DØ Note XXXX

muo_cert package

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Abstract

A package that measures muon chamber and central tracking reconstruction and trigger efficiencies using $Z \to \mu^+\mu^-$ events.

Contents

1 Overview

The muo_cert package uses Z $\rightarrow \mu^+\mu^-$ events that have been selected using the wzreco package [1] to measure various offline and trigger efficiencies. For documentation on the methods of the classes used in the muo_cert package please see the documentation of the wzreco package [1].

The reasoning behind the selection criteria for Z $\rightarrow \mu^+\mu^-$ events and the methods used for measuring efficiencies are described in detail in [2] and in an abbreviated version in [3].

The muo_cert executable fills histograms and TTrees which are written to a root file named **muoeff.root**. Note that all the features described in this document are not guaranteed to be present in the previous versions of this package (eg: v02-03-01).

2 Explaining the code

2.1 Implementaiton of the "tag and probe" method

The MuoCert.cpp file accesses ZMuTrack and ZMuMuid (inherently ZMuObject) objects using the WZReco::get_ZMuTrack() and WZReco::get_ZMuMuid() methods. ZMuTrack objects are Z $\rightarrow \mu^+\mu^-$ candidates that are used to measure central track and Level-3 track trigger efficiencies. A pair of MuonParticle pointers is created, the first muon in the pair acts as a *control* or *tag* muon and the second as a *test* or *probe* muon which measures the efficiency. The *control* muon is identified in both the central tracker and the muon chambers and the *test* muon is identified purely either in the muon chambers or in the tracking system. A schematic view of this *tag* / *probe* method is shown in Figure 1.

If both muons satisfy the conditions for *control* and *test* muons then an event will have two ZMuTrack objects where the only difference between the two is the order of the muons. ZMuMuid objects are used to measure muon reconstruction and muon trigger efficiencies in a similar way. (In this case the *test* muon is identified by a high p_t track).

All ZMuTrack / ZMuMuid objects are looped around. If the ZMuObject member function **string passesAllBut()** returns "NONE" then this object has passed all cuts and is used for efficiency studies.

2.2 The efficiencies computed by muo_cert

A summary of all measured efficiencies and what they are measured as a function of as well as the name of the efficiency histograms is given in section 4.2.

Due to historical reasons, the Level-11 tracking efficiencies is available twice in the output. Once from ZMuMuTrack objects and a second time, as other trigger objects, from ZMuMuid objects. It is recommended to study Level-1 tracking from ZMuMuTrack objects.

In the same way, the Level-3 tracking efficiencies is available three times in the output. Once from ZMuMuTrack objects, once for ZMuMuCandidate objects and a last time, as other trigger objects, from ZMuMuid objects. It is recommended to study Level-3 tracking from ZMuMuTrack objects.

2.2.1 Tracking

The computation starts from ZMuTrack objects. For the tracking efficiency the quality of the track is controlled by rcps that are listed in Table 1. If any of these parameters are left as **-1**

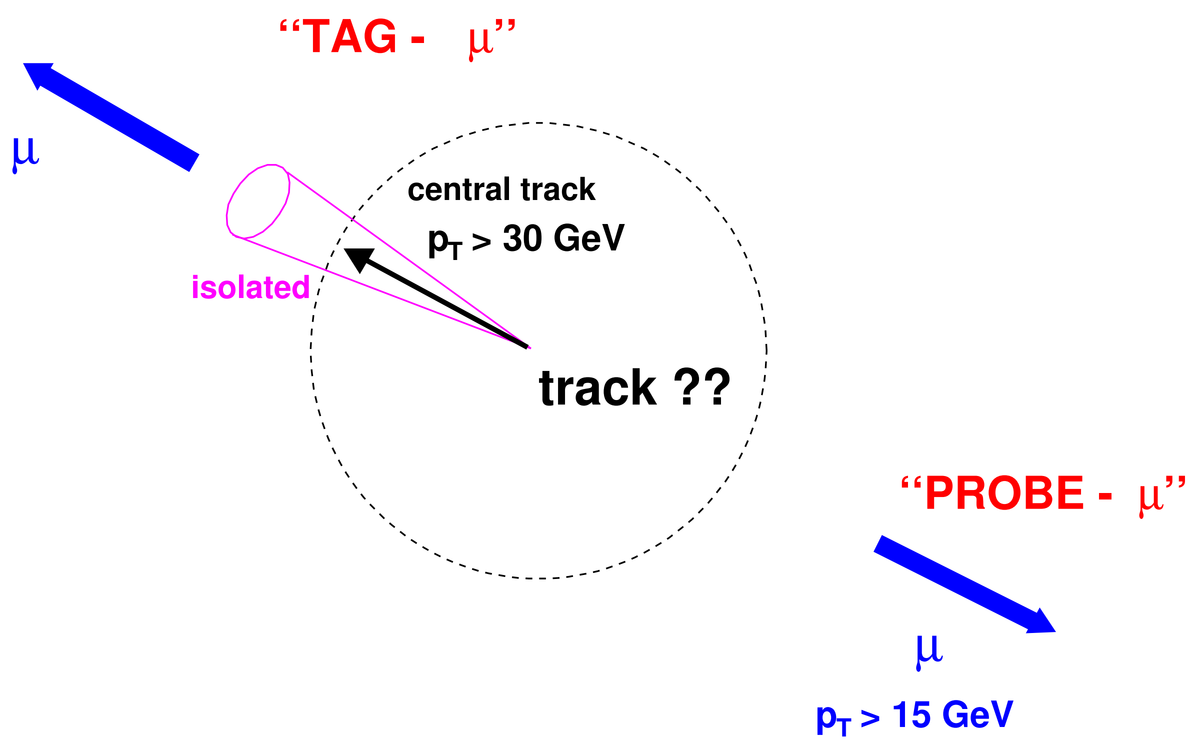

Figure 1: A schematic view of the *tag* and *probe* muon method used to measure the tracking efficiency. The *tag* is identified both in the muon chambers and the central tracker and the *probe* muon is identified in the muon chambers only. One has also to make sure that the event fired a muon-system trigger (without L1 or L3 tracking requirements).

(default) the condition will not be tested for.

In addition to these criteria, we defined three qualities of tracks: loose, medium, tight, based upon the RCP described in Table 2. Note that a track is loose, or medium or tight, if it first fulfills the criteria of Table 1.

Note: The tracking efficiency does not include the matching efficiency between the central track and the muon.

2.2.2 L3-tracking old way (still present in recent version)

The computation starts from ZMuMuCandidate objects. The Level-3 track trigger efficiency (Level 3 cut $p_t > 10$ GeV) is measured with respect to the track quality used in the tracking efficiency. In addition a furthur p_t cut can be made on the *test* track in question, this is controlled by the rcp **l3track_wrt_pt**. The p_t of the Level-3 object is controlled by the rcp **l3track_pt**.

2.2.3 L3-tracking new way (v04-00-00 and after)

The computation starts from ZMuTrack objects and is performed for several pt cut (5, 8, 10, 12, 15 GeV). The Level-3 track trigger efficiency can be measured with respect to tracking criteria (or absolut measurement can be done). Table 6 lists the rcps used for this purpose and their default values. A list of possible values to go in these vectors of strings is given in Table 3. In addition a furthur p_t cut can be made on the *test* test track, this is controlled by the rcp **l3track_wrt_pt**.

2.2.4 L1-tracking new way (v04-00-00 and after)

The computation starts from ZMuTrack objects and is performed for several pt cut (5, 10 GeV). The Level-3 track trigger efficiency can be measured with respect to tracking criteria (or absolut measurement can be done). Table 6 lists the rcps used for this purpose and their default values. A list of possible values to go in these vectors of strings is given in Table 3.

2.2.5 SMT hit efficiency

The computation starts from ZMuMuCandidate objects. The efficiency to pick at least one SMT hit is measured with respect to the track quality used in the tracking efficiency.

2.2.6 Muonid and triggers

The computation starts from ZMuMuid objects.

What the muon identification and trigger efficiencies are measured with respect to is controlled by rcps. For example if you want the Level-1 loose wire efficiency to be measured with respect to a medium offline muon that has fired the Level-1 tight scintillator trigger you would set **string l1wire_wrt = ("MEDIUM" "L1SCINT")**. A list of possible values to go in this vector of strings is given in Table 5. Table 7 lists the rcps used for this purpose and their default values.

Note: The muon id efficiency includes the matching efficiency between the central track and the muon.

2.2.7 Isolation

The isolation efficiency calculation is perfomed on ZMuMuCandidate after requiring the control muon to be isolated. The efficiencies for the two isolation criteria used in the wzreco package are measured in muo_cert. In addition, a user defined isolation criterion is built with the "user_iso" and "user_iso_cut RCPs". Its efficiency is measured relative to another isolation criterion defined by the "user_iso_wrt" and "user_iso_wrt_cut" RCPs.

```
Example: To measure the efficiency for Halo<2.5 && EtrkCone5<3.5
relative to the cut EInCone6<10, the RCPs will be:
  string user_iso = (  "HALO" , "TRKCONE5" )
  string user_iso_cut = (  2.5 , 3.5 )
  string user_iso_wrt = ( "CONE6")
  string user_iso_wrt_cut = (  10 )
```

2.3 The output

All of the histograms are written to a root file, *muoeff.root*. In order to calculate the efficiencies it is necessary to divide the "inefficient" histograms by the sum of the "inefficient" and "efficient" histograms. This is done in a root macro that is stored in the *macro* directory of the package.

The macro is called *muo_plot.C*, an example of how to run it is given in section 3. The output is another root file, *eff.root*, containing histograms of the efficiencies and a postscript file with almost all relevant plots.

3 How to use the muo_cert package

3.1 Running on p14 data (no more supported)

In order to use the muo_cert package you must first check out the wzreco ande muo_cert packages from CVS:

```
 setup D0RunII p16.07.00
 setup d0cvs
 cd <working_area
 newrel -t p14.06.00 EXAMPLE
 cd EXAMPLE
 addpkg wzreco v01-00-03
 addpkg muo_cert v02-03-01
 d0setwa
 setenv LINK_SHARED yes
 gmake all
 setup d0tools

###  to run on SAM
 rund0exe -exe=MuoCert_x -defname=SAM_DEF_NAME -nofpe -shlib \
-rcp=runMuoCertSAM.rcp -rcppkg=muo_cert -localbuild -localrcp -localfwkrcp  \
-userscript=wzreco/scripts/initWZReco.sh \
 -sourcescript=chunkanalyzesource.sh  -initscript=initchunkanalyze.sh

### to run on files on disk
 rund0exe -exe=MuoCert_x -filelist=FILE_LIST -nofpe -shlib \
-rcp=runMuoCert.rcp -rcppkg=muo_cert -localbuild -localrcp -localfwkrcp \
-userscript=wzreco/scripts/initWZReco.sh  \
-sourcescript=chunkanalyzesource.sh  -initscript=initchunkanalyze.sh
```

3.2 Running on p17 data

```
  setup D0RunII p18.03.00
  newrel -t p18.03.00 EXAMPLE
  cd my  EXAMPLE
  addpkg muo_cert v03-00-03
  addpkg wzreco v03-00-03
  setenv LINK_SHARED yes
  d0setwa
  gmake
  setup d0tools


###  to run on SAM
 rund0exe -exe=MuoCert_x -defname=SAM_DEF_NAME -nofpe -shlib \
-rcp=runMuoCertSAM.rcp -rcppkg=muo_cert -localbuild -localrcp -localfwkrcp  \
-userscript=wzreco/scripts/initWZReco.sh \
```

```
 -sourcescript=chunkanalyzesource.sh  -initscript=initchunkanalyze.sh

### to run on files on disk
 rund0exe -exe=MuoCert_x -filelist=FILE_LIST -nofpe -shlib \
-rcp=runMuoCert.rcp -rcppkg=muo_cert -localbuild -localrcp -localfwkrcp \
-userscript=wzreco/scripts/initWZReco.sh  \
-sourcescript=chunkanalyzesource.sh  -initscript=initchunkanalyze.sh
```

3.3 Analyzing the results

The output directory will contain a root file named *muoeff.root*. A macro *muo_plot.C* in the *muo_cert/macro* directory can be executed with the *muoeff.root* file as input in order to make plots of the efficiencies and divide the appropriate histograms:

```
root [0] .L muo_plot.C
root [1] draw(``muoeff.root'')
```

The output of this is both a postscript file, "eff.ps" and a root file with the efficiencies "eff.root". See section 4.2 for the naming conventions.

3.4 Splitting the job

Alternatively, it is possible to split the initial samples and run several jobs in parallel. This can be done on cab using sam and rund0exe or using the following example:

```
  split -l 4 FILE_LIST muo_cert_skim_

  foreach i ( muo_cert_skim_??)
  rund0exe -exe=MuoCert_x -shlib\
 -batch   -filelist=$i   -name=test_$i  \
 -localfwkrcp -localbuild  -nofpe  \
 -localrcp  -rcppkg=muo_cert -rcp=runMuoCert.rcp \
 -userscript=wzreco/scripts/initWZReco.sh  \
 -sourcescript=chunkanalyzesource.sh  -initscript=initchunkanalyze.sh
  rm $i
  end
```

Once all the results are there, a macro allows you to merge the different outputs into one single file. You should first, put the filenames of the different outputs into a txt file "root_files.txt", then run the muo_cert/macro/Merge.cpp. The resulting file, "merged_muocert.root", can be analyzed as previously:

```
  find . -name muoeff.root > root_files.txt
  root -l -b -q muo_cert/macro/Merge.cpp
  root
  root [0] .L muo_plot.C
  root [1] draw(``merged_muocert.root'')
```

3.5 Using TTrees

The TTree usage is described in the TTree section (4.2.2).

4 Efficiencies and RCPs

4.1 RCP switches

rcp	description	default value
int track_cft	number of CFT hits	-1
int track_smt	number of SMT hits	-1
float track_chi_smt	χ^2 for tracks with SMT hits	-1
float track_chi_nosmt	χ^2 for tracks with no SMT hits	-1
float track_dca_smt	dca wrt beamspot for tracks with SMT hits	-1
float track_dca_nosmt	dca wrt beamspot for tracks with no SMT hits	-1
float track_pt	minimum p_t of central track to be considered	-1
float l3track_pt	p_t of Level-3 track object	10
float l1track_run	first run with exploitable Level-1 tracking information	194600
float l3track_run	first run with exploitable Level-3 tracking information	170000
float l3muo_run	first run with exploitable Level-3 muon information	194600
float l3track_wrt_pt	track p_t that Level-3 ϵ is wrt	-1

Table 1: *rcps that control the quality of the tracks in the central tracking and Level-3 track trigger efficiencies.*

rcp	default value	description of vector
string track_quality_name	(TRACK_LOOSE TRACK_MEDIUM TRACK_TIGHT)	names for track quality types.
int track_quality_ncft_cut	(0 0 0)	minimum number of cft hits
int track_quality_nsmt_cut	(0 0 1)	minimum number of smt hits
float track_quality_dca_cut	(0.2 0.2 0.2)	dca cut
float track_quality_chisq_cut	(-1 4 4)	chisq/ndof cut
float track_quality_dca_smt_cut	(0.02 0.02 0.02)	dca cut if track has smt hit(s)
float track_quality_chisq_smt_cut	(-1 4 4)	chisq/ndof cut if has smt hit(s)

Table 2: *rcps that control the different track quality types. This rcps are vectors of parameters for the different types.*

condition name	description
TRACK	has a track associated to test muon
HIGHPT	has a hight p_t track associated to test muon
MATCHEDTRACK	has a track matched (muonid definition) to test muon
MATCHEDHIGHPT	has a high p_t track matched (muonid definition) to test muon
TRACK_LOOSE	has a track fulfilling loose quality criteria.
TRACK_MEDIUM	has a track fulfilling medium quality criteria.
TRACK_TIGHT	has a track fulfilling tight quality criteria.
L1TRK5	has a Level-1 $p_t > 5$ GeV track.
L1TRK10	has a Level-1 $p_t > 10$ GeV track.
L1ITRK10	has a Level-1 $p_t > 10$ GeV isolated track.
L3TRK5H10	has a Level-3 track with 10 axial hits $p_t > 5$ GeV track.
L3TRK8H10	has a Level-3 track with 10 axial hits $p_t > 8$ GeV track.
L3TRK10	has a Level-3 $p_t > 10$ GeV track.
L3ITRK12	has a Level-3 $p_t > 12$ GeV isolated track.

Table 3: *Conditions for the test muon in tracking to have passed.*

rcp	default value	description
string user_iso float user_iso_cut	("HALO" , "TRKCONE5") (2.5 , 2.5)	variables entering the isolation definition. cuts associated to previous line. The different conditions are 'and'ed
string user_iso_wrt float user_iso_wrt_cut	( ) ( )	isolation criteria with respect to which the efficiency is computed cuts associated to previous line. The different conditions are 'and'ed The different conditions are 'and'ed
float pt_cut_njet	6.	Pt threshold used when counting jets

Table 4: *rcps that control user defined isolation efficiency.*

condition name	description
MUON	Near to a muon. ($\Delta R < 0.5$)
MTC	Muon is calorimeter muon.
LOOSE	Muon is loose.
MEDIUM	Muon is medium.
TIGHT	Muon is tight.
P13LOOSE	Muon is p13 loose.
P13MEDIUM	Muon is p13 medium.
P13TIGHT	Muon us p13 tight.
NSEG3	Muon has $\|nseg\| = 3$.
NSEG2	Muon has $\|nseg\| = 2$.
NSEG1	Muon has $\|nseg\| = 1$.
COSMICVETO	Muon passes cosmic veto cut.
MATCHED	Muon is matched to the track (reco matching).
L1SCINT	Matched to a Level-1 tight scint obj.
L1SCINTWIDE	Matched to a wide Level-1 tight scint obj.
L1SCINTOBJ	Level-1 tight scint obj there.
L1WIRE	Matched to a Level-1 loose wire obj.
L1WIREWIDE	Matched to a wide Level-1 loose wire obj.
L1WIREOBJ	Level-1 loose wire obj there.
L2M0	Matched to a Level-2 medium muon.
L2M3	Matched to a Level-2 medium muon, $p_t > 3$ GeV.
L2M5	Matched to a Level-2 medium muon, $p_t > 5$ GeV.
L2OBJ	Level-2 medium muon there.
L1ATN0	Matched to a Level-1 tight scint muon in all region (old name: L1SCINT)
L1WTN0	Matched to a wide Level-1 tight scint muon (old name: L1SCINTWIDE)
L1ANL0	Matched to a Level-1 loose wire muon in all region (old name: L1WIRE)
L1WNL0	Matched to a wide Level-1 loose wire muon (old name: L1WIREWIDE)
L1WLN10	Matched to a wide Level-1 loose scintillator and $p_t > 10$ GeV muon
L1WNL10	Matched to a wide Level-1 loose wire and $p_t > 10$ GeV muon
L1WTN10	Matched to a wide Level-1 tight scintillator and $p_t > 10$ GeV muon
L1WNT0	Matched to a wide Level-1 tight wire muon
L1BTN0	Matched to a between Level-1 tight scintillator muon
L1BNT0	Matched to a between Level-1 tight wire muon
L1TRK10	Matched to a Level-1 $p_t > 10$ GeV track
L1ITRK10	Matched to a Level-1 $p_t > 10$ GeV isolated track
L3L0	Matched to a Level-3 loose muon
L3L3	Matched to a Level-3 $p_t > 3$ GeV loose muon
L3L4	Matched to a Level-3 $p_t > 4$ GeV loose muon
L3L5	Matched to a Level-3 $p_t > 5$ GeV loose muon
L3L6	Matched to a Level-3 $p_t > 6$ GeV loose muon
L3L10	Matched to a Level-3 $p_t > 10$ GeV loose muon
L3L15	Matched to a Level-3 $p_t > 15$ GeV loose muon
L3TRK5H10	Matched to a Level-3 $p_t > 5$ GeV track with 10 axial hits
L3TRK8H10	Matched to a Level-3 $p_t > 8$ GeV track with 10 axial hits
L3TRK10	Matched to a Level-3 $p_t > 10$ GeV track
L3TRK12	Matched to a Level-3 $p_t > 12$ GeV track
L3TRK12H10	Matched to a Level-3 $p_t > 12$ GeV track with 10 axial hits
L3CML12	Matched to a Central Matched muon (Loose match) $p_t > 12$ GeV
L3L12TRK12	Matched to a Level-3 $p_t > 12$ GeV loose muon and $p_t > 12$ GeV track

Table 5: *Conditions for the test track in muon id to have passed.*

rcp	default value
string track_l1trk5_wrt	(“TRACK_LOOSE”)
string track_l1trk10_wrt	(“TRACK_LOOSE”)
string track_l1itrk10_wrt	(“TRACK_LOOSE”)
string track_l3trk5_wrt	(“TRACK_LOOSE”)
string track_l3trk8_wrt	(“TRACK_LOOSE”)
string track_l3trk10_wrt	(“TRACK_LOOSE”)
string track_l3trk12_wrt	(“TRACK_LOOSE”)

Table 6: *rcps that control what track qualities the track trigger efficiencies are measured with respect to (ZMuTrack Objects).*

rcp	default value
string muonid_wrt	(“TRACK_MEDIUM”-)
string l1scint_wrt	(“LOOSE” “MATCHED”)
string l1wire_wrt	(“LOOSE” “MATCHED”)
string l2m0_wrt	(“LOOSE” “MATCHED”)
string l2m3_wrt	(“LOOSE” “MATCHED”)
string l2m5_wrt	(“LOOSE” “MATCHED”)
string l3l0_wrt	(“LOOSE” “MATCHED”)
string l3l3_wrt	(“LOOSE” “MATCHED”)
string l3l4_wrt	(“LOOSE” “MATCHED”)
string l3l5_wrt	(“LOOSE” “MATCHED”)
string l3l6_wrt	(“LOOSE” “MATCHED”)
string l3l10_wrt	(“LOOSE” “MATCHED”)
string l3l5_wrt	(“LOOSE” “MATCHED”)
string l3l12trk12_wrt	(“LOOSE” “MATCHED”)
string l1trk5_wrt	(“TRACK_LOOSE”)
string l1trk10_wrt	(“TRACK_LOOSE”)
string l1itrk10_wrt	(“TRACK_LOOSE”)
string l3trk5_wrt	(“TRACK_LOOSE”)
string l3trk8_wrt	(“TRACK_LOOSE”)
string l3trk10_wrt	(“TRACK_LOOSE”)
string l3trk12_wrt	(“TRACK_LOOSE”)

Table 7: *rcps that control what muon id and trigger efficiencies are measured with respect to (ZMuMuId Objects).*

4.2 Available efficiencies and naming conventions

4.2.1 Histograms

One of the outputs of muo_cert consists of efficiency histograms. The content of an histograms is given by its name, **eff_VAR_TYPE**:
-**VAR** is the variables as a function of which the efficiency has been computed. The possibilities are quoted in Table 8.
-**TYPE** is the type of efficiencies (tracking, trigger,...) The possibilities are quoted in Table 9.
Example of Names: eff_eta_muid_loose, eff_z_track, eff_eta_phi_l1wire_all.

Name of variables	description
eta	physics η for tracking and L3 tracking and SMT hit efficiencies detector η for muonid and trigger efficiency
cft_eta	cft detector eta for tracking efficiency
phi	ϕ of muon
z	z of control muon for tracking efficiency z of test muon otherwise
pt	p_t measured in local system for tracking efficiency p_t measured in centrak tracker for tracking efficiency
tick	tick number
lumi	instantenous luminosity per tick scaled by 36 (10^{30}cm^{-2}s^{-1})
run	run number
int	number of reconstructed primary vertices
eta_phi eta_pt eta_z	two dimension eta vs phi efficiency (see eta and phi row) two dimension eta vs pt efficiency two dimension eta vs z efficiency

Table 8: *Naming convention for the histograms: variable names*

Name of type	description
track	tracking efficiency
track_loose	loose tracking efficiency
track_medium	medium tracking efficiency
track_tight	tight tracking efficiency
track_bin_i	tracking efficiency in i^{th} bin of z
smt	smt hit efficiency
l3	Level-3 tracking efficiency (p_t cut control by RCP) (from ZMuMuCandidates)
trkcone5	isolation with track (cut defined in wzreco rcp)
halo	isolation with halo efficiency (cut defined in wzreco rcp)
iso_user	user defined isolation (defined in muo_cert rcp)
muid_loose	offline loose muon efficiency
muid_medium	offline medium muon efficiency
muid_mediumnseg3	offline medium with nseg=3 muon efficiency
muid_tight	offline tight muon efficiency
l1scint_all	Level-1 tight scintillator "all region"
l1scint_wide	Level-1 tight scintillator "wide region"
l1wire_all	Level-1 loose wire "all region"
l1wire_wide	Level-1 loose wire "wide region"
l2m0	Level-2 medium muon efficiency
l2m3	Level-2 medium muon efficiency $p_t > 3$ GeV
l2m5	Level-2 medium muon efficiency $p_t > 5$ GeV
l1atn0	Level-1 all region tight scintillator (equivalent to l1scint_all)
l1wtn0	Level-1 wide region tight scintillator (equivalent to l1scint_wide)
l1anl0	Level-1 all region loose wire (equivalent to l1wire_all)
l1wnl0	Level-1 wide region loose wire (equivalent to l1wire_wide)
l1wln10	Level-1 wide region loose scint and TTK10
l1wnl10	Level-1 wide region loose wire and TTK10
l1wtn10	Level-1 wide region tight scint and TTK10
l1wnt0	Level-1 wide region tight wire
l1btn0	Level-1 forward region tight scint
l3l0	Level-3 loose muon efficiency
l3l4	Level-3 loose muon with $p_t > 4$ GeV
l3l3	Level-3 loose muon with $p_t > 3$ GeV
l3l5	Level-3 loose muon with $p_t > 5$ GeV
l3l6	Level-3 loose muon with $p_t > 6$ GeV
l3l10	Level-3 loose muon with $p_t > 10$ GeV
l3l15	Level-3 loose muon with $p_t > 15$ GeV
l3l12trk12	Level-3 track and muon with $p_t > 12$ Gev

Table 9: *Naming convention for the histograms: type names*

Name of type	description
l1trk10	Level-1 tracking (TTK10) efficiency (for expert)
l1itrk10	Level-1 isolated tracking (TIS10) efficiency (for expert)
l3trk5	Level-3 tracking with $p_t > 5$ GeV (for expert)
l3trk8	Level-3 tracking with $p_t > 8$ GeV (for expert)
l3trk10	Level-3 tracking with $p_t > 10$ GeV (for expert)
l3trk12	Level-3 tracking with $p_t > 12$ GeV (for expert)

Table 10: *Naming convention for the histograms: type names for track triggers computed from ZmumuMuid objects (probe is a track).*

Name of type	description
track_l1trk5	Level-1 tracking (TTK5) efficiency
track_l1trk10	Level-1 tracking (TTK10) efficiency
track_l1itrk10	Level-1 isolated tracking (TIS10) efficiency
track_l3trk5	Level-3 tracking with $p_t > 5$ GeV
track_l3trk8	Level-3 tracking with $p_t > 8$ GeV
track_l3trk10	Level-3 tracking with $p_t > 10$ GeV
track_l3trk12	Level-3 tracking with $p_t > 12$ GeV

Table 11: *Naming convention for the histograms: type names for track triggers computed from ZmumuTrack objects (probe is muon).*

4.2.2 TTrees

One of the muo_cert output consists of root TTrees from which it is possible to recompute the previous histograms and to study correlations and dependencies. There are five TTrees called: **track_tree**, **l3_tree**, **smt_tree**, **iso_tree** and **muid_tree**. Each entry in these TTrees corresponds to a "tag and probe" di-muon, the values of boolean variables say if the di-muon pass the tag and probe cuts and if the probe pass the tested requirements. The contents of these trees are described in Tables 12, 14, 13, 15 and 16.

variable name	description
run	run number
trigvers	trigger list version number
event	event number
tick	tick number
lumi	instantenous luminosity per tick scaled by 36 ($10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$)
nvert	number of reconstructed vertices
mass	di-muon invariant mass
phi	ϕ of test muon
eta	physics η of test
cft_eta	cft detector η of test
pt	p_t of control muon
z	z of control muon
cft	number of cft hit of attached track
track	usable for tracking efficiency study
track_yes	test has a track (=boolean efficiency)
track_loose	test has a loose track(=boolean efficiency)
track_medium	test has a medium track(=boolean efficiency)
track_tight	test has a tight track(=boolean efficiency)
smt	number of smt hit if there is an attached track
chisq	chi square of track fit if there is an attached track
dca	dca wrt beam position if there is an attached track
phi_track	phi of track if there is an attached track
l1trk10/l1trk10_yes	usable for l1trk10 efficiency calculation/matched to l1trk10 object
l1itrk10/l1itrk10_yes	usable for l1itrk10 efficiency calculation/matched to l1itrk10 object
l3trk5/l3trk5_yes	usable for l3trk5 efficiency calculation/matched to l3trk5 object
l3trk8/l3trk8_yes	usable for l3trk8 efficiency calculation/matched to l3trk8 object
l3trk10/l3trk10_yes	usable for l3trk10 efficiency calculation/matched to l3trk10 object
l3trk12/l3trk12_yes	usable for l3trk12 efficiency calculation/matched to l3trk12 object

Table 12: *Variables in the TTree "track_tree".*

variable name	description
run	run number
trigvers	trigger list version number
event	event number
tick	tick number
lumi	instantenous luminosity per tick scaled by 36 (10^{30}cm^{-2}s^{-1})
nvert	number of reconstructed vertices
mass	di-muon invariant mass
phi	ϕ of test muon
eta	physics η of test
cft_eta	cft detector η of test
pt	p_t of test muon
z	z of test muon
track	usable for smt hit efficiency
track_yes	test has smt hit (=boolean efficiency)

Table 13: *Variables in the TTree "smt_tree".*

variable name	description
run	run number
trigvers	trigger list version number
event	event number
tick	tick number
lumi	instantenous luminosity per tick scaled by 36 (10^{30}cm^{-2}s^{-1})
nvert	number of reconstructed vertices
mass	di-muon invariant mass
phi	ϕ of test muon
eta	physics η of test
cft_eta	cft detector η of test
pt	p_t of test muon
z	z of test muon
track	usable for L3 trk10 efficiency
track_yes	test has Level-3 track (=boolean efficiency)

Table 14: *Variables in the TTree "l3_tree".*

variable name	description
run	run number
trigvers	trigger list version number
event	event number
tick	tick number
lumi	instantenous luminosity per tick scaled by 36 ($10^{30}\mathrm{cm}^{-2}\mathrm{s}^{-1}$)
nvert	number of reconstructed vertices
mass	di-muon invariant mass
phi	ϕ of test muon
eta	physics η of test
cft_eta	cft detector η of test
pt	p_t of test muon
z	z of test muon
trkcone5	Sum of pT of tracks in cone of 0.5 around muon
halo	Hollow cone (0.1,0.4) transverse energy in calorimeter
cone6	calorimter energy in cone of 0.6 around muon
halo_yes	pass the halo cut (defined in wzreco rcp)
trkcone5_yes	pass the trkcone5 cut (defined in wzreco rcp)
user_iso_yes	pass the user defined (muo_cert rcp) isolation criterion
user_iso_wrt_yes	pass the user defined (muo_cert rcp) isolation wrt criterion

Table 15: *Variables in the TTree "iso_tree".*

variable name	description
run	run number
trigvers	trigger list version number
event	event number
tick	tick number
lumi	instantenous luminosity per tick scaled by 36 (10^{30}cm^{-2}s^{-1})
nvert	number of reconstructed vertices
mass	di-muon invariant mass
phi	ϕ of test muon
deteta	extrapolated eta detector of the test track
pt	p_t of test track
z	z of test track
nseg	nseg of test muon
muonid	muon usable for muonid efficiency
loose	track matched to loose muon
medium	track matched to medium muon
mediumnseg3	track matched to medium nseg3 muon
tight	track matched to tight muon
l1scint	track usable for l1 tight scintilator efficiency
l1scint_wide/l1scint_all	track matched to l1 tight scintillator object in wide/all region
l1wire	track usable for l1 loose wire efficiency
l1scint_wide/l1scint_all	track matched to l1 loose wire object in wide/all region
l1atn0/l1atn0_yes	usable for l1atn0 efficiency calculation/matched to l1atn0 object
l1wtn0/l1wtn0_yes	usable for l1wtn0 efficiency calculation/matched to l1wtn0 object
l1anl0/l1anl0_yes	usable for l1anl0 efficiency calculation/matched to l1anl0 object
l1wnl0 /l1wnl0 _yes	usable for l1wnl0 efficiency calculation/matched to l1wnl0 object
l1wln10 /l1wln10 _yes	usable for l1wln10 efficiency calculation/matched to l1wln10 object
l1wnl10/l1wnl10_yes	usable for l1wnl10 efficiency calculation/matched to l1wnl10 object
l1wtn10/l1wtn10_yes	usable for l1wtn10 efficiency calculation/matched to l1wtn10 object
l1wnt0 /l1wnt0 _yes	usable for l1wnt0 efficiency calculation/matched to l1wnt0 object
l1btn0 /l1btn0 _yes	usable for l1btn0 efficiency calculation/matched to l1btn0 object
l1bnt0/l1bnt0_yes	usable for l1bnt0 efficiency calculation/matched to l1bnt0 object
l2m0/l2m0_yes	usable for l2m0 efficiency calculation/matched to l2m0 object
l2m3/l2m3_yes	usable for l2m3 efficiency calculation/matched to l2m3 object
l2m5/l2m5_yes	usable for l2m5 efficiency calculation/matched to l2m5 object
l3l0/l3l0_yes	usable for l3l0 efficiency calculation/matched to l3l0 object
l3l4/l3l4_yes	usable for l3l4 efficiency calculation/matched to l3l4 object
l3l6/l3l6_yes	usable for l3l6 efficiency calculation/matched to l3l6 object
l3l10/l3l10_yes	usable for l3l10 efficiency calculation/matched to l3l10 object
l3l15/l3l15_yes	usable for l3l15 efficiency calculation/matched to l3l15 object
l3l12trk12	boolean: track usable for l3l12trk12 efficiency calculation
l3l12trk12_yes	boolean: track matched to l3l12trk12 object
l3trk5/l3trk5_yes	usable for l3trk5 efficiency calculation/matched to l3trk5 object
l3trk8/l3trk8_yes	usable for l3trk8 efficiency calculation/matched to l3trk8 object
l3trk10/l3trk10_yes	usable for l3trk10 efficiency calculation/matched to l3trk10 object
l3trk12/l3trk12_yes	usable for l3trk12 efficiency calculation/matched to l3trk12 object
l1trk10/l1trk10_yes	usable for l1trk10 efficiency calculation/matched to l1trk10 object
l1itrk10/l1itrk10_yes	usable for l1itrk10 efficiency calculation/matched to l1itrk10 object

Table 16: *Variables in the TTree "muid_tree". The Naming conventions are described in Table 9.*

4.3 Using TTrees

It is easy to understand how to use the TTrees by the mean of some examples:

```
First example: ploting tracking efficiency vs cft_eta for tracks with z>10cm
> root merged_muocert.root
root[0]  TH1F * h0 = new TH1F ("h0","cft_eta_efficiency",60,-3,3 )
root[1]  TH1F * h1 = new TH1F ("h1","cft_eta_efficiency",60,-3,3 )
root[2]  h0->Sumw2();h1->Sumw2();
root[3]  track_tree->Project("h0","cft_eta","z>10")
root[4]  track_tree->Project("h1","cft_eta","yes&&z>10")
root[5]  h1->Divide(h1,h0,1,1,"B")
root[6]  h1->Draw()

Second example: Getting the same results in one line, using profile histograms:
> root merged_muocert.root
root[0] track_tree->Draw("yes:cft_eta>>cft_effi(60,-3,3)","z>10","prof")

Third example: The SMT hit efficiency as a function of eta and z
> root merged_muocert.root
root[0] gStyle->SetPalette(1)
root[1] smt_tree->Draw("yes:cft_eta:z>>h(100,-100,100,60,-3,3)","","profcolz")

Fourth example: user defined isolation efficiency as a function of the
number of vertices:
> root merged_muocert.root
root[0] iso_tree->Draw("user_iso_yes:nvert>>h(10,0,10)","user_iso_wrt_yes","prof")

Fifth example: calorimeter Halo combined with luminosity as a function
of luminosity:
> root merged_muocert.root
root[0] iso_tree->Draw("(halo-0.01*lumi<2.5):lumi>>h(30,0,120)","","prof")

Sixth example: medium efficiency as a function of detetor eta
> root merged_muocert.root
root[0] muid_tree->Draw("medium:deteta","muonid","prof")

Seventh example: Level 1 scintillator efficiency in wide region as a function
of luminosity for run prior v13 triggerlist:
 muid_tree->Draw("l1scint_wide:lumi","l1scint&&abs(deteta)<1.5&&run<195000","prof")
// or alternatively
 muid_tree->Draw("l1wtn0_yes:lumi","l1wtn0&& run<195000","profsame")
```

References

[1] http://www-d0.fnal.gov/d0dist/dist/releases/development/wzreco/

[2] Emily Nurse and Paul Telford, DØ Note 4231, 'Measurement of σ.Br for Z $\rightarrow \mu^+\mu^-$ in p$\bar{\text{p}}$ collisions at $\sqrt{s} = 1.96$ TeV'.

[3] Emily Nurse and Paul Telford, DØ Note 4284, 'Measurement of σ.Br for Z $\rightarrow \mu^+\mu^-$ in p$\bar{\text{p}}$ collisions at $\sqrt{s} = 1.96$ TeV (abbreviated version)'.