FERMILAB-Proposal-0796

JUNE 1, 1988

Letter of Intent

A Measurement of the CP Violation Parameter η_{+-0}

The Son of E621

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We intend to submit a proposal to the Fermilab Physics Advisory Committee, in the fall of 1988, for an experiment to measure η_{+-o}, the CP violation parameter in the decay $K_S^o \rightarrow \pi^+\pi^-\pi^o$. This is a follow-up experiment to E621, and we plan to use the two-beam, two-target geometry that was very effective there. The improvement to the experiment consists primarily of building a new spectrometer to replace the one we have been using for 15 years. The new spectrometer will be very similar in configuration to our old one, but will use "modern" technology to achieve higher running rates and larger acceptance. The Proton Center beam line can be used, with modifications, although other beams at the laboratory might be more appropriate. We give details below. In an 8 month long fixed target running period we will collect 90M $K_{\pi 3}$ decays, and measure $|\eta_{+-o}|$ to an accuracy of $\pm 0.4*10^{-3}$ (which is $|\eta_{+-}|/5$), and $\arg(\eta_{+-o})$ to $\pm 12^o$. We wish to run in 1991.

Experiments that shed light on CP violation can make important contributions to our understanding of the electroweak interaction. The experiment that can reach the highest precision in measuring ratios of CP violation parameters, measuring η_{oo}/η_{+-} (or equivalently ϵ'/ϵ), is being performed by the E731 and NA31 collaborations. They seem to be getting the same answer, that $\eta_{00}/\eta_{+-} = 0.990$, and when they have analyzed all their data, if they still agree, and have a clearly nonzero value for ϵ', then they will have killed the superweak model, but several extensions of the original Weinberg-Salam-Glashow theory will still be viable. Because of theoretical uncertainties, the ϵ'/ϵ experiment will not be able to distinguish among the Kobayashi-Maskawa model, the multiple Higgs model (originated by Weinberg and T.D. Lee), and the $SU(2)_L \times SU(2)_R \times U(1)$ isospin symmetric model (by Mohapatra and Pati).

Of other experiments that might illuminate this situation, those easiest to perform study CP violation in K_s^o decays. In separate experiments one would measure η_{+-o} and η_{ooo}. In the K-M model η_{+-o} is within a few percent of η_{+-}; in the multiple Higgs model it might be 50% larger, and in the isospin symmetric model it might be 100% larger. Each of these numbers is very uncertain, but measuring η_{+-o} to be significantly different from η_{+-} would definitely give us a new slant on CP violation. If the result were $\eta_{+-o} = \eta_{+-}$, it would strengthen the K-M model. Our previous η_{+-o} experiment was E621, which is now in the advanced data analysis stage. It has the sensitivity to measure η_{+-o} if it is unexpectedly large.

In E621 we collected about 3M $K_{\pi 3}$'s in the 1985 fixed target running period. Figure 1 is a plan view of the apparatus. One important aspect of the experiment was that we took data from two targets. One was located at the entrance of the Proton Center hyperon magnet, and kaons from this target exhibited pure K_L^o and K_s^o decays, and K_L^o-K_s^o interference, when they decayed in our apparatus. The other target was 24.6 m farther upstream, and K_s^o decays and interference from this target were damped out by the time the kaons reached the decay region. CP violation shows up in this experiment as a difference in the proper-time distributions of kaons from the two targets.

Fig. 2 shows the proper time distribution, R(t): the ratio of the time distribution of the downstream target to that of the upstream target. 305,000 $K_{\pi 3}$ decays from a preliminary analysis of 10% of the E621 data sample went into Fig. 2. We performed a maximum likelihood fit to this data to determine the best values of Re(η_{+-o}) and Im(η_{+-o}). An important constraint comes from the fact that $\eta_{+-o} = \epsilon + i\epsilon_1$, where ϵ_1 is known to be real, so that to good accuracy, Re(η_{+-0}) = Re(η_{+-}). The result was Im(η_{+-o}) = -0.001±0.016, giving $|\eta_{+-o}|$ = 0.002±0.016, and $\phi_{+-o} = -19^0 \pm 84^0$. For comparison, the result of relaxing the constraint is $|\eta_{+-o}|$ = 0.035±0.016 and $\phi_{+-o} = -221^0 \pm 28^0$, in agreement with the constrained fit.

We have plotted the two fit results on the complex η_{+-o} plane in Fig. 3. The Particle Data Group's upper limit (based on experiments before E621), that $|\eta_{+-o}|<0.35$, is the area within the circle in Fig. 3. Finally, if we predict the uncertainty in $|\eta_{+-o}|$ when all 3M events are analyzed with our final analysis program, we expect $\delta|\eta_{+-0}|$ = 0.003. Statistical errors dominate in our current analysis, and we expect this to be equally true when all the E621 data is analyzed.

In planning the Son of E621, we have a solid base of data from which to extrapolate. We expect the following four changes to yield 90 M events in one running period.

1. Double the length of the decay region → *2 in events.
2. Maximize the acceptance for p>80 GeV/c → *2.5
3. Double the area of the collimator hole → *2
4. Triple the beam intensity (to 1.0 E12) → *3.

The spectrometer still looks similar to Fig. 1, but the distance between the V1 and S1 counters is doubled, an array of photon detectors is placed after the C3 chamber covering the front face of the analysis magnet from its 2 ft x 2 ft aperture out to 4 ft x 4 ft, and the main photon detector array is tripled in area. An additional photon detector must be placed behind the beam hole in the main photon detector array.

The geometric acceptance of this spectrometer design is very high, 91% for p>80 GeV/c, and >95% for most bins in p and z. Not only does this design collect more events, but also makes the acceptance easiest to calculate. These changes result in a factor of 30 increase in statistics, which, when applied to the E621 result, would yield $\delta|\eta_{+-o}| = 0.0006$.

We will also take a step to increase the sensitivity of the experiment: use a 5 m long hyperon magnet to define the neutral beam. A shorter hyperon magnet gives us more events at smaller proper times, where the interference term is larger. The result of these improvements is $\delta|\eta_{+-o}| = 0.0004$.

Our requests of Fermilab are:

1. We need a beam with about 1000 ft of drift space to make the double proton beam, about 300 ft of space to separate and focus the proton beams, a hyperon magnet 5 m long producing a central field large enough to separate the 800 GeV/c protons from the neutral beam, and an experimental hall about 100 m long. The Proton Center beam would be fine except for the narrow experimental hall and that the hyperon magnet there is 7.3 m long. The PC4 pit extension angles to the east at 17 mrad, where we need a straight extension. If a new excavation were made, this experimental hall would be adequate.

2. We need an analysis magnet for our spectrometer with 1.7 GeV/c transverse momentum kick, and an aperture 2 ft high by 2 ft wide.

3. We have to build a new spectrometer, and acquire many more shower counters than we currently have. We may need the services of the Lab's

shops. The data rate of the experiment will be relatively high: 1-2 kHz of triggers (about 100 word events) to be handled with low dead-time by a modern data-acquisition system. 100 2.5 GByte cassette tapes should hold the data.

We are submitting a letter of intent because we want to analyze a lot more than 10% of E621's data before writing a proposal. We expect to have this analysis done by the end of the summer. In addition, our calculations are based on estimates of the dilution factor; we are now engaged in measuring it using $K_{\pi 2}$ decays from the E621 upstream targets.

This letter of intent is the result of calculations and discussions that have convinced us that it is possible to perform the next-generation η_{+-o} experiment, and achieve the stated goals. We feel that our current design is an existence proof of this. We are submitting this letter now so the PAC can think about this experiment at its 1988 Aspen meeting.

Figure Captions

Figure 1. Plan View of E621 Apparatus. The two targets, hyperon magnet, and Vee spectrometer are shown. V1, S1, P1, and P2 are scintillation counters; C1 - C6 are MWPC's; A, B, and π are hodoscopes.

Figure 2. Proper Time Graph from 305,000 $K_{\pi 3}$ Decays. R(t) is the ratio of the proper time distribution of the downstream target divided by that of the upstream target, averaged over momentum. The curve is the result of the constrained fit described in the text.

Figure 3. The Complex η_{+-0} Plane. The two data points are the results of the analysis of 1/10 of the E621 data. The one closest to the origin comes from the constrained fit described in the text. The circle represents the Particle Data Group upper limit based on experiments previous to E621, $|\eta_{+-0}| < 0.35$.

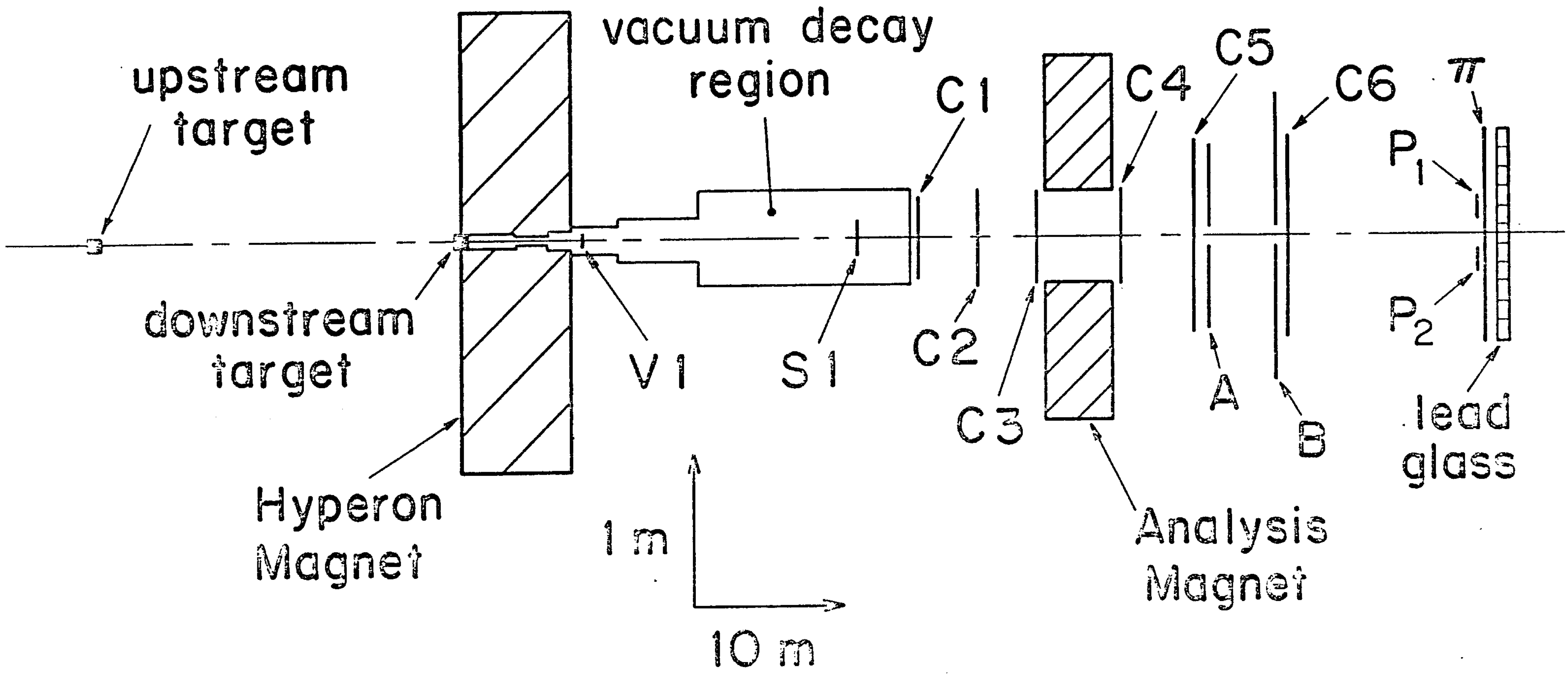
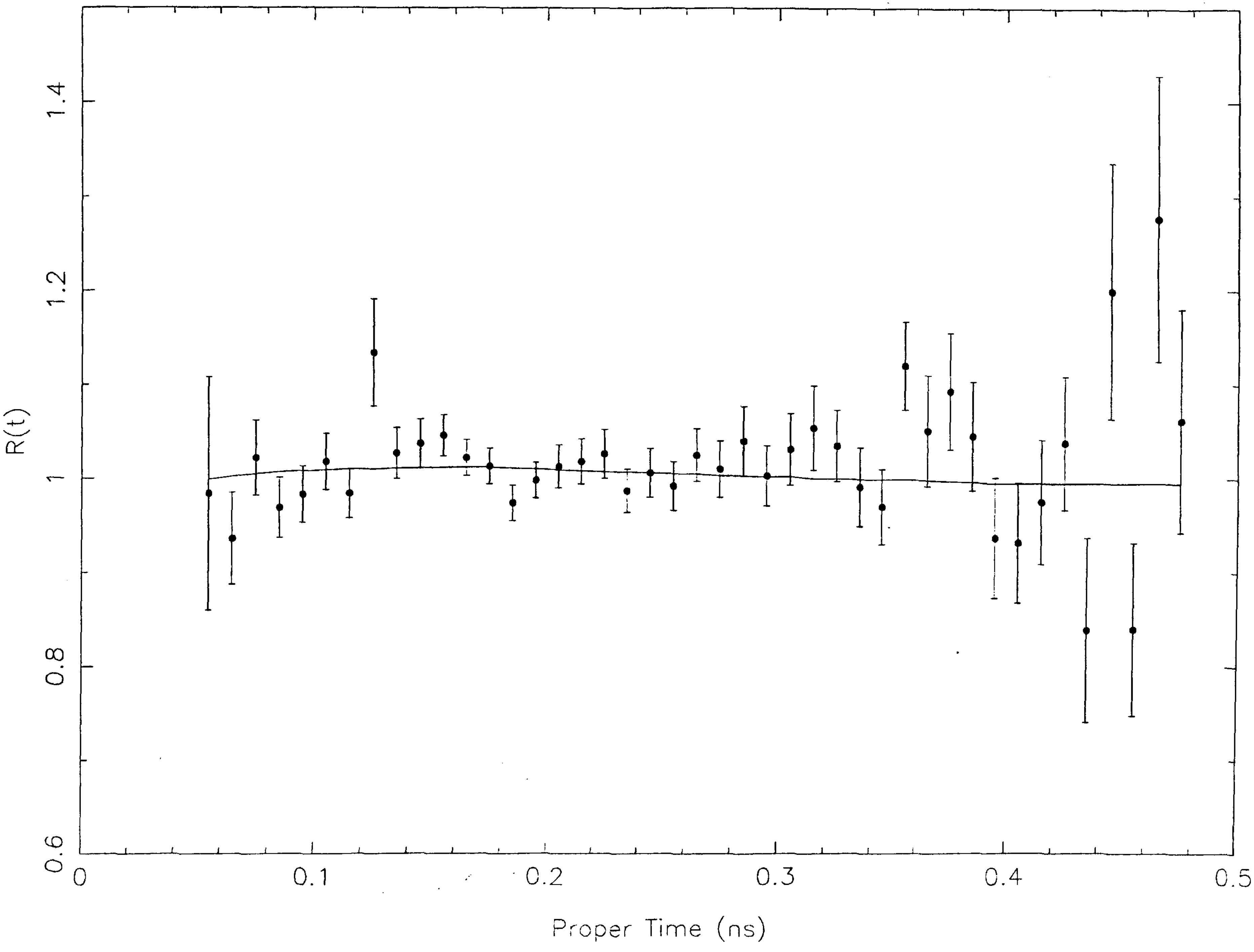


Figure 1. Plan View of E621 Apparatus

Figure 2



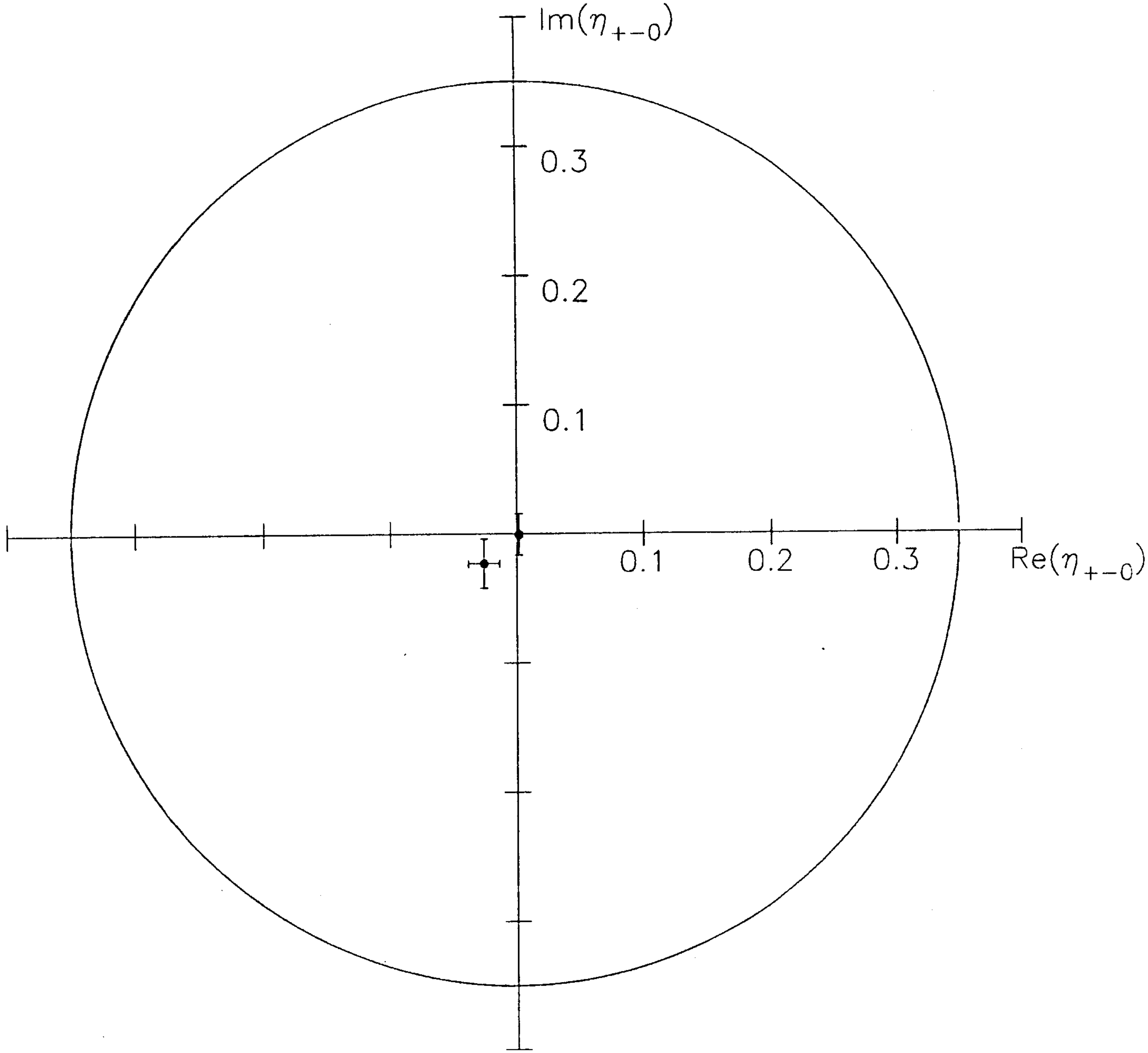


Figure 3