

A Brief Guide to TopoAna

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Outline

- 1 Why
- 2 What
- 3 How
- 4 Summary

Why do we need topology analysis?

- One of the most important parts in physics analyses is event selection, or in other words, to veto backgrounds.
- As for it, inclusive Monte Carlo (MC) samples are very helpful, because they contain a basic knowledge of the backgrounds from collision.
- However, the information in the inclusive MC samples is overwhelming, which makes it difficult for us to see the main backgrounds from the raw MC information directly.
- To find the main backgrounds quickly, topology analysis programs are developed.
- Then, by analyzing the differences between the main backgrounds and the signal, one can optimize the selection criteria to suppress backgrounds.

Why do I write the TopoAna package?

- A program called “Topo”, developed by Prof. Shuxian Du, is widely used by people in the BESIII collabration.
- You can find it in the following directory on the IHEPCC servers lxslc5.ihep.ac.cn and lxslc6.ihep.ac.cn:

[`/ihepbatch/bes/dusx/common/topo`](#)

- Now, it is very mature and its latest version is Topo-19.
- Thus, it is still the best choice for the BESIII users.
- I learned the idea of topology analysis and a lot of programming techniques from it.
- To practice devolving analysis tools and revise it to meet my own needs, I decide to write a new topology analysis package from scratch.

What files are contained in the TopoAna package?

- You can find the TopoAna package in the following directory on the KEKCC servers login.cc.kek.jp:
`/home/belle2/zhouxy/workarea/tools/topoana/v1.0.0`
- Three directories are contained in the package:
 - **core** — the core part of the package
 - **doc** — the documents related to the package
 - **test** — A test example of the package

```
[zhouxy@cw05 v1.0.0]$ pwd
/home/belle2/zhouxy/workarea/tools/topoana/v1.0.0
[zhouxy@cw05 v1.0.0]$ ls
core/  doc/  test/
[zhouxy@cw05 v1.0.0]$ ls core
complile.sh*  pid_texpnm.dat  topoana.card  topoana.exe*
pid_3pchrq.dat  pid_txtpm.dat  topoana.cpp  topoana.h
[zhouxy@cw05 v1.0.0]$ ls doc
evt.pdl@  pid_psymb.pdf  readme.pdf
[zhouxy@cw05 v1.0.0]$ ls test
clean.sh*          mixed2.root          mixed_topoana.out    mixed_topoana.tex
getPdfFlFromTexFl.sh*  mixed_topoana.card  mixed_topoana.pdf    mixed_topoana.txt
mixed1.root        mixed_topoana.err    mixed_topoana.root    topoana.sh*
```

What files are contained in the TopoAna package?

core

- `topoana.h` — the header file
- `topoana.cpp` — the source file
- `topoana.exe` — the executable file
- `compile.sh` — the shell script used to get `topoana.exe` from `topoana.h` and `topoana.cpp`
- `topoana.card` — the empty template of cards to specify input and output information and other optional arguments
- `pid_3pchrg.dat` — the data file containing pairs of particle PDG code to 3 times particle charge
- `pid_txtpnm.dat` — the data file containing pairs of particle PDG code to txt particle name
- `pid_texpnm.dat` — the data file containing pairs of particle PDG code to tex particle name

What files are contained in the TopoAna package?

core — pid_3pchrg/txtptnm/txpnm.dat

```
[zhouxy@cw02 core]$ pwd
/home/belle2/zhouxy/workarea/tools/topoana/v1.0.0/core
[zhouxy@cw02 core]$ ls
compile.sh*  pid_texpnm.dat  topoana.card  topoana.exe*
pid_3pchrg.dat  pid_txtptnm.dat  topoana.cpp  topoana.h
[zhouxy@cw02 core]$ wc -l pid_3pchrg.dat
578 pid_3pchrg.dat
[zhouxy@cw02 core]$ wc -l pid_txtptnm.dat
586 pid_txtptnm.dat
[zhouxy@cw02 core]$ wc -l pid_texpnm.dat
269 pid_texpnm.dat
[zhouxy@cw02 core]$
```

[zhouxy@cw02 core]\$ head pid_3pchrg.dat	
1	-1
-1	1
2	2
-2	-2
3	-1
-3	1
4	2
-4	-2
5	-1
-5	1

```
[zhouxy@cw02 core]$
```

[zhouxy@cw02 core]\$ head pid_texpnm.dat	
1	d
-1	\bar{d}
2	u
-2	\bar{u}
3	s
-3	\bar{s}
4	c
-4	\bar{c}
5	b
-5	\bar{b}

[zhouxy@cw02 core]\$ head pid_txtptnm.dat	
1	d
-1	anti-d
2	u
-2	anti-u
3	s
-3	anti-s
4	c
-4	anti-c
5	b
-5	anti-b

What files are contained in the TopoAna package?

doc

- **evt.pdl** — the symlink pointing to the particle data list file of the EvtGen generator: `/cvmfs/belle.cern.ch/sl6/externals/v01-04-01/share/evtgen/evt.pdl`
(You can refer to it when adding a new pair of particle PDG code to tex particle name in `pid_txtpnm.dat`)
- **pid_psympb.pdf** — the Monte Carlo particle numbering scheme from PDG 2016
(You can refer to it when adding a new pair of particle PDG code to tex particle name in `pid_texpnm.dat`)
- **readme.pdf** — a brief guide to TopoAna, **just this one**
(You can get a basic knowledge of TopoAna from it)

```
[zhouxy@cw05 doc]$ ls
evt.pdl@ pid_psympb.pdf readme.pdf
[zhouxy@cw05 doc]$ ll evt.pdl
lrwxrwxrwx 1 zhouxy b2_belle2 65 Jan  7 18:51 evt.pdl -> /cvmfs/belle.cern.ch/sl6/externa
ls/v01-04-01/share/evtgen/evt.pdl
[zhouxy@cw05 doc]$ █
```


What files are contained in the TopoAna package?

doc — evt.pdl

```
[zhouxy@cw05 doc]$ head -20 evt.pdl
```

```
*-----  
* 5/10/2013 Updated by R. Godang. The format and convention are based on the current evt.pdl and PDG 2012  
*-----
```

*	name	id	mass/GeV	width/GeV	max_Dm/GeV	3*charge	2*spin	lifetime*c/mm	PythiaId
add p Particle	K_4**	329	2.0450000e+00	1.9800000e-01	2.0000000e-01	3	8	0.0000000e+00	0
add p Particle	h_b(2P)	110553	1.0255000e+01	0.0000000e+00	0.0000000e+00	0	2	0.0000000e+00	110553
add p Particle	b	5	5.0000000e+00	0.0000000e+00	0.0000000e+00	-1	1	0.0000000e+00	5
add p Particle	anti-nu_e	-12	0.0000000e+00	0.0000000e+00	0.0000000e+00	0	1	0.0000000e+00	-12
add p Particle	D_2*0	425	2.4611000e+00	4.3000001e-02	3.0900000e-01	0	4	0.0000000e+00	425
add p Particle	Upsilon	553	9.4603000e+00	5.4000022e-05	5.0000000e-04	0	2	0.0000000e+00	553
add p Particle	anti-B'_10	-20513	5.7570000e+00	2.5027080e-01	2.0000000e-01	0	2	0.0000000e+00	-20513
add p Particle	anti-K0	-311	4.9761400e-01	0.0000000e+00	0.0000000e+00	0	0	0.0000000e+00	-311
add p Particle	Lambda(1405)0	13122	1.4060000e+00	5.0000015e-02	7.0000000e-02	0	1	0.0000000e+00	0
add p Particle	K*+	323	8.9166000e-01	5.0800012e-02	2.3000000e-01	3	2	0.0000000e+00	323
add p Particle	e+	-11	5.1099891e-04	0.0000000e+00	0.0000000e+00	3	1	0.0000000e+00	-11
add p Particle	B0H	510	5.2795300e+00	0.0000000e+00	0.0000000e+00	0	0	4.5718350e-01	0
add p Particle	K_2*-	-325	1.4256000e+00	9.8500006e-02	7.0000000e-01	-3	4	0.0000000e+00	-325
add p Particle	B'_10	20513	5.7570000e+00	2.5027080e-01	2.0000000e-01	0	2	0.0000000e+00	20513
add p Particle	K-	-321	4.9367700e-01	0.0000000e+00	0.0000000e+00	-3	0	3.7114306e+03	-321
add p Particle	eta_b2(2D)	110555	1.0441000e+01	0.0000000e+00	0.0000000e+00	0	4	0.0000000e+00	110555

```
[zhouxy@cw05 doc]$
```

What files are contained in the TopoAna package?

doc — pid_psymb.pdf

Footnotes to the Tables:
 a) Numbers or names in bold face are new or have changed since the 2014 Review.
 b) Particular in the third generation, the left and right silicon states may mix, as shown. The lighter mixed state is given the smaller number.
 c) The physical $\bar{\tau}$ states are admixtures of the pure $\bar{\tau}$, \bar{Z}^0 , \bar{W}^0 , \bar{R}_1^0 , \bar{R}_2^0 , and \bar{R}^+ states.
 d) \bar{U}^- and \bar{E}^+ are alternate names for $\bar{U}(1365)$ and $\bar{U}(1330)$.

What files are contained in the TopoAna package?

doc — readme.pdf

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What files are contained in the TopoAna package? test (1)

```
[zhouxy@cw05 test]$ ls
clean.sh*          mixed1.root  mixed_topoana.card
getPdfFromTexFl.sh* mixed2.root  topoana.sh*
[zhouxy@cw05 test]$ ../core/topoana.exe mixed_topoana.card >mixed_topoana.out 2>mixed_topoana.err
[zhouxy@cw05 test]$ ls
clean.sh*          mixed2.root          mixed_topoana.out  mixed_topoana.tex
getPdfFromTexFl.sh* mixed_topoana.card  mixed_topoana.pdf  mixed_topoana.txt
mixed1.root        mixed_topoana.err    mixed_topoana.root topoana.sh*
```

Input files:

- **mixed1.root and mixed2.root** — the root files containing the MC truth for topology analysis, which includes
 - **Nps** — Number of particles
 - **Pid** — Array of particle identifications
 - **Midx** — Array of mother indices of particles
- **mixed_topoana.card** — the card file specifying input and output information and other optional arguments

What files are contained in the TopoAna package? test (2)

Output files:

- **mixed_topoana.root** — The root file containing data included in the input root files with new tags.
- **mixed_topoana.pdf/tex/txt** — The pdf/tex/txt file containing the summary information on event topology.

Other files:

- **mixed_topoana.out/err** — the stdout/stderr information
- **topology.sh** — you can use it to submit jobs to the queue.
- **getPdfFIFromTexFI.sh** — The shell script to compile the tex file manually.
- **clean.sh** — The shell script to clean the output files

What files are contained in the TopoAna package?

test — mixed[1-2].root

```
[zhouxy@cw05 test]$ root -l
root [0] TFile f("mixed1.root")
(TFile &) Name: mixed1.root Title:
root [1] f.ls()
TFile**          mixed1.root
TFile*           mixed1.root
KEY: TTree      evt;1
root [2] evt->Show(0,200)
=====> EVENT:0
exp_no          = 0
run_no          = 0
evt_no          = 170002
Nps             = 33
Pid             = 300553,
                511, -511, -411, 223, 211, 113, 413, -211, -211, 211,
                111, 313, 13, -14, 111, 22, 211, -211, 421, 211,
                22, 22, 321, -211, 22, 22, 20213, -321, 113, 211,
                211, -211
Midx            = 0,
                0, 0, 1, 1, 1, 1, 2, 2, 2, 2,
                2, 3, 3, 3, 4, 4, 6, 6, 7, 7,
                11, 11, 12, 12, 15, 15, 19, 19, 27, 27,
                29, 29
m_nCands        = 0
m_iCand         = 0
```

What files are contained in the TopoAna package?

test — mixed_topoana.card — input and output

```
[zhouxy@cw05 test]$ sed -n '1,24p' mixed_topoana.card
Begin names of input root files
mixed1.root
mixed2.root
End names of input root files

Begin tree name
evt
End tree name

Begin branch name of the number of particles
Nps
End branch name of the number of particles

Begin branch name of the array of particle identifications
Pid
End branch name of the array of particle identifications

Begin branch name of the array of the mother indeces of particles
Midx
End branch name of the array of the mother indeces of particles

Begin main name of output files
mixed_topoana
End main name of output files
```

What files are contained in the TopoAna package?

test — concepts used in the package

particle

- $\Upsilon(4S)$

event branch

- $\bar{B}^0 \rightarrow K_S J/\psi$

event tree

- $e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0\bar{B}^0, B^0 \rightarrow e^+\nu_e\bar{D}^{*-}, \bar{B}^0 \rightarrow K_S J/\psi, \bar{D}^{*-} \rightarrow \pi^-\bar{D}^0, K_S \rightarrow \pi^+\pi^-\gamma, J/\psi \rightarrow e^+e^-\gamma, \bar{D}^0 \rightarrow K_L\pi^+\pi^-$

event initial-final states

- $e^+e^- \rightarrow e^+e^+e^-\nu_e K_L\pi^+\pi^+\pi^-\pi^-\pi^-\gamma\gamma$

What files are contained in the TopoAna package?

test — mixed_topoana.card — signals (1)

```
[zhouxy@cw05 test]$ sed -n '25,48p' mixed_topoana.card
```

```
Begin signal particle names
```

```
J/psi  
psi(2S)
```

```
End signal particle names
```

```
Begin signal event branches
```

0	B0	-1
1	K S0	0
2	\bar{J}/ψ	0
3	pi+	1
4	pi-	1
5	mu+	2
6	mu-	2

0	anti-B0	-1
1	K S0	0
2	\bar{J}/ψ	0
3	pi+	1
4	pi-	1
5	mu+	2
6	mu-	2

```
End signal event branches
```

What files are contained in the TopoAna package?

test — mixed_topoana.card — signals (2)

```
[zhouxy@cw05 test]$ sed -n '49,69p' mixed_topoana.card  
Begin signal event trees
```

0	Upsilon(4S)	-1
1	B0	0
2	anti-B0	0
3	e+	1
4	nu_e	1
5	D*-	1
6	K_S0	2
7	J/psi	2
8	pi-	5
9	anti-D0	5
10	pi+	6
11	pi-	6
12	gamma	6
13	mu+	7
14	mu-	7
15	gamma	7
16	K_L0	9
17	pi+	9
18	pi-	9

```
[zhouxy@cw05 test]$
```

What files are contained in the TopoAna package?

test — mixed_topoana.card — signals (3)

```
[zhouxy@cw05 test]$ sed -n '70,90p' mixed_topoana.card
```

0	Upsilon(4S)	-1
1	B0	0
2	anti-B0	0
3	e+	1
4	nu_e	1
5	D*-	1
6	K_S0	2
7	J/psi	2
8	pi-	5
9	anti-D0	5
10	pi+	6
11	pi-	6
12	gamma	6
13	e+	7
14	e-	7
15	gamma	7
16	K_L0	9
17	pi+	9
18	pi-	9

```
End signal event trees
```

```
[zhouxy@cw05 test]$
```

What files are contained in the TopoAna package?

test — mixed_topoana.card — signals (4)

```
[zhouxy@cw05 test]$ sed -n '91,117p' mixed_topoana.card  
Begin signal event final states
```

0	e+
1	nu_e
2	mu+
3	mu-
4	K_L0
5	pi+
6	pi+
7	pi-
8	pi-
9	pi-
10	gamma
11	gamma

0	e+
1	nu_e
2	e+
3	e-
4	K_L0
5	pi+
6	pi+
7	pi-
8	pi-
9	pi-
10	gamma
11	gamma

```
End signal event final states
```

What files are contained in the TopoAna package?

test — mixed_topoana.card — restrictions

```
[zhouxy@cw05 test]$ sed -n '118,$p' mixed_topoana.card
```

```
Begin maximum number of events to be processed
```

```
400000
```

```
End maximum number of events to be processed
```

```
Begin cut to select events
```

```
Nps==19
```

```
End cut to select events
```

```
[zhouxy@cw05 test]$
```

What files are contained in the TopoAna package?

test — tags in mixed_topoana.root/pdf/tex/txt

- iEvtTr — index of event tree
- iEvtIFSts — index of event initial-final states
- nSigP — array of numbers of signal particles
- nSigEvtBrs — array of numbers of signal event branches
- iSigEvtTr — index of signal event tree
- iSigEvtIFSts — index of signal event initial-final states related to signal event tree
- iSigEvtIFSts2 — index of signal event initial-final states

What files are contained in the TopoAna package?

test — mixed_topoana.root

```
[zhouxy@cw05 test]$ root -l
root [0] TFile f("mixed_topoana.root")
(TFile &) Name: mixed_topoana.root Title:
root [1] f.ls()
TFile**      mixed_topoana.root
TFile*       mixed_topoana.root
KEY: TTree   evt;1
root [2] evt->Show(0,200)
=====> EVENT:0
  exp_no      = 0
  run_no      = 0
  evt no      = 170514
  Nps         = 19
  Pid         = 300553,
              -511, 511, -313, 443, 111, 315, 22, -321, 211, 22,
              321, -311, -211, 22, 22, 321, -211, 130
  Midx        = 0,
              0, 0, 1, 1, 1, 2, 2, 3, 3, 4,
              4, 4, 4, 5, 5, 6, 6, 12
  m_nCands    = 0
  m_iCand     = 0
  iEvtTr      = 0
  iEvtIFSts   = 0
  nSigPid     = 1,
              0
  nSigEvtBrs  = 0,
              0
  iSigEvtTr   = -1
  iSigEvtIFSts = -1
  iSigEvtIFSts2 = -1
root [3]
```

What files are contained in the TopoAna package?

test — mixed_topoana.pdf — (1)

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

index	event tree (event initial-final states)	iEvtTr	iEvtIFSts	nEvs	nCmltEvs
1	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow e^+ \nu_e D^{*-}, \bar{B}^0 \rightarrow e^- \bar{\nu}_e D^{*+}, D^{*-} \rightarrow \pi^- D^0, D^{*+} \rightarrow \pi^+ \pi^+ K^-,$ $\bar{D}^0 \rightarrow \pi^0 \pi^+ K^+$ $(e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma)$	118	33	3	3
2	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^+ \bar{B}^-, B^+ \rightarrow \mu^+ \nu_\mu D^{*-}, \bar{B}^- \rightarrow \mu^- \bar{\nu}_\mu D^{*+}, D^{*-} \rightarrow \pi^- \bar{D}^0, D^{*+} \rightarrow e^+ \nu_e \bar{K}^0,$ $\bar{D}^0 \rightarrow e^- \bar{\nu}_e K^+ \gamma, \bar{K}^0 \rightarrow K_S$ $(e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \mu^+ \mu^- \nu_\mu \bar{\nu}_\mu \pi^- K_S K^+ \gamma)$	1	1	2	5
3	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow \mu^+ \nu_\mu D^-, \bar{B}^0 \rightarrow \mu^- \bar{\nu}_\mu D^+, D^- \rightarrow \pi^- K_S, D^+ \rightarrow \mu^+ \nu_\mu \bar{K}^+ \gamma,$ $K_S \rightarrow \pi^+ \pi^-, \bar{K}^+ \rightarrow \pi^+ K^-$ $(e^+e^- \rightarrow \mu^+ \mu^+ \mu^- \nu_\mu \nu_\mu \bar{\nu}_\mu \pi^+ \pi^- \pi^- K^- \gamma)$	2	2	2	7
4	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow e^+ \nu_e D^{*-} \gamma, \bar{B}^0 \rightarrow \pi^+ \pi^- \eta, D^{*-} \rightarrow \pi^- D^0, \eta \rightarrow \gamma \gamma,$ $\bar{D}^0 \rightarrow \pi^0 \pi^+ K^+$ $(e^+e^- \rightarrow e^+ \nu_e \pi^+ \pi^- \pi^- \pi^- K^+ \gamma \gamma \gamma \gamma)$	3	3	2	9
5	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^+ \bar{B}^-, B^+ \rightarrow \mu^+ \nu_\mu D^{*-} \gamma, \bar{B}^- \rightarrow \pi^- K^+ K^- D^+, D^- \rightarrow \pi^- \pi^- K^+, D^+ \rightarrow e^+ \nu_e \bar{K}^0 \gamma,$ $\bar{K}^0 \rightarrow K_L$ $(e^+e^- \rightarrow e^+ \nu_e \mu^+ \nu_\mu K_L \pi^- \pi^- \pi^- K^+ K^- \gamma \gamma)$	4	4	2	11
6	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^+ \bar{B}^-, B^+ \rightarrow e^+ \nu_e \pi^- D^{*0}, \bar{B}^- \rightarrow e^- \bar{\nu}_e D^{*+}, D^{*0} \rightarrow D^0 \gamma, D^{*+} \rightarrow \pi^+ \pi^+ K^-,$ $\bar{D}^0 \rightarrow \pi^+ \pi^+ \pi^- \pi^-$ $(e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^- K^- \gamma)$	5	5	2	13
7	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^+ \bar{B}^-, B^+ \rightarrow \mu^+ \nu_\mu D^-, \bar{B}^- \rightarrow \pi^- \pi^- \pi^- D^0, D^- \rightarrow e^- \bar{\nu}_e \pi^- K^+, D^0 \rightarrow \mu^+ \nu_\mu K^-$ $(e^+e^- \rightarrow e^- \bar{\nu}_e \mu^+ \mu^+ \nu_\mu \nu_\mu \pi^+ \pi^- \pi^- K^+ K^- \gamma \gamma)$	6	6	2	15
8	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow D^- a_1^+, \bar{B}^0 \rightarrow e^- \bar{\nu}_e D^{*+} \gamma, D^- \rightarrow \pi^- \pi^- K^+, a_1^+ \rightarrow \rho^+ \pi^+ \gamma,$ $D^{*+} \rightarrow K_L \pi^+, \rho^+ \rightarrow \pi^+ \pi^-$ $(e^+e^- \rightarrow e^- \bar{\nu}_e K_L \pi^+ \pi^+ \pi^+ \pi^- \pi^- K^+ \gamma \gamma)$	7	7	2	17
9	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow e^+ \nu_e D^{*-}, \bar{B}^0 \rightarrow \mu^- \bar{\nu}_\mu D^{*+}, D^{*-} \rightarrow \pi^- D^0, D^{*+} \rightarrow \pi^+ \pi^+ K^-,$ $\bar{D}^0 \rightarrow \mu^- \bar{\nu}_\mu \pi^+ K^0, K^0 \rightarrow K_L$ $(e^+e^- \rightarrow e^+ \nu_e \mu^- \mu^- \bar{\nu}_\mu \bar{\nu}_\mu K_L \pi^+ \pi^+ \pi^- K^- \gamma)$	8	8	2	19
10	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow e^+ \nu_e D^{*-}, \bar{B}^0 \rightarrow e^- \bar{\nu}_e D^{*+}, D^{*-} \rightarrow \pi^- D^0, D^{*+} \rightarrow \mu^+ \nu_\mu K^+,$ $\bar{D}^0 \rightarrow \pi^- K^+, \bar{K}^+ \rightarrow \pi^+ K^- \gamma$ $(e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \mu^+ \nu_\mu \pi^+ \pi^- \pi^- K^+ K^- \gamma)$	9	9	2	21
11	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow e^- \nu_e D^{*-}, \bar{B}^0 \rightarrow D^{*-} \eta \bar{\nu}_\mu, D^{*-} \rightarrow \mu^- \bar{\nu}_\mu K^0, D^{*+} \rightarrow \pi^+ D^0,$ $K^0 \rightarrow K_L, D^0 \rightarrow K_L K_L \pi^+ \pi^-$ $(e^+e^- \rightarrow e^+ \nu_e \mu^- \bar{\nu}_\mu K_L K_L K_L \pi^+ \pi^+ \pi^- \eta \bar{\nu}_\mu)$	10	10	2	23
12	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0 \bar{B}^0, B^0 \rightarrow e^+ \nu_e D^{*-} \gamma, \bar{B}^0 \rightarrow \eta \bar{K}_S^0, D^{*-} \rightarrow e^- \bar{\nu}_e K^+ \gamma, \eta \rightarrow \gamma \gamma,$ $\bar{K}_S^0 \rightarrow \pi^+ K^-, K^+ \rightarrow \pi^- K^+$ $(e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \pi^+ \pi^- K^+ K^- \gamma \gamma \gamma \gamma)$	11	11	2	25

What files are contained in the TopoAna package?

test — mixed_topoana.pdf — (2)

Table 2: Event initial-final states.

index	event initial-final states	iEvtIFSts	nEvs	nCmItEvs
1	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e K_L \pi^+ \pi^- \pi^+ \pi^- K^+ \gamma$	22	6	6
2	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e K_L \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma \gamma$	81	6	12
3	$e^+e^- \rightarrow e^+e^- \nu_e \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma$	40	5	17
4	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma$	33	5	22
5	$e^+e^- \rightarrow \mu^+ \mu^- \mu^- \nu_\mu \nu_\mu \bar{\nu}_e K_L \pi^+ \pi^- \pi^+ \pi^- K^+ \gamma$	69	4	26
6	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \mu^+ \nu_\mu K_L \pi^+ \pi^- \pi^+ \pi^- K^+ \gamma \gamma$	73	4	30
7	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \mu^+ \nu_\mu \pi^+ \pi^- K^+ K^- \gamma \gamma \gamma$	61	4	34
8	$e^+e^- \rightarrow e^+e^- \nu_e \mu^+ \bar{\nu}_\mu \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma$	94	4	38
9	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \mu^+ \nu_\mu K_L \pi^+ \pi^- \pi^+ \pi^- K^+ \gamma \gamma$	102	4	42
10	$e^+e^- \rightarrow e^+e^- \nu_e \mu^+ \bar{\nu}_\mu \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma$	152	4	46
11	$e^+e^- \rightarrow e^+e^- \bar{\nu}_e \nu_e \mu^+ \nu_\mu \pi^+ \pi^- \pi^+ \pi^- K^+ \gamma$	52	3	49
12	$e^+e^- \rightarrow e^+e^+e^- \nu_e \nu_e \bar{\nu}_e \mu^+ \bar{\nu}_\mu \pi^+ \pi^- K^+ K^-$	55	3	52
13	$e^+e^- \rightarrow \mu^+ \mu^- \nu_\mu \bar{\nu}_\mu \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^-$	104	3	55
14	$e^+e^- \rightarrow e^+e^- \nu_e \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma$	148	3	58
15	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma$	46	3	61
16	$e^+e^- \rightarrow e^+e^- \nu_e \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma \gamma$	154	3	64
17	$e^+e^- \rightarrow e^+e^- \nu_e K_L \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma$	16	2	66
18	$e^+e^- \rightarrow e^+e^- \nu_e \mu^+ \nu_\mu K_L \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- \gamma \gamma$	17	2	68
19	$e^+e^- \rightarrow \mu^+ \mu^- K_L \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma$	18	2	70
20	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e K_L \pi^+ \pi^- K^+ K^- K^- \gamma \gamma \gamma$	19	2	72
21	$e^+e^- \rightarrow \mu^+ \bar{\nu}_\mu K_L \pi^+ \pi^- \pi^+ \pi^- K^+ K^- K^- \gamma \gamma$	20	2	74
22	$e^+e^- \rightarrow e^+e^- \nu_e \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ \gamma$	21	2	76
23	$e^+e^- \rightarrow K_L \pi^+ \pi^- \pi^+ K^+ K^- K^- \gamma \gamma \gamma \gamma$	0	2	78
24	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \mu^+ \nu_\mu K_L \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma$	23	2	80
25	$e^+e^- \rightarrow e^+e^-e^- \nu_e \bar{\nu}_e \bar{\nu}_e \mu^+ \nu_\mu \pi^+ \pi^- K^+ K^- \gamma$	24	2	82
26	$e^+e^- \rightarrow \mu^+ \mu^- \nu_\mu \bar{\nu}_\mu K_L \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^-$	25	2	84
27	$e^+e^- \rightarrow e^+e^- \nu_e \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma \gamma$	26	2	86
28	$e^+e^- \rightarrow e^+e^- \nu_e \mu^+ \nu_\mu K_L \pi^+ \pi^- \pi^+ \pi^- \gamma \gamma$	27	2	88
29	$e^+e^- \rightarrow e^+e^- \nu_e \mu^+ \bar{\nu}_\mu K_L \pi^+ \pi^- \pi^+ \pi^- \gamma \gamma \gamma$	28	2	90
30	$e^+e^- \rightarrow e^+e^- \nu_e \mu^+ \mu^- \nu_\mu \nu_\mu \pi^+ \pi^- \pi^+ \pi^- K^+ K^- \gamma$	29	2	92
31	$e^+e^- \rightarrow \mu^+ \mu^- \nu_\mu \bar{\nu}_\mu K_L \pi^+ \pi^- \pi^+ \pi^- K^+ K^-$	30	2	94
32	$e^+e^- \rightarrow \mu^+ \mu^- \nu_\mu \bar{\nu}_\mu K_L K_L \pi^+ \pi^- \gamma \gamma$	31	2	96
33	$e^+e^- \rightarrow e^+e^- \nu_e \nu_e \mu^+ \bar{\nu}_\mu \pi^+ K^+ K^- n \bar{n} \gamma \gamma$	32	2	98
34	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e \mu^+ \mu^- \nu_\mu \bar{\nu}_\mu \pi^+ K_S K^+ \gamma$	1	2	100
35	$e^+e^- \rightarrow e^+e^- \nu_e \mu^+ \nu_\mu \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ K^+ \gamma$	34	2	102
36	$e^+e^- \rightarrow \mu^+ \mu^- \nu_\mu \bar{\nu}_\mu \pi^+ \pi^- \pi^+ \pi^- K^+ n \bar{p} \gamma$	35	2	104
37	$e^+e^- \rightarrow \mu^+ \nu_\mu \pi^+ \pi^- \pi^+ \pi^- K^+ K^- n \bar{p} \gamma \gamma$	36	2	106
38	$e^+e^- \rightarrow e^+e^+e^- \nu_e \nu_e \bar{\nu}_e \mu^+ \bar{\nu}_\mu K_L \pi^+ K^+ \gamma$	37	2	108
39	$e^+e^- \rightarrow e^+e^- \nu_e \bar{\nu}_e K_L \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- K^+ \gamma \gamma$	38	2	110
40	$e^+e^- \rightarrow e^+e^- \nu_e \mu^+ \bar{\nu}_\mu \pi^+ \pi^- \pi^+ \pi^- K^+ p \bar{p}$	39	2	112

What files are contained in the TopoAna package?

test — mixed_topoana.pdf — (3)

index	signal particle	iSigPid	nEvs	nCmItEvs
1	J/ψ	0	22	22
2	ψ'	1	0	22

index	signal particle	iSigPid	nEvs	nCmItEvs
1	J/ψ	0	22	22
2	ψ'	1	0	22

index	signal event branches	iSigEvtBrs	nEvts	nCmltEvts
1	$B^0 \rightarrow K_S J/\psi, K_S \rightarrow \pi^+ \pi^-, J/\psi \rightarrow \mu^+ \mu^-$	0	0	0
2	$B^0 \rightarrow K_S J/\psi, K_S \rightarrow \pi^+ \pi^-, J/\psi \rightarrow \mu^+ \mu^-$	1	0	0

index	signal event branches	iSigEvtBrs	nEvts	nCmltEvts
1	$B^0 \rightarrow K_S J/\psi, K_S \rightarrow \pi^+ \pi^-, J/\psi \rightarrow \mu^+ \mu^-$	0	0	0
2	$B^0 \rightarrow K_S J/\psi, K_S \rightarrow \pi^+ \pi^-, J/\psi \rightarrow \mu^+ \mu^-$	1	0	0

index	signal event tree (signal event initial-final states)	iSigEvtTr	iSigEvtIFSts	ievtTr	ievtIFSts	nEvts	nCultEvts
1	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0\bar{B}^0, B^0 \rightarrow e^+\nu_e D^{*-}, \bar{B}^0 \rightarrow K_S J/\psi, D^{*-} \rightarrow \pi^- D^0,$ $K_S \rightarrow \pi^+\pi^-\gamma, J/\psi \rightarrow \mu^+\mu^-\gamma, \bar{D}^0 \rightarrow K_L\pi^+\pi^-$ $(e^+e^- \rightarrow e^+\nu_e\mu^-\mu^-K_L\pi^+\pi^-\pi^-\pi^-\pi^-\gamma\gamma)$	0	0	12	12	2	2
2	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0\bar{B}^0, B^0 \rightarrow e^+\nu_e D^{*-}, \bar{B}^0 \rightarrow K_S J/\psi, D^{*-} \rightarrow \pi^- D^0,$ $K_S \rightarrow \pi^+\pi^-\gamma, J/\psi \rightarrow e^+e^-\gamma, \bar{D}^0 \rightarrow K_L\pi^+\pi^-$ $(e^+e^- \rightarrow e^+e^-\nu_e K_L\pi^+\pi^-\pi^-\pi^-\gamma\gamma)$	1	1	—	—	0	2

index	signal event tree (signal event initial-final states)	iSigEvtTr	iSigEvtIFSts	ievtTr	ievtIFSts	nEvts	nCultEvts
1	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0\bar{B}^0, B^0 \rightarrow e^+\nu_e D^{*-}, \bar{B}^0 \rightarrow K_S J/\psi, D^{*-} \rightarrow \pi^- D^0,$ $K_S \rightarrow \pi^+\pi^-\gamma, J/\psi \rightarrow \mu^+\mu^-\gamma, \bar{D}^0 \rightarrow K_L\pi^+\pi^-$ $(e^+e^- \rightarrow e^+\nu_e\mu^-\mu^-K_L\pi^+\pi^-\pi^-\pi^-\pi^-\gamma\gamma)$	0	0	12	12	2	2
2	$e^+e^- \rightarrow \Upsilon(4S), \Upsilon(4S) \rightarrow B^0\bar{B}^0, B^0 \rightarrow e^+\nu_e D^{*-}, \bar{B}^0 \rightarrow K_S J/\psi, D^{*-} \rightarrow \pi^- D^0,$ $K_S \rightarrow \pi^+\pi^-\gamma, J/\psi \rightarrow e^+e^-\gamma, \bar{D}^0 \rightarrow K_L\pi^+\pi^-$ $(e^+e^- \rightarrow e^+e^-\nu_e K_L\pi^+\pi^-\pi^-\pi^-\gamma\gamma)$	1	1	—	—	0	2

index	signal event initial-final states	iSigEvtFSts	iEvtFSts	nEvs	nCmltEvs
1	$e^+e^- \rightarrow e^+\nu_e\mu^+\mu^-K_L\pi^+\pi^-\pi^-\pi^-\gamma\gamma$	0	12	2	2
2	$e^+e^- \rightarrow e^+e^+e^-\nu_eK_L\pi^+\pi^-\pi^-\pi^-\gamma\gamma$	1	—	0	2

index	signal event initial-final states	iSigEvtFSts	iEvtFSts	nEvs	nCmltEvs
1	$e^+e^- \rightarrow e^+\nu_e\mu^+\mu^-K_L\pi^+\pi^-\pi^-\pi^-\gamma\gamma$	0	12	2	2
2	$e^+e^- \rightarrow e^+e^+e^-\nu_eK_L\pi^+\pi^-\pi^-\pi^-\gamma\gamma$	1	—	0	2

index	signal event initial-final states	iSigEvtIFSts2	iEvtIFSts	nEvs	nCmltEvs
1	$e^+e^- \rightarrow e^+\nu_e\mu^+\mu^-K_L\pi^+\pi^+\pi^-\pi^-\pi^-\gamma\gamma$	0	12	2	2
2	$e^+e^- \rightarrow e^+e^+e^-\nu_e K_L\pi^+\pi^+\pi^-\pi^-\pi^-\gamma\gamma$	1	—	0	2

index	signal event initial-final states	iSigEvtIFSts2	iEvtIFSts	nEvs	nCmltEvs
1	$e^+e^- \rightarrow e^+\nu_e\mu^+\mu^-K_L\pi^+\pi^+\pi^-\pi^-\pi^-\gamma\gamma$	0	12	2	2
2	$e^+e^- \rightarrow e^+e^+e^-\nu_e K_L\pi^+\pi^+\pi^-\pi^-\pi^-\gamma\gamma$	1	—	0	2

How to run the TopoAna program?

- 1 save necessary quantities in the input root files with the `NtupleMCGenTruthForTopoAnaTool`
- 2 fill out the input card file
- 3 execute the TopoAna program

NtupleMCGenTruthForTopoAnaTool (1)

```
[zhouxy@cw05 release-00-09-00]$ pwd
/home/belle2/zhouxy/workarea/releases/release-00-09-00
[zhouxy@cw05 release-00-09-00]$ ls analysis/NtupleTools/include/NtupleMCGenTruthForTopoAnaTool.h
analysis/NtupleTools/include/NtupleMCGenTruthForTopoAnaTool.h
[zhouxy@cw05 release-00-09-00]$ ls analysis/NtupleTools/src/NtupleMCGenTruthForTopoAnaTool.cc
analysis/NtupleTools/src/NtupleMCGenTruthForTopoAnaTool.cc
[zhouxy@cw05 release-00-09-00]$ grep -C 2 "NtupleMCGenTruthForTopoAnaTool" analysis/NtupleTools/src/NtupleToolList.cc
#include <analysis/NtupleTools/NtupleMCGenKinematicsTool.h>
#include <analysis/NtupleTools/NtupleMCGenCMSKinematicsTool.h>
#include <analysis/NtupleTools/NtupleMCGenTruthForTopoAnaTool.h>

using namespace Belle2;

--
    else if (strToolName == "MCGenKinematics") return new NtupleMCGenKinematicsTool(tree, d, strOption);
    else if (strToolName == "MCGenCMSKinematics") return new NtupleMCGenCMSKinematicsTool(tree, d, strOption);
    else if (strToolName == "MCGenTruthForTopoAna") return new NtupleMCGenTruthForTopoAnaTool(tree, d, strOption);
    B2WARNING("NtupleTool " << strToolName << " is not available!");
    return NULL;
[zhouxy@cw05 release-00-09-00]$ scons
scons: Reading SConscript files ...
Checking for Belle II environment setup...(cached) yes
Checking for analysis setup...(cached) no

scons: done reading SConscript files.
scons: Building targets ...
scons: building associated VariantDir targets: build/Linux_x86_64/opt
*** symlinking : include/analysis/NtupleTools/NtupleMCGenTruthForTopoAnaTool.h
*** compiling : /cvms/belle.cern.ch/sl6/releases/release-00-09-00/framework/io/src/RootIOUtilities.cc
*** linking : lib/Linux_x86_64/opt/libframework_io.so
*** compiling : analysis/NtupleTools/src/NtupleMCGenTruthForTopoAnaTool.cc
*** compiling : analysis/NtupleTools/src/NtupleToolList.cc
*** linking : bin/Linux_x86_64/opt/test_framework
*** linking : modules/Linux_x86_64/opt/libseqroot.so
*** linking : modules/Linux_x86_64/opt/libbeast_microtpc_modules.so
*** linking : modules/Linux_x86_64/opt/libBGOOverlayInput.so
*** linking : modules/Linux_x86_64/opt/librootio.so
*** linking : bin/Linux_x86_64/opt/create_dedx_PDFs
*** linking : bin/Linux_x86_64/opt/merge_basf2_files
*** linking : lib/Linux_x86_64/opt/libmva.so
*** linking : modules/Linux_x86_64/opt/libbeast_analysis_modules.so
*** linking : bin/Linux_x86_64/opt/test_all
*** linking : lib/Linux_x86_64/opt/libanalysis_NtupleTools.so
*** linking : modules/Linux_x86_64/opt/libNtupleMaker.so
scons: done building targets.
[zhouxy@cw05 release-00-09-00]$
```

NtupleMCGenTruthForTopoAnaTool (2)

```
[zhouxy@cw05 mixed]$ pwd
/home/belle2/zhouxy/workarea/releases/release-00-09-00/analysis/mytests/NtupleTools/MCGen
TruthForTopoAna/mixed
[zhouxy@cw05 mixed]$ ls
NtupleTools_MCGenTruthForTopoAna_mixed_test.py
mdst_000018_prod00002218_task00000018.root
[zhouxy@cw05 mixed]$ basf2 NtupleTools_MCGenTruthForTopoAna_mixed_test.py >NtupleTools_MC
GenTruthForTopoAna_mixed_test.out 2>NtupleTools_MCGenTruthForTopoAna_mixed_test.err
[zhouxy@cw05 mixed]$ ls
NtupleTools_MCGenTruthForTopoAna_mixed_test.err
NtupleTools_MCGenTruthForTopoAna_mixed_test.out
NtupleTools_MCGenTruthForTopoAna_mixed_test.py
mdst_000018_prod00002218_task00000018.root
mixed1.root
[zhouxy@cw05 mixed]$
```

NtupleMCGenTruthForTopoAnaTool (3)

```
[zhouxy@cw05 mixed]$ cat NtupleTools_MCGenTruthForTopoAna_mixed_test.py
#!/usr/bin/env python3
# -*- coding: utf-8 -*-

from basf2 import *
from modularAnalysis import inputMdst
from modularAnalysis import ntupleFile
from modularAnalysis import ntupleTree
from modularAnalysis import analysis_main

# load input ROOT file
inputMdst('default', 'mdst_000018_prod00002218_task00000018.root')

# define Ntuple tools
toolsEvt = ['EventMetaData', 'e+']
toolsEvt += ['MCGenTruthForTopoAna', '^e+']

ntupleFile('mixed1.root')
ntupleTree('evt', '', toolsEvt)

# Process the events
process(analysis_main)

# print out the summary
print(statistics)
```

NtupleMCGenTruthForTopoAnaTool (4)

```
[zhouxy@cw05 mixed]$ root -l
root [0] TFile f("mixed1.root")
(TFile &) Name: mixed1.root Title:
root [1] f.ls()
TFile**          mixed1.root
  TFile*          mixed1.root
    KEY: TTree    evt;1
root [2] evt->Show(0,200)
=====> EVENT:0
  exp_no          = 0
  run_no          = 0
  evt_no          = 170002
  Nps             = 33
  Pid             = 300553,
                  511, -511, -411, 223, 211, 113, 413, -211, -211, 211,
                  111, 313, 13, -14, 111, 22, 211, -211, 421, 211,
                  22, 22, 321, -211, 22, 22, 20213, -321, 113, 211,
                  211, -211
  Midx            = 0,
                  0, 0, 1, 1, 1, 1, 2, 2, 2, 2,
                  2, 3, 3, 3, 4, 4, 6, 6, 7, 7,
                  11, 11, 12, 12, 15, 15, 19, 19, 27, 27,
                  29, 29
  m_nCands        = 0
  m_iCand         = 0
```

Summary

- The **TopoAna** package is written for topology analysis.
- The **NtupleMCGenTruthForTopoAnaTool** at Belle II is specifically developed for the **TopoAna** package.
- Up to now, I haven't found a way to run the **NtupleMCGenTruthForTopoAnaTool** on the grid. It would be appreciated very much if you could help me about this.

Welcome to use it, Thank you!

Please let me know:

- if you have any problems with it;
- if you have any questions about it;
- if you have any suggestions on how to improve it;
- if you find any bugs in it;
- if you want to extend its functions.

I hope it can be helpful to your studies.