

τ -EDM with polarized beams



Gabriel González Sprinberg
Instituto de Física, Facultad de Ciencias
Montevideo Uruguay

gabrielg@fisica.edu.uy

EUROPHYSICS CONFERENCE
ON HIGH ENERGY PHYSICS
MANCHESTER, ENGLAND
19-25 JULY 2007.

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

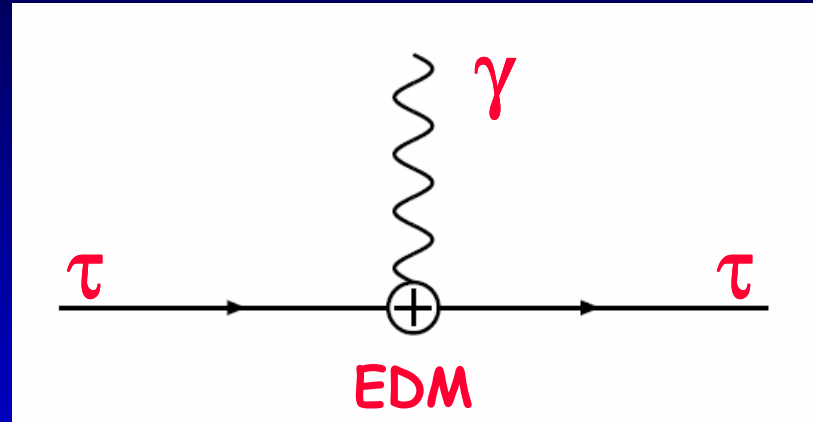
Same H with non-relativistic limit of Dirac's equation:

$$H = \bar{\Psi} (i(\not{\partial} + eA) - m) \Psi + \frac{i}{2} d \bar{\Psi} \gamma^5 \sigma^{\mu\nu} \Psi F_{\mu\nu}$$

CPT: CP and T are equivalent

1. EDM

1.1 Definition



SM :

- vertex corrections
- at least 4-loops for leptons

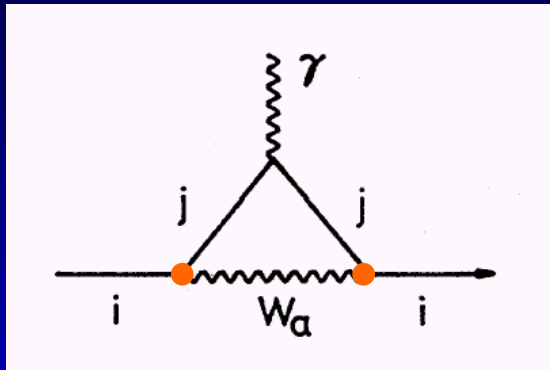
Beyond SM:

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

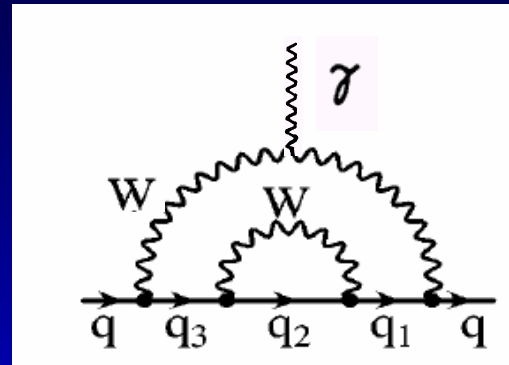
1. EDM

1.1 Definition

SM :



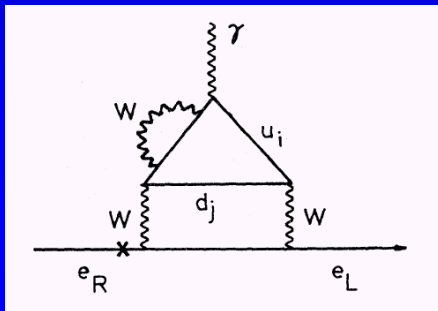
V_{CKM} V_{CKM}^*



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

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

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

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 $\mathbf{s}_i^+ \cdot \mathbf{s}_j^-$
Linear polarizations \mathbf{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)

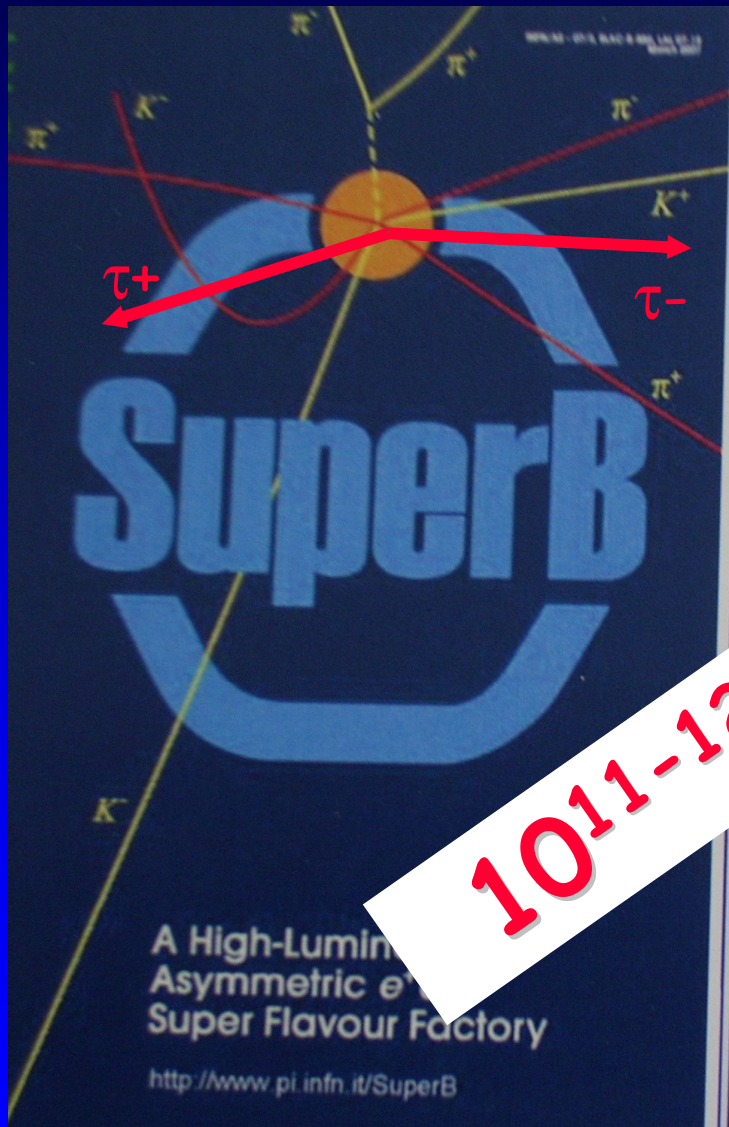
NORMAL POLARIZATION: T-odd P-even

Vs.

EDM: T-odd P-odd

Polarized beams provide another P-odd source

2. Observables



The image shows the SuperB logo, which is a stylized blue 'S' with a white 'B' inside. Above the logo, there are several particle tracks in red and yellow, labeled with π^+ , π^- , K^+ , K^- , τ^+ , and τ^- . A red arrow points from the center of the logo towards the right, and another red arrow points from the center towards the left, both labeled with τ^+ and τ^- respectively.

SuperB
A High-Luminosity Asymmetric e^+e^- Super Flavour Factory
<http://www.pi.infn.it/SuperB>

SuperB is a new enterprise aimed at constructing a very high luminosity ($>10^{36}\text{cm}^{-2}\text{s}^{-1}$) asymmetric e^+e^- flavour factory that will measure the effects of extensions to the Standard Model at and beyond the TeV scale in a wide range of new observables.

To learn more visit www.pi.infn.it/SuperB

In the UK, please contact:

- Adrian Bevan (a.j.bevan@qmul.ac.uk)
- Tim Gershon (T.J.Gershon@warwick.ac.uk)
- Steve Playfer (S.M.Playfer@ed.ac.uk)

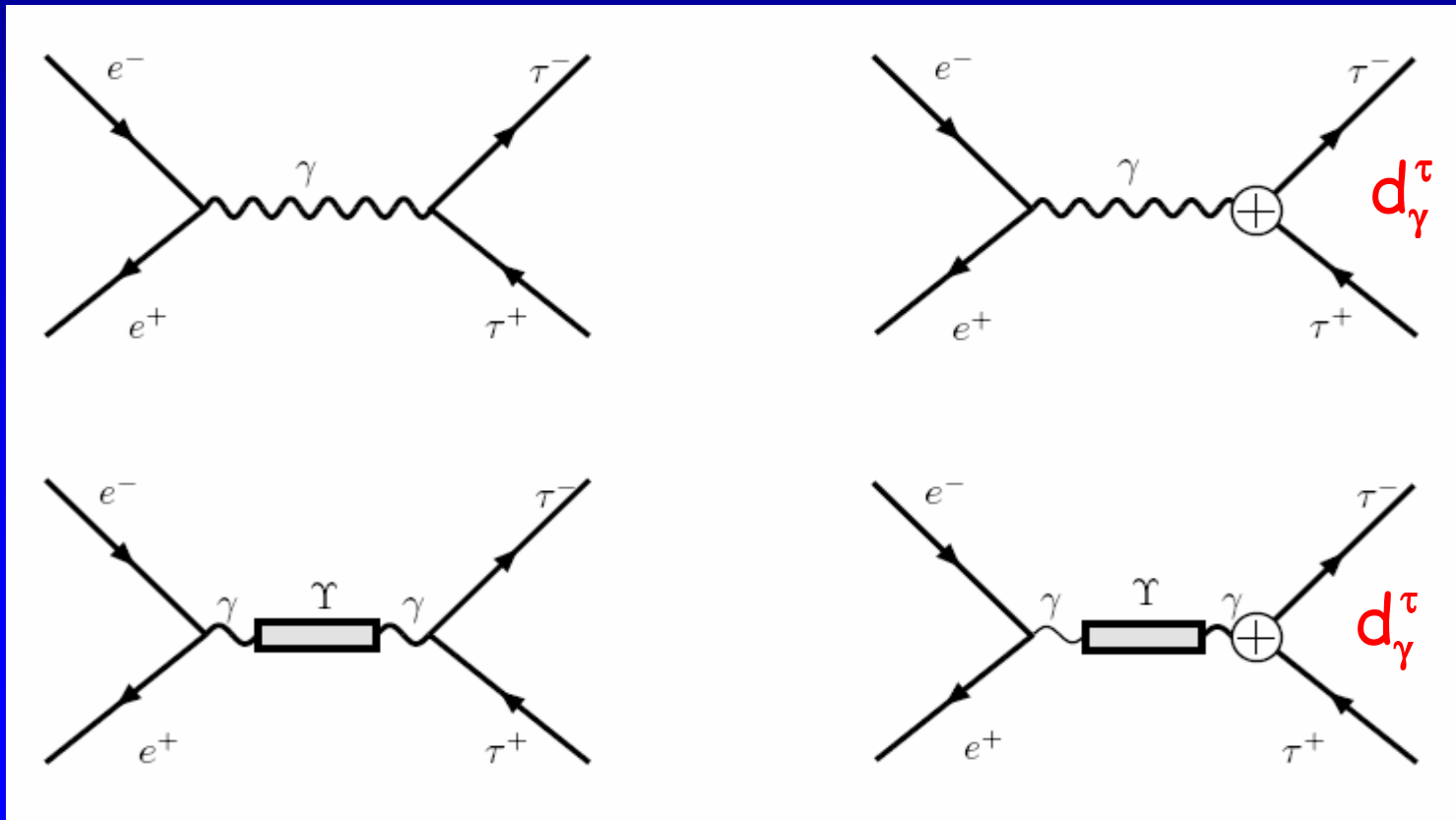
F.Wilson, RAL, 19 July 2007

1011-12 TAU PAIRS

2. Observables

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

Diagrams



2. Observables

e^+e^- at Υ energies

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

RESONANT PRODUCTION

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

2. Observables

Normal polarization:
EDM and polarized beams can produce a P-even observable

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

where

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

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

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

2. Observables

For polarized beams

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

Angular asymmetries (P_N^τ) are proportional to EDM

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

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

~~CP~~ :

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

2. Observables

Bounds:

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

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

$$1 \text{ ab} = 10^{-18} \text{ b}$$

3. Conclusions

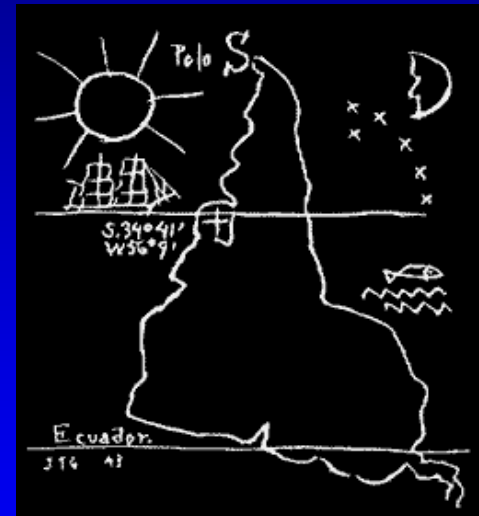
- We studied linear polarization CP -odd observables at SuperB factories.
- Normal Tau polarization observables and polarized beams allow to put strong limits on the EDM.
- These observables are independent from other low and high energy observables already investigated.
- These bounds are 3 orders of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

3. Conclusions

Discussions with J. Bernabéu, J. Vidal and A. Santamaria
are gratefully acknowledged

SOME REFERENCES

- J. Bernabéu, G-S., Jordi Vidal
Nuclear Physics B763 (2007) 283-292
- D. Gomez-Dumm, G-S.
Eur. Phys. J. C 11, 293-300 (1999)



Gabriel González Sprinberg,
Facultad de Ciencias, Uruguay
gabrielg@fisica.edu.uy