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τ-Decays to Five Mesons in TAUOLA

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ABSTRACT

The τ-decay library TAUOLA has gained popularity over the last decade. However, with continuously increasing precision of the data, some of its functionality has become insufficient. One of the requirements is the implementation of decays into five mesons plus neutrino with a realistic decay amplitude. This note describes a step into this direction. For the $2\pi^-\pi^+2\pi^0$-mode the three decay chains $\tau^- \to a_1^-\nu \to \rho^-(\to \pi^-\pi^0)\omega(\to \pi^-\pi^+\pi^0)\nu$, $\tau^- \to a_1^-\nu \to a_1^-(\to 2\pi^-\pi^+)f_0(\to 2\pi^0)\nu$, and $\tau^- \to a_1^-\nu \to a_1^-(\to \pi^-2\pi^0)f_0(\to \pi^+\pi-)\nu$ are introduced with simple assumptions about the couplings and propagators of the various resonances. Similar amplitudes (without the $\rho\omega$-contributions) are adopted for the $\pi^-4\pi^0$- and $3\pi^-2\pi^+$-modes.

The five-pion amplitude is thus based on a simple model, which, however, can be considered as a first realistic example. Phase space generation includes the possibility for presampling the ω and a_1 resonances, however, in one channel only. This is probably sufficient for the time being, both for physics applications and for tests.

The technical test of the new part of the generator is performed by comparing Monte Carlo and analytical results. To this end a non-realistic, but easy to calculate, purely scalar amplitude for the decay into five massless pions was used.

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1. INTRODUCTION

Early studies of semileptonic tau-decays have concentrated on final states with few mesons only. The recent advent of high statistic samples in experiments at LEP and CESR and the perspective of further increasing event rates at B-meson factories allow and require the study of relatively rare decay modes and thus of multibody final states. These configurations are of particular importance for a precise determination of the semileptonic branching ratio and for an improved limit on the mass of the tau neutrino. Final states with up to six pions have been observed up to now.

Complementary to the experimental studies Monte Carlo simulations are required to determine the efficiencies of the detectors. The generator TAUOLA [3, 2, 1] has been specifically designed to simulate a wide variety of tau-decay modes and includes spin effects in the case of polarized tau-decays. These simulations necessarily have to include form factors which model the resonant structure of intermediate hadronic states, like ρ-, ω- or a_1-mesons. The combination of Monte Carlo simulation and experimental studies thus allows to test the model input and leads to additional information about hadron physics at low energies.

For a few channels only and in a limited kinematical range the form factors can be predicted from a firm theoretical basis. In many cases additional input, like vector dominance and phenomenological parametrizations are required. At present only final states with up to four pions can be simulated on the basis of realistic form factors [1], which have their basis in chiral Lagrangians and vector dominance models. In the present paper we describe an extension of TAUOLA to five pion final states. The model for the amplitude is based on the observation, that the $2\pi^-\pi^+2\pi^0$ decay is dominated by the $\omega\pi^-\pi^0$ channel, with only about 20% left for the remainder, which does not exhibit sharp resonance structures. The amplitude is therefore constructed to accomodate this feature. It includes the dominant $W^* \to \omega 2\pi$ amplitude and an amplitude of the form $W^* \to a_1(\to \rho\pi)f_0(\to \pi\pi)$ with various charge assignments. The second amplitude is also used to describe the two remaining charge combinations, $\pi^-4\pi^0$ and $3\pi^-2\pi^+$. (The charge-conjugate combinations for the τ^+-decay are considered in parallel.) In the narrow width approximation important technical tests of the generator can be performed. The details of the new amplitude (effectively the transition matrix element of the hadronic current, often just denoted "current") and of the phase space generation are described in chapter 2. Tests of the program and results for some characteristic distributions are collected in chapter 3. Chapter 4 contains our summary and conclusions.

2. Hadronic currents and phase space generation

For each decay mode the basic ingredient for TAUOLA can be grouped into three parts: (i) the phase space generator for a fixed number of particles in the final state, (ii) the algorithm for the calculation of the spin dependent matrix element from the hadronic

currents and from the properties of the electroweak interaction between the W-boson, the τ-lepton and its neutrino and (iii) the hadronic current per se.

The structure of the program is decscribed in detail in refs [3, 1] (see also [4]) and there is no need to recall it here. The relation between the hadronic current and the matrix element remains the same as for the two-, three- and four-meson case presented before.

Some comments are required concerning the new five-pion phase space generator, although its structure is very similar to the well-documented case of four-pions. The number of generated angles and invariant masses is, of course, increased. Since no extensive studies of amplitudes with narrow resonances are forseen at present, the phase space presampler is only prepared to compensate for possible sharp peaks in the invariant mass of the five-pion system in total and in one subsystem, namely the three-pion system (in one single channel) only. To improve efficiency, this mode of generation is merged with the flat phase space sub-generator, again accordingly to the rules described in detail in [3, 1].

The most interesting ingredient necessary for this generator is the matrix element of the hadronic current. For the decay into a n-pion state it is given by

$$J_\mu(q_1, q_2, ..., q_n) \equiv \langle \pi(q_1), \pi(q_2), ...\pi(q_n)|J_\mu(0)|0\rangle \tag{1}$$

where the same letter J has been used for the operator and its matrix element. The decay into an odd number of pions proceeds through the axial part of the current only.

We now construct the amplitude as a sequence of (partly virtual) resonance decays and transitions and concentrate, in a first step, on the most complicated channel $2\pi^-\pi^+2\pi^0$. From experiment we observe that the decay through omega seems to constitute the dominant mode in this case, with a branching ratio $\mathrm{Br}(\tau \to h^-\omega\pi^0) = (4.4 \pm 0.5) \times 10^{-3}$, to be compared with $\mathrm{Br}(\tau \to h^-h^-h^+2\pi^0(ex.K^0, \omega, \eta) = (1.1 \pm 0.4) \times 10^{-3}$. The first part will be implemented in a first step (current A), and the remainder (current B) subsequently. Normalizations will be appropriately set as can be seen in Secton 3. From isospin conservation — and the fact that the total hadronic system has isospin one, the omega, however, isospin zero — it follows that the two pions are also in an isospin-one configuration, corresponding to a state with ρ-meson-like quantum numbers. We thus have to find a convenient description for the amplitude which describes the transition $W^*(Q) \to \omega\rho$. Let us denote polarization and momentum of the ρ meson by ϵ_ρ and p_ρ and similarly for the ω meson. Three possible amplitudes describing the decay of a 1^{++} to two 1^{--} states can be constructed

$$\begin{aligned}
F^1_\mu &= (\epsilon_\rho, \epsilon_\omega, Q, \mu) \\
F^2_\mu &= (\epsilon_\rho, \epsilon_\omega, p_\rho - p_\omega, \mu) - (\epsilon_\rho, \epsilon_\omega, p_\rho - p_\omega, Q)\frac{Q_\mu}{Q^2} \\
F^3_\mu &= (\epsilon_\rho, \epsilon_\omega, p_\rho, p_\omega)\Big((p_\rho - p_\omega)_\mu - (p_\rho - p_\omega)Q\frac{Q_\mu}{Q^2}\Big)
\end{aligned} \tag{2}$$

each of which is of course multiplied by a function of Q^2, where $Q = \sum_i q_i$. For simplicity we adopt amplitude F^1, which depends on the lowest power of the relative momentum $p_\rho - p_\omega$. Furthermore we multiply this amplitude by a Breit-Wigner factor

$$c(Q^2) = c_0 BW_a(Q^2) \equiv c_0 \frac{m_a^2}{m_a^2 - Q^2 - i m_a \Gamma_a} \tag{3}$$

simulating the a_1 enhancement. For the constant c_0, which is determined by the product of $W^* a_1$- and $a_1 \omega \rho$-coupling we adopt the value $c_0 = 3$ such as to reproduce the desired branching ratio of 0.4 %. (That is 0.024 in Γ_e units, see table with numerical results in Section 3.) Furthermore we take $m_a = 1.26$ GeV and $\Gamma_a = 0.4$ GeV. With the symbol $(\epsilon_\rho, \epsilon_\omega, Q, \mu)$ we denote the totally antisymmetric Levi-Civita symbol, contracted with three four-vectors ϵ_ρ, ϵ_ω (polarization vectors for ρ and ω) and Q; the last index μ remains open.

The amplitude for the "subsequent" decay of the virtual ρ is given by

$$\mathcal{M}_\rho^\mu = g_{\rho\pi\pi}(q_4 - q_5)^\mu \tag{4}$$

which leads to the decay rate

$$\Gamma_\rho = \frac{|g_{\rho\pi\pi}|^2}{48\pi} \frac{(m_\rho^2 - 4m_\pi^2)^{3/2}}{m_\rho^2}. \tag{5}$$

To reproduce the input parameters $m_\rho = 776$ MeV and $\Gamma_\rho = 150$ MeV the value $g_{\rho\pi\pi} = 6.0$ is adopted. For the ω we adopt the corresponding decay chain $\omega \to \pi\rho$, where all three pion and ρ-charges contribute with equal weight. We start from an ω-ρ-π coupling of the form

$$\mathcal{M}_{\omega\rho\pi} = \frac{1}{2} f_{\omega\rho\pi}(\epsilon_\omega, p_\omega, \epsilon_\rho, q_\pi) \tag{6}$$

where the coupling $f_{\omega\rho\pi}$ has dimension $(\text{mass})^{-1}$. Including the ρ decay according to eq. 4, and taking the antisymmetric isopin wave function of the three poins into account, which implies an antisymmetric momentum wave function, one finally arrives at

$$\mathcal{M}_{\omega 3\pi} = \frac{f_{\omega\rho\pi} g_{\rho\pi\pi}}{m_\rho^2}(\epsilon_\omega, q_1, q_2, q_3)(BW_\rho(s_1) + BW_\rho(s_2) + BW_\rho(s_3)) \tag{7}$$

q_1, q_2, q_3 denote the momenta of π^+, π^-, π^0, and $s_1 = (q_2 + q_3)^2$ etc.. This leads to the decay rate

$$\begin{aligned} \Gamma_\omega \;=\; & \frac{1}{3}\frac{1}{128}\frac{1}{(2\pi)^3}\frac{1}{m_\omega^3}\frac{(f_{\omega\rho\pi} g_{\rho\pi\pi})^2}{m_\rho^4} \int \mathrm{d}s_1 \mathrm{d}s_2 |BW_\rho(s_1) + BW_\rho(s_2) + BW_\rho(s_3)|^2 \\ & \times (s_1 s_2 s_3 - m_\pi^2 (Q^2 - m_\pi^2)^2) \end{aligned} \tag{8}$$

If the sum of the three ρ Breit-Wigners is dropped (i.e. replaced by a constant taken to be 1) and the pion masses are set zero, one finds

$$\Gamma_\omega = \frac{1}{3}\frac{1}{128}\frac{1}{(2\pi)^3} m_\omega^7 \frac{(f_{\omega\rho\pi} g_{\rho\pi\pi})^2}{120 m_\rho^4} \tag{9}$$

This formula will be useful for cross checks of the program. Whenever numerical vaules are required, we take $f_{\omega\rho\pi} = 0.07$ MeV^{-1} and $g_{\rho\pi\pi} = 6$, that is only the first significant digits.

The full five pion amplitude is obtained by including the rho- and omega-propagators

$$\begin{aligned} J^A_\mu(q_1,q_2,q_3,q_4,q_5) &= c_0 \frac{f_{\omega\rho\pi} g^2_{\rho\pi\pi}}{m^4_\rho m^2_\omega} BW_a(Q^2) BW_\rho((q_4+q_5)^2) BW_\omega((q_1+q_2+q_3)^2) \\ &\quad (\mu, q_4-q_5, \alpha, Q)(\alpha, q_1, q_2, q_3)(BW_\rho(s_1)+BW_\rho(s_2)+BW_\rho(s_3)) \end{aligned} \quad (10)$$

The pictorial illustration of this decay amplitude is shown in Fig.1a. (Caption: dominant decay amplitude for the decay of tau into five pions through an omega plus a rho resonance (a) and through an f_0 plus $a_1(\to \rho\pi)$ (b).)

This formula is directly applicable in the case of a narrow omega, if we identify, as stated above, q_1, q_2, q_3 with the momenta of π^+, π^- and π^0 from the omega decay, q_4 and q_5 with the momenta of the remaining π^- and π^0. Without this approximation the symmetrization between q_2 and q_4 one hand and q_3 and q_5 on the other hand has to be performed

$$\begin{aligned} J^{A;total}_\mu(q_1,q_2,q_3,q_4,q_5) &= J^A_\mu(q_1,q_2,q_3,q_4,q_5) + J^A_\mu(q_1,q_4,q_3,q_2,q_5) + \\ &\quad J^A_\mu(q_1,q_2,q_5,q_4,q_3) + J^A_\mu(q_1,q_4,q_5,q_2,q_3) \end{aligned} \quad (11)$$

and the phase space has to be divided by 4 to take the identical particle statistical factor into account. At present we use the arrangement suitable for the narrow width approximation though.

For a test of the proper implementation of the matrix element (eq.11), the narrow width approximation for a_1, ρ and ω is employed. (For this test $(m_\rho + m_\omega) < m_a$ must be assumed.) In this approximation the rate derived from the current J^A can be integrated analytically. (Again the sum of three ρ Breit Wigner amplitudes in the ω decay is replaced by 1 and m_π is set zero for this test.)

$$\begin{aligned} \Gamma_A/\Gamma_e &= \frac{1}{4}\frac{m^2_{a_1}}{m^2_\tau}(1-\frac{m^2_{a_1}}{m^2_\tau})^2(1+2\frac{m^2_{a_1}}{m^2_\tau}) c_0^2 \frac{m_{a_1}\pi}{\Gamma_{a_1}} f(m^2_{a_1}, m^2_\rho, m^2_\omega) R \\ f(m^2_{a_1}, m^2_\rho, m^2_\omega) &\equiv 2\frac{2p}{m_{a_1}}(\frac{p^2}{m^2_\rho}+\frac{p^2}{m^2_\omega}+3) \\ p &\equiv \frac{\lambda^{1/2}(m^2_{a_1}, m^2_\rho, m^2_\omega)}{2m_{a_1}} \end{aligned} \quad (12)$$

The factor $R = \frac{\Gamma^p_\rho}{\Gamma_\rho}\frac{\Gamma^p_\omega}{\Gamma_\omega}$ consists of the product of the partial widths for ρ and ω as given by eqs. 5 and 9, divided by total widths used as numerical inputs in the Breit Wigner amplitudes and the decay rate is normalized to $\Gamma_e \equiv \Gamma(\tau \to e\bar{\nu}_e\nu_\tau)$.

For a test of the generator, in particular of the phase space integration, the following, totally unphysical form of the current

$$\begin{aligned} J^C_\mu &= c_1\, Q_\mu \\ c_1 &= \frac{1}{m_\tau^3} 4!(4\pi)^3\sqrt{20} \end{aligned} \tag{13}$$

was used, with the pion mass again set to zero[1] The analytical result

$$\Gamma^C/\Gamma_e = \cos^2\theta_{Cabbibo} = 0.950625 \tag{14}$$

is well reproduced by the generator. The numerical results of the second test, based on the narrow width approximation, eq.12, will be discussed below.

The decay mode into $\omega\pi\pi$ is obviously only possible for the $2\pi^0 2\pi^-\pi^+$ final state. In contrast the amplitude introduced in the following will contribute to all three charge combinations $\pi^- 4\pi^0$, $2\pi^- 2\pi^0\pi^+$ and $3\pi^- 2\pi^+$. For this second amplitude we use the transition of the virtual W into a a_1 which subsequent transition into a_1 plus two pions in an isospin zero, angular momentum zero configuration, parametrized by the broad f_0-resonance. For the $a_1 a_1 f_0$-coupling the simplest Lorentz-structure with minimal momentum dependence has been adopted. The a_1 subsequently decays into a ρ-meson plus a pion, with equal amplitude for the two charge modes $\pi^- 2\pi^0$ and $\pi^+ 2\pi^-$ similar to the parametrization of the tau decay into three pions.

This leads to the following current:

$$\begin{aligned} &J^B_\mu(p_1,p_2,p_3,p_4,p_5) \equiv \quad \frac{c}{m_a^4 m_f^2 m_\rho^2} f_{aaf} f_{f\pi\pi} g_{a\rho\pi} g_{\rho\pi\pi} \times \\ &BW_a((p_1+p_2+p_3+p_4+p_5)^2) BW_a((p_1+p_2+p_3)^2) BW_{f_2}((p_4+p_5)^2) \times \\ &\Big[\Big(\frac{Q_\mu Q_\nu}{Q^2} - g_{\mu\nu}\Big)\Big(\frac{p_2(p_1-p_3)}{(p_1+p_2+p_3)^2}(p_1+p_2+p_3)^\nu - (p_1-p_3)^\nu\Big) BW_\rho((p_1+p_3)^2) \\ &\quad +(1 \leftrightarrow 2)\Big] \end{aligned} \tag{15}$$

with the momentum assigments $a_1(\rightarrow \pi_-(p_1)\pi_-(p_2)\pi_+(p_3)) + f(\rightarrow \pi_0(p_4)\pi_0(p_5))$. The pictorial illustration is shown in Fig.1b. (In the program we have used: $m_f = 0.8$ GeV, $\Gamma_f = 0.6$ GeV, $G_{a\rho\pi} = 6$, $f_{aaf} = 4$, $f_{f\pi\pi} = 5$ and $c = 4$. The last constant was introduced to normalize the branching ratio for this channel to 0.11%. The amplitude is, by construction, symmetric under the exchange p_1 vs. p_2 and p_4 vs. p_5, as requested from Bose symmetry for the f_0- and a_1-decays. Alternatively, the two π_0 may originate from the a_1 with the f_0 then decaying into $\pi^-\pi^+$. In this case the symmetrization with respect to the momenta of the π^- has to be performed explicitly. For consistency we have to

[1] As an alternative, in principle we could also use $c_2 = 4!(4\pi)^3/Q^3$ and obtain the same result. In such a case numerical stability problems could appear, as for masless pions $\frac{1}{Q^3}$ may approach integrable infinity within the allowed phase space.

adopt the same momentum assignment as before: $\pi^+(q_1)\pi^-(q_2)\pi^0(q_3)\pi^-(q_4)\pi^0(q_5)$. The properly symmetrized amplitude thus reads:

$$J_\mu^{B;total}(q_1,q_2,q_3,q_4,q_5) = J_\mu^B(q_2,q_4,q_1,q_3,q_5) + J_\mu^B(q_3,q_5,q_2,q_1,q_4) + J_\mu^B(q_3,q_5,q_4,q_1,q_2) \tag{16}$$

We include the same statistical factor $\frac{1}{4}$ as before into the normalization of the phase space. The relative rate $[f(+-) + a(00)] : [f(00) + a(-+)] = 2 : 1$ is recovered in the narrow width approximation for a_1 and f_0. At present there is no analytical benchmark for the overall normalization available for this channel.

The extension of this model to the description of the remaining charge configurations is straightforward. Let us start with $\pi^- 4\pi^0$ and adopt the following momentum assignment: $\pi^-(q_3)\pi^0(q_1)\pi^0(q_2)\pi^0(q_4)\pi^0(q_5)$. Using the definition (15) for J^B, as in eq. 15, the amplitude has to be symmetrized with respect to the momenta of π^0. Since J^B is already symmetric with respect to the first two and the last two momenta, only 6 out of the 4! permutations have to be considered. This leads to the current

$$\begin{aligned} J_\mu^{00-00}(q_1,q_2,q_3,q_4,q_5) &= J_\mu^B(q_1,q_2,q_3,q_4,q_5) + J_\mu^B(q_5,q_2,q_3,q_4,q_1) + J_\mu^B(q_2,q_4,q_3,q_1,q_5) \\ &\quad + J_\mu^B(q_1,q_4,q_3,q_2,q_5) + J_\mu^B(q_1,q_5,q_3,q_4,q_2) + J_\mu^B(q_4,q_5,q_3,q_1,q_2) \end{aligned} \tag{17}$$

For the evaluation of the rate the statistical factor 1/4! must be included.

In complete analogy we obtain for the $3\pi^- 2\pi^0$ mode

$$\begin{aligned} J_\mu^{--++-}(q_1,q_2,q_3,q_4,q_5) &= J_\mu^B(q_1,q_2,q_3,q_4,q_5) + J_\mu^B(q_5,q_2,q_3,q_4,q_1) + J_\mu^B(q_1,q_5,q_3,q_4,q_2) \\ &\quad + J_\mu^B(q_1,q_2,q_4,q_3,q_5) + J_\mu^B(q_5,q_2,q_4,q_3,q_1) + J_\mu^B(q_1,q_5,q_4,q_3,q_2) \end{aligned} \tag{18}$$

where the momentum assignment $\pi^-(q_1)\pi^-(q_2)\pi^+(q_3)\pi^+(q_4)\pi^-(q_5)$ has been adopted and a statistical factor $1/2!3! = 1/12$ is used in the evaluation of the rate.

For the "non-ω"-decays and in the narrow width approximation this ansatz predicts the following abundances of the subchannels

$$f(00)a(--+) : f(-+)a(00-) : f(00)a(00-) : f(-+)a(--+) = 1 : 2 : 1 : 2 \tag{19}$$

and the following relative rates

$$2\pi^0 2\pi^- \pi^+ : \pi^- 4\pi^0 : 3\pi^- 2\pi^+ = 3 : 1 : 2 \tag{20}$$

Note that this prediction is specific to the resonance and isospin structure of the model. Once more experimental information on the five pion channel will be available, more elaborate possibilities can be considered.

3. Results

While checking the program we were able to verify eq.14 for the current J^C (defined in eq.13) in the case of masless pions with a precision better than 0.1%. This result was stable and independent of the choice of our phase space presampler, providing a first test of its correct operation. A second test, namely of eq.12 for the current defined in eq.11 was far more demanding on our phase space generator. A precision of about 1% only was reached. Because of the complex structure of the resonances a_1, ρ and ω it was impossible to generate events in a sufficiently efficient manner. The ρ Breit-Wigner could only be generated in a very inefficient manner from a flat distribution. The variance of the generated raw sample was deteriorating quite fast with decreasing width, not only rendering the generator slow, but also risking to arrive at numerically unstable results. We have nonetheless completed this test for several choices of masses and widths of a_1, ρ and ω resonances.

The corresponding currents A, B, and C are coded in the new version of TAUOLA as channels 31, 33 and 32 for $2\pi^-\pi^+2\pi^0$ channels. In case of channels 31, current A is not symmetrized, formula (10) is used directly and order of pions as used and generated by TAUOLA is: $--+00$. This order is also used in the case of test channel 32 (current C). Such a choice was motivated for the convenience of the tests; more precisely requirements of the pre-sampler running in the narrow resonance mode. Pre-sampler is only partly optimized. In general case, channel 33 of $2\pi^-\pi^+2\pi^0$ mode the order of pions is $+--00$. Both current B and A can be activated simultaneously and symmetrizations can be performed. The $\pi^-4\pi^0$ is placed in channel 34 and $3\pi^-2\pi^+2$ in 35; order of particles in TAUOLA output is respectively –0000 and $-++--$. Let us start collecting numerical results with the one suitable for tests and collected in the first table:

Current	Γ_X/Γ_e MC	Γ_X/Γ_e semian	except param.	comment
A	0.02404 ±0.1 %	—	–	–
B	0.00928 ±0.1 %	—	–	–
C	0.10690 ±0.2 %	—	unphysical.	benchmark curr.
A	$1.38{\cdot}10^7\pm$ 1%	$1.41{\cdot}10^7$	m_ρ=0.373, all Γ's=0.001(5)	masless π's
C	0.95030 ± .03%	0.950625	—	masless π's

In these cases currents A and B are not symmetrized, formulas (10,15) are used directly. In general numerical values of input parameters are as explained in the text. Exceptional changes are explicitly marked. For numerical results in narrow width approximation mas of π^0 was set equal mass of $\pi^\pm$. Mass of f was set to 0.45 GeV and mass of a_2 to 1.160 GeV. All widths were set to 0.01 GeV, except the width and mass of a_2 saturating the propagator for 5-pion system, where the standard values are left.

The 2.5 % difference in case of masless test for current A, is due to non residual contributions, remaining large, even in such an extereme narrow width case of $\Gamma_\omega = \Gamma_{a_1} = 0.001$ and $\Gamma_\rho = 0.005$ GeV. This is important to notice as it illustrates the relative importance of non-resonant contribution in this channel.

In the last table we collect complete results for currents A and B as given respectively in formulas (11) and (16) for channel 33 and by formulas (17) and (18) for channels 34 and 35:

Channel no	final state.	currents used	Γ_X/Γ_e	Γ_X/Γ_e narrow widths
33	$2\pi^-\pi^+2\pi^0$	A ; total	0.02530 ± 0.1 %	–
33	$2\pi^-\pi^+2\pi^0$	B ; total	0.00605 ± 0.2 %	2192 ± 1.0 %
33	$2\pi^-\pi^+2\pi^0$	A+B ; total	0.03135 ± 0.1 %	–
34	$\pi^-4\pi^0$	B ; total	0.00937 ± 0.1 %	788 ± 0.5 %
35	$3\pi^-2\pi^+$	B ; total	0.01103 ± 0.1 %	1469 ± 0.5 %

As one can see, only in case of narrow width approximation the relations (20) are reproduced.

Otherwise effects of interferences significantly change the predictions for ratios of branching fractions and differential distributions as well. This is not of a surprize having in mind phase space packed with multitude of curents, originating from symmetrization. saturated with broad intermediate resonances, thus prone to interfere, especially as phase space and secondary decay effects are not included in parametrization of form factors. Obviously, the case of current A where relatively narrow ω is present is a bit cleaner and interferences contribute less profoudly, but still in a significant manner.

This observation has to be taken into account from the very begining in more realistic approaches to current modelling as well as in construction of Monte Carlos where cascade decay chains are to be used. Large interference may be the consequence of precise treatment of phase space and fixed widhts used in parametrization of intermediate resonance propagators. This point was carefully discussed and inconsistencies avoided in other tau decay modes parametrizations of TAUOLA, see [5].

4. Summary

In this note we have documented the recent developments in TAUOLA for τ-decays into five mesons. For the $2\pi^-\pi^+2\pi^0$-mode two amplitudes were introduced. The first is motivated by the experimental observation of a dominant $\omega\pi\pi$-channel, the second corresponds to a non-ω contribution annd is parametrized by a transition through an intermediate $a_1 + f_0$-combination. This second amplitude was also used to predict the two remaining charge combinations for τ-decays into five pions. The corresponding channels have also been implemented into TAUOLA. A third current, J^C, was introduced for tests of the phase space generator. With the help of these currents basic technical tests of the algorithm were succesfully completed. No sophisticated fits to the data were attempted. The model amplitude can, however, be used as a starting point for more detailed theoretical and experimental investigations. We have observed again, that effects due to interferences (enhanced for inclusive quantities by different type of threshold effects) are large. They

must be taken into account in any approach to fits and/or Monte Carlo designs if precision is required. If at this point approximations are used, such as used in [7], see also appendix B in [8], painful difficulties may appear in later steps of programs development.

Finally let us point that presented here extensions for TAUOLA are avialble from directory `tauola-BBB` of the standard distribution system for TAUOLA versions. The use of directory `tauola-BBB` is not documented in any published document, but use of `tauola-BBB` is identical to `tauola-F` sub-directory, explained in [4]. The up to date code is available from the web page [6], and the results of standard tests performed with the help of MC-TESTER [9] are also available [10].

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