Low energy $\gamma\gamma$ colliders to perform fundamental physics -- τ lepton properties --

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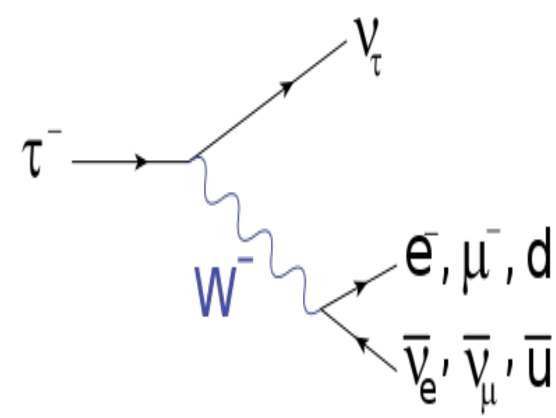
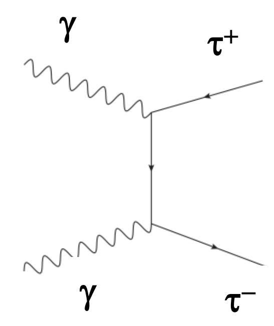


Proposal for $\gamma\gamma$ collider at the $\tau\tau$ threshold



$3.6\ \text{GeV} < E_{\gamma\gamma} < 8\ \text{GeV}$

Or $2m_\tau < E_{\gamma\gamma} < 2m_b$

Away from bb thresholds to avoid contamination from B to τ decays

Indirect search for new physics

1. First precise measurement of the g-2 of the τ (a_τ)
   - $\tau\tau\gamma$ vertex
2. Improve g-2 of the μ (a_μ) *
   - Hadronic decays of the τ like τ to $\nu_\tau \pi^\pm \pi^0$

Direct search for new physics

3. Search for lepton flavor violation (i.e. $\tau \rightarrow \mu\gamma$, $\mu\mu\mu$, etc.) *
4. Search for CP and T -Violation in τ measured from dipole moment and rate, angular and polarization asymmetries from τ decays

** Topics part of the Intensity Frontier program in the USA*

QED: Electromagnetic and Weak Dipole Moments

- Electromagnetic coupling of spin-1/2 charged lepton to the virtual photon involves 3 form factors:

$$\mathcal{M}_{\ell\bar{\ell}\gamma^*} = e\,Q_\ell\,\varepsilon_\mu(q)\,\bar{u}_\ell(\vec{p}')\left[F_1(q^2)\,\gamma^\mu + i\,\frac{F_2(q^2)}{2m_\ell}\,\sigma^{\mu\nu}q_\nu + \frac{F_3(q^2)}{2m_\ell}\,\sigma^{\mu\nu}\gamma_5\,q_\nu\right]u_\ell(\vec{p})$$

$$F_1(0) = 1$$

Charge conservation

$$\mu_\ell \equiv \frac{e}{2m_\ell}\,\frac{g_\ell^\gamma}{2} = \frac{e}{2m_\ell}\,[1 + F_2(0)]$$

Magnetic moment

$$d_\ell^\gamma = \frac{e}{2m_\ell}\,F_3(0)$$

Dipole moment

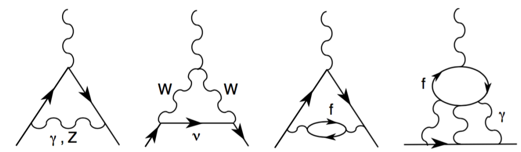
- $F_i(q^2)$ sensitive to a possible lepton substructure
- d^γ good probe of CP and T violation

➔ Polarization useful for these measurement

The τ anomalous magnetic and dipole moment have an enhanced sensitivity to new physics because of the large τ mass

Anomaly in the μ (g-2) is well know, however g-2 of the τ is basically unknown

$$a_\ell \equiv (g_\ell^\gamma - 2)/2$$



μ

$10^{10} \times a_\mu^{\mathrm{th}}$	$= 11\,658\,471.895\,1$	$\pm 0.008\,0$	QED	
	$+\ 15.4$	± 0.1	EW	
	$+\ 696.4$	± 4.6	$\mathrm{hvp}^{\mathrm{LO}}$	$(701.5 \pm 4.7)_\tau \quad (692.3 \pm 4.2)_{e^+e^-}$
	$-\ 9.8$	± 0.1	$\mathrm{hvp}^{\mathrm{NLO}}$	
	$+\ 10.5$	± 2.6	lbl	
	$= 11\,659\,184.4$	± 5.3	$(11\,659\,189.5 \pm 5.4)_\tau \quad (11\,659\,180.3 \pm 4.9)_{e^+e^-}$	

τ

$10^{8} \times a_\tau^{\mathrm{th}}$	$= 117\,324$	± 2	QED
	$+\ 47.4$	± 0.5	EW
	$+\ 337.5$	± 3.7	$\mathrm{hvp}^{\mathrm{LO}}$
	$+\ 7.6$	± 0.2	$\mathrm{hvp}^{\mathrm{NLO}}$
	$+\ 5$	± 3	lbl
	$= 117\,721$	$\pm 5\,.$	

$$a_e = (1\,159\,652\,180.73 \pm 0.28) \times 10^{-12}\,,$$
$$a_\mu = (11\,659\,208.9 \pm 6.3) \times 10^{-10}\,.$$

$$-0.052 < a_\tau < 0.013$$

From Weizsacker Williams radiation events

$\sigma(e^+e^- \to e^+e^-\tau^+\tau^-)$ at $\sqrt{s}$ between 183 and 208 GeV at LEP2