A Note on Systematic Errors

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February 23, 1998

Abstract

This brief note details the values chosen for the systematic errors in this series of χ_c hadronic decay analyses. Further haggling over these values might improve the precision of this estimate, but seems unlikely to improve the accuracy.

1 Input

Taking note of a recent comparison[1] of the performance of kinematic fits (using TELESIS) for data and Monte Carlo, the following observations are made:

mode	**CL cut**	Error: $\Delta(MC - data)$
$e^+e^- \rightarrow \gamma\gamma(\gamma)$	1%	+9.0%
$e^+e^- \rightarrow \gamma\gamma(\gamma)$	5%	+18.3%
$\psi' \rightarrow \pi^+\pi^- J/\psi \rightarrow \mu^+\mu^-$	5%	−16.9%

To apply these to the χ_c analyses performed recently[2], some fiddling with the values is needed. Ideally, such *ad hoc* corrections should be painstakingly avoided, but there currently appears no recourse to obtaining the best estimate of the systematic errors for these decays using BES for the ψ' data set.

2 Error Parameterization

Taking on the issue of how to interpret the γ performance, it is noted that the resolution function used for the BES Shower Counter (BSC) corresponds to the values given in the table below.

BSC Resolution Function	γ Energy	$E_{resolution}$
	1800 MeV	18.6%
$E_{res} = \frac{25\%}{\sqrt{E}}$	300 MeV	45.6%
	128 MeV	71%

The two lower energy γ values correspond roughly to the high and low energy limit for the radiative ψ' γ's. With the BSC performance taken into consideration, for an equivalent discrepancy in the error calculation between MC and data, there is roughly more than a factor of two difference in absolute energy resolution. Also noting that the results of TELESIS fits often jerk around the value of the fitted energy for this γ substantially, with respect to the value found in TRKLST, a factor of two dilution is chosen. That is, for the 5% CL cut used typically in the referenced analyses, the systematic error contribution of the gamma is deemed to be:

$$+18.3\%/\sqrt{2} \; = \; 12.94\% \text{ and } 12.94\% \cdot \frac{1}{2} \; = \; +\mathbf{6.47}\%/\text{Radiative } \gamma$$

For the hadronic track performance, taking the results above without modification leads to

$$-16.9\%/\sqrt{4} \; = \; -\mathbf{8.45}\%/\text{track}$$

3 Results

Previously, a 20% systematic error had been added to all of the MC results used in the branching ratio calculations. This value was completely *ad hoc*, but not completely unrealistic. It is always possible to be more dour in the assessment and worsen the systematic errors, but below is an attempt to most accurately represent the errors as they are currently understood.

3.1 Radiative Decay Plus $\pi^0\pi^0$

In this mode with a 1% CL cut, the deviation is estimated as $+9\%/2\gamma \rightarrow +6.4\%/\gamma$. Since in general some of these photons can have higher energies, no correction like that for the ψ' radiative γ is applied, which means this value is perhaps slightly overestimated.

Mode	Contribution	Product	Final Result†
$\gamma\ +\ 2\pi^0$	$\sqrt{5}\cdot +6.4\%$	$+14.3\%$	20%

3.2 Radiative Decay Plus Charged Hadronic Tracks

Adding the contribution from the radiative gamma to the systematic error for the number of hadronic tracks (tracks added in quadrature), the results are tabulated below.

Mode	Contributions	Sum	Final Result†
γ + 2 Track	$+6.47\% - 11.95\%$	-5.48%	7.8%
γ + 4 Track	$+6.47\% - 16.9\%$	-10.4%	14.7%
γ + 6 Track	$+6.47\% - 20.7\%$	-14.2%	20.0%
γ + 8 Track	$+6.47\% - 23.9\%$	-17.4%	24.6%
γ + 10 Track	$+6.47\% - 26.72\%$	-20.3%	28.6%

† *This includes a final scaling of* $\cdot\sqrt{2}$; *an "Ignorance Tax" which has been applied to account for some of the wild extrapolations made above, as well as uncertainties about:* γ *detection efficiency at low energy, tracking error matrix performance of hadrons versus leptons, simulation errors of the BES muon system, etc.*

Note that these values have a direct impact on the ability of BES to make an accurate comparision with previous results[3]. A further refinement to these numbers for the χ_c case would require a calibration mode such as was used for the direct ψ' decays. One such mode would be $\chi_c \rightarrow \gamma + J/\psi$. However, this mode has serious background from the direct decay $\psi' \rightarrow \pi^0 J/\psi$. In addition, requiring the calibration mode to involve a χ_c already drops the statistics by an order of magnitude, which will limit its usefulness as a calibration.

3.3 Detector Lineshape

A 5% systematic error has been added to the fit number of events to account for the fact that gaussians are used to fit the event spectra. While this differs slightly from the detector response function (which isn't necessarily correct, as indicated by the above discrepancies), given the typically low statistics involved, it does not contribute significantly to the error. In addition, it permits a direct estimate of the statistical error from the fit, which is not readily accessible if fitting with a histogram. Note this was done for all modes except for $3(\pi^+\pi^-)$ (excluded for technical reasons), but is a tiny effect with respect to the other systematic errors involved in extracting the branching ratios.

References

[1] C.Z. Yuan, *Is TELESIS Reliable?*, BES ψ' Group Memo, Nov. 1997.

[2] G.S. Varner "Analysis Note: χ_{cJ} Decays to High Multiplicity $\pi^+\pi^-$ Pairs", BES Analysis Memo, Dec. 1997.
G.S. Varner "Analysis Note: χ_{cJ} Decays to Two Charged Hadronic Tracks", BES Analysis Memo, Jan. 1998.
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G.S. Varner "Analysis Note: χ_{cJ} χ_c Decays Involving π^0's ", BES Analysis Memo, Feb. 1998.

[3] R.M. Barnett *et al.*, Phys. Rev. **D54**, 1 (1996).