# Table of Contents

**Gaudi Python FAQ**

- Introduction ................................................................................................................. 1
- Getting Started ............................................................................................................... 1
- FAQs ............................................................................................................................... 1
  - How to get access and instantiate an LHCb Event class ............................................ 1
  - How to access common classes (e.g. STL containers, ROOT::Math classes etc.) ............. 1
  - How to run the new MC associators ........................................................................... 2
  - How to access DoxyGen documentation for C++ class/instances? ............................... 2
  - How to run using a job options file several iterations ................................................ 2
  - How to access Linker tables ..................................................................................... 2
  - How to do a vertex fit .............................................................................................. 3
  - How to deal with Gaudi/AIDA histograms in GaudiPython? ...................................... 3
  - How to deal with Gaudi N-tuples in GaudiPython? .................................................... 5
  - How to access Relation tables in (Gaudi)Python? ..................................................... 5
  - How to access LHCb::Track -> MC truth Relation tables in (Gaudi)Python? ............... 8
Introduction

Welcome to the Gaudi Python FAQ page. If you have questions (and answers) please add them to the page. The goal of this page is to create documentation for the Gaudi Python package.

Getting Started

Have a look at the following tutorials:

- Introduction to GaudiPython (Ulrich Kerzel, 35th software week, 9th December 2008)
- Seeing a DST as a Big Ntuple (Thomas Ruf)
- Package Tutorial/GaudiPythonTutor (Juan Palacios). This contains exercises and example solutions geared at simple analysis on LHCb DSTs and MicroDSTs

FAQs

How to get access and instantiate an LHCb Event class

The LHCb Event classes now live in the namespace "LHCb". In order to get access you have to use this namespace. GaudiPython.Bindings.gbl represents the C++ global namespace (::) You can abbreviate the namespace with assignments:

```python
from GaudiPython.Bindings import gbl
std  = gbl.std
LHCb = gbl.LHCb
```

Then you can create your own instances of LHCb event model types:

```python
myMCParticle = LHCb.MCParticle()
myRecVertex  = LHCb.RecVertex()
```

How to access common classes (e.g. STL containers, ROOT::Math classes etc.)

We get access to the global namespace and create shortcuts as explained above. Then we can instantiate some STL types

```python
from GaudiPython.Bindings import gbl
std  = gbl.std
myvector = std.vector('double')()
particleVector = std.vector('const LHCb::Particle *')(50, 0)
```

Root::Math Generic Vector and Transformation classes, as well as LHCb-specific geometry classes and functions are available in the LHCbMath module:

```python
import LHCbMath
vXYZ = LHCbMath.XYZVector(0.,1.,45)
p = print(vXYZ.x(), " ", vXYZ.y(), " ", vXYZ.z())
```
How to run the new MC associators

From DaVinci v23r0 onwards, new MC association is available. This is implemented in terms of simple tool interfaces that lend themselves very well to interactive use in Python. GaudiPython examples are here.

How to access DoxyGen documentation for C++ class/instances?

Starting from LHCb v22r9 it is very easy to get an easy access to the DoxyGen documentation pages for the certain classes, types, objects and instances:

1800>>> import LoKiCore.doxygenurl as doxy
1810>>> o = ...  # arbitrary object
1820>>> doxy.browse ( o )  ## ask DoxyGen for the objects
1830>>> doxy.browse ( "LHCb::MCVertex" )  ## ask doxyGen for the class by name
1840

The idea from Thomas Ruf has been used.

How to run using a job options file several iterations

This is a minimalistic example on how to run a gaudi job (DaVinci in this case) for a number of events several times. In between the runs the user can access any information or change the algorithms or their properties.

from GaudiPython import AppMgr
gaudi = AppMgr( outputlevel = 3, 
               joboptions  = '$DAVINCIROOT/options/DVDC06MCParticleMaker.opts')
gaudi.initialize()
gaudi.run(10)
#---You can change the algorimths or other parameters here
gaudi.evtsel().rewind()
gaudi.run(10)

How to access Linker tables

The LHCb linker tables can be accessed in Python via the eventassoc.py module in Event/LinkerInstances.

First, do not forget to add in the requirements file the line

use LinkerInstances v* Event

Then the usage is standard. For the sake of example, let's assume that the variable track contains a VELO Track you are interested in, from the 'Rec/Track/Velo' container. A simple manipulation is:

>>> from eventassoc import linkedTo
>>> location = 'Rec/Track/Velo'
>>> Track = gbl.LHCb.Track
>>> MCParticle = LHCb.MCParticle
>>> LT = linkedTo(MCParticle,Track,location)
>>> LT.notFound() == False
True
>>> range = LT.range(track)
>>> range
<ROOT.vector<LHCb::MCParticle*> object at 0xfe27e90>
>>> range.size()
How to do a vertex fit

First get the vertex fitter tool:

```python
appMgr = gaudimodule.AppMgr(outputlevel=3)
OfflineVertexFitter = appMgr.toolsvc().create('OfflineVertexFitter', interface='IVertexFit')
```

Then create the mother particle and vertex along the lines of

```python
pidMother = gaudimodule.gbl.LHCb.ParticleID(pidOfMother)
MotherVertex = gaudimodule.gbl.LHCb.Vertex()
MotherCand = gaudimodule.gbl.LHCb.Particle(pidMother)
```

Put the daughters which you want to fit into a vector of LHCb::Particle*:

```python
particleVector = gaudimodule.gbl.std.vector('LHCb::Particle *')
daughterVect = particleVector()
daughterVect.push_back(dau1)
daughterVect.push_back(dauN)
```

Finally, perform the vertex fit:

```python
sc = OfflineVertexFitter.fit(daughterVect, MotherCand, MotherVertex)
```

How to deal with Gaudi/AIDA histograms in GaudiPython?

There are three major ways of dealing with Gaudi/AIDA histograms in GaudiPython:

- Direct manipulation with histogram service
- Usage of functionality offered by HistoUtils module
- Access to "the nice" histogramming through the base-class inheritance (OO-spirit)

Direct manipulation with the histogram service allows to book and fill histogram from the simple (Gaudi)Python scripts in a relatively intuitive way:

```python
# get the service (assume that gaudi is the ApplMgr object):
svc = gaudi.histosvc()

# book the histogram
h1 = svc.book('some/path', 'id', 'title', 100, 0.0, 1.0)

# fill it (e.g. in a loop):
for i in range(0,100): h1.fill( math.sin( i ) )
```

The module HistoUtils (available from Gaudi v19r5) provides couple of functions, which simplified a bit the booking of histograms and profiles:

```python
from HistoUtils import book
```

How to access Linker tables
Also it provides "powerful fill" with implicit loop and selection:

```python
from HistoUtils import fill

# book the histogram
histo = ...

# fill it with single value:
fill ( histo, value )

# fill it with arbitrary sequence of objects, convertible to double:
fill ( histo, [1,2,3,4,5,6,7] )

# use the sequence and apply the function:
fill histogram with 1*1, 2*2, 3*3, 4*4
fill ( histo, [1,2,3,4,5] , lambda x : x*x )

# use the sequence and apply the function:
# for each track in sequence evaluate "pt()" and fill the histo
tracks = ...
fill ( histo, tracks, lambda t : t.pt() )

# use the sequence, apply the function, but filter out even values:
fill ( histo, [1,2,3,4,5,6,7] , lambda x : x*x , lambda y : 0==y%2 )

# use the sequence and apply the function:
# for each track in sequence evaluate "p()" and fill the histogram with track momentum,
# keeping only track with small transverse momentum:
tracks = ...
fill ( histo, tracks, lambda t : t.p() , lambda t : t.pt() < 1000 )
```

Also the module exports two functions which provides the access to the histogram by their location in Histogram Transient Store:

```python
import HistoUtils

# get as AIDA:
aida = HistoUtils.getAsAIDA ( path )

# get as native ROOT:
root = HistoUtils.getAsROOT( path )
```

HistoUtils are partly inspired by Tadashi Maeno' API from ATLAS' PyKernel.

OO-spirit is described in detail here and it allows to reuse the whole functionality of easy-and-friendly histograms, including booking-on-demand. Also it is a recommended way for prototyping, since the resulting code is very easy to be converted into C++ lines using almost "1->1" correspondence.
How to deal with Gaudi N-tuples in GaudiPython?

The direct manipulation (booking & filling of columns) with the native Gaudi N-tuples in Python seems to be a very difficult task. Up to now no good and easy disprove of this statement are known. Therefore one needs to find an alternative way. Three relatively easy options have been demonstrated:

1. A direct manipulation with ROOT \((T)\)-trees \& N-tuples
2. Use of "smart-and-easy" N-tuples via \texttt{TupleUtils} module (starting from Gaudi version v19r5\(\))
3. Access to "the nice" N-tuples through the base-class inheritance (OO-spirit)

Please consult ROOT manual for the first way, here we describe only the second way. The third way (OO-spirit) is described in detail here and it allows to reuse the whole functionality of easy-and-friendly N-tuples, including booking-on-demand. It is nice, simple, safe and it represents the recommended way for prototyping, since the resulting code is very easy to be converted into C++ lines using almost "1->1" correspondence.

The module \texttt{GaudiPython.TupleUtils} (appears in Gaudi v19r5\(\)) contains essentially one important function \texttt{nTuple}:

```python
import GaudiPython
import GaudiPython.TupleUtils as TupleUtils

nTuple = TupleUtils.nTuple

gaudi = GaudiPython.AppMgr()
gaudi.HistogramPersistency = 'ROOT'
ntSvc = GaudiPython.iService ('NTupleSvc')
ntSvc.Output = [ "MYLUN1 DATAFILE='TupleEx4_1.root' OPT='NEW'"
] 
gaudi.config()
gaudi.initialize()
# get N-tuple (book-on-demand)

t = nTuple ( '\the/path/to/the/directory' , ## path
 'MyNtupleID' , ## the literal ID of the tuple
 'It is the title for my N-tuple ' , ## title
 LUN = 'MYLUN1' ) ## logical unit

# fill it with data e.g. trivial scalar columns:
import math
for i in range ( 1 , 1000 ) :
    t.column ( 'i' , i ) # integer scalar
    t.column ( 'a' , math.sin(i) ) # float scalar
    t.column ( 'b' , math.cos(i) ) # one more float scalar
    t.write () # commit the row
```

It is important at the end of the job to release all implicitly acquired n-tuples:

```python
import TupleUtils
# get the list of "active" N-tuples:
print TupleUtils.activeTuples()
# release all "active" N-tuples:
TupleUtils.releaseTuples() 
```

How to access Relation tables in (Gaudi)Python?

There are many Relation tables flying around in Gaudi/LHCb software. They are used in many areas:

1. As representation of Monte Carlo truth links for Calorimeter objects
As the dynamic extension of reconstruction classes, e.g. $\chi^2$-matching of Calorimeter clusters with recontructed tracks

3. As the main representation of Monte Carlo links for (Proto)Particles for LoKi

The relation tables provides easy, intuitive and efficient way for relation between any objects in Gaudi. The python interface looks very similar to C++ interface. E.g. the following example shows how one can use the relation table of C++ type `Relation::RelationWeighted<LHCb::CaloCluster, LHCb::MCParticle, float>` for selection of Monte Carlo "merged" neutral pions.

```python
#!/usr/bin/env python2.4
# import everything from bender
from Bender.MainMC import *

# Simple examples of manipulations with relation tables
# @author Vanya BELYAEV ibelyaev@physics.syr.edu
# @date 2007-09-26

class MergedPi0(AlgoMC):
    ## simple class to plot dikaon mass peak 
    def __init__(self, name = 'MergedPi0'):
        return AlgoMC.__init__(self, name)

    def analyse(self):
        finder = self.mcFinder(" pi0->2gamma MC-finder")
        mcpi0 = finder.find("pi0 -> gamma gamma");
        if mcpi0.empty(): return self.Warning("No MC-pi0 is found (1)", SUCCESS)

        mccut = mc1 & mc2 & mc3
        mcpi = self.mcselect("mcpi", mcpi0, mccut)
        if mcpi.empty(): return self.Warning("No MC-pi0 are found (2)", SUCCESS)

        # get only pi0s, which satisfy the criteria:
        # 1) large Pt
        mc1 = MCPT > 500 * Gaudi.Units.MeV
        # 2) valid origin vertex
        mc2 = MCOVALID
        # 2) vertex near the primary vertex
        mc3 = abs ( MCVFASPF( MCVZ ) ) < 500 * Gaudi.Units.mm

        mcut = mc1 & mc2 & mc3
        mcpi = self.mcselect("mcpi", mcpi0, mcut)

        if mcpi.empty(): return self.Warning("No MC-pi0 are found (2)", SUCCESS)

        # get the relation table from TES
        table = self.get("Relations/Rec/Calo/Clusters")
        # invert the table(create the inverse table) for local usage
        iTable = cpp.Relations.RelationWeighted(LHCb.MCParticle, LHCb.CaloCluster, 'float')
        itable = iTable( table , 1 )

        # construct "Ecal-acceptance" cuts
        outer = ( abs(MCPY/MCPZ) < 3.00/12.5 ) & ( abs(MCPX/MCPZ) < 4.00/12.5 )
        inner = ( abs(MCPY/MCPZ) > 0.32/12.5 ) | ( abs(MCPX/MCPZ) > 0.32/12.5 )
        accept = outer & inner

        # loop over mcpi0:
        for pi0 in mcpi:
            # get daughter MC-photons
```

How to access Relation tables in (Gaudi)Python?
gamma1 = pi0.child(1)
if not gamma1 : continue
gamma2 = pi0.child(2)
if not gamma2 : continue

# both MC-photons in Ecal acceptance
if not accept ( gamma1 ) : continue
if not accept ( gamma2 ) : continue

pt   = MCPT ( pi0 ) / 1000
mnpt = min( MCPT ( gamma1 ) , MCPT ( gamma2 ) ) / 1000
self.plot (   pt , "ALL pi0->gamma gamma                    ", 0 ,  5 )
self.plot ( mnpt , "ALL pi0->gamma gamma : min pt of photon ", 0 ,  5 )
clus1 = itable.relations ( gamma1 )
clus2 = itable.relations ( gamma1 )

# each photon have some associated cluster(s) in ECAL
if clus1.empty() or clus2.empty() : continue
self.plot (   pt , "ECAL pi0->gamma gamma                    ", 0 ,  5 )
self.plot ( mnpt , "ECAL pi0->gamma gamma : min pt of photon ", 0 ,  5 )

# select only 1 or 2-cluster pi0s
clus0 = itable.relations ( pi0 )
if 1 != clus0.size() and 2 != clus0.size() : continue
self.plot (   pt , " 1||2 pi0->gamma gamma                    ", 0 ,  5 )
self.plot ( mnpt , " 1||2 pi0->gamma gamma : min pt of photon ", 0 ,  5 )

# select only true "2-cluster" pi0
if 2 == clus0.size() and 1 == clus1.size() and 1 == clus2.size() and clus1.front().to() != clus2.front().to() :
    self.plot (   pt , " 2 pi0->gamma gamma                    ", 0 ,  5 )
    self.plot ( mnpt , " 2 pi0->gamma gamma : min pt of photon ", 0 ,  5 )

# select only true "1-cluster" pi0
if 1 == clus0.size() and 1 == clus1.size() and 1 == clus2.size() and clus1.front().to() == clus2.front().to() :
    self.plot (   pt , " 1 pi0->gamma gamma                    ", 0 ,  5 )
    self.plot ( mnpt , " 1 pi0->gamma gamma : min pt of photon ", 0 ,  5 )

return SUCCESS

The example illustrate:

- retrieval the relation table from Transient Event Store (the line 01410)
- inversion of table (on-flight conversion to the C++ type
  Relations::RelationWeighted<LHCb::MCParticle,LHCb::CaloCluster,float> , see the lines
  01440-01450)
- selection of $\pi^0 \rightarrow \gamma\gamma$, which:
  - satisfy the decay pattern "pi0 -> gamma gamma" (the line 01220)
  - have an origin vertex within +/-50 centimeters in z-direction around the primary vertex (the
    line 01320)
  - each of the photon is in the geometrical acceptance of Ecal (the lines 01620-01630)
- Retrieve from the relation table the number of associated Ecal clusters for $\pi^0$ and each of the daughter
  photons (the lines 01710-01720&01810)
- makes the plots of the transverse momentum of the $\pi^0$ and the minimal pt of dauhter photons for each case.

In addition one can make an explicit loop e.g. through all associated clusters e.g. compare with lines
01800-01810 in the previous listing:

How to access Relation tables in (Gaudi)Python?
# select only 1 or 2-cluster pi0s
clus0 = itable.relations ( pi0 )

# make explicit loop over related clusters:
for link in clus0 :
    cluster = link.to()
    weight = link.weight()

It is worth to compare these lines with corresponding C++ example from Ex/LoKiExample package, see the file $LOKIEXAMPLEROOT/src/LoKi_MCMergedPi0s.cpp

How to access LHCb::Track -> MC truth Relation tables in (Gaudi)Python?

To access Relation tables for LHCb::Track->MC Truth in python one needs to activate "on-demand" conversion of Linker objects into Relation tables. it can be done just in one line:

# activate automatic "on-demand" conversion of LHcbTrack->MC Linker objects into Relation tables
import LoKiPhysMC.Track2MC_Configuration

# OPTIONALLY: decorate the relation tables, e.g. for easy iteration
import Relations.Rels

# OPTIONALLY: decorate MC-particles for "nice" methods
import LoKiMC.MC

As soon as it is done, the rest is trivial. e.g. exploiting "direct" relations ( LHCb::Track -> MC ):

# get the tracks for Transient Event Store
tracks = evt['Rec/Track/Best']
print ' #number of tracks: ', tracks.size()

# get the relation table from the Transient Event Store
relation_table = evt['Relations/Rec/Track/Default']
print ' Relation table, # of links', relation_table.relations().size()

# loop over the tracks
for track in tracks :
    mcps = relation_table.relations ( track )
    if mcps.empty() : continue
    print ' # of related MC-Particles ', mcps.size()

    mcp = mcps[0].to()
    weight = mcps[0].weight()
    print ' the first associated particle ', mcp.pname(), weight

The inverse relations ( MC -> LHCb::Track) are also trivial:

# get MC-particles for TES
mcparticles = evt['MC/Particles']
print ' #number of tracks: ', mcparticles.size()

# get the relation table from the Transient Event Store
relation_table = evt['Relations/Rec/Trac/Default']
print ' Relation table, # of links', table.relations().size()

# get 'inverse'-view for the relation table:
itable = table.inverse()

# loop over mc-particles
for mcp in mcparticles :
    trks = itable.relations ( mcp )
    print ' # of related tracks: ', trks.size()
    if trks.empty() : continue

    # get the first related track:
    track = trks[0].to()
    weight = trks[0].weight()
    print ' the first associated track ', track.key() , weight

The corresponding example in Bender is attached here

Note that very similar examle in C++ is provided here.

-- Vanya Belyaev - 06-May-2k+10
-- Vanya Belyaev - 30-Apr-2k+10
-- StefanRoiser - 13 Apr 2006
-- Vanya Belyaev - 25 Sep 2k+7
-- JuanPalacios - 27 Jun 2009