RA2: MC Results and Expected Limits

Christian Autermann
Universität Hamburg

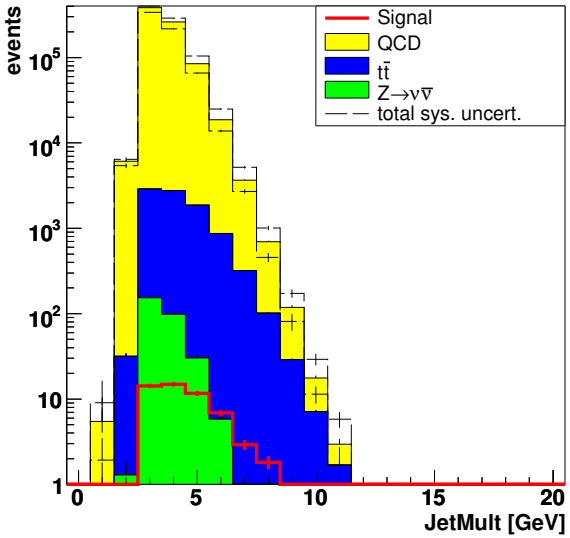
05.05.2010

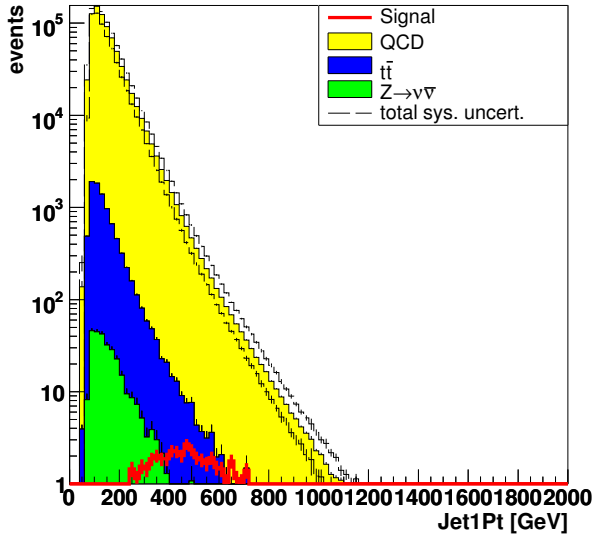
Hamburg SUSY Group Meeting

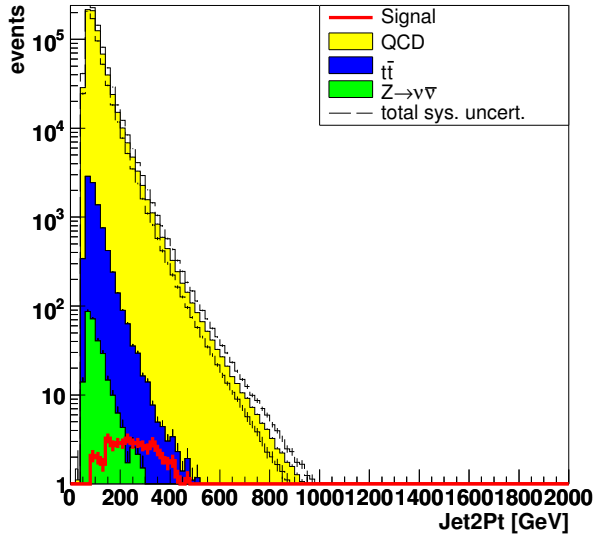
Overview

- RA2 Selection
  - Preselection
  - Cutflow
  - Final Plots
  - Rebinning
- CLs
- Conclusion

Preselection $L = 100\ \mathrm{pb}^{-1}$



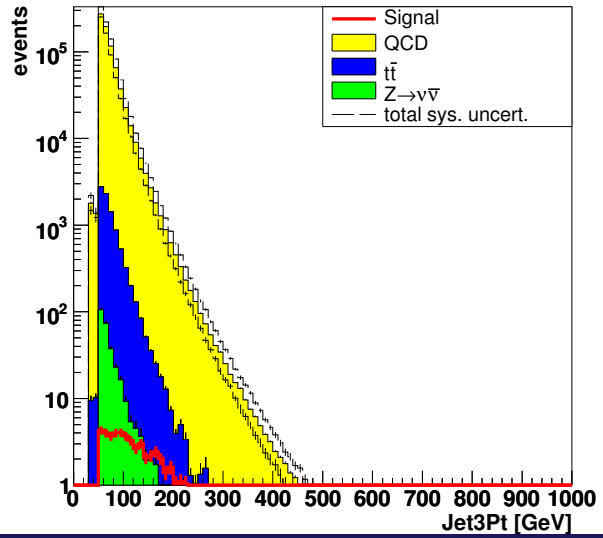


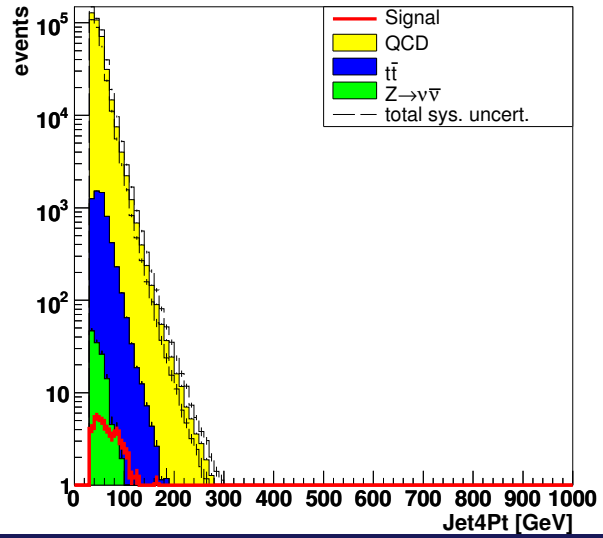


Preselection:

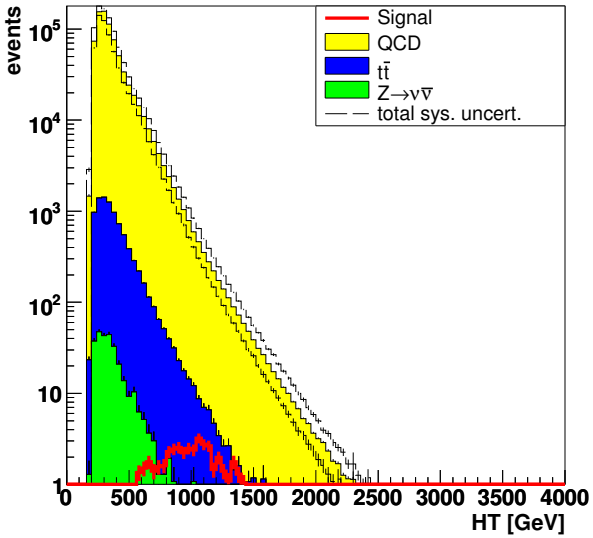
- 3rd jet $p_T >$ 50 GeV
- $HT > 200$ GeV
- $MHT > 50$ GeV

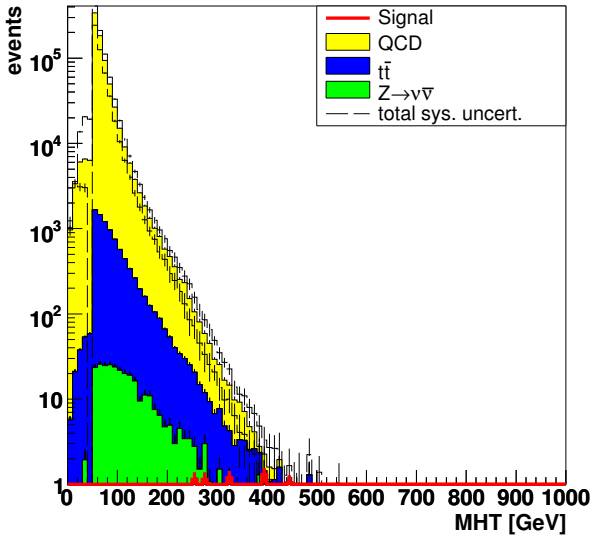
some bugs discovered:
E.g. diff. HT definition for plotting and cutting

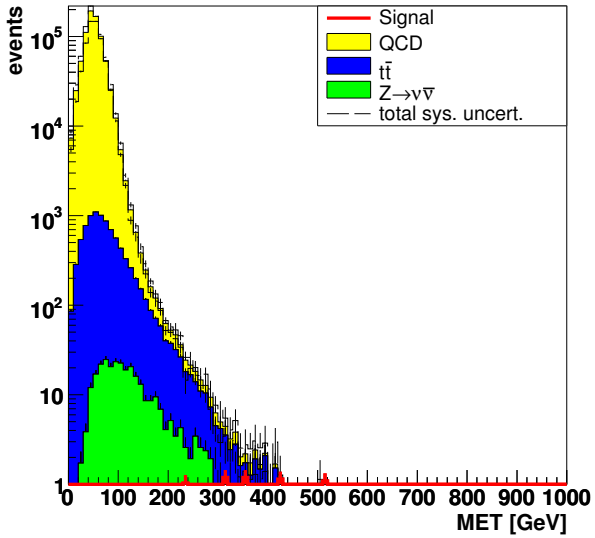


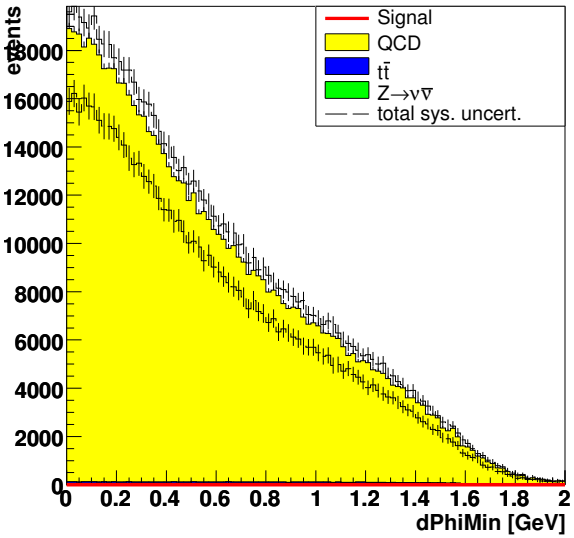


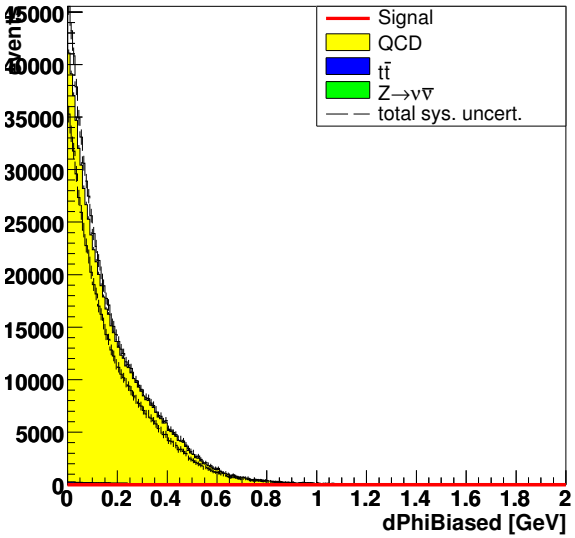
Preselection $L = 100\ \mathrm{pb}^{-1}$

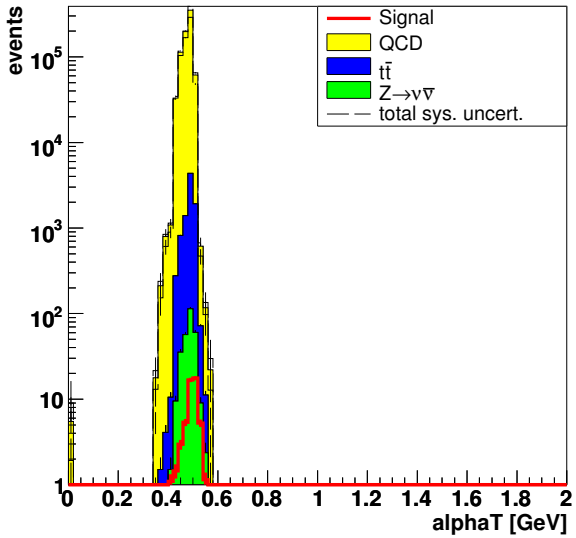












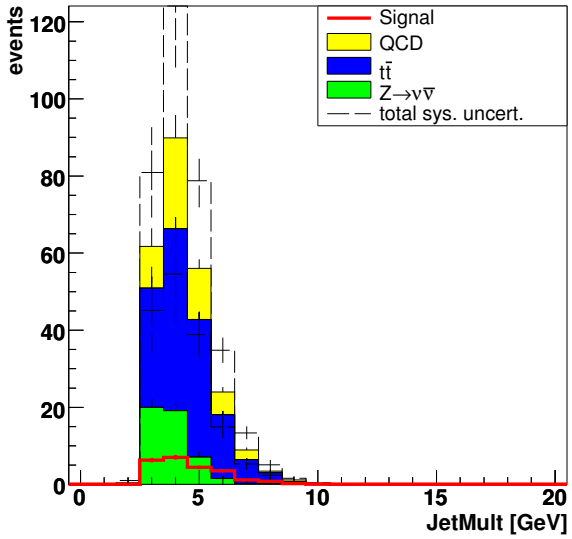
Cutflow - Signal

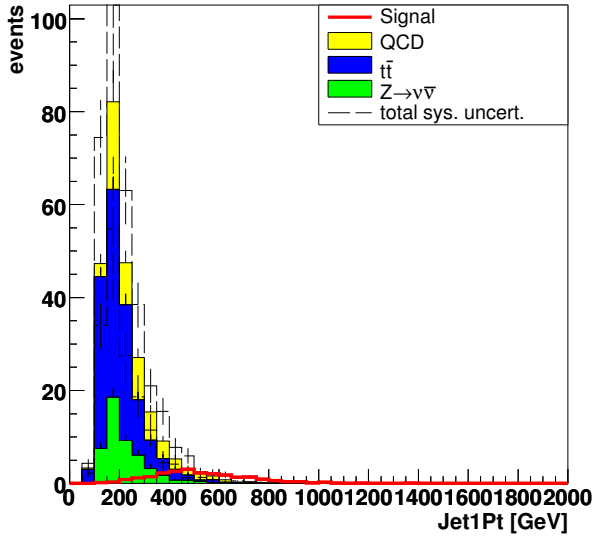
$M_0 = 450$ GeV, $M_{1/2} = 400$ GeV, m$(\tilde{g}) = m(\tilde{q}) = 957$ GeV, m$(\tilde{\chi}_0^1) = 159$ GeV, $\sigma_{\mathrm{LO}} = 2.7$ pb @ 14 TeV ($\sigma_{\mathrm{LO}} = 0.17$ pb @ 7 TeV).

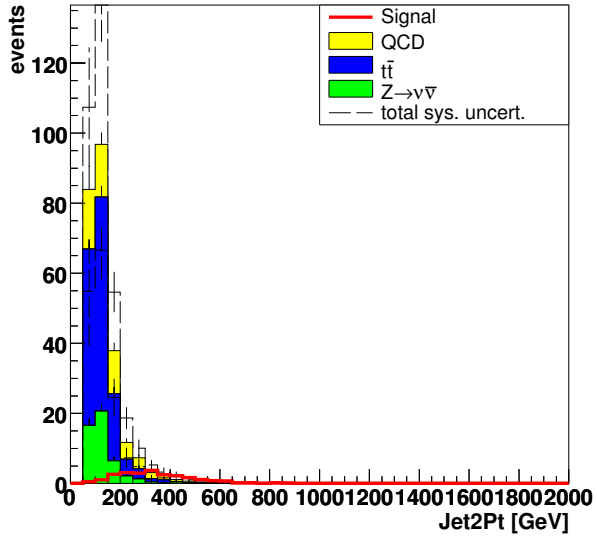
Total events after preselection = 153.1, average weight = 0.054

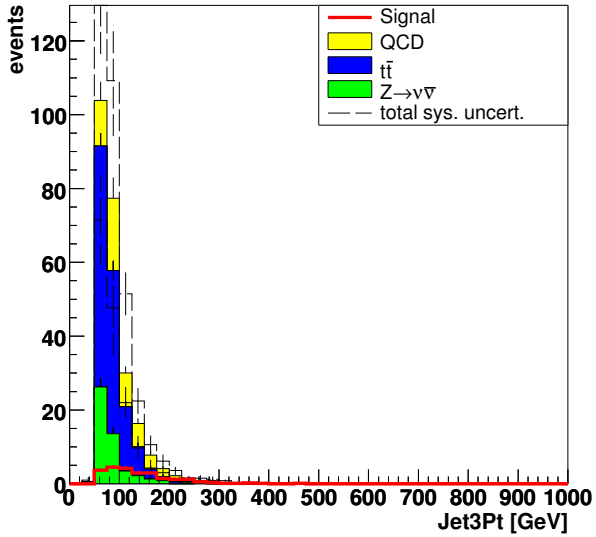
variable	cut	(eff)	n-1	(eff)	cumulative	(eff)
JetPreSelection	153	(1)	69	(1)	153	(1)
PrimaryVertex	153	(1)	69	(1)	153	(1)
JetEMFrac	153	(1)	69	(1)	153	(1)
ChargedFrac	153	(1)	69	(1)	153	(1)
HT	150	(0.98)	69	(0.99)	150	(0.98)
MHT	135	(0.88)	81	(0.85)	134	(0.87)
MHTdPhiMin	82	(0.54)	134	(0.51)	69	(0.45)
LeptonVeto	153	(1)	69	(1)	69	(0.45)

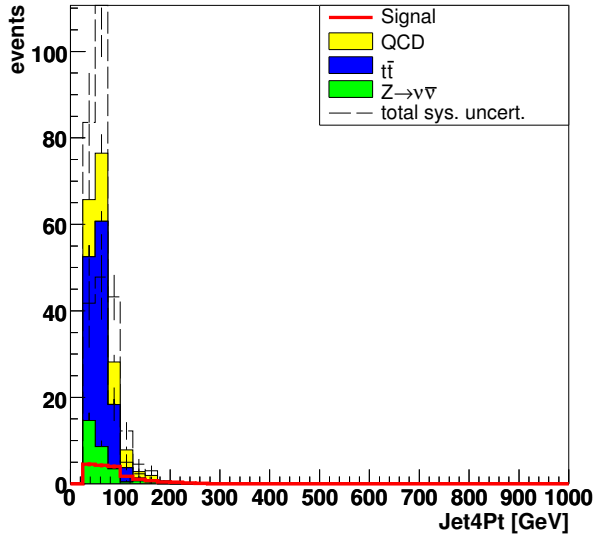
Final selection $L = 100\ \mathrm{pb}^{-1}$



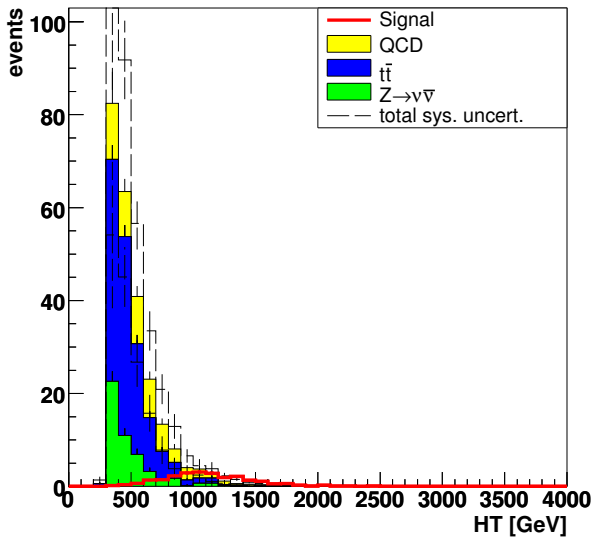


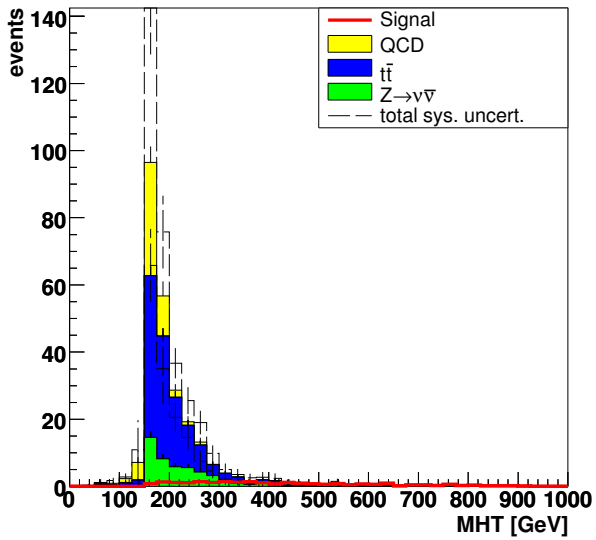


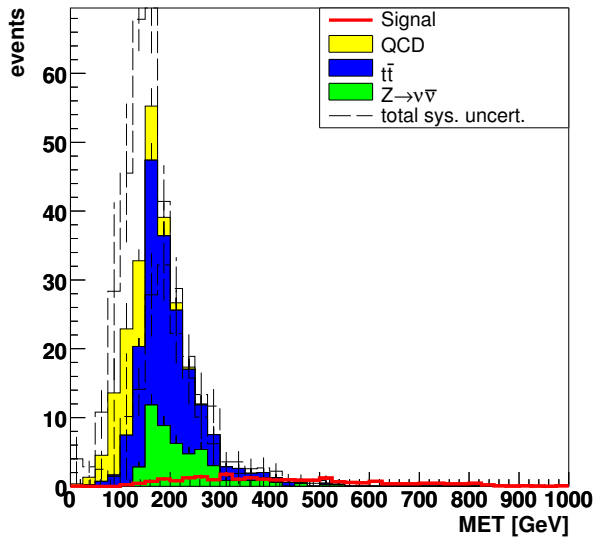


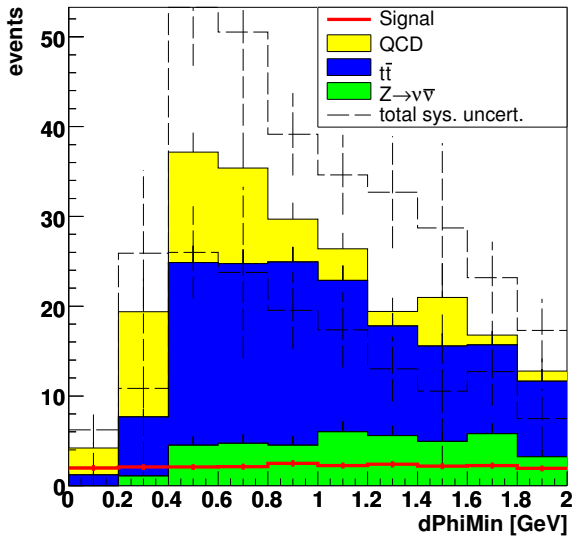


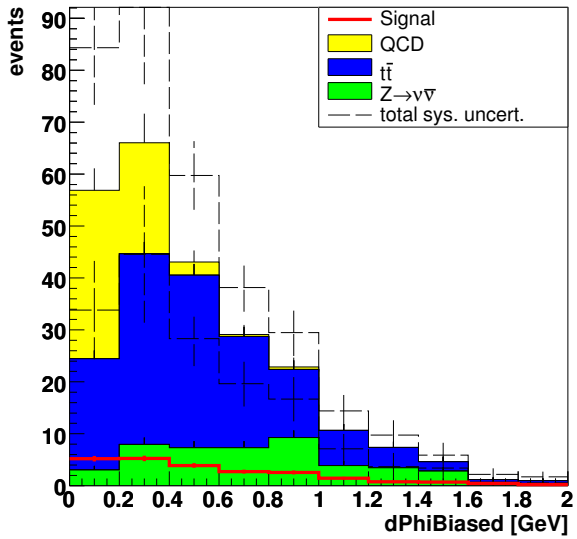
Final selection $L = 100\ \mathrm{pb}^{-1}$

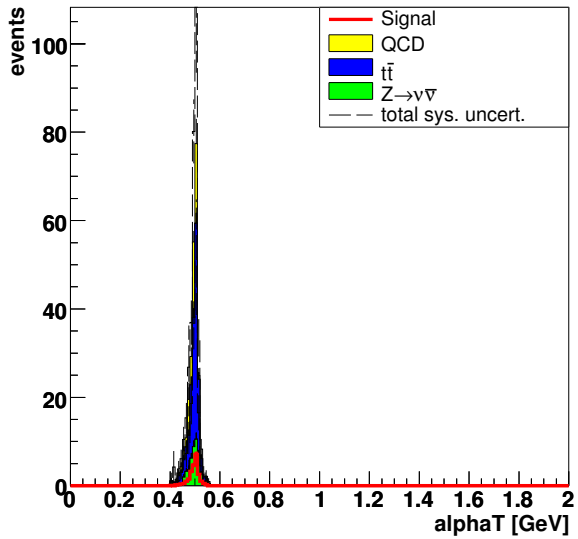












Summary table $L = 100$ pb^{-1}

Variable	data	signal	background	+ sys	- sys	+-stat
HT	0	23.6	245.8	53.5	-44.2	8.1
MHT	0	23.3	245.8	53.5	-44.2	8.1
MET	0	23.4	245.8	53.5	-44.2	8.1
Jet1Pt	0	23.6	245.8	53.5	-44.2	8.1
Jet2Pt	0	23.6	245.8	53.5	-44.2	8.1
Jet3Pt	0	23.6	245.4	53.1	-44.2	8.1
Jet4Pt	0	17.3	183.7	43.8	-36.0	6.6

Detailed table $L = 100$ pb^{-1}

Variable	Sample	events	+ JEC	- JEC	+ Lumi	- Lumi	+ MuIso	- MuIso	+-stat
HT	Signal	23.6	0.6	-1.0	1.2	-1.2	0.0	-0.0	1.1
HT	QCD	57.2	34.0	-20.7	2.9	-2.9	0.1	-0.1	6.5
HT	$t\bar{t}$	140.2	40.1	-36.2	7.0	-7.0	0.3	-0.3	3.6
HT	$Z \rightarrow \nu\nu$	48.4	6.0	-12.3	2.4	-2.4	0.1	-0.1	3.2
MHT	Signal	23.3	0.5	-0.7	1.2	-1.2	0.0	-0.0	1.1
MHT	QCD	57.2	34.0	-20.7	2.9	-2.9	0.1	-0.1	6.5
MHT	$t\bar{t}$	140.2	40.1	-36.2	7.0	-7.0	0.3	-0.3	3.6
MHT	$Z \rightarrow \nu\nu$	48.4	6.0	-12.3	2.4	-2.4	0.1	-0.1	3.2
MET	Signal	23.4	0.8	-1.1	1.2	-1.2	0.0	-0.0	1.1
MET	QCD	57.2	34.0	-20.7	2.9	-2.9	0.1	-0.1	6.5
MET	$t\bar{t}$	140.2	40.1	-36.2	7.0	-7.0	0.3	-0.3	3.6
MET	$Z \rightarrow \nu\nu$	48.4	6.0	-12.3	2.4	-2.4	0.1	-0.1	3.2
Jet1Pt	Signal	23.6	0.6	-1.0	1.2	-1.2	0.0	-0.0	1.1
Jet1Pt	QCD	57.2	34.0	-20.7	2.9	-2.9	0.1	-0.1	6.5
Jet1Pt	$t\bar{t}$	140.2	40.1	-36.2	7.0	-7.0	0.3	-0.3	3.6
Jet1Pt	$Z \rightarrow \nu\nu$	48.4	6.0	-12.3	2.4	-2.4	0.1	-0.1	3.2
Jet2Pt	Signal	23.6	0.6	-1.0	1.2	-1.2	0.0	-0.0	1.1
Jet2Pt	QCD	57.2	34.0	-20.7	2.9	-2.9	0.1	-0.1	6.5
Jet2Pt	$t\bar{t}$	140.2	40.1	-36.2	7.0	-7.0	0.3	-0.3	3.6
Jet2Pt	$Z \rightarrow \nu\nu$	48.4	6.0	-12.3	2.4	-2.4	0.1	-0.1	3.2
Jet3Pt	Signal	23.6	0.6	-1.0	1.2	-1.2	0.0	-0.0	1.1
Jet3Pt	QCD	57.0	33.9	-20.7	2.9	-2.9	0.1	-0.1	6.5
Jet3Pt	$t\bar{t}$	140.2	39.6	-36.2	7.0	-7.0	0.3	-0.3	3.6
Jet3Pt	$Z \rightarrow \nu\nu$	48.2	6.0	-12.3	2.4	-2.4	0.1	-0.1	3.2
Jet4Pt	Signal	17.3	0.4	-0.9	0.9	-0.9	0.0	-0.0	0.9
Jet4Pt	QCD	46.2	29.6	-19.2	2.3	-2.3	0.1	-0.1	5.4
Jet4Pt	$t\bar{t}$	109.3	31.5	-28.6	5.5	-5.5	0.2	-0.2	2.9
Jet4Pt	$Z \rightarrow \nu\nu$	28.2	3.0	-8.6	1.4	-1.4	0.0	-0.0	2.5

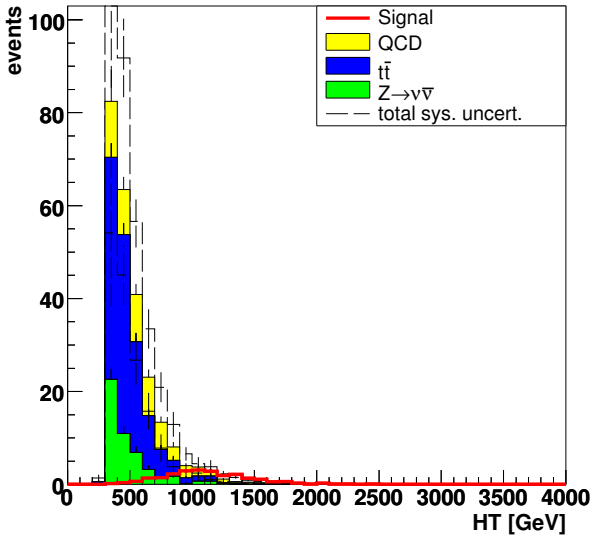
Auto-Rebinning

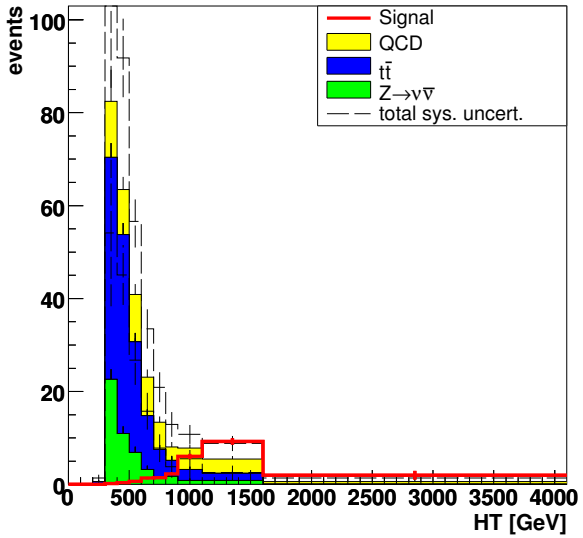
Criterion:

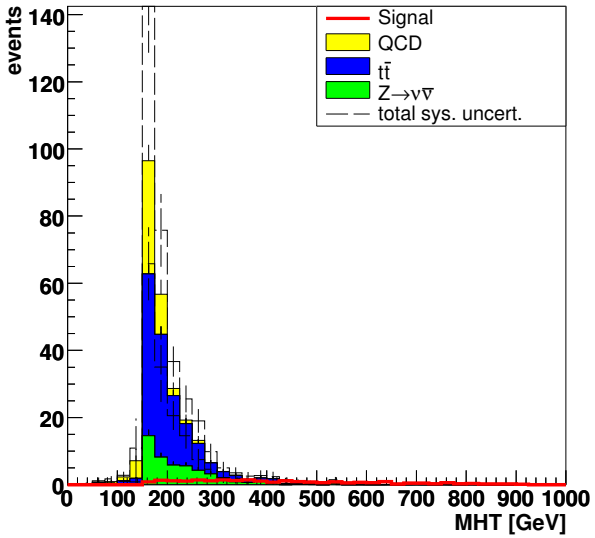
$$\left.\frac{\sum_i b_i}{\sigma_b^{tot}}\right|_{\text{in each bin}} \geq \text{cut}$$

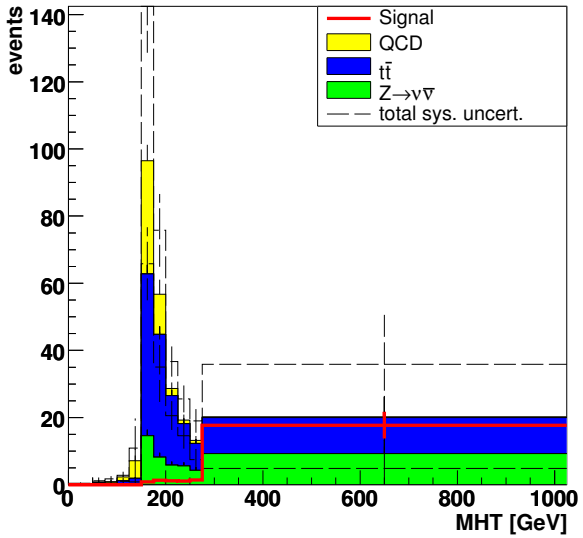
left plots: normal bin-width

right plots: cut = 10









Overview

- RA2 Selection
- CLs
  - Modified frequentist approach
  - LEP Higgs limit example
  - RA2 expected limits
- Conclusion

The modified Frequentist procedure (CLs)

CLs is a frequentist like statistical analysis which avoids excluding or discovering signals, that the analysis is not really sensitive to.

The null-hypothesis is that there is no signal and the alternate hypothesis that it exists.

The modified Frequentist procedure (CLs)

CLs is a frequentist like statistical analysis which avoids excluding or discovering signals, that the analysis is not really sensitive to.

The null-hypothesis is that there is no signal and the alternate hypothesis that it exists.

Example: Observing less than the mean expected background events could be accommodated best with a negative signal cross-section. The exclusion may be so strong that even zero signal is ecluded at a certain confidence level.

The modified Frequentist procedure (CLs)

CLs is a frequentist like statistical analysis which avoids excluding or discovering signals, that the analysis is not really sensitive to.

The null-hypothesis is that there is no signal and the alternate hypothesis that it exists.

Example: Observing less than the mean expected background events could be accommodated best with a negative signal cross-section. The exclusion may be so strong that even zero signal is ecluded at a certain confidence level.

This is a perfectly valid result in terms of statistics, but it says more about fluctuations of the (known) background, than about the hypothetical signal we are interested in!

The modified Frequentist procedure (CLs)

CLs is a frequentist like statistical analysis which avoids excluding or discovering signals, that the analysis is not really sensitive to.

The null-hypothesis is that there is no signal and the alternate hypothesis that it exists.

Example: Observing less than the mean expected background events could be accommodated best with a negative signal cross-section. The exclusion may be so strong that even zero signal is ecluded at a certain confidence level.

This is a perfectly valid result in terms of statistics, but it says more about fluctuations of the (known) background, than about the hypothetical signal we are interested in!

$\longrightarrow$ Normalize the confidence level in the signal+background hypothesis CL_{s+b} to the confidence level for the background-only hypothesis CL_b.

Introducing CLs method

The modified frequentist re-normalization is simply:

$$CL_s = \frac{CL_{s+b}}{CL_b}$$

CL_s gives an approximation to the confidence in the signal hypothesis one might have obtained if the experiment had been performed in the complete absence of background. CL_s tries to reduce the dependency on the uncertainty due to the background.

Strictly, CL_s is not a confidence, but a ratio of confidences.

- Consequentially, the false exclusion rate is generally less than the nominal rate CL,
- it increases the „coverage" of the analysis,
- it gives a consistent performance compared to CL_{s+b} at small expected signal but different background rates.

Frequentists confidence levels

If d_i data events are observed, then this leads to a value Q_{obs} of the test-statistics. CL_{s+b} is then given by:

$$\begin{aligned} CL_{s+b} &= P_{s+b}(Q \leq Q_{obs}) \\ &= -2 \int_{Q_{obs}}^{\infty} \ln Q_{s+b} dx \end{aligned}$$

Small values of CL_{s+b} indicate poor compability with the $s + b$ hypothesis and favour the background-only hypothesis.

CL_b is calculated likewise:

$$CL_b = -2 \int_{Q_{obs}}^{\infty} \ln Q_b dx$$

CLs: Single counting experiment

For a counting experiment with a single channel, CL_s takes the following form:

$$\begin{aligned} CL_s &= \frac{CL_{s+b}}{CL_b} \\ &= \frac{\text{Poisson}(s+b, d_{obs})}{\text{Poisson}(b, d_{obs})} \end{aligned}$$

where $s+b$ (or b) come from the Poisson distributions of number of events for the signal+background (background-only) hypotheses, and d_{obs} is the number of events observed.

The modified frequentist signal exclusion confidence becomes:

$$CL = 1 - \frac{\sum_{n=0}^{d_{obs}} \frac{e^{-(b+s)}(b+s)^n}{n!}}{\sum_{n=0}^{d_{obs}} \frac{e^{-b} b^n}{n!}}$$

(Which is similar to the result of a constrained Bayesian integral).

CLs: Likelihood-ratio test-statistic for a counting experiment

Using a likelihood-ratio as test-statistic to compute CL_{s+b} and CL_b:

$$Q = \frac{\text{Poisson}(s(m_H) + b, d_{obs})}{\text{Poisson}(b, d_{obs})}$$

Where the expected signal s depends e.g. on a model parameter as the Higgs mass m_H. Likelihoods are multiplicative, different N channels can be combined:

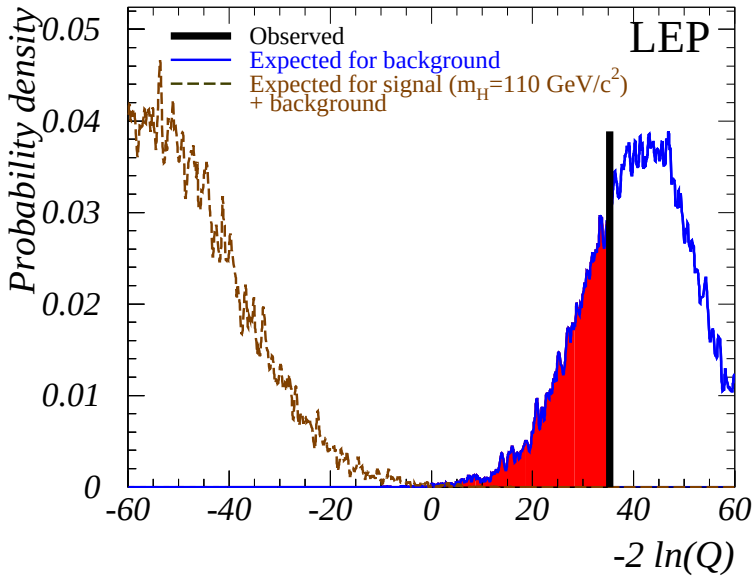
$$Q(m_h) = \prod_i^N Q_i(m_h)$$

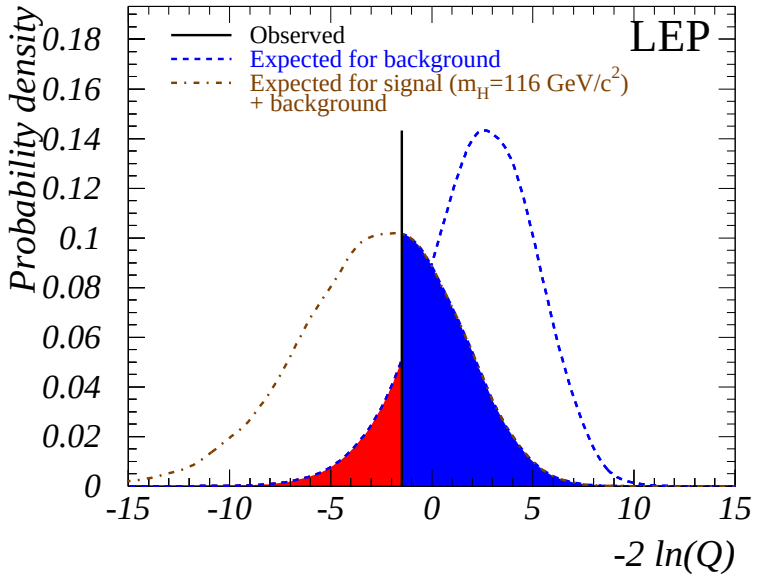
The negative logarithm of this test-statistic becomes:

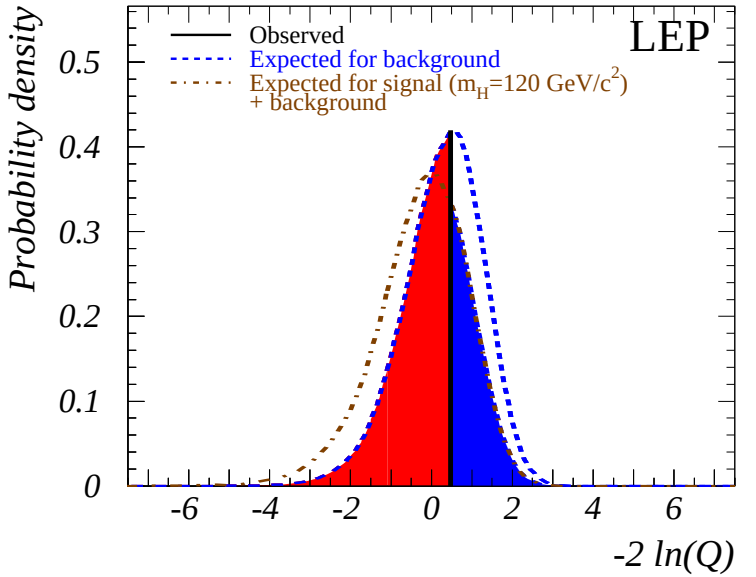
$$\begin{aligned} -2\ln Q(m_H) &= -2\sum_{i=1}^{N}\left(d_i \cdot \ln(1+\frac{s_i}{b_i}) - s_i\right) \\ &= \lim_{\mu\to\infty} \chi^2_{s+b} - \chi^2_b \end{aligned}$$

The p.d.f for the signal+background (and background-only) hypotheses are constructed by generating many pseudo-experiments using either $\mu = s + b$ (or $\mu = b$) to generate different Poisson-distributed expected data events d_i.

LEP combined SM Higgs limits





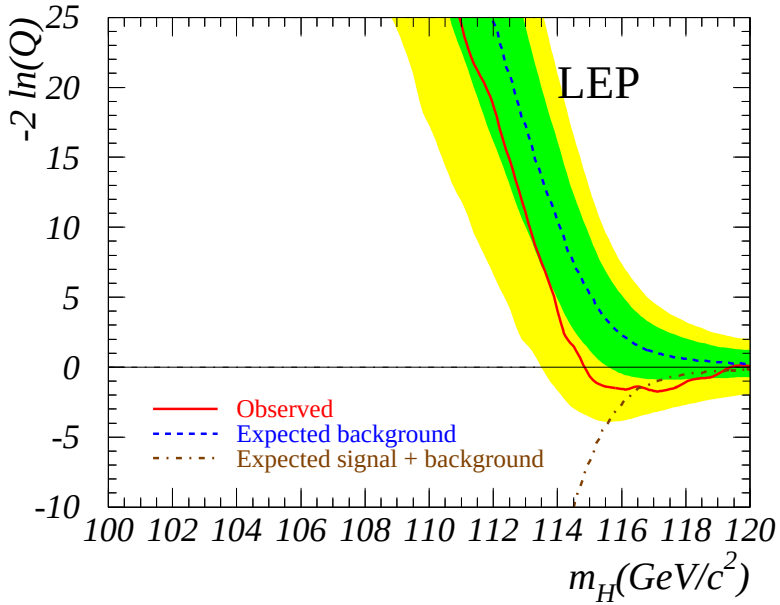


Probability density functions corresponding to fixed test-masses for the b and $s+b$ hypotheses. The observed test-statistic $-2\ln Q = Q_{obs}$ is indicated by the vertical line.

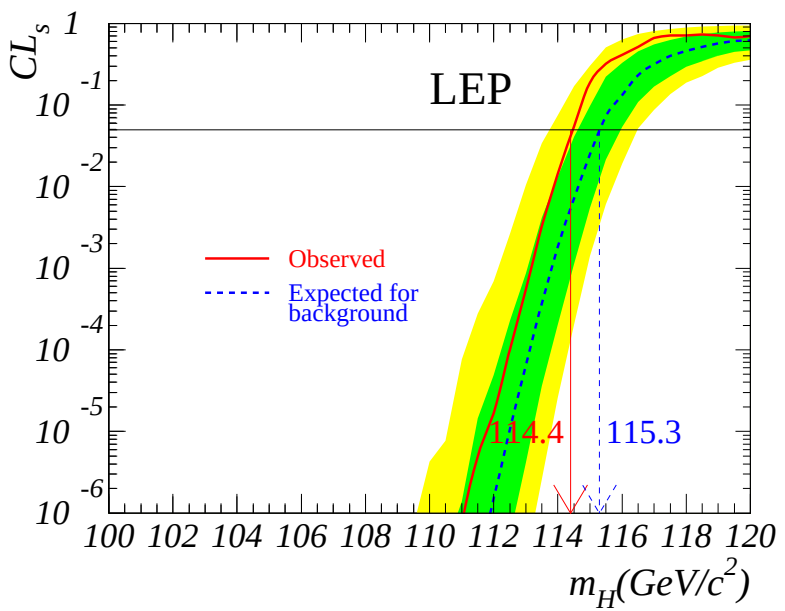
The shaded areas refer to $1 - CL_b$ and CL_{s+b}.

LEP combined SM Higgs limits

LHWG Note/2002-01 „Search for the Standard Model Higgs Boson at LEP"

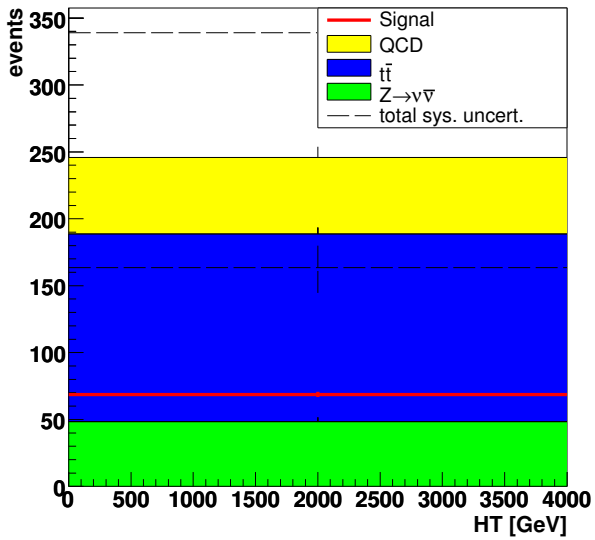


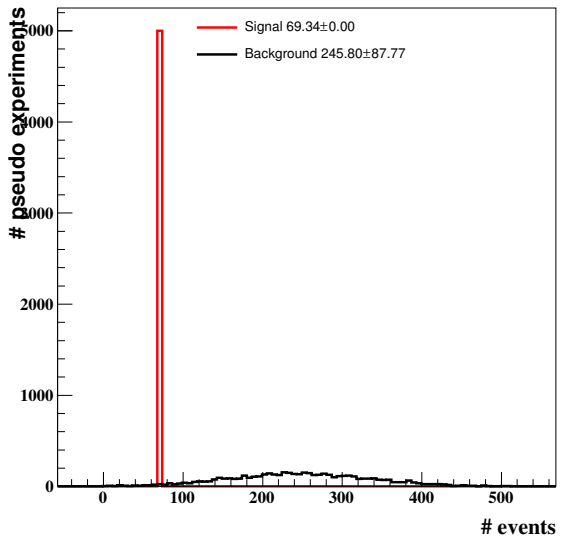
Observed and expected behaviour of the test-statistic $-2\ln Q$ as a function of the test mass m_H.

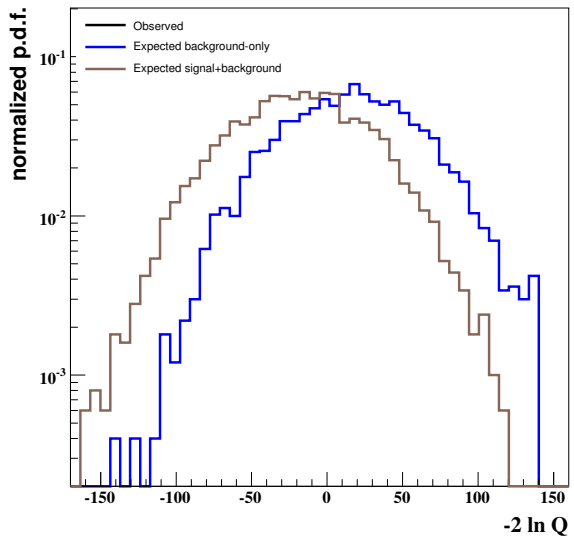


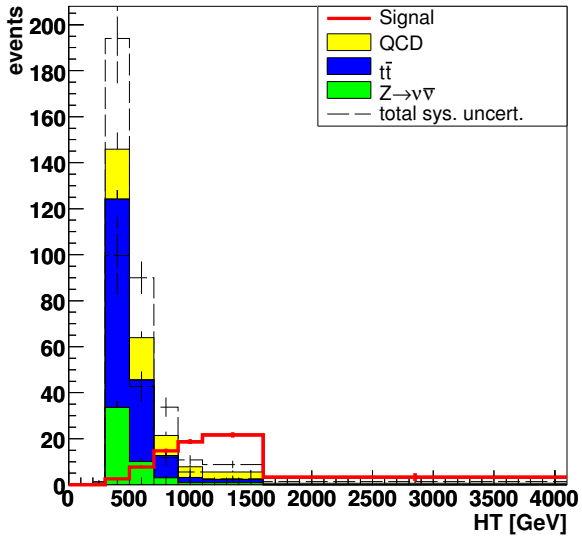
Confidence level CL_s for the signal+background hypothesis. The intersection of the observed limit with the horizontal $CL_s = 0.05$ line determines the 95% CL lower mass limit.

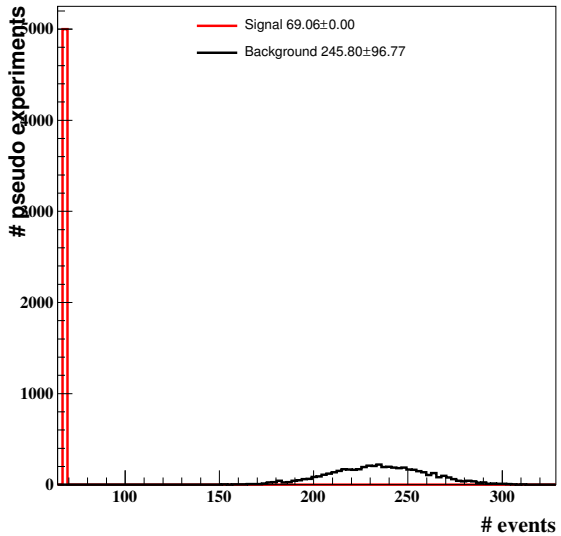
Binning, pseudo-experiments, and test-statistics

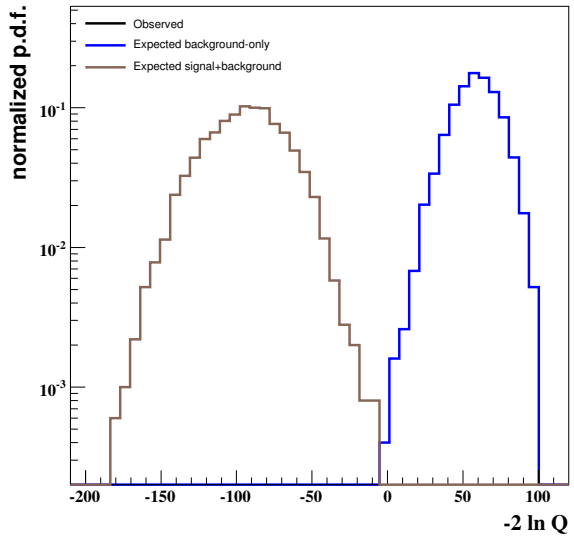




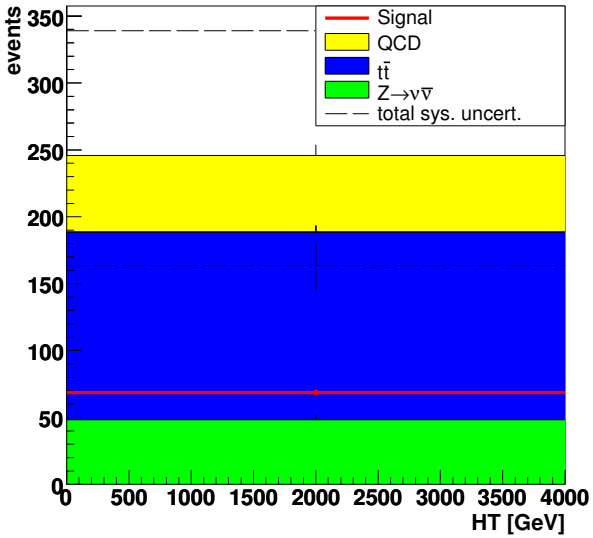


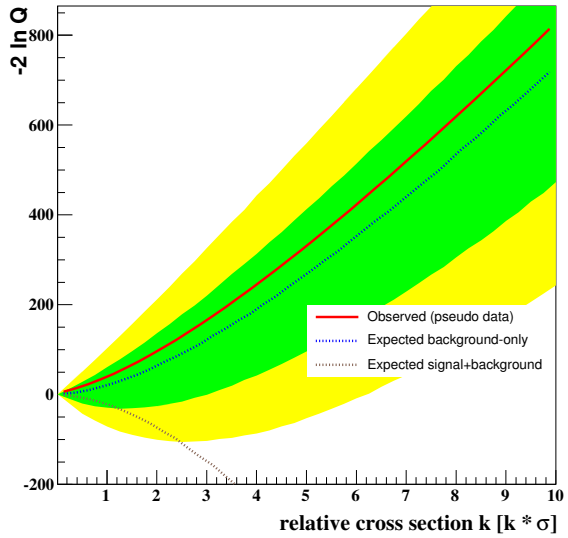


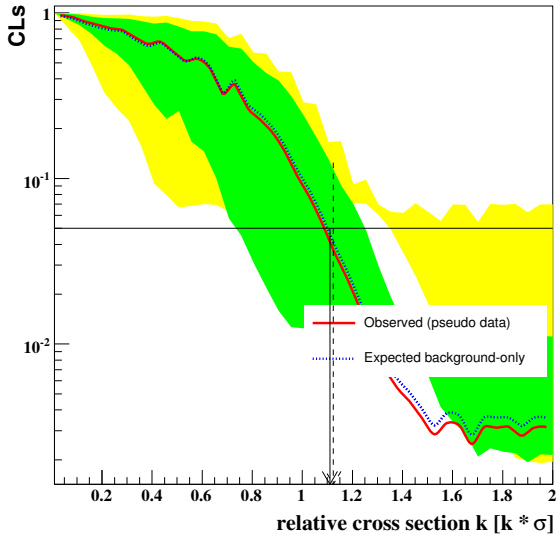


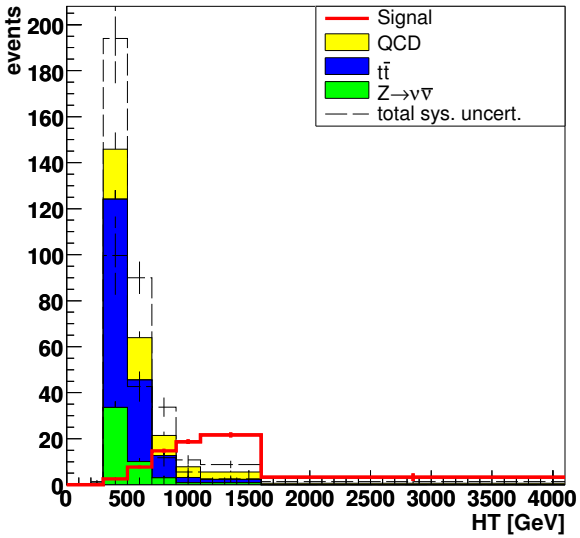


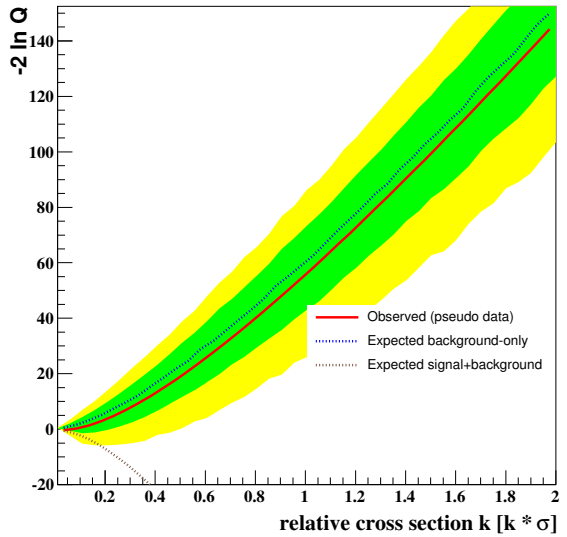
-2lnQ and CLs vs. signal cross-section

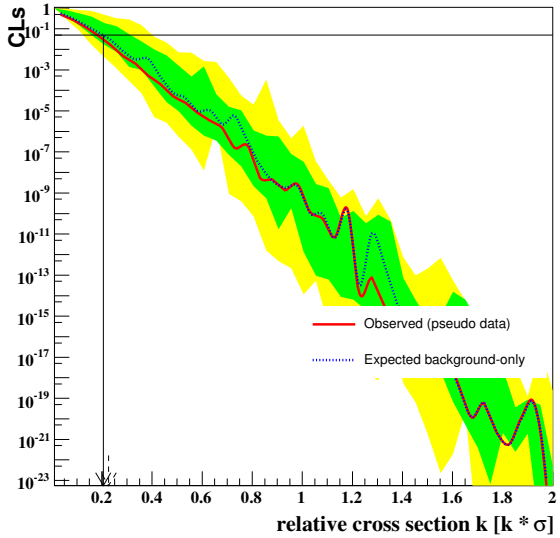






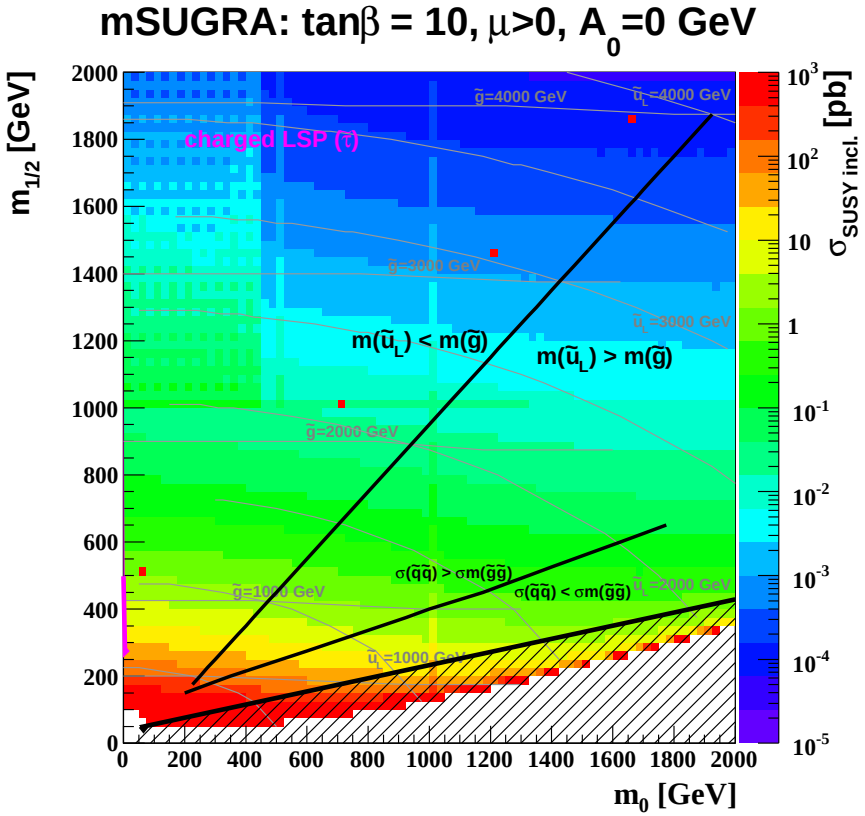


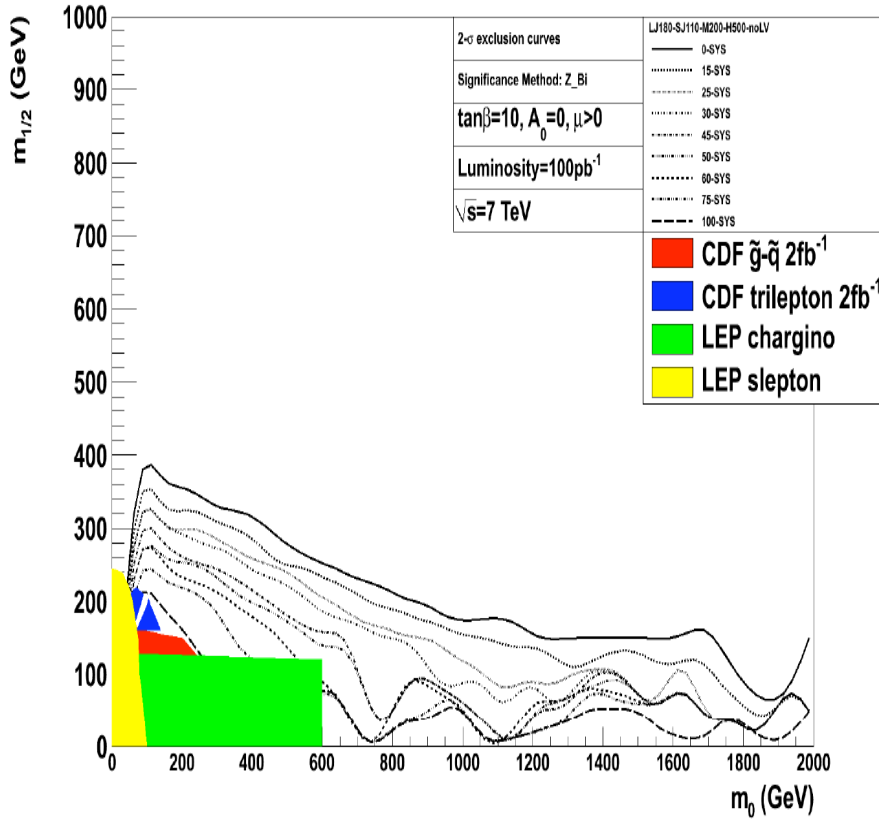




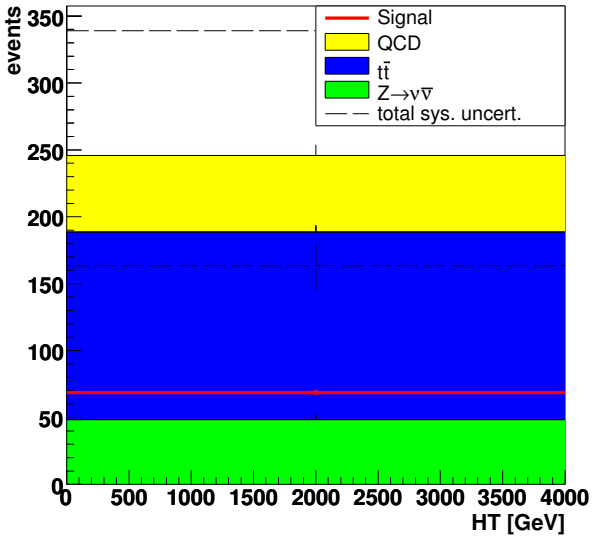
The mSUGRA plain

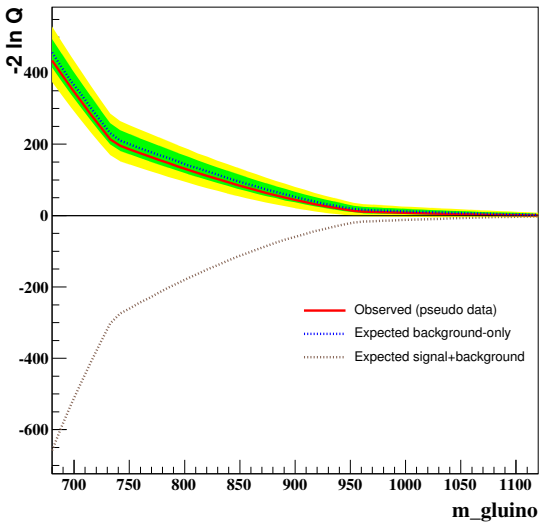
The cross-section on the z-axis are for 14 TeV, 7-TeV scan is still running...

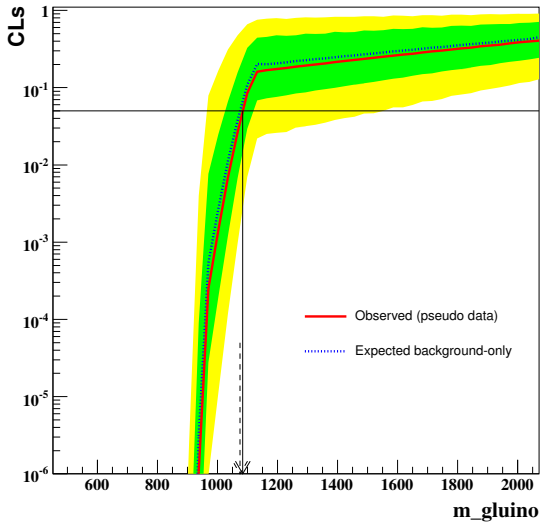


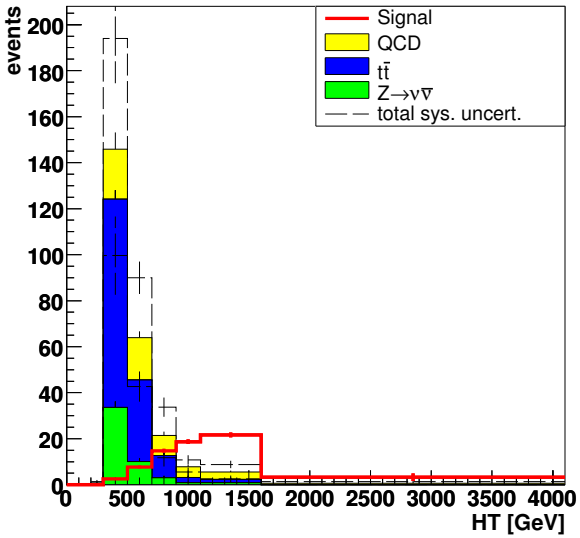


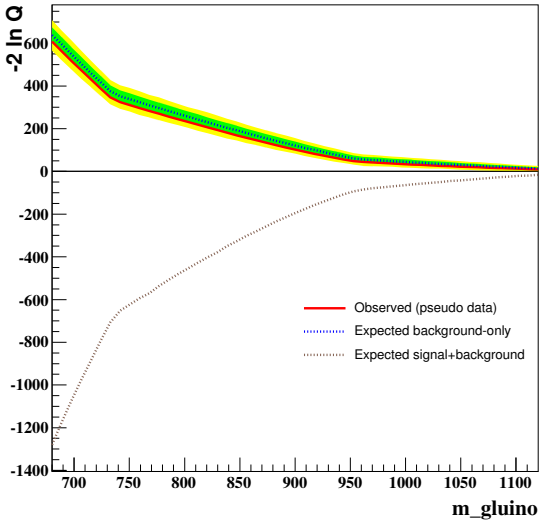
-2lnQ and CLs vs. gluino mass (7 TeV)

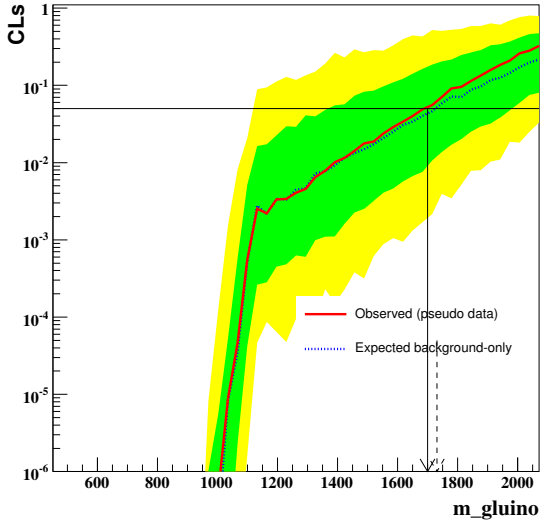




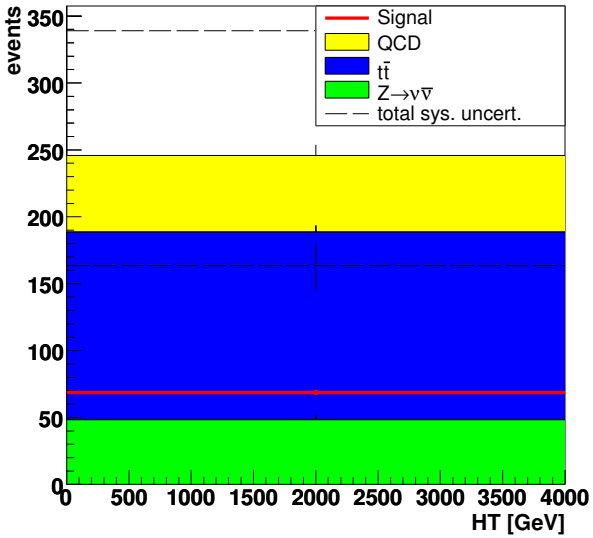


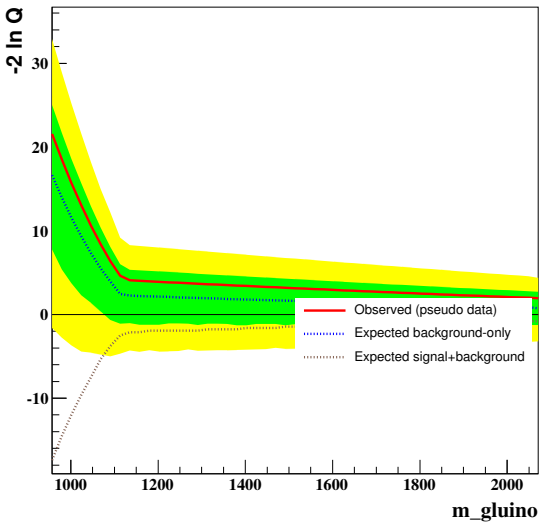


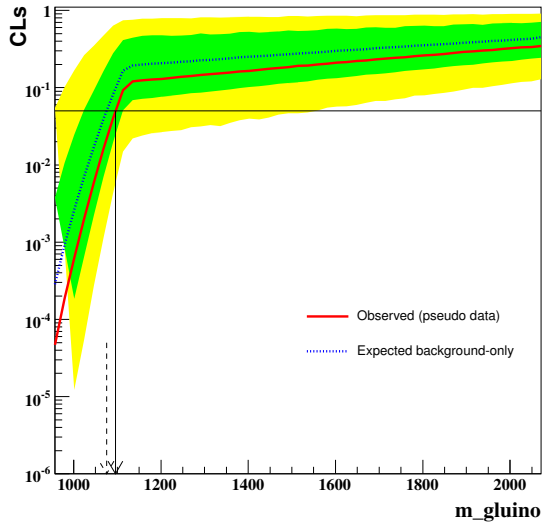


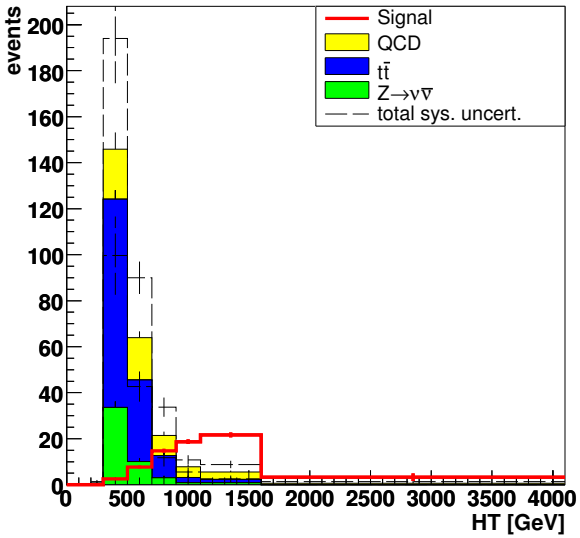


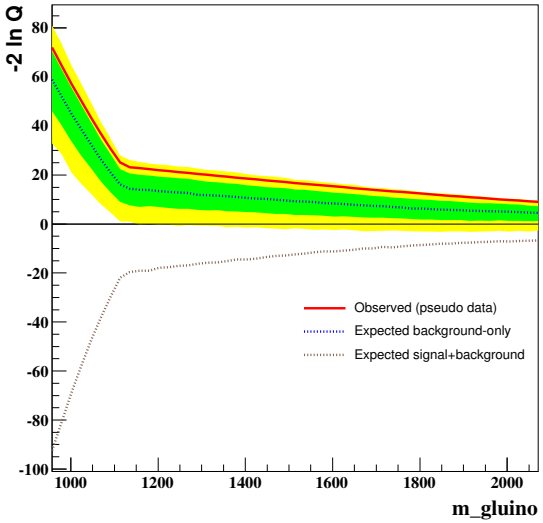
-2lnQ and CLs vs. gluino mass (14 TeV)

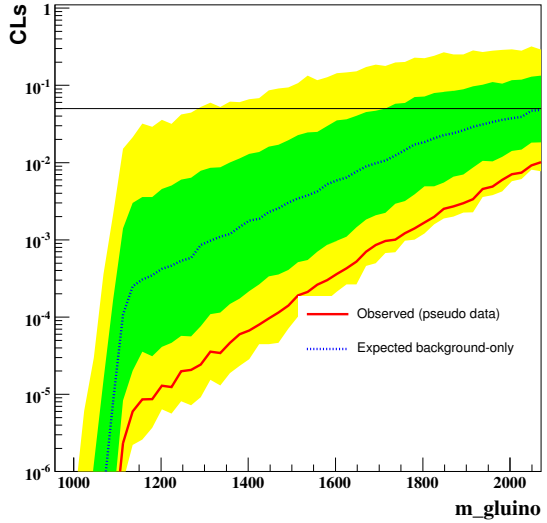






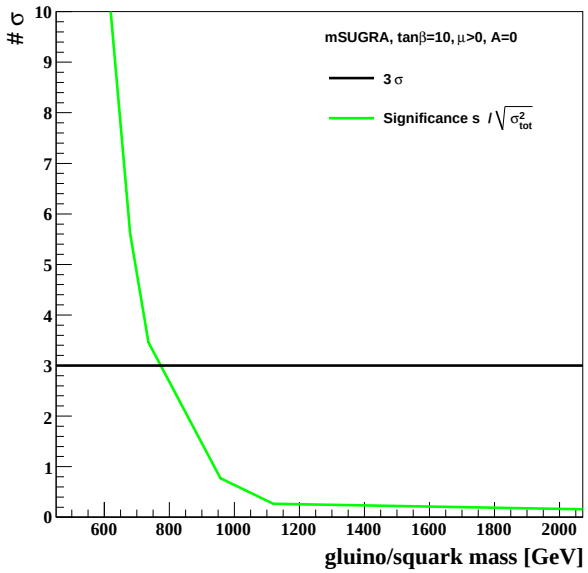


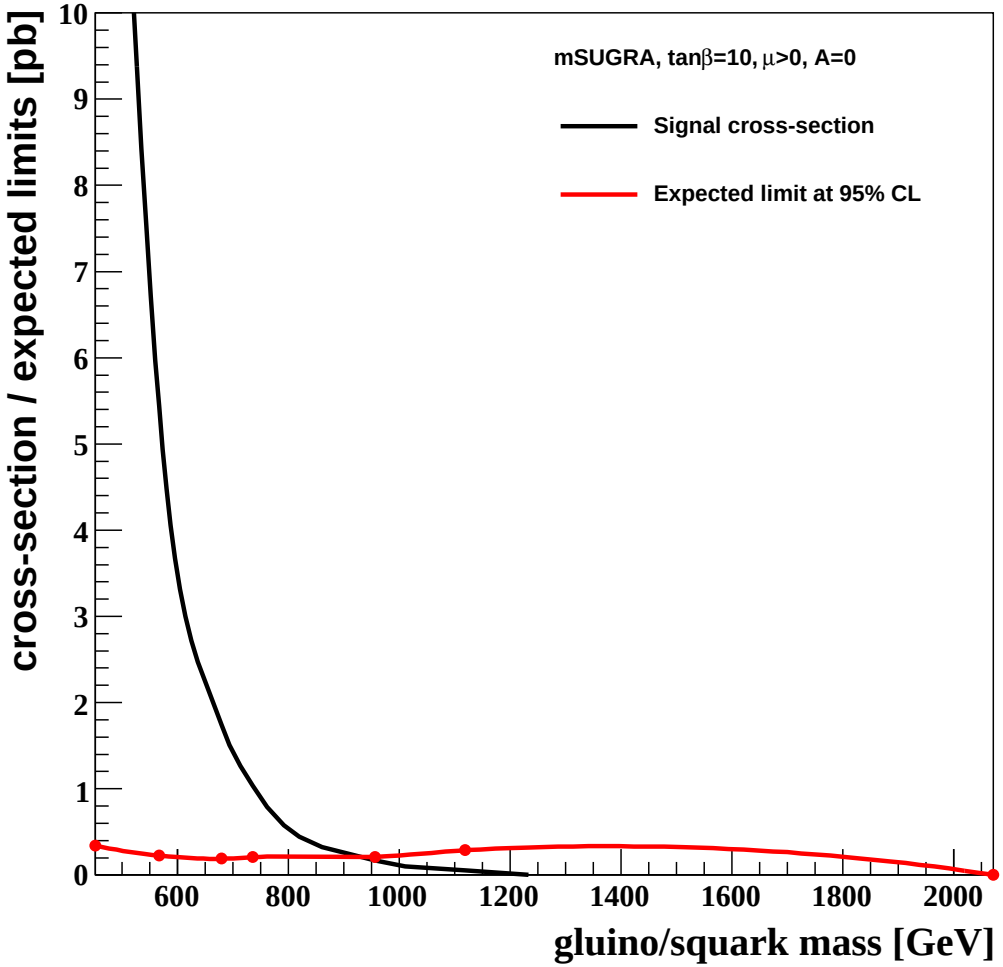




Cross-section limits vs. gluino mass (7 TeV)

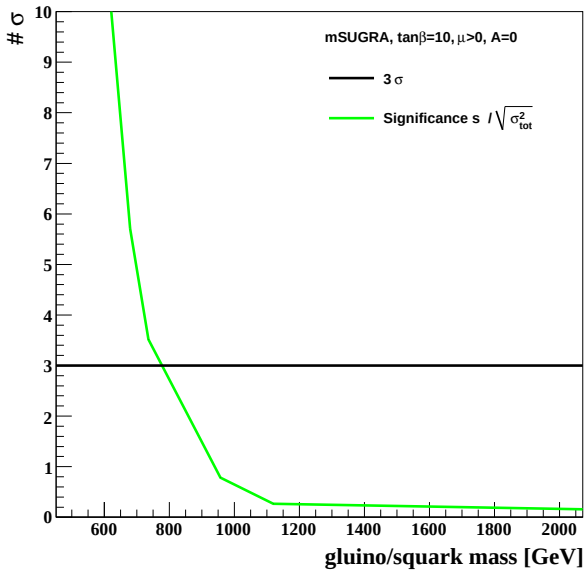
From one-bin histogram (counting experiment) with all systematic uncertainties.

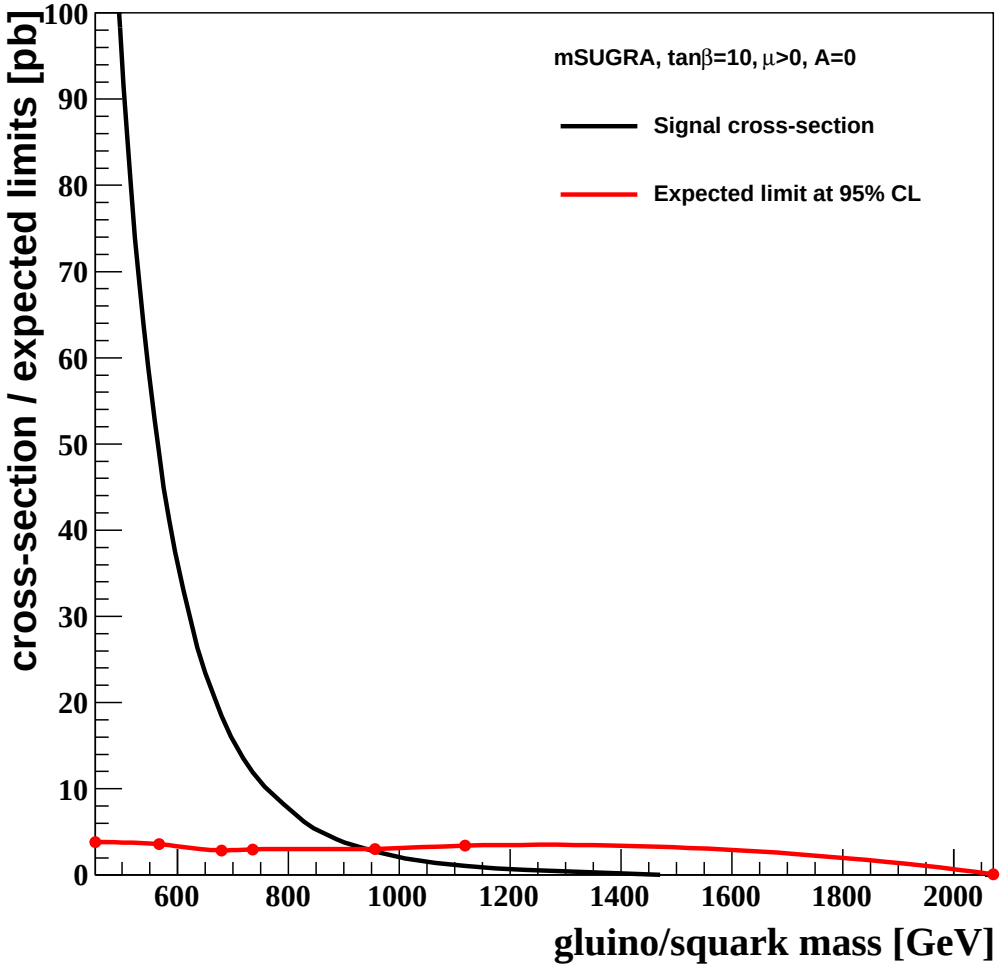




Cross-section limits vs. gluino mass (14 TeV)

From one-bin histogram (counting experiment) with all systematic uncertainties.





Overview

- RA2 Selection
- CLs
- Conclusion

Conclusion

Summary

- ...
- Need more Signal MC points for better scans