The Large Hadron Collider (LHC) ITER and the WHO

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Frontier science on a global scale

- The U.S. should be among the leaders in international research.
- Major laboratories may not be located on U.S. soil.
- The time frame to develop projects and realize the scientific potential may take several decades.
- Unprecedented challenges
  - Geographic
  - Collaborative
  - Technical
  - Operational
  - Computational
  - Managerial
  - Fiscal
  - And…Educational


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Teruel
Tarragona
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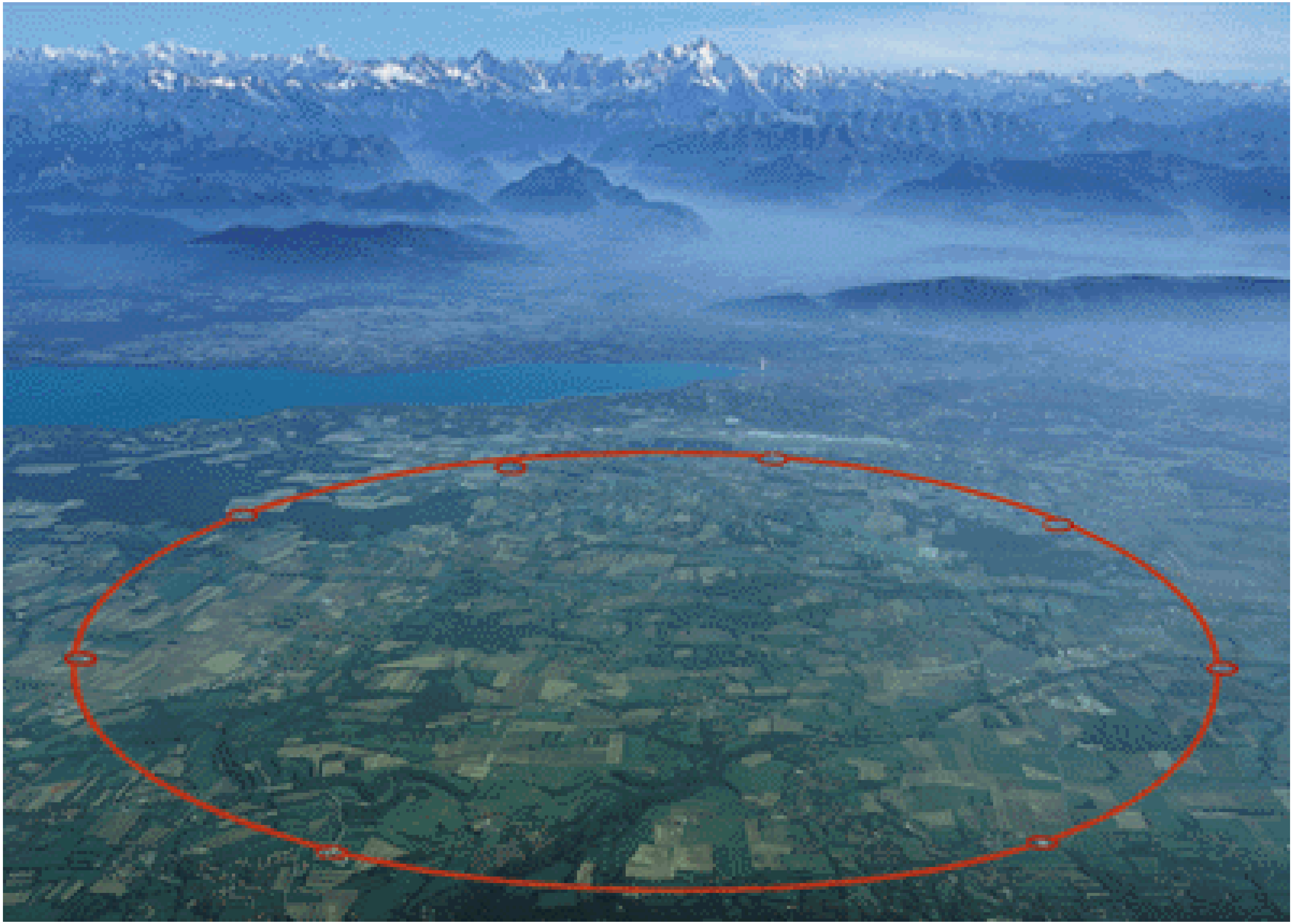
Cuenca
Palma De Mallorca
Cagliari
Kërkira
Cosenza

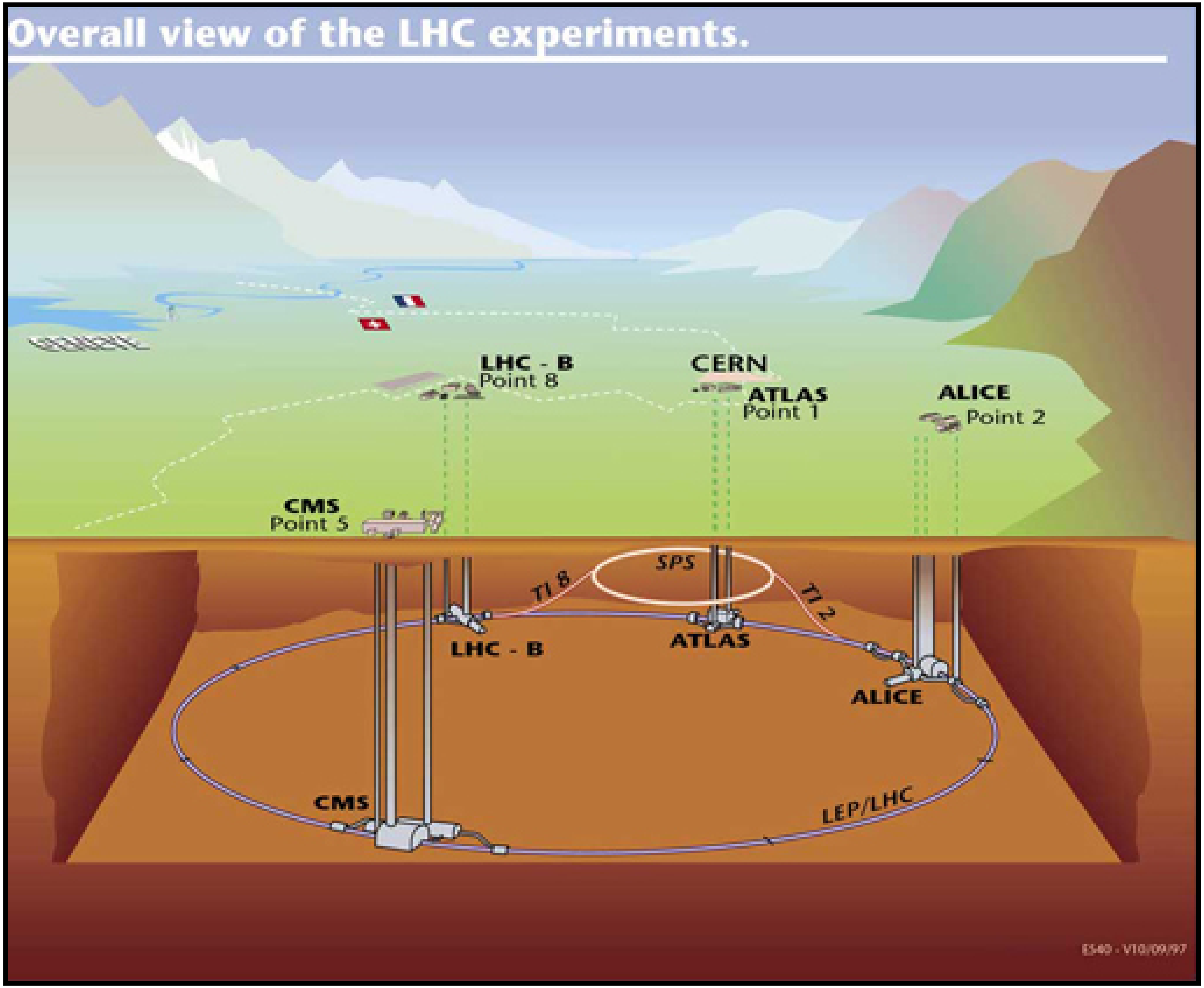
The LHC

- **The largest scientific machine in the world...**
- **The fastest racetrack on the planet…**
- **The emptiest space in the Solar System…**
- **The hottest spots in the galaxy, but even colder than outer space...**
- **The biggest and most sophisticated detectors ever built...**
- **The most powerful supercomputer system in the world...**

Half the world's particle physicists

- CERN employs just around 2500 people.
  - The Laboratory's scientific and technical staff designs and builds the particle accelerators and ensures their smooth operation.
  - They also help prepare, run, analyse and interpret the data from complex scientific experiments.
- Some 8000 visiting scientists, half of the world's particle physicists, come to CERN for their research.
  - They represent 580 universities and 85 nationalities.




Overall view of the LHC experiments.
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
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LHC - B
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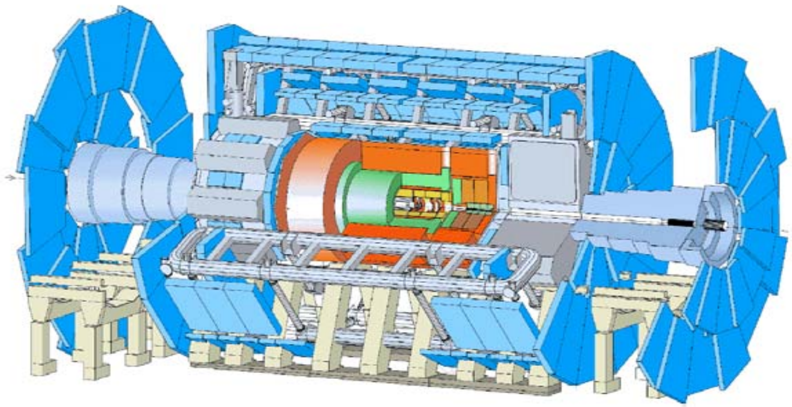
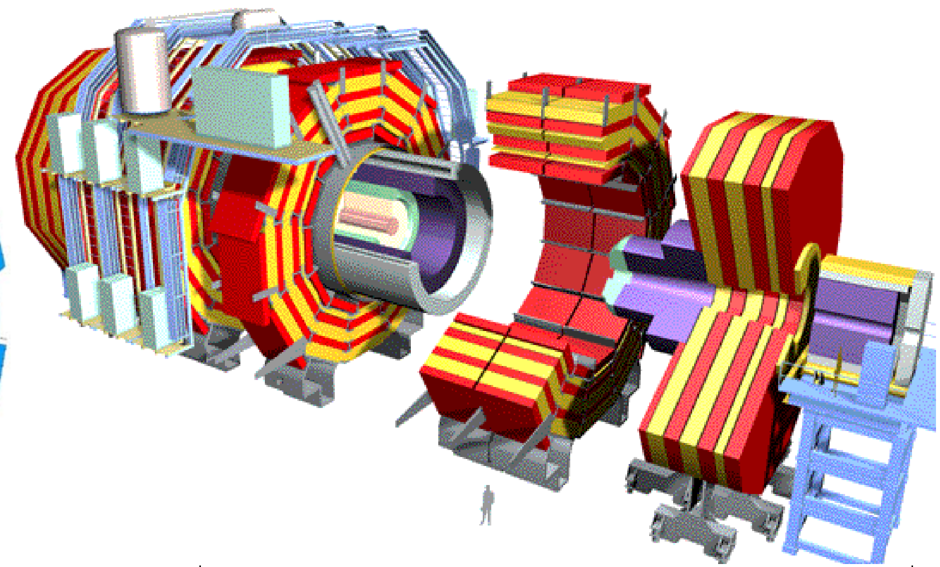
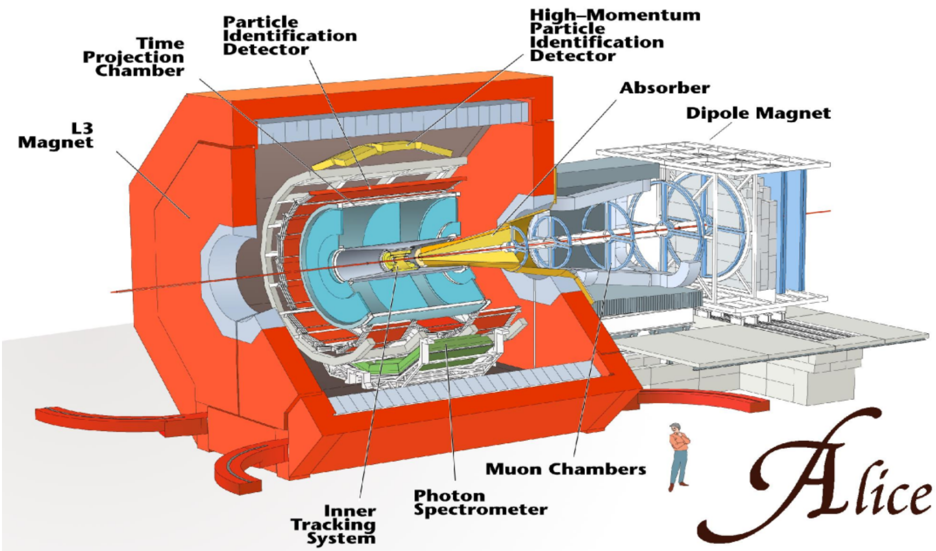
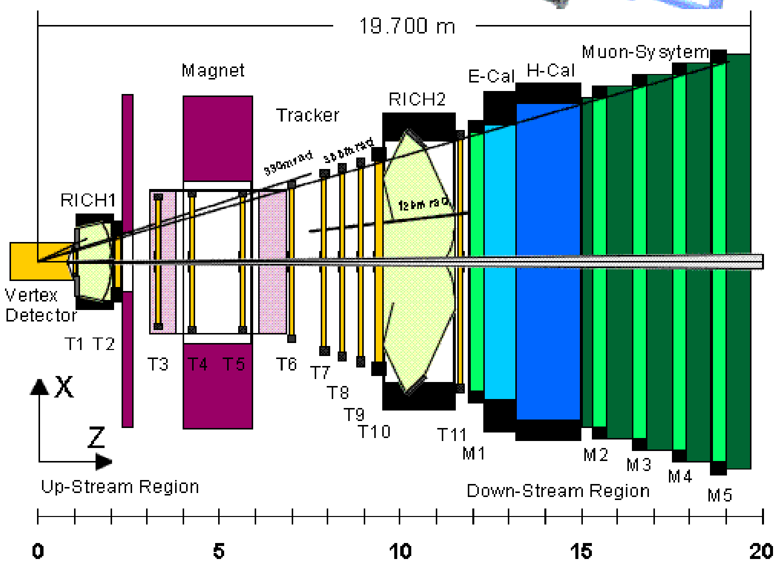
LHC Experiments

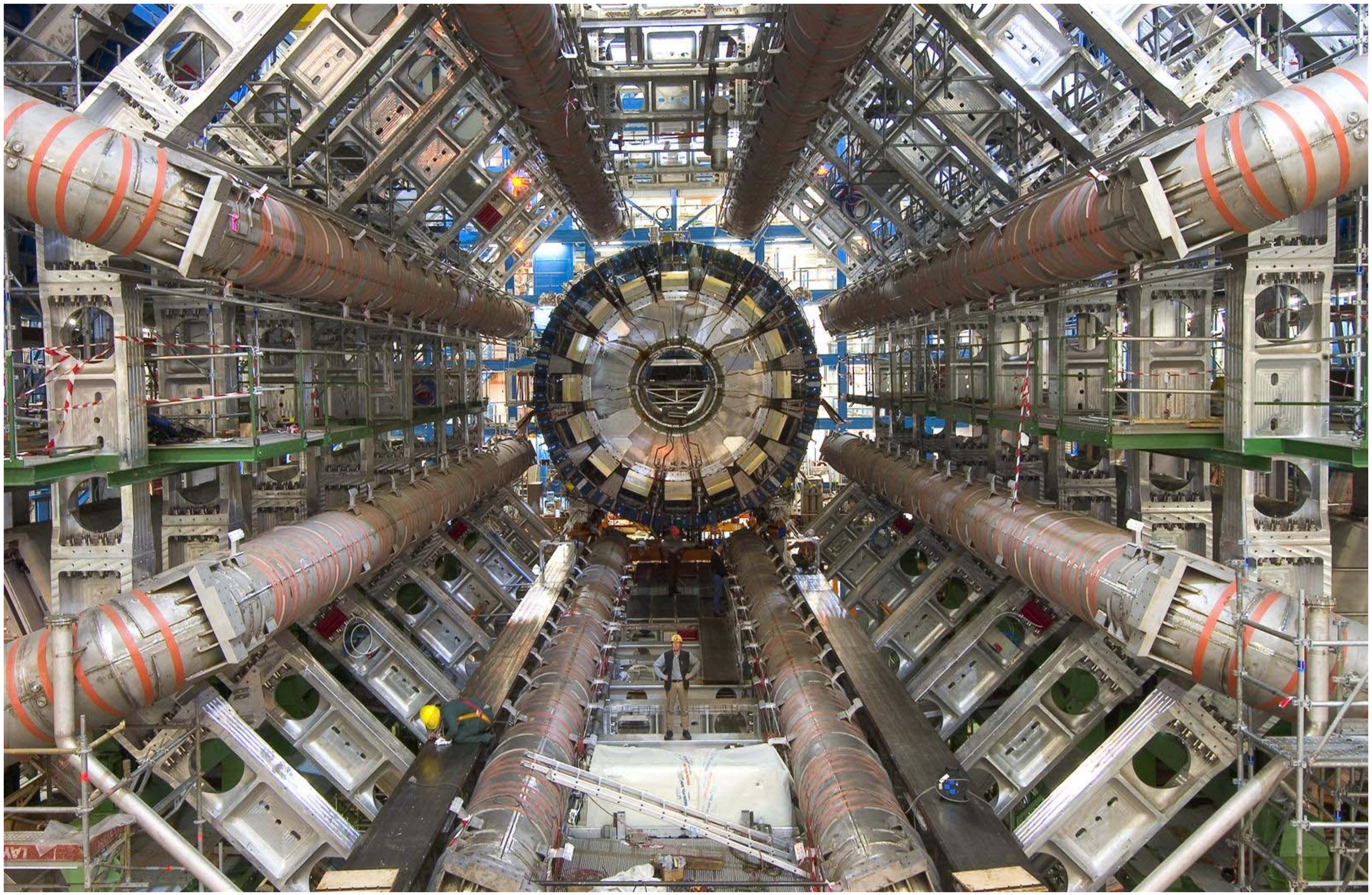




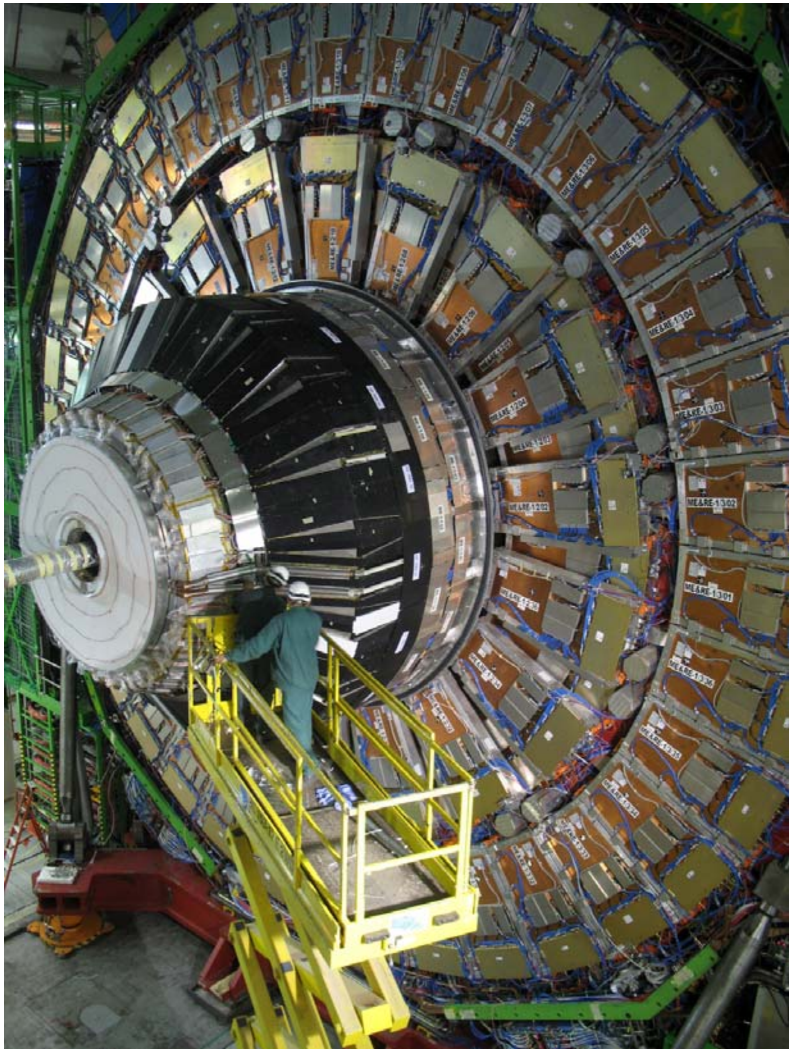


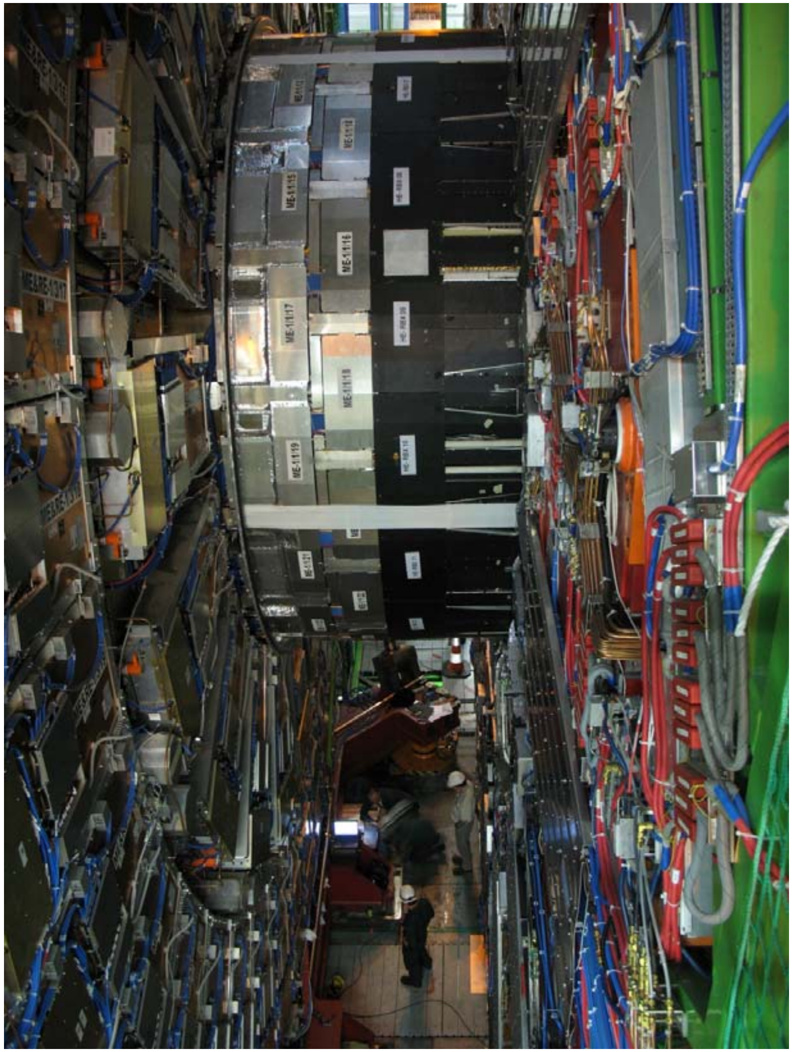


ATLAS during construction



CMS during construction



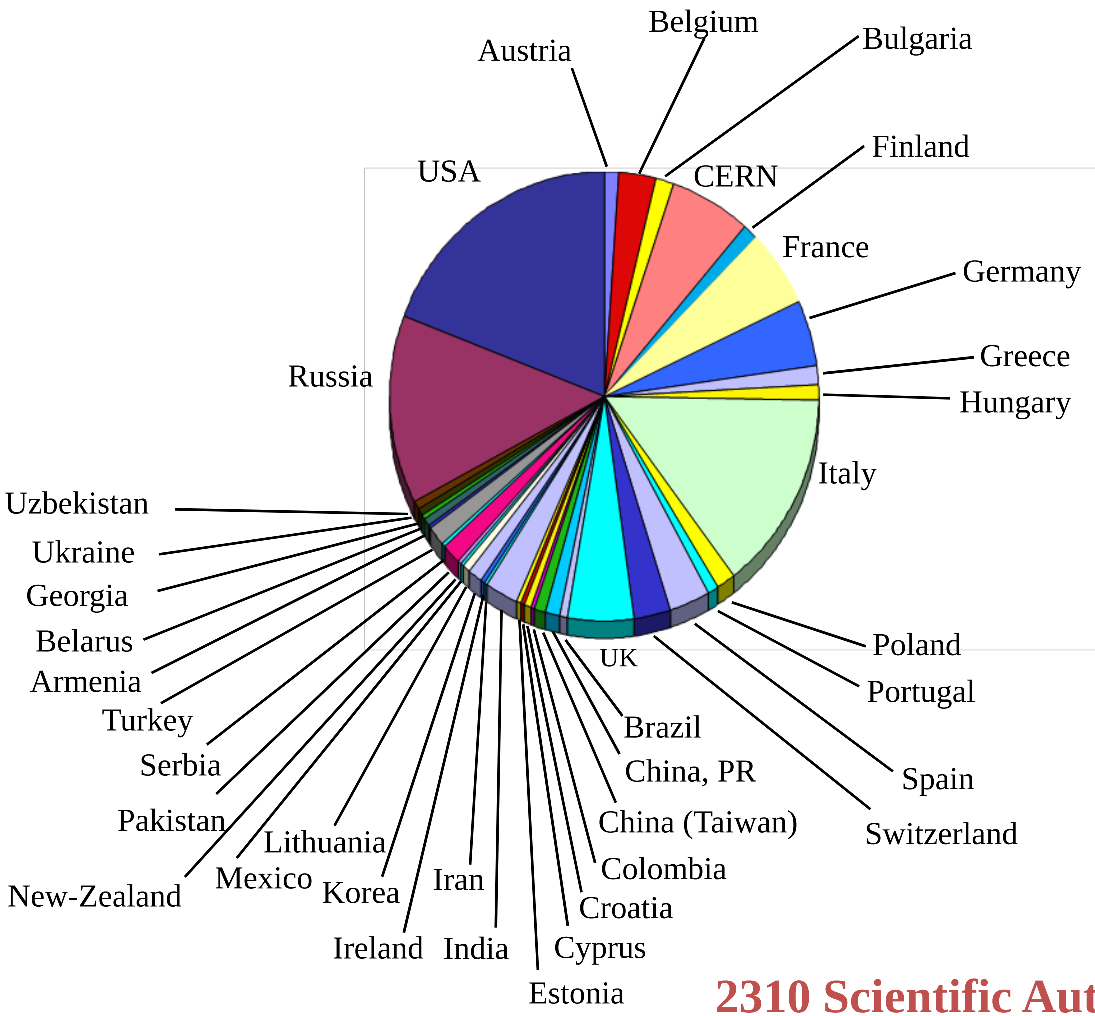


The CMS Collaboration

	Number of Laboratories
Member States	59
Non-Member States	67
USA	49
Total	175

	# Scientific Authors
Member States	1084
Non-Member States	503
USA	723
Total	2310

Associated Institutes	
Number of Scientists	62
Number of Laboratories	9



2310 Scientific Authors
38 Countries
175 Institutions

Oct. 3rd 2007/gm

Why an educational challenge…

- It is 1998…
  - There is an international physics project called the LHC in Geneva, Switzerland.
    - The project will take over a decade to build.
    - We are expecting to have first collisions of protons on protons at 10TeV CM Energy late in 2009.
  - A graduate student (age 25 in 2009) is…
    - 14 years old…(in 1998)
  - As a scientific researcher…
    - How do you deal with this? How do you attract young students to the excitement of science at the energy frontier?

Unprecedented opportunity…

- For physicists…
- And more…
- Other critical professionals…
  - Extreme engineering
  - Technical skills
  - Managerial skills
  - Research computing skills
  - Networking skills
  - Diplomatic skills
  - …

- This is an opportunity of a lifetime…
- How do you connect…?

Some answers…

- Research Experiences for Undergraduates.
  - REU Site Program at CERN
- Research Experiences for secondary school teachers.
- Why secondary school teachers?
  - They are engaged with the students in and out of class.
- Strategy:
  - One-on-one partnership with scientific mentors
  - Direct participants
    - Members of the collaboration
    - Have immersive research experiences
    - Build and operate equipment
    - Develop code, decode and analyze data
    - Recognized in publications
- QuarkNet was born from this concept…
  - While the LHC experiments were being built, we built QuarkNet
  - Enlightened self interest

QuarkNet

52 Centers in 25 states and Puerto Rico

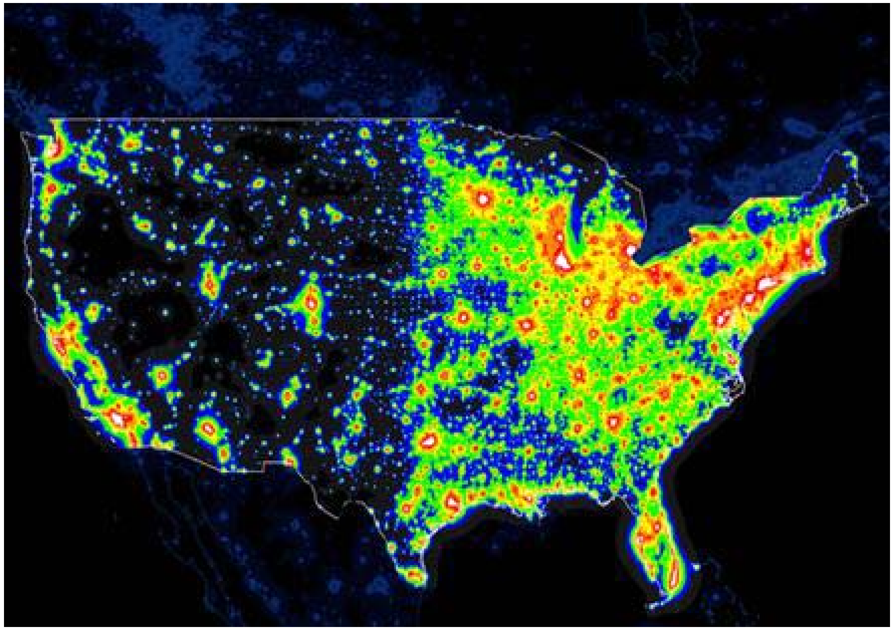
500 HS Teachers
150 Particle Physicist mentors
100 HS Students annually

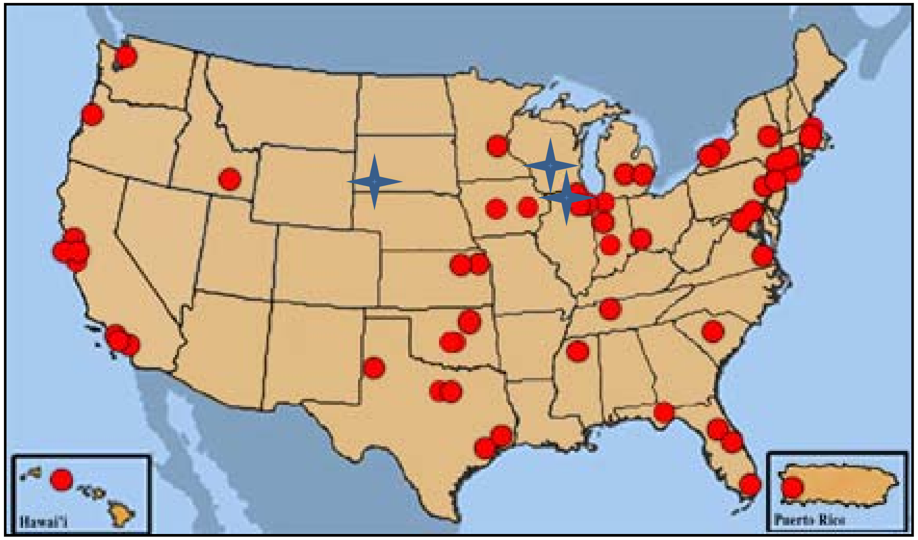
A professional development program for HS Teachers with immersive research experience for HS teachers and students.

A wide spectrum of experiments.

Now in its 12th year. Supported by NSF and DOE

http://quarknet.fnal.gov/

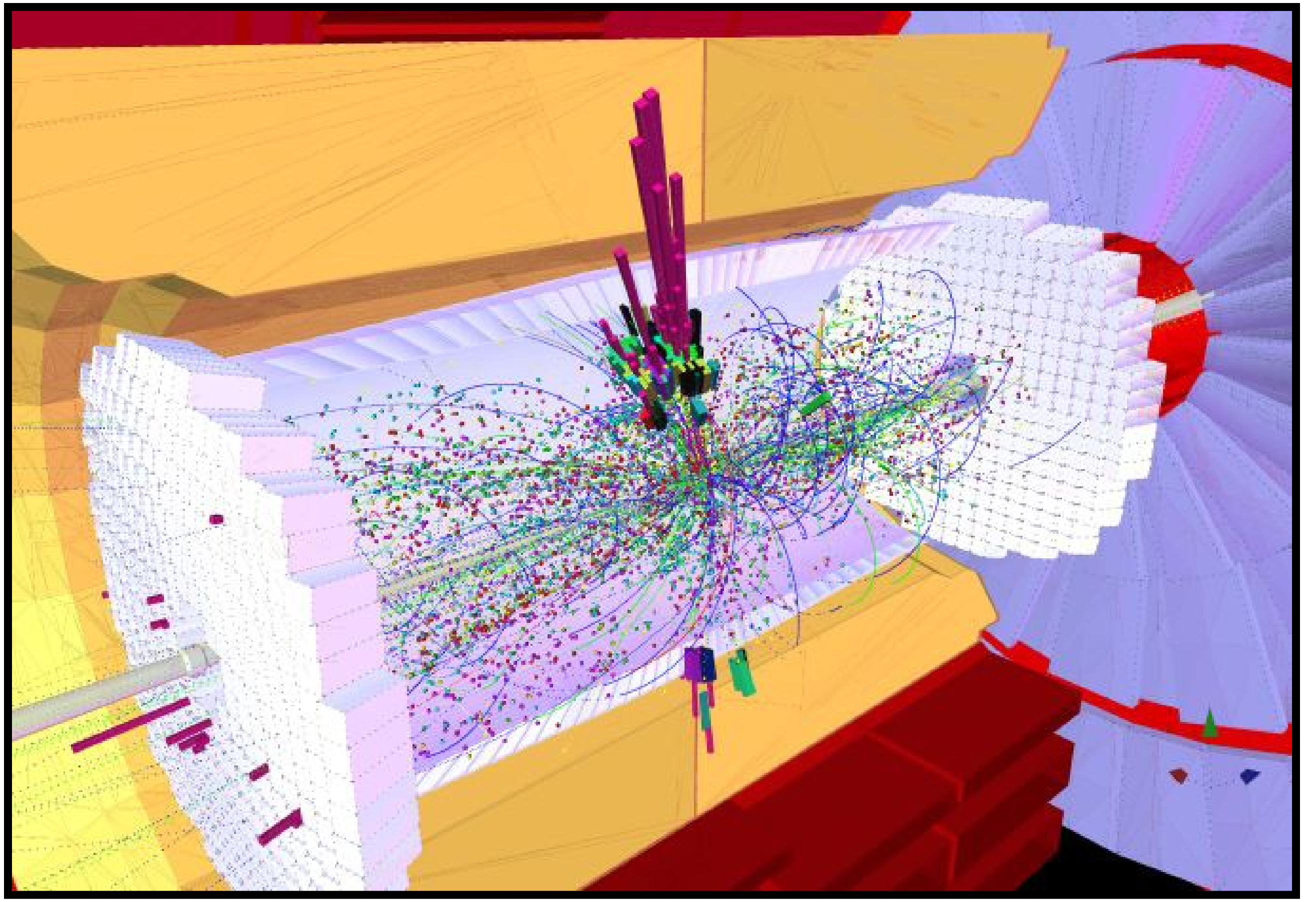




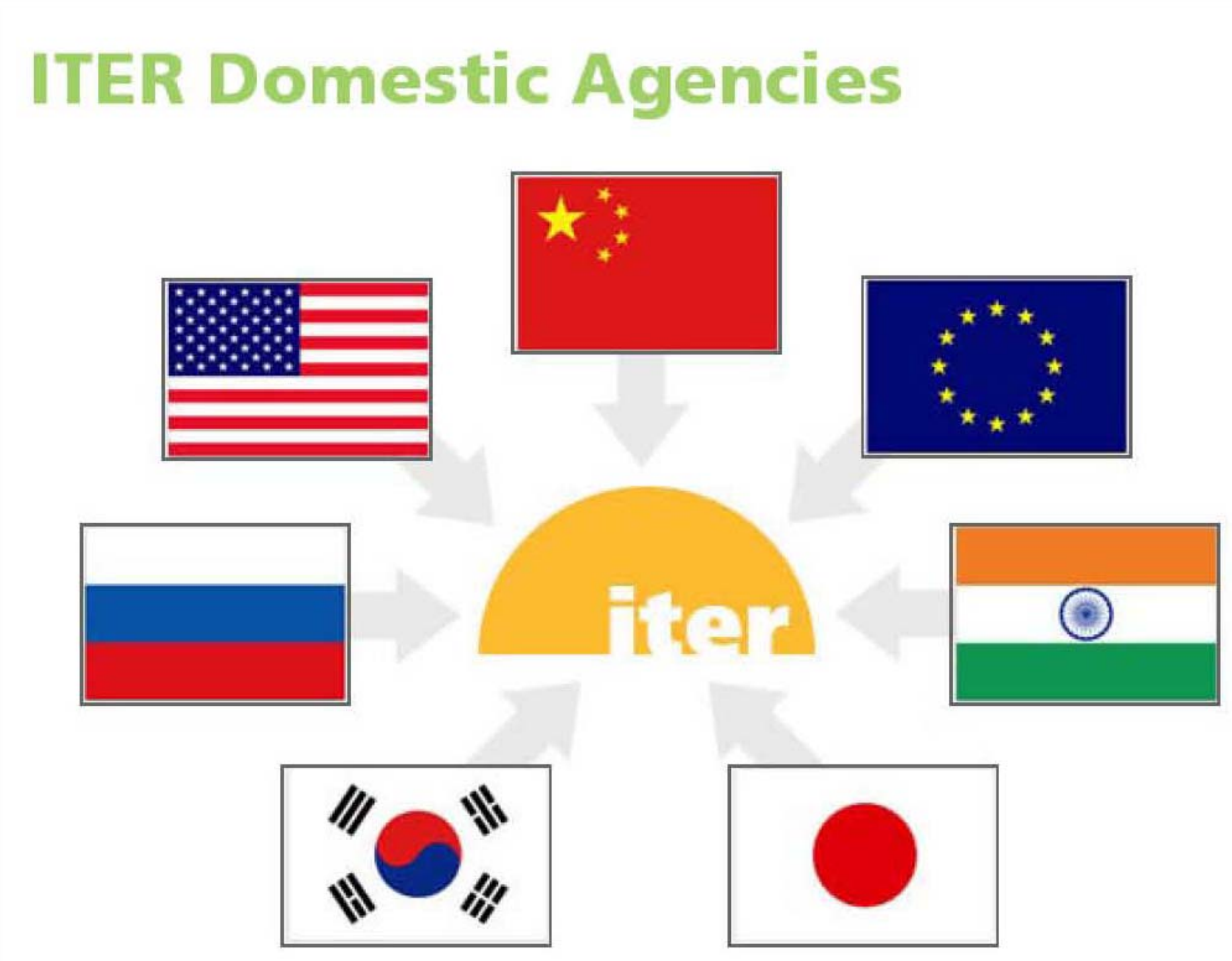
It is now 2009

- Research teams are in place in Geneva
  - Faculty, post docs and graduate students
  - Technical personnel
  - From many universities
- The research programs at CERN can provide a sustained opportunity to attract, engage, and educate students
  - We should not miss this opportunity

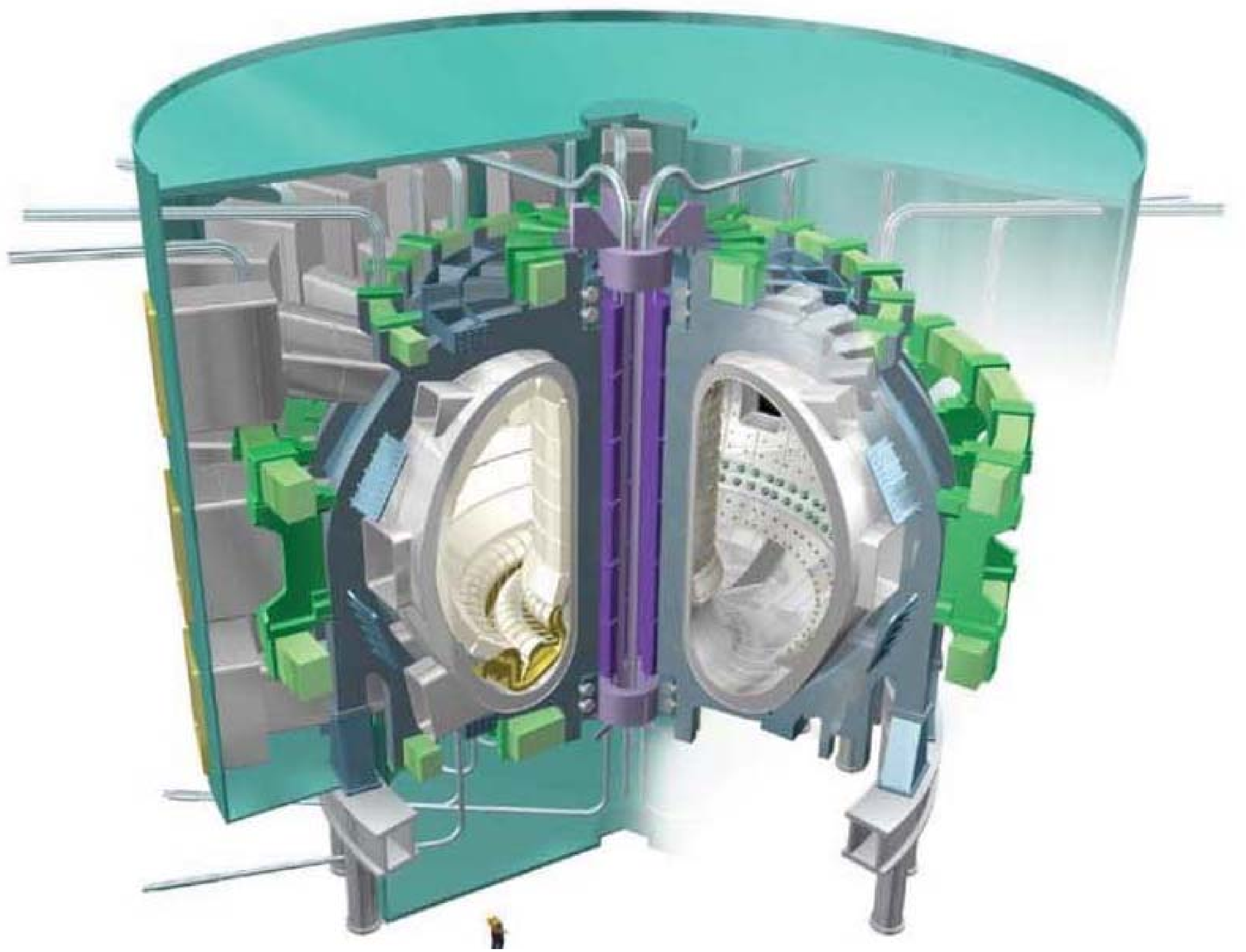
A hypothesized new particle Z'



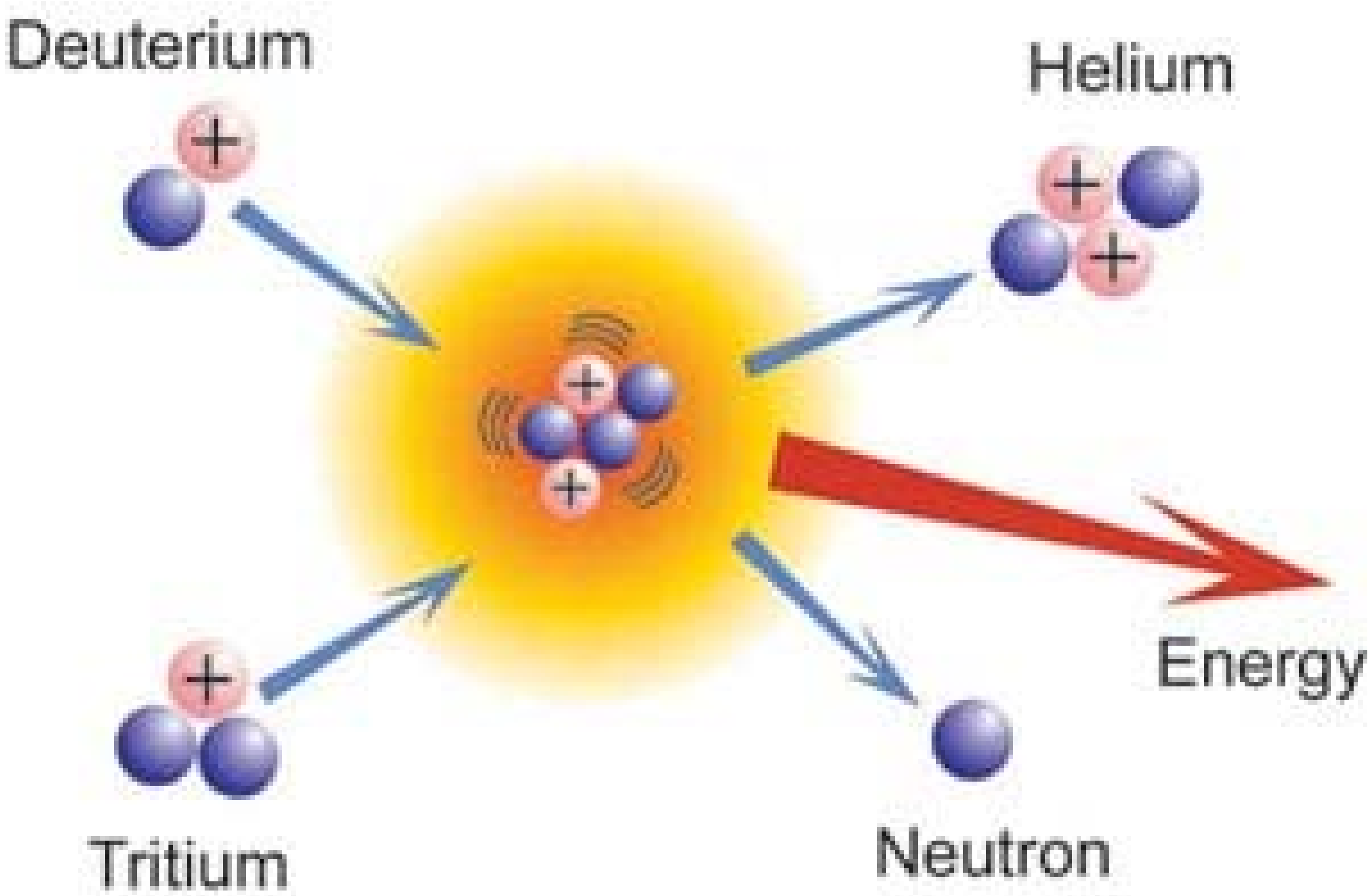
Fusion Energy



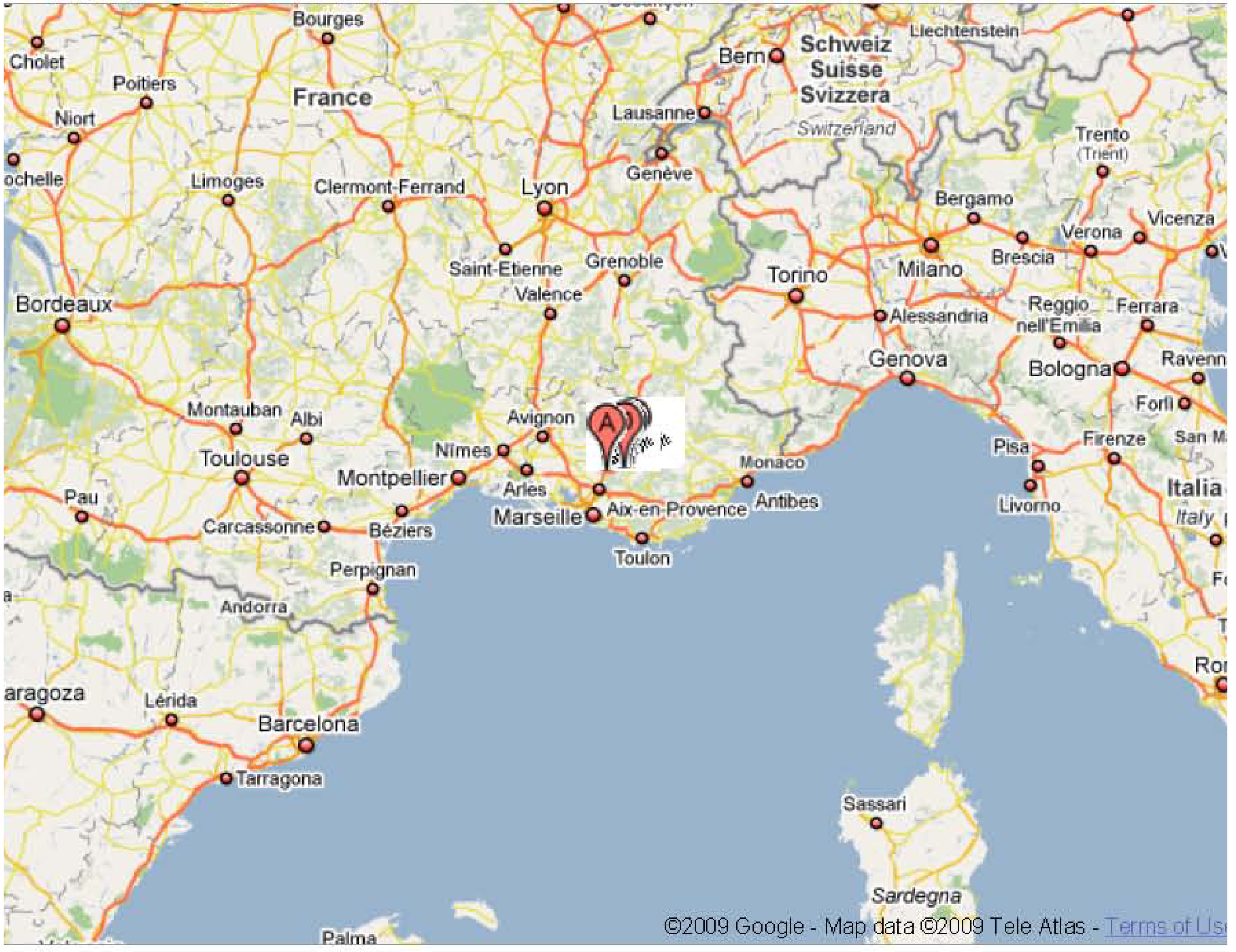
ITER – The World's Largest Tokamak



How does fusion produce energy?

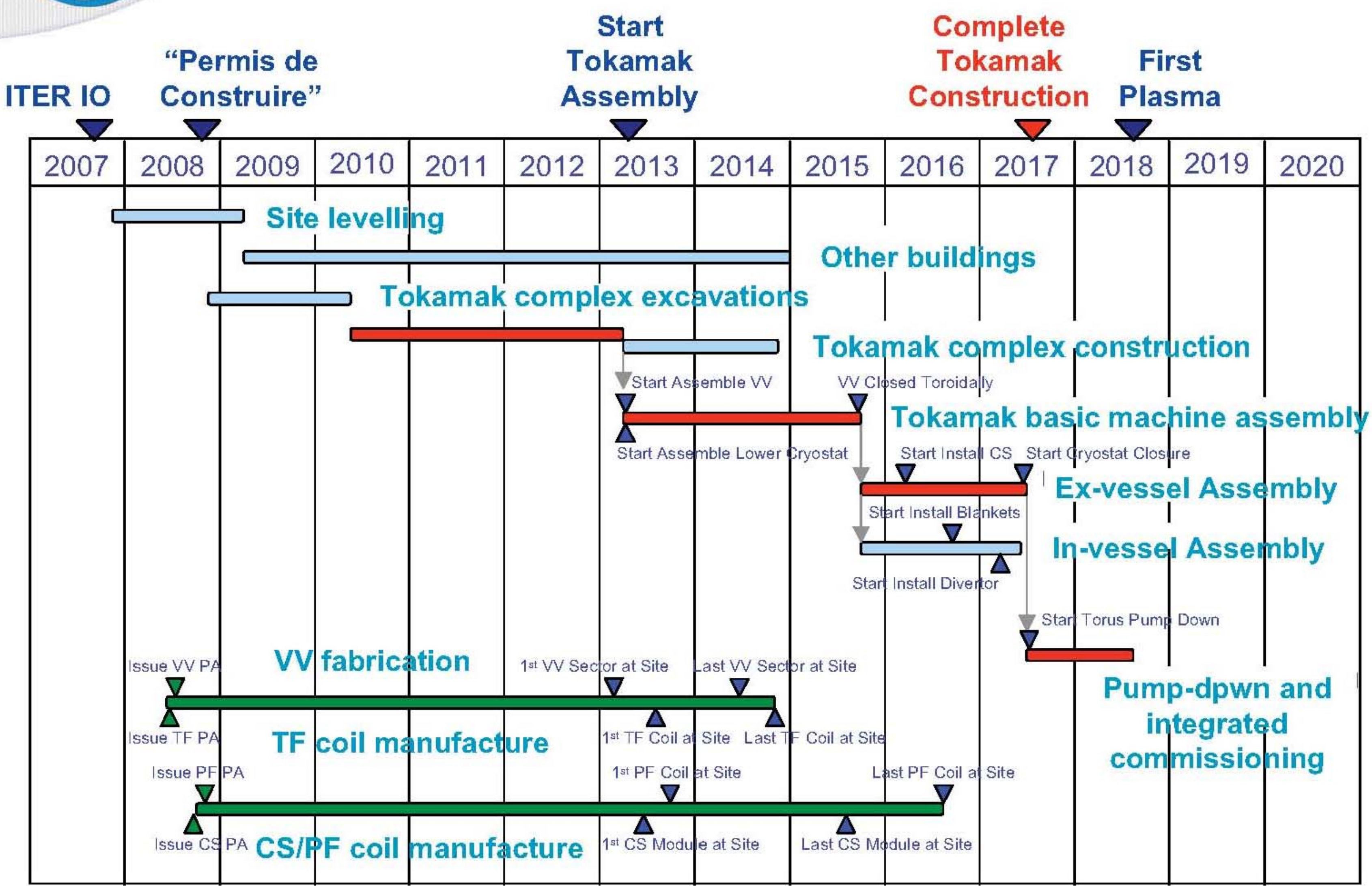


The Location of ITER



ITER

ITER reference project schedule



World Health Organization

- All countries which are Members of the United Nations may become members of WHO by accepting its Constitution.
- Other countries may be admitted as members when their application has been approved by a simple majority vote of the World Health Assembly.
- Territories which are not responsible for the conduct of their international relations may be admitted as Associate Members upon application made on their behalf by the Member or other authority responsible for their international relations.
- Members of WHO are grouped according to regional distribution (193 Member States).

The WHO Agenda

- Promoting Development
- Fostering Health Security
- Strengthening health systems
- Harnessing research, information and evidence
- Enhancing partnerships
- Improving performance

WHO: Education and training

- In May 2006, the World Health Assembly adopted Resolution WHA59.23 urging Member States to affirm their commitment to the education and training of more health workers.
- This Resolution gave WHO a mandate to:
- provide technical support to Member States, as needed, in their efforts to revitalize health education and training institutions, and rapidly increase the health workforce;
- encourage global health partners to support education and training institutions;
- encourage Member States to engage in partnerships intended to improve the capacity and quality of health-professional education in developing countries;
- encourage and support Member States in the development of health-workforce planning teams, and the use of innovative approaches to teaching, including the use of information and communications technology.

Summary

- The programs described have been built fundamentally through international partnership.
  - These often involve unique challenges.
- It requires creative work.
  - In the external communities involved…and in the funding agencies…and through diplomatic involvement…
- To be successful (and valuable), these efforts must be sustained for extended periods of time
  - And, these can afford exceptional educational opportunities for US students

BACK UP SLIDES

CERN

- The current Member States are: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom.

CERN

- **Observer States and Organizations** currently involved in CERN programmes are: the European Commission, India, Israel, Japan, the Russian Federation, Turkey, UNESCO and the USA.
- **Non-Member States** currently involved in CERN programmes are: Algeria, Argentina, Armenia, Australia, Azerbaijan, Belarus, Brazil, Canada, Chile, China, Colombia, Croatia, Cuba, Cyprus, Estonia, Georgia, Iceland, Iran, Ireland, Lithuania, Mexico, Montenegro, Morocco, New Zealand, Pakistan, Peru, Romania, Serbia, Slovenia, South Africa, South Korea, Taiwan, Thailand, Ukraine and Vietnam.

The LHC

- **The largest scientific machine in the world...**
- The precise circumference of the LHC accelerator is 26 659 m, with a total of 9300 magnets inside. Not only is the LHC the world's largest particle accelerator, just one-eighth of its cryogenic distribution system would qualify as the world's largest fridge. All the magnets will be pre-cooled to -193.2°C (80 K) using 10 080 tonnes of liquid nitrogen, before they are filled with nearly 60 tonnes of liquid helium to bring them down to -271.3°C (1.9 K).

- At full power, trillions of protons will race **The fastest racetrack on the planet...**
- around the LHC accelerator ring 11 245 times a second, travelling at 99.99% the speed of light. Two beams of protons will each travel at a maximum energy of 7 TeV (tera-electronvolt), corresponding to head-to-head collisions of 14 TeV. Altogether some 600 million collisions will take place every second.

The hottest spots in the galaxy, but even colder than outer space...

- The LHC is a machine of extreme hot and cold. When two beams of protons collide, they will generate temperatures more than 100 000 times hotter than the heart of the Sun, concentrated within a minuscule space. By contrast, the 'cryogenic distribution system', which circulates superfluid helium around the accelerator ring, keeps the LHC at a super cool temperature of -271.3°C (1.9 K) – even colder than outer space!

The emptiest space in the Solar System...

- To avoid colliding with gas molecules inside the accelerator, the beams of particles travel in an ultra-high vacuum – a cavity as empty as interplanetary space. The internal pressure of the LHC is 10^{-13} atm, ten times less than the pressure on the Moon!

The biggest and most sophisticated detectors ever built...

- To sample and record the results of up to 600 million proton collisions per second, physicists and engineers have built gargantuan devices that measure particles with micron precision. The LHC's detectors have sophisticated electronic trigger systems that precisely measure the passage time of a particle to accuracies in the region of a few billionths of a second. The trigger system also registers the location of the particles to millionths of a metre. This incredibly quick and precise response is essential for ensuring that the particle recorded in successive layers of a detector is one and the same.

The most powerful supercomputer system in the world...

- The data recorded by each of the big experiments at the LHC will fill around 100 000 dual layer DVDs every year. To allow the thousands of scientists scattered around the globe to collaborate on the analysis over the next 15 years (the estimated lifetime of the LHC), tens of thousands of computers located around the world are being harnessed in a distributed computing network called the Grid.

A Computing Grid

- The Large Hadron Collider will produce roughly 15 petabytes (15 million gigabytes) of data annually – enough to fill more than 1.7 million dual-layer DVDs a year!
- Thousands of scientists around the world want to access and analyse this data, so CERN is collaborating with institutions in 33 different countries to operate a distributed computing and data storage infrastructure: the LHC Computing Grid (LCG).

The impact of data

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How does fusion produce energy?

- Atoms never rest: the hotter they are, the faster they move. In the core of our Sun, temperatures reach 15 000 000° Celsius. Hydrogen atoms are in a constant state of agitation, colliding at very great speeds. The natural electrostatic repulsion that exists between the positive charges of their nuclei is overcome, and the atoms fuse. The fusion of two light Hydrogen atoms (H-H) produces a heavier element, Helium.

  The mass of the resulting Helium atom is not the exact sum of the two initial atoms, however: some mass has been lost and great amounts of energy have been gained. This is what Einstein's formula $E=mc^2$ describes: the tiny bit of lost mass (m), multiplied by the square of the speed of light (c^2), results in a very large figure (E) which is the amount of energy created by a fusion reaction.

  Every second, our Sun turns 600 million tons of Hydrogen into Helium, releasing an enormous amount of energy. But without the benefit of gravitational forces at work in our Universe, achieving fusion on Earth has required a different approach.

Fusion on Earth

- 20th century fusion science has identified the most efficient fusion reaction to accomplish in the laboratory setting: the reaction between two Hydrogen isotopes Deuterium (D) and Tritium (T).
- In ITER, the fusion reaction will be achieved in a **tokamak** device that uses magnetic fields to contain and control the hot plasma. The fusion between Deuterium and Tritium (D-T) will produce one Helium nuclei, one neutron and energy.
- The Helium nucleus carries an electric charge which will respond to the magnetic fields of the tokamak, and remain confined within the plasma. However some 80% of the energy produced is carried away from the plasma by the neutron which has no electrical charge and is therefore unaffected by magnetic fields.
- The neutrons will be absorbed by the surrounding walls of the tokamak, transferring their energy to the walls as heat.
- In ITER, this heat will be dispersed through cooling towers. In the subsequent fusion plant prototype DEMO and in future industrial fusion installations, the heat will be used to produce steam and - by way of turbines and alternators - electricity.

On to DEMO

- ITER is not an end in itself: it is the bridge toward a first plant that will demonstrate the large-scale production of electrical power and Tritium fuel self-sufficiency. This is the next step after ITER: the Demonstration Power Plant, or DEMO for short. A conceptual design for such a machine could be complete by 2017. If all goes well, DEMO will lead fusion into its industrial era, beginning operations in the early 2030s, and putting fusion power into the grid as early as 2040.

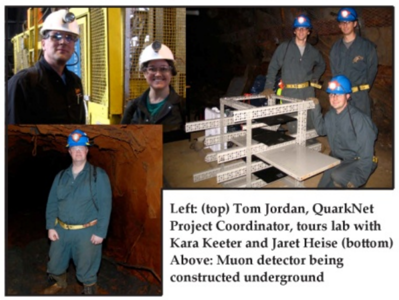
Interactions in Understanding the Universe (I2U2)

- A partnership:
  - Domain sciences and experiments
  - Educators (formal and informal)
  - Computer science including Grid
- Develops tools for student research directly in the classroom or a museums
  - eLabs, iLabs
  - The opportunity is available nationwide (and internationally)

Research at DUSEL
(Deep Underground Science and Engineering Lab)

Mining for New Physics

Dr. Kara Keeter is establishing a nuclear and particle astrophysics program at Black Hills State University that studies the very smallest particles in the universe in order to understand structures as large as stars, supernova, and even galaxies. Two elusive particles, neutrinos and dark matter, are the current subject of intense debate and interest. In fact, national advisory committees list investigating the nature of dark matter and neutrinos among the highest priority questions in particle physics today.



Left: (top) Tom Jordan, QuarkNet Project Coordinator, tours lab with Kara Keeter and Jaret Heise (bottom) Above: Muon detector being constructed underground

Although these particles arrive at the Earth from space, they are so hard to "see" that it is necessary to place the detectors deep underground, to shield from background "noise" found on surface. DUSEL will be among the world's premier locations for such research, and work has already begun at the interim Sanford Lab. BHSU scientists are involved in collaborations with physicists from prestigious institutions throughout the United States and the world to study neutrinos and dark matter.

These internationally-recognized experiments have the potential to change the basic Standard Model of Particle Physics and to forever enhance our understanding of the universe. QuarkNet at Black Hills State University offers teachers a unique opportunity to participate in this ground-breaking research.

Two Main DUSEL Projects

BHSU is involved in two important DUSEL Physics Projects: DArCSide and Majorana.

DArCSide

- Multi-ton Dark Matter Detector using ultrapure liquid argon
- Collaboration includes BHSU, Fermilab, MIT, Princeton, Temple, U. of Houston, U. of Massachusetts at Amherst, and Notre Dame
- We will build a Trace Gas Analyzer based on the latest Cavity Ring-Down Spectroscopy technology
- Our design, in collaboration with the inventor Kevin Lehmann from University of Virginia, will improve upon existing technology
- This is also cruicial to LUX and other collaborations and industry and may be patentable.

Majorana

- Neutrinoless Double Beta Decay Detector using germanium crystals
- Collaboration includes BHSU, U. of Washington, Los Alamos, UNC, and many others

BHSU's proximity to DUSEL means we will be vital in the clean room and ultra-low-level background counting facility.

The BHSU Astroparticle Physics team includes: Dr. Kara Keeter, Dr. Dan Durben, Dr. Michael Zehfus, and Dr. Jaret Heise.

The BHSU team holds leadership positions in the 2010 Research Center as well as several pending NSF proposals.

Graduate Credit

QuarkNet offers optional graduate credit in natural science and mathematics through Aurora University, Aurora, IL with whom Fermilab has an ongoing agreement. The current cost is **$75 per credit hour** paid by the enrolling student.

Year 1
The **eight-week** appointment through the "TRAC Teacher Research Program, NSM 5408" carries 4.5 hours of credit.

Year 2
The **three-week** institute through the "QuarkNet Teacher Institute II, NSM 5062" course carries 6 hours of credit.

Year 3
The **one-week** follow-on through the "QuarkNet Teacher Institute III, NSM 6208" course carries 3 hours of credit.

Alternatively, graduate credit is available through BHSU in Physical Sciences. An end-of-project report is required. The current cost is **$50 per credit hour**.

For more information, contact:

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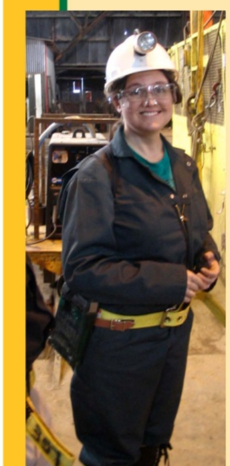
Black Hills State University
~Transforming Lives~

QuarkNet at BHSU



QuarkNet is a teacher professional development program funded by the National Science Foundation and the US Department of Energy and administered by Fermi National Laboratory.

Dr. Kara Keeter, Astroparticle physicist, BHSU, is a member of the Majorana and the DArCSide collaborations.