



Event Model and Relations

What is the event model

- Constraints and requirements, persistency
- Data access, containers

XML, GOD and dictionaries

- Building new classes
- Relations
 - With Linker

Event Model





What is an Event Model ?

Standard description of data classes

- C++ objects containing data
 - Basically only setters and getters

Allows persistency

- Objects can be written on storage, and read back by another program
- The way to convert them must be specified.
 - Streamers = piece of code to put the bytes of the objects one after the other (writing) or to reconstruct the object from a byte stream.
 - Old implementation with ROOT, abandoned in 2003
 - Automatic conversion with dictionaries
 - Standard POOL technology, implies that we have a dictionary for each object and collections of it.
- Imposes some constraints of what can be in an object



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Reference between objects are special

A simple C++ pointer can be written with POOL

- →This is new compared to old Gaudi persistency
- Works only if the pointed object is owned, and known only by the parent object.
- Gaudi has SmartRef objects to handle references between autonomous objects
 - It behaves like a pointer for normal usage.
 - But it makes a logical reference to the pointed object when written
 - This reference can be transformed back to a pointer when reading data.
 - In fact identifies an object by the container it belongs to, plus its position / key in the container
 - Example: MCVertex has a list of MCParticles, and MCParticle has a parent MCVertex...





Hand written creation of objects is discouraged

- We have a tool to generate the C++ header and the dictionary, starting from a formal description in XML: GOD. This is an acronym for Gaudi Object Description, and will be discussed later in this presentation
- This tool gives a standard layout of setters and getters, handles relations and builds all the ingredients needed for persistency.



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How do we use it ?

Event classes are in dedicated packages

- Usually under the Event hat, e.g. Event/CaloEvent.
- These are shared by most applications
 - They are in the high level "project" LHCb, used by the various applications Boole, Brunel, DaVinci, Panoramix.

These packages must be stable

- Change in the object implies difficulties to read back data produced with previous versions
 - In principle, POOL provides a way to handle this "schema evolution", but with strong restrictions, in practice only addition of new information will most probably work, but modification may work only in very limited cases

Objects must then be WELL DESIGNED.

• Reviews and discussions with experts are mandatory.



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Event classes must be identified by a classID

- This is how the system knows the type of the object
- These ID are allocated by Marco, see the Event Model web pages for a list of the known ones.
- Using a wrong ID can be annoying...

But "private" event classes are possible also

- If they are never written, the constraints are smaller
 - Schema evolution is limited to a complete recompilation of the relevant application
 - No need for a real ID
- But frequently this is to build a prototype for a future persistent object.
 - Follow the rules, and your object can be upgraded to an 'official' object whenever needed.



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Containers

Objects can exist as a single instance

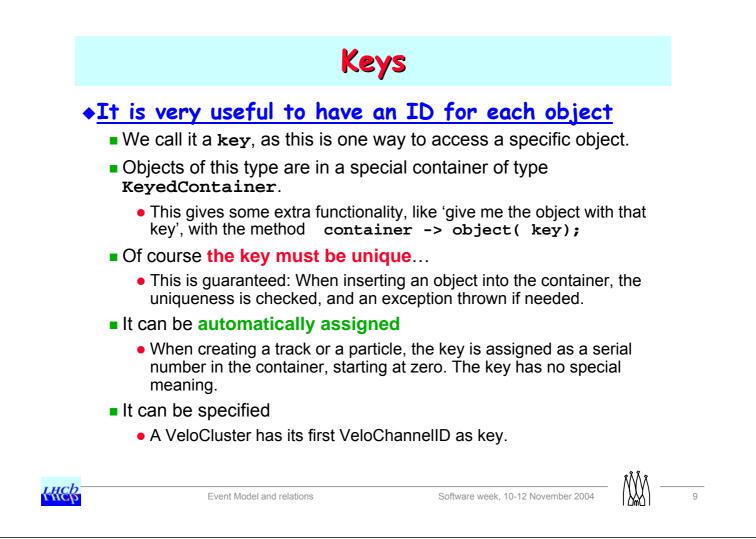
- Single copy per event, e.g. EventHeader
- It is then accessed on its own
 - The location to access it is specified in the event model
 - Usually this is something like EventHeaderLocation::Default
 - Other locations can be pre-defined, changing the name after ::

◆A more frequent use case is a collection of objects

- Digits, clusters, tracks, particles,...
- Objects are placed in a container, and can be accessed only via the container
 - In fact the object is created by new and the pointer to the object is in the container
 - This is just technical: The object belongs to the container. The container is the only access path to the object.







Access to data objects

Access is by the location on TES

- TES means "Transient Event Store"
- This is a piece of memory managed by the EventDataService, where objects are identified by their 'location'
 - Resemble a file system, with a tree structure.
- To get an object, one has to specify its type and its location
 - To retrieve either a simple data object, or a container
 - TrgTracks* myTr = get<TrgTracks>(TrgTrackLocation::Velo);
 - The argument is a string,
 - A good practice is to have a member variable there, initialized in the creator to a proper default, and with a property to change it by job option.
 - exist check if the object exists, sometimes useful as get throw an exception in case it doesn't exist...





Missing or Empty containers ?

- We make a strong difference between an empty container and a missing container
 - Empty = the algorithm in charge of creating the objects has run, but hasn't produced any object
 - Missing = the algorithm in charge has not run / has failed
 This is an abnormal condition, and the job should abort.

More complex access

- Gaudi has more basic ways, described in old documentation.
 - They are discouraged, you should use the 'get' and 'exist' methods of GaudiAlgorithm / GaudiTool from now on.
- If you see them in existing code, please report to the author of the code: Conversion to GaudiAlgorithm or GaudiTool was probably not yet done on this code !



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Storing an object is even simpler

put(object, location);

- object is a pointer to the object, created by new, which can be a container
- Iocation is a string, usually ObjectLocation::Default.
- An exception is thrown if an object with this name already exists.

Accessing keyed objects

- First retrieve the container
 - Note: When a keyed object 'Example' is defined, the event model specifies also the type of the container by putting the name plural
 - →Example → Examples is a typedef for KeyedContainer<Example>→Vertex → Vertices
- Then access the object in the container
 - Frequent use: iterate on the all objects in the container
 - But access by key is possible





```
To access all objects in a container
```

```
MyObjects* container = get<MyObjects>( m_location );
for ( MyObjects::const_iterator it = container->begin();
        container->end() != it; ++it ){
    MyObject* obj = *it;
    ... Work with obj ...
}
```

To access an object knowing its key

```
MyObjects* container = get<MyObjects>( m_location );
MyObject* obj = container->object( aKey );
```



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```

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Creating and populating a container is simple

```
MyObjects* container = new MyObjects(); // create
put( container, m_location ); // register in TES
for ( ... ) {
   ...
   MyObject* obj = new MyObject(); // create object
   ...
   container->insert( obj );
   container->insert( obj , key ); // to specify the key
}
```





Ownership

This is a delicate question

- In principle, the creator of an object should take care of its deletion, to avoid memory leak
 - Non deleted objects use memory, that can not be re-used !
- EXCEPT that objects on the TES are cleaned up at the end of the event by the store itself
 - Registering an object in the TES implies a transfer of ownership !

NEVER ever even think of ...

- Deleting a container in the TES
- Deleting an object in a container
- And even modifying an object in the TES.
 - You are not the owner ! Other algorithms may expect it...



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Data On Demand

New feature of Gaudi

- Some data is NOT on the TES, is not on the input file, but we know a method to produce the data if needed
 - Example: re-create clusters from the RawBuffer in DaVinci

Triggered by accessing a non-existent TES object

- If not in the TES, if not in the input file
- Ask the DataOnDemandSvc if he knows how to produce this named object
- If yes, the relevant algorithm is executed, and the created data is returned to the user
 - One cannot see if the data was read, or produced on the spot
- Of course the pair 'object name' + 'algorithm' must be specified to the service by job options.





Usage has started

- In DaVinci
 - For decoding Calo data only when needed.
- In Brunel
 - For decoding the RawBuffer

Will probably (soon) replace the algorithm specification in the Associator package

This was a 'manual' implementation of the same functionality

May become a default for accessing raw data

- Decoding from RawBuffer on demand.
- Avoids repeating the same raw data in two formats, a compact one (RawBuffer) and a verbose one (container of cluster objects).



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XML and GOD

"In GOD we trust"

Stefan Roiser, the father of GOD







XML

◆What is XML ?

- This is a language to describe 'objects'
- Based on elements to identify the entities
- Attributes can be attached to elements
- Elements have a name

Syntax (short version !)

- "<" and ">" are used to mark the structured part of the text
- Entities have a name. Two forms exist
 - <name attribute = "value" />
 - <name attribute = "value" > ...something... </name>
 - The first form allows to specify a few properties inside the entity
 - The second form allows defining complex entities, with a lot of structures inside, like other entities and so on.



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Inside an entity, one specifies attributes

- Syntax is simple
 - Key = "value"
- This means only text values.
- No separation between successive keys

```
name = "test" type = "int"
```

desc = "This is the test number"

- Line breaks are not relevant
 - Some people like to have one attribute per line, vertically aligned
 - The tools to edit xml files (XmlEditor or emacs menu) tend to put everything on the same line, even what was previously vertically aligned...

Indentation helps to see when an entity ends...

Automatic inside emacs.





Some characters are reserved

- < > & are used for the syntax of xml
- If you want to use then as character, you have to specify them by name:
 - > gives the character ">"
 - **<**; gives the character "<"
 - & gives the character "&"
 - " gives the character "
 - ' gives the character ""
- This is mainly used when putting C++ code fragments in XML
 - You can imagine that this becomes unreadable quite fast !
 Try to code
 - if (a && b) info() << " a = " << a << endreq;
- XML compiler diagnostics were poor on that, but this is now fixed in the recent versions.

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Comments have beginning and end tags

- <!-- is the begin tag</pre>
- --> is the end tag

A few magic incantations are needed

- At the beginning of the file, to specify the version of XML used and the name of the file defining the syntax of your XML
 - XML can be used (in LHCb) for detector description or for event object description, and clearly the entities and their possible attributes are different !
 - The appropriate dictionary is copied in your package when configuring it, provided you have the proper requirements file, see later
 - This is used by emacs/xmleditor to propose entities and attributes

The rest is quite simple

- When you get used to it, of course !
- Looking at existing files is a good idea...





GOD and XML

◆GOD means Gaudi Object Description

Gaudi product developed and maintained by Stefan Roiser

This is a "compiler"

- It converts the xml files to
 - C++ header files in the Event directory
 - C++ header and dictionary files in the dict dictionary
- The dictionary files are compiled, and can be used by POOL when writing and reading those objects
 - Also used when interacting with them with Python, or in Panoramix
- In fact the parsing is done by an open source product 'Xerces'
 - Uniform look and feel of all objects
 - Automatic generation of setters and getters
 - Standard format for Doxygen comments



An event model package has several features

- A requirements file with special content
 - Defines directories xml, Event, dict for special purposes
 - Declares GOD and what to do to generate header and dictionaries
 - emacs generates a good requirement file when creating the file in a package whose name contains the string Event.
- The source files are created in the xml directory
 - Plus possible implementation files in src, as usual.
 - Event classes should usually have only simple methods, automatically generated by GOD
 - Implementation files are rare, and discouraged.
 - One can have some short inlined code in the xml description.
 Careful with the reserved characters < > and &.

The Event directory is declared to be known to the compiler

• So that the header file can be included in other packages.



new



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The dictionary must be declared for containers

- For POOL, a KeyedContainer<plunk> has no relation to plunk, this is a completely independent object.
- A dictionary must be created not only for the object, but for containers thereof.
 - This is the reason for the magic incantation

&KeyedObject;

in the files describing objects inheriting from KeyedObject, that should be religiously copied when creating keyed objects.



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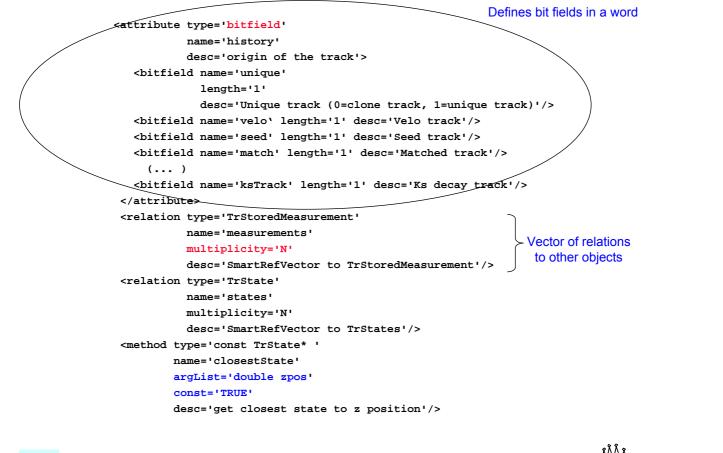


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Examples (TrStoredTrack)

```
<?xml version='1.0' encoding='UTF-8'?>
                                                   Magic incantations
<!DOCTYPE gdd SYSTEM 'gdd.dtd'>
<gdd>
 <package name='TrEvent'>
   <class name = 'TrStoredTrack'
           location = 'Rec/Tr/Best' Default location
           id = '10003'
           author = 'Jeroen van Tilburg'
           desc
                  = 'An TrStoredTrack is a track which can be made persistent'>
       <location name="Velo" place="Rec/Tr/Velo"/>
       <location name="Seed" place="Rec/Tr/Seed"/>
       <location name="Match" place="Rec/Tr/Match"/>
                                                                 Other locations
       <location name="Forward" place="Rec/Tr/Forward"/>
       <location name="Follow" place="Rec/Tr/Follow"/>
       <location name="VeloTT" place="Rec/Tr/VeloTT"/>
       <location name="KsTrack" place="Rec/Tr/KsTrack"/>
       <base name='KeyedObject&lt;int&gt;'/>
                                              Defines the base class, and the vectors/containers/...
       &KeyedObject;
       <attribute type='double'
                                           Standard data member. Generate set and get methods
                  name='charge'
                  desc='particle charge'/>
       <attribute type='int'
                  name='errorFlag'
                  desc='error flag'/>
```





```
LHCb
```

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```
<method type="double"

name="lastChiSq"

const="TRUE"

desc="Get the last chi^2 of the track fit."/>

<method virtual='TRUE'

type='bool'

name='isLong'

const='TRUE'

desc='Is the track a long track'>

</method>

</class>

</package>

</gdd>
Close the elements
```





Recent news from GOD

New version v7r0 of GaudiObjDesc

- In the Gaudi release pipe-line, for v16r0.
- Written in Python for easier management
 - Writing C++ from C++ is a pain !
- Fixes several requests from RICH and Tracking
- No change in the xml files nor in the resulting header files
 - Their functionality and generated names are identical
 - But better layout → better user readability.
 →Better alignment
- The number of lines of code in GaudiObjDesc has been reduced by a factor 5, allowing better management.

Thanks Stefan !



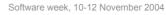
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Relations with Linker







What are Relations ?

This is a 'link' between two objects

- Tracks to MCParticles having produced them
- Tracks to Measurements used to build the track.

Some relations are structural

- Measurements are constituents of the track in some sense
- The relation exists inside the object.
 - They are indicated in xml by the <relation /> entity.
 - Methods are generated by GOD to populate, copy, retrieve the set of relations
 - The implementation is by **SmartRef** or **SmartRefVector** according to the multiplicity of the relation
 - →One to one, or one to many
- This is handled by the Event Model.



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Many relations are weaker

- Relation to MC truth is not available in real data.
 - Access to MC truth is not part of the structure of the event classes.
- One can specify something like "this object is related to that object"
 - And even qualify this relation with a weight.

Relations are independent objects

- This is implemented as a 'table'
 - Imagine an array with source, target and weight as rows...
- A tool is usually provided to use these relations
 - Named 'Associator'
- An algorithm is needed to create the relations
 - It runs usually when the source and target objects are all created
 - It can be complex, like the track associator to MCParticle





Original implementation by Vanya

- Set of highly templated classes, where source and target can be any object, and weight anything including an object.
 - Basically a vector of pairs of a source and a vector of pairs of a target and a weight.
- But the generation of dictionary (POOL requirement) for these classes requires some trick
 - Each possible relation has to be described.
 - Special package EventAssoc with one line of xml for each relation to store.

Speed is an issue

- When reading, as the relation table is sorted by the pointer to the objects, which are different upon reading.
 - Sorting is needed for fast access
 - Sorting each time an element is added is expensive
 - Sorting is not preserved when reading

 \rightarrow As the pointed objects are in different memory locations.



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"Linker" implementation

Basic idea: Solve the previous problems !

Of course there are limitations

Same table for all relations

- Represent objects by their container name and key
 - Works only with KeyedObject inserted in a container.
- But can also use a key independent of an object
 - Can link a channel ID to a MCParticle
 - The relation is valid for digits, clusters, or internal representation in the L1 and HIt packages
- Use the standard link table of any container to store the name of the containers to which there are relations
 - Source (and target) objects can be in several containers







◆<u>Reading is fast</u>

- There is no sorting at all.
- The table is just a collection of int and double.
 - Plus strings for the container names in the hidden features of a container.

Access is simplified

- There is no need for a tool with options
 - But Vanya's implementation can also be used this way, if we don't use the automatic invocation of the algorithm if the relation doesn't exist.
- A simple wrapper class do the job
 - This is created once per event, and answers with a simple syntax
- This relation can not be looked at as a STL container with iterators



How to use Linker relations ?

This is described in LHCb 2004-007

Creating a relation

SOURCE can be omitted if it the source inherits from KeyedObject<int> 'name' is a string, gives the location in the TES of the relation. One can use the same name as a container, as the name is prefixed with /link

```
myLink.link( source, target, weight = 1. );
```

That's it...





Using a relation is as simple



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The reverse relation can be retrieved also

LinkedFrom instead of LinkedTo

This is in use since DC'04

- Needed to store the truth relations for L1 and HLT
 - Velo, IT and OT clusters by key.
- Also available for TrStoredTracks
 - Copy of the standard relations.





