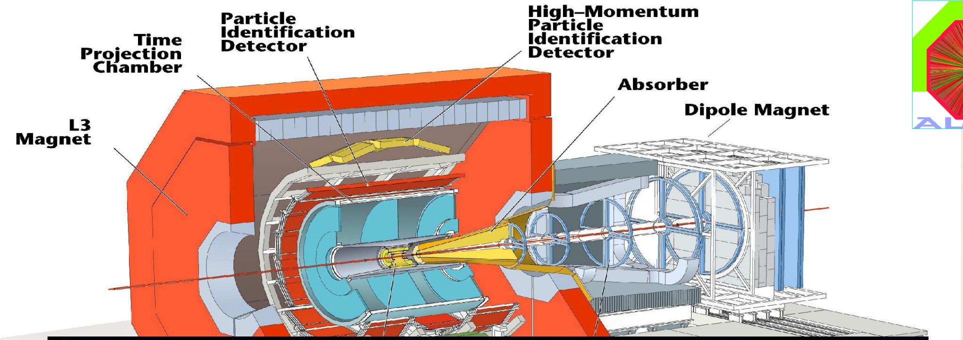
Detector Simulation & GRID Technology

F.Carminati

Erice, September 28, 2003

Alice collaboration


Time
Projection
Chamber
Particle
Identification
Detector
High-Momentum
Particle
Identification
Detector
Absorber
Dipole Magnet
L3
Magnet

Total weight	**2,000t**
Overall length	**17.3m**

U. S. S. MISSOURI BB - 63

Total weight	**53,000t**
Overall length	**270.4m**

nd

e

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/sec)

proc

GB/

2 - F

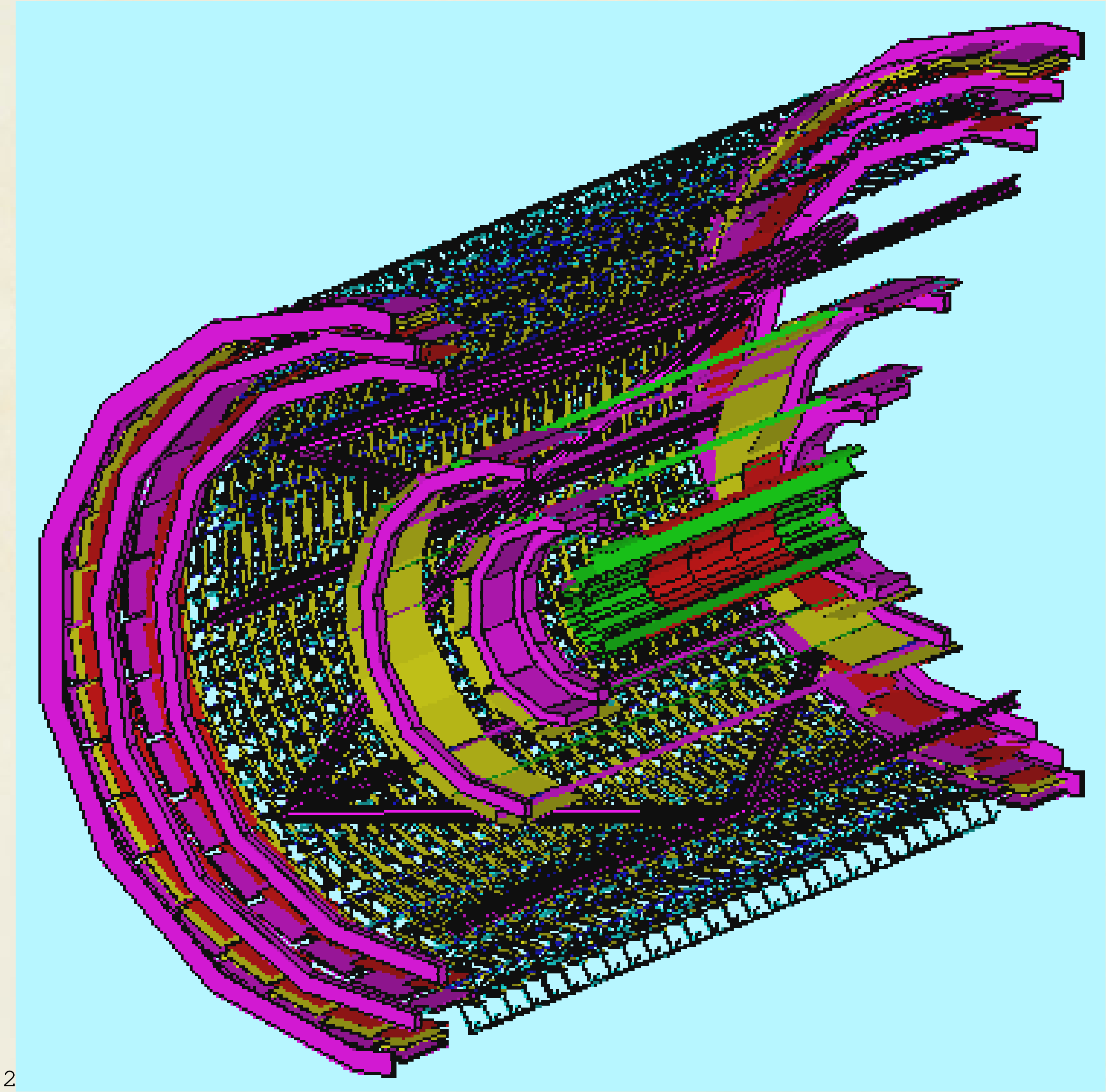
30

(1.25 G

data rec

offline analysis

ALICE Event/100



The question of simulation

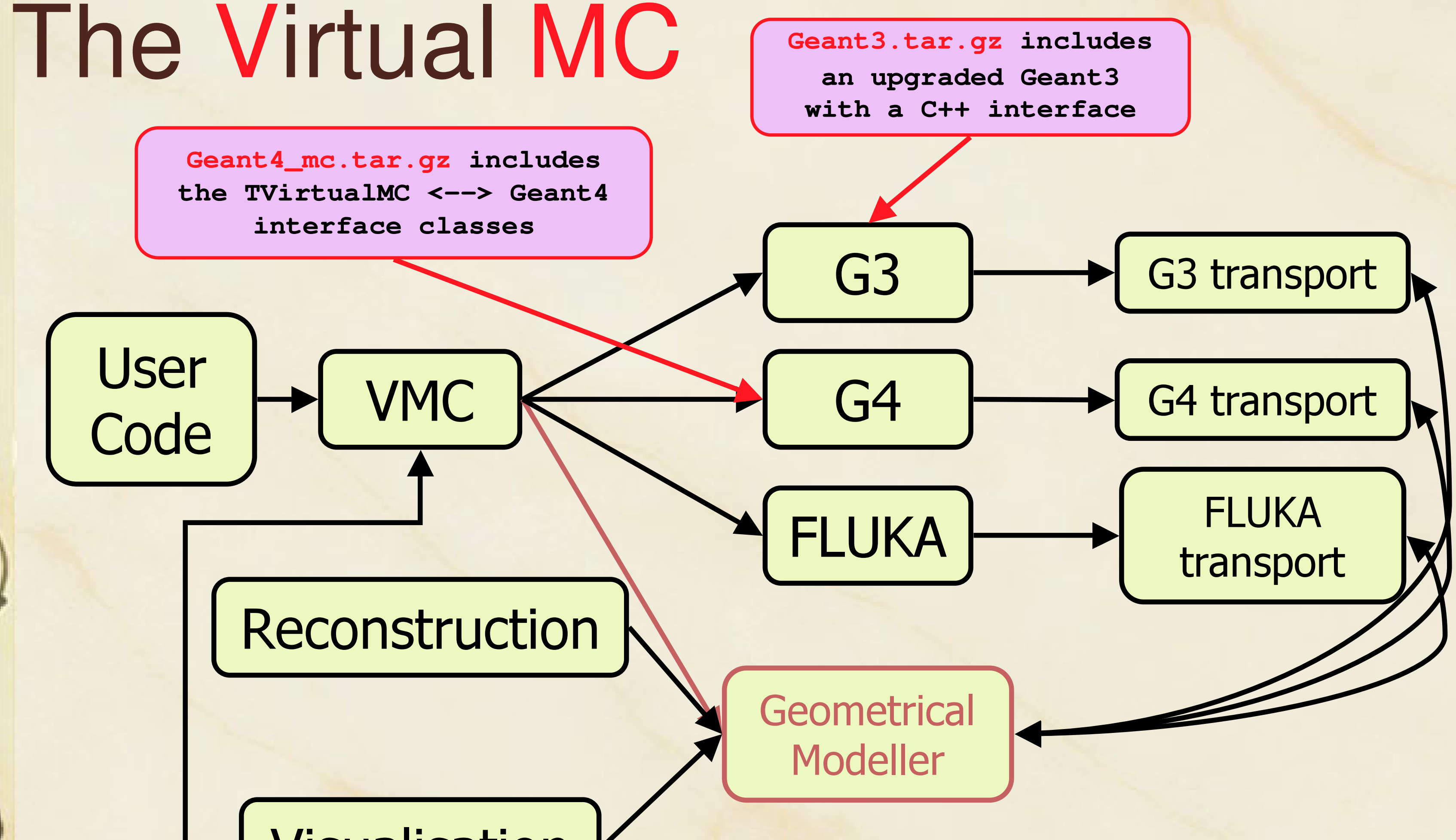
- Simulation is vital for HEP to evaluate the performance of the detector and estimate background

BUT

- Using GEANT 3.21
  - Stay with FORTRAN, old physics and geometry
- Using GEANT 4
  - Not yet completely validated
- Using FLUKA
  - Good physics but limited user interfa

We are in trouble!

The Virtual MC



Geant3.tar.gz includes an upgraded Geant3 with a C++ interface

Geant4_mc.tar.gz includes the TVirtualMC <--> Geant4 interface classes

User Code

VMC

G3

G4

FLUKA

G3 transport

G4 transport

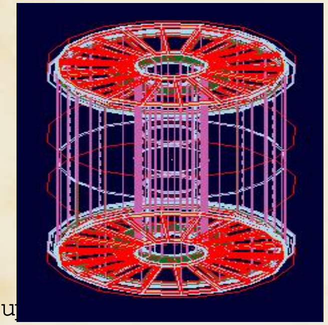
FLUKA transport

Reconstruction

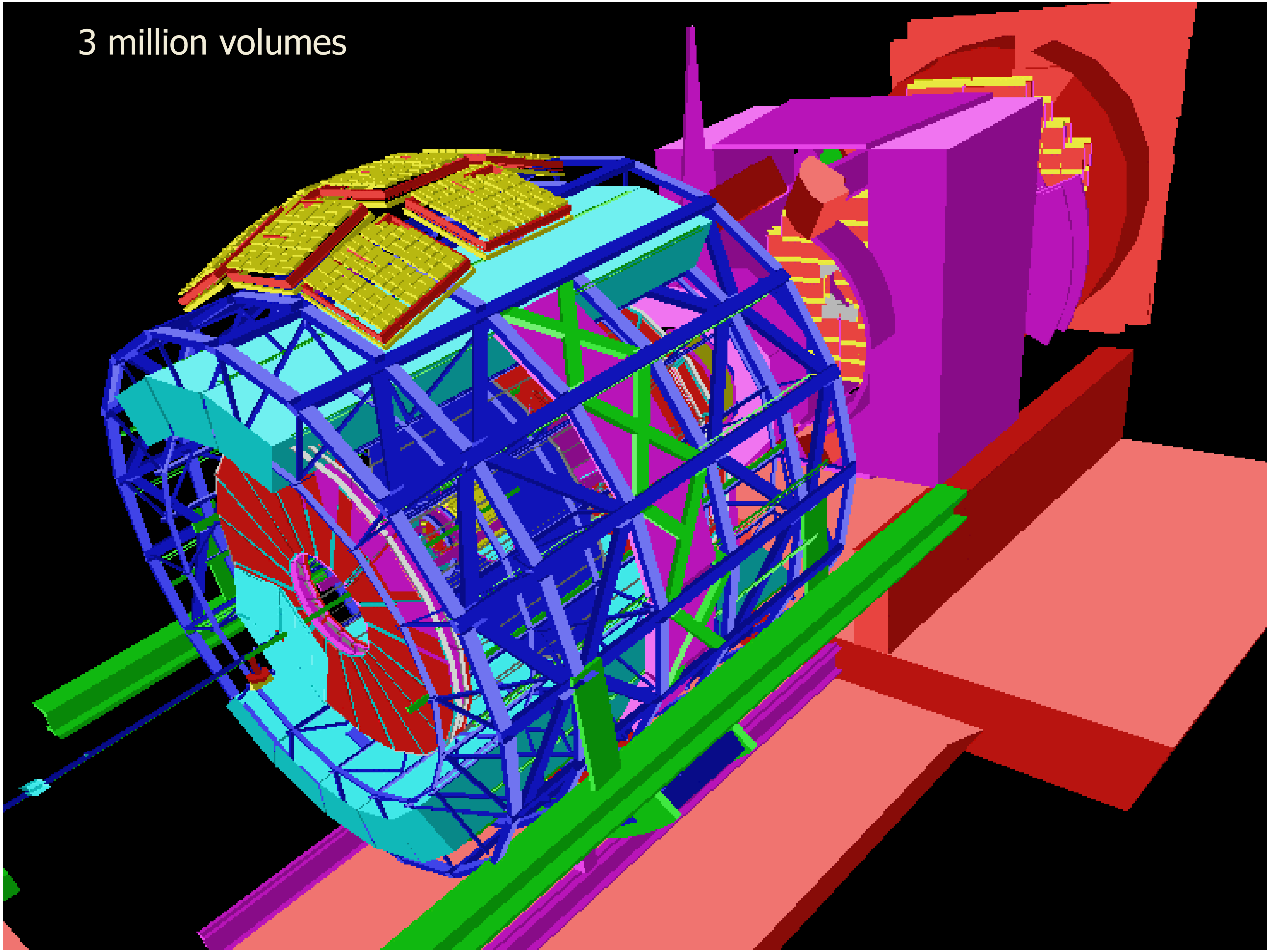
Geometrical Modeller

Visualisation

Generators



3 million volumes



Issues in simulation

- Reliability of the MC
  - The simulation result are (at best!) as reliable as the MC used!
  - The problem is how well a MC describe a non existing detector in an inexperienced domain of energy
  - Multi-million €choices depend on this
- Availability of adequate computing power
  - Cannot beat the 1/√n law
  - Variance reduction techniques are not commonplace in all HEP MC’s, and they are not of general use

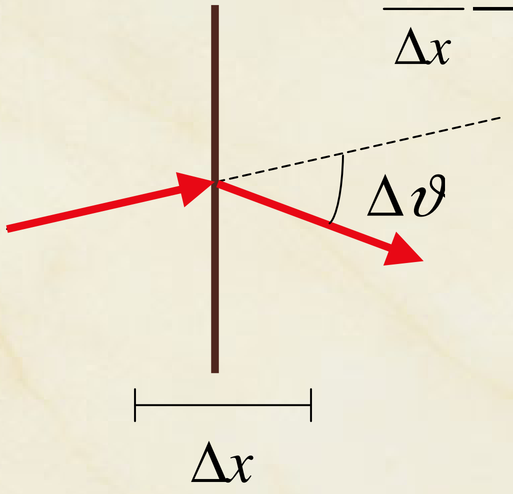
Reliability

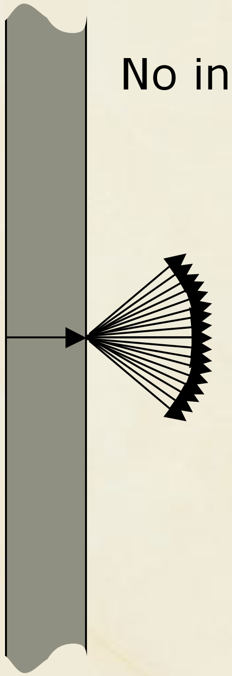
- The question usually asked is what is the precision needed for the different processes
- Unfortunately this question is ill posed
  - The interaction between processes is highly non linear
  - It is almost impossible to determine “a priori” which process is important for a given case
- The best strategy is
  - Describe processes “as well as possible” (sic!)
  - Constantly control the quality of the MC with experimental data
- BTW, the same applies with cuts

Do we know everything about multiple scattering?

Boundary

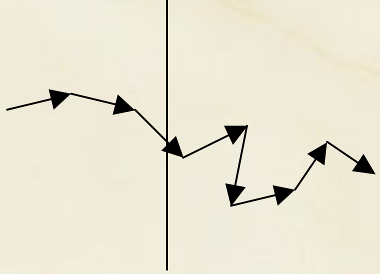
$$\frac{\Delta\vartheta}{\Delta x}\xrightarrow[x\to 0]{}\infty$$



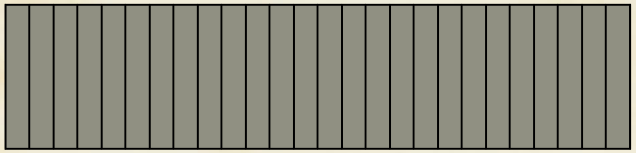


No initial deviation?

Single scattering through the boundary



Affects e/π in finely segmented media



Parametrisation and physics

- All MCs contain parametrisations to be tuned… however
  - If these are the parameters of a spline, no application to a set of data different from the original is allowed
    - This is the case of GHEISHA (page 3 of the GHEISHA manual), still largely used for LHC simulations!
  - If these are parameters of a physic model, a little more optimism is allowed
    - This is the case for FLUKA and the latest developments in GEANT4

MC validation

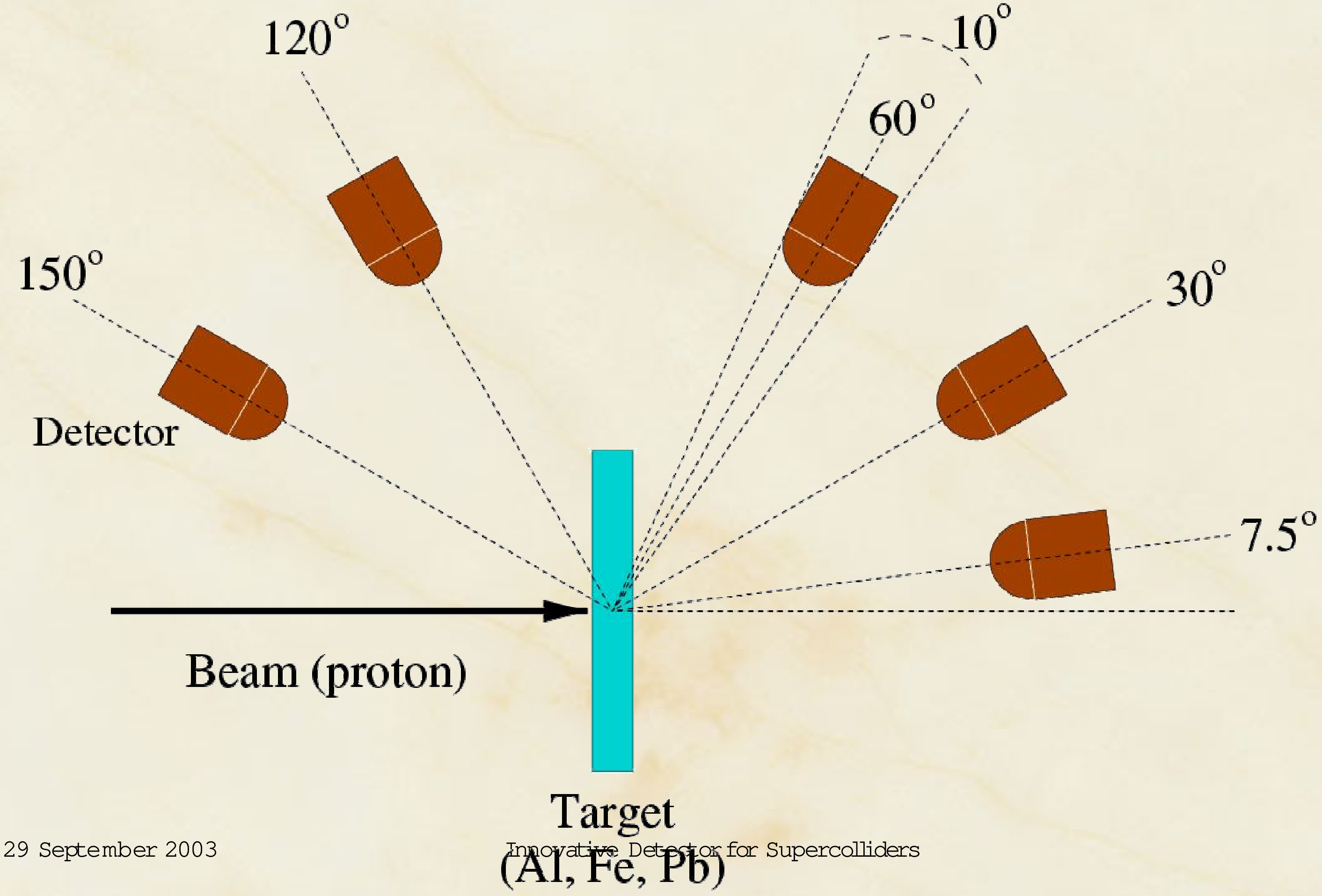
- Future supercolliders will need predictive simulations
    - Good parametrisations can only be derived from good simulations!
- To have some hope that a MC is predictive two kind of tests have to be performed exhaustively
    - Single process tests
    - Test beam validations
- Experimental errors have to be considered attentively
    - Do not confuse systematic and statistical errors!
- Very hard work…

An example with GEANT4

- Low momentum hadrons are important for ALICE
  - Open geometry (no calorimeter to absorb particles)
  - Small magnetic field (0.4 T)
  - Account for most of the energy deposit
- Particles "leaking" through the front absorbers and beam-shield generate background which limits the performance in central Pb-Pb collisions
- In the forward direction also the high-energy hadronic collisions are of importance

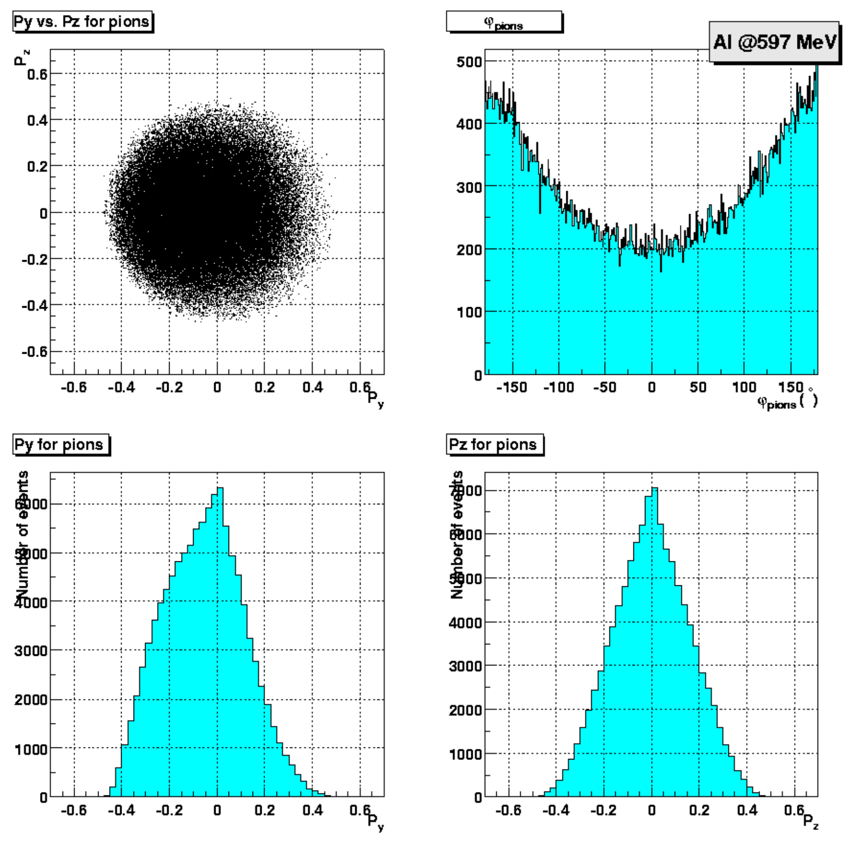
Proton Thin Target Experimental Set-Up

Data from Los Alamos in: Nucl. Sci. Eng., Vol. 102, 110, 112 & 115

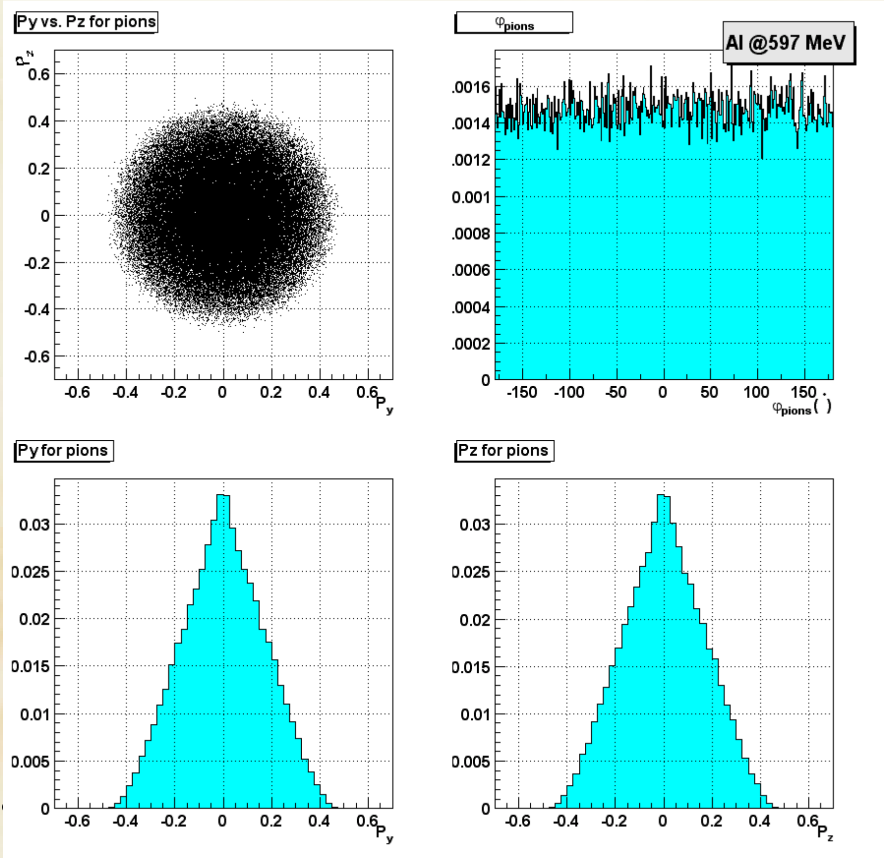

120°
10°
60°
150°
30°
Detector
7.5°
Beam (proton)
Target
(Al, Fe, Pb)

Parameterised model: φ_{pions}: (p,Al) @ 597 MeV

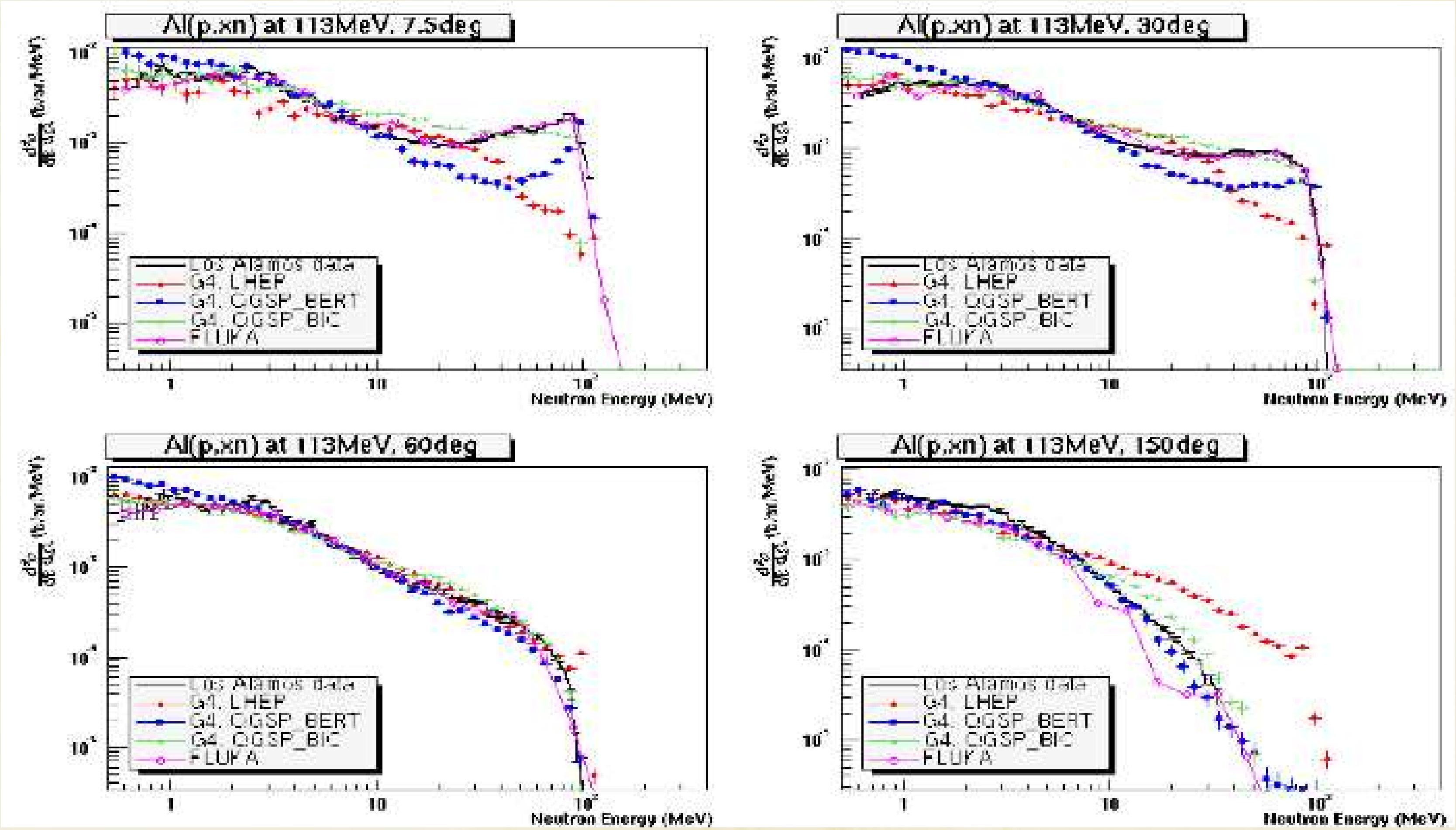
Before



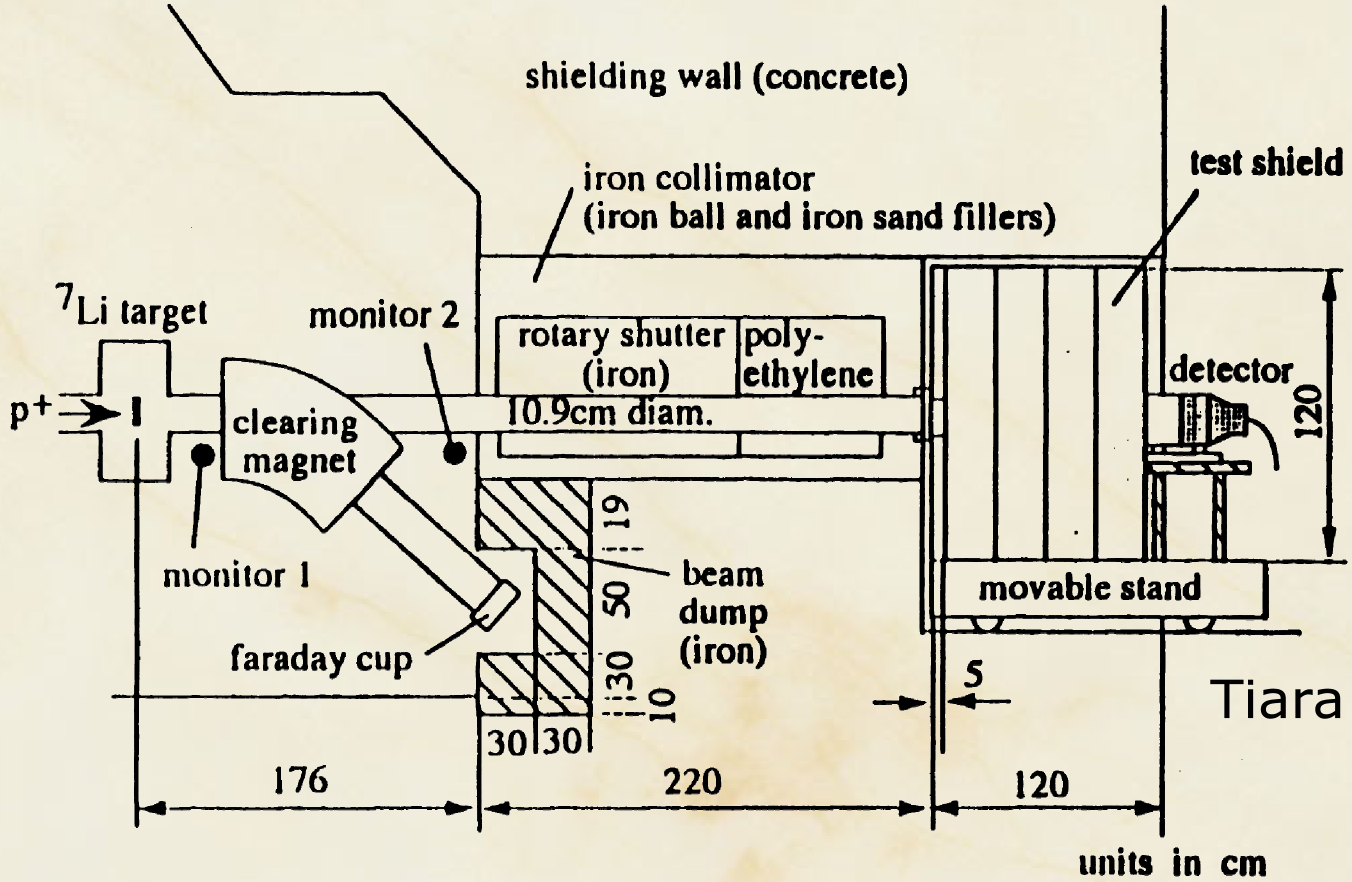
Now



Double differentials



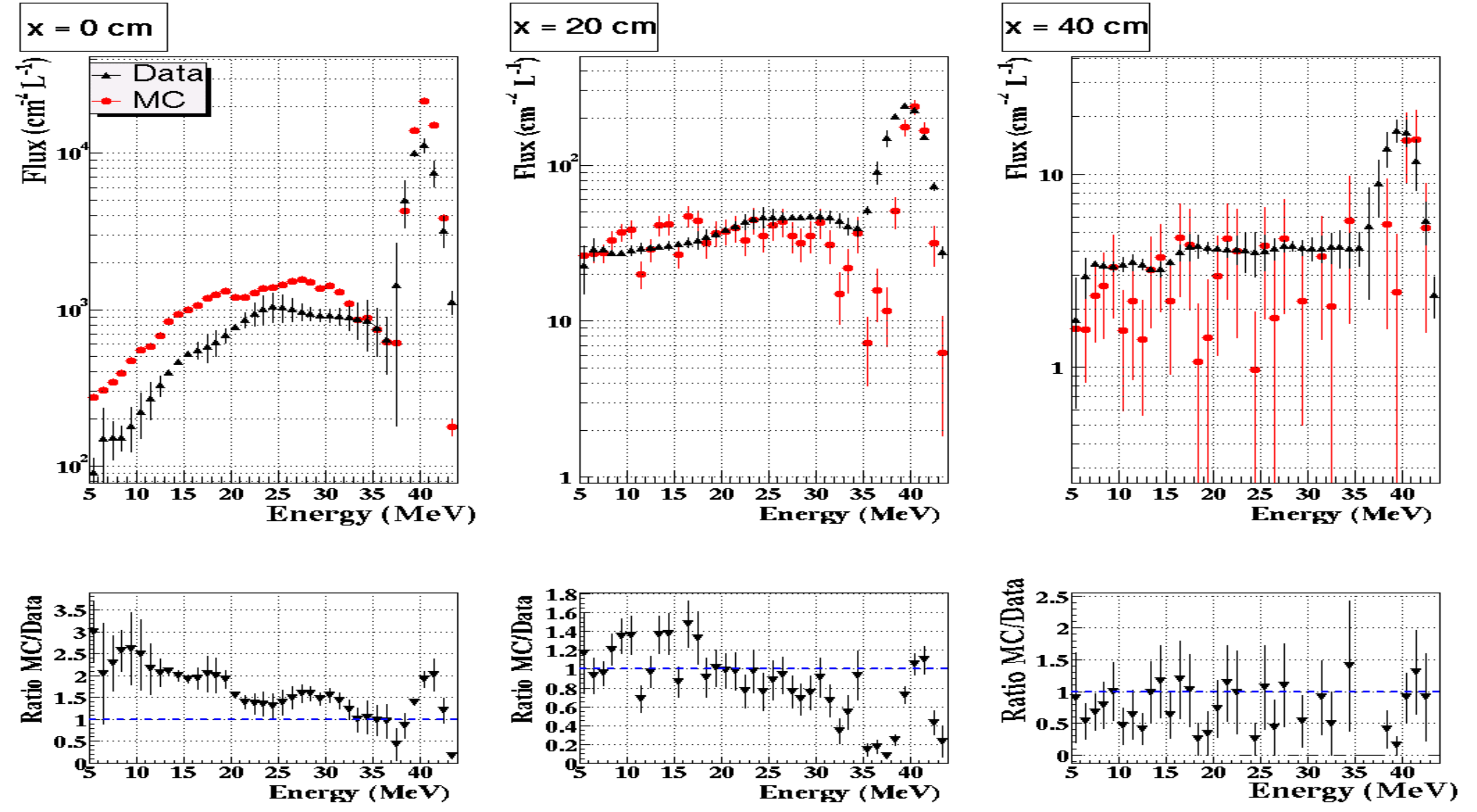
Low energy neutrons


shielding wall (concrete)
iron collimator
(iron ball and iron sand fillers)
test shield
^{7}Li target
monitor 2
rotary shutter
(iron)
poly-
ethylene
detector
p+
clearing
magnet
10.9cm diam.
120
19
50
30
10
monitor 1
beam
dump
(iron)
movable stand
faraday cup
5
30
30
176
220
120
units in cm

Tiara facility

Preliminary Results: 43 *MeV*

Test Shield: Iron – Thickness: 20 *cm*



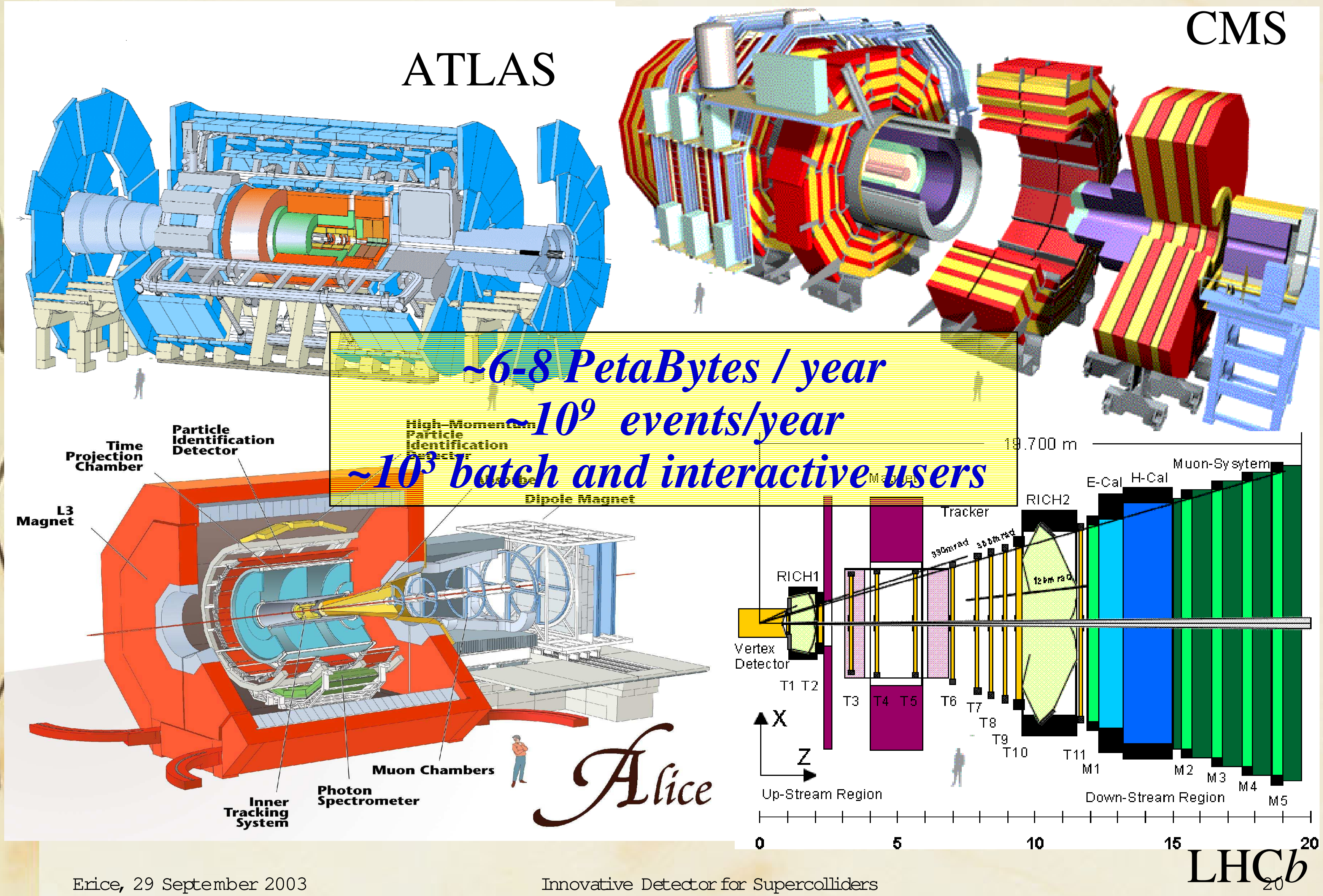
Simulation and LCG

- The LCG project is taking very seriously simulation activity
  - (At last!) a common project includes FLUKA and GEANT4
  - A principle agreement has been found for the distribution of the FLUKA source
- Single process and test beam validations are programmed for FLUKA and GEANT4
  - Should have been started 10 years ago!
- The project has decided to
  - Adopt the ALICE Virtual MonteCarlo as generic framework
  - Adopt the ALICE geometrical modeller

But where to find the necessary computing power?

- The needs of simulation are very large
  - For the next Data Challenge ALICE will need 1400kSI2K and 300TB for six months
    - Approximately 1400 high-end PCs running continuously!
- But the computing needs to collect, store, reconstruct and analyse LHC data are even larger!

The LHC Detectors

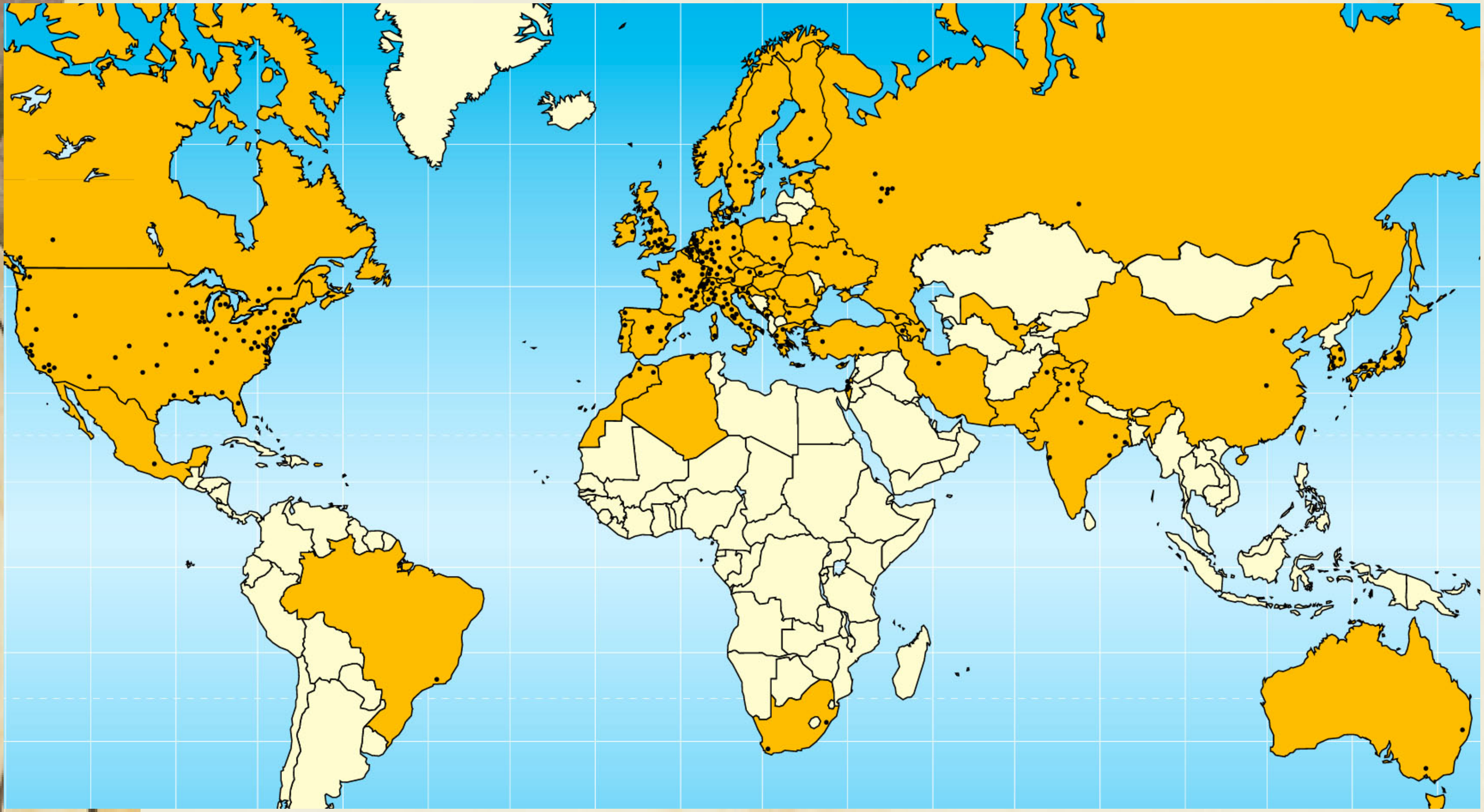

ATLAS
CMS
Particle Identification Detector
Time Projection Chamber
L3 Magnet
High-Momentum Particle Identification Detector
Dipole Magnet
Muon Chambers
Photon Spectrometer
Inner Tracking System
Alice
19.700 m
Muon-Sy sytem
E-Cal
H-Cal
RICH2
Tracker
RICH1
Vertex Detector
T1 T2
T3 T4 T5
T6
T7
T8
T9
T10
T11
M1
M2
M3
M4
M5
X
Z
Up-Stream Region
Down-Stream Region
0
5
10
15
20
LHCb

~6-8 PetaBytes / year

~10^9 events/year

~10^3 batch and interactive users

CERN’s Network in the World



Europe: 267 institutes, 4942 users
Elsewhere: 208 institutes, 1752 users

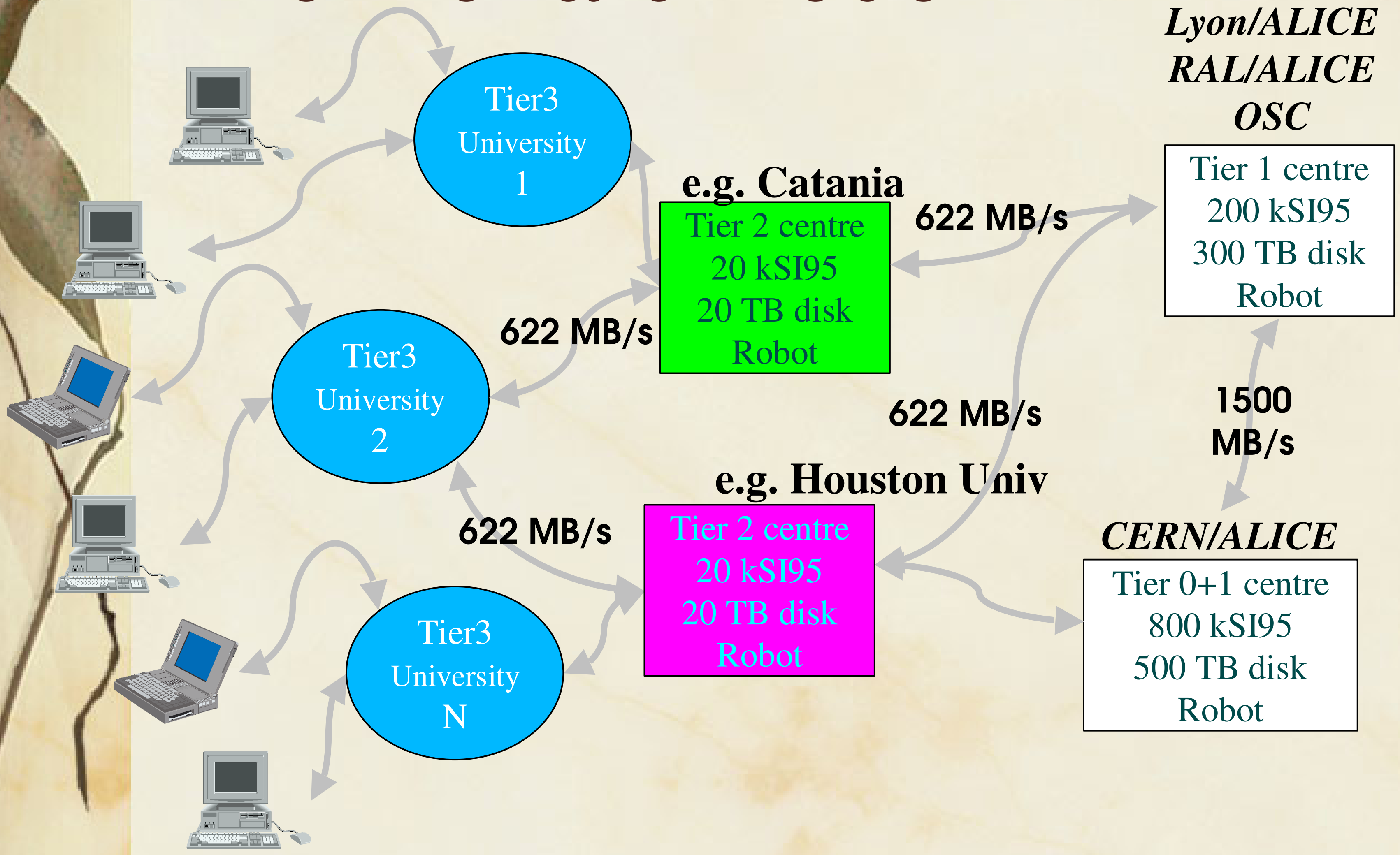
Why distributed computing?

- The investment for LHC computing is massive
- For ALICE only
  - 1.25 GB/s in HI mode
  - ~3 PB/y of tape
  - ~1.5 PB of disk
  - ~16,000 kSI2k (~16,000 PC2003)
  - ~ 8M€ of hardware
    - Without personnel + infrastructure and networking
  - Millions lines of code to develop and maintain for 20 years
- Politically, technically and sociologically it cannot be concentrated in a single location
  - Whenever possible countries prefer national investments
  - Competence is naturally distributed
  - A concentrated facility would force people to travel to CERN often

The distributed computing model

- Every physicist should have equal access to data and resources
- Resources for HEP computing (CPUs' and data) will be distributed
  - Co-located in so-called regional centres
- The centres should work as an integrated system to provide
  - Maximisation of the usage of the resources
  - Redundancy and fault tolerance
  - Security
  - Maximum transparency of usage
- The system will be extremely complex
  - Number of sites & components in each site
  - Different tasks performed in parallel: simulation, reconstruction, scheduled and unscheduled analysis
- Physicists have realised the challenge of this since few years
  - Studies started already some years ago (MONARC project)

The Monarc Model



Tier3
University
1

Tier3
University
2

Tier3
University
N

e.g. Catania

Tier 2 centre
20 kSI95
20 TB disk
Robot

e.g. Houston Univ

Tier 2 centre
20 kSI95
20 TB disk
Robot

Lyon/ALICE
RAL/ALICE
OSC

Tier 1 centre
200 kSI95
300 TB disk
Robot

CERN/ALICE

Tier 0+1 centre
800 kSI95
500 TB disk
Robot

The challenge

- Bad news is that the basic tools are missing (at production quality)
  - Distributed resource management
  - Distributed namespace for files and objects
  - Distributed authentication
  - Local resource management of large clusters
  - Data replication and caching
  - WAN/LAN monitoring and logging
- Good news is that we are not alone
  - All the above issues are central to the new developments going on in the US and in Europe under the collective name of GRID

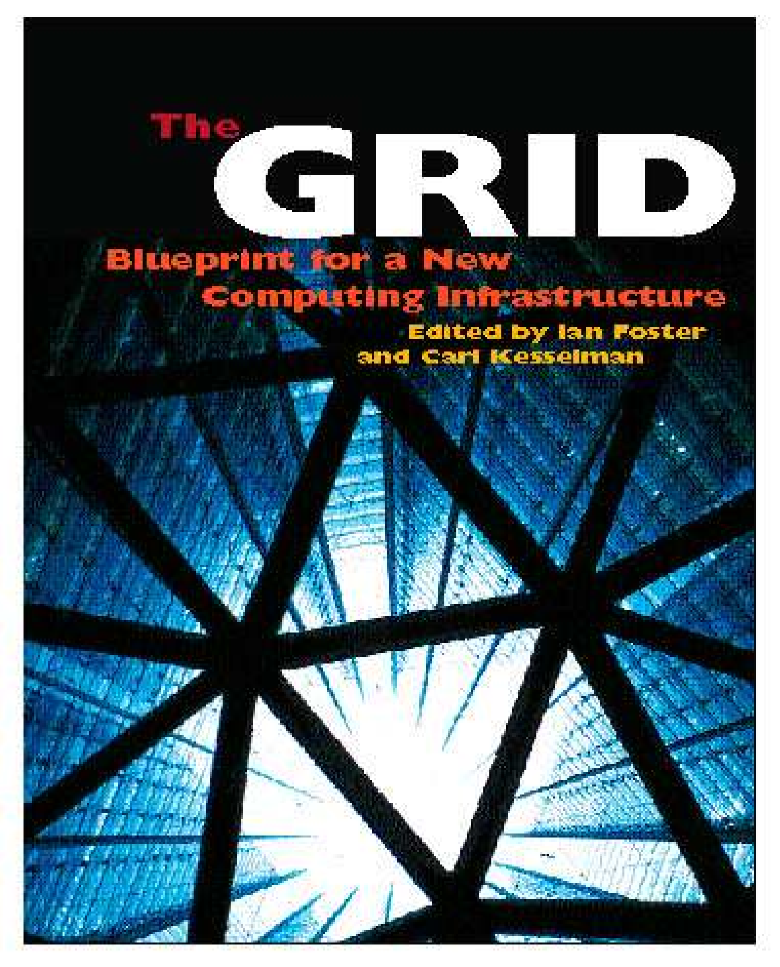
The Grid:
Blueprint for a New Computing Infrastructure

I. Foster, C. Kesselman (Eds), Morgan Kaufmann, 1999

- ✓ Available July 1998;
- ✓ ISBN 1-55860-475-8
- ✓ 22 chapters by expert authors including Andrew Chien, Jack Dongarra, Tom DeFanti, Andrew Grimshaw, Roch Guerin, Ken Kennedy, Paul Messina, Cliff Neuman, Jon Postel, Larry Smarr, Rick Stevens, and many others

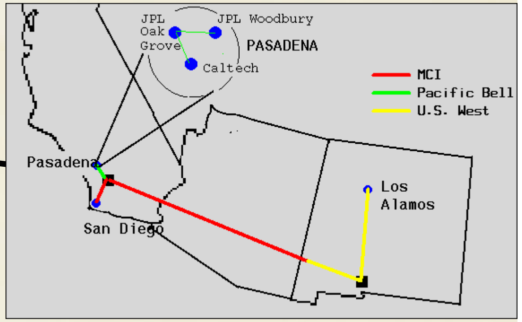
"A source book for the history of the future" -- Vint Cerf

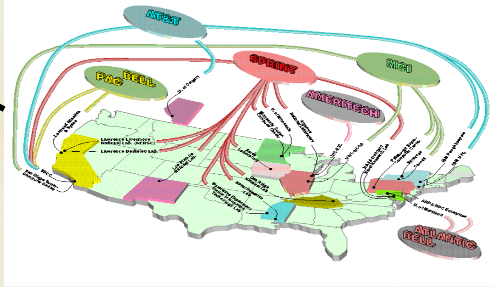
http://www.mkp.com/grids


The GRID
Blueprint for a New Computing Infrastructure
Edited by Ian Foster and Carl Kesselman

A Brief History

- Early 90s
  - Gigabit testbeds, metacomputing
- Mid to late 90s
  - Early experiments (e.g., I-WAY), academic software projects (e.g., Globus, Legion), application experiments
- 2001 – now
  - Major application communities emerging
  - Major infrastructure deployments
  - Growing technology base
  - Global Grid Forum: ~500 people, >90 orgs, 20 countries
- The “Grid problem” is about *resource sharing & coordinated problem solving in dynamic, multi-institutional virtual organizations*
  - Data is often the focus as opposed to classical numerically intensive simulations
  - Analogy with the power grid

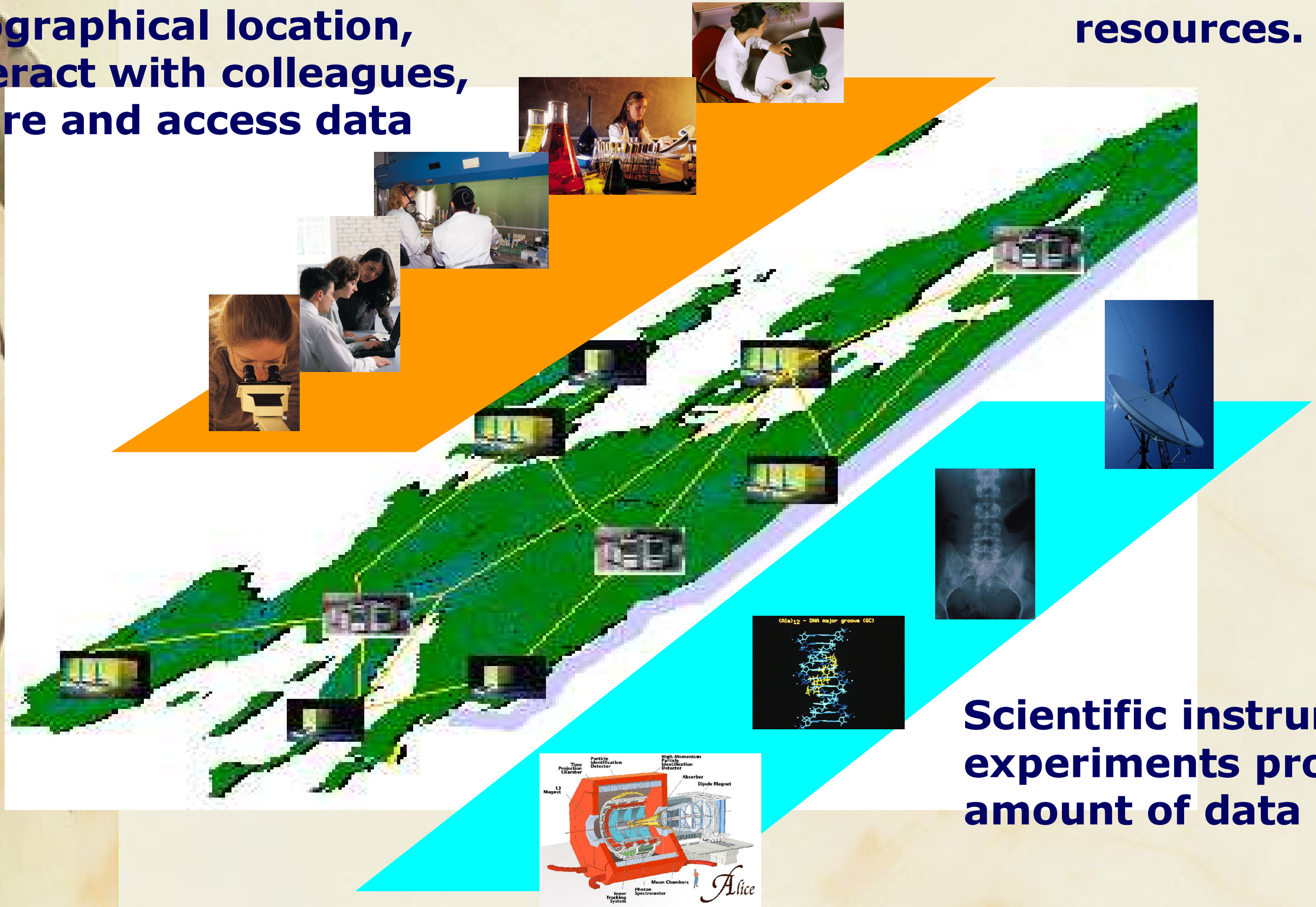

JPL Oak Grove
JPL Woodbury
PASADENA
Caltech
MCI
Pacific Bell
U.S. West
Pasadena
San Diego
Los Alamos


AT&T
SPRINT
MCI
PAC BELL
AMERITECH
ATLANTIC BELL

The Grid Vision

Researchers perform their activities regardless geographical location, interact with colleagues, share and access data

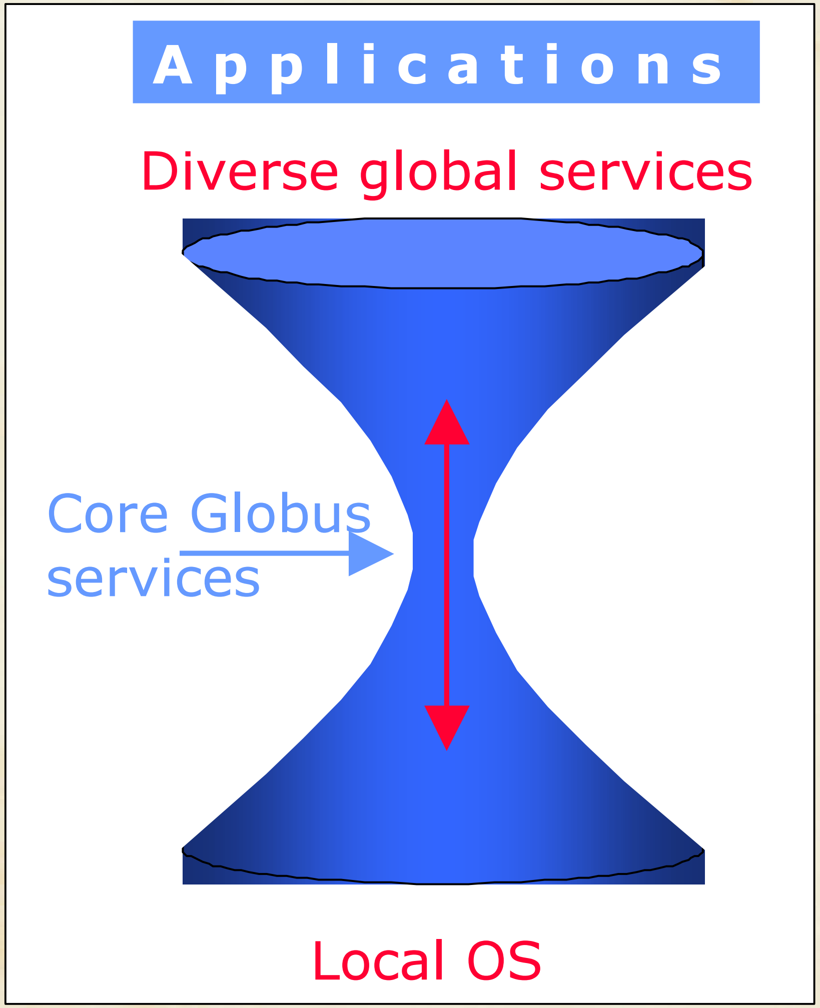
The GRID: networked data processing centres and ”middleware” software as the “glue” of resources.


(Ala)$_{12}$ - DNA major groove (GC)
Time Projection Chamber
Particle Identification Detector
High-Momentum Particle Identification Detector
L3 Magnet
Absorber
Dipole Magnet
Muon Chambers
Inner Tracking System
Photon Spectrometer
Alice

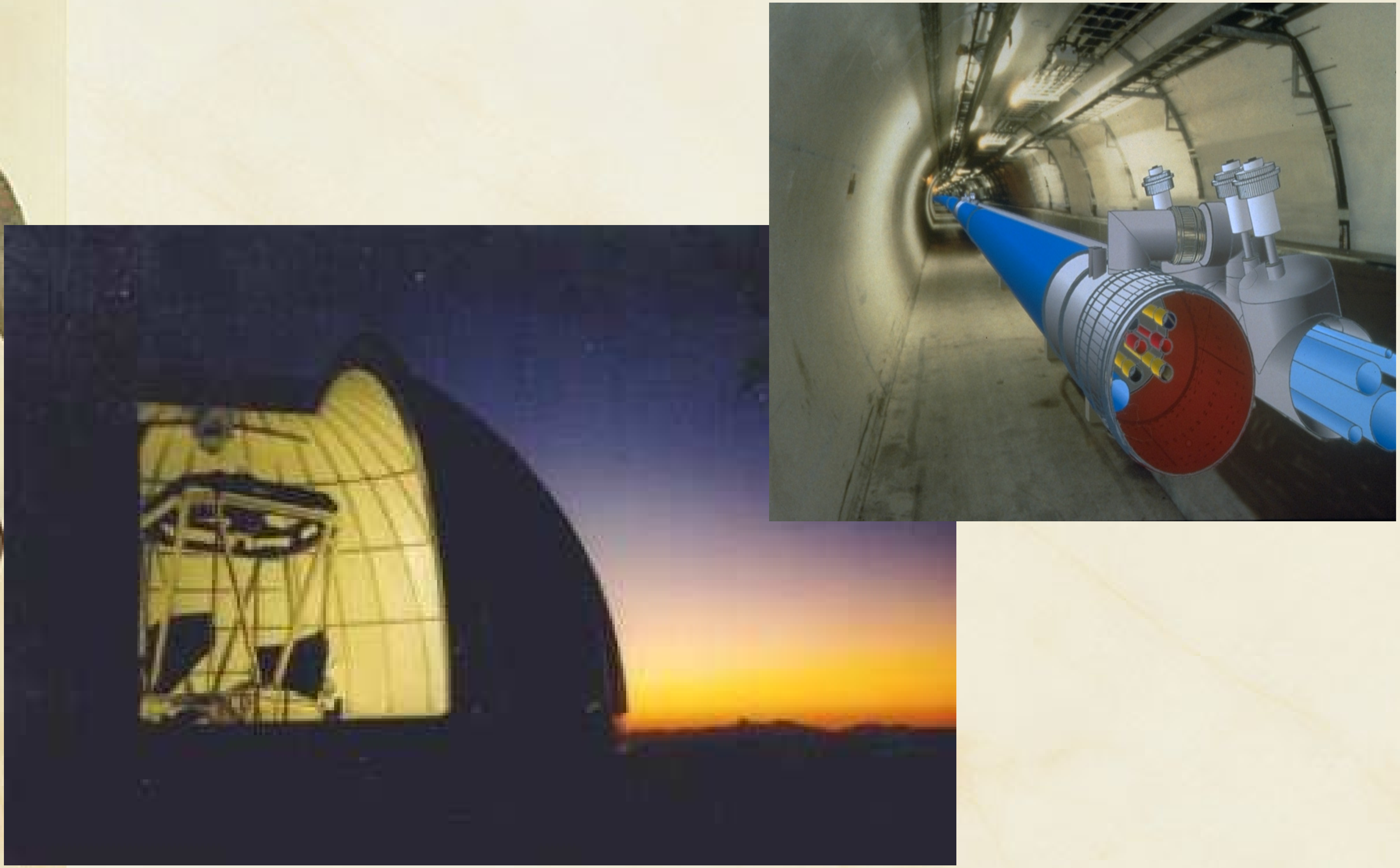
Scientific instruments and experiments provide huge amount of data

GLOBUS hourglass, a model for middleware

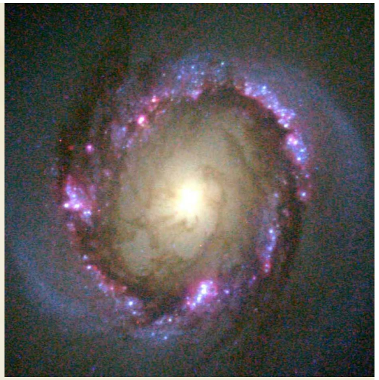
- Focus on architecture issues
  - Low participation cost, local control and support for adaptation
  - Use to construct high-level, domain-specific solutions
- A set of toolkit services
  - Security (GSI)
  - Resource management (GRAM)
  - Information services (MDS)
  - Remote file management (GASS)
  - Communication (I/O, Nexus)
  - Process monitoring (HBM)


Applications
Diverse global services
Core Globus services
Local OS

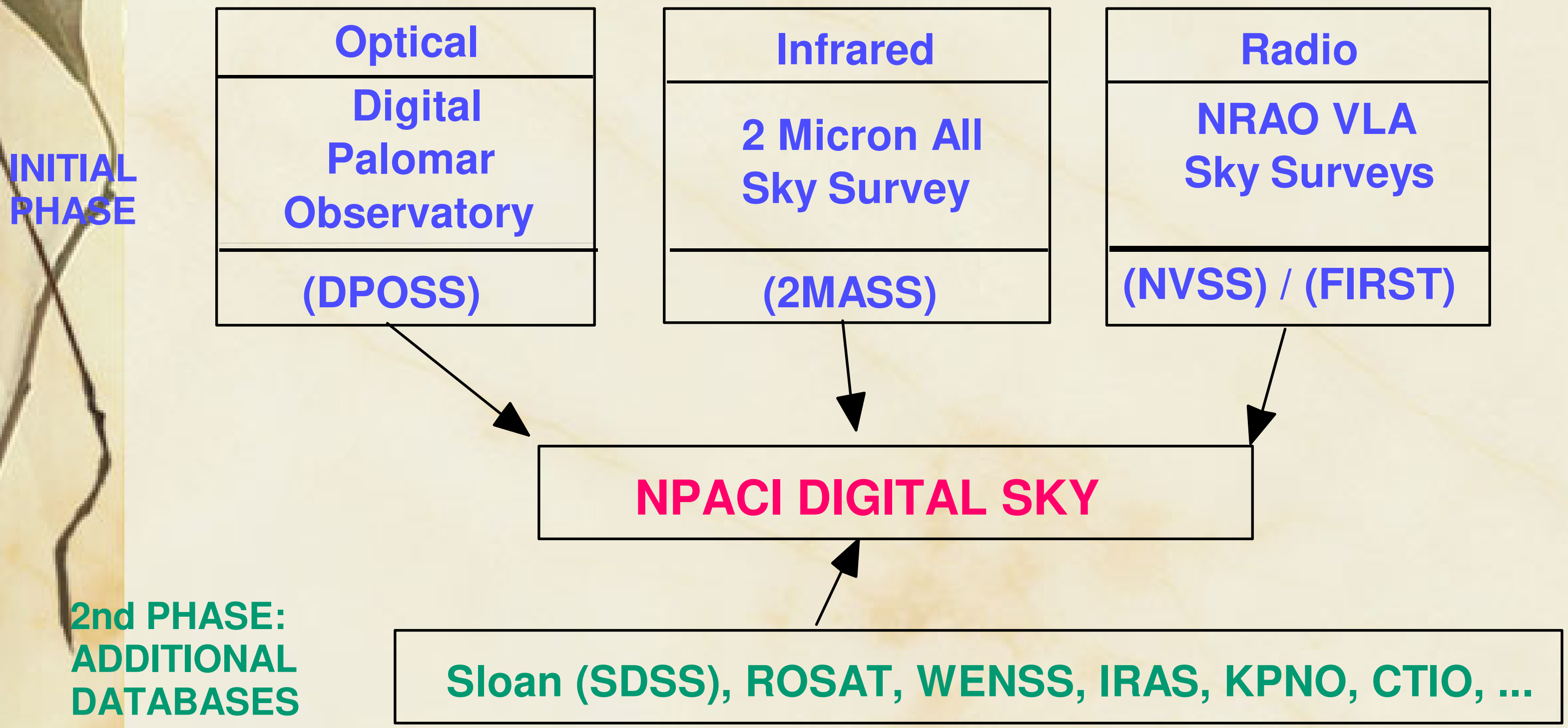
Instruments are expensive



Virtual Observatory: an example of the scientific opportunities



- The planned Large Synoptic Survey Telescope will produce over 10PB/y by 2008!
    - All-sky survey every few days: fine-grain time series for the first time
- The **National Academy of Sciences** recommends, as a first priority, the establishment of a **National Virtual Observatory**
    - http://www.nap.edu/books/0309070317/html/



INITIAL PHASE

Optical	Infrared	Radio
Digital Palomar Observatory	2 Micron All Sky Survey	NRAO VLA Sky Surveys
(DPOSS)	(2MASS)	(NVSS) / (FIRST)

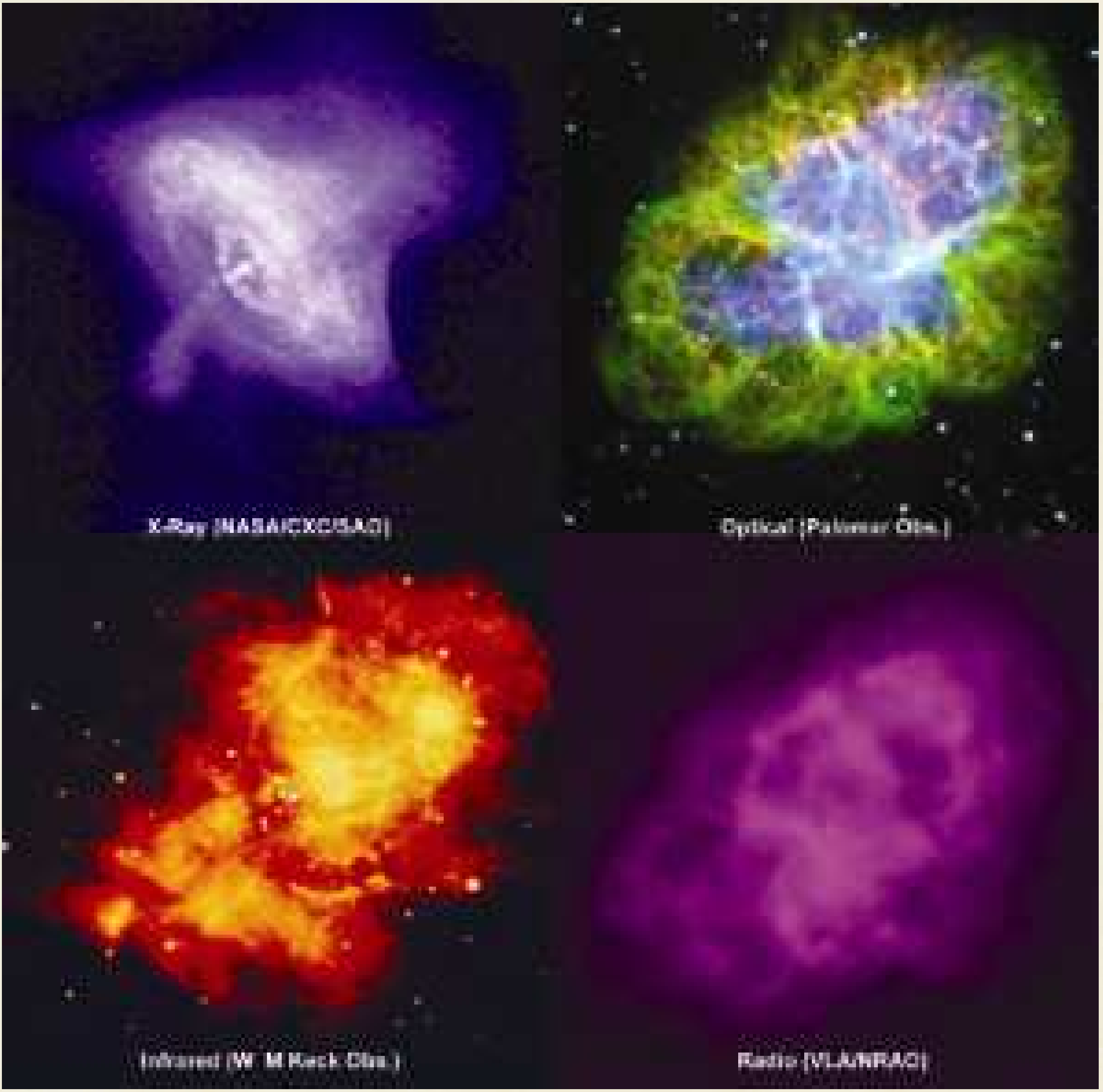
NPACI DIGITAL SKY

2nd PHASE: ADDITIONAL DATABASES

Sloan (SDSS), ROSAT, WENSS, IRAS, KPNO, CTIO, ...

Crab Nebula in 4 spectral regions

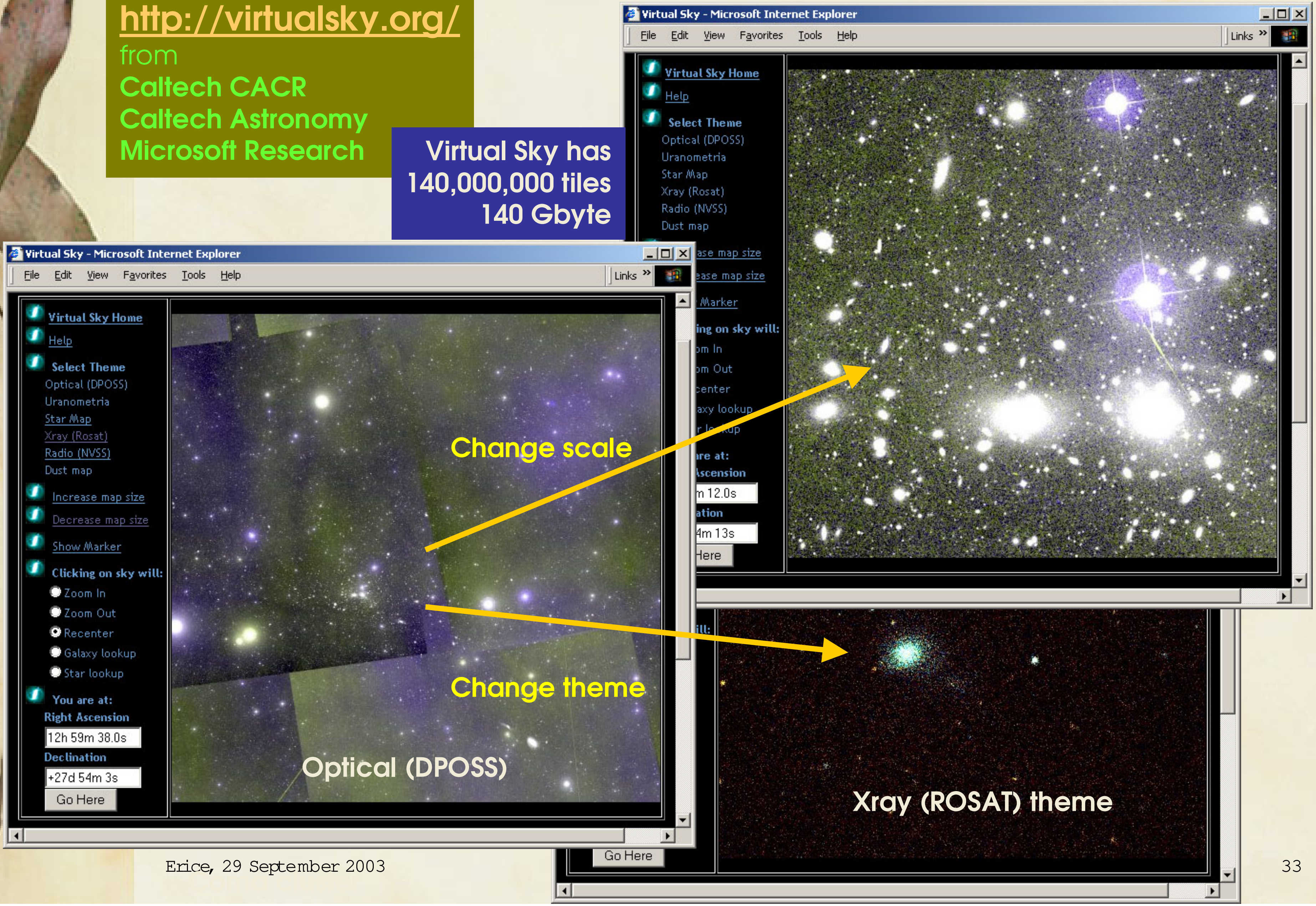
X-ray, optical, infrared, radio


X-Ray (NASA/CXC/SAO)
Optical (Palomar Obs.)
Infrared (W. M Keck Obs.)
Radio (VLA/NRAO)

Virtual Sky: Image Federation

http://virtualsky.org/
from
Caltech CACR
Caltech Astronomy
Microsoft Research

Virtual Sky has
140,000,000 tiles
140 Gbyte


Virtual Sky - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Links
Virtual Sky Home
Help
Select Theme
Optical (DPOSS)
Uranometria
Star Map
Xray (Rosat)
Radio (NVSS)
Dust map
Increase map size
Decrease map size
Show Marker
Clicking on sky will:
○ Zoom In
○ Zoom Out
● Recenter
○ Galaxy lookup
○ Star lookup
You are at:
Go Here

Right Ascension: 12h 59m 38.0s

Declination: +27d 54m 3s

Change scale

Change theme

Optical (DPOSS)

Xray (ROSAT) theme

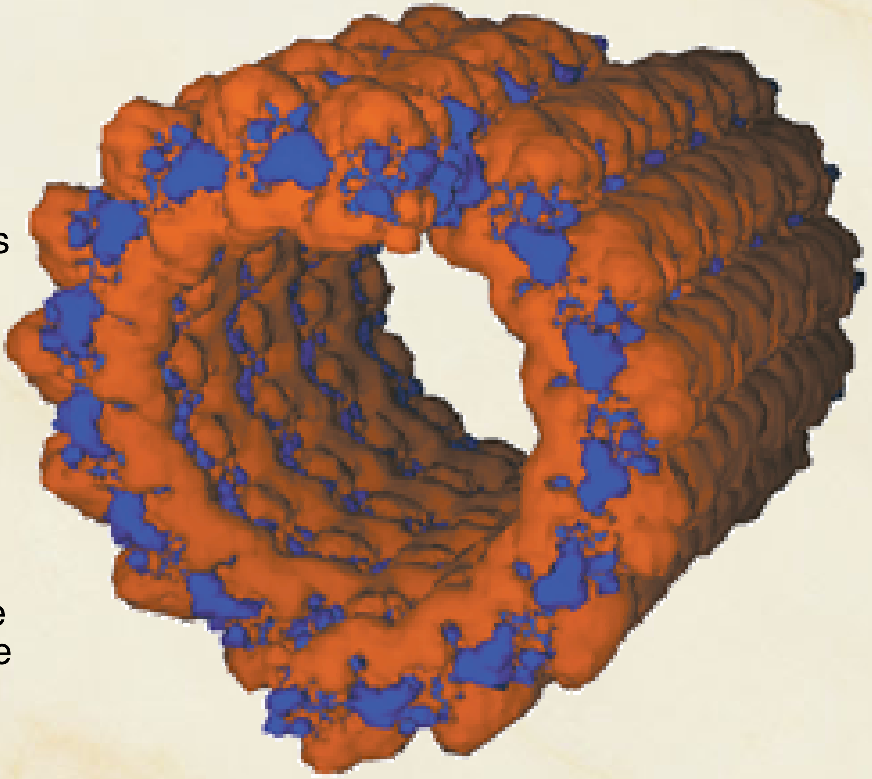
Not a centralized resource

- The catalogs are NOT ingested into the Virtual Sky server, but left in place (maintained by their curators), and accessed by the accompanying web service
- This is an important point: leave the resources and the responsibility for managing them where they would normally be

Results Possible on TeraGrid

Modelling Cell Structures

- **Pre-Blue Horizon:**
  - Possible to model electrostatic forces of a structure with up to **50,000** atoms -- a single protein or small assembly
- **Pre-TeraGrid:**
  - Possible to model **one million** atoms – enough to simulate drawing a drug molecule through a microtubule or tugging RNA into a ribosome
- **TeraGrid:**
  - Models of **10 million** atoms will make it possible to model function, structure movement, and interaction at the cellular level **for drug design and to understand disease**

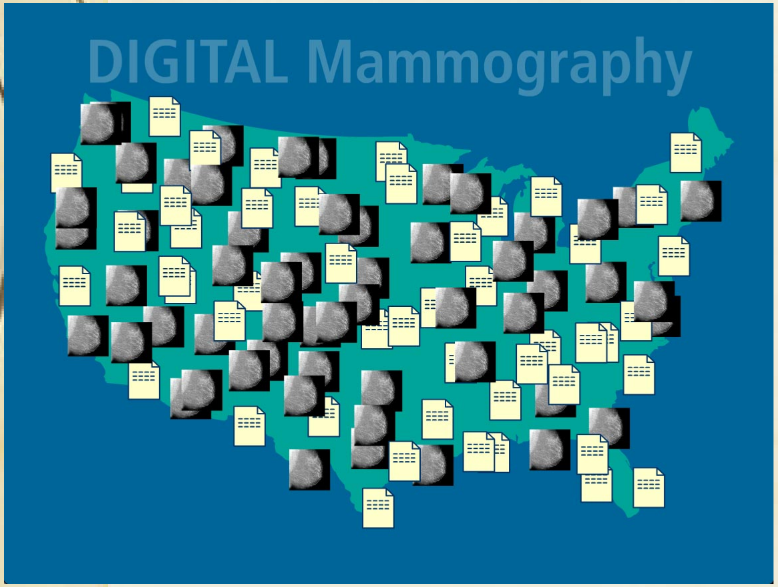


Baker, N., Sept, D., Joseph, S., Holst, M., and McCammon, J. A. *PNAS* **98**: 10037-10040 (2001).

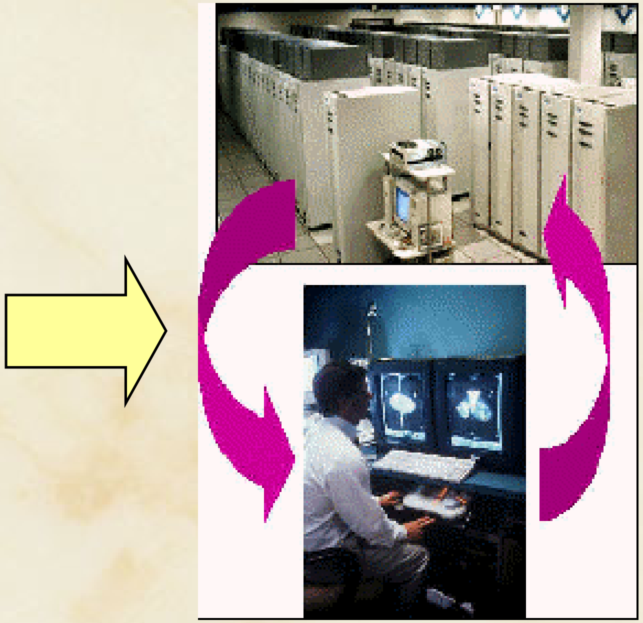
mammograms X-rays
MRI
cat scans
endoscopies, ...

Digital Radiology (Hollebeek, U. Pennsylvania)

- Hospital Digital Data
  - Very large data sources - great clinical value to digital storage and manipulation and significant cost savings
  - 7 Terabytes per hospital per year
  - dominated by digital images
- 2000 Hospitals x 7 TB per year x 2 = 28 PetaBytes per year

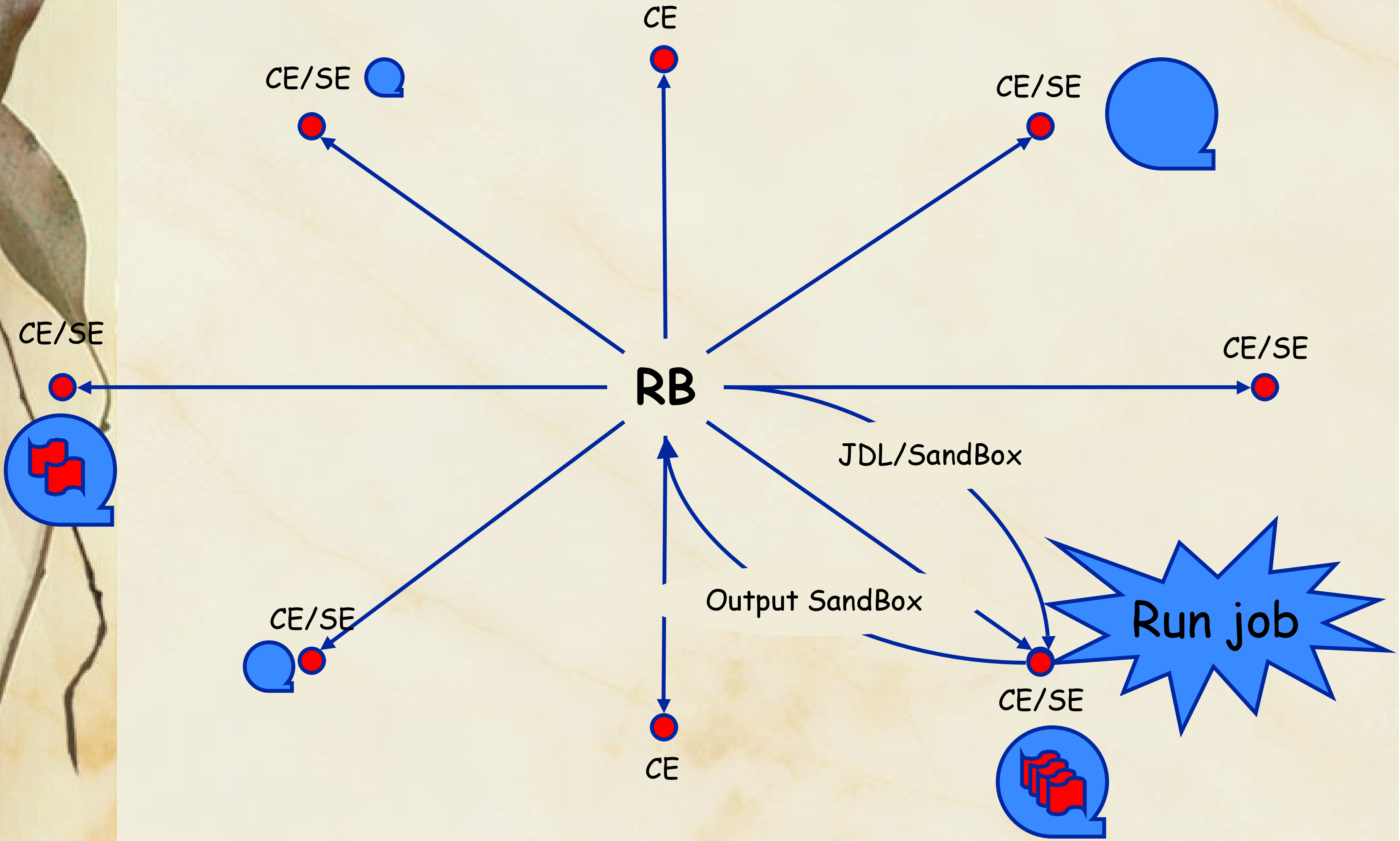


Highly Distributed Source

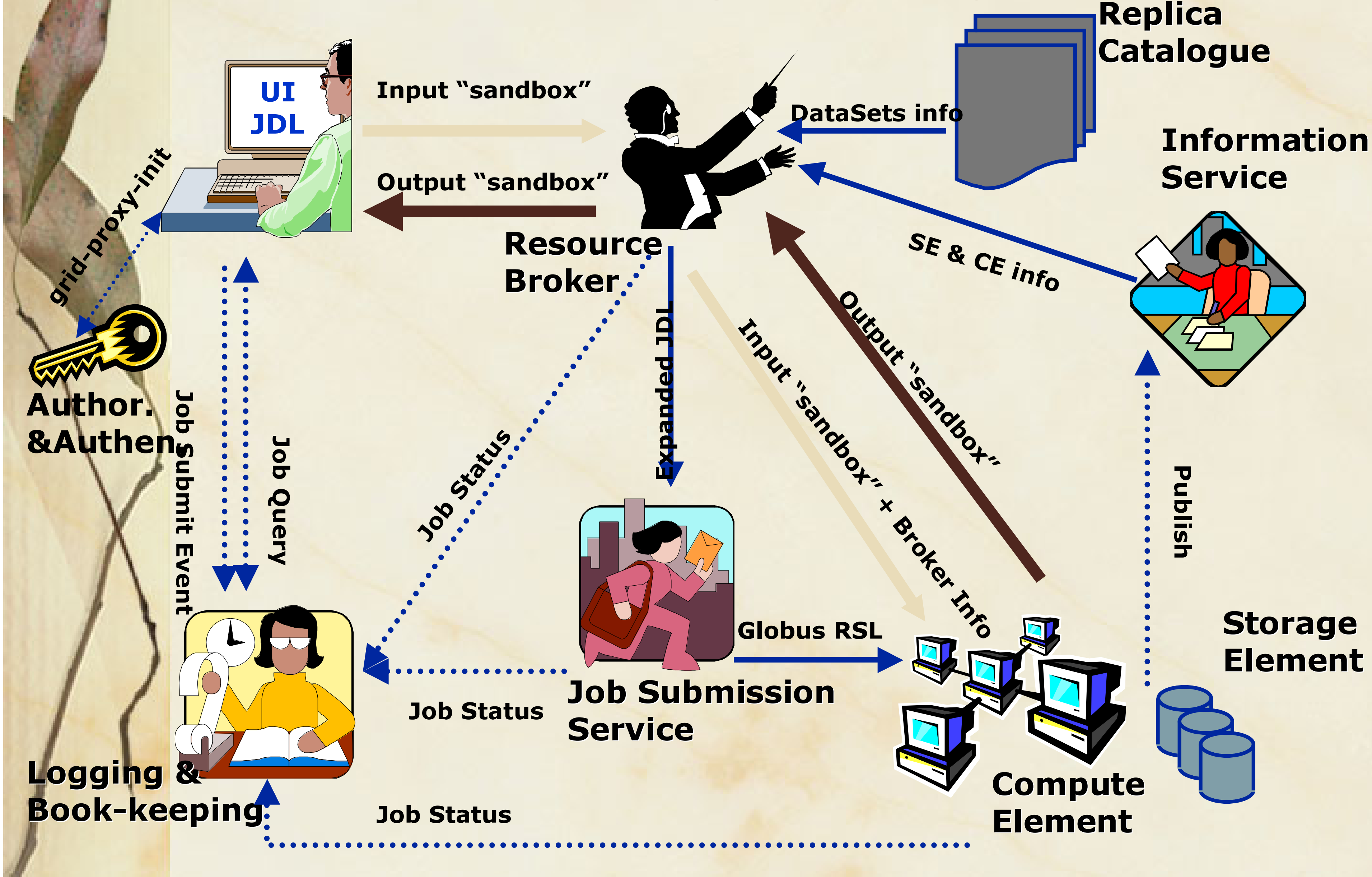


Hierarchical Storage and Indexing

Resource brokering (easy)


CE
CE/SE
CE/SE
CE/SE
RB
CE/SE
JDL/SandBox
Run job
Output SandBox
CE/SE
CE/SE
CE

Resource brokering (in reality)



UI
JDL

Input “sandbox”

Output “sandbox”

Resource
Broker

DataSets info

Replica
Catalogue

Information
Service

SE & CE info

grid-proxy-init

Author.
&Authen.

Job Submit Event

Job Query

Job Status

Expanded JDL

Input "sandbox" + Broker Info

Output "sandbox"

Publish

Globus RSL

Job Submission
Service

Storage
Element

Compute
Element

Job Status

Logging &
Book-keeping

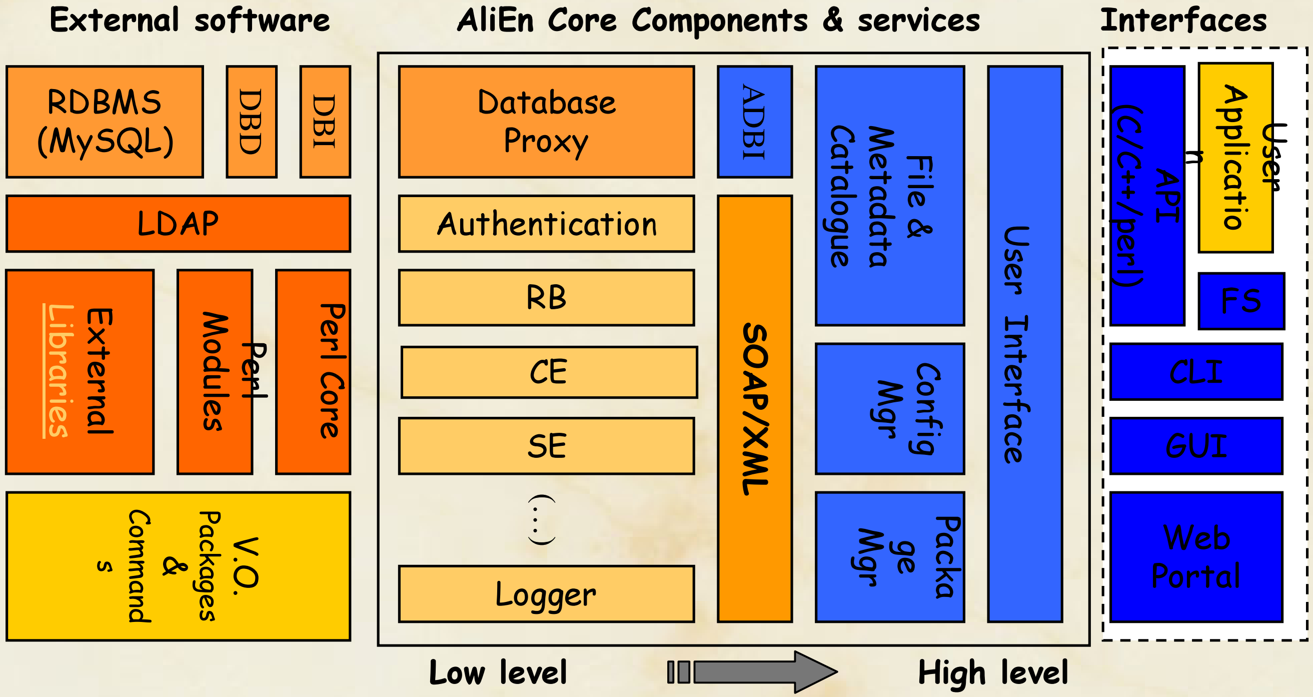
Job Status

Grid projects

- Several GRID projects have been launched by EU and US funding agencies
- They have all started designing “the GRID”
  - Although based on common components such as GLOBUS
- Tremendous richness of architectures and products
- But worrying lack of stable testbeds where to experiment and provide feedback
- At the moment only friendly and advanced users can use the system
- Which of course creates a vicious circle…

An alternative approach

- Standards are now emerging for the basic building blocks of a GRID
  - There are millions lines of code in the OS domain dealing with these issues
- Why not using these to build the *minimal GRID* that *does the job*?
  - Fast development of a prototype, no problem in exploring new roads, restarting from scratch etc etc
  - Hundreds of users and developers
  - Immediate adoption of emerging standards
- An example, AliEn by ALICE (5% of code developed, 95% imported)



External software

RDBMS (MySQL)

DBD

DBI

LDAP

External Libraries

Perl Modules

Perl Core

V.O. Packages & Commands

AliEn Core Components & services

Database Proxy

ADBI

Authentication

RB

CE

SE

(…)

Logger

SOAP/XML

File & Metadata Catalogue

Config Mgr

Package Mgr

User Interface

Interfaces

API (C/C++/perl)

User Application

FS

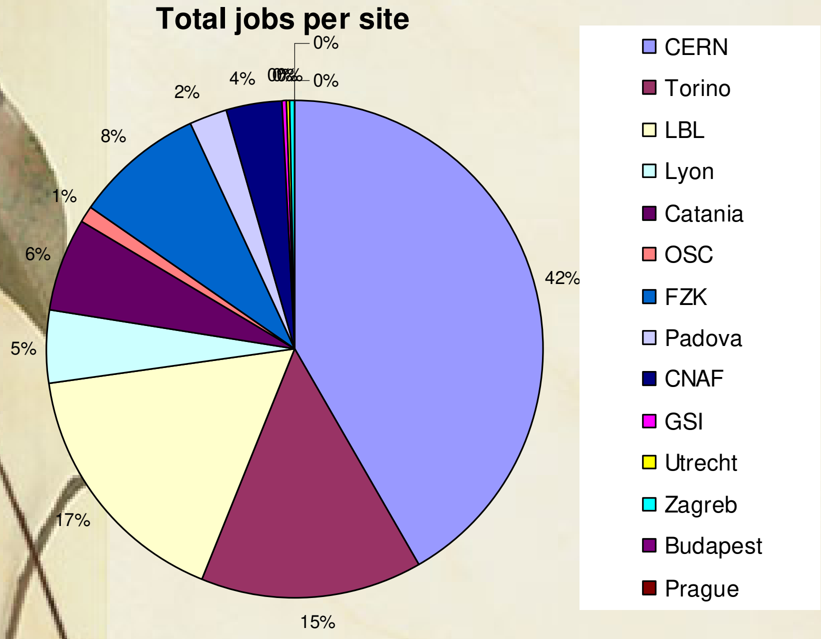
CLI

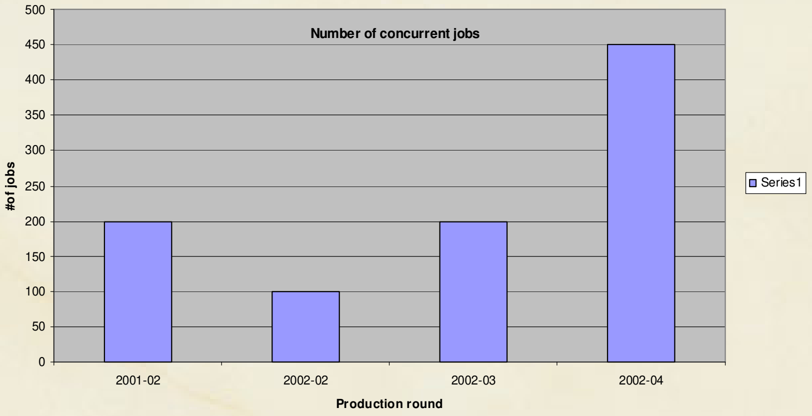
GUI

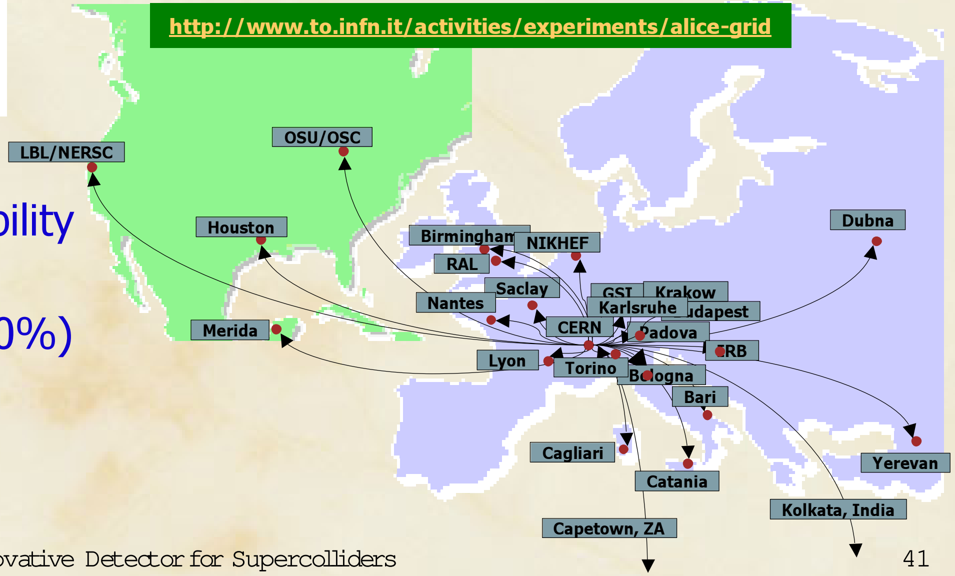
Web Portal

Low level **High level**

AliEn activity

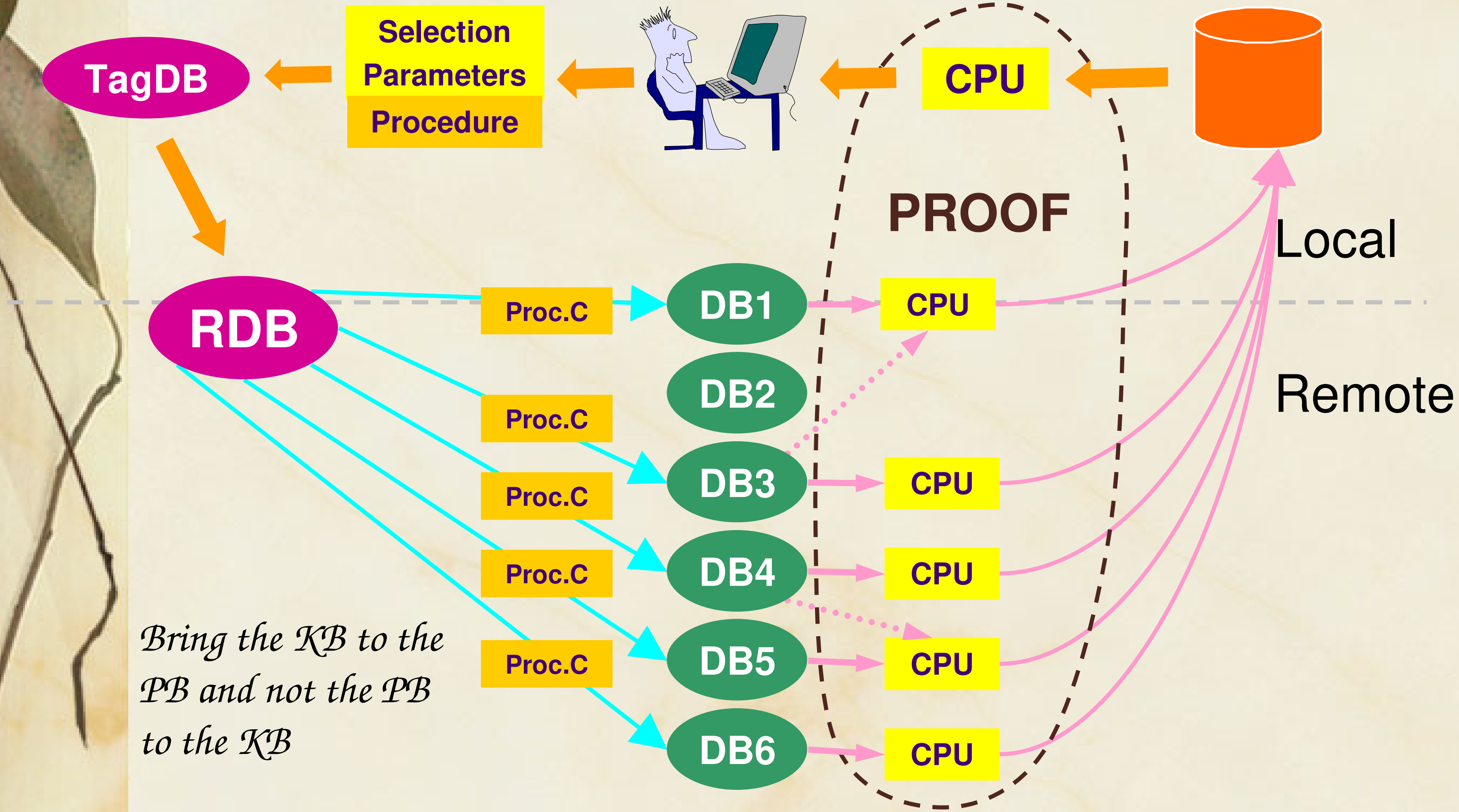





http://www.to.infn.it/activities/experiments/alice-grid
LBL/NERSC
OSU/OSC
Houston
Merida
Birmingham
NIKHEF
RAL
Saclay
Nantes
GSI
Krakow
Karlsruhe
Budapest
CERN
Padova
IRB
Lyon
Torino
Bologna
Bari
Dubna
Cagliari
Catania
Yerevan
Kolkata, India
Capetown, ZA

- 32 sites configured
- 5 sites providing mass storage capability
- 12 production rounds
- 22773 jobs validated, 2428 failed (10%)
- Up to 450 concurrent jobs
- 0.5 operators

Distributed analysis model



TagDB

Selection Parameters

Procedure

CPU

PROOF

Local

Remote

RDB

Proc.C

Proc.C

Proc.C

Proc.C

Proc.C

DB1

DB2

DB3

DB4

DB5

DB6

CPU

CPU

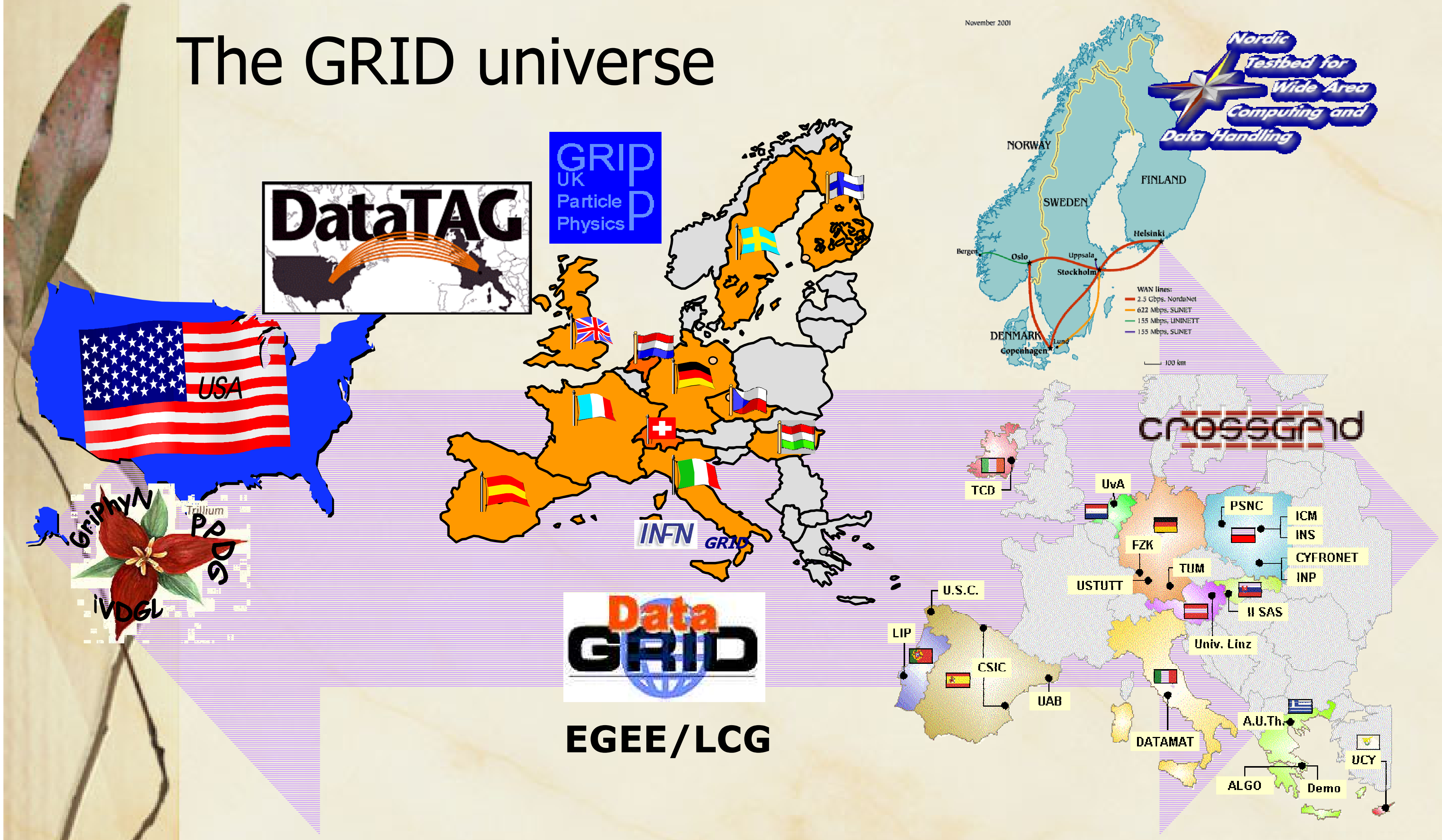
CPU

CPU

CPU

Bring the KB to the PB and not the PB to the KB

The GRID universe

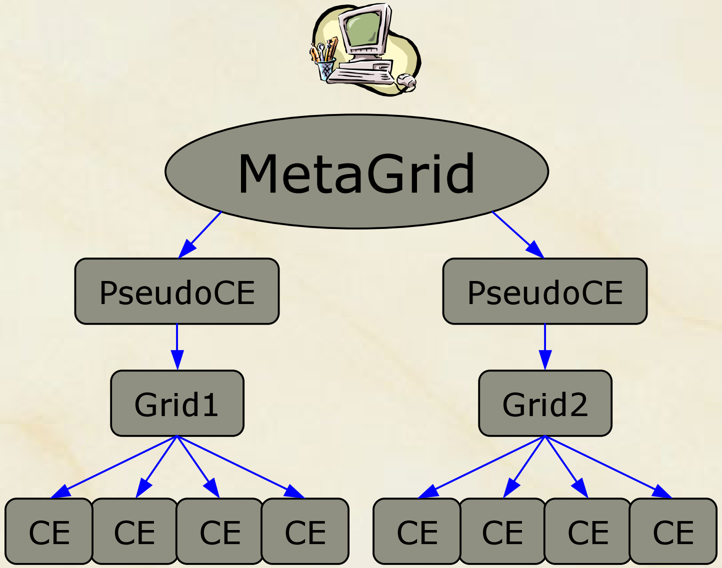

DataTAG
GRID UK Particle Physics
USA
GriPhyN
PPDG
iVDGL
Trillium
INFN GRID
DataGRID
EGEE/LCG
November 2001
Nordic Testbed for Wide Area Computing and Data Handling
NORWAY
SWEDEN
FINLAND
DENMARK
Bergen
Oslo
Uppsala
Stockholm
Helsinki
Copenhagen
Lund
WAN lines:
2.5 Gbps, NorduNet
622 Mbps, SUNET
155 Mbps, UNINETT
155 Mbps, SUNET
100 km
crossgrid
TCD
UvA
FZK
PSNC
ICM
INS
CYFRONET
INP
USTUTT
TUM
II SAS
Univ. Linz
U.S.C.
LIP
CSIC
UAB
DATAMAT
A.U.Th.
ALGO
Demo
UCY

- **The real problem is how to avoid divergence!**

MetaGrid and Grid federations

- It has been realised that there will be many Grids and not a single one
  - However users will not want to learn more than one
- The concept of Grid federation and Meta Grid are now explored
- Unfortunately this sometimes looks like building on sand…
  - As we still do not have a stable base on which to build
- And it does not help an early adoption and response from the users

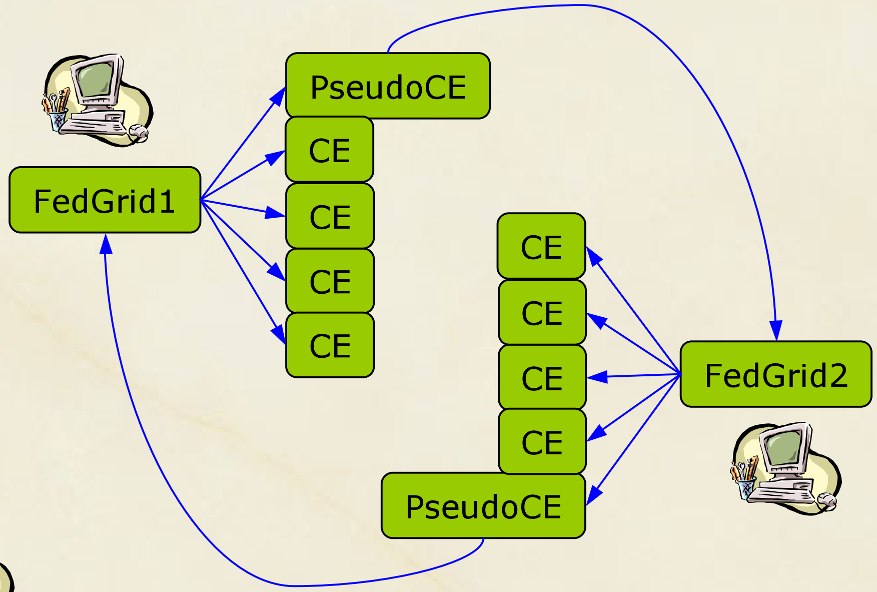
Meta and Federated grids



MetaGrid

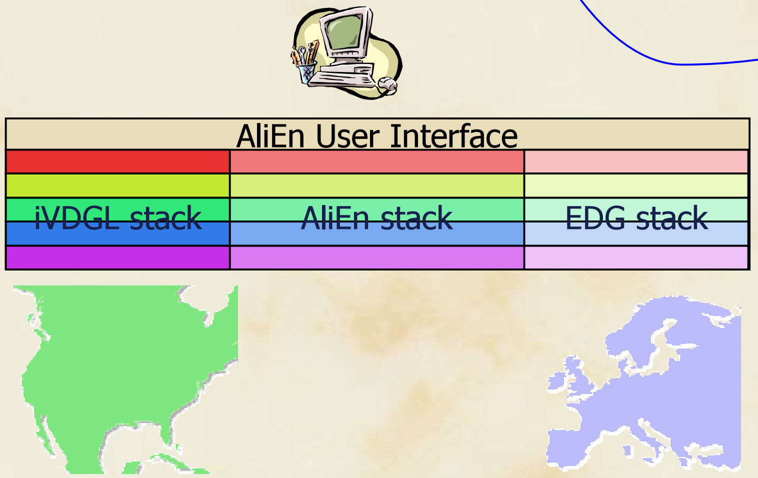
PseudoCE → Grid1 → CE CE CE CE

PseudoCE → Grid2 → CE CE CE CE



FedGrid1 → PseudoCE, CE, CE, CE, CE

FedGrid2 → CE, CE, CE, CE, PseudoCE



AliEn User Interface

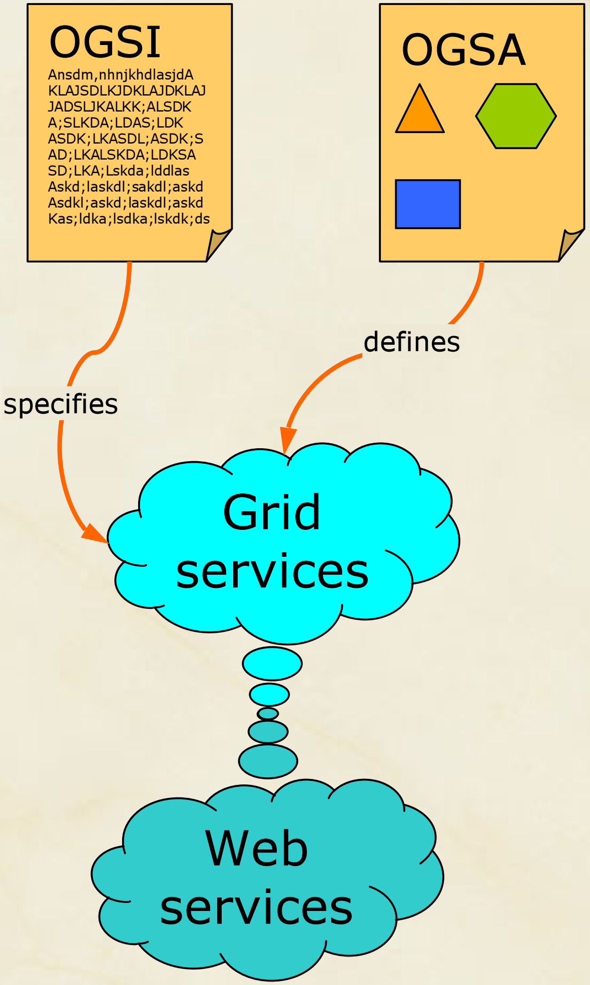
iVDGL stack

AliEn stack

EDG stack

A new standard emerging?

- Grid Services are defined by OGSA: what Grid Services should be capable of, what types of technologies they should be based on
- Grid Services are specified by OGSI, which is a formal and technical specification of the concepts described in OGSA, including Grid Services
- Grid Services extend Web Services
- Suppose you want to build a new house, you need
  - An architecture (OGSA)
  - A detailed engineering plan (OGSI)
  - Workers that build the hous (the real GRID)


OGSI
Ansdm,nhnjkhdlasjdA
KLAJSDLKJDKLAJDKLAJ
JADSLJKALKK;ALSDK
A;SLKDA;LDAS;LDK
ASDK;LKASDL;ASDK;S
AD;LKALSKDA;LDKSA
SD;LKA;Lskda;lddlas
Askd;laskdl;sakdl;askd
Asdkl;askd;laskdl;askd
Kas;ldka;lsdka;lskdk;ds
OGSA
specifies
defines
Grid services
Web services

Standard interoperable technologies
XML, WSDL, SOAP

LCG new strategy

- LHC experiments are proposing to LCG to
  - Start from the architecture of a demonstrated working product (strongly inspired from AliEn)
  - Develop components based on standards and/or adopt existing components
  - Deploy very quickly a prototype and expose it to the users
  - Refine iteratively the architecture and the services as needs and standards evolve
  - Don’t write doc, write working code!
- Apparently LCG is receptive to these arguments

Software development

- In the *LEP era* the code was 90% written in FORTRAN
  - ~10 instructions, 50 pages!
- In the *LHC era* the code is in many cooperating languages, mainly C++
  - ~ 50 instructions, 700 pages – nobody understands it completely (B.Stroustrup)
- Users are heterogeneous, sparse and without hierarchical structure
  - From very expert analysts to users, from 5% to 100% of time devoted to computing
- People come and go with a very high rate
  - Programs have to be maintained by people who did not develop them
  - Young physicists need knowledge they can use also outside physics
- Modern SE ("Agile Methodologies") propose to value

Individuals and interactions	**OVER**	*processes and tools*
Working software		*huge documentation*
Customer collaboration		*contract negotiation*
Responding to change		*following a plan*

That is, while there is value in the items on the right, we value the items on the left more.

HEP, LHC & GRID

- Funding for HEP is becoming scarce
- There is a serious personnel deficit (also!) in HEP computing
- The exceptional interest spreading in most countries for GRID resulted in an acute need for GRID-trained CSs
- HEP (which invented the web) looked as an ideal place where to train young scientists in GRID technologies
- This was seen as a unique opportunity to alleviate the personnel problems of LHC computing

HEP, LHC & GRID

- People are sent at CERN to work and train on GRID
- LHC experiments may greatly profit from GRID
- CERN has experience in large distributed collaborations
- This could be a good deal, however
  - Mostly young and non-experienced CSs are sent at CERN
    - No knowledge of HEP habits and needs, little experience
  - CERN has no record in distributed computing research
  - LHC computing needs go beyond GRID middleware
    - There is a pressure to launder personnel into other roles
  - People come at CERN with agendas and constraints
  - GRID developed at CERN is specific for the need of HEP
    - However a working middleware for HEP would go a long way in satisfying most applications

GRID as the environment for science?

- The killer applications are there
  - Biomedical, Environmental, Industrial
- Governments see major potential benefits, economic and societal
- Technologies continue to improve with resources in Peta units
- And then miracle happens…
  - Funding agencies worldwide have MOUs for sharing resources
  - Research projects give timely access to their data
  - GGF etc successfully fostered GRID standards
  - Grid MW is included in the system software

What about the people?

- Opportunity to work on the forefront of development
  - Pushing technology boundary
- Profit from and contribute to GRID research from any location
  - No need of big computers or fast network to be part of the game!
  - Middleware comes from brainware, not hardware!
  - Contributions from “peripheral” areas can have the same impact than large and established institutions
- The old dream of low-inertia hi-tech industry coming true?
- Work now is on basic principles, almost at a philosophical level
  - Prototypes can be assembled quickly and have a large impact
- Agile Technologies are widely used in GRID developments

Summary

- Simulation is a fundamental issue
  - Fundamental work is still needed
  - Finally LHC seems to realise it!
- GRIDs may not be "the solution", but they will be part of it, helping
  - Make "more real" the *third methodology* for scientific research, alongside experiment and theory
  - Expand the pool of people who can do forefront research
  - Leverage investments in research infrastructure