τ— EDM with polarized beams

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τ— EDM with polarized beams

τ electric dipole moment can be bounded from high statistic B/Super B factories data. For polarized beams we study new CP-odd observables and we find that limits of the order of 10^{-19} e-cm can be obtained.

OUTLINE

1. τ ELECTRIC DIPOLE MOMENT (EDM)
   - 1.1 Definition
   - 1.2 Experiments
2. OBSERVABLES
3. CONCLUSIONS

1. EDM 1.1 Definition

P and T-odd interaction of a fermion with gauge fields (Landau 1957):

Besides, chirality flipping (insight into the mass origin)

Classical electromagnetism
Ordinary quantum mechanics

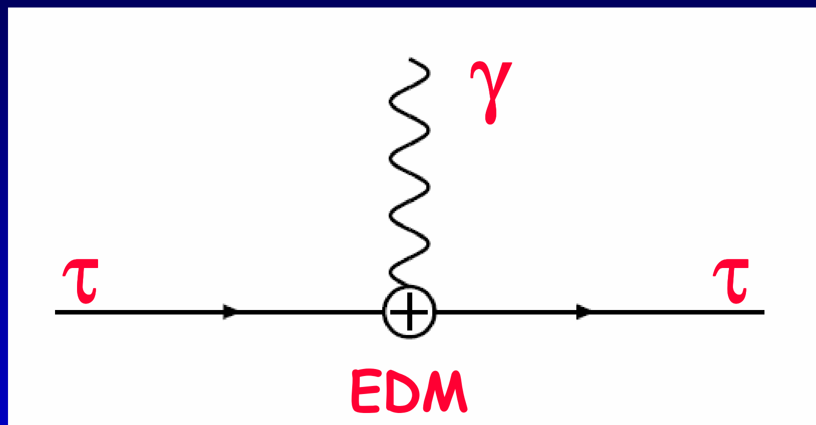
$$H_{EDM} = -\vec{d} \cdot \vec{E} \,, \quad \vec{d} = d \, \vec{s}$$

Same H with non-relativistic limit of Dirac's equation:

$$H = \bar{\Psi} \left(i(\partial\!\!\!/ + eA\!\!\!/) - m \right) \Psi + \frac{i}{2} d \, \bar{\Psi} \gamma^5 \sigma^{\mu\nu} \Psi F_{\mu\nu}$$

CPT: CP and T are equivalent

1. EDM 1.1 Definition



SM :

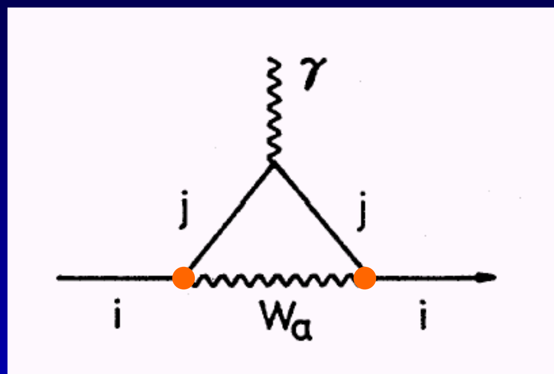
- vertex corrections
- at least 4-loops for leptons

Beyond SM:

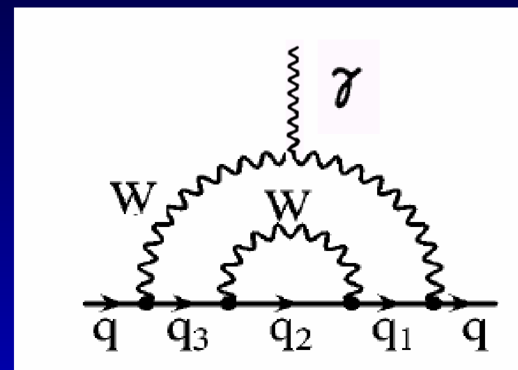
- one loop effect (SUSY, 2HDM, ...)
- dimension six effective operator

1. EDM 1.1Definition

SM :



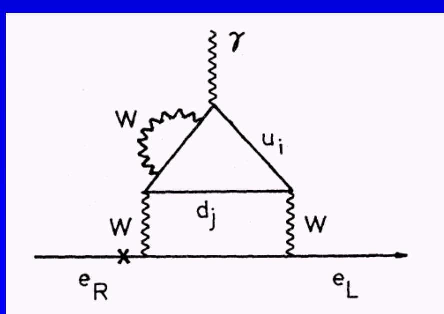
V_{CKM} V^*_{CKM}



E.P.Shabalin '78

= 0 !!!

We need 3-loops for a quark-EDM, and 4 loops for a lepton...



$$d_\tau \approx e G_F m_\tau \alpha^2 \alpha_s J/(4\pi)^5 \approx 10^{-34}\ \text{ecm}$$

1. EDM 1.2 Experiments

BOUNDS:

PDG '06 95% CL
EDM BELLE '02

$$\mathrm{Re}(d_\gamma^\tau):\ (-2.2 \text{ to } 4.5)\times 10^{-17}\ e\,\mathrm{cm}$$

$$\mathrm{Im}(d_\gamma^\tau):\ (-2.5 \text{ to } 0.8)\times 10^{-17}\ e\,\mathrm{cm}$$

1. EDM 1.2 Experiments

Light Fermions :

- Stables or with enough large lifetime
- EDM : spin dynamics in electric fields

Heavy Fermions:

- Short living particles
- Spin matrix and angular distribution of decay products in TAU-pair production may depend on the EDM

1. EDM 1.2 Experiments

HOW DO WE MEASURE τ **ELECTRIC DIPOLE MOMENTS?**

Total cross sections	$e^+e^- \longrightarrow \gamma \longrightarrow \tau^+\tau^-$
	$e^+e^- \longrightarrow e^+e^- \tau^+\tau^-$
Partial widths	$Z \longrightarrow \tau^+\tau^- \gamma$

Sensitive to many contributions

Spin correlations	$s_i^+ \cdot s_j^-$
Linear polarizations	$s_i^\pm$

Correlations and asymmetries observables select EDM by symmetry properties

2. Observables

Tau pair production

Normal polarization: $P_N^{\tau} \leftrightarrow T-\text{odd},\ P-\text{even}$

and needs helicity-flip so for the Tau it is mass enhanced

Genuine ~~CP~~ if $P_N^{\tau^+} \leftrightarrow P_N^{\tau^-}$

J.Bernabéu,GGS,J.Vidal
Nucl. Phys B763 (2007)

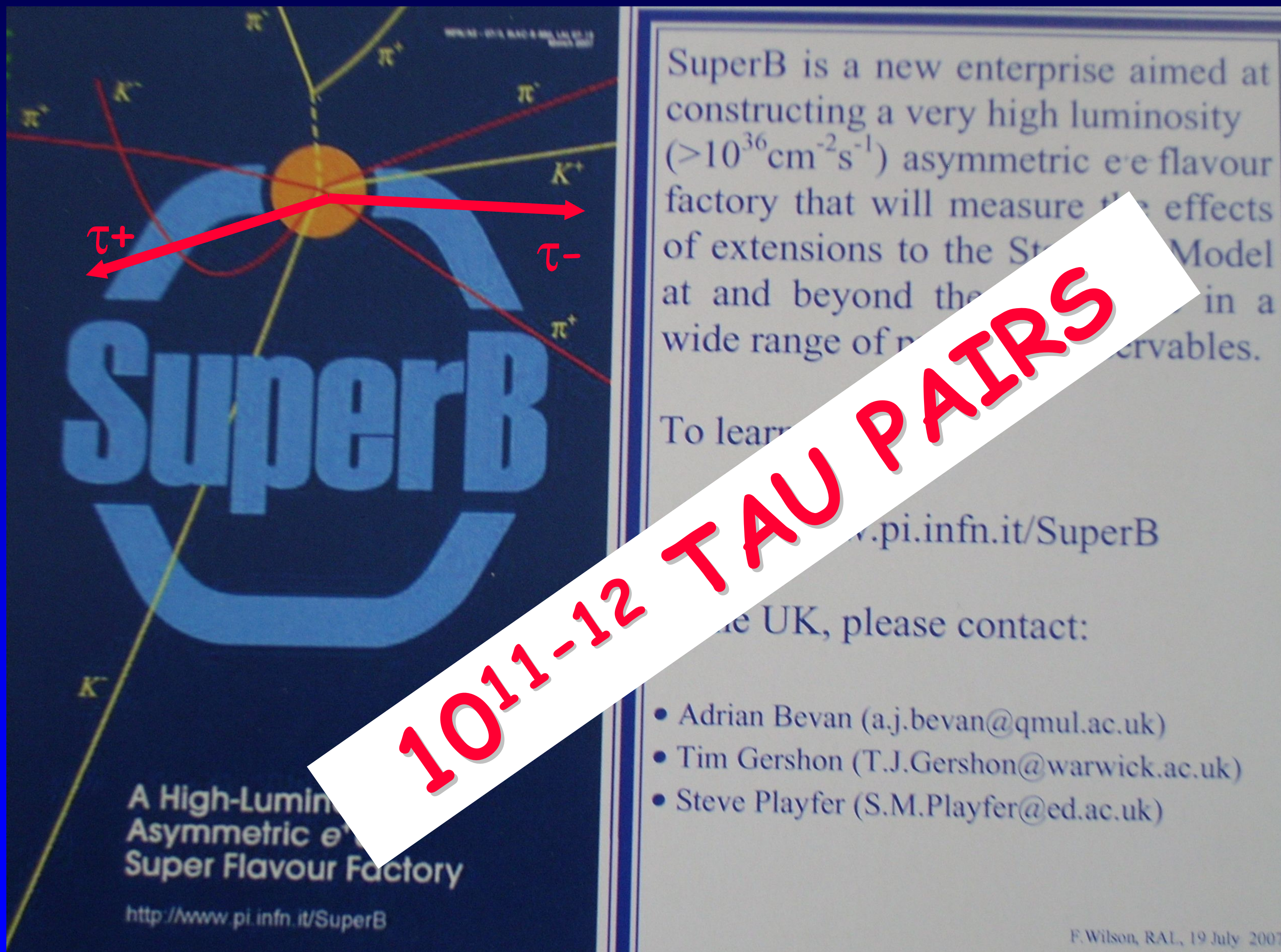
NORMAL POLARIZATION: T-odd P-even

Vs.

EDM: T-odd P-odd

Polarized beams provide another P-odd source

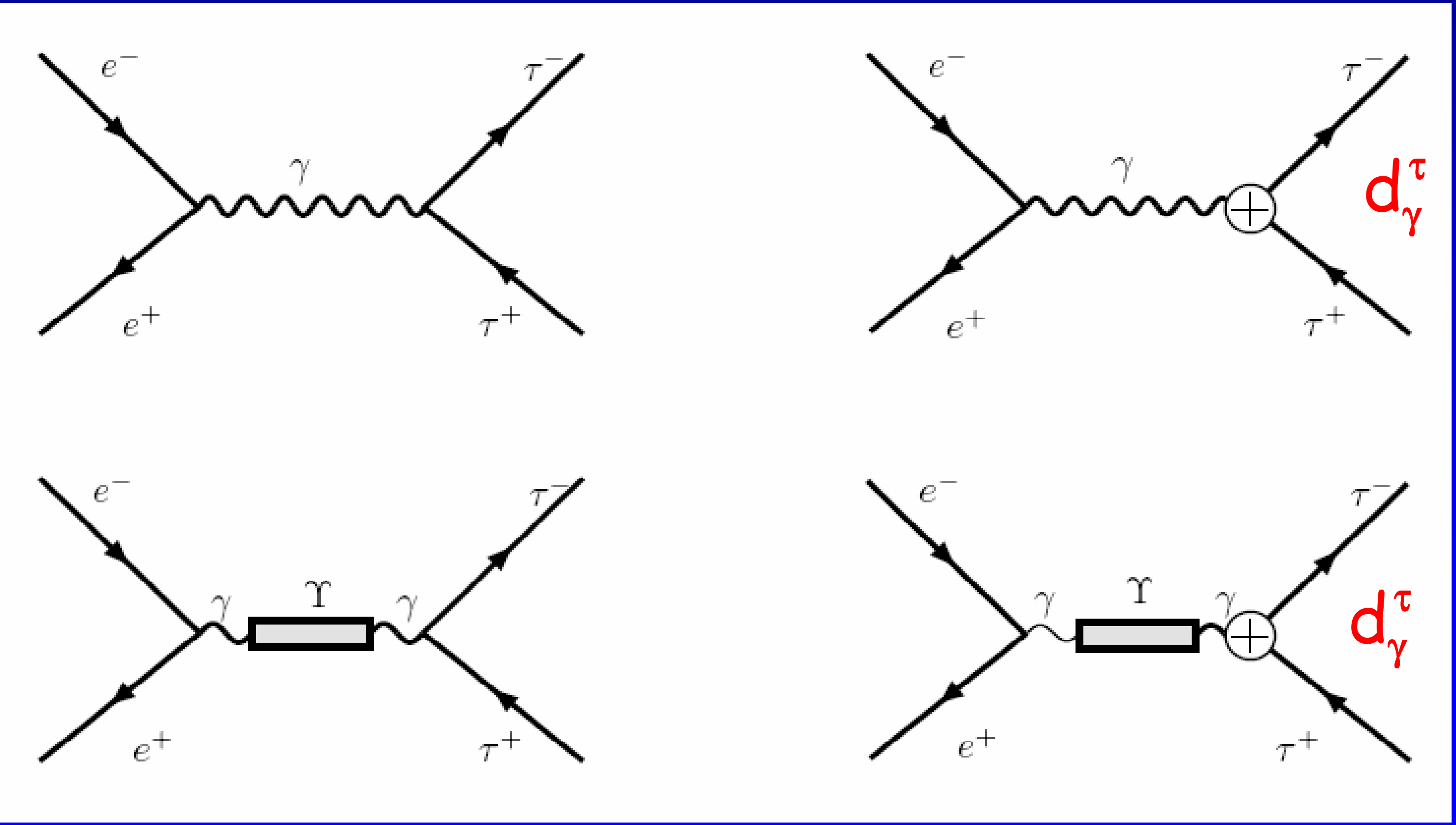
2. Observables



2. Observables

$$e^+e^- \to \gamma, \Upsilon \to \tau^+(s_+)\,\tau^-(s_-)$$

Diagrams



2. Observables

e^+e^- at Υ energies

τ pair production: $e^+e^- \to \Upsilon \to \tau^+\tau^-$

RESONANT PRODUCTION

$$|H(M_\Upsilon)|^2 = \left(\frac{e^2 Q_b^2 |F_\Upsilon|^2}{\Gamma_\Upsilon M_\Upsilon^3}\right)^2 = \left(\frac{3}{\alpha} Br(\Upsilon \to e^+e^-)\right)^2$$

2. Observables

Normal polarization:

EDM and polarized beams can produce a P-even observable

$$\left.\frac{d\sigma^S}{d\Omega_{\tau^-}}\right|_\lambda = \frac{\alpha^2}{16s}\beta\{\lambda[(s_- + s_+)_x X_+ + (s_- + s_+)_z Z_+ + (s_- - s_+)_y Y_-] + (s_- - s_+)_x X_- + (s_- - s_+)_z Z_-\},$$

where

$$X_+ = \frac{1}{\gamma}\sin\theta_{\tau^-}, \qquad X_- = -\frac{1}{2}\sin(2\theta)\frac{2m_\tau}{e}\mathrm{Im}\{d_\tau^\gamma\},$$

$$Z_+ = -\cos\theta_{\tau^-}, \qquad Z_- = -\frac{1}{\gamma}\sin^2\theta\frac{2m_\tau}{e}\mathrm{Im}\{d_\tau^\gamma\},$$

$$Y_- = \gamma\beta^2\cos\theta_{\tau^-}\sin\theta_{\tau^-}\frac{2m_\tau}{e}\mathrm{Re}\{d_\tau^\gamma\}$$

2. Observables

For polarized beams

$$P_N^\tau \propto \lambda\gamma\beta^2 \cos\theta_\tau \sin\theta_\tau \frac{m_\tau}{e}\mathrm{Re}(d_\tau^\gamma)$$

Angular asymmetries (P_N^τ) are proportional to EDM

$$A_N^\mp = \frac{\sigma_L^\mp - \sigma_R^\mp}{\sigma_L^\mp + \sigma_R^\mp} = \alpha_\mp \frac{3\pi\gamma\beta}{8(3-\beta^2)} \frac{2m_\tau}{e}\mathrm{Re}(d_\tau^\gamma)$$

One can also measure A for τ^+ and/or τ^-

$\not{CP}$:

$$A_N^{CP} \equiv \frac{1}{2}(A_N^+ + A_N^-)$$

2. Observables

Bounds:

$$\left|\mathrm{Re}(d_\gamma^\tau)\right| \le 1.6\times 10^{-19}\,e\,\mathrm{cm}$$ SuperB factory, 1yr running, 15 ab^{-1}

$$\left|\mathrm{Re}(d_\gamma^\tau)\right| \le 7.2\times 10^{-20}\,e\,\mathrm{cm}$$ SuperB factory, 5yrs running, 75 ab^{-1}

1 ab = 10^{-18} b

3. Conclusions

- We studied linear polarization CP-odd observables at SuperB factories.
- Normal Tau polarization observables and polarized beams allow to put strong limits on the EDM.
- These observables are independent from other low and high energy observables already investigated.
- These bounds are 3 orders of magnitude below current limits.

3. Conclusions

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<u>SOME REFERENCES</u>

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