Measurement of Michel parameters in τ decays at high luminosity e^+e^- factories

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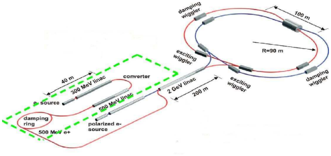
Outline:



Introduction: Michel parameters in τ decays

In the SM, charged weak interaction is described by the exchange of $W^\pm$ with a pure vector coupling to only left-handed fermions ("V-A" Lorentz structure). Deviations from "V-A" indicate New Physics. $\tau^- \to \ell^- \bar{\nu}_\ell \nu_\tau$ ($\ell = e, \mu$) decays provide clean laboratory to probe electroweak couplings.

The most general, Lorentz invariant four-lepton interaction matrix element:

$$\mathcal{M} = \frac{4G}{\sqrt{2}} \sum_{\substack{N=S,V,T\\ i,j=L,R}} g_{ij}^N \left[\bar{u}_i(l^-)\Gamma^N v_n(\bar{\nu}_l)\right]\left[\bar{u}_m(\nu_\tau)\Gamma_N u_j(\tau^-)\right],$$

$$\Gamma^S = 1,\ \Gamma^V = \gamma^\mu,\ \Gamma^T = \frac{i}{2\sqrt{2}}(\gamma^\mu\gamma^\nu - \gamma^\nu\gamma^\mu)$$

Ten couplings g_{ij}^N, in the SM the only non-zero constant is $g_{LL}^V = 1$

Four bilinear combinations of g_{ij}^N, which are called as Michel parameters (MP): $\boldsymbol{\rho}$, $\boldsymbol{\eta}$, $\boldsymbol{\xi}$ and $\boldsymbol{\delta}$ appear in the energy spectrum of the outgoing lepton:

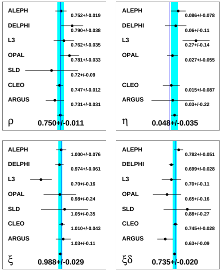
$$\frac{d\Gamma(\tau^\mp)}{d\Omega dx} = \frac{4G_F^2 M_\tau E_{\max}^4}{(2\pi)^4}\sqrt{x^2 - x_0^2}\Bigg(x(1-x) + \frac{2}{9}\boldsymbol{\rho}(4x^2 - 3x - x_0^2) + \boldsymbol{\eta} x_0(1-x)$$

$$\mp\frac{1}{3}P_\tau cos\theta_\ell \boldsymbol{\xi}\sqrt{x^2 - x_0^2}\left[1 - x + \frac{2}{3}\boldsymbol{\delta}\left(4x - 4 + \sqrt{1 - x_0^2}\right)\right]\Bigg),\ x = \frac{E_\ell}{E_{\max}},\ x_0 = \frac{m_\ell}{E_{\max}}$$

In the SM: $\boldsymbol{\rho} = \frac{3}{4}$, $\boldsymbol{\eta} = 0$, $\boldsymbol{\xi} = 1$, $\boldsymbol{\delta} = \frac{3}{4}$

Introduction: Current status

Michel par.	Measured value	Experiment	SM value
ρ (e or μ)	$0.747 \pm 0.010 \pm 0.006$ 1.2%	CLEO-97	3/4
η (e or μ)	$0.012 \pm 0.026 \pm 0.004$ 2.6%	ALEPH-01	0
ξ (e or μ)	$1.007 \pm 0.040 \pm 0.015$ 4.3%	CLEO-97	1
$\xi\delta$ (e or μ)	$0.745 \pm 0.026 \pm 0.009$ 2.8%	CLEO-97	3/4
ξ_h (all hadr.)	$0.992 \pm 0.007 \pm 0.008$ 1.1%	ALEPH-01	1



In BSM models the couplings to τ are expected to be enhanced in comparison with μ.

- **Type II 2HDM:** $\eta_\mu(\tau) = \frac{m_\mu M_\tau}{2}\left(\frac{\tan^2\beta}{M^2_{H^\pm}}\right)^2$; $\frac{\eta_\mu(\tau)}{\eta_e(\mu)} = \frac{M_\tau}{m_e} \approx 3500$
- **Tensor interaction:** $\mathcal{L} = \frac{g}{2\sqrt{2}} W^\mu \left\{ \bar{\nu}\gamma_\mu(1-\gamma^5)\tau + \frac{\kappa^W_\tau}{2m_\tau}\partial^\nu \left(\bar{\nu}\sigma_{\mu\ nu}(1-\gamma^5)\tau\right)\right\}$,
  $-0.096 < \kappa^W_\tau < 0.037$: DELPHI Abreu EPJ C16 (2000) 229.
- **Unparticles:** Moyotl PRD 84 (2011) 073010, Choudhury PLB 658 (2008) 148.
- **Lorentz and CPTV:** Hollenberg PLB **701** (2011) 89
- **Heavy Majorana neutrino:** M. Doi *et al.*, Prog. Theor. Phys. **118** (2007) 1069.

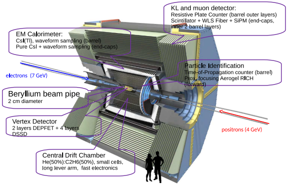
With $\times$300 Belle statistics it was confirmed that the statistical uncertainties of Michel parameters can be reduced by one order of magnitude

Belle II with unpolarized beams

Planned integrated luminosity is 50 ab^{-1}

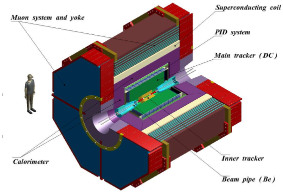
$$\sigma(b\bar{b}) = 1.05\ \text{nb} \quad N_{b\bar{b}} = 53 \times 10^9$$
$$\sigma(c\bar{c}) = 1.30\ \text{nb} \quad N_{c\bar{c}} = 65 \times 10^9$$
$$\boldsymbol{\sigma(\tau\tau) = 0.92\ \text{nb} \quad N_{\tau\tau} = 46 \times 10^9}$$

Belle II detector



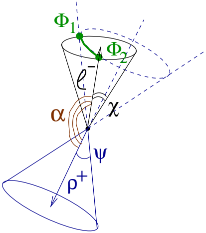
Super Charm-Tau factory with polarized e^- beam

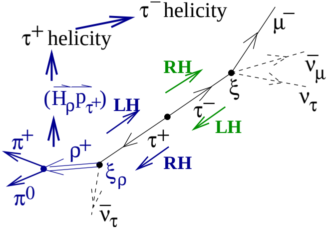
In five c.m.s. energy points
($2E = 3.554,\ 3.686,\ 3.770,\ 4.170,\ 4.650$ GeV)
it is planned to accumulate 7 ab^{-1}, which
corresponds to $\boldsymbol{N_{\tau\tau} = 21 \times 10^9}$

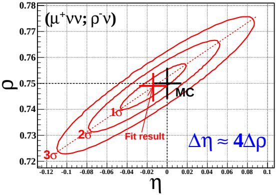


The polarized e^- beam results in the nonzero average polarization of single tau, which provide advantages in the measurement of ξ and δ Michel parameters.

Effect of τ spin-spin correlation is used to measure ξ and δ MP.
Events of the ($\tau^\mp \to \ell^\mp \nu\nu$; $\tau^\pm \to \rho^\pm \nu$) topology are used to measure: ρ, η, $\xi_\rho \xi$ and $\xi_\rho \xi \delta$, while ($\tau^\mp \to \rho^\mp \nu$; $\tau^\pm \to \rho^\pm \nu$) events are used to extract ξ_ρ^2.







$$\frac{d\sigma(\ell^\mp\nu\nu, \rho^\pm\nu)}{dE^*_\ell d\Omega^*_\ell d\Omega^*_\rho dm^2_{\pi\pi} d\tilde{\Omega}_\pi d\Omega_\tau} = A_0 + \rho A_1 + \eta A_2 + \xi_\rho \xi A_3 + \xi_\rho \xi \delta A_4 = \sum_{i=0}^{4} A_i \Theta_i$$

$$\mathcal{F}(\vec{z}) = \frac{d\sigma(\ell^\mp\nu\nu, \rho^\pm\nu)}{dp_\ell d\Omega_\ell dp_\rho d\Omega_\rho dm^2_{\pi\pi} d\tilde{\Omega}_\pi} = \int\limits_{\Phi_1}^{\Phi_2} \frac{d\sigma(\ell^\mp\nu\nu, \rho^\pm\nu)}{dE^*_\ell d\Omega^*_\ell d\Omega^*_\rho dm^2_{\pi\pi} d\tilde{\Omega}_\pi d\Omega_\tau} \left| \frac{\partial(E^*_\ell, \Omega^*_\ell, \Omega^*_\rho, \Omega_\tau)}{\partial(p_\ell, \Omega_\ell, p_\rho, \Omega_\rho, \Phi_\tau)} \right| d\Phi_\tau$$

$$L = \prod_{k=1}^{N} \mathcal{P}^{(k)}, \;\; \mathcal{P}^{(k)} = \mathcal{F}(\vec{z}^{(k)})/\mathcal{N}(\vec{\Theta}), \;\; \mathcal{N}(\vec{\Theta}) = \int \mathcal{F}(\vec{z}) d\vec{z}, \;\; \vec{\Theta} = (1, \rho, \eta, \xi_\rho\xi_\ell, \xi_\rho\xi_\ell\delta_\ell)$$

$$\mathcal{P}_{\textbf{total}} = (1 - \sum_{i=1}^{4} \lambda_i) \mathcal{P}^{\ell-\rho}_{signal} + \lambda_1 \mathcal{P}^{\ell-3\pi}_{bg} + \lambda_2 \mathcal{P}^{\pi-\rho}_{bg} + \lambda_3 \mathcal{P}^{\rho-\rho}_{bg} + \lambda_4 \mathcal{P}^{other}_{bg} \,\textbf{(MC)}$$

MP are extracted in the unbinned maximum likelihood fit of $(\ell\nu\nu;\ \rho\nu)$ events in the 9D phase space $\vec{z} = (p_\ell,\ \cos\theta_\ell,\ \phi_\ell,\ p_\rho,\ \cos\theta_\rho,\ \phi_\rho,\ m^2_{\pi\pi},\ \cos\tilde{\theta}_\pi,\ \tilde{\phi}_\pi)$ in CMS.

Method: theoretical framework

W. Fetscher, Phys. Rev. D **42** (1990) 1544. K. Tamai, Nucl. Phys. B **668** (2003) 385.

$$\frac{d\sigma(\vec{\zeta},\vec{\zeta}')}{d\Omega} = \frac{\alpha^2}{64E_\tau^2}\beta_\tau(D_0 + D_{ij}\zeta_i\zeta_j')$$

$$\frac{d\Gamma(\tau^\mp(\vec{\zeta}^*) \to \ell^\mp\nu\nu)}{dx^* d\Omega_\ell^*} = \kappa_\ell(A(x^*) \mp \xi\vec{n}_\ell^*\vec{\zeta}^* B(x^*)),\ x^* = E_\ell^*/E_{\ell max}^*$$

$$A(x^*) = A_0(x^*) + \rho A_1(x^*) + \eta A_2(x^*),\ B(x^*) = B_1(x^*) + \delta B_2(x^*)$$

$$\frac{d\Gamma(\tau^\pm(\vec{\zeta'}^*) \to \rho^\pm\nu)}{dm_{\pi\pi}^2 d\Omega_\rho^* d\tilde{\Omega}_\pi} = \kappa_\rho(A' \mp \xi_\rho\vec{B'}\vec{\zeta'}^*)W(m_{\pi\pi}^2) = \kappa_\rho A'(1 \mp \xi_\rho\vec{H}_\rho\vec{\zeta'}^*)W(m_{\pi\pi}^2)$$

$$\vec{H}_\rho = \frac{\vec{B'}}{A'} - \text{polarimeter vector},\ \xi_\rho = -\frac{2Re(c_V^* c_A)}{|c_V|^2 + |c_A|^2} = -h_{\nu_\tau}\ (h_{\nu_\tau} = -1 \text{ in the SM})$$

$$A' = 2(q,Q)Q_0^* - Q^2 q_0^*,\ \vec{B'} = Q^2\vec{K}^* + 2(q,Q)\vec{Q}^*,\ W = |F_\pi(m_{\pi\pi}^2)|^2\frac{p_\rho(m_{\pi\pi}^2)\tilde{p}_\pi(m_{\pi\pi}^2)}{M_\tau m_{\pi\pi}}$$

$$\frac{d\sigma(\ell^\mp,\rho^\pm)}{dE_\ell^* d\Omega_\ell^* d\Omega_\rho^* dm_{\pi\pi}^2 d\tilde{\Omega}_\pi d\Omega_\tau} = \kappa_\ell\kappa_\rho\frac{\alpha^2\beta_\tau}{64E_\tau^2}(D_0 A' A(E_\ell^*) + \xi_\rho\xi_\ell D_{ij} n_{\ell i}^* B_j' B(E_\ell^*))W(m_{\pi\pi}^2)$$

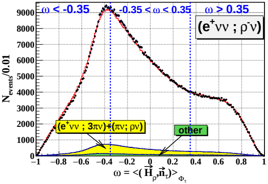
$$\frac{d\sigma(\ell^\mp,\rho^\pm)}{dp_\ell d\Omega_\ell dp_\rho d\Omega_\rho dm_{\pi\pi}^2 d\tilde{\Omega}_\pi} = \int_{\Phi_1}^{\Phi_2}\frac{d\sigma(\ell^\mp,\rho^\pm)}{dE_\ell^* d\Omega_\ell^* d\Omega_\rho^* dm_{\pi\pi}^2 d\tilde{\Omega}_\pi d\Omega_\tau}\left|\frac{\partial(E_\ell^*,\Omega_\ell^*,\Omega_\rho^*,\Omega_\tau)}{\partial(p_\ell,\Omega_\ell,p_\rho,\Omega_\rho,\Phi_\tau)}\right| d\Phi_\tau$$

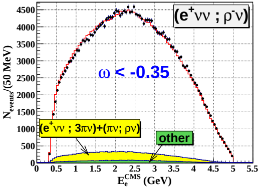
Method: helicity sensitive variable

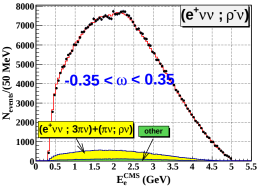
M. Davier *et. al* Phys. Lett. B **306** (1993) 411.

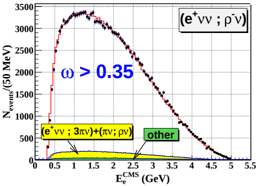
Helicity sensitive variable ω is introduced as:

$$\omega = \frac{1}{\Phi_2 - \Phi_1}\int_{\Phi_1}^{\Phi_2} (\vec{H}_{\rho\pm}, \vec{n}_{\tau\pm}) d\Phi = < (\vec{H}_{\rho\pm}, \vec{n}_{\tau\pm}) >_{\Phi_\tau}$$









Spin-spin correlation manifests itself through momentum-momentum correlations of final lepton and pions.

Method: corrections, detector effects, background

Physical corrections:

- All $\mathcal{O}(\alpha^3)$ QED and electroweak higher order corrections to $e^+e^- \to \tau^+\tau^-(\gamma)$ are included
- Radiative leptonic decays $\tau^- \to \ell^-\bar{\nu}_\ell\nu_\tau\gamma$
- Radiative decay $\tau^- \to \pi^-\pi^0\nu_\tau\gamma$

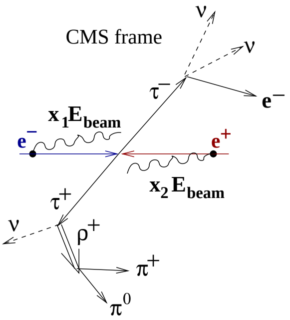
Detector effects:

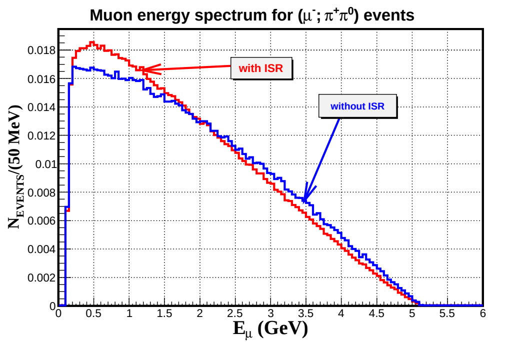
- Track momentum resolution
- γ energy and angular resolution
- Effect of external bremsstrahlung for $e-\rho$ events
- Beam energy spread
- EXP/MC efficiency corrections (trigger, track rec., π^0 rec., ℓID, πID)

Background at Belle:
The main background comes from $(\ell\nu\nu;\ \pi 2\pi^0\nu)(\sim 10\%)$, $(\pi\nu;\ \pi\pi^0\nu)(\sim 1.5\%)$ and $(\rho^+\nu;\ \rho^-\nu)(\sim 0.5\%)$ events, it is included in PDF analytically. The remaining background($\sim$2.0%) is taken into account using MC-based approach.

Background from the non-$\tau\tau$ events is $\lesssim 0.1\%$.

Initial state radiation (ISR)





$$\frac{d\sigma_{\text{vis}}(s)}{dp_\ell d\Omega_\ell dp_\rho d\Omega_\rho dm^2_{\pi\pi} d\tilde{\Omega}_\pi} = \iint_0^1 dx_1 dx_2 D(x_1) D(x_2) \frac{d\sigma(s(1-x_1)(1-x_2))}{dp'_\ell d\Omega'_\ell dp'_\rho d\Omega'_\rho dm^2_{\pi\pi} d\tilde{\Omega}_\pi} \left|\frac{\partial(p'_\ell,\Omega'_\ell)}{\partial(p_\ell,\Omega_\ell)}\right| \left|\frac{\partial(p'_\rho,\Omega'_\rho)}{\partial(p_\rho,\Omega_\rho)}\right|$$

- $D(x) = x^{\beta/2-1}h(x)$ - probability function for initial $e^\mp$ to emit a γ-quantum jet carrying $x_{1,2}$ part of $e^\mp$ energy $E_{\text{beam}} = \sqrt{s}/2$. $\beta = \frac{2\alpha}{\pi}(\ln\frac{s}{m^2} - 1)$, $h(x)$ - smooth limited function.
- $\left|\frac{\partial(p'_i,\Omega'_i)}{\partial(p_i,\Omega_i)}\right|$ $(i = \ell,\ \rho)$ - Jacobian of transformation from the $\tau^+\tau^-$ rest frame to the Belle CMS.

At the Super Charm-Tau factory the impact of the ISR is expected to be essentially smaller.

Description of background at Belle

Total PDF

$$\mathcal{P}(x) = \frac{\overline{\varepsilon(x)}}{\bar{\varepsilon}}\Bigg((1-\sum_i \lambda_i)\frac{S(x)}{\int \frac{\overline{\varepsilon(x)}}{\bar{\varepsilon}} S(x)dx} + \lambda_{3\pi}\frac{\tilde{B}_{3\pi}(x)}{\int \frac{\overline{\varepsilon(x)}}{\bar{\varepsilon}} \tilde{B}_{3\pi}(x)dx} + \lambda_{\pi}\frac{\tilde{B}_{\pi}(x)}{\int \frac{\overline{\varepsilon(x)}}{\bar{\varepsilon}} \tilde{B}_{\pi}(x)dx} + \lambda_{\rho}\frac{\tilde{B}_{\rho}(x)}{\int \frac{\overline{\varepsilon(x)}}{\bar{\varepsilon}} \tilde{B}_{\rho}(x)dx} +$$

$$+(1-\sum_i \lambda_i)\frac{N^{\rm sel}_{\rm rest}(x)}{N^{\rm sel}_{\rm sig}(x)} S_{\rm SM}(x)\Bigg)$$

$$\tilde{B}_{3\pi}(x) = \int 2(1-\varepsilon_{\pi^0}(y))\varepsilon_{\rm add}(y) B_{3\pi}(x,y)dy,\ \tilde{B}_{\pi}(x) = \frac{\varepsilon^{\mu ID}_{\pi\to\mu}(p_\ell,\ \Omega_\ell)}{\varepsilon^{\mu ID}_{\mu\to\mu}(p_\ell,\ \Omega_\ell)} B_{\pi}(x)$$

$$\tilde{B}_{\rho}(x) = \frac{\varepsilon^{\mu ID}_{\pi\to\mu}(p_\ell,\ \Omega_\ell)}{\varepsilon^{\mu ID}_{\mu\to\mu}(p_\ell,\ \Omega_\ell)} \int (1-\varepsilon_{\pi^0}(y))\varepsilon_{\rm add}(y) B_{\rho}(x,y)dy,\ \overline{\varepsilon(x)} = \epsilon^{\rm EXP}_{\rm corr}(x)\varepsilon(x)$$

- $x = (p_\ell,\ \Omega_\ell,\ p_\rho,\ \Omega_\rho,\ m^2_{\pi\pi},\ \tilde{\Omega}_\pi);\ y = (p_{\pi^0},\ \Omega_{\pi^0})$;
- $S(x)$ - theoretical density of signal ($\ell^\mp\nu\nu,\ \rho^\pm\nu$) events;
- $B_{3\pi}(x,y)$ - theoretical density of background ($\ell^\mp\nu\nu,\ \pi^\pm 2\pi^0\nu$) events;
- $B_\pi(x)$ - theoretical density of background ($\pi^\mp\nu,\ \rho^\pm\nu$) events;
- $B_\rho(x)$ - theoretical density of background ($\rho^\mp\nu,\ \rho^\pm\nu$) events;
- $\varepsilon(x)$ - detection efficiency for signal events (**common multiplier**);
- $N^{\rm sel}_{\rm rest}(x)/N^{\rm sel}_{\rm sig}(x)$ - number of the selected (remaining/signal) MC events in the multidimensional cell around "x". Admixture of the remaining background is $(1 \div 2)\%$.
- λ_i - i-th background fraction (from MC)
- $\varepsilon_{\pi^0}(y)$ - π^0 detection efficiency (tabulated from MC);
- $\varepsilon_{\rm add}(y) = \varepsilon^{3\pi}_{\rm add}(y)/\varepsilon^{\rm sig}_{\rm add}$ - ratio of the $E^{\rm LAB}_{\gamma \rm rest}$ cut efficiencies (tabulated from MC);
- $\varepsilon^{\mu ID}_{\pi\to\mu}(p_\ell,\ \Omega_\ell)/\varepsilon^{\mu ID}_{\mu\to\mu}(p_\ell,\ \Omega_\ell)$ is tabulated from MC;
- $\epsilon^{\rm EXP}_{\rm corr}(x)$ - EXP/MC efficiency correction.

Systematic uncertainties at Belle

Source	$\Delta(\rho)$, %	$\Delta(\eta)$, %	$\Delta(\xi_\rho\xi)$, %	$\Delta(\xi_\rho\xi\delta)$, %
Physical corrections				
ISR+$\mathcal{O}(\alpha^3)$	0.10	0.30	0.20	0.15
$\tau \to \ell\nu\nu\gamma$	0.03	0.10	0.09	0.08
$\tau \to \rho\nu\gamma$	0.06	0.16	0.11	0.02
Background	0.20	0.60	0.20	0.20
Apparatus corrections				
Resolution $\oplus$ brems.	0.10	0.33	0.11	0.19
$\sigma(E_{\mathrm{beam}})$	0.07	0.25	0.03	0.15
Normalization				
$\Delta\mathcal{N}$	0.11	0.50	0.17	0.13
without EXP/MC corr.	**0.3**	**1.0**	**0.4**	**0.4**

Effect of the e^- beam polarization

At the Super Charm-Tau factory with polarized electron beam the average polarization of single τ is nonzero, hence the differental decay probability will contain both, τ spin-dependent and spin-independent parts.

$$\frac{d\sigma(\vec{\zeta}^-,\vec{\zeta}^+)}{d\Omega_\tau} = \frac{\alpha^2}{64E_\tau^2}\beta_\tau(D_0 + D_{ij}\zeta_i^-\zeta_j^+ + \mathcal{P}_e(F_i^-\zeta_i^- + F_j^+\zeta_j^+))$$

$$D_0 = 1+\cos^2\theta + \frac{1}{\gamma_\tau^2}\sin^2\theta,\ \mathcal{P}_e = \frac{N_e(+)-N_e(-)}{N_e(+)+N_e(-)}$$

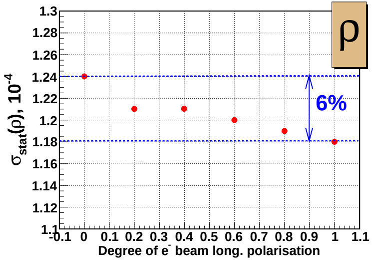
$$D_{ij} = \begin{pmatrix} (1+\frac{1}{\gamma_\tau^2})\sin^2\theta & 0 & \frac{1}{\gamma_\tau}\sin 2\theta \\ 0 & -\beta_\tau^2\sin^2\theta & 0 \\ \frac{1}{\gamma_\tau}\sin 2\theta & 0 & 1+\cos^2\theta - \frac{1}{\gamma_\tau^2}\sin^2\theta \end{pmatrix}$$

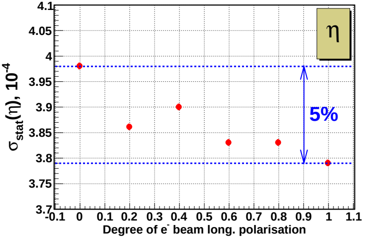
Single τ studies at the Super Charm-Tau factory:

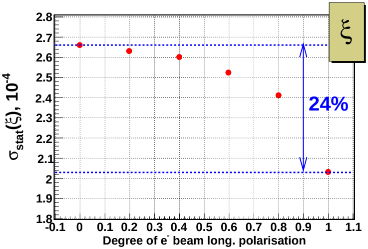
$$\frac{d\sigma(\vec{\zeta}^-)}{d\Omega_\tau} = \frac{\alpha^2}{32E_\tau^2}\beta_\tau(D_0 + \mathcal{P}_e F_i^-\zeta_i^-)$$

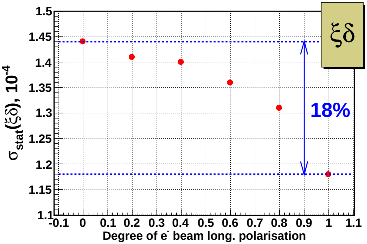
Belle II with polarized e^- beam

In case of the usage of spin-spin correlation as well as the polarized electron beam for the $\ell - -\rho$ events, the improvement of the sensitivity due to the electron beam is $\lesssim$ 10%









Single τ decay with polarized e^- beam

$$\frac{d\sigma(\vec{\zeta})}{d\Omega_\tau} = \frac{\alpha^2}{32E_\tau^2}\beta_\tau(D_0 + \mathcal{P}_e F_i \zeta_i)$$

$$\frac{d\Gamma(\tau^\mp(\vec{\zeta}^*) \to \ell^\mp \nu\nu)}{dx^* d\Omega_\ell^*} = \kappa_\ell(A(x^*) \mp \xi_\ell \vec{n}_\ell^* \vec{\zeta}^* B(x^*)),\ x^* = E_\ell^*/E_{\ell max}^*$$

$$A(x^*) = A_0(x^*) + \rho A_1(x^*) + \eta A_2(x^*),\ B(x^*) = B_1(x^*) + \delta B_2(x^*)$$

$$\frac{d\sigma(\ell^\mp)}{dE_\ell^* d\Omega_\ell^* d\Omega_\tau} = \kappa_\ell \frac{\alpha^2\beta_\tau}{32E_\tau^2}(D_0 A(E_\ell^*) \mp \mathcal{P}_e \xi_\ell F_i n_{\ell i}^* B(E_\ell^*))$$

$$\frac{d\sigma(\ell^\mp)}{dp_\ell d\Omega_\ell} = \int\limits_{\Omega_\tau-\text{sector}} \frac{d\sigma(\ell^\mp)}{dE_\ell^* d\Omega_\ell^* d\Omega_\tau}\left|\frac{\partial(E_\ell^*, \Omega_\ell^*)}{\partial(p_\ell, \Omega_\ell)}\right| d\Omega_\tau$$

Ω_τ-sector is determined by the kinematical constraint $m_{\nu\nu} > 0$

- All Michel parameters (ρ, η, $\mathcal{P}_e\xi$, $\mathcal{P}_e\xi\delta$) are measured in the unbinned maximum likelihood fit of ($\tau^- \to \ell^-\bar{\nu}_\ell\nu_\tau;\ \tau^+ \to \text{all}$) events in the **3D** phase space.
- The reduced 3D phase space allows one to tabulate various EXP/MC corrections to the detection efficiency more precisely.

Due to the nonuniform detection efficiency for the decays of the opposite tau, there is still some contribution from the spin-spin correlation term.

$\tau^- \to \pi^-/\rho^-\nu_\tau$ decay to monitor $\mathcal{P}_e$

$$\frac{d\sigma(\vec{\zeta})}{d\Omega_\tau} = \frac{\alpha^2}{32E_\tau^2}\beta_\tau(D_0 + \mathcal{P}_e F_i \zeta_i)$$

$$\frac{d\Gamma(\tau^\mp \to \pi^\mp\nu)}{d\Omega_\pi^*} = \kappa_\pi\left(1 \pm \xi_\pi \vec{\zeta}\vec{n}_\pi^*\right), \quad \frac{d\Gamma(\tau^\mp \to \rho^\mp\nu)}{dm_{\pi\pi}^2 d\Omega_\rho^* \tilde{\Omega}_\pi} = f(\vec{k}_1, \vec{k}_2)(1 \pm \xi_\rho \vec{\zeta}\vec{H}_\rho^*)$$

$$\frac{d\sigma(\pi^\mp)}{d\Omega_\pi^* d\Omega_\tau} = \kappa_\pi \frac{\alpha^2\beta_\tau}{32E_\tau^2}(D_0 \pm \mathcal{P}_e\xi_\pi F_i n_{\pi i}^*)$$

$$\frac{d\sigma(\rho^\mp)}{d\Omega_\rho^* dm_{\pi\pi}^2 \tilde{\Omega}_\pi d\Omega_\tau} = f(\vec{k}_1, \vec{k}_2)\frac{\alpha^2\beta_\tau}{32E_\tau^2}(D_0 \pm \mathcal{P}_e\xi_\rho F_i H_{\rho i}^*)$$

$$\frac{d\sigma(\pi^\mp)}{dp_\pi d\Omega_\pi} = \int_0^{2\pi} \frac{d\sigma(\pi^\mp)}{d\Omega_\pi^* d\Omega_\tau}\left|\frac{\partial(\Omega_\pi^*, \Omega_\tau)}{\partial(p_\pi, \Omega_\pi, \Phi_\tau)}\right| d\Phi_\tau$$

$$\frac{d\sigma(\rho^\mp)}{dp_\rho d\Omega_\rho dm_{\pi\pi}^2 \tilde{\Omega}_\pi} = \int_0^{2\pi} \frac{d\sigma(\rho^\mp)}{d\Omega_\rho^* dm_{\pi\pi}^2 \tilde{\Omega}_\pi d\Omega_\tau}\left|\frac{\partial(\Omega_\rho^*, \Omega_\tau)}{\partial(p_\rho, \Omega_\rho, \Phi_\tau)}\right| d\Phi_\tau$$

Parameters ($\mathcal{P}_e\xi_\pi$, $\mathcal{P}_e\xi_\rho$) are measured in the unbinned maximum likelihood fit of the ($\tau^- \to \pi^-/\rho^-\nu_\tau$; $\tau^+ \to$ all) events. These decays can be used to monitor $\mathcal{P}_e$ with high precision.

Summary

- The procedure to measure 4 Michel parameters (MP) (ρ, η, ξ, $\xi\delta$) in leptonic τ decays at B factory has been developed and tested. It is based on the analysis of the $(\ell^{\mp}\nu\nu;\ \rho^{\pm}\nu)$, $\ell = e,\ \mu$ events and utilizes spin-spin correlation of tau leptons.
- We confirmed that with the whole Belle data sample the statistical accuracy of MP is by one order of magnitude better than in the previous best measurements (CLEO, ALEPH).
- The main background components $((\ell\nu\nu;\ \pi 2\pi^0\nu), (\pi\nu;\ \rho\nu), (\rho\nu;\ \rho\nu))$ are described analytically in the fitter.
- Various EXP/MC efficiency corrections provide the dominant contribution to the systemtic uncertainties of MP.
- Nonzero average polarization of single τ at the Super Charm-Tau factory provides the possibility to measure all Michel parameters without tagging the opposite tau. Better systematic uncertainty can be reached due to the smaller impact of the ISR as well as notably reduced phase space (PS).
- Effect of the remaining contribution of the spin-spin correlation due to the nonuniformity of the detection efficiency in the PS for the decays of the opposite tau should be studied with realistic MC simulation.
- Better background description in the smaller PS.
- The reduced phase space allows one to tabulate various EXP/MC corrections to the detection efficiency more precisely.
- **Good potential for the Super Charm-Tau factory to improve the results obtained at B factories and compete with Belle II.**

Backup slides

Michel parameters

$$\rho = \frac{3}{4} - \frac{3}{4}\left(|g^V_{LR}|^2 + |g^V_{RL}|^2 + 2|g^T_{LR}|^2 + 2|g^T_{RL}|^2 + \Re(g^S_{LR}g^{T*}_{LR} + g^S_{RL}g^{T*}_{RL})\right)$$

$$\eta = \frac{1}{2}\Re\left(6g^V_{RL}g^{T*}_{LR} + 6g^V_{LR}g^{T*}_{RL} + g^S_{RR}g^{V*}_{LL} + g^S_{RL}g^{V*}_{LR} + g^S_{LR}g^{V*}_{RL} + g^S_{LL}g^{V*}_{RR}\right)$$

$$\xi = 4\Re(g^S_{LR}g^{T*}_{LR}) - 4\Re(g^S_{RL}g^{T*}_{RL}) + |g^V_{LL}|^2 + 3|g^V_{LR}|^2 - 3|g^V_{RL}|^2 - |g^V_{RR}|^2 +$$

$$+5|g^T_{LR}|^2 - 5|g^T_{RL}|^2 + \frac{1}{4}|g^S_{LL}|^2 - \frac{1}{4}|g^S_{LR}|^2 + \frac{1}{4}|g^S_{RL}|^2 - \frac{1}{4}|g^S_{RR}|^2$$

$$\xi\delta = \frac{3}{16}|g^S_{LL}|^2 - \frac{3}{16}|g^S_{LR}|^2 + \frac{3}{16}|g^S_{RL}|^2 - \frac{3}{16}|g^S_{RR}|^2 - \frac{3}{4}|g^T_{LR}|^2 + \frac{3}{4}|g^T_{RL}|^2 +$$

$$+\frac{3}{4}|g^V_{LL}|^2 - \frac{3}{4}|g^V_{RR}|^2 + \frac{3}{4}\Re(g^S_{LR}g^{T*}_{LR}) - \frac{3}{4}\Re(g^S_{RL}g^{T*}_{RL})$$