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Bottom Acceptance, Trigger Efficiency and Resolution at Fermilab Fixed-Target Experiments*

M. V. Purohit
Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

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Abstract

We present results on the acceptance, trigger efficiencies and resolutions expected for bottom events produced by a 900 GeV proton beam on a fixed target. Also examined is the question of a central hole in such a detector, its impact on acceptance and radiation damage.

FIXED TARGET BOTTOM PHYSICS

Several groups working at Fermilab's fixed target program are trying to obtain samples of bottom events or will attempt to do so in the near future[1,2,3]. Fermilab's major advantage is the high rate and high momentum at which bottom is produced at the fixed target program. However, the large background to signal ratio makes any bottom experiment very difficult. Here we shall examine the easier questions of acceptance and efficiency while leaving the question of adequate background reduction for the future.

GEOMETRIC ACCEPTANCE

Most experimenters are considering few-body channels of B-meson decay, viz. 2-, 3-, 4-, 5- and 6-body decays into charged tracks with no additional neutrals. This choice reduces the experiment to tracking, momentum measurement and particle identification while covering most physics issues including CP violation (if it were detectable). Typically, experiments are limited in geometric acceptance by the maximum angle covered, e.g., by the last plane of Silicon. In figure 1 we show the geometric acceptance for n-body decays, assuming the Lund model of decays. The acceptance depends somewhat on the particular mode under consideration, this is illustrated by comparison with figure 1b. Figure 1b also shows 4 and 5 body modes, but only for $B^0 \to \Psi\pi^+\pi^-$ and $B^- \to \Psi\pi^+\pi^-\pi^-$ with the Ψ always decaying into $\mu^+\mu^-$.

Some investigators have considered the possibility of a hole in their detector to allow the high intensity beam particles to pass through. This naturally means some minimum angle of coverage and we illustrate the effects of such a hole on the acceptance in fig. 1c.

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As before, the acceptance is a function of the exact mode under consideration — figure 1d is the acceptance for $B^0 \to \pi^+\pi^-$ and $B^- \to \pi^+\pi^-\pi^-$. In order to investigate the entire range of possible apertures, we show in figures 2a and 2b the 2- and 3-body decay acceptances for $B^0 \to \pi^+\pi^-$ and $B^- \to \pi^+\pi^-\pi^-$ as contours of acceptance in a space of minimum and maximum angles.

EFFECT OF A HOLE IN THE APPARATUS

It is almost a given that any major bottom experiment will have planes of silicon strips (or pixels) as a vertex detector. These detectors are expected to withstand radiation damage at the level of $D=10^{14}$ particles/cm^2. The intensity of produced particles falls off as the distance R from the beam line increases, independent of the distance z from the target. If there are 3 particles per unit of rapidity, the flux is given by

$$Particles/cm^2 = \frac{3}{2\pi R^2}$$

Thus an anticipated integrated luminosity of L_0 leads to a minimum radius from the beam of

$$R = \sqrt{\frac{3L_0}{2\pi D}}$$

For instance, if $L_0=10^{14}$ particles/cm^2, R=0.7 cm. The value of R sets the minimum angle covered.

The requirement of optimizing the effect of intrinsic spatial resolution on the angular resolution implies that the distance of any plane to its next downstream plane must equal its distance to the target. Hence, the i^{th} plane is at a distance $z_i=z_0 2^{i-1}$ from the target. Coupled with the requirement that every track go through at least 3 stations of silicon, we arrive at the additional relations:

$$T = 3R$$

where T is the transverse dimension of the station and R is the size of the hole and

$$z_0 \leq 4R$$

Furthermore, the momentum of a particle is determined by the first plane it hits, assuming a $< p_T >$ of 350 MeV/c^2. This in turn leads to a minimum transverse spatial resolution at the target due to multiple scattering in the first silicon station. Assuming a 1% radiation length for each station leads to

$$z_i \Delta\theta = 43\mu m R$$

where R is in cm. Clearly this is too large and creates a problem for background reduction. Note however that bottom meson decay tracks have a much larger p_T and a Monte Carlo simulation shows that the vertex spatial resolution of such tracks for a typical detector is only of order of 5–10μm, i.e., quite acceptable.

TRIGGERS

Any fixed target bottom experiment must achieve a large background rejection at the trigger stage itself, of the order of 100 – 10000 or more, depending on data acquisition and off-line computing capabilities. A back-of-the-envelope calculation (borne out by a detailed Monte Carlo) of the background from strange decays is enough to show that not more tha a factor of 50 can be achieved from a perfect vertex trigger that triggers on every event which has a secondary vertex in the B decay region. More information about the vertex must be used to achieve additional rejection. At the lower level, multiplicity jump and E_T triggers have been proposed. Figure 3 shows the efficiencies of these triggers (if they were perfect) for minimum bias and bottom events. Clearly, these triggers may be relied on for the first factor of 50 – 100 or so with high bottom efficiency. Both triggers are plagued by problems, including secondary interactions, nuclear fragments and the $A^{1.6}$ rise of high-E_T events.

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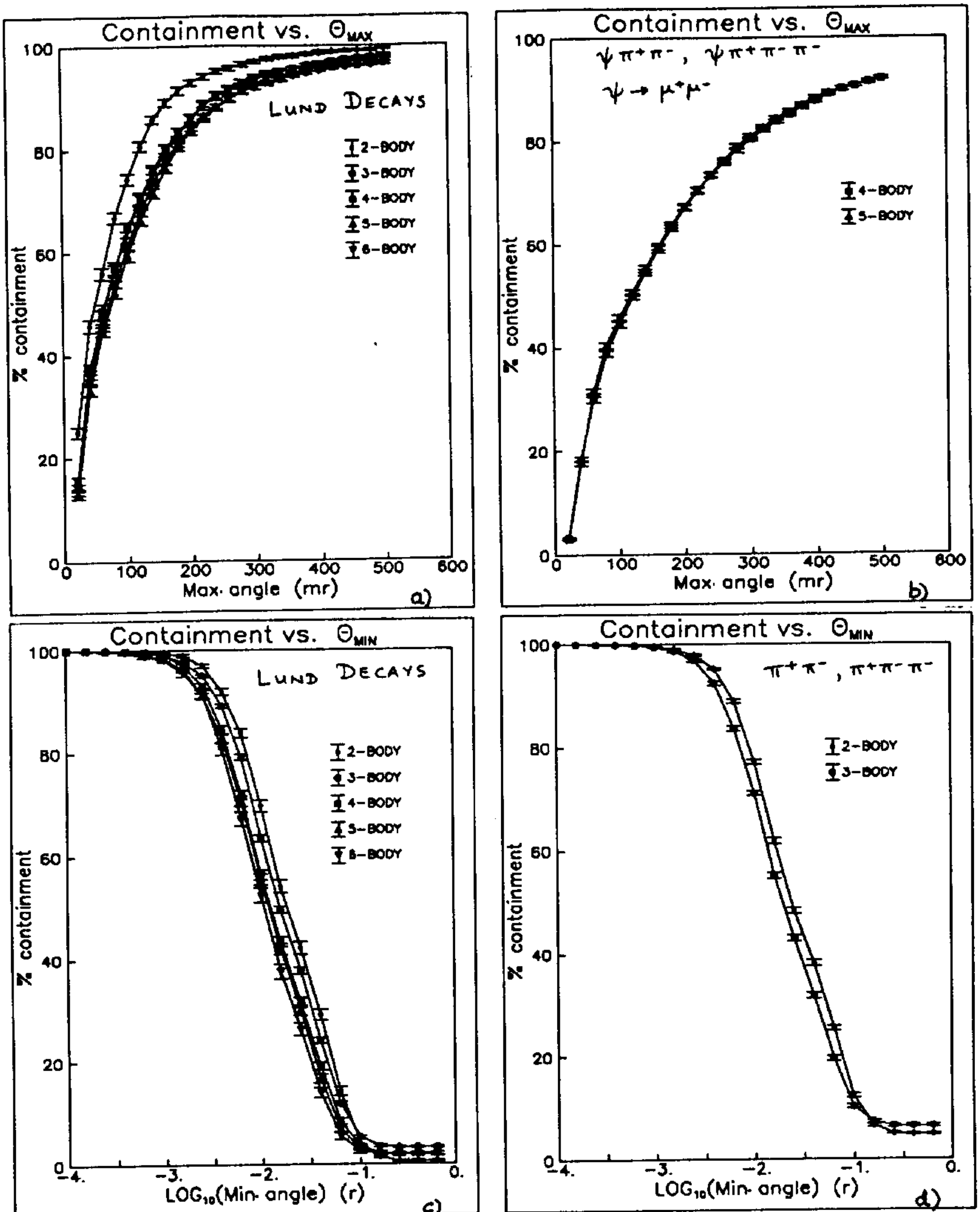

Figure 1. Containment of bottom decay products. a) and c) are for the Lund model of bottom decays, while b) and d) are for the modes mentioned in the text.

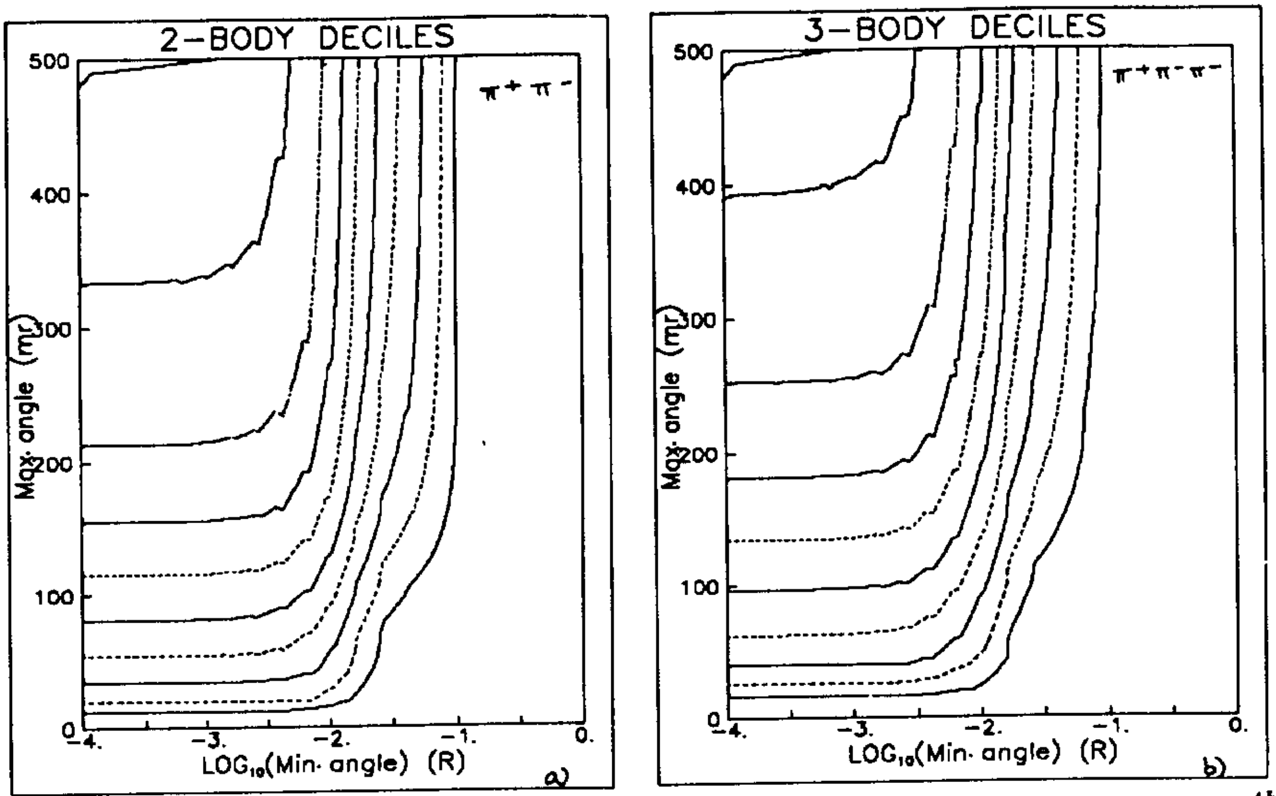

Figure 2. The acceptance of a detector with a central hole. The contours are for every 10^{th} percentile. a) and b) are for 2- and 3-body decays into pions respectively.

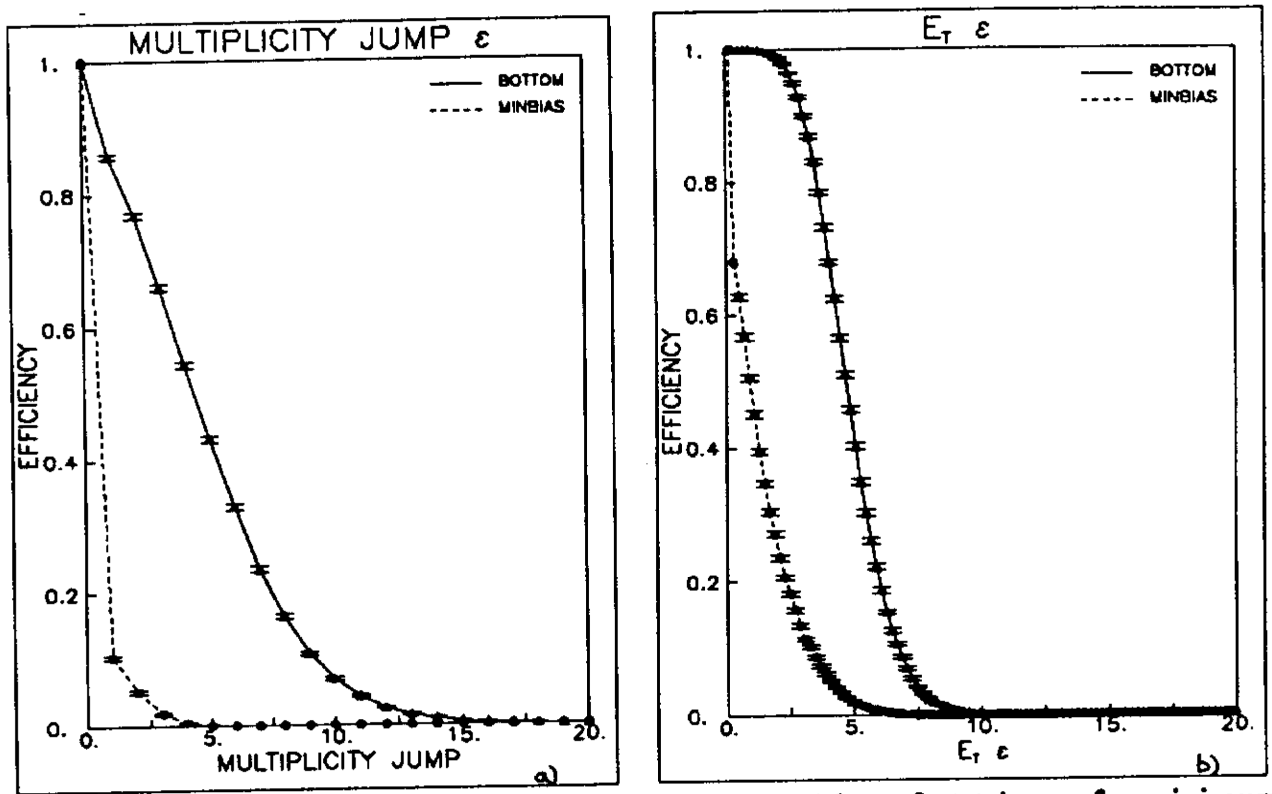

Figure 3. Multiplicity jump and E_T trigger efficiencies with perfect triggers for minimum bias and bottom events.