Reconstruction and Analysis Software Environment of LHCb

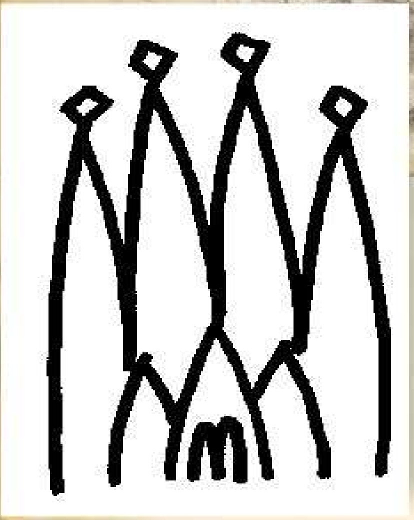
- LHCb reconstruction and analysis
- Software Architecture “**Gaudi**”
- Some Examples:
  - High-Level Trigger
  - Event Display
  - Interactive Analysis

Patrick Koppenburg

CERN / PH

On behalf of the LHCb collaboration

Software Environment of LHCb



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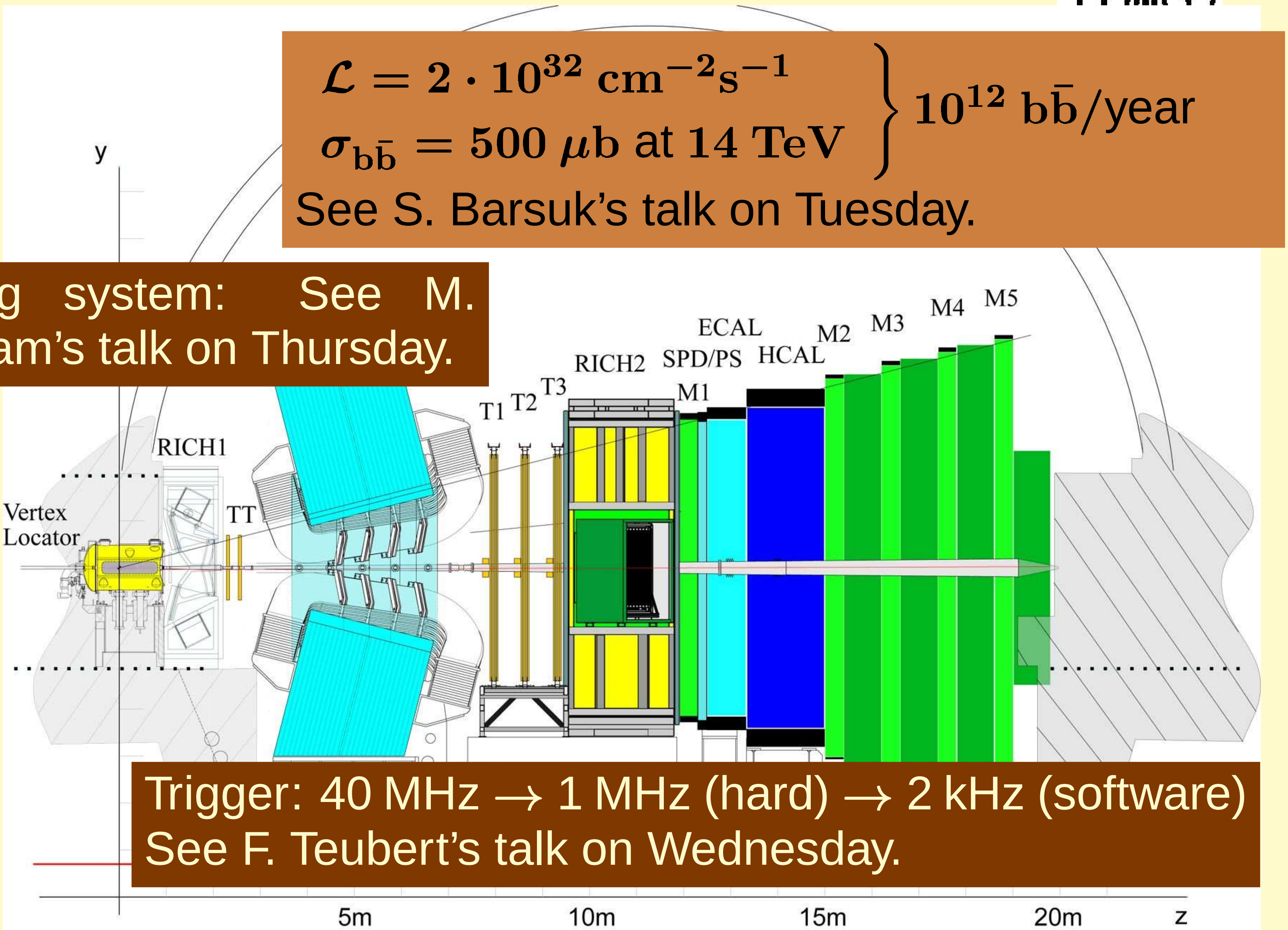
LHCb

$$\left.\begin{array}{l}\mathcal{L} = 2 \cdot 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1} \\ \sigma_{\mathrm{b\bar{b}}} = 500\ \mu\mathrm{b}\ \text{at}\ 14\ \mathrm{TeV}\end{array}\right\} 10^{12}\ \mathrm{b\bar{b}}/\text{year}$$

See S. Barsuk’s talk on Tuesday.

Tracking system: See M. Needham’s talk on Thursday.



Trigger: 40 MHz → 1 MHz (hard) → 2 kHz (software)
See F. Teubert’s talk on Wednesday.

LHCb Software strategy

Structure: Develop an *Architecture* ("blueprint") and a *Framework* (real code) to be used at all stages of LHCb data processing

- Software triggers, simulation, reconstruction, analysis, visualization. . .
- One single framework used by all members of the collaboration for all code

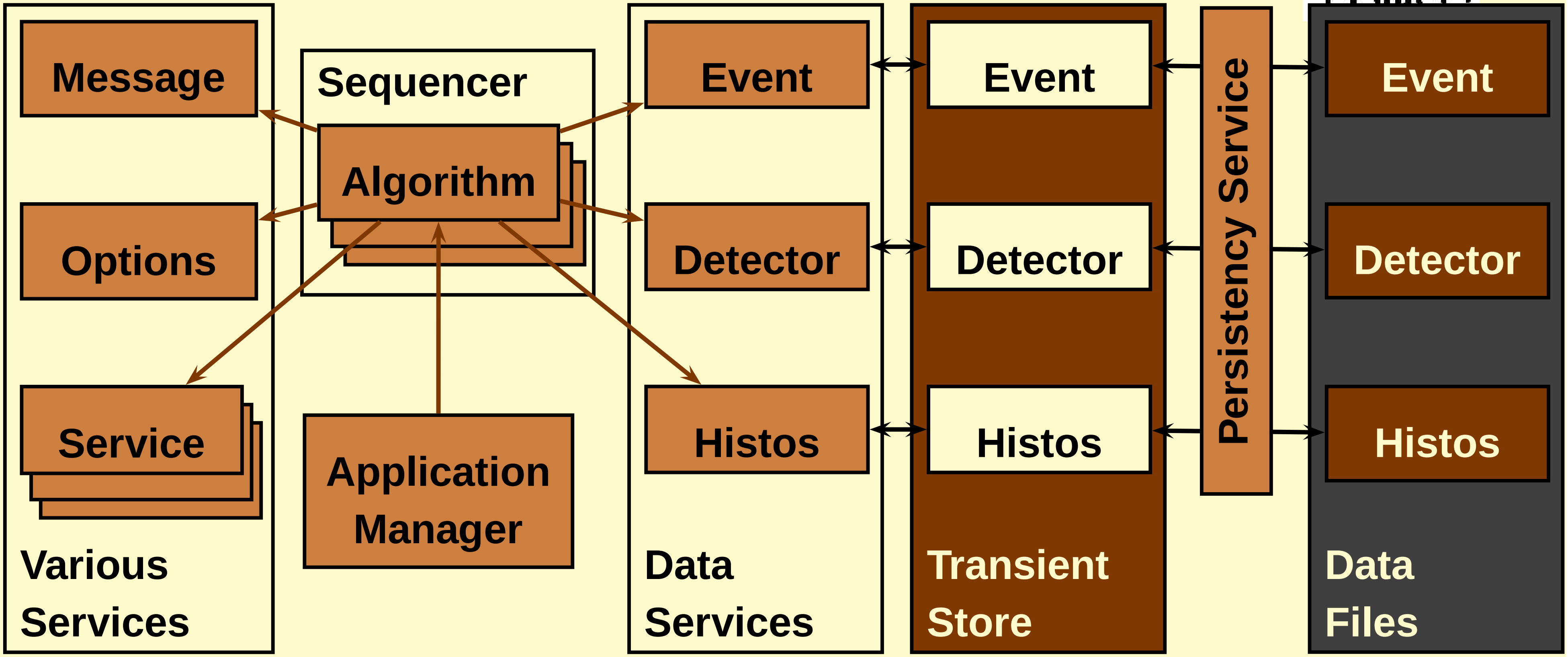
→ **Gaudi**

Development: Avoid duplication of computing effort

- Develop simple components that can be used in any environment
- Use common interfaces to allow easy "plug-and-play" switching of tools. Ex: Vertex Fitters, Cuts. . .

Applications are developed by customizing the framework.

Gaudi Architecture



- Separation of “data” and “algorithms”: Write 00 code, but profit from decades of HEP experience
- Separation of “transient” and “persistent” data
- Physicist code encapsulated in specific places (Algorithms)

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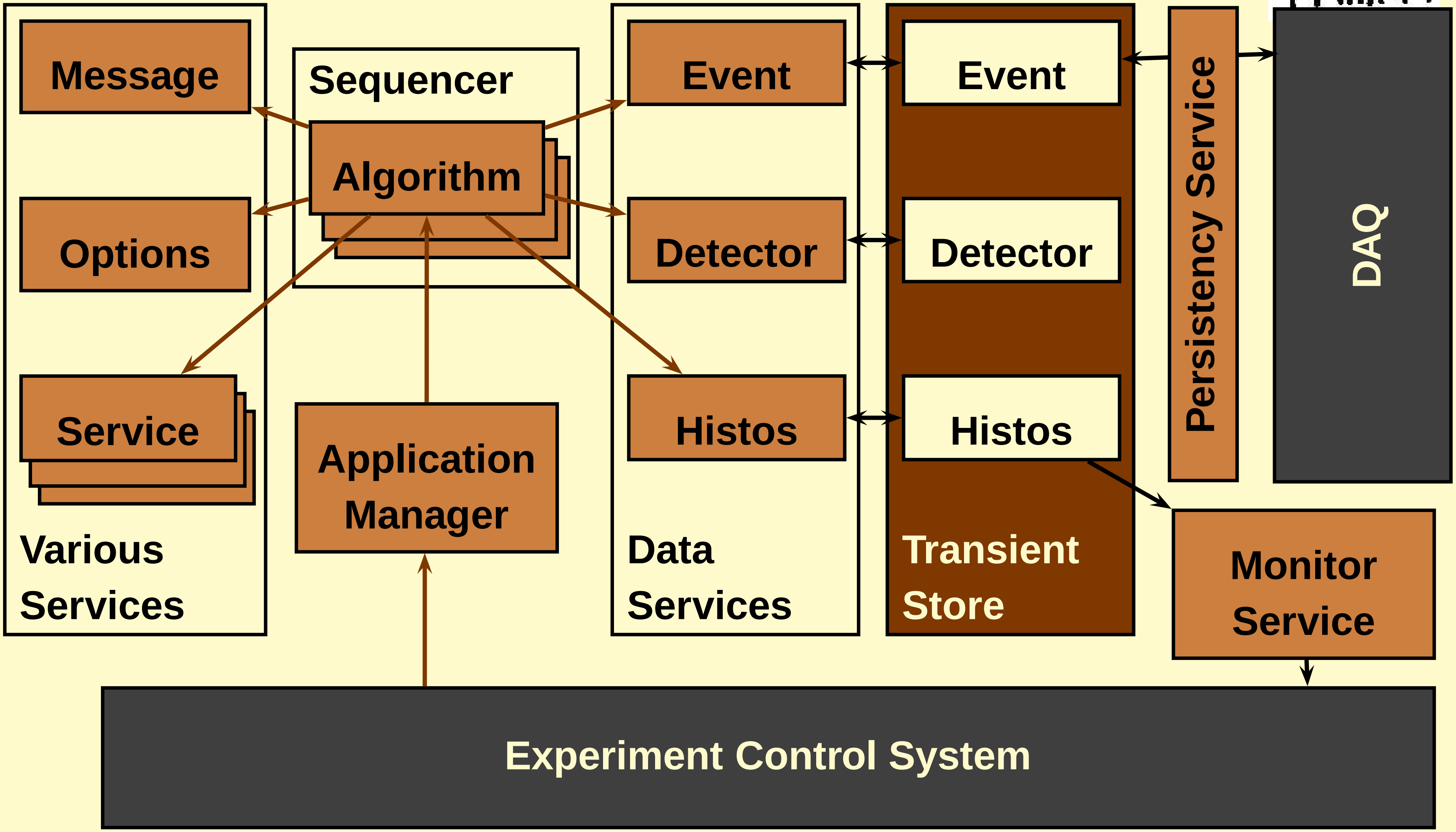
Gaudi Architecture



The same architecture is used online in the software triggers
→ The same algorithms are used

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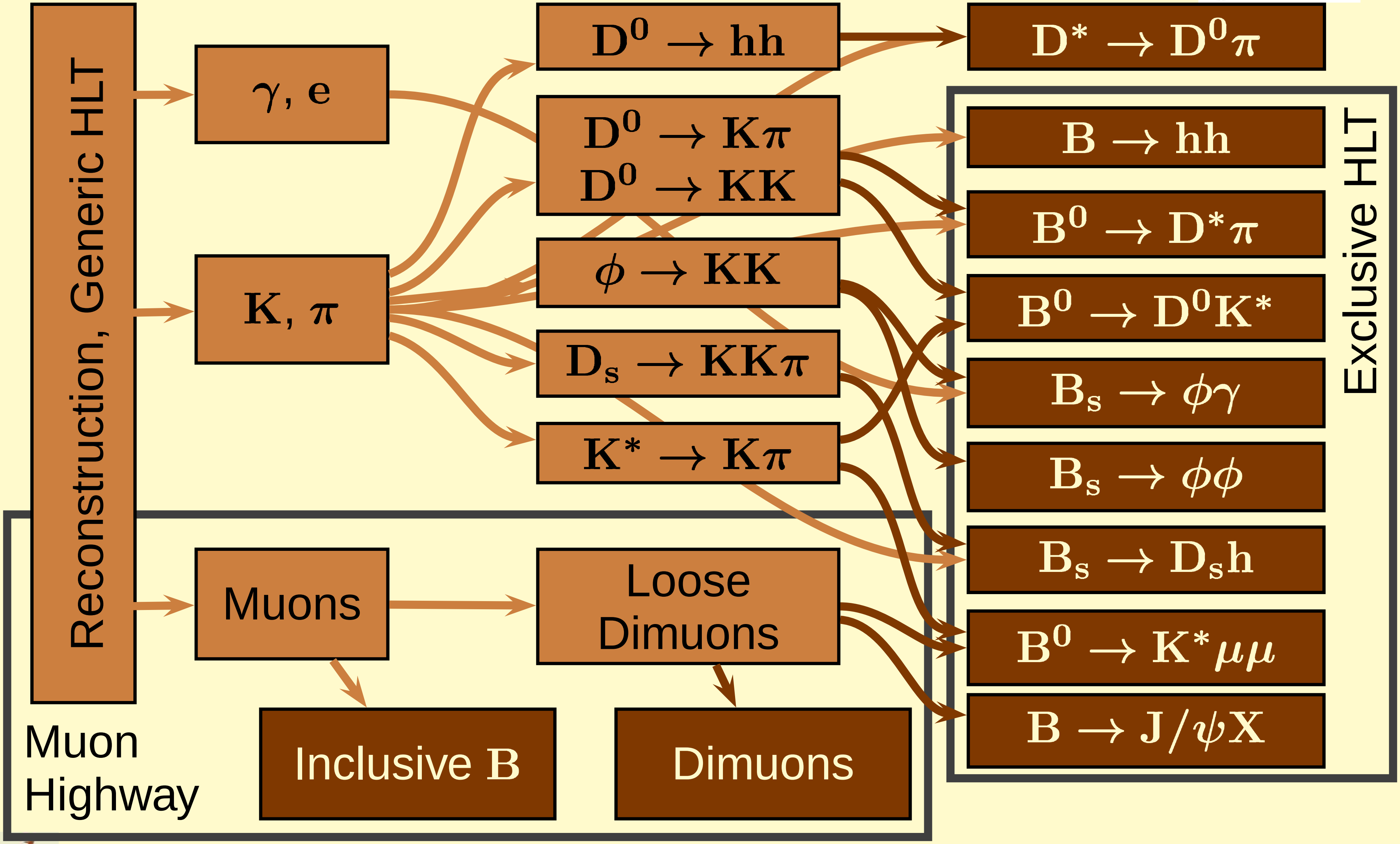
Example: High-Level Trigger



Reconstruction, Generic HLT

γ, e

K, π

Muons

$D^0 \rightarrow hh$

$D^0 \rightarrow K\pi$

$D^0 \rightarrow KK$

$\phi \rightarrow KK$

$D_s \rightarrow KK\pi$

$K^* \rightarrow K\pi$

Loose Dimuons

$D^* \rightarrow D^0\pi$

Exclusive HLT

$B \rightarrow hh$

$B^0 \rightarrow D^*\pi$

$B^0 \rightarrow D^0K^*$

$B_s \rightarrow \phi\gamma$

$B_s \rightarrow \phi\phi$

$B_s \rightarrow D_sh$

$B^0 \rightarrow K^*\mu\mu$

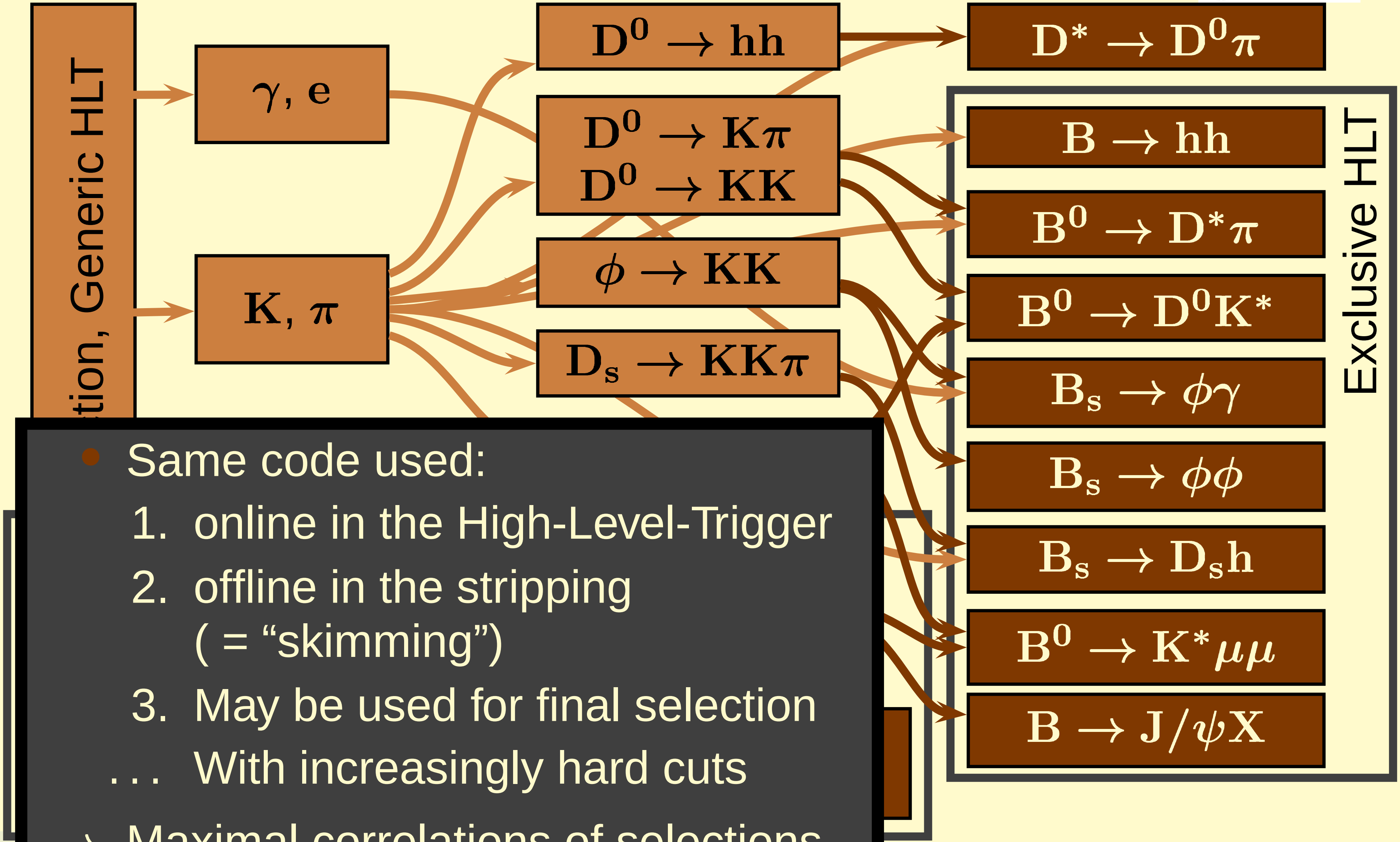
$B \rightarrow J/\psi X$

Muon Highway

Inclusive B

Dimuons

Example: High-Level Trigger



- Same code used:
  1. online in the High-Level-Trigger
  2. offline in the stripping (= “skimming”)
  3. May be used for final selection

  . . . With increasingly hard cuts

→ Maximal correlations of selections

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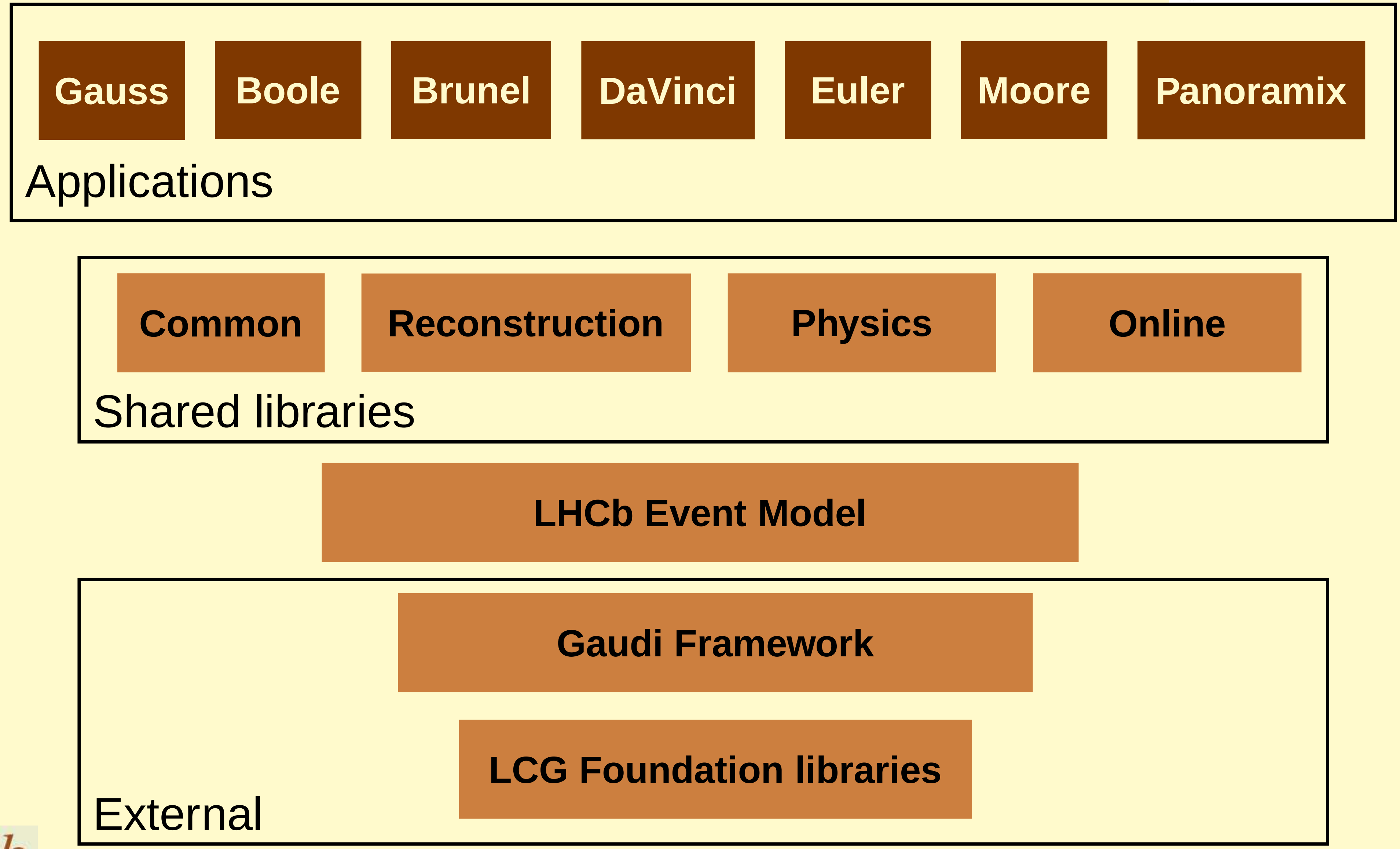
The software pyramid



Gauss Boole Brunel DaVinci Euler Moore Panoramix

Applications

Common Reconstruction Physics Online

Shared libraries

LHCb Event Model

Gaudi Framework

LCG Foundation libraries

External

Applications

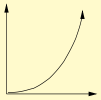
Gauss: Simulation.
Uses generators and **Geant 4**.

Boole: Digitization. Simulates detector response and transforms to “raw” data format.

Brunel: Reconstruction.
Full pattern recognition and PID.

DaVinci: Analysis. Deals with “Particles” and “Vertices”. Final event selection.

Euler: L1 Trigger. For on- and offline use.

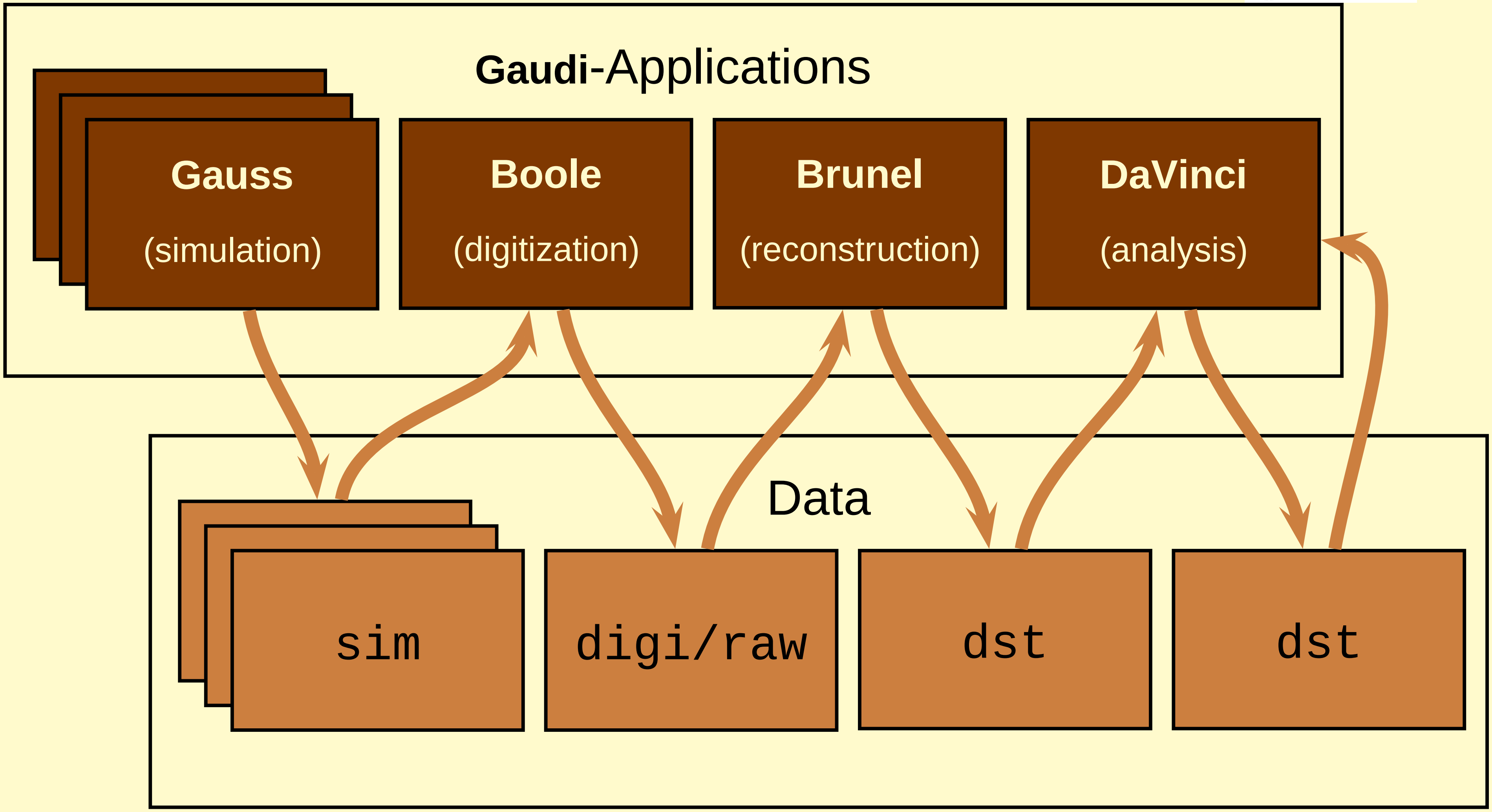


Moore: High-Level Trigger. For on- and offline use.

Panoramix: Visualization.

Bender: Interactive Analysis in `python`.

Data Production Flow



~ 400 million events produced during 2004 data challenge

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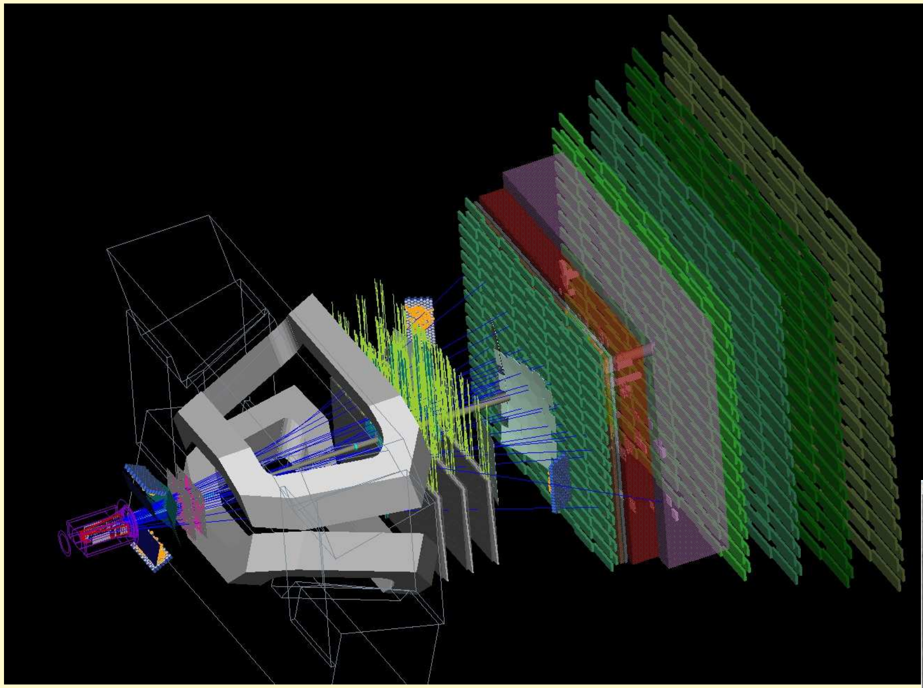
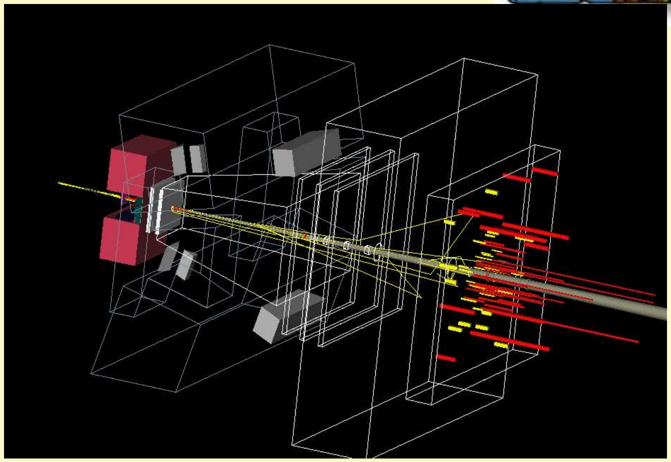
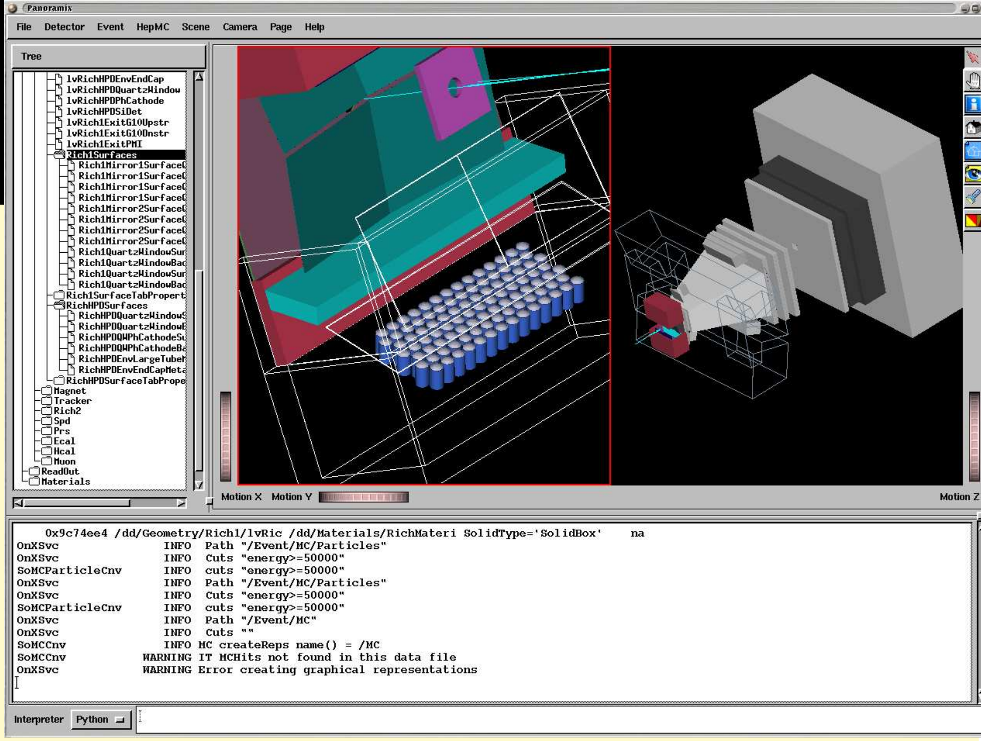
Example: Panoramix Display





- Visualization application based on **Gaudi**, **OnX** and **OpenInventor**
- Scripting based on `python`
- Allows to (re-)process everything



```
    0x9c74ee4 /dd/Geometry/Rich1/lvRic /dd/Materials/RichMateri SolidType='SolidBox'    na
OnXSvc                 INFO  Path "/Event/MC/Particles"
OnXSvc                 INFO  Cuts "energy>=50000"
SoMCParticleCnv        INFO  cuts "energy>=50000"
OnXSvc                 INFO  Path "/Event/MC/Particles"
OnXSvc                 INFO  Cuts "energy>=50000"
SoMCParticleCnv        INFO  cuts "energy>=50000"
OnXSvc                 INFO  Path "/Event/MC"
OnXSvc                 INFO  Cuts ""
SoMCCnv                INFO MC createReps name() = /MC
SoMCCnv             WARNING IT MCHits not found in this data file
OnXSvc              WARNING Error creating graphical representations
```

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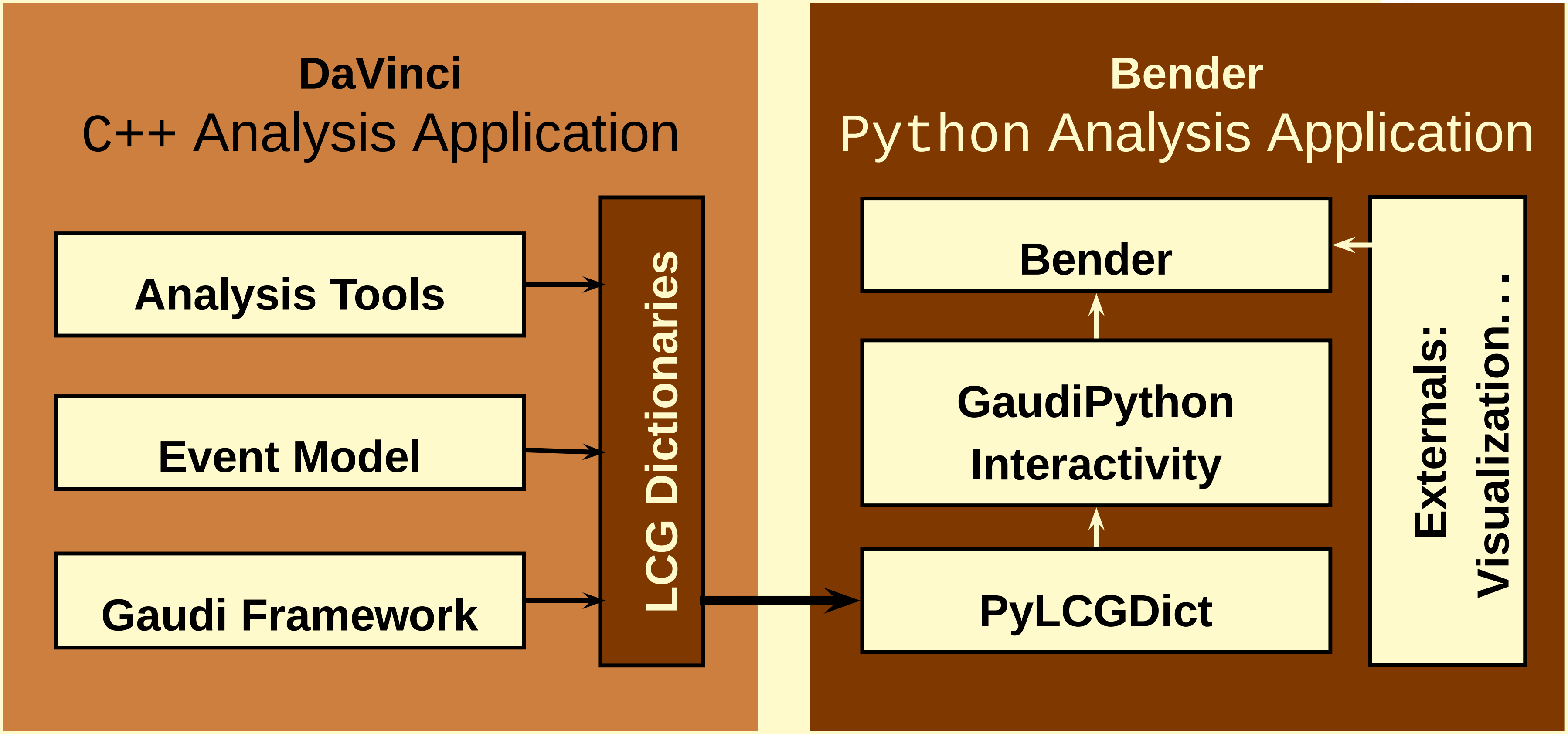
Example: Interactive analysis



DaVinci
C++ Analysis Application

Analysis Tools

Event Model

Gaudi Framework

LCG Dictionaries

Bender
Python Analysis Application

Bender

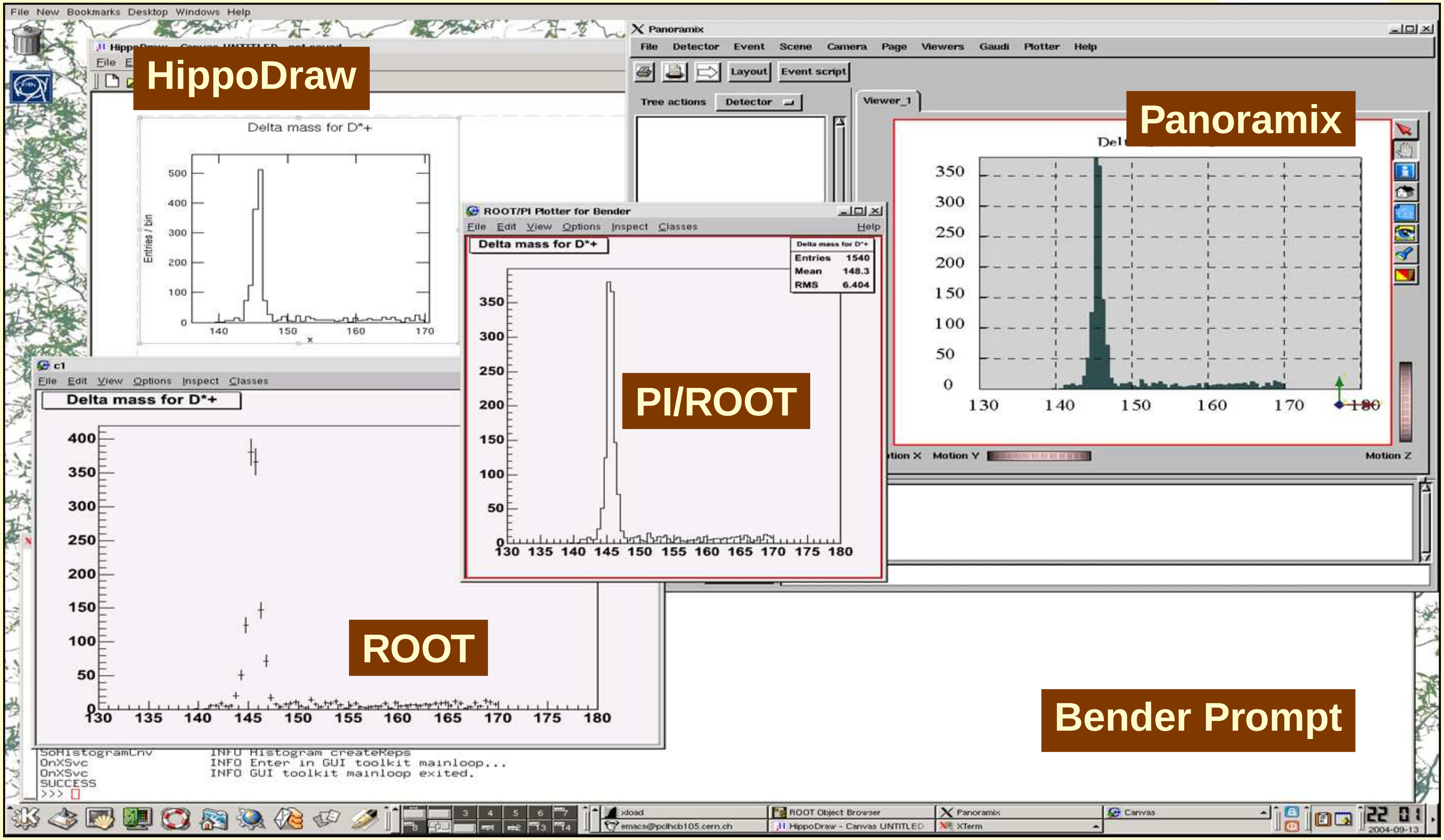
GaudiPython
Interactivity

PyLCGDict

Externals:
Visualization. . .

- **Bender** combines a `python`-wrapping of the **DaVinci** tools, the LHCb Event Model and the **Gaudi** framework
- It allows to perform interactive physics analysis. . .
- . . . and access to many external tools.

Example: Interactive analysis


File New Bookmarks Desktop Windows Help
HippoDraw - Canvas UNTITLED - not saved
Delta mass for D*+
Entries / bin
x
c1
File Edit View Options Inspect Classes
Delta mass for D*+
ROOT/PI Plotter for Bender
File Edit View Options Inspect Classes Help
Delta mass for D*+
Panoramix
File Detector Event Scene Camera Page Viewers Gaudi Plotter Help
Layout
Event script
Tree actions
Detector
Viewer_1
Motion X
Motion Y
Motion Z
xload
emacs@pclhcb105.cern.ch
ROOT Object Browser
HippoDraw - Canvas UNTITLED
Panoramix
XTerm
Canvas
2004-09-13

Delta mass for D*+
Entries 1540
Mean 148.3
RMS 6.404

```
SoHistogramCnv          INFO Histogram createReps
OnXSvc                  INFO Enter in GUI toolkit mainloop...
OnXSvc                  INFO GUI toolkit mainloop exited.
SUCCESS
>>> 
```

HippoDraw

Panoramix

PI/ROOT

ROOT

Bender Prompt

Conclusion

- A well defined structure for 500 users
- One framework for 8 applications:
  - Data production
  - Analysis
  - Trigger
  - Interactivity
- Facilitates migration of algorithms between applications
- Encourages optimal usage of the code
- Helps to minimize inefficiencies
- Allows analysis in `C++` or `python`