A SINGLE γ AND γγ EXPERIMENT FOR A 20 TeV FIXED TARGET MACHINE

Ronald Lipton
Carnegie-Mellon University
Pittsburgh, Pennsylvania 15213

I. Introduction

The primary advantage of a fixed target accelerator for studies of direction photon and diphotons is efficient rejection of backgrounds from π^0 and η^0 decays. This results from the forward collimation of the event which allows detectors of moderate size to efficiently contain both photons. A fixed target machine will clearly not compete with its high luminosity collider companion in the range of $P_\perp$ values addressed. This is due to the $(1-x_T)^{8-9}$ suppression of prompt photon production. We must assume by the time a 20 TeV machine is built the interests of photon physics will be less on a gross measurement of the γ/π^0 rates but on the details of the strong interaction revealed by the QCD compton effect. To some extent, however the extremes of transverse momentum may not matter as much as a very clean measurement of event characteristics with good statistics and low background. In this context we require an experiment with:

1) excellent π^0, η^0 rejection
2) good measurement of the opposite side jet
3) good segmentation
4) high rate capability

II. Scaling direct γ experiments

Rejection and measurement of η^0 and π^0 background will drive the design of many direct photon experiments. This in turn depends on energy resolution, 2 photon separation capability, and acceptance. The requirement for good 2 photon separation sets the length scale of the experiment. We want the two photons from the decay of a high $P_\perp$ π^0 (∿30 GeV) to separate by ∿2 cm ($\gamma_{cm} = 100$)

$$\theta^2_{min} = \frac{\sqrt{2M}}{(\frac{E\pi}{2})^2} = 3.5 \times 10^{-4} \text{ rad.}$$

This leads to an experiment ∿100 meters long. Some additional length may be necessary to avoid overlaps in the forward jets. At $\sqrt{s} = 200$ $1/\gamma$ cm is 10 mr, this implies that a detector which covers the forward hemisphere at Z = 150 meters is 3 meters x 3 meters. Extending the detector somewhat into the backward hemisphere is necessary to provide a reasonable fiducial area for centrally produced direct photons.

Energy resolution of a good electromagnetic calorimeter scales as ∿$10\%/\sqrt{E}$ for $\sigma(E)/E$. At photon energies of 100 GeV this is 1%. For a calorimeter with many elements (10^3 - 10^4) - such as is needed for good 2 separation .5% may be a limit for system calibration. Energy and position resolution will also be compromised by shower overlaps in the detector. By fitting to the known electromagnetic shower shape, current liquid argon detectors have achieved submillimeter position resolutions. This resolution will improve only slowly with energy and allows angle measurement in our detector of

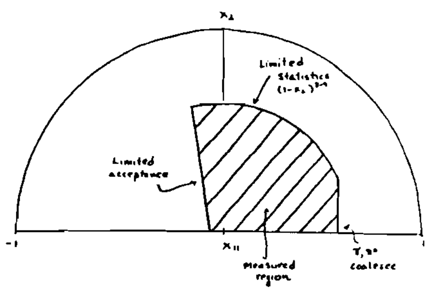
$$\delta\theta \sim \frac{10^{-3}\text{m}}{150 \text{ m}} \sim .7 \ \mu \text{ radians}$$

In terms of 2 TeV π^0's mass resolution, $\delta m/m$, for symmetric decays is dominated by this angle measurement. For asymmetric decays the $\delta\theta$ and δE contributions to the mass resolution are about equal when $E\gamma_1/E_{\pi^0} \sim .05$.

III. π^0 and ^{0} Rejection

We expect γ's and π^0's to be indistinguishable above $E_{\pi^0} \gtrsim 5$ TeV. This corresponds to transverse momenta of ∿50 GeV/c. In addition the detector needs to contain both photons from π^0 and ^{0} decay. If we choose an interior fiducial area ∿25-30 cm from the detector edge we expect to contain both photons from >90% of π^0 and ^{0} decays. At this level experiments may be limited by other effects such as particle overlaps and misassigned photons. Limits in the kinematic range covered are shown in figure 1.

Figure 1



The Peyrou plot characteristic of limitations of direct γ experiments.

IV. Two photon spectroscopy

Rejection of π^0 and ^{0} decays at the >90% level allows one to imagine clean γγ spectroscopy both in the continuum and as a search for resonances. We estimate the backgrounds by assuming the primary background is

$$p + p \rightarrow \gamma + \text{jet}$$

where the recoil jet contains a π^0 which simulates a direct photon. Assuming a 90% π^0 rejection factor and a leading π^0 cross section at 1% of the γ-jet cross section we have:

$$\sigma_{background} = \sigma(\gamma\text{-jet})\big|_{p_\perp \gtrsim m/2} \left(\frac{1}{100}\right) \text{Prob}(\pi^0, \eta^0 \text{ single } \gamma)$$
$$\gtrsim 10^{-3} \sigma(\gamma\text{-jet}).$$