

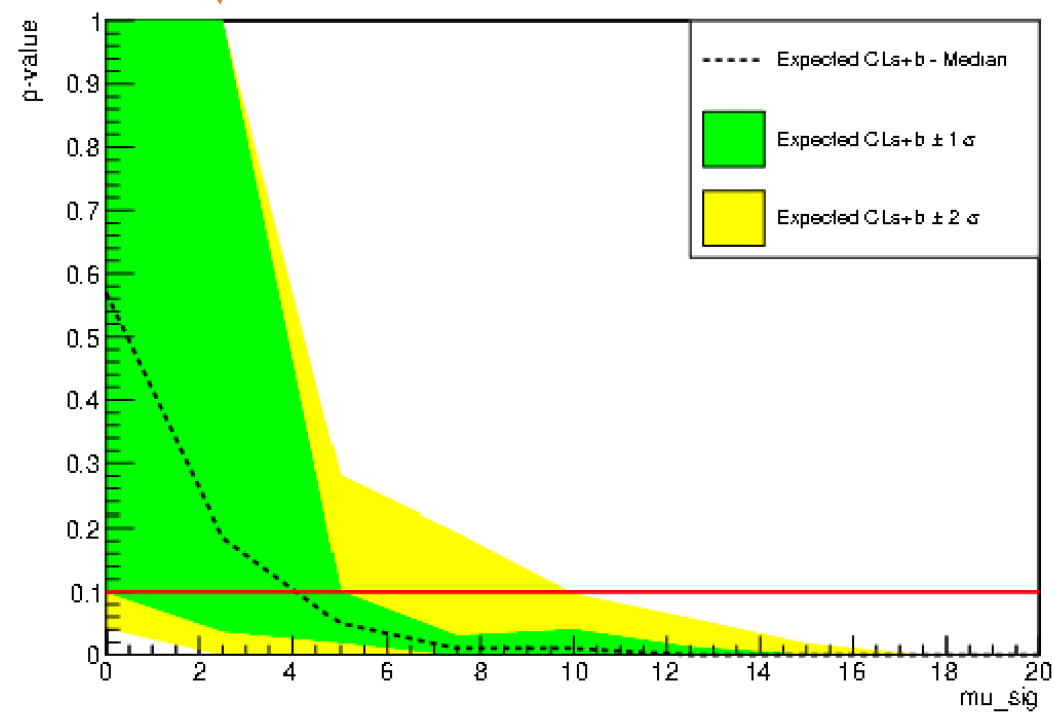
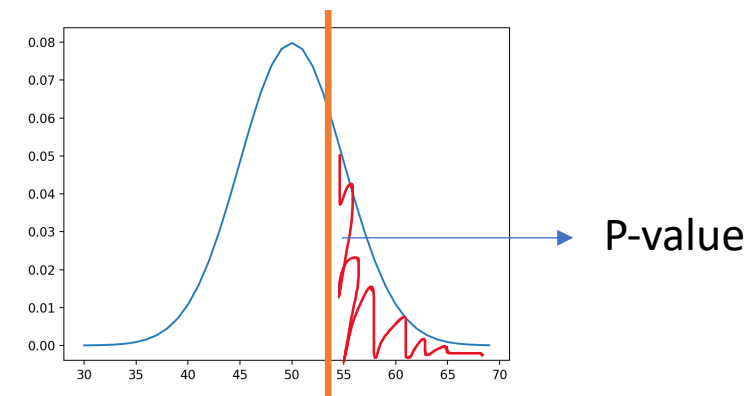
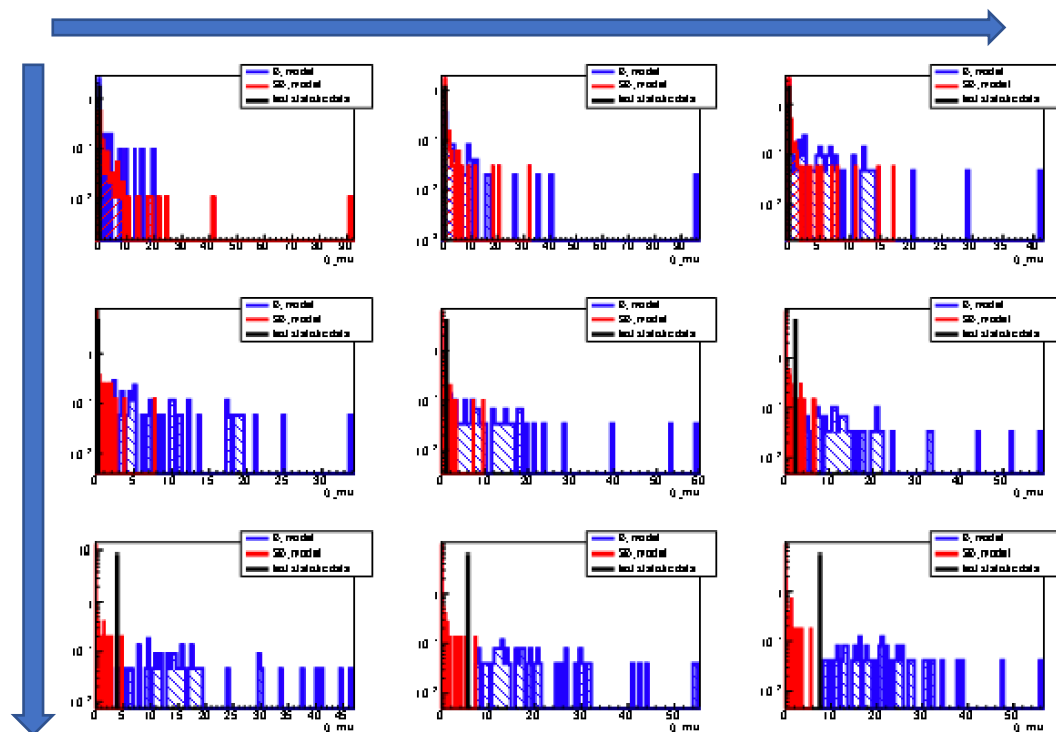
LZStats

Yitong Liu

What's new?

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

POI = 0 ~ 20



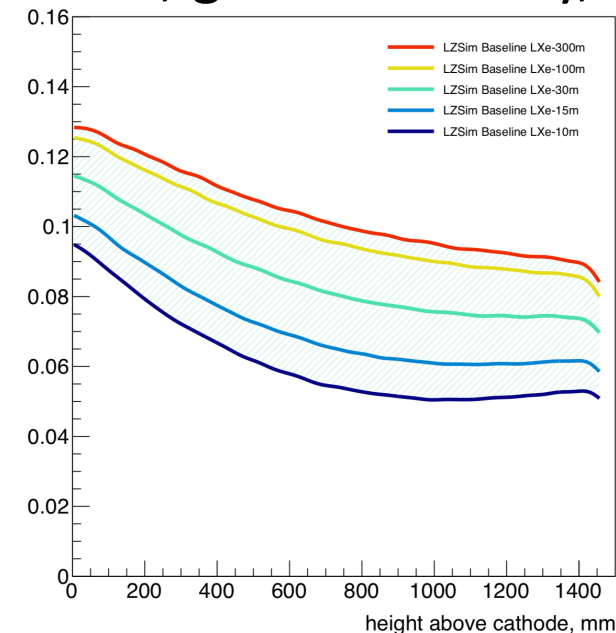
g1

- 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

$g1_{\text{min}} \sim 0.05$

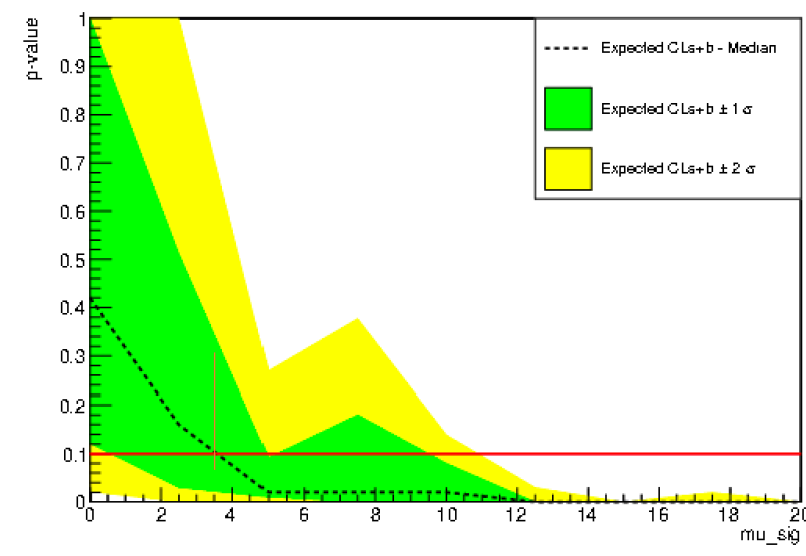
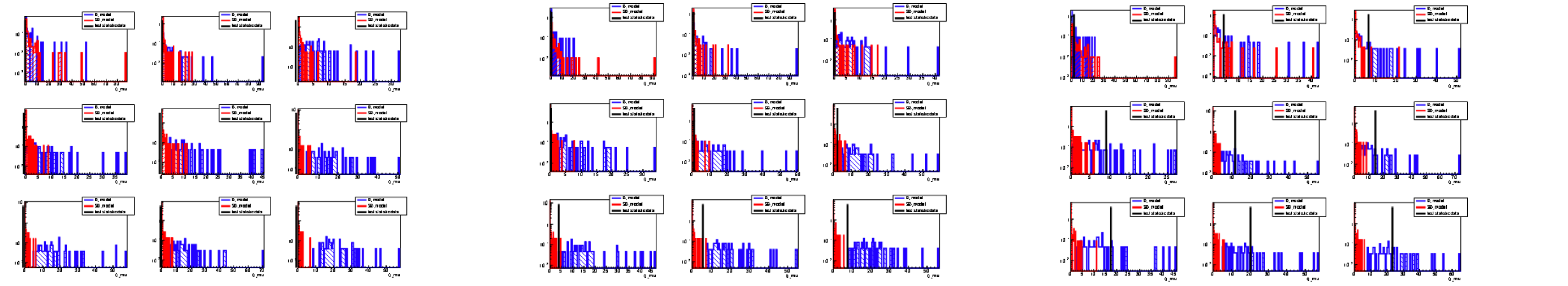
$g1_{\text{default}} \sim 0.118$

$g1_{\text{max}} \sim 0.13$

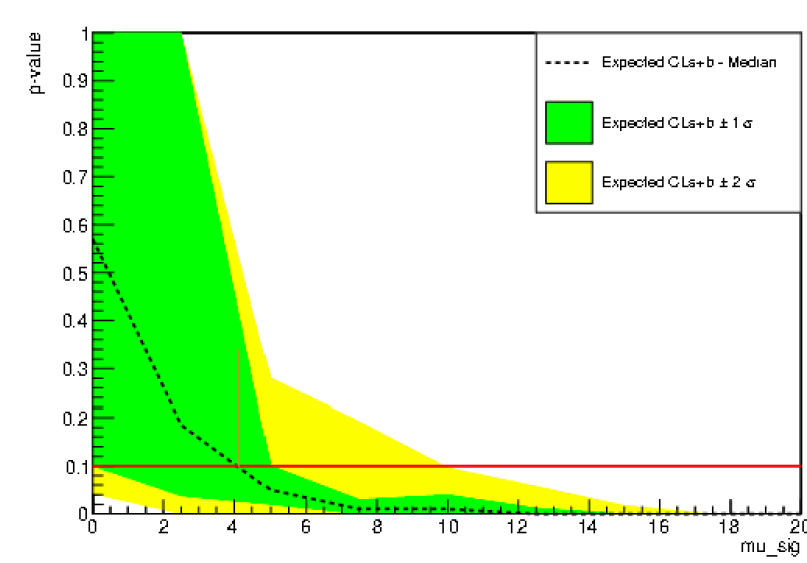


Code

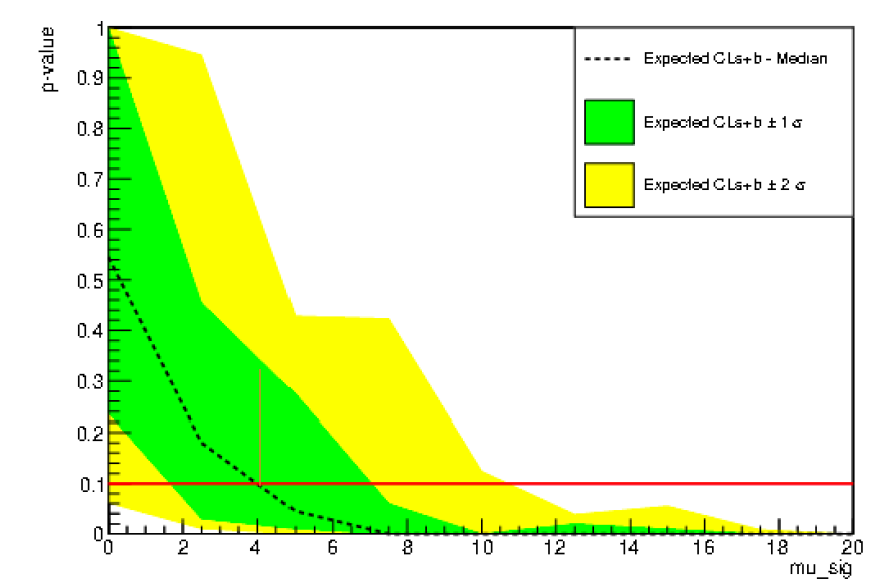
- LZNESTUtils
 - Change Detector parameters
 - Source setup.sh
 - Source .ci/build.sh
 - Get new NESTInterference
- PdfMaker
 - Recompile signal and background codes with the new NESTInterference



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



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

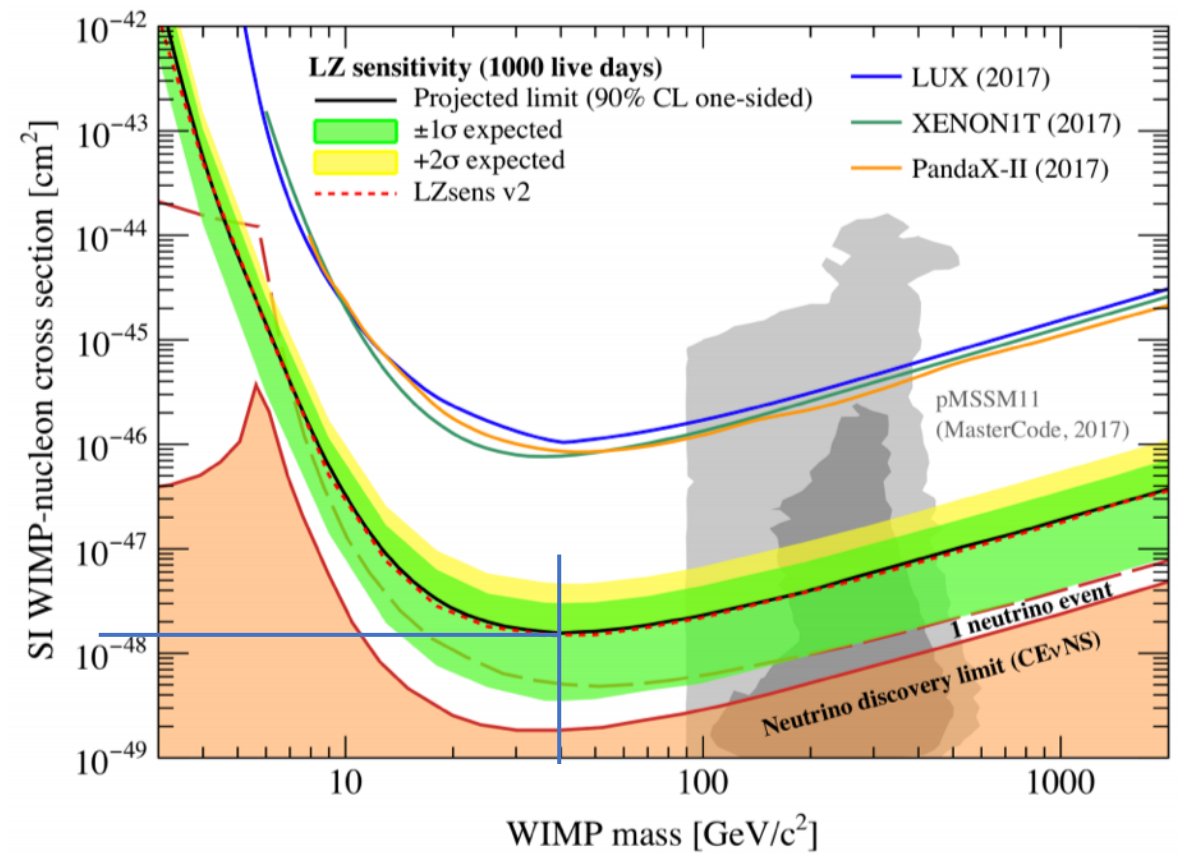


$g1 = 0.13$
 $\mu_{sig} = 3.9835$
 $cross_section = 1.05e^{-48}$

To do

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

$\sim 1.5e^{-45}$



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

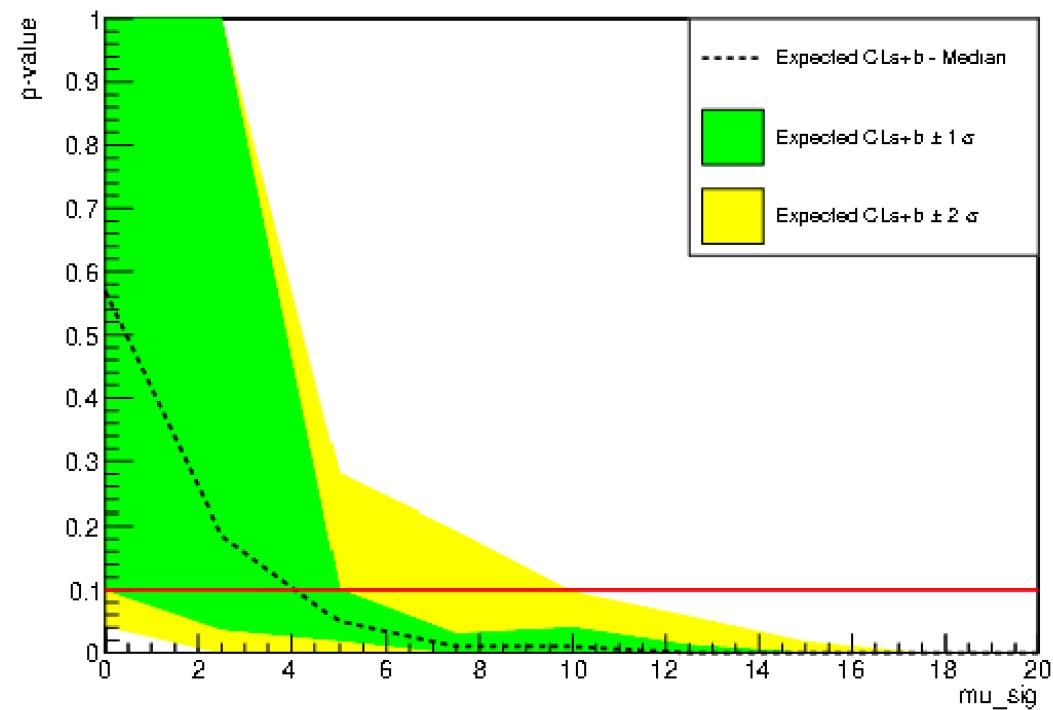
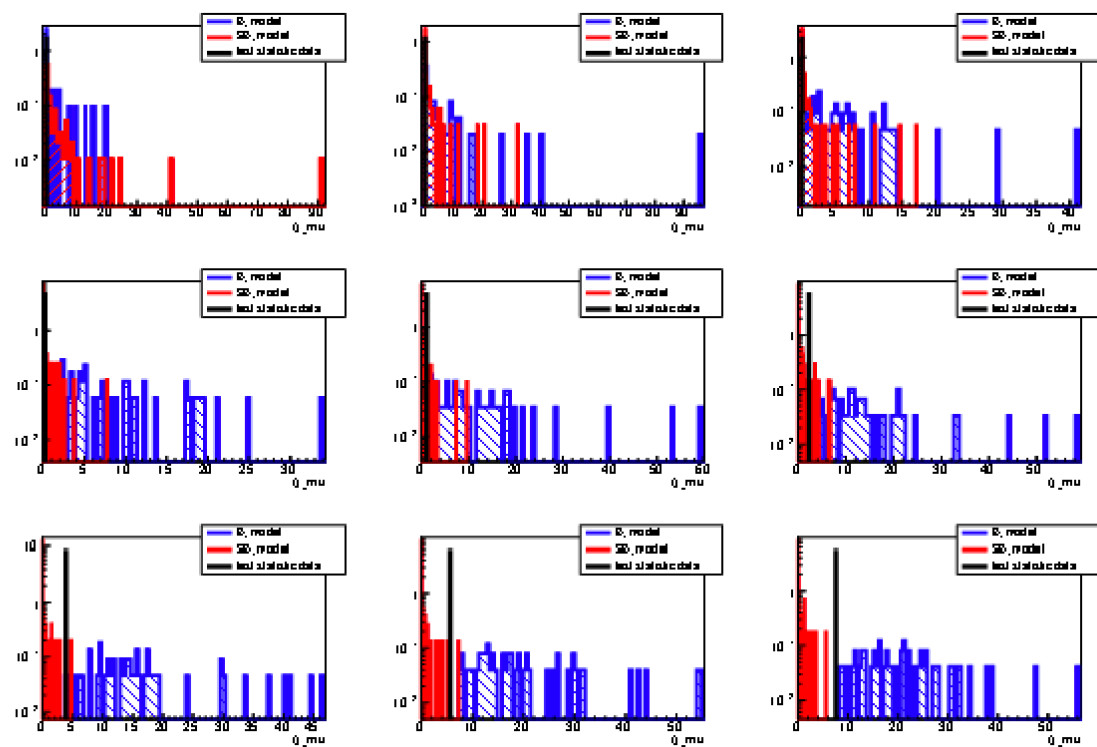
Constraint: Gaussian
distribution of
(x=mu_pp
mean = a_pp,
Sigma = sigma_pp)

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

- 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)



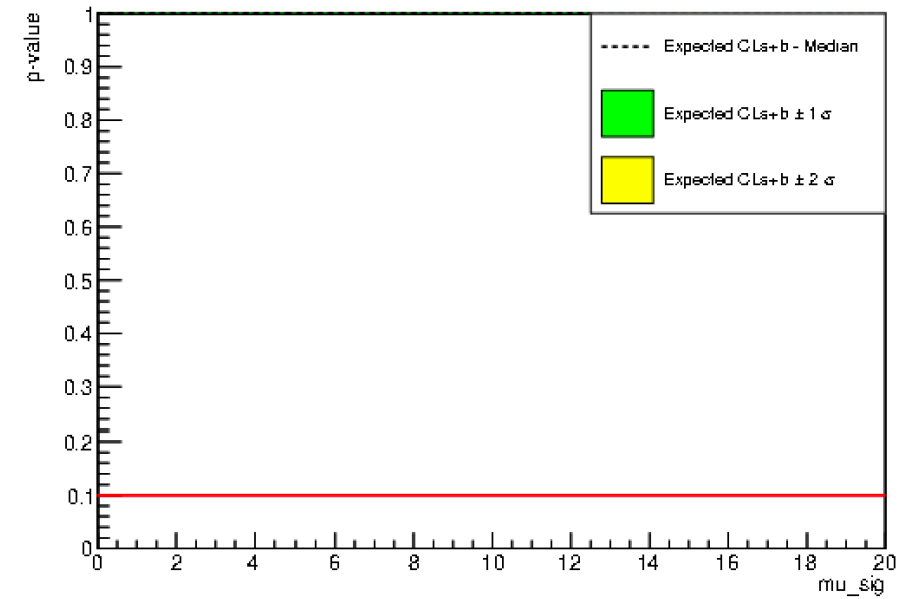
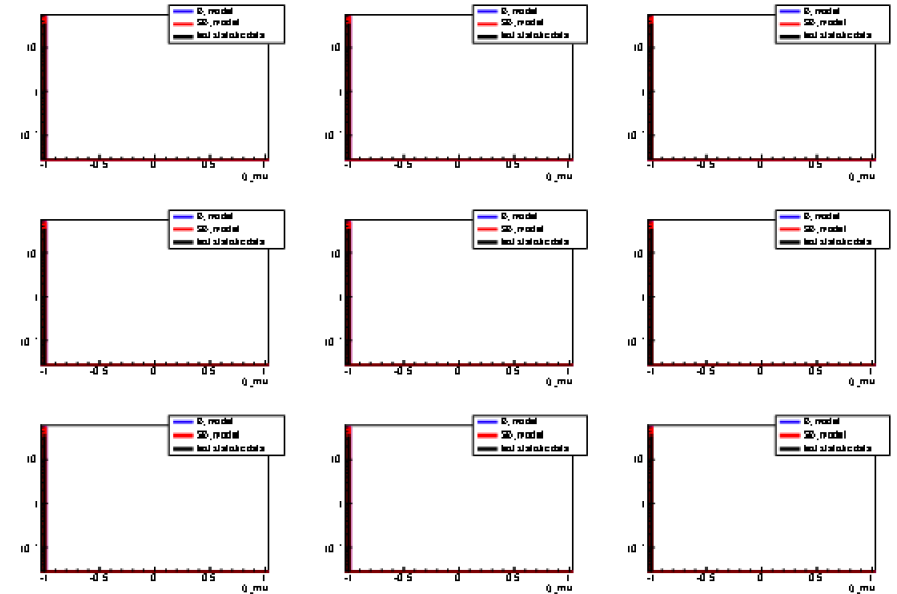
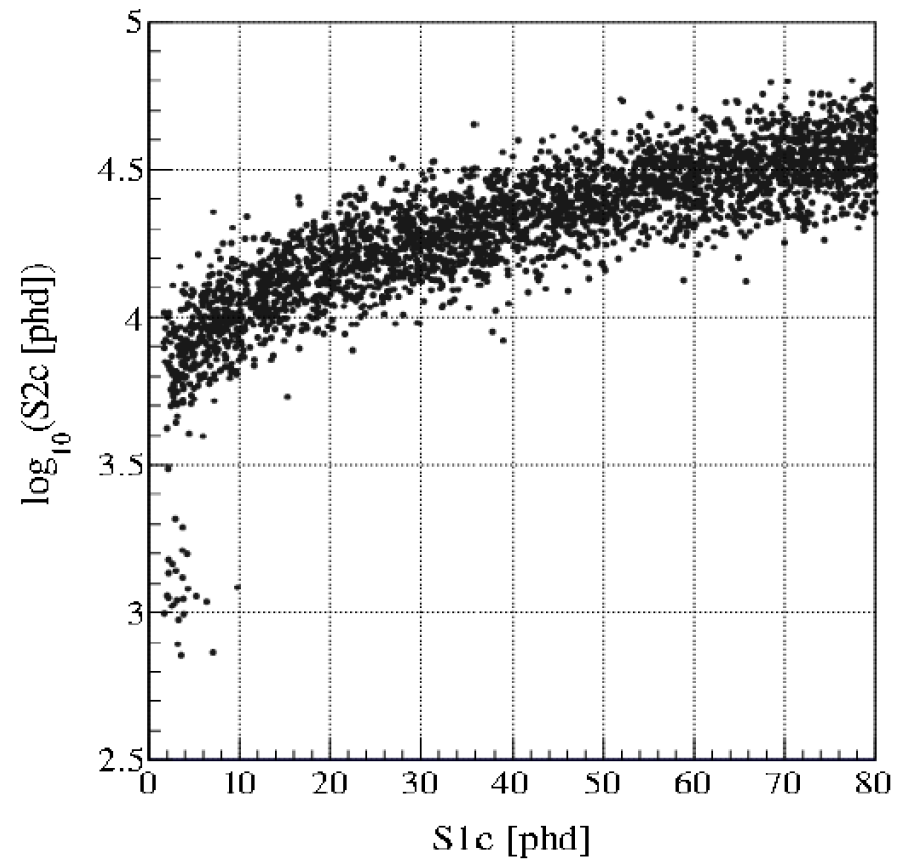
What's done

- 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

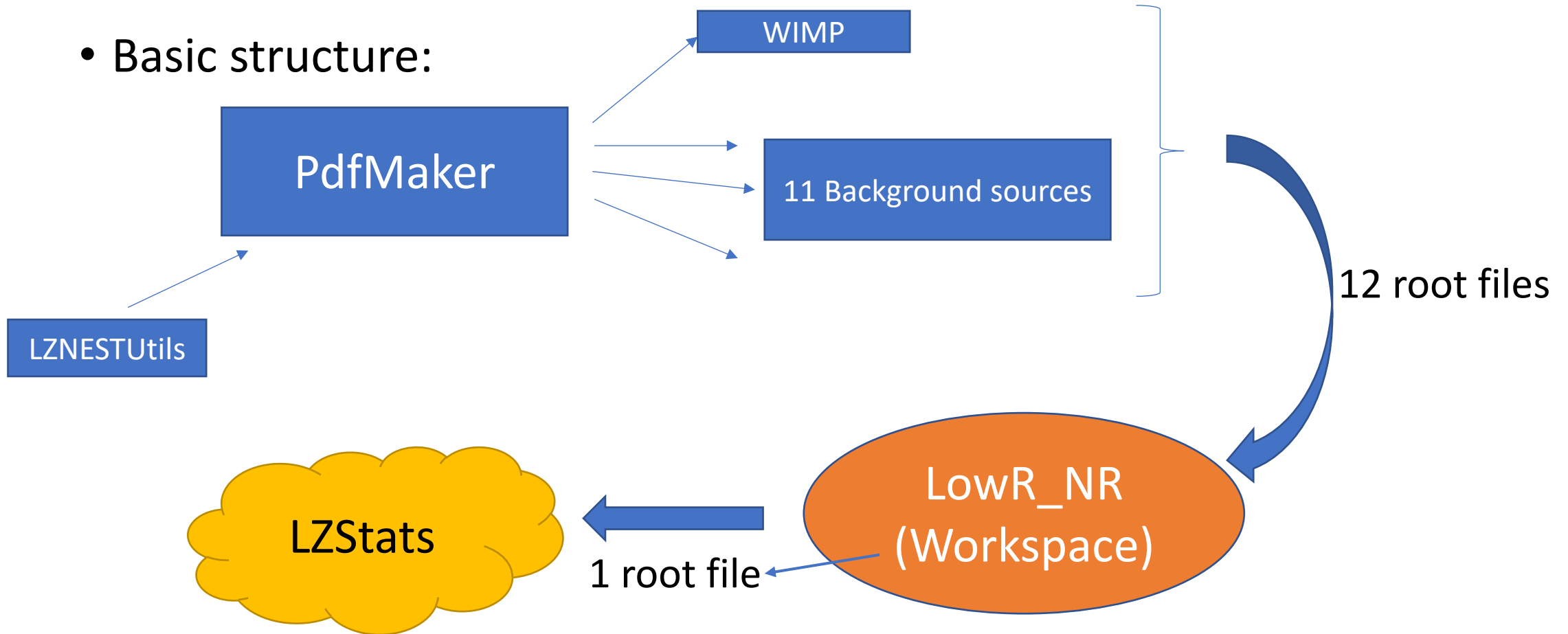
Problem



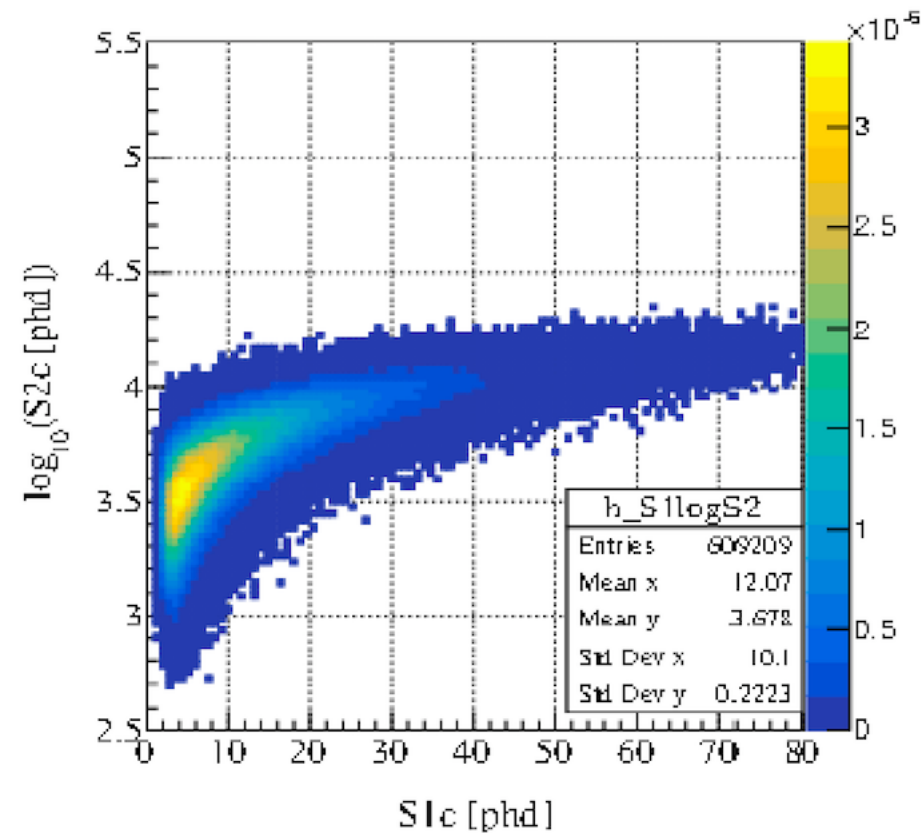
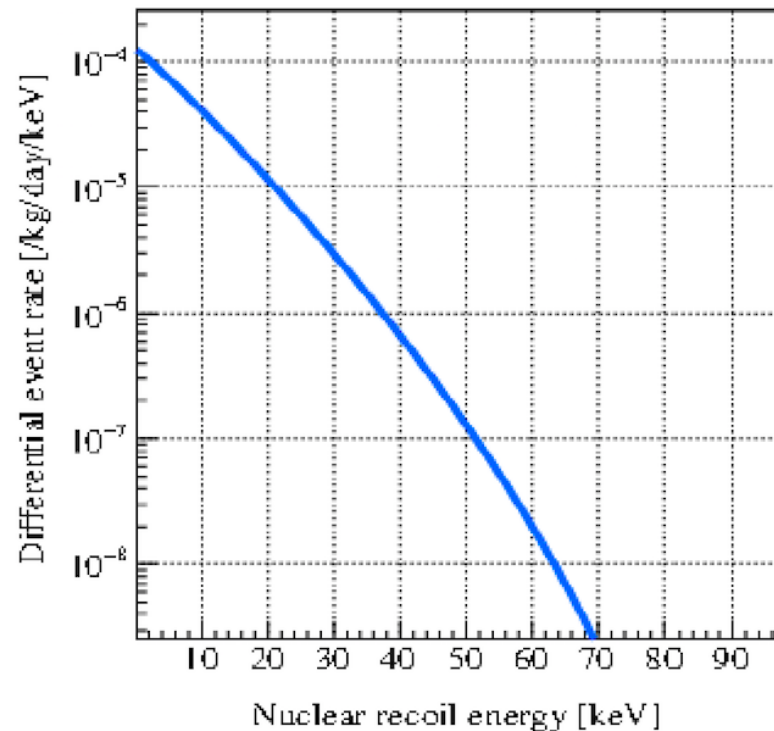
```
Error in <ROOT::Math::FitResult>: FitConfiguration and Minimizer result are not  
consistent  
Number of free parameters from FitConfig = 12  
Number of free parameters from Minimizer = 11
```

Changed LZStats

- Basic structure:



Output of signal (40GeV WIMP) from PdfMaker



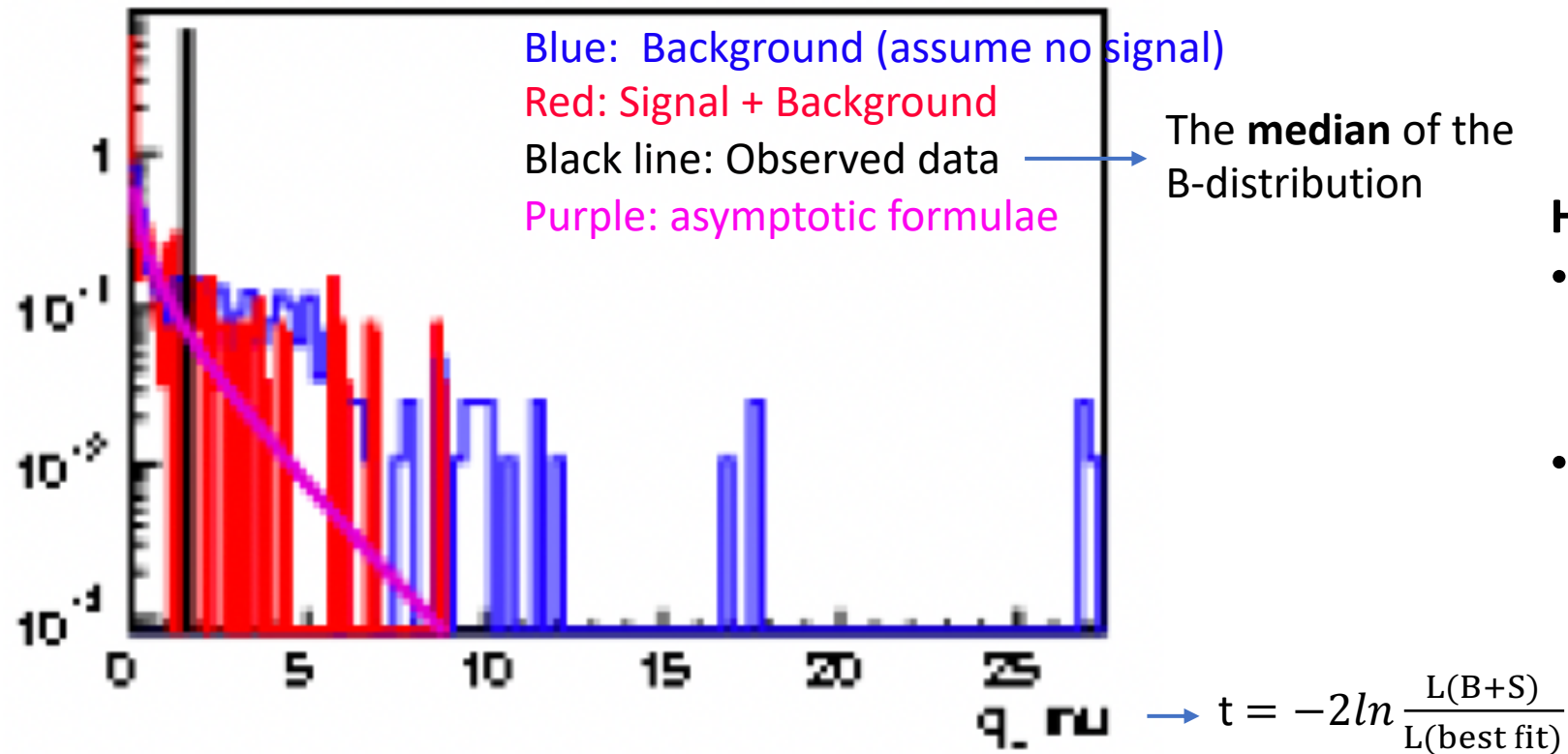
Workspace → RooWorkspace

- 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.

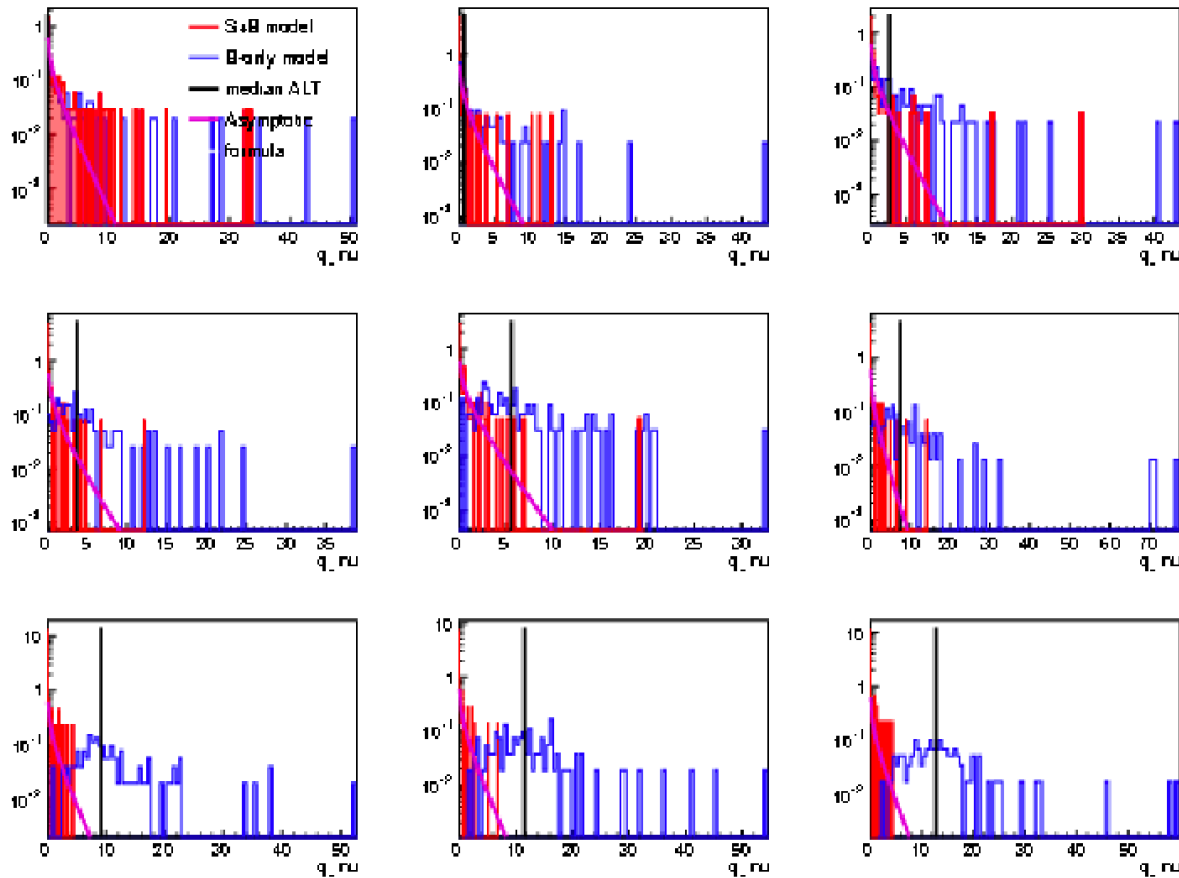
Analysis of a single graph



Hypothesis:

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

Increasing POI (0~15)



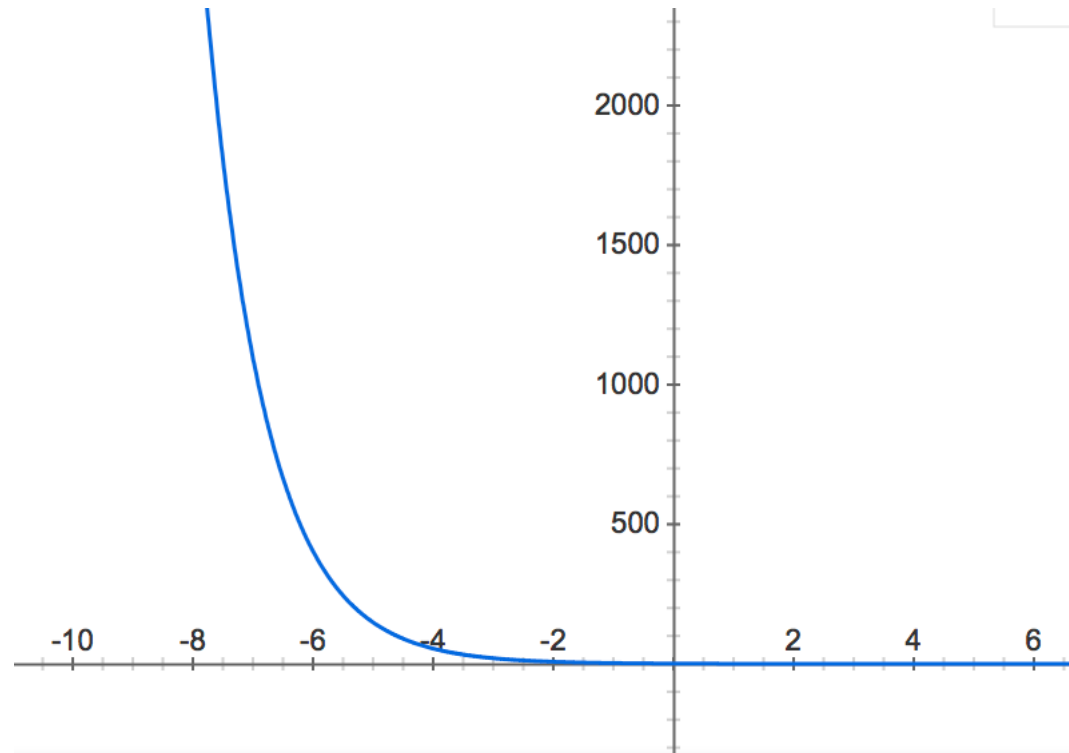
Method

- 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



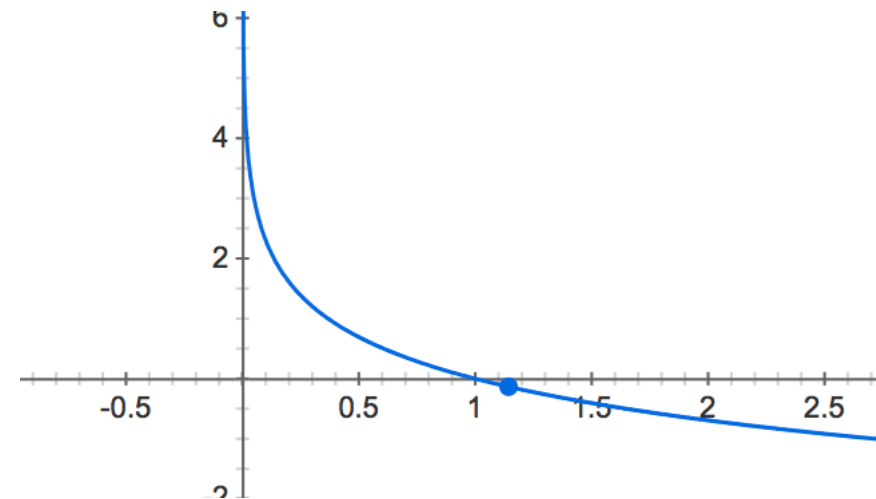
Equations & Graphs

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

μ : fixed
 $\hat{\mu}$: floating

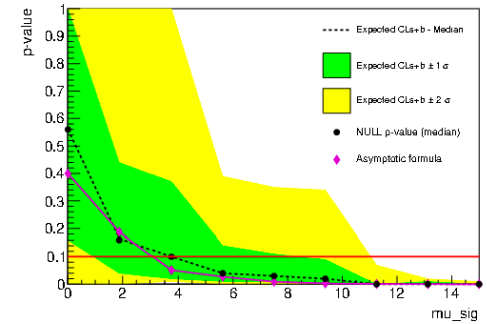
$$t_{\mu} = -2 \ln \lambda(\mu)$$

$\ln x$ vs x



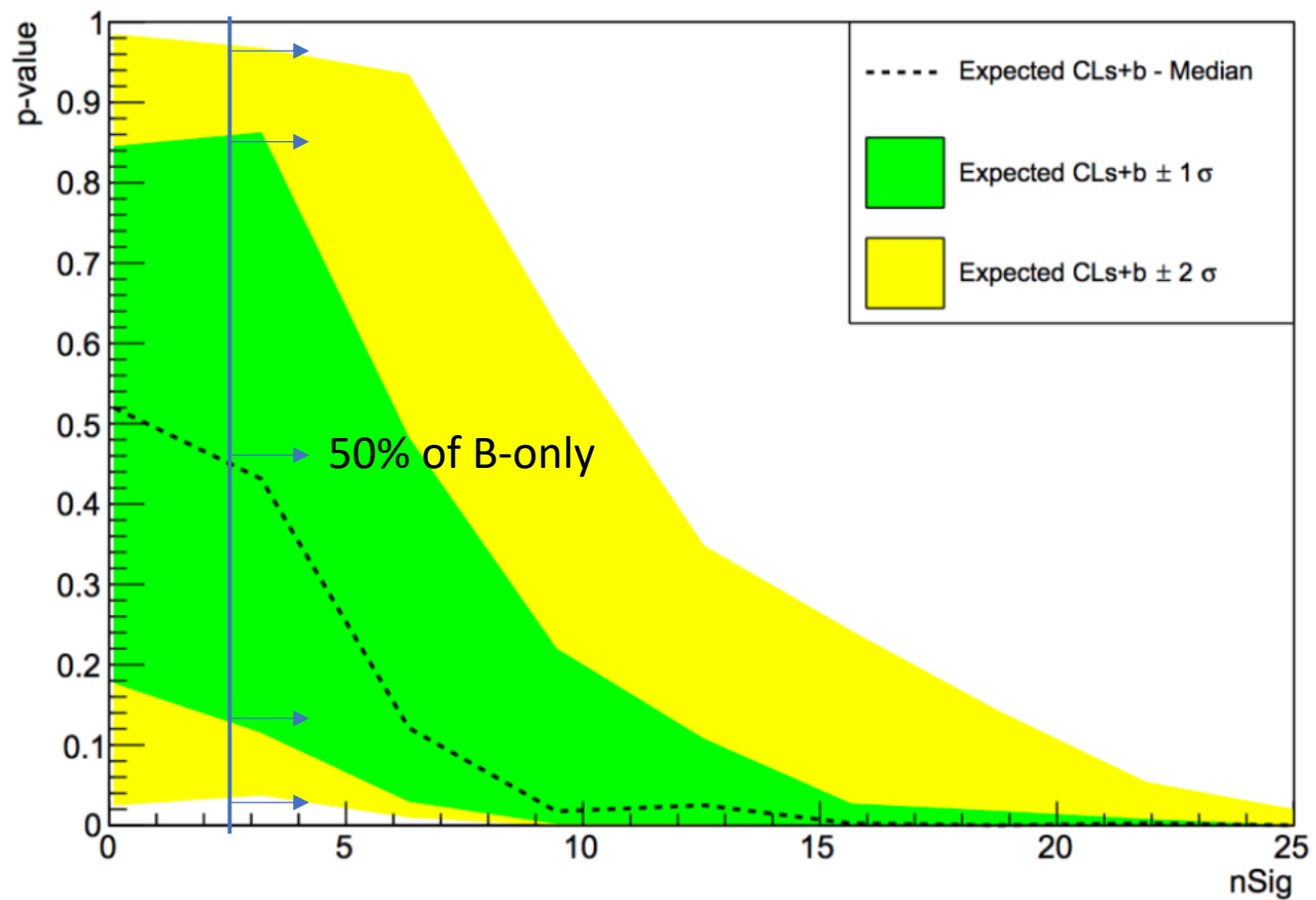
To do

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

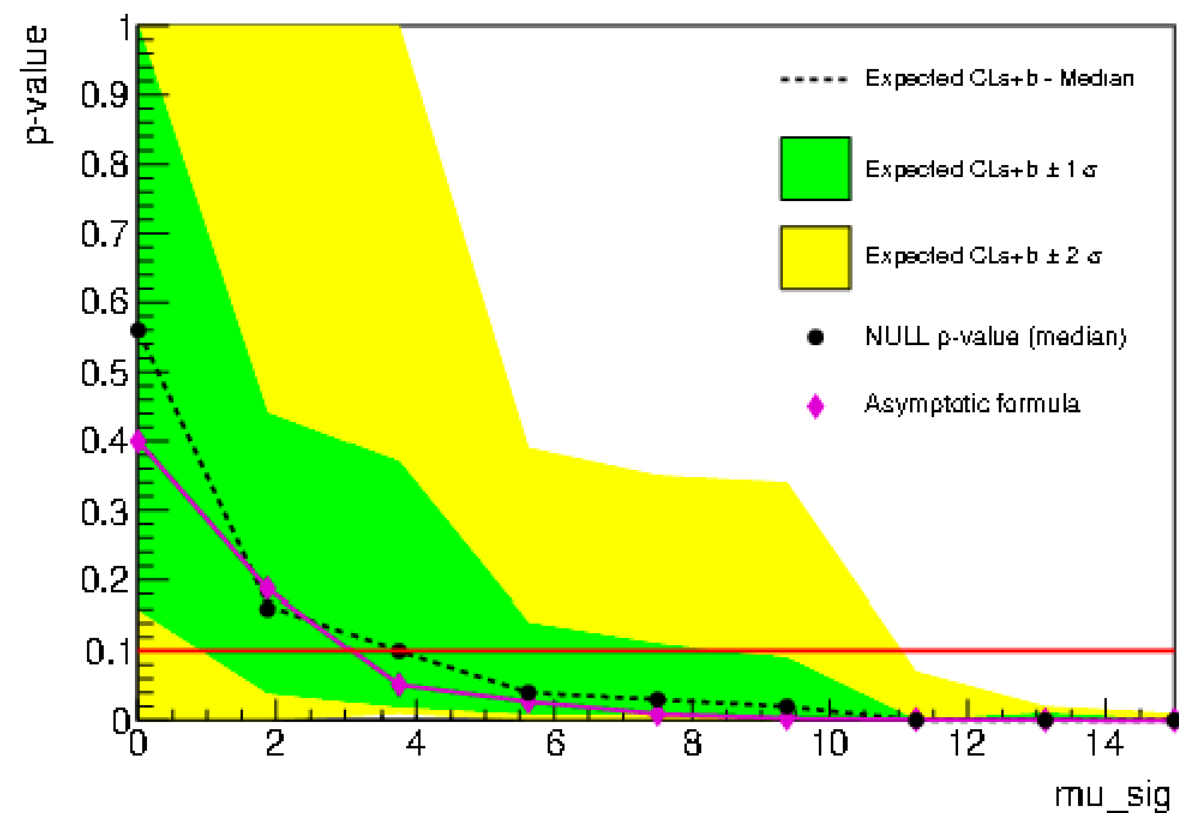
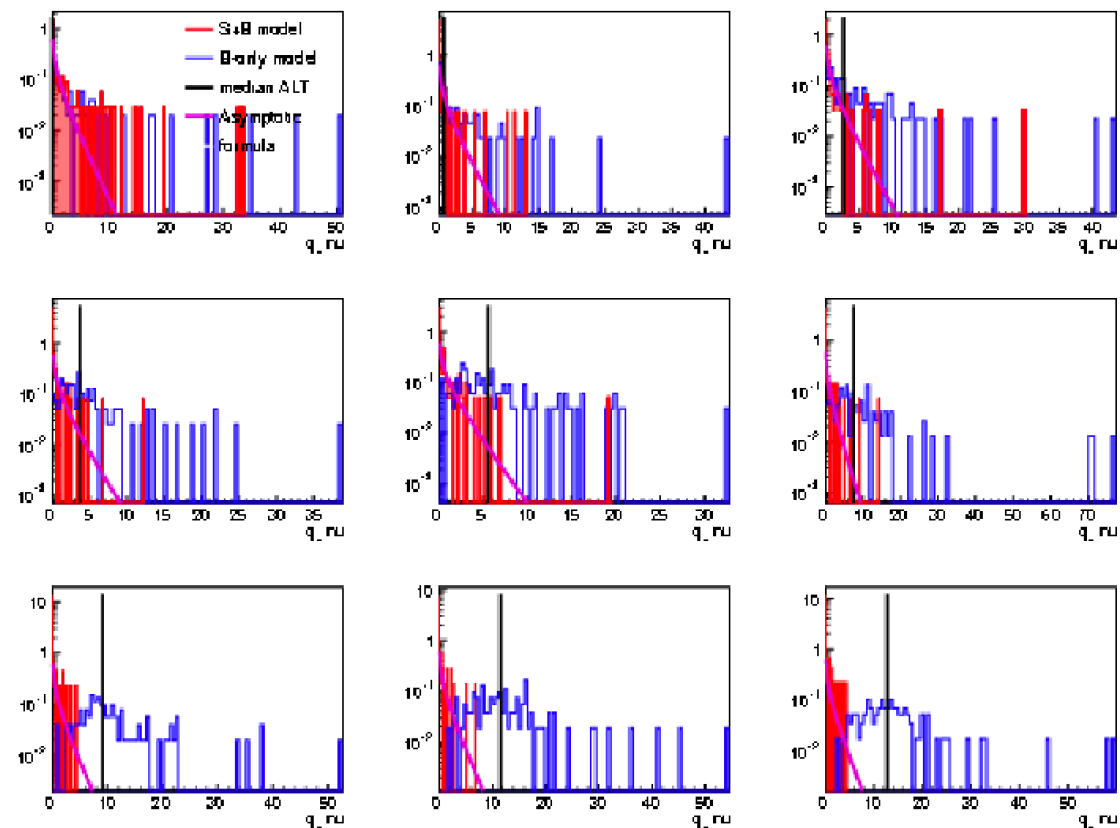


Done:

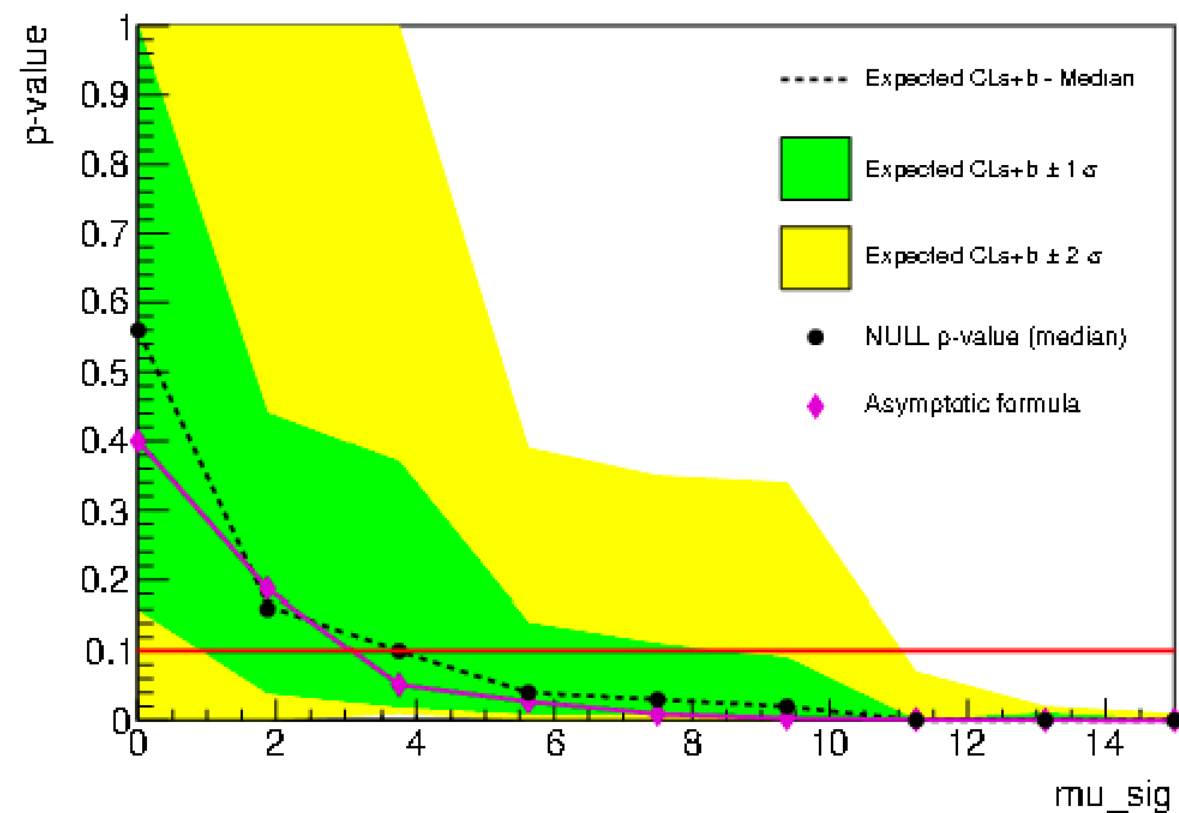
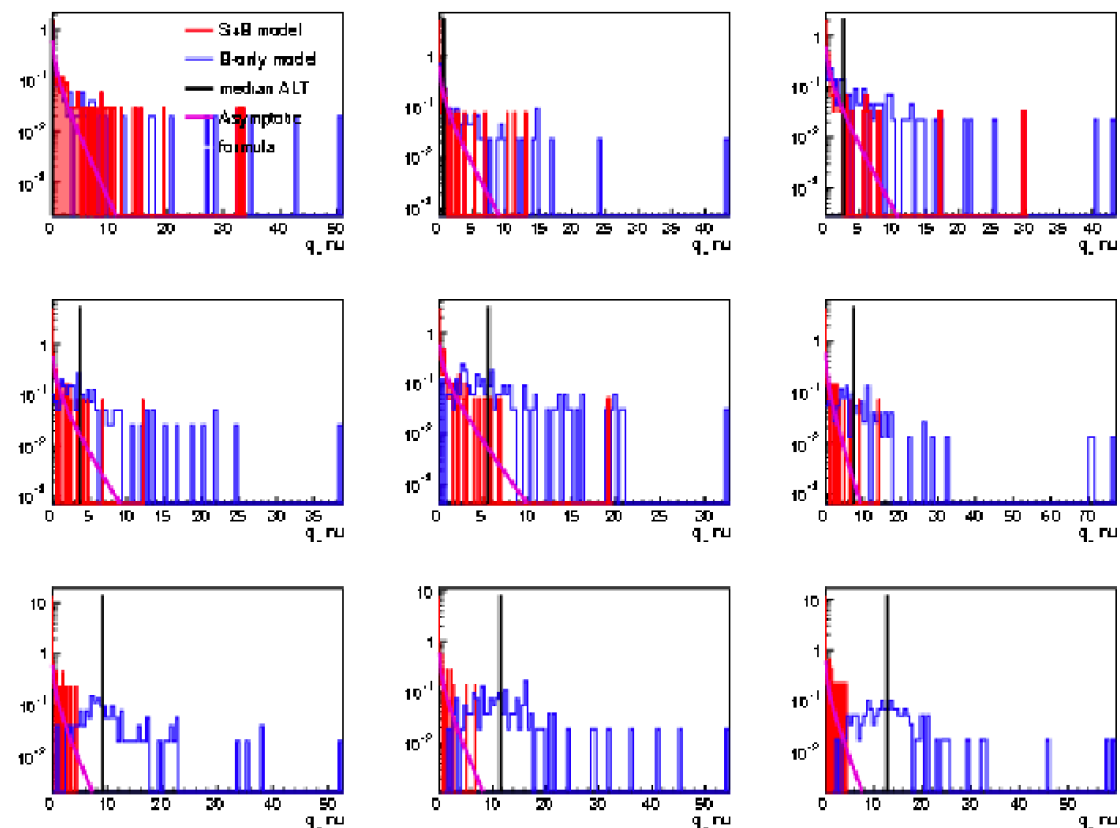
- For mass = 2.0000 GeV
 - ERROR: WIMP histogram is empty for mass 2.0 → Mass 2.0 is too small
- Mass: 10, 16.2222, 27.8256, 46.4159, 66.6667, 100, 200, 1000
- Moved the output from scratch to hdfs.
- Settings: 100 Ntoys, 1e7 samples, take 9 POI, 1000 livedays



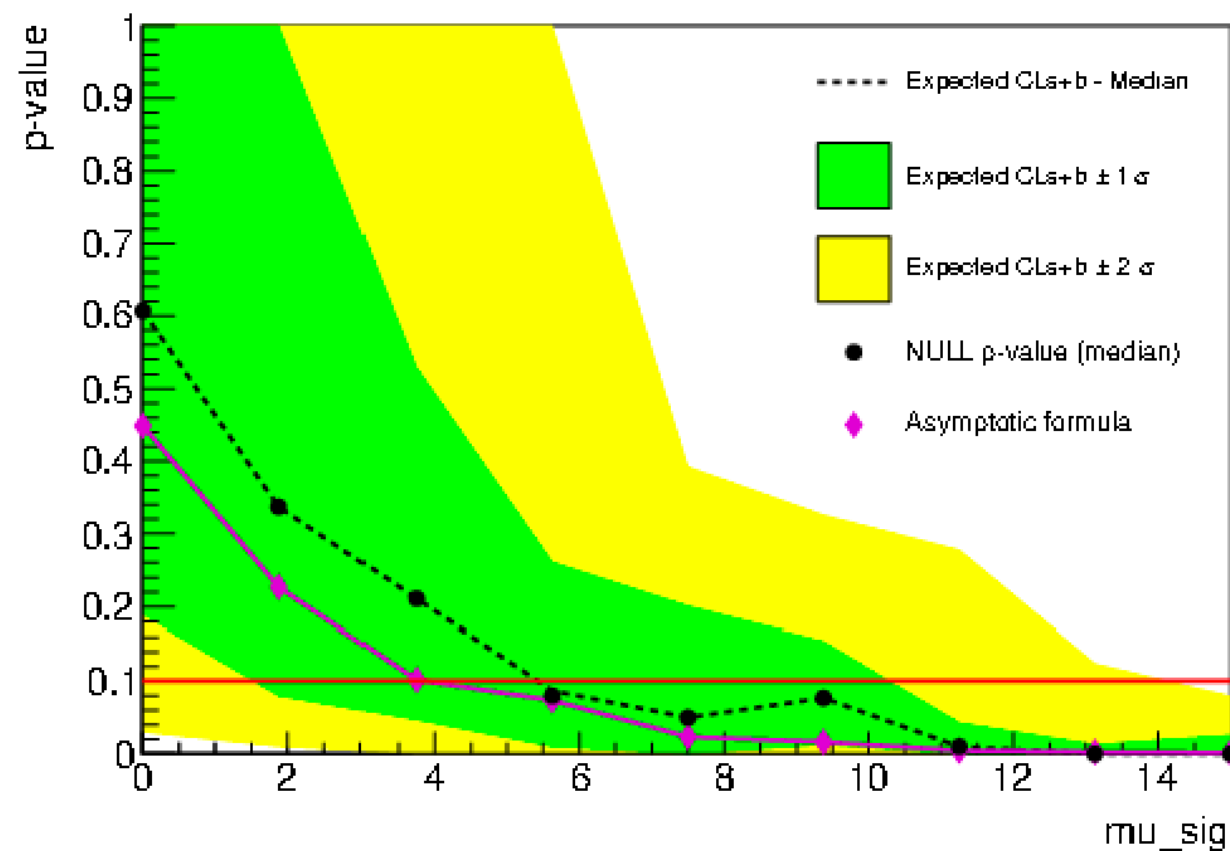
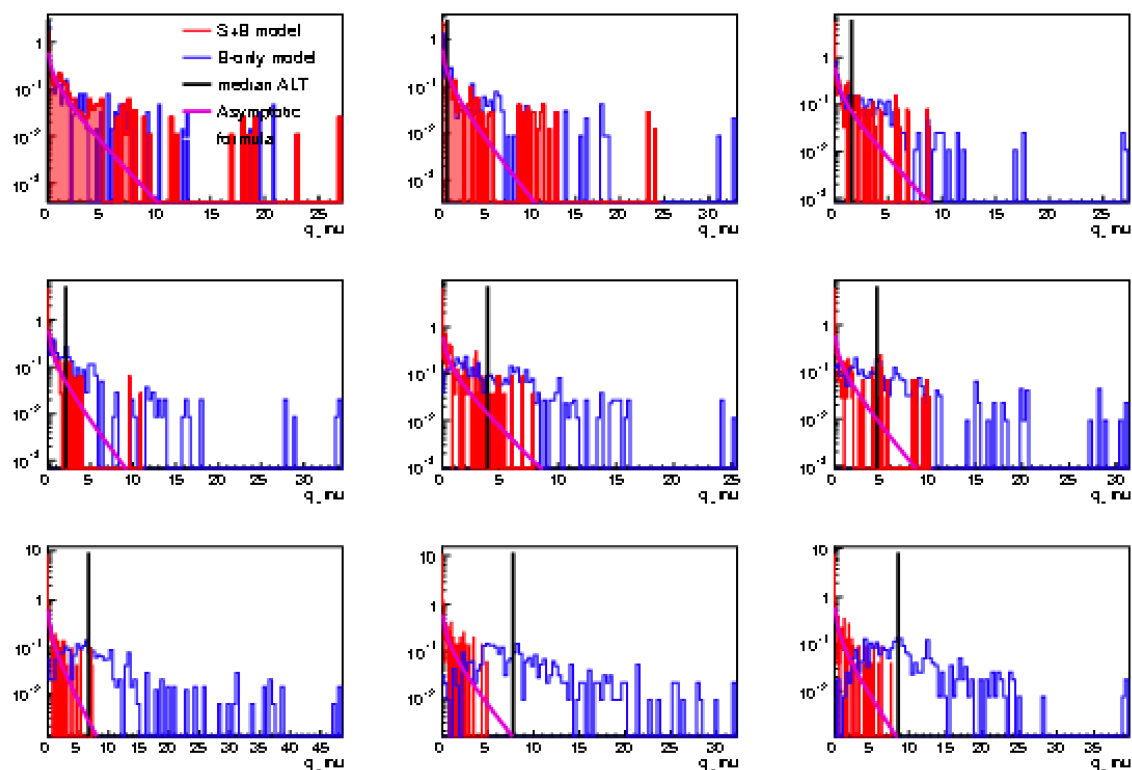
Mass = 16.2222

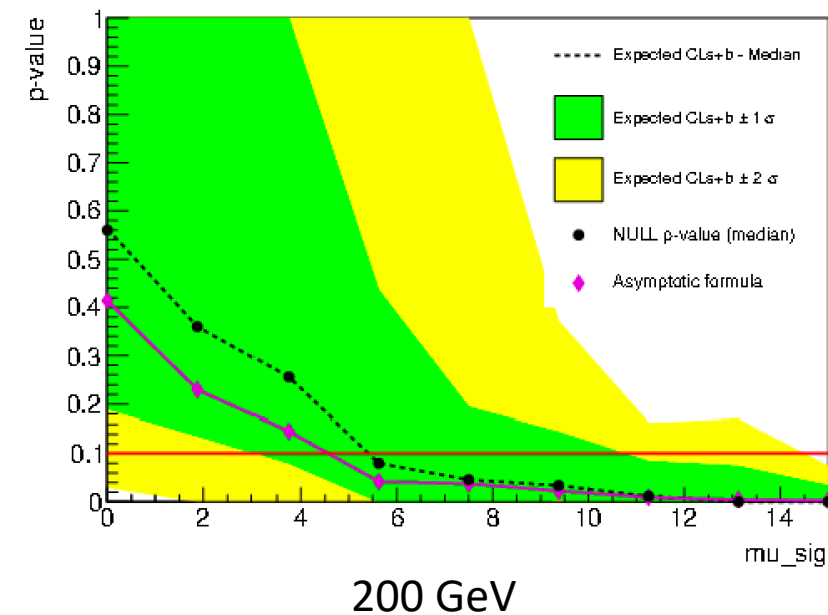
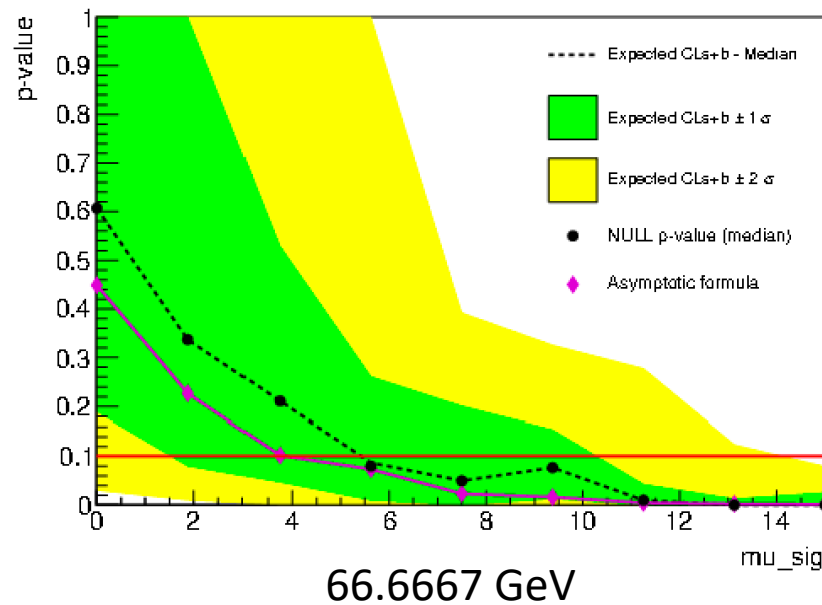
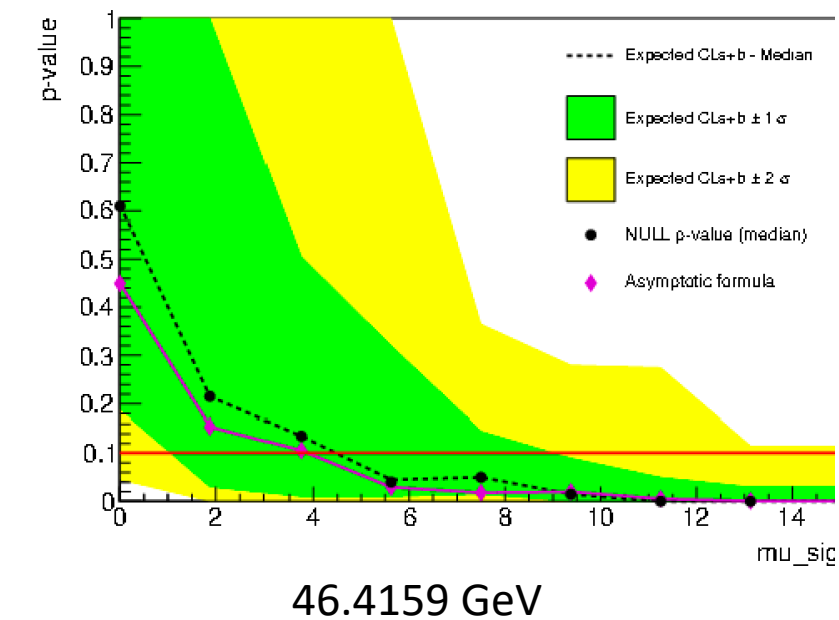
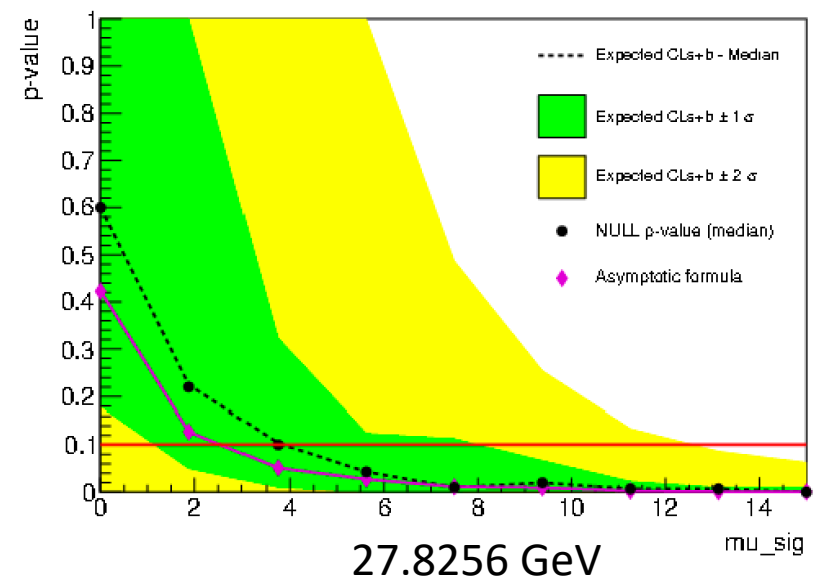
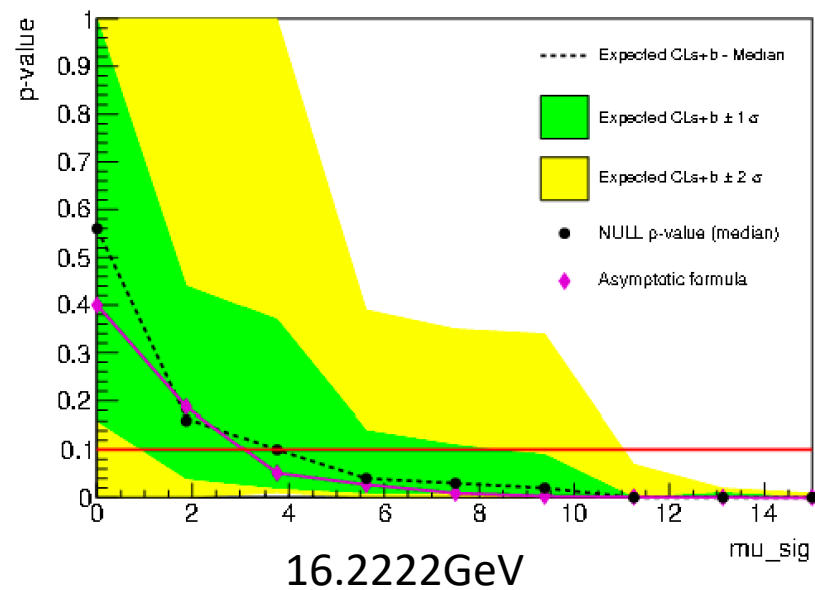
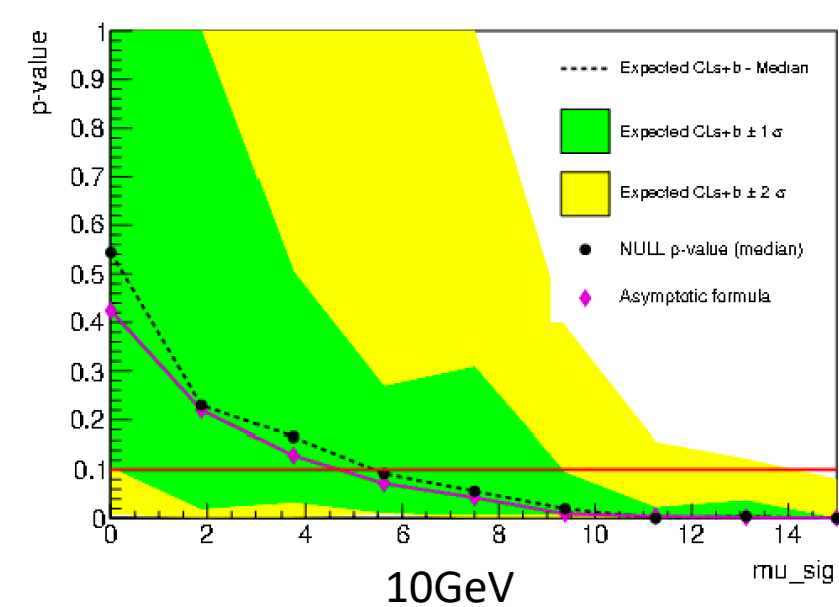


Mass = 16.2222

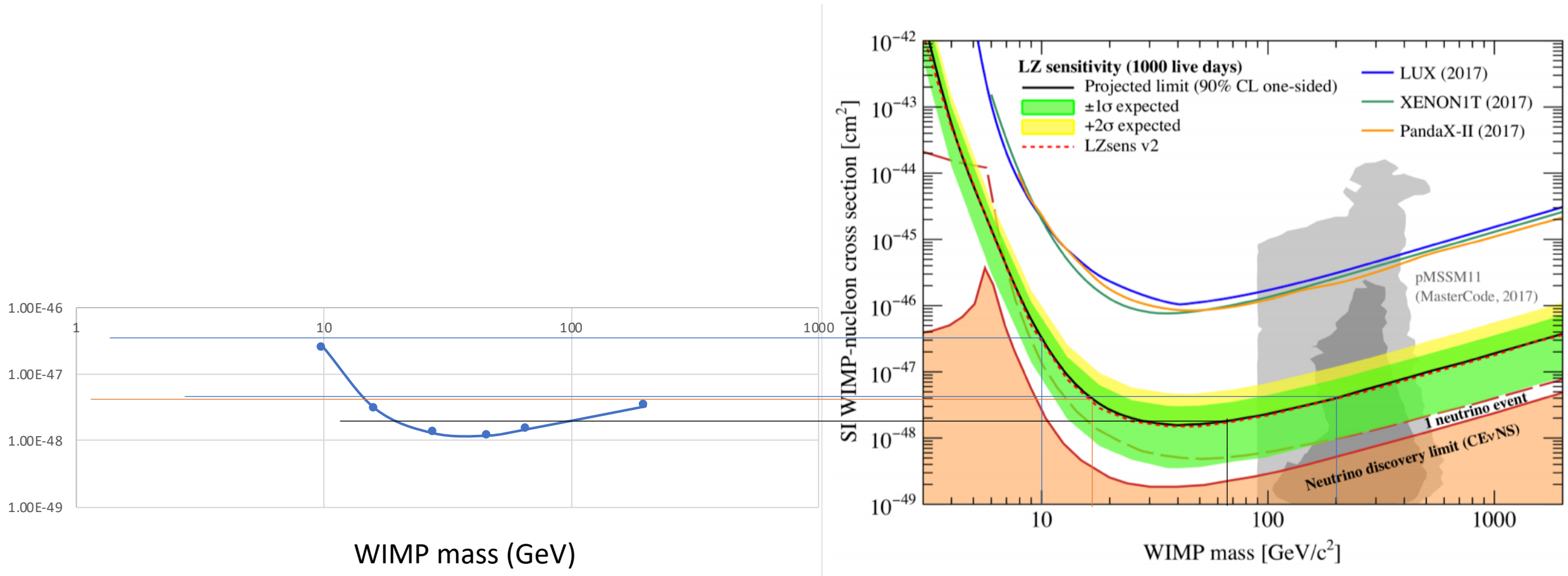


Mass = 66.6667





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