Simulation of J/ψ and ψ' decay

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June 19, 1998

OUTLINE

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1 Motivation

1. After studying LUND model in the BEPC continuum energy region, it is valued to develop LUND model in the J/ψ and ψ' resonance energy region, and study features of Charmonia decay with BES data.

2. Determine the detection efficiency for the hadronic events produced by J/ψ and ψ'. It will be useful to the following project:

   (a) Determination of the total number of ψ' in BES.

   (b) Measurement of absolute branching ratios of Charmonia decay channels.

   (c) Measurement of R value at J/ψ and ψ' energy region.

3. It can be used to other experiments,
   e.g. $B\bar{B}$, $\tau\bar{\tau} \rightarrow c\bar{c} + X$

2 Method

Possible method:

1. Input all known decay channel parameters according to PDG(96).
   Question: How to deal with unknown decay channels?

2. Build a frame according to a theoretic model.
   Question: Can any model describe all of experimental facts?

My approach, combine both:

Following four decay modes of J/ψ and $\psi(2S)$ (see Fig. 1):

1. Input branching ratios of direct decay channels (l^+l^-, Charmonia transition, $q\bar{q}$, $\gamma gg, ggg$).

2. $q\bar{q}$ and $\gamma gg, ggg$ decays are simulated by the modified LUND model.

Simulation of Charmonia decay:

1. Input parameters

   (a) Decay into $c\bar{c}$ Charmonia: Input each branching ratio of Charmonia decays. (see Fig.2 and List 1)

   (b) Decay into γ^*: Input branching ratios of l^+l^- and $q\bar{q}$.

   (c) Decay into $\gamma gg/ggg$: Input their total branching ratio;
   $\Gamma(\gamma gg)/\Gamma(ggg) = \frac{36}{5}\frac{e_c^2\alpha_{em}}{\alpha_s(m_c^2)}$.
   (Measured value of J/ψ decay: $\Gamma(\gamma gg)/\Gamma(ggg) = 10\%$.) (Ref. W. Kwong PRD 37(1988)3210)

   (see List 1)

2. Unstable hadron decays are simulated by the developed LUND model.

3. $\gamma gg/ggg$ production are simulated by a subroutine modified from LUONIA.F, one subroutine of jetset7.4.

4. Hadronization of quarks and gluons are simulated by the LUND string model.

5. Some parameters of jetset7.4, such as diquark ratio and V/P meson ratio, are tuned.

6. General conservation laws, such as energy, momentum, charge and flavor conservation laws, are satisfied by the LUND model.

7. In addition, following parity conservation laws are included in our simulation.

   (a) G parity conservation law is included.

i. G parity conservation law is satisfied when a unflavored meson, which consists of u,d quark or $c\bar{c}$ quarkonia, decays into pure unflavored meson system via hadronic decay.

A. J/ψ and $\psi(2S)$ decay into pure unflavored mesons via ggg.

B. Unflavored or $c\bar{c}$ mesons decay into pure unflavored mesons via $ggg/gg \to q\bar{q}$.

ii. G parity of multiple meson system is the multiplication of each meson's G parity.

(b) C parity conservation law is included.

i. C parity conservation law is satisfied when a neutral unflavored meson decays into pure meson system via electromagnetic decay or hadronic decay, such as via $q\bar{q}$, γgg or ggg decay.

ii. C parity of a multiple meson system is the multiplication of C parity of each neutral unflavor meson and the C parity of charged meson system.

iii. As assumption, C parity of a charged meson system is $(-1)^J$, where J=L+S is the angular momentum of the system.

3 Test of the simulation

Table 1. Branching ratios of Charmonia decays
(from 1000000 M.C.events)

	J/ψ			$\psi(2S)$		
Mode	Channel	input	MC.out	Channel	input	MC.out
$c\bar{c}+X$	$\gamma\eta_c$	0.013	0.01294	$\pi^+\pi^-J/\psi$	0.324	0.32376
				$\pi^0\pi^0J/\psi$	0.184	0.18398
				π^0J/ψ	0.00097	0.00096
				$\eta J/\psi$	0.027	0.02714
				$\gamma\chi_{c0}$	0.093	0.09332
				$\gamma\chi_{c1}$	0.087	0.08659
				$\gamma\chi_{c2}$	0.078	0.07773
				$\gamma\eta_c$	0.0028	0.00267
γ^*	e^+e^-	0.0602	0.05991	e^+e^-	0.0088	0.00881
	$\mu^+\mu^-$	0.0601	0.05995	$\mu^+\mu^-$	0.0077	0.00776
				$\tau^+\tau^-$	0.00320	0.00323
Sum		0.1333	0.1328		0.81647	0.81595
γ^*	$q\bar{q}$	.17	.17035	$q\bar{q}$	.029	0.02913
$\gamma gg/ggg$	hadrons	0.6967	0.69685	hadrons	0.15453	0.15492
γgg	hadrons		0.06900	hadrons		0.01595
ggg			0.28742			0.08162
gg			0.34043			0.05735
Sum		0.8797			0.18673	

<u>Conclusion:</u> Our simulation works!

Table 2. Branching ratios of Charmonia exclusive decays
(from 3000000 M.C.events)

J/ψ			$\psi(2S)$		
Channel	PDG96	M.C.	Channel	PDG96	M.C.
$2(\pi^+\pi^-)\pi^0$	0.0337	0.03181	$2(\pi^+\pi^-)\pi^0$	0.0031	0.002376
$3(\pi^+\pi^-)\pi^0$	0.029	.03224	$3(\pi^+\pi^-)\pi^0$	0.0035	.0054502
$\pi^+\pi^-\pi^0$	0.015	.01531	$\pi^+\pi^-\pi^0$	0.00009	.0009784
$\pi^+\pi^-\pi^0K^+K^-$	0.012	.01275	$\pi^+\pi^-K^+K^-$	0.0016	.0000389
$\pi^+\pi^-K^+K^-$	0.0072	.00041	$\pi^+\pi^-p\bar{p}$	0.0008	.0004585
$\pi^+\pi^-p\bar{p}$	0.006	.00226	$2(\pi^+\pi^-)$	0.0004	.0000525
$3(\pi^+\pi^-)$	0.004	.00537	$3(\pi^+\pi^-)$	0.00015	.0007145
$n\bar{n}\pi^+\pi^-$	0.004	.00247	$p\bar{p}\pi^0$	0.00014	.0002581
$2(\pi^+\pi^-)$	0.004	.00048	$p\bar{p}$	0.00019	
$\pi^+\pi^-\pi^0p\bar{p}$	0.0023	.00177	$\pi^+\pi^-$	0.00008	
$p\bar{p}$	0.00214	.00198	K^+K^-	0.0001	
$2(\pi^+\pi^-)K^+K^-$	0.0031	.00637			
$p\bar{n}\pi^-$	0.002	.00166			
$n\bar{n}$	0.0019	.00199			
$p\bar{p}\pi^0$	0.00109	.00123			
K^+K^-	0.000237	.00059			
$\pi^+\pi^-$	0.000147	.00169			
$\gamma\pi^+\pi^-2(\pi^0)$	0.0083	.00947			
$\gamma 2(\pi^+\pi^-)$	0.0028	.00117			
$\gamma p\bar{p}$	0.00038	.00059			
$2(K^+K^-)$	0.0007				
$K^0_SK^0_L$	0.000108				

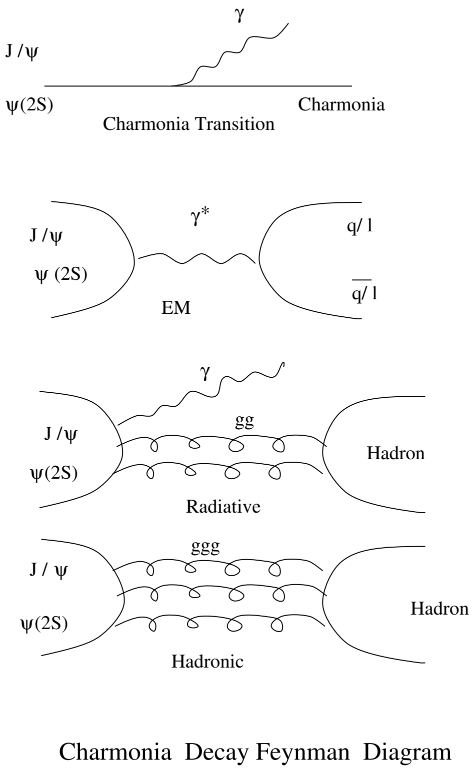

Figure 1: Charmonia Decay: B($c\bar{c}$)+$B(\gamma^*)$+$B(\gamma gg)$+B(ggg)=1

4 Summary

1. LUND model is developed to simulate J/ψ and ψ' decays.
   (a) Input branching fractions of PDG96.
   13.33% for J/ψ and 81.647% for $\psi(2S)$ including $c\bar{c} + X$ and $\gamma^* \to l^+l^-$
   Others fractions are $\gamma^* \to q\bar{q}$ and γgg, ggg

   (b) Decay of unstable hadron is simulated by the developed LUND model.
   (c) Hadronization of $q\bar{q}$ and $\gamma gg/ggg$ is simulated by the developed LUND model.
      i. General conservation laws are satisfied in the LUND model , such as energy, momentum, charge, flavor conservation.
      ii. In addition, following parity conservation laws are satisfied in our simulation.
         A. G parity conservation in decays of unflavor mesons.
         B. C parity conservation in decays of neutral mesons.
2. Simulated branching fractions agree with the inputed values.
3. Most exclusive decays of J/ψ and $\psi(2S)$ are also simulated.
4. Poor simulation: few channels of low branching fractions.

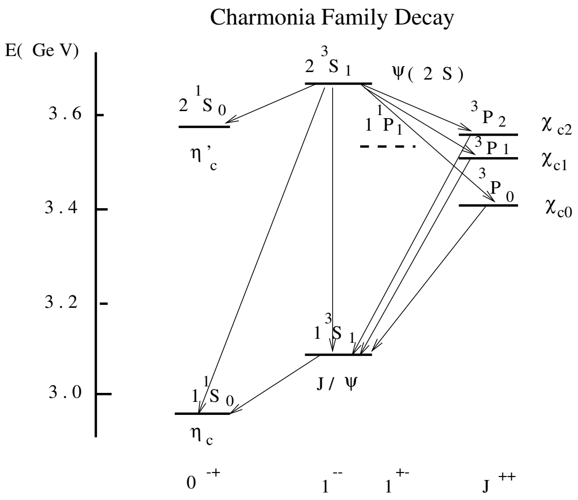

Figure 2: Charmonia Family Transition Decay

5. Further efforts: tune parameters to satisfy J/ψ, $\psi(2S)$ data sample distributions(e.g. N_{chrg}, momentum, . . .).

6. Cheers! We have J/ψ, $\psi(2S)$ decay generators at BES.

Closing address

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19 June, 1998

(The script of the talk has not been received)