SLAC-Pub-5709
December 1991
(T/E)

The Tau-Charm Factory: Concept and Construction*

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Abstract

The first part of this paper explains the tau-charm factory concept: a high luminosity, low-energy, two-ring, electron-positron collider which enables precise and probing studies of the physics of the charm quark, tau lepton, and tau neutrino. The second part describes the plans for construction of a tau-charm factory in Spain.

A. The Tau-Charm Factory: Concept and Physics

A.1 Concept

As shown in Table 1, eleven elementary fermions are known and a twelfth, the t quark, is expected but not yet discovered.

Table 1.

GENERATION	LEPTONS		QUARKS	
First	e	ν_e	u	d
Second	μ	ν_μ	c	s
Third	τ	ν_τ	(t)	b

Of the known fermions there are four which are poorly known and require a great deal more experimental study, these are the c, τ, ν_τ, and b. **The purpose of the tau-charm factory is to enable precise and fundamental studies of the properties and interactions of the c, τ, and ν_τ,** using data sets 100 to 1000 times larger than sets which exist now or will exist in the near future.

The tau-charm factory [1, 2, 3, 4, 5] is a high luminosity, two-ring, electron-positron collider, (Fig. 1), and detector with the following properties:

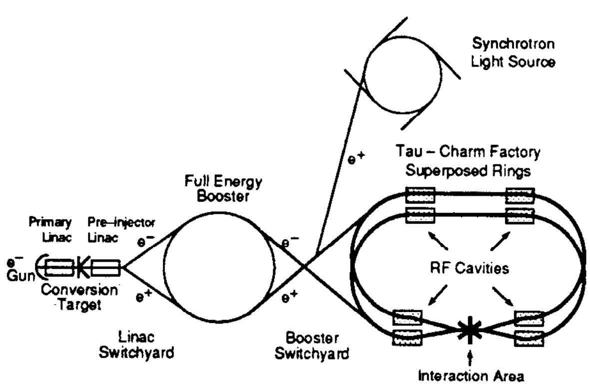

Figure 1

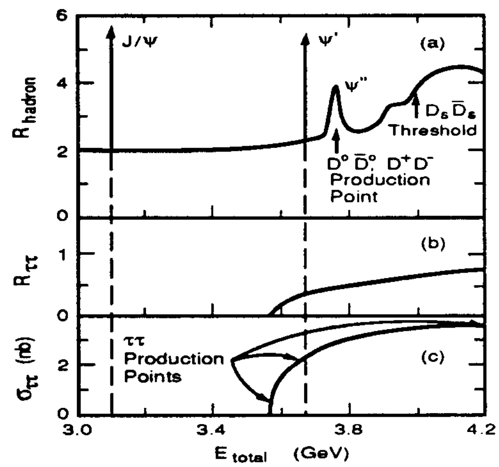

Figure 2

- Range of total energy = 3.0 to 5.0 GeV.
- Design luminosity = 10^{33} cm^{-2} s^{-1} at 4 GeV. (1)
- High resolution, large acceptance detector specially designed for tau and charm physics.

The energy range, Fig. 2, is set to encompass the thresholds and resonances for the basic particle production processes:

Tau pair production: $e^+ + e^- \rightarrow \tau^+ + \tau^-$ (2a)

Charmed meson production:
$e^+ + e^- \rightarrow D^+ + D^-$
$e^+ + e^- \rightarrow D^0 + \bar{D}^0$
$e^+ + e^- \rightarrow D^0 + \bar{D}^{*0}$ (2b)
$e^+ + e^- \rightarrow D_s^+ + D_s^-$
$e^+ + e^- \rightarrow D_s^+ + D_s^{*-}$

Charmed baryon production: $e^+ + e^- \rightarrow \Lambda_c + \bar{\Lambda}_c$ (2c)

Charmonium production:
$e^+ + e^- \rightarrow J/\Psi$ (2d)
$e^+ + e^- \rightarrow \Psi'$

In experiments at the tau-charm factory the particles are produced at resonances or at energies a little above production thresholds, as shown in Fig.2. This allows direct determination and study of backgrounds. For example, D^+D^- and $D^0\bar{D}^0$ production is carried out at the Ψ'' resonance. Not only is the D pair production cross section large at the Ψ'',

*Work supported by the Department of Energy, contract DEAC03-76SF00515.

Invited talk presented at the Nuclear Science Symposium, Santa Fe, New Mexico, November 5-9, 1991

but backgrounds from other processes can be directly determined by running the collider just below the Ψ''.

Similarly, the primary operating energies for τ pair production are:

3.57 GeV: just above the τ pair threshold
3.67 GeV: just below the Ψ' resonance

At these energies there is no production of charm or bottom hadrons, the only background is from ordinary hadrons, and that background is almost constant between these operating energies and the energy just below τ pair threshold. Suppose a surprising small but new phenomenon is observed in tau decays. Is it new physics or is it from hadronic background contamination? This can be settled by operating below the τ pair threshold. In present tau research it is difficult or impossible to answer such a question with certainty because the hadronic backgrounds can only be obtained from models of hadron production.

In some τ studies the background can be directly eliminated, then data can be taken at:

4.25 GeV: maximum τ pair cross section

The control of, and measurement of, backgrounds is one of the four basic elements of the tau-charm factory concept [4, 5, 6, 7]:

- Control of and direct measurement of backgrounds and contaminations.
- Very large statistics (Table 2).
- Production of particles in known quantum mechanical states. (3)
- Detector with very high quality particle identification, very good momentum and energy resolution, and close to 4π acceptance.

These are very large data sets by contemporary standards. For example the largest tau data sets which can be produced by existing colliders will contain about 10^6 τ pairs while data sets from several years of τ studies at the tau-charm factory may contain 10^8 τ pairs. The situation is the same with respect to charm particles, where data sets from several years of Ψ'' running at the tau-charm factory may contain 10^8 D mesons, several orders of magnitude greater than those anticipated from fixed target experiments in the same time frame.

Table 2. Particle production rates at the tau-charm factory year, based on fb^{-1} per year

Particle	Events per year
D^0 (single)	5.8×10^7 at Ψ''
D^+ (single)	4.2×10^7 at Ψ''
D_s (single)	1.8×10^7 at 4.14 GeV
$\tau^+\tau^-$ (pairs)	0.5×10^7 at 3.57 GeV
$\tau^+\tau^-$ (pairs)	2.4×10^7 at 3.67 GeV
$\tau^+\tau^-$ (pairs)	3.5×10^7 at 4.25 GeV
J/Ψ (events)	1.7×10^{10}
Ψ' (events)	0.4×10^{10}

In the next three sections we outline the particle physics potential of experiments at a tau-charm factory. This material is taken directly from Perl and Schindler [8].

A.2 D and D_s Physics at the Tau-Charm Factory

There are six powerful advantages in studying the physics of the charm mesons at the tau-charm factory using the production process in Eq 2a at the Ψ'' and the D_s threshold energies indicated in Fig. 2:

- The ability to produce very large data sets over short collection times.
- The ability to cleanly select D and D_s by single-tagging of the events. That is, only one D or D_s decay is identified in order to select the pair in an event.
- The availability of kinematic constraints using the beam energy for the rejection of backgrounds. (4)
- The production of the D meson pair in an initial state that is also a coherent quantum mechanical state, allowing further background control and also allowing certain unique physics studies to be performed.
- The absence of backgrounds from heavier meson decays, since production is at threshold.
- The ability to *directly measure*, as necessary, backgrounds from non-charm events by moving below the Ψ'' resonance or below the D_s threshold.

We can already foresee five classes of charm meson physics which will be done at the tau-charm factory [6, 7, 9, 10, 11, 12], by dividing the physics into:

(i) Pure leptonic decays of the D mesons.
(ii) Semileptonic decays of the D mesons.
(iii) Hadronic decays of the D mesons. (5)
(iv) D meson decays through penguin diagrams.
(v) Rare and forbidden decays of the D mesons.

We shall write a few paragraphs about the first two classes of experiments.

The pure leptonic decays:

$$\begin{aligned} D^+ &\to e^+ + \nu_e \\ D^+ &\to \mu^+ + \nu_\mu \\ D^+ &\to \tau^+ + \nu_\tau \\ D_s^+ &\to e^+ + \nu_e \\ D_s^+ &\to \mu^+ + \nu_\mu \\ D_s^+ &\to \tau^+ + \nu_\tau \end{aligned} \tag{6}$$

which will occur through the diagram in Fig. 3 **have never been observed.**

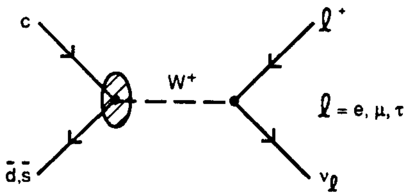

Figure 3

The decay width is given by:

$$G(D^+ \to L^+ + \nu_L) = \frac{G_F^2}{8\pi} f_D^2 M_D M_L^2 \, |V_{cd}|^2 \left(1 - \frac{M_L^2}{M_D^2}\right)^2 \tag{7}$$

Here V_{cd} is the Cabibbo-Kobayashi-Maskawa (CKM) matrix element, f_D is the weak decay constant, and M refers to the meson or lepton mass. The proportionality to M_L^2 makes the τ mode the easiest to observe and the e mode too small to observe. For the μ and τ modes we expect the branching ratios to be in the range:

$$B = 10^{-2} \text{ to } 10^{-4} \tag{8}$$

The basic information to be obtained within the standard model from the observation and measurement of the μ and τ pure leptonic decay modes of the D and D_s is a precise and consistent determination of f_D, f_{D_s}, V_{cd}, and V_{cs}. Using produced DD^* pairs it is also possible to measure the vector meson decay constants as well as the psuedoscalar ones.

In addition, these pure leptonic decays can be used to search for new physics beyond the standard model. For example, the conventional process in Fig. 3 takes place through the exchange of a W^+ boson, but it could also take place through the exchange of an unknown particle such as a charged Higgs (H^+).

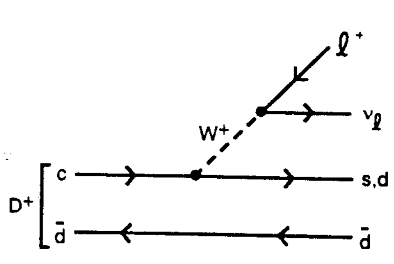

Figure 4

The general semileptonic decays, Fig. 4, are:

$$\begin{aligned} D^+ &\to L^+ + \nu_L + (\text{hadrons})^0 \\ D^0 &\to L^+ + \nu_L + (\text{hadrons})^- \end{aligned} \tag{9}$$

where L means e, μ, or τ. There are analogous decays for the D_s. Unlike the pure leptonic decays, these semileptonic decays have been observed and studied when their branching ratios are in the range:

$$B = 10^{-1} \text{ to } 10^{-2} \tag{10}$$

But the measurements at present, even for the dominant D^0 and D^+ semileptonic decays are confused, and those of the D_s are observed only indirectly. The present experimental techniques cannot reach below $B \approx 10^{-2}$ to study the rarer and more interesting decays.

The studies of the semileptonic decays which will be carried out at the tau-charm factory will give us precise information about V_{cd} and V_{cs} and will provide thorough measurements of the various form factors involved in these decays. Particularly beautiful will be the ability to compare the measurements of the CKM matrix elements made in two different ways, each to high precision, using these semileptonic decays and the previously discussed pure leptonic decays.

The tau-charm factory studies of these semileptonic decays will also enable the experimenter to look beyond conventional D meson physics to study second order weak interactions, such as $D^0\bar{D}^0$ mixing. $D^0\bar{D}^0$ mixing is one of the few second order weak processes that will ever be measured. Consider the conventional decays:

$$\begin{aligned} D^0 &\to K^- + e^+ + \nu_e \\ \bar{D}^0 &\to K^+ + e^- + \bar{\nu}_e \end{aligned} \tag{11}$$

If there is $D^0\bar{D}^0$ mixing, we would observe the comparatively rare final state:

$$(D^0\bar{D}^0) \to (K^- + e^+ + \nu_e) + (K^- + e^+ + \nu_e) \tag{12}$$

This final state is a unique signature for $D^0\bar{D}^0$ mixing, and cannot be mimicked by any other process. The so-called "mixing parameter" is defined:

$$r_D = \frac{\text{events with mixing}}{\text{events without mixing}} \tag{13}$$

It is expected from the standard model to be in the range:

$$r_D = 10^{-4} \text{ to } 10^{-5} \tag{14}$$

The present measured upper limit is $r_D < 4 \times 10^{-3}$. In several years of data, experimenters using the tau-charm factory will probe to $r_D = 10^{-5}$. No other experiment can reach within a factor of 10 of this sensitivity. Demonstrating the observation of $D^0\bar{D}^0$ mixing at this sensitivity will be the first step in the longer range goal of designing and executing experiments **to search for CP violation in D decay,** at a tau-charm factory.

In addition to six general classes of charm physics, Eq. 5, which will be done at the tau-charm factory there are other charm physics areas:

- A systematic and precise study of hadronic and semileptonic decays of charmed baryons below 2.5 GeV in mass.
- The absolute branching ratios of all charmed D and D_s mesons and baryons at the 1% level of precision.
- Measurement of *all* Cabbibo allowed and singly forbidden hadronic and semileptonic decays of the D mesons, and many of the doubly forbidden hadronic decays.
- Search for other radiative charmed meson and baryon decays.
- Search for other rare multilepton plus hadron final states not protected by gauge principles.

A.3 τ and ν_τ Physics at the Tau-Charm Factory

There are four powerful advantages in studying the physics of the tau lepton and tau neutrino at the tau-charm factory using:

$$e^+ + e^- \rightarrow \tau^+ + \tau^- \qquad (15)$$

at the major operating energies for τ pair production:

3.57 GeV: just above the τ pair threshold
3.67 GeV: just below the Ψ' resonance

These advantages are:

- The availability of large data sets collected over short times.
- The selection of a τ pair data sample by single-tagging of events. That is, only one τ decay need be identified in order to select the event.
- There are no backgrounds from D or B meson decays.
- The backgrounds from non-τ pair events are *directly* measured as necessary, by moving below the τ pair threshold.

(16)

There are a very large number of areas of τ and ν_τ physics which require the tau-charm factory [11, 12, 13, 14, 15]. Five general classes are:

(i) Precision measurements of branching ratios.

(ii) Complete study of τ-W-ν_τ vertex.

(iii) Untangling multiple π^0 and η decay modes. (17)

(iv) More sensitive probes of the ν_τ mass.

(v) Searches for unconventional and forbidden τ decays.

We shall discuss the first and last class.

There are five τ decay modes whose branching fractions we should try to measure with high precision because we can calculate the relative branching fractions with high precision. These modes and the current average measured values of their branching fractions are:

$$\tau^- \rightarrow \nu_\tau + e^- + \bar{\nu}_e \qquad (17.7 \pm 0.4\%)$$

$$\tau^- \rightarrow \nu_\tau + \mu^- + \bar{\nu}_\mu \qquad (17.8 \pm 0.4\%)$$

$$\tau^- \rightarrow \nu_\tau + \pi^- \qquad (11.0 \pm 0.5\%) \qquad (18)$$

$$\tau^- \rightarrow \nu_\tau + K^- \qquad (0.68 \pm 0.19\%)$$

$$\tau^- \rightarrow \nu_\tau + \rho^- \qquad (22.7 \pm 0.8\%)$$

We are prevented from making exact calculations of the branching fractions for most hadronic decay modes by our ignorance of how to use the theory of quantum chromodynamics in the energy region of τ decays. For the five modes listed above we can however calculate their decay widths, Γ_i, and hence can calculate the ratios of branching fractions:

$$B_i / B_e = \Gamma_i / \Gamma_e \qquad (19)$$

We use $B_e = B(\tau^- \rightarrow \nu_\tau + e^- + \bar{\nu}_e)$ as the reference branching fraction.

Looking at the errors in the measured B's quoted above, and recognizing that these errors may be underestimated due to correlated systematic errors [16], we see that even the best measurements give the error in B_i / B_e:

$$\delta (B_i / B_e) \approx 0.05 \qquad (20)$$

It is important to significantly reduce such errors to allow:

- Precise tests of the standard model.
- Searches for new physics in tau decays. For example new physics might show up by the tau decay occurring through a particle other than the $W^\pm$.

By measuring the above branching fractions close to the τ pair threshold at the tau-charm factory, these errors can be reduced by a factor of 10 or more [17]! Experimenters can achieve:

$$\delta (B_i / B_e) = 0.002 \text{ to } 0.005 \quad (21)$$

Two features of the production and decay of τ's at a tau-charm factory make this precision possible. First, due to the coulombic attraction between the pair of τ's, the cross section at threshold is not zero but instead about 0.2 nb; a few MeV above threshold the cross section rises to about 0.4 nb. Thus, just above threshold, the τ's can be produced *copiously and almost at rest* Because they are nearly at rest, the second special feature comes into play, namely, that the two-body channels of interest (eg: $\tau^- \rightarrow \nu_\tau + \pi^-$) will produce in their decay nearly monochromatic pions, thereby providing an unambiguous τ pair tag. Precise measurements of these branching fraction ratios can uncover new physics such as a higgs-like particle or leptoquarks [17, 18, 19, 20].

Now we consider the last class in Eq. 17: searches for unconventional and forbidden τ decays. There have been several searches for tau decays which violate lepton number conservation, modes such as:

$$\begin{aligned} \tau^- &\rightarrow e^- + \gamma \\ \tau^- &\rightarrow \mu^- + \gamma \\ \tau^- &\rightarrow e^- + \pi^0 \\ \tau^- &\rightarrow e^- + e^+ + e^- \end{aligned} \quad (22)$$

No modes violating lepton number conservation have been found and present upper limits on the branching fractions are typically:

$$B < 1\text{-}5 \times 10^{-5} \quad (23)$$

The large statistics available in tau-charm factory experiments will allow probing for such forbidden decays to levels of:

$$B \approx 10^{-7} \text{ to } 10^{-8} \quad (24)$$

However there is another type of unconventional decay which is much more difficult to search out. These are decays of the class:

$$\begin{aligned} \tau^- &\rightarrow e^- + X^0 \\ \tau^- &\rightarrow \mu^- + X^0 \end{aligned} \quad (25)$$

where the X^0 is an unconventional weakly interacting particle of integer spin such as a Goldstone boson. Sensitive searches for such decays can only be made at a tau-charm factory because of the need to completely understand contaminations which might mimic such decays. For example the conventional decay $\tau^- \rightarrow \pi^- + \nu_\tau$ would be a contamination if the π were incorrectly identified as an e or a μ.

Unconventional decays such as:

$$\begin{aligned} \tau^- &\rightarrow \nu_\tau + e^- + \bar{\nu}_e + X^0 \\ \tau^- &\rightarrow \nu_\tau + \pi^- + X^0 \end{aligned} \quad (26)$$

are even more difficult to explore and again require a tau-charm factory.

There are many other areas of tau and tau neutrino physics which are best studied at a tau-charm factory:

- Study of radiative tau decays.
- Precise, comparative study of Cabibbo-suppressed tau decay modes.
- Detailed study of 5-charged particle and 7-charged particle tau decay modes.
- Study of electromagnetic moments of the tau.
- Tests of tau neutrino stability.

And finally there is the concept of making the $\tau^+ - \tau^-$ atom, called tauonium, in analogy to the $e^+ - e^-$ atom positronium [21, 22, 23].

A.4 Charmonium Physics at the Tau-Charm Factory

The tau-charm factory will operate over the center of mass energy range from 3 to 5 GeV. It will be the *first* e^+e^- storage ring in this energy regime to have adequate luminosity to perform detailed probes of all of the $c\bar{c}$ bound and unbound states and the transitions amongst them. These unique measurements of the $c\bar{c}$ interquark potential provide a necessary compliment to similar studies of the $b\bar{b}$ potential at a b-factory and the $t\bar{t}$ potential near threshold at a future linear collider. In combination, these measurements will precisely test the form and the flavor independence of the strong interaction, as predicted by the theory of quantum chromodynamics.

In addition to the detailed exploration of the 3-5 GeV region, several of the known charmonium resonances have special importance either because of their proximity to charmed meson production thresholds (eg: Ψ''), or because their very large cross sections (eg: J/Ψ) can provide copious numbers of light quark mesons, baryons, glueballs and admixtures. For example, the production rate of J/Ψ events is very large at the tau-charm factory:

$$\frac{J/\Psi \text{ events}}{\text{month}} \approx 10^9 \quad (27)$$

In the first half decade of operation, the tau-charm factory will probably operate at the J/Ψ and Ψ' resonances for a total of about four weeks per year. These weeks will probably be spread out over the year since events from these resonances are very useful for detector calibration. Even so, this will represent a sample 100 times the size of samples that might exist from other storage rings.

There is a large array of measurements to be done with such large data sets in a detector matched well to the physics. For the sake of brevity we only outline here the general physics topics employing J/Ψ decays:

- J/Ψ Radiative and Hadronic Decays
  Use to study hadronic resonances and to search for pure gluon bound states. Source for light quark spectroscopy, and baryon spectroscopy. Exotic bound states of quarks and gluons.

- η_c
  Study properties and decay modes of η_c.

- Rare Decays of the J/Ψ
  There is a large new area of particle physics in the rare decay modes of the J/Ψ. For example the weak decay:

$$J/\Psi \rightarrow D_s + \text{hadrons} \tag{28}$$

has not been observed. And looking further into the future at the tau-charm factory, a very interesting search can be made for *direct CP violation* in Λ decays using:

$$\begin{array}{ccccc} J/\Psi & \rightarrow & \Lambda & + & \bar{\Lambda} \\ & & \downarrow & & \downarrow \\ & & p\pi^- & & \bar{p}\pi^+ \end{array} \tag{29}$$

This experiment may require about a year of tau-charm factory operation at the J/Ψ, where the tau-charm rings are run with monochrometer optics to further reduce the beam energy spread, and enhance the cross section. Operation of an e^+e^- storage ring in this mode will also provide a unique accelerator physics experiment.

B. THE TAU-CHARM FACTORY: CONSTRUCTION AND STATUS

B.1 Design Requirements and Construction

Jowett (Jowett 1987) first worked out the basic design for a tau-charm factory which would have the four required properties:

$$\begin{aligned} &\bullet\ 3.0 \le E_{tot} \le 5.0\ \text{GeV}. \\ &\bullet\ L_{design} = 10^{33}\ \text{cm}^{-2}\ \text{s}^{-1}. \\ &\bullet\ \text{Highly flexible and reliable operation.} \\ &\bullet\ \Delta E_{tot} \approx \text{few MeV}. \end{aligned} \tag{30}$$

These requirements are met using the following design principles:

(i) Multiple bunches: about 20 to 30 in each ring to increase the bunch crossing frequency.

(ii) 1-2 $\times 10^{11}$ particles per bunch.

(iii) Only one interaction region at startup.

(iv) Separate e^+ and e^- rings to eliminate all other parasitic bunch crossings.

(v) Strong focussing of the bunches at the interaction point.

(vi) Rings having relatively large radius to minimize the synchrotron radiation power loss and to allow the use of a conventional beam pipe.

(vii) Low frequency superconducting RF with a substantial RF overvoltage and low beam pipe impedence to maintain short bunch lengths.

(viii) A feedback system to control multibunch instabilities.

(ix) A high intensity e^+ and e^- injector to maintain luminosity by "top-off" of the circulating bunches.

After the original work of Jowett, further design work was carried out at the 1989 Tau-Charm Factory Workshop [11]. This group confirmed that Jowett's $L_{design} = 10^{33}$ cm^{-2} s^{-1} was feasible with present technology [24] and also published a conceptual design [25].

A separate conceptual design, also with a luminosity of 10^{33} cm^{-2} s^{-1}, was carried out in France by Gonichen, Le Duff, Mouton, and Travier [26]. This report discusses the accelerator physics in more detail, for example comparing flat beam and round beam optics.

Danilov et al [27] have also discussed tau-charm factory design.

The most recent design [28] was carried out by physicists from CERN, LAL in France, and CIEMAT in Spain. Figure 1 shows the schematic design. The circumference of this 10^{33} cm^{-2} s^{-1} luminosity collider is 360 m. The high intensity e^+ and e^- injector consists of a linear accelerator followed by a booster synchrotron. Since the lifetime of stored beams in the rings is only 2 hours, the injector must be able to "top-off" the tau-charm rings in a few minutes each hour. As shown in the figure, the injector would also be used to fill a *separate* synchrotron radiation ring during the balance of the time. This design is the basis for the present planning for a tau-charm factory in Spain.

The full design of the tau-charm factory is just beginning, but we can note some of the general properties of the design. At the interaction point :

$$\beta^*_y \approx 1\ \text{cm} \tag{31a}$$
$$\sigma^*_y \approx 8\ \mu\text{m to } 14\ \mu\text{m} \tag{31b}$$

and in correspondence:

$$\beta^*_x \approx 20 \text{ cm} \quad (32a)$$
$$\sigma^*_x \approx 440 \ \mu m \text{ to } 280 \ \mu m \quad (32b)$$

An important bunch shape parameter is the rms length σ_z which has the approximate value:

$$\sigma_z \approx 6 \text{ mm} \quad (33)$$

The bunch length must be kept short to make use of the tight focussing of the bunches. This small σ_z imposes two more requirements on the design. First, the RF cavities, which will be superconducting, must produce a large overvoltage. The present plan is to use 400MHz and the same design planned for the LHC superconducting RF cavities. Second, the impedence of the beam pipe must be kept small.

The total current per beam is about 0.5 A at the 10^{33} cm^{-2} s^{-1} design luminosity. This is a large current for an e^+e^- collider and care is required in the design of beam pipe, interaction region, and RF cavities. The maximum synchrotron radiation power dissipated in the beam pipe is about 2 kW/m, hence a conventional beam pipe design can be used.

Finally a great deal of thought has been given to instability problems which could limit the luminosity. The general specifications on the RF cavities, feedback systems, and beam pipe have been worked out.

Thus the engineering and construction of the tau-charm factory requires substantial care but all the components are based on standard accelerator technology and the collider can be expected from the beginning to work well and provide for rich physics opportunities. There is an additional cushion in the very large advance in luminosity which is made by this collider. Upon commissioning we will certainly achieve a luminosity of 10^{32} cm^{-2} s^{-1} , and within a year we expect 3×10^{33} cm^{-2} s^{-1}. Thus within a year of turn on the tau-charm factory will provide 10 to 30 times the luminosity of other old or new e^+e^- colliders in this energy region.

The total cost of building the tau-charm factory at a new site has been calculated by Baconnier et al [28] at 1990 prices to be 300 MSF (Million Swiss Francs). About half of this cost is for the collider and injector themselves, the technical components and the civil construction. The other half of the cost consists of two parts. There is the cost of preparing the new site, office buildings, utilities and so forth. And the 300MSF includes what we in the United States call pre-operations R&D. This cost does not include the proposed addition of a 1 to 2 GeV *separate* positron ring for synchrotron for synchrotron radiation. This ring, which would be build once the collider was completed, would be fed by the same injector, a very efficient arrangement.

As emphasized in [4, 8] an essential part of the power of the tau-charm factory concept is the use of a high resolution, large acceptance detector specially designed for tau and charm physics. The general design of such a detector has been studied beginning at the 1989 Tau-Charm Factory Workshop at SLAC [11], with studies continuing as recently reported at the 1991 Tau-Charm Factory Workshop at Seville [12]. The calculated cost of the detector is about 74M$ (Million U. S. Dollars) at 1991 prices.

The schedule for constructing and commissioning both the collider and the detector is six years.

B.2 Tau-Charm Factory Project: People and Plans

We conclude this paper with an informal history of how the proposal for the Tau-Charm Factory in Spain developed, and an informal review of present status and progress.

In the last three years a strong interest in doing physics at a tau-charm factory developed among physicists in the United States, Spain, CERN, France, and Germany. It was and is clear that world wide funding for new projects in high energy physics is strictly limited, and that most funding for new projects is needed for the large projects such at the SSC and the LHC. Therefore these tau-charm physicists decided to work together to encourage and support the building of a tau-charm factory somewhere in the world.

At the same time in the past 20 years there has been a rapidly growing effort in scientific research in Spain and a concurrent growing effort in elementary particle research in Spain. This growth in scientific research has gone along with Spain's rise to be the fifth largest industrial and technological nation in Western Europe. In Western Europe the largest gross national products in order are Germany, France, Italy, Great Britain and Spain, with Spain just a little below Great Britain. Thus Spain is the fifth largest contributor of funding to CERN, providing about 8 per cent of CERN's budget.

But Spain does not have its own particle accelerator laboratory, Spanish particle physics experimenters work at CERN, DESY and other laboratories outside of Spain. The Spanish community of particle physicists has also grown rapidly, now numbering 150 theorists and 120 experimentalists. Experimental groups are based at the national laboratory CIEMAT in Madrid and in the Universities Autónoma of Barcelona, Autónoma of Madrid, Santander, Santiago de Compostela and Valencia. Groups at the Universities of Zaragoza and of Complutense of Madrid work in non-accelerator particle physics.

Therefore it was a natural and exciting idea of the Spanish high energy physics community and Spanish leaders in science and technology that the tau-charm factory be built in Spain. Under the leadership of J. A. Rubio the idea has developed and is turning into reality.

There are four crucial elements involved in the process of the tau-charm factory in Spain becoming reality:

(i) Scientific, technical, organizational, and funding support by the Spanish Federal and Regional Authorities.

(ii) Scientific and technical support, particularly in accelerator design and construction, by the CERN laboratory.

(iii) Scientific, technical, and some funding support from non-Spanish European countries such as France, Germany and other countries.

(iv) Scientific, technical, and some funding support from the United States.

First, some details on Item (i). The Spanish Federal and Regional Governments are indeed supporting the construction and operation of a Tau-Charm Factory Laboratory in Spain. It seems that Spain would provide the majority of the funds to build the Laboratory, about two thirds of the required 300 MSF. A regional government has made an initial appropriation to be used in 1991 and early 1992 for site selection, initial building and collider design, document preparation, and detector R&D by Spanish universities.

Thus Spain would be the host country but the Laboratory would be international in the sense that: (a) it will be used by international groups of physicists, (b) it will have formal connections with non-Spanish institutions, and (c) that part of the collider and detector will be built with non-Spanish funds. An interesting aspect of the international planning is that the Tau-Charm Factory would have two data processing and data analysis centers one in Spain and the other in the United States.

Turning next to Item (ii). At present there are only a few accelerator physicists and engineers in Spain. Therefore the design and construction of the collider, and the training of Spanish accelerator physicists and engineers, requires some help from the tremendously skillful and experienced CERN staffs in these areas. One of the advantages to Europe and to CERN of providing such help is that the tau-charm factory in Spain will be a new, low energy, particle physics facility, the kind of "low energy initiative" which has been discussed for Europe. This leaves the major laboratories in Europe free to concentrate on the new, large, high energy facilities: LEP and the LHC at CERN, HERA at DESY and perhaps an e^+e^- linear collider effort led by DESY. There is also a strong interest in tau-charm factory particle physics at CERN [4, 5].

Next we consider Item (iii): the crucial role of non-Spanish European countries. There are now about 80 staff and faculty experimental physicists in the informal international tau-charm factory collaboration. About half are from Spain, CERN, France, Germany, and Portugal, with additional groups interested from Italy and Great Britain. The other half are from nine institutions in the United States. The collaboration plans for an eventual total of about 120 staff and faculty physicists, about one third each from the Spain, about one third from non-Spanish European countries, and about one third from the United States. The interest in non-Spanish European countries goes along with the ability of those countries to provide scientific, technical, and some funding support to the tau-charm factory effort. For example, there is the possibility the French groups could support the design and construction of the injector complex consisting of the linear accelerator and the booster synchrotron.

Finally we turn to Item (iv): scientific, technical, and some funding support from the United States. From the beginning of discussions to build a tau-charm factory, United States physicists and institutions have had a leading role in the discussions and plans. Much of that leading role comes from the broad experience of U. S. physicists in tau and charm physics research, and particularly from the Mark III Experiment at SPEAR. Thus U. S. physicists now constitute about one half of the International Tau-Charm Collaboration, and when the Collaboration reaches full size will constitute about one third of the Collaboration. The nine U. S. institutions now participating are:

University of California-Santa Cruz
University of Cincinnati
University of Illinois
Massachusetts Institute of Technology
University of Oregon
Rutgers University
Stanford Linear Accelerator Center
University of Texas-Dallas
University of Washington

In discussions with Spanish authorities, with the U. S. Department of Energy, with the U.S. National Science Foundation, and with the international tau-charm collaboration, the U. S. physicists have proposed that U. S. funds be used to build about one third of the detector.

We conclude this paper with an overview of current tau-charm factory activities.The present work on the project falls into eight categories:

(1) Site selection.
(2) Site layout and building design.
(3) Collider design.
(4) Detector design with R&D on prototypes for detector components.
(5) Development of organization plans for the tau-charm factory laboratory and staffing.
(6) Development of an agreements between Spain and CERN.
(7) Development of agreements between Spain and institutions in other European countries.
(8) Development of agreements between Spain and United States institutions.

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