Measurement of the τ Anomalous Magnetic Moment

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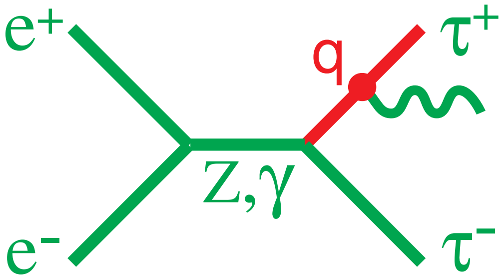
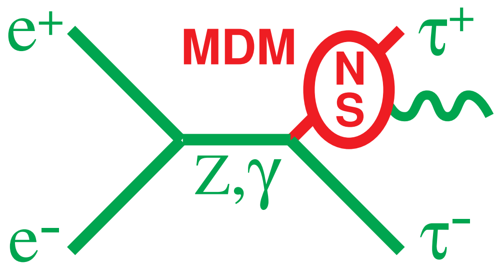
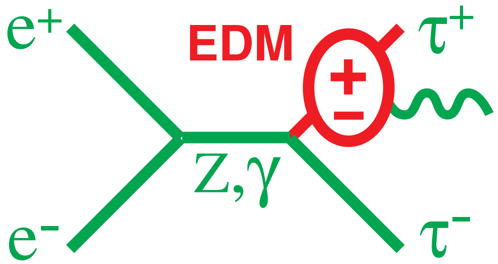
- $\tau\tau\gamma$ analysis at L3
- Conclusions and future outlook

Introduction







$F_1(q^2)\gamma^\mu$	$F_2(q^2)\frac{i}{2m_f}\sigma^{\mu\nu}q_\nu$	$F_3(q^2)\sigma^{\mu\nu}\gamma^5 q_\nu$
$\Downarrow$	$\Downarrow$	$\Downarrow$
Electric charge, q_τ	Anomalous Magnetic Moment, a_τ	Electric Dipole Moment, d_τ
$q_\tau \equiv F_1(q^2=0)$	$a_\tau \equiv F_2(q^2=0)$ $= (g-2)/2$	$d_\tau \equiv eF_3(q^2=0)$
	$a_\tau(\mathrm{SM}) = \alpha/2\pi + \ldots$ ≈ 0.0011	$d_\tau(\mathrm{SM}) = 0$ (non-zero $\Rightarrow \not{T}$ & $\not{P}$)

Parametrising effects of anomalous moments

Bremsstrahlung probability $\propto |\mathcal{A}_{\rm SM} + \mathcal{A}_{\rm MDM} + \mathcal{A}_{\rm EDM}|^2$

Neglect:
- terms linear in F_2 and F_3 ($\propto \mathrm{m}_\tau^2/\mathrm{m}_\mathrm{Z}^2$)
- γ exchange
- interference with ISR and SM FSR

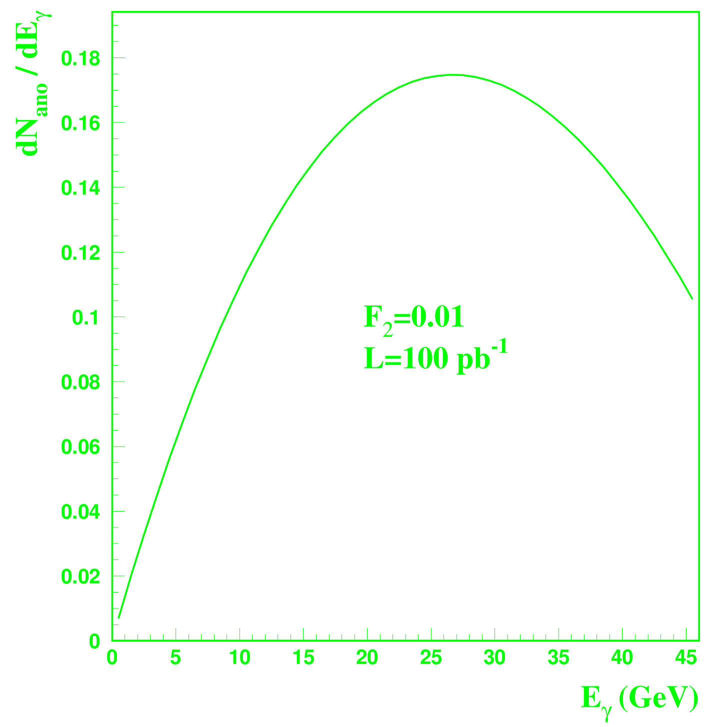
$$\boxed{\frac{d\Gamma_{\tau\tau\gamma}}{dE_\gamma} = \frac{d\Gamma_{\rm SM}}{dE_\gamma} + \frac{d\Gamma'(F_2,F_3)}{dE_\gamma}}$$

N.B. we parametrize effects of anomalous moments – we do not calculate expected magnetic moment in SM due to loops

Effects of $F_{2(3)} > F_{2(3)}^{\mathrm{SM}}$

- increased rate of $\tau\tau\gamma$ events
- changed shape of the photon energy spectrum

Spectrum of "Anomalous" Photons



⇒ analysis strategy:

① Select $\tau\tau(\gamma)$ events

② Select photons in $\tau\tau(\gamma)$ events

③ Fit E_γ spectrum for F_2, F_3

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Selection of $\tau\tau(\gamma)$ events

Use 1992–1994 on-peak data ($\int \mathcal{L} = 84pb^{-1}$) in BGO barrel

Low charged track multiplicity	➠	reject hadronic events
Low energy cluster multiplicity	➠	reject hadronic events
2 jets with $E_1 > 6GeV$, $E_2 > 2GeV$	➠	reject two-photon events
No muon with momentum $> 42GeV$	➠	reject dimuon events
No muon track opposite a MIP	➠	reject dimuon events
No ECAL bump of $E > 40GeV$ (unless it's an isolated photon)	➠	reject Bhabha events
Total BGO energy $< 78GeV$	➠	reject Bhabha events (especially $\mathrm{e^+e^-}\gamma$)

➪ select 66 218 candidate $\tau\tau(\gamma)$ events

Selection of $\tau\tau(\gamma)$ events

Monte Carlo studies with:

KORALZ V4.0	$(e^+e^- \to \tau^+\tau^-)$
TAUOLA V2.4	(for τ decays)
PHOTOS	(for SM radiation)
GEANT	(detector simulation)

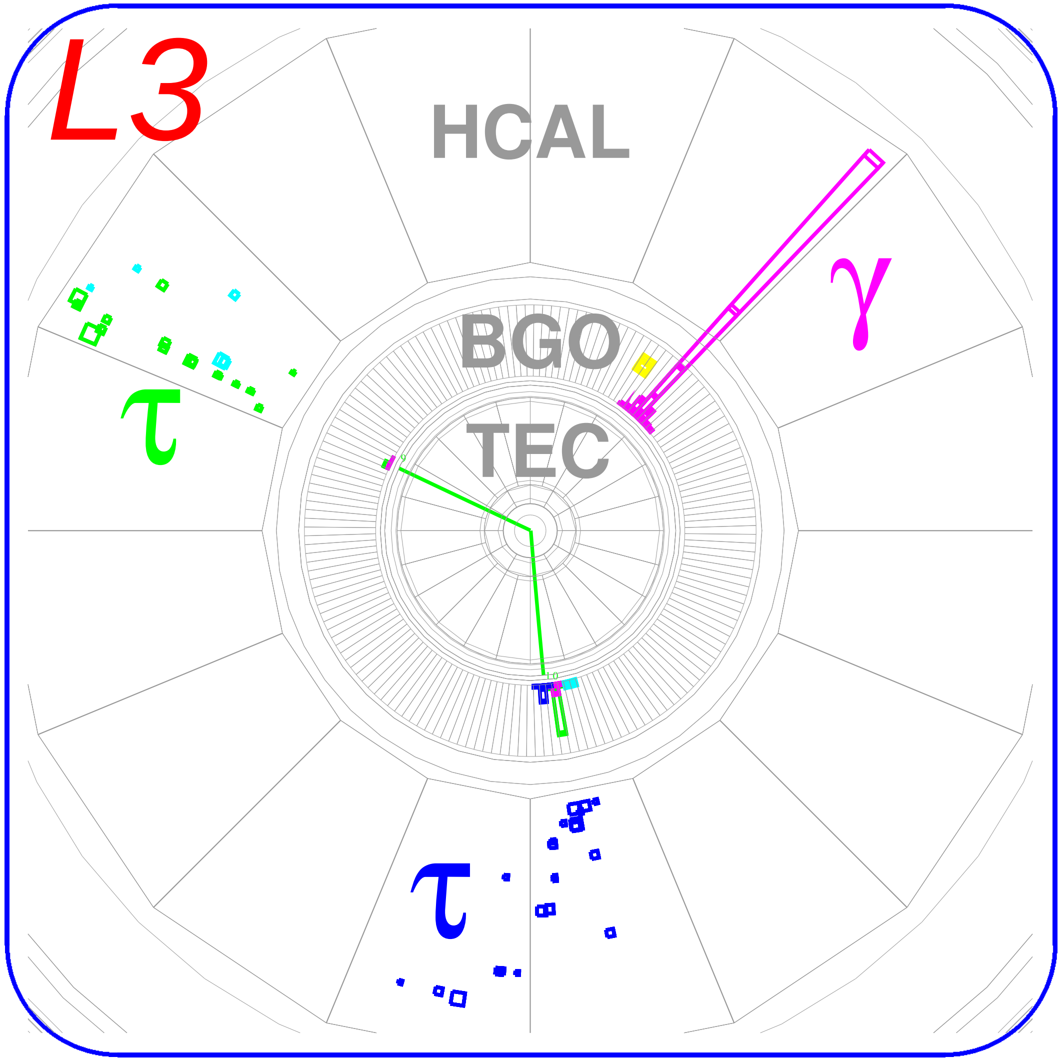
$\Rightarrow$ Estimated total background $= 3.2 \pm 0.5\%$

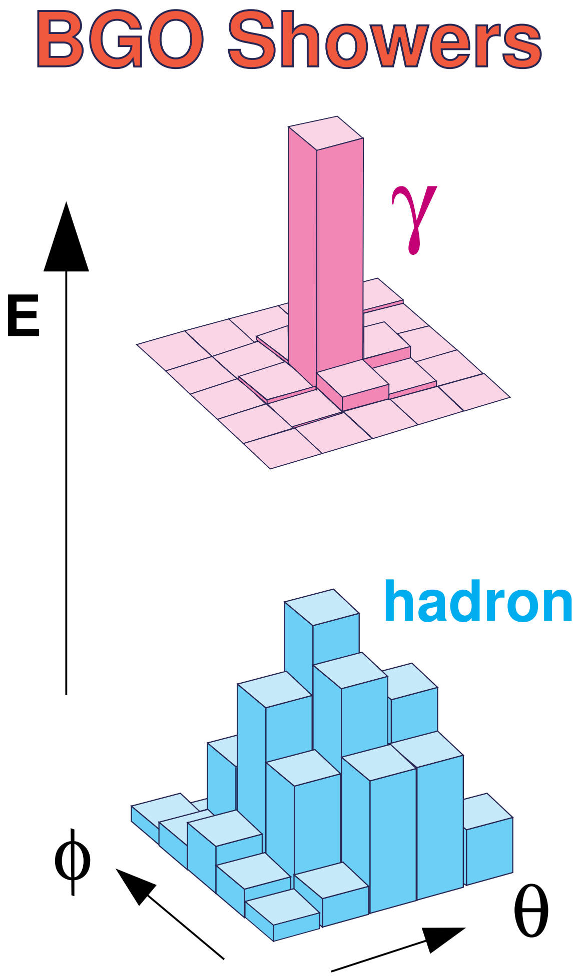
$\Rightarrow$ $\tau\tau$ efficiency in fiducial volume $= 83.4 \pm 0.1\%$
(global $\tau\tau$ selection efficiency $= 51.5 \pm 0.1\%$)

Check cross-section at $\sqrt{s} \approx m_Z$: $\boxed{\sigma_{\tau\tau} = 1.483 \pm 0.015\,\mathrm{nb}}$

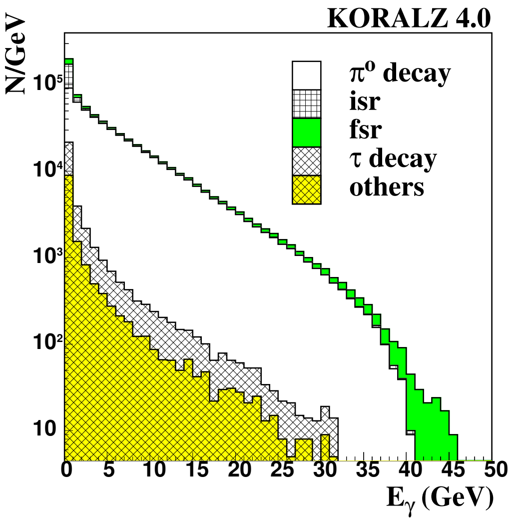
Agrees with prediction of ZFITTER: $\boxed{\sigma_{\tau\tau} = 1.48\,\mathrm{nb}}$

Selection of photons in $\tau\tau(\gamma)$ events





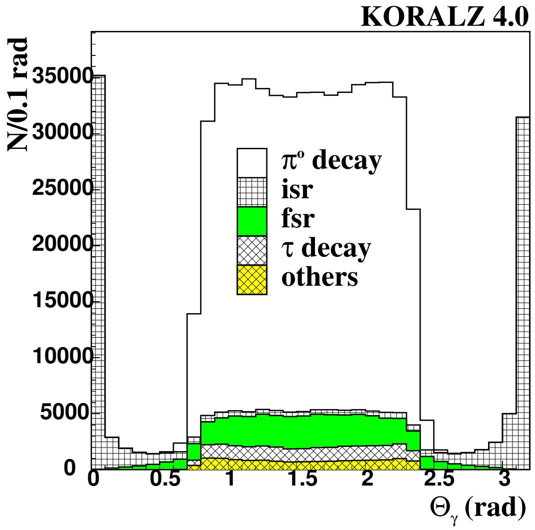
Selection of photons in $\tau\tau(\gamma)$ events



$E_\gamma > 3.5\,GeV$

$\Downarrow$

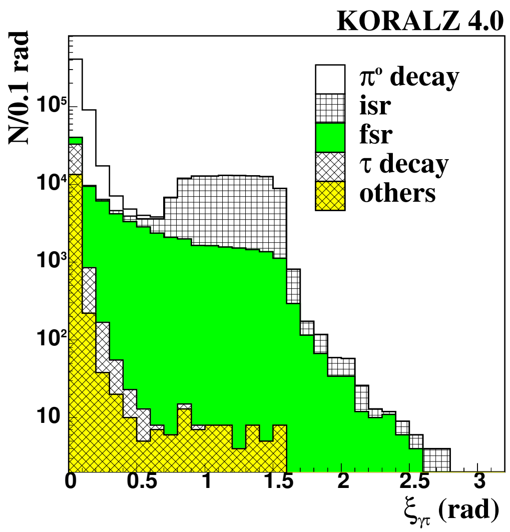
Rejects ISR,
Decay & Others



$|\cos(\Theta_\gamma)| < 0.7$

$\Downarrow$

Rejects ISR

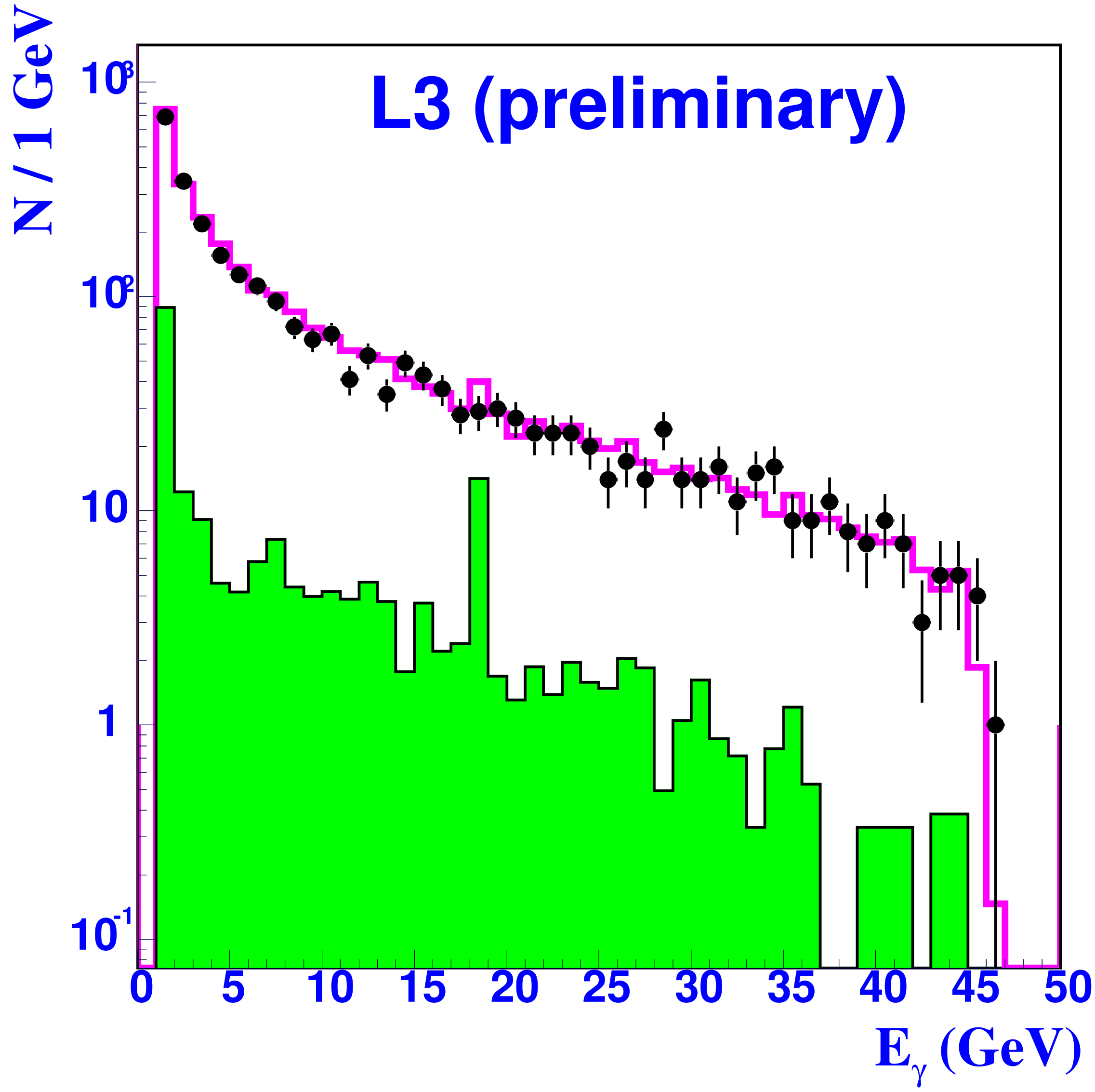


$\xi_{\gamma\tau} > 280\mathrm{mrad}$

$\Downarrow$

Rejects π^0,
Decay & Others

Photon Energy Spectrum



Background	Contribution (%)
FSR	97.7 ± 1.7
ISR	1.9 ± 0.2
π^0	0.4 ± 0.1

Fitting for the τ anomalous moment

Perform a maximum likelihood fit to the measured photon energy spectrum allowing for integrated luminosity

Standard Model (background) contribution:

☞ use KORALZ events with full detector simulation

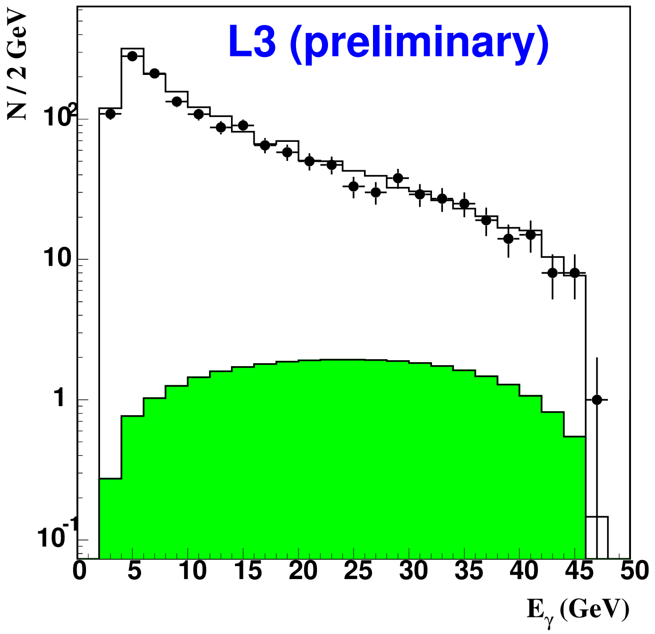
Anomalous photon contribution:

☞ Use analytical expression and reweight E_γ bins for:

- polar angular acceptance (detector)
- phase space acceptance (kinematic cuts)
- $\tau\tau(\gamma)$ selection efficiency (detector & selection cuts)

$\boxed{F_2^2(0) \text{ is the only free parameter}}$

Results



$$F_2^2(0) \equiv a_\tau^2 = -0.0028 \pm 0.0020^{+0.0010}_{-0.0007}$$

Systematics dominated by efficiency uncertainties and MC statistics

Set limit: $a_\tau^2 < 0.0024$ (90% CL)

$\boxed{a_\tau < 0.049}$ (90% CL)

Limit on electric dipole moment: $a_\tau \times e/(2m_\tau) \Rightarrow d_\tau$

$\boxed{d_\tau < 2.7 \times 10^{-16} e\,\mathrm{cm}}$ (90% CL)

Perspective

a_e^{SM}	$= 0.001\,159\,652\,46(15)$	Kinoshita&Lindquist, PRL **47** (1981) 1573
a_e^{expt}	$= 0.001\,159\,652\,193(10)$	Cohen&Taylor, RMP **59** (1987) 1121
a_μ^{SM}	$= 0.001\,165\,920\,2(20)$	Hughes&Kinoshita, CNPP **14** (1985) 341
a_μ^{expt}	$= 0.001\,165\,923\,0(84)$	Cohen&Taylor, RMP **59** (1987) 1121
a_τ^{SM}	$= 0.001\,177\,3(3)$	Samuel, Li,&Mendel, PRL **67** (1991) 668;
a_μ^{expt}	< 0.02 ❇	Silverman&Shaw, PR **D27** (1983) 1196
	< 0.01 ❇	Escribano&Masso, PL **B301** (1993) 419
	< 0.11 ★	Grifols&Mendez, PL **B255** (1991) 611
	< 0.049	L3 (this analysis)

($d_\ell \neq 0$ forbidden by both T and P invariance)

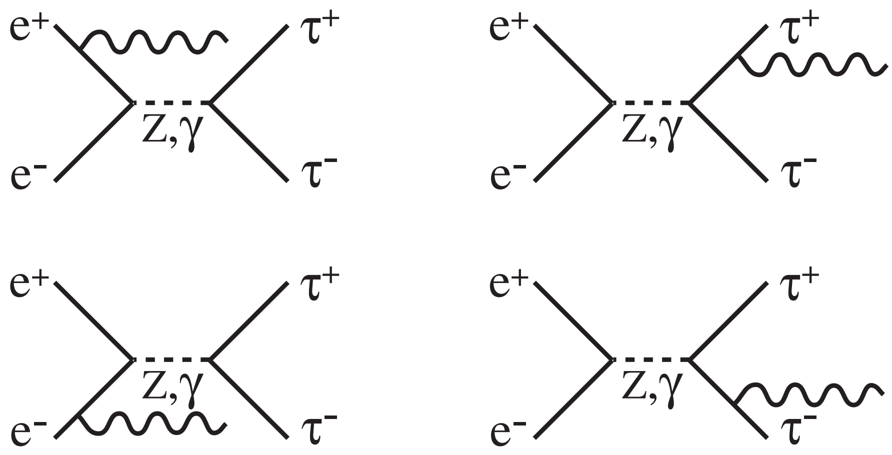
d_e^{expt}	$= (-2.7 \pm 8.3) \cdot 10^{-27}\, e\,\mathrm{cm}$	Abdullah *et al.*, PRL **65** (1990) 2347
d_μ^{expt}	$= (3.7 \pm 3.4) \cdot 10^{-19}\, e\,\mathrm{cm}$	Bailey *et al.*, JPG **4** (1978) 345
d_τ^{expt}	$< 1.4 \cdot 10^{-16}\, e\,\mathrm{cm}$ ❇	del Aguia&Sher, PL **B252** (1990) 116
	$< 0.5 \cdot 10^{-16}\, e\,\mathrm{cm}$ ❇	Escribano&Masso, PL **B301** (1993) 419
	$< 6.0 \cdot 10^{-16}\, e\,\mathrm{cm}$ ★	Grifols&Mendez, PL **B255** (1991) 611
	$< 2.7 \cdot 10^{-16}\, e\,\mathrm{cm}$	L3 (this analysis)

❇ from $e^+e^- \to \tau^+\tau^-$ rates and/or angular distributions ($q^2 \neq 0$)

★ simplistic analysis of early L3 $\tau\tau\gamma$ data

Outlook and Conclusions

- L3 has set the first limits on τ magnetic & electric dipole moments (at $q^2 = 0$)
- 25% more data to be processed but the analysis is still statistics limited
- Improved model (in progress) includes:
  - Full kinematics ($\tau\tau\gamma$ 4-vectors)
  - Z *and* γ photon exchange
  - All interference terms



  - Contributions linear in F_2 and F_3
  - Explicit calculation for F_3

Nonetheless, the τ-lepton still appears to be point-like