

DECAY.DEC update to PDG 2008

Mark Whitehead

March 10, 2009

1 Introduction

DECAY.DEC is the file that provides the EvtGen[1] package with information about particle decays. All particles in the simulation have their decay channels listed, along with the branching fraction of each channel. Many of these branching fractions have not been updated since 2004 so are therefore out of date as more accurate measurements have been published.

Particle names used in this document are those from the PDG[2]. The names of particles used in EvtGen are listed in the file evt.pdl¹.

2 Methods and Notes

2.1 PDG notation

The PDG has recently switched from using $K^0\bar{K}^0$ to $K_S^0 K_L^0$ where measurements allowed. This resulted in many decay channels including $K^0\bar{K}^0$ being split into 3 separate fractions. One version for both K_S^0 and K_L^0 and the original decay channel with a branching fraction of zero to prevent PYTHIA[3] generating the decay channel. In most cases the PDG only listed the K_S^0 which was then copied for the K_L^0 fraction. This is not a perfect solution but provided a decent estimate.

Final state decay channels are often listed with the resonance states which form the final state branching fraction. If the resonance states are listed in DECAY.DEC in addition to the final state then care must be taken not to double count a resonant decay mode. For example, from the D^+ meson:

$$K^- \pi^+ e^+ \nu_e \rightarrow (3.9 \pm 0.5) \%$$

$$\bar{K}^{*0} e^+ \nu_e \rightarrow (3.6 \pm 0.3) \%$$

$$\bar{K}^{*0} \rightarrow K^- \pi^+$$

Clearly, entering branching fractions of 3.9% and 3.6% for the K^- and \bar{K}^{*0} channels respectively is incorrect.

Inclusive measurements such as $\pi\pi$ are often used in the PDG. To write down the correct branching fractions, all possible combinations of pions are considered and the total branching fraction split between them accordingly. In all cases the relative fractions had been calculated in advance. For example in the decay of a neutral particle $\pi\pi$ can be either $\pi^+\pi^-$ or $\pi^0\pi^0$.

Some measurements in the PDG are presented as an inequality such that a branching fraction is below the value given. These measurements were normally entered into DECAY.DEC to the correct order of magnitude.

¹This is located in /cmtuser/GaussvXXrX/Gen/DecFiles/scripts in the lxplus user area.

2.2 Weighting

Very few particles listed in the PDG have all 100% of the total branching fraction measured. To prevent EvtGen from applying unknown weights the branching fractions were weighted to total 100% in DECAF.DEC. The method to do so changed depending on the particle.

For the most massive mesons (the B sector for example) some 40% of the branching fraction is missing and controlled by the PYTHIA software package. After the fractions listed in the PDG were updated the PYTHIA fractions were changed to reach a total of 100%.

Particles with very small missing portions did not use PYTHIA. Instead each branching fraction was weighted by a factor of $n\sigma$. Where n was a number and σ the uncertainty on that branching fraction listed in the PDG.

2.3 Adding Decay Modes

Nearly all new modes were added using the PHSP² decay model since they typically included more particles than the more specific decay models could use. A full list of the decay models is available[1] so that the correct model can be chosen for each new decay mode. If the correct model to use was not obvious then PHSP was used.

3 Updated Particles

3.1 Light Mesons

The light mesons that required updating were:

$$\eta \quad \omega \quad \eta' \quad f_2(1270) \quad f_1(1285) \quad a_2(1320) \quad f_0(1500)$$

There were no new modes to be added for the seven particles above. The existing decay modes were updated and then adjusted within the PDG uncertainties to get a total branching fraction of 1.

The ϕ meson had 3 new modes added. The existing modes were also updated and the total branching fraction forced to unity.

3.2 K mesons

The K particles updated were the K_S^0 meson and the $K^*(892)^\pm$. The existing branching fractions were updated, no modes added.

The $K_2^*(1430)$ family of mesons updated with one new mode, $K\omega$, that was added to all 4 varieties.

²This model is a general purpose phase space decay model.

3.3 D mesons

The main D mesons (D^0 , \bar{D}^0 , D^+ and D^-) were updated. Several branching fractions no longer in the PDG were commented out (all those over 1% of the total). Weights, of order 0.25σ , were applied using the uncertainties listed in the PDG. New decay modes were added to all 4 particles.

D_S^\pm mesons updated and new decay channels were added. Weights of approximately 0.16σ used.

$D^{*\pm}$ branching fractions updated.

3.4 $c\bar{c}$ mesons

6 states updated: η_c J/ψ $\psi(2S)$ χ_{c0} χ_{c1} χ_{c2} $\psi(3770)$

All 7 mesons were missing several decay modes with branching fractions of order $\times 10^{-3}$ so all such modes were added. All of these mesons have a fair portion of the branching fraction being sent to the PYTHIA package. After updating and adding the new fractions the total branching fraction was set to unity by changing the PYTHIA contribution.

3.5 B mesons

The 4 main B mesons (B^0 , \bar{B}^0 , B^+ and B^-) were updated and several new modes were included. These mesons have several different fractions sent to PYTHIA. Therefore to reach a total branching fraction of 1, all PYTHIA fractions were multiplied by the same factor to keep the relative sizes consistent.

3.6 $b\bar{b}$ mesons

$\Upsilon(1S)$, $\Upsilon(2S)$ and $\Upsilon(3S)$ all updated. No modes added and the PYTHIA fractions altered to keep the total branching fraction equal to one.

3.7 Baryons

Λ^0 updated, no modes added. The Σ^\pm baryons also updated with a new mode, $p\pi^0$, added.

3.8 τ lepton

Several new modes added and existing fractions brought up to date. Without a PYTHIA fraction, all measurements from the PDG were weighted down by 0.8σ to reach a total branching fraction of unity.

4 Particles that were not updated

There were several reasons for a particle to not be updated. Firstly, for many particles, the branching fractions in the PDG were identical to those in DECAY.DEC. If there were no new modes to add the particle was left alone. This applied to particles such as the π^0 and other low mass particles.

Many of the higher mass excited state particles do not have branching fractions listed in the PDG because they are poorly studied. Clearly this prevented the branching fractions in DECAY.DEC being updated.

A few particles are not decayed in the EvtGen package so are not even listed in DECAY.DEC. Examples include the π^\pm and K^\pm mesons.

4.1 Future Work

Updating DECAY.DEC is a never ending job, one could always include more decay modes of lower and lower order. The level of branching fractions included varies across the different particles. Some include modes down to $\times 10^{-5}$ and others stop at modes of order $\times 10^{-3}$.

The updated $c\bar{c}$ mesons, in section 3.4, could all be updated to include modes of order $\times 10^{-4}$. There are between 50 and 100 modes that fall into this category.

Particles such as the B_S and the B_C are poorly measured so the PDG has too little information to update the theoretical predictions listed in DECAY.DEC. Since LHCb will see many of these particles the decay modes and branching fractions should be reviewed.

The PHOTOS model, for final state radiation from charged particles, could be added to decay modes where appropriate. A large percentage of charged final states do not use the PHOTOS model.

References

- [1] Ryd et al., BAD 522 V6, *EvtGen A Monte Carlo generator for B-physics*. 2004.
- [2] Particle Data Group, <http://pdg.lbl.gov/index.html>. 2009
- [3] PYTHIA, <http://home.thep.lu.se/~torbjorn/Pythia.html>. 2009