

Topology Analysis ^{*†‡}

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[†]This package is implemented referring to a program called TOPO, which is first developed by Prof. Shuxian Du from Zhengzhou University and later extended and maintained by Prof. Gang Li from Institute of High Energy Physics, Chinese Academy of Sciences. The TOPO program has been widely used by colleagues in BESIII collaboration. Several years ago, when I was a Ph.D. student working on the BESIII experiment, I learned the idea of topology analysis and a lot of programming techniques from the TOPO program. So, I really appreciate the original works of Prof. Du and Prof. Li very much. To meet my own needs and to practice developing analysis tools with C++, ROOT, and LaTeX, I wrote the package from scratch. At that time, the package functioned well but was relatively simple. At the end of 2017, my co-supervisor, Prof. Chengping Shen reminded me that it could be a useful tool for the Belle II experiment as well. So, I revised and extended it, making it more well-rounded and suitable for the Belle II experiment. Here, I would like to thank Prof. Du and Prof. Li for their original works, and Prof. Shen for his suggestion, guidance, support, and encouragement.

[‡]Besides, I would like to thank all of the people who have helped me in the development of the program. I am particularly grateful to Prof. Xingtao Huang for his comments on the principles and styles of the program, to Remco de Boer for his suggestions on the tex output and the use of GitHub, and to Xi Chen for his discussions on the core algorithms. I am especially indebted to Prof. Xiqing Hao, Longke Li, Xiaoping Qin, Ilya Komarov, Yubo Li, Guanda Gong, Suxian Li, Junhao Yin, Prof. Xiaolong Wang, Yeqi Chen, and Hannah Wakeling for their advice in extending and perfecting the program. Also, I thank Xi'an Xiong, Runqiu Ma, Wencheng Yan, Sen Jia, Lu Cao, Dong Liu, Hongpeng Wang, Jiawei Zhang, Hongrong Qi, Jiajun Liu, Maoqiang Jing, Yi Zhang, Wei Shan, and Yadi Wang for their efforts in helping me test the program.

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Table 1: Decay trees and their respective initial-final states.

rowNo	decay tree (decay initial-final states)	iDcyTr	nEtr	nCEtr
1	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \eta J/\psi, \bar{B}^0 \rightarrow \tau^- \bar{\nu}_\tau \pi^+, \eta \rightarrow \gamma\gamma, J/\psi \rightarrow \mu^+ \mu^-, \tau^- \rightarrow e^- \bar{\nu}_e \nu_\tau$ ($\Upsilon(4S) \rightarrow e^- \bar{\nu}_e \mu^+ \mu^- \nu_\tau \bar{\nu}_\tau \pi^+ \gamma\gamma$)	9	4919	4919
2	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \tau^+ \nu_\tau \pi^-, \bar{B}^0 \rightarrow \eta J/\psi, \tau^+ \rightarrow \mu^+ \nu_\mu \bar{\nu}_\tau, \eta \rightarrow \gamma\gamma, J/\psi \rightarrow \mu^+ \mu^-$ ($\Upsilon(4S) \rightarrow \mu^+ \mu^+ \mu^- \nu_\mu \nu_\tau \bar{\nu}_\tau \pi^- \gamma\gamma$)	20	4857	9776
3	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow K^* \gamma, \bar{B}^0 \rightarrow \nu_\tau \bar{\nu}_\tau, K^* \rightarrow \pi^0 K_S^0, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow \nu_\tau \bar{\nu}_\tau \pi^0 \pi^+ \pi^- \gamma$)	17	4846	14622
4	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \eta J/\psi, \bar{B}^0 \rightarrow \eta \bar{X}_{sd}, \eta \rightarrow \gamma\gamma, J/\psi \rightarrow e^+ e^-, \eta \rightarrow \gamma\gamma,$ $\bar{X}_{sd} \rightarrow \rho^0 K_S^0, \rho^0 \rightarrow \pi^+ \pi^-, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow e^+ e^- \pi^+ \pi^+ \pi^- \pi^- \gamma\gamma\gamma\gamma$)	11	4837	19459
5	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow X_{sd} \gamma, \bar{B}^0 \rightarrow \gamma\gamma, X_{sd} \rightarrow \rho^0 K_S^0, \rho^0 \rightarrow \pi^+ \pi^-, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow \pi^+ \pi^+ \pi^- \pi^- \gamma\gamma\gamma$)	7	4829	24288
6	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \nu_e \bar{\nu}_e K^*, \bar{B}^0 \rightarrow \mu^+ \mu^-, K^* \rightarrow \pi^- K^+$ ($\Upsilon(4S) \rightarrow \nu_e \bar{\nu}_e \mu^+ \mu^- \pi^- K^+$)	19	4815	29103
7	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \tau^+ \tau^- X_{sd}, \bar{B}^0 \rightarrow \eta J/\psi, \tau^+ \rightarrow e^+ \nu_e \bar{\nu}_\tau, \tau^- \rightarrow \mu^- \bar{\nu}_\mu \nu_\tau, X_{sd} \rightarrow \rho^0 K_S^0,$ $\eta \rightarrow \gamma\gamma, J/\psi \rightarrow e^+ e^-, \rho^0 \rightarrow \pi^+ \pi^-, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow e^+ e^+ e^- \nu_e \mu^- \bar{\nu}_\mu \nu_\tau \bar{\nu}_\tau \pi^+ \pi^+ \pi^- \pi^- \gamma\gamma$)	0	4789	33892
8	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \eta J/\psi, \bar{B}^0 \rightarrow \tau^+ \tau^- \bar{X}_{sd}, \eta \rightarrow \pi^0 \pi^+ \pi^-, J/\psi \rightarrow e^+ e^-, \tau^+ \rightarrow \mu^+ \nu_\mu \bar{\nu}_\tau,$ $\tau^- \rightarrow e^- \bar{\nu}_e \nu_\tau, \bar{X}_{sd} \rightarrow \rho^0 K_S^0, \rho^0 \rightarrow \pi^+ \pi^-, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow e^+ e^- e^- \bar{\nu}_e \mu^+ \nu_\mu \nu_\tau \bar{\nu}_\tau \pi^0 \pi^+ \pi^+ \pi^- \pi^- \pi^-$)	5	4786	38678
9	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \nu_\tau \bar{\nu}_\tau \gamma, \bar{B}^0 \rightarrow \bar{K}^* \gamma, \bar{K}^* \rightarrow \pi^0 K_S^0, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow \nu_\tau \bar{\nu}_\tau \pi^0 \pi^+ \pi^- \gamma\gamma$)	8	4785	43463
10	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \nu_\tau \bar{\nu}_\tau, \bar{B}^0 \rightarrow \omega K_S^0, \omega \rightarrow \pi^0 \pi^+ \pi^-, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow \nu_\tau \bar{\nu}_\tau \pi^0 \pi^+ \pi^- \pi^-$)	15	4773	48236
11	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \pi^0 J/\psi, \bar{B}^0 \rightarrow \nu_e \bar{\nu}_e \bar{K}^0, J/\psi \rightarrow \mu^+ \mu^-, \bar{K}^0 \rightarrow K_S^0, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow \nu_e \bar{\nu}_e \mu^+ \mu^- \pi^0 \pi^+ \pi^-$)	2	4773	53009
12	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \gamma\gamma, \bar{B}^0 \rightarrow \eta J/\psi, \eta \rightarrow \pi^0 \pi^+ \pi^-, J/\psi \rightarrow e^+ e^-$ ($\Upsilon(4S) \rightarrow e^+ e^- \pi^0 \pi^+ \pi^- \gamma\gamma$)	13	4752	57761
13	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow e^+ e^-, \bar{B}^0 \rightarrow \nu_e \bar{\nu}_e \bar{K}^*, \bar{K}^* \rightarrow \pi^+ K^-$ ($\Upsilon(4S) \rightarrow e^+ e^- \nu_e \bar{\nu}_e \pi^+ K^-$)	4	4743	62504
14	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \pi^0 J/\psi, \bar{B}^0 \rightarrow \tau^- \bar{\nu}_\tau \pi^+, J/\psi \rightarrow e^+ e^-, \tau^- \rightarrow \nu_\tau \pi^-$ ($\Upsilon(4S) \rightarrow e^+ e^- \nu_\tau \bar{\nu}_\tau \pi^0 \pi^+ \pi^-$)	12	4725	67229
15	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \tau^+ \nu_\tau \pi^-, \bar{B}^0 \rightarrow \eta J/\psi, \tau^+ \rightarrow \bar{\nu}_\tau \pi^+, \eta \rightarrow \pi^0 \pi^+ \pi^-, J/\psi \rightarrow \mu^+ \mu^-$ ($\Upsilon(4S) \rightarrow \mu^+ \mu^- \nu_\tau \bar{\nu}_\tau \pi^0 \pi^+ \pi^+ \pi^- \pi^-$)	16	4724	71953

rowNo	decay tree (decay initial-final states)	iDcyTr	nEtr	nCEtr
16	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \mu^+ \mu^-, \bar{B}^0 \rightarrow \nu_\tau \bar{\nu}_\tau \gamma$ ($\Upsilon(4S) \rightarrow \mu^+ \mu^- \nu_\tau \bar{\nu}_\tau \gamma$)	1	4716	76669
17	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \eta J/\psi, \bar{B}^0 \rightarrow \tau^- \bar{\nu}_\tau \pi^+, \eta \rightarrow \pi^0 \pi^+ \pi^-, J/\psi \rightarrow \mu^+ \mu^-, \tau^- \rightarrow \mu^- \bar{\nu}_\mu \nu_\tau$ ($\Upsilon(4S) \rightarrow \mu^+ \mu^- \mu^- \bar{\nu}_\mu \nu_\tau \bar{\nu}_\tau \pi^0 \pi^+ \pi^+ \pi^-$)	14	4715	81384
18	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \tau^+ \nu_\tau \pi^-, \bar{B}^0 \rightarrow \pi^0 J/\psi, \tau^+ \rightarrow e^+ \nu_e \bar{\nu}_\tau, J/\psi \rightarrow \mu^+ \mu^-$ ($\Upsilon(4S) \rightarrow e^+ \nu_e \mu^+ \mu^- \nu_\tau \bar{\nu}_\tau \pi^0 \pi^-$)	10	4685	86069
19	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \eta X_{sd}, \bar{B}^0 \rightarrow \pi^0 J/\psi, \eta \rightarrow \gamma \gamma, X_{sd} \rightarrow \rho^0 K_S^0, J/\psi \rightarrow e^+ e^-,$ $\rho^0 \rightarrow \pi^+ \pi^-, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow e^+ e^- \pi^0 \pi^+ \pi^+ \pi^- \pi^- \pi^- \gamma \gamma$)	3	4685	90754
20	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \omega K_S^0, \bar{B}^0 \rightarrow \bar{X}_{sd} \gamma, \omega \rightarrow \pi^0 \pi^+ \pi^-, K_S^0 \rightarrow \pi^+ \pi^-, \bar{X}_{sd} \rightarrow \rho^0 K_S^0,$ $\rho^0 \rightarrow \pi^+ \pi^-, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow \pi^0 \pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^- \pi^- \gamma$)	18	4680	95434
21	$\Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \nu_e \bar{\nu}_e K^0, \bar{B}^0 \rightarrow e^+ e^-, K^0 \rightarrow K_S^0, K_S^0 \rightarrow \pi^+ \pi^-$ ($\Upsilon(4S) \rightarrow e^+ e^- \nu_e \bar{\nu}_e \pi^+ \pi^-$)	6	4566	100000