Task J

SEARCH FOR CP & CPT VIOLATION IN THE NEUTRAL KAON SYSTEM

AND

A HIGH SENSITIVITY SEARCH FOR $K_L \rightarrow \pi^0 e^+ e^-$

Progress Report

for period May 1, 1990 - April 30, 1991

DOE/ER/40560--T4

DE91 001948

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September 1990

Prepared for

The U.S. Department of Energy

Award no. DOE DE F602 290ER40560 Task J

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The research progress of this task during the last two years could be best summarized by the following:

- 1) Eight papers has been submitted and published of which six are on physics (Phys. Rev. Lett. and Phys. Rev. D) and two are on detector instrumentation (see publication list);
- 2) E-799 was approved by Fermilab PAC in June 89 (the only major physics experiment approved for two Fixed Target runs till ~1993);
- 3) E-773 and E-799 Phase I is scheduled to take data at the beginning of 1991 for five months;
- 3) a full size prototype TRD (Transition Radiation Detector) was designed and beam tested. This is a crucial piece of equipment for E-799.
- 4) conceptual design of a TRD trigger (both front and back ends) for Phase II of E-799 has been started.

Descriptions of each of the above follows:

1) Physics results:

Since the data-taking ended in February 1988, we have published five papers to Physical Review (four letters and one in D). They are on $K_L \rightarrow \pi^0 e^+ e^-$, $K_L \rightarrow \pi^0 \gamma \gamma$, ϵ'/ϵ and $\phi^{00} \rightarrow \phi^{+-}$; all these results are based on 20% of the total data set except the $K_L \rightarrow \pi^0 e^+ e^-$ mode and each of them represents significant improvements over the previous measurements. The ϵ'/ϵ result, which is $(-3 \pm 14 \pm 6) \times 10^{-4}$ was first announced in the 89 Stanford Lepton Photon Symposium. It is especially interesting since it contradicts the CERN NA-31 result which is $(+33 \pm 11) \times 10^{-4}$ by about two standard deviation. The CERN result favors a lighter top quark mass within Standard Model. But with the top mass getting heavier (CDF result with $m_t > 89$ GeV), the result from our total sample will be most important from the viewpoint of both Standard Model and CP violation (which could

be at least five σ disagreement from the CERN result if our current value holds). The 100% data summary tapes production with the Fermilab ACP started October 1989 and was finished in January 1990. Physics result is expected at the end of 1990.

The following table gives a summary of the physics that has been published or being investigated upon:

Physics:	E731 Sensitivity :	Comment:
ϵ'/ϵ	± 0.0007	Inconsistent with CERN measurement as mentioned above; [pub]
$\phi^{00} - \phi^{+-}$	$\pm 1.5^0$	Improvement of factor of 4 over last measurement which is $12^0 \pm 6^0$; [pub]
$K_L \rightarrow \pi^0 e^+ e^-$	$< 7.5 \times 10^{-9}$	Consistent with BNL E845 result; [pub]
$K_L \rightarrow \pi^0 \gamma \gamma$	$(1.7 \pm 0.7) \times 10^{-6}$	Consistent with the CERN NA31 result; [pub]
$\pi^0 \rightarrow e^+ e^-$	$< 2.0 \times 10^{-7}$	Comparable to the just published SIN result but with no background.
$K_L \rightarrow \pi^+ \pi^0 e^- \nu$	~ 700 events	~ 10 evts seen previously with major bkg.
$K_{L,S} \rightarrow \pi^+ \pi^- \gamma$	~ 4000 events	Previous measurement dominated by systematics and statistics, first measurement of $\eta_{+-\gamma}$
δ from K_{e3}	~ 100 million	About a factor of 2 improvement.

The analysis of the complete E-731 data set will be carried on for at least another year and is of high priority within the group to finish the analysis and publish all the results.

Two technical papers of the Hardware Cluster Finding Trigger Processor were submitted

and published.

2) and 3) E-773 and E-799 Phase I :

Fermilab E-773 :

Fermilab E-773 with the goal of measuring the phase difference between ϕ^{00} and ϕ^{+-} to better than 0.50 is currently scheduled to run from January 1991 for two months.

Although the Fermilab schedule is in constant revision due to budget situation, all scenarios of run schedule presented by the Laboratory so far include both E-773 and E-799 Phase I with no cut in beam time.

During the setting up and data taking phase of E-773, this task has the following responsibilities:

- (1) testing of the full size prototype TRD which includes the longitudinal drift chambers, the VME based FADC and its readout electronics, the FASTBUS based charge integrating ADC and the monitoring of the Xe gas system;
- (2) neutral trigger, namely the Hardware Cluster Trigger Processor and its associated electronics.

Fermilab E-799 :

Fermilab E-799 titled " A Proposal to Search for the Rare Kaon Decay Mode $K_L \rightarrow \pi^0 e^+ e^-$ " was approved by the PAC in June 1989. This proposal outlined the detail to achieve a sensitivity of $<10^{-11}$ with two Fixed Target runs. It could be viewed as a program to research on rare neutral kaon decay. The following table shows the sensitivity for some of the more important ones:

<u>Decay Mode</u>	<u>Best so far</u>	<u>E-799</u>	<u>Comment</u>
$K_L \rightarrow \pi^0 e^+ e^-$	$<7.5 \times 10^{-9}$ (E731) $<5.0 \times 10^{-9}$ (BNL)	$<1 \times 10^{-11}$	Direct CP signal; if it's there, we want to see it first.

$K_L \rightarrow \pi^0 \gamma \gamma$	$(2.1 \pm .6) \times 10^{-7}$ (NA31) $(1.7 \pm .7) \times 10^{-7}$ (E731)	4×10^3 evts	Important to measure and untangle the CP conserving part of $K_L \rightarrow \pi^0 e^+ e^-$.
$\pi^0 \rightarrow e^+ e^-$	$< 1.2 \times 10^{-7}$ (SIN) $< 2.0 \times 10^{-7}$ (E731)	1×10^3 evts	Unitarity test.
$K_{L,S} \rightarrow \pi^+ \pi^- \gamma$	4×10^3 evts (E731)	1×10^6 evts	Direct emission vs inner brems; kaon vertex form factor.
$K_L \rightarrow \mu \mu \gamma$		4×10^4 evts	Muonic Kaon Dalitz.
$K_L \rightarrow \pi^+ \pi^0 e^- \nu$	700 evts (E731)	3×10^5 evts	$\pi\pi$ phase shift; relevance to ϵ'/ϵ .
$K_L \rightarrow e e e e$	$< 2.6 \times 10^{-6}$	70 evts	Double Dalitz.

The Phase I of E-799 is scheduled to run for 2-3 months following E-773. With the most current Fermilab schedule scenario, it will start around March 1991. Three modules of TRD will be constructed and delivered before the end of 1990 to the beamline.

The Transition Radiation Detector (TRD), which is the most crucial item of the experiment, was started as an R & D project by this task for the past one year. Figure 1 shows the top and side view of the chamber, its local gas routing and onboard electronics. Some highlights on the construction technique include: i) the stretching of a single piece of large area (3m x 3m) mylar film (.002" thick) with "air-bar" to just below the shearing point to ensure we've the strongest chamber window cathode (for Xe gas pressure compensation); ii) the usage of very cheap "Pac-man" to align wires with position precision better than .0005"; iii) design of Surface Mount Technology amplifier boards with the state of the art transconductance amplifiers and associated electronics. Finally with the

VME-based FADC system, the relative merits of 'total charge' and 'cluster counting' methods would be identified.

This task's prototype project is highly successful. One module was finished and delivered to the beamline in June 1990 for beam test. With 3×10^{12} protons on target which is the maximum beam intensity for the upcoming run, the chamber drawn only $3 \mu\text{A}$ compared to the $150 \mu\text{A}$ drawn by the existing drift chambers. Analysis offline shows that the π/e rejection is 4.5. And with the full three modules system, the expected rejection will be 70.

There are also conceptual work done on a trigger electronics system for the TRD. This is absolutely needed for the Phase II of E-799.

Publication :

Journal -

1. 'First Result on a New Measurement of ϵ'/ϵ in the Neutral-Kaon System' Phys.Rev. Lett., **60**,1695 (1988).
2. 'New Limits on $K_{LS} \rightarrow \pi^0 e^+ e^-$ ' Phys. Rev. Lett. **61**, 2661 (1988).
3. 'A Cluster Finding Trigger Processor For a High Energy Physics Experiment Searching For New Source of CP Violation' IEEE Trans.Nucl. Sci. **36**,358(1989).
4. 'Search for $K_L \rightarrow \pi^0 \gamma \gamma$ ' Phys. Rev. Lett. **63**, 28 (1989).
5. 'A Cluster Finding Trigger Processor for a High Energy Experiment' NIM **A291**, 577 (1990).
6. 'New Limit on $K_L \rightarrow \pi^0 e^+ e^-$ ' Phys. Rev. **D41**, 3546 (1990).
7. 'A Determination of ϵ'/ϵ by the Simultaneous Detection of the Four $K_L \rightarrow 2\pi$ Decay Modes' Phys. Rev. Lett. **64**, 1491 (1990).
8. 'A Measurement of the Phase Difference between η_{00} and η_{+-} in $K_L \rightarrow 2\pi$ Decays'

Phys. Rev. Lett. **64**, 2976 (1990).

Conference Contributions -

1. 'A Progress Report of Fermilab Experiment E-731: A Precision Experiment to Measure ϵ'/ϵ and Rare Decay modes of the Neutral Kaon' The Second International Symposium on the Fourth Family of Quarks and Leptons (1989), Annals of New York Acad. of Science, Vol.578, 162 (1989).
2. 'Precision Experiments to Determine $\text{Re}(\epsilon'/\epsilon)$ by And to Study Neutral Kaon Rare Decay', Proceeding of the 1989 Theoretical Advanced Study Institute in Elementary Particle Physics (TASI), World Scientific, 725 (1989).

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