GEM TN-92-215
IP-ASTP-09-92

Higgs into 2 Electrons and 2 Muons via Z - Z Decay at High Luminosity (10^{34}), for an 800 GeV Higgs ($H^0 \rightarrow Z^0 Z^0 \rightarrow e^+ e^- \mu^+ \mu^-$ (M_H = 800 GeV) at £=10^{34} cm^{-2}s^{-1})

Jaroslav Antos
Academia Sinica, Taiwan

October 1992

Abstract:

Strategy for 800 GeV Higgs hunting at GEM is suggested.

IP - ASTP - 09 - 92

$H^0 \to Z^0 Z^0 \to e^+e^-\mu^+\mu^-$ ($M_H = 800\,\mathrm{GeV}$) at $\mathcal{L} = 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$

Jaroslav Antoš

Institute of Physics
Academia Sinica
Nankang Taipei Taiwan

Most important topic of SSC physics is discovery of Higgs particle. Because theoretical predictions about its mass are not suficiently precise to help in optimising apparatus, SSC setups should be able to cover broad range of scenarios of Higgs production. We carry out study to explore excelent possibility by GEM to work at $\mathcal{L} = 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. We want to demonstrate that GEM has reasonable chance in one year of runing to prove or disprove existence of H^0 at $M_H = 800\,\mathrm{GeV}$ in decays to $\rightarrow Z^0 Z^0 \rightarrow e^+e^-\mu^+\mu^-$.

Analysis of this reaction at $\mathcal{L} = 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ in the context of GEM setup (or similar) was realised some time ago [1,2]. Purpose of this note is also to incorporate improved specifications of GEM components and to use more realistic simulation of them.

For estimate of corresponding physical processes **PYTHIA** version 5.5 [3] has been used. For estimate of detector response fast monte carlo developed by GEM simulation groupes called **FAST1** [4] has been used, specialy components developed for central tracker, liquid argon calorimeter and muon system simulation. Cross section times branching ratio for a given process (estimated by PYTHIA) is 2.9 fb.

There are two kinds of background. So called reducible background consists mainly of dijet production whose response can imitate response of leptons from H^0 decay. This background can be in principle reduced by proper selection of cuts to improve identification of electrons and their isolation from jets. Most important reducible background comes from $t\bar{t}$ dijet production. Their production cross section for $t\bar{t}$ mass greater then 200 GeV and transverse momentum of t ($\bar{t}$) quark $p_t > 20\,\mathrm{GeV}$ is 9.2 nb.

Irreducible background consist of pair production of Z^0 by q $\bar{q}$ or gg fusion. Production cross section for q $\bar{q}$ mechanism was estimated by PYTHIA. According to [5,6] gg mechanism can be accounted for just by 65 % increase of previous cross section. Finally we have cross section times branching ratio for production and decay to $e^+e^-\mu^+\mu^-$ of Z^0Z^0 pair of effective mass greater than 300 GeV 45.9 fb. On fig.1 there is a comparison of

—mass distribution Z^0Z^0 pairs from irreducible background and from decay of H^0

—p_t distribution of Z^0Z^0 pairs from irreducible background and from decay of H^0

—p_t distribution of $Z^{0\prime}s$

—p_t distribution of leptons from decay chain of irred. background and H^0

One can see striking differences in corresponding distributions which can be used to reduce otherwise irreducible background and to improve signal to background ratio.

Strategy for reduction of reducible background is based on excelent properties of GEM for identification of isolated electrons or muons. We define following variables :

— isolation variable for electron candidates ξ_e

$$\xi_e = \sum_{R<.3} E_t - 1.1 * E_t^e$$

where E_t is transverse energy in electromagnetic calorimeter R is radial distance from electron candidate in pseudorapity (η_e), asimutal angle (ϕ_e) space $R = \sqrt{(\eta_e - \eta)^2 + (\phi_e - \phi)^2}$ Transverse energy of electron candidate is measured in electromagnetic calorimeter in a cone of $R = 0.1$

— isolation variable for muon candidate ξ_μ

$$\xi_\mu = \sum_{R<.3} E_t^{em+had} - 0.3 * p_{t\mu}$$

— ratio of energy measured in electromagnetic calorimeter of electron candidate to summ of energy in electromagnetic and hadronic calorimeter in a cone $R = 0.3$ around electron candidate r_{em}

$$r_{em} = E_{em}/(E_{em} + E_{had})$$

— number of charged particles in a cone $R = 0.15$ with $p_t > 5.GeV$ around candidate (including) n_{ch}

On fig.2 there is a comparison of distributions of above defined variables for t $\bar{t}$ jets and for electrons from H^0. Last row corresponds to muons originating in t ($\bar{t}$) jets and from H^0.

Following cuts and conditions reduce reducible background below level of irreducible background :

for electrons

1. $\xi_e \leq 0.$
2. $r_{em} \geq 0.9$
3. $n_{ch} = 1$
4. $E_t > 20.$

for muons

1. $p_t > 20.GeV$
2. $n_{ch} = 1$
3. $\xi_\mu \leq 0.$

Effective mass of pairs of the same kind should be $M_{Z^0} \pm 10GeV$ We divide $t\bar{t}$ jets into two categories. Electromagnetic-like jets (if there is at least one electron of $p_t \geq 5.GeV$

in a cone of R=.15 around jet axis) and hadronic-like jets. About 10 % of all $t\bar{t}$ jets are electromagnetic-like. Rejection power by above given set of cuts is approx. factor 100 for hadronic-like jets and factor 3 for electromagnetic-like ones, $\approx$ 1000 for punchthrough hadrons per $t\bar{t}$ dijet event, $\approx$ 600 for dimuons per $t\bar{t}$ dijet event. From these numbers one concludes that most "dangerous" are jets which have a leptonic component. Therefore we generated $t\bar{t}$ dijets with $m_t > 600 GeV/c^2$ and with forced [7] decay modes for both t quarks $t \rightarrow bl\nu$ and $b \rightarrow l\nu$. Estimated cross section for such process 1.9 pb. From 5000 generated events no event passed all cuts which gives estimate of cross section for this kind of background less than 0.39 fb.

What influence have these cuts on a signal ?

Starting number of H^0's	10000
condition that all leptons from decay of H^0 should be in	
kinematic region $\eta \in (-2.5, 2.5)$ satisfies	7600
both muons accepted by muon system	6457
$\xi_\mu \leq 0.$ passed	6250
condition $p_t > 20\,\mathrm{GeV}$ for all leptons satisfies	5957
$\xi_e \leq 0.$	5250
$r_{em} > .9$	5011
$n_{ch} = 1$ (for all four leptons)	4831
mass of the same kind of lept. pair should be $M_{Z^0} \pm 10\,\mathrm{GeV}$	3944
p_t of $Z^0 > 150\,\mathrm{GeV}$	3679

Last cut substantialy reduces so called irreducible background. On fig.3 there is in first column effective mass distribution of four leptons from H^0, irreducible background Z^0Z^0 and sum of both after all cuts have been applied exept last one. Result after cut $p_{tZ^0} > 150\,\mathrm{GeV}$ is shown in second column. Normalisation is to integrated luminosity $10^{41}\,\mathrm{cm}^{-2}$ (one SSCD year). One has 97 H^0 events in mass region (600,1100) GeV. In the same mass region are 38 events of irreducible background.

References

[1] GEM Collaboration, "GEM Letter of Intent",November 30, 1991

[2] B. Zhou, Monte Carlo Calculation and Simulations for SSC Physics, BUHEP -90-21, August 1990

[3] H.-U. Bengtsson and T. Sjostrand, A manual to the Lund Monte Carlo for Hadronic Processes PYTHIA version 5.5

[4] to be GEM Internal Note

[5] SDC Collaboration, "Letter of Intent", SSC-LOI0001 (1990)

[6] E.W.N. Glover and J.J. Van Der Bij, Phys. Lett. 219 (1989)488

[7] T. Sjostrand, private communication

Figure captions

fig.1 A comparison of corresponding distributions originating from irreducible background (first column) and from H^0 (second column)

fig.2 A comparison of distributions for reducible background and for electrons (muons) originating in considered Higgs decay chain. Corresponding variables are explained in text.

fig.3 Expected mass distribution of H^0, $Z^0 Z^0$ ireducible background and sum for integrated luminosity 10^{41} cm^{-2} after all cuts have been applied except cut on $p_{t\,Z^0}$ (first column) and after application of $p_{t\,Z^0} > 150\,\mathrm{GeV}$ cut (second column)

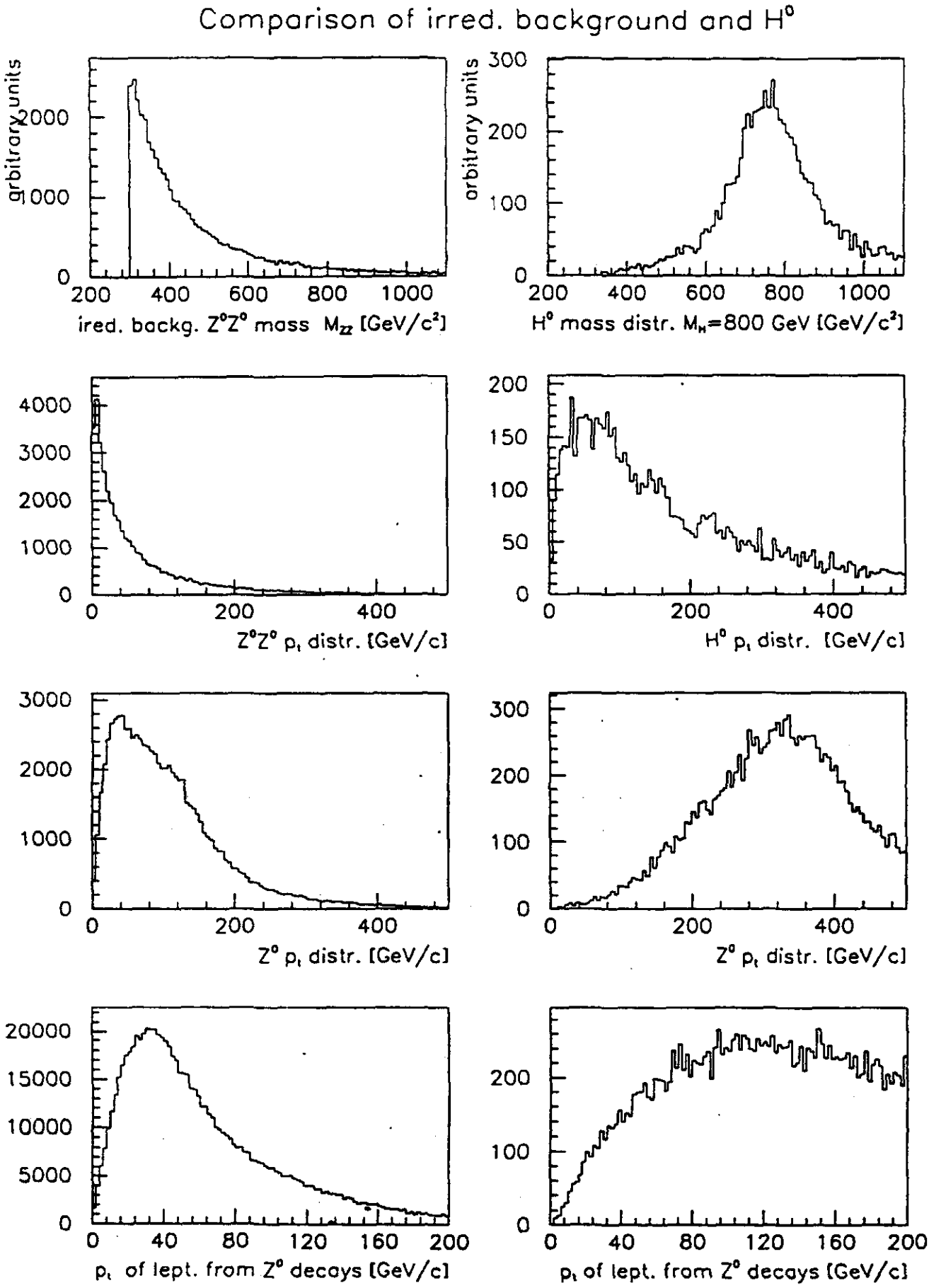
Comparison of irred. background and H°
arbitrary units
ired. backg. Z°Z° mass M_{ZZ} [GeV/c²]
H° mass distr. M_H=800 GeV [GeV/c²]
Z°Z° p_t distr. [GeV/c]
H° p_t distr. [GeV/c]
Z° p_t distr. [GeV/c]
Z° p_t distr. [GeV/c]
p_t of lept. from Z° decays [GeV/c]
p_t of lept. from Z° decays [GeV/c]

fig. 1

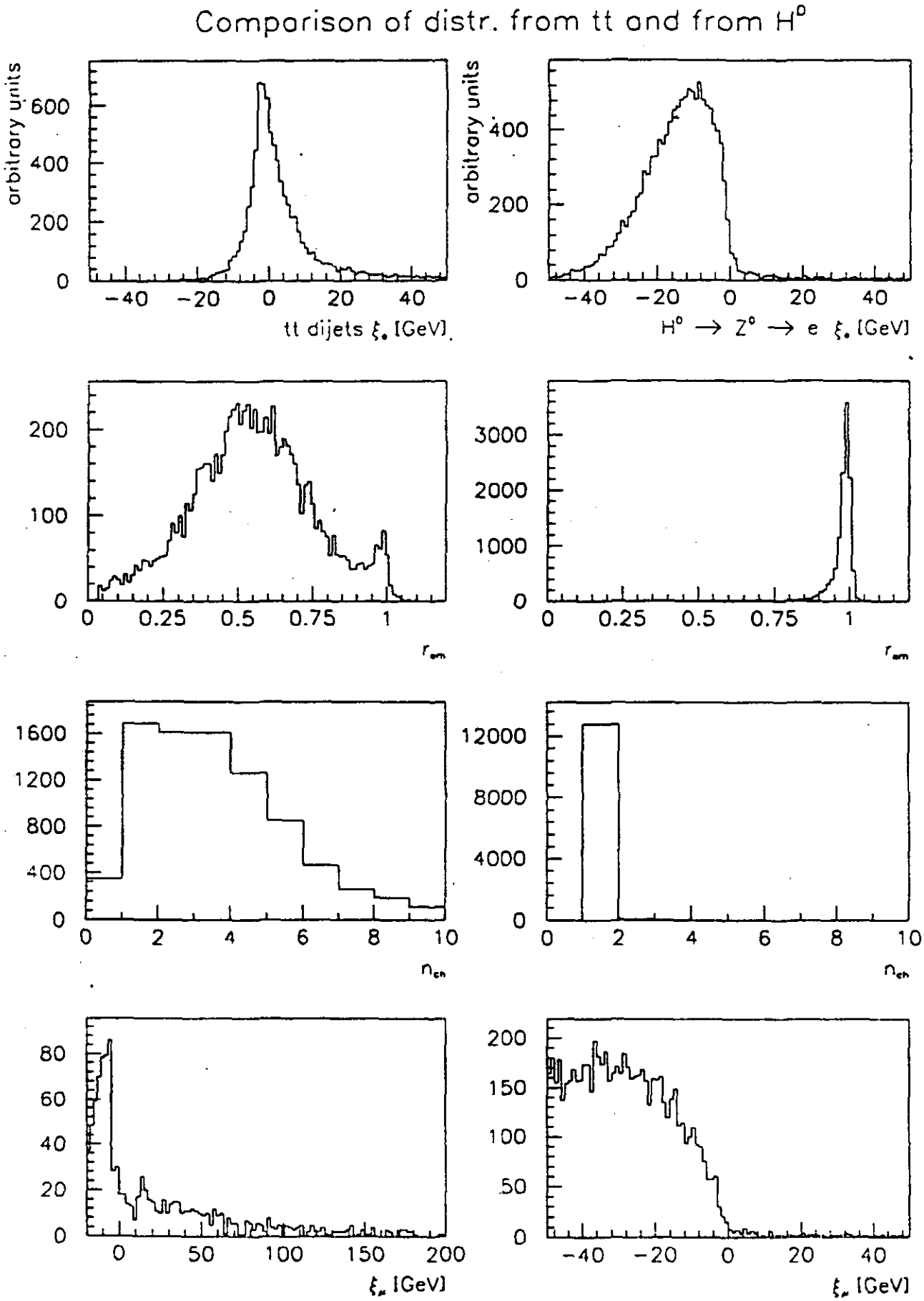
Comparison of distr. from tt and from H°
arbitrary units
tt dijets ξ* [GeV]
H° → Z° → e ξ* [GeV]
r_em
n_ch
ξ_μ [GeV]

fig. 2

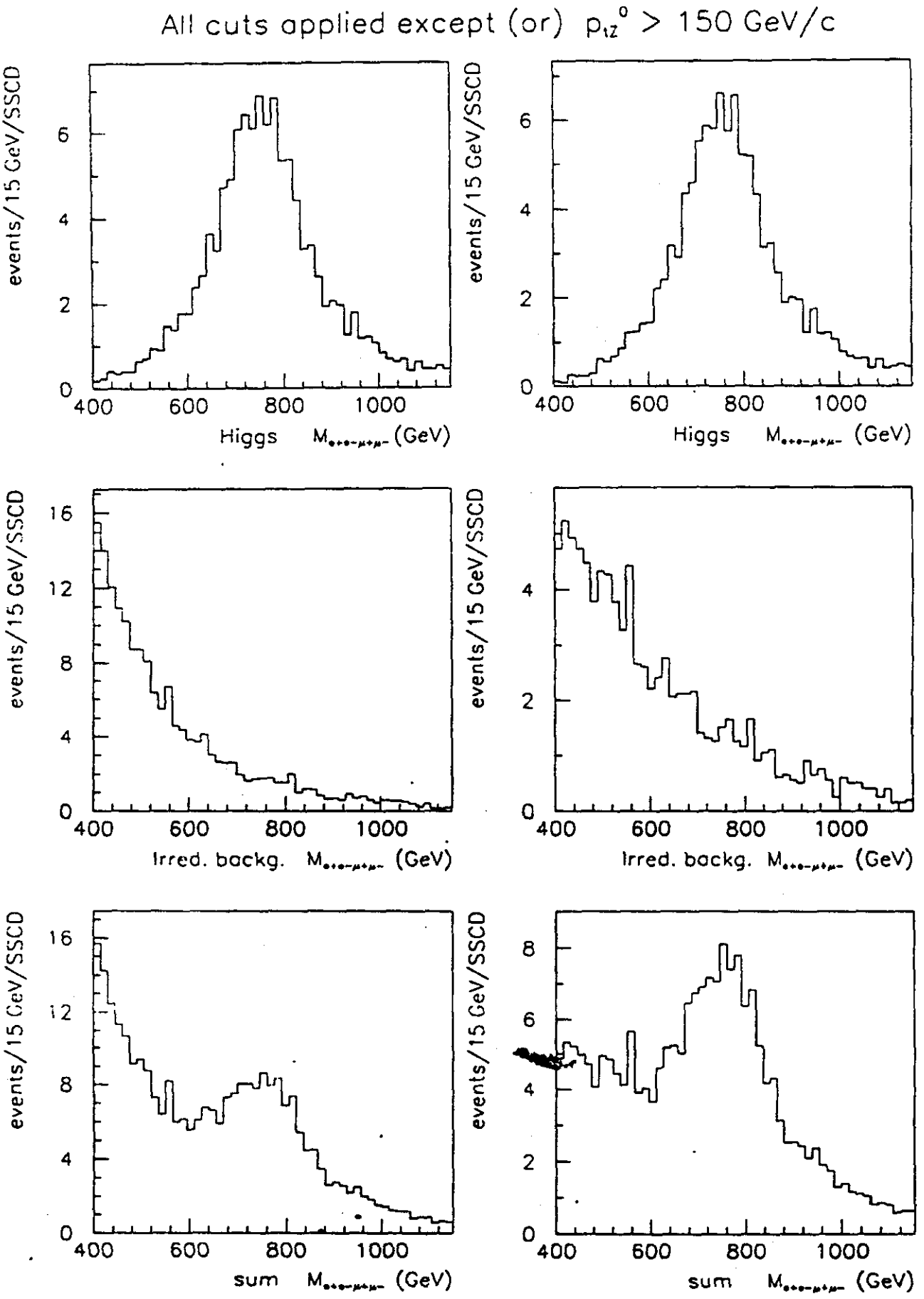
All cuts applied except (or) $p_{tZ}^{0} > 150$ GeV/c
events/15 GeV/SSCD
Higgs $M_{e^+e^-\mu^+\mu^-}$ (GeV)
Irred. backg. $M_{e^+e^-\mu^+\mu^-}$ (GeV)
sum $M_{e^+e^-\mu^+\mu^-}$ (GeV)

fig. 3