Monte Carlo Tau Decays :
Incorporating multi-prong decay modes

R. Rameika

January 2002

PDG 2000 reports :

Tau Mass : 1.777 GeV
Tau Lifetime : 290.6×10^{-15}

Decay Modes : 84.7% "1-prong"
15.2% "3-prong"
0.1% "5-prong"

I have used the following modes and branching ratios in the Monte Carlo to quantitatively study the multi-prong modes for reconstruction efficiency as well as to develop a signal to background parameter analysis.

Decay Mode	**Branching Ratio**	**Decay Type**	**Observed**
$\tau^{\pm} \rightarrow \rho^{\pm}\,\nu$; $\rho \rightarrow \pi^{\pm}\,\pi^{0}$	25.4	2-body (×2)	1-prong
$\tau^{\pm} \rightarrow e^{\pm}\,\nu\,\nu$	17.8	3-body	1-prong
$\tau^{\pm} \rightarrow \mu^{\pm}\,\nu\,\nu$	17.4	3-body	1-prong
$\tau^{\pm} \rightarrow \pi^{\pm}\,\nu$	11.1	2-body	1-prong
$\tau^{\pm} \rightarrow \pi^{\pm}\,\pi^{\pm}\pi^{\pm}\nu$	9.3	4-body	3-prong
$\tau^{\pm} \rightarrow \pi^{\pm}\,\pi^{0}\pi^{0}\nu$	9.1	4-body	1-prong
$\tau^{\pm} \rightarrow \pi^{\pm}\,\pi^{\pm}\pi^{\pm}\,\pi^{0}\nu$	4.1	5-body	3-prong
$\tau^{\pm} \rightarrow \omega^{0}\pi^{\pm}\nu$; $\omega \rightarrow \pi^{\pm}\,\pi^{\pm}\pi^{0}$	1.6	3-body (×2)	3-prong
$\tau^{\pm} \rightarrow K^{*\pm}\nu$; $K^{*\pm} \rightarrow K\pi$	1.4	2-body (×2)	1-prong
$\tau^{\pm} \rightarrow \pi^{\pm}\,K^{0}\,\nu$	1.0	3-body	1-prong
$\tau^{\pm} \rightarrow K^{*\pm}\pi^{0}\nu$; $K^{*\pm} \rightarrow K\pi$	0.8	3-body; 2-body	1-prong
$\tau^{\pm} \rightarrow \omega^{0}\pi^{\pm}\nu$; $\omega \rightarrow \pi^{0}\gamma$	0.6	3-body; 2-body	1-prong
$\tau^{\pm} \rightarrow \omega^{0}\pi^{\pm}\nu$; $\omega \rightarrow \pi^{\pm}\,\pi^{\pm}$	0.3	3-body; 2-body	3-prong
$\tau^{\pm} \rightarrow \pi^{\pm}\,\pi^{\pm}\pi^{\pm}\pi^{\pm}\pi^{\pm}\nu$	0.1	6-body	5-prong

In GEANT, particles which have a lifetime are decayed by the routine GDECAY, according to the decay modes and branching ratios specified in the constants data structure, or by the user supplied data by invoking a call to GSDK. GEANT 3.21 does not define or decay the TAU lepton, so we had to define the TAUS as new particles, with the correct mass and lifetime. In UGINIT taus (anti) were defined with particle id 123 (122), and a mass and lifetime of 1.777 GeV/c2 and 290 10-15 seconds respectively. Decay modes and branching ratios were input via the Monte Carlo control file. However, since GDECAY only does 2 and 3 body decay modes, only a limited number of tau branching ratio's have been studied, and they have been specifically limited to the prominent ones giving the 1-prong topology.

In order to incorporate decay modes of more than three particles the user has to write their own decay routine. This routine will be called by GEANT if a particle is given a lifetime but NO branching ratios are filled by a call to GSDK. In such a case, GDECAY will call the user routine GUDCAY, which can be uniquely coded to do any kind of decay.

I will present results from a version of the Monte Carlo which calls GUDCAY, which in turn calls a routine which I wrote called DECAY_TAU. DECAY_TAU sets up the proper variables for each mode and then calls the CERNLIB routine GENBOD. Rather than generate events according to branching ratios, I generate each of the 14 modes with equal probability and carry through weights which reflect both the event's branching ratio and a weight resulting from the GENBOD routine. These can be used in later analysis of distributions related to the event and its decay particles.