UCLA-CAA0075-4-91DBC

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THE UCLA ϕ FACTORY PROJECT: AN EXAMPLE OF UNIVERSITY, INDUSTRY AND NATIONAL LABORATORY COOPERATION IN "MEZZO SCIENCE"

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ABSTRACT

In the 1940's – 60's there were important nuclear and particle physics facilities at university sites. This role has now been taken over by the national laboratories to the partial detriment of student PhD training and active participation by university research scientists. In addition, the experimental equipment at universities has rapidly deteriorated. We present here a counter example of a project being proposed for a university campus that combines powerful scientific goals, strong PhD training and cooperation with the national laboratories and industry to build equipment on a university campus.

INTRODUCTION

High Energy Physics and Nuclear Physics in the USA is rapidly being centralized into a small number of huge laboratories. FNAL, SLAC and the SSC for High Energy and CEBAF, RHIC (at BNL) for Nuclear Physics. The role of the university scientist is partially to feed manpower and ideas into these machines. PhD student training is not the central focus of the effort nor is university research excellence among the goals. It is *catch as catch can* for the universities, in general.

While it is understood that the nature of the deep scientific problems still to be solved (ie. the Higgs Boson for Particle Physics and the Quark Gluon Phase Transition for High Energy Nuclear Physics) require large facilities; many believe that it is important to maintain some decentralization or these will soon be only one or two great

laboratories for all of particle and nuclear physics in the USA. How can this decentralized research be fostered and carried out? First and foremost there must be credible scientific goals that could fit into a university based facility. Presumably the universities are still the backbone of the scientific research, training and pool of new ideas in the US. There are many problems in physics that lend themselves to the high intellectual level and modest facilities of a university. A few examples are: (1) the search for Cosmic Dark Matter using Novel Detectors, (2) Double β Decay search, (3) the study of CP Violation at a ϕ Factory, (4) measurement of the (g-2) for electrons and Muons, (5) Gravity Wave Detection, (6) Weak Neutral Current study using Atomic Systems. I am certain there are an equal number which I have left out. Questions such as neutrino mass and magnetic moment, lepton violation, CP Violation are all very deep. However, in some cases the project requires more technical infrastructure than is normally available at a university. In this case, a collaboration with a national laboratory and/or industry can provide the needed help.

Such a collaboration would benefit industry and perhaps the laboratories since new ideas are being tested that may open up useful areas for these institutions to pursue later on. It is well known that examples of such cooperation is more rare in the USA than in Japan or Western Europe. This may therefore be a partial reason in itself for the decline of American competitiveness in the world market by not pursuing this interaction. If this is true, examples of cooperation and interaction between universities, industry and national laboratories could serve as role models in increasing the competitiveness of the USA.

Another point in favor of supporting research facilities at US universities is that, as is well known, the technical research equipment available to students and researchers at US universities is out of date and in terrible shape. There is a strong possibility this may be due to the centralization of the science, i.e. the equipment is mainly at

the national laboratories. Perhaps even more to the point, in the obsolete or surplus stock of many large national laboratories one can find considerably better electronic equipment than is available at most technically advanced universities in the USA. For this reason, establishing some modest scientific projects at universities will help provide more up to date equipment for the use of the students, an important goal for those teaching future PhD's.

Finally, from the point of view of the university researcher with a small number of graduate students and post docs, the overwhelming downside of large laboratories is the requirement (mainly for political reasons) for huge groups, eg. already 600 in one SSC experiment alone. This creates a lack of identification on the part of the students, resulting in a less enthusiastic response since group identification and interaction is made difficult if not impossible due to such large groups, the *lost in a crowd* syndrome which has come to be synonymous with lack vitality and diversity at every level. Smaller, more interactive projects at university sites may prove more innovative provided the scientific goals are high and provide a definite advantage.

All of the points mentioned above lead us to suggest that modest scientific projects, technically advanced, should be considered for the university campus. Such projects would provide improved equipment for student use and a more desirable environment to insure that students feel not only welcome but encouraged to be innovative and fully involved.

THE UCLA ϕ FACTORY

In light of the above, we present a description of the ϕ Factory project being proposed at UCLA which has many of the attributes of what might be called new university science[1,2] . This type of science program has been recently labeled "mezzo science" by, among others, R. Orbach, Provost in the College of Letters and Science

at UCLA. It is science that can not fit into the existing buildings and infrastructure provided by most large universities in the US but could still be accommodated on the university campus.

The UCLA Consortium (to be described later) is proposing to construct a ϕ factory on the UCLA southwest campus[2] . The initial step in establishing this "mezzo science" opportunity at UCLA was to establish the UCLA Center for Advanced Accelerators as a basic framework. This was done in 1987. A crucial step is the construction of a new building on the UCLA campus to house the CAA and the Institute for Plasma Fusion (IPFR) whose director is R. Conn of the UCLA Nuclear Engineering Department. The CAA has two primary purposes: PhD training and the exploration of new concepts in accelerator and detector physics. The project being proposed to advance these goals is the UCLA ϕ Factory. The scientific advantage of such a ϕ factory can best be described by first discussing a valuable contribution possible should such a ϕ factory exist.

The ϕ meson is a particle of mass 1020 MeV that has the quantum numbers of a pure vector meson. It decays mainly into pairs of strange particles with an important decay

$$\phi \rightarrow K_S^0\,(CP \simeq +1) + K_L^0\,(CP \simeq -1) \tag{1}$$

the final state has one nearly pure [CP = +1] state and one nearly pure [CP = -1] state, where the CP of the system is the symmetry under charge configuration and parity reversal of the state. Any observed correlation between these two particles will indicate a violation of CP invariance or possibly of CPT invariance. Thus, the whole system acts as an "Interferometer" for symmetry violation helping to clarify the processes involved.

Keeping the above in mind, the goals of the ϕ factory project specifically are[1] :

(1) the study of CP violation to the level of $\sim 10^{-4}$ for a direct component[3]

(2) the search for CPT violation at the level of[4]

$$[(M_{K^0} - M_{\bar{K}0})/M_K] \leq 10^{-19} \tag{2}$$

(3) the study of exotic decays of K,η,ω,ϕ,$\rho \cdots$ mesons[5]

(4) new tests of the EPR paradox in quantum mechanics[6]

(5) training of accelerator physicists and engineers at the PhD level with hands on experience

(6) a regional and Pacific Rim consortium to participate in all of the above

In order to pursue these goals, the UCLA group has formed a consortium with Lawrence Livermore National Laboratory, individuals from Lawrence Berkeley Laboratory, Los Alamos National Laboratory, Stanford Linear Accelerator Center, Brookhaven National Laboratory, and with industrial partners: General Dynamics Corp., Maxwell Laboratories and Rocketdyne Division of Rockwell International Corp. This consortium was formed for the purpose of designing and constructing the ϕ factory complex. Some specifics of this project are as follows.

The ϕ factory consists of a very compact superconducting storage ring, a 500 MeV electron linac and positron source, and a state of the art detector (Fig. 1). It will be housed in the new building being constructed on the southwest sector of the UCLA campus. The UCLA administration is strongly behind this project as well as elements from the state of California itself. In Table 1 we summarize some of the unique scientific goals of the ϕ factory. In Fig. 2 we provide a schematic drawing of the most recent design made by the consortium for a US Department of Energy review team in December, 1990[2] .

There is one central reason why industry should be interested in the UCLA ϕ Factory beyond it's concern for the scientific community. The compact nature of the

machine and high average current make a ϕ factory project a strong candidate for a second generation compact synchrotron light source for future high speed silicon chip development. As is well known, there is an intense world-wide effort to develop commercial compact light sources with the Japanese developing six separate models and the West Germans and USA having one each. It was stated at an accelerator conference held in Europe in 1990 that the development of commercial compact light sources is potentially a multi-billion dollar business. Obviously, US industry would be interested in being a part of this potential market.

Another important goal of the UCLA ϕ Factory not yet mentioned is to test new principles of high luminosity storage rings. These storage rings could be valuable for future larger scale projects such as beauty factories and/or charm factories. One idea that is being designed into the UCLA project by C. Pellegrini is the Quasi-Isochronous Ring[7] . This clever concept provides a machine with zero dispersion. This means that <u>all</u> particles have the same revolution time, independent of their momentum. The net result of development of this ring would be two-fold:

(1) short bunches in the machine

(2) the ability to focus the beams to smaller size than in conventional storage rings.

Thus, with this development, one would increase luminosity for smaller beam current. The successful realization of this idea for the UCLA ϕ Factory could lead to much cheaper $\bar{B}B$ and charm factories in the future. Another idea along this line which might be tested at the UCLA ϕ Factory is the Quasi-linear Collider[8] .

The concepts presented above provide example of the flexibility of a university based system compared to that at a national laboratory. The size and cost of accelerator construction at national laboratories forces design considerations which prove inflexible in comparison to smaller more *manageable* projects. Objectives involving greater diversity

in design, application and experimentation are a result of such smaller and more flexible projects when placed within a university environment.

CONCLUSION

We have presented a schematic view of one example of a possible "mezzo science" for a university campus. The UCLA ϕ Factory project, if approved and funded, could provide a small but significant step in revitalizing the research capacity of the university campus and help form a new link between industry, national laboratories and universities.

ACKNOWLEDGEMENTS

The work on the ϕ Factory project done by people at UCLA alone represents an effort of many people: C. Pellegrini, W. Barletta, D. Robin, M. Atac, K. Arisaka, C. Buchanan, Th. Müller, J. Park, C. Berg, J. Quackenbush, A. Boden. The list of names of those collaborators at other institutes and from industry would be equally long. I want to thank all of them for their help in providing the contents of this paper. I also wish to thank John O'Fallon, David Sutter and P.K. Williams of the Department of Energy for their patience and support at all stages of the project. The creative spirit and cooperative involvement demonstrated by everyone over the past four years is further justification of the value of such a "mezzo science" environment.

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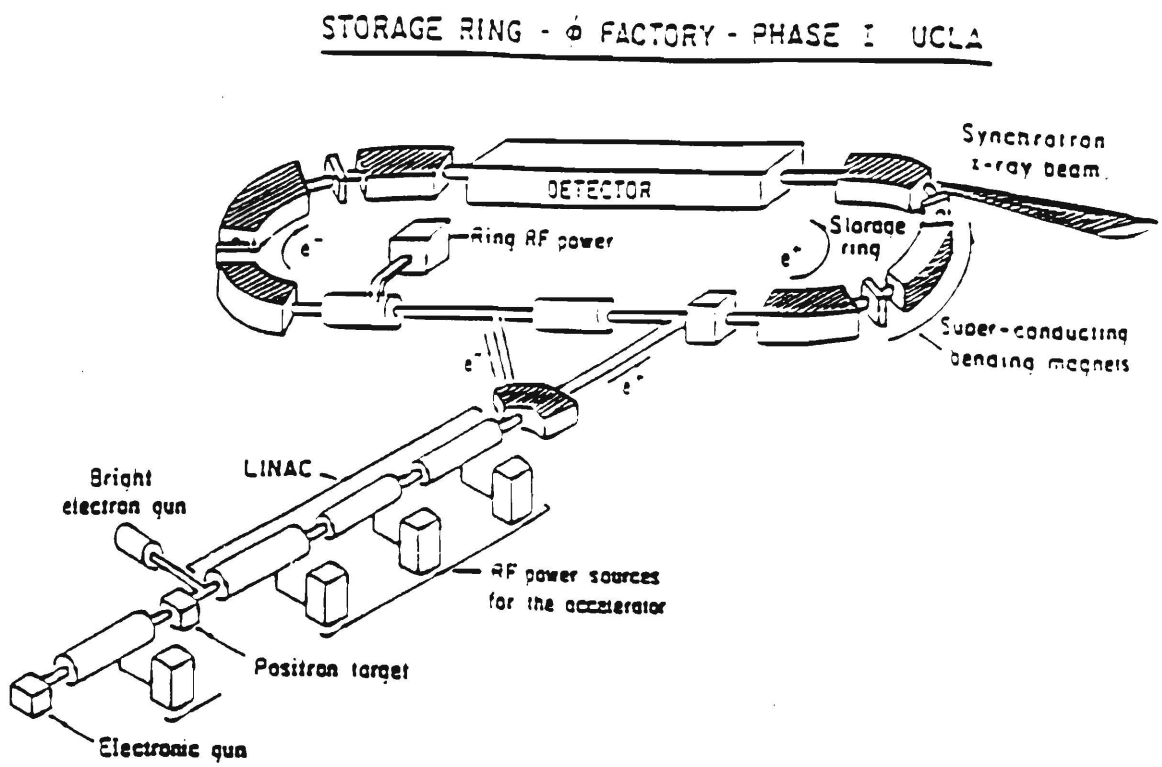

FIG. 1 A schematic view of the UCLA ϕ Factory e^+e^- colliding beam storage ring that uses six superconducting magnets and has a circumference of $\sim 20\,\mathrm{m}$. The electron linac provides full energy e^- injection and e^+ production and acceleration.

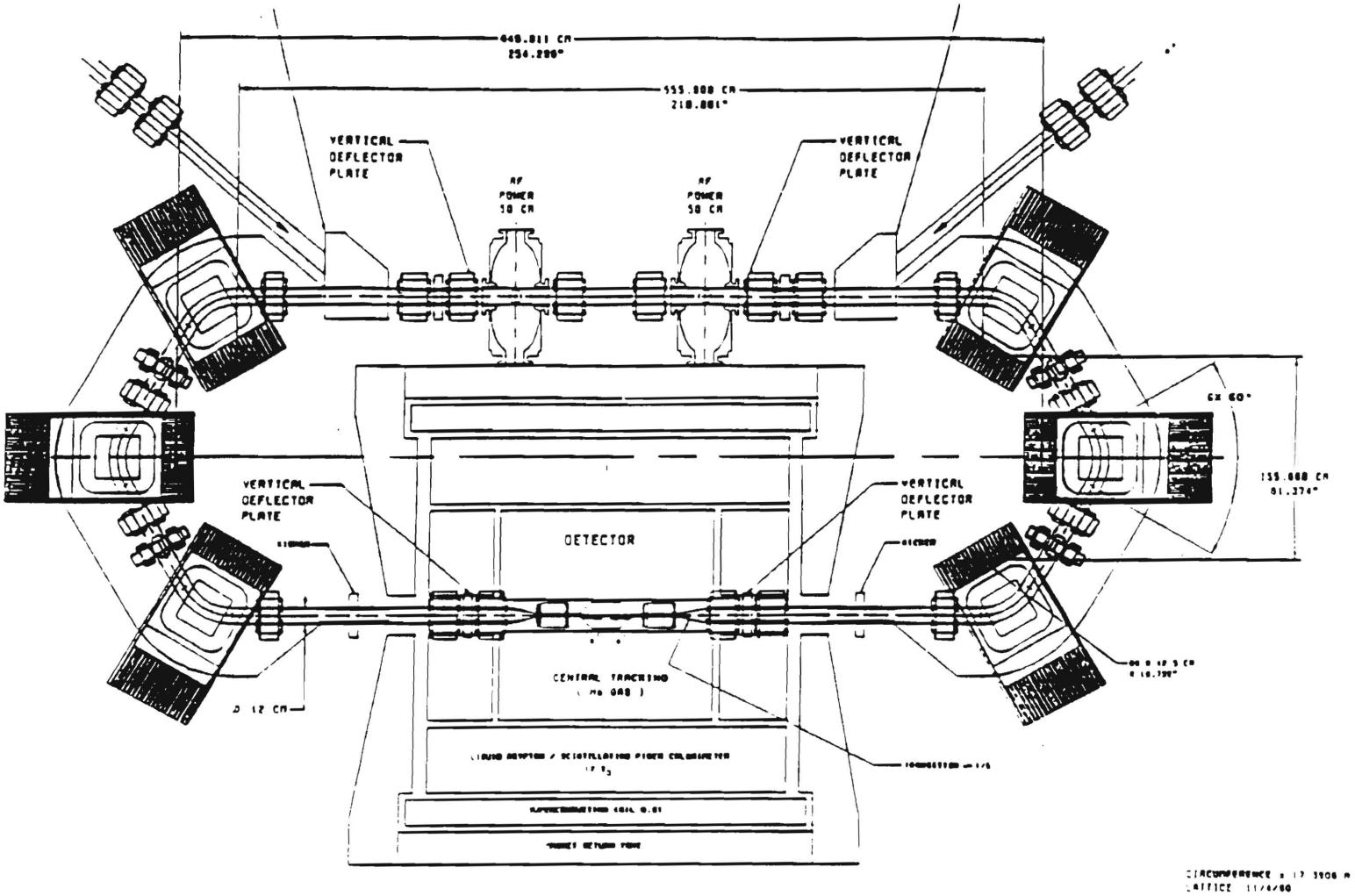

FIG 2. A more detailed design of the superconducting storage ring and the proposed ϕ Factory elementary particle detector.

TABLE 1.

DIFFERENT ASPECTS OF ϕ PHYSICS TO BE USED

	PHYSICS:	**WHY UNIQUE TO ϕ FACTORY:**
1)	Search for Direct CP Violation to 10^{-4}	Control of Systematics Large Number of $K_S K_L$ pairs ($\sim 10^7$) Extremely Clean Environment Interference Effects
2)	Search for CP Violation in Charged K	Creation of $\sim 10^9$ $K^{\pm}$ decays **in vacuum** Reverse Magnetic Field, etc.
3)	Measurement of CP Violation for K_S^0	Source of Pure K_S^o
4)	Test of $\Delta S = +\Delta Q$ Rule to New Level	Tag every event Compare $\pi^+ \ell^- \nu$ to $\bar{\pi} \ell^+ \nu$ (Similar to the $K^{\pm}$ slope experiment)
5)	Very Sensitive Test of CPT Theorem	Several channels can be used $\pi\pi$ (Imϵ' test) Mixture of Semileptonic and $\pi\pi$, etc. **Inclusive CPT** Test, Absolute ϕ_{+-}
6)	Search for Exotic Transitions in the K_S^0 Meson	Search for vacuum regeneration of $K_S^o \sim$, e.g. $K_S^o + \nu \rightarrow K_L^o + \nu$ ($K_L \rightarrow K_S$ can't be detected) **pure K_S - tagged by K_L**
7)	Test of the EPR Paradox in New Way: The Symmetric Regeneration Paradox	Test Quantum Mechanics with CP amplitudes in new way
8)	Gravitaional effects of the K_S^0 and K_L^0 System	Isotropic $K_S K_L$ production can compare up vs. side events (long shot)
9)	$K_L \rightarrow$ New Particles	Suppose $K_S \rightarrow$new types of particles and Tag the K_S^0 Study large samples of K_L decay - detector dependent
10)	Rare and Exotic Decays of K, η, η', ω, ρ and ϕ Mesons	

Definition of Symbols for Table 1:

C ..... Charge Conjugation operator
P ..... Parity operator
T ..... Time Reversal operator
K ..... Charged or Neutral Strange Meson
ΔS ..... Change of Strangeness in the reaction
ΔQ ..... Change of Charge in the reaction
K_S^0 ..... Short Lived K^0 Meson
K_L^0 ..... Long Lived K^0 Meson
$\eta, \eta', \omega, \rho, \phi$ .... Low Mass Non-Strange Mesons
EPR ..... Einstein-Rosen-Podalsky Paradox