HEP Grid Initiatives in Brazil

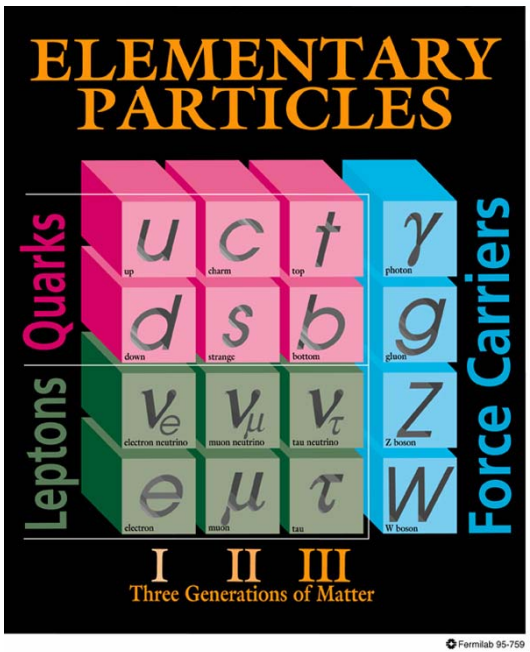
S. F. Novaes

UNESP

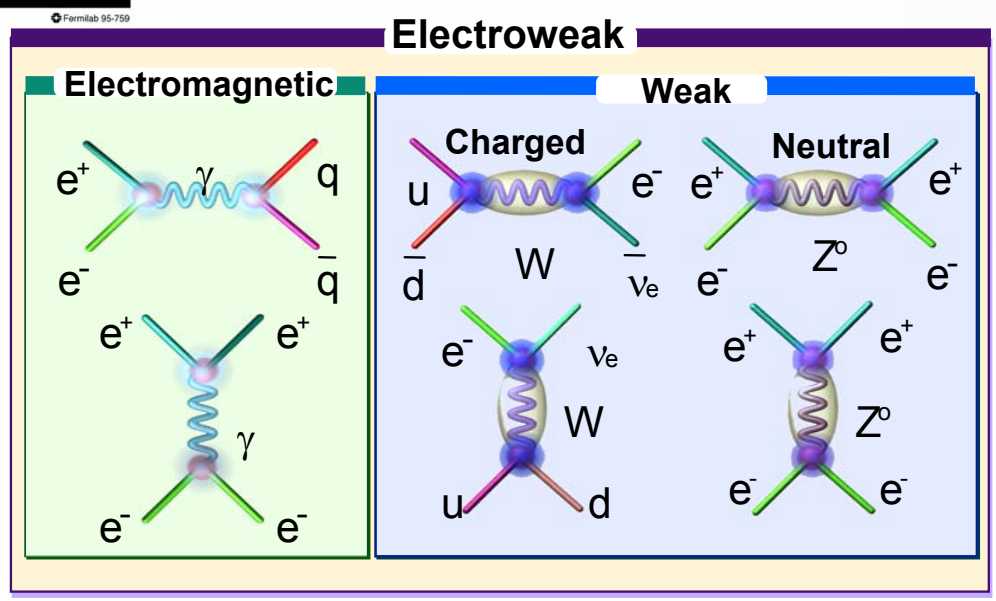
HEP Grid

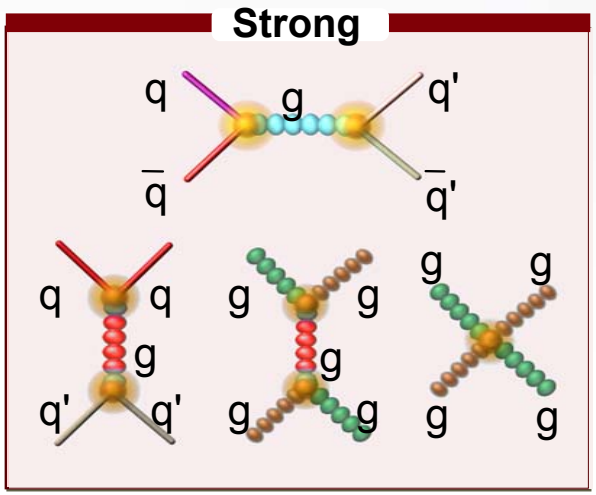
- Purpose of HEP
- Complexity of HEP
- DØ (Fermilab) and CMS (CERN)
- An avalanche of Data
- Grid: A New Computing Architecture
- Brazilian Initiatives
- Future Outlook

Purpose of High Energy Physics

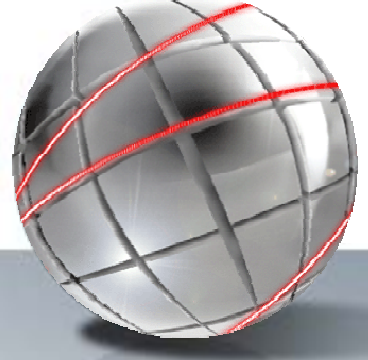


Investigate the building blocks of matter and their interaction



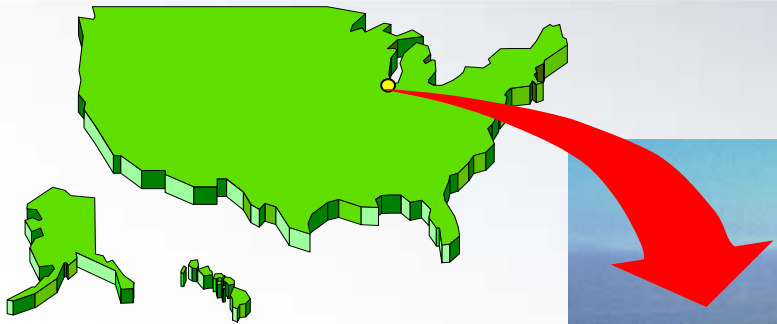


High Energy Physics Complexity



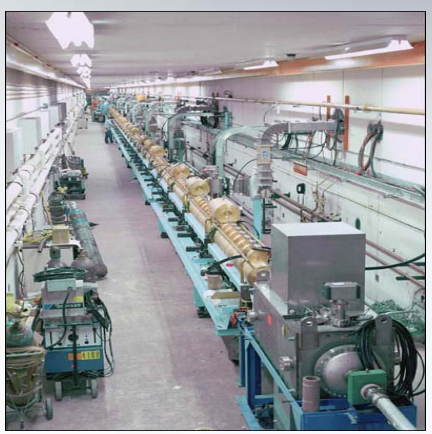
- HEP has some singular characteristics:
  - Has a very complex instrumentation (hardware, electronics)
  - Requires the expertise from several different areas
  - Involves large collaborations from widely spread institutions
  - Yields very complex events (collisions)
  - Produces an enormous amount of data
- HEP needs:
  - Efficient communication among all over the world
  - Very large computer power

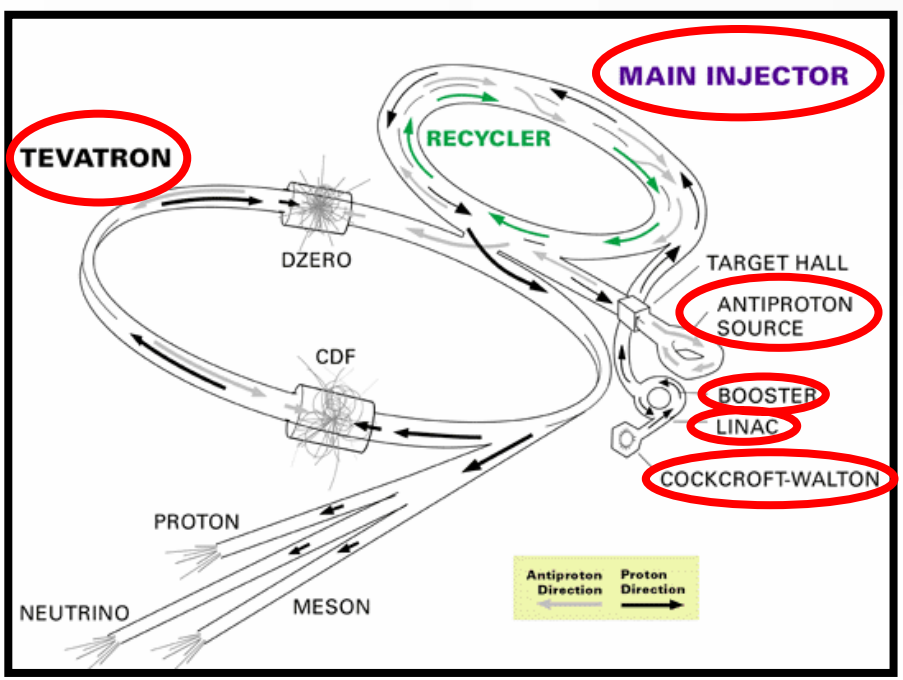
Tevatron at Fermilab

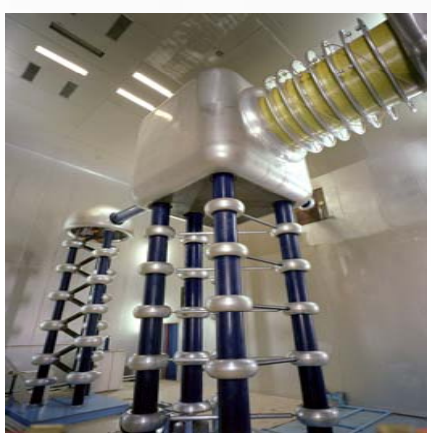


- World's highest energy
  - E = 1.96 TeV
  - Luminosity = 0.7 fb^{-1}
- Two interaction points:
  - CDF
  - DØ

Tevatron Components

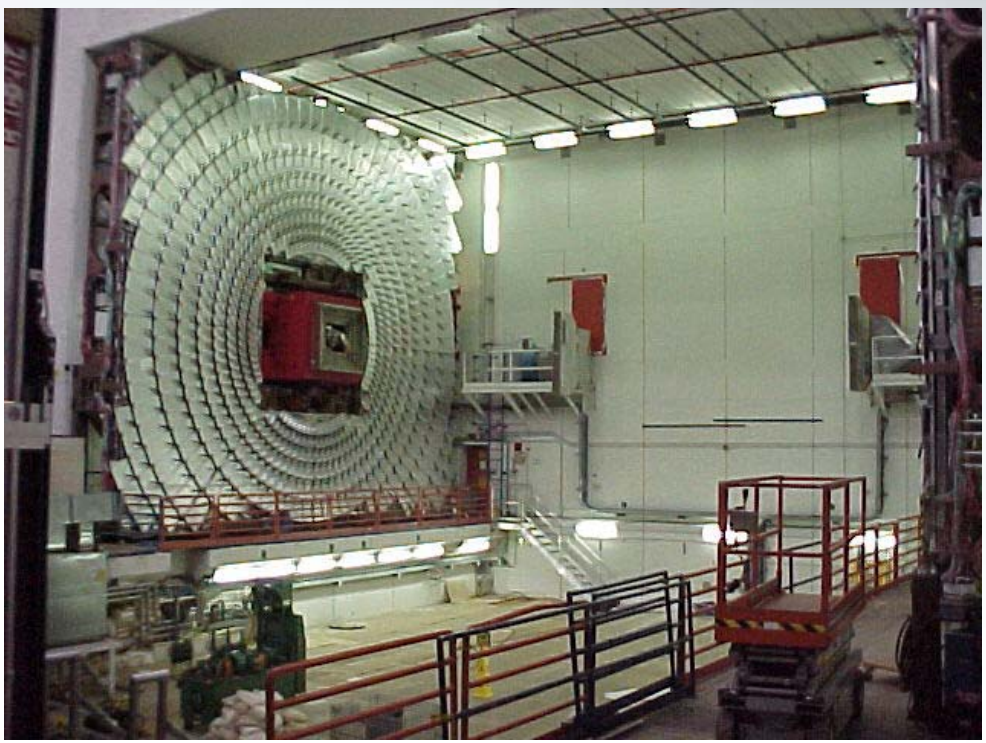






DØ Control Room

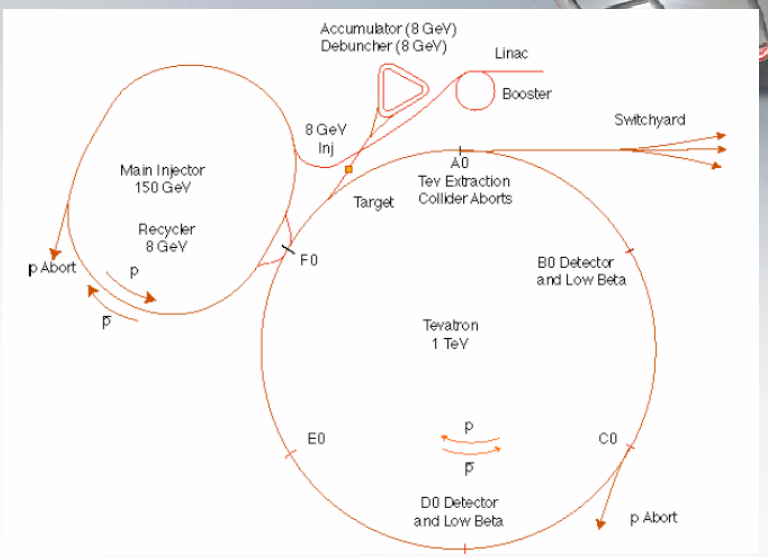
DØ Detector and Collision Hall

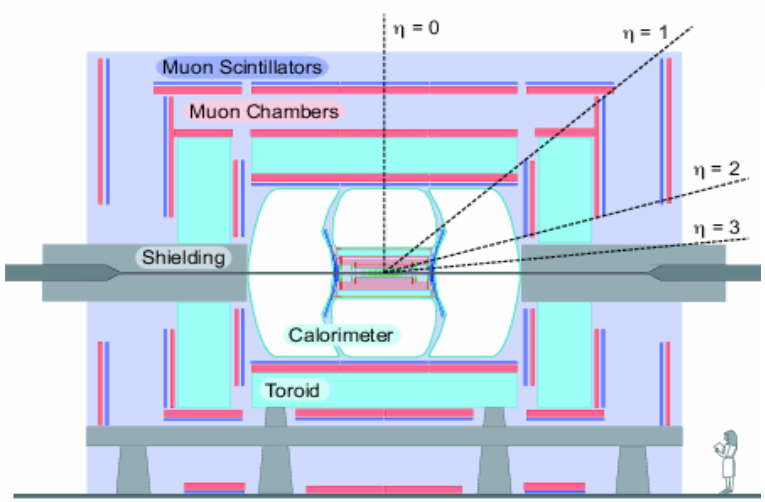


February 2001

Tevatron/DØ Trivia

- Synchrotron with 6.28 km
- 1,000 Superconducting magnets
- 36 proton/antiproton bunches
- 27 (8) X 10^{10} nucleons/bunch
- 396 ns between collisions
- 3,000,000 collisions/second
- Budget US$ 300 millions (40% HEP)





- 5 stores high
- 20 meters long
- 5,500 tons
- 800,000 electronic channels
- 1,500 km of wires
- Software:
  - **700 Packages**
  - **2 GB of Code (5.3 GB executable)**
  - **2 GB of Libraries**

The DØ Collaboration

18 countries

North, Central,
South Americas
Europe, Asia

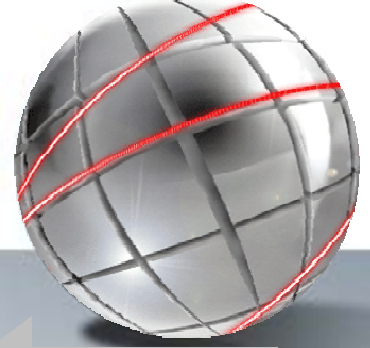
73 institutions

33 US
40 non-US

646 physicists

334 US
312 non-US

Physics Program



2008

15 fb^{-1}
- 5σ Higgs signal @ m_H = 115 GeV
- 3σ Higgs signal @ m_H = 115-135, 150-175 GeV
- Reach ultimate precision for top, W, B physics

10 fb^{-1}
- 3σ Higgs signal @ m_H = 115-125, 155-170 GeV
- Exclude Higgs over whole range of 115-180 GeV
- Possible discovery of supersymmetry in a larger fraction of parameter space

5 fb^{-1}
- 3σ Higgs signal @ m_H = 115 GeV
- Exclude SM Higgs 115-130, 155-170 GeV
- Exclude much of SUSY Higgs parameter space
- Possible discovery of supersymmetry in a significant fraction of minimal SUSY parameter space (the source of cosmic dark matter?)

Run IIb

2 fb^{-1}
- Measure top mass ± 3 GeV and W mass ± 25 MeV
- Directly exclude m_H = 115 GeV
- Significant SUSY and SUSY Higgs searches
- Probe extra dimensions at the 2 TeV (10^{-19} m) scale
- B physics: constrain the CKM matrix

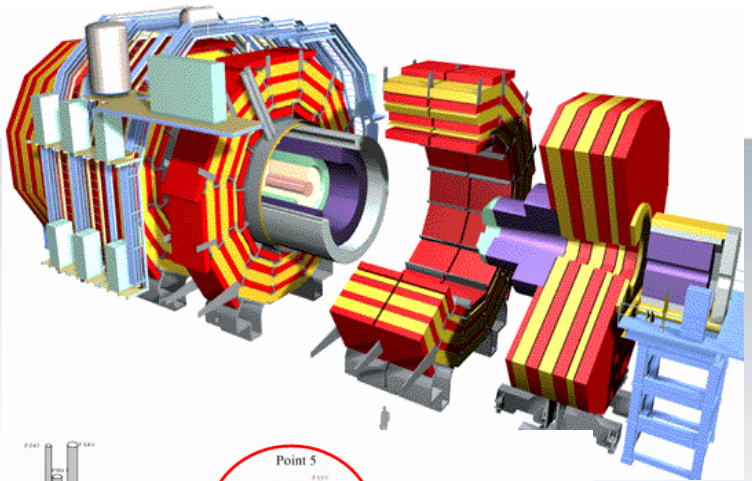
2005

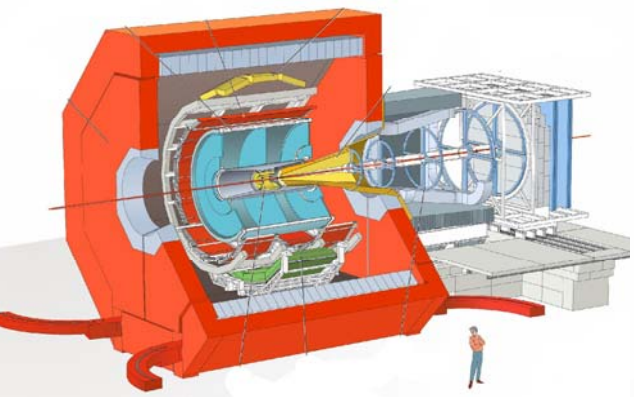
300 pb^{-1}
- Improved top mass measurement
- High p_T jets constrain proton structure
- Start to explore B_S mixing and B physics
- SUSY Higgs search @ large tan β
- Searches beyond Run I sensitivity

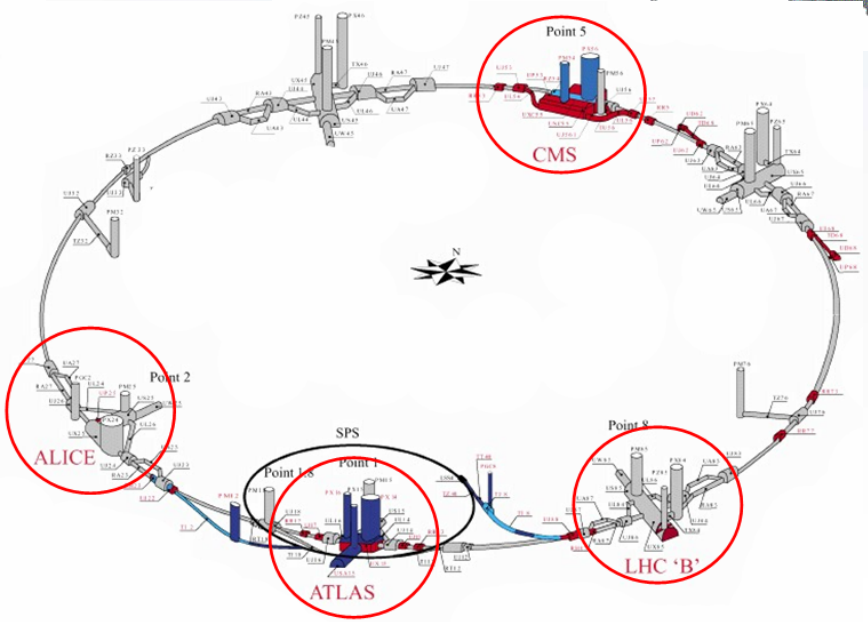
Run IIa

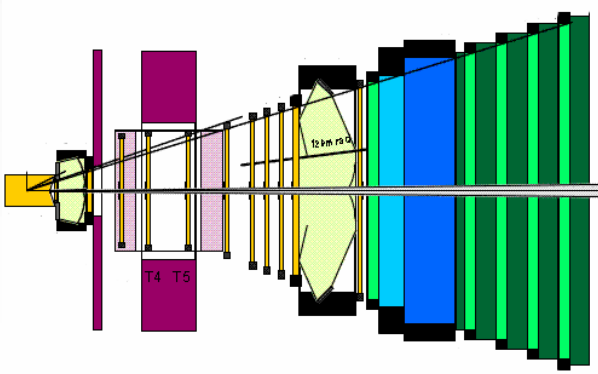
CERN

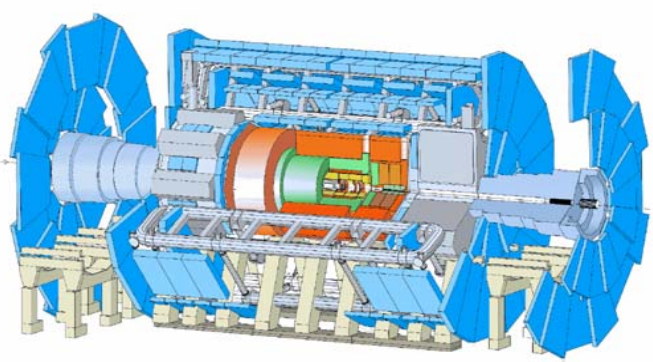
LHC





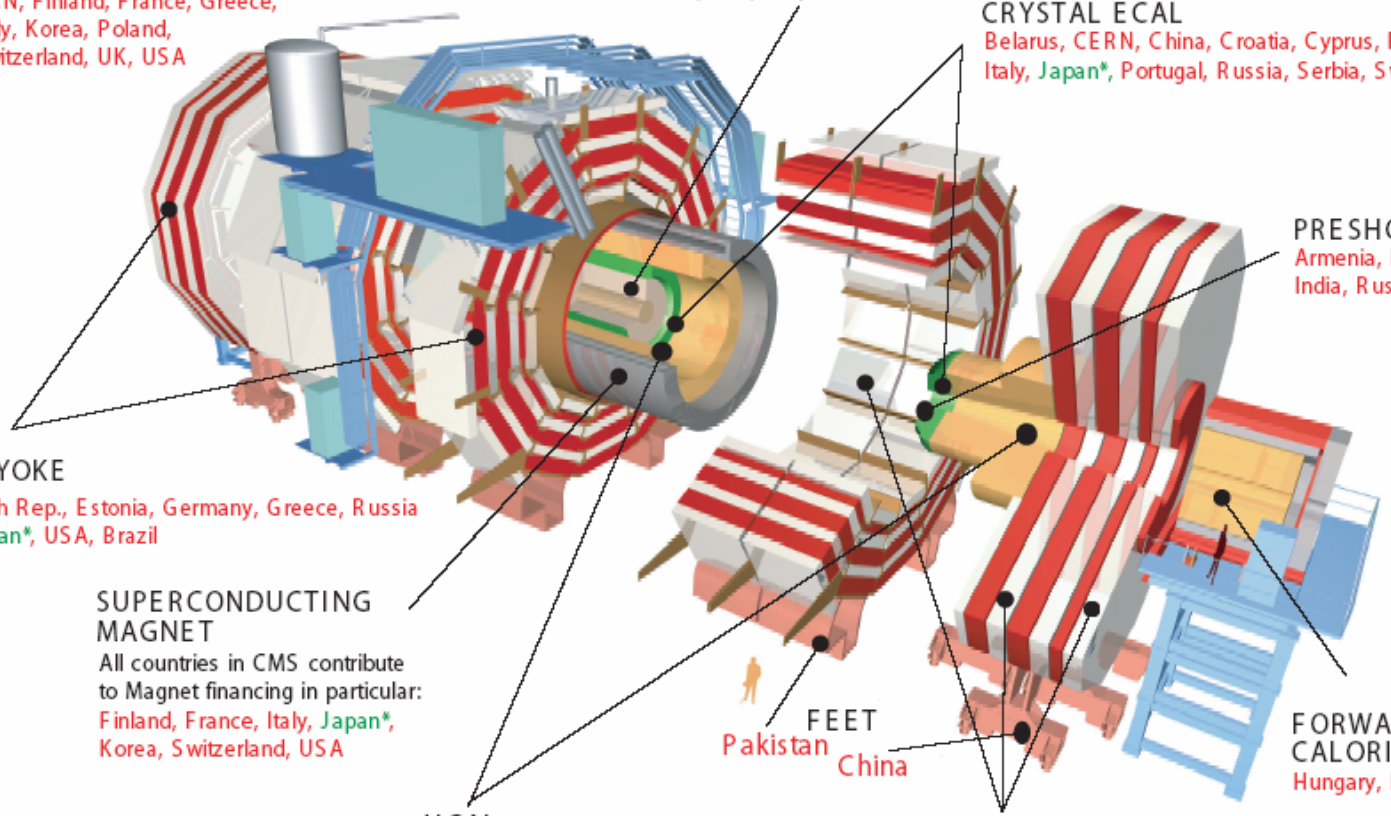






CMS Collaboration

36 Nations, 160 Institutions, 2008 Scientists and Engineers (November 2003)



TRIGGER & DATA ACQUISITION
Austria, CERN, Finland, France, Greece, Hungary, Italy, Korea, Poland, Portugal, Switzerland, UK, USA

TRACKER
Austria, Belgium, CERN, Finland, France, New Zealand Germany, Italy, Japan*, Switzerland, UK, USA

CRYSTAL ECAL
Belarus, CERN, China, Croatia, Cyprus, France, Ireland Italy, Japan*, Portugal, Russia, Serbia, Switzerland, UK, USA

PRESHOWER
Armenia, Belarus, CERN, Greece, India, Russia, Taipei, Uzbekistan

RETURN YOKE
Barrel: Czech Rep., Estonia, Germany, Greece, Russia
Endcap: Japan*, USA, Brazil

SUPERCONDUCTING MAGNET
All countries in CMS contribute to Magnet financing in particular:
Finland, France, Italy, Japan*, Korea, Switzerland, USA

FEET
Pakistan
China

FORWARD CALORIMETER
Hungary, Iran, Russia,Turkey, USA

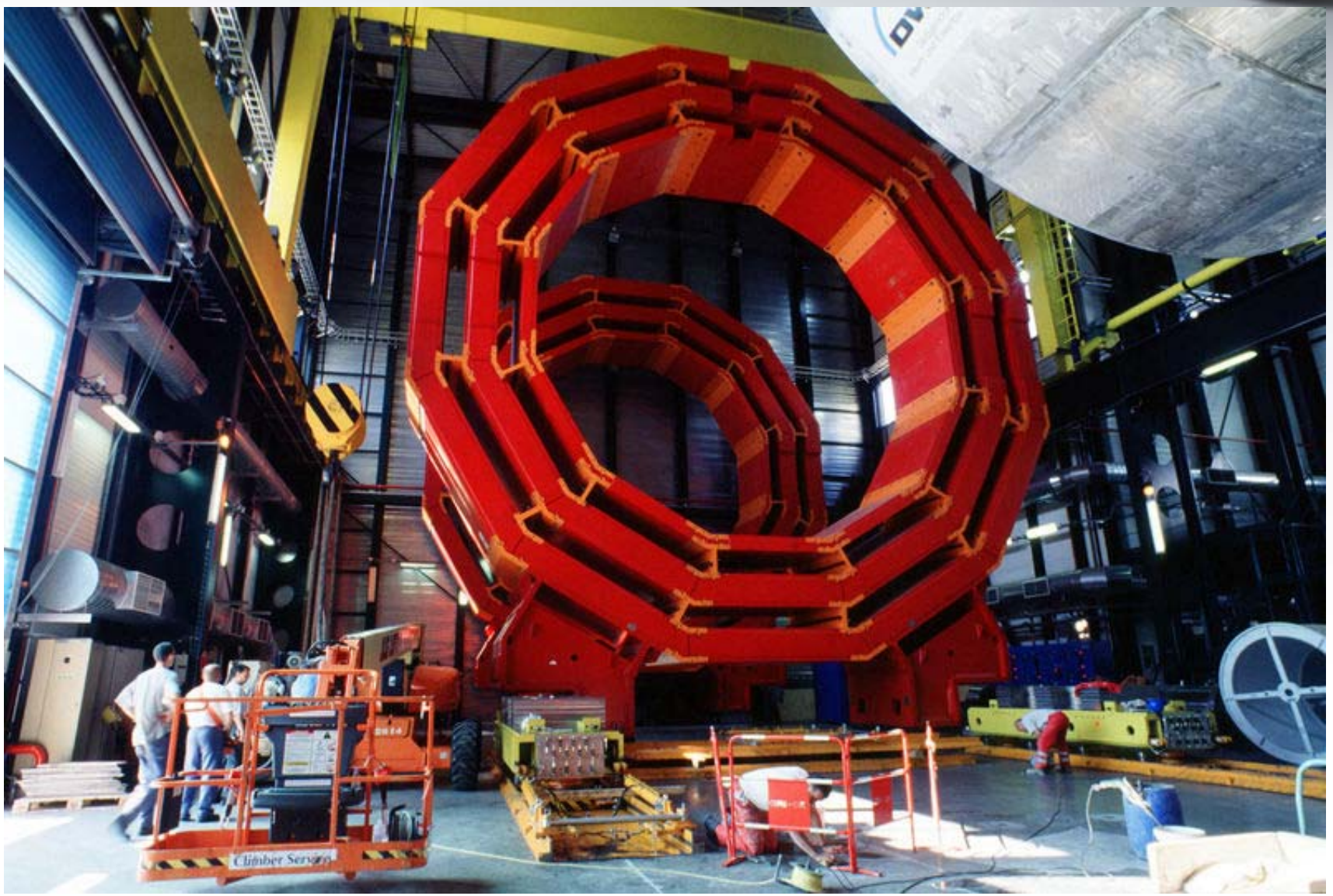
HCAL
Barrel: Bulgaria, India, Spain*, USA
Endcap: Belarus, Bulgaria, Russia, Ukraine
HO: India

MUON CHAMBERS
Barrel: Austria, Bulgaria, CERN, China, Germany, Hungary, Italy, Spain,
Endcap: Belarus, Bulgaria, China, Korea, Pakistan, Russia, USA

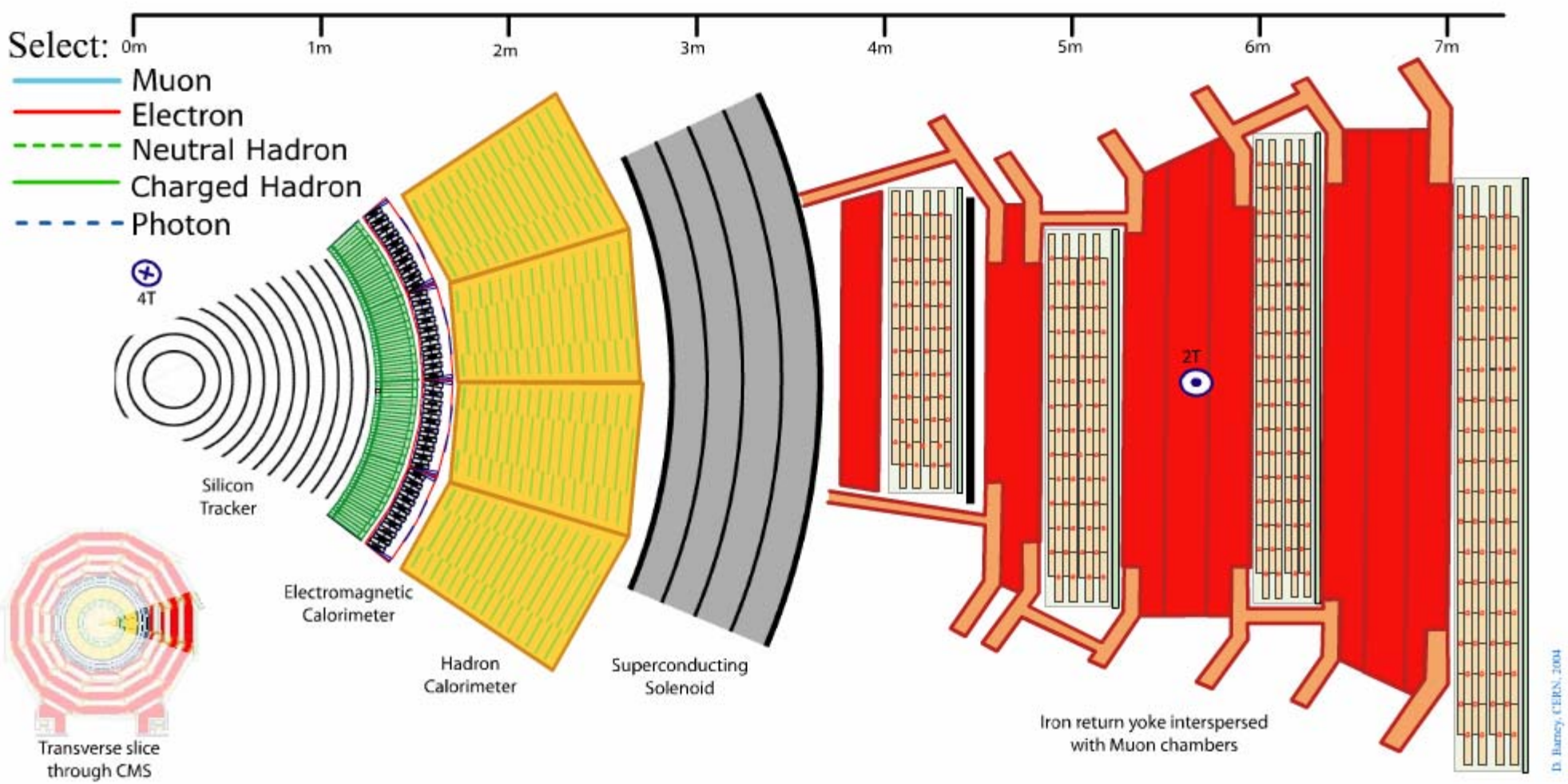
Total weight	:	12500 T
Overall diameter	:	15.0 m
Overall length	:	21.5 m
Magnetic field	:	4 Tesla

* Only through industrial contracts

CMS Detector

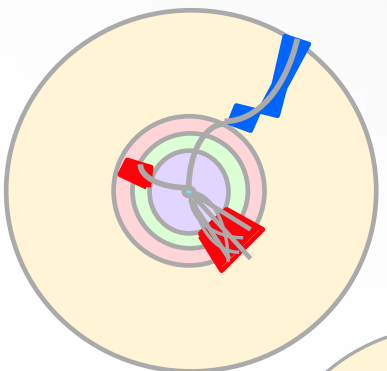


Particles in the CMS Detector



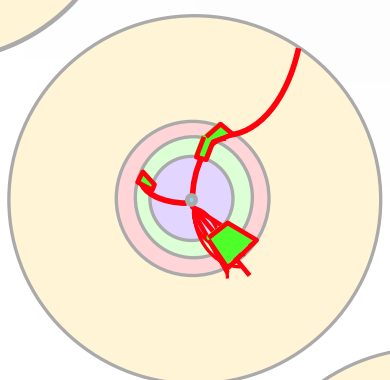
CMS Trigger

Collision rate 10^9 Hz



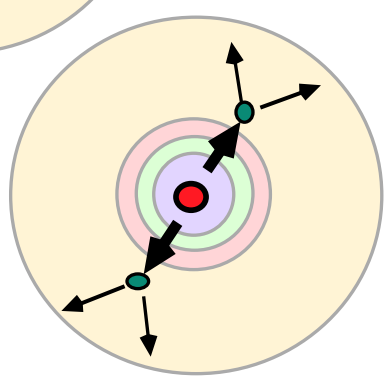
Level 1 selected events 10^5 Hz

Particle identification (e, μ, jets, missing E)



Level 2 selected events 10^3 Hz

Clean particle signature (Z, W, ..)

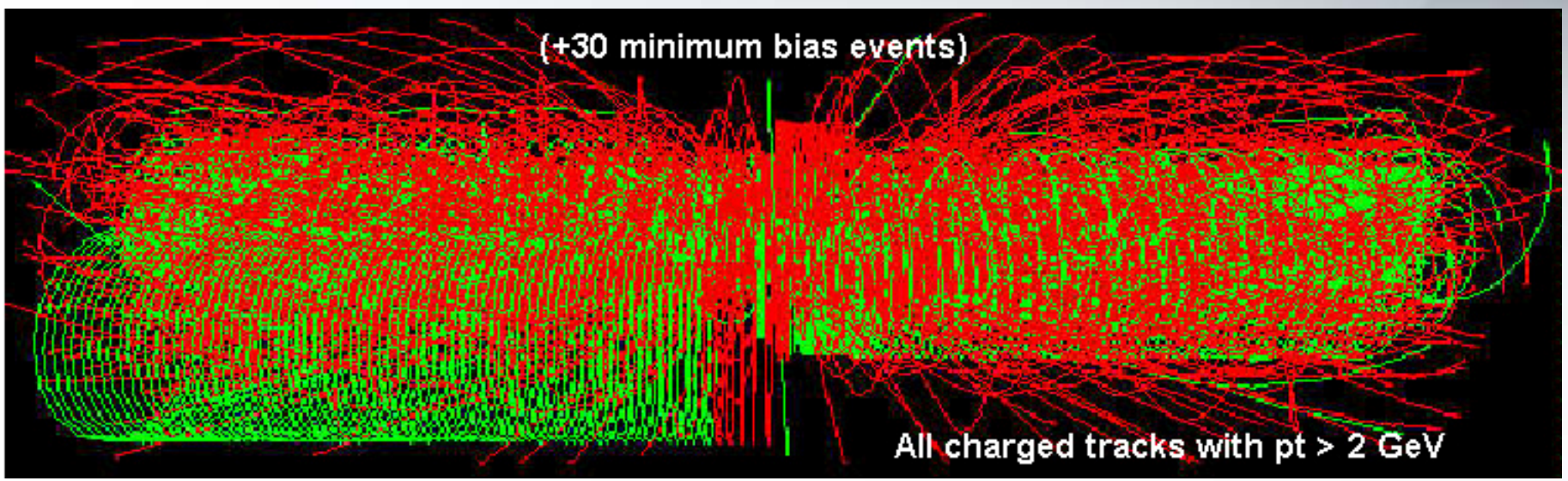


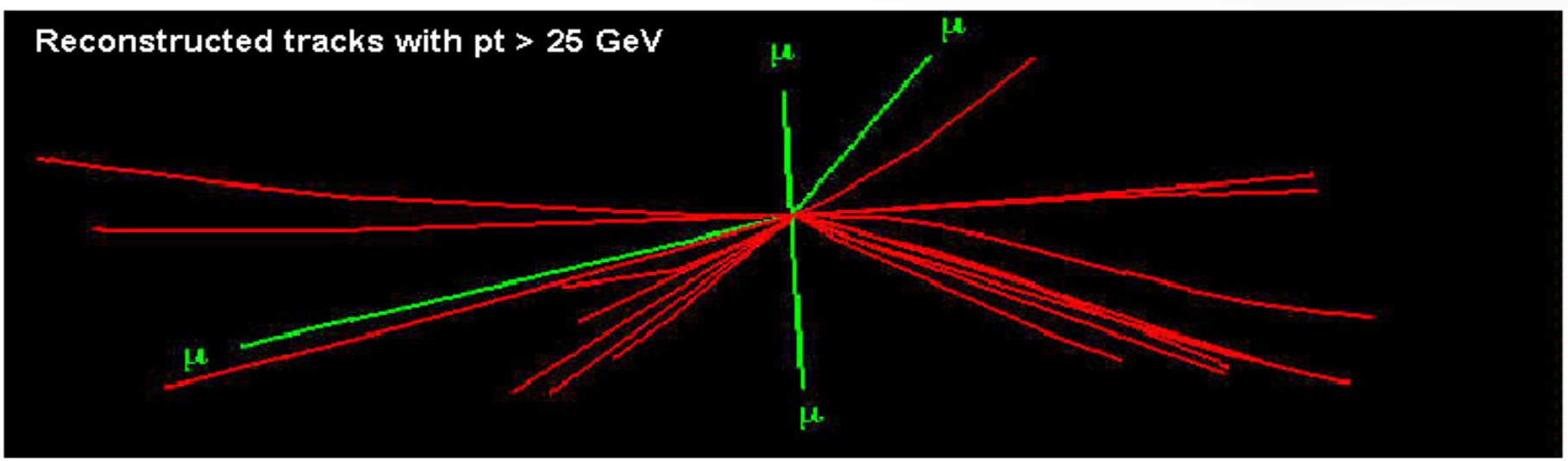
Level 3 events to tape 10^2 Hz

Physics process identification

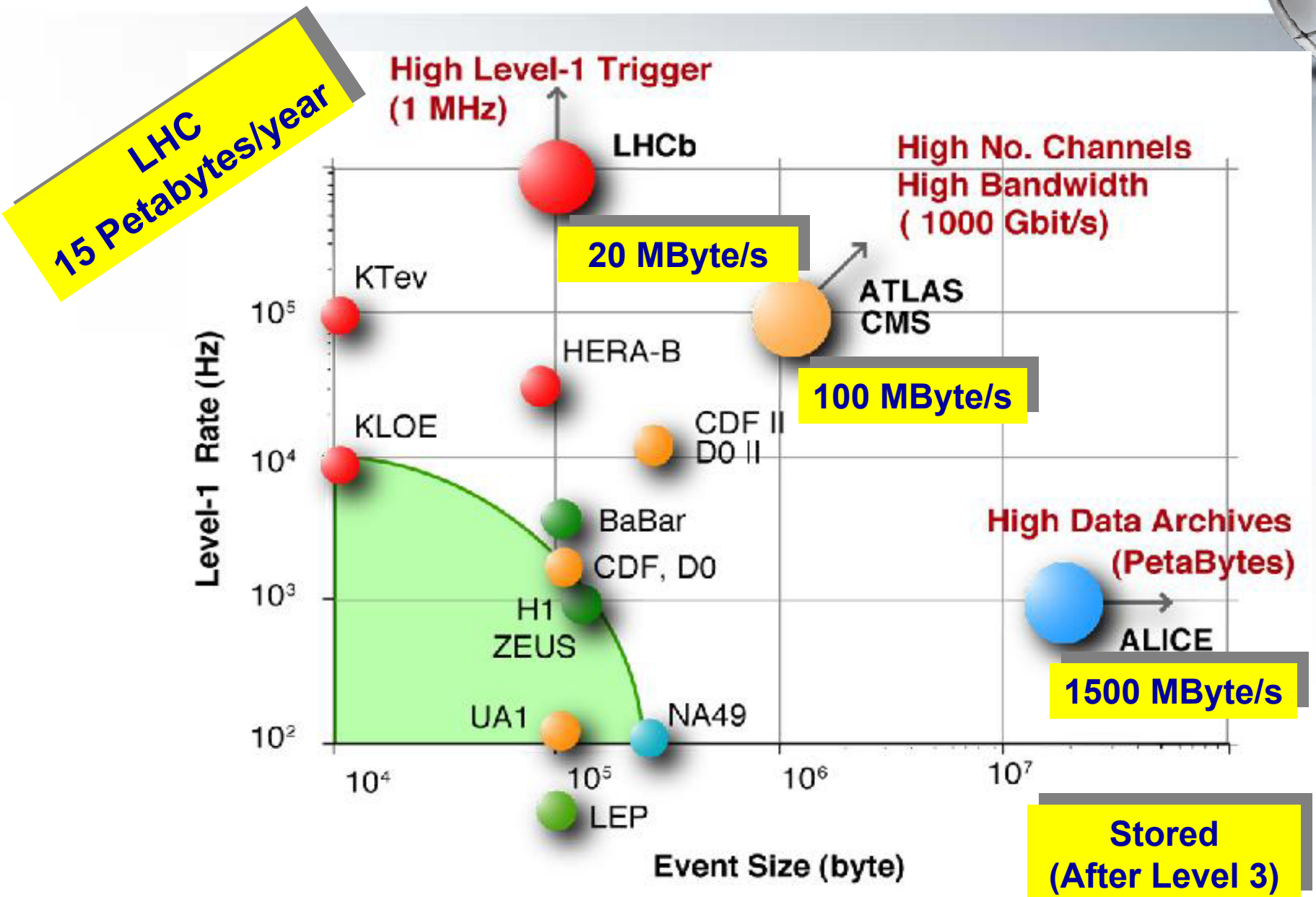
Extremely complex events

$$H \rightarrow Z(\rightarrow \mu^+\mu^-) + Z(\rightarrow \mu^+\mu^-)$$





Rates and Event Size



LHC: The Exabyte Era

1 Caracter (letter, number, etc)	*1 byte*
1/2 Page of text	*1 KB (Kilobyte) = 10^3 bytes*
1 Book	*1 MB (Megabyte) = 10^6 bytes*
1 High Fidelity Simphony	*1 GB (Gigabyte) = 10^9 bytes*
1/20 US Congress Library	*1 TB (Terabytes) = 10^{12} bytes*
1/10 All the information in the Web	*1 PB (Petabyte) =10^{15} bytes*
1/5 All the information generated in 2002	*1 EB (Exabyte) =10^{18} bytes*

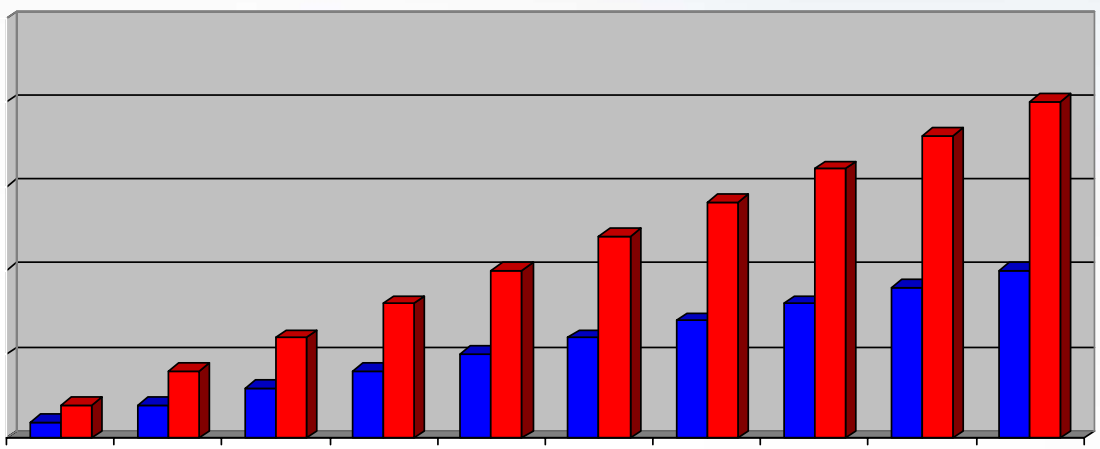
- LHC: 1 Exabyte of data in 5–8 years
  - Equivalent to 1.43 billion of CD's
    - **Stack of 1,857 km**
    - **4,700 Sugar Loaf**
    - **210 Mount Everest**

Computer Power X Network

Processor	Year	Transistor
4004	1971	2,250
8008	1972	2,500
8080	1974	5,000
8086	1978	29,000
286	1982	120,000
386™	1985	275,000
486™ DX	1989	1,180,000
Pentium®	1993	3,100,000
Pentium II	1997	7,500,000
Pentium III	1999	24,000,000
Pentium 4	2000	42,000,000

Technology	Year	Connection (bps)
Analogic	1985	9.600
Digital	1989-1994	256.000
Shared	1990-1993	1.500.000
	1996-1998	4.000.000
	1999-2000	20.000.000
	2001-2002	310.000.000
	2002-2003	622.000.000
Lambda	2003-2004	2.500.000.000
	2005	10.000.000.000

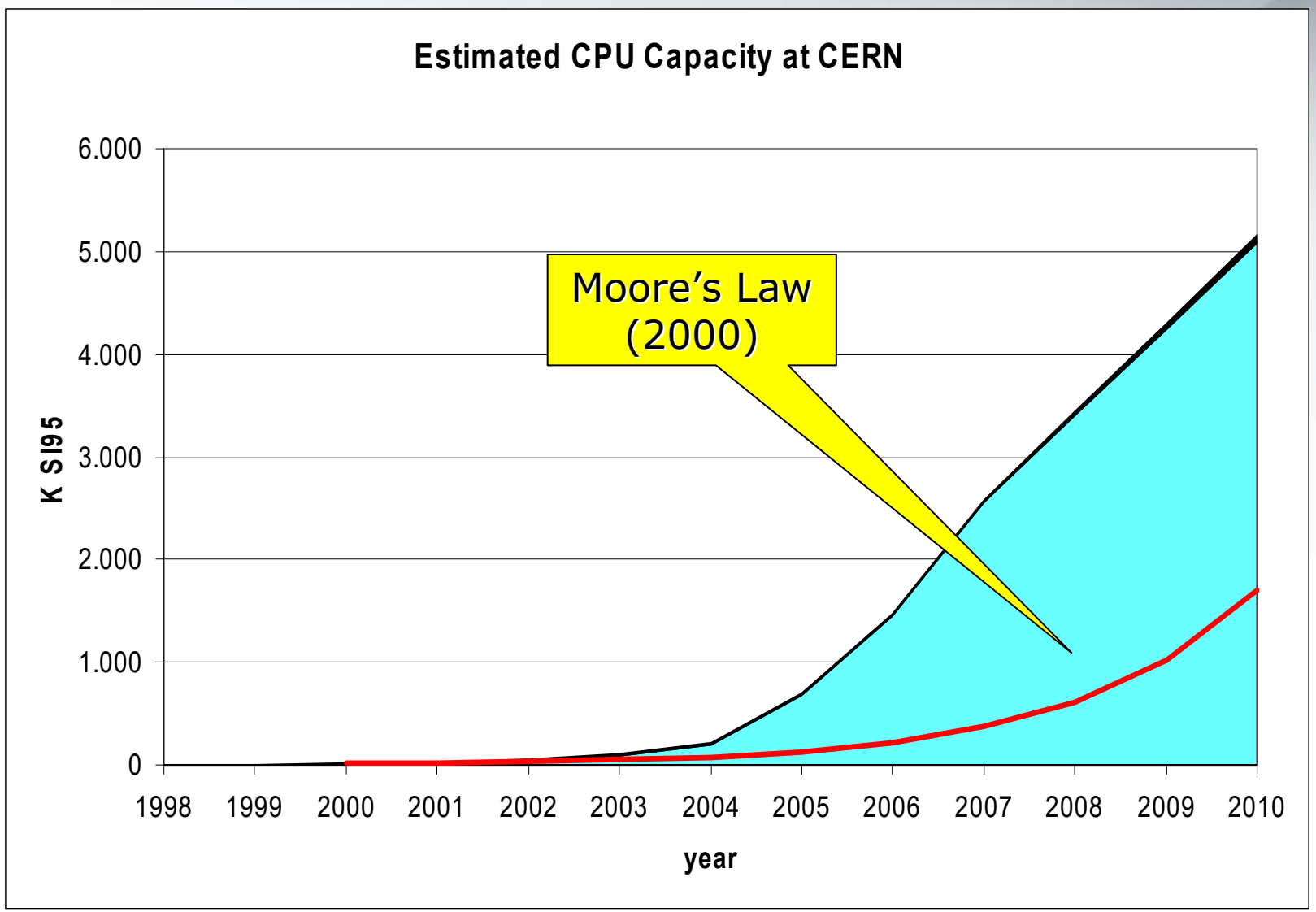
- Transistors doubles every 18 months
- Bandwidth doubles every 9 months



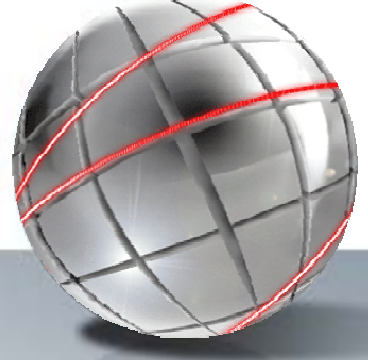
Two orders of magnitude in 10 years

LHC: Beyond Moore's Law

1 K SI95 = 10 Intel P4 2GHz CPU



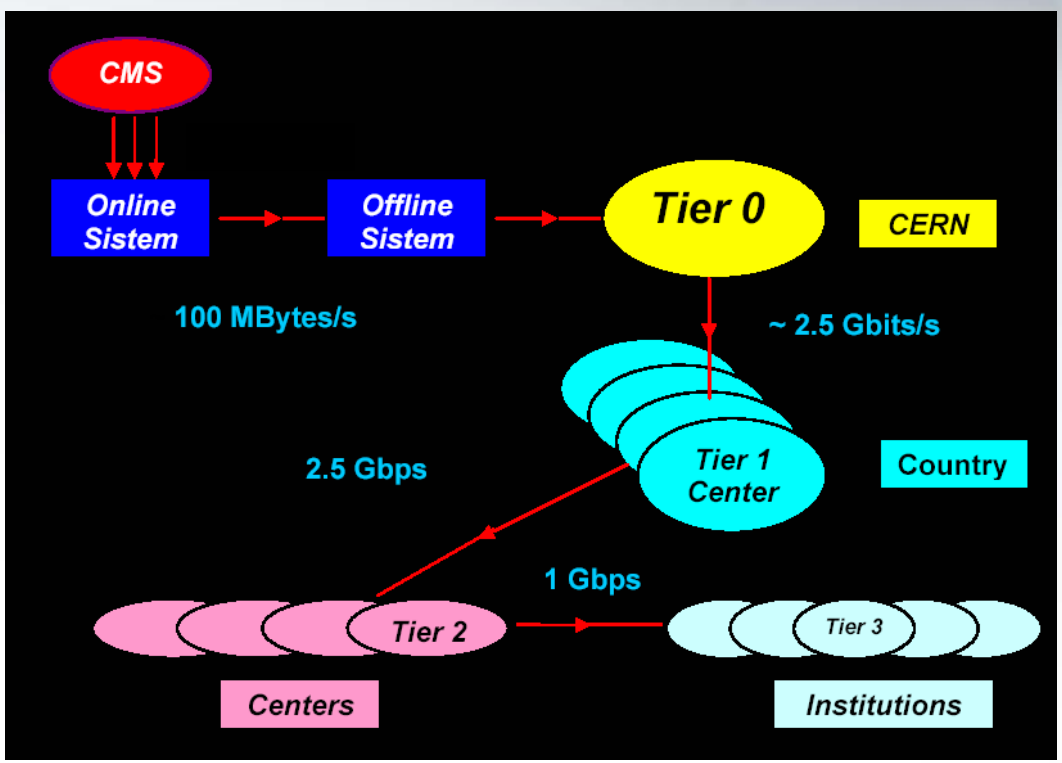
Grid



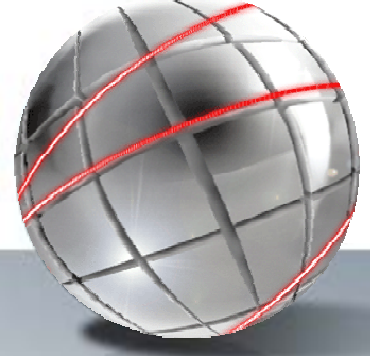
- *"A **Grid** is a collection of distributed computing resources available over a local or wide area network that appear to an end user or application as one large virtual computing system. The vision is to create virtual dynamic organizations through secure, coordinated resource-sharing among individuals, institutions and resources." (IBM)*
- *"A computational **Grid** is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities." (Kesselman, Foster, 1998)*
- ***Grid** is a system that:*
  - ***Coordinates resources** that are not subject to centralized control*
  - *Uses standard, open, general-purpose **protocols and interfaces** (authentication, authorization, resource discovery, and resource access).*
  - *Resources are used in a coordinated fashion to deliver various qualities of service, to meet complex user demands, so that the utility of the **combined system is significantly greater than that of the sum of its parts**.*

Hierarchical Tier Structure

- **Tier 0**
  - Record and distribute raw and reconstructed data to Tier 1
- **Tier 1**
  - Permanent storage and management of data
  - Provide Grid-enabled data service
  - Data-heavy analysis and re-processing data
  - Provide to Tier 2: long-term storage, management of the generated data, support services (Grid expertise, software distribution, maintenance)
- **Tier 2**
  - Grid-enabled disk storage
  - Simulation
  - End-user analysis

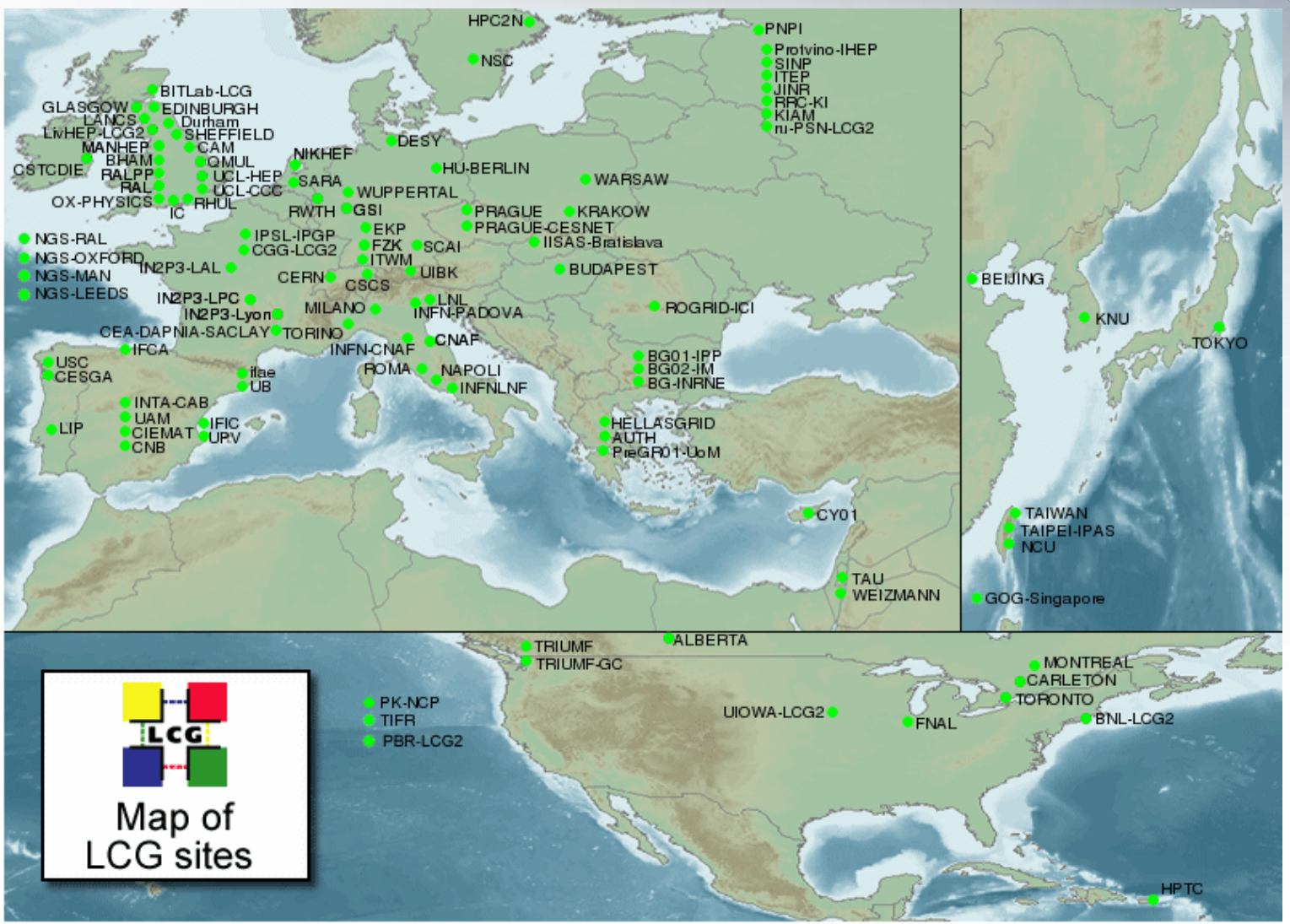


LHC Computing Grid Project



- A collaboration to deploy the computing environment that will be used by the experiments to analyze the LHC data
  - Support for applications
  - Development and operation of a computing service
  - Exploits the resources available to LHC experiments in institutes and universities around the world
  - Phase 1: 2002 – 2005
    - Build a service prototype, based on existing Grid middleware
    - Gain experience in running a production Grid service
    - Produce the TDR for the final system
  - Phase 2: 2006 – 2008
    - Build and commission the initial LHC computing environment

LCG Grid Operations Centre

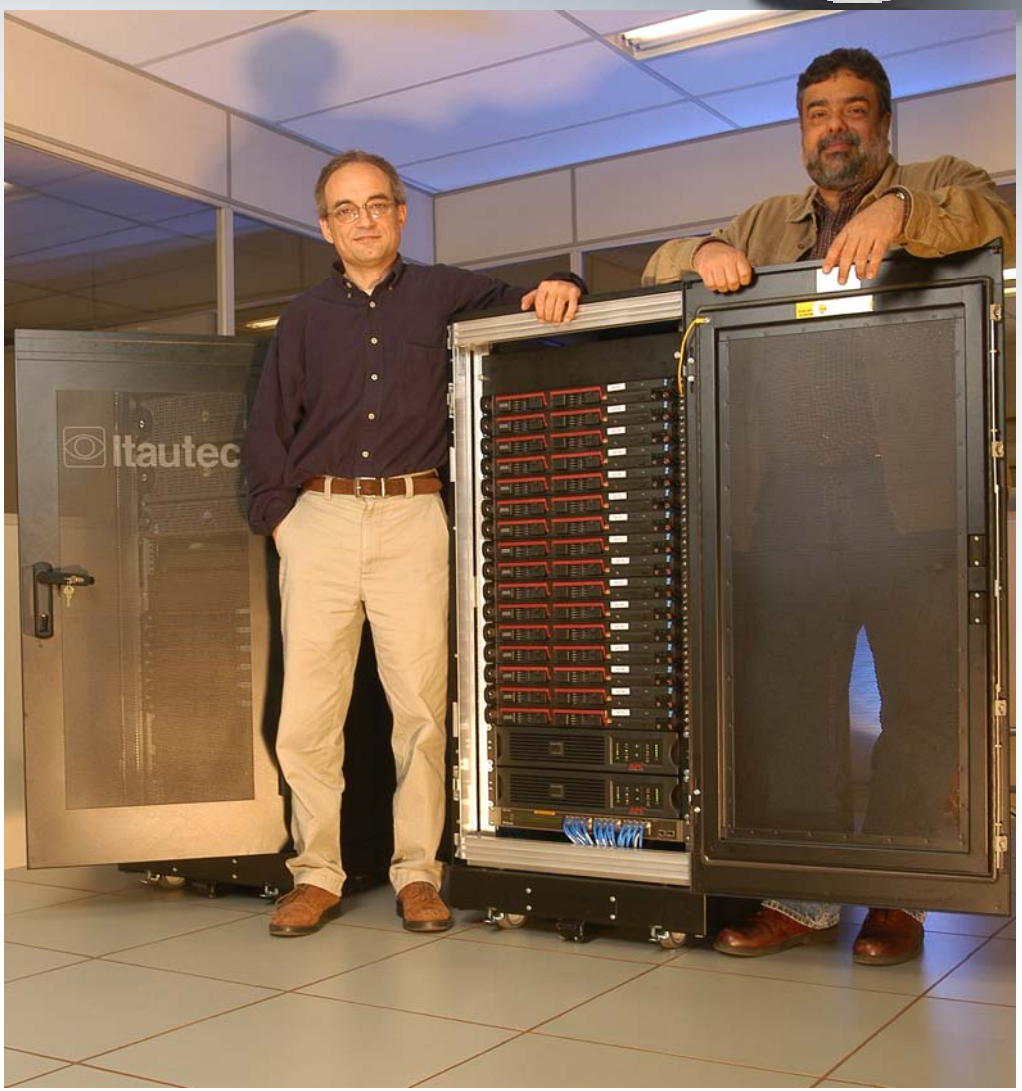


http://goc.grid-support.ac.uk/gppmonWorld/cert_maps/CE.html

São Paulo Regional Analysis Center

- Funded by FAPESP
- Implemented in 3 phases

	Phase 1 (2004)	Phase 2 (2005)	Phase 3 (2006)
CPU	50	115	180
Comp. Power (GHz)	125	325	550
Storage (TB)	4	12	12



State University of Rio de Janeiro

Ganglia Cluster Toolkit
http://ganglia.sourceforge.net

Cluster Report for Thu, 17 [redacted] → **Since 23 March 2004**

Get Fresh Data

Metric load_one **Last** hour **Sorted** descending

Physical View

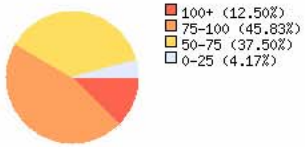
Grid > **SPRACE** > --Choose a Node

CPUs Total:	48
Hosts up:	24
Hosts down:	0

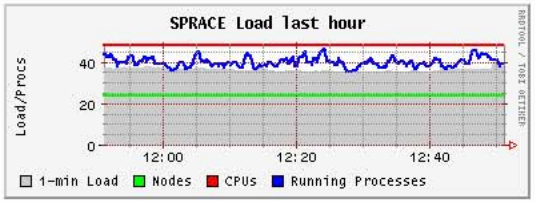
Avg Load (15, 5, 1m):
79%, 77%, 73%

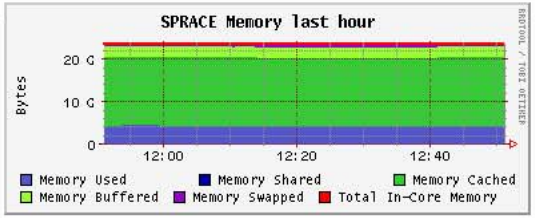
Localtime:
2004-06-17 12:51

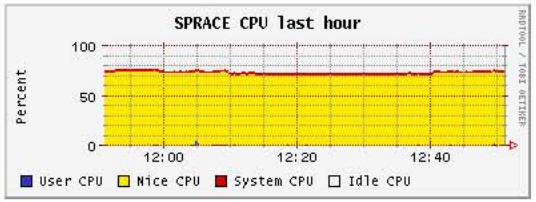
Cluster Load Percentages

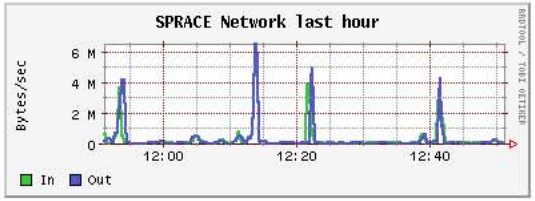


Overview of SPRACE

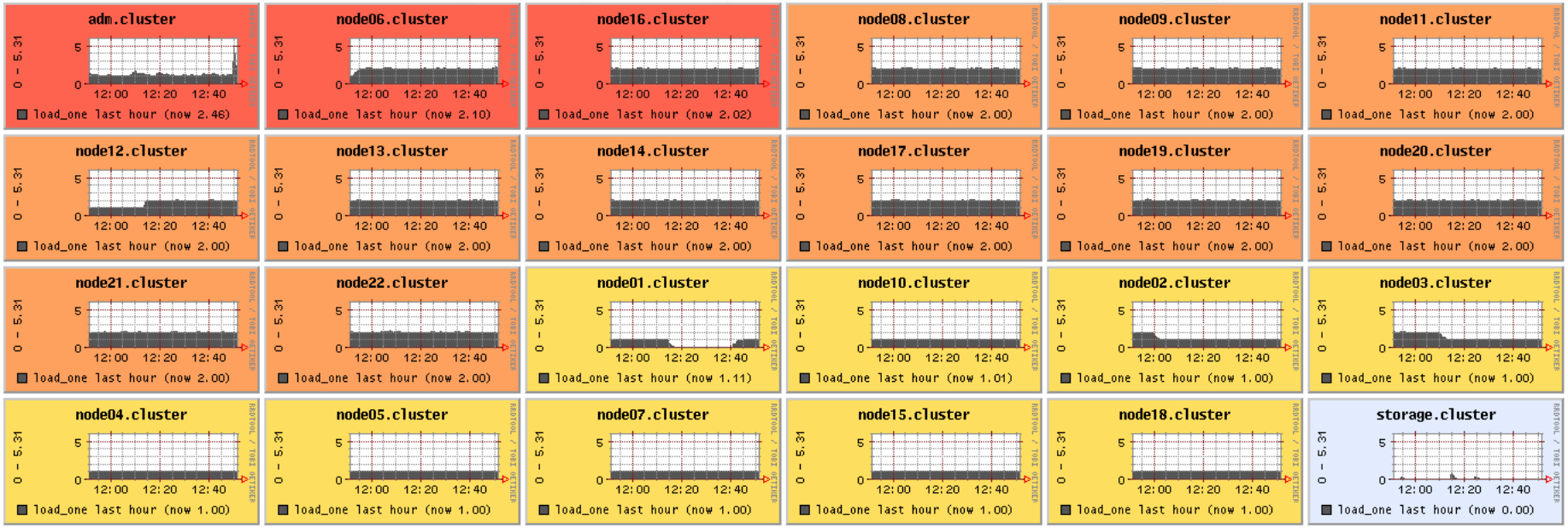








Show Hosts: yes ◉ no ○ | SPRACE **load_one** last **hour** sorted **descending** | Columns 6

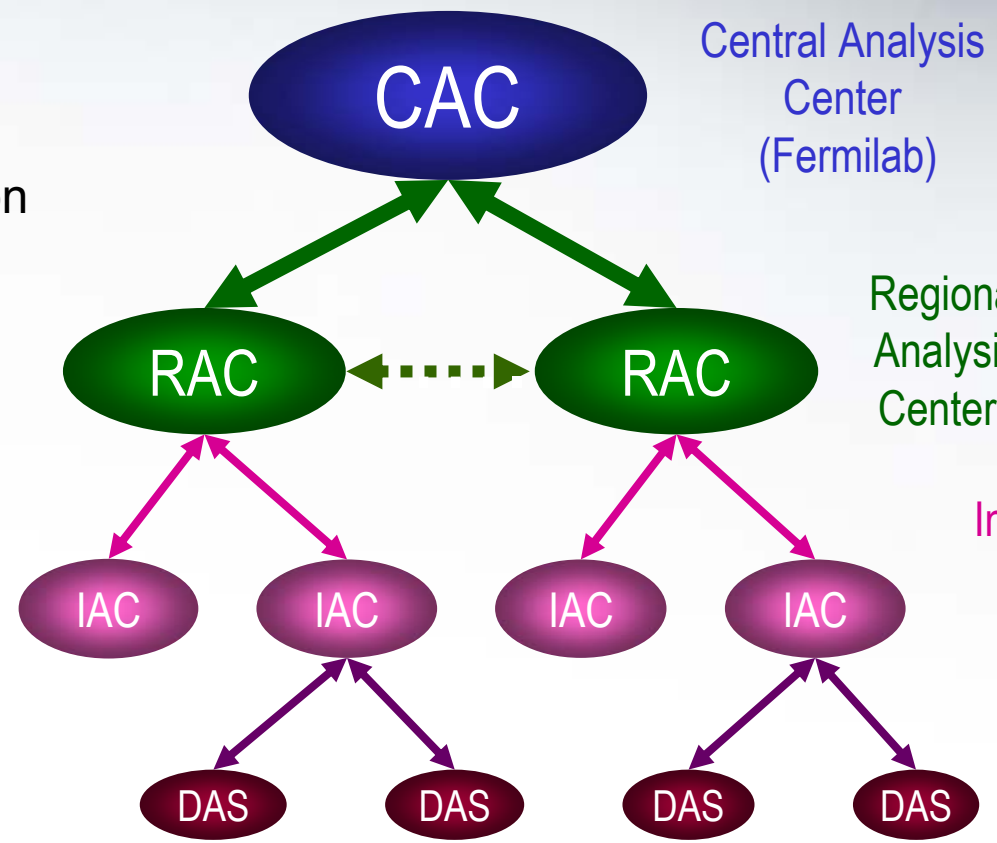


(Nodes colored by 1-minute load) | Legend

DOSAR

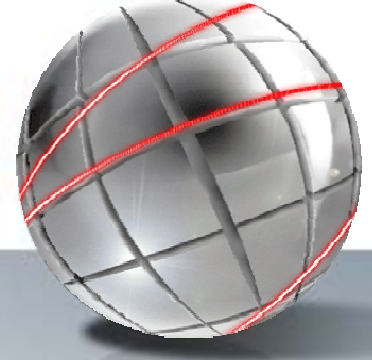
Distributed Organization of Scientific and Academic Research
(350 CPU's and 70 TB)

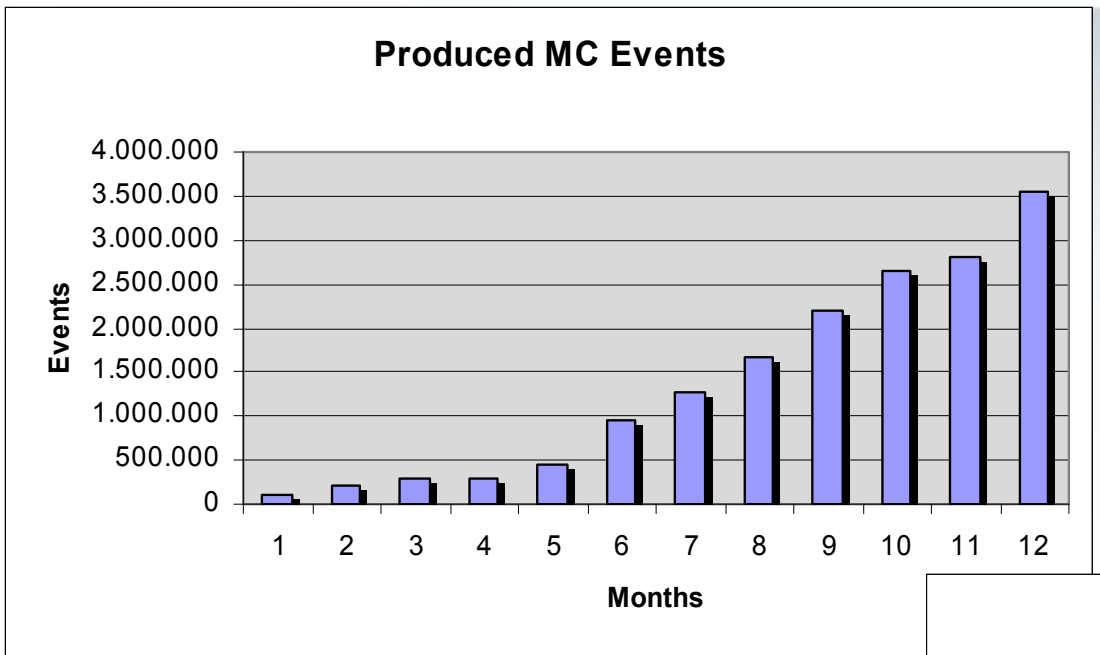
- University of Texas at Arlington
- Louisiana Tech University
- Langston University
- University of Oklahoma
- Tata Institute (India)
- Cinvestav, Mexico
- SPRACE, Brazil
- University of Kansas
- Kansas State University
- Ole Miss, MS
- Rice University, TX
- University of Arizona, Tucson, AZ



DOSAR

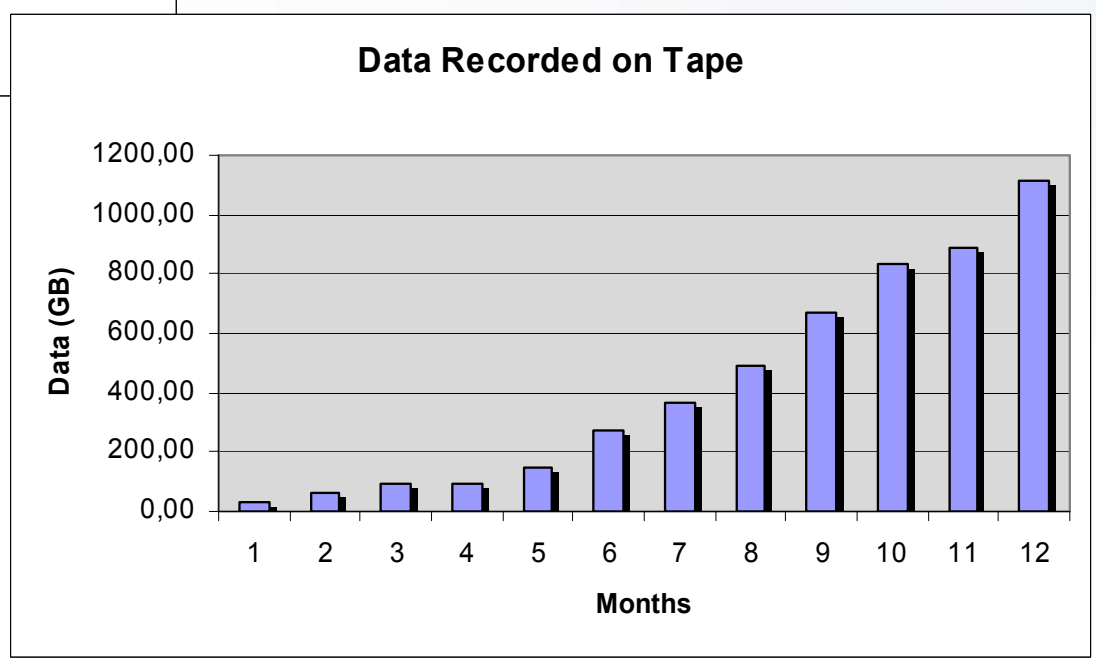
SPRACE: One Year of Operation



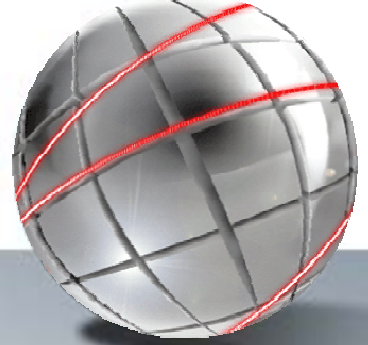


3.55 Millions of MC Events

1.11 TeraByte of Data

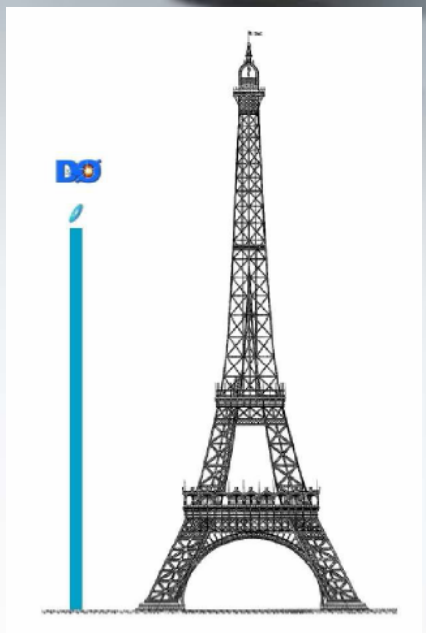


From DØ to CMS



Reprocessing of DØ Data

- Started on March 25th
- Improved understand of the detector
- Redo reconstruction of all data (~ 500 pb^{-1})
- Running at Fermilab and remote sites
- 3,500 CPU's (PIII, 1 GHz) for 6 months
- 10^9 events and 70 TB data



Open Science Grid

Open Science Grid

- OSG: US Grid infrastructure involving many labs and universities
- OSG is cooperating with other national and international Grid infrastructures to achieve global interoperability.

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