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BEGET: The B-Factory Event Generator Version 21

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BEGET: The B-Factory Event Generator Version 21

Douglas M. Wright
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Abstract

This note is a reference manual for the B-Factory Event Generator (BEGET V21) software package which generates physics events relevant to B-Factory detector studies. The package provides a standard framework that can easily interface to various external generators and simulation applications. Version 21 of BEGET contains a number of physics and background generators and is interfaced to the JETSET and KORALB generators and the GEANT and ASLUND simulation programs.

MASTER

Questions and comments should be addressed to wright20@llnl.gov.

This document is also available in hypertext and postscript form:
<http://babar1.llnl.gov/wright/beget.html>

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1 Introduction

The B-Factory Event Generator (BEGET) provides a simple framework for generating events appropriate for a detector at an asymmetric e^+e^- colliding beam detector. The current version of BEGET, Version 21, can be run in stand-alone mode (for generator level studies) or called from GEANT[1] or ASLUND[2].

BEGET has both built-in generators and interfaces to external generators, such as JETSET[3] and KORALB[4]. For all generators, BEGET handles global tasks such as setting beam energies, smearing the primary vertex, and boosting to the final (beam asymmetric) reference frame. It also has a number of features to facilitate CP asymmetry studies. For example, there are switches to activate the rare B decay modes to CP eigenstates and routines that simulate CP violation and mixing.

Calling BEGET produces a single event stored in a FORTRAN common block in a format defined by the STDHEP software package[5]. The common block contains a list of the generated particles with their associated four-vectors and vertices. STDHEP defines not only the common block but also the particle code convention, so that the interface to any external simulation package is handled by a single subroutine that reads the common block.

BEGET is controlled by an ASCII file containing keywords and parameters, called 'data cards.' The data cards are defined and read in with the FFREAD[6] package from the CERN library. Except for some of the beam related background generators, no external data files are required to run the program. All defaults are built-in; however, the user can override nearly every aspect of the program through data cards and external files. For example, the decay table for selected particles (or all particles) can be replaced.

The generators currently available in BEGET are:

1. Single particle. The user specifies the particle and four-vector range.
2. $\Upsilon(4S)$ decay via JETSET.
3. Hadronic continuum events from JETSET (i.e. $e^+e^- \rightarrow q\bar{q}$).
4. Quark "Onia" resonance decays via JETSET.
5. KORALB $\tau^+\tau^-$ decays.
6. Beam background from off-momentum particles.
7. Background from beam-gas interactions.
8. Cosmic rays.

Additional generators and decay packages (e.g. QQ from CLEO) are in the works, and users are encouraged to interface their own favorite generators.

1.1 $\Upsilon(4S)$ Decay

The current $\Upsilon(4S)$ generator uses JETSET and is a modified version of what is found in the native ASLUND generator. A proper treatment of $\Upsilon(4S)$ production that includes the upsilon width has not yet been implemented. The $\Upsilon(4S)$ decays into an equal mixture of $B^0\bar{B}^0$ and B^+B^- final states.

The standard JETSET decay tables are modified with updated (circa 1992) heavy meson decay data (B and D) from CLEO and ARGUS. See subroutines BEGFILCST and BDECAY for more details. I have added the B^0 decay modes of interest for CP violation studies which are listed in Table 1.¹

Table 1: Decay modes of interest for CP violation.

B^0 Decay Mode	BR ($\times 10^{-4}$)
ψK_L^0	3.85
ψK_S^0	3.85
ψK^{*0}	12.60
$D^+ D^-$	6.00
$D^{*+} D^{*-}$	15.00
$\pi^+ \pi^-$	0.20
$\rho^\pm \pi^\mp$	0.80
$a_1^\pm \pi^\mp$	0.80

A built-in switch allows all B^0 (or $\bar{B}^0$) decay modes to be turned off except for a selected mode. For example, to generate the following decay:

$$\Upsilon(4S) \rightarrow (B^0 \rightarrow \psi K_L^0) (\bar{B}^0 \rightarrow \mu^- \bar{\nu}_\mu X)$$

One would use the following data card: BOB0 11 3. The keyword is BOB0, the first number specifies the B^0 decay (11 = ψK_L^0) and the second specifies the $\bar{B}^0$ decay (3 = $\mu^- \bar{\nu}_\mu X$). Instead of using the built-in switches the user can alter the B^0 decay, or any other decay, with an external file that contains the desired changes to the decay table (data card JETD).

By default, CP violation and B^0 mixing is turned off. The user can activate it with data card CP. In the current implementation, the CP part only works on pure CP eigenstate modes. There is also an option in JETSET to do B^0 mixing. Currently, the user must activate this by hand (i.e. by setting the value in the appropriate JETSET common block).

Section 5 on page 12 contains a complete description of the available data cards.

1.2 Acknowledgments

Acknowledgments traditionally appear at the end of a document but are included here so that they do not become lost to the reader among the details of the text.

¹The branching ratios match those in the BaBar LOI [7]

BEGET began as a synthesis of old and new subroutines. The old was taken primarily from ASLUND and the only credit that I can ascribe comes from comments left in the source code itself. The ASLUND simulation began as a modification of another fast, parametrized simulation. Alan Weinstein created the original ASLUND and Art Snyder maintains and develops the current version. Some of the JETSET modifications and utilities should be attributed to Patrick Roudeau and Jon Guy. In particular the heavy meson decay modifications come from them. The routines that simulate CP asymmetry are due to Alan Weinstein with modifications from Gautier Hamel de Monchénault, Dave Coupal, and Walt Innes.

A number of people have contributed to BEGET since its first release (Version 0, January 1994). In particular Fred Kral has implemented the KORALB interface, the beam-gas interaction interface, and a cosmic ray generator. Ezio Torassa contributed a routine for picking background rays from TURTLE files prepared by Art Snyder. Dave Coupal has made extensive changes to this routine.

Contributions from others are soon to be incorporated and as the program matures I hope that this section continues to grow.

2 Using BEGET

A single event is generated by calling subroutine BEGET (i.e. CALL BEGET). This fills the STDHEP common block with the final state particles and the intermediate particles that decayed. Subsequent calls to the BEGET subroutine put a new event into the common block.

The general purpose part of BEGET must be initialized before the first call to the BEGET subroutine. This initialization is handled by a different subroutine that depends on whether one is running BEGET stand-alone or from GEANT or ASLUND. The main purpose of the initialization is to read in the data cards that define what to generate.

The proper calling structure is already built-in to ASLUND and BBSIM,² so users of those programs do not need to modify their code. The initialization for a particular generator package (e.g. JETSET) is automatically called in the first pass through the BEGET subroutine, so no special user action is required. Be aware that BEGET is not currently configured to allow input parameters to change between generated events.

2.1 Using BEGET for Generator Studies

The following two program examples can be found in the `example` directory of the source code distribution. Shell scripts `beget1` and `beget2` contain the proper compilation and linking commands.

To make a stand-alone version of BEGET, use a main program like the following (which generates 10 events).³

```
program main
  call beginput ! define and read in data cards
```

²BBSIM = B-Factory GEANT detector simulation.

³Unlike BBSIM, users do not need to copy any of the BEGET source code.

```

do n = 1, 10
  call beget ! generate an event
enddo
end

```

Link the program using the following command,

```
f77bb -link -o beget1.exe beget1.f ` $BFLIB/libbeget.Link `
```

where the main program has been saved in file `beget1.f`. The back quotes (```) are important, they cause the output of the `libbeget.Link` script to be included on the command line. The `libbeget.Link` script produces the appropriate list of libraries needed to link BEGET. Linking is discussed in detail in Section 2.5.

This small example results in a complete, functioning version of BEGET. It can be used to familiarize oneself with the function of the various BEGET data cards.

For generator studies one needs access to the STDHEP common block, which is defined in the include file `stdhep.inc`.⁴ A slightly more complicated main program that illustrates how one might read the common blocks is given below.

```

      program main
#include "stdhep.inc"
#include "beget.inc"

      parameter( ID_PIO = 111 )
      call beginput           ! define and read in data cards
      do n = 1, Nbeg_events   ! Nbeg_events is defined by EVNT data card
        call beget           ! generate an event

*.....analyze this event
      Npi0 = 0
      do i=1, NHEP           ! loop over particles in the event
        if( IDHEP(i) .eq. ID_PIO ) Npi0 = Npi0 + 1
      enddo
      print *, 'There are ', Npi0, ' pi0''s in this event'
    enddo
  end

```

This example merely counts the number of π^0 's in the current event by looping over all of the particles and checking the particle code in array `IDHEP`. Section 6 contains a summary of all of the variables defined in the STDHEP common block.

The BEGET internal common block, defined in `beget.inc`, gives the user access to the values of the input data cards and other internal BEGET variables. To compile and link this program, one must specify the location of the includes files. The following commands will do the trick:

⁴The include file is stored with the source code which is typically kept in `$BROOT/src/stdhep/pro`.

```
f77bb -cpp "-I$BFR00T/src/beget/pro/src -I$BFR00T/src/stdhep/pro" beget2.F
f77bb -link -o beget2.exe beget2.o '$BFLIB/libbeget.Link'
```

The above examples expect that the f77bb shell script is used for the compilation and linking of the program, however, this is not a requirement. The libbeget.Link script is general enough to work with any UNIX linker and the main program will work with a generic FORTRAN compiler if the C style includes (#include) are changed to FORTRAN style includes.

2.2 Using BEGET in GEANT

To use BEGET with GEANT⁵ make a GUKINE subroutine like the following.

```
subroutine gukine
call beget_geant ! generate an event
end
```

and make sure that the following call is made before the call to GFFGO.

```
call begffkey ! define BEGET FFREAD data cards
```

The GEANT implementation works by calling the BEGET subroutine and then subroutine HEP2GEANT to load the contents of the STDHEP common block into the GEANT KINE and VERT banks.

Link your GEANT program with '\$BFLIB/libbeget.Link' as an argument to your link command (note the ` 's are important). For more information on linking see Section 2.5.

2.3 Using BEGET in ASLUND

The BEGET interface is already built in to ASLUND, however, it is not linked into the ASLUND executable by default. To link with BEGET you must uncomment the line

```
#define BEGET
```

in the ASLUND user/Imakefile and remake your executable.

Once you have a version of ASLUND that contains BEGET, set IFL=-99 in the runtime input file, this turns off the built-in generator and turns on BEGET. BEGET data cards should be embedded in the runtime file, they are not read in separately. For ASLUND to recognize the BEGET data cards ;BEGETBEGIN must appear on a separate line before the first card and ;BEGETEND must follow on a separate line after the last card, For example:

```
;BEGETBEGIN
BOBO 3 11
GENP 1
;BEGETEND
```

⁵BBSIM users: BEGET is already implemented in BBSIM, so there is no need to change any source code.

This only applies to ASLUND. The stand-alone and GEANT version of BEGET do not require ;BEGETBEGIN, ;BEGETEND.

The default beam energies are taken from ASLUND variables instead of BEGET, but the defaults can be overridden by the BEGET data cards BEAM and SBEAM. Also, ASLUND does its own vertex smearing so data cards VERT, SVERT, IVERT should not be used at this time.

ASLUND is not built around STDHEP, it looks directly at the JETSET common blocks to find the generated particles. The BEGET interface to ASLUND makes use of a STDHEP translation routine that converts STDHEP to JETSET. So non-JETSET generators (in BEGET) are automatically available in ASLUND.

2.3.1 Comments on Particle Codes for ASLUND

Some ASLUND extensions to the JETSET particle code conventions are not compatible with STDHEP (i.e. particle codes are used that either map incorrectly into the STDHEP scheme or do not exist at all). In general this is not a problem. Users who modify the JETSET decay tables with an external file may run into trouble if they try to use the same file with BEGET. However, by following a few guidelines an external file can be made that works with both BEGET and the ASLUND native generator.

Traditionally ASLUND uses 40553 as the code for $\Upsilon(4S)$, which is not defined by JETSET, but is defined by STDHEP as code 70553. The STDHEP convention for $b\bar{b}$ resonances is given in Table 2. The ASLUND user may select particle 70553 as $\Upsilon(4S)$ but must be

Table 2: Particle Code Convention for $b\bar{b}$ resonances.

	Particle Code	
	ASLUND	STDHEP
$h_b(2P)$		40553
$\chi_{b1}(2P)$		50553
$\Upsilon(3S)$		60553
$\Upsilon(4S)$	40553	70553
$\Upsilon(5S)$	50553	80553

careful to use the correct “compressed” code associated with it. Particle codes in JETSET are “compressed”, i.e. mapped to a contiguous range of numbers 1-500. The function LUCOMP(kf) returns the compressed code for particle code kf. JETSET does not define the mapping for particles with compressed codes 400-500. It is up to the user to define the mapping.

The ASLUND version of LUCOMP has a mapping given in Table reflucomp. In ASLUND there are (at least) two ways to get a compressed code of 404. For example 70553 and 4000511 both compress to 404. To make decay table files that are compatible with both the native ASLUND generator and BEGET, use code 70553 and compressed code 404 for $\Upsilon(4S)$, and make sure that any other user particles give a compressed code greater than 410.

Table 3: ASLUND version of LUCOMP mapping.

KF	LUCOMP(KF)
40553	401
50553	402
60553	403
70553	404
80553	405
nXXXXXX	400 + abs(n)

The stand-alone and GEANT version of BEGET do not respect the LUCOMP mapping of ASLUND for particle codes nXXXXXX (i.e. > 99,999) because of the possible inconsistencies stated above. So decay table files can be shared between the ASLUND native generator and BEGET only within ASLUND. With sufficient user interest, the discrepancies in the LUCOMP mapping could be eliminated.

2.4 User Hooks and Utilities

A few hooks are provided to allow a more detailed control of BEGET. The following subroutines are dummies in the BEGET library. The user may write his/her own subroutines and link them before the BEGET libraries.

- Subroutine BEGUSER is called instead of any other generator, if GEN -99. It provides a means for users to write their own generators or develop a new interface to an external generator.
- Subroutine BEGUNIT is called after the requested generator has been initialized, but before any events are generated, to give the user an opportunity to change the initialization of the generator.
- Logical Function BEGUREJECT allows the user to reject the event and request a new one before returning from the BEGET subroutine.

None of the subroutines or functions take any arguments.

Some BEGET subroutines that may be of interest to users are:

- HEPROBO performs Lorentz boosts on all of the particles in the STDHEP common block.
- BEGHBOOK initializes the HBOOK histogramming package.
- HEP2GEANT reads the STDHEP common block and places the undecayed particles in the GEANT KINE and VERT banks.

Please refer to the source files in the src directory of the BEGET distribution for more information.

2.5 Linking BEGET

Since a number of libraries and object modules are needed to link BEGET with your program a shell script (`libbeget.Link`) is provided to produce the proper linker arguments. This not only simplifies linking but also allows the easy switching of BEGET versions and the selective linking of external generators (such as KORALB).

The script produces a text string that contains the actual linker arguments in the appropriate order. The standard unix trick of using ``` permits the output of the script to be included as part of another command, e.g. `f77bb -link test.o `libbeget.Link``. To see the output of the script enter it as a regular UNIX command without the ```'s.

The BEGET version number is hardwired into the script so that it always links a specific version (even if the script is accessed via a link). The script looks for the beget libraries in the same directory in which the script resides (e.g. `$BFLIB/libbeget.Link` looks in `$BFLIB`). In addition the script requires two environment variables `$BFLIB` and `$CERN_ROOT`, the first is needed to locate the STDHEP library and the second is used to locate the CERN libraries.

A few examples:

<code>`\$BFLIB/libbeget.Link`</code>	Link the defaults version of BEGET.
<code>`\$BFLIB/libbeget.v021.Link`</code>	Link BEGET version 21.
<code>`\$HOME/libbeget.v999.Link`</code>	Link BEGET version 999 found in the user's home directory.

2.5.1 Selective Linking of Generators

By default BEGET links the JETSET library. JETSET is required for the random track generators (to do the particle decays if the user requested a non-stable particle) and the $\Upsilon(4S)$, $q\bar{q}$, and quark "Onium" generators. Other external generators are not linked automatically. This keeps the resulting executable small, minimizes linking time and eliminates the need for every site to install every generator.

Currently, the only external generator available is KORALB. To activate it you must install the KORALB library on your system (a development version is already installed at SLAC) and add an argument to the linker script to tell BEGET where it is.

For example if KORALB is installed as `libkoralb.vdev.a` in the `$BFLIB` directory then

```
`$(BFLIB)/libbeget.Link -lkoralb.vdev`
```

would produce a BEGET program that can access KORALB. ASLUND users must edit a line in the ASLUND `user/Imakefile` to look like the following:

```
BEGETLIBS = `$(BFLIB)/libbeget.Link aslund -lkoralb.vdev`
```

To actually generate KORALB events the user must select the GEN 10 data card at run time.

New external generators (for example QQ) will be made available via the same mechanism. They will not be linked automatically unless the user requests them.

3 Installing BEGET

The master copy of BEGET is stored on the SLAC unix cluster in CVS. There are three methods to install it at a remote site:

1. Copy the binaries and include files.
2. Copy the 'tar' file and compile BEGET.
3. Check out the CVS version and compile BEGET.

The third method has the advantage that bug fixes can be automatically incorporated at the remote site.

BEGET has been successfully installed under the following operating systems: HP-UX, AIX, SunOS, Alpha/OSF, and Ultrix. Any problems with these or other platforms should be reported to wright20@llnl.gov.

3.1 Method 1 (Copying the Binaries)

Copy the most recent version of the following files from a site that has installed BEGET, of course the CPU type must match your system.⁶

```
libbeget.v021.Link  
libbeget.v021.a  
libbeget.v021.dummy.a  
libbeget.v021.o  
libstdhep.a
```

Make a link `libbeget.Link` to `libbeget.v021.Link`.

If you wish to perform generator studies you must also copy two include files:

```
$BFROOT/src/beget/v021/beget.inc  
$BFROOT/src/stdhep/pro/stdhep.inc
```

3.2 Method 2 and 3 (Compiling BEGET)

Installing BEGET from the source code is a three step process:

1. Copy the source code to your system from either
 - the most recent tar file in `$BFROOT/src/beget`
 - via CVS: `cvs -R co -r v021 -d v021 beget`

Store the source code in `$BFROOT/src/beget/v021` and maintain a `pro` link to the current version, which in this case is `v021`.

⁶The SLAC unix cluster has the IBM RS6000 version (`$BFROOT/lib.aix6000`) and the HP version (`$BFROOT/lib.hp`).

2. Compile the code. Type **gmake** in the BEGET directory you just created. This builds the libraries in the current directory. You may have to edit the **GNUMakefile** to specify the location of the **stdhep** include file, i.e. edit the line:

```
hepinc := $(BFR00T)/src/stdhep/pro
```

3. Move the libraries to the **\$BFLIB** area. Type **gmake install** to move the libraries from the working directory to the **\$BFLIB** area.

3.3 Software Requirements

Table 4 outlines the software required to install BEGET which does not come with the BEGET distribution.

Table 4: BEGET software requirements

Required Environment Variables:

BFLIB	final location of BEGET libraries
CERN_ROOT	location of cern libraries (e.g. /cern/pro)

Required to install BEGET:

f77bb	shell script for compiling FORTRAN
libstdhep.a	STDHEP library
stdhep.inc	include file for STDHEP common block
libpacklib.a	CERN library
libmathlib.a	CERN library
libjetset.a	CERN library

Optional

libkoralb.a	KORALB library
-------------	----------------

4 Caveats

Caveats on running BEGET.

- When linked to GEANT the following particles: K_S^0 , $\Sigma^{\pm 0}$, Ξ^{-0} , Λ^0 , Ω^- , are declared to be stable (which JETSET normally decays). This allows them to be passed on to GEANT which then handles their decay.
- The $\Upsilon(4S)$ width is not used when beam smearing is activated.
- KORALB does not handle smearing of beam energies. This would require reinitializing KORALB at every event, which has not been implemented.
- When linked to ASLUND, the default beam energies are taken from ASLUND variables instead of BEGET, but the defaults can be overridden by the BEGET data cards BEAM and SBEAM.
- When running ASLUND do not use data cards VERT, SVERT, or IVERT, since ASLUND does its own vertex smearing after the event has been generated.
- When linked to ASLUND, BEGET uses the ASLUND version of subroutine LUCOMP instead of its own version. The mapping of user defined particles is different in the two cases. Power users who exploit the mapping of these non-standard particles should review Section 2.3.1.

Carefully constructed decay table files can therefore be used with the ASLUND native generator or BEGET. The stand-alone and GEANT version of BEGET use a different version of LUCOMP which is more robust. With sufficient user interest, the discrepancies in the LUCOMP mapping could be eliminated.

5 Controlling BEGET

This section describes the data cards used to control BEGET. The data cards are read in with the FFREAD package from the CERN library. The defaults are set in subroutine BEGFFKEY and BEGINIT.

5.1 Data Card Overview

Data Card	Function
Generator Controls	
GEN	Choose what to generate
BACK	Activate beam background from TURTLE files
BACD	Specify a directory containing TURTLE files
CP	Select CP violation and/or B^0 - $\bar{B}^0$ mixing
Decay Controls	
B0B0	Selectively deactivate B^0 and/or $\bar{B}^0$ decay modes
JPSI	Control J/ψ decay
JETD	Specify a file to read in JETSET decay information
Beam Controls	
BEAM	Set the beam energies
SBEAM	Set the beam energy spread
VERT	Set the primary vertex location
SVERT	Set the primary vertex spread
IVERT	Set the primary vertex smearing method
General Controls	
GENP	Print event information on the terminal
JETO	Print the decay table for the listed particles
RAN	Control the random number seeds
EVNT	Set the number of events to generate
REJE	Control user event rejection

5.2 Data Card Default Values

Data Card	Default Value	Default Function
Generator Controls		
GEN	2	Generate $\Upsilon(4S) \rightarrow B^0 B^0$, decay using JETSET.
BACK	0	do not add TURTLE background
BACD	"	default directory to find TURTLE files is \$BROOT/src/beget/pro/dat
CP	0	No CP violation or B^0 - $\bar{B}^0$ mixing.
Decay Controls		
BOBO	1 1	Turn on all B^0 decays.
JPSI	-1	Turn on all J/ψ decays, unless BOBO is not 1 1 (see below)
JETD	"	Do not read any external decay file
Beam Controls		
BEAM	9.0 -3.109	$p_z(e^-) = 9.0 \text{ GeV}/c$, $p_z(e^+) = -3.109 \text{ GeV}/c$
SBEAM	0. 0.	zero energy spread on beam (no smearing)
VERT	0. 0. 0.	event origin is (0,0,0)
SVERT	0. 0. 0.	no vertex smearing
IVERT	0 0 0	use gaussians (sigmas set by SVERT)
General Controls		
GENP	0 0	Do not print the events on the terminal.
JETO	0*20	no print out of decay tables
RAN	1 0	use default seed #1 = 9876 54321
EVNT	1	set Nbeg_events = 1
REJE	0	accept all events

5.3 Data Card Definitions

GEN: Choose what to generate

```
*****
GEN      IMODE KF x1 x2 x3 x4 x5 x6          Choose what to generate
*****
```

```
GEN      2 0 0. 0. 0. 0. 0. 0.          Defaults
```

OVERVIEW

```
+-----+
| -100   NULL Physics Generator          |
| -99    call BEGUSER                    |
+-----+
|           Single Particle (Pt)         |
| -13 kf Ptmin Ptmax cos(themin) cos(themax) phimin phimax |
| -12 kf Ptmin Ptmax themin themax phimin phimax            |
| -11 kf Pt cos(theta) phi              |
| -10 kf Pt theta phi                    |
+-----+
|           Single Particle (P)          |
| -3 kf Pmin Pmax cos(themin) cos(themax) phimin phimax    |
| -2 kf Pmin Pmax themin themax phimin phimax              |
| -1 kf P cos(theta) phi                          |
| 0 kf P theta phi                                    |
+-----+
| 1      Upsilon(4S)                      |
| 2      Upsilon(4S) -> B0 B0~ only        |
| 3      Upsilon(4S) -> B+ B-  only        |
+-----+
| 4 kf   e+e- -> qq~ (JETSET)             |
| 5 kf   e+e- -> gamma -> "onium" (JETSET call luonia)    |
+-----+
| 10     tau+ tau- KORALB                  |
| 11     beam-gas EPC                      |
| 12     cosmic rays HemiCosm              |
+-----+
```

DETAILS

IMODE=0 User defined particle and four-vector. The particle is

allowed to decay using JETSET.

KF = JETSET code to identify particle

x1 x2 x3 = P Theta Phi

x4 x5 x6 = ignored

P = momentum of particle in lab frame (GeV/c)

Theta, Phi = direction of mom. vector in lab frame (degrees)

IMODE=-1 same as IMODE=0 except:

x1 x2 x3 = P cos(theta) Phi

Angles in degrees, Momentum in GeV/c

IMODE=-2 same as IMODE=0 except:

x1 x2 = Pmin Pmax

x3 x4 = The_min The_max

x5 x6 = Phi_min Phi_max

A random value for P, theta and phi is chosen for each event
in the ranges specified by x1-x6

Angles in degrees, momentum in GeV/c

IMODE=-3 same as IMODE=-2 except:

x3 x4 = cos(The_min) cos(The_max)

Angles in degrees, momentum in GeV/c

IMODE=-10 to -13 same as IMODE 0 to -3 except:

Pt (momentum transverse to beam pipe) instead of P
momentum in GeV/c

IMODE=-99 Call subroutine BEGUSER to generate the event.

IMODE=-100 Do not call any physics generators.

IMODE=1 Generate Upsilon(4S) at rest in cm frame. Decay using JETSET
and boost to lab frame.

IMODE=2 Same as IMODE=1 with Upsilon(4S) -> B0 B0⁻ decay only.

IMODE=3 Same as IMODE=1 with Upsilon(4S) -> B+ B- decay only.

IMODE=4 Generate e+e- -> q q~ with JETSET, decay with JETSET.
Get Ecm and boost from BEAM parameters.

KF=0 Generate all quark pairs up to heaviest allowed by Ecm
KF=n Generate only quark pairs defined by n
n=1,2,3,4,5 = d,u,s,c,b

IMODE=5 Generate e+e- -> gamma -> "onium" -> ggg or gg gamma
-> parton shower
with JETSET, decay with JETSET.
Get Ecm and boost from BEAM parameters.

KF=0 Generate g g g events only
KF=n Generate mixture of ggg and gg gamma determined by
Q^2 of n
n=1,2,3,4,5 = d,u,s,c,b

IMODE=10 Generate tau+ tau- using KORALB

IMODE=11 Generate Beam-Gas interactions

EPC library calculates the cross-sections

IMODE=12 cosmic-ray generator

BACK: Activate beam background from TURTLE files

```
*****
BACK  Iback Tback 'file'      Activate beam background from TURTLE files
*****
BACK  0 3. ''                Defaults
```

Add off-momentum beam particles and bremsstrahlung photons to the current event. The current implementation samples particles from a set of TURTLE files previously prepared.

If no GEN data card is present then no physics generator will be called, i.e. the event will contain only background.

Iback

0 No background is added
1 Generate background by picking particles out of

- previously prepared TURTLE files
- 2 Read background from a file previously prepared from Iback=1
(the filename is required, see the examples below)

Tback = Amount of time (in microseconds) to accumulate background

file Save the generated background particles in a file (Iback=1)

examples:

```
BACK 1           # generate background for 3 micro seconds per event
BACK 1 4.        # generate background for 4 micro seconds per event
BACK 1 4. 'back.out' # same as above and save the selected background
                  # particles in back.out
BACK 2 'back.out' # read the particles from file back.out
                  # (one event at a time)
```

BACD: Directory to find TURTLE files

```
*****
BACD 'dir'           Directory to find TURTLE files
*****
BACD ''             Defaults
```

dir = directory containing TURTLE files with generated
background particles

if dir = '' then the default is
\$BROOT/src/beget/pro/dat'

BEGET expects four files to be present:

```
heb+.inp    leb+.inp
heb-.inp    leb-.inp
```

heb = High Energy Beam + = +z
leb = Low Energy Beam - = -z

CP: Select CP violation and/or B^0 - $\bar{B}^0$ mixing

```
*****
CP      Ichoice Par1 Par2 Par3 Par4 IPar      Select CP violation/B0 mixing
*****
```

CP 0 Defaults
 Ichoice=0 no CP violation or B0 mixing
 Ichoice=1 use BBKING version of CP/mixing routine ASMXCP_BBKING
 Ichoice=2 use ASLUND version of CP/mixing routine ASMXCP_ASLUND

Defaults for Ichoice=1 and 2 are different

CP 1 xd xs sincp coscp icp
 .7 8. .5 0. 1 Defaults
 CP 2 sin_2alpha sin_2beta sin_2gamma coscp
 .5 .8 .5 0. Defaults

B0B0: Selectively deactivate B^0 and/or $\bar{B}^0$ decay modes

 BOB0 IBO IBO~ Selectively deactivate B0 and/or B0~ decay modes

BOB0 1 1 Defaults
 IBO = controls B0 decay
 IBO~ = controls B0~ decay
 processed by subroutine BDECAY

example: generates:
 GEN 2 Upsilon(4S) -> B0 B0~
 BOB0~ 11 3 | +---> mu- nu_mu~ X
 +-----> Psi KOL
 +-----> e+e- or mu+mu-

For decay modes 11,12, and 13 the Psi decay modes are switched to e+e- and mu+mu- only. The user can override this with the JPSI data card (see below)

IBO=0 turn off all decays
 1 allow all decays
 2 only B0 -> e nu_e X
 3 -> mu nu_mu X
 4 -> tau nu_tau X
 5 unused
 6 unused
 7 unused

```

8 only B0 -> e X or mu X or tau X
9          -> e X or mu X
10 unused
11 only B0 -> Psi KOL \
12          -> Psi KOS | Psi -> e+e- or mu+mu-
13          -> Psi K*0 / (see JPSI data card)
14          -> D+ D-
15          -> D*+ D*-
16          -> pi+ pi-
17          -> rho+/- pi-/+
18          -> a1+/- pi-/+

```

JPSI: Control J/ψ decay modes

```

*****
JPSI  n                                     Control J/Psi decay modes
*****
JPSI  -1          Defaults
      n=-1        all decays allowed unless BOB0 selected decay 11,12,13
                        then only e+e- and mu+mu- allowed
      0          turn off all decays
      1          all decays allowed
      2          Psi -> e+e- only
      3          mu+mu- only
      9          e+e- and mu+mu- only

```

JETD: Specify a file to read in JETSET decay information

```

*****
JETD  'filename'      Specify a file to read in JETSET decay information
*****
JETD  ''              Defaults
                        WARNING!!!!
                        WARNING!!!! You must use single quotes around the filename
                        WARNING!!!! e.g. JETD 'myfile.dat'
                        WARNING!!!!

      filename = Relative or absolute pathname that contains JETSET decay
                  information a la LUUPDA. This info overrides the built-in
                  decays. The file must contain the full decay table for a
                  given particle but does not need to redefine every particle.
                  ASLUND and BBKING users will recognize this as .newdat

```

The LUCOMP mapping in the stand-alone and GEANT version is

KF	LUCOMP(KF)	
70533	404	Upsilon(4S)
80533	405	Upsilon(5S)
nXXXXX	410+abs(n)	user definable particles

See Section 2.3.1 concerning LUCOMP in ASLUND

BEAM: Set the beam energies

```
*****
BEAM  Pz(electron) Pz(positron) Ecm    (GeV)          Set the beam energies
*****
```

```
BEAM  9.0 -3.1 0.  Defaults
      Pz_electron, Pz_positron    z component of momentum of electron and
                                  positron beam (GeV). Px = Py = 0.
      Ecm                        center-of-mass energy in (GeV)
```

You may set EITHER the two beam momenta OR one beam momentum and the center-of-mass energy. Set the unused quantity to zero and it will automatically be filled in with the correct value. Note that the sign of the beam momenta is important.

SBEAM: Set the beam energy spread

```
*****
SBEAM  Sigma(electron) Sigma(positron) (GeV)          Set the beam energy spread
*****
SBEAM  0.  0.  Defaults
```

The beam smearing is handled as in the native ASLUND generator, which smears the nominal beam energy by a gaussian for every event. For each event the center-of-mass is calculated and the mass of the Upsilon(4S) is set equal to this energy. The Upsilon(4S) is then generated with zero momentum. The boost of the final state is also based on the smeared energies on an event by event basis.

Warning, If the center-of-mass energy for a smeared event happens to be below the mass threshold for B0 production an empty event will be

generated. The actual threshold in JETSET is slightly higher than twice the B0 mass.

VERT: Set the primary vertex location

```
*****
VERT x y z      (mm)                Set the primary vertex location
*****
VERT 0. 0. 0.   Defaults
```

The given coordinates, in millimeters, sets the primary vertex position

SVERT: Set the primary vertex spread

```
*****
SVERT dx dy dz (mm)                Set the primary vertex spread
*****
SVERT 0. 0. 0.   Defaults
```

IVERT: Set the primary vertex smearing method

```
*****
IVERT Ix Iy Iz                Set the primary vertex smearing method
*****
IVERT 0 0 0   Defaults
                0=smear with gaussian (sigma given by SVERT)
                1=smear with flat distribution (-delta,delta),
                  (delta given by SVERT)
```

GENP: Print event information on the terminal

```
*****
GENP  IHEP ILUND IGPKINE IGPVERT   Print event information on the terminal
*****
GENP   0 0 0 0   Defaults
                IHEP >0   call heplist(IHEP) after every event to list particles
                ILUND >0  call lulist(ILUND) after every event to list particles
```

IGPKINE>0 call GPKINE(0) after every event to list GEANT particles
 IGPVERT>0 call GPVERT(0) after every event to list GEANT vertices
 IGPKINE and IGPVERT work only in GEANT programs

All four printouts can be activated simultaneously

JETO: Print the decay table for the listed particles

```
*****
JETO KF1 KF2 ... KF          Print the decay table for the listed particles
*****
JETO 0 0 ... 0    Defaults
```

For any non-zero JETSET particle code the decay table for that particle will be listed at the end of the initialization pass through the JETSET generator.

example:

JETO 511 443 # list the decay table for B0 and J/PSI

RAN: Control the random number seeds

```
*****
RAN Iseed1 Iseed2          Control the random number seeds
*****
RAN 1 0    Defaults
```

This data card initializes the random number seed for the BEGET random number generator (RANECU). RAN behaves exactly like the RNDM data card of GEANT.

The preselected random number seeds (see below) result in distinct sequences 1 billion numbers apart. Not all integer seeds result in a good or random sequence, so the authors recommend using the preselected ones.

Iseed2=0 Iseed1 can be a number between 1 and 100 that causes a preselected seed to initialize the random number generator.

Iseed2<>0 The random number generator will be initialized with seeds

Iseed1 and Iseed2.

EVNT: Set the number of events to generate

```
*****
EVNT Nbeg_events          Set the number of events to generate
*****
EVNT 1                    Defaults
```

This data card merely sets a variable (Nbeg_events) in the BEGET common block. It is up to the user to check it and call the BEGET subroutine the appropriate number of times.

ASLUND and BBSIM users should not use this card since event counting is already built in to those programs.

6 STDHEP Common Block

The variables in the STDHEP common block are given in Table 5. The complete documentation including a table comparing the STDHEP particle codes with those of the Particle Data Group, JETSET, ISAJET, and HERWIG can be found in Reference [5].

Table 5: STDHEP common block variables.

NEVHEP	event number
NHEP	number of entries in the event
For each entry i	
ISTHEP(i)	status code for particle
IDHEP(i)	particle ID code
JMOHEP(1,i)	position of mother particle
JMOHEP(2,i)	position of second mother particle
JDAHEP(1,i)	position of first daughter
JDAHEP(2,i)	position of last daughter
PHEP(1-3,i)	p_x, p_y, p_z in (GeV/c)
PHEP(4,i)	Energy (GeV)
PHEP(5,i)	Mass (GeV/c ²)
VHEP(1-3,i)	x,y,z or vertex (mm)
VHEP(4,i)	production time (mm/c)

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