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SIMULATION STUDY OF B→$X_s\gamma$

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1. INTRODUCTION

A comprehensive study of charm and beauty decays is proposed in P867 as an extension of Fermilab experiment E771. Most of the decay modes studied for the proposal rely on the detection of a high p_t muon or high mass dimuon pair in the spectrometer. The addition of a Ring Imaging Cerenkov Counter, which is under consideration, would increase the number of decay modes accessible. No major upgrades are planned for the electromagnetic detector, but it may be possible to use the existing calorimeter to detect photons from rare beauty decays.

As part of the ongoing simulation for P867, we have studied the decay $b \rightarrow s\gamma$. We expect several $\times$ 10^4 such events to be produced, with about 10^3 satisfying the acceptance and trigger. The main problem in detecting the signal is that there is a very significant photon background. Our simulations suggest that with good electromagnetic calorimetry and by optimizing cuts, adequate background suppression will be possible, and the signal will be detectable.

2. $b \rightarrow s\gamma$ SIMULATION

Simulation studies are being conducted of the photons from the inclusive decay $b \rightarrow s\gamma$ using the Monte Carlo program PYTHIA to generate B events. Since $b \rightarrow s\gamma$ decays are not implemented in PYTHIA, we treat the decay as a two body decay, assuming that the s and spectator quarks hadronise into a state with a mean mass halfway between the K^* and the K_4^*. This generates a mass distribution with FWHM equal to the K_4^* - K^* mass difference. The shape is a Gaussian, truncated at the low end at the mass of the K^* and at the high end at the mass of the B.

We assume an energy resolution of $\frac{10\%}{\sqrt{E}}$, an angular resolution of 1 mrad for γ's, and (since the calorimetric photon measurement will dominate the resolution) a perfect momentum resolution for hadrons.

The transverse momentum distributions for γ's from B events have been obtained. The B background includes all γ's; the signal includes only those γ's originating from the b quark. Figure 1 shows the p_t spectrum of γ's from 10,000 B background events. Figure 2 shows the p_t spectrum of γ's from 1,000 $b \rightarrow s\gamma$ events. The $b \rightarrow s\gamma$ photons were broadly

peaked in the transverse momentum, with a mean of 2.3 GeV and rms width of 0.8 GeV, while the photons from B background events had a mean p_t of 0.2 GeV, and the distribution fell off somewhat more slowly than exponential. The p_t spectrum of γ's from 1,000 non-B events was also obtained to permit background subtraction (Figure 3). The transverse momentum of the photons had a mean p_t of 0.17 GeV and a maximum p_t of 2.5 GeV.

According to Ali[1] the standard model prediction for the branching ratio of $b \rightarrow s\gamma$ is $(2\sim5)\text{x}10^{-4}$. Assuming a branching ratio of $4\text{x}10^{-4}$, there should be 20 signal events corresponding to the 50,000 background events we generated. Since even at the peak of the signal p_t the background exceeds the signal by 2 orders of magnitude, we have investigated several cuts to see whether we can extract the signal from the background.

In order to suppress γ's from π^0, we exclude from the analysis all γ's which are consistent (within the calorimeter resolution) with combining with any other γ in the event to form a π^0. Various $\gamma\gamma$ mass-range cuts are examined. If the mass range $0\leq m_{\gamma\gamma} \leq 0.2$ GeV is excluded, the signal to background ratio is improved by a factor of 142, with a signal retention of 55%. Figure 4 shows the invariant mass distribution of $\gamma\gamma$ pairs from background B events. The upper and lower mass limits of the π^0 mass range cut are indicated. The distribution peaks at the π^0 mass, with a π^0 mass resolution (σ) of 7.1 MeV. Table 1 summarizes the π^0 mass resolution as a function of photon energy resolution in the calorimeter.

Table 1. π^0 Mass Resolution

Energy Resolution at 1 Gev in rms (%)	π^0 Mass Resolution (Mev/c^2)
5	4.62
7	5.75
10	7.09
15	9.36

After the π^0 mass range cut of $0\leq m_{\gamma\gamma} \leq 0.2$ GeV is applied, the background γ's from π^0 are entirely eliminated. This leaves high-p_t γ's from B or D to η decays, which may be overrepresented in PYTHIA, as evidenced by the apparent lack of such background in CLEO data.

Figure 5 shows the p_t distributions of γ's from 250,000 B background events superimposed on 1,000 B signal events after the π^0 mass range cut of $0\leq m_{\gamma\gamma} \leq 0.2$ GeV is applied. There are about 20 γ's from signal events with $p_t \geq 3.5$GeV, and these are all from η decays. Figure 6 shows the p_t spectrum of γ's from 250,000 B background events superimposed on 1,000 B signal events, with the mass cut $0\leq m_{\gamma\gamma} \leq 0.2$ GeV and with $\eta \rightarrow \gamma\gamma$ suppression. For the region $p_t \geq 3.6$ GeV the background is completely suppressed, but the signal is statistically significant. The signal retention is 6.34%.

Table 2 shows the numbers of γ's from 1,000 $B \rightarrow X_s\gamma$ events and from 250,000 B background events as functions of the minimum p_t cut. The threshold p_t of 3.6 GeV is not sensitive to an E_γ cut. This is shown in Table 3, which includes an additional cut of $E_\gamma \geq$ 70 GeV.

Figure 7 shows the invariant mass distribution of γ pairs which survived the π^0 mass range cut described above. It peaks at the η mass with η mass resolution (σ) of 74.5 MeV.

Table 2. Signal to Background Ratio with no E_γ Cut

p_t Cut (GeV/c)	No. of γ's from 1K Signal	No. of γ's from 250K Background	Normalised Background using BR of $4\text{x}10^{-4}$	(Signal/Bkg) –
2.8	127	22±5	220±47	0.58
3.0	101	14^{+4}_{-3}	140^{+41}_{-34}	0.72
3.2	72	7^{+3}_{-2}	70^{+30}_{-24}	1.03
3.4	56	3^{+2}_{-1}	30^{+22}_{-15}	1.33
3.6	46	0^{+1}_{-0}	0^{+12}_{-0}	–
3.8	34	0^{+1}_{-0}	0^{+12}_{-0}	–
4.0	26	0^{+1}_{-0}	0^{+12}_{-0}	–
4.2	19	0^{+1}_{-0}	0^{+12}_{-0}	–
4.4	15	0^{+1}_{-0}	0^{+12}_{-0}	–
4.6	10	0^{+1}_{-0}	0^{+12}_{-0}	–
4.8	6	0^{+1}_{-0}	0^{+12}_{-0}	–

Table 3. Signal to Background Ratio with $E_\gamma \geq 70$ GeV.

p_t Cut (GeV/c)	No. of γ's from 1K Signal	No. of γ's from 250K Background	Normalised Background using BR of $4\text{x}10^{-4}$	(Signal/Bkg) –
2.8	71	10^{+4}_{-3}	100^{+35}_{-29}	0.71
3.0	60	6^{+3}_{-2}	60^{+28}_{-22}	1.00
3.2	46	3^{+2}_{-1}	30^{+22}_{-15}	1.53
3.4	40	3^{+2}_{-1}	30^{+22}_{-15}	1.33
3.6	33	0^{+1}_{-0}	0^{+12}_{-0}	–
3.8	24	0^{+1}_{-0}	0^{+12}_{-0}	–
4.0	18	0^{+1}_{-0}	0^{+12}_{-0}	–
4.2	15	0^{+1}_{-0}	0^{+12}_{-0}	–
4.4	14	0^{+1}_{-0}	0^{+12}_{-0}	–
4.6	9	0^{+1}_{-0}	0^{+12}_{-0}	–
4.8	5	0^{+1}_{-0}	0^{+12}_{-0}	–

3. FURTHER STUDIES

Preliminary studies are also being conducted of the exclusive decay mode $B \rightarrow K^*\gamma$.

First, all Kπ combinations are formed, and events in which the invariant mass is outside the range of the K^* (0.7 GeV to 1.1 GeV) are vetoed. Then we select Kπ pairs consistent with the K^* mass, and form all combinations of these K* candidates and γ's which survived the π^0 mass cut. The following additional cuts are then applied: an invariant mass cut on K^*-γ; a cut on the opening angle of the K^*-γ; and a primary vertex cut on the K^*-γ.

Further studies are needed using the GEANT simulation of the proposed P867 detector.

4. CONCLUSION

Simulation studies have been conducted of the photons from the inclusive decay b$\rightarrow$sγ using the Monte Carlo program PYTHIA to generate B events. An energy resolution of $\frac{10\%}{\sqrt{E}}$ and an angular resolution of 1 mrad for γ's are assumed. The signal is extracted by applying π^0 and η mass cuts. For the region $p_t \geq 3.6$ GeV the background is completely suppressed but the signal is still statistically significant. The results show that B's may be observed from this decay.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

1. A. Ali, T.Ohl and T. Mannel, *Phys. Lett.* **B 298** (1993) 195.

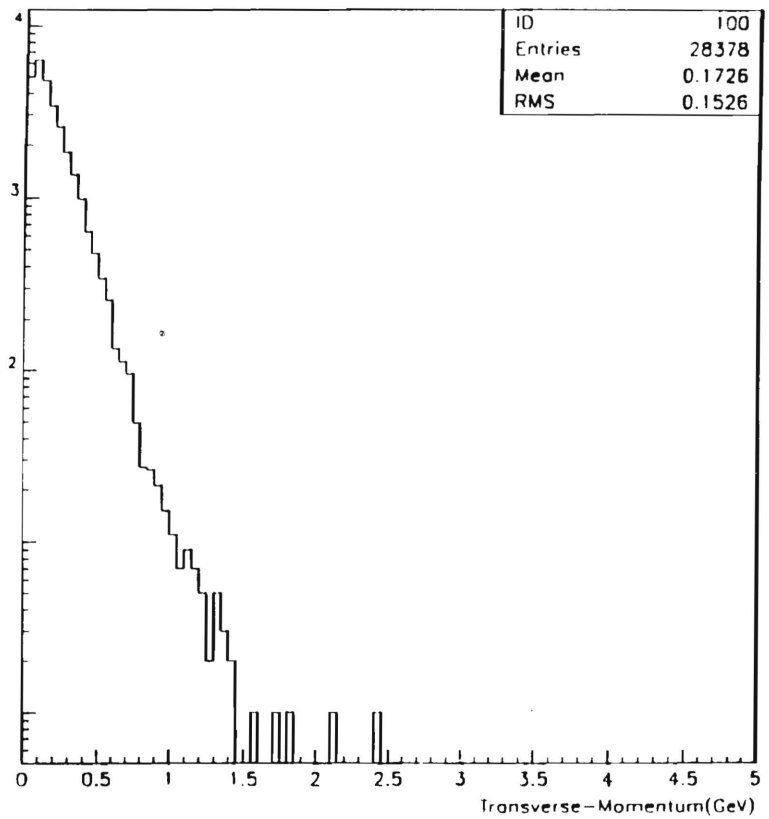

Figure 3: The p_t distributions for γ's from 1,000 minimum bias events.

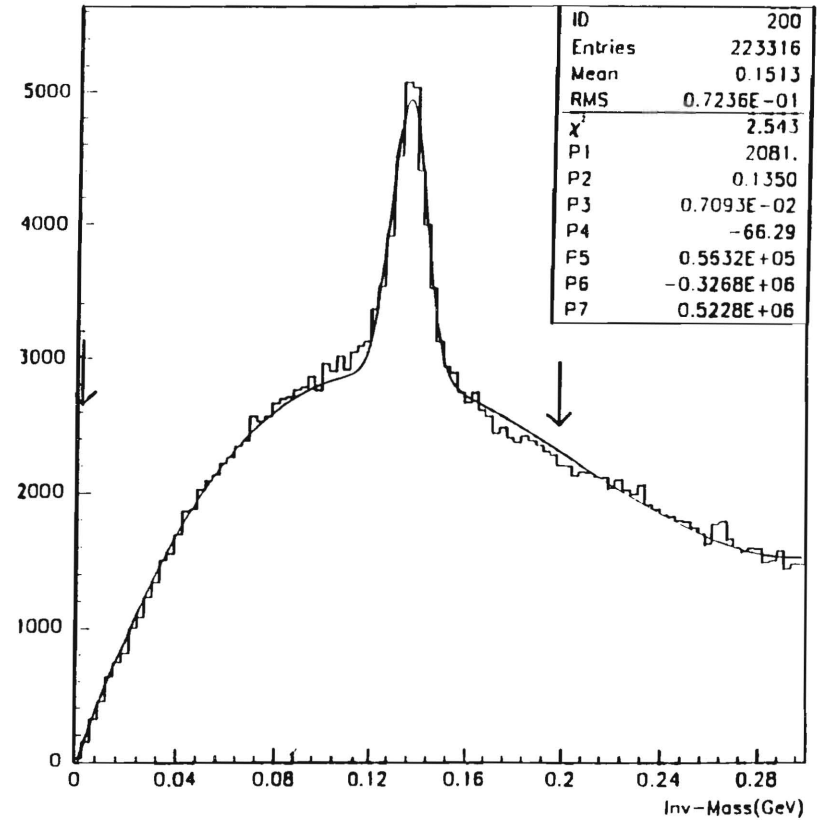

Figure 4: The invariant mass distribution of $\gamma\gamma$ pairs from background B events. The upper and lower mass limits of the π^0 mass cut are marked.

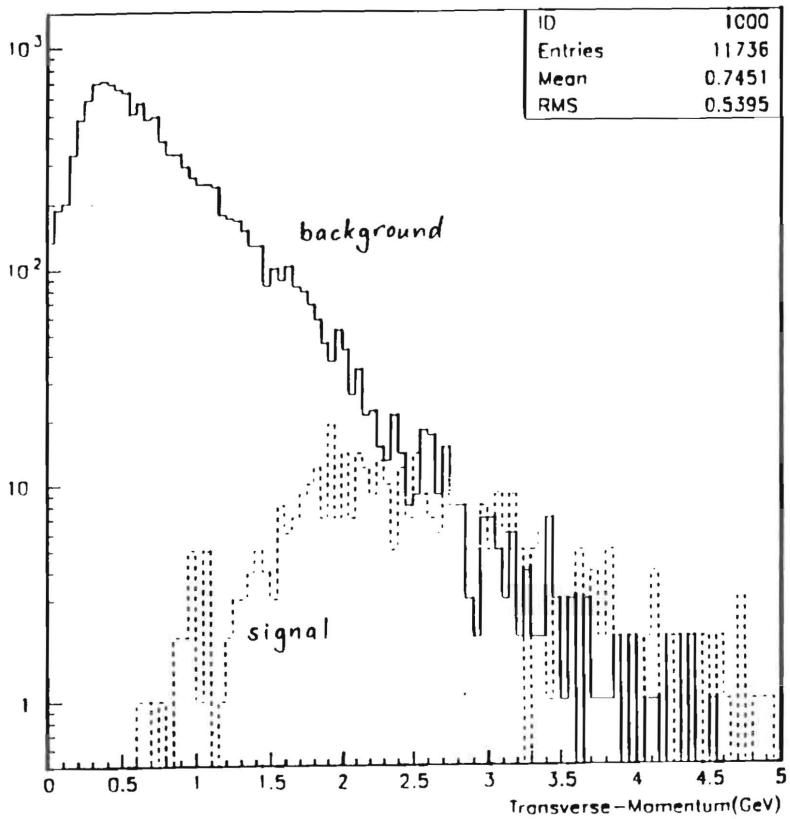

Figure 5: The p_t distributions of γ's from B background events and B signal events.

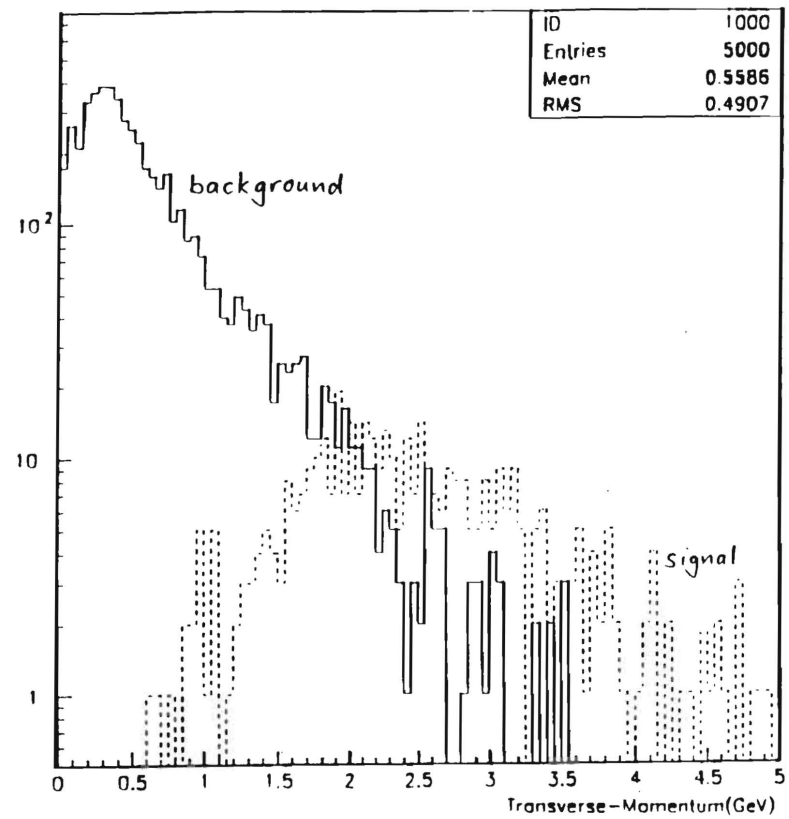

Figure 6: The p_t distributions of γ's from B background events and B signal events, with $\eta \to \gamma\gamma$ suppression.

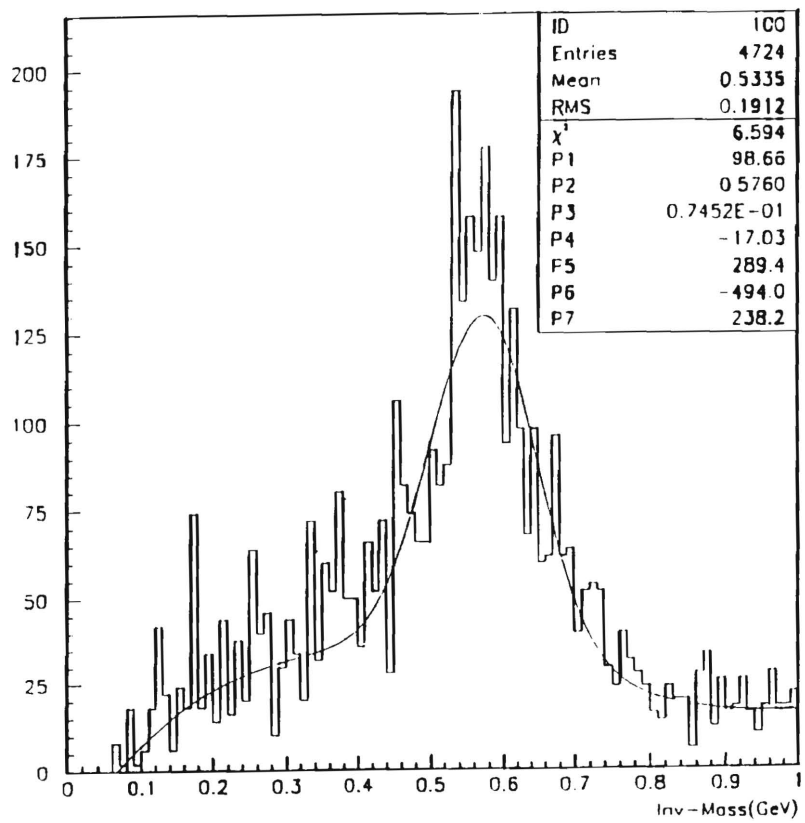

Figure 7: The invariant mass distribution of $\gamma\gamma$ pairs which survive the π^0 mass cut.