ALEPH 92-150
PHYSIC 92-138
P. Colrain et al.
6.10.1992

The BTAGDST : A Data Set for Heavy Flavour Analyses based on the Mini-DST

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October 6, 1992

Abstract

A private data set, produced in a reduced Mini-DST format suitable for heavy flavour analyses, is described. It combines energy-flow with three b-tagging methods. In addition, general event and truth variables are pre-calculated. ALPHA-style unpacking functions are provided. Details of available tapes of data and Monte Carlo events are listed.

1 Introduction

Many heavy flavour analyses involving complex, high-level calculations require the use of the large ALEPH data set of hadronic events. These analyses may involve many cpu-intensive procedures such as energy-flow, jet-clustering and various b-tagging algorithms. The purpose of the BTAGDST is to provide the user with a consistent, pre-calculated set of physics quantities. The events were written to tape using the standard ALEPH mini package [1]. The availability of three independent b-tags allows cross-checks between the tags, selection of singly-tagged events and isolation of specific flavour samples.

In addition to many of the standard Mini-DST banks, the BTAGDST provides information from the following sources :

(a) lepton, impact-parameter and event-shape b-tagging algorithms;

(b) the ENFLW package;

(c) real and parton jet-clustering together with event axes calculation;

(d) high-level Monte Carlo truth.

2 Event Selection

BTAGDST's have been created for the 1990 and 1991 data and corresponding Monte Carlo samples. Due to differences in the event selection criteria of the three b-tagging methods, a general event selection procedure has been adopted leaving the selection of specific subsamples of events to the user with SRUN cards. The following selection criteria are applied during the BTAGDST production :

(i) CLAS 16 events [2].

(ii) The data quality must be either PERF or MAYB.

(iii) The ENFLW objects must be available as all the b-tagging algorithms require this information.

When analysing a BTAGDST, sets of SRUN cards files are provided for the 1990 and 1991 data samples to allow selection of those runs which are useful for the lepton tag or the impact-parameter tag:

LTSRUN91 CARDS - heavy flavour selection for 1991[1],
LTSRUN90 CARDS - heavy flavour selection for 1990,
VDSRUN91 CARDS - VDET selection for 1991.

These SRUN cards are stored on the HALLEY 200 disk on CERNVM. The event-shape tag runs on almost all events with ENFLW information and so does not require any further specific selection. This protocol retains all useful events whilst allowing the user to exclude runs not useful for a particular analysis.

3 Tagging Algorithms

For each event passing the hadronic event selection, the following three b-tagging algorithms are performed. If the tag is successful, its result is written out. The user-interface package described in Section 4 allows the user to select singly or multiply tagged events. Each tagging algorithm has different requirements and provides a different type of information. The tags are described briefly in the following sections.

3.1 The Lepton Tag

The LEPTAG package [3], which selects high momentum leptons in hadronic events, was written specifically for the BTAGDST project. After identification of such leptons their transverse momentum is calculated for use in a heavy flavour tag.

The routine implements the lepton selection criteria described in a recent ALEPH note by the heavy flavour lepton group [4]. Anticipating future developments, LEPTAG uses the FRF2 track bank as opposed to the FRFO track information that is presently used by the heavy flavour lepton group. The effect of this difference is minimal.

In a very small number of cases, once per 28000 hadronic events, an electron/positron candidate will also be identified as a muon. In these cases LEPTAG assumes the particle to be a muon.

After identifying any high momentum leptons, the inclusive and exclusive $P_\perp$ is calculated for each lepton. The inclusive $P_\perp$ is calculated using the ALPHA function QPPER. To calculate the exclusive $P_\perp$, the energy flow object corresponding to the lepton is removed from the associated jet. The $P_\perp$ is then formed using the lepton FRF2 track and the remaining jet.

Provision has been made to store the six event weights which predict from which source the lepton originated. As soon as the fit across the P, $P_\perp$-plane is available for FRF2 tracks these quantities will be filled.

For Monte Carlo events lepton source truth information (LEPDCY, see Section 5.1) is provided.

Extensive consistency checks have been made, including a comparison to a benchmark selection provided by the heavy flavour lepton group. The agreement on the event selection was found to be 99.7 % or better and the exclusive $P_\perp$ was reproduced to high accuracy.

[1] selected requiring HE.AND.HH.AND.HM.AND.HD.

The lepton information is stored in the BMLT bank for all events containing (an) identified lepton(s) (approximately 14 % of all hadronic events). If no leptons were found the BMLT bank is not written out.

3.2 The Impact-Parameter Tag

The QIPBTAG package [5] is used to tag events using charged tracks with significant lifetime information by studying their impact-parameters. The algorithm makes use of the GET_BP [6] and QFNDIP routines [7] to locate the beam spot and interaction points respectively. As these algorithms rely on the presence of VDET information, the tag is only available for 1991 data and Monte Carlo events. The tag provides several pieces of information which are available on the BTAGDST :

- The probability that the charged tracks in a given hemisphere arise from the fragmentation of a *u, d* or *s* quark.
- The probability that the complete event is due to $u\bar{u}$, $d\bar{d}$ or $s\bar{s}$ production.
- The impact-parameter, error and flight distance along the jet axis of selected charged tracks used in the tag.

The tag has been re-calibrated using the ENFLW objects and provides purities and efficiencies consistent with those observed using the PCPA based energy-flow algorithm [5]. The tag information is available for approximately 85% of all hadronic events with VDET information. The most significant loss of events is due to jets lying outside the angular acceptance[2].

3.3 The Event-Shape Tag

The BEETAG [8] package is used to calculate the likelihood of a given hemisphere arising from a *b*-quark. This algorithm requires the ENFLW objects as input and returns two likelihoods, one for each hemisphere. Using all ENFLW objects, the event is divided into two hemispheres defined by the plane perpendicular to the event axis. For each event, the axis is determined by solving for the first eigenvector of the weighted inertial matrix (WIM) defined by :

$$\lambda_{ij} = \sum_{m=1}^{n} \frac{-p_m^i \cdot p_m^j}{|\vec{p}_m|} \quad and \quad \lambda_{kk} = \sum_{m=1}^{n} \frac{(p_m^i)^2 + (p_m^j)^2}{|\vec{p}_m|} \quad (k \neq i,j) \tag{1}$$

where $p_m^{i,j}$ is a component of the momentum vector of the m^{th} particle, and i, j, k run over the three Cartesian coordinates. Once the event has been divided into two, using all particles, an axis is determined for each hemisphere. The two axes are then recomputed using only those particles whose momenta make an angle of less than 45° with them. These axes will be referred to as the cone axes and is denoted by $\vec{\epsilon}_{CONE}$. Finally particles are associated to the two cones if their momentum vectors are within an angle of less than 45° to the final cone axes.

It is expected that the momentum spectrum and multiplicity of decay products from b decays are similar to those produced by lighter quarks. However, these decay particles can be expected to be more isotropically distributed in the centre of mass system of the B hadron. In order to distinguish this effect, the energy flow in the centre of mass frame away from the cone axis in the laboratory frame is used. More precisely, the absolute

[2] Currently $| \cos\theta | \leq 0.9$.

values of the momenta of the particles in the cone boosted into their own rest frame are summed if :

$$|\vec{p}^{\,i}_{boosted} \cdot \vec{\epsilon}_{CONE}| < .707. \tag{2}$$

The spectrum of the logarithm of this quantity is referred to as the transverse mass (or TM). It is also expected that, in the rest frame of the cone, the particles will be distributed more uniformly, or less jet-like. Therefore, the second quantity used, is the ratio of the first eigenvalue to the sum of the three eigenvalues :

$$\frac{\lambda_1}{\lambda_1 + \lambda_2 + \lambda_3} \tag{3}$$

of the WIM evaluated using the momenta of the particles in one cone in their own rest frame. This quantity is referred to as the moment of inertia (or MI).

In order to form a tag, two-dimensional histograms of log(TM) versus MI with 50 by 50 bins have been filled using fully reconstructed Monte Carlo events for b, $(\bar{b})$ cones and for all cones. Note that in the method of constructing cones, each event has *precisely* two cones. These two histograms are then divided, giving a likelihood or probability, that a cone in a given bin is due to a b quark. A cut requiring the likelihood to be greater than some value will preferentially select b cones. A full event likelihood could be formed by multiplying the likelihoods for the two cones, $L = L_A \cdot L_B$.

4 Histogram Output Monitoring of the BTAGDST

Details of the BTAGDST production have been stored in the form of histograms:

```
DATA1991 HIST
DATA1990 HIST
MCAR1991 HIST
MCAR1990 HIST
```

which can be found on the HALLEY 200 disk on CERNVM.
The information has been grouped together in PAW subdirectories:

Subdirectory	Monitors
HADSEL	hadronic event selection
BMFLP	energy flow
BMTGPL	general event quantities
BMESPL	event shape tag
BMVDPL	impact-parameter tag
DTRAPL	additional DTRA information
BMLTPL	lepton selction
BMPJPL	parton clustering

An example of handling of one of these PAW directories would be:

```
PAW> hist/file 1 data1991.hist.w
PAW> ldir (lists the available subdirectories)
```

```
PAW> cd //lun1/BMESPL
PAW> hist/plot 1
```

5 Access to Information

A set of routines and macros have been developed to allow easy access to the additional information stored on the BTAGDST in a similar way to those already provided in ALPHA. The package consists of the BMLIB object code which should be linked with the user's analysis code. The BMLIB object and source files may be found on the HALLEY 200 disk. For each event, the following call :

```
CALL BMINIT(IFLAG)
```

is required to obtain pointers and fill the variables for this event. The variable IFLAG is used to inform the user of the BTAGDST information available for this event by checking[3] the following bit-pattern :

Bit	Bank	Meaning if .TRUE.
0	DTRA	Tracking available.
1	BMFL	Energy flow information available.
2	BMLT	Identified leptons were found.
3	BMTG	General event information available.
4	BMVD	Impact-parameter tag information available.
5	BMES	Event-shape information is available.
6	BMPJ	Parton jet information is available.

The following INCLUDE files contain the necessary functions and pointers :

BMDECL.INC	contains the variable type definitions;
BMCDE.INC	contains the COMMONS and various PARAMETERS;
BMMACRO.INC	contains the statement function definitions.

An example ALPHA job is given in Appendix A. The variables used to access the additional BTAGDST information are described in the following sections.

5.1 The *b*-Tag Information

b-Tag information is made available using the functions shown in Table 1. ID refers to the identified lepton ALPHA track number which is in the range :

KFLEP to KLLEP

If the lepton track was not used in the ENFLW calculations, then KJETPO(ID) and KEFOBNO(ID) will return zero for this lepton.

[3]Note that bit 0 is always set due to the event selection described in Section 2.

Tagger	Variable	Available	Description
Lepton	KALPTR(ID)	Data & MC	ALPHA track number of the lepton
Lepton	KPARTY(ID)	Data & MC	The lepton type, either : $2 \rightarrow e^+$ $3 \rightarrow e^-$ $5 \rightarrow \mu^+$ $6 \rightarrow \mu^-$
Lepton	KJETPO(ID)	Data & MC	ALPHA jet pointer
Lepton	QPTINC(ID)	Data & MC	"Lepton included" p_T
Lepton	QPTEXC(ID)	Data & MC	"Lepton excluded" p_T
Lepton	KLEPTR(ID)	Data & MC	Lepton "truth" flag : $1 \rightarrow$ muon IDF 13 $2 \rightarrow$ muon IDF 14 $3 \rightarrow$ genuine e^+ or e^-
Lepton	QWEIGHT(ID,1) QWEIGHT(ID,2) QWEIGHT(ID,3) QWEIGHT(ID,4) QWEIGHT(ID,5) QWEIGHT(ID,6)	Data & MC Data & MC Data & MC Data & MC Data & MC Data & MC	Weight for lepton to be from primary b Weight for lepton to be from secondary c Weight for lepton to be from primary c Weight for lepton to be from $B \rightarrow \tau$ decay Weight for lepton to be from a non-prompt source Weight for "lepton" to be a misidentified hadron
Lepton	KDECTYP(ID)	MC Only	Lepton decay type : $-1 \rightarrow$ Unknown decay type $0 \rightarrow$ No associated MC track $1 \rightarrow$ Primary b $2 \rightarrow$ Secondary c $3 \rightarrow$ Primary c $4 \rightarrow$ Semileptonic tau decay $5 \rightarrow$ Non-prompt decay $6 \rightarrow$ Misidentified hadron
Lepton	KDECCAT(ID)	MC Only	Decay category : when KDECTYP(ID)=2 then $1 = b \rightarrow c \rightarrow l$ $2 = b \rightarrow \bar{c} \rightarrow l$ when KDECTYP(ID)=5 then $0 =$ none of the following : $1 =$ gamma conversion $3 = b$ decay $4 = c$ decay $5 = \tau$ decay
Lepton	KLEPPAC(ID)	MC Only	Particle code of the lepton parent
Lepton	KEFOBNO(ID)	Data & MC	ENFLW object number of lepton track
Impact	QVDEP	Data & MC	Probability that the event is from $u\bar{u}$, $d\bar{d}$, or $s\bar{s}$ production
Impact	QVDH(IH)	Data & MC	Probability that hemisphere IH is from a u,d or s
Shape	QESH(IH)	Data & MC	Probability that hemisphere IH is from a b

Table 1: Unpacking functions for the b-tag information.

5.2 Energy-flow Objects

These may be accessed in an identical way to the ENFLW package described in the UPHY documentation using the following ALPHA track indices :

ENFLW Object Type	ALPHA Track Index
First ENFLW object	KFREFW
Last ENFLW object	KLSEFW
Total	LTOT
First charged object	KFRTOT(1)
Last charged object	KLSTOT(1)
Total	LCH
First V^0 object	KFRTOT(2)
Last V^0 object	KLSTOT(2)
Total	LVO
First photon object	KFRTOT(3)
Last photon object	KLSTOT(3)
Total	LMG
First hadron object	KFRTOT(4)
Last hadron object	KLSTOT(4)
Total	LMH
First lumi. object	KFRTOT(5)
Last lumi. object	KLSTOT(5)
Total	LUM

The ordering is preserved from the original ENFLW call. The ENFLW objects may be selected for processing using the ALPHA QJxxxx routines by the usual :

```
CALL QJOPTR('NO','ENFW')
```

5.3 Real and Parton Jet Information

Jet-clustering is carried out using both the energy-flow objects and the quarks and gluons at the end of the parton shower evolution in Monte Carlo events. These are made available via the following ALPHA track indices :

Object Description	ALPHA index
first real jet	KFRJET
last real jet	KLRJET
no. of real jets	KNRJET
first parton jet	KFPJET
last parton jet	KLPJET
no. of parton jets	KNPJET

The ALPHA functions QX, QY, QZ, QP and QE may be used as normal.

Jet-clustering using QJMMCL is performed on all energy-flow objects with a low y_{cut} enabling further clustering to be performed later. A value of $(6.0/\mathrm{QELEP})^2$ is used, as required by the lepton b-tag. All energy-flow objects, including charged tracks, may be associated with the corresponding real jet's ALPHA index using the function :

```
KJETPO(ITK)
```

where ITK is the energy-flow object number, charged track or identified lepton index.

The parton jet-clustering has been performed using the DURHAM algorithm with a y_{cut} of 0.003. The parton jet "type" may be determined using the function :

KJETYP(ITK)

where ITK is the ALPHA index of the parton jet. This returns a value for each parton jet which is interpreted as :

Positive Integer	A "quark" jet where the magnitude of the integer indicates the surplus of unpaired quarks in the jet
Zero	A "gluon" jet containing either no, or equal, numbers of quarks and antiquarks
Negative Integer	An "anti-quark" jet where the magnitude of the integer indicates the surplus of unpaired anti-quarks in the jet

The parton jets can be selected for processing using the ALPHA QJxxxx routines by :

CALL QJOPTR('NO','PJETS')

and for the real jets using :

CALL QJOPTR('NO','RJETS')

5.4 General Event Information

For each event, a set of general quantities are available. These include thrust and sphericity vectors calculated using ENFLW objects and an extensive set of Monte Carlo truth quantities. These are summarised in Table 2 where IH is set to 1 for the $+z$ and 2 for the $-z$ hemispheres respectively. The B meson logicals allow the user to select hemispheres containing either a B_d or B_s meson and determine whether or not it has mixed.

5.5 General Track Information

In addition to the standard FRF2 tracking information, the BTAGDST provides the additional quantities in Table 3 for certain tracks. If this information is unavailable for a given track, ITK, then the corresponding function returns zero in all cases. To save space when storing the ENFLW objects, charged tracks are only stored once (in the DTRA bank). The function KEFOBNO is used to relate the charged tracks to the ALPHA index of the ENFLW object. On the BTAGDST the VDET hit pattern is stored in the DTRA bank and may be obtained using the VDHITS routine in the ALEPHLIB.

6 The BTAGDST Structure

The BTAGDST contains the following standard Mini-DST banks :

DEID DJET DTBP DTRA DVER DHEA EVEH REVH

Redundant words in the standard DTRA bank are filled with impact parameter information for tracks which are used by QIPBTAG. Several other BTAGDST specific banks are used to store the Monte Carlo truth quantities and b-tagging information. BTAGDST specific banks are prefixed by the letters "BM" :

BMFL BMVD BMES BMLT BMTG BMPJ

Variable	Available	Description
QTHX	Data & MC	X-component of the thrust axis.
QTHY	Data & MC	Y-component of the thrust axis.
QTHZ	Data & MC	Z-component of the thrust axis.
QSPX	Data & MC	X-component of the sphericity axis.
QSPY	Data & MC	Y-component of the sphericity axis.
QSPZ	Data & MC	Z-component of the sphericity axis.
KFLAV	MC Only	Integer signed event flavour : $1, 2, 3, 4, 5 \rightarrow u, d, s, c, b$ and positive if the positively charged quark is in the +Z hemisphere.
KLHAD(IH)	MC Only	ALEPH particle code of the leading hadron in hemisphere IH.
QPLHX(IH)	MC Only	p_x of leading hadron in hemisphere IH.
QPLHY(IH)	MC Only	p_y of leading hadron in hemisphere IH.
QPLHZ(IH)	MC Only	p_z of leading hadron in hemisphere IH.
XBO(IH)	MC Only	.TRUE. if hemisphere IH contained a neutral B meson.
XBOS(IH)	MC Only	.TRUE. if hemisphere IH contained a neutral B_s meson.
XMIX(IH)	MC Only	.TRUE. if hemisphere IH contained a neutral B meson which mixed.

Table 2: List of general event information

Variable	Available	Description
KJETPO(ITK)	Data & MC	Real jet containing this track.
KEFOBNO(ITK)	Data & MC	Energy-flow object for this track.
QIMPAR(ITK)	Data & MC	Impact-parameter of this track.
QIMERR(ITK)	Data & MC	Impact-parameter error of this track.
QFLDIST(ITK)	Data & MC	Flight distance of track along jet.
KPARENT(ITK)	MC Only	Particle code of heavy meson parent.

Table 3: List of general track information

The standard banks are created by the ALEPH Mini-DST code within the framework of a normal ALPHA job. The BTAGDST-specific bank descriptions are contained in Appendix C.

Energy-flow objects are stored in the BTAGDST specific BMFL bank as a standard Mini-DST format for ENFLW was not yet established at the time of writing[4]. The energy flow jets are stored in the standard DJET bank.

An outline of the BTAGDST production program structure is given in Appendix D.

Some numbers on the performance of the BTAGDST are:

- Event Size : 48890 events can be stored on 182.4 MB, giving an average of 3.73 kB per hadronic event.
- Speed: The speed of unpacking the data has been estimated using an empty job. Without a call to BMINIT the average time to read an event is 0.128 IBM-168 seconds, and with the call to BMINIT it is 0.142 seconds.

7 Acknowledgments

We would like to thank Elizabeth Mannelli, Dave Brown, Steven Haywood, Patrick Janot, Leo Bellantoni, Susan Cartwright, Simon Patton and Liz Veitch for their suggestions and help with various aspects of the code.

References

[1] S. Haywood, "ALEPH Mini-DST User's Guide", ALEPH 92-54, (1992)

[2] D. Decamp et al. (ALEPH Collaboration) Z. Phys. **C48**, (1990), 365-391.

[3] Written by Mark Parsons and Ingrid ten Have.

[4] D. Abbaneo et al., "Lepton and Jet Definitions for the Lepton Paper", ALEPH 92-101, (1992).

[5] D. Brown & M. Frank, "Tagging b Hadrons using Track Impact Parameters", ALEPH 92-135, (1992).

[6] D.Brown & G.Redlinger, "1991 Beam Spot and Beam Envelope Measurement", ALEPH 92-008

[7] D. Brown, "A Primary Vertex Finder", ALEPH 92-47, (1992).

[8] Written by Elizabeth Mannelli.

[4] This is to be implemented in future and will be incorporated into BTAGDST.

A Example Program

```
C##########################################################################
      SUBROUTINE QUINIT
C-----------------------------------------
      IMPLICIT NONE
      INCLUDE 'QDECL INC *'
      INCLUDE 'QCDE INC *'
      INCLUDE 'QMACRO INC *'
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  999 RETURN
      END
C##########################################################################
      SUBROUTINE QUEVNT(QT,KT,QV,KV)
C-----------------------------------------
      IMPLICIT NONE
      INCLUDE 'QDECL INC *'
      INCLUDE 'BMDECL INC *'

      INCLUDE 'QCDE INC *'
      INCLUDE 'BMCDE INC *'

      REAL    QT(KCQVEC,*), QV(KCQVRT,*)
      INTEGER KT(KCQVEC,*), KV(KCQVRT,*)

      INTEGER IFLAG

      INCLUDE 'QMACRO INC *'
      INCLUDE 'BMMACRO INC *'
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
      CALL BMINIT(IFLAG)
C
C
C alpha-style analysis code goes here
C
C
  999 RETURN
      END
C##########################################################################
      SUBROUTINE QUTERM
C-----------------------------------------
      IMPLICIT NONE
      INCLUDE 'QDECL INC *'
      INCLUDE 'QCDE INC *'
      INCLUDE 'QMACRO INC *'
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
  999 RETURN
      END
```

B Tape Listings and Data Description

1990 DATA		
Tape	Events	Size (Mb)
AG2209	47,217	173.860
AG2211	48,693	179.392
AG2213	49,465	181.867
AG2215	15,440	56.497
(Total)	160,815	
1991 DATA		
AG2198	48,890	182.478
AG2200	48,819	186.114
AG2202	49,182	186.450
AG2204	48,731	185.258
AG2206	49,621	188.344
AG2208	24,752	94.783
(Total)	269,995	
1990 MONTE CARLO		
AG2212	43.957	182.906
AG2199	43,959	182.906
AG2205	43,818	182.173
AG2214	14,309	59.309
(Total)	146,043	
1991 MONTE CARLO new D^* branching ratios and new b baryon lifetimes		
AD2935	42,835	179.697
AD0673	46,752	183.700
AD2940	21,417	90.352
(Total)	111,004	
1991 MONTE CARLO new D^* branching ratios and old b baryon lifetimes		
AD0672	42,785	183.303
AD0032	46,762	182.386
AG2210	25,653	97.381
(Total)	111,004	
1991 MONTE CARLO old D^* branching ratios and old b baryon lifetimes		
AG2201	42,866	179.300
AG2207	42,854	179.820
(Total)	85,720	

Table 4: List of cartridges at CERN containing the BTAGDST's for the 1990 and 1991 data sets.

C BTAGDST Specific Bank Definitions

```
*------*                                                    *------*
| BMFL | Energy Flow Bank                                   | BMFL |
*------*                                                    *------*
.....................................................................
          1      I   Number of words per neutral
                     energy flow object  (=6)
          2      I   Number of neutral energy flow objects
.....................................................................
          1  PX  I    x-comp of object's momentum        [*,*]
          2  PY  I    y-comp of object's momentum        [*,*]
          3  PZ  I    z-comp of object's momentum        [*,*]
          4  EN  I    Energy of object                   [0,*]
          5  TP  I    Type of object                     [2,5]
                         2: V0
                         3: photon
                         4: neutral hadron
                         5: LCAL object
          6  AJ  I    Associated jet                     [1,*]
.....................................................................

*------*                                                    *------*
| BMVD |  VDET Impact parameter                             | BMVD |
*------*                                                    *------*
.....................................................................
.....................................................................
          1  EP  I    Event Probability                  [0,1]
          2  H1  I    Hemisphere 1 probability           [0,1]
          3  H2  I    Hemisphere 2 probability           [0,1]
.....................................................................

*------*                                                    *------*
| BMES |  Event Shape parameter                             | BMES |
*------*                                                    *------*
.....................................................................
.....................................................................
          1  H1  I    Hemisphere 1 probability           [0,1]
          2  H2  I    Hemisphere 2 probability           [0,1]
.....................................................................
```

```
*-------*                                                     *------*
| BMLT |  Lepton tag                                          | BMLT |
*-------*                                                     *------*
..............................................................
           1       I    Number of words per lepton (=17)
           2       I    Number of leptons
..............................................................
           1  TN   I    JULIA track number                [1,*]
           2  PA   I    Particle type:                    [2,23]
                          2 => e+
                         12 => e+ in crack region
                         22 => e+ in overlap region
                          3 => e-
                         13 => e- in crack region
                         23 => e- in overlap region
                          5 => mu+
                          6 => mu-
           3  JT   I    Pointer to jet in DJET bank       [1,*]
           4  PI   I    Transverse momentum               [0,*]
                           lepton inclusive
           5  PE   I    Transverse momentum               [0,*]
                           lepton exclusive
           6  TR   I    IDF/Truth flag                    [1,*]
                           Bit 0: Muon IDF 13
                           Bit 1: Muon IDF 14
                           Bit 2: Genuine electron/
                                          positron
           7  MO   I    Total momentum                    [0,*]
           8  W1   I    Source prediction: primary b      [*,*]
           9  W2   I    Source prediction: secondary c    [*,*]
          10  W3   I    Source prediction: primary c      [*,*]
          11  W4   I    Source prediction: B->tau decay   [*,*]
          12  W5   I    Source prediction: non-prompt     [*,*]
          13  W6   I    Source prediction: mis-id hadron  [*,*]
          14  DT   I    Decay type from LEPDCY            [-1,6]
          15  DC   I    Decay category from LEPDCY        [0,5]
          16  LP   I    Code of the lepton parent         [0,367]
          17  ET   I    Energy flow object number         [1,*]
..............................................................
```

```
*------*                                                    *------*
| BMTG |  Source/Mixing/Thrust/Sphericity                   | BMTG |
*------*                                                    *------*
................................................................
................................................................
           1  SF  I    Signed event flavour             [-5,5]
                        (+ sign => + charge quark forward)
                        (- sign => - charge quark forward)
           2  MF  I    Mixing flag (binary)             [0,64]
                        Integer flag with first 2 bits set as:
                            00 = no mixing in either hemsiphere,
                            10 = mixing in only the +Z hemisphere,
                            01 = mixing in only the -z hemisphere,
                            11 = mixing in both hemispheres.
                        and the second 2 bits set as:
                            00 = Bd's in both hemispheres,
                            10 = Bs in the +z hemisphere, Bd in -z,
                            01 = Bd in the +z hemisphere, Bs in -z,
                            11 = Bs's in both hemispheres.
                        and the third 2 bits set as:
                            00 = No B0's in either hemisphere,
                            10 = A B0 in the +z hemisphere, not in -z,
                            01 = A B0 in the -z hemisphere, not in +z,
                            11 = B0's in both hemispheres.
           3  L1       Code of leading hadron number 1   [1,367]
           4  X1  I    x-component of leading hadron 1   [*,*]
           5  Y1  I    y-component of leading hadron 1   [*,*]
           6  Z1  I    z-component of leading hadron 1   [*,*]
           7  L2       Code of leading hadron number 2   [1,367]
           8  X2  I    x-component of leading hadron 2   [*,*]
           9  Y2  I    y-component of leading hadron 2   [*,*]
          10  Z2  I    z-component of leading hadron 2   [*,*]
          11  TX  I    x-component of thrust axis        [*,*]
          12  TY  I    y-component of thrust axis        [*,*]
          13  TZ  I    z-component of thrust axis        [*,*]
          14  SX  I    x-comp of sphericity axis         [*,*]
          15  SY  I    y-comp of sphericity axis         [*,*]
          16  SZ  I    z-comp of sphericity axis         [*,*]
................................................................
```

```
*------*                                                     *------*
| DTRA |  Charged Tracks                                     | DTRA |
*------*                                                     *------*
.....................................................................
          1      I   Number of words per track (=35)
          2      I   Number of tracks
.....................................................................
          1
          .          As per standard DTRA bank
          .
          11
          12 IP  I   Impact Parameter                          [*,*]
          13 IR  I   Impact parameter error                    [*,*]
          14 FD  I   Flight distance along jet                 [0,*]
          .
          19 MP  I   Heavy meson parent code                   [*,*]
          20 AJ  I   Pointer to jet in DJET bank               [0,*]
          21 EF  I   Energy flow object number                 [1,*]
          22
          .          As per standard DTRA bank
          .
          35
.....................................................................


*------*                                                     *------*
| BMPJ |  Parton jets made from partons at the end          | BMPJ |
*------*  of the shower process using the Durham            *------*
          algorithm and a very low y-cut.

 ....................................................................
     1          I    Number of Words per Jet (=5)
     2          I    Number of Jets
 ....................................................................
     1   PX     I    Px (MeV)                                  [0,*]
     2   PY     I    Py (MeV)                                  [0,*]
     3   PZ     I    Pz (MeV)                                  [0,*]
     4   E0     I    Energy (MeV)                              [0,*]
     5   JT     I    Jet type                                  [-3,+3]
                       +ve for quark jets
                       0   for gluon jets
                       -ve for antiquark jets
 ....................................................................
```

D Outline of Program Structure