

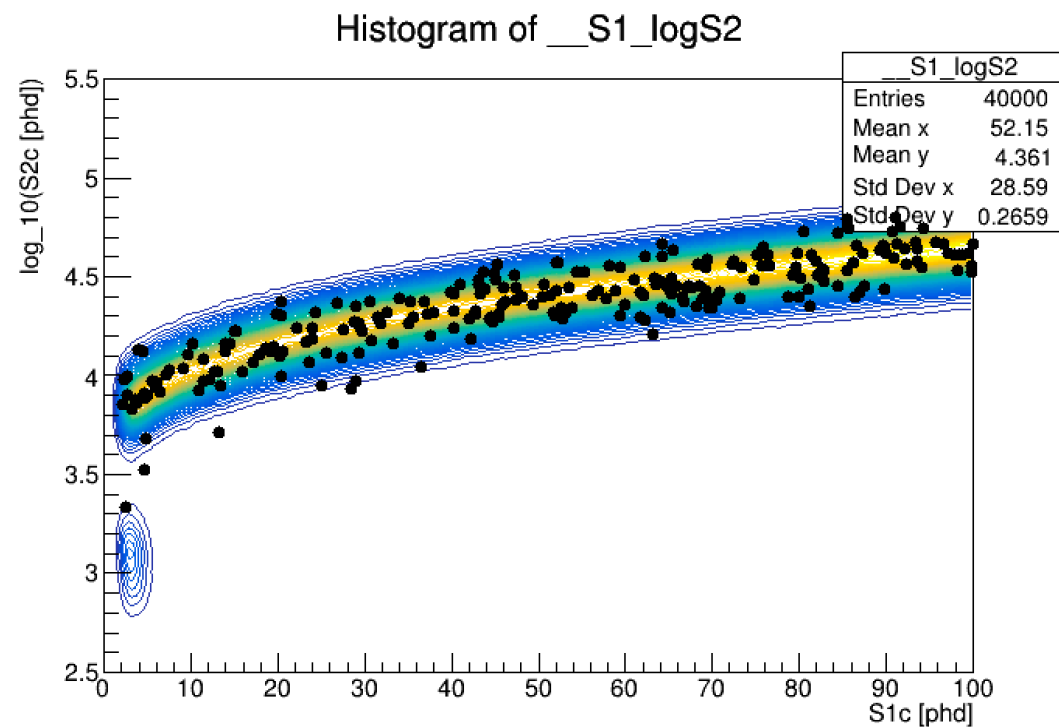
LZStats

Yitong Liu

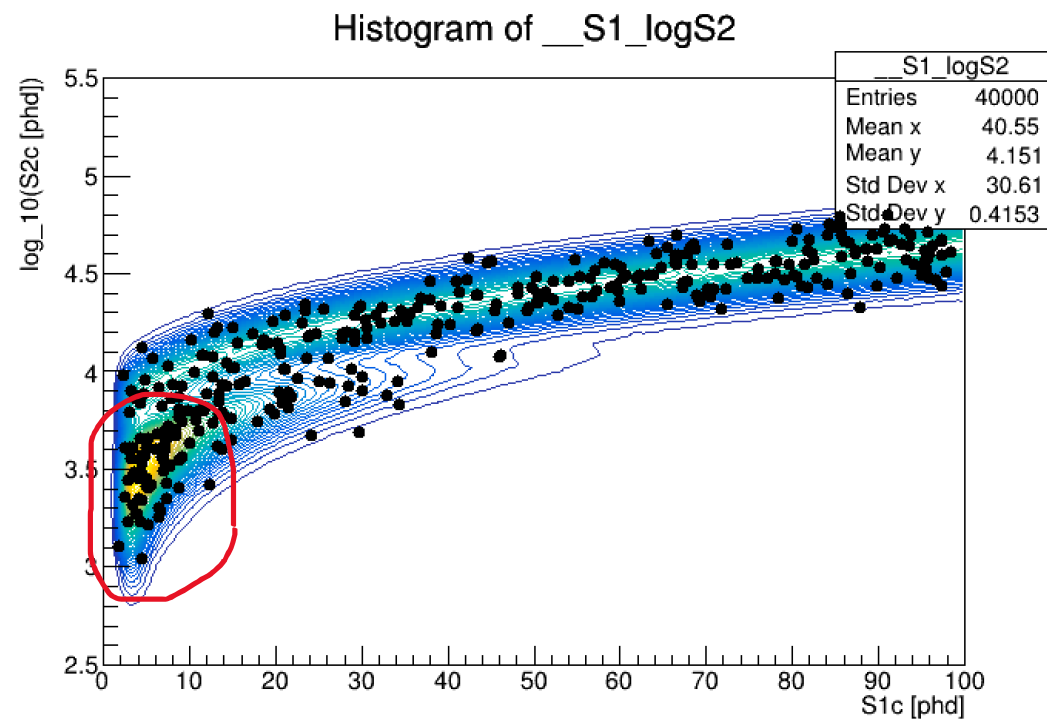
Update

- 10 Runs for with constraint and w/out constraint

Obs_data generated from workspace
60d, 40 GeV
Wall Model (80, 3)



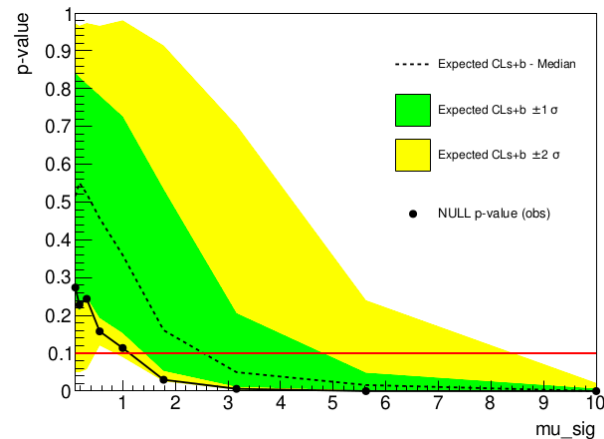
Model+Data,cst
Mu_sig set to 0



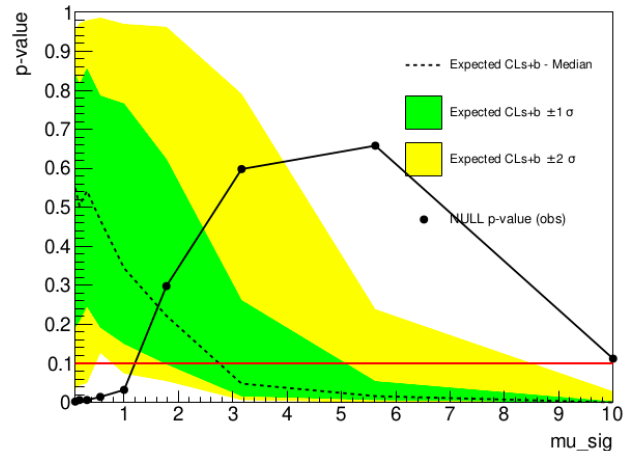
Model+Data,cst

500 Toys

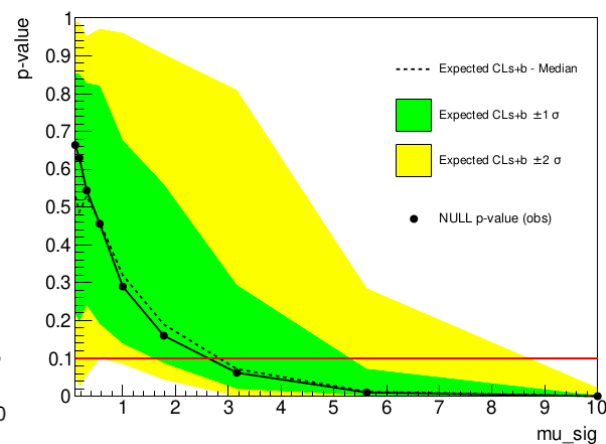
Calculator type = 0



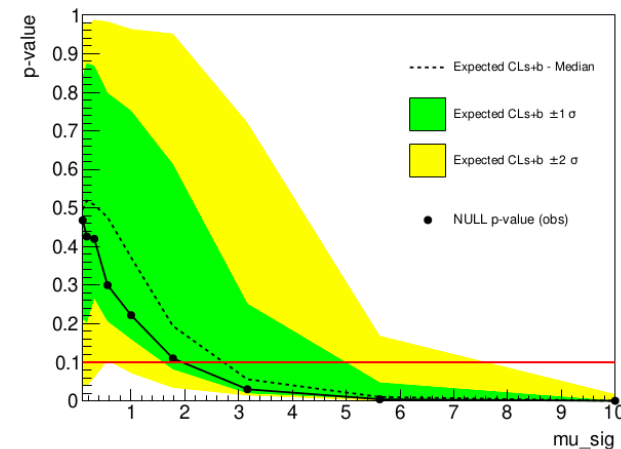
NDWM



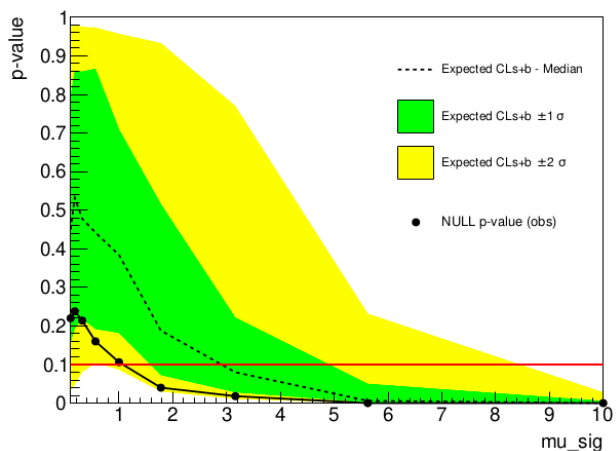
WDNM



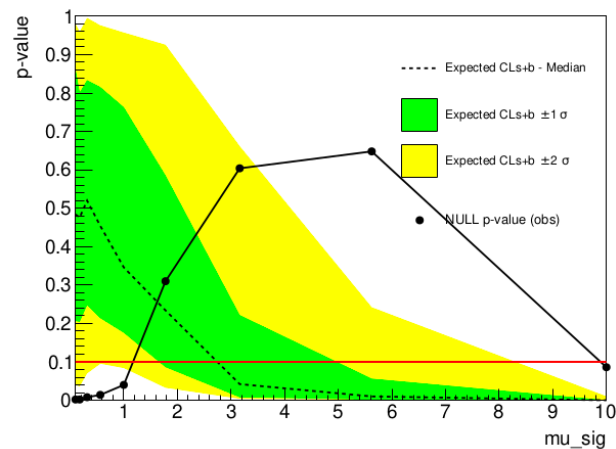
WDWM



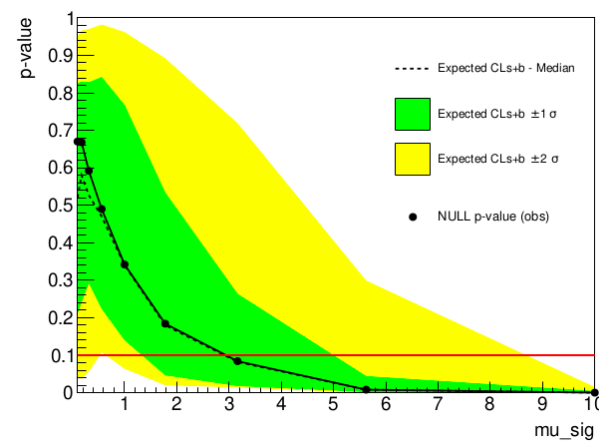
NDNM



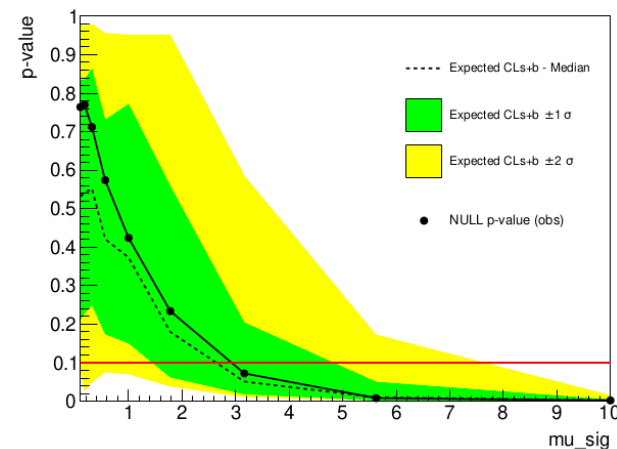
NDWM, cst



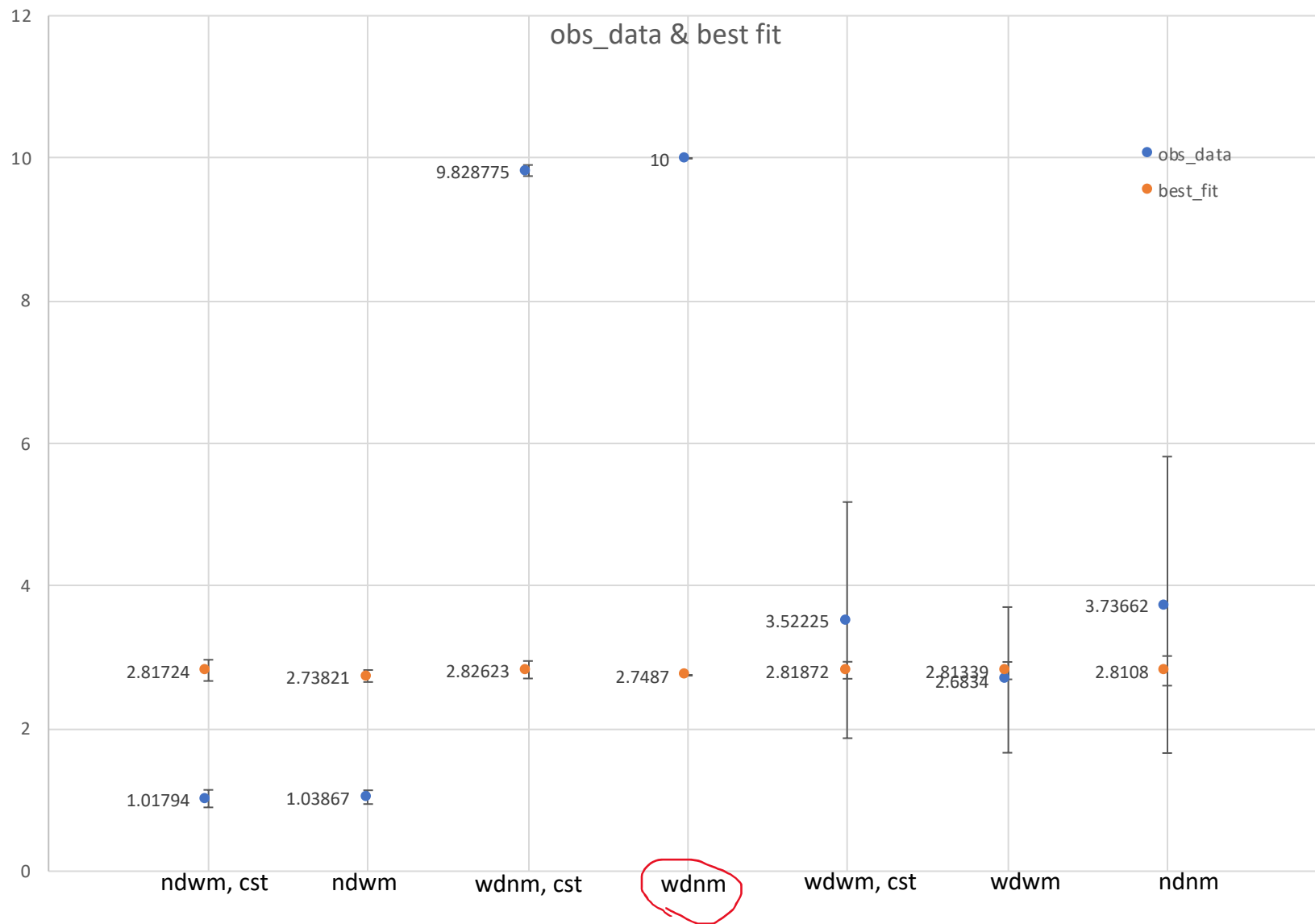
WDNM, cst



WDWM, cst



NDNM

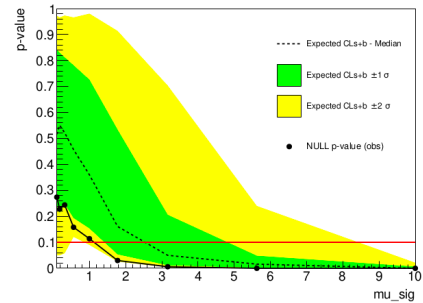


10 runs,
500 Toys
Calculator type = 0
60 d

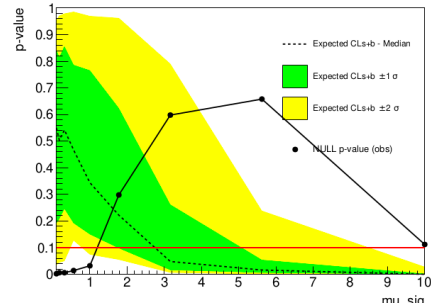
To do

- Run with $1/5$ S1 value on wall model for comparison
- Play with the width of sigma for wall constraint
- Include +/- 1sig, 2 sig in the comparison?

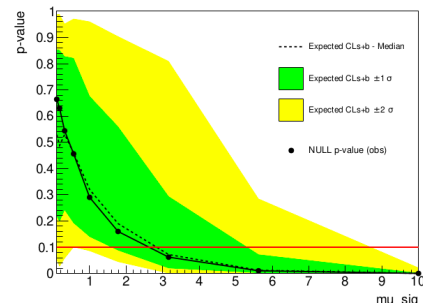
Previous Slides



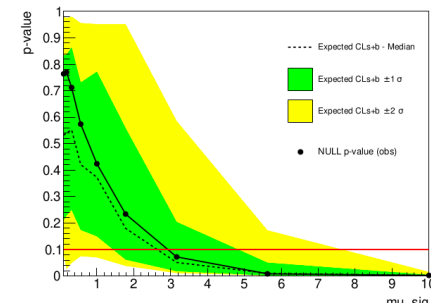
NDWM



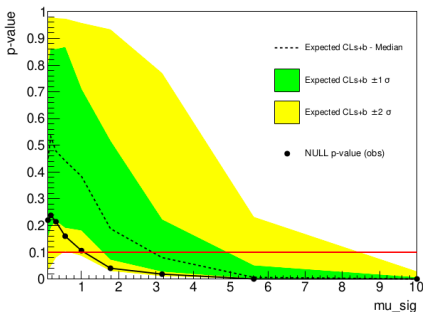
WDNM



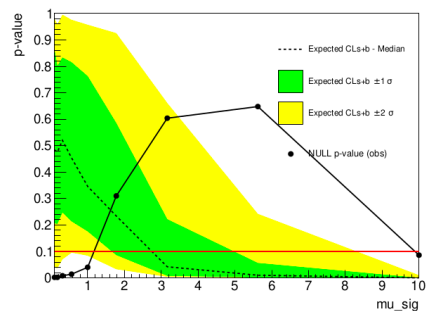
WDWM



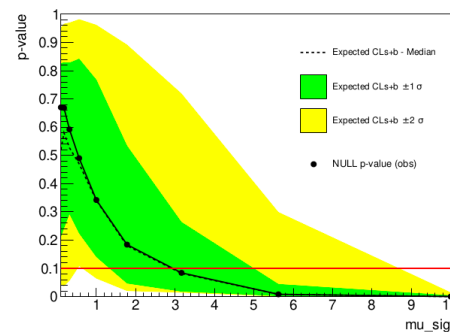
NDNM



NDWM, cst



WDNM, cst



WDWM, cst

Update

- 1. Fixed the entry problem
 - Set initial μ_{sig} value to be 0 (Thanks to Jonathan's intuition😊)
 - Able to run No model + data case
- 2. Tried the discovery case

60 d problem

Sensitivity

OBSERVED DATA

```
*****  
>> Generating a random dataset  
mu_bckg = 247.045  
mu_sig = 0  
mu_total = 247.045  
n_0 (Poisson) = 247
```

Data+model

Generate data.root file

OBSERVED DATA

```
*****  
Data file:  
/afs/hep.wisc.edu/home/liu674/LowE_NR_group/projects/MDC3/DataWithWall.root  
RooDataSet::obs_data[S1,logS2] = 341 entries
```

mu_B8	=	1.36605	+/-	0.0556527	(limited)
mu_beta	=	163.847	+/-	24.5343	(limited)
mu_highnr	=	29.9979	+/-	1.95864	(1
mu_pp	=	0.00842288	+/-	0.000168463	(1
mu_sig	=	<u>105.319</u>	+/-	<u>10.2295</u>	(limited)
mu_vvBB	=	<u>40.251</u>	+/-	21.0395	(limited)
mu_wall	=	0.697606	+/-	0.383162	(limited)

OBSERVED DATA

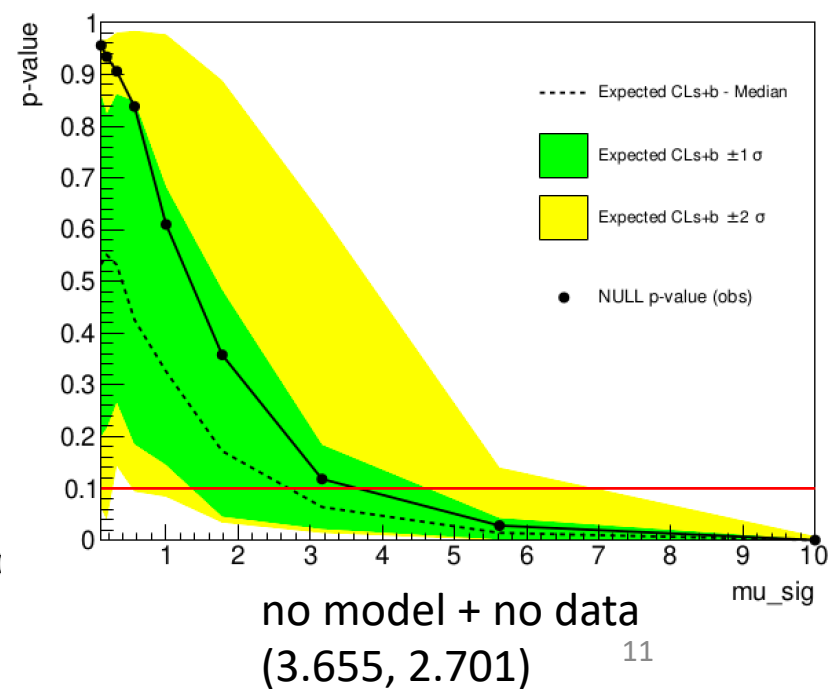
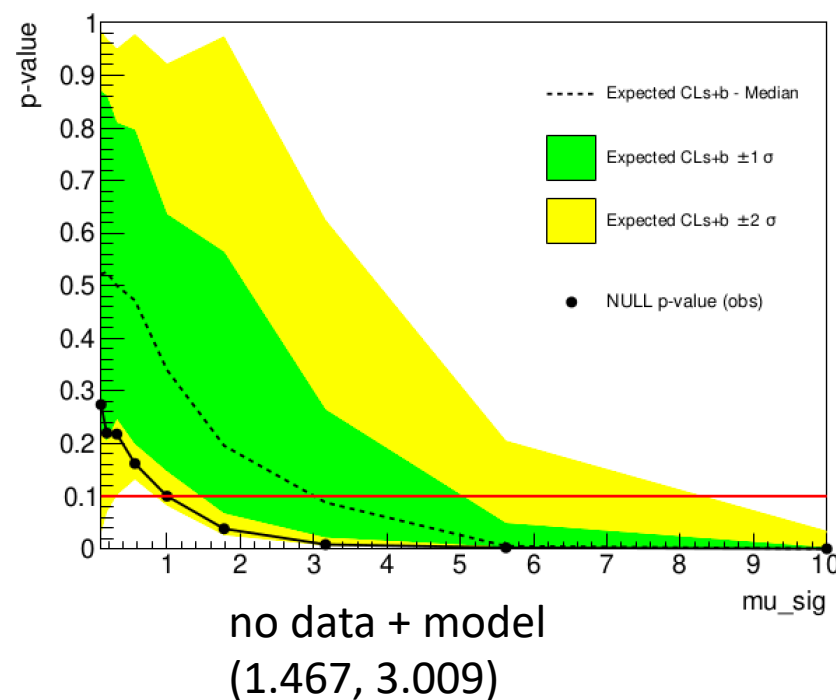
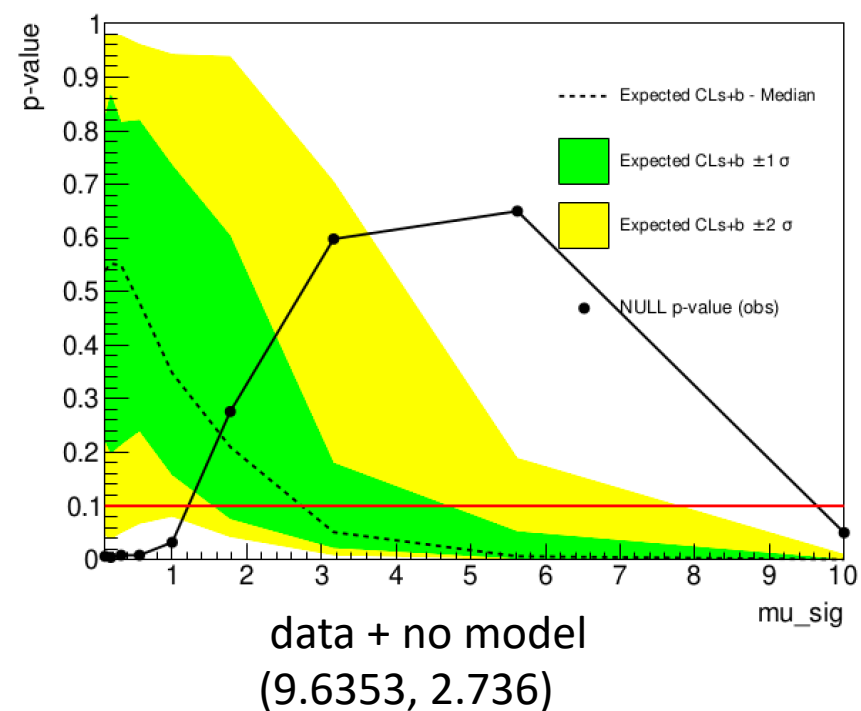
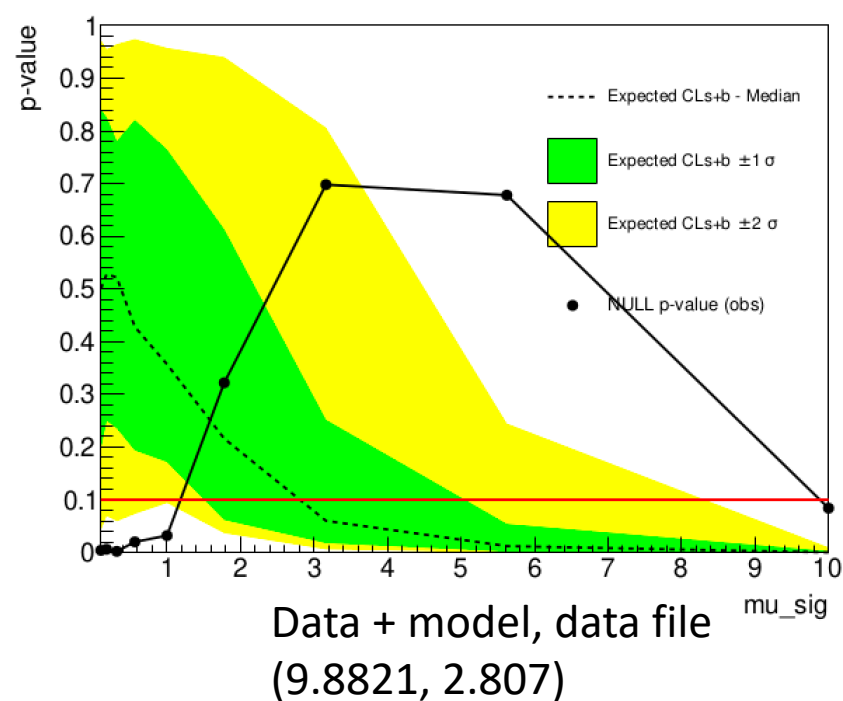
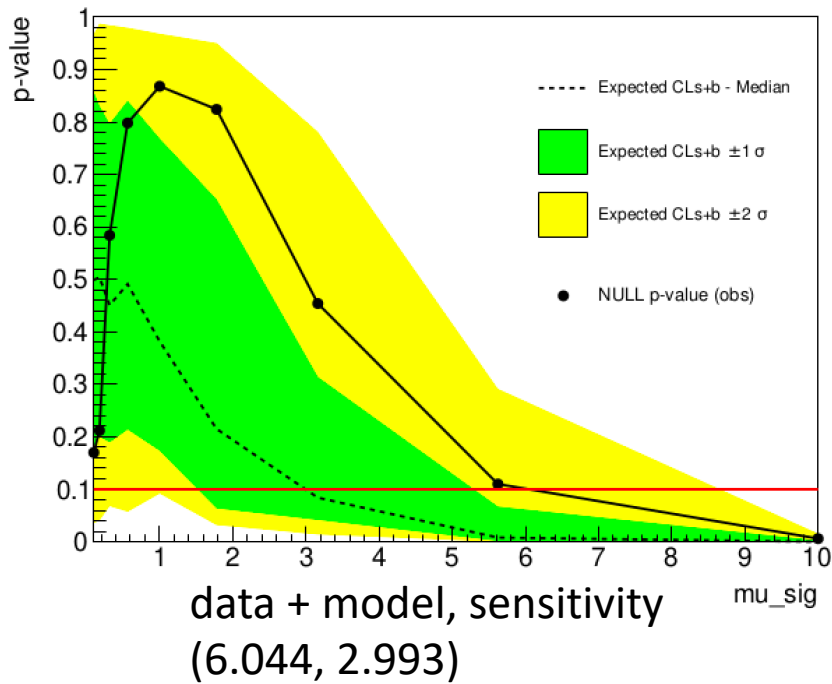
```
*****  
Data file:  
/afs/hep.wisc.edu/home/liu674/LowE_NR_group/projects/MDC3/DataNoWall.root  
RooDataSet::obs_data[S1,logS2] = 340 entries
```

No Data+model

OBSERVED DATA

```
*****  
Data file:  
/afs/hep.wisc.edu/home/liu674/LowE_NR_group/projects/MDC3/DataNoWall.root  
RooDataSet::obs_data[S1,logS2] = 340 entries
```

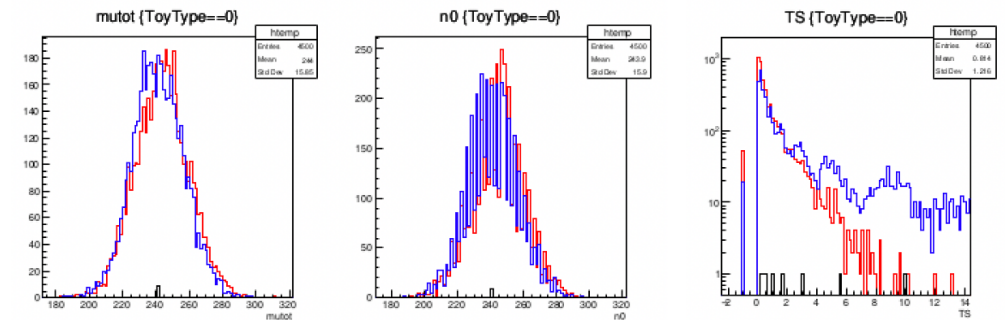
mu_B8	=	1.36777	+/-	0.0546722	(limited)
mu_beta	=	160.101	+/-	25.8269	(limited)
mu_highnr	=	30	+/-	22.5884	(limited)
mu_pp	=	0.00842287	+/-	0.000168458	(1
mu_sig	=	106.25	+/-	<u>10.7453</u>	(limited)
mu_vvBB	=	<u>40.8155</u>	+/-	20.4589	(limited)
mu_wall	=	0.829442	+/-	0.432274	(limited)



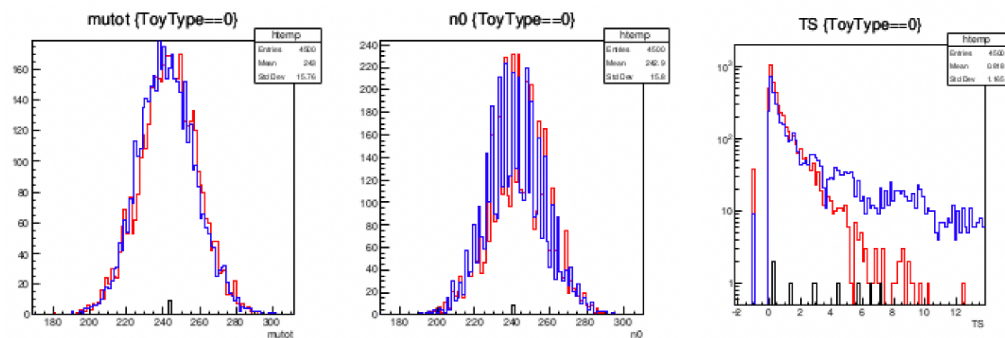
60 livedays
 500 Toys
 Calculator
 Type = 0

	WDWM, sensitivity	WDWM, data	NDWM	WDNM	NDNM
Entries	240	241	240	241	239
Mu_sig	1.38 +/- 1.95	4.36 +/- 2.62	6.63e-6 +/- 0.57	4.36 +/- 2.62	7.04e-13 +/- 0.94
Mu_wall	0.70 +/- 0.45	0.69 +/- 0.45	0.71 +/- 0.45	-----	-----

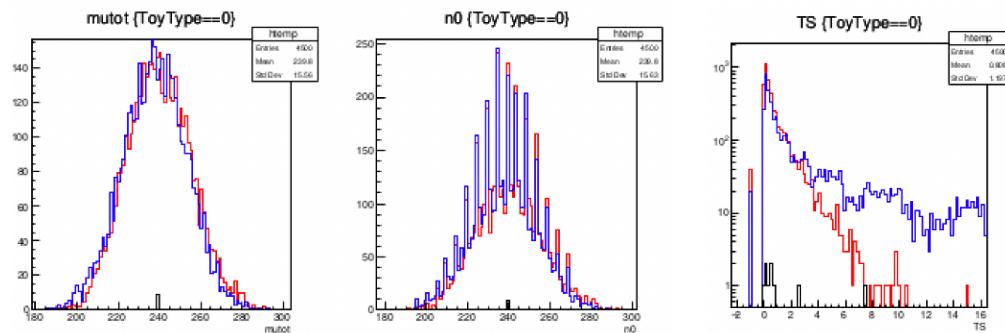
No data+model



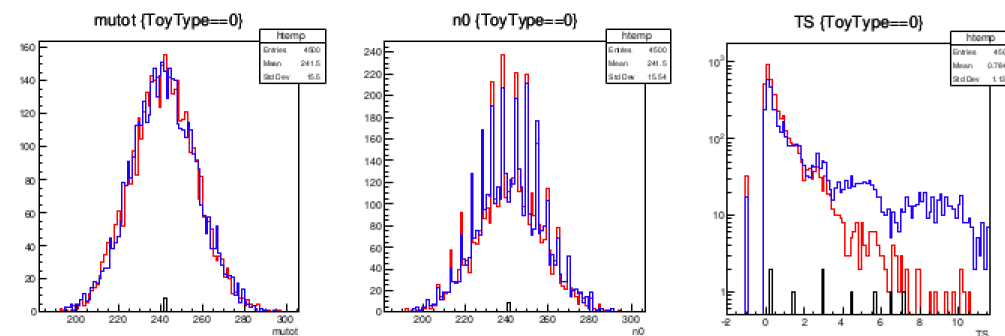
data+model, data



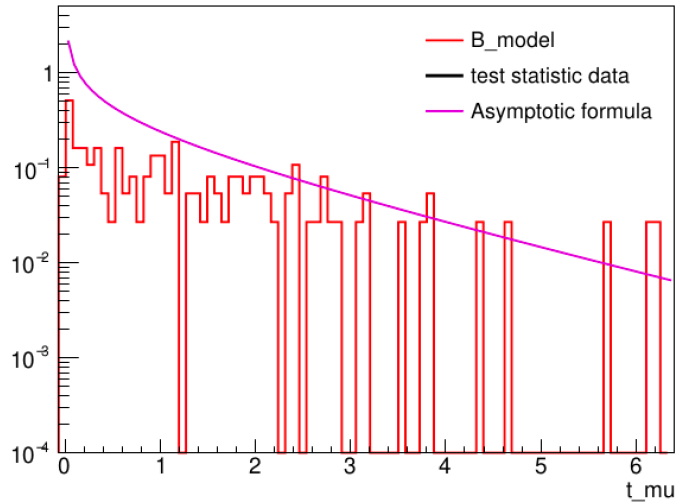
data+model, sensitivity



data+ no model

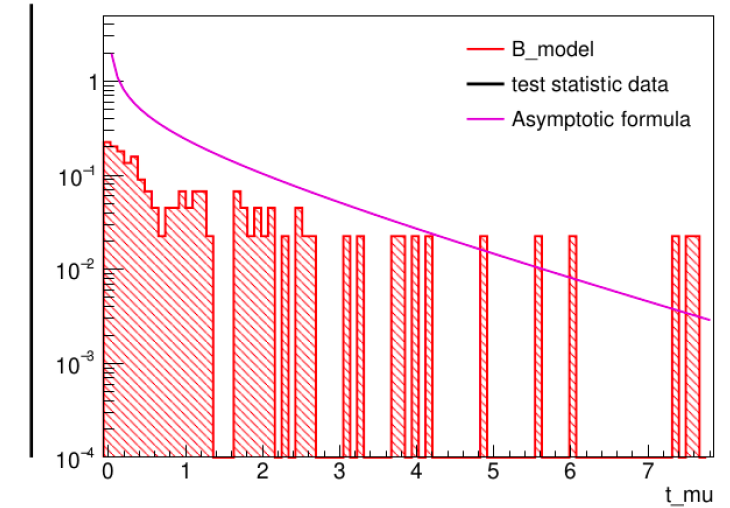


Discovery case



Model+data, input: data file
generated from the workspace that
has wall model

Error
To be continued.....



Model+data, sensitivity

No data+model

OBSERVED DATA

Data file:

/afs/hep.wisc.edu/home/liu674/LowE_NR_group/projects/MDC3/DataWithWall1_1000.root

t

RooDataSet::obs_data[S1,logS2] = 241 entries

mu_B8	=	1.36456	+/-	0.0546767	(limited)
mu_beta	=	167.588	+/-	31.97	(limited)
mu_highnr	=	26.8552	+/-	27.9975	(1
mu_pp	=	0.00842286	+/-	0.000168457	(1
mu_sig	=	4.36398	+/-	2.61586	(limited)
mu_vvBB	=	41.7393	+/-	20.6331	(limited)
mu_wall	=	0.694122	+/-	0.450323	(limited)

Data+model

OBSERVED DATA

Data file:

/afs/hep.wisc.edu/home/liu674/LowE_NR_group/projects/MDC3/DataNoWall1_1000.root

RooDataSet::obs_data[S1,logS2] = 240 entries

mu_B8	=	1.36613	+/-	0.0546374	(limited)
mu_beta	=	183.551	+/-	31.967	(limited)
mu_highnr	=	17.2461	+/-	23.1274	(limited)
mu_pp	=	0.00842285	+/-	0.000168457	(limited)
mu_sig	=	6.63435e-06	+/-	0.568307	(limited)
mu_vvBB	=	38.9405	+/-	20.4845	(limited)
mu_wall	=	0.710063	+/-	0.448702	(limited)

No Data+model

Model + Data, sensitivity

OBSERVED DATA

>> Generating a random dataset

mu_bckg = 240.734

mu_sig = 0

mu_total = 240.734

n_0 (Poisson) = 240

>> Random data file created successfully:

./output/lzstats-workspace_change_wall_60d_wdwm_sun

req-nPOI_9-two_sided-NP_on-run1/data/mockData.root

RooDataSet::obs_data[S1,logS2] = 240 entries

```
..... ---
mu_B8      = 1.36882      +/- 0.0546152 (limited)
mu_beta    = 162.13      +/- 25.749    (limited)
mu_highnr   = 29.9997     +/- 19.2077   (1
mu_pp       = 0.00842288 +/- 0.000168457 (1
mu_sig      = 1.38307    +/- 1.95374   (limited)
mu_vvBB     = 42.7318    +/- 20.5285   (limited)
mu_wall    = 0.69713    +/- 0.450321 (limited)
```

Model+data, data

OBSERVED DATA

Data file:

/afs/hep.wisc.edu/home/liu674/LowE_NR_group/p

RooDataSet::obs_data[S1,logS2] = 241 entries

```
mu_B8      = 1.36456      +/- 0.0546767 (limited)
mu_beta    = 167.588      +/- 31.97     (limited)
mu_highnr   = 26.8552     +/- 27.9975   (1
mu_pp       = 0.00842286 +/- 0.000168457 (1
mu_sig      = 4.36398    +/- 2.61586   (limited)
mu_vvBB     = 41.7393    +/- 20.6331   (limited)
mu_wall    = 0.694122   +/- 0.450323 (limited)
```

Model+ No data

OBSERVED DATA

Data file:

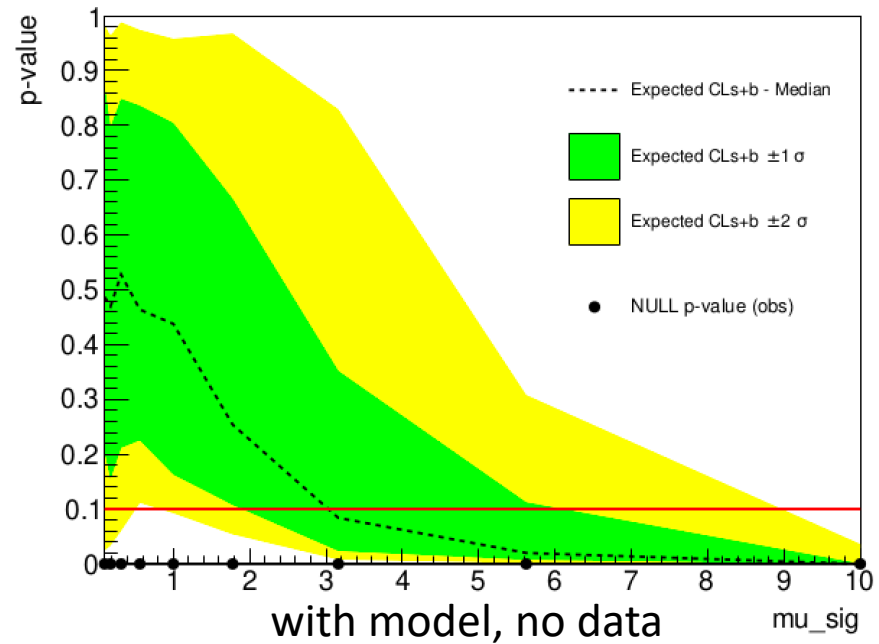
/afs/hep.wisc.edu/home/liu674/LowE_NR_group/p

RooDataSet::obs_data[S1,logS2] = 240 entries

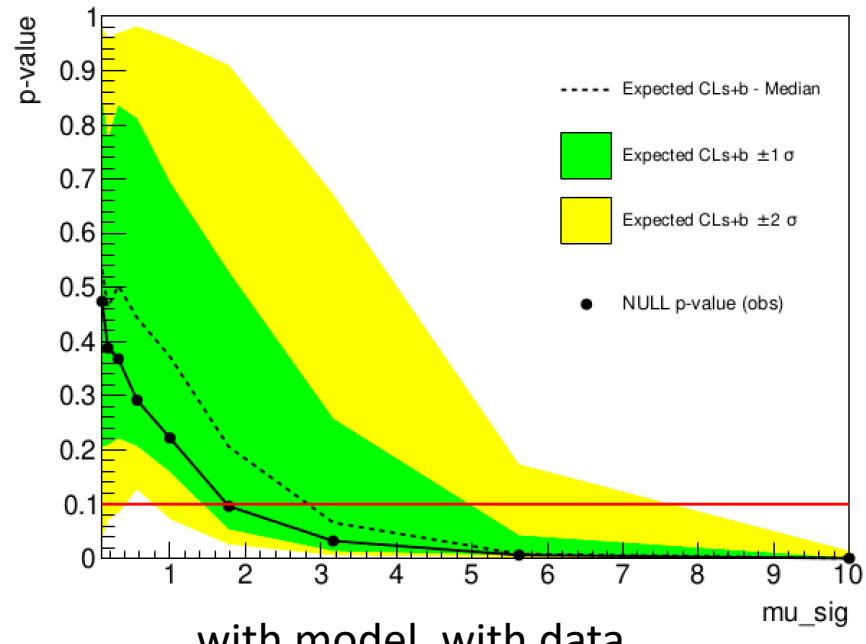
```
..... ---
mu_B8      = 1.36613      +/- 0.0546374 (limited)
mu_beta    = 183.551      +/- 31.967    (limited)
mu_highnr   = 17.2461     +/- 23.1274   (1
mu_pp       = 0.00842285 +/- 0.000168457 (1
mu_sig      = 6.63435e-06 +/- 0.568307 (limited)
mu_vvBB     = 38.9405    +/- 20.4845   (limited)
mu_wall    = 0.710063   +/- 0.448702 (limited)
```

Update

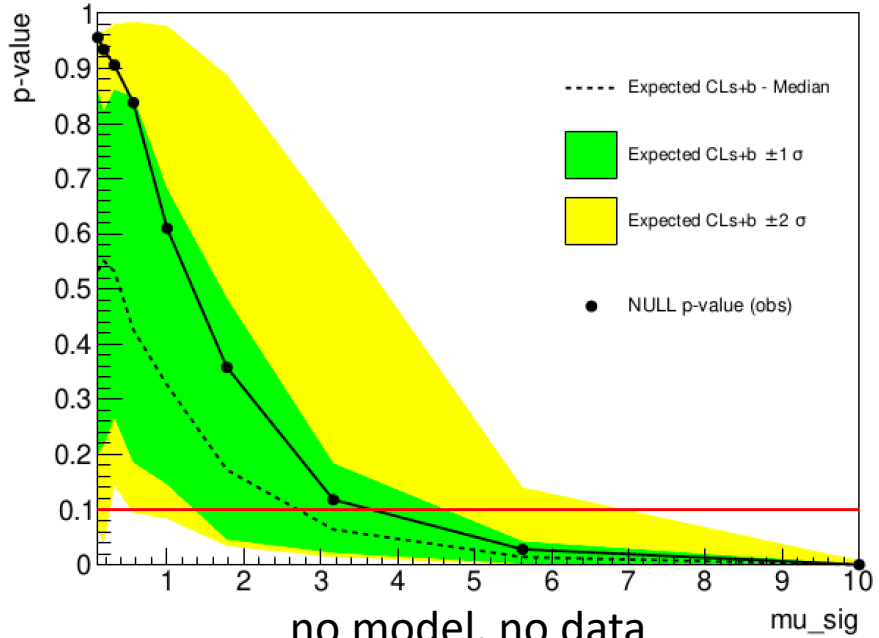
- Add constraint function to wall model
 - Run model + data, model+no data case for 60d
 - Run LZStats with calculator type 1, with 500 toys caused a crash in the middle
 - Compare the result of calculator type = 1 and 0 (Toy = 100)
- Run no data, with model case with other background source (vvBB) -->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



with model, no data
(0, 3.032)

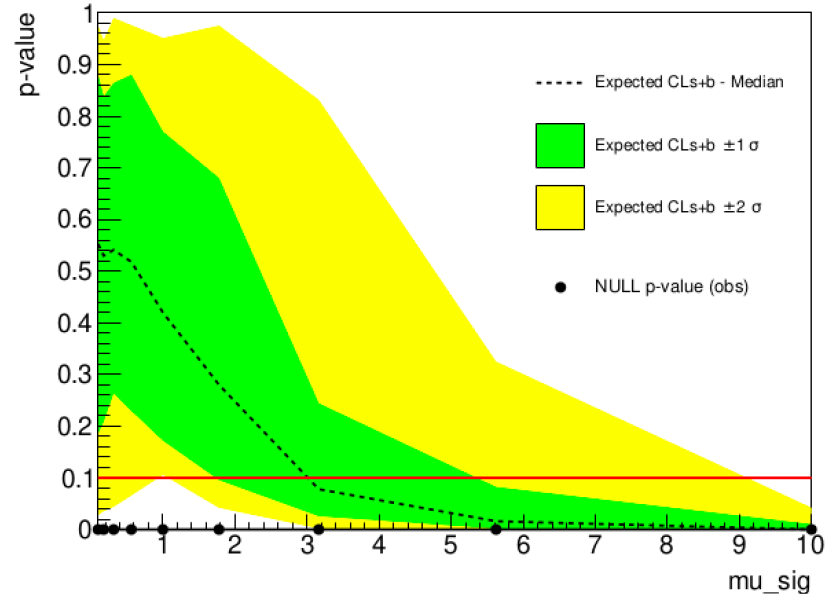


with model, with data
(1.7536, 2.8262)

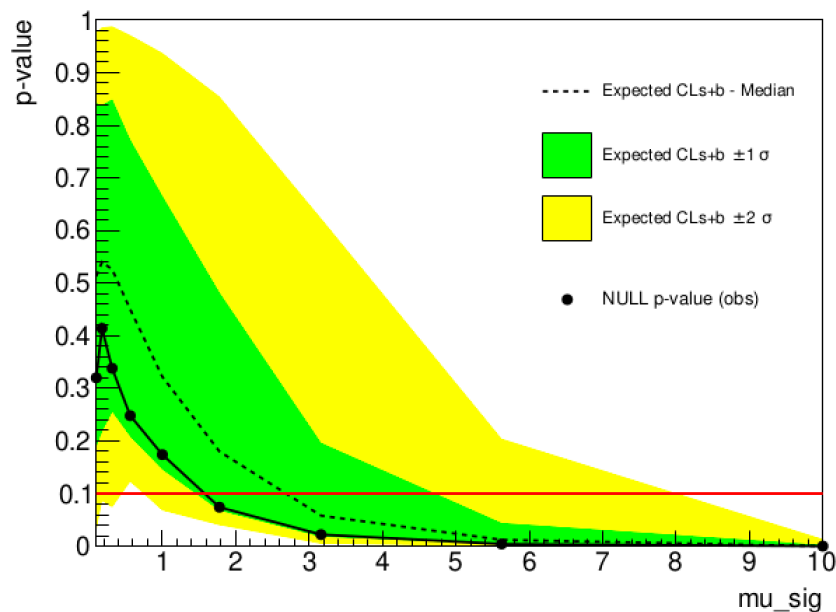


no model, no data
(2.7009, 3.6545)

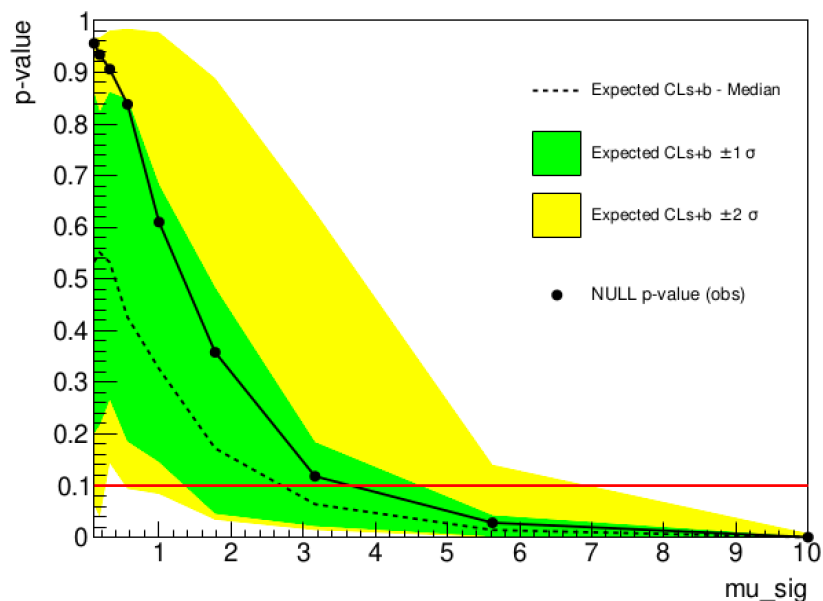
60 livedays
500Toys
40GeV
With wall constraint
Calculator Type = 0



with model, no data
(0, 3.0115)



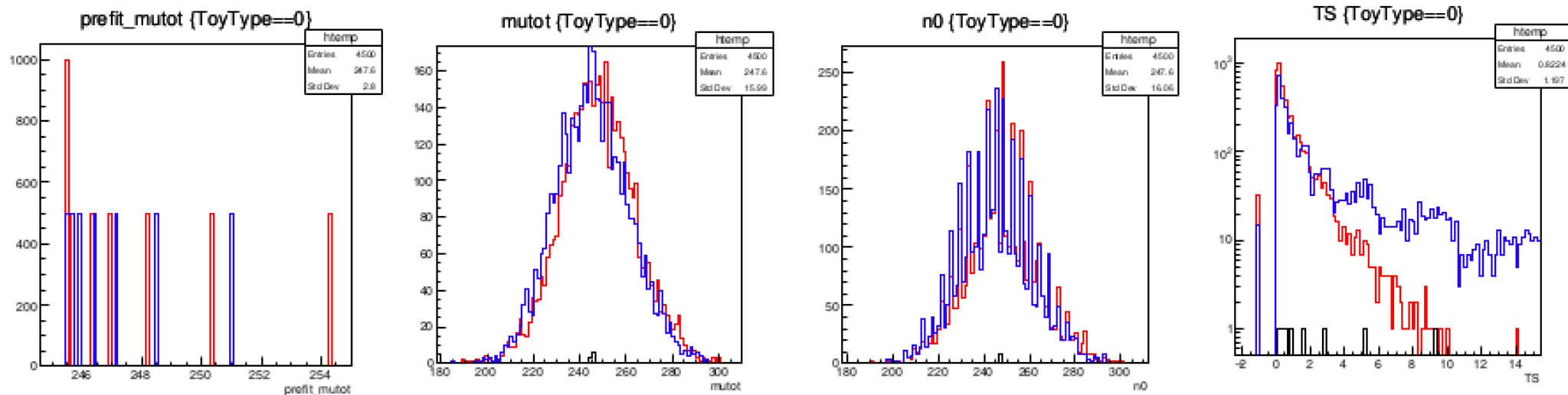
with model, with data
(1.5759, 2.6897)



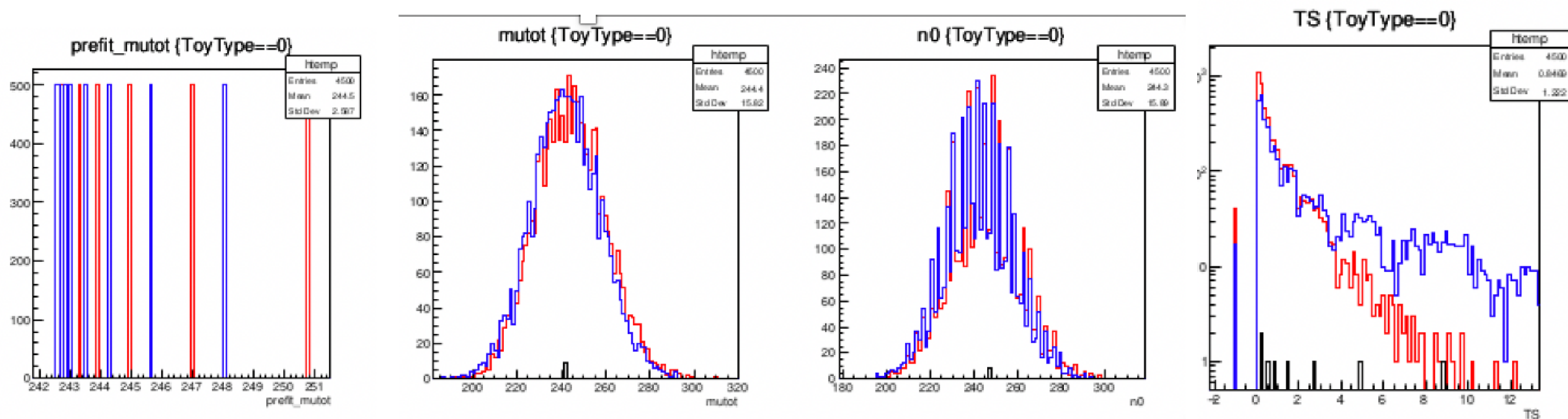
no model, no data
(2.7009, 3.6545)

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

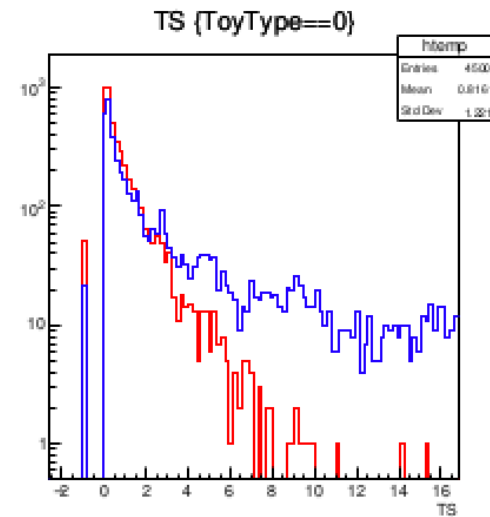
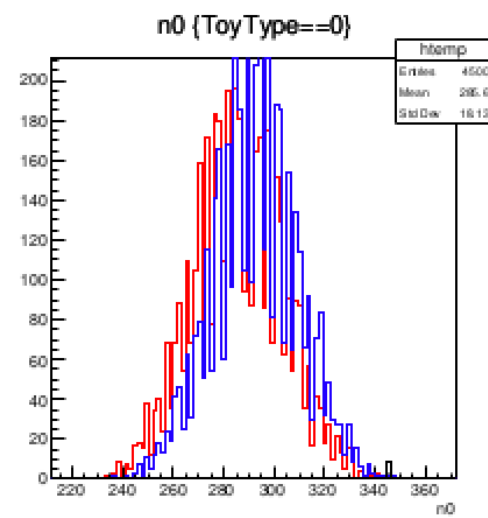
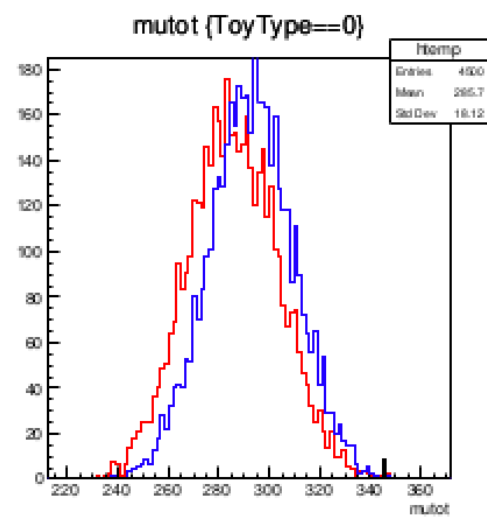
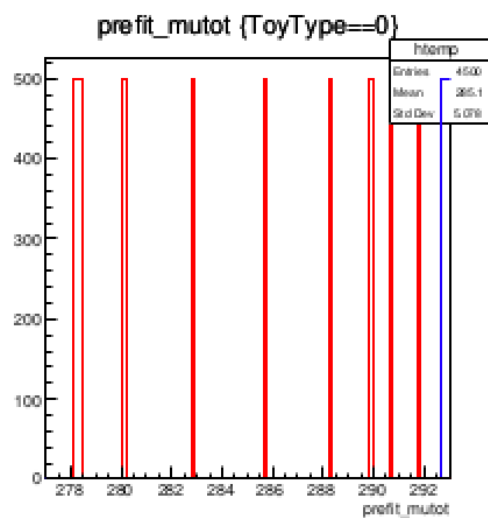
60 d
Data+model
No wall constraint



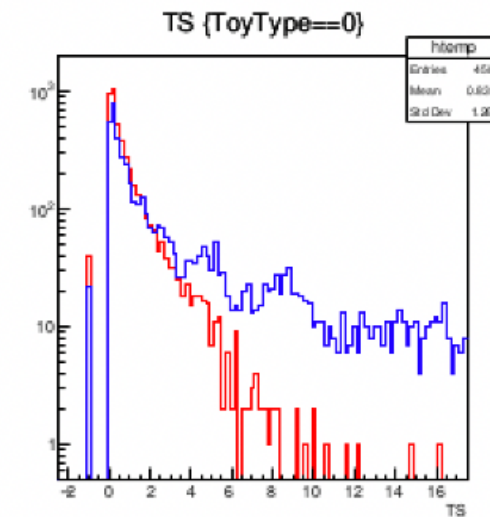
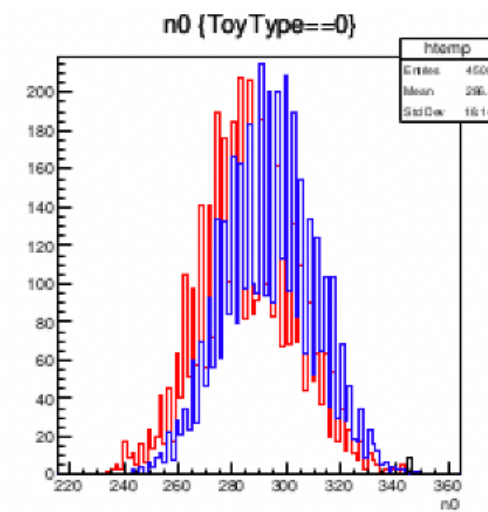
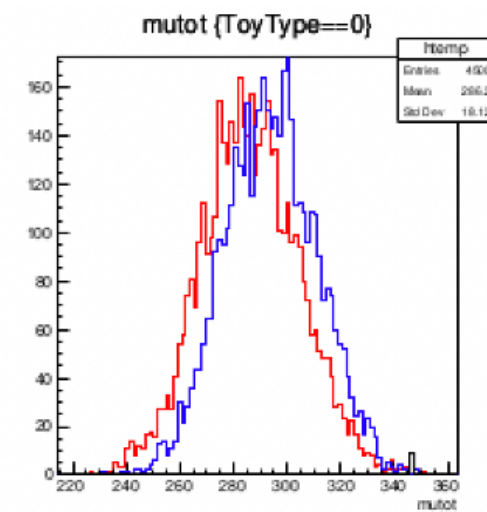
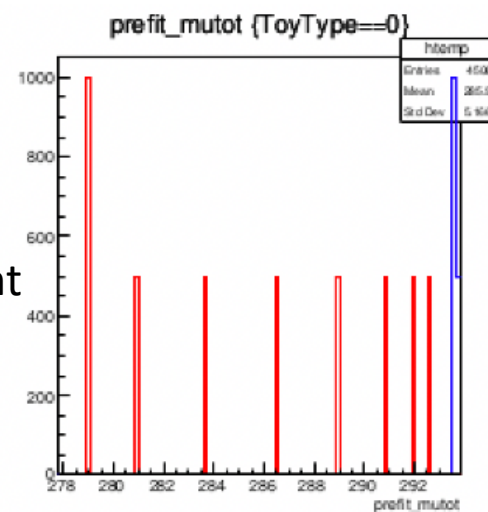
60 d
Data+model
With wall constraint

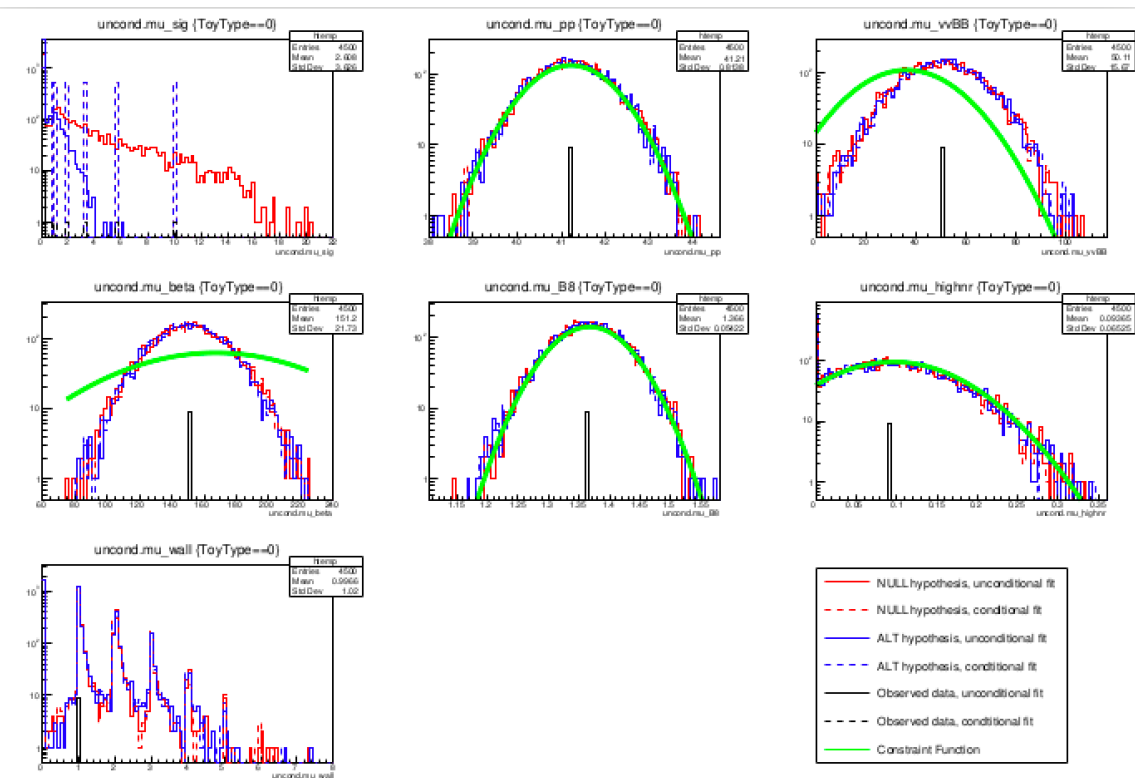


60 d
No Data+model
No wall constrain

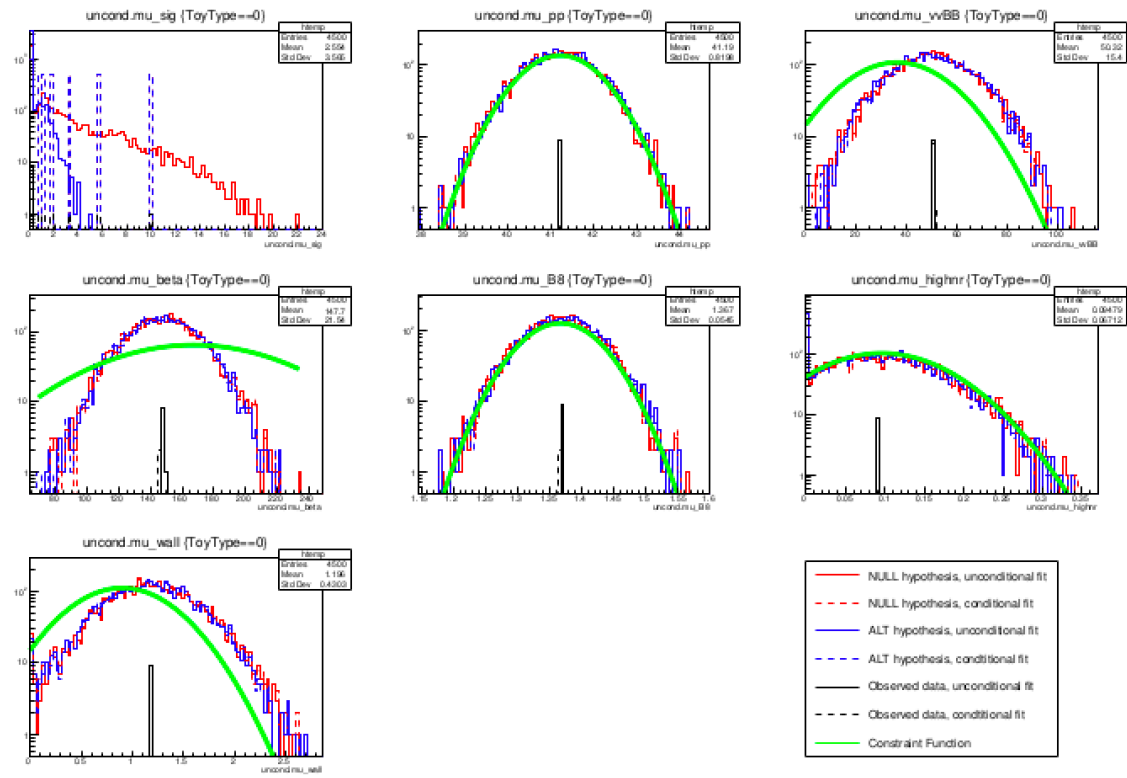


60 d
No Data+model
With wall constraint

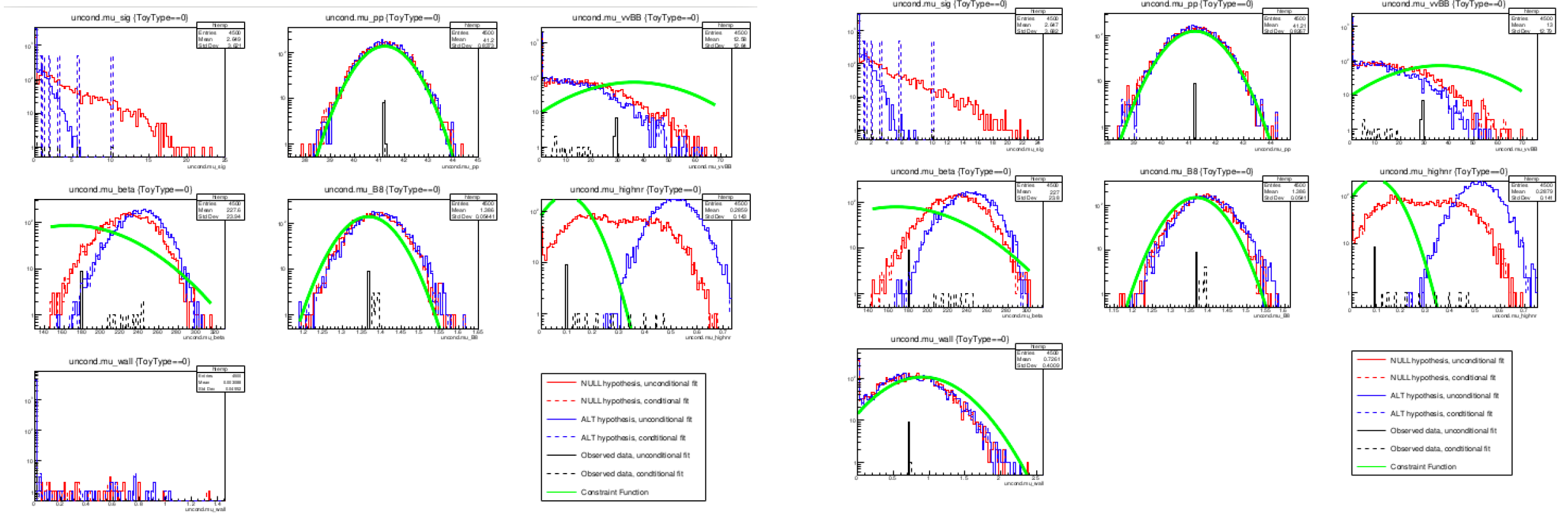




60 d
Data+model
No wall constraint



60 d
Data+model
With wall constraint

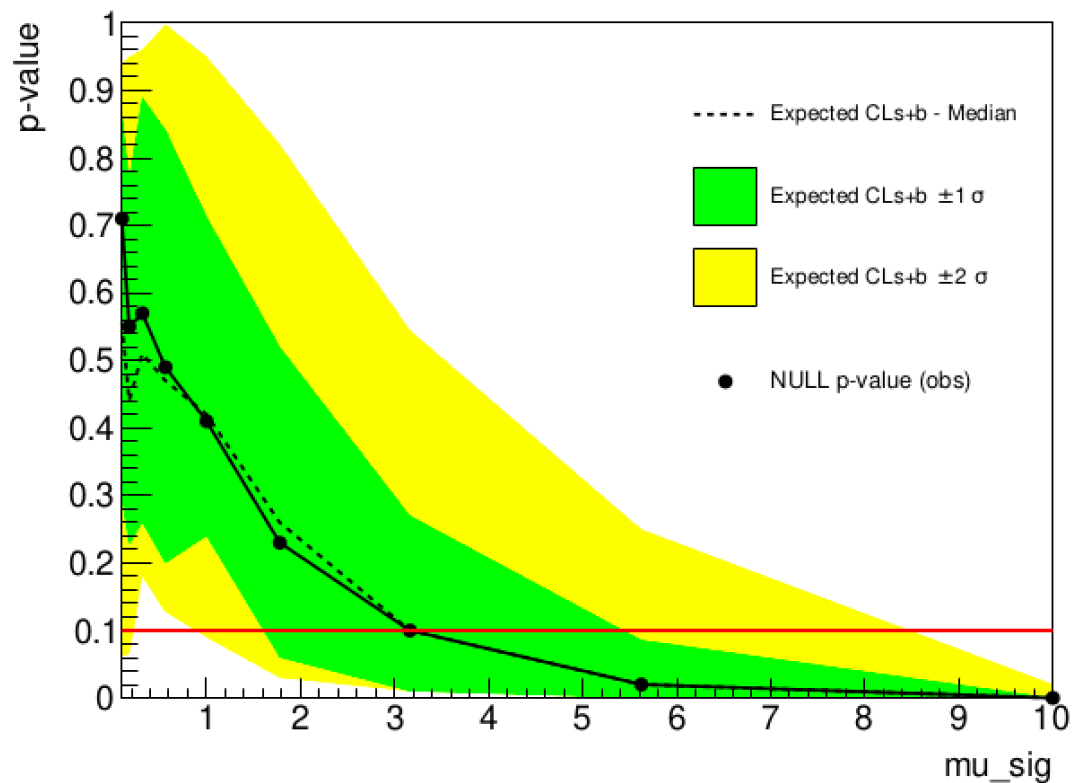


60 d
No Data+model
No wall constraint

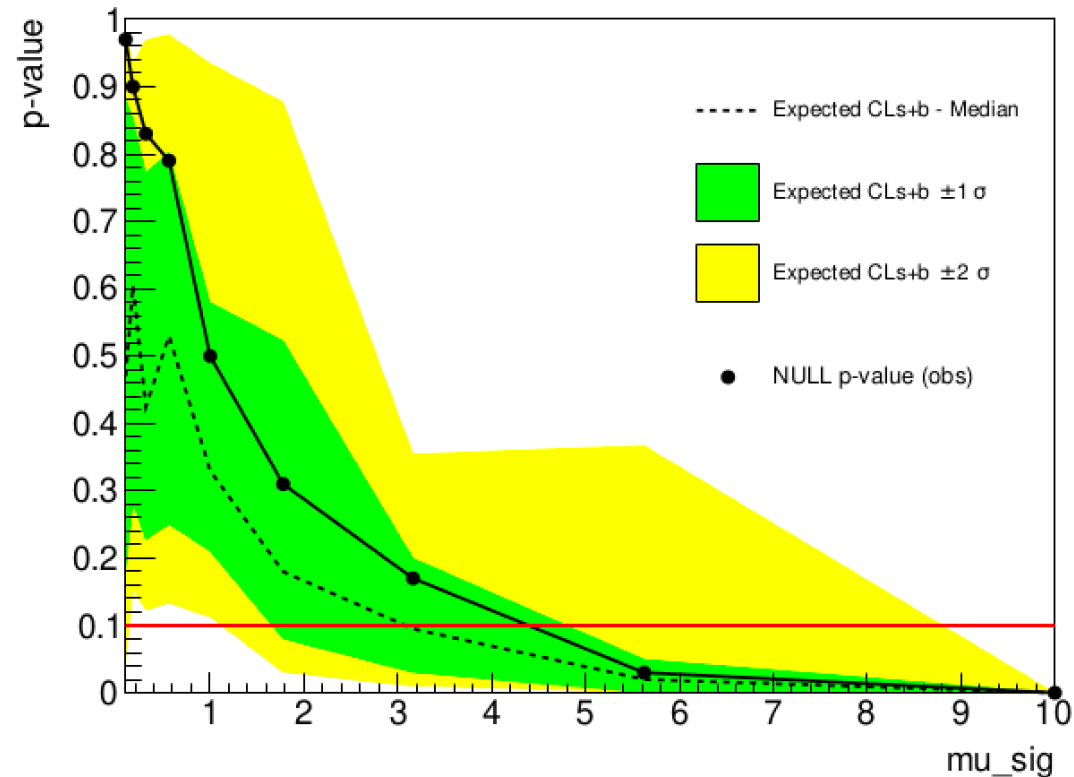
60 d
No Data+model
With wall constraint

Calculator type

60 livedays
100Toys
40GeV
With wall constraint



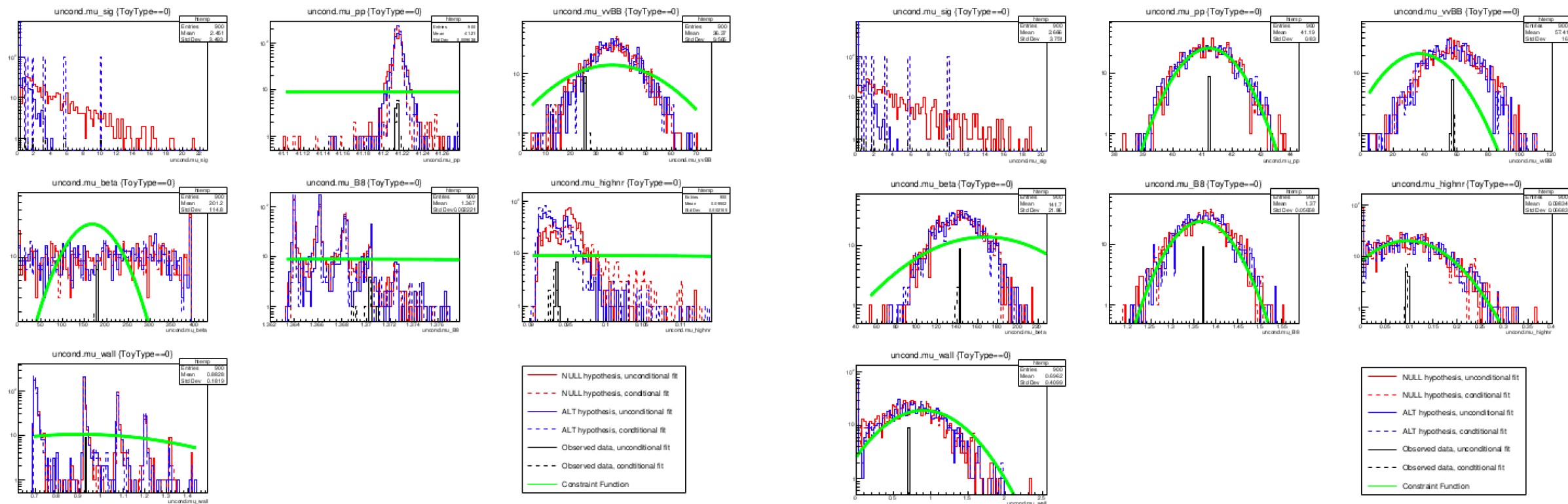
With Model, with data
Calculator Type = 1
(3.1623, 3.1623)



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

Calculator type

60 livedays
100Toys
40GeV
With wall constraint

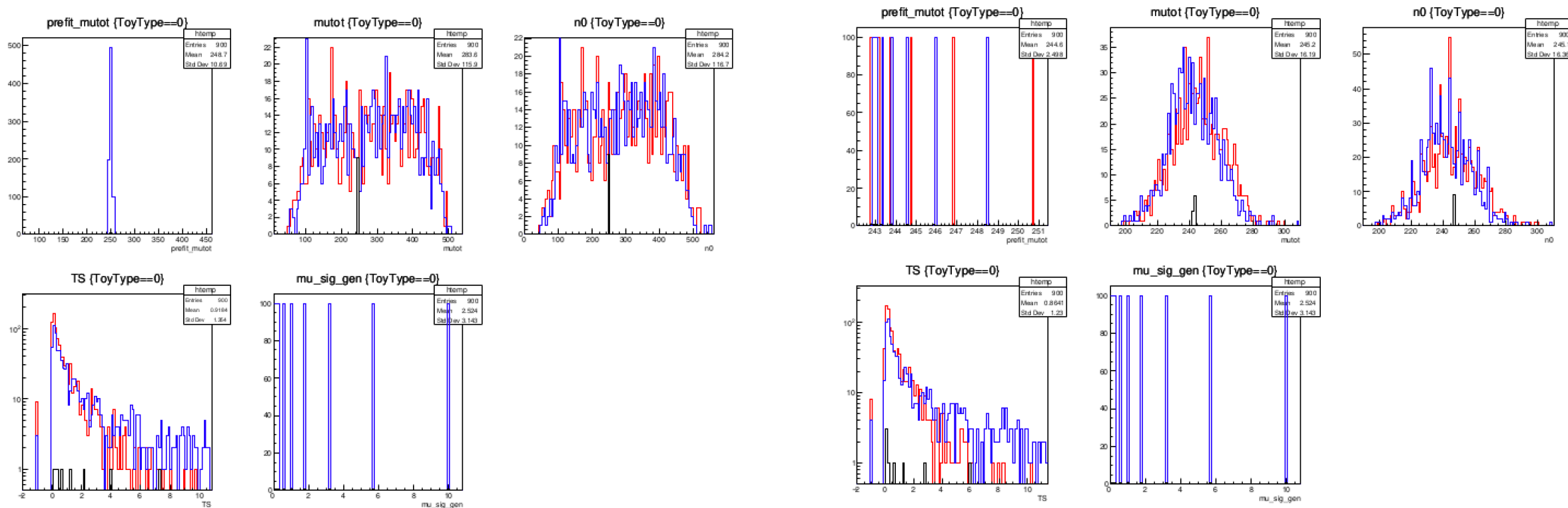


With Model, with data
Calculator Type = 1

With model, with data
Calculator Type = 0

Calculator type

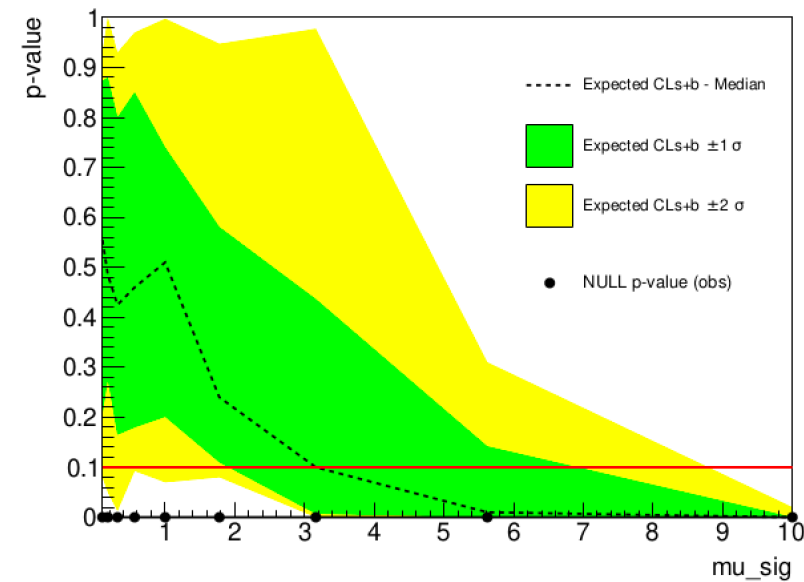
60 livedays
100Toys
40GeV
With wall constraint



With Model, with data
Calculator Type = 1

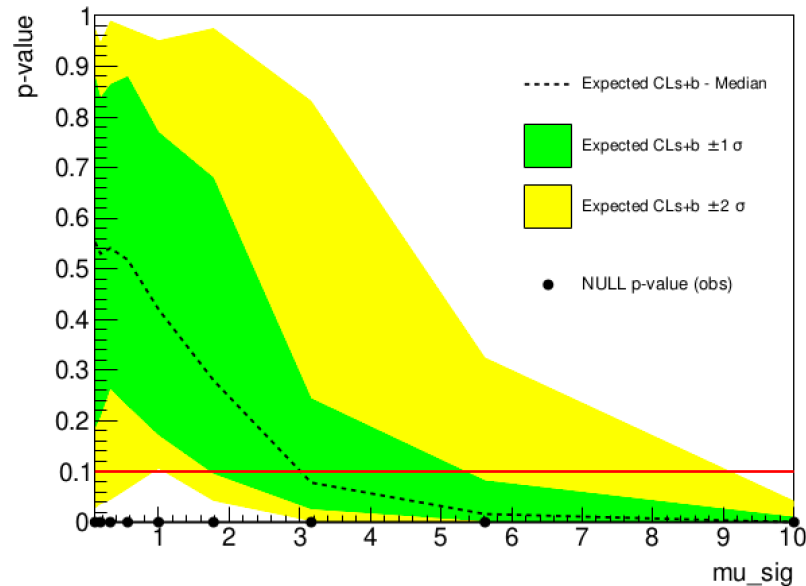
With model, with data
Calculator Type = 0

vvBB 60 d



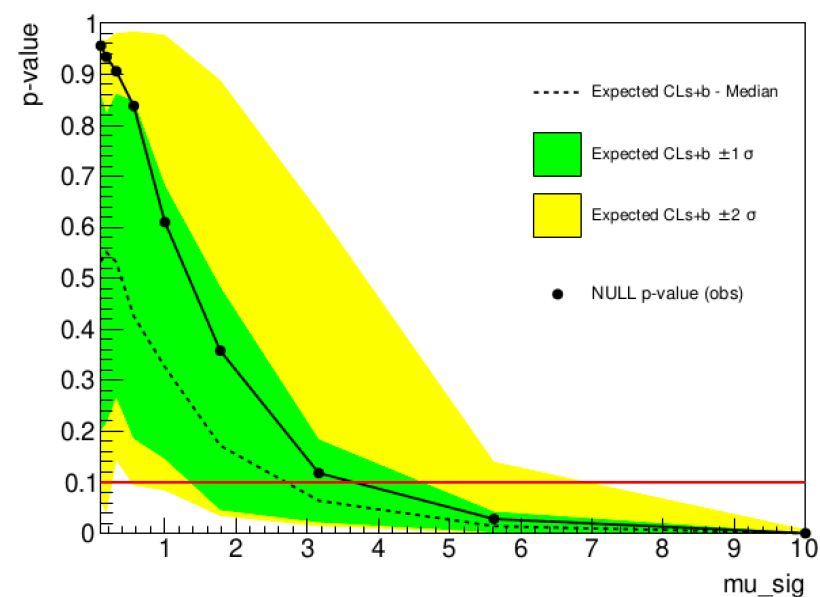
no vvBBdata + model
(0, 3.1623)

μ_{B8}	=	1.37045	+/-	0.0546247	(limited)
μ_{beta}	=	124.442	+/-	25.0879	(limited)
μ_{highnr}	=	29.9959	+/-	21.4604	(1)
μ_{pp}	=	0.00842288	+/-	0.000168457	(1)
μ_{sig}	=	97.6774	+/-	10.1734	(limited)
μ_{vvBB}	=	43.095	+/-	20.5078	(limited)



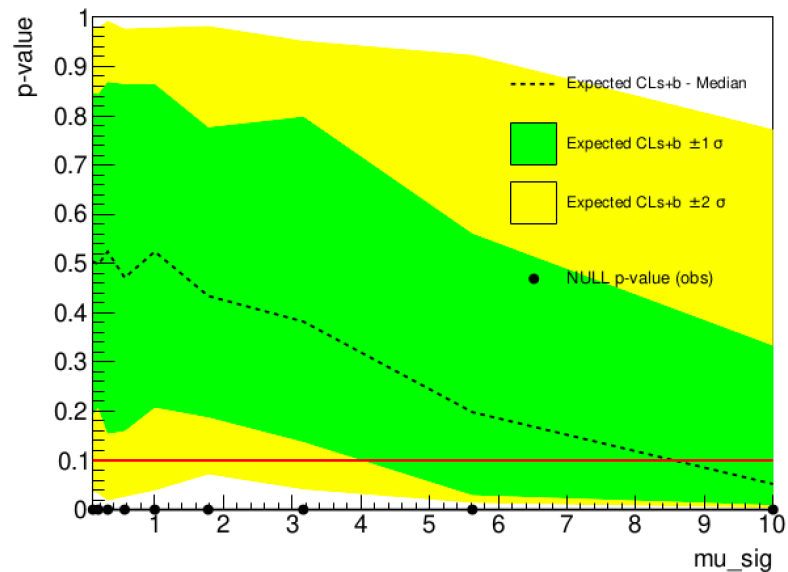
no wall data + model
(0, 3.0115)

μ_{B8}	=	1.36838	+/-	0.0546394	(limited)
μ_{beta}	=	179.293	+/-	22.1503	(limited)
μ_{highnr}	=	0.0961636	+/-	0.0718755	(limit)
μ_{pp}	=	41.2129	+/-	0.824277	(limited)
μ_{sig}	=	95.0326	+/-	10.2029	(limited)
μ_{vvBB}	=	29.0058	+/-	15.7028	(limited)
μ_{wall}	=	0.717923	+/-	0.449614	(limited)

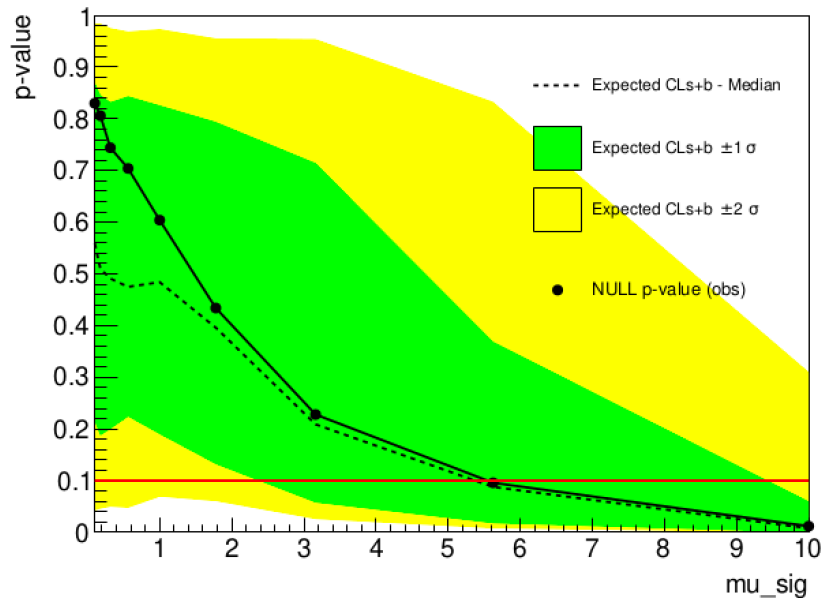


with vvBB data + model
(2.7009, 3.6545)

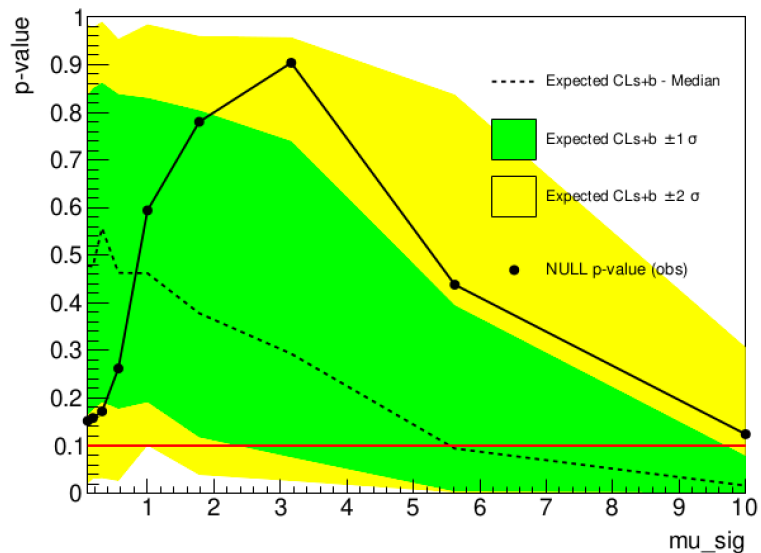
μ_{B8}	=	1.3685	+/-	0.0545922	(limited)
μ_{beta}	=	148.658	+/-	21.7967	(limited)
μ_{highnr}	=	0.0920129	+/-	0.0719094	(limited)
μ_{pp}	=	41.2149	+/-	0.824283	(limited)
μ_{sig}	=	3.76949e-06	+/-	0.656966	(limited)
μ_{vvBB}	=	49.9272	+/-	15.5211	(limited)
μ_{wall}	=	1.19545	+/-	0.379159	(limited)



with model, no data
(0, 8.5611)



with model, with data
(5.5488, 5.3783)



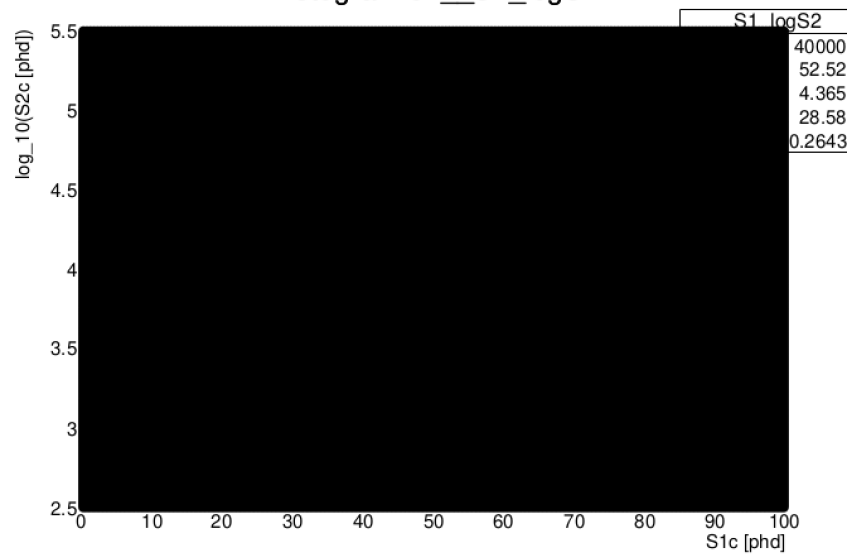
no model, no data
(0, 5.5492)

1000livedays
500Toys
40GeV
S1 = 16

New update

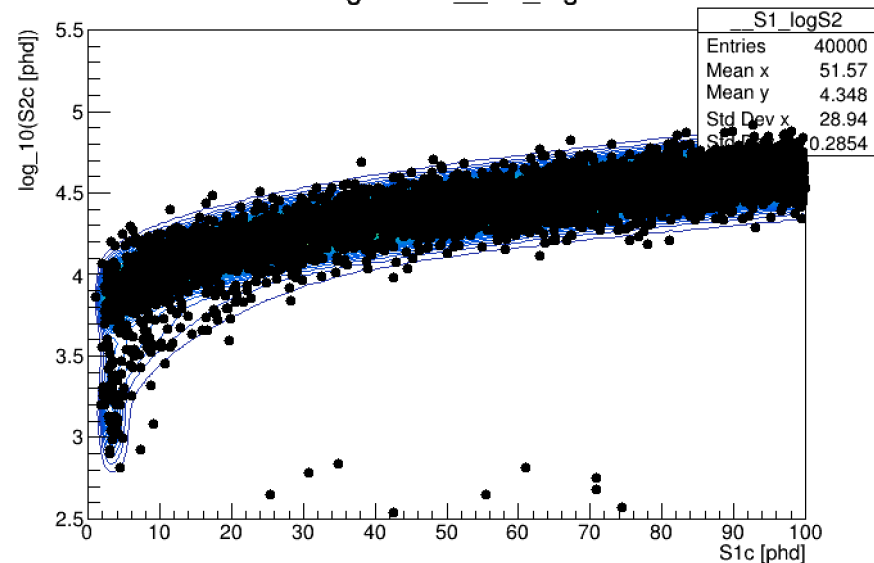
- Create wall data
- Finished four cases of the wall model and the data for 1000d, 1500~1700min to run
- Change 1000d -> 60d, 80~100min to run
- Change S1 value (80) of the wall model -> 1/5 S1 (16)

Histogram of __S1_logS2



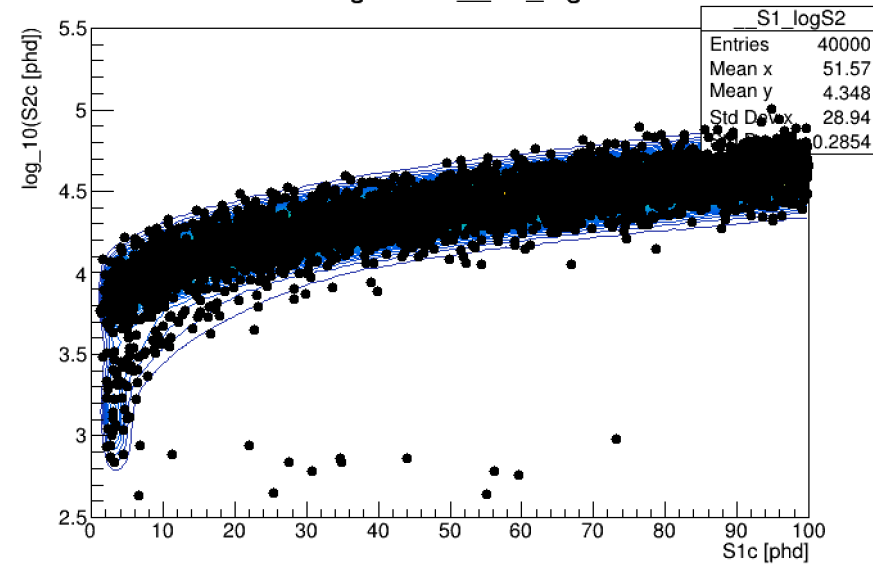
Interpolation order = 0

Histogram of __S1_logS2



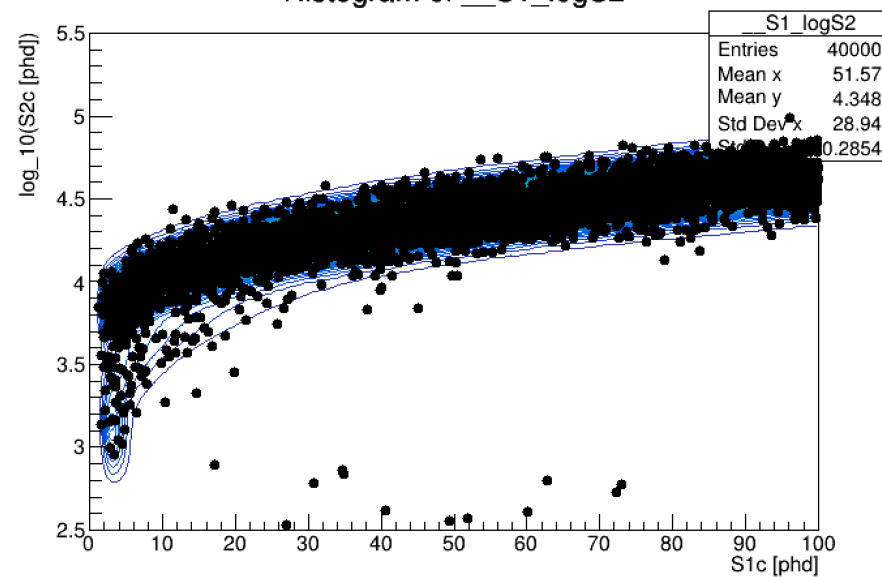
Interpolation order = 2

Histogram of __S1_logS2

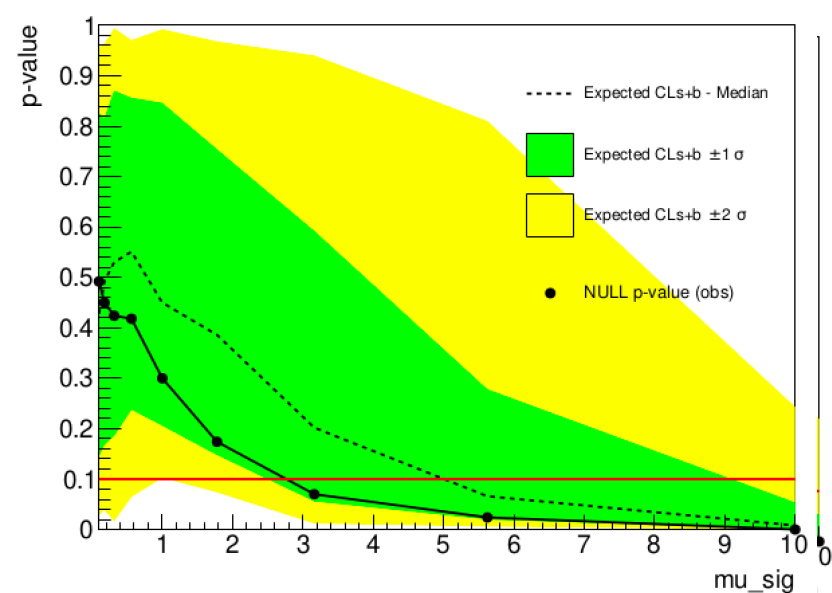


Interpolation order = 1

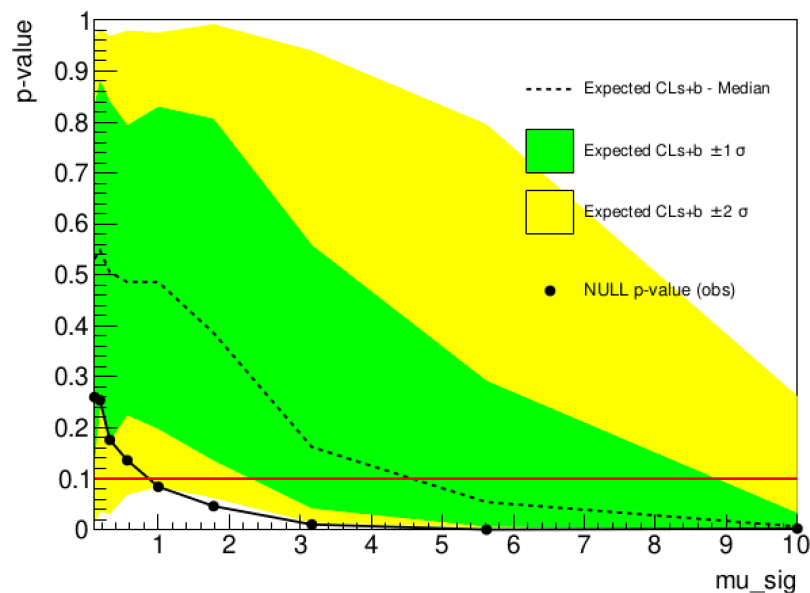
Histogram of __S1_logS2



Interpolation order = 3

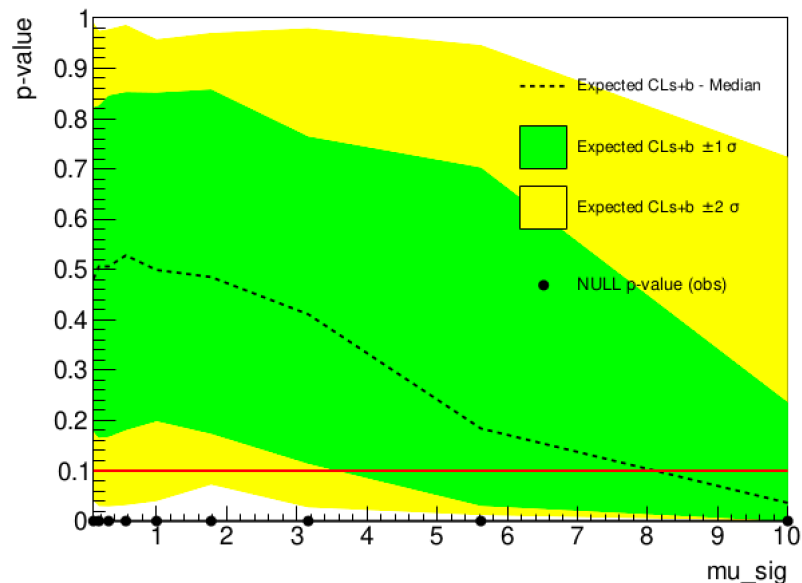


With model, with data
(2.763, 5.0081)



No model, no data
(0.8653, 4.5748)

1000 livedays
500 Toys
40GeV



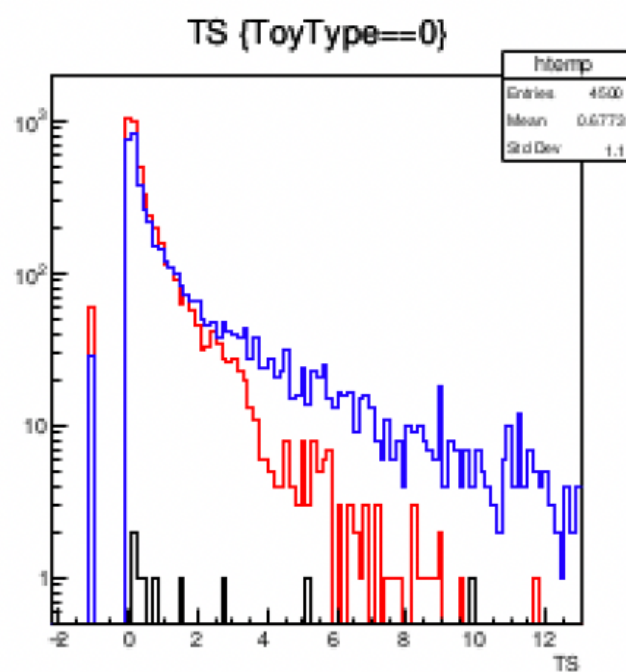
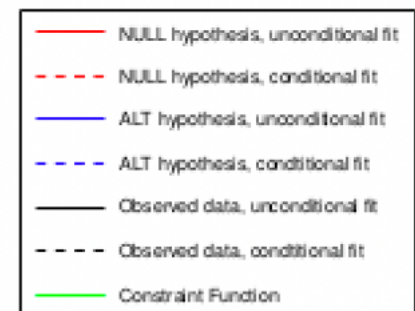
With model, no data
(0, 8.1071)

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

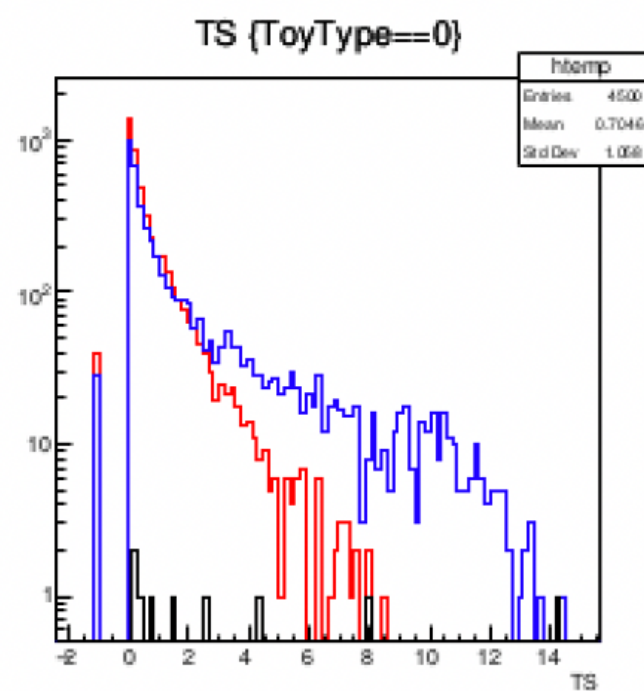
Error Log

```
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_BB=33.7589, mu_beta=2788.13, mu_highnr=1.59861, mu_pp=685.575, mu_sig=2, mu_vvBB=6
03.82
```

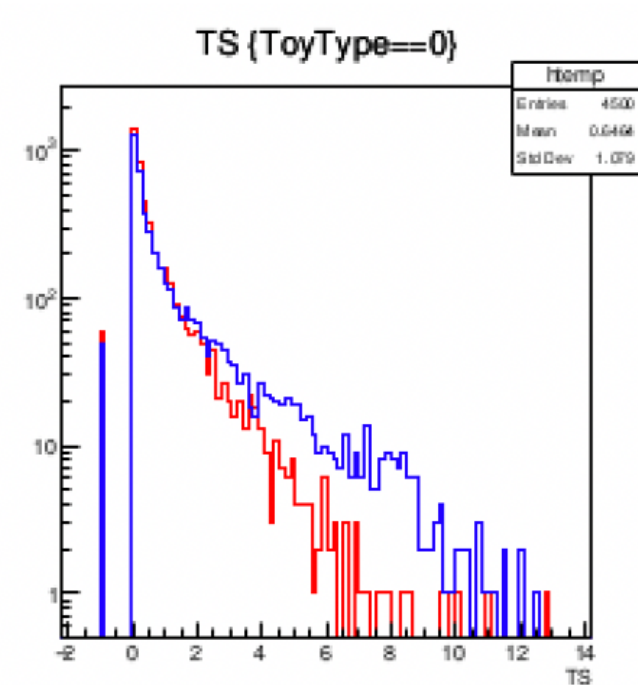
No model, with data



With model, with data

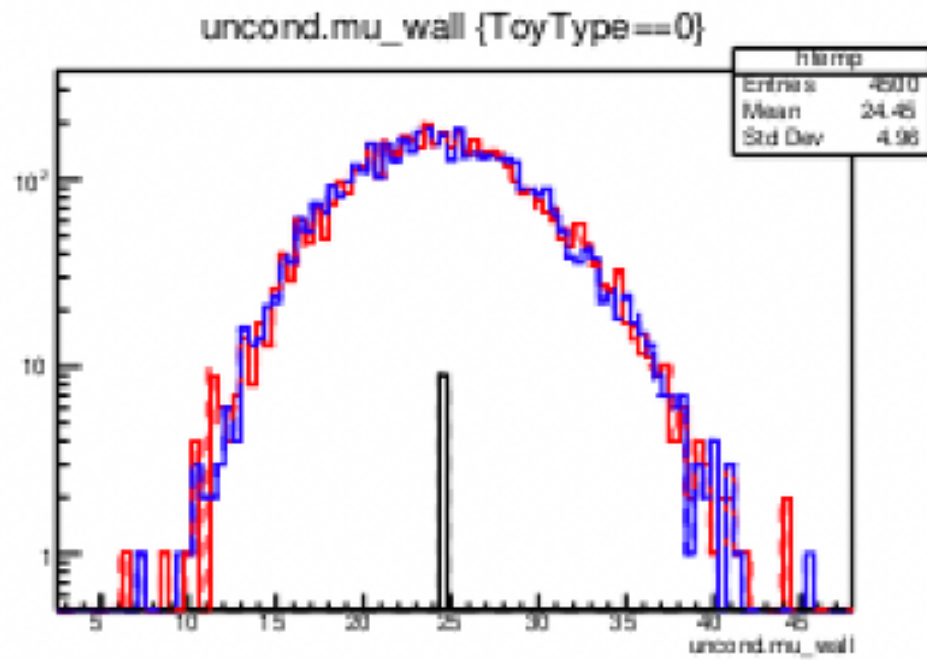


No model, no data

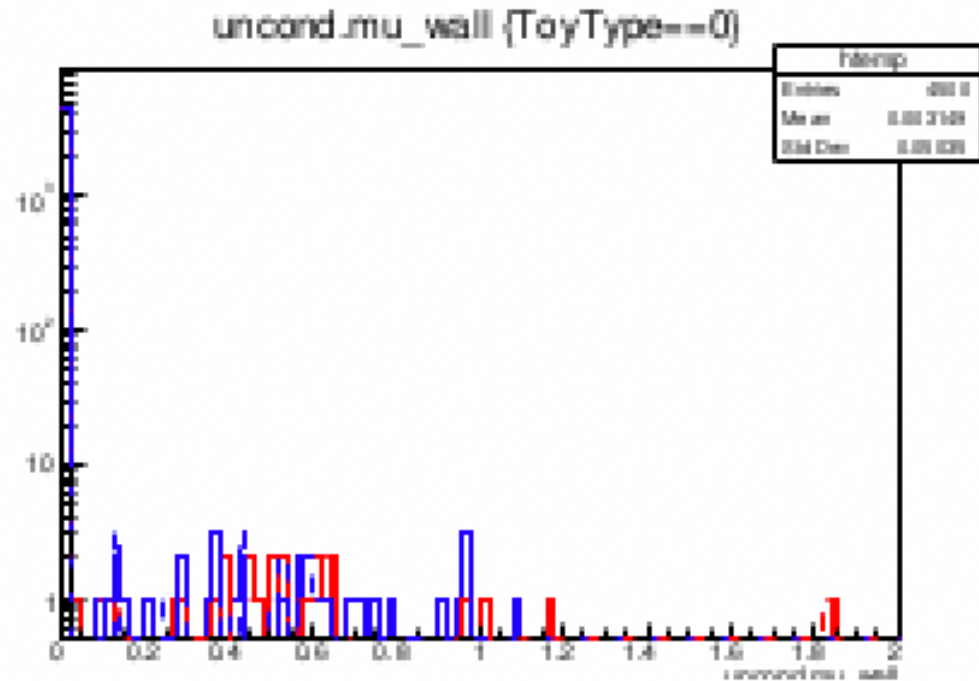


With model, no data

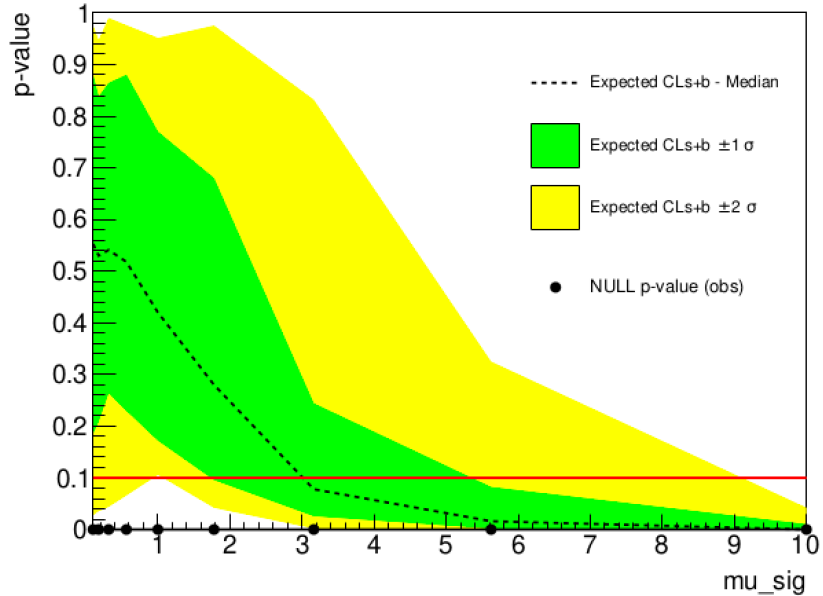
Mu_wall



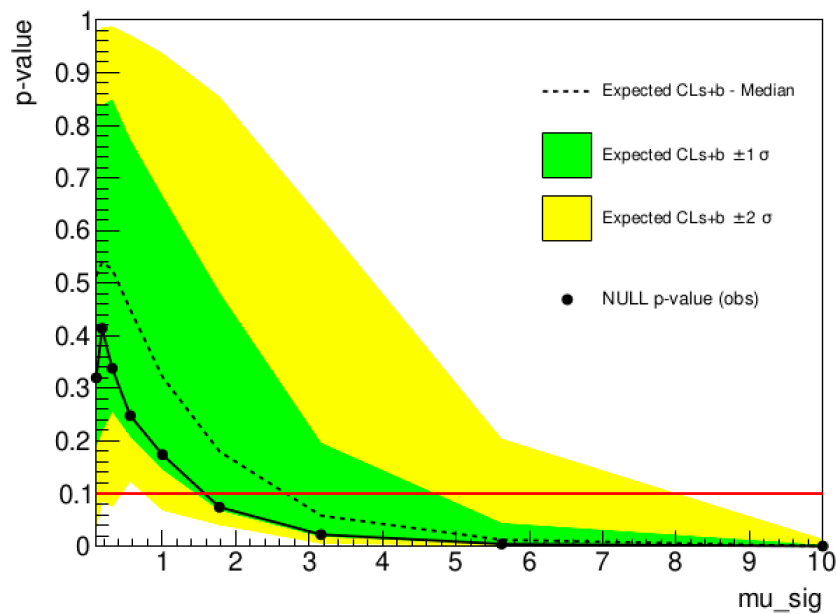
With model, with data



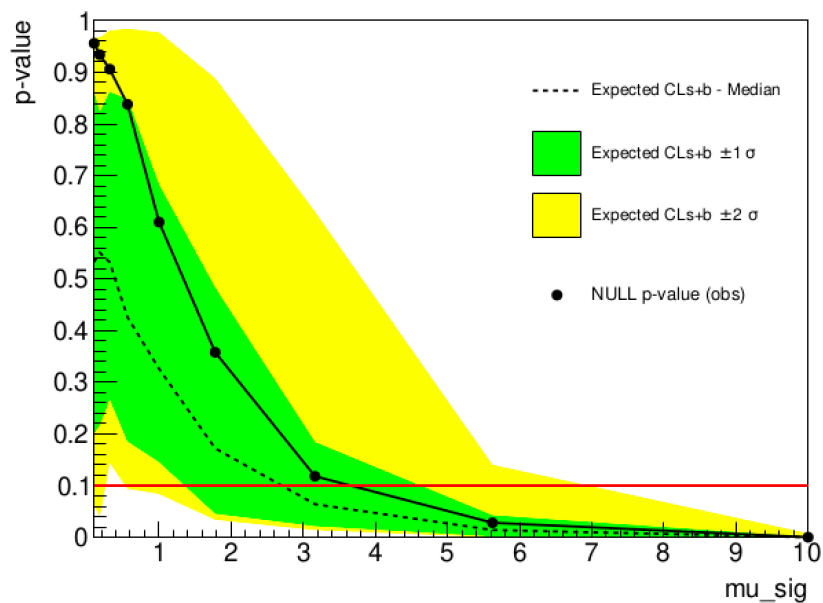
With model, no data



with model, no data
(0, 3.0115)



with model, with data
(1.5759, 2.6897)



no model, no data
(2.7009, 3.6545)

60 livedays
500Toys
40GeV

1000d S1 = 80

NMND

```

mu_B8      = 22.6238      +/- 0.900904 (limited)
mu_beta    = 2601.55      +/- 125.835  (limited)
mu_highnr  = 1.91342      +/- 1.1663   (limited)
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  (limited)
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   (limited)
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  (limited)
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 (limited)
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 (limited)
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)

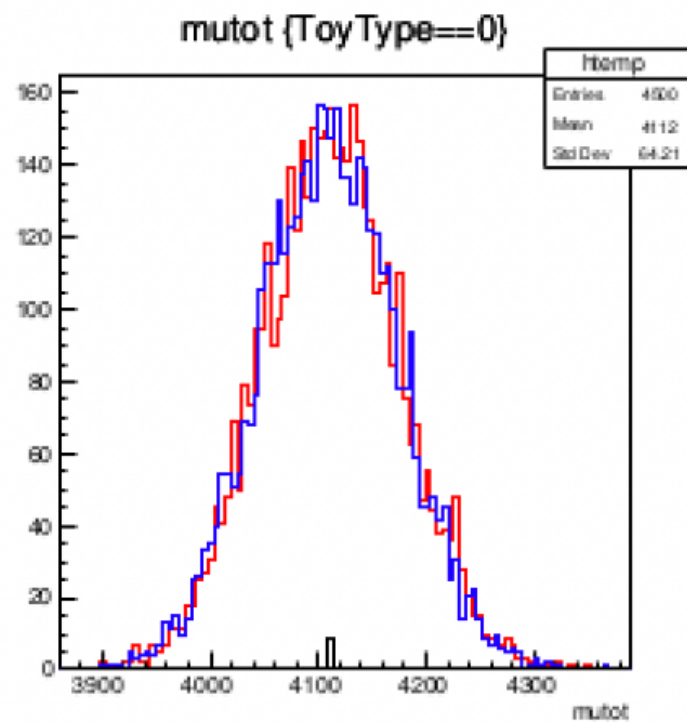
```

```

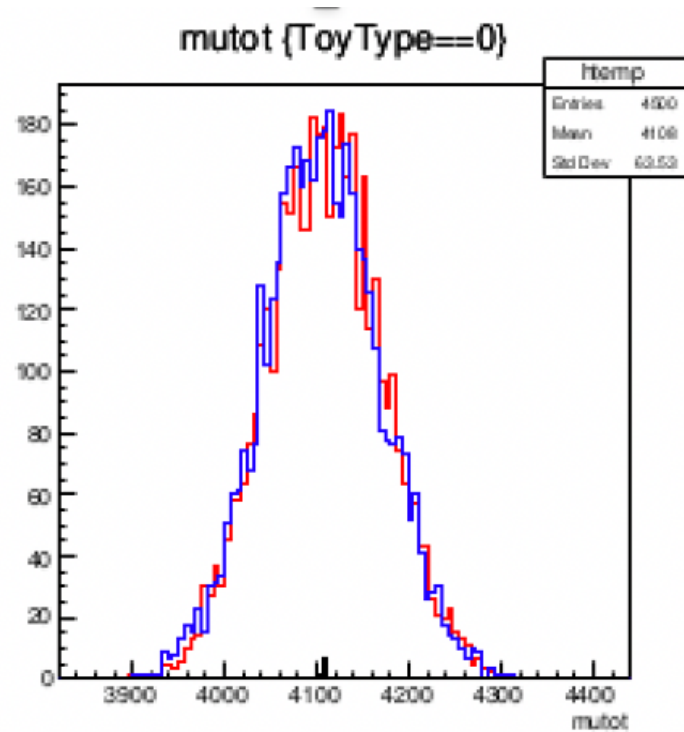
mu_B8      = 1.36836      +/- 0.054593 (limited)
mu_beta    = 156.383      +/- 21.5197  (limited)
mu_highnr  = 0.0951341    +/- 0.0718702 (limited)
mu_pp      = 41.2111      +/- 0.824279 (limited)
mu_sig     = 2.46738e-05  +/- 0.755975 (limited)
mu_vvBB    = 44.4113      +/- 15.3156  (limited)
mu_wall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

```

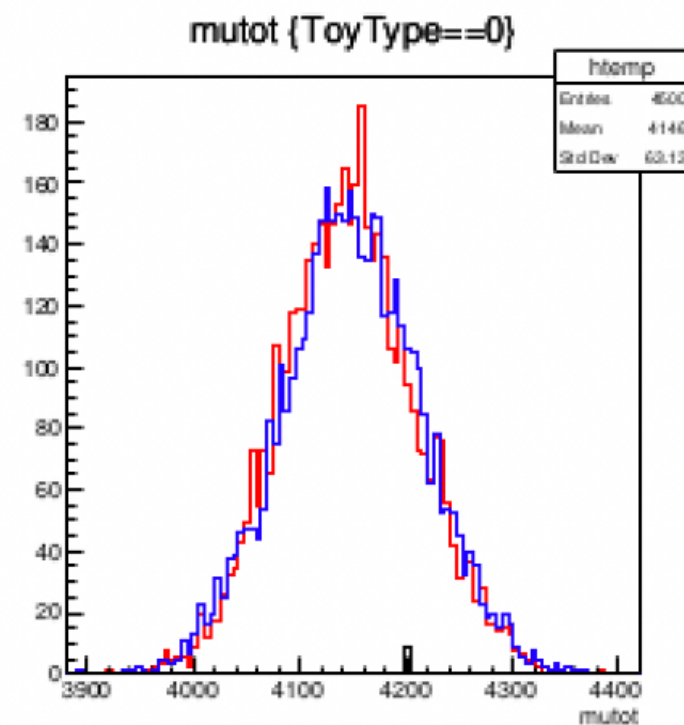
With model, with data



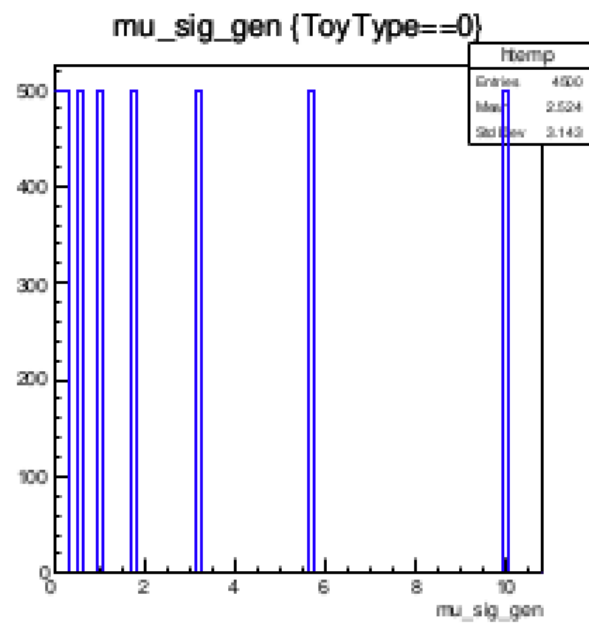
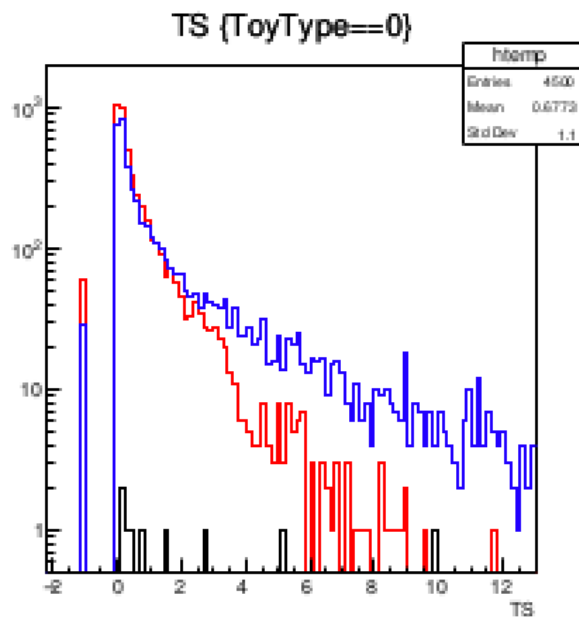
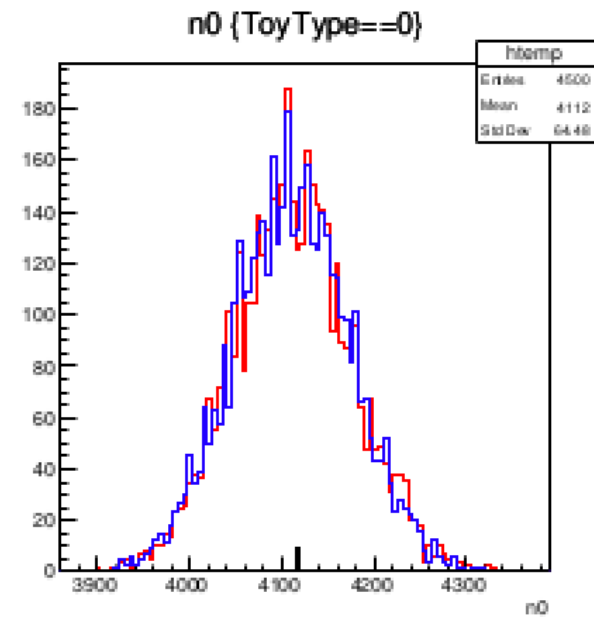
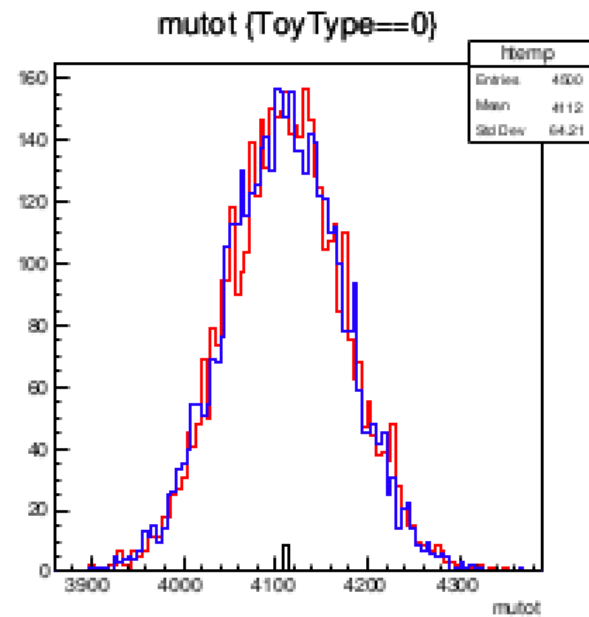
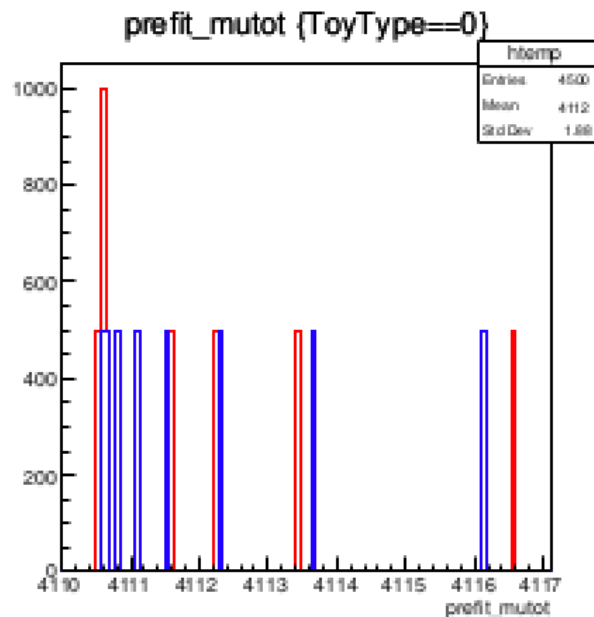
No model, no data

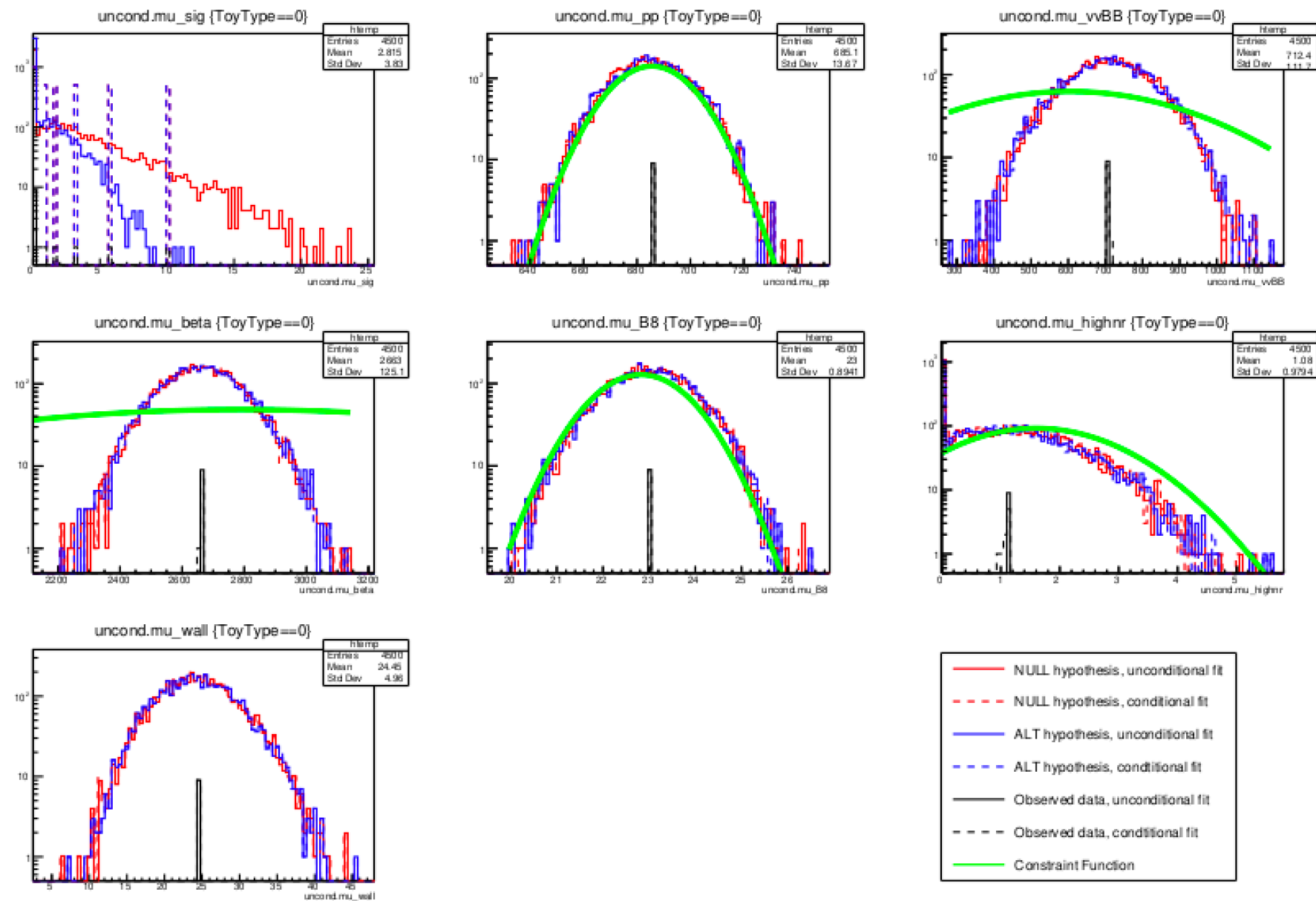


With model, no data

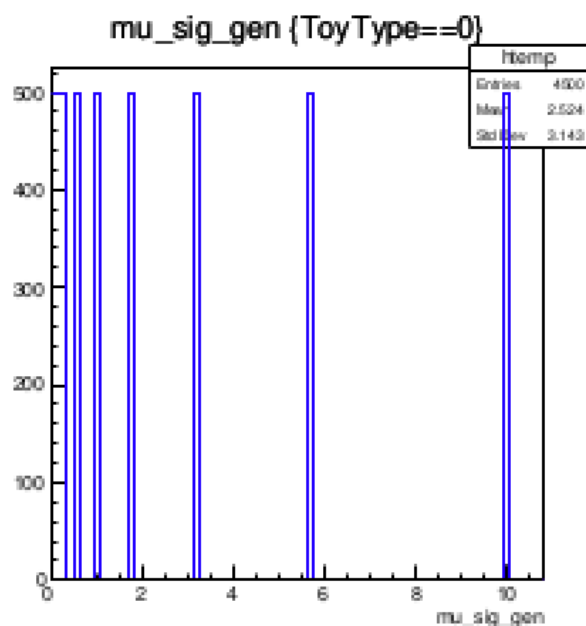
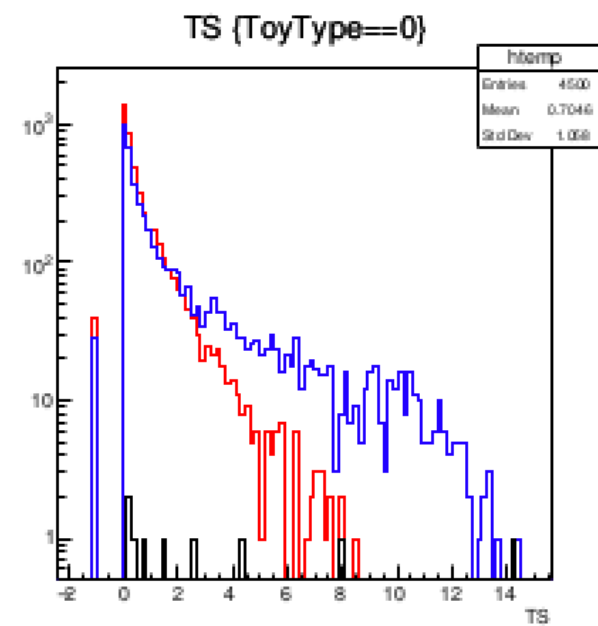
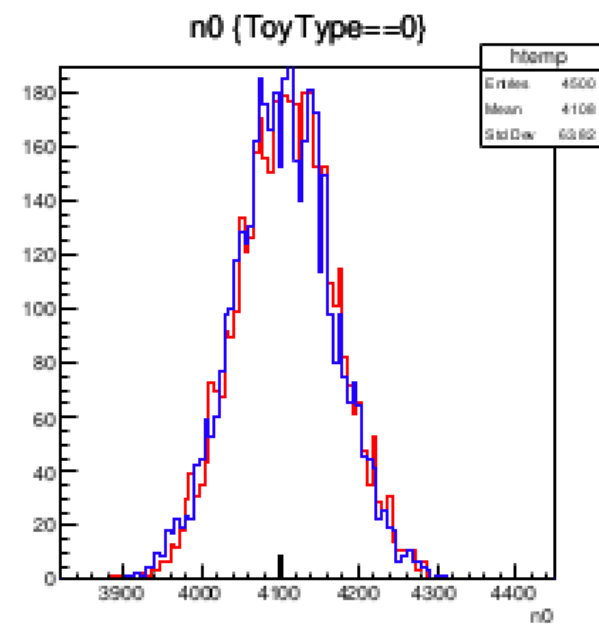
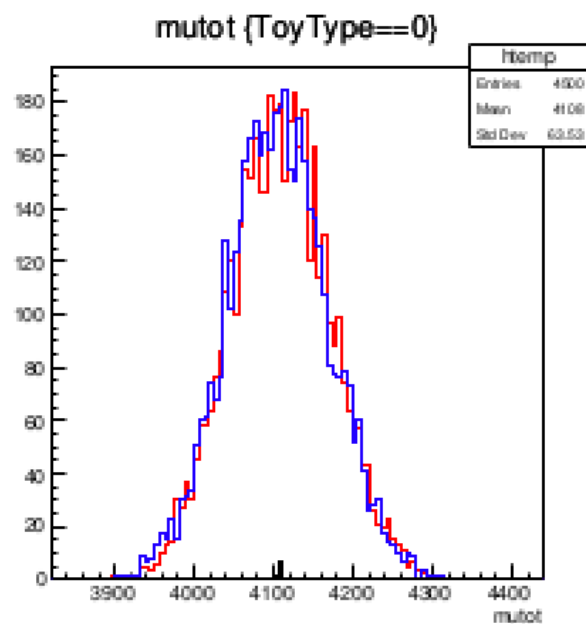
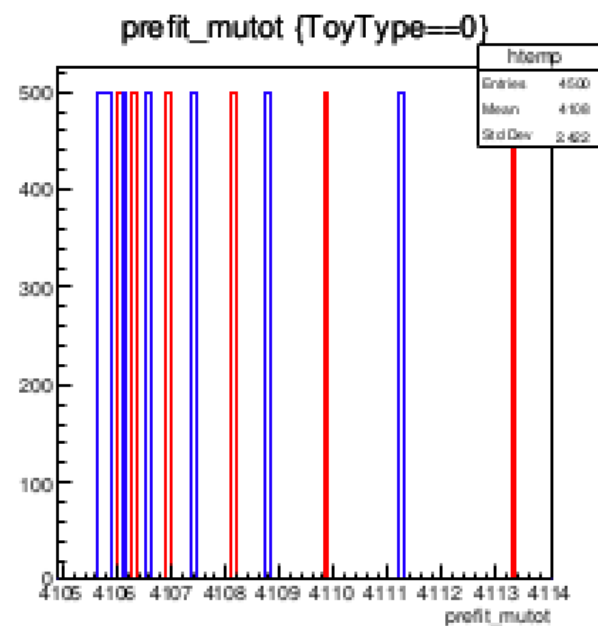


WM, WD

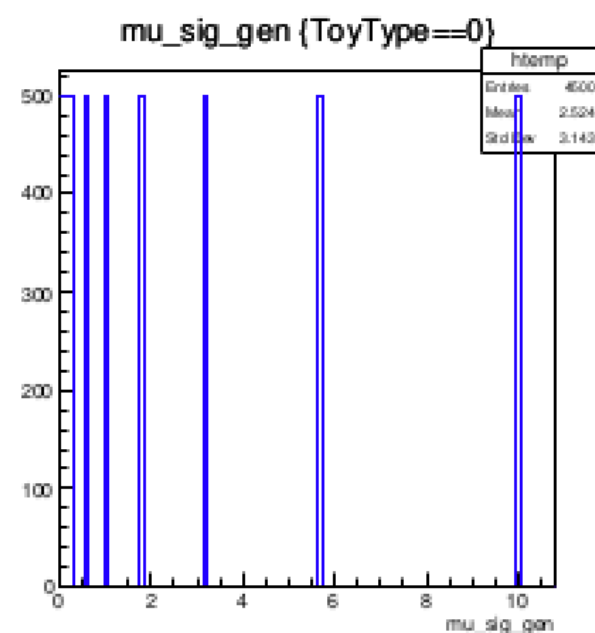
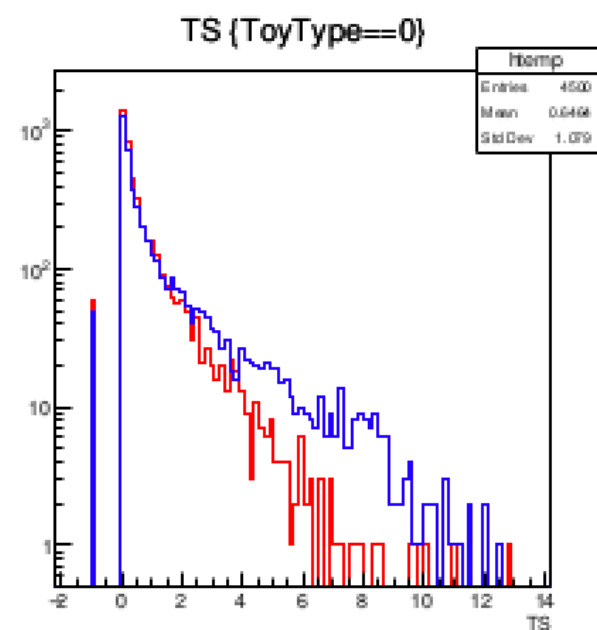
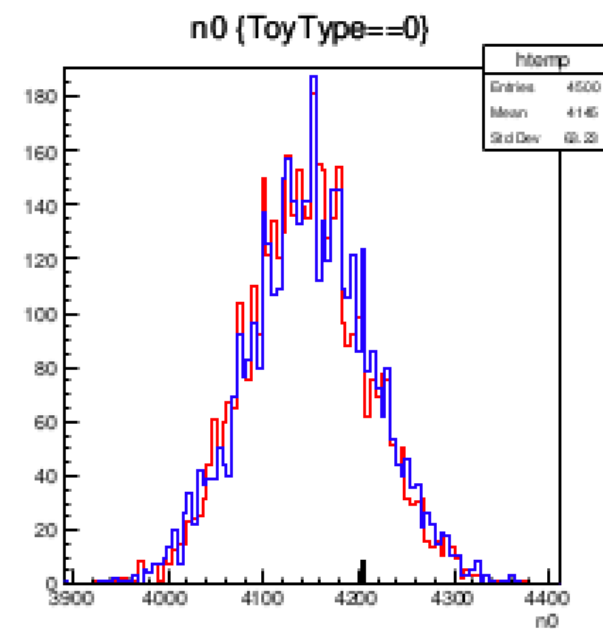
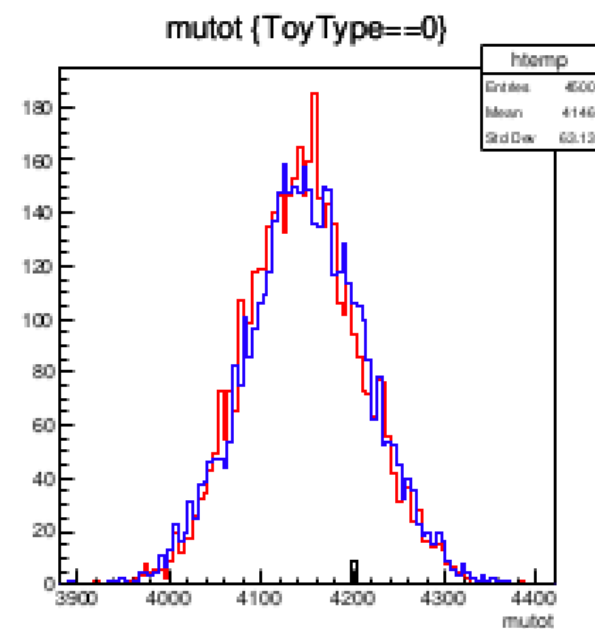
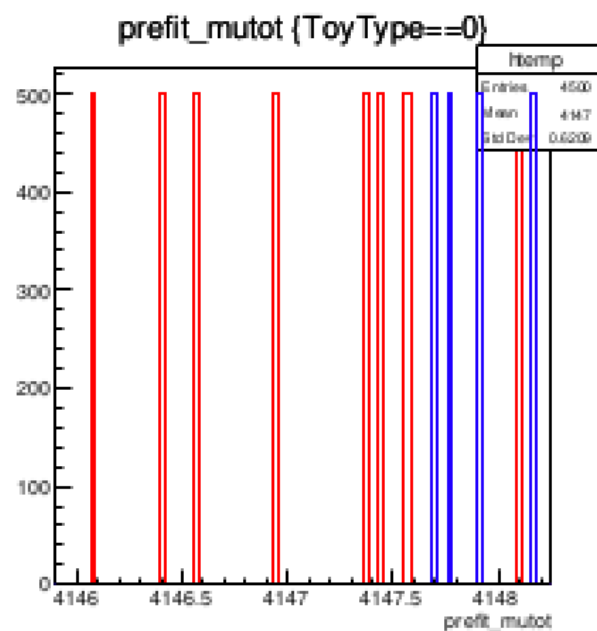


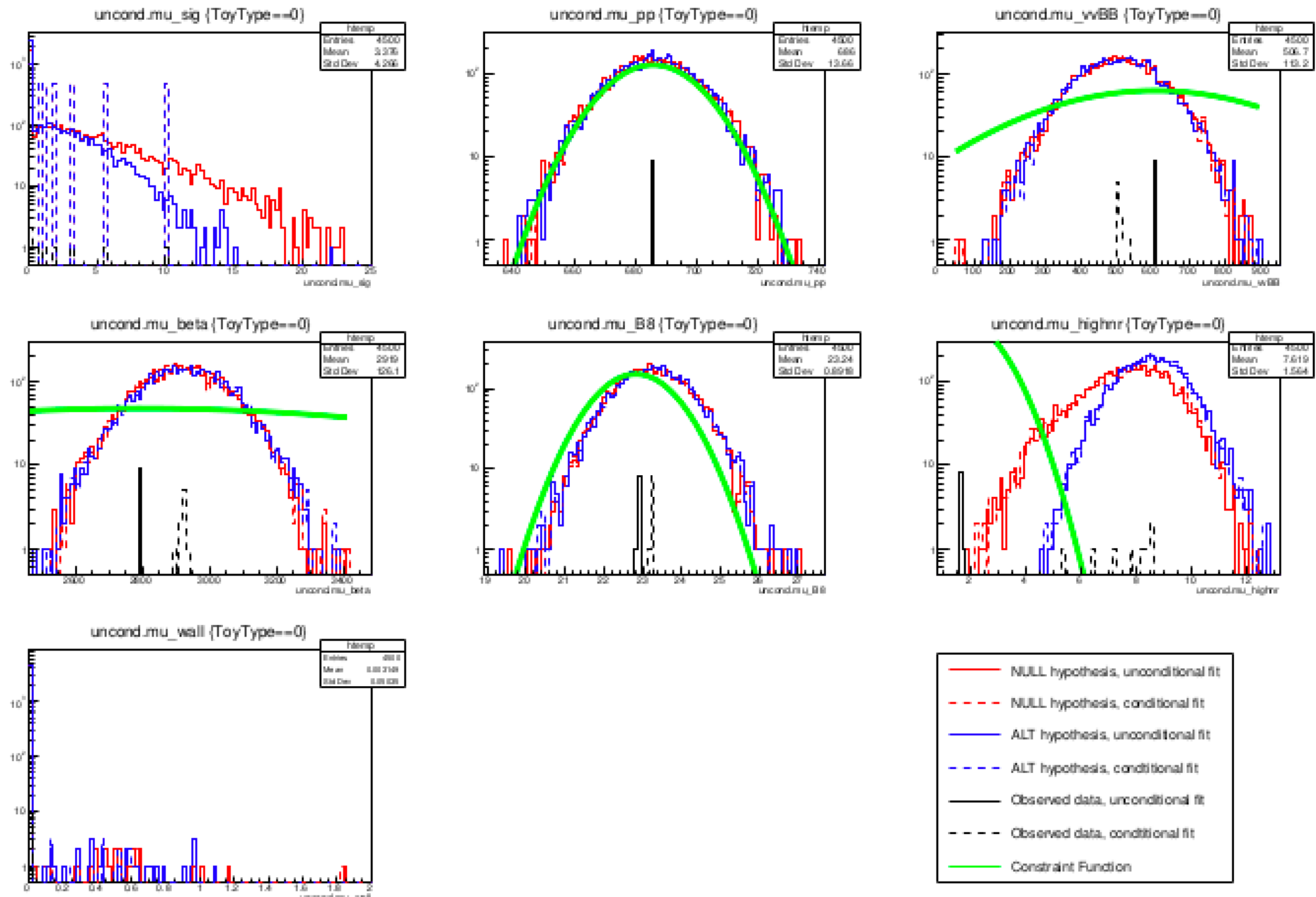


NW,ND



ND,WM





Update

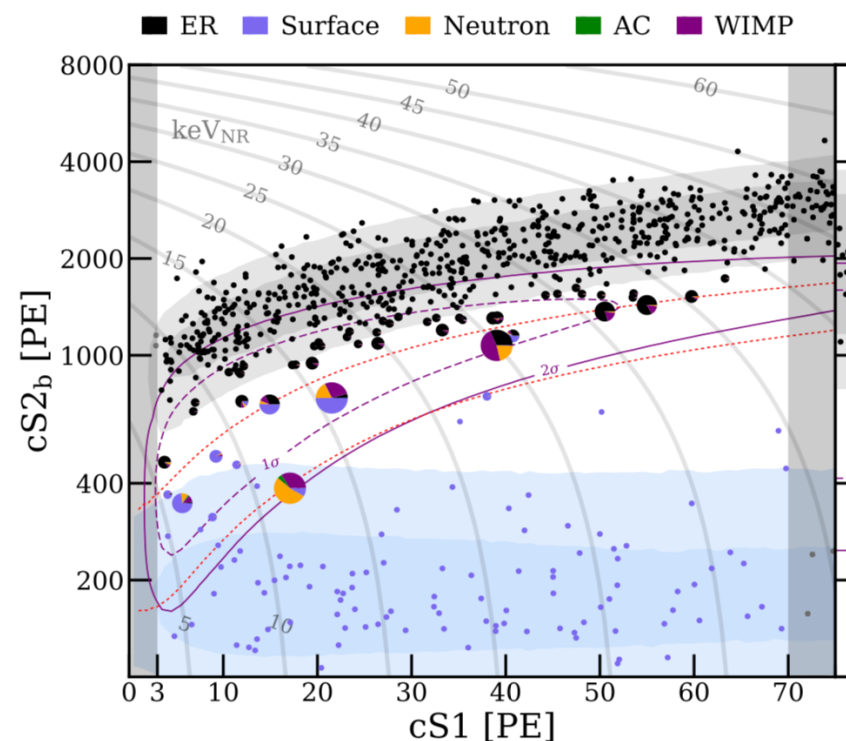
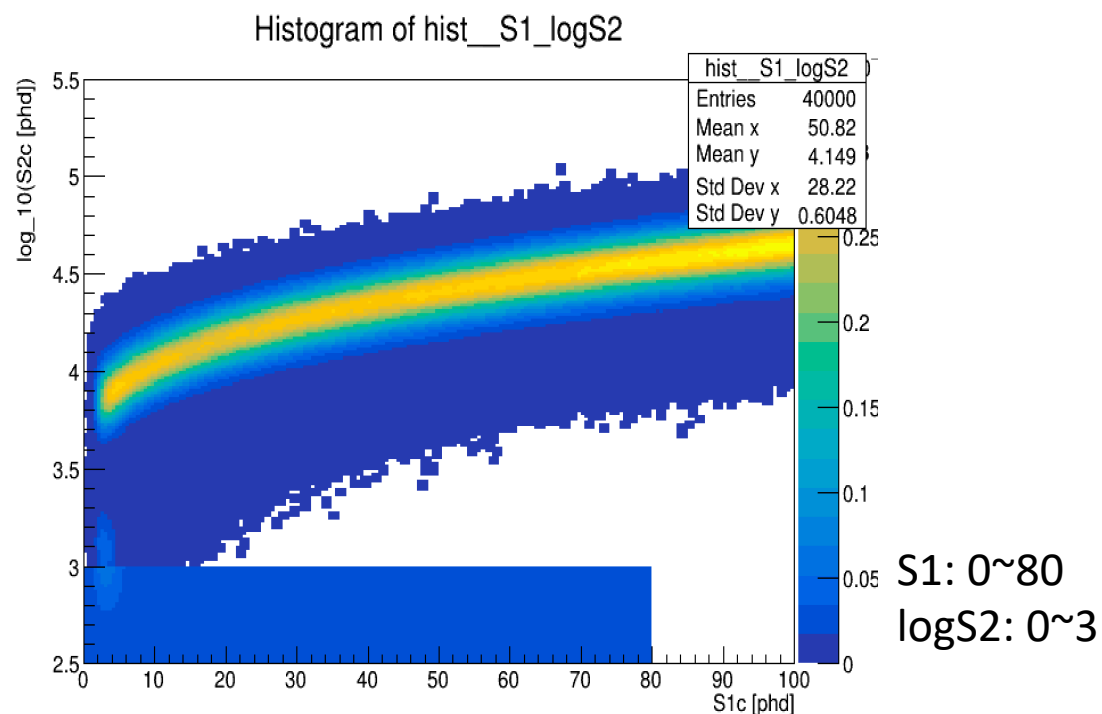
- How the wall model affects the limit
- Learnt a lot about RooFit
- With Jonathan's great help, able to create the wall model and add it to the workspace.
- 4 cases

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

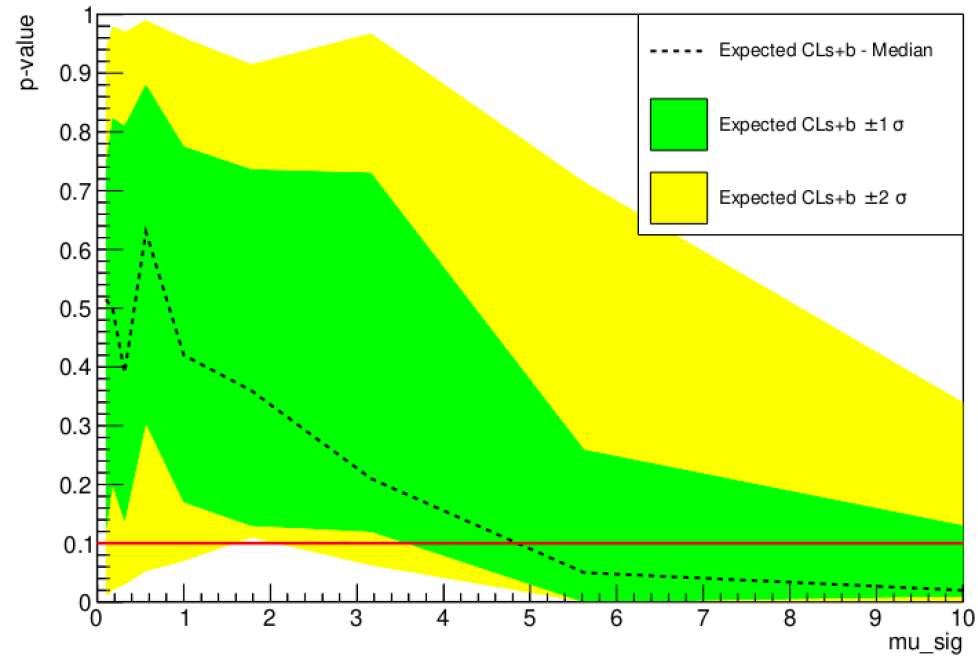
Wall model

- Create workspace:

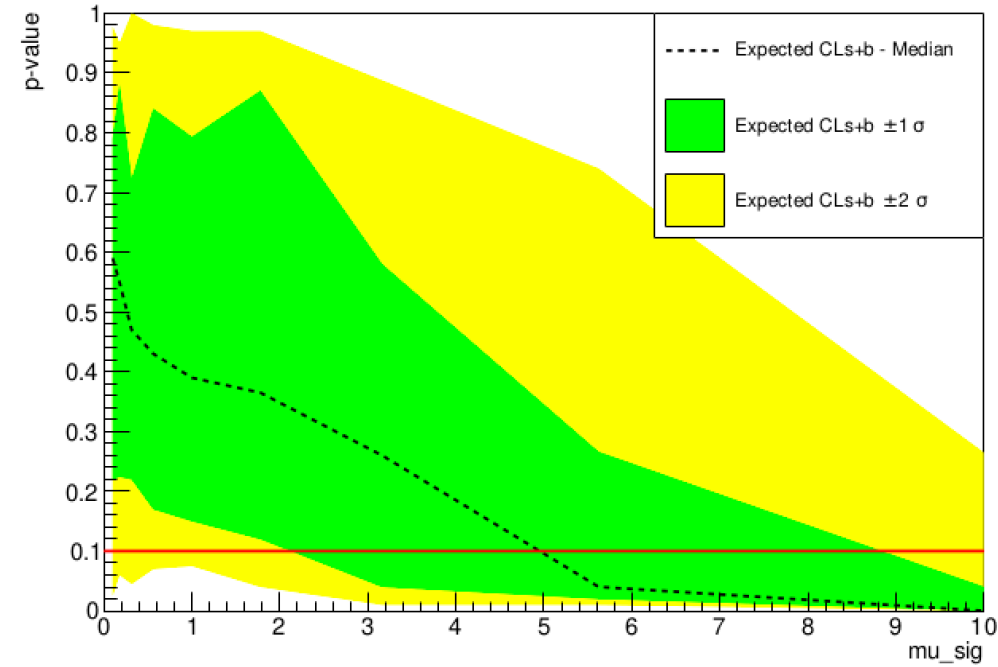
- Wall model: create 2 step functions, S1, and logS2, and take their product and add it to the EventModel
- Can control the expected event of wall model: `w->var("mu_wall")->setVal();`
- Set the mu_wall to be 15, for 1000 livedays



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
 $\mu_{\text{sig}} = 4.8543$



With wall model, with wall data
 $\mu_{\text{sig}} = 4.9522$

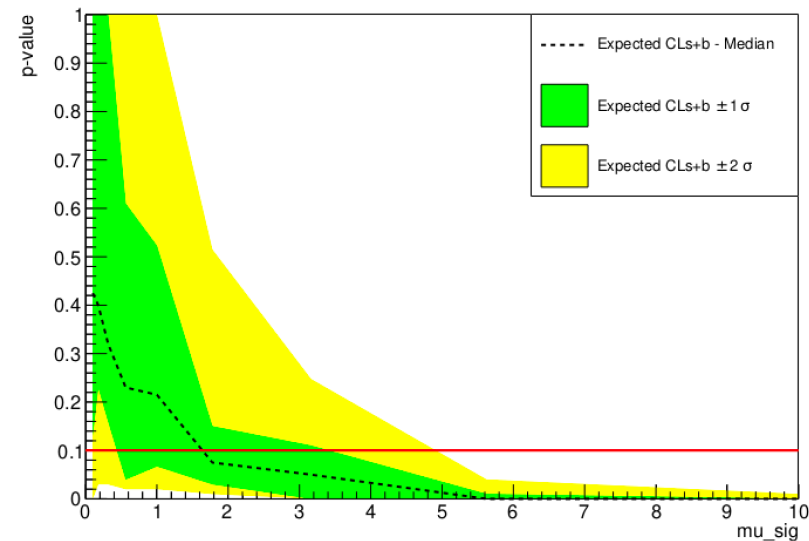
To Do

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

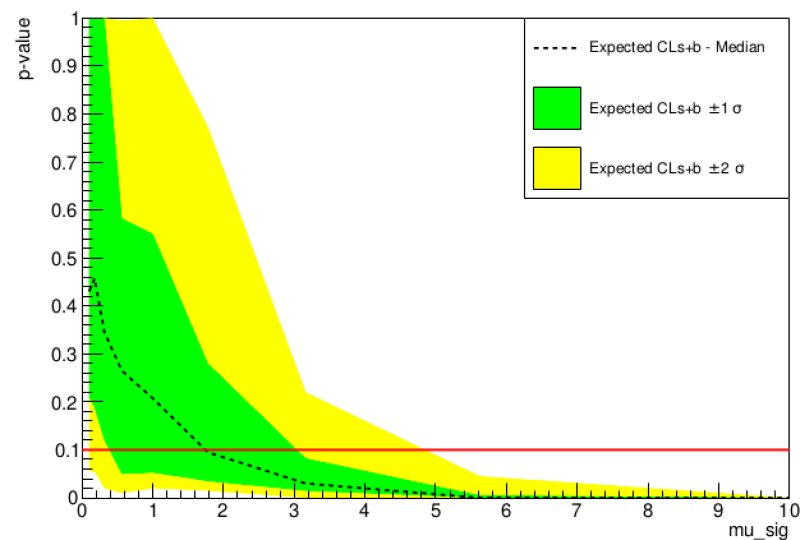
What's new

- 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)

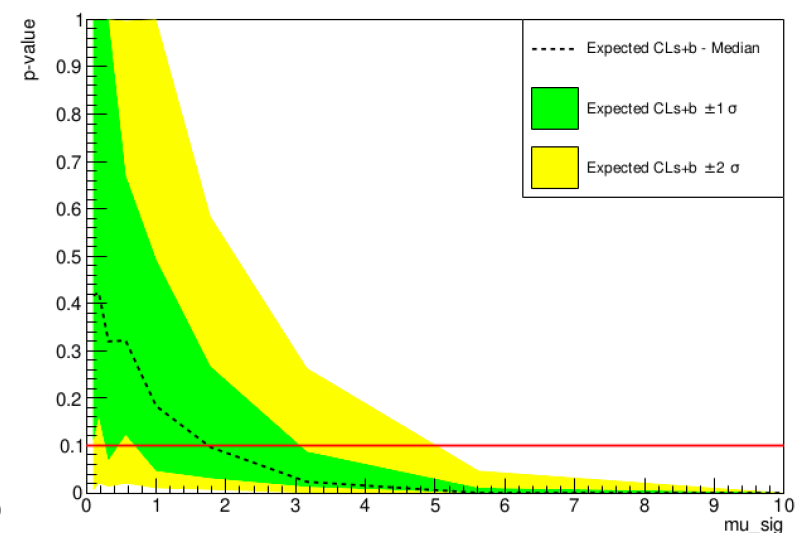
NSCAN_POI = 9, log scan



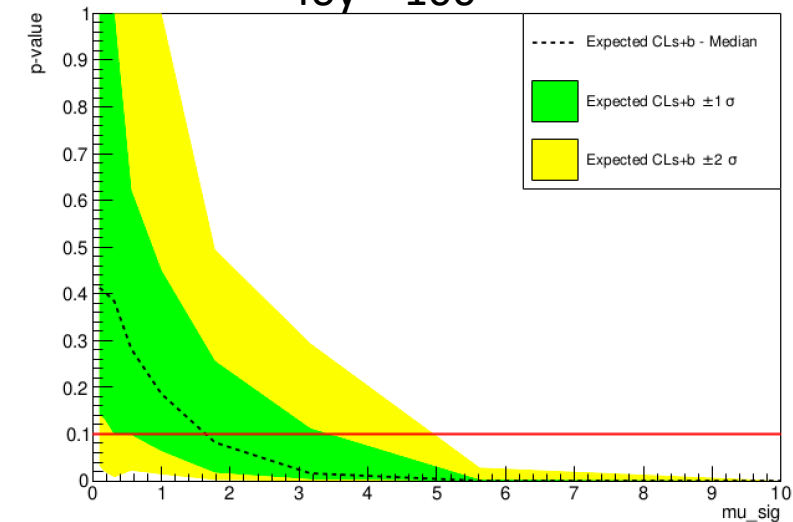
Toy = 100



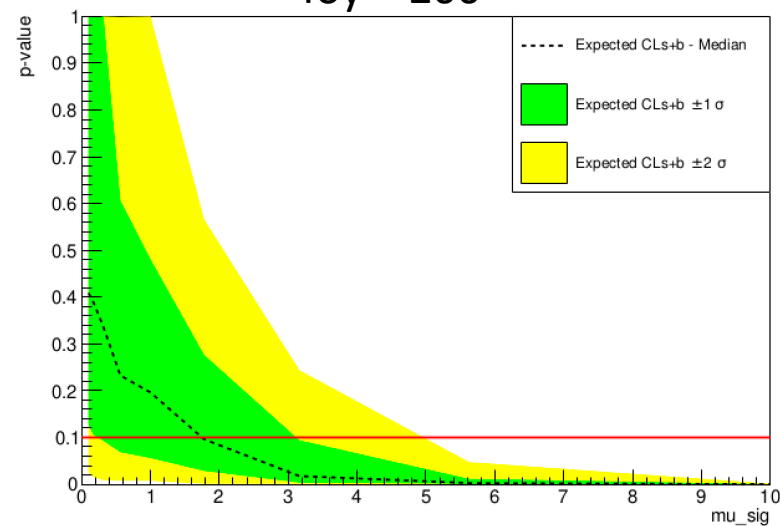
Toy = 200



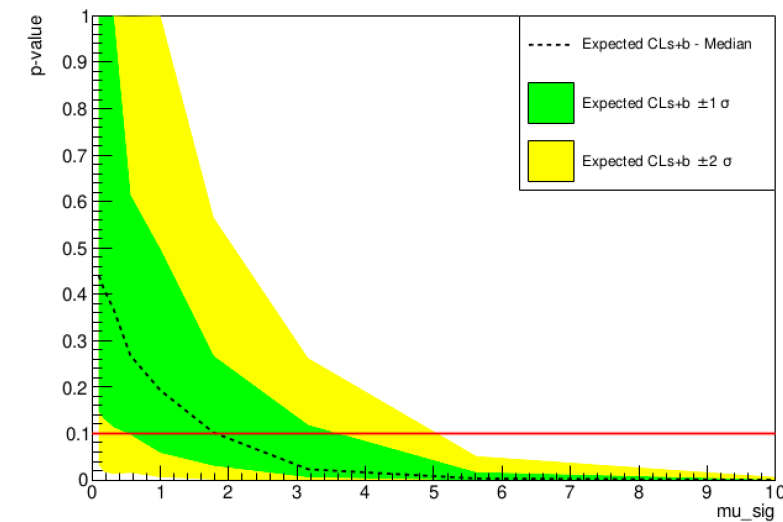
Toy = 300



Toy = 500

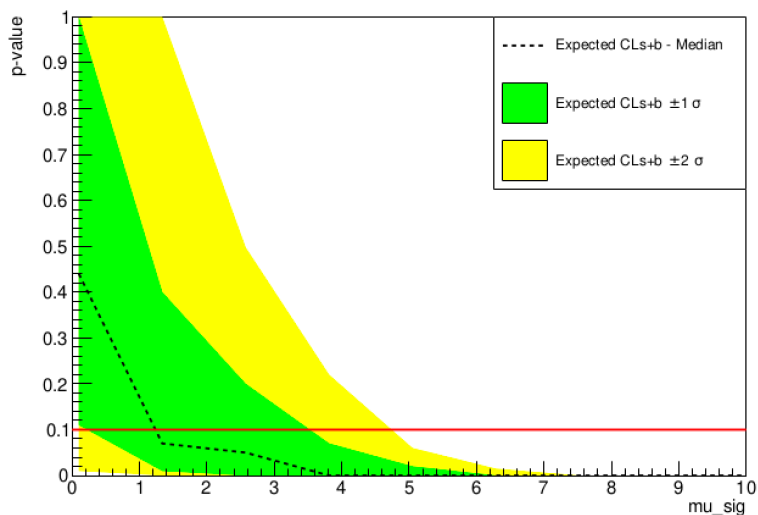


Toy = 800

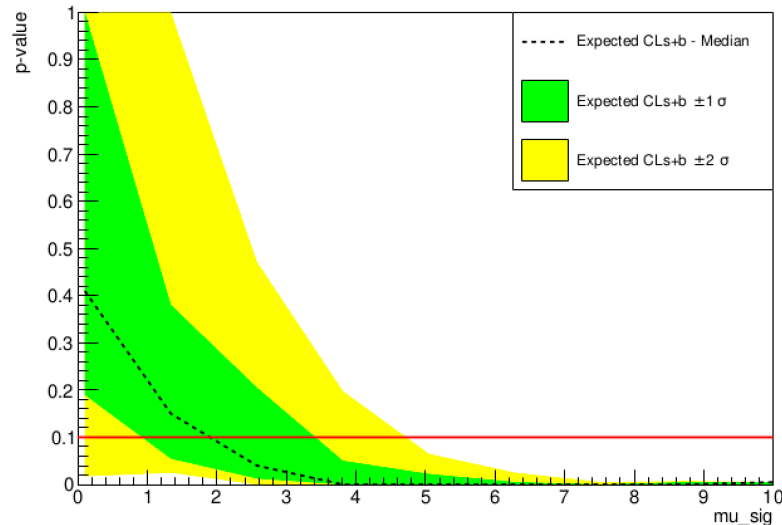


Toy = 1000

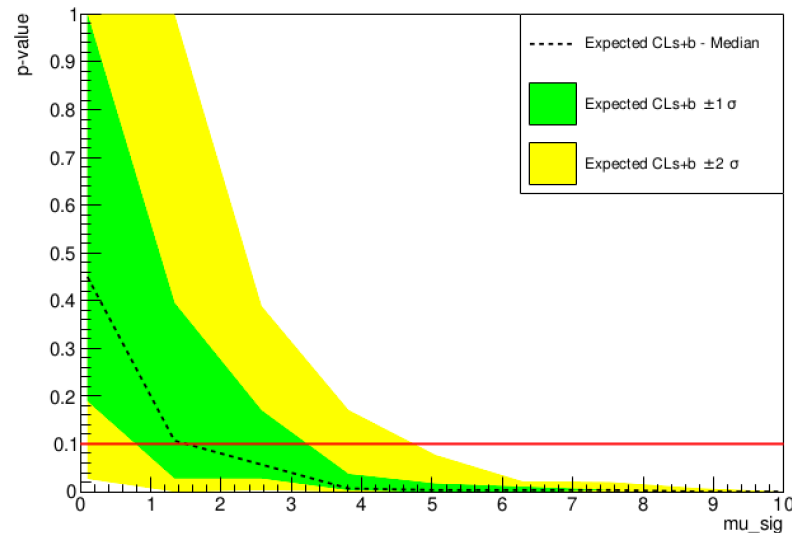
NSCAN_POI = 9, non-log scan



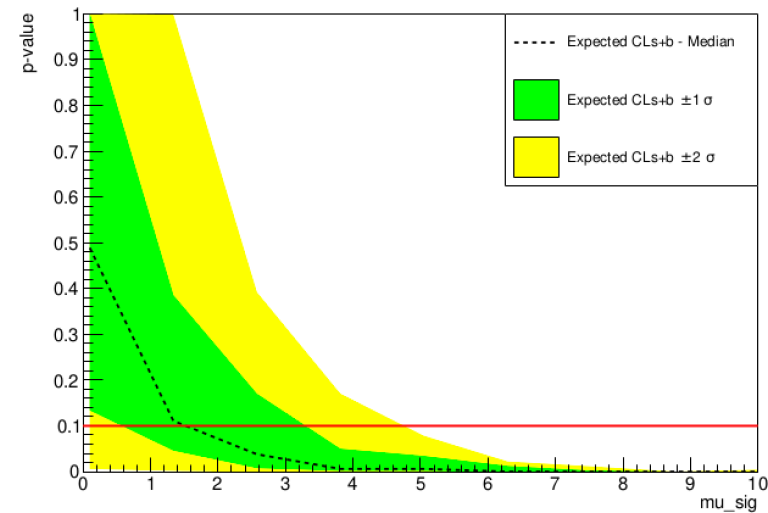
Toy = 100



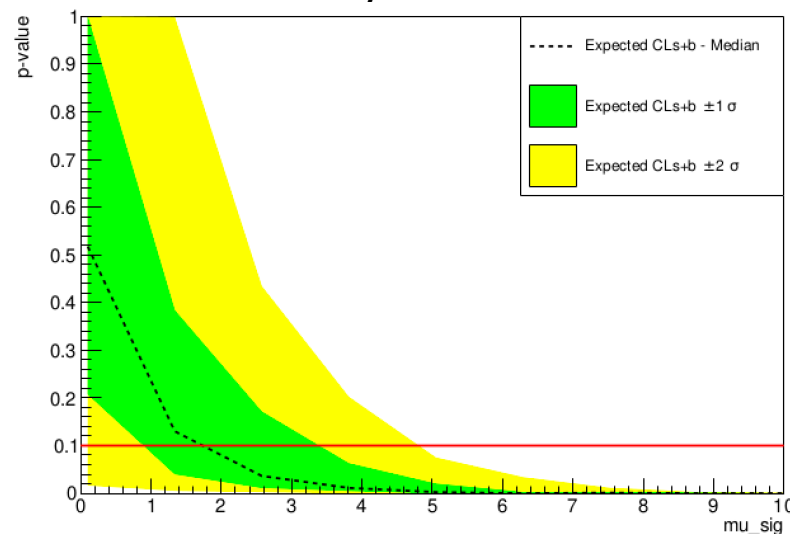
Toy = 200



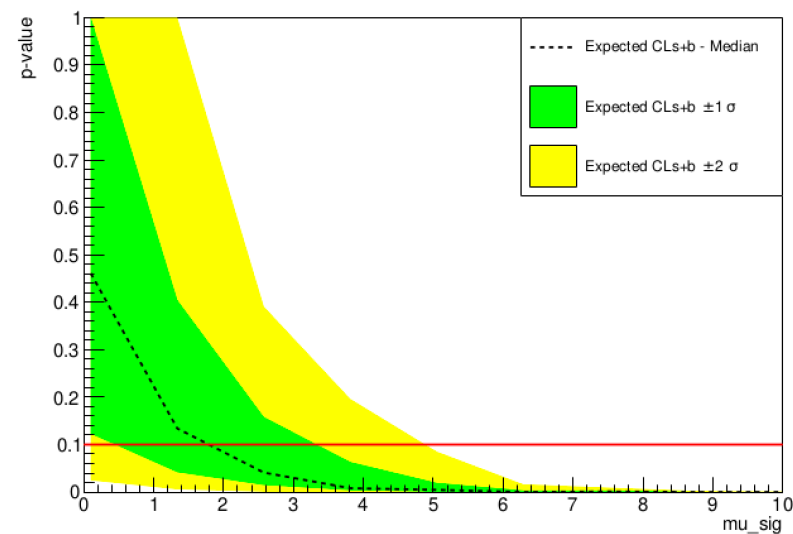
Toy = 300



Toy = 500

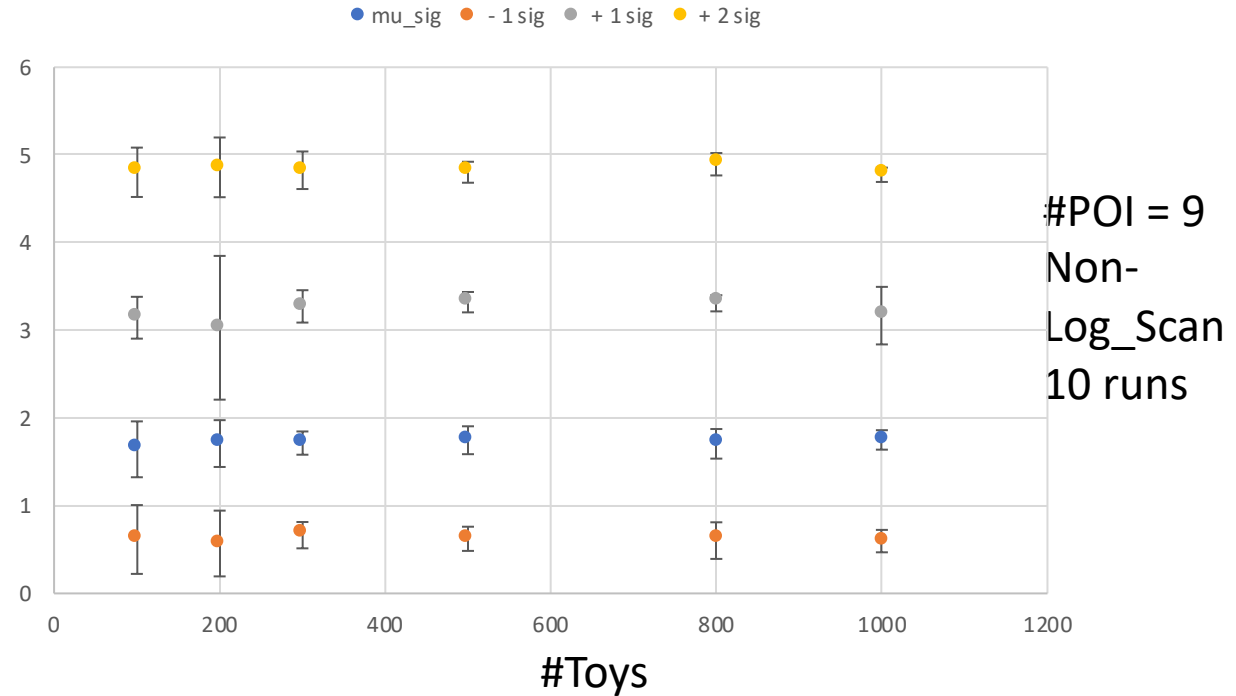
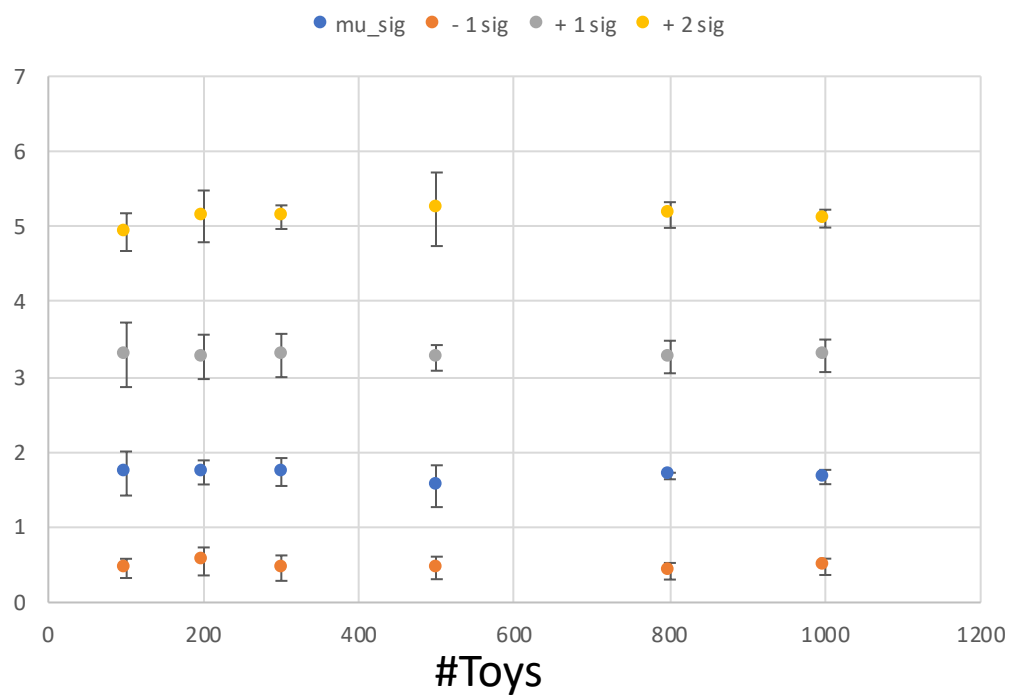


Toy = 800

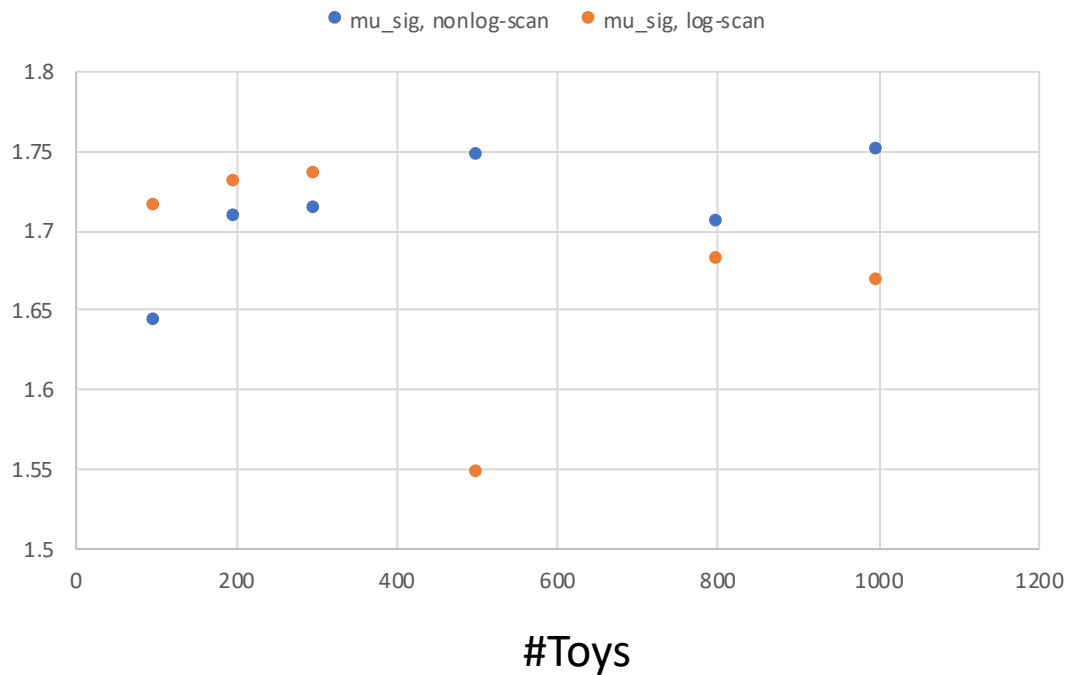


Toy = 1000

#POI = 9
Log_Scan
10 runs



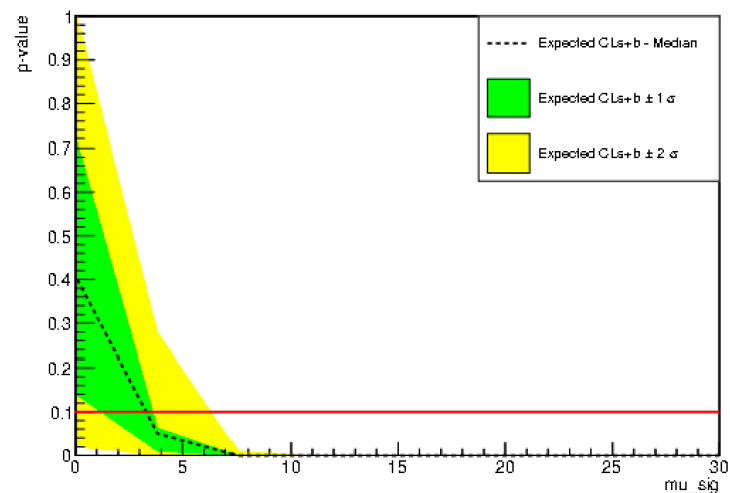
#POI = 9
Non-
Log_Scan
10 runs



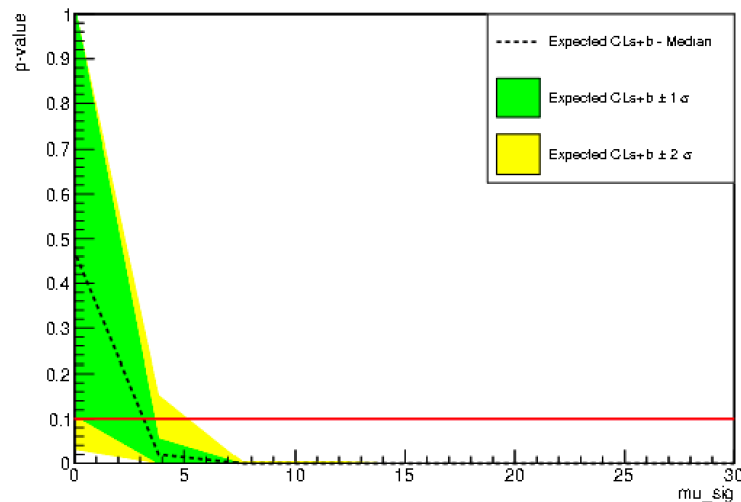
What's new

- 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)

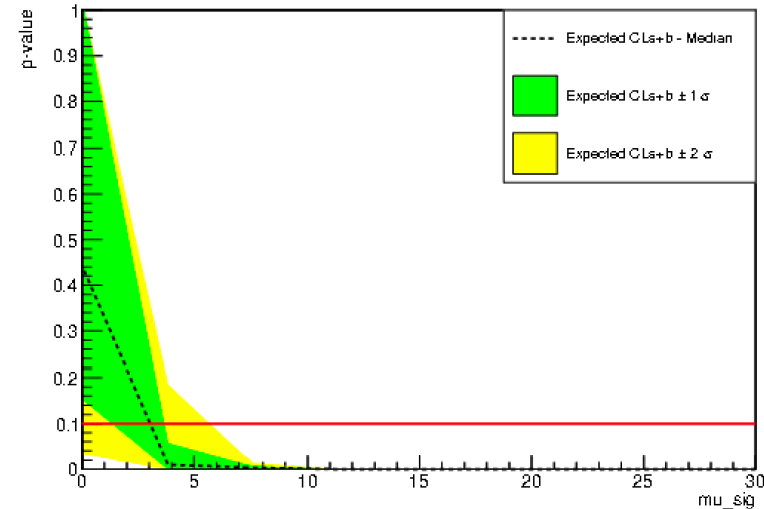
NSCAN_POI = 9, non-log scan



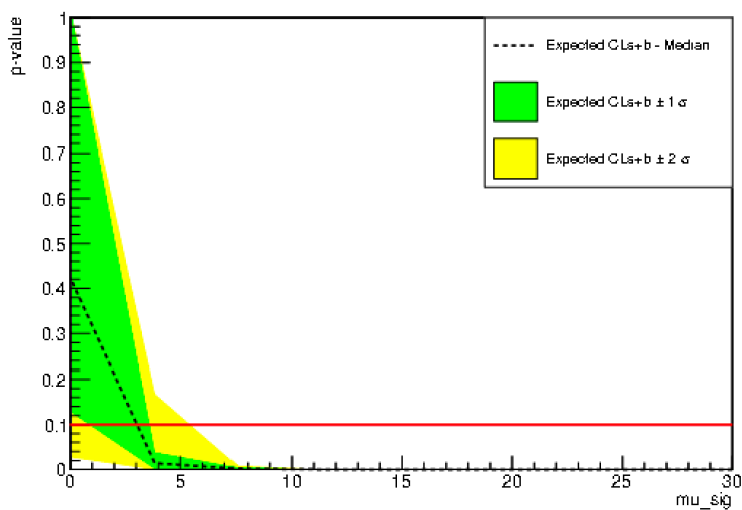
Toy = 100



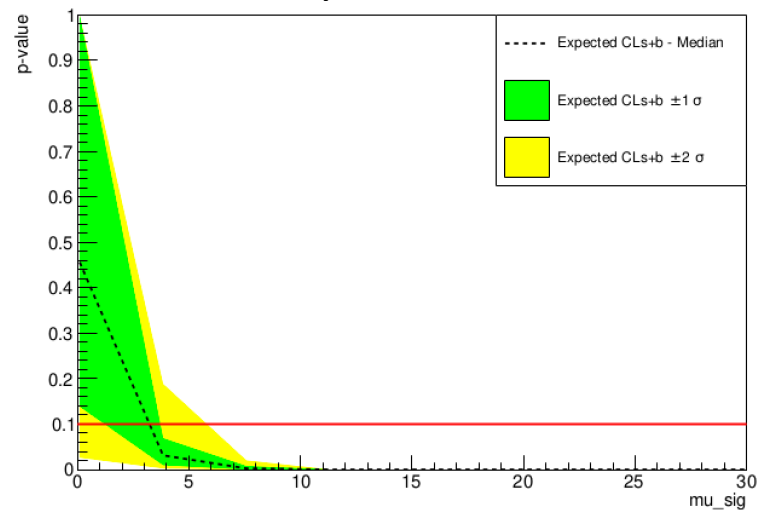
Toy = 200



Toy = 300

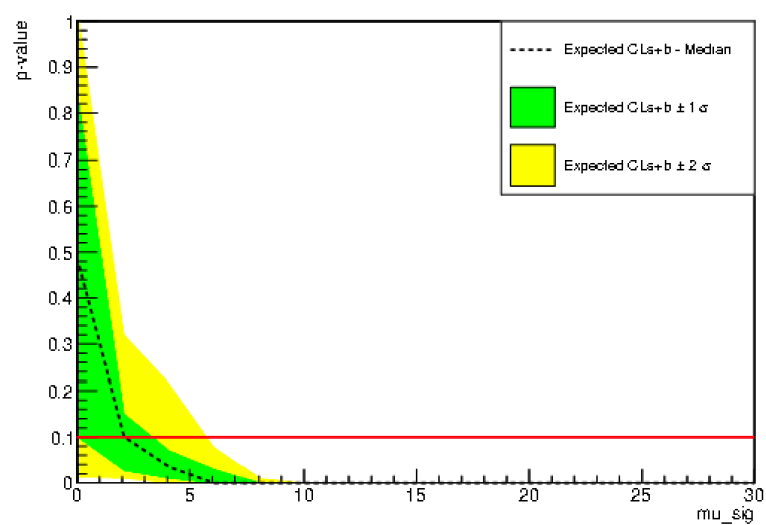


Toy = 500

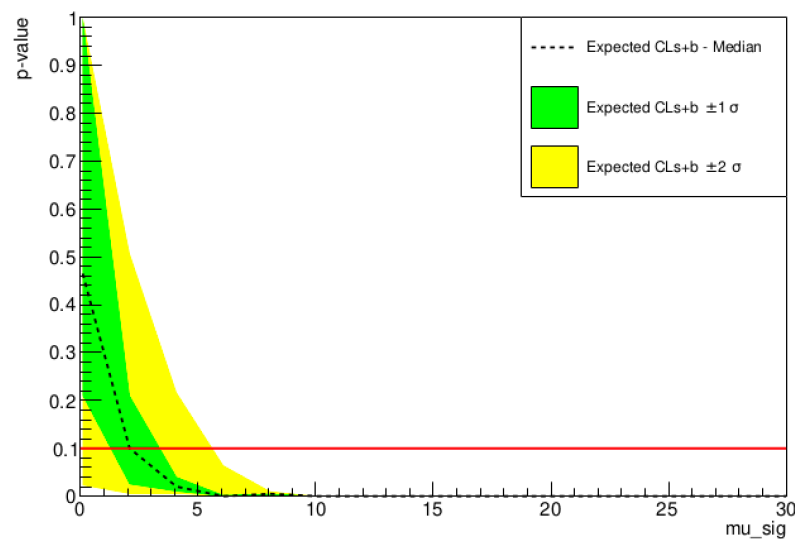


Toy = 800

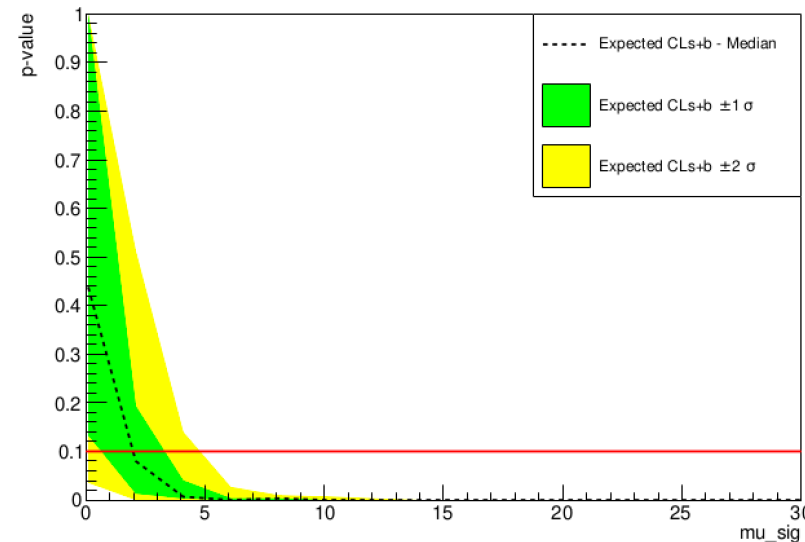
NSCAN_POI = 16, non-log scan



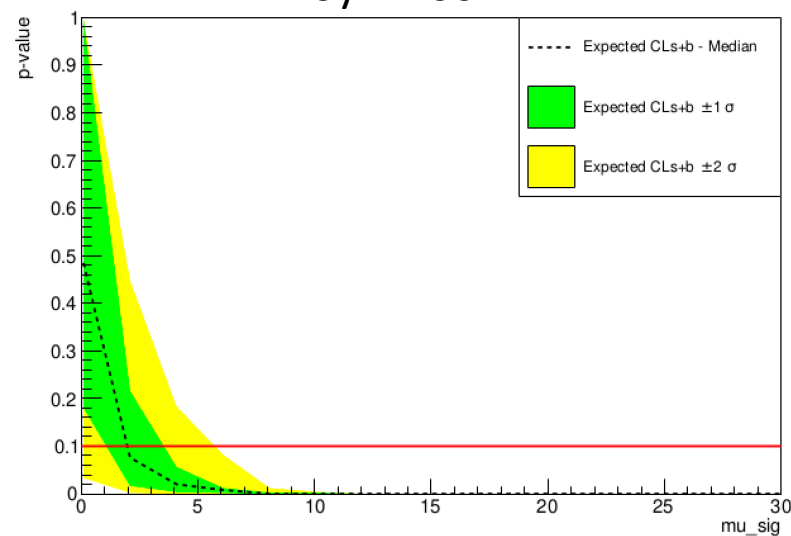
Toy = 100



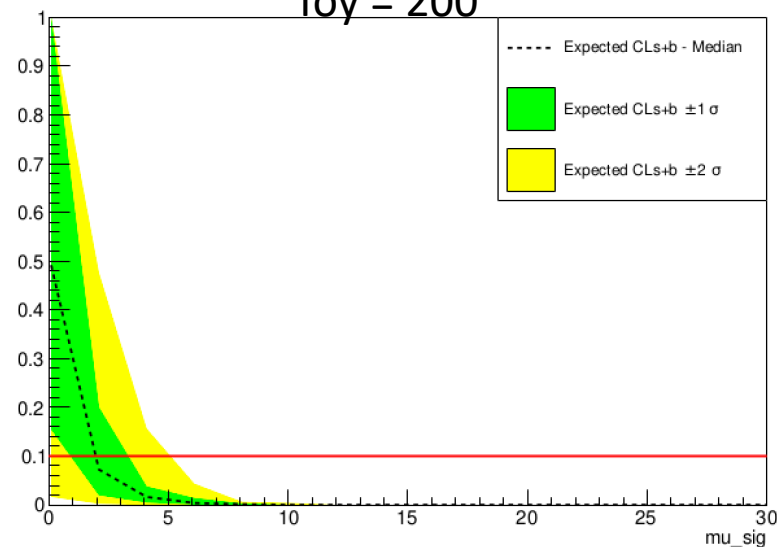
Toy = 200



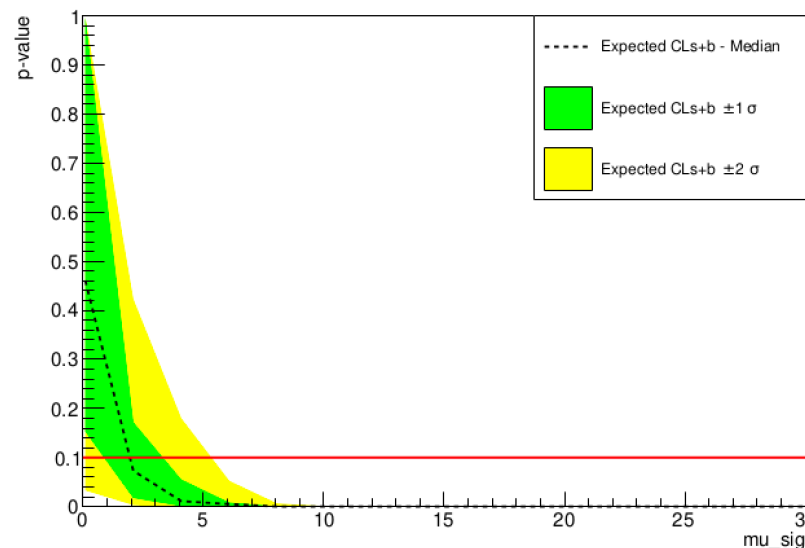
Toy = 300



Toy = 500

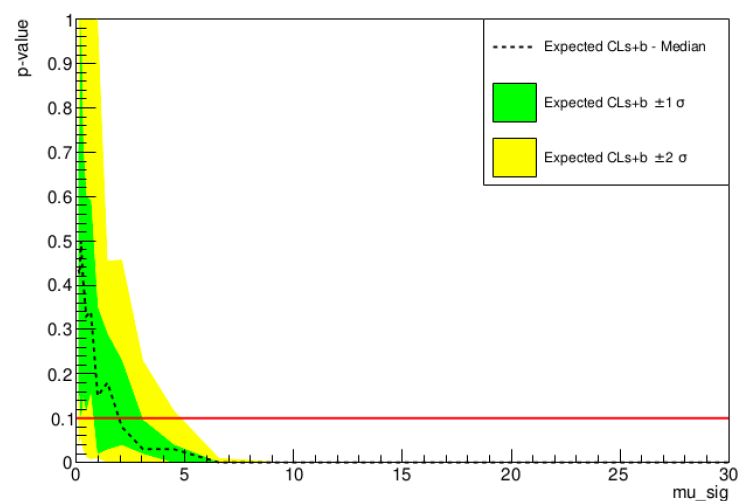


Toy = 800

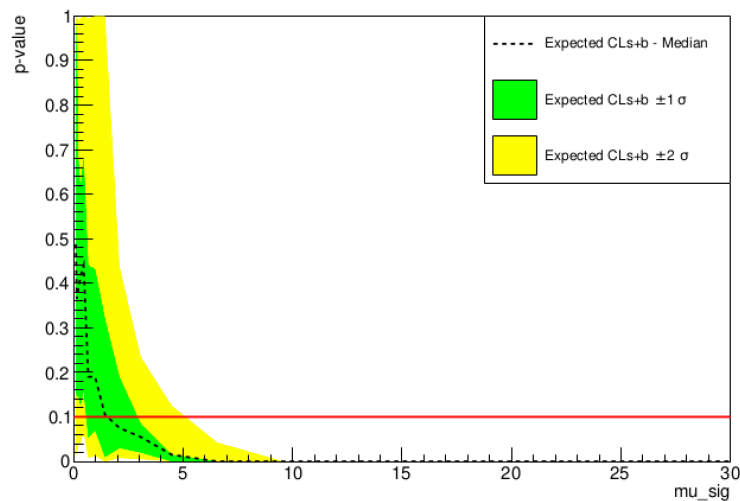


Toy = 1000

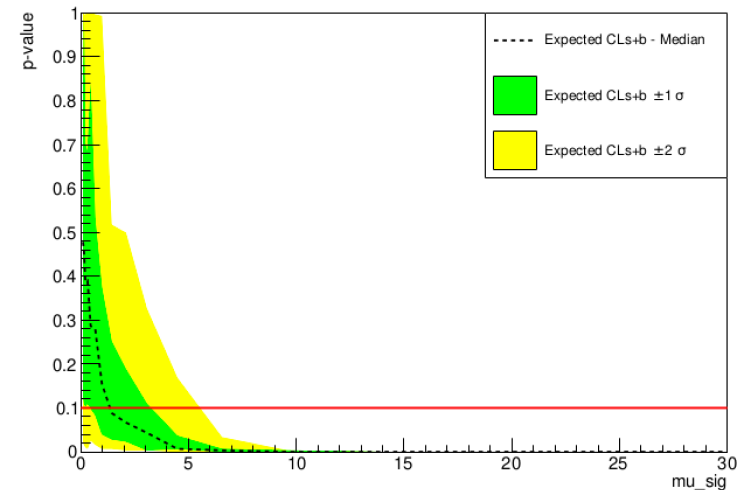
NSCAN_POI = 16, log_scan



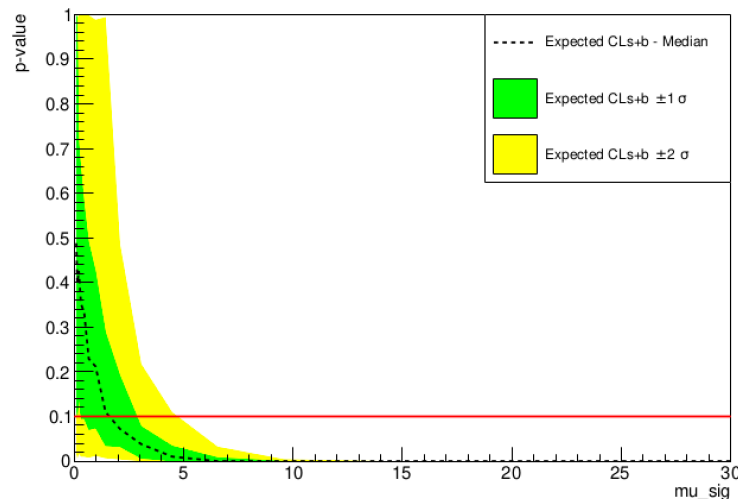
Toy = 100



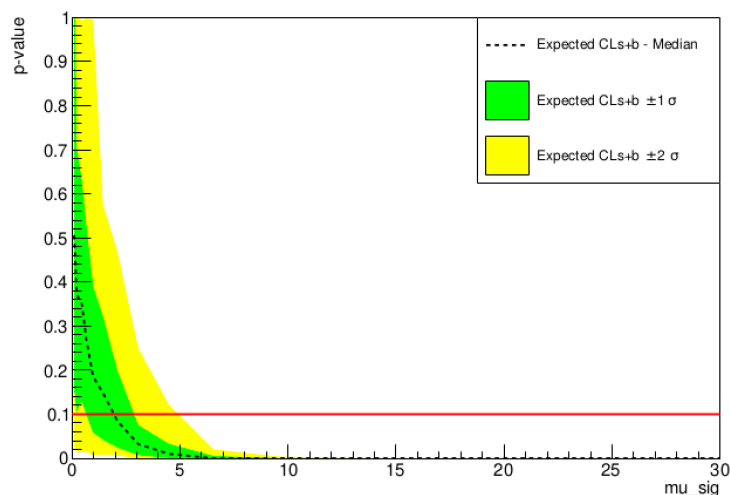
Toy = 200



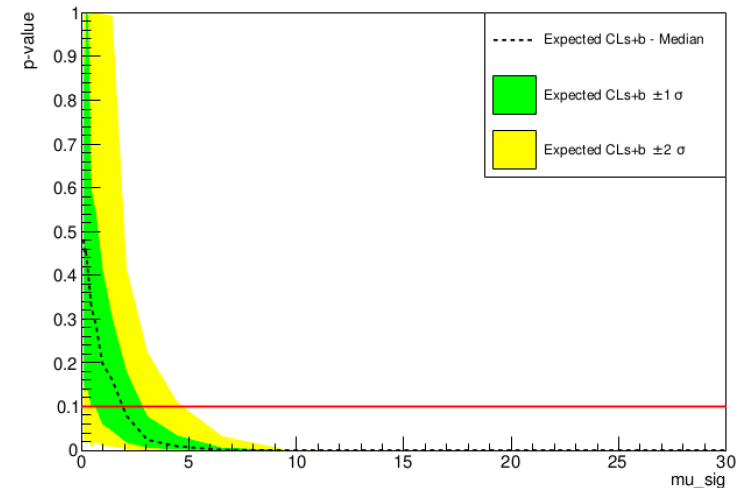
Toy = 300



Toy = 500



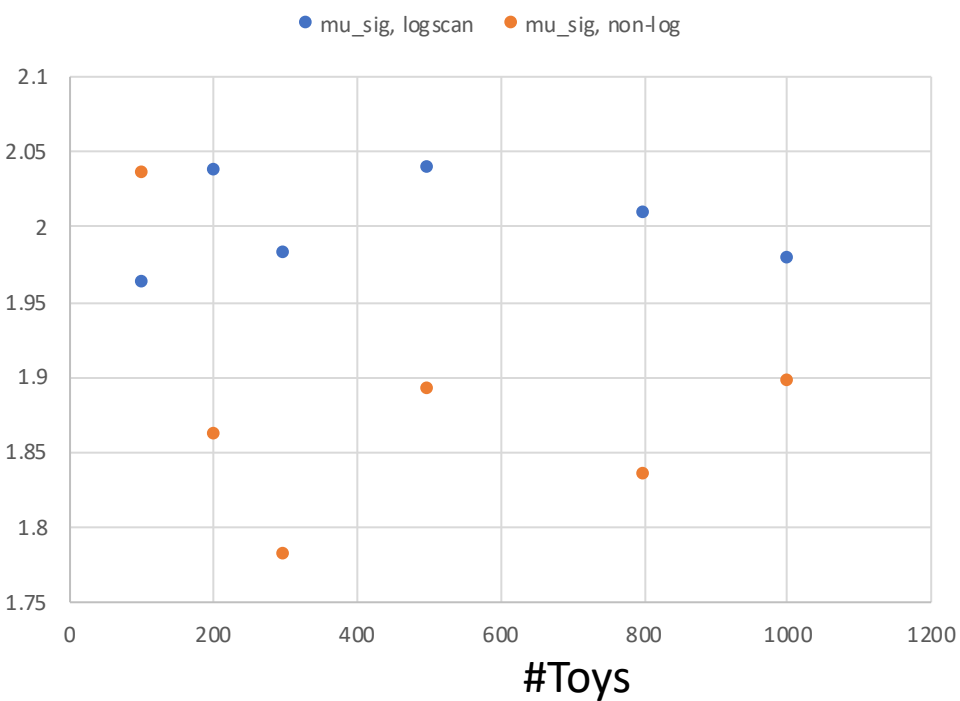
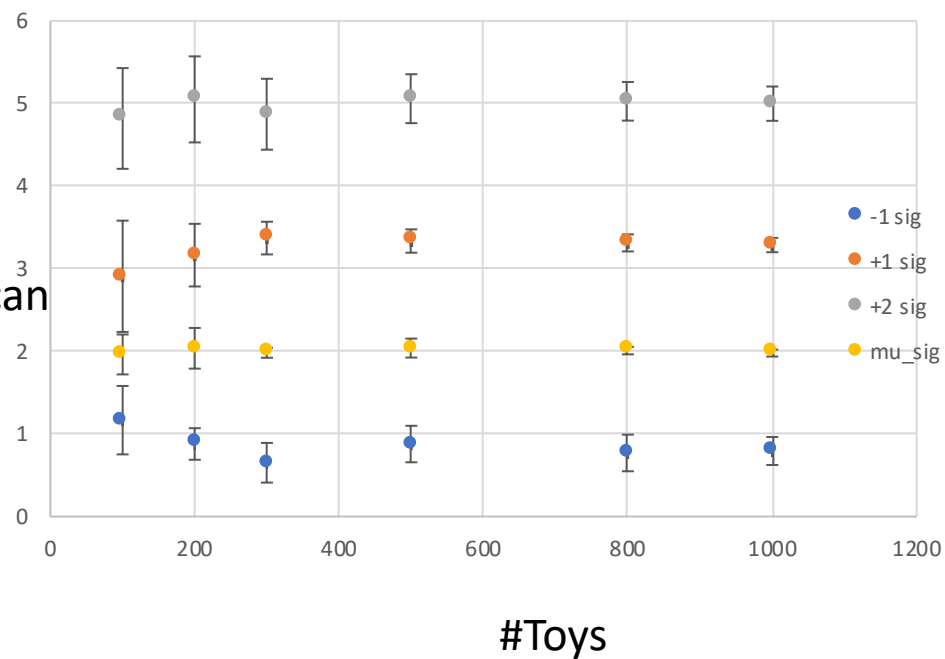
Toy = 800



Toy = 1000

#POI = 16
Non-Log_Scan
10 runs

#POI = 16
Log_Scan
5 runs



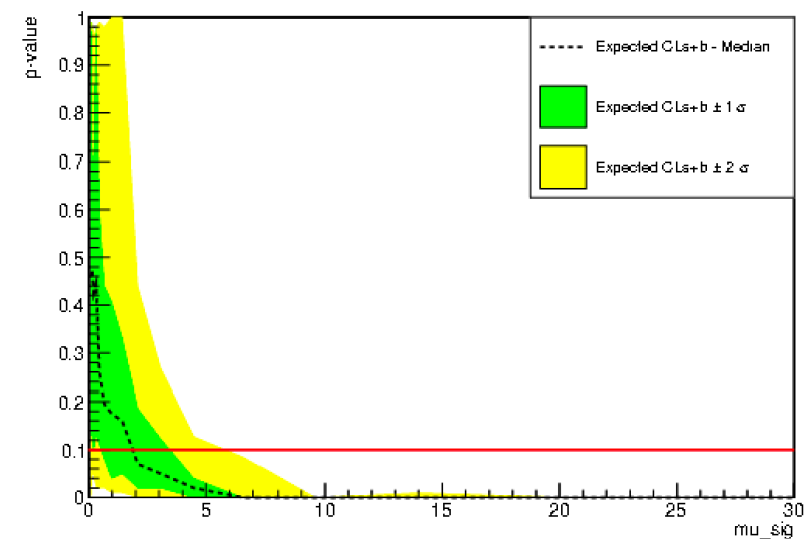
	Mu_sig		Cross section	
100	2.035	1.962	2.304E-47	2.221E-47
200	1.862	2.037	2.108E-47	2.306E-47
300	1.782	1.983	2.017E-47	2.244E-47
500	1.891	2.039	2.141E-47	2.309E-47
800	1.834	2.009	2.076E-47	2.274E-47
1000	1.896	1.979	2.146E-47	2.240E-47

Next Step

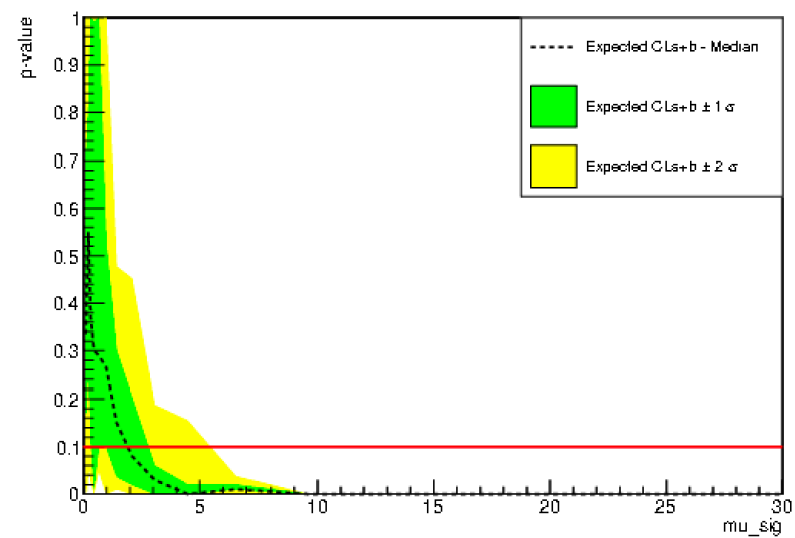
- The # toy test I did before was on 10 GeV, or do a test on lower WIMP mass, $\sim 6\text{GeV}$

New Update

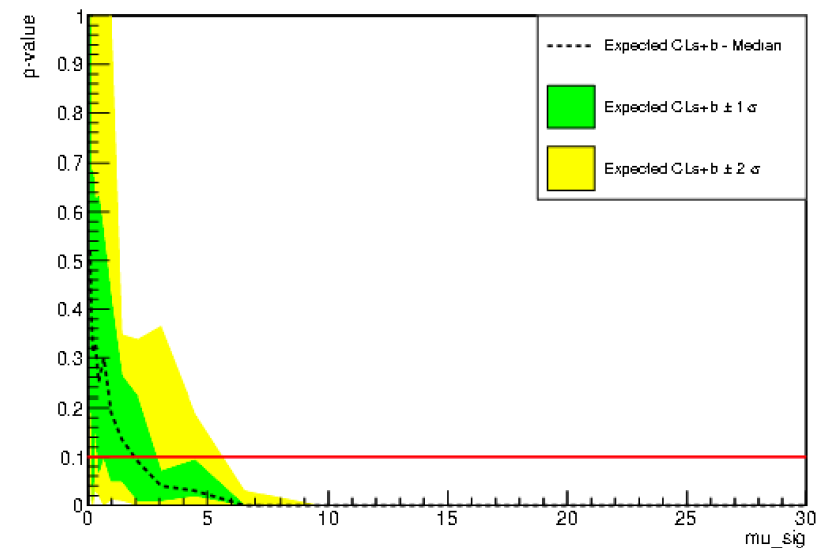
- Create new workspace for WIMP = 40 GeV, μ_{sig} (-100, 100), (-5, 100) (0, 200)
 - $n_{\text{sample}} = 1\text{e}6$
 - Fiducial mass (kg): 5600
 - Livetime (days): 24
 - Min POI = 0.1
 - Max POI = 30
 - Toys/point: 100
- Compare the graphs for different sources at the lower boundary of μ_{sig} (-100, -5, 0)



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

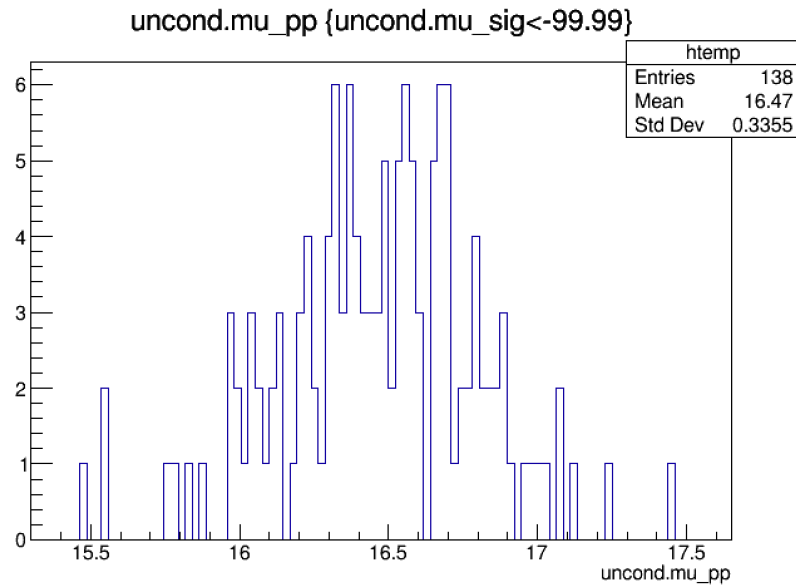


Mu_sig: (-5, 100)
 Mu_sig: 1.9449
 Cross section: $2.2e-47$

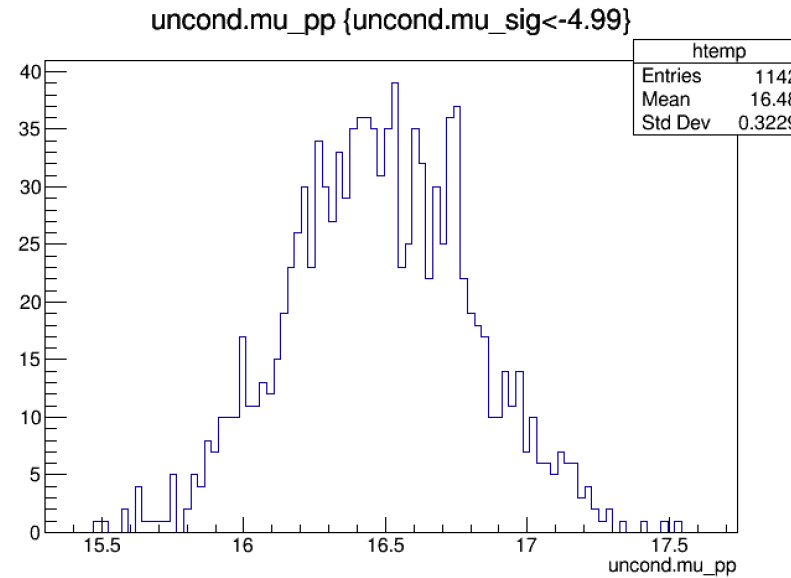


Mu_sig: (0, 200)
 Mu_sig: 1.9457
 Cross section: $2.2e-47$

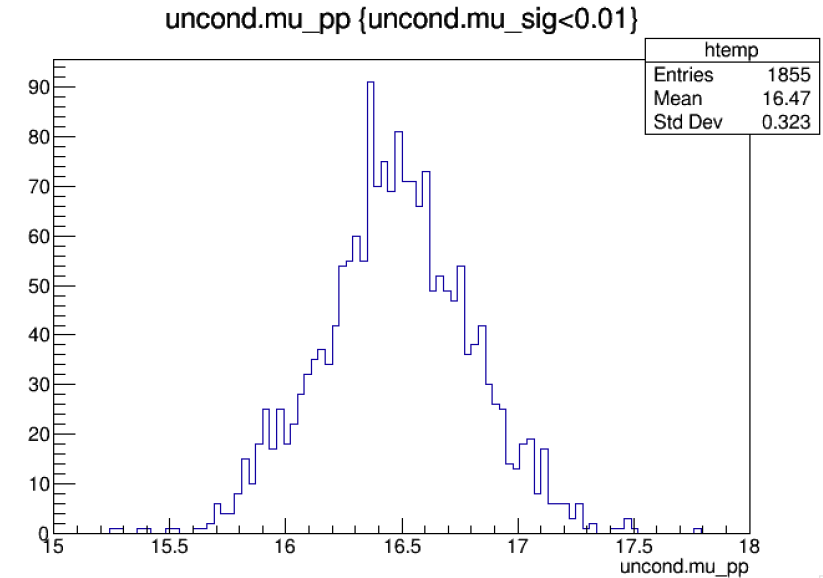
uncond.mu_pp



Mu_sig: (-100, 100)

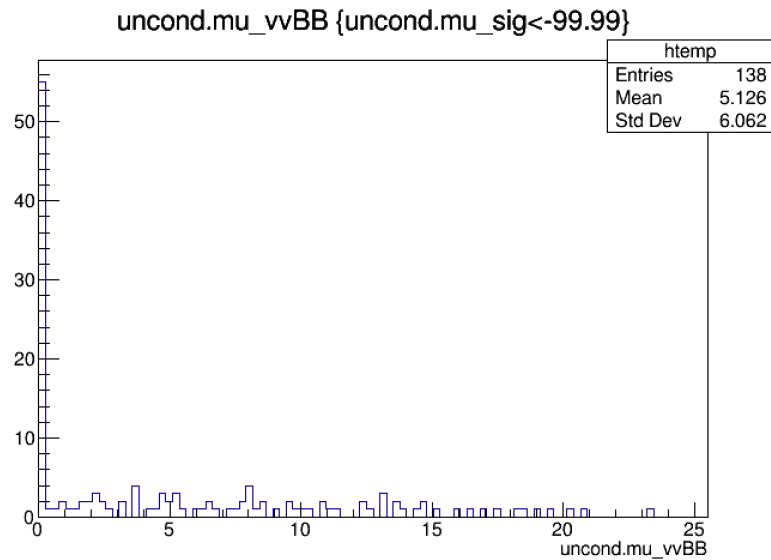


Mu_sig: (-5, 100)

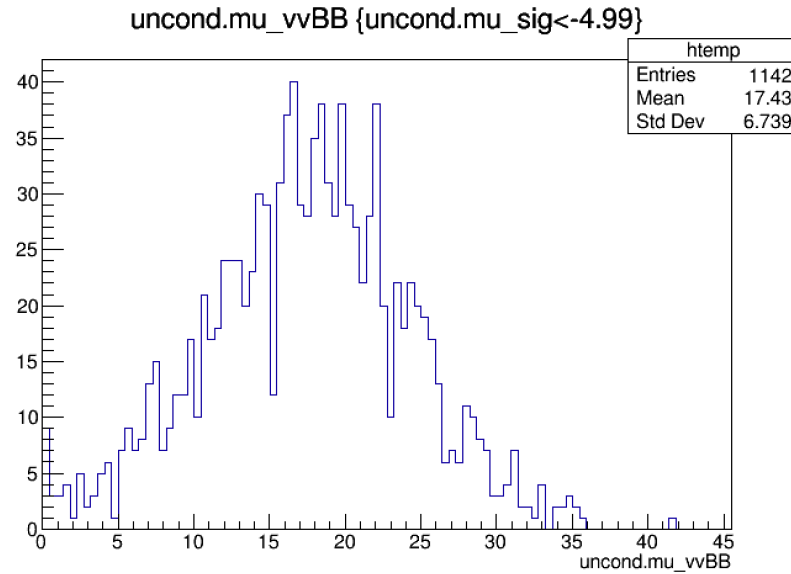


Mu_sig: (0, 200)

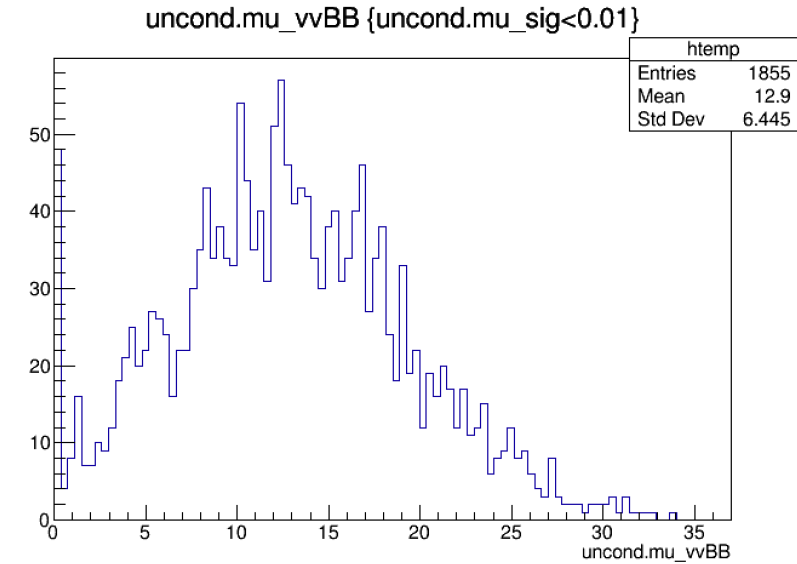
uncond.mu_vvBB



Mu_sig: (-100, 100)

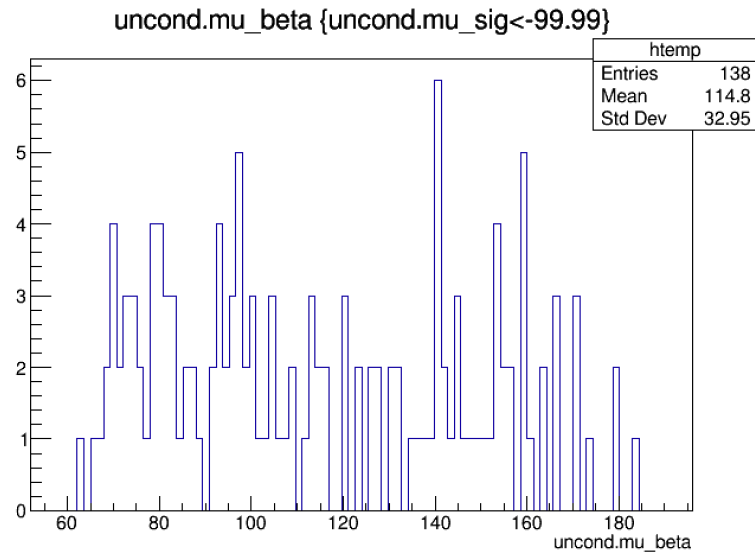


Mu_sig: (-5, 100)

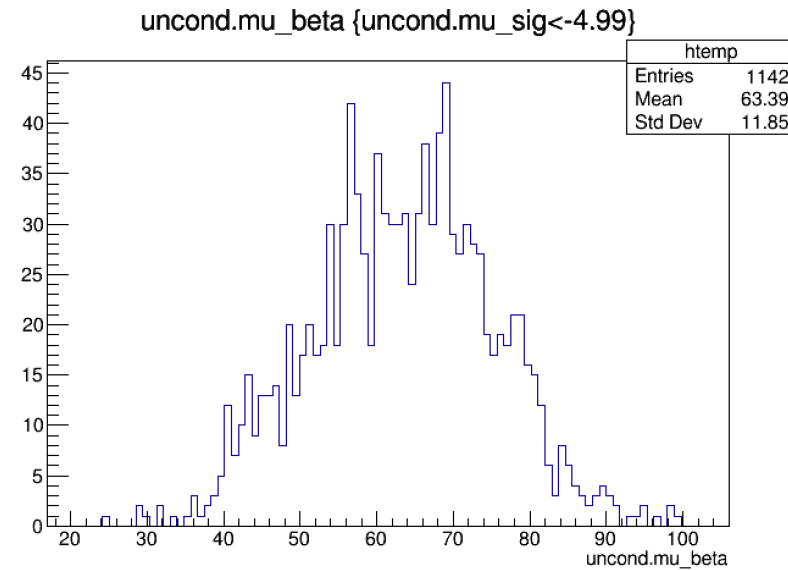


Mu_sig: (0, 200)

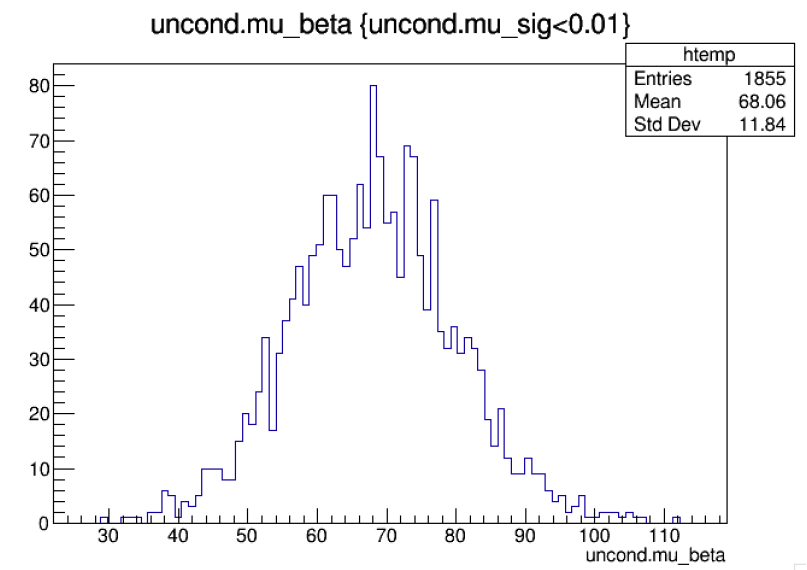
uncond.mu_beta



Mu_sig: (-100, 100)

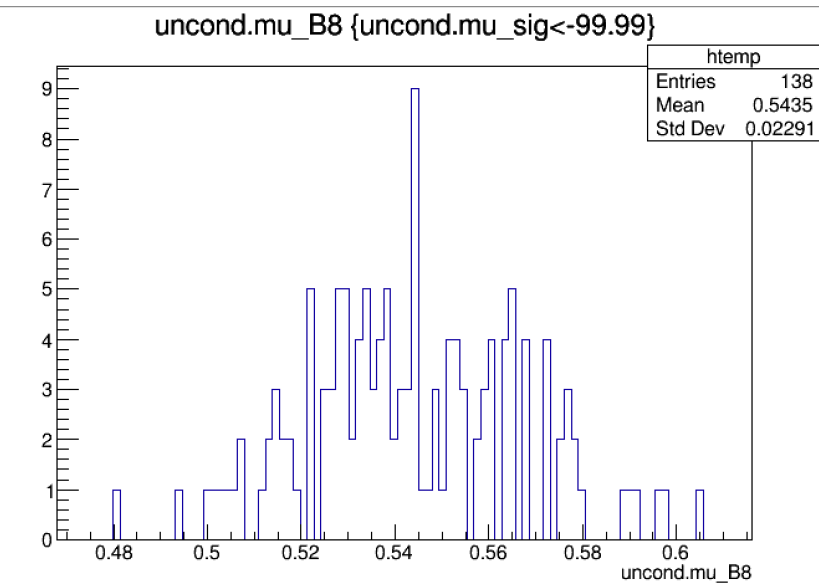


Mu_sig: (-5, 100)

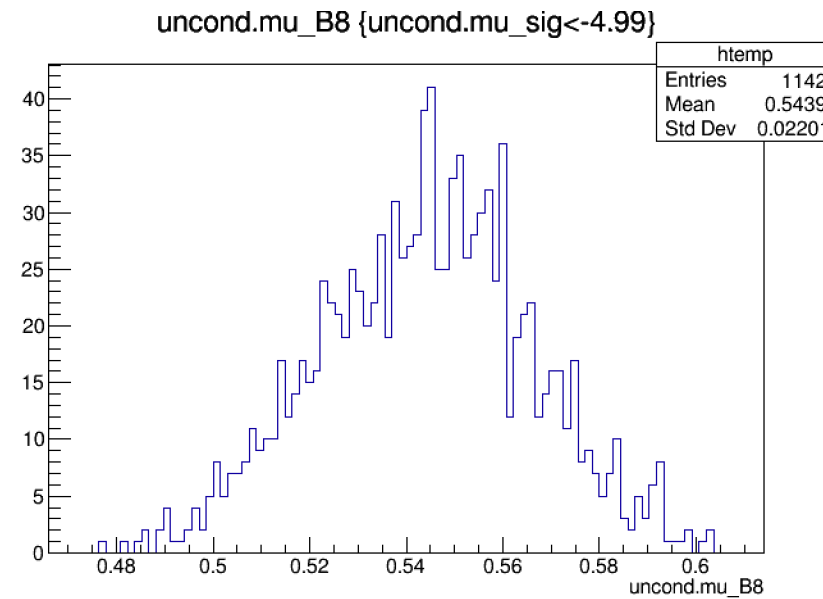


Mu_sig: (0, 200)

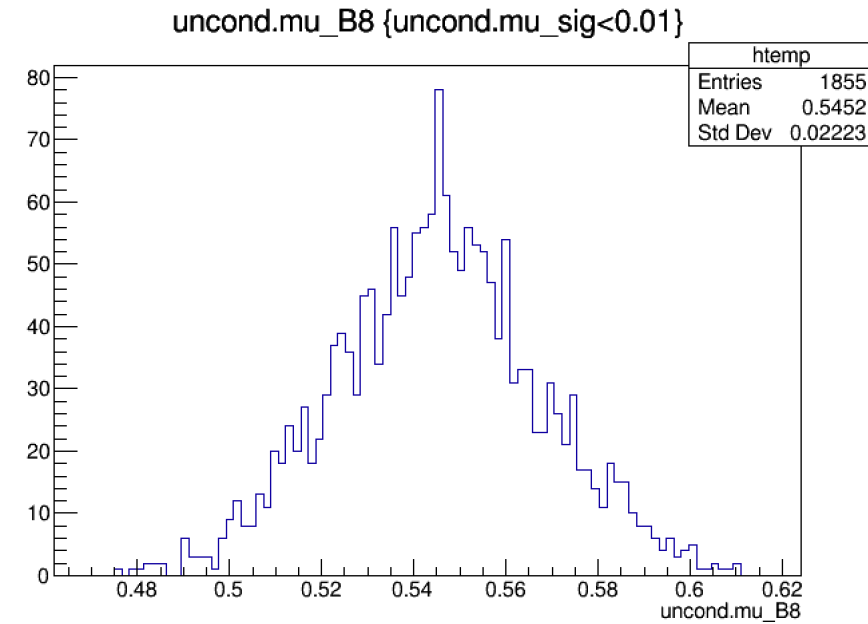
uncond.mu_B8



Mu_sig: (-100, 100)

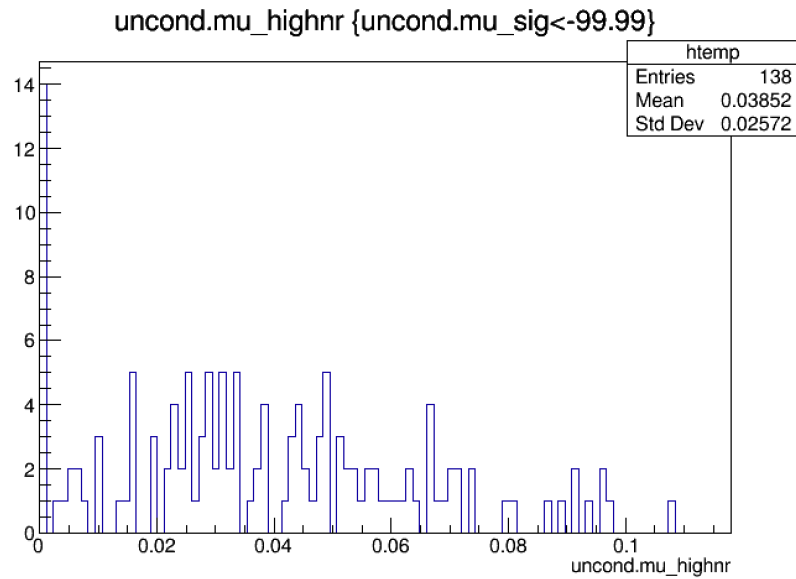


Mu_sig: (-5, 100)

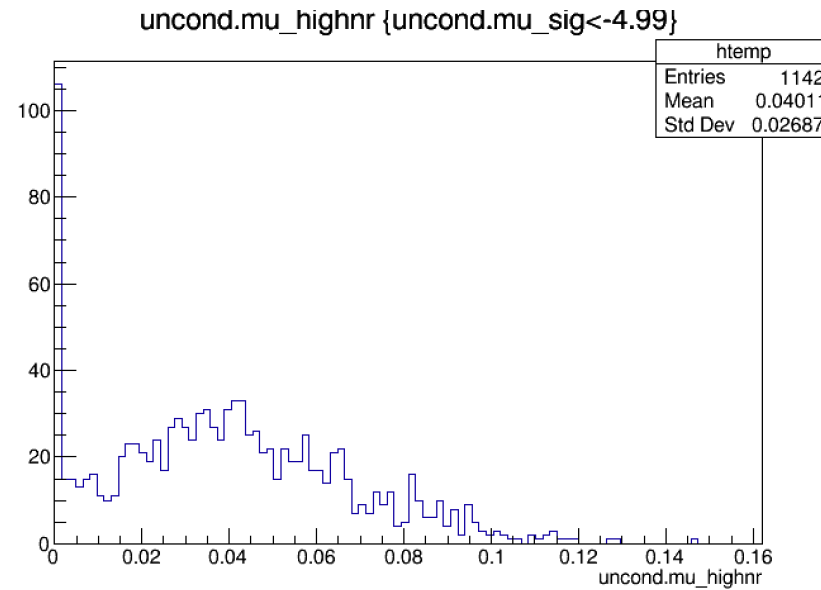


Mu_sig: (0, 200)

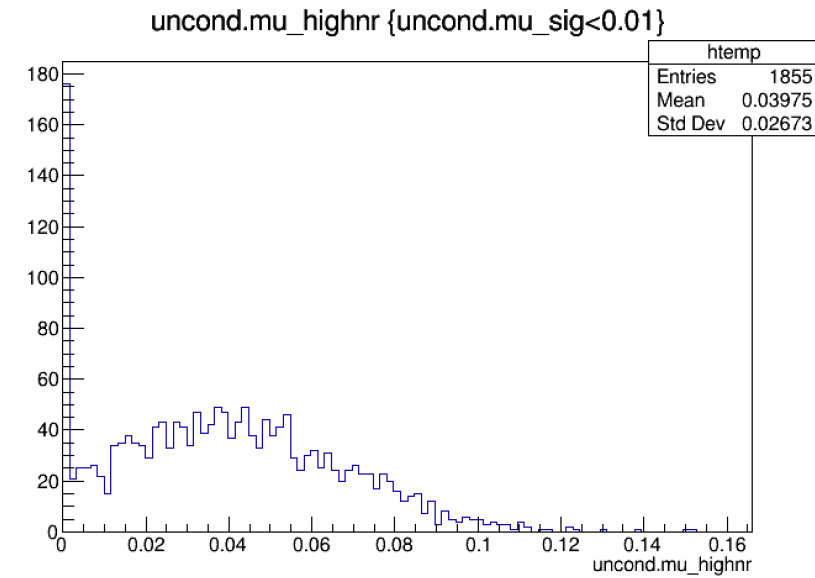
uncond.mu_highnr



Mu_sig: (-100, 100)

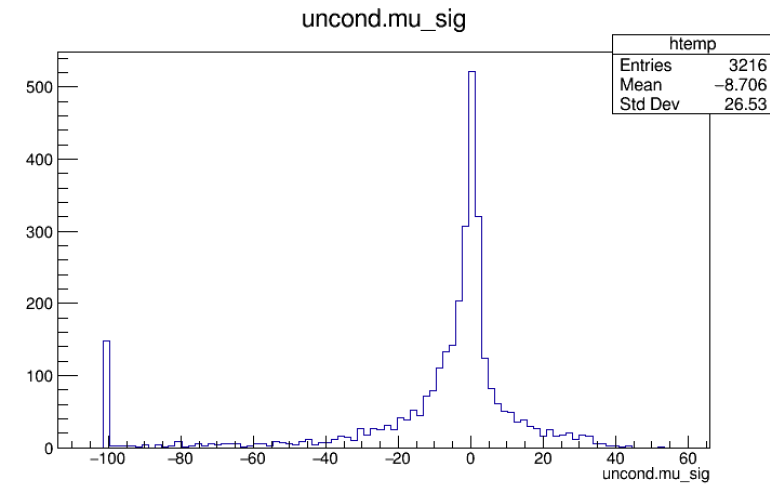


Mu_sig: (-5, 100)

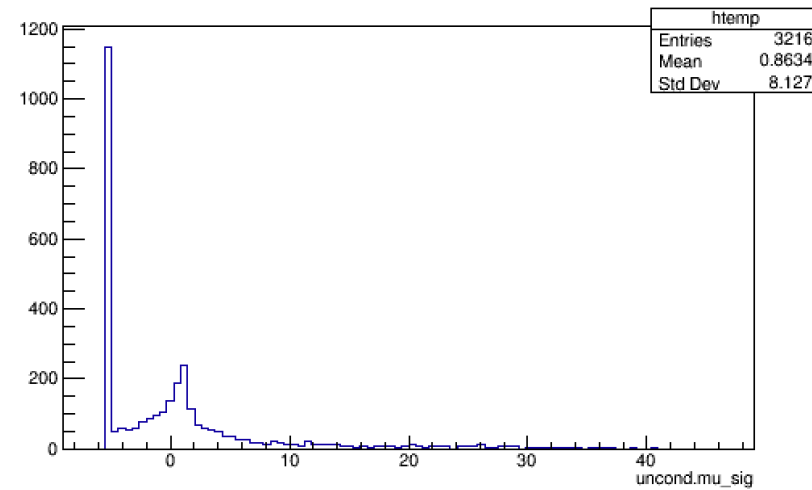


Mu_sig: (0, 200)

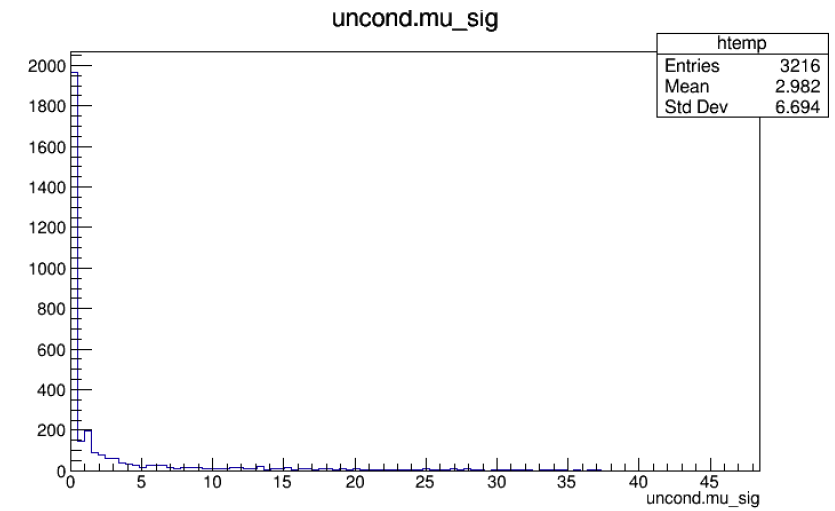
uncond.mu_sig



Mu_sig: (-100, 100)

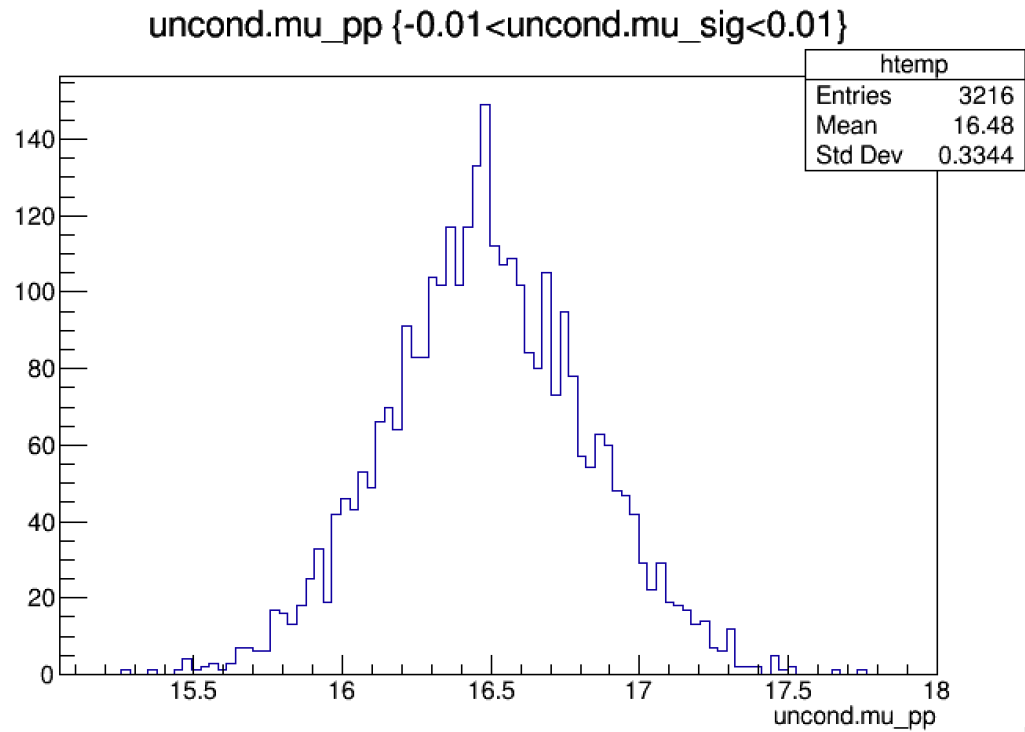


Mu_sig: (-5, 100)

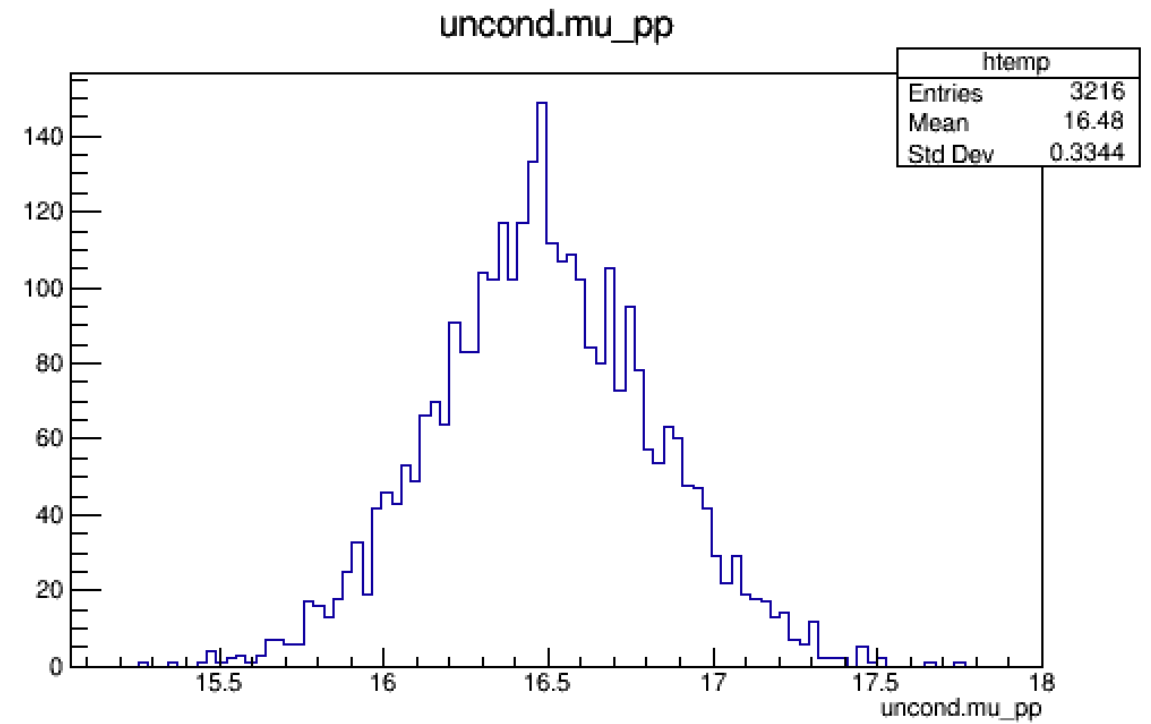


Mu_sig: (0, 200)

Problem



□

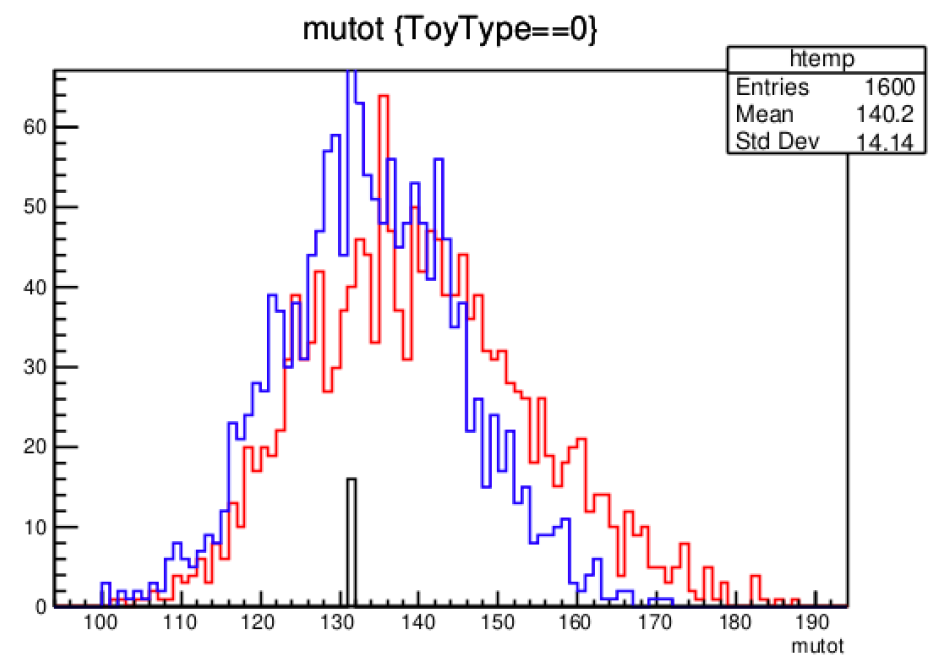
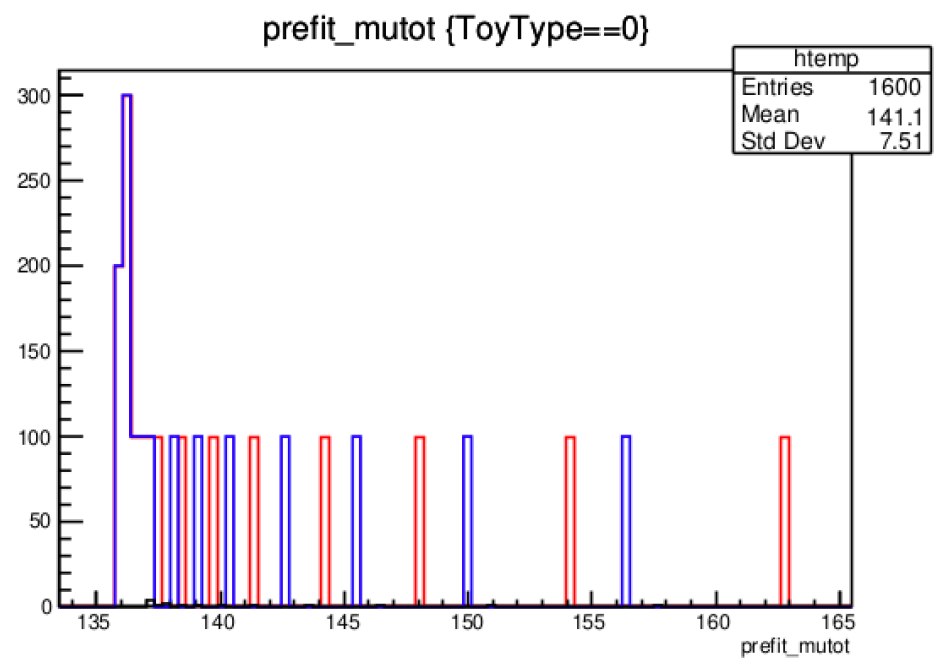


plr_analyser

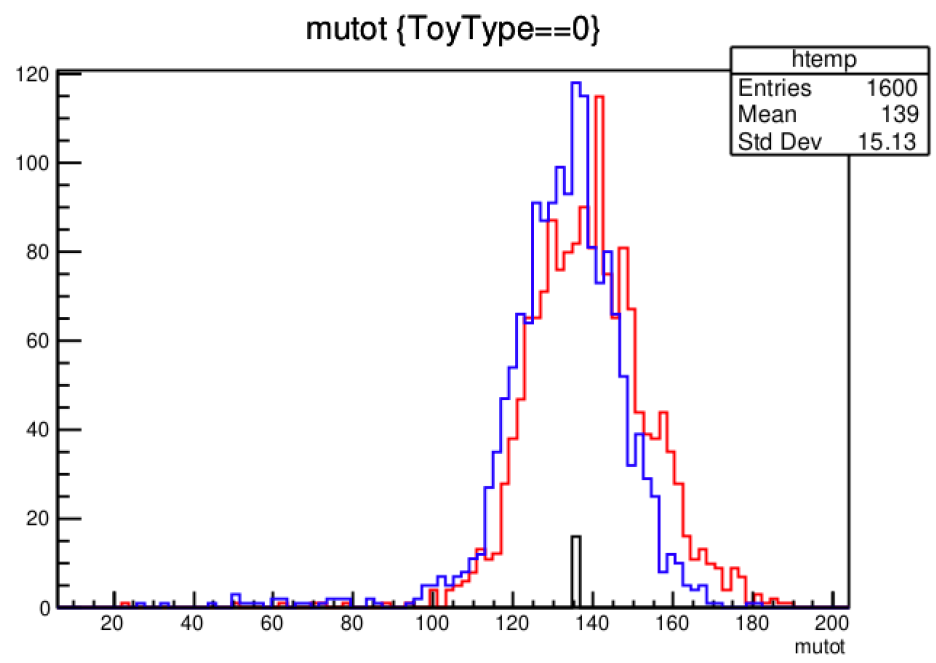
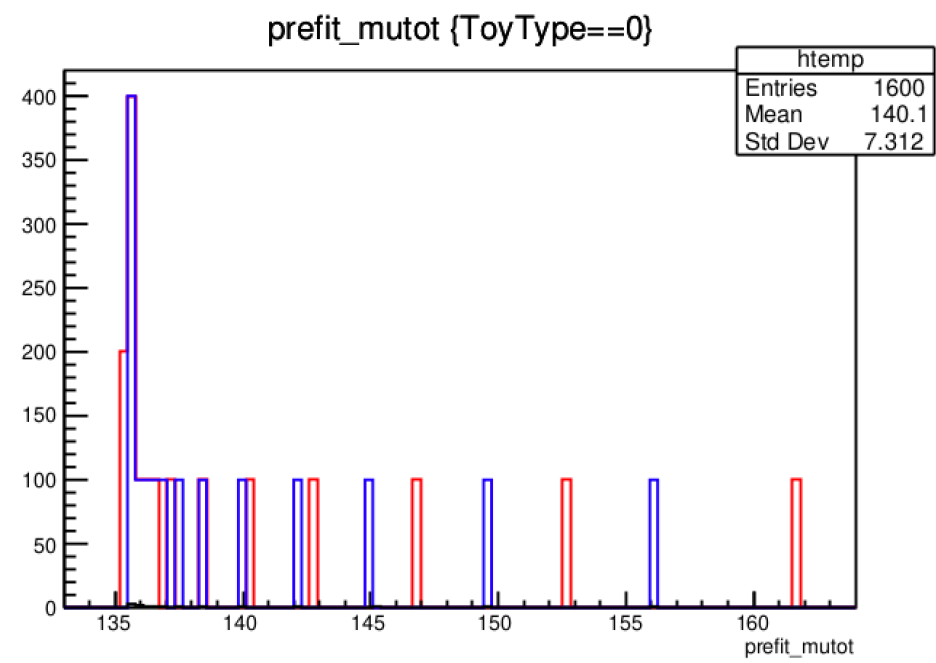
$$\lambda(\boldsymbol{\theta}) = \frac{L(\boldsymbol{\theta}, \hat{\boldsymbol{\nu}})}{L(\hat{\boldsymbol{\theta}}, \hat{\boldsymbol{\nu}})}$$

- 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

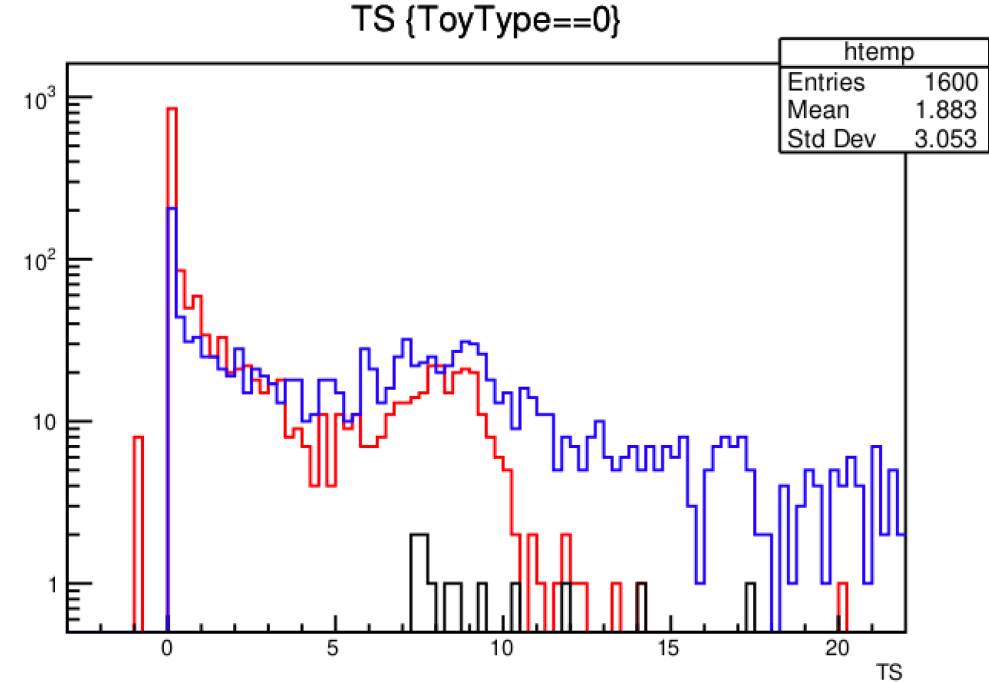
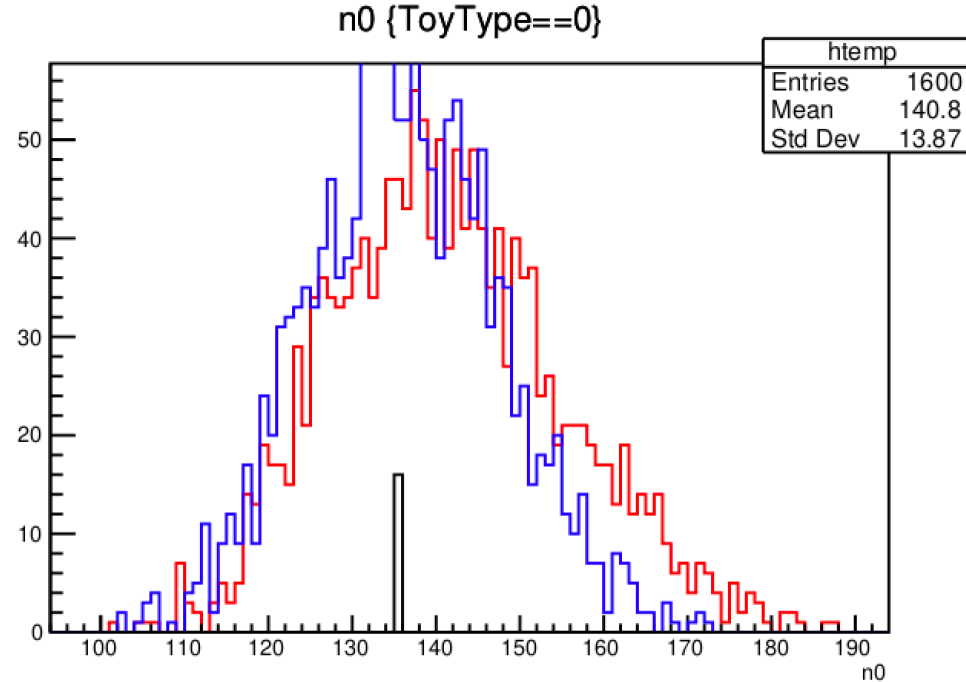
mu_sig (-5, 100)



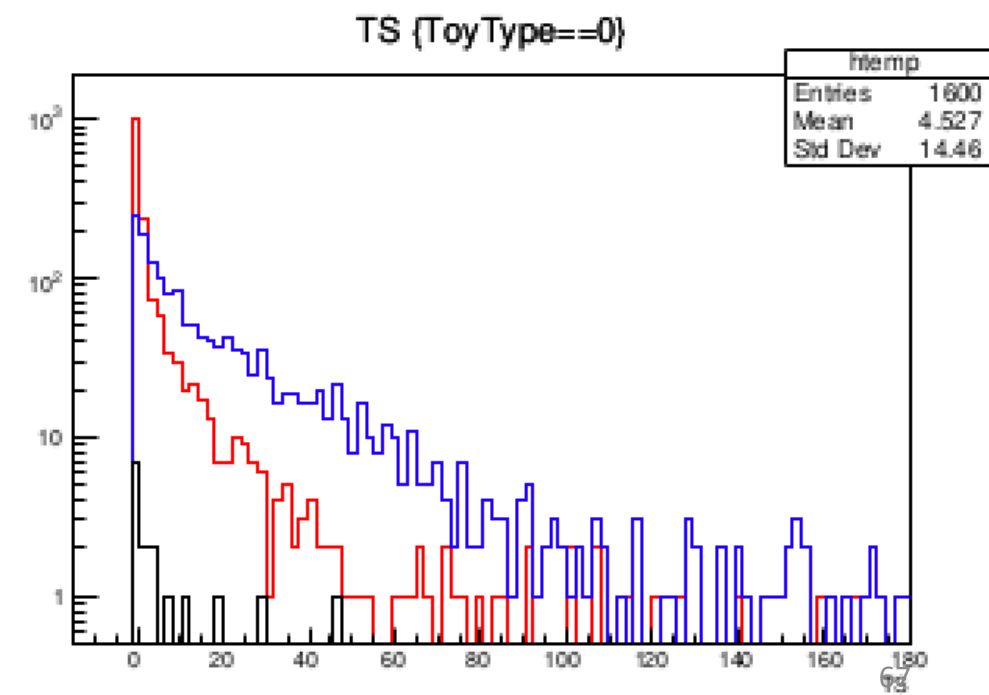
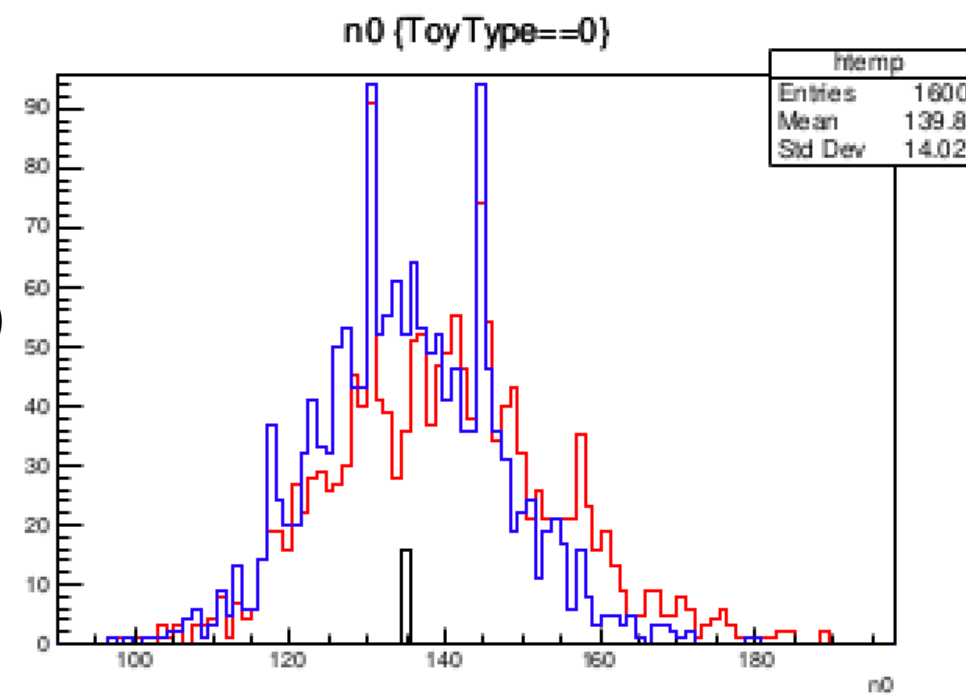
mu_sig (-100, 100)



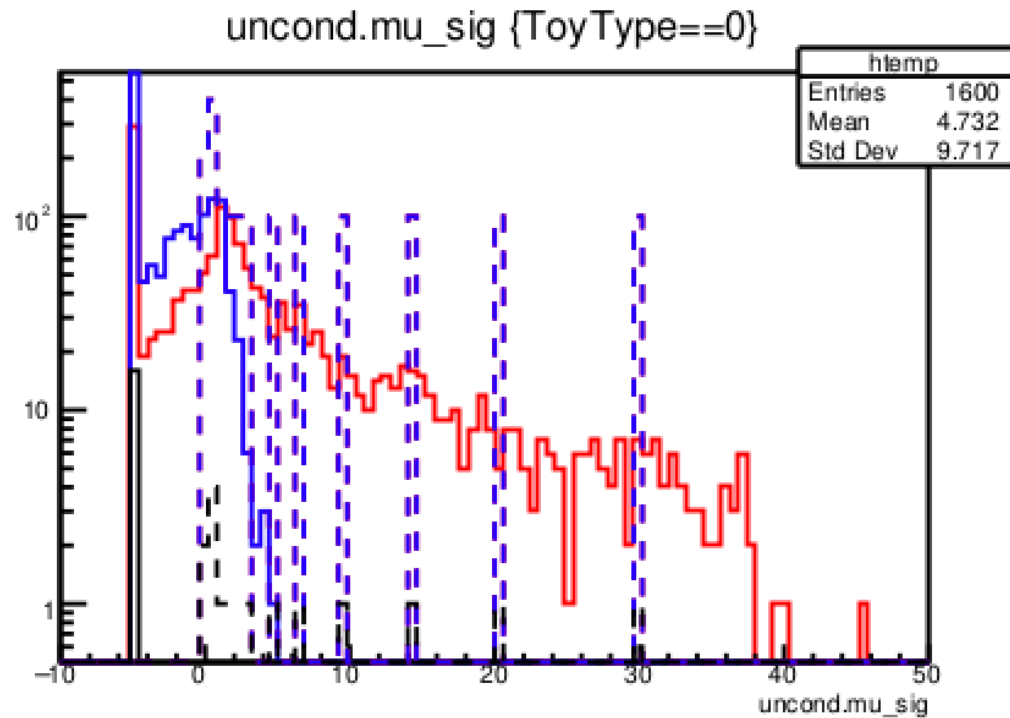
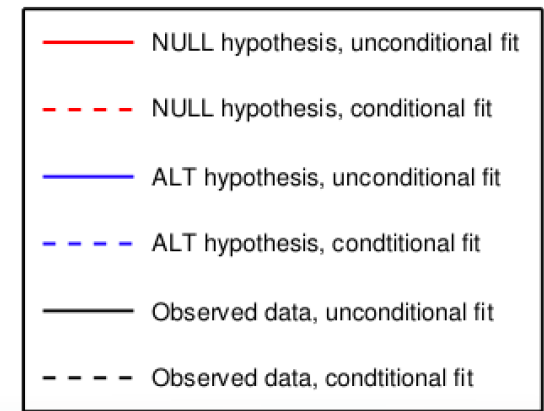
$\mu_{\text{sig}} (-5, 100)$



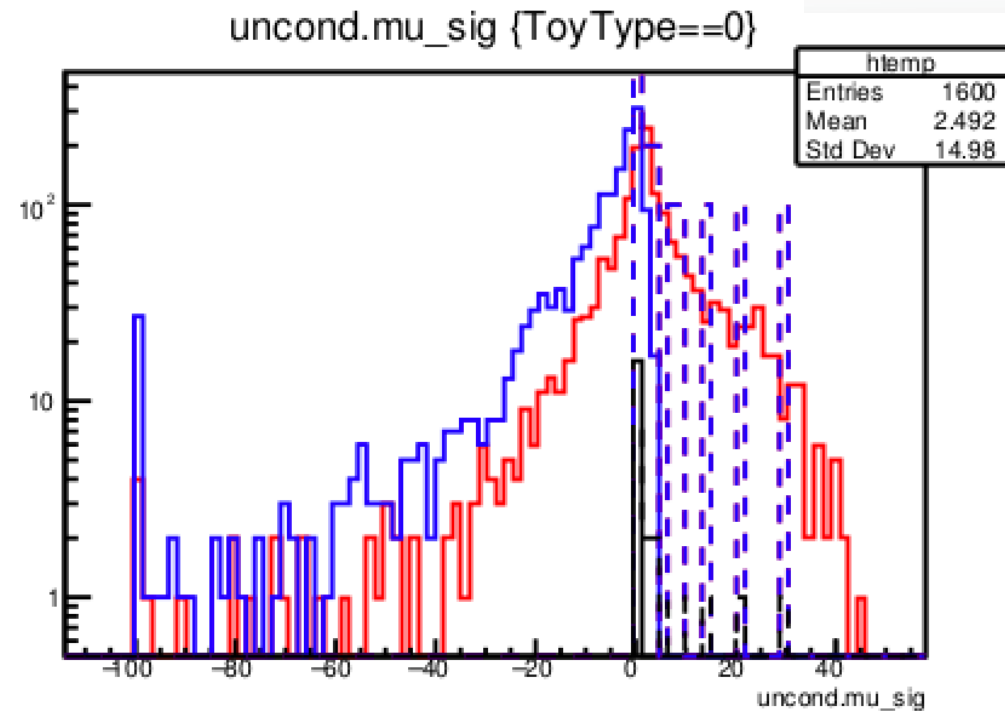
$\mu_{\text{sig}} (-100, 100)$



uncond.mu_sig (40 GeV)

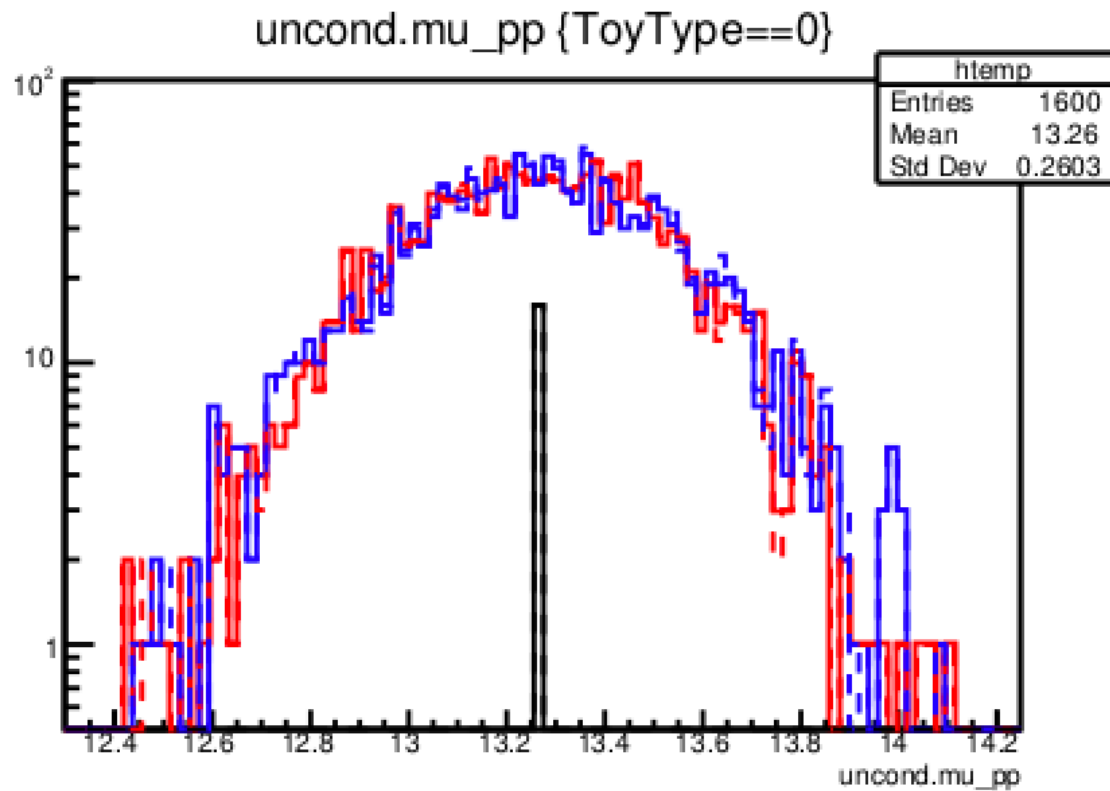


mu_sig (-5, 100)

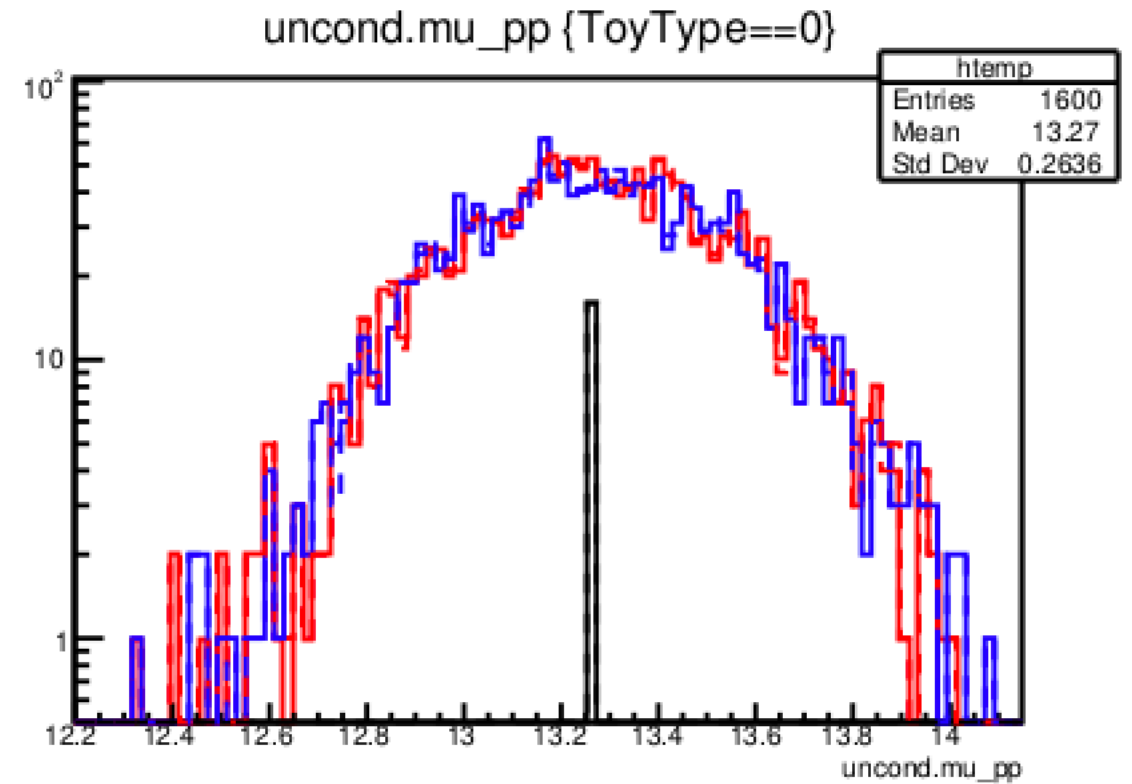


mu_sig (-100, 100)

uncond.mu_pp

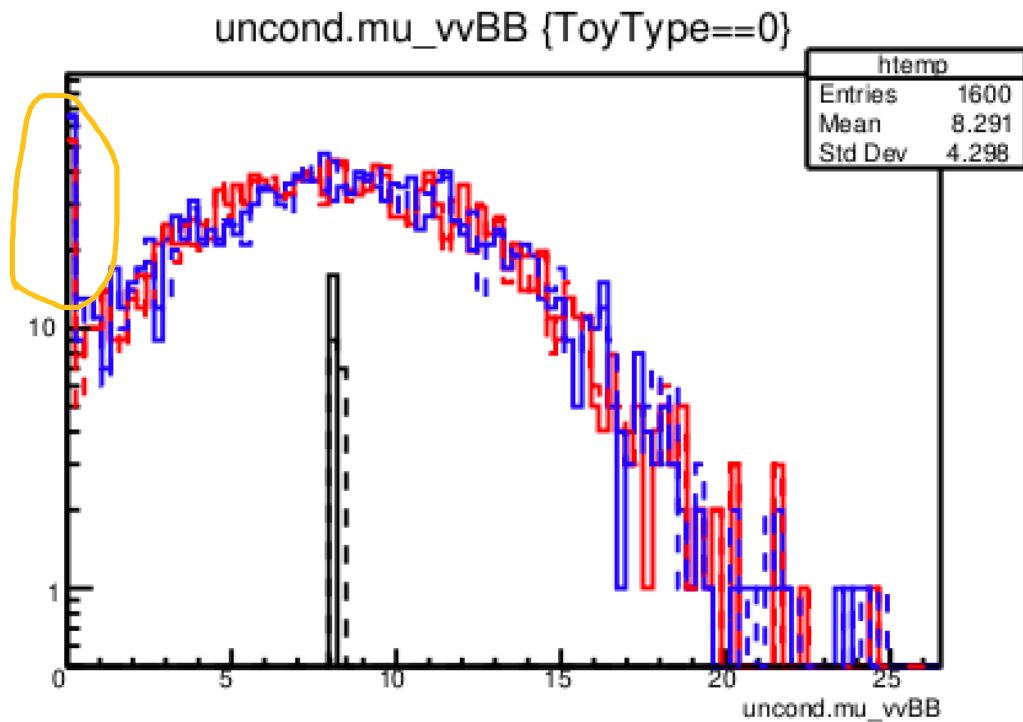


mu_sig (-5, 100)

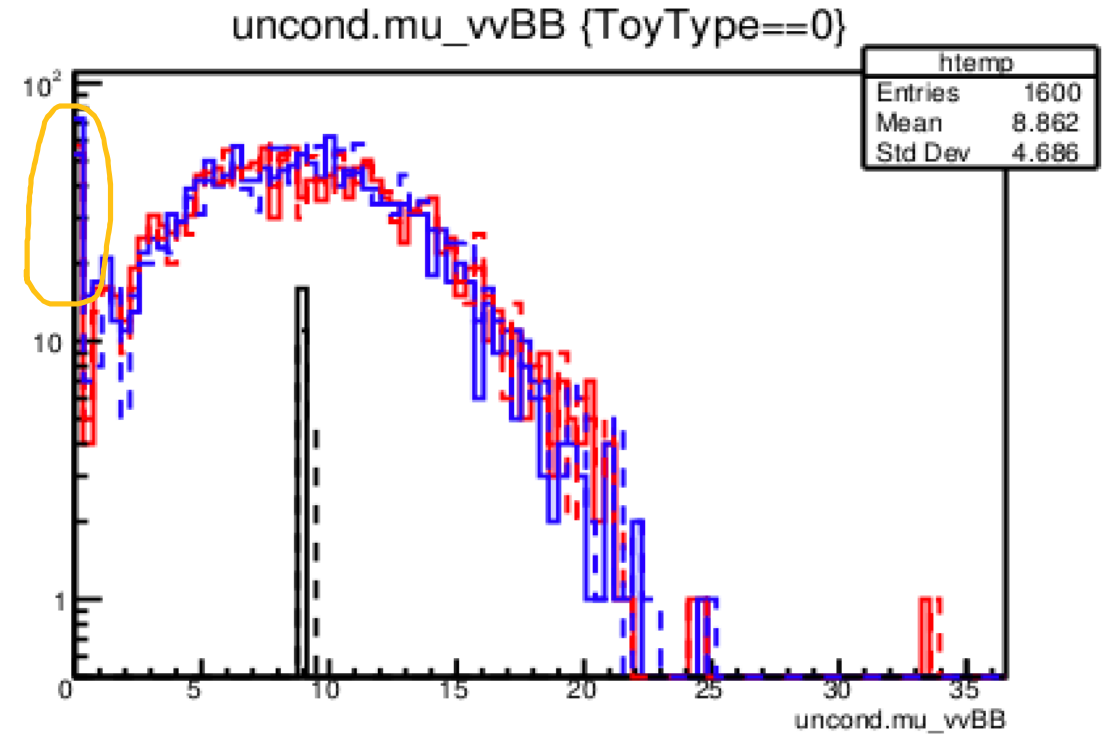


mu_sig (-100, 100)

uncond.mu_vvBB

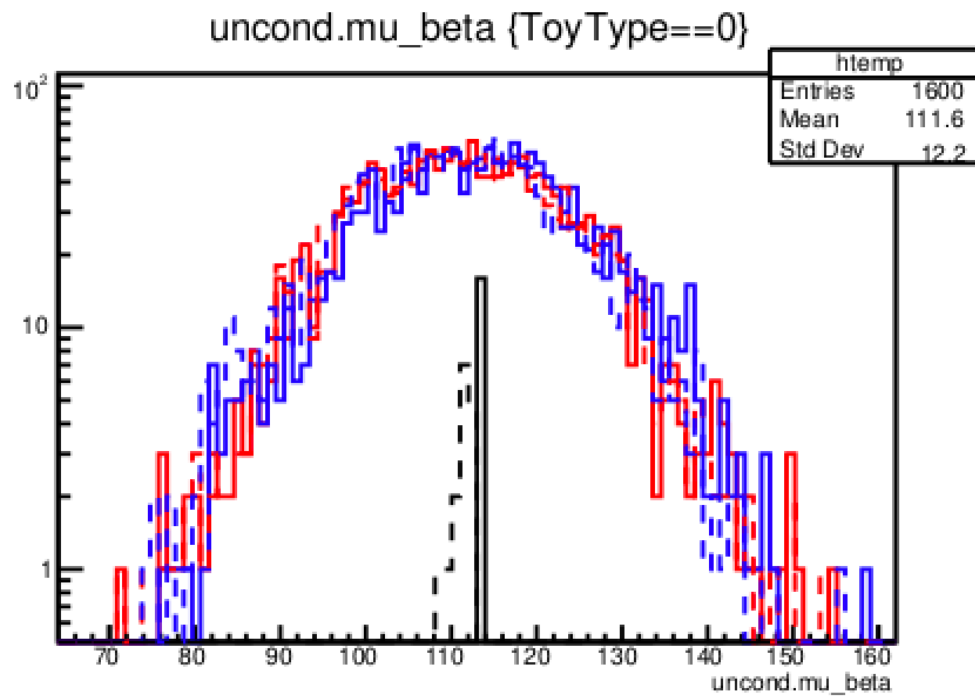


mu_sig (-5, 100)

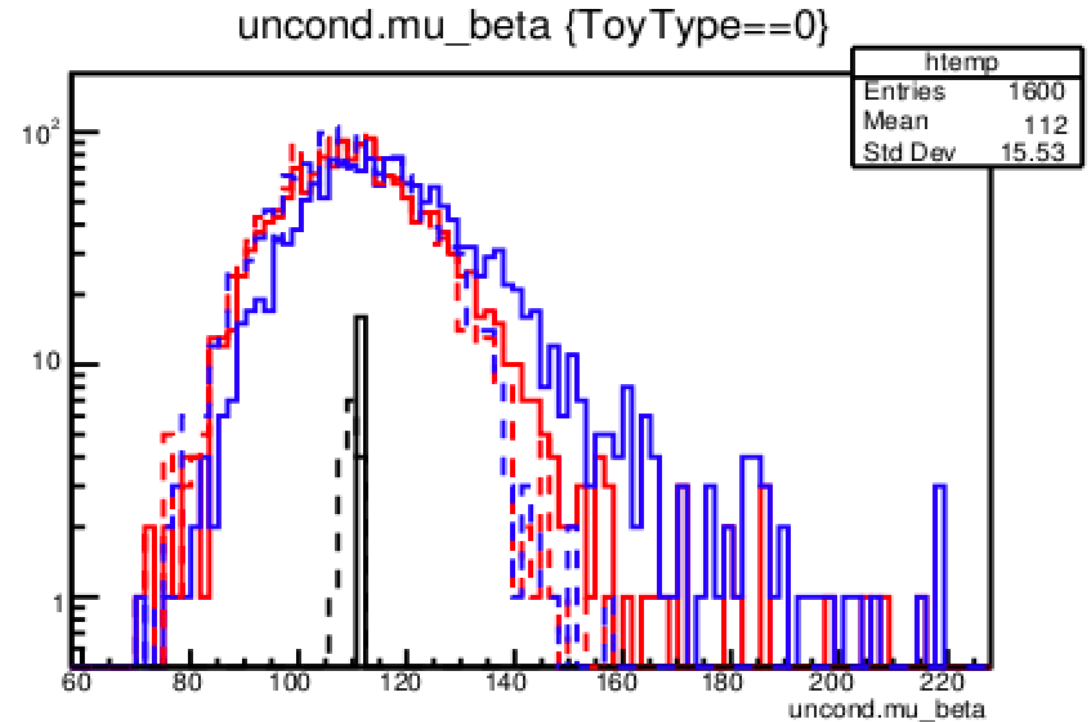


mu_sig (-100, 100)

uncond.mu_beta

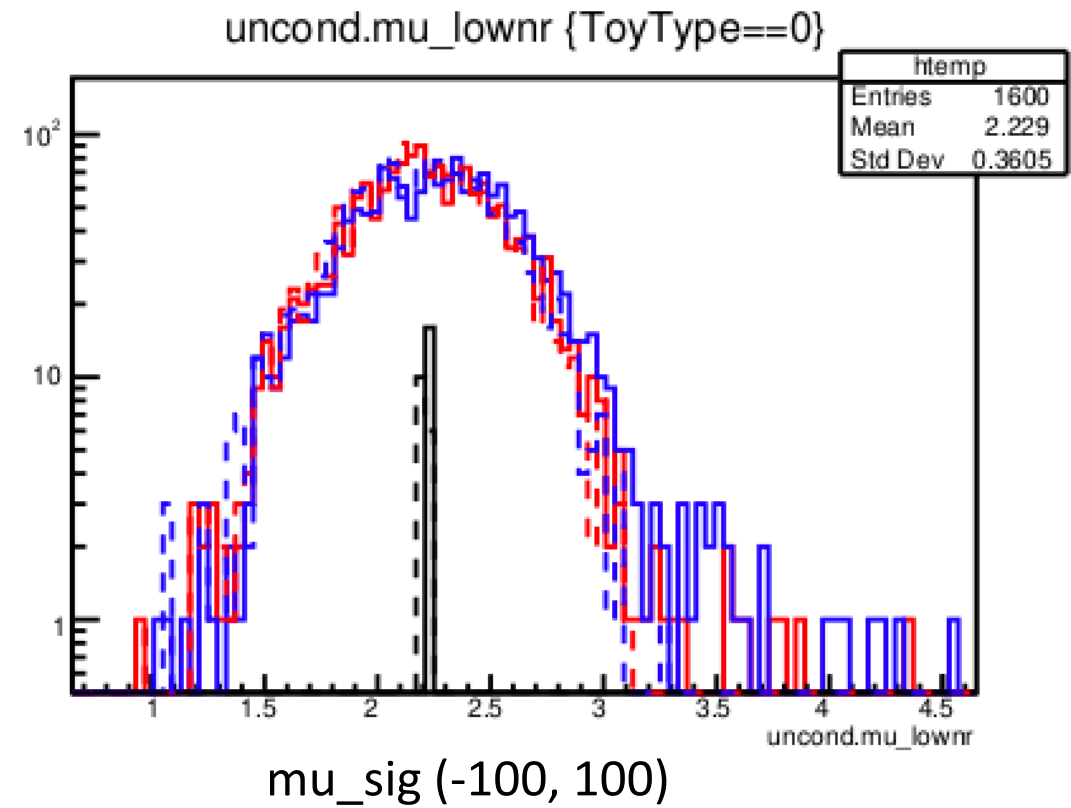
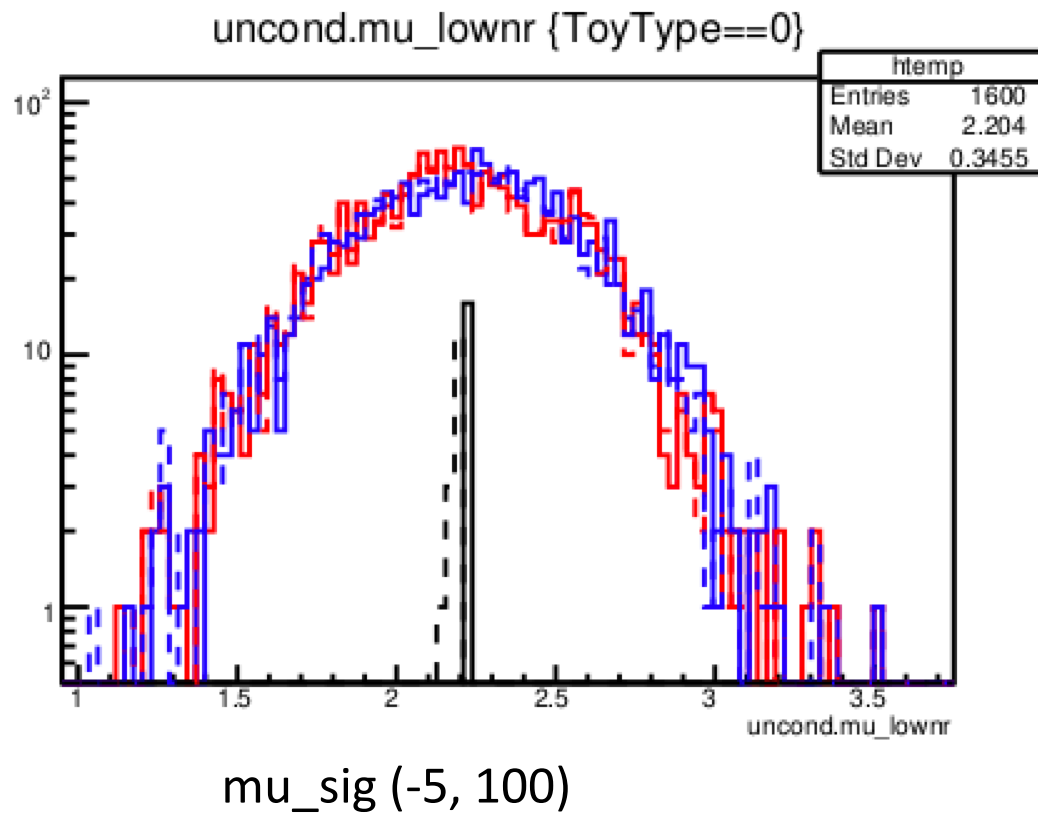


mu_sig (-5, 100)

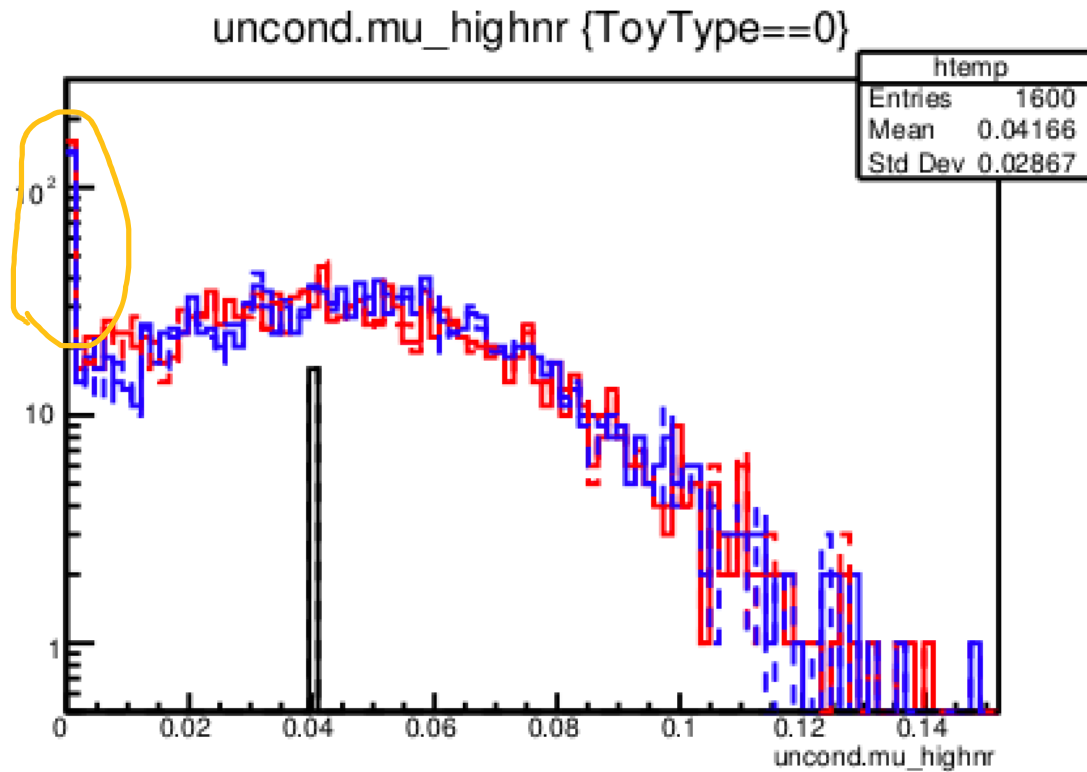


mu_sig (-100, 100)

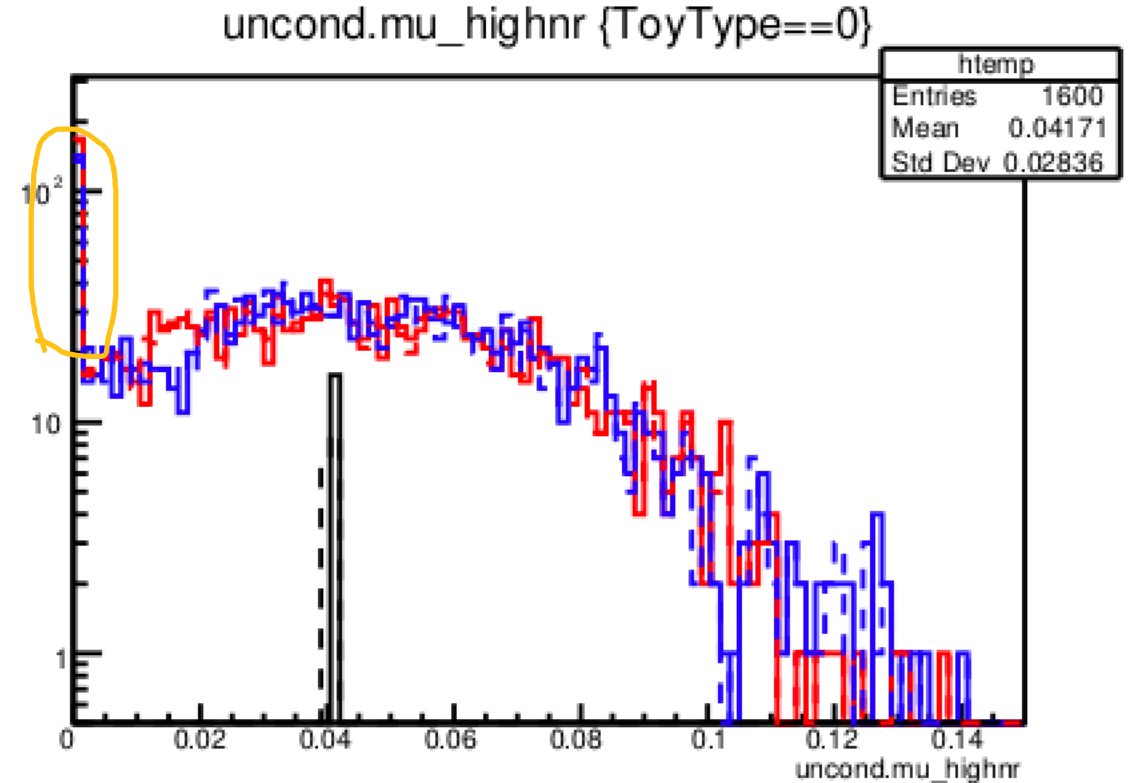
uncond.mu_lownr



uncond.mu_highnr

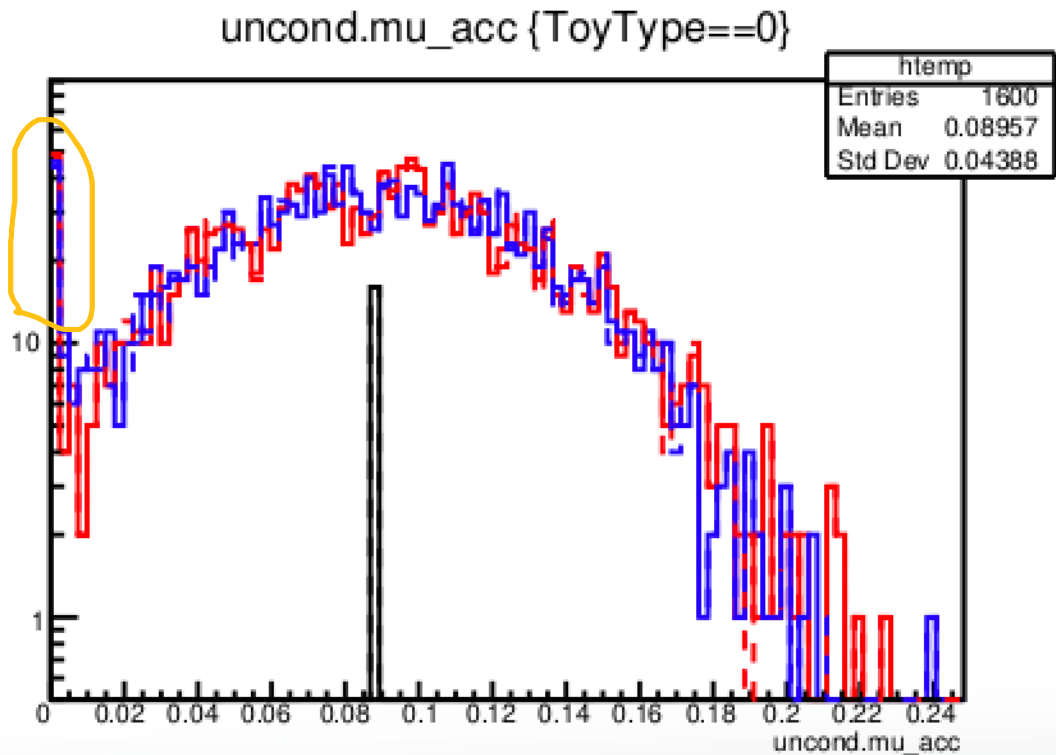


mu_sig (-5, 100)

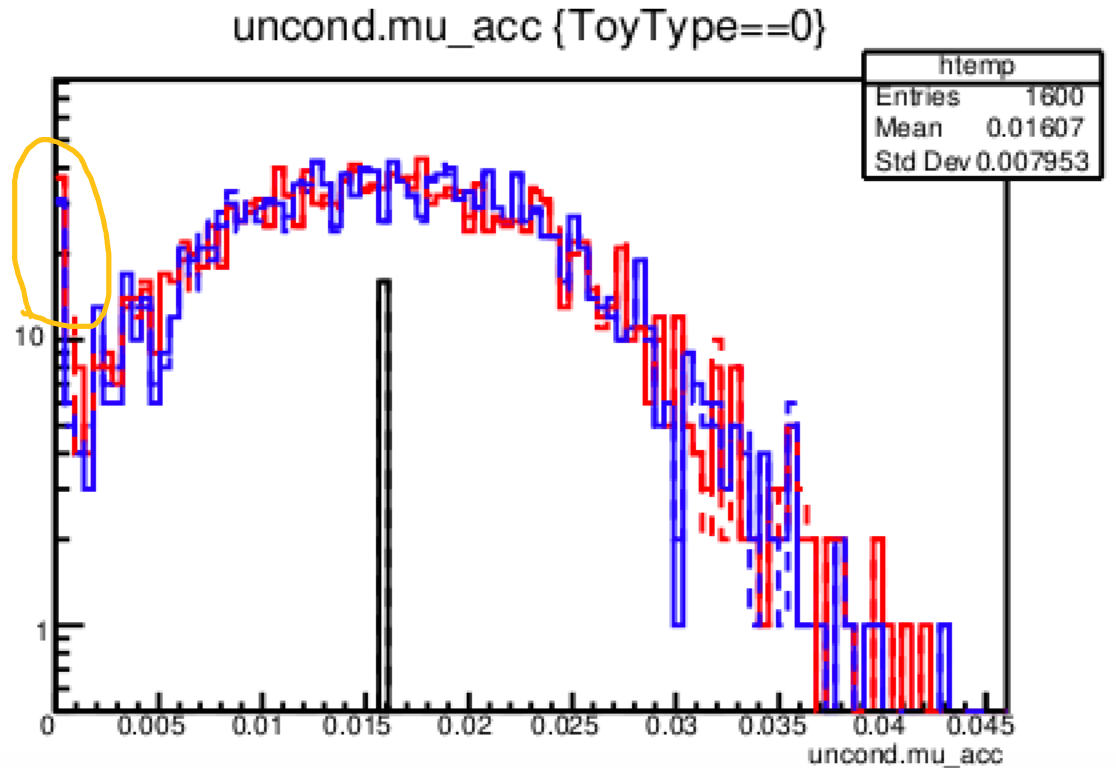


mu_sig (-100, 100)

uncond.mu_acc



mu_sig (-5, 100)

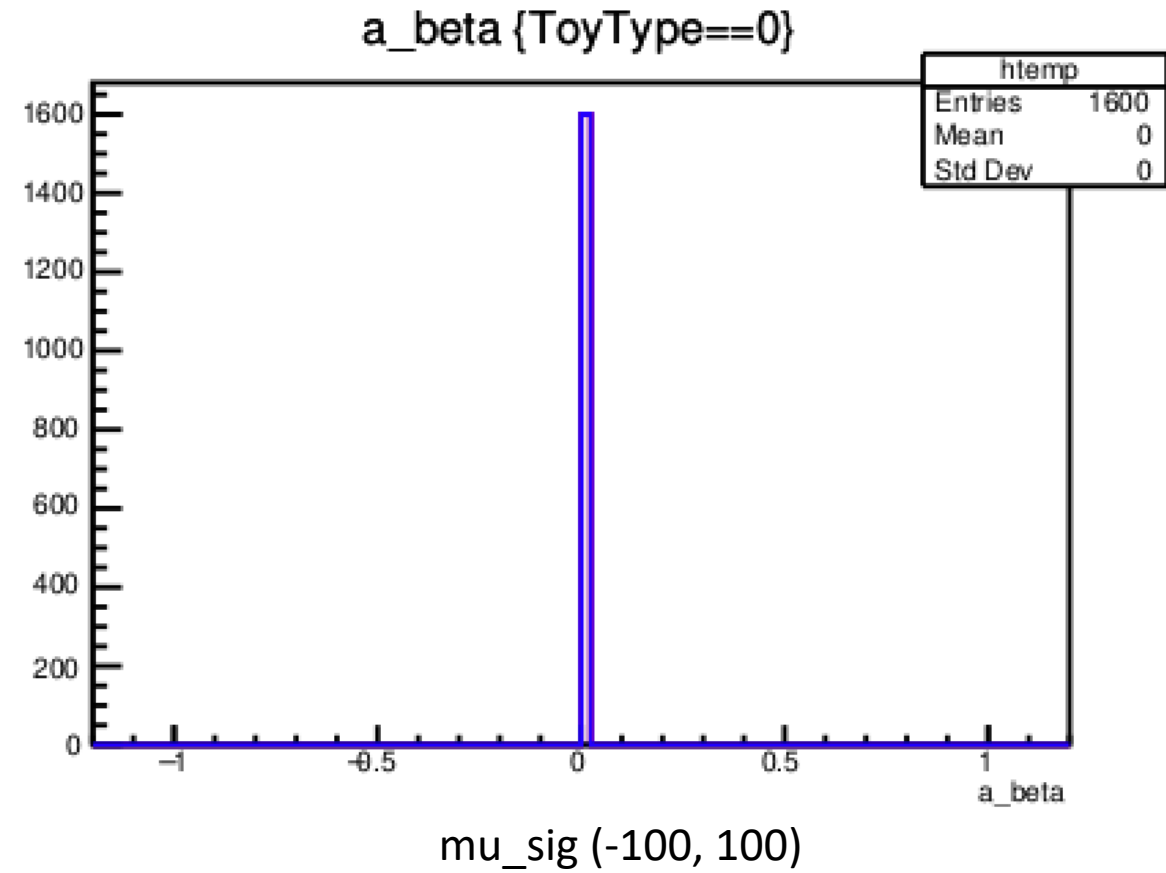


mu_sig (-100, 100)

Error message

```
Error in <TTreeFormula::Compile>: Bad numerical expression : "a_sig"
Info in <TSelectorDraw::AbortProcess>: Variable compilation failed: {a_sig,ToyType==0}
Error in <TTreeFormula::Compile>: Bad numerical expression : "a_sig"
Info in <TSelectorDraw::AbortProcess>: Variable compilation failed: {a_sig,ToyType==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,ToyType==0}
Error in <TTreeFormula::Compile>: Bad numerical expression : "a_beta"
Info in <TSelectorDraw::AbortProcess>: Variable compilation failed: {a_beta,ToyType==1}
a_lownr a_lownr
a_highnr      a_highnr
a_acc  a_acc
Info in <TCanvas::Print>: pdf file fitResults_glob_lzstats-20200423_workspace_sumbkg_freebetas_wimp_m40.0_SI_lowPOIbound_5-Freq-one_sided-NP_on-run1.pdf has been 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 been created
```

Global observable (Beta)



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 μ_{sig} (-100, 100), no errors with the workspace μ_{sig} (-5, 100)

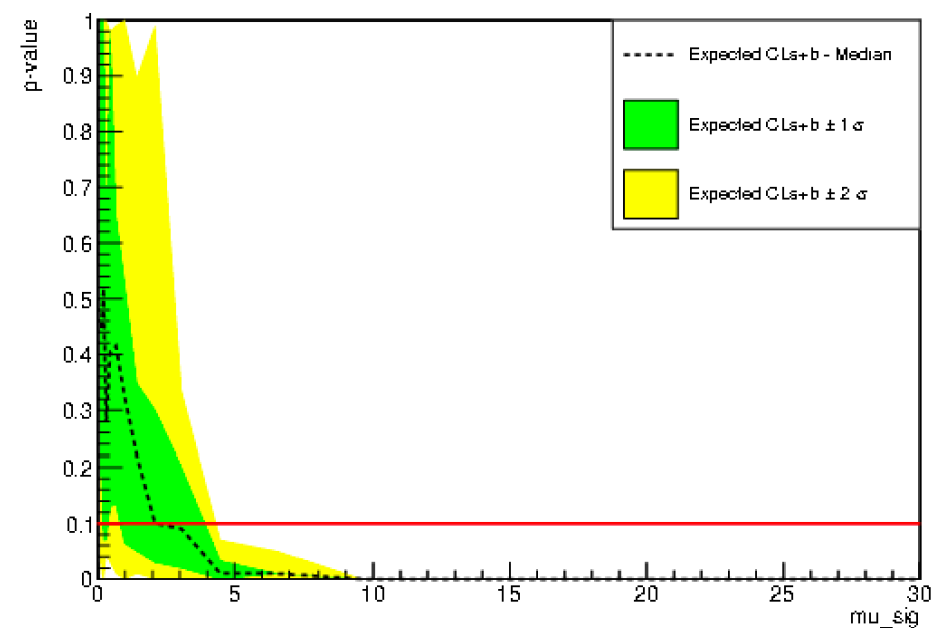
Observed data

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

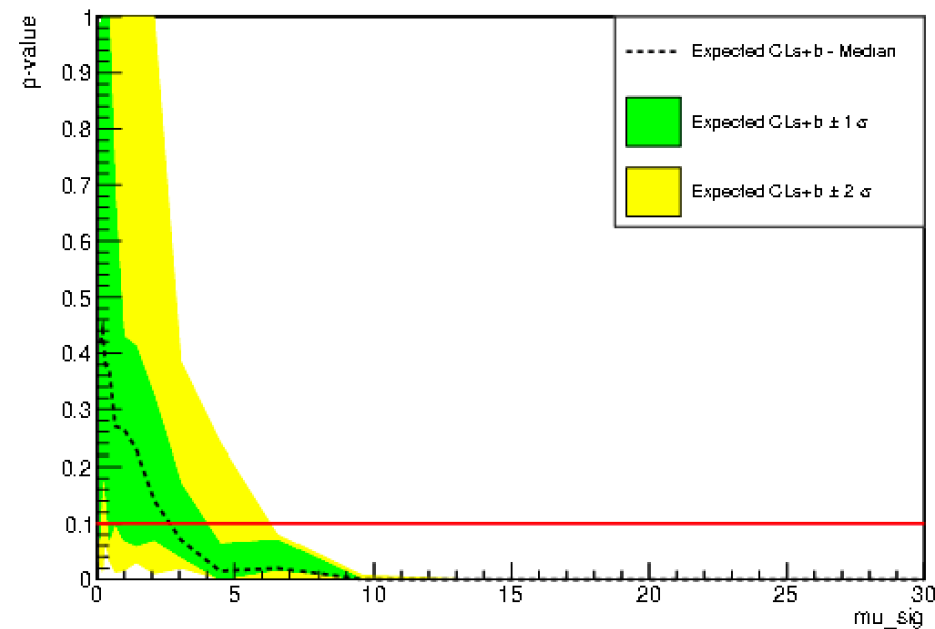
```
[#0] WARNING:Minization -- RooMinimizerFcn: Minimized function has error status.
```

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

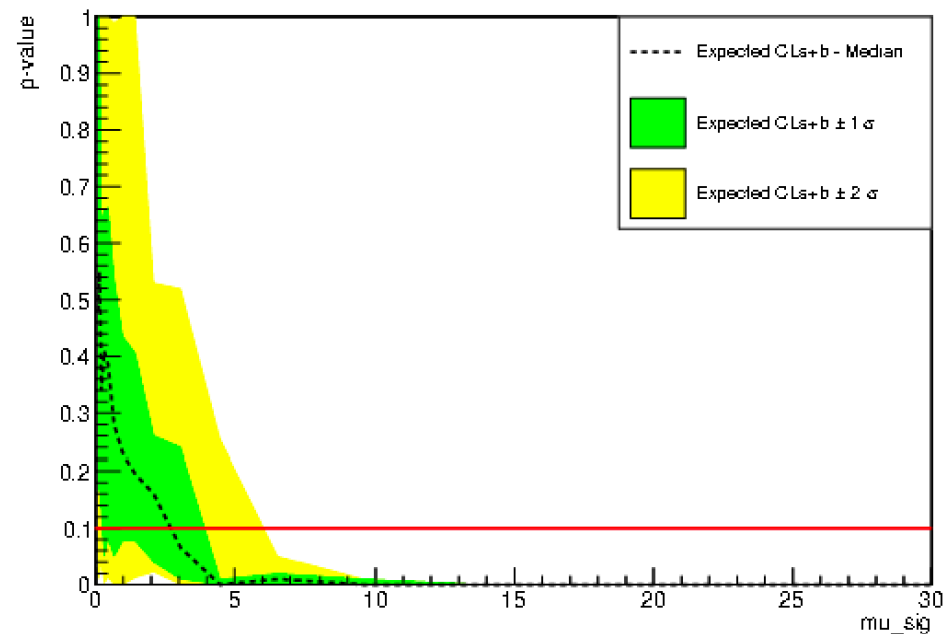
```
[#0] WARNING:Eval -- HypoTestInverterResult::CalculateEstimatedError - cannot estimate the lower limit error
```



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



$\mu_{\text{sig}} = (-100, 100)$, negative bound setting

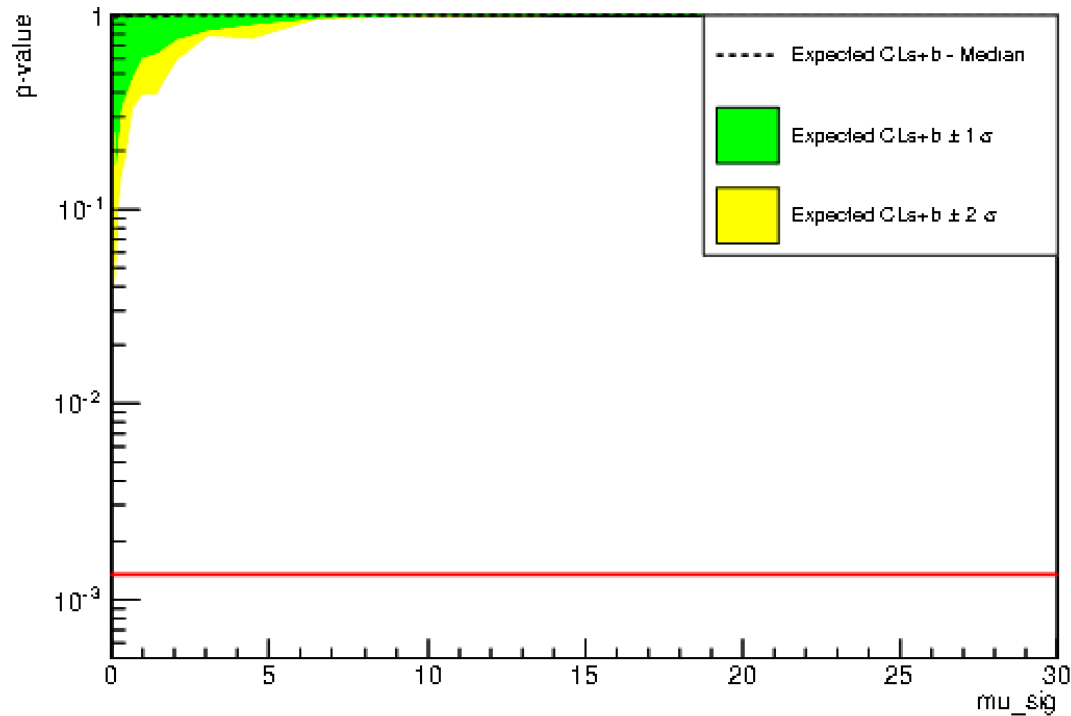


46 GeV w, μ_{sig} (0,100)



No more this error

Error (Discover)

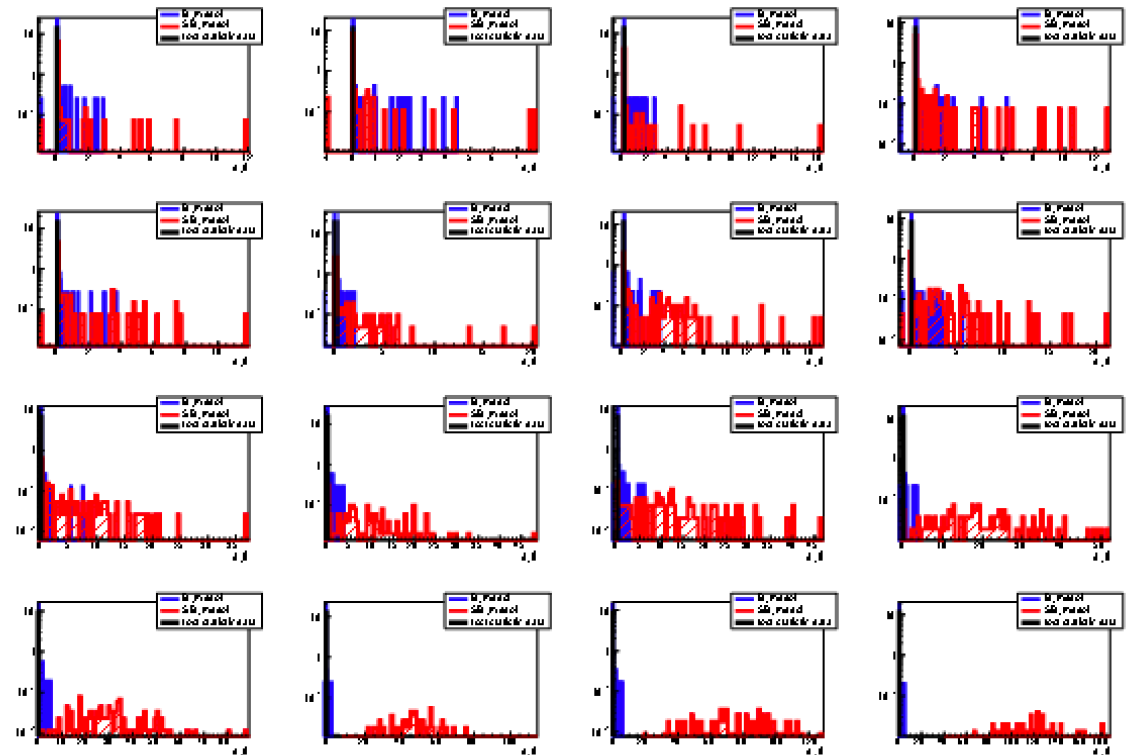


40 GeV, μ_{sig} : (-100, 100)

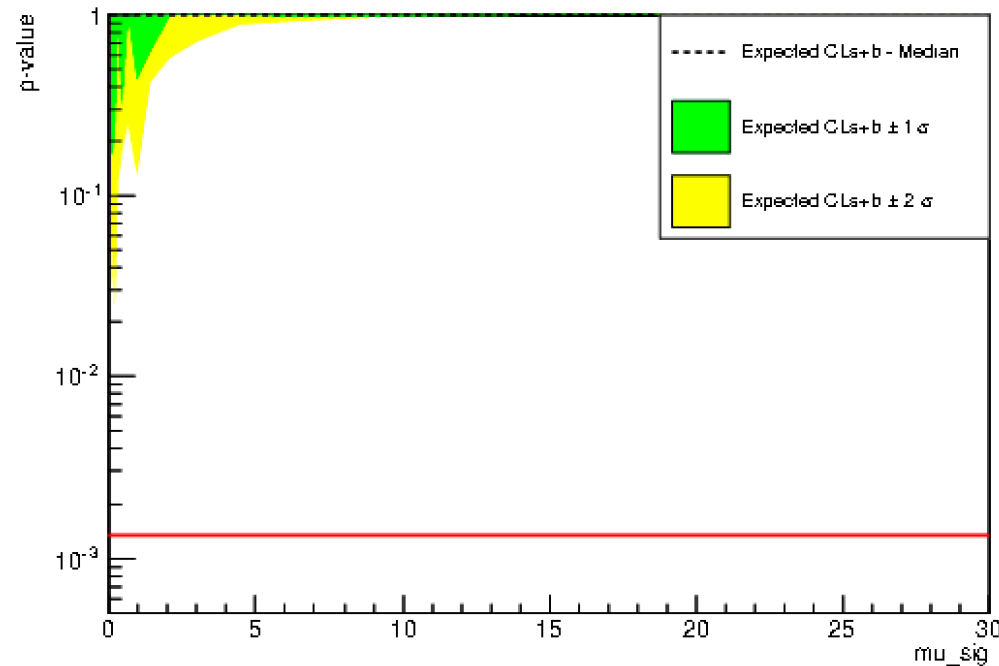
Error: generation

H0: only background, $\mu_{\text{signal}} = 0$

H1: both background and signal



New Error (Discovery)



46 GeV, $\mu_{\text{sig}} (0, 100)$

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 μ_{sig} to (0, 100), limiting μ_{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

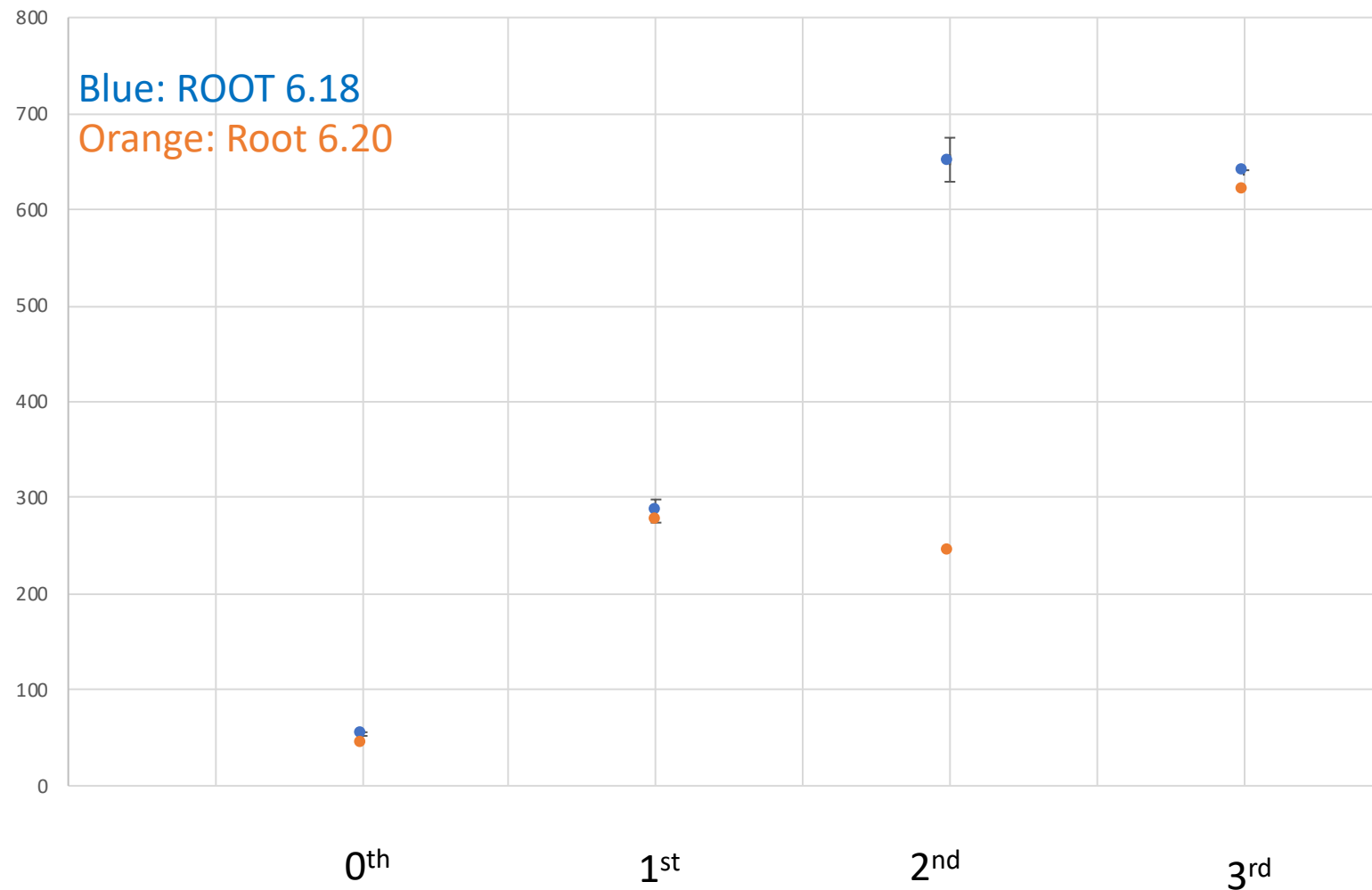
New update

- 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

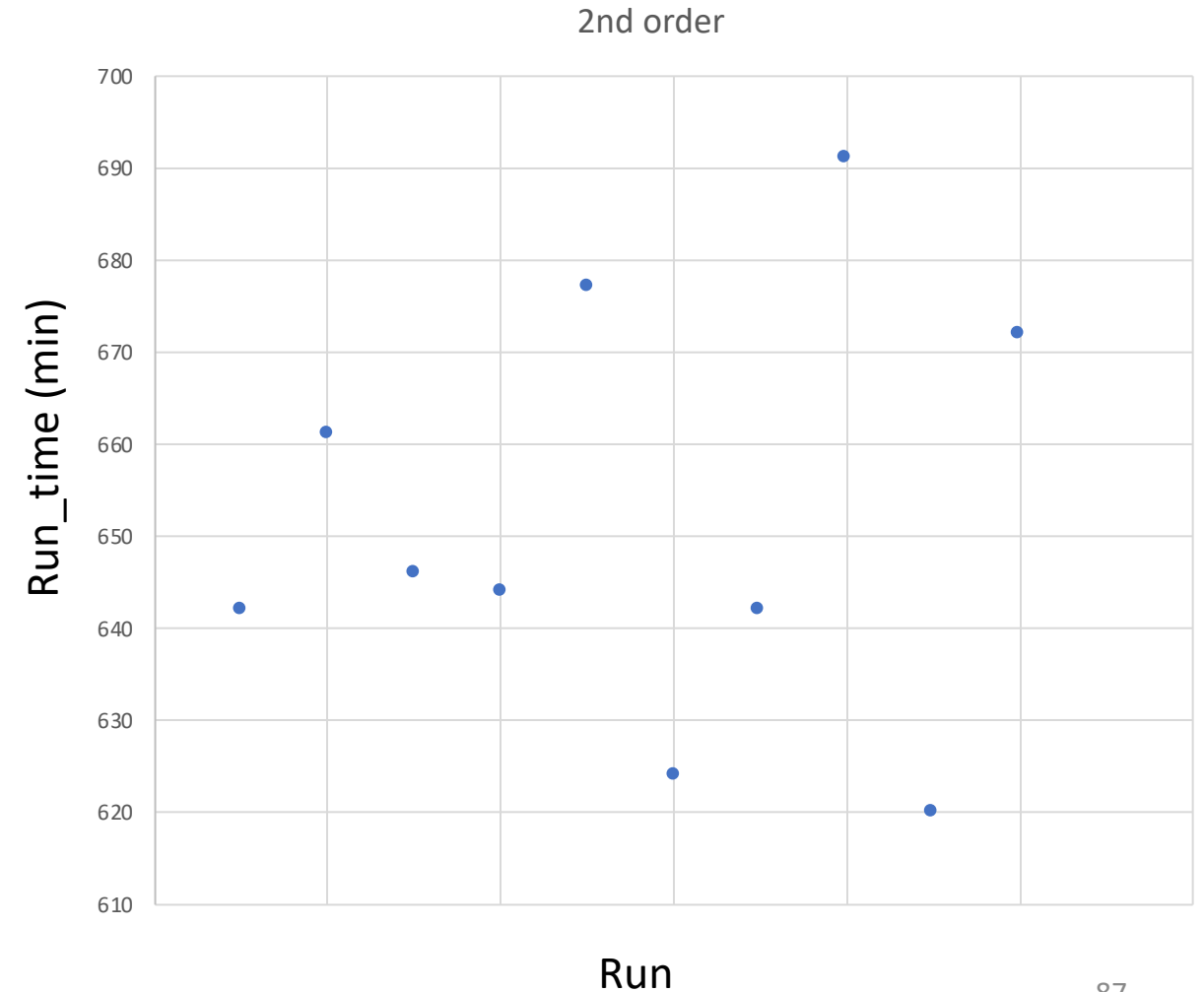
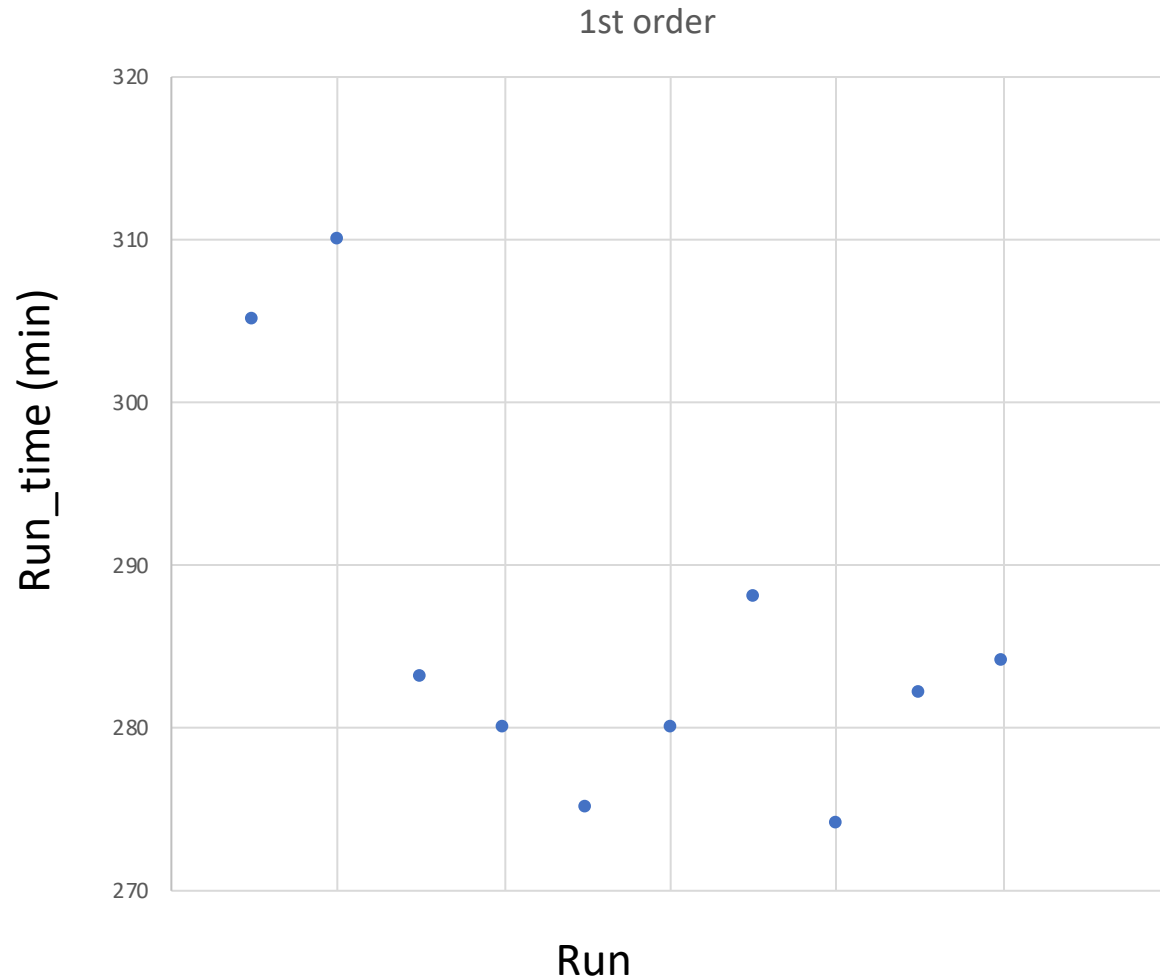
	0th	1st	2nd	3rd
run_time(min)	53.9 (10 runs)	286.1 (10 runs)	651.9 (10 runs)	641
STD	1.9	12.1	22.9	
run_time(min)	44	278.5 (2 runs)	245?	621

run_time vs. order



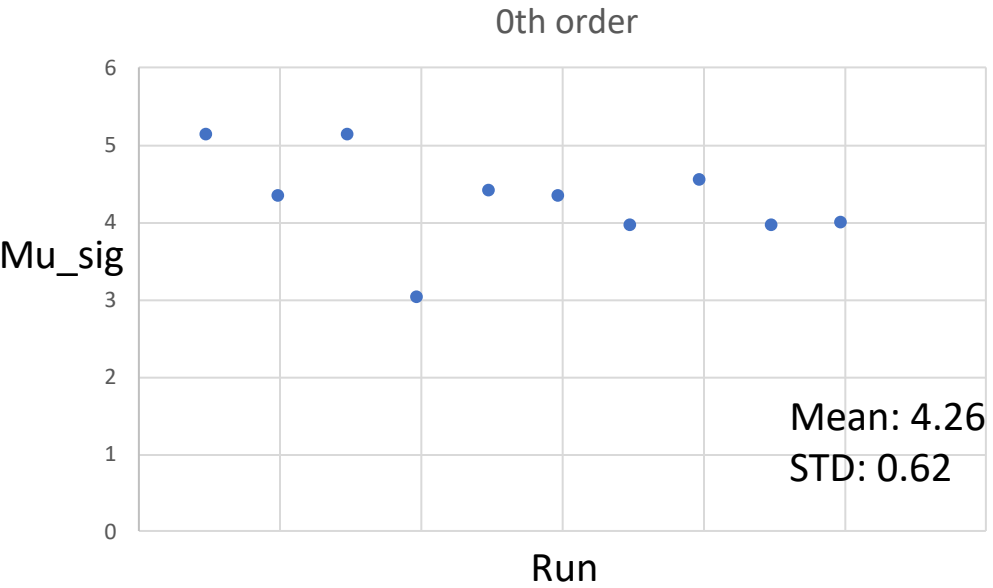
1st & 2nd orders

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

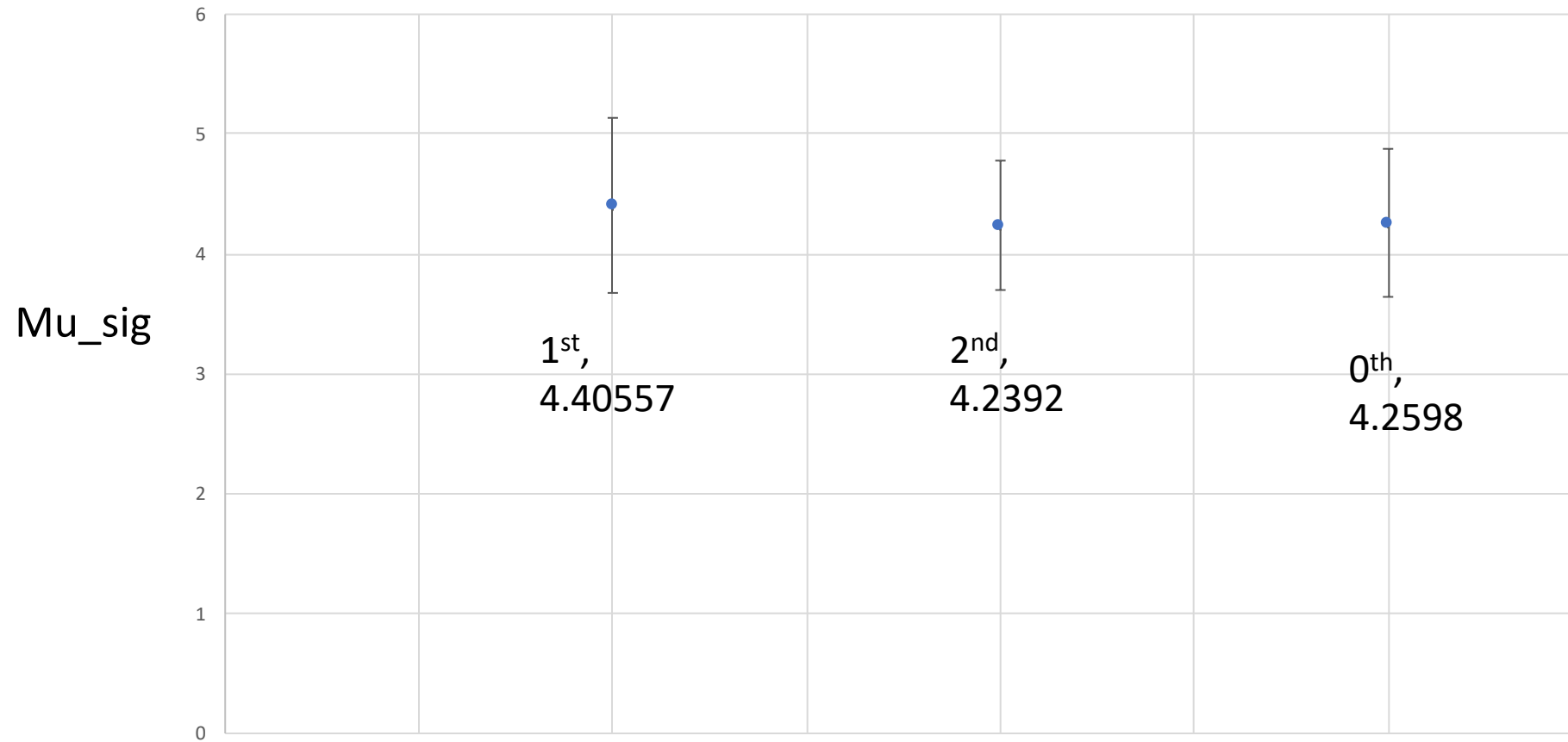


Interpolation

WIMP mass: 10GeV
N_sample: 10 ^6



mu_sig vs. order



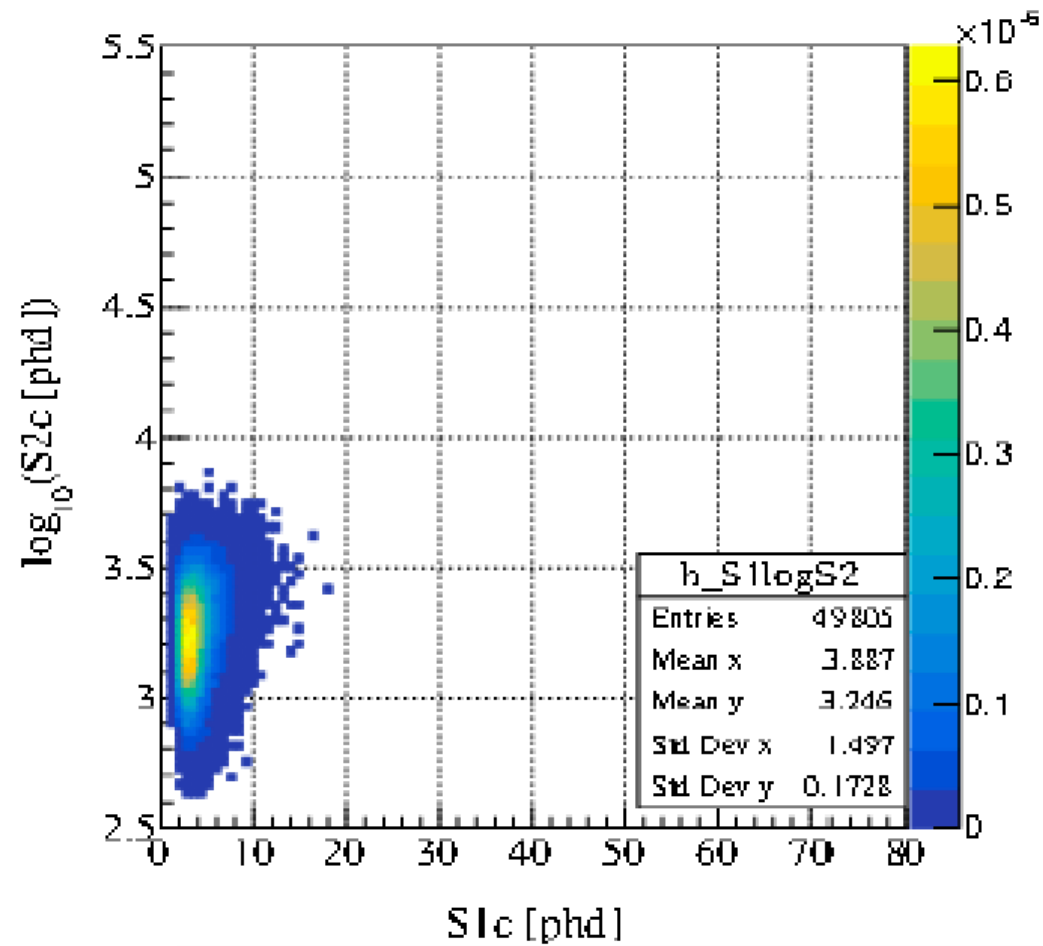
What's new?

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

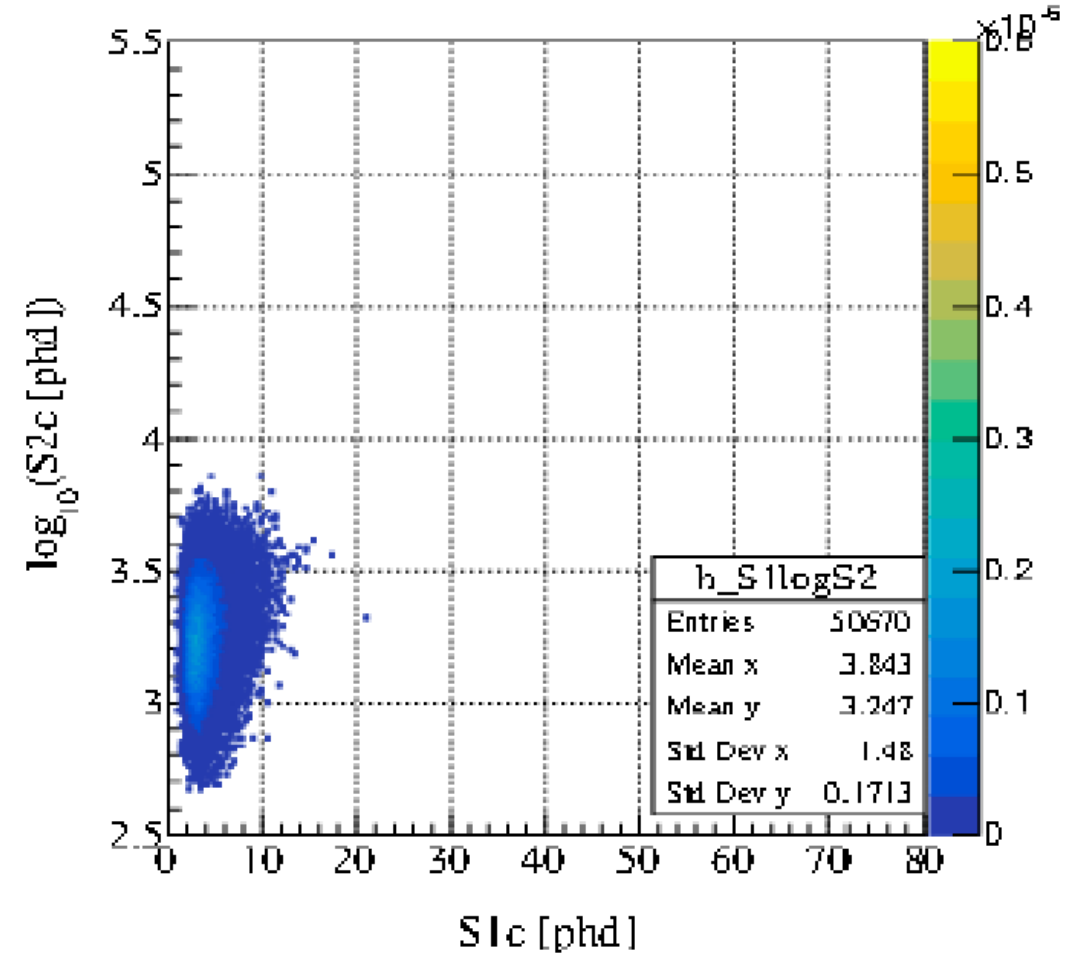
New update (Detector)

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



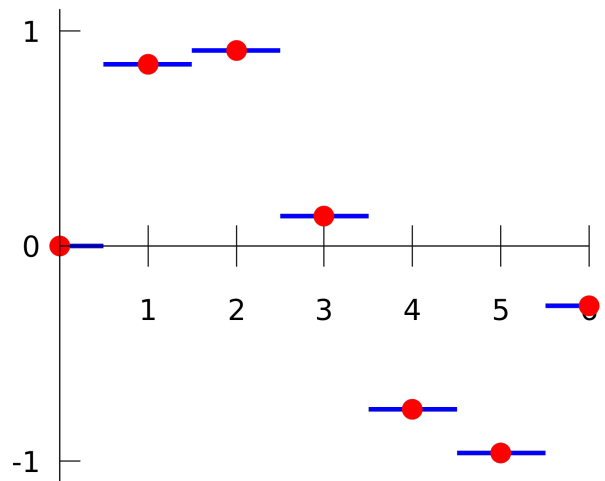
Before



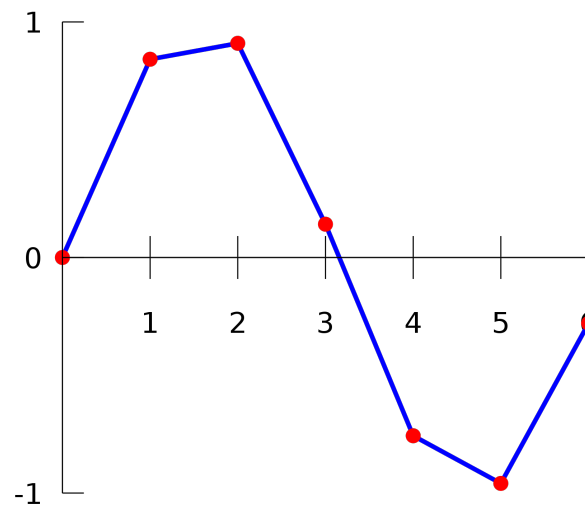
After

Interpolation Method

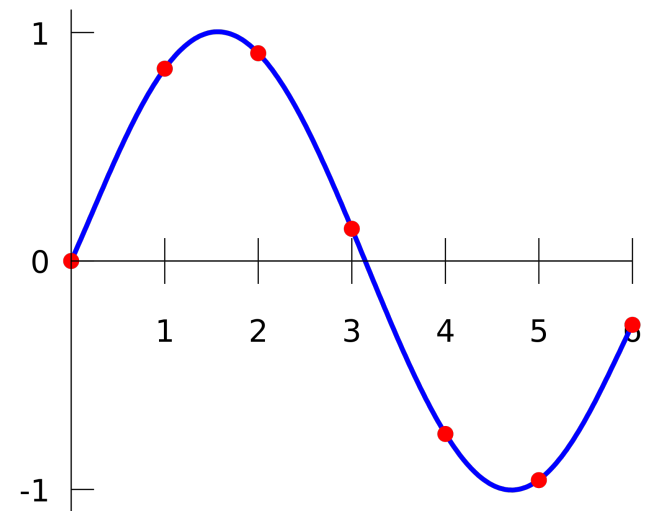
- Construct new data points within the range of know data points (discrete set) → bring up the bins surrounded by 0 events
- Change interpolation order 0~3(in the code to create workspace)



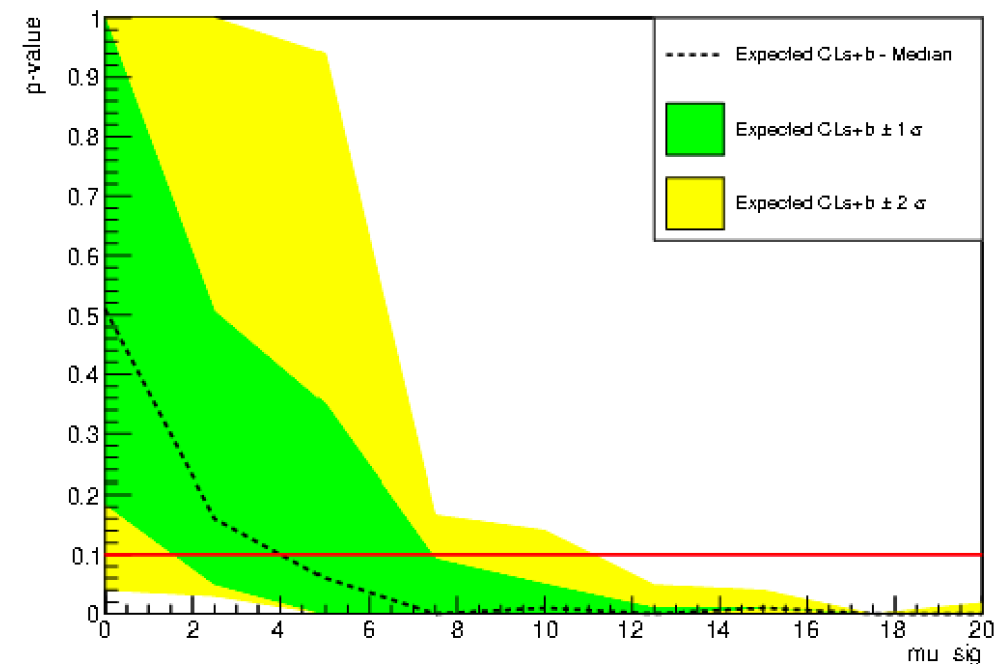
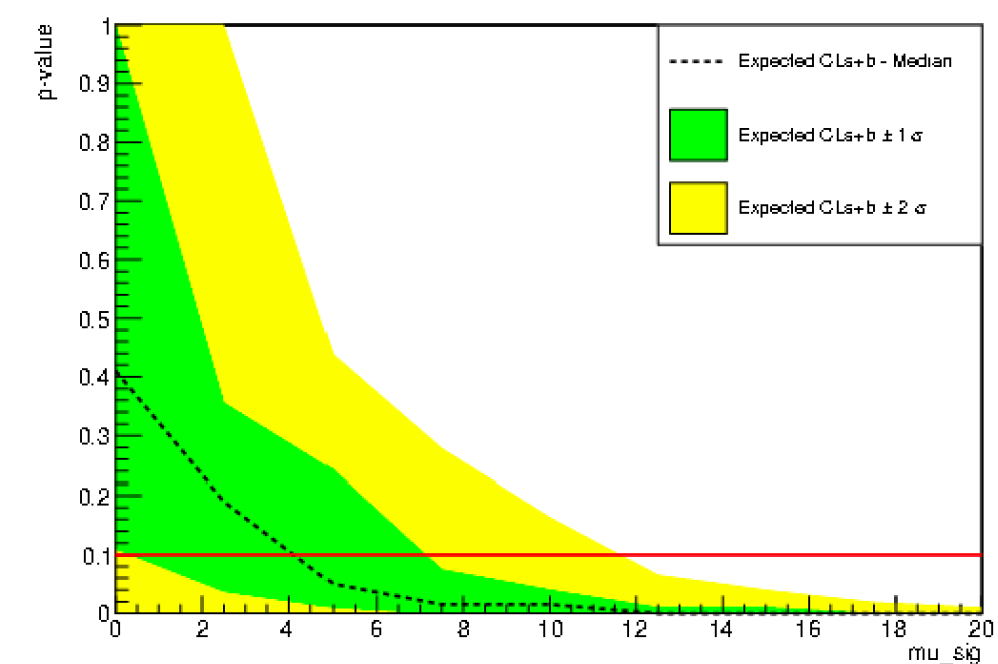
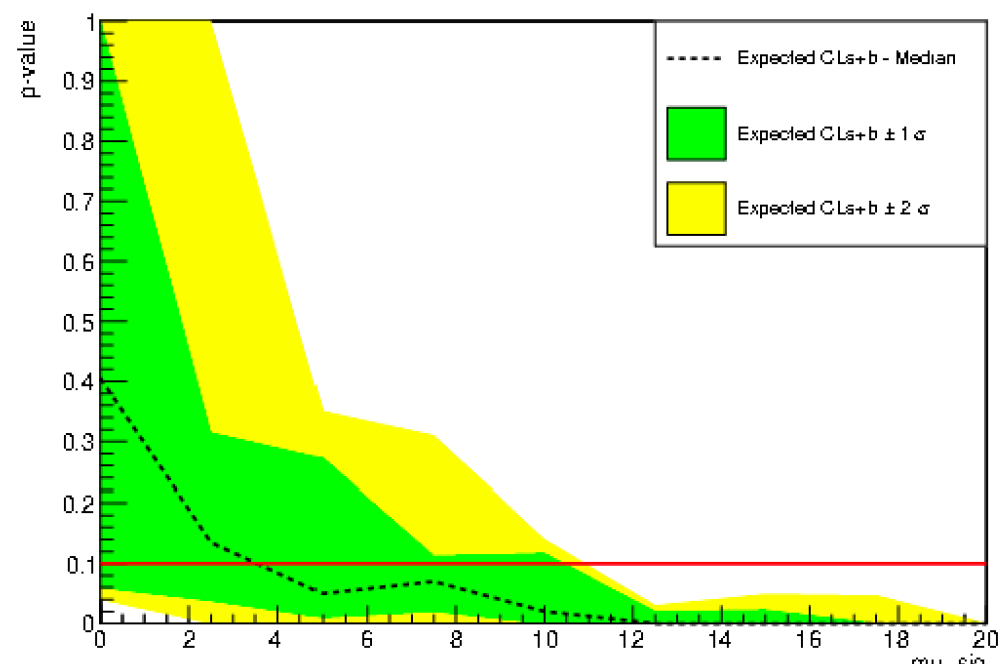
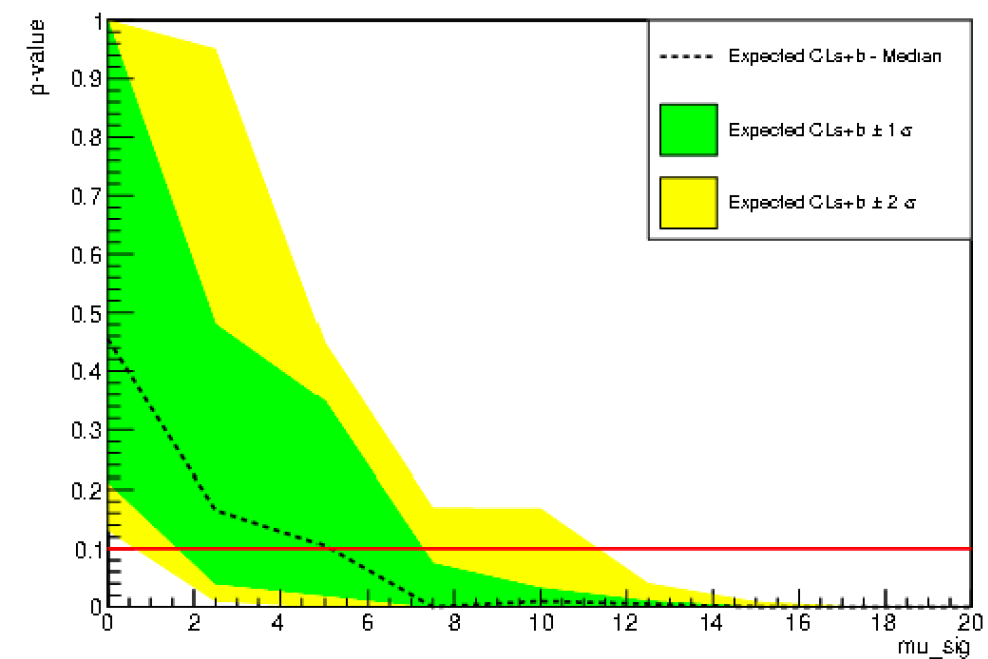
0th

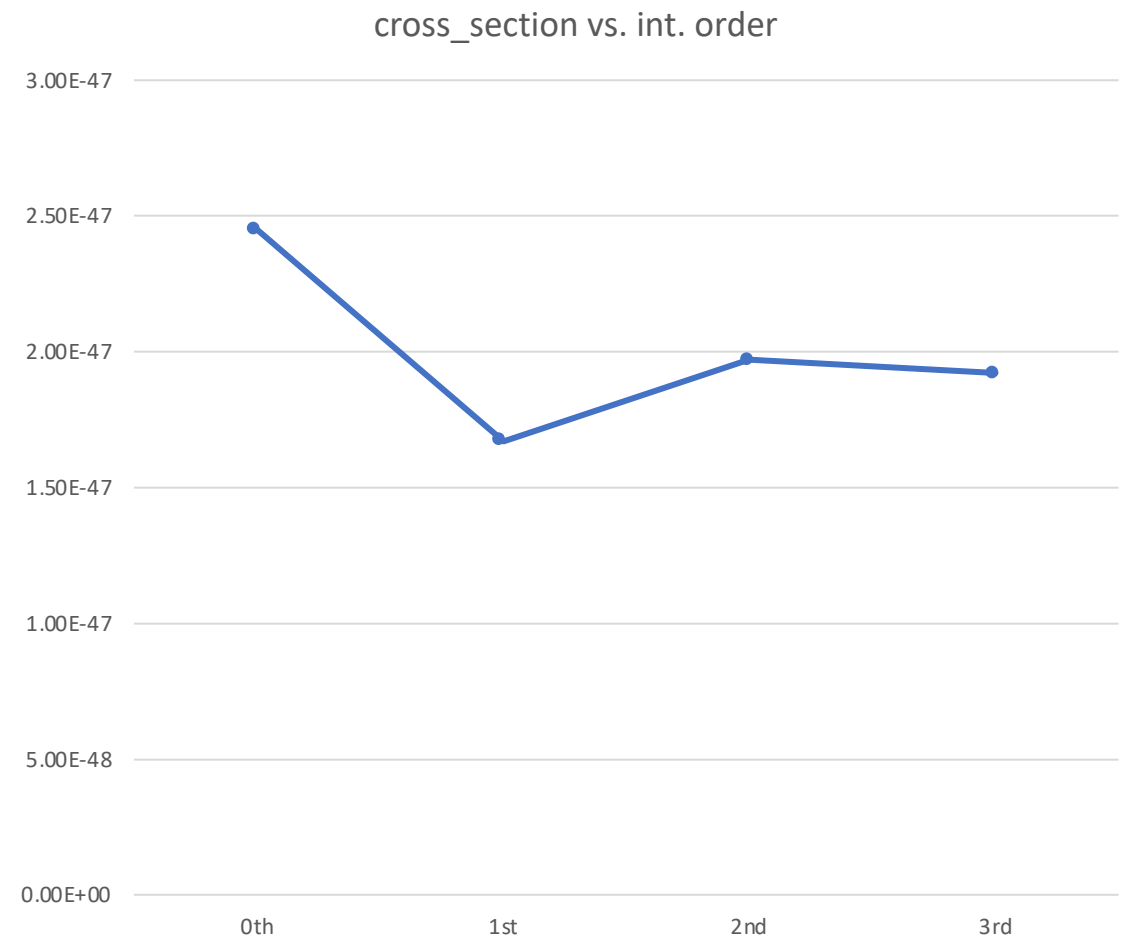
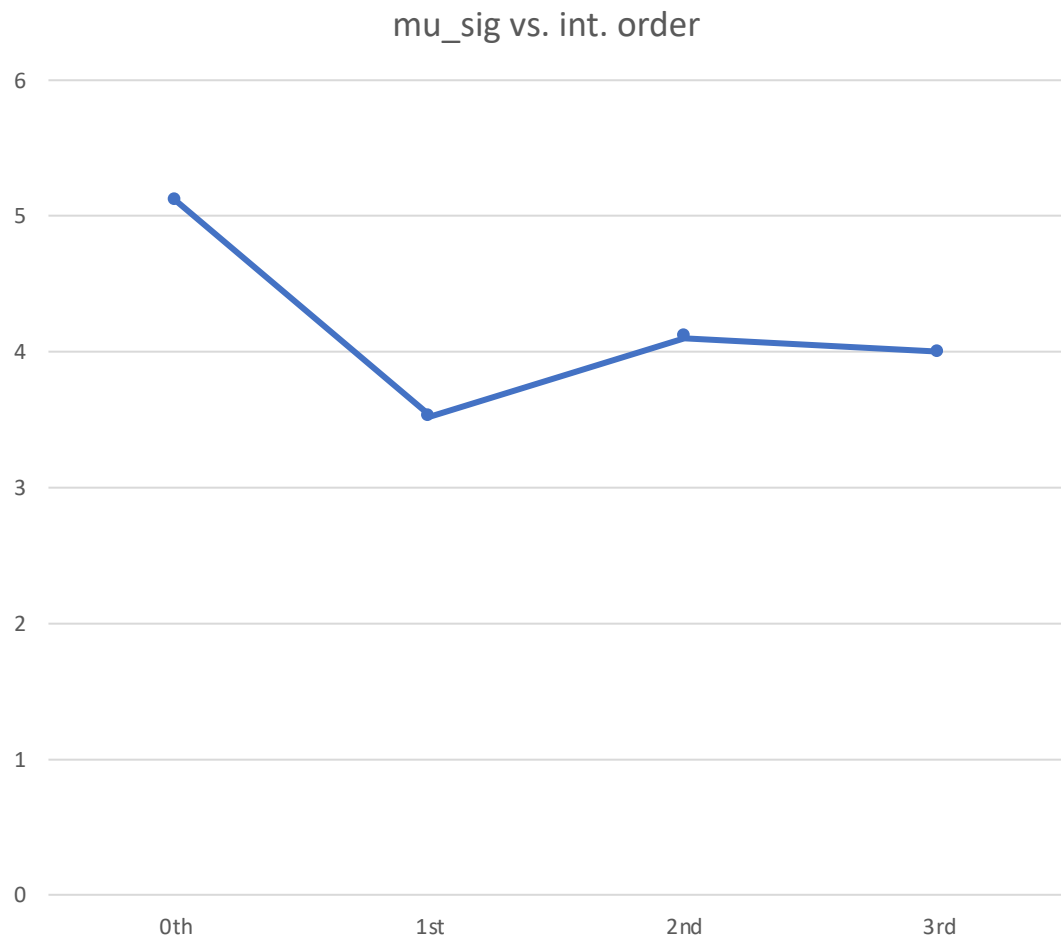


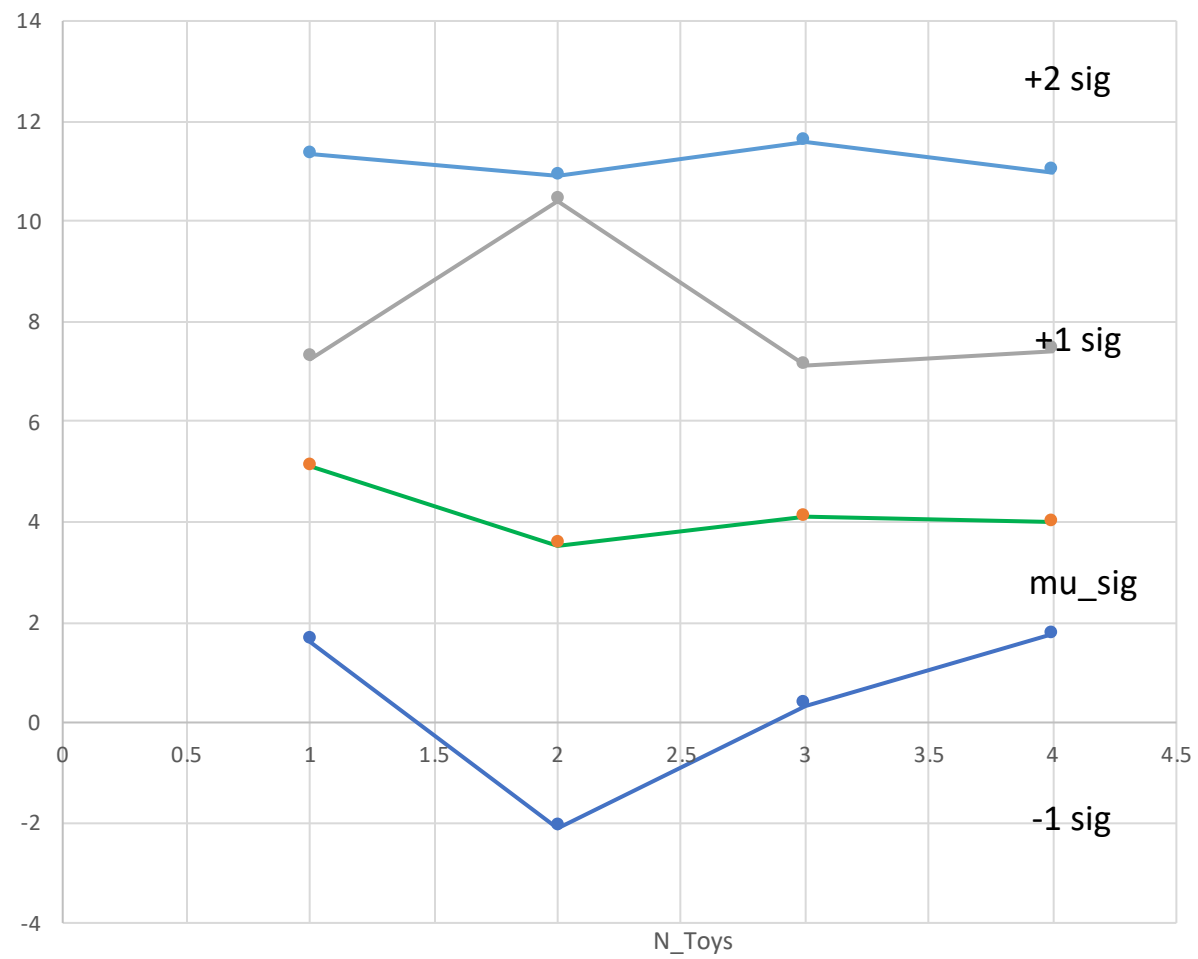
1st



2nd?



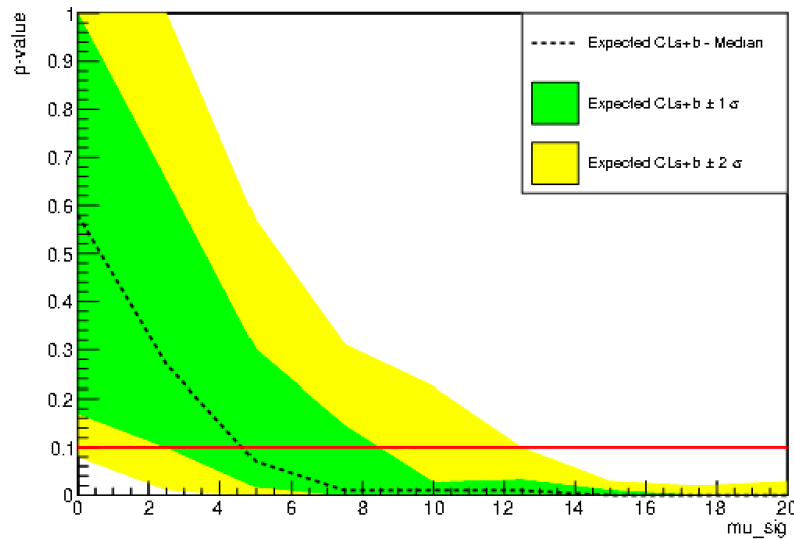




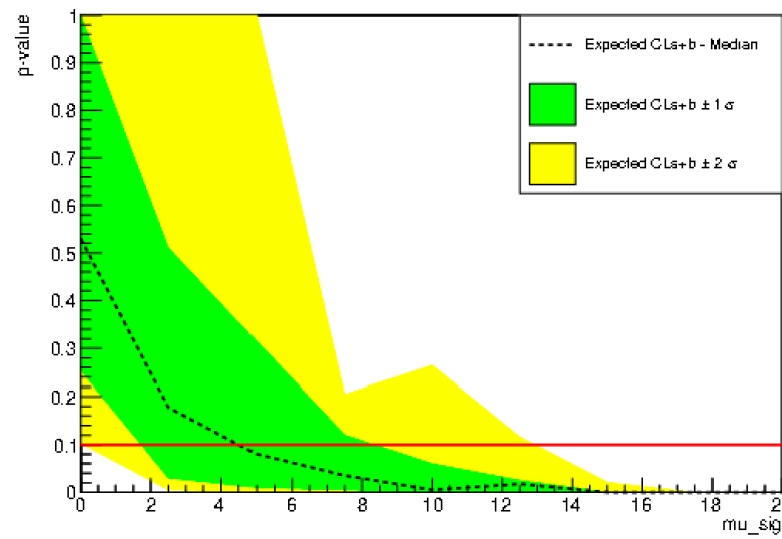
What's new?

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

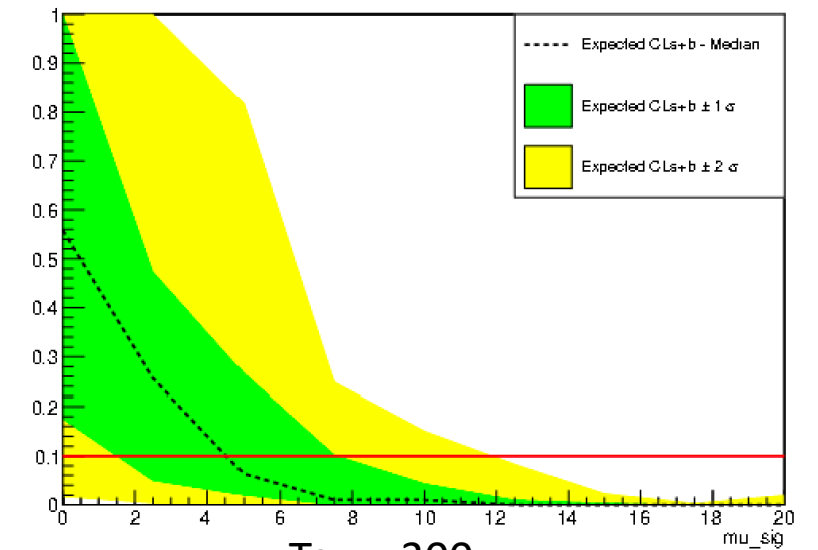
$g1 = 0.118$, 10^7 sample size



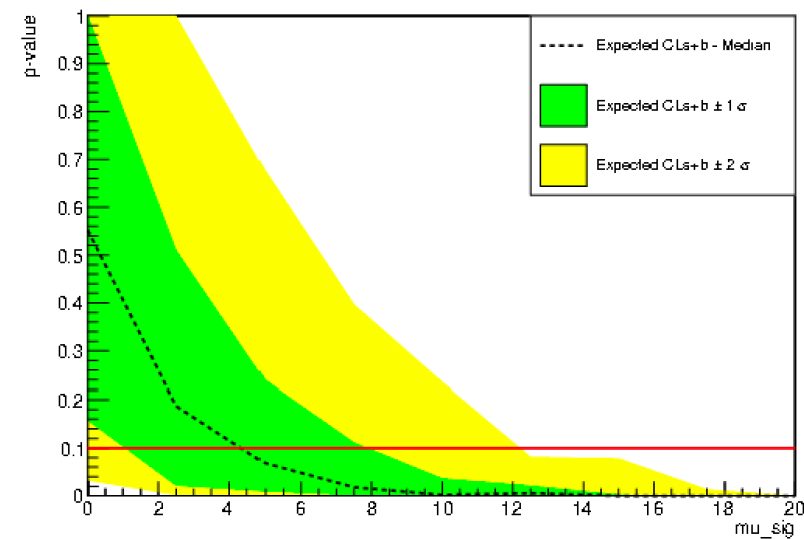
Toy = 100



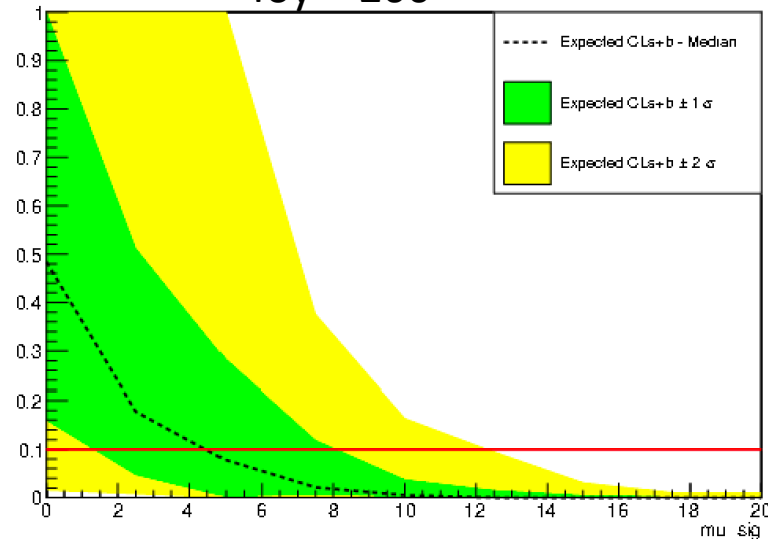
Toy = 200



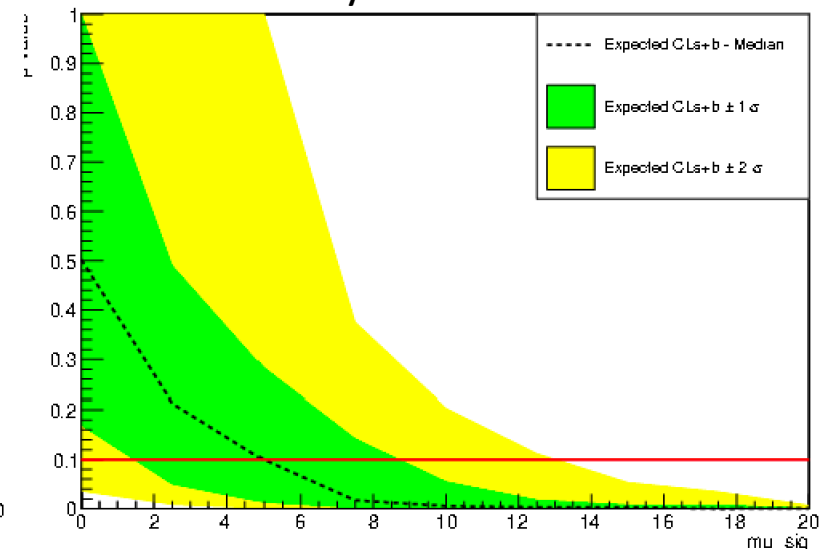
Toy = 300



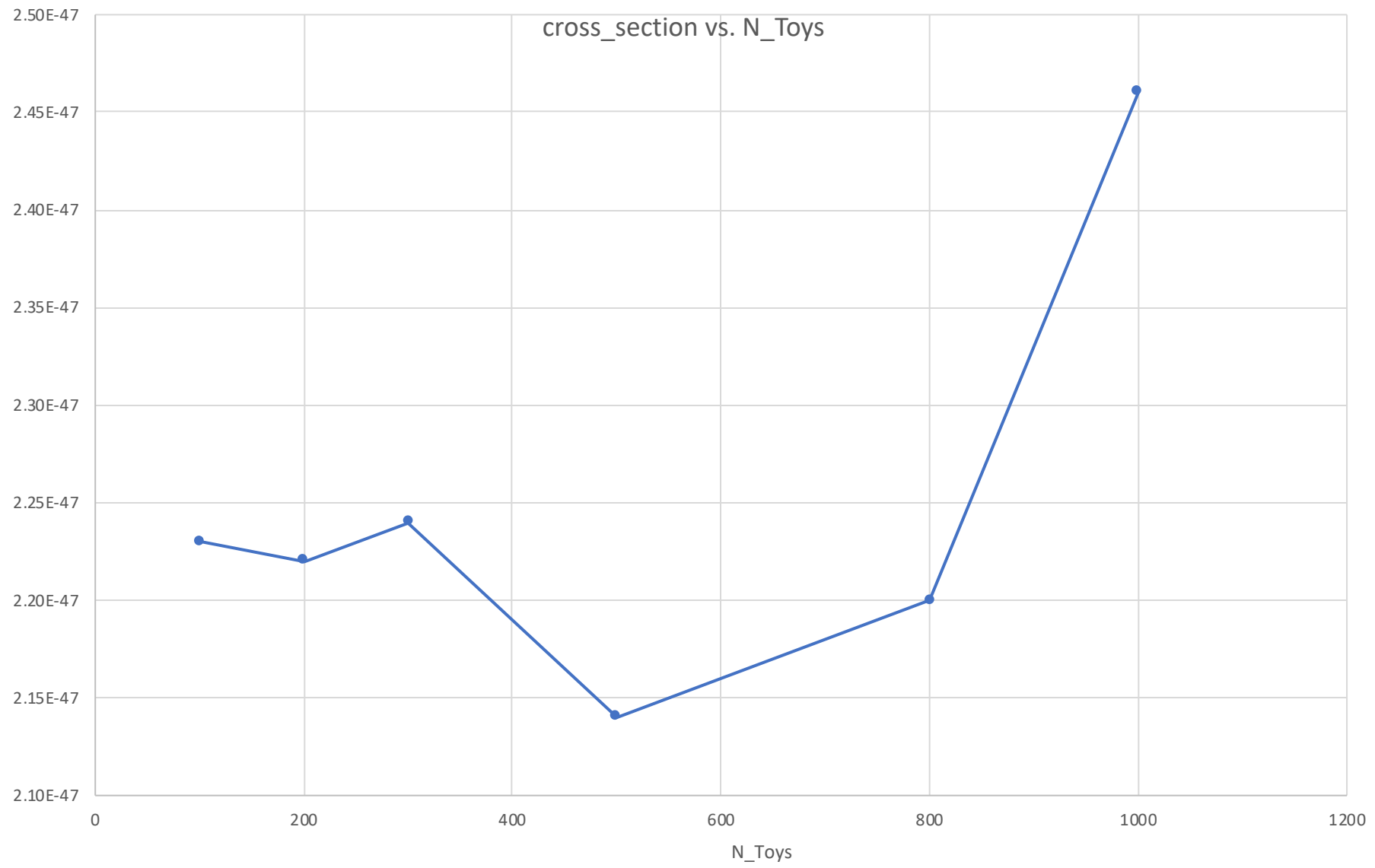
Toy = 500

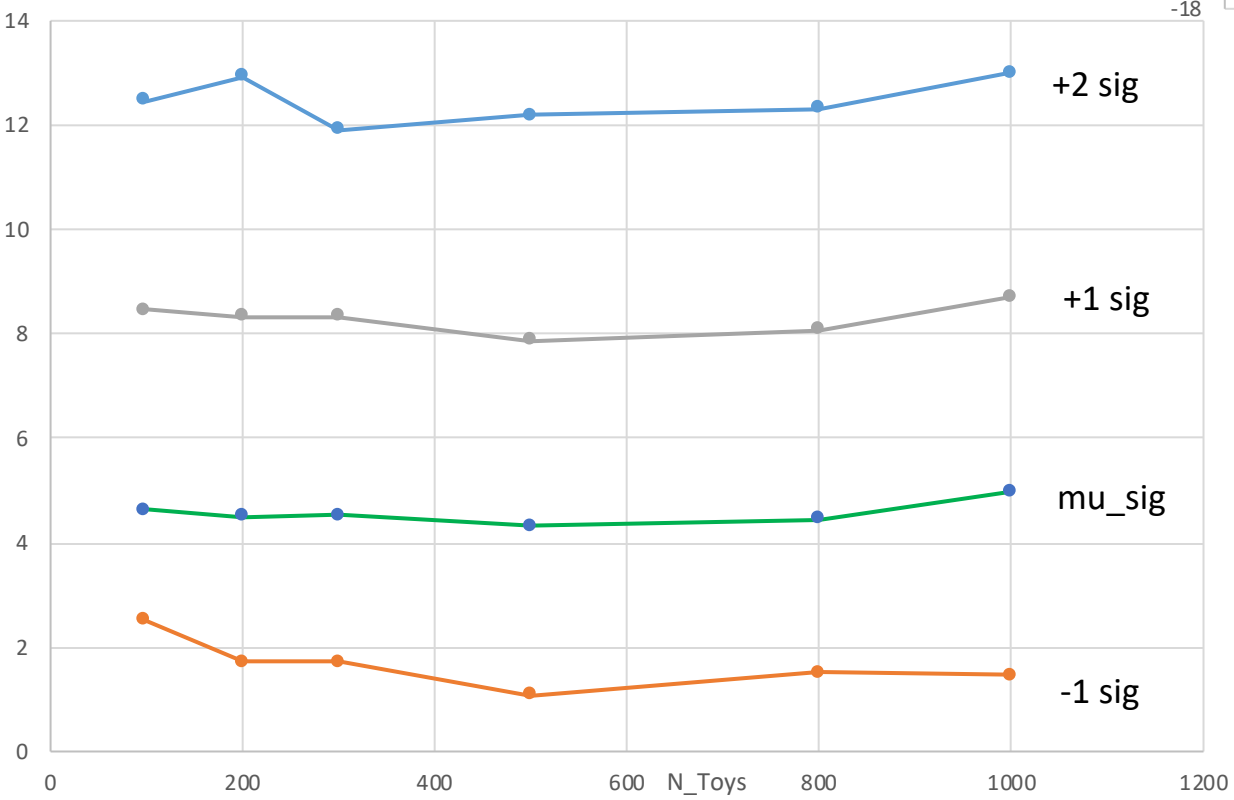
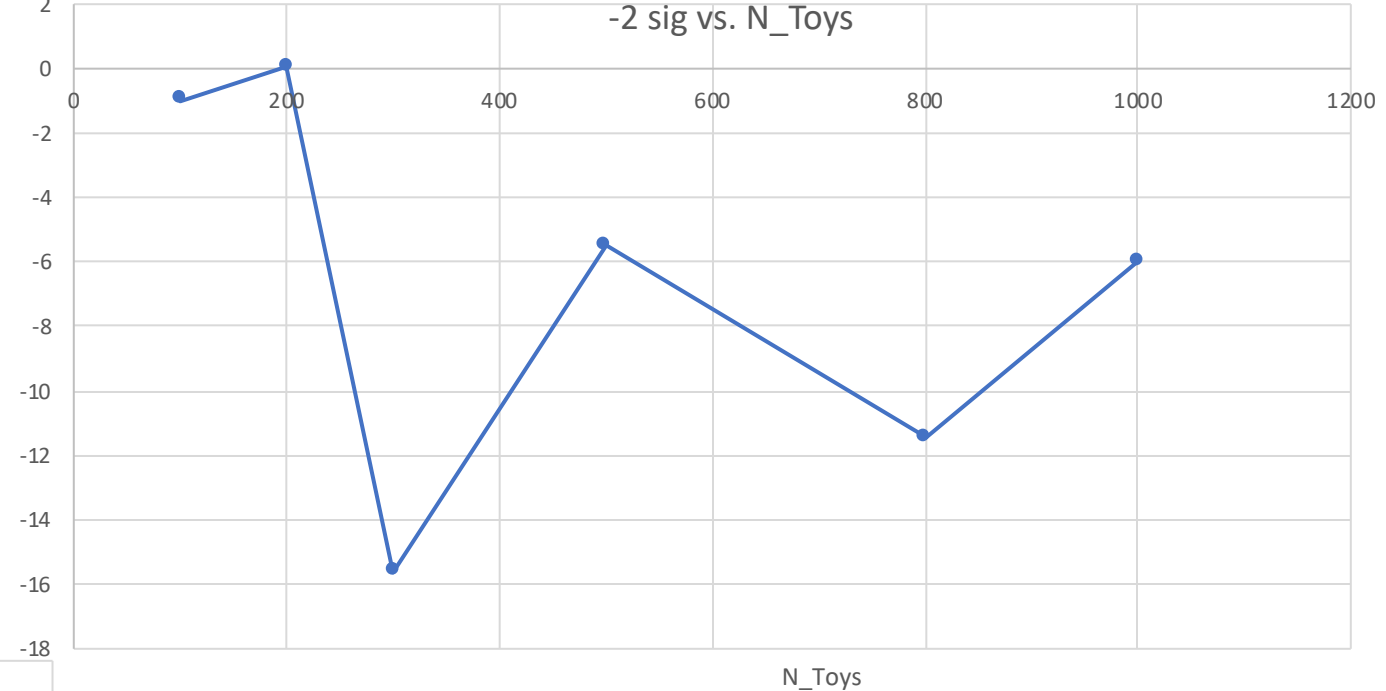


Toy = 800



Toy = 1000



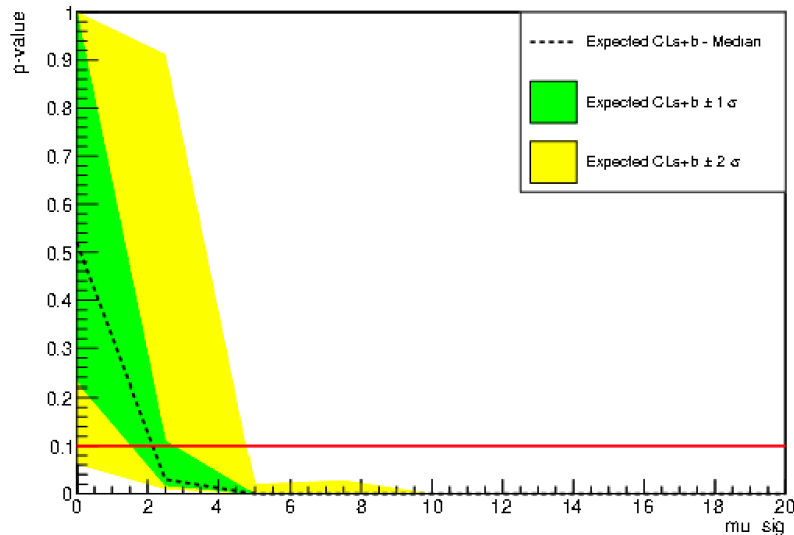


What's new?

- Run 10 GeV WIMP mass with changing g_1 values (0.05, 0.118, 0.13) and changing n_{sample} values (10^6 & 10^7)

10 GeV

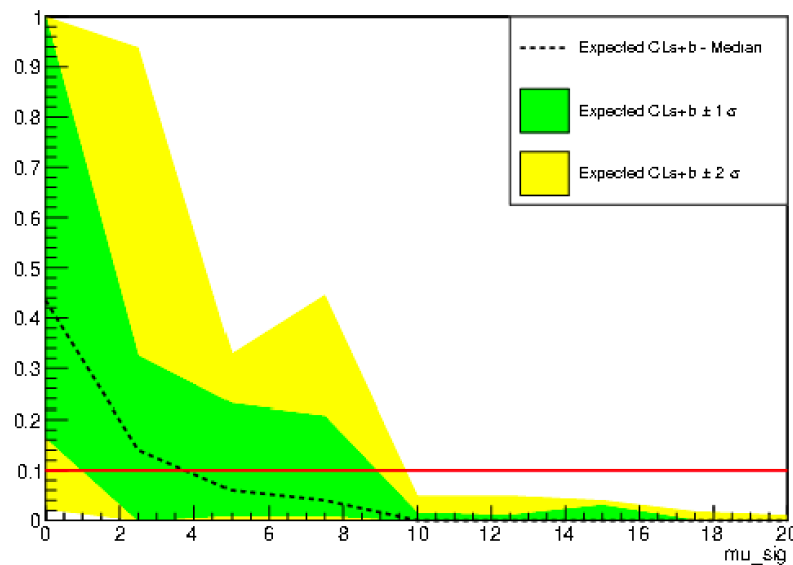
$n_{\text{sample}} = 10^6$



$g_1 = 0.05$

$\mu_{\text{sig}} = 2.1429$

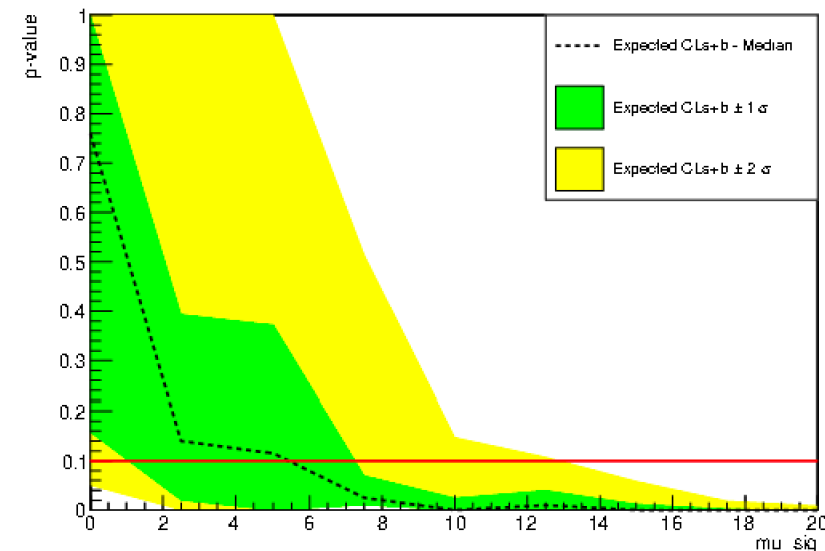
$\text{cross_section} = 6.8\text{e-}47$



$g_1 = 0.118$

$\mu_{\text{sig}} = 3.7500$

$\text{cross_section} = 1.84\text{e-}47$

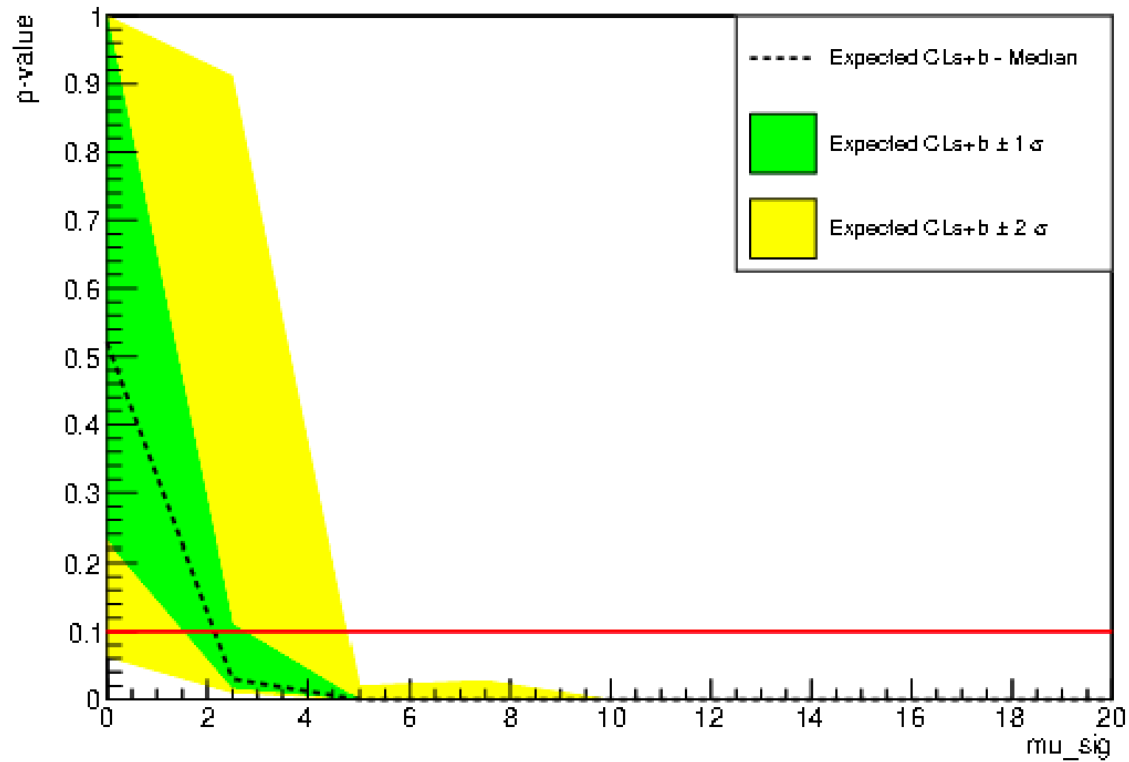


$g_1 = 0.13$

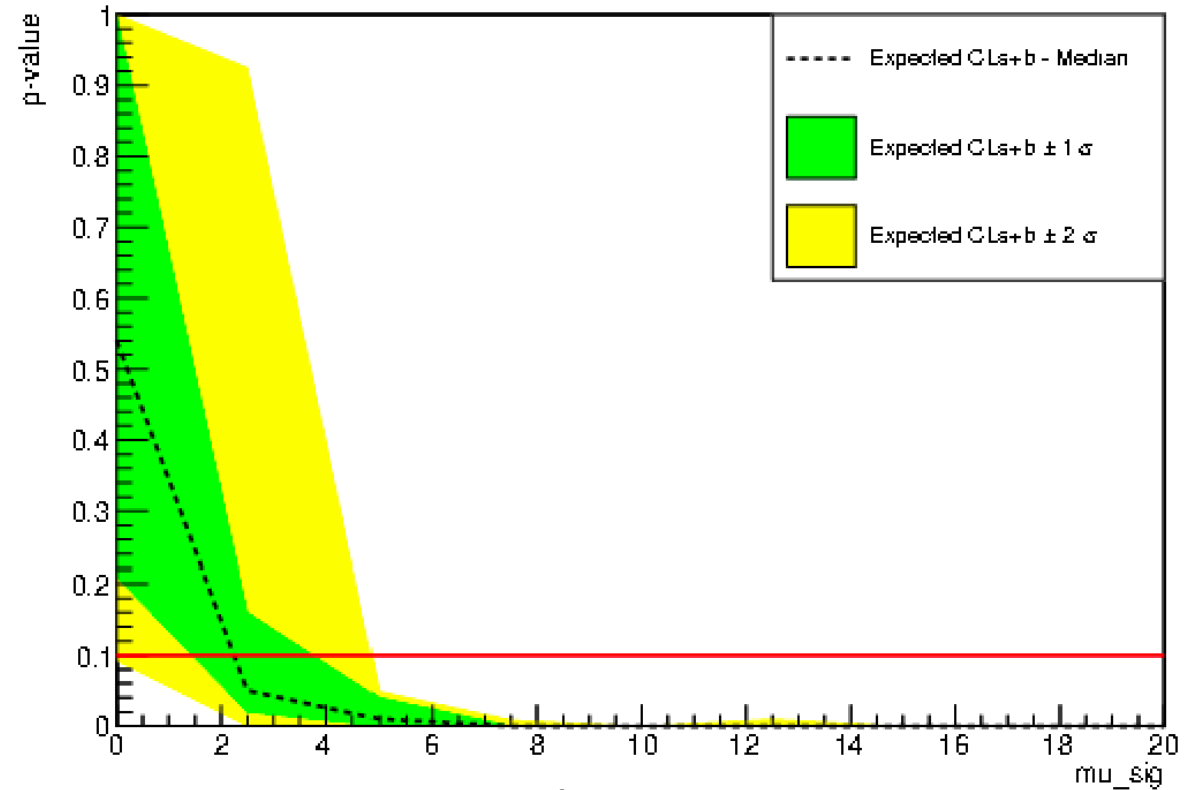
$\mu_{\text{sig}} = 5.4167$

$\text{cross_section} = 2.3\text{e-}47$

10 GeV, $g_1 = 0.05$

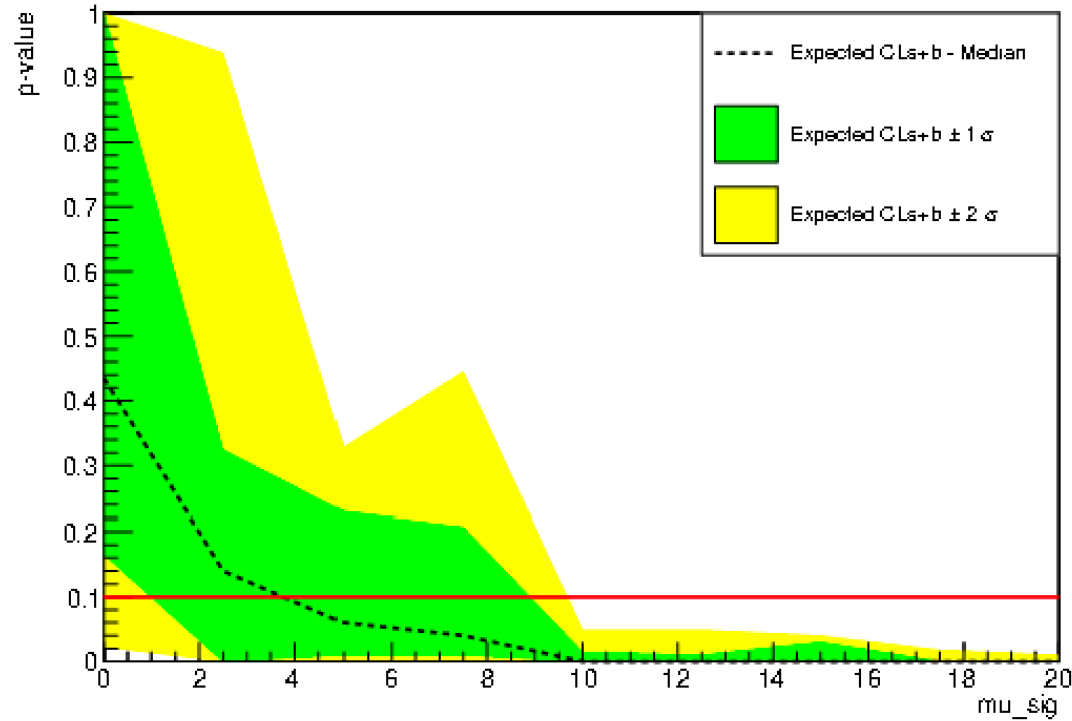


$N_{\text{sample}} = 10^6$
 $\mu_{\text{sig}} = 2.1429$
 $\text{cross_section} = 6.8\text{e-}47$

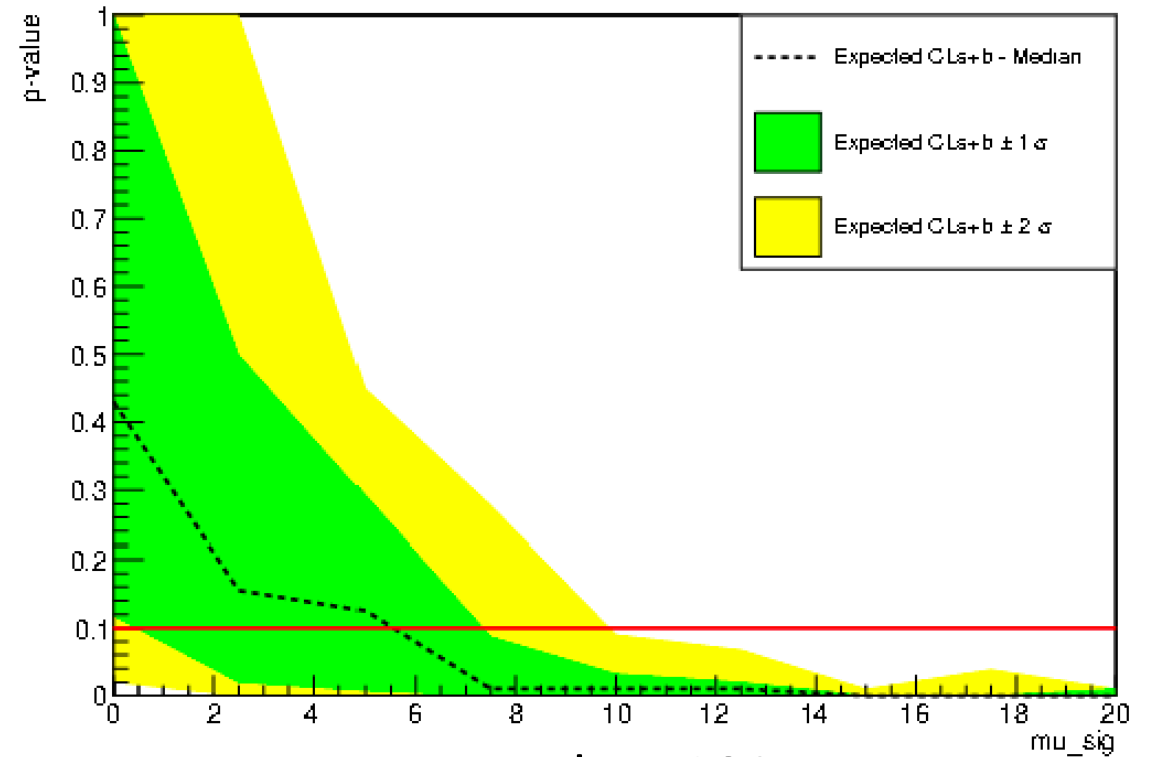


$N_{\text{sample}} = 10^7$
 $\mu_{\text{sig}} = 2.2449$
 $\text{cross_section} = 7.2\text{e-}47$

10 GeV, $g_1 = 0.118$

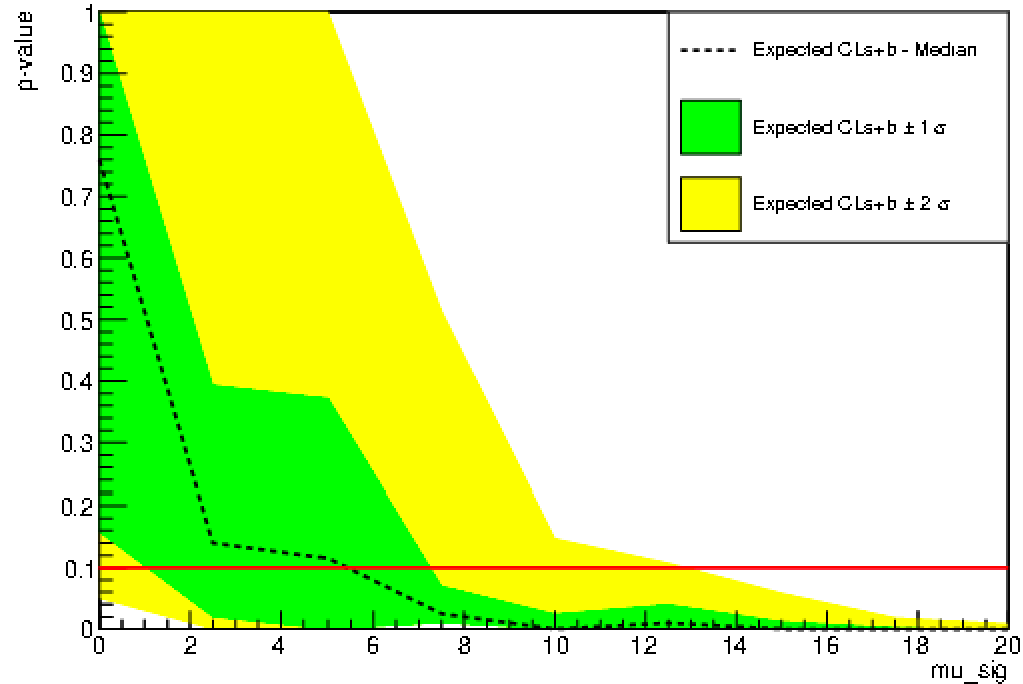


$N_{\text{sample}} = 10^6$
 $\mu_{\text{sig}} = 3.7500$
 $\text{cross_section} = 1.84\text{e-}47$

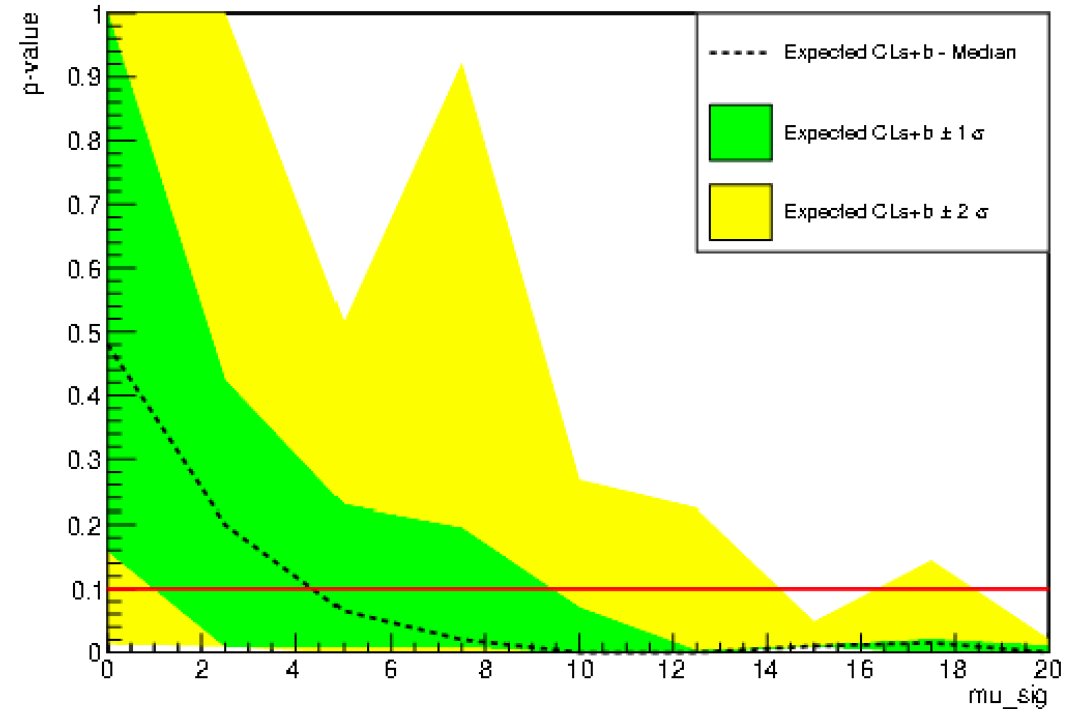


$N_{\text{sample}} = 10^7$
 $\mu_{\text{sig}} = 5.54$
 $\text{cross_section} = 2.74\text{e-}47$

10 GeV, $g_1 = 0.13$

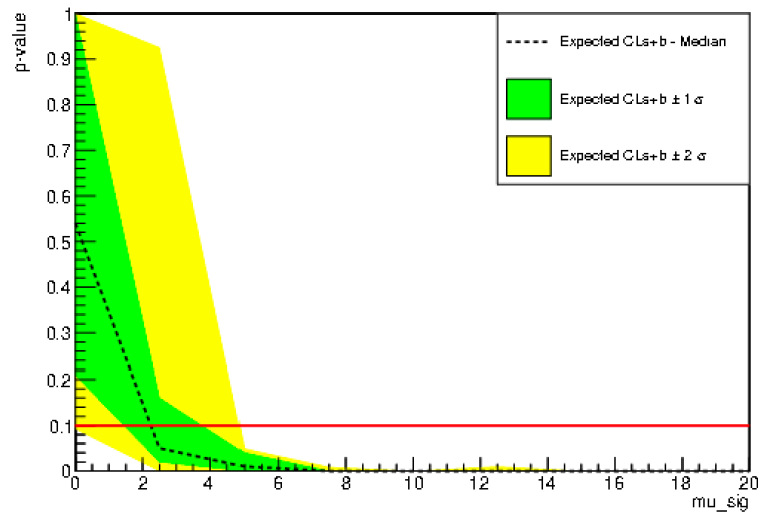


$N_{\text{sample}} = 10^6$
 $\mu_{\text{sig}} = 5.4167$
cross_section = 2.3×10^{-47}

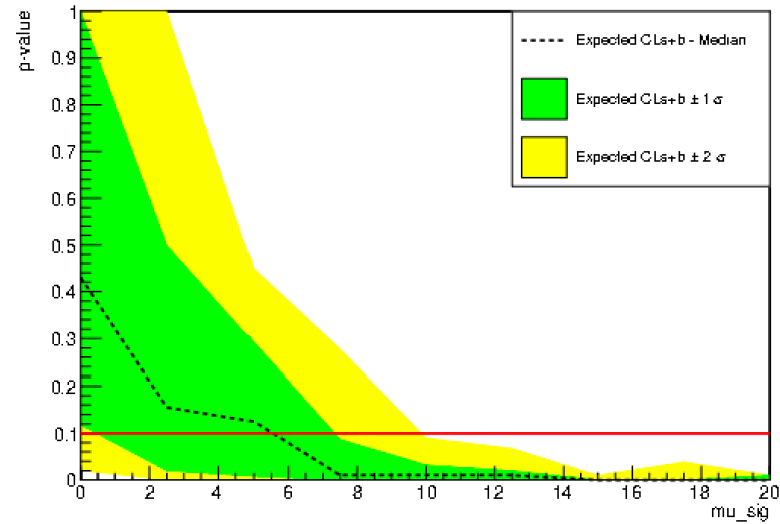


$N_{\text{sample}} = 10^7$
 $\mu_{\text{sig}} = 4.3544$
cross_section = 1.8×10^{-47}

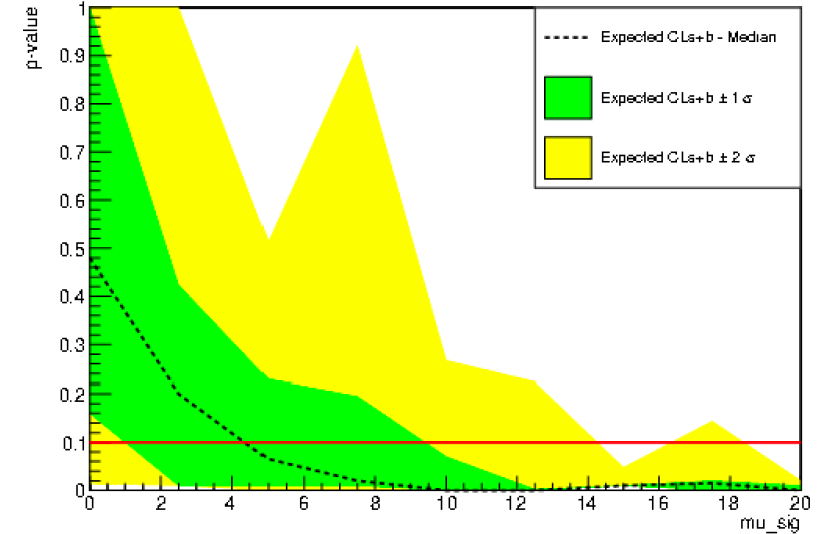
10 GeV
 $n_{\text{sample}} = 10^7$



$g_1 = 0.05$
 $\mu_{\text{sig}} = 2.2449$
 $\text{cross_section} = 7.2\text{e-}47$



$g_1 = 0.118$
 $\mu_{\text{sig}} = 5.54$
 $\text{cross_section} = 2.74\text{e-}47$



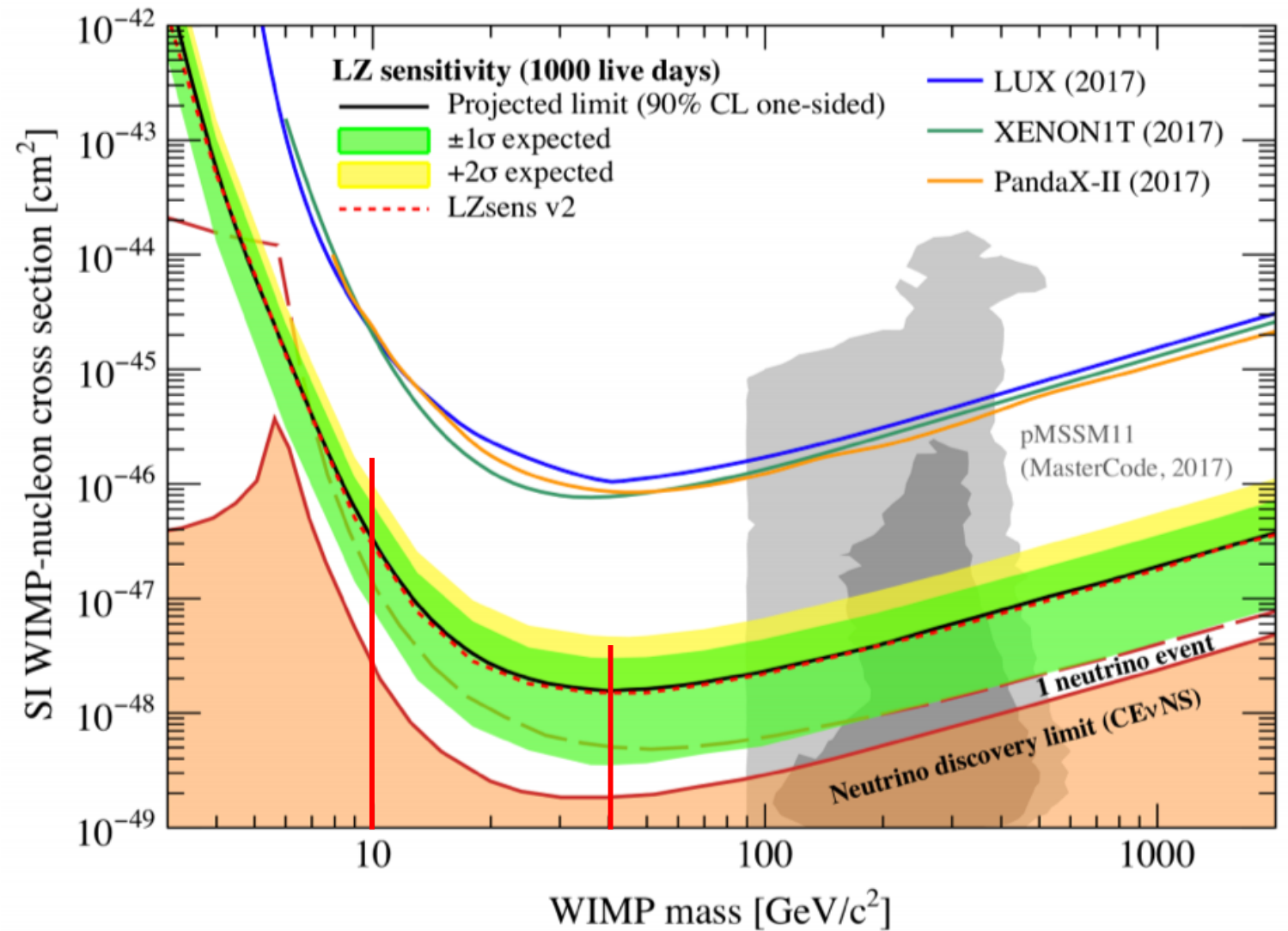
$g_1 = 0.13$
 $\mu_{\text{sig}} = 4.3544$
 $\text{cross_section} = 1.8\text{e-}47$

Comparison (10 GeV vs 40 GeV)

- Change g_1 from 0.05 $\rightarrow$ 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 g_1 ?

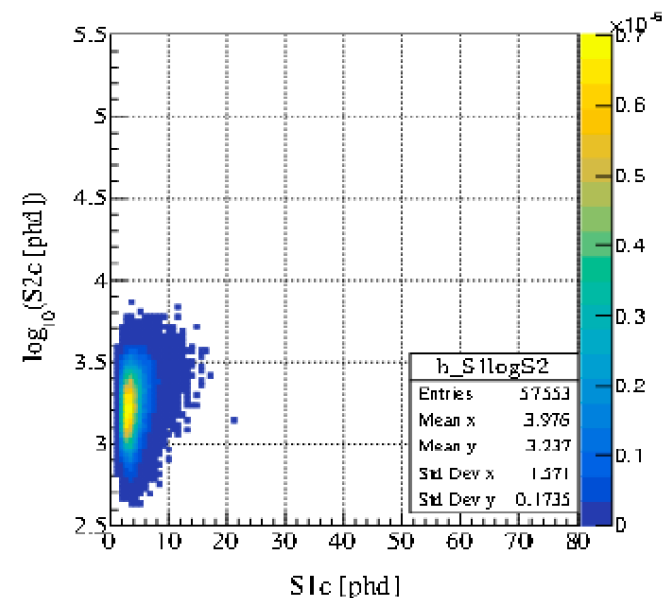
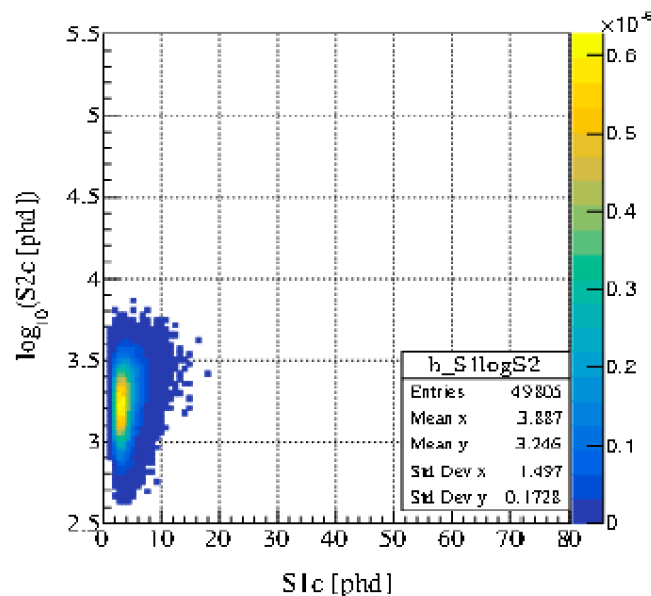
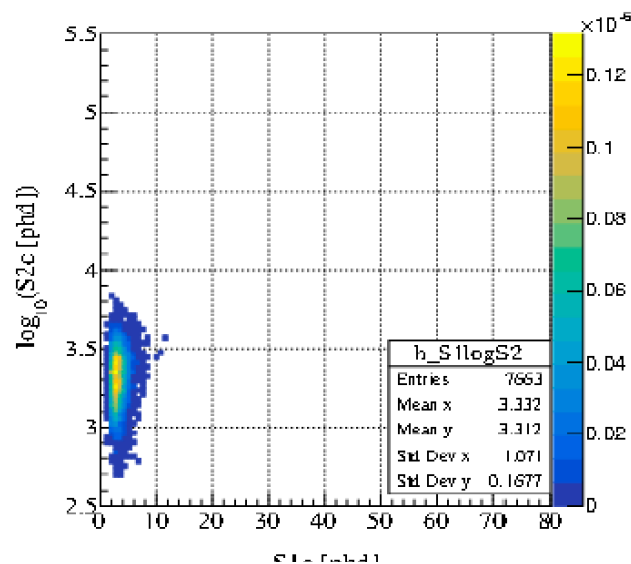
Limit plot

$10 \text{ GeV} \sim 3e^{-47}$

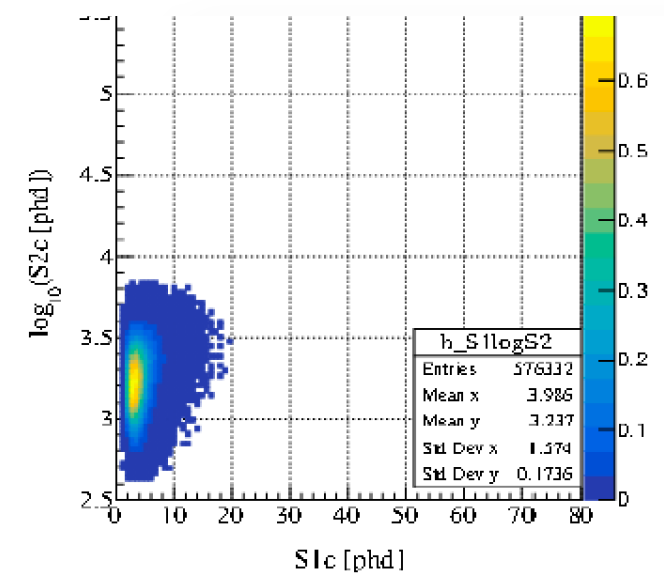
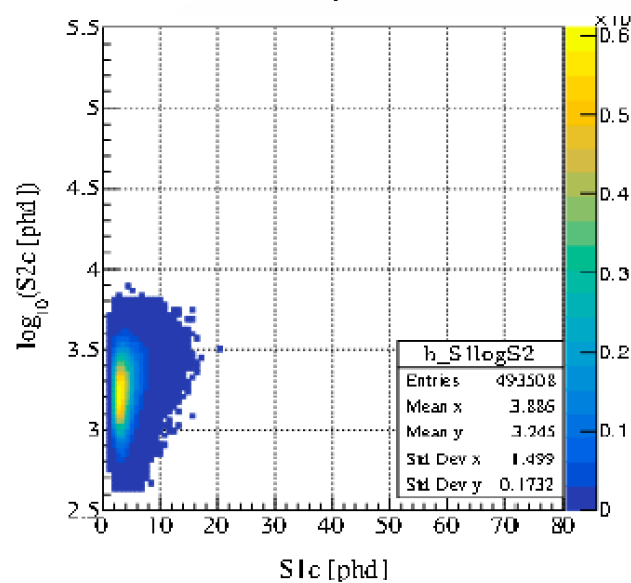
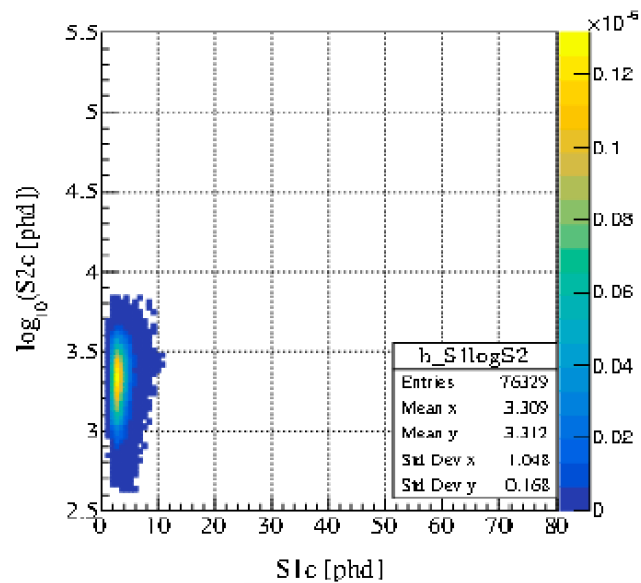


WIMP 10GeV

$N_{\text{sample}} = 10^6$



$N_{\text{sample}} = 10^7$



$g1 = 0.05$

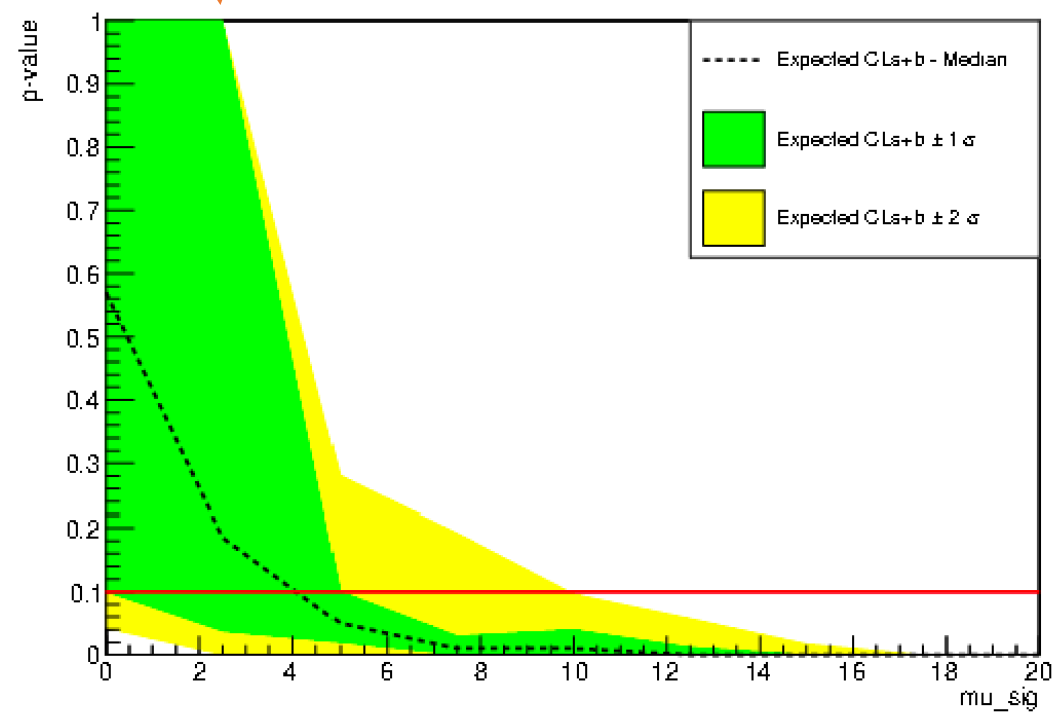
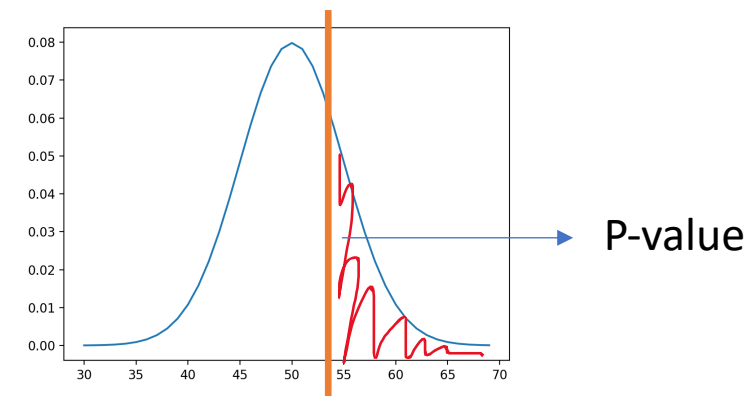
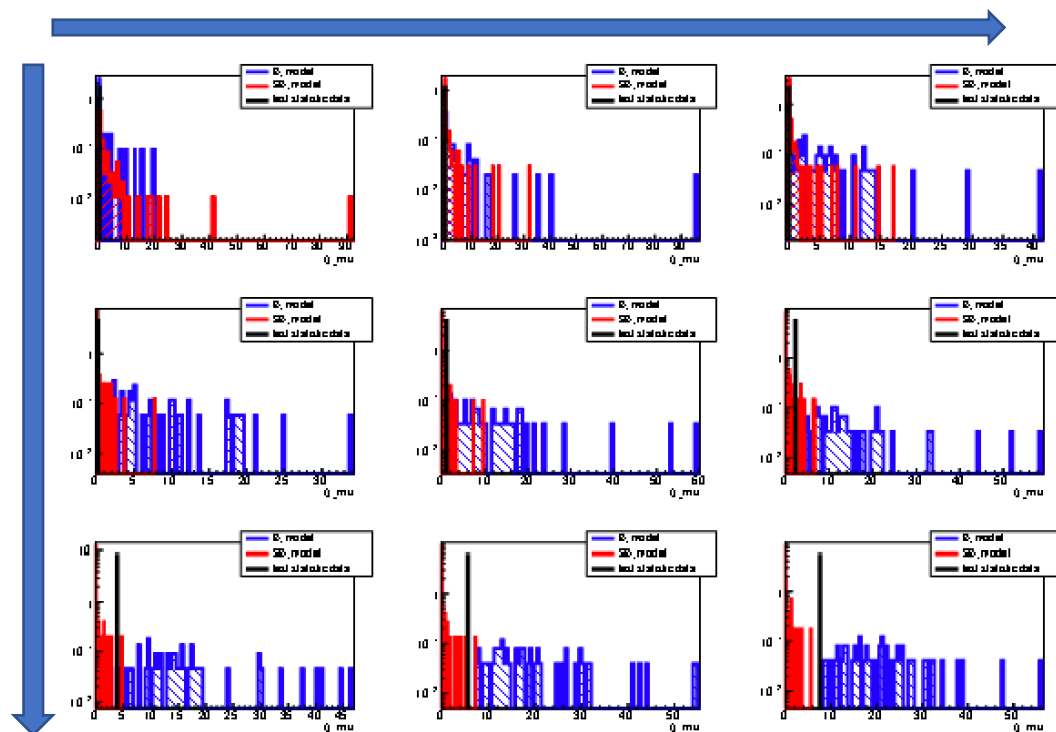
$g1 = 0.118$

$g1 = 0.13$

What's new?

- Analyze the graph
- Change g_1 value and compare the limits

POI = 0 $\sim$ 20



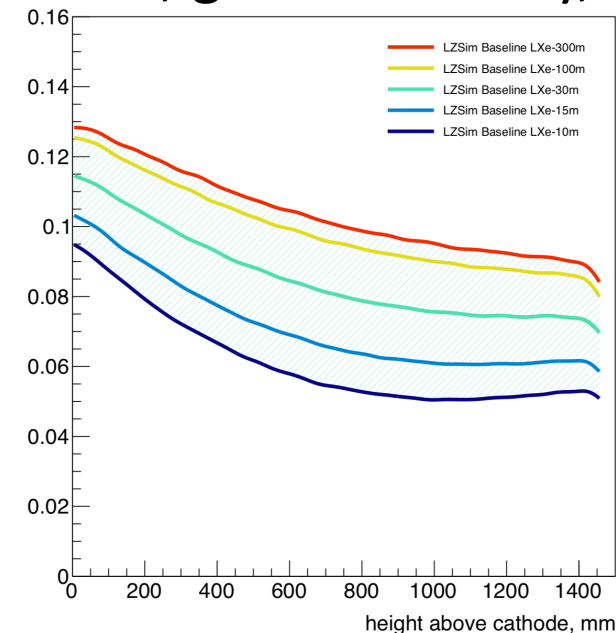
g1

- 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

$g1_{\min} \sim 0.05$

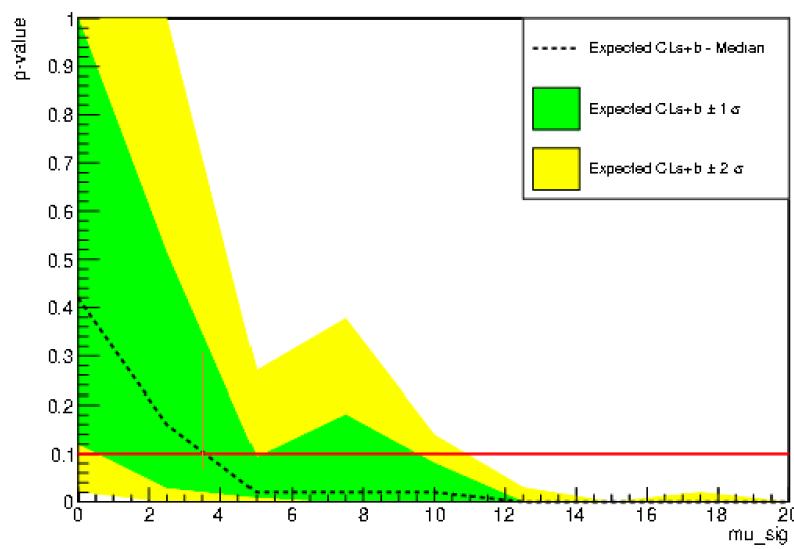
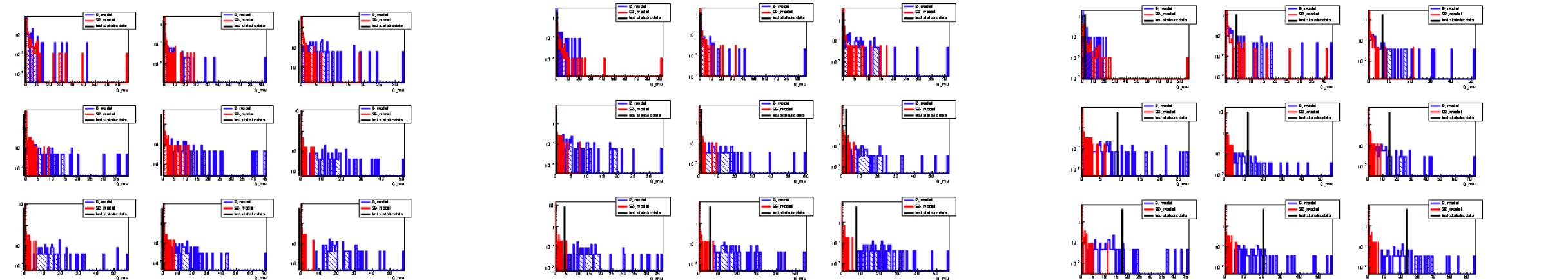
$g1_{\text{default}} \sim 0.118$

$g1_{\max} \sim 0.13$

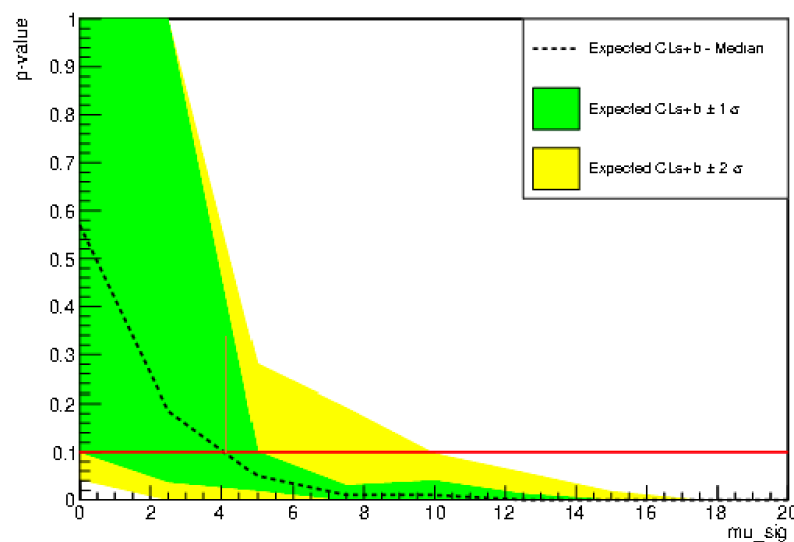


Code

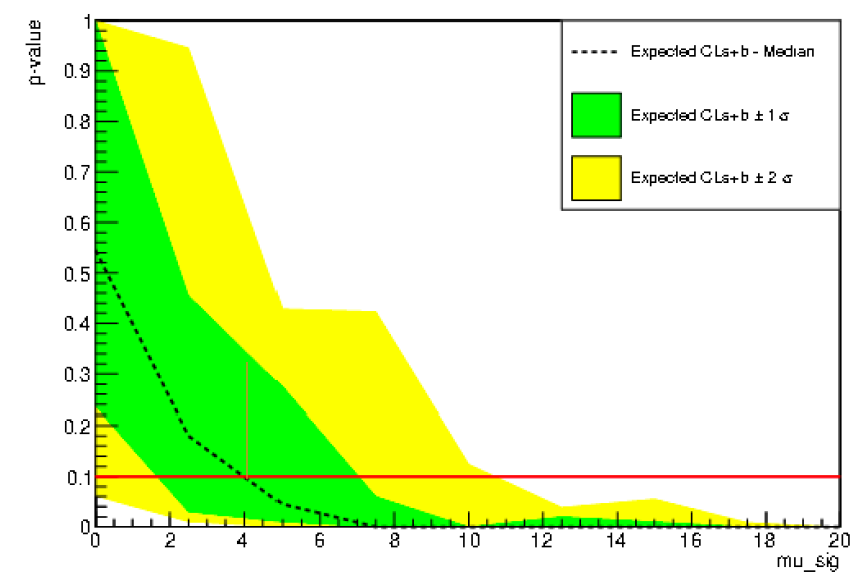
- LZNESTUtils
 - Change Detector parameters
 - Source setup.sh
 - Source .ci/build.sh
 - Get new NESTInterference
- PdfMaker
 - Recompile signal and background codes with the new NESTInterference



$g1 = 0.05$
 $\mu_{sig} = 3.5027$
 $cross_section = 1.44e^{-48}$



$g1 = 0.118$
 $\mu_{sig} = 4.0625$
 $cross_section = 1.12e^{-48}$



$g1 = 0.13$
 $\mu_{sig} = 3.9835$
 $cross_section = 1.05e^{-48}$

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
<pre>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</pre>	<pre>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</pre>
<pre>w->factory("Gaussian::constraint_pp(mu_pp,a_pp,sigma_pp)");</pre>	

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

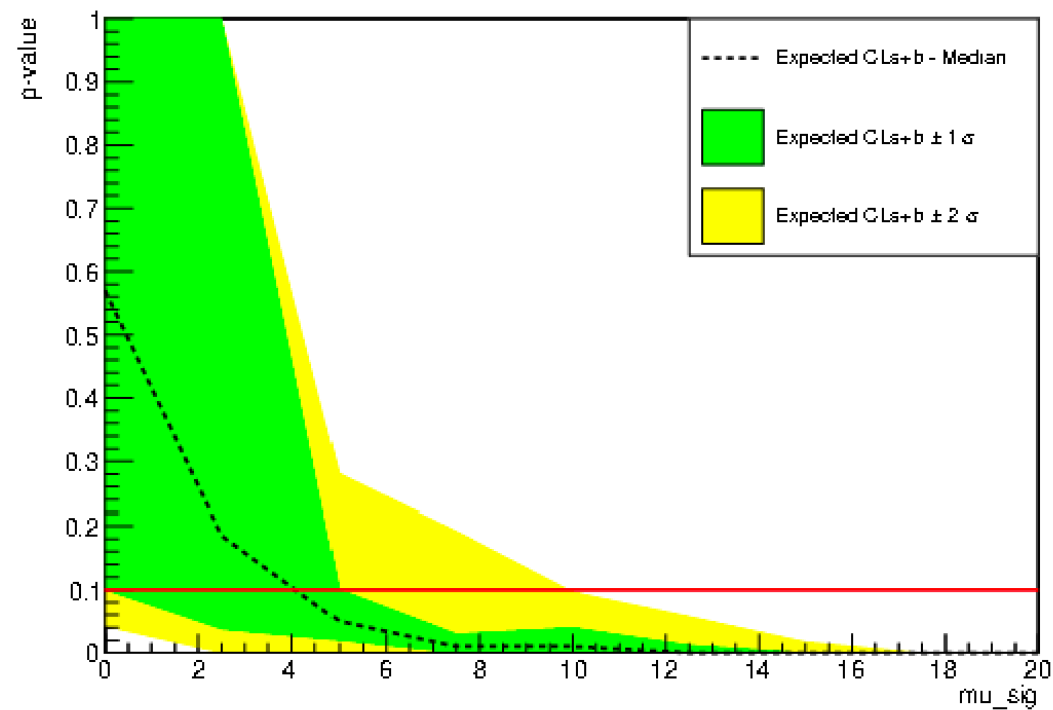
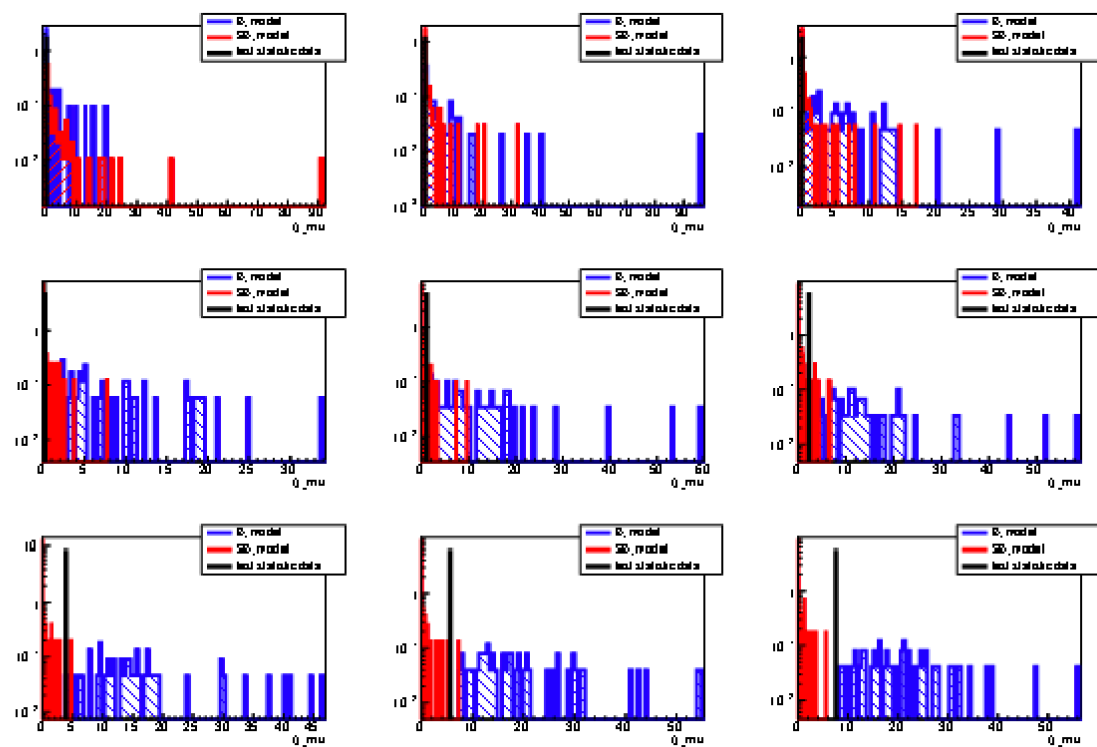
Constraint: Gaussian
distribution of
(x=mu_pp
mean = a_pp,
Sigma = sigma_pp)

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

- 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)



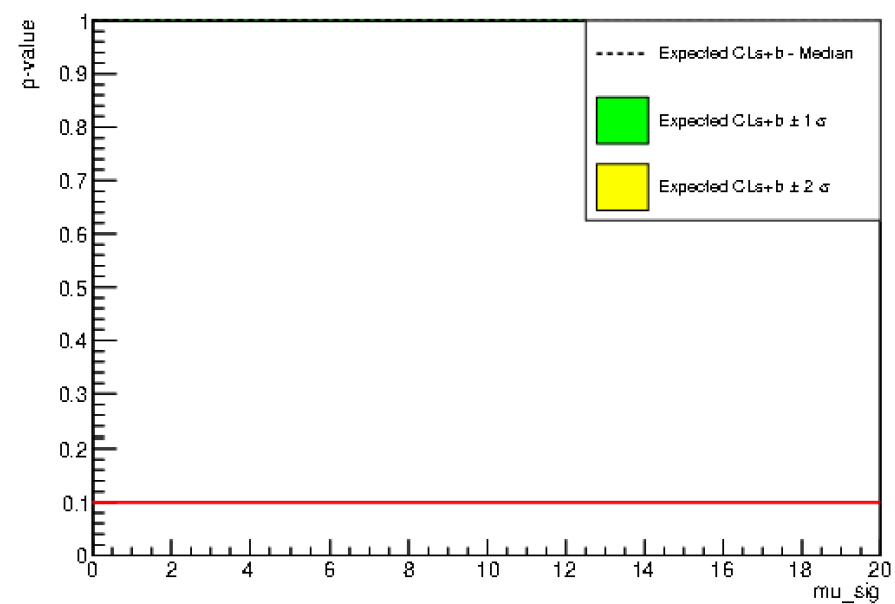
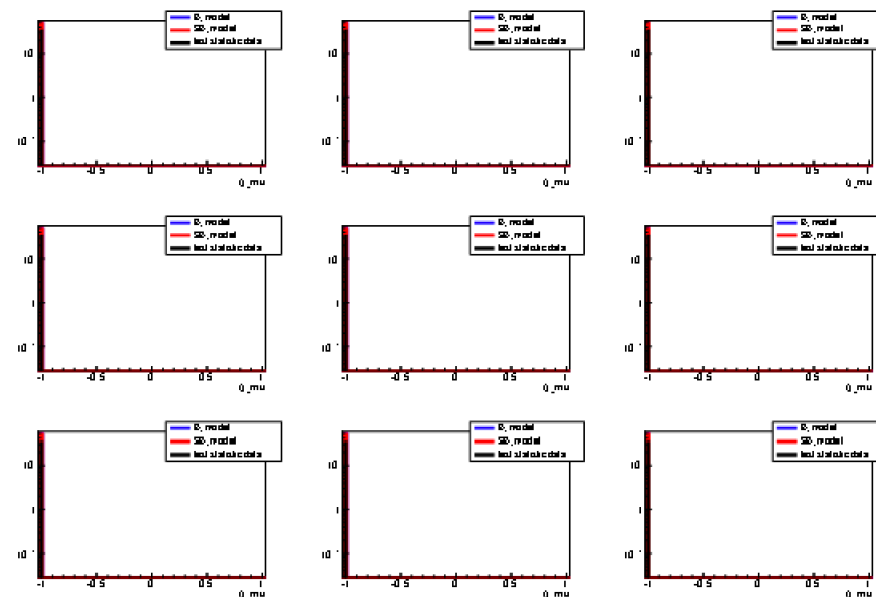
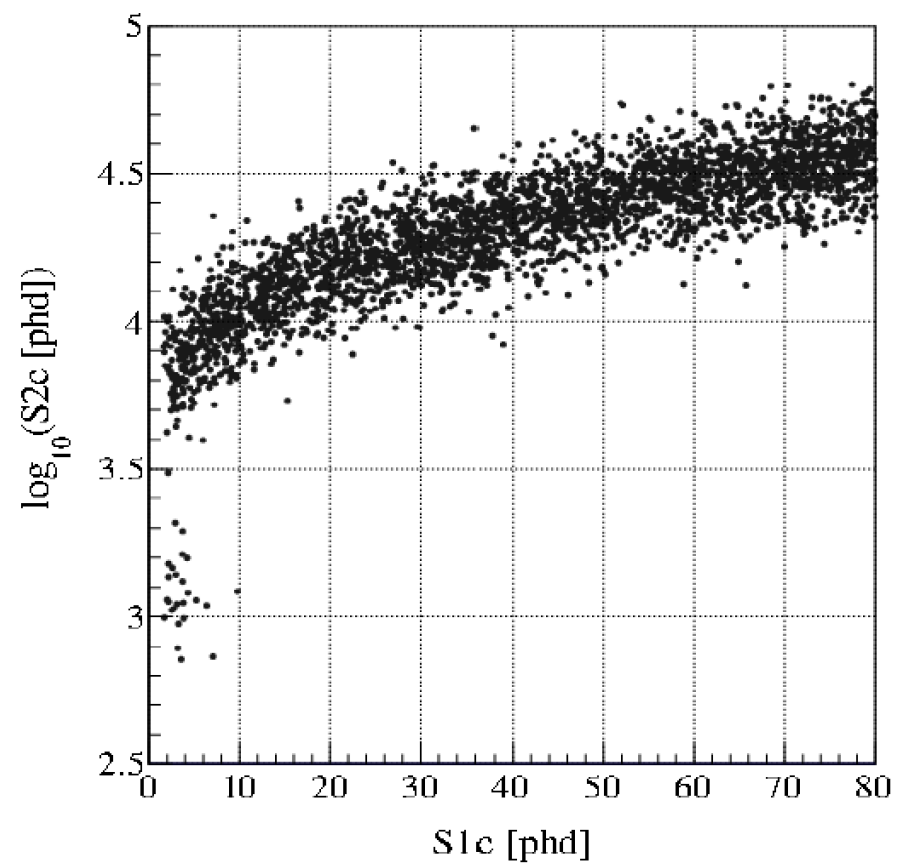
What's done

- 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

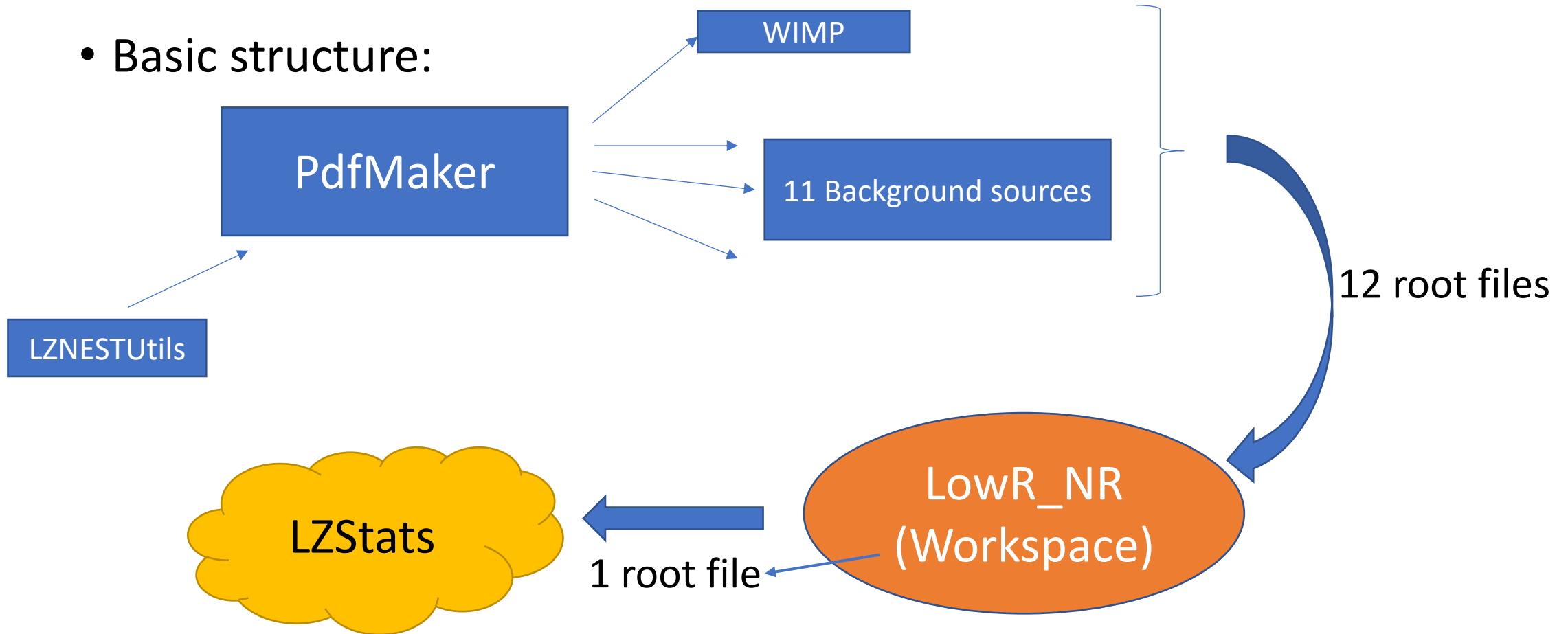
Problem



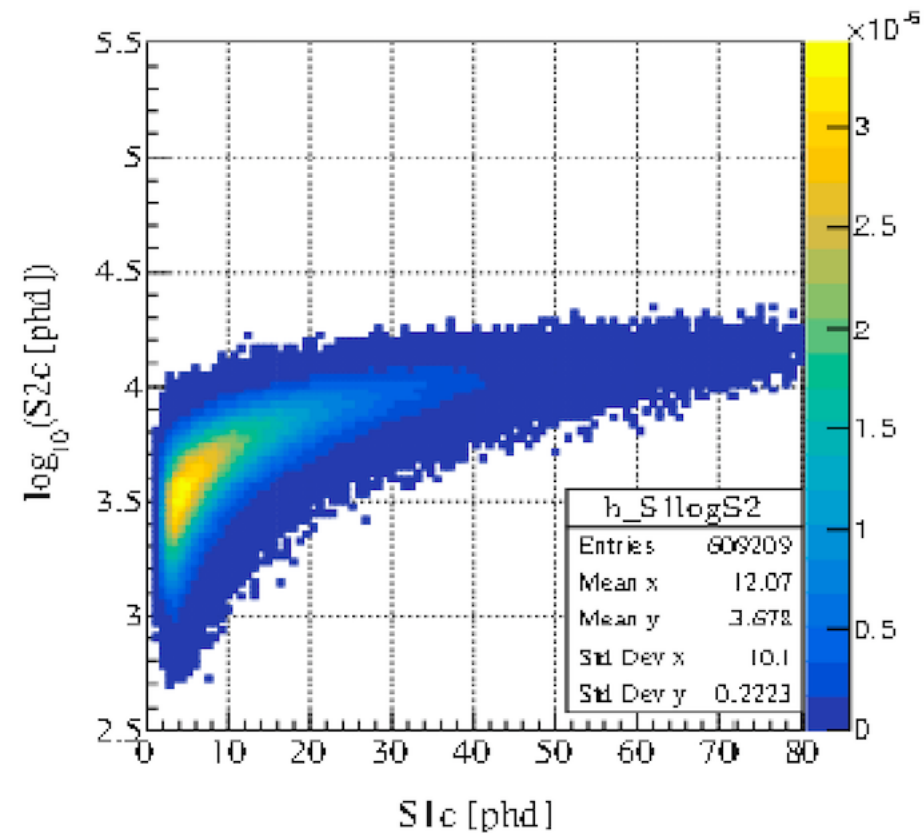
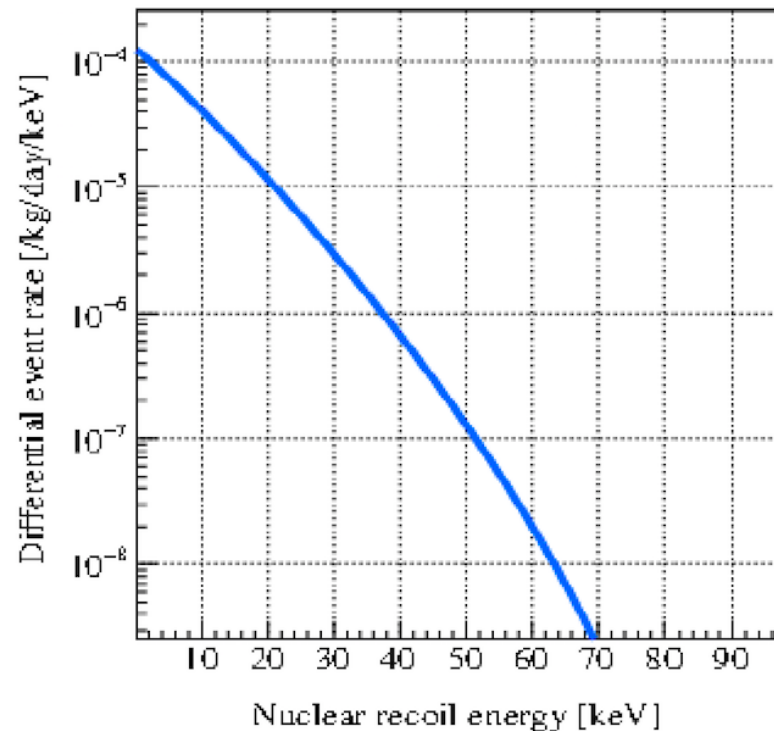
```
Error in <ROOT::Math::FitResult>: FitConfiguration and Minimizer result are not  
consistent  
Number of free parameters from FitConfig = 12  
Number of free parameters from Minimizer = 11
```

Changed LZStats

- Basic structure:



Output of signal (40GeV WIMP) from PdfMaker



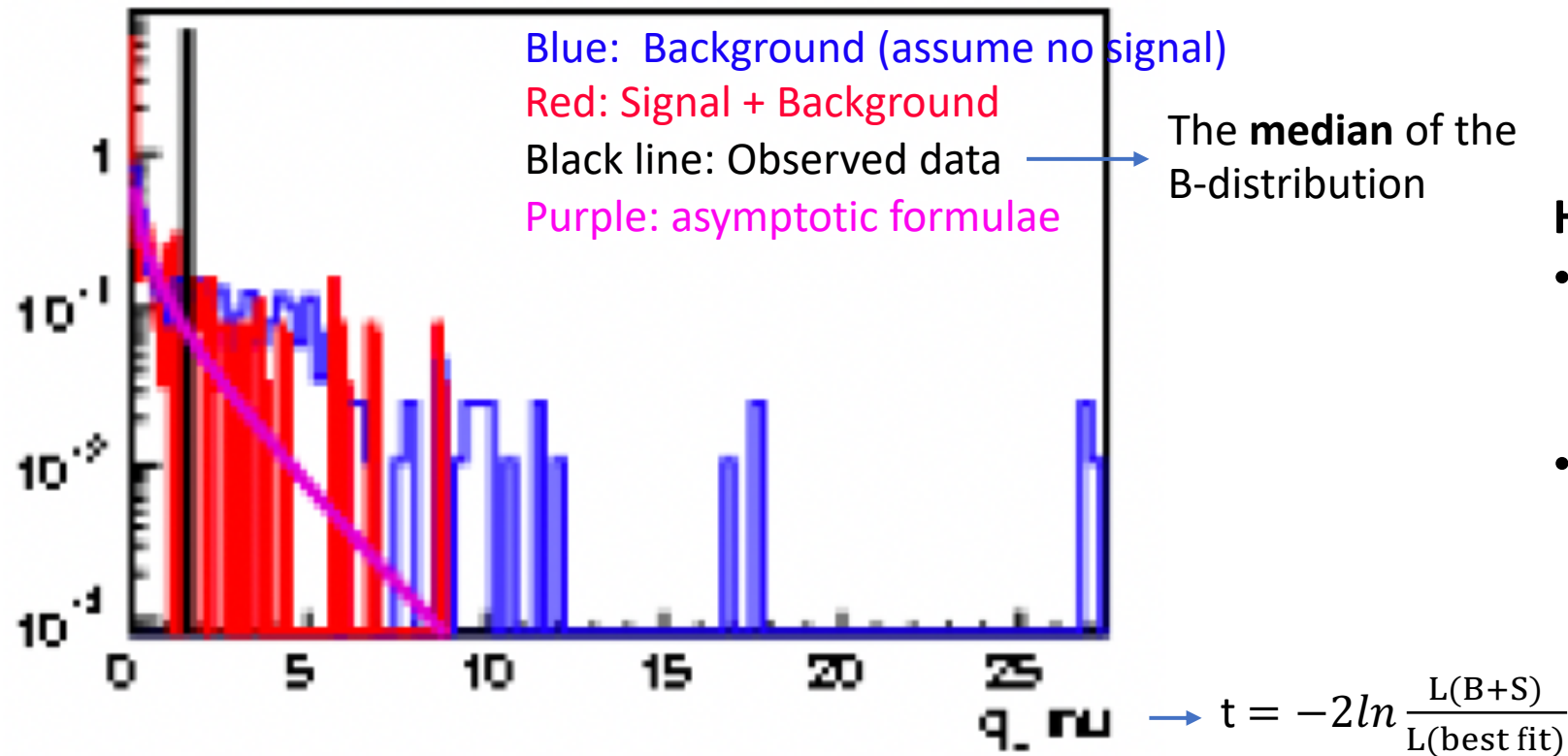
Workspace → RooWorkspace

- 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.

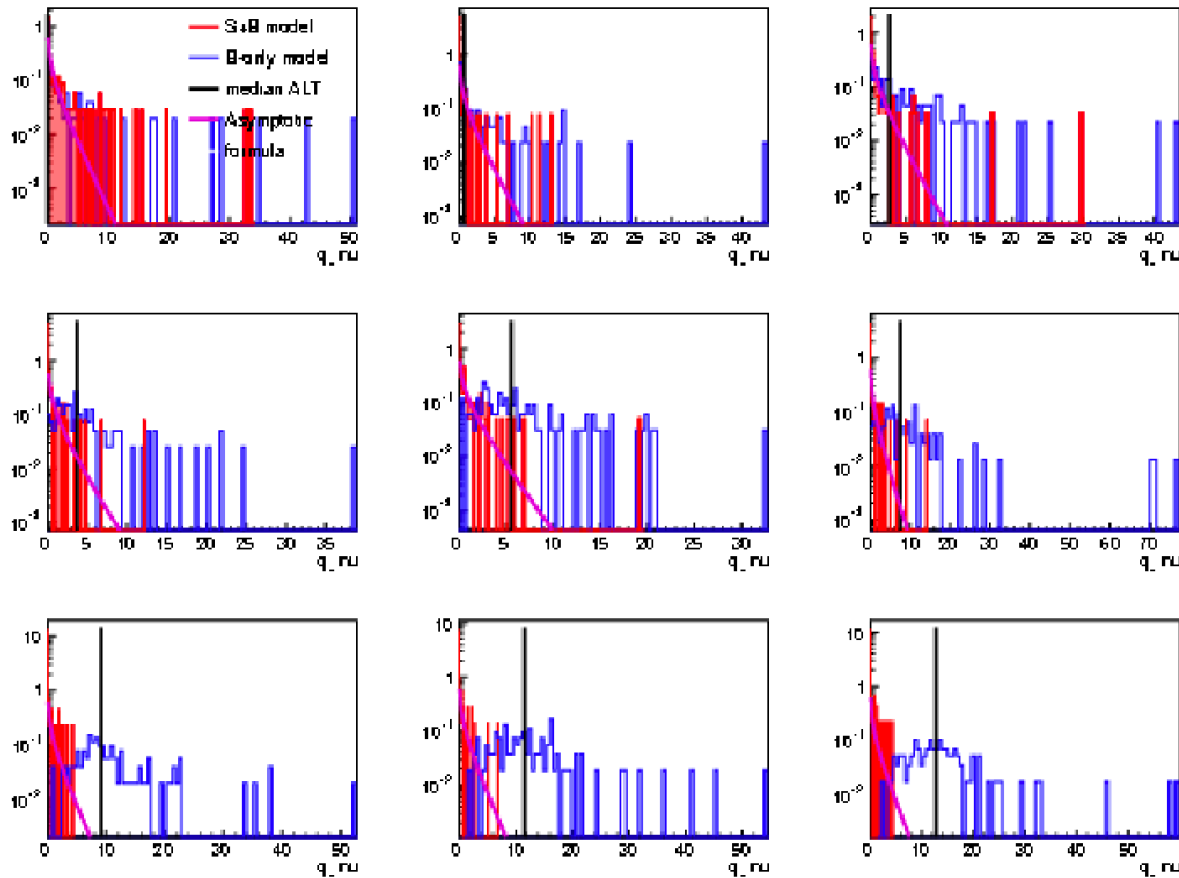
Analysis of a single graph



Hypothesis:

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

Increasing POI (0~15)



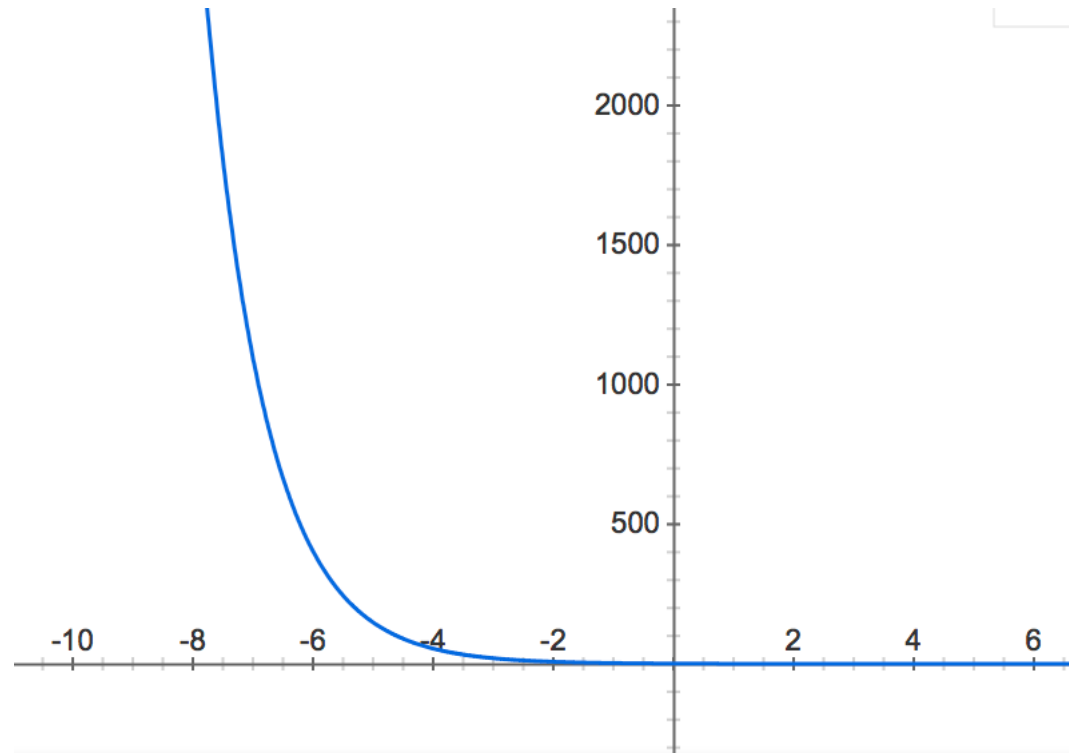
Method

- Background is fixed for different WIMP masses
- For one WIMP mass, increasing values of the parameter of interest (POI) $\rightarrow$ 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 $\rightarrow$ high μs_j



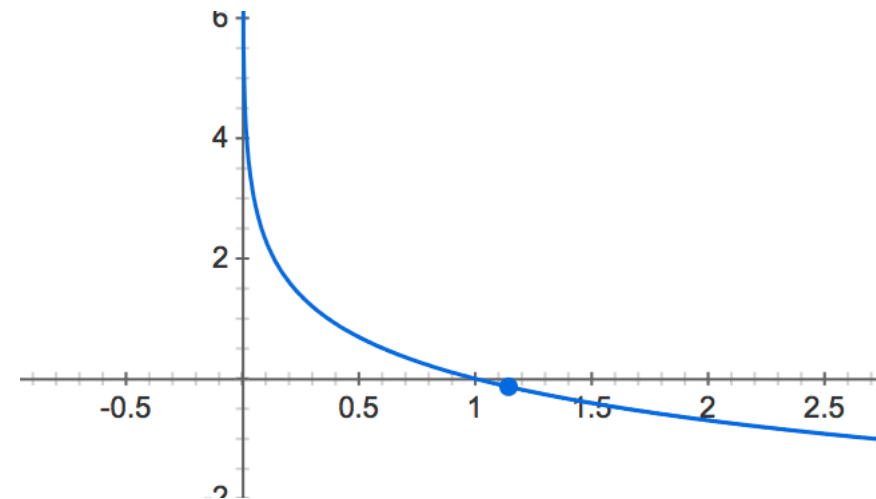
Equations & Graphs

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

μ : fixed
 $\hat{\mu}$: floating

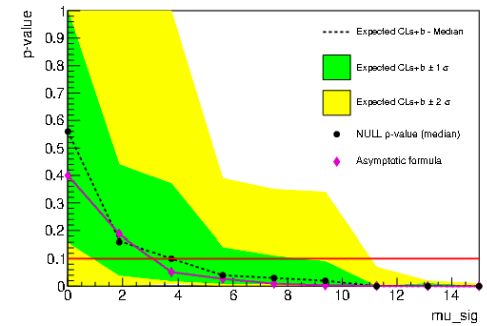
$$t_{\mu} = -2 \ln \lambda(\mu)$$

$\ln x$ vs x



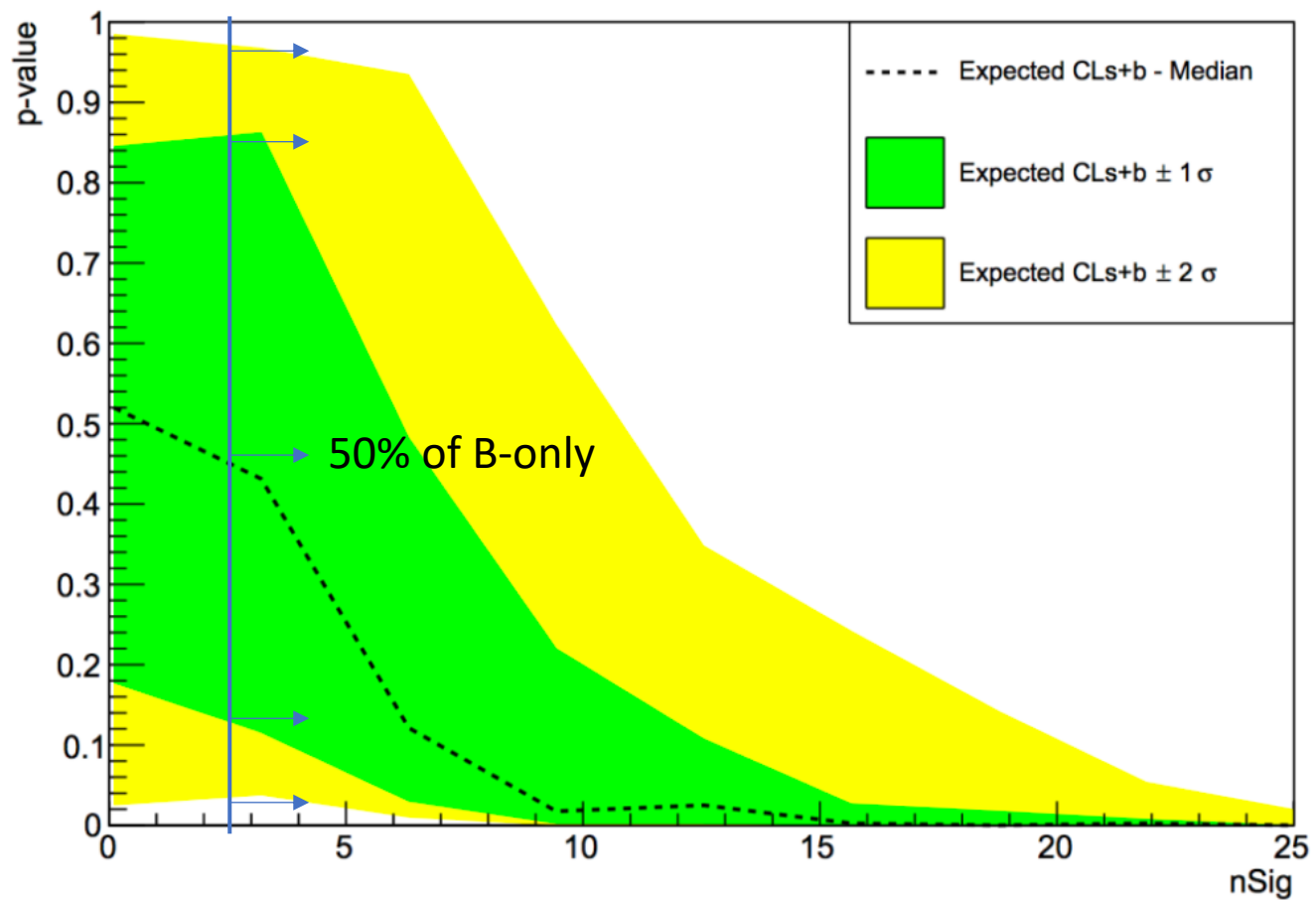
To do

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

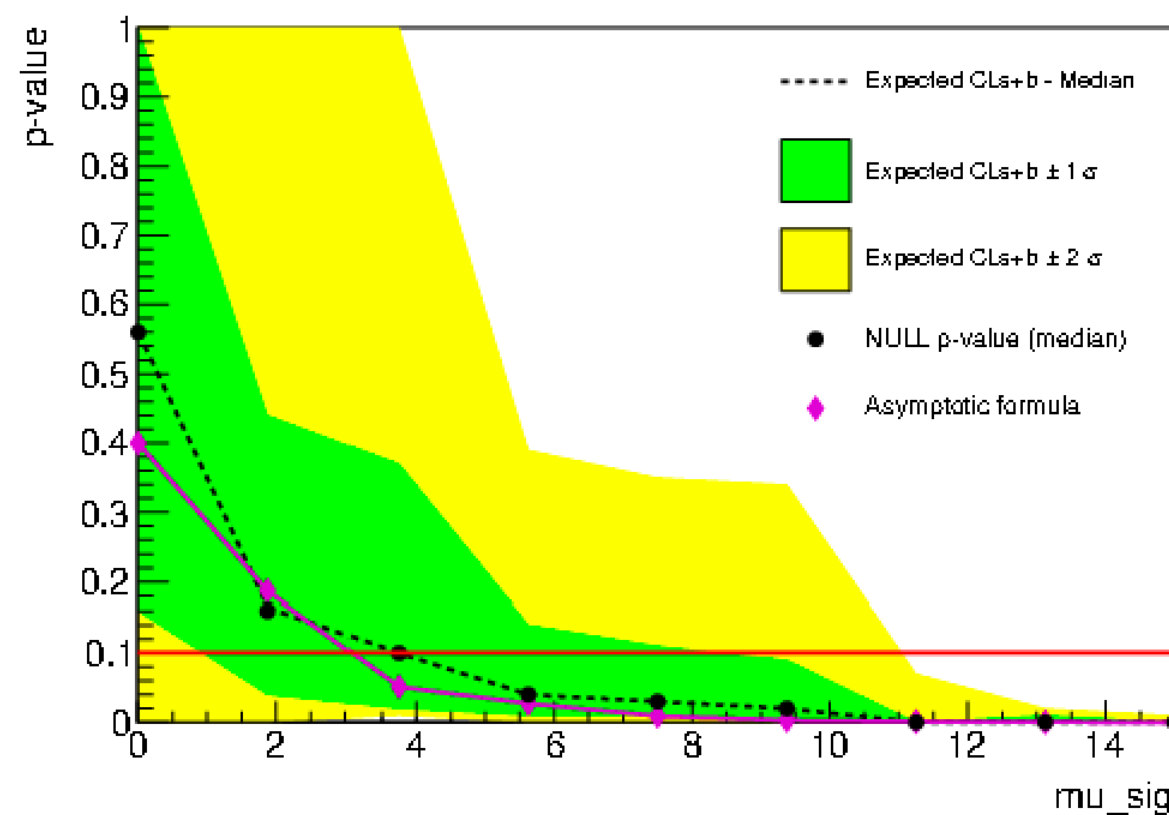
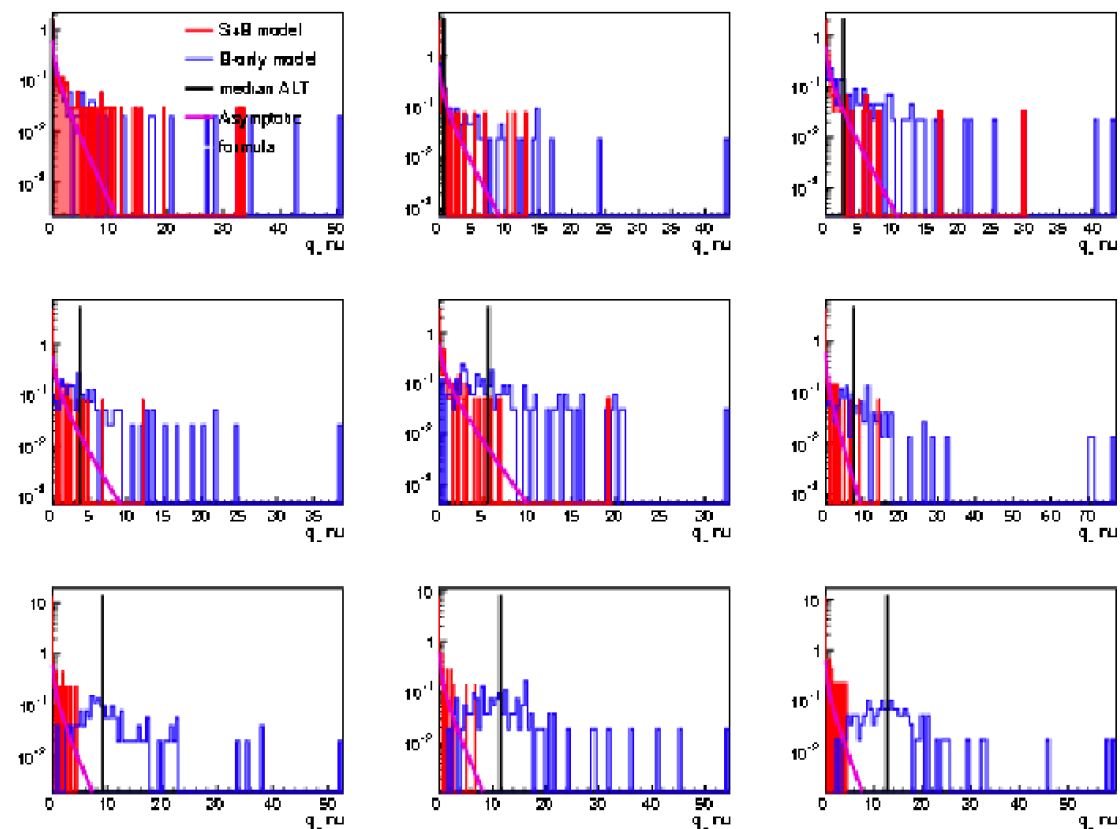


Done:

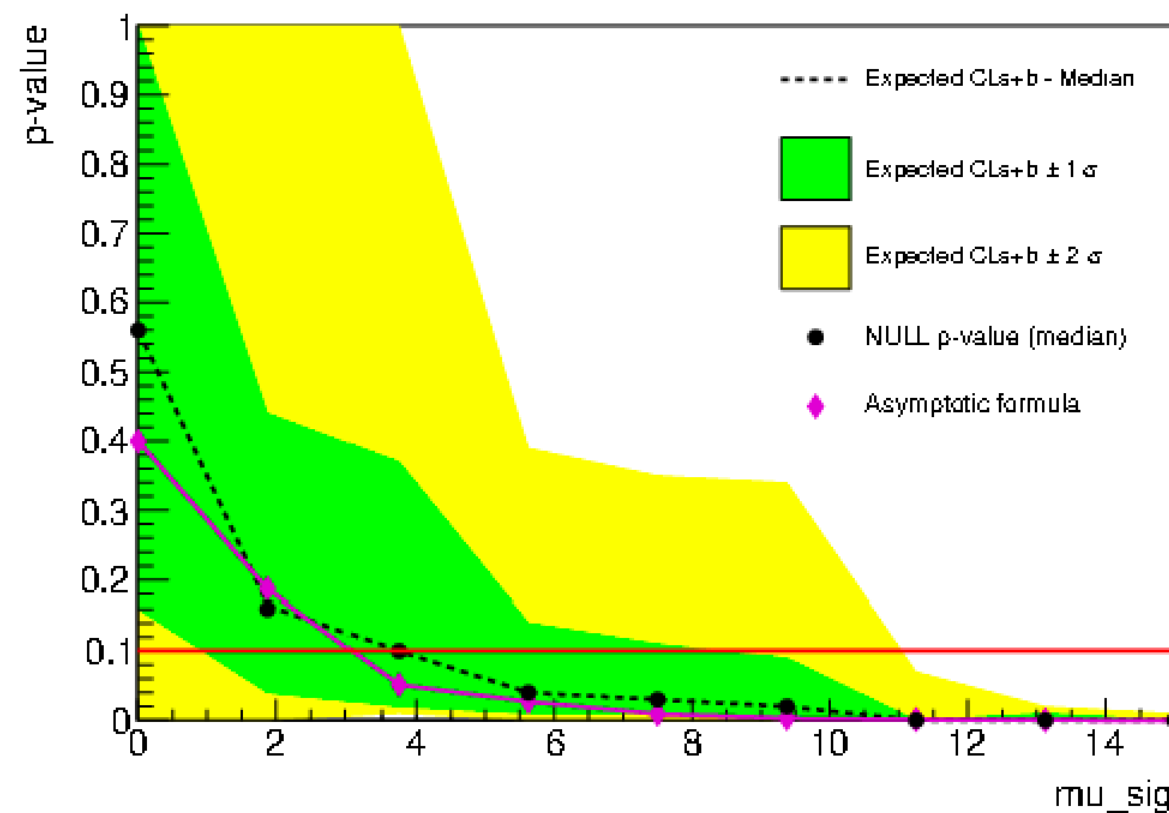
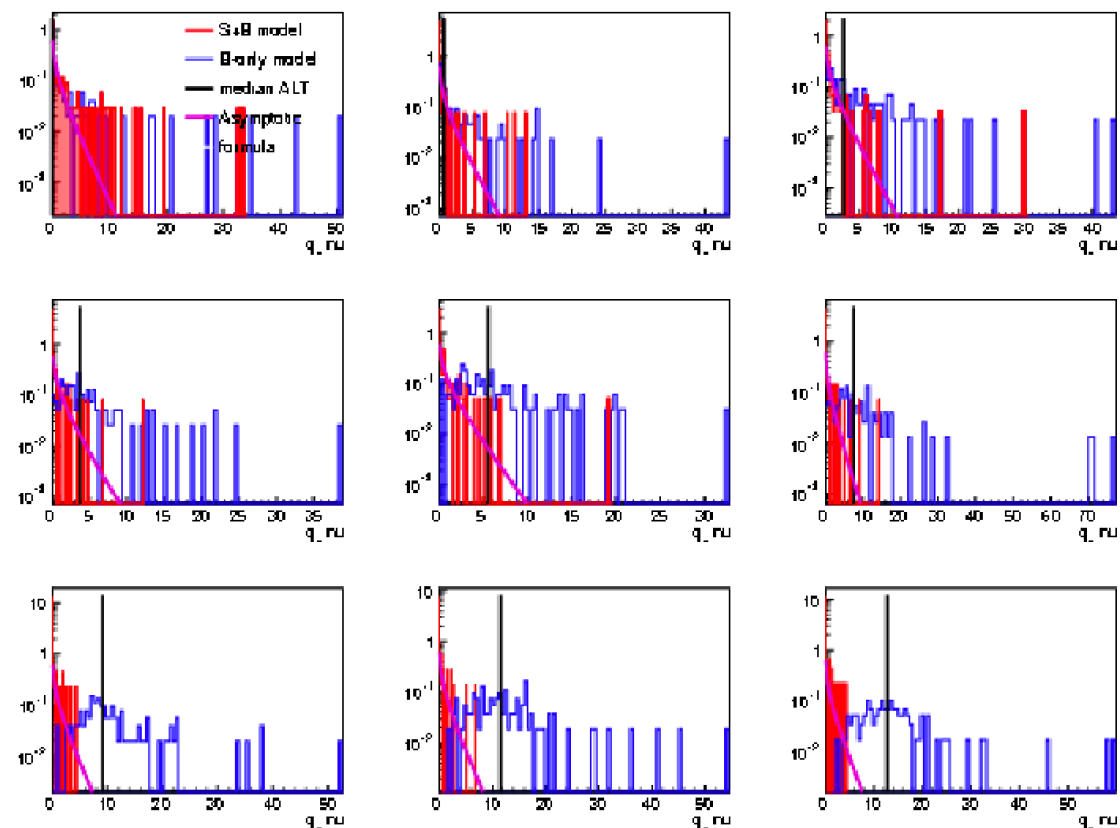
- For mass = 2.0000 GeV
 - ERROR: WIMP histogram is empty for mass 2.0 → Mass 2.0 is too small
- Mass: 10, 16.2222, 27.8256, 46.4159, 66.6667, 100, 200, 1000
- Moved the output from scratch to hdfs.
- Settings: 100 Ntoys, 1e7 samples, take 9 POI, 1000 livedays



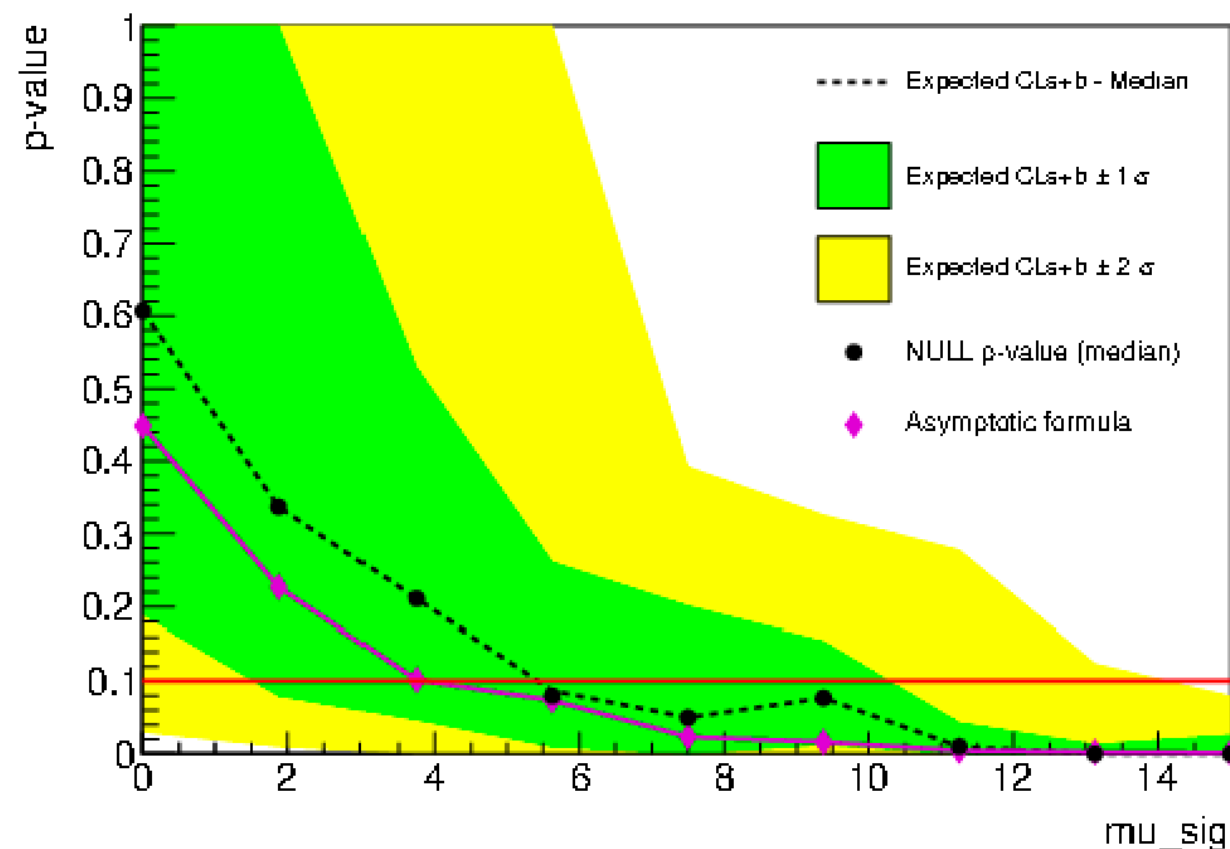
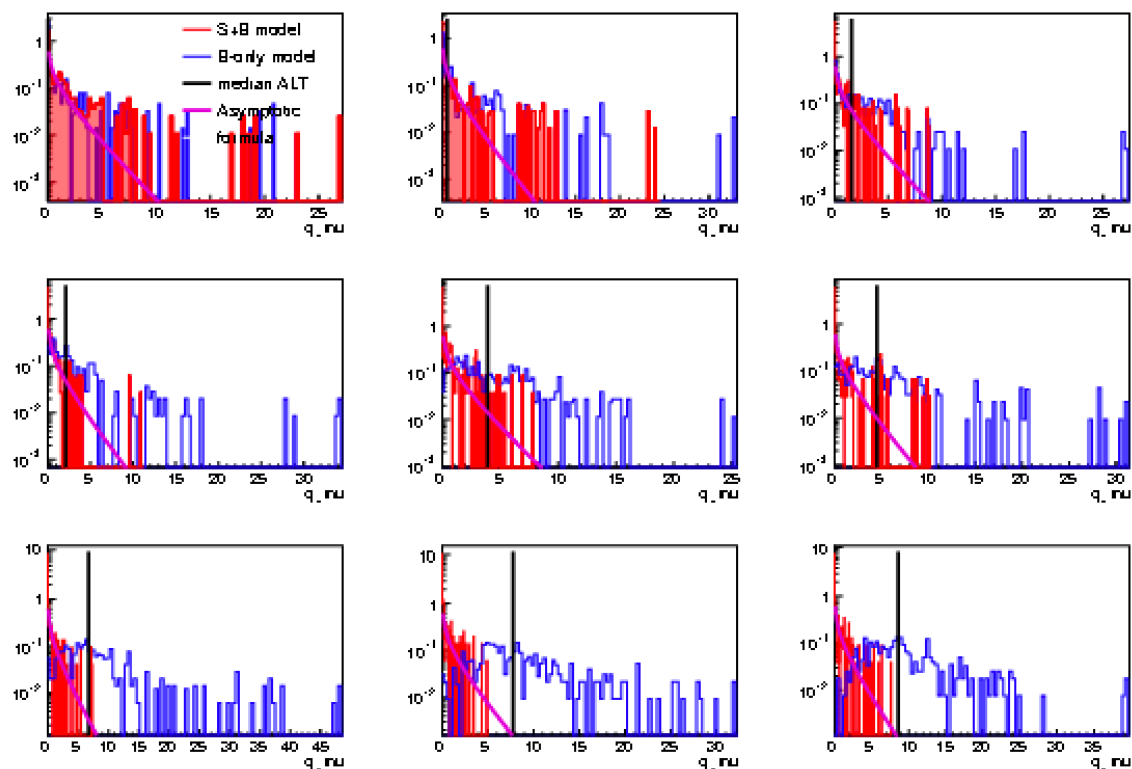
Mass = 16.2222

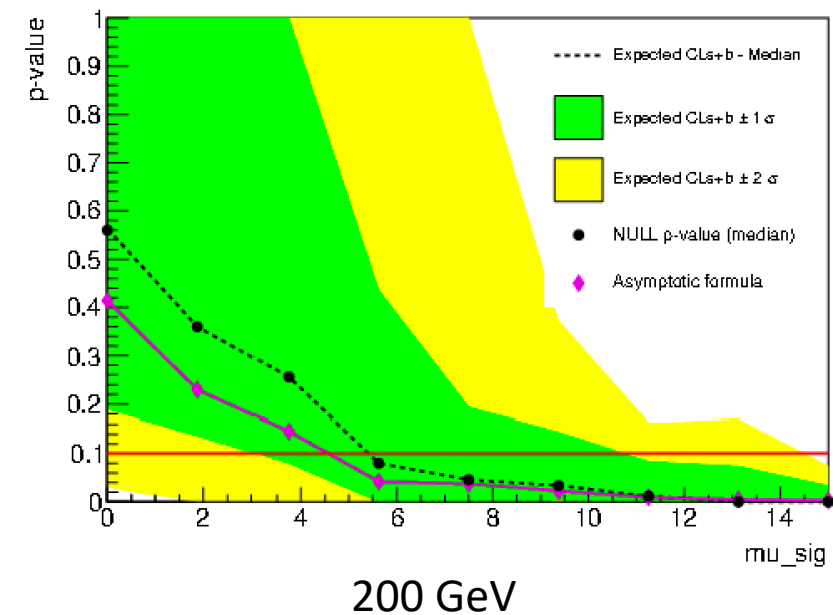
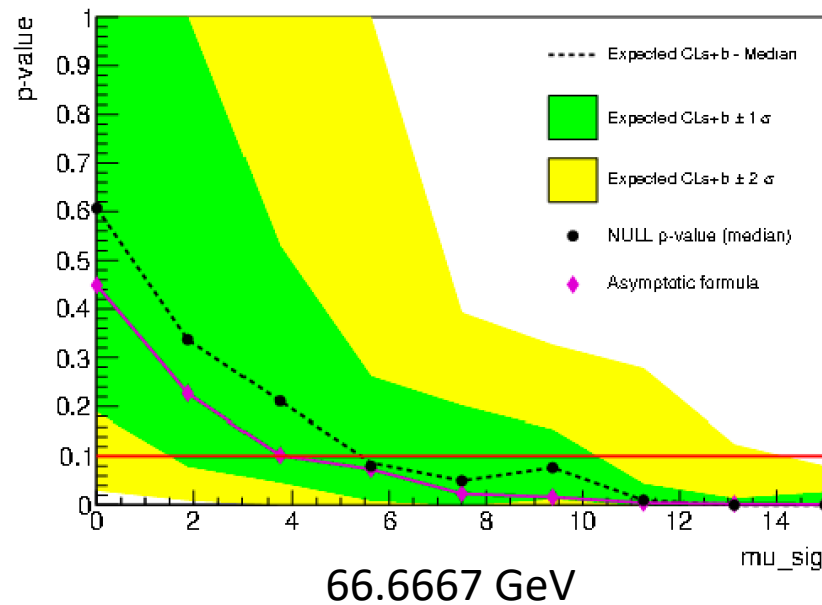
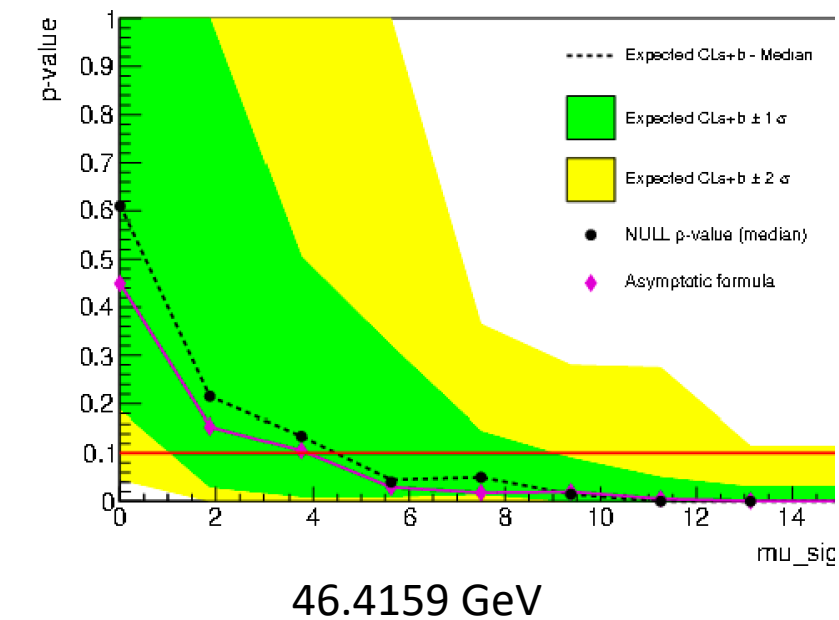
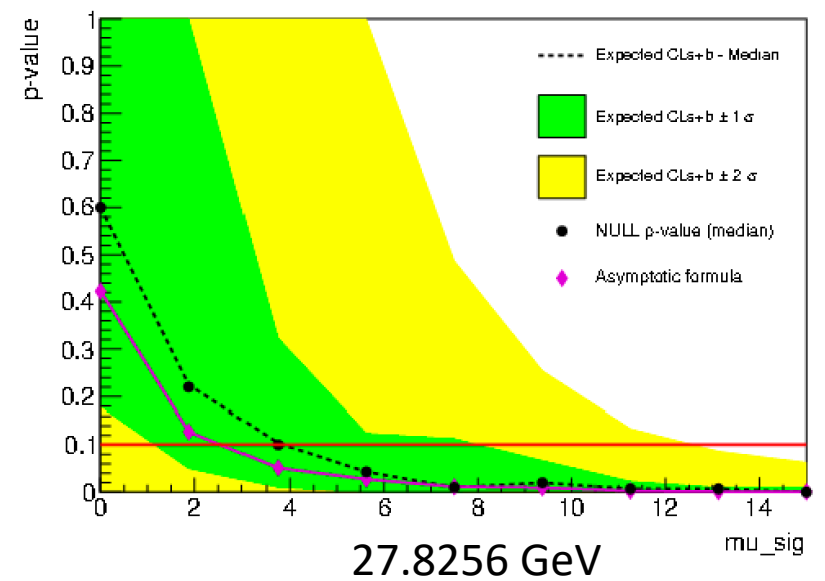
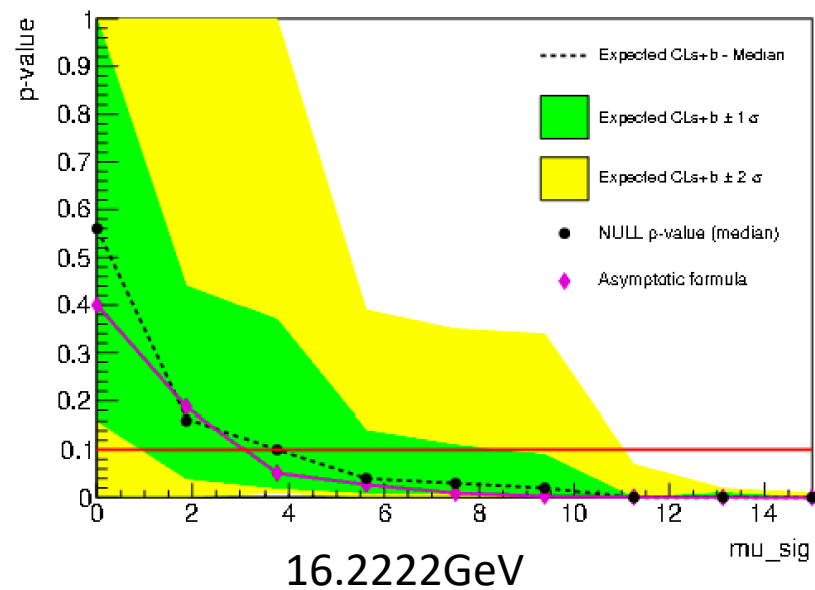
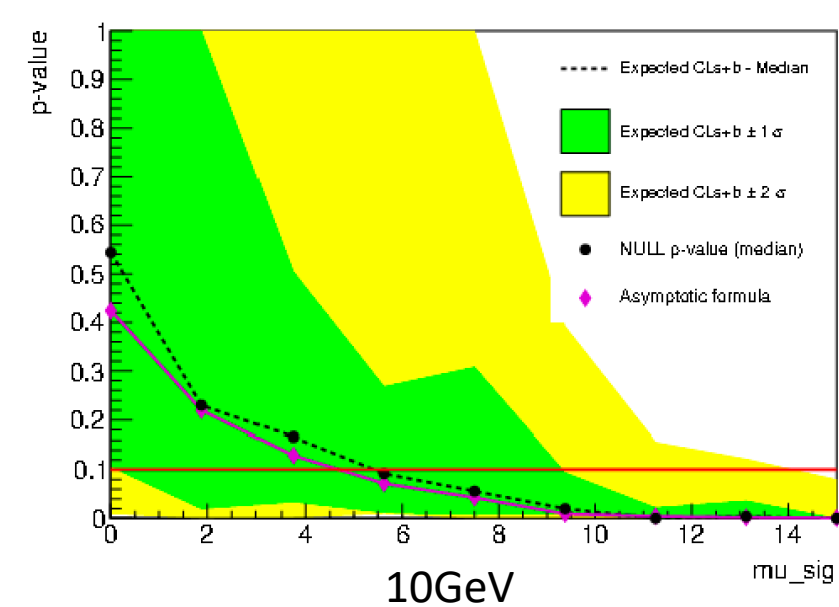


Mass = 16.2222

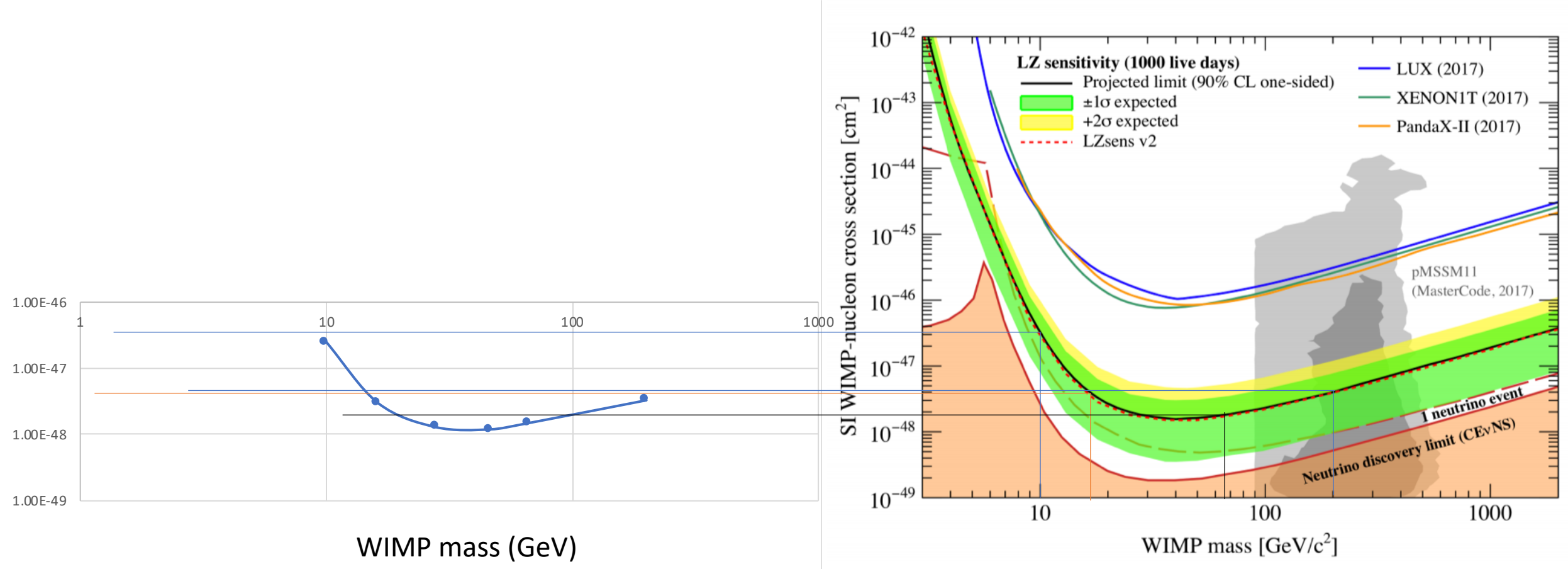


Mass = 66.6667





log scale lz sensitivity :



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 <RoWorkspace::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