SEARCH FOR WEAK DIPOLE MOMENTS OF THE TAU LEPTON WITH THE ALEPH DETECTOR

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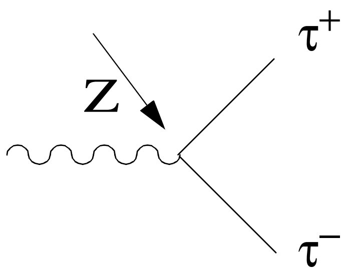
Weak Dipole Moments



In the SM:

$$ie\left[\frac{v_\tau}{2s_w c_w}\gamma^\mu - \frac{a_\tau}{2s_w c_w}\gamma^\mu\gamma^5\right]$$

With WEDM and WMDM the τ-Z vertex is written as

$$ie\left[\frac{v_\tau}{2s_w c_w}\gamma^\mu - \frac{a_\tau}{2s_w c_w}\gamma^\mu\gamma^5 + i\frac{\mu_\tau(M_Z^2)}{2m_\tau}\sigma^{\mu\nu}q_\nu + \frac{d_\tau(M_Z^2)}{2m_\tau}\gamma^5\sigma^{\mu\nu}q_\nu\right]$$

On-shell definitions

At tree level both the WEDM and WMDM are 0 in the SM

WEDM violates CP

Weak Dipole Moments

J. Bernabeu et al. have calculated at 1 loop $\mu_\tau(M_Z{}^2)$ in the SM

$$\mu_\tau(M_Z^2) = -(2.10 + 0.61i) \times 10^{-6}$$

Not measurable with present experiments. We try to look for possible desviations from the SM value.

For the WEDM the theoretical predictions is much less precise. One has to go to three-loops to get a non-vanishing contribution. An estimate found in the bibliography is

$\left|d_\tau(M_Z^2)\right| < 10^{-7} T_{SM}$ with T_{SM} the typical amplitude in the SM

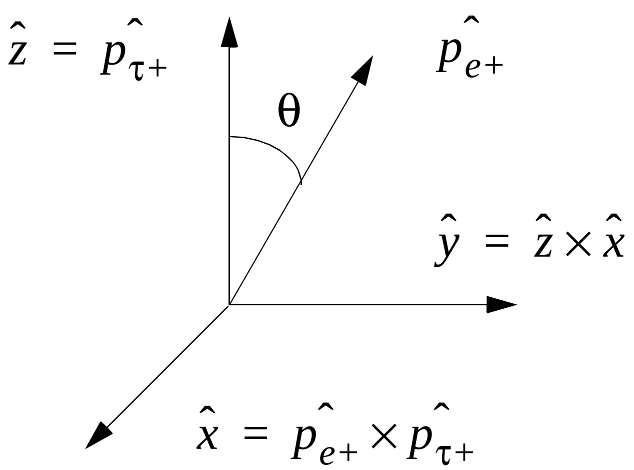
Theoretical approach to Weak Dipole Moments

In a general way, the differential cross section for unpolarized beams to produce $\tau^+\tau^-$ at the Z peak is given by (Stiegler)

$$\boxed{\frac{d^3\sigma}{d\Omega\, d\vec{w}_1\, d\vec{w}_2} = R_{00} + \sum_{a=1,3} R_{a0} w_1^a + \sum_{b=1,3} R_{0b} w_2^b + \sum_{a,b=1,3} R_{ab} w_1^a w_2^b}$$

with R_{ab} matrix elements than depends on the couplings and the production angle and $\overline{w}_1$, $\overline{w}_2$ are the quantisation axes for the spin measurement.

Choosing the following frame:



Theoretical approach to Weak Dipole Moments

More relevant terms for the determination of μ_τ:

$$(R_{02}) \propto \frac{1}{m}\sin\theta\cos\theta(|a_e|^2+|v_e|^2)\Re(a_\tau\mu_\tau)+\ldots$$
$$(R_{31}) \propto -\frac{1}{m}\sin\theta\cos\theta(|a_e|^2+|v_e|^2)\Im(a_\tau\mu_\tau)+\ldots$$

For d_τ :

$$(R_{01}) \propto -\frac{1}{m}\sin\theta\cos\theta(|a_e|^2+|v_e|^2)\Re(a_\tau d_\tau)+\ldots$$
$$(R_{32}) \propto \frac{1}{m}\sin\theta\cos\theta(|a_e|^2+|v_e|^2)\Im(a_\tau d_\tau)+\ldots$$

Present LEP analysis have used only R_{02} and R_{01} for μ_τ. One of the new features of this analysis is used the information from R_{31} in the determination of $\Im(\mu_\tau)$.

This technique

- In the case of $e^+ e^- \rightarrow \tau^+ \tau^-$ the “polarisation” of the τ (the $\overline{w}_1,\overline{w}_2$) can be inferred from the way the τ decays.

- The decay of τ the is assumed to occur through the W-current, in the SM.

- The way the τ decays in the SM is given by the TAUOLA program. Each decay can be described by

$$d\Gamma \propto (1 + \vec{h} \cdot \vec{w}) dLips$$

  - where $\overline{w}$ is the spin of the τ and $\overline{h}$ a vector that depends on the decay particle momenta. The expressions for $\overline{h}$ are taken from the TAUOLA code and are analitic.
  - For the π:

$$\vec{h} = \frac{2m_\tau}{m_\tau^2 - m_\pi^2} \vec{p}_\pi$$

$\vec{p}_\pi$ momentum in tau rest frame

- Channel to be used: π, $\rho \rightarrow \pi\pi^o$, $a_1^\pm \rightarrow \pi^\pm\pi^\pm\pi^\mp$ and $a_1^\pm \rightarrow \pi^\pm\pi^o\pi^o$

- Use selection and identification tools from previous ALEPH analysis.

This technique

- Both hemispheres have to be identified:
  - to measured the spin correlations
  - to reconstruct the τ direction.

- Total number of events (in 1990-1995) in those channels is ~48600. This includes most of the hadronic decays.

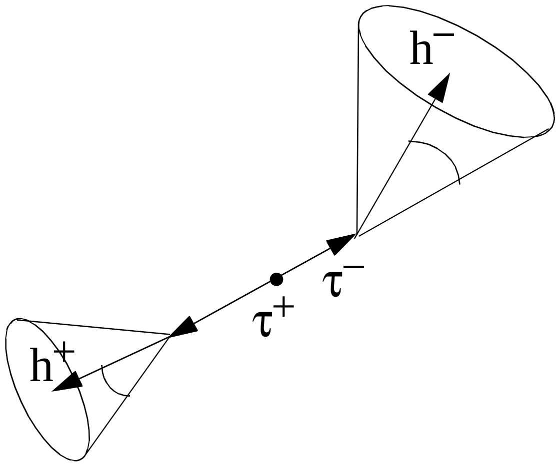
- Method to extract the anomalous couplings: minimize the following expression

$$L = -\sum_{n=1}^{N_{events}} \ln\left(\frac{\dfrac{d^3\sigma}{d\Omega\, d\vec{h}_1\, d\vec{h}_2}}{R_{00}}\right)$$

This technique

Tau Direction Reconstruction

- To build the polarimeters the tau direction is needed ➡ use only hadronic decays to minimize the loose of information on E-momenta due to neutrinos.
- In this case, assumming that the taus are produced back-to-back the tau direction can be determined with a two-fold ambiguity.



- Attempts have been done in ALEPH to use the information from the VERTEX detector to distinguish between both solutions, but only for about 60 % of the events the good tau solution is chosen.
- Here, no attempt is made to reconstruct the direction. The two solutions are “summed” (i.e. the event is used twice).
- Only events where there are two solutions are taken. This reduces the data sample to 30555 events.

This technique

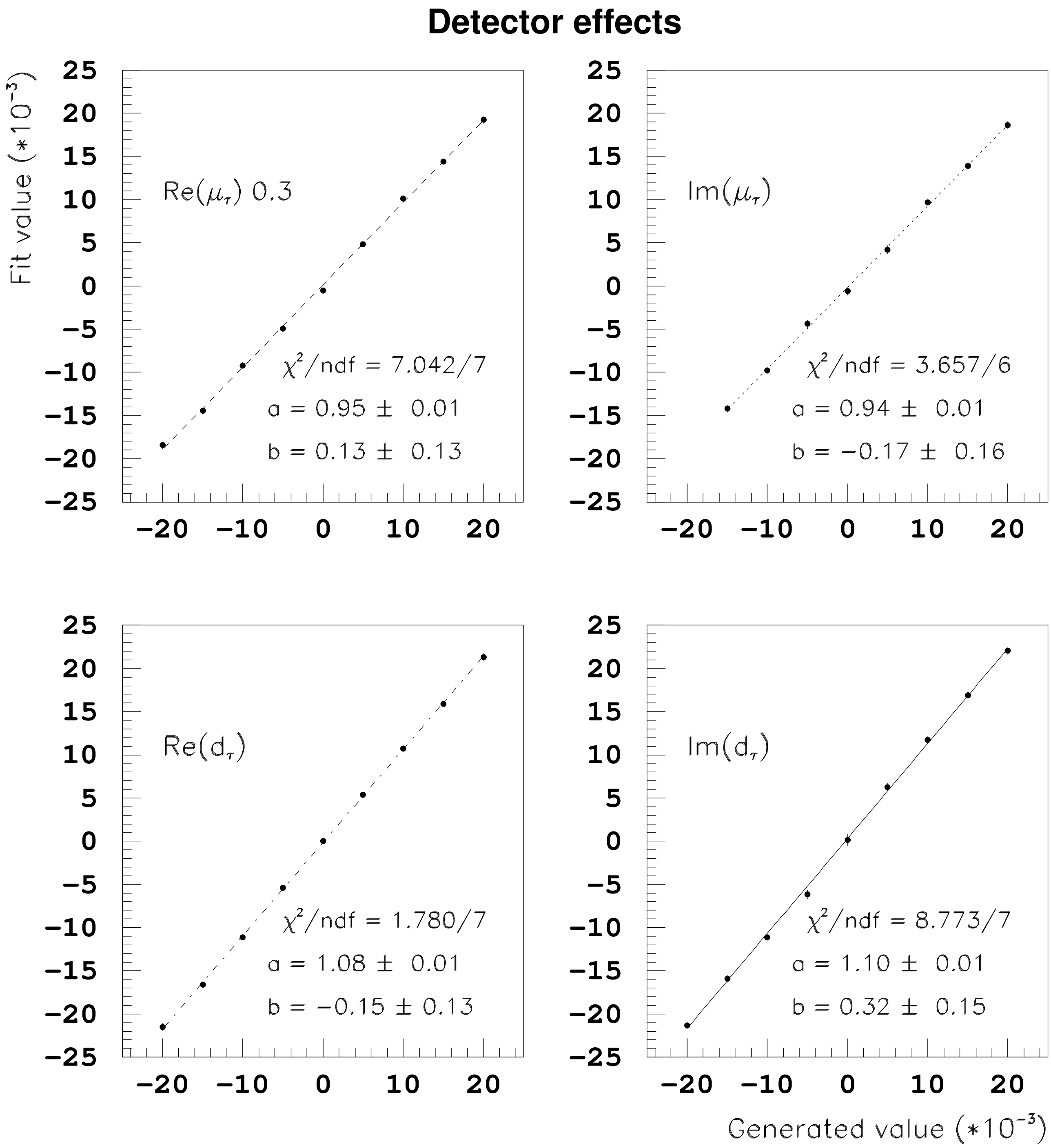
Checks done:

- With SCOT, fit fine at generator level, also including anomalous couplings.
- With KORB02, also results fine at generator level for ππ, ρρ and a_1a_1 generated events. (The recovered anomalous couplings are compatible with zero.)
- Detector effects studied with SCOT through detector similation, for πρ channels (18000 events). (No ISR). $\longrightarrow$
- Detector effects + ISR for πρ channels $\longrightarrow$
- DATA 1990-1995 (PRELIMINARY)

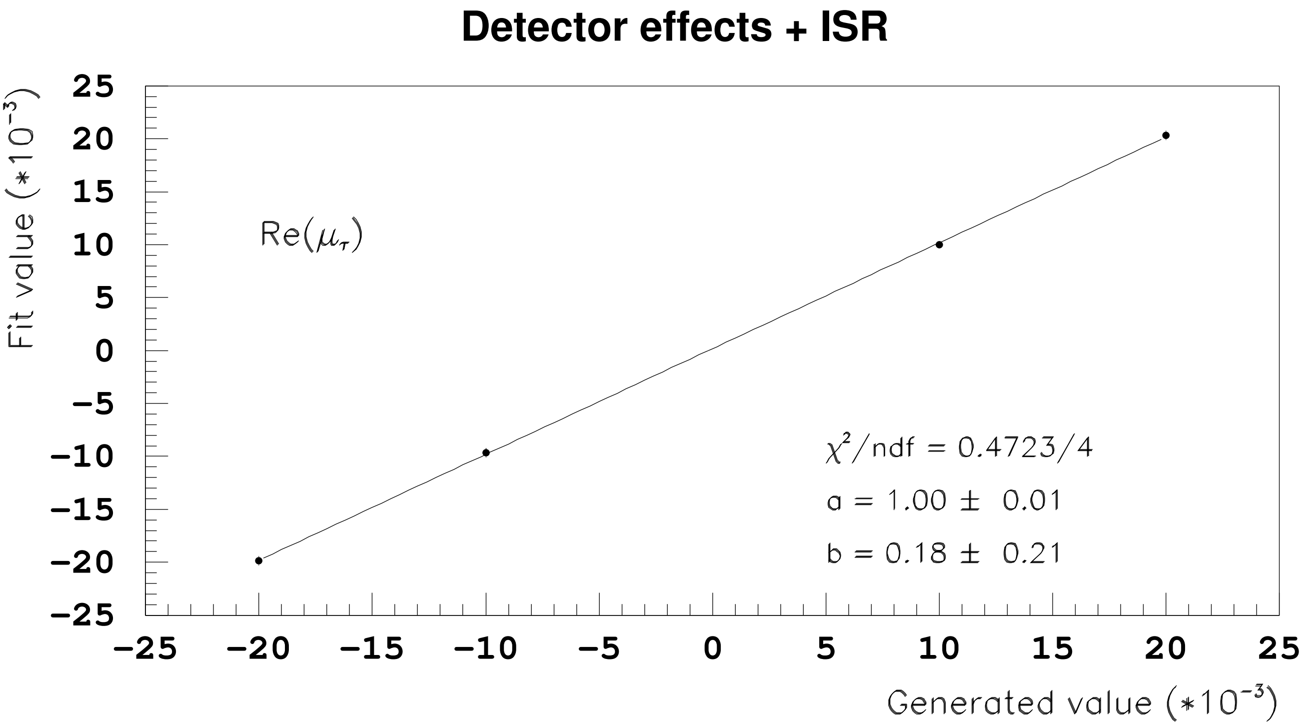
$$\begin{aligned}\Re(\mu_\tau) &= (0.801 \pm 0.405) \times 10^{-3} \\ \Im(\mu_\tau) &= -(0.398 \pm 0.573) \times 10^{-3}\end{aligned} \qquad 1\,\sigma$$

$$\Re(d_\tau) = -(0.288 \pm 0.387) \times 10^{-3}$$
$$\Im(d_\tau) = -(0.212 \pm 0.542) \times 10^{-3}$$

This technique



This technique



Outlook and Conclusions

- Longitudinal-normal spin correlations are being used for the first time to determine $\Im(\mu_\tau)$.

- To access the spin information, TAUOLA polarimeters are used.

- The anomalous couplings are extracted by mean of an event by event log-likelihood to maximize the information available in the data sample.

- Results very promising and competitive.

- Still some work to do to properly quote the systematics.