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Calorimeter Depth and Dijet Leakage into the Gluino Signal

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Introduction

A calorimeter of finite depth will necessarily generate a spurious missing energy signal due to leakage fluctuations in the amount of energy deposited in the calorimeter. Depending on the magnitude of the leakage, the spurious missing Et cross section so generated may swamp the real signal due to neutrinos from various topologically similiar processes. A familiar example is gluino production which is topologically similiar to QCD jet production. Thus, if the detector leaks badly, a spurious gluino signal will be generated.

The cross section at the SSC (40 TeV cm energy) is shown in Fig.1 for multijet production. A simple gluon-gluon fusion Monte Carlo was written to model the dijet process, which is in good agreement with the dijet mass distribution which more sophisticated models predict. The dijet mass predicted by the model, as seen in Fig.1 is in fact a good representation of the expected cross section.

Leakage vs Depth and Energy

Leakage estimates were made using data taken in calibration hadron beam test runs with thick neutrino detectors. [1] The data for 450 GeV incident hadrons is shown in Fig.2. The three data sets correspond to the offline software truncation of the real calorimeter to 6, 8, and 10 nuclear interaction lengths. Note the very long tails where a large fraction of the incident energy is not sampled in the truncated calorimeters. A rough representation of the energy leakage is given as;

$$E/Ein = f \qquad (1)$$
$$N(f) = \exp(-f/fo).$$

In this equation f is the containment fraction, or the fraction of incident energy Ein seen in the calorimeter. As seen in Fig.2, the distribution in f can be taken to be exponential, with a characteristic containment fraction fo.

$$fo = 0.3*\ln(Ein)*\exp(-lambda/2.2) \qquad (2)$$

Note that each 2.2 interaction length increase in thickness results in a factor of e decrease in the containment fraction. Clearly, as seen in Fig.2, a 6 lambda calorimeter will leak 20% of the incident energy ~ 10% of the time, while for a 10 lambda calorimeter the fraction is ~ 4%.

The energy dependence was estimated using a parametrization [2] of hadron data. The motivation for the logarathmic dependence is simply the well known fact that hadron showers have a total length with this dependence. Results of the model, which underestimates the leakage somewhat, are shown in Fig.3 for an 8 lambda calorimeter with 100 GeV and 800 GeV incident hadrons. * This parametrized single particle leakage was then used in subsequent evaluation of jet leakage.

Missing Et in Dijets vs Gluino Production

Dijet events were generated, as illustrated in Fig.1. The jets were then allowed to fragment using a parametrized fragmentation function, which is a reasonable representation of that observed in hadron collider jet data.

$$zD(z) = (1-z) ** 5 \qquad (3)$$

The jet was fragmented by choosing z out of the distribution D(z) with z between 1 and Mpie/PtJ. Fragments were chosen until the sum of the z of the fragments was = 1. Typically, a 2 TeV dijet had a jet multiplicity of about 50 for each jet. Most of the jet fragments are quite soft, and do not contribute substantially to the leakage energy. It is the fragments arising from hard fragmentation fluctuations which lead to large spurious missing Et backgrounds.

The jet fragments were then incident on a calorimeter of fixed depth. The containment fraction f for each fragment was chosen from an exponential distribution, with fo as given in Eq.2. An example of the correlation between PtJ and missing Et for an 8 lambda calorimeter is shown in Fig.4. Note that missing energies in excess of 400 GeV occur, albeit rarely. The distribution of missing Et for the MJJ > 2 TeV dijets incident on 6 and 8 lambda calorimeters is shown in Fig.5. Note that the mean of the distribution has shifted significantly lower in adding only 2 lambda to the depth of the calorimeter.

The Physics at issue is the production of gluinos, which leads to a sizable missing Et signal. The cross section at the SSC, [3], for a 300 GeV and a 500 GeV gluino is shown in Fig.6 (10**33/(cm*cm*sec) design luminosity, 10**7 sec/year of running). Also shown are the spurious cross sections for missing Et induced by a 6 and a 10 lambda calorimeter. Clearly, the 10 lambda detector can detect these low mass gluinos, while a 6 lambda detector must resort to other topological cuts, assuming that they are indeed available. Clearly, gluino detection is rather more gracefully performed in the case of a 10 lambda calorimeter.

In fact, a study of high mass dijet mass resolution, [4], led to a similiar depth criterion. That depth was adopted by the SDC collaboration as a prudent total depth [3].

References

1. Andy Beretvas, private communication

2. HF data, NIM paper

4. DRG - note on depth requirements

3. SDC TDR

Figure Captions

Figure 1. Jet mass distribution predicted at the SSC collider. The discrete points (*) are generated by the simple model described in the text, normalized to the dijet cross section at 2 TeV mass.

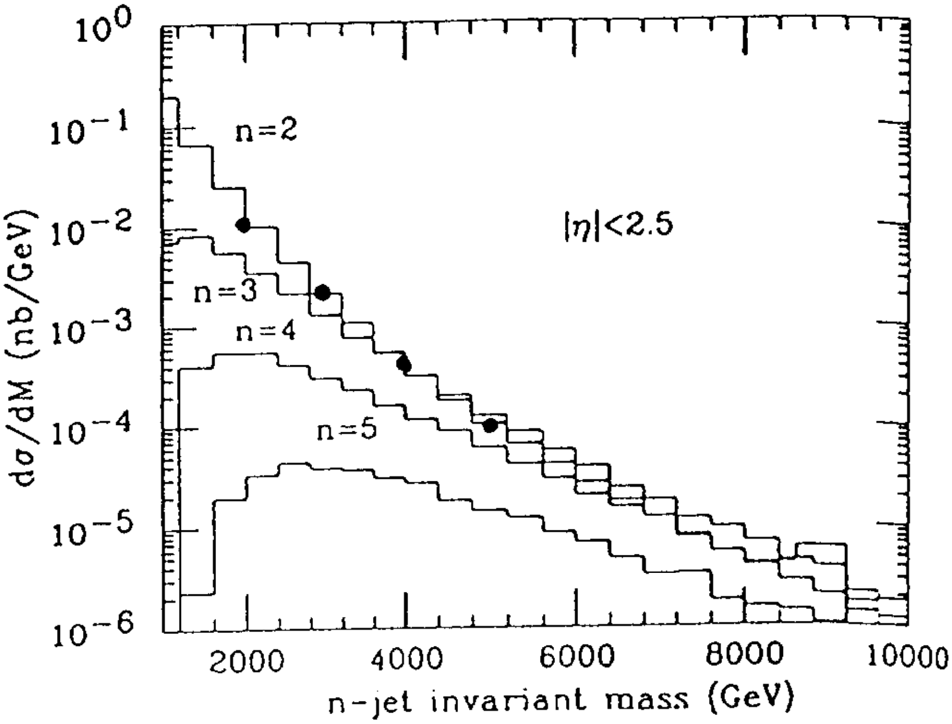
Figure 2. Distribution of energy containment fraction f for 450 GeV pions incident on a very deep calorimeter. The curves are the distribution of points for artificial truncation of the calorimeter at 6, 8, and 10 interaction lengths.

Figure 3. Distribution of energy containment fraction at a fixed depth of 8 interaction lengths and 2 incident energies, 100 and 800 GeV. The points are generated using a parametrized model for the hadronic shower development, then smearing the initial interaction point and the effective neutral energy fraction in the cascade.

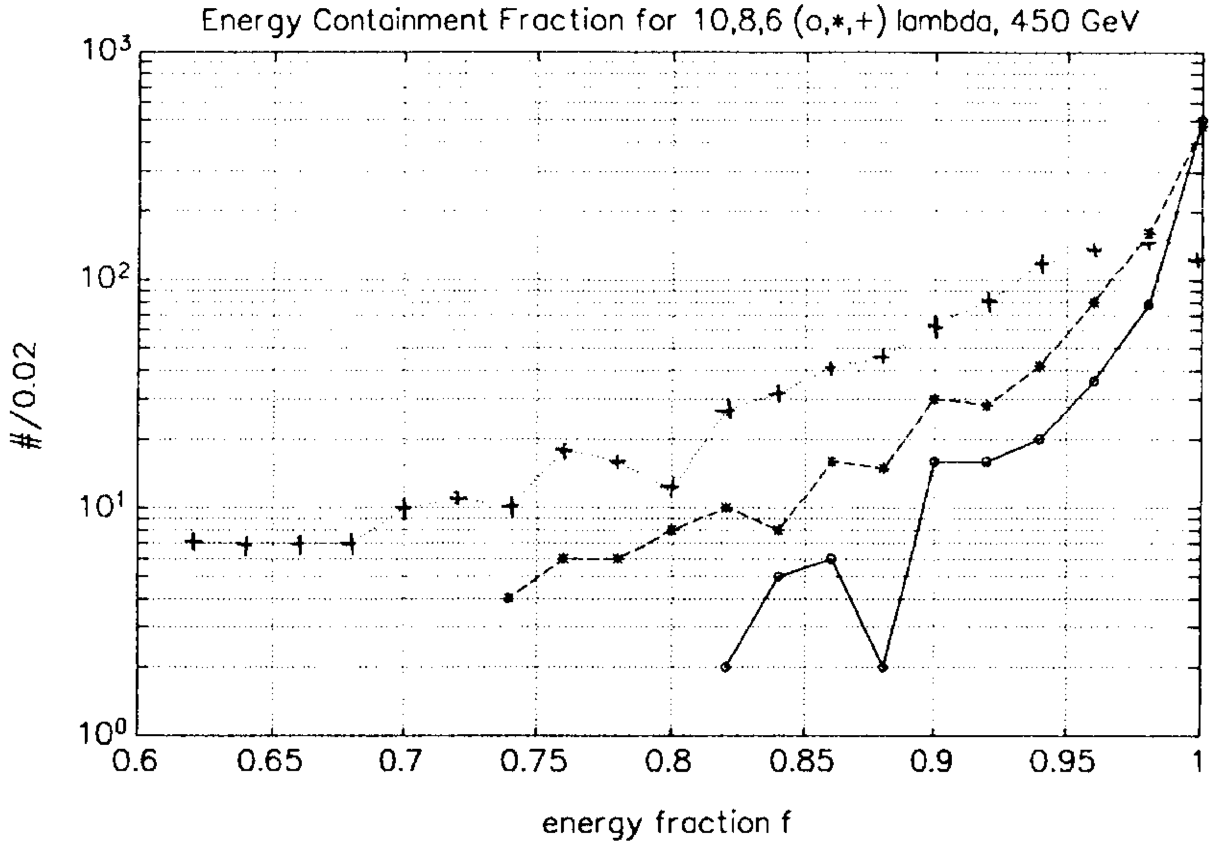
Figure 4. Correlation between the jet transverse energy, PtJ, in a dijet event and the missing transverse energy, Et , due to leakage of both jets for a 8 interaction length calorimeter.

Figure 5. Distribution of missing energy due to leakage of dijet events with MJJ > 2 TeV.
a. A 6 interaction length calorimeter.
b. A 8 interaction length calorimeter.

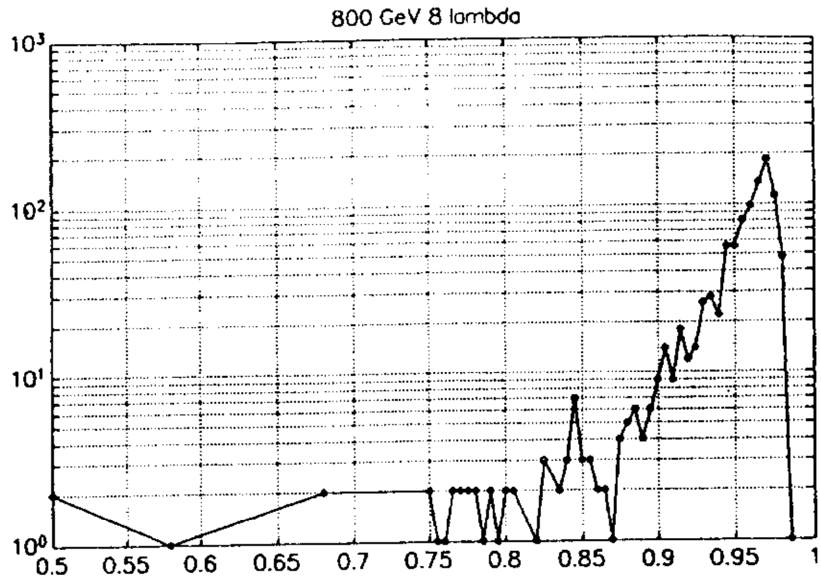
Figure 6. Cross section as a function of missing Et for 300 and 500 GeV gluinos. Also shown is the spurious cross section generated by dijet events with MJJ > 2 TeV leaking out of 6 (*) and 10 (o) interaction length calorimeters.

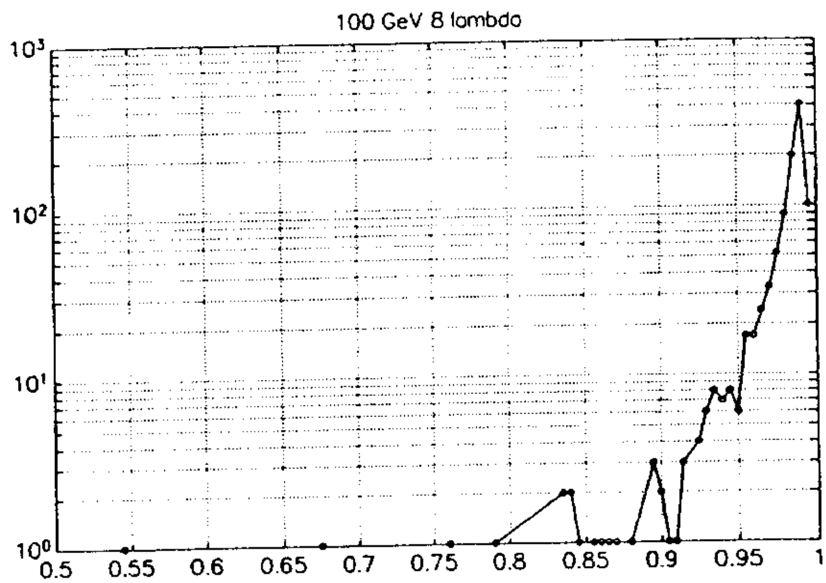


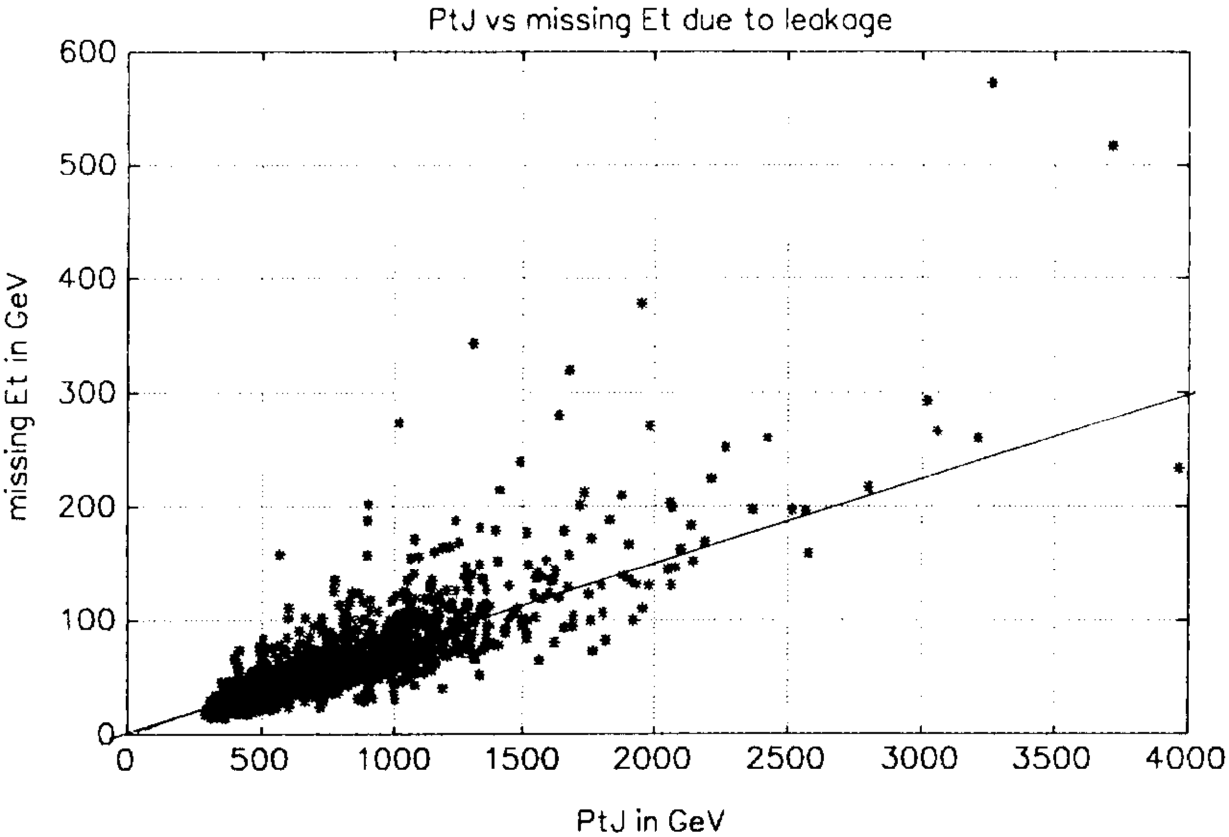
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
n=2
n=3
n=4
n=5
$|\eta|<2.5$
$d\sigma/dM$ (nb/GeV)
2000
4000
6000
8000
10000
n-jet invariant mass (GeV)

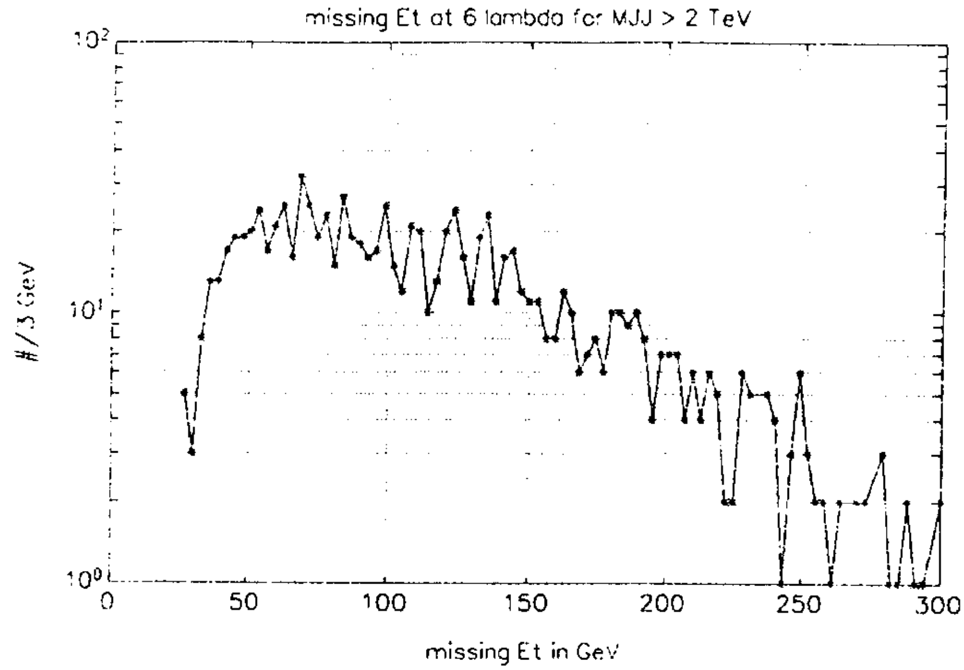


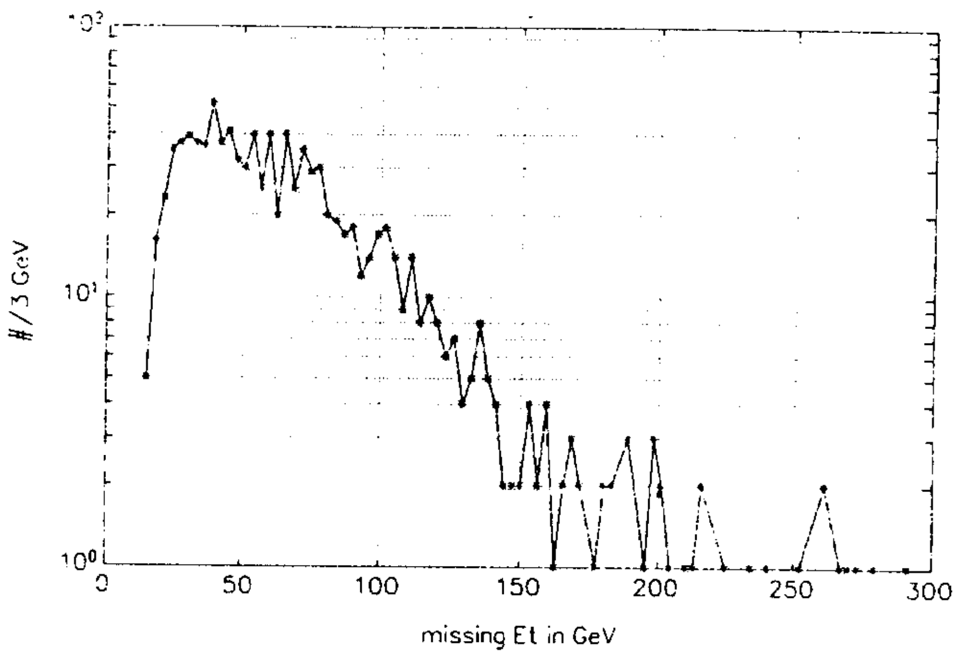
Energy Containment Fraction for 10,8,6 (o,*,+) lambda, 450 GeV
#/0.02
energy fraction f
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
10^0
10^1
10^2
10^3

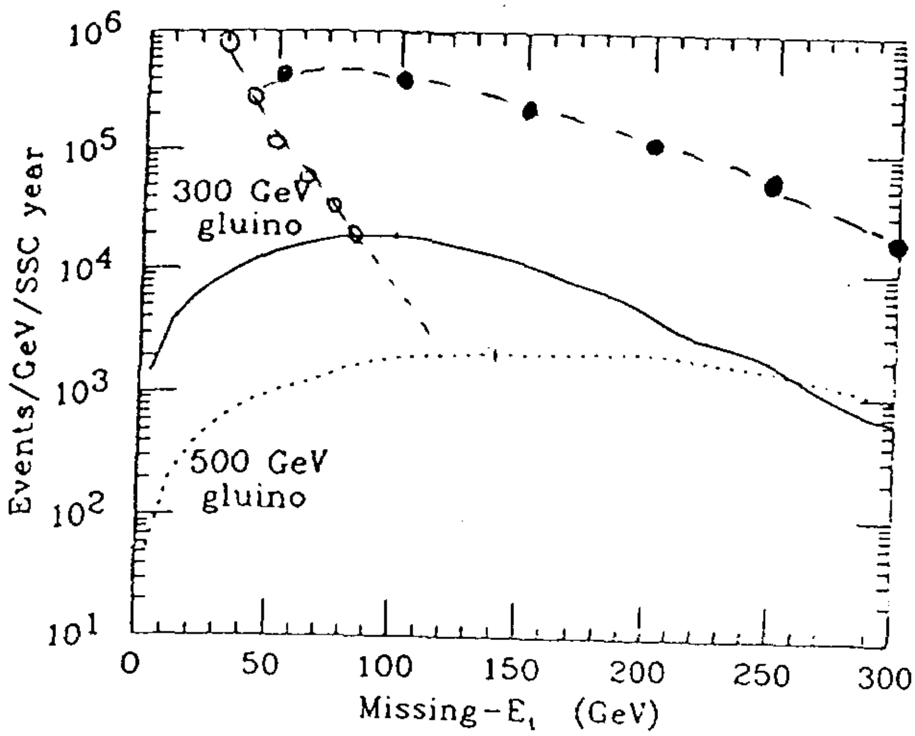

800 GeV 8 lambda
10^3
10^2
10^1
10^0
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1


100 GeV 8 lambda
10^3
10^2
10^1
10^0
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1


PtJ vs missing Et due to leakage
missing Et in GeV
PtJ in GeV
0
100
200
300
400
500
600
0
500
1000
1500
2000
2500
3000
3500
4000


missing Et at 6 lambda for MJJ > 2 TeV
#/3 GeV
missing Et in GeV


#/3 GeV
missing Et in GeV



10^6
10^5
10^4
10^3
10^2
10^1
Events/GeV/SSC year
300 GeV
gluino
500 GeV
gluino
0
50
100
150
200
250
300
Missing-E_t (GeV)