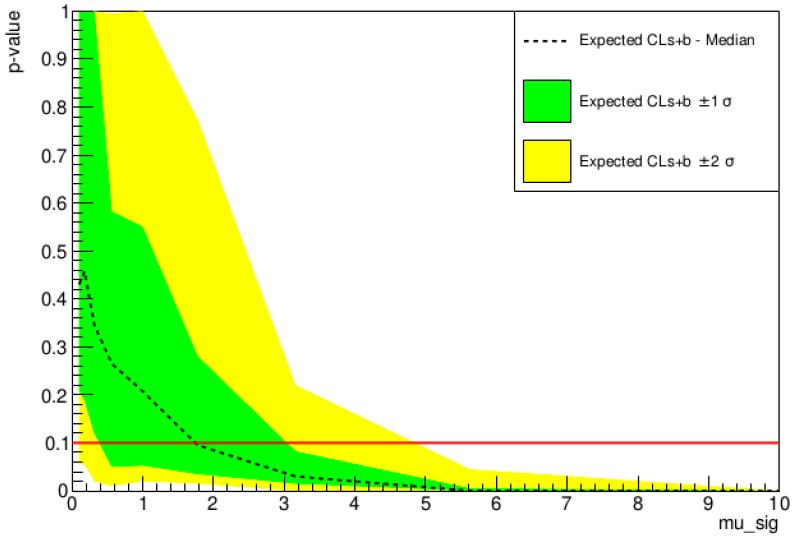
What's new

- Test on the number of toys (100, 200, 300, 500, 800, 1000)
- Setting:
  - MIN_POI = 0.1
  - MAX_POI = 10
  - WIMP_mass = 6 GeV
  - N_POI = 9
  - Nest_sample_size = 10^8
  - mu_sig range = (0, 200)

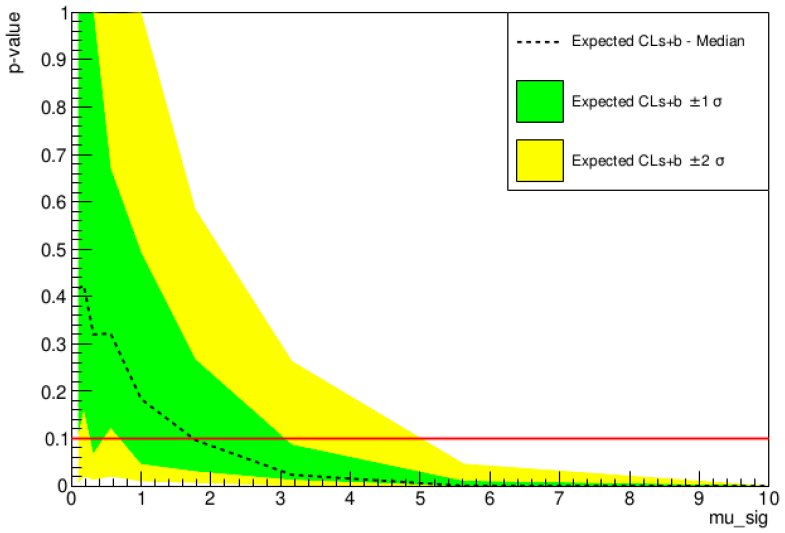
NSCAN_POI = 9,log scan



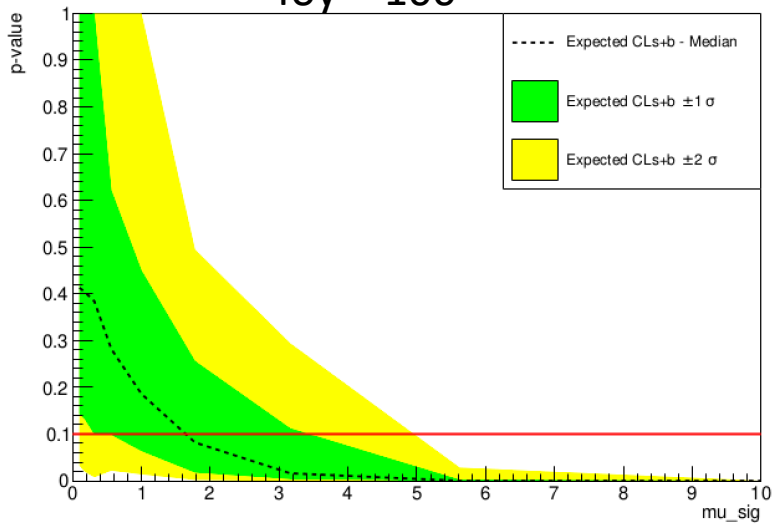
Toy = 100



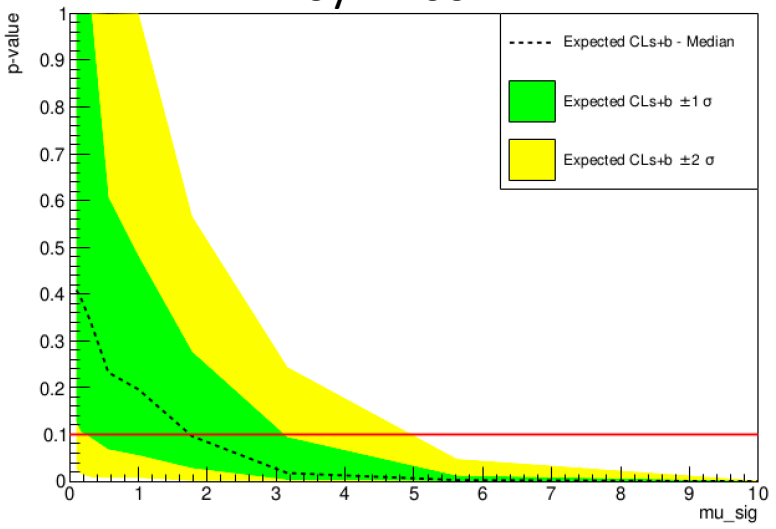
Toy = 200



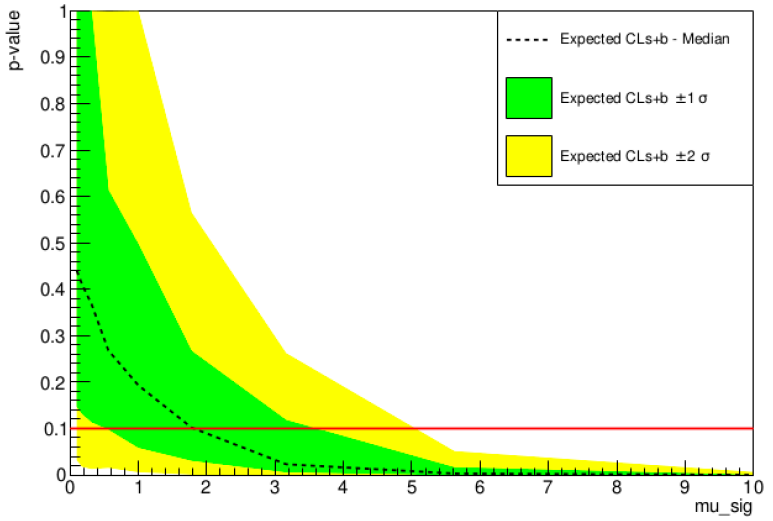
Toy = 300



Toy = 500

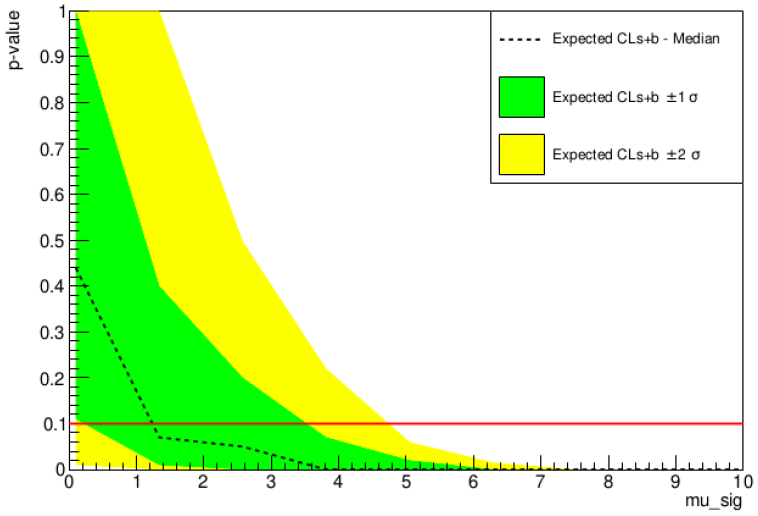


Toy = 800

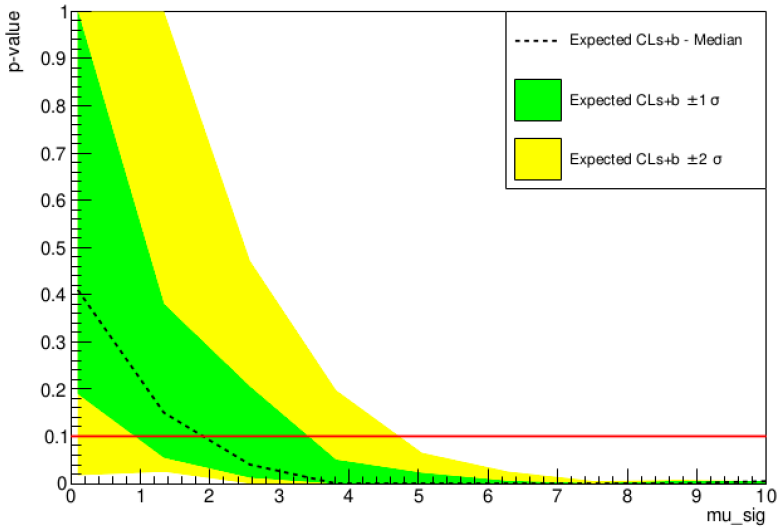


Toy = 1000

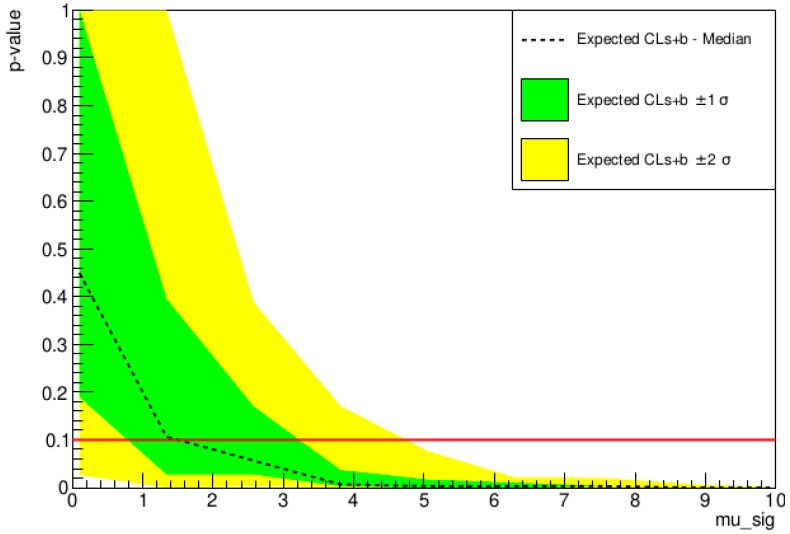
NSCAN_POI = 9,non-log scan



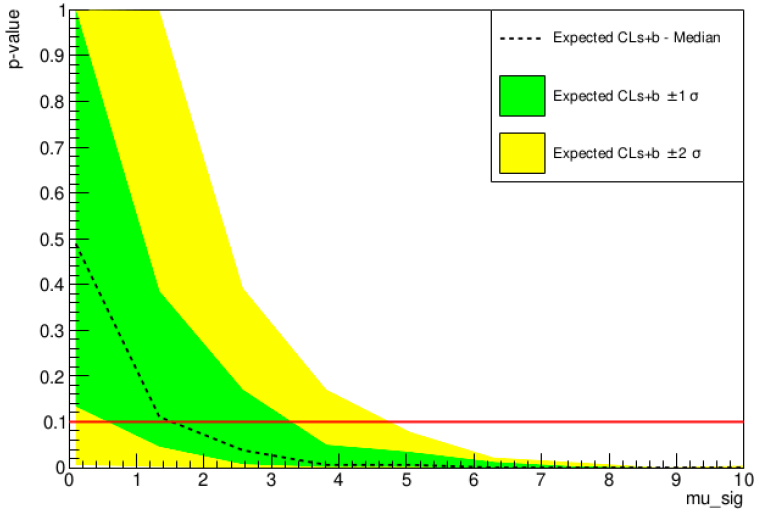
Toy = 100



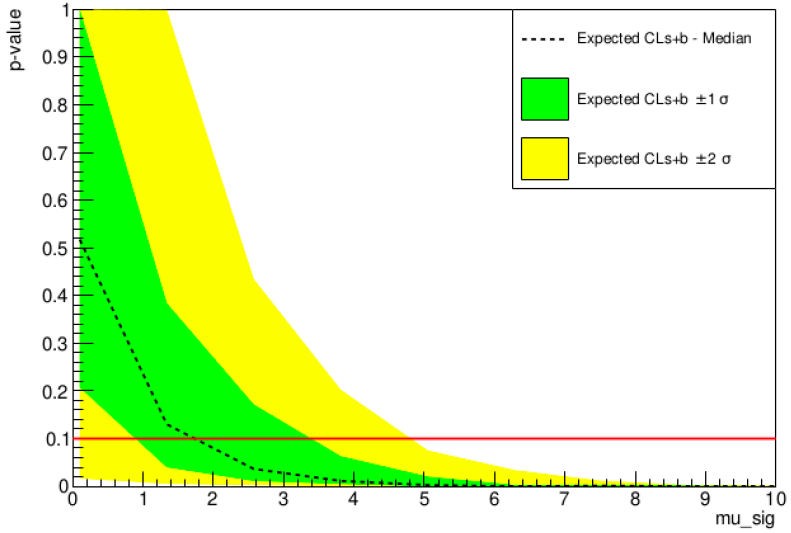
Toy = 200



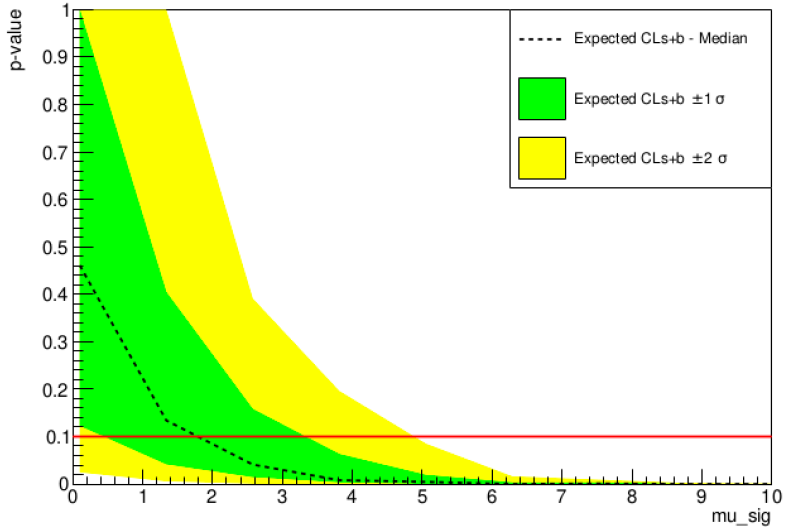
Toy = 300



Toy = 500

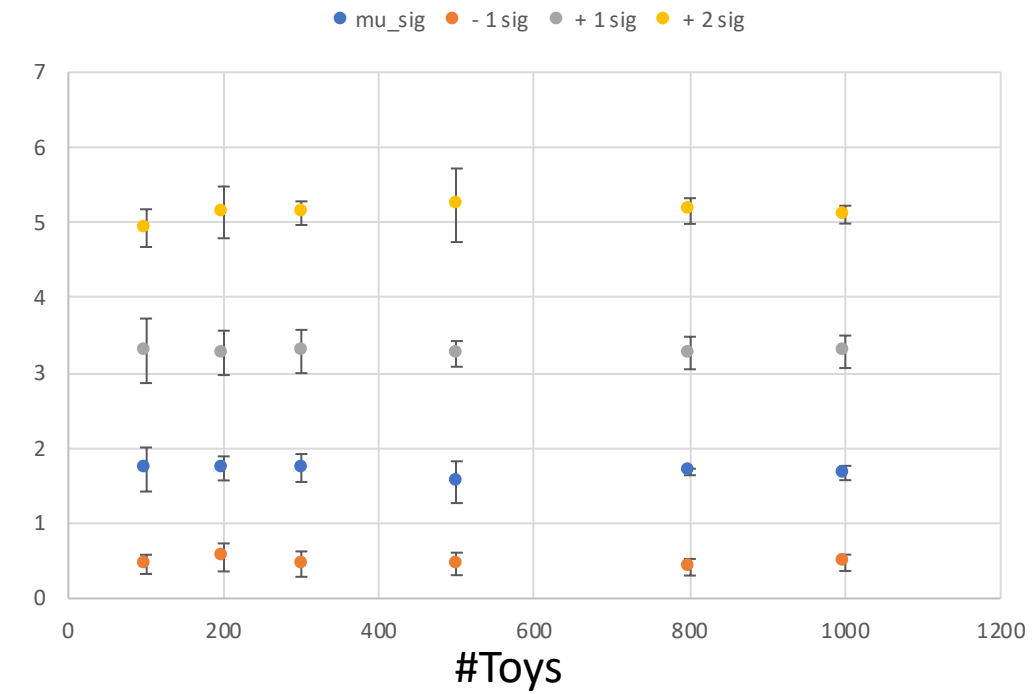


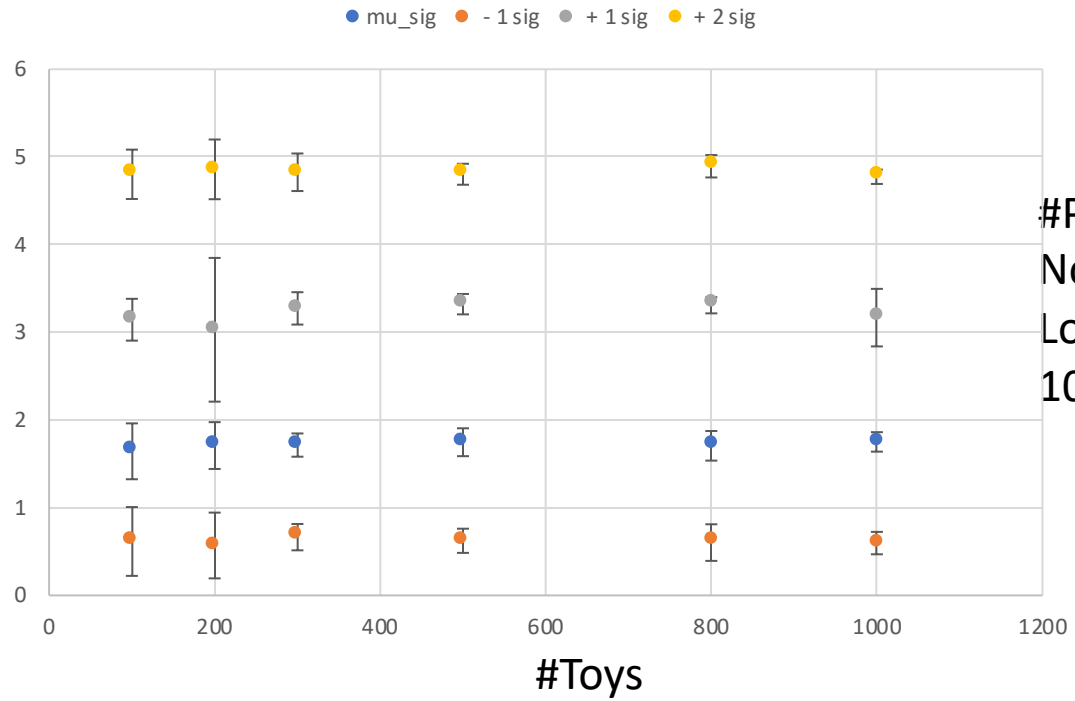
Toy = 800



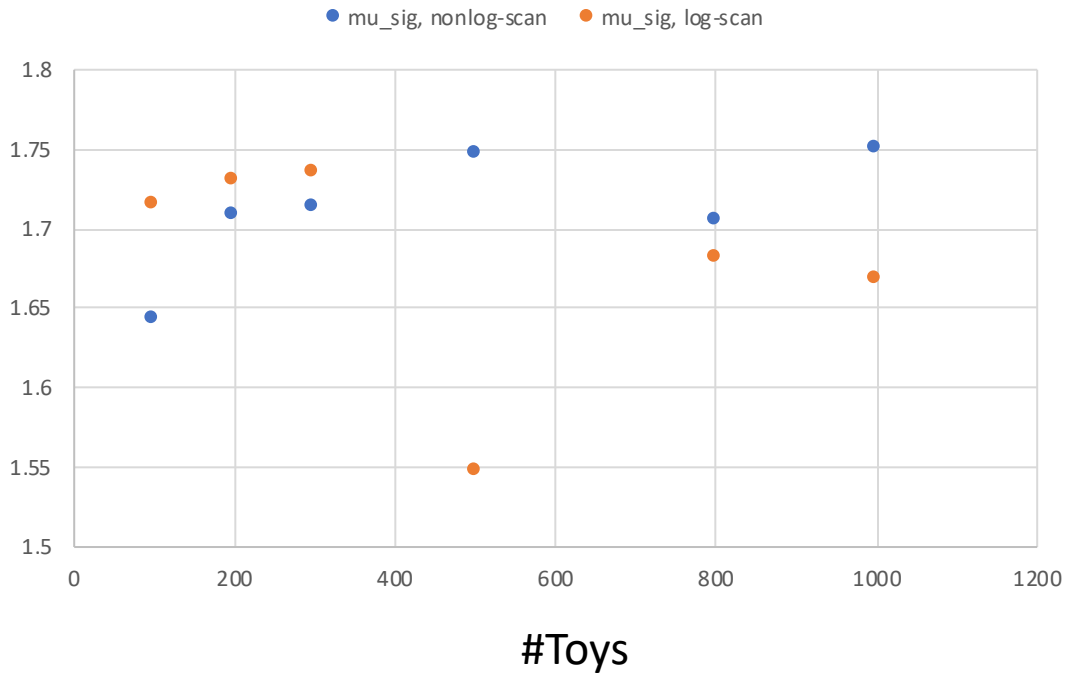
Toy = 1000

#POI = 9
Log_Scan
10 runs





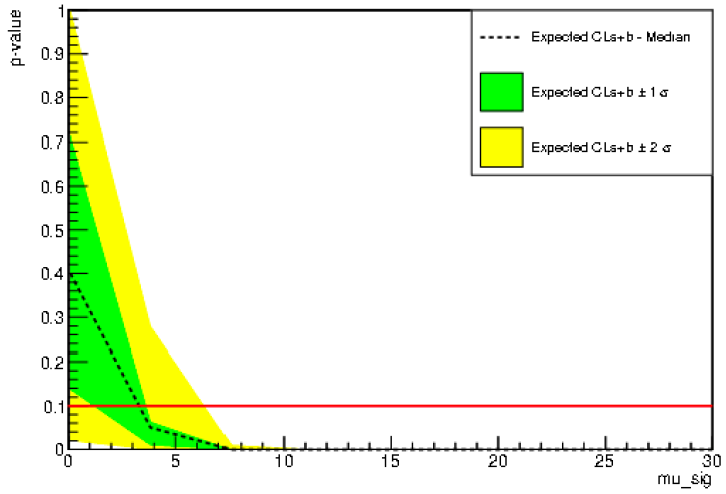
#POI = 9
Non-
Log_Scan
10 runs



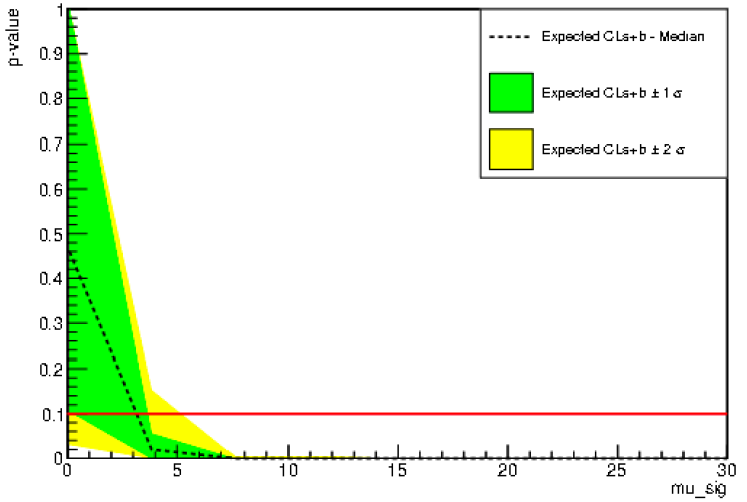
What's new

- With the new update, test on the number of toys (100, 200, 300, 500, 800, 1000)
- Setting:
  - MIN_POI = 0.1
  - MAX_POI = 30
  - WIMP_mass = 40 GeV
  - Nest_sample_size = 10^7
  - mu_sig range = (0, 200)

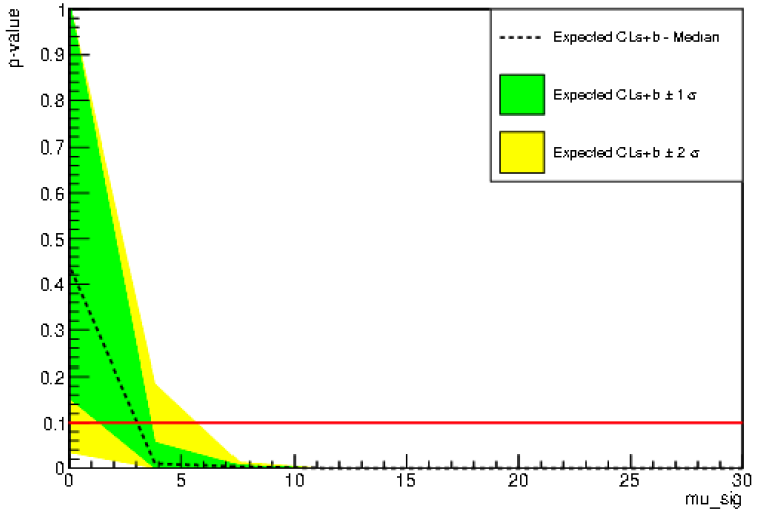
NSCAN_POI = 9, non-log scan



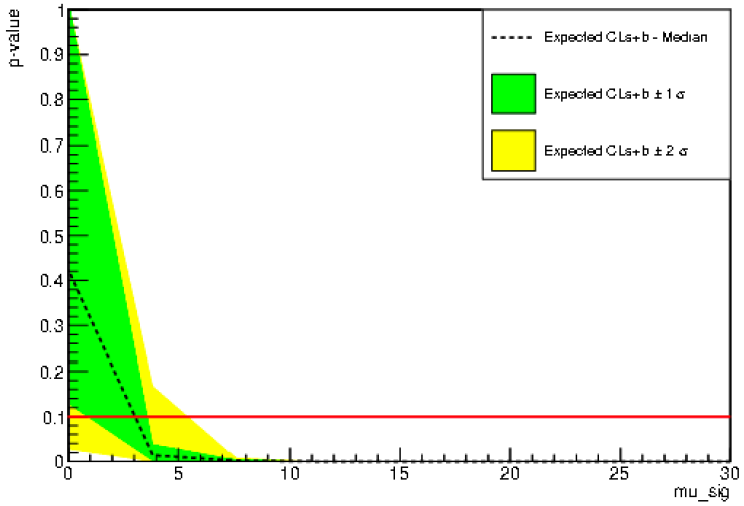
Toy = 100



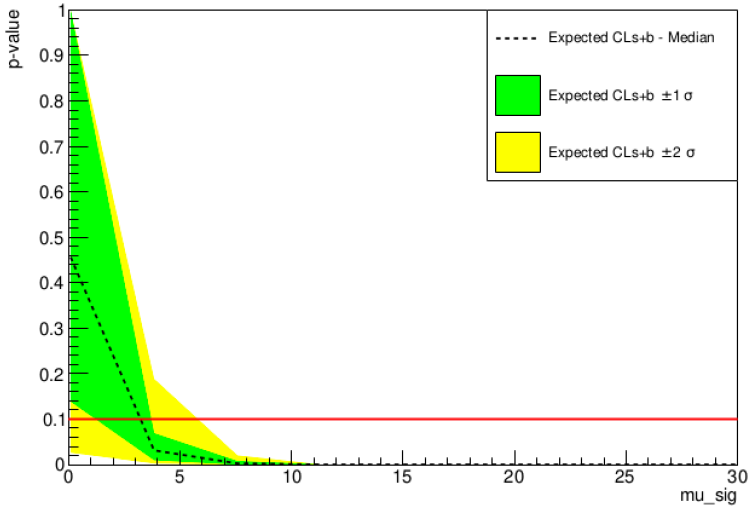
Toy = 200



Toy = 300

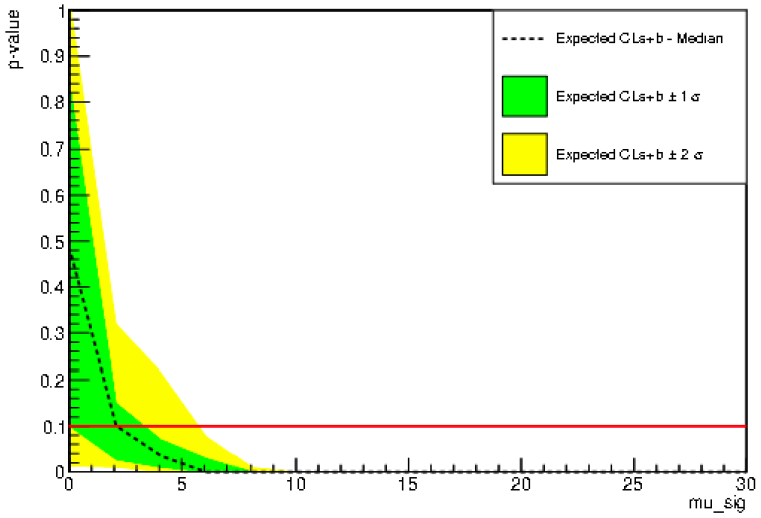


Toy = 500

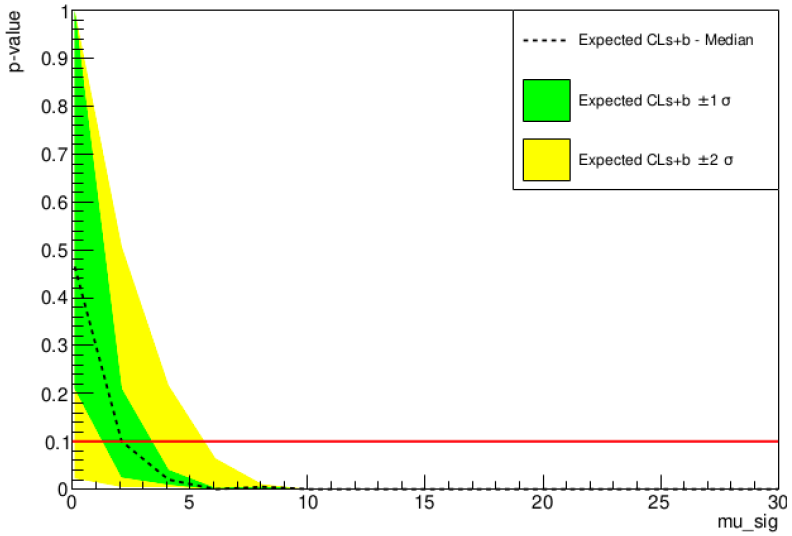


Toy = 800

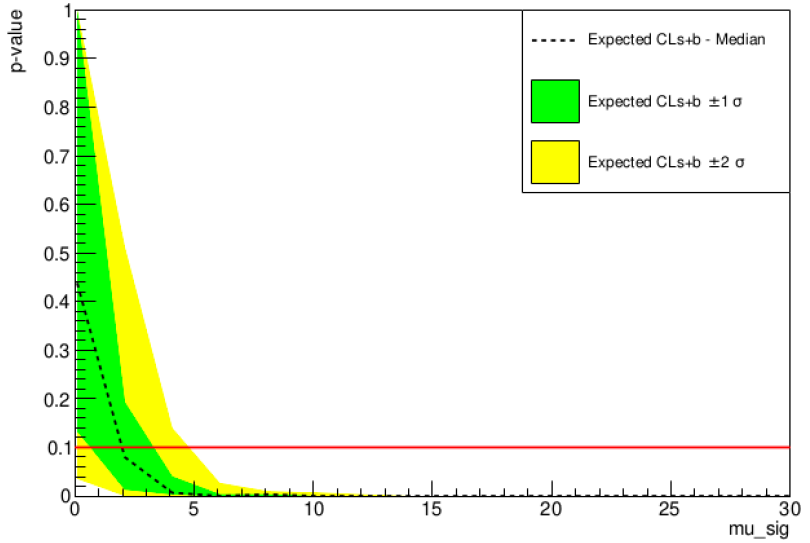
NSCAN_POI = 16, non-log scan



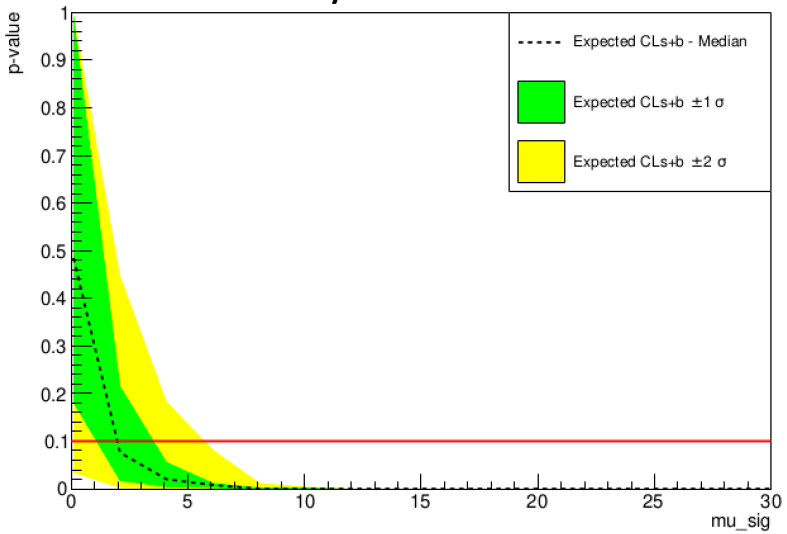
Toy = 100



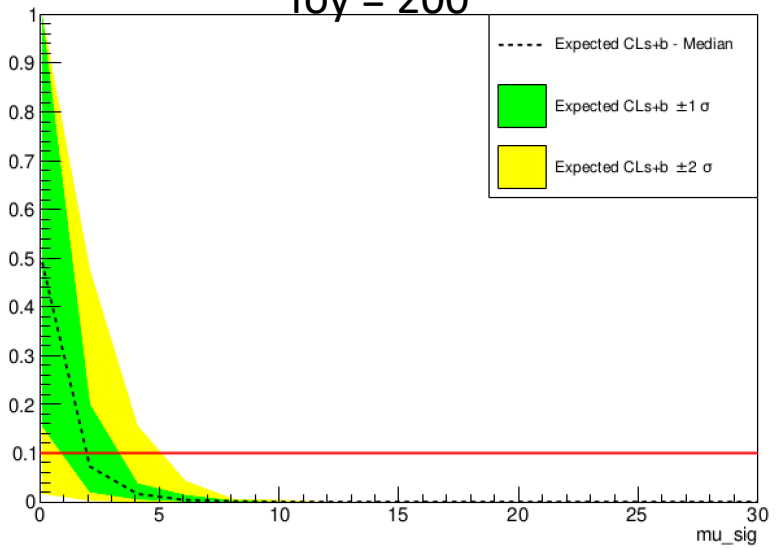
Toy = 200



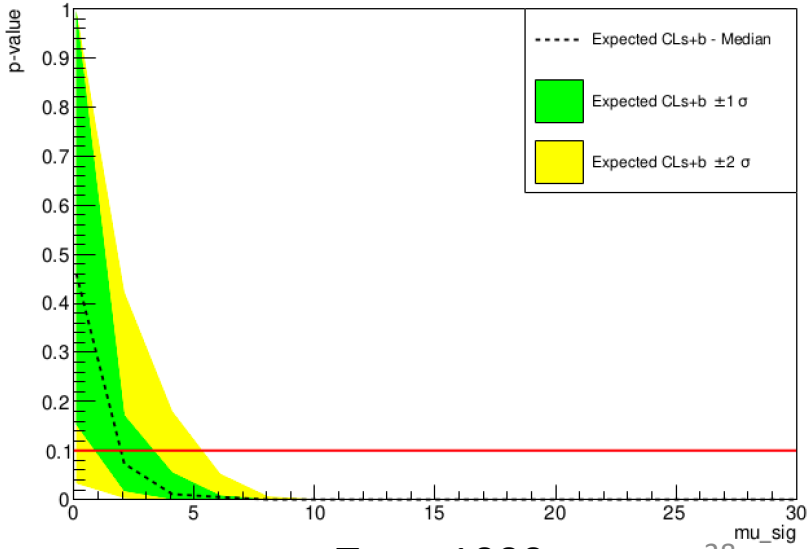
Toy = 300



Toy = 500

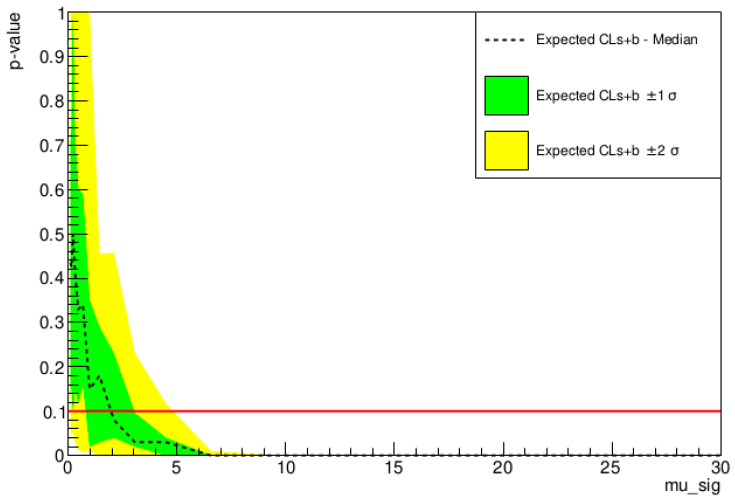


Toy = 800

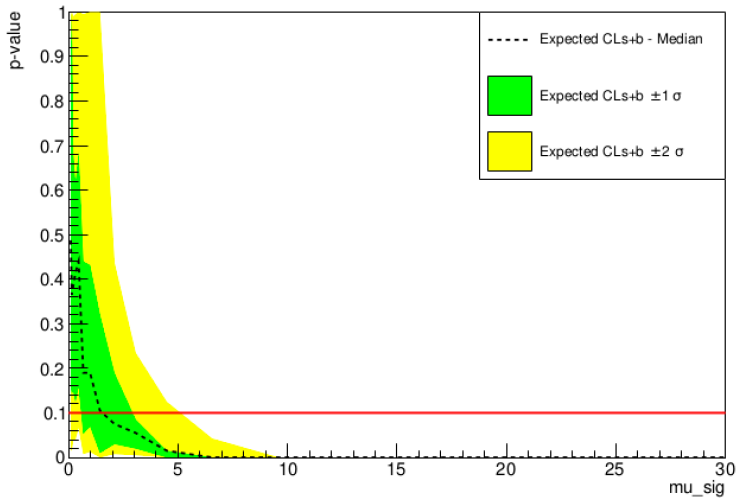


Toy = 1000

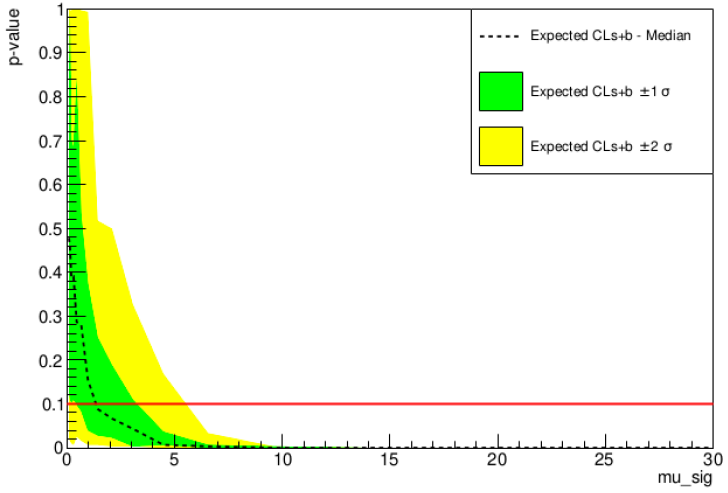
NSCAN_POI = 16, log_scan



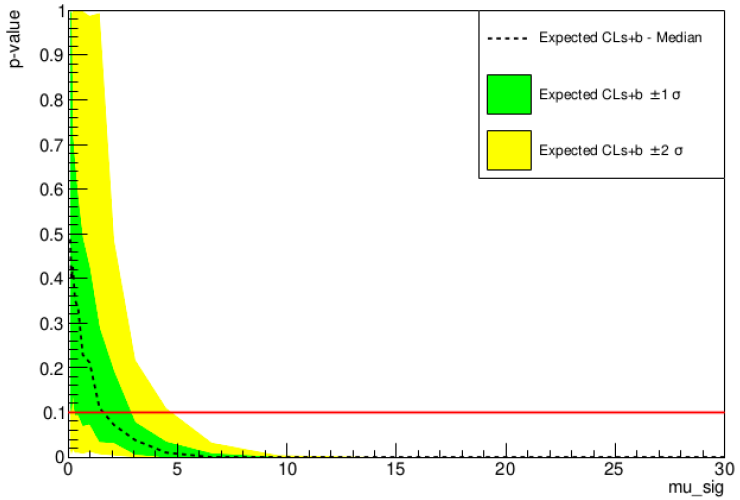
Toy = 100



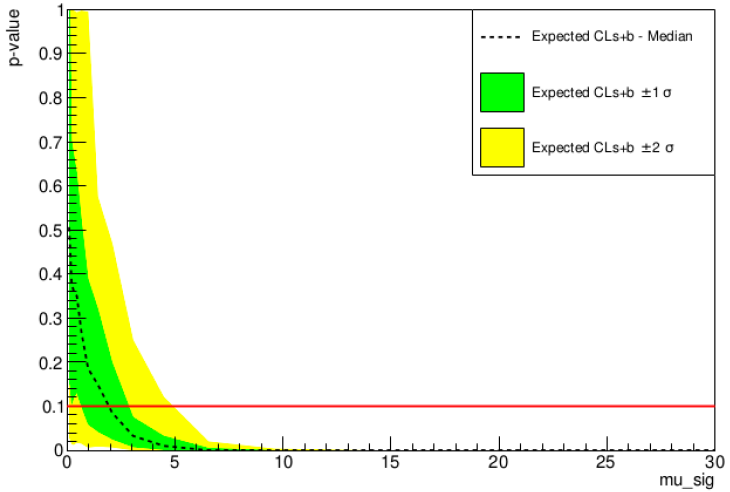
Tov = 200



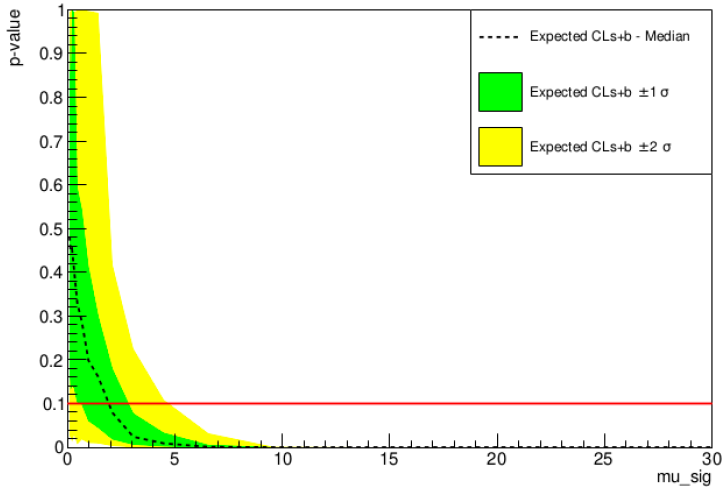
Toy = 300



Toy = 500

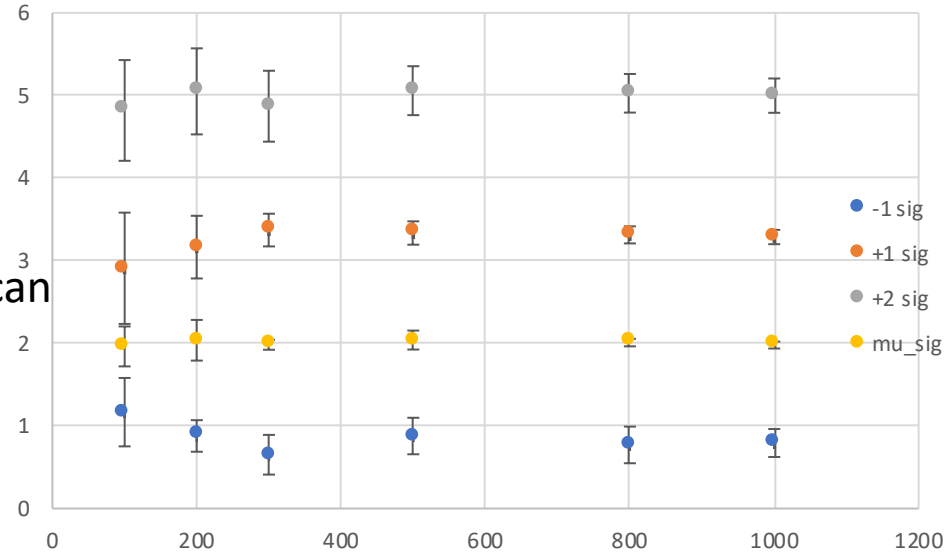


Toy = 800



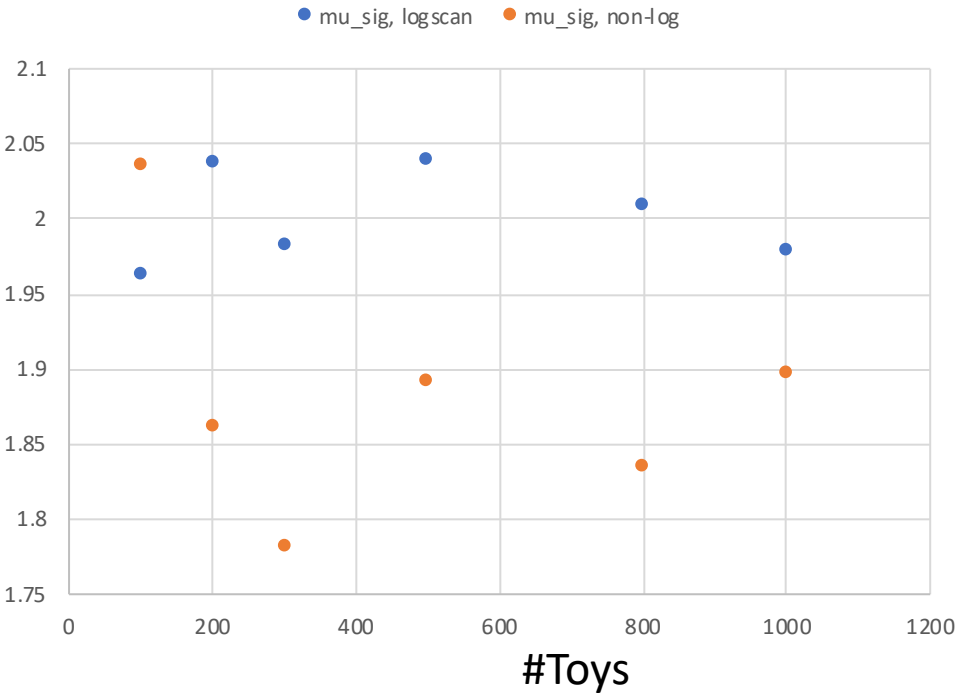
Toy = 1000

#POI = 16
Non-Log_Scan
10 runs



#Toys

#POI = 16
Log_Scan
5 runs



#Toys

#Toys

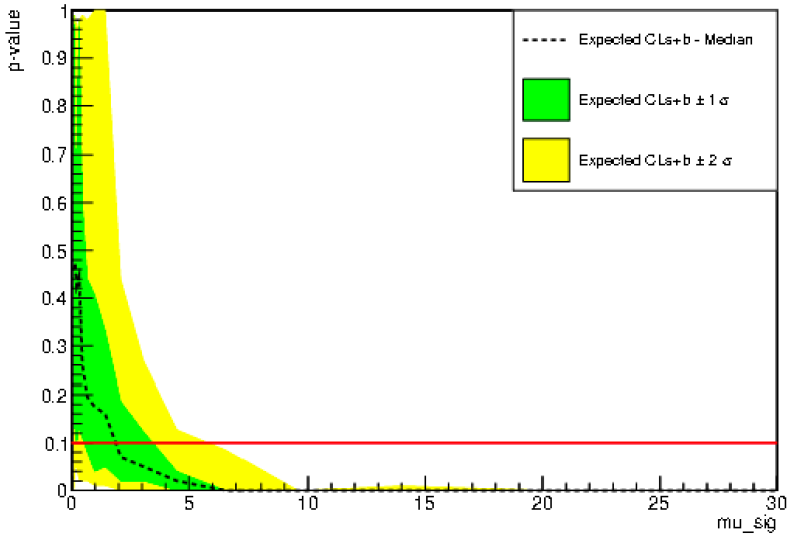
	Mu_sig		Cross section	
100	2.035	1.962	2.304E-47	2.221E-47
200	1.862	2.037	2.108E-47	2.306E-47
300	1.782	1.983	2.017E-47	2.244E-47
500	1.891	2.039	2.141E-47	2.309E-47
800	1.834	2.009	2.076E-47	2.274E-47
1000	1.896	1.979	2.146E-47	2.240E-47

Next Step

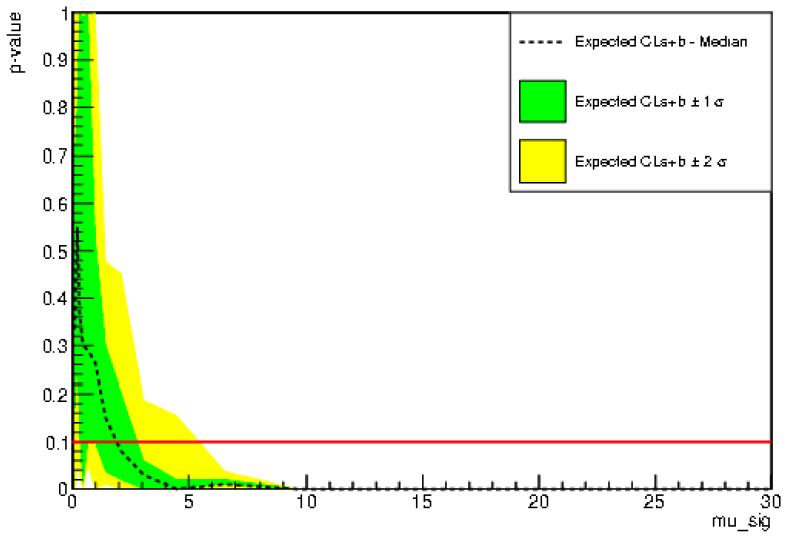
- The # toy test I did before was on 10 GeV, or do a test on lower WIMP mass, ~ 6GeV

New Update

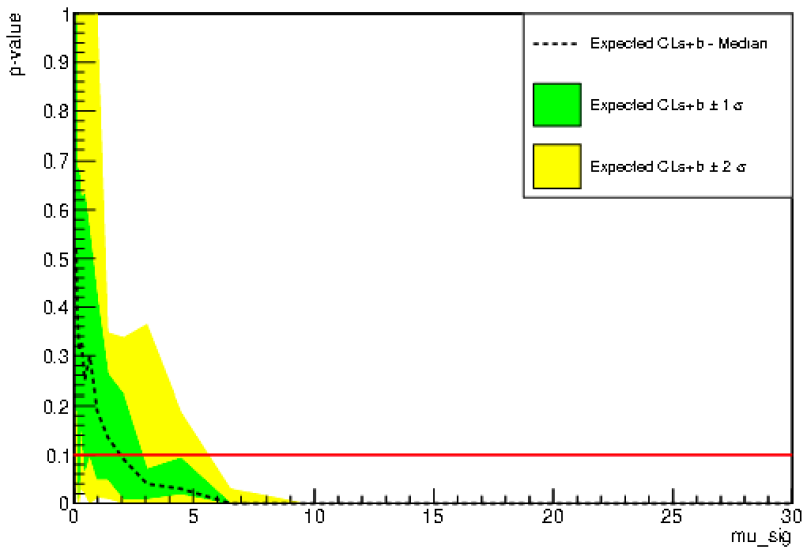
- Create new workspace for WIMP = 40 GeV, mu_sig (-100, 100), (-5, 100) (0, 200)
  - n_sample = 1e6
  - Fiducial mass (kg): 5600
  - Livetime (days): 24
  - Min POI = 0.1
  - Max POI = 30
  - Toys/point: 100
- Compare the graphs for different sources at the lower boundary of mu_sig (-100, -5, 0)



Mu_sig: (-100, 100)
Mu_sig: 1.9457
Cross section:2.2e-47

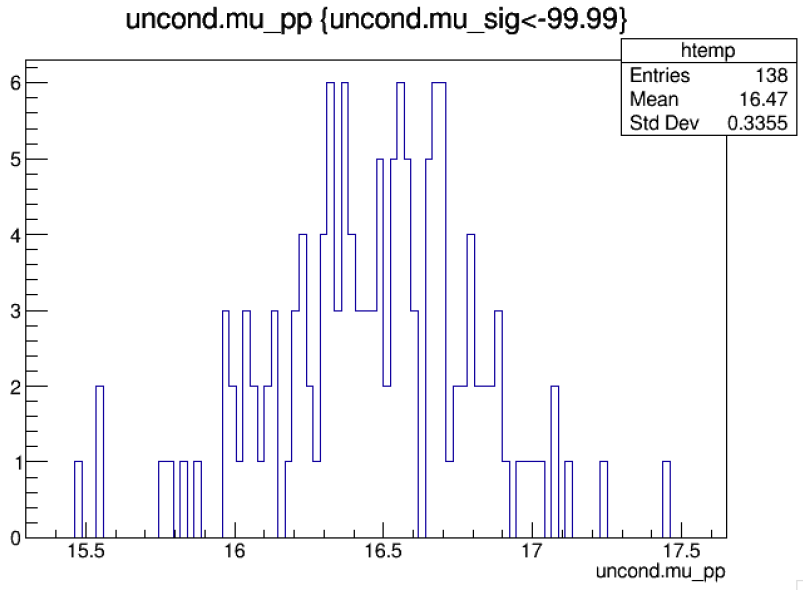


Mu_sig: (-5, 100)
Mu_sig: 1.9449
Cross section: 2.2e-47

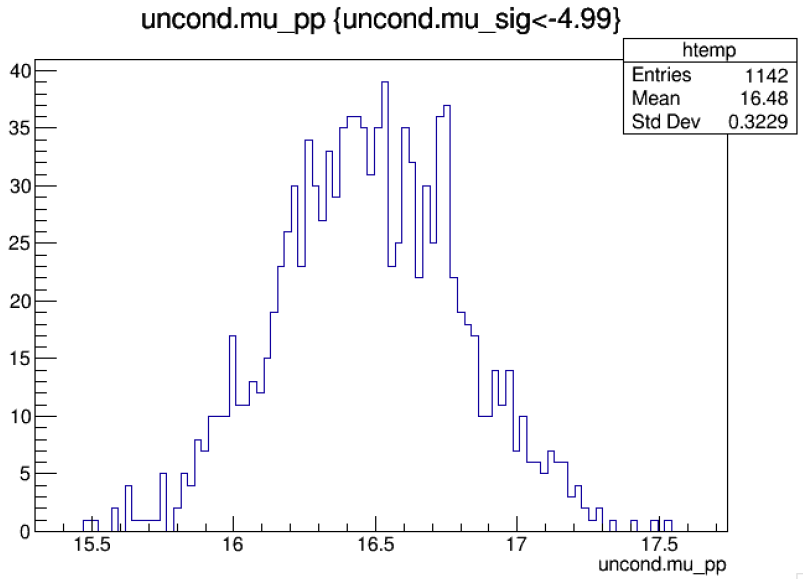


Mu_sig: (0, 200)
Mu_sig: 1.9457
Cross section: 2.2e-47

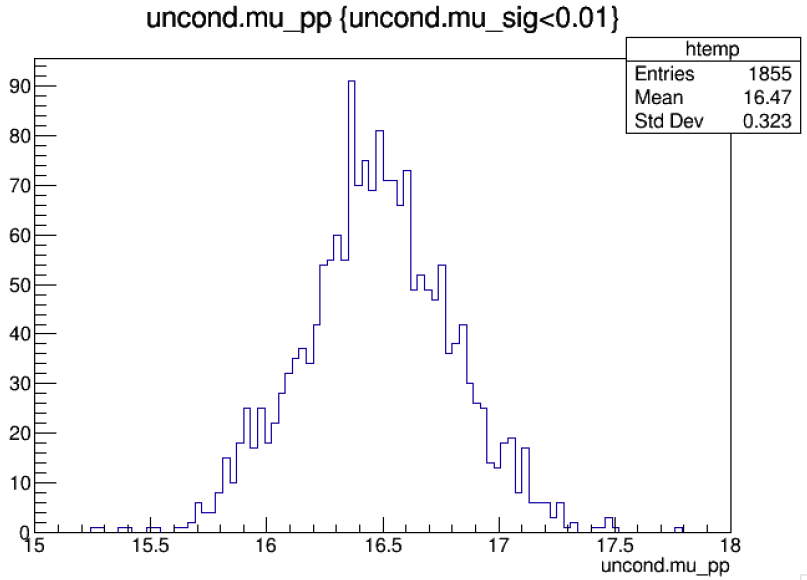
uncond.mu_pp



Mu_sig: (-100, 100)

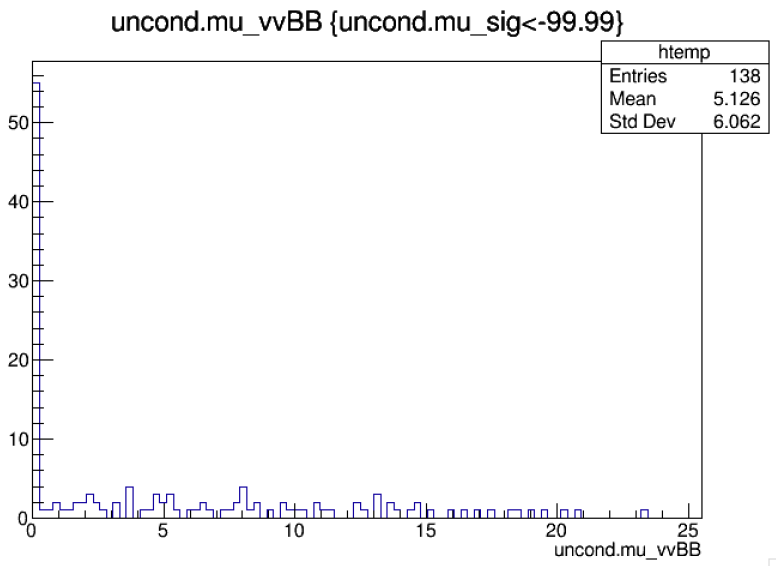


Mu_sig: (-5, 100)

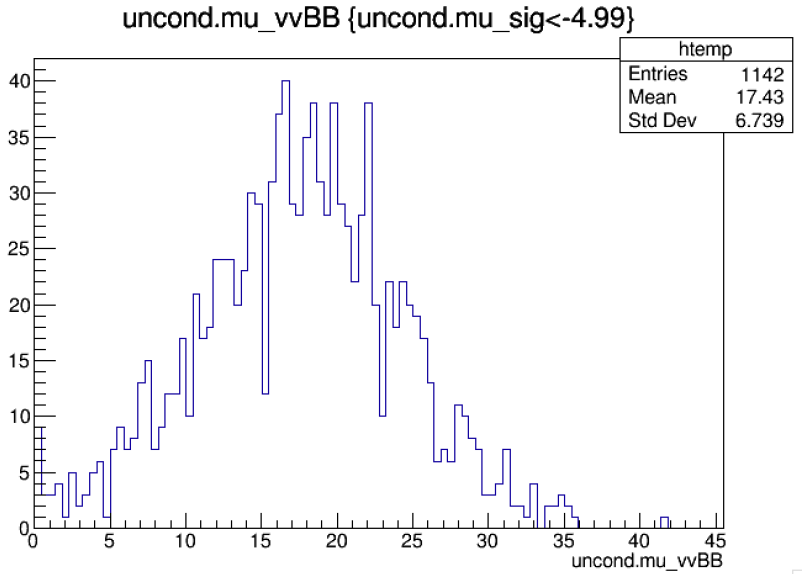


Mu_sig: (0, 200)

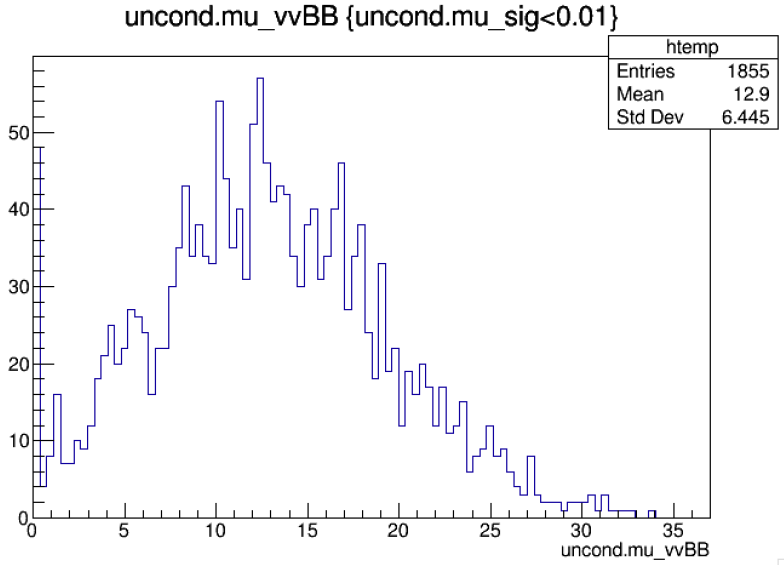
uncond.mu_vvBB



Mu_sig: (-100, 100)

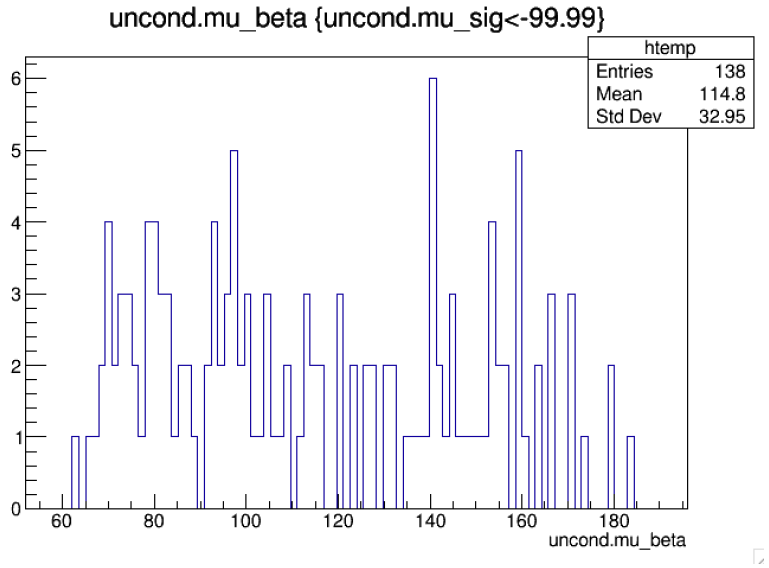


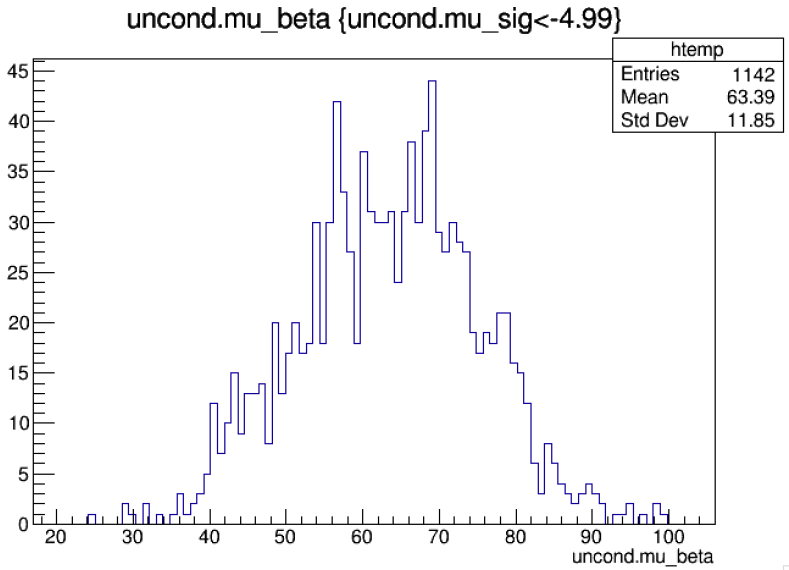
Mu_sig: (-5, 100)

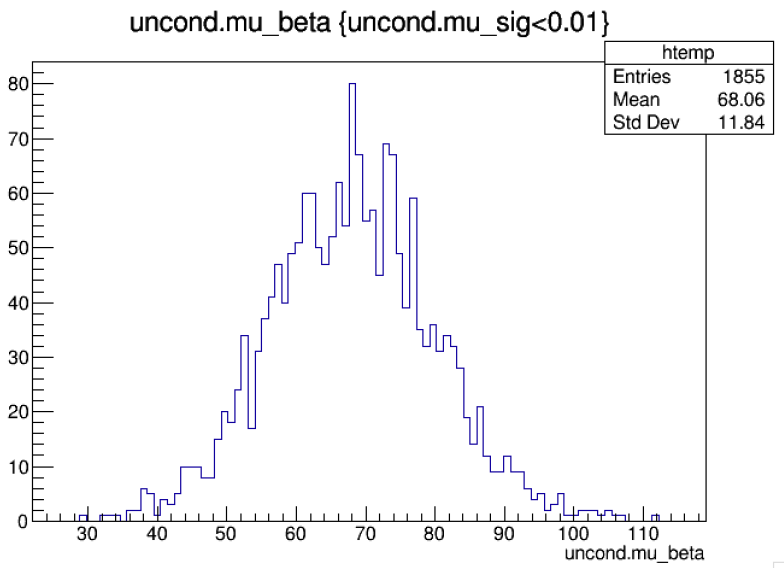


Mu_sig: (0, 200)

uncond.mu_beta





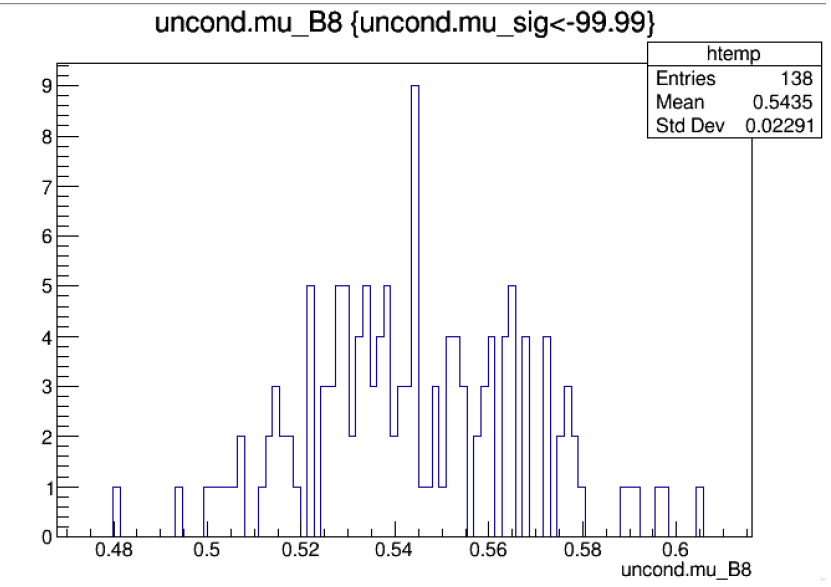


Mu_sig: (-100, 100)

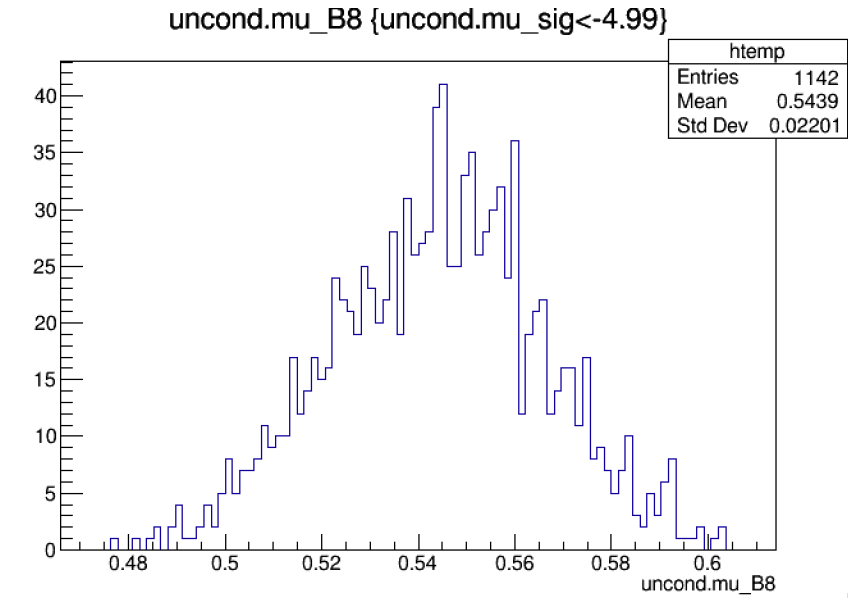
Mu_sig: (-5, 100)

Mu_sig: (0, 200)

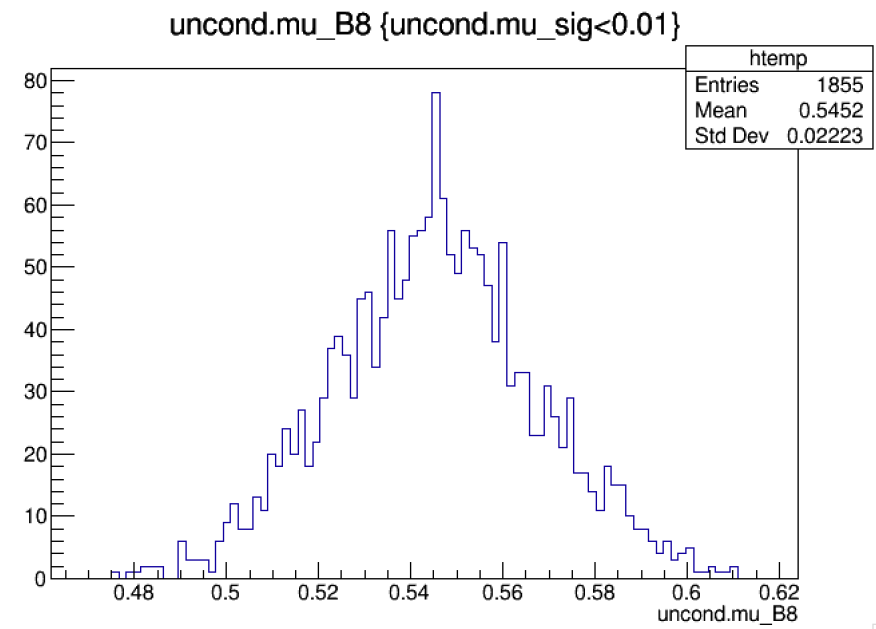
uncond.mu_B8



Mu_sig: (-100, 100)

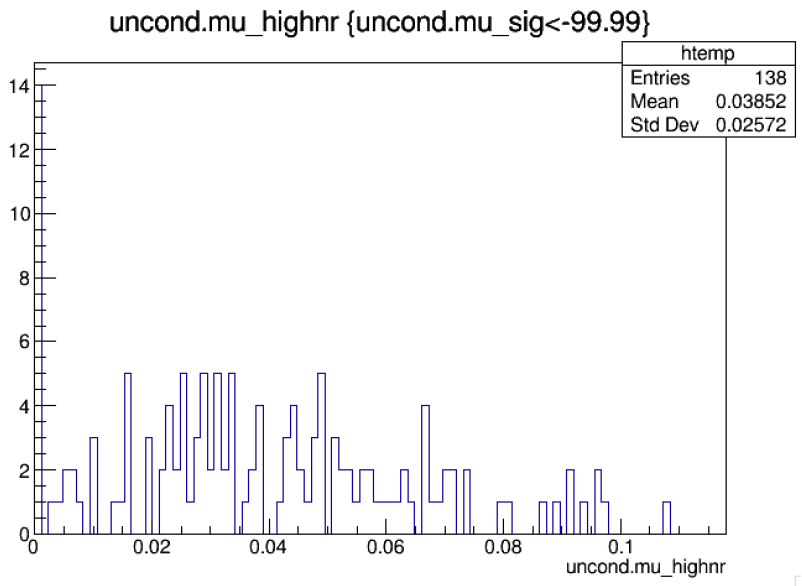


Mu_sig: (-5, 100)

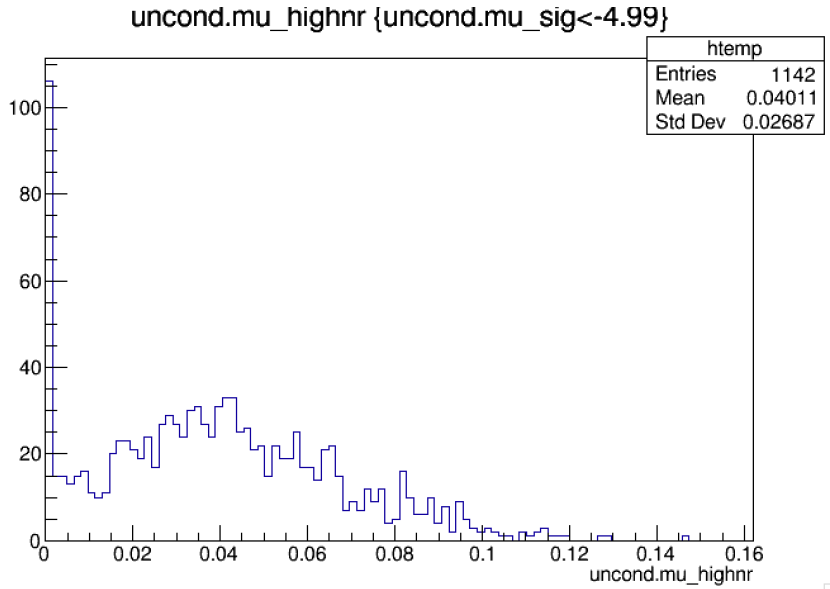


Mu_sig: (0, 200)

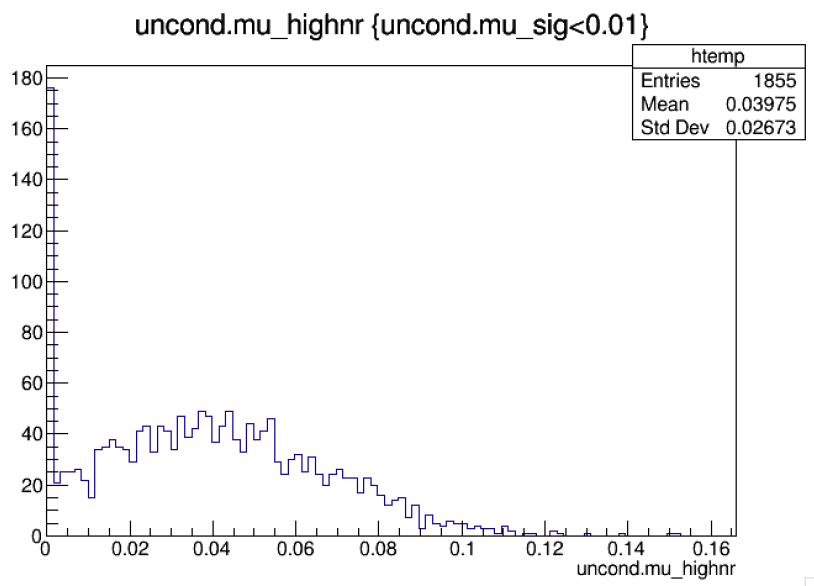
uncond.mu_highnr



Mu_sig: (-100, 100)

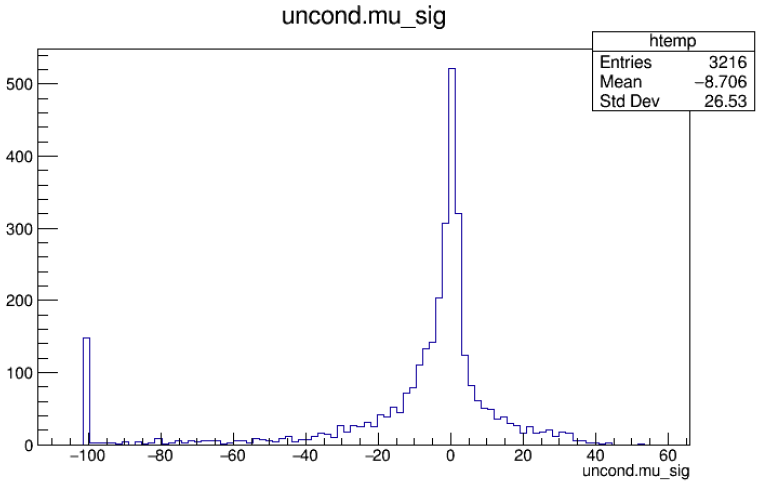


Mu_sig: (-5, 100)

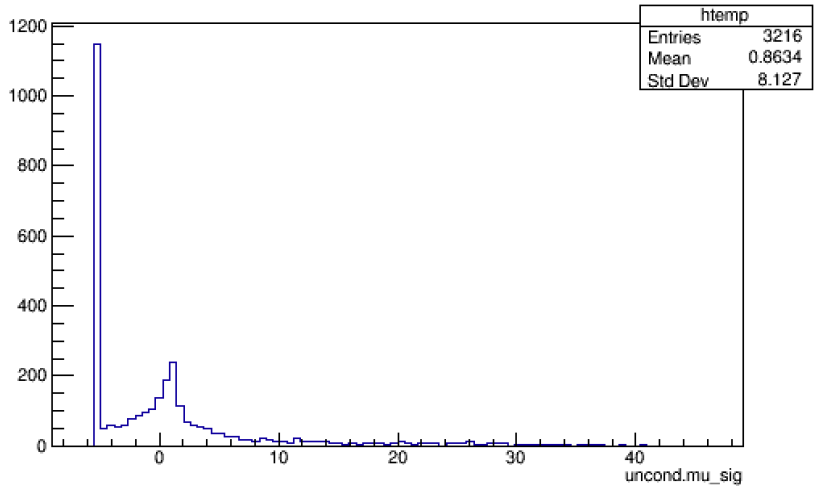


Mu_sig: (0, 200)

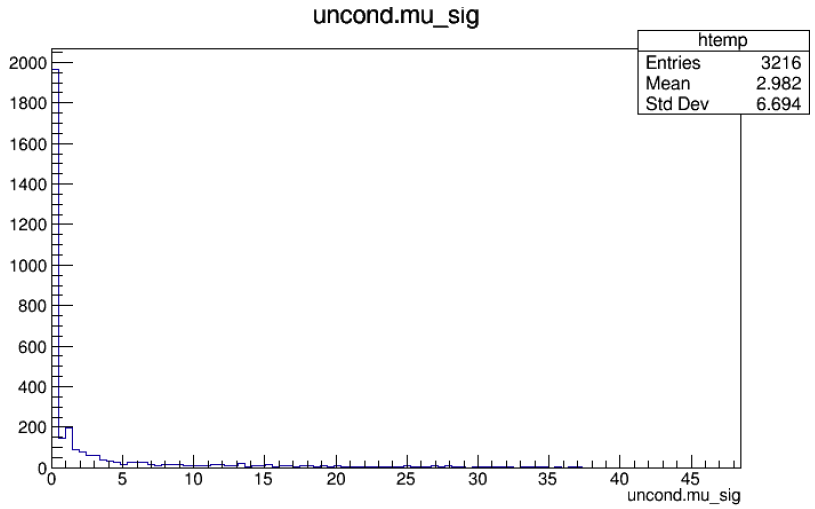
uncond.mu_sig



Mu_sig: (-100, 100)

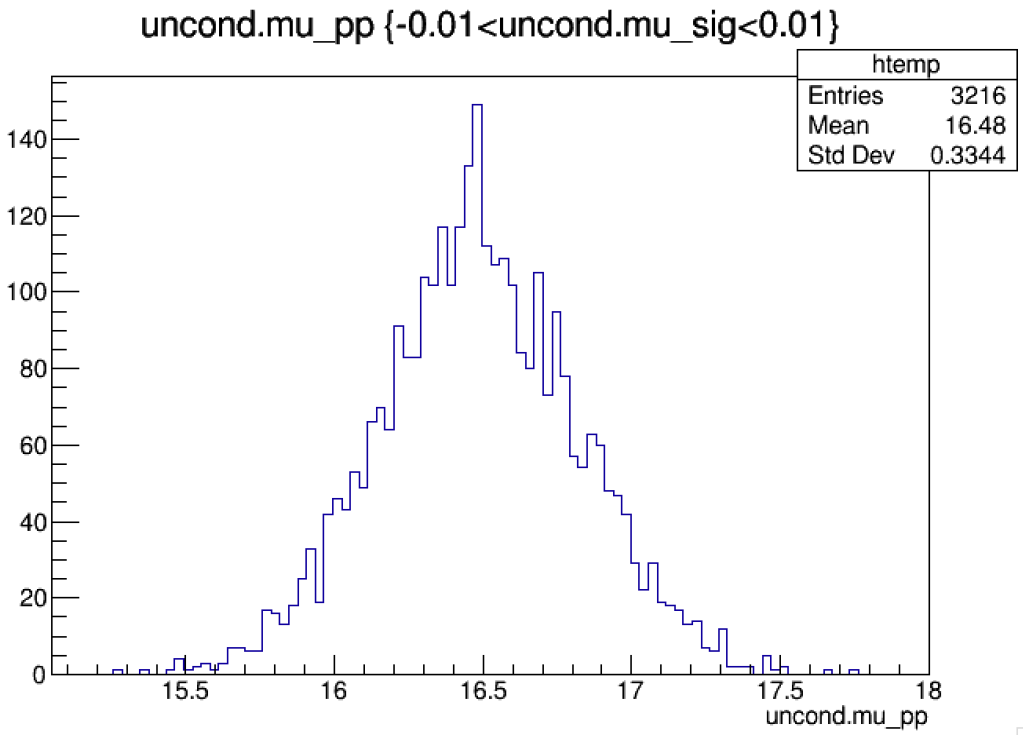


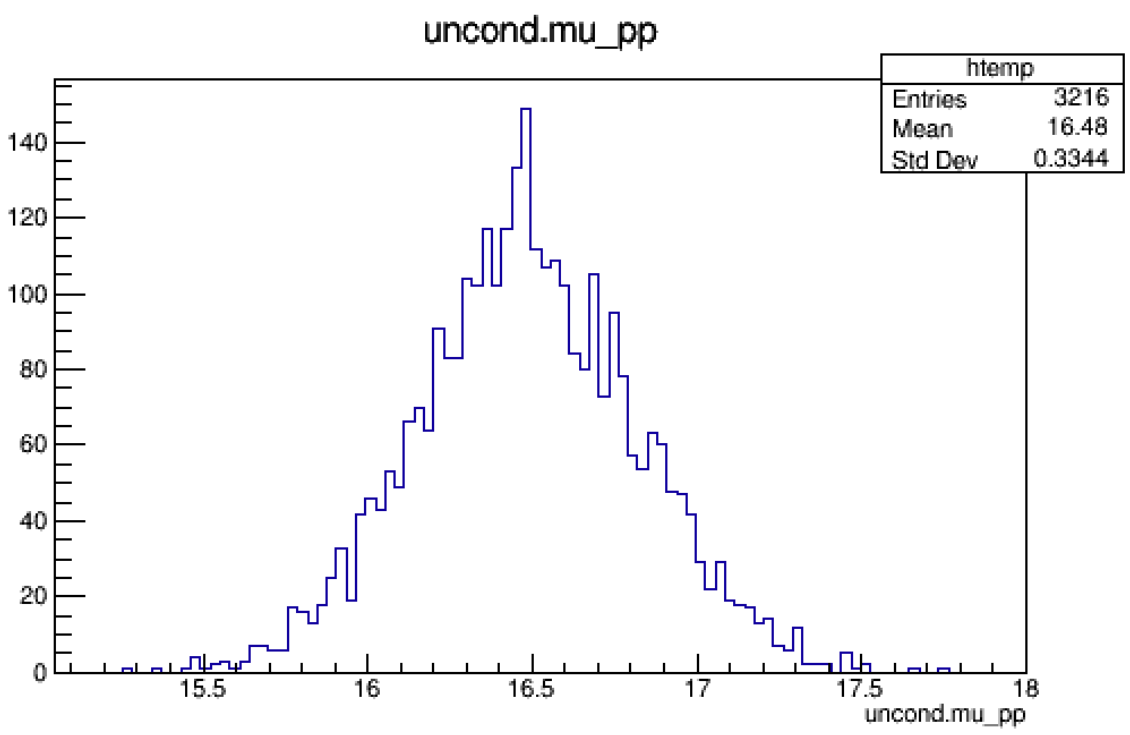
Mu_sig: (-5, 100)



Mu_sig: (0, 200)

Problem


uncond.mu_pp {-0.01<uncond.mu_sig<0.01}
htemp
Entries 3216
Mean 16.48
Std Dev 0.3344
140
120
100
80
60
40
20
0
15.5
16
16.5
17
17.5
18
uncond.mu_pp

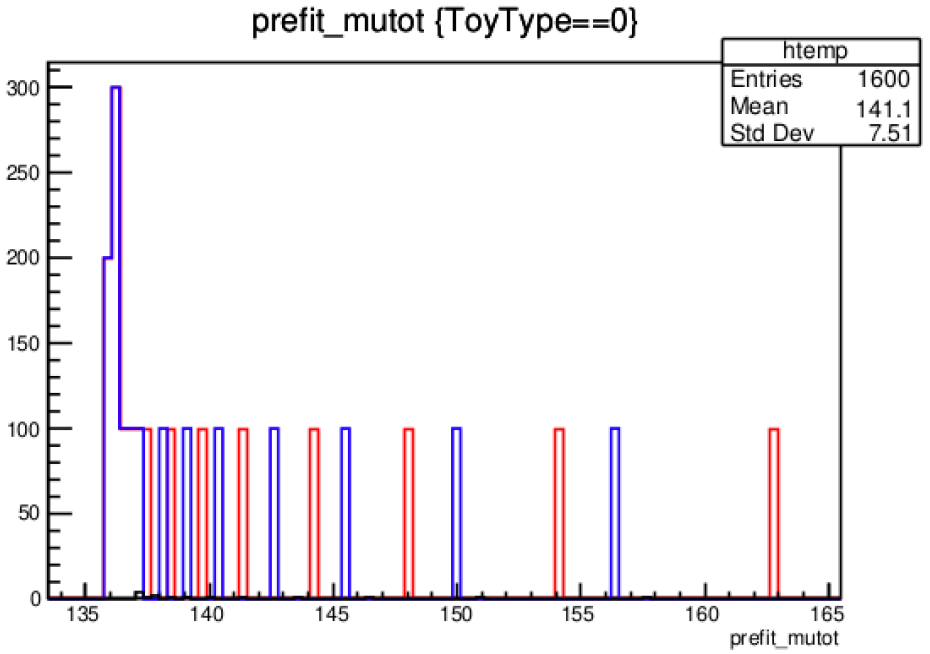

uncond.mu_pp
htemp
Entries 3216
Mean 16.48
Std Dev 0.3344
140
120
100
80
60
40
20
0
15.5
16
16.5
17
17.5
18
uncond.mu_pp

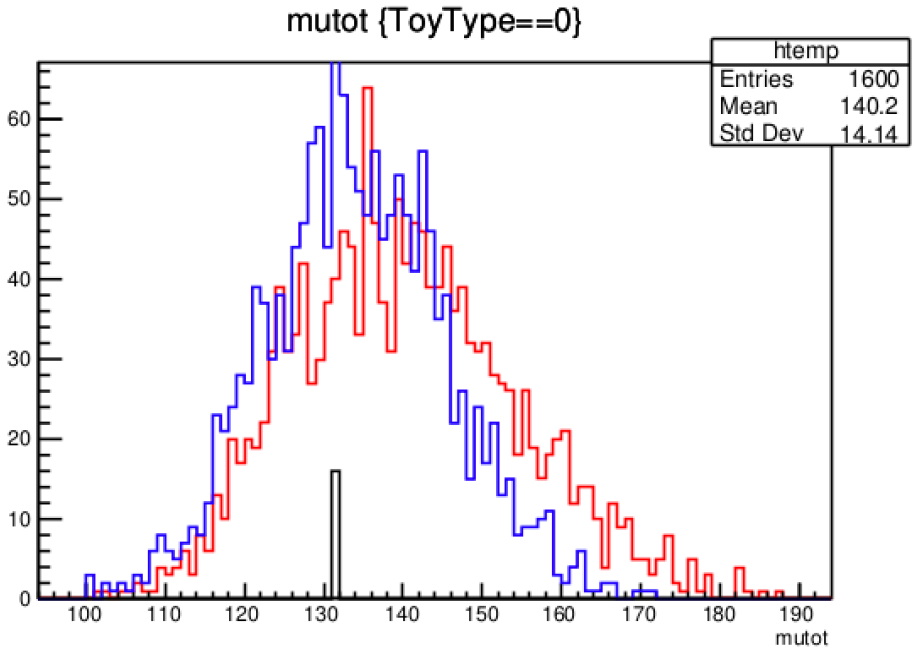
plr_analyser

$$\lambda(\boldsymbol{\theta}) = \frac{L(\boldsymbol{\theta}, \hat{\hat{\boldsymbol{\nu}}})}{L(\hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\nu}})}$$

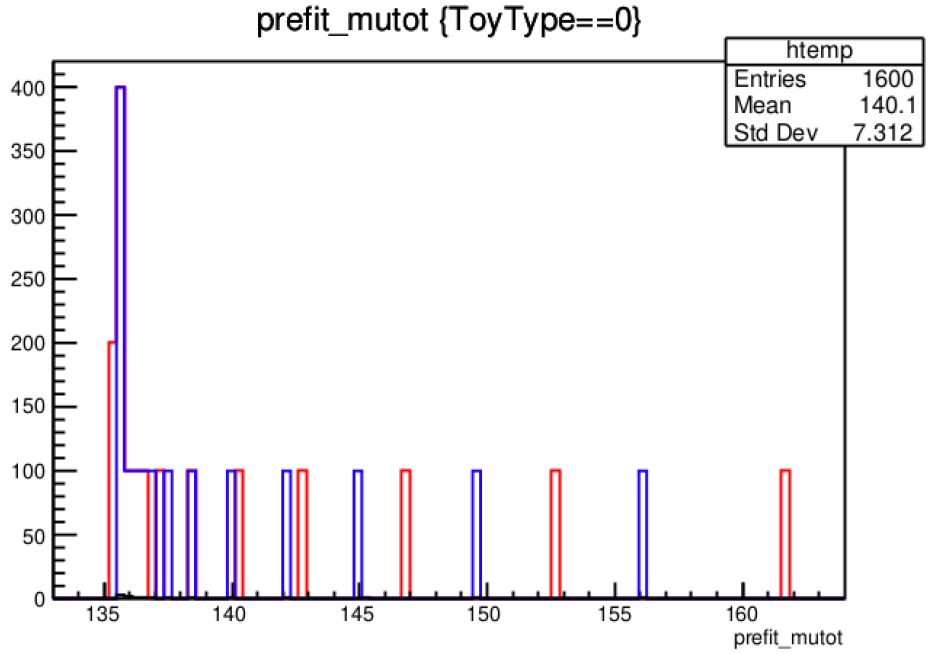
- For each run, a FitResults.root is generated
  - **Conditional & unconditional fit** of mu_sig and backgrounds mu_(pp, vvBB, beta, lownr, highnr, acc)
  - **Global observables** a_(pp, vvBB, beta, lownr, highnr, acc)
  - Conditional fit & unconditional fit for **negative log likelihood**
  - **Test statistic**
  - **Toy type**
  - **prefit_mutot**: the “expected events” with the prefit values of nuisance parameters
  - **mutot**: : the “expected events” with the best fit values of nuisance parameters
  - **n0**: the true number of events inside the toy dataset
- Run PlotFitResults.C and compare different mu_sig range

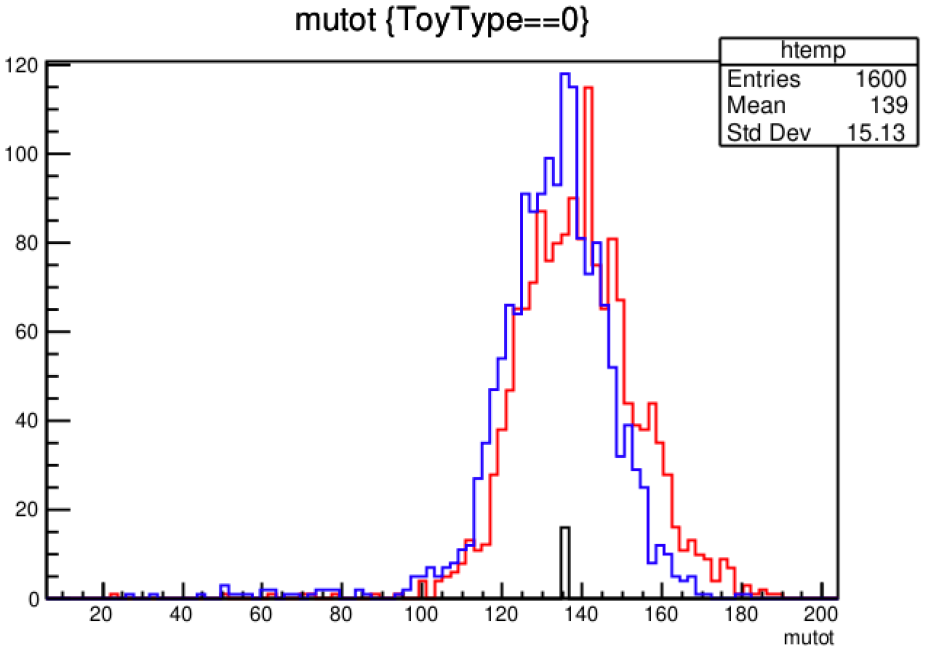
mu_sig (-5, 100)



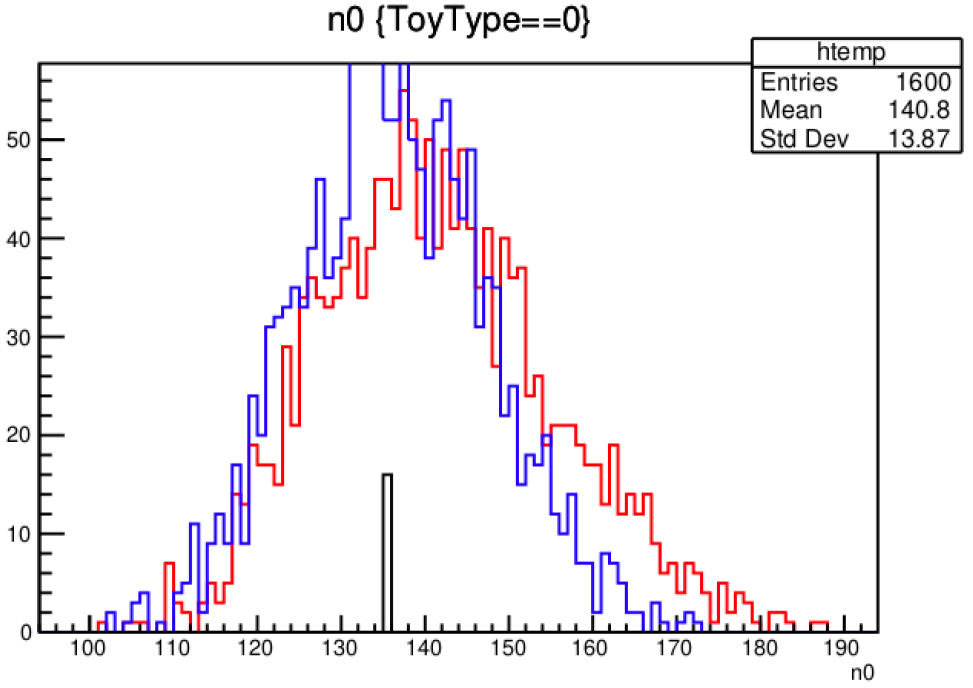


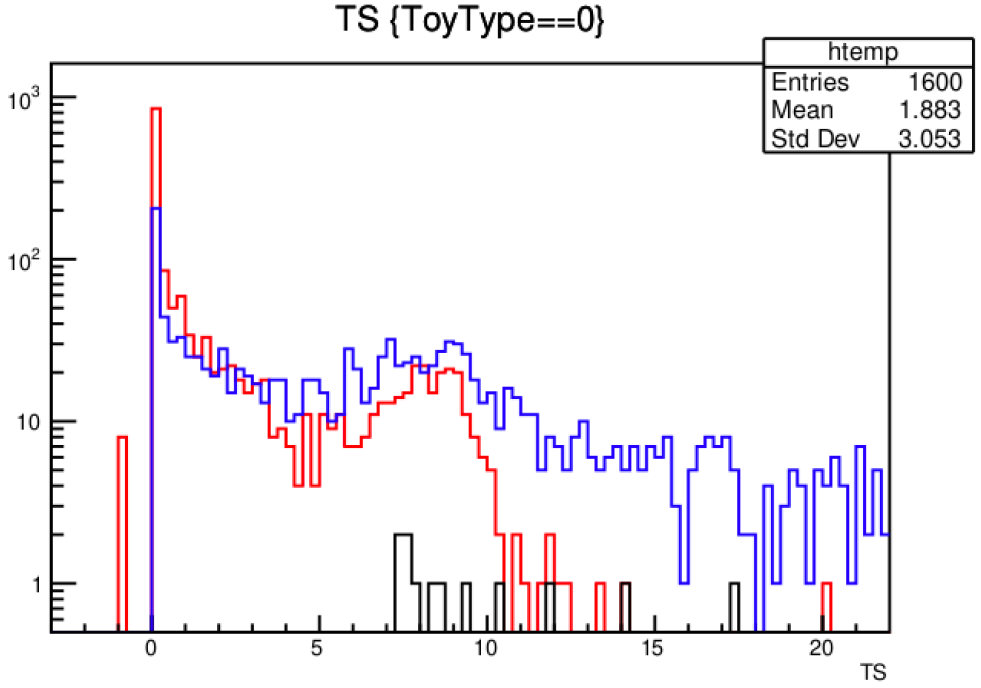
mu_sig (-100, 100)



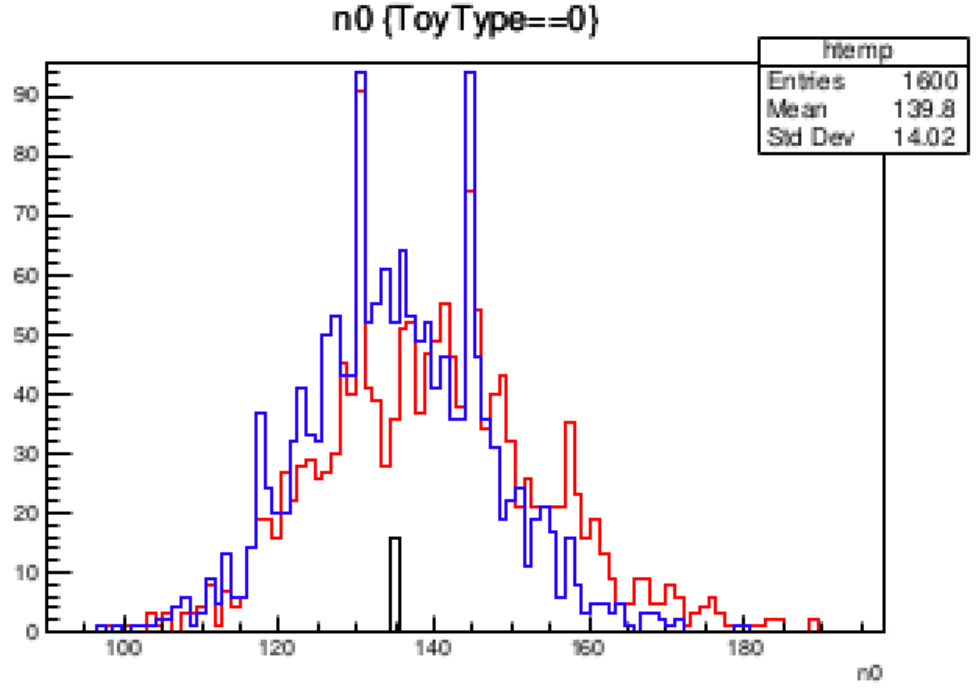


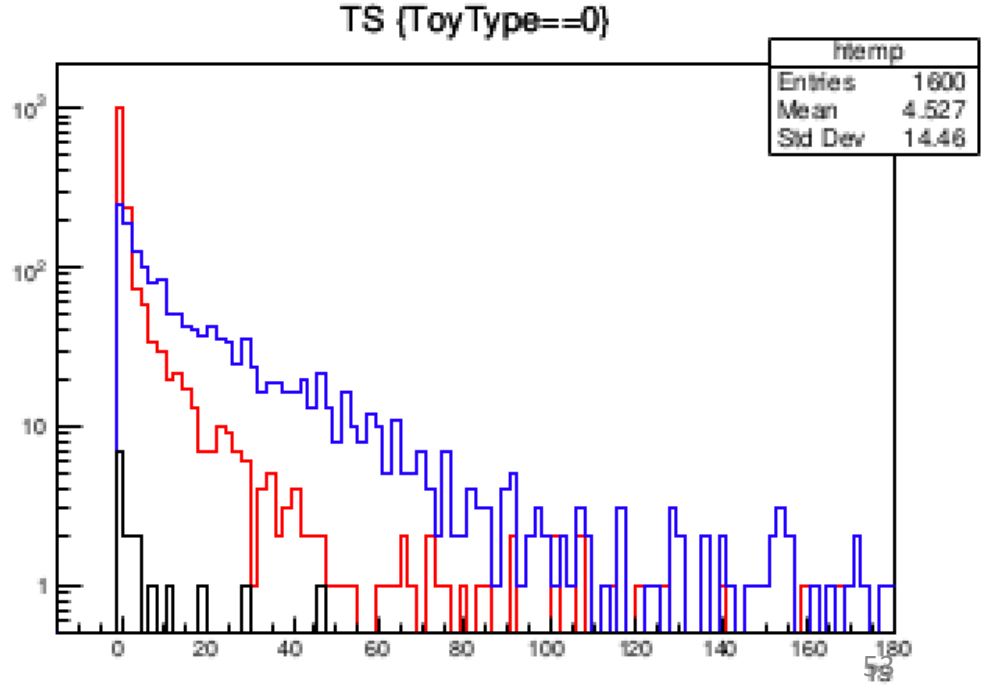
mu_sig (-5, 100)



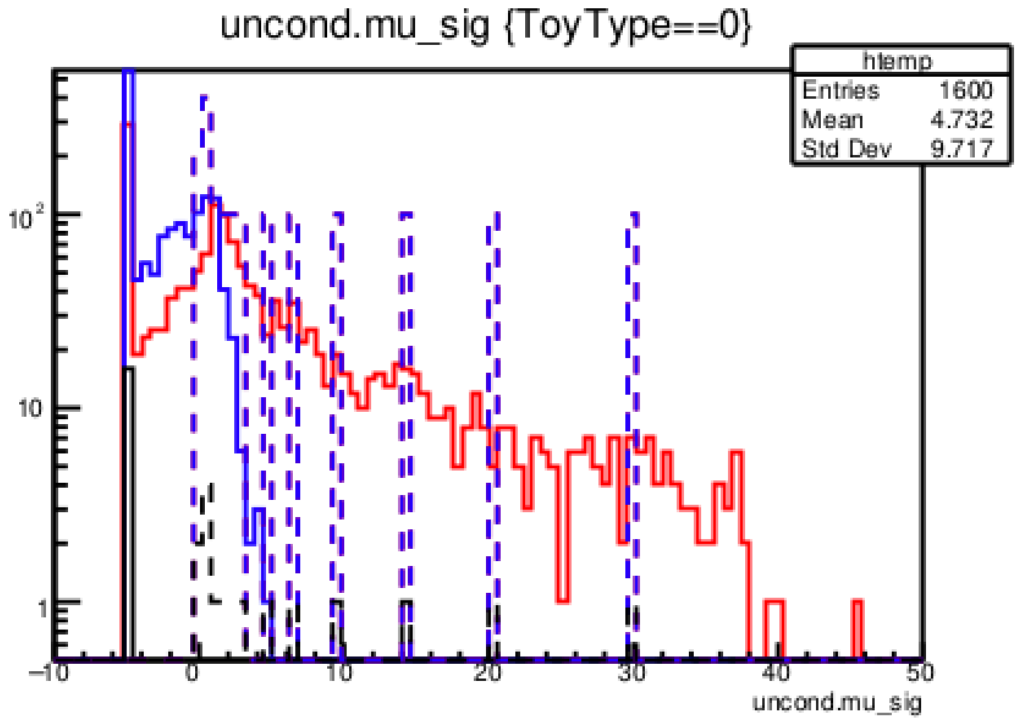


mu_sig (-100, 100)

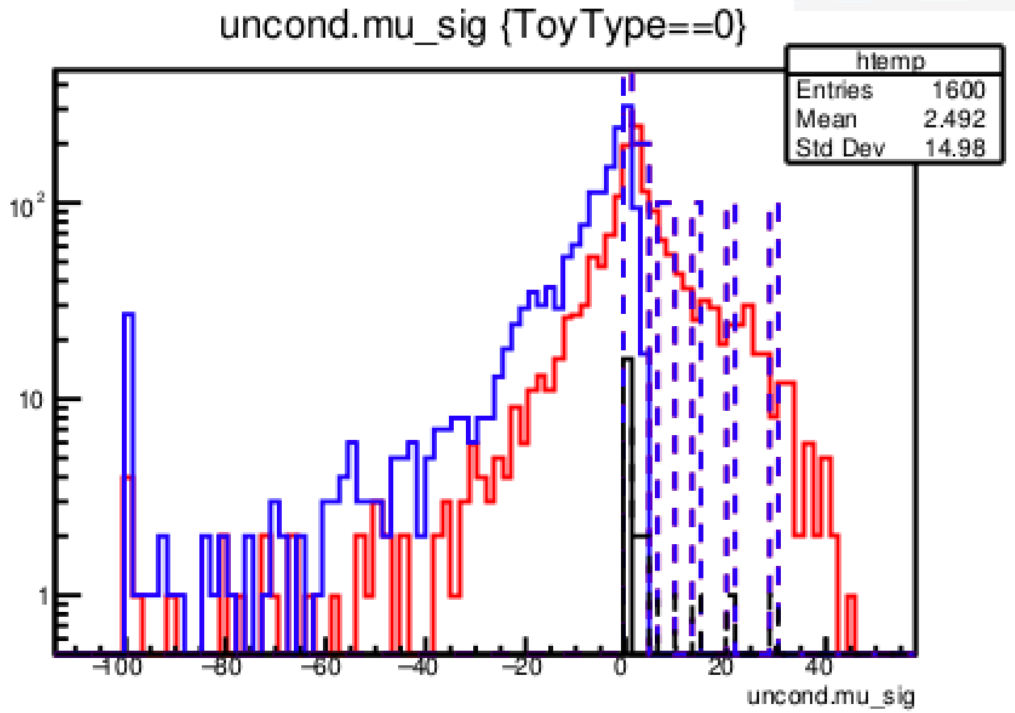




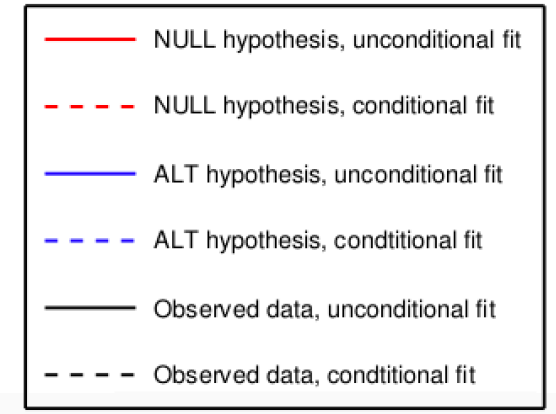
uncond.mu_sig (40 GeV)



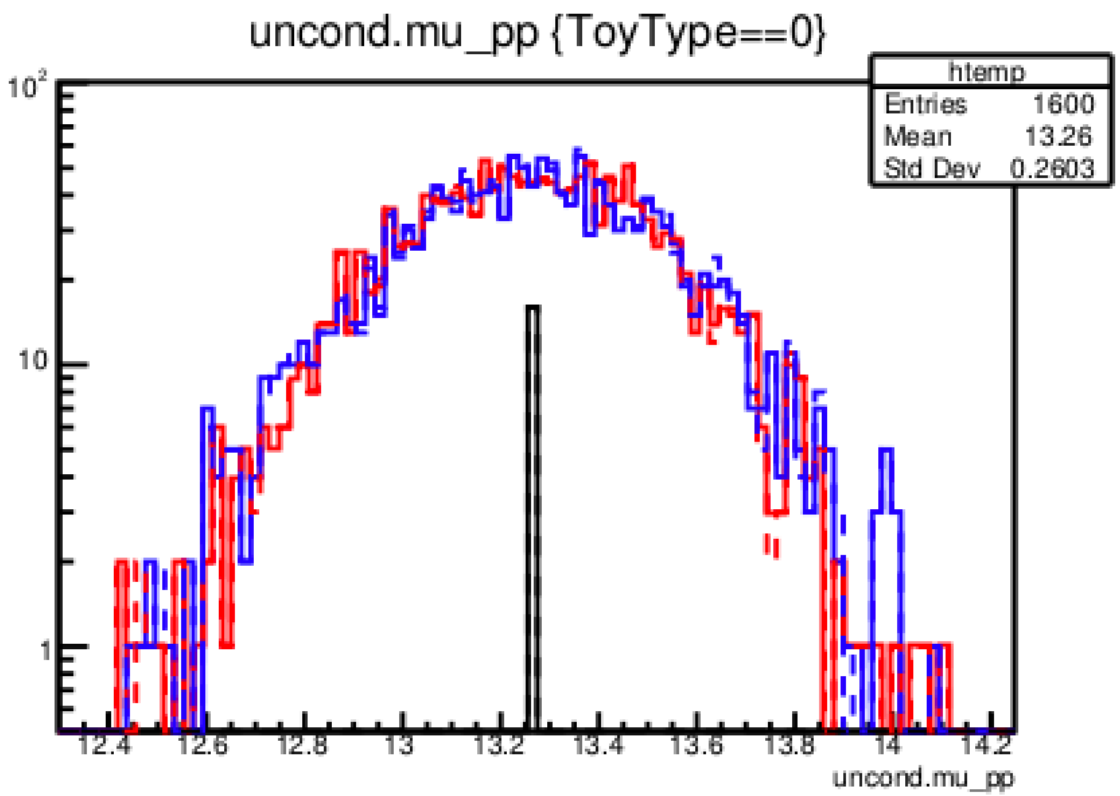
mu_sig (-5, 100)



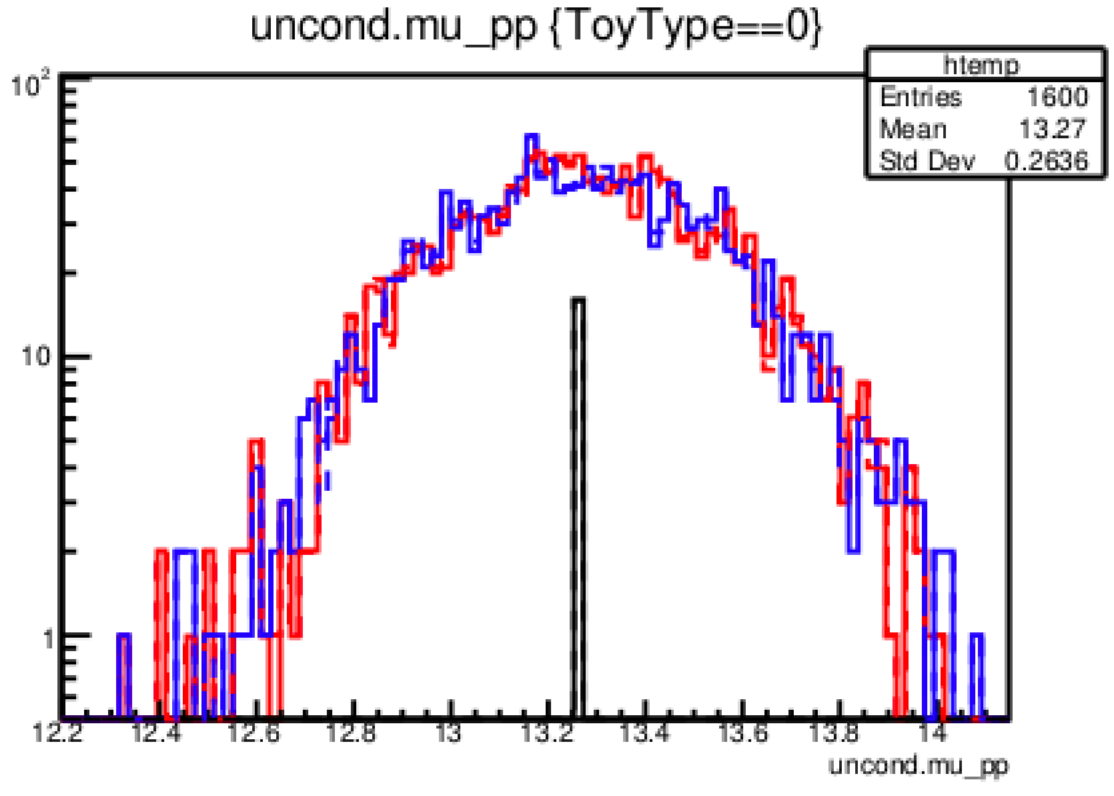
mu_sig (-100, 100)



uncond.mu_pp

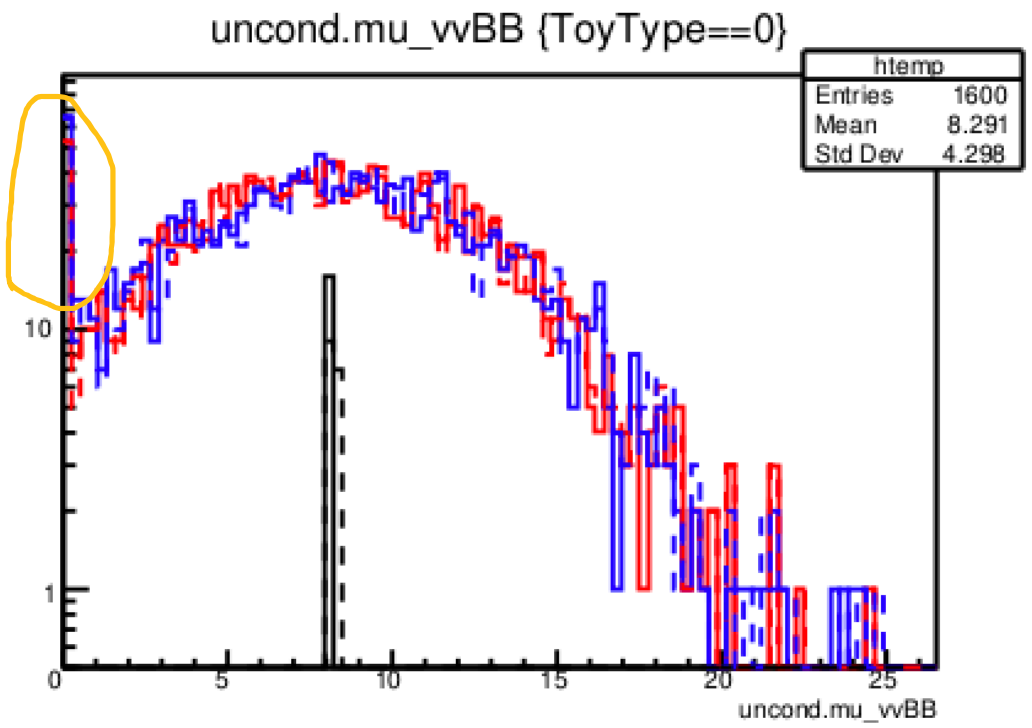


mu_sig (-5, 100)

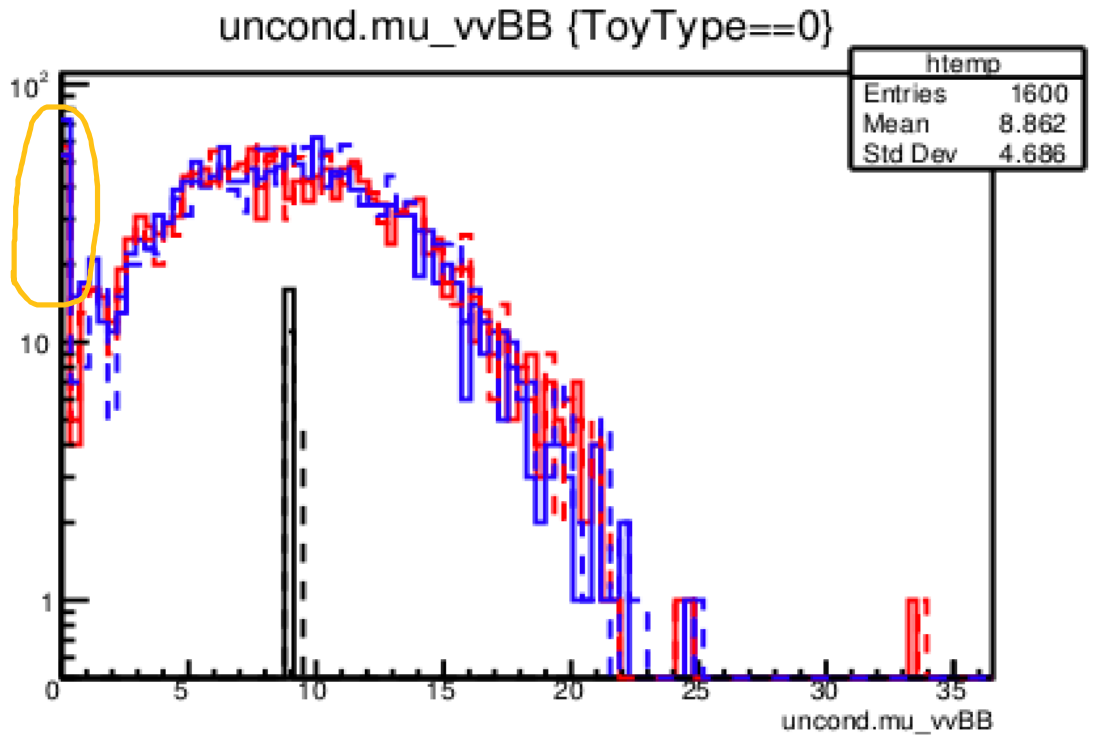


mu_sig (-100, 100)

uncond.mu_vvBB

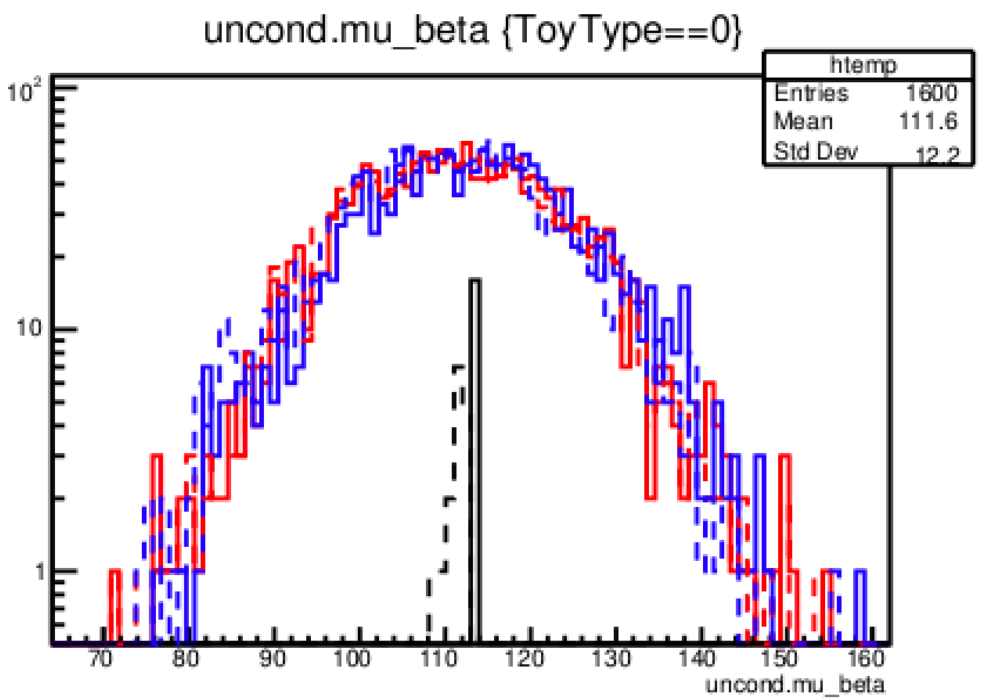


mu_sig (-5, 100)

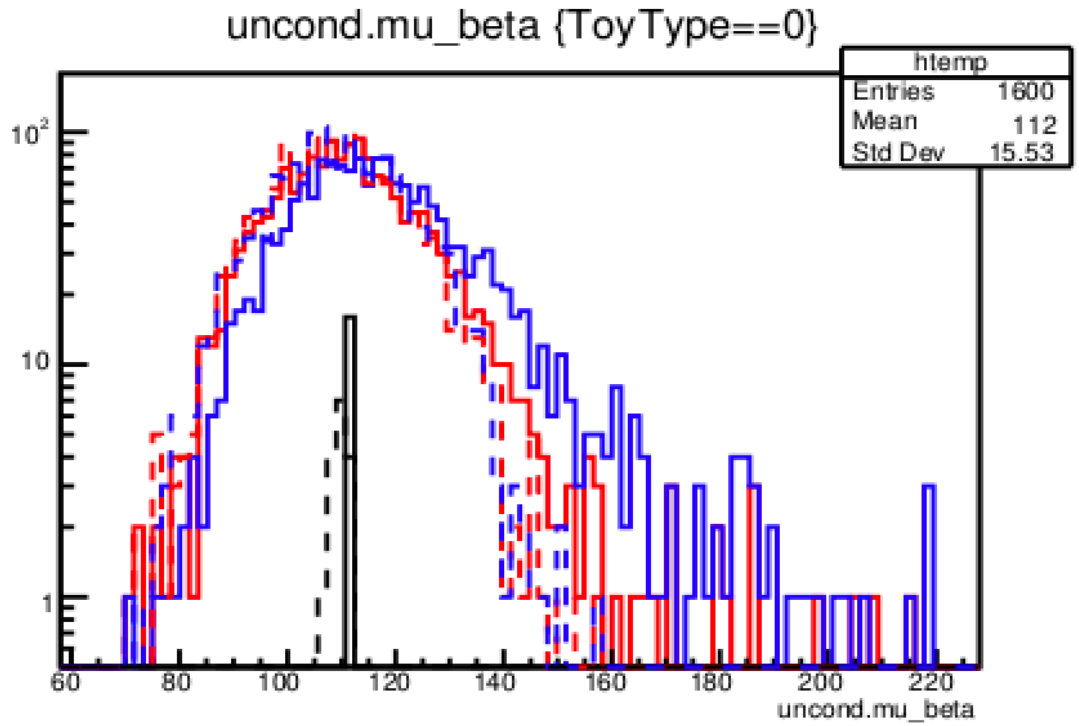


mu_sig (-100, 100)

uncond.mu_beta

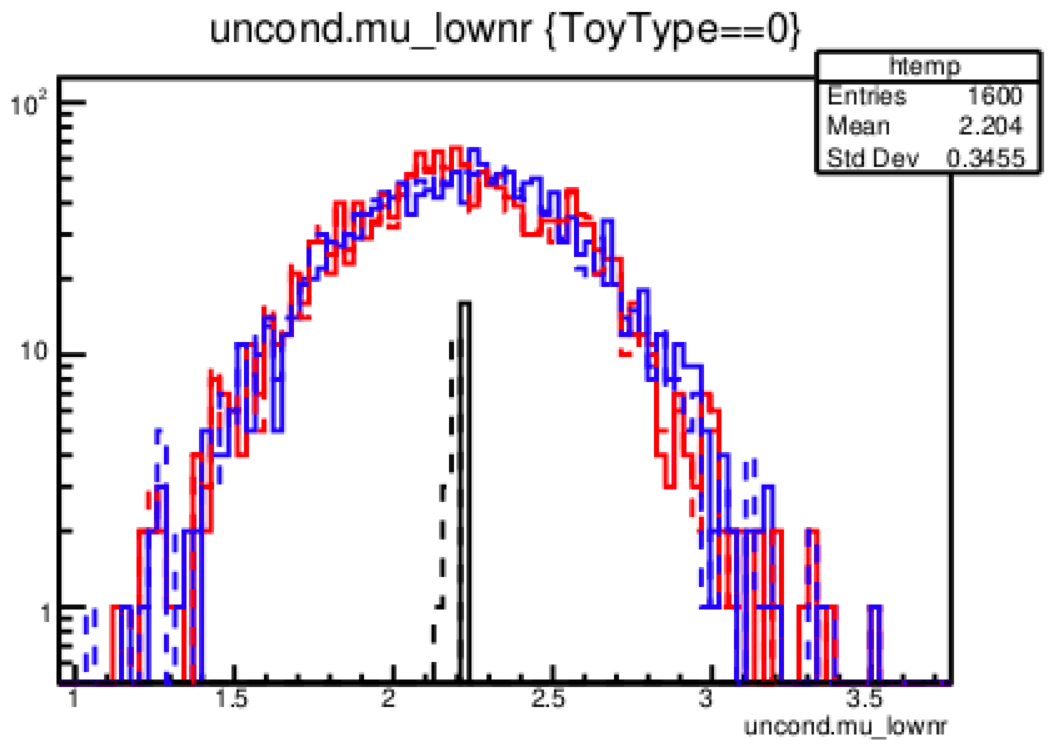


mu_sig (-5, 100)

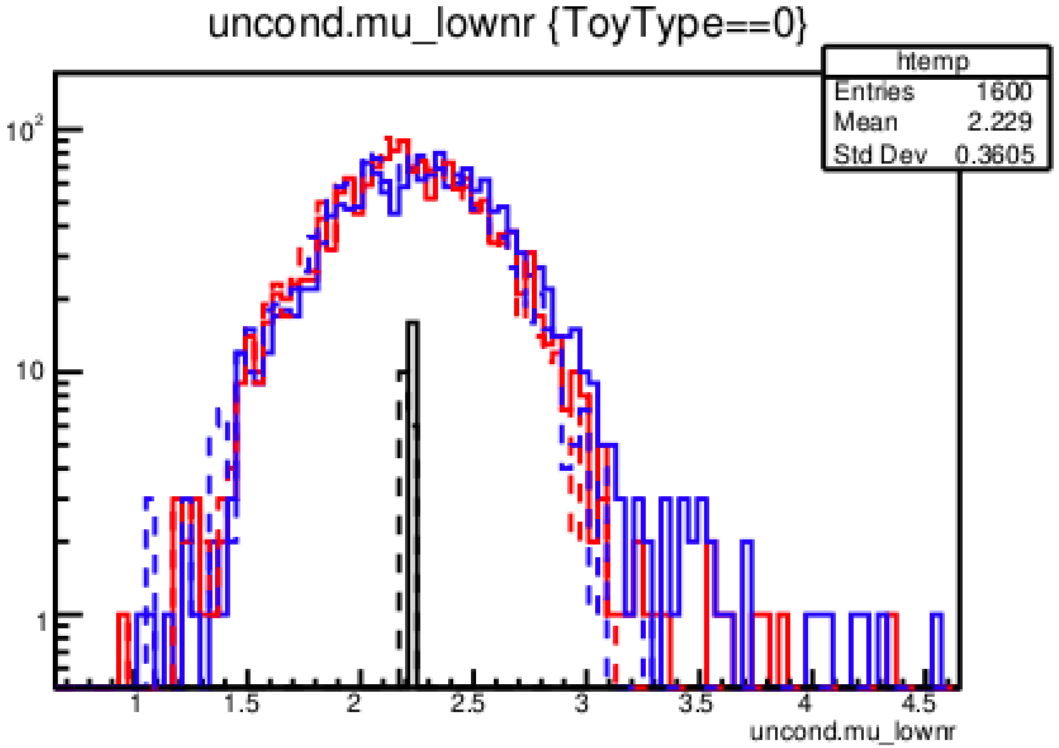


mu_sig (-100, 100)

uncond.mu_lownr

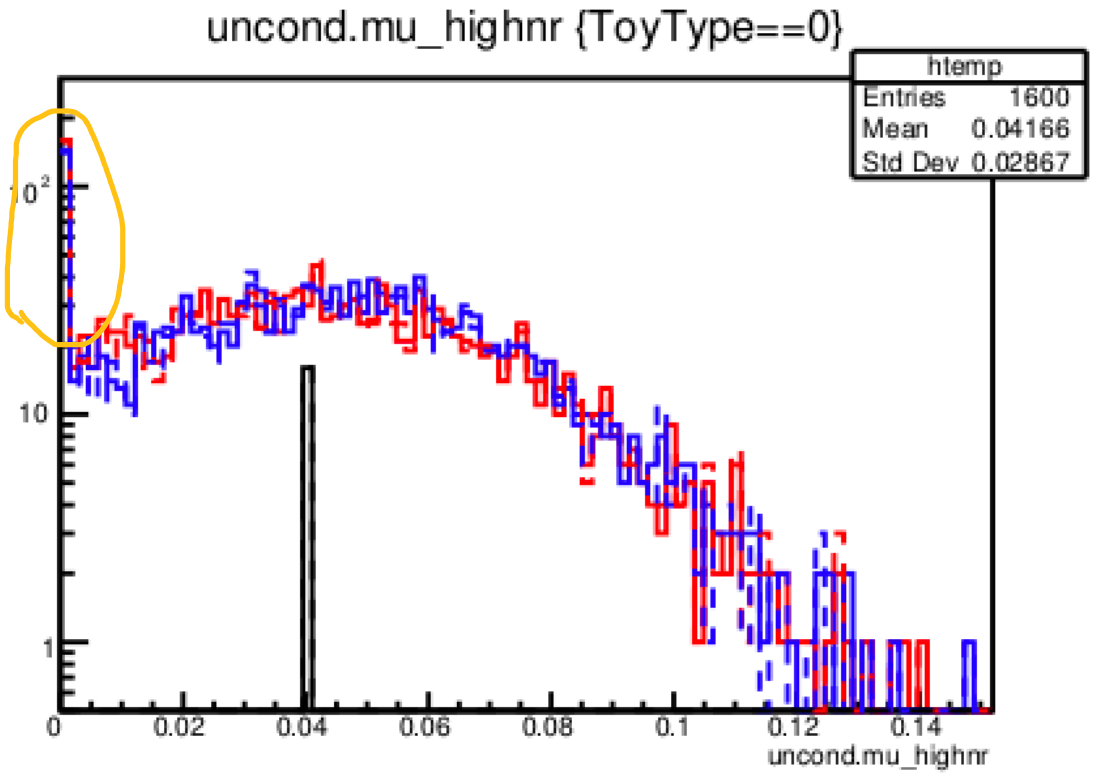


mu_sig (-5, 100)

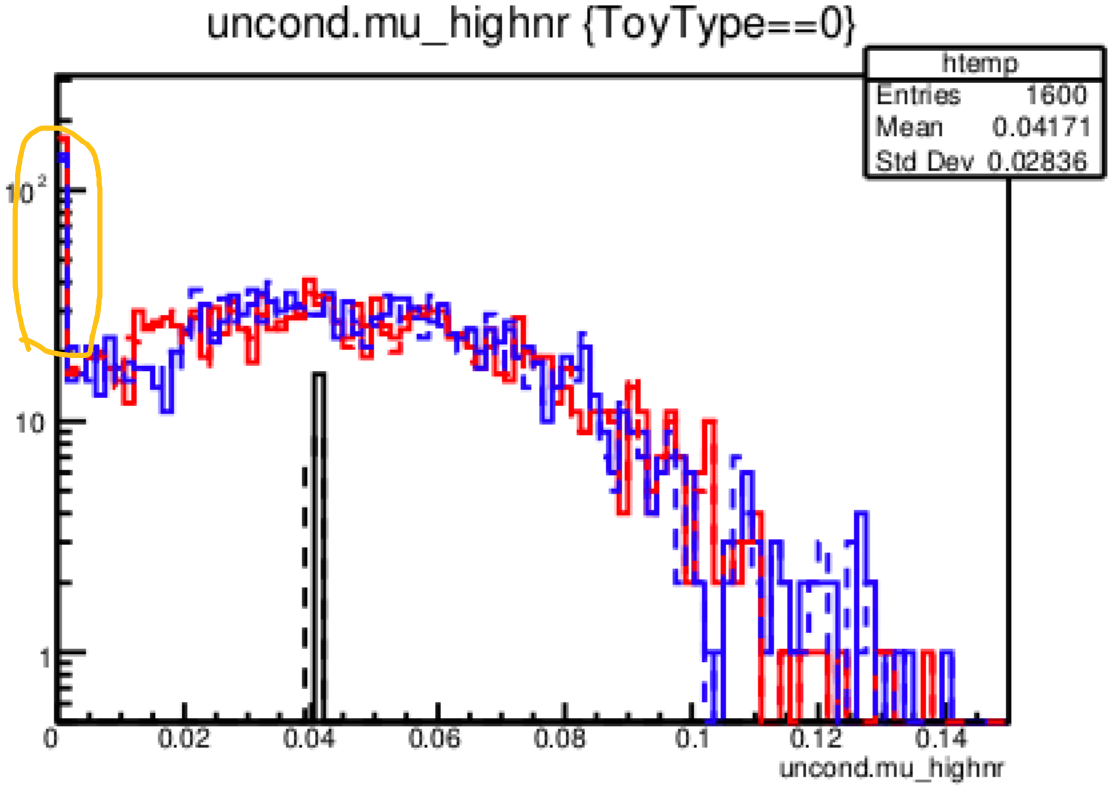


mu_sig (-100, 100)

uncond.mu_highnr

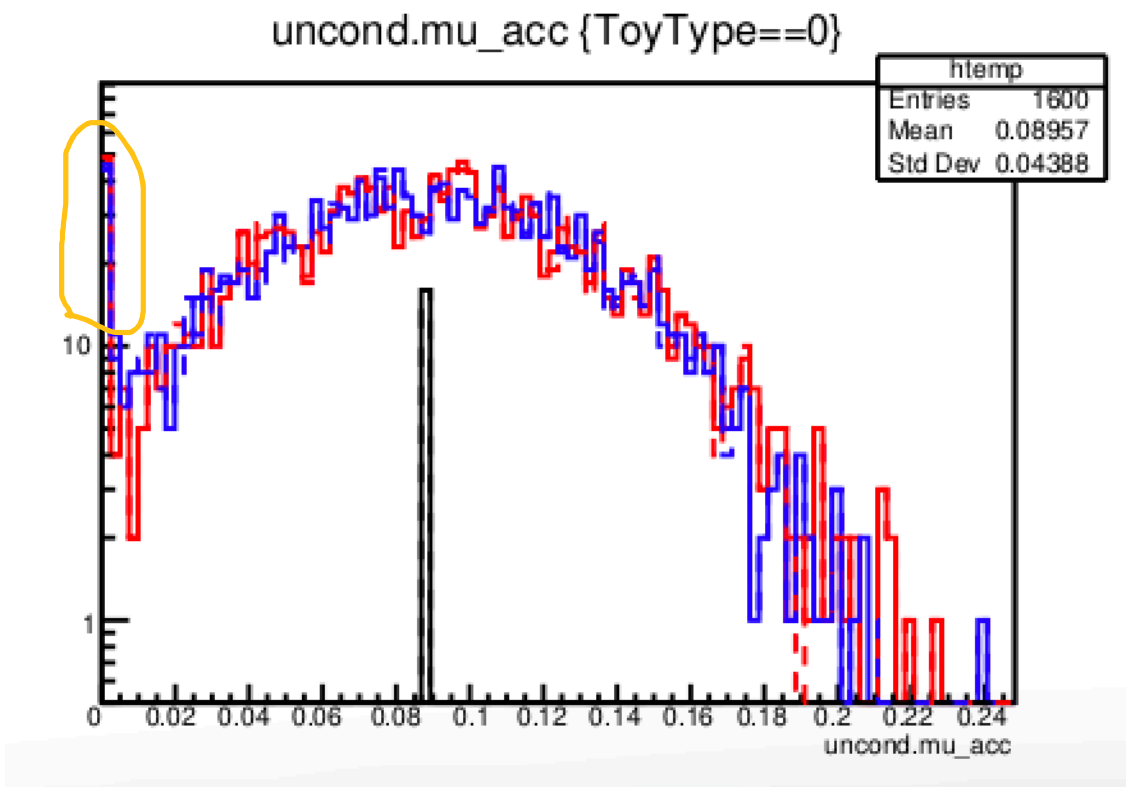


mu_sig (-5, 100)

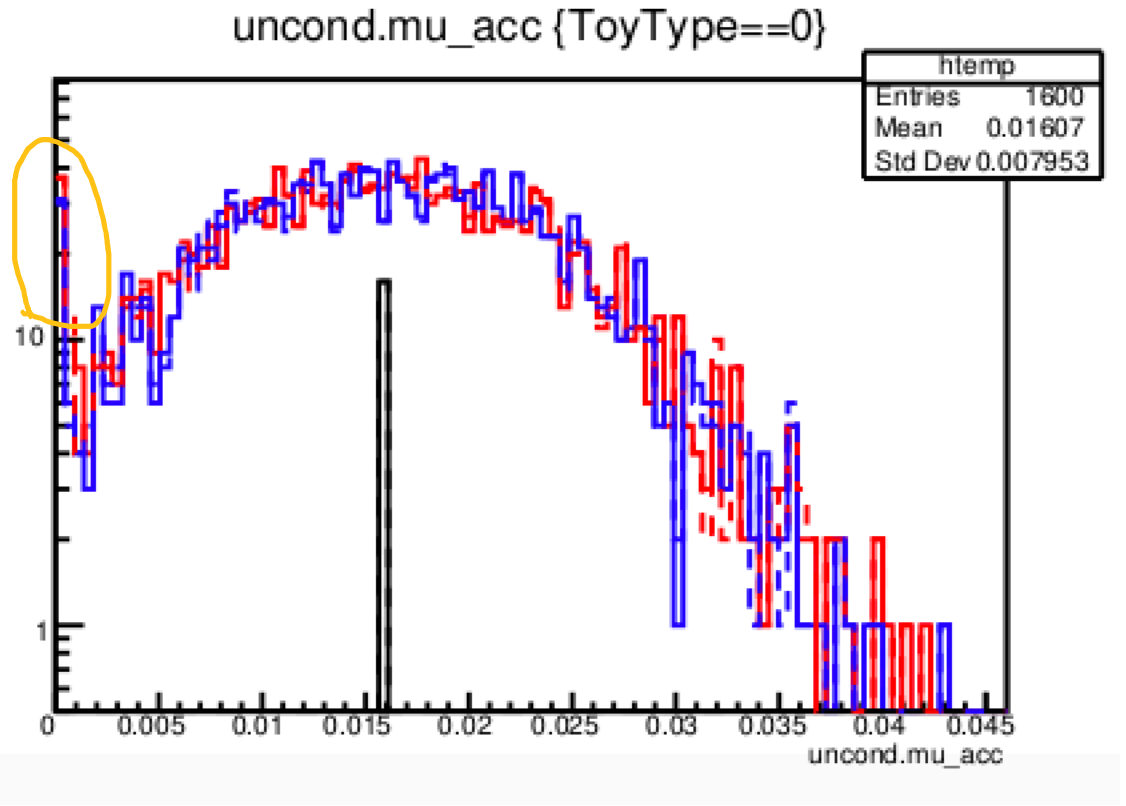


mu_sig (-100, 100)

uncond.mu_acc



mu_sig (-5, 100)

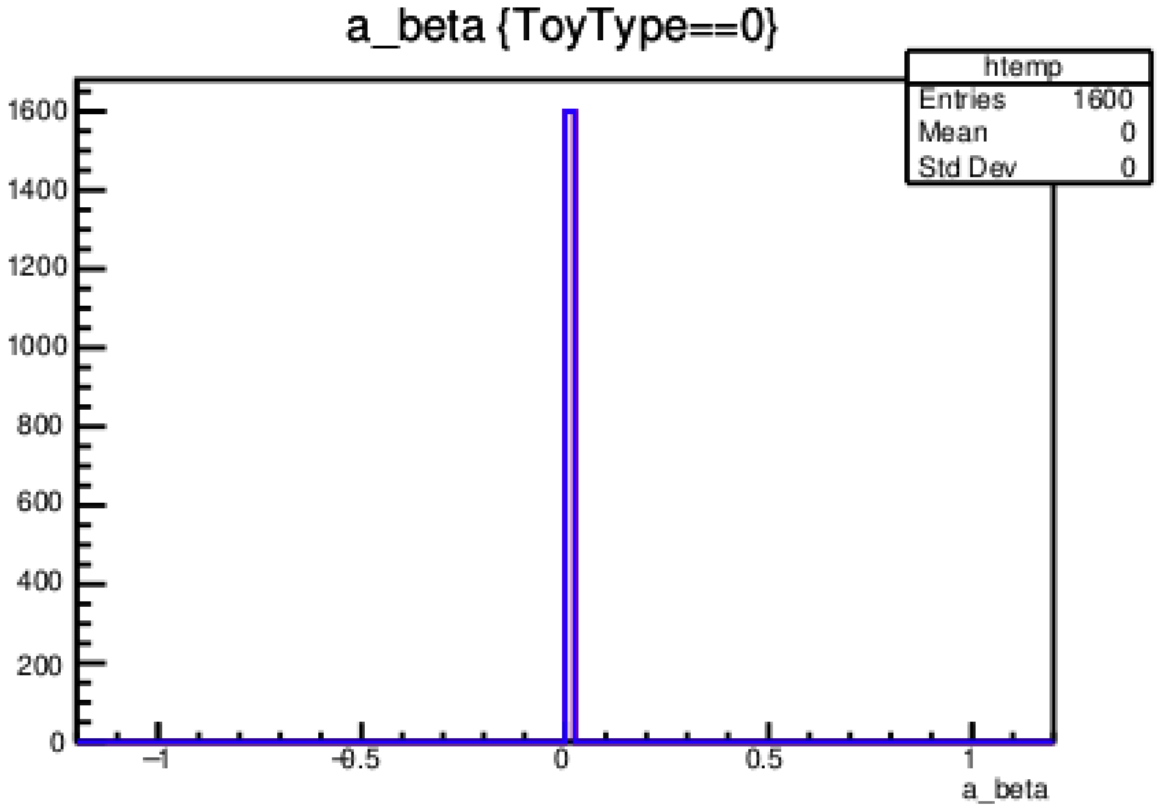


mu_sig (-100, 100)

Error message

```
Error in <TTreeFormula::Compile>:  Bad numerical expression : "a_sig"
Info in <TSelectorDraw::AbortProcess>: Variable compilation failed: {a_sig,ToyTy
pe==0}
Error in <TTreeFormula::Compile>:  Bad numerical expression : "a_sig"
Info in <TSelectorDraw::AbortProcess>: Variable compilation failed: {a_sig,ToyTy
pe==1}
a_pp    a_pp
a_vvBB  a_vvBB
Error in <TTreeFormula::Compile>:  Bad numerical expression : "a_beta"
Info in <TSelectorDraw::AbortProcess>: Variable compilation failed: {a_beta,ToyT
ype==0}
Error in <TTreeFormula::Compile>:  Bad numerical expression : "a_beta"
Info in <TSelectorDraw::AbortProcess>: Variable compilation failed: {a_beta,ToyT
ype==1}
a_lownr a_lownr
a_highnr        a_highnr
a_acc   a_acc
Info in <TCanvas::Print>: pdf file fitResults_glob_lzstats-20200423_workspace_su
mbkg_freebetas_wimp_m40.0_SI_lowPOIbound_5-Freq-one_sided-NP_on-run1.pdf has bee
n created
Info in <TCanvas::Print>: pdf file fitResults_counts_lzstats-20200423_workspace_
sumbkg_freebetas_wimp_m40.0_SI_lowPOIbound_5-Freq-one_sided-NP_on-run1.pdf has b
een created
```

Global observable (Beta)



mu_sig (-5, 100)

mu_sig (-100, 100)

New update

- New workspace:
  - WIMP: 40GeV
  - Fiducial mass (kg): 5600
  - Livetime (days): 24
  - Min POI = 0.1
  - Max POI = 30
  - Toys/point: 100
- Generation errors with the workspace mu_sig (-100, 100), no errors with the workspace mu_sig (-5, 100)

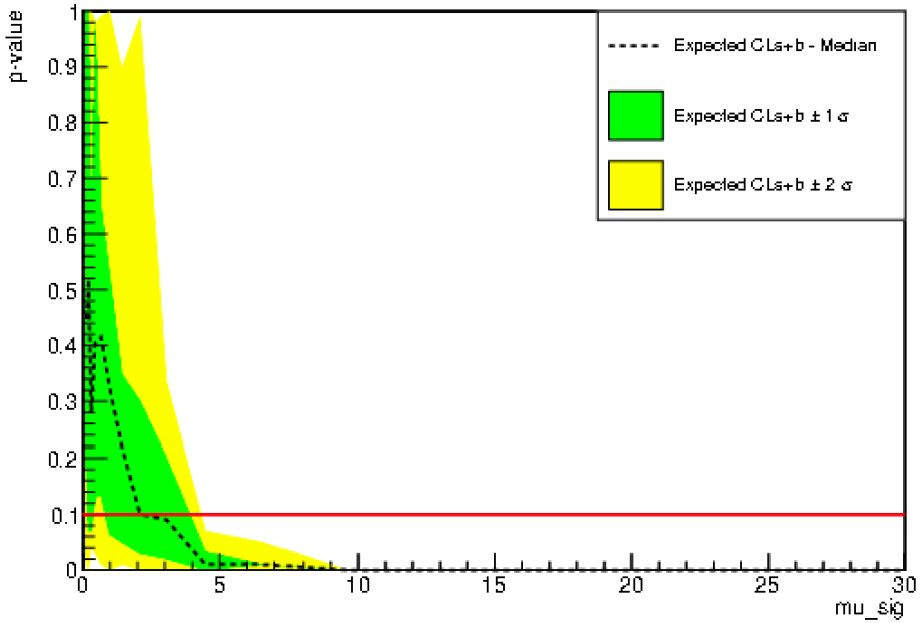
Observed data

- Pass MDC3_unsalted_wimp_data as the observed data instead of “sensitivity”.
- Errors:

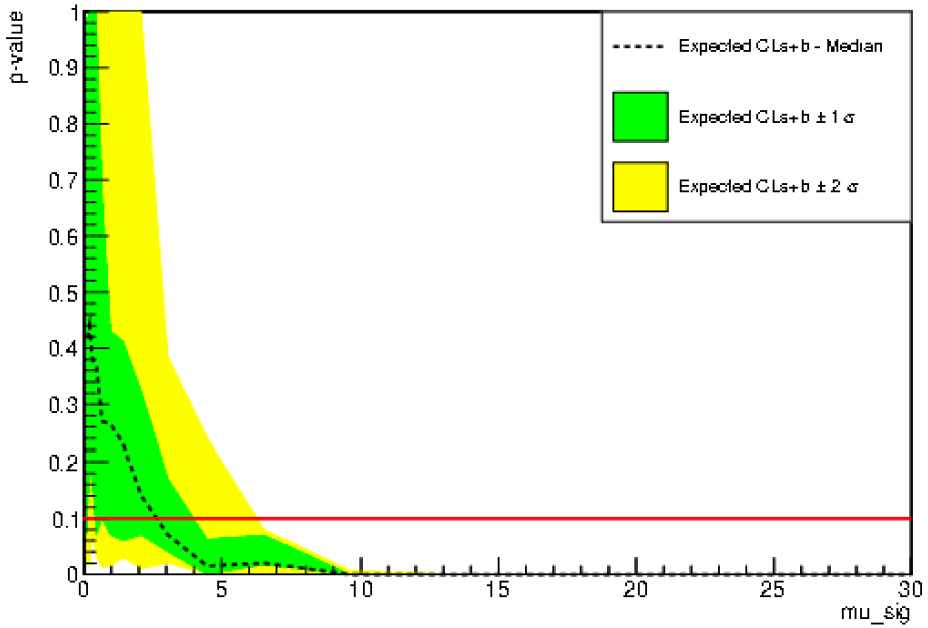
```
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
```

```
p.d.f value is less than zero (-0.000170), forcing value to zero @ !
```

```
[#0] WARNING:Eval -- HypoTestInverterResult::CalculateEstimatedError - cannot es
timate  the lower limit error
```

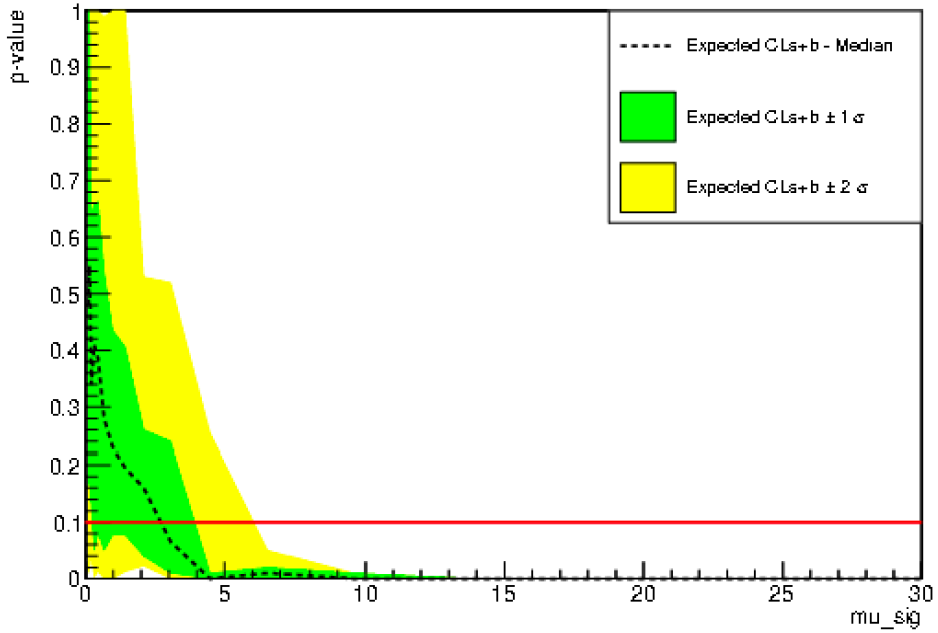


Mu_sig: (-5, 100)
Mu_sig: 2.0947
Cross section: 2.15e-47



Mu_sig: (-100, 100)
Mu_sig: 2.9341
Cross section: 3e-47

Mu_sig: (-5, 100)
Mu_sig: 3.0639
Cross section: 3.14e-47
Unsalted_wimp_data



Error (limit setting)

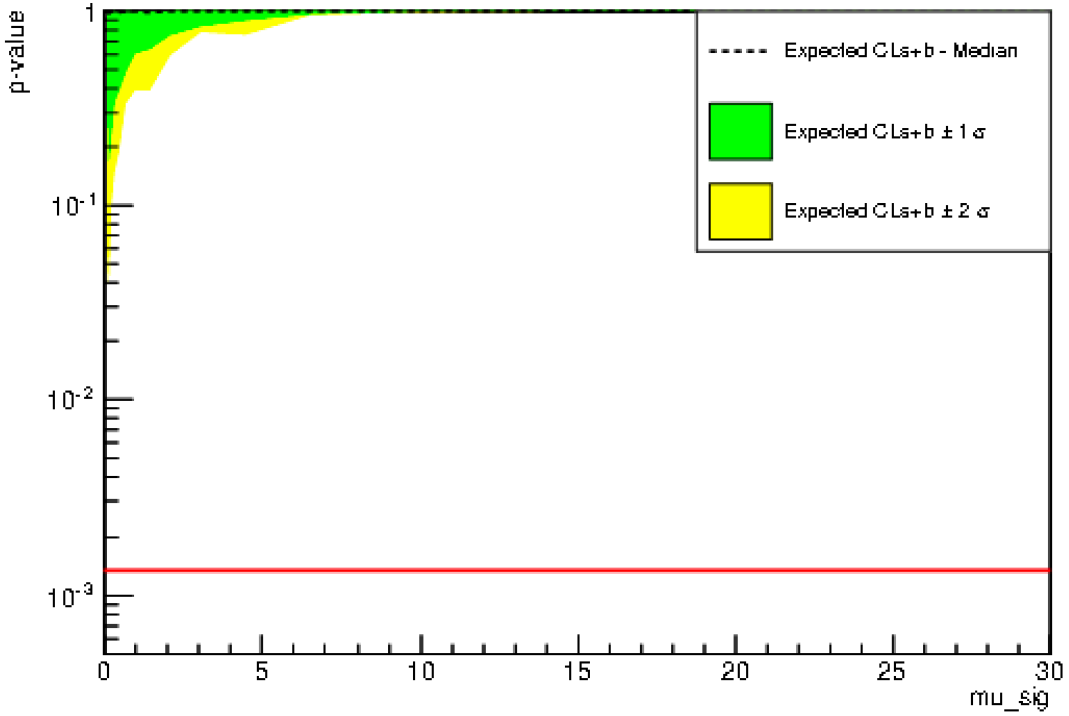
```
EvalPLR: POI_test = 30, POI_hat = -4.71328, uncond_ML = -50.3983, cond_ML = -16.
9961, TS = 66.8045, time (create/fit1/2) 0, 2.54, 0.79, status (U/C) 0, 0
[#0] ERROR:Generation -- a_beta::RooRealVar:randomize: fails with unbounded fit
range
----> Trying with Migradimproved
----> Trying with Scan
```

Each toy run has this error, 3 GeV and 40 GeV

mu_sig = (-100, 100), negative bound setting

46 GeV w, mu_sig (0,100)  No more this error

Error (Discover)

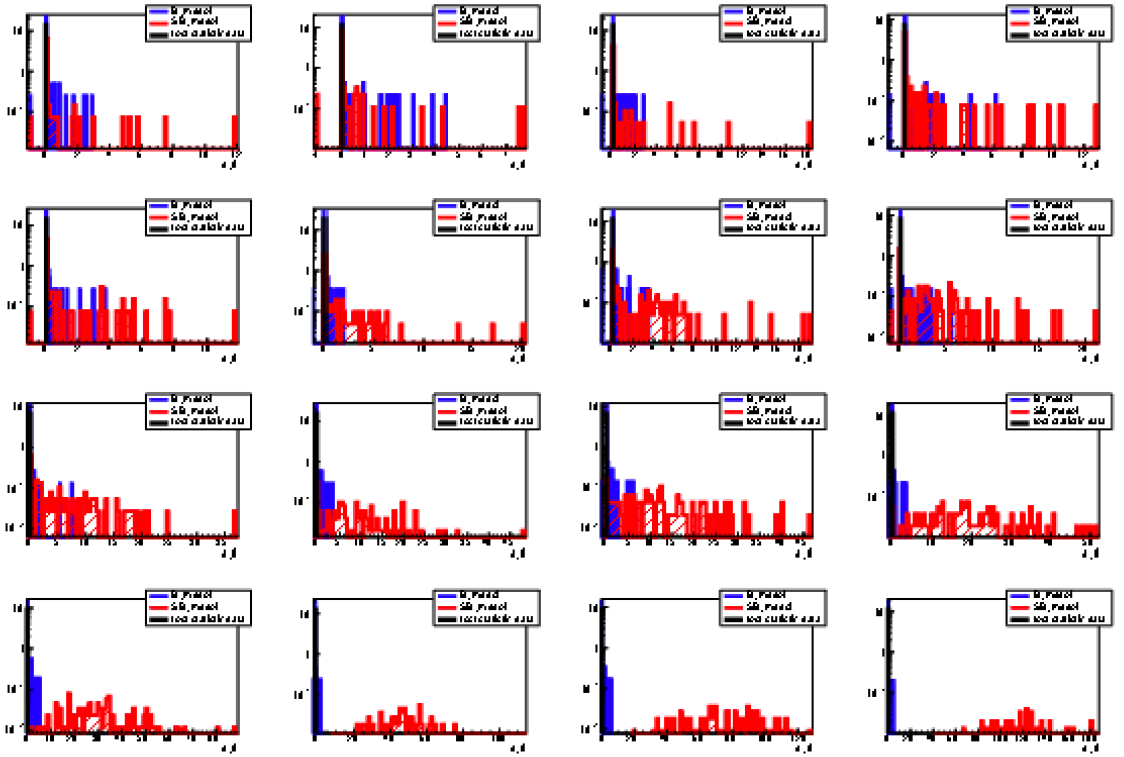


40 GeV, mu_sig: (-100, 100)

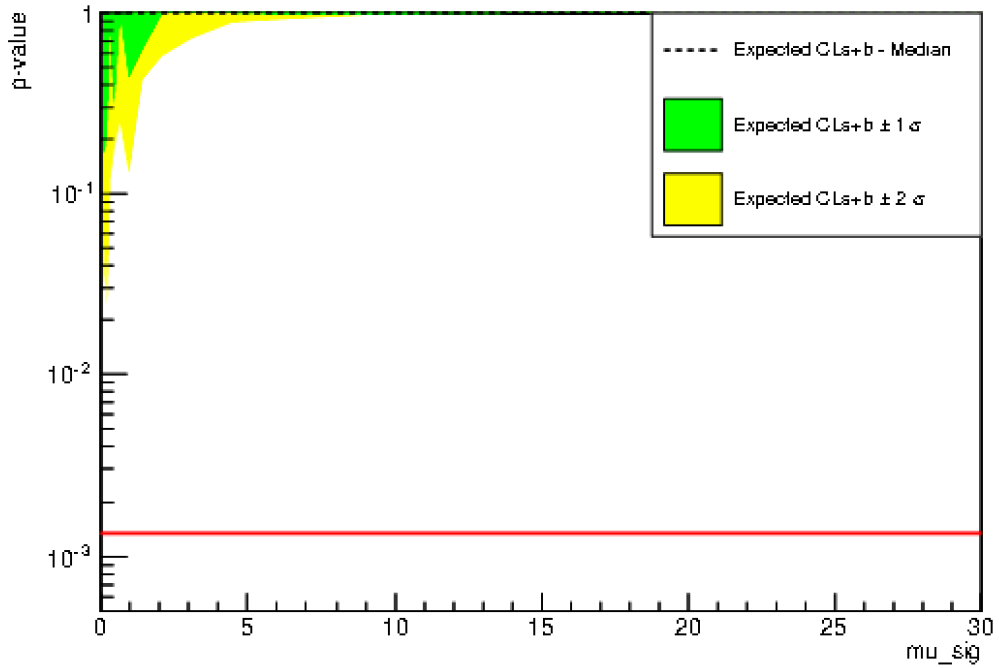
Error: generation

H0: only background, mu_signal = 0

H1: both background and signal



New Error (Discovery)



46 GeV, mu_sig (0, 100)

Fraction: 1839 errors out of 3200 total toy run

```
 -> test statistic is negative (fit failed) - setting it to -1
EvalPLR: POI_test = 0, POI_hat = 8.32396e-06, uncond_ML = -2.8915, cond_ML = -2.
89173, TS = -1, time (create/fit1/2) 0, 0.3, 0.17, status (U/C) 0, 0
 -> test statistic is negative (fit failed) - setting it to -1
```

To do

- Dig into the cause of errors:
  - Start with 3 GeV, change the mu_sig to (0, 100), limiting mu_sig to positive value.

Update+To do

- Fitting errors at the low mass (3GeV) for the new workspace→ write a code to count the total errors →figure out what causes the error

- Also errors for the 40 GeV.
  - Screen, can only see the parts starting from POI=12.5, no errors after that
  - Run 40 GeV again, errors at lower POI

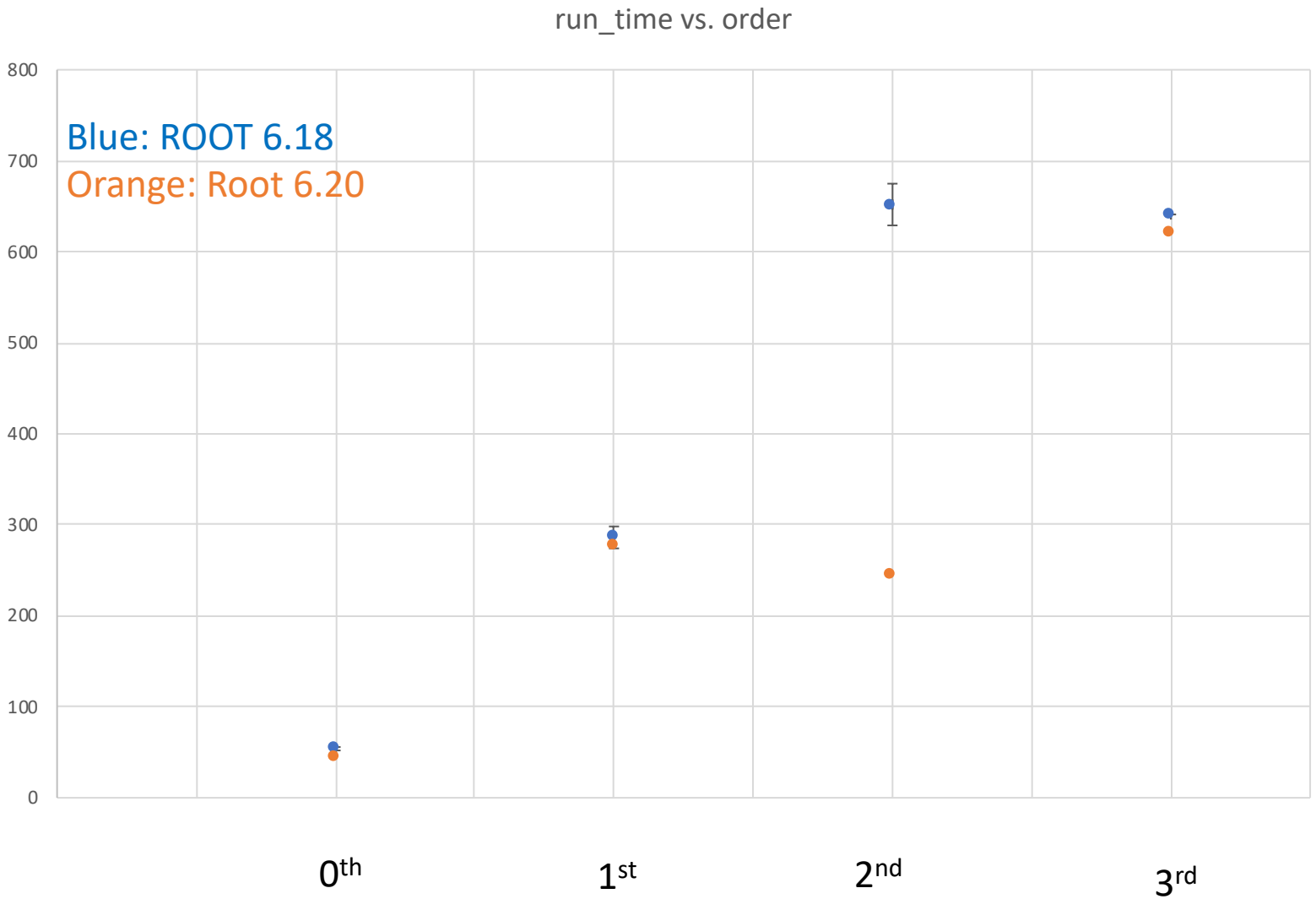
- Have problem with the master branch on LZStats

New update

- PdfMaker: add YAML configuration to WIMP & Background PDF
  - Do not need to change parameters in LZNESTUtils and source setup & build everytime changes a parameter
  - Tested n_sample parameter in YAML config, it works as expected!
- LZStats:
  - When source setup.sh, it changes ROOT to version 6.16
  - Works on Jonathan's git branch (jn_ROOT6.20.00) to test how ROOT 6.20 affect the run time of different interpolation order

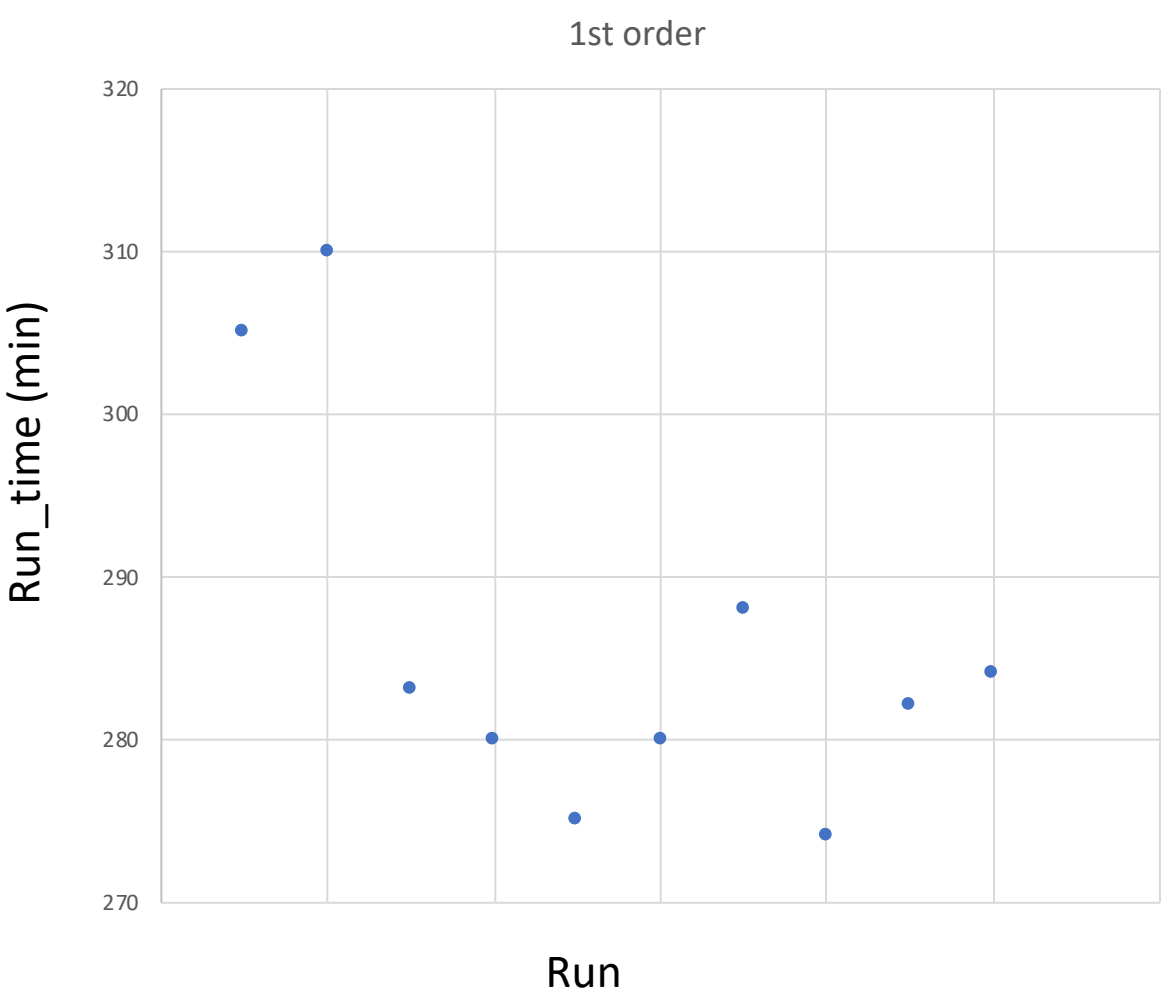
ROOT 6.18 & 6.20

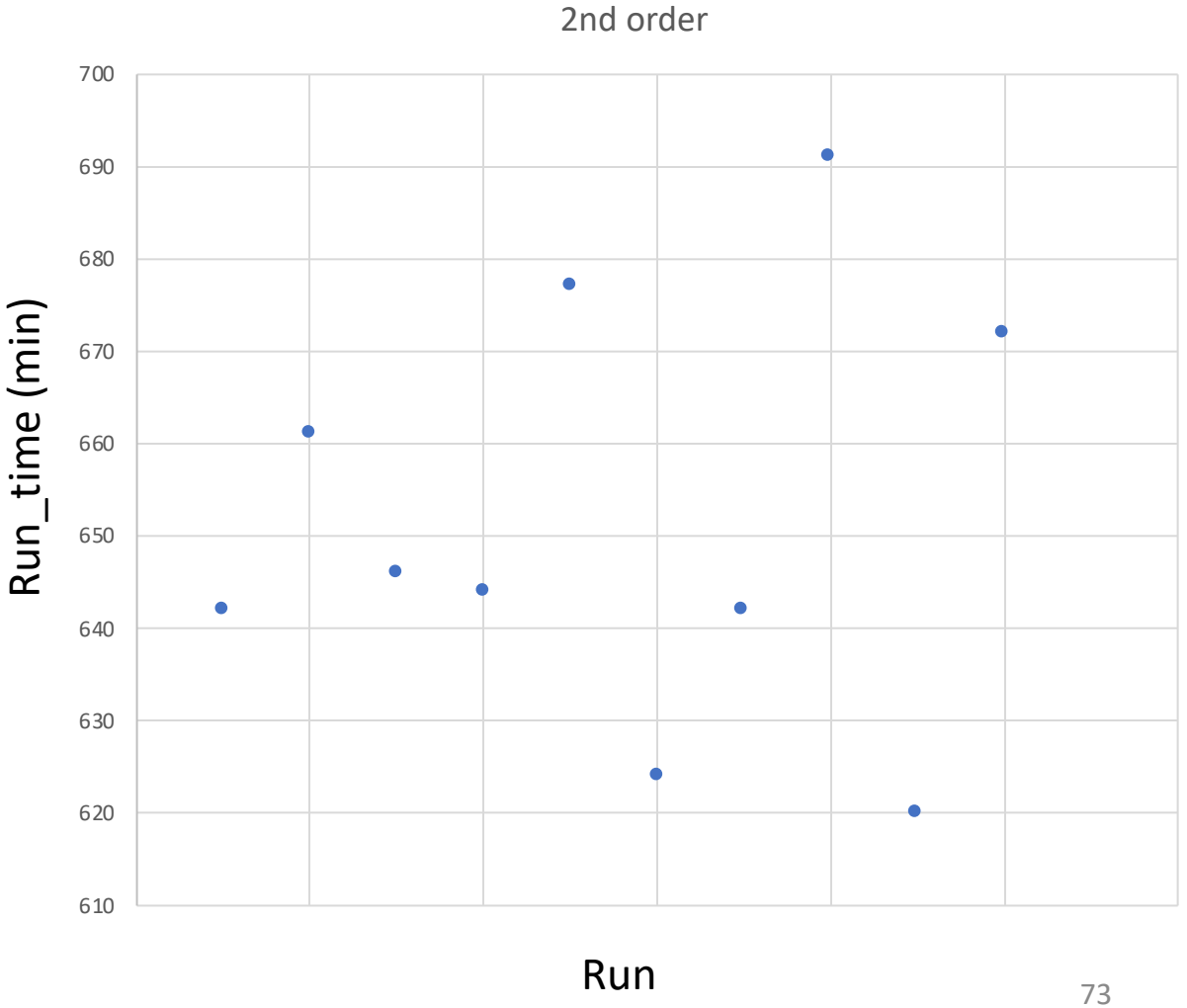
	0th	1st	2nd	3rd
run_time(min)	53.9 (10 runs)	286.1 (10 runs)	651.9 (10 runs)	641
STD	1.9	12.1	22.9	
run_time(min)	44	278.5 (2 runs)	245?	621



1st & 2nd orders

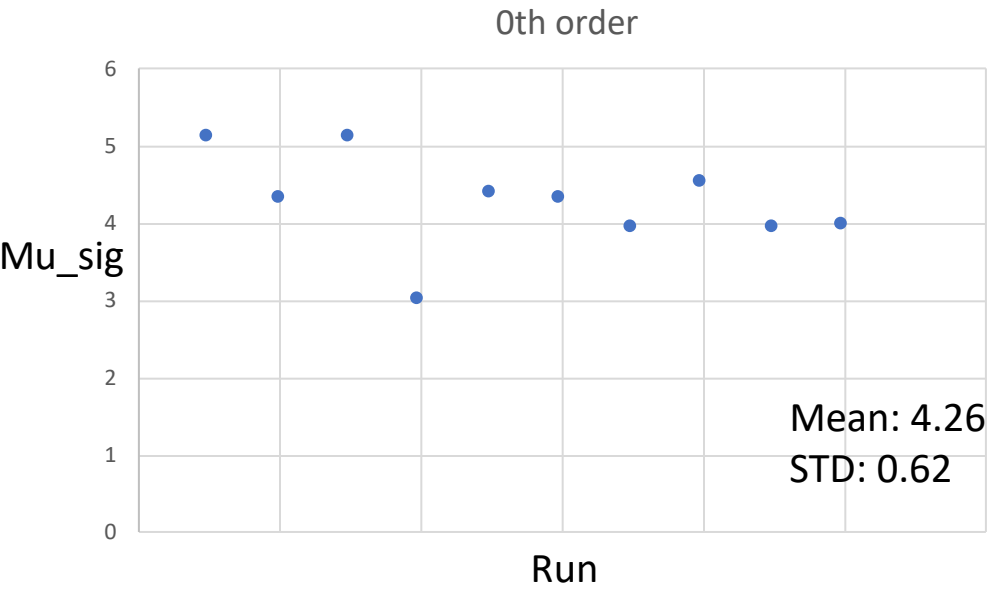
Submit 10 runs at the same time, some runs are not using 100% CPU at the beginning -> higher run time for these specific runs-> higher STD

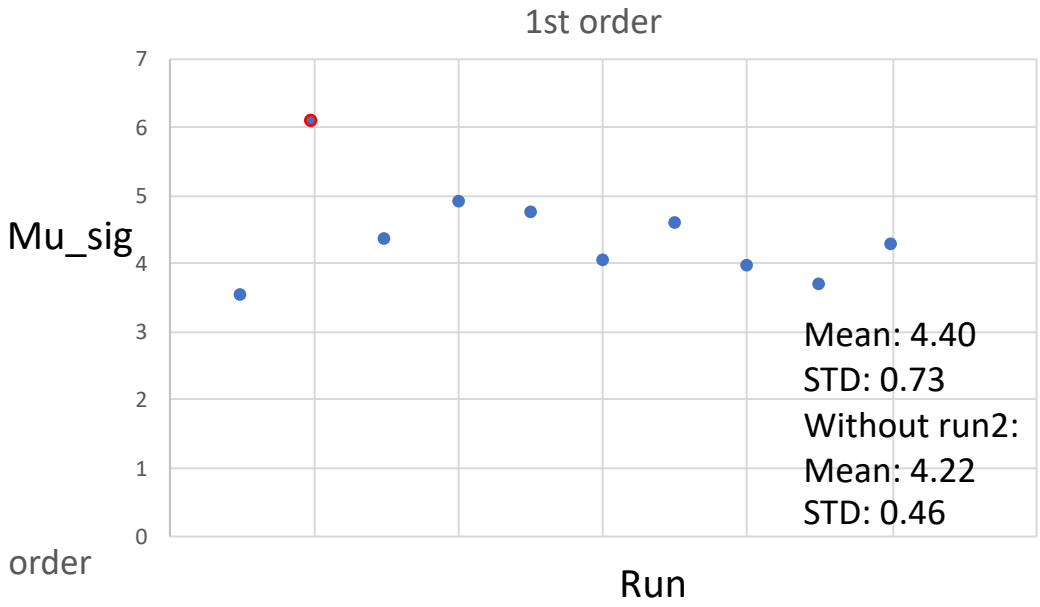


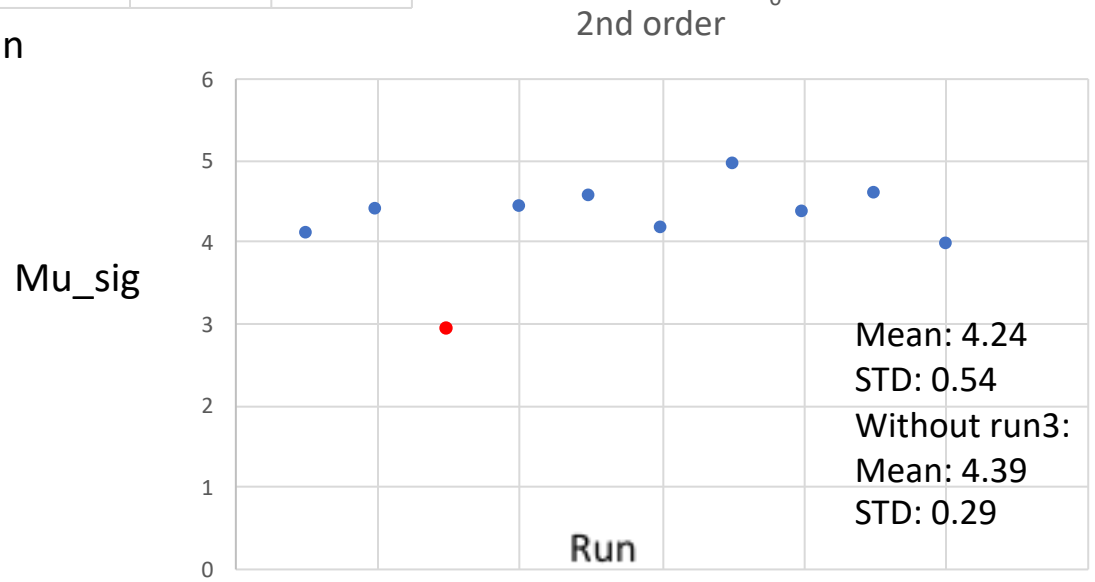


Interpolation

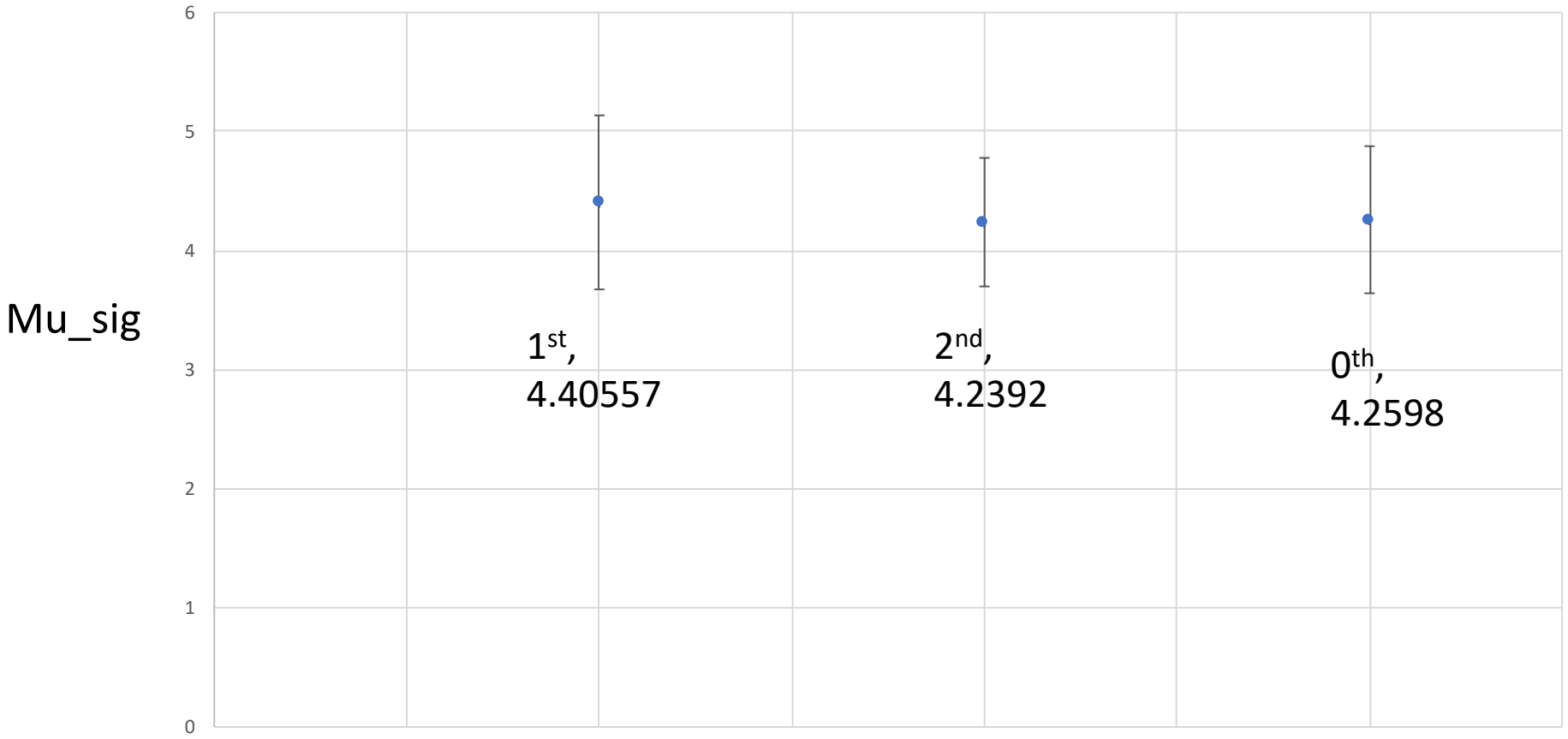
WIMP mass: 10GeV
N_sample: 10 ^6







mu_sig vs. order



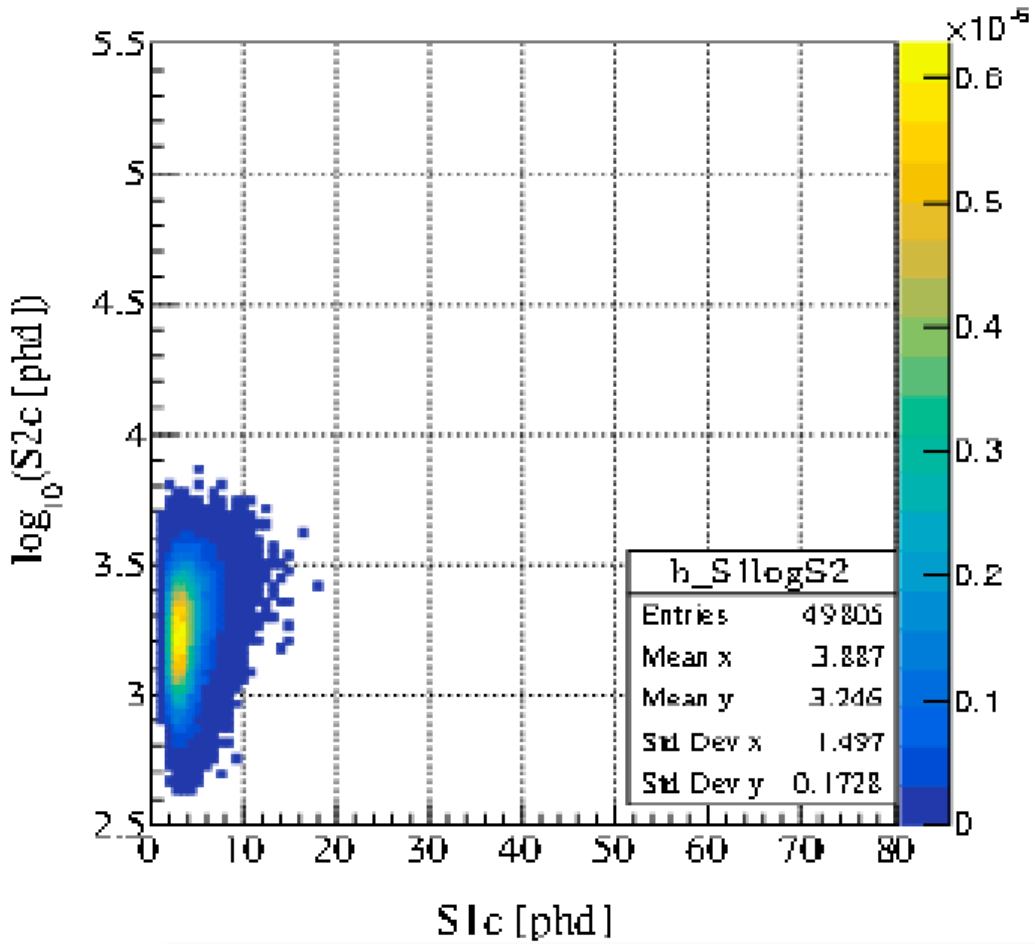
What’s new?

- New update
- Try different interpolation order 0~3
- Organize the output

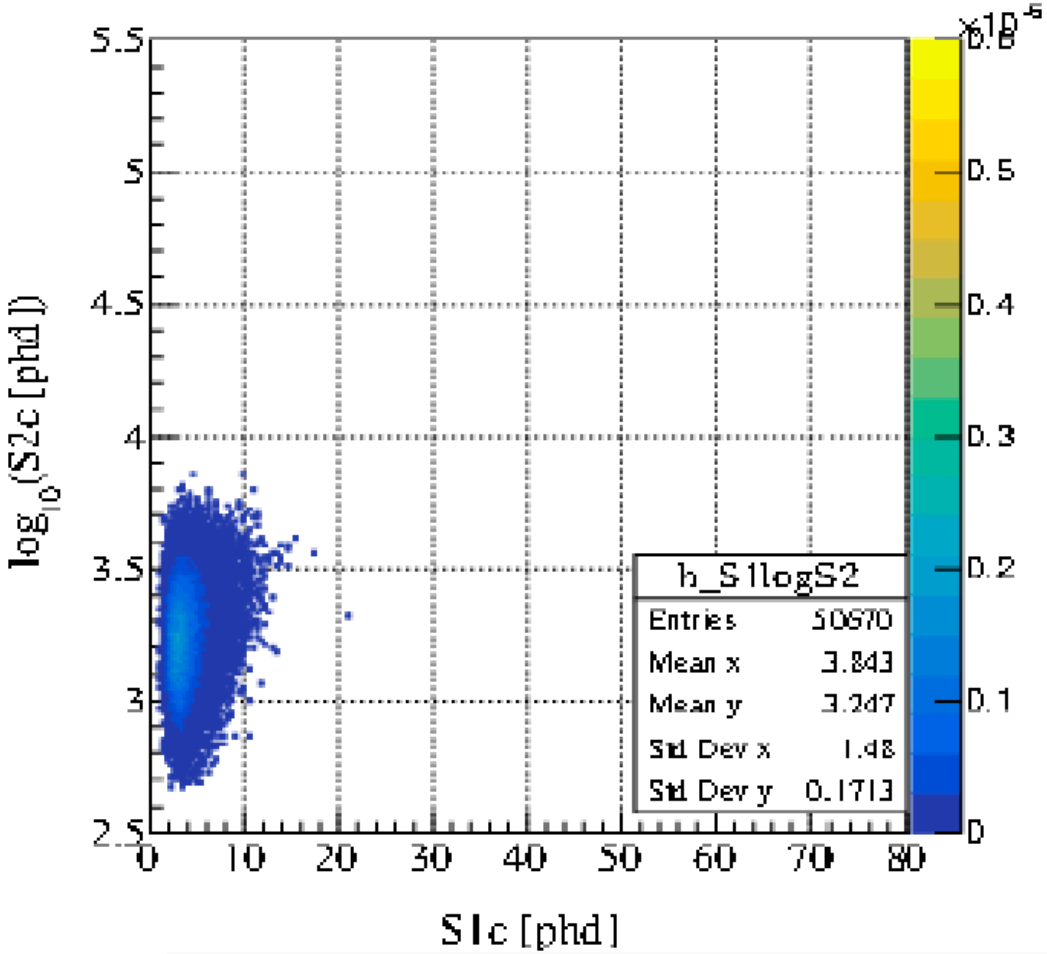
New update (Detector)

Parameter	Before	After
g1	0.118735	0.150
g1_gas	0.1018	0.1186
eLife_us	850	944.56
r_max_fiducial	688 cm	688 mm
z_max_fiducial	1330 cm	1330 mm

WIMP signal PDF



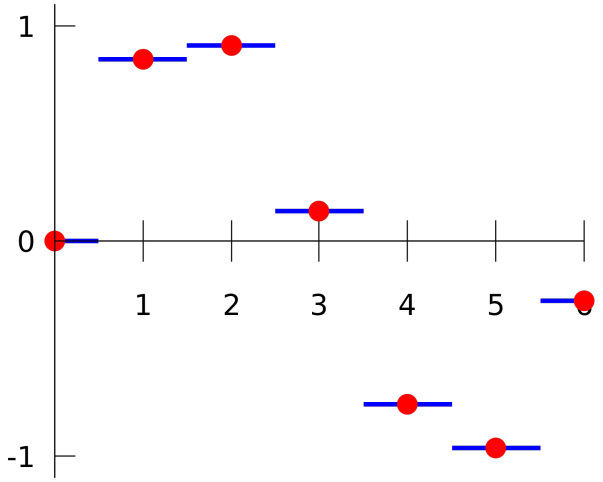
Before



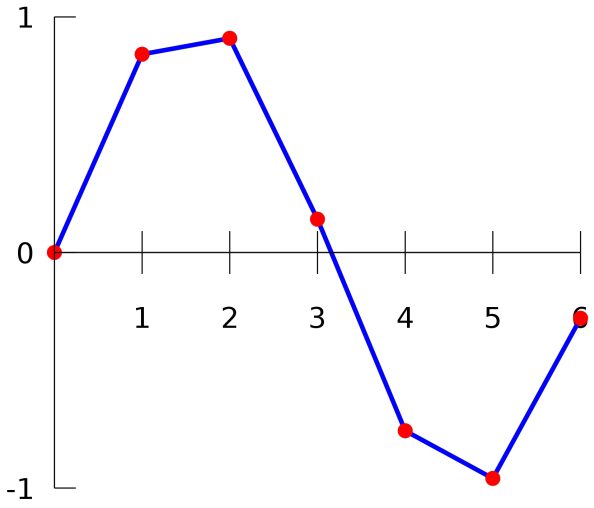
After

Interpolation Method

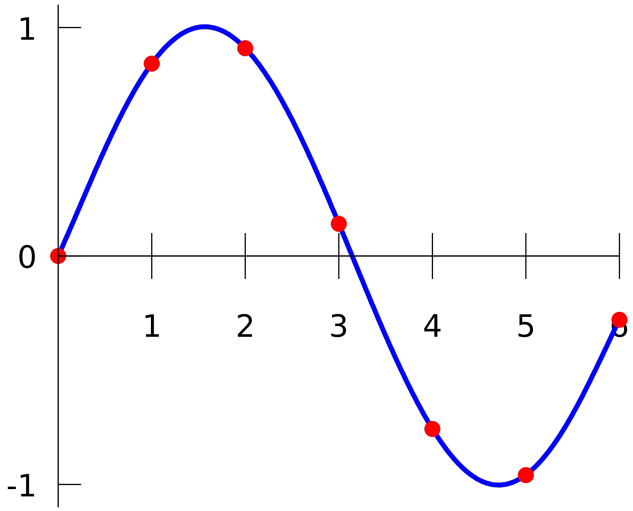
- Construct new data points within the range of know data points (discrete set)→ bring up the bins surrounded by 0 events
- Change interpolation order 0~3(in the code to create workspace)



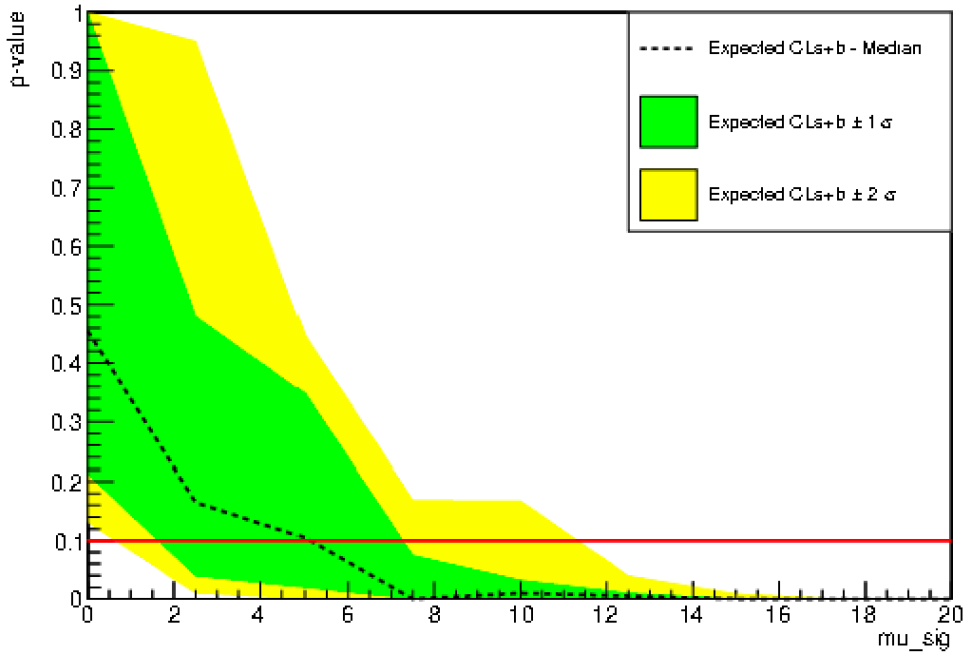
0th



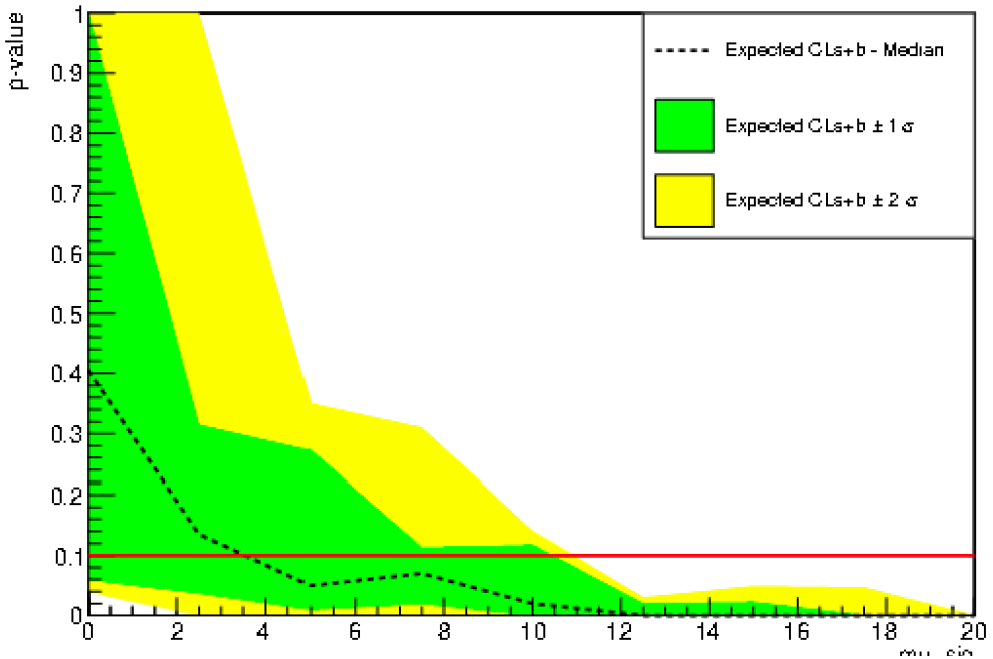
1st



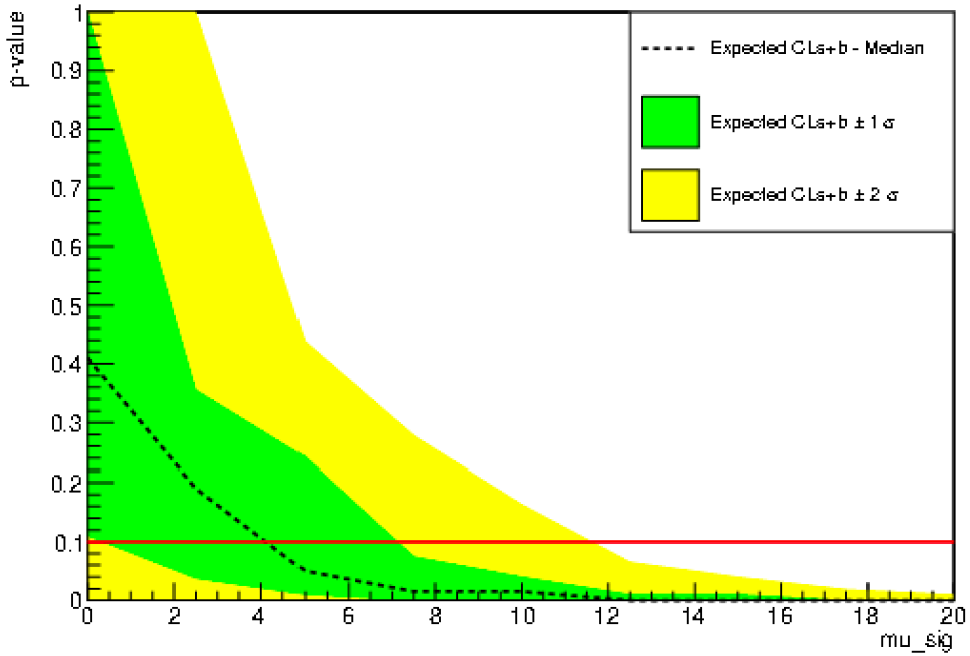
2nd?



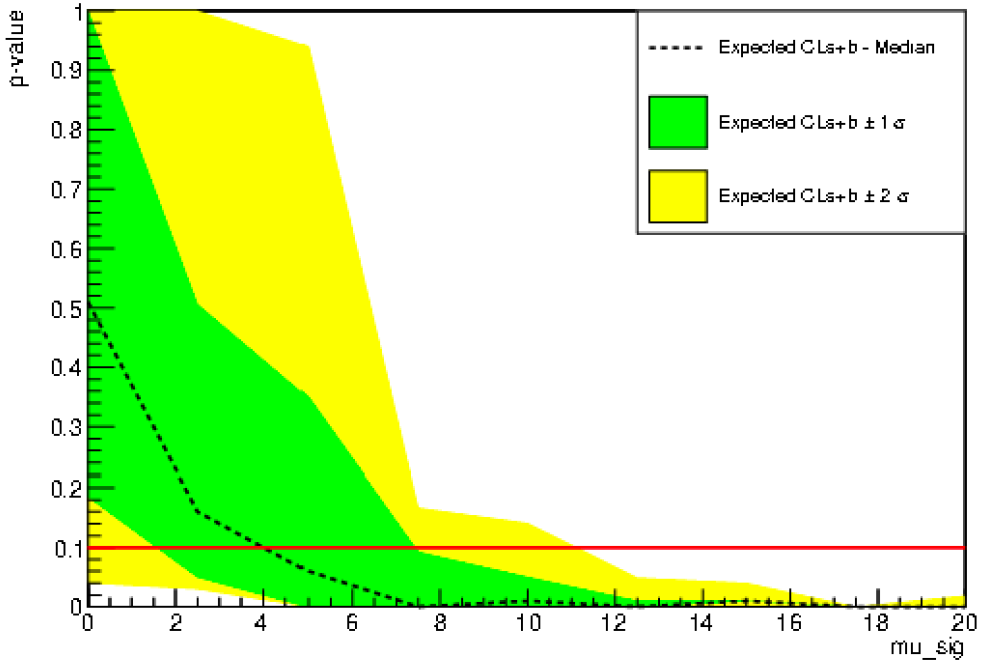
0th order
~1 h



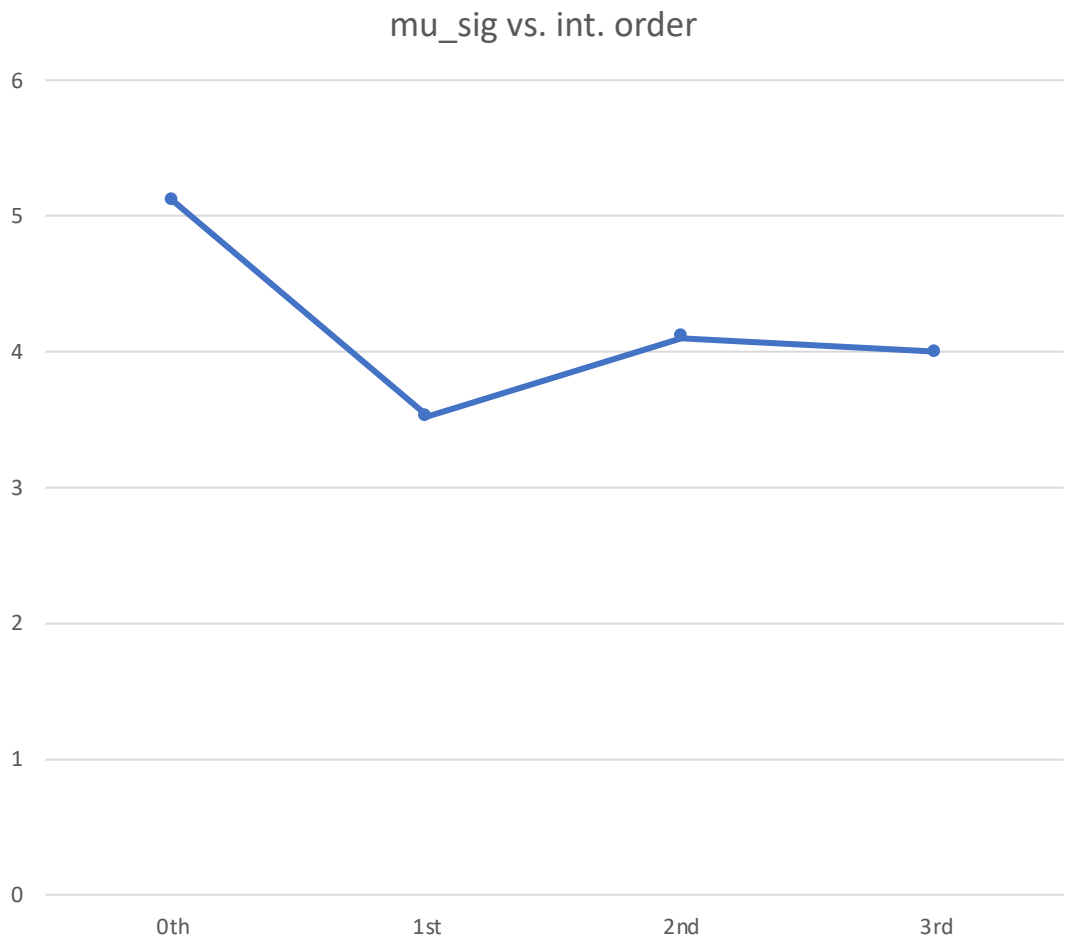
1st order
~5 h

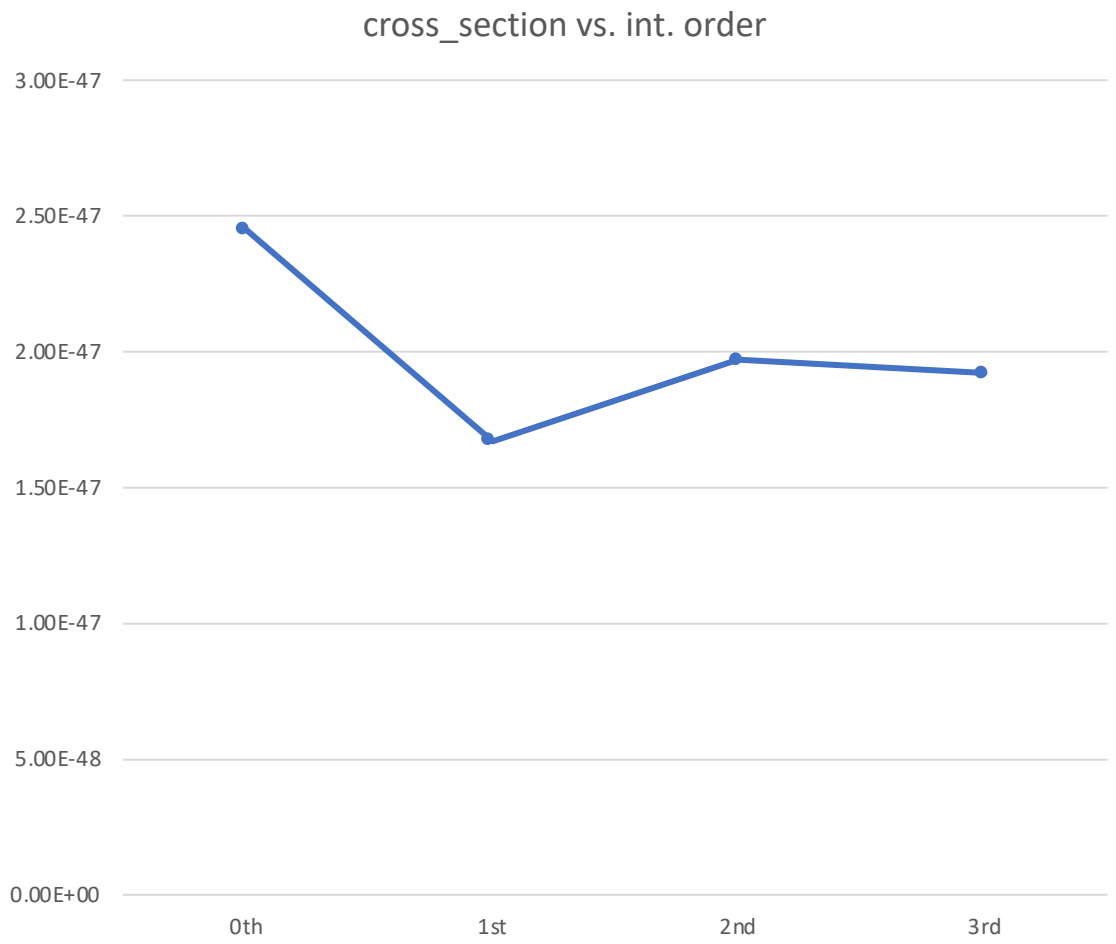


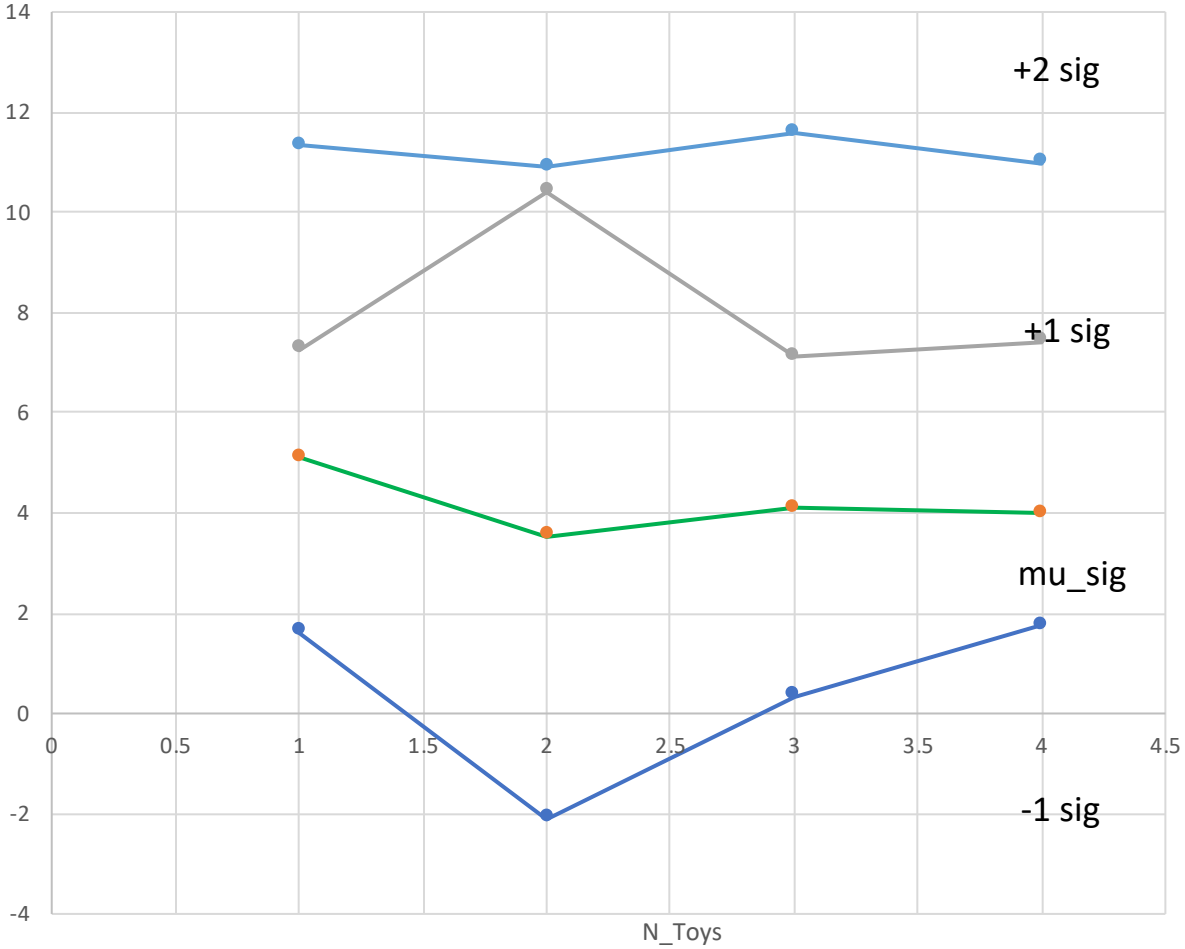
2nd order
~8 h



3rd order
~10.5h


mu_sig vs. int. order
6
5
4
3
2
1
0
0th
1st
2nd
3rd


cross_section vs. int. order
3.00E-47
2.50E-47
2.00E-47
1.50E-47
1.00E-47
5.00E-48
0.00E+00
0th
1st
2nd
3rd

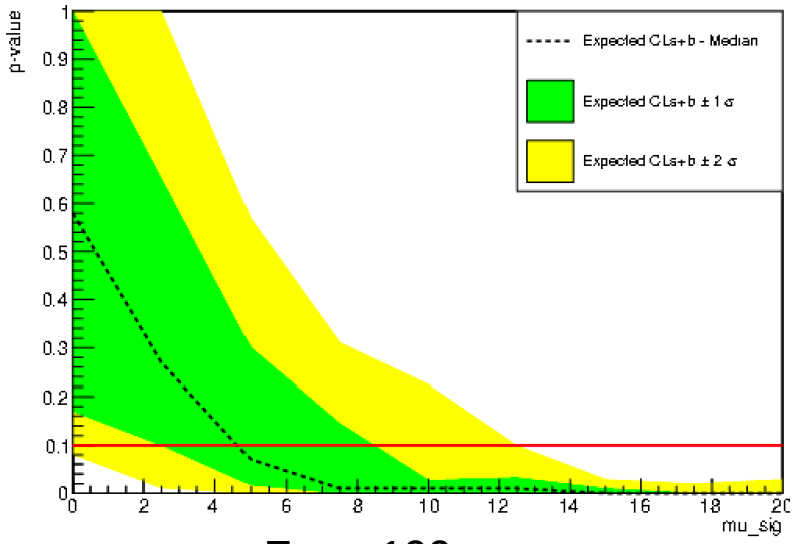

+2 sig
+1 sig
mu_sig
-1 sig
N_Toys
14
12
10
8
6
4
2
0
-2
-4
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5


-2 sig vs. order
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0th
1st
2nd
3rd

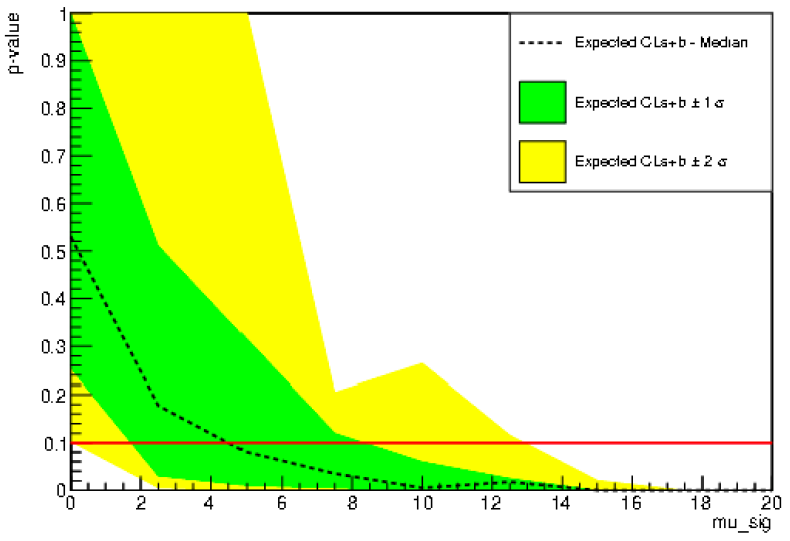
What’s new?

- Try different # of Toys.
- Plot mu_sig, -1 sig, +1 sig, -2 sig, +2sig, cross section vs. NToys

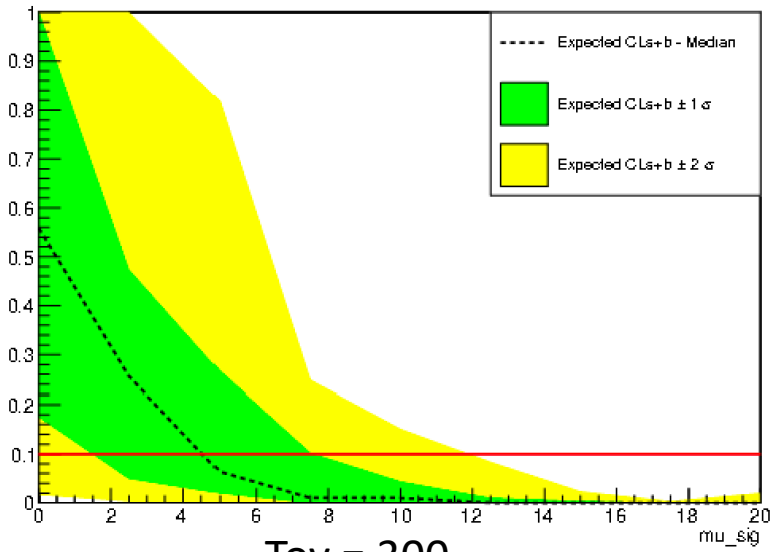
g1 = 0.118, 10^7 sample size



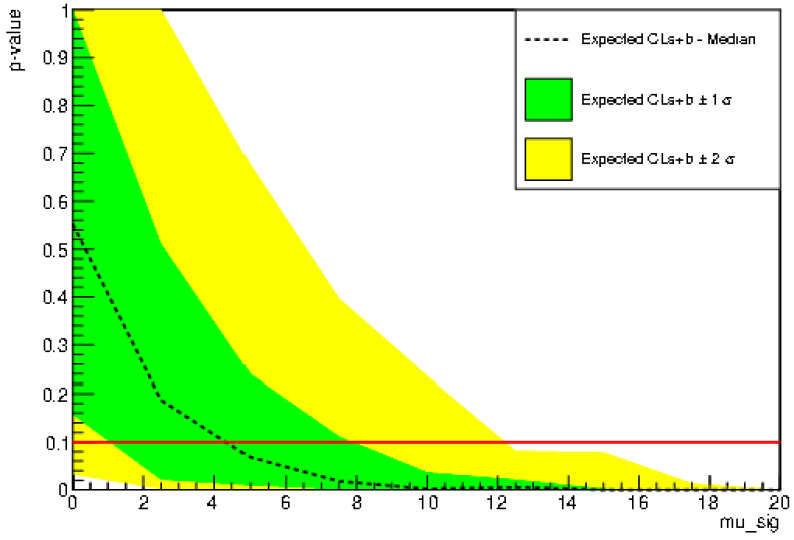
Toy = 100



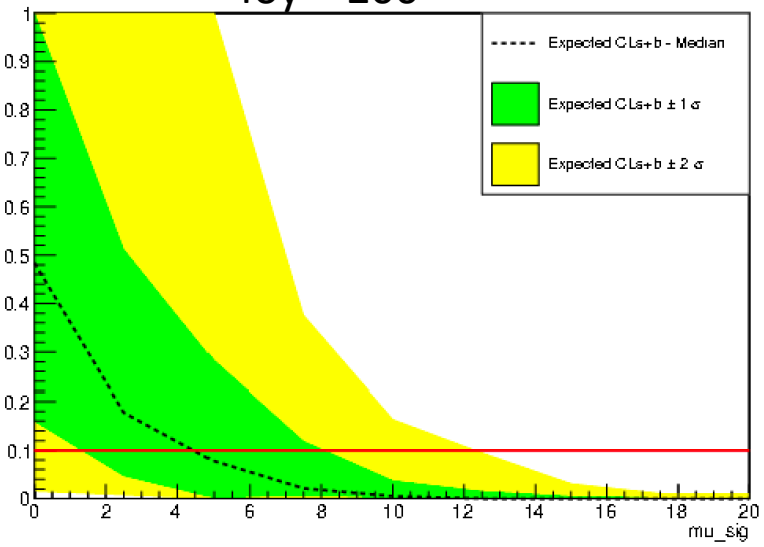
Toy = 200



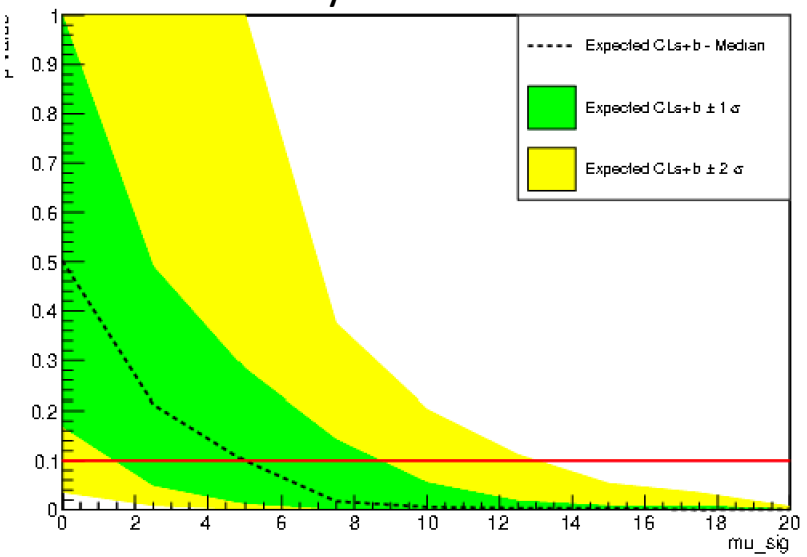
Toy = 300



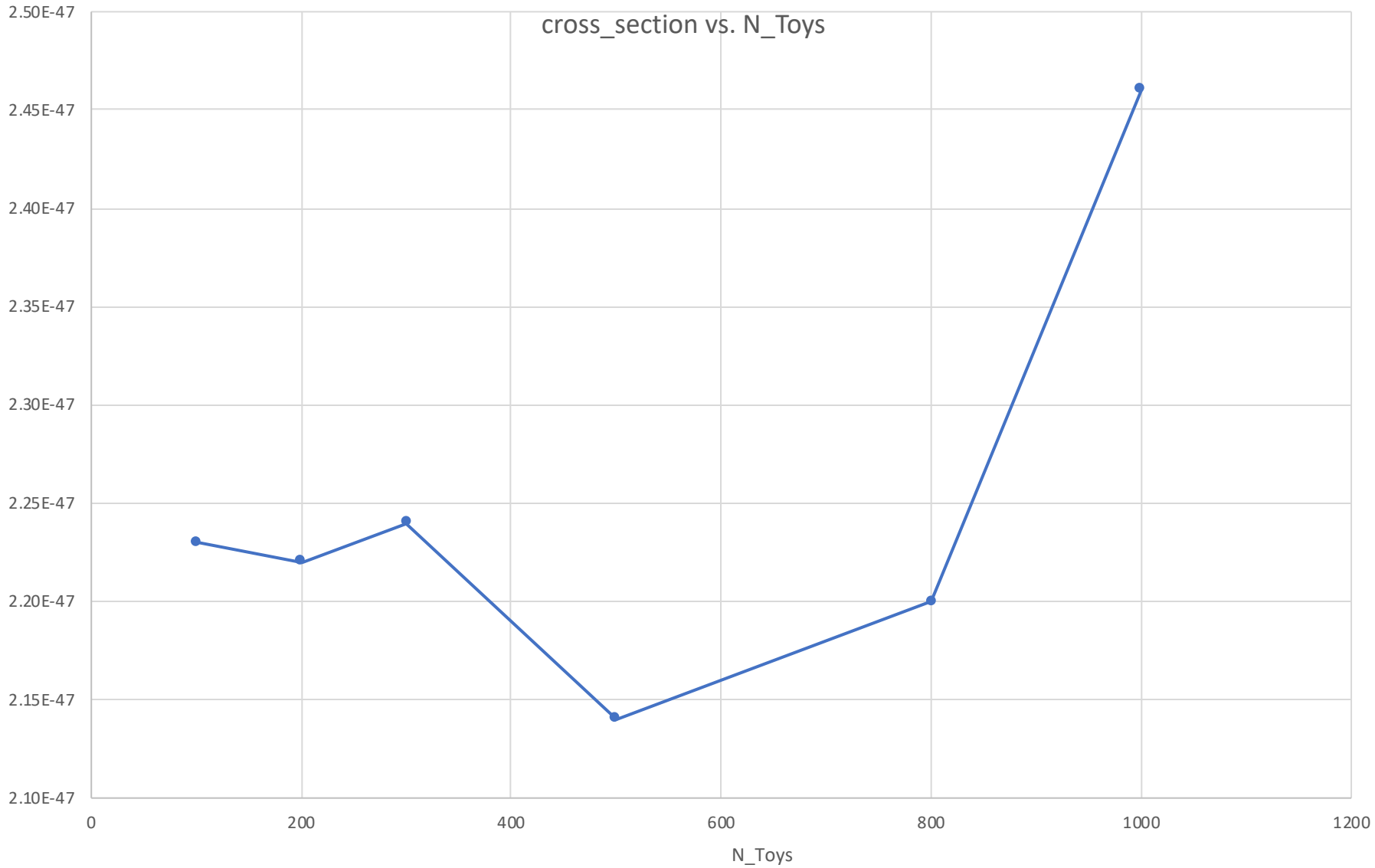
Toy = 500

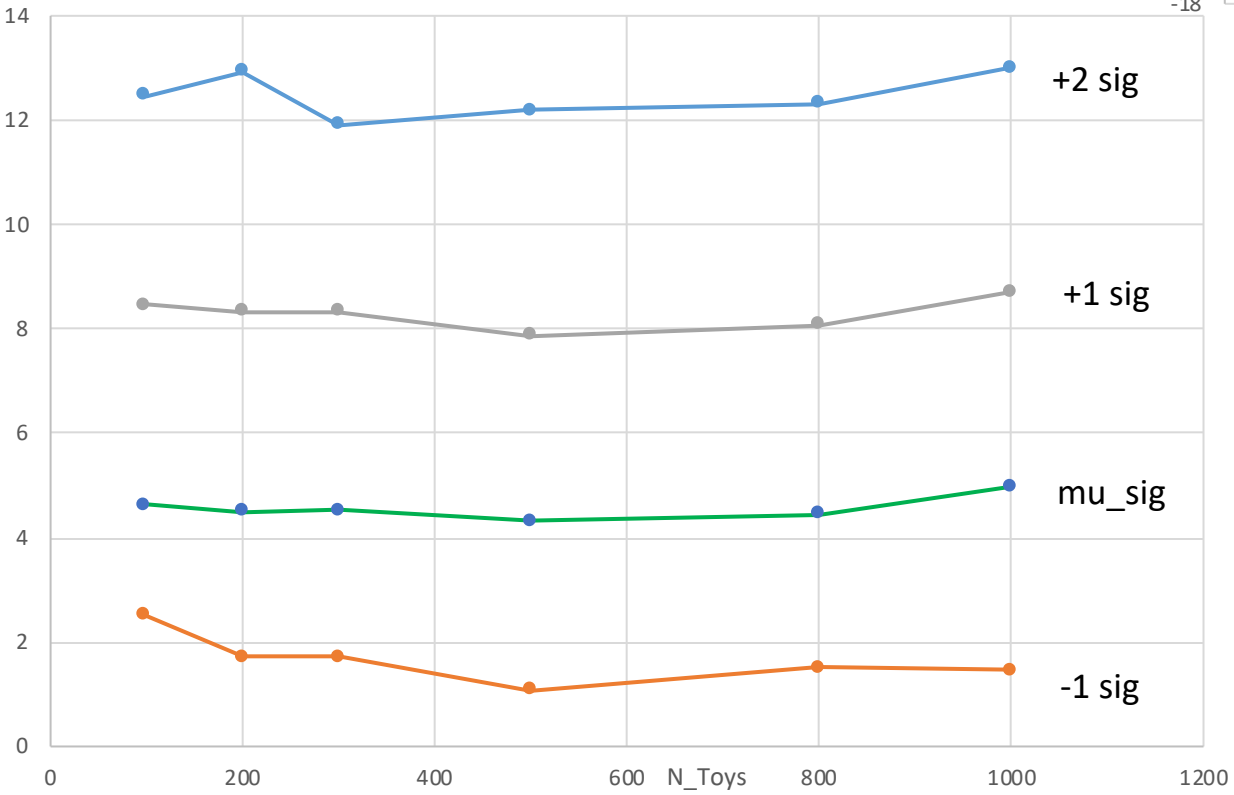


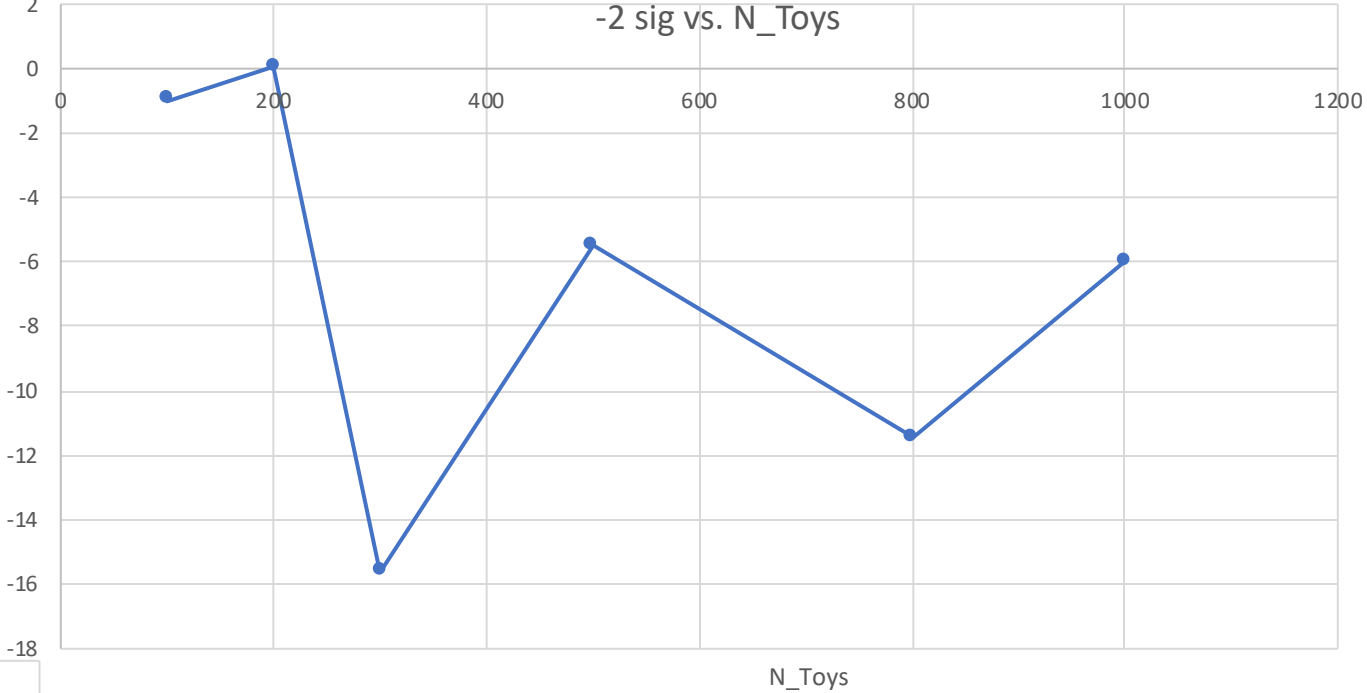
Toy = 800



Toy = 1000


cross_section vs. N_Toys
2.50E-47
2.45E-47
2.40E-47
2.35E-47
2.30E-47
2.25E-47
2.20E-47
2.15E-47
2.10E-47
0
200
400
600
800
1000
1200
N_Toys

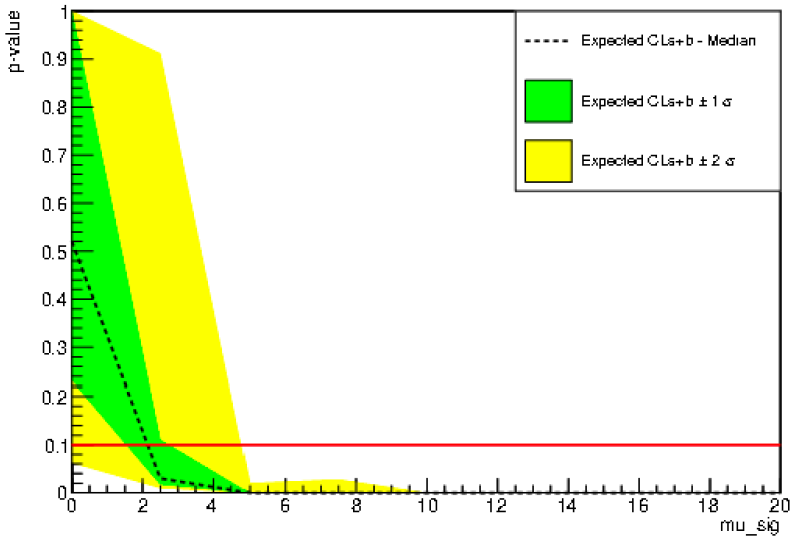

14
12
10
8
6
4
2
0
0
200
400
600
N_Toys
800
1000
1200
+2 sig
+1 sig
mu_sig
-1 sig


-2 sig vs. N_Toys
2
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
0
200
400
600
800
1000
1200
N_Toys

What's new?

- Run 10 GeV WIMP mass with changing g1 values (0.05, 0.118, 0.13) and changing n_sample values (10^6 & 10^7)

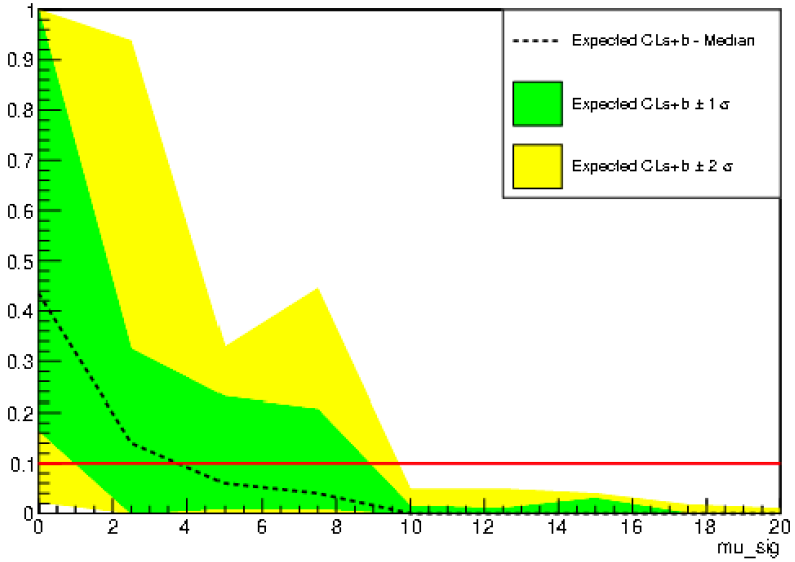
10 GeV
n_sample = 10^6



g1 = 0.05

mu_sig = 2.1429

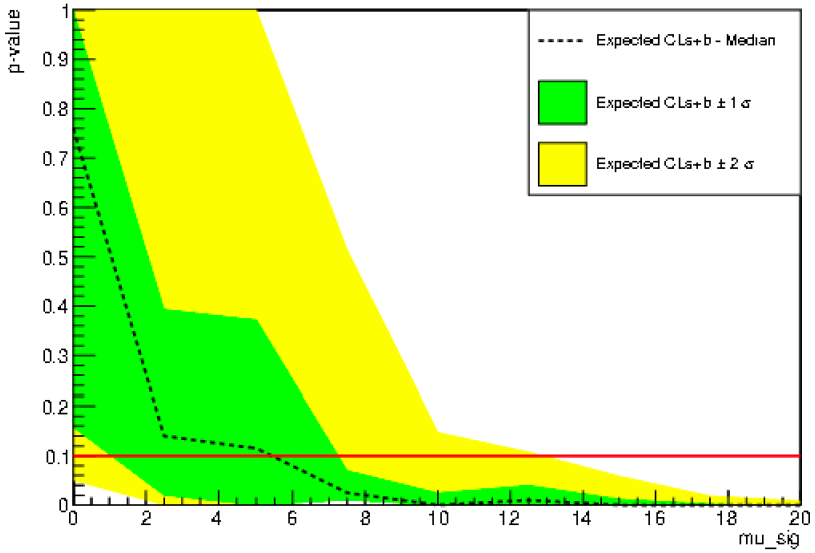
cross_section = 6.8e-47



g1 = 0.118

mu_sig = 3.7500

cross_section = 1.84e-47

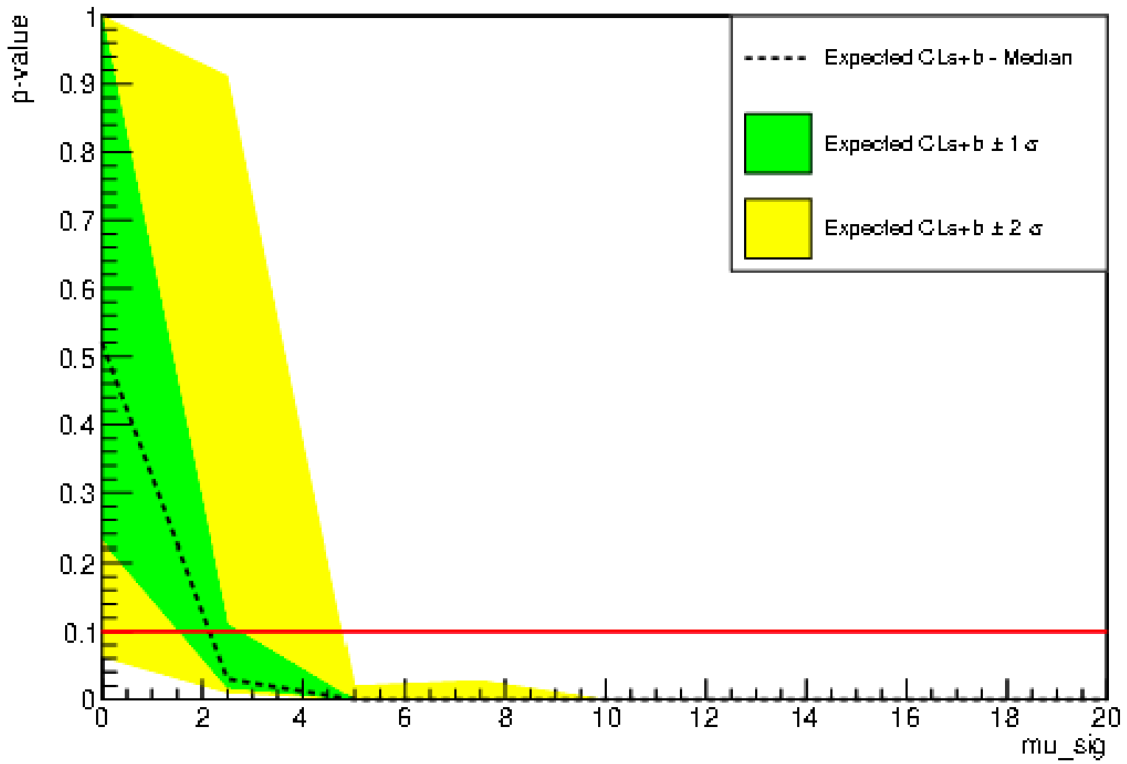


g1 = 0.13

mu_sig = 5.4167

cross_section = 2.3e^-47

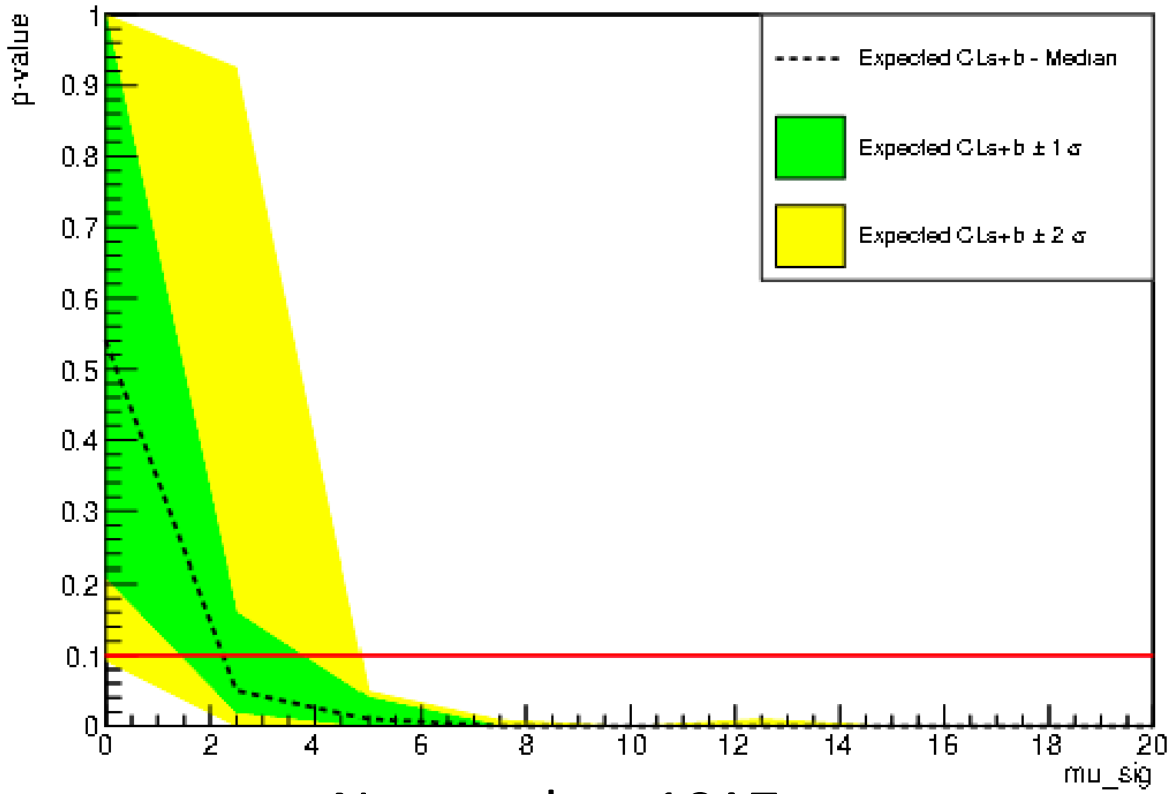
10 GeV, g1 = 0.05



N_sample = 10^6

mu_sig = 2.1429

cross_section = 6.8e-47

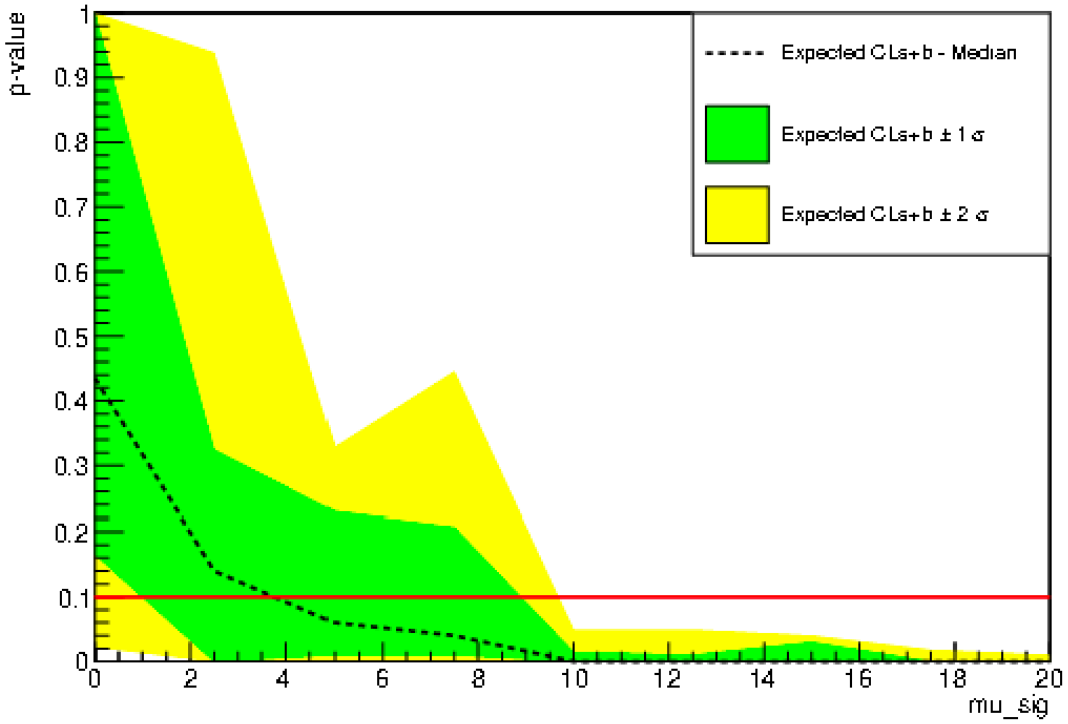


N_sample = 10^7

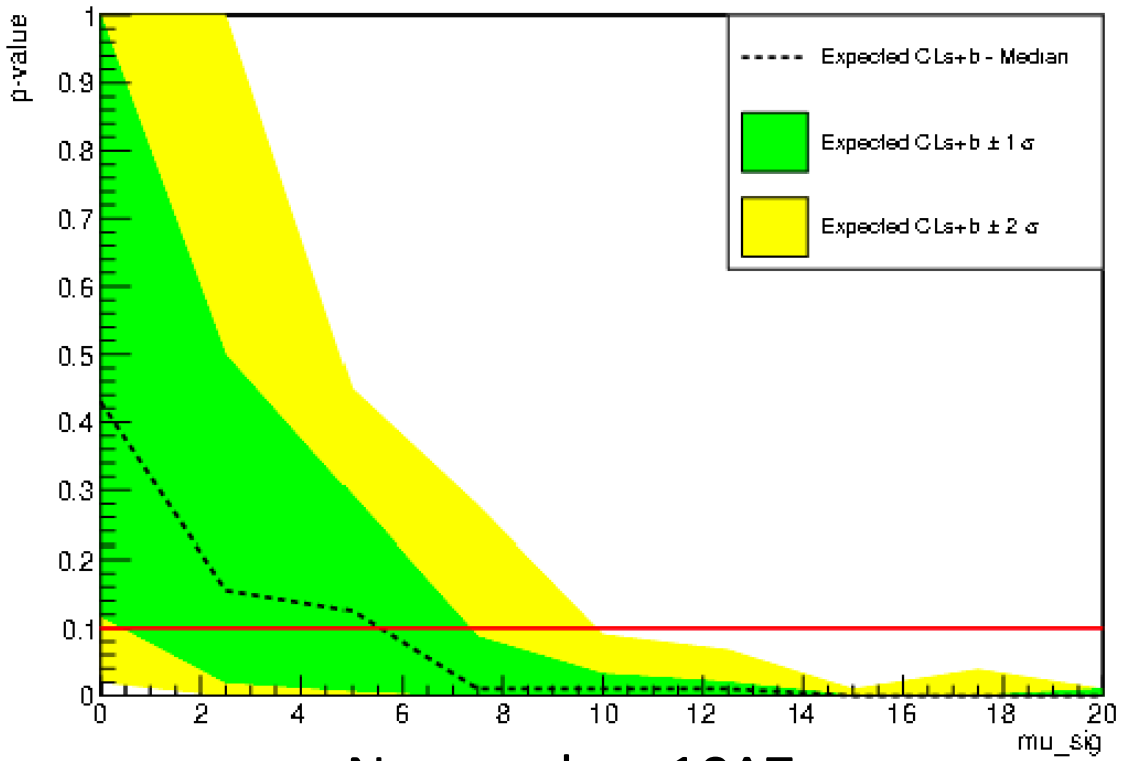
mu_sig = 2.2449

cross_section = 7.2e-47

10 GeV, g1 = 0.118

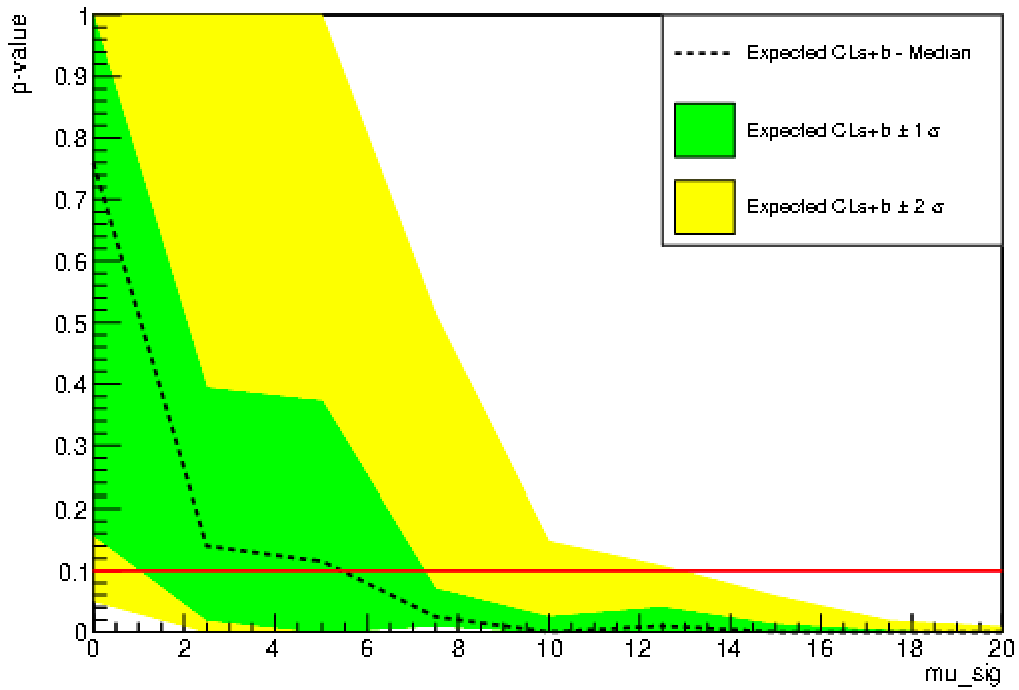


N_sample = 10^6
mu_sig = 3.7500
cross_section = 1.84e-47



N_sample = 10^7
mu_sig = 5.54
cross_section = 2.74e-47

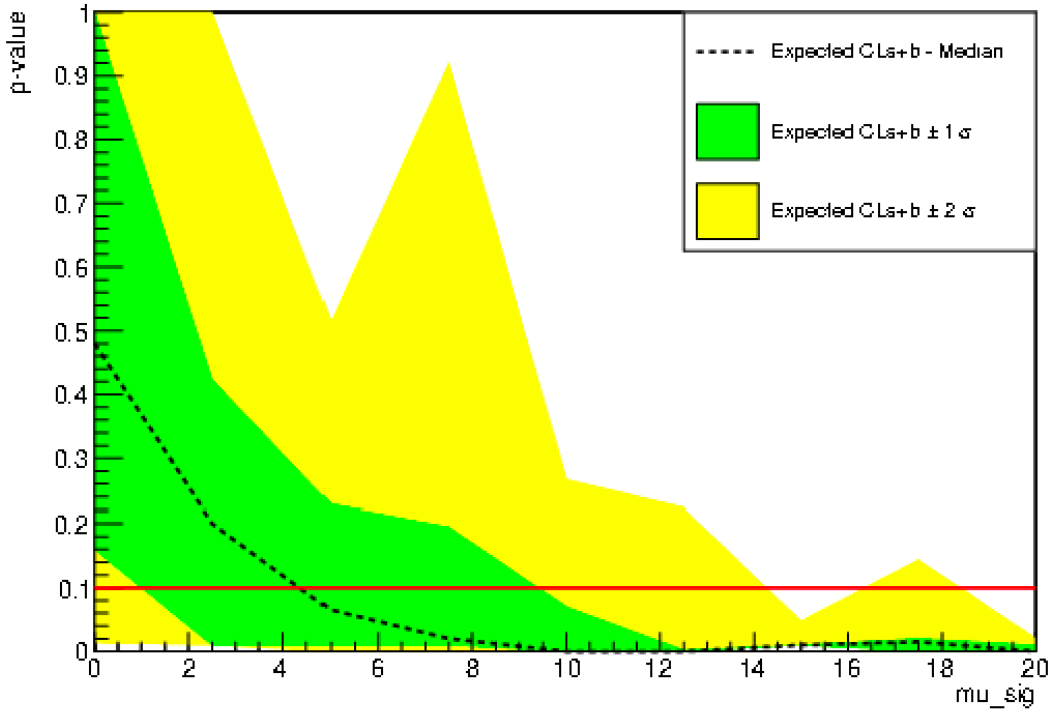
10 GeV, g1 = 0.13



N_sample = 10^6

mu_sig = 5.4167

cross_section = 2.3e-47

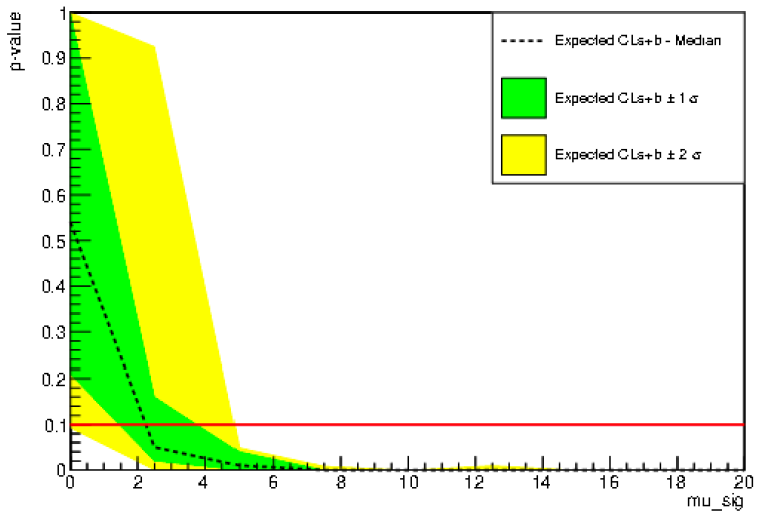


N_sample = 10^7

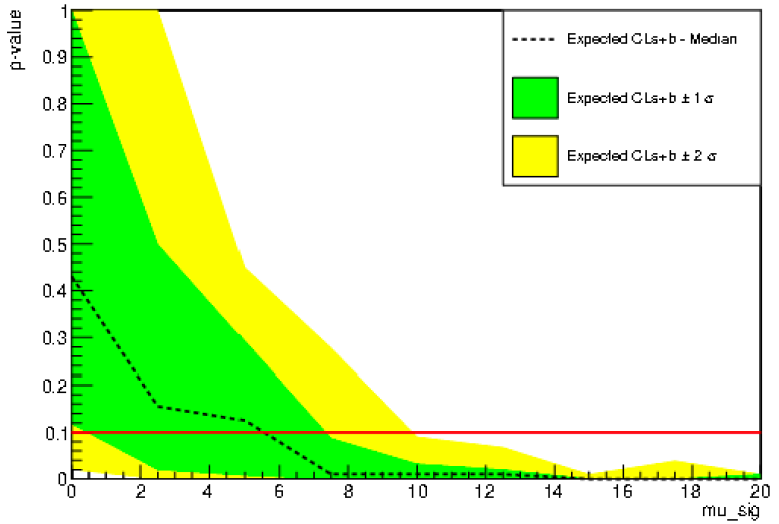
mu_sig = 4.3544

cross_section = 1.8e-47

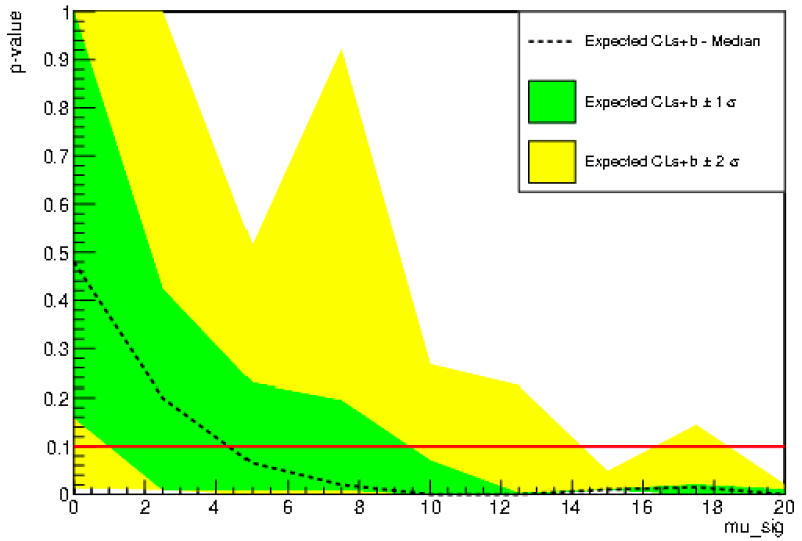
10 Gev
n_sample = 10^7



g1 = 0.05
mu_sig = 2.2449
cross_section = 7.2e-47



g1 = 0.118
mu_sig = 5.54
cross_section = 2.74e-47



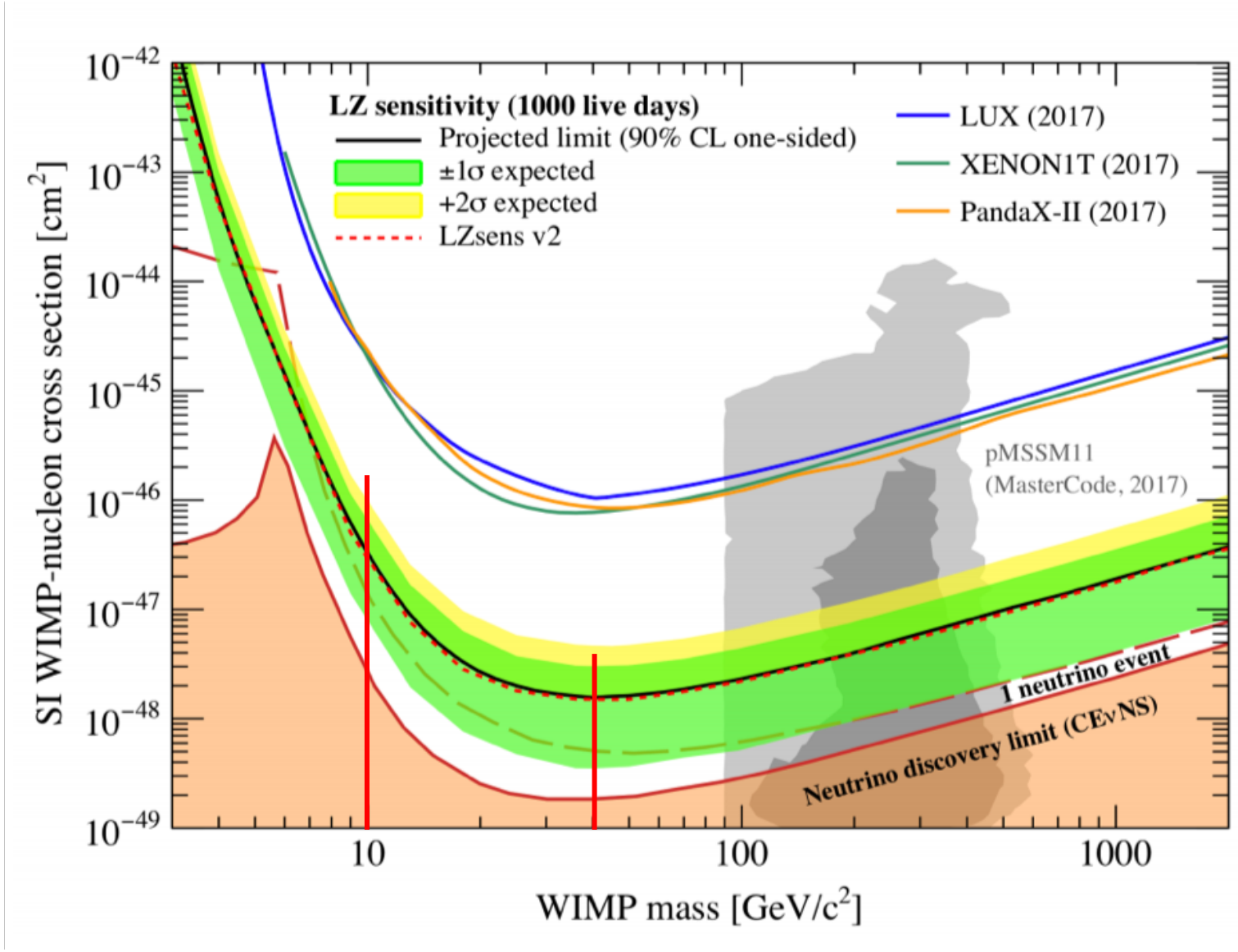
g1 = 0.13
mu_sig = 4.3544
cross_section = 1.8e-47

Comparison (10 GeV vs 40 GeV)

- Change g1 from 0.05 -> 0.13
  - Cross section for 10 GeV changes 75%
  - Cross section for 40 GeV changes 27%
- Why is there a more dramatic change in lower WIMP mass when changing g1 ?

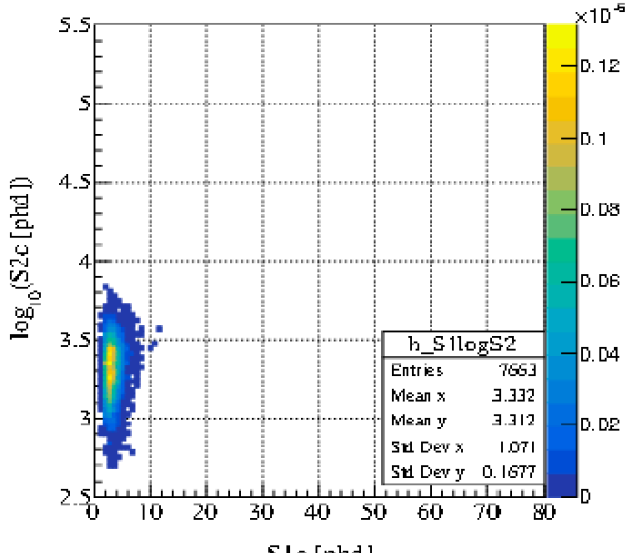
Limit plot

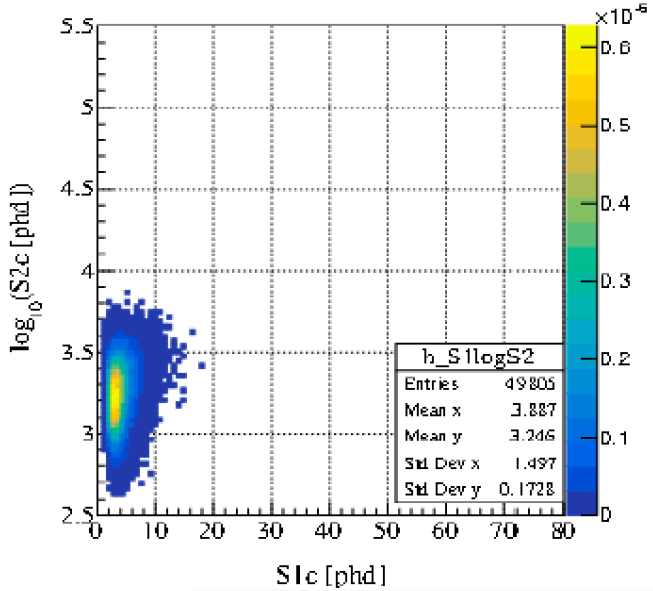
10 GeV ~ 3e^-47

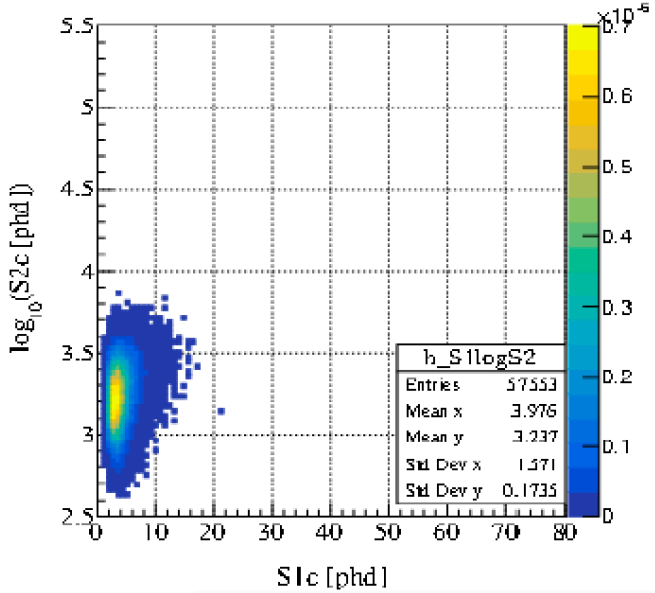


WIMP 10GeV

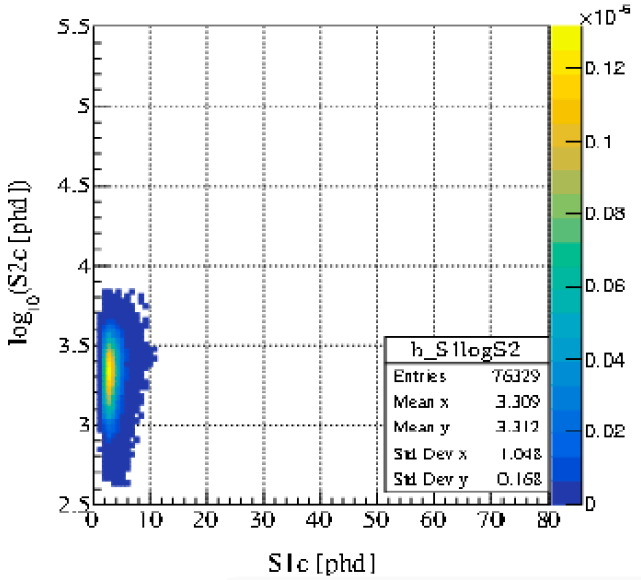
N_sample = 10^6

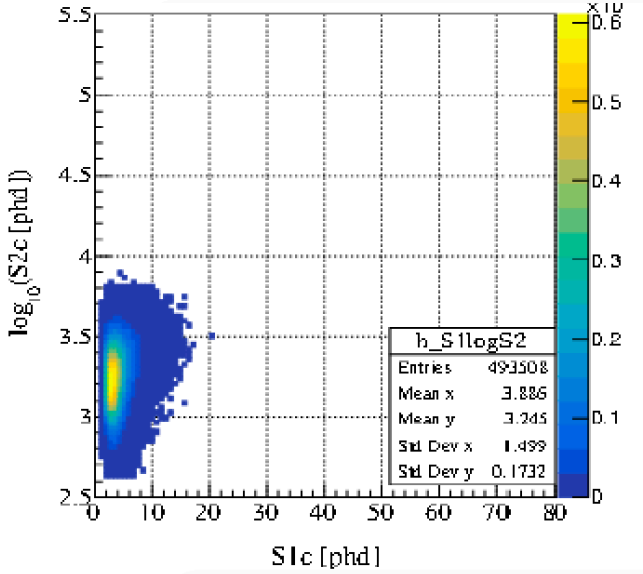


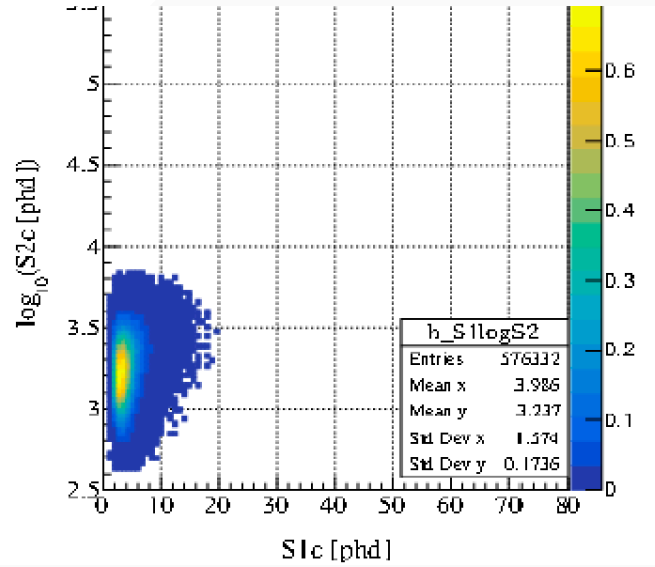




N_sample = 10^7







g1 = 0.05

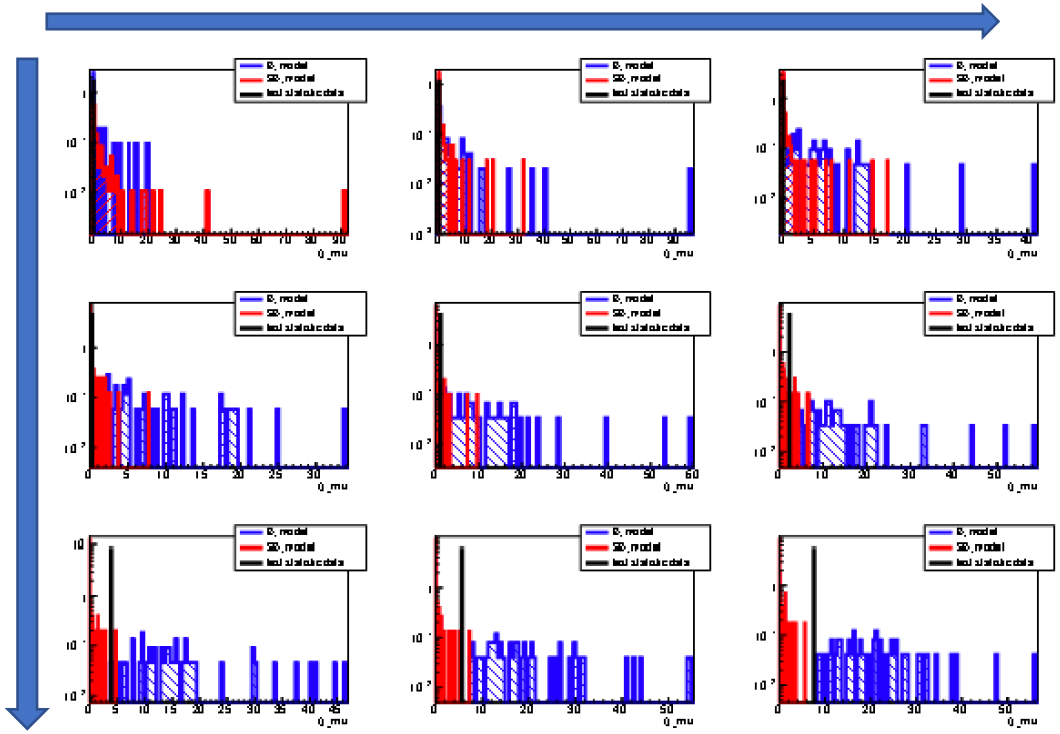
g1 = 0.118

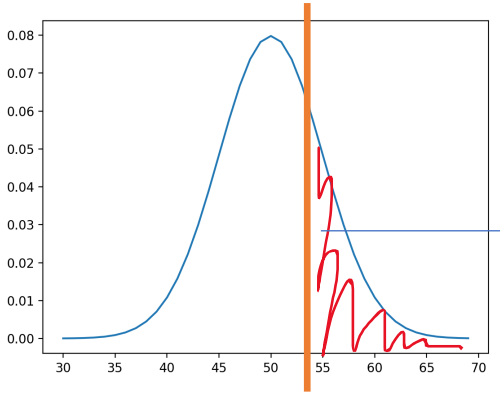
g1 = 0.13

What’s new?

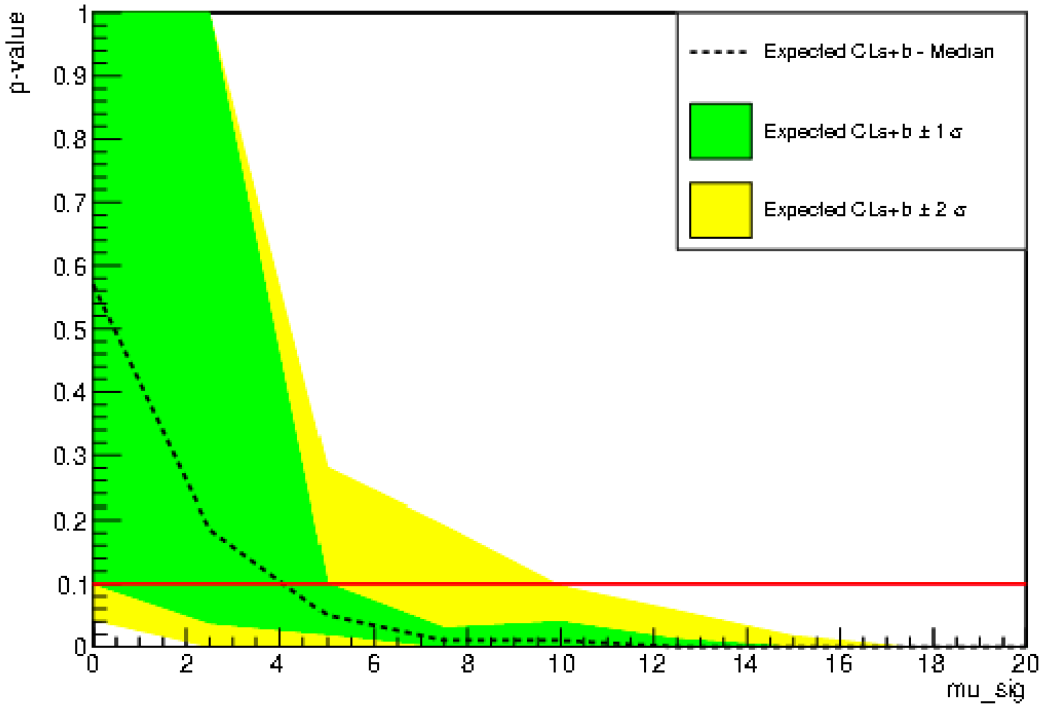
- Analyze the graph
- Change g1 value and compare the limits

POI = 0 ~ 20





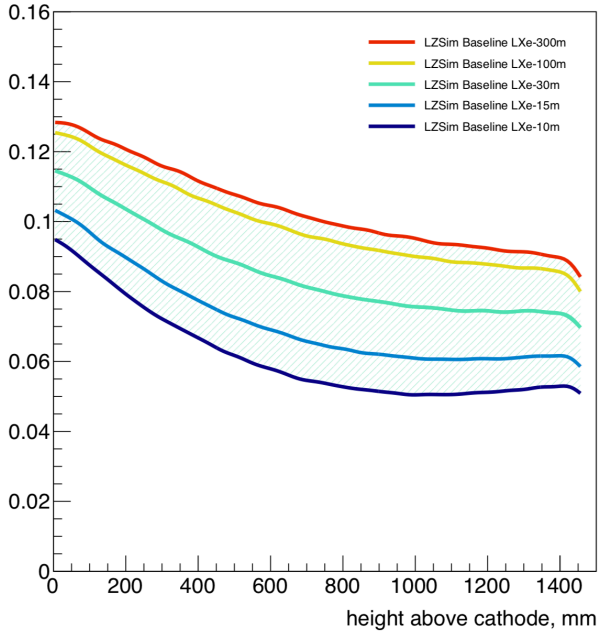
P-value



g1

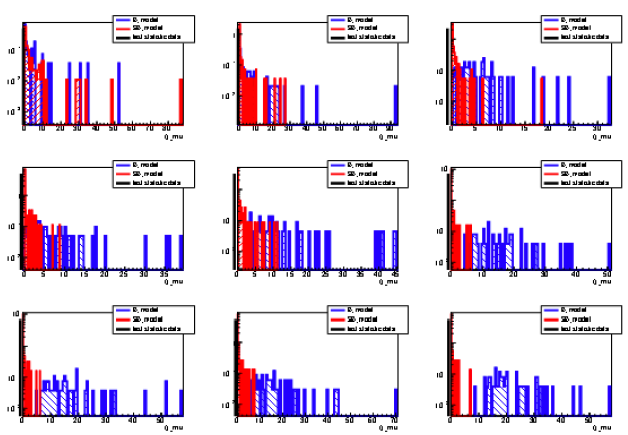
- g1
  - Photon detection efficiency: the average fraction of S1 light that is detected by PMTs.
  - Detected photoelectrons/emitted scintillation photon
  - Property of the combination of PMTs and detector, grid reflectivity, Xe absorption of light…
- LZsim baseline in Liquid Xe

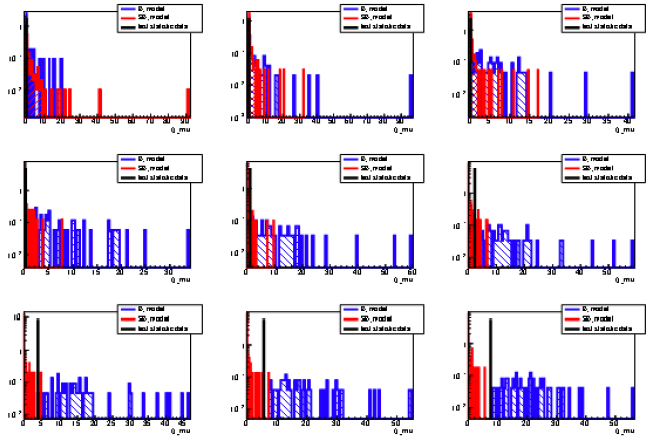
g1_min ~ 0.05
g1_default ~ 0.118
g1_max~0.13

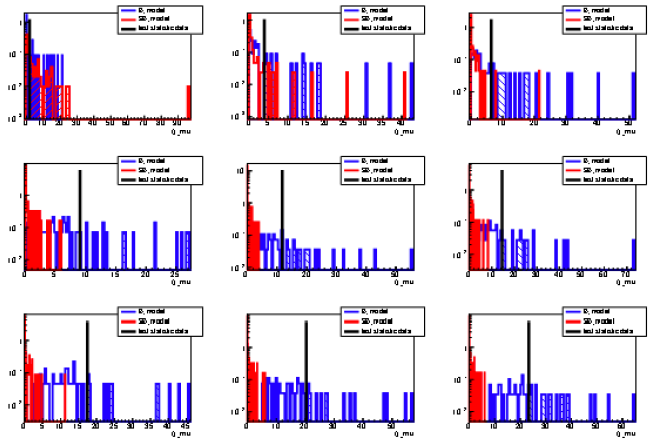


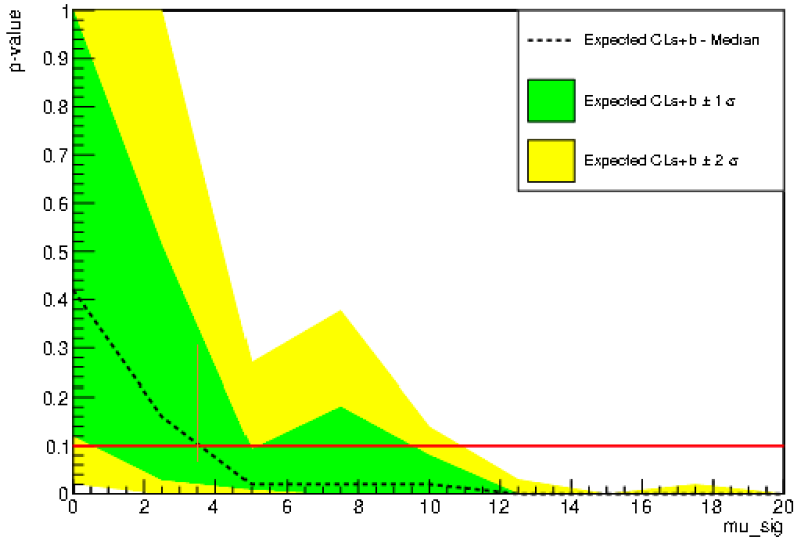
Code

- LZNESTUtils
  - Change Detector parameters
  - Source setup.sh
  - Source .ci/build.sh
  - Get new NESTInterference
- PdfMaker
  - Recompile signal and background codes with the new NESTInterference





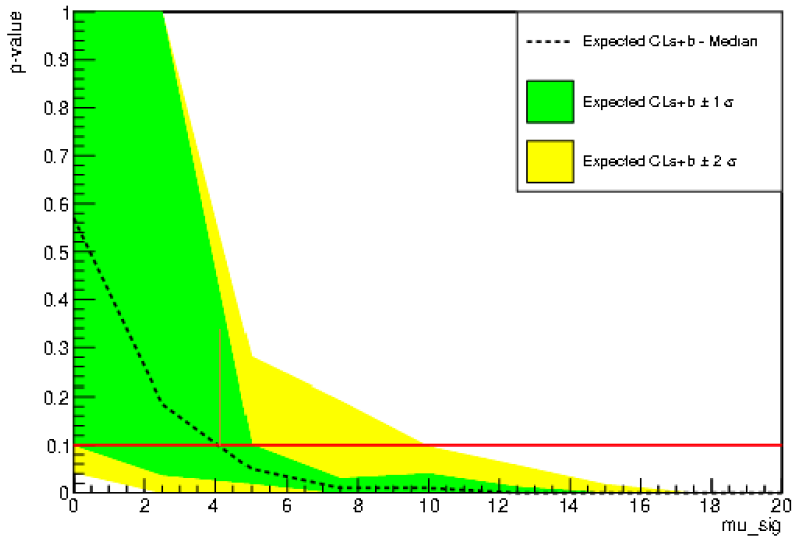




g1 = 0.05

mu_sig = 3.5027

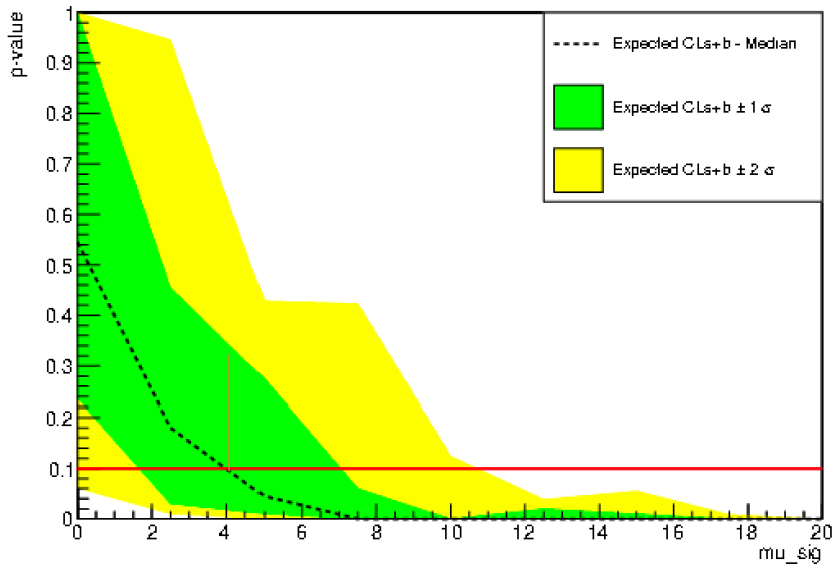
cross_section = 1.44e^-48



g1 = 0.118

mu_sig = 4.0625

cross_section = 1.12e^-48



g1 = 0.13

mu_sig = 3.9835

cross_section = 1.05e^-48

To do

- Try lower WIMP mass (10GeV) and see how the sensitivity changes.

What's new:

- Figure out what's causing the error.
  - Constant pp value→ in the code(for HypoTestInversion), remove any constant parameters → number of parameters are not consistent.
- Update the Low_NR_Groups, re-generate the workspace.
  - No more problem running the LZStats.
- Compare the two versions of code and workspaces

Code (pp)

Before	After
a0_tmp = bckg_rate * exposure = bckg_rate*livedays*fiducial_mass = 542.16 a_pp = a0_tmp mu_pp = Range (507, 574) sigma_pp = systematic_uncertainties * a0_tmp = 2% * 542.16 ~10	a0_tmp = bckg_rate * exposure = bckg_rate*livedays*fiducial_mass = 542.16 a_pp = a0_tmp mu_pp = a0_tmp sigma_pp = systematic_uncertainties * a0_tmp = 2% * 542.16 ~10

```
w->factory("Gaussian::constraint_pp(mu_pp,a_pp,sigma_pp)");
```

Workspace (comparison)

- Information printed out from workspace:
  - Constraints changed:

Background	Before	After
B8	0.011109	1
DSN	0.011109	1
DetER	0.011109	1
DetNR	0.011109	1
Kr85	0.011109	1
Rn220	0.011109	1
Rn222	0.572416	1
atm	0.011109	1
hep	0.011109	1
pp	0.000521151	1
vvBB	0.825786	1

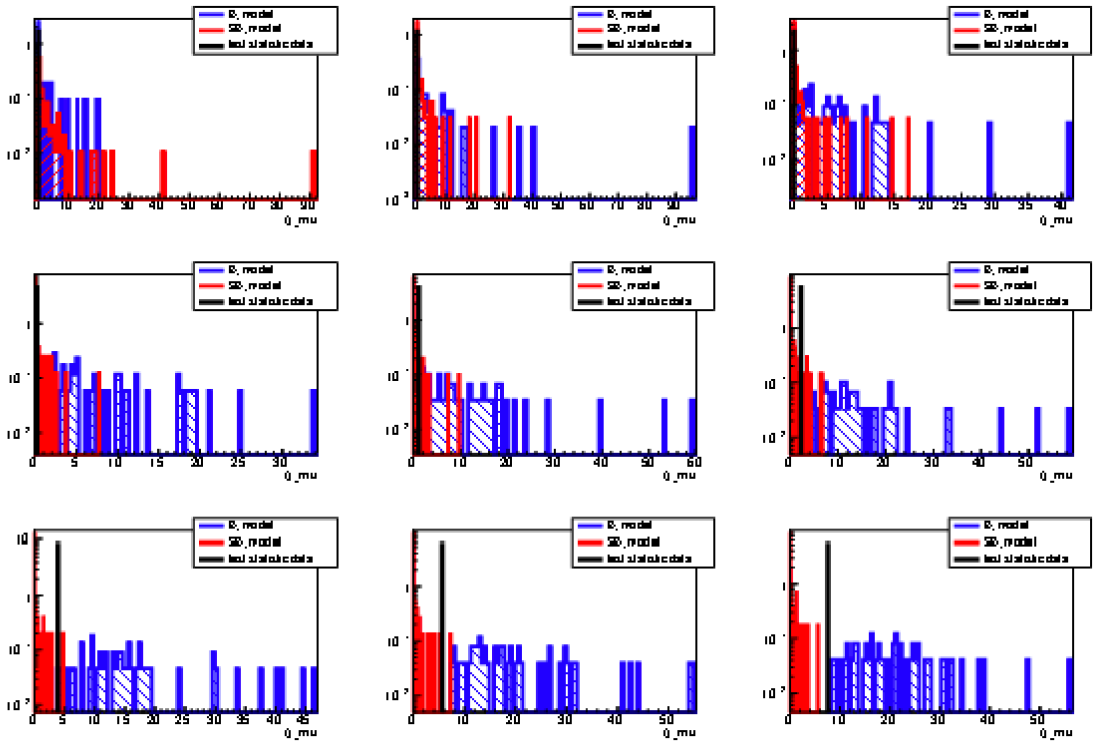
Constraint: Gaussian distribution of
(x=mu_pp
mean = a_pp,
Sigma = sigma_pp)

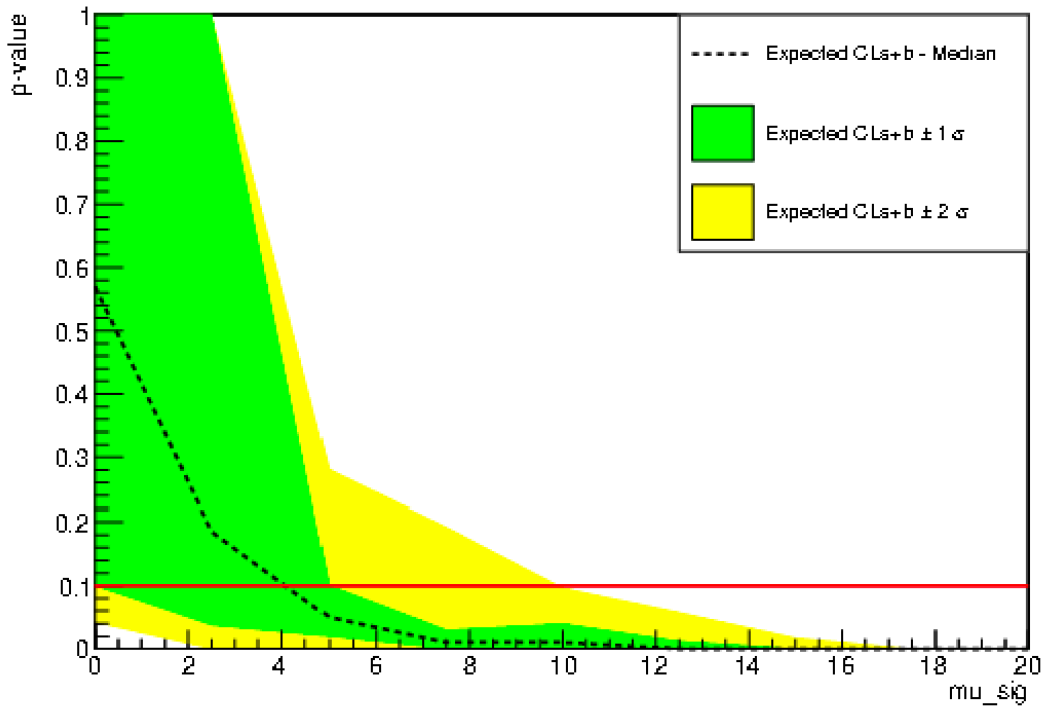
$$\sim \frac{(x-\mu)^2}{\sigma^2}$$

- Total Event Model:
  - Event Model * Total Constraints

	Before	After
Event Model	8.09546e-13	4.80763e-13
Total Event Model	4.62575e-32	4.80763e-13

WIMP (40GeV)




p-value
mu_sig
Expected CLs+b - Median
Expected CLs+b ± 1 σ
Expected CLs+b ± 2 σ

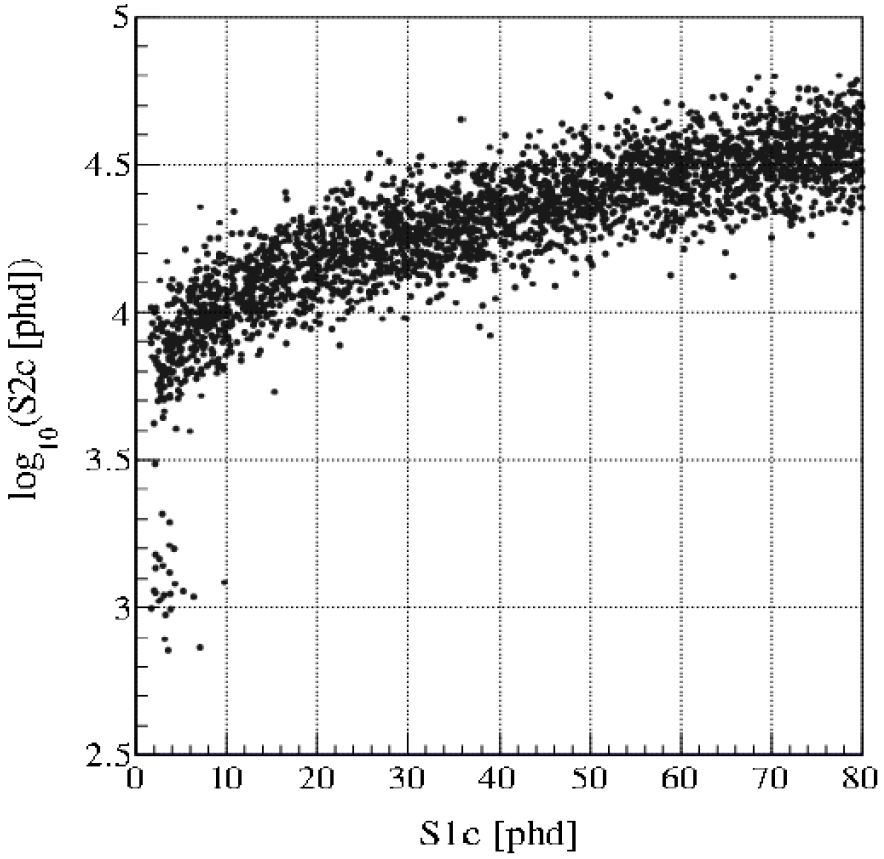
What’s done

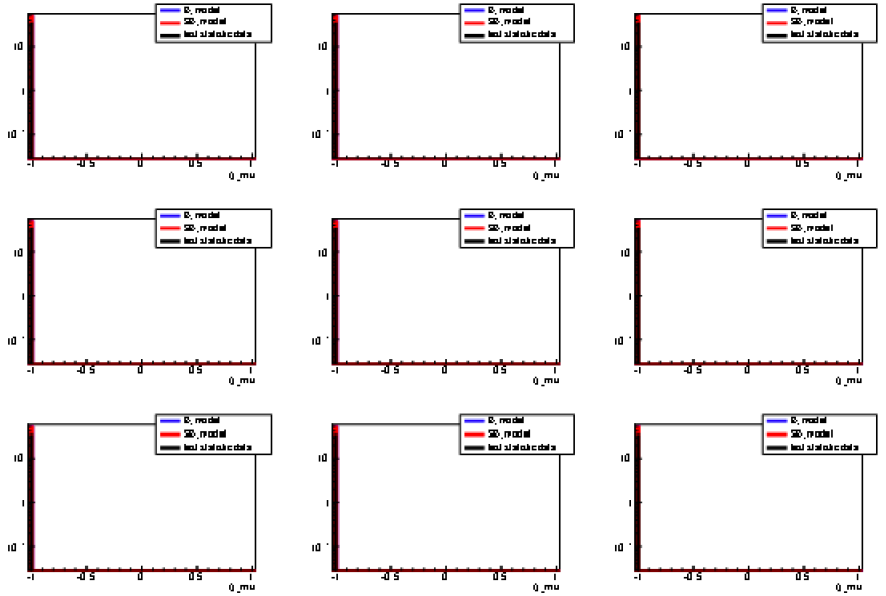
- LZNESTUtils: Change to a new branch
- PdfMakers: compile the background code successfully
- LowR_NR: passed 12 root files (1 signal +11 backgrounds) to make a workspace (1 root file)
- LZStats: run the code locally with the workspace generated from the LowR_NR

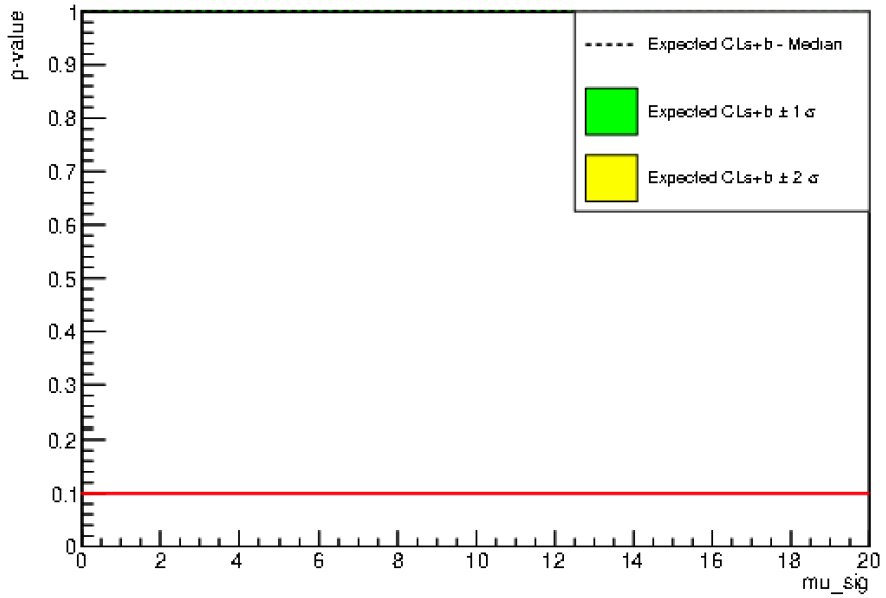
Running LZStats

- Frequentist Analysis (limit setting)
  - Confidence level: 90%
  - Fiducial mass (kg): 5600
  - Livetime(days) : 1000
  - Paritcle mass (GeV): 40
  - MC toys per point : 100
  - Number of Points: 9
  - Min POI: 0
  - Max POI: 20

Problem


log10(S2c [phd])
S1c [phd]
5
4.5
4
3.5
3
2.5
0
10
20
30
40
50
60
70
80

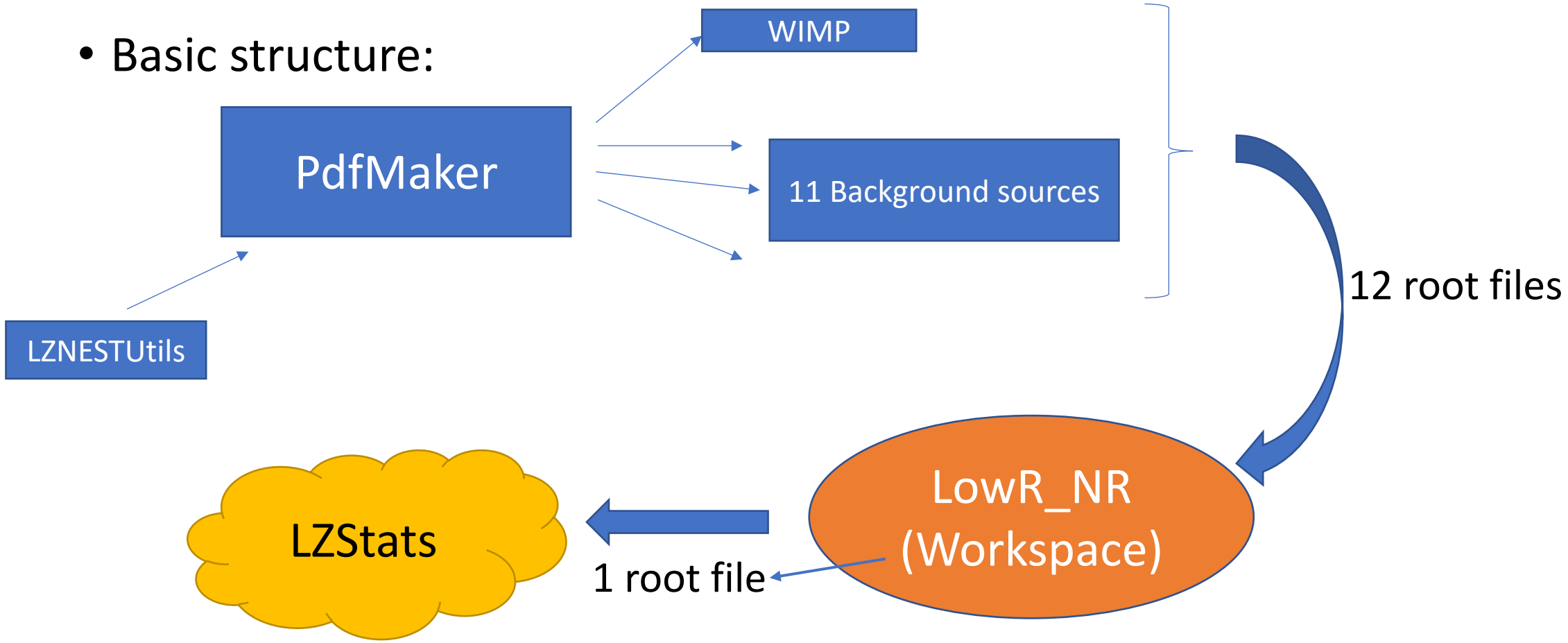



p-value
mu_sig
Expected CLs+b - Median
Expected CLs+b ± 1 σ
Expected CLs+b ± 2 σ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16
18
20

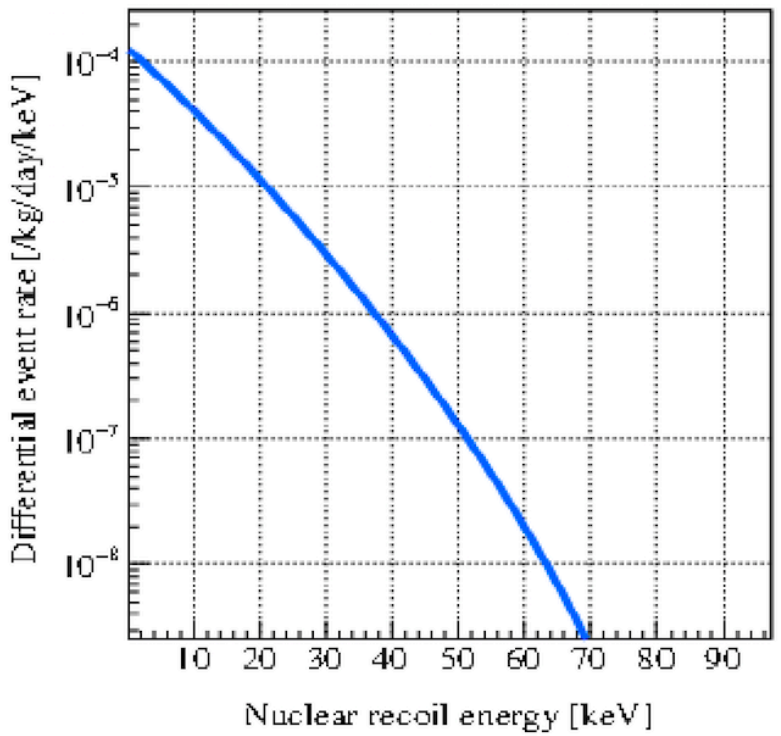
```
Error in <ROOT::Math::FitResult>: FitConfiguration and Minimizer result are not
consistent
Number of free parameters from FitConfig = 12
Number of free parameters from Minimizer = 11
```

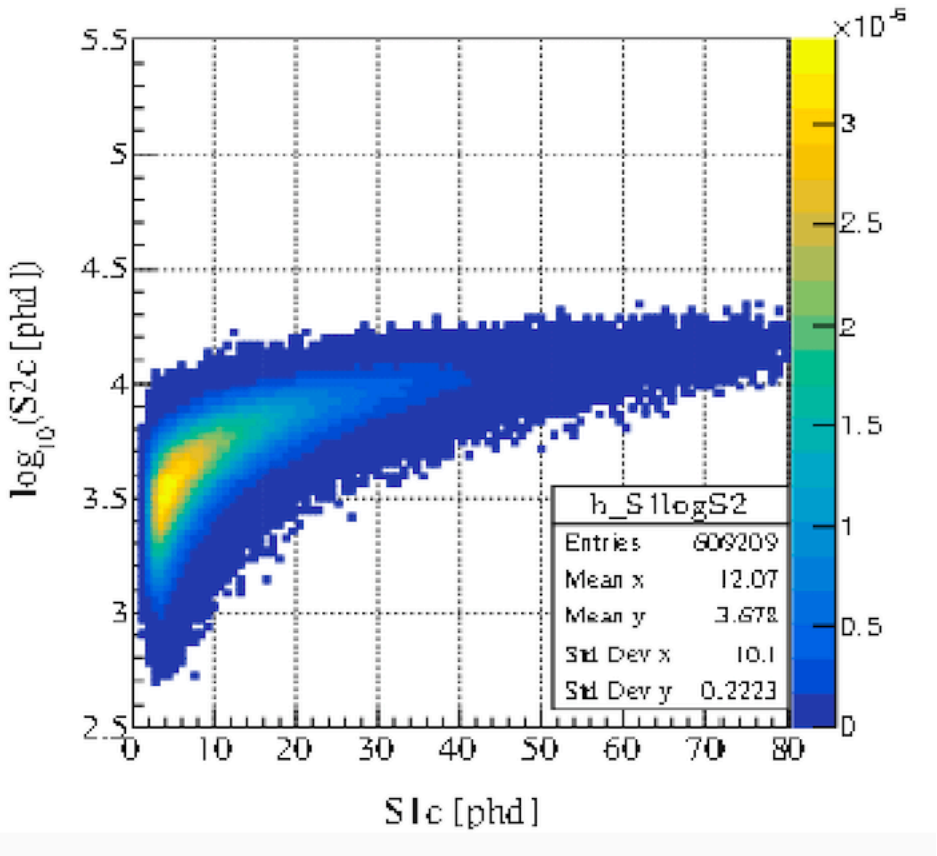
Changed LZStats

- Basic structure:



Output of signal (40GeV WIMP) from PdfMaker





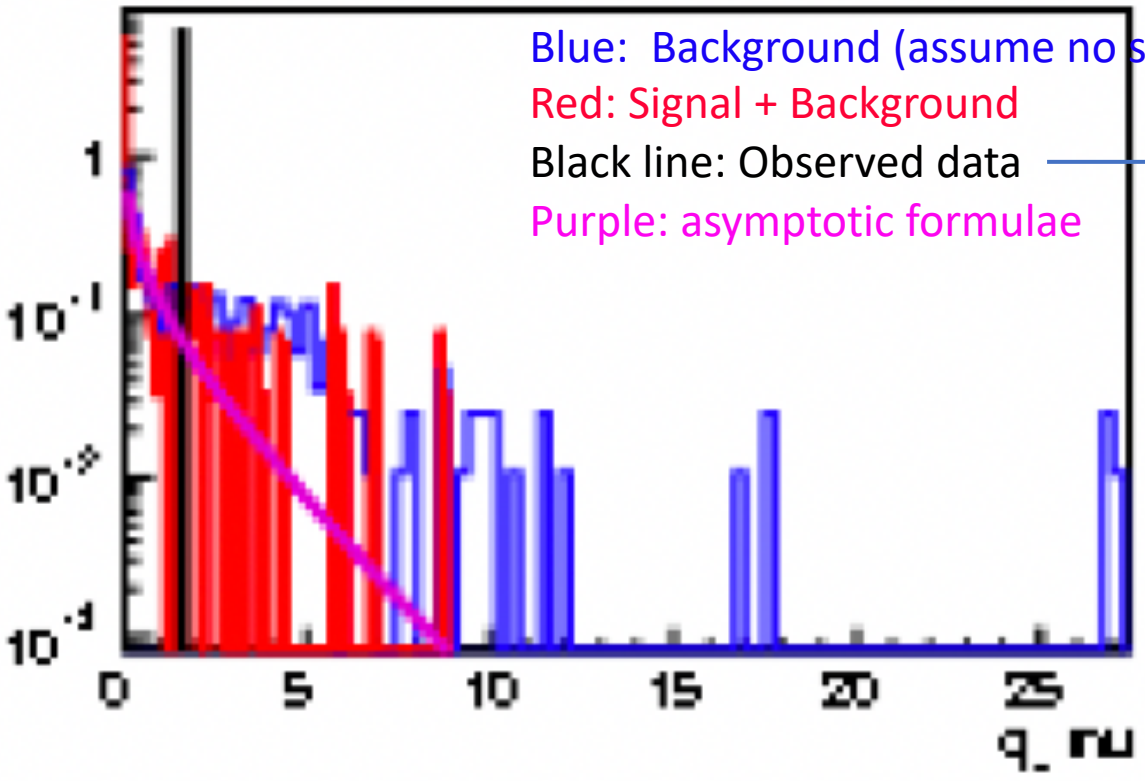
Workspace → RooWorkspace

- Settings
  - WIMP_mass = 40
  - Interaction type = Spin Independent
  - Livedays = 1000
  - Fiducial (kg) = 5600

Problem/To do

- Have trouble compiling the background code, one function in the background code is not defined in the LZNESTUtils → possible solution: change branches in the LZNESTUtils.

Analysis of a single graph



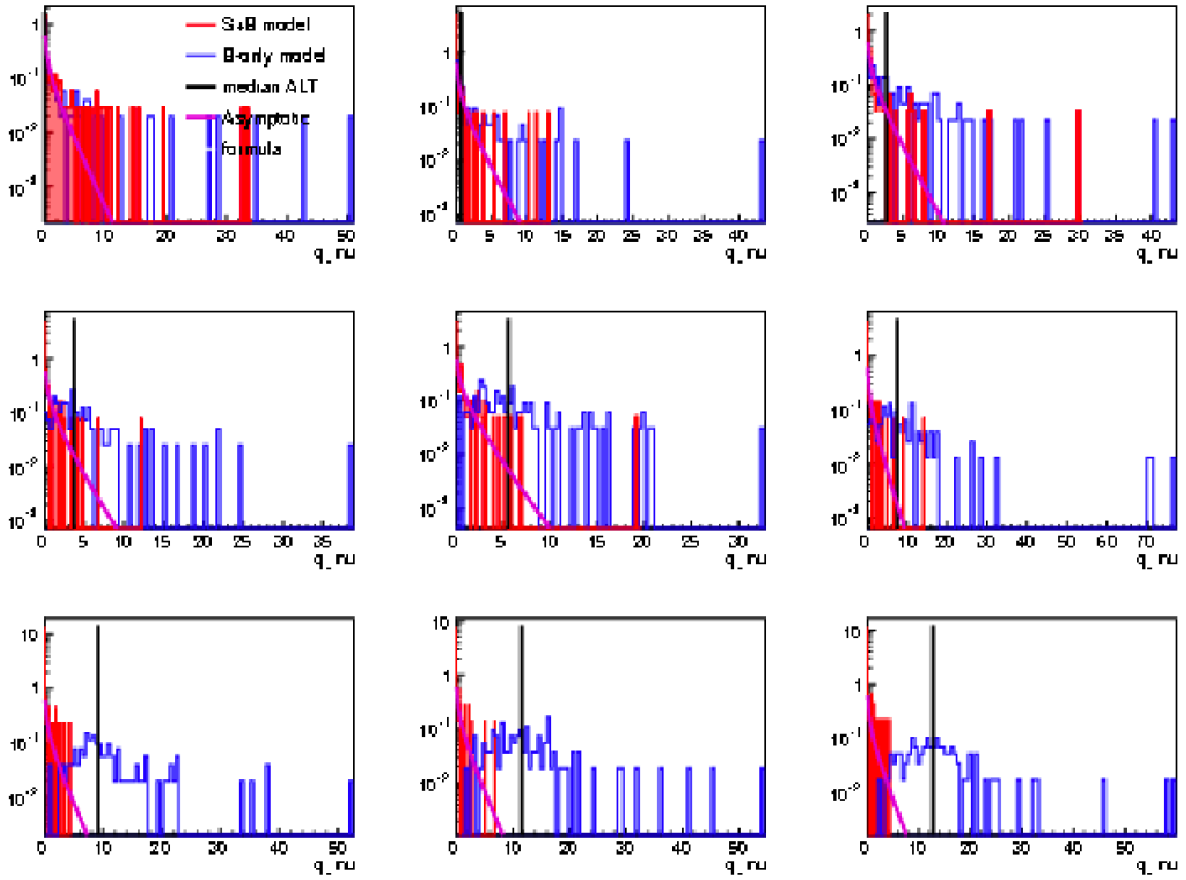
The **median** of the B-distribution

$$t = -2ln\frac{L(B+S)}{L(\text{best fit})}$$

Hypothesis:

- **H0**: The data has both background and signal events fixed signal
- **H1**: The data only has background events floating

Increasing POI (0~15)

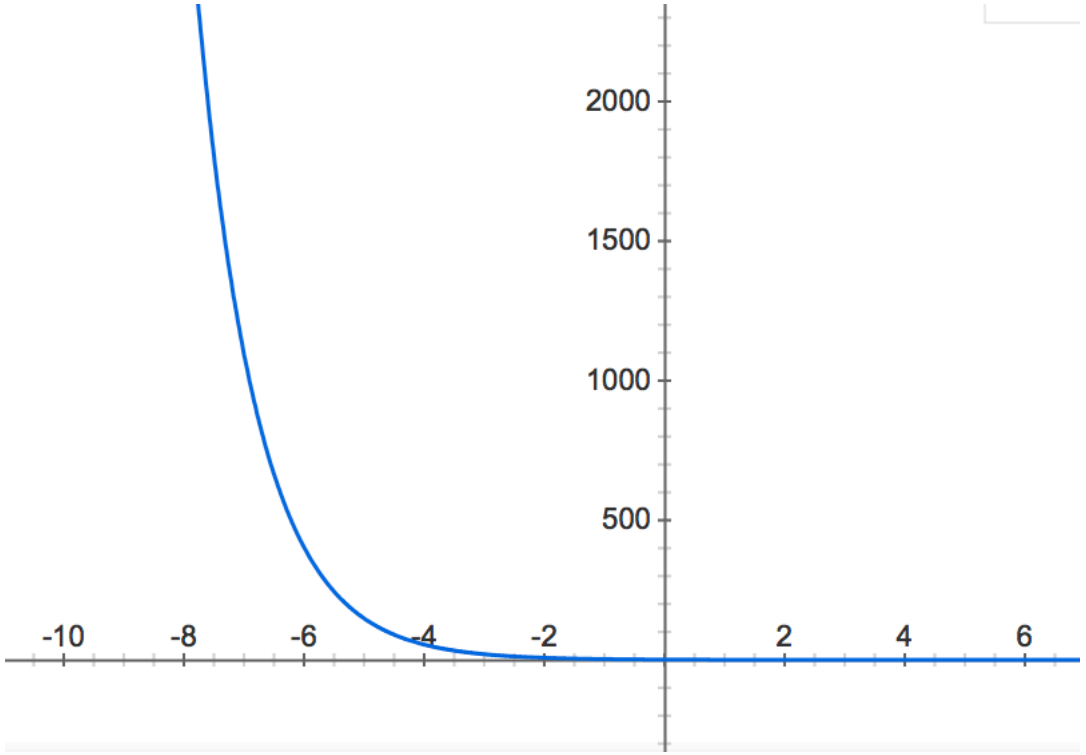


Method

- Background is fixed for different WIMP masses
- For one WIMP mass, increasing values of the parameter of interest (POI)→ the cross section of the WIMP's interaction with Xenon
- Find the upper limit on the POI

$$L(\mu, \boldsymbol{\theta}) = \prod_{j=1}^{N} \frac{(\mu s_j + b_j)^{n_j}}{n_j!} e^{-(\mu s_j + b_j)} \prod_{k=1}^{M} \frac{u_k^{m_k}}{m_k!} e^{-u_k}$$

For high POI → high μsj



Equations & Graphs

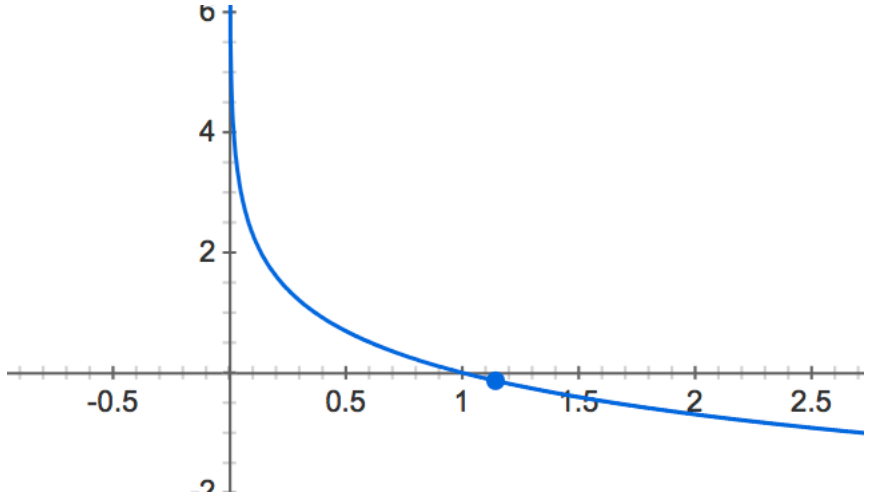
$$\lambda(\mu) = \frac{L(\mu, \hat{\hat{\boldsymbol{\theta}}})}{L(\hat{\mu}, \hat{\boldsymbol{\theta}})}$$

μ : fixed

$\hat{\mu}$: floating

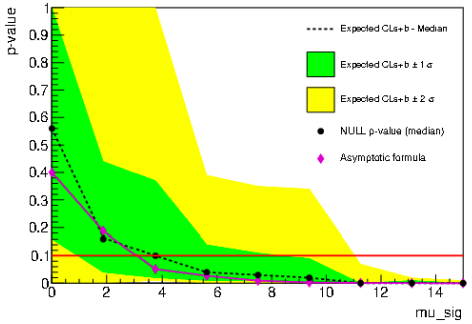
$$t_\mu = -2 \ln \lambda(\mu)$$

$\ln x$ vs x



To do

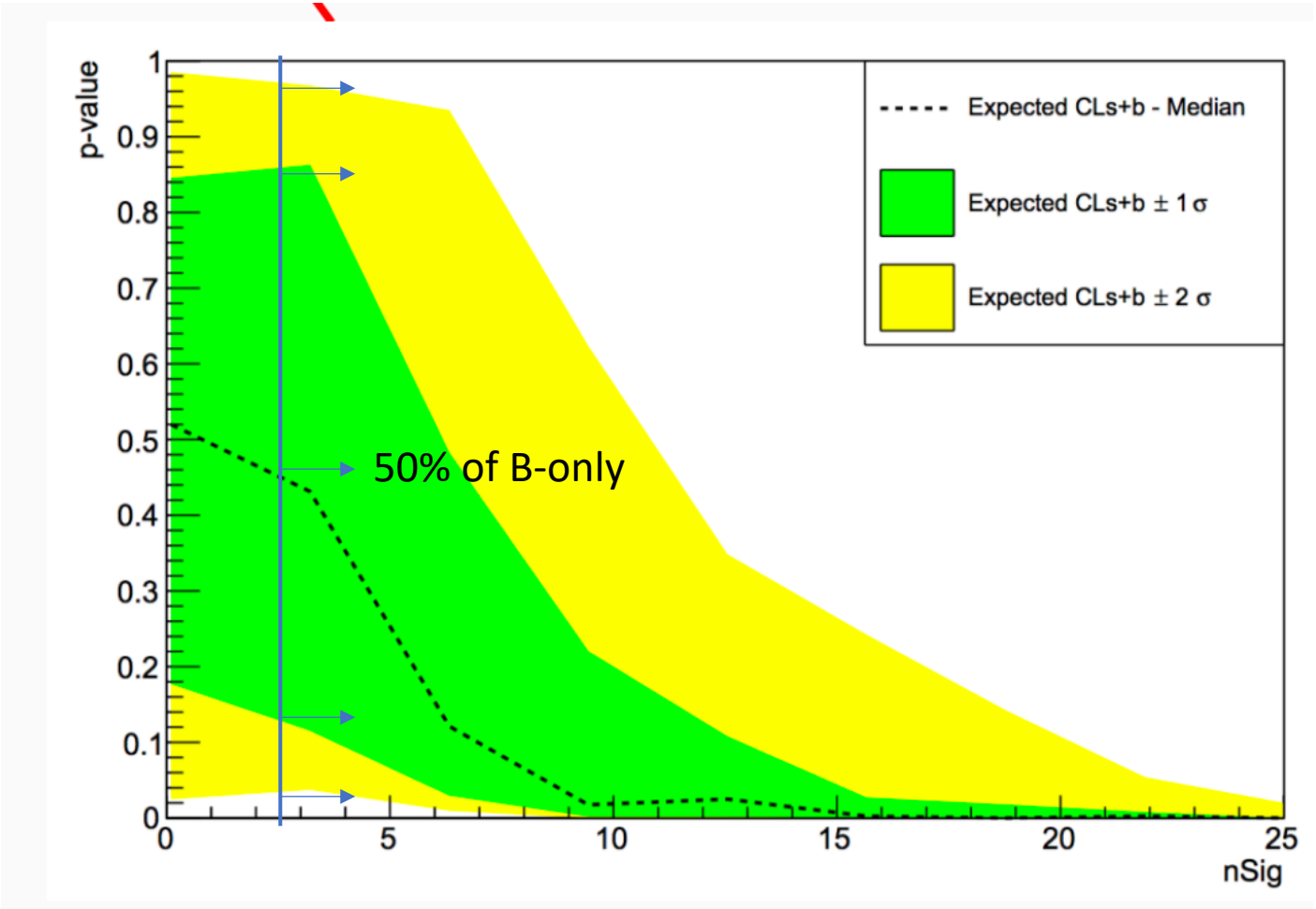
- How to get the upper limit, basically how to get this graph from the nine graphs.
- Analyze the graph



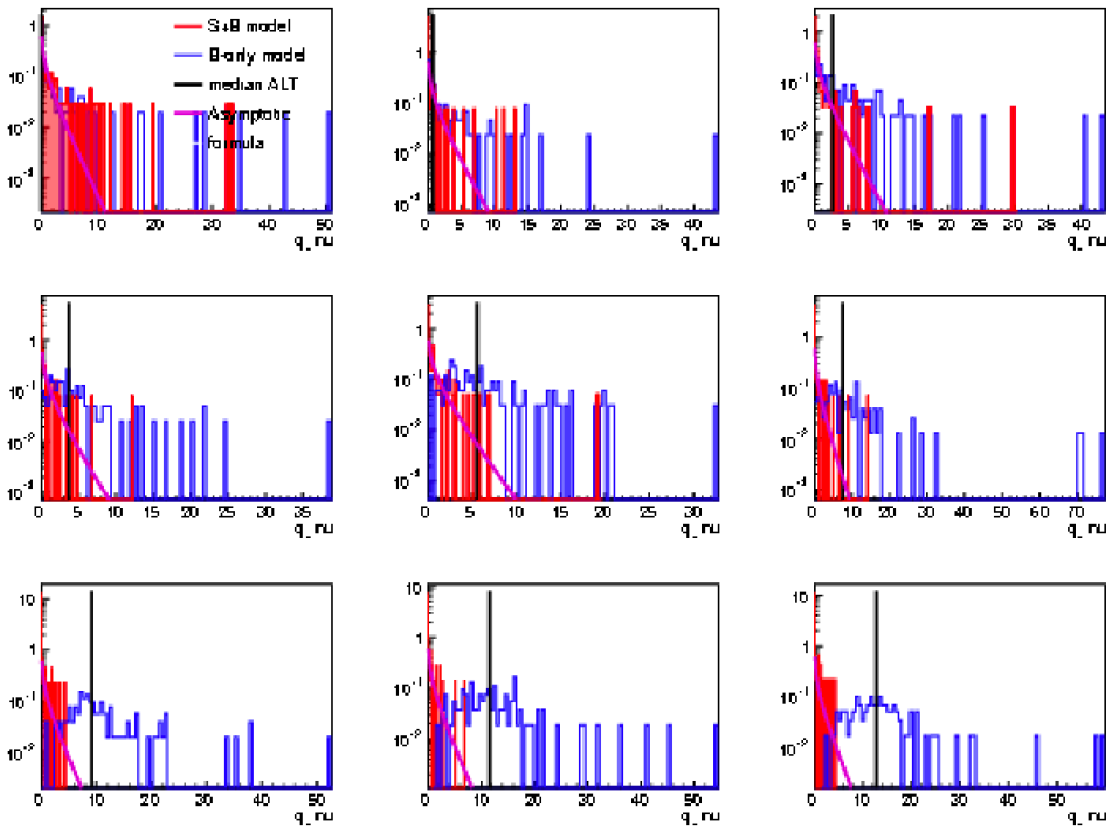
Done:

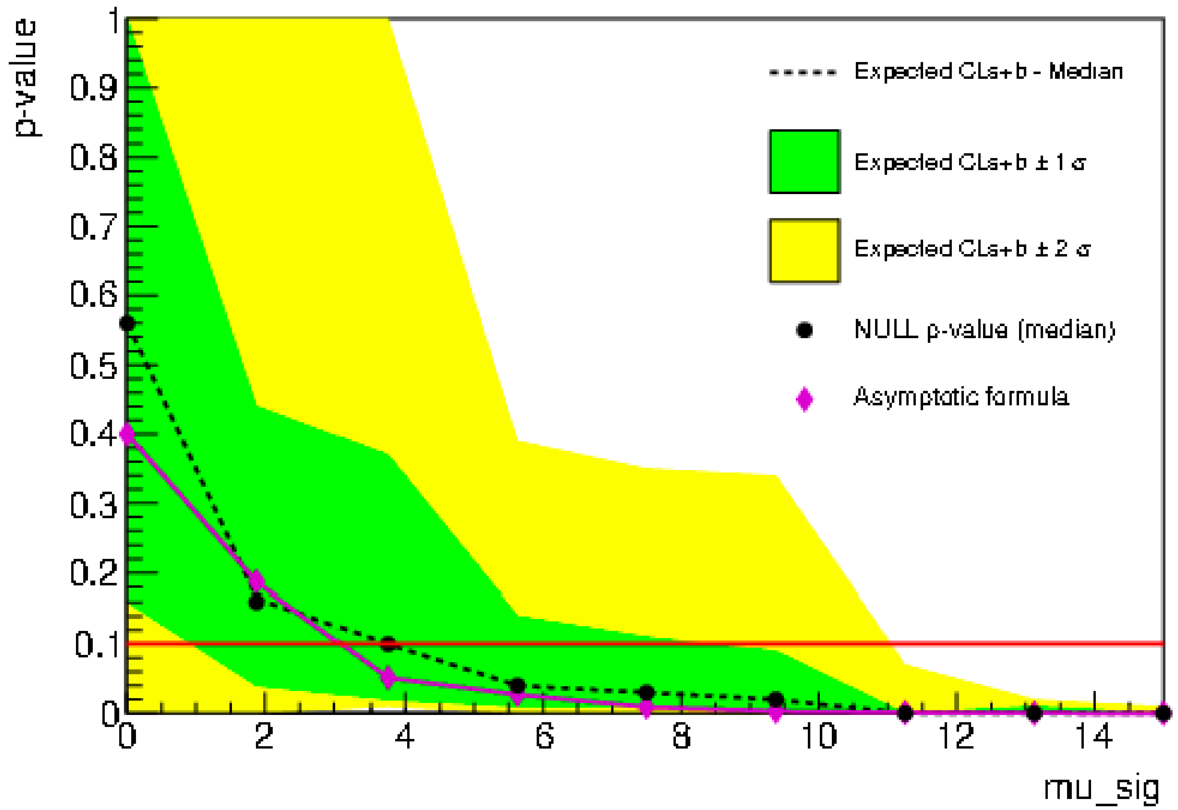
- For mass = 2.0000 GeV
  - ERROR: WIMP histogram is empty for mass 2.0 → Mass 2.0 is too small
- Mass: 10, 16.2222, 27.8256, 46.4159, 66.6667, 100, 200, 1000
- Moved the output from scratch to hdfs.

- Settings: 100 Ntoys, 1e7 samples, take 9 POI, 1000 livedays

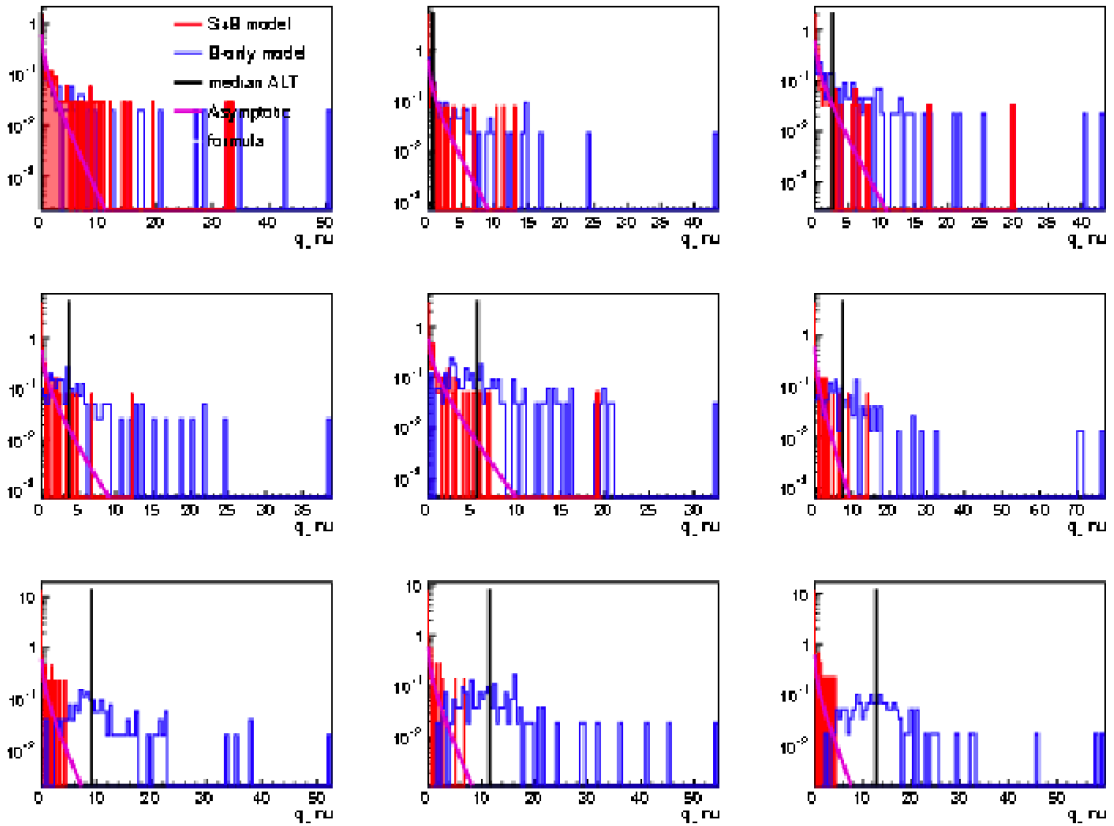

p-value
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
nSig
Expected CLs+b - Median
Expected CLs+b ± 1 σ
Expected CLs+b ± 2 σ
50% of B-only

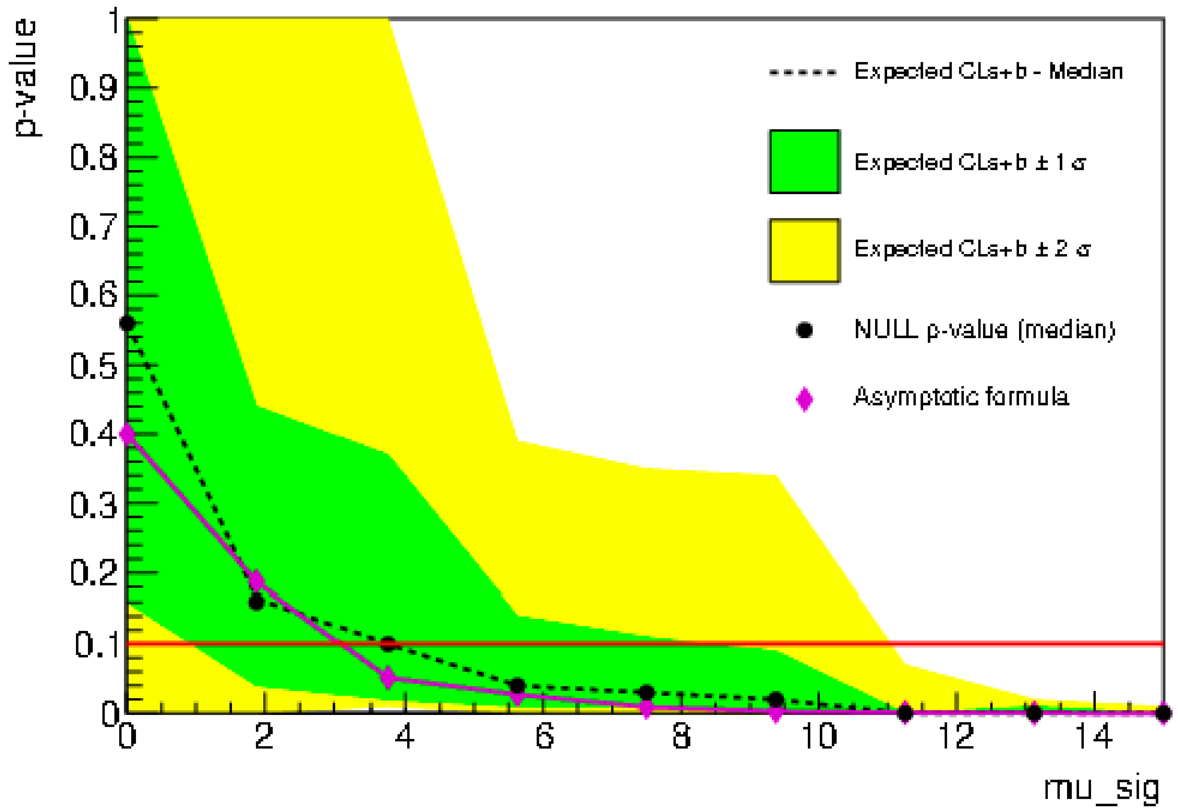
Mass = 16.2222


S+B model
B-only model
median ALT
Asymptotic formula
q_mu

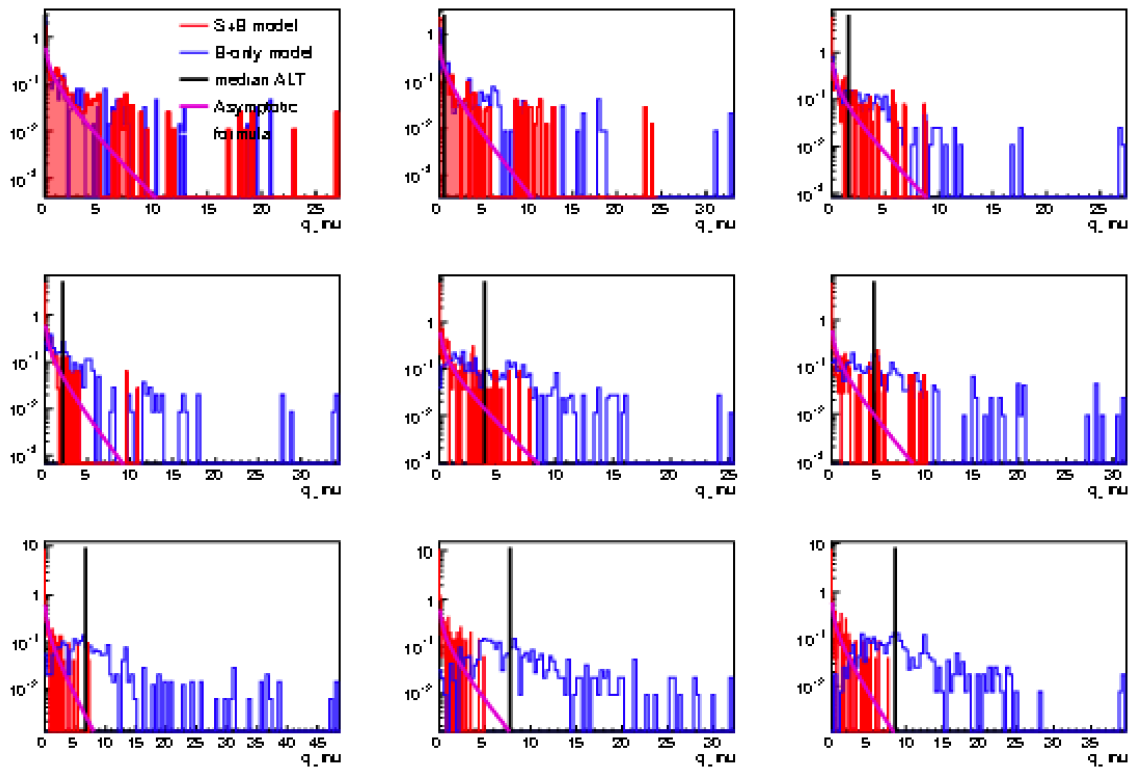

p-value
mu_sig
Expected CLs+b - Median
Expected CLs+b ± 1 σ
Expected CLs+b ± 2 σ
NULL p-value (median)
Asymptotic formula

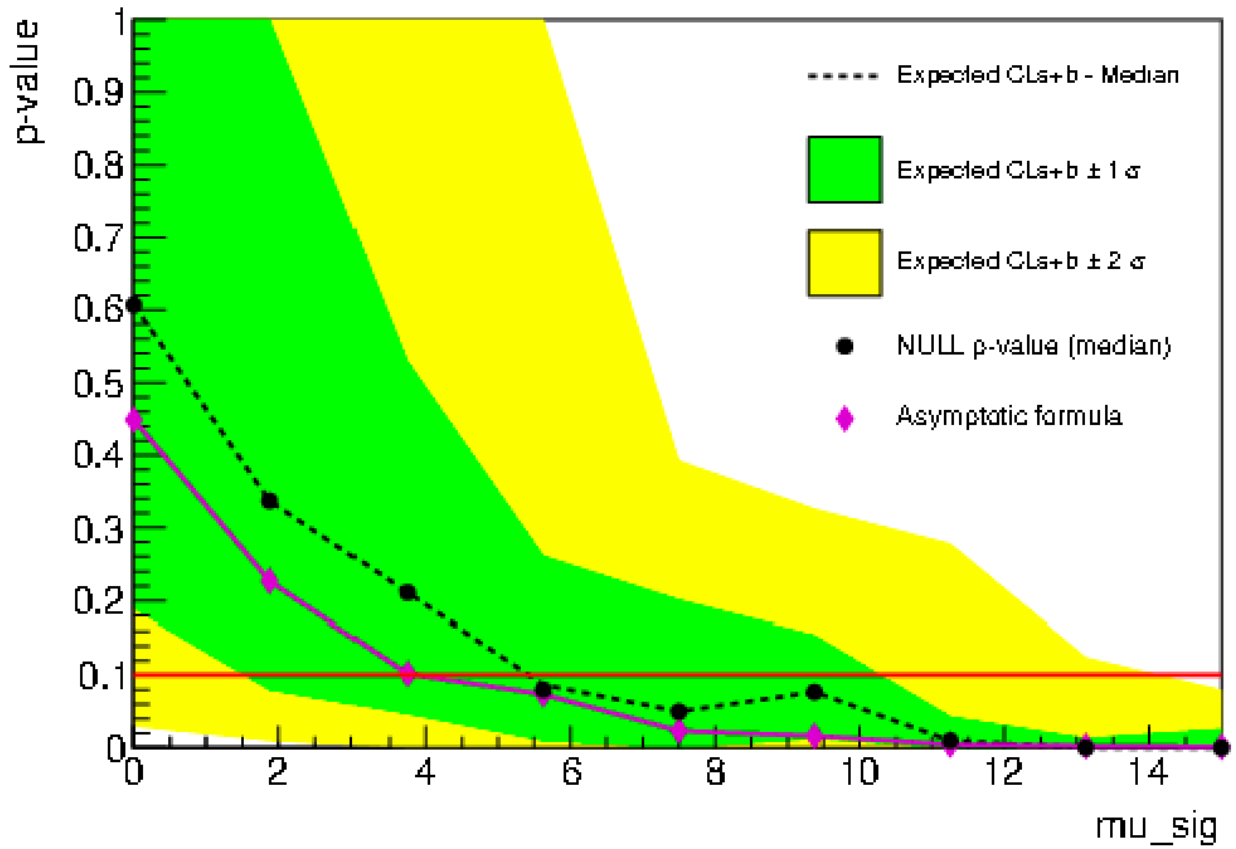
Mass = 16.2222

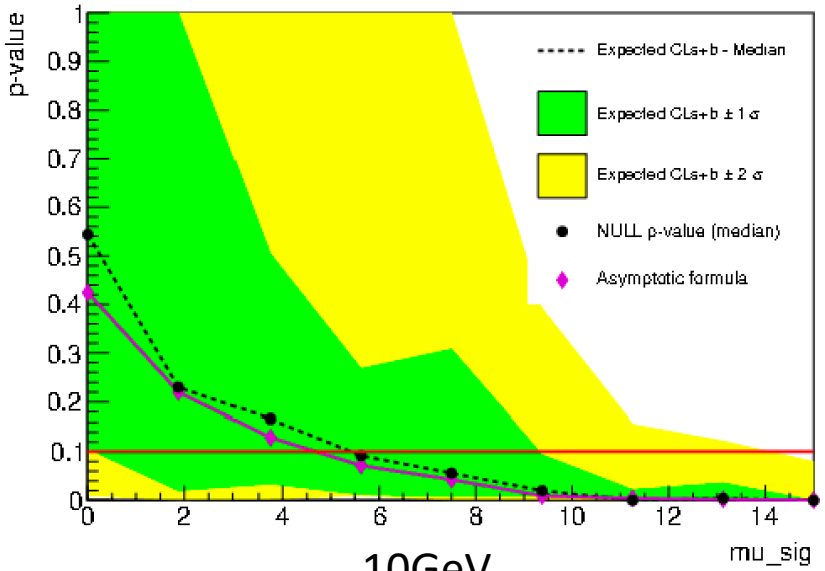

S+B model
B-only model
median ALT
Asymptotic formula
q_mu


p-value
mu_sig
Expected CLs+b - Median
Expected CLs+b ± 1 σ
Expected CLs+b ± 2 σ
NULL p-value (median)
Asymptotic formula

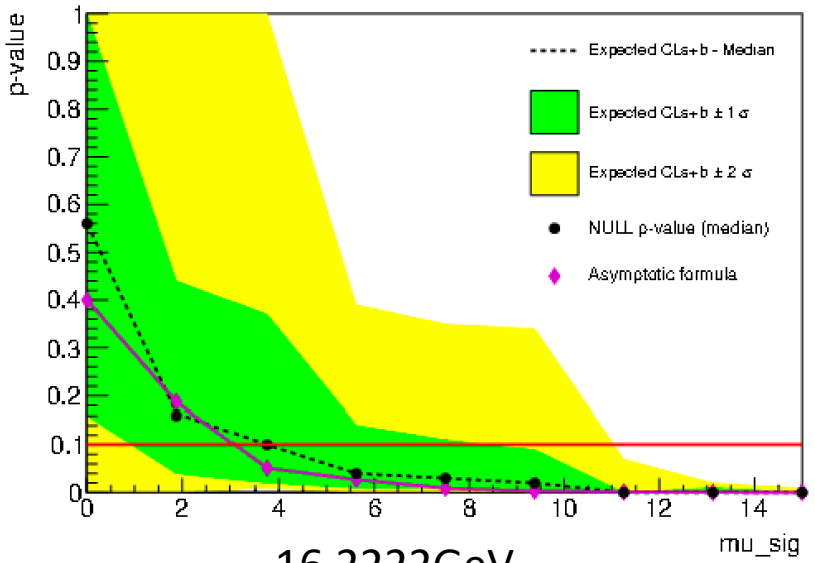
Mass = 66.6667


S+B model
B-only model
median ALT
Asymptotic formula
q_mu

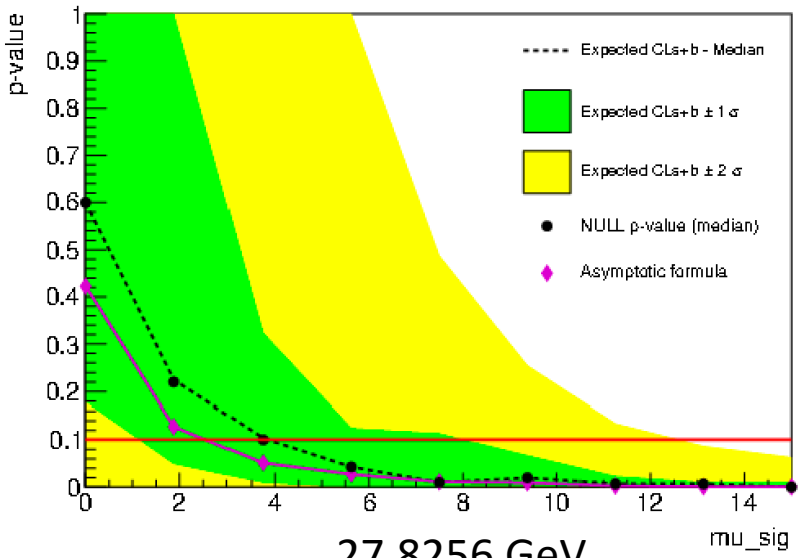

p-value
mu_sig
Expected CLs+b - Median
Expected CLs+b ± 1 σ
Expected CLs+b ± 2 σ
NULL p-value (median)
Asymptotic formula



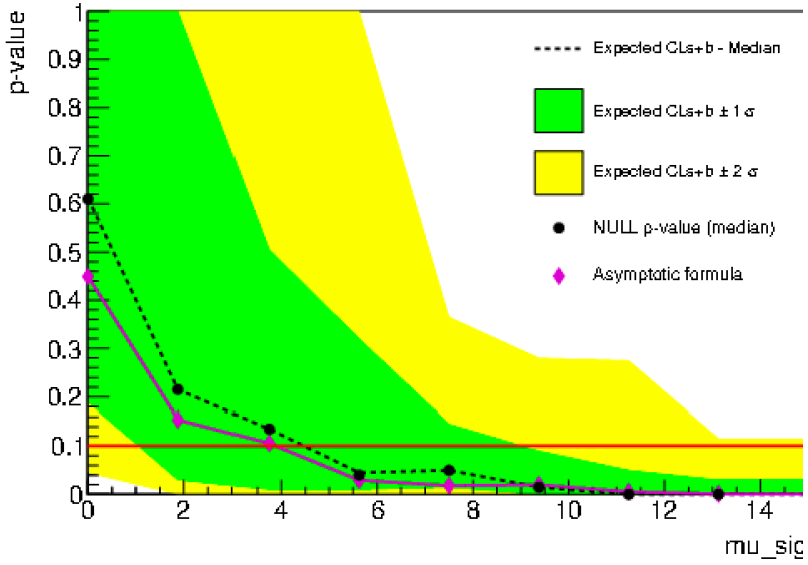
10GeV



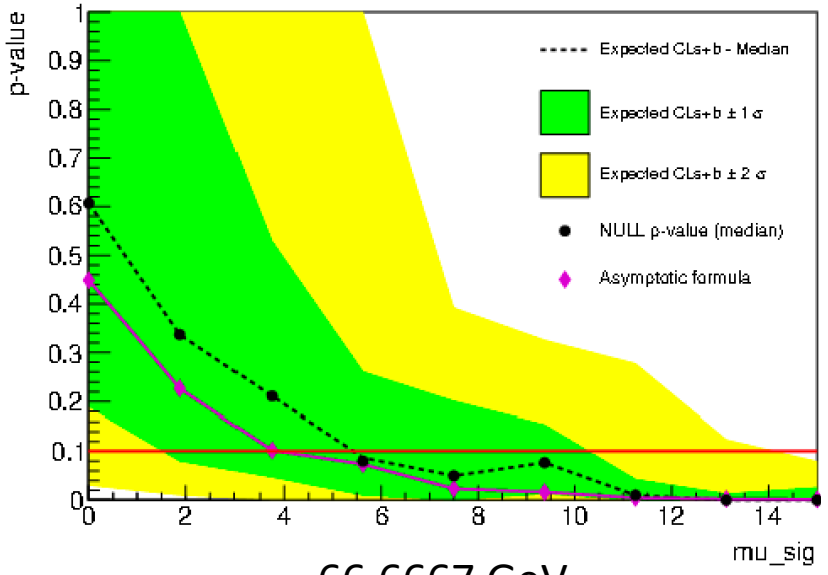
16.2222GeV



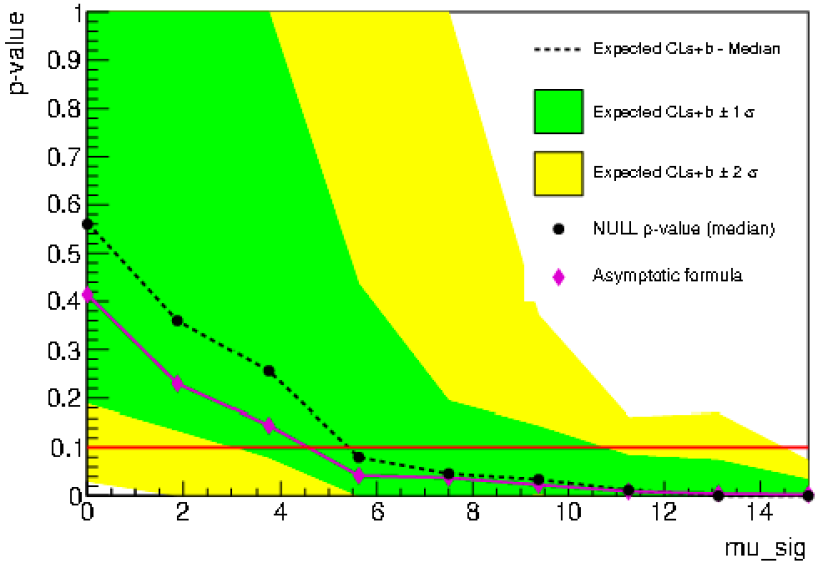
27.8256 GeV



46.4159 GeV

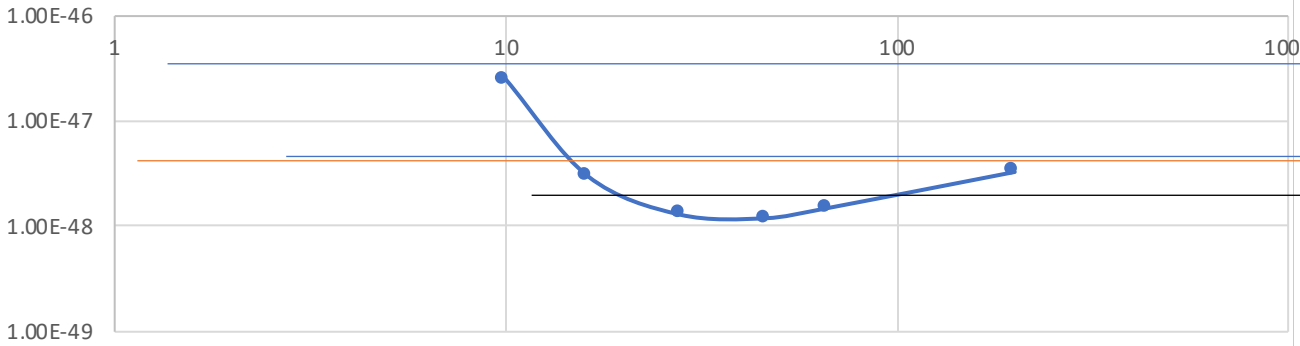


66.6667 GeV

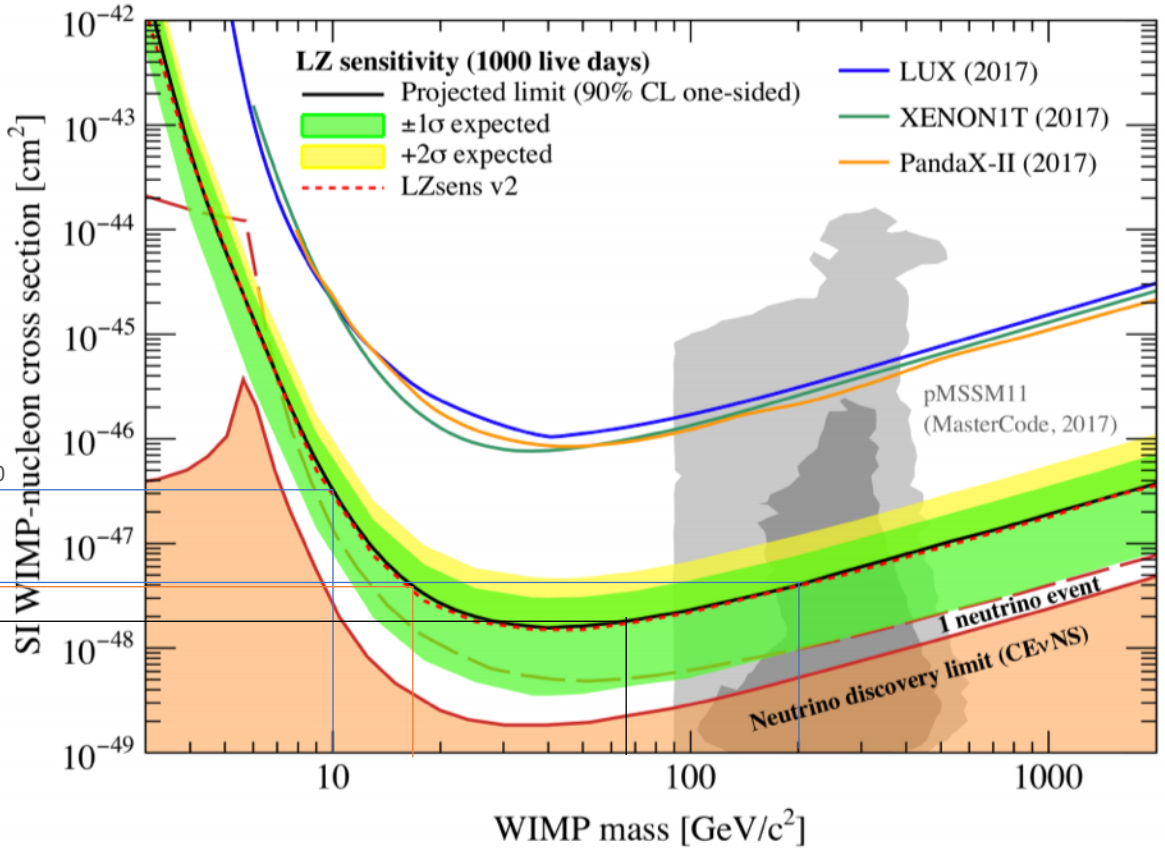


200 GeV

log scale lz sensitivity :



WIMP mass (GeV)



Understanding the structure of LZStats

- **Submit_MassJobs.sh:**
  - calls for the other two scripts, the one that submits jobs to the cluster
  - Kr mass = 2.0000 & 66.6667
  - #jobs for each mass = 10
- **runWiscJobs.py:**
  - Defines variables and parameters for a job running
- **Submit_lzstats.sh:**
  - When run Submit_MassJobs.sh, each job runs this script on the cluster
- **Setup.sh:**
  - set up the environment

Problem

- For one mass, when extracting 10 tar.gz files, only get one result "…run1"
- Check the error text, ImportError

```
ImportError: /cvmfs/lz.opensciencegrid.org/external/Python/2.7.15/x86_64-centos7
-gcc7-opt/lib/python2.7/lib-dynload/array.so: undefined symbol: _PySlice_Unpack
Info in <RooWorkspace::SaveAs>: ROOT file ./output/lzstats-LZ projected 1e7-WIMP
```

- Ask Jonathan:
  - For the Jobs submitted to the cluster, the python cannot load the yaml package → unable to change the run number → all the runs have the same run number, run1
- The yaml package is exported in setup.sh