Monte Carlo Study of Tau-Charm Factory

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August 16, 1994

Monte Carlo study of Tau-Charm Factory has been seriously done by \( \tau \)cF team working at CERN and Spain. In order to prepare a specific proposal for a Tau-Charm Factory construction in Beijing, a Monte Carlo group in IHEP was set up in May 1994 to study the physics goals of Tau-Charm Factory.

In our Monte Carlo simulation, a simple MC frame was constructed. We did not consider the detailed structure of detector, events are generated by MC generators, then the track parameters are smeared according to the detector performances which are completely based on the talk presented at the Third Workshop on the Tau-Charm Factory by Professor Jasper Kirkby\(^1\).

\(^1\)Jasper Kirkby, presented at the Third Workshop on the Tau-Charm Factory, Marbella, Spain, 1–6 June, 1993.
Following aspects are covered in this talk:

1. $m_\tau$ measurement at $\tau cF$.

2. $m_{\nu_\tau}$ measurement at $\tau cF$.

3. Measurement of Michel Parameter at $\tau cF$.

4. $D$ purely leptonic decay at $\tau cF$.

5. $D\bar{D}$ mixing at $\tau cF$.

6. $D_s$ purely leptonic decay at $\tau cF$. 
1. $\tau$ Mass Measurement at $\tau$-Charm Factory

BES

- Scanning near the threshold of $\tau^+\tau^-$ pair production, data-driven maximum likelihood searching strategy.

- 12 energy points.

- $\int L dt \sim 5000nb^{-1}$.

Based on the $e\mu$ channel:

$$m_\tau = 1776.9 \pm 0.4 \pm 0.2 \text{ MeV}$$

Synthesizing all 6 decay modes ($e\mu, e\pi, ee, \mu\pi, \mu\mu, \pi\pi$) to decrease the statistical error, $m_\tau$ has been got:

$$m_\tau = 1776.87 \pm 0.23 \pm 0.20 \text{ MeV}$$
τ-Charm Factory

- Same method as BES.
- 20 energy points.

- $\int Ldt \sim 20 \times 1000nb^{-1} \sim 20pb^{-1}$.

$L_{\tau c} \sim 100L_{DEPC}$, $\sim 2$ days.
- $\varepsilon_{e\mu} = 45\%$ (conservative).

- $\Delta = 0.5$ MeV, 1.0 MeV.

BES: 1.4 MeV.

τcF: 1.0 MeV (standard mode).
τcF: 0.1 MeV (monochromator mode).

- $m_{\tau}^{input} = 1777.00$ MeV.

- $\sigma_B \sim 1\% \sigma$. 
Flow Chart of one time Monte Carlo Simulation for tau Mass

Flow Chart of one time Monte Carlo Simulation for tau Mass

Flow Chart of one time Monte Carlo Simulation for tau Mass
**Tau Charm Factory Monte Carlo Simulation**

\( \Delta = 0.5 \text{ MeV} \)

### Error of tau Mass (+MeV)

- ID: 101
- Entries: 100
- Mean: \(0.7500 \times 10^{-2}\)
- RMS: \(0.7155 \times 10^{-1}\)

### Error of tau Mass (-MeV)

- ID: 102
- Entries: 100
- Mean: \(-0.1040\)
- RMS: \(0.1597 \times 10^{-1}\)

- ID: 103
- Entries: 100
- Mean: \(-0.1620\)
- RMS: \(0.2818 \times 10^{-1}\)
Tau Charm Factory Monte Carlo Simulation

Moutput - Minput (MeV)

<table>
<thead>
<tr>
<th>ID</th>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>100</td>
<td>0.7500E-02</td>
<td>0.7155E-01</td>
</tr>
</tbody>
</table>

Error of tau Mass (+MeV)

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Error of tau Mass (-MeV)

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<td>100</td>
<td>-0.1620</td>
<td>0.2818E-01</td>
</tr>
</tbody>
</table>
$\tau$ Mass

Based on $e\mu$ channel, $m_\tau$ is expected to be obtained as (only statistical error):

\[
m_\tau \pm 0.10_{0.16} \quad (\Delta = 0.5 \text{ MeV})
\]
\[
m_\tau \pm 0.17_{0.24} \quad (\Delta = 1.0 \text{ MeV})
\]

Synthesizing all 6 decay modes ($e\mu, e\pi, ee, \mu\pi, \mu\mu, \pi\pi$) to decrease the statistical error, $m_\tau$ is expected to be obtained as (only statistical error):

\[
m_\tau \pm 0.05_{0.08} \quad (\Delta = 0.5 \text{ MeV})
\]
\[
m_\tau \pm 0.09_{0.12} \quad (\Delta = 1.0 \text{ MeV})
\]

The statistical error on $\tau$ mass is expected to be 0.1 MeV/$c^2$ or less at $\tau cF$. It is important to precise test of lepton universality!
Systematic Error

- Unstability of beam energy.

- Uncertainty of beam energy spread.

- Uncertainty in detector acceptance.

- Errors in luminosity measurement.

- Background events for each decay channel.

- Bias deduced from the energy step during the scanning.

BES: ~ 0.20 MeV/c^2.

τcF: < 0.10 MeV/c^2 is expected!
2. $\tau$ Neutrino Mass Measurement at $\tau$CF

1. Operating Energy Points

<table>
<thead>
<tr>
<th>$\sqrt{S}$ (GeV)</th>
<th>$\sigma_{\tau\tau}$ (nb)</th>
<th>$N_{\tau\tau}$/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.555 $^1$)</td>
<td>0.22</td>
<td>$3.4 \times 10^6$</td>
</tr>
<tr>
<td>4.25 $^2$)</td>
<td>3.56</td>
<td>$5.5 \times 10^7$</td>
</tr>
<tr>
<td>10 $^3$)</td>
<td>0.86</td>
<td>$4.0 \times 10^7$</td>
</tr>
</tbody>
</table>

- $\tau$-C: $L \sim 10^{33} cm^{-2}s^{-1}$
- B: $L \sim 3 \times 10^{33} cm^{-2}s^{-1}$

1) $\tau$ is produced almost at rest.
2) With maximum $\sigma_{\tau\tau}$.
3) With back-to-back topology.
2. Channel Selection

<table>
<thead>
<tr>
<th>Mode</th>
<th>$\tau \rightarrow KK\pi\nu$</th>
<th>$\tau \rightarrow 5\pi\nu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Br $m_T - m_h$</td>
<td>$(2.2 \pm 1.1) \times 10^{-3}$</td>
<td>$(5.6 \pm 1.6) \times 10^{-4}$</td>
</tr>
<tr>
<td>$\bar{p}(\sqrt{S} = 10\text{GeV})$</td>
<td>$\sim 0.65$ GeV</td>
<td>$\sim 1.08$ GeV</td>
</tr>
<tr>
<td>$\bar{p}(\sqrt{S} = 4\text{GeV})$</td>
<td>$\sim 1.25$ GeV</td>
<td>$\sim 0.83$ GeV</td>
</tr>
<tr>
<td>$\sigma_m(\sqrt{S} = 10\text{GeV})$</td>
<td>$6.0$ MeV</td>
<td>$-$</td>
</tr>
<tr>
<td>$\sigma_m(\sqrt{S} = 4\text{GeV})$</td>
<td>$3.5$ MeV</td>
<td>$-$</td>
</tr>
</tbody>
</table>

- $\tau$CF: TOF + dE/dX.

Only $\tau \rightarrow KK\pi\nu$ process has been analysed so far due to the time limitation. The analyses of $\tau \rightarrow 5\pi\nu$ is in progress.

2) For same upper limit of $m_{\nu}$, $\sigma_{m\nu} \propto \sigma_m/\sqrt{N}$,

$$\sigma_m(BF) \sim 1.6 \times \sigma_m(\tau$CF$$

$$N_{KK\pi}(BF) \sim 2N_{KK\pi}(\tau$CF)$$
\[ \sqrt{s} = 3.55 \text{ GeV} \]
\[ \sigma_m = 3.4 \text{ MeV} \]

\[ \sqrt{s} = 4.25 \text{ GeV} \]
\[ \sigma_m = 3.6 \text{ MeV} \]

\[ \sqrt{s} = 10 \text{ GeV} \]
\[ \sigma_m = 6.0 \text{ MeV} \]
### Particle Decay to All Known Channels

<table>
<thead>
<tr>
<th>Mode</th>
<th>DATA</th>
<th>$\tau^+\tau^-$</th>
<th>$q\bar{q}$</th>
<th>$DD^*$</th>
<th>$D^<em>D^</em>$</th>
<th>$D_s^+D_s^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Prong, $N_\gamma=0$</td>
<td>3.4%</td>
<td>5.9%</td>
<td>4.5%</td>
<td>1.4%</td>
<td>0.5%</td>
<td>0.9%</td>
</tr>
<tr>
<td>$P_{miss} &gt; 200MeV$</td>
<td>2.7%</td>
<td>5.8%</td>
<td>3.1%</td>
<td>1.4%</td>
<td>0.5%</td>
<td>0.9%</td>
</tr>
<tr>
<td>$e/\mu$ tag</td>
<td>0.3%</td>
<td>1.7%</td>
<td>0.2%</td>
<td>0.4%</td>
<td>0.2%</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

- $\tau^+\tau^-$: KORALB
- $q\bar{q}$: LUND 6.2
3. The Upper Limit of $m_{\nu_{\tau}}$

1) $\tau \rightarrow \rho''(1750)\nu_{\tau} \rightarrow KK\pi\nu_{\tau}$

Tag: $\tau \rightarrow e\nu_{e}\nu_{\tau}, \mu\nu_{\mu}\nu_{\tau}$.

2) Global selection efficiency.

$\tau$-C: $\varepsilon_{lKK\pi}(\sqrt{S} \sim 4 GeV) \sim 15\%$
B: $\varepsilon_{lKK\pi}(\sqrt{S} \sim 10 GeV) \sim 25\%$
BES: $\varepsilon_{lKK\pi} \sim 10\%$
ARGUS: $\varepsilon_{l3\pi} \sim 25\%$

3) The fraction of event with $m_{KK\pi} > 1.75 GeV$,

$f_{\text{end}} \sim 1.5\%$

4) Tagged Events

$N_{\text{tagged}} \sim 2N_{\tau\tau} \times (B_{c} + B_{\mu}) \times Br(KK\pi) \times f_{\text{end}} \times \varepsilon_{lKK\pi}$

$\sim 8$ events/year $\sqrt{S} = 3.555$ GeV
$\sim 130$ events/year $\sqrt{S} = 4.25$ GeV
$\sim 150$ events/year $\sqrt{S} = 10$ GeV
\( \tau \rightarrow K K \pi \nu \bar{\nu} \)

- \( m_{\nu\tau} = 0 \)
- \( m_{\nu\tau} = 15 \text{ MeV} \)

\( (\sqrt{s} = 3.5 \text{ GeV}) \)
5) Estimation of $m_{\nu_{\tau}}$ limit.

\[
L_i(m_{\nu_{\tau}}) = \int_{2m_{K^+}\pi^-}^{m_{\nu_{\tau}}} \frac{d\Gamma(m, m_{\nu_{\tau}})/dm}{\Gamma_{tot}} R(m, m') dm
\]

\[
L(m_{\nu_{\tau}}) = \prod_{i=1}^{N} L_i(m_{\nu_{\tau}})
\]

\[
C.L. = \int_{0}^{m_{\nu_{\tau}}} L(m_{\nu_{\tau}}) dm_{\nu_{\tau}}
\]

The statistical upper limit (95% C.L.) on the $\nu_{\tau}$ mass is $\sim 5$ MeV/$c^2$ from $\tau^\pm \rightarrow K^- K^+ \pi^\pm \nu_{\tau}$ events, it is almost the same as that given by Jasper Kirkby (4.7 MeV/$c^2$). He also showed that the statistical upper limit (95% C.L.) on the $\nu_{\tau}$ mass is 3.5 MeV/$c^2$ from $\tau^\pm \rightarrow 5\pi^\pm \nu_{\tau}$ events. Combining both decays gives an upper limit (95% C.L.) of 2.9 MeV/$c^2$.

In order to realize this accuracy, very careful control of backgrounds and systematic errors will be required.
3. Michel Parameter Measurement at $\tau$eF

For tau leptonic decay,

$$\tau \rightarrow e^- + \bar{\nu}_e + \nu_{\tau}$$

In tau rest frame,

$$\frac{dN}{dx} \sim x^2 [12(1-x) - \frac{8}{3} \rho (3-4x) + r(x)]$$

$$x = \frac{E_e}{E_{max}}.$$  \hspace{1cm} \rho = \frac{3}{4} \frac{(g_V - g_A)^2}{(g_V - g_A)^2 + (g_V - g_A)^2}.$$  \hspace{1cm} r(x) : radiative corrections.

- Possible $\rho$ value

  - V-A type: $\rho = \frac{3}{4}$
  - Pure V type: $\rho = \frac{3}{8}$
  - Pure A type: $\rho = \frac{3}{8}$
  - V+A type: $\rho = 0$

- In standard model $\rho = \frac{3}{4}$.

- Present experimental result: $\rho_{\tau} = 0.727 \pm 0.033$ ($\sqrt{s} \sim 10$ GeV).
If Tau-Charm Factroy operates at tau rest frame, tag channels,

\[ \tau \rightarrow \pi \nu_\tau, \, K\nu_\tau \]

Monochromatic Pion and Kaon momentum can ensure clean data sample!

In our Monte Carlo simulation,

- \( \sqrt{s} = 3.555 \) GeV, \( \rho \) is sensitive in whole x region.

- \( \sqrt{s} = 4.25 \) GeV, \( \rho \) is not sensitive in whole x region.

- \( \sqrt{s} = 10 \) GeV, \( \rho \) is fairly not sensitive in whole x region.

We expect \( \rho \) accuracy to be 0.5 % at \( \tau \text{cF} \).
4. Pure Leptonic Decay of D at τcF

1) Importance

- Foundamental decay constant (upper limit $f_D < 290$MeV).
- $f_B$ can be extrapolated reliably by $f_D$.
- Test to theoretical models (Lattice QCD, Potential, Bag, ...).

2) Advantages over B-Factory

- Large data sample (for one year running).

<table>
<thead>
<tr>
<th>Particle</th>
<th>MKIII (9.3pb$^{-1}$)</th>
<th>B-F (2fb$^{-1}$)</th>
<th>τcF (10fb$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D^0$ (single)</td>
<td>$5.4 \times 10^4(\psi^\prime\prime)$</td>
<td>$1.5 \times 10^7$ (10GeV)</td>
<td>$5.8 \times 10^7(\psi^\prime\prime)$</td>
</tr>
<tr>
<td>$D^+$ (single)</td>
<td>$3.9 \times 10^4(\psi^\prime\prime)$</td>
<td>$0.7 \times 10^7$ (10GeV)</td>
<td>$4.2 \times 10^7(\psi^\prime\prime)$</td>
</tr>
</tbody>
</table>

- Pure $D\bar{D}$ final states near threshold.
- Backgrounds can be directly measured above or below threshold.
- Tagging technique can be used to tag D signal.
- Particle seperation is easier than that at high energy region ($\sqrt{S} \sim 10$ GeV).
3) Expected Pure Leptonic Events

\[ B_r(D^+ \rightarrow \mu^+\nu) = \frac{G_F^2}{8\pi} f_D^2 \tau_D m_D m_\mu^2 |V_{cd}|^2 (1 - \frac{m_\mu^2}{m_D^2})^2 \]

\[ f_D = 175 \text{ MeV} \quad \Rightarrow \quad B_r = 2.7 \times 10^{-4} \]
\[ f_D = 250 \text{ MeV} \quad \Rightarrow \quad B_r = 5.5 \times 10^{-4} \]

\[ N_{\text{tag}} = 2N_{D\bar{D}}B_r(D \rightarrow K\pi\pi)B_r(D \rightarrow \mu\nu)\epsilon_{K\pi\pi}\epsilon_{\mu\nu} \]

- In our Monte Carlo, \( N_{D\bar{D}} = 2.1 \times 10^7 \).
- Only \( D \rightarrow K\pi\pi \) is used as the tagged channel.

\[ B_r(D \rightarrow K\pi\pi) = 8\% \quad \epsilon(D \rightarrow K\pi\pi) \sim 60\% \]
\[ B_r(D \rightarrow \mu\nu) = 2.7 \times 10^{-4} \quad \epsilon(D \rightarrow \mu\nu) \sim 80\% \]

- From MKIII's experience, a factor of 1.5 should be introduced to \( N_{\text{tag}} \). In \( \tau \)cF, more channels available for tagging, at least a factor of 2 should be applied to \( N_{\text{tag}} \).

- Conservative estimation on \( N_{\text{tag}} \).

\[ N_{\text{tag}}(D \rightarrow \mu\nu) \approx 1100 \]
Psi(3770) --- DDbar Pure Leptonic Decay (Single Tagged)

- MU Momentum
- D Inv Mass
- D BC Mass
- NU Missing Mass**2

Entries 1110
4) Backgrounds

\[ D^+ \rightarrow \bar{K}^0\pi^+, \bar{K}^0\mu^+\nu, \pi^0\pi^+, \ldots \]

\( \nu \) square missing masses from the backgrounds lie in high mass band, well separated from signal.

5) Statistical Error

From 1100 detected events, 3\% statistical error for \( \text{Br}(D \rightarrow \mu\nu) \) is expected, since \( \text{Br} \propto f_D^2 \), 1 \( \sim 2\% \) statistical error for \( f_D \) is expected.

6) Systematic Error

Systematic errors arise from:

- uncertainties in detector efficiency.
- contribution from background events.
- uncertainties in particle identification, fake photons, mis-tracked particles etc..

It is expected that the systematic error for \( f_D \) will be the same level as its statistical error.
Psi(3770) --- DDbar Pure Leptonic Decay ( + Background)

Entries 1110

D → μν

D → K^0π + K^0π + π^0π^0
5. \( D^0 \bar{D}^0 \) Mixing at \( \tau cF \)

1) Current Status

- Standard Model predicts,

\[
r_D \equiv \frac{Br(D^0 \rightarrow D^0 \rightarrow f)}{Br(D^0 \rightarrow f)} \leq 10^{-5} - 10^{-4}
\]

- Present upper limit: \( r_D < 10^{-3} \) at 90\% C.L.

2) Signature of Mixing

\[
\psi'' \rightarrow D^0 \bar{D}^0 (\rightarrow D^0) \rightarrow (K^-\pi^+)(K^-\pi^+) \\
\psi'' \rightarrow D^0 \bar{D}^0 (\rightarrow D^0) \rightarrow (K^-e^+\nu)(K^-e^+\nu).
\]

Double Cabbibo Suppressed Decay (DCSD), same final state as \( D^0 \bar{D}^0 \) mixing,

I.I. Bigi\(^*\) proved: DCSD is impossible in the above processes due to the quantum statistics violation!

3) Backgrounds Simulation

\[ \psi'' \rightarrow D^0 \bar{D}^0 \rightarrow (K^-\pi^+)(K^+\pi^-). \text{ dominant} \]

\[ \psi'' \rightarrow D^0 \bar{D}^0 \rightarrow (K^-\pi^+)(K^+K^-). \]

\[ \psi'' \rightarrow D^0 \bar{D}^0 \rightarrow (K^-\pi^+)(\pi^+\pi^-). \]

Strong ability of particle identification at \( \tau \text{CF} \) is essential for background rejection.

In our Monte Carlo, a small sample of background \((K^-\pi^+)(K^+\pi^-)\) events (5000) was produced, no contamination \((K^-\pi^+)(K^-\pi^+)\) found. ENCOURAGING! More background events need to be produced to carefully study the misidentification of particles (MKIII had 3 like-sign kaon events, unable to see if they came from backgrounds at \( \sigma_{TOF} = 200 \text{ ps} \)).

AIM: To keep the background to the level of one event or less!

4) Optimistic estimation on mixing events

Suppose: \( r_D = 10^{-4}, \epsilon_1 = \epsilon_2 = 80\% \),

\[ N_m = 2N_{D^0\bar{D}^0}Br(D^0 \rightarrow K^-\pi^+)Br(\bar{D}^0 \rightarrow K^-\pi^+)\epsilon_1\epsilon_2 = 2 \times 2.9 \times 10^7 \times (3.65 \times 10^{-2})^2 \times 10^{-4} \times (0.80)^2 \approx 5 \]

A few mixing events expected under \( r_D = 10^{-4} \).
6. Pure Leptonic Decay of $D_s$ at $\tau$CF

The width of pure leptonic decays of $D_s$ is,

$$\Gamma(D_s \rightarrow l\nu) = \frac{G_F^2 f_{D_s}^2 m_{D_s} m_l^2 |V_{cs}|^2}{8\pi} (1 - \frac{m_l}{m_{D_s}})^2$$

which can be determined from the branching ratio and lifetime,

$$Br(D_s \rightarrow l\nu) = \frac{\Gamma(D_s \rightarrow l\nu)}{\Gamma_{total}} = \tau_{D_s} \cdot \Gamma(D_s \rightarrow l\nu)$$

so the weak decay constant $f_{D_s}$ can be experimentally determined.

1) $\tau$-Charm Factory

- $\sqrt{S} = 4.03$ GeV, $\sigma \sim 400$pb.
- $\int Ldt \sim 10 fb^{-1}$ in one year.
- $N_{D_s^+D_s^-} \sim 400 pb \times 10 fb^{-1} \sim 4 \times 10^6$. 
\( e^+e^- \rightarrow D_s^+D_s^- , \ D_s^+ \rightarrow \eta'\rho^+ , \ D_s^- \rightarrow \nu\nu \\
\rho^+ \rightarrow \pi^+\pi^0 , \ \eta' \rightarrow \gamma\rho^0 \\
\rho^0 \rightarrow \pi^+\pi^- , \ \pi^0 \rightarrow \gamma\gamma \ 9.5\% \times 30.0\% \times 98.798\% = 2.82\% \\

\( e^+e^- \rightarrow D_s^+D_s^- , \ D_s^+ \rightarrow \eta'\rho^+ , \ D_s^- \rightarrow \nu\nu \\
\rho^+ \rightarrow \pi^+\pi^0 , \ \eta' \rightarrow \pi^+\pi^-\eta \\
\pi^0 \rightarrow \gamma\gamma , \ \eta \rightarrow \gamma\gamma \ 9.5\% \times 44.1\% \times 98.798\% \times 38.9\% = 1.61\% \\

\( e^+e^- \rightarrow D_s^+D_s^- , \ D_s^+ \rightarrow \eta\rho^+ , \ D_s^- \rightarrow \nu\nu \\
\rho^+ \rightarrow \pi^+\pi^0 , \ \eta \rightarrow \gamma\gamma \\
\pi^0 \rightarrow \gamma\gamma \ 7.9\% \times 38.9\% \times 98.798\% = 3.04\% \\

\( e^+e^- \rightarrow D_s^+D_s^- , \ D_s^+ \rightarrow \eta\rho^+ , \ D_s^- \rightarrow \nu\nu \\
\rho^+ \rightarrow \pi^+\pi^0 , \ \eta \rightarrow \pi^+\pi^-\pi^0 \\
\pi^0 \rightarrow \gamma\gamma , \ \pi^0 \rightarrow \gamma\gamma \ 7.9\% \times 23.6\% \times 98.798\% \times 98.798\% = 1.82\% \\

\( e^+e^- \rightarrow D_s^+D_s^- , \ D_s^+ \rightarrow K^0K^+ , \ D_s^- \rightarrow \nu\nu \\
K^+ \rightarrow K^\pm\pi^\mp \ 2.6\% \\

\( e^+e^- \rightarrow D_s^+D_s^- , \ D_s^+ \rightarrow K^*0K^+ , \ D_s^- \rightarrow \nu\nu \\
K^*0 \rightarrow K^\pm\pi^\mp , \ K^*+ \rightarrow K^+\pi^0 \\
\pi^0 \rightarrow \gamma\gamma \ 5.0\% \\

\( e^+e^- \rightarrow D_s^+D_s^- , \ D_s^+ \rightarrow \phi\pi^+ , \ D_s^- \rightarrow \nu\nu \\
\phi \rightarrow K^+K^- \ 2.8\% \times 49.1\% = 1.37\% \\

\( e^+e^- \rightarrow D_s^+D_s^- , \ D_s^+ \rightarrow \phi\rho^+ , \ D_s^- \rightarrow \nu\nu \\
\rho^+ \rightarrow \pi^0\pi^+ , \ \phi \rightarrow K^+K^- \\
\pi^0 \rightarrow \gamma\gamma \ 5.2\% \times 49.1\% \times 98.798\% = 2.52\% \\

\( e^+e^- \rightarrow D_s^+D_s^- , \ D_s^+ \rightarrow \eta'\pi^+ , \ D_s^- \rightarrow \nu\nu \\
\eta' \rightarrow \gamma\rho^0 \\
\rho^0 \rightarrow \pi^+\pi^- \ 3.7\% \times 30.0\% = 1.11\%
2) Advantages Over B-Factory

- Measuring backgrounds experimentally by lowering the beam energy below the threshold.
- Lower backgrounds.
- Operating near threshold, single-tagging technique can be used.
- Particle identification is easier than that at high energy region ($\sqrt{S} \sim 10$ GeV).

3) Monte Carlo Simulation

- $^{\text{C}_3\text{I(Tl)}}$ calorimeter enables us to tag some neutral decay channels with large branching ratios.
- at least $\sim 25\%$ branching fraction of total $D_s$ decay modes can be used to tag $D_s$ signal.
- single-tagging efficiency $\epsilon_s \sim 60\%$
- resolution of $D_s$ invariant mass $\sigma_{m}^{inv} \sim 10$ MeV.
- resolution of $D_s$ beam constrained mass $\sigma_{m}^{bc} \sim 1.2$ MeV.

A more detailed Monte Carlo study shows that the backgrounds from $D\bar{D}, DD^*, D^*D^*$ contribute less in the $D_s$ signal region, the signal can be clearly distinguished.
$e^+e^- \rightarrow D_s^+D_s^-$, $D_s^+\rightarrow \phi\pi^+$, $D_s^-\rightarrow \mu^-\nu_\mu$

$D_s^-\rightarrow \mu^-\nu_\mu$

$D_s^-\rightarrow K^0\bar{K}^-$

$D_s^-\rightarrow \tau\nu_\tau \rightarrow \pi\nu_\tau$
Square mass of missing
4) Estimation of $f_D$.

Assuming the branching ratio of $D_s \rightarrow \mu \nu$ is $5 \times 10^{-3}$. According to our Monte Carlo simulation, the detector acceptance for this process is $\sim 75\%$, 4000 - 5000 $D_s \rightarrow \mu \nu$ events will be expected in one year's running. The statistical error for $f_D$ can be reached $1 \sim 2\%$.

Systematic errors arise from:

- uncertainties in detector efficiency.
- contribution from background events.
- uncertainties in particle identification, fake photons, mis-tracked particles etc..

It is expected that the systematic error for $f_D$ will be the same level as its statistical error.
$e^+e^- \rightarrow D_s^+D_s^-, \ D_s^+ \rightarrow \phi \pi^+, \ D_s^- \rightarrow \mu \nu, \ \phi \rightarrow K^+K^-$
$s = 3.591$

**RH00M**

**ETAPM**

**ETAPM**

**Inv. mass of Ds**

**R.C. mass of Ds**

**B.C. mass of Ds**
Summary

At Tau-Charm Factory:

\[
\begin{align*}
\sigma_{m_r} \text{ (MeV)} & \quad < 0.1 \text{ MeV} \\
\text{Upper Limit of } m_{\nu_r} \text{ (MeV)} & \quad \sim 3 \text{ MeV} \\
\sigma_{D} \text{ (%)} & \quad O(0.5\%) \\
D - \bar{D} \text{ Mixing} & \quad r_D \sim 10^{-4} \\
\sigma_{f_D} \text{ (%)} & \quad O(2\%) \\
\sigma_{f_{D*}} \text{ (%)} & \quad O(2\%)
\end{align*}
\]

Based on full advantages of the large increase in statistics expected at Tau-Charm Factory, and a high-resolution detector, \( \tau \text{cF.} \) will provide a super experimental tool to fundamental measurement with unprecedented precision in a wide range involving \( \tau \), charm and charmonium decays. The threshold region can offer the best control of systematic errors.

\( \tau \text{cF} \) and B-factory are complementary rather than replaceable each other.