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Preliminary Results from ASP on Tests of QED to Order α^4 in e^+e^- Annihilation at $\sqrt{s} = 29$ GeV *

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ABSTRACT

Tests of QED to order α^4 performed with the ASP detector at PEP are presented. Measurements have been made of exclusive $e^+e^-e^+e^-$, $e^+e^-\gamma\gamma$ and $\gamma\gamma\gamma\gamma$ final states with all particles above 50 milliradians with respect to the e^+e^- beam line. These measurements represent a significant increase in statistics over previous measurements. All measurements agree well with theoretical predictions.

The ASP detector[1] was designed to search for single photon events at the PEP e^+e^- storage ring at SLAC ($\sqrt{s} = 29$ GeV). The large acceptance of the detector makes it well suited for studying relatively rare, high-order QED processes. We have measured the following processes and compared them with theoretical predictions: $e^+e^- \rightarrow e^+e^-e^+e^-$, $e^+e^-\gamma\gamma$ and $\gamma\gamma\gamma\gamma$.

The ASP detector is fully hermetic with coverage extending to within 21 mrad of the beam line. Its major component is a central lead-glass and proportional wire chamber (PWC) calorimeter that provides energy, tracking and pattern recognition information. A set of PWC tubes located between the calorimeter and the beam pipe serves to distinguish charged and neutral tracks. The forward regions are covered by lead-scintillator sandwich calorimeters with tracking provided by PWCs and drift chambers.

The total data sample of approximately 30 million events was collected over a two year period, with an integrated luminosity of 109.6 pb^{-1}. This sample was reduced by the ASP production filter, which discarded events not originating from the beam interaction point. The final sample was selected by a series of track origin (along the beam line) cuts, angular and energy acceptance cuts, and shower width cuts. The acceptance criteria for events in this study were as follows:

1. The event was required to have four or five reconstructed tracks (charged or neutral), total measured energy E_{tot} >15.0 GeV and missing longitudinal momentum (along the beam line) p_l < 4.0 GeV/c.
2. At least two and no more than five tracks were required in the central detector, polar angle (as measured from the beam line) $\theta > 20.0°$ and energy E > 0.30 GeV. All central tracks had to be separated from each other by at least 15.0° in θ or 20.0° in azimuth.

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3. Any remaining tracks had to be in the forward acceptance region, defined as $50 < \theta < 100$ mrad and $120 < \theta < 180$ mrad with respect to the beam line. Forward tracks were required to have E > 4.0 GeV and transverse momentum > 0.40 GeV/c. No more than one track was allowed on each side in Z, where the Z axis is along the e^+ beam direction.

All remaining events were hand scanned at least twice by a physicist. The scan rejected 6% of the events as third-order QED or obvious junk, classified 4% as fifth-order QED and rejected 3% as miss tracked fourth-order events that are out of the defined acceptance. The remaining events are summarized in Table 1.

The theoretical predictions were obtained from matrix element calculations made by Berends *et al.*[2] which used all fourth-order diagrams for each process. Berends *et al.* also provided a Monte Carlo program that produced unweighted (i.e. all weights the same) events for the $e^+e^-e^+e^-$ case. It was necessary to write such programs[3] for the $e^+e^-\gamma\gamma$ and $\gamma\gamma\gamma\gamma$ cases. All unweighted events were passed through a detailed detector simulation process which used a full EGS[4] shower simulation for all central systems. Simulated events were then passed through the same analysis code and hand scan criteria used for the real data analysis.

The agreement of data with theory is excellent, as shown in Table 1. The distributions in angle, energy and invariant mass agree well with the Monte Carlo predictions. These measurements represent a significant increase in statistics over previous measurements for large angle production of four-body QED final states[5].

Table 1. Summary of results. Uncertainties for data and predictions are systematic. Uncertainties for ratios are systematic and statistical uncertainties combined in quadrature.

Topology	Data	Prediction	Data	Prediction	Data	Prediction
	$e^+e^-e^+e^-$		$e^+e^-\gamma\gamma$		$\gamma\gamma\gamma\gamma$	
2 central	555 ± 4	550 ± 7.6	355 ± 4	348 ± 14	11 ± 1	13.0 ± 0.6
3 central	40 ± 2	39.7 ± 2.3	169 ± 2	188 ± 10	11 ± 1	11.1 ± 0.6
4 central	15 ± 1	16.1 ± 1.5	324 ± 1	349 ± 14	23 ± 1	23.2 ± 0.8
All	610 ± 7	606 ± 8	844 ± 7	885 ± 21	45 ± 2	47.3 ± 1.2
Data/Pred	1.007 ± 0.045		0.954 ± 0.040		0.95 ± 0.15	

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