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STATUS OF THE TAU-CHARM FACILITY AND HIGHLIGHTS OF ITS PHYSICS PROGRAM[1]

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ABSTRACT

In this paper I will first discuss the history and current status of the Tau-Charm Facility. I will then focus on the unique aspects of the heavy meson and tau physics program of such a facility, which motivates its construction and operation in the mid-1990's.

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1. HISTORY

The Tau-Charm Facility was first proposed[1] in 1987 as a dedicated facility which would represent the first of the *next-generation* high luminosity ($2 \times 10^{33} cm^{-2} sec^{-1}$) two ring symmetric e^+e^- colliders. Machine design has been ongoing at SLAC, Orsay, KEK since its inception at CERN; the first workshop exploring the physics and the machine was held at SLAC in May 1989.[2] The machine and detector projects are currently under review in Europe for possible siting in Spain or France. A strong participation of US groups on the detector is anticipated.

2. GENERAL CONSIDERATIONS ON THE PHYSICS GOALS

Tests of the Standard Model (SM) can either be performed in new higher energy facilities - seeking to produce new particles, or by precision measurements at lower energies of those quantities predicted unambiguously by the Standard Model itself. Historically, the clean and direct analysis of heavy quarks and leptons at production threshold in e^+e^- has provided the most detailed tests of our understanding of quarks and leptons and their interactions within the context of the Standard Model.

To achieve significant progress in tau-charm and b-physics, future data samples must be characterized by: (i) significantly higher statistics, (ii) low backgrounds, (iii) well thought-out programs targeted specifically at the reduction of systematic errors, and finally (iv) third and fourth generation detectors matched to the b- and c-quark and tau physics, respectively. Thus, the next logical step for the study of charm, beauty and the tau-lepton are the construction and operation of a next generation of *dedicated* high luminosity storage rings operating near each respective fermion-pair threshold.

Studies[3] show that the luminosity requirements of the Tau Charm Facility are 100-1000X present facilities, leaving it at least one order of magnitude higher than competing facilities in the mid 1990's. For studies of the charm quark,[4] the luminosity is most important, allowing the possibility of examining second order weak interactions of DD mixing, doubly Cabibbo-forbidden weak hadronic decays (DCSD), rare and radiative decays, Penguin decays, making precision tests of CKM matrix unitarity through studies of the semileptonic and pure leptonic decays of the charmed mesons. **The charm physics program strongly compliments any program that eventually studies B-meson decay at a similar precision.**

Studies of the tau-lepton emphasize both the high luminosity and clean production available in an e^+e^- threshold environment. Measurements of tau decay (for example, one-prong branching ratios) and the Lorentz spin structure (the Michel parameters) represent precision tests of the Standard Model, which unlike the study of charm mesons rely not only upon the high luminosity and large event samples produced by the Tau-Charm ring, but also require precise (and unprecedented) control of systematics. To achieve the necessary control of systematic errors, the measurements must be made operating the ring at several beam energies, making these studies unique to the machine. The stringent limits on the tau-neutrino mass and on rare tau decays that are accessible at Tau-Charm depend largely on the customization of the detector and trigger to the study of these specific processes, in addition to the Tau-Charm machine's ability to copiously produce and cleanly tag tau-leptons.

In addition to the two programs highlighted and discussed herein, a rich parallel program of charmonium, light quark and gluonium spectroscopy is also available, with little impact on either of the two longer term base programs.

For completeness and comparison, I summarize in Table 1 the projected data samples of CESR/CLEO-II by the beginning of 1995, (perhaps the earliest that a new Tau-Charm ring could turn on), together with the yearly samples from a B-factory and the Tau-Charm Facility . For the CESR yield, the curve is based on anticipated improvements[9].

The fixed target experiments expected to come online in this period will be FNAL E-687 and E-791(photo- and hadro-production). These should collect 10X greater statistics than E-691, which reconstructed roughly 10^4 charmed mesons (about 2X the Mark III *tagged* data sample from SPEAR). The experiments foreseen within the next five years should thus have in the range of 10^5 reconstructed charm events, which is to be compared with the few$\times 10^7$ *tagged D* mesons expected in a year's run at the Tau-Charm Facility .

Table 1

Primary Charm and Tau Yields

Channel	CLEO II 1995	B-Factory $L = 10^{33}$ (per year)	Tau-Charm $L = 10^{33}$ (per year)
D^0	3.9×10^7	1.0×10^7	8.7×10^7
D^+	1.8×10^7	0.5×10^7	6.3×10^7
D_s	1.2×10^7	0.3×10^7	2.7×10^7
$\tau^+\tau^-$	5.1×10^7	0.7×10^7	0.7×10^7 (3.57 GeV) 3.6×10^7 (3.67 GeV) 5.3×10^7 (4.25 GeV)
ψ	-	-	1×10^{10}
ψ'	-	-	5×10^9

3. PHYSICS HIGHLIGHTS IN CHARM DECAYS

The most unique contributions of the Tau-Charm Facility in the area of charm meson physics will come in four areas:

1. The second order weak interactions ($D^0\bar{D}^0$ Mixing) and limits on CP violation in the charm meson decays,

2.) The pure leptonic decays of D^+ and D_s, yielding f_D and f_{D_s},

3.) The semileptonic decays, yielding precision CKM matrix parameters and the lepton spectrum, and

4.) Rare D^0, D^+, D_s decays, measuring radiative and hadronic penguins, and searches for decays outside the Standard Model.

3.1 Second Order Weak Interactions $D^0\bar{D}^0$ Mixing and CP Violation

The observation of mixing from the second order weak interaction in the D^0 meson system is a fundamental measurement for the understanding of the weak

hadronic interaction. For charm mesons, in the Standard Model, the mixing parameter r_D is predicted[illegible] to lie between 10^{-5} to 10^{-4}. Thus, an experiment should be able to set a *limit* on $r_D \leq 1 \times 10^{-5}$, or measure a significant signal within this range.

The present limit on r_D is 4×10^{-3} at 90% CL, from E-691. In the fixed target experiments, and proposed B-Factories, mixing measurements rely on the vertexing of D^0 mesons to measure the decay length of D^0 whose parentage has been tagged through $D^{*+} \to D^0\pi^+$. These time evolution approaches rely on the fact that the mixing rate is proportional to $t^2 \times e^{-\Gamma t}$, while the background from DCSD is proportional to $e^{-\Gamma t}$. However, DCSD background will always exist, limiting the ultimate sensitivity for potentially small r_D values.

In the Tau-Charm Facility, $D^0\bar{D}^0$ mixing is measured by exploiting the quantum coherence of the initial state and does *not* rely on a time evolution measurement. The background from DCSD suppressed decays can be turned-off or made to selectively interfere with a mixing signal by preparation of the initial state, allowing r_D (the total mixing rate) and its individual components ($\Delta M/\Gamma$ and $\Delta\Gamma/\Gamma$) to be measured, when independent information on DCSD amplitudes is incorporated.

It is proposed to study $D^0\bar{D}^0$ mixing in the Tau-Charm Facility by making at least seven independent measurements, indicated in Table II. Table II also summarizes estimates for either limits on r_D or observation of mixing signals. These techniques independently limit r_D from 8×10^{-4} to 6×10^{-5}, or combined are sensitive to $r_D \leq 3 \times 10^{-5}$. Running over several years, a limit on r_D below 10^{-5} becomes possible.

CP violation in the charm sector can occur either through $D^0\bar{D}^0$ mixing or directly through a difference in the decay amplitude to a final state for the particle and its anti-particle. A more detailed discussion is available elsewhere.[illegible] Briefly, The mixing dependent CP violation can be determined from an asymmetry measurement in the process $e^+e^- \to D^{*0}\bar{D}^0 \to [(\gamma(D^0\text{semileptonic decay})(\bar{D}^0$ CP eigenstate decay (*e.g.*, K^+K^-))]. One feature is that any detector induced asymmetries can be accounted for by observing the expected null signal in those similar events in which the D^{*0} decays to a π^0 rather than to a γ. A one year run at the Tau-Charm Fa-

Table II

$D^0 D^0$ Mixing (1 Yr at L=10^{33}, * = scaled)

$e^+e^- \rightarrow$	Final State	Rate	Events (right sign)	Bckgnd	r_D 90% CL	r_D 5σ signal
$D^0 D^0$	$(K^-\pi^+)(K^-\pi^+)$	r_D	34900	0.4	7.0×10^{-5}	1.7×10^{-4}
$D^0 D^0 \gamma$	$(K^-\pi^+)(K^-\pi^+)\ \gamma$	$3r_D + 8(\frac{\Delta\Gamma}{2\Gamma})\tan^2\theta_c\hat{\rho} + 4\tan^4\theta_c\hat{\rho}^2$	3300*	–	–	–
$D^0 D^0\ \pi^0$	$(K^-\pi^+)(K^-\pi^+)\ \pi^0$	r_D	2750*	0.1*	7.6×10^{-4}	1.7×10^{-3}
$D^0 D^0$	$(K^-e^+\nu)(K^-e^+\nu)$	r_D	15500	0.9		
	$(K^-e^+\nu)(K^-\mu^+\nu)$	r_D	23300	2.4	8.6×10^{-5}	3.1×10^{-4}
	$(K^-\mu^+\nu)(K^-\mu^+\nu)$	r_D	12700	2.8		
	$(K^*l\nu)(Kl\nu)$	r_D	68000*	9*	6.4×10^{-5}	2.3×10^{-4}
	$(K^*l\nu)(K^*l\nu)$	r_D	22000*	3*		
$D^0 D^0\ \gamma$	$(K^-l^+\nu)(K^-l^+\nu)\ \gamma$	$3r_D$	11600*	1*	7.5×10^{-5}	2.3×10^{-4}
$D^0 D^0\ \pi^0$	$(K^-l^+\nu)(K^-l^+\nu)\ \pi^0$	r_D	9600*	1*		
$(D^0\pi^+)D^-$	$[\pi^+(K^+e^-\nu)(K^+\pi^-\pi^-)]$	r_D	9400	<0.5		
	$[\pi^+(K^+\mu^-\nu)(K^+\pi^-\pi^-)]$	r_D	7000*	1*		
	$[\pi^+(K^*l\nu)(K^+\pi^-\pi^-)]$	r_D	8000*	1*	8.3×10^{-5}	2.7×10^{-4}
	$[\pi^+(K/K^*l\nu)(D^-\ \text{tag})]$	r_D	24000*	2*		

cility should yield a sensitivity to the CP asymmetry at the ~ 1% level. Direct CP violation searches are best carried out at the ψ''. An asymmetry measurement in the process $\psi'' \rightarrow$(semileptonic decay)(CP eigenstate decay) would allow a determination of the magnitude of any CP violating amplitude to an accuracy of ~ $\frac{1}{2}$ % in a one year run. The phase of the CP violating amplitude can be determined from the observation of final $D^0 D^0$ states in which both D's decay into different states with the same CP. If CP were completely violated, we would expect to see ~ 1000/year.

Although the levels of CP violation which can be probed do not reach the Standard Model predictions, the Tau-Charm Facility would provide the first look into potential CP violation in the up-quark sector. Any such signal observed would provide unequivocal evidence for New Physics.

3.2 Leptonic Decays of D^+ and D_s (f_D and f_{D_s})

The pure leptonic decays of heavy mesons directly measure the axial vector decay constants f_D and f_{D_s}. Precision measurements of the leptonic decays of the D^+ and D_s allows the unambiguous determination of f_D or f_{D_s}:

$$B(D^+ \to \mu^+ \nu) = \frac{G_F^2}{8\pi} f_D^2 \tau_D M_D m_\mu^2 \, | V_{cd} |^2 \left(1 - \frac{m_\mu^2}{M_D^2} \right)^2$$

where M_D is the meson mass, m_μ the muon mass, V_{cd} the CKM matrix element, G_F the Fermi constant, and τ_D the lifetime of the D^+. The decay constants measure the overlap of the heavy and light quarks in the meson, and thus appear in calculations of annihilation and exchange processes and in particular, in second order weak interactions (*i.e.*: heavy meson mixing). In the latter, they appear in conjunction with the B-constant, under the vacuum insertion approximation. While in principle they may be calculated[8] in relativistic and non-relativistic potential models, the more fundamental estimates come from lattice QCD (see Table III). The lattice calculations should in the next 5 years be able to calculate these constants with a precision of 5% or better. Since a specific scaling from f_D to f_{D_s} will be predicted, the measurement of *both* these constants with an accuracy of 5% or better will provide an important benchmark test of lattice QCD. Naively, the decay constants scale like the square root of the inverse of the heavy quark mass times the reduced mass to a power between one and two. This mass dependence already appears reproduced on the lattice.[9] Thus, scaling from the values of two constants (f_D and f_{D_s}) will probably provide the *only* reliable estimate of f_B, since accurate lattice calculations will probably not occur until rather far into the future and it is rather easy to demonstrate that an experimental measurement of f_B is unlikely to be made in any of the machines of the next decade(s).

Table III

Theoretical Estimates of Weak Decay Constants

Author	Year	Type	f_D	f_{D_s}	f_{B_d}	f_B/f_D
Mathur and Yamawaki	(81)	QCD SUM RULE	192	232	241	1.3
Aliev and Eletskii	(83)	QCD SUM RULE	170	-	132	0.8
Shifman	(87)	QCD SUM RULE	170	-	110/130	0.7/0.8
Narison	(87)	QCD SUM RULE	173	-	187	1.1
Dominguez and Paver	(87)	QCD SUM RULE	220	270	140/210	0.6/1.0
Reinders	(88)	QCD SUM RULE	170	-	132	0.8
Krasemann	(80)	POTENTIAL	150	210	125	0.8
Suzuki	(85)	POTENTIAL	138	-	89	0.6
Godfrey and Isgur	(85-86)	POTENTIAL	231	391	191	0.8
Bernard	(88)	LATTICE	174	231	105	0.6
DeGrand and Loft	(88)	LATTICE	134	157	-	-
Golowich	(80)	BAG	147	166	-	-

About 1000 (2000) events/year are detected for $f_D(f_{D_s})$, in the final state $\mu\nu_\mu$. The reconstruction of $D_s \to \tau\nu$ is possible, requiring the concomitant measurement and subtraction of many hadronic D_s channels that may feed into it. About 5000 events/year could be reconstructed, providing a complimentary measurement for f_{D_s}.

3.3 Semileptonic Decays

The study of semileptonic decays in the Tau-Charm Facility will provide the *first* test of the unitarity of the second row of the CKM matrix through a systematic study of all possible D_{l3} and D_{l4} decays.[10] Existing measurements are at the 15-20% level while the Tau-Charm Facility anticipates an ultimate measurement at the *few*% level, including systematics (see Table IV). The Tau-Charm Facility will also be the first experiment sensitive to leptonic final states of D and D_s mesons that do not occur through ordinary semileptonic graphs. Examples of the latter are: $D \to gg + l\nu$ and resonant decays $D \to$ *gluonia* $+ l\nu$. The existence of these final states would significantly alter our picture of D and B meson decays.

Table IV

Reconstructed Semileptonic Decays/Year $L = 10^{33}$

$D^0 \to$	BR	$N_{Xe\nu_e}$	$N_{X\mu\nu_\mu}$	CKM
$K^- \ell^+ \nu$	0.034	2.9×10^5	2.2×10^5	V_{cs}
$\pi^- \ell^+ \nu$	0.004	3.7×10^4	3.0×10^4	V_{cd}
$K^{*-} \ell^+ \nu$	0.06	1.5×10^5	1.2×10^5	V_{cs}
$\rho^- \ell^+ \nu$	0.004	1.6×10^4	1.3×10^4	V_{cd}
$D^+ \to$				
$K^0 \ell^+ \nu$	0.07	1.1×10^5	8.6×10^4	V_{cs}
$\pi^0 \ell^+ \nu$	0.004	1.4×10^4	1.1×10^4	V_{cd}
$\eta \ell^+ \nu$	0.0015	3.3×10^3	2.6×10^3	V_{cd}
$\eta' \ell^+ \nu$	0.0005	9.2×10^2	6.2×10^2	V_{cd}
$K^{*0} \ell^+ \nu$	0.05	2.0×10^5	1.5×10^5	V_{cs}
$\rho^0 \ell^+ \nu$	0.0025	1.3×10^4	1.0×10^4	V_{cd}
$\omega \ell^+ \nu$	0.0025	5.5×10^3	4.0×10^3	V_{cd}
$D_S \to$				
$\eta \ell^+ \nu$	0.02	6.7×10^3	5.1×10^3	V_{cs}
$\eta' \ell^+ \nu$	0.006	1.5×10^3	8.5×10^2	V_{cs}
$K^0 \ell^+ \nu$	0.002	4.7×10^2	3.6×10^2	V_{cd}
$\phi \ell^+ \nu$	0.034	4.4×10^3	3.2×10^3	V_{cs}
$K^{*0} \ell^+ \nu$	0.0013	4.5×10^2	3.4×10^2	V_{cd}

The D_{l3} decays have branching ratios proportional to the product $\mid V_{cx} \mid^2 \times \int (f_+(t)^2 p^3 dt)$ where V_{cx} is the appropriate CKM element, and f_+(t)is the vector form factor. The Tau-Charm Facility itself is experimentally sensitive to a ~ 1% deviation in the shape of $f_+(t)$ from single vector pole dominance of the next higher vector meson. To test CKM unitarity by measuring V_{cd} and V_{cs}, an *absolute* D_{l3} branching ratio is required, as well as theoretical input to evaluate $f_+(0)$. Current techniques such as QCD sum rules are reliable at the 10% level and with measurements of all Cabibbo allowed and Cabibbo forbidden D_{l3} and D_{l4} decays could be improved to the ~ 5% level. Each D_{l4} channel has three form factors, V(t), A_0(t) and A_1(t); the Tau-Charm Facility will provide precise information on their t-dependence, the ratios of their magnitudes, and the polarization of the vector mesons in their decays. By systematically reproducing the features of the D_{l3} and D_{l4} decays, we anticipate that the lattice theory within the same time frame as Tau-Charm Facility , can be used to reliably evaluate $f_+(0)$, thus allowing the precise extraction of the CKM parameters.

Just as in the case of the pure leptonic decays, the precise measurements of semileptonic decays will provide the benchmark for QCD sum rules, and then for lattice QCD.

In addition to measurements of the CKM parameters, the Tau-Charm Facility will be able to probe semileptonic branching fractions in the $10^{-4}-10^{-5}$ range, in search of deviations from the spectator picture. With largely background free measurements the Tau-Charm Facility will be sensitive to the non-spectator decays with gluonic couplings to the η', θ and ι.

3.4 Rare, Radiative and Penguin Decays of the D^0, D^+, D_s

Experimental tests of extensions to the Standard Model require either the observation of new particles or their manifestation in single loop graphs. It is argued[11] that all such extensions with new scalars or vector bosons, will have rates scaling like: $B(D \to l^+l^-X) \propto \frac{g_{XY}^2 \times g_{Xll}^2}{M_X^4}$. Flavor changing neutral currents in the Standard Model (ie: lepton family number violating decays, LFNV), are forbidden to all orders. Any non-zero rate observed would thus signal the onset of New Physics. Examples are D^0 or $D^+ \to e^+\mu^-X$, where X is a light hadron. Lepton family number conserving decays (LFNC) can be simulated by effective FCNC, that are allowed in the SM *only* through higher order weak and/or electromagnetic processes; the simplest examples are D^0 or $D^+ \to l^+l^-X$) These one-loop induced FCNC are the most sensitive to New Physics and *compliment* all searches in the down quark sector because the couplings to new particles may *a priori* be flavor dependent, either through mass-dependent couplings or through mixing angles. With the inclusion of long-distance effects, all these classes of decays are expected to occur at inclusive rates of 10^{-7}. Specific channels may however be as much as an order of magnitude smaller in branching fraction.[12]

All current limits are at the few $\times 10^{-4}$ level. The mass sensitivity to New Physics is ~0.2 TeV (choosing unit couplings for g_{qY} and g_{Yl} and factoring out helicity suppression). The Tau-Charm factory brings these into the TeV range for the helicity suppressed class of decays, and to the ~ 20 to 200 TeV scale for non helicity suppressed decays (see Table V).

Table V

Sensitivity to Rare Decays

Channel	Estimated Background	Limit at 90% CL.	Signal at 5σ
$D^0 \to e^+e^-$	$\leq$0.2 evts	3×10^{-8}	6.0×10^{-8}
$D^0 \to \mu^+e^-$	$\leq$1.3 evts	5×10^{-8}	1.2×10^{-7}
$D^0 \to \mu^+\mu^-$	$\leq$10. evts	8×10^{-8}	2.9×10^{-7}
$D^0 \to \rho^0e^+e^-$	$\leq$1.6 evts	4×10^{-8}	1.3×10^{-7}
$D^0 \to K^0e^+e^-$	$\leq$1.5 evts	2×10^{-7}	7.3×10^{-7}

An area of recent interest are the Penguin-type hadronic and radiative decays. The former lead to ordinary Cabibbo suppressed final states, and thus present a problem in disentangling them from the much larger "ordinary" physics. The latter Penguins are GIM suppressed to a level of O(10^{-8}): $A \sim \frac{(m_s^2 - m_d^2)}{M_W^2}$. Rescattering processes (long-range effects) may however enhance the electromagnetic graphs to a level of O(10^{-5}). Furthermore, a number of recent calculations suggest that QCD radiative corrections may enhance the Penguin graph even further. At a level of 10^{-5}, decays such as $D^+ \to \gamma\rho^+$ will be detectable in the Tau-Charm Factory, through tagging.

The importance of seeking Penguins in charm decay where the tree graph is very small is to establish the strength of long-range rescattering and QCD radiative corrections. Both these "corrections" must exist for B decay, and in fact may *dominate* the more interesting t-quark (or New Physics) contribution. If Penguin decays are found in D decay to be large (O($10^{-6} - 10^{-5}$)), it may be *impossible* to unambiguously resolve the t-quark contribution to electromagnetic-penguin B decay from the long-range effect. Thus, the contribution of the understanding of Penguin decays is *unique* here.

3.5 Other Charmed Physics

In addition to the topics described here, the Tau-Charm Facility will address the measurement of the full pattern of weak hadronic decays of the D^0, D^+ and D_s with sensitivity beyond the DCSD level ($\sim 10^{-4}$). Combined with precise measurements of their absolute branching fractions ($\sim$ 1% systematics level), the semileptonic and pure leptonic decays, their lifetimes (from SLC and LEP) and the parallel measurements of B-mesons at CLEO-II, a unique opportunity exists for a thorough understanding of the weak-hadronic decays of heavy mesons. The Tau-Charm Facility also offers the possibility of similar studies of charmed baryons.

4. PHYSICS HIGHLIGHTS IN TAU DECAYS

The Tau-Charm Facility best addresses four areas in tau-physics:

(1) The absolute branching ratios for $e\nu\nu, \mu\nu\nu, \pi\nu, K\nu$ and the precise measurements of all other τ decay rates.

(2) The ν_τ mass.

(3) The Lorentz structure of tau-decay matrix elements.

(4) Limits on the rare or forbidden decays.

4.1 Precise Measurements of $\tau \to e\nu\nu, \mu\nu\nu, \pi\nu,$ and $K\nu$

The one prong branching fractions can be accurately predicted by the Standard Model. It is important to test the theory at least to the level of the electroweak radiative corrections ($\sim \frac{1}{2} - 1\%$). Any deviation from the predictions would of course indicate New Physics, with the most likely candidates being intermediate particles that couple either to mass or generation number, such as Higgs or leptoquarks.

A detailed study of the 1-prong branching fraction measurements at the Tau-Charm Facility is given in the Workshop.[13] The main background in these measurements is the confusion of one τ decay with another. By running slightly (1 MeV) above threshold, the powerful kinematic separation of particles (see Figure 1), is possible allowing the determination of with absolute branching ratios to $\sim \frac{1}{2}$% fractional error.

4.2 The ν_τ Mass

The current experimental limit on the ν_τ mass (35 MeV) is far weaker, relative to its charged partner, than the corresponding limits on the ν_e and ν_μ masses. If neutrinos do have mass, one expects a hierarchy leaving the ν_τ as the most massive. It is important to search with increasing sensitivity for a finite ν_τ mass.

A detailed study of the ν_τ mass measurement has been done.[14] The key feature here is that the τ decay products have a low momentum allowing better mass resolution. he The measurement of m_{ν_τ} also requires that the absolute mass scale be correct to 10^{-3} of the mass measured. calibrate the mass scale. D^+ decays with mass very close to endpoint of 5π from τ decay provide large statistics to check for systematics. We estimate that r 3 MeV limit on m_{ν_τ} can be set with a one-year sample, for the measurement of m_{ν_τ} using the endpoint of the mass distribution in the $\pi^+\pi^+\pi^+\pi^-\pi^-$ ν_τ final state. 5 pion mass distributions for various ν_τ masses for the Tau-Charm expected data sample are shown in Figure 2.

4.3 Lorentz Structure of Matrix Elements

Measurement of the Lorentz structure of the tau-lepton provides a sensitive test of the universality of weak-interactions, and the presence of non V-A components that may arise from scalars (charged Higgs) or right handed gauge bosons. Unlike the muon case, we know very little about the spin structure of the τ. At present, of the Michel parameters, only ρ is measured and not very well ($\sim$ 10% accuracy), however, only the full set of Michel parameters are sensitive to New Physics, (eg: right handed W's), whereas ρ alone is not.

The measurement of the Lorentz structure for τ decay is decribed in detail elsewhere.[15] We estimate that at the Tau-Charm Facility the Michel parameters can be measured with an accuracy comparable to those for muon decay (see Table VI).

Table VI

Precision of Tau-Decay Parameters

Lepton	ρ	η	ξ	δ	ξ_μ
μ - present	0.003	0.013	0.01	0.004	-
τ - present	0.05	-	-	-	-
$\tau(L = 10^{32})$	0.01	0.03	0.03	0.03	0.30
$\tau(L = 10^{33})$	0.003	0.02	0.02	0.02	0.10

4.4 Rare or Forbidden Decays

The advantage of a Tau-Charm Facility for measuring rare τ decays is that the maximum cross-section for $\tau\tau$ pairs occurs at 4.2 GeV, where it is ~4X that at the $\Upsilon(4S)$; this translates directly to sensitivity for rare or forbidden τ decays. In particular, we anticipate being sensitive to τ branching fractions on the order of 10^{-8}, if backgrounds are reducible. Furthermore, the observation of a positive signal is easily tested by moving below $\tau\tau$ threshold.

5. CONCLUSIONS

A 10^{33} Tau-Charm Facility provides an extensive program of fundamental physics, *e.g.*, to measure second order weak interactions ($D^0\bar{D}^0$ mixing) at the Standard Model level, to make precise measurements of fundamental constants ($f_D, f_{D_s}, V_{cd}, V_{cs}, m_{\nu_\tau}$), to make precise tests of the theory (1-prong branching fractions of the τ), and to reach a high sensitivity for rare processes that would signal the onset of New Physics(*e.g.* in the charm sector, CP violation or flavor-changing neutral currents). A rich parallel program of charmonium, light-quark and gluonium spectroscopy also becomes available.

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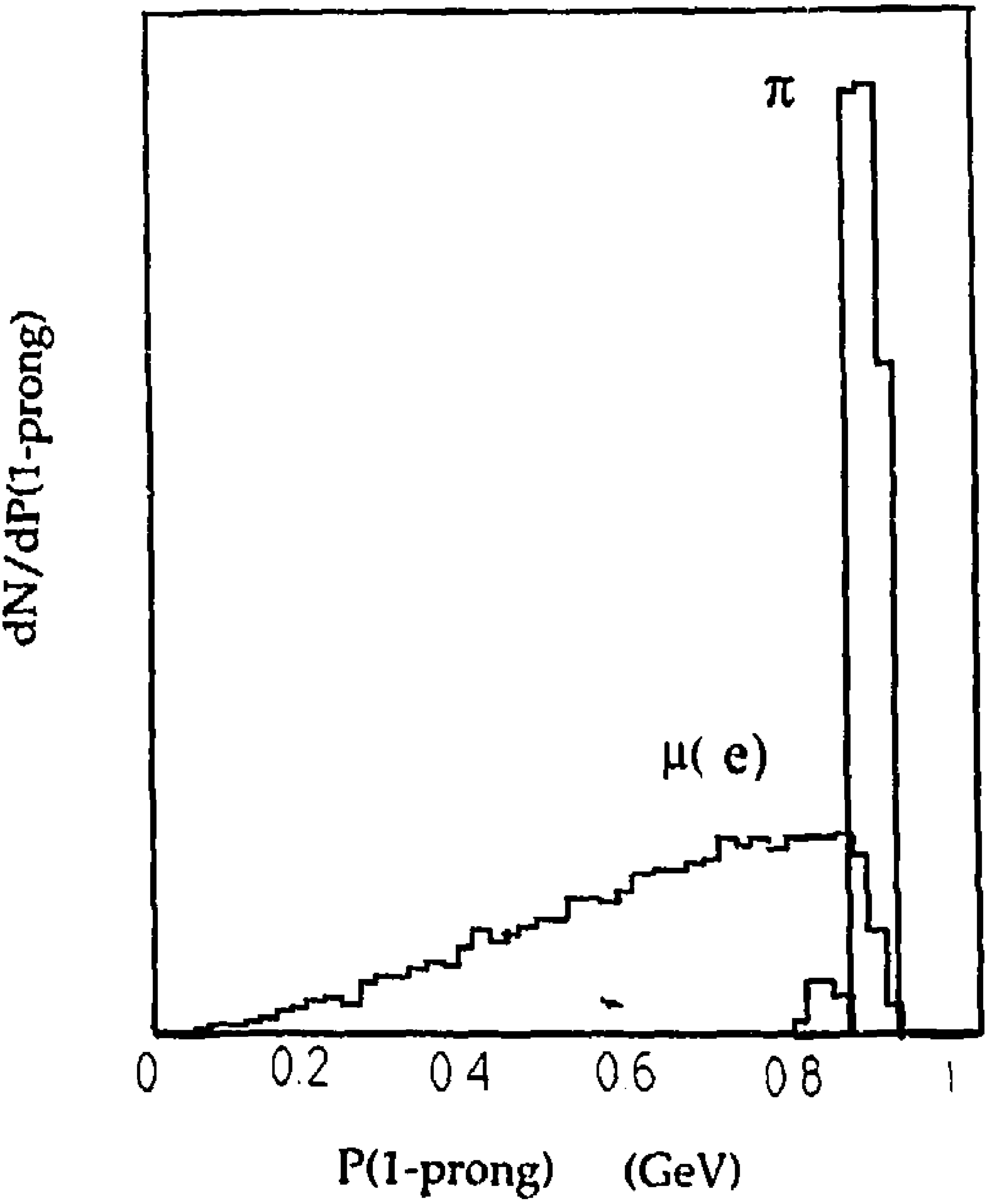

Fig. 1 The momentum distribution of π, K, and $e(\mu)$ just above τ-pair threshold for one-prong τ decays.

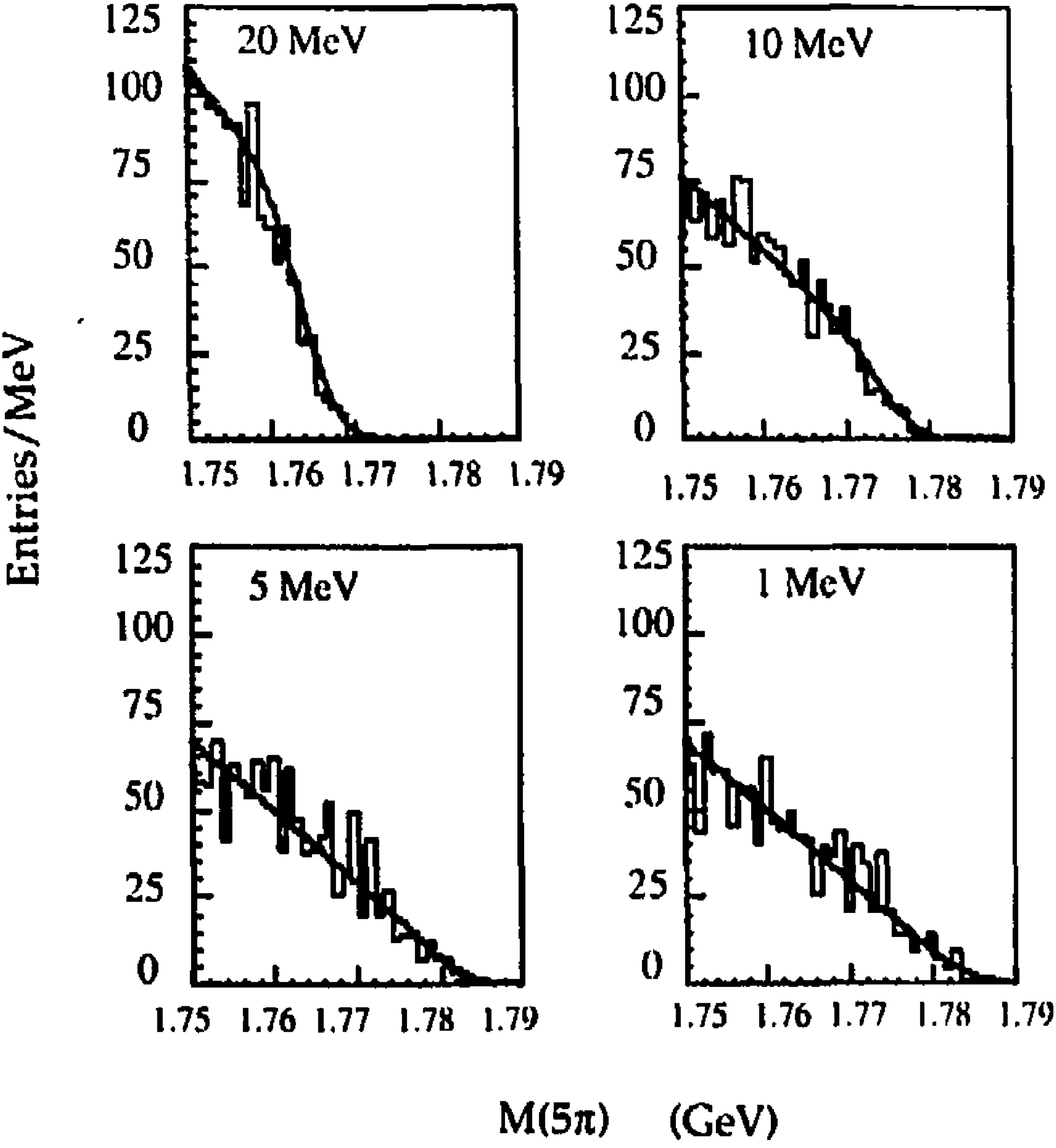

Fig. 2 The 5 pion mass distribution from τ decay assuming ν_τ masses of 20, 10, 5 and 1 MeV, respectively. Statistics correspond to a 1 year run at $\sqrt{s} = 4.2 GeV/c^2$. Curve indicates fit to the distribution with detector resolution.