Event Generator for $V \to VP$ or PP at BES

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Contents:

Introduction

- Many VP or PP mode in J/ψ and $\psi(2S)$ decays, such as $\rho\pi$, KK^*, $\omega\pi^0$, $\gamma\eta$, and $\pi^+\pi^-$, $K\overline{K}$, etc
- No generic generator available at that time, only several individual ones
- Some people still use HOWL (phase space only) and multiply some correction factor, which is
  - Inconvenient
  - Unreliable
  - Systematic error or bias introduced
- The angular distribution for $V \to VP$ and $V \to PP$ is definitely determined

It would be convenient to have a generic event generator for these decays.

Angular Distribution

1. $V \to V_1 P_1$
   $WT = WT_{V1} \times WT_{P1}$

   (a) For V_1, WT_{V1}=

   - $1 + \cos^2\theta_v$, if V_1 does not decays
   - $\sin^2\theta_1(1 + \cos^2\theta_v + \sin^2\theta_v \cos 2\phi_1)$, if $V_1 \to PP$ or PPP

   where θ_V is polar angle of V_1 , θ_1 and ϕ_1 are the polar and azimuth angles of pseudo-scalar P in $V_1 \to PP$ or PPP

2. For P_1, WT_{P1} =

   - 1, if P_1 does not decay in cascade
   - $\sin^2\theta_2$, if $P_1 \to V_2 V_3 (\to P_2 P_3)$

3. $V \to PP$, the angular distribution is $\sin^2\theta$

Generator

HOWL + weight of angular distribution
— *Setup of helicity coordinate system*

Since θ_1 and ϕ_1 are the polar and azimuth angles of pseudo-scalar in the helicity coordinate of V_1 , the helicity coordinate should be defined. it is defined as:

- axis-z' along moving direction of V_1
- axis-y' along $\overrightarrow{z} \times \overrightarrow{z'}$
- axis-x' is $\overrightarrow{y'} \times \overrightarrow{z'}$ of course

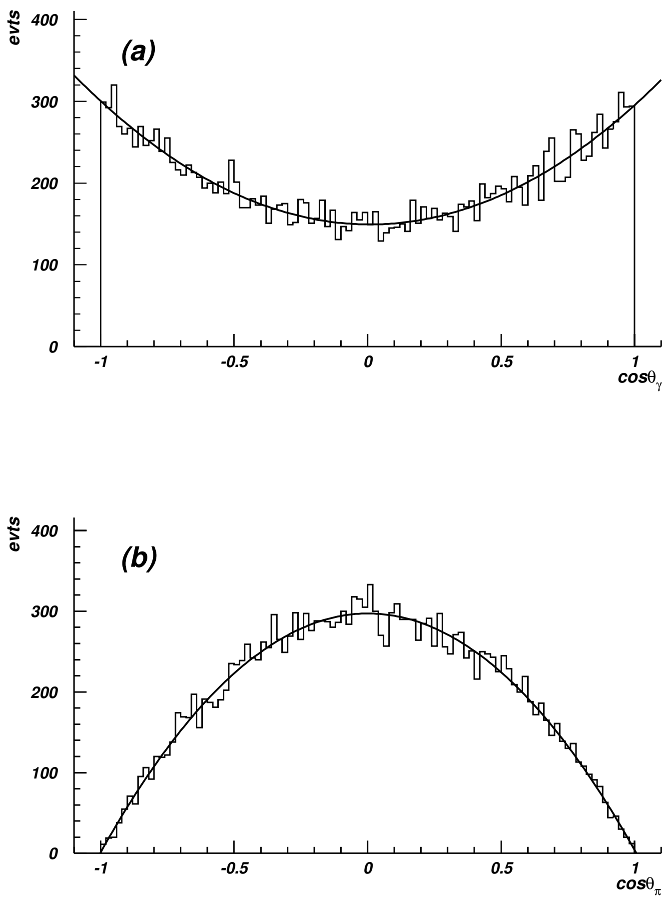
Hence, the transformation between the lab coordinate frame and the helicity coordinate system is

$$\left\{ \begin{array}{lcl} \vec{\imath}' & = & \cos\theta_V \cos\phi_V \vec{\imath} + \cos\theta_V \sin\phi_V \vec{\jmath} - \sin\theta_V \vec{k} \\ \vec{\jmath}' & = & -\sin\phi_V \vec{\imath} + \cos\phi_V \vec{\jmath} \\ \vec{k}' & = & \sin\theta_V \cos\phi_V \vec{\imath} + \sin\theta_V \sin\phi_V \vec{\jmath} + \cos\theta_V \vec{k} \end{array} \right.$$

— *Check for the angular distribution*

1. Using this generator, the process of $\psi(2S) \to \gamma\eta'(958)(\to \gamma\rho,\ \rho \to \pi^+\pi^-)$, that is, $V \to V_1 P_1 (\to V_2 V_3,\ V_3 \to P_2 P_3)$, is produced. The distributions are

Figure 1: θ_γ (a) and θ_π (b) in $\psi(2S) \to \gamma\eta'(958)(\to \gamma\rho,\ \rho \to \pi^+\pi^-)$



- θ_γ , that is, θ_V, in the distribution of $1 + \cos^2\theta_v$
- θ_π , that is, θ_2 in $P_1 \to V_2V_3(\to P_2P_3)$, distributed in $\sin^2\theta_2$

2. $\psi(2S) \to \pi^0\omega(\to \pi^+\pi^-\pi^0)$ is produced in the mode of $V \to P_1V_1(\to PPP)$, the angular distribution should be $\sin^2\theta_1(1 + \cos^2\theta_v + \sin^2\theta_v \cos 2\phi_1)$. The angles are

   - θ_1 in $\sin^2\theta_1$, after integrating over θ_v and ϕ_1
   - ϕ_1 in $2 + \cos 2\phi_1$, after over θ_1 and θ_v
   - θ_v in $1 + \cos^2\theta_v$, after over θ_1 and ϕ_1
   - ϕ_v in uniform distribution

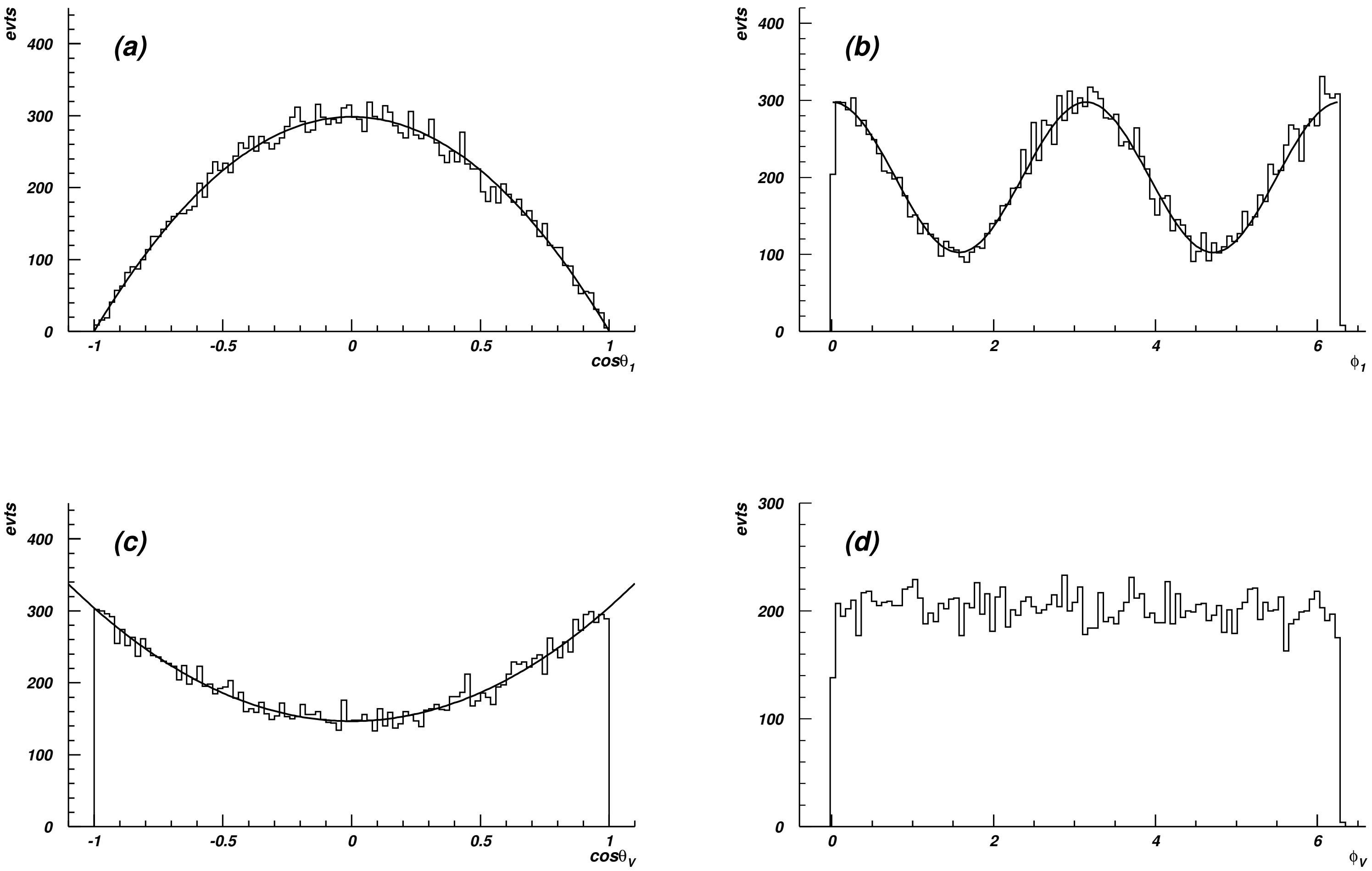


Figure 2: θ_1 (a), ϕ_1 (b), θ_v (c), ϕ_v (d) in $\psi(2S) \to \pi^0\omega(\to \pi^+\pi^-\pi^0)$

Usage

An example of $\psi(2S) \to \gamma\eta'(958)$, where $\eta' \to \gamma\rho(\to \pi^+\pi^-)$

```
*LINK ~yesw/bes/src/wtuse
EVT_type 1 ; /* HOWL invoked */
/*  ψ(2S) → γη'(958)  , Vector first !! */
    NEUT_TRKS 0., 0.95777 ;
    SPIN_PRT TRK# 1 SPIN 1.0 PARITY -1 ;
    SPIN_PRT TRK# 2 SPIN 0.0 PARITY -1 ;
    GAMMA 1 ;
/*  η' → γρ  */
    RESONANCE TRK# 2 WIDTH 0.201e-3 ;
        NEUT_TRKS 0. , 0.7699 ;
        SPIN_PRT TRK# 3 SPIN 1.0 PARITY -1 ;
        SPIN_PRT TRK# 4 SPIN 1.0 PARITY -1 ;
        GAMMA 3 ;
/*  ρ → π+π-  */
        RESONANCE TRK# 4 WIDTH 0.1512 ;
            CHRG_TRKS = +0.13957 , -0.13957 ;
            SPIN_PRT TRK# 5 SPIN 0.0 PARITY -1 ;
            SPIN_PRT TRK# 6 SPIN 0.0 PARITY -1 ;
```

Another example of $\psi(2S) \to \pi^+\pi^- J/\psi$, where $J/\psi \to \omega\eta$, and $\omega \to \pi^+\pi^-\pi^0$, $\eta \to \gamma\gamma$

```
*LINK ~yesw/bes/opt/ppgen_dst.opt
*LINK ~yesw/bes/src/wtuse
EVT_TYPE = 24 ;        /* generator PPGEN called */
MPARAM(1) = 1, 10 ;    /* π+π- J/ψ + HOWL */
/* Description of J/ψ decay used in HOWL */
/*===================================*/
/*  J/ψ → ωη  , Vector first !! */
    NEUT_TRKS 0.78194, 0.54745  ;
```

```
    SPIN_PRT TRK# 1 SPIN 1.0 PARITY -1 ;
    SPIN_PRT TRK# 2 SPIN 0.0 PARITY -1 ;
/*   ω → π+π−π0   */
    RESONANCE TRK# 1 WIDTH 8.43e-3 ;
        CHRG_TRKS = 0.13957 , -0.13957 ;
        NEUT_TRKS 0.1349764  ;
        SPIN_PRT TRK# 3 SPIN 0.0 PARITY -1 ;
        SPIN_PRT TRK# 4 SPIN 0.0 PARITY -1 ;
        SPIN_PRT TRK# 5 SPIN 0.0 PARITY -1 ;
        AUTODECAY 5;
/*   η → γγ   */
    RESONANCE TRK# 2 WIDTH 1.20e-7 ;
        NEUT_TRKS 0. , 0. ;
        SPIN_PRT TRK# 6 SPIN 1.0 PARITY -1 ;
        SPIN_PRT TRK# 7 SPIN 1.0 PARITY -1 ;
        GAMMA 6 7 ;
/*==================================*/
```

Online Guide:

~yesw/bes/mem/wtuse.mem

Summary

The established event generator is

- Taking into account the angular distribution of $V \to VP$ or PP
- Generic for VP or PP mode of Vector such as J/ψ and $\psi(2S)$ decay
- Also applicable to J/ψ decay coming from $\psi(2S)$
- Convenient and reliable because of its generality and its interface to HOWL