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Missing ET Signature for Gluino Production in the GEM Detector for the SSC

Stephen A. Kahn
Brookhaven National Laboratory
Upton, NY 11973

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Abstract:

The feasibility of looking for gluino pair production at the SSC with the GEM detector is examined. If the gluino mass is lighter than the squark mass, gluino production would have the largest cross section for a SUSY signature. This study compares rates for production of 300 GeV gluinos with background form QCD and Z^0 production. The background to 300 GeV gluinos from QCD is expected to be large, however with reasonable cuts a signal to noise ratio of 5 : 1 is achieved for $150 < \not{E}_T < 300$ GeV.

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INTRODUCTION

This note examines the feasibility of using the large missing E_T signature to detect the presence of gluino pair production. In the minimal supersymmetric extension of the standard model SUSY particles are produced in pairs. In a hadron collider, $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$, $\tilde{q}\tilde{\tilde{q}}$, $\tilde{q}\tilde{q}$, $\tilde{g}\tilde{\gamma}$, and $\tilde{q}\tilde{\gamma}$ should all be present. The cross sections for their production are all calculatable in perturbative QCD. This note concentrates on the $\tilde{g}\tilde{g}$ channel as its cross section is an order of magnitude larger than the next largest. The gluino signatures are affected by the existence of cascade decays, which because in the minimal SUSY model there are two Higgs doublets, leading to four neutral color-singlet superparticles $\tilde{\chi}_i^0, i =$ 1-4, and two charged ones $\tilde{\chi}_i^{\pm}, i=$ 1-2.[1] Since the final product of the cascade decay chain (most likely the $\tilde{\chi}_1^0$) is weakly interacting, an event with a gluino pair should have large missing transverse energy, $\not{E}_T$.

SIMULATION OF THE DETECTOR

The detector is assumed to be a toy calorimeter that has a $\Delta\eta \times \Delta\phi$ segmentation of 0.08×0.08. The calorimeter covers a rapidity range of $-5 < \eta < 5$. It is assumed that the calorimeter is hermetic in this region. Resolution smearing is applied to the calorimeter in the following manner:

- A gaussian energy smearing is applied to each particle as cell energy summing is performed:

$$\sigma_E = \sqrt{\frac{a^2}{E} + b^2}$$

where a and b are chosen to represent either the liquid argon or the BaF_2/liquid scintillator options for the calorimeter. In this current analysis a and b are chosen as

parameter	EM Calorimeter	Hadron Calorimeter
a	7.5	50
b	0.5	2

to represent liquid argon.

- A different resolution is applied in the transition region to the forward calorimeter at $\eta = 3$. The calorimeter response in this region was determined for the EMPACT detector.[2]
- To each reconstructed jet a nominal thermal and pile-up noise is applied corresponding to the chosen calorimeter option. For liquid argon a thermal noise of 1 GeV was applied to each jet in the hadron calorimeter. In addition pileup noise of 1 GeV is added to each jet.
- No lateral jet smearing has been applied at this point. This is envisioned in the future.

ANALYSIS

The minimal supersymmetric model under various assumptions[3] allows four independent variables to describe it. These are generally chosen as the gluino mass ($M_{\tilde{g}}$), the charged Higgs mass (M_{H^+}), the supersymmetric Higgs mass parameter (μ), and the ratio of vacuum expectation values of the two Higgs doublets ($tan\beta = v_2/v_1$). Furthermore the squark mass is assumed to be sufficiently heavier than the gluino mass so that the gluinos decay directly to gauginos. In this analysis $M_{\tilde{g}}$ has been chosen to be 300 Gev. $\not{E}_T$ is strongly dependent upon $M_{\tilde{g}}$, however it is insensitive to values of $tan\beta$ and μ. $\not{E}_T$ distributions for other values of $M_{\tilde{g}}$ have been previously reported for the EMPACT detector.[4] The principle backgrounds to the gluino signature come from Z^o decaying to neutrinos and from QCD events with heavy quark decays. The QCD heavy quark background is of major concern for all gluino masses whereas the Z^o which occurs at larger $\not{E}_T$ is important for higher mass gluinos. In this analysis the following event samples were generated:

- 20000 $\tilde{g}\tilde{g}$ events with $M_{\tilde{g}}$= 300 GeV, μ= -300 GeV, and $tan\beta = 2$.
- 20000 $Z^o \rightarrow \nu\bar{\nu}$.
- 86000 QCD events producing heavy quarks. These events were produced as QCD events and only those events with a c, b, or t quark were retained. In order to enhance efficiency of generation each event is multiply evolved and multiply fragmented keeping only events with heavy quarks or events with neutrinos that have $E_\nu > 50$ GeV. This sample represents the equivalent number of 2×10^6 QCD events.

The gluino signal can be enhanced over the heavy quark and Z^o background with cuts that distinguish between their characteristics. Fig. 1 shows a distribution of the number of jets in the gluino events, the heavy quark events and $Z^o \rightarrow \nu\bar{\nu}$ events. A jet is restricted to have $|\eta| < 3$ and have $P_T > 75$ GeV/c. Fig. 1d compares the number of jets distributions between signal and background keeping the relative normalizations. The background overtakes the signal at $n_{jets} \geq 4$. Another quantity that shows a distinction between the signal and background is the transverse sphericity, S:

$$S = 2 \times \frac{Q_1}{Q_1 + Q_2}$$

where Q_1 is the larger of the two principal moments Q_1, Q_2 of P_T. Fig. 2 gives the S distributions for the gluino signal, the heavy quark, and the Z^o backgrounds. S approaching

one indicate more spherical events which the $\tilde{g}\tilde{g}$ events tend to be. Events with S near zero are more *back-to-back* as are the QCD and vector boson jets.

Several variations of the cuts were tried. A reasonably good background rejection was obtained with the following set of cuts:

- The number of hadron jets with $P_T > 75$ GeV be at least 5. This reflects the fact each gluino decays to $q\bar{q}'\chi$. The events typically have four or more jets.
- The transverse sphericity S be greater than 0.3. More rejection would occur at a more stringent cut, but the statistics would also fall.
- Events are rejected if they have an isolated electron or muon. This is used to reduce some of the top background from QCD. The signal is still visible without this cut, but the cut improves it.

Fig. 3 shows $\frac{d\sigma}{d\not{E}_T}$ in $nb/50\ \ GeV$ for the $\tilde{g}\tilde{g}$ sample along with the heavy quark and Z^o backgrounds. The heavy quark distribution is biased at low $\not{E}_T$ since events are rejected if E_ν is less than 50 GeV. The signal-to-noise ratio is approximately 3 in the region 100 GeV $< \not{E}_T <$ 350 GeV. For 300 GeV gluinos the Z^o background is not important. Fig. 4 shows $\frac{d\sigma}{dp_{T,out}}$ in $nb/20\ \ GeV$. $P_{T,out}$ is defined to be the momentum out of the plane formed by the transverse thrust direction and the beam momentum. This shows a similar signal to background ratio as the $\not{E}_T$.

REFERENCES

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2. The $\eta = 3$ transition region response for the EMPACT calorimeter was determined by G. Forden using a GEANT simulation..
3. H.Haber & G.Kane, *The Search for Supersymmetry: Probing Physics Beyond the Standard Model*, Physics Reports 117 p75 (1985).
4. V. Fonseca et al., *Gluino Searches at the SSC*, BNL report 45357 and V. Fonseca et al., *SUSY Searches at the SSC*, EMPACT note 228..

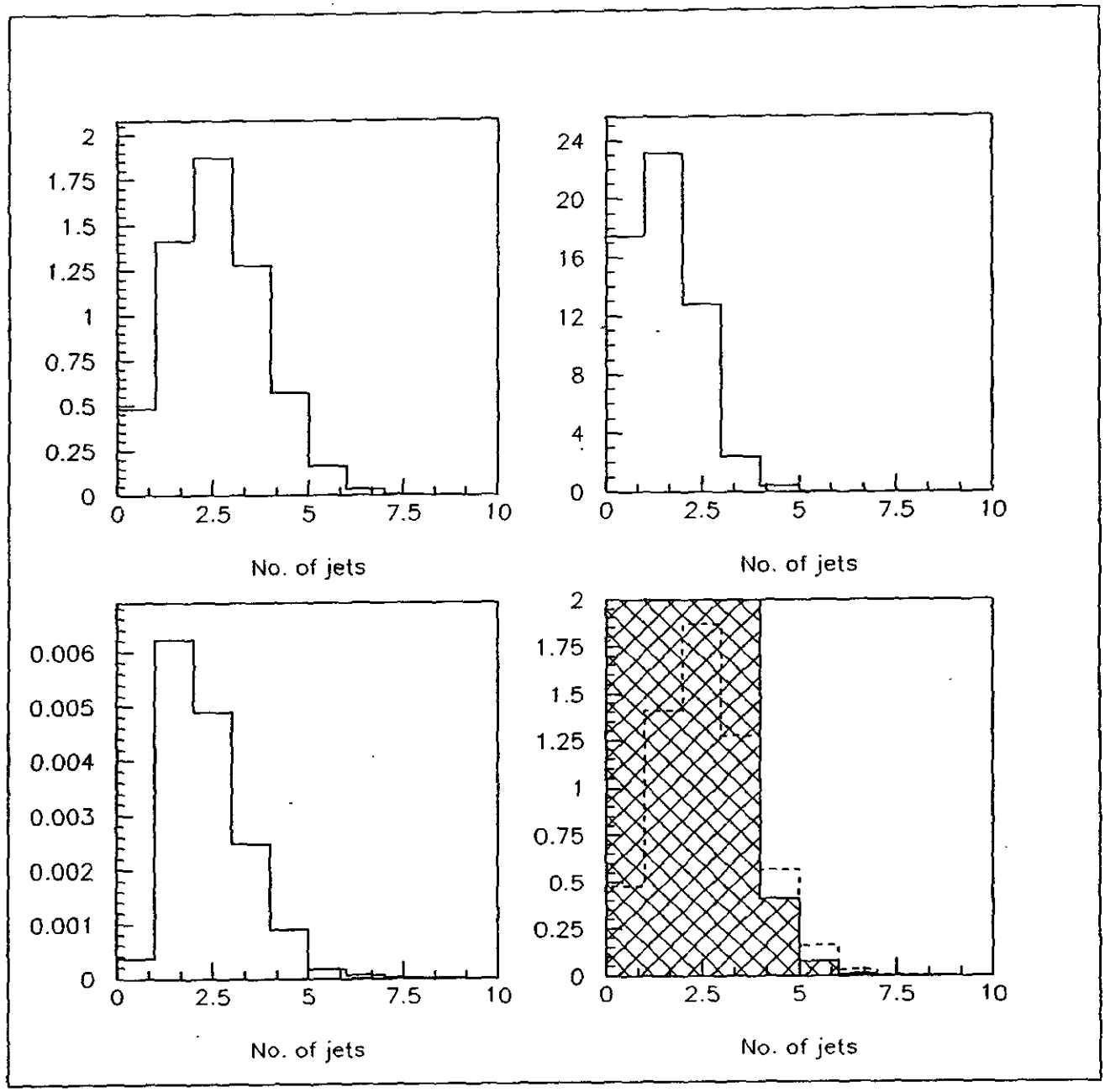

Figure 1: Distribution of the number of jets for (a) the $\tilde{g}\tilde{g}$ signal, (b) the QCD heavy quark background, (c) the $Z^o \rightarrow \nu\bar{\nu}$ background. (d) shows the gluino signal and the background superimposed keeping the normalization. A jet is defined by *UA1* algorithm and is required to have $P_T > 75$ GeV/c.

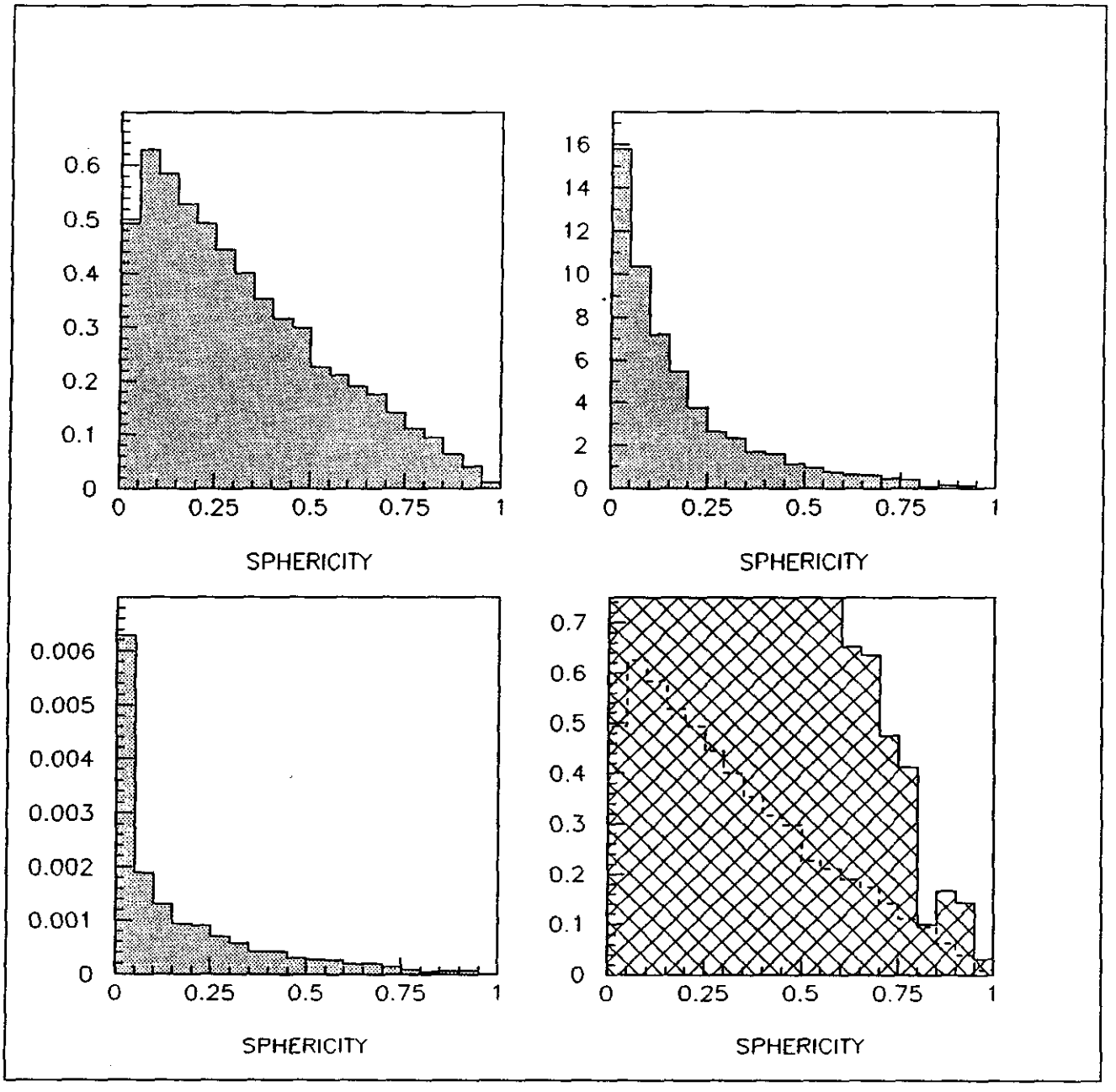

Figure 2: Distribution of transverse sphericity for (a) the $\tilde{g}\tilde{g}$ signal, (b) the QCD heavy quark background, (c) the $Z^o \to \nu\bar{\nu}$ background. (d) shows the gluino signal and the background superimposed keeping the normalization.

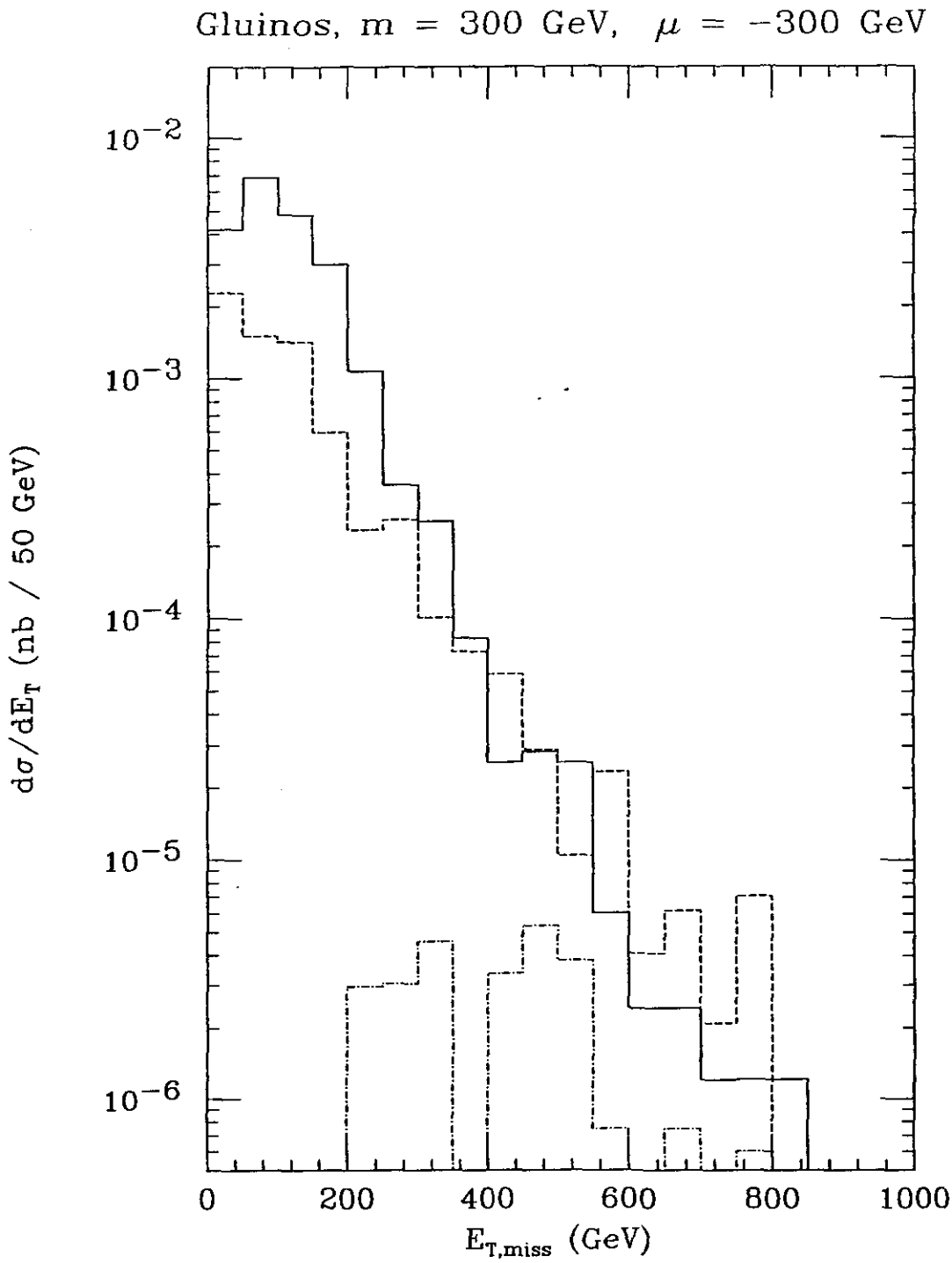

Figure 3: Distribution of $\not{E}_T$ for the $\tilde{g}\tilde{g}$ signal (solid), the QCD heavy quark background (dashed), and the $Z^o \to \nu\bar{\nu}$ background (dot-dashed).

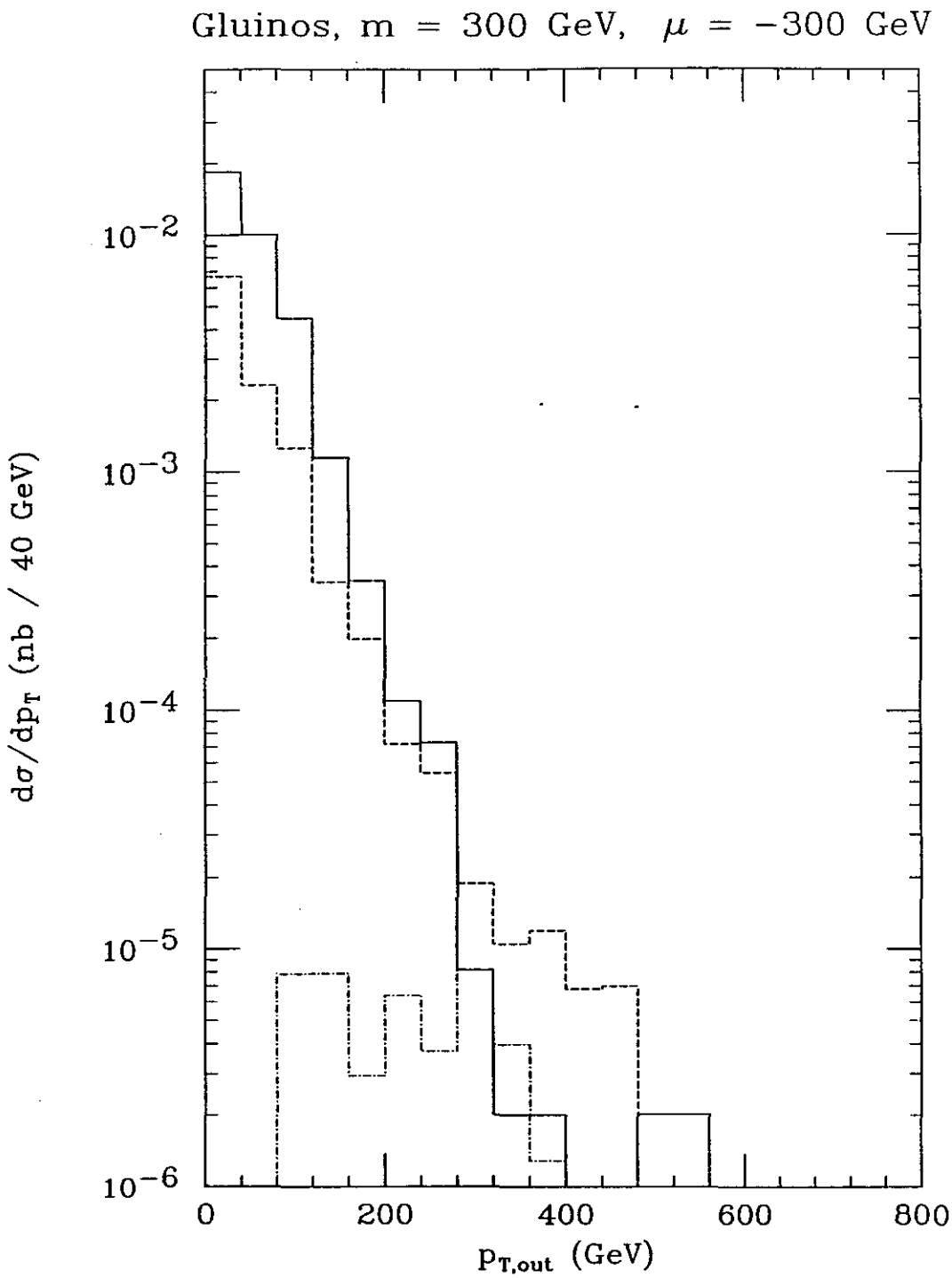

Figure 4: Distribution of $P_{T,out}$ for the $\tilde{g}\tilde{g}$ signal (solid), the QCD heavy quark background (dashed), and the $Z^o \to \nu\bar{\nu}$ background (dot-dashed).