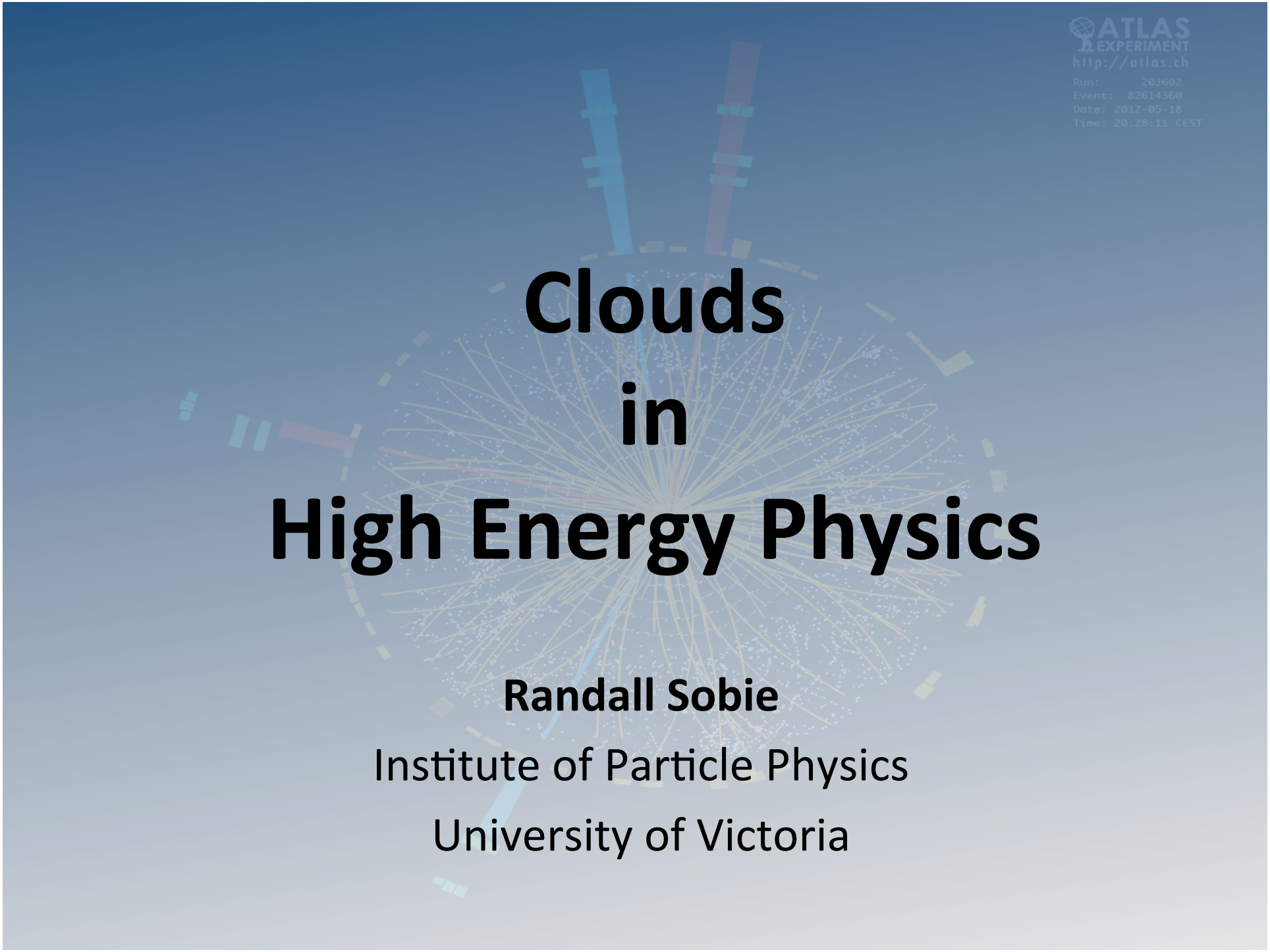



# Clouds in High Energy Physics

**Randall Sobie**

Institute of Particle Physics

University of Victoria

# High Energy Physics

(Particle Physics)

The area of physics that studies the fundamental particles of nature and their interactions.

**Accelerators**

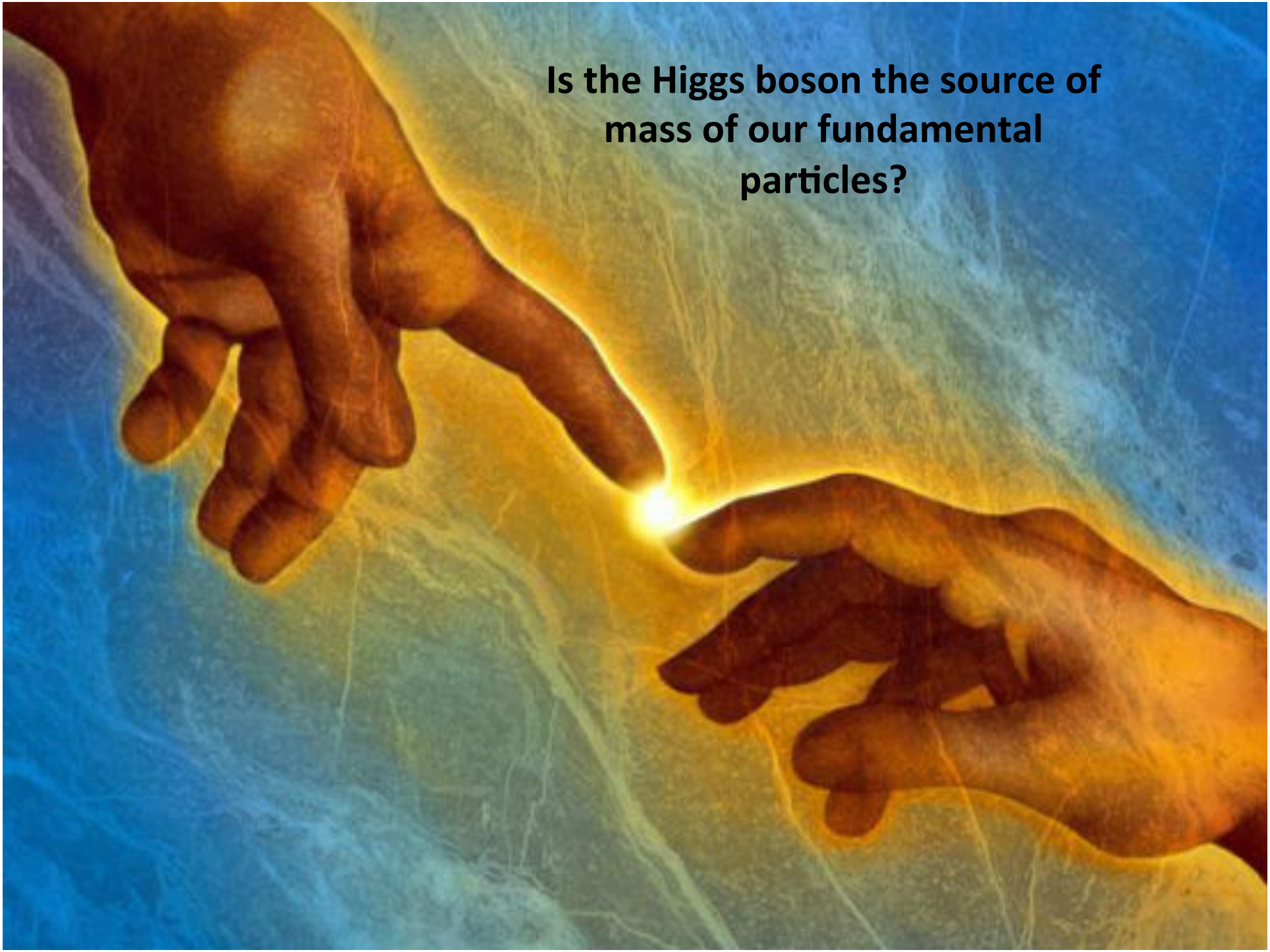
SLAC Linear Accelerator

**Underground labs**

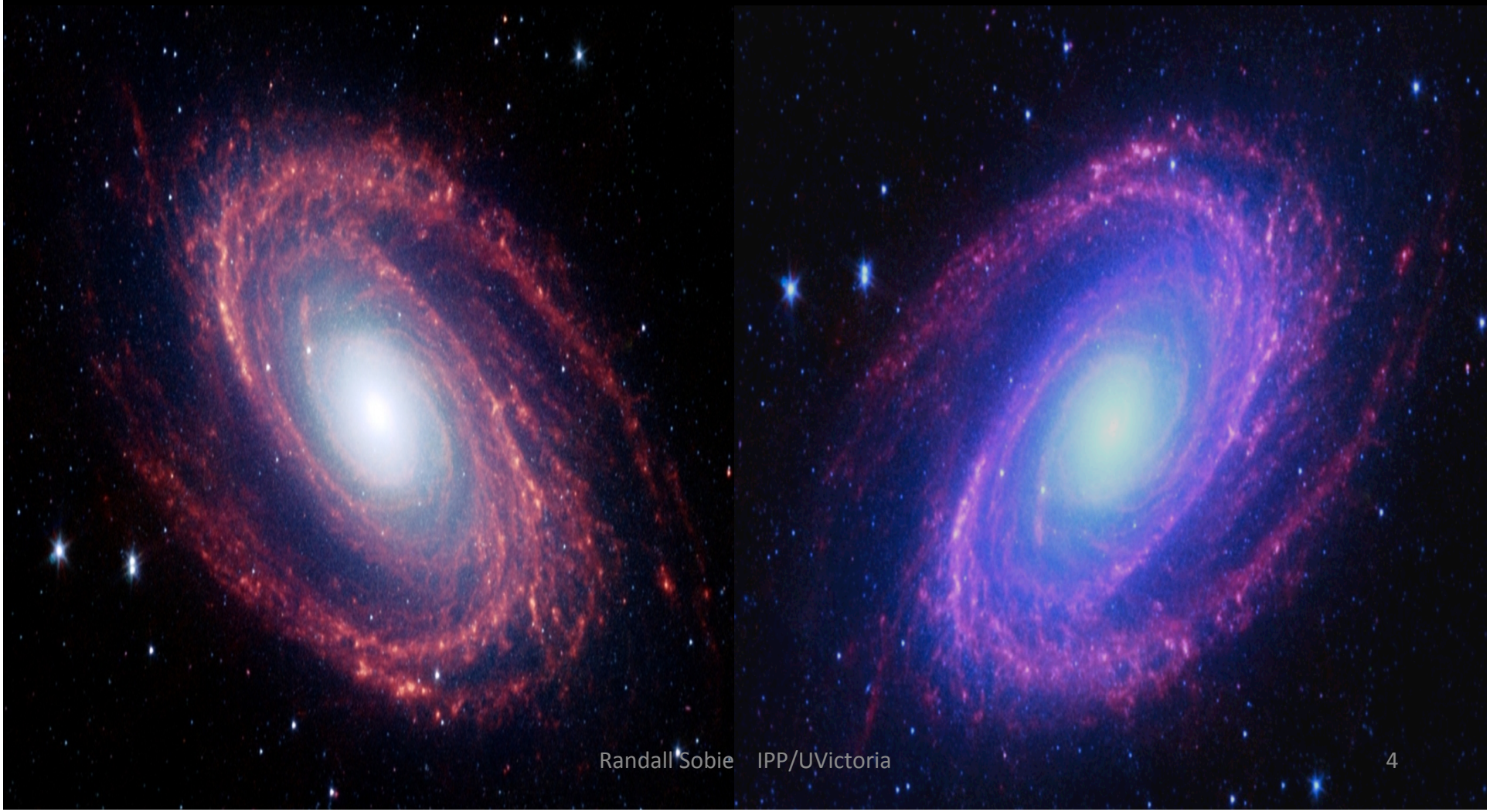
Sudbury Solar Neutrino Detector

**Orbiting labs**

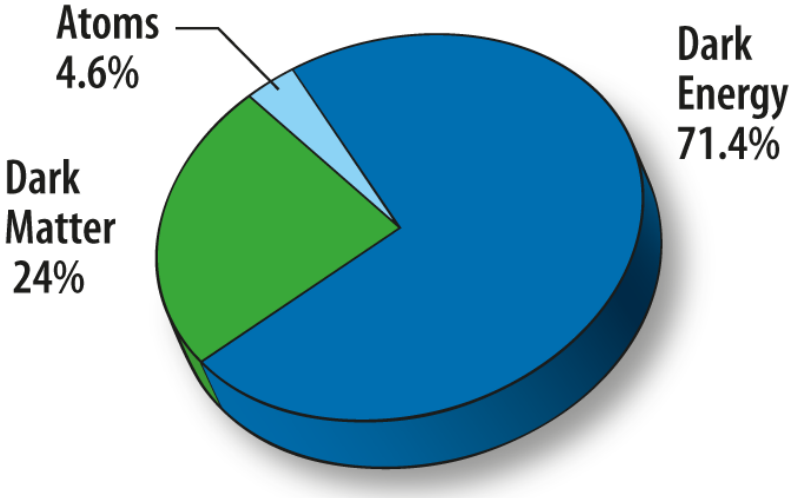
Alpha Magnetic Spectrometer
Space Station


Is the Higgs boson the source of mass of our fundamental particles?

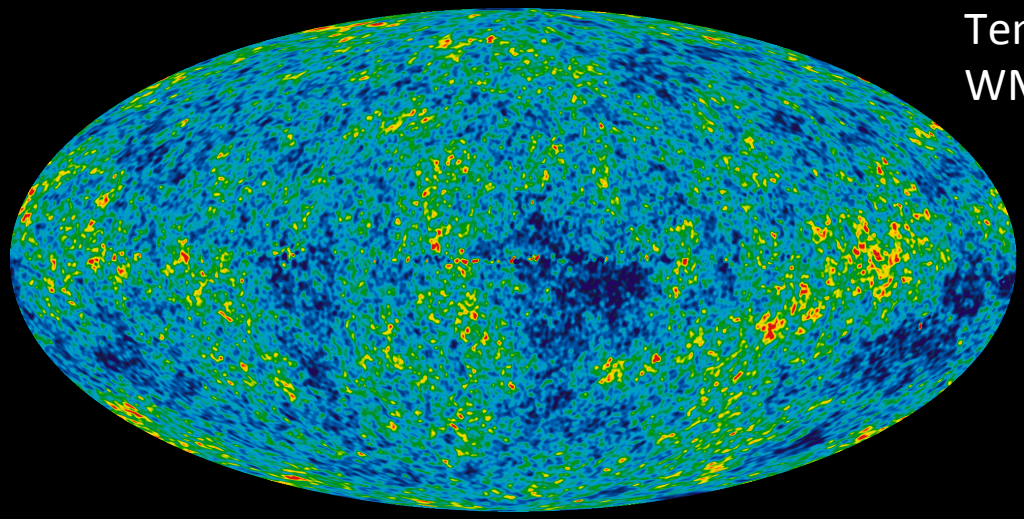
# Why is the universe made of matter and not equal amounts of matter/antimatter?



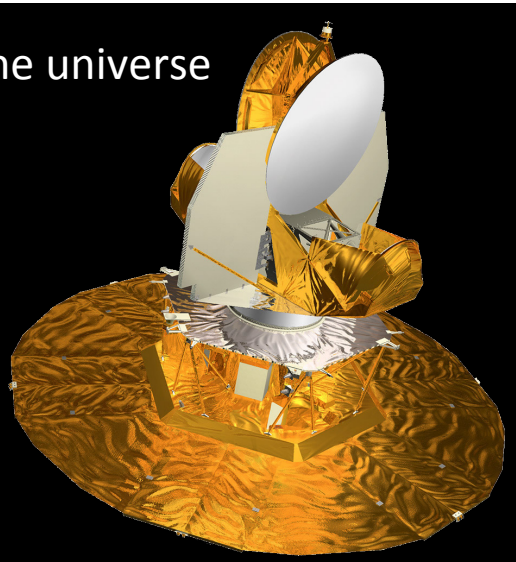
# What is origin of Dark Matter and Dark Energy?



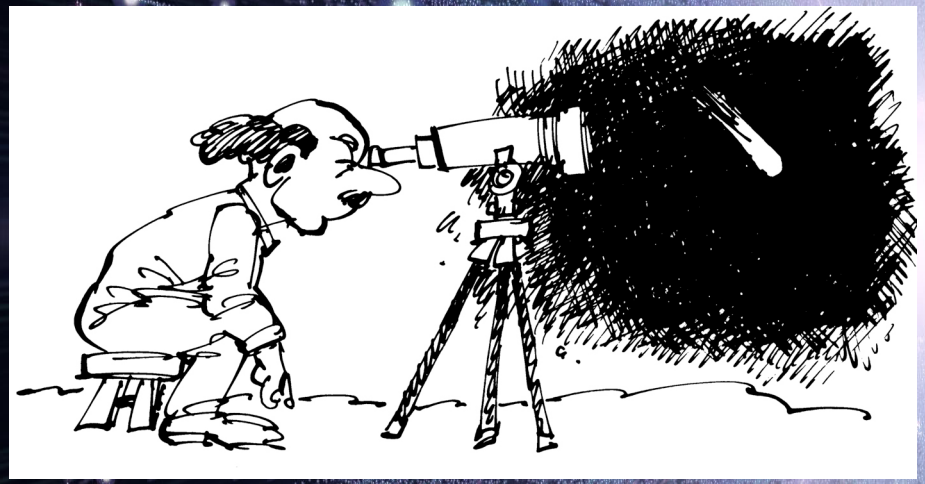

We do not know the composition of 95% of the universe



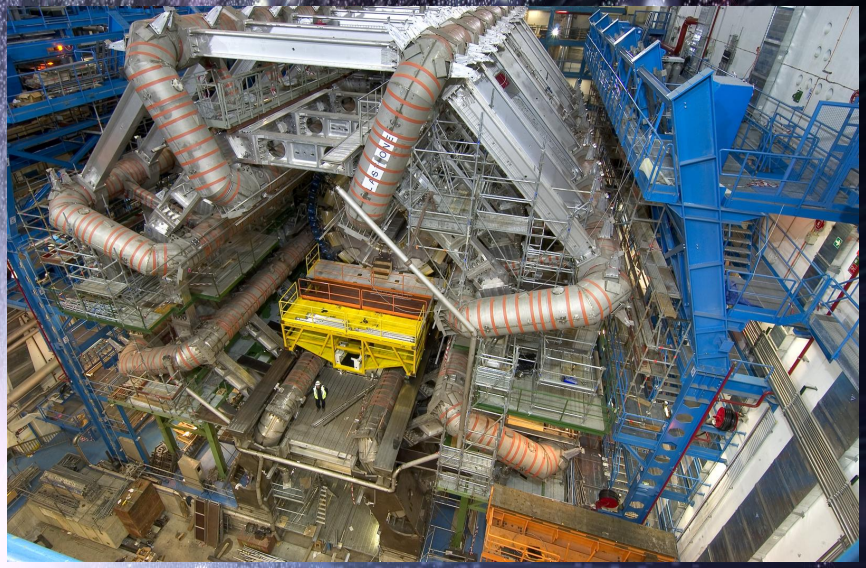
Temperature of the universe
WMAP satellite



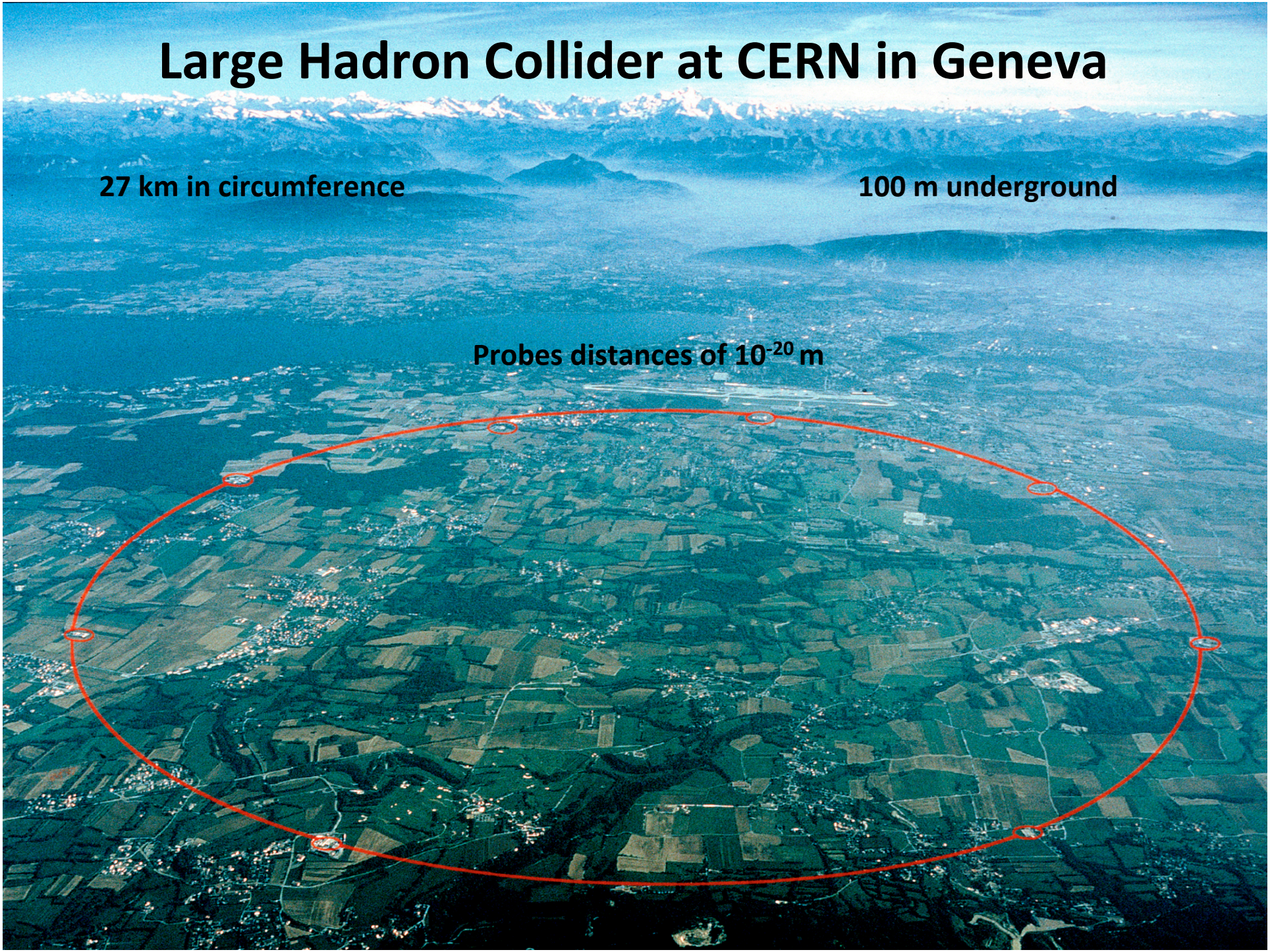
# Understanding our World



# Understanding our World



# Large Hadron Collider at CERN in Geneva

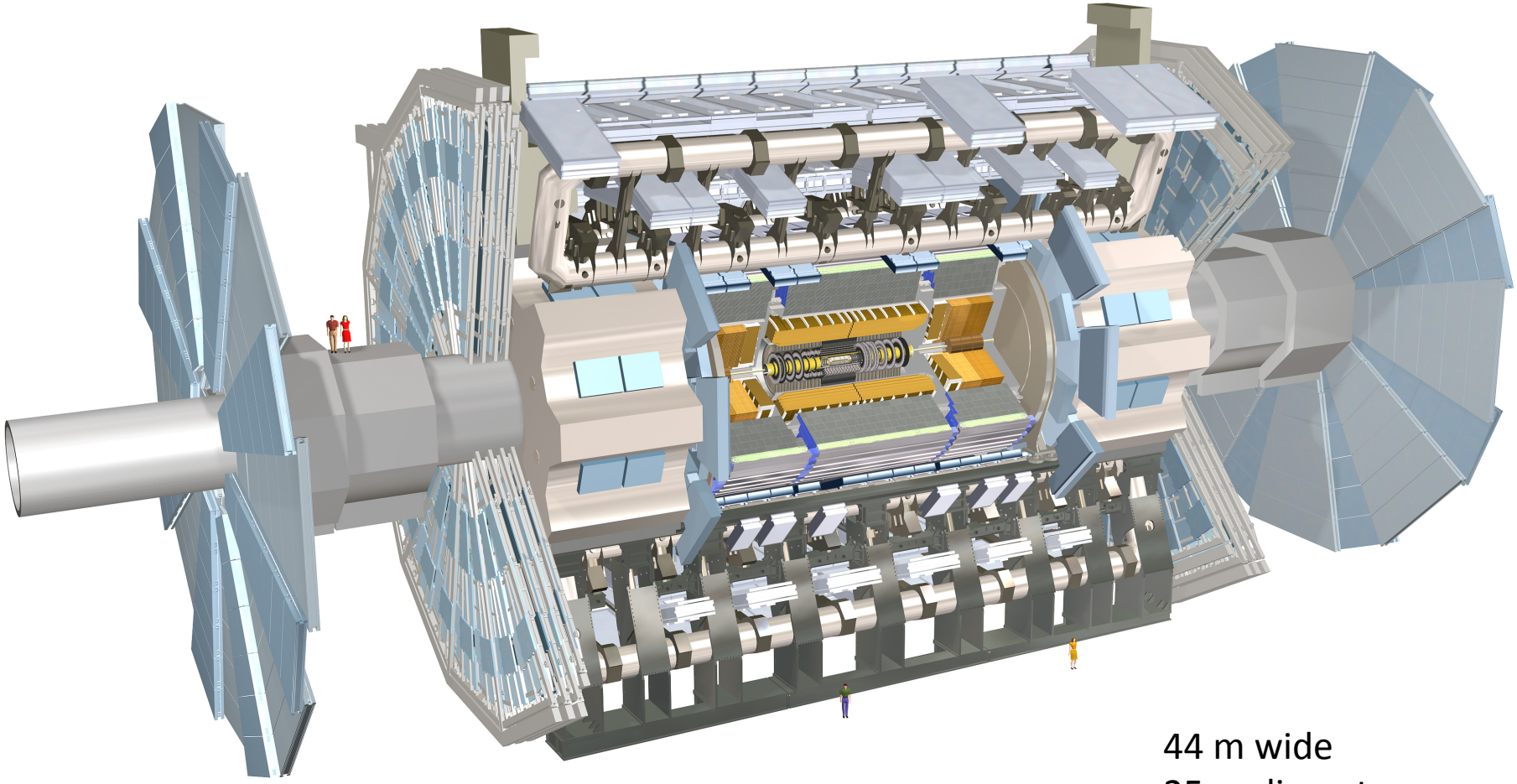


# Large Hadron Collider at CERN in Geneva

**27 km in circumference**

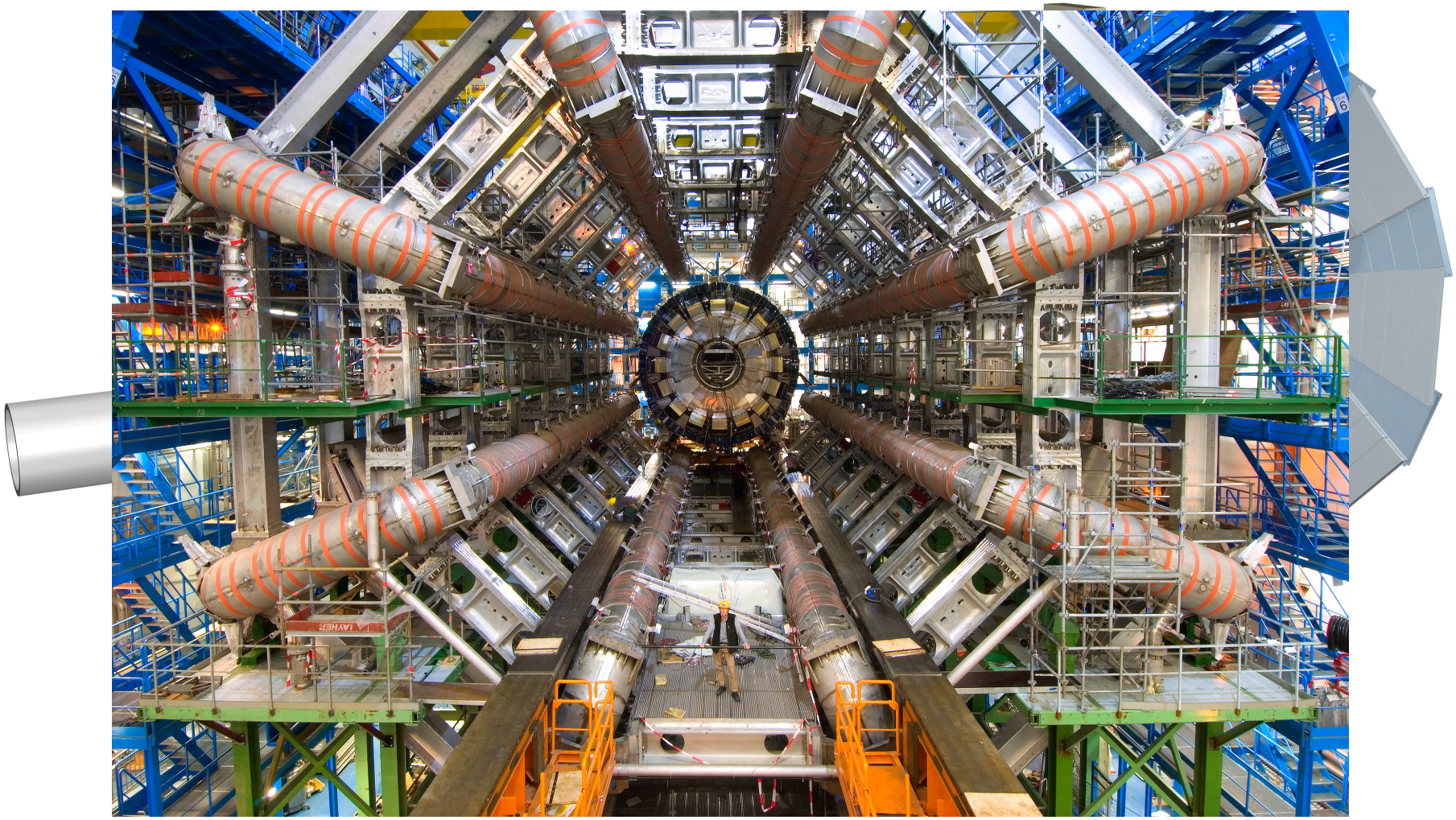
**100 m underground**

# ATLAS Detector

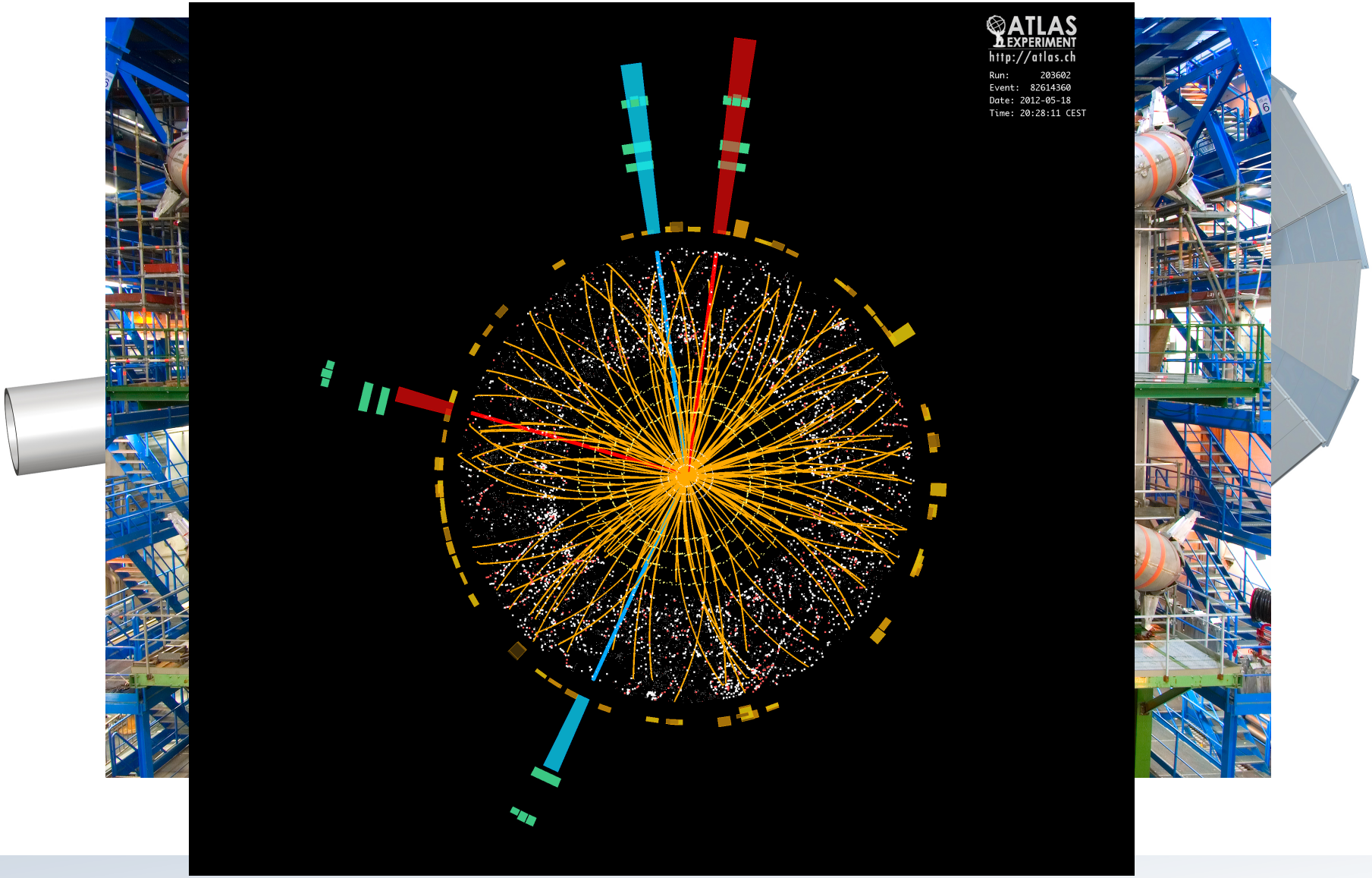


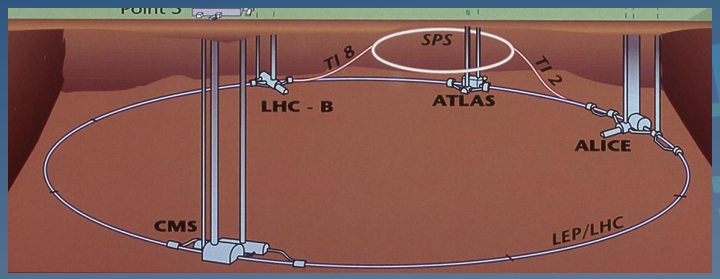
44 m wide
25 m diameter

# ATLAS Detector

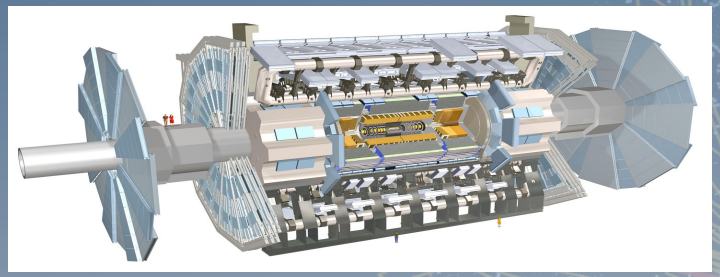


# ATLAS Detector






40 million collisions per second



100,000 collisions selected

200 events per second

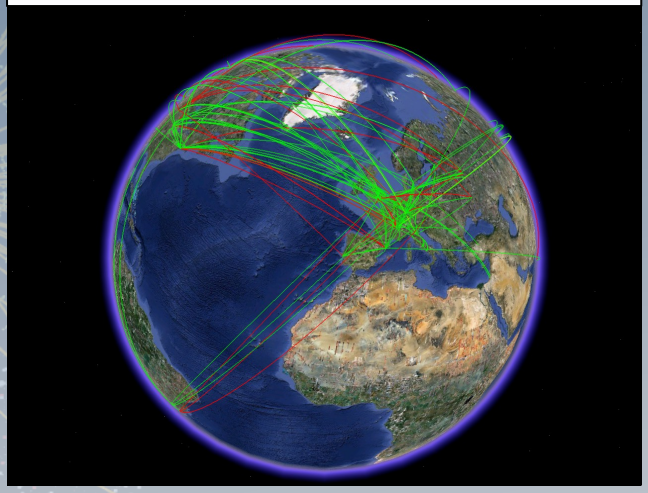
**WLCG Computing Grid**

CERN Tier 0

10 Tier1 sites

60+ Tier2 sites

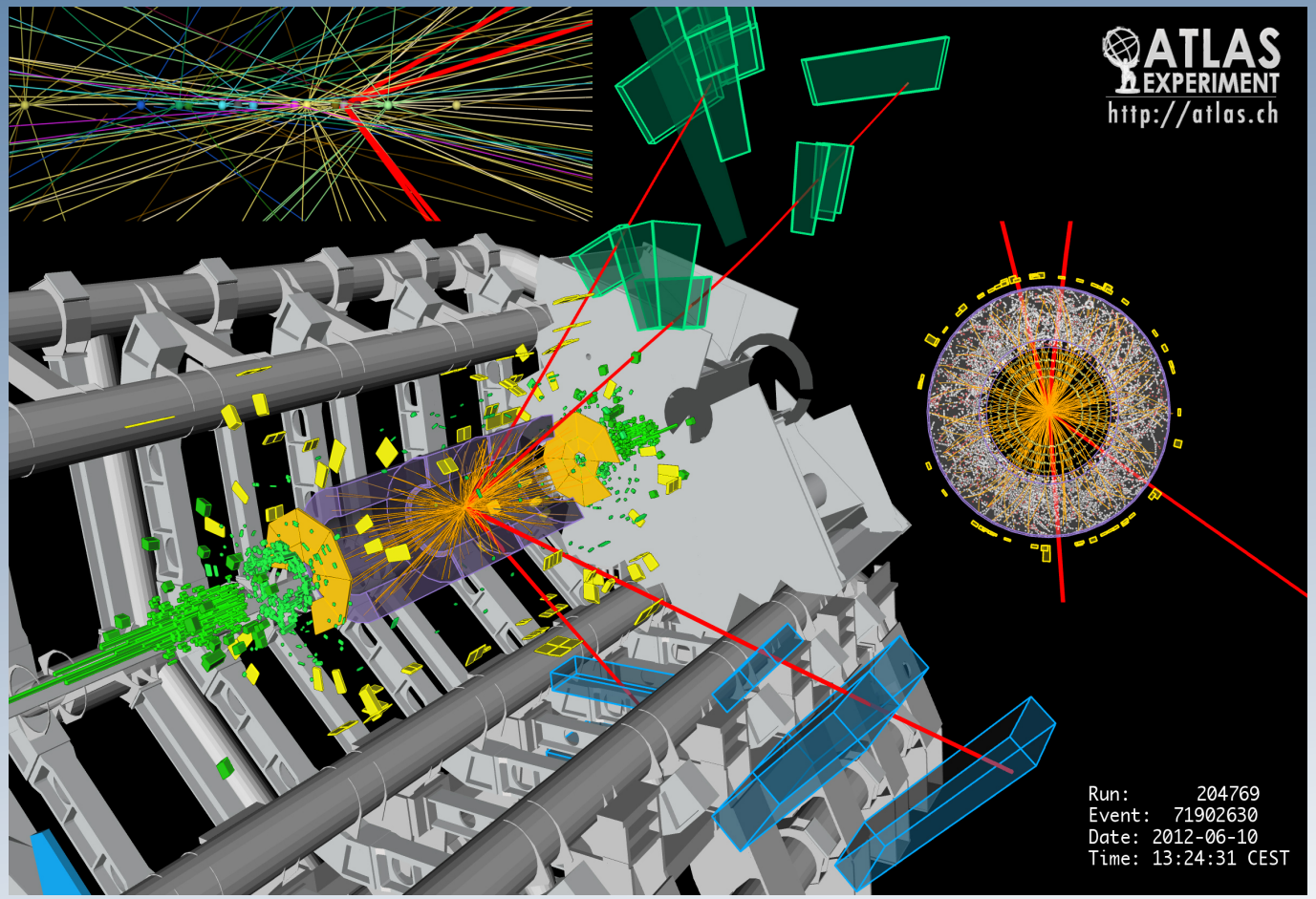
140 PB data



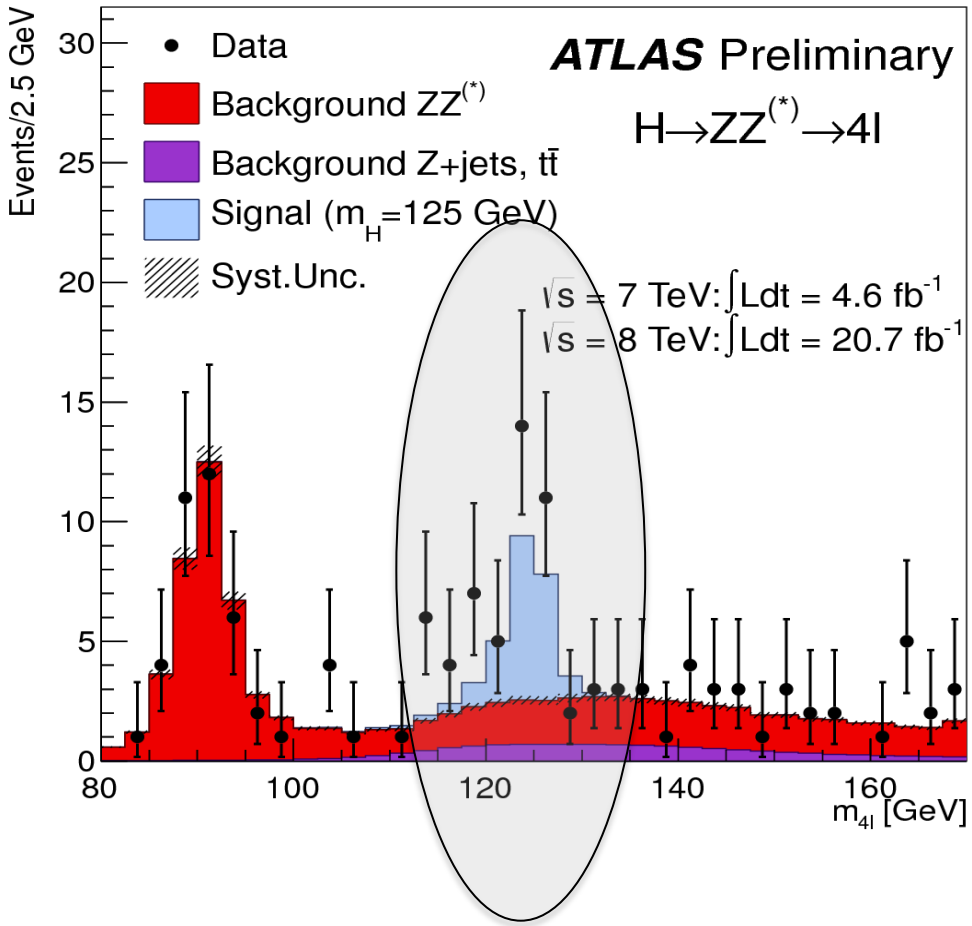
# Higgs Discovery in 2012

The ATLAS and CMS experiments see evidence for a Higgs-like particle

Picture shows an event where the Higgs candidate decays to 4 electron-like particles



# Search for Higgs decays to 4 "leptons" (electrons or muons)




Number of candidates (vertical axis)

Mass of the candidates (horizontal axis)

***We observe an excess of candidates with a mass of 125 proton-masses***

*Also observed in the CMS experiment*

The New York Times

# Science

July 4, 2012

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

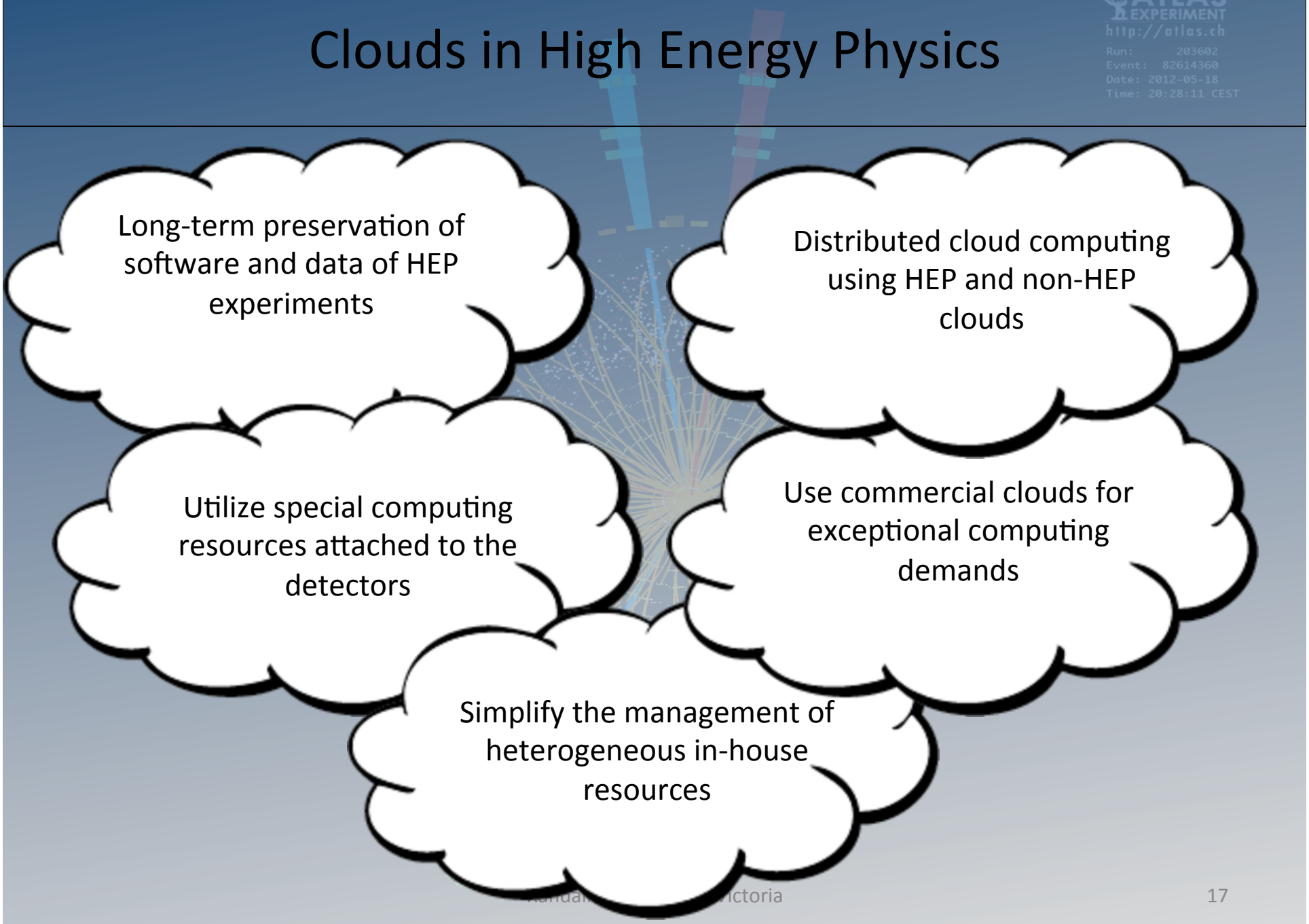
ENVIRONMENT | SPACE & COSMOS

## Physicists Find Elusive Particle Seen as Key to Universe

Pool photo by Denis Balibouse

Scientists in Geneva on Wednesday applauded the discovery of a subatomic particle that looks like the Higgs boson.

# Clouds in High Energy Physics




Long-term preservation of software and data of HEP experiments

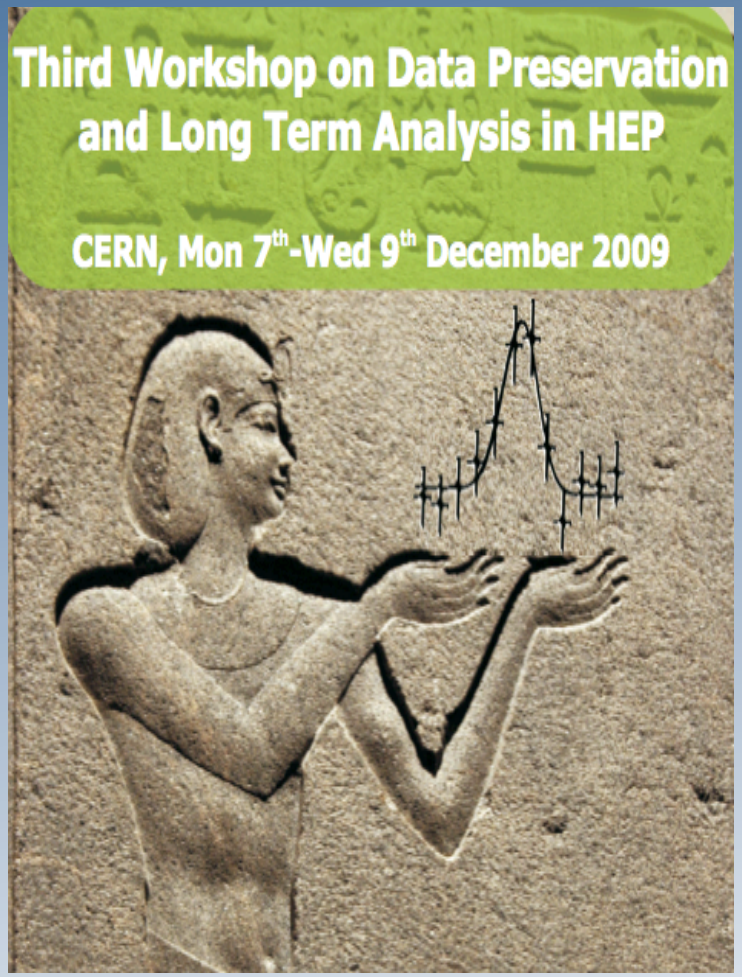
Distributed cloud computing using HEP and non-HEP clouds

Utilize special computing resources attached to the detectors

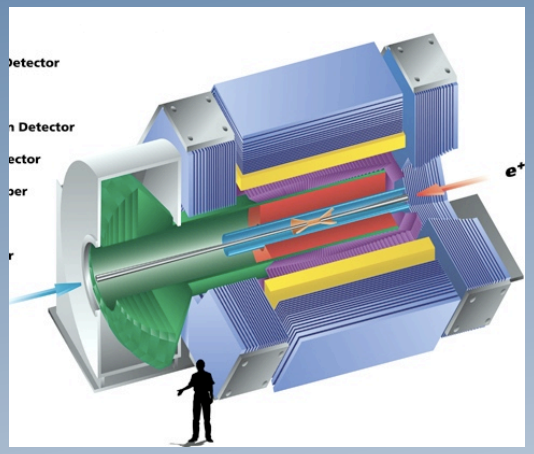
Use commercial clouds for exceptional computing demands

Simplify the management of heterogeneous in-house resources

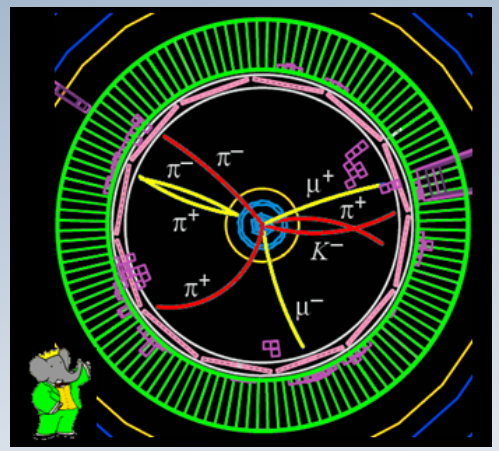
# Using Clouds for Data Preservation



SLAC Linear Accelerator



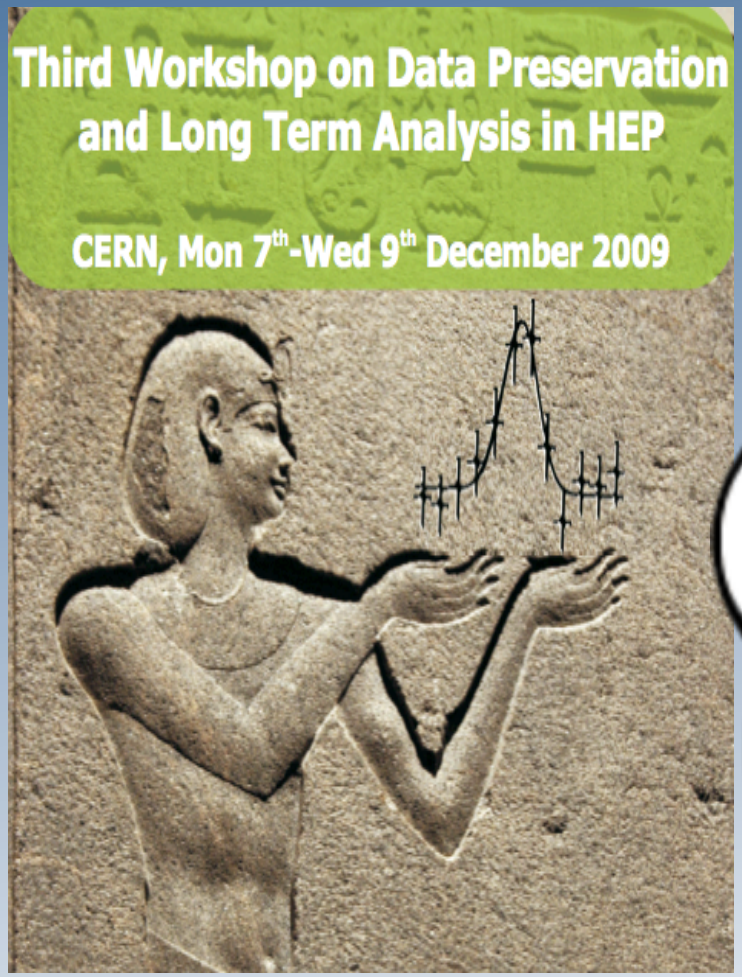

BaBar Detector

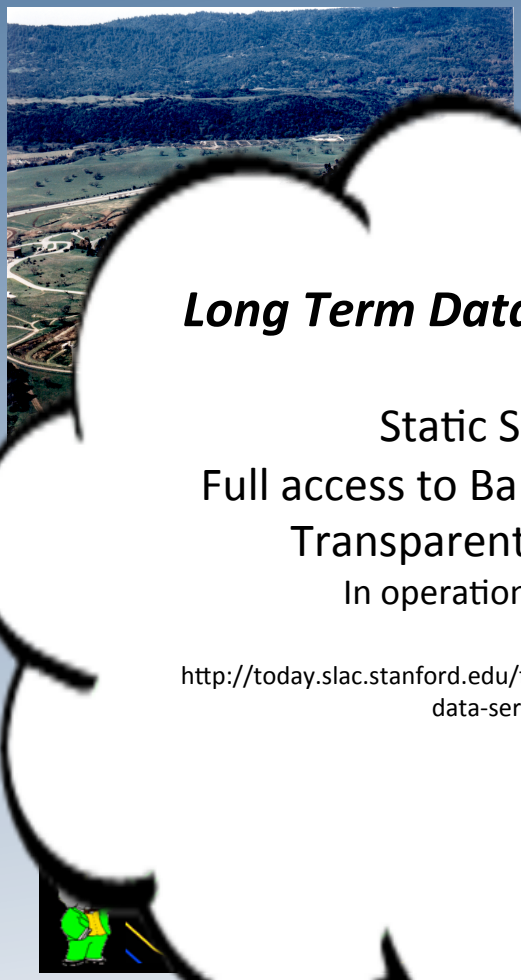


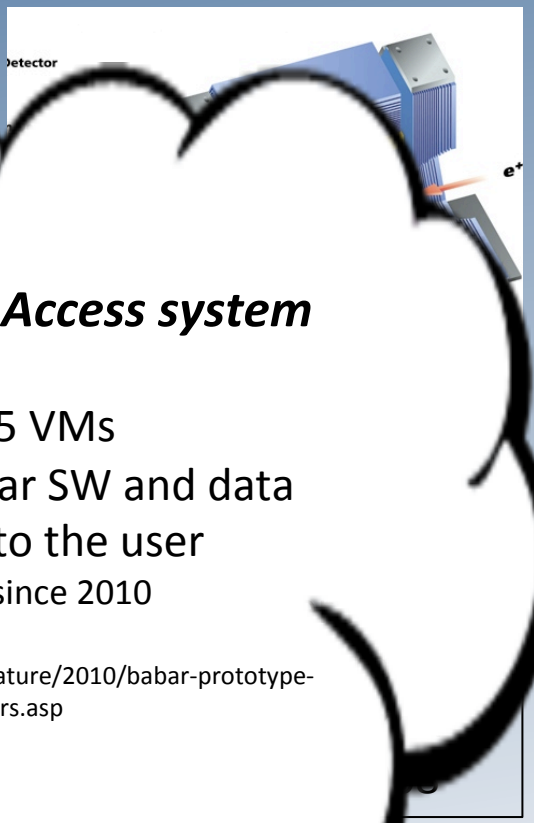

Electron-positron collision

BaBar experiment stopped recording electron-positron collisions in 2008

# Using Clouds for Data Preservation





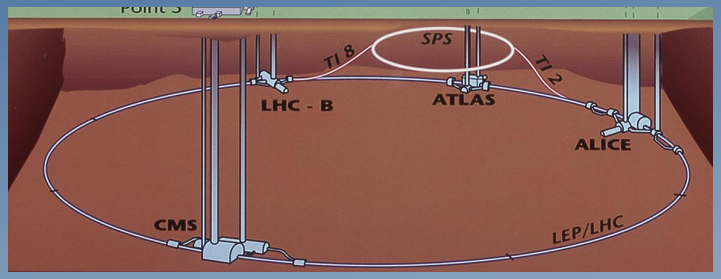

***Long Term Data Access system***

Static SL5 VMs
Full access to BaBar SW and data
Transparent to the user
In operation since 2010

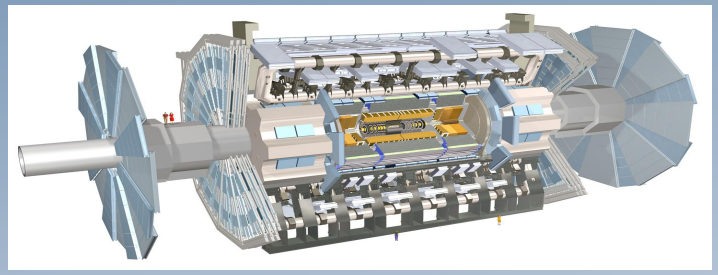
http://today.slac.stanford.edu/feature/2010/babar-prototype-data-servers.asp

Electron-p… co…

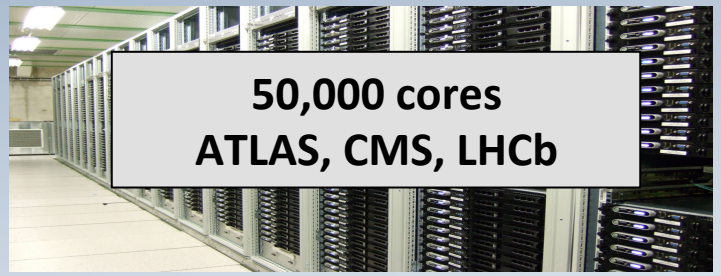
# ATLAS/CMS High Level Trigger Clouds




40 million collisions per second



100,000 collisions selected




200 events per second

**HLT Farms**

These systems are used in real-time when there is colliding beams

The aim is to use the resources during the idle periods for other purposes

Enabled as private OpenStack clouds

***See talk by Toni Perez***
***Wednesday 1100***

# Private and commercial clouds

**Ibex @ CERN** (J. van Eldik, T. Bell, B.Moreira)

OpenStack cloud with 5000 cores
Provide batch services and cloud services

***HEP using Amazon, Google, Rackspace and others***

Star Experiment at RHIC (Brookhaven NL)
Belle Experiment at KEK (Japan)
ATLAS Experiment

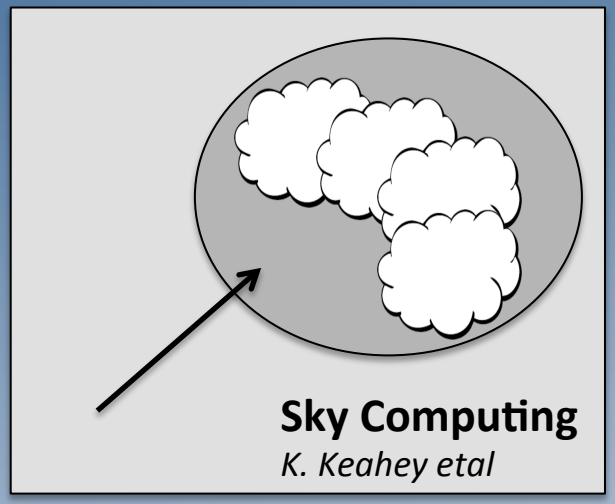
*Commercial clouds used for exceptional low I/O demands*

*Challenges: identity management, API compatibility, VM configuration and network connectivity*

*Costs are higher than our private resources*

# Distributed cloud computing

*Grid of Clouds*



**Sky Computing**
*K. Keahey etal*

Seamlessly use multiple, heterogeneous IaaS clouds for batch workloads

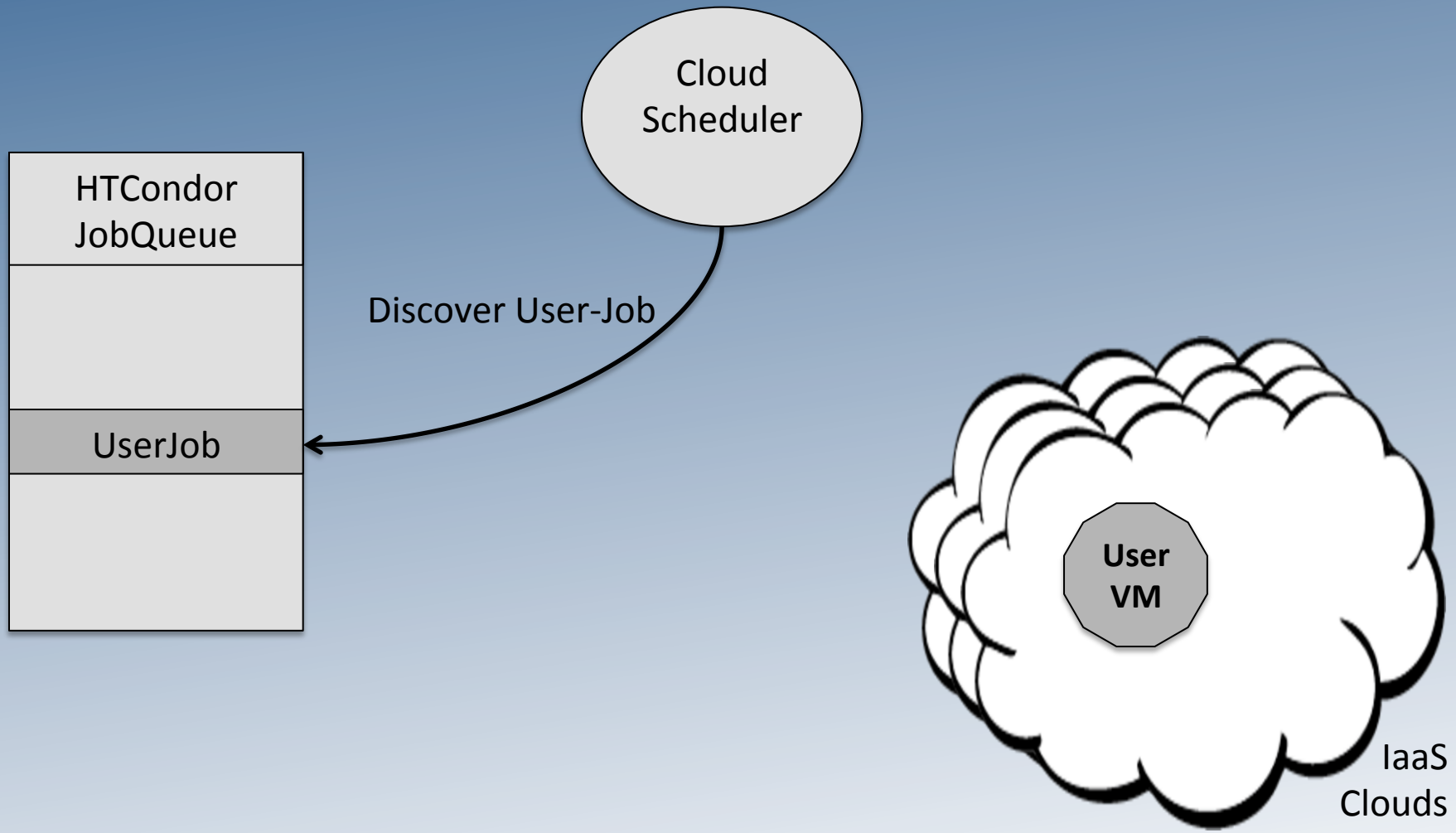
Use dedicated HEP and non-HEP opportunistic resources

Independent of the IaaS cloud type

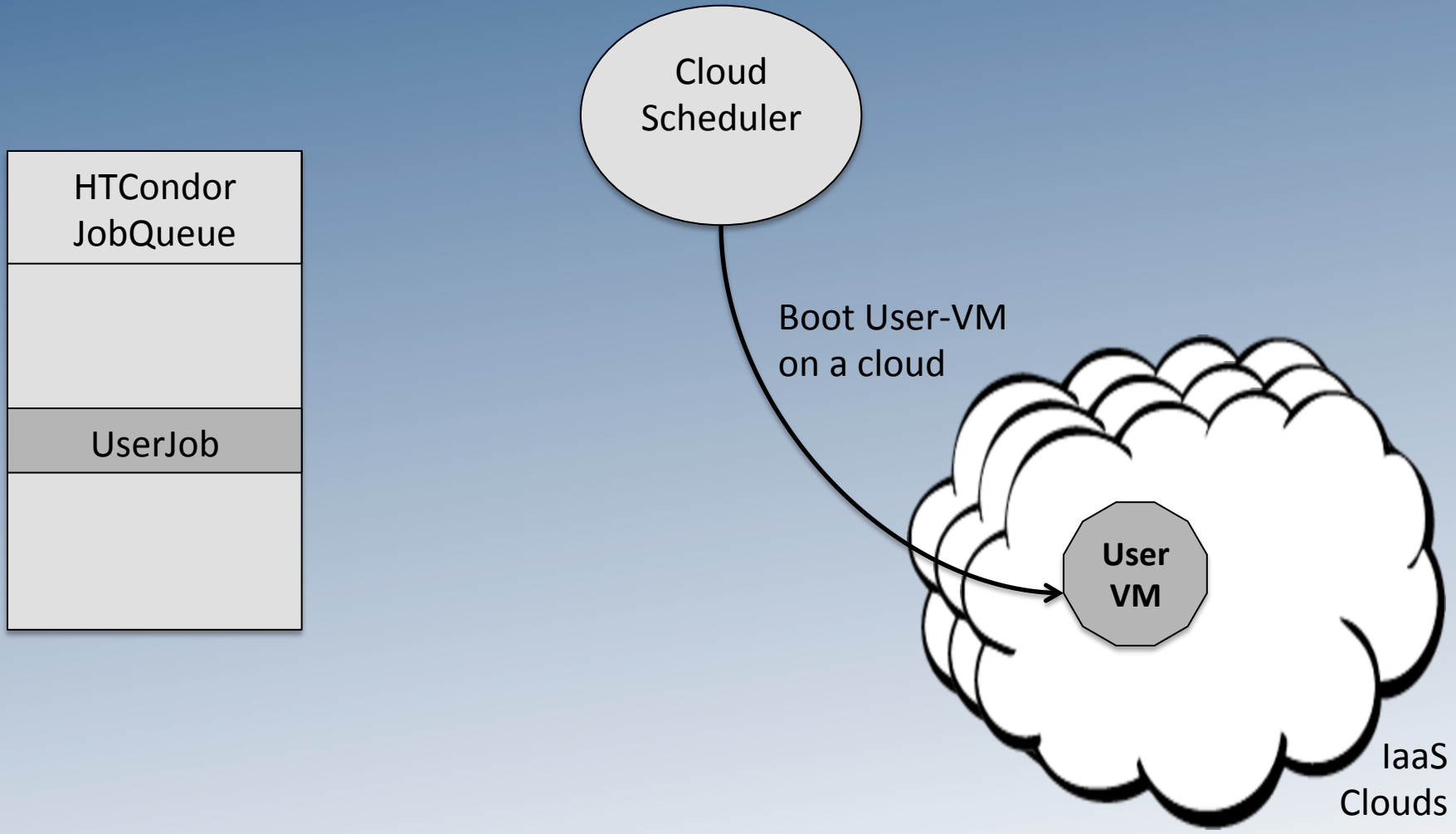
Removes any application requirements from remote site

Support multiple projects

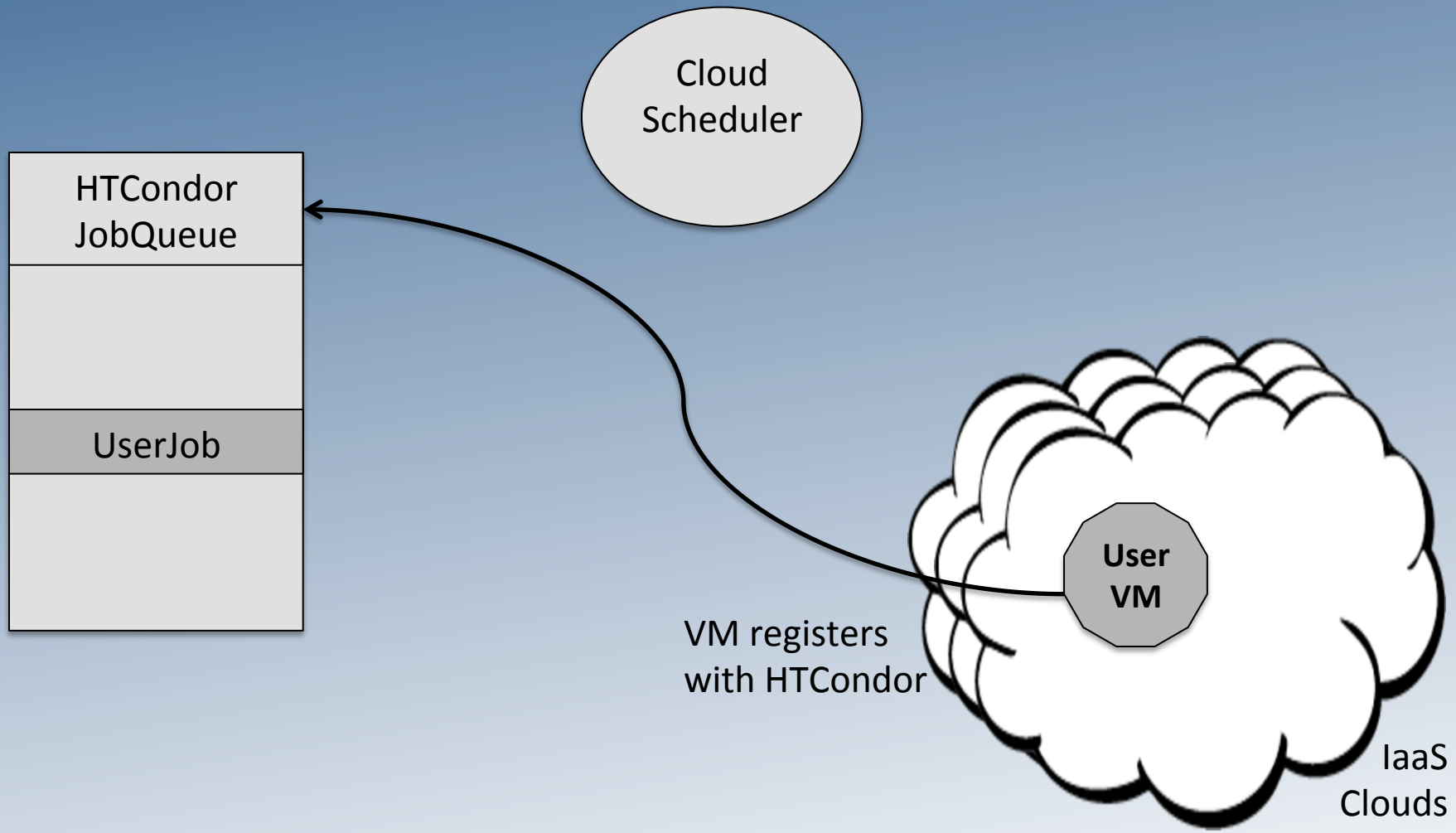
# Distributed cloud overview



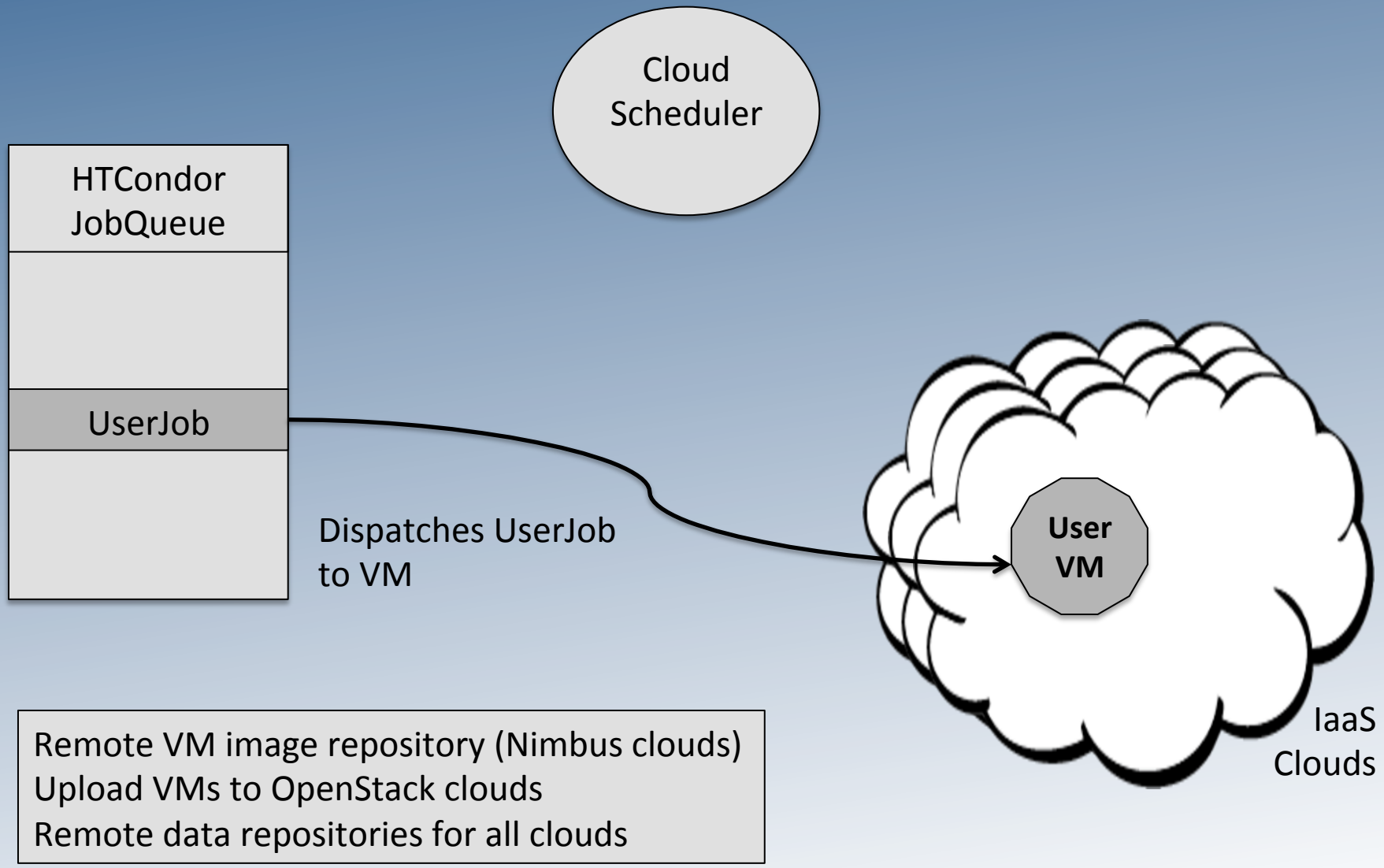
# Distributed cloud overview



# Distributed cloud overview

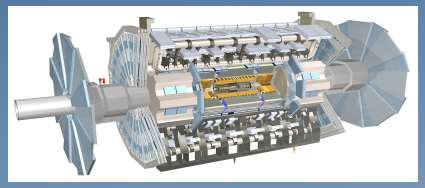


# Distributed cloud overview




Remote VM image repository (Nimbus clouds)
Upload VMs to OpenStack clouds
Remote data repositories for all clouds

# Distributed cloud status



The Canadian Astronomy Data Centre

If you have used CADC facilities for your research, please include the following acknowledgment:
This research used the facilities of the Canadian Astronomy Data Centre
operated by the National Research Council of Canada with the support of the Canadian Space Agency.

**Operational since Nov 2011**

Approximately 250K jobs
(Astronomy 500K jobs)

Using 10 clouds for ATLAS jobs
500-1000 simultaneous jobs
12 hour jobs

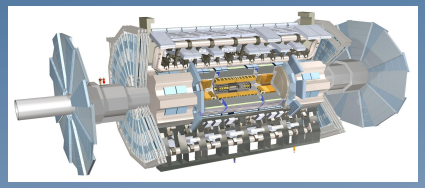
ATLAS jobs submitted from CERN

**Nimbus**
Victoria(3)
Ottawa
FG Chicago
FG SanDiego
FG Florida

**OpenStack**
Melbourne
CERN
Edmonton
Oxford

Amazon EC2
Google GCE

# Distributed cloud status

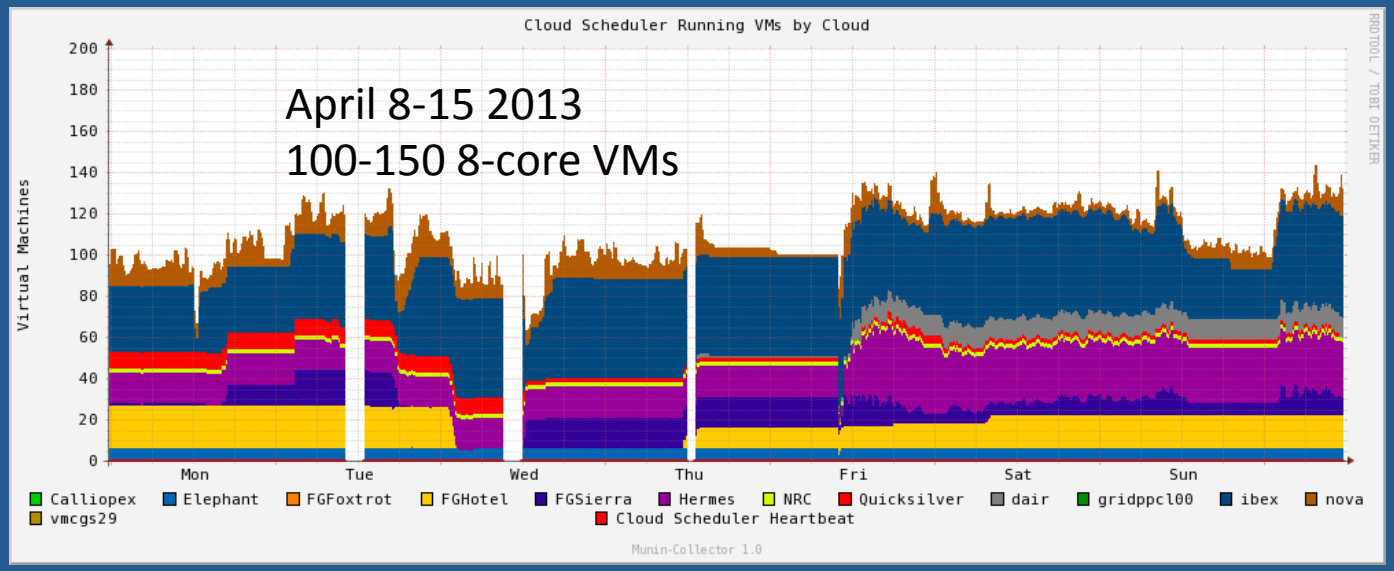


April 9 2013
8 clouds
100-120 8-core VMs

The Canadian Astronomy Data Centre

If you have used CADC facilities for your research, please include the following acknowledgment:
This research used the facilities of the Canadian Astronomy Data Centre
operated by the National Research Council of Canada with the support of the Canadian Space Agency.

**Nimbus**
Victoria(3)
Ottawa
FG Chicago
FG SanDiego
FG Florida




Melbourne
CERN--Ibex
CANARIE
WG-Victoria
NRC-Ottawa
Victoria
FG-San Diego
FG-Chicago
Victoria

# Technology innovation for new science

*We see ourselves as integrators rather than developers of cloud technology*

openstack™

***The OpenStack developer community can help us***

Common authentication
Centralized VM image storage
Consistent meta-data
Unique cloud names

***Simplify the integration of OpenStack clouds for us***

# Summary




## Understand our Universe

Studying the Higgs
Search for Dark Matter
Difference between antimatter/matter

**High Energy Physics**

## Impact on society

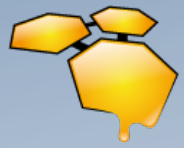
CERN is the birthplace of the WWW
Medical physics
Technology innovation
HQP

## Computing

Large distributed systems
Global research network
Novel use of computing technologies

# Acknowledgements

canarie



nectar

Contact information: rsobie@uvic.ca

Web sites: http://rjs.phys.uvic.ca/
http://heprc.phys.uvic.ca/home/