The ROOT System

A Data Storage & Analysis Framework

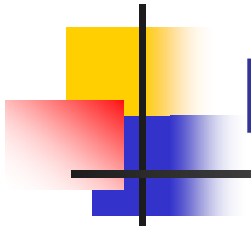
Mission to CERN in Distributed IT Applications

CERN 30 June 2004

René Brun

CERN

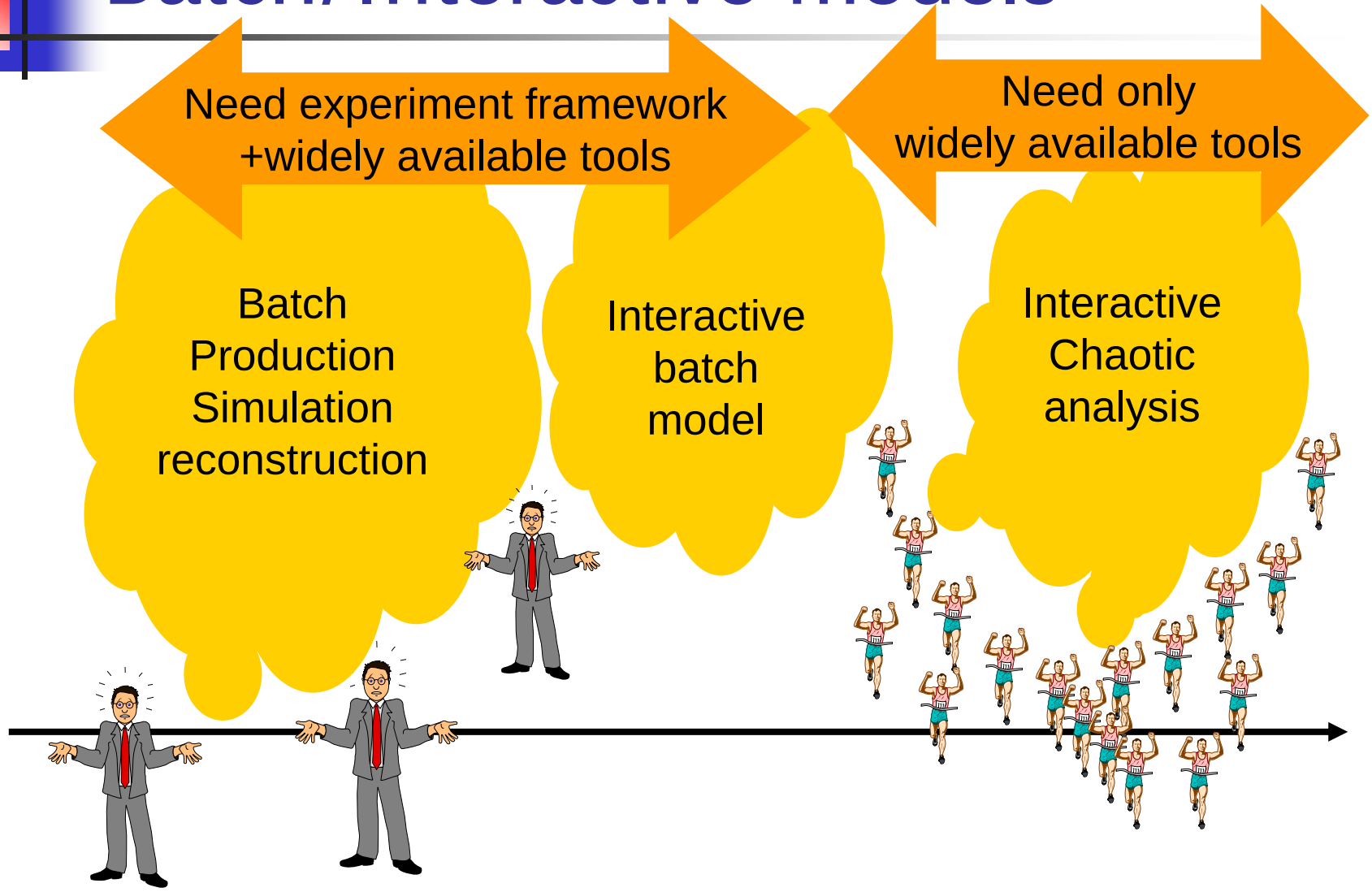
http://root.cern.ch



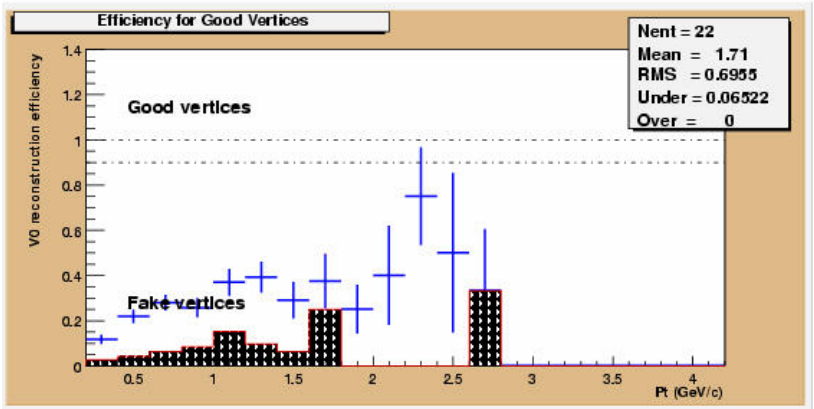
ROOT in a nutshell

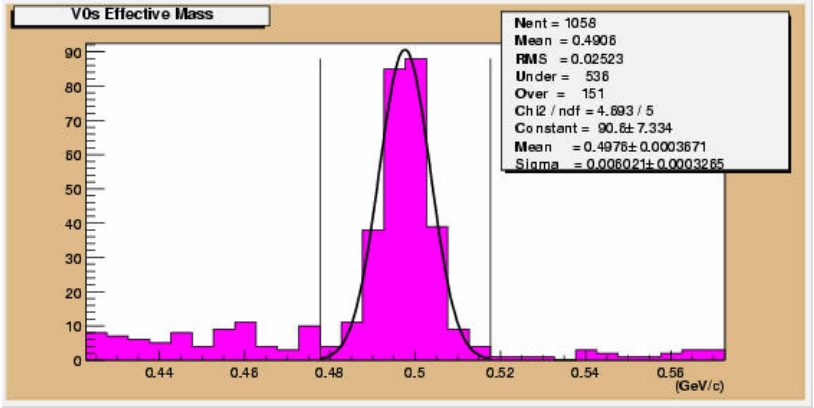
- An efficient data storage and access system designed to support structured data sets in very large distributed data bases (Petabytes).
- A query system to extract information from these distributed data sets.
- The query system is able to use transparently parallel systems on the GRID (PROOF).
- A scientific visualisation system with 2-D and 3-D graphics.
- An advanced Graphical User Interface
- A C++ interpreter allowing calls to user defined classes.
- An Open Source Project

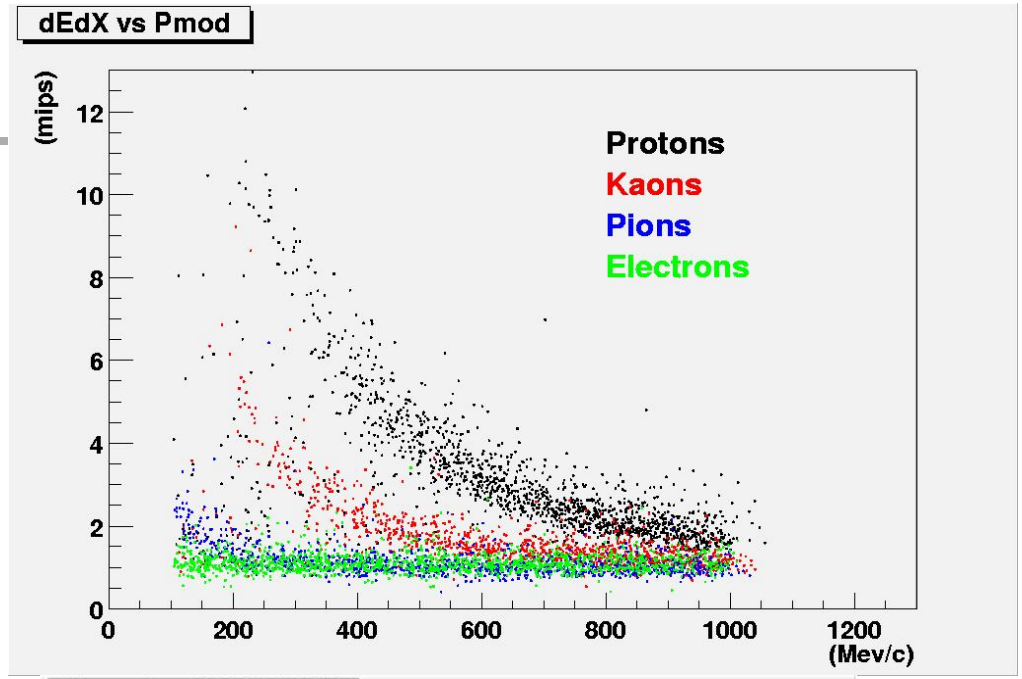
Batch/Interactive models

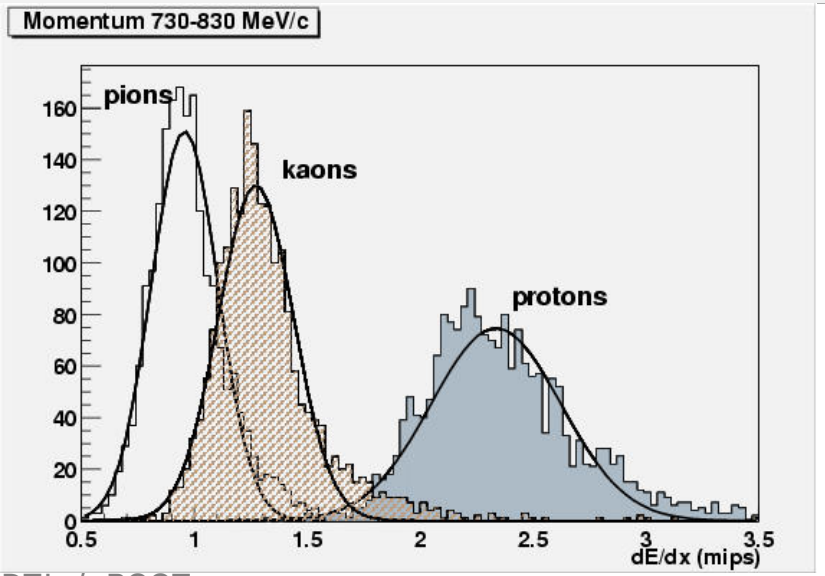


A Data Analysis & Visualisation tool

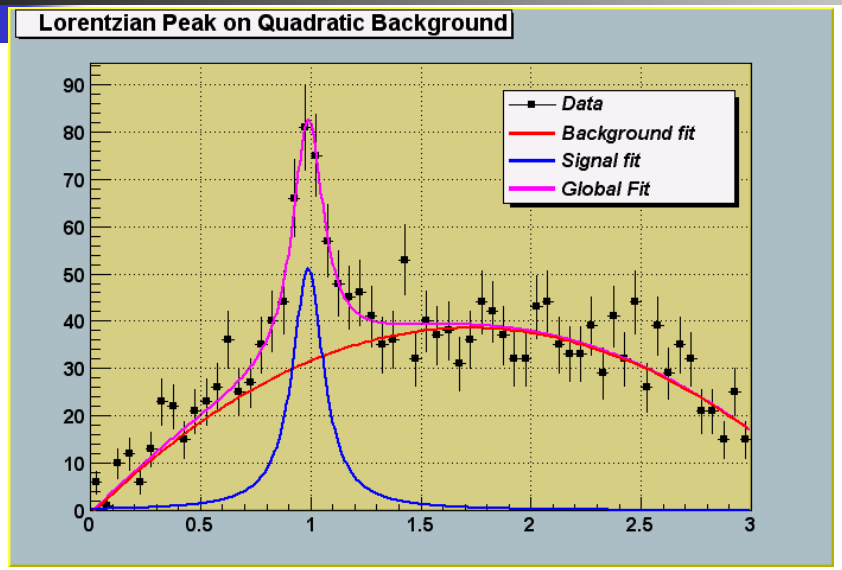


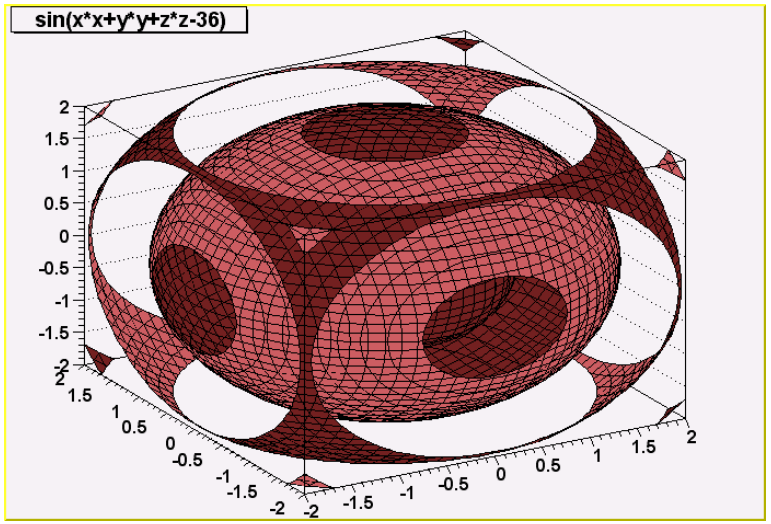


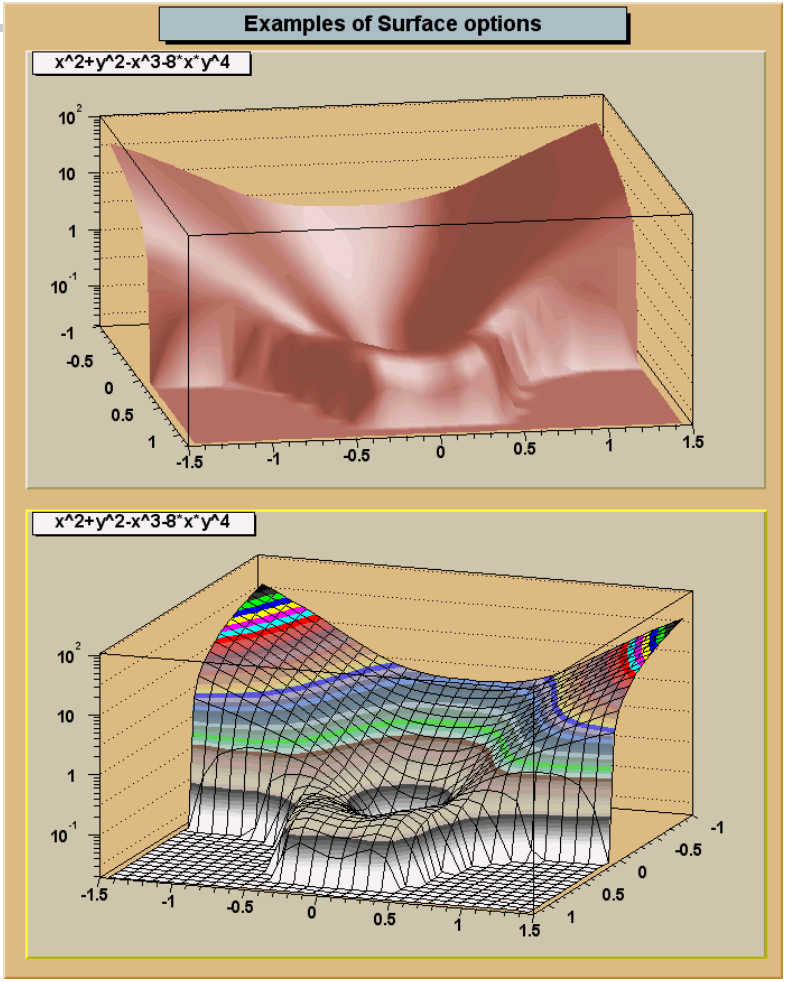




Graphics : 1,2,3-D functions







Full LateX support on screen and postscript

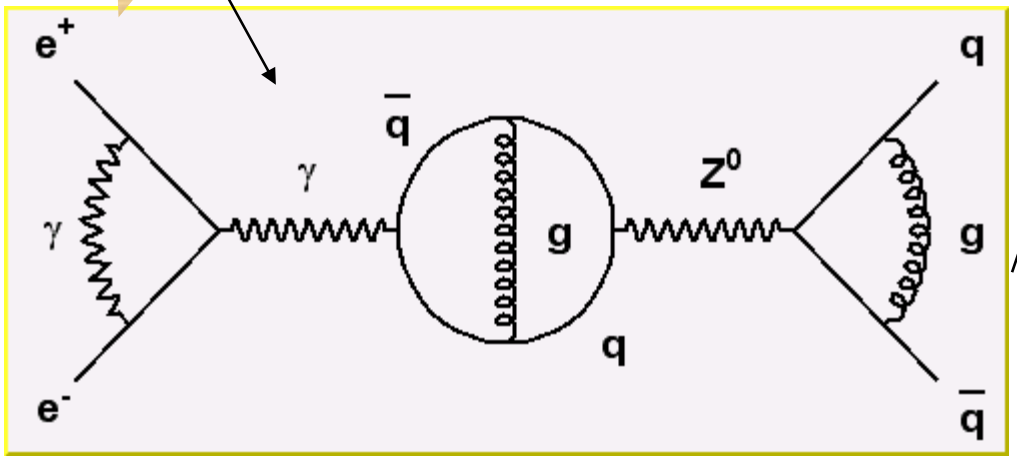
Born equation

$$\frac{2s}{\pi\alpha^2}\frac{d\sigma}{d\cos\theta}(e^+e^- \to f\bar{f}) = \left|\frac{1}{1-\Delta\alpha}\right|^2 (1+\cos^2\theta)$$

$$+ 4\,\mathrm{Re}\left\{\frac{2}{1-\Delta\alpha}\chi(s)\left[\tilde{g}^{e}_{v}\tilde{g}^{f}_{v}(1+\cos^2\theta) + 2\,\tilde{g}^{e}_{a}\tilde{g}^{f}_{a}\cos\theta\right]\right\}$$

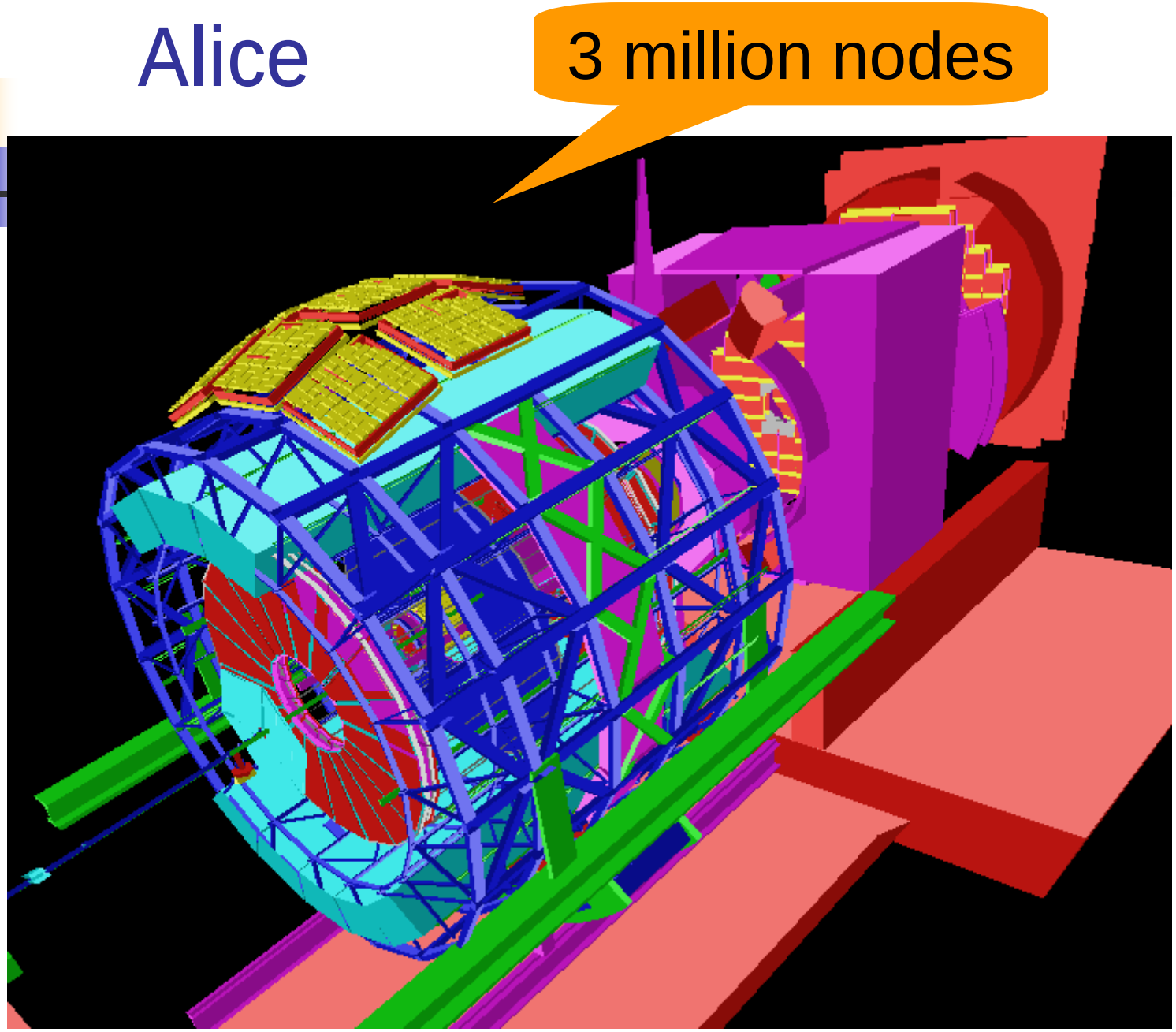
$$+ 16\left|\chi(s)\right|^2\left[(\tilde{g}^{e^2}_{a} + \tilde{g}^{e^2}_{v})(\tilde{g}^{f^2}_{a} + \tilde{g}^{f^2}_{v})(1+\cos^2\theta) + 8\,\tilde{g}^{e}_{a}\tilde{g}^{f}_{a}\tilde{g}^{e}_{v}\tilde{g}^{f}_{v}\cos\theta\right]$$

Formula or diagrams can be edited with the mouse

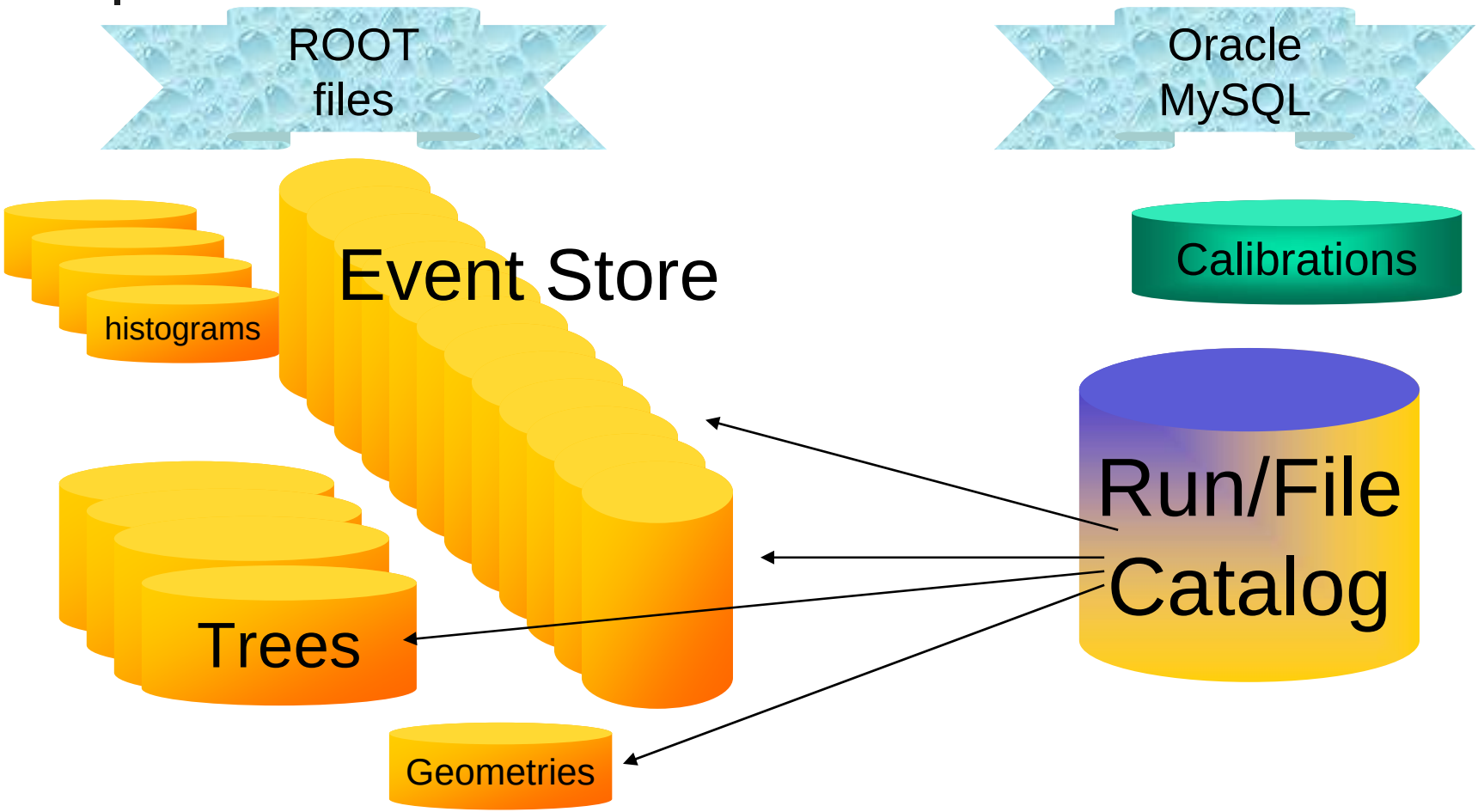


TCurlyArc
TCurlyLine
TWavyLine
and other building blocks for Feynmann diagrams

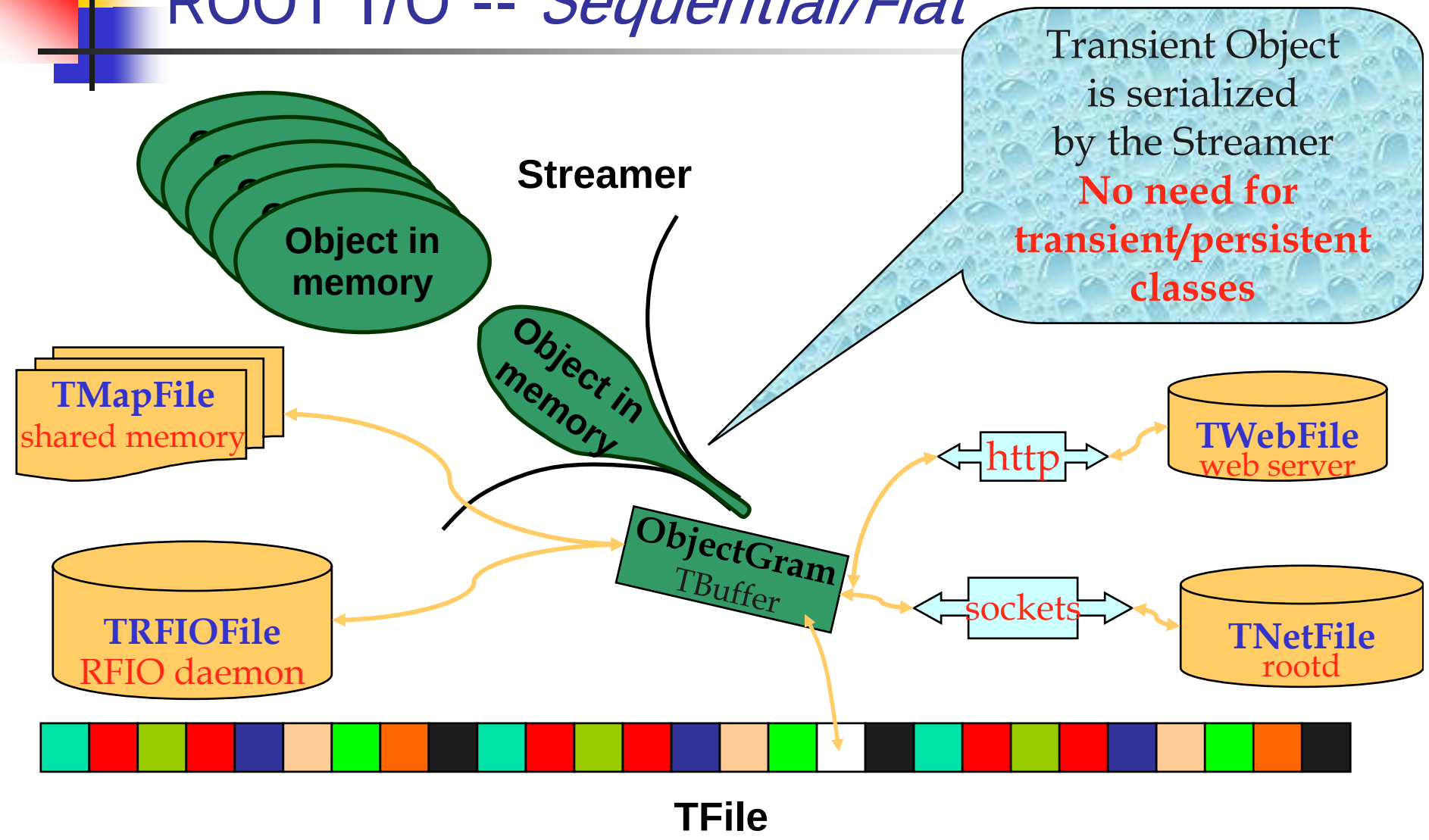
Alice



ROOT + RDBMS Model



ROOT I/O -- *Sequential/Flat*

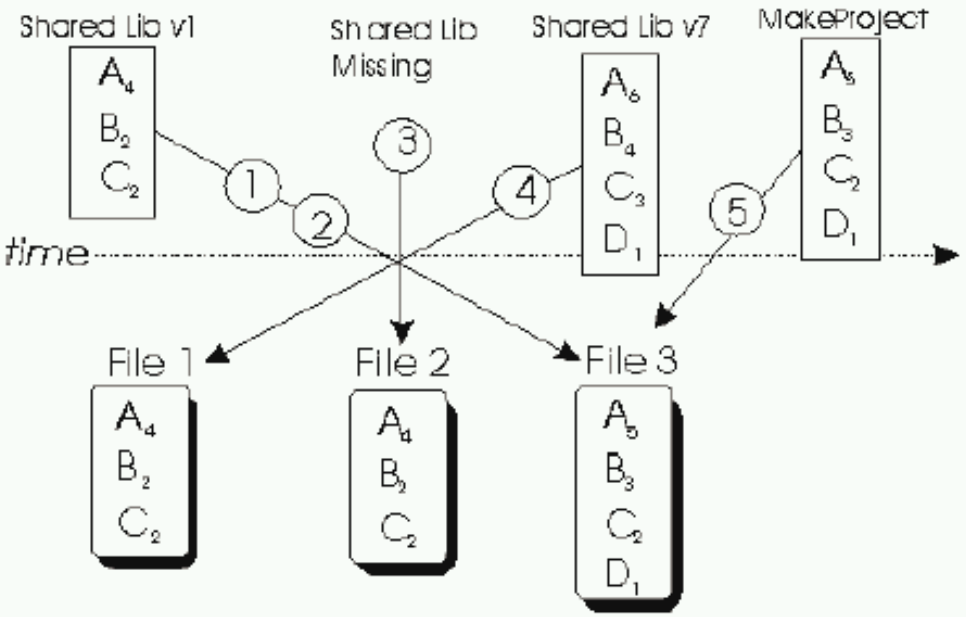


Self-describing files

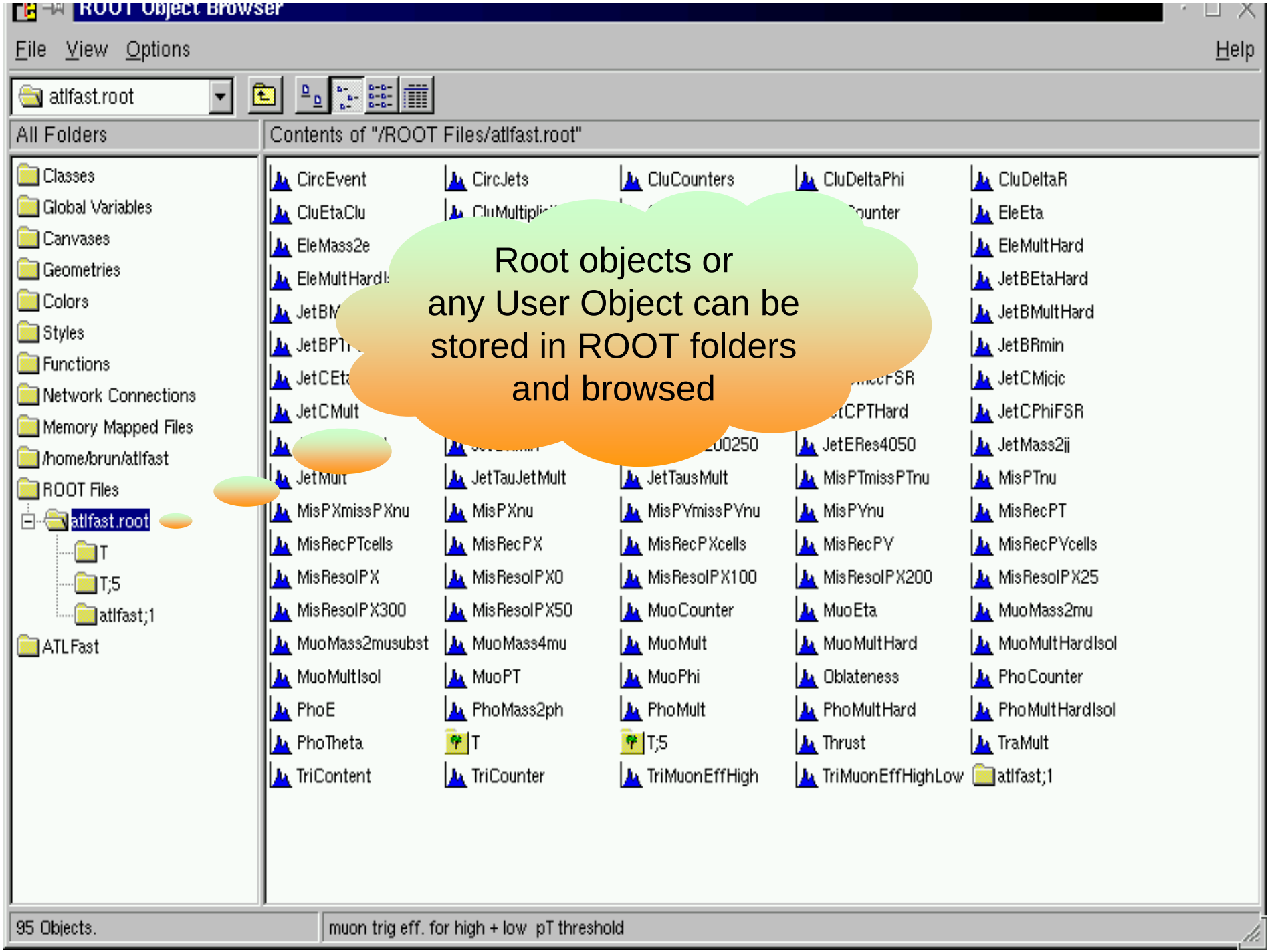
- Dictionary for persistent classes written to the file.
- ROOT files can be read by foreign readers
- Support for Backward and Forward compatibility
- Files created in 2001 must be readable in 2015
- Classes (data objects) for all objects in a file can be regenerated via TFile::MakeProject

```
Root >TFile f("demo.root");
Root > f.MakeProject("dir","*","new++");
```

Automatic Schema Evolution

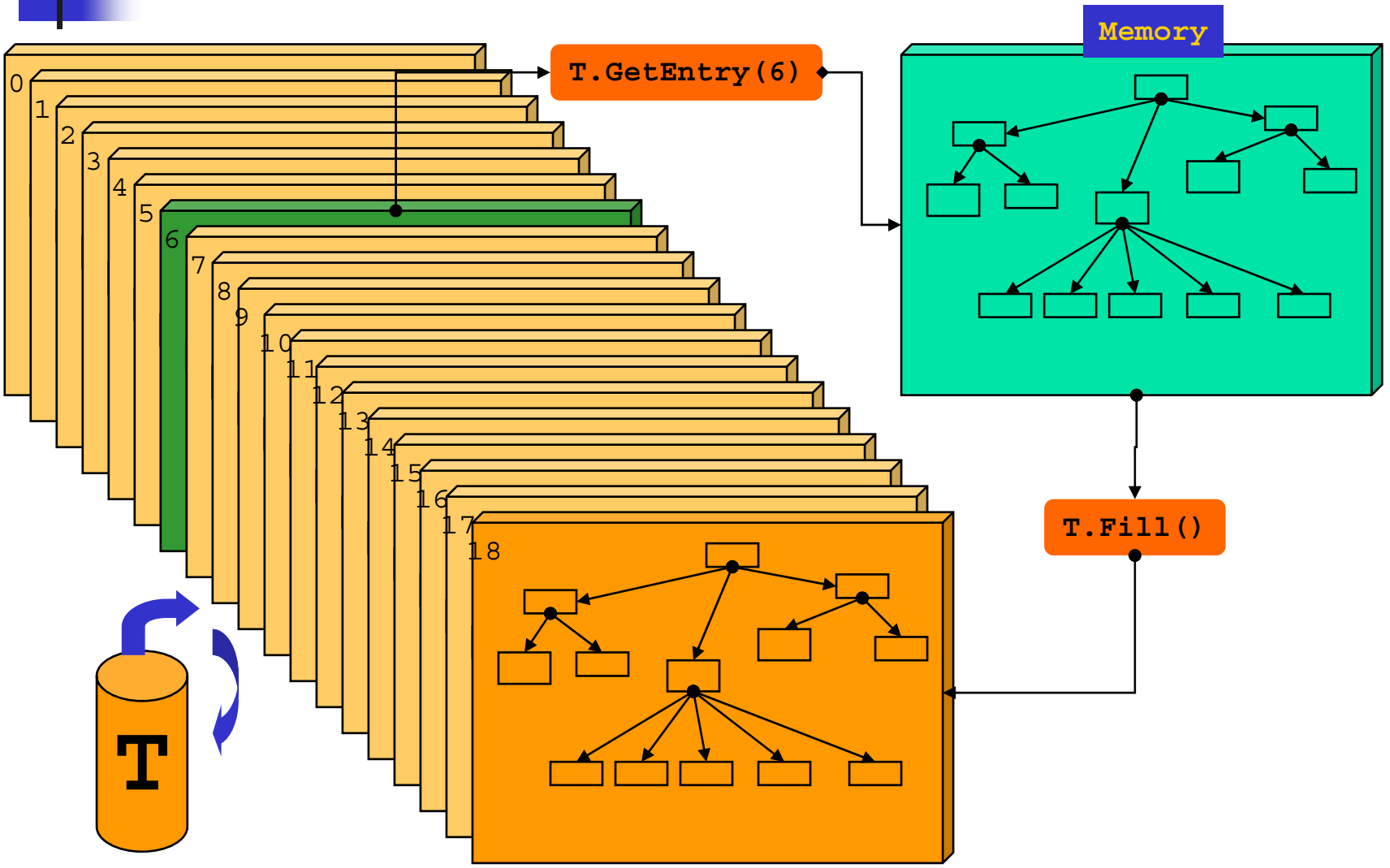


1) An old version of a shared library and a file with new class definitions. This can be the case when someone has not updated the library and is reading a new file.
2) Reading a file with a shared library that is missing a class definition (i.e. missing class D).
3) Reading a file without any class definitions. This can be the case where the class definition is lost, or unavailable.
4) The current version of a shared library and an old file with old class versions (backward compatibility). This is often the case when reading old data.
5) Reading a file with a shared library built with `MakeProject`. This is the case when someone has already read the data without a shared library and has used ROOT's `MakeProject` feature to reconstruct the class definitions and shared library (`MakeProject` is explained in detail later on).

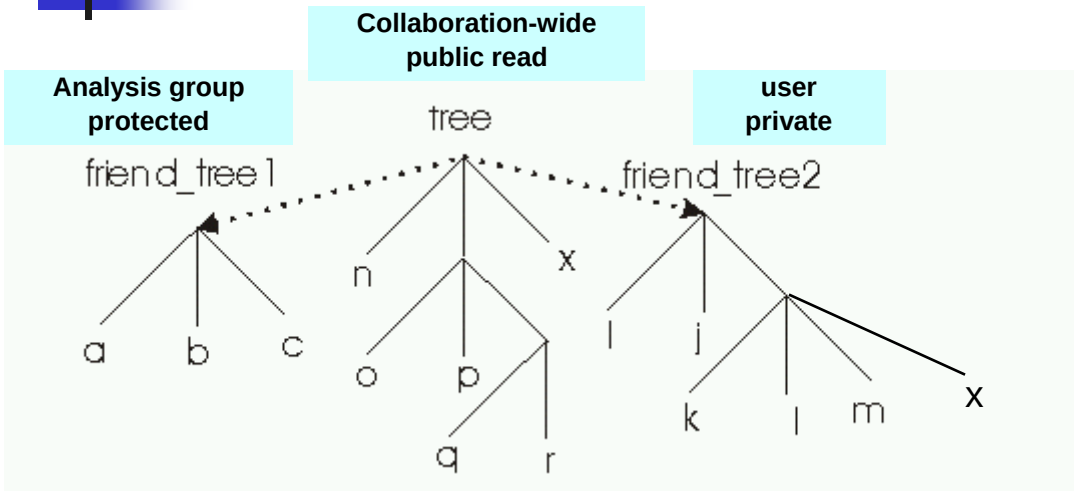

ROOT Object Browser
File View Options Help
atlfast.root
All Folders
Contents of "/ROOT Files/atlfast.root"
Classes
Global Variables
Canvases
Geometries
Colors
Styles
Functions
Network Connections
Memory Mapped Files
/home/brun/atlfast
ROOT Files
atlfast.root
T
T;5
atlfast;1
ATLFast
CircEvent
CircJets
CluCounters
CluDeltaPhi
CluDeltaR
CluEtaClu
EleEta
EleMass2e
EleMultHard
JetBEtaHard
JetBMultHard
JetBRmin
JetCMicjc
JetCPhiFSR
JetCMult
JetERes4050
JetMass2jj
JetMult
JetTauJetMult
JetTausMult
MisPTmissPTnu
MisPTnu
MisPXmissPXnu
MisPXnu
MisPYmissPYnu
MisPYnu
MisRecPT
MisRecPTcells
MisRecPX
MisRecPXcells
MisRecPY
MisRecPYcells
MisResolPX
MisResolPX0
MisResolPX100
MisResolPX200
MisResolPX25
MisResolPX300
MisResolPX50
MuoCounter
MuoEta
MuoMass2mu
MuoMass2musubst
MuoMass4mu
MuoMult
MuoMultHard
MuoMultHardIsol
MuoMultIsol
MuoPT
MuoPhi
Oblateness
PhoCounter
PhoE
PhoMass2ph
PhoMult
PhoMultHard
PhoMultHardIsol
PhoTheta
T
T;5
Thrust
TraMult
TriContent
TriCounter
TriMuonEffHigh
TriMuonEffHighLow
atlfast;1
Root objects or
any User Object can be
stored in ROOT folders
and browsed
95 Objects.
muon trig eff. for high + low pT threshold

Memory <--> Tree

Each Node is a branch in the Tree



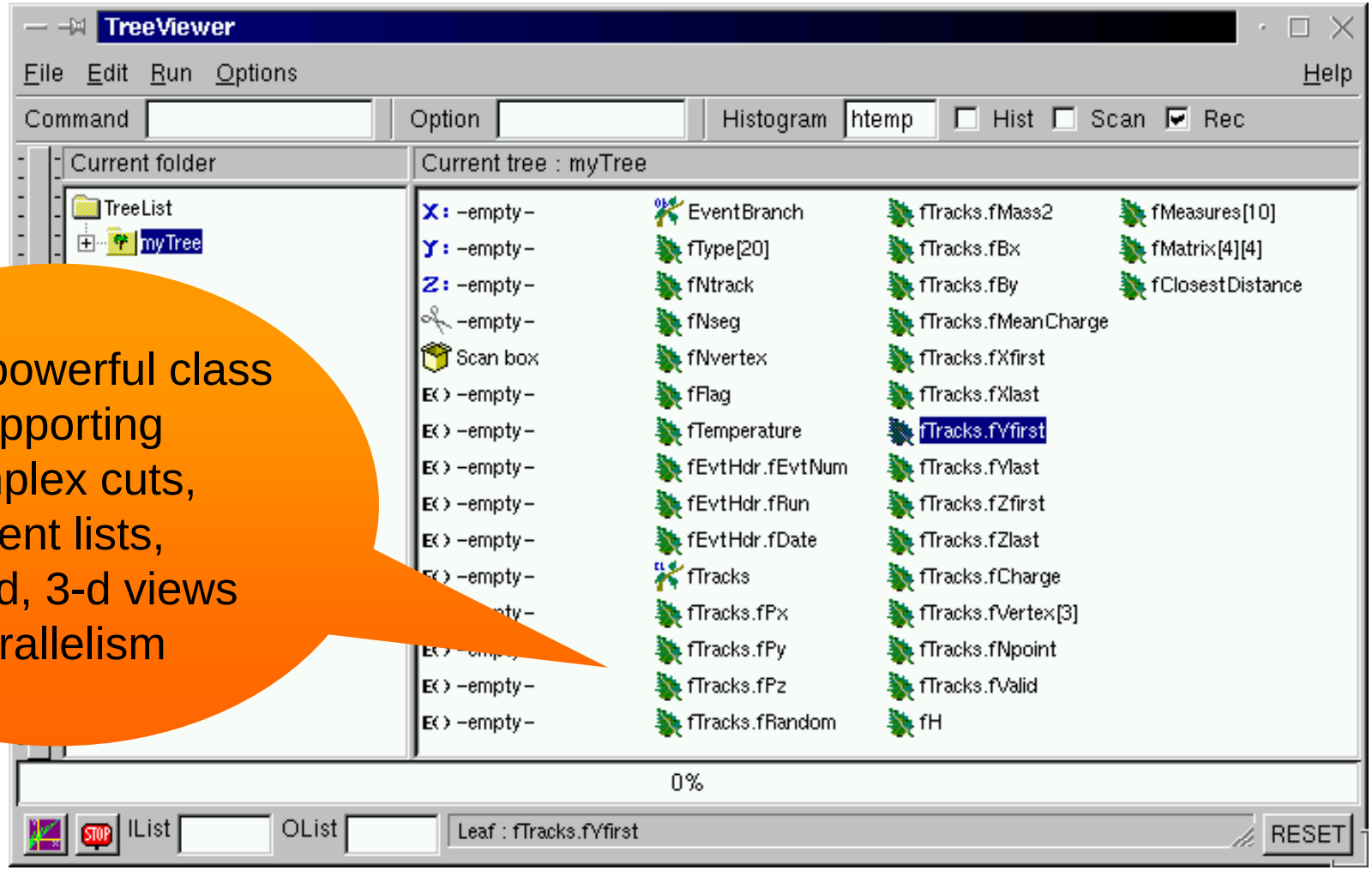
Tree Friends



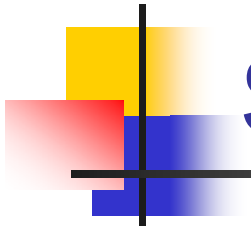
Processing time independent of the number of friends unlike table joins in RDBMS

```
Root > TFile f1("tree1.root");
Root > tree.AddFriend("tree2","tree2.root")
Root > tree.AddFriend("tree3","tree3.root");
Root > tree.Draw("x:a","k<c");
Root > tree.Draw("x:tree2.x","sqrt(p)<b");
```

The Tree Viewer & Analyzer



A very powerful class supporting complex cuts, event lists, 1-d,2-d, 3-d views parallelism

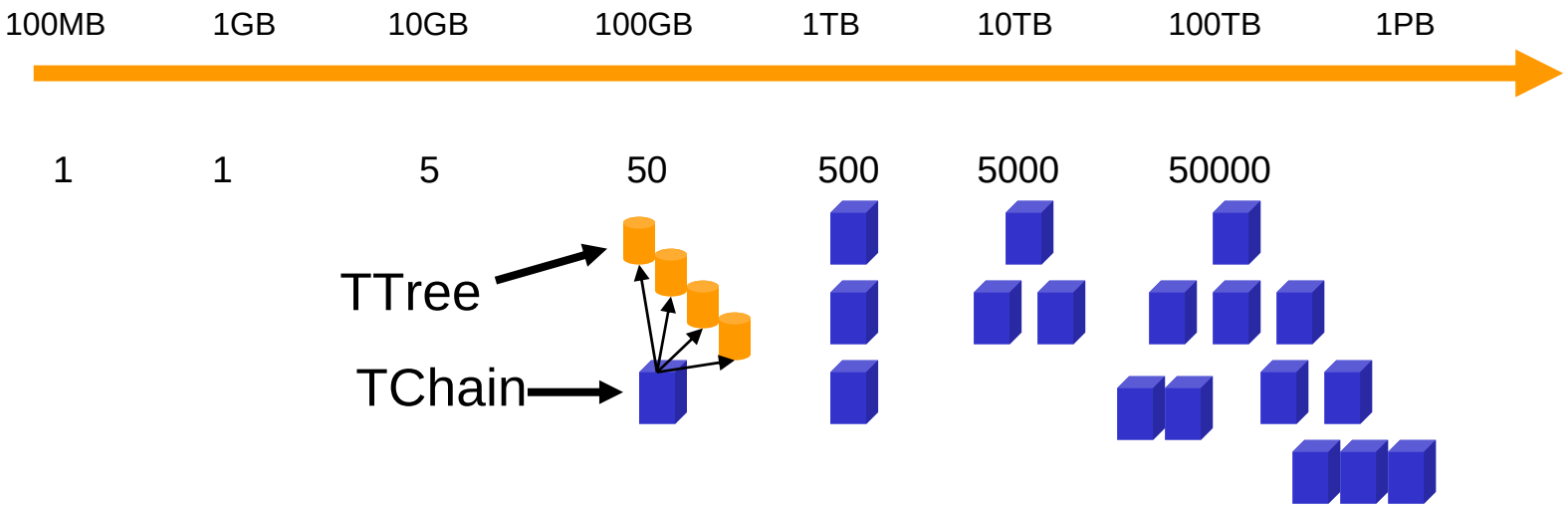


Selectors

- A Selector script can be run
  - In batch
  - Interactive ROOT
  - Interactive ROOT + PROOF
  - Interactive or batch ROOT + PROOF + GLITE
- A Selector script can be
  - Interpreted tree.Process("myselector.C")
  - Or compiled tree.Process("myselector.C++")

Smooth transition between batch and interactive sessions

Data Volume & Organisation



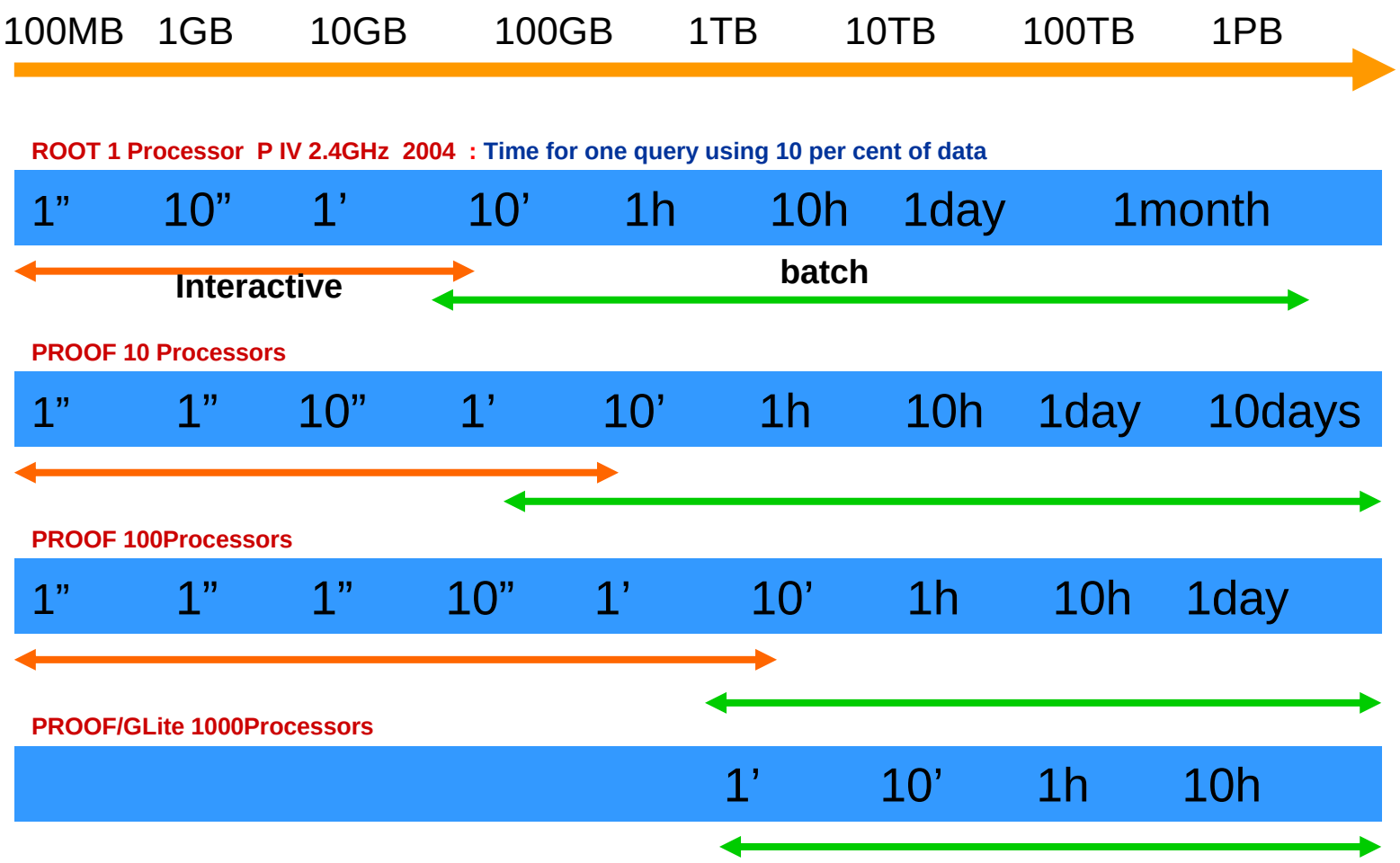
A TFile typically contains 1 TTree (or a few)

A TChain is a collection of TTrees or/and TChains

A TChain is typically the result of a query to the file catalogue

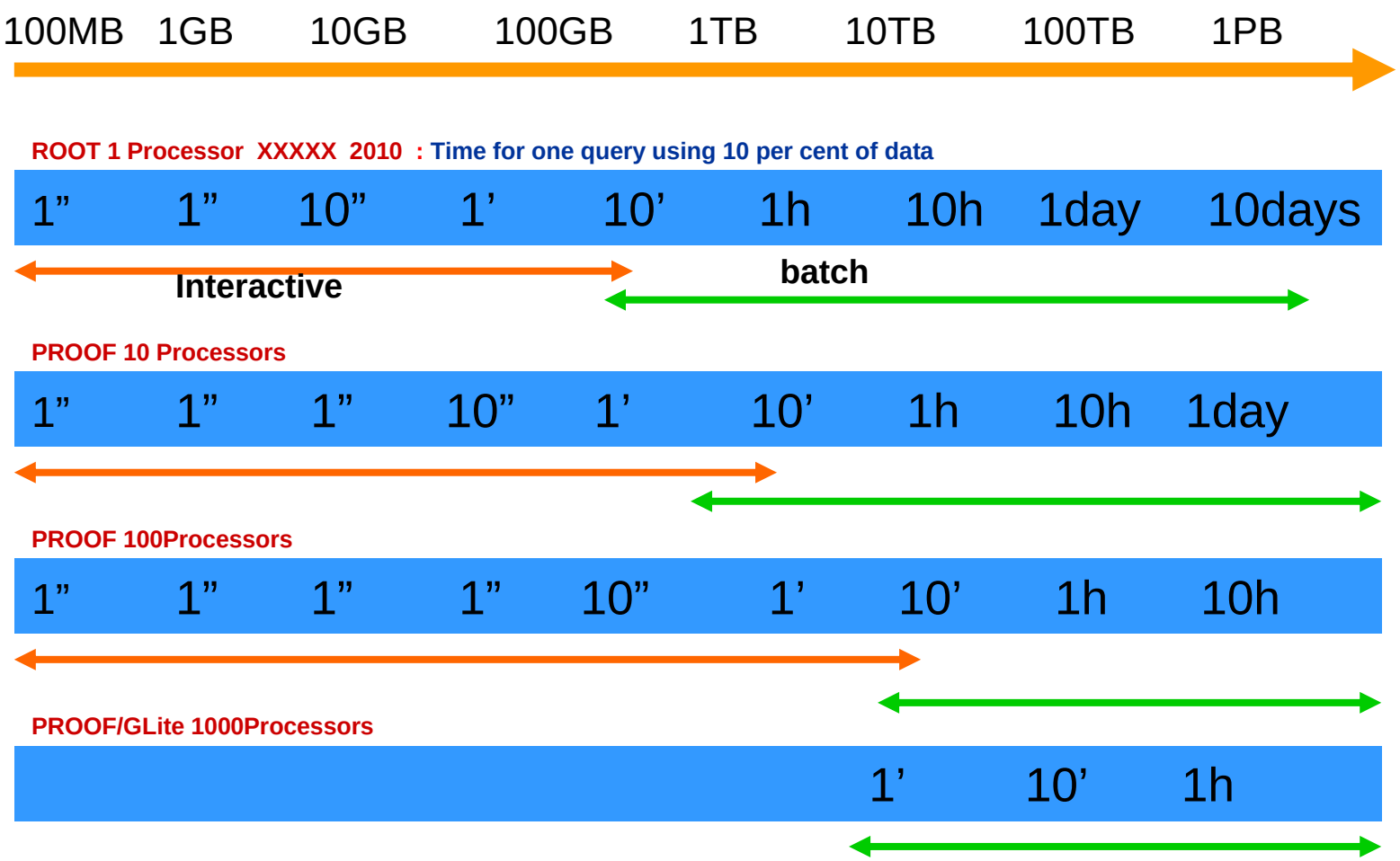
Data Volume & Processing Time

Using technology available in 2004



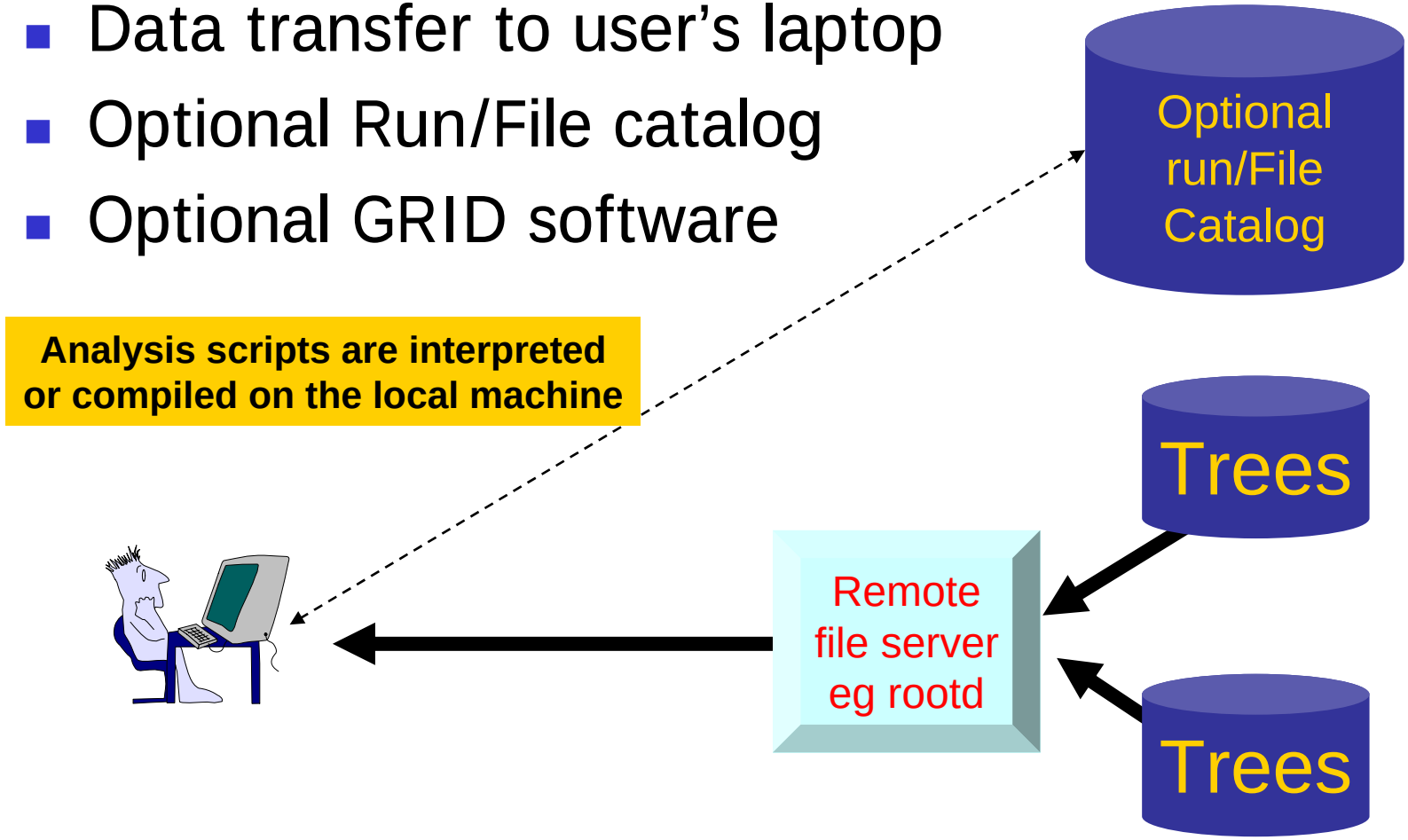
Data Volume & Processing Time

Using technology available in 2010



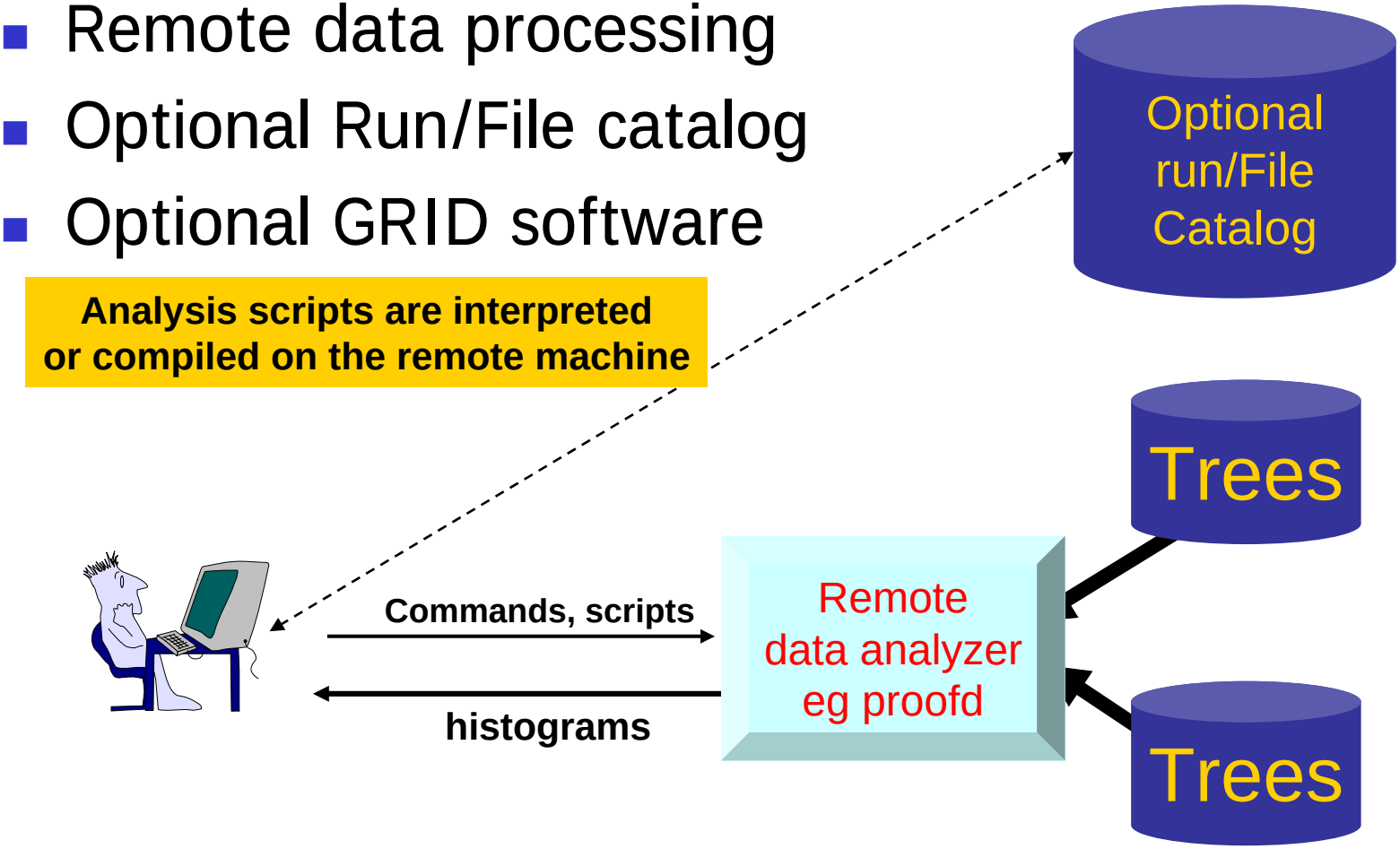
GRID: Interactive Analysis Case 1

- Data transfer to user's laptop
- Optional Run/File catalog
- Optional GRID software



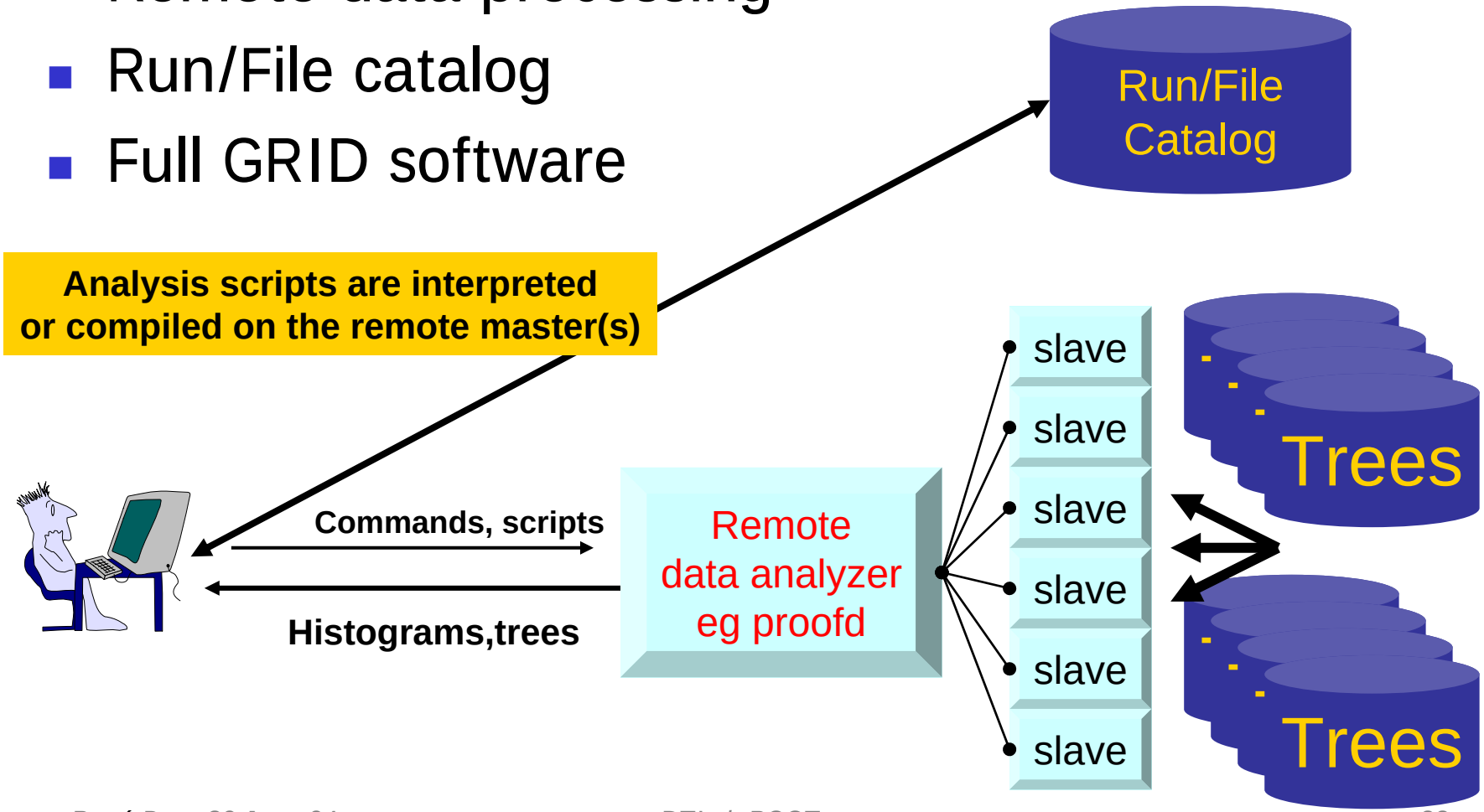
GRID: Interactive Analysis Case 2

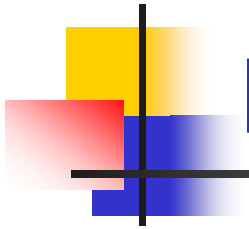
- Remote data processing
- Optional Run/File catalog
- Optional GRID software



GRID: Interactive Analysis Case 3

- Remote data processing
- Run/File catalog
- Full GRID software



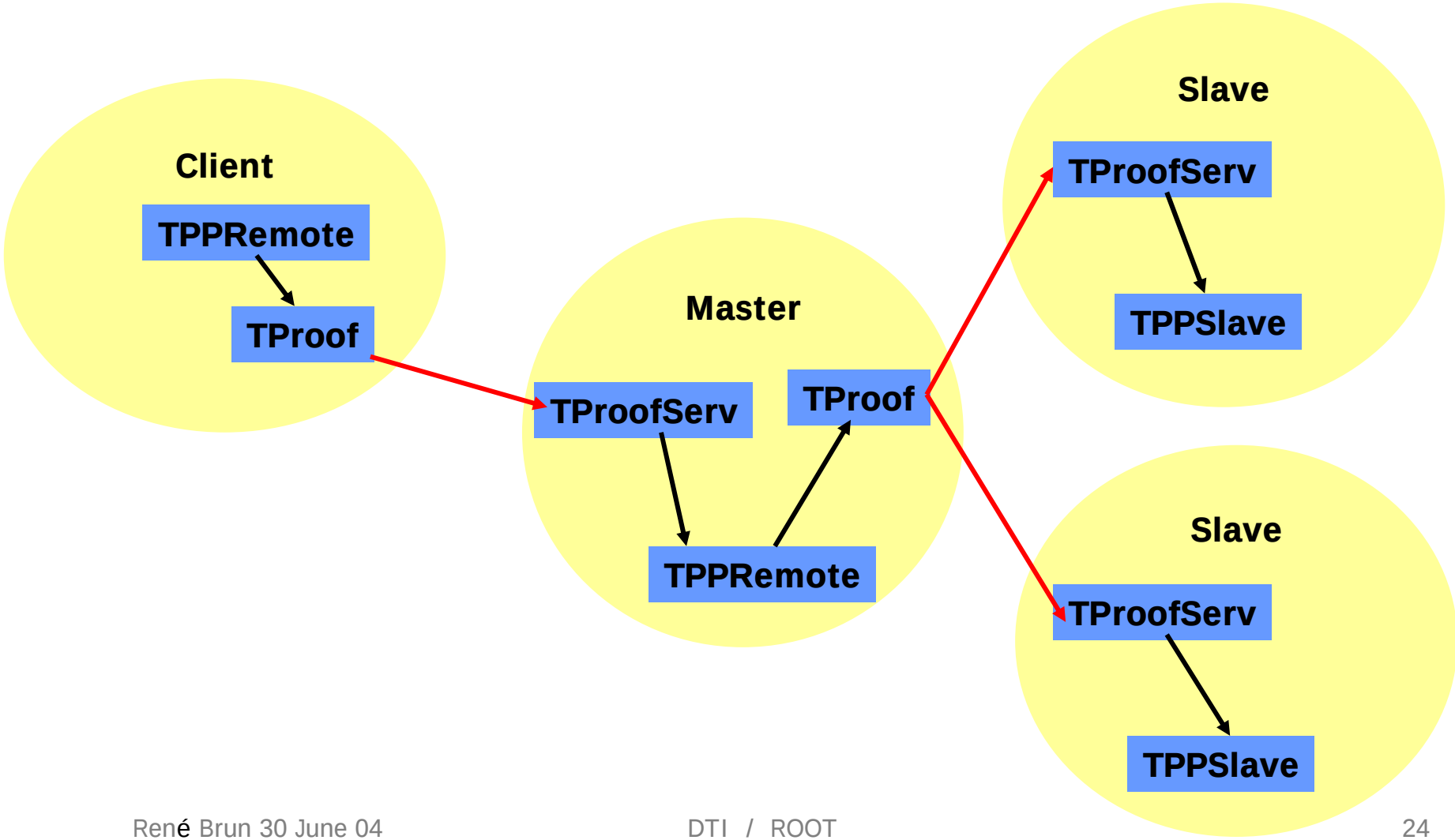


Parallel ROOT Facility

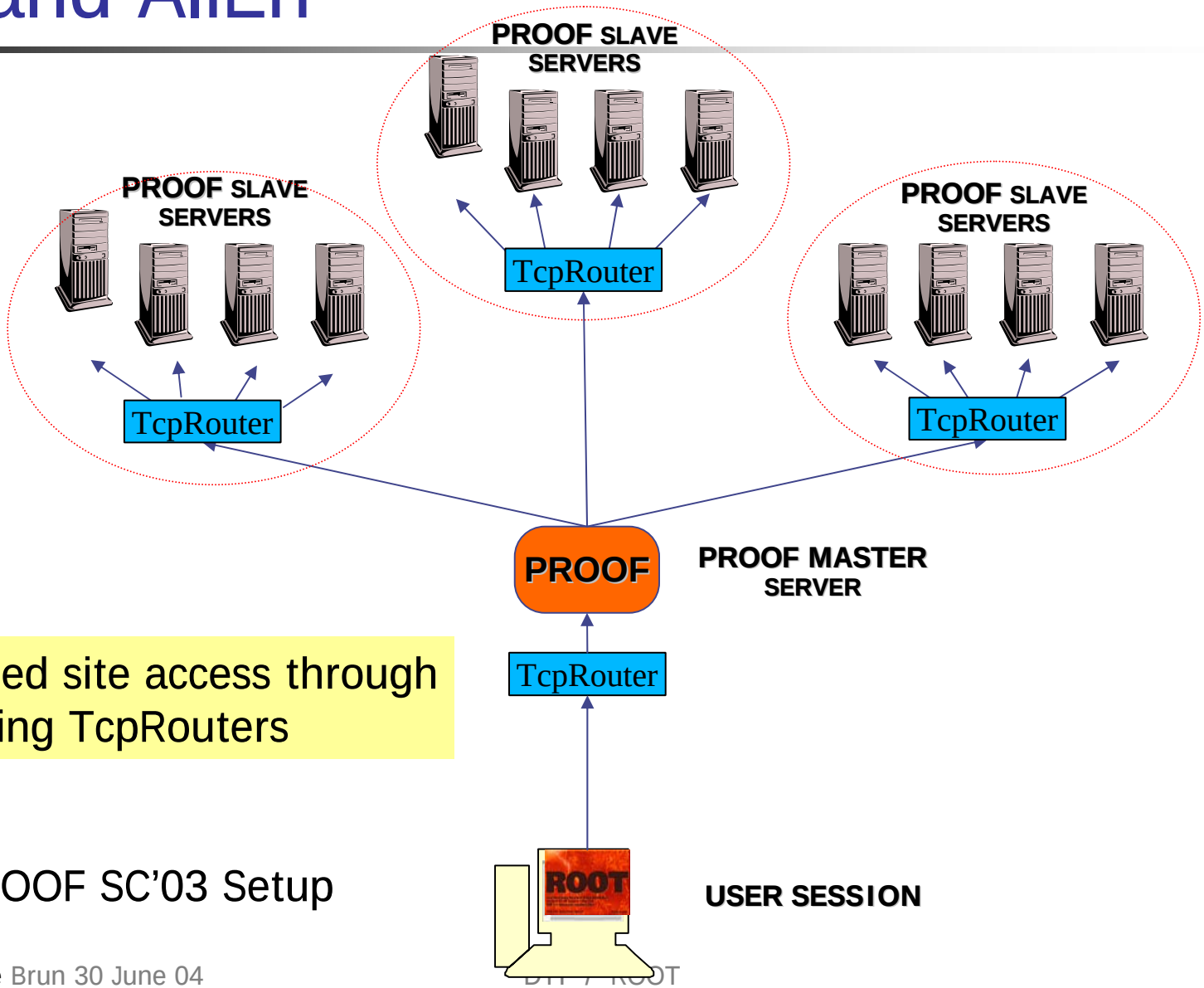
- The PROOF system allows:
  - Parallel analysis of trees in a set of files
  - Parallel analysis of objects in a set of files
  - Parallel execution of scripts

  on clusters of heterogeneous machines
- Its design goals are:
  - Transparency, scalability, adaptability

PROOF: Client-Master-Slaves

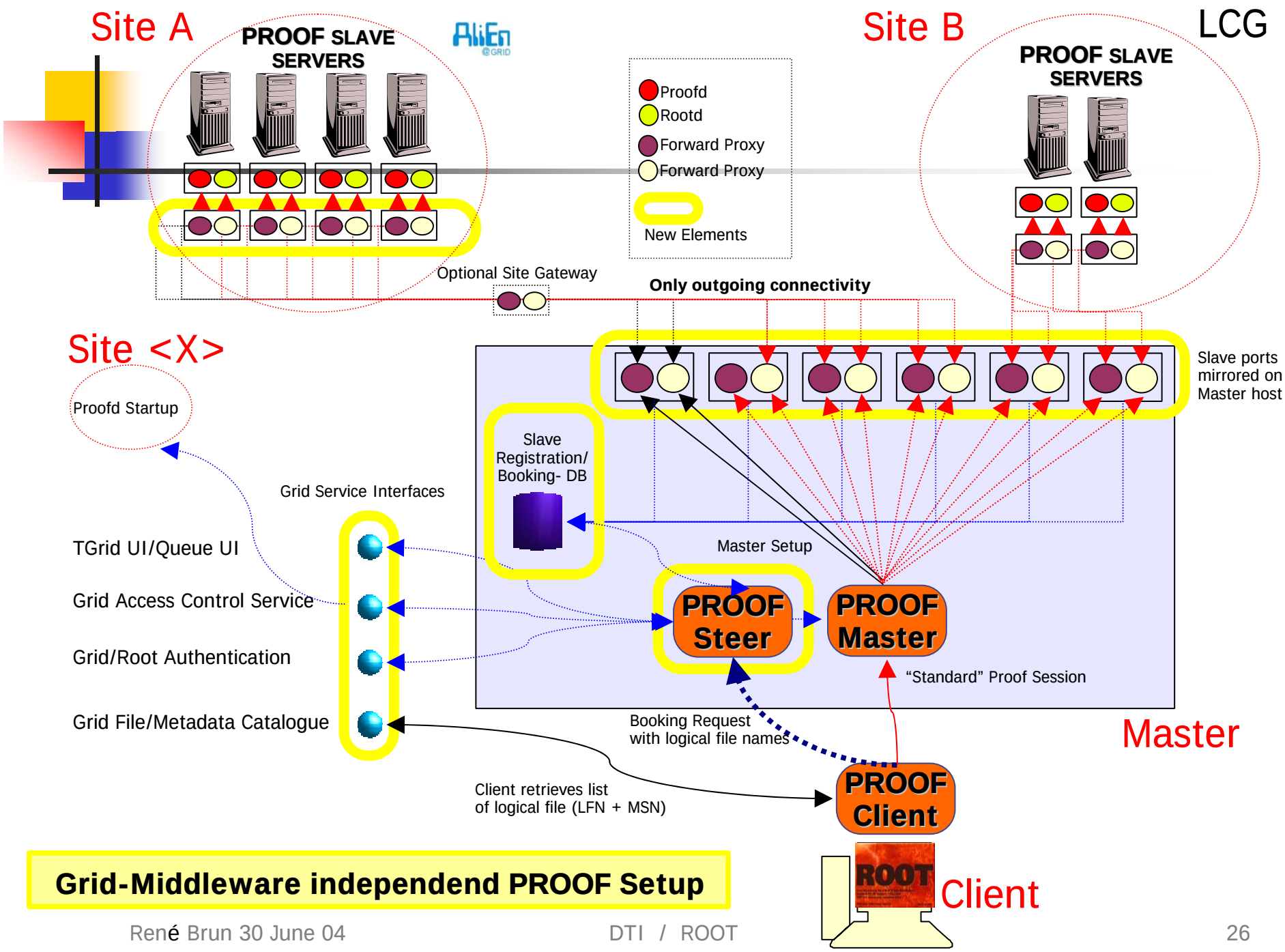


Interactive Analysis with PROOF and AliEn

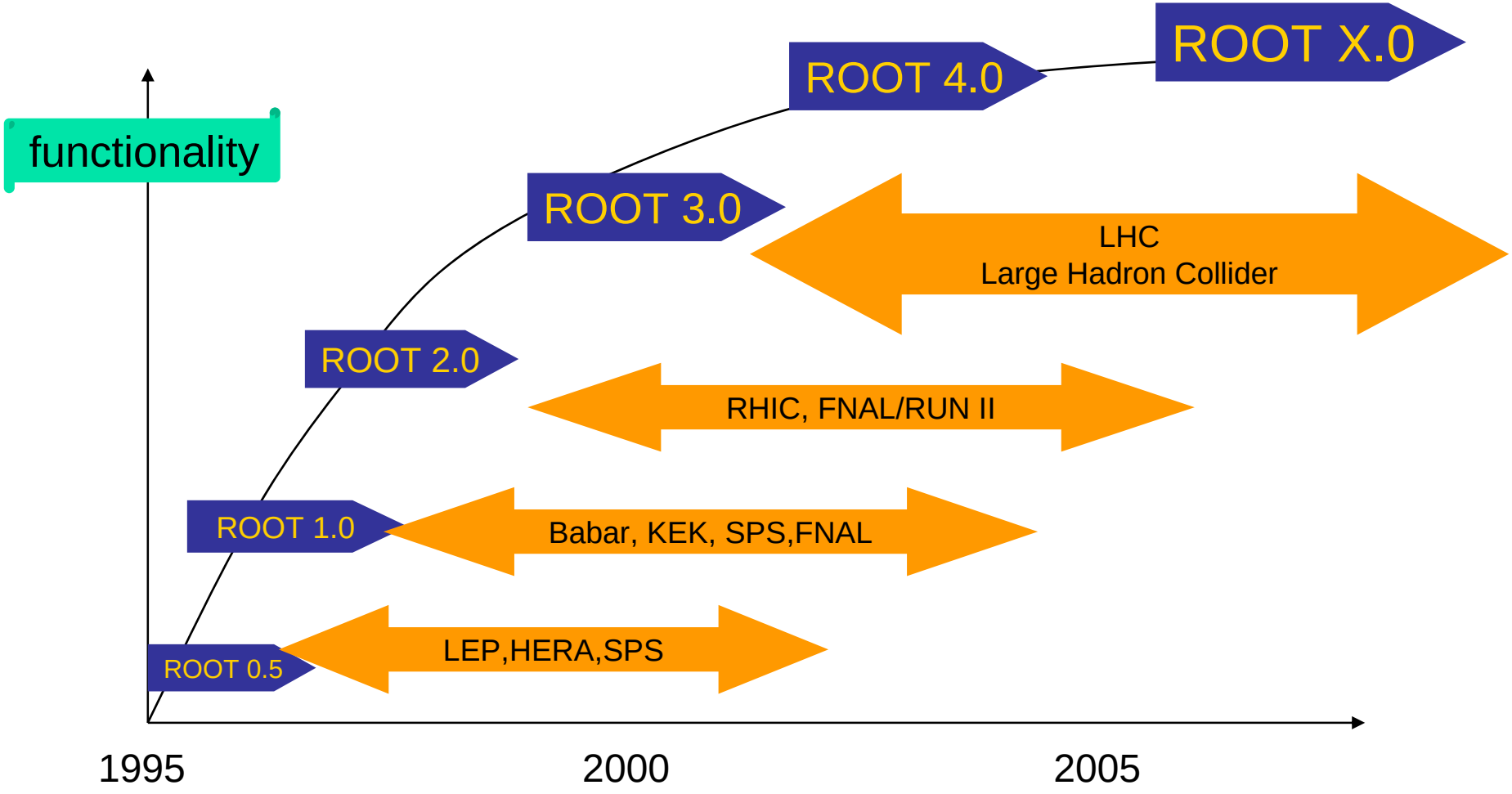


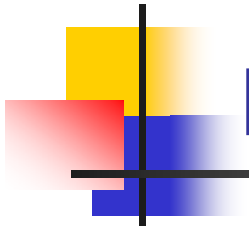
Guaranteed site access through Multiplexing TcpRouters

AliEn/PROOF SC'03 Setup


Site A
PROOF SLAVE SERVERS
Site B
LCG
PROOF SLAVE SERVERS
Proofd
Rootd
Forward Proxy
Forward Proxy
New Elements
Optional Site Gateway
Only outgoing connectivity
Site <X>
Proofd Startup
Slave ports mirrored on Master host
Slave Registration/ Booking- DB
Grid Service Interfaces
TGrid UI/Queue UI
Grid Access Control Service
Grid/Root Authentication
Grid File/Metadata Catalogue
Master Setup
PROOF Steer
PROOF Master
"Standard" Proof Session
Booking Request with logical file names
Master
Client retrieves list of logical file (LFN + MSN)
PROOF Client
ROOT
Client
Grid-Middleware independend PROOF Setup

The ROOT Project



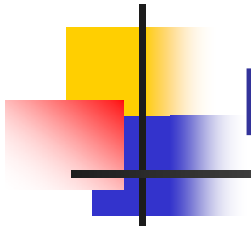


Project Size & Development cost

Using the COCOMO model

And the SlocCount tool from A.Wheeler

Total Physical Source Lines of Code (SLOC) = 1,247,994
Development Effort Estimate, Person-Years = 356.49
(Basic COCOMO model, Person-Months = 2.4 * (KSLOC1.05))**
Schedule Estimate, Years (Months) = 5.00 (59.95)
(Basic COCOMO model, Months = 2.5 * (person-months0.38))**
Estimated Average Number of Developers (Effort/Schedule) = 71.36
Total Estimated Cost to Develop = $ 48,157,590
(average salary = $56,286/year, overhead = 2.40).



ROOT: An Open Source Project

- The project is developed as a collaboration between :
- Full time developers:
  - 6 people full time at CERN
  - 1 key developer at FermiLab
  - 1 key developer in Japan (Agilent Technologies)
  - 1 key developer at MIT
  - 1 mathematician at CERN sponsored by a US Finance Company
- Many contributors spending a substantial fraction of their time in specific areas (> 50)
- Key developers in large experiments using ROOT as a framework
- Several thousand users given feedback and a very long list of small contributions.

ROOT: Users

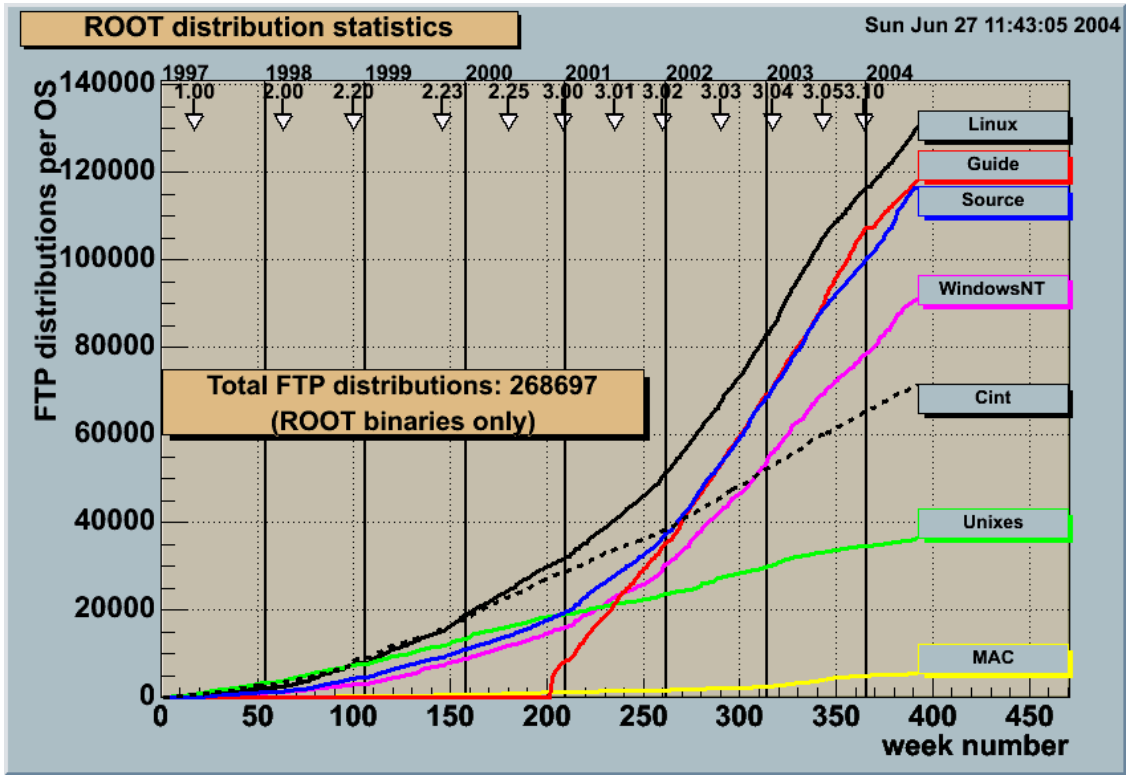
- The system has been developed with High Energy or Nuclear Physics in mind.
- However, we see a very important fraction of the users in other fields of science, industry or finance.

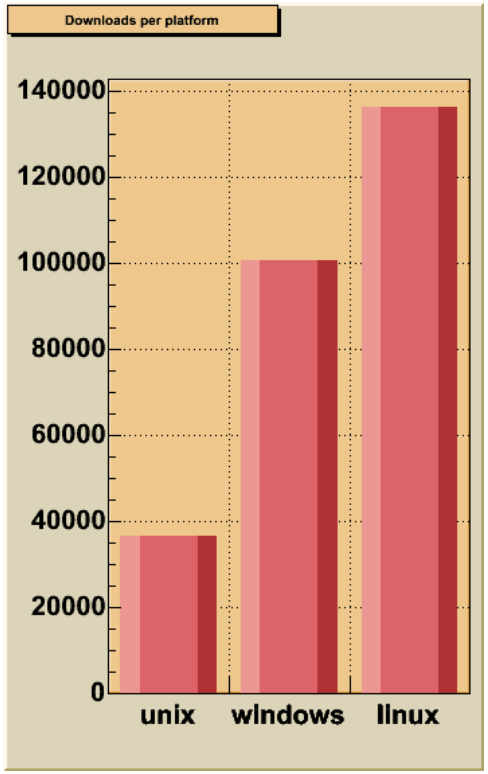
** Electronic User Registration Form **

Date: 2004-06-25 09:04:04
Name: Gabriele Susinno
E-mail address: susinno@finance-and-physics.org
Institute:
Experiment: finance-and-physics
Category: science
Mailing list: y
Privacy: n

DESCRIPTION OF APPLICATION:
Build a Data Acquisition system and a data mining tool to analyse very high frequency financial data.This in a econophysics project finance by the Italian Research Council.

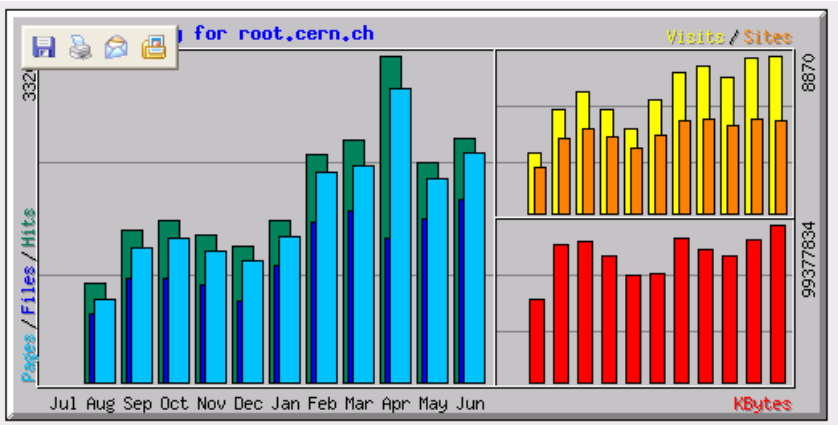
ROOT: Users


ROOT distribution statistics
Sun Jun 27 11:43:05 2004
FTP distributions per OS
1997
1998
1999
2000
2001
2002
2003
2004
1.00
2.00
2.20
2.23
2.25
3.00
3.01
3.02
3.03
3.04
3.05
3.10
Linux
Guide
Source
WindowsNT
Cint
Unixes
MAC
Total FTP distributions: 268697
(ROOT binaries only)
0
20000
40000
60000
80000
100000
120000
140000
0
50
100
150
200
250
300
350
400
450
week number


Downloads per platform
0
20000
40000
60000
80000
100000
120000
140000
unix
windows
linux

ROOT: Users

ftp



http

Summary by Month

Month	Daily Avg				Monthly Totals					
	Hits	Files	Pages	Visits	Sites	KBytes	Visits	Pages	Files	Hits
Jun 2004	28628	20818	22844	3417	38218	13244975	99098	662481	603738	830239
May 2004	25523	17795	20146	3435	48541	12534862	106514	624536	551670	791236
Apr 2004	29344	20727	22346	4011	57177	13316142	120354	670402	621822	880327
Mar 2004	29714	19948	23682	4645	59028	13800203	144023	734150	618388	921164
Feb 2004	22106	14620	17483	4071	56549	9696494	118073	507008	423999	641081
Jan 2004	24856	17456	20533	3918	52381	13407635	121474	636523	541153	770566
Dec 2003	23041	15673	17150	3307	48189	21984568	102519	531676	485867	714280
Nov 2003	26567	19776	21279	3508	49462	16336498	105255	638389	593307	797019
Oct 2003	24140	16974	19417	3466	49988	10632075	107462	601948	526221	748365
Sep 2003	23827	16429	19151	3324	45099	9594504	99724	574544	492897	714825
Aug 2003	17432	11438	14650	2327	24780	4790789	46546	293011	228771	348657
Totals						**139338745**	**1171042**	**6474668**	**5687833**	**8157759**