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# Search for Gauge-mediated breaking SUSY with photons

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**Abstract**

We present the search for the Gauge-mediated breaking SUSY in the $\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma$ decay in the context of the 2007 Analysis efforts.The note details the readiness of the analysis components including Monte Carlo generation for signal, optimized signal selection criteria, definition of control samples to estimate background from data, and the definition of the skims using High Level Trigger (HLT) information.

# Contents

# 1 Introduction

General introduction to be added from Francesco's thesis (Brad, Sh)

In Gauge mediated minimal super symmetric models (GMSB) where R parity is conserved the neutralino ($\tilde{X}_1^0$) fills the role of next to least massive (NLSP) supersymmetric particle which then decays to gravitino ($\tilde{G}$) plus photon. Here the gravitino would be the least massive supersymmetric particle (LSP) and a prime candidate for dark matter. Therefore, it is critical to have a strategy to search in the 14 TeV proton interactions at the LHC for neutralino decays.

In simulating neutralino production we have assumed a GMSB model with parameters given in Table 1 below in which pairs of gluinos ($\tilde{g}$) are produced in proton proton interactions followed by decays chains that result in two(or more) neutrinos in the final state.

| Parameter | Value |
|---|---|
| $\Lambda$ | 140 GeV |
| $M_{messenger}$ | $2\Lambda$ |
| tan$\beta$ | 15 |
| $N_{messenger}$ | 1 |
| sgn($\mu$) | + |
| $C_{grav}$ | 1 |

Table 1: GMSB model parameters for $pp \rightarrow \tilde{g}\tilde{g}$ production

The cross section for the $pp \rightarrow \tilde{g}\tilde{g}$ process is $5.23 \times 10^{-11}$mb. The yields of signal events (and the background estimates) in the present study are based on an integrated luminosity of one $fb^{-1}$.

# 2 Monte Carlo Samples

(Bob)

The signal events were generated and simulated in CMSSW version 1.4.6 and reconstructed using CMSSW 1.6.4. The neutralino mass was 197 GeV/c$^2$. The lifetime of the neutralino mandated by this model is 0.06 mm so the decay of the neutralinos is "prompt". The topology of the neutralino events, given that each event will contain at least two neutralinos, is that of two photons that appear to come from the primary vertex plus missing $E_T$ (MET) (due to the two gravitinos which exit the CMS detector without interacting).

## 2.1 Validation of SLHA files

(Bob,Francesco) We might finally have a set of reliable files for generation. Once confirmed details will be added

### 2.1.1 Comparison between CMSSW and ORCA samples

(Robert)

Robert has plots comparing with Francesco's results. Will meet with him Thursday 18 Oct to incorporate his contribution

# 3 Trigger studies

We study the use of current HLT paths to

## 3.1 Monte Carlo samples

For this study we use a total of 2000 simulated events: 900 at GM1b, 800 at GM1c, and 300 at GM1d. Parameters of each working point are described in section 2.1. We intend to extend the studies also to GM1e and GM1g points as soon as new MC samples are available.

PreCSA07 samples are used to estimate the background rate and include

- QCD jets (all $p_T$ bin)

- Photon jets (all $p_T$ bin)
- $W \to e\nu$ and $Z \to ee$

For the moment, about 44000 events of QCD jets and 9000 events of photon jets are used for rate calculation. More background samples are being processed now.

## 3.2 Tools and method used

The study is being done under $CMSSW\_160$, and optimized for start-up luminosity of $10^{32} cm^{-2} s^{-1}$.

This analysis is focused on the validation of HLT paths for photons. Use and validation of the jets and MET HLT paths will be included in the near future.

### 3.2.1 HLT paths for photons

There are two types of $e\gamma$ cuts in the L1 trigger: isolated and non-isolated. The isolated cuts look for $e\gamma$ whose energy is more localized in the ECAL, whereas non-isolated cuts allow more spread.

There are 4 HLT paths for photons, which are Single photon (s), Relaxed Single photon (rs), Double photon (d), and Relaxed Double photon (rd). The two relaxed paths connect with non-isolated L1 seeds, and the other two (s and d) connect with isolated L1 seeds. Each HLT photon path includes mainly five modules:

- *L1Match*. Reconstructed super-cluster in the ECAL is required to match L1 energy deposit in some $\eta$ and $\phi$ windows.
- *Et*. Et of super-cluster in the ECAL is required to exceed a threshold.
- *IEcal*. ECAL isolation, total Et of all clusters with $\Delta R < 0.3$ around the photon candidate, excluding those belonging to the super-cluster itself.
- *IHcal*. HCAL isolation, total Et of hadron calorimeter towers with $\Delta R < 0.3$ around the photon candidate.
- *Itrack*. Track isolation, number of tracks with Pt>1.5GeV inside a cone $\Delta R < 0.3$ of photon candidate.

The four photon HLT paths together with the default thresholds of modules are listed in the table 2.

| | Single Photon | Relaxed Single Photon | Double Photon | Relaxed Double Photon |
|---|---|---|---|---|
| Et (GeV) | 30 | 40 | 20 | 20 |
| IEcal (GeV) | 1.5 | 1.5 | 2.5 | 2.5 |
| IHcal (Barrel)(GeV) | 6 | 6 | 8 | 8 |
| IHcal (Endcaps)(GeV) | 4 | 4 | 6 | 6 |
| Itrack | 1 | 1 | 3 | 3 |

Table 2: the 4 photon HLT paths and the default thresholds

### 3.2.2 HLT offline validation package

HLTriggerOffline/Egamma package is used for this study. The package reads in RAW data from an event, and runs electron and photon HLT paths without the default HLT modules (such as Et cut module, three isolation modules, etc. for photon paths), then save the HLT cut variables to the event for trigger study.

To save disk space and CPU, electron candidates are dropped. In addition, L1Match and Et cuts ($Et > 20GeV$) in HLTriggerOffline/Egamma are also applied.

### 3.2.3 Optimization of trigger thresholds

Figure 1 is a general distribution of Signal Efficiency vs. Rate. Now there is a question: how to optimize the trigger thresholds in the Efficiency vs. Rate figures in an objective way? As I know, there is no general and objective method till now to determine the trigger threshold. Usually the cuts are determined to give reasonable

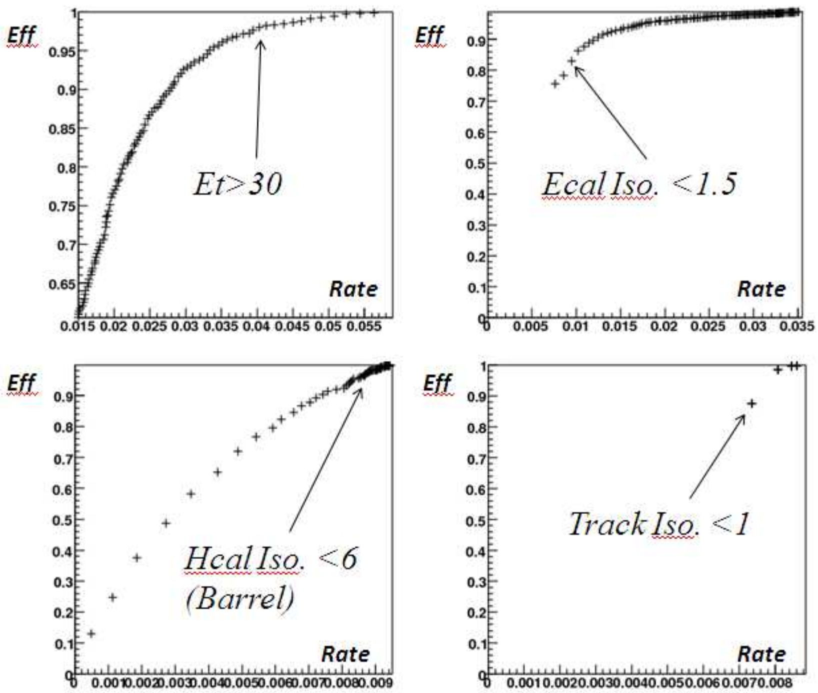


Figure 1: Signal Efficiency (photonic GMSB) vs. Rate in Single Photon Path. The four figures are plotted with different HLT variables: *Et, Ecal Iso., Hcal Iso,* and *Track Iso.*; the arrow points show the default thresholds.

values of efficiency and rate, but not in a mathematically objective way. The question is, with a definite resource (electronics, CPU, storage, etc), how can we record as much information as possible related to interesting physics? My thoughts are as follows,

- The information theory has been highly developed since it was first introduced by C. Shannon in 1948.
- Suppose we have $N_S$ signal events, $N_B$ background events. The amount of signal information can be defined as $log_2 N_S$ (or $-log_2(1/N_S)$) (see N. Wieners book).
- You can understand in this way: $N_S$ is number of messengers who take signal information, final physical results are the meaning of information taken by a sequence of such messengers. So the amount of information is $log_2 N_S$ .
- The above definition of information has the following property: $log_2(N_1 N_2) = log_2 N_1 + log_2 N_2$ , and its the only solution (with a variable constant) with such property.
- Suppose a trigger cut gives signal efficiency $\epsilon$ and background (or rate) efficiency $b$ ($0 < \epsilon,\ b \leq 1$). The signal information after this trigger cut is $log_2(N_S \epsilon)$; the background information after this trigger cut is $log_2(N_B b)$.
- *Our aim is*: with a definite resource, make $log_2 \epsilon / log_2 b$ as small as possible ($log_2$ can also be $log_{10}$ or $log_e$).
- We can plot $log(\epsilon)/log(b)$ vs. trigger cut variables and choose the minimum point as the trigger threshold. There are two ways to do this: *1)* Global optimization: $(\sum log\epsilon_i)/(\sum log b_i)$ is a function with multiple variables (each variable is a trigger cut), we minimize it globally in an ACCEPTED efficiency-rate region ($\epsilon = \prod \epsilon_i,\ b = \prod b_i$). *2)* Step optimization: For each $a_i = log(\epsilon_i)/log(b_i)$ , we get a minimum point $a_i^{min}$; suppose $a_1^{min} < a_2^{min} < a_3^{min} < \ldots$; if finally we are not satisfied with efficiency (too small), we can loose $a_k$, drop $a_k$, loose $a_{k-1}$, drop $a_{k-1}$, ..., until we are satisfied with efficiency; or if we are not satisfied with rate (too large), we can vary $a_1$ from $a_1^{min}$ up to $a_2^{min}$, or vary $a_1 = a_2$ from $a_2^{min}$ up to $a_3^{min}$, ..., until we are satisfied with rate.
- Figure 2 show a plot which can compare with the plot of efficiency vs. rate. Since $log(\epsilon)/log(b) < a \Longrightarrow \epsilon > b^a$ $(0 < \epsilon,\ b,\ a \leq 1)$.

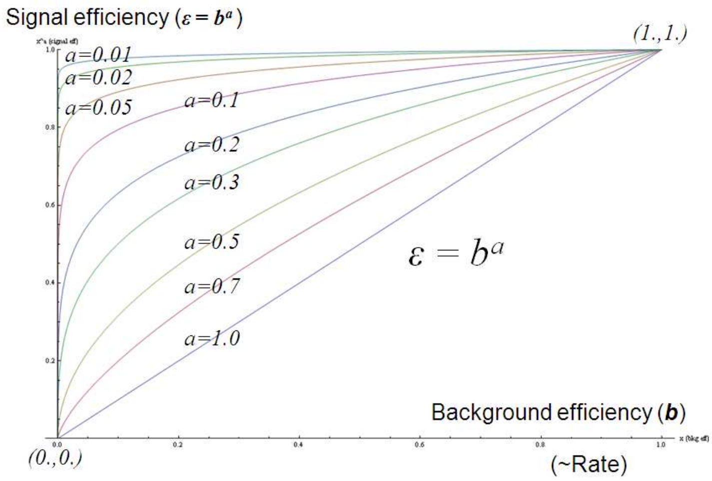


Figure 2: Functions of $\epsilon = b^a$ , $a$ is a parameter.

#### 3.2.4 Optimizing number of background events for rate calculation

The question here is: how many events in each background samples do we need to process in the rate calculation.

- Suppose the $i$-th sample has cross section $\sigma_i$ ; with a definite integrated luminosity there will be $N_i$ events of $i$-th sample ; with some cuts we will select $k_i$ events; efficiency of cuts on the $i$-th sample is $\epsilon_i = k_i/N_i$.
- Both $k_i$ and $N_i$ are Poisson distribution, and independent, so error of $\epsilon_i$ is $\sigma(\epsilon_i) = \sqrt{\epsilon_i(1+\epsilon_i)/N_i}$. With instant luminosity $L$, rate of $i$-th sample is $L\sigma_i\epsilon_i$, with an error of $L\sigma_i\sigma(\epsilon_i)$.
- To keep a small error of total rate and reduce the number of events to process, we require $L\sigma_i\sigma(\epsilon_i) = L\sigma_j\sigma(\epsilon_j)$, so $N_i/N_j = (\sigma_i/\sigma_j)^2[\epsilon_i(1+\epsilon_i)]/[\epsilon_j(1+\epsilon_j)]$.
- Process the $i$-th sample with small number of events (finally needs to select $\sim 100$ events, so the relative error of $\epsilon_i$ is $\sim 10\%$); roughly determine the efficiency $\epsilon_i$ with all default HLT paths will use. Then get the ratio of $N_i/N_j$.

This method is difficult to apply in reality since $N_i/N_j$ may be very large if $\sigma_i/\sigma_j$ is large. We do not have so many events for the large cross-section samples, and we also do not want to waste much CPU on such samples. So usually the large cross-section samples give almost the whole contribution to the error of total rate, and we can ignore the error contributions from small cross-section samples. We have definite number of events for large cross-section samples; using them we can get the error of rate; if the *rate contribution* (not error of rate contribution) from a sample (usually has small cross-section) is much less than above error of rate, we can ignore such a sample in rate calculation.

So usually for the large cross-section samples we need to process a large amount of events. For the small cross-section samples we need to process enough to get a relative accurate efficiency.

### 3.3 Efficiency and rate for signal and background samples

### 3.4 Optimize the HLT photon paths

Figure 8, 9,10, and 11 show the distributions of $log(\epsilon)/log(b)$ vs. HLT variables in the 4 photon HLT paths. Where $\epsilon$ is signal efficiency, $b$ is rate efficiency. The $log(\epsilon)/log(b)$ will play an important role in my method to optimize the trigger thresholds. As introduced above, the smaller $log(\epsilon)/log(b)$, the better.

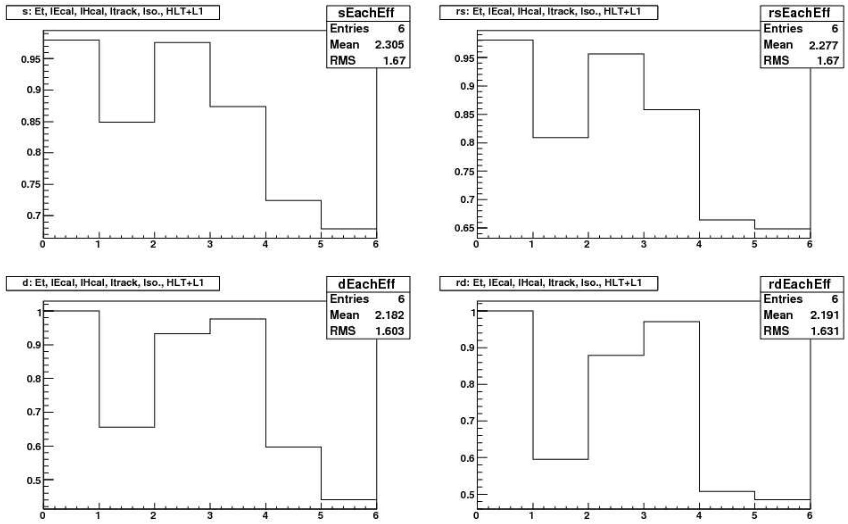


Figure 3: Signal efficiency for each trigger path, and each module in the path. Upper left is single photon path, upper right is relaxed single photon path, down left is double photon path, and down right is relaxed double photon path. The histogram bins from left to right are efficiency of Et, Ecal Iso., Hcal Iso., track Iso., all Iso. together, and HLT+L1 together. The Iso. efficiency are 72.4%, 66.4%, 59.7%, and 50.8% for the 4 pathes separately; the HLT+L1 efficiency are 67.9%, 64.9%, 44.1%, and 48.5% for the 4 pathes separately.

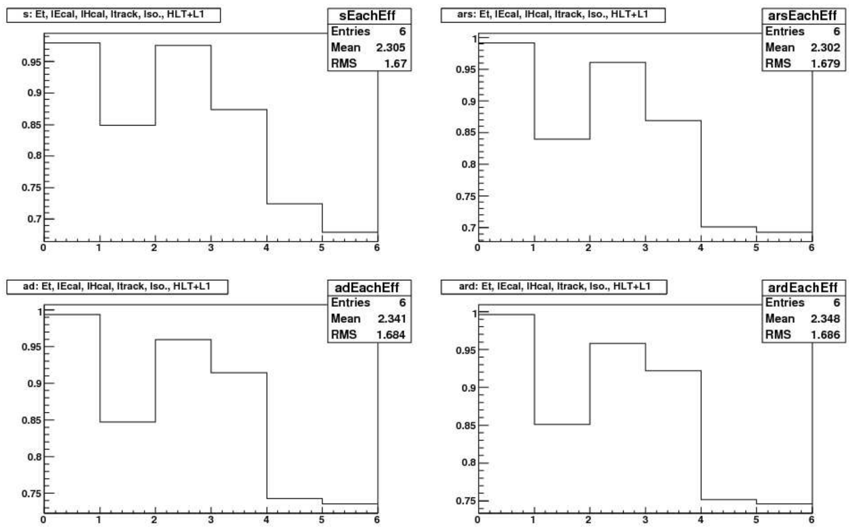


Figure 4: Signal efficiency for multiple photon paths and each module in the paths. Upper left is S (single) photon path, upper right is S or RS (relaxed single) photon path, down left is S or RS or D (double) photon path, and down right is S or RS or D or RD (relaxed double) photon path. The histogram bins have the same meaning as above figure. The Iso. efficiency are 72.4%, 70.1%, 74.3%, and 75.2% for the 4 figures separately; the HLT+L1 efficiency are 67.9%, 69.3%, 73.6%, and 74.6% for the 4 figures separately.

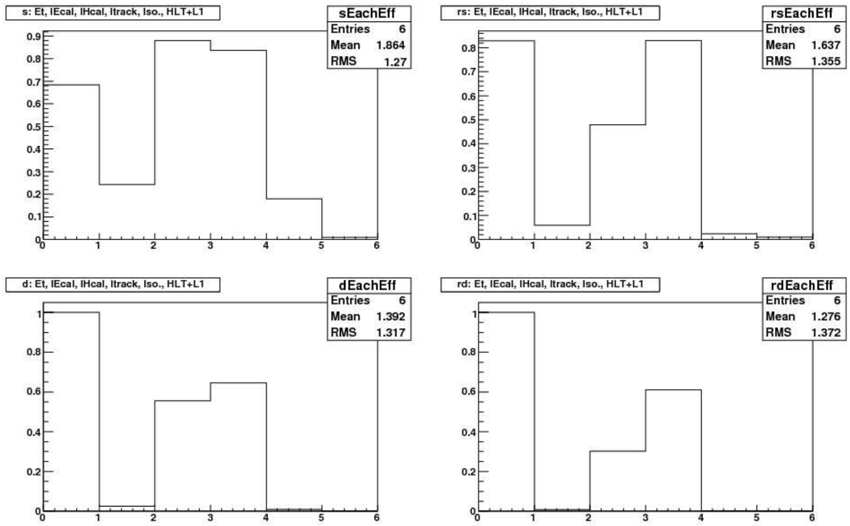


Figure 5: Background efficiency (or rate efficiency) for each photon path, and each module in the path. The Iso. efficiency are 17.9%, 2.4%, 0.93%, and 0.15% for the 4 pathes separately; the HLT+L1 efficiency are 0.99%, 1.01%, 0.01%, and 0.03% for the 4 pathes separately.

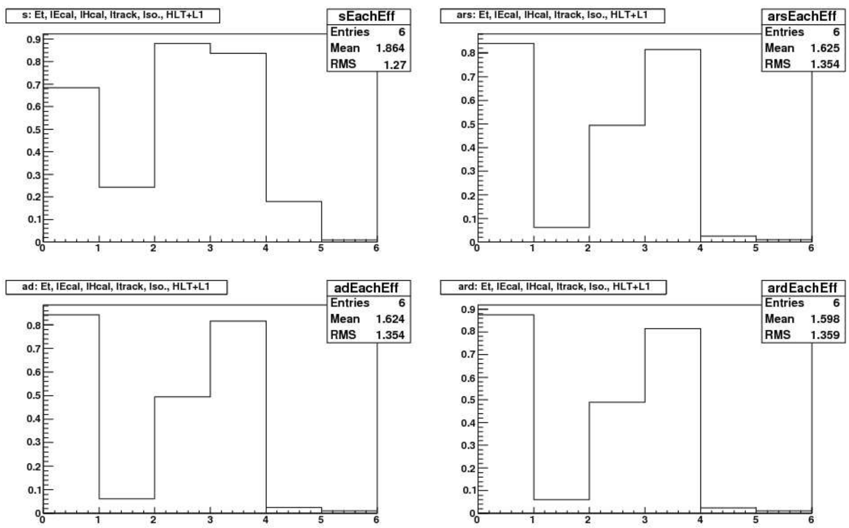


Figure 6: Background efficiency (or rate efficiency) for multiple photon paths, and each module in the paths. The Iso. efficiency are 17.9%, 2.5%, 2.5%, and 2.4% for the 4 figures separately; the HLT+L1 efficiency are 0.99%, 1.09%, 1.09%, and 1.10% for the 4 figures separately.

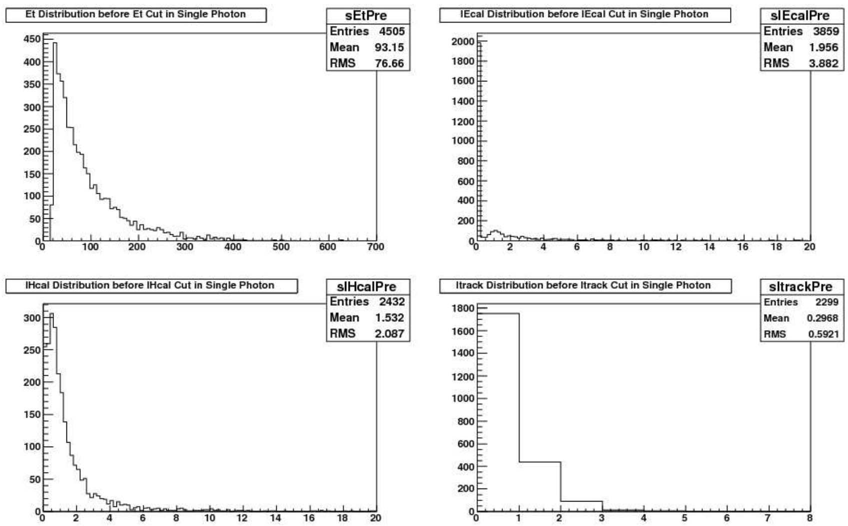


Figure 7: Distributions of HLT variables in single photon path before applying the relative cut. Upper left is Et, upper right is Ecal iso., down left is Hcal Iso., down right is track iso.

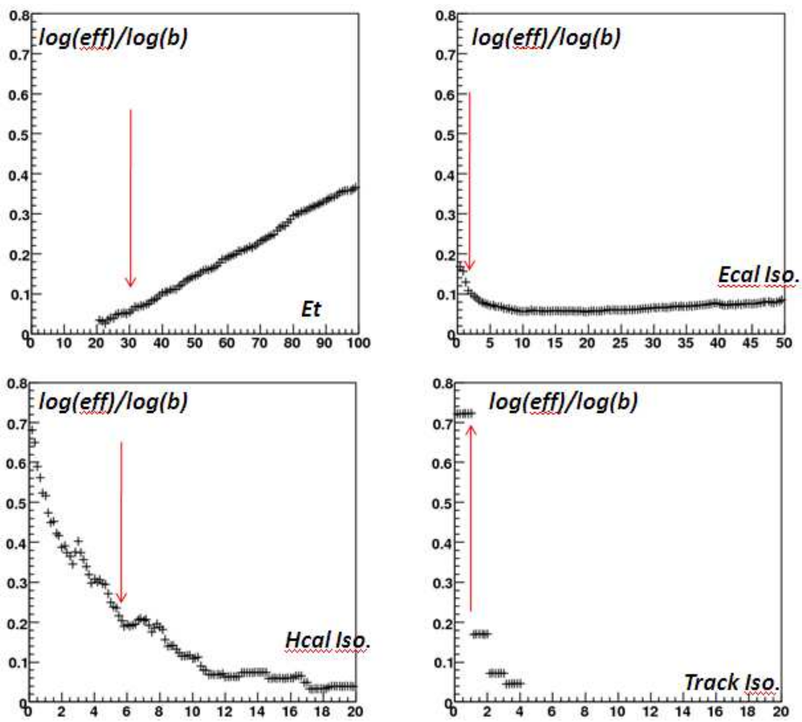


Figure 8: $log(\epsilon)/log(b)$ vs. HLT variables in single photon path. $\epsilon$ is signal efficiency, $b$ is rate efficiency. Upper left is $log(\epsilon)/log(b)$ vs. $Et$, upper right is $log(\epsilon)/log(b)$ vs. $EcalIso.$, down left is $log(\epsilon)/log(b)$ vs. $HcalIso.$, and down right is $log(\epsilon)/log(b)$ vs. $trackIso.$. The red arrows are the default thresholds.

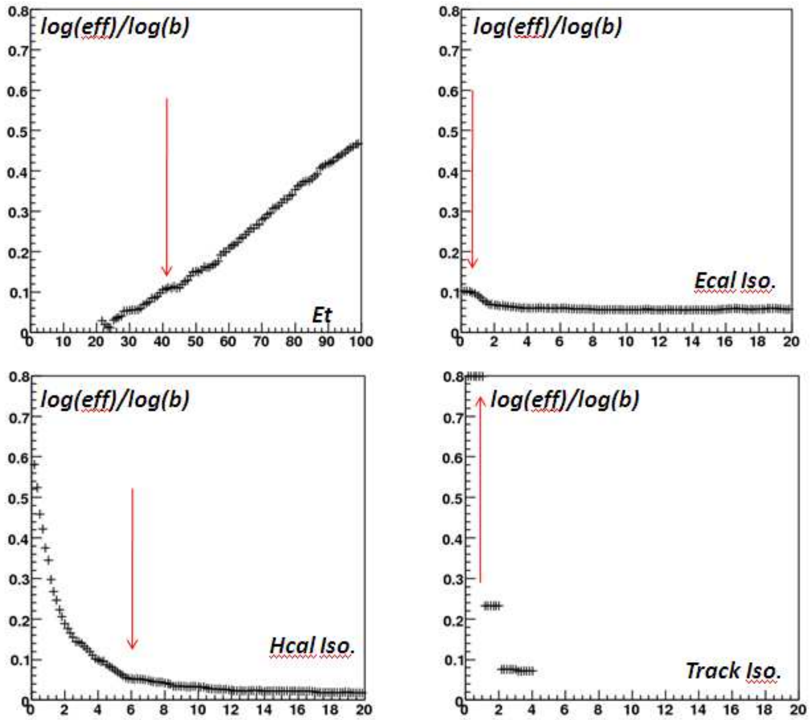


Figure 9: $log(\epsilon)/log(b)$ vs. HLT variables in relaxed single photon path.

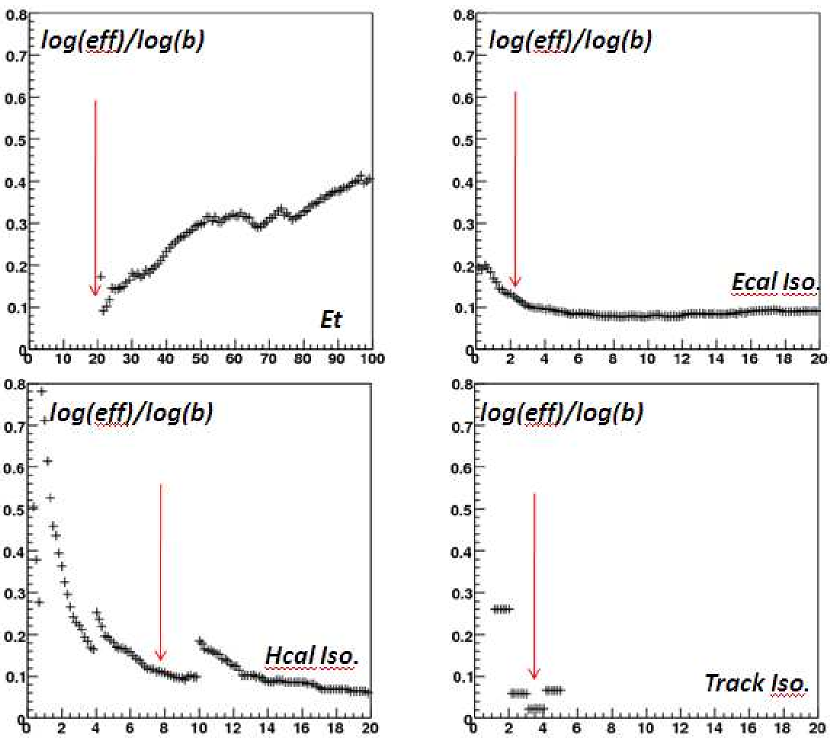


Figure 10: $log(\epsilon)/log(b)$ vs. HLT variables in double photon path

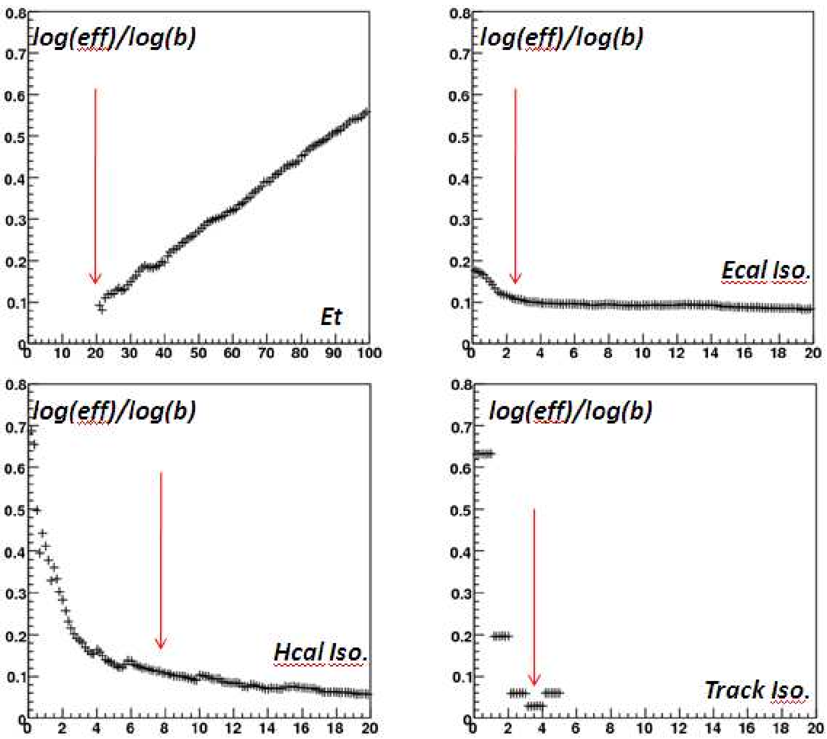


Figure 11: $log(\epsilon)/log(b)$ vs. HLT variables in relaxed double photon path

# 4 GMSB Skims

(Bernadette, Daniele)

Skims are used to reduce the primary datasets in subsamples to be processed by the analyzers. The basic idea is to have a reasonably small number of events as input to analysis code so that they can be reprocessed in a short time. There are two different levels of skims:

- secondary skims, which are quite general and based on simple cuts on reconstructed physics objects. The input is represented by the primary datasets and the output is sent to the T2 centers. The production of secondary skims is part of the CMS production.
- tertiary skims, which select events using analysis dependent selection criteria. They are run on secondary skims and produce a sample of small root files used to perform the final analysis. They should be run by users.

The definition of the secondary skim for the SUSYBSM analyzes is still in progress. There are two possible options, one is is based on the "or" of all HLT bits related to photons and electrons, and the other one is the "or" of all the SUSYBSM tertiary skims which use em objects.

We implemented two tertiary skims devoted to the GMSB analysis with photons which are detailed below.

## 4.1 HLT paths

The first skim (SUSYHighPtPhoton) selects a GMSB signal-enriched sample, while the other one (SUSYControl-HighPtPhoton) selects the control sample needed to get the MET shape of the EW background. The two skims have a similar selection except for the request of an electron instead of a photon.

**SUSYHighPtPhoton** The selection starts with a requirement on the HLT bits, represented by the "or" of the following bits: HLT1PhotonRelaxed, HLT2PhotonRelaxed, HLT1Photon, HLT2Photon. Then a cut on the minimum $p_T$ of the first and second highest $p_T$ photon is applied. Here photons correspond to the reconstructed collection called $photons$. The skim includes the possibility to apply isolation criteria on the reconstructed photons. The isolation is based on tracking and it requires that the sum of the $p_T$ of all tracks ($ctfWithMaterialTracks$) in a $\Delta R < 0.2$ cone is below 9GeV.

**SUSYControlHighPtPhoton** Events are preselected using the HLT1Electron bit. Then, the selection criteria are identical to the SUSYHighPtPhotonSkim case except that the most energetic photon is replaced by an electron ($pixelMatchGsfElectrons$ reconstructed collection).

## 4.2 Performance

A preliminary check of the performances of the skim selection have been done using a sample of 800 GMSB events simulated with release CMSSW_1_3_1 and reconstructed with CMSSW_1_6_0_pre9. The events have been generated with the parameters detailed in Table 3. We studied the selection efficiencies varying the different cuts ($pT_1$, $pT_2$, and isolation) and switching on and off the HLT bit selection. As an example, Fig. 12 shows the efficiency of the SUSYHighPtPhoton skim as a function of the threshold on the $p_T$ of the first photon with no isolation applied. Results are in agreement with the ones obtained with the ORCA based analysis. Most of the inefficiency is due to the HLT selection and deserves a more in-depth analysis of the HLT trigger.

The skim selection was also run on a number of RelVal145 samples processed with CMSSW_1_6_0. As expected efficiencies are very low ($< 0.0047$) for all of these background samples. More detailed studies will be performed when large background samples will be available.

## 4.3 Selection criteria in CSA07

We set the default cuts for the skims as: $pT_1 = 80GeV$, $pT_2 = 20GeV$. From the study of the skim efficiency detailed above and in comparison with previous ORCA analysis, these criteria look sufficiently loose. We decided to turn off the cut on isolation, given that this variable is very sensitive to pile-up and backgrounds and needs to be further investigated. A summary of the final selection criteria is detailed in Table 4.

| GMSB Event Sample Parameter Values | |
|---|---|
| $\Lambda\ (TeV)$ | 100 |
| $Mm\ (Tev)$ | $2\Lambda$ |
| $Nm$ | 1 |
| $tan\beta$ | 15 |
| $sign\mu$ | $+1$ |
| $C_grav$ | 1 |
| NLSP | neutralino |
| $M_NLSP\ (GeV)$ | 138.8 |
| $\Gamma_NLSP\ (GeV)$ | $2.0 \cdot 10^{-12}$ |
| $c\tau_NLSP\ (mm)$ | 0.10 |

Table 3: Parameters used to generate the GMSB sample used in skim selection efficiency studies.

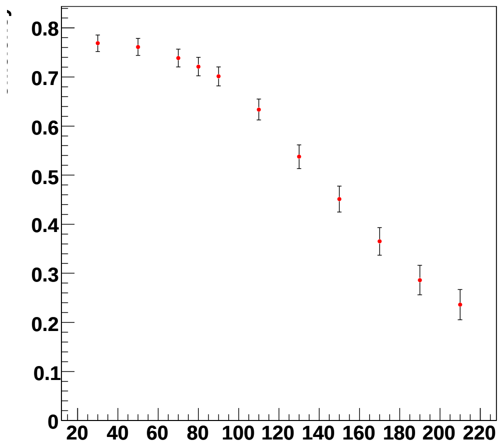


Figure 12: Skim efficiency as a function of the $p_T$ cut on the highest $p_T$ photon with no isolation applied.

| Cut | SUSYHighPtPhoton | SUSYControlHighPtPhoton |
|---|---|---|
| HLT Bits | HLT1Photon<br>HLT2Photon<br>HLT1PhotonRelaxed<br>HLT2PhotonRelaxed | HLT1Electron |
| Minimum pT | $pT_1(\gamma) = 80GeV$<br>$pT_2(\gamma) = 20GeV$ | $pT_1(e^+) = 80GeV$<br>$pT_1(\gamma) = 20GeV$ |
| IsolationCut | OFF<br>(When on, $\Delta R < 0.2$ and $\Sigma p_T = 9GeV$) | OFF<br>(When on, $\Delta R < 0.2$ and $\Sigma p_T = 9GeV$) |

Table 4: Summary of the skim selection criteria

# 5 Analysis technique

(Brad, Shahram?) Overview of analysis strategy to be added from Francesco's analysis

Brad has provided first draft of analysis section

## 5.1 Selection criteria

The physics cuts applied to select signal events that are due to double neutralino decay to gravitino + photon decays are shown in Table 5 (no high level trigger was applied to these events since no high level trigger was available for the background Monte Carlo).

| Photon Level Cut | Cut if |
|---|---|
| photon proximity to $e^{\pm}$ | within $\Delta$R$\leq$0.1 |
| HCAL/ECAL Ratio | $\geq$0.1 |
| $\Sigma p_T$ tracks | sum $\geq$9 GeV/c inside $\Delta$R=0.3 |
| Event Level Cut | Cut if |
| highest photon $p_T$ | $\leq$ 90 GeV/c |
| second highest photon $p_T$ | $\leq$ 30 GeV/c |
| missing $E_T$ | No cut yet |
| $\eta$ | barrel only or barrel plus endcap |

Table 5: Physics Cuts on neutralino events

The efficiency for retention of signal events with these cuts is 47.6% for the barrel only and 54.1% for the barrel plus endcaps. This yields 25 events using the barrel only and 28 events using both barrel and endcaps accumulated in a one $fb^{-1}$ integrated luminosity run.

While the cuts described in Table 5 are efficient in collecting neutralino decays, a second level of study will be necessary to correctly determine which photons in the neutralino events are associated with the neutralino decays to gravitinos. The percentage of selected neutralino events in this sample where one or both photons do not belong to the neutralino decay is 60% for the barrel alone and 58% for the barrel plus endcap.

## 5.2 Control samples for background estimate

describe the method tested in ORCA (Shahram?)

## 5.3 Electroweak control sample

(Brad)

The major electroweak background studied so far is the inclusive production and decay of $W^{\pm} \rightarrow e^{\pm}\nu$. The background was obtained from a set of Monte Carlo simulations in bands of $p_t$ given in Table 6 given below. These events were generated in CMSSW 1.3.1 and reconstructed in CMSSW 1.3.3 (with the electron and endcap asymmetry fixes and no high level trigger applied). Also included in Table 6 are the cross sections per band, the number of generated events, the number of events surviving skim and physics cuts and the net efficiency for each band. See Table 7 for a list of the skim cuts and refer back to Table 5 for the physics cuts, the same cuts as were applied to the neutralino signal events. These yields include the endcaps.

The overall cross section for the electroweak background is $2.53 \times 10^{-7}$ mb for the $p_T$ region 80 to infinity. The overall efficiency for events in this $p_T$ region is 3.6/

In Figs. 13, 14, and 15 are shown the properly normalized $p_T$ of the highest and second highest photons and the missing $E_T$ of the signal neutralino decays as well as the electroweak background. The first plot in each figure shows the distributions for the barrel ECAL only while the second plot shows the entire ECAL detector both barrel and endcap. As can be seen, the signal only begins to be comparable to the electroweak background when the $p_T$ of the leading photon is greater than 350 GeV/c. A less demanding criterion for selecting neutralino events is when the missing $p_T$ exceeds 200 GeV/c.

## 5.4 Ideas for a QCD control sample

Work still has to be done here, pending availability of QCD samples

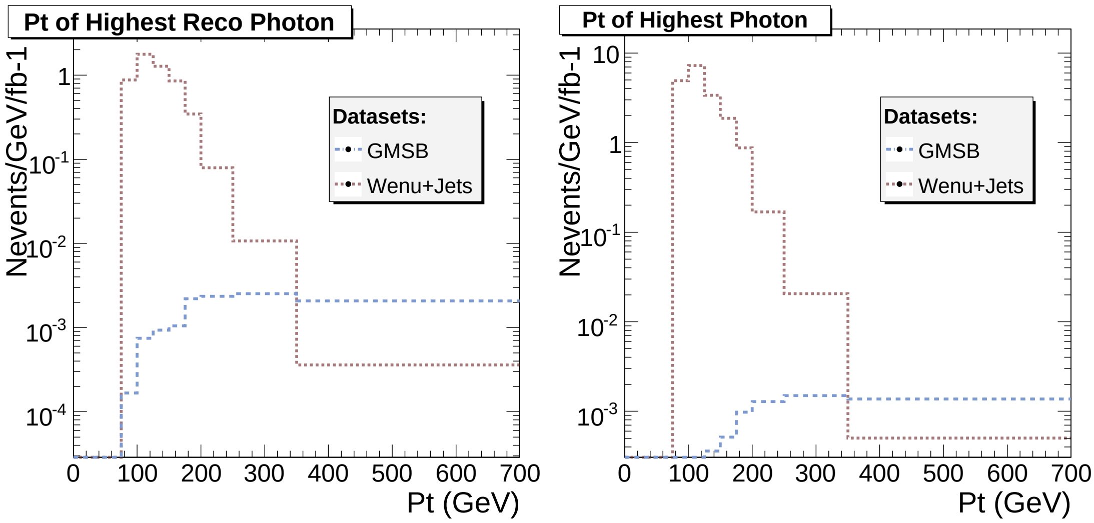


Figure 13: $p_T$ distribution of the highest photon a)no endcap b)with endcap

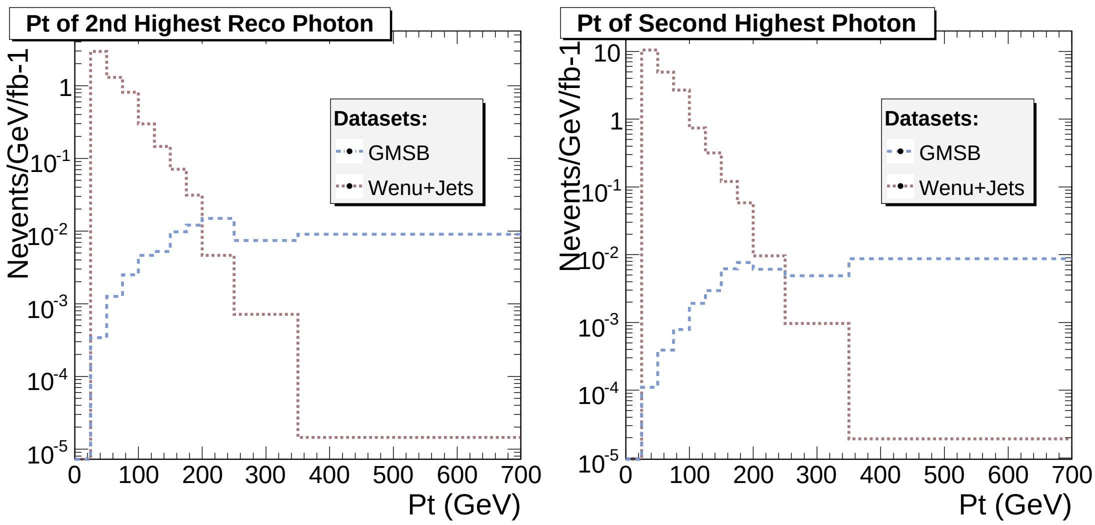


Figure 14: $p_T$ distribution of the second highest photon a)no endcap b) with endcap

| $p_T$ GeV/c | Cross Section | generated events | after skim | after phys cuts | eff. % |
|---|---|---|---|---|---|
| 80-120 | $1.53 \times 10^{-7}$ | 27117 | 461 | 79 | 0.29 |
| 120-170 | $6.96 \times 10^{-8}$ | 25000 | 751 | 287 | 0.35 |
| 170-230 | $2.03 \times 10^{-8}$ | 25000 | 1095 | 509 | 2.04 |
| 230-300 | $6.23 \times 10^{-9}$ | 26899 | 1436 | 716 | 2.66 |
| 300-380 | $2.03 \times 10^{-9}$ | 26000 | 1637 | 918 | 3.53 |
| 380-470 | $7.05 \times 10^{-10}$ | 25867 | 1895 | 1176 | 4.55 |
| 470-600 | $2.95 \times 10^{-10}$ | 26963 | 2059 | 1346 | 4.99 |
| 600-800 | $1.01 \times 10^{-10}$ | 12959 | 988 | 717 | 5.53 |
| 800-1000 | $2.00 \times 10^{-11}$ | 15255 | 1239 | 939 | 6.16 |
| 1000-1400 | $6.63 \times 10^{-12}$ | 16410 | 1354 | 1020 | 6.22 |
| 1400-1800 | $6.66 \times 10^{-13}$ | 15070 | 1092 | 805 | 5.34 |
| 1800-2200 | $8.69 \times 10^{-14}$ | 15255 | 1100 | 809 | 5.30 |
| 2200-2600 | $1.28 \times 10^{-14}$ | 15122 | 892 | 639 | 4.20 |
| 2600-3000 | $1.95 \times 10^{-15}$ | 12959 | 663 | 466 | 3.60 |
| 3000-3500 | $3.17 \times 10^{-16}$ | 13500 | 583 | 384 | 2.84 |
| 3500- | $2.91 \times 10^{-17}$ | 13000 | 505 | 347 | 2.67 |

Table 6: $W \to e\nu$ background events/efficiencies in $p_T$ bands

| Photon Level Cut | Cut if |
|---|---|
| photon proximity to $e^{\pm}$ | within $\Delta$R$\leq$0.3 |
| HCAL/ECAL Ratio | $\geq$0.1 |
| $\Sigma p_T$ tracks | sum $\geq$10 GeV/c inside $\Delta$R=0.3 |
| Event Level Cut | Cut if |
| highest photon $p_T$ | $\leq$ 50 GeV/c |

Table 7: Skim cuts on electroweak background events (inclusive $W \to e\nu$ events)

### 5.5 Determination of signal yield with likelihood fit

Likelihood fit method from Francesco to be described here (Shahram?)

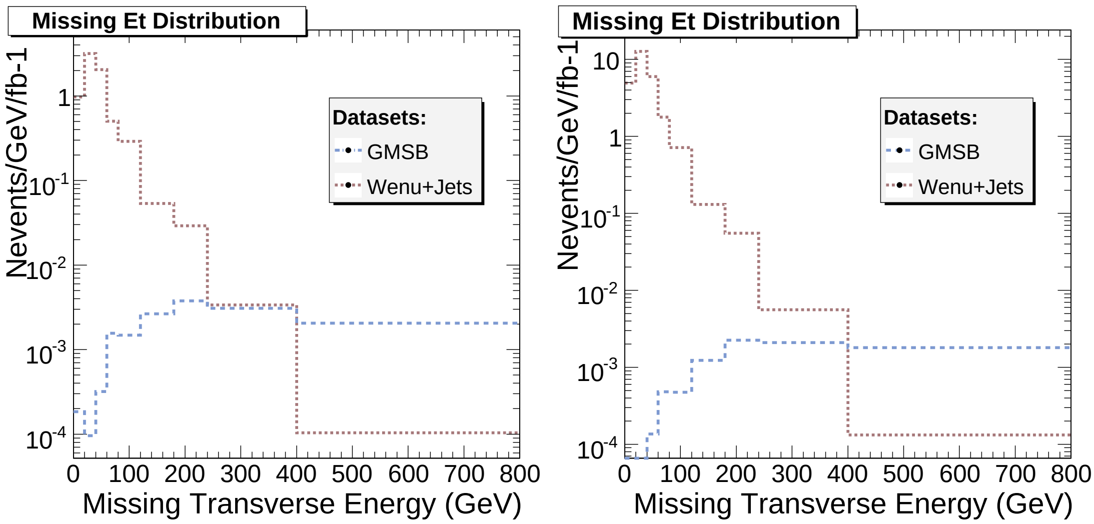


Figure 15: a) Missing $E_T$ a)no endcap b)with endcap

# 6 First data scenarios

## 6.1 10 $pb^{-1}$

## 6.2 100 $pb^{-1}$

# 7 Conclusions

# A Release and tags used in this analysis

# References