

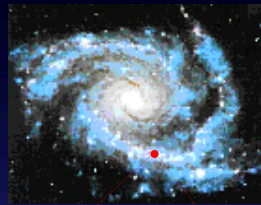
# High Energy Physics

## An Example of Global Science

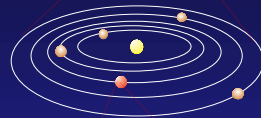
*Siegfried Bethke  
Max-Planck-Institut für Physik  
(Werner Heisenberg Institut)  
München*

- The innermost Structure of Matter
- History of the Universe
- Particle Accelerator Labs in the World
- CERN and the Large Hadron Collider
- LHC Data and Computing
- The LHC Computing Model
- Universal Science

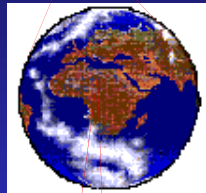
# Dimensionen und Struktur der Materie



Universum  $10^{26} \text{ m}, 10^{52} \text{ kg}$



Galaxie  $10^{21} \text{ m}, 10^{41} \text{ kg}$



Sonnensystem  $10^{13} \text{ m}, 10^{30} \text{ kg}$

Erde  $10^7 \text{ m}, 10^{24} \text{ kg}$



Mensch  $10^0 \text{ m}, 10^2 \text{ kg}$



Atom  $10^{-10} \text{ m}, 10^{-26} \text{ kg}$



Atomkern  $10^{-14} \text{ m}, 10^{-26} \text{ kg}$



Nukleon  $10^{-15} \text{ m}, 10^{-27} \text{ kg}$

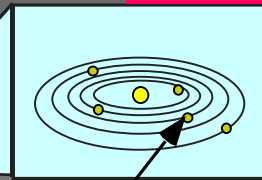


Quark, Lepton  $<10^{-18} \text{ m}, 10^{-30} \text{ kg}$



????? ? ?

# History of the Universe

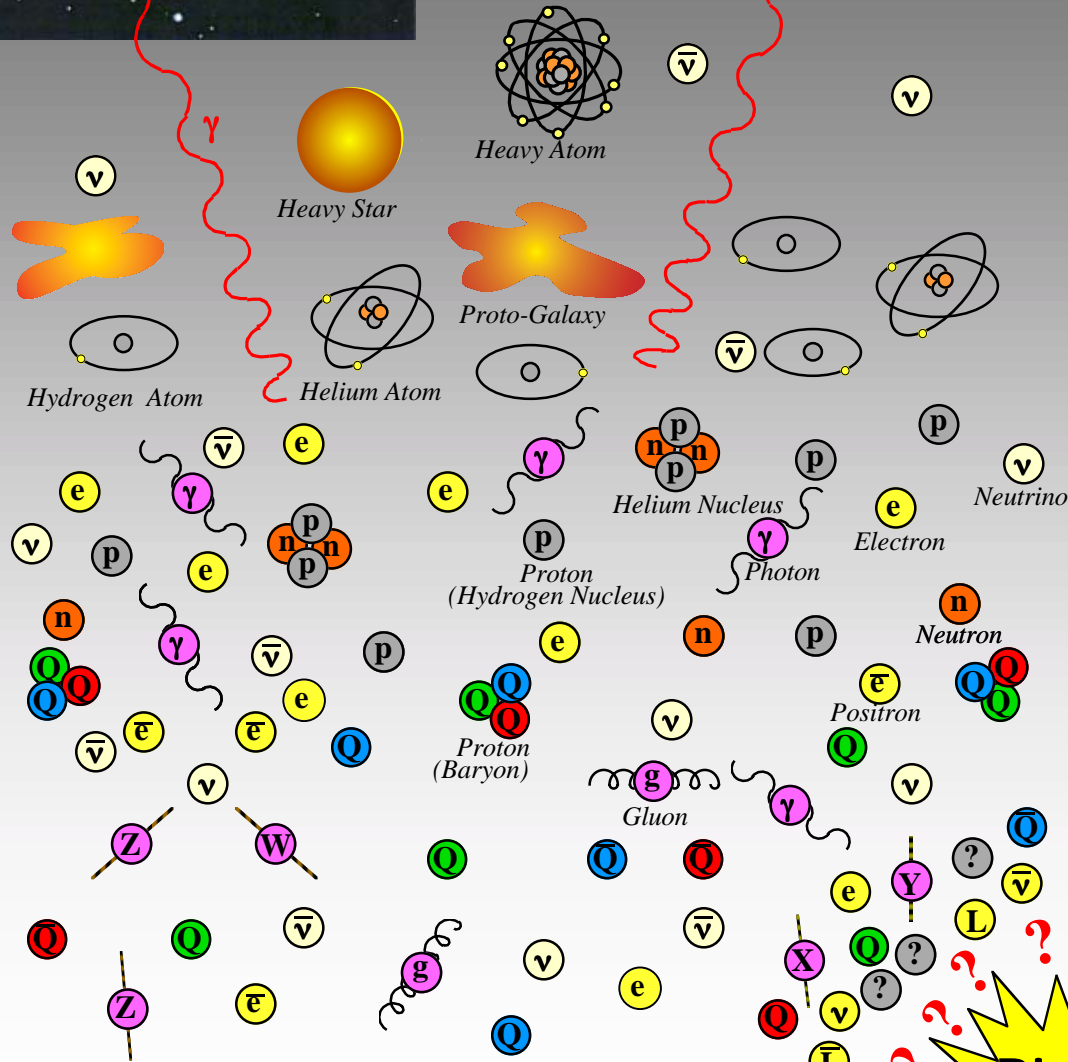


We are here

Time

Matter dominated era

Radiation dominated era



Temperature Age

2.7 K 15 Billion years

Today

First Supernovae

Formation of Stars and Galaxies

11 K 1 Billion years

Universe becomes transparent

Formation of atoms.  
Decoupling of  
Radiation from Matter.

1,000 K 300 000 years

Nukleosynthesis of Helium

Positrons disappear

$10^{10}$  K 1 sec.

Formation of Protons and Neutrons

Antiquarks disappear

$10^{15}$  K  $10^{-10}$  sec

Asymmetry  $Q - \bar{Q}$   $L - \bar{L}$

Inflation

$10^{27}$  K  $10^{-34}$  sec

Grand Unification

QUANTUM-GRAVITATION

$10^{31}$  K  $10^{-43}$  sec




# Particle Accelerator Labs in the World



# CERN / Geneva

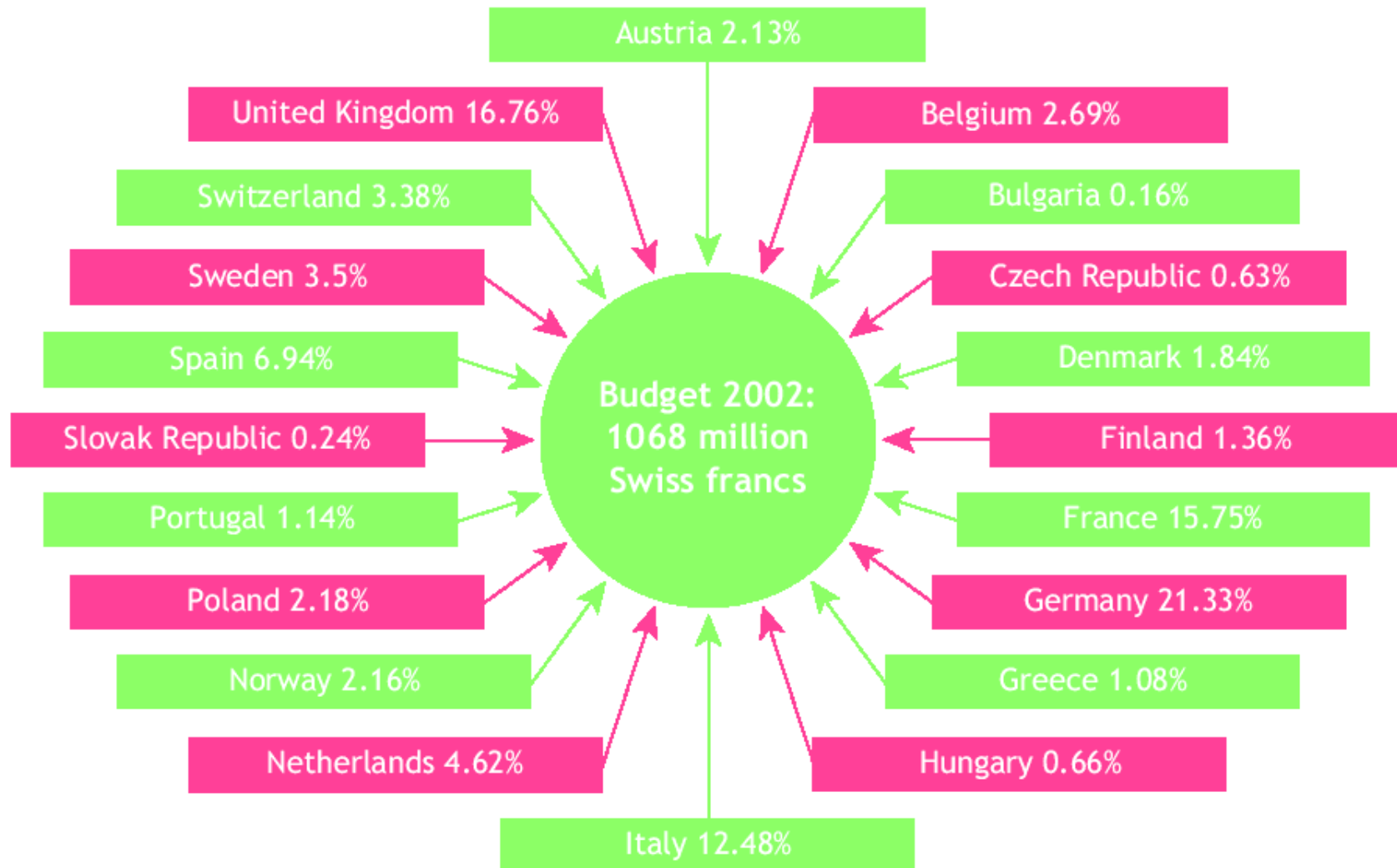
LEP / LHC

An aerial photograph of the CERN facility in Geneva, Switzerland. The image shows a vast landscape of green fields and some urban areas. Overlaid on the photograph are several circular and linear paths representing particle accelerators. A large circle, labeled 'LEP / LHC', encircles the central part of the facility. Inside and around this circle, there are smaller circles and a complex network of lines, some solid and some dotted, representing the various experimental areas and beamlines. The sky is blue with scattered white clouds.

# Member States of CERN

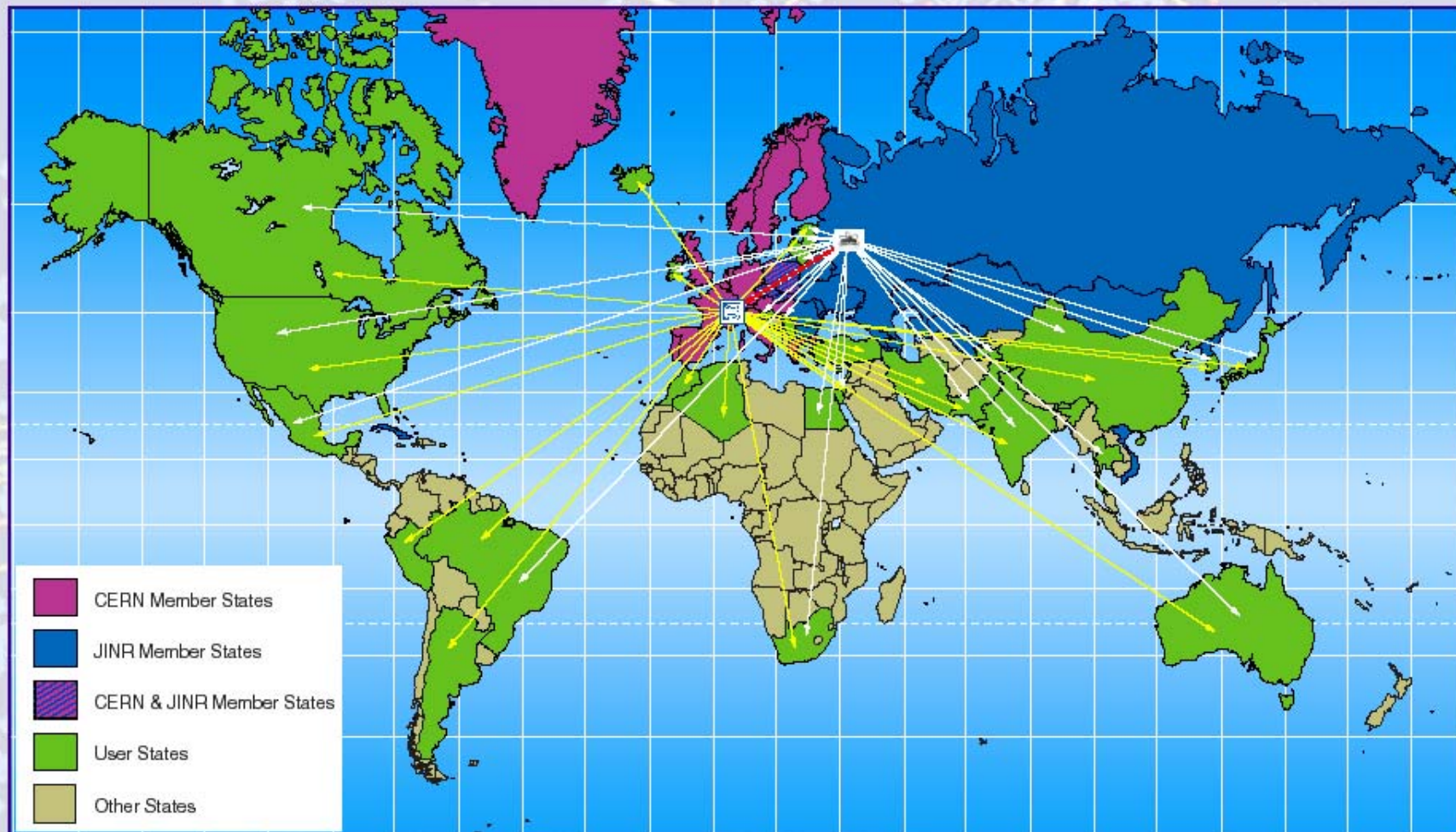


# Member States of CERN





# Connecting the World

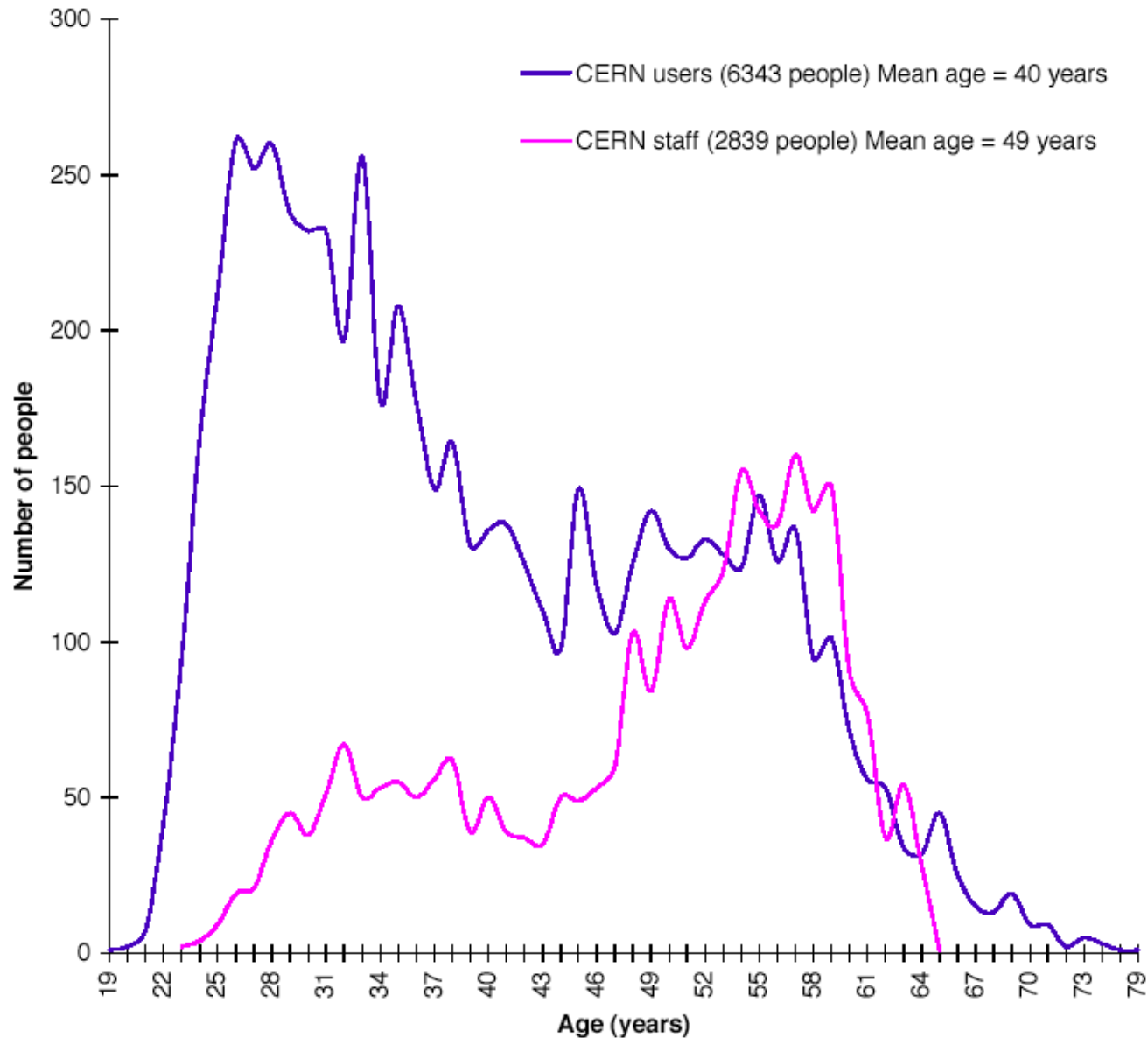


Science Bringing Nations Together





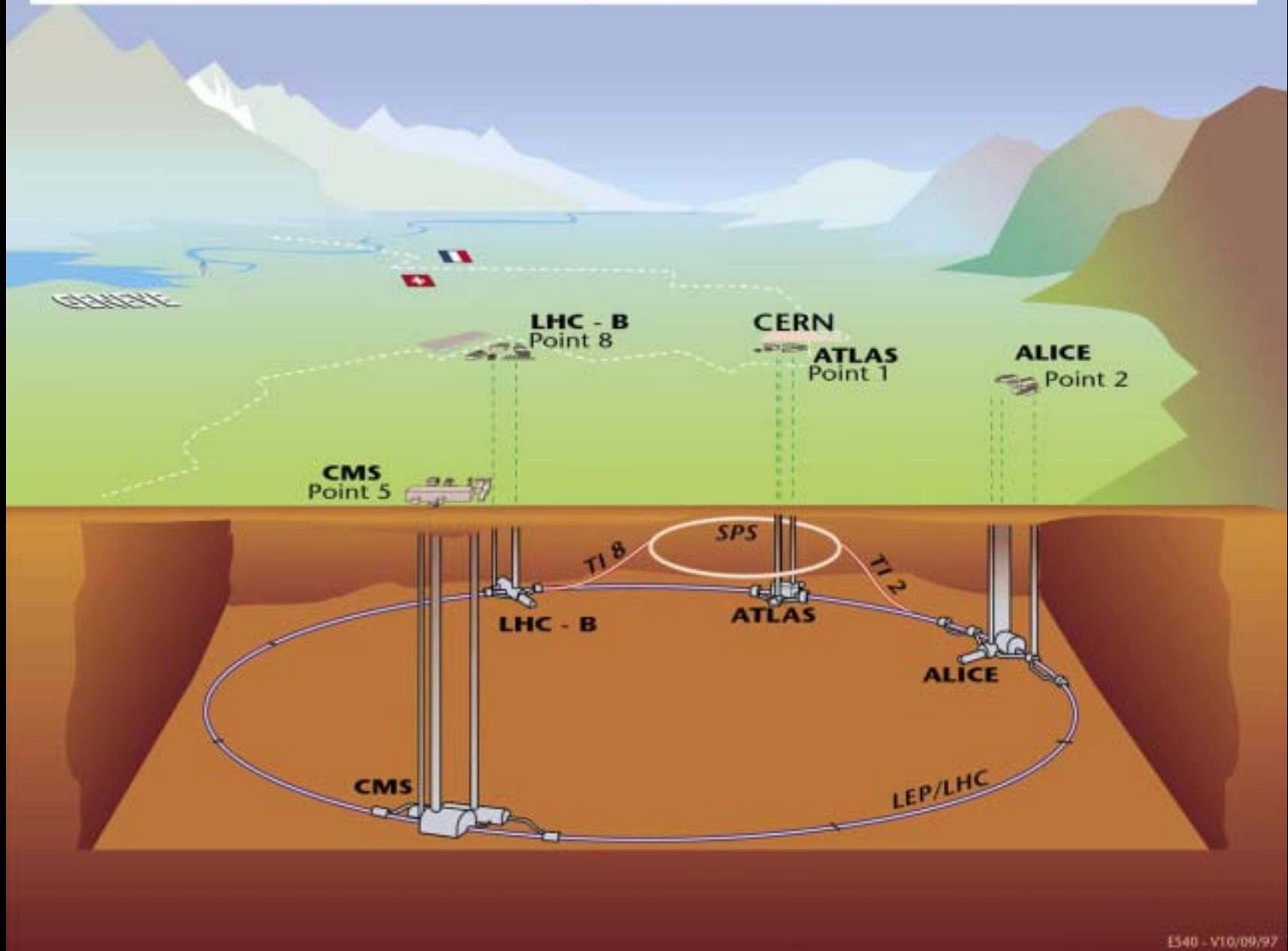
# Cern's staff and users age distributions



# LHC

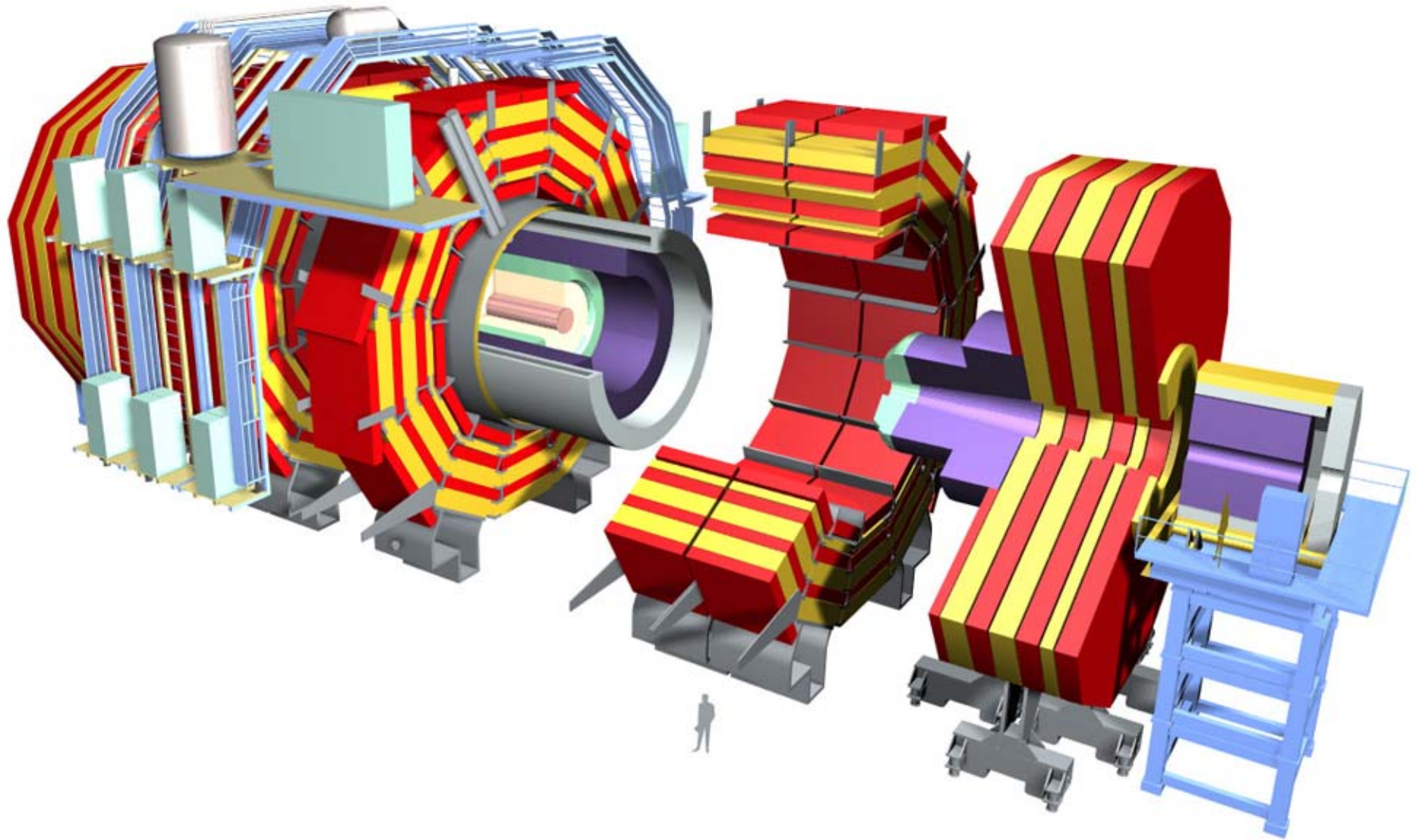


# Overall view of the LHC experiments.




E540 - V10/09/97

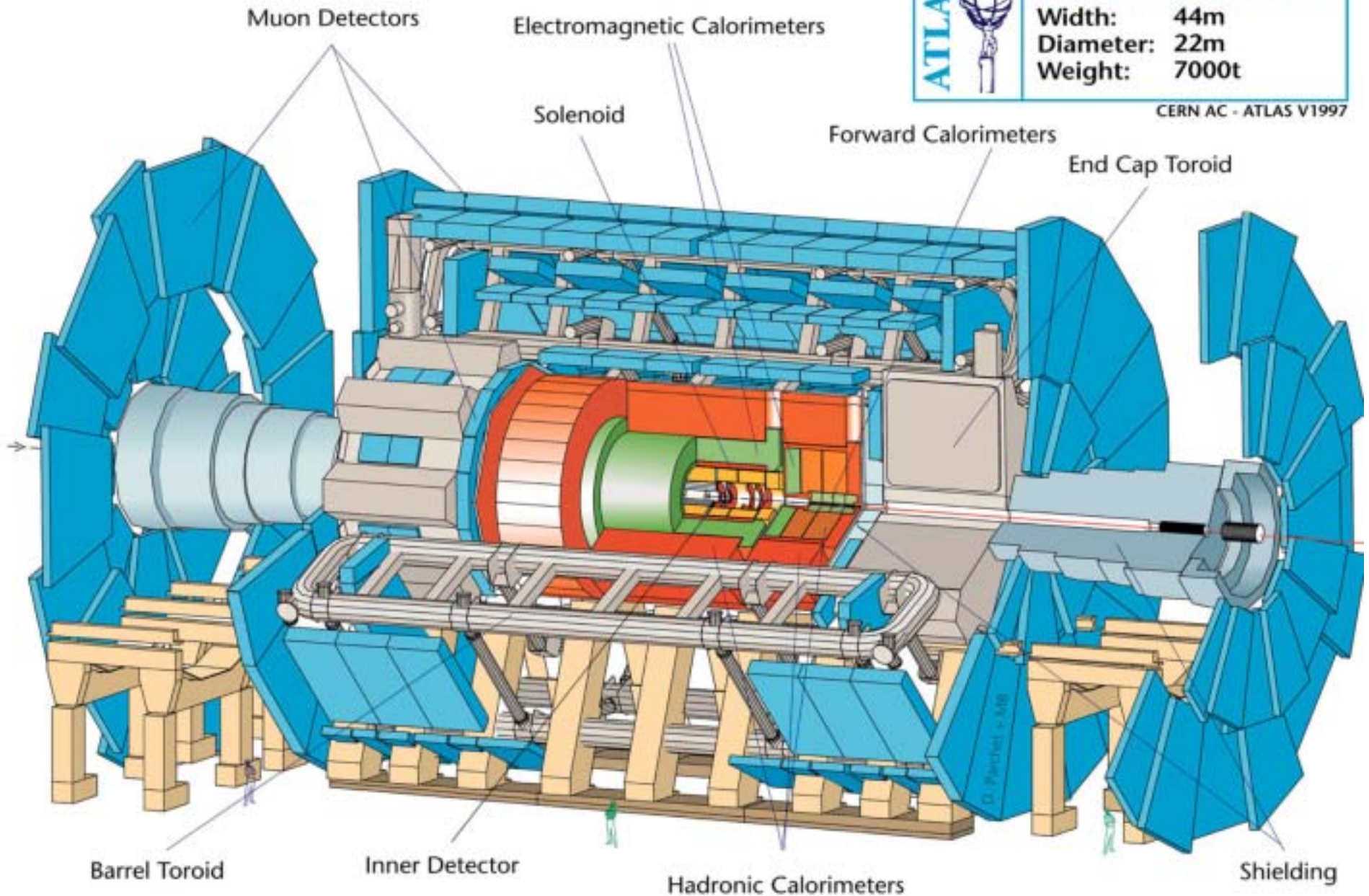
# The CMS Detector at the LHC



# The ATLAS Detector

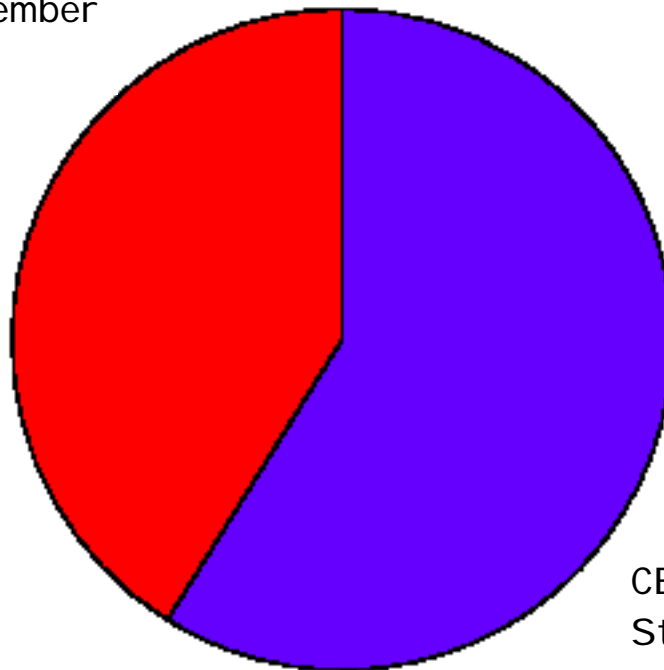
<b>ATLAS</b> 	<b>Detector characteristics</b>	
	<b>Width:</b>	<b>44m</b>
	<b>Diameter:</b>	<b>22m</b>
	<b>Weight:</b>	<b>7000t</b>

CERN AC - ATLAS V1997



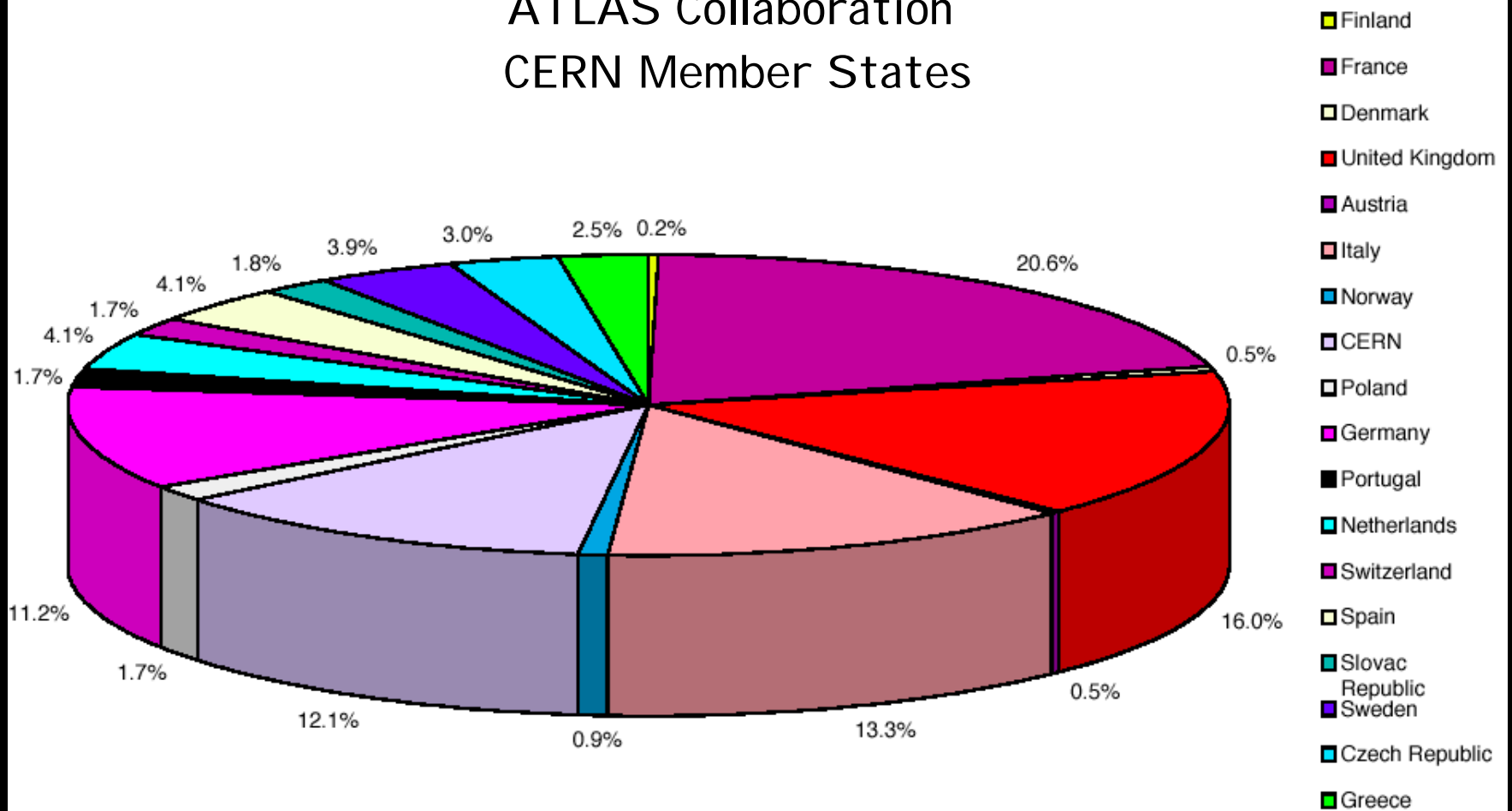
## ATLAS Collaboration in May 1997 (1685 people / 144 Institutes)

CERN Non-Member  
States 41%

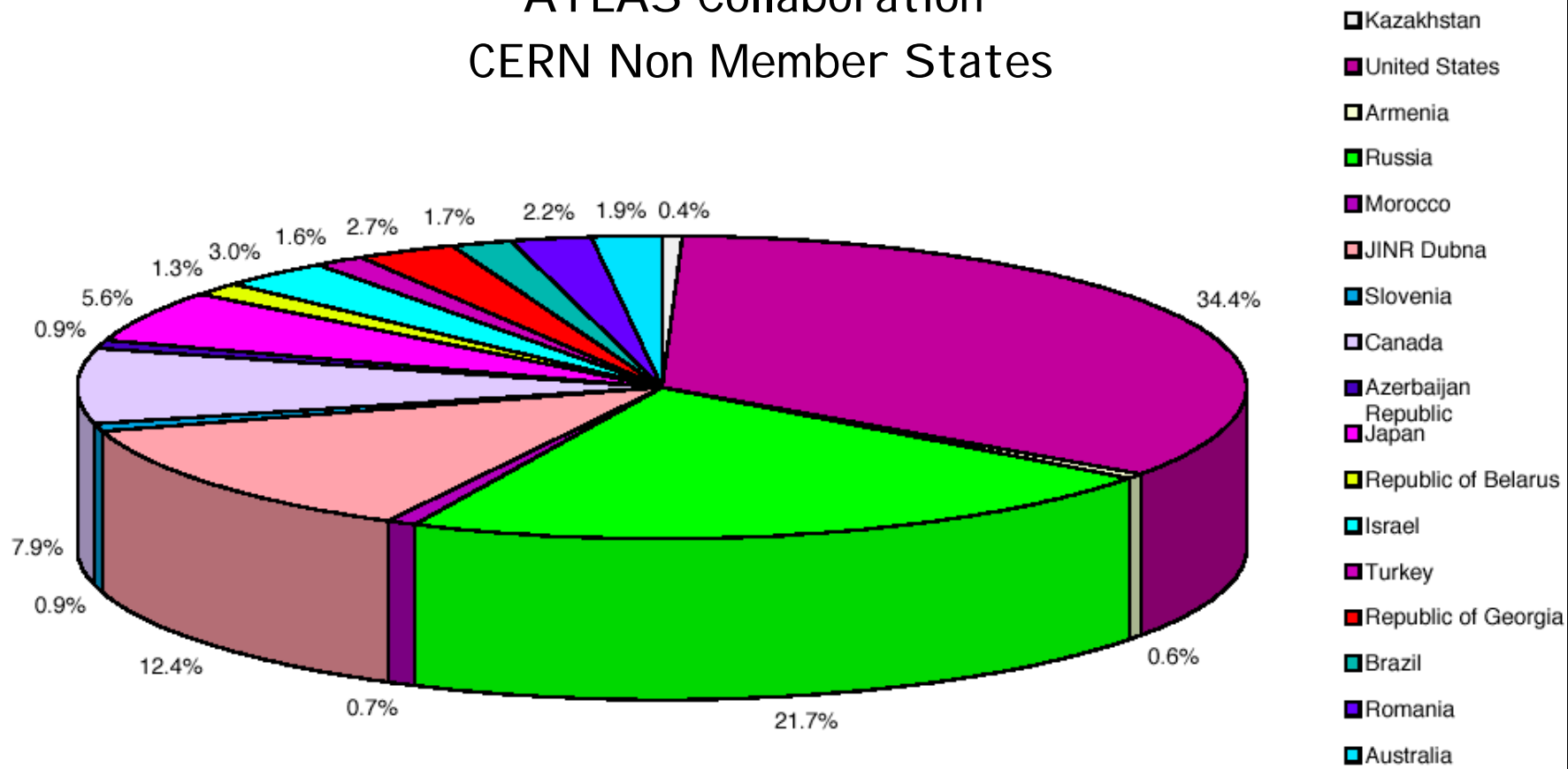


CERN Member  
States 59%

# ATLAS Collaboration CERN Member States



## ATLAS Collaboration CERN Non Member States





# LHC Data and Computing

## the challenge:

- 40 MHz collision rate → unfiltered data flow  $\sim 10^{14}$  B/s  
(~10 Billion phone calls)
- 4 experiments; 50-200 Hz data taking rate
- raw event size: 0.12 / 1 / 1-25 MB (LHCb / ATLAS-CMS / ALICE)
- total raw data storage: 7 PB/a  
( $7 \cdot 10^{15}$  Bytes/year;  
100 000 km thick  
pile of A4-paper)
- total simulated Data storage: 3.2 PB/a
- world-wide\* tape storage: 28.5 PB/a (40 million CD-Rom's)
- world-wide\* disk storage: 10.4 PB/a (140k disks à 75 GB)
- world-wide\* CPU capacity: 7350 k SI -95 (360k today's PCs)
- WAN bandwidth (Tier-0/-1): 1500 Mbps (1 experiment)  
(5000 Mbps when serving all 4 exp.'s)

\* all Tier-0, Tier-1 and Tier-2 computing centres, excl. Tier-3 and -4

CERN/LHCC/2001-004

CERN/RRB-D 2001-3

Original: English

22 February 2001

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE  
**CERN** EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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REPORT OF THE STEERING GROUP\*

OF THE LHC COMPUTING REVIEW

<http://lhc-computing-review-public.web.cern.ch>

# MEMBERSHIP OF THE REVIEW

## Steering Group

<b>Members:</b>	S. Bethke (MPI Munich) H.F. Hoffmann (CERN) D. Jacobs (CERN) M. Calvetti (INFN Florence) M. Kasemann (FNAL) D. Linglin (CC-IN2P3 / CNRS)	Chair CERN Director for Sc. Computing Secretary Chair of the Mgmt and Resources Panel Chair of the Software Project Panel Chair of the Computing Panel	
<b>In Attendance:</b>	IT Division ALICE ATLAS CMS LHCb	<b>Representative</b> M. Delfino (CERN) F. Carminati (CERN) N. McCubbin (RAL) M. Pimia (CERN) H. Newman (CALTECH) J. Harvey (CERN) M. Cattaneo (CERN)	<b>Alternate</b> L. Robertson (CERN) K. Safarik (CERN) G. Poulard (CERN)
<b>Observers:</b>	R. Cashmore (CERN) J. Engelen (NIKHEF)	CERN Director for collider programmes LHCC Chairman	

## Worldwide Analysis / Computing Model Panel

	D. Lenglin (CC-IN2P3 / CNRS) F. Gagliari (CERN)	Chair Secretary	
<b>Expt. Reps.:</b>	ALICE ATLAS CMS LHCb	<b>Representative</b> A. Masoni (INFN Rome) A. Putzer (U. Heidelberg) H. Newman (CALTECH) F. Harris (U. Oxford) C. Michau (UREC-STIC / CNRS)	<b>Alternate</b> A. Sandoval (GSI Darmstadt) L. Perini (U. Milan) W. Jank (CERN) M. Schmelling (MPI Heidelberg)
<b>Experts:</b>	Y. Morita (KEK)		

## Software Project Panel

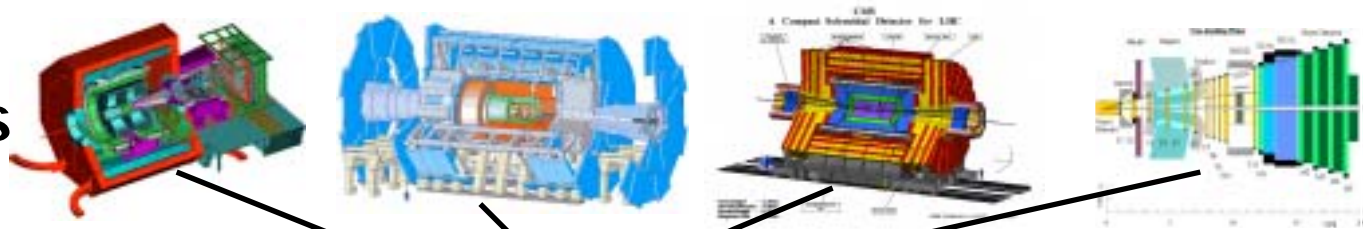
	M. Kasemann (FNAL) A. Pfeiffer (CERN)	Chair Secretary and CERN-IT representative	
<b>Expt. Reps.:</b>	ALICE ATLAS CMS LHCb	<b>Representative</b> R. Brun (CERN) D. Barberis (U. Genoa) L. Taylor (Northeastern U.) P. Mato (CERN)	<b>Alternate</b> A. Morsch (CERN) M. Bosman (U.A. Barcelona) T. Todorov (IN2P3 Strasbourg) O. Callot (LAL Orsay)
<b>Experts:</b>	V. White (FNAL)		

## Management and Resources Panel

	M. Calvetti (INFN Florence) M. Lamanna (INFN Trieste and CERN)	Chair Secretary	
<b>Expt. Reps.:</b>	ALICE ATLAS CMS LHCb	<b>Representative</b> P. Vande Vyvre (CERN) J. Huth (Harvard) P. Capiluppi (INFN Bologna) J. Harvey (CERN) J. Gordon (RAL) T. Wenaus (BNL)	<b>Alternate</b> K. Safarik (CERN) H. Meinhard (CERN) I. Willers (CERN) J.P. Dufey (CERN) L. Robertson (CERN) K. Woller (DESY)
<b>Experts:</b>	F. Etienne (IN2P3 Marseille) F. Ruggieri (INFN Bari) G. Wormser (IN2P3 Paris)		

# The LHC Computing Model

Experiments



Tier-0

CERN

The Grid

Tier-1

Region 1

Region 2

GridKa

Region 4

CERN

Tier-2

Country 1

Country 2

Country 3

Country 4

Country 5

...

Tier-3

Lab 1

Uni 2

Uni 3

Lab 4

Uni 5

Lab 6

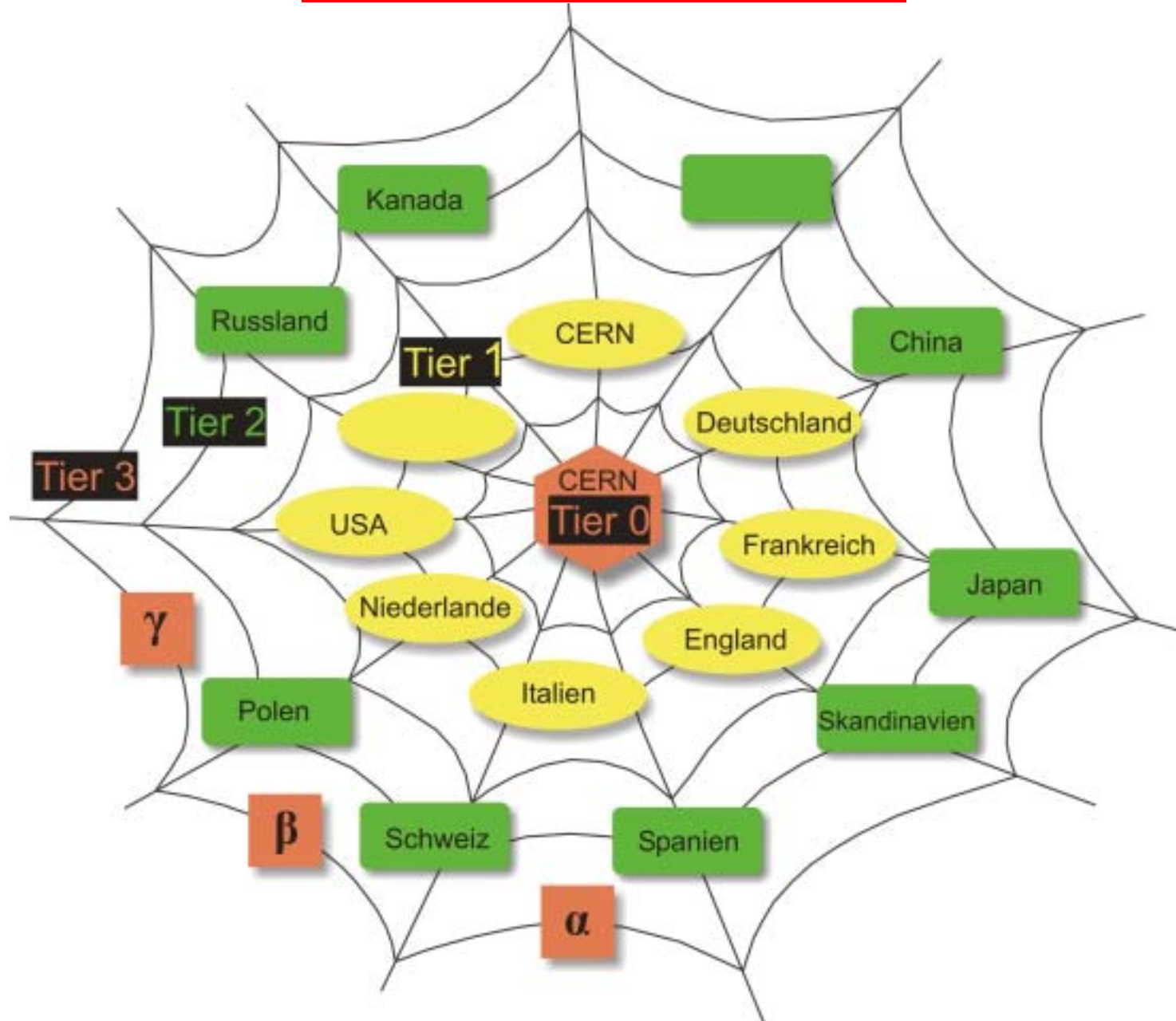
...

Tier-4



...

# The LHC Data Grid



# High Energy Physics...

- ... has initiated and created the **World Wide Web**
- ... is about to become the first global **Data Grid**
- ... is a true example of **Universal** Science

