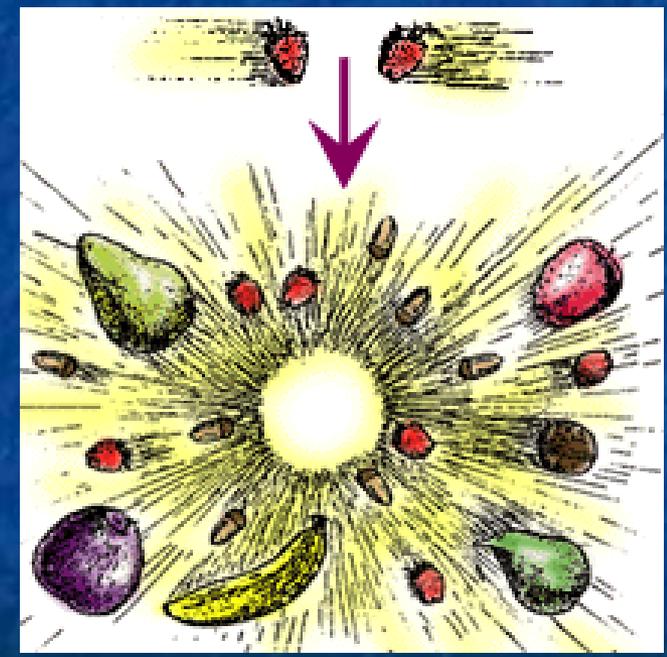


Particle physics and colliders

By Charles A. CURRAT - LBNL/NSD

Canyon School visit, May 25th 2004



Who am I?



5/25/04

- Young (european) research physicist
- High school in sciences
- Medical school at U. Lausanne (1 year)
- Swiss Institute of Technology in physics (5 years)
- Graduate student work in particle physics (5 years)
- Postdoctorate work in particle physics (2 years)
- Postdoctorate work in nuclear physics, current

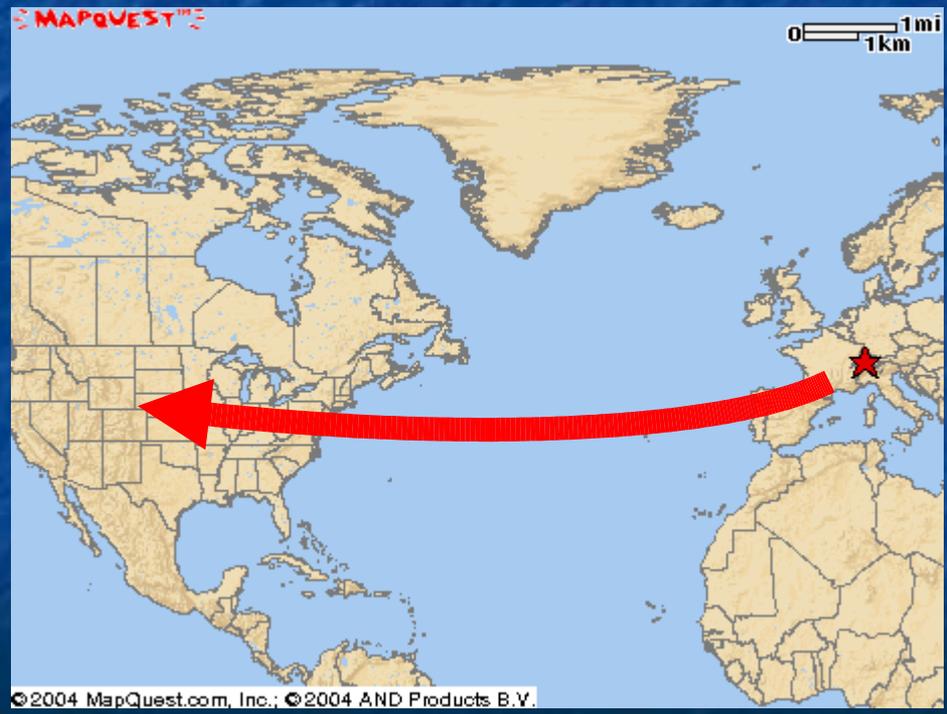


Physics is nice!



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The laws of physics are universal =
the physics is the same everywhere in the world!
... so why not travel?!



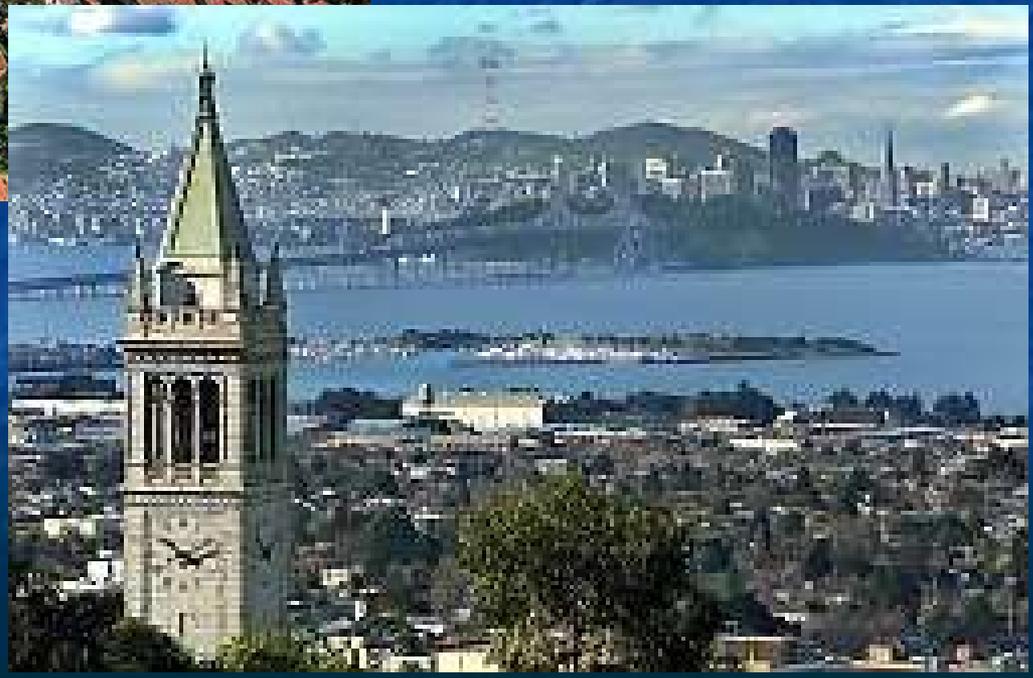
Physicists like symmetries



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Lausanne, Switzerland

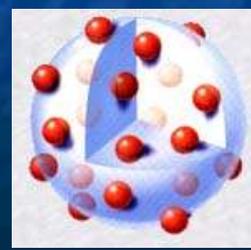
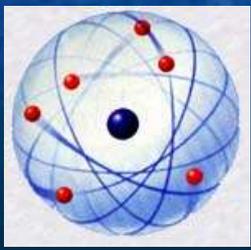


Berkeley, CA

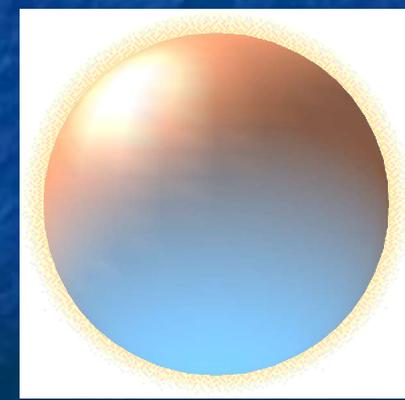


What things are made of?

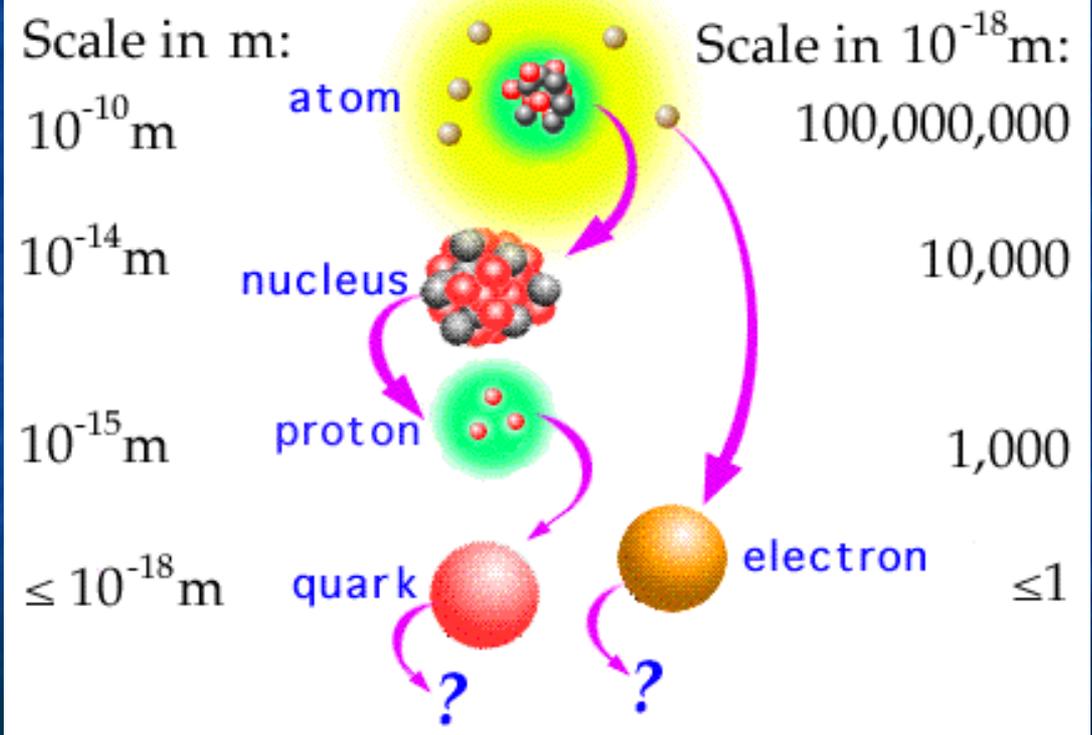
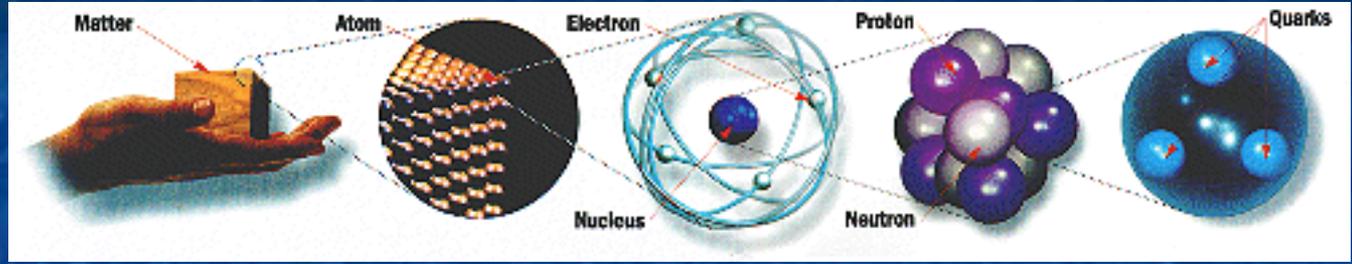
- 5th century BC: Empedocles, 4 elements
- 4th century BC: Democritus, indivisible particle = atom
- Middle Age: alchemy, sulfur, lead, ...
- 19th century AC: chemical elements made of atoms
- End of 19th century... there's more than atoms!!



Atom ~ 1960
~~Atom ~ 1850~~



About size and scale



- The Earth
- A football field!
- A house!
- A golf ball!



How do we know that?



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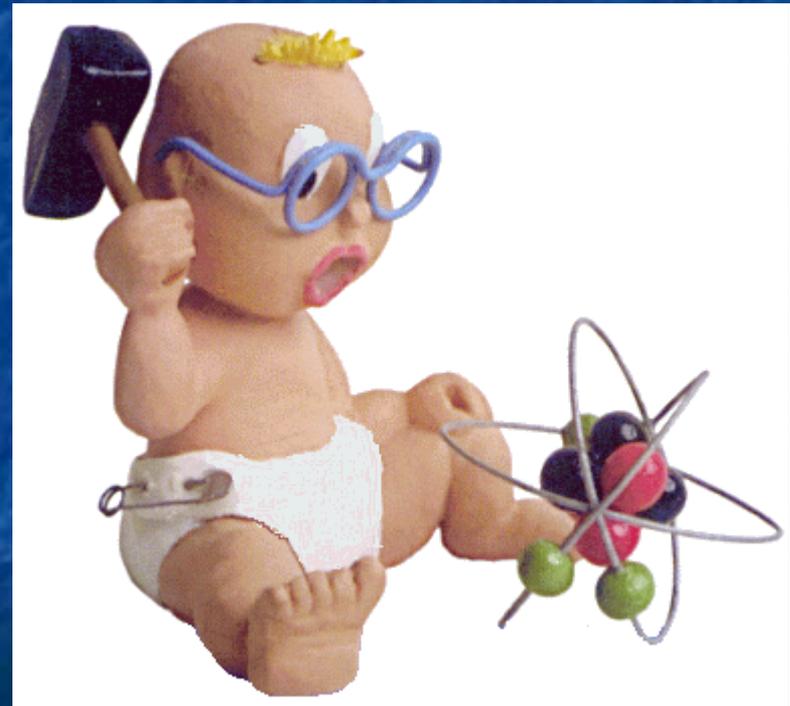
Observe

Classify

Understand



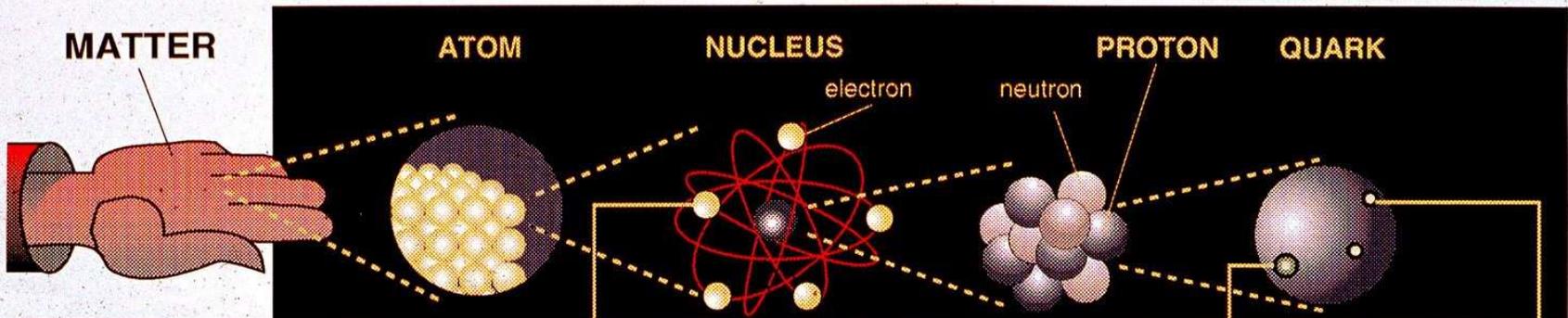
- By opening the box...
- By cutting things open...
- By observing how the parts are arranged together...
- By trying to reproduce whatever one observes!





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The family of elementary particles



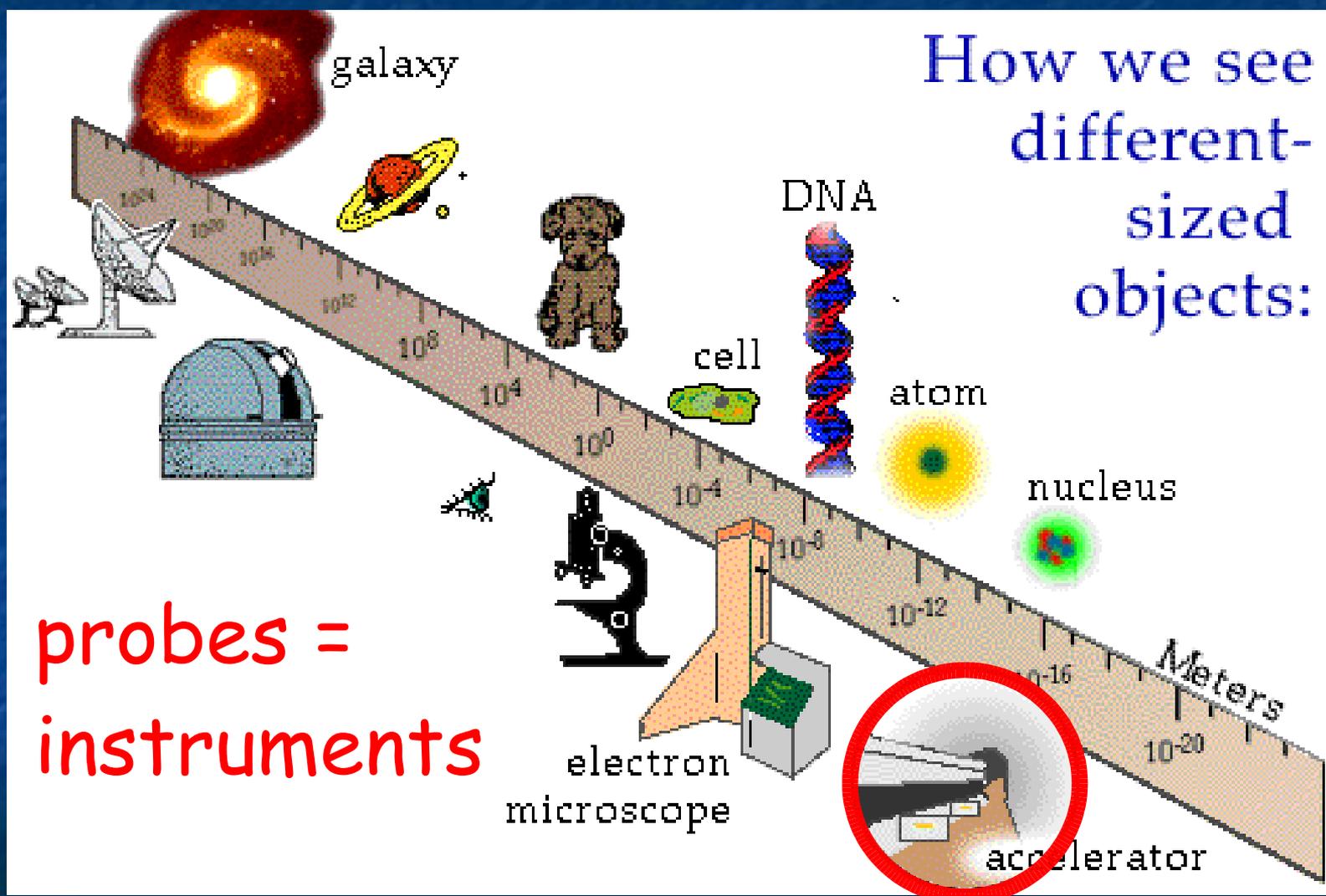
<p>ALL ORDINARY MATTER BELONGS TO THIS GROUP.</p>	LEPTONS		QUARKS	
	<p>RESPONSIBLE FOR ELECTRICITY AND CHEMICAL REACTIONS</p>	<p>electron Electric charge -1.</p>	<p>electron neutrino Electric charge 0. Rarely interacts with other matter.</p>	<p>up Electric charge $+2/3$. Protons have 2 up quarks Neutrons have 1 up quark</p>
<p>THESE PARTICLES EXISTED JUST AFTER THE BIG BANG.</p> <p>NOW THEY ARE FOUND ONLY IN COSMIC RAYS AND ACCELERATORS.</p>	<p>muon A heavier relative of the electron.</p>	<p>muon neutrino Created with muons when some particles decay.</p>	<p>charm A heavier relative of the up.</p>	<p>strange A heavier relative of the down.</p>
	<p>tau Heavier still.</p>	<p>tau neutrino Not yet observed directly.</p>	<p>top Heavier still, recently observed.</p>	<p>bottom Heavier still.</p>

ANTIMATTER
Each particle also has an antimatter counterpart ... sort of a mirror image.



A probe for each object

How we see different-sized objects:



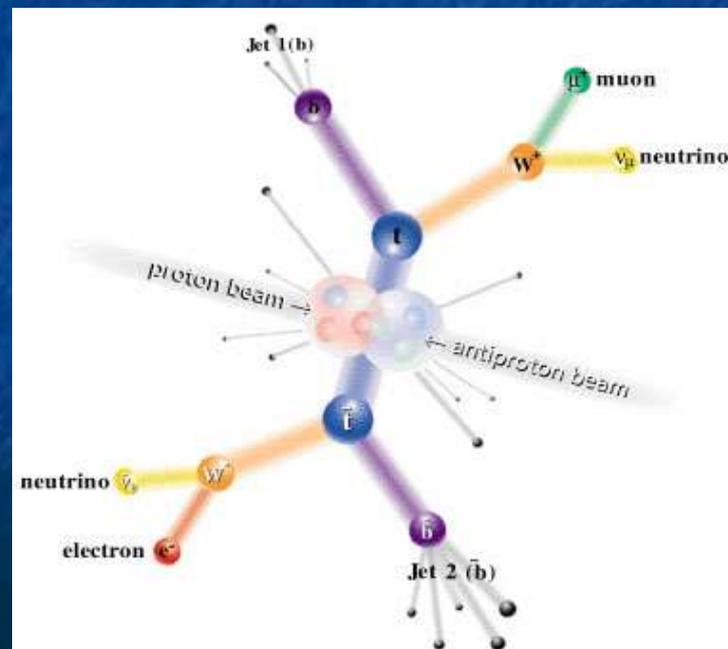
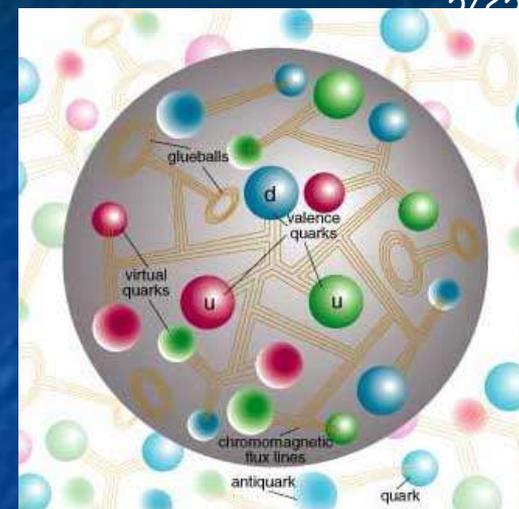
probes = instruments

Smashing particles together



... to gain insight!!!

- We want to figure out how particles behave when they interact with each other
- We want to know if there's other particles we failed to predict



Some engineering



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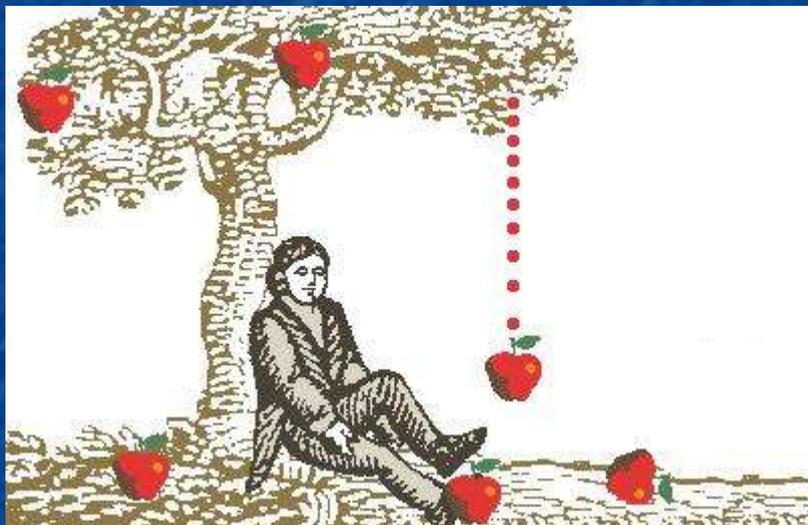
Let's see how a particle
accelerator works...

Gravity and electricity



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Gravity is...



Electricity is...



Gravity and electricity also are...

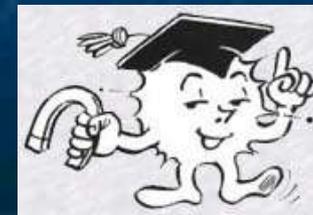
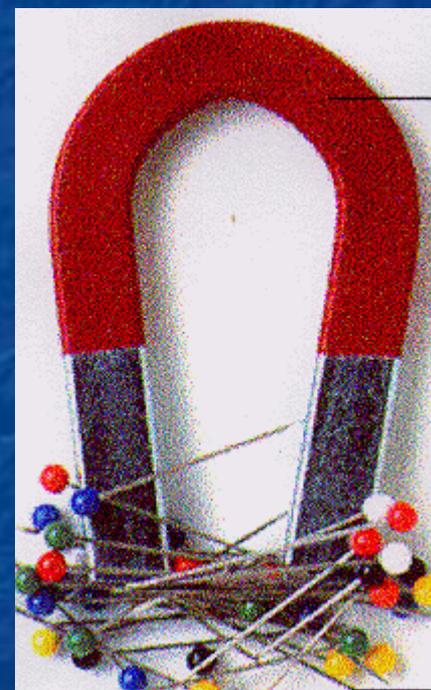


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Planets orbiting...

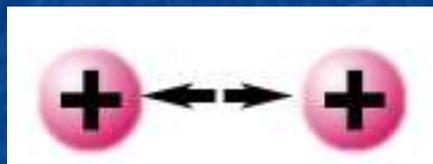


Magnetism...



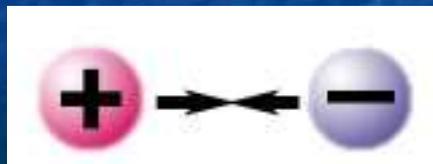
The electric charge

- Like objects/particles have mass, objects/particles have an electric charge
- Only one kind of mass, but 2 kinds of electric charge
- Most objects/atoms around us have zero total electric charge... but watch out for accidents!



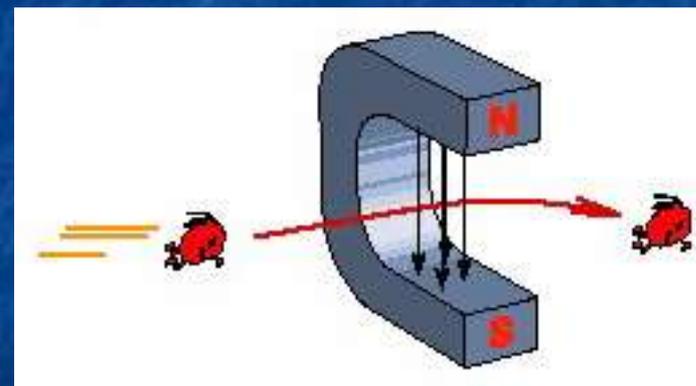
Like-charged objects repel

Proton = +



Oppositely-charged objects attract

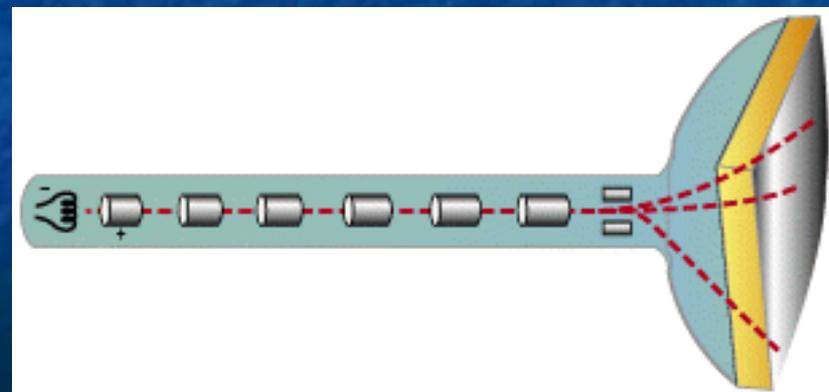
Electron = -



Charged particles can feel magnetic

How to accelerate a particle?

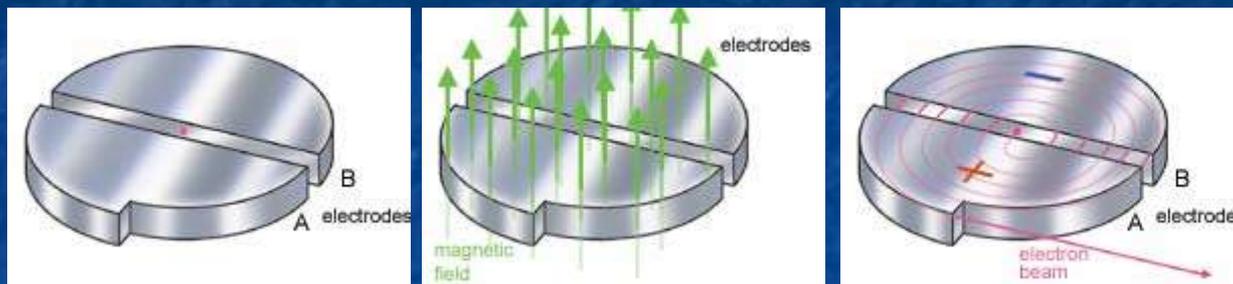
- One needs to do 2 things simultaneously:
- PUSH the particle, to make it go faster
- BEND its trajectory, to guide it



Circular accelerator

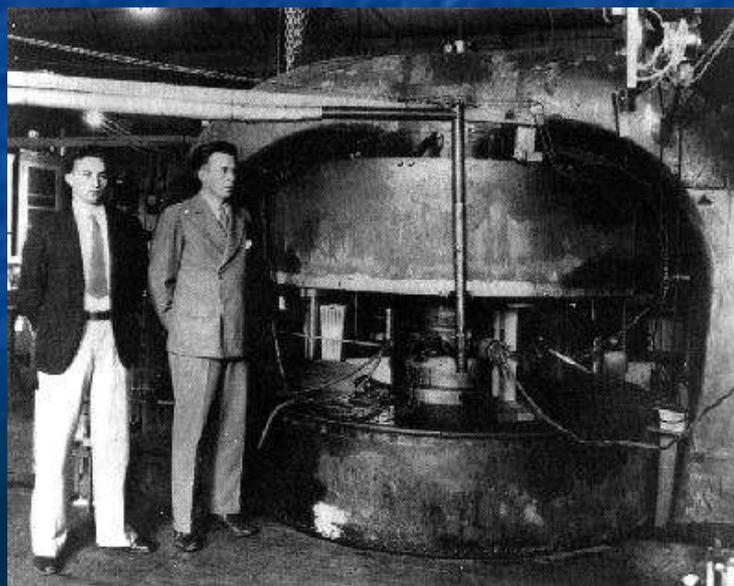


5/25/04

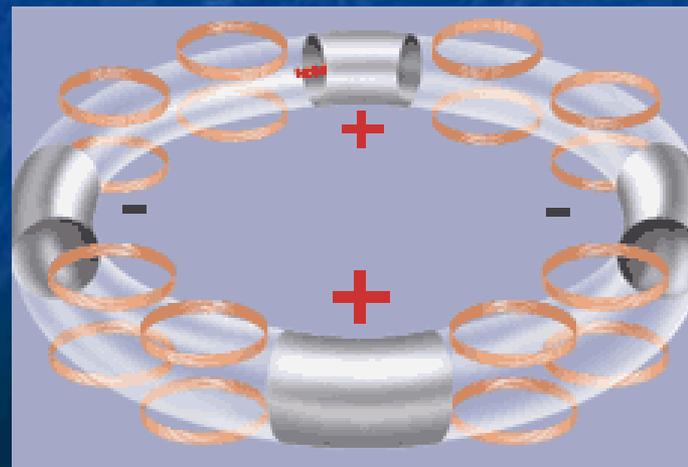


Cyclotron, ~1930
Ernest O. Lawrence

Up to ~10 million eV



Synchrotron, ~1950
more efficient, up to
~6 billion eV!

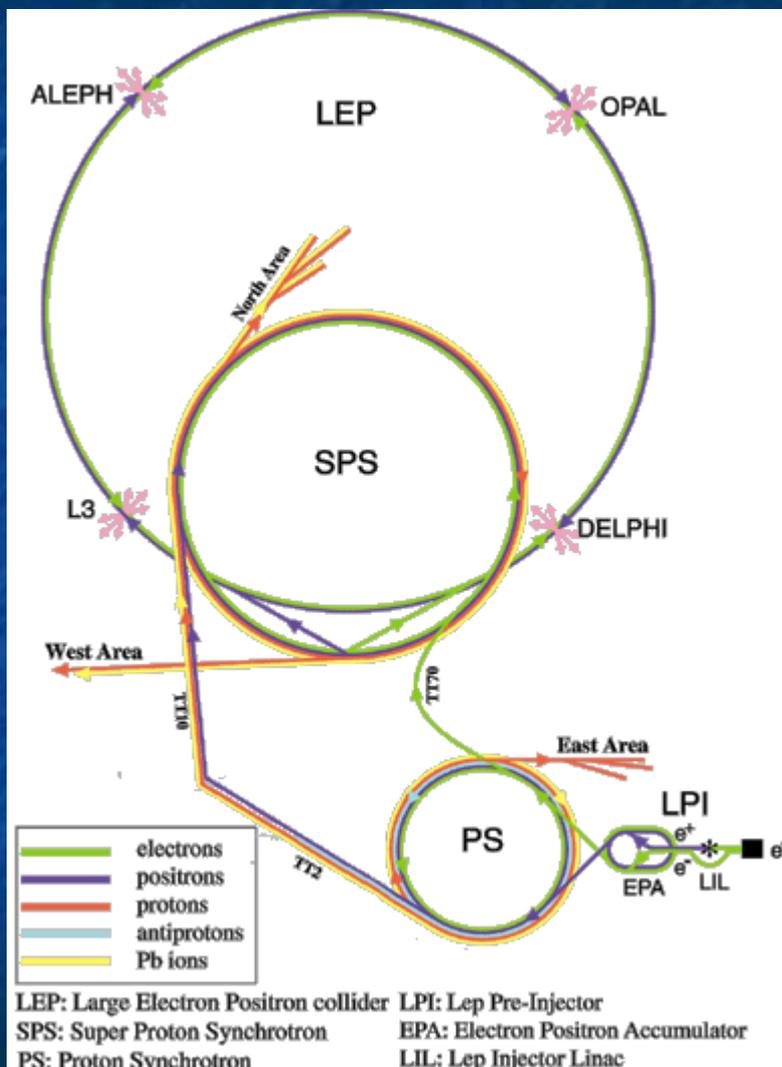




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Accelerator facilities

CERN, Switzerland/France
most powerful accelerator in the world



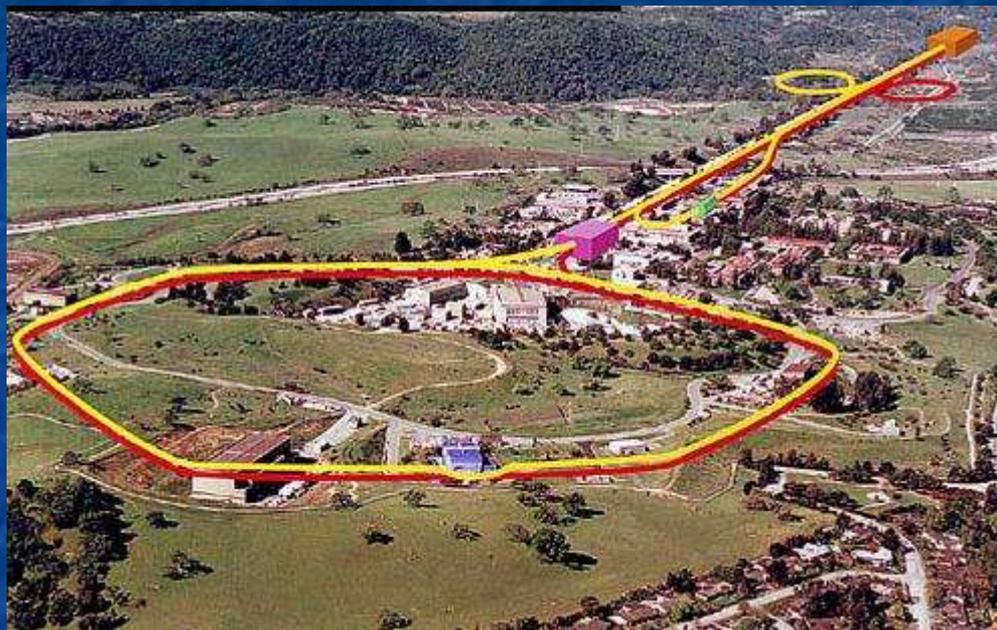
Up to ~15 million million eV!



Accelerator facilities

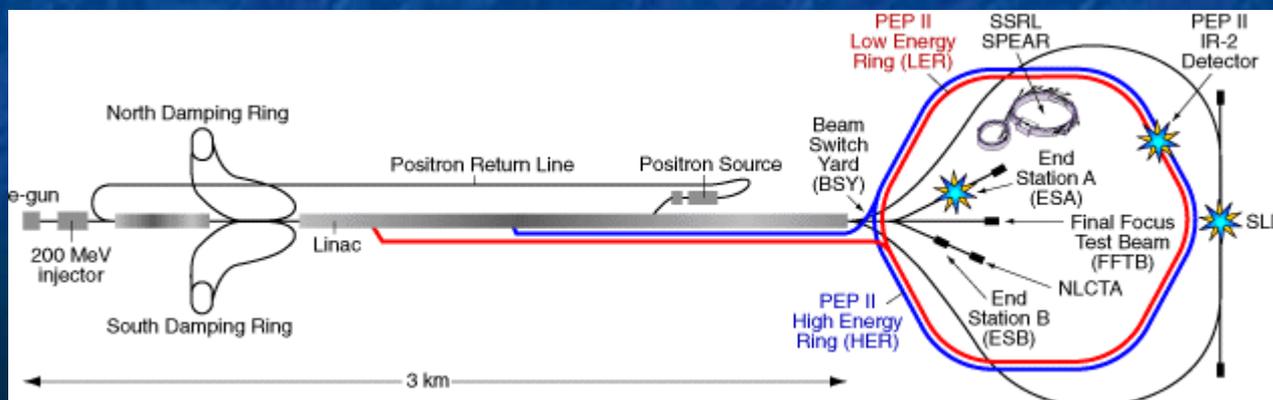


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SLAC, Stanford CA
... right across the bay!

Up to ~10 billion eV!



Let's accelerate particles



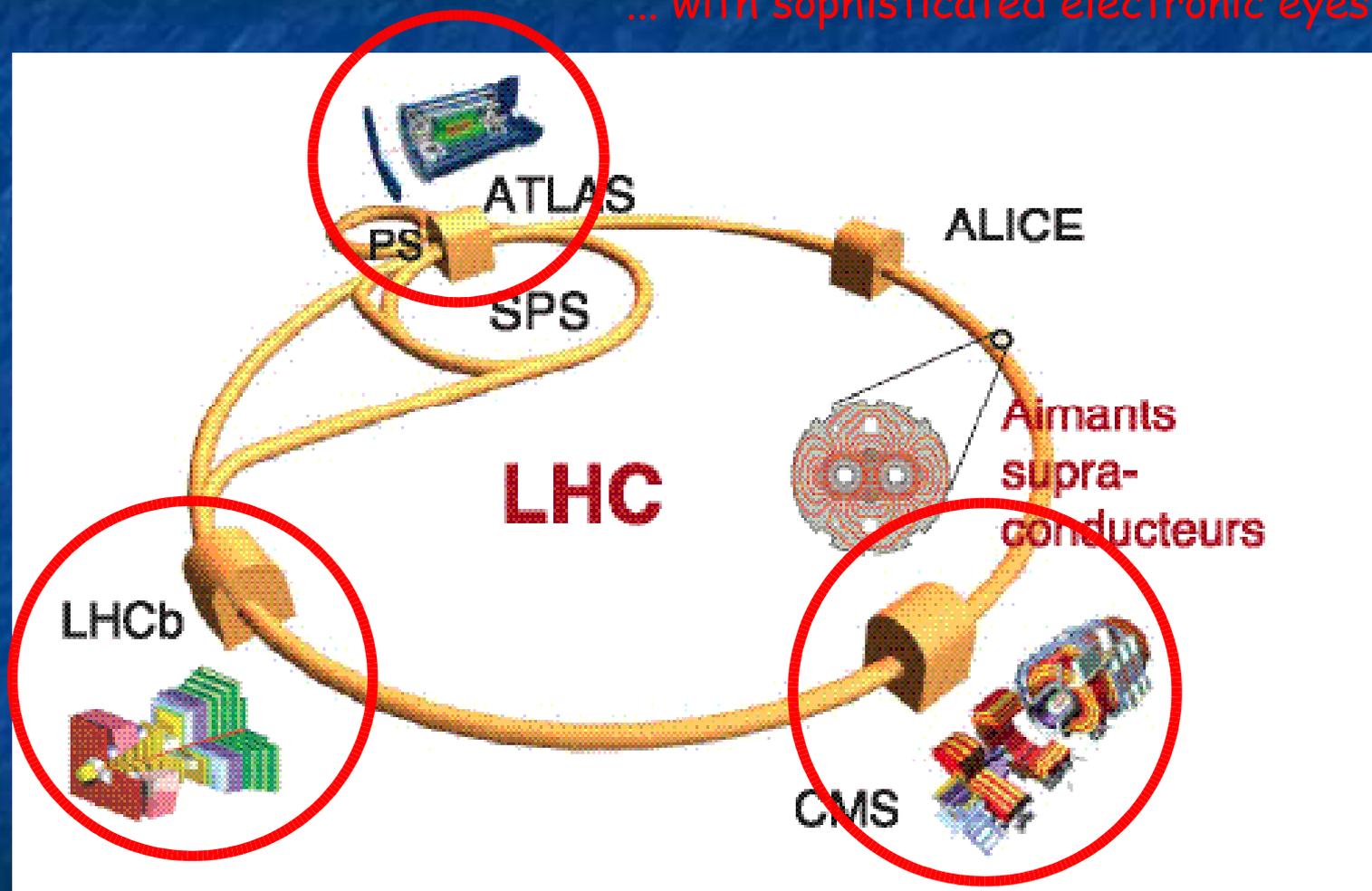
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- http://microcosm.web.cern.ch/Microcosm/RF_cavity/ex.html
- <http://hepweb.rl.ac.uk/ppep/exhibits/accels/CernComplex/LEPsim.htm>



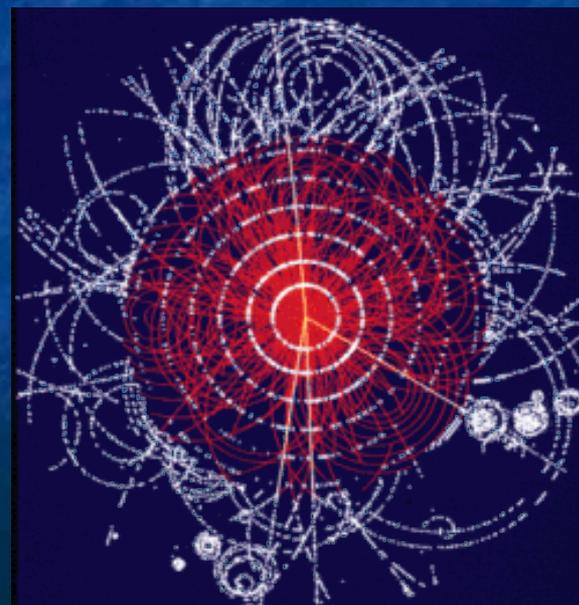
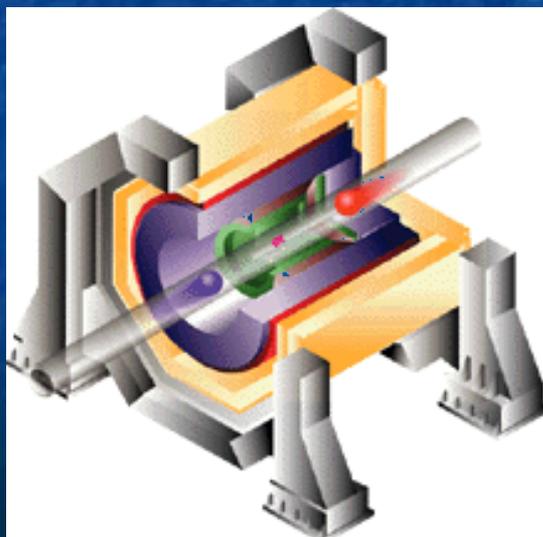
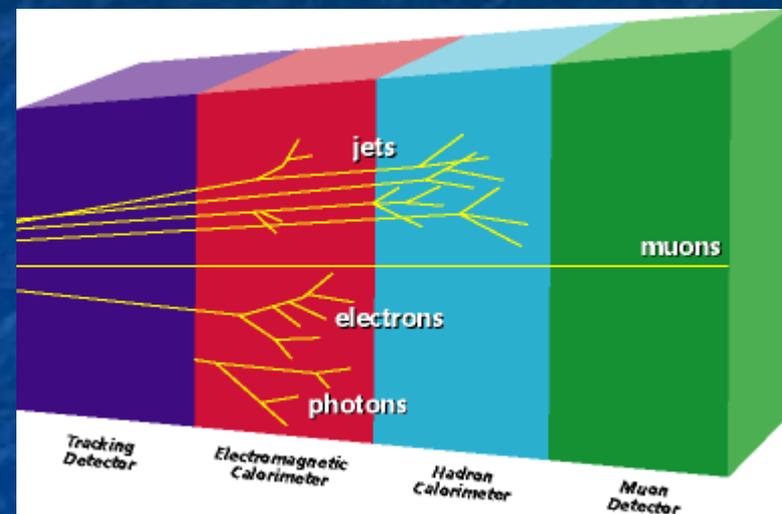
Observing colliding particles

... with sophisticated electronic eyes!



What is a particle detector?

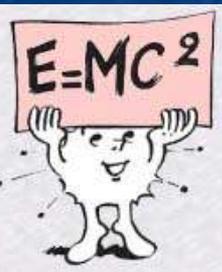
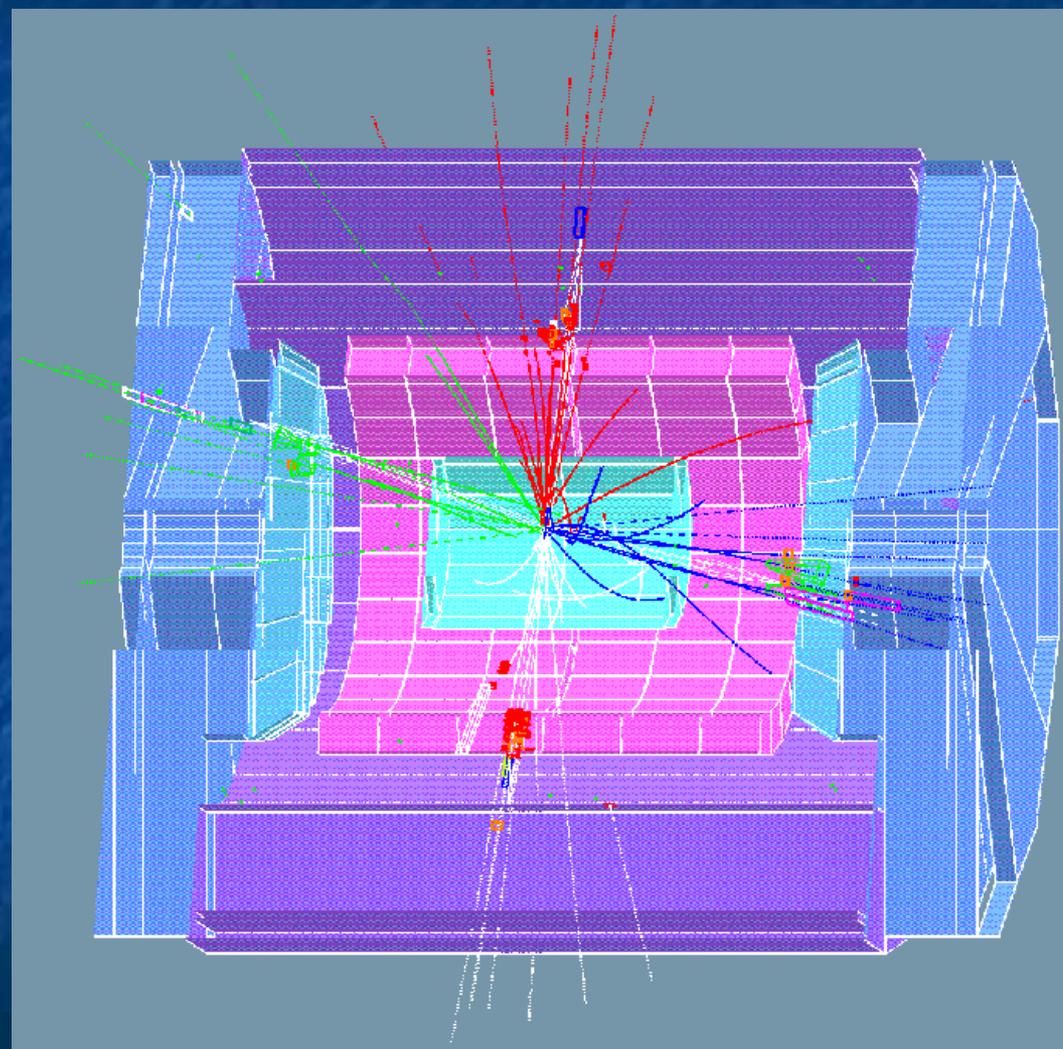
- A particle interaction detector allows to take a "snapshot" of what happened in a collision = sophisticated camera!!



A real particle interaction!



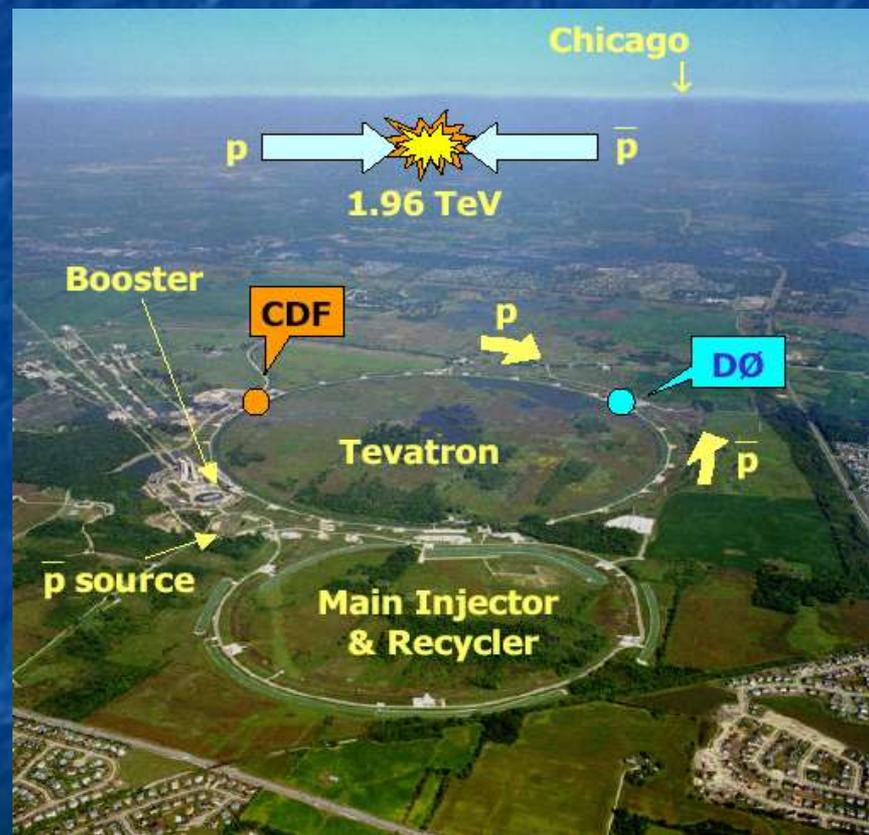
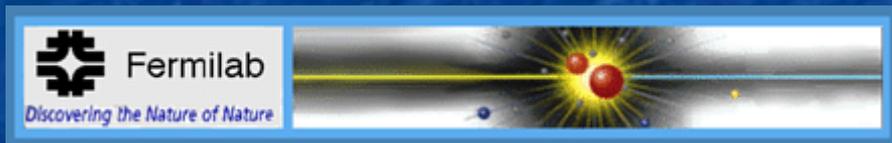
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Let's travel in the US!

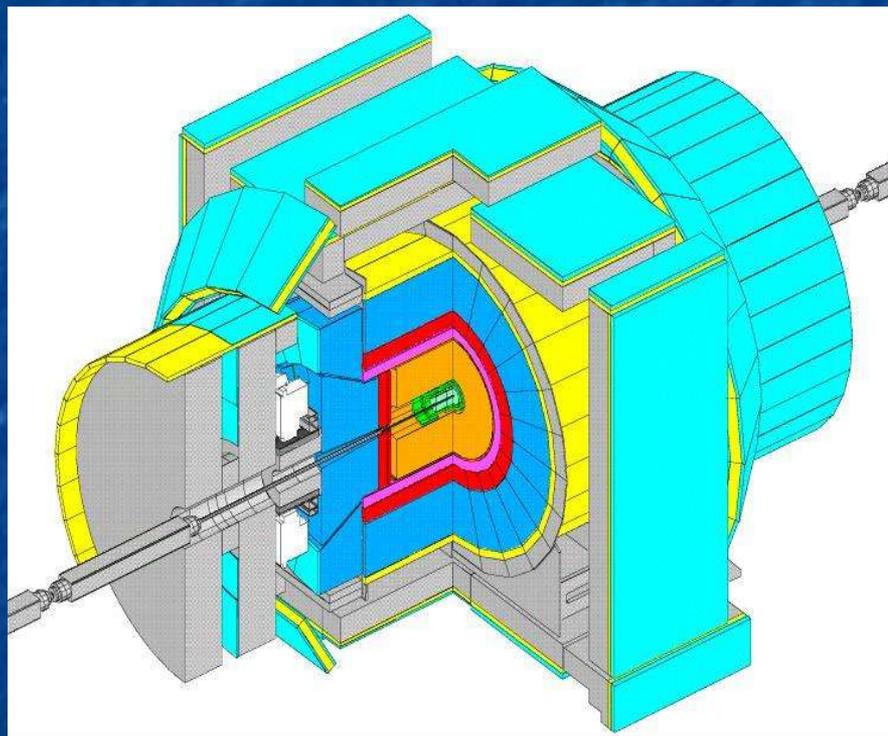
... going to Chicago suburbs, IL at the Fermi National Lab, the main accelerator facility in the US



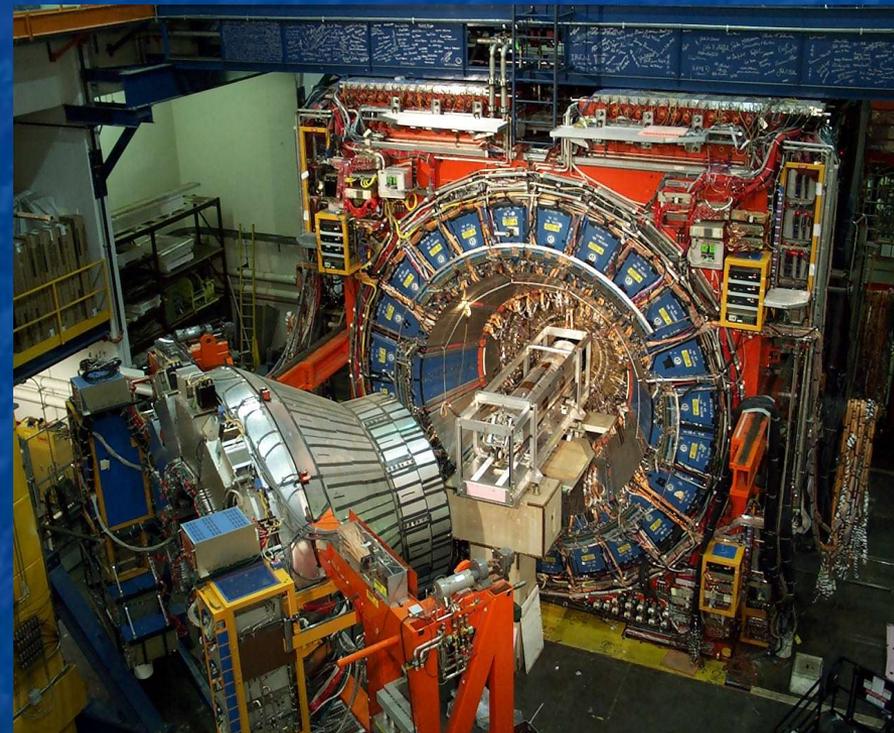
Up to ~2 million million eV!

A particle interaction detector

... currently in use, the CDF2 detector at Fermi National Lab



Cartoon view



Real view

Looking for new particles

Top quark

New particles would open new channels = looking for signature of specific reactions!

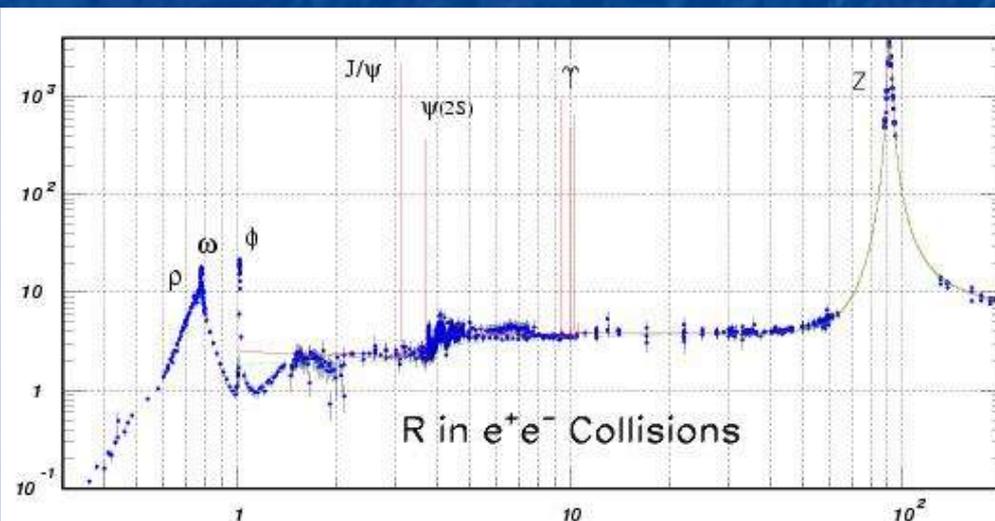
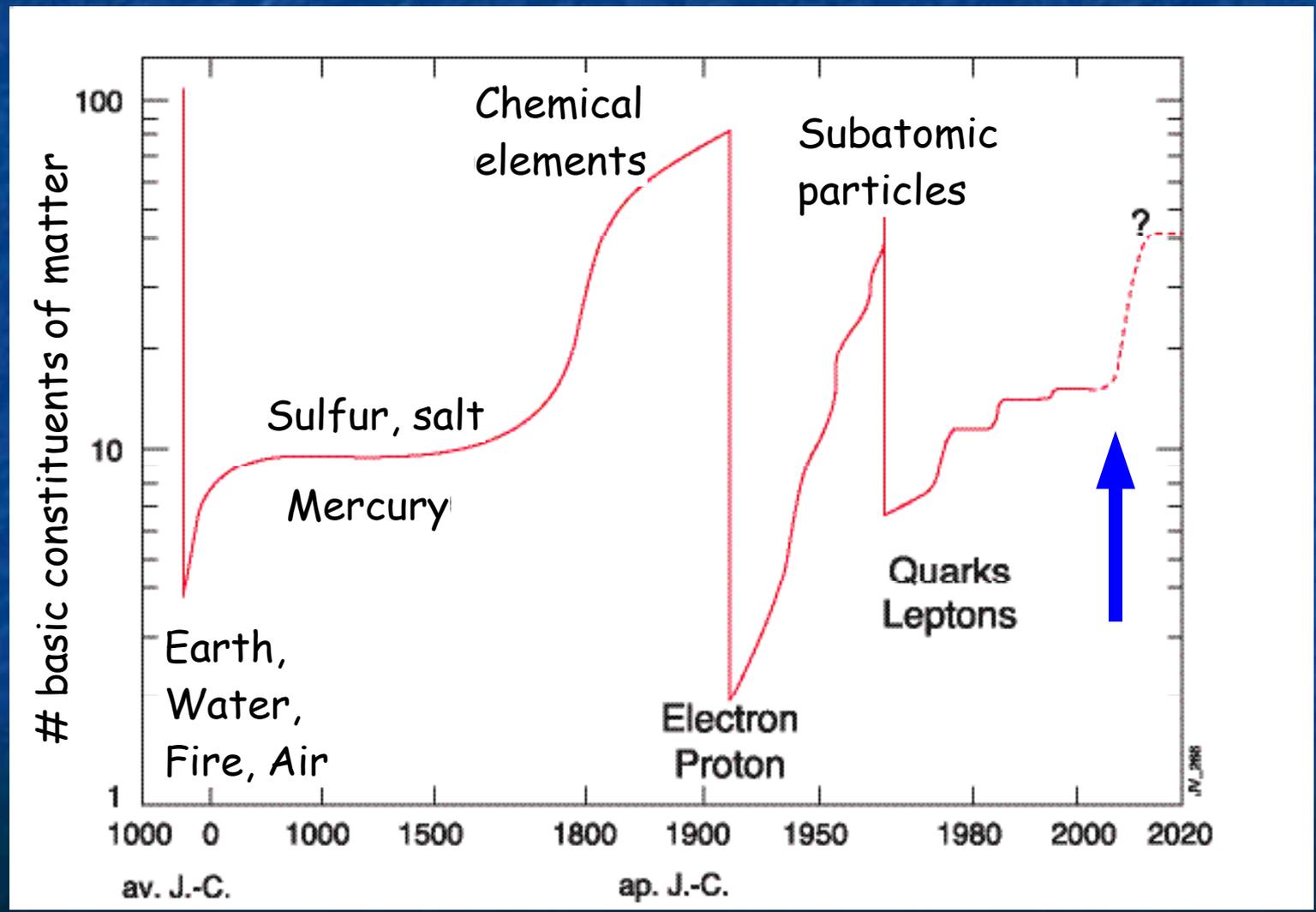


Figure 2: *R*-ratio. Data set is the same as in Figure 1. Solid curve is the *R*-ratio prediction in the three-loop QCD approximation with non-zero quark masses. Dashed curve is a “naive” quark parton model prediction for the ratio parameter *R*.





Do we really know all the elementary particles?



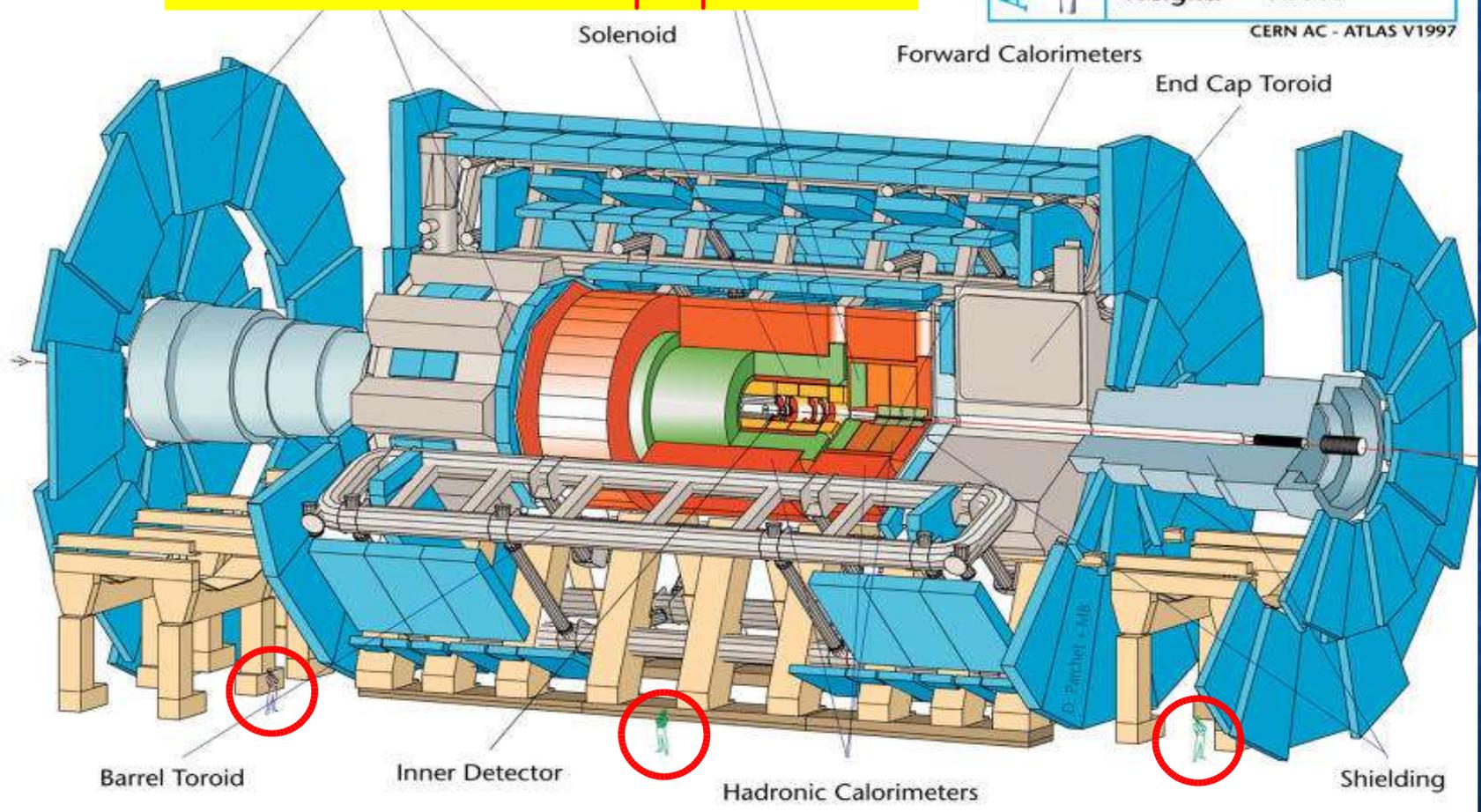
This is not a spaceship!!



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... this is the next generation particle interaction detector in preparation!

	Detector characteristics	
	Width:	44m
	Diameter:	22m
	Weight:	7000t
CERN AC - ATLAS V1997		



Yet another detector in preparation!



5/25/04



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

HCAL

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

FEET

Pakistan
China

FORWARD CALORIMETER

Hungary, Iran, Russia, Turkey, USA

MUON CHAMBERS

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

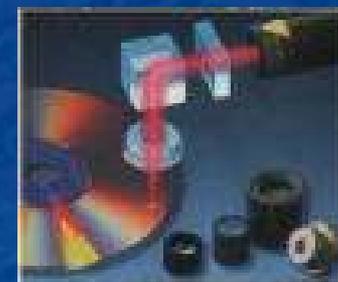
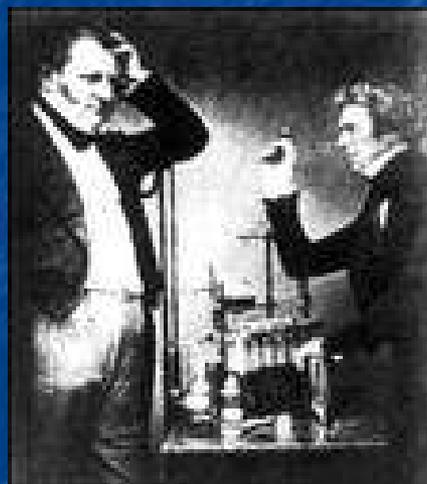
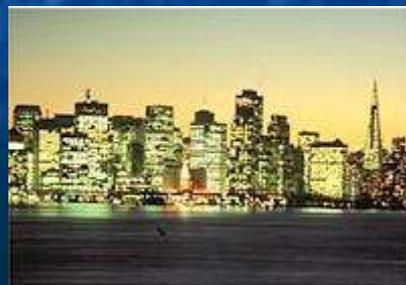
* Only through industrial contracts

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

What to remember?

Today's research is tomorrow's technology!

Faraday in the 1830's



All about curiosity and motivation



Wright brothers, Dec 17th 1903,
Kitty Hawk NC, 12 s long flight...



NASA/JPL, Jan 4th 2004,
300 million miles flight to Mars

Credits



5/25/04

Hope you enjoyed it! This presentation benefited from abundant material collected throughout several web sites:

- <http://www.galacticsurf.com>
- <http://particleadventure.org>
- <http://www.schoolscience.co.uk>
- <http://perso.club-internet.fr/molaire1> (in french)
- <http://voyage.in2p3.fr> (in french)
- <http://cdsweb.cern.ch> --> Multimedia & Outreach
- <http://hands-on-cern.physto.se>

