Grid computing and forward

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ESIPAP, the European School in Instrumentation for Particle and Astroparticle Physics
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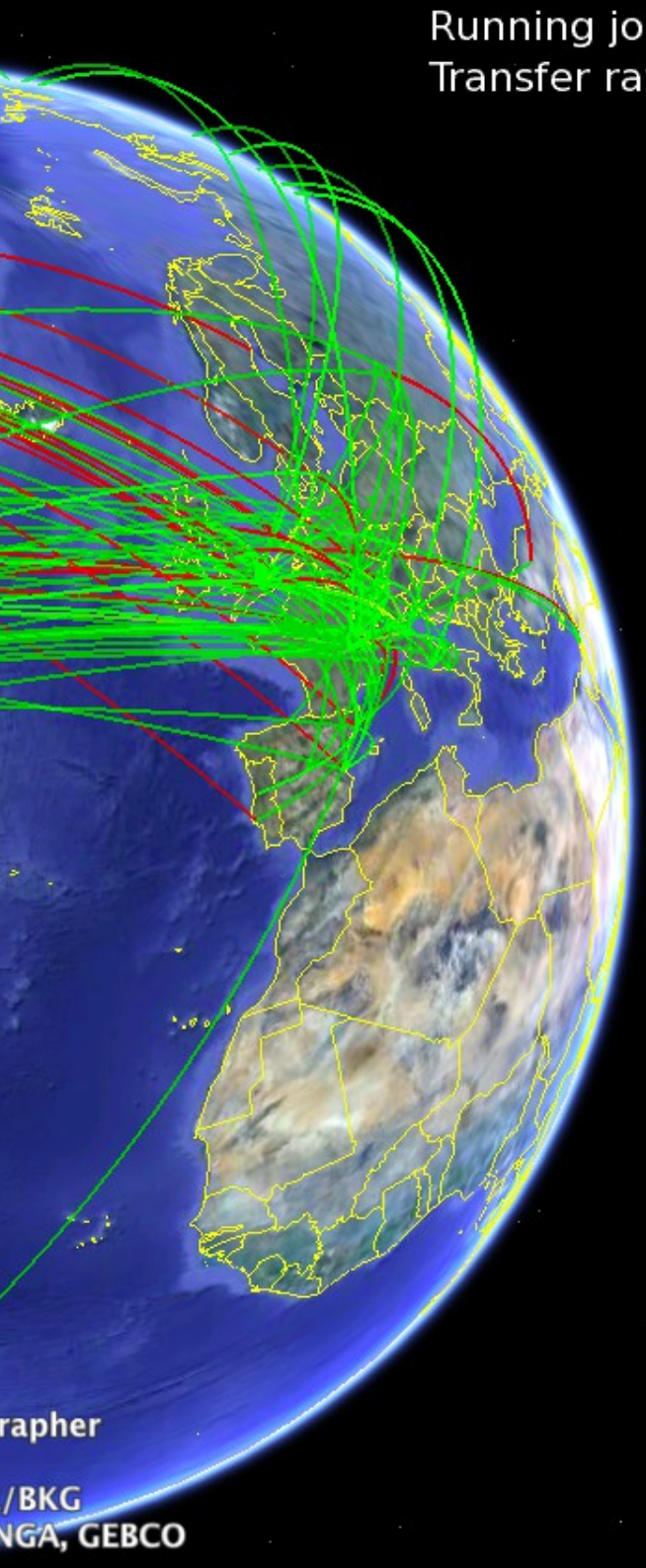


Today, Together

- Why grid computing
  - A success story: the grid for the LHC
- Other Grids
- Behind the scenes
  - Technical details
- Going forward
  - Standards, simplicity, clouds
- Accessing the grid

A few words on the speaker

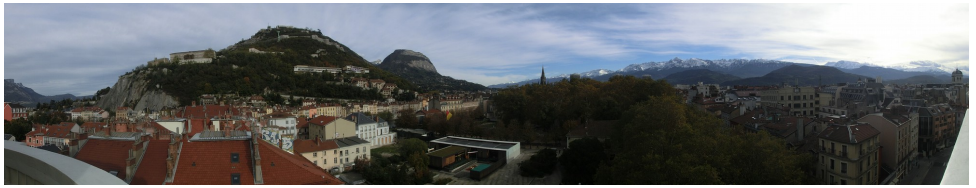
- Before 2011: experimental particle physicist (colliders)

Detector in US, Chicago, ppbar collider Tevatron $\sqrt{s}$ = 2 TeV
- calorimetry, simulation, SUSY search

Detector at CERN, Geneva, pp collider LHC $\sqrt{s}$ = 14 TeV
- calorimetry, non standard Higgs boson search
- responsible for the ATLAS computing activities in a major centre (T1)

- Since 2011: Research engineer in computing at IN2P3 (National Institute for Nuclear and Particle Physics in France), part of CNRS (National Centre for Scientific Research)

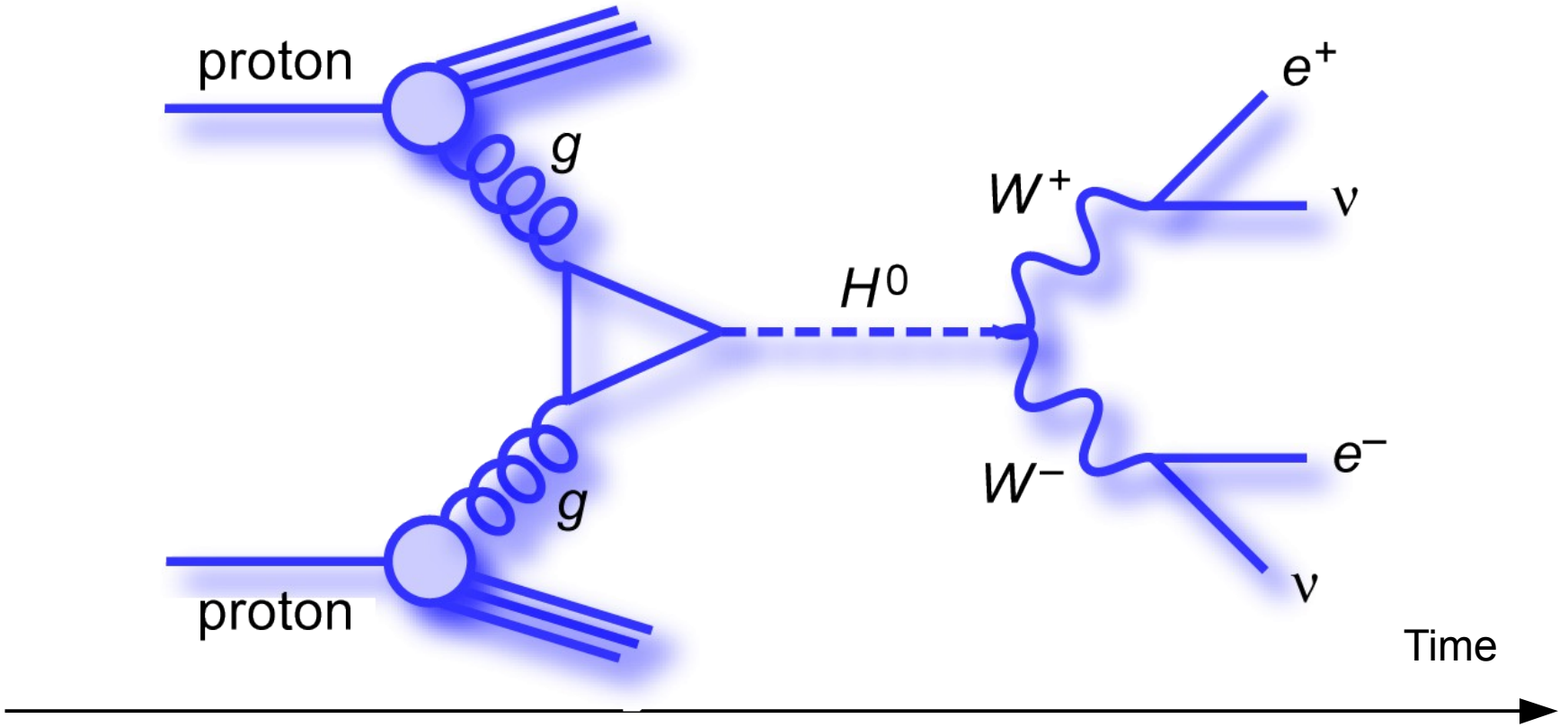
  - Grid computing
  - Application porting
  - Technical coordination LCG-France



Why grid computing ?

Searching for the Higgs

The Higgs boson could be produced in the collision of two protons



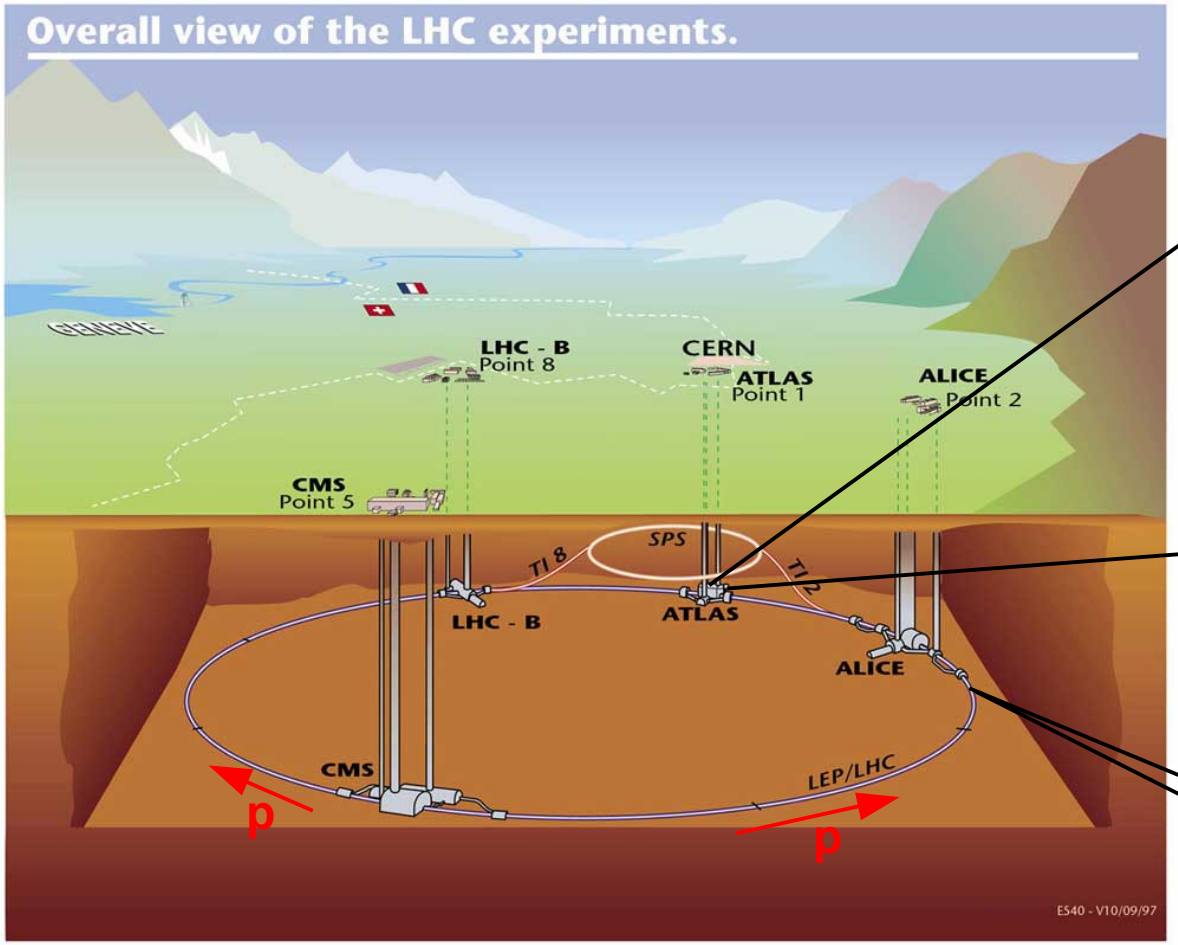
Two protons collide

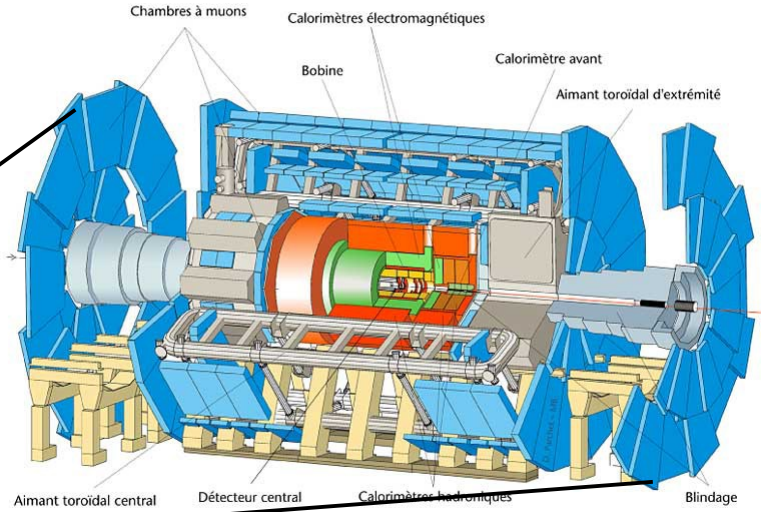
Two gluons (constituents Of the protons) do fusion and a Higgs boson gets created

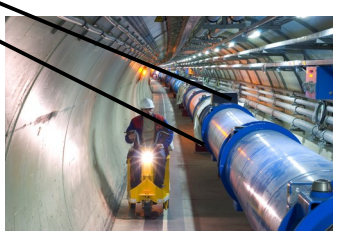
The Higgs decays instantaneously in a W boson pair (which decay themselves further)

The stable particles in the final state (here e, ν) get to the detector

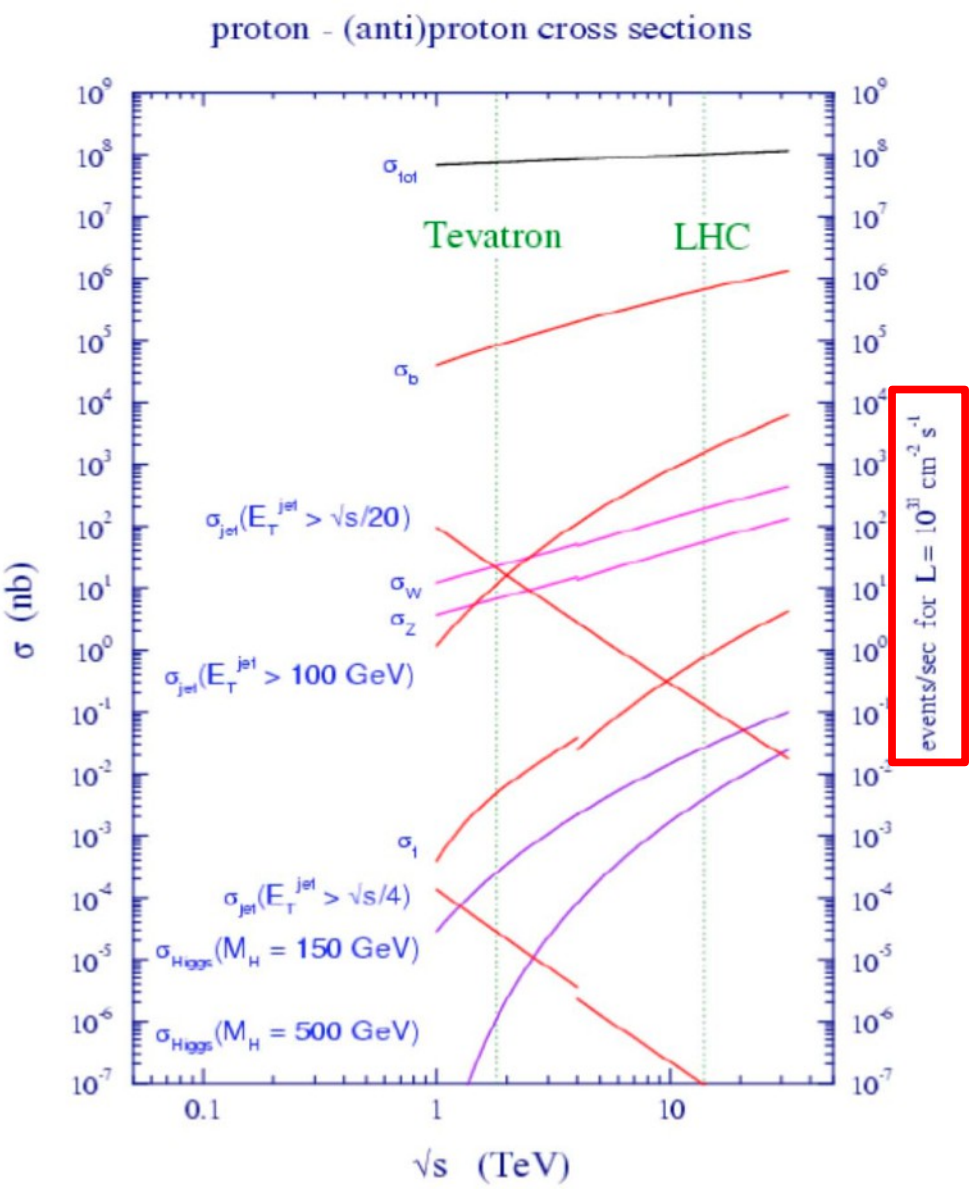
In practice


Overall view of the LHC experiments.
GENEVE
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC
p
p
ES40 - V10/09/97


Chambres à muons
Calorimètres électromagnétiques
Bobine
Calorimètre avant
Aimant toroïdal d'extrémité
Aimant toroïdal central
Détecteur central
Calorimètres hadroniques
Blindage



Event production rate at the LHC



- Bunch crossing: 40 MHz
  - 100 000 CDs written / s
  - Distance (moon-earth) /3 months

- Expensive to store
- Difficult to share
- Long to analyse

- But: all events do not carry the same interest for physics

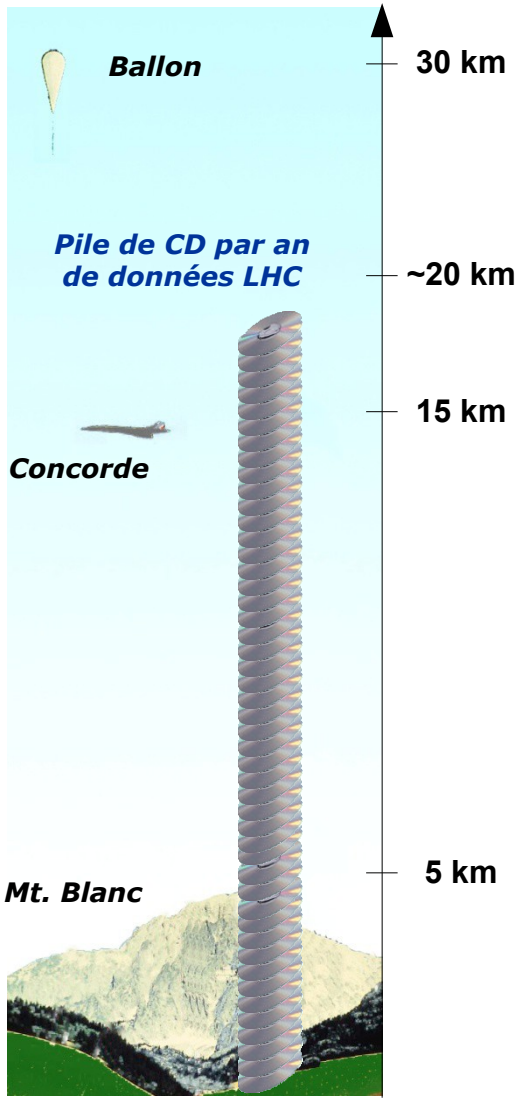
- First selection at the experiment level before storage
  - Trigger (very fast electronic and algorithms)

Quantity of stored data

- Let's do a quick calculation
  - Each experiment stores ~100 events /s
  - Each event counts for ~1-2 MB

→ several PB of data produced per year and per experiment

  - equivalent to 600 000 DVDs movies produced per experiment and per year



1 MB
1 digital picture
1 dictionnaire
1 CD = 650 MB

1 GB = 1000 MB
5GB = 1 DVD movie

1TB = 1000 GB
Livres produits par an

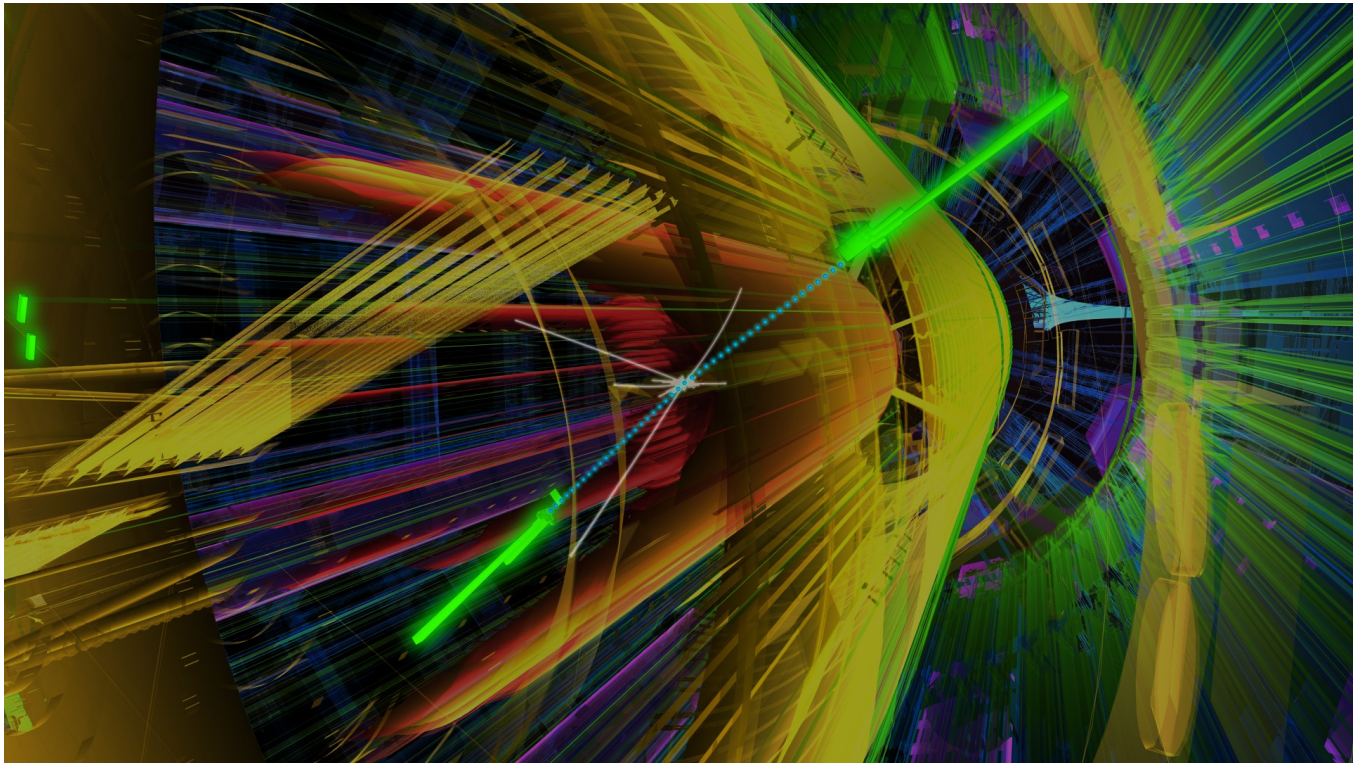
1PB = 1000 TB
Production par an de
1 expérience LHC

1 EB = 1000 PB
Production mondiale
d'information en 1 an

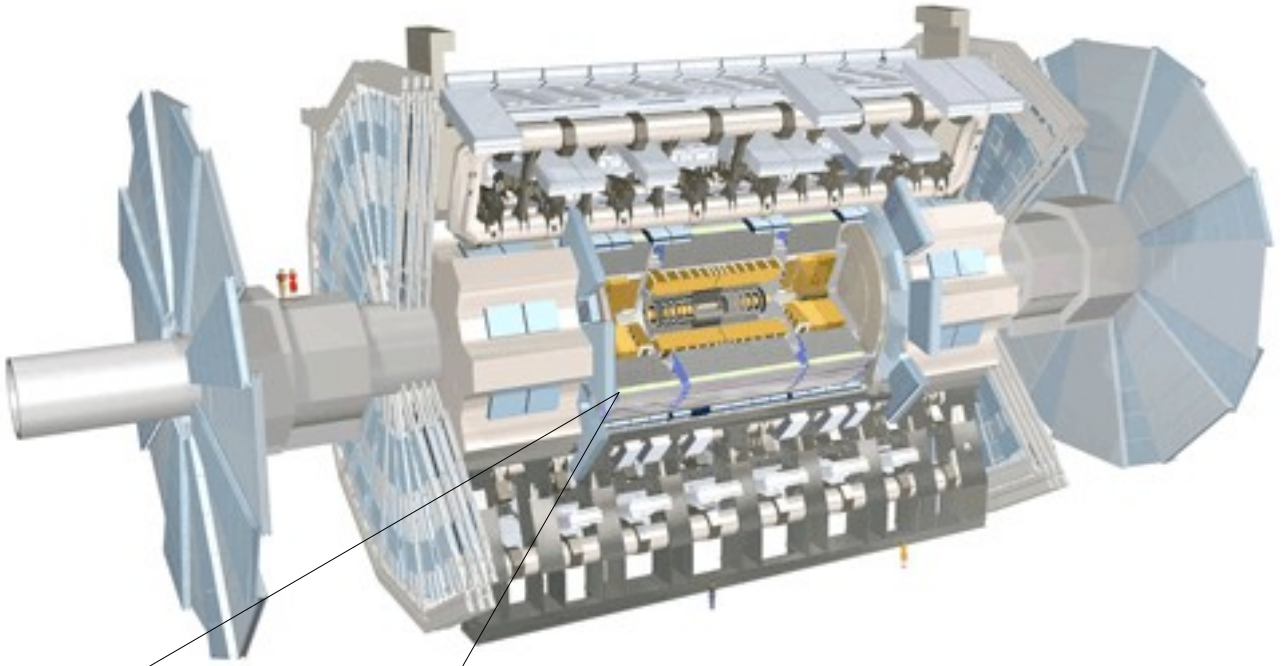
Enormous amount of data
to analyse and to store;
No single computing centre
could manage it alone.

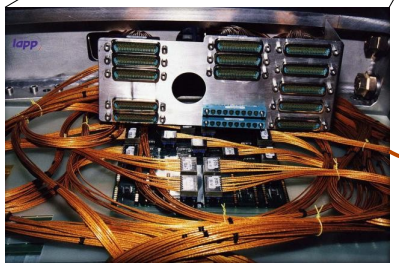
“Events”

- Data are organised in “events”
  - A “picture” of a collision
  - With millions of sensors
- Each event is independent from other events
  - And it is quite small
- Algorithms process events one by one



Raw data





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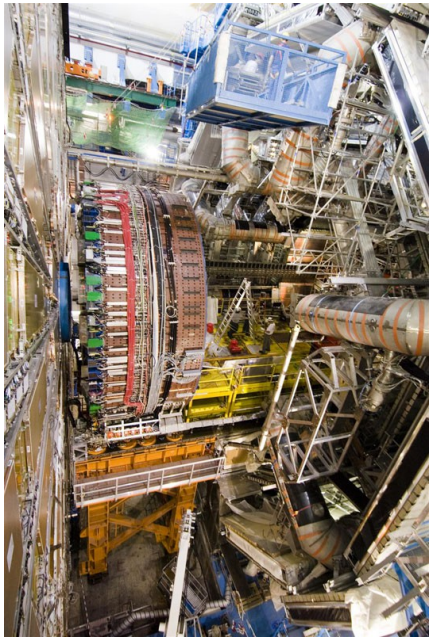
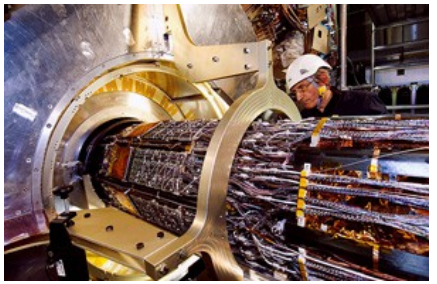
101100 101011 010001
110111 001011 001100
100001 111100 100110
110101 110011 100101
001010 101000 001010
111001 100101 000011
010111 001001 010100
100010 010100 101111
100100 101001 001010
000010 100101 111001
```

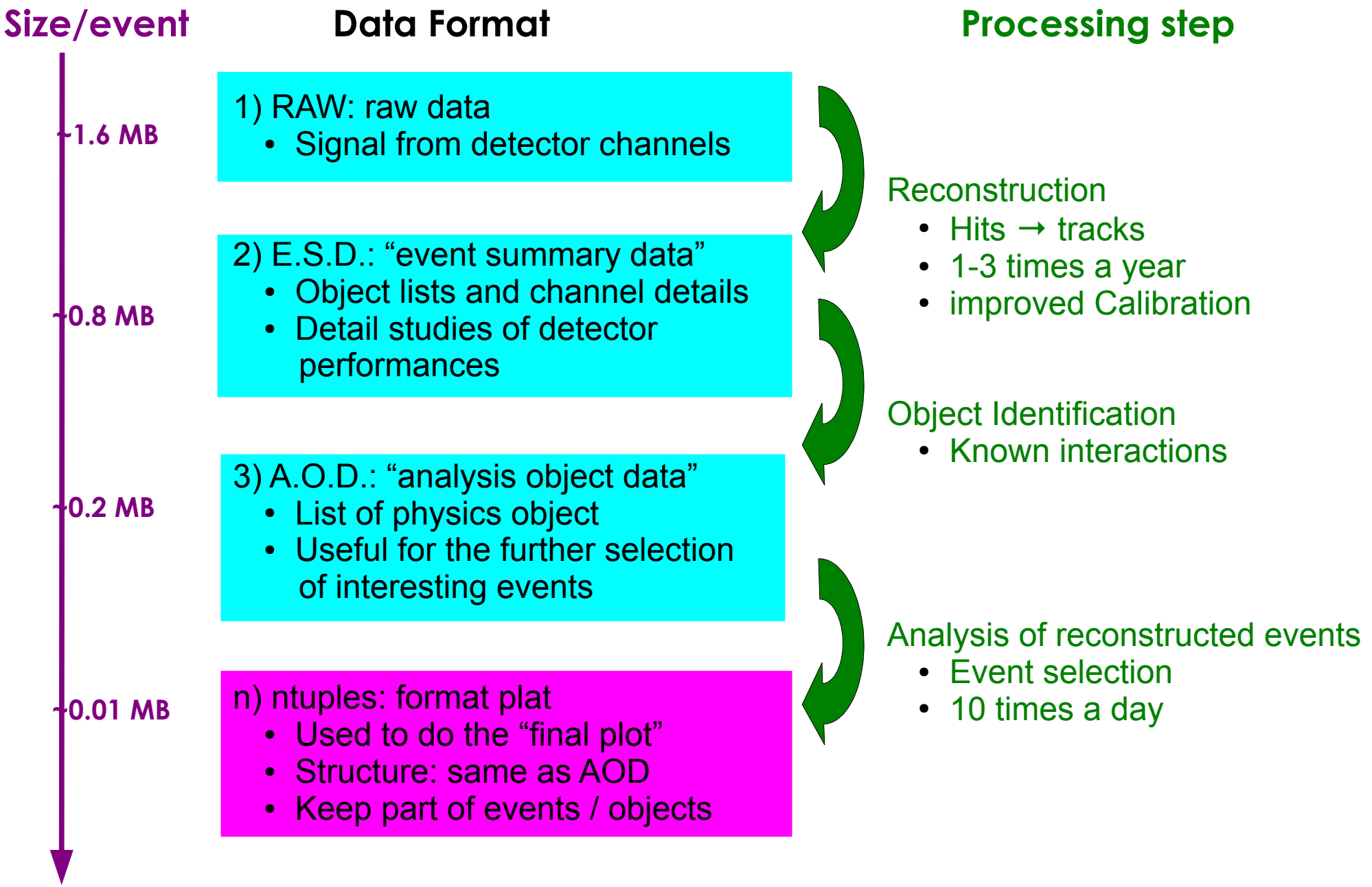
Pixels → yes/no
Calo → voltage

Stored on tape at CERN





How do we look into data



How do we look into data

Size/event

Data Format

Processing step

~1.6 MB

1) RAW: raw data
- Signal from detector channels

Reconstruction
- Hits → tracks
- 1-3 times a year
- improved Calibration

~0

bject Identification
- Known interactions

~0

~0

nalysis of reconstructed events
- Event selection
- 10 times a day

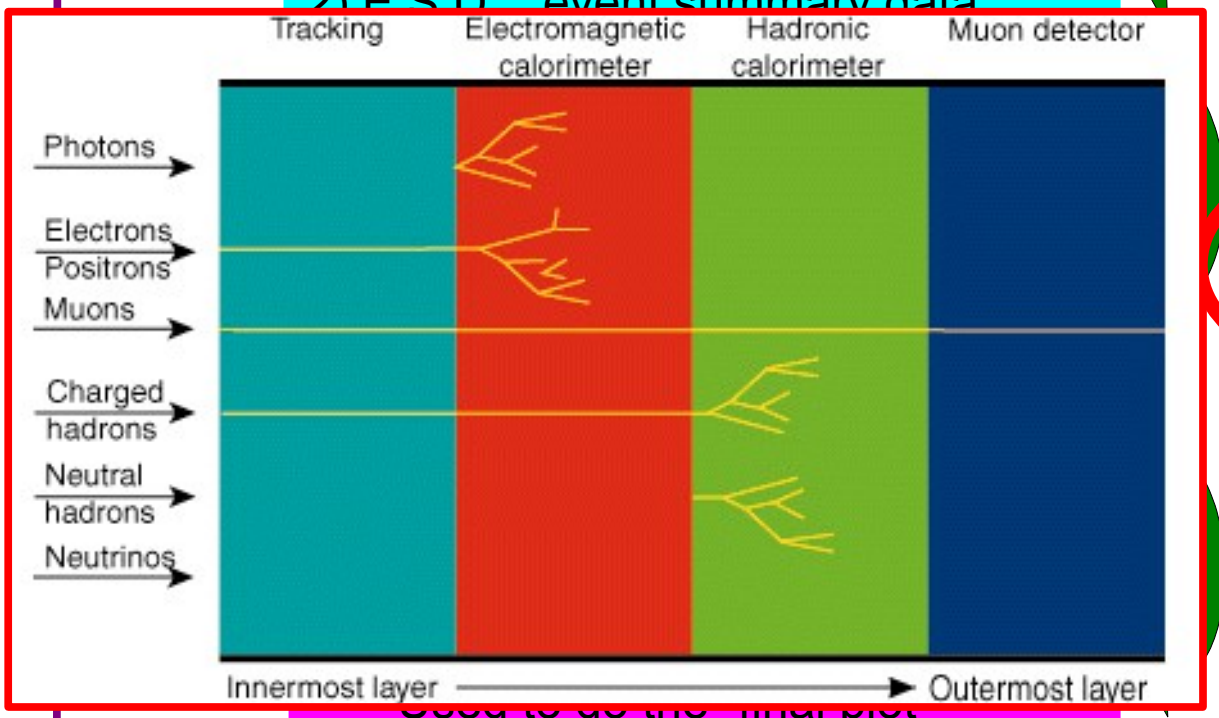
How do we look into data

Size/event | **Data Format** | **Processing step**

~1.6 MB

1) RAW: raw data
- Signal from detector channels

2) E.S.D.: "event summary data"



- Structure: same as AOD
- Keep part of events / objects

Reconstruction
- Hits → tracks
- 1-3 times a year
- improved Calibration

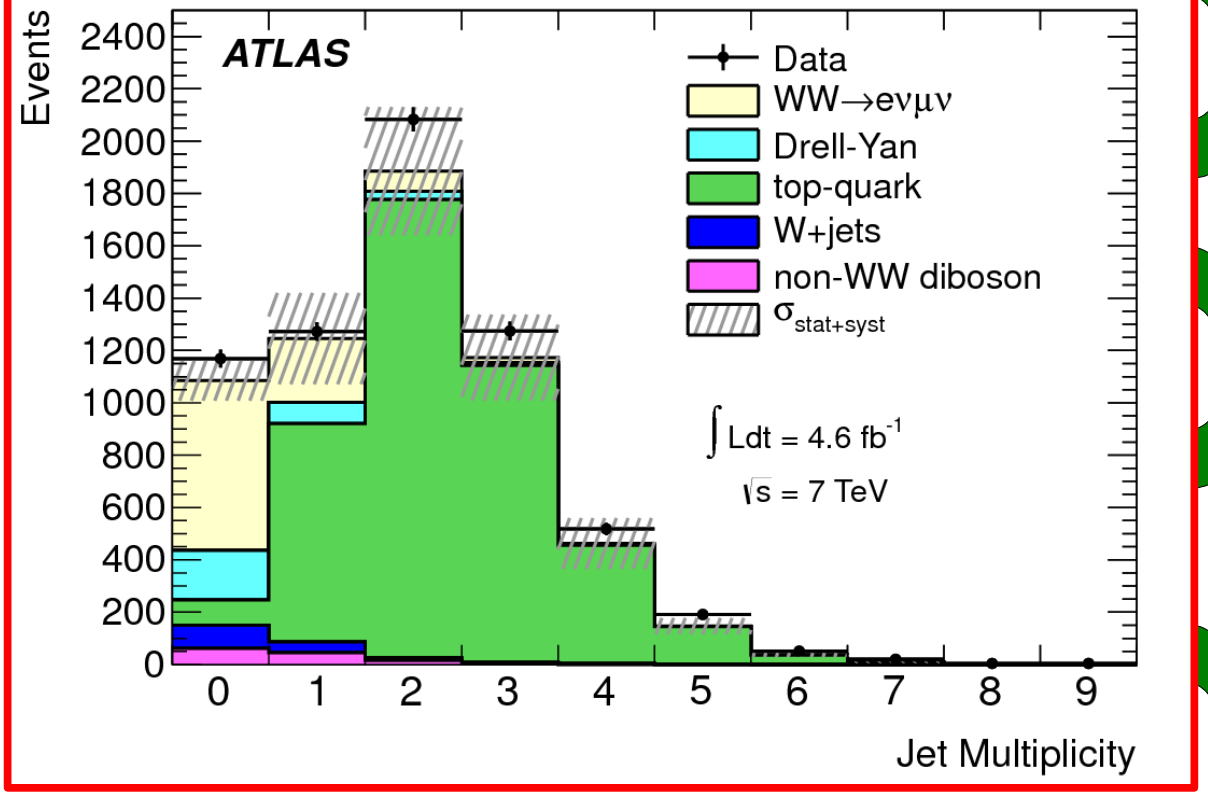
Object Identification
- Known interactions

Analysis of reconstructed events
- Event selection
- 10 times a day

How do we look into data

Size/event | **Data Format** | **Processing step**

1) RAW: raw data



Reconstruction
- Hits → tracks
- 1-3 times a year
- improved Calibration

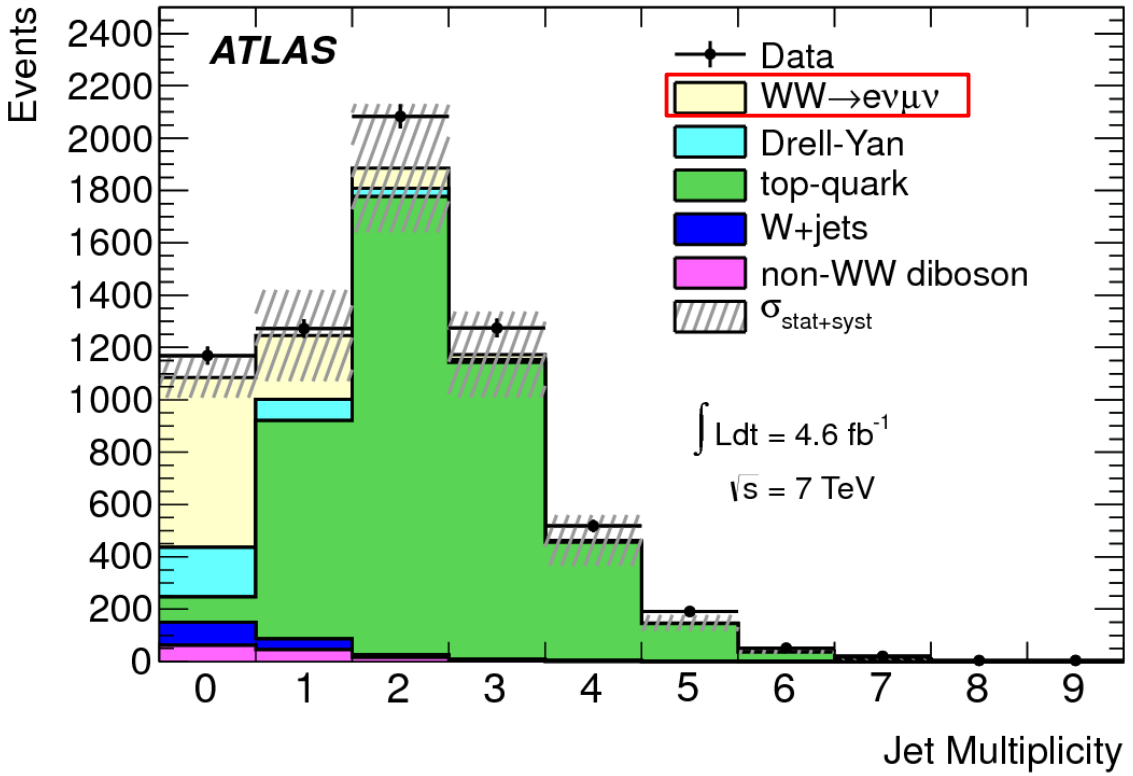
Object Identification
- Known interactions

Analysis of reconstructed events
- Event selection
- 10 times a day

~0.01 MB

n) ntuples: format plat
- Used to do the "final plot"
- Structure: same as AOD
- Keep part of events / objects

Interpreting data



In other words:

Compare the data with a model (MS).

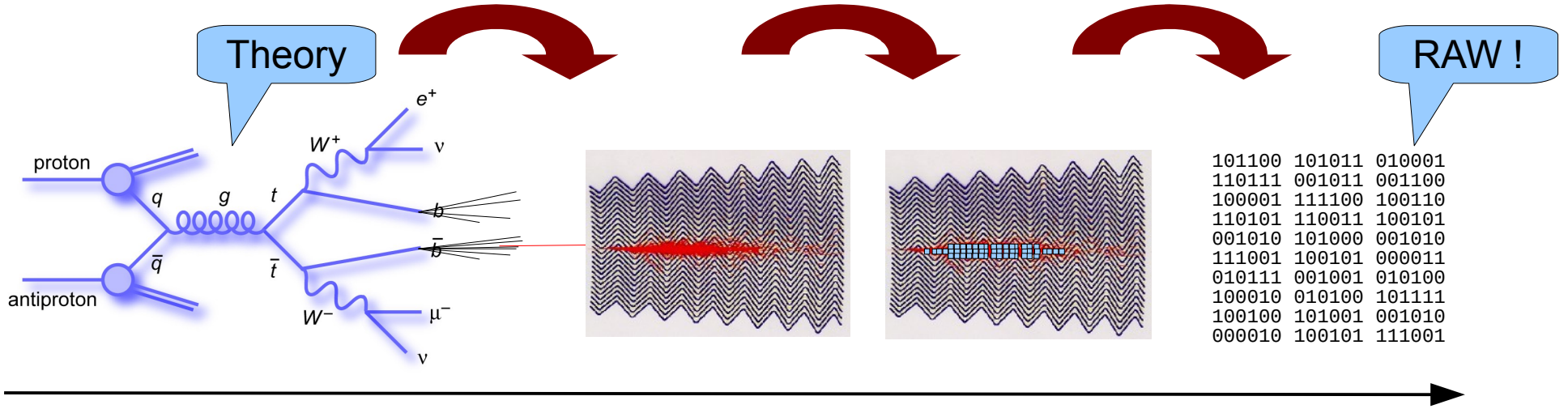
- Agreement data/simulation (understanding of the detector)
- Find deviations (discovery of new phenomena)

Getting results from an experiment: no way without simulation !

Simulation of RAW data

Three ingredients :

1) “Physics” modelisation (collisions, hard process, ...)
2) Particle/matter interactions in the detector layout
3) Signals transmitted by the detector

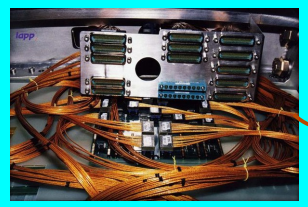


Summary

Centralised operations

Reconstruction

Identification



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101100 010001
110111 001100
111100 100110
110101 110011
001010 001010
100101 000011
010111 010100
```
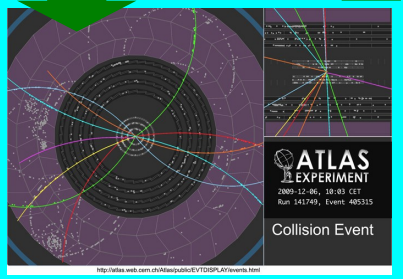
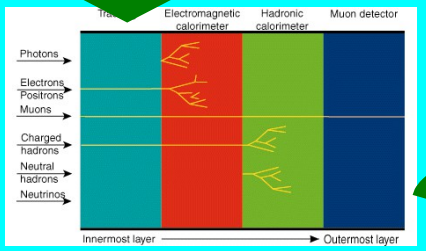
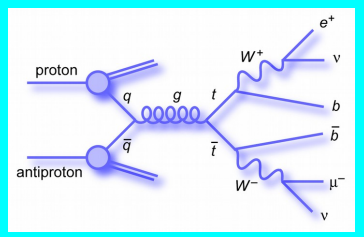





Simulation

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101100 010001
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111100 100110
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001010 001010
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010111 010100
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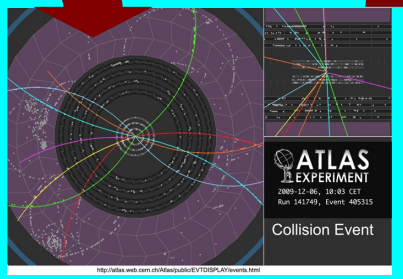
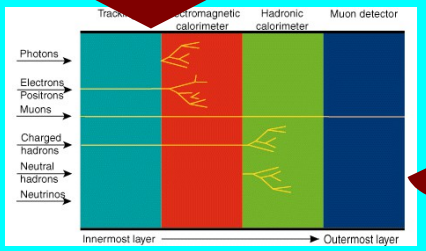
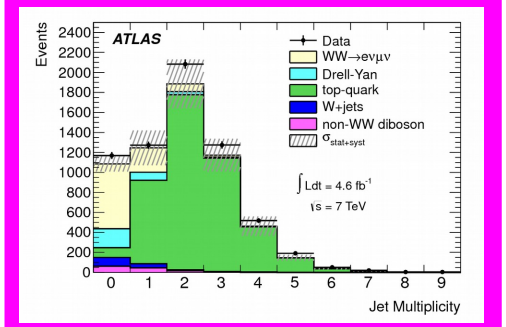


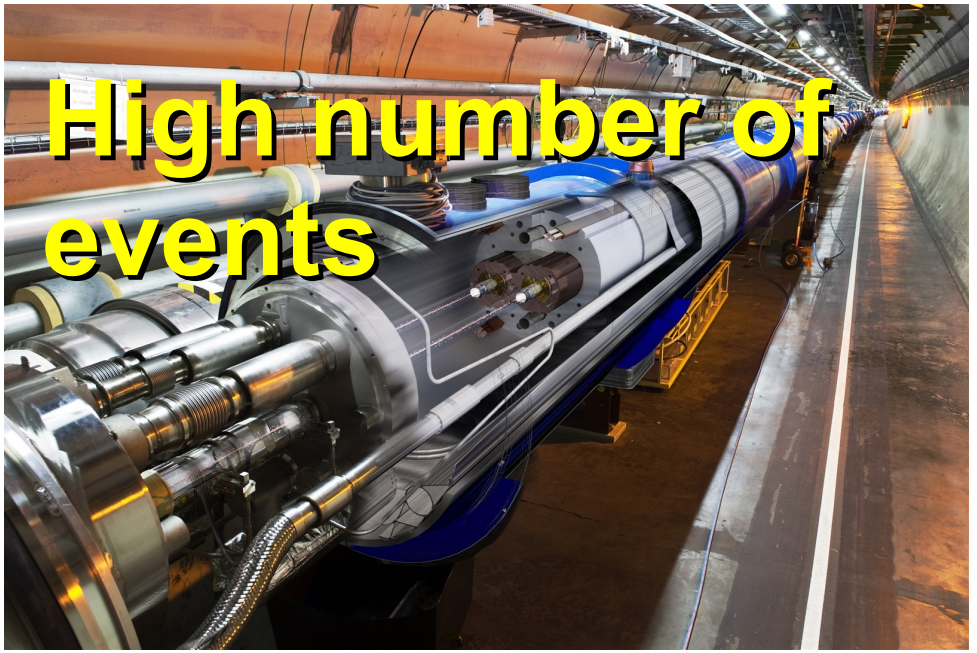


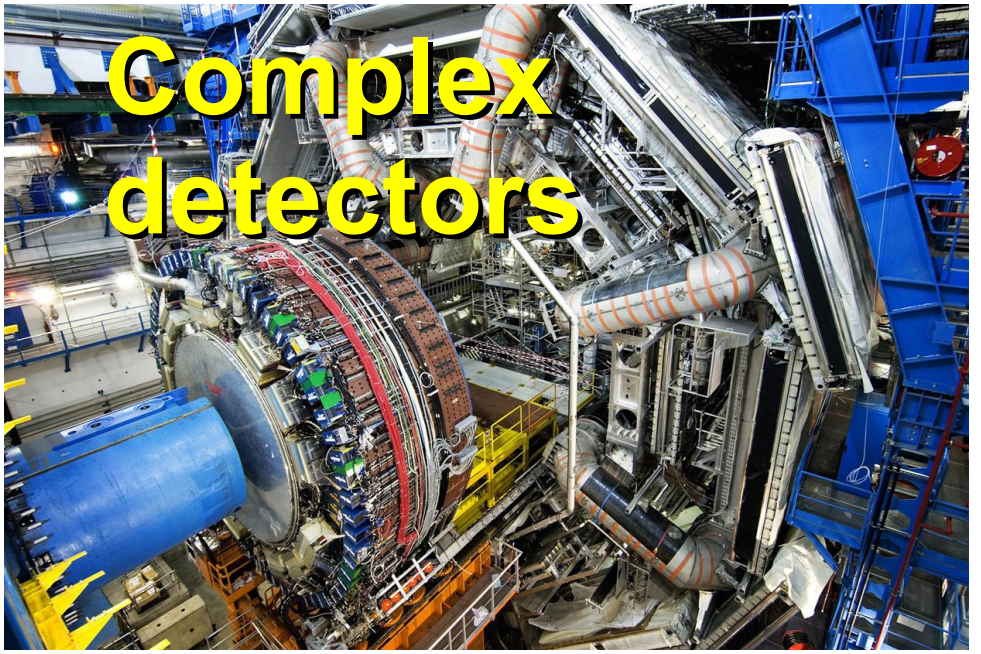
group/individual

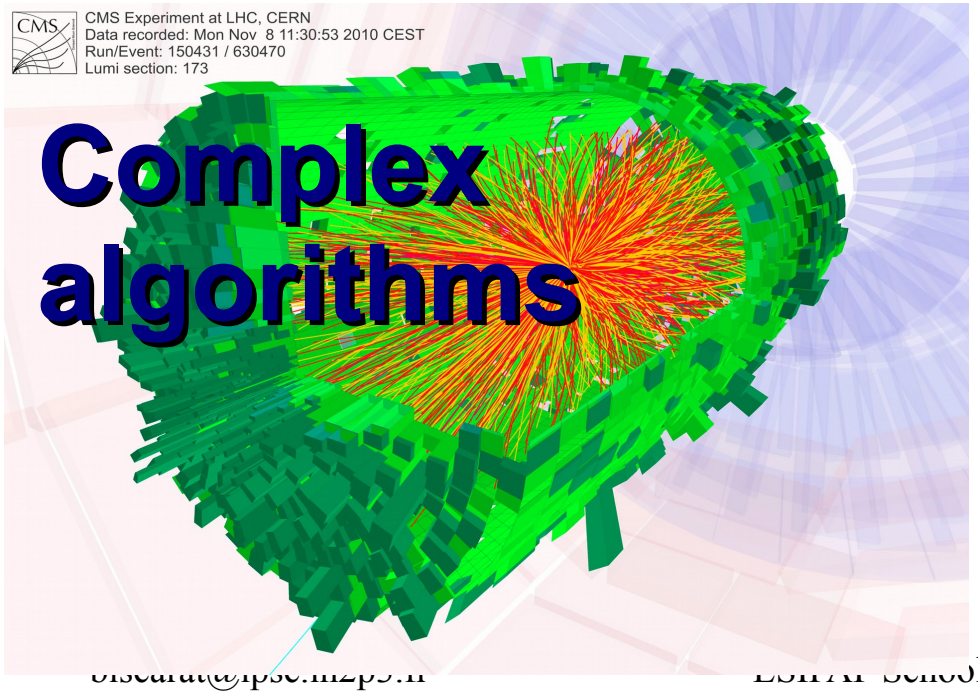
Final analysis (n times / day)

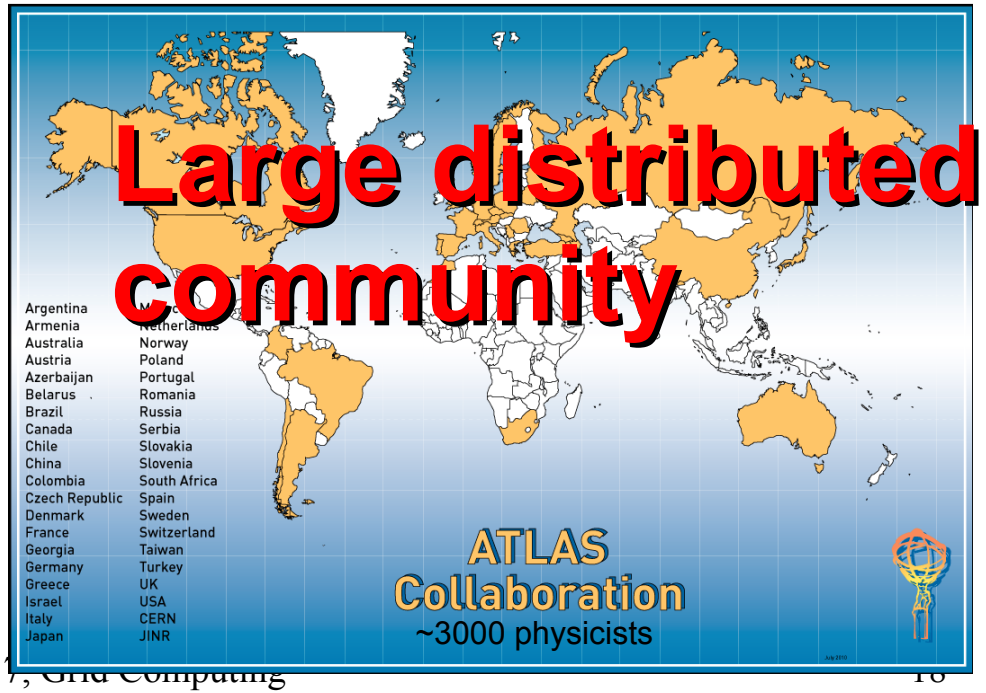


A new order of magnitude





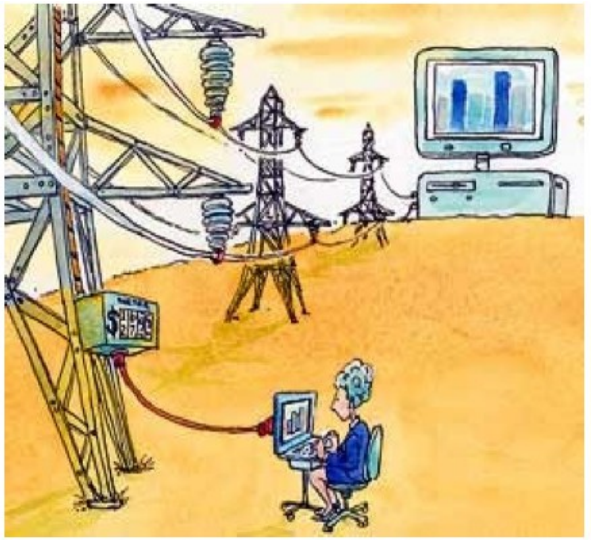




A new Challenge

- No new concepts, but new orders of magnitude

→ one single site could not do all the computing alone
(e.g. resources, cooling, money)

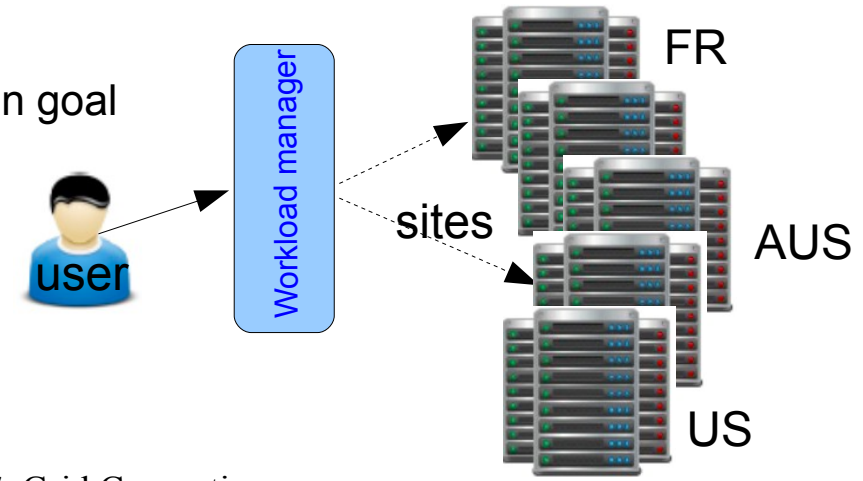


Term taken from the "electric power grid"

- Though,
  - Computing centers already existing worldwide
    - Often shares between several communities
  - Founding is provided locally
  - Concepts of grid computing fits to the HEP model
    - Authentication / trust / solutions for heterogeneity

→ decision (technical & political) to build a grid infrastructure for the LHC computing

- Share of resources from several units for a common goal



Building WLCG

Grid Computing concepts

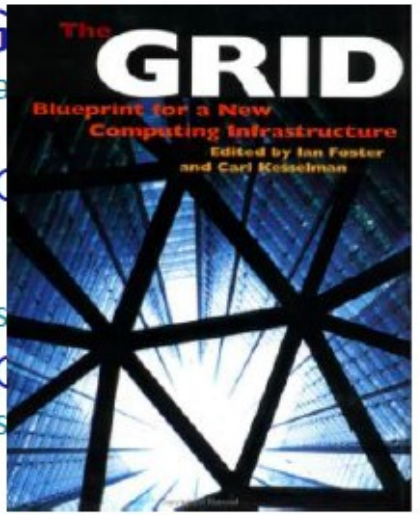
The Grid: 1998 and 2003 (2nd Ed.)
Grid is used by analogy with the electric power grid…
has had a dramatic impact on human capabilities…

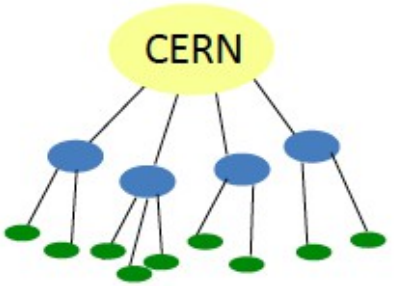
- Coordination of resources not centrally managed
- Use of standards protocols
- Access rights

Catalyser: development of high rate and extended networks (GEANT in 2000)

A few words about history

- 1999 - MONARC project
  - First LHC computing architecture – hierarchical distributed model, focus on network control
- 2000 – growing interest in grid technology
  - HEP community main driver in launching the DataGrid project
- 2001-2004 - EU DataGrid project
  - middleware & testbed for an operational grid
- 2002-2005 – LHC Computing G
  - deploying the results of DataGrid to provide a production facility for LHC experiments
- 2004-2006 – EU EGEE project p
  - starts from the LCG grid
  - shared production infrastructure
  - expanding to other communities and sciences
- 2006-2008 – EU EGEE project p
  - expanding to other communities and sciences
  - Scale and stability
  - Interoperations/Interoperability
- 2008-2010 – EU EGEE project phase 3
  - More communities
  - Efficient operations
  - Less central coordination
- 2010 – 201x EGI and EMI
  - Sustainable infrastructures based on National Grid Infrastructures
  - Decoupling of middleware development and infrastructure
  - Merging middleware stacks in europe





DataGRID

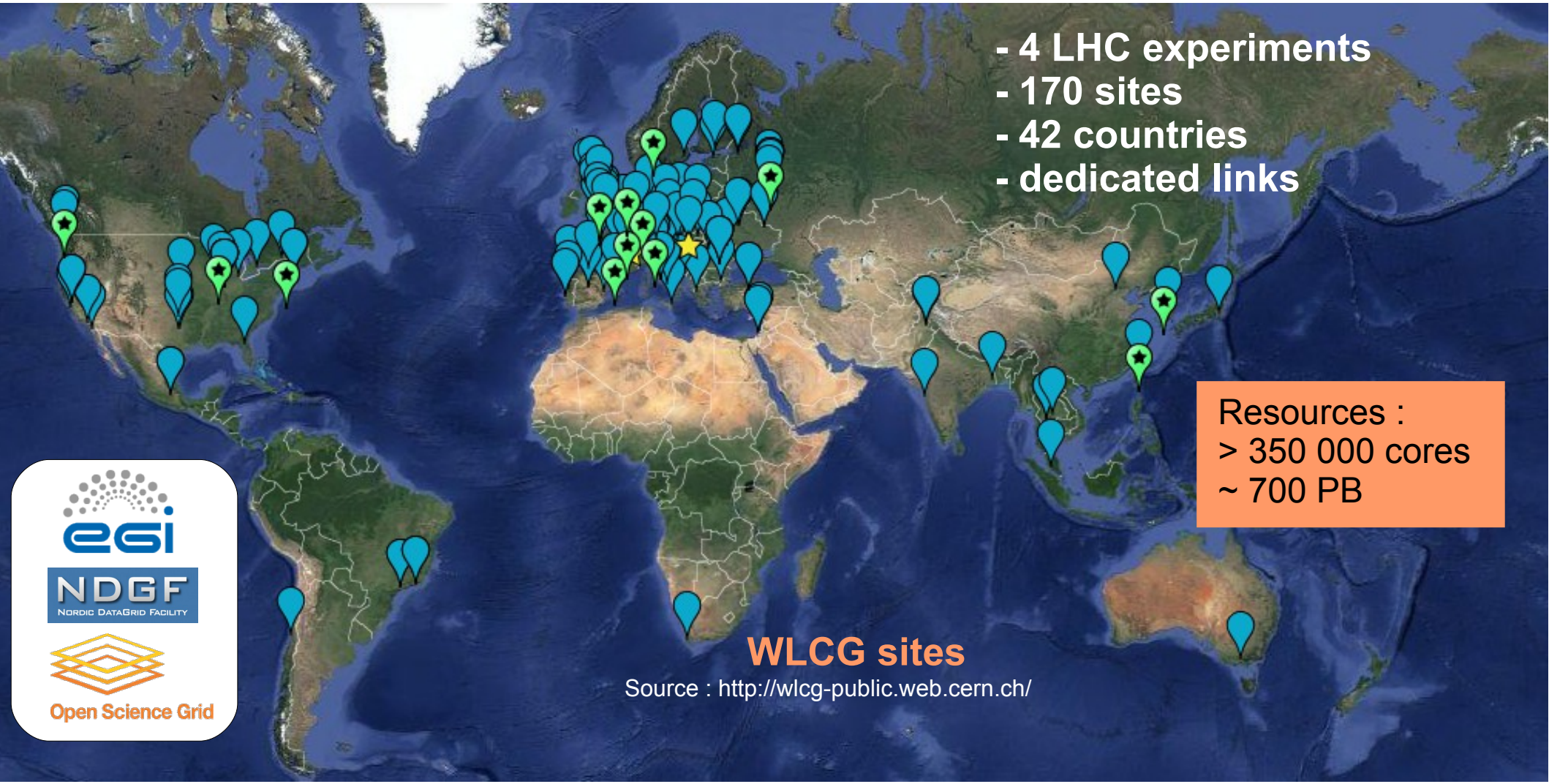
LCG

eGee
Enabling Grids for E-sciencE

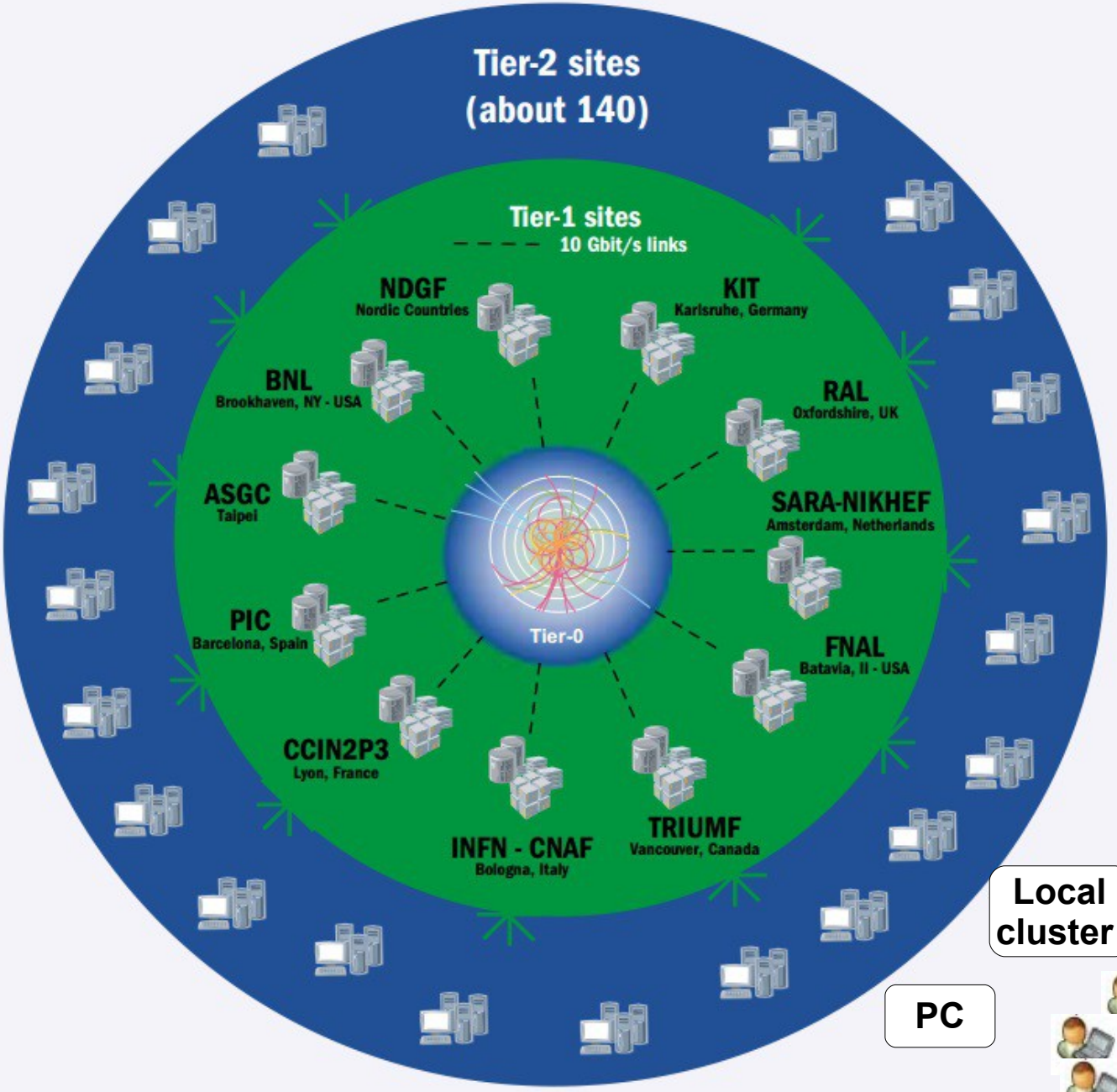
EUROPEAN MIDDLEWARE INITIATIVE

egi

Sites around the world



Sites hierarchy



Tier0 (CERN):
- Raw data storage
- Initial reco pass
- Data distribution

Tier-1:
- Permanent storage
- Subsequent reco passes

Tier-2:
- Simulation
- End user analysis

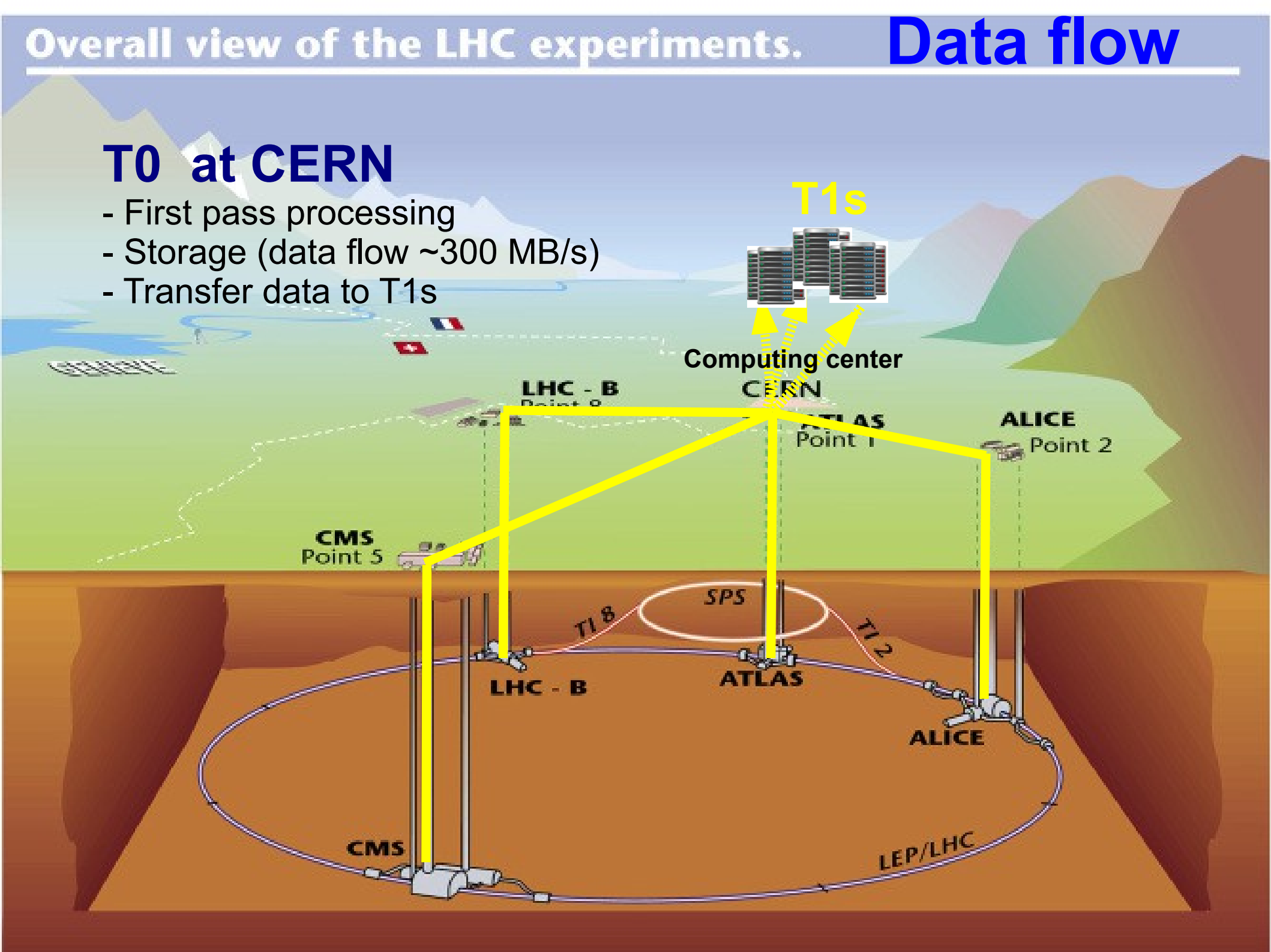
In addition (end user analysis):
- Tier-3
- Local clusters

Overall view of the LHC experiments.

Data flow

T0 at CERN

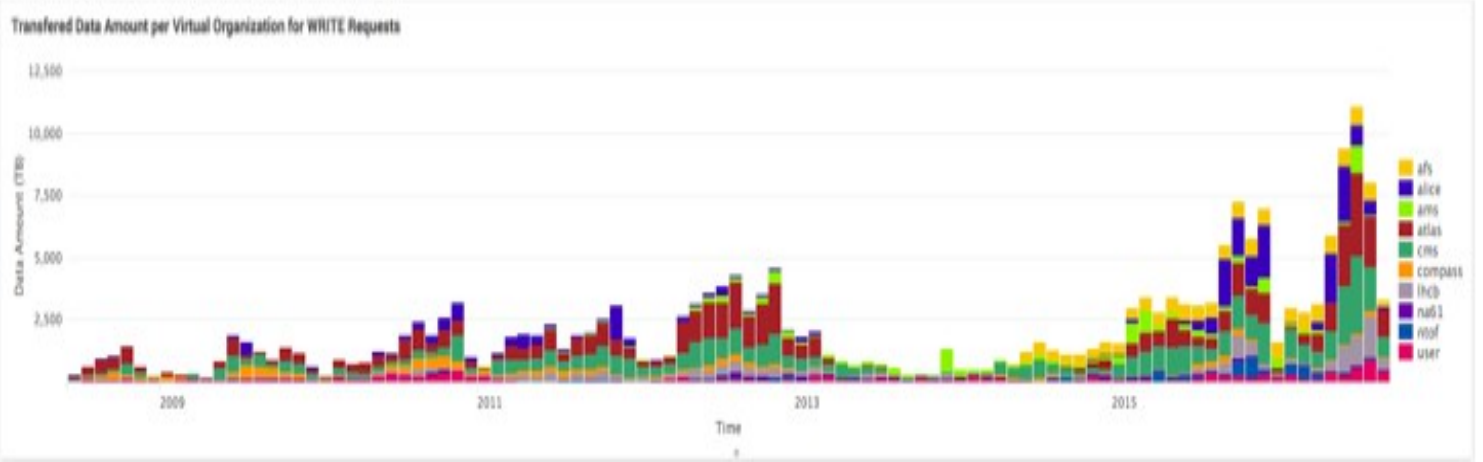
- First pass processing
- Storage (data flow ~300 MB/s)
- Transfer data to T1s

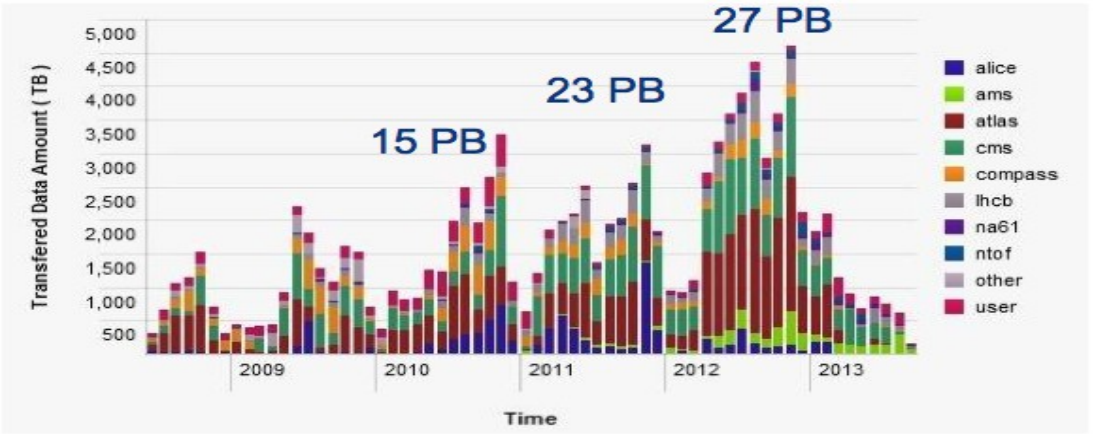


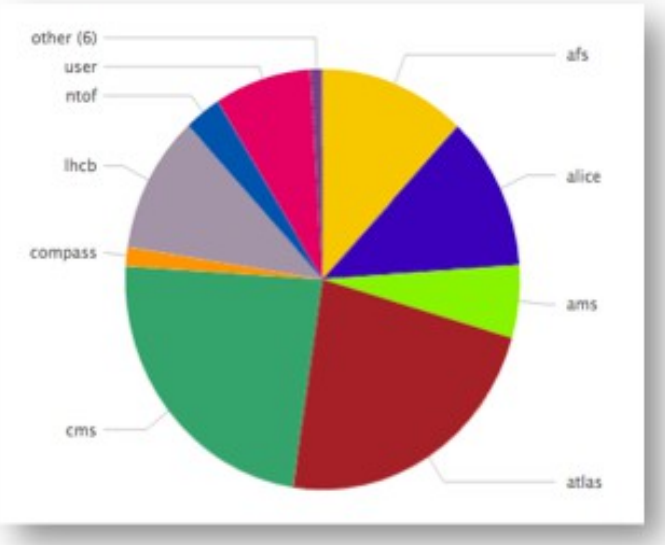
CERN tape writes

CERN tape writes

June-July 2016:
> 500 TB per day



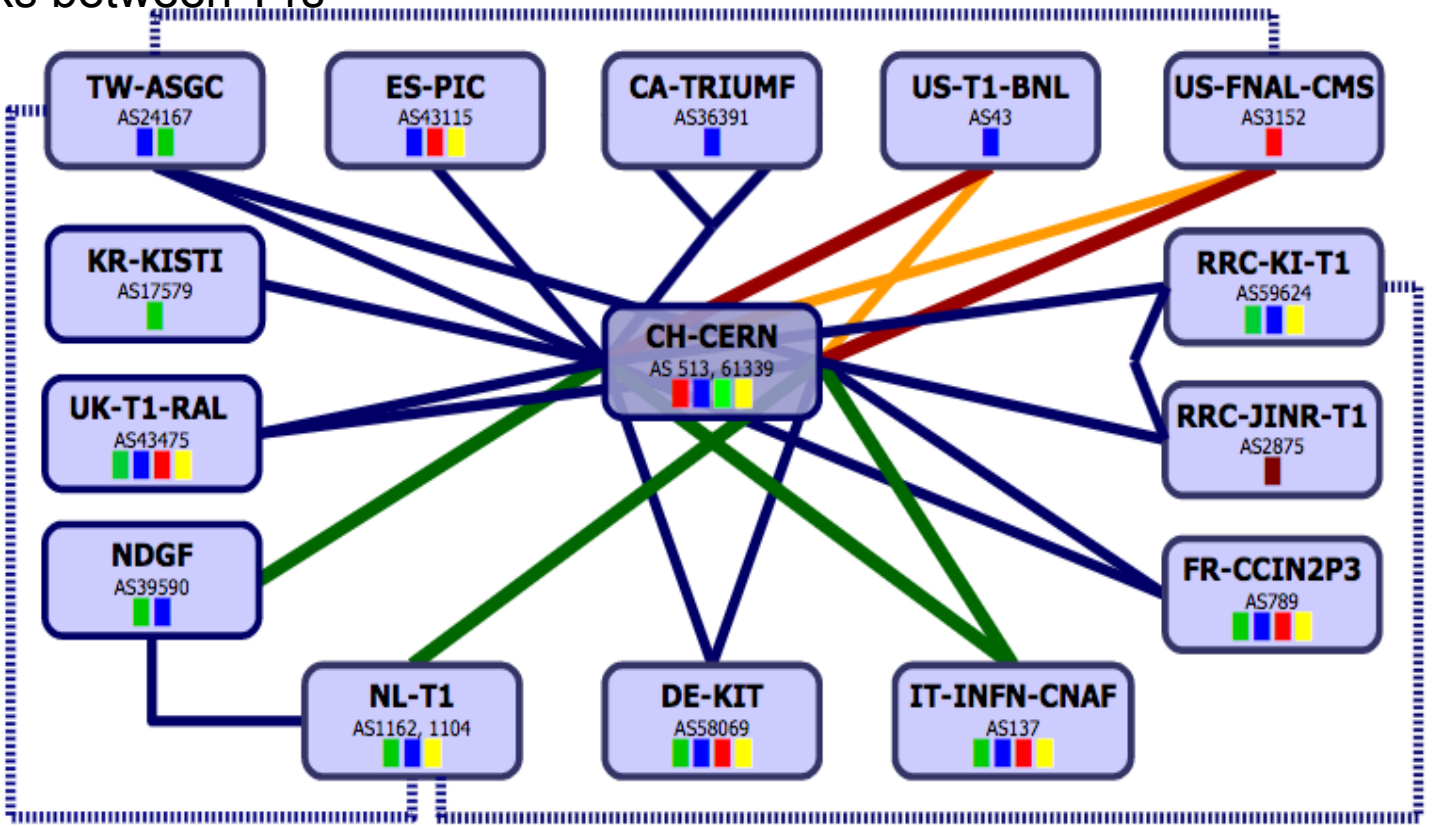




2016 data acquired

LHC Optical Private Network (T0-T1)

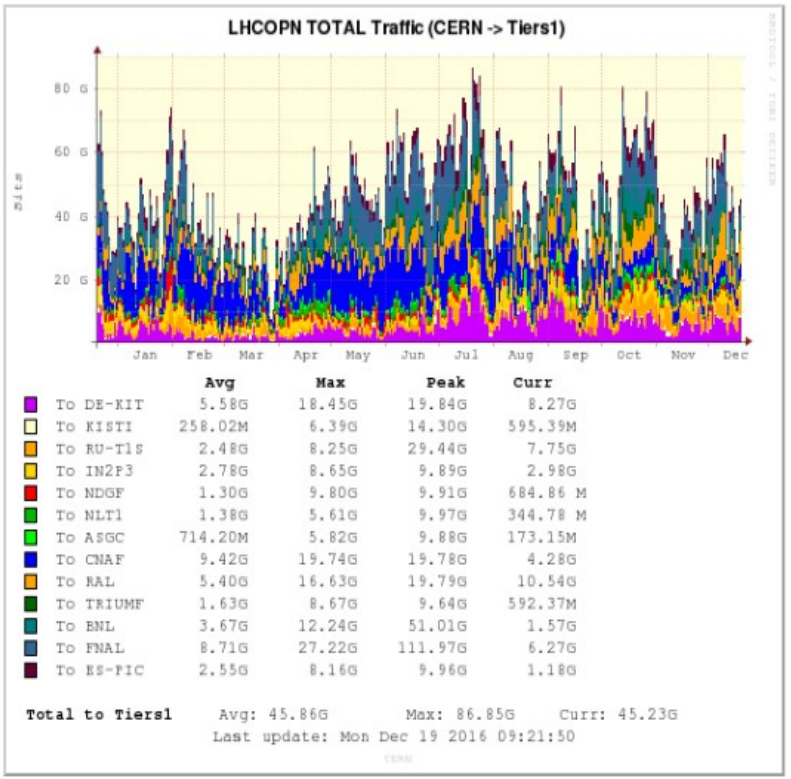
Agreements to provide
back-up links between T1s



LHCOPN

LHC Optical Private Network (T0-T1)

2016 traffic statistics



	Avg	Max	Peak	Curr
To DE-KIT	5.58G	18.45G	19.84G	8.27G
To KISTI	258.02M	6.39G	14.30G	595.39M
To RU-T1S	2.48G	8.25G	29.44G	7.75G
To IN2P3	2.78G	8.65G	9.89G	2.98G
To NDGF	1.30G	9.80G	9.91G	684.86 M
To NLT1	1.38G	5.61G	9.97G	344.78 M
To ASGC	714.20M	5.82G	9.88G	173.15M
To CNAF	9.42G	19.74G	19.78G	4.28G
To RAL	5.40G	16.63G	19.79G	10.54G
To TRIUMF	1.63G	8.67G	9.64G	592.37M
To BNL	3.67G	12.24G	51.01G	1.57G
To FNAL	8.71G	27.22G	111.97G	6.27G
To ES-PIC	2.55G	8.16G	9.96G	1.18G

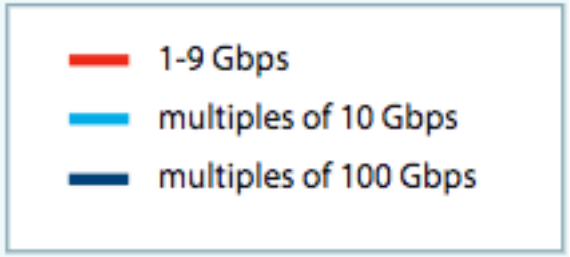
Total to Tiers1 Avg: 45.86G Max: 86.85G Curr: 45.23G

Last update: Mon Dec 19 2016 09:21:50

~180PB moved in 2016

70% increase compared to 2015 (was ~105PB)

In Europe

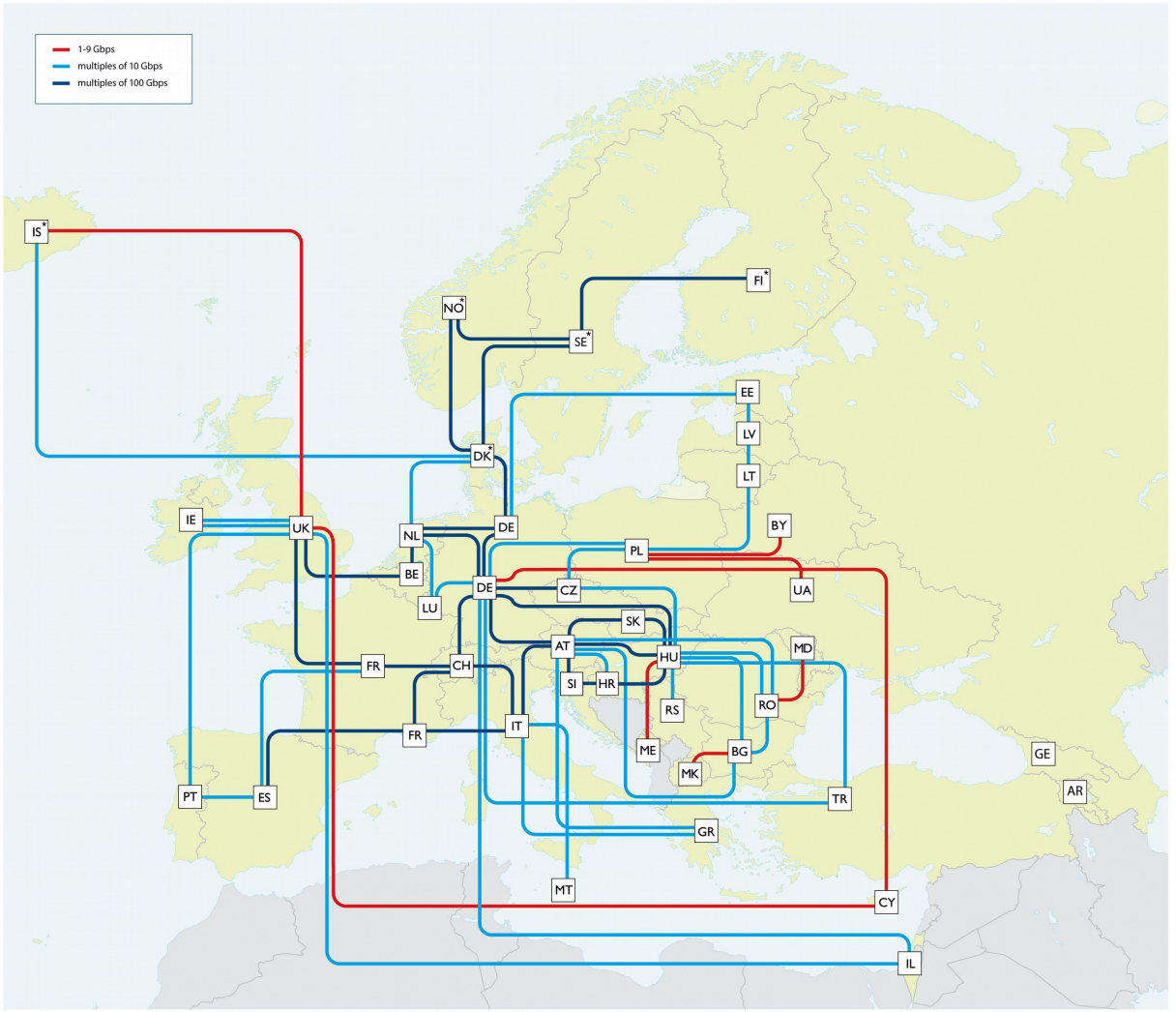


https://www.geant.org/

DFN Deutsches Forschungsnetz
DE Germany

RENATER CONNECTEUR DE SAVOIRS
FR France

GÉANT's pan-European research and education network interconnects Europe's National Research and Education Networks (NRENs).
Together we connect over 50 million users at 10,000 institutions across Europe.



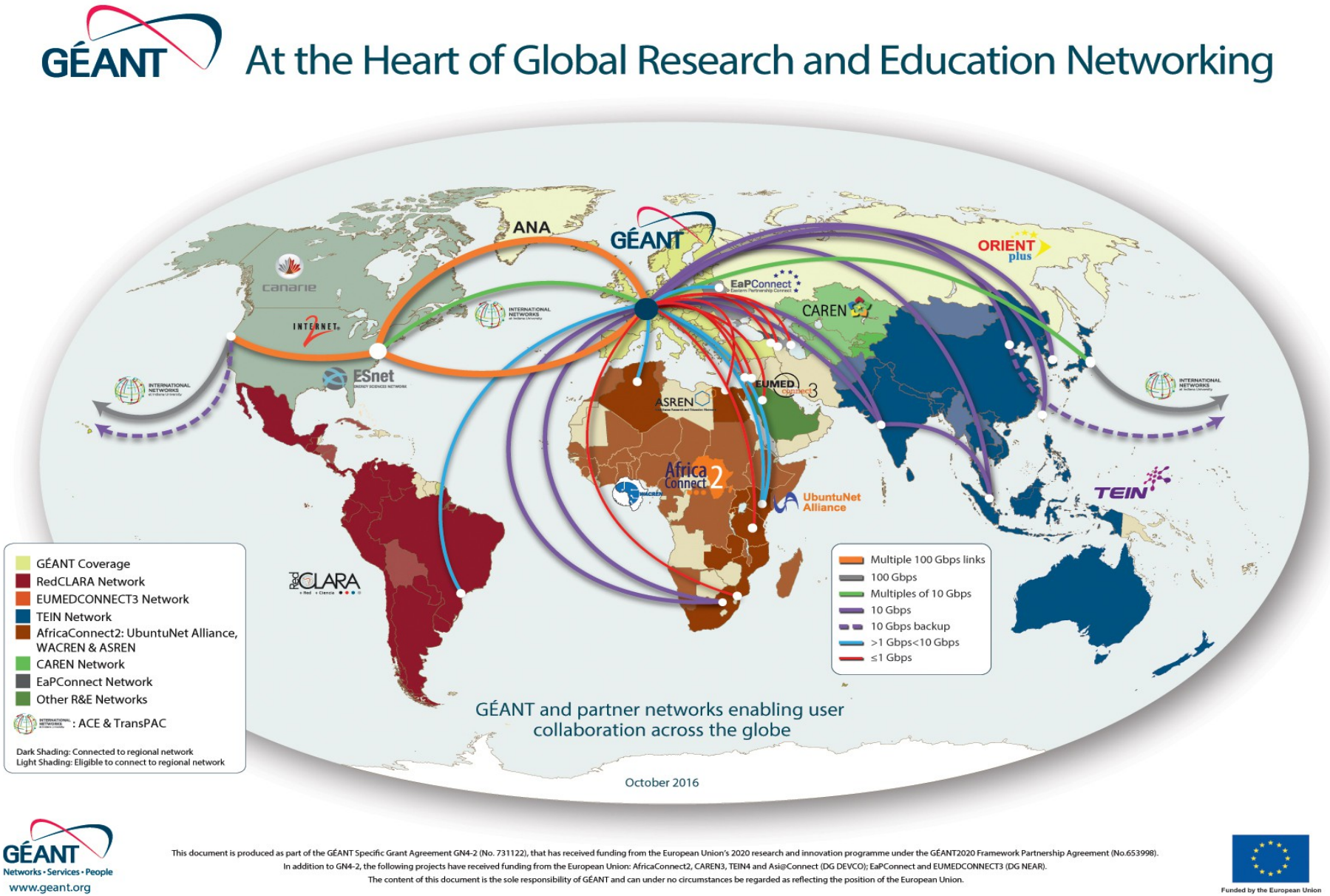
GÉANT's pan-European network is funded by the GÉANT Project (GN4-2). This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 731122. The map shows topology as at January 2017. The GN4-2 partners are listed below.

AR Armenia · CH Switzerland · DK Denmark* · FR France · HU Hungary · IT Italy · ME Montenegro · NO Norway* · RS Serbia · MD Moldova · UA Ukraine
AT Austria · CY Cyprus · EE Estonia · GE Georgia · IE Ireland · LT Lithuania · MK F.Y.R. Macedonia · PL Poland · BY Belarus* · SK Slovakia
BE Belgium · CZ Czech Republic · ES Spain · GR Greece · IL Israel · LU Luxembourg · MT Malta · PT Portugal · SE Sweden · TR Turkey
BG Bulgaria · DE Germany · FI Finland* · HR Croatia · IS Iceland* · LV Latvia · NL Netherlands · RO Romania · SI Slovenia · UK United Kingdom

*Connections between these countries are part of NORDUnet (the Nordic regional network)

biscarat@lpsc.in2p3.fr

Connect to the world



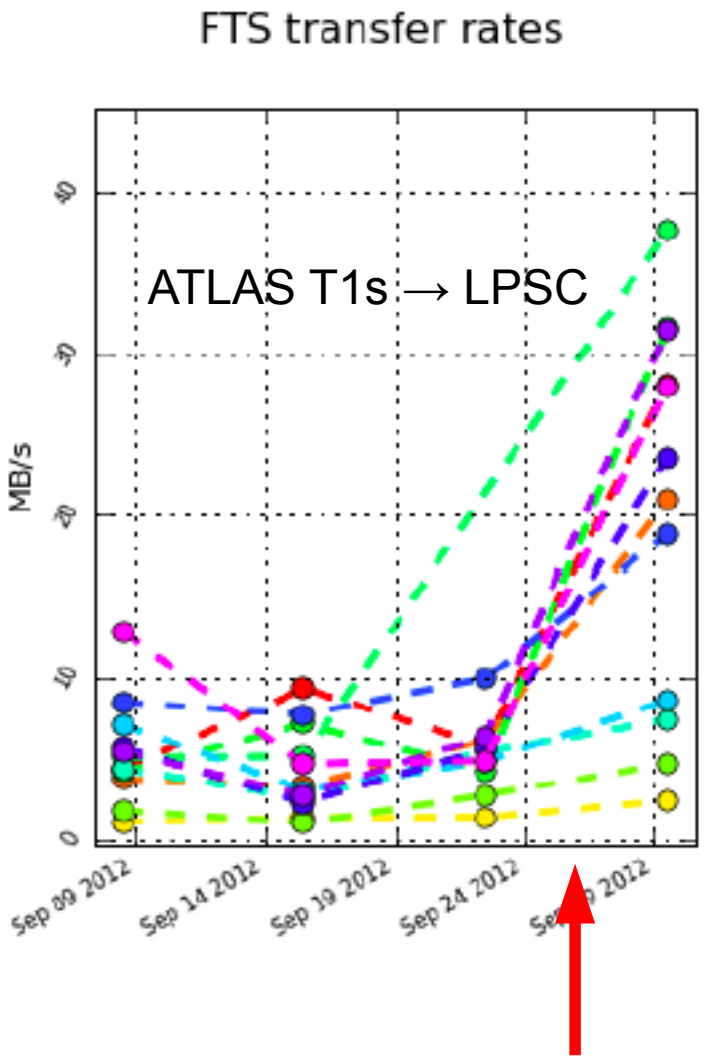
GÉANT
Networks • Services • People
www.geant.org

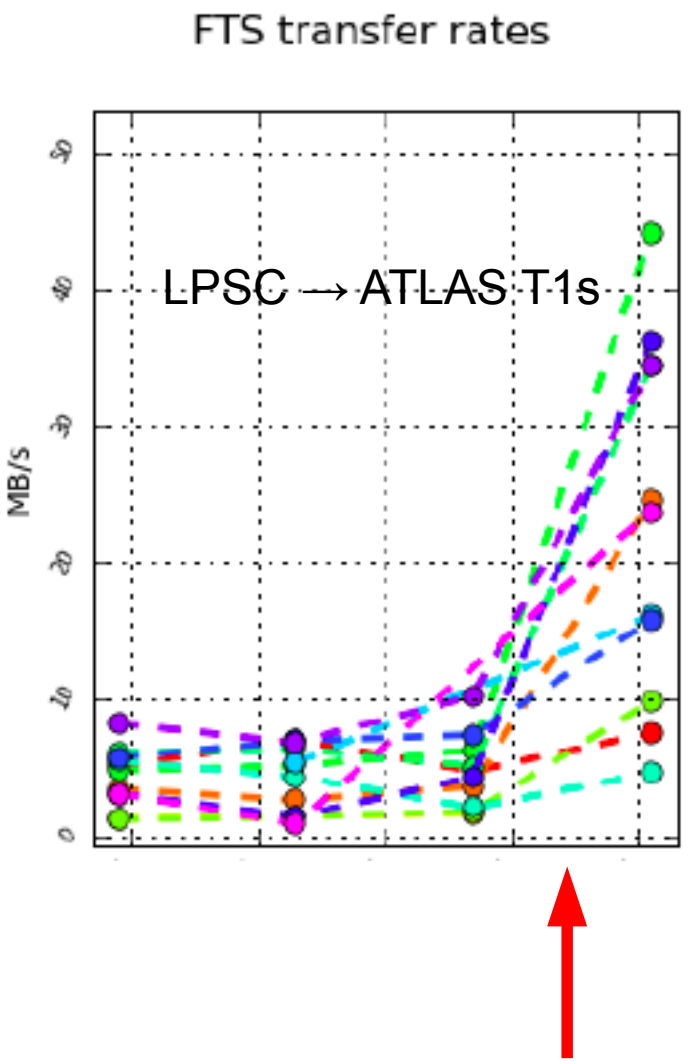
This document is produced as part of the GÉANT Specific Grant Agreement GN4-2 (No. 731122), that has received funding from the European Union's 2020 research and innovation programme under the GÉANT2020 Framework Partnership Agreement (No.653998).
In addition to GN4-2, the following projects have received funding from the European Union: AfricaConnect2, CAREN3, TEIN4 and Asi@Connect (DG DEVCO); EaPConnect and EUMEDCONNECT3 (DG NEAR).
The content of this document is the sole responsibility of GÉANT and can under no circumstances be regarded as reflecting the position of the European Union.

Funded by the European Union

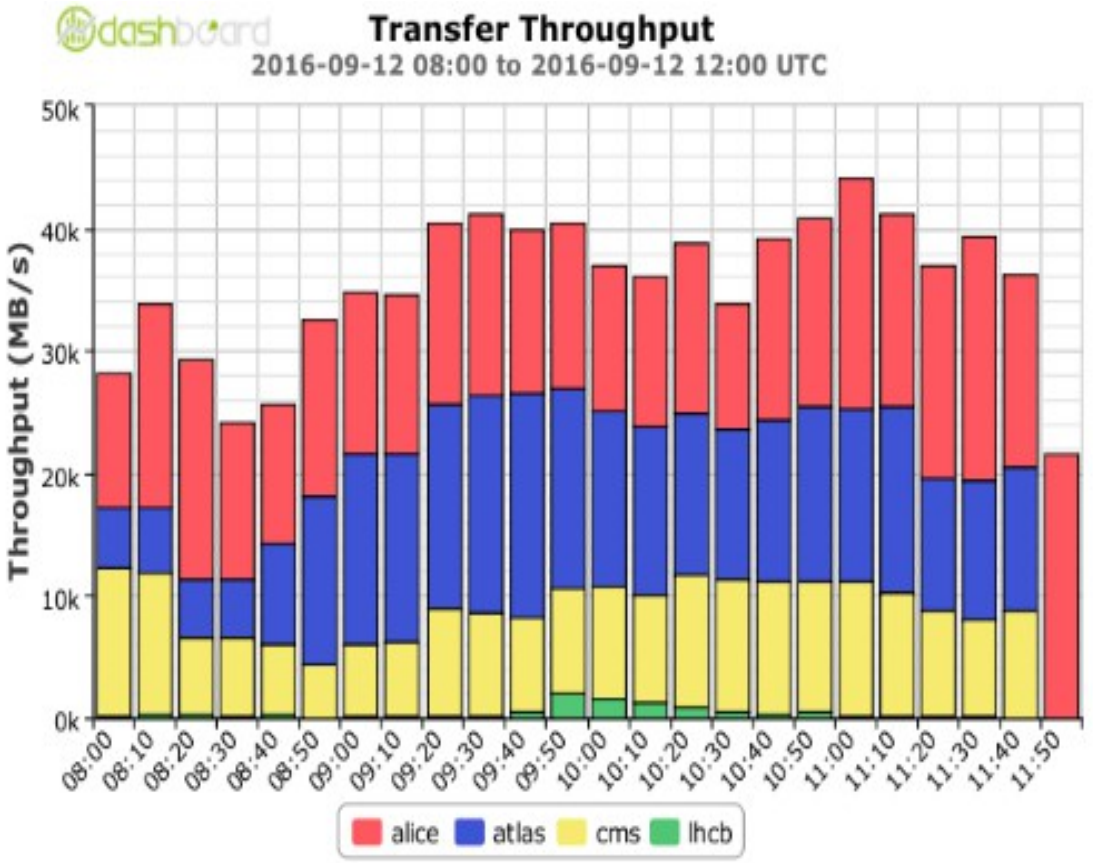
Upgrading the network

LPSC site, a WLCG Tier-2, serves ALICE and ATLAS
Network upgrade from 700Mb/s to 5Gb/s





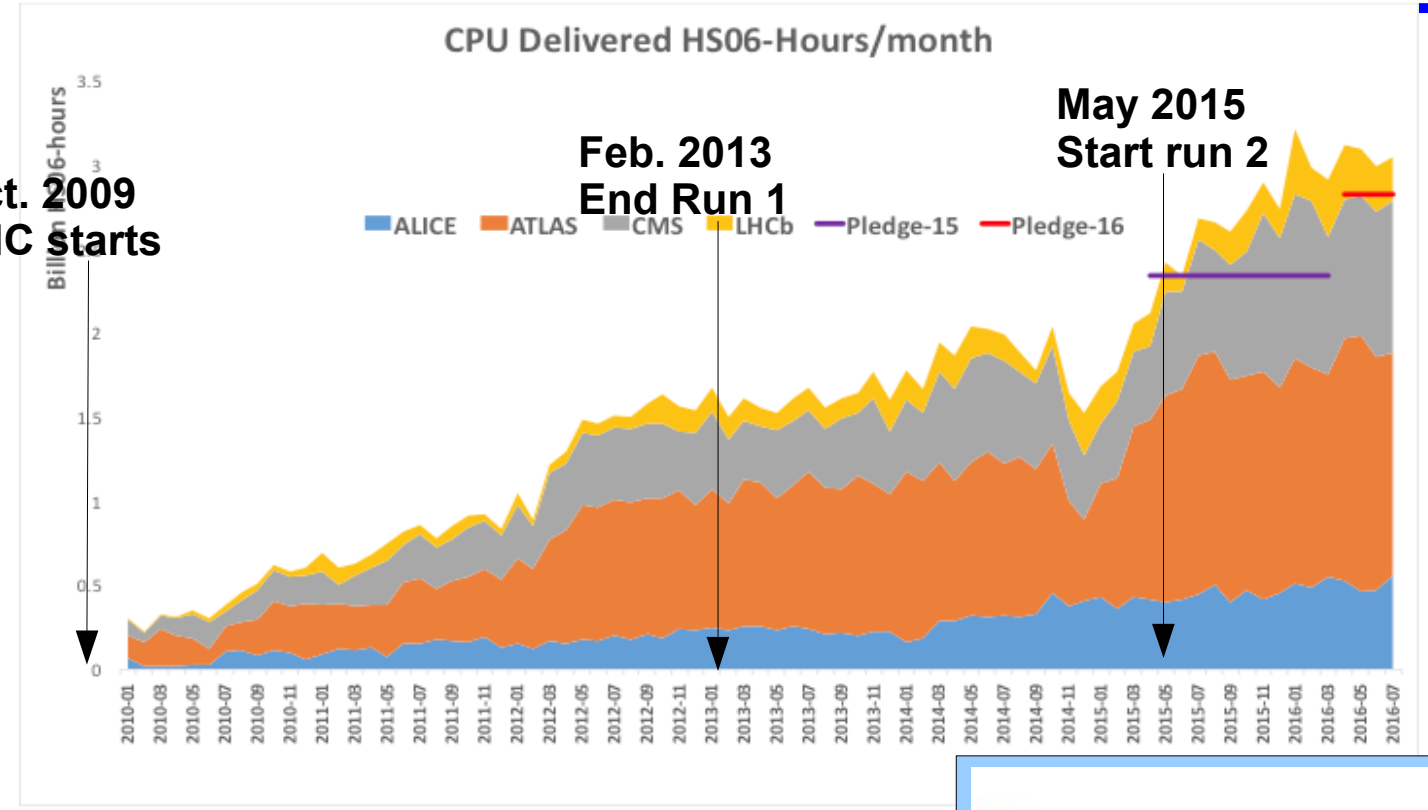
Global transfers



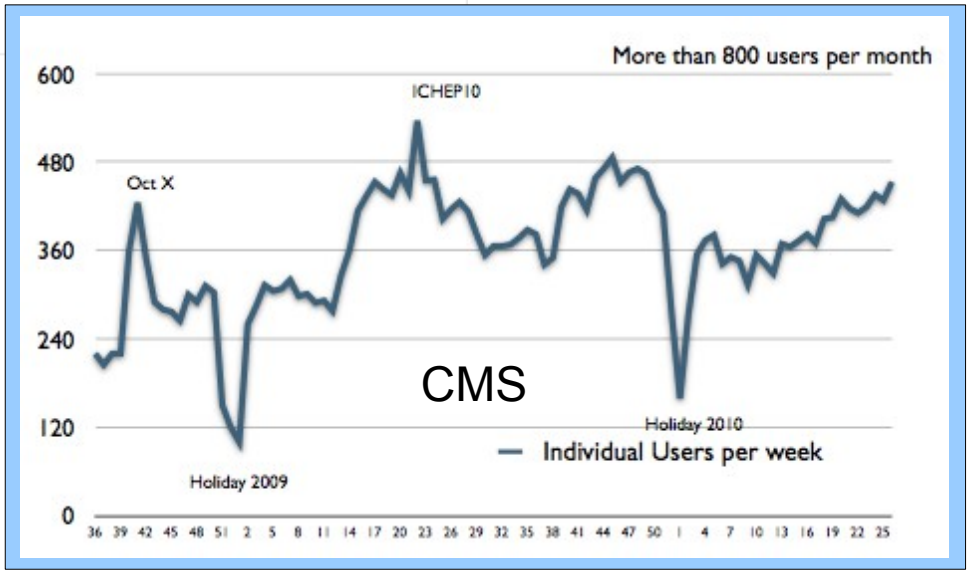
Data transfer rates > 40 GB/s

Regular transfers of > 80 PB/month

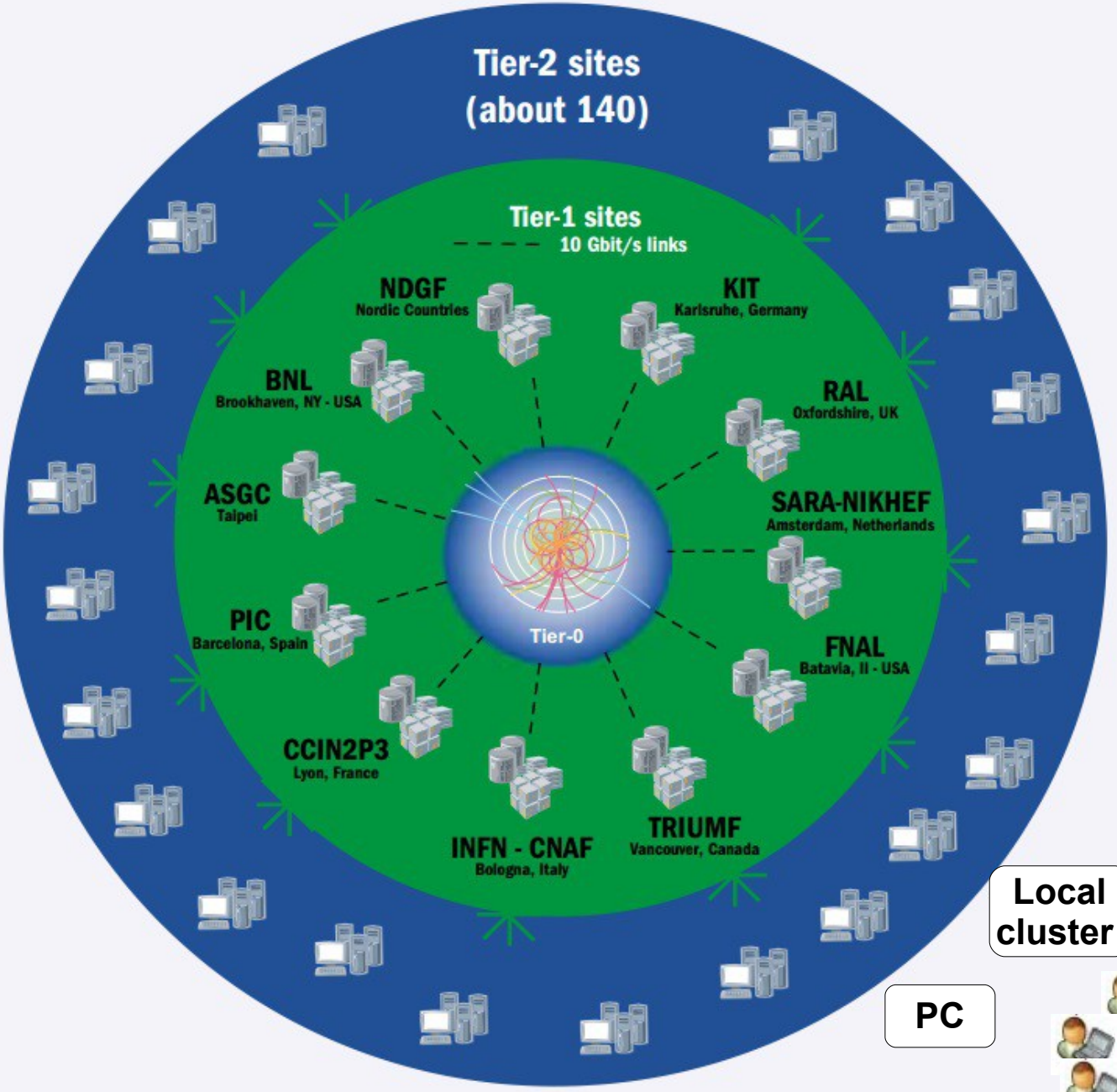
CPU delivered



Ref :
http://accounting.egi.eu/



Sites hierarchy

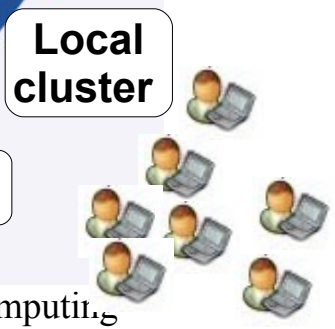


Tier0 (CERN):
- Raw data storage
- Initial reco pass
- Data distribution

Tier-1:
- Permanent storage
- Subsequent reco passes

Tier-2:
- Simulation
- End user analysis

In addition (end user analysis):
- Tier-3
- Local clusters



MoU requirements

T1 centres

Memorandum of Understanding between CERN and the institutions participating in WLCG

(CERN-C-RRB-2005-1/ Rev. April 2009)

Only an extract !

Service	Maximum delay in responding to operational problems			Average availability[5] measured on an annual basis	
	Service interruption	Degradation of the capacity of the service by more than 50%	Degradation of the capacity of the service by more than 20%	During accelerator operation	At all other times
Acceptance of data from the Tier-0 Centre during accelerator operation	12 hours	12 hours	24 hours	99%	n/a
Networking service to the Tier-0 Centre during accelerator operation	12 hours	24 hours	48 hours	98%	n/a
Data-intensive analysis services, including networking to Tier-0, Tier-1 Centres outwith accelerator operation	24 hours	48 hours	48 hours	n/a	98%
All other services[6] – prime service hours[9]	2 hour	2 hour	4 hours	98%	98%
All other services[6] – outwith prime service hours[9]	24 hours	48 hours	48 hours	97%	97%

The response times in the above table refer only to the maximum delay before action is taken to repair the problem. The mean time to repair is also a very important factor that is only covered in this table indirectly through the availability targets. All of these parameters will require an adequate level of staffing of the services, including on-call coverage outside of prime shift.

MoU requirements

T2 centres

- Less constraints
  - Receive no data from detectors
- Availability > 95%

Availability: time site is available / total time

Reliability: time site is available / (total time – scheduled downtime)

Test suit per experiment with monthly report

Tier-2 Availability and Reliability Report

ATLAS

February 2014

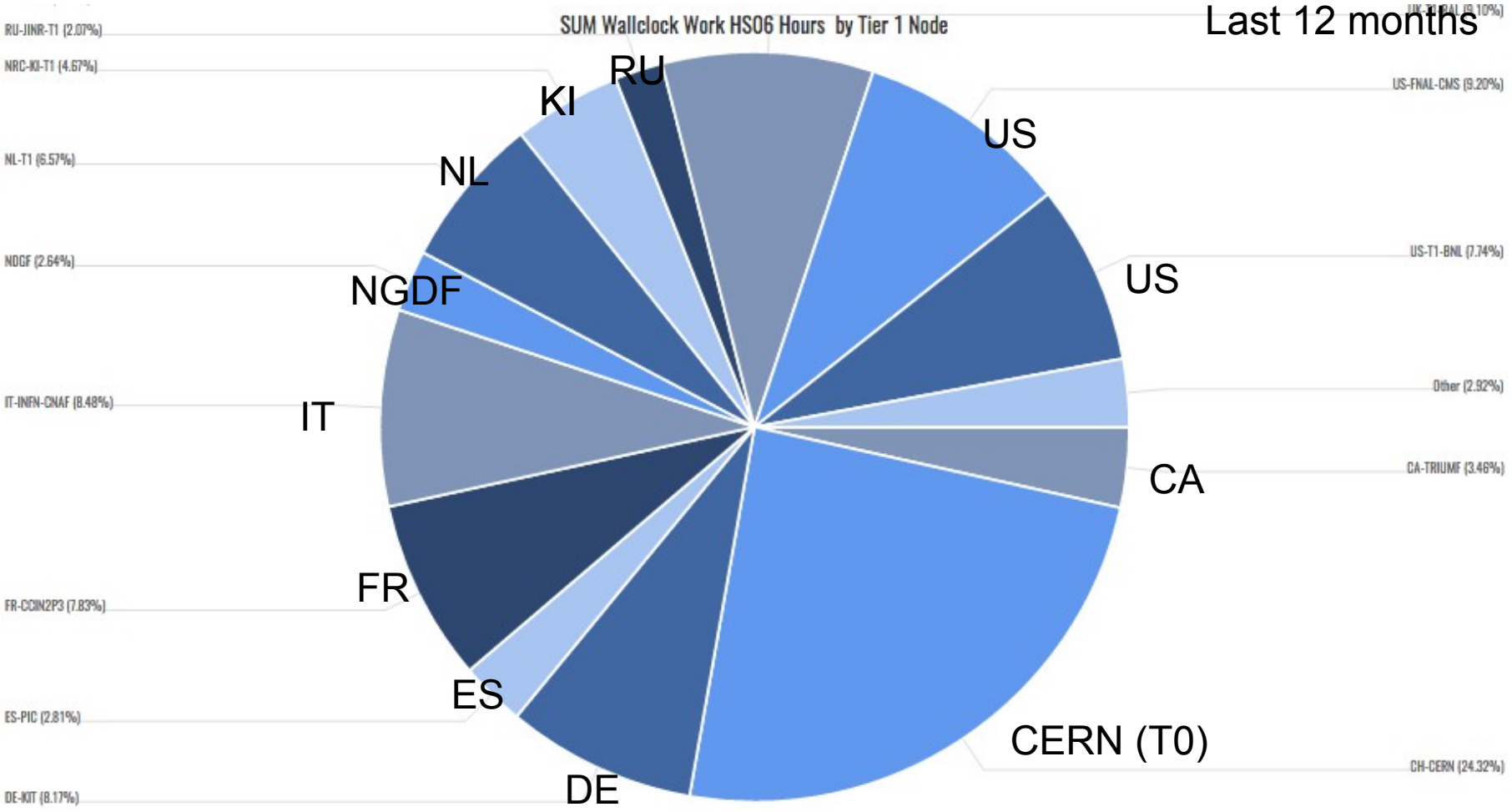
Federation Details

Colour coding : N/A | <30% | <60% | <90% | >=90%

Availability Algorithm: (OSG-CE + CE + CREAM-CE) * (SRMv2 + OSG-SRMv2)

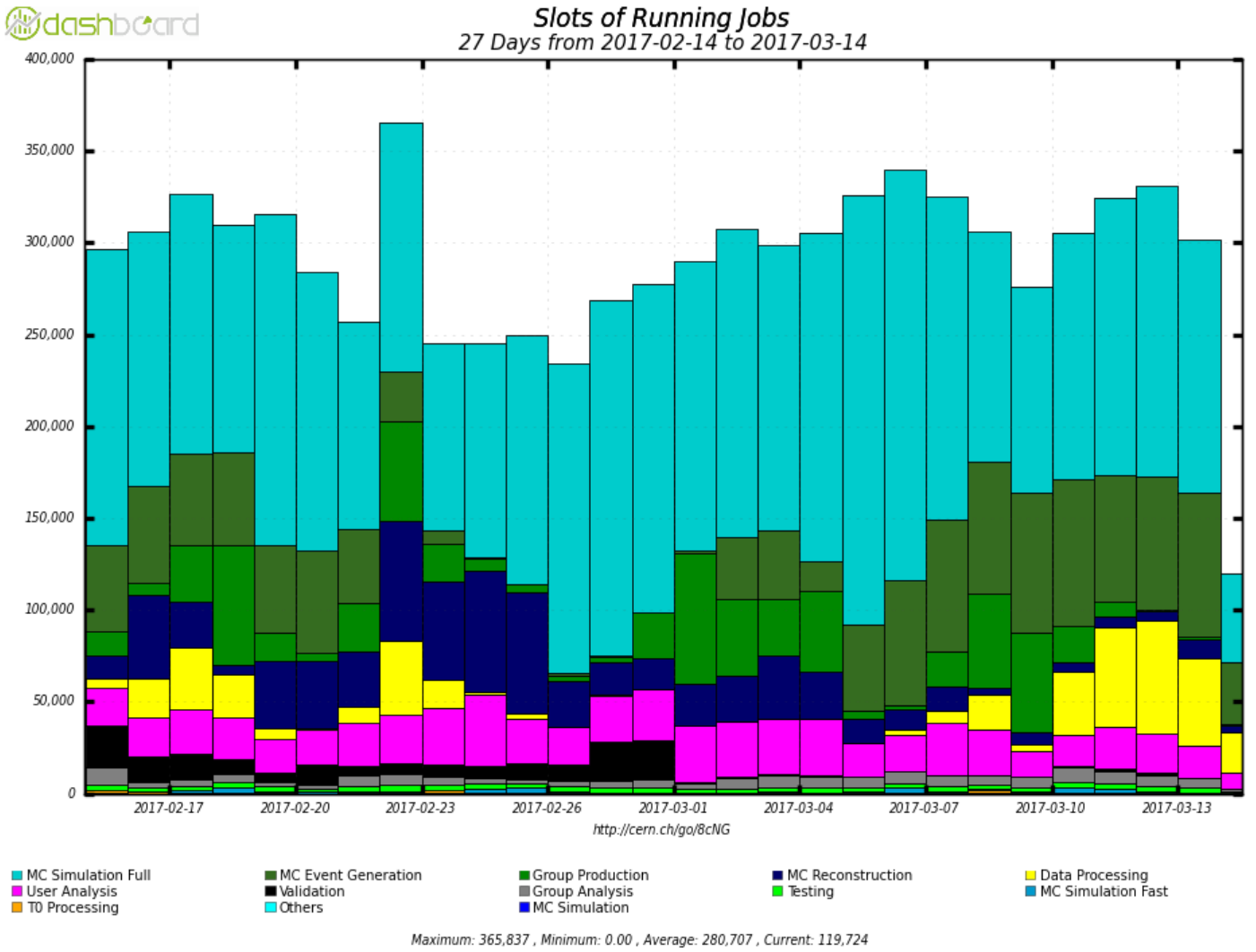
Federation	Site	Phy-CPU	Log-CPU	HS06	Availability	Reliability	Unknown	Availability History Nov 2013	Dec 2013	Jan 2014
FR-IN2P3-LPSC										
	IN2P3-LPSC	136	660	5399	99 %	99 %	3 %	93 %	100 %	94 %

Tier-1

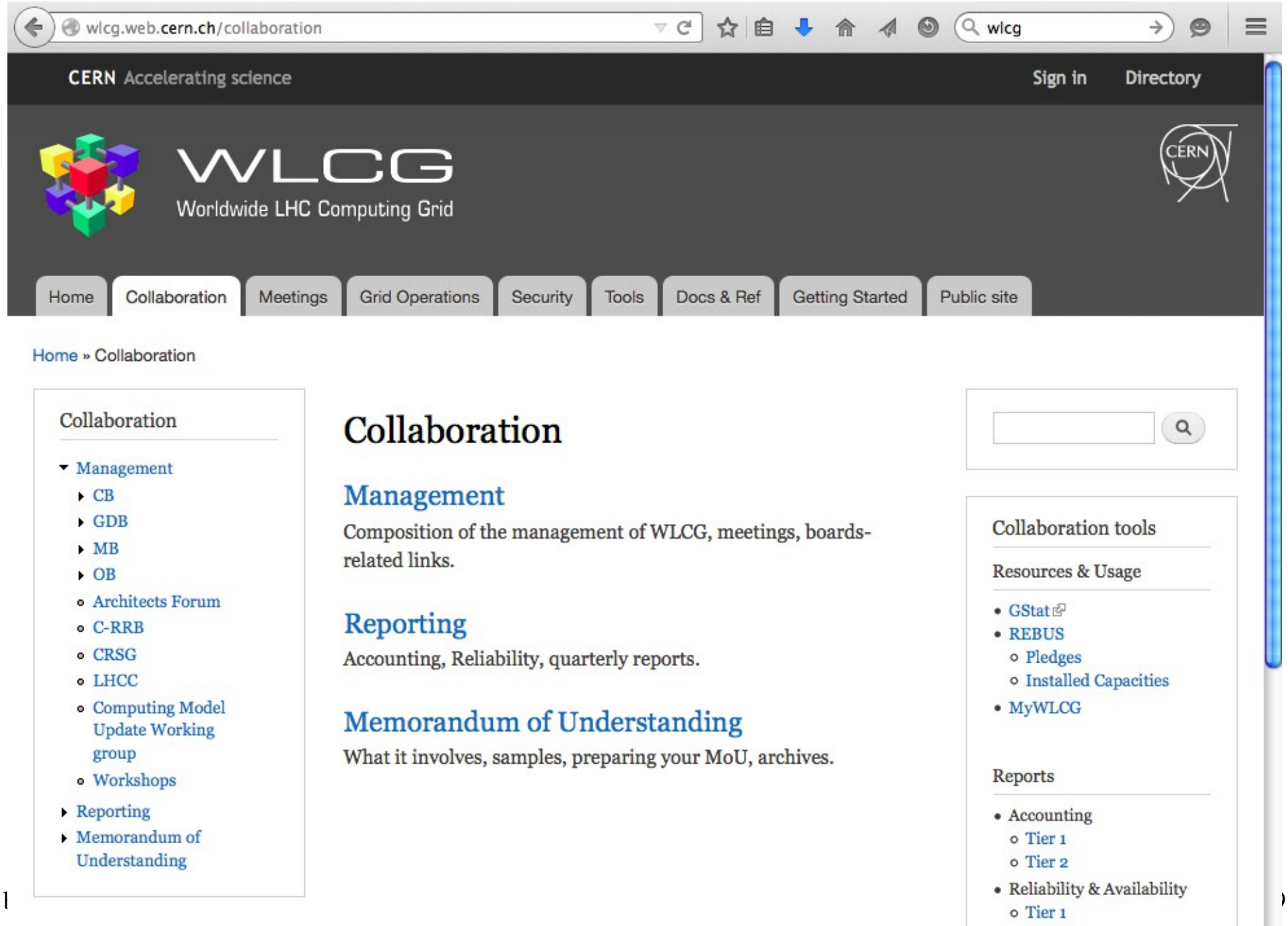

SUM Wallclock Work HS06 Hours by Tier 1 Node
Last 12 months
RU-JINR-T1 (2.07%)
NRC-KI-T1 (4.67%)
NL-T1 (6.57%)
NDGF (2.64%)
IT-INFN-CNAF (8.48%)
FR-CCIN2P3 (7.83%)
ES-PIC (2.81%)
DE-KIT (8.17%)
US-FNAL-CMS (9.20%)
US-T1-BNL (7.74%)
Other (2.92%)
CA-TRIUMF (3.46%)
CH-CERN (24.32%)
RU
KI
NL
NGDF
IT
FR
ES
DE
US
US
CA
CERN (T0)

ATLAS alone

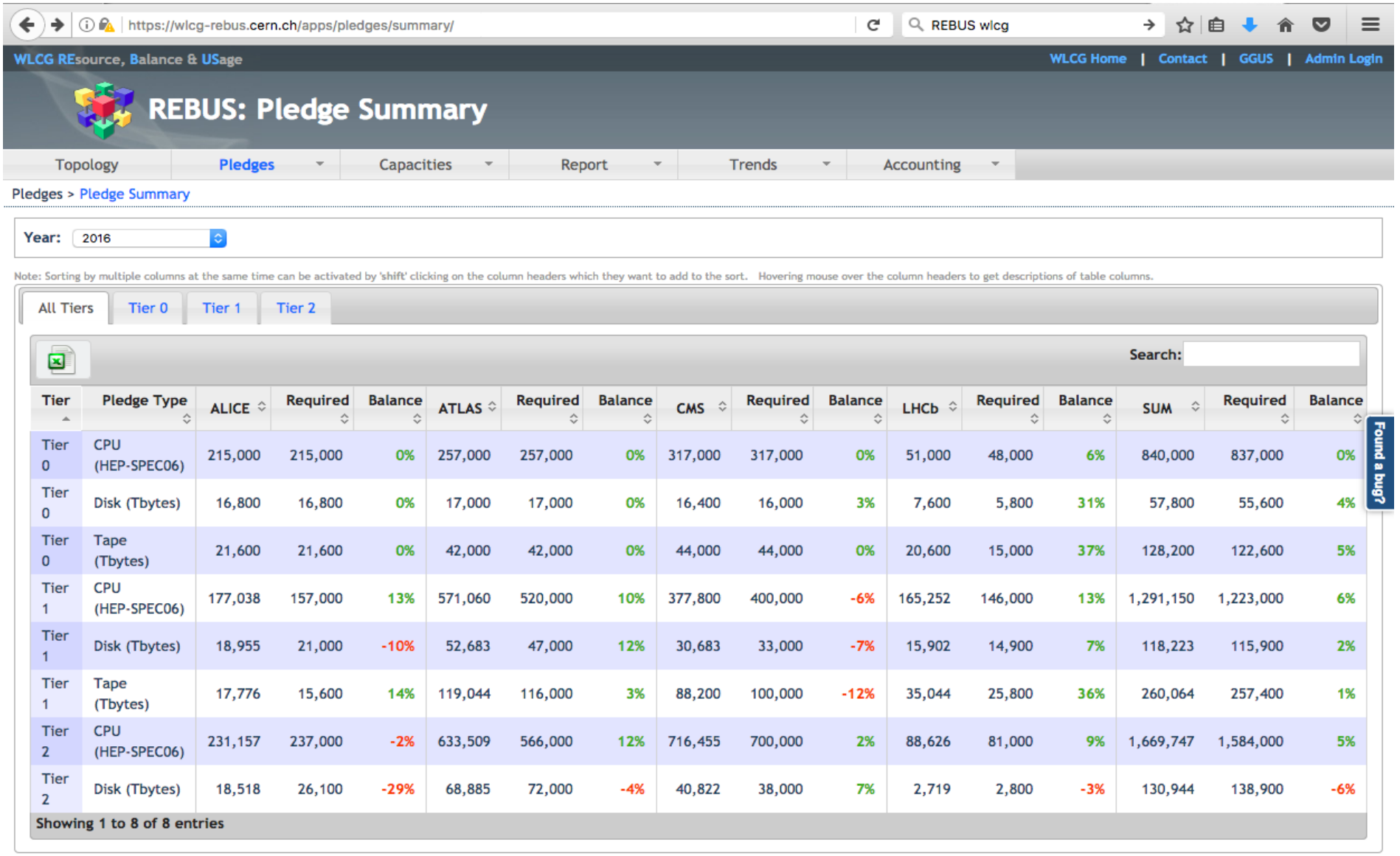
Average/ day:
1 Million job completed



WLCG Collaboration



Pledges



https://wlcg-rebus.cern.ch/apps/pledges/summary/

REBUS wlcg

WLCG REsource, Balance & USage

WLCG Home | Contact | GGUS | Admin Login

REBUS: Pledge Summary

Topology | Pledges | Capacities | Report | Trends | Accounting

Pledges > Pledge Summary

Year: 2016

Note: Sorting by multiple columns at the same time can be activated by 'shift' clicking on the column headers which they want to add to the sort. Hovering mouse over the column headers to get descriptions of table columns.

All Tiers | Tier 0 | Tier 1 | Tier 2

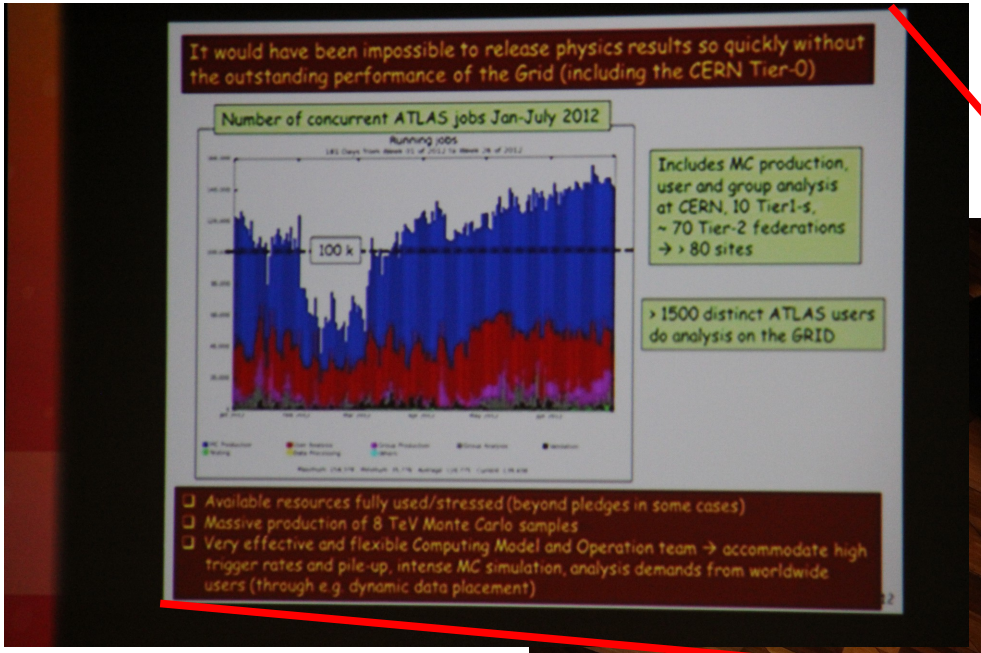
Search:

Tier	Pledge Type	ALICE	Required	Balance	ATLAS	Required	Balance	CMS	Required	Balance	LHCb	Required	Balance	SUM	Required	Balance
Tier 0	CPU (HEP-SPEC06)	215,000	215,000	0%	257,000	257,000	0%	317,000	317,000	0%	51,000	48,000	6%	840,000	837,000	0%
Tier 0	Disk (Tbytes)	16,800	16,800	0%	17,000	17,000	0%	16,400	16,000	3%	7,600	5,800	31%	57,800	55,600	4%
Tier 0	Tape (Tbytes)	21,600	21,600	0%	42,000	42,000	0%	44,000	44,000	0%	20,600	15,000	37%	128,200	122,600	5%
Tier 1	CPU (HEP-SPEC06)	177,038	157,000	13%	571,060	520,000	10%	377,800	400,000	-6%	165,252	146,000	13%	1,291,150	1,223,000	6%
Tier 1	Disk (Tbytes)	18,955	21,000	-10%	52,683	47,000	12%	30,683	33,000	-7%	15,902	14,900	7%	118,223	115,900	2%
Tier 1	Tape (Tbytes)	17,776	15,600	14%	119,044	116,000	3%	88,200	100,000	-12%	35,044	25,800	36%	260,064	257,400	1%
Tier 2	CPU (HEP-SPEC06)	231,157	237,000	-2%	633,509	566,000	12%	716,455	700,000	2%	88,626	81,000	9%	1,669,747	1,584,000	5%
Tier 2	Disk (Tbytes)	18,518	26,100	-29%	68,885	72,000	-4%	40,822	38,000	7%	2,719	2,800	-3%	130,944	138,900	-6%

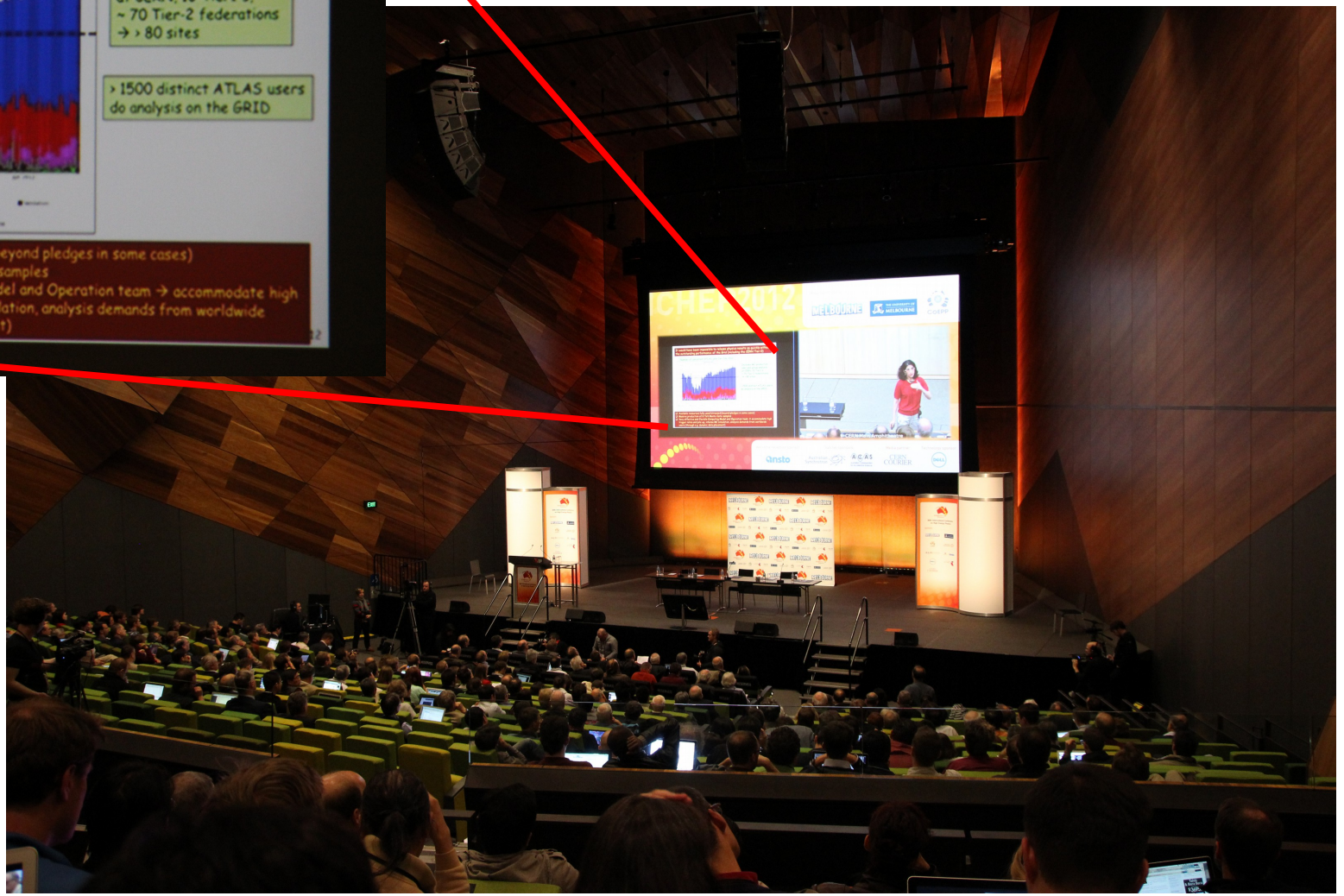
Showing 1 to 8 of 8 entries

Found a bug?

“Computing enables physics”



Photography: C. Biscarat



CERN seminar, July 4th 2012, retransmitted at ICHEP (Melbourne)


Running jobs: 236092
Transfer rate: 11.41 GiB/sec
rapher
/BKG
NGA, GEBCO

Other grids

European Grid Initiative

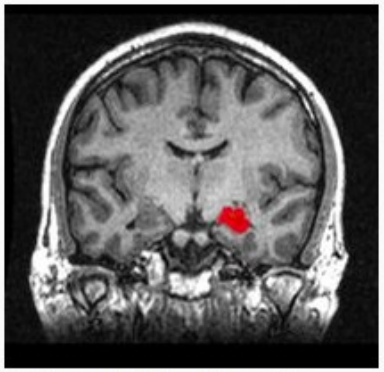
- The WLCG shares the infrastructures with EGI
  - Organised in National Grid Initiative

- EGI project (and ancestors)
  - Build a large scale production grid
  - Secured and robust
  - Promote international collaboration
  - For sciences and technologies

- ~ 300 different user communities
- Large spectra of scientific domains
- Tail of sciences

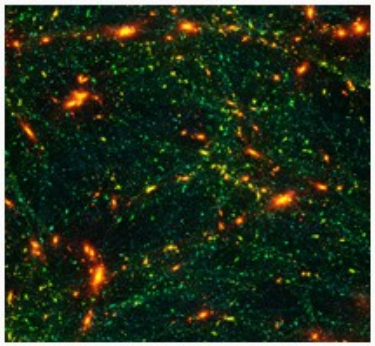
EGI web site: http://www.egi.eu/

Many sciences



MRI scan with location of the hippocampus
Image: Amber Rieder, Jenna Traynor (wikicommons)

Medical and Health Sciences
Processing of thousands of MRI scans from patients with Alzheimer's disease

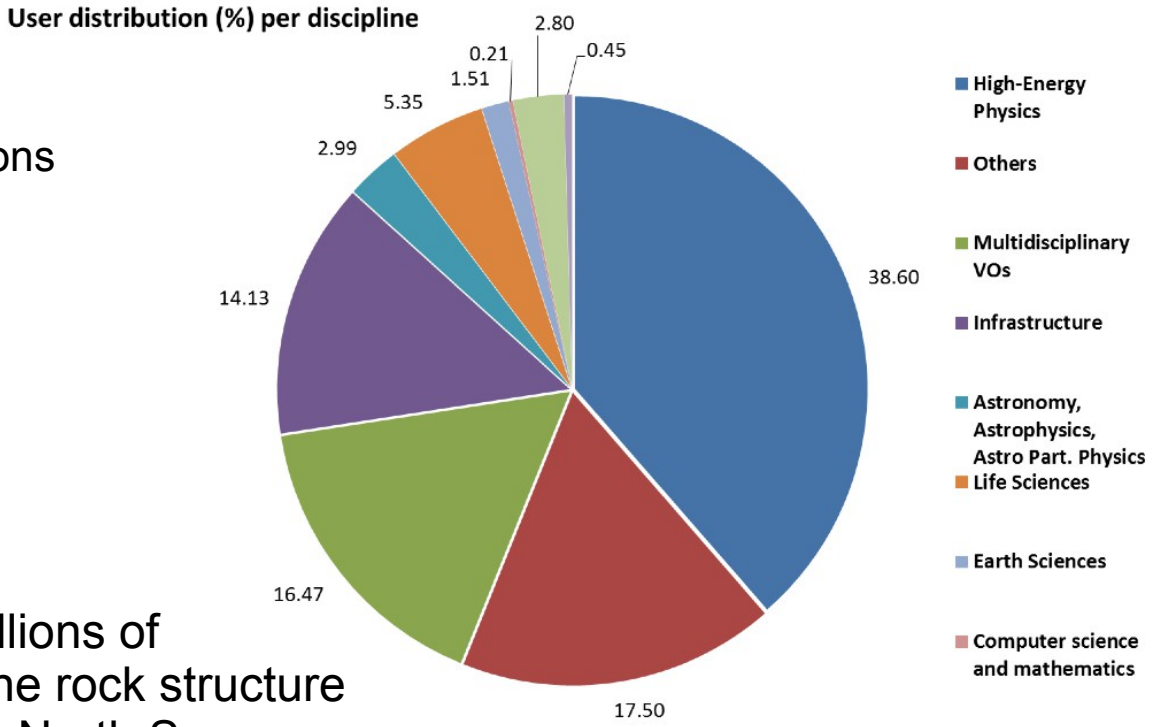


Seventy million elements of a cosmological N-body simulation using VisIVO and Splotch.

Physical Sciences
Creation of 3D visualisations of astronomical data on unprecedented scales.

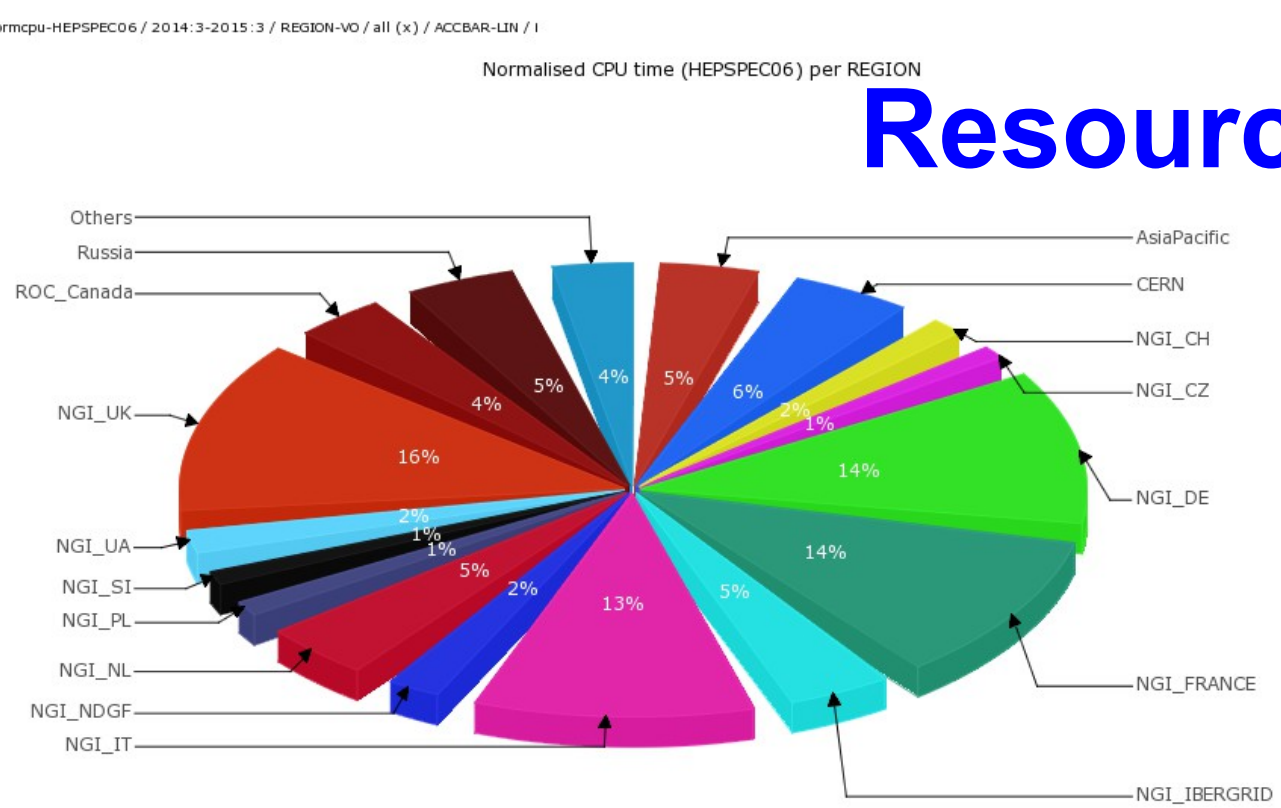
Oil exploration in the North Sea depends on a good knowledge of the underground rock structure. Grid computing helps scientists to make sense of all the seismic data.

Natural sciences
Correlate data from millions of calculations to unveil the rock structure of an oil field under the North Sea.



From ISGC 2013

Resource consumption



Normalised CPU time
March '14- March '15
- Per region
- Per VO

https://accounting.egi.eu/

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A few user example

Pierre Auger Observatory
studying the universe's highest energy particles

ilc international linear collider

cta
cherenkov telescope array

An observatory for ground-based gamma-ray astronomy

ATLAS EXPERIMENT

DØ

CDF II

H.E.S.S.
High Energy Stereoscopic System

LHCb

IceCube
SOUTH POLE NEUTRINO OBSERVATORY

Compact Muon Solenoid
experiment at CERN's LHC

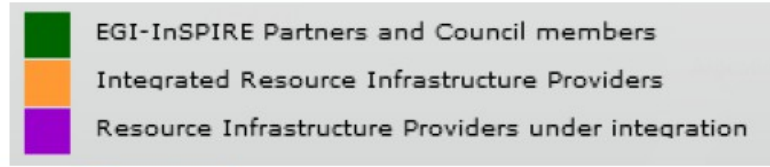
CMS

ALICE

T2K

EGI partners and resource providers

- The most extended grid infrastructure, 35 countries.

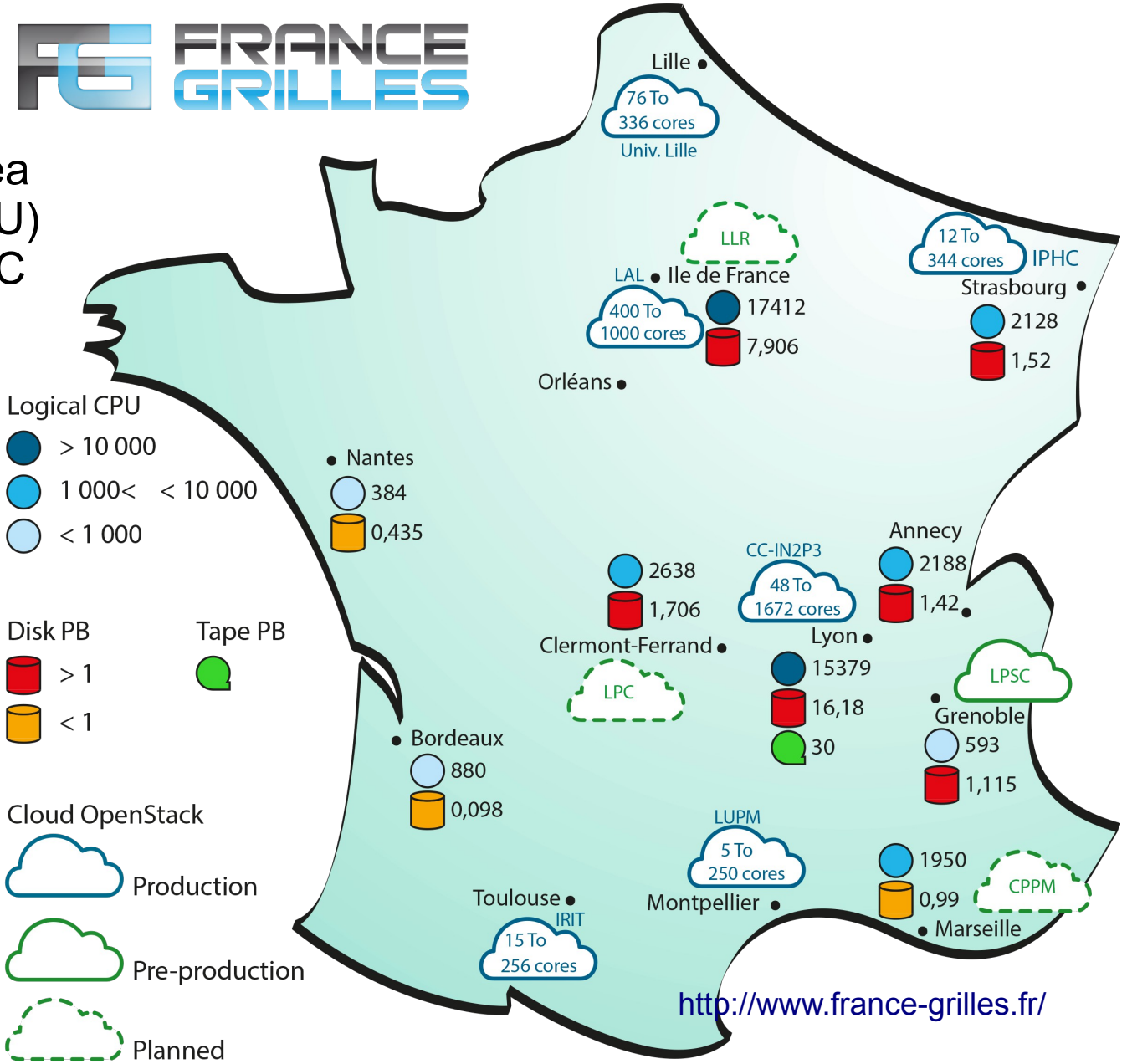


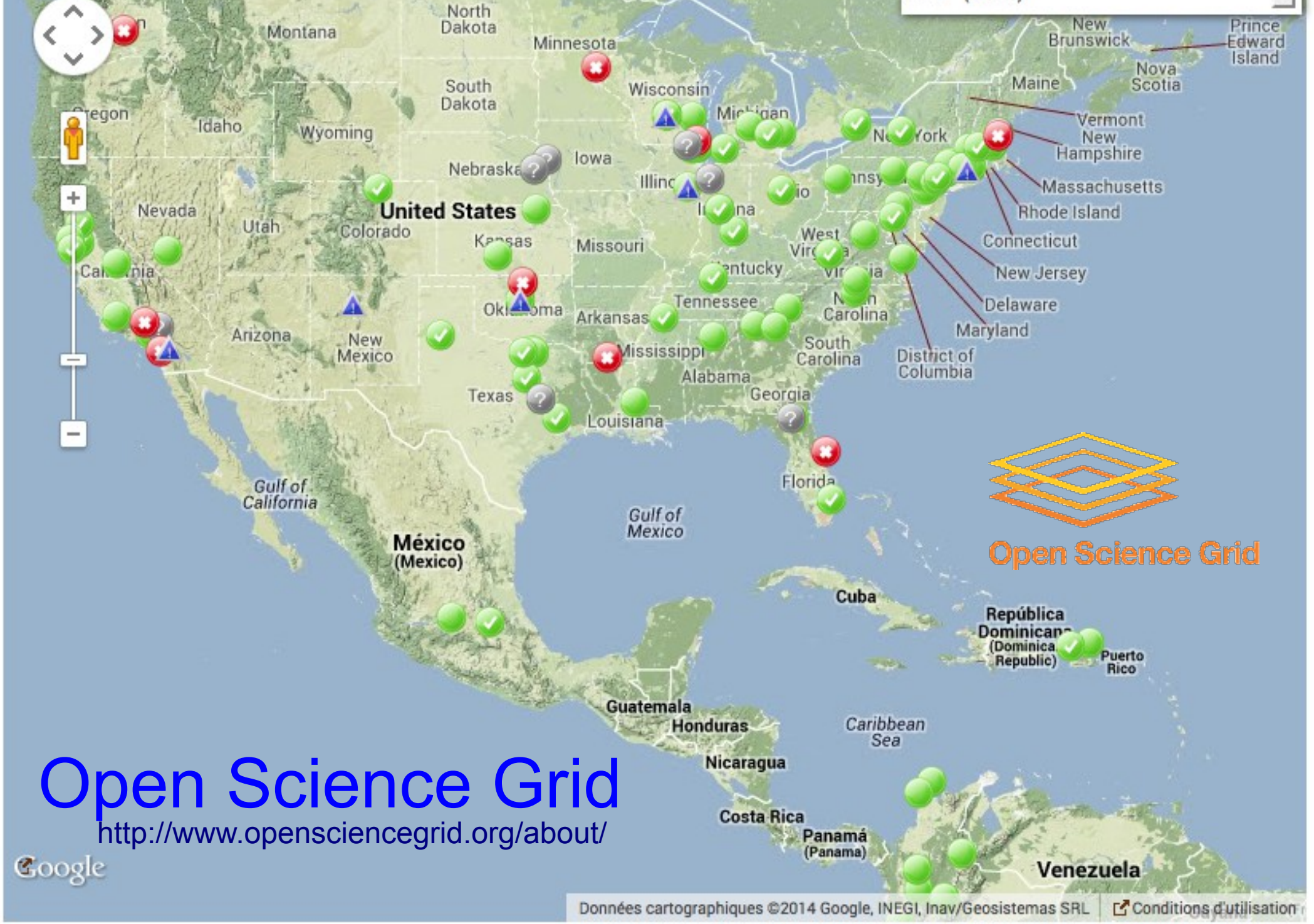
Avril 2012

Open Science Grid (OSG)
Own operations tools and procedures, compatible policies

French NGI

- Open to any scientific area
- 18 sites (storage and CPU)
  - Half of them serves LHC




Open Science Grid
http://www.opensciencegrid.org/about/
Open Science Grid
United States
México
(Mexico)
Cuba
Guatemala
Honduras
Nicaragua
Costa Rica
Panamá
(Panama)
Venezuela
Gulf of California
Gulf of Mexico
Caribbean Sea
Montana
North Dakota
Minnesota
South Dakota
Wisconsin
Maine
Vermont
New Hampshire
Massachusetts
Rhode Island
Connecticut
New Jersey
Delaware
Maryland
District of Columbia
Nova Scotia
Prince Edward Island
New Brunswick
Oregon
Idaho
Wyoming
Nebraska
Iowa
Nevada
Utah
Colorado
Kansas
Missouri
Arizona
New Mexico
Arkansas
Tennessee
Mississippi
Alabama
Georgia
South Carolina
Florida
Texas
Louisiana
Puerto Rico
Google
Données cartographiques ©2014 Google, INEGI, Inav/Geosistemas SRL
Conditions d'utilisation

Many kinds of grids

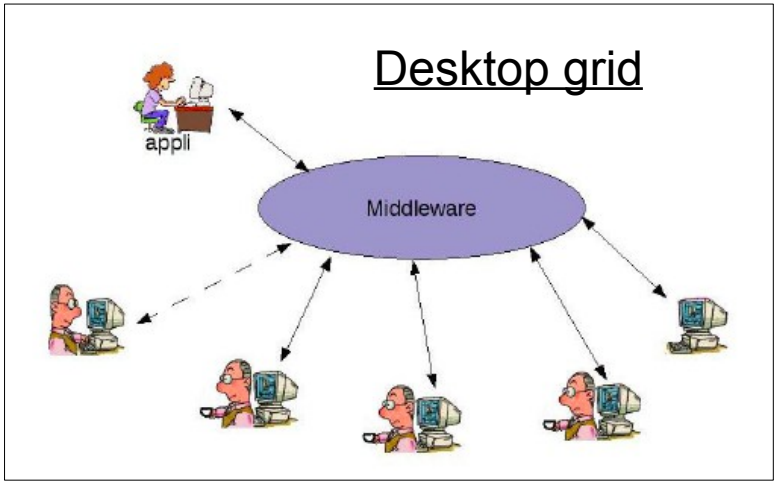
They might have different goals:

- Production grid
  - Shared resources for a common goal, known users
  - Shared “interfacing” software (middleware)
- Development grid (Grid5000 in France)
  - Shared resources for a common goal, known users
  - Testing grid software
- Volunteer grid (BOINC)
  - Resources given to a project with unknown users

They may differ in heterogeneity:

- Desktop grid (BOINC,...)
- Service grid (EGI, OSG,...)
- HPC grid (DEISA, TeraGrid, CNGrid...)

They may be interoperable (EGI+OSG)

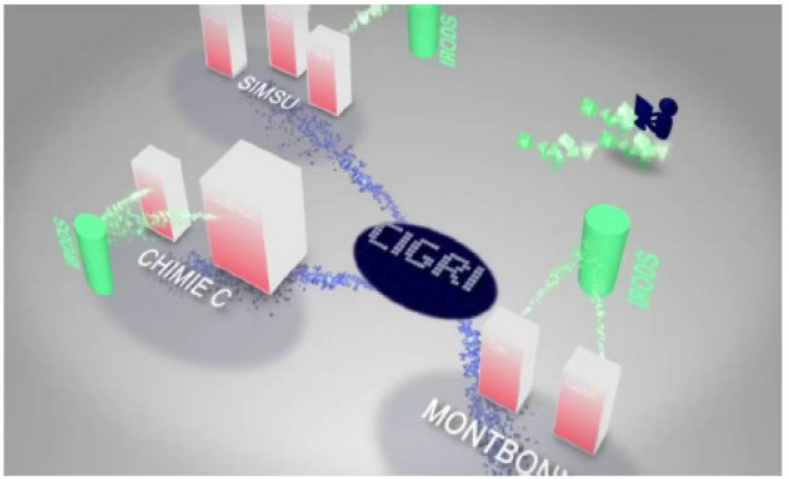


Many kinds of grids

Geographically:
- International grid
- Regional grid
-

In term of science field:
- Thematic grid
- Multidisciplinary grid

GRISBI: bioinformatic (France)

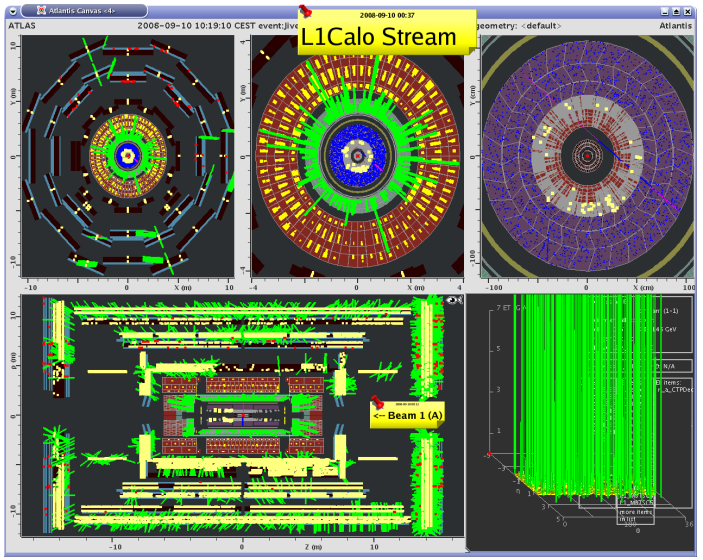


CIGRI: grid on top of T2 HPC clusters (Grenoble Universities, INPG, and National research labs) – opportunistic usage

Behind the scenes

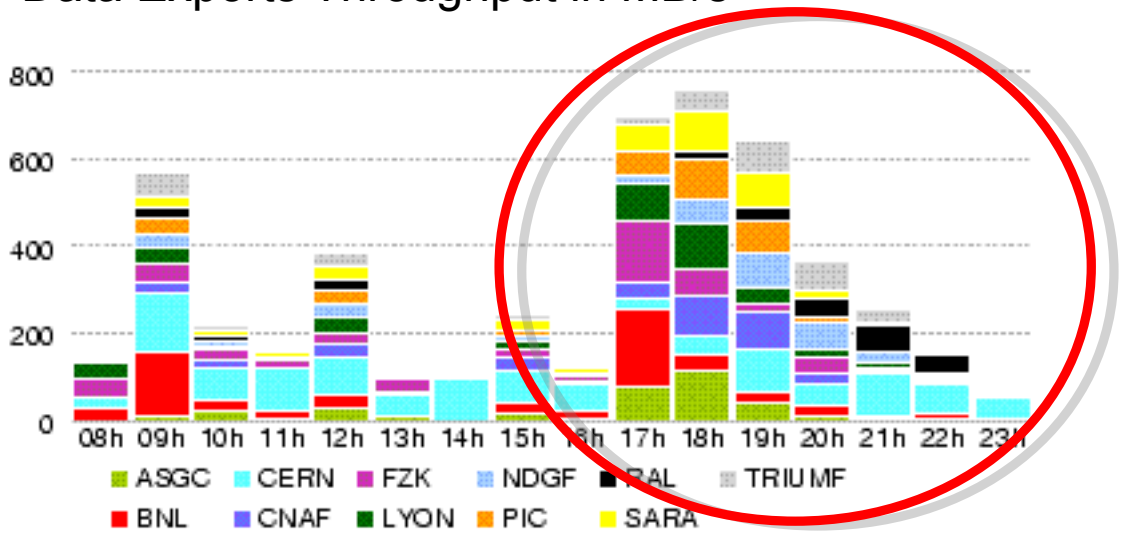
D-day « LHC first beam »

- Sept. 10th 2008

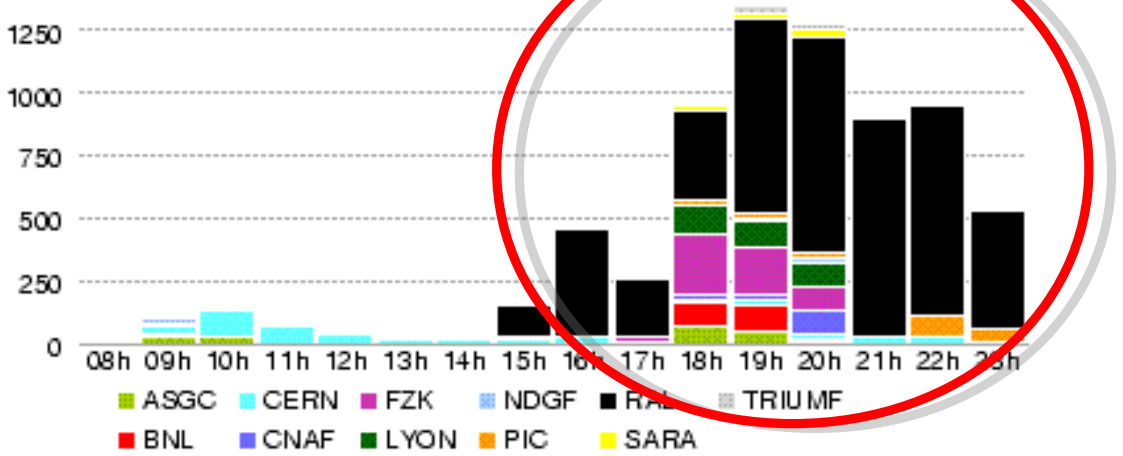


D-day « LHC first beam »

Data Exports Throughput in MB/s



Number of errors



In the Computing control room (2nd floor)

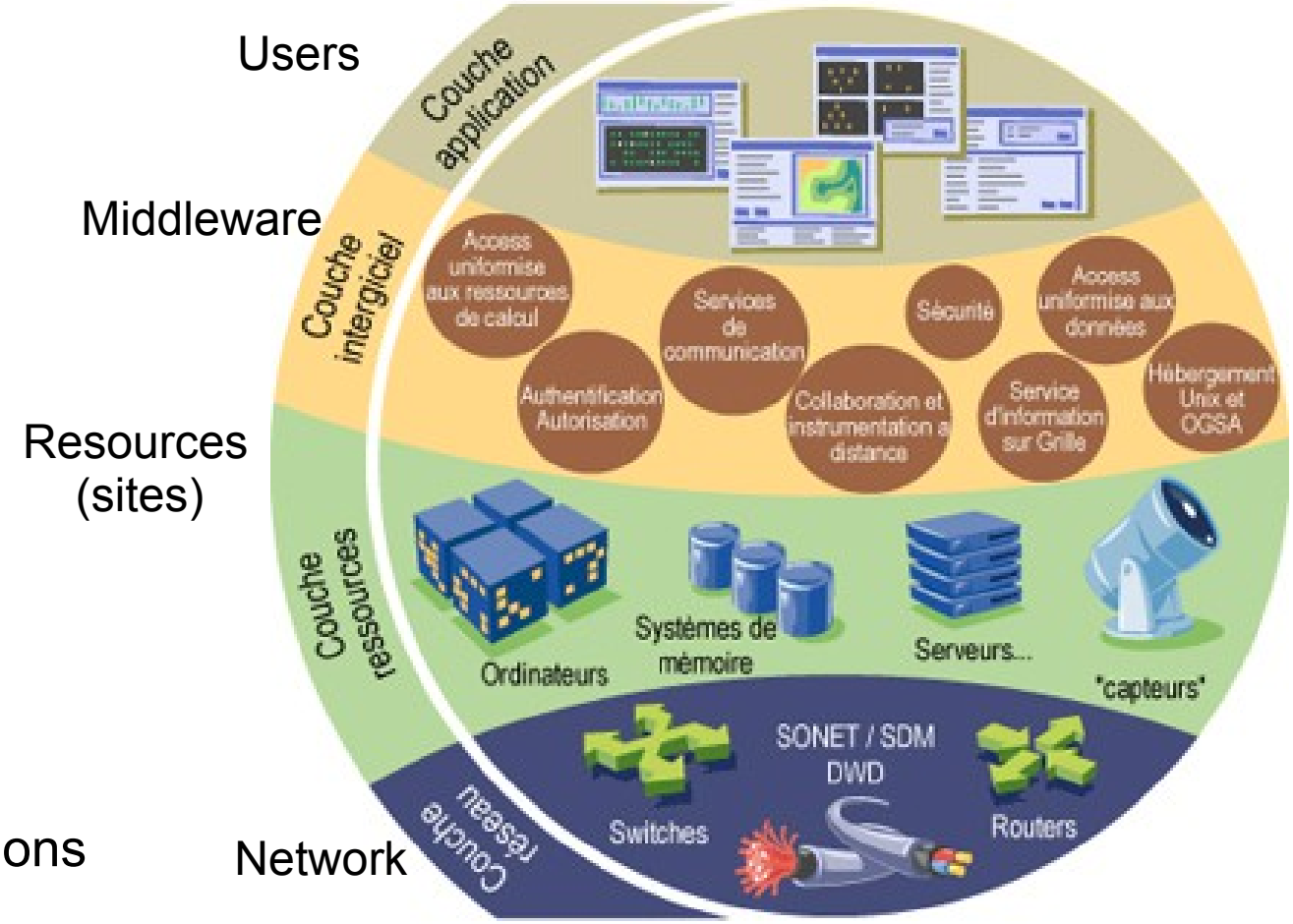
Concurrent access to data on central servers by the end-users

Middleware

- Heterogeneity of the sites
  - Batch systems
  - Storage
  - Operating systems
  - Worker nodes capacity
  - Authentication

Middleware

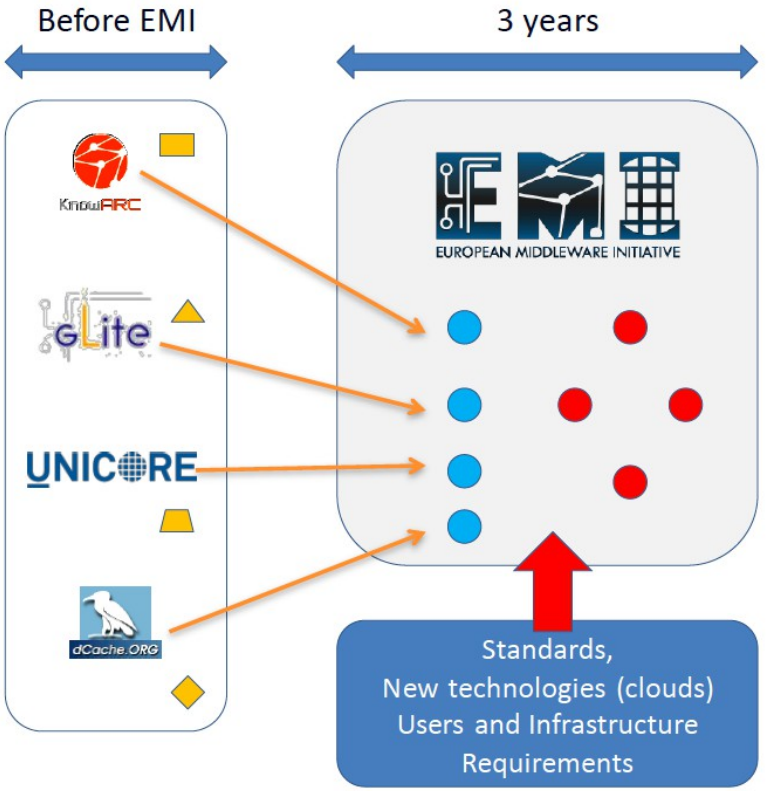
- Software layer
- Hiding and simplifying
  - No local user registration
  - Abstraction of resources
  - Interface to user applications



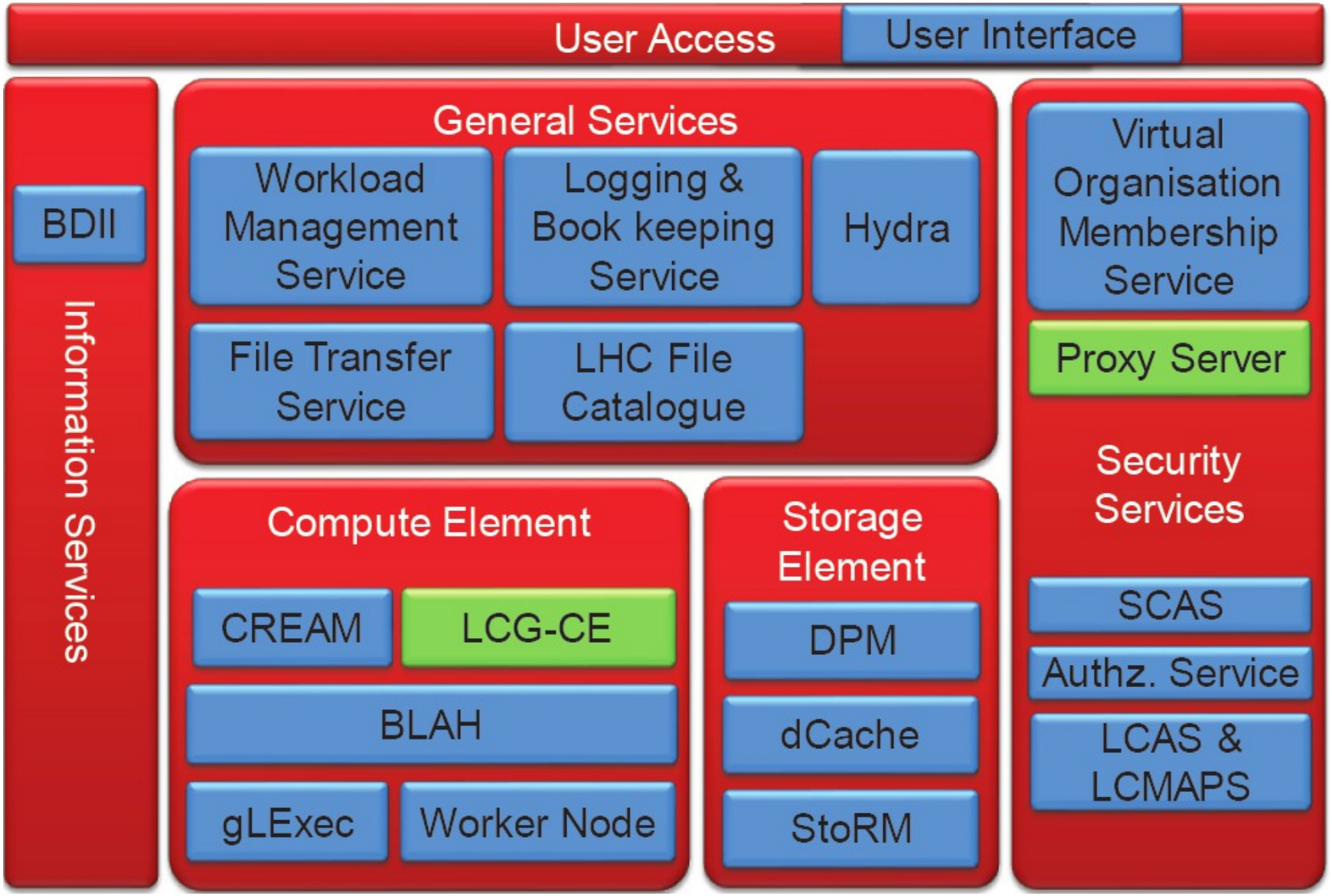
Ref : gridCafe

Towards standardisation

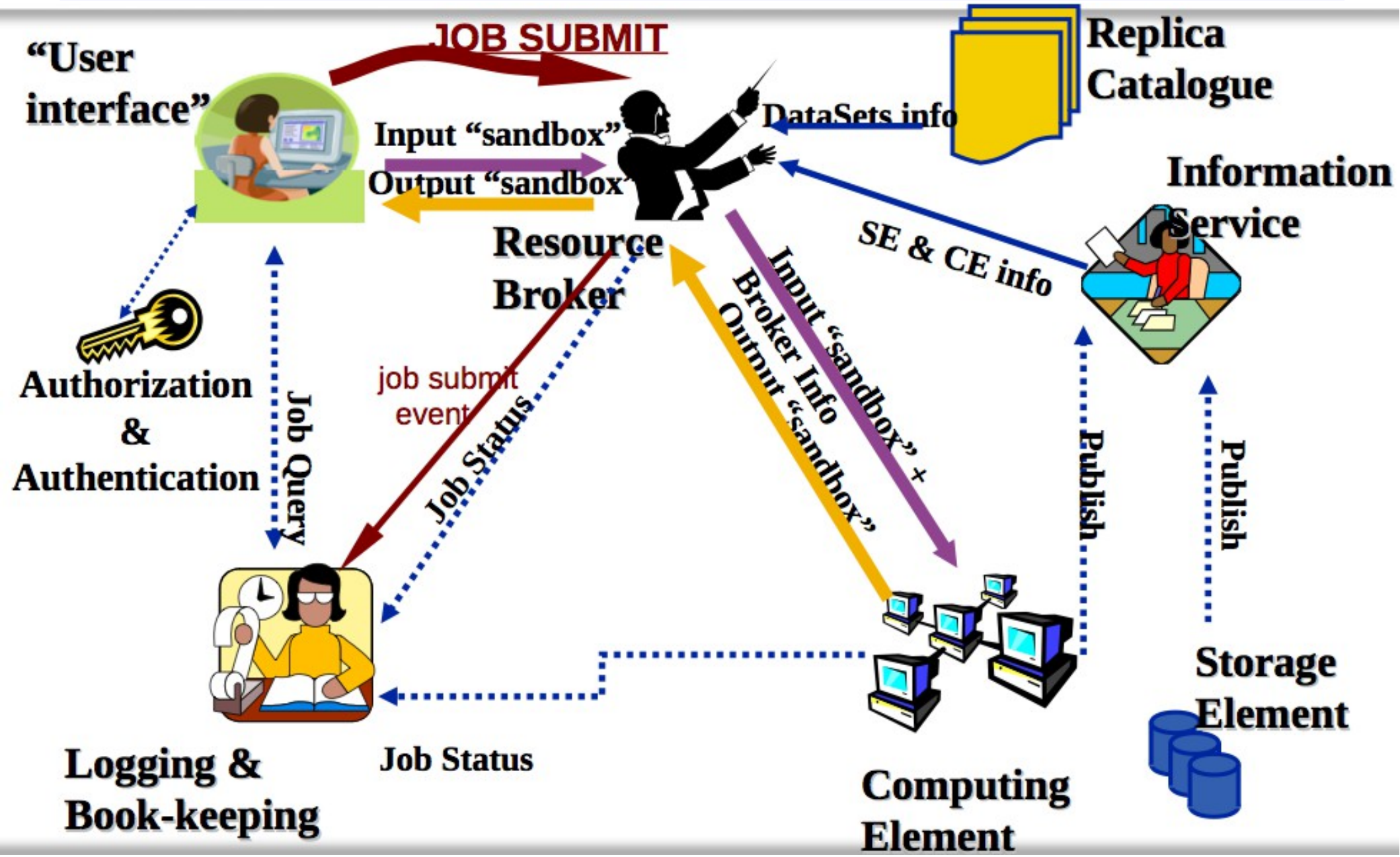
- Origin
  - Idea became popular in 1998 with the book “The Grid” (I. Foster & K. Kesselman)
  - Globus: the first middleware (1998) – evolution to globustoolkit-5
- Now : hundreds of middleware, tentative for standardisation
- In EGI: develop and use of EMI (European Middleware Initiative)



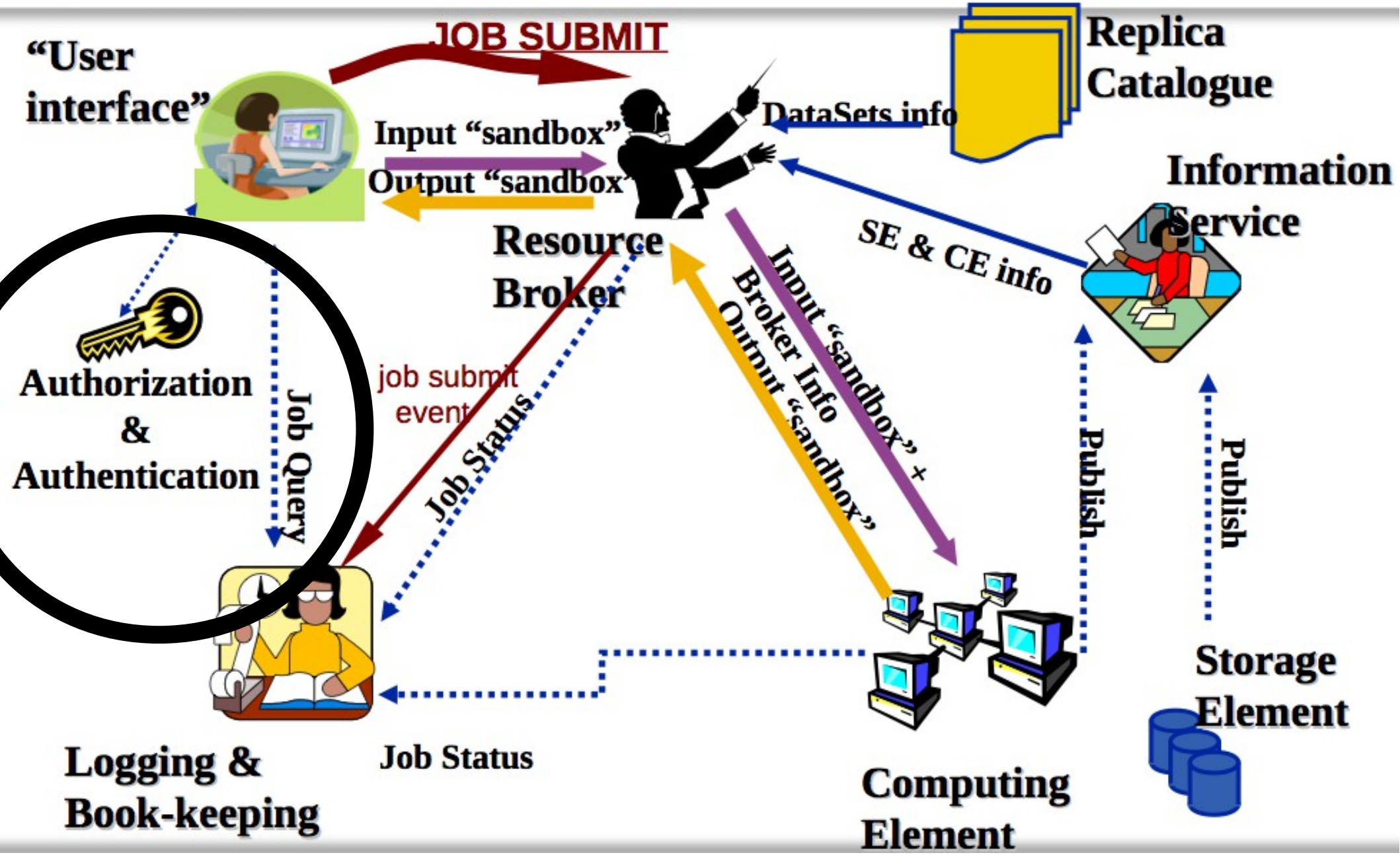
Major EMI services



Putting it all together



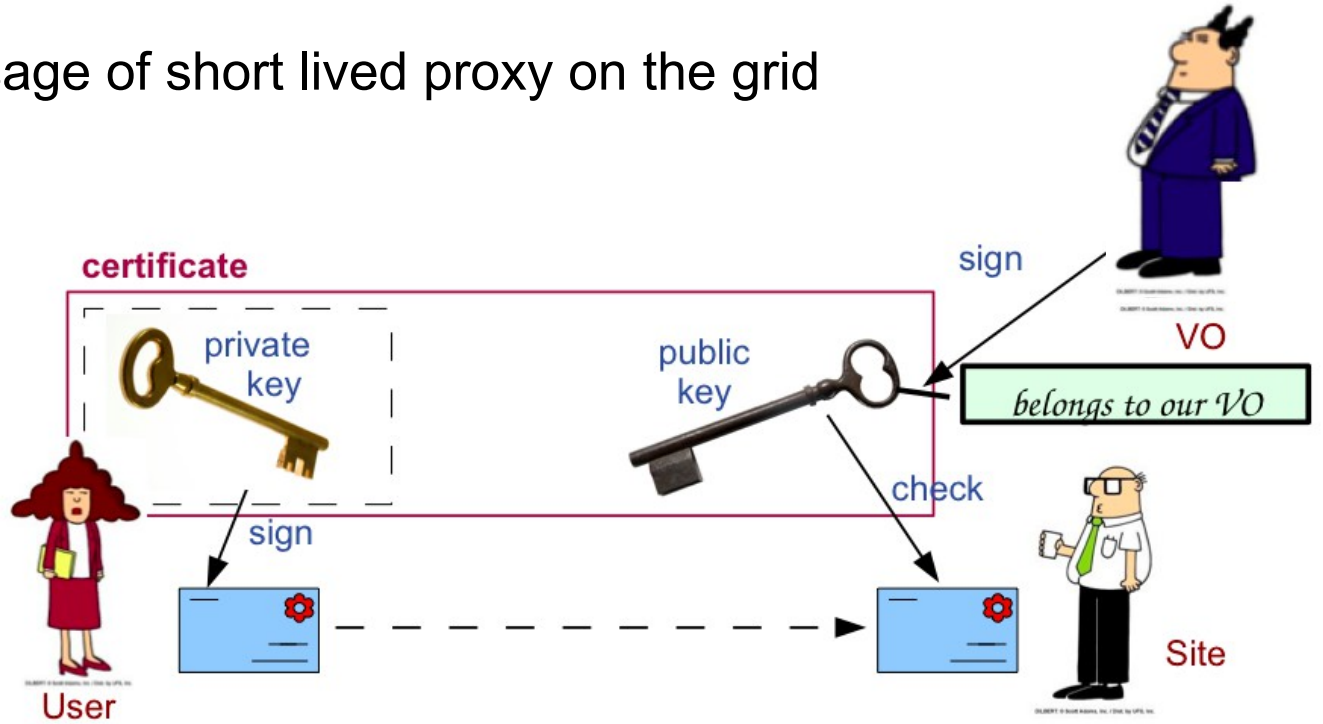
A word on


"User interface"
JOB SUBMIT
Input "sandbox"
Output "sandbox"
Resource Broker
DataSets info
Replica Catalogue
Information Service
SE & CE info
Authorization & Authentication
Job Query
job submit event
Job Status
Input "sandbox" + Broker Info
Output "sandbox"
Publish
Publish
Logging & Book-keeping
Job Status
Computing Element
Storage Element

Authentication

- The grid is large and (almost) nobody knows you

- **Authentication : who you are**
  - Certificate authority delivers certificate (long lived)
    - What you may already use in your web browser
  - Based on a public/private pair of keys
  - X509
  - For security, usage of short lived proxy on the grid



Authorisation

- **Authorisation: what can you do**

- Users are organised in Virtual Organisation (VOs)
  - They generally belong to different organisations
  - They have a common goal / accept to share resources
  - Examples: one VO per LHC experiment, CTA, biomed, france-grilles, …

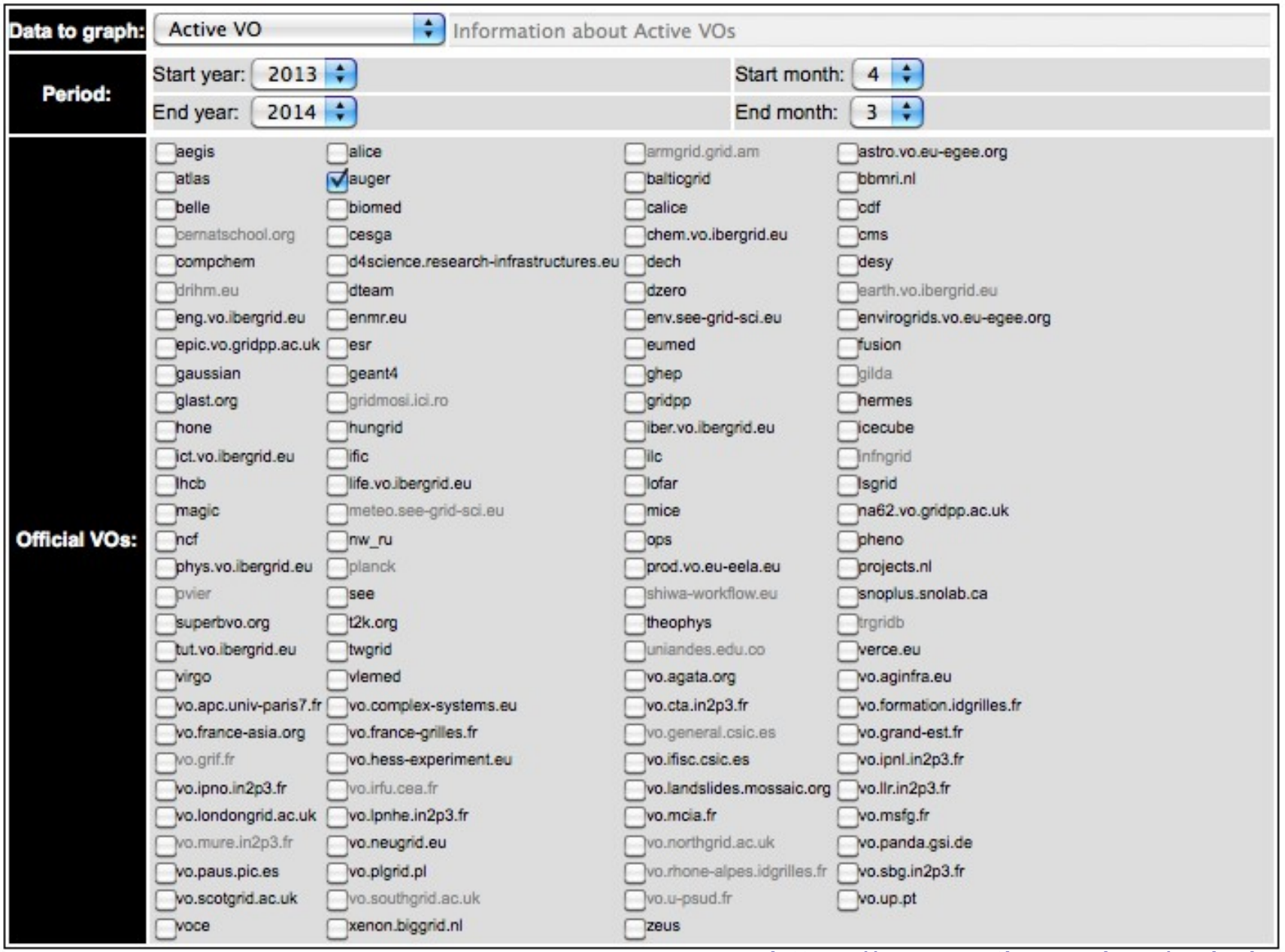
- VOMS (virtual Organisation MemberShip)
  - Delivered by your VO
  - Allow groups and roles (capabilities)

→ additional attributes to your personal certificate

- Authorisation system must be agreed with all partners

- Key ingredient : trust

EGI virtual organisations



https://accounting.egi.eu/egi.php

VO ID Card

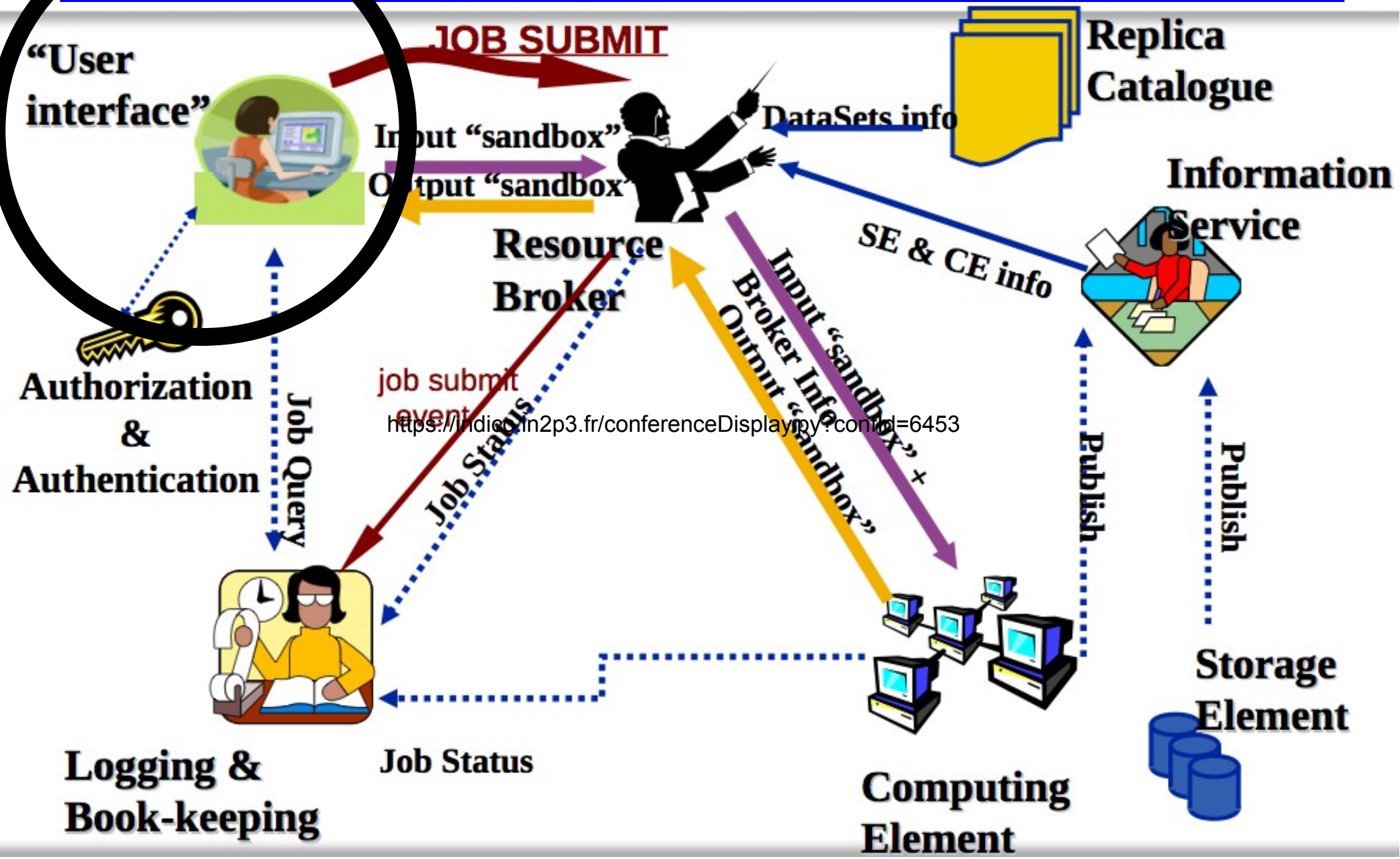
http://operations-portal.in2p3.fr/vo/view/voname/atlas

Groups and Roles

Group/Role	Type	Description	VO share(%)	Used for account generation
/atlas/alarm	Other	Team members	0	
/atlas/calib-muon	Other	Muon calibration group	0	
/atlas/Role=pilot		Analysis pilots	0	✔
/atlas/it		Italian users	0	
/atlas/Role=software		US software manager	0	
/atlas/Role=root		Not used	0	
/atlas/Role=lcgadmin		LCG software manager	0	✔
/atlas/Role=AMIWriter		AMI writer	0	
/atlas/Role=AMIManager		AMI Manager	0	
/atlas/de		German users	0	
/atlas/nl		Netherland users	0	
/atlas/Role=production		Production	0	✔
/atlas/au		Australian users	0	
/atlas		ATLAS users	0	✔
/atlas/ca		Canadian users	0	
/atlas/det-indet		Inner detector	0	
/atlas/det-larg		Liquid Argon calorimeter	0	
/atlas/det-muon		Muon spectrometer	0	
/atlas/det-tile		Tile calorimeter	0	
/atlas/fr		French users	0	

General informations
Acceptable Use Policy
Resources
Generic Contacts
Mailing lists
Groups and Roles

A word on


"User interface"
JOB SUBMIT
Input "sandbox"
Output "sandbox"
Resource Broker
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Replica Catalogue
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Input "sandbox" + Broker Info
Output "sandbox"
Publish
Publish
https://indico.in2p3.fr/conferenceDisplay.py?confId=6453
Logging & Book-keeping
Job Status
Computing Element
Storage Element

User Interface

- For the user to access to the Middleware
- Sites generally provides a UI machine
- Installed:
  - Command lines
  - Applications

```
voms-proxy-init --voms vo.france-grilles.fr
glite-ce-job-submit -a -r lpsc-ce.in2p3.fr:8443/cream-pbs-france_grilles test.jdl
glite-ce-job-list lpsc-ce.in2p3.fr:8443
glite-ce-job-status  https://lpsc-ce.in2p3.fr:8443/CREAM050473948

#with

bash-3.2$ cat test.jdl
Executable = "/bin/sleep";
arguments="180";
StdOutput = "std.out";
StdError = "std.err";
bash-3.2$
```

Job Description Language

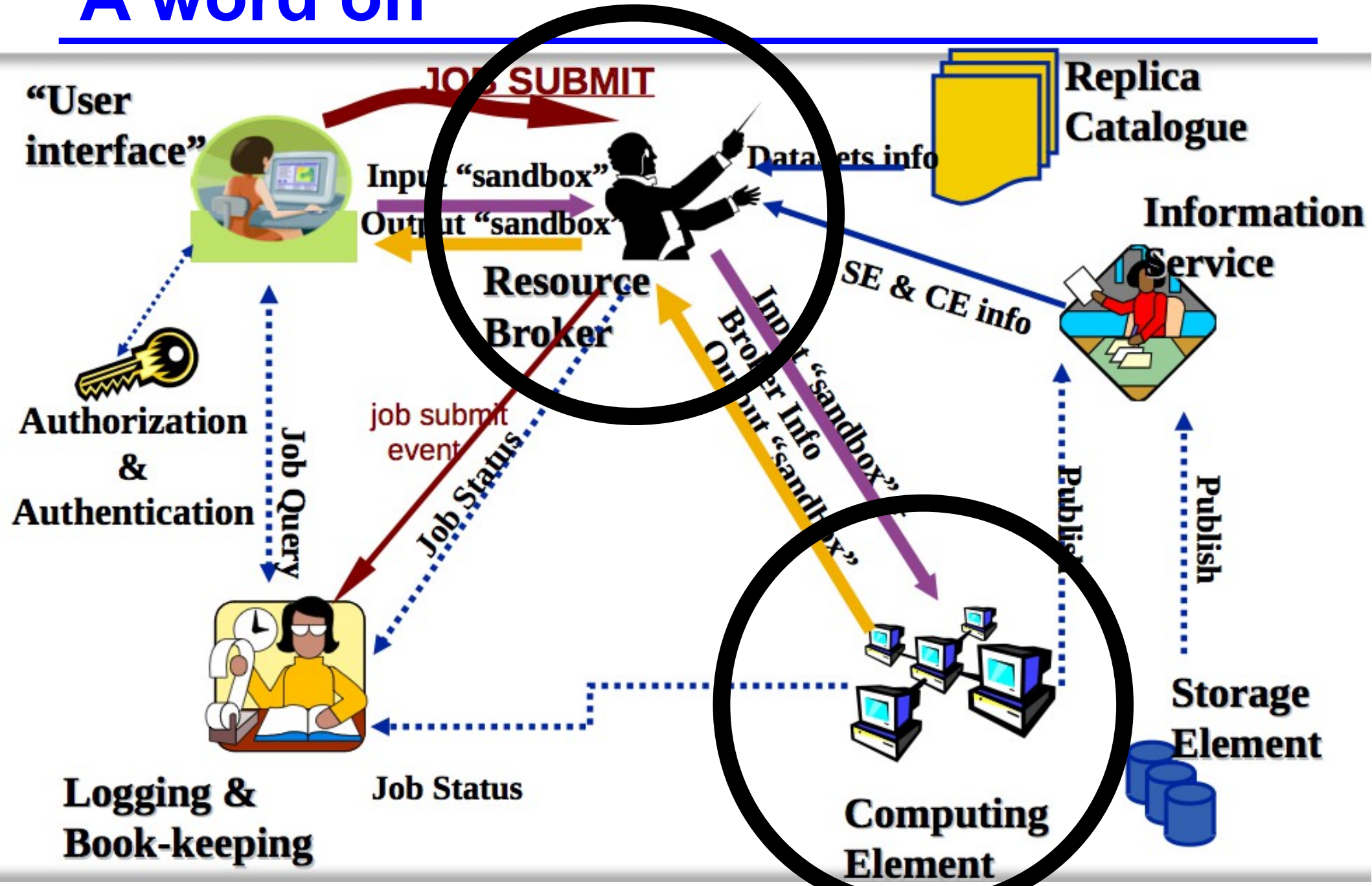
attribut job

attribut données

attributs ressources

```
Executable = "gridTest";
StdError = "stderr.log";
StdOutput = "stdout.log";
InputSandbox = {"/home/joda/test/gridTest"};
OutputSandbox = {"stderr.log", "stdout.log"};
InputData = "lfn:testbed0-00019";
DataAccessProtocol = "gridftp";
Requirements = other.Architecture=="INTEL" && \
               other.OpSys=="LINUX" && other.FreeCpus\
   >=4;
Rank = other.GlueHostBenchmarkSF00;
```

A word on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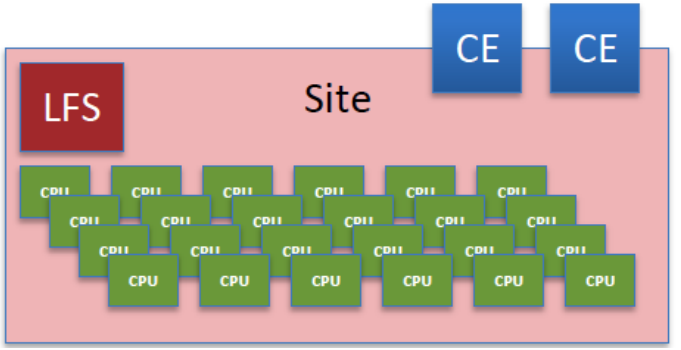
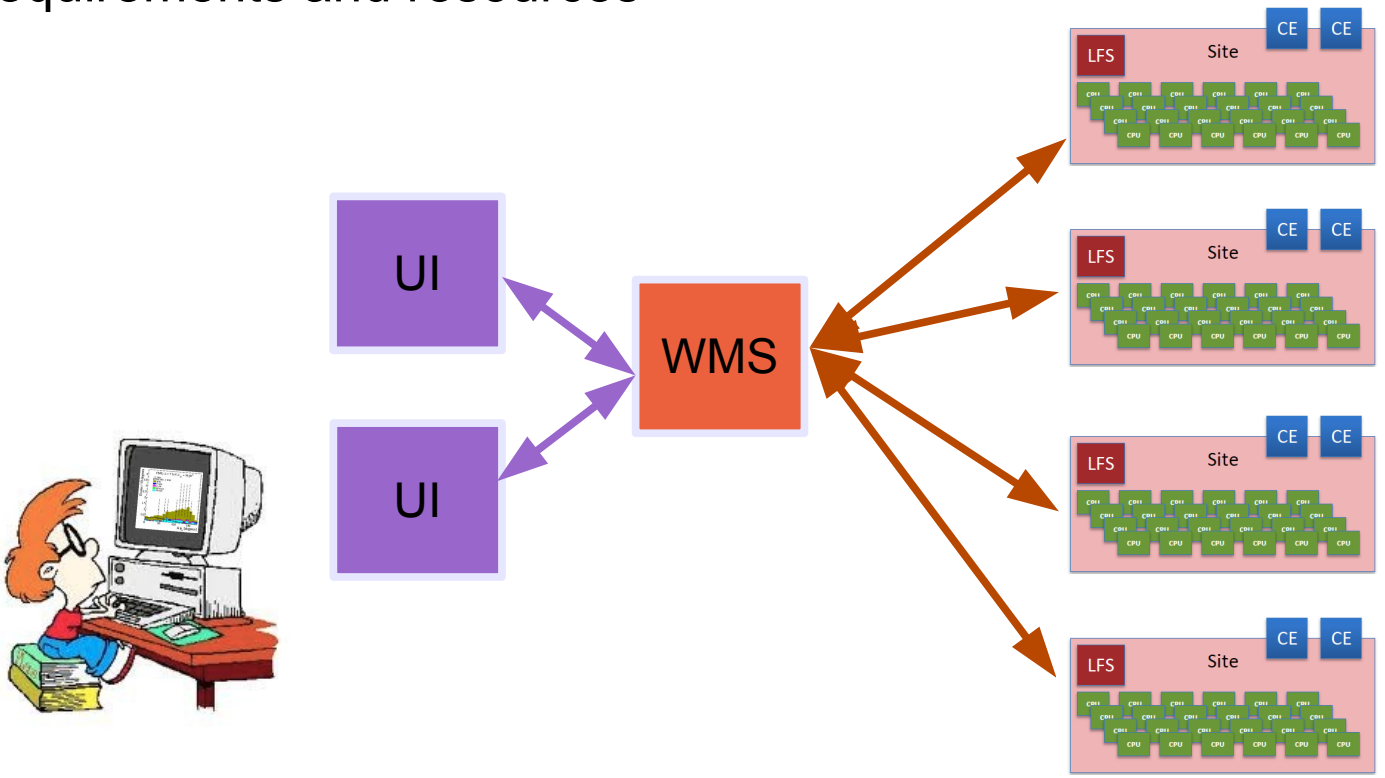
Workload management

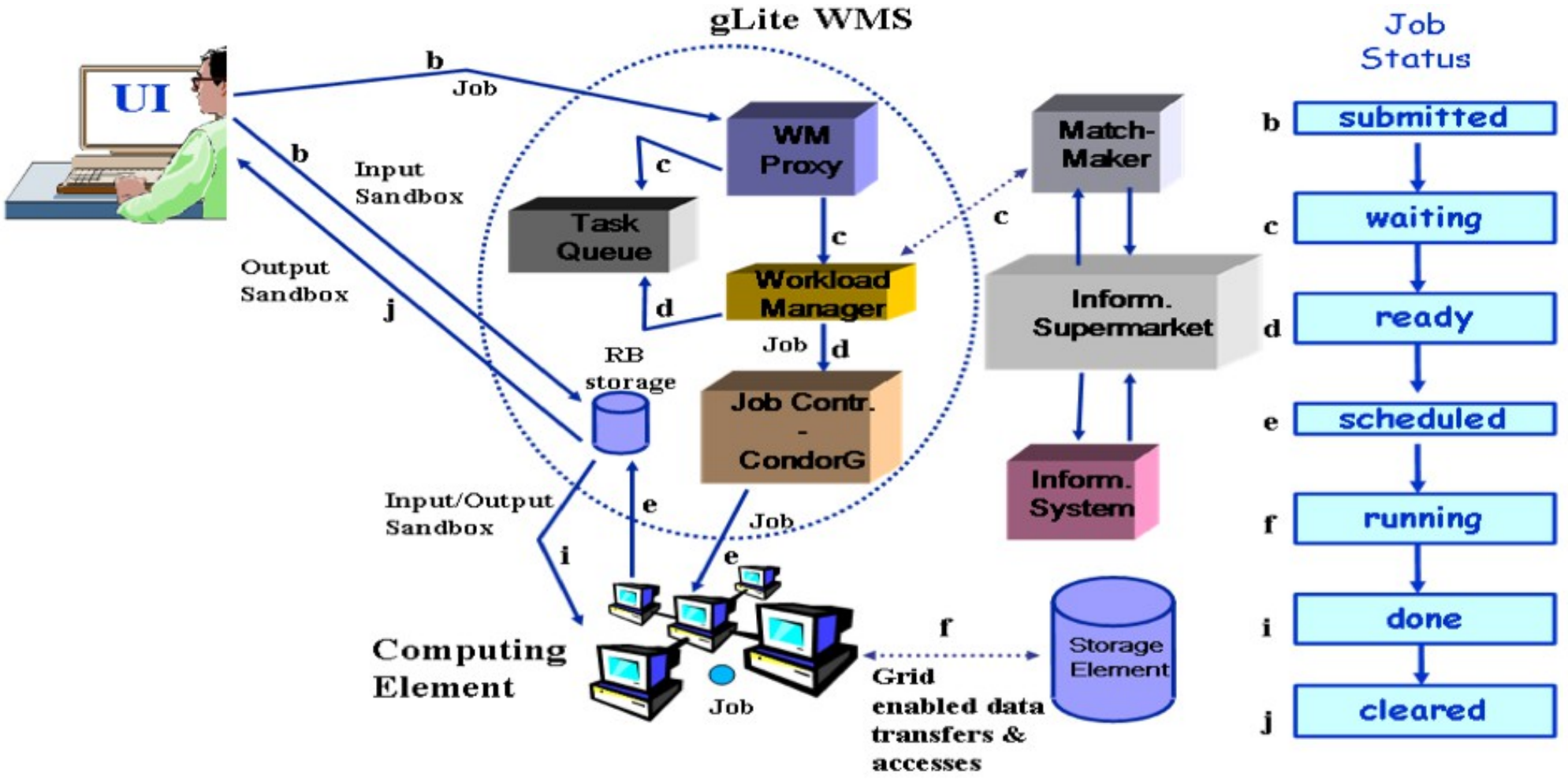
- Computing elements
  - Gateways to the local computing resources



- Workload management system
  - akas Resource broker
  - Matches requirements and resources

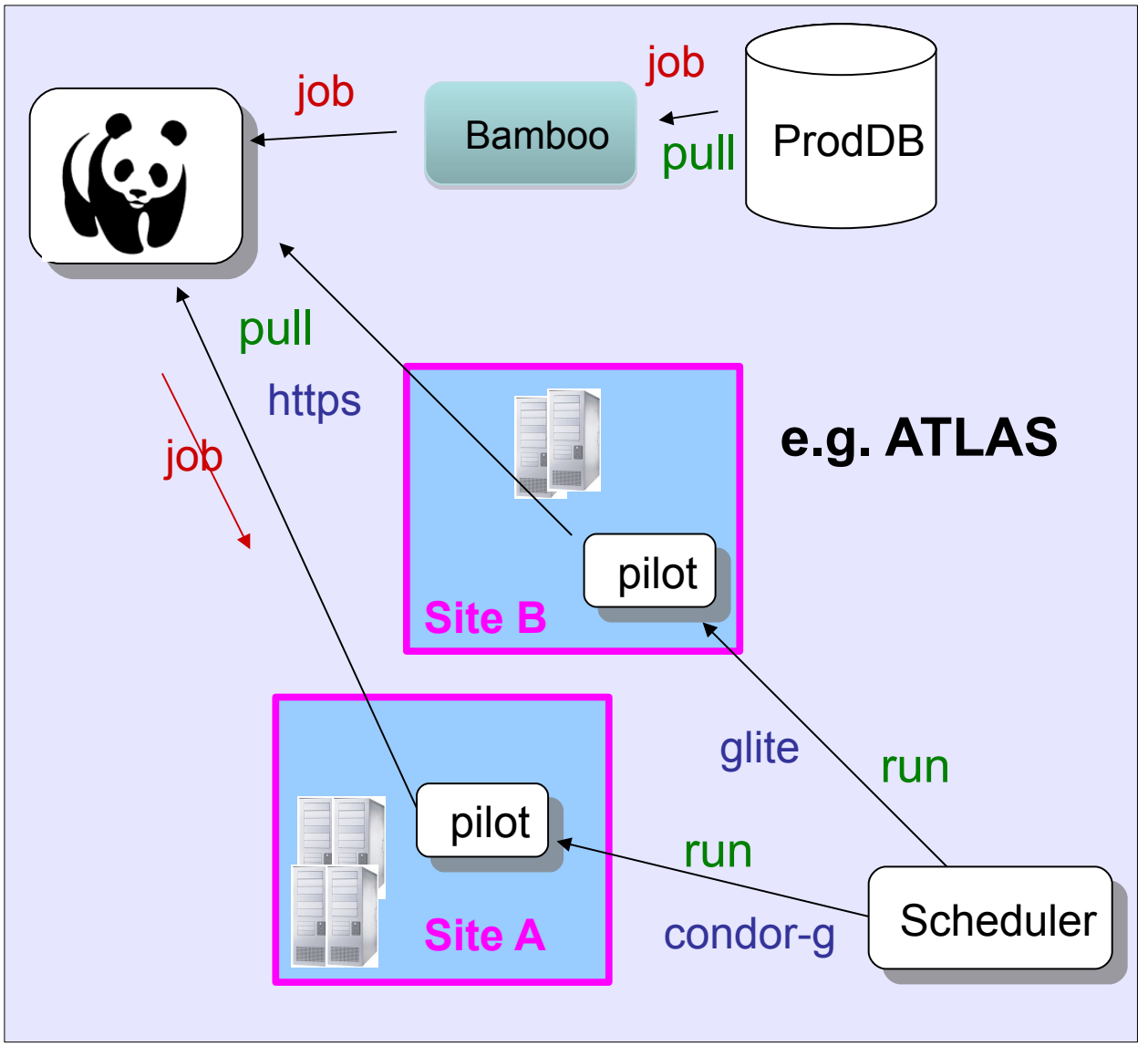


WMS – jobs route



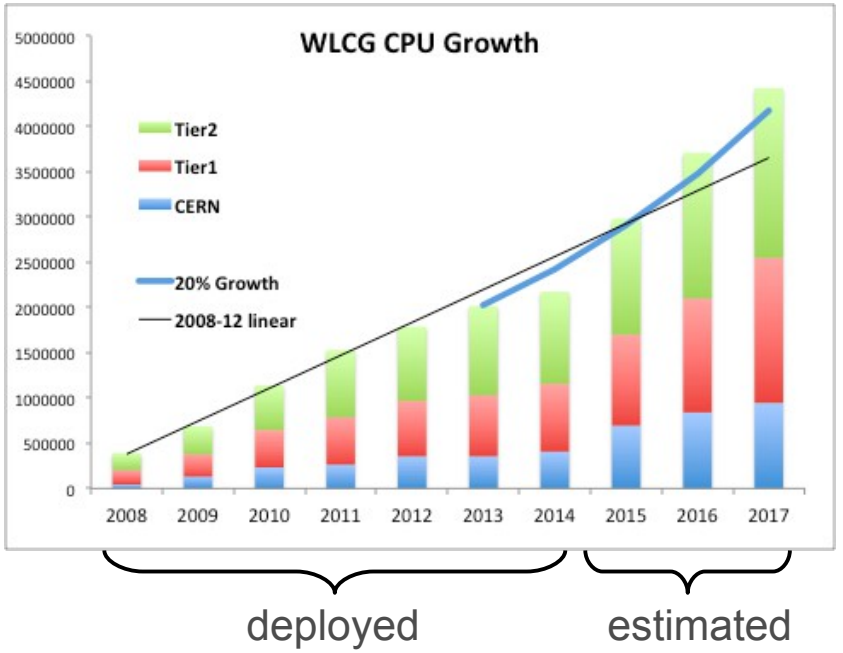
Pilot job mechanism

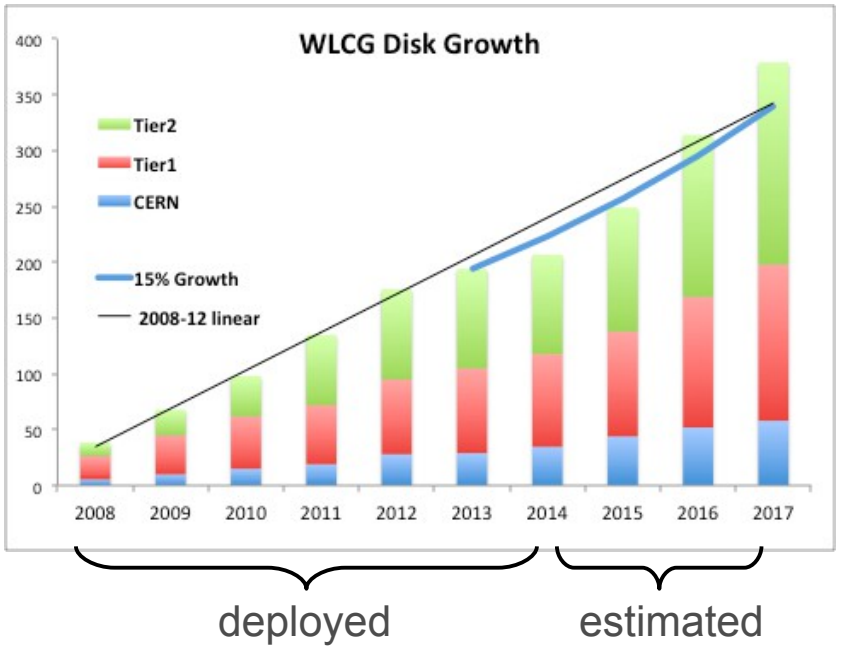
- Place holder jobs get queued at the sites
- Real jobs get puled according to the available resources and the environment
- Each LHC experiment uses pilot jobs



Going forward

Growing needs





- Behind the success of the grid
  - High complexity
  - High human resource demand

- We have gained in experience and we are still improving
  - Very stable network → new data model
  - Federated storage
  - Building common tools/interfaces

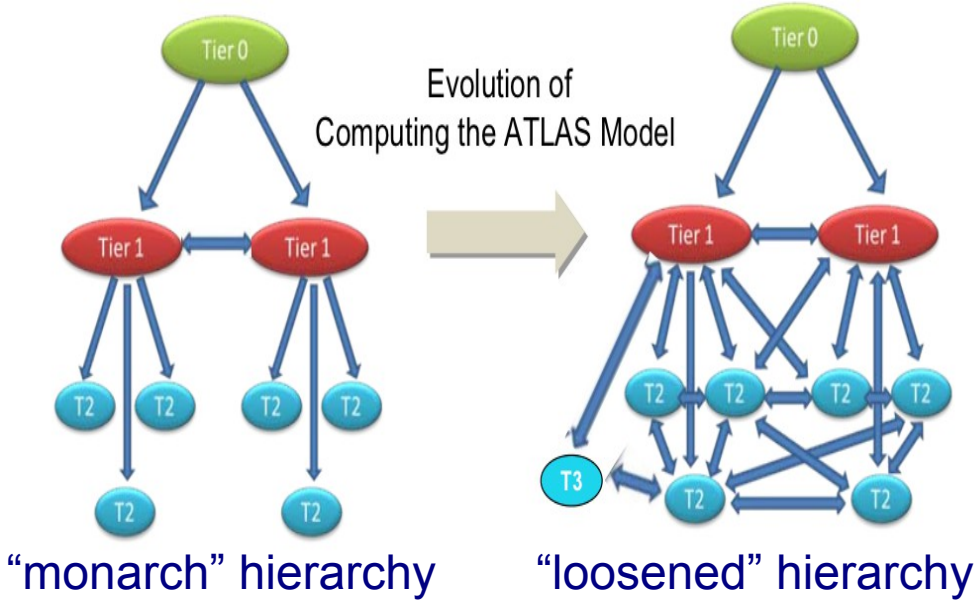
Network

"The Network infrastructure is the most reliable service we have"

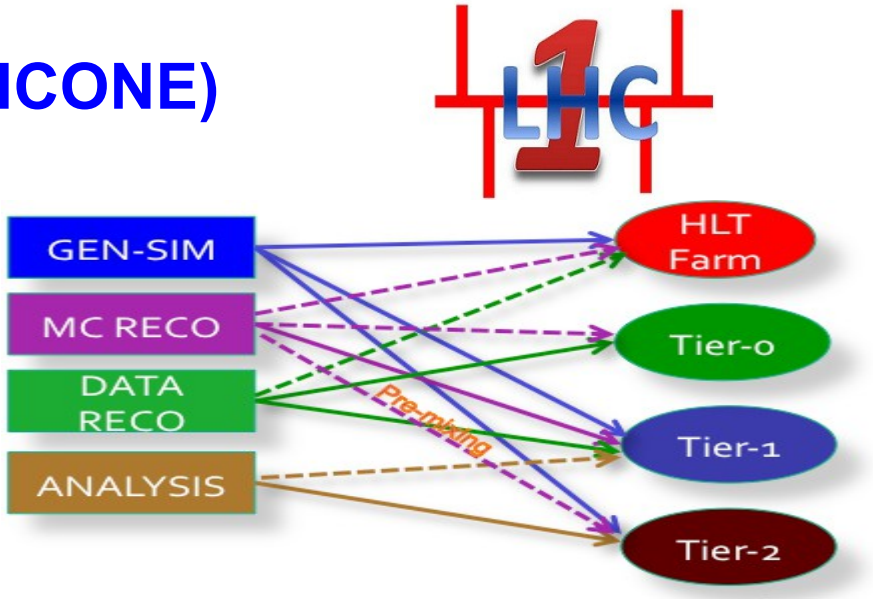
"Network Bandwidth (rather than disk) will need to scale more with users and data volume"
Ian Bird, WLCG project leader

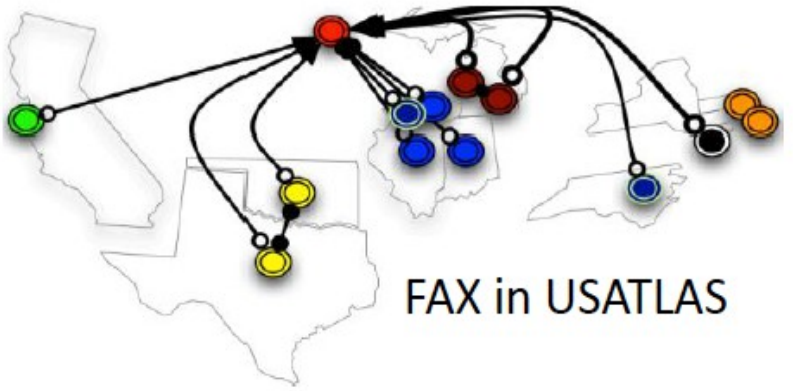
LHC Open Network Environment (LHCONE)

The T0/T1/T2 hierarchy is wiped out

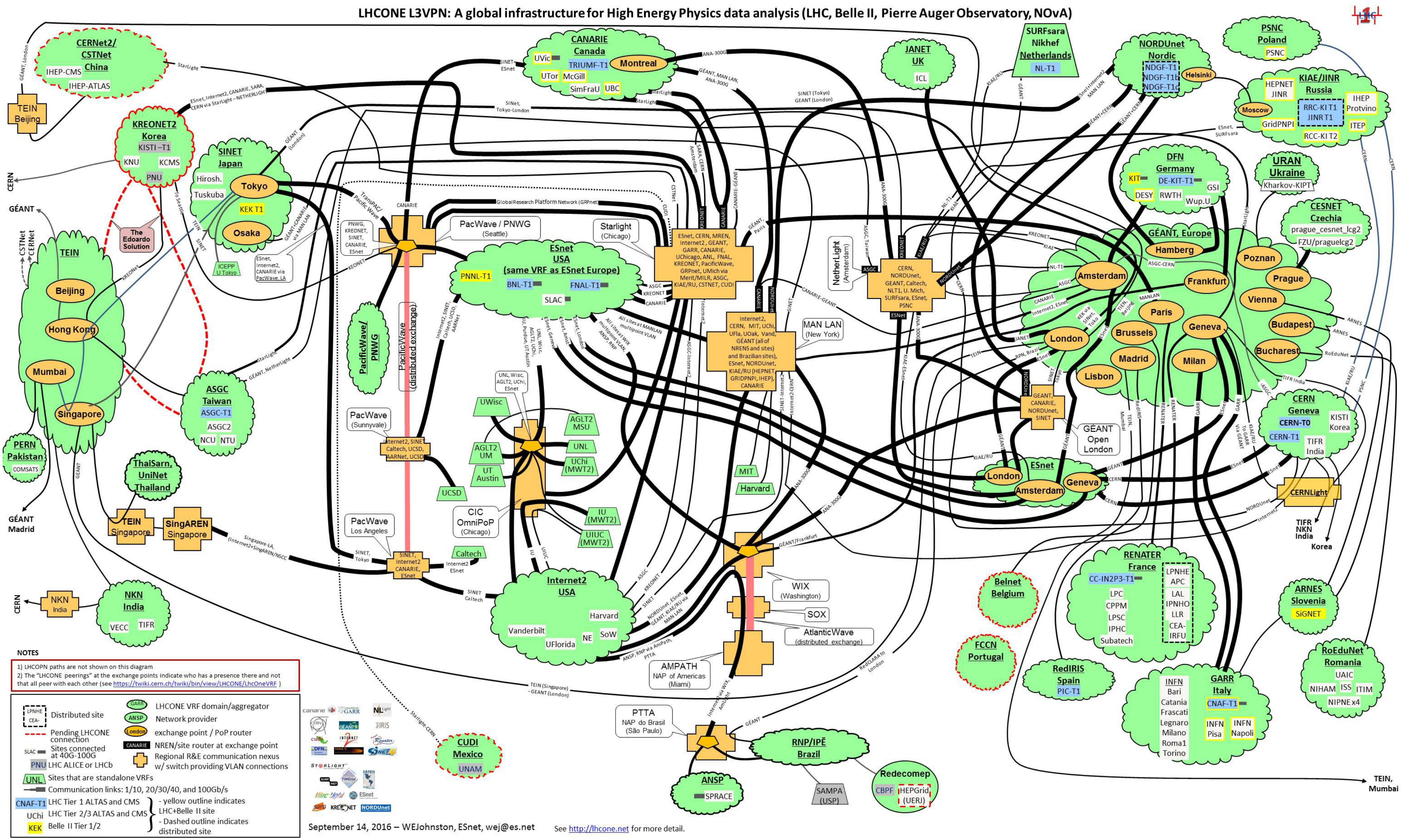


"monarch" hierarchy "loosened" hierarchy



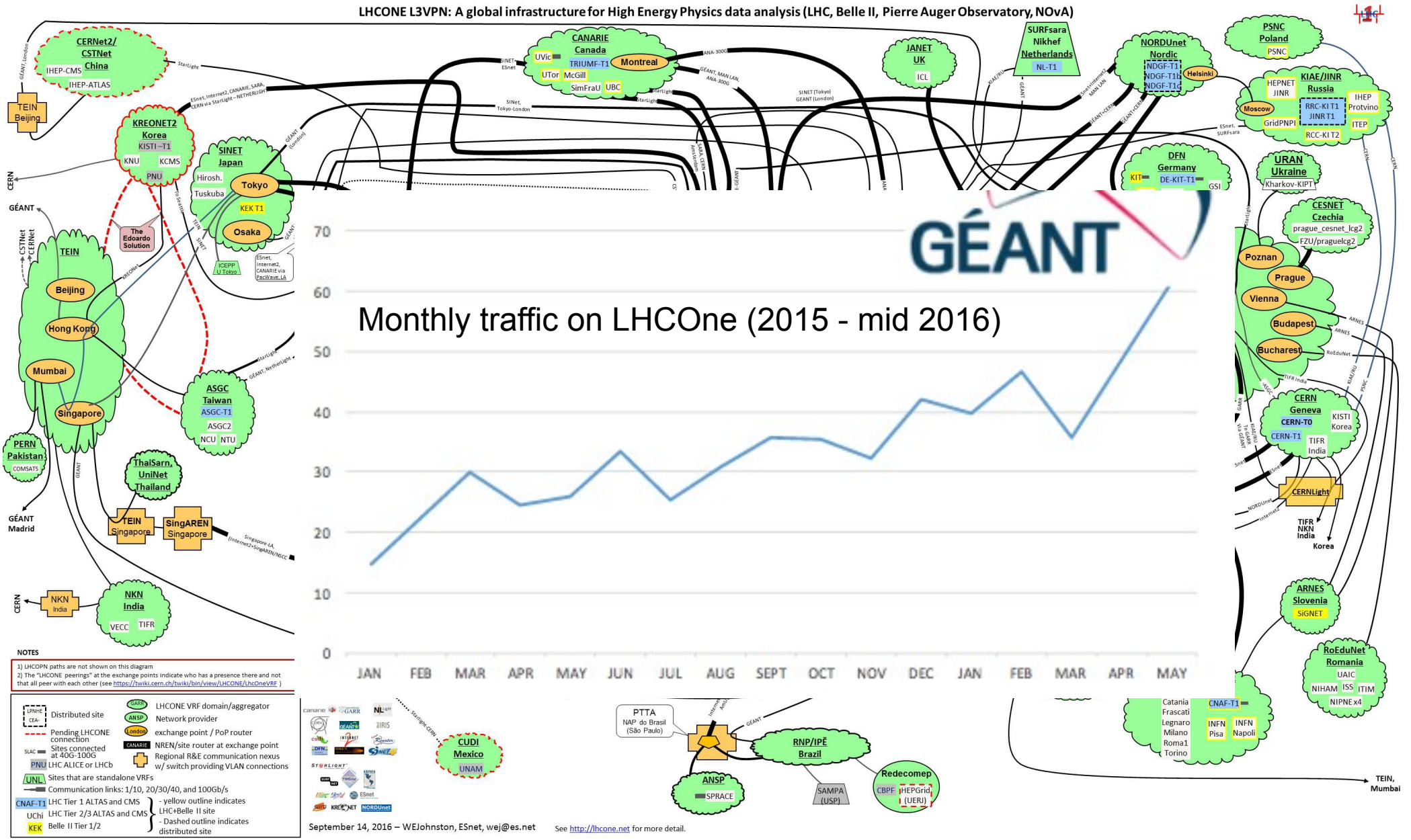


LHCOne



LHCONE L3VPN: A global infrastructure for High Energy Physics data analysis (LHC, Belle II, Pierre Auger Observatory, NOvA)
CERNet2/ CSTNet China
IHEP-CMS
IHEP-ATLAS
TEIN Beijing
KREONET2 Korea
KISTI –T1
KNU
KCMS
PNU
SINET Japan
Hirosh.
Tuskuba
Tokyo
KEK T1
Osaka
ICEPP U Tokyo
The Edoardo Solution
TEIN
Beijing
Hong Kong
Mumbai
Singapore
PERN Pakistan
COMSATS
ASGC Taiwan
ASGC-T1
ASGC2
NCU
NTU
ThaiSarn, UniNet Thailand
TEIN Singapore
SingAREN Singapore
NKN India
VECC
TIFR
CANARIE Canada
UVic
TRIUMF-T1
Montreal
UTor
McGill
SimFraU
UBC
PacWave / PNWG (Seattle)
Starlight (Chicago)
ESnet USA (same VRF as ESnet Europe)
PNNL-T1
BNL-T1
FNAL-T1
SLAC
PacificWave/ PNWG
PacificWave (distributed exchange)
PacWave (Sunnyvale)
PacWave Los Angeles
CIC OmniPoP (Chicago)
UWisc
AGLT2 MSU
AGLT2 UM
UNL
UT Austin
UChi (MWT2)
UCSD
IU (MWT2)
UIUC (MWT2)
Caltech
Internet2 USA
Vanderbilt
UFlorida
NE
SoW
Harvard
MIT
MAN LAN (New York)
WIX (Washington)
SOX
AtlanticWave (distributed exchange)
AMPATH NAP of Americas (Miami)
PTTA NAP do Brasil (São Paulo)
RNP/IPÊ Brazil
ANSP
SPRACE
SAMPA (USP)
Redecomep
CBPF
HEPGrid (UERJ)
CUDI Mexico
UNAM
JANET UK
ICL
SURFsara Nikhef Netherlands
NL-T1
NetherLight (Amsterdam)
NORDUnet Nordic
NDGF-T1a
NDGF-T1b
NDGF-T1c
Helsinki
PSNC Poland
PSNC
KIAE/JINR Russia
HEPNET JINR
Moscow
RRC-KI T1
JINR T1
IHEP Protvino
GridPNPI
ITEP
RCC-KI T2
DFN Germany
KIT
DE-KIT-T1
GSI
DESY
RWTH
Wup.U
URAN Ukraine
Kharkov-KIPT
CESNET Czechia
prague_cesnet_lcg2
FZU/praguelcg2
GÉANT, Europe
Hamberg
Amsterdam
Frankfurt
Poznan
Prague
Vienna
Paris
Budapest
Brussels
Geneva
London
Madrid
Milan
Bucharest
Lisbon
GEANT Open London
ESnet
London
Amsterdam
Geneva
CERN Geneva
CERN-T0
CERN-T1
KISTI Korea
TIFR India
CERNLight
TIFR NKN India
Korea
RENATER France
CC-IN2P3-T1
LPNHE
APC
LPC
LAL
CPPM
IPNHO
LPSC
LLR
IPHC
CEA-IRFU
Subatech
Belnet Belgium
FCCN Portugal
RedIRIS Spain
PIC-T1
GARR Italy
INFN Bari
Catania
Frascati
Legnaro
Milano
Roma1
Torino
CNAF-T1
INFN Pisa
INFN Napoli
ARNES Slovenia
SiGNET
RoEduNet Romania
UAIC
NIHAM
ISS
ITIM
NIPNE x4
GÉANT Madrid
TEIN, Mumbai
NOTES
1) LHCOPN paths are not shown on this diagram
2) The "LHCONE peerings" at the exchange points indicate who has a presence there and not that all peer with each other (see https://twiki.cern.ch/twiki/bin/view/LHCONE/LhcOneVRF)
Distributed site
Pending LHCONE connection
Sites connected at 40G-100G
LHC ALICE or LHCb
Sites that are standalone VRFs
Communication links: 1/10, 20/30/40, and 100Gb/s
LHC Tier 1 ALTAS and CMS
LHC Tier 2/3 ALTAS and CMS
Belle II Tier 1/2
- yellow outline indicates LHC+Belle II site
- Dashed outline indicates distributed site
LHCONE VRF domain/aggregator
Network provider
exchange point / PoP router
NREN/site router at exchange point
Regional R&E communication nexus w/ switch providing VLAN connections
September 14, 2016 – WEJohnston, ESnet, wej@es.net
See http://lhcone.net for more detail.

LHCOne


LHCONE L3VPN: A global infrastructure for High Energy Physics data analysis (LHC, Belle II, Pierre Auger Observatory, NOvA)
Monthly traffic on LHCOne (2015 - mid 2016)
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
GÉANT
CERNet2/ CSTNet China
IHEP-CMS
IHEP-ATLAS
TEIN Beijing
KREONET2 Korea
KISTI –T1
KNU
KCMS
PNU
SINET Japan
Hirosh.
Tuskuba
Tokyo
KEK T1
Osaka
CANARIE Canada
UVic
TRIUMF-T1
Montreal
UTor
McGill
SimFraU
UBC
JANET UK
ICL
SURFsara Nikhef Netherlands
NL-T1
NORDUnet Nordic
NDGF-T1
NDGF-T1b
NDGF-T1c
Helsinki
PSNC Poland
PSNC
KIAE/JINR Russia
HEPNET JINR
Moscow
GridPNPI
RRC-KI T1
JINR T1
RCC-KI T2
IHEP Protvino
ITEP
DFN Germany
KIT
DE-KIT-T1
GSI
URAN Ukraine
Kharkov-KIPT
CESNET Czechia
prague_cesnet_lcg2
FZU/praguelcg2
Poznan
Prague
Vienna
Budapest
Bucharest
CERN Geneva
CERN-T0
CERN-T1
KISTI Korea
TIFR India
CERNLight
TIFR NKN India
Korea
ARNES Slovenia
SiGNET
RoEduNet Romania
UAIC
NIHAM
ISS
ITIM
NIPNE x4
TEIN
Beijing
Hong Kong
Mumbai
Singapore
PERN Pakistan
COMSATS
GÉANT Madrid
ASGC Taiwan
ASGC-T1
ASGC2
NCU
NTU
ThaiSarn, UniNet Thailand
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SingAREN Singapore
NKN India
VECC
TIFR
The Edoardo Solution
ICEPP / U Tokyo
CERN
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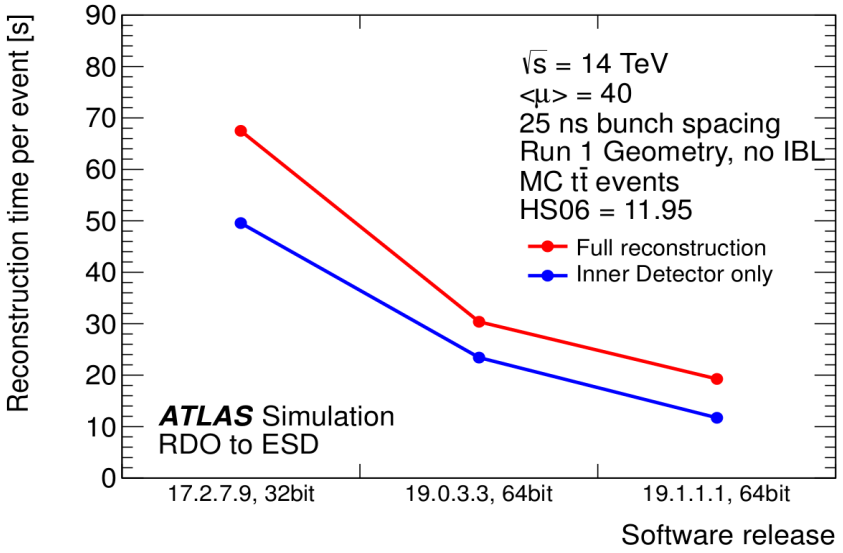
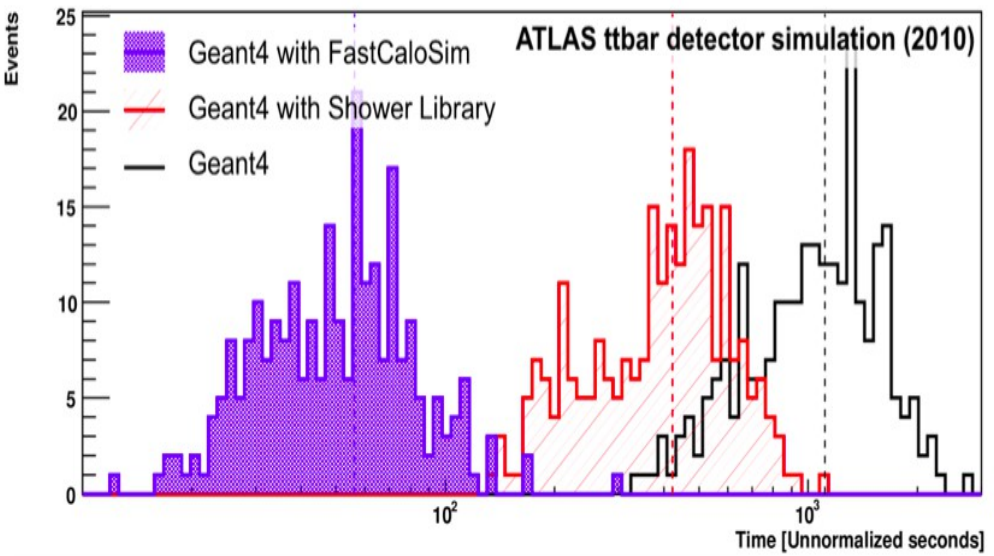
UNAM
PTTA
NAP do Brasil (São Paulo)
RNP/IPÊ Brazil
ANSP
SPRACE
SAMPA (USP)
Redecomep
CBPF
HEPGrid (UERJ)
Catania
Frascati
Legnaro
Milano
Roma1
Torino
CNAF-T1
INFN Pisa
INFN Napoli
TEIN, Mumbai
September 14, 2016 – WEJohnston, ESnet, wej@es.net
See http://lhcone.net for more detail.

Saving CPU time

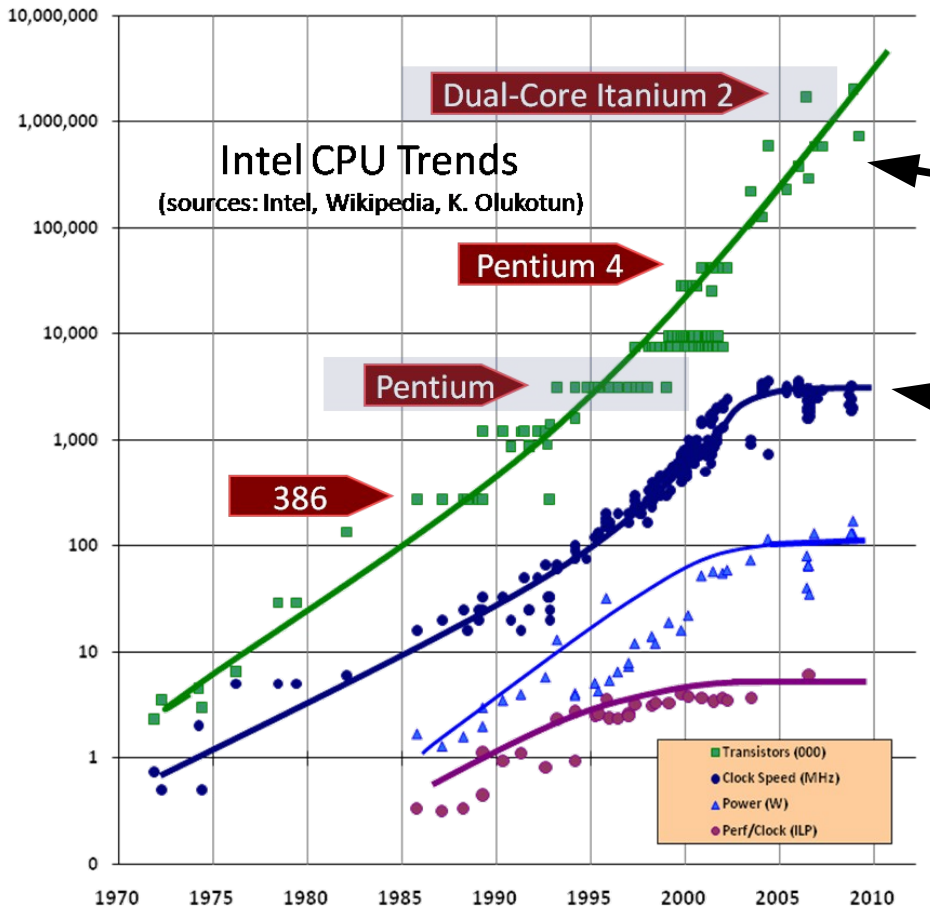




CHEP2013

2005: “The free lunch is over”

- Performance of standard CPU does not improve anymore
- Since HEP needs increase, we must get ready for the new architectures: multi-cores, many-cores, GPU (games consoles)

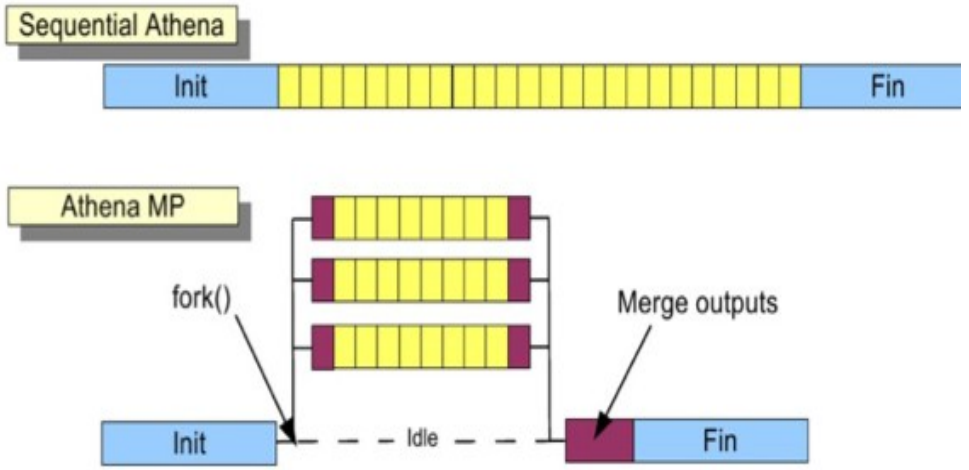


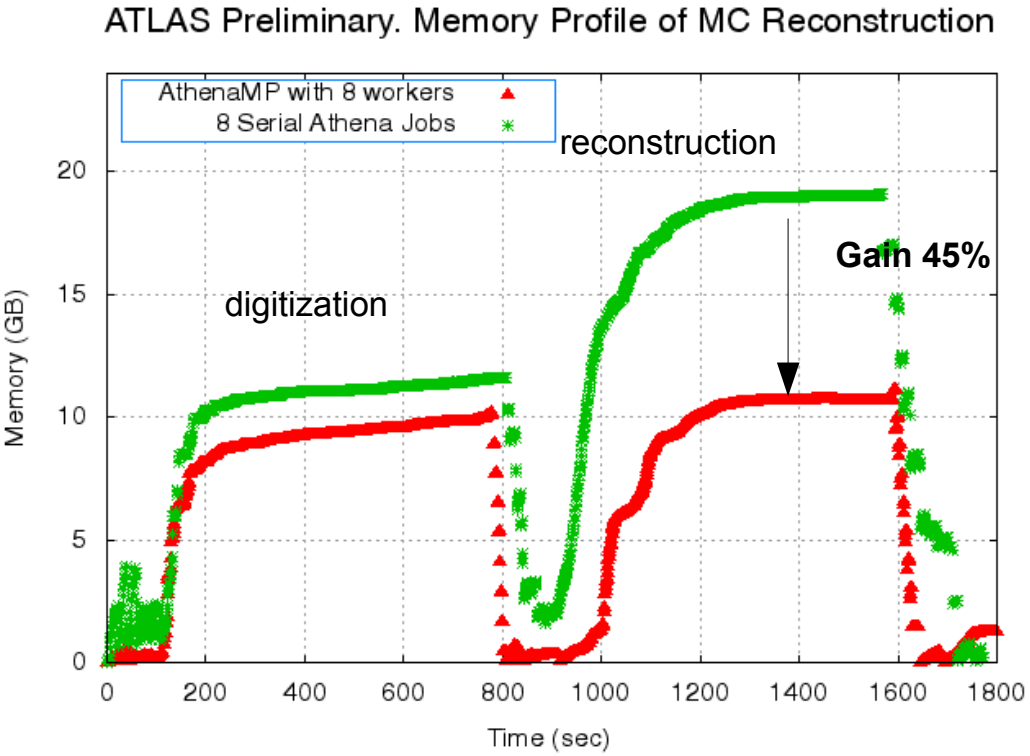
Nowadays multi-cores
- Memory / core /IO per IO is limited

CPU clock reaches a plateau

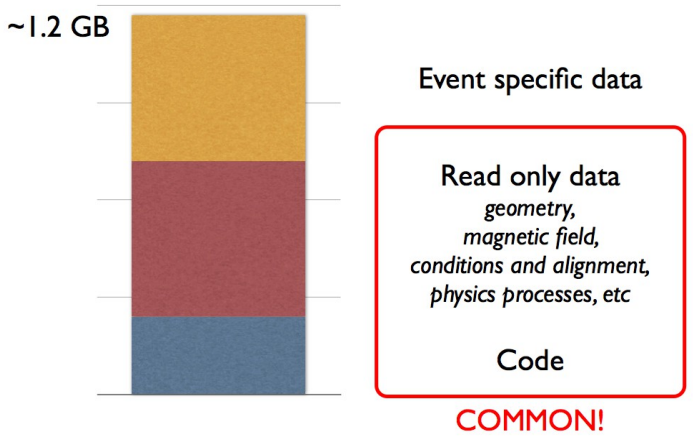
Saving Memory

ATLAS

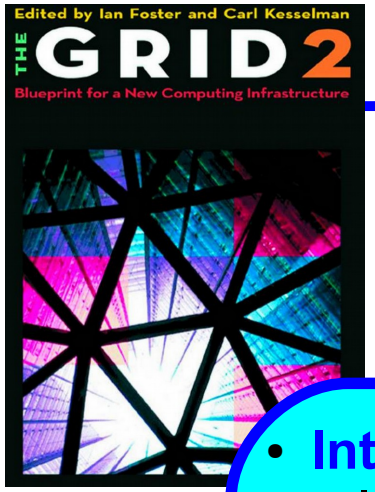




CMS offline software memory budget



CMS is going further and making parallelism at the algorithm level.

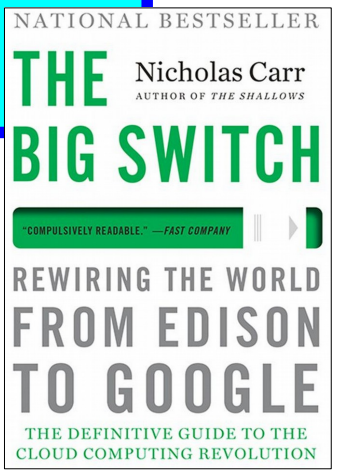


The "Cloud"

The Grid: 1998 and 2003 (2nd Ed.)
Grid is used by analogy with the electric power grid…
has had a dramatic impact on human capabilities…

- **Introduces the concept of virtualisation**
  - Isolates the user software (virtual) from physical hardware (real)
  - Remember that grid sites are heterogenous
- Flexible and dynamic resource sharing
- On-demand usage of resources
- Virtualisation already proved to be helpful "on the grid" (CVMFS)
- Clouds already successfully used by experiments
  - In many domains

The Big Switch [to the Cloud]: 2009
Computing is turning into a utility… will ultimately change society as completely as cheap electricity did…



Which types of Services?

Software-as-a-Service (SaaS)
Applications are available on demand (e.g. email)

Platform-as-a-Service (PaaS)
One can develop ones own applications on top of services (e.g. web servers)

Infrastructure-as-a-Service (IaaS)
A virtual machine is given, one installs owns own image (e.g. compute power)

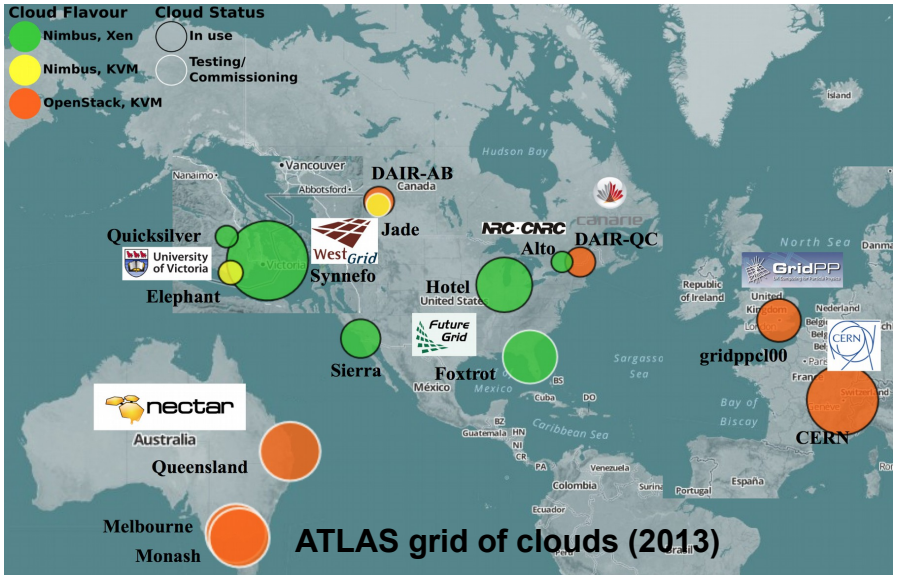
Grid sites can be clouds

Advantages
- Decoupling HW and SW
- Flexibility

Integrated in the experiments workflow
- Private or academic
- Overhead < 5% (tuning)
- Looking at containers

The Tier-0 is extended
- Resources orchestrated in a cloud
- > 125 000 cores

Farms dedicated to event triggering
- Additional layer for a raid switch online/offline (LHC shutdowns, inter-fill)



Opportunistic resources

Commercial clouds - Elasticity

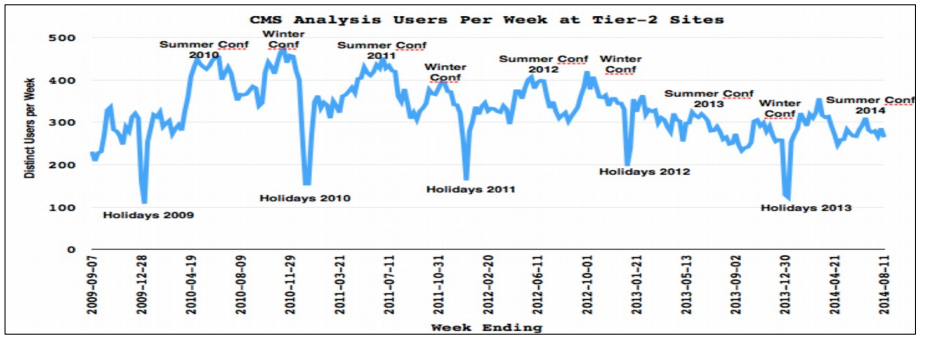
- Some experience : Google, HELIXNebula, Amazon Web Service
- In Europe, HNSciCloud (2016)
  - Prototype of *cloud* public/privé
  - Comprendre et maitriser les coûts

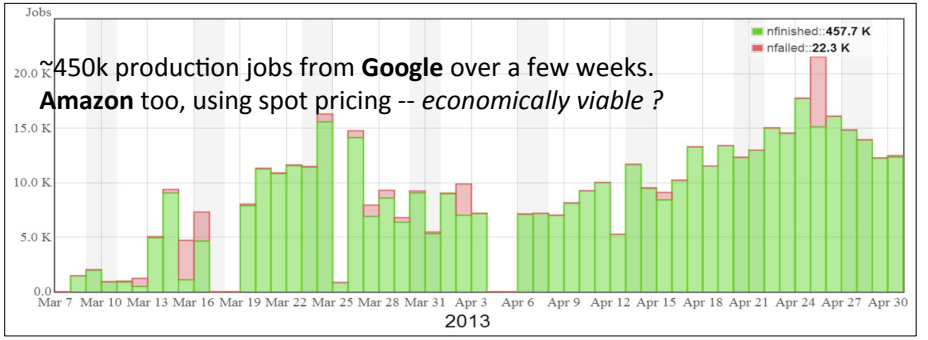
BOINC and the @home projects

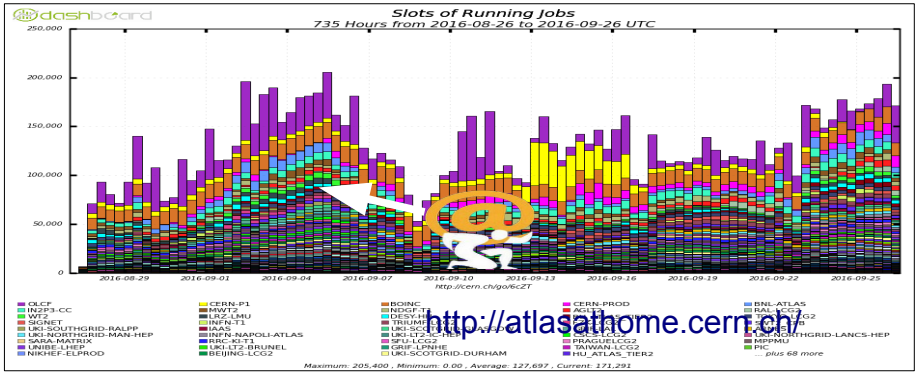
- Same model as SETI@home
- First initiative for the LHC: ATLAS@home

Supercomputers

- HEP: no genuine needs for supercomputers
- Some of the biggest HPC centers are interfaced with WLCG and the grid stack







- Preferred payloads : IO intensive, interrupt tolerant

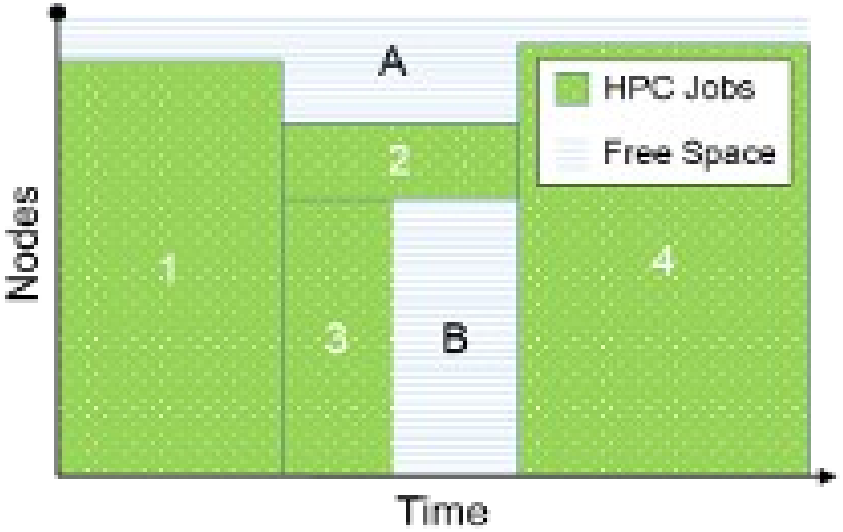
Supercomputers

Remember

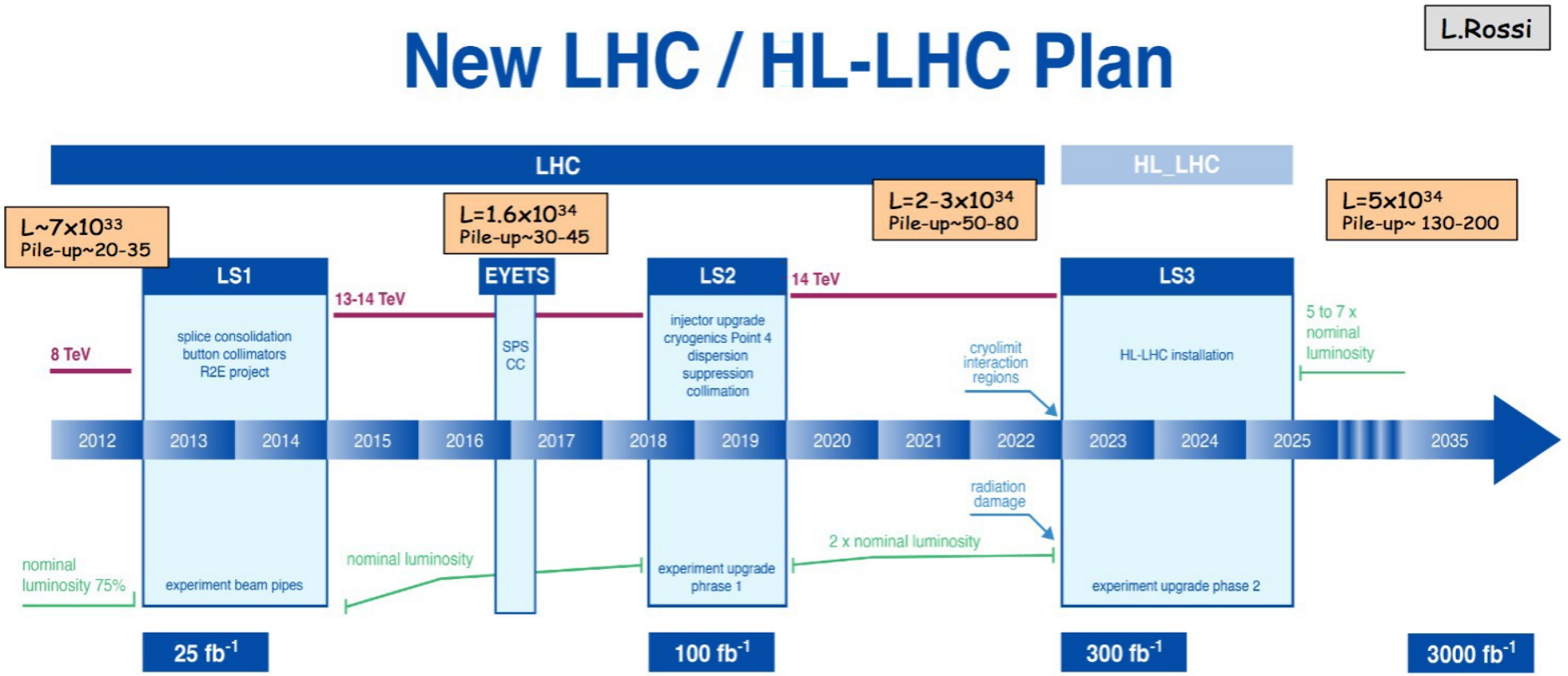
- Grid is ideal for a large number of independent jobs (High Throughput Computing)

Needs for supercomputers

- One task must be executed on hundreds of cores
  - Very fast communication between cores
  - Large available memory
- HPC (High Performance Computing)
- Pyramidal Tiers-0/1/2 in Europe
  - France: “Curie” with 92 000 cores
- Seismology, mathematics, chemistry, aerodynamics … + astro particles
- By construction, difficult to fill the machines leaving empty cycles

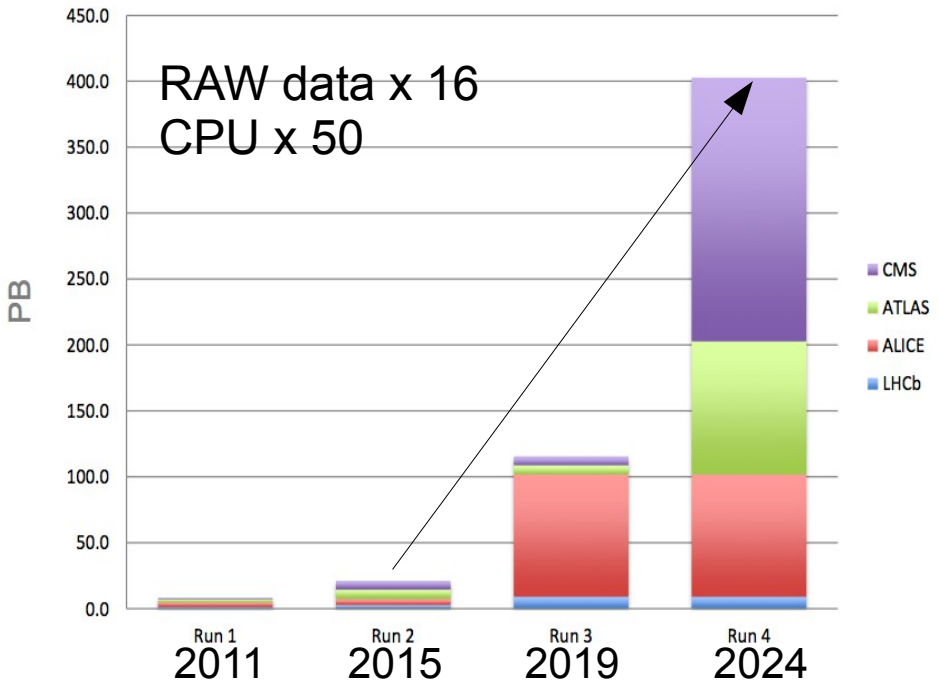


The end ?



Pile-up : event complexity
Integrated Lumi.: nb of events

Further challenges



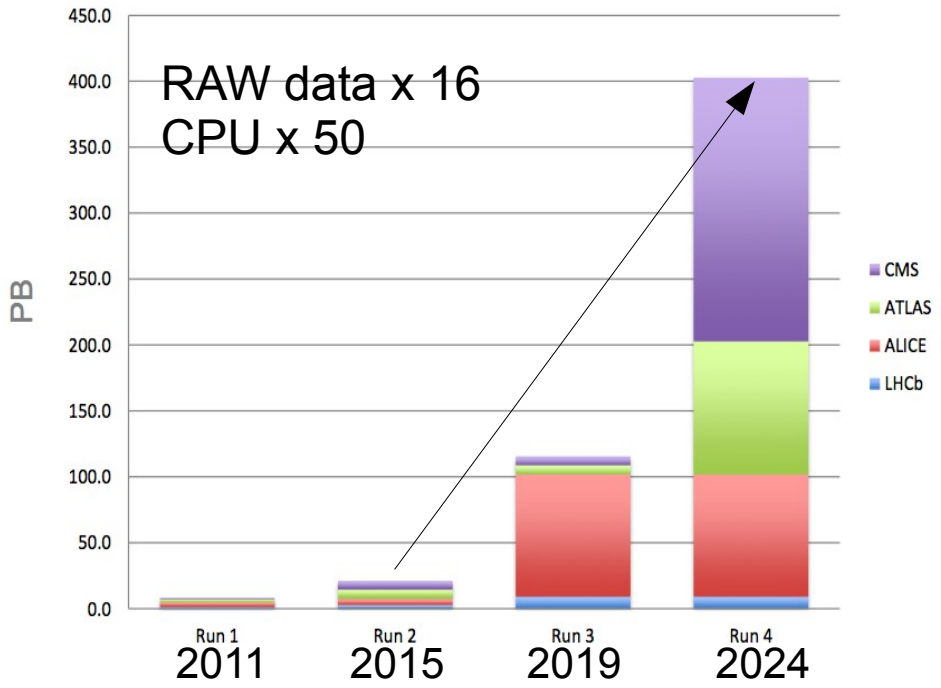
Evolution of RAW data set size for the LHC experiments

- derived data is not included
- cleaning of deprecated data is included

0.5 to 1 Exabytes of RAW data / year

- Run 3: ALICE and LHCb detector upgrades
  - Calibration and reconstruction online
- Run 4: ATLAS and CMS detector upgrades : we miss a factor of 5-10
  - New HW
  - New computing models
  - New CPU/disk/network balance

Further challenges



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  - New computing models
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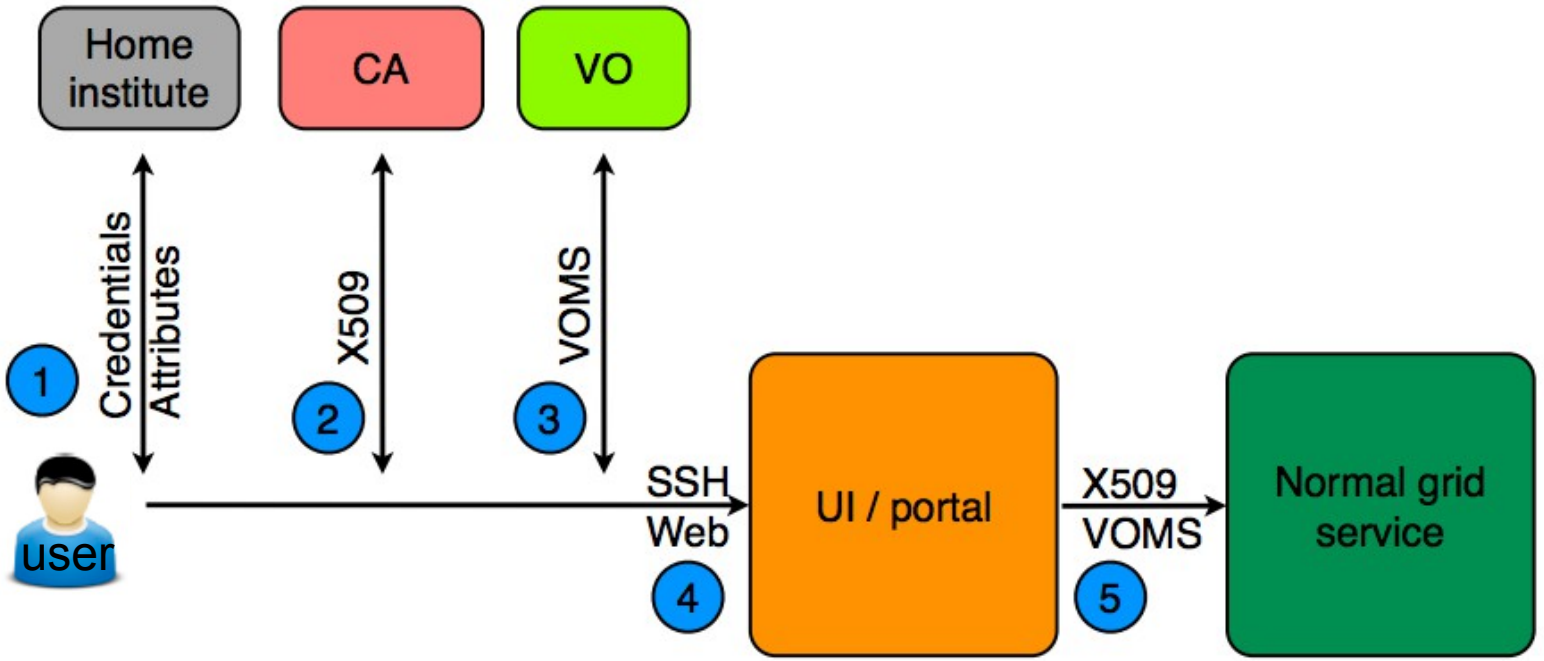
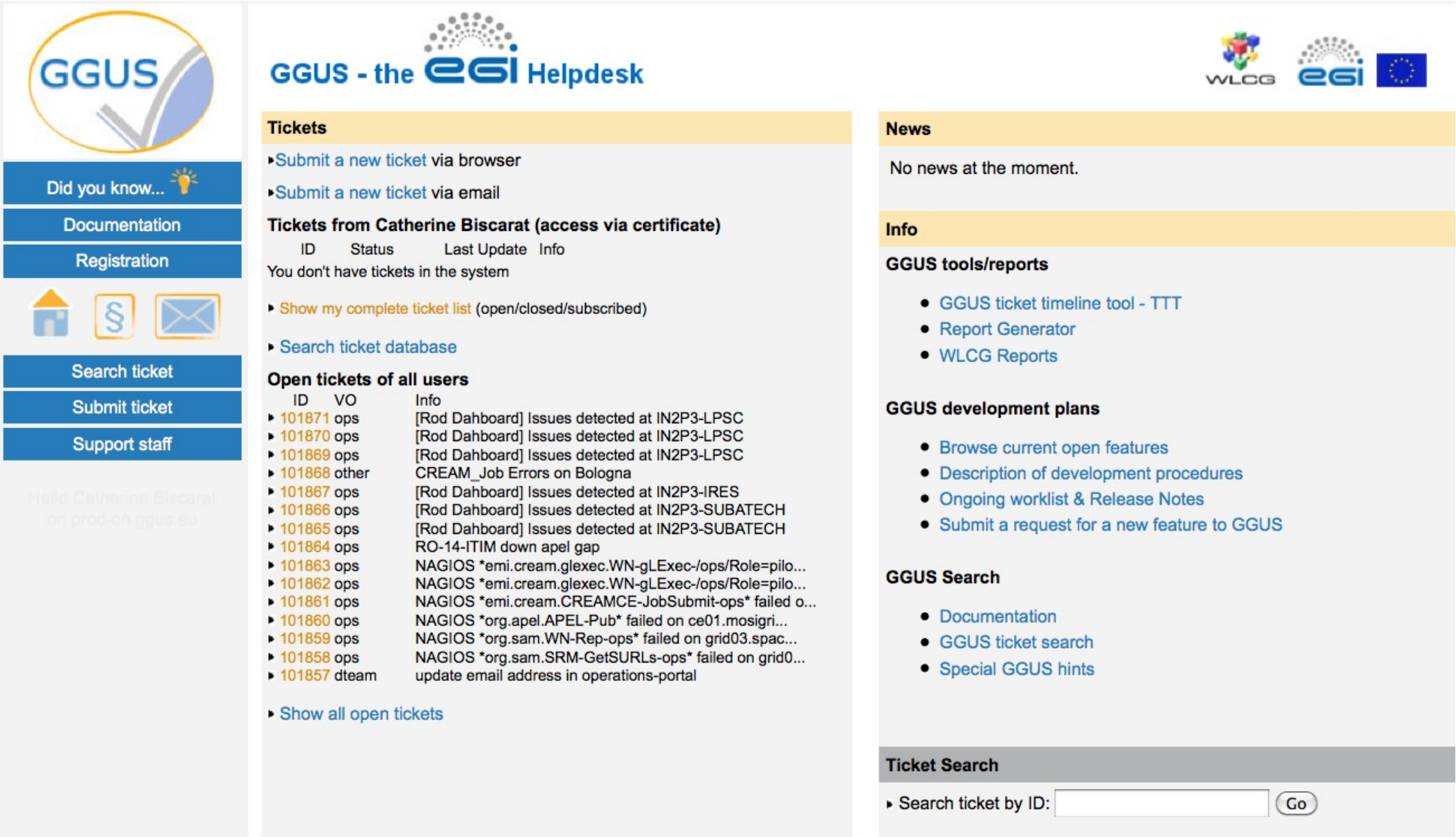
Accessing “the” grid

Authentication + User Interface

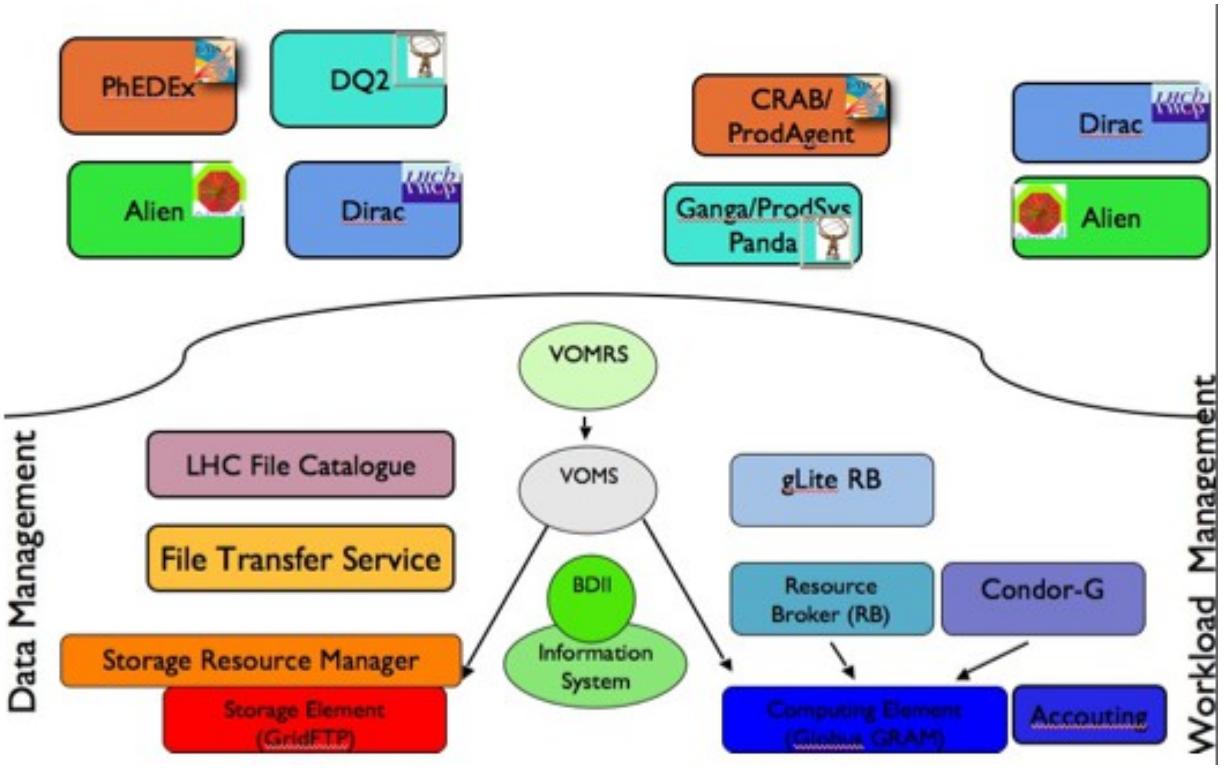


Global Grid User Support



Experiments own Middleware

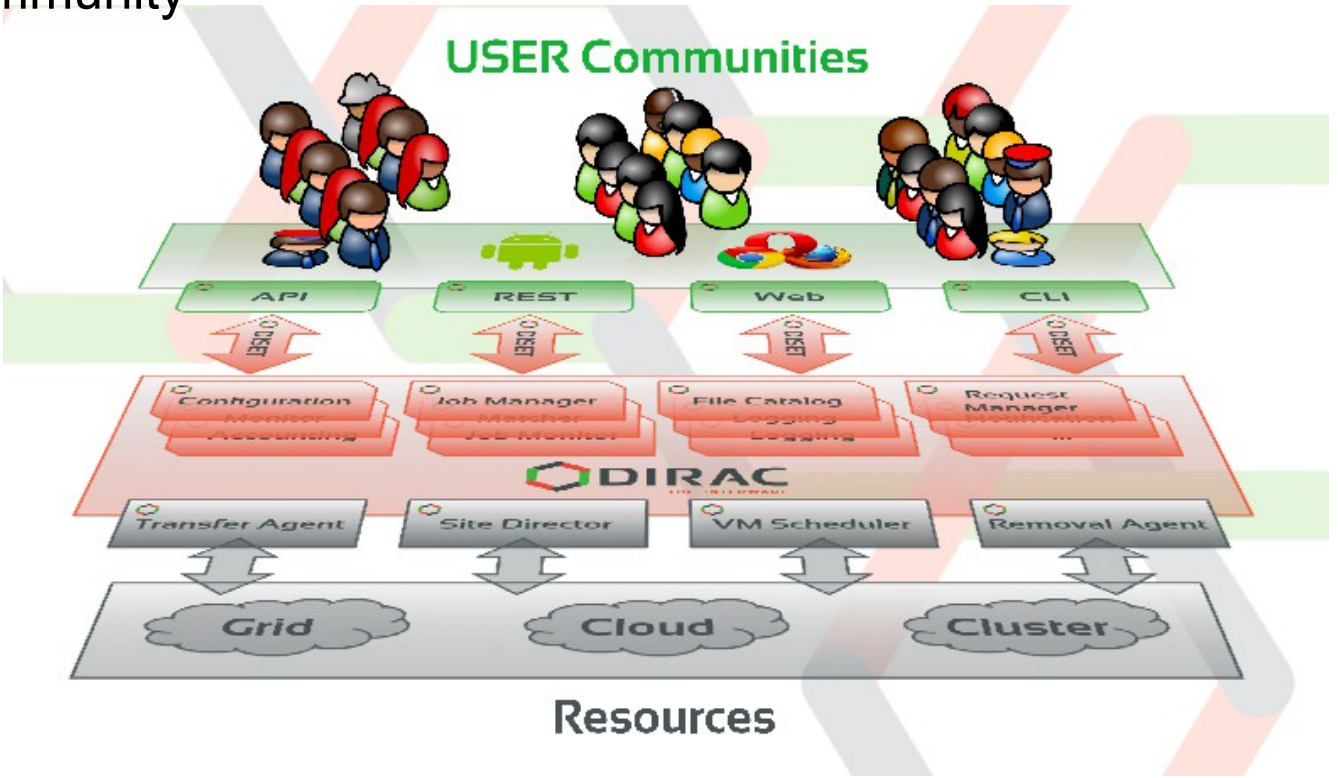
- HEP experiments pioneered the massive use of grids
- CERN Director General Rolf Heuer about the Higgs discovery:
  "*It was a global effort and it is a global success. The results today are only possible because of the extraordinary performance of the accelerators, including the infrastructure, the experiments, and the Grid computing.*"
- Large VOs have developed their own Middleware
  - Easy to use interfaces
  - Better control



DIRAC
THE INTERWARE

- Initially developed by the LHCb experiment (LHC)
- In 2009 decision to generalise the software
  - Separate specific LHCb functionalities
- 2013: DIRAC consortium

- DIRAC is now a general-purpose Middleware, offering services to any scientific community
  - Fermi-LAT, Glast
  - LSST
  - CTA
  - …
  - Will replace the the resource broker



EGI Federated Cloud

https://www.egi.eu/services/cloud-compute/ egi federated cloud

SERVICES | FEDERATION | USE CASES | BUSINESS | ABOUT

EGI / SERVICES / CLOUD COMPUTE

Cloud Compute

Run virtual machines on-demand with complete control over computing resources

REQUEST THIS SERVICE

ASK FOR INFORMATION

Cloud Compute gives you the ability to deploy and scale virtual machines on-demand. It offers guaranteed computational resources in a secure and isolated environment with standard API access, without the overhead of managing physical servers.

Cloud Compute offers the possibility to select pre-configured virtual appliances (e.g. CPU, memory, disk, operating system or software) from a catalogue replicated across all EGI cloud providers.

With Cloud Compute you can:

- Execute compute- and data-intensive workloads (both batch and interactive)
- Host long-running services (e.g. web servers, databases or applications servers)
- Create disposable testing and development environments on virtual machines and scale your infrastructure needs
- Select virtual machine configurations (CPU, memory, disk) and application environments to fit your requirements
- Manage your Cloud Compute resources in a flexible way with integrated monitoring and accounting capabilities

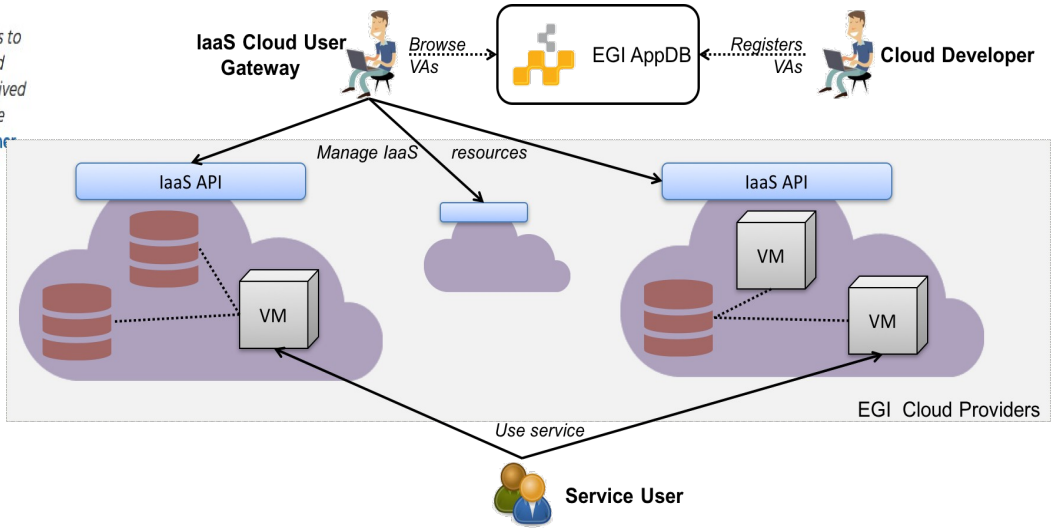
First person

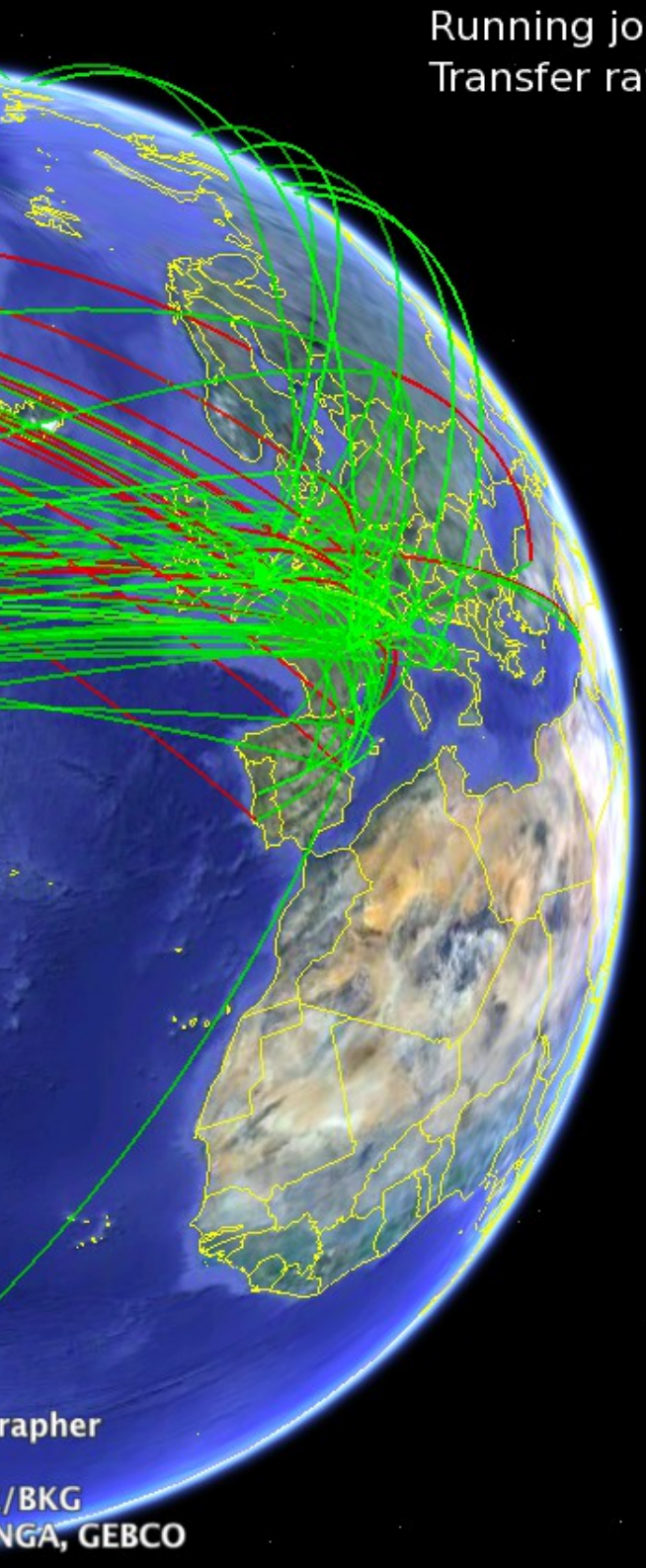
"EGI Cloud Compute helped us to handle computational demand peaks when new data sets arrived and by that sped up the whole process significantly." K. Förstner

More services

Cloud Container Compute

High-Throughput Compute





Today, Together

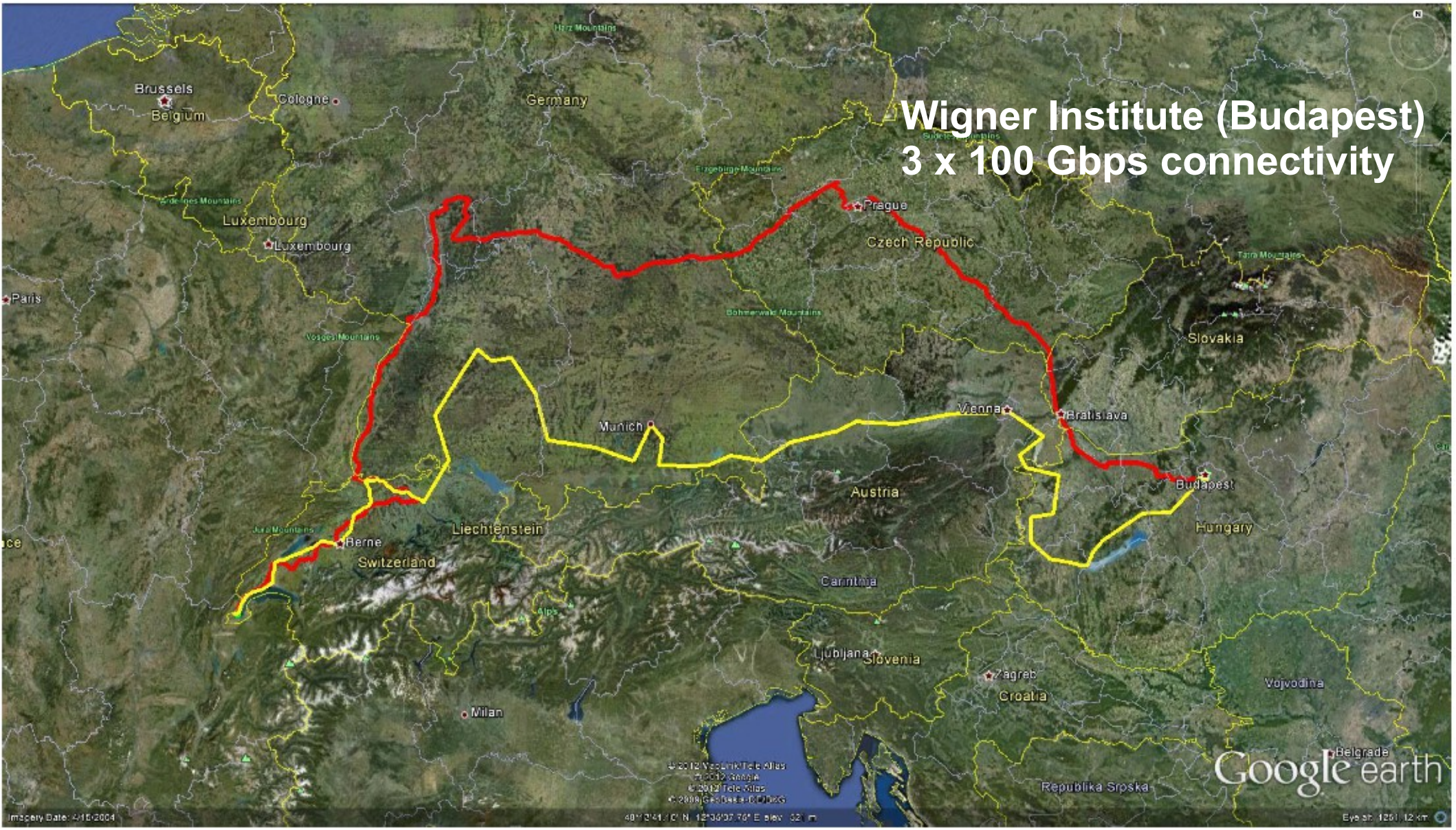
- Why grid computing
  - A success story : the grid for the LHC
- Other Grids
- Behind the scene
  - Technical details
- Going forward
  - Standards, simplicity, clouds
- Accessing the grid

References

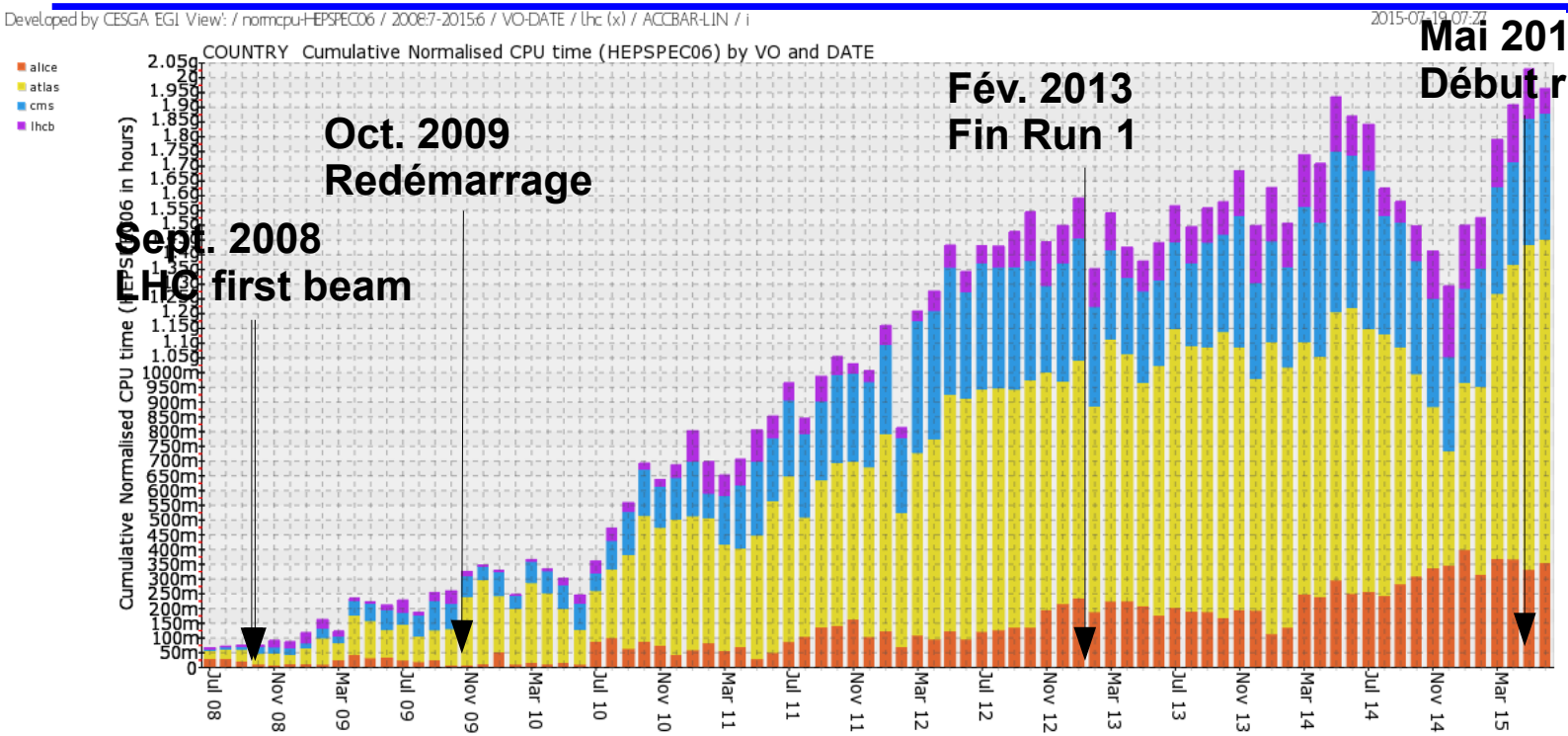
- International Conference on Computing in High Energ§y and Nuclear Physics (CHEP): http://www.chep2013.org/
- French summer school “Rencontres de physique de l'infiniment grand à l'infiniment petit”:
  - https://indico.in2p3.fr/conferenceDisplay.py?confId=7293
- French meeting “Les Journées réseaux” : https://conf-ng.jres.org/2013
- “Formation utilisateurs France-Grilles”: https://indico.in2p3.fr/conferenceDisplay.py?confId=6453
- International Symposium on Grids and Clouds (ISGC) 2013: http://indico3.twgrid.org/indico/conferenceDisplay.py?confId=370
- French Tutorial about the EGI usage: https://indico.in2p3.fr/conferenceDisplay.py?confId=6453
- CERN Summer Student Lecture 2011: https://indico.cern.ch/event/134624/

Additional material

Remote Tier-0

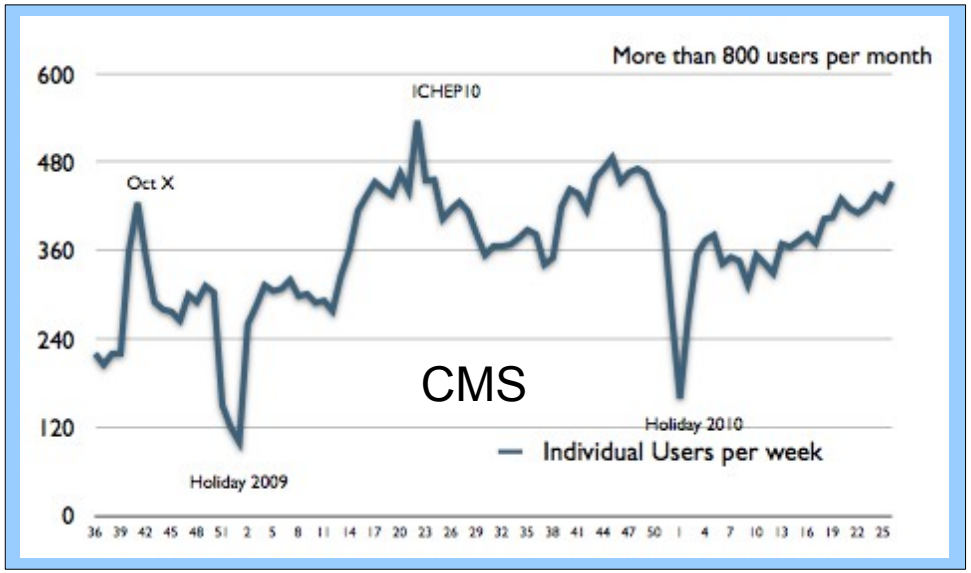


CPU delivered



CPU normaliseé

Ref : http://accounting.egi.eu/

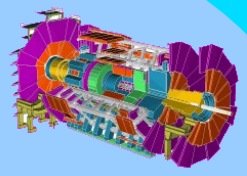


Specialised tasks

Tier-1

Tier-1

Tier-0



Tier-1

Tier-1

Tier-2

Tier-3

Tier-2

Tier-3

1 Tier-0
First processing
of raw data

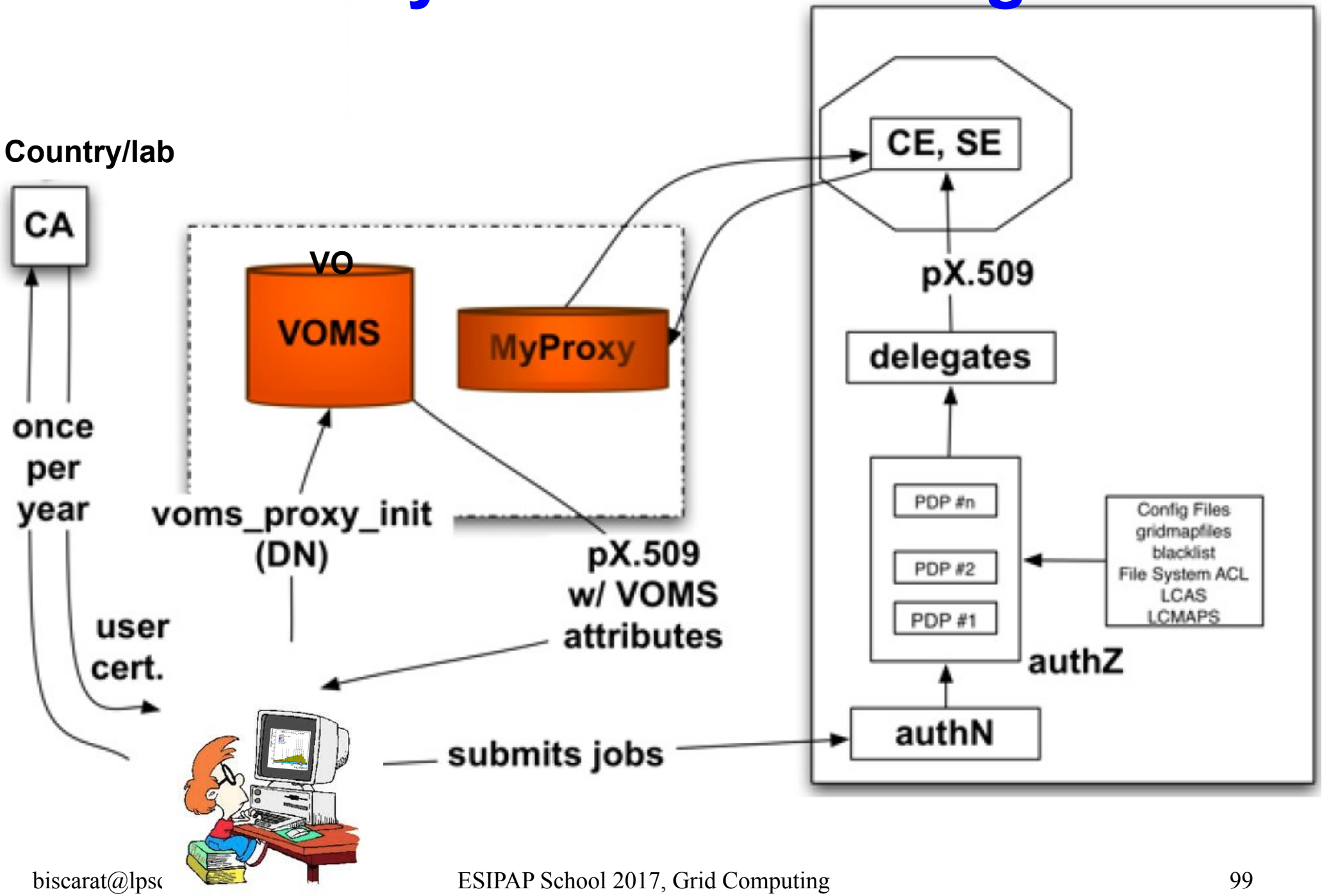
13 Tier-1
storage, re-construction
of raw data

150 Tier-2
Simulation

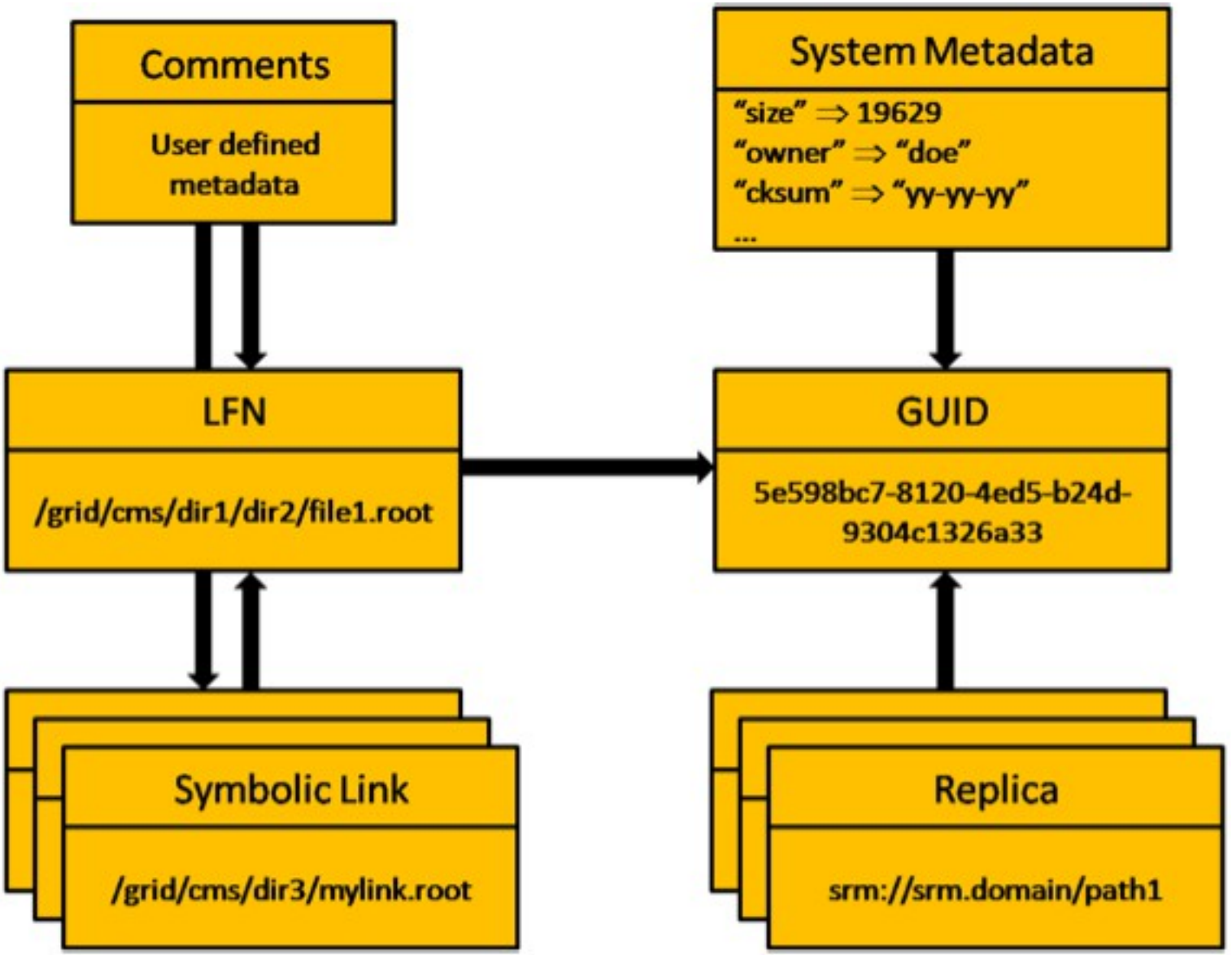
Tier-3
End-user analysis

Outside the grid
Final plot

Security: the root of the grid



LFC architecture

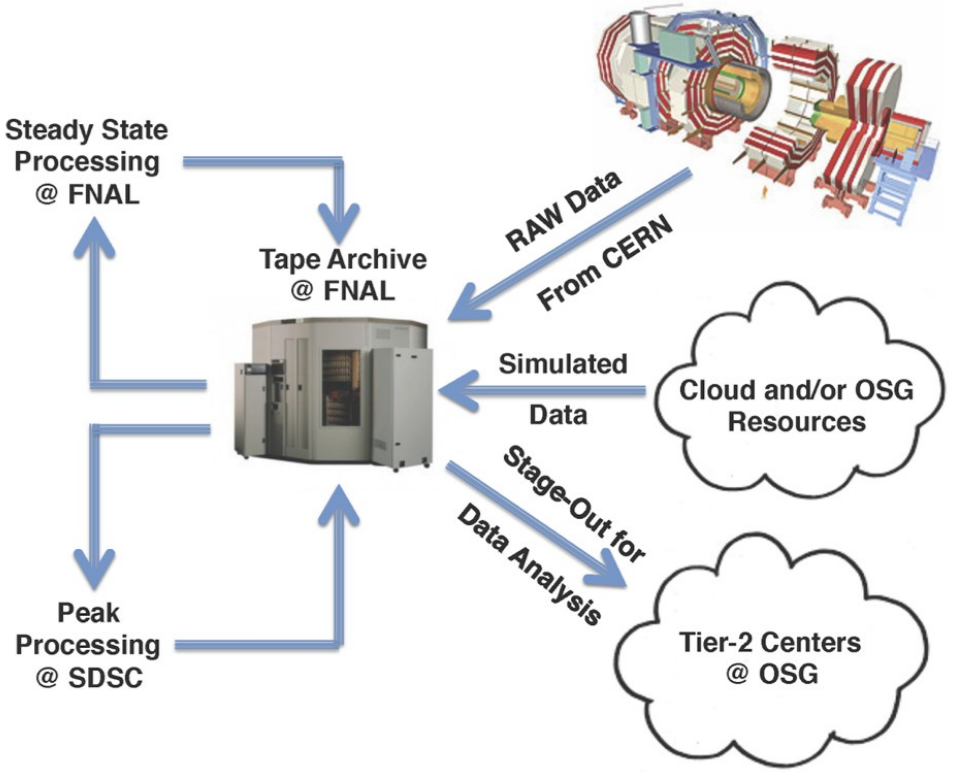


Usage of HPC centres for LHC

CMS using SDSC's Gordon Supercomputer

1024 Sandy Bridge nodes, 16 cores/node, 4 GB/core
Plus large memory supernodes
300 TB SSD storage

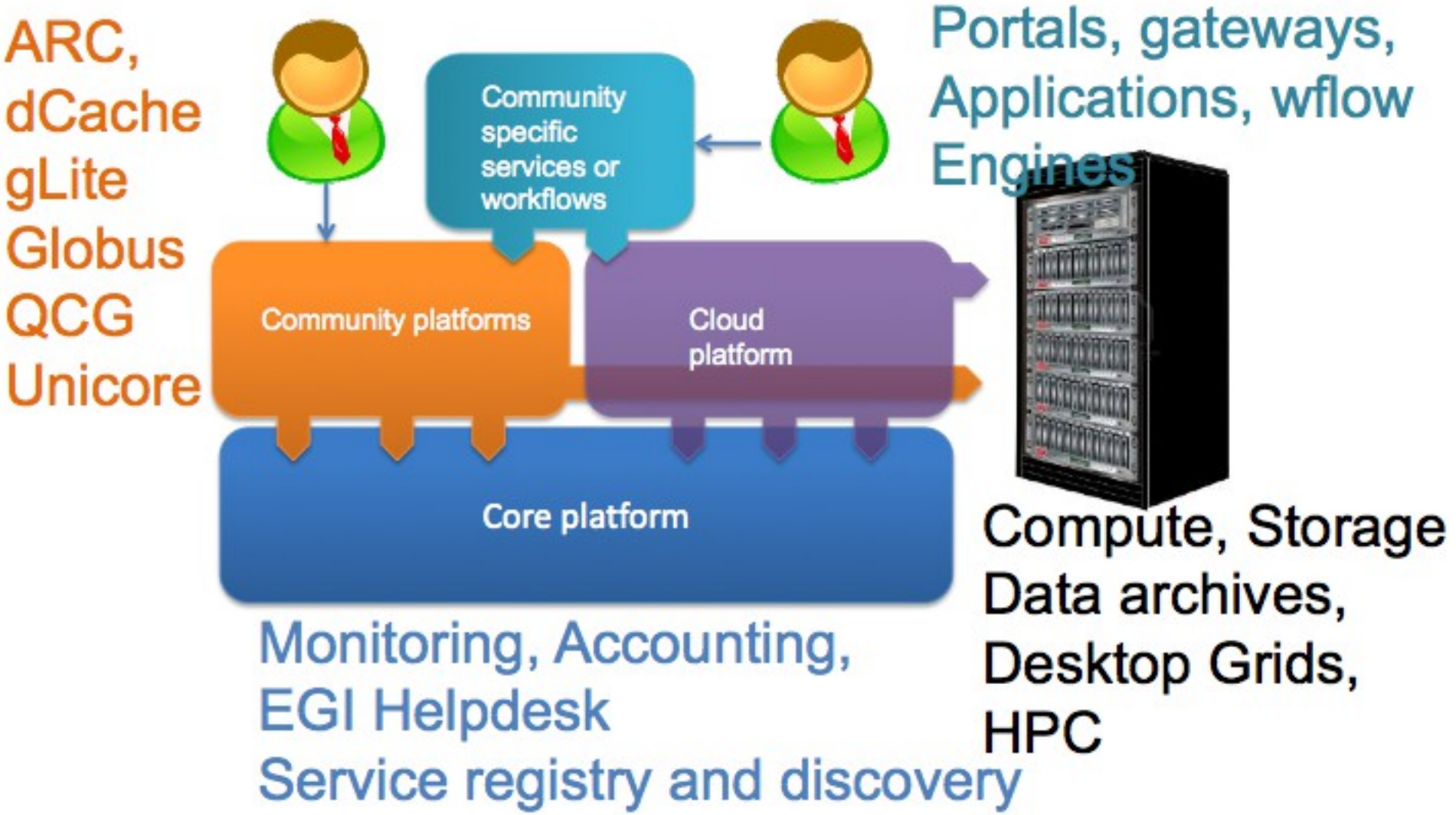
- early processing of 2012 parked data
- 125 TB in → 150 TB out



Number of HPC T2s

→ many other initiatives in this area

EGI platforms



EGI service evolution

- 'Old' Model
  - Isolated Technology Platforms
  - High Throughput Computing
- 'Current' Model
  - Integrated Technology Platforms
  - HPC, HTC, Data
- 'Future' Model
  - Federated Cloud Platform
  - Community Platforms

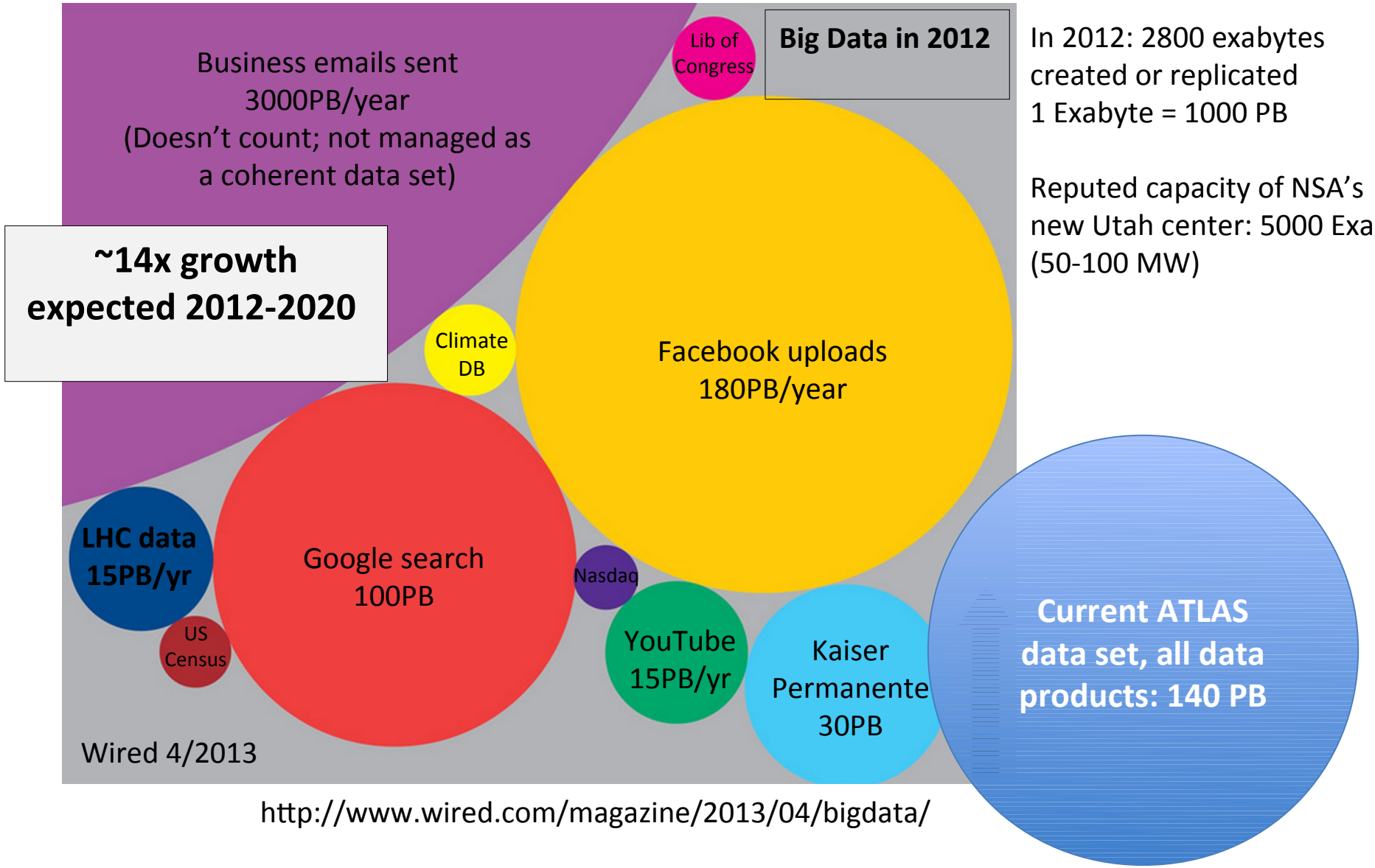
Still improving

- Behind the success of the grid
  - High complexity
  - High human resources

- We have gained in experience and we are still improving
  - Very stable network → new data model
  - Federated storage
  - Building common tools/interfaces

- Meanwhile we were developing the grid
  - Other areas do treat enormous amount of data
  - Standards tools have been developed
  - The “cloud” is born

Data set sizes

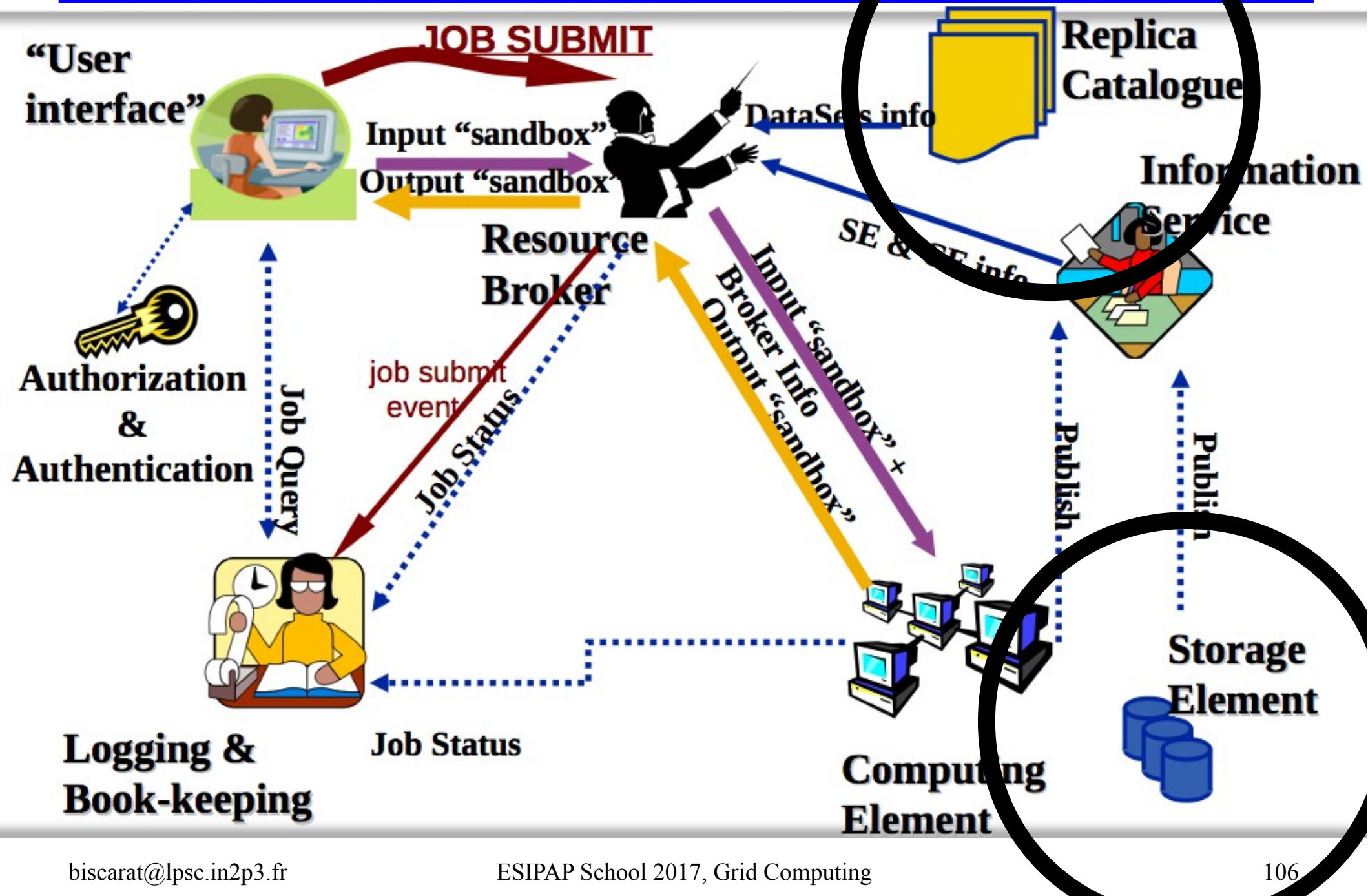


In 2012: 2800 exabytes created or replicated
1 Exabyte = 1000 PB

Reputed capacity of NSA's new Utah center: 5000 ExaB (50-100 MW)

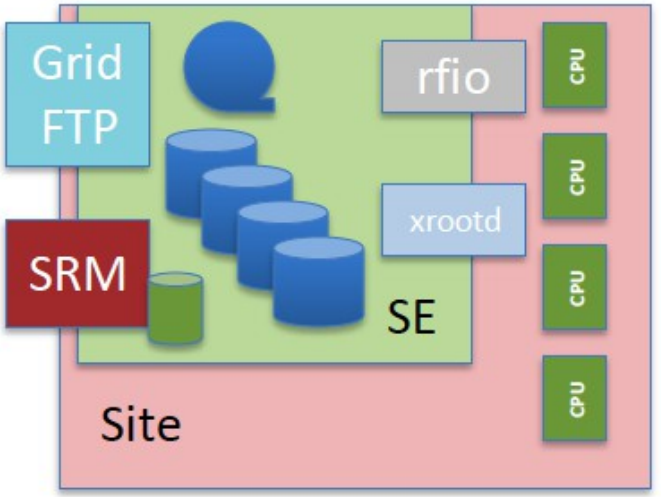
http://www.wired.com/magazine/2013/04/bigdata/

A word on


"User interface"
JOB SUBMIT
Input "sandbox"
Output "sandbox"
Resource Broker
DataSets info
Replica Catalogue
Information Service
SE & CE info
Authorization & Authentication
Job Query
job submit event
Job Status
Input "sandbox" + Broker Info
Output "sandbox"
Publish
Publish
Logging & Book-keeping
Job Status
Computing Element
Storage Element

Data management

- **Storage elements (SE)**
  - External interface to physical storage at sites
  - Different protocols (rfio, srm,)
  - Different storage system (dCache, xrootd, ...)

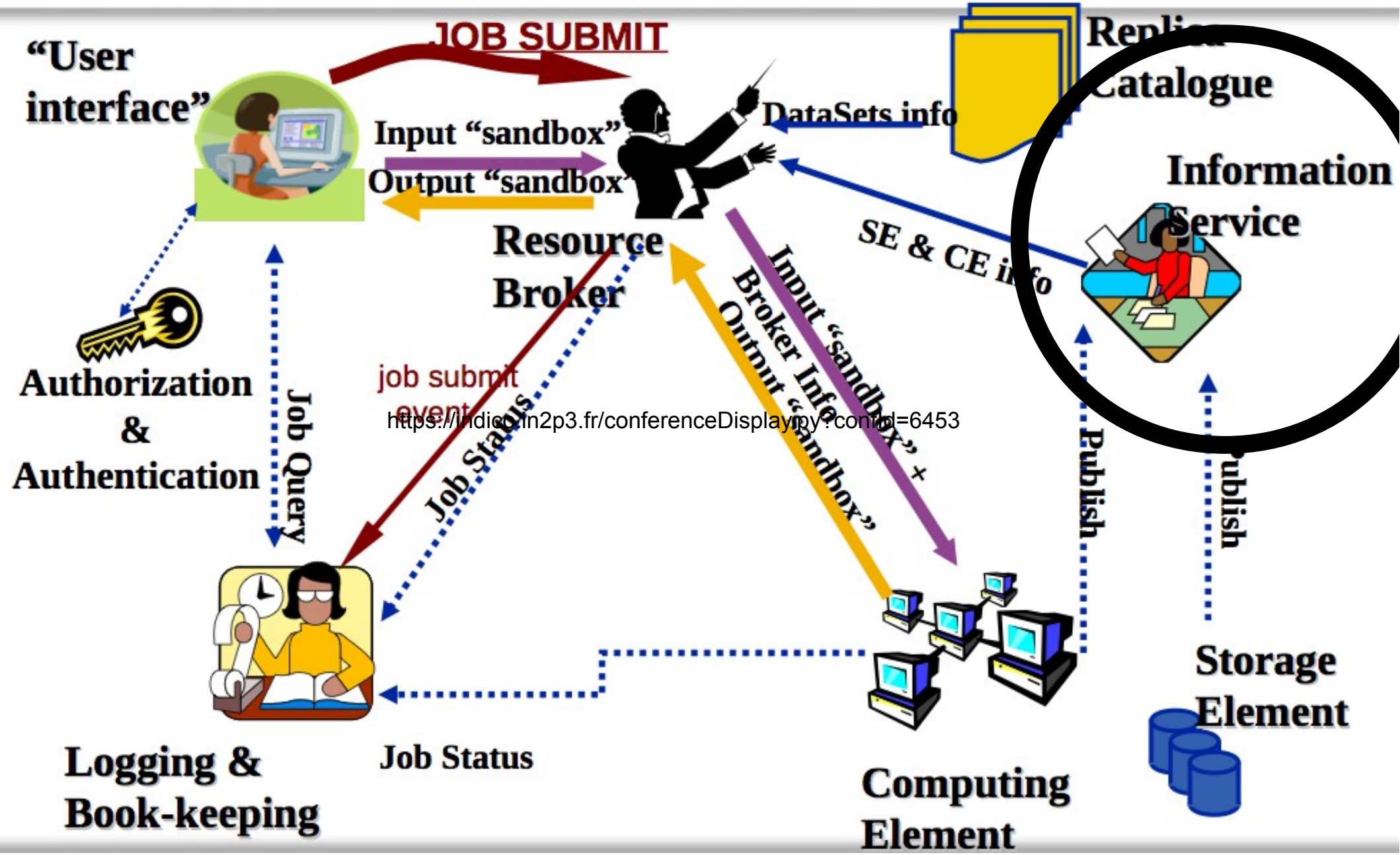


- **Storage resource manager (SRM)**
  - Hide heterogeneous systems
  - Handle authorisation

- **Local File Catalog (LFC)**
  - Locate files on the grid
  - Keep track of the file (user's name ↔ file location)

- **File Transfer Service (FTS)**
  - Multi-VO service
  - Handles prioritisation

A word on


JOB SUBMIT
"User interface"
Input "sandbox"
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DataSets info
Catalogue
Information Service
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Resource Broker
Authorization & Authentication
Job Query
job submit event
Job Status
Input "sandbox" + Broker Info
Output "sandbox"
Publish
Publish
https://indico.in2p3.fr/conferenceDisplay.py?confId=6453
Logging & Book-keeping
Job Status
Computing Element
Storage Element

Information system

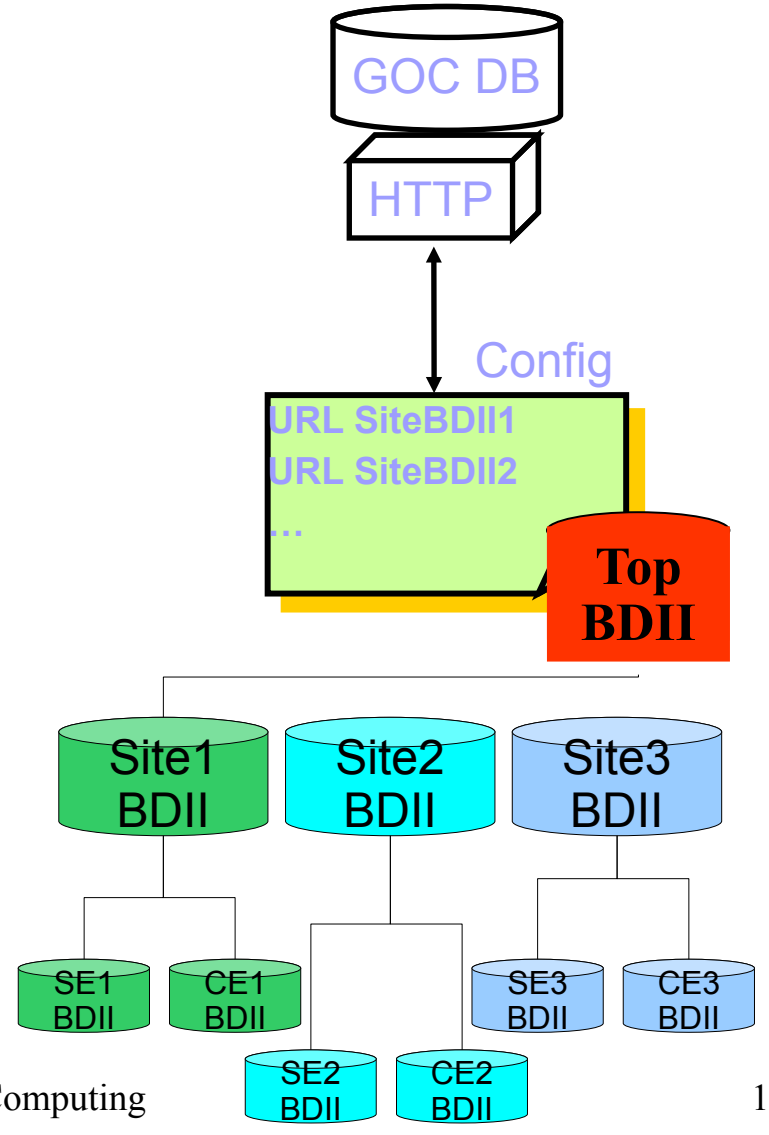
- In charge of collecting the information on the status of the site and services
  - Format understandable by both parties

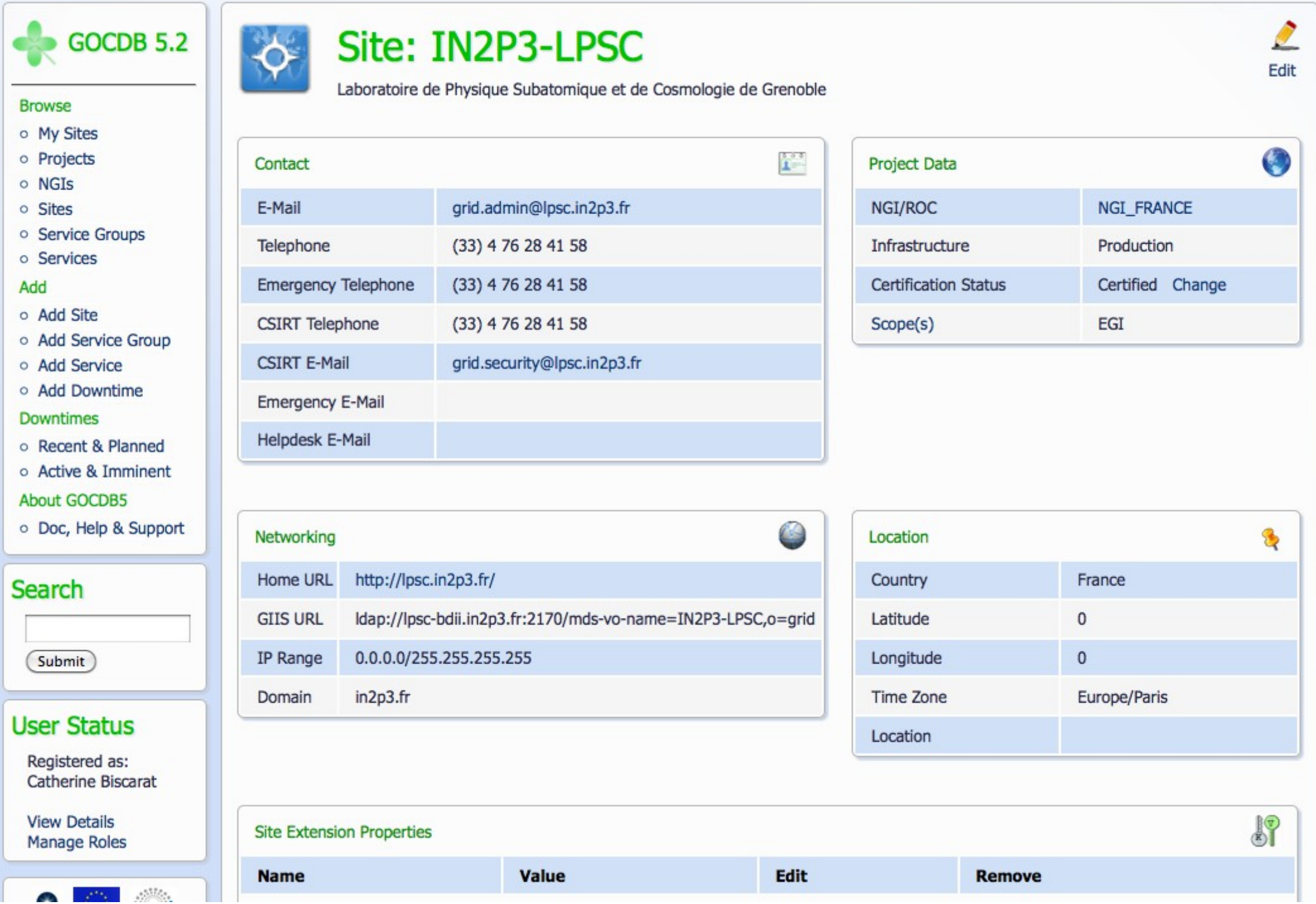
- Sites publish:
  - Status of the services
  - Their resources
- VOs publish:
  - The software installed on the sites

- BDII (GlueSchema):
  - Sites BDII
  - Top BDII
  - Commands:
    - Ldapsearch
    - lcg-infosites

- GOC DB: reference for all the EGI sites

  http://goc.egi.eu/



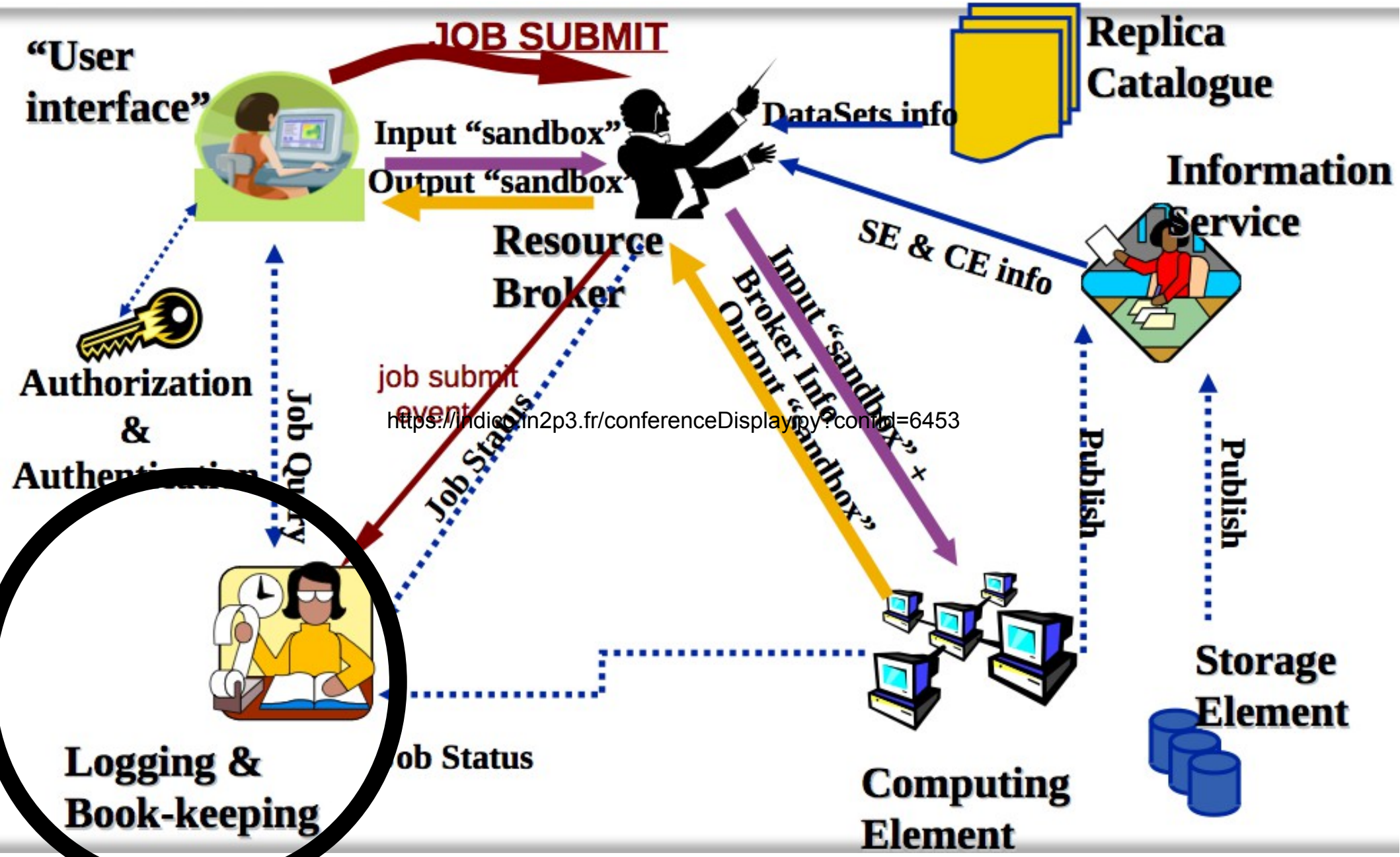

GOCDB 5.2
Browse
My Sites
Projects
NGIs
Sites
Service Groups
Services
Add
Add Site
Add Service Group
Add Service
Add Downtime
Downtimes
Recent & Planned
Active & Imminent
About GOCDB5
Doc, Help & Support
Search
Submit
User Status
Registered as:
Catherine Biscarat
View Details
Manage Roles
Site: IN2P3-LPSC
Laboratoire de Physique Subatomique et de Cosmologie de Grenoble
Edit
Contact
E-Mail grid.admin@lpsc.in2p3.fr
Telephone (33) 4 76 28 41 58
Emergency Telephone (33) 4 76 28 41 58
CSIRT Telephone (33) 4 76 28 41 58
CSIRT E-Mail grid.security@lpsc.in2p3.fr
Emergency E-Mail
Helpdesk E-Mail
Project Data
NGI/ROC NGI_FRANCE
Infrastructure Production
Certification Status Certified Change
Scope(s) EGI
Networking
Home URL http://lpsc.in2p3.fr/
GIIS URL ldap://lpsc-bdii.in2p3.fr:2170/mds-vo-name=IN2P3-LPSC,o=grid
IP Range 0.0.0.0/255.255.255.255
Domain in2p3.fr
Location
Country France
Latitude 0
Longitude 0
Time Zone Europe/Paris
Location
Site Extension Properties
Name
Value
Edit
Remove

Services

Hostname (service type)	URL	Production	Monitored	Scope(s)
lpsc-cream-ce.in2p3.fr (APEL)		✓	✓	EGI
lpsc-bdii.in2p3.fr (Site-BDII)		✓	✓	EGI
lpsc-vobox.in2p3.fr (VO-box)		✓	✓	EGI
lpsc-ce.in2p3.fr (CREAM-CE)		✓	✓	EGI
lpsc-cream-ce.in2p3.fr (CREAM-CE)		✓	✓	EGI
lpsc-se-dpm-server.in2p3.fr (SRM)		✓	✓	EGI
lpsc-ce.in2p3.fr (gLExec)		✓	✓	EGI
lpsc-cream-ce.in2p3.fr (gLExec)		✓	✓	EGI
lpsc-ce.in2p3.fr (eu.egi.MPI)		✓	✓	EGI
lpsc-cream-ce.in2p3.fr (eu.egi.MPI)		✓	✓	EGI
lpsc-perfsonar.in2p3.fr (net.perfSONAR.Bandwidth)		✓	✓	EGI
lpsc-perfsonar2.in2p3.fr (net.perfSONAR.Latency)		✓	✓	EGI
lpsc-ce2.in2p3.fr (CREAM-CE)		✓	✓	EGI
lpsc-ce2.in2p3.fr (eu.egi.MPI)		✓	✓	EGI
lpsc-ce2.in2p3.fr (gLExec)		✓	✓	EGI

Add Service

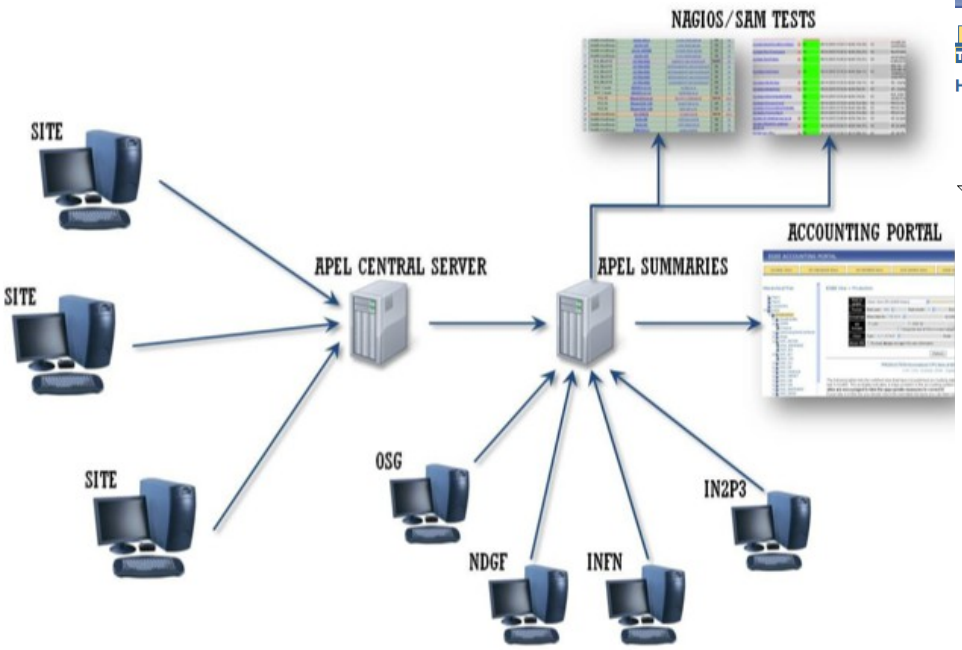
A word on

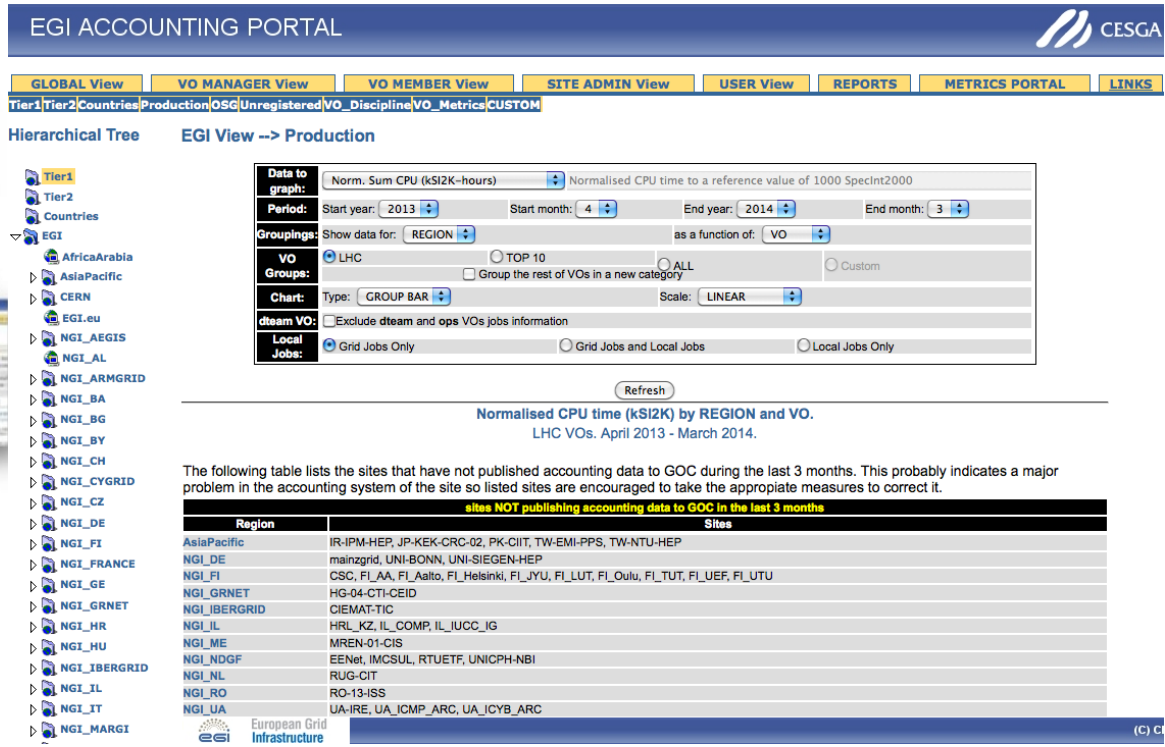


https://indico.in2p3.fr/conferenceDisplay.py?confId=6453

Accounting

- Accounting for the computing and storage resources
  - Sites share VOs
  - MoU signed with “pledges”





http://accounting.egi.eu/egi.php