2.4 COMBINING JET PHYSICS AND HIGH p_T SINGLE PHOTONS IN ONE EXPERIMENT

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The virtues of single high p_T photons are very evident from the recent ISR results and the discussions by C. Bromberg and J. Owens at this workshop. Briefly, the expected dominance of $qg \to \gamma q$ and $q\bar{q} \to \gamma g$ (the latter much elucidated if one can use both p and π beams) leads to many interesting tests of QCD, etc., difficult or impossible with hadron + hadron $\to$ jet + jet + beam, target fragments. However, it appears to us unwise to set up an experiment dedicated only to single-photon physics in such a way as to severely compromise jet studies; a more comprehensive experiment is called for, given the long time scale until TeV II experiments, and it can even yield a great improvement to the single-photon physics.

Another reason for combining setups is the competition from photoproduction of jets. A Tevatron experiment on $\gamma + p \to$ two high p_T jets + target fragmentation would explore nearly the same underlying physics and looks very promising as to gamma flux and energy, with a new photon beam or even with the existing tagged photon beam. J. Owens points out that the photon energy goes entirely into the hard process unlike the x fraction for a constituent of an incoming hadron, so that 600-900 GeV hadronic reactions should be compared to $\lesssim$ 300-GeV photon reactions and 600-GeV photons should be compared to ISR hadrons. An experiment dedicated to secondary single photons would be in almost direct competition while a combined experiment would have other merits to stand on, offering an attractive range of physics possibilities.

We will start by exploring the possibilities of adapting existing equipment plus necessary additions, then mention the costs of extensions to an "ideal" experiment. The discussion is based on the largest existing calorimeter arrays, E-557 (2.3 m × 3.0 m) and E-609 (somewhat smaller but comparable), and a 48D48 or larger magnet. Since this author is on E-557 the illustrations will be based on it. It's obvious that the ratio of two photon resolution (for telling π^0 from γ) to calorimeter size is the important parameter, and that dividing the detector system into 2-3 systems covering different c.m.s. regions will reduce the cost of the calorimeters. The game is to compromise the simplicity of a jet-only experiment with one calorimeter by moving the calorimeter downstream to where γ and π^0 can be separated, then filling in the vacated polar angle regions with more calorimeters. This has the added benefit of improving Cherenkov secondary-particle identification. (See "Preliminary Design of a Ring Imaging Cherenkov System for a Tevatron Jet Experiment," D. McLeod, included in these workshop proceedings.)

Before we continue on the layout, we should discuss the need for a hadron calorimeter. It is probably necessary, as L. Cormell has pointed out, to trigger an experiment on a single high p_T π^0 or γ (I don't see how they can be separated in triggering, at least beyond some level) **and** a jet on the other side. If a single high p_T trigger is used, K_T smearing (intrinsic Fermi motion plus gluon effects) severely complicates the analysis of events. A trigger involving neutral e-m energy plus fast computation of all the charged hadron momenta sounds fantastically complex because of the high multiplicity of these reactions. A hadronic calorimeter (plus the electromagnetic detector) allows a straightforward trigger. Upon analysis, it yields resolution for high-momentum particles superior to that of a magnetic spectrometer even, in many cases, at full field; the spectrometer can be regarded as a device to identify tracks, determine their charge, and measure momenta only for low-momentum tracks. (Full field might be used with a "smart" trigger p_T calculation adding p_T before deflection so the p_T kick bias is irrelevant to this discussion.) To conclude, hadronic calorimeters are available, well understood (E-557/609), and ideal for a more comprehensive experiment involving jets.

A sample layout is shown in Fig. 1. With the E-557 calorimeter 18 meters from the target, the center-of-mass $\beta \approx 1$ angles are covered out to a little less than $\pm 120°$ horizontally by $\pm 100°$ vertically. This removes an uncomfortably large part of the backward angles from detection; to restore them we add calorimeters near the target. Because of the kinematics the resulting rather coarse laboratory angular resolution for these calorimeters is not so bad in the center of mass. The sign of charge is lost; with a magnet of larger aperture it might be possible to put these large angle calorimeters downstream of the magnet. Not shown in the illustration is another calorimeter, etc., still further downstream. To improve the worst π^0/γ separation it would be useful to enlarge the central hole in the E-557 calorimeter, covering this instead with the far downstream system. (The figure shows the existing hole.) Thus, we plan a three-detector system with single photon/π^0 discrimination on the two downstream ones forward of 100°-120° c.m.s. One calorimeter, E-557, already exists (the lead could be replaced with steel in the front portion for additional absorption depth); the downstream one, which may be partly built during E-557, could be on a fixed stand and calibrated by deflecting beam into modules while the upstream ones ought to be a very modular system easily rearranged and moved into the beam for calibration.

The γ/π^0 resolution appears to be a little marginal, but feasible. At 90° c.m., 48 mr in the laboratory, an 8 GeV/c p_T π^0 has a laboratory momentum of 167 GeV/c so that **minimum** opening-angle photons are separated by 3 cm. This is somewhat larger than shower sizes in reasonably compact detectors so that discrimination should be possible on the basis of second and fourth moments of the lateral ionization distribution, even if the peaks are not totally separate. The discrimination of course requires

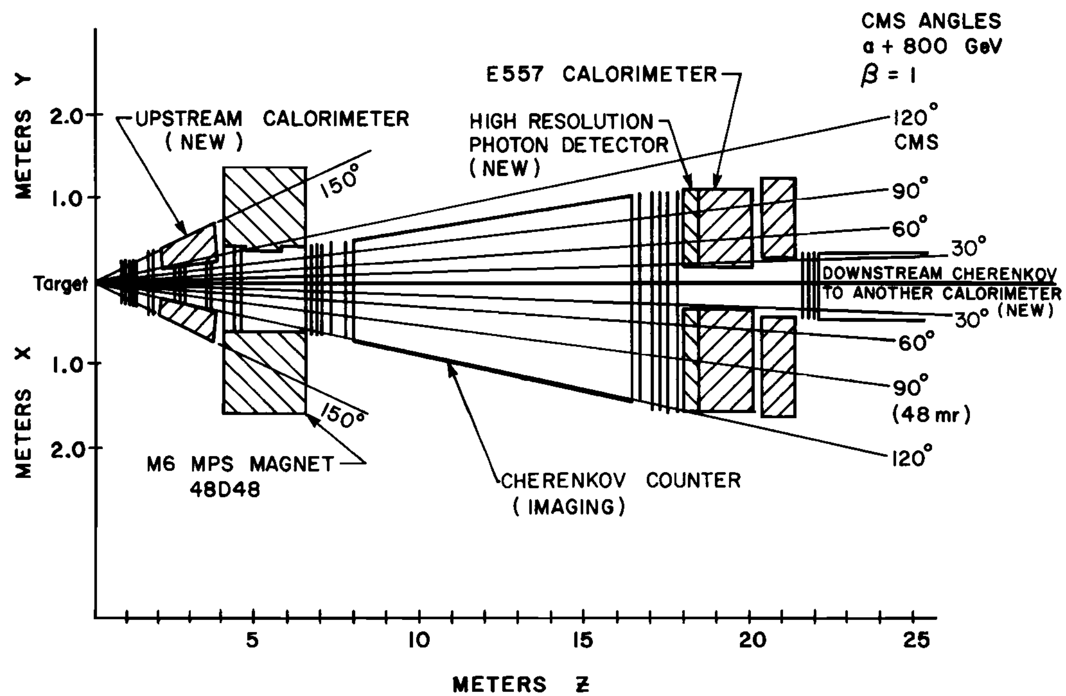

Fig. 1. Combined jet-single photon layout.
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more detailed study. A liquid argon detector with strips a few mm wide has been proposed; another possibility **if** it has enough lateral resolution is a gas-sampling ionization detector[1] which won't involve cryogenics and is faster. Of course, there is a swindle here in that smaller angle π^0 also use this portion of the detector system, with worse resolution because of their larger laboratory momenta at a given p_T.

There are substantial attendent advantages to jet physics in the proposed combination. Note that the Cherenkov detector can be >8 meters long versus the 5 meters assumed in this report; this allows more photons/ring and/or higher momentum discrimination. The high-resolution electromagnetic detector allows excellent discrimination of $\eta, \eta' \to 2\gamma$ and other neutral particle decays, which may be a good handle on gluon vs quark jets. The granularity of the central calorimeter is finer because it is further downstream. Another advantage of the high resolution electromagnetic detector is the improved discrimination on e^+e^- for high p_T Drell-Yan production, discussed elsewhere in these proceedings. The idea is to trigger on high p_T (say, greater than 2 GeV/c each or 4 GeV/c total p_T) **and** high mass (>1-2 GeV/c^2) e^+e^- pairs; these requirements and the requirement of an away side high p_T jet may overcome the otherwise fatal backgrounds which normally require $\mu^+\mu^-$ for such studies. A high lateral resolution e-m detector will help eliminate hadronic contamination on detection, driving it well below the inevitable ~1% per particle from Dalitz decays, etc. and π^0 conversions. The lateral resolution will allow a rather sharp e^+e^- mass cutoff with a moderately smart trigger.

To extend these ideas to a more "ideal" system, the choices are i) improve γ resolution (it appears to be pushing limits in the systems proposed so far), ii) increase the calorimeter sizes, or iii) add more stations extending the idea of a calorimeter for each of several bands of c.m.s. polar angle. The latter two choices are now made easier by the invention of "Altustipe" scintillator costing little more than plexiglass. How far one goes in this direction will unfortunately have to be governed by judgments about the financial worth of the physics.

Reference

1. M. Atac et al., A Gas Ionization Sampling Electromagnetic Shower Detector, paper 0526 submitted to the XXth International Conf. on High Energy Physics, Madison, July 1980.