GAUDI - A Software Architecture and Framework for Building HEP data processing Applications

Developed in the context of the LHCb Experiment

Pere Mato, CERN

August 1999

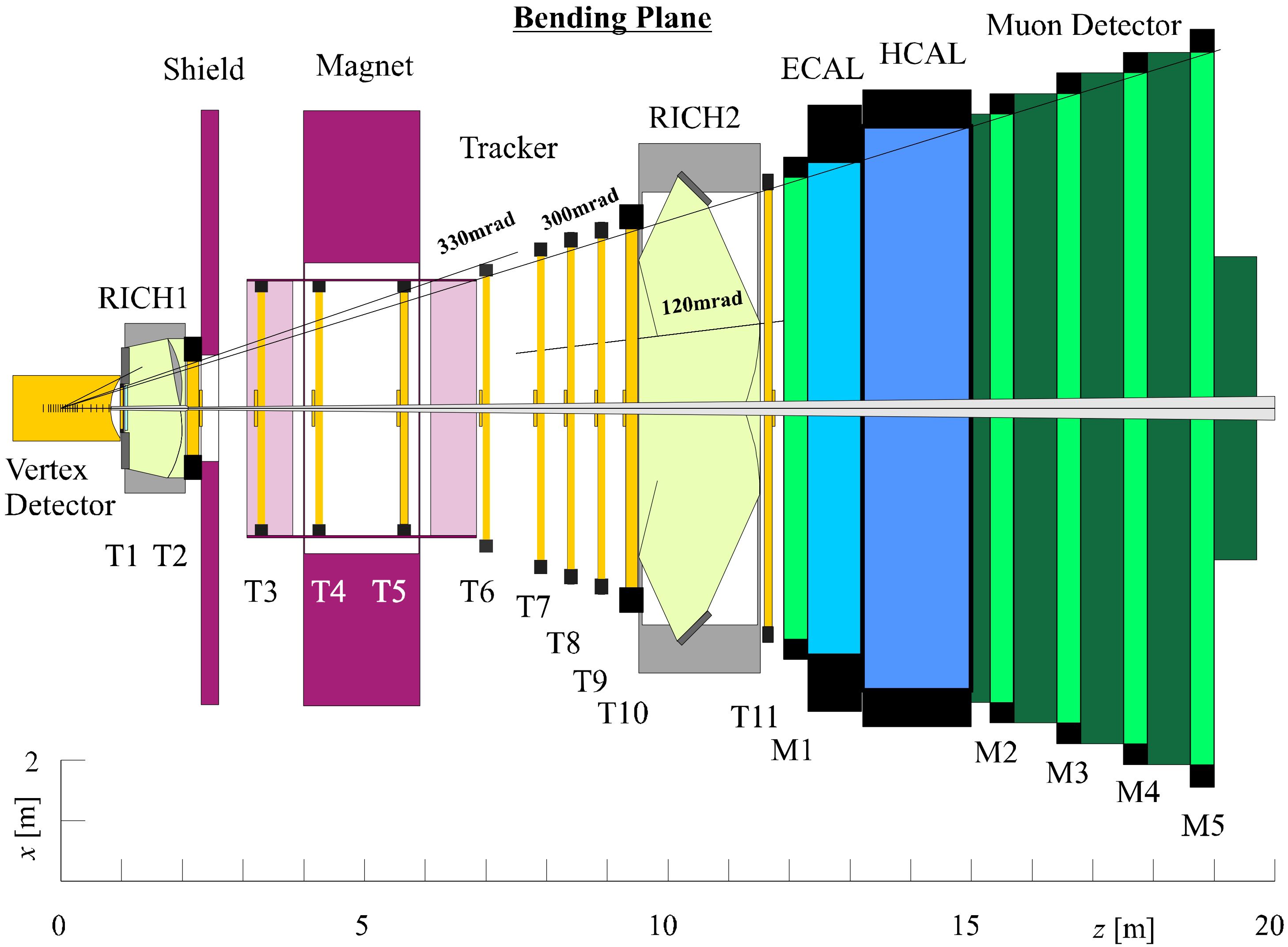
Outline

- Introduction
  - The LHCb experiment
  - Computing organization strategy
  - Software development strategy
- GAUDI architecture
  - Goals and scope
  - Design choices
  - Selected topics
- Implementation
  - Technology choices, Tools, ...
  - Schedule so far

LHCb: Physics Goals

- LHCb is a dedicated experiment at LHC collider for precision measurements of CP-violation and rare decays
  - CP violation currently observed in kaon decays is consistent with Standard Model, but cannot exclude that CP violation is partly or even entirely due to new physics.
  - Cosmology (baryon genesis) suggests that an additional source of CP violation other than the Standard Model is needed.
- LHC is an ideal place to produce lots of Bd and Bs
- All interesting decay channels have 10^{-5} visible branching fractions.

LHCb: The Detector



LHCb: The Detector

- Single-arm spectrometer with forward angular coverage from ~10 mrad to ~300(250) mrad.
  - Vertex detector
    - Si r-ϕ strip detector, single-sided 150 μm
  - Tracking system
    - Outer: drift chamber honeycomb. Inner: MSGC with GEM or MCSC
  - RICH system
    - RICH1: Aerogel + C_4F_{10}. RICH2: CF_4
  - Calorimeter system
    - Preshower: single layer Pb/Si. ECAL: Shashilik. HCAL: Atlas Tile Cal.
  - Muon system
    - Multi-gap RPC and CPC

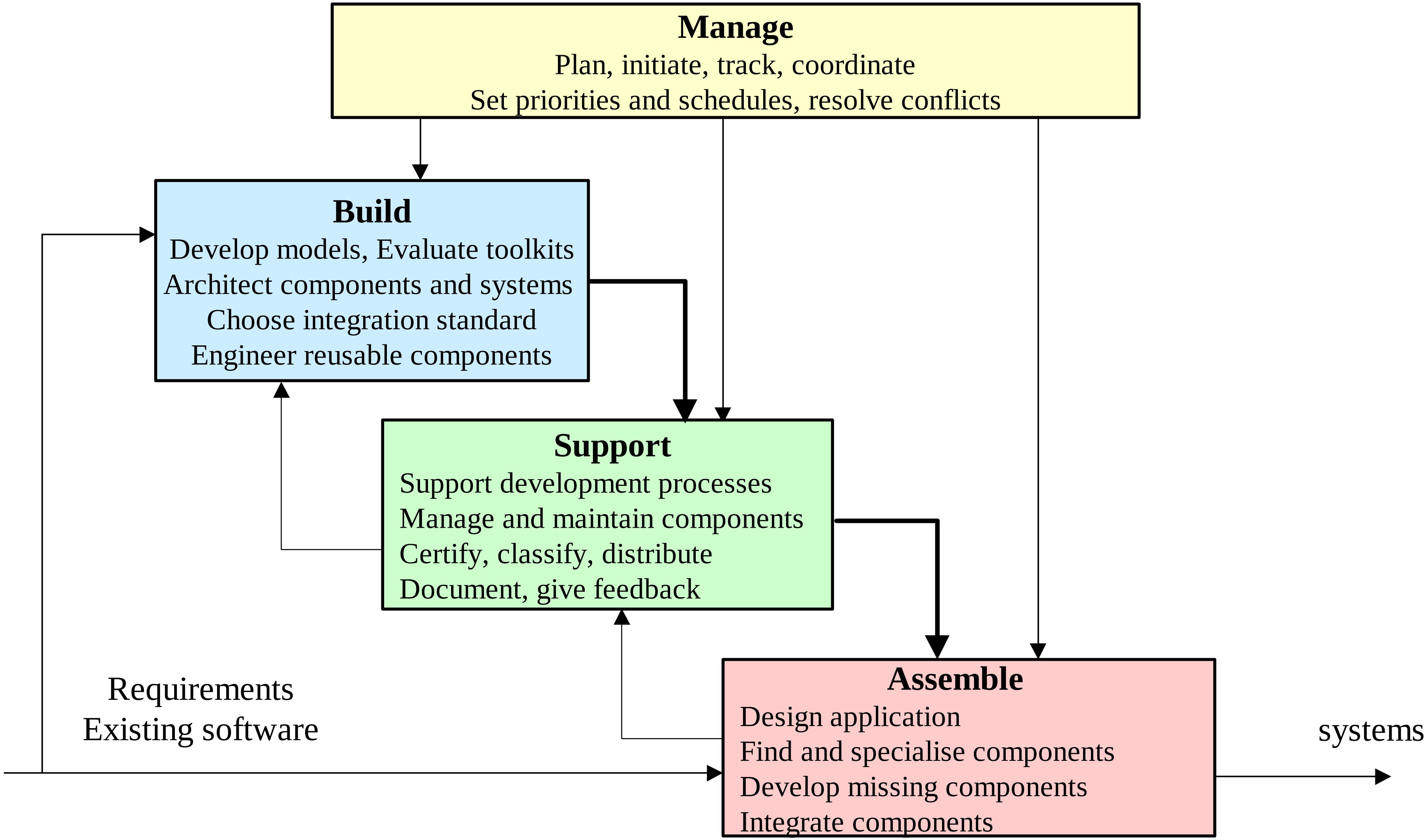
LHCb in numbers

- Collaboration: ~45 Institutes, ~350 participants
- Cost of the experiment: 86 MCHF
- Electronics: $\sim 10^6$ readout channels
- Trigger System: 4 Levels. 40 MHz $\rightarrow$ 1 MHz $\rightarrow$ 40 kHz $\rightarrow$ 5 kHz $\rightarrow$ 200 Hz
- Data Acquisition: 100 kB/event. 2-4 GB/s $\rightarrow$ 20 MB/s. 1.5 10^6 MIPs
- Status of the Experiment:
  - Technical proposal submitted in February 1998
  - Approved in September 1998
  - R&D phase for ~2 years

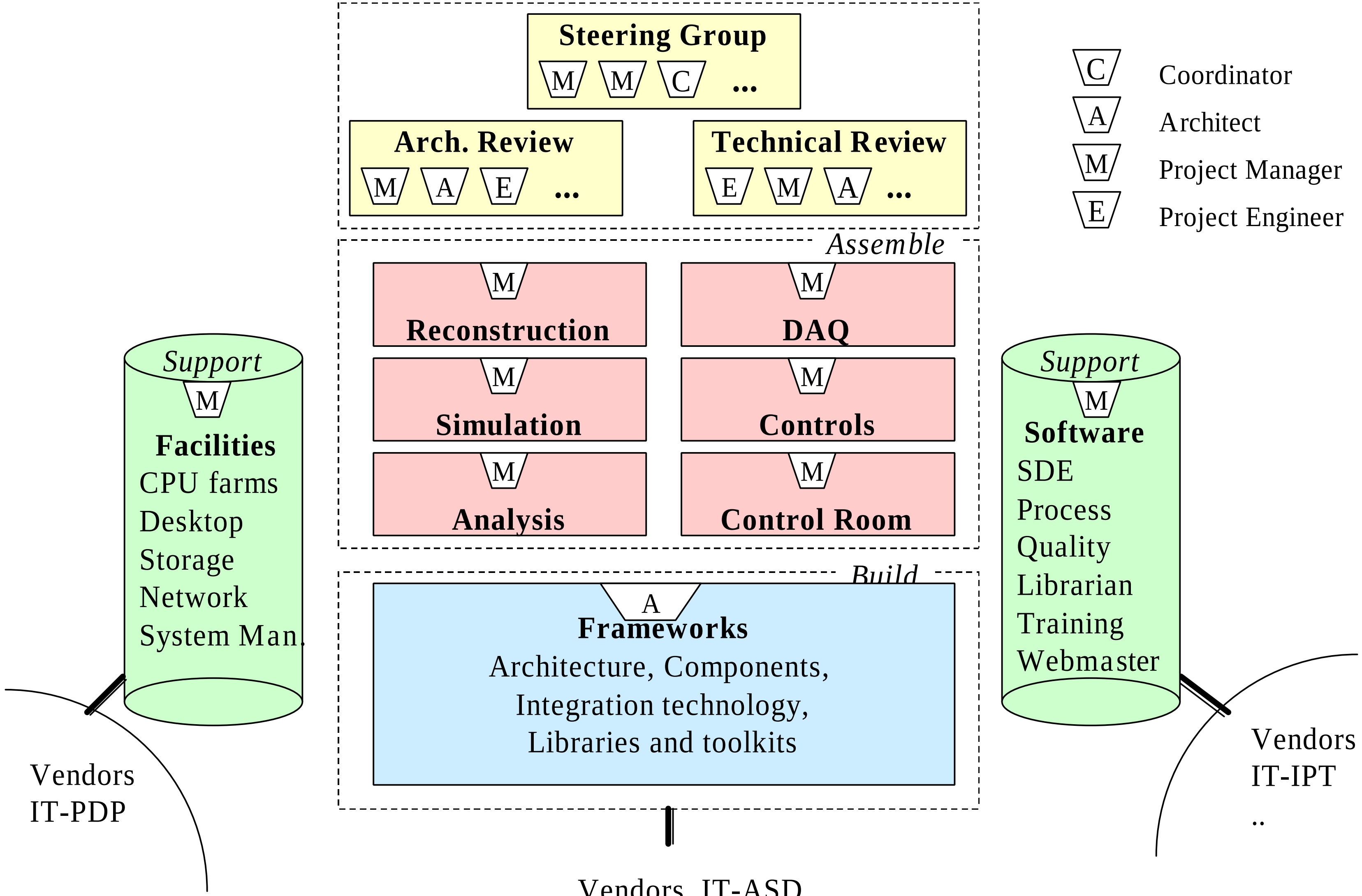
LHCb Computing: Goals

- Need to focus on quality but at the same time be efficient in use of resources
- Identify all the roles and their responsibilities
  - system architect, project leaders, librarian, framework developers, client developers, ...
- Good communication to arrive at common aims and understanding
  - need to know at all times what everybody is doing (regular meetings)
  - Procedures for taking decisions must be agreed and followed
- Common language supported through documentation and training
  - Web
  - Handbooks (user, engineering, management)
  - Formal training

Organizing software development activities



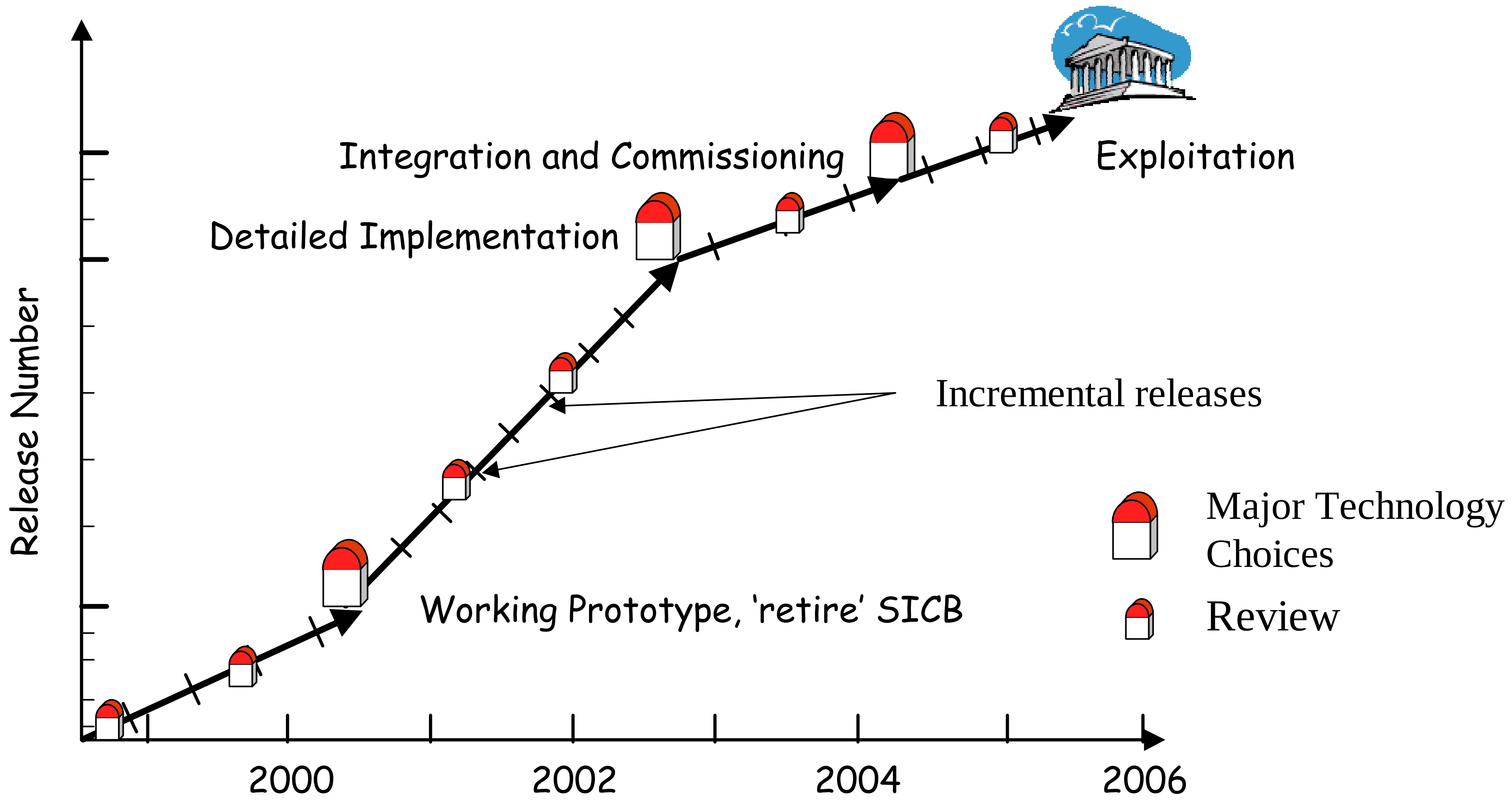
Project Organization



Strategy for development of new software

- Start with a small design team 6-8 people
  - architect, librarian, domain specialists with design/programming experience
- Collect URs and scenarios, use to validate design
- Establish the basic criteria for overall design
- Make technology choices for implementations of first prototypes
- Incremental approach to development. Releases every ~4 months.
- Development cycle is user-driven. Priorities, feedback, etc.
- Strategic decisions taken following thorough review (~1/year)
- Releases accompanied by complete documentation
- Expand development team to cover new domains

LHCb Offline software road map



GAUDI Architecture

Antoni Gaudí
Barcelona (1852-1926)
Modernist style architect

GAUDI: Scope

- We want to develop an **Architecture** and **Framework** to be used in ALL the **LHCb event data processing applications** in all stages:
  - High level trigger, simulation, reconstruction, analysis.
  - Control applications are not included (slow control, run control)
- Physicists will develop applications by customizing the framework by subclassing, composing and configuring.
- Components will be developed in general using other specialized frameworks (GUI, object persistency, simulation, …)

GAUDI: Expected Benefits

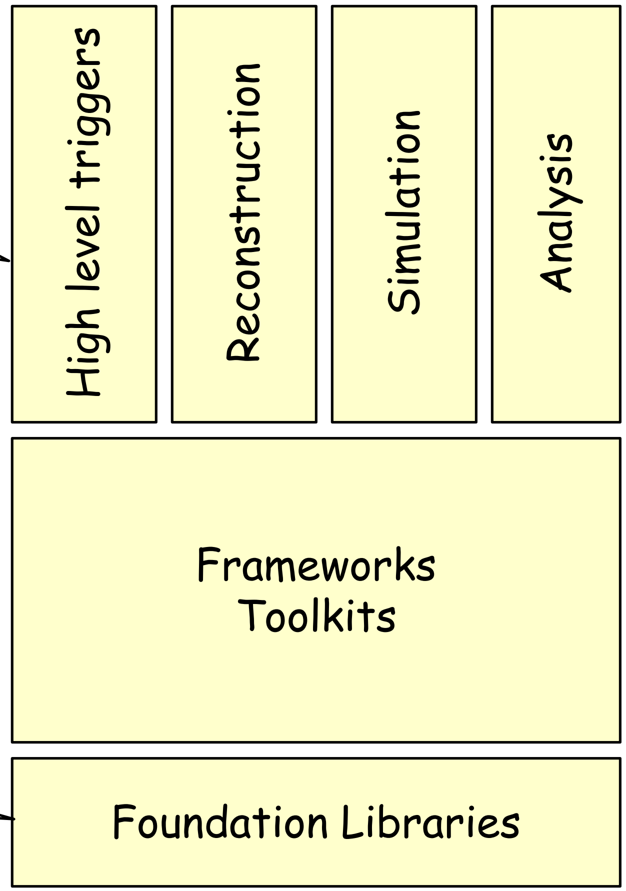
- Allow physicists to focus on solving the physics problem.
  - Must be easy to use
  - Non physics-related functionality implemented by the framework
- Common vocabulary, better specifications of what needs to be done.
- Ensure low coupling between concurrent developments.
- Guarantee a later smooth integration of developments.
- Facilitate software re-use

Software Structure

A series of data processing applications built on top of the frameworks and implementing the required physics algorithms.

A series of Frameworks and Toolkits. One main framework: **GAUDI**, various specialized frameworks: visualization, persistency, interactivity, simulation (Geant4), etc.

A series of basic libraries widely used: STL, CLHEP, etc. (**Vocabulary**)



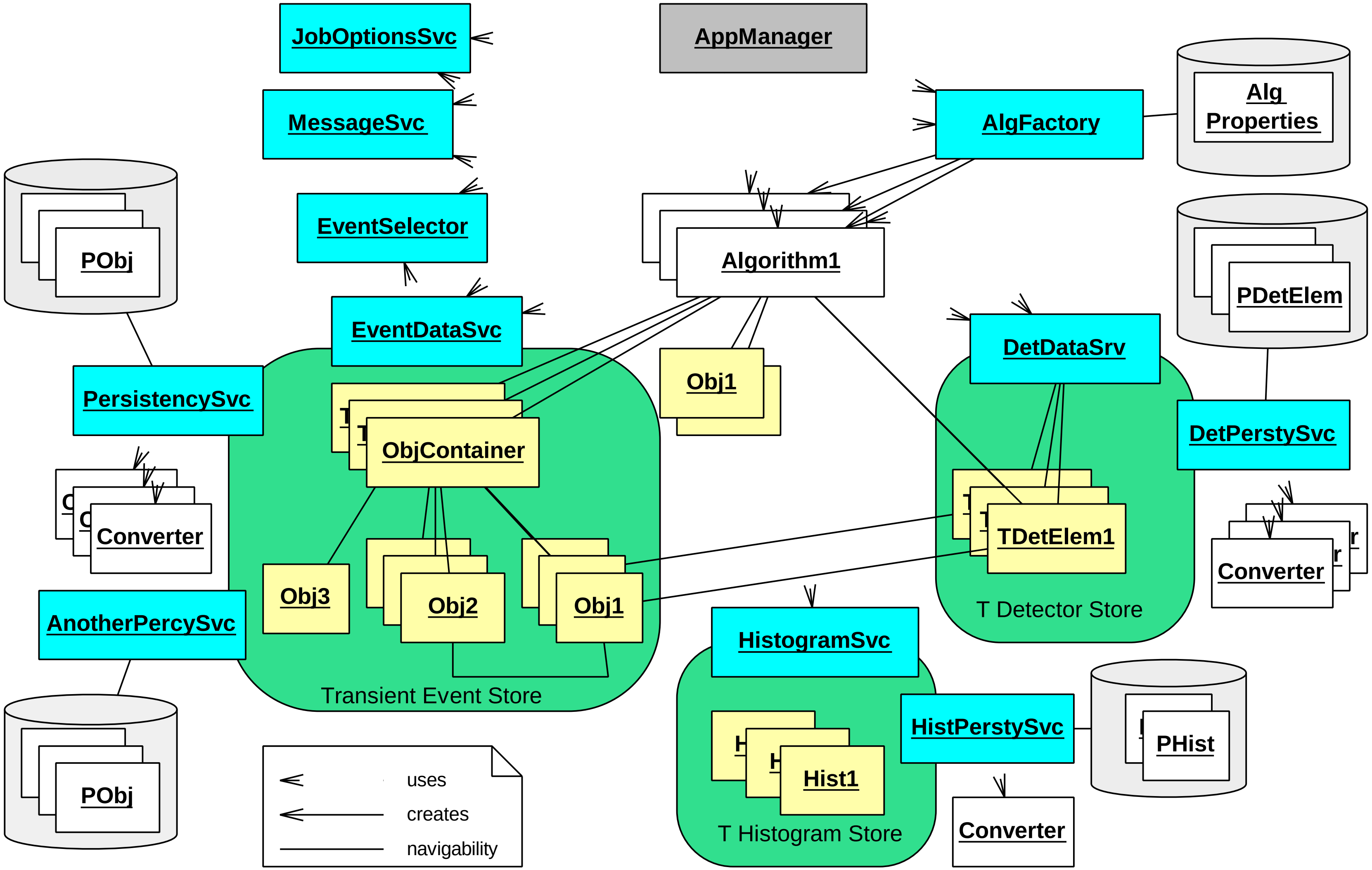
Major design criteria

- Separation between “data” and “algorithms”
- Three basic types of data:
  - **event data** (data obtained from the particle collisions)
  - **detector data** (structure, geometry, calibration, alignment, environmental parameters,..)
  - **statistical data**: (histograms, …)
- Separation between “persistent data” and “transient data”.
  - Isolation of user’s code.
  - Different/incompatible optimization criteria.
  - Transient as a bridge between various representations.

Major design criteria (2)

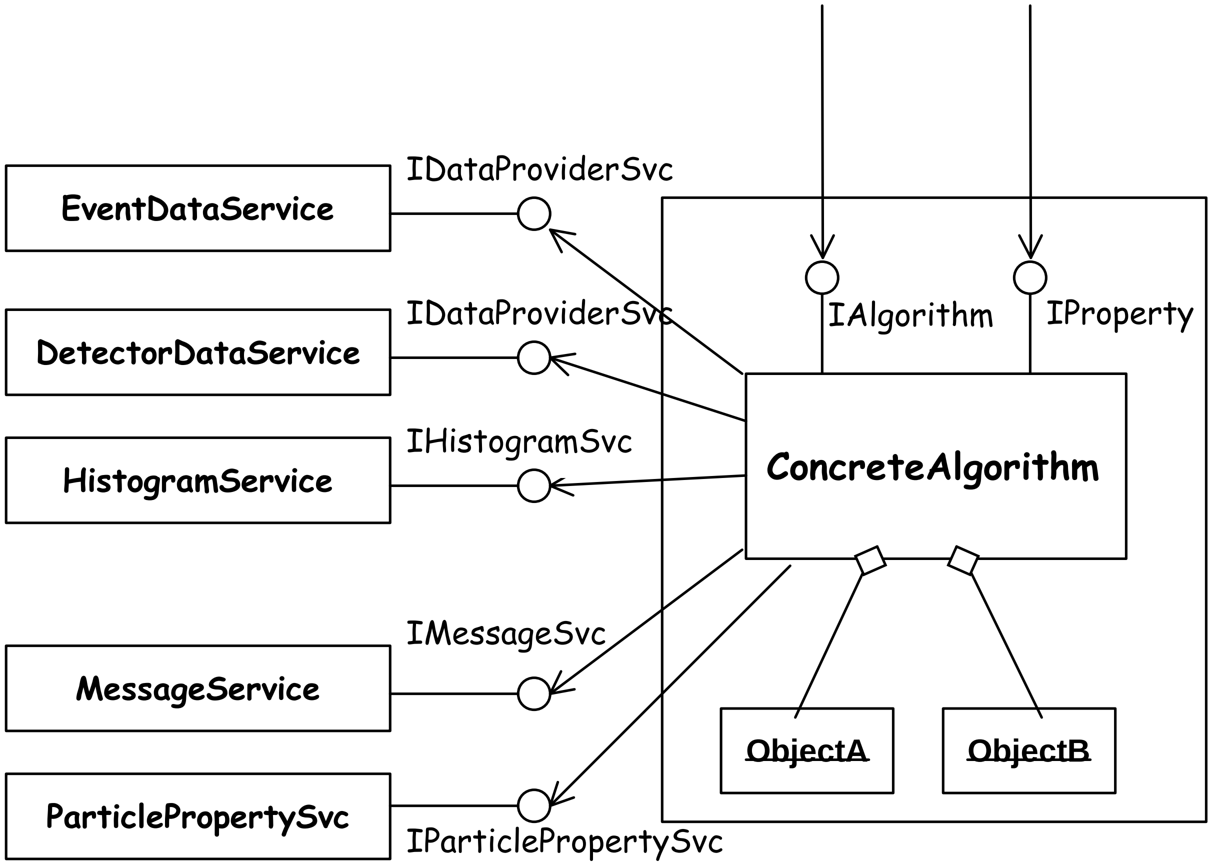
- Data store centered architectural style.
  - “Algorithms” as data producers and consumers.
- *User code* encapsulated in few specific places:
  - “Algorithms”: Physics code
  - “Converters”: Converting data objects into other representations
- All components with well defined “interfaces” and as “generic” as possible.
- Design principles
  - Low coupling, inheritance, static storage, ...

Object diagram

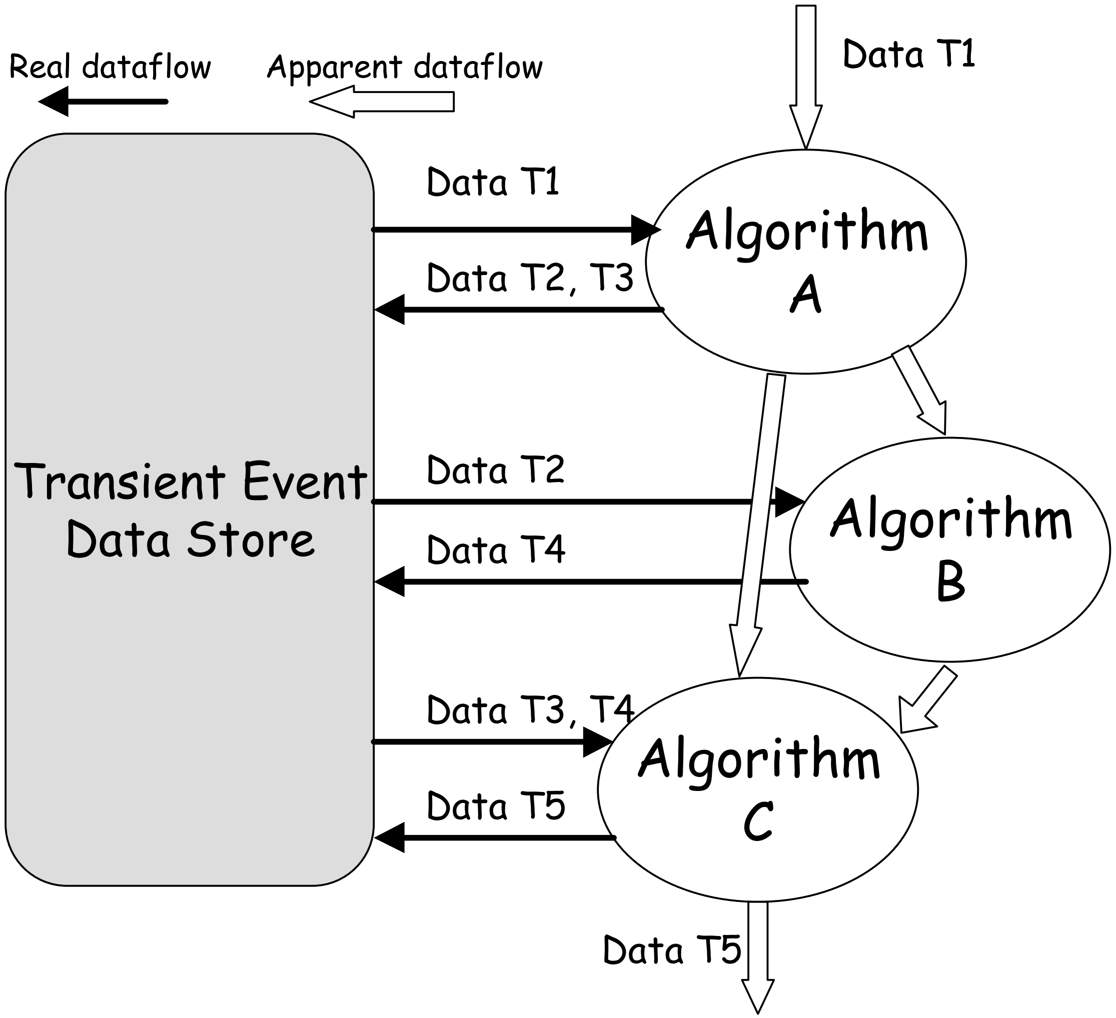


Interfaces

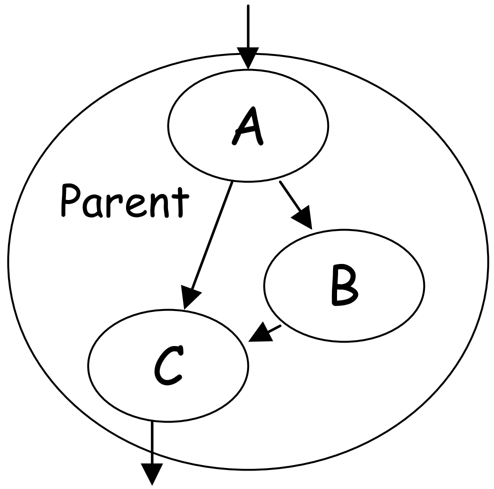
- Each component **implements** a number of interfaces
- Each component **uses** a number of interfaces from other components
- An ***Algorithm*** uses many **Services**



Algorithms

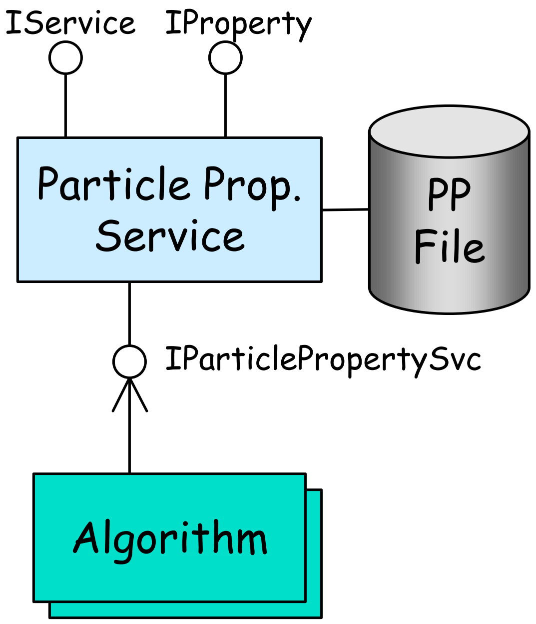


- Each Algorithm only knows what data (type and name) is expecting as input and creating as output.
- The only coupling is through the data.
- **Scheduling of sub-algorithms** is the responsibility of the parent algorithm.

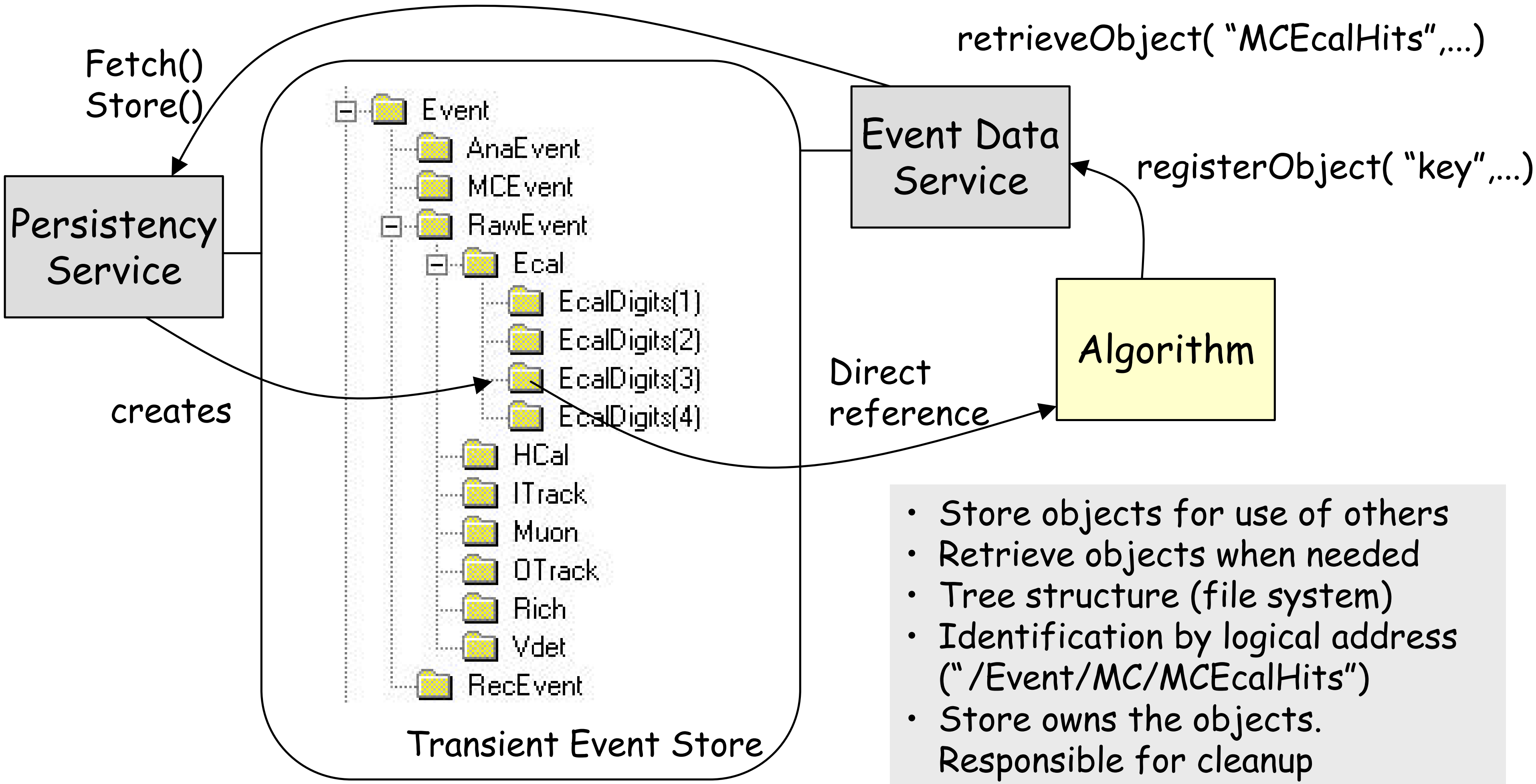


Services

- Services are provided to *Algorithms*
- Examples:
  - Job Options service (card files)
  - Message reporting service
  - Event/Detector/Histogram data service
  - Event Selector
  - Persistency and Conversion services
  - User Interface (GUI)
  - Particle property service
  - ...

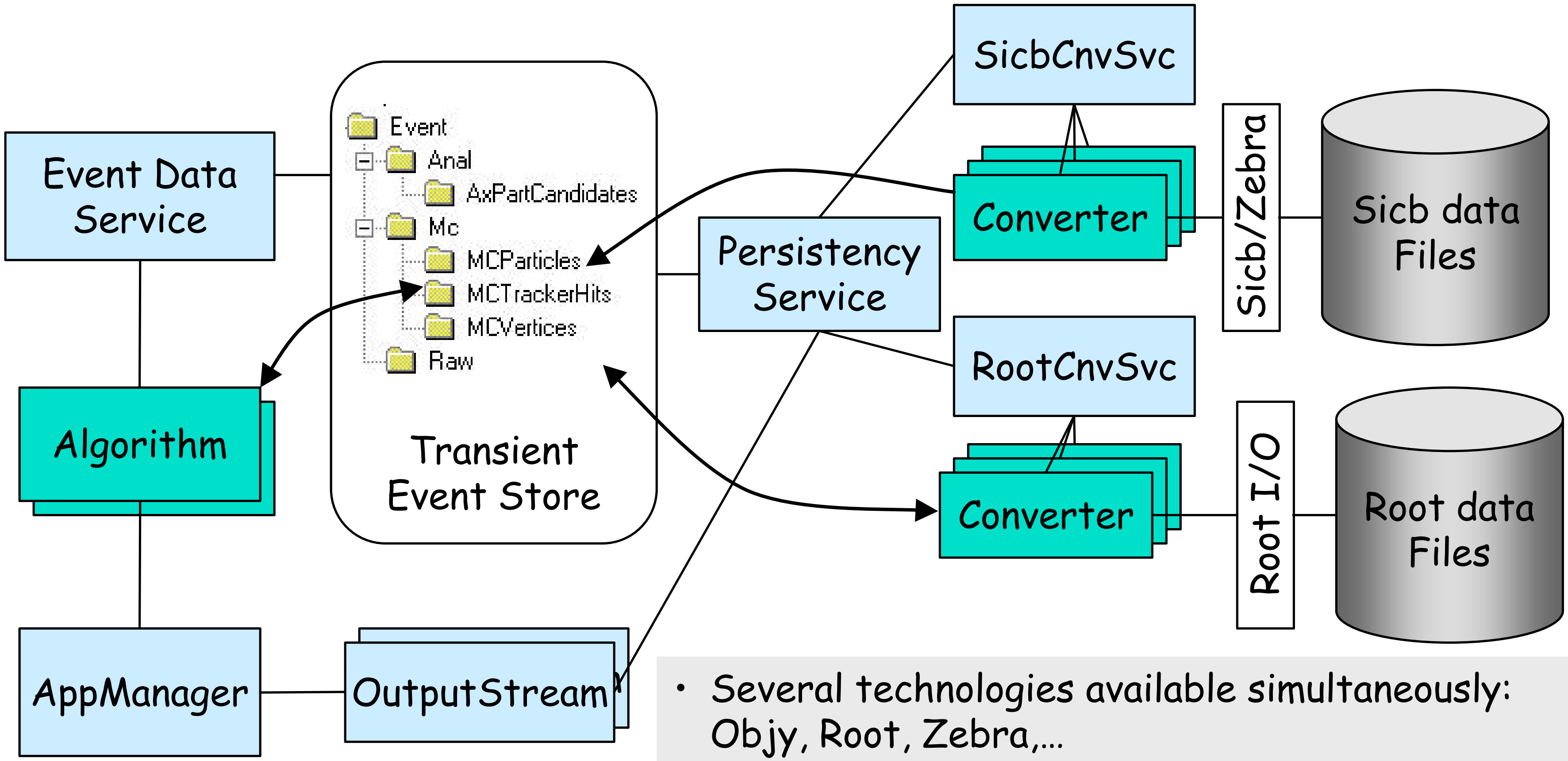


Event Data Store



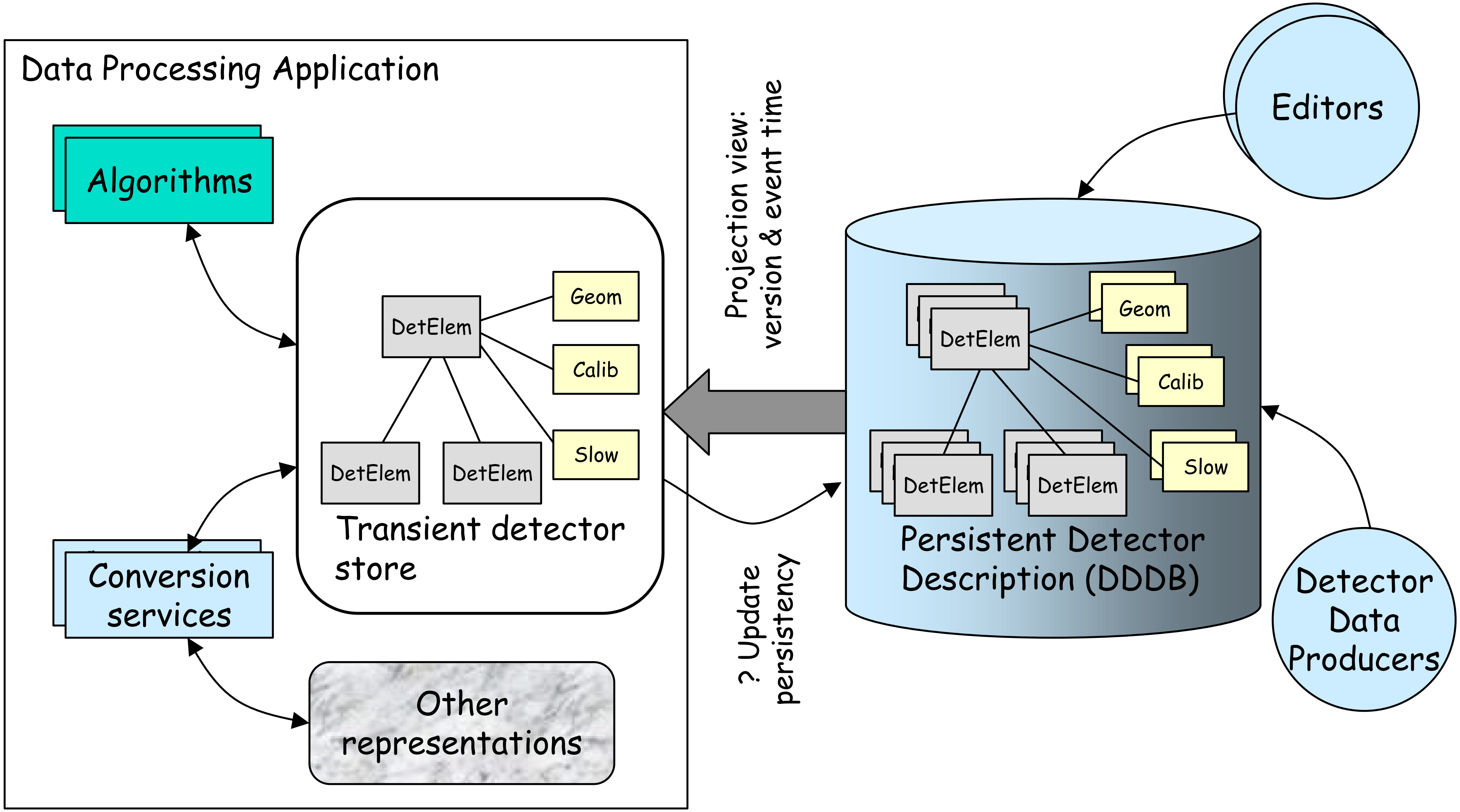
- Store objects for use of others
- Retrieve objects when needed
- Tree structure (file system)
- Identification by logical address (“/Event/MC/MCEcalHits”)
- Store owns the objects. Responsible for cleanup

Event Persistency

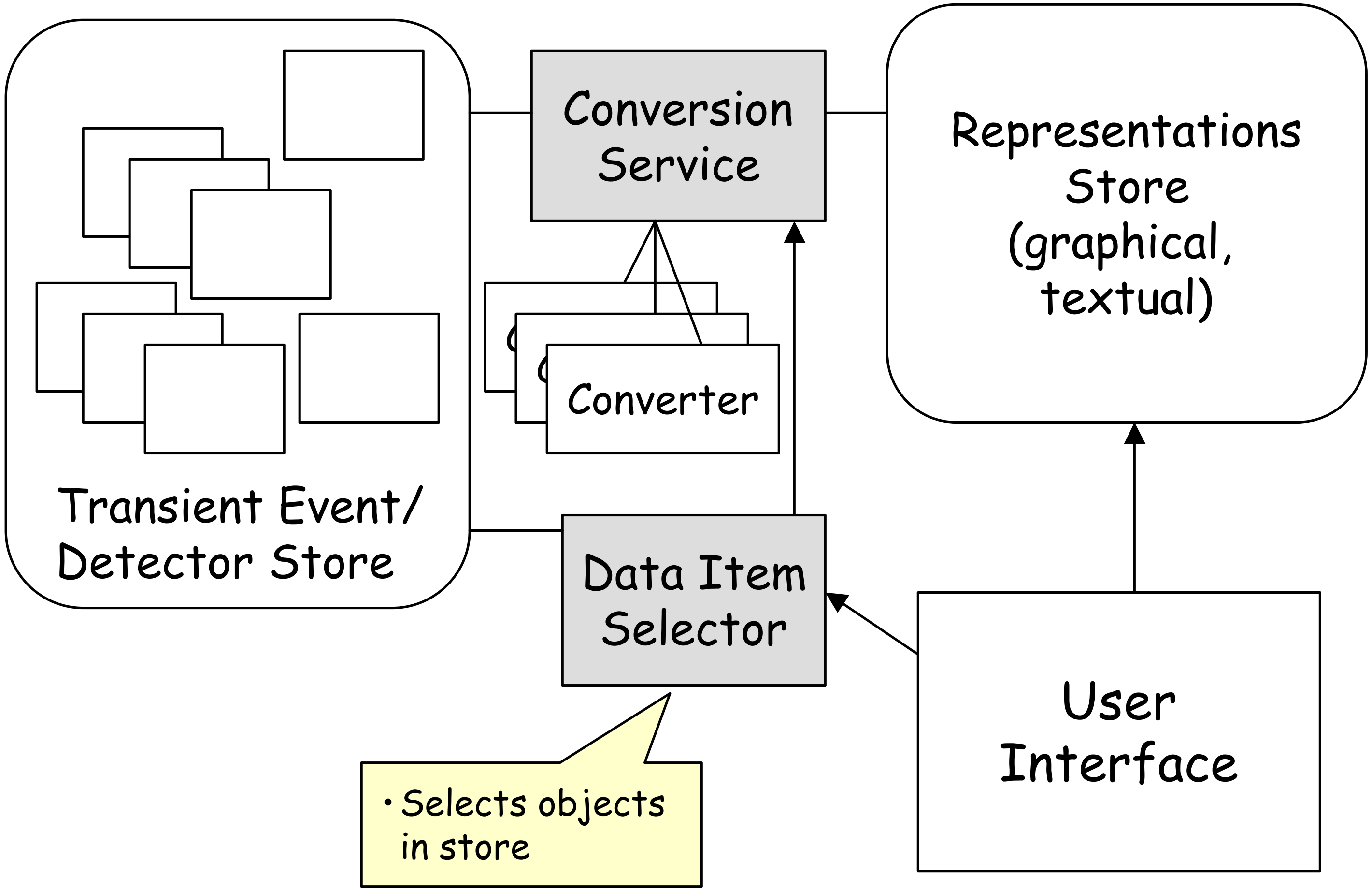


- Several technologies available simultaneously: Objy, Root, Zebra,...
- **Converters** to transform objects from one representation to another
- **Generic links** between objects in the persistent world

Detector Description



Data Visualization

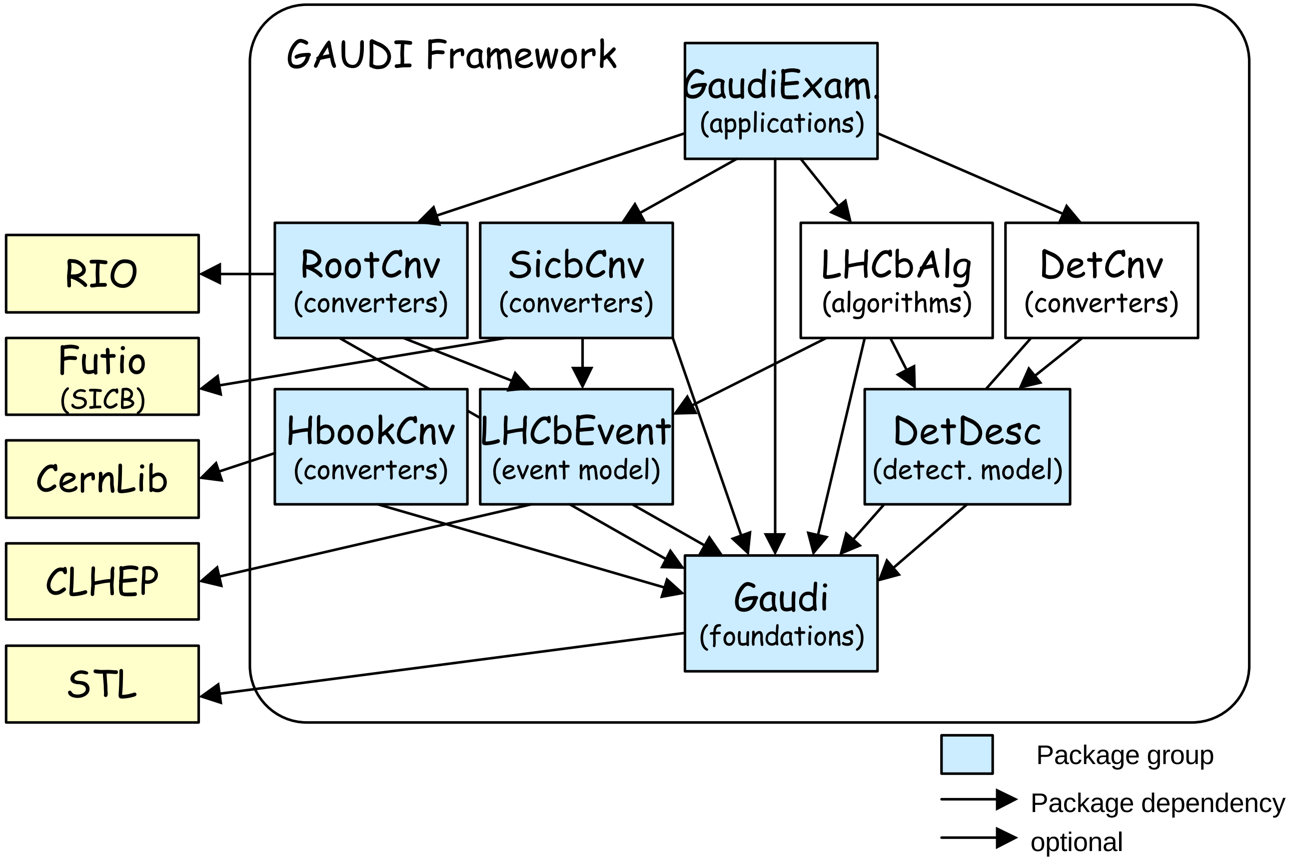


Application Configuration

- What are the knobs at our disposal?
  - JobOptions. Simple usage. It allows the end-user to overwrite any property of any algorithm or service.
  - Algorithm/Service properties database. A more sophisticated way to modify the properties of the algorithms and services.
  - Detector database edition to create new versions or releases.
  - Write specific code. Configure your application by setting properties at runtime.
  - User interface component. Graphical (a la Visual Basic), command line (scripting language), etc.

Packages

- **Physical design** (packaging) is an architectural issue.
- Big consequences on:
  - compilation time
  - link dependencies
  - configuration management
  - executable size
  - ...
- Package interdependencies require approval of architect.
- Avoid cyclic dependencies



Implementation

- Platforms:
  - **WNT, Linux**, IBM AIX, HP-UX
- Tools and Libraries:

Design tools	Visual Thought, Rational Rose
Coding rules	Interim LHCb coding conventions, SPIDER
Code Management	Visual Source Safe, CVS
Configuration Management	CMT
Problem tracking	Planned to use Remedy
Compilers/Debuggers	Visual C++, GNU EGCS
Libraries	STL, CLHEP, NAG C, HTL, RIO
Documentation	FrameMaker
Source code documentation	Object Outline, DOC++

Schedule so far

- Sept 98 - architect appointed, design team 6 people assembled
- Nov 25 '98 - 1 day architecture review
  - goals, architecture design document, URD, scenarios
- Feb 8 '99 - GAUDI first release
  - first software week with presentations and tutorial sessions
  - plan second release
  - expand GAUDI team
- May 30 '99 - GAUDI second release
  - second software week …
  - plan third release
  - expand GAUDI team (GEANT4 simulation toolkit)
- Nov '99 - next GAUDI release and software week planned

Conclusions

- Almost completed the first year of the journey towards O-O
  - Architecture being defined (interfaces, functional components)
  - Two releases of the framework with basic functionality to test the ideas.
- Currently working on:
  - Integration of GEANT4
  - Data visualization, event display
  - Detector description
  - Algorithms and tools for data analysis
  - Java evaluation
- We would like to get advice from experienced people
  - Organization, physical design, development tools, libraries, foundation libraries, etc.
  - Strategic design decisions, existing frameworks and solutions, etc.