Analysis with AIDA and Anaphe

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Outline

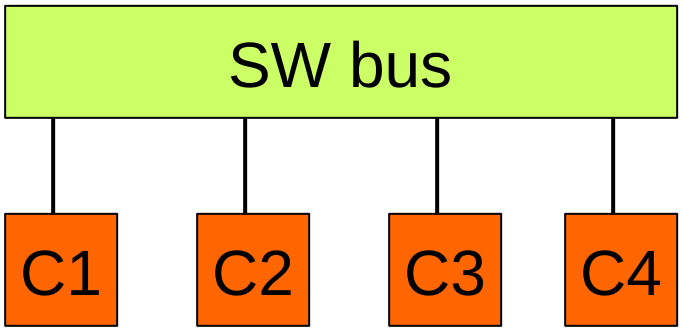
- AIDA (Abstract Interfaces for Data Analysis)
  - concept and design
- AIDA implementations (Anaphe)
- Description of the interfaces
- User examples
- Conclusions

What is AIDA ?

- AIDA : Abstract Interfaces for Data Analysis
- Open source project with the goal to define abstract interfaces for common physics analysis objects
  - Histograms, ntuples, functions, fitter, plotter, tree and data storage
- Defines a common XML format for data exchange
- Allows multiple implementations and multiple languages
  - C++, Java and Python
- Exist three AIDA implementations:
  - Anaphe (CERN) in C++
  - JAS/JAIDA (SLAC) in Java
  - OpenScientist (Orsay) in C++

Abstract Interfaces

- An Abstract Interface (Class) specifies a protocol how clients may access and manipulate a component
- Defines no implementation but only functionality
- Essential element of OO to achieve a modular design:
  - Clean separation of specification and implementation
  - Clean separation of components
  - Components can be upgraded or replaced without effecting usage (plug in /out model)

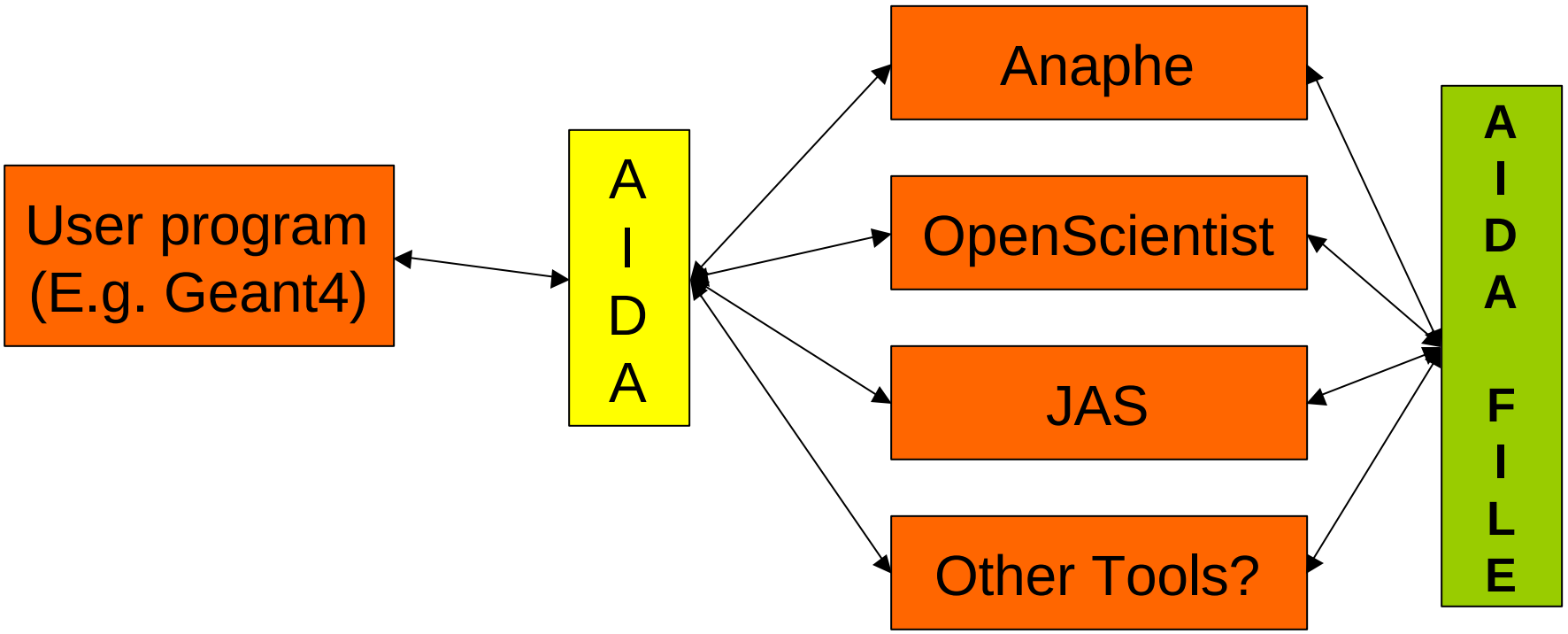


Interfaces are the communication protocol of the bus

components

AIDA

- User code sees only the abstract interfaces
  - Implementation can be selected at run time without any change to the code (loading shared libraries)



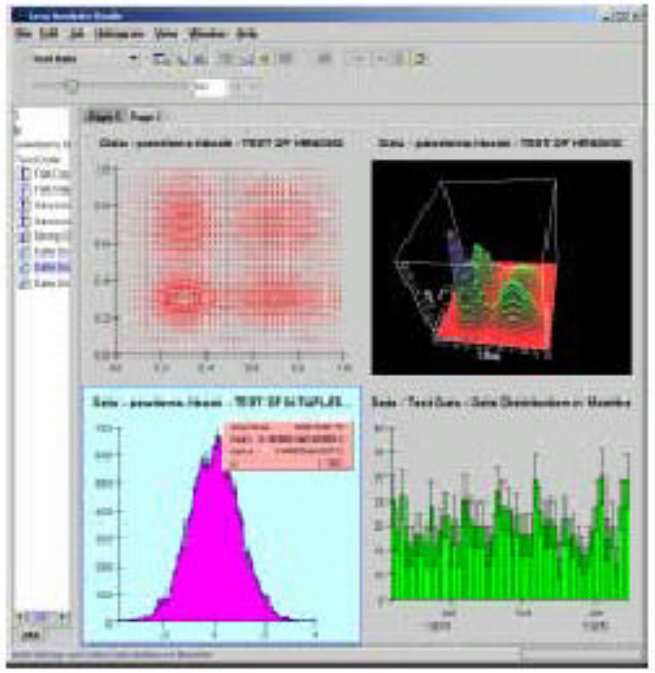
AIDA History

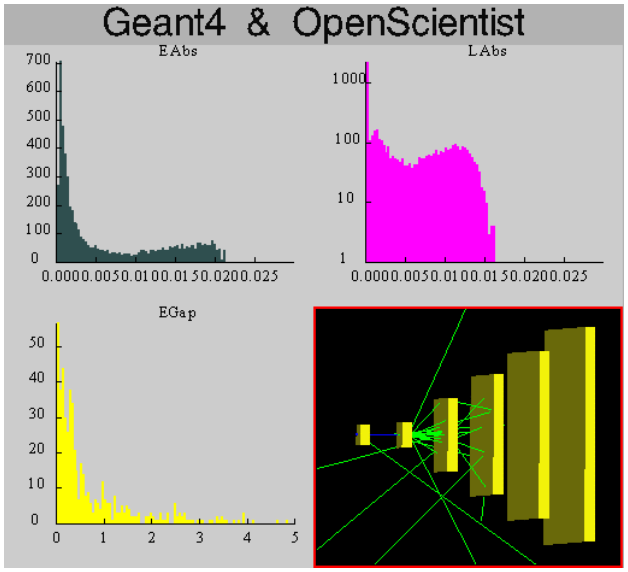
- AIDA started in 2000 by defining a common interfaces for histograms
- First end-user release (v. 2.2) end of 2001
- New AIDA release 3.0 in October 2002
  - large improvement in functionality (fitter and plotter)
  - New Anaphe and JAS releases implementing AIDA 3.0
  - OpenScientist release is expected soon
- Geant4 adopted AIDA for analysis
- AIDA is used also within Gaudi (SW framework used by LHCb, ATLAS and HARP)
- Recommended for adoption by LHC Computing Grid project (LCG)

AIDA implementations

⌘ JAS (Java Analysis Studio)

- jas.freehep.org/
- Analysis tools developed a SLAC written in Java
- Easy to use and robust, multi platform, flexible and easy extendable
- JAIDA: Java packages implementing AIDA interfaces





⌘ OpenScientist

- http://www.lal.in2p3.fr/OpenScientist
- Modular tool developed by G. Barrand (Orsay)
- Collections of various C++ packages (histogramming, visualisation, storage)

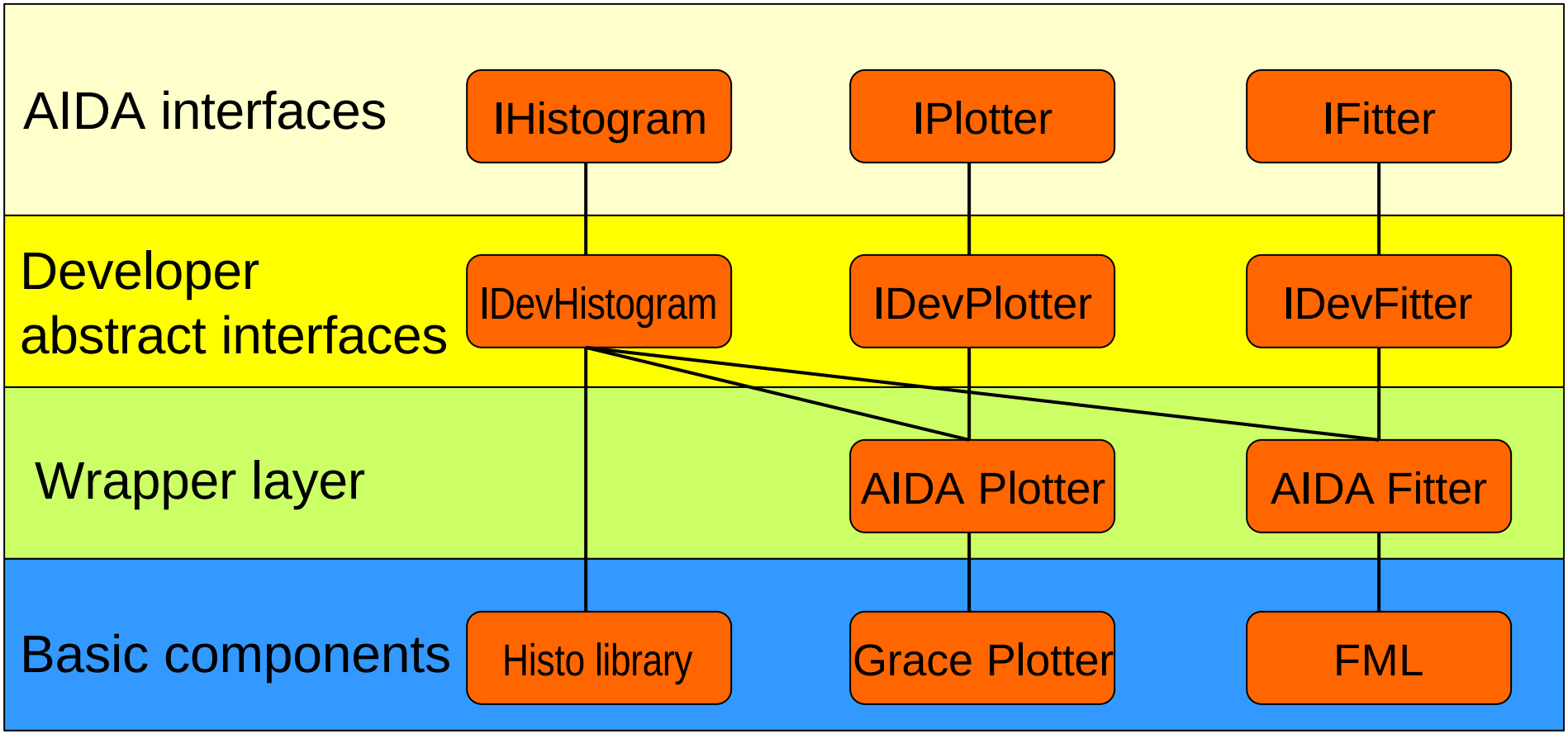
Anaphe

- Anaphe : Analysis for Physics Experiments
- An project in CERN IT division
  - Follow up from LHC++ project (1997-2000) which provided OO/C++ libraries alternative to the Cernlib
- First production release in Summer 2001
- Implementation of the AIDA 3.0 interfaces in version 5 (October 2002)
- Provides component C++ libraries implementing AIDA interfaces
- Lizard: Interactive analysis tool in Python to use AIDA

Layered Architecture of Anaphe

- Basic functionalities (histograms, fitting, etc.) are available as individual C++ class libraries (components)
- A thin wrapper layer implementing AIDA using the component libraries
  - ➔ Easy to adapt to changes in interfaces due to user request (e.g. adding functionality)
- A developer interfaces level extending the AIDA interfaces
  - More efficient (extra functionality is needed internally)
  - Maintain insulation
  - ➔ Easy to replace a component without affecting usage
- User sees only top level (AIDA)

Anaphe Architecture

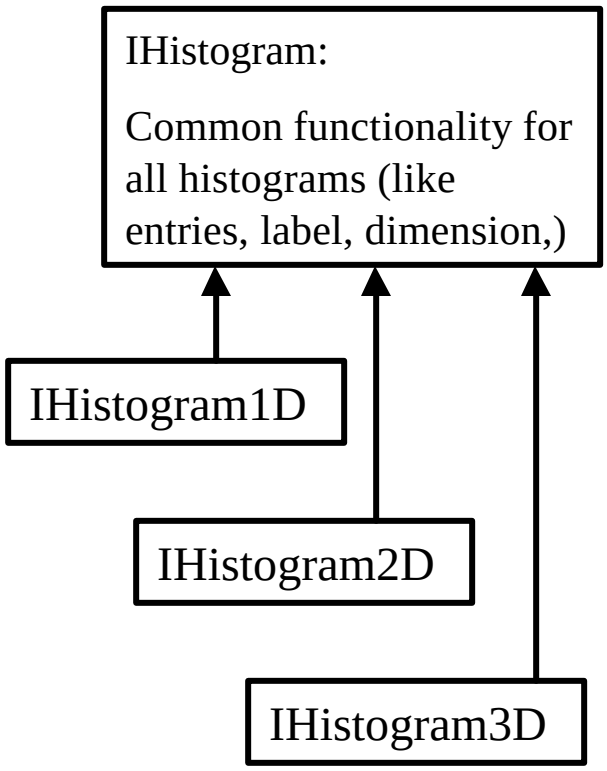


AIDA Interfaces Summary

- Histograms
  - Binned 1-,2-,3- dimensional histograms
  - Unbinned 1-,2-,3- dimensional histograms (Clouds)
  - 1-,2- dimensional profile histograms
- Tuples
- DataPointSet (Vector of Points)
- Functions
- Fitting interfaces
- Plotter interfaces
- Management of analysis objects:
  - Tree
  - Factories

Histograms

⌘ Example: IHistogram interfaces (binned histograms)



IHistogram1D interface

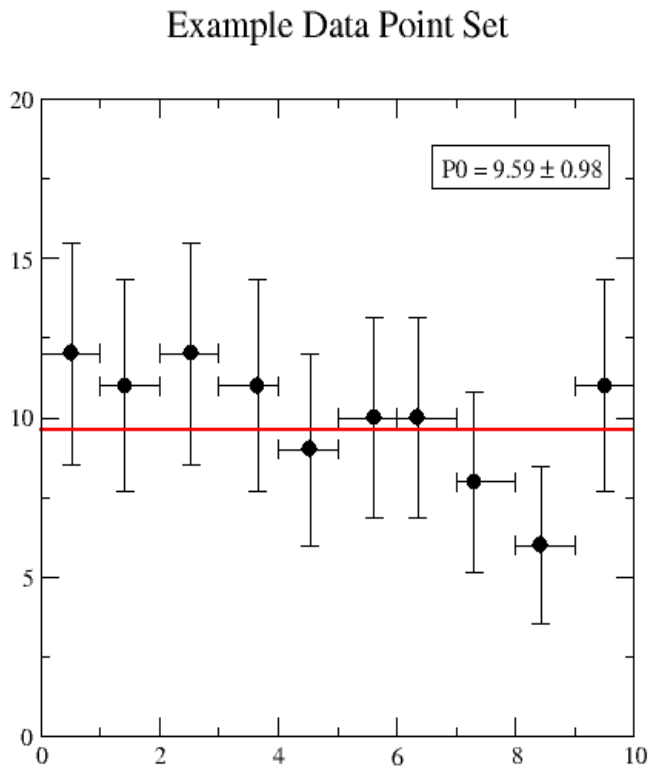
```
public interface IHistogram1D extends IHistogram {

    public void fill(double x);
    public void fill(double x, double weight);

    public double binCentre ( int index );
    public int binEntries(int index);
    public double binHeight(int index);
    public double binError(int index );

    public double mean();
    public double rms();

    public IAxis axis();
    public int coordToIndex(double coord);
}
```

Tuples

- **Tuple** - interface
  - Support for basic C++ types (float/double/int/bool)
  - Support for nested tuples (tuple in tuple)
    - E.g. Track/events/hits or Hbook column wise tuples
  - Projection into histograms, clouds and profiles using evaluator and filters (weight and cuts)
    - IEvaluator and IFilter interfaces defined in AIDA and use C++ compiles expressions
  - Support for chaining of tuples
- Implemented C++ library with
  - read/write of Hbook tuples (raw and column wise)
  - Library is completed decoupled from the specific store in use

Data Point Set

- Data Point Set (Vector of Points)
  - Simple container for n-dimensional measurement points (values and positive/negative errors)
    - IDataPointSet
      - IDataPoint
        - IMeasurement
  - Used for arithmetic operations, plotting and fitting
  - Support conversion from histograms to DataPointSets



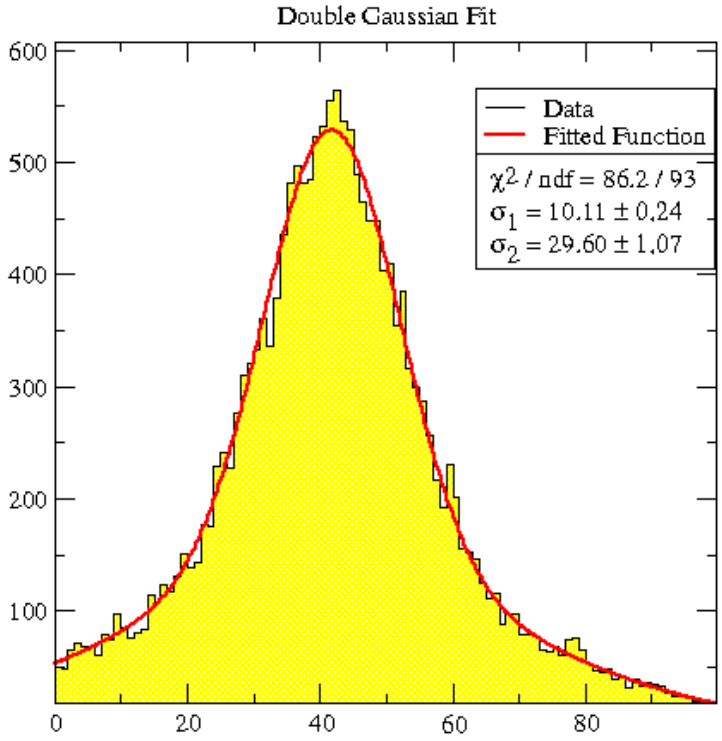
Functions and Fitting

- Function interface
  - Generic interface to n-dimensional function
  - Allows to set/retrieve parameters and get function value
  - Can provide gradient
- Fitting interfaces
  - IFitData: generic interface used to connect to data sources (Histograms, Clouds, DataPointSets, Tuples)
  - IFitter: interface allows to perform the fit and to configure it
    - E.g. setting different fitting methods (Chi2/ maximum likelihood)
  - IFitResult : to retrieve results (fitted parameters, errors,…)
  - IFitParameterSettings: to set bounds or fix the parameters
  - IFitRange to set ranges on the source data

Fitting library

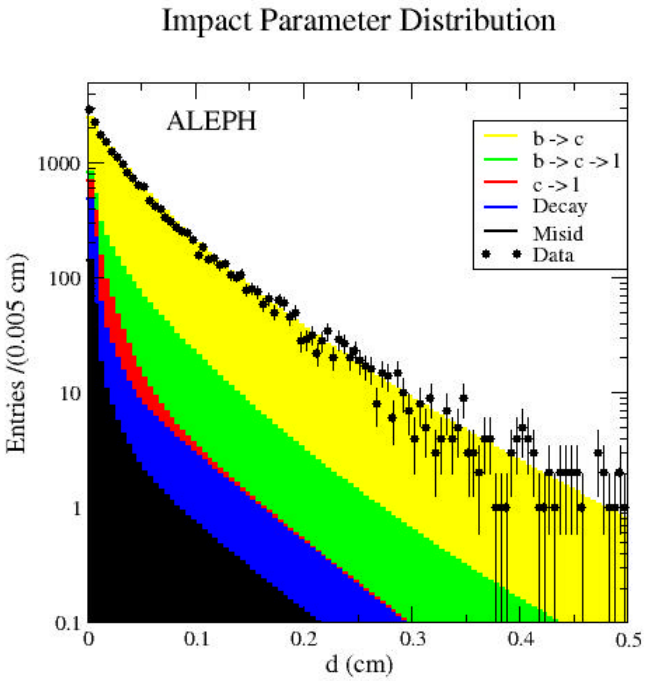
Fitting and minimization library (FML)

- Flexible OO library implementing AIDA interfaces
- Using minimization engine based currently on NAGC/MINUIT but easy extendable to others (GSL in the future?)
- Support for $\chi 2$, binned and unbinned maximum likelihood fits
- Plug-in mechanism to load user functions



Plotting

- Plotter and Region interfaces
- Style interfaces
  - To control the way objects are drawn
  - Styles for markers, lines, text, axes, fill area , etc…
- Libray based on GRACE implementing AIDA
  - a open source graphics package under GPL license
  - Very high quality graphics and powerful (publication quality plots)
  - Convenient point and click user interface
  - Flexible and easily extendable
  - Easy integration in Anaphe



Management and persistency

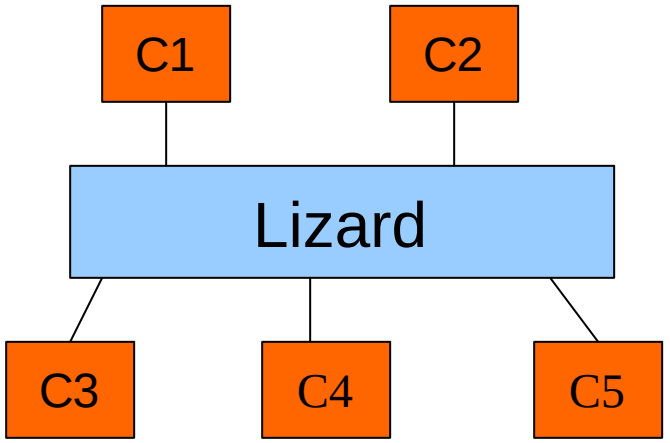
- Hide implementations from user
  - Use factories to create analysis objects (Histograms, Ntuples,….)
- Objects are managed in a tree-directory structure (ITree interface)
  - Support for Unix-like directory and commands (ls, cp, mv, …)
- Tree hides store details from the user
  - User chooses store type at run time (when creating the tree)
- Multi store types functionality
  - can run with two different store type at the same time !
- Support in Anaphe for three store types:
  - XML (compress and uncompress) defined within AIDA
    - Possible to exchange files with other AIDA implementations (JAS)
  - HBook (only histograms and Tuples)
  - Objectivity using HEPOBDMS
- Easy extendable to new types

AIDA XML data format

- Defined an XML format to store all analysis objects of AIDA
  - Histograms, Functions, Tuples, etc…
- Allows transfer between different implementations
  - Anaphe files can be read from JAS and vice versa
- Support for compression (zipped) format
- Format (schema) is defined in :
  - `http://aida.freehep.org/schemas/3.0/aida.dtd`

Interactivity: Lizard

- Lizard : Python environment for interactive analysis
  - Unified user interface at top level
  - AIDA types and methods mapped into Python commands
    - use SWIG to generate the mapping from the C++ classes
  - User modules can be plugged in as required
  - Analyzer module provides on-the-fly compilation and running of user code
- Python as scripting language:
  - Easy to use
  - Object Oriented language
  - Maps well to C++ and Java
  - Huge user base with lots of free software (networking, GUI, OS, scientific etc)

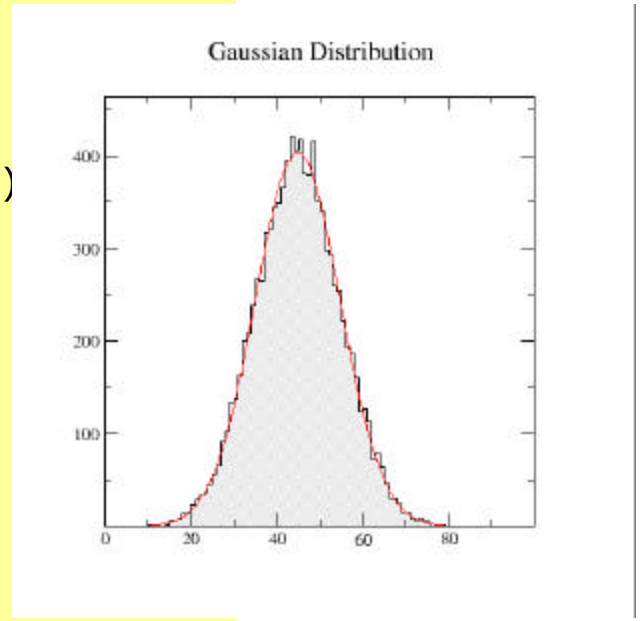


C++ component libraries

Example of Lizard code (Python)

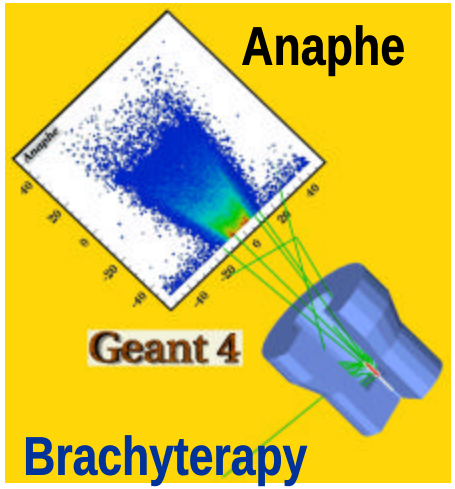
- Creating an Histogram, filling, fitting and saving the result in an XML store

```
# create the tree with an XML store
tree=tf.create ("myExample.xml","XML",0,1)
# create histogram (first factory)
hf = af.createHistogramFactory(tree)
h1 = hf.createHistogram1D("MyHisto", "Gaussian
Distribution", 100, 0, 100)
# filling with random gaussian points
for i in range(0,10000) :
   h1.fill(random.gauss(45, 10), 1)

#fitting – create first function
funf = af.createFunctionFactory(tree)
fun = funf.createFunctionByName("MyFunction","G")
# set function's initial parameters (optional)
p = [50,10,10]
p.setParameters(p)
# create fitter and fit the histogram
fitter = fitterFactory.createFitter("Chi2","")
fitResult = fitter.fit(h1,f)

#save all in XML file
tree.commit()
```



AIDA/Anaphe Users

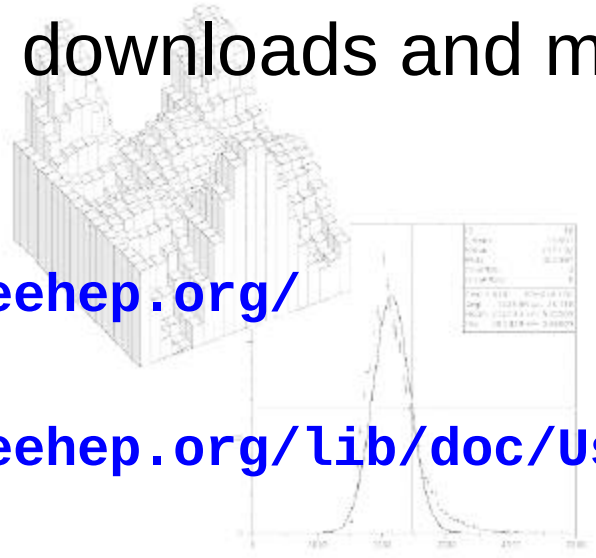
- Users from HEP and non HEP community
- Interest in AIDA also from LHC Computing Grid project (LCG)
- Geant 4 has adopted AIDA as a tool-independent analysis standard
- Anaphe starts being used in GEANT4
  - E.g. analysis of underground, astroparticle experiments and even in medical applications (radiotherapy)
  - Being adopted for GEANT4 test and validation process



Summary

- AIDA interfaces define a protocol for the analysis objects
  - Remove dependency (compile time) of user code from analysis library
  - User code needs no change if changing implementations
  - Allow interoperability between different frameworks
- Anaphe is a layered set of loosely coupled C++ components for data analysis and an interactive Python framework (Lizard)
  - Easy to use
  - Applicable to different environment
  - Committed to AIDA compliance
- Open to new requirements and feedbacks from users

References



- For documentation, downloads and more information
  - **AIDA:**
    - **http://aida.freehep.org/**
  - **AIDA User Guide**
    - **http://aida.freehep.org/lib/doc/UsersGuide/index.shtml**
  - **ANAPHE:**
    - **http://cern.ch/anaphe**
- or send mail to
    - **anaphe-editors@cern.ch**