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Possible $H \rightarrow W^+W^-$ Signal for $2m_W < m_H < 2m_Z$

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Frank E. Paige
Brookhaven National Laboratory

Abstract:

A possible signature $H \rightarrow W^+ W^- \rightarrow e^{\pm} \mu^{\pm} X$ for $2m_W < m_H < 2m_Z$ is considered.

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Frank E. Paige
Physics Department
Brookhaven National Laboratory
Upton, NY 11973

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ABSTRACT

A possible signture $H \to W^+W^- \to e^\pm\mu^\mp X$ for $2m_W < m_H < 2m_Z$ is considered.

We consider a standard model Higgs bosen with $m_H = 170\,\text{GeV}$. For this mass the decay $H \to W^+W^-$ is allowed, but the decay $H \to Z^0Z^0$ is forbidden, and the ZZ^* rate is rather small, so this mass is particularly difficult to detect. In this note we examine the decay

$$H \to W^+W^- \to e^\pm\mu^\mp X$$

The main backgrounds are $q\bar{q} \to W^+W^-$ and $gg \to t\bar{t}$. For inessential technical reasons, all calculations were done for the $\mu^+\mu^-$ mode, although this would be hopelessly swamped by $Z^0 \to \mu^+\mu^-$. Hence all cross sections shown in the figures must be multiplied by 2 to get the rates for $e^\pm\mu^\mp$.

The observable quantity is the invariant mass $M_{\ell\ell}$ of the two leptons. This obviously satisfies $M_{\ell\ell} < m_H$ for the Higgs signal. The signal and the W^+W^- background were generated with ISAJET 6.43. They are found to be comparable for low masses, and the distribution for $M_{\ell\ell} > m_H$ provides a normalization for the W^+W^- continuum. There is a change in the shape of the distribution, not just in the normalization.

The principle difficulty is to remove the $t\bar{t}$ continuum, which is orders of magnitude larger. To examine this, 60K events with $t \to \mu^+\nu b$ and $\bar{t} \to \mu^-\bar{\nu}\bar{b}$ were generated with ISAJET 6.43. The events were generated in two bins:

$$20\,\text{GeV} < p_{T,t} < 100\,\text{GeV} \qquad \sigma = 0.80 \times 10^{-5}\,\text{mb}$$

$$100\,\text{GeV} < p_{T,t} < 300\,\text{GeV} \qquad \sigma = 0.76 \times 10^{-5}\,\text{mb}$$

These cross sections were multiplied by 0.01 to account for the leptonic branching ratios. The events were analysed using CALSIM with perfect resolution, and jets were found with GETJET using $\Delta R = 0.7$. The four-vectors of all jets and leptons, the lepton isolation energies, and the global event properties were then saved in a DST file.

The events were required to have only two muons with $p_T > 5\,\mathrm{GeV}$. Both muons were required to have $E_T < 5\,\mathrm{GeV}$ in a cone $\Delta R < 0.4$ and to have $|\eta| < 1.0$ to force the events to be central. The η cut is quite inefficient, and other possible choices have not yet been tried. Since CALSIM deposits the muon energy in the calorimeter, the muons were also found as jets by GETJET. Hence jets were eliminated if they matched a muon within $\Delta R = 0.2$. This cut was adequate because both muons are also required to be isolated and extra muons were not allowed. Events were then rejected if they had any remaining jet with $p_T > 10\,\mathrm{GeV}$ and $|\eta| < 3.0$. These cuts leave about three Monte Carlo events, with a cross section that seems rather smaller than the signal or the W^+W^- background. The DST files occupy about 50 MB, so to increase the statistics substantially a more compact format would be needed.

The p_T distribution of the highest-p_T jet is shown in Fig. 1, with the solid curve being the signal, the dashed curve being the W^+W^- background, and the dotted curve being the $t\bar{t}$ background. The hole is a result of the minimum p_T imposed in GETJET. The $M_{\ell\ell}$ distribution is shown in Fig. 2. The same distribution converted to events and plotted on a linear scale is shown in Fig. 3. One needs to multiply by a factor of 2 to convert these $\mu^+\mu^-$ numbers to the wanted $e^\pm\mu^\mp$ numbers. Thus the signal is an excess of events peaking at $M_{\ell\ell} \approx 75\,\mathrm{GeV}$.

Obviously the signal is marginal, but it does not look hopeless. It might at least confirm a ZZ^* signal. More work is needed to optimize the cuts. One must also look at the effects of calorimeter resolution and at better ways of rejecting jet activity, e.g., using high-p_T tracks and/or high-E_T electromagnetic cells.

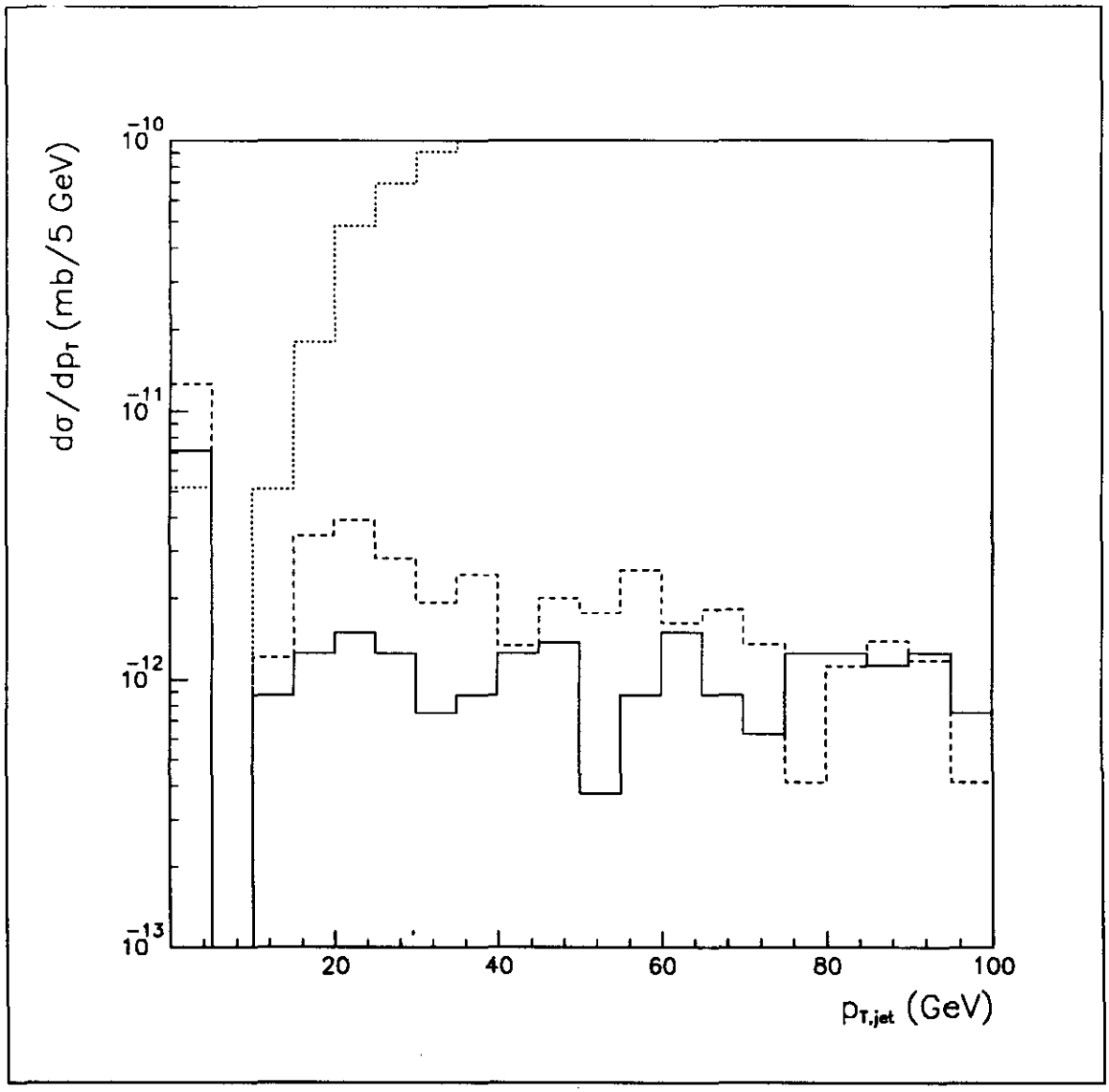

Figure 1: Highest p_T jet. Solid: Higgs signal. Dashed: W^+W^- background. Dotted: $t\bar{t}$ background.

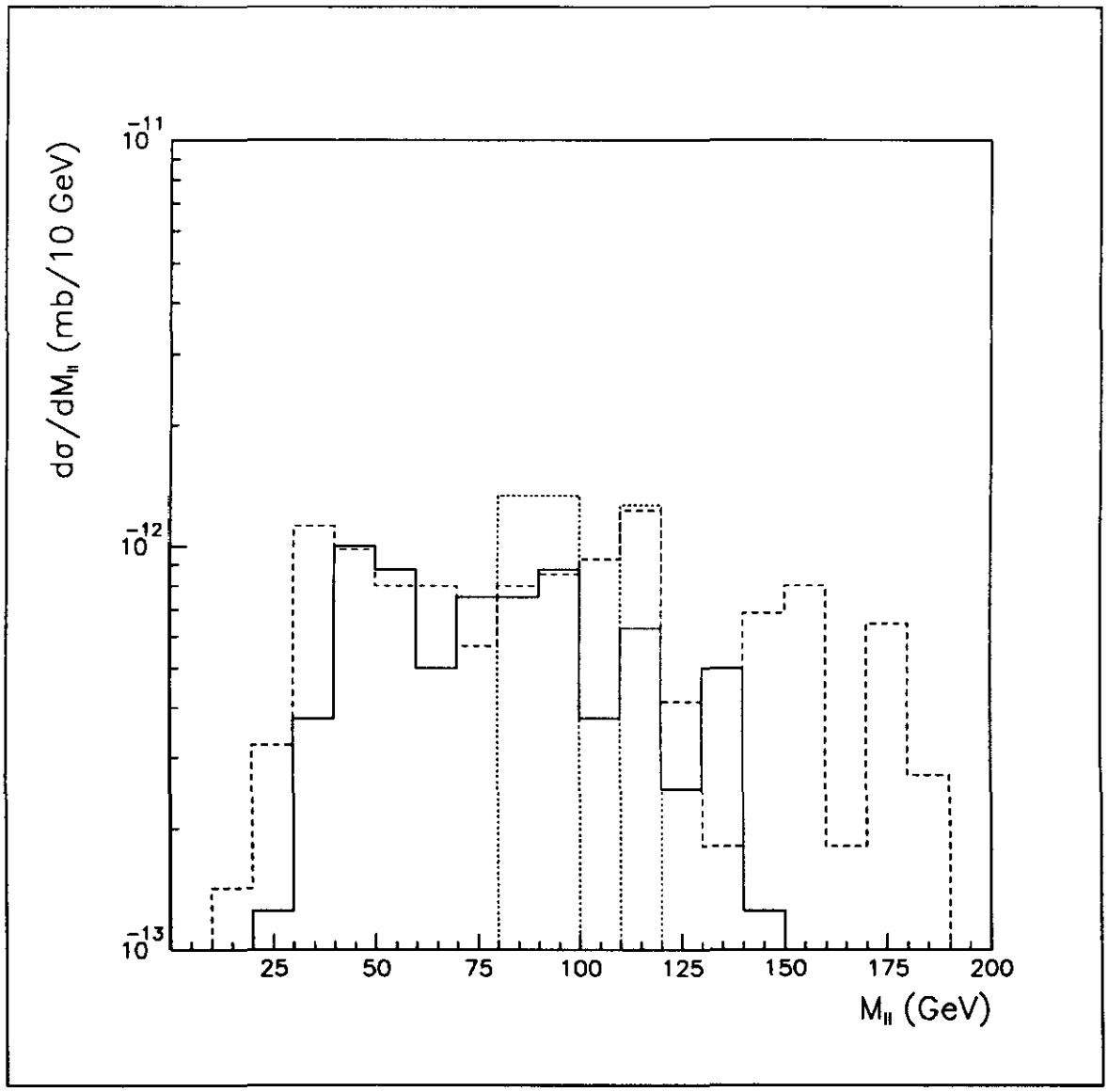

Figure 2: Mass of $\ell^+\ell^-$. Solid: Higgs signal. Dashed: W^+W^- background. Dotted: $t\bar{t}$ background.

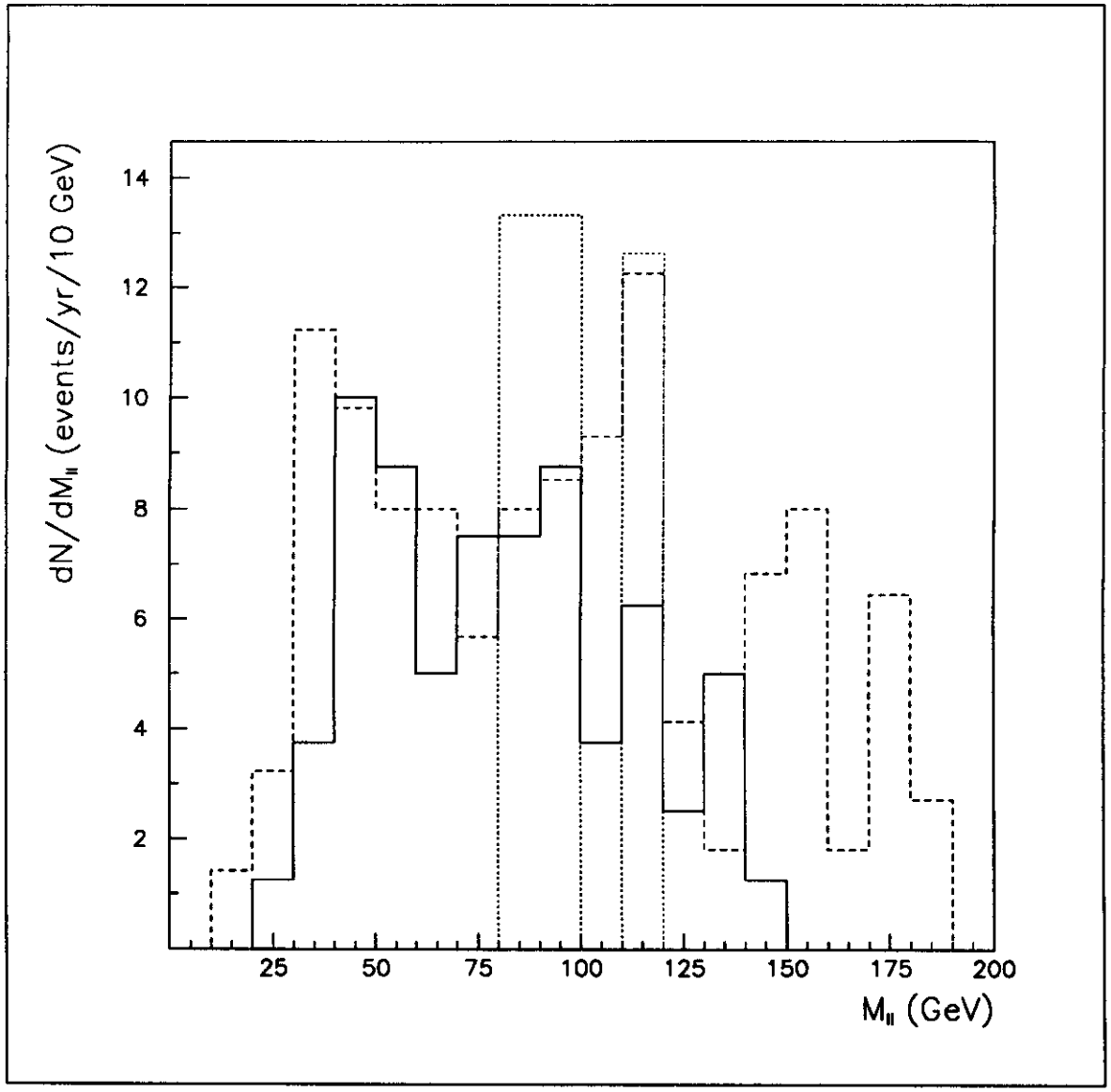

Figure 3: Mass of $\ell^+\ell^-$ pair. Solid: Higgs signal. Dashed: W^+W^- background. Dotted: $t\bar{t}$ background.