abstract 5

abstract 721
P. Eerola et al.

Tools for Simulation and Analysis

http://www.ge.infn.it/geant4/talks/G4ichep2002.ppt

Andreas Pfeiffer, CERN

Maria Grazia Pia, INFN Genova

on behalf of the Geant4 & Anaphe Collaborations

ICHEP 2002 Conference

Amsterdam, 24-31 July 2002

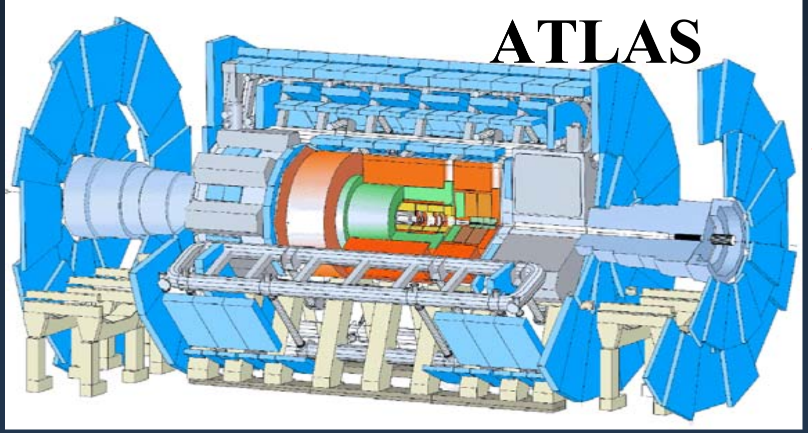
http://cern.ch/**anaphe**

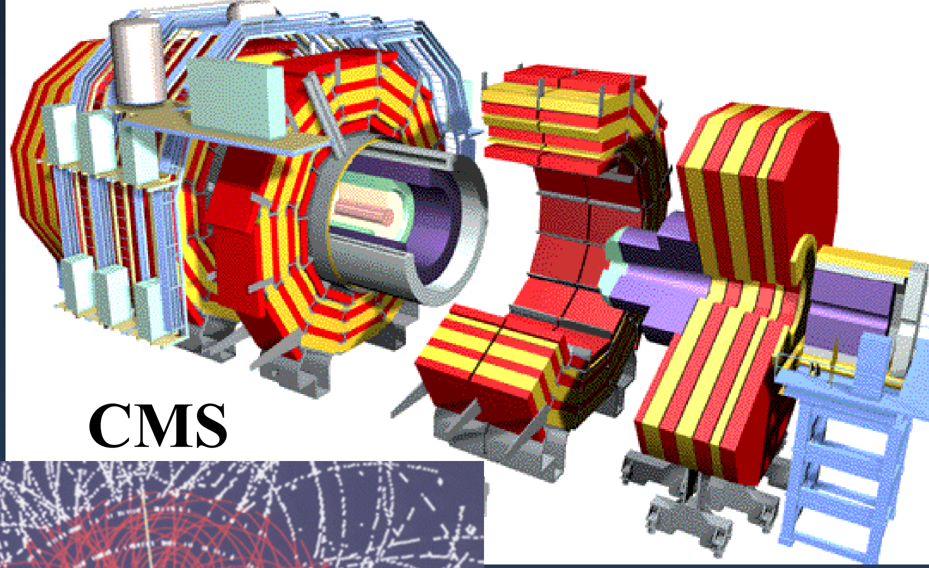
http://cern.ch/**geant4**

http://www.**nordugrid**.org

Complexity

of **physics**
of **detectors**
of the **environment** where they operate

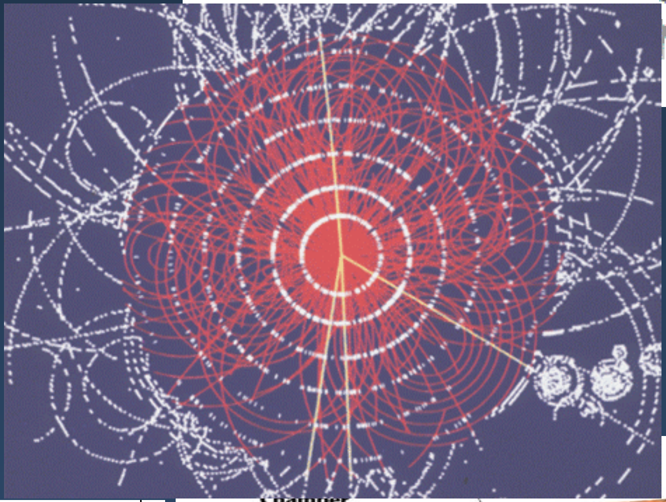




Storage

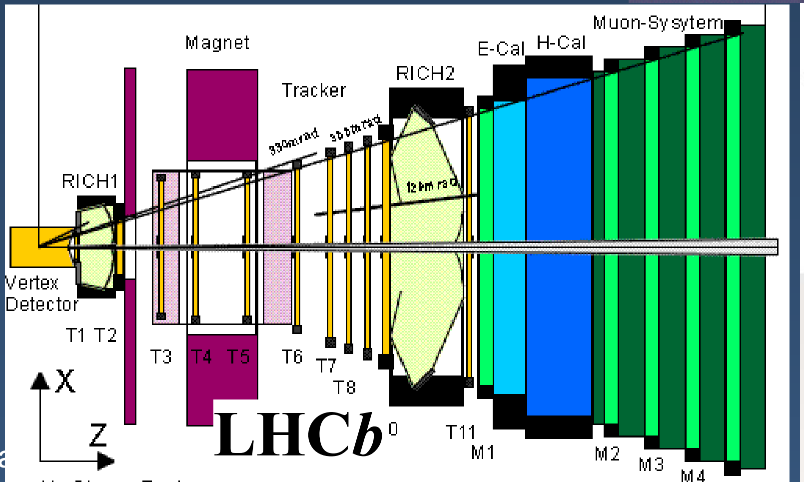
Raw recording rate 0.1–1 GByte/s

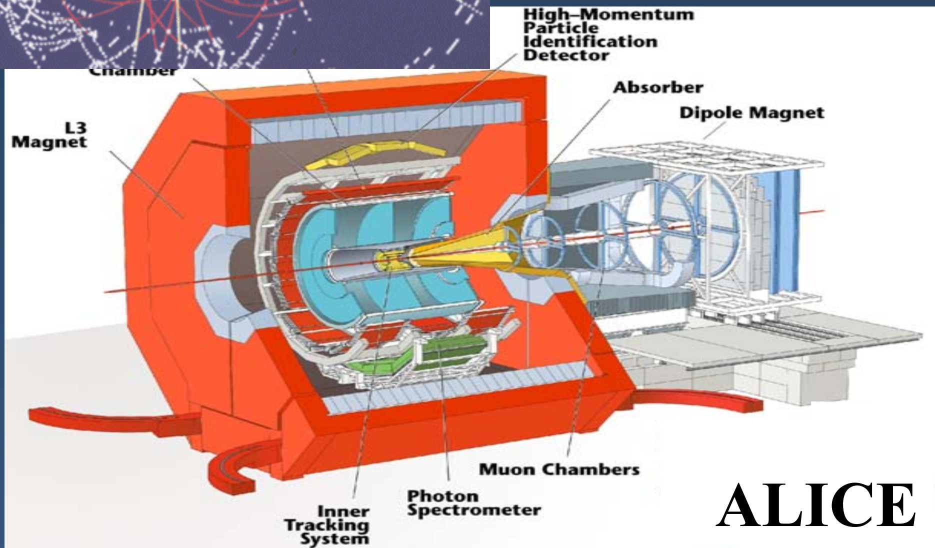
Accumulating at 5-8 PBytes/year



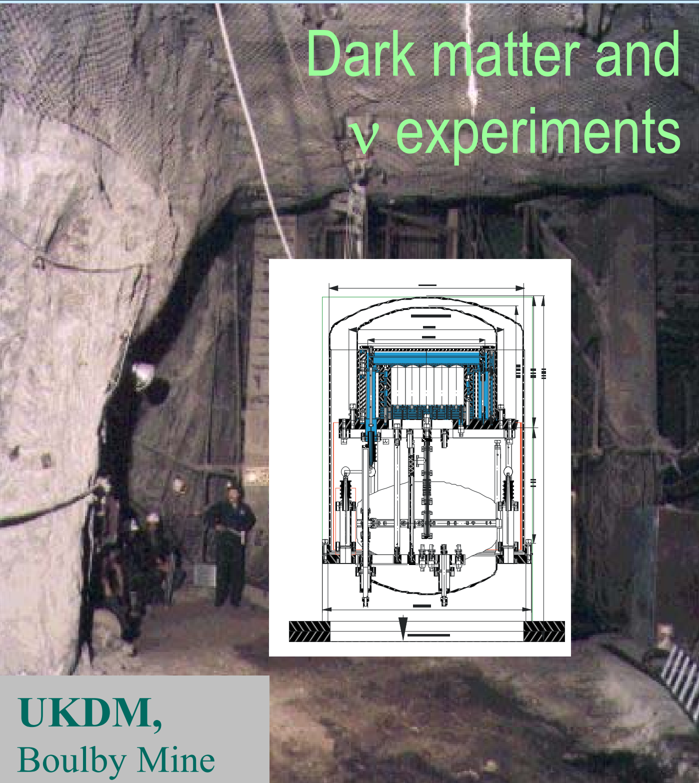
Processing

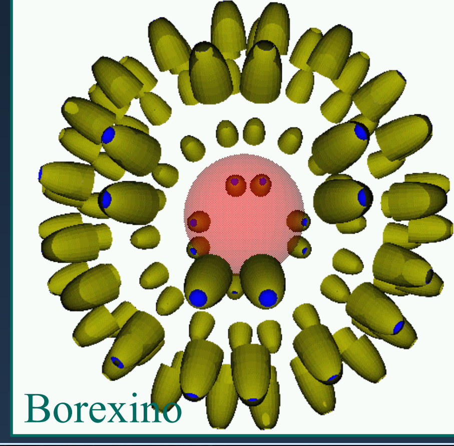
200,000 **of today's fastest PCs**



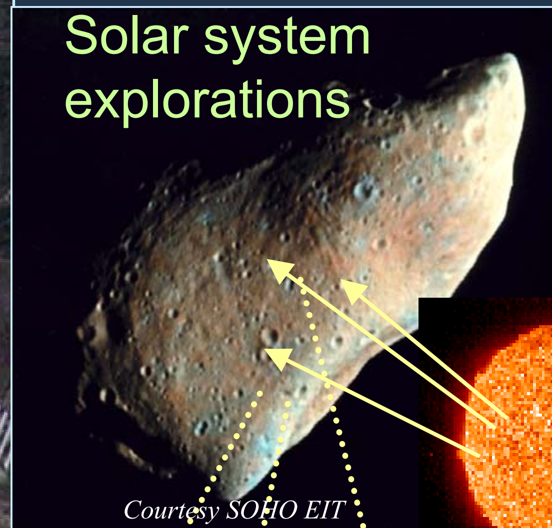


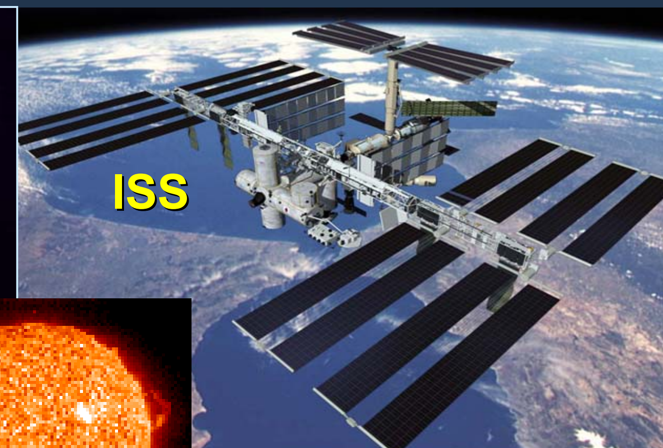
From deep underground…

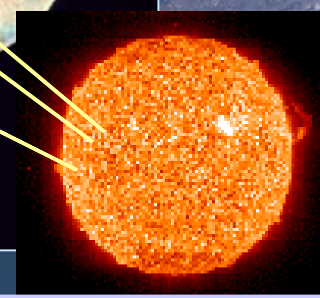




…to space







Variety of requirements from diverse applications

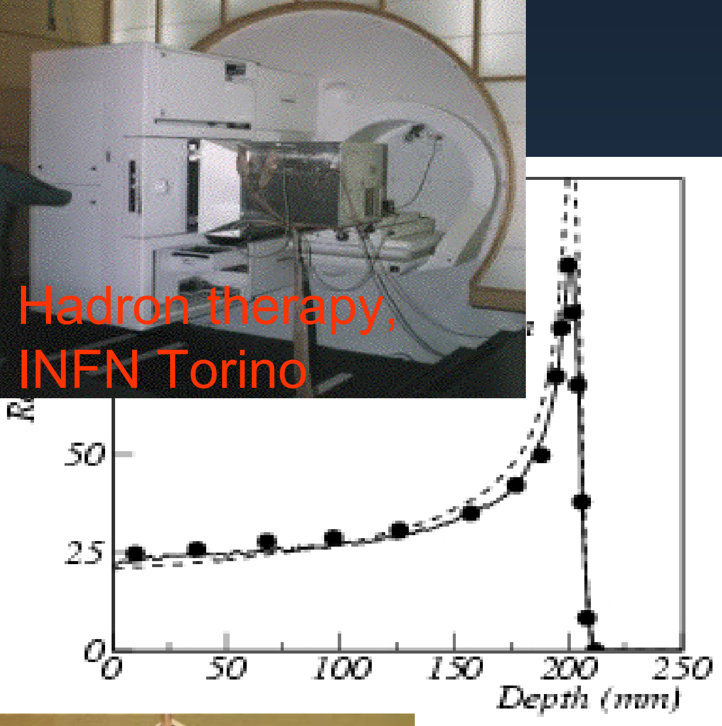
Models of detectors, spacecrafts and environments — Physics from the eV to the PeV scale

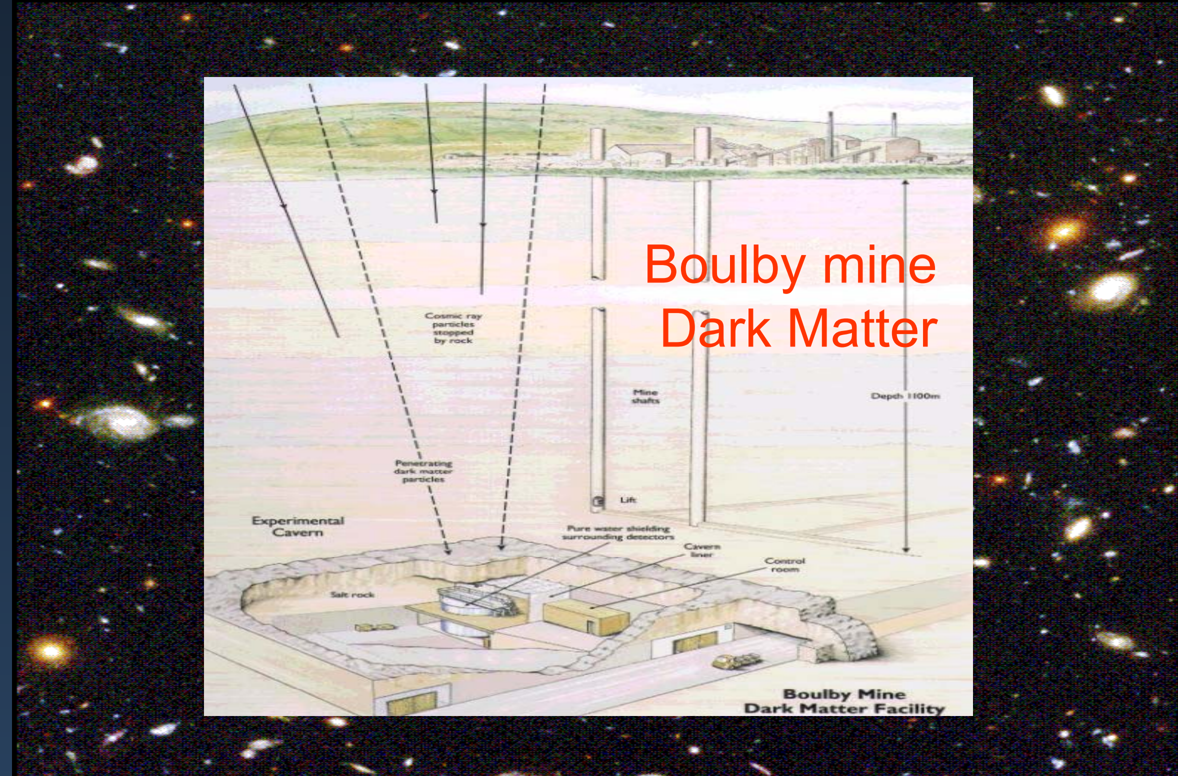
For such experiments simulation is often **mission critical**

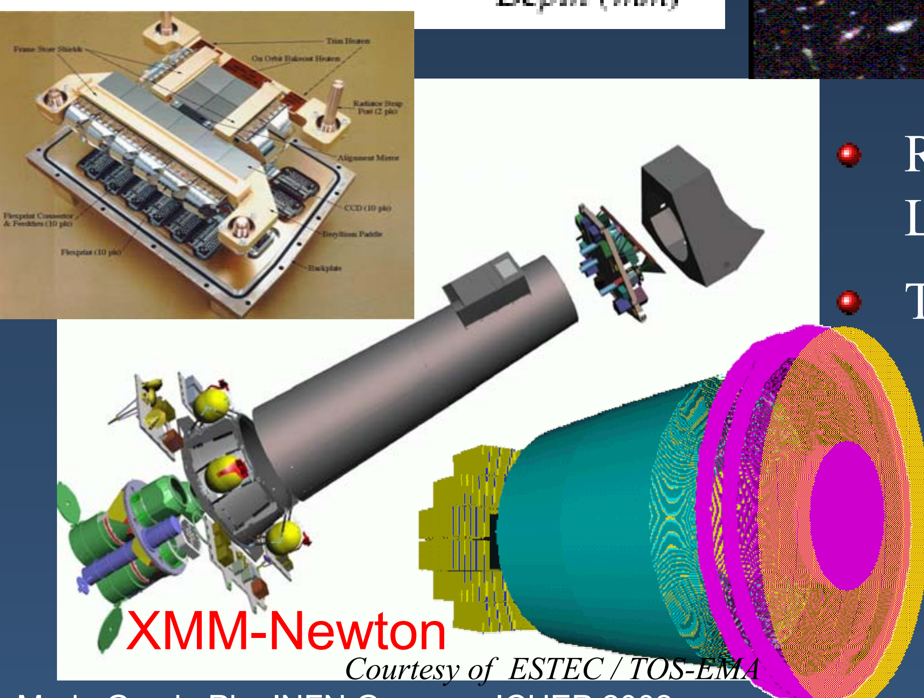
Require reliability, rigorous software engineering standards scientific...

Globalisation

Sharing requirements and functionalities across diverse fields



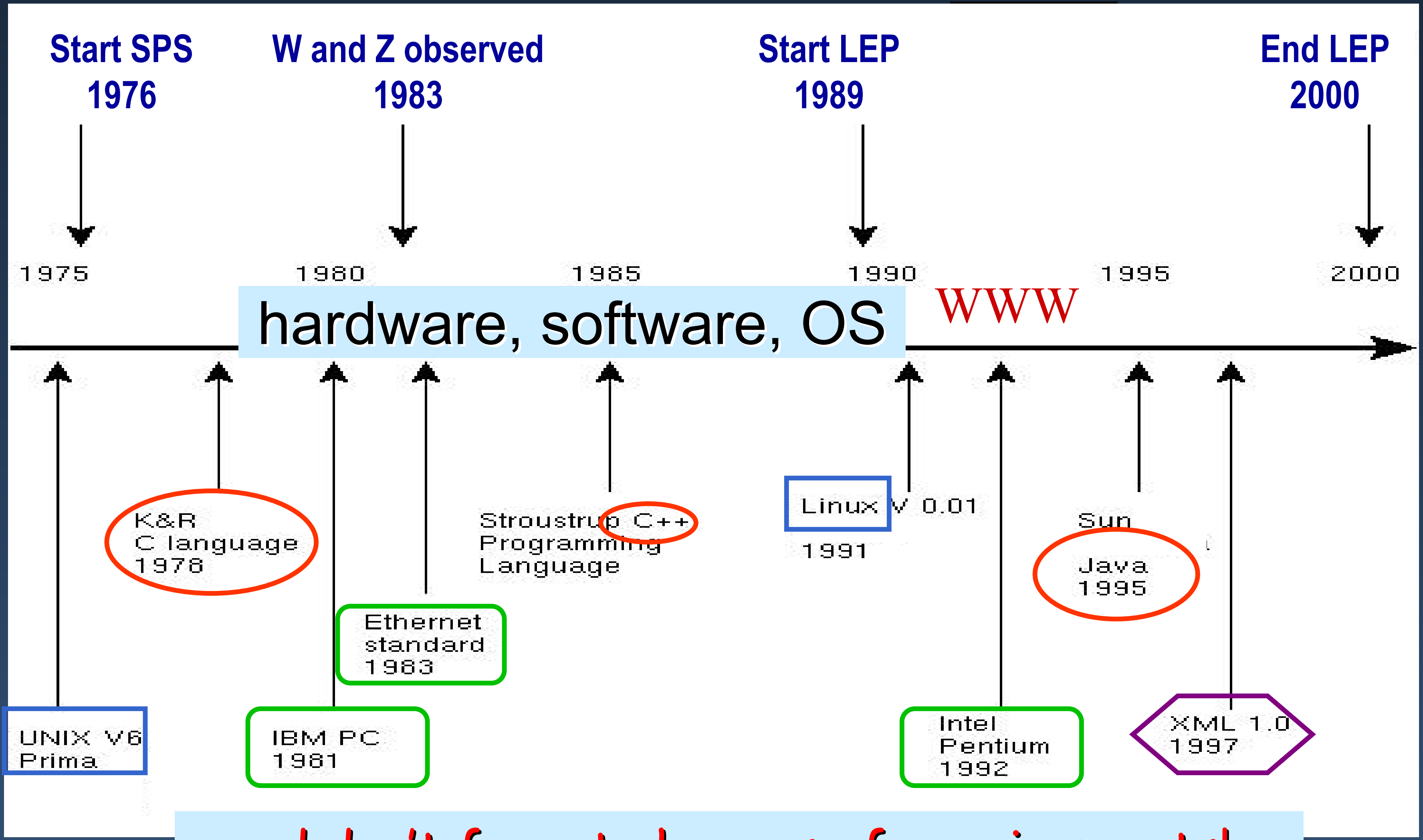




Courtesy of ESTEC / TOS-EMA

- Recent interest on LowE physics models from LHC for precision detector simulation
- They profit of the fact that the code
  - does already exist
  - has been extensively tested and experimentally validated by other groups

…in a fast changing computing environment



…and don't forget changes of requirements!

Evolution towards greater diversity ➡ we must anticipate changes

The response

Rigorous software engineering

OO technology

Transparency

Collaboration

Openness to **extension** and **evolution**

- thanks to *polymorphism* and *dynamic binding,* new implementations can be added without changing the existing code

Robustness, transparency, ease of **maintenance**

- thanks to *encapsulation,* objects have crisp boundaries
- coupling is minimised through defined protocols and dependencies

Strategic vision
(Geant4, AIDA, Anaphe…)

Toolkit

OO technology

A toolkit is a set of compatible **components**

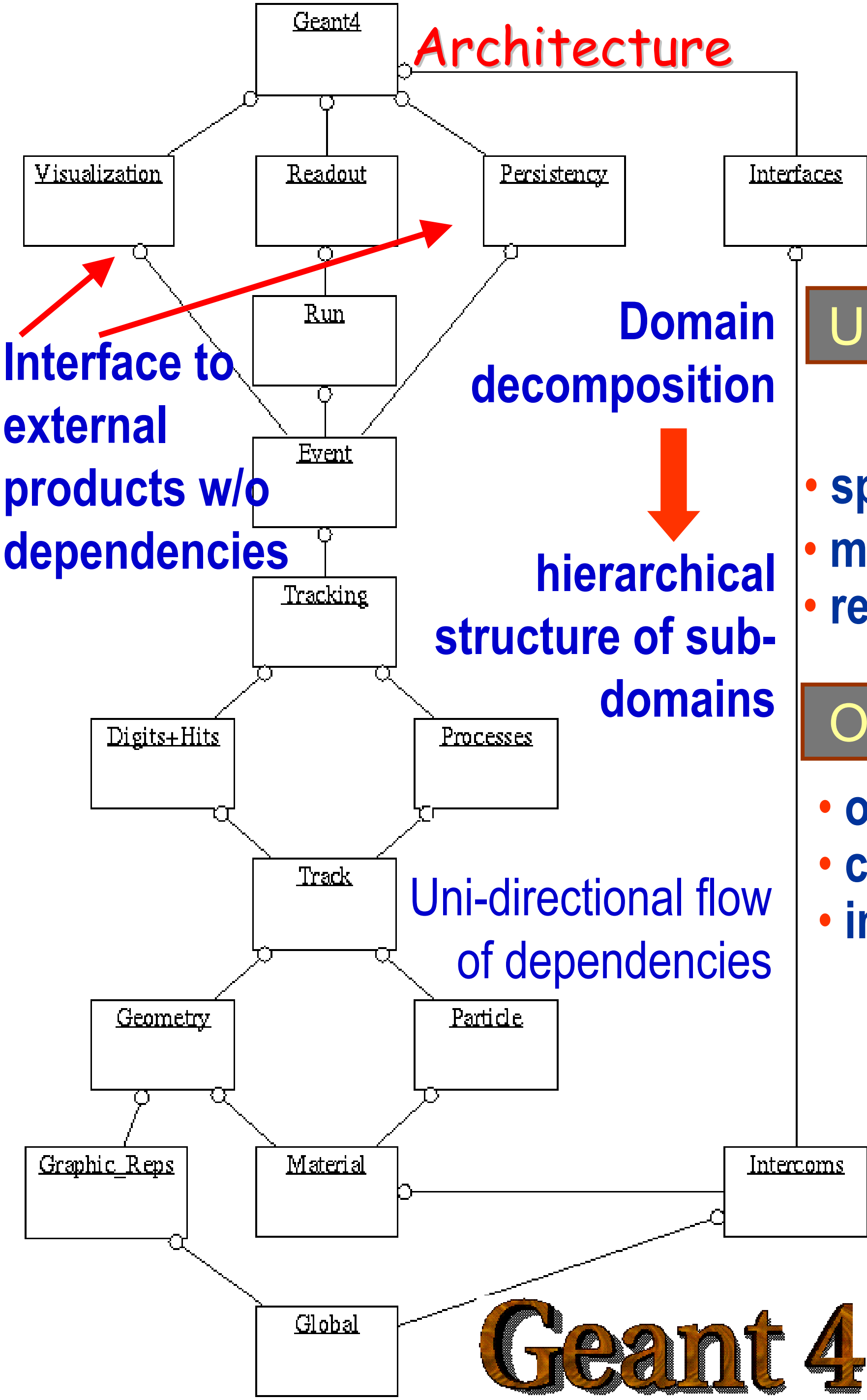
- each component is **specialised** for a specific functionality
- each component can be **refined** independently to great detail
- components can be **integrated** at any degree of complexity
- it is easy to provide (and use) **alternative** components
- the user application can be **customised** as needed
- **maintenance** and **evolution** - *both of the components and of the user application* - is greatly facilitated

Physics

Geant 4

From the Minutes of LCB (LHCC Computing Board) meeting on 21 October, 1997:

"It was noted that experiments have requirements for **independent**, **alternative physics models**. In Geant4 these models, differently from the concept of packages, allow the user to **understand** how the results are produced, and hence improve the **physics validation**. Geant4 is developed with a modular architecture and is the ideal framework where existing components are integrated and new models continue to be developed."



Software Engineering

plays a fundamental role in Geant4

User Requirements
- formally collected
- systematically updated

Software Process
- spiral iterative approach
- monitored following the ISO 15504 model
- regular assessments and improvements: SPI process

Object Oriented methods
- OOAD
- use of CASE tools
- openness to extension and evolution
- contribute to the transparency of physics
- interface to external software w/o dependencies

Quality Assurance
- commercial tools
- code inspections
- automatic checks of coding guidelines
- testing procedures at unit and integration level
- dedicated testing team

Use of Standards
- de jure and de facto

Geant 4

Geant 4

- run, event and track management
- tracking
- geometry and materials
- detector response
- PDG-compliant particle management
- user interface
- visualisation
- persistency
- **physics processes**

- Code and documentation publicly distributed from web
- 1st production release: end 1998
  - 2 new releases/year since then
- Developed and maintained by an international collaboration of physicists and computer scientists

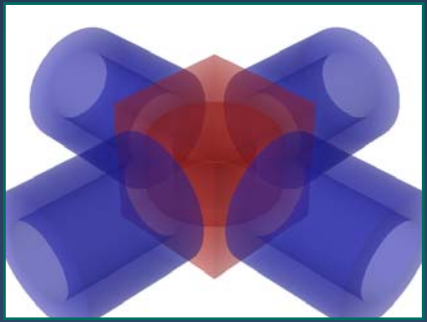
Geant 4

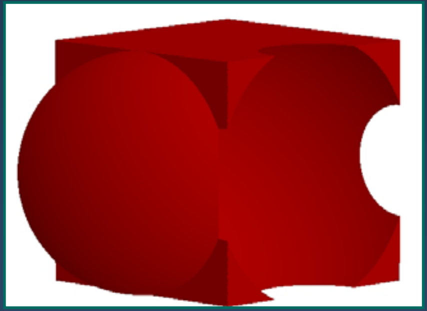
Geometry

Detailed detector description and efficient navigation

Multiple representations
Same abstract interface

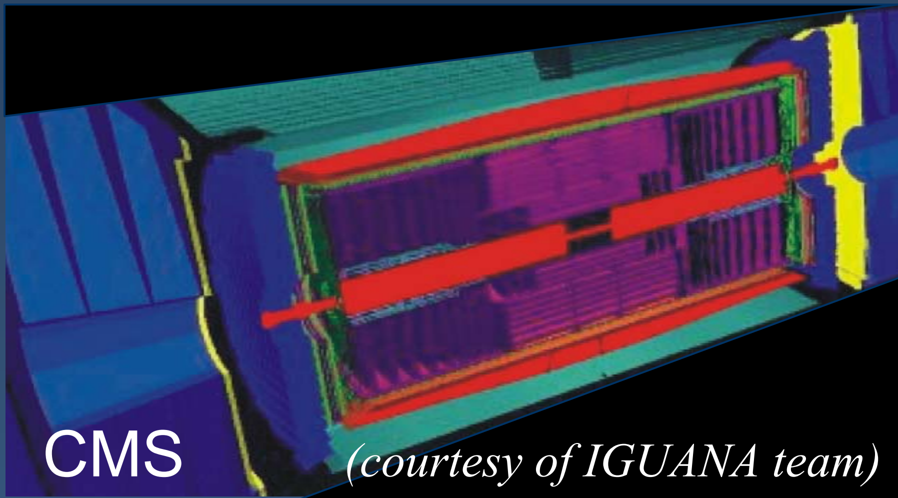
- CSG (*Constructed Solid Geometries*)
  - simple solids
- BREPS (*Boundary REPresented Solids*)
  - volumes defined by boundary surfaces
  - polyhedra, cylinders, cones, toroids etc.
- Boolean solids
  - union, subtraction…





CAD exchange: ISO STEP interface

Fields: variable non-uniformity and differentiability



(courtesy of IGUANA team)

Geant 4 physics

- OOD: implement or modify any physics process w/o changing other parts of the software
  - → *open to extension and evolution*
- **Tracking** independent from **physics**
- **Final state** independent from **cross sections**
- Complementary/alternative **physics models**
- Use of public **evaluated databases**

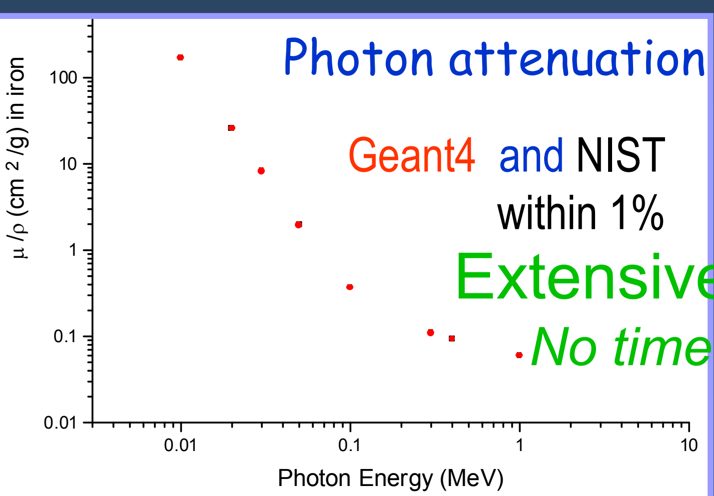
Electromagnetic

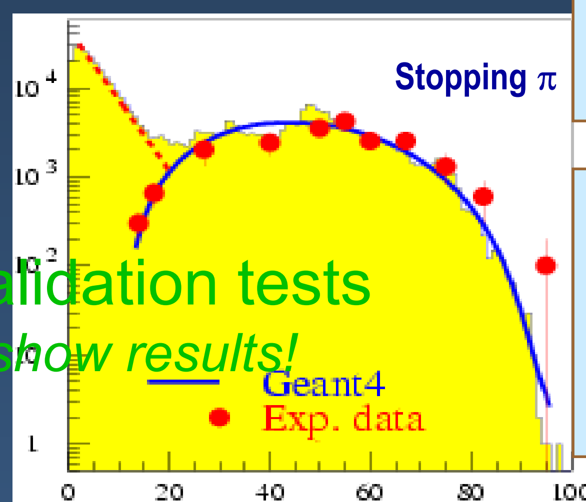
- Multiple scattering
- Bremsstrahlung
- Ionisation
- Annihilation
- Photoelectric effect
- Compton scattering
- Rayleigh effect
- γ conversion
- e^+e^- pair production
- Synchrotron radiation
- Transition radiation
- Cherenkov
- Refraction
- Reflection
- Absorption
- Scintillation
- Fluorescence
- Auger

Hadronic

- data-driven
- parameterised
- theoretical

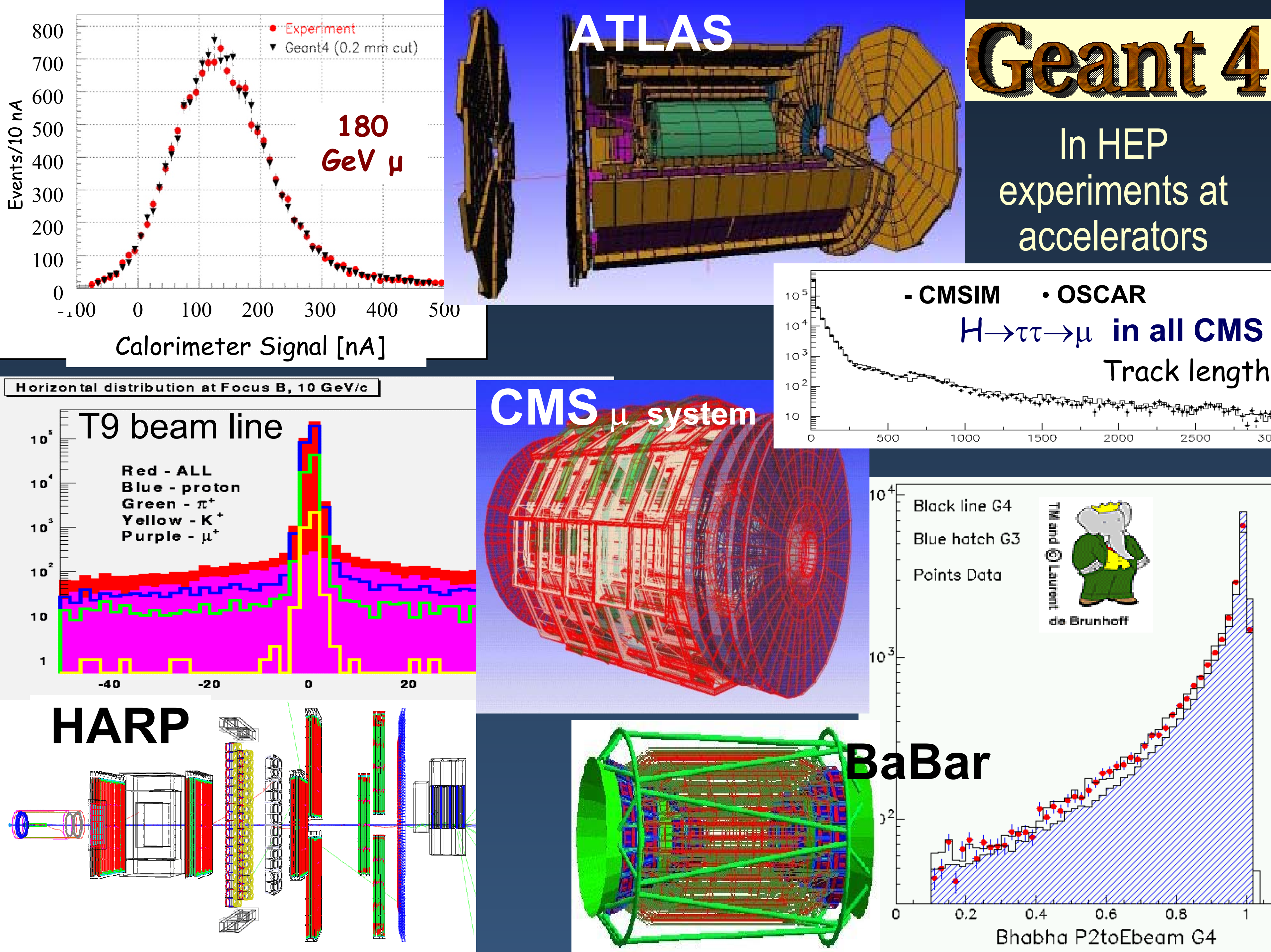
models





Extensive validation tests

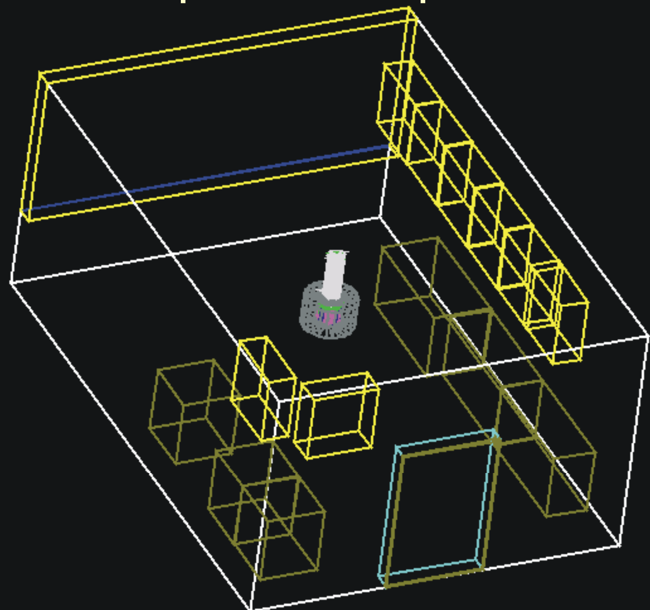
No time to show results!



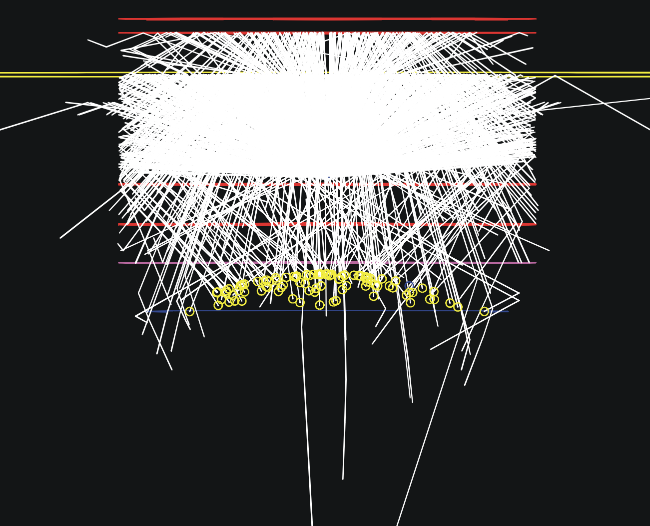
Geant 4
In HEP experiments at accelerators
ATLAS
Experiment
Geant4 (0.2 mm cut)
180 GeV μ
Events/10 nA
Calorimeter Signal [nA]
- CMSIM
• OSCAR
H→ττ→μ in all CMS
Track length
Horizontal distribution at Focus B, 10 GeV/c
T9 beam line
Red - ALL
Blue - proton
Green - π+
Yellow - K+
Purple - μ+
CMS μ system
HARP
BaBar
Black line G4
Blue hatch G3
Points Data
TM and © Laurent de Brunhoff
Bhabha P2toEbeam G4

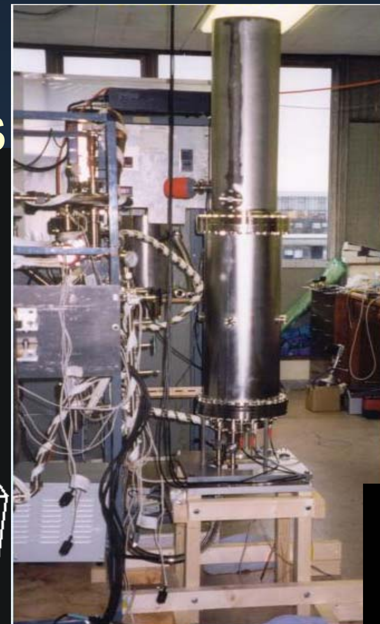
Geant 4

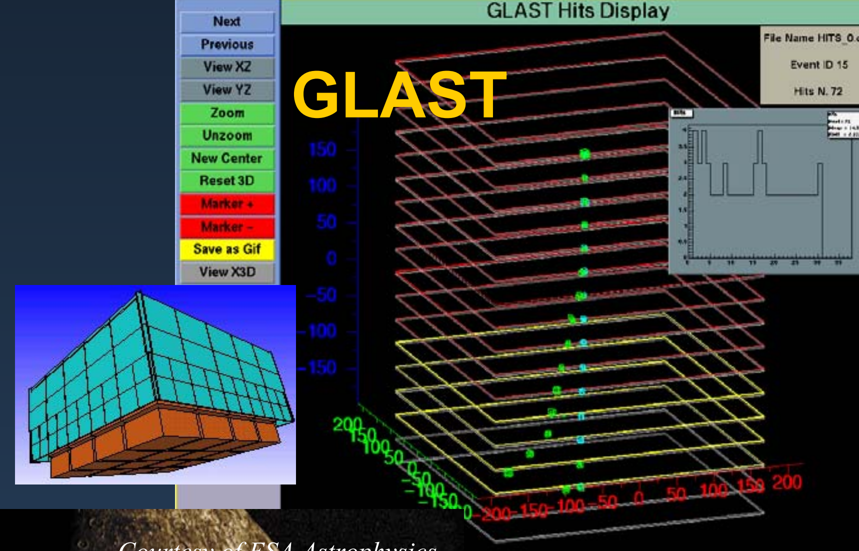
In astroparticle experiments



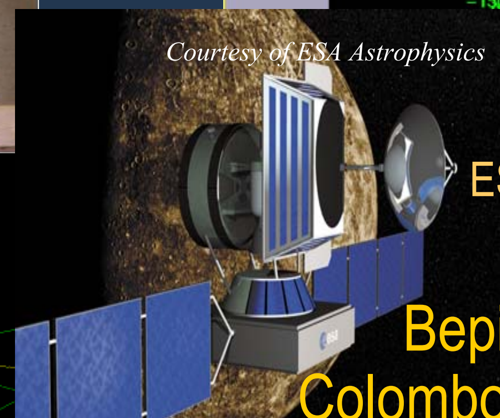
UK Dark Matter





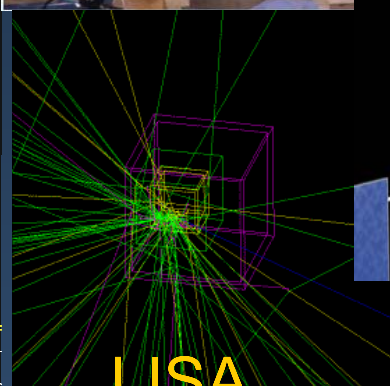


GLAST

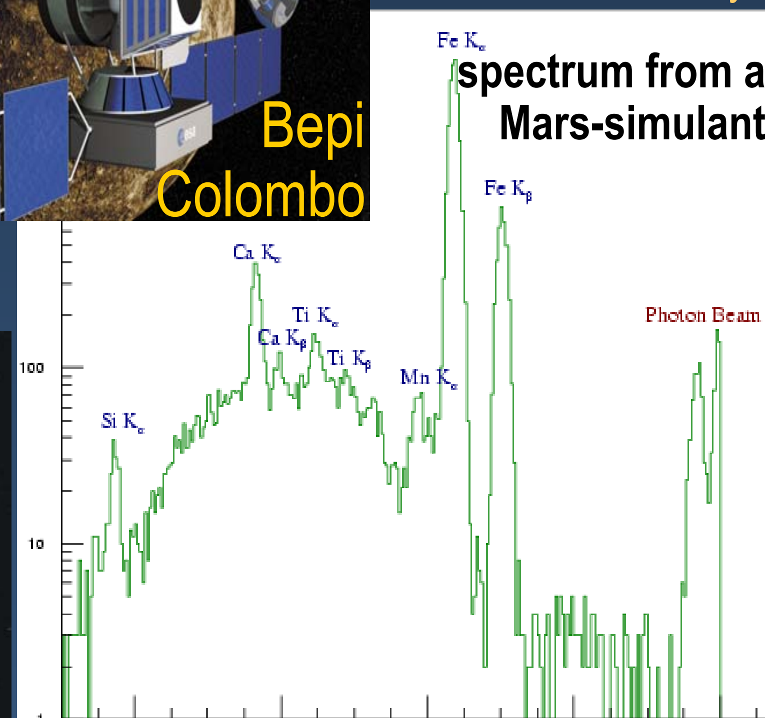


ESA mission to Mercury

Bepi Colombo



LISA

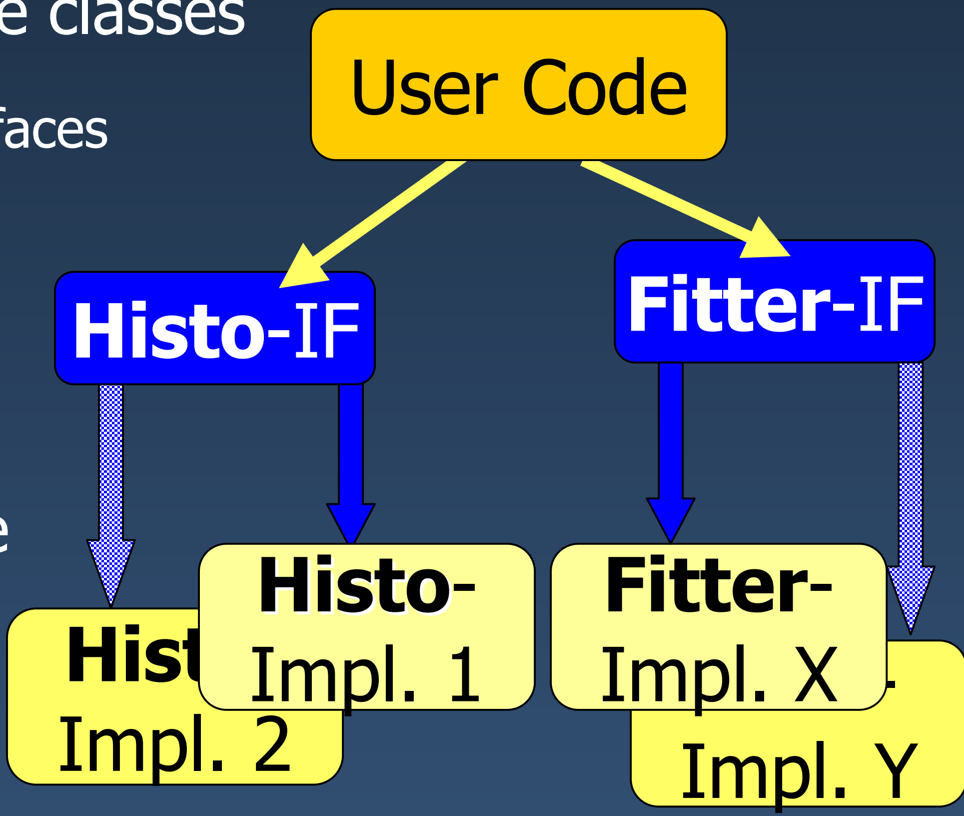


spectrum from a Mars-simulant

AIDA - Abstract Interfaces for Data Analysis

"The goals of the AIDA project are to define abstract interfaces for common physics analysis objects, such as *histograms, ntuples, vectors, fitters etc*.

- User Code uses only Interface classes
  - pure abstract (à la Java) interfaces
- Actual implementations are selected at run-time
  - ➔ loading of shared libraries
- No change at all to user code
- but keep freedom to choose implementation



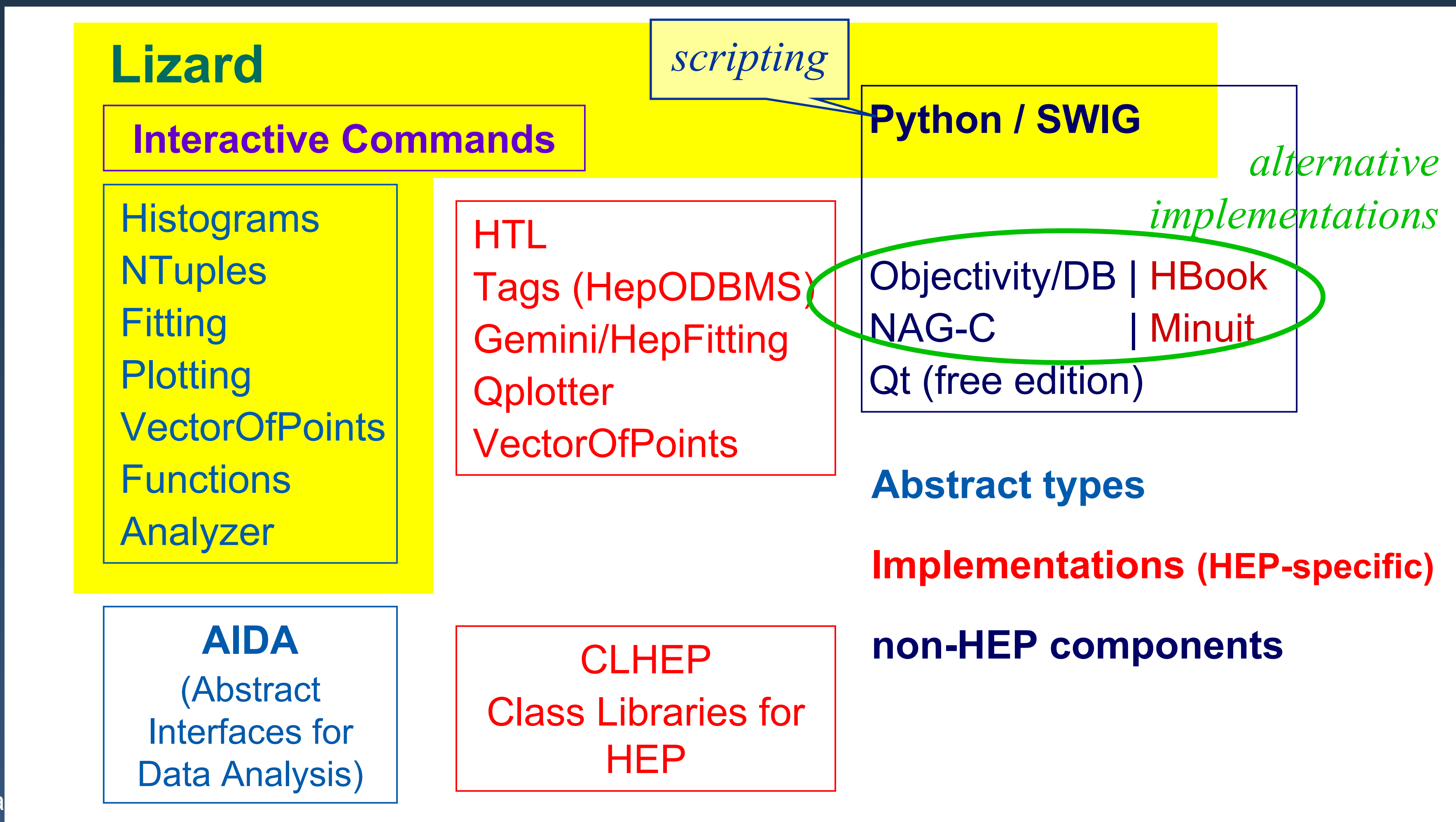
Anaphe/Lizard *(C++)*
http://cern.ch/anaphe

JAS *(Java)*
http://jas.freehep.org/

Open Scientist *(C++)*
http://www.lal.in2p3.fr/OpenScientist

Anaphe

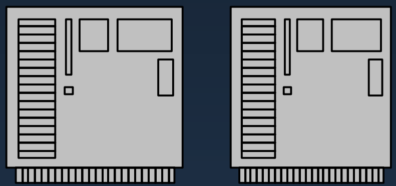
- Analysis for physics experiments
- Modular replacement of *CERNLIB functionality*
- Basic functionalities (histograms, fitting, etc.) available as individual C++ class libraries
- Insulate **components** through **Abstract Interfaces**



Globalisation

Sharing resources across the world

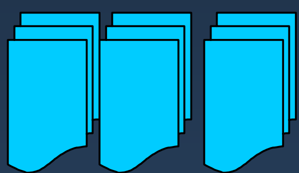
The GRID vision



Computing resources

Complex problem

Instruments



Data

People

Knowledge

"Eventually, users will be unaware they are using any computer but the one on their desk, because it will have the capabilities to reach out across the (inter-)national network and obtain whatever computational resources are necessary"
(Larry Smarr and Charles Catlett, 1992)

NorduGrid is a GRID research project which provides a fully operational GRID system

- 10 GRID-connected sites with about 210 CPUs
- On-going simulation tasks: ATLAS (Data Challenges), theoretical physics at NORDITA

Nordic Testbed for Wide Area Computing and Data Handling

Technology transfer

Particle physics software aids space and medicine

"Geant4 is a showcase example of technology transfer from particle physics to other fields such as space and medical science"

Medical applications of Geant4:

- *radiotherapy*
- *metabolic therapy*
- *design of accelerators*
- *radiodiagnostics (PET)*
- *etc.*

Conclusions

Complexity of physics, detectors, environments

A rapidly changing computing environment

Similar requirements across diverse fields (HEP, astrophysics, medicine…)

The response:

- rigorous approach to software engineering
- OO technology
- collaboration to share resources

Achieve:

- openness to extension and evolution
- maintainability over an extended time scale
- transparency

Adopted by:

- Geant4 *(simulation)*
- AIDA + Anaphe *(analysis tools)*