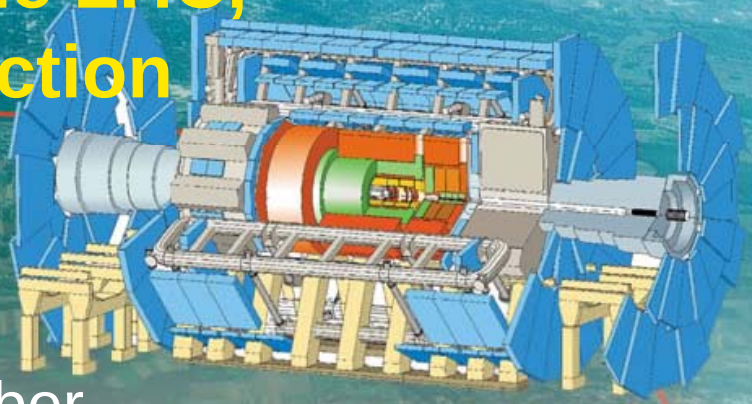
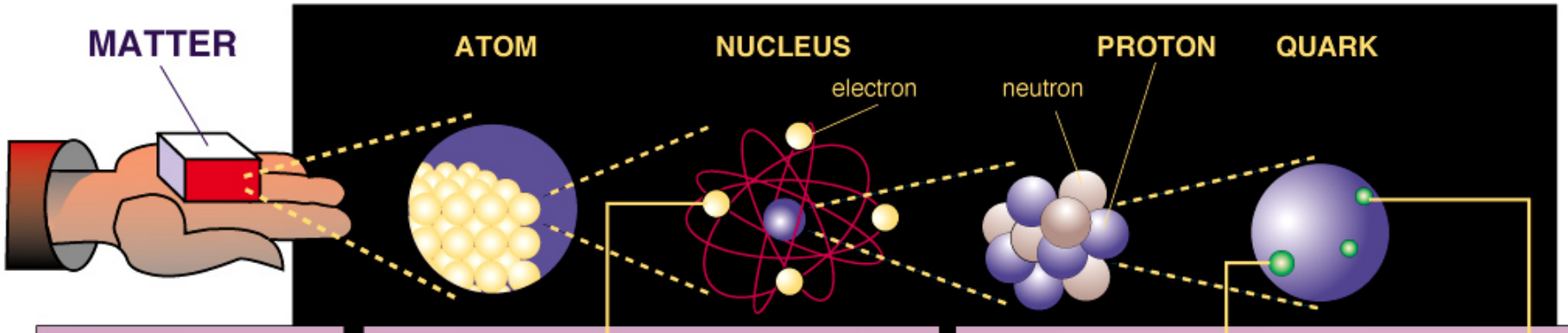
CERN and the LHC, an introduction



Roger Ruber

Uppsala University

Particle Physics Looks at Matter's Smallest Dimensions



ALL ORDINARY MATTER BELONGS TO THIS GROUP.

FOR THE MOST PART, THESE PARTICLES EXISTED IN THE EARLY MOMENTS AFTER THE BIG BANG.

LEPTONS

electron
Electric charge - 1
Responsible for electricity and chemical reactions

electron neutrino
Electric charge 0 .
rarely interacts with other matter.

muon
A heavier relative of the electron.

muon neutrino
Created with muons when some particles decay.

tau
Heavier still.

tau neutrino
observed

QUARKS

up
Electric charge + 2/3
Protons have 2 up quarks...
Neutrons have 1 up quark.

down
Electric charge - 1/3 .
Protons have 1 down quark
Neutrons have 2 down quarks

charm
A heavier relative of the up.

strange
A heavier relative of the down.

top
recently observed

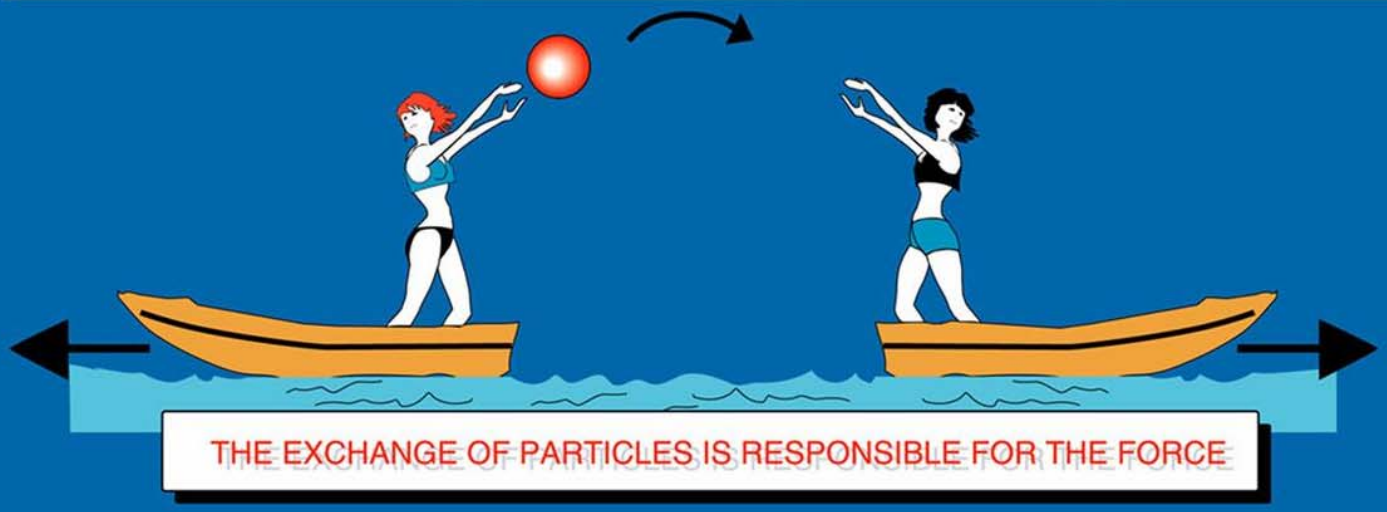
bottom
Heavier still.

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

from Time magazine

Particle Physics Looks at the Forces in Nature

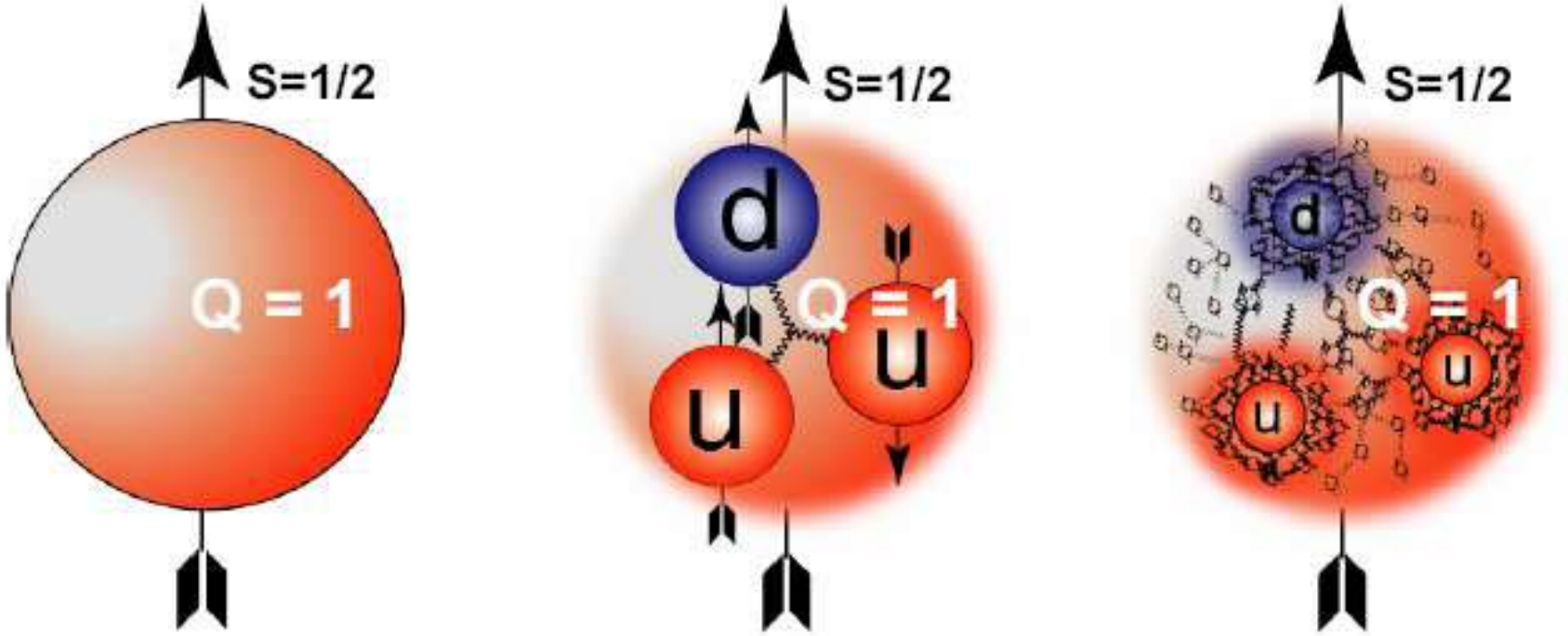
TYPE	INTENSITY OF FORCES (DECREASING ORDER)	BINDING PARTICLE (FIELD QUANTUM)	OCCURS IN :
STRONG NUCLEAR FORCE	~ 1	GLUONS (NO MASS)	ATOMIC NUCLEUS
ELECTRO -MAGNETIC FORCE	~ 10^{-3}	PHOTONS (NO MASS)	ATOMIC SHELL ELECTROTECHNIQUE
WEAK NUCLEAR FORCE	~ 10^{-5}	BOSONS Z^{o} , W+ , W- (HEAVY)	RADIOACTIVE BETA DESINTEGRATION
GRAVITATION	~ 10^{-38}	GRAVITONS (?)	HEAVENLY BODIES



The Proton and Neutron are the "Hydrogen Atoms" of QCD

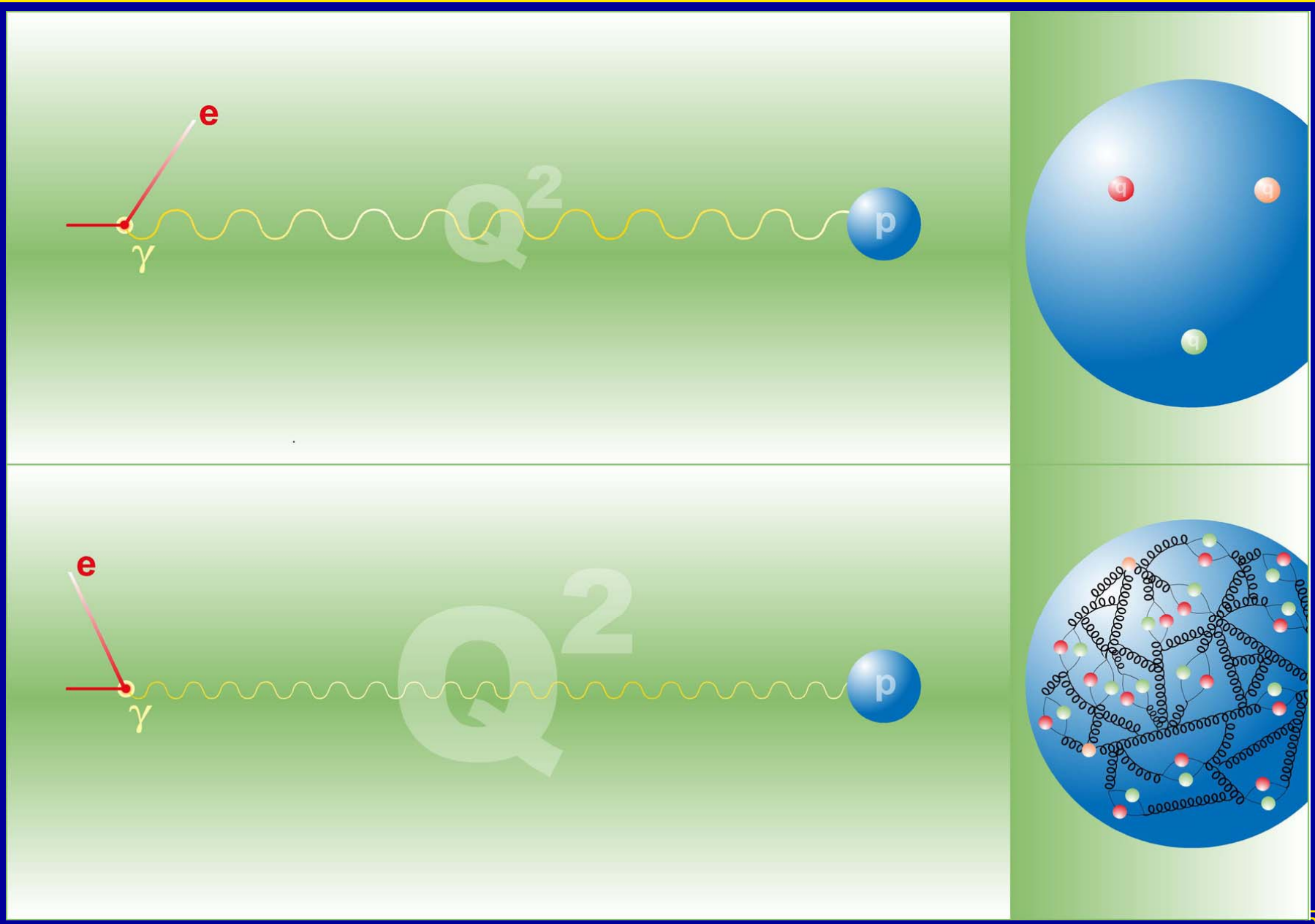
What we "see" changes with spatial resolution

>1 fm	0.1 — 1 fm	< 0.1 fm
Nucleons	Constituent quarks and glue	"bare" quarks and glue

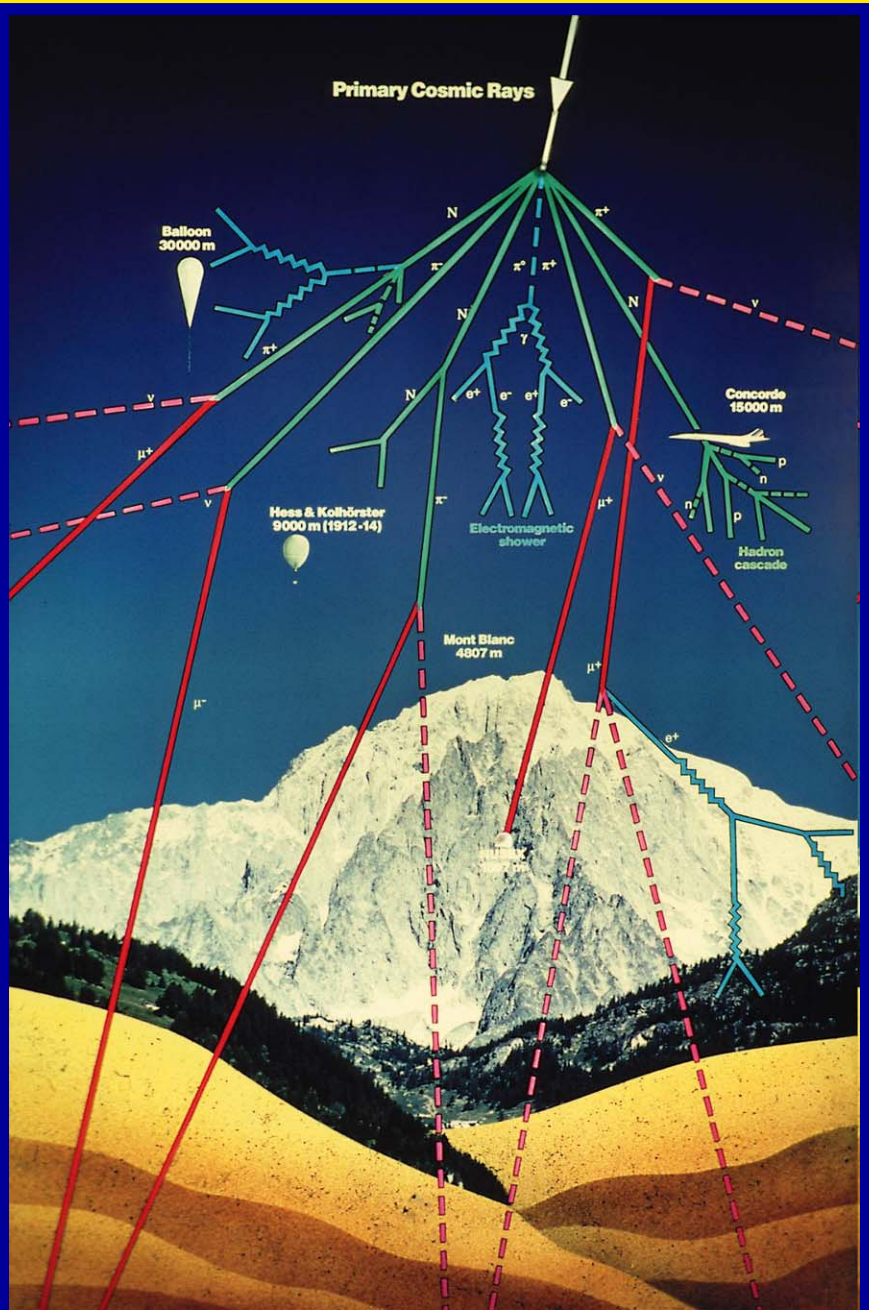


Courtesy L. Cardman/B. Badelek

Particle Interaction as Microscope



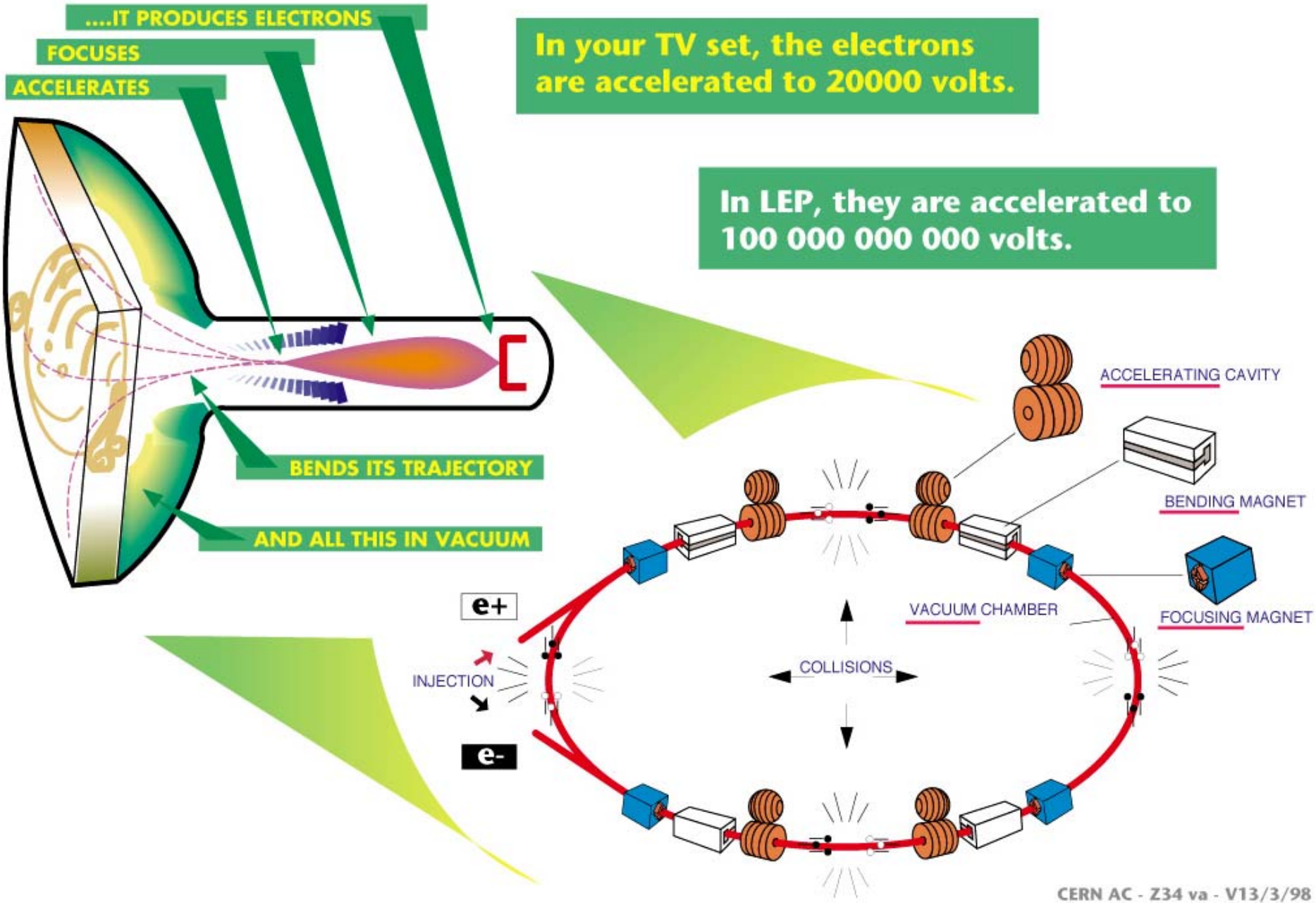
How to Observe the Micro-world?



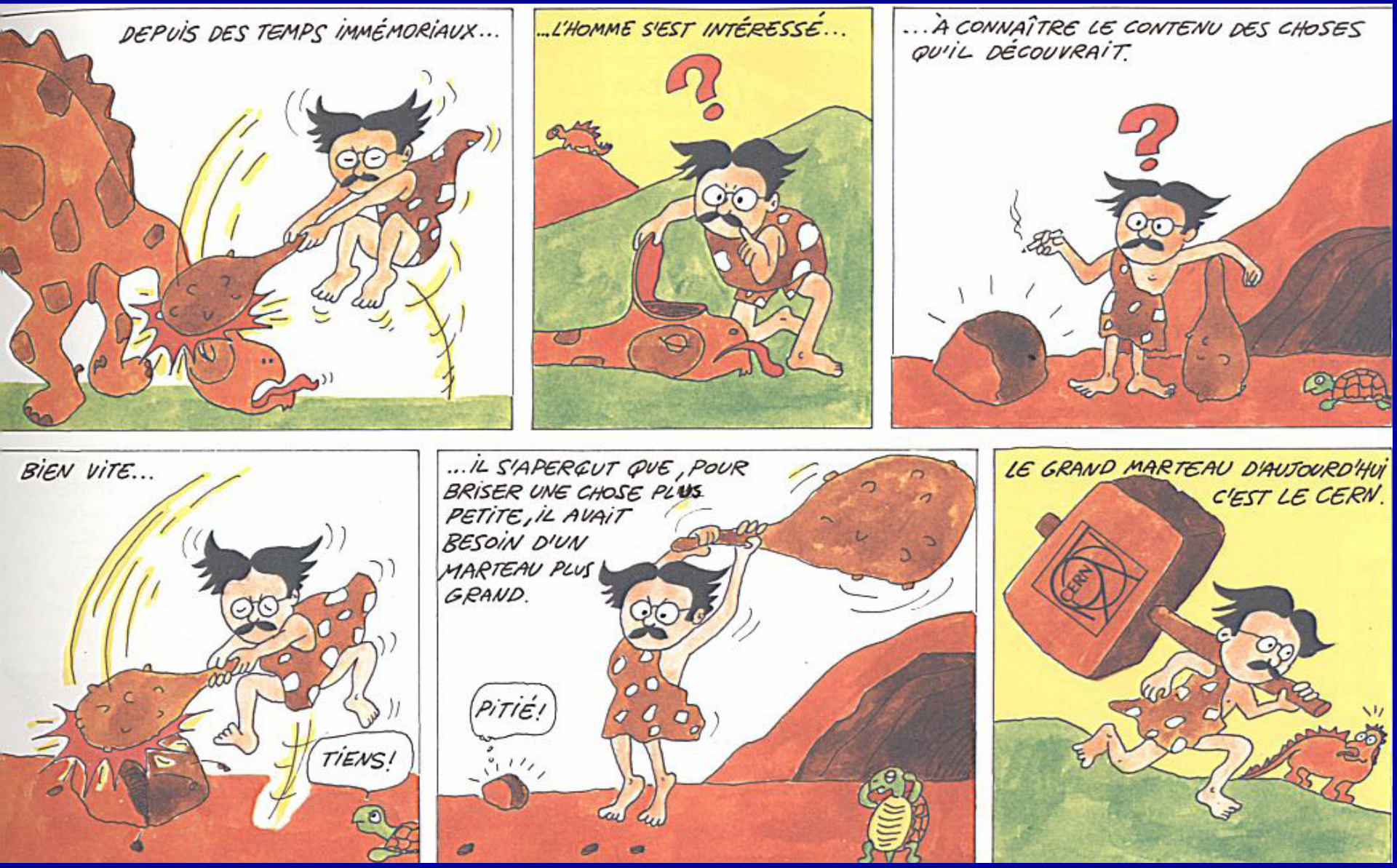
Collisions between particles at high energies allow the production of heavy elementary particles and probing small distance scales

To reach high energies implies large and technologically advanced accelerators and detectors

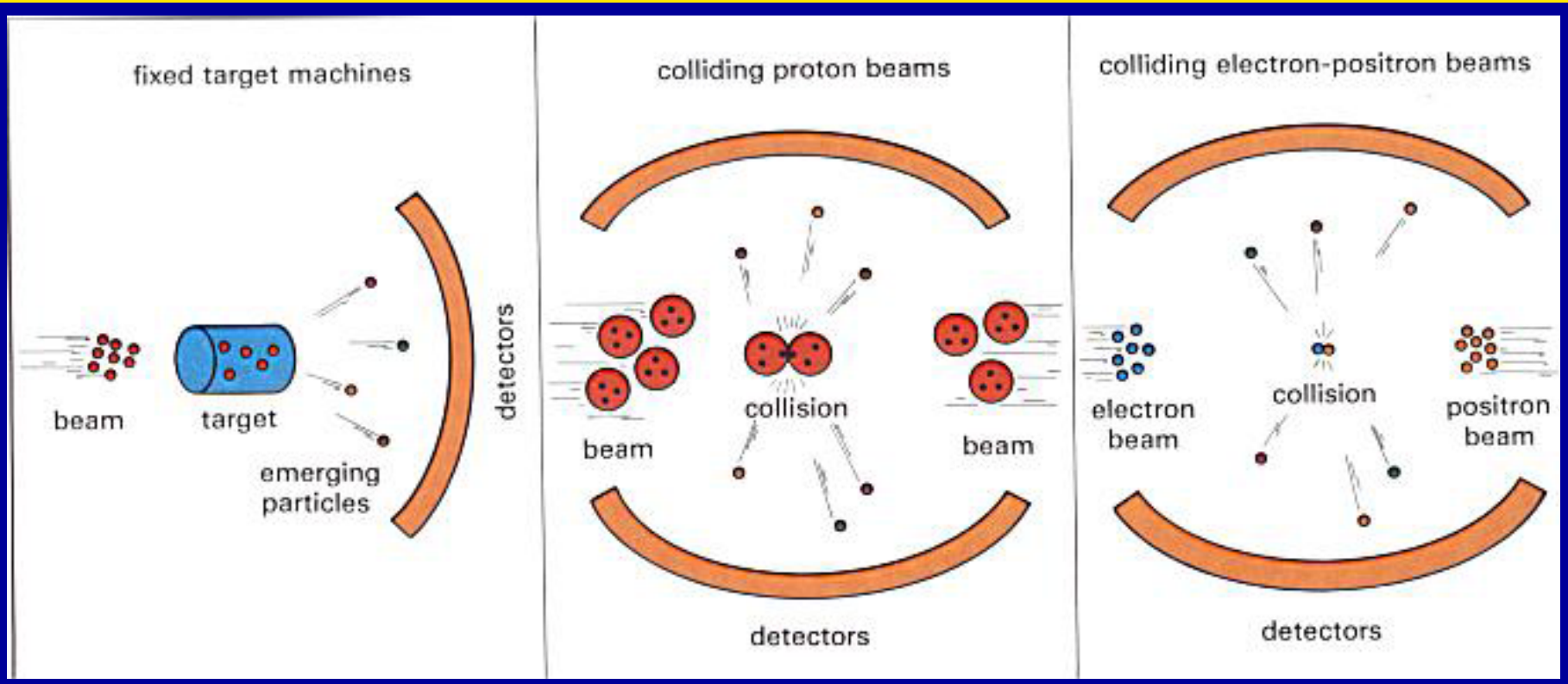
How Does an Accelerator Work?



Large Science …



How to do the experiments



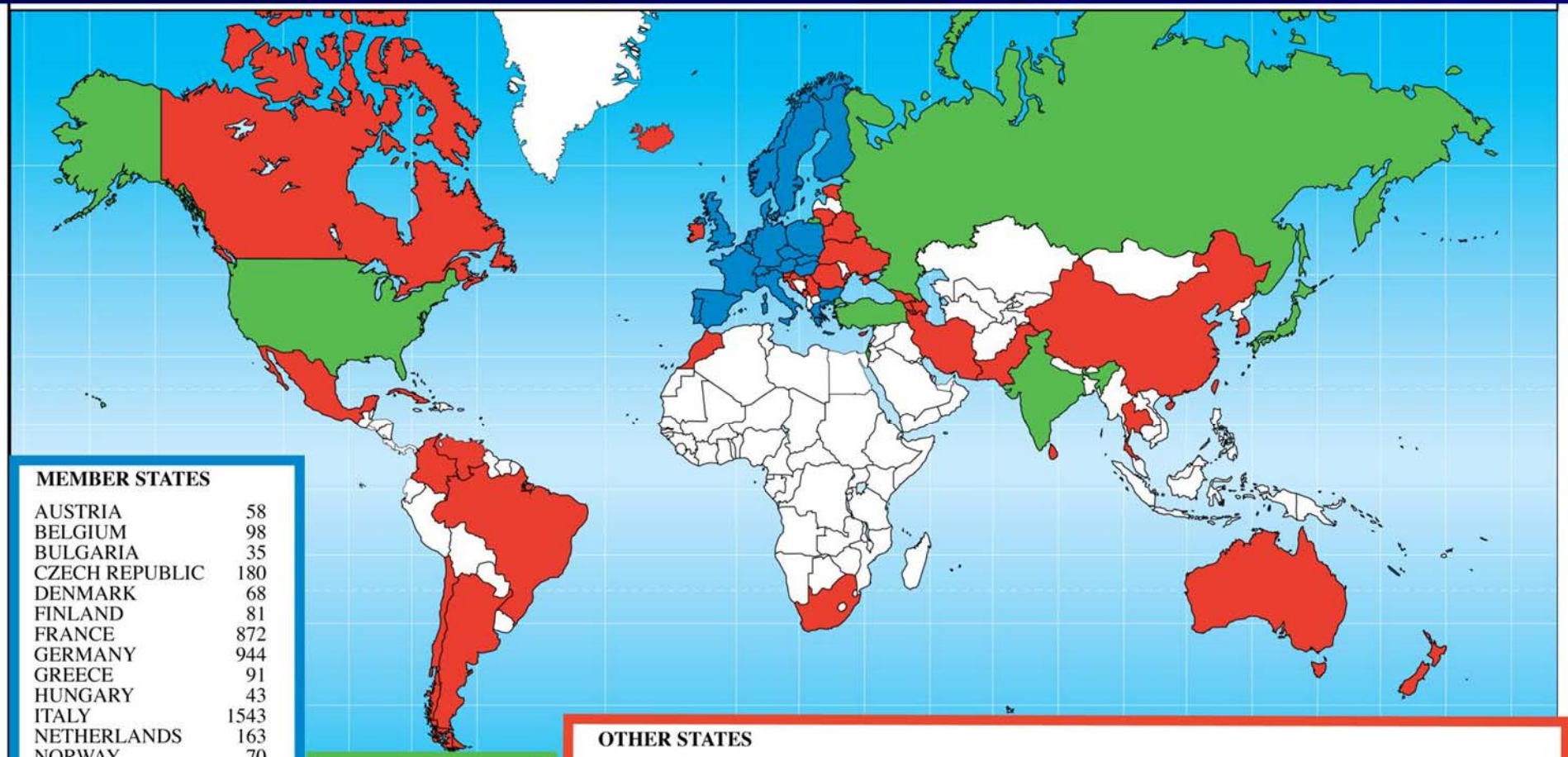
- choose a the beam (probe) and target (object to be probed)
- measure beam momentum
- identify collision products, and measure their momenta
- reconstruct the reaction

The Twenty Member States of CERN

Member States (Dates of Accession)

- AUSTRIA (1959)
- BELGIUM (1953)
- BULGARIA (1999)
- CZECH FR (1993)
- DENMARK (1953)
- FINLAND (1991)
- FRANCE (1953)
- GERMANY (1953)
- GREECE (1953)
- HUNGARY (1992)
- ITALY (1953)
- NETHERLANDS (1953)
- NORWAY (1953)
- POLAND (1991)
- PORTUGAL (1986)
- SLOVAK FR (1993)
- SPAIN (1/1961-12/1968-1/1983)
- SWEDEN (1953)
- SWITZERLAND (1953)
- UNITED KINGDOM (1953)

Distribution of All CERN Users by Nation of Institute on 5 February 2008



MEMBER STATES

AUSTRIA	58
BELGIUM	98
BULGARIA	35
CZECH REPUBLIC	180
DENMARK	68
FINLAND	81
FRANCE	872
GERMANY	944
GREECE	91
HUNGARY	43
ITALY	1543
NETHERLANDS	163
NORWAY	70
POLAND	175
PORTUGAL	109
SLOVAKIA	46
SPAIN	270
SWEDEN	74
SWITZERLAND	344
UNITED KINGDOM	645

5909

OBSERVER STATES

INDIA	93
ISRAEL	64
JAPAN	182
RUSSIA	940
TURKEY	35
USA	1278

2592

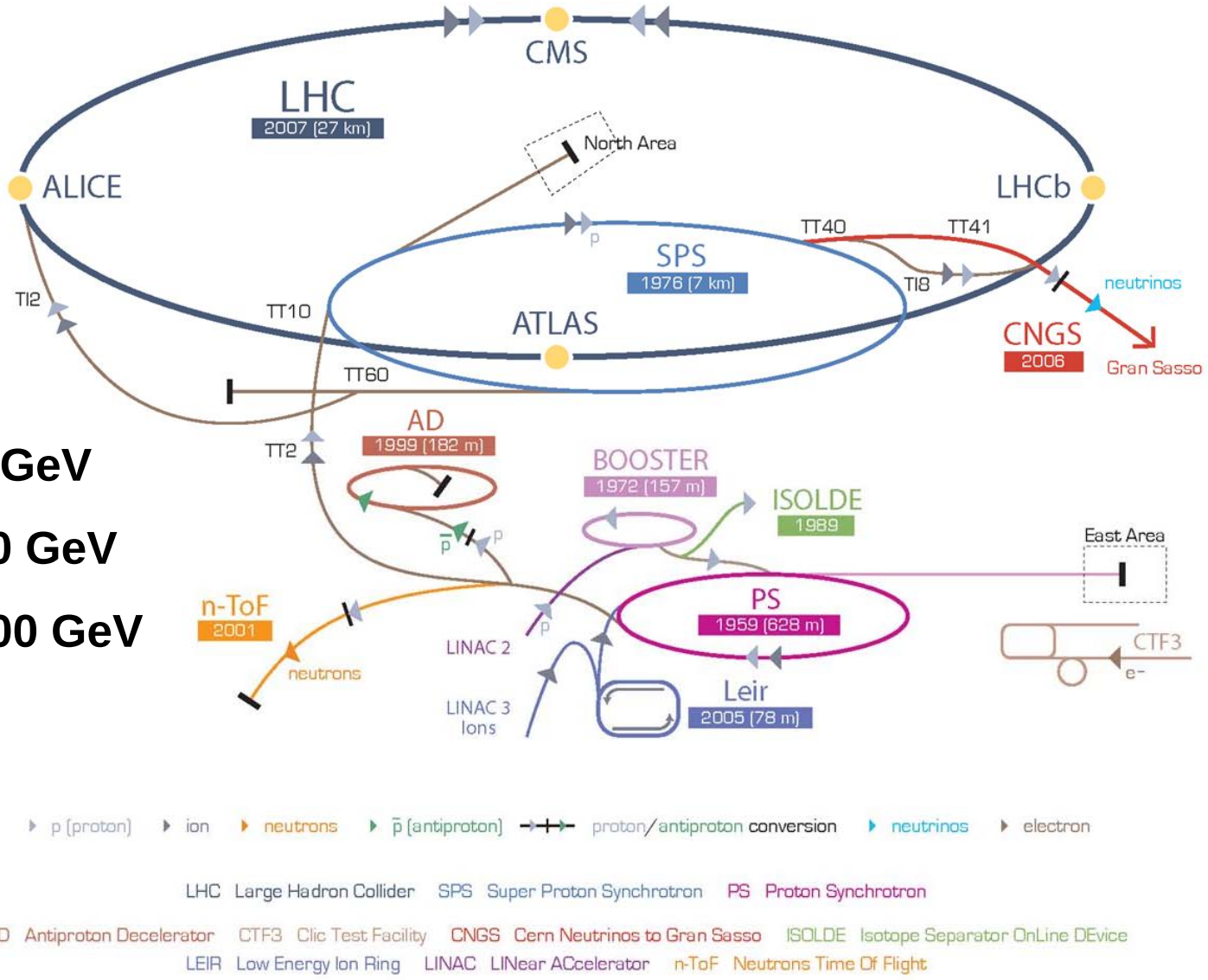
OTHER STATES

ARGENTINA	8	CROATIA	17	MEXICO	23	TAIWAN	40
ARMENIA	17	CUBA	3	MONTENEGRO	1	THAILAND	1
AUSTRALIA	13	CYPRUS	6	MOROCCO	6	UKRAINE	17
AZERBAIJAN	1	ESTONIA	10	NEW ZEALAND	7		
BELARUS	23	GEORGIA	9	PAKISTAN	23		
BRAZIL	68	ICELAND	1	ROMANIA	46		
CANADA	119	IRAN	6	SERBIA	16		
CHILE	4	IRELAND	14	SLOVENIA	16		
CHINA	60	KOREA	44	SOUTH AFRICA	2		
COLOMBIA	5	LITHUANIA	5	SRI LANKA	1		

632

Crossing Borders at CERN

CERN Accelerator Complex

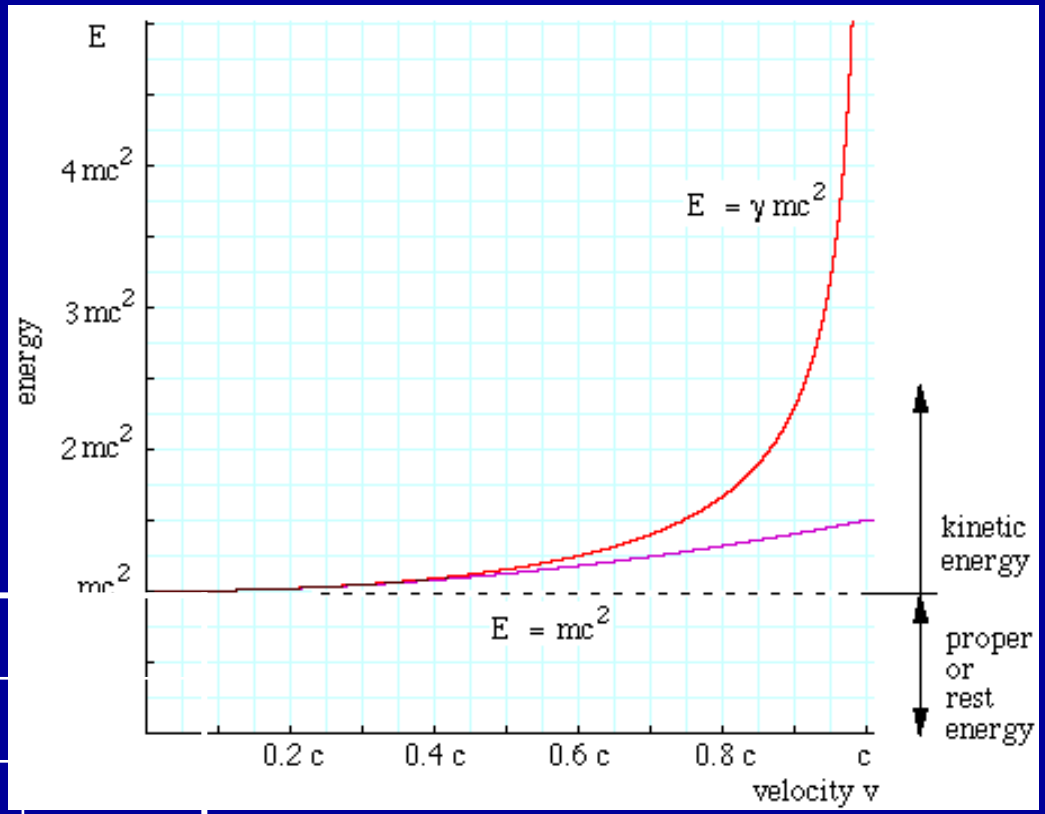


PS: 25 GeV

SPS: 450 GeV

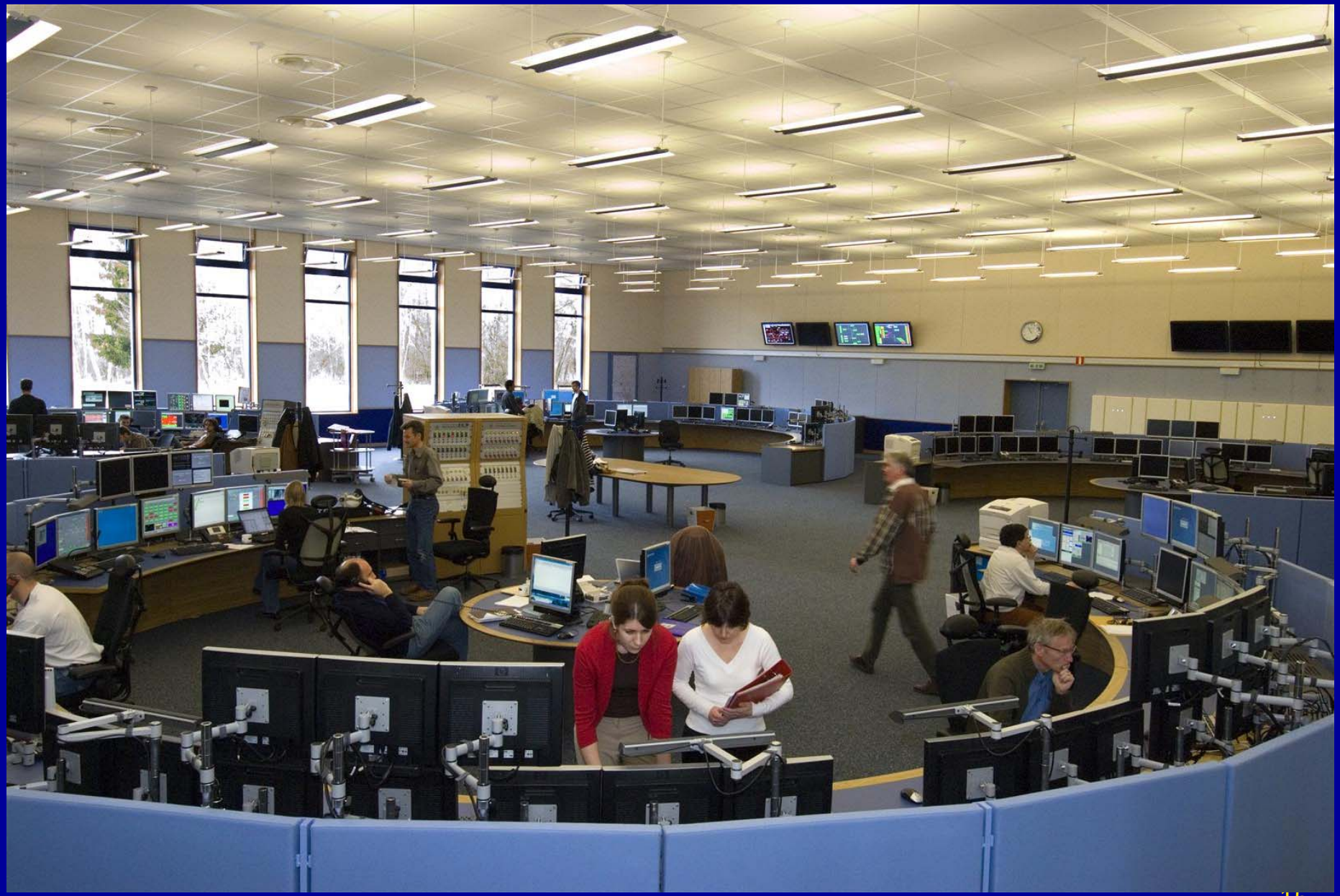
LHC: 7000 GeV

Accelerating Particles

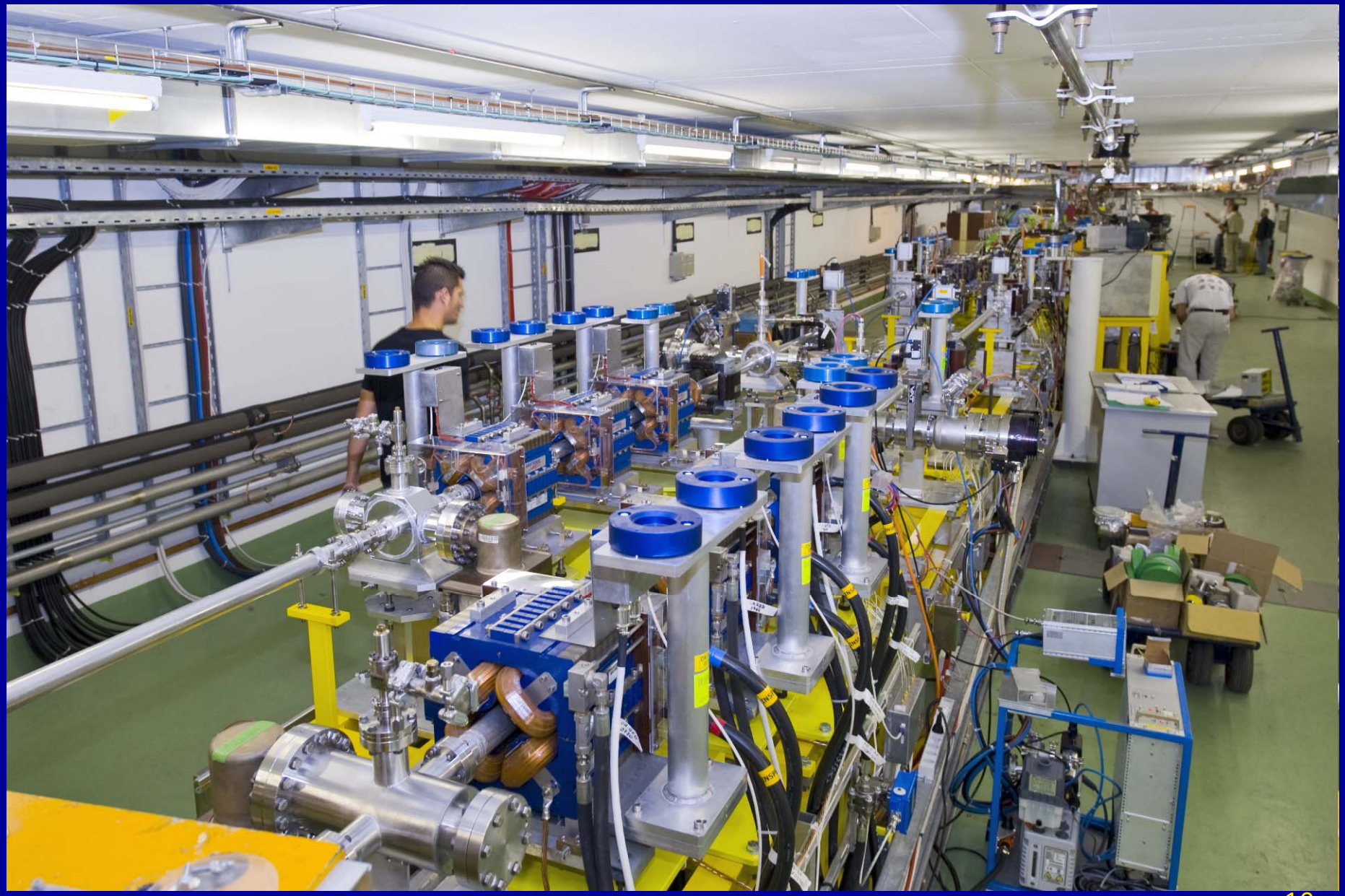


Proton		
Kinetic Energy	Velocity / c	
50 MeV	0.314	
1.4 GeV	0.916	
25 GeV	0.999 3	PS
450 GeV	0.999 998	SPS
7 TeV	0.999 999 991	LHC

CERN Control Centre

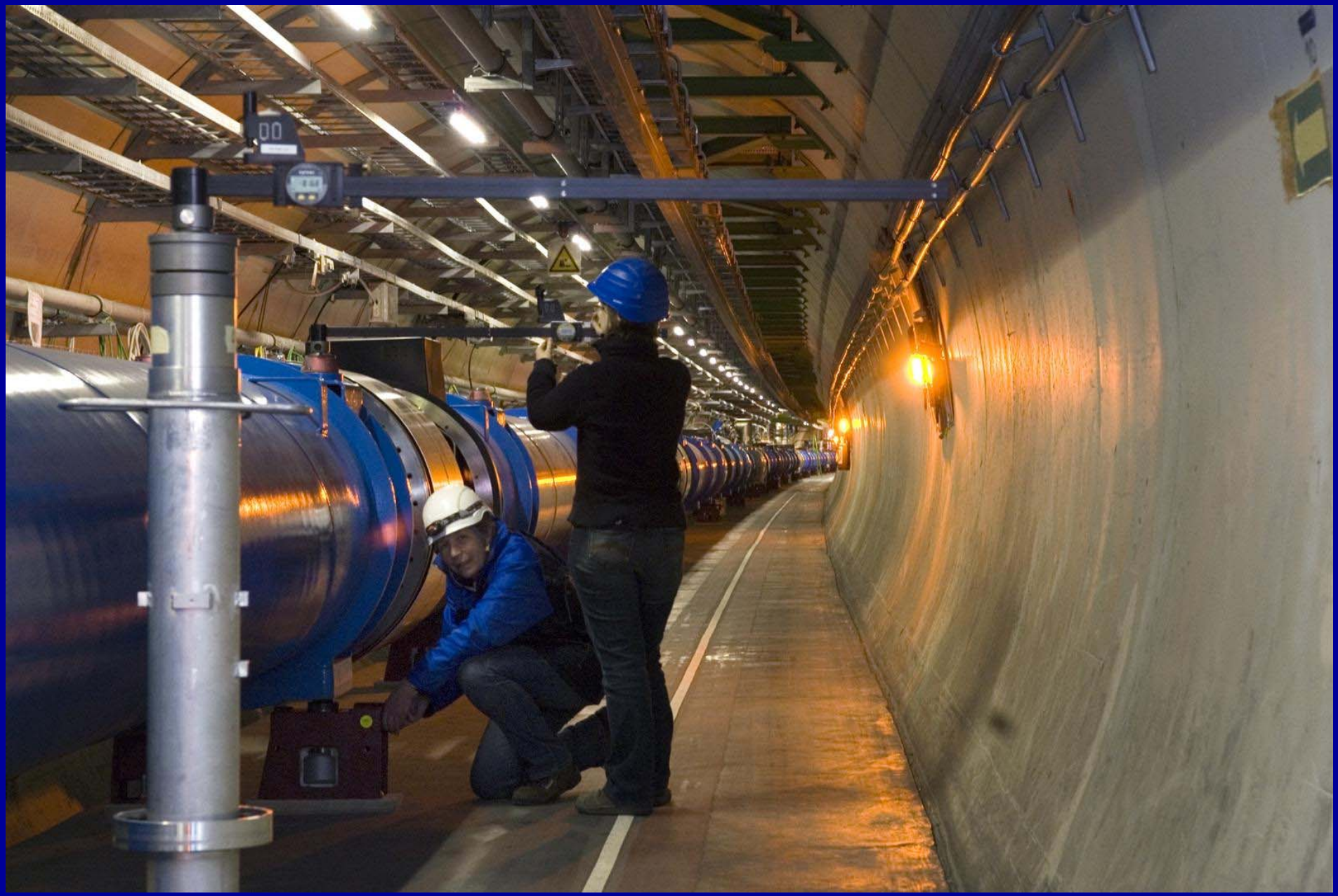


CERN CTF3 Two-beam Test-stand (2008, 150 MeV)

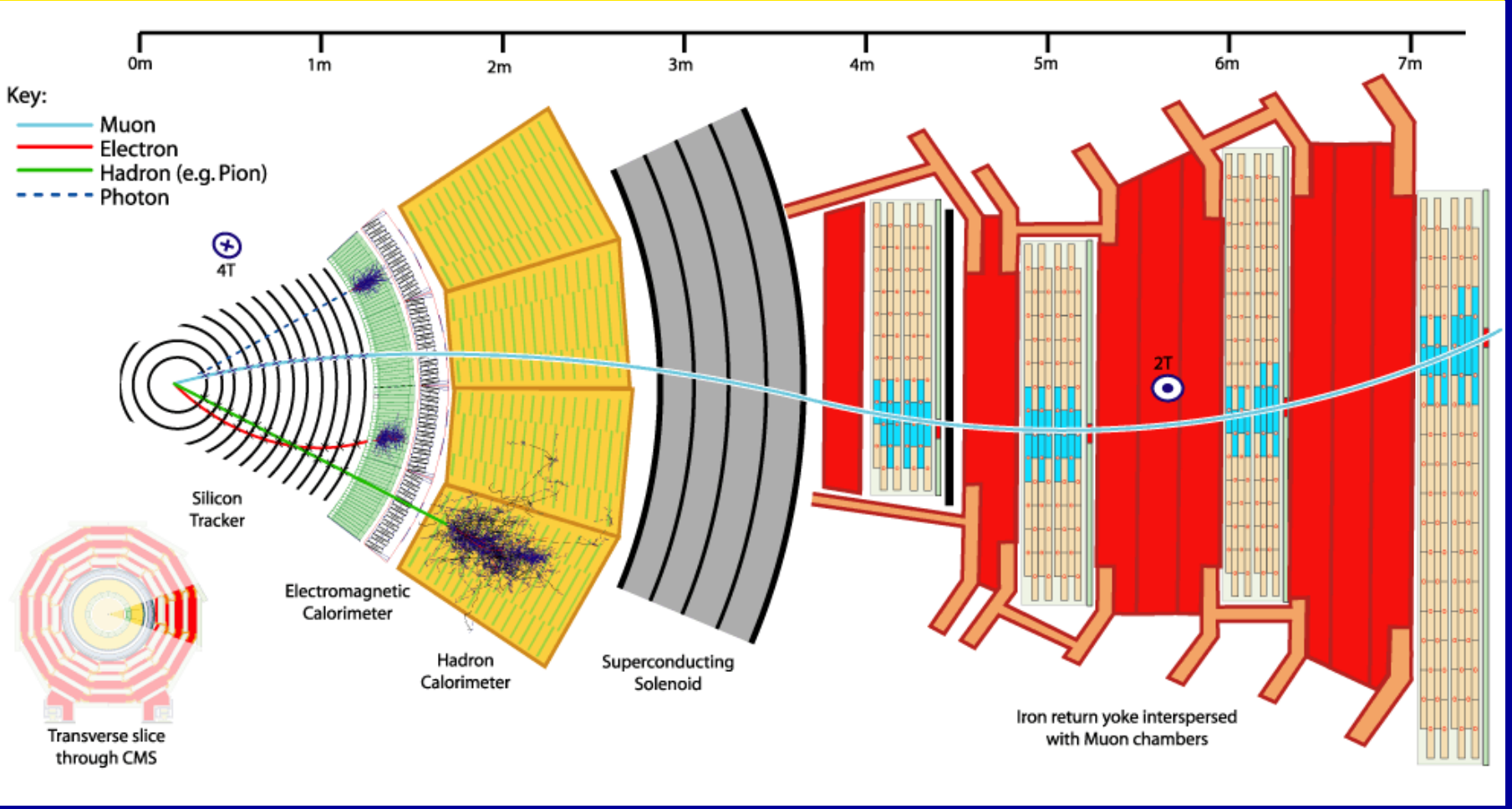


CERN SPS Accelerator (1978, 450 GeV)

CERN LHC Accelerator (2008, 7 TeV)



“Generic” Experimental Set-up

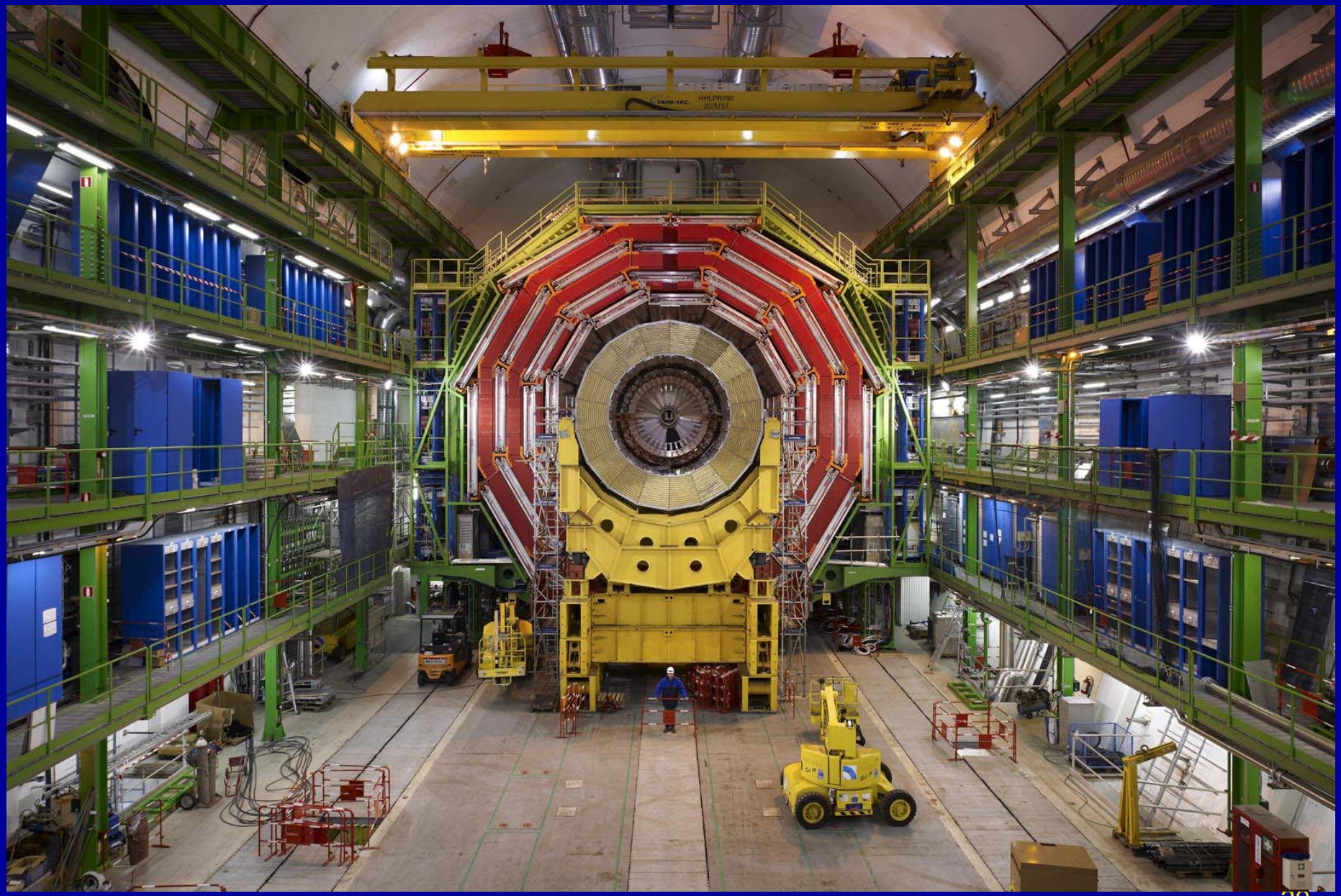


Deflection ~ BL2/p → need high B (superconducting) and large magnets

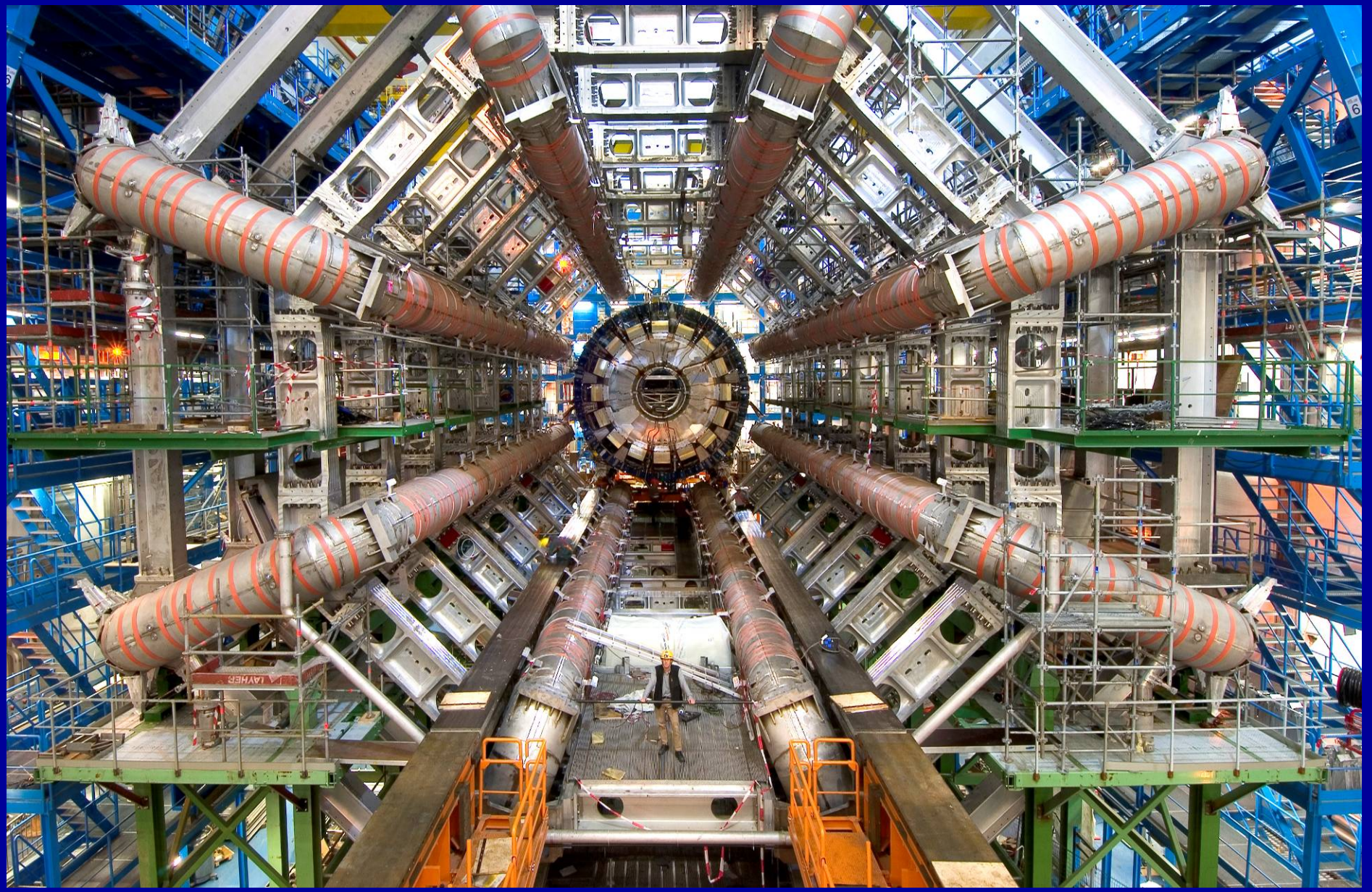
High resolution position measurements (10 -100μm) at large momentum

Energy & position measurement through total absorption (photon, electron, hadron)

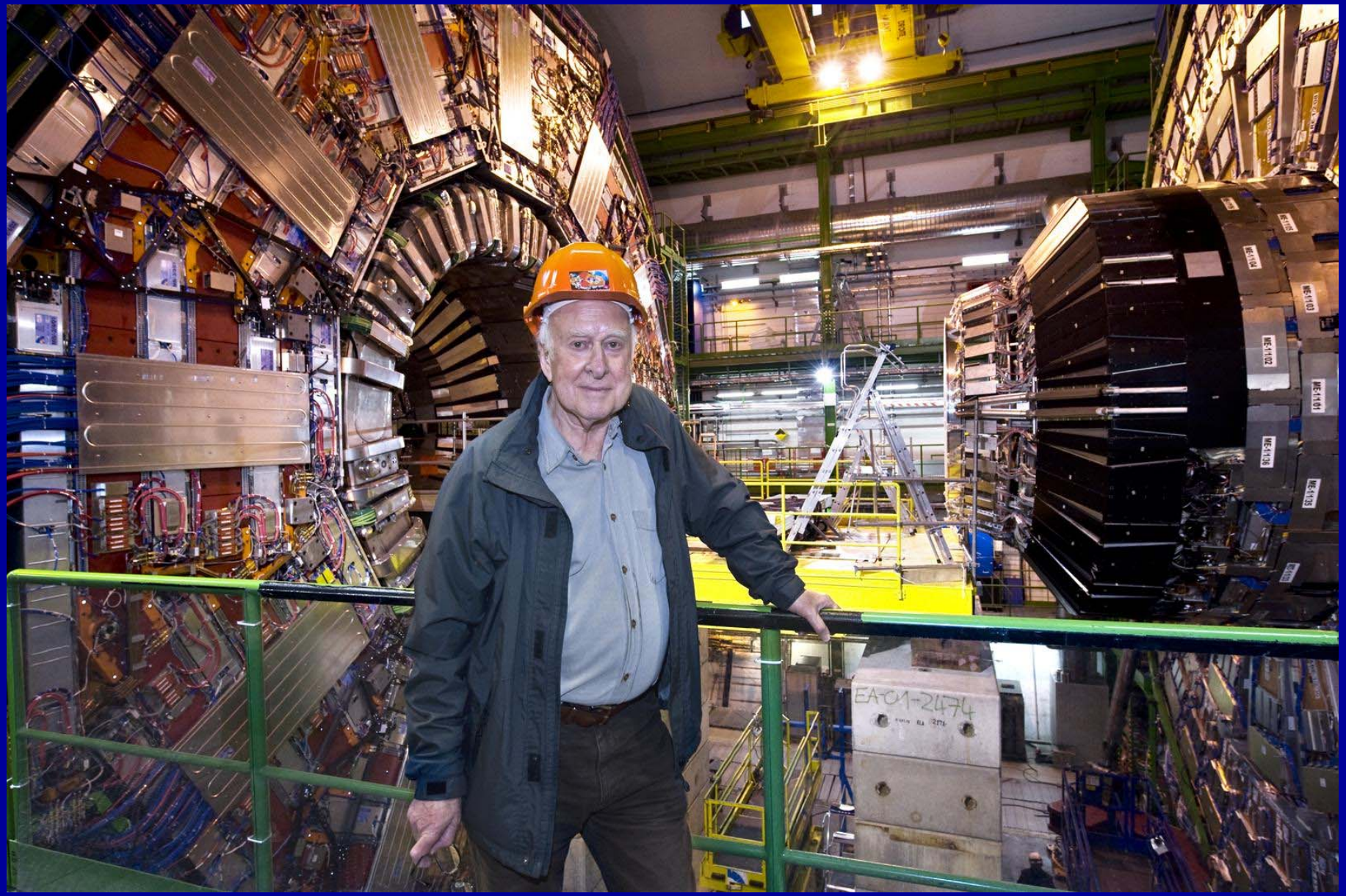
CMS Detector



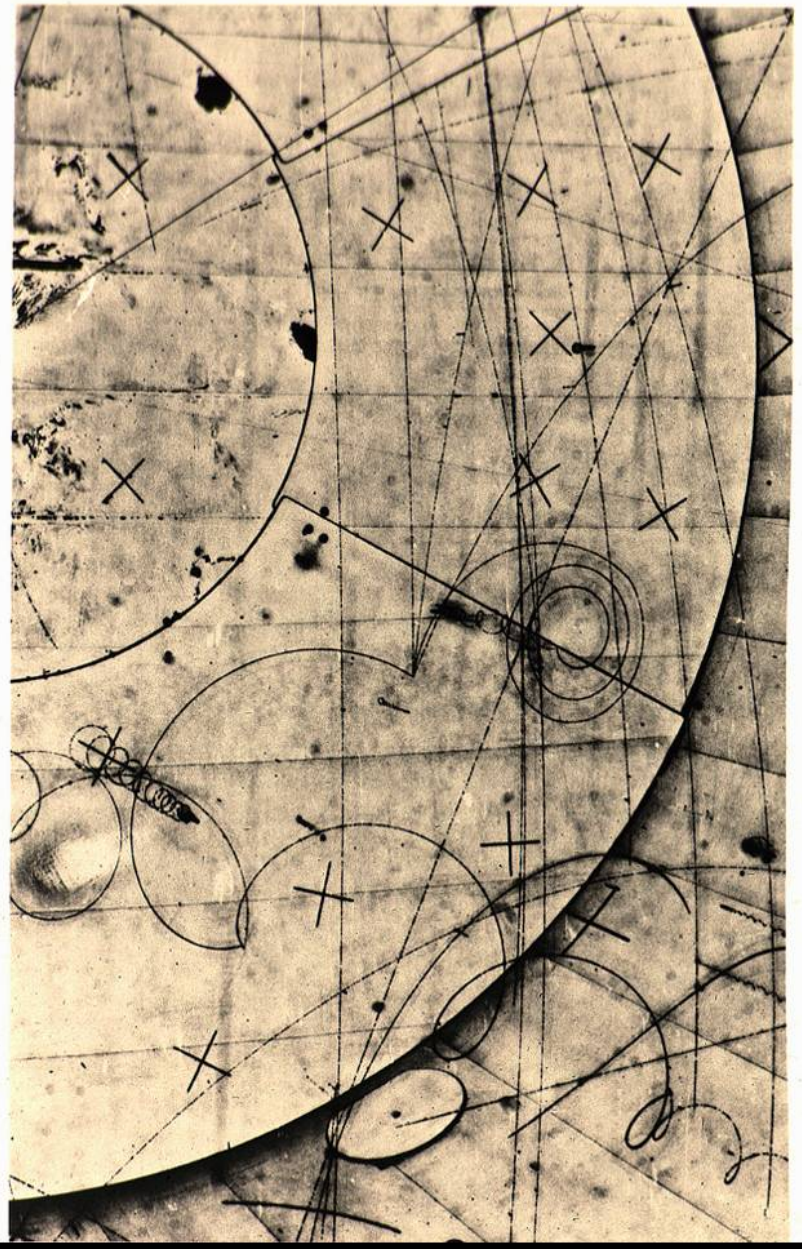
ATLAS Detector

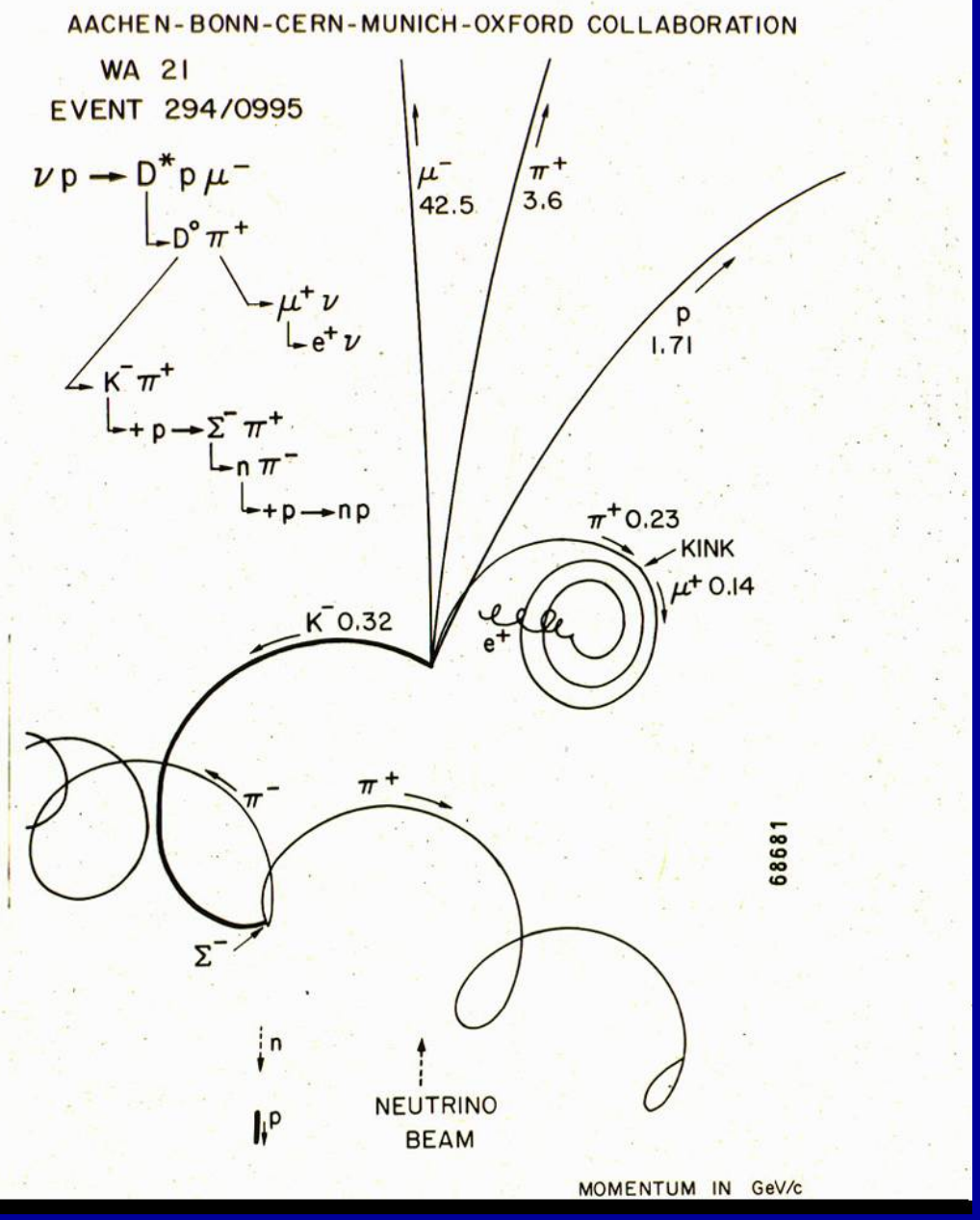


What do we look at?

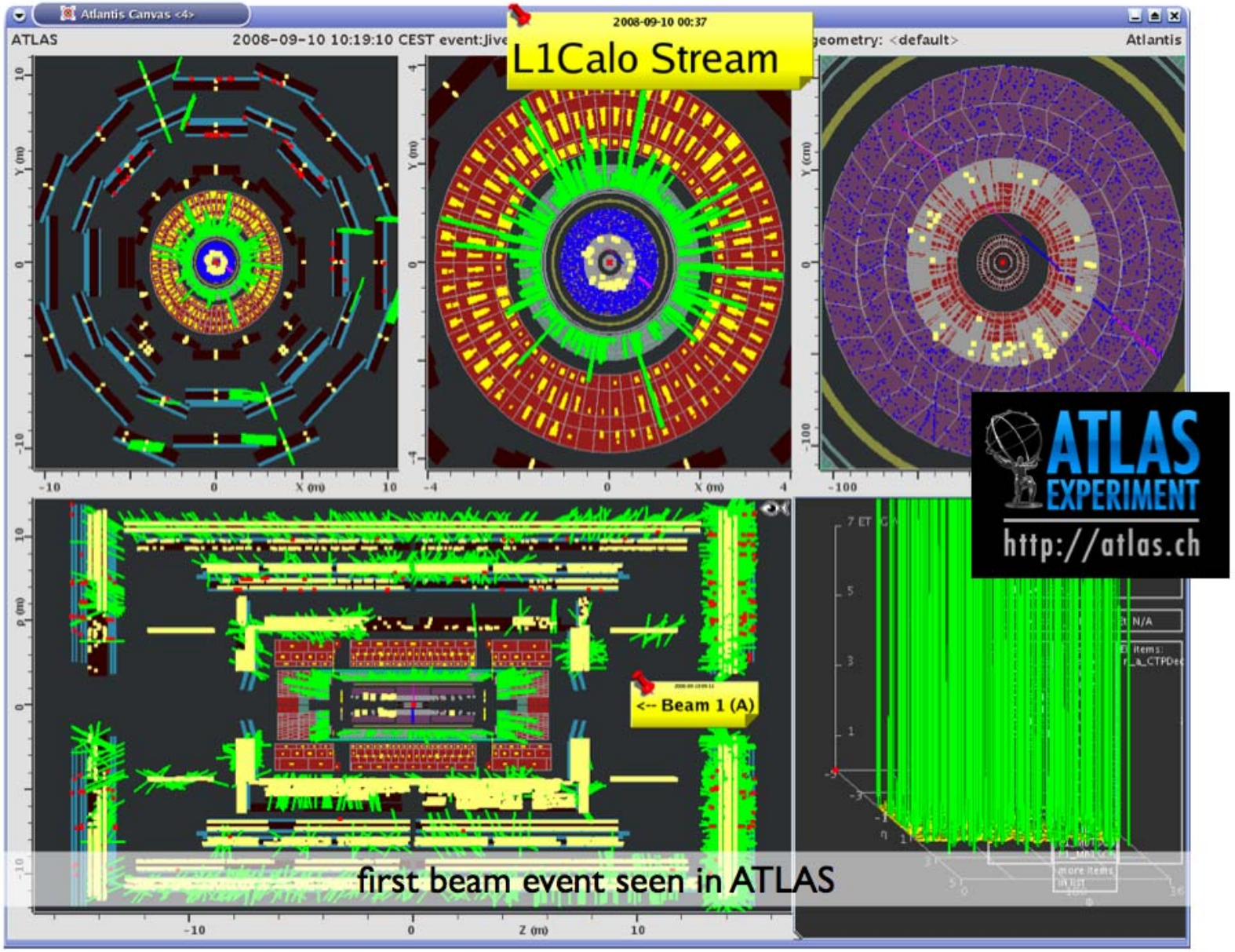


An Event (bubble chamber, Dec. 1978)





First Beam Event in ATLAS (10 Sep. 2008)



Practical Applications