# PARTICLE PHYSICS RESEARCH: A *BRIEF* INTRODUCTION

Teacher Research Internship

Fermilab – Summer 2011

# …also known as …

# …also known as …

# a search for tiny particles…

…also known as …

a search for tiny particles…

using large detectors…

…also known as …

a search for tiny particles…

using large detectors…

which generate massive amounts of data…

…also known as …

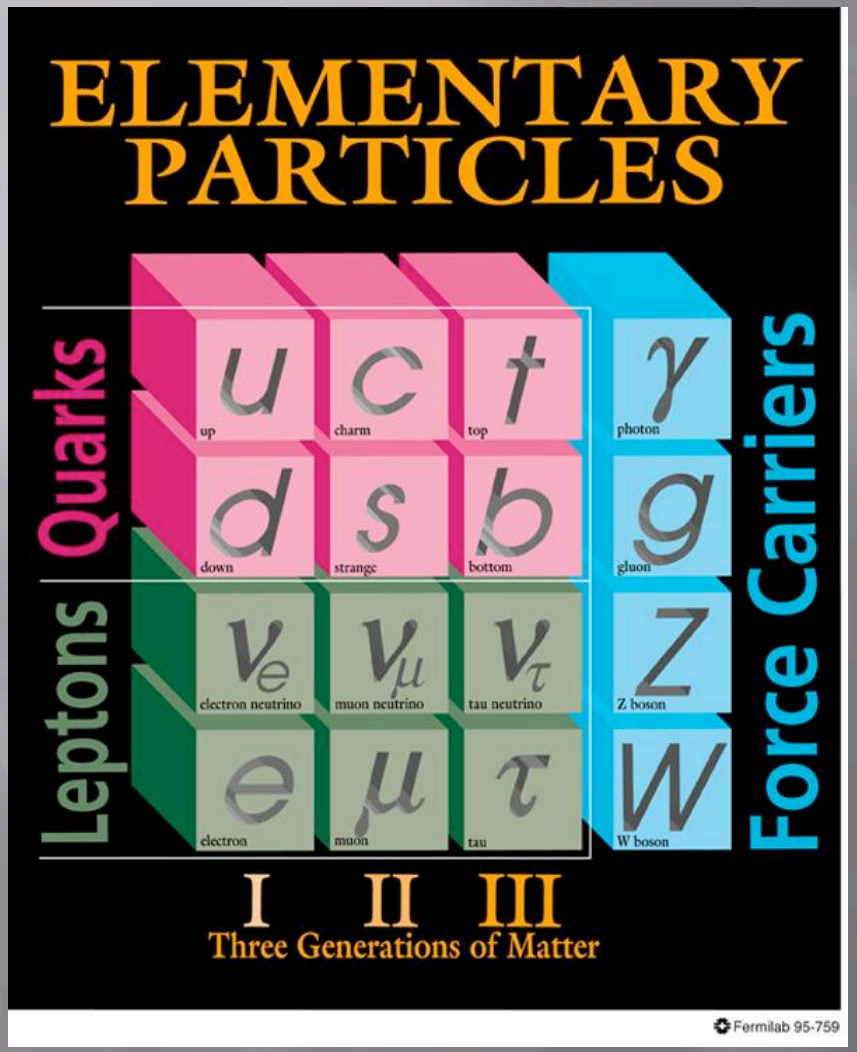
a search for tiny particles…

using large detectors…

which generate massive amounts of data…

**in order to make Phenomenal discoveries!!**

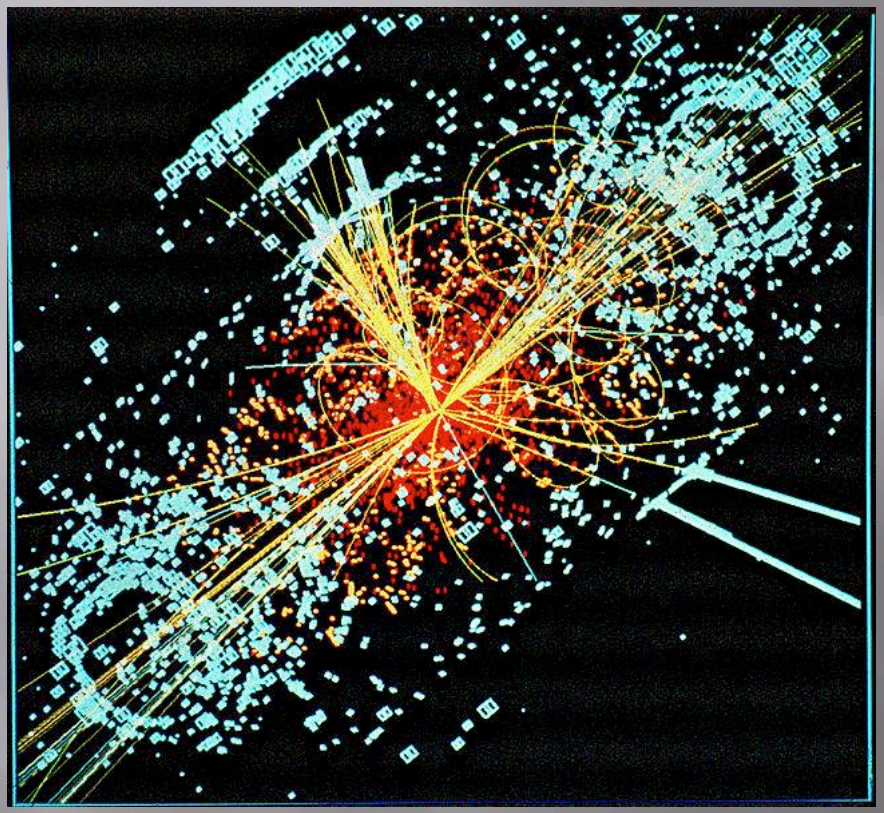
# …a search for tiny particles…




16 Particles Observed:

- ✓ Photon - 1895
- ✓ Electron - 1897
- ✓ Muon - 1937
- ✓ Electron neutrino – 1956
- ✓ Muon neutrino – 1962
- ✓ Up, Down & Strange Quarks – 1969
- ✓ Charm Quark – 1974
- ✓ Tau – 1975
- ✓ Bottom Quark* – 1975
- ✓ Gluon – 1979
- ✓ W & Z Bosons – 1983
- ✓ Top Quark* – 1995
- ✓ Tau Neutrino* - 2000

# …a search for tiny particles…

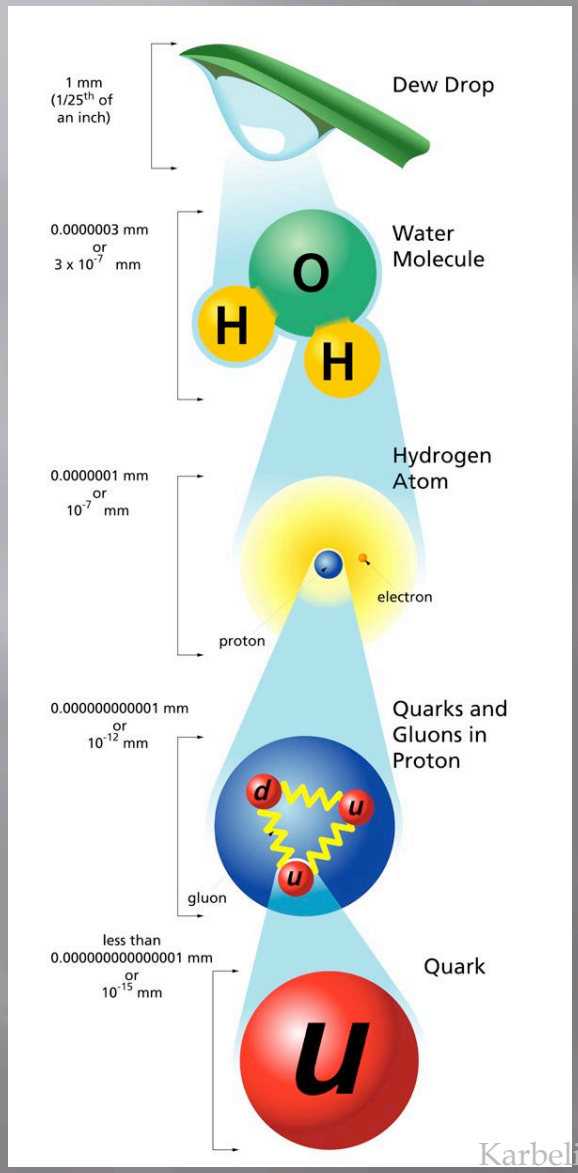


What is left to find?

**Higgs Boson**

- Last particle to complete SM theory
- Believed to explain how massive particles have mass, and others do not
- Search is ongoing

# …a search for tiny particles…




How tiny are the particles?

- Heaviest: Z Boson 91.2 GeV = $1.6*10^{-25}$ kg
- Require indirect observation
- Clever detectors:
  - Silicon detectors
  - Sintilators
  - Photomultiplier Tubes
  - LOTS of Electronics!

# … using large detectors…

- Accelerator Labs in US:
  - Fermi National Accelerator Laboratory (Batavia, IL)
  - SLAC National Accelerator Laboratory (Menlo Park, CA)
  - Jefferson Lab (Newport News, VA)
- World's Highest Energy Particle Accelerator – Large Hadron Collider (LHC) (Geneva, Switzerland)

Fermilab

SLAC NATIONAL ACCELERATOR LABORATORY

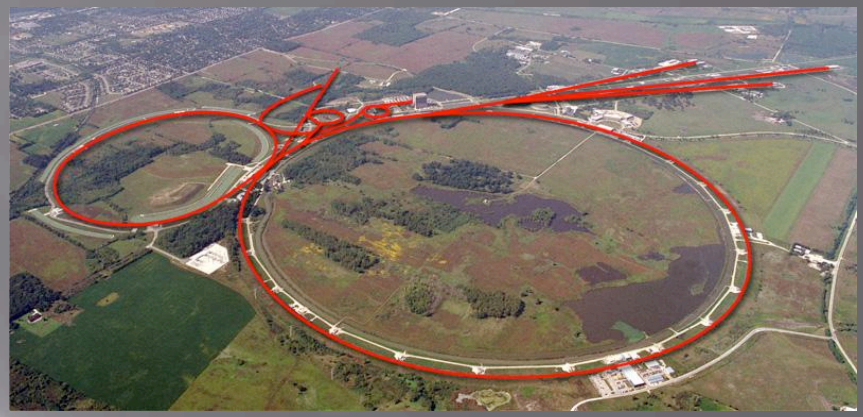
Jefferson Lab
EXPLORING THE NATURE OF MATTER

CERN

# … using large detectors…

**Accelerator Experiments at Fermilab**

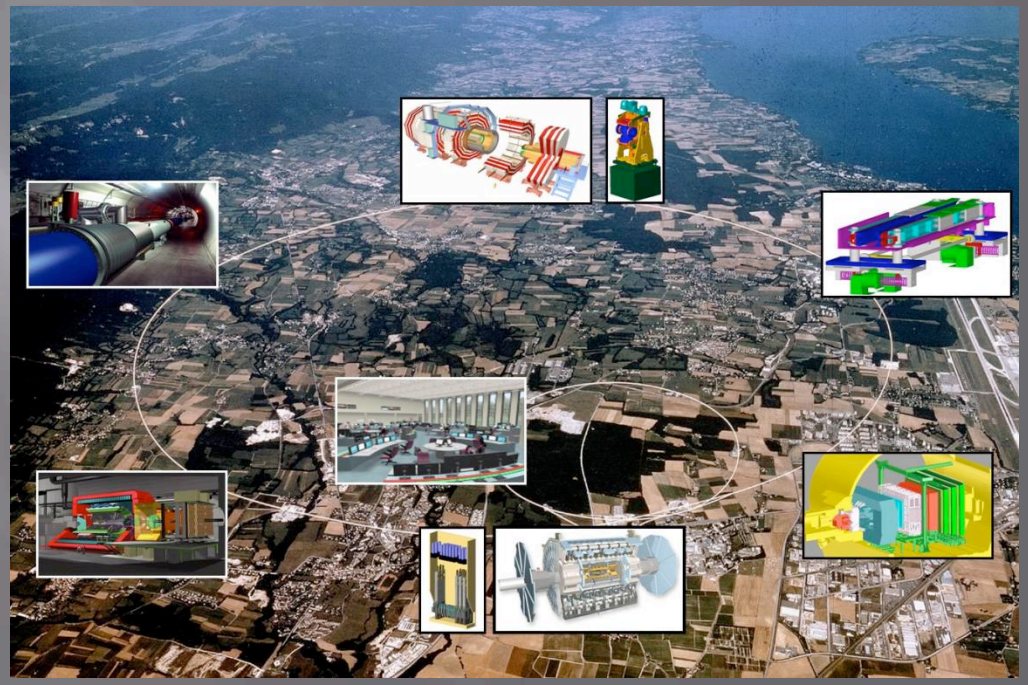
- Tevatron:
  - Proton – Antiproton collisions
  - Particles accelerated to **99.999954%** speed of light
  - Beam frequency: 48,000Hz
  - 4 mile ring
- Detectors:
  - CDF
  - DZero



# … using large detectors…

## Large Hadron Collider

- Details:
  - Proton – Proton collisions
  - 99.9999991% speed of light
  - 7 times more energy than Tevatron
  - 16.5 mile ring
- Experiments:
  - CMS & ATLAS
  - ALICE, LHCb, LHCf, TOTEM

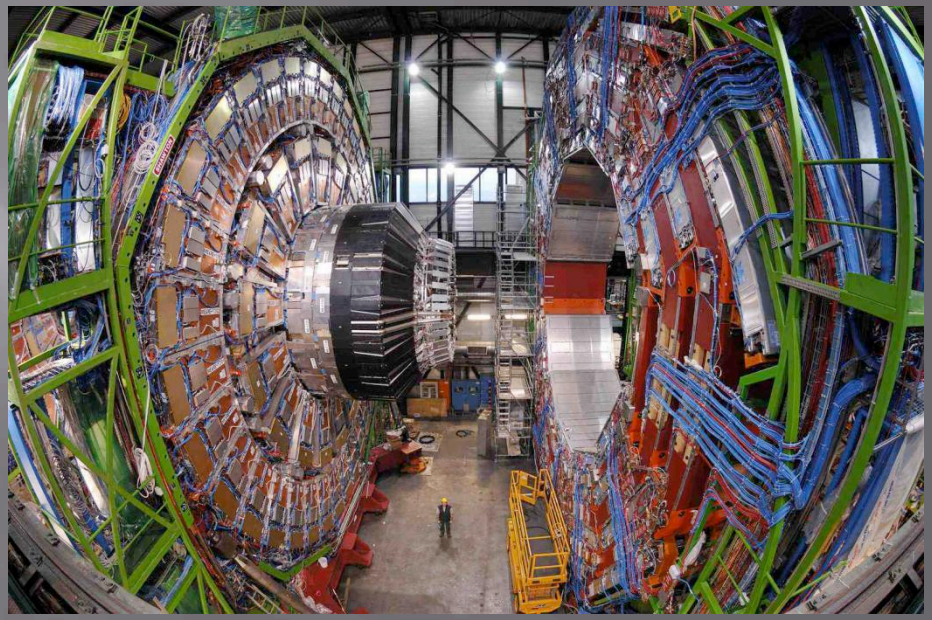


# … using large detectors…

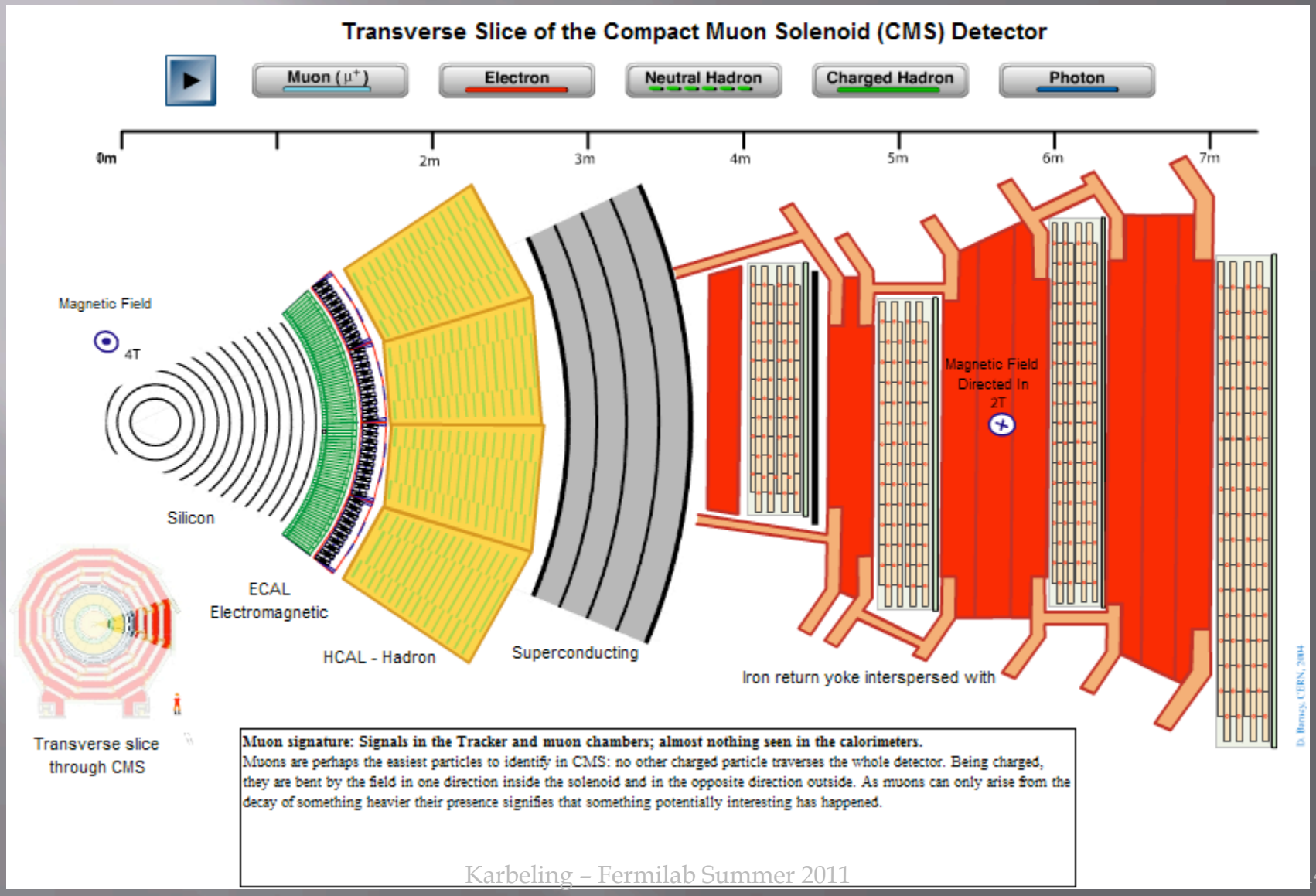
**Compact Muon Solenoid**

Details:

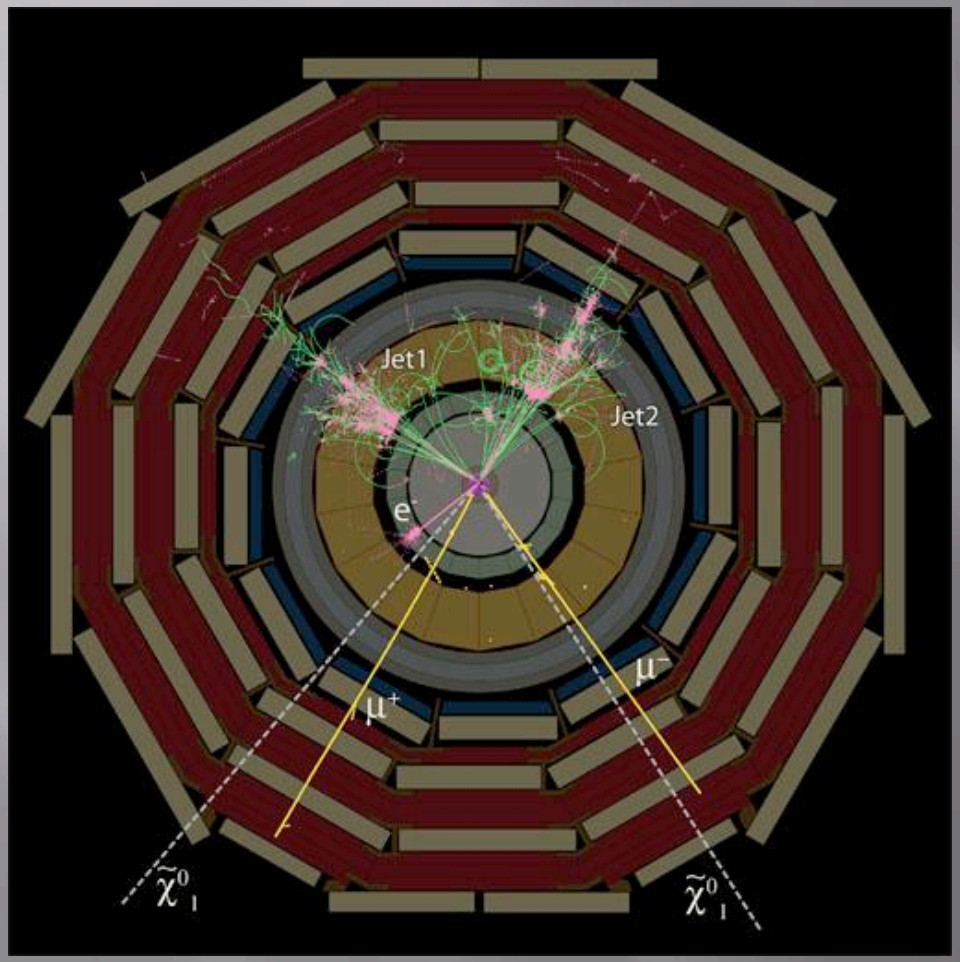
- B-Field: 4 T = 100,000 times Earth's
- 15 meters high
- 14,000 tons
- 100 meters below ground
- Electromagnets cooled to 4.6 K = - 451 degrees F



# … using large detectors…



# … massive amounts of data…




## CMS Data Analysis

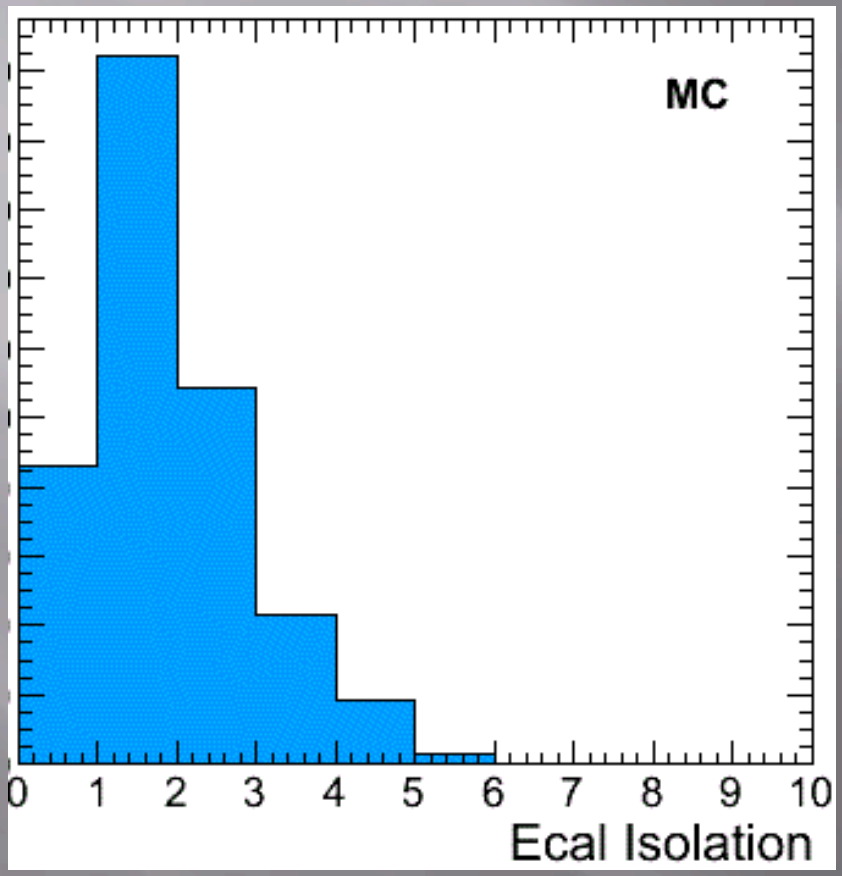
- Collisions: 40 million times per second
- Luminosity: over $1fb^{-1}$ March -June 2011

  $70*10^{12}$ collisions
- Triggers: identify interesting events

  - From 1 billion to 100 per second
- Data storage: Tier system

# … massive amounts of data…

**E-Cal Isolation - Distribution**




**CMS Data Analysis – Photon + Jet Events**

- Perform

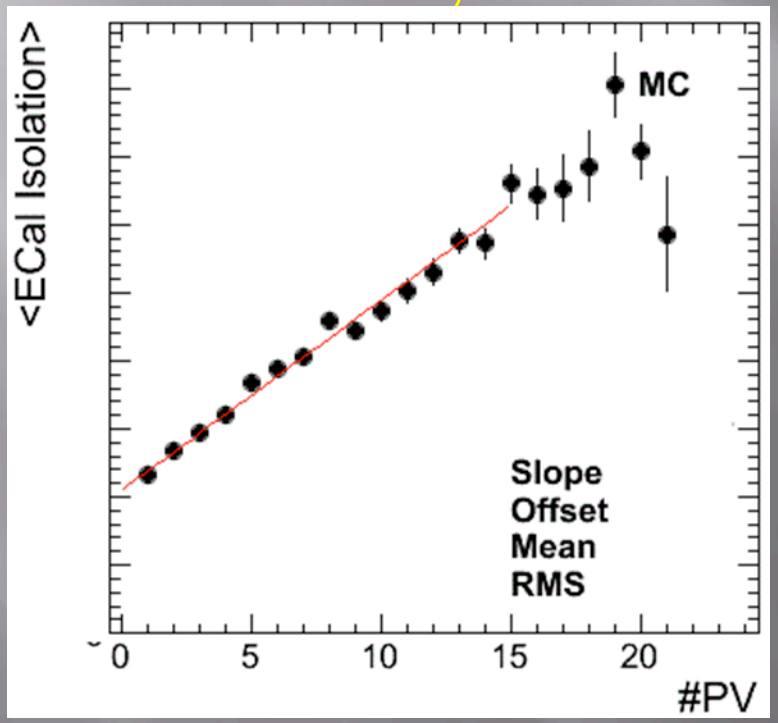
  "Sanity Checks"
- Compare data with theoretical predictions – Monte Carlo method

# … massive amounts of data…

## CMS Data Analysis –

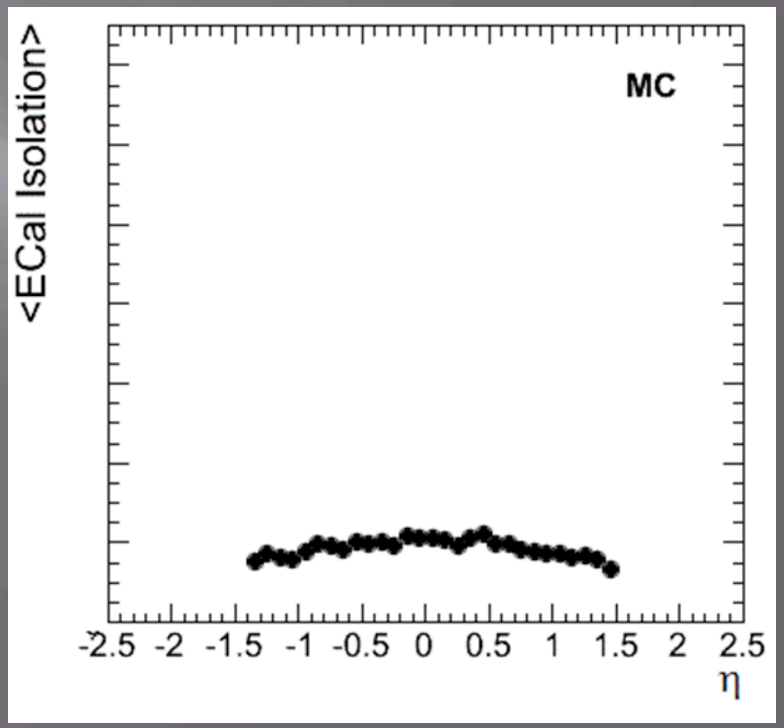
**Number of Primary Verticies**

**a.k.a "Money Plot"**

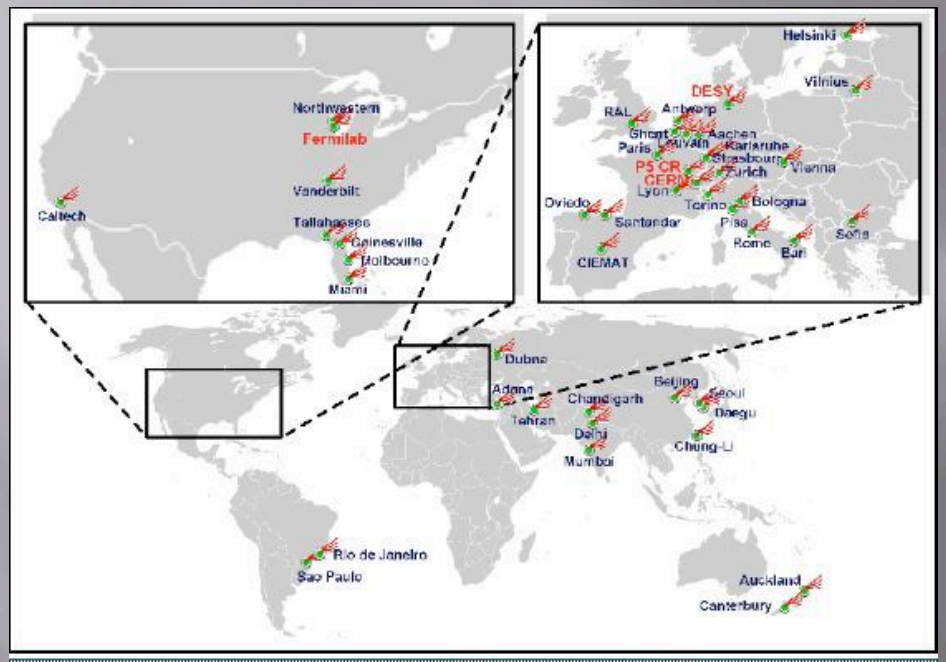



## Photon + Jet Events

**Photon distribution in η**



# … massive amounts of data…



Current map of current CMS Centers worldwide, courtesy of CERN

## CMS Data Analysis

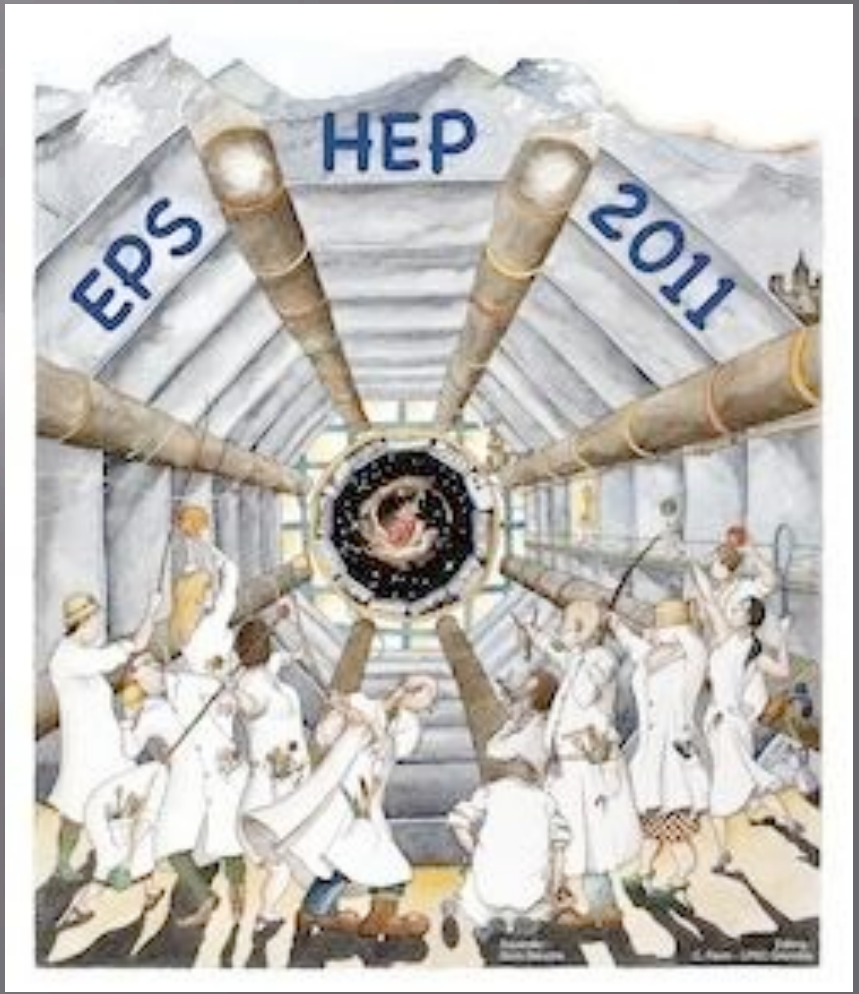
- Collaboration locally and internationally
- Over 3000 scientists
- Presentation of findings
  - collaboration groups
  - larger committees
  - conferences

# … to make Phenomenal discoveries!!

**Results announced during Summer 2011**

**"Higgs buzz at summer physics conference"**

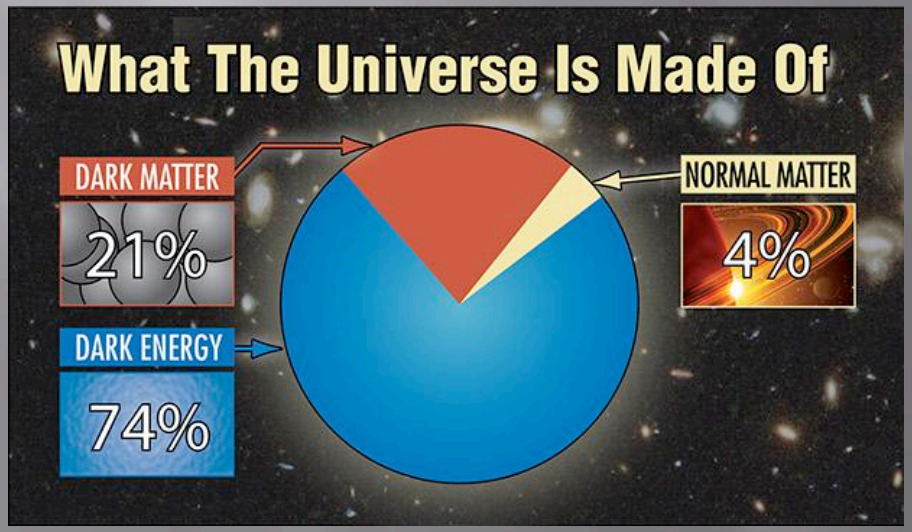
- DZero
- CDF
- CMS
- ATLAS

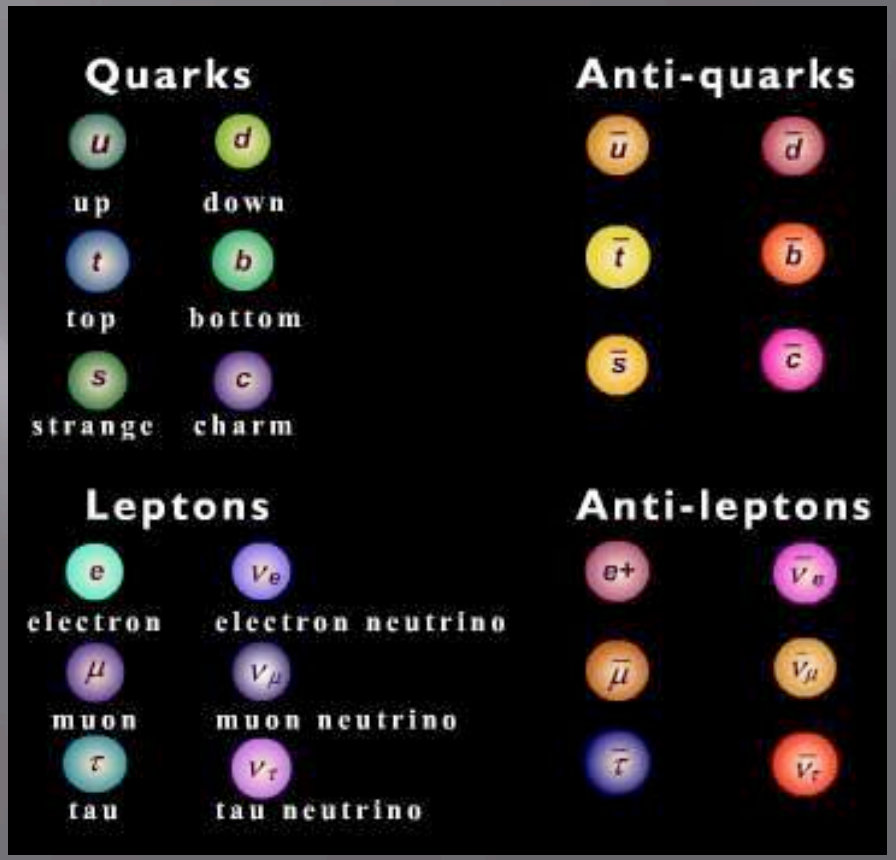


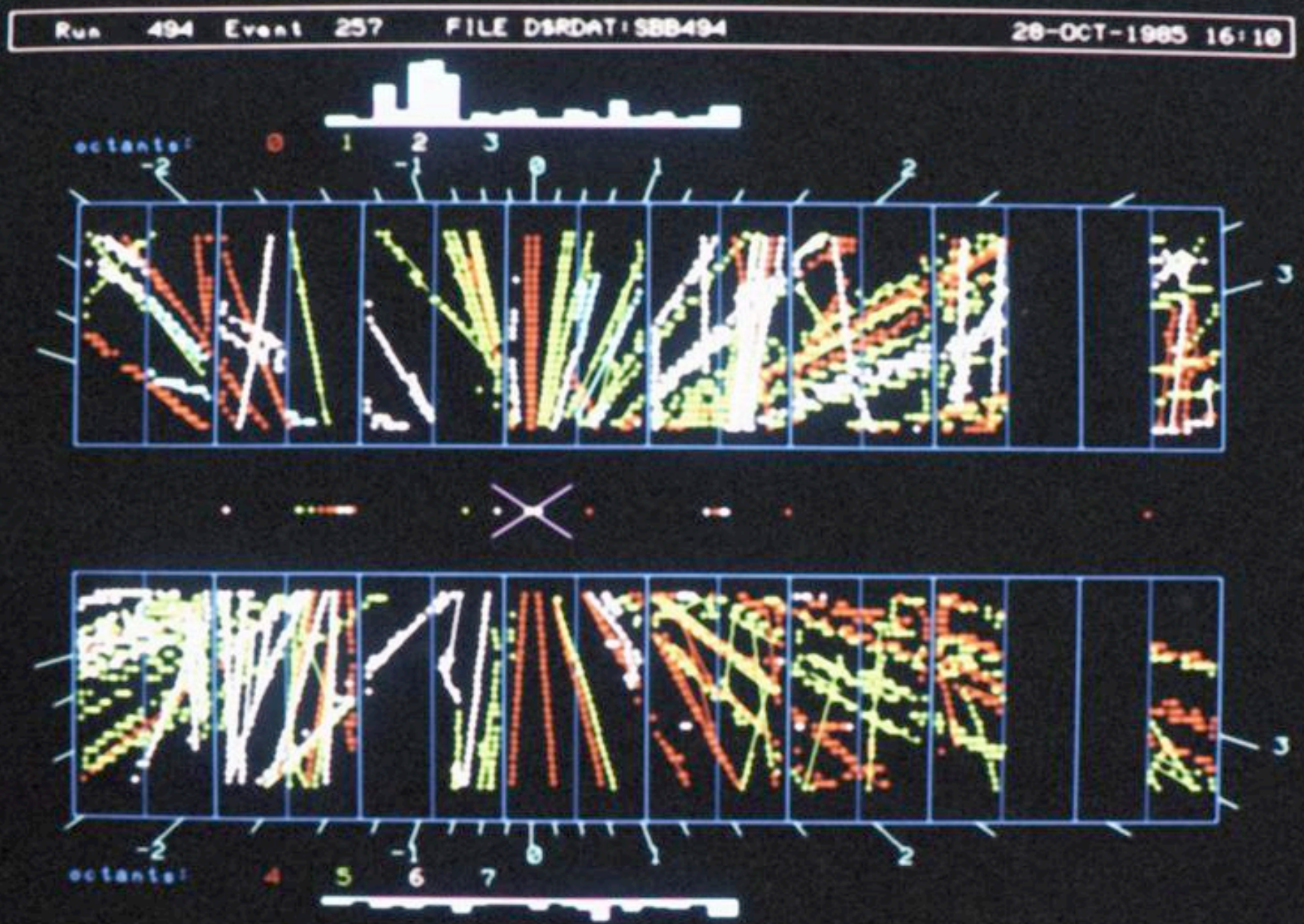
# … to make Phenomenal discoveries!!

**Further questions…**

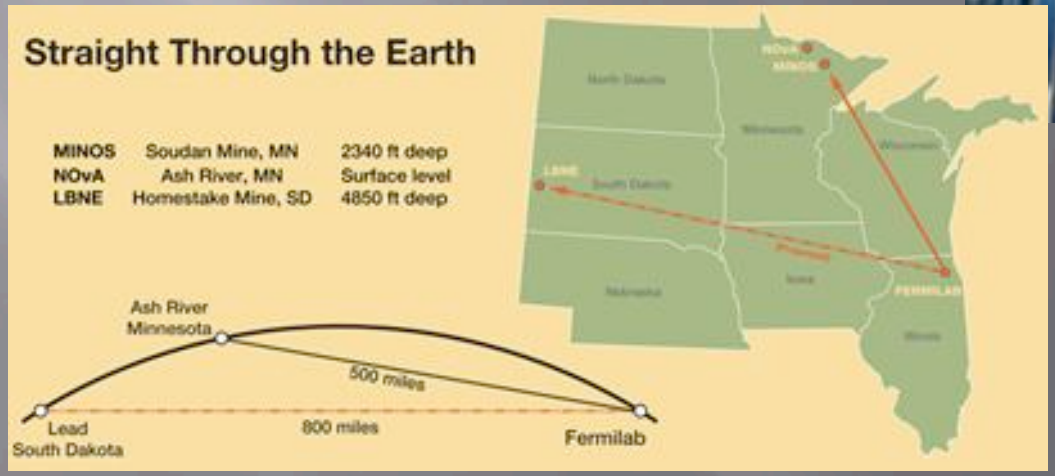
- Dark Matter
- Dark Energy
- Anti-matter




Run 494 Event 257 FILE DSRDAT:SBB494 28-OCT-1985 16:10
octants: 0 1 2 3
-2
-1
0
1
2
3
-2
-1
0
1
2
3
octants: 4 5 6 7

# … using large detectors…

## Experiments at Fermilab

- Neutrino Experiments
  - MINOS
  - MINERvA
  - MiniBooNE
  - NOvA