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The new Efficiency algorithms

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Abstract

This note describes the generic efficiency algorithms which have been developed within the DaVinci framework. These algorithms can be used to evaluate the efficiency of reconstructibility and reconstructedness for specific decays, based on the Monte Carlo truth, and to evaluate the efficiency and purity of corresponding selection algorithms. Previously, this has been done by the unique algorithm PhysSelEff. In the new code which is presented here, these two functionalities have been separated. The first part, (efficiency for reconstructibility and reconstructedness according to the Monte Carlo truth), can now be used independently, for example, for trigger studies. The main features of the algorithms, their steering through job options, are described and illustrated for specific examples.

Contents

1 Introduction

The main purpose of the efficiency algorithms is to provide a generic way to evaluate the performance of trigger and off-line selection algorithms in terms of their efficiency and purity. They are based on the evaluation of and comparison to the Monte Carlo truth information using a standard definition of "reconstructibility" and "reconstructedness" for a large number of signal topologies.

A first version of such an algorithm (PhysSelEff, developed by Gloria Corti and Peter Igo-Kemenes) has already been used to evaluate the efficiency and purity for a number of physics selections for the "Reevaluation Technical Design Report". The old code performed, sequentially, the following steps:

- Evaluation of the Monte Carlo truth for a specific signal process

- Identification of the Decay of Interest (DoI) with MC DST events and the corresponding final state (stable) particles
- Find and count the reconstructible DoIs
- Find and count the reconstructed DoIs

• Checking of the outcome of a specific selection algorithm for that signal process

- Using the χ^2 associator
- Using the "composite link" associator
- Count the DoIs which are selected and associated

• Comparison of the selected and true DoI

- Using the χ^2 associator
- Using the "composite link" associator
- Count the DoIs which are selected and associated
- Efficiency $= \frac{\text{N(selected and associated)}}{\text{N(reconstructed)}}$
- Purity $= \frac{\text{N(selected and associated)}}{\text{N(selected)}}$

• Evaluation of the efficiency and purity of the selection without/with applying a specified mass window

The results of the evaluation have been summarized in a Table which was part of the log output.

The new code has essentially the same functionality but it is presented in a more modular form. The evaluation of the Monte Carlo truth is now done by a separate, independent, algorithm MCEffBuilder which can be used as stand-alone and which produces its own output. This is then followed by the EffSelCheck algorithm which does the remaining part of the job. The communication between the two algorithms is done via the transient event store (TES). This is illustrated in Figure 1.

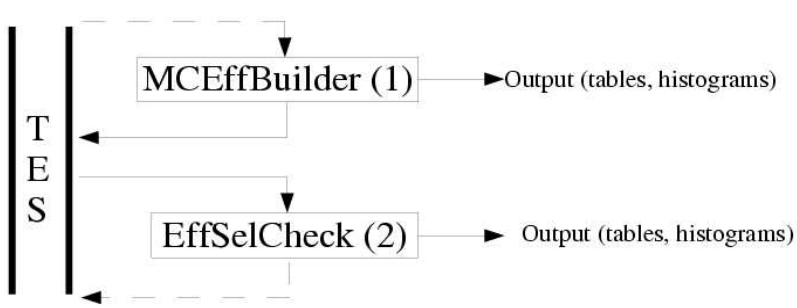

Figure 1: The efficiency algorithms communicate via the TES.

2 Monte Carlo Truth Efficiency algorithms

The Monte Carlo Truth Efficiency algorithms are mainly composed of two parts: the MCEffBuilder algorithms, which compute all the relevant information and store it to the Transient Event Store (TES) and the Event model classes stored in the TES (hereafter referred as "MCEff" classes). Both parts are explained in more detail in the following subsections.

2.1 The Event model classes

Two classes have been added to the Event model (package `Event/Event v4r4` or higher): the MCEffTree class and the MCEffParticle class.

2.1.1 The MCEffParticle class

This class contains a reference to a stable MCParticle and two integer flags: one for reconstructibility and one for reconstructedness. A stable MCParticle is an particle which is flagged in the decay descriptor string of the MCEffTree class (see 2.1.2). This class in not available directly through the TES, but only through the MCEffTree class which is stored in the TES.

2.1.2 The MCEffTree class

The MCEffTree class represents the Decay of Interest (DoI) and provides the following information:

- Decay descriptor string - It describes the Decay of Interest according to the MC Decay Finder syntax
- Reference to the head MCParticle of the decay tree
- Vector of stable MCEffParticles of the decay tree
- Basic reconstructed / reconstructible flag for the DoI (detailed information is available through the MCEffParticle class)
- Boolean flag if the decay is found

The decay descriptor string and the boolean flag are always filled. The other quantities are only filled if the DoI is found in the event (i.e. if the boolean flag is true). The decay descriptor string is used by the Phys/MCTools/MCDecayFinder tool and thus has to follow the same syntax as defined by the MCDecayFinder tool. It is very important to *flag* the particles that the users declares as stable with a ˆ symbol, otherwise the algorithm will exit with a FATAL message.

Example 1 *This is an example of a decay descriptor string for the* $B_s^0 \to D_s^- \pi^+$ *channel, with a* D_s *decaying to two kaons and a pion with implicit resonances:*

```
{[[B_s0]nos -> (D_s- => ^K+ ^K- ^pi-) ^pi+]cc,
 [[B_s0]os  -> (D_s+ => ^K+ ^K- ^pi+) ^pi-]cc}
```

Note that you have to use `[]cc` if you want to consider the corresponding charged conjugate channel as well (for non-CP eigenstates), `[]os` respectively `[]nos` to include both B_s^0s that may or not have oscillated. Please also note that the current version of the MCDecayFinder (`Phys/MCTools v1r6`) cannot handle the expansion between `[]cc` and `[]os/nos` (see above example).

A container of MCEffTrees is stored in the TES at

- /Event/Phys/MCEffTrees location for offline analysis studies
- /Event/Trg/MCEffTrees location for trigger studies

2.2 Reconstructibility and Reconstructedness

2.2.1 ... for MCParticles

An MCParticle is *reconstructible* if it has "enough clusters/digits" in the Velo, the Trigger Tracker (TT) or the three tracking stations according to the MCTrackInfo[1] wrapper. The reconstructible flag in the MCEffParticle class can have several integer values:

- 0, for non reconstructible tracks,
- 1, for reconstructible as long tracks (Velo to T),
- 2, for reconstructible as upstream tracks (Velo to TT),
- 3, for reconstructible as downstream tracks (TT to T),
- 4, for reconstructible as neutral tracks (only geometrical acceptance).

An MCParticle is *reconstructed for offline analysis studies*, if it is associated to a ProtoParticle. As for reconstructibility, the reconstructed flag in the MCEffParticle class can have five integer values: not reconstructed, reconstructed as long, up-, downstream or neutral tracks.

An MCParticle is *reconstructed for trigger studies*, if it is linked to a TrgTrack. For the moment, only "reconstructed as upstream track" (category 3) is available for trigger studies.

2.2.2 ... for Decays of Interest

A DoI is reconstructible / reconstructed of one of the following is true for each stable MCParticle of the DoI:

- if the MCParticle comes from a K_S^0

[1]Phys/MCtools v1r2 or higher

  - it is reconstructible / reconstructed as a long or a downstream track

- if the MCParticle does not come form a K_S^0
  - if it is neutral, see if it is reconstructible / reconstructible as neutral
  - if it is charged, see if it is reconstructible / reconstructed as a long track

The corresponding reconstructible / reconstructed flag in the MCEffTree class is the set to 1. If more sophisticated information is needed for the reconstructibility / reconstructedness of a DoI, the user has either to consider himself the corresponding information available in the MCEffParticle classes, or consider the detailed particle report (see subsection 2.6).

2.3 The MCEff algorithms

There are to MCEff algorithms: MCEffBuilder and MCEffMonitor, both situated in the `Phys/MCTools v1r6` or higher package.

2.3.1 The MCEffBuilder algorithm

- Computes reconstructibility information for the DoI (stored in the MCEffTree class)
  - via the MCEffReconctructible tool. This tool computes the reconstructible information for MCParticles - this information is then stored in the MC-EffParticle class by the MCEffBuilder. The MCEffReconstructible tool can either be used for offline analysis or trigger studies. It can also be run as standalone.
- Computes reconstructedness information for the DoI (stored in the MCEffTree class)
  - via the MCEffReconstructed tool. This tool computes the reconstructed information for MCParticles - this information is then stored in the MC-EffParticle class by the MCEffBuilder. There are two different implementations for this tool: MCEffReconstructed.h for offline analysis, situated in the `Phys/DaVinciEff v3r0` or higher package, and TrgMCEffReconstructed.h for trigger studies, situated in `Trg/TrgTool v4r0` or higher package. Both implementations share the same interface IMCEffReconstructed.h situated in the `Phys/MCTools v1r6` or higher package. This tool can also be used in standalone mode.
- Fills the MCEff classes and stores them into the TES.
- Computes efficiencies
- If specified: computes a detailed particle report and fills histograms (see subsection 2.6)

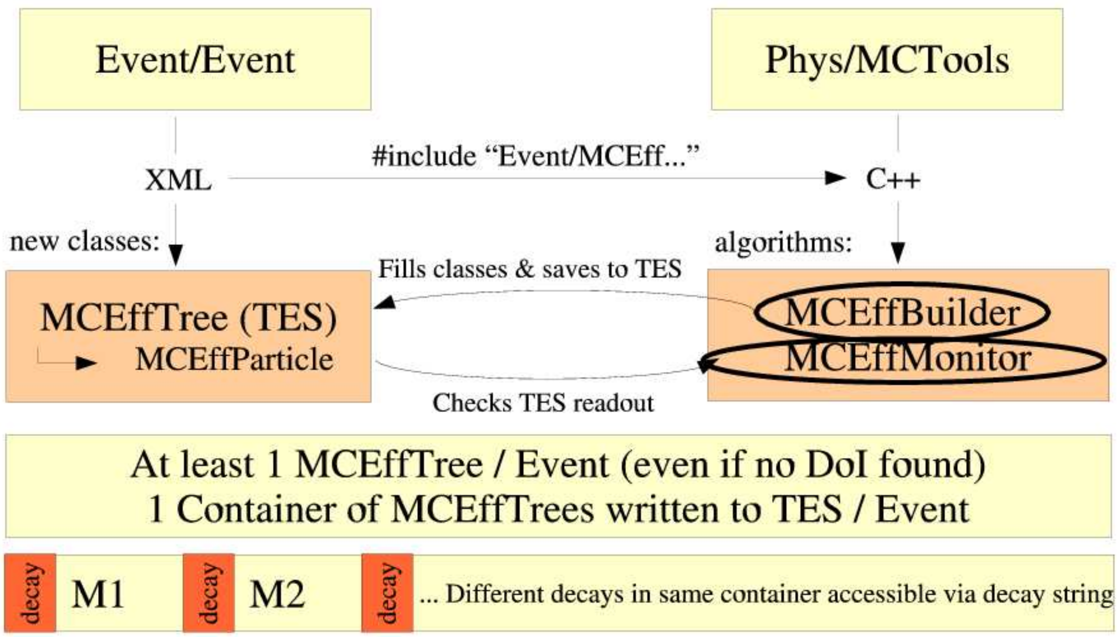

Figure 2: Interplay between MCEff classes and MCEff Algorithms

– via the MCEffBreakdown tool, situated situated in the `Phys/MCTools v1r6` or higher package.

2.3.2 The MCEffMonitor algorithm

This algorithm is a simple monitoring algorithm to check what the MCEffBuilder algorithm has written to TES. It can be used as a basis by the user who wants to read the MCEff classes with his own algorithms.

2.4 MCEff classes and MCEff algorithms

Figure (2) shows a summary flowchart of how the MCEff classes and MCEff algorithms work together.

At least one MCEffTree class is stored per event, even if no DoI is found. The class then remains empty apart from the decay descriptor and the “DoI found” boolean flag, which is set to “false”. One container of MCEffTrees is used to store the MCEffTrees classes in the TES, even if more than one instance of the MCEffBuilder algorithm is used. The MCEffBuilder algorithm checks for the container and only creates it if it does not already exist. Thus several different types of DoIs (with different decay descriptors) can be found in a single container. The decay descriptor has then to be used to loop over the container and to retrieve the information relevant to the DoI needed.

2.5 Output example

Table (1) shows the standard output of the MCEffBuilder algorithm for the $B_s^0 \to D_s^- \pi^+$ channel.

```
*********************************************************
***************  Output from MCEffBuilder  ***************
*********************************************************

Decay analyzed (MC truth) {[[B_s0]nos -> (D_s- => ^K+ ^K- ^pi-) ^pi+]cc,
                           [[B_s0]os  -> (D_s+ => ^K+ ^K- ^pi+) ^pi-]cc}
Events processed                                          1000
Decay Of Interest Generated               ( / Events )    1000     1
DoIs Gen, Reconstructible (ALL)        ( / Generated )     149     0.149
DoIs Gen, Reconstructed (ALL)          ( / Generated )     145     0.145
---------------------------------------------
DoIs Gen, Rec'ble & Rec'ted (ALL)                          116
Rec. efficiency: (Rec'tible & Rec'ted)/Rec'tible (ALL):  0.778523 +- 0.0340178
```

Table 1: Output of MCEffBuilder algorithm

2.6 Particle Report

The particle report is computed for each subdecay present in the decay tree.

Example 2 *The $B_s^0 \to D_s^- \pi^+$ decay described by the following decay descriptor:*

```
{[[B_s0]nos -> (D_s- => ^K+ ^K- ^pi-) ^pi+]cc,
 [[B_s0]os  -> (D_s+ => ^K+ ^K- ^pi+) ^pi-]cc}
```

contains the following subdecays:

```
D_s-   -> K- pi- K+
B_s~0  -> K- pi- pi+ K+
D_s+   -> K- pi+ K+
B_s0   -> K- pi- pi+ K+
```

Note that unlike the particle report of the old DaVinciEff algorithms, the new one can now handle implicit resonances (marked by `=>` in the decay descriptor string).

The particle report information is dynamically gathered and filled "on the fly", each time a certain (already found before or new) subdecay is found, on event by event basis.

The particle report contains:

- detailed reconstructible / reconstructedness counters presented in matrix form in the output logfile for each subdecay
- counter and monitor histograms for each subdecay.

```
==================================================================================================
********** Particle Report for B_s0 -> K- pi- pi+ K+  decay *************
==================================================================================================
==================================================================================================
--------------------------------------------------------------------------------------------------
------------------   RECONSTRUCTIBILITY (columns) vs. RECONSTRUCTION (rows)  --------------------
--------------------------------------------------------------------------------------------------
 (0): The DoI is not reconstructible/reconstructed
 (1): The DoI contains only Long tracks
 (2): The DoI contains (Long and/or downstream) tracks
 (3): The DoI contains (Long and/or downstream and/or upstream) tracks
 (4): The DoI contains only Neutral particles
 (5): The DoI contains Neutrals and Long tracks
 (6): The DoI contains Neutrals and (Long and/or downstream) tracks
 (7): The DoI contains Neutrals and (Long and/or downstream and/or upstream) tracks
--------------------------------------------------------------------------------------------------
      |    (0)   |    (1)   |    (2)   |    (3)   |    (4)   |    (5)   |    (6)   |    (7)   |    sum   |
--------------------------------------------------------------------------------------------------
 (0)  |       39 |        0 |        0 |        0 |        0 |        0 |        0 |        0 |       39 |
 (1)  |        1 |        6 |        2 |        1 |        0 |        0 |        0 |        0 |       10 |
 (2)  |        0 |        1 |        0 |        0 |        0 |        0 |        0 |        0 |        1 |
 (3)  |        2 |        0 |        0 |        2 |        0 |        0 |        0 |        0 |        4 |
 (4)  |        0 |        0 |        0 |        0 |        0 |        0 |        0 |        0 |        0 |
 (5)  |        0 |        0 |        0 |        0 |        0 |        0 |        0 |        0 |        0 |
 (6)  |        0 |        0 |        0 |        0 |        0 |        0 |        0 |        0 |        0 |
 (7)  |        0 |        0 |        0 |        0 |        0 |        0 |        0 |        0 |        0 |
---------------------------------------------------------------------------------------------------
 sum  |       42 |        7 |        2 |        3 |        0 |        0 |        0 |        0 |          |
---------------------------------------------------------------------------------------------------
Total sum over columns: 54
Total sum over lines: 54
```

Table 2: Output of the particle report for one specific subdecay

2.6.1 Logfile output

Table (2) shows the matrix form output for one of the four subdecays of example (2). There are 7 non-overlapping reconstructible / reconstructed categories (see table).

Let us take a closer look at this table:

- There are 54 B_s^0 events (and 46 $\bar{B}_s^0$)
- From this 54 there are:
  - 39 not reconstructible and not reconstructed
  - 10 reconstructible as long tracks, from which :
    - 1 not reconstructed
    - 6 reconstructed as long track
    - 2 reconstructed as long and/or downstream track
    - 1 reconstructed as long and/or downstream and/or upstream tracks
  - 1 reconstructible as long and/or downstream tracks which is reconstructed with only long tracks
  - 4 reconstructible as long and/or downstream and/or upstream tracks, from which :
    - 2 are not reconstructed

  * 2 are reconstructed as long and/or downstream and/or upstream tracks

2.6.2 Histogram output

Histograms work in both PAW and ROOT. They are organized in a tree directory structure according to the subdecay they belong to. Each directory contains:

- A 2D histogram representing the counter matrix
- a 1D histogram with reconstructible, reconstructed, reconstructible and reconstructed counters, where reconstructible / reconstructed means reconstructible / reconstructed in one of the 7 categories,
- 3 subdirectories with MC information for reconstructible, reconstructed, reconstructible and reconstructed DoIs.
  - MC information contains: mass, momentum, transverse momentum, decay vertex position (z and r), origin vertex position (z and r), decay length and proper time. Units are standard LHCb units (MeV, mm, ns).

2.7 Job options

In this subsection we suppose that we have declared an instance of the MCEffBuilder algorithm with the name "MyEff" and an instance of the MCEffMonitor algorithm with the name "MyEffMonitor".

2.7.1 MCEffBuilder Job options

Decay Descriptor string There is only one job options which *must* be specified (i.e. has no default value): the decay descriptor string for the DoI. Note that stable particles have to be marked with a ˆ. The decay descriptor for $B_s^0 \to D_s^- \pi^+$ channel is:

```
MyEff.MCDecay = "{[[B_s0]nos -> (D_s- => ^K+ ^K- ^pi-) ^pi+]cc,
                  [[B_s0]os  -> (D_s+ => ^K+ ^K- ^pi+) ^pi-]cc}";
```

The Runtime Environment For an offline analysis using associators to ProtoParticles to determine the reconstructedness, the option "Phys" has to be used (default). For trigger studies the reconstructedness is determined with the help of the linkers to TrgTracks. In this case the "Trg" option has to be specified. These options also determine the location of the MCEff classes in the TES (/Event/Phys/MCEffTrees or /Event/Trg/MCEffTrees). The runtime environment is set with the following option:

```
MyEff.setRuntimeEnvironment = "Phys"; // default or
MyEff.setRuntimeEnvironment = "Trg";
```

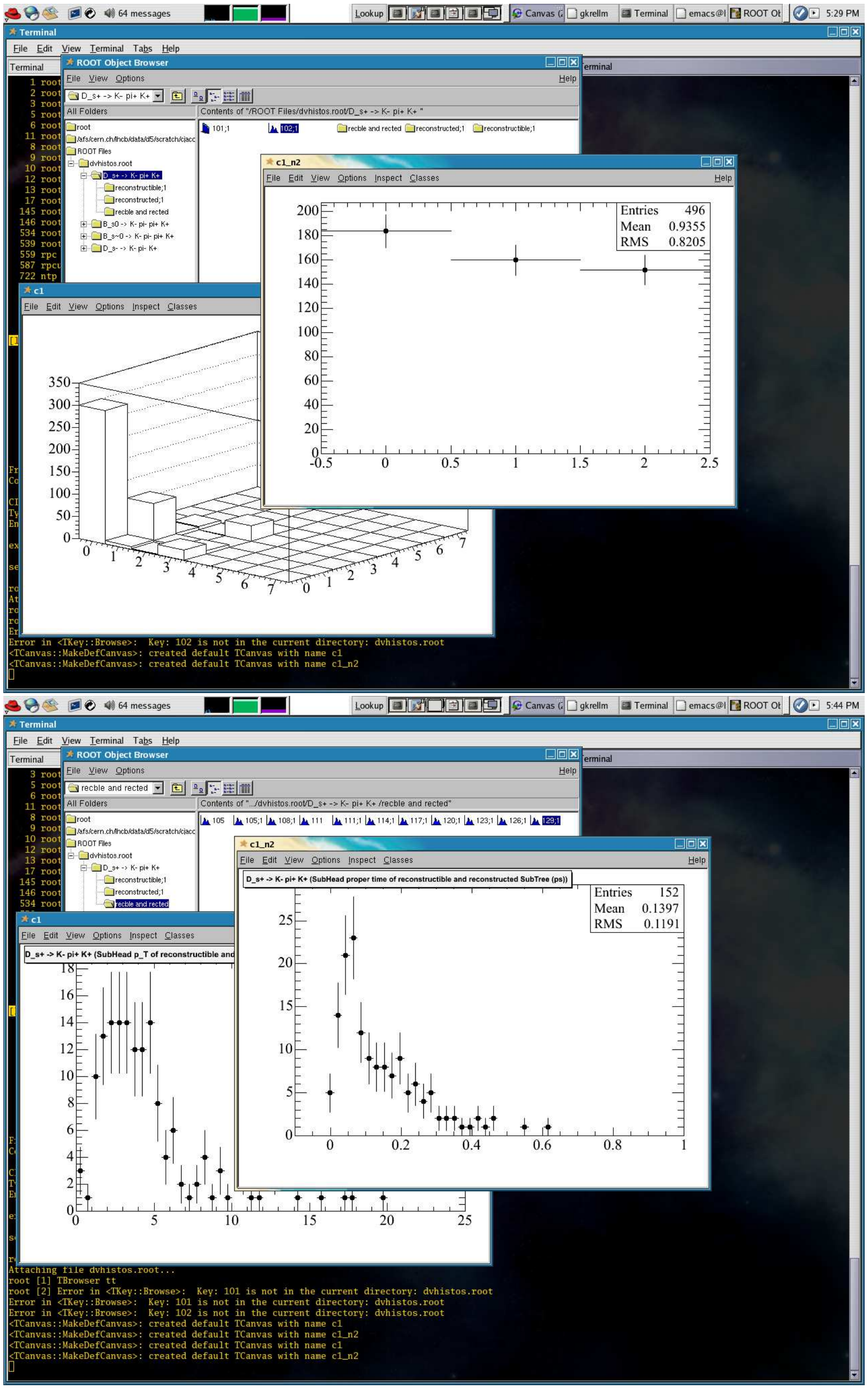

Figure 3: Top: This screenshot shows the generated directory structure for histograms. On the left bottom the 2D counter histogram is represented. On middle right the reconstructible, reconstructed, reconstructible and reconstructed counter histograms are shown. Bottom: Proper time and transverse momentum are shown for the $D_s^+ \to K^-\pi^+K^+$ subdecay. All Histgrams shown are for the $D_s^+ \to K^-\pi^+K^+$ subdecay.

The Particle Report To enable the particle report, the "useBreakDown" option has to be set to "true" (its default is "false"). Particle report is toggled on with:

```
MyEff.useBreakdown = true;
```

2.7.2 MCEffBreakdown tool job options

Histograms Monitoring and counter histograms can be switched on or off with the "Histogram" option. The default for this option is "true". Histograms can be switched on or off with the following option:

```
MyEff.MCEffBreakdown.Histograms = true;
```

Histogram boundaries Histogram boundaries can be changed with the options below. The values shown are all default values. Standard LHCb units are used (MeV, mm, ns).

```
MyEff.MCEffBreakdown.MassLim      = 100;     // mass boundary in MeV
MyEff.MCEffBreakdown.MomLim       = 500000.; // momentum boundary in MeV
MyEff.MCEffBreakdown.PtLim        = 25000.;  // transverse momentum boundary in MeV
MyEff.MCEffBreakdown.DeczLim      = 150.;    // decay vertex z position boundary in mm
MyEff.MCEffBreakdown.DecrLim      = 2.;      // decay vertex r position boundary in mm
MyEff.MCEffBreakdown.PrimzLim     = 150.;    // origin vertex z position boundary in mm
MyEff.MCEffBreakdown.PrimrLim     = 2.;      // origin vertex r position boundary in mm
MyEff.MCEffBreakdown.DeclLim      = 25.;     // decay length boundary in mm
MyEff.MCEffBreakdown.ProptLim     = 1.;      // proper time boundary in ns
```

2.7.3 MCEffMonitor job options

Location of MCEffTrees The location of the MCEffTree container in the TES is specified by the "TreeLocation" option. Its default points to "/Event/Phys/MCEffTrees" for offline analysis studies. For trigger studies, the location should be "/Event/Trg/MCEffTrees":

```
MyEffMonitor.TreeLocation = "/Event/Phys/MCEffTrees"; //default  or
MyEffMonitor.TreeLocation = "/Event/Trg/MCEffTrees";
```

3 The Selection Efficiency / Purity algorithm

The generic algorithm `EffSelCheck` provides a standard way for the evaluation of the performance (efficiency and purity) of selection algorithms which exist in the DaVinci framework. It is based on the comparison of the results of the selection algorithm to the MC truth information using two types of associators: the "χ^2" associator and the "composite link" associator.

When `EffSelCheck` is run following the MC Truth algorithm `MCEffBuilder` (described in the previous section), it provides the following outputs.

- Tables of counters and efficiency/purity, produced in the finalization phase of the algorithm as part of the log-output
- Monitoring histograms for a set of physics quantities and their resolutions

- Event-by-event information written to the TES which can be added to the event record.

In the following description, the decay $B_d^0 \rightarrow (J/\psi \rightarrow \mu^+\mu^-)(K_s^0 \rightarrow \pi^+\pi-)$ will be used as an example. In the case of this decay, all the above information (table, histograms, TES info) is provided separately for each of the "sub-decay heads", that is for J/ψ, K_s^0, and B^0 (which is also considered, technically, as a sub-decay head).

The algorithm EffSelCheckMonitor allows the information written to the TES to be retrieved for further use.

3.1 Configuring and running EffSelCheck and (optionally) EffSelCheckMonitor

The configuring of DaVinci is done via the option file DVEff... .opts
(see below for the decay $B_d^0 \rightarrow J/\psi K_s^0$).

```
%
/*
 *  Option DVEffBd2Jpsi2MuMu_Ks2PiPi.opts
 *  to run DaVinci with EffSelCheck for
 *  Bd -> J/Psi (mu+ mu-) Ks (pi+ pi-)
 */

// 1. Execute the Selection algorithm
#include "$BD2JPSIKSROOT/options/DVTDRselBd2Jpsi2MuMu_Ks2PiPi.opts"

// 2. Execute the Efficiency algorithm
#include "$DAVINCIEFFROOT/options/EffBd2Jpsi2MuMu_Ks2PiPi.opts"
EffSelCheck.OutputLevel = 3;

// 3. Execute the EffSelCheckMonitor algorithm (optional)
//ApplicationMgr.TopAlg += { "EffSelCheckMonitor" };
//EffSelCheckMonitor.OutputLevel = 3;

// Print algorithm name with 20 characters
MessageSvc.Format = "% F%20W%S%7W%R%T %0W%M";

// Histogram persistency
ApplicationMgr.HistogramPersistency = "HBOOK";
HistogramPersistencySvc.OutputFile = "Bd2JpsiKs.hbook";
//ApplicationMgr.ExtSvc += { "NTupleSvc" };
//NTupleSvc.Output={"FILE1 DATAFILE='DVNtuples.hbook' TYP='HBOOK' OPT='NEW'"};

// Input data
EventSelector.Input   = {
"DATAFILE='PFN:rfio:/castor/cern.ch/lhcb/DC04/00000542_00000013_5.dst' TYP='POOL_ROOTTREE' OPT='READ'",
"DATAFILE='PFN:rfio:/castor/cern.ch/lhcb/DC04/00000542_00000018_5.dst' TYP='POOL_ROOTTREE' OPT='READ'",
"DATAFILE='PFN:rfio:/castor/cern.ch/lhcb/DC04/00000542_00000035_5.dst' TYP='POOL_ROOTTREE' OPT='READ'",
"DATAFILE='PFN:rfio:/castor/cern.ch/lhcb/DC04/00000542_00000038_5.dst' TYP='POOL_ROOTTREE' OPT='READ'"};

// Events to be processed
ApplicationMgr.EvtMax    = 1000;
EventSelector.FirstEvent = 0;
EventSelector.PrintFreq  = 1;
%
```

3.2 EffSelCheck options

The EffSelCheck algorithm is written in such a way as to require a minimum of options. The decay descriptors have to be specified for which the selection is done, for which the MC truth is evaluated and for which the EffSelCheck algorithm is supposed to evaluate the efficiencies (not necessarily identical). The decay descriptors follow the grammar of the DaVinci tools DecayFinder and MCDecayFinder. The final-state stable particles have to be indicated by the symbol " ˆ " preceding the particle name (e.g., `^ mu, ^ pi`). Furthermore, there is a bool to control the histogram option. The recommended `Eff...   .opts` file for the decay $B_d^0 \to J/\psi K_s^0$ is shown below.

```
%
/** @file
 *  Recommended options for the EffSelCheck algorithm:
 *  EffBd2Jpsi2MuMu_Ks2PiPi.opts
 *  to run on Bd -> J/Psi (mu+ mu-) Ks (pi+ pi-)
 */

// 1. Execute the EffMcTruth algorithm
ApplicationMgr.TopAlg += { "MCEffBuilder/EffMcTruth" };
EffMcTruth.setRuntimeEnvironment = "Phys";
EffMcTruth.MCDecay =  "[B0 -> (KS0 -> ^pi+ ^pi-) (J/psi(1S) -> ^mu+ ^mu- {, gamma})]cc";
EffMcTruth.OutputLevel = 3;

// 2. Execute the EffSelCheck algorithm
ApplicationMgr.TopAlg += { "EffSelCheck/EffBd2JpsiKs" };
EffBd2JpsiKs.MCDecay = "[B0 -> (KS0 -> ^pi+ ^pi-) (J/psi(1S) -> ^mu+ ^mu- {, gamma})]cc";

// Flag to steer histogramming
// ---------------------------
EffBd2JpsiKs.Histograms = true;
```

Histogram limits are steered by the list of properties below (the preset values are given in parentheses). Central mass values for the sub-head masses and reasonable ranges for the decay length and proper time histograms are calculated automatically using the Particle Property Service.

```
%
  double m_massLim      ;   ///< ( 0.1) Half range of mass histo (GeV)
  double m_momLim       ;   ///< (500.) Full range of momentum histo (GeV)
  double m_ptLim        ;   ///< ( 25.) Full range of transv.mom. histo (GeV)
  double m_deczLim      ;   ///< (150.) Full range of decay point (z) histo (mm)
  double m_decrLim      ;   ///< (  2.) Full range of decay point (r) histo (mm)
  double m_primzLim     ;   ///< (150.) Full range of primary vtx (z) histo (mm)
  double m_primrLim     ;   ///< ( 0.5) Full range of primary vtx (r) histo (mm)
  double m_declLim      ;   ///< ( 25.) Full range of decay length histo (mm)
  double m_proptLim     ;   ///< ( 2.5) Full range of proper time histo (ps)

  double m_resmassLim   ;   ///< ( 0.1) Half range of mass resol histo (GeV)
  double m_resmomLim    ;   ///< ( 2.5) Half range of mom. resol histo (GeV)
  double m_resptLim     ;   ///< (0.25) Half range of transv.mom. resol histo (GeV)
  double m_resdeczLim   ;   ///< ( 2.5) Half range of dec.point (z) resol histo (mm)
  double m_resdecrLim   ;   ///< (0.25) Half range of dec.point (r) resol histo (mm)
  double m_resprimzLim  ;   ///< ( 0.5) Half range of prim.vtx (z) resol histo (mm)
  double m_resprimrLim  ;   ///< ( 0.1) Half range of prim.vtx (r) resol histo (mm)
  double m_resdeclLim   ;   ///< ( 2.5) Half range of dec.length resol histo (mm)
  double m_resproptLim  ;   ///< ( 0.1) Half range of proper time resol histo (ps)
%
```

3.3 Output: Efficiency tables

Tables of selection efficiency and purity are provided for each of the sub-decay heads (e.g., for J/ψ, K_s^0, and B_d^0). These tables are printed at the end of the DaVinci job log-file. See below, as an example, the tables which are provided in the case of 1000 $B_d^0 \to J/\psi K_s^0$ decays.

%

```
*************************************************************************************
EffMcTruth             INFO
*************************************************************************************
****************             Output from MCEffBuilder             *******************
*************************************************************************************

Decay analyzed (MC truth) [B0 -> (KS0 -> ^pi+ ^pi-) (J/psi(1S) -> ^mu+ ^mu- {, gamma})]cc
Events processed                                            1000
Decay Of Interest Generated              ( / Events )        933     0.933
DoIs Gen, Reconstructible (ALL)       ( / Generated )        156     0.167203
DoIs Gen, Reconstructed (ALL)         ( / Generated )        116     0.12433
---------------------------------------------
DoIs Gen, Rec'ble & Rec'ted (ALL)                            103
Rec. efficiency: (Rec'tible & Rec'ted)/Rec'tible (ALL):  0.660256 +- 0.0379201


*************************************************************************************
*******************           Output from EffSelCheck             *******************
*************************************************************************************

Decay analysed (truth) [B0 -> (KS0 -> ^pi+ ^pi-) (J/psi(1S) -> ^mu+ ^mu- {, gamma})]cc

*************************************************************************************
*******************       Summary of MC Truth information         *******************
*************************************************************************************
Events processed                                                1000
Decay Of Interest (DoI-s) found (truth)       ( / Events )      933       0.933
DoI-s Reconstructible (truth)              ( / DoI found )      156     0.167203
DoI-s Reconstructed (truth)      ( / DoI Reconstructible )      116     0.74359
*******************       Summary of Selection information        *******************
*************************************************************************************
*************************************************************************************

*************************************************************************************

*******************    Sub-tree head ... J/psi(1S)    *******************
Mass window for this sub-tree head ... 3.09687 +- 0.05 (GeV/c2)
*************************************************************************************
DoIs Selected                         ( / Reconstructed )       83     0.715517
DoIs Selected, in Mass Window                                   83     0.715517
-------------------------------------------------------------------------------------
DoIs Sel, Associated (Comp)                ( / Selected )       80     0.963855
DoIs Sel, Assoc (Comp), in Mass Window                          80     0.963855
-------------------------------------------------------------------------------------
DoIs Sel, Associated (Chi2)                ( / Selected )       82     0.987952
DoIs Sel, Assoc (Chi2), in Mass Window                          82     0.987952
-------------------------------------------------------------------------------------
DoIs Sel, Associated (Comp.OR.Chi2)        ( / Selected )       83     1
DoIs Sel, Assoc (Comp.OR.Chi2), in Mass Window                  83     1
-------------------------------------------------------------------------------------
DoIs Sel, Associated (Comp.AND.Chi2)       ( / Selected )       79     0.951807
DoIs Sel and Assoc (Comp.AND.Chi2), in Mass Window              79     0.951807
-------------------------------------------------------------------------------------
Efficiency: (Sel and Assoc(.OR.))/Reconstructed              0.715517 +- 0.0418899
Efficiency: (Sel and Assoc(.OR.) and Mass)/Reconstructed     0.715517 +- 0.0418899
Purity:    (Selected and Associated(.OR.))/Selected          1 +- 0
*************************************************************************************

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*******************    Sub-tree head ... KS0    *******************
Mass window for this sub-tree head ... 0.497672 +- 0.05 (GeV/c2)
*************************************************************************************
```

```
DoIs Selected                          ( / Reconstructed )      198     1.7069
DoIs Selected, in Mass Window                                   187     1.61207
-----------------------------------------------------------------------------------------
DoIs Sel, Associated (Comp)                 ( / Selected )       44     0.222222
DoIs Sel, Assoc (Comp), in Mass Window                           44     0.222222
-----------------------------------------------------------------------------------------
DoIs Sel, Associated (Chi2)                 ( / Selected )       41     0.207071
DoIs Sel, Assoc (Chi2), in Mass Window                           41     0.207071
-----------------------------------------------------------------------------------------
DoIs Sel, Associated (Comp.OR.Chi2)         ( / Selected )       44     0.222222
DoIs Sel, Assoc (Comp.OR.Chi2), in Mass Window                   44     0.222222
-----------------------------------------------------------------------------------------
DoIs Sel, Associated (Comp.AND.Chi2)        ( / Selected )       41     0.207071
DoIs Sel and Assoc (Comp.AND.Chi2), in Mass Window               41     0.207071
-----------------------------------------------------------------------------------------
Efficiency: (Sel and Assoc(.OR.))/Reconstructed              0.37931 +- 0.0450511
Efficiency: (Sel and Assoc(.OR.) and Mass)/Reconstructed     0.37931 +- 0.0450511
Purity:    (Selected and Associated(.OR.))/Selected          0.222222 +- 0.0295453
*****************************************************************************************

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*******************    Sub-tree head ... B0    *******************
Mass window for this sub-tree head ... 5.2794 +- 0.05 (GeV/c2)
*****************************************************************************************
DoIs Selected                          ( / Reconstructed )       59     0.508621
DoIs Selected, in Mass Window                                    58     0.5
-----------------------------------------------------------------------------------------
DoIs Sel, Associated (Comp)                 ( / Selected )       56     0.949153
DoIs Sel, Assoc (Comp), in Mass Window                           56     0.949153
-----------------------------------------------------------------------------------------
DoIs Sel, Associated (Chi2)                 ( / Selected )       55     0.932203
DoIs Sel, Assoc (Chi2), in Mass Window                           55     0.932203
-----------------------------------------------------------------------------------------
DoIs Sel, Associated (Comp.OR.Chi2)         ( / Selected )       58     0.983051
DoIs Sel, Assoc (Comp.OR.Chi2), in Mass Window                   58     0.983051
-----------------------------------------------------------------------------------------
DoIs Sel, Associated (Comp.AND.Chi2)        ( / Selected )       53     0.898305
DoIs Sel and Assoc (Comp.AND.Chi2), in Mass Window               53     0.898305
-----------------------------------------------------------------------------------------
Efficiency: (Sel and Assoc(.OR.))/Reconstructed              0.5 +- 0.0464238
Efficiency: (Sel and Assoc(.OR.) and Mass)/Reconstructed     0.5 +- 0.0464238
Purity:    (Selected and Associated(.OR.))/Selected          0.983051 +- 0.0168049

*****************************************************************************************
*******************           End Output from EffSelCheck            *******************
*****************************************************************************************
%
```

The efficiency of the selection algorithm is defined as the ratio of the number of "decays of interest" (sub-decay heads) which are found by the selection algorithm and successfully associated to the MC truth to the number of decays of interest which are "reconstructed" according to the MC truth. Both the "χ^2- and the "composite link"-associators are used (and their logical .OR. and .And. is also counted) but for a successful association it is sufficient that either of the two associations be successful.

A second efficiency is provided where one also requires that the selected decay of interest has its mass within predefined bounds. By default, this bound is preset to ± 0.05 GeV as indicated in the head of the table; it can be changed by the property m_massSig in the .opt file.

The purity is defined as the ratio of the number of selected and successfully associated decays of interest to the number of selected decays of interest.

3.4 Output: Monitor histograms

Monitor histograms are produced and stored in five directories of an hbook file (e.g., B02JpsiKs.hbook).

- The COUNTERS directory reproduces, in the form of histograms, some of the information contained in the efficiency tables.

  Hgr.No.80: MC truth information for the head of the decay (e.g., B_d^0)

  1: number of events processed

  2: of DoI-s found

  3: of DoI-s reconstructible

  4: of DoI-s reconstructed

  Hgr.No. 90, (91,92,...): for the different sub-tree heads

  5: number of DoI-s selected

  6: ... and within the mass-window

  11: number of DoI-s selected and associated (comp.part. associator)

  12: the number of DoI-s selected and associated (χ^2 associator)

  13: ... by either of the two associators

  14: ... by both associators

- The SELECTED directory contains histograms of distributions of physical quantities (mass, momentum, transverse momentum, primary vertex (z, r), decay vertex (z, r), decay length and proper time) for those decays of interest which are reconstructed (MC truth) and selected by the selection algorithm. The sets of histograms for the different sub-decay heads follow each other. (Caveat: for the moment, the "decay length" is taken as the distance of the decay to the primary vertex (so it is slightly wrong for the sub-tree heads) and this decay length is propagated to obtain the proper decay time.)

- The ASSOCIATED directory contains the same distributions, in the same order, for those decays of interest which are also associated (by the Chi^2 associator).

- The MCTRUTH directory contains the distributions of MC truth quantities, for the same selection of events as the ones in the ASSOCIATED directory.

- The RESOLUTIONS directory contains distributions of the differences between the physical quantities derived from the selection and from the MC truth. It includes the same DoI-s as the ones in the ASSOCIATED directory.

3.5 Output: to be written to the TES

For each event that is processed, a container `EffCheckResults` is written to the TES. It contains one entry ("class" `EffCheckResult`) for each DoI (sub-tree head) that has been recognised as reconstructed (MC truth) and selected by the selection algorithm. The class `EffCheckResult` contains the following elements.

- A reference to the selected sub-tree-head (from which the head of the tree can be obtained)
- The Decay descriptor of the selection
- A bool (yes/no) for the χ^2 association
- ... and a reference to the corresponding true sub-tree head
- ... and a reference to the corresponding true head of tree
- A bool (yes/no) for the composite link association
- ... and a reference to the corresponding true sub-tree head
- ... and a reference to the corresponding true head of tree

Comments and suggestions are welcome. For the algorithms MCEffBuilder and MCEffMonitor, send comments to Christian.Jacoby@cern.ch; comments concerning the algorithms EffSelCheck and EffSelCheckMonitor should be sent to Peter.Igo-Kemenes@cern.ch.