On some new CP violation

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The CP violation relating τ -lepton

Effective $\mathcal{L}$: $\mathcal{L}_{eff} = \mathcal{L}_0 + \frac{1}{\Lambda^2}\sum C_i O_i + \mathcal{O}(\frac{1}{\Lambda^4})$

$$O_{LW} = i\left[\bar{L}\gamma^\mu\tau^I D^\nu L - \overline{D^\nu L}\gamma^\mu\tau^I L\right] W^I_{\mu\nu},$$

$$O_{LB} = i\left[\bar{L}\gamma^\mu D^\nu L - \overline{D^\nu L}\gamma^\mu L\right] B_{\mu\nu},$$

$$O_{\tau B} = i\left[\bar{\tau}_R\gamma^\mu D^\nu\tau_R - \overline{D^\nu\tau_R}\gamma^\mu\tau_R\right] B_{\mu\nu},$$

$$O^{(1)}_{\Phi L} = \left[\Phi^\dagger D_\mu\Phi + (D_\mu\Phi)^\dagger\Phi\right]\bar{L}\gamma^\mu L,$$

$$O^{(3)}_{\Phi L} = \left[\Phi^\dagger\tau^I D_\mu\Phi + (D_\mu\Phi)^\dagger\tau^I\Phi\right]\bar{L}\gamma^\mu\tau^I L,$$

$$O_{\Phi\tau} = \left[\Phi^\dagger D_\mu\Phi + (D_\mu\Phi)^\dagger\Phi\right]\bar{\tau}_R\gamma^\mu\tau_R,$$

$$O_{\tau 1} = i(\Phi^\dagger\Phi - \frac{v^2}{2})\left[\bar{L}\tau_R\Phi - \Phi^\dagger\bar{\tau}_R L\right],$$

$$O_{D\tau} = i\left[(\bar{L}D_\mu\tau_R)D^\mu\Phi - (D^\mu\Phi)^\dagger(\overline{D_\mu\tau_R}L)\right],$$

$$O_{\tau W\Phi} = i\left[(\bar{L}\sigma^{\mu\nu}\tau^I\tau_R)\Phi - \Phi^\dagger(\bar{\tau}_R\sigma^{\mu\nu}\tau^I L)\right] W^I_{\mu\nu},$$

$$O_{\tau B\Phi} = i\left[(\bar{L}\sigma^{\mu\nu}\tau_R)\Phi - \Phi^\dagger(\bar{\tau}_R\sigma^{\mu\nu}L)\right] B_{\mu\nu}.$$

$$|\mathrm{Re}\, d^Z_\tau| \leq 3.6\times 10^{-18}\ \mathrm{e\ cm}\quad (95\%\ C.L.).$$

⇓

$$\left|\frac{C_{LW}}{\Lambda^2}\right| < 6.8\times 10^{-5}\ \mathrm{GeV}^{-2},$$

$$\left|\frac{C_{D\tau}}{\Lambda^2}\right| < 1.7\times 10^{-6}\ \mathrm{GeV}^{-2},$$

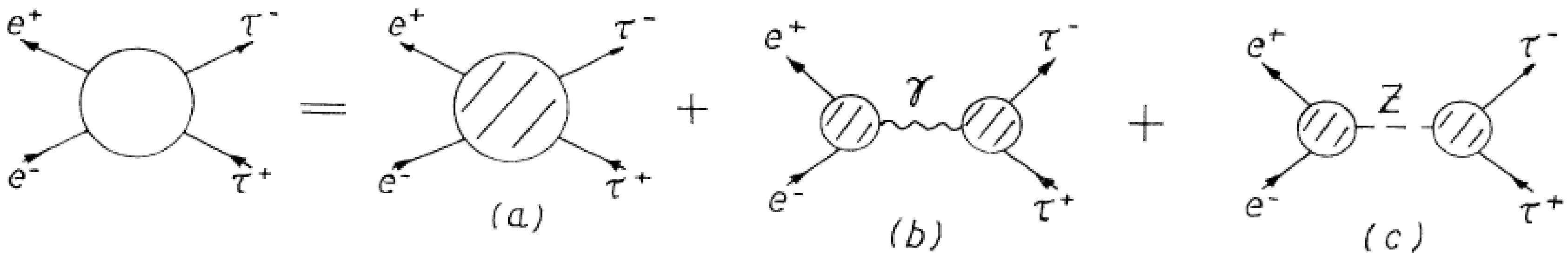
$$\left|\frac{C_{\tau W\Phi}}{\Lambda^2}\right| < 3.5\times 10^{-7}\ \mathrm{GeV}^{-2},$$

$$\left|\frac{C_{LB}}{\Lambda^2}\right|, \left|\frac{C_{\tau B}}{\Lambda^2}\right| < 6.3\times 10^{-5}\ \mathrm{GeV}^{-2},$$

$$\left|\frac{C_{\tau B\Phi}}{\Lambda^2}\right| < 3.2\times 10^{-7}\ \mathrm{GeV}^{-2}.$$

New CP violation (different from CKM phase)

On some new CP violation



Lagrangian:

$$L_{CP} = -\frac{1}{2} i \bar{\tau} \sigma^{\mu\nu} \gamma_5 \tau (d_\tau F_{\mu\nu} + \tilde{d}_\tau Z_{\mu\nu})$$

Observables:

$$A_{ij} = \hat{k}_{+i} [\hat{\mathbf{k}}_+ \times (\sigma \otimes 1 - 1 \otimes \sigma)]_j + (i \leftrightarrow j) ,$$

$$B_{ij} = \hat{k}_{+i} [(\sigma \otimes 1) \times (1 \otimes \sigma)]_j + (i \leftrightarrow j) - \frac{2}{3} \delta_{ij} (\text{trace}) ,$$

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Models: electric and/or weak dipole of leptons has

$$d_\tau \approx \tilde{d}_\tau \approx \left(\frac{m_\tau}{m_\mu}\right)^3 d_\mu \approx \left(\frac{m_\tau}{m_e}\right)^3 d_e$$

W, γ

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LEP-I example:

the data samples recorded between 1991 and 1995 with OPAL

69778 τ-pair events

CPV of $V_{Z\tau\tau}$:

(weak dipole)

$$\mathrm{Re}(d_\tau^w) = (0.72 \pm 2.46 \pm 0.24) \times 10^{-18}\, e\ \mathrm{cm}$$
$$\mathrm{Im}(d_\tau^w) = (0.35 \pm 0.57 \pm 0.08) \times 10^{-17}\, e\ \mathrm{cm}$$

If we define: $\epsilon_\tau \equiv \frac{\Delta\Gamma_{Z^0\to\tau^+\tau^-}}{\Gamma_{Z^0\to\tau^+\tau^-}}$, where $\Delta\Gamma_{Z^0\to\tau^+\tau^-} = \frac{|d_\tau^w|^2}{24\pi} m_Z^3 \left(1 - \frac{4m_\tau^2}{m_Z^2}\right)^{3/2}$

The limit means:

$\epsilon_\tau < 7.2 \times 10^{-3}$ using $|d_\tau^w|$ and

$\epsilon_\tau < 8.9 \times 10^{-4}$ assuming $\mathrm{Im}(d_\tau^w) = 0$

$\Gamma_{Z^0\to\tau^+\tau^-} = (83.88 \pm 0.39)$ MeV

precision of the test of $\mathcal{CP}$ invariance

a level of one in thousand

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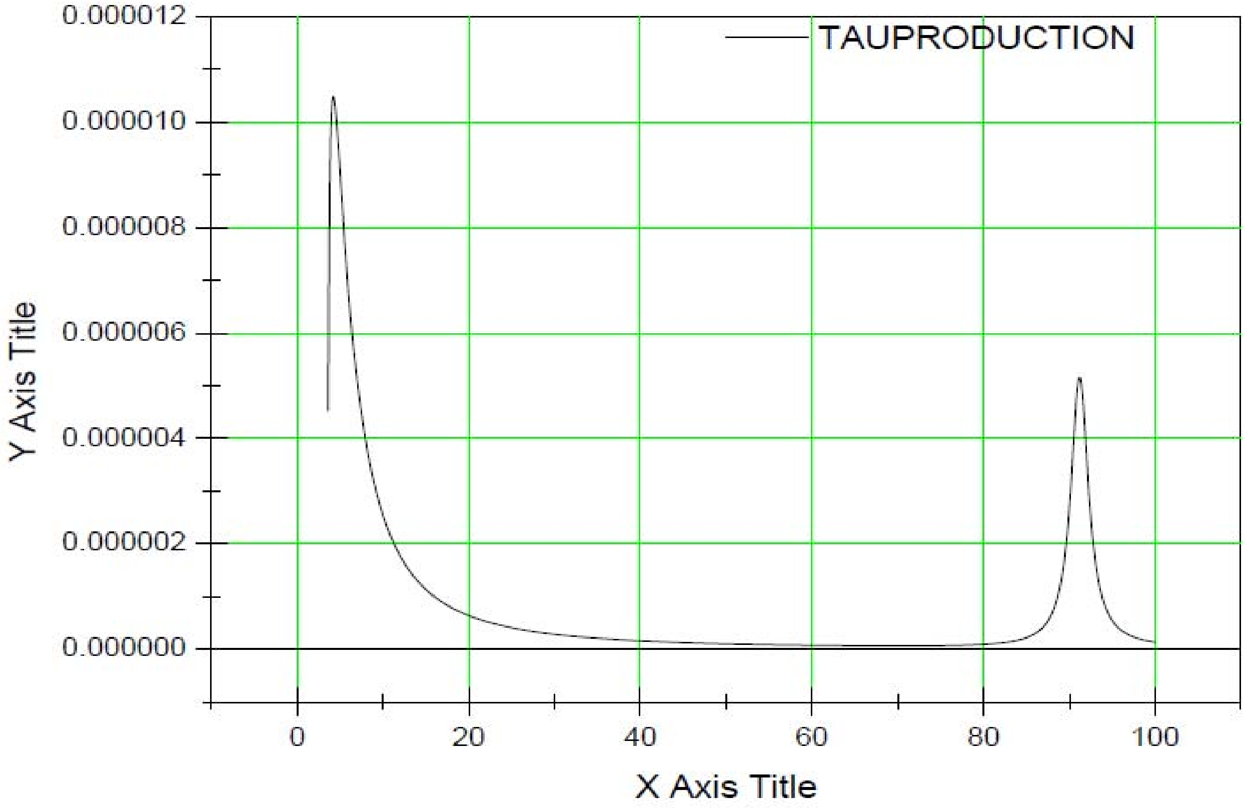
The sources of τ -lepton



Competition from B-factory and Z-factory

Thanks !

Summary of physics @Super Z-factory

Great (unique) advantages:

- In study of precise properties of Z-boson:
  flavor changes, lepton number violation; 10^{34} ↑
- In study of CP violation beyond CKM phase 10^{35} ↑
  CPV in the Z-vertex vs CPV in τ - lepton decays;
- In study of τ - lepton physics; 10^{34} ↑
- In measuring FFs and nonpertubative QCD; 10^{34} ↑
- In study of physics for c, b binding systems; 10^{35} ↑
- In searching for new physics; 10^{35} ↑
- To open new approach to study of neutrinos; 10^{36-37} ↑

etc.

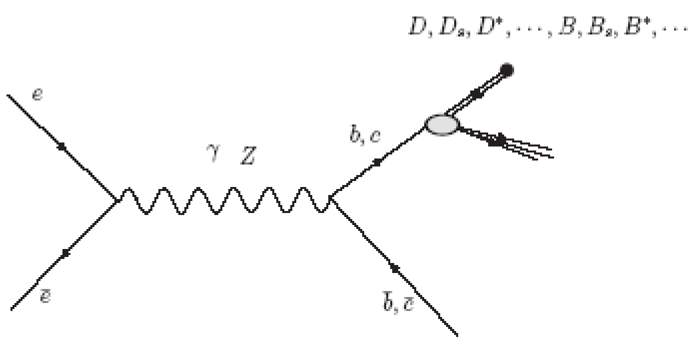
QCD: Fragmentation Functions

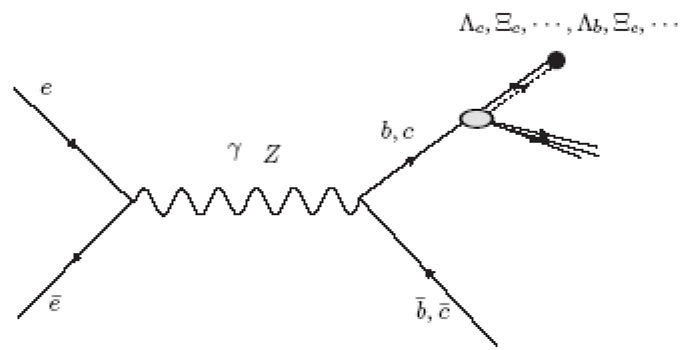
- **Quark hadronization (from partons to hadrons):**

Non-perturbative fragmentation models: LUND , Webber Cluster, Quark Combination (ShangDong) Model etc. The best place to test the models.

- **Fragmentation functions (FFs) & polarized ones**

QCD fundamental quantities & useful in hadronic collider experiments





$D_c^{J/\psi}, D_c^{\eta_c}, \cdots \quad D_c^{B_c}, D_c^{B_c^*}, \cdots D_b^{\Upsilon}, D_b^{\eta_b}, \cdots \quad D_b^{B_c}, D_b^{B_c^*}, \cdots$

$D_c^{\Xi_{cc}}, D_c^{\Xi_{bc}}, \cdots \quad D_b^{\Xi_{bc}}, \quad D_b^{\Xi_{bb}}, \cdots$

Very important for flavor-tagging !

QCD: Fragmentation Functions

The best place for measuring FFs (accurate and various):

No 'initial state effects', but very high statistics and very energetic jets!

Significances:

Theoretically:

To offer 'polarized' FFs in principle, because Z boson decays to a quark pair, that is polarized !

Pertubative QCD and nonperturbative QCD models.

Experimentally:

Various (mesons and baryons) and accurate FFs;

To increase the (heavy flavors) tag efficiency.

Interphase of perturbative and non-perturbative QCD (as PDFs).

QCD: c & b-Hadron Physics

The studies of the spectroscopy for heavy and double (triple) heavy hadrons:

Heavy meson: $(c\overline{q})$, $(b\overline{q})$ **etc**

Heavy baryon: (cqq), (bqq) **etc**

Double heavy meson: $(c\overline{c})$, $(c\overline{b})$, $(b\overline{b})$ **etc**

Double heavy baryon: (ccq), (bbq), (cbq) **etc**

The spectrum of the systems, except $(c\overline{c})$ and $(b\overline{b})$, and transitions among the excited and ground states are not complete!

Super-B factory and LHCb may do a lot of the physics but LHCb may not observe the excited states of the systems and Super-B factory cannot observe those systems which involve a b-quark (except B, Bs).

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