SDC-91-00080

SDC
SOLENOIDAL DETECTOR NOTES

ON THE OBSERVABILITY OF HEAVY PARTICLES DECAYING TO JET-JET AND e^+e^- WITH SDC

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On the Observability of Heavy Particles Decaying to jet-jet and e^+e^- with SDC*

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Abstract

This document discusses the signal to background ratio that must be overcome if a resonance is to be observed via its decay into two jets at SSC. It also discusses the resolution requirements of the electromagnetic and hadronic calorimeters if the properties of such resonances are to be observed.

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1 Hadronic Detection

It has been brought to my attention that the ability to reconstruct a new Z' via its decay to 2 jets is being considered as a criterion to determine the resolution of the SDC calorimeter. This note points out the enormous signal to background ratio that must be overcome even with a perfect detector. I consider a Z' of a mass 1 TeV and standard model couplings. Such a particle has a width of 31 GeV ($= \Gamma_Z M_{Z'}/m_Z$). Other models tend to have a Z' with smaller width and proportionally smaller production cross section[1]. I select events in which there are two jets each of which has $|\eta| < 1.5$ and $p_t > 200GeV$. Figure 1 shows the dijet mass spectrum from QCD events. I have used jet energy resolutions of 0%, 1%, 2%, 4% and 8%. Figure 2 shows the same final state produced from the decay of a 1 TeV Z'. Comparison of these figures shows that, in the case of perfect resolution, there are about 40000 events in the 10 GeV bin at a mass of 1000 GeV over a background of approximately 5000000 in one SSC year.[1] This is a statistically significant effect however none of these events will pass the dijet trigger which must be set at $P_t \gtrsim 1TeV$ if the dijet rate is not to exceed 1 Hz[2]. CDF has not reported the observation of a W or Z via its hadronic decay where the signal/background ratio is comparable.

Figures 3 and 4 show the same distributions for a Z' of mass 4 TeV where in a 40 GeV wide bin at the peak there are 320 signal and 20000 background events in the case of perfect resolution. This peak is of marginal statistical significance. For a mass of 10 TeV the production rate is entirely negligible – 2 signal and 60 background events in a bin width 100 GeV. (see figures 5 and 6)

It is possible that cuts on the jet multiplicity in the events can be used to clean up the background. This idea is based upon the fact that the signal is produced via $q\overline{q}$ annihilations whereas the background arises dominantly from gg and gq processes; the larger gluon charge results in more radiation and hence more jet activity in the latter case.

Since the jet-jet invariant mass peak arising from a Z' is not easy to see, one should ask what other high mass resonances are likely to be observed. In order to increase the production rate, one must increase the partial width of the

[1]The statistical fluctuations in the Monte-Carlo are too big to allow the figures to be superimposed.

particle into either *gluon* − *gluon* or quark anti-quark. In the case of a new Z' of mass 4 TeV an increase in the total production rate of a factor of 3, which would make the particle visible over background, would increase its width to 360 GeV. This width will put almost no constraint on the hadron calorimeter resolution.

A hypothetical particle that does decay to two jets with a rate large enough to be seen is the axigluon[3]. It has a larger width than a Z' and couples to gg rather than quark-antiquark. The larger gluon flux aids in the observability. Figure 7 shows the effect of a 1 TeV axigluon. Figures 8 and 9 show the effect of an axigluon of mass 4 and 10 TeV. A peak is clearly visible in the last two cases. In the first case, there is a statistically significant excess of events in the region around 1 TeV. Note that the degradation of the signal due to calorimeter resolution is not apparent provided that the calorimeter resolution is better than 3%. For resolutions worse than 5% the ability to extract a mass is seriously compromised. It can be seen from Figure 9 that there are sufficient events in the case of a 10 TeV resonance for it to be observed in 1 year of running at design luminosity. Axi-gluons of mass less than 13 TeV or so should be observable with this luminosity.

2 Detection via e^+e^- final state.

As discussed in Ref. [1], The mass and width of a new Z' will be measured via its decay to e^+e^-. Figures 10, 11 and 12 show the signal and background for a masses of 1, 4 and 10 TeV. Clearly the ability to determine the width is compromised if the resolution is worse than 2%. The 10 TeV particle is beyond the limit of observability in one year of running at the standard luminosity (less than 1 event),

It is possible that the width of a new Z would be smaller than that expected using standard model couplings. In this case the electromagnetic resolution needs to be better if the width is to be measured. As an example, consider the Z_η present in E_6 models.[1] Figures 13 and 14 show the rates for masses of 1 and 4 TeV. Notice that the resonance is narrower and the rate less than that shown in figures 10 and 11. A resolution of order 1% is now needed to measure the width.

References

[1] I. Hinchliffe, M. Mangano and M. Shapiro SSC-90-00036; I. Hinchliffe and M. Shapiro SSC-90-00115; G. Eppley and H. Miettinen SSC-SDC-90-00125.

[2] I. Hinchliffe SSC-SDE-3.

[3] J. Bagger *et al.* *Phys. Rev.* **D37**, 1189 (1988)

Figure Captions

Figure 1: The dijet mass spectrum in Events/SSC-Year/10-GeV as a function of the dijet invariant mass from QCD processes. Both jets must have $|\eta| < 1.5$ and $p_t > 200$ GeV. The assumed hadron resolution is taken to be 0%, 1%, 2%, 4% and 8%.

Figure 2: The dijet mass spectrum in Events/SSC-Year/10-GeV as a function of the dijet invariant mass from the decay of a Z' of mass 1 TeV. Both jets must have $|\eta| < 1.5$ and $p_t > 200$ GeV. The assumed hadron resolution is taken to be 0%, 1%, 2%, 4% and 8%.

Figure 3: The dijet mass spectrum in Events/SSC-Year/40-GeV as a function of the dijet invariant mass from QCD processes. Both jets must have $|\eta| < 1.5$ and $p_t > 500$ GeV. The assumed hadron resolution is taken to be 0%, 1%, 2%, 4% and 8%.

Figure 4: The dijet mass spectrum in Events/SSC-Year/40-GeV as a function of the dijet invariant mass from the decay of a Z' of mass 4 TeV. Both jets must have $|\eta| < 1.5$ and $p_t > 500$ GeV. The assumed hadron resolution is taken to be 0%, 1%, 2%, 4% and 8%.

Figure 5: The dijet mass spectrum in Events/SSC-Year/100-GeV as a function of the dijet invariant mass from QCD processes. Both jets must have $|\eta| < 1.5$ and $p_t > 1000$ GeV.

Figure 6: The dijet mass spectrum in Events/SSC-Year/100-GeV as a function of the dijet invariant mass from from the decay of a Z' of mass

107 TeV. Both jets must have $|\eta| < 1.5$ and $p_t > 1000$ GeV. The assumed hadron resolution is taken to be 0%, 1%, 2%, 4% and 8%.

Figure 7: The dijet mass spectrum in Events/SSC-Year/20-GeV as a function of the dijet invariant mass showing the signal from an axigluon of mass 1 TeV above the background from QCD processes. Both jets must have $|\eta| < 1.5$ and $p_t > 200$ GeV. The assumed hadron resolution is taken to be 0%, 1%, 2%, 4% and 8%.

Figure 8: The dijet mass spectrum in Events/SSC-Year/40-GeV as a function of the dijet invariant mass showing the signal from an axigluon of mass 4 TeV above the background from QCD processes. Both jets must have $|\eta| < 1.5$ and $p_t > 500$ GeV. The assumed hadron resolution is taken to be 0%, 1%, 2%, 4% and 8%.

Figure 9: The dijet mass spectrum in Events/SSC-Year/100-GeV as a function of the dijet invariant mass showing the signal from an axigluon of mass 10 TeV above the background from QCD processes. Both jets must have $|\eta| < 1.5$ and $p_t > 1000$ GeV. The assumed hadron resolution is taken to be 0%, 1%, 2%, 4% and 8%.

Figure 10: The e^+e^- mass spectrum in Events/SSC-Year/10-GeV as a function of the e^+e^- invariant mass. Both electrons must have $|\eta| < 1.5$ and $p_t > 200$ GeV. The assumed electromagnetic resolution is taken to be 0%, 1%, 2%, 4% and 8%. The background arises from Drell-Yan and the peak from a Z' with standard model couplings and a mass of 1 TeV.

Figure 11: The e^+e^- mass spectrum in Events/SSC-Year/40-GeV as a function of the e^+e^- invariant mass. Both electrons must have $|\eta| < 1.5$ and $p_t > 500$ GeV. The assumed electromagnetic resolution is taken to be 0%, 1%, 2%, 4% and 8%. The background arises from Drell-Yan and the peak from a Z' with standard model couplings and a mass of 4 TeV.

Figure 12: The e^+e^- mass spectrum in Events/SSC-Year/100-GeV as a function of the e^+e^- invariant mass. Both electrons must have $|\eta| < 1.5$

and $p_t > 1000$ GeV. The assumed electromagnetic resolution is taken to be 0%, 1%, 2%, 4% and 8%. The background arises from Drell-Yan and the peak from a Z' with standard model couplings and a mass of 10 TeV.

Figure 13: The e^+e^- mass spectrum in Events/SSC-Year/10-GeV as a function of the e^+e^- invariant mass. Both electrons must have $|\eta| < 1.5$ and $p_t > 200$ GeV. The assumed electromagnetic resolution is taken to be 0%, 1%, 2%, 4% and 8%. The background arises from Drell-Yan and the peak from a Z_η that arises in an E_6 model standard model couplings and a mass of 1 TeV.

Figure 14: The e^+e^- mass spectrum in Events/SSC-Year/40-GeV as a function of the e^+e^- invariant mass. Both electrons must have $|\eta| < 1.5$ and $p_t > 500$ GeV. The assumed electromagnetic resolution is taken to be 0%, 1%, 2%, 4% and 8%. The background arises from Drell-Yan and the peak from a Z_η that arises in an E_6 model standard model couplings and a mass of 4 TeV.

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Figure 1

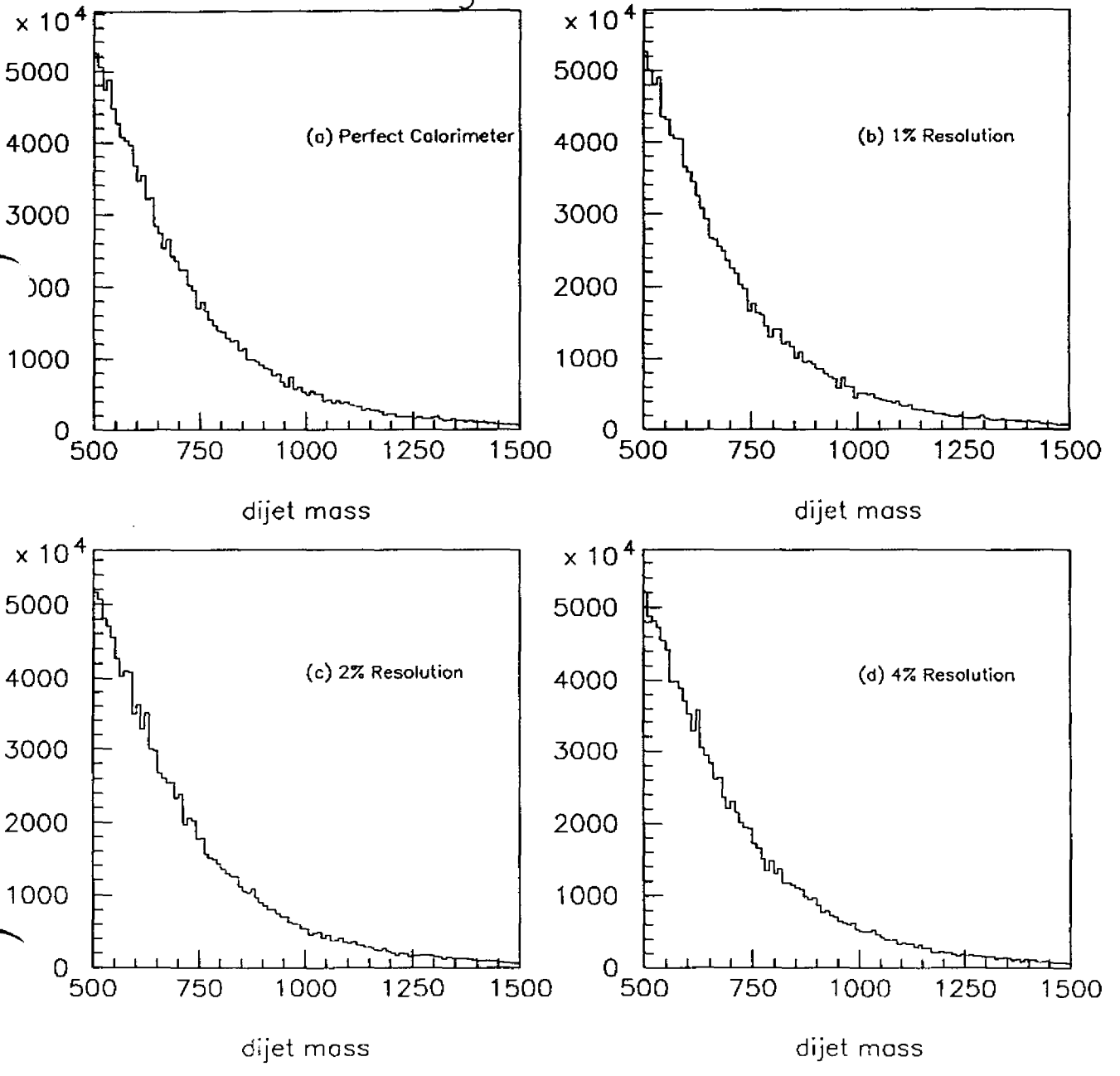

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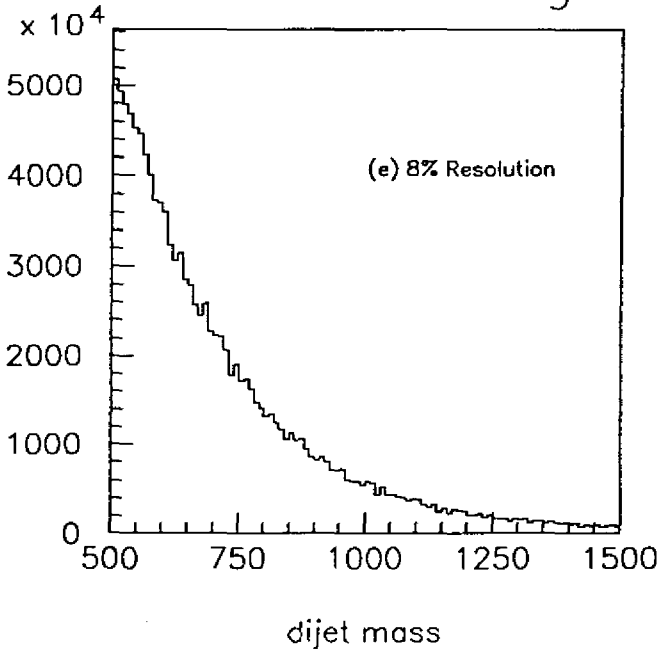
Figure 1



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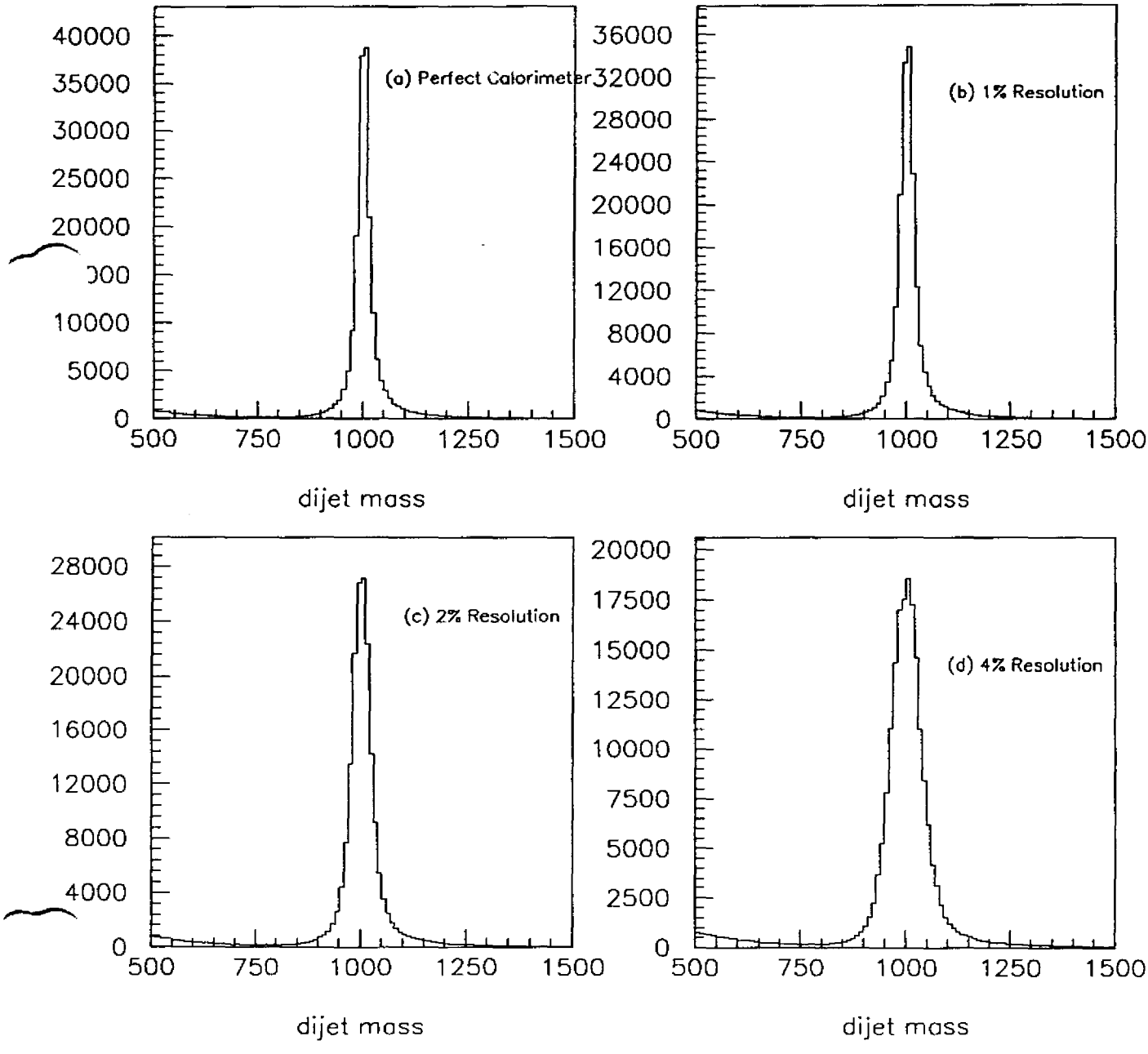

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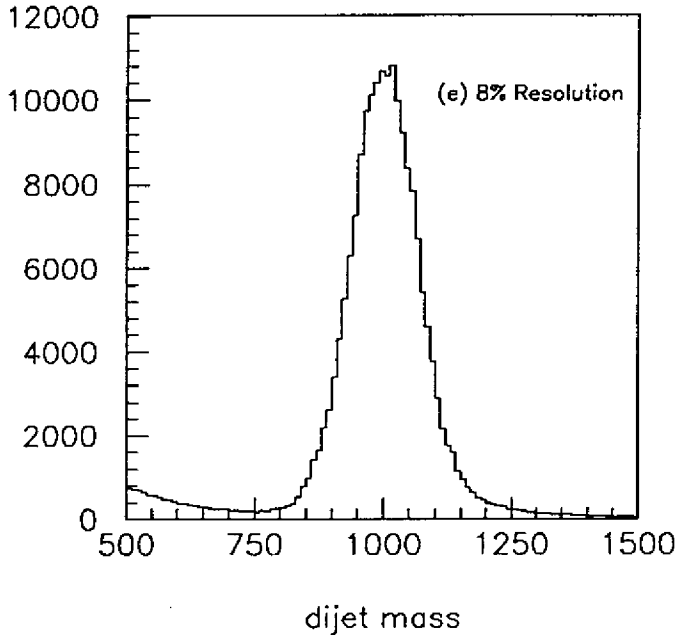

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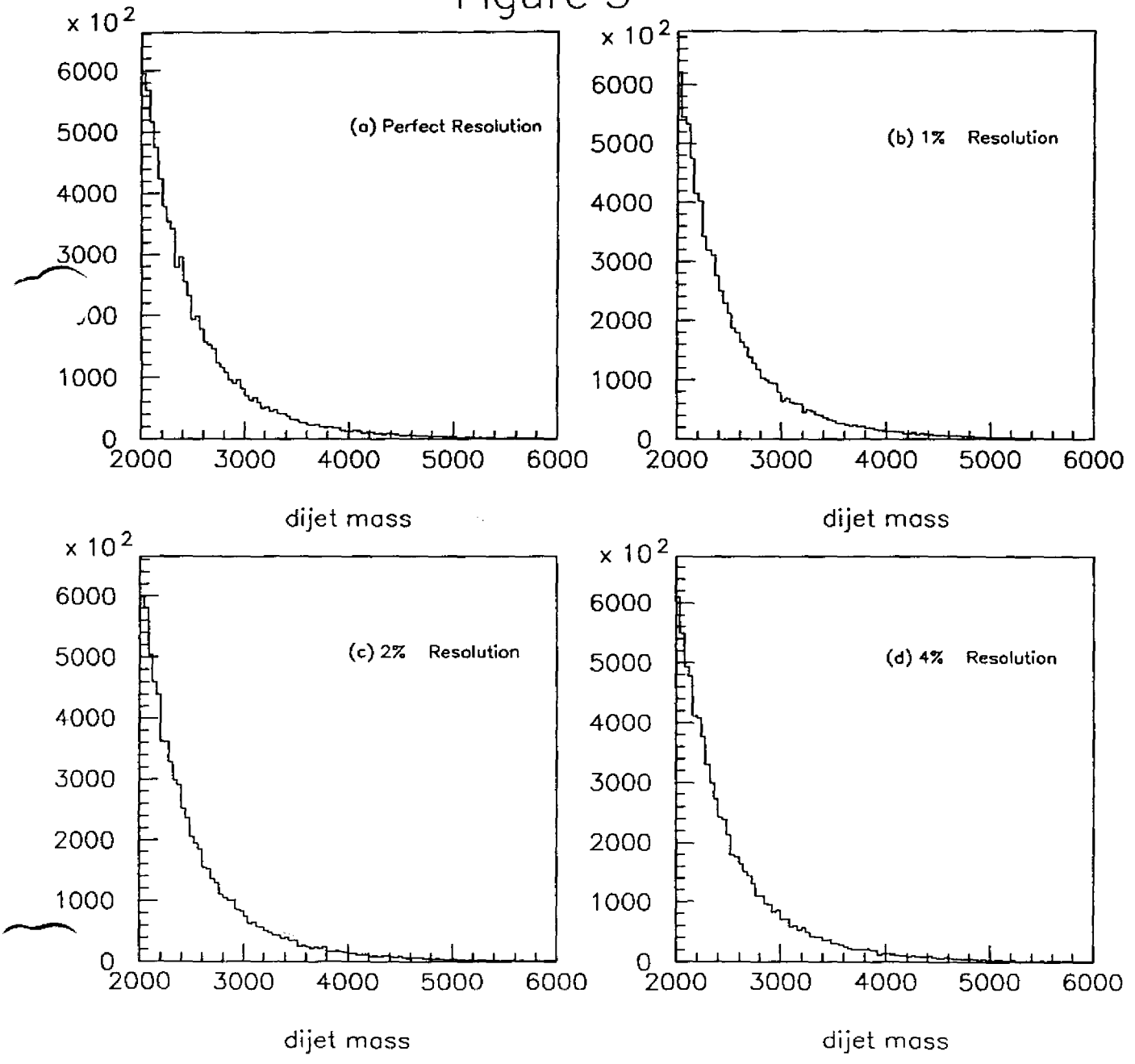

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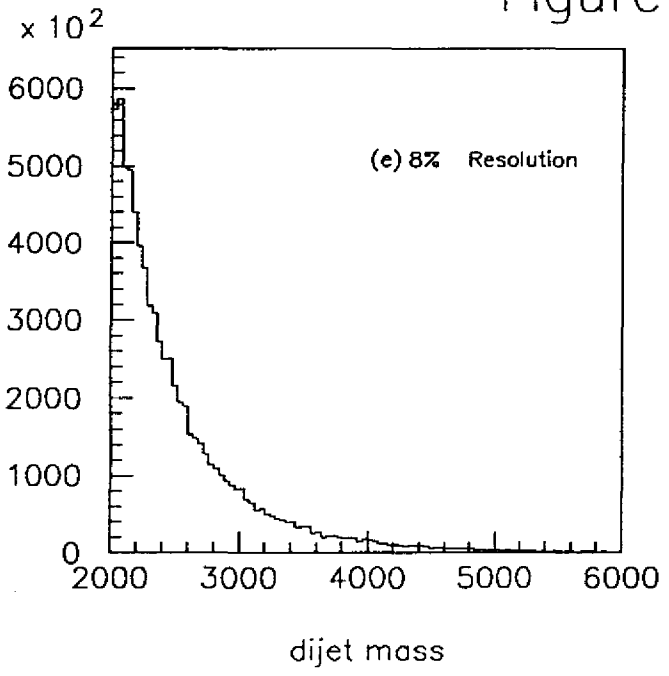

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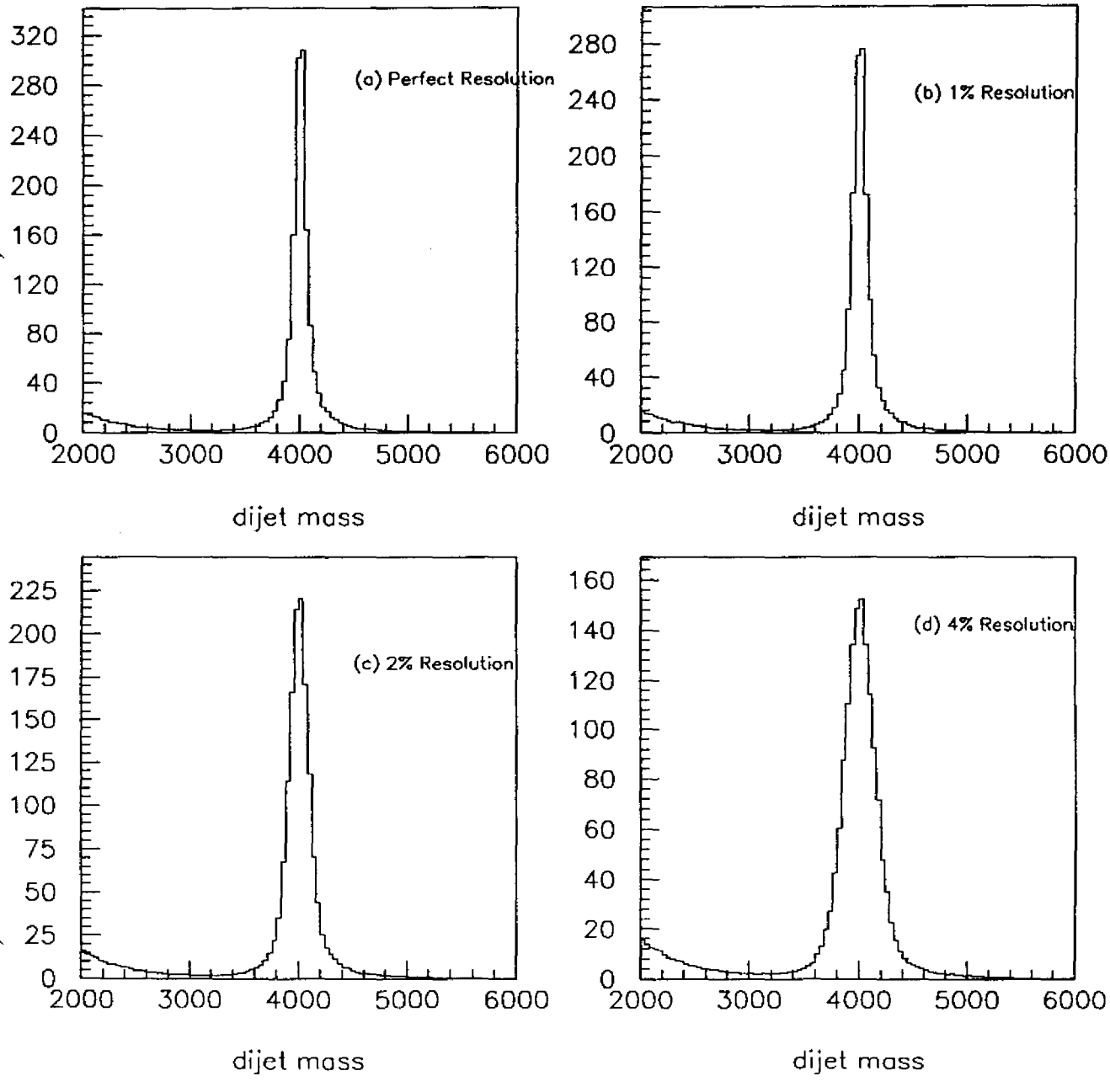

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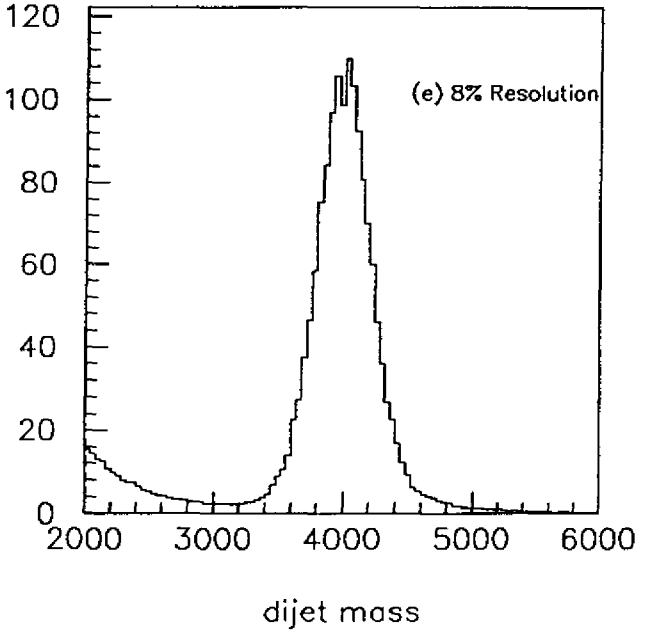

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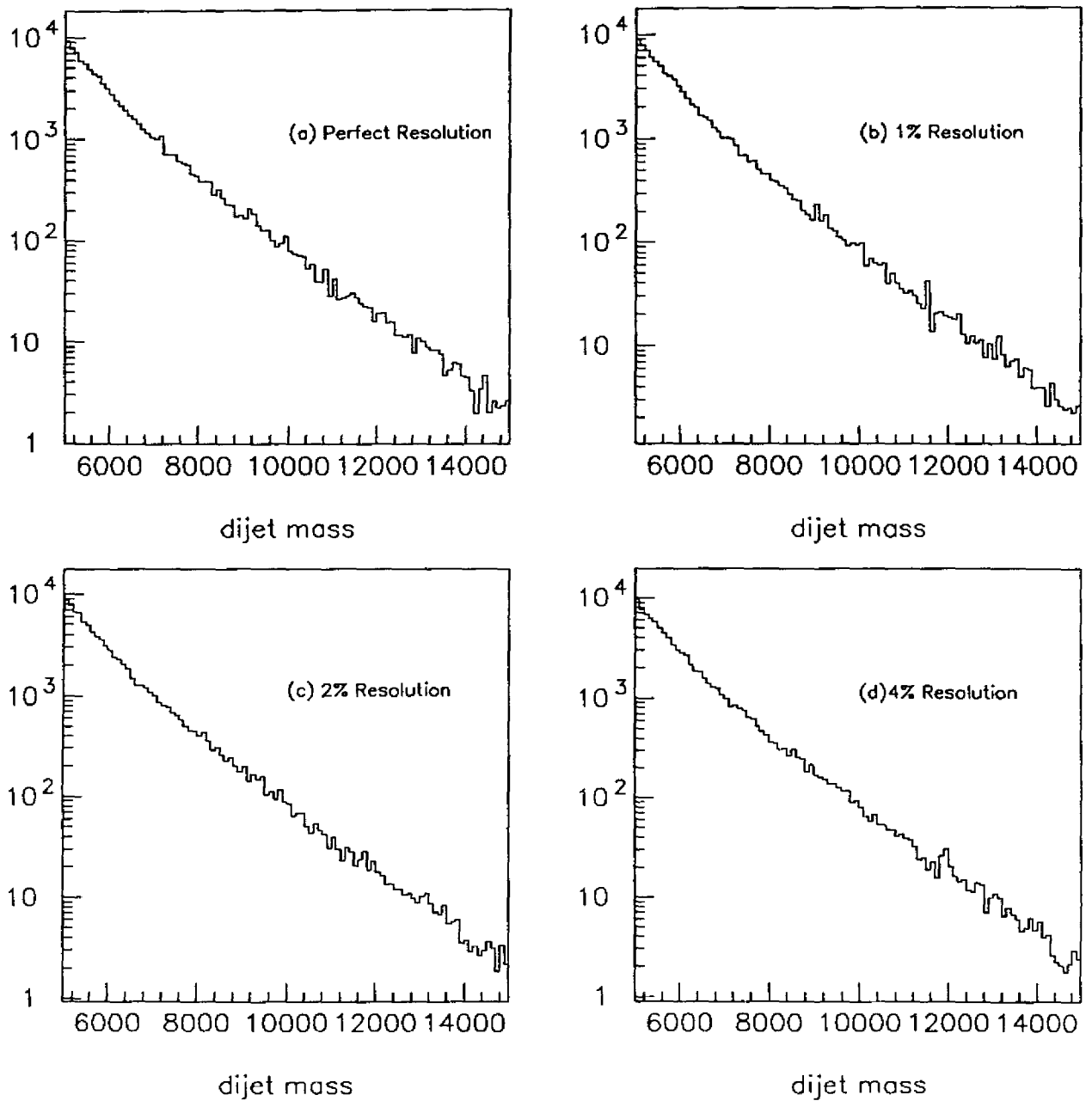

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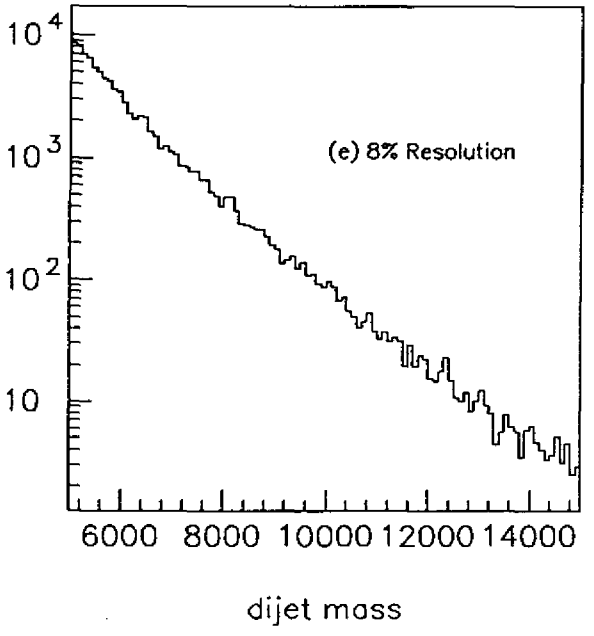

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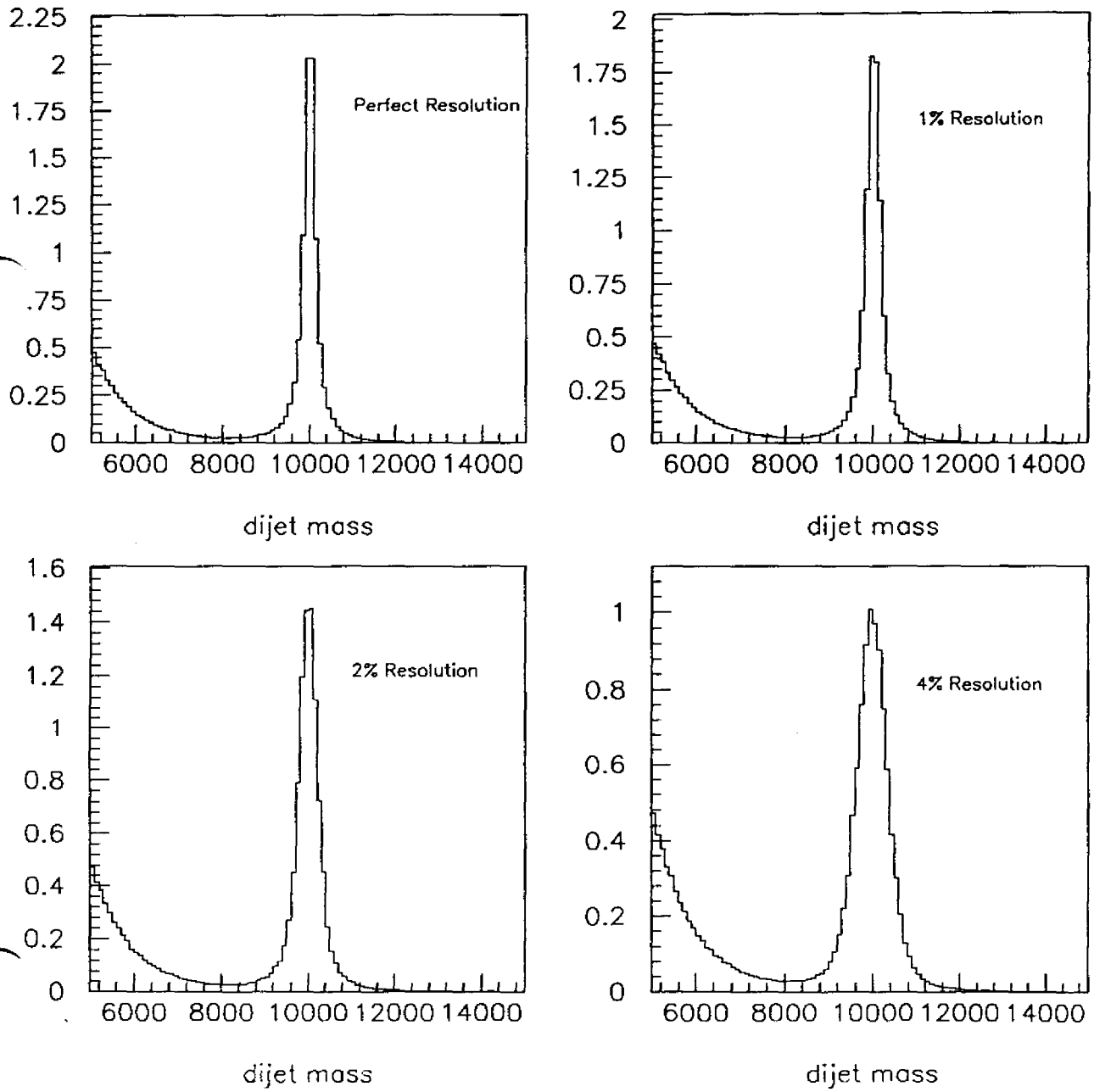

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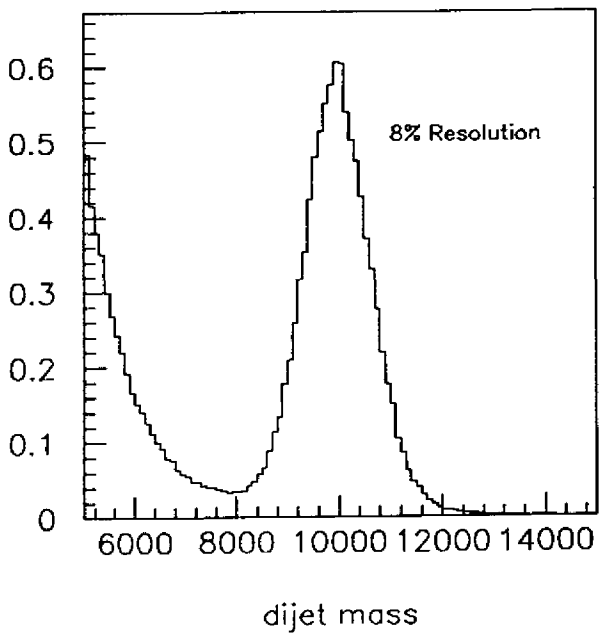

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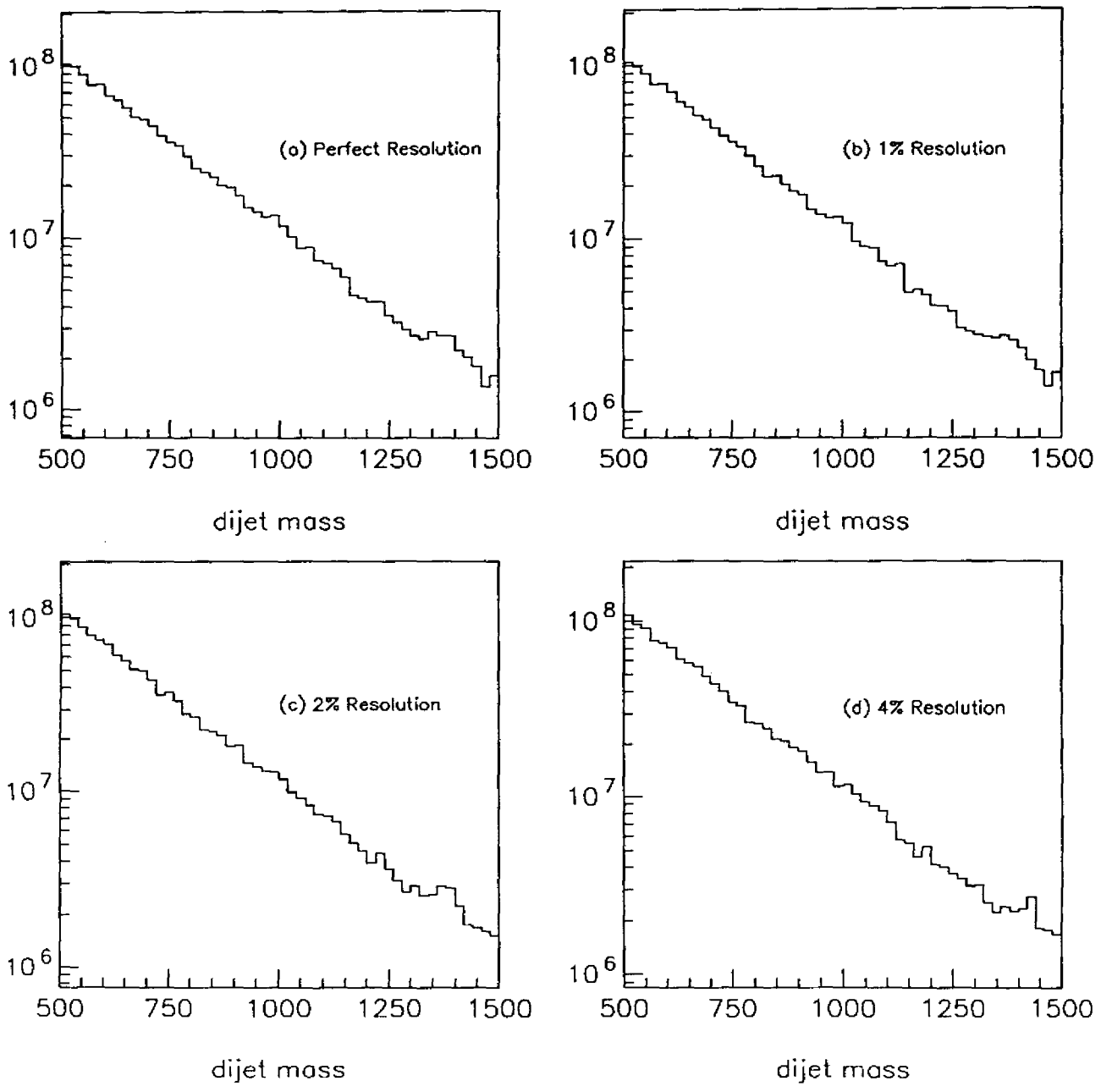

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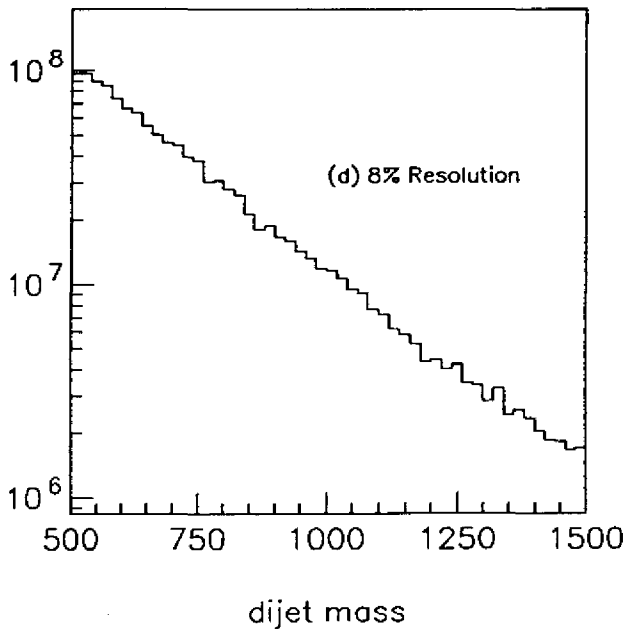

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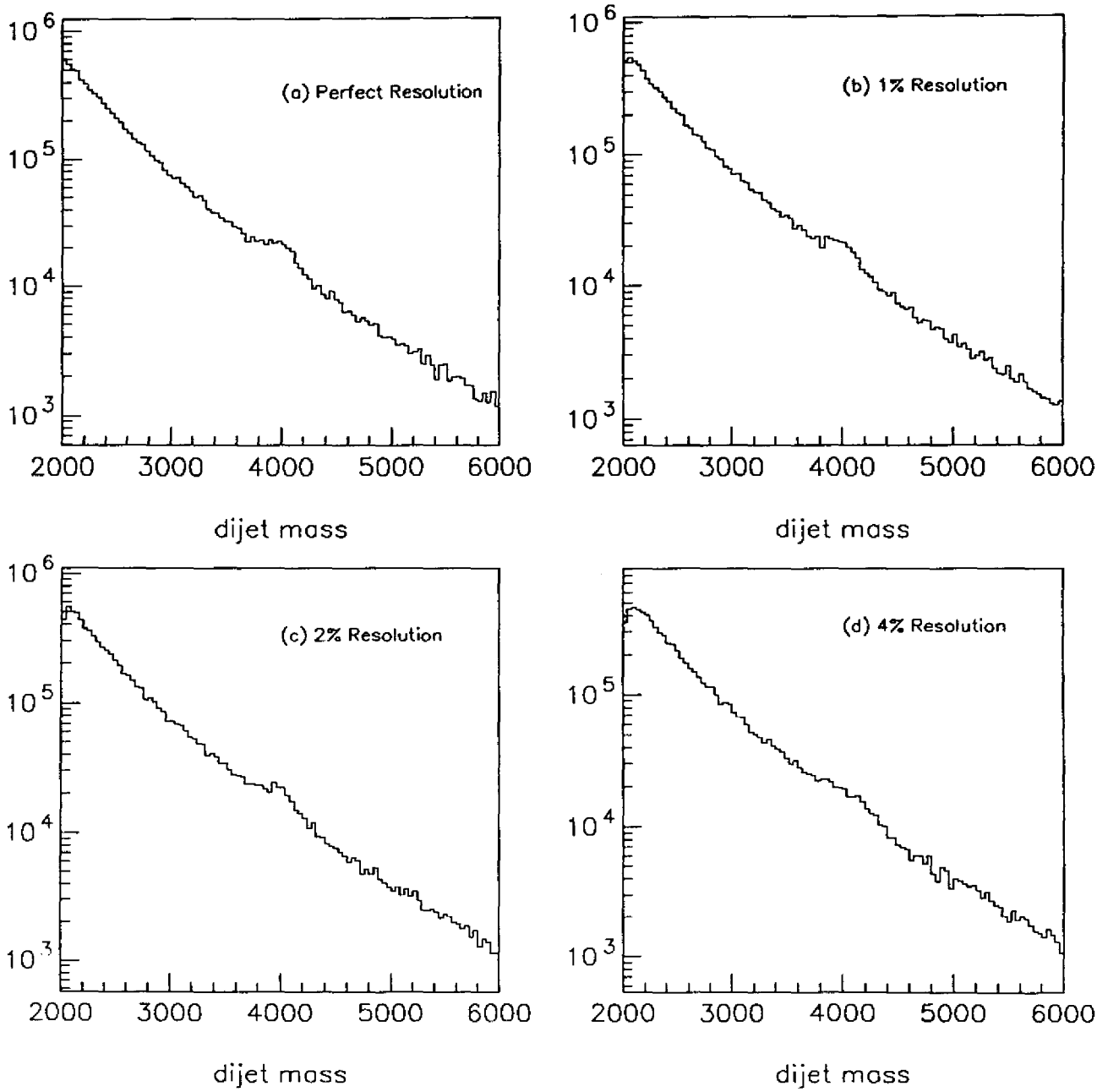

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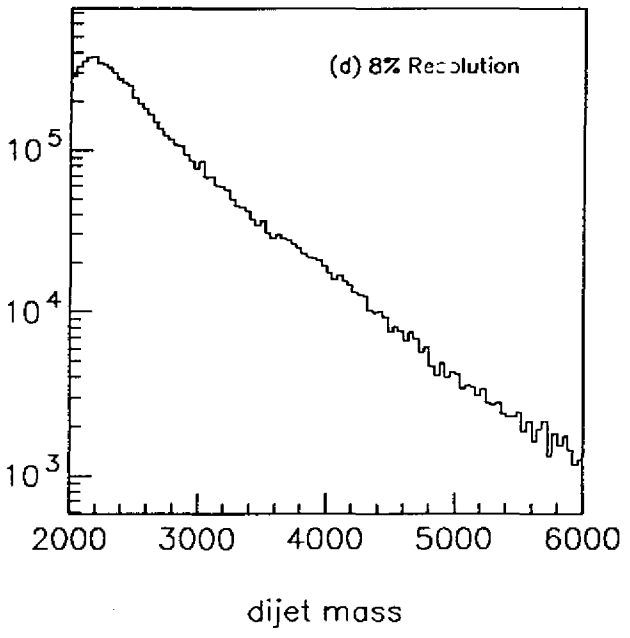

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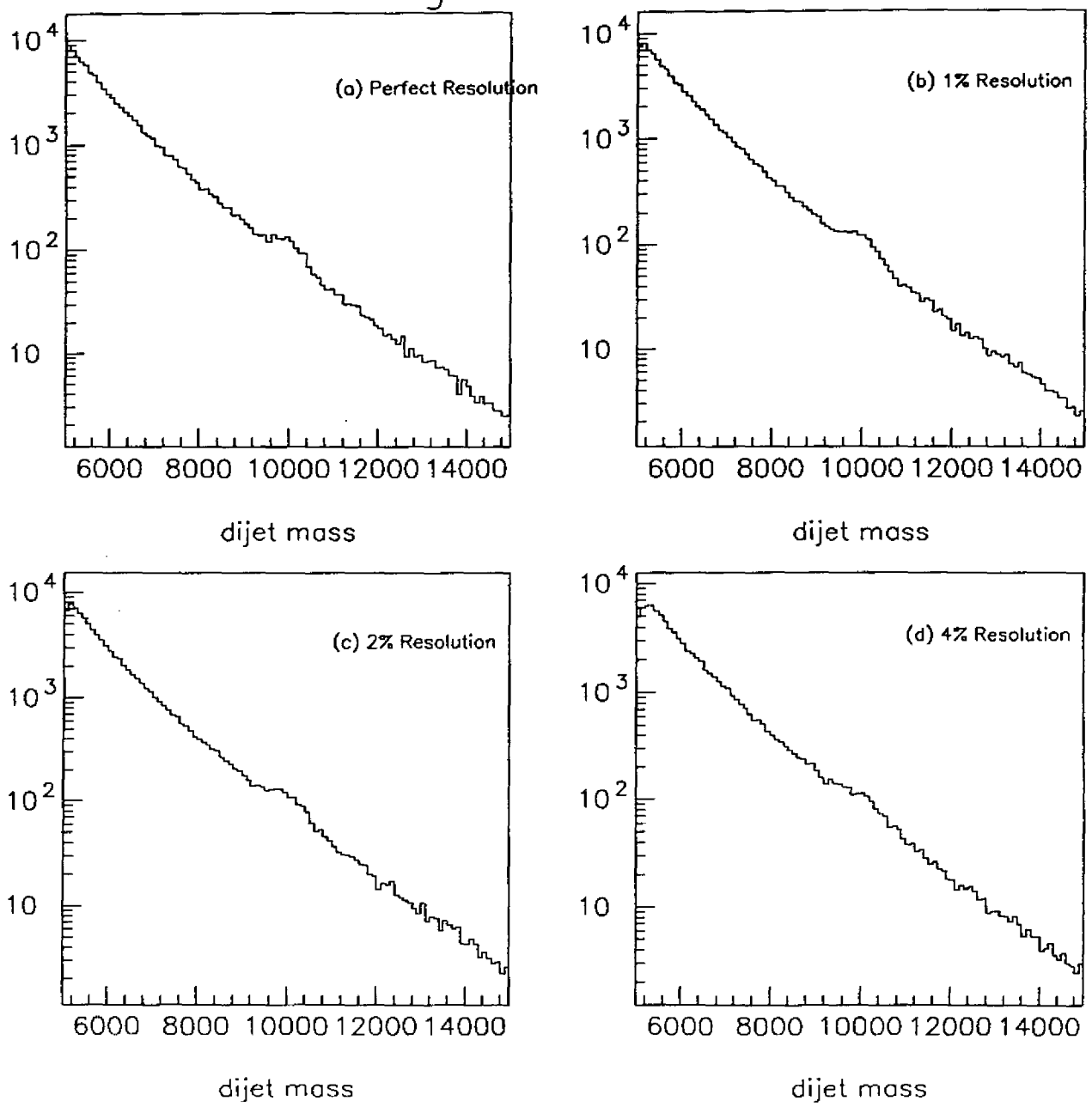

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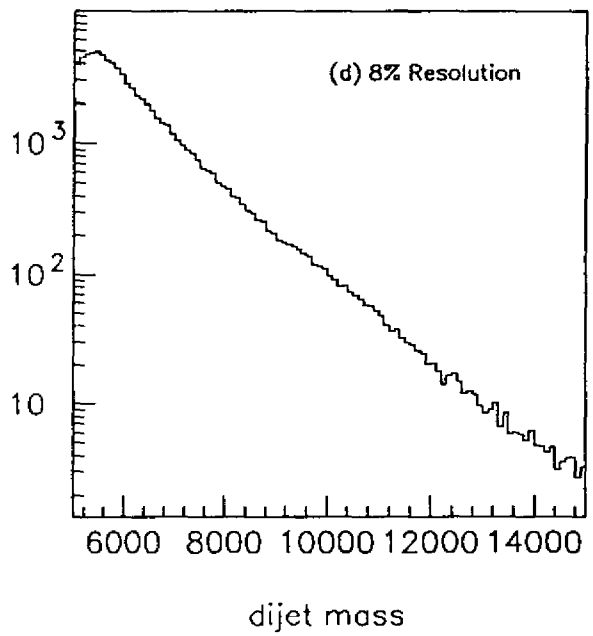

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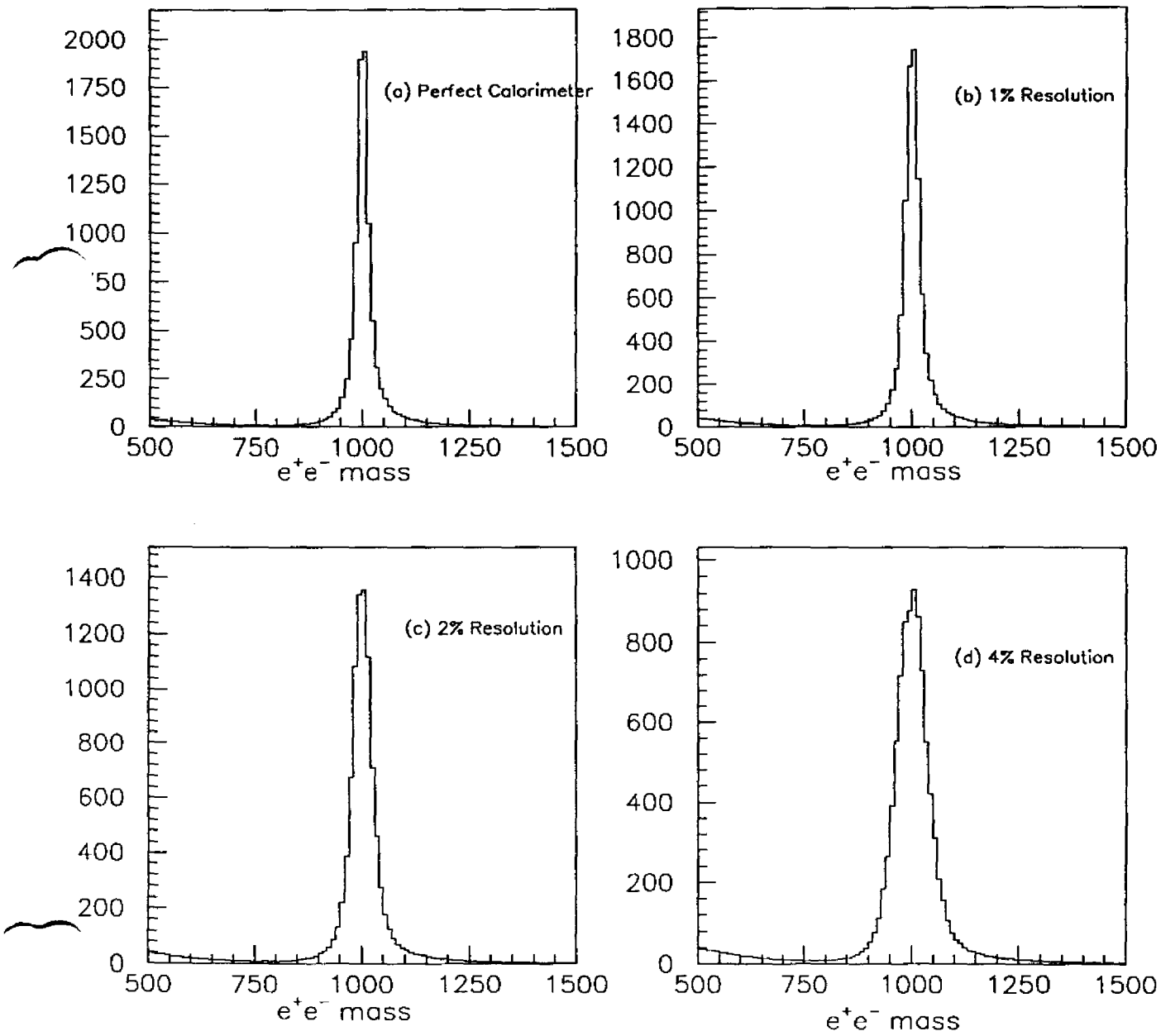

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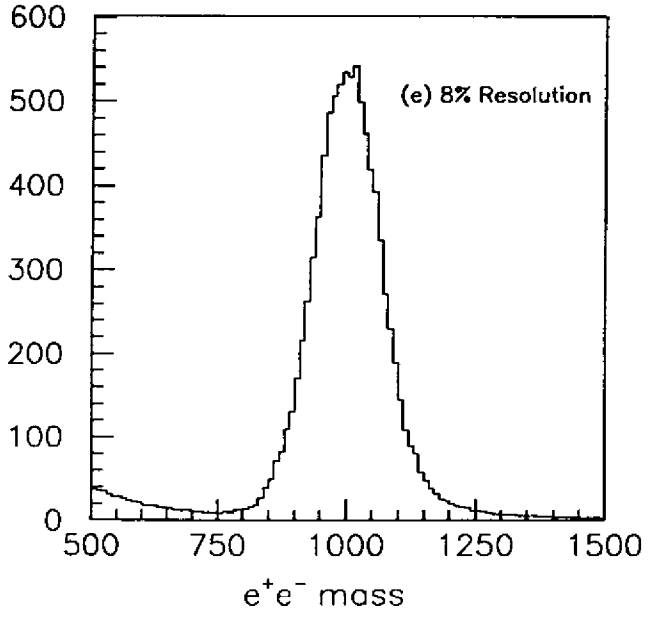

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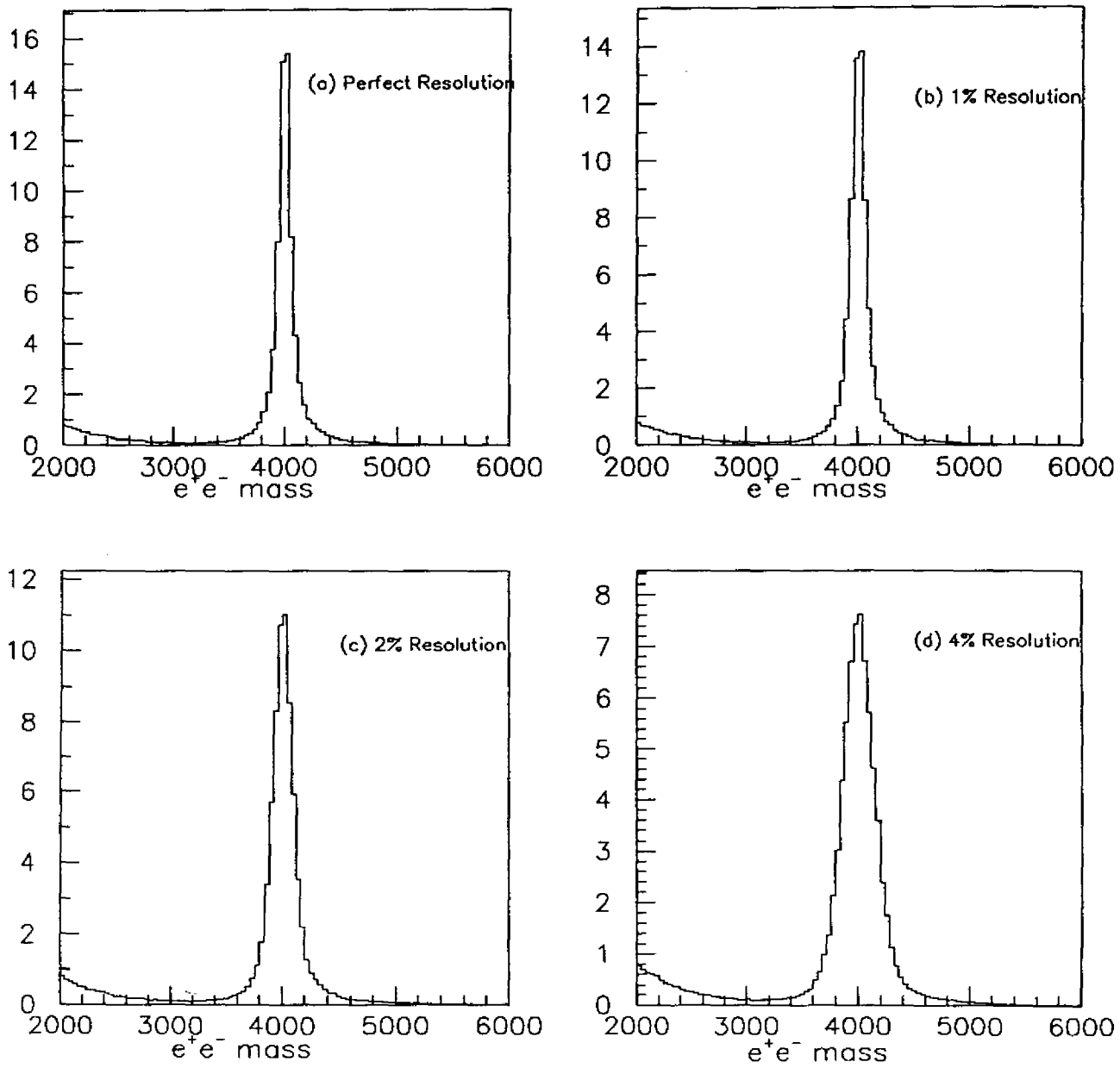

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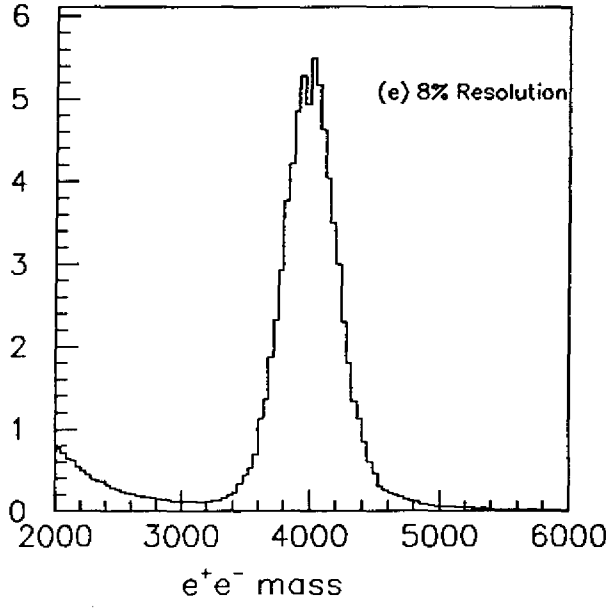

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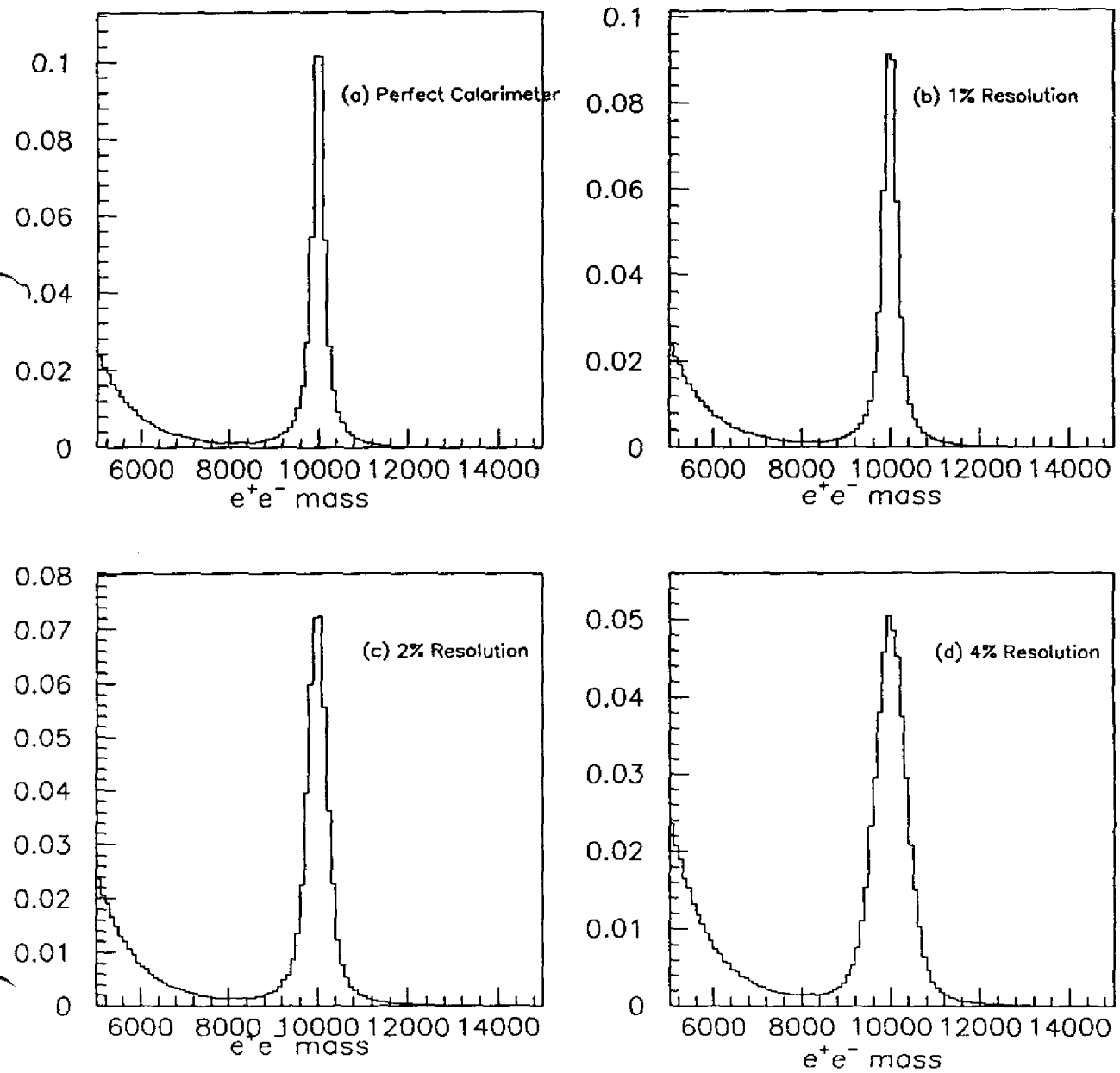

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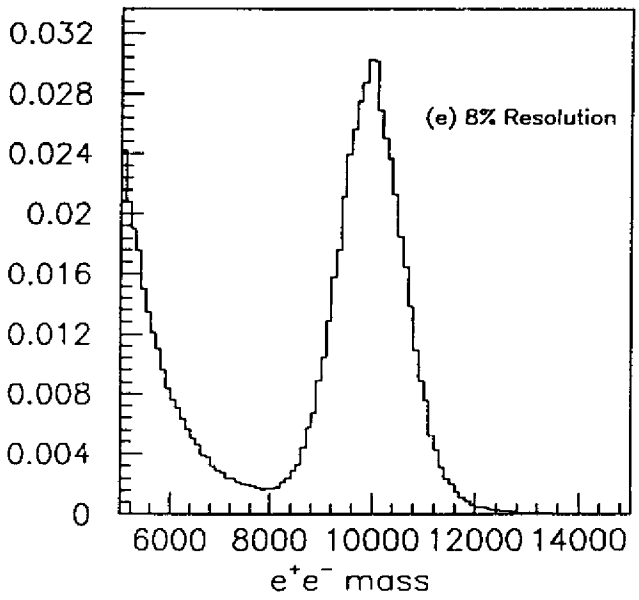

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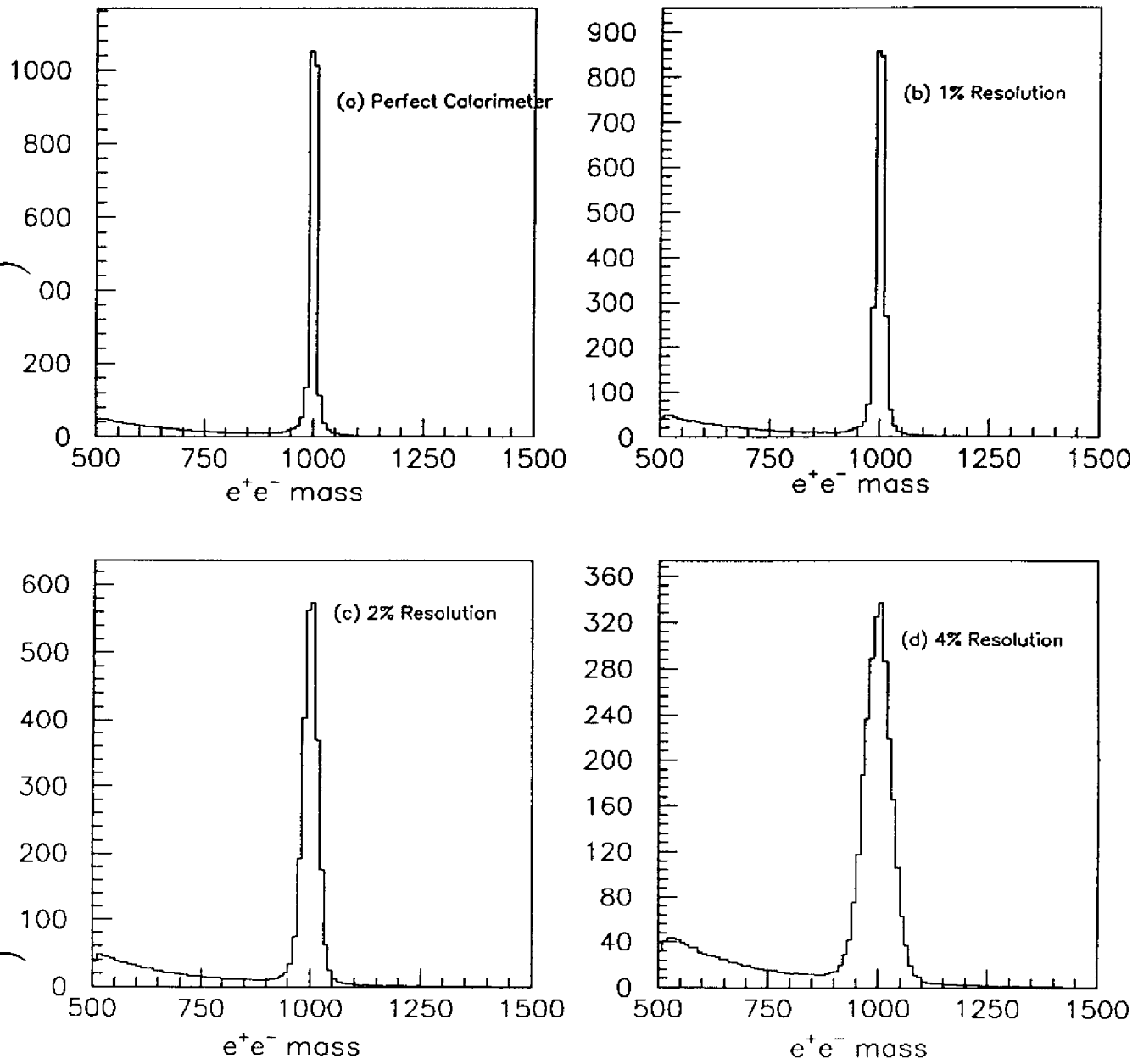

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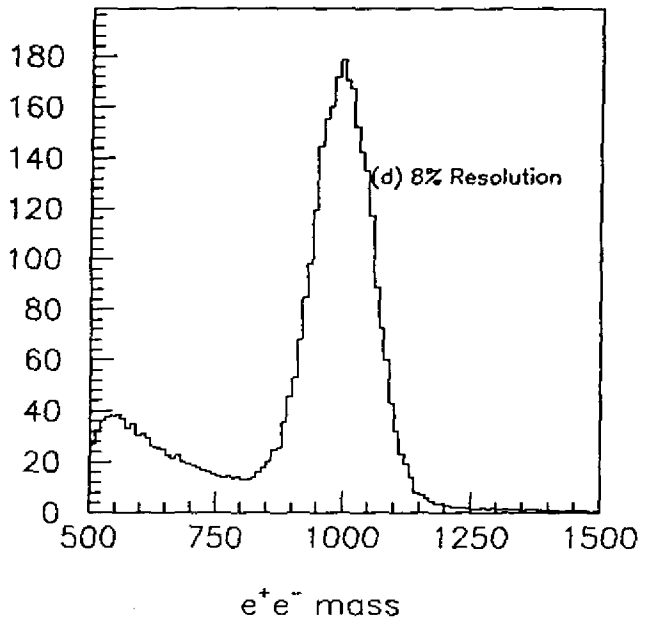

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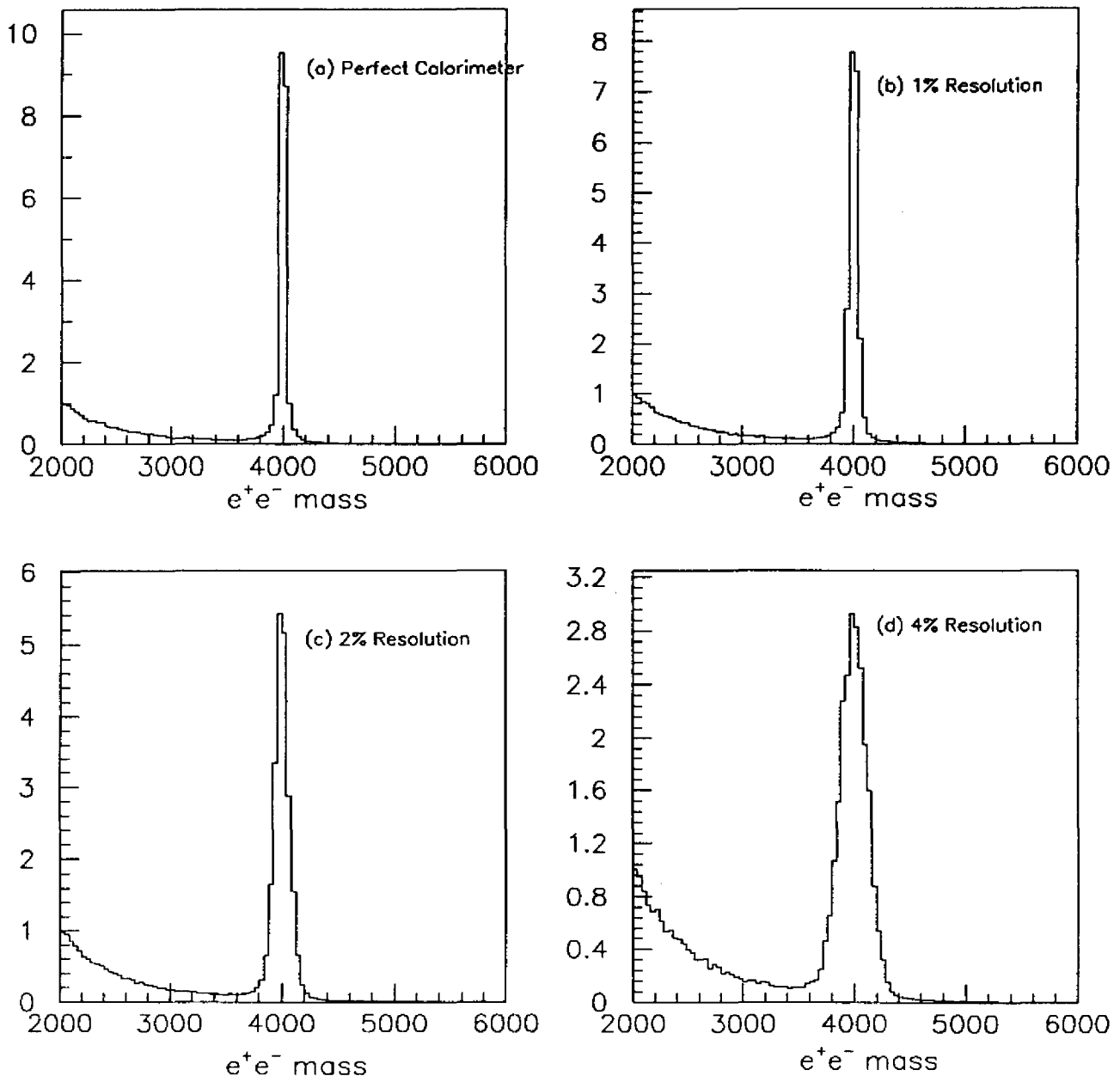

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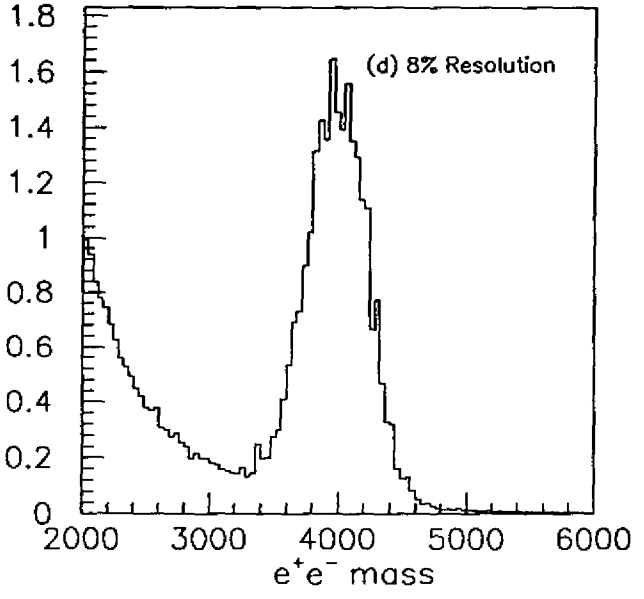
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