Fermilab-Misc-1975-07

COMPARISON OF P456 (E216) AND P446 (E69)

An Evaluation by the Proponents of P456
November 19, 1975

INTRODUCTION

We compare the principle features of the two proposals primarily with regard to the quality of the measurement of the kaon charge radius. There are four principle differences between the two proposals.

1. Event Rate for K-e Scattering

The bulk of the data expected in P446, greater than 80%, is at very low Q^2 ($Q^2 \leq 0.03$ $(GeV/c)^2$) where the data is the least sensitive to the kaon form factor. In the range of Q^2 between 0.030 $(GeV/c)^2$ and 0.130 $(GeV/c)^2$, the statistics of the two proposals are comparable. In the high Q^2 region, $Q^2 \geq 0.065$ $(GeV/c)^2$, where the data is the most sensitive to the kaon form factor, the statistics of P456 are superior to those of P446.

2. Positive Electron Identification

In addition to the added kinematical constraint imposed by the measurement of the recoiling electron momentum, P456 makes a positive identification of the electron for every event by showering it in an array of Pb-glass detectors where its energy is measured to better than 10%. P446 neither measures the momentum of the recoiling electron nor makes any positive identification that the particle accompanying the kaon is an electron. This electron identification is crucial in eliminating residual hadronic background at high Q^2.

3. High Q^2 Backgrounds

P446 presents in its Fig. 5 a missing mass plot from E69 which is dominated by a large spike at the electron mass arising from π-e scattering events. This peak is dominated by low Q^2 events. The residual hadronic background is 5%, which in the high Q^2 region can be expected to be equal in magnitude to the K-e scattering signal. This highly Q^2 dependent signal to background ratio produces a relatively more serious systematic error in P446 than it would be for P456 because the estimated overall normalization uncertainty is 3% for P446, while it is 1% for P456. Furthermore, it is the experience of E216 in a 200 GeV test run that positive electron identification is crucial to the elimination of this background which is present to a significant degree after imposing the four elastic scattering constraints. P446 has only three constraints.

4. Trigger Rate

P446 estimates a trigger rate of 1.5×10^{-3} per counted beam particle using a single particle trigger; whereas, P456 expects a trigger rate of 3×10^{-4} per counted beam particle using a two particle trigger. It has been the experience of E216 in studying one and two particle trigger rates at 100 and 200 GeV that the trigger rate estimate of P446 is too low by a factor of 3 to 5. An increased rate would saturate the data acquisition system of P446. If the kaon statistics are not to be sacrificed, the necessary reduction in sampled pions can be expected to decrease the precision of the simultaneous measurement of the pion form factor to a level inferior to that of the completed 216 experiment.

The expected precision of the measurement of the kaon radius is 0.030 F for P456 which is better than the 0.036 F expected for P446. The problem of Q^2 dependent biases from hadronic backgrounds can be expected to increase the error of P446's measurement by a significant factor.

DETAILS

In Table I we present a list of parameters which summarize a number of the characteristics of the two proposals. The remainder of our discussion will develop in more detail some of the points made in the introduction as well as other differences listed in Table I.

TABLE I

Parameter	P456	P446
Angular Resolution	30 micro-radians	30 micro-radians
Multiple Coulomb Scattering		
1) Block I	0.014 r.1	
2) LH_2	50 cm = 0.056 r.1	54 cm = 0.063 r.1
3) Block II	0.033 r.1	
Spectrometer ($\Delta p/p$)	0.32% at 125 GeV	0.14% at 125 GeV
Incident Beam ($\Delta p/p$)	1%	0.03%
Recoiling Meson Measurements		
1) Momentum	Yes	Yes
2) Scattering angles	Yes	Yes
Recoiling Electron Measurements		
1) Momentum	Yes	No
2) Energy (Pb-glass)	Yes 10%	No
3) Scattering angles	Yes	Yes
Background Rejection		
1) Constrained fit	4C	3C
2) Longitudinal momentum balance	Yes	No
3) Transverse momentum balance	Yes	No
4) Coplanarity	Yes	Yes
5) "D" cut	Yes	Partial yes *
Background Rejection by Positive Electron Identification	Yes	No
Background by Q^2 Range		
0.030 $(GeV/c)^2$ to 0.065 $(GeV/c)^2$	~0.06%	>1.0%
0.065 $(GeV/c)^2$ to 0.132 $(GeV/c)^2$	~0.58%	>9.4%
Data Taking		
1) Incident beam flux	5×10^5	10^6
2) Spills/hour	360	450
3) Interval between beam particles	1 μsec	0.2 μsec
4) Trigger	Two particle	Single particle
5) Trigger vetoes		
a) target vetoes	No	Yes-requires correction
b) hole veto	Yes-small correction	Yes-small correction
c) beam veto	No	Yes-requires correction
6) Trigger rate	3×10^{-4}	1.5×10^{-3} (their estimate) $4\text{-}8 \times 10^{-3}$ (our estimate)
7) Triggers/spill	0.25	300 (their estimate) 800-1600 (our estimate)

TABLE I (continued)

Parameter	P456	P446
8) Acceptable triggers/spill	20	300
9) Useful K's/spill	8×10^3	15×10^3
10) Beam time		
a) Data taking	500 hours	600 hours
b) Target empty and calibration	100 hours	none requested
c) Tune up	200 hours	200 hours
Total Beam Hours	800 hours	800 hours
Events by Q^2 Range		
0.031 to 0.065 $(GeV/c)^2$	8500	14,200
0.065 to 0.132 $(GeV/c)^2$	1500	900
Error on $< r_K >^{1/2}$	0.030 F	0.036 F
*P446 requires calculation of the electron momentum from the elastic hypothesis in order to apply this cut.		

1. Spectrometers

The angular resolutions of the spectrometers in P446 and P456 are identical (30 micro-radians). The precision of the angular measurements of the recoiling particles are [illegible] dominant factors in determining the utility of kinematic cuts in rejecting background, or alternatively, of a χ^2 cut after fitting the event to the elastic hypothesis. Consequently, the difference in the momentum resolution of the two spectrometers is unimportant. P456 does have the advantage over P446 of one additional constraint in a fit approach (4C as compared with 3C). It is also possible for P456 to use a cut approach in analyzing the data using conventional kinematic quantities. By not measuring the electron momentum, P446 gives up the possibility of cutting on either the transverse or longitudinal momentum balance in analyzing their data. The "D" cut, which is a comparison of the expected and measured scattering angles of the recoiling particles, depends on knowing the momentum of both recoiling particles to calculate the expected recoil angles. Since P446 must determine the unmeasured momentum by assuming elasticity, this D cut is weaker in P446 which is why we list P446 as a partial yes for this cut. Both proposals have the coplanarity cut.

We note that the electron in P446 does not make it through the spectrometer for K-e scattering, but buries itself somewhere inside the aperture. The resulting forward shower of photons could conceivably cause some confusion in the proportional chambers behind the spectrometer. In contrast the electron passes cleanly through the apparatus of P456.

The E216 spectrometer will be ready for data taking with the installation of the Dubna drift chambers, which is going forward at the present time. Thus, P456 can run and wants to run by spring.

2. High Q^2 Background

In P446 the Q^2 acceptance of the experiment is 0.013 $(GeV/c)^2 \leq Q^2 \leq Q^2_{max} = 0.093$ $(GeV/c)^2$. This can be compared with the Q^2 range of P456, 0.031 $(GeV/c)^2 \leq Q^2 \leq Q^2_{max} = 0.132$ $(GeV/c)^2$. For P446 the ratio of events above a Q^2 of 0.05 $(GeV/c)^2$ to the total event sample is approximately the ratio of the cross sections, 0.67 μb/11.7 μb = 5.7%. In Fig. 5 of P446 a missing mass plot is shown with an electron spike from low Q^2 π-e events taken during the E69 running. The hadronic background under the electron peak appears to be of the order of 5%. Background studies using a two-particle trigger in conjunction with E216 have indicated that the hadronic background is independent of Q^2. If the present E69 apparatus with a one-particle trigger accepts roughly the same hadronic background, then the ratio of signal to background at high Q^2 can be expected to be about one if we use the ratio of cross sections given above.

P446 proposes to measure the scattering angles of the recoiling electron. This increases the number of constraints on the fit from one to three. In this eventuality the apparatus approaches the kinematic power of the E216 apparatus with drift chambers where the fit to the data is 4C. E216 has made a background study of π-e scattering at 200 GeV. Based on a 4C fit to the data, we find that the residual background in the Q^2 range 0.031 to

0.186 $(\mathrm{GeV}/c)^2$ is approximately 7%. The inclusion of drift chambers should reduce this background by a factor of 10. The E216 apparatus has one additional requirement that can be used in eliminating this remaining hadronic background which is absent in P446. The E216 apparatus directly identifies the electron and measures its energy with a resolution of 10% HWHM in an array of Pb-glass, independently of the momentum measurement of the spectrometer. This gives the E216 apparatus an additional large rejection factor which could be an order of magnitude and which is not available to the proponents of P446.

The final rejection of high Q^2 hadronic background through the positive identification of the electron is crucial to the experiment. In Table II we present results showing the effect of Q^2 dependent biases from high Q^2 backgrounds in both proposed experiments. The approach used was to Monte-Carlo a distribution of events according to the known point cross section times the square of an assumed form factor ($F_K = \dfrac{1}{1 + \dfrac{\langle r_K^2 \rangle Q^2}{6}}$ and $\langle r_K \rangle^{1/2} = 0.58$ F). For both proposals the appropriate Q^2 range was used. A background flat in its Q^2 distribution was added, and the data fit to extract $\langle r_K \rangle^2$. The projected normalization uncertainties of 1% (P456), and 3% (P446) were used in the fits. For both proposals the same background at a given Q^2 was used, scaled by the ratio of the cross sections for the two proposals at that Q^2. The background chosen is based on our 200 GeV test measurements. Case I is the result with no positive electron identification, the limiting case for P446. In fact the P446 background can be expected to be worse than this by some unknown factor because the E216 trigger, which is much stronger than that of P446, naturally biases against hadronic backgrounds. Case II shows the power of identifying the electron, as in P456. It can be seen that an unbiased measurement of the kaon radius is critically dependent on the background rejection achieved by the electron identification of P456.

TABLE II

P456		P446	
Case I: No electron identification			
No background	Background (1.35%)	No background	Background (0.3%)
$r_K^2 = 0.35\ F^2$	$r_K^2 = 0.26\ F^2$	$r_K^2 = 0.33\ F^2$	$r_K^2 = 0.26\ F^2$
Case II: Electron identification using Pb-glass detectors			
No background	Background (0.13%)	NOT POSSIBLE	
$r_K^2 = 0.35\ F^2$	$r_K^2 = 0.35\ F^2$		

3. Trigger Rates

One major difference between proposals P446 (E69) and P456 (E216) are the triggers used in taking data. P446 uses a single particle trigger very similar to the trigger of the original E69 experiment; whereas P456 requires a much more restrictive two-particle trigger. The loose single particle trigger of P446 is justified on the basis of high data taking capability, approximately 800 events/spill (100% deadtime). P456 requires the relatively more restrictive two particle trigger in order to avoid severe deadtime limitations from the wire-spark chambers. It seems to us that the looseness of the trigger in P446 will severely tax the data taking capability of the E69 data acquisition system.

P446 indicates that they expect about 300 events/spill while sampling approximately 2×10^5 beam particles/spill. This corresponds to a trigger rate of 1.5×10^{-3}. We believe this rate is overly optimistic. The trigger rate during the E69 data taking was 4×10^{-3}.*

Based on the experiences of E216 at 100 and 200 GeV, we believe the trigger rate estimate of P446 is too low by a factor of from 3 to 5. In this case they could expect from 800 to 1600 events per spill.

Thus, if P446 wishes to take 3×10^4 kaons/spill, the requirement of a reasonable event rate, which they suggest is 300/spill, will force a reduction of the pion sampling to considerably less than 10^5 pions/spill. E216 required 330 hours of data taking at 10^5 pions/spill to make a precise measurement of the pion radius.

The additional features of the trigger in P446 which go beyond the E69 trigger are a set of target vetoes (apart from the downstream hole veto already present in E69), and a hardware momentum determiner (HMD). It was our experience with target vetoes at Serpukhov that only the downstream hole veto is effective in reducing the trigger rate. Wide angle target vetoes can be expected to be even less effective at the higher energies of Fermilab

---

*C. Ankenbrandt et al., Fermilab-Conf-75/61-Exp (7100.069), p. 6.

where the hadronic debris is more forward. Furthermore, one pays the price of a correction resulting from the veto of π-e or K-e events with accompanying wide-angle delta rays. The usefulness of the HMD is doubtful, since they already include in the trigger a scintillation counter whose location at the rear of the spectrometer essentially requires that any particle from the target striking it will have a momentum different from the incident beam.