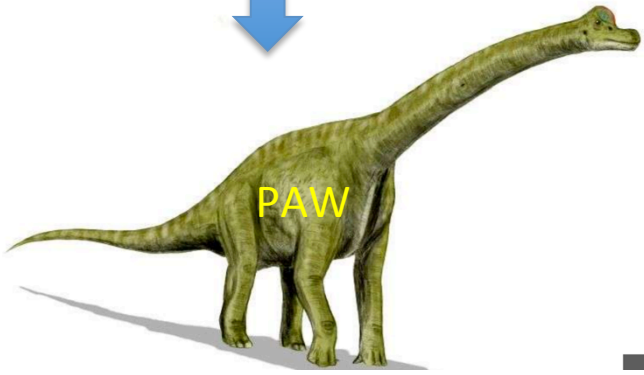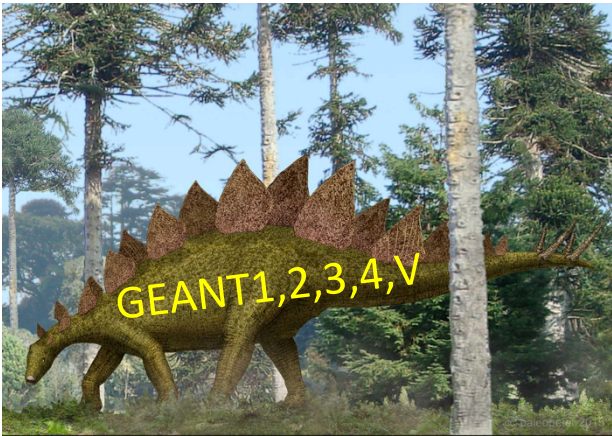# Evolution of the HBOOK,ZEBRA,GEANT PAW, ROOT systems

GSI April 25 2018

René Brun

CERN

Preliminary remarks

- I am going to talk about many projects created over several decades.

- Some of these projects did not materialize, some had just a few years lifetime, some have been used more than 30 years.

- All these projects were not achieved by one single person. They were the result of a lot of work by many colleagues.

- I have been a privileged person in this context, having a permanent position at CERN, this was not always the case for several of my collaborators.

- This work could not have been achieved without the contacts with thousands of users contributing by their comments and criticisms to the global success.
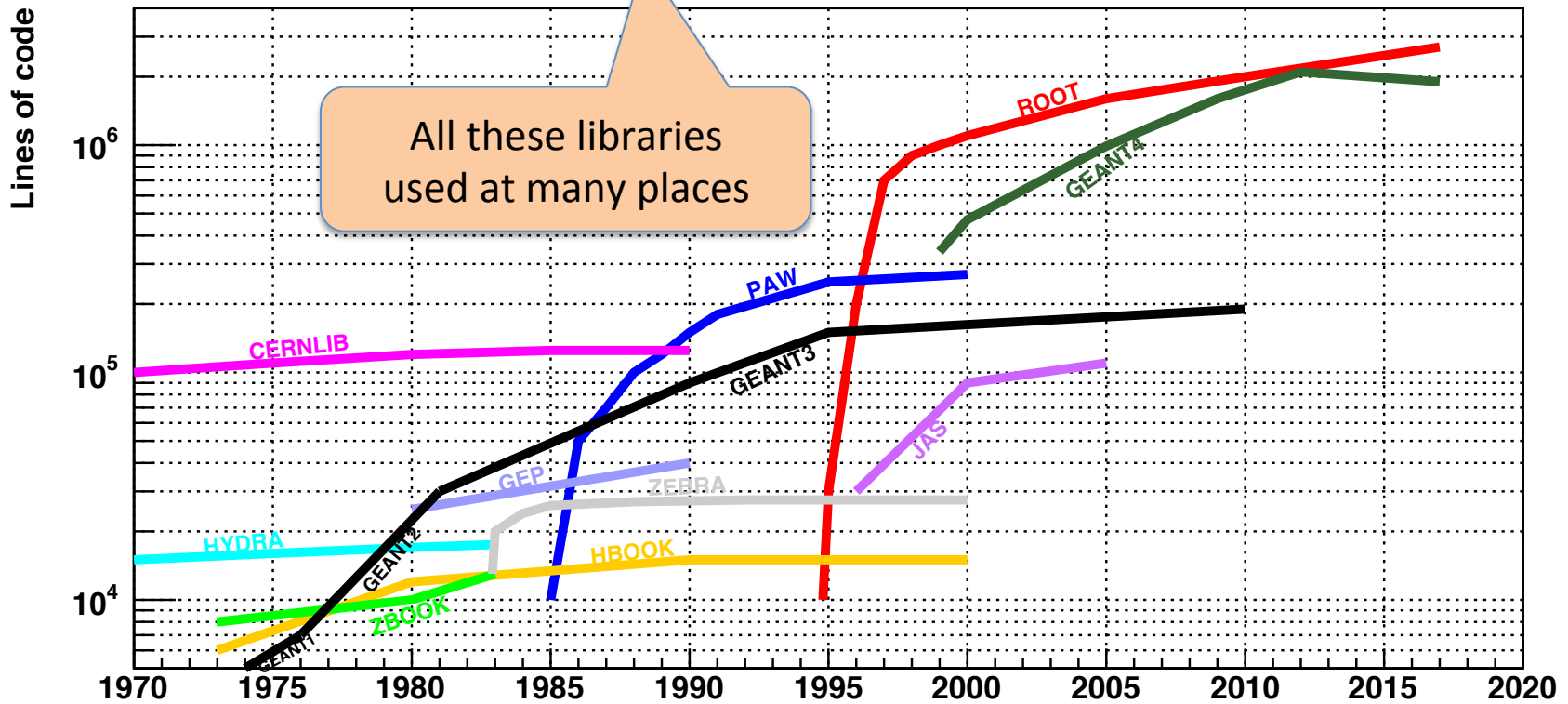
- MANY THANKS TO ALL.

Darwin & HEP Software
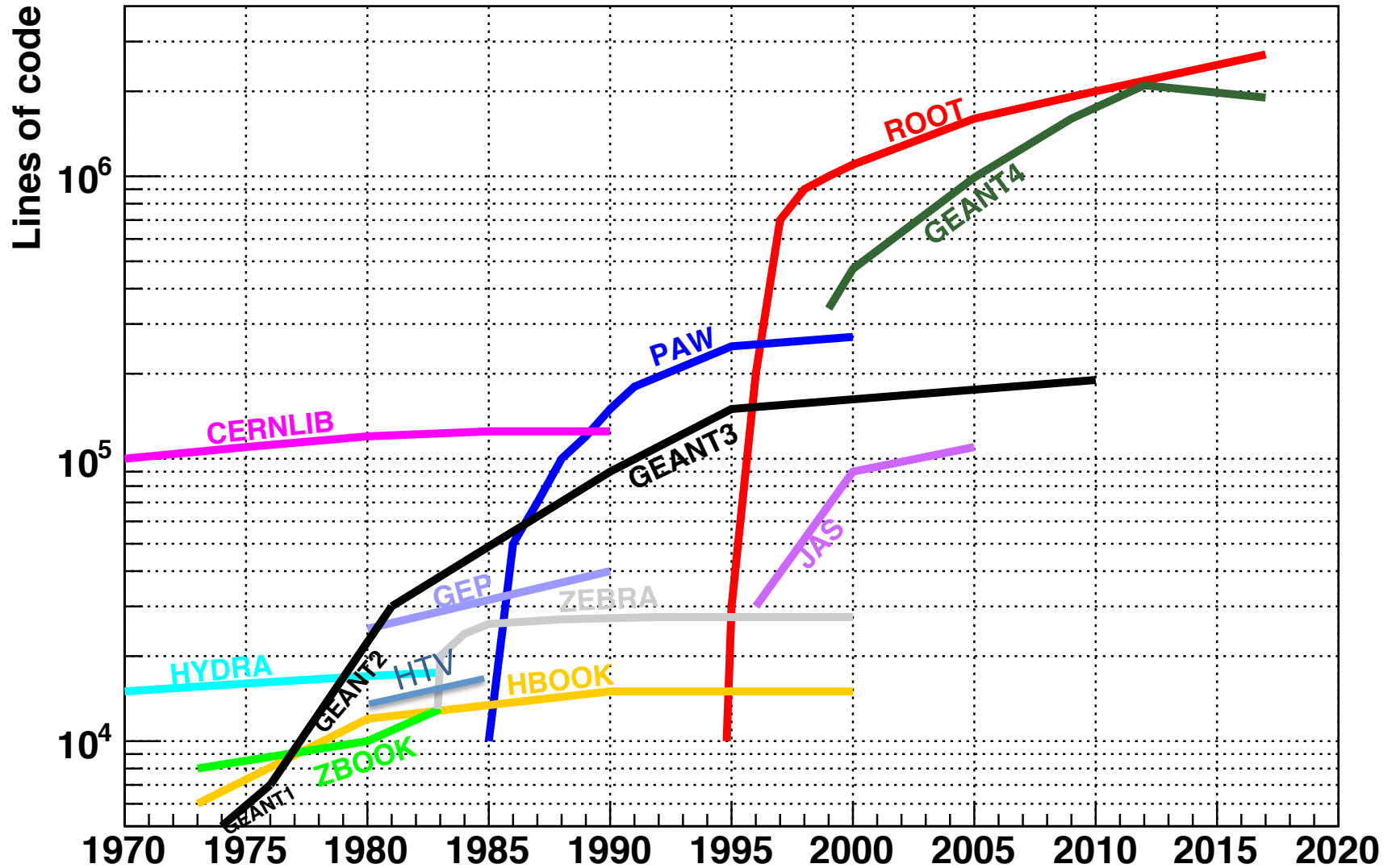
Users@

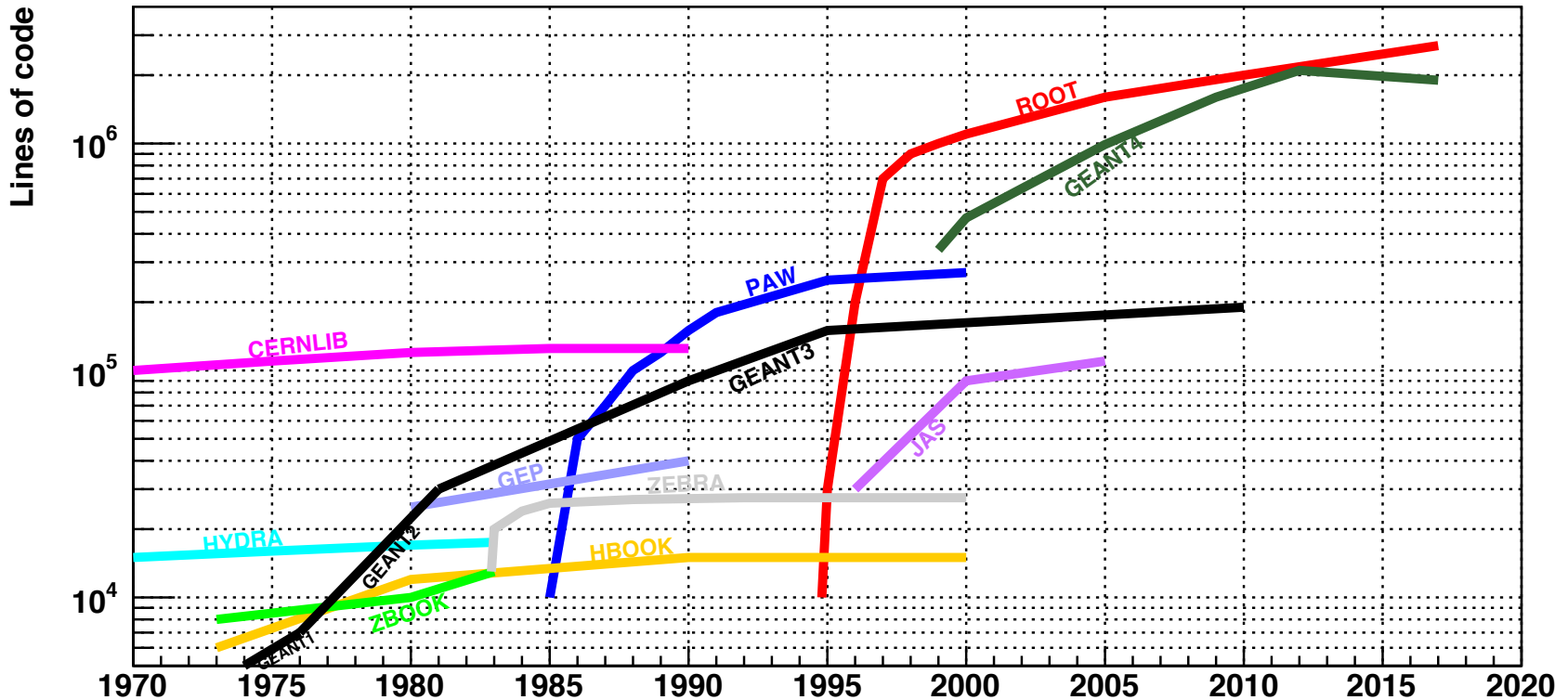(cosmics)

Pierre Auger

Bubble Chambers   Serpukhov   JINR   SLC   KEK   HESS   IceCube

GANIL   DESY   GSI   Triumph   AMS   Biology

LBL   SLAC   SSC   JLAB   BNL   FNAL   Fermi   finance

PS   ISR   SPS   LEP   LHC   Grand Sasso   industry

Computers Hardware/word-length

CDC6400 [60] CDC7600 [60] PERQ Apollo [32] DEC [32] SUN [32] HP [32/64] INTELyy [32/64]

Transputers

BESM6 [56]

SGI [32/64] IBM [32/64]

PDP11 [16] VAX780 [32] CYBER205 [64]

INTELzz [32/64]

CII [16/32] NORD10/50 [16/32/48] CRAY [64] CM5 [32/64] Pentium [32/64] GPUs [32/64]

UNIVAC [36] IBM3090 [32/64]

Programing languages

Mortran

Algol

ADA

COMIS

Modula2

CINT

CLING

PERL

Python

Pascal

OCCAM

Eiffel

Oberon

Csharp

Ruby

Javascript

Fortran 4,77,90

ObjectiveC

Java

GO

CUDA

Assembler

Compass

PL1

C

Prolog

Basic

C++

Julia

I/O, DBMS

HYDRA   ZBOOK   PAW/GEANT   Oracle   Objectivity
    RDBMS   OODBMS

BOS   HBOOK
  RWNT
  CWNT

File formats   RFIO   ROOTD
specs   DCACHE

ROOT XROOTD

ZEBRA

Graphics Hard-Software

GD3   HPLOT   PIONS   HIGZ

Web Browsers

Java script

Tektronix4015

Microfilm   Workstations   PCs   Laptops

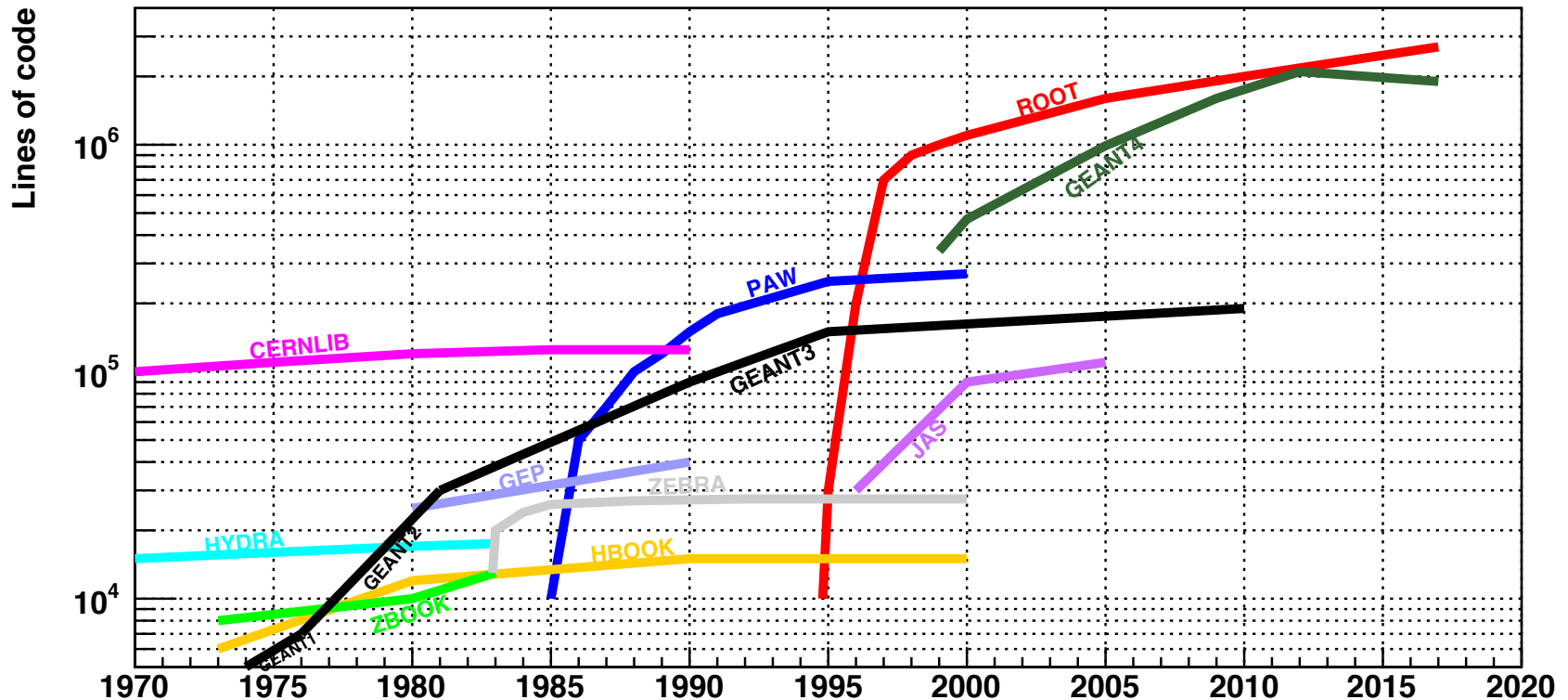Calcomp plotter   Falco   GKS   PHIGS

Line printer   RS232   Megatek   X11   GL
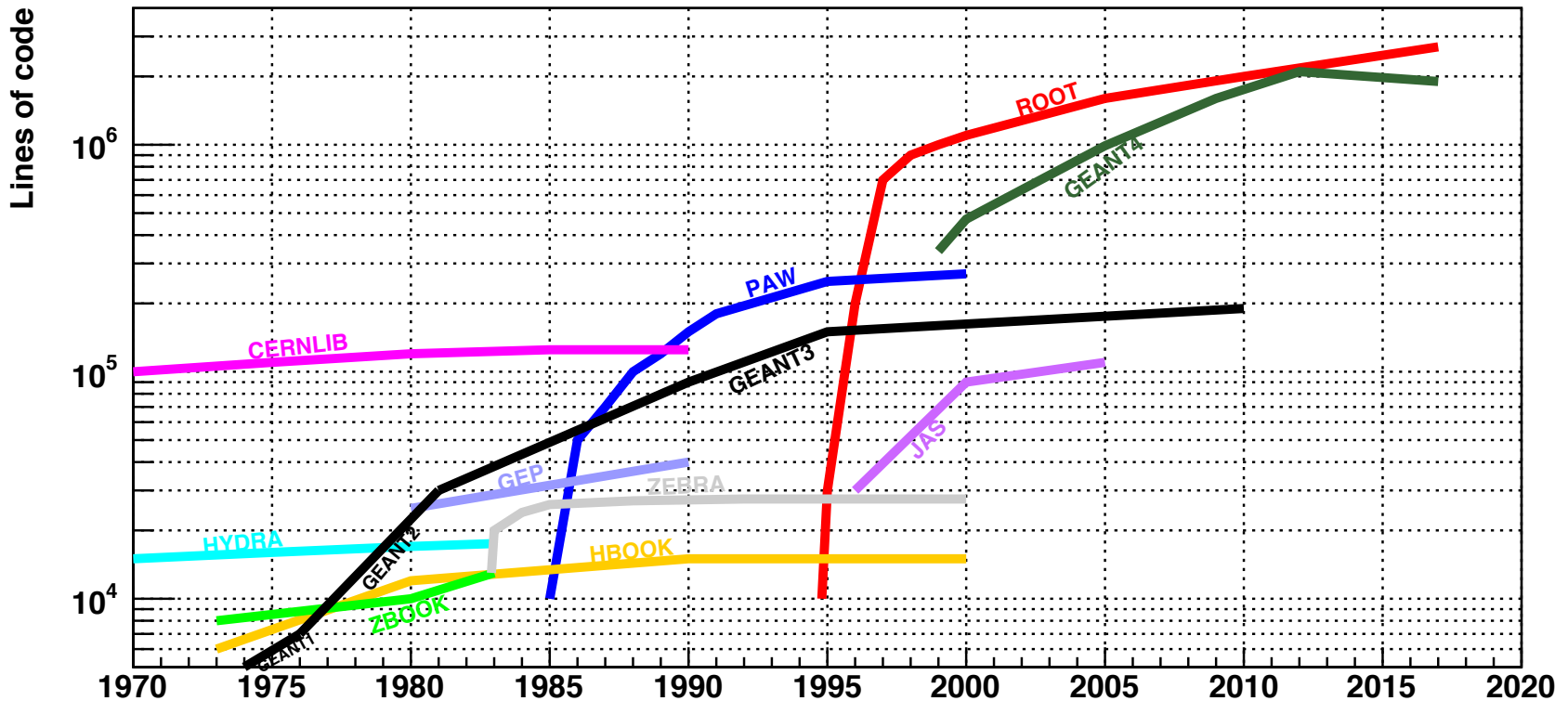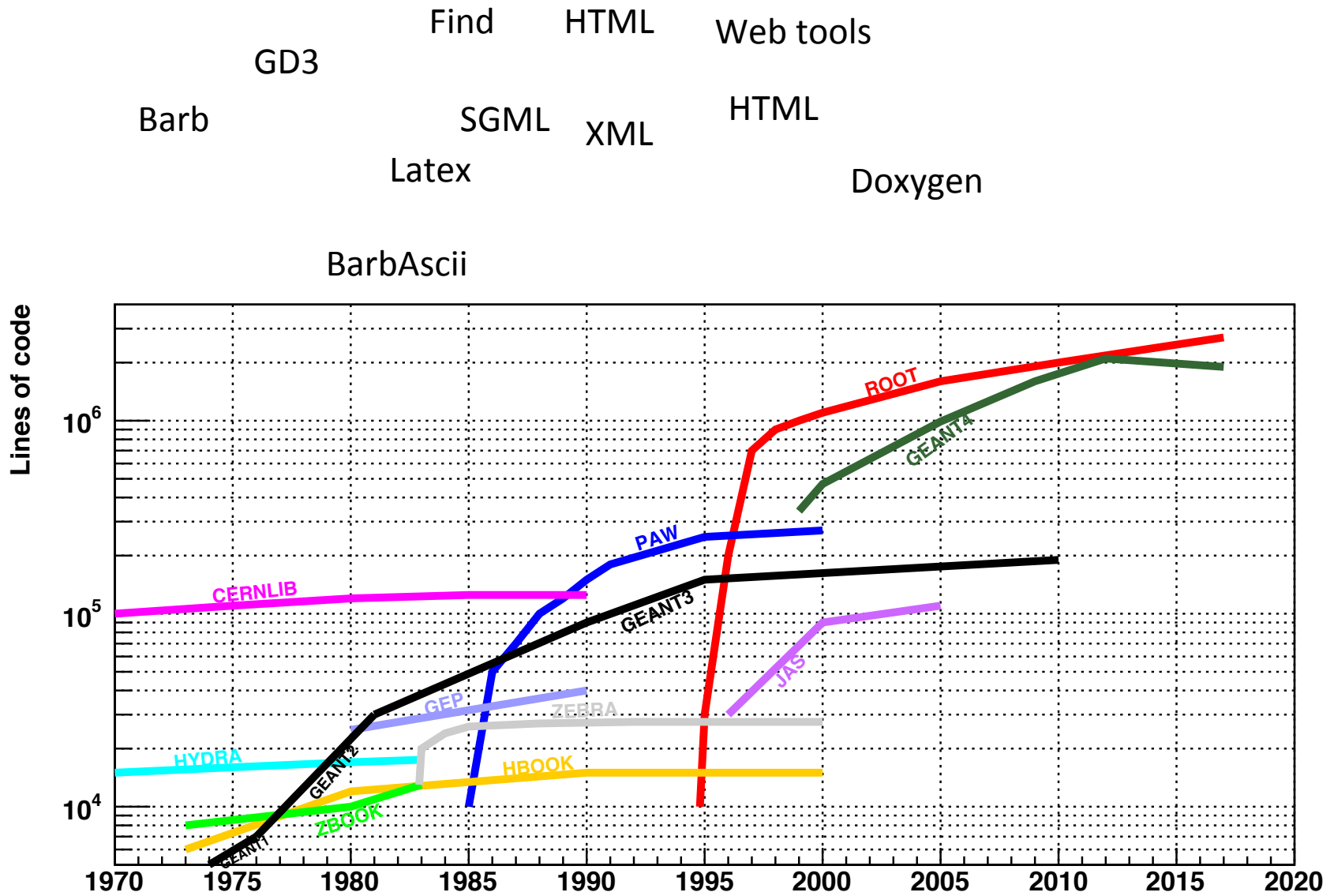
Development Tools

Punched cards   teletypes   Alphanumeric terminals   Graphics terminals   workstations   laptops

Savannah   JIRA
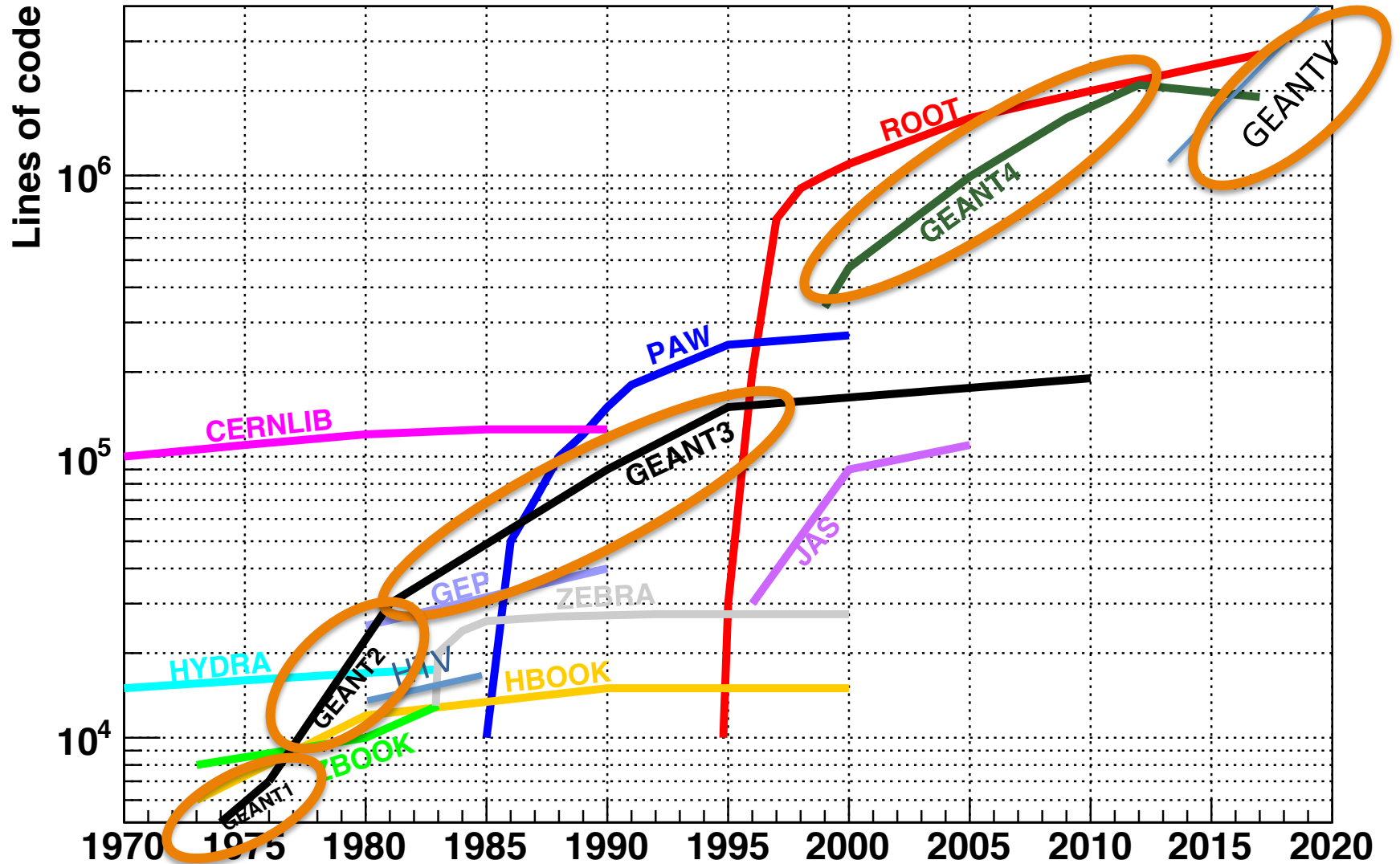
Patchy   Update   YPatchy   CMZ   CVS   SVN   GIT

Documentation Tools

GEANT versions

HBOOK (1973-> 20xx)

September 1973

Documentation sur HBOOK

Dans ce rapport nous décrivons brièvement l'utilisation, les caractéristiques et les fonctions principales d'une subroutine destinée à la construction et à l'édition d'histogrammes à une ou deux dimensions : Ceci constitue une nouvelle version des subroutines qui ont eu pour noms : HISTHE et HBOOK.

Principe de HBOOK

Toute l'information relative aux histogrammes est contenue dans un blank common : Nous rappellerons au passage que les adresses des variables d'un blank common sont les dernières de la mémoire.

Pour chaque histogramme nous faisons d'abord un booking, c'est à dire que nous reservons les locations nécessaires pour la définition de toutes les variables : Suivant le nombre de bins réservés, la longueur de chaque bin, le nombre de bits reservés pour un mot dans le cas d'histogrammes à 2 dimensions, nous aurons besoin de plus ou moins de mots mémoire. Un pointeur au prochain histogramme nous donne en fait la longueur du precedent. Un identificateur permet ensuite de faire le remplissage de l'histogramme considéré

- Subroutine HBOOK
- COMMON // LINE, BOOK(100)
- Externals, LBCHZB, VZERO, BITSZA, UBUNCH, UBLANK, UFILL,
  UZERO, UCOPY, DATEZB
- ENTRY POINTS HFILL, HISTGO, HISTDO, HMSET, HMSAVE
- Files referenced : TAPE 10 si on utilise HMSET
  TAPE 20 si on utilise HMSAVE

05/03/74

TO HBOOK USERS

FROM R BRUN, V FRAMMERY, M HANSROUL, P PALAZZI

ABOUT HBOOK VERSION 1.1 FOR THE 6500/7600 AND CERNSCOPE

A NEW VERSION OF HBOOK (1.1) IS INTRODUCED STARTING 05.03.1974. IT FEATURES A FEW IMPROVEMENTS AND A BUG CORRECTION .

IMPROVEMENTS

HBOOK IS WORKING UNDER CERN SCOPE

LOGARITHMIC VERTICAL SCALE ON 1-DIMENSIONAL HISTOGRAMS IS AVAILABLE

BUG CORRECTION

1-DIMENSIONAL HISTOGRAM DESTROYED BY PREVIOUS HISTOGRAM BEING EMPTY NO LONGER OCCURS

PARTICULAR VALUES IN THE HISTOGRAM INDEX, PRINTED WITH THE G FORMAT APPEAR AS RRRRR DUE TO A BUG IN THE SYSTEM ROUTINE KODER. THIS BUG WILL DISAPPEAR ONCE THE NEW VERSION OF THE COMPILER/LIBRARY IS INTRODUCED.

FUTURE IMPROVEMENTS

WE RECEIVED VALUABLE SUGGESTIONS FROM USERS, AND WE ARE WORKING ON A NEW VERSION OF THE PACKAGE, BACKWARD COMPATIBLE. IT WILL INCLUDE, AMONG OTHER THINGS, AN AUTOMATIC INTERFACE WITH GD3 TO PRODUCE HISTOGRAMS AND SCATTERGRAMS ON THE PLOTTER.

University of California
Berkeley, California 94720
Telephone 415/843-2740

Walter Brückner

Bldg.50A, room 5115

August 10, 1977

R. Brun
Data Handling Division
CERN
CH-1211 Geneve 23
Switzerland

Dear Mr. Brun,
I am using the version 2.1 of your magnificent HBOOK very succesfully here at
LBL's CDC 7600 and so do my collaborators.
There is certainly a more recent version of Hbook. So I wonder if you could do me
the favour and send me a magtape with the update file of HBOOK LONG on it. I could
thenextract the "compass,CDC" part of it as I did with version 2.1. If you don't
mind, please write the tape in record type "u" at 800 BpI (9 track or 7 track).
If that is not possible, record type "s" at 800 BpI, 7 track only, would be another
solution. Or, finally, record type "x" at 8oo BpI (9 track or 7 track) is
acceptable,too. Please add a HBOOK manual to the tape.

In a couple of weeks from now we'll get a PDP 11/34 computer equipped with
112 K 16-bit-words of memory and rsx version 3 software. Since this software allows
programs of any length to be loaded we would like to run HBOOK on this machine,too.
Could you write down for me the changes I have to implement in order to fit HBOOK
to the PDP 11 ? I shall write the bit manipulating routines myself.

Finally, I would be most gratefull if you would use AIRMAIL for tape and manual.

I thank you very much in advance

sincerely yours

HPLOT (1974->20xx)

HPLOT

Y251

USERS GUIDE

FOR VERSION 1.5

NOVEMBER 1976

PROGRAM LIBRARY LONG WRITE-UP Y251

CERN COMPUTER CENTRE
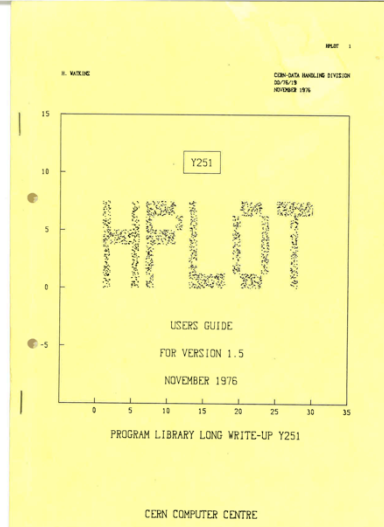
SP GROUP
DATA HANDLING DIVISION   29/03/74

TO   HBOOK USERS

FROM   RENE BRUN

ABOUT   HOW TO OBTAIN HBOOK OUTPUT ON CALCOMP AND
            MICROFILM (35 MM ROLL OR MICROFICHE)

        A FACILITY FOR STRAIGHTFORWARD OUTPUT OF HBOOK -GENERATED
HISTOGRAMS AND SCATTERGRAMS ONTO PLOTTER AND MICROFILM IS NOW
AVAILABLE,IN THE FORM OF AN AUTOMATIC INTERFACE WITH THE
GRAPHIC DISPLAY PACKAGE GD3 .ONCE THE HISTOGRAMS ARE FULL,WITH
ONLY 1 SUBROUTINE CALL

                    CALL HPLOT(ID)

        PLUS THE APPROPRIATE EXECUTION OF THE INTERPRETER (CPPLOT
OR MFILM/MCARD) ,ONE CAN OBTAIN

A -   THE HISTOGRAM OR SCATTERGRAM ID ON PLOTTER PAPER,
            IN A SIZE SUITABLE FOR IMMEDIATE USE IN A REPORT
            OR PREPRINT (A4).

B -   A SLIDE READY TO BE PROJECTED

CONTROL DATA

Rene',

I've read in one of the last computer newsletter
issues your articles about HPLOT etc.. and got
caught by the fact that changed software character
generator to Hershey characters.

I'm very much interested in that. I have a listing
of the tape with Hershey characters coordinates,
but I would much prefer not to type them.
So I would appreciate you giving me the
tape (if possible) + all installations details
etc, namely how did you install it — as a random
access files with 1rec/character or 1rec/alphabet
or how? What are the fortran (4 or 5?)
routines you had to write to support those chars?
Etc.... I cannot get hold of you on the phone,
it's really desparate...

If you want to talk to me before, send me
a note to CDC (Nils Buss) or call line
83.49.11 or call me directly to
(022) 47.22.11 (it's EPFL)
↳ secretaries ⇒ ask for me

And thanks a lot!

Zdenek SEKERA

HBOOK,,,,,

Dr. Michael Weinert in
WEHRWISSENSCHAFTLICHE DIENSTSTELLE
DER BUNDESWEHR FÜR ABC-SCHUTZ

Wehrwissenschaftliche Dienststelle der Bundeswehr für ABC-Schutz
Postfach 1320 · 3042 Munster

The
Program Librarian
Data Handling Division
CERN
CH 1211   Genf   23

(Bitte bei Antwort angeben)
Geschäftszeichen

234

Hausruf

5141

Munster

31. Juli 1978

HBOOK (Y 250) / HPLOT (Y 251)

Gentlemen,

Thank you very much for the long write-ups of HBOOK and HPLOT. As we
have access to a Telefunken Computer TR 440 I want to know wether
these packages are still installed on a TR 440. The following Ger-
man Universities have a TR 440 Computer : Aachen, Berlin, Bielefeld,
Bochum, Braunschweig, Clausthal-Zellerfeld, Düsseldorf, Erlangen,
Geesthacht, Hamburg, Kaiserslautern, Kassel, Konstanz, Marburg,
München, Oldenburg, Osnabrück, Regensburg, Saarbrücken, Stuttgart,
Tübingen, Ulm and Würzburg.

Thanking you in advance for your kindness.

CERN

DG-RSU/1496

24th February, 1978

HBOOK manual Dubna 1978

To : Dr. N. Tyurin
Representative of the USSR State Committee at CERN

From : Co-Chairman, Scientific Committee
CERN-State Committee of the USSR

H-BOOK

Mr. R. Brun (DD Division) informed me that, following contacts with Mr. L. Kaminsky and others at Serpukhov, the CERN H-BOOK program had been adapted to run on the ICL computer of IHEP. It seems that, in the course of the adaptation, the compatibility between the CERN and the Serpukhov versions was lost.

In view of the above, I would like to draw your attention to the mutual benefit we would derive from a Serpukhov H-BOOK version compatible with the CERN one, widely used also outside CERN, in the case of joint experiments being partly analysed at Serpukhov.

The H-BOOK program used at other computers is regularly updated by CERN with the collaboration of the local programmers and experts, and the same assistance could also be given to IHEP.

G. Fidecaro

ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
ДУБНА

P10 -11850

Р.Брун. З.М.Иванченко. И.М.Иванченко.

С.Г.Каданцев. Г.Л.Мазный

ПОЛУАВТОМАТИЧЕСКАЯ АДАПТАЦИЯ СИСТЕМЫ
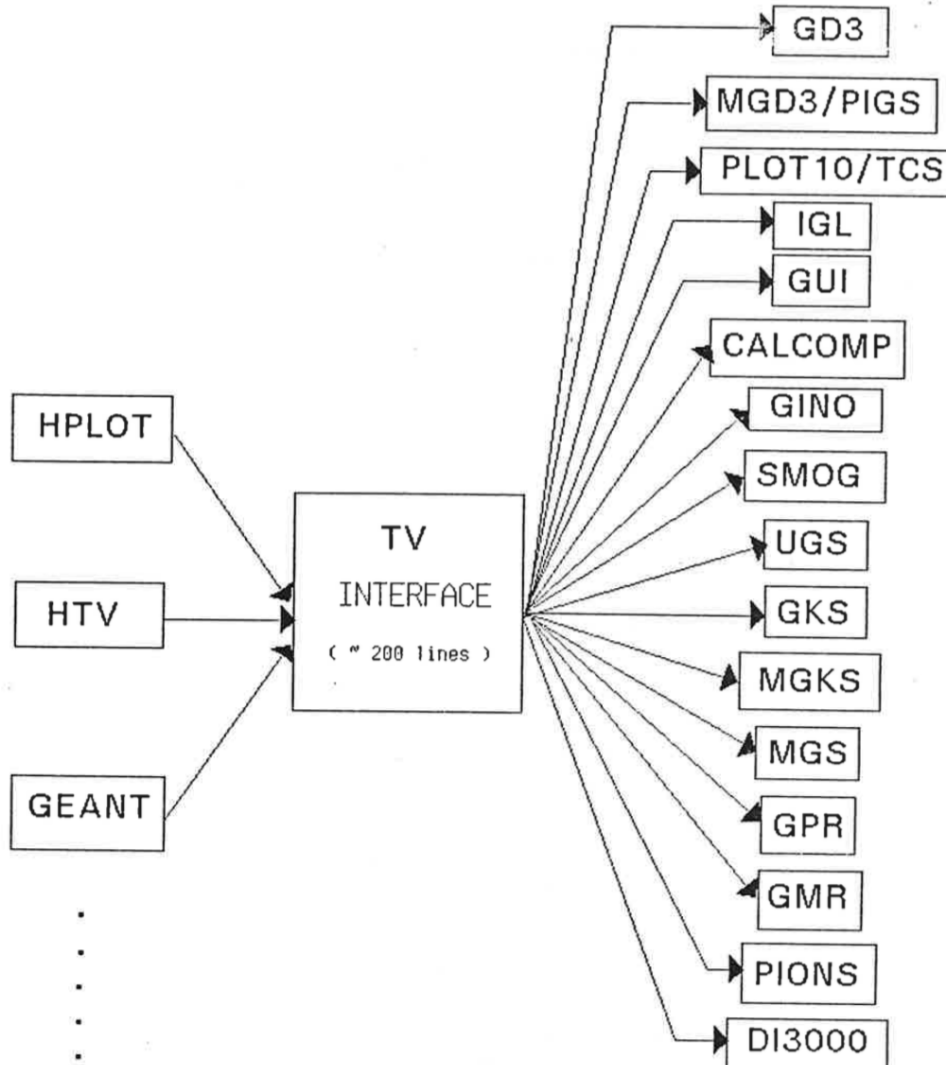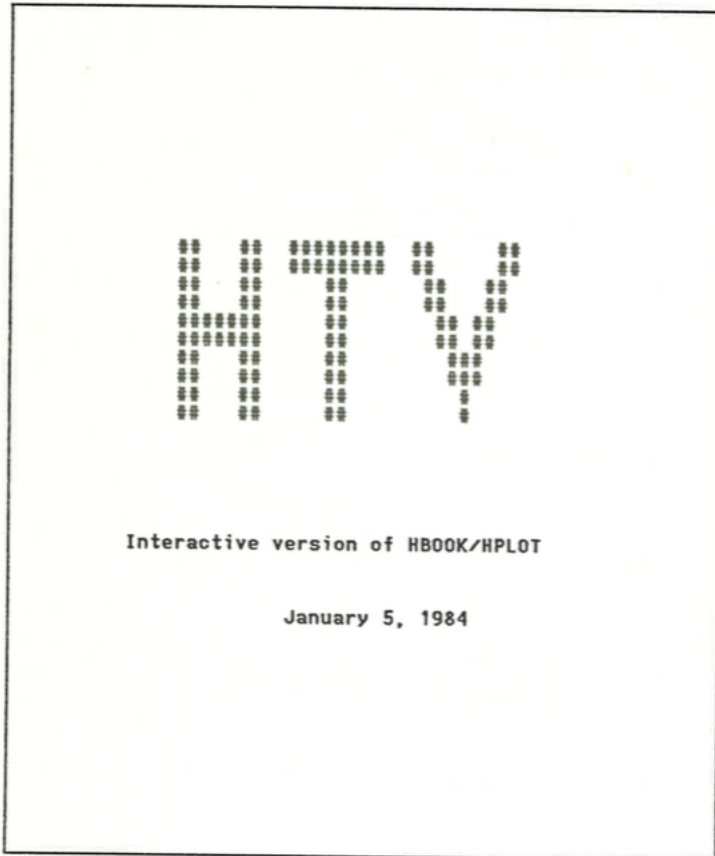ГИСТОГРАММИРОВАНИЯ **HBOOK** НА ЭВМ БЭСМ-6

1978

HTV (1980-1985)

Experimental Data Evaluation Group

Author : R. Brun

CERN - DATA HANDLING DIVISION
DD/EE/80-5
DD/US/87
Revised 10 December 198

```
##  ##   #######   ##       ##
##  ##   #######   ##       ##
##  ##      ##      ##       ##
#######     ##       ##     ##
#######     ##       ##     ##
##  ##      ##        ##   ##
##  ##      ##        ## ###
##  ##      ##         ####
##  ##      ##          ##
```

Interactive version of HBOOK/HPLOT

January 5, 1984

R.Brun: So

Mainframes & workstations

1982   Apollo

HTV

1980
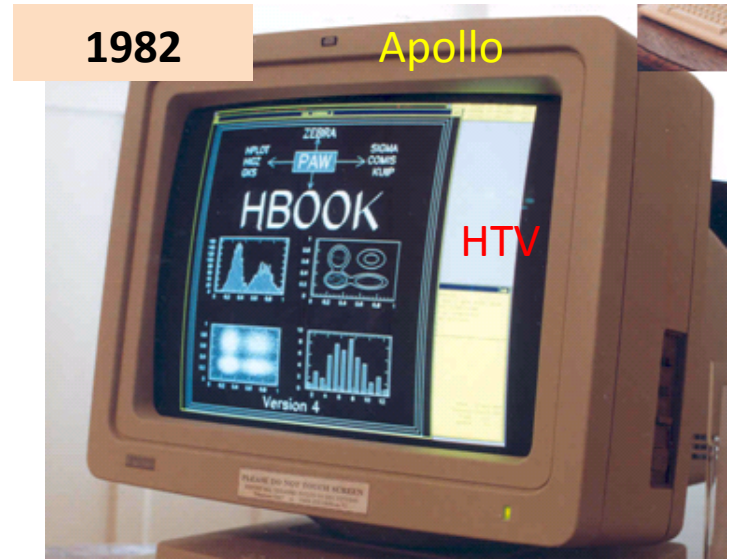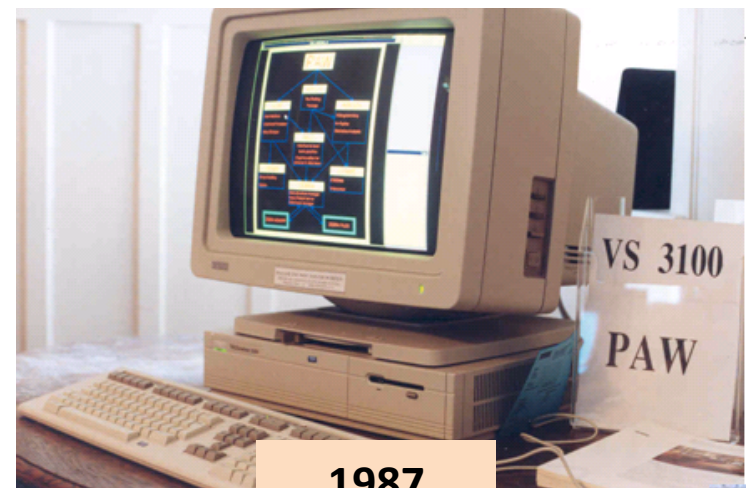
1987

GEM birth(1982) & fate(1984)

ZBOOK

Hydra

gem

ZEBRA (1984->20xx)

ZBOOK   +   HYDRA

R.Brun: Software in HENP
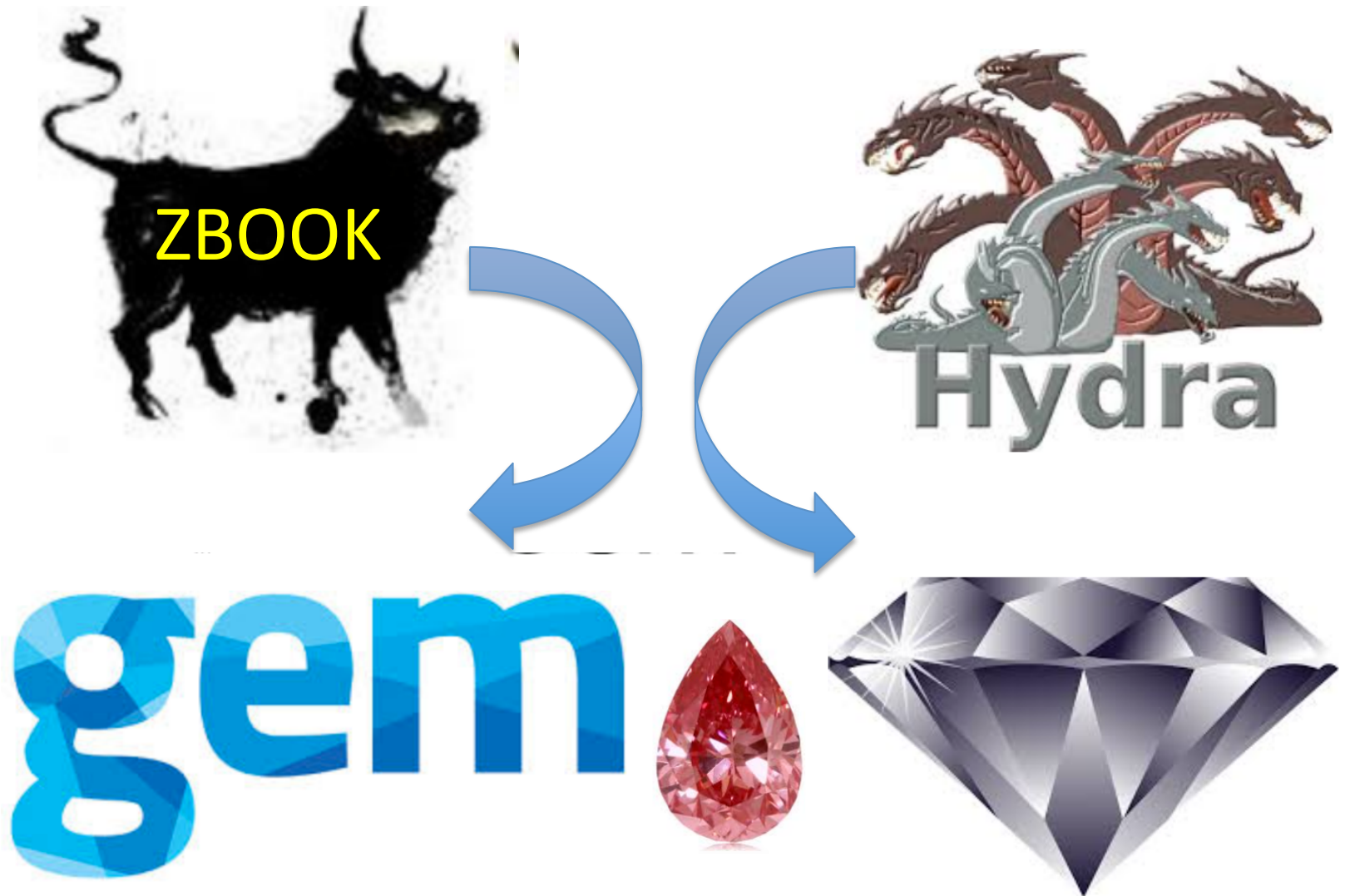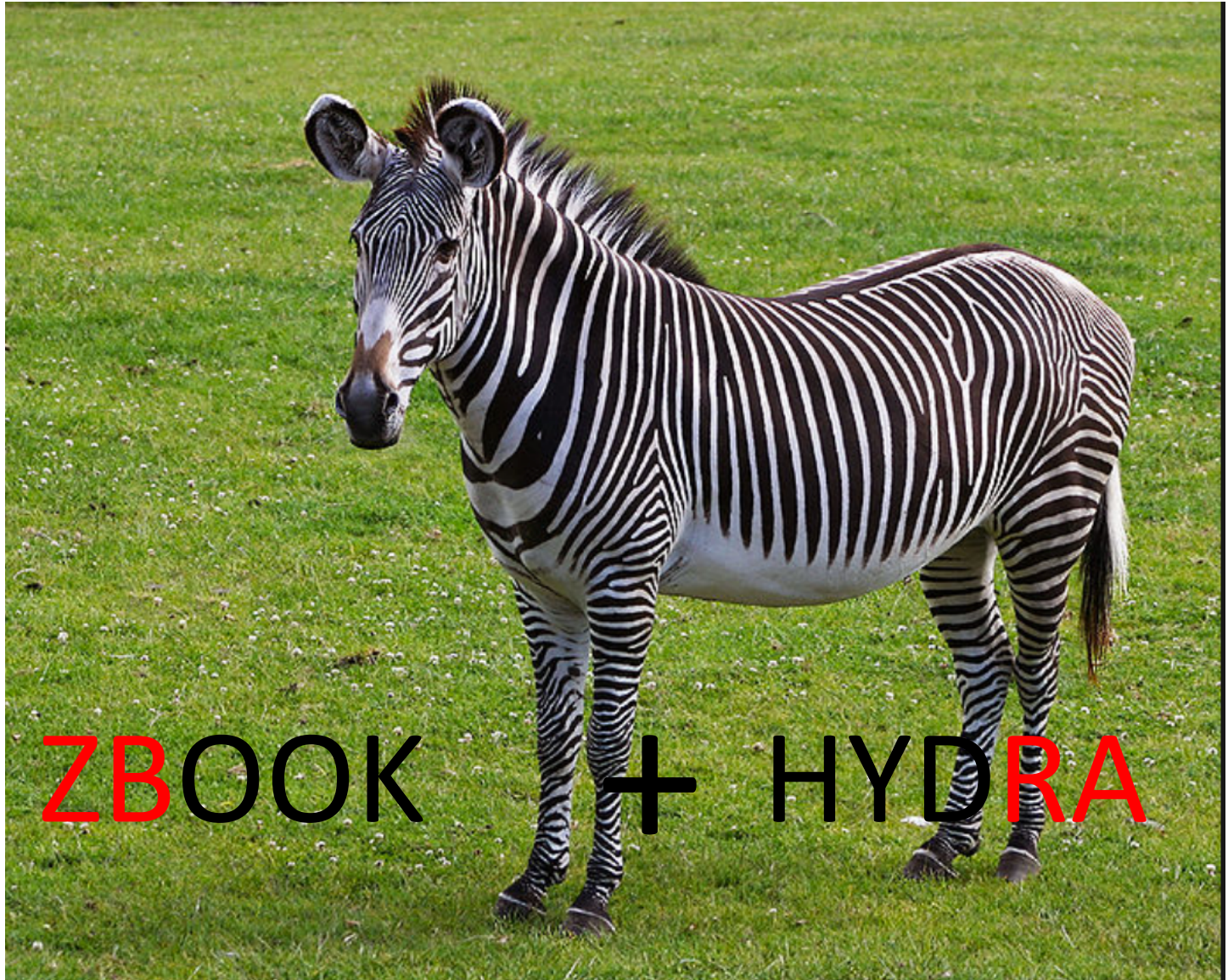
The Zebra system

- Main data structure management system used by PAW and Geant3 and also many collaborations.

- Powerful machine independent I/O

- FZ: sequential

- RZ: direct access (PAW ntuples)

- Nice Data structure documentation system, including an interactive browser DZDOC.

Towards a Physics Analysis Workstation

R.K.Bock, R.Brun, L.Pape, J.-P.Revol

1. Introduction

We discuss in this note the possibility of development of software for a physicist workstation for data analysis. Such a station would make use of the modern workstation hardware now becoming popular in the High Energy Physics community, and would be based as much as possible on existing software. We think of packages adaptable to different hardware, all based on the idea of iterative interactive creation, hierarchical storage and comparative analysis of statistical information, with possibilities for high quality output. We believe an investment of several man years can produce general tools with considerable impact on that part of physics analysis which uses less CP time than event processing, but takes substantially more other resources on computer systems (tapes, disks, MSS, output devices) and a much larger fraction of physicists′ time. The time scale for development should easily meet requirements of LEP or ACOL experiments.

+ 3 pages of specs

PAW

Minutes of PAW Meeting of 30 Aug 85
Present: R.K.Bock, R.Brun, L.Pape, J.-P.Revol

1. The 'Project Definition' Note PAW−TN/01 was accepted to contain more or less the right level of presentation, and has been finalized (date 29 Aug). It is freely available to anyone interested.

2. The guiding principles were discussed and accepted:
   − Use existing material wherever possible, but don't overevaluate compatibility (with the exception of HBOOK, which will be amended only in its output capabilities).
   − Avoid too big a project, we want some working station in roughly a year from now.
   − Give high weight to a simple and largely self-teaching user interface.
   − Try to keep the software components as modular and independent as conceivable, to ease future evolution.
   − Make a serious attempt at producing a professional product ('commercial quality').

3. Next task is to obtain technical specifications, in particular for the following data formats (general assumption is that ZEBRA formats are used wherever portability is required):

   − numerical Data Base (HBOOK output, i.e. histograms 1D and 2D, arrays), proposal expected from RB;
   − graphical data base (HPLOT output, i.e. graphical information), RB + PZ (Pietro Zanarini) + JB (Jurgen Bettels)
   − PAW support data base (i.e. macros, functions, vetcors), RKB
   − command menu data (i.e. input to the command processor), LP + RKB
   − μDST format: to be seen with P(hillippe G(avillet).

4. The question of where the dividing line between the graphics editor and the editing facilities in the PAW (HTV) would be, is open until better understanding exists of what Apollo will do, how MacDraw can be used and how the graphical data base will allow editing access.

5. The question of existing software that would obviate some or all of the project was discussed. SAS (IBM) was mentioned. RKB to check.
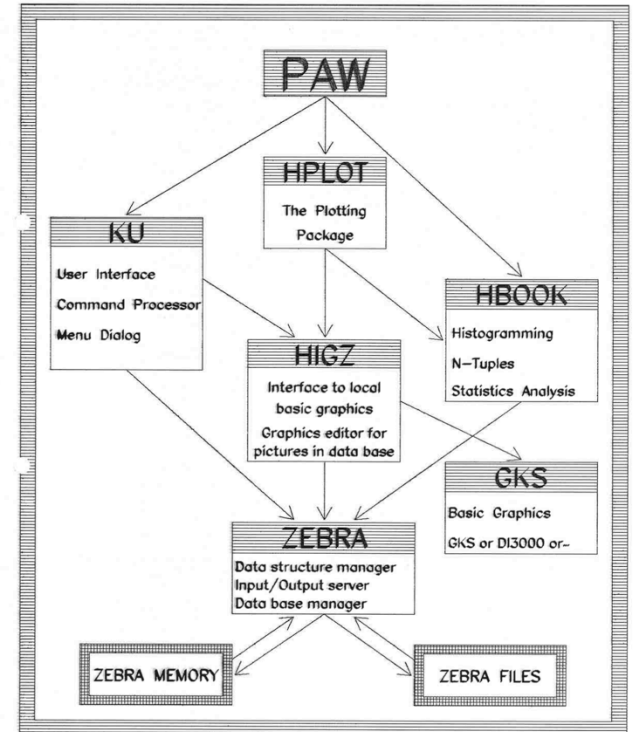
PAW (1985 -> 20xx)
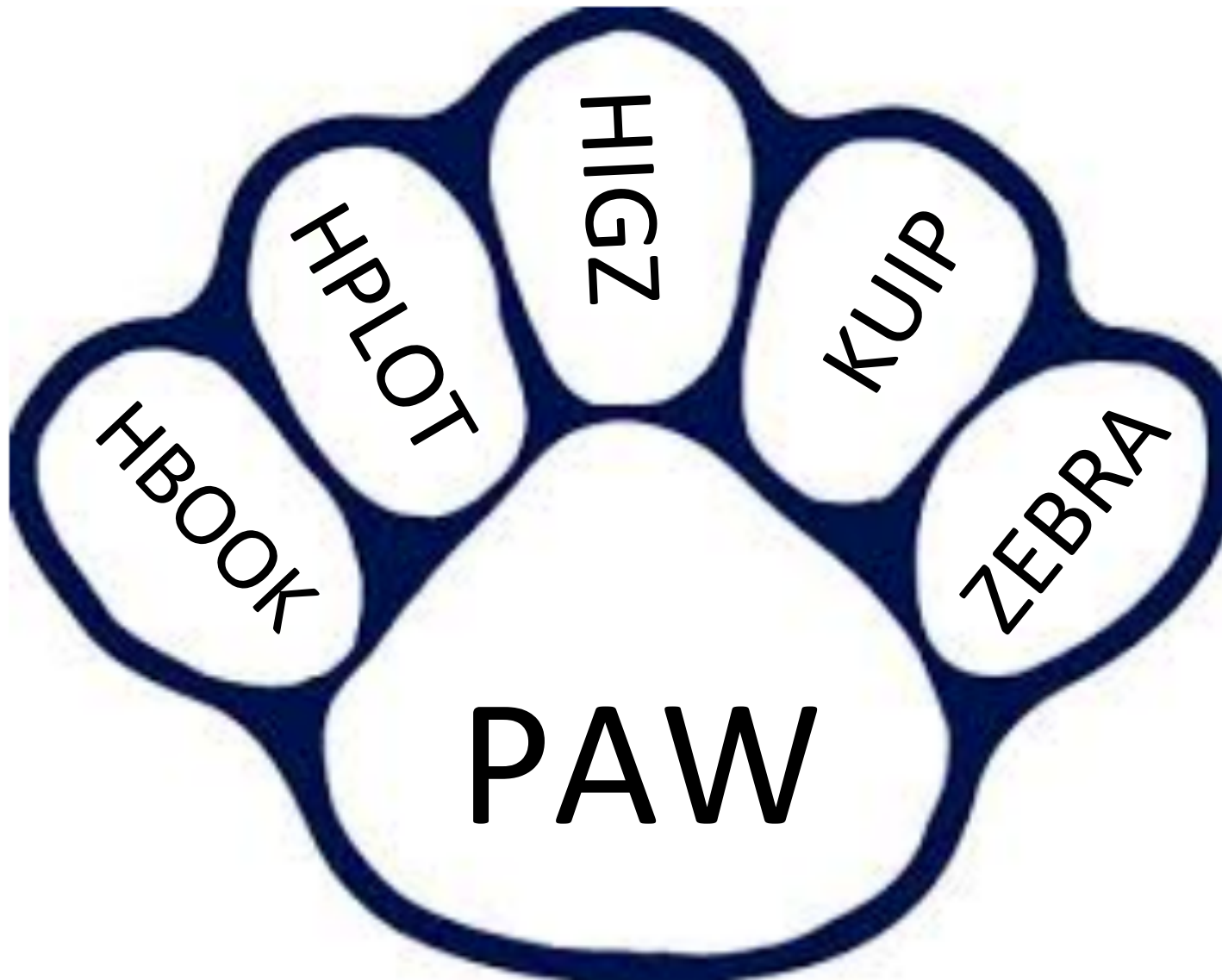
PAW and GEP

MEMORANDUM   13 March 1986

To: H.-F. Hoffmann, DESY

From: E.Bassler, DESY, R.K.Bock and R.Brun, CERN

Copy to: E.Freytag, DESY, and CCC

Subject: Collaboration DESY/CERN in Developing Interactive Physics Analysis Software

RKB

1. Background

Presently, CERN is in the process of revising seriously the existing software for interactive statistical event analysis. This is done in view of making better use of market offerings of quickly evolving hardware with increasingly attractive pricing. No adequate commercially available software product adapted to the high level of data understanding and, frequently, technical competence of physicist users is known. A cycle of partial rewriting of existing modules, and of combining them into a solid user interface with low learning threshold has therefore been proposed, under the name of PAW (Physics Analysis Workstation).

DESY has written its own product for this purpose over the last few years (named GEP), and is offering it to its collaborations, with a sizeable number of terminals being made available free of charge. It has therefore seemed useful to explore the possibilities of combining the efforts of the two laboratories, and possibly to end up with identical working conditions and fully transportable data in the high energy physics community. We have done so in a two-day meeting on 6 and 7 March, and present in this memo our conclusions. In short, such a collaboration could be very fruitful and seems desirable, but is not indicated if DESY and CERN continue to follow a computer service policy which constrains software development in a very different way.

2. The situation at DESY

DESY has been concentrating over many years on offering to its user community maximal stability (under the operating system MVS) and homogeneous, in principle non-exportable services. For our particular application, a fast (home-developed) data connection, the operating system extensions known as NEWLIB, the installation of standard twin terminals for graphical work, and the concepts that went into GEP (software for statistical analysis) all bear the mark of this policy.

Some examples: GEP makes use of full-screen communication with the physicist, possible because high-speed lines connect him in all cases. GEP's interactive part is written in PL/I, because no portability was needed. GEP makes use of partitioned data sets to store histograms, arrays, and graphics informations, which makes interface programs necessary if data have to be brought to a different computer system. The first attempt of running GEP on a non-IBM machine (VAX under VMS) is of very recent date.

The DESY user community gladly accepts these services, and is indeed well served by the modest number of available staff. Small incremental updates following user suggestions can be implemented, adherence to newly emerging standards (e.g. GKS in GEP) is possible, but constitutes a major effort.

3. The Situation at CERN

CERN has a history of offering software not so much for exclusive use at CERN, but for the entire community of HEP. Many of the packages produced in the past were explicitly designed for portability, and have been installed on hundreds of computer systems worldwide. Naturally, adaptability to different hardware and ease of installation (left to CERN's 'customers') rank high in the design criteria. Portability of data has also been made an important consideration in many applications.

It should be noted that many of the programs being distributed by CERN have been written with serious contributions from outside laboratories.

> GEP was a very successful data analysis package at DESY
> but written in PL1

> During a 2 days visit at DESY, we proposed a collaboration to the author Eric Bassler

PAW Ntuples

Old Ntuples

(The ROW-WISE Ntuples)

- 2-D tables with a fixed number of columns (up to
- Only one data type : Floating points
- No packing
- Designed for one user
- Very simple concept and very simple to use
- Efficient and robust implementation

These "Phase 1" Ntuples have been essential to
- Understand user requirements and behaviour
- Develop a user interface
- Implement the various selection mechanisms
- Have something working rather than "Dreams

Oldnt   R.Brun/CERN

NEW Ntuples

- New Data types
- Data Compression
- Structures (loop on tracks, clusters, etc..)
- New Storage model
  - Column wise instead of row wise
  - Histogramming one column from a 300 column ntuple
  - requires reading only 1/300 of the total data set
- Experiment wide ntuples as opposed to private ntuples
- Support for very large ntuples (200 Mbytes or more)
- Support for ntuple chains (big production mode)
- Performance

Example: 200 Mbytes ntuple with 160 columns (310000 events)
Ntuple/plot Id.VAR   ONE second on HP735 with New PAW
Ntuple/plot ID.VAR   THREE minutes with Old PAW

NEWNT   R.Brun CN/MEDDLE 1 Dec 92

PAW Development & Users

- Rapid development cycle in a rapidly moving hardware environment.

- Boosted by users requests and criticisms.

- Raising but not effective other products competition

Why is it hard to find someone who likes PAW ?

T. Burnett

U. of Washington (not CERN)

11 March 1992

- praise for PAW's objectiv... capabilities
- analysis of how PAW works, using an example
- an alternative approach: Aida, IDA
- thoughts about how to do it right

The PAW development was substantially reduced in 1994, but the number of happy users continued to grow until about 2005

CERNLIB and PAW are still on Linux distributions today

25/04/18

The main authors of **PAW** appear on the photo above (left to right):

Rene Brun – project coordinator
Pietro Zanarini – author of the user interface module, KUIP
Olivier Couet (standing) – author of the graphics module, HIGZ
Carlo Vandoni – author of the array manipulation module, SIGMA

Crisis: 1990 → 1999 → ?

> the Chinese word for "crisis" (危機, weiji in Chinese, kiki in Japanese) is composed of the two characters for "danger" and "opportunity". This reveals the wise Oriental insight that a crisis is an opportunity for progress

- Is Fortran90 the right solution for the future?
- Erice workshop (many system sellers) (1991)
- Emerging WEB (1990,91,92)
- MOOSE project (1992)
- ZOO, ProdiG (1994)
- Fights between F90, OO, commercial software
- RD44(GEANT4), RD45(OODBMS) (1994)
- ROOT (1995)

Erice Workshop (11-18 Nov 1990)

Proceedings of the 14th Workshop of the INFN Eloisatron Project

Data Structures for Particle Physics Experiments: Evolution or Revolution?
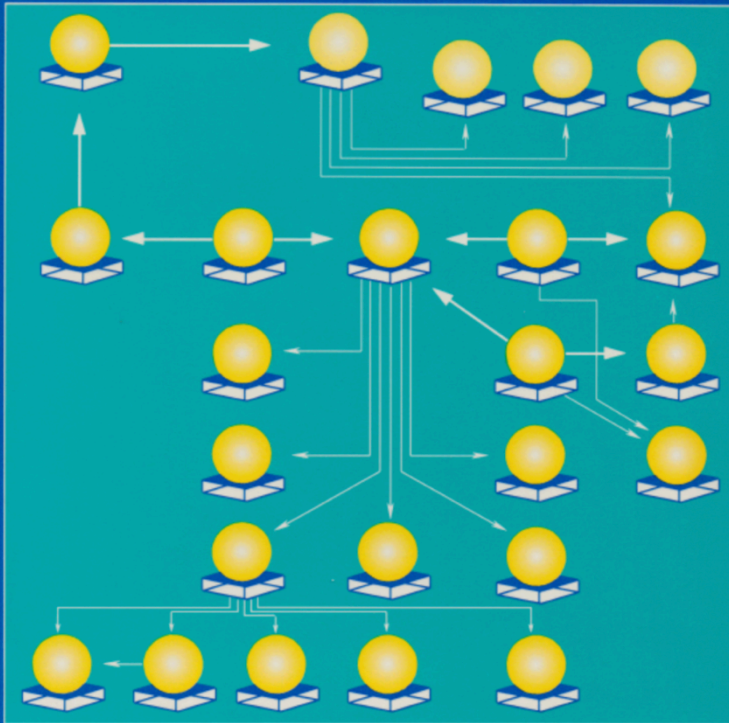
Editors: Rene Brun, Paul Kunz & Paolo Palazzi

World Scientific

BOS and Related Packages
  V. Blobel

JAZELLE: History, Status and Future Plans
  A. S. Johnson, H. Hissen, G. B. Word, M. Breidenbach,
  P. F. Kunz and D. J. Sherden

The ADAMO Data System: Past, Present (, Future?)
  P. Palazzi

The Cheetah Data Management System
  P. F. Kunz and G. B. Word

Data Organization in the H1 Experiments
  H.-U. Martyn

Use of ZEBRA in L3
  F. Bruyant

D0 Data Management
  S. Protopopescu

Experience with ADAMO in ZEUS
  J. C. Hart

A Comparison of Data Management Systems used in High Energy Physics
  T. Hansl-Kozanecka

COSMOS: A COmprehensive Super MOnte carlo System
  F. Anselmo, O. di Rosa, G. La Commare, J. F. Pusztaszeri,
  B. van Eijk, J. Alberty, E. Eskut, D. Hatzifotiadou,
  M. Marino, C. Maidantchik, G. Xezés and L. Cifarelli

The CAB Database
  G. Xezéo, G. La Commare and J. de Souza

Information Modelling for Monte Carlo Event Generators
  O. Di Rosa, B. van Eijk, F. Carminati, I. Zacharov
  and D. Hatzifotiadou

ZEUS Reconstruction Program Organization and Control
  E. Tscheslog

A ZEBRA Bank Documentation and Display System
  O. Schaile

Data Design with the Entity Relationship Model
  M. G. Green

Data Structure Design and User Interfaces
  P. LeBrun

A Framework for Data Analysis: DAFEY
  C. Arnault, G. Barrand, S. Du, C. Helft and A. Perus

PROLOG as a Data Analysis Language
  A. Bonissent

The GISMO Project: Application of Object-Oriented Techniques to Detector Simulation
  T. H. Burnett, W. B. Atwood, R. Cailliau, D. Myers,
  and .K. M. Storr

Towards the Data Abstraction in HEP
  I. Zacharov

Parallel Architectures, Languages and Data Structures
  A. Schneider

Path Finder and Code Generator for the Entity Relationship
  A. Bonissent

The ALEPH Off-Line Database System
  A. Putzer

The L3 Database Management System: A Critical Review
  L. M. Barone

Sequential I/O for ZEUS Reconstruction
  R. Glaeser

Distributed Architecture for PIGAL
  Z. Qian

Remarks on Distributed Data Structures
  P. LeBrun

Graphics and Interactive Data Handling in D0
  S. Hagopian

The DELPHI Interactive Graphics Systems
  F. Rademakers

FANAL: An Interactive tool for ALEPH Analysis
  H. Videau

Why not f90 ?

- In 1989,90,91 assumption was f90
- A lot of work invested in I/O with f90 (to support derived types).
- We could not solve this problem, because no formal way to parse the f90 module descriptors.
- In 1992 many forces pushing towards OO
- Crisis in Dec 1992
  - 1/3 in favor of f90
  - 1/3 in favor of commercial solutions
 - 1/3 in favor of C++

1993,1994,1995

- ZOO, NextPaw, Geant3.5 proposals
    - ZOO: Zebra in the OO world
    - NextPaw: Paw evolution ->C->C++
    - Geant3.5: Implement geometry package in C++
- Geant4 proposal
- RD45/Objectivity project
- ROOT project starts (in NA49)

ZOO proposal 1994

ZOO was supposed to provide the ZEBRA functionality in the C++ world.
It was supporting back compatibility for PAW & GEANT

OOf
The project was rejected

: Software in HENP
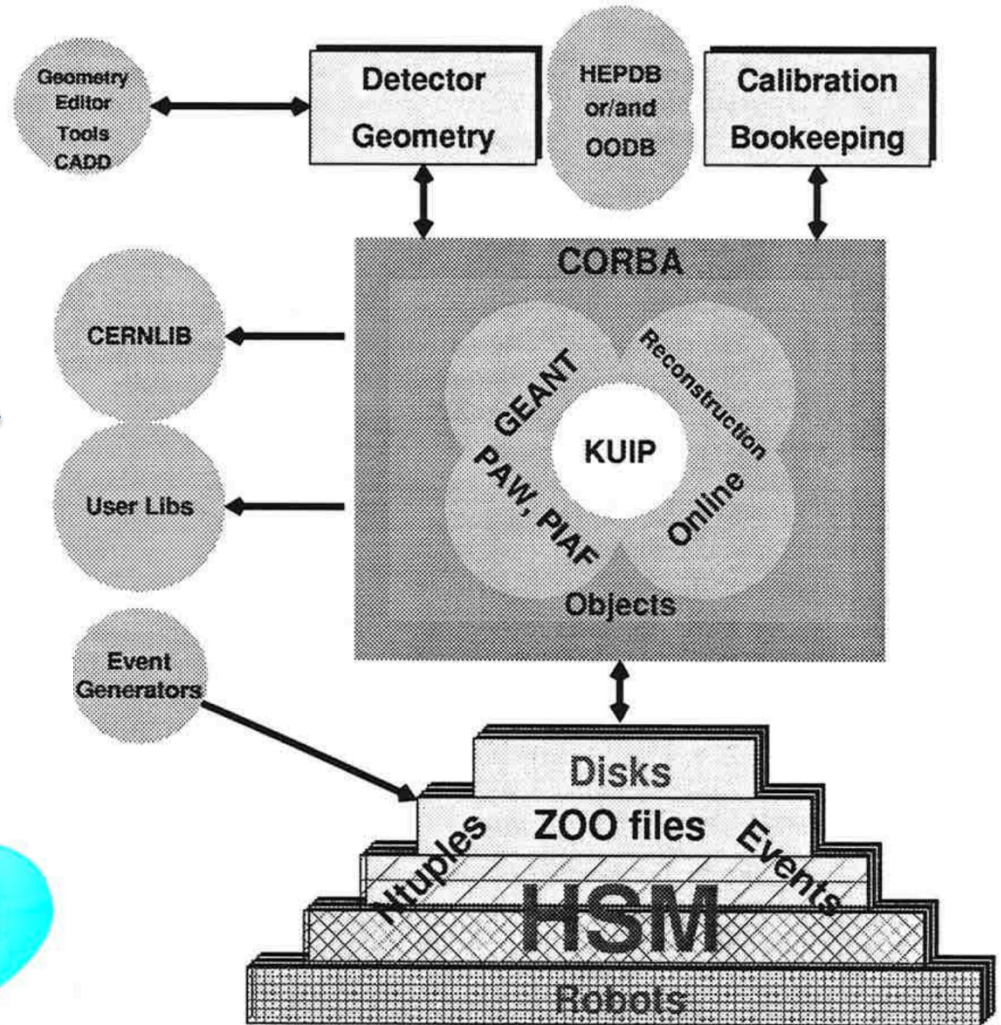
NA49 Software Meeting

3 March 1995

Rene Brun, Fons Rademakers

Proposal for the development

of an Object Oriented Software Environment

Description of the ROOT prototype

ROOT Specs Nov 95

Slides presented in November95 In a crowded IT amphi

ROOT Framework

☐ **A large subset of CERNLIB redesigned with new technology**

☐ **Assumes standard C++ environment (no other special tools)**

☐ **The same language C++ for Batch and Interactive work**

☐ **A very powerful and mature C++ interpreter**

☐ **User describes the data model in C++ header files**

☐ **Dynamic load of shared libraries**

☐ **A rich set of container classes**

☐ **Histograming and Ntuples(more than PAW/HBOOK)**

☐ **Minimization (Minuit class)**

☐ **Automatic Object-Oriented User interface and graphics**

☐ **Automatic html documentation for user files**

☐ **2-D and 3-D graphics (far more than HPLOT and HIGZ) + OPENGL**

☐ **Automatic code generation for I/O and User Interface**

☐ **Complete machine independent I/O subsystem**

☐ T̶r̶a̶n̶s̶... I/O (Ntuples generalized to Objects)

25/04/18

Tree data structure still valid today

PAW style user interface

paw > set col 2

paw > hi/plot 1

paw > set col 4

paw > hi/plot 2 same
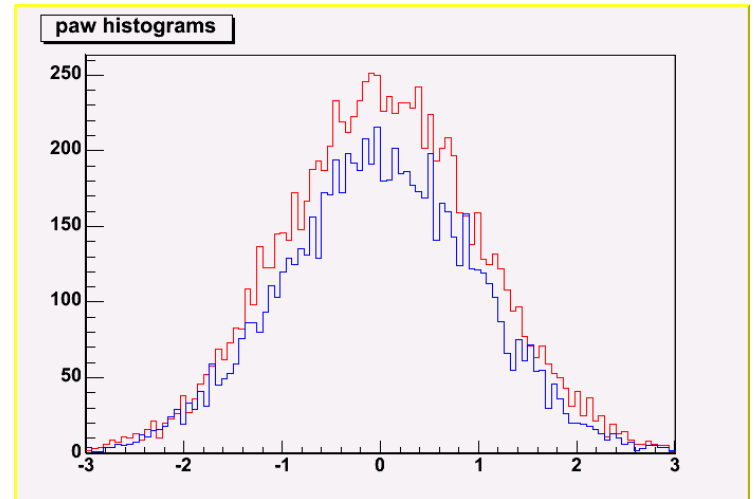
paw > ntuple/plot 100 px:py px*px+py*py>1
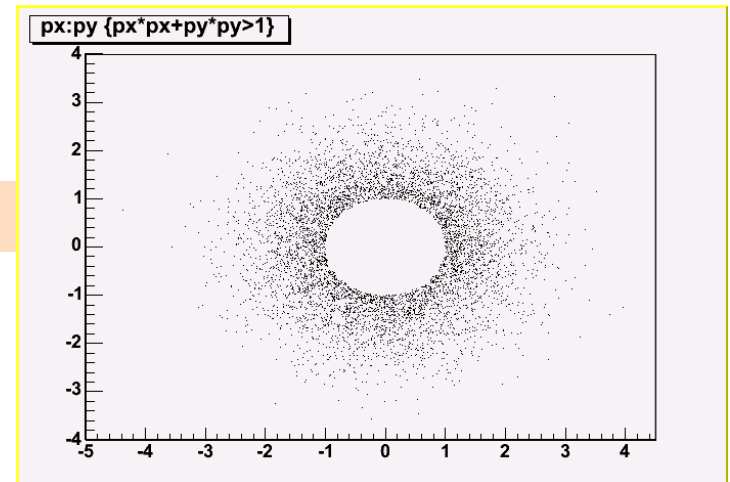
ROOT style interface

root > h1.SetLineColor(2)

root > h2.SetLineColor(4)

root > h1.Draw()

root > h2.Draw("same")
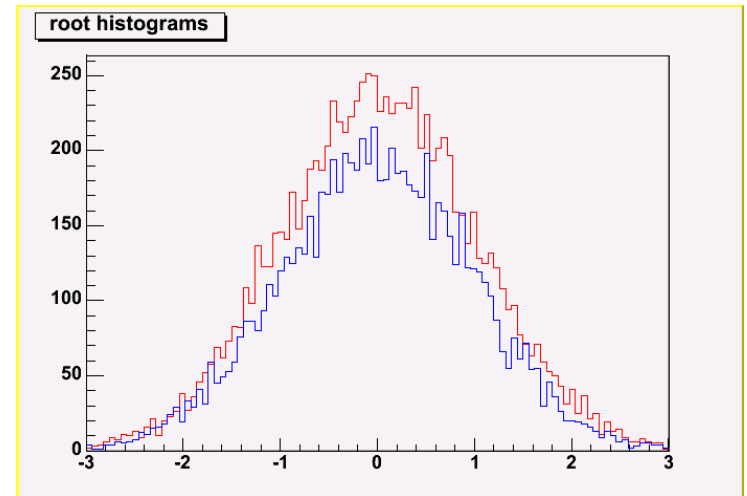
root > t.Draw("px:py","px*px+py*py>1")

root > myobject.DoSomething(…)
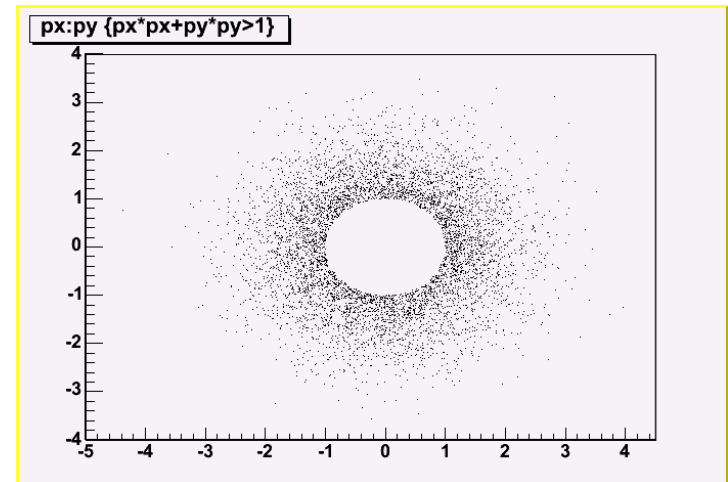
LCRB

LCRB review, March 1996

- The RD45 project has made excellent progress in identifying and applying solutions for object persistence for HEP based on standards and commercial products

- RD45 should be approved for a further year

- The LCRB agrees with the program of future work outlined in the RD45 status report and regards the following activities (below) and milestones (next) as particularly important:

  - Provide the object persistence services needed for the first release of GEANT4 in early 1997

  - Collaborate with ATLAS and CMS in the development of those aspects of the Computing Technical Proposals which may be affected by the nature of object persistence services

OODBMS (ie Objectivity)

- Hope:
  - Address one single object in a petabyte data base
  - Resolve all the object catalog issues
- Reality:
  - 64 bits OID did not scale above 10 terabytes
  - Request for 128 bits OID never implemented
  - Locking problems when many users in read mode.
  - Central DB mismatch with GRID
  - No automatic schema evolution
  - Transient data members are streamed
  - Data sets machine dependent
  - No member-wise streaming
  - No compression
  - No interactivity, etc,etc,etc,etc, etc

The I/O challenge
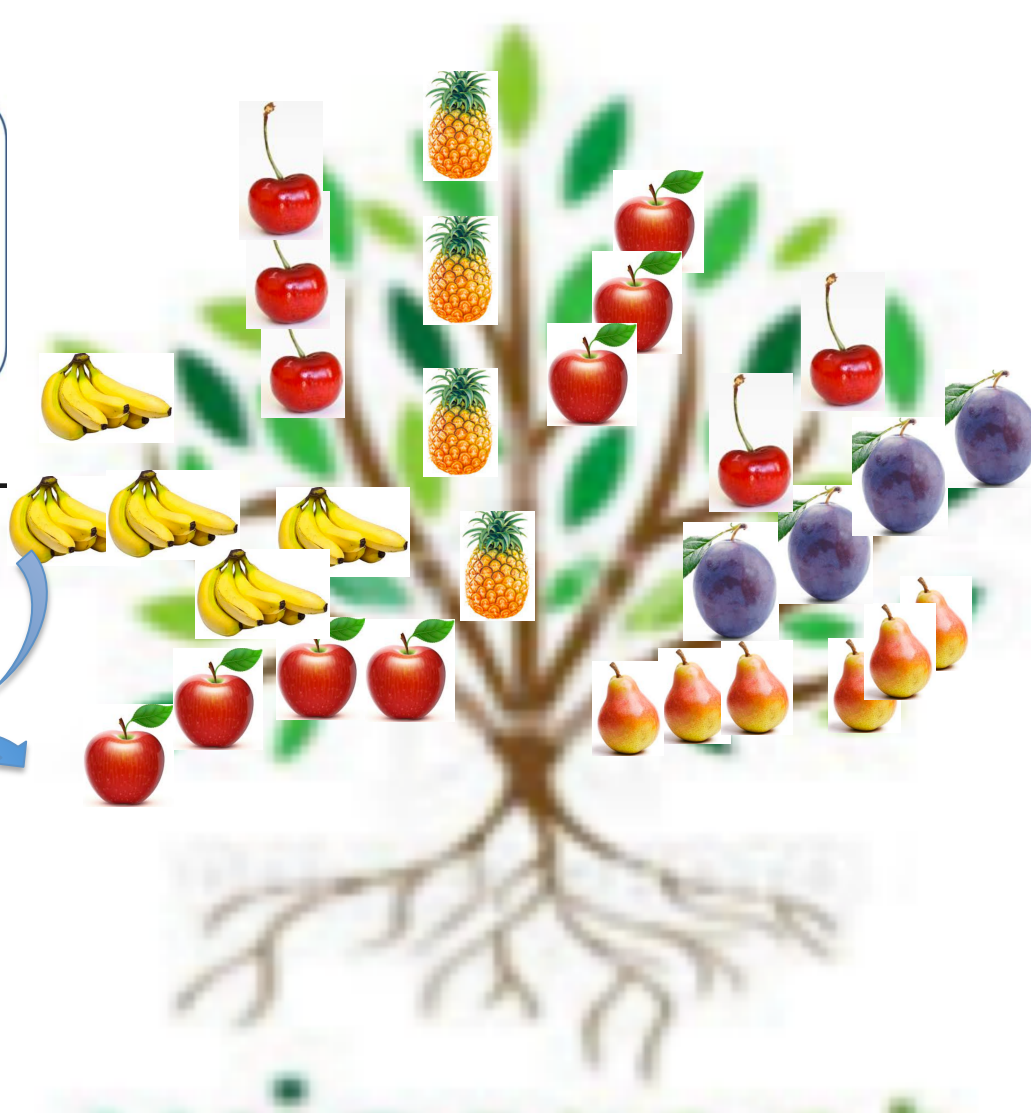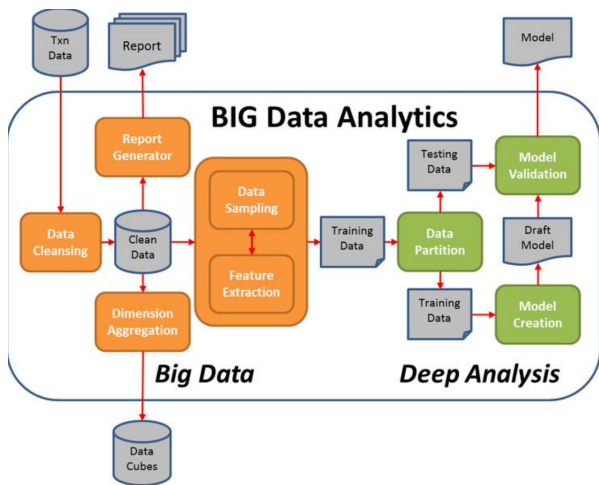
ROOT Seism (12/04/1996)

To: LHC Experiment Spokespersons - J. Schukraft, ALICE

From: L. Foà

Subject: CERN Support for Software Packages

Recent announcements and presentations have indicated clearly that the authors of the ROOT package intend that it should aim at covering a significant fraction of the data retrieval, processing, and presentation functionality required for general LHC software packages. This clearly puts ROOT into direct competition with the work of the RD44 (GEANT-4) and RD45 (A Persistent Object Manager for HEP) collaborations, which are in the process of investigating major aspects of the software packages required for LHC.

From our ongoing discussions on the availability of resources, we know that it will be extremely difficult in many areas for CERN to provide the level of staffing requested by the LHC experiments, and the situation for computing and software will be one of the most difficult areas to deal with.

In these circumstances it would be unthinkable for CERN to provide the resources to develop and support two parallel and competing general LHC software packages. I must advise you, therefore, that CERN will continue to support only the RD44/RD45 line, which has been approved by the DRDC, LHCC and Research Board, and which is regularly refereed and monitored by the LC(R)B.

May I suggest that you bring this note to the attention of the relevant people in your collaboration?

Post-Seism 1996

- What to do ? Stop? Resist?

- Strong support from NA49, ALICE

- Most people lost in f77->C++

- Many encouraging signs of support from users not understanding what happens with LHC++ and OODBMS.

- BUT, we were totally convinced that Objectivity was a dead-end for many technical reasons that were hard to follow by people with no expertise in OO and DBMS.
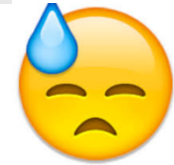
Project History 1

- Jan 95: Thinking/writing/rewriting/???
- November 95: Public seminar, show Root 0 5
- Spring 96: decision to use CINT **SEISM**
- Jan 97: Root version 1.0
- Jan 98: Root version 2.0
- Mar 99: Root version 2.21/08 (1st Root workshop FNAL)
- Feb 00: Root version 2.23/12 (2nd Root workshop CERN)
- Mar 01: Root version 3.00/06
- Jun 01: Root version 3.01/05 (3rd Root workshop FNAL)
- Jan 02: Root version 3.02/07 (LCG project starts: RTAGs)
- Oct 02: Root version 3.03/09 (4th Root workshop CERN)
- Dec 03: Root version 3.10/02 (last PRO release)
- Feb 04: Towards version 4.00 (5th Root workshop SLAC)

CHEP98, Chicago
FNAL chooses ROOT
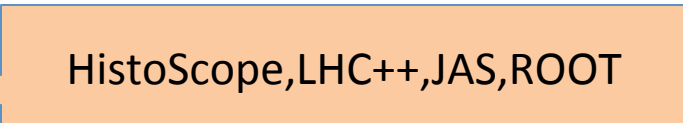
CERN support

ROOT in EP/SFT

ROOT GROUP

FNAL decision 1998

- In view of Run2, FNAL launched 2 projects in Dec97 with very clear definitions, objectives and skilled participants

  – Data storage

  – Data Analysis&Visualization

  Oracle,Objy,CDF local project,ROOT

  candidates

  HistoScope,LHC++,JAS,ROOT

- At the end of CHEP98 in Chicago serious problems spotted in Babar and progress with OODBMS slower than expected.

- Following CHEP98, ROOT was selected by FNAL for the 2 projects.

ROOT team in 1999/2000

Fons Rademakers

26/3/1999

Masa Goto

Suzanne Panacek

Philippe Canal

Valery Fine

ROOT2001 - Rene Brun

ROOT Progress Report

23/9/2000

Makefiles

> We moved to CVS In 2001

- 3 major OS (Unix, Windows, Mac OS/X)
- 10 different compilers
    - gcc with many flavors on nearly all platforms,
    - Solaris:CC4,5, HPUX:CC:aCC, SGI:CC, AIX:xlC
    - Alpha:CXX6, Windows:VC++6
    - KAI on SGI, Linux, Solaris
- 37 Makefiles

```
(pcnotebrun) [732] ls ~/root/config
ARCHS                Makefile.freebsd4       Makefile.linuxdeb2     Makefile.linuxsuse6   Makefile.solarisCC5
CVS                  Makefile.hpux           Makefile.linuxdeb2ppc  Makefile.lynxos       Makefile.solarisegcs
Makefile.aix         Makefile.hpuxacc        Makefile.linuxegcs     Makefile.macosx       Makefile.solarisgcc
Makefile.aixegcs     Makefile.hpuxegcs       Makefile.linuxia64gcc  Makefile.mklinux      Makefile.solariskcc
Makefile.alphacxx6   Makefile.in             Makefile.linuxia64sgi  Makefile.sgicc        Makefile.win32
Makefile.alphaegcs   Makefile.linux          Makefile.linuxkcc      Makefile.sgiegcs      config.in
Makefile.alphakcc    Makefile.linuxalphaegcs Makefile.linuxpgcc     Makefile.sgikcc       root-config.in
Makefile.config      Makefile.linuxarm       Makefile.linuxppcegcs  Makefile.sgin32egcs   rootrc.in
Makefile.freebsd     Makefile.linuxdeb       Makefile.linuxrh42     Makefile.solaris
```

Today full time on the project (2002)

- Ilka Antcheva (LCG staff) (since 1st Aug 2002) GUI/Doc
- Maarten Ballintijn (MIT/Phobos) PROOF (since Sep 2001)
- Rene Brun: PH/SFT group and Alice part time
- Philippe Canal (FNAL/CD) (since 1998)
- Olivier Couet CERN (since 1st Jun 2002) Graphics
- Gerri Ganis (LCG) (since Dec 2002) Authentication
- Andrei Gheata: (Alice) Geometry package (since Sep 2001)
- Masa Goto (Agilent technologies) CINT fulltime!
- Eddy Offermann (from Finance world. Sabatical for 1 year)
- Valeriy Onuchin (LCG) GUI/Win32gdk (since 1st Feb 2002)
- Fons Rademakers: Alice and PH/SFT group

https://root.cern.ch/project-founders
https://root.cern.ch/previous-developers
https://root.cern.ch/team

Up-to-date list
In 2017

Interpreter & Compiler integration

root > .x script.C

execute file **script.C**

root > DoSomething(…);

execute function **DoSomething**

root > .x script.C++

compile file **script.C**
and execute it

root > .x script.C+

compile file **script.C**
if file has been modified.
execute it

gROOT->ProcessLine(".L script.C+");

gROOT->ProcessLine("DoSomething(…)");

same from
compiled
or interpreted code

Current ROOT structure & libs (2002)

Root CORE Classes

Base · Cont · Meta · ZIP · Unix · WinNT · Net · Cint

Physics · Geom · Matrix · Hist · Tree · Rint

EG · Quadp · Graf · HistPainter

EGPythia · GeomPainter · Graf3d

VirtualMC

G3_vmc · G4_vmc · GPad · TreePlayer

MLP · Proof

Ged · Gui · TreeViewer

Alien	Castor
RXML	Chirp
Dcache	RFIO
Minuit	Fumili
RGL	X3D
Postscript	html
MySQL	PgSQL
Oracle	SapDB
Table	Hbook
Thread	AsImage
Ruby	PyROOT

All libs need Core
Arrows show lib dependencies
CINT can be used independently
Green libs loaded by PluginManager

GWin32 · GX11 · GX11TTF · GQt · New

ROOT Libraries Dependencies

25/04/18

Applications Area Organization in 2002
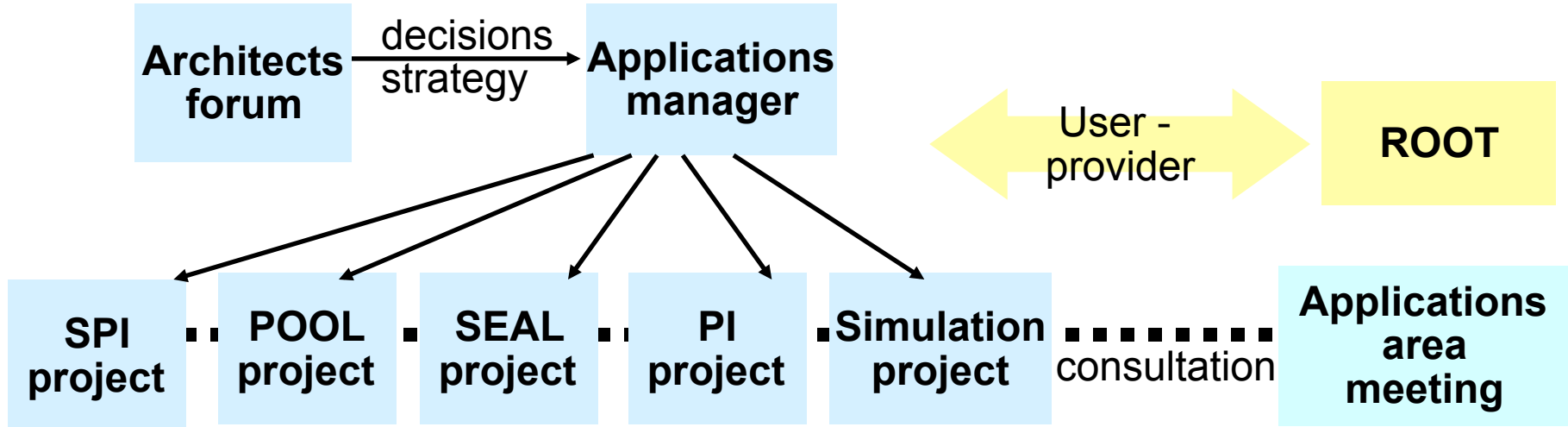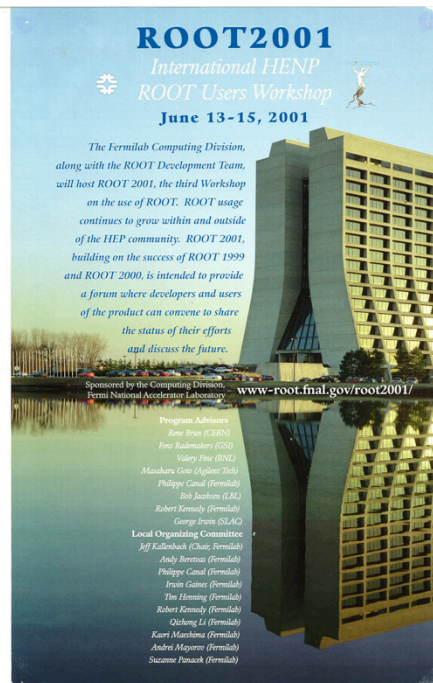
We are currently discussing with our colleagues in LCG/AA to see if a convergence on key items is possible in the medium & long term.
With SEAL a possible cooperation is envisaged for
- a common Dictionary approach
- the design/implementation of a MATHLIB

ROOT Workshops

- Opportunity to present and discuss the latest developments.
- Get feedback

Evolution of ROOT I/O

1995

- Hand-written Streamers
- Streamers generated via rootcint
- Support for Class Versions
- Support for ByteCount
- Persistent class Dictionary written to files
- rootcint modified to generate automatic Streamers
- Support for Automatic Schema Evolution
- Can generate code for "DataObjects" classes in a file
- Support for complex C++ cases
- Can read files without the classes
- Persistent Reference pointers
- Support for foreign classes
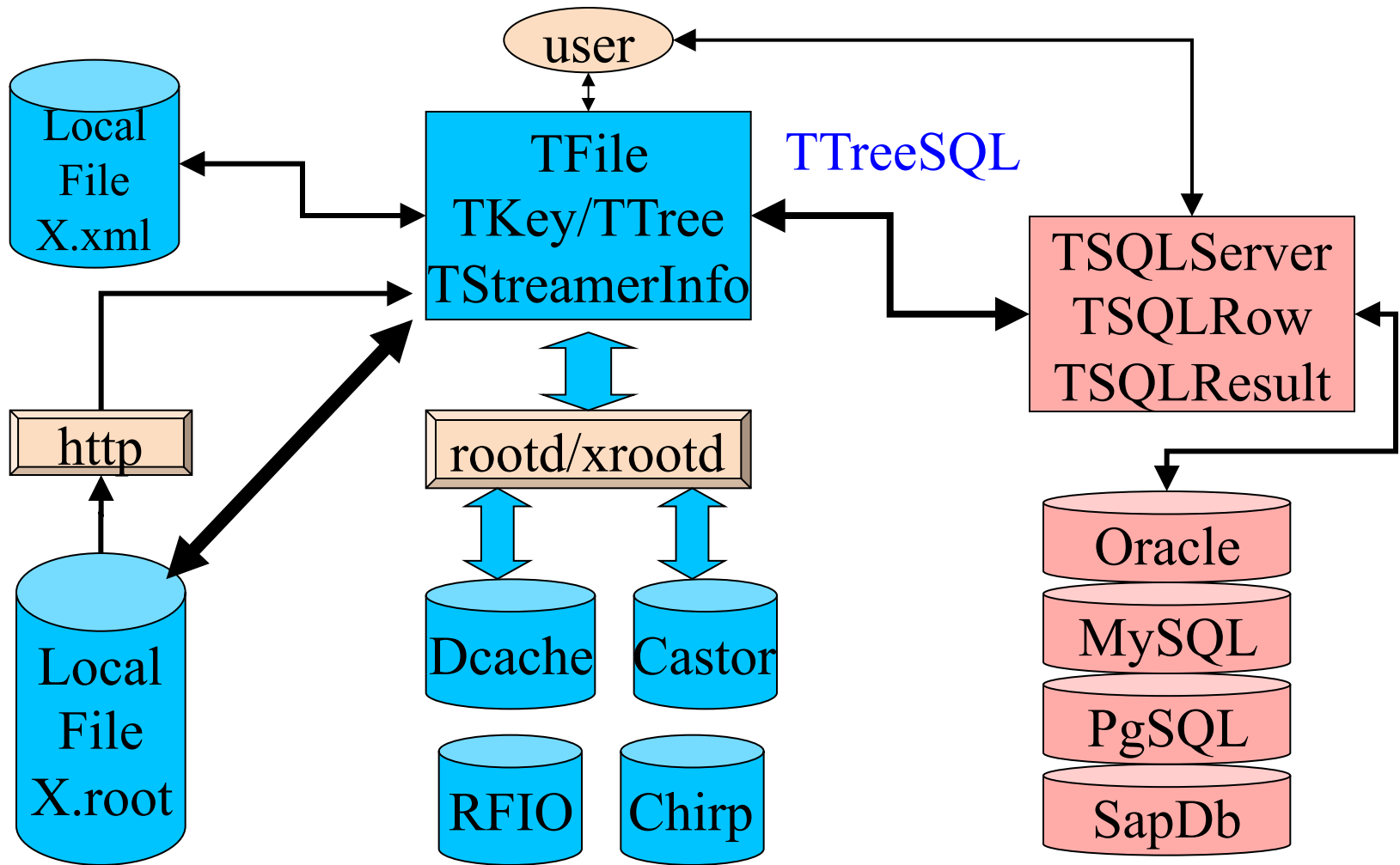- Full support for STL

2005

3.00

3.01

3.02

3.04

4.02

R.Brun: Software in HENP

File types & Access in 4.01/xx (2004)

I/O Overview in 2010

Several enhancements to ROOT I/O performance

- Prefetching (a.k.a. *TTreeCache*)

- Clustering the baskets

- I/O challenges in ***CMS***

- Optimizing the streaming engine

Consolidation: 2012->2018

I retired

- User Interface: CINT → CLING, Growing use of Python
- Graphics: Ps, gif, pdf, GL,Tex,web (2,3-D)
- JavaScript ROOT interfaces for I/O and visualization; Jupyter kernel, THttpServer
- Math: fitting, stats,TMVA, R, Scikit-Learn
- I/O,Multi-tasking,threading
- TTree clusters, prefetch, TTreeReader
- Build, QA, documentation and Test system
- User support: mail ->Forum ->...
- transition to CMake, switch to doxygen
- 4000 bugs fixed, 61000 forum posts.

DEEP ROOT

ROOT

Thanks Axel

Challenges

- Evolution vs Revolution
- Follow technology trends
- Be open to other worlds
- Make things simpler for beginners
- "OK Google" ➔ "OK ROOT" ➔ code
- Talk at Sarejevo ROOT workshop in September

Conditions for success

- Top priority: Instantaneous user support
- Understand & prioritize users requirements
- Project members must follow all branches
- Stability & continuity even with revolutions
- Code quality: dash boards, coverity, etc
- Do not duplicate user interfaces
- Simplify installation
- Tools for beginners
- Last but not least

Nothing great was ever achieved without enthusiasm.