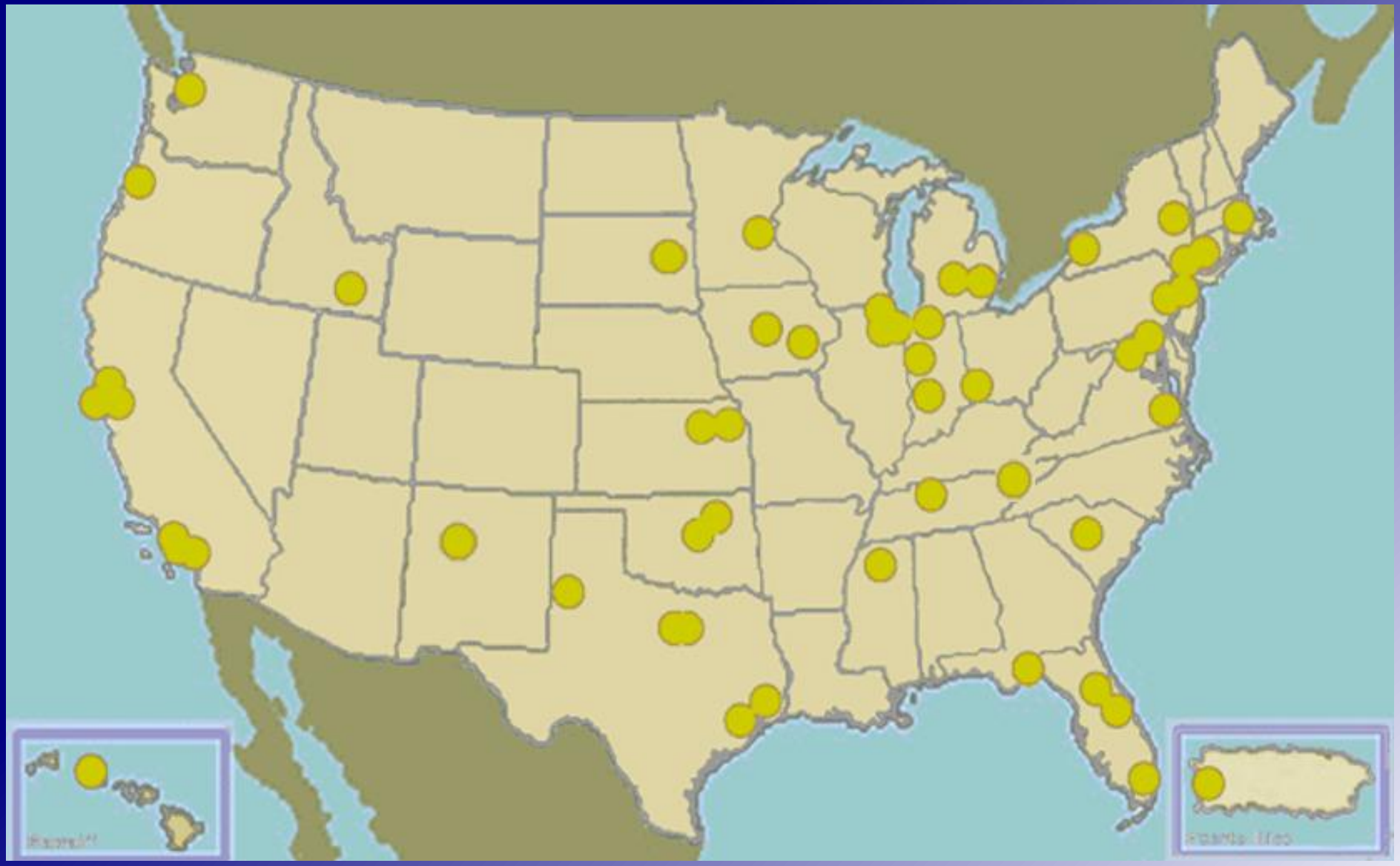
QuarkNet:
A Teacher's Perspective

Jeremy Smith

Hereford HS / QuarkNet JHU

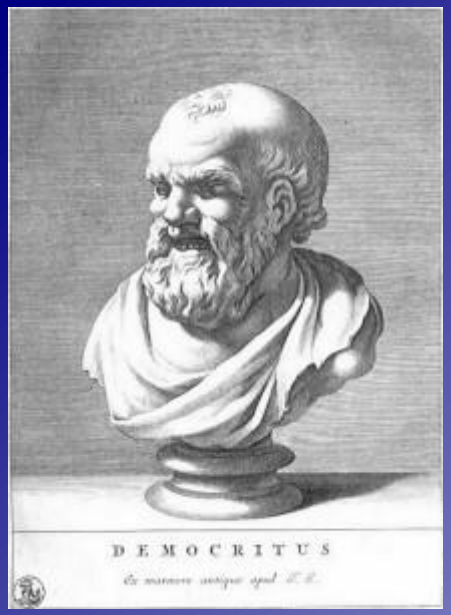
~50 Centers; ~600 Teachers



Topics

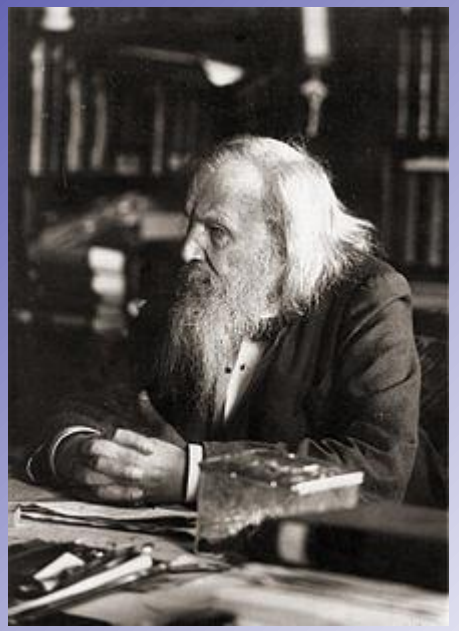
- The Standard Model
- Detectors
- Fermilab Happenings
- Stuff for Teachers to Do

Prehistory



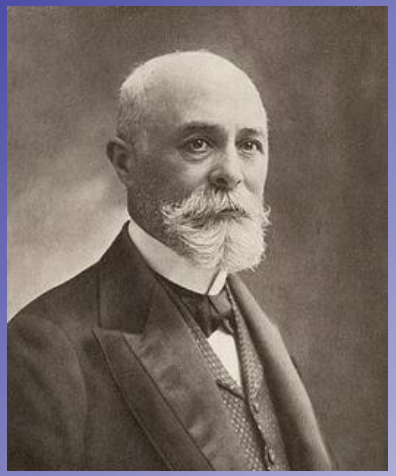
Dobereiner's triads | Known to Mendeleev | Unknown to Mendeleev

	H 1.01									
He 4.00	Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0			
Ne 20.2	Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5			
Ar 40.0	K 39.1	Ca 40.1	Sc 45.0	Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 58.7
	Cu 63.5	Zn 65.4	Ga 69.7	Ge 72.6	As 74.9	Se 79.0	Br 79.9			
Kr 83.8	Rb 85.5	Sr 87.6	Y 88.9	Zr 91.2	Nb 92.9	Mo 95.9	Tc (98)	Ru 101	Rh 103	Pd 106
	Ag 108	Cd 112	In 115	Sn 119	Sb 122	Te 128	I 127			
Xe 131	Ce 133	Ba 137	La 139	Hf 179	Ta 181	W 184	Re 186	Os 194	Ir 192	Pt 195
	Au 197	Hg 201	Tl 204	Pb 207	Bi 209	Po (210)	At (210)			
Rn (222)	Fr (223)	Ra (226)	Ac (227)	Th 232	Pa (231)	U 238				



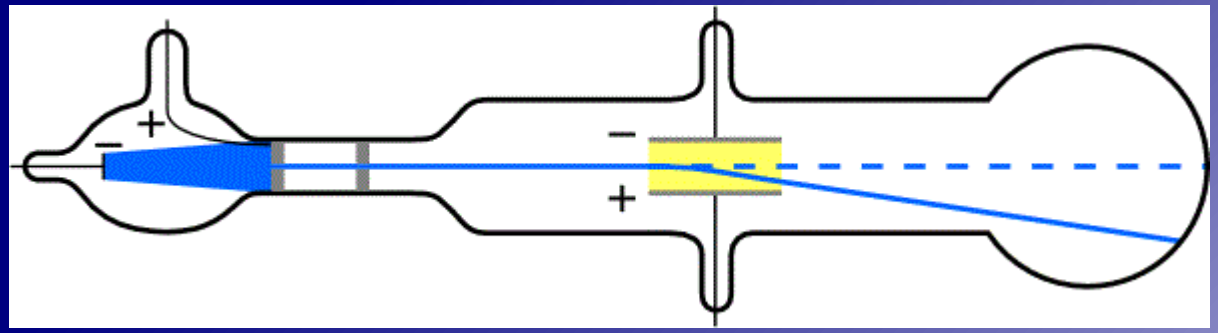
Roentgen, Becquerel, Curies, et al

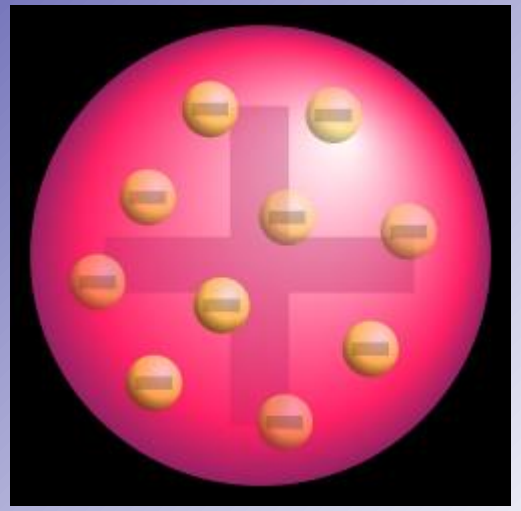
- Particles & Rays!



JJ Thomson

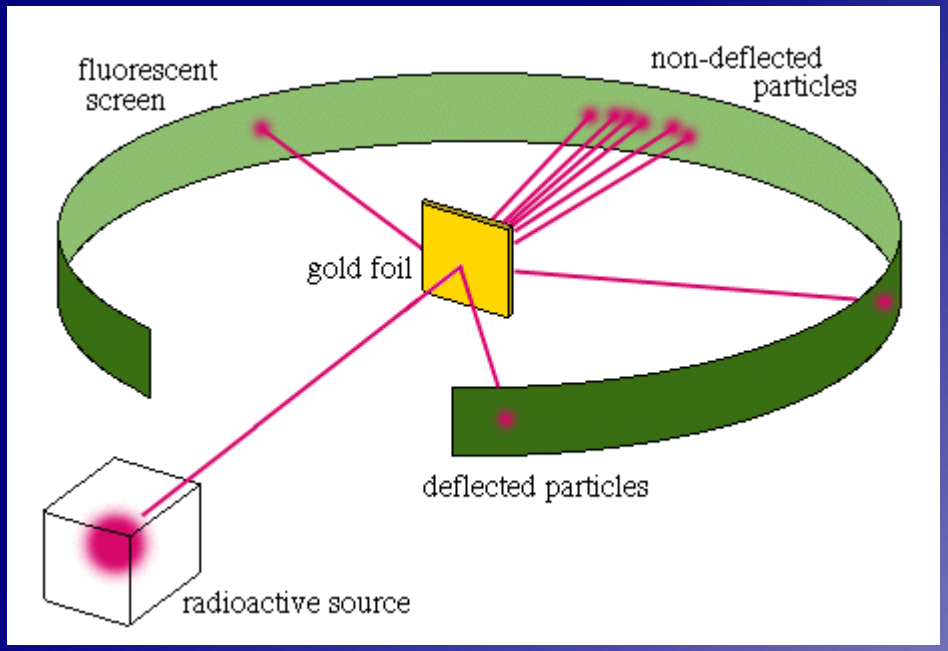
- Atoms have structure!
- Cathode rays are particles!





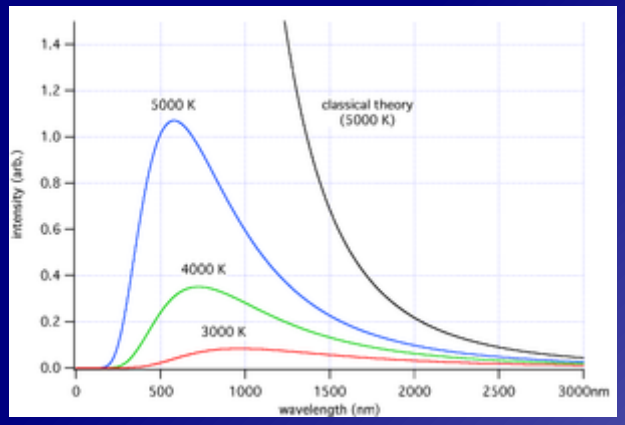
Rutherford (Geiger/Marsden)

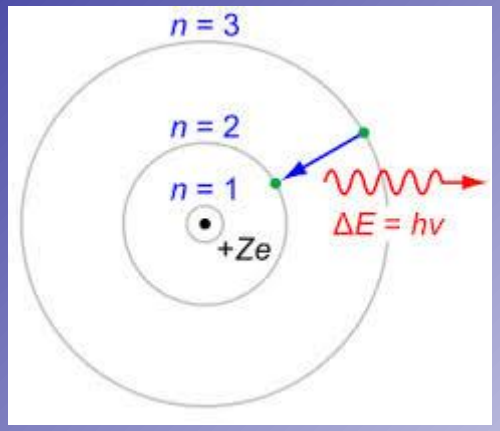
- Nucleus!
- First “Collider” Experiment

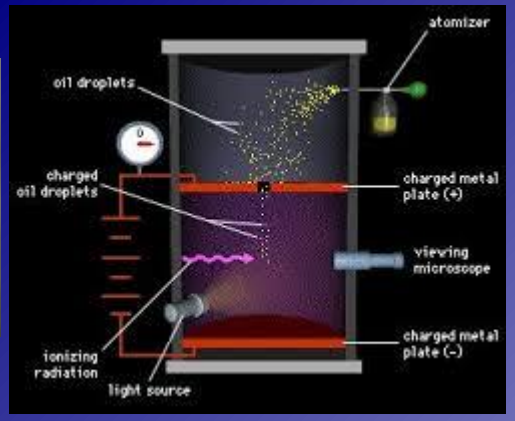


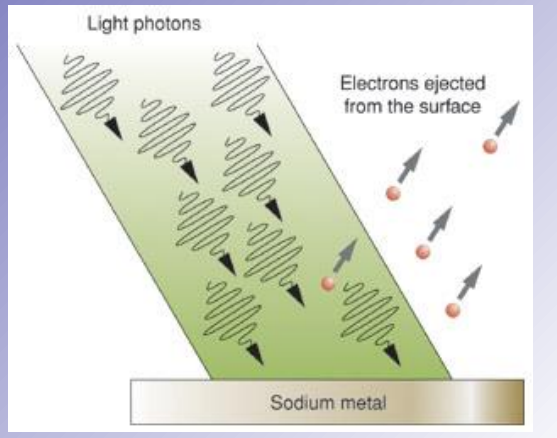
Plank, Millikan, Bohr, Einstein...

- Continuum → Quantum



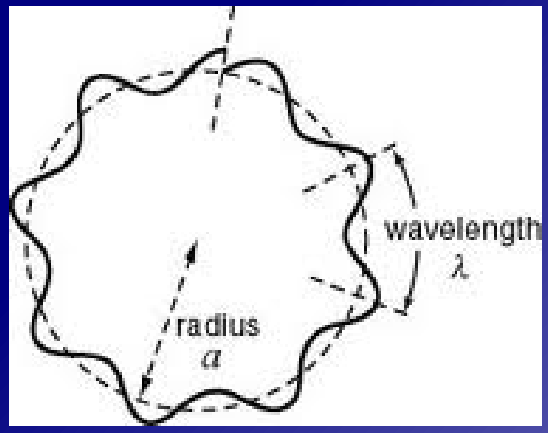




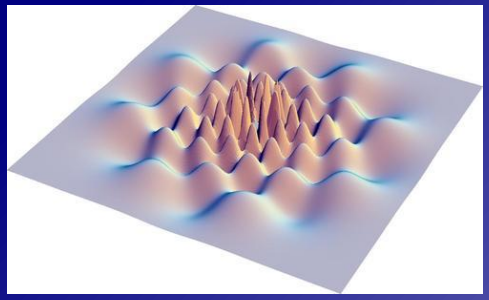


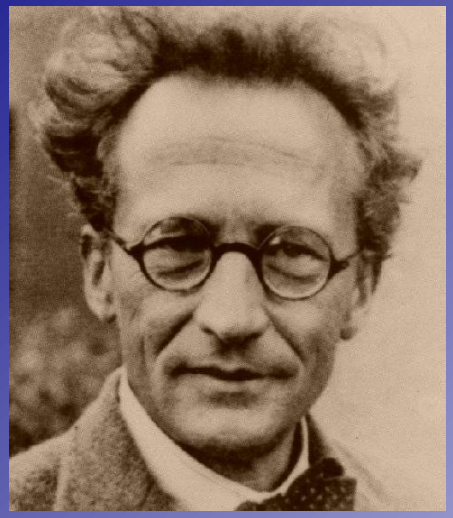
Schrodinger, DeBroglie, Born

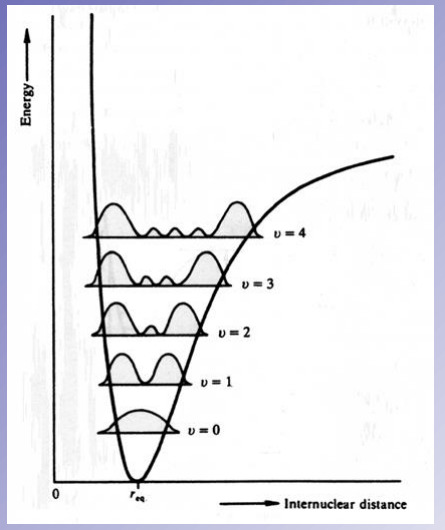
- Wave Theories



$$H(t)\,|\,\psi(t)\rangle = i\hbar\frac{d}{dt}\,|\,\psi(t)\rangle$$







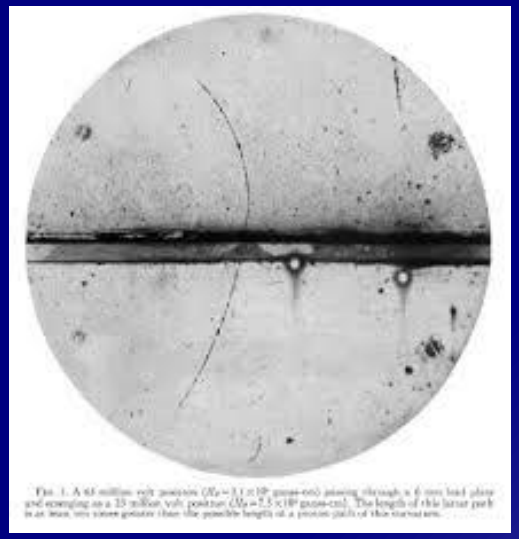
Heisenberg, Born, Jordan

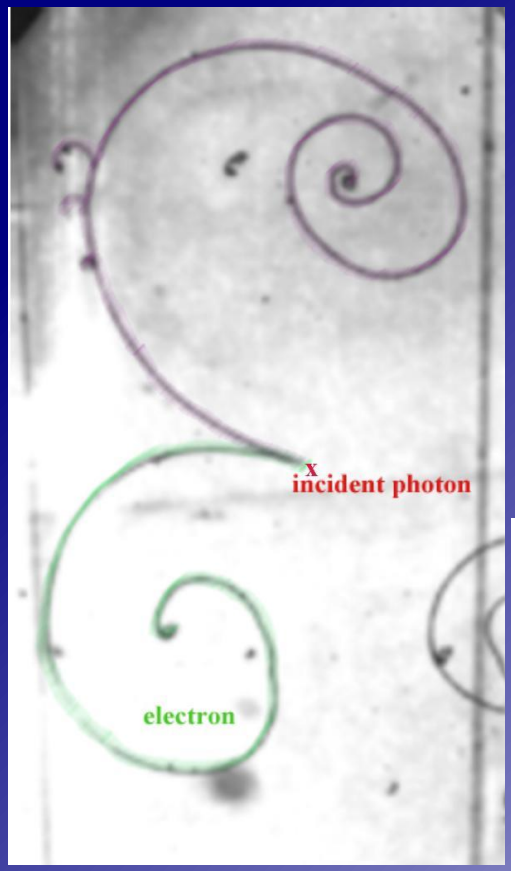
- Quantum (Matrix) Mechanics
- Uncertainty!

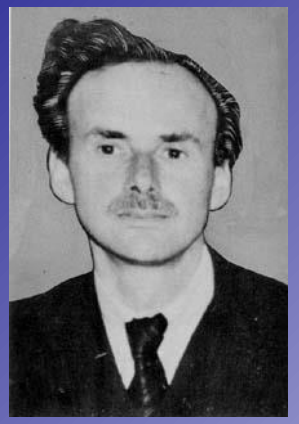
$$S_z \doteq \frac{\hbar}{2}\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix} \begin{matrix} ++ \\ +- \\ -+ \\ -- \end{matrix}$$

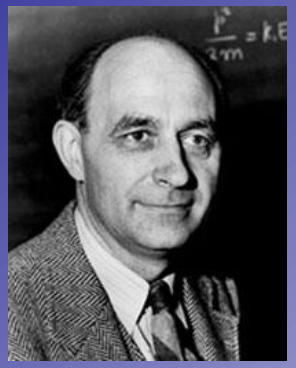
Pauli, Dirac, Fermi, Anderson...

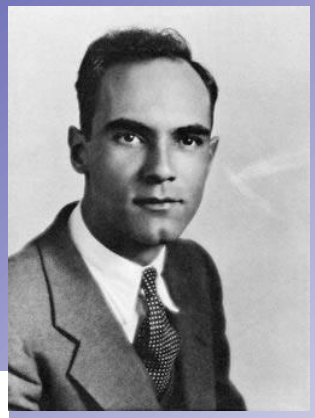
- New particles!

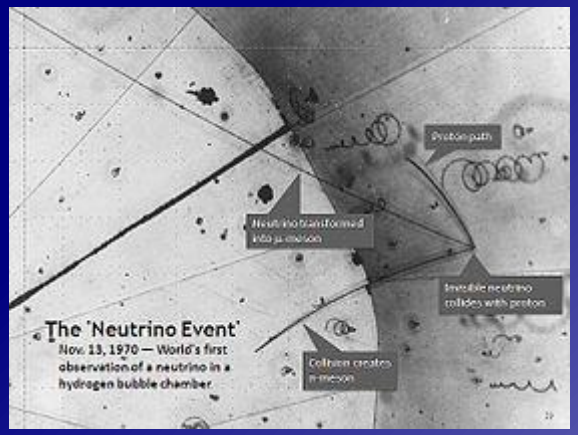


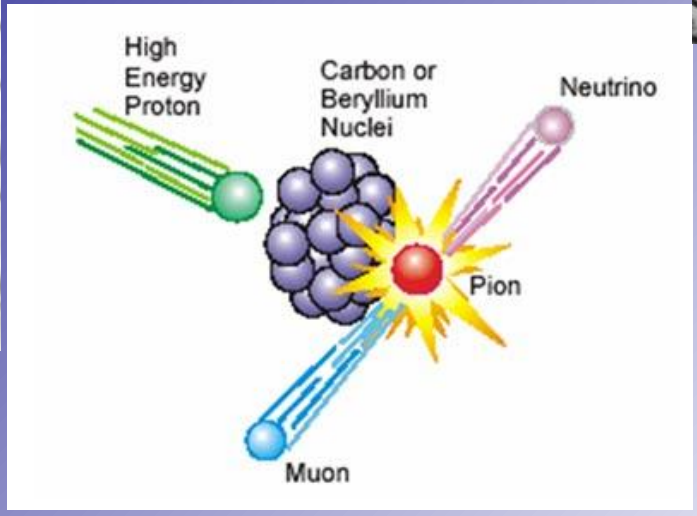






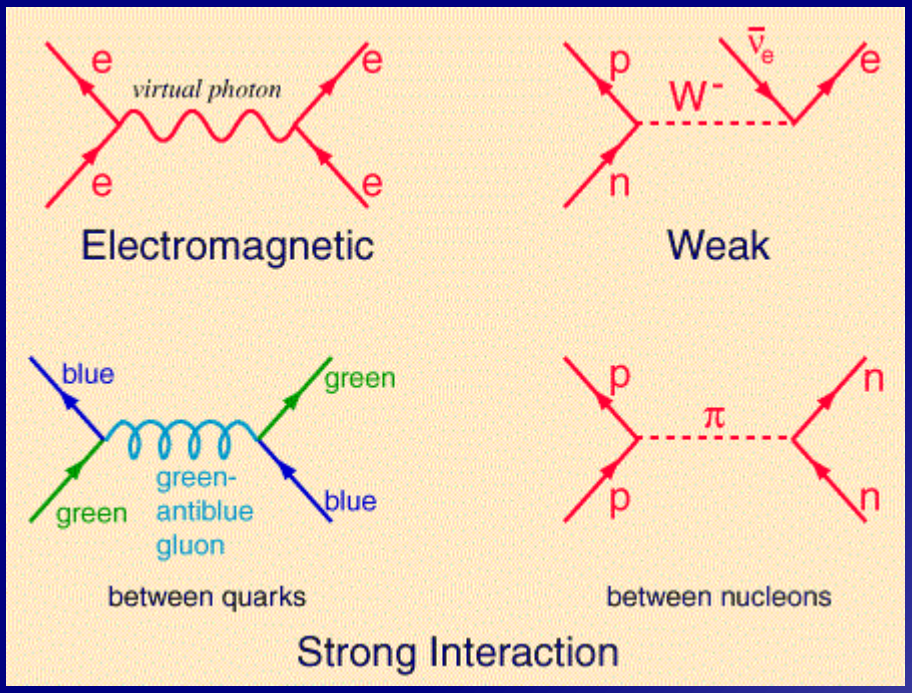


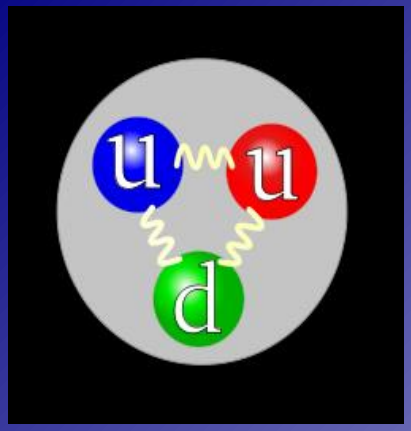




Zoo of Particles; People

QED, QFT, QCD...


e
e
virtual photon
e
e
Electromagnetic
p
n
W-
$\bar{\nu}_e$
e
Weak
blue
green
green
green-
antiblue
gluon
blue
between quarks
p
p
π
n
n
between nucleons
Strong Interaction


u
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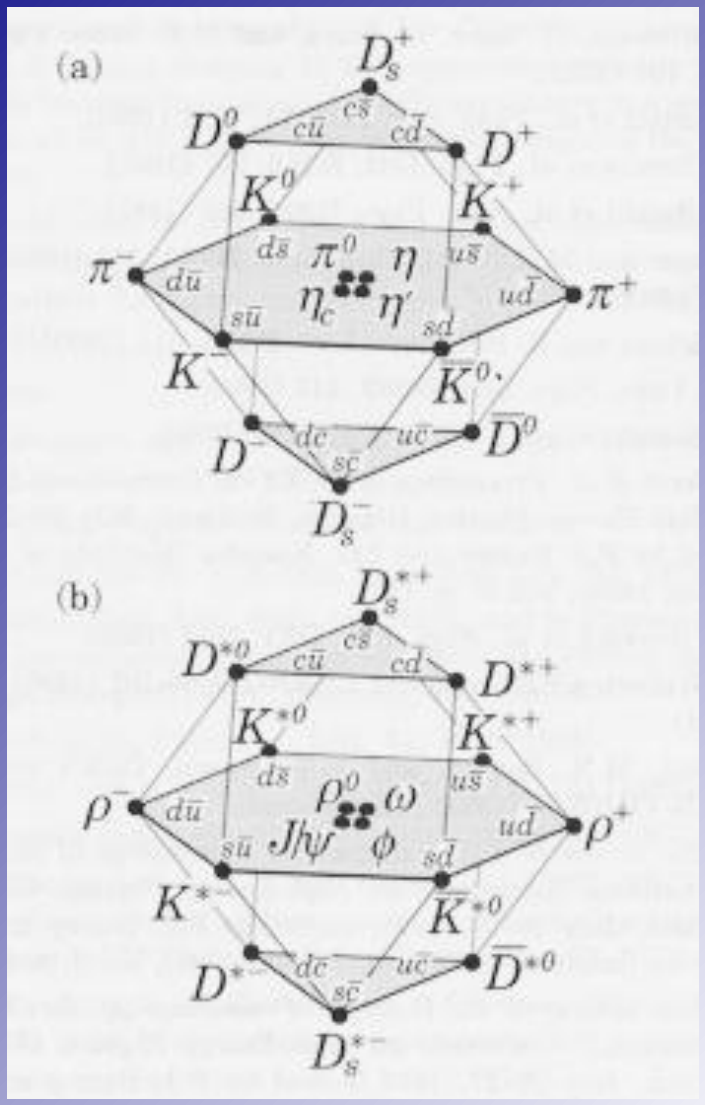
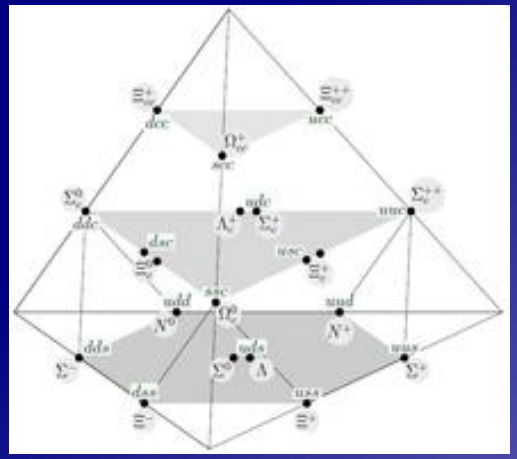
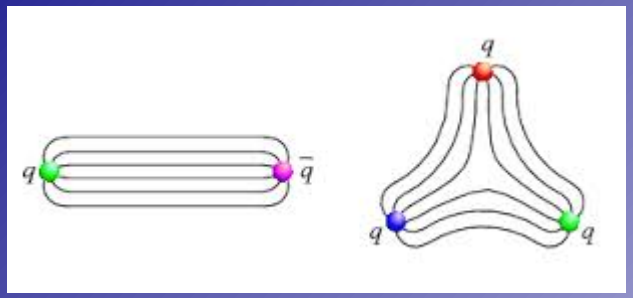
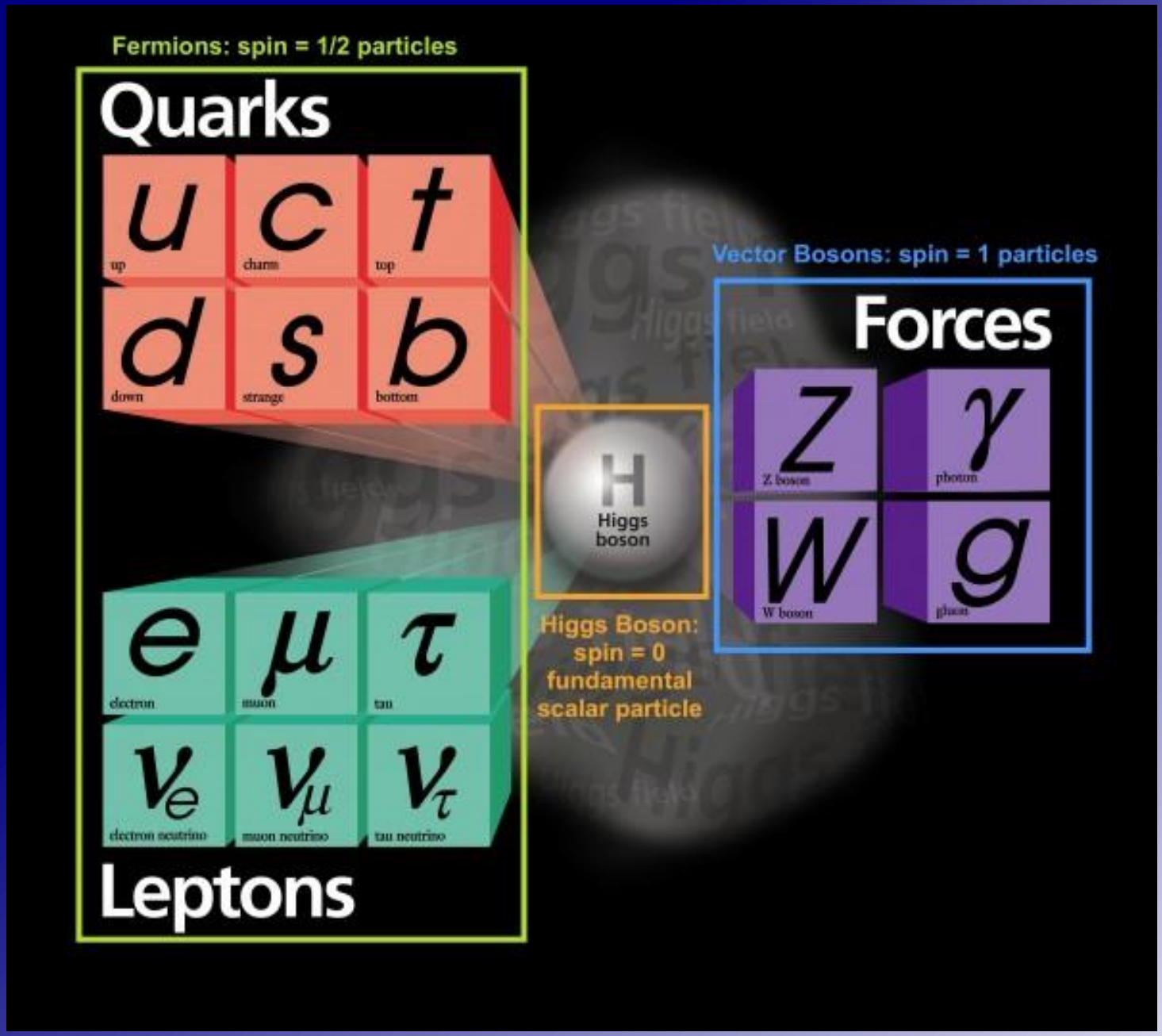
d

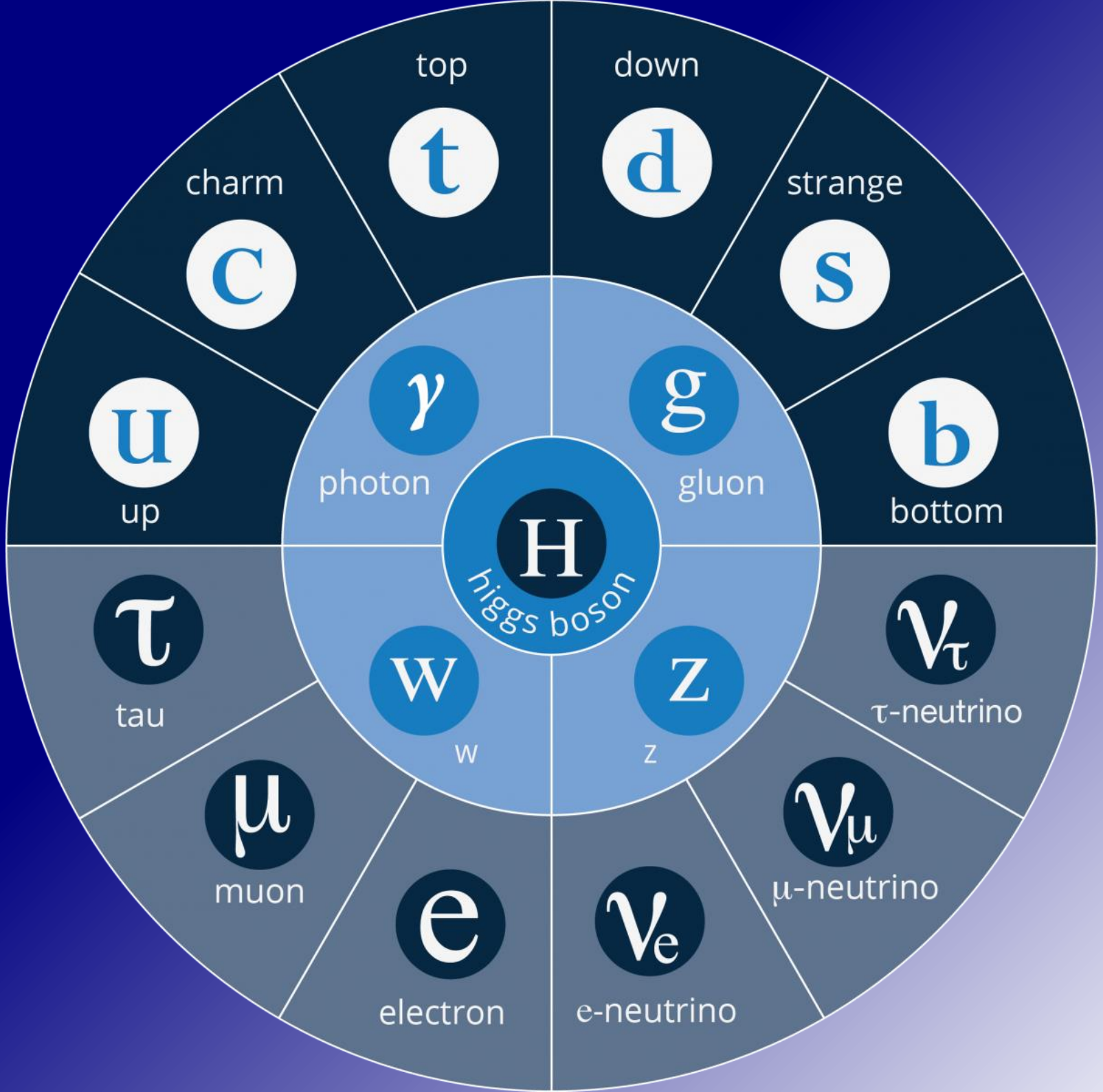

(a)
(b)




q
$\bar{q}$
q
q
q

Coherence

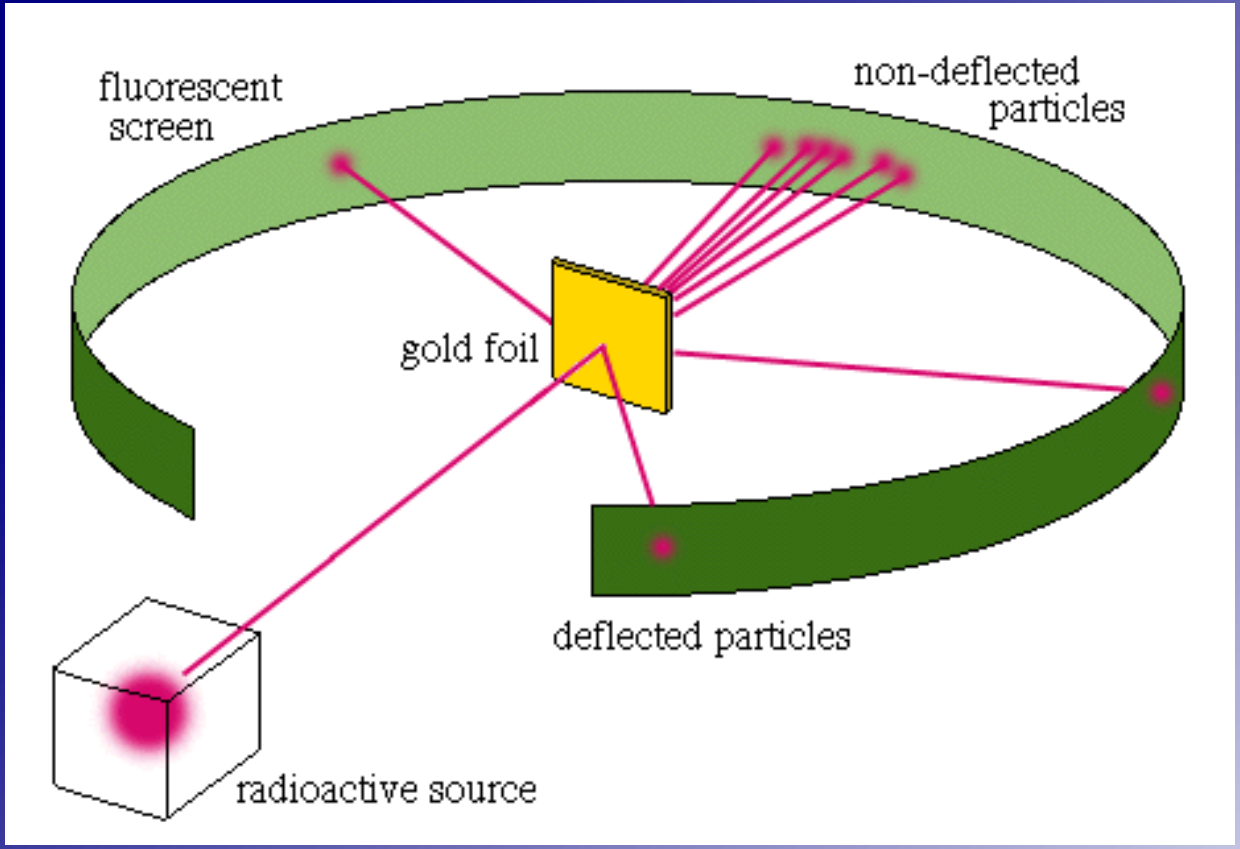

Fermions: spin = 1/2 particles
Quarks
u
up
c
charm
t
top
d
down
s
strange
b
bottom
e
electron
μ
muon
τ
tau
νe
electron neutrino
νμ
muon neutrino
ντ
tau neutrino
Leptons
H
Higgs boson
Higgs Boson: spin = 0 fundamental scalar particle
Vector Bosons: spin = 1 particles
Forces
Z
Z boson
γ
photon
W
W boson
g
gluon


top
t
down
d
charm
c
strange
s
u
up
γ
photon
g
gluon
b
bottom
H
higgs boson
τ
tau
W
w
Z
z
ντ
τ-neutrino
μ
muon
νμ
μ-neutrino
e
electron
νe
e-neutrino

Detectors

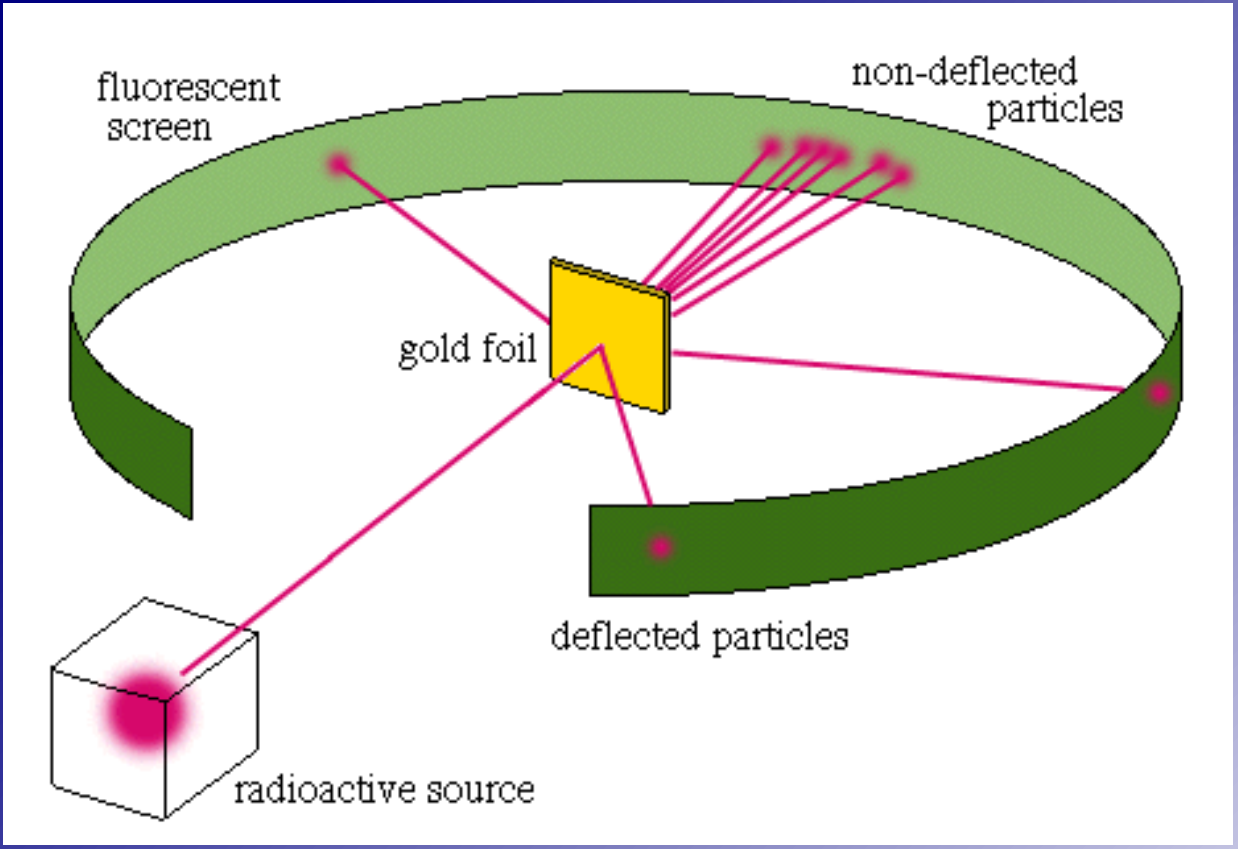
Recall Rutherford

"First particle collider experiment"

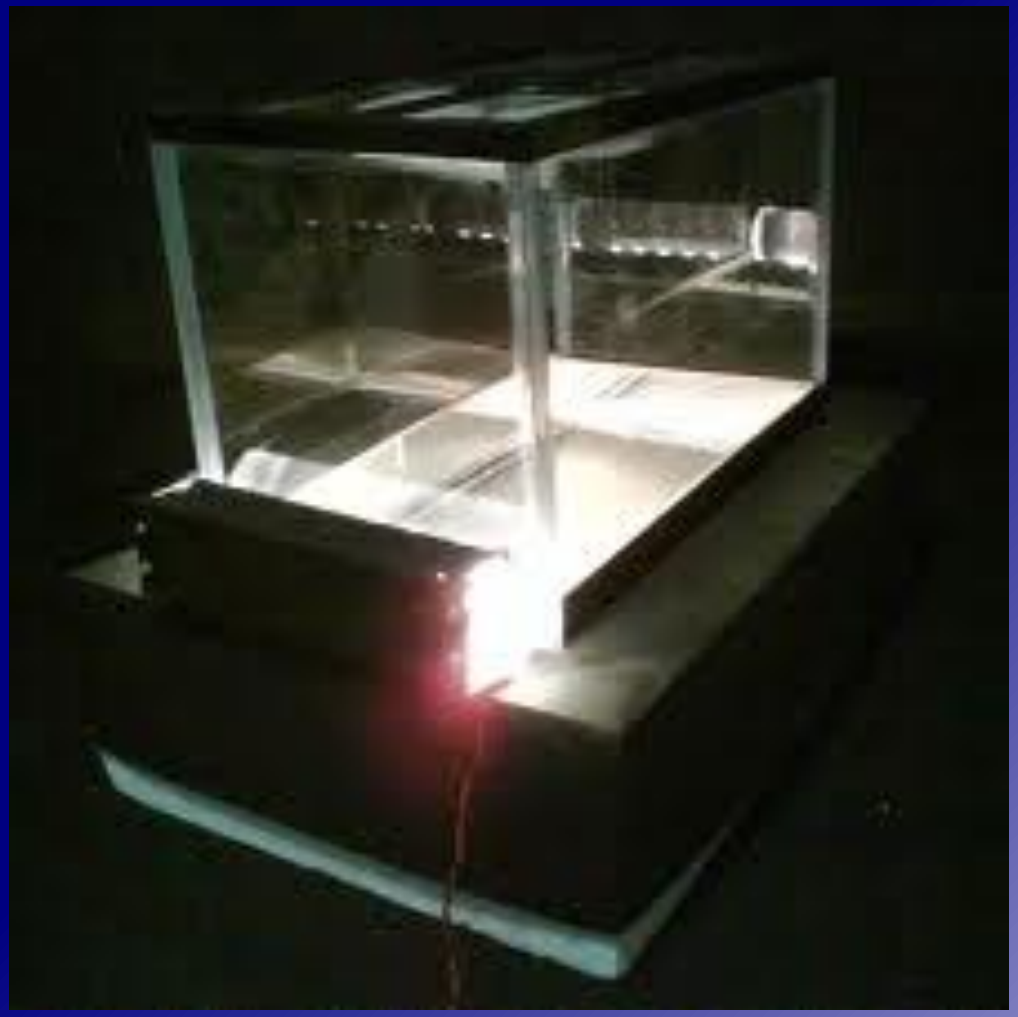


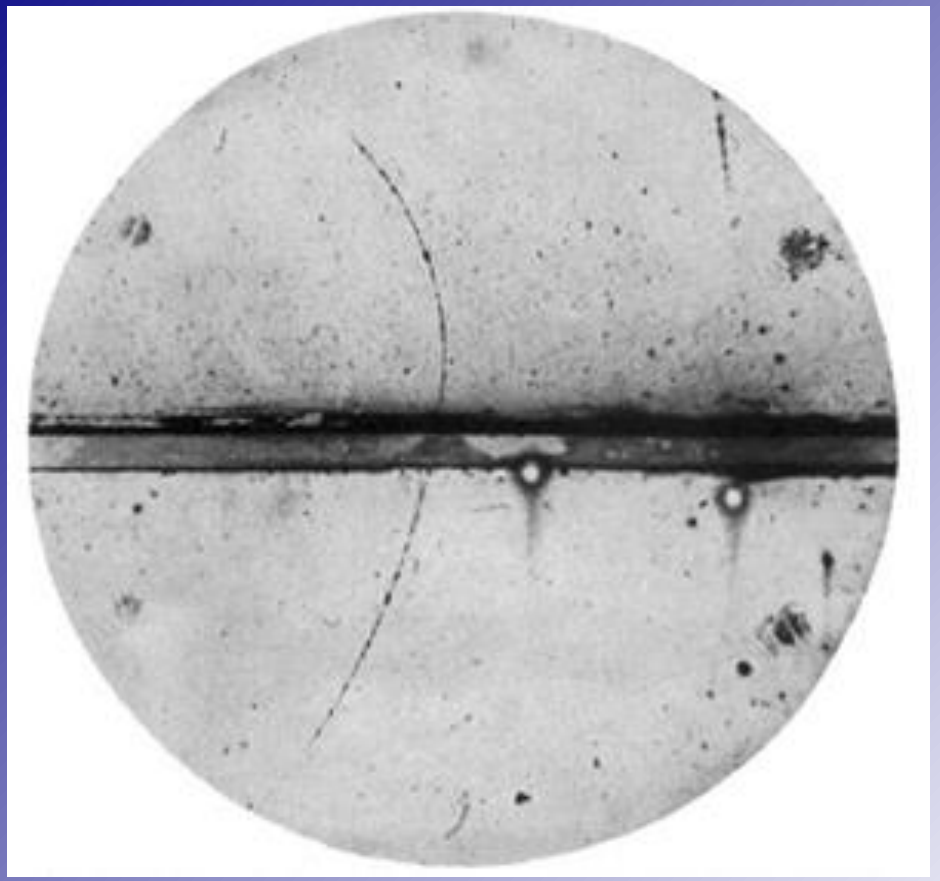
Recall Rutherford

Components: Beam, Target, Detector

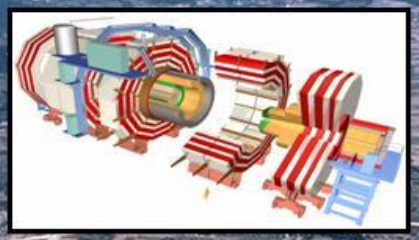


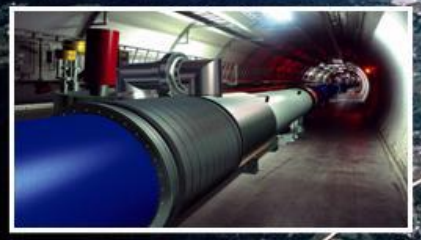
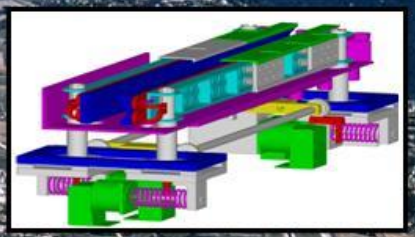
Cloud Chamber

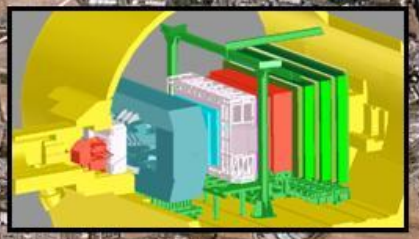
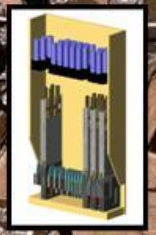




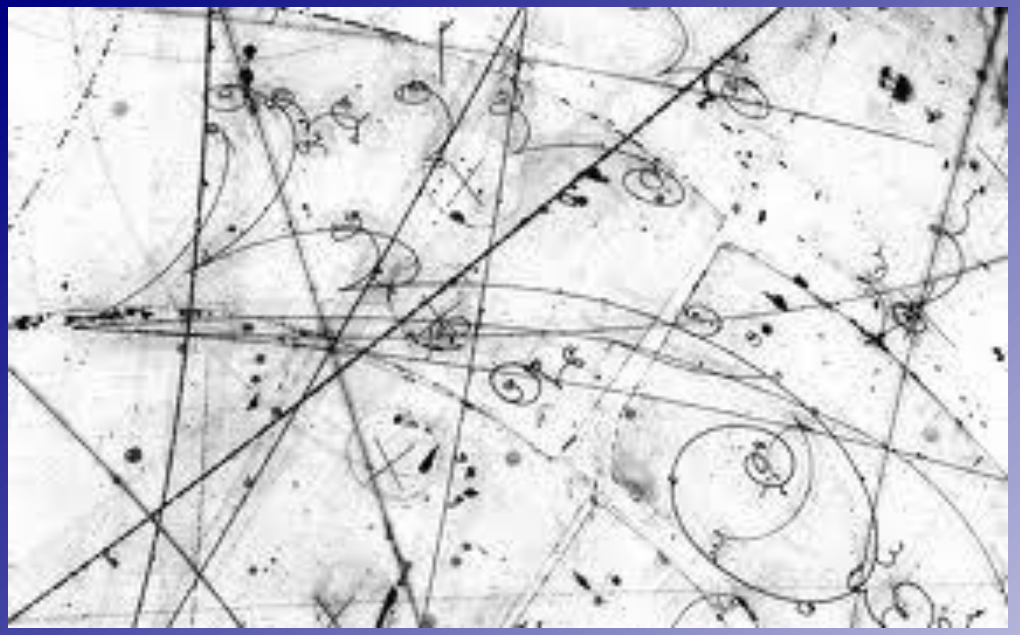
How do you get circles?

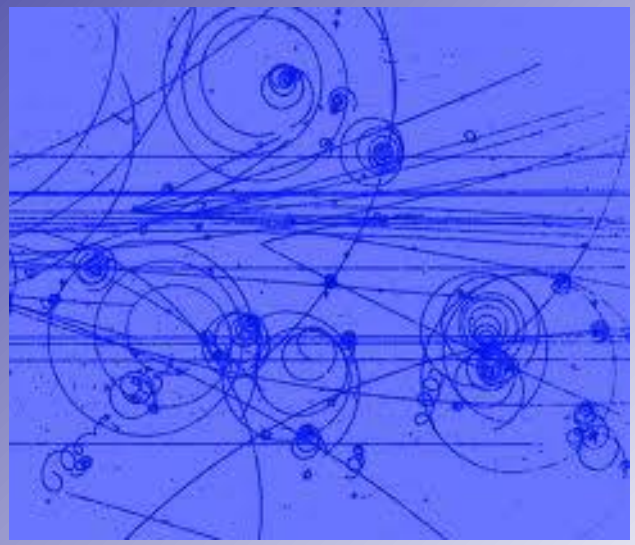


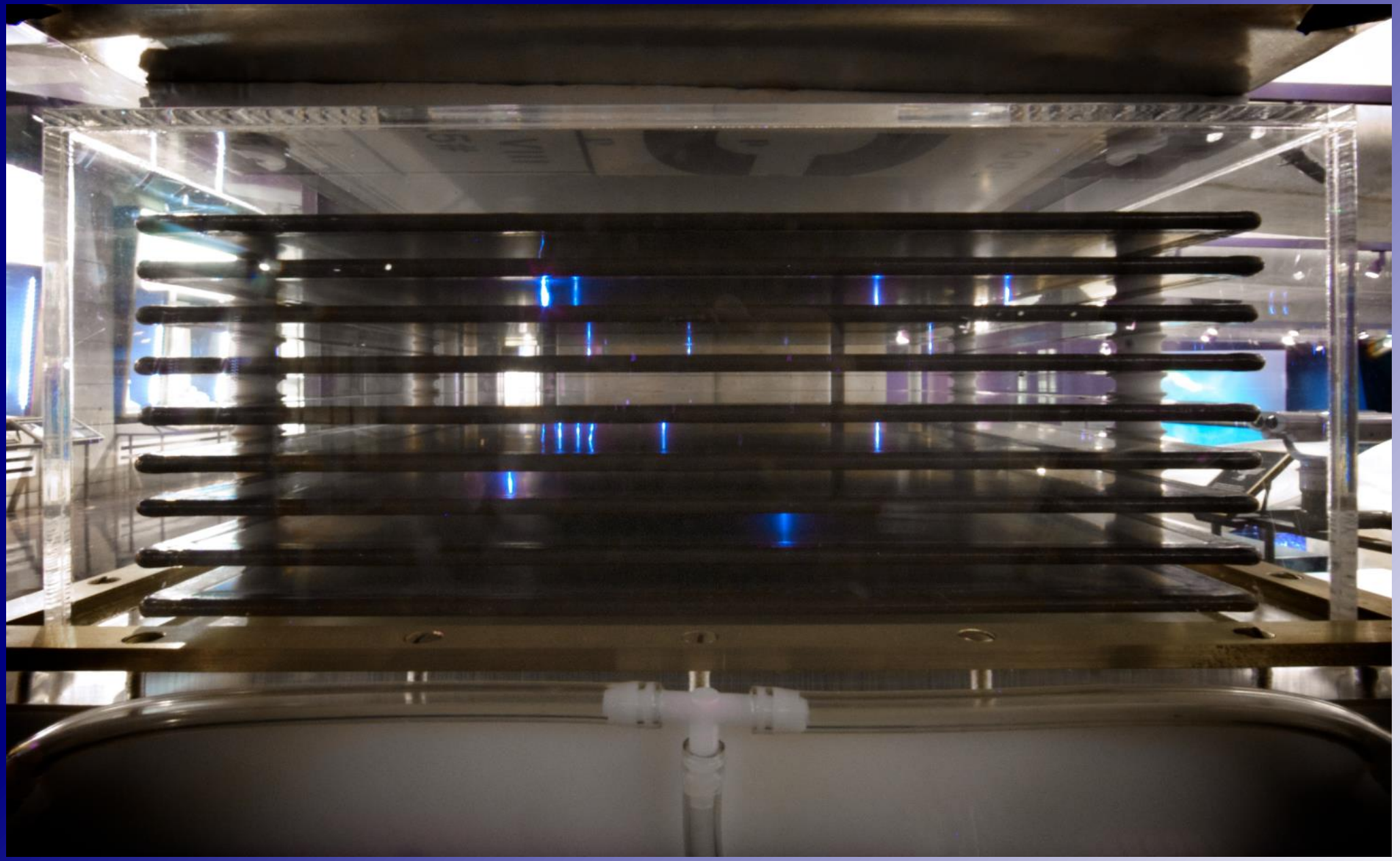



Bubble Chamber





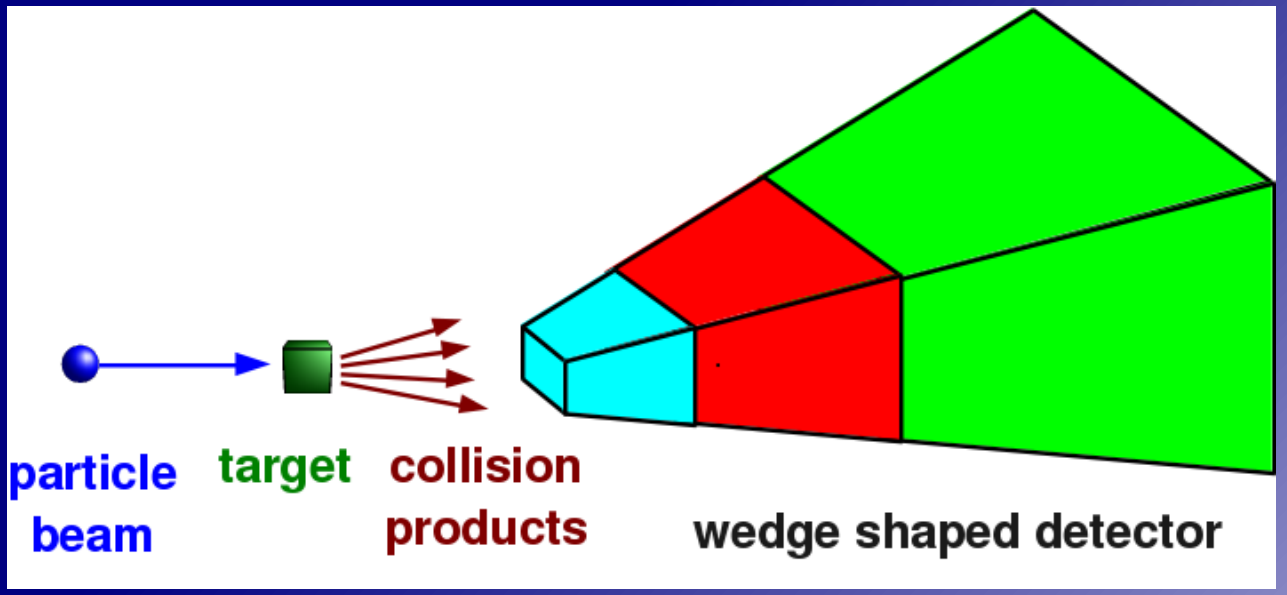
Spark Chamber

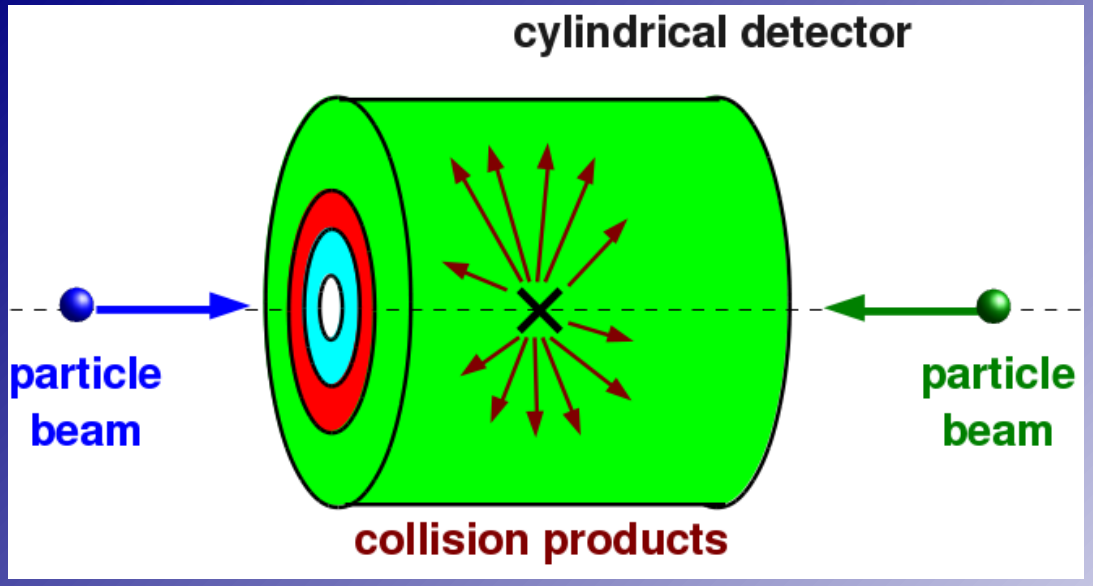


PREINJECTEU
LIN 2
ATT ION
HAUTE ION
HIGH GER
100
H2
PREINJECTEUR
LINAC 2
HAUTE
HIGH
TENSION
DANGE
A PROTON SOURCE

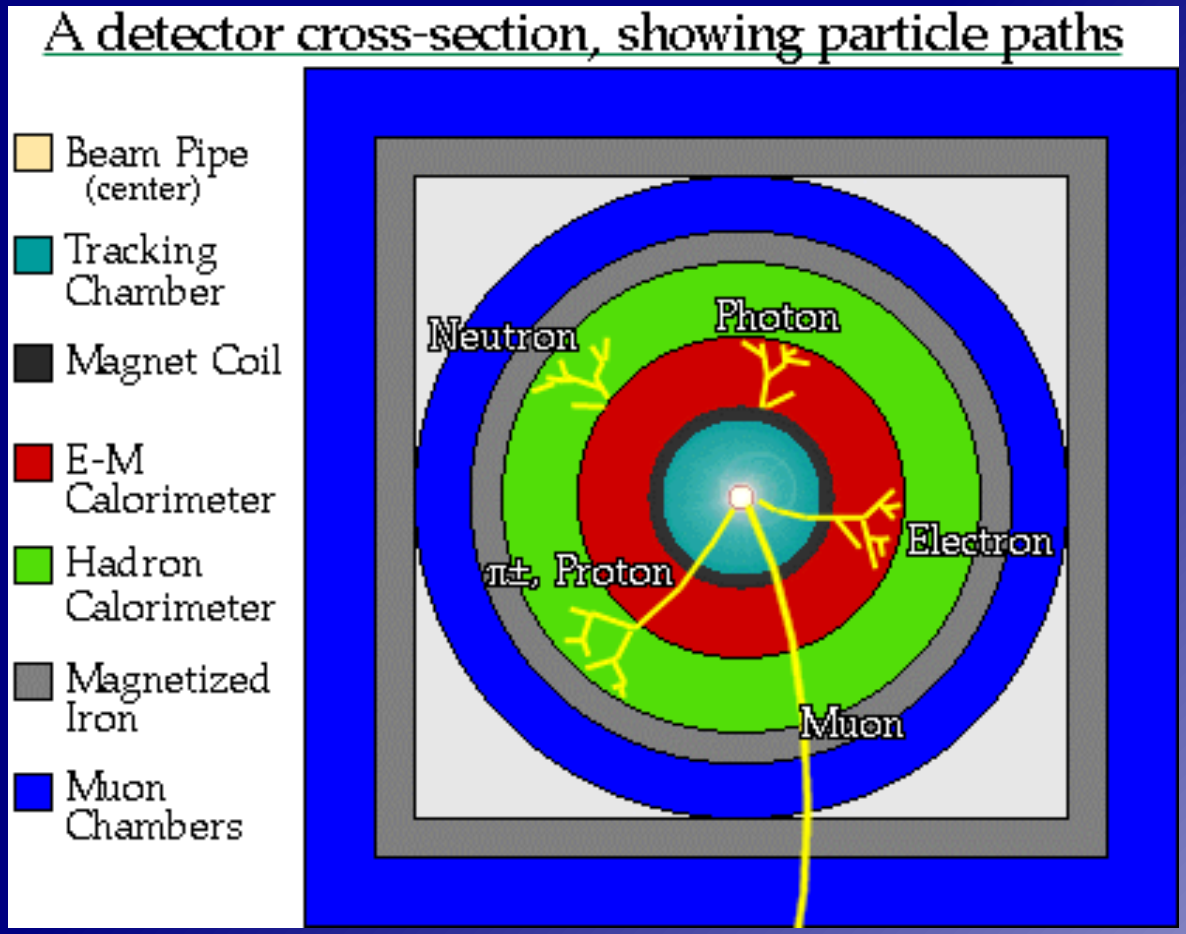
1000 KG
1000 KG
ENTREE INTERDITE
ENTRANCE FORBIDDEN
21
RADIATION
ZONE CONTRÔLÉE
CONTROLLED AREA
LIMITED STAY
SÉJOUR LIMITÉ

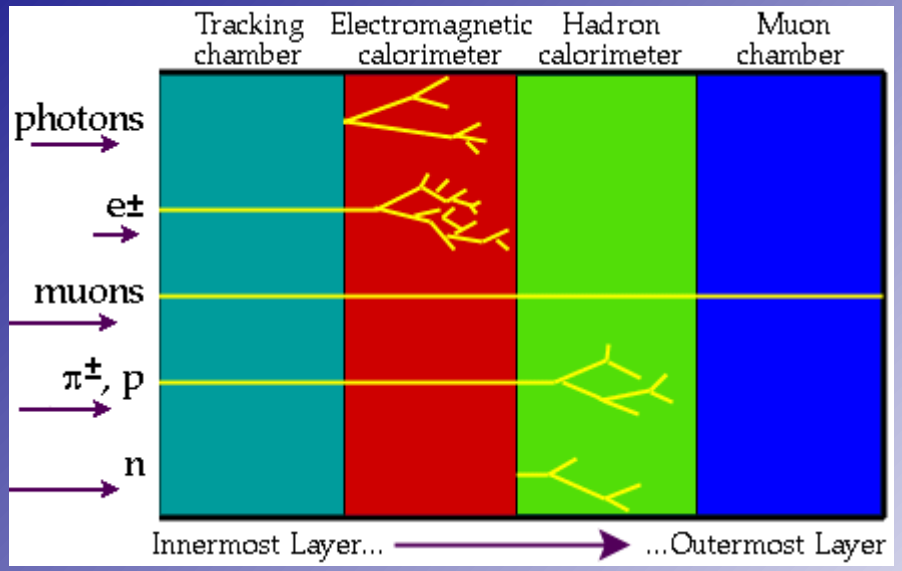
Experiment Types



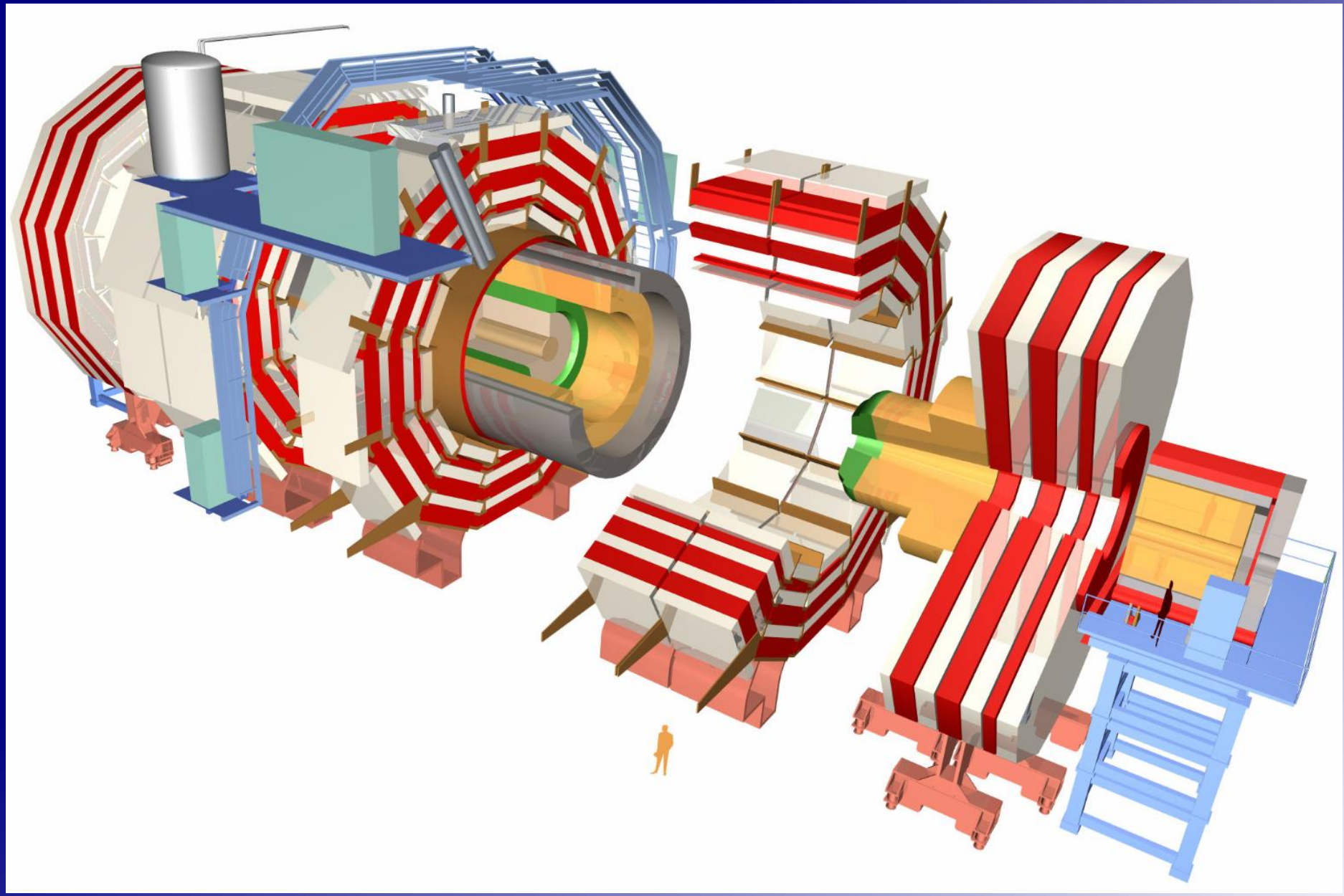


Detector Pieces

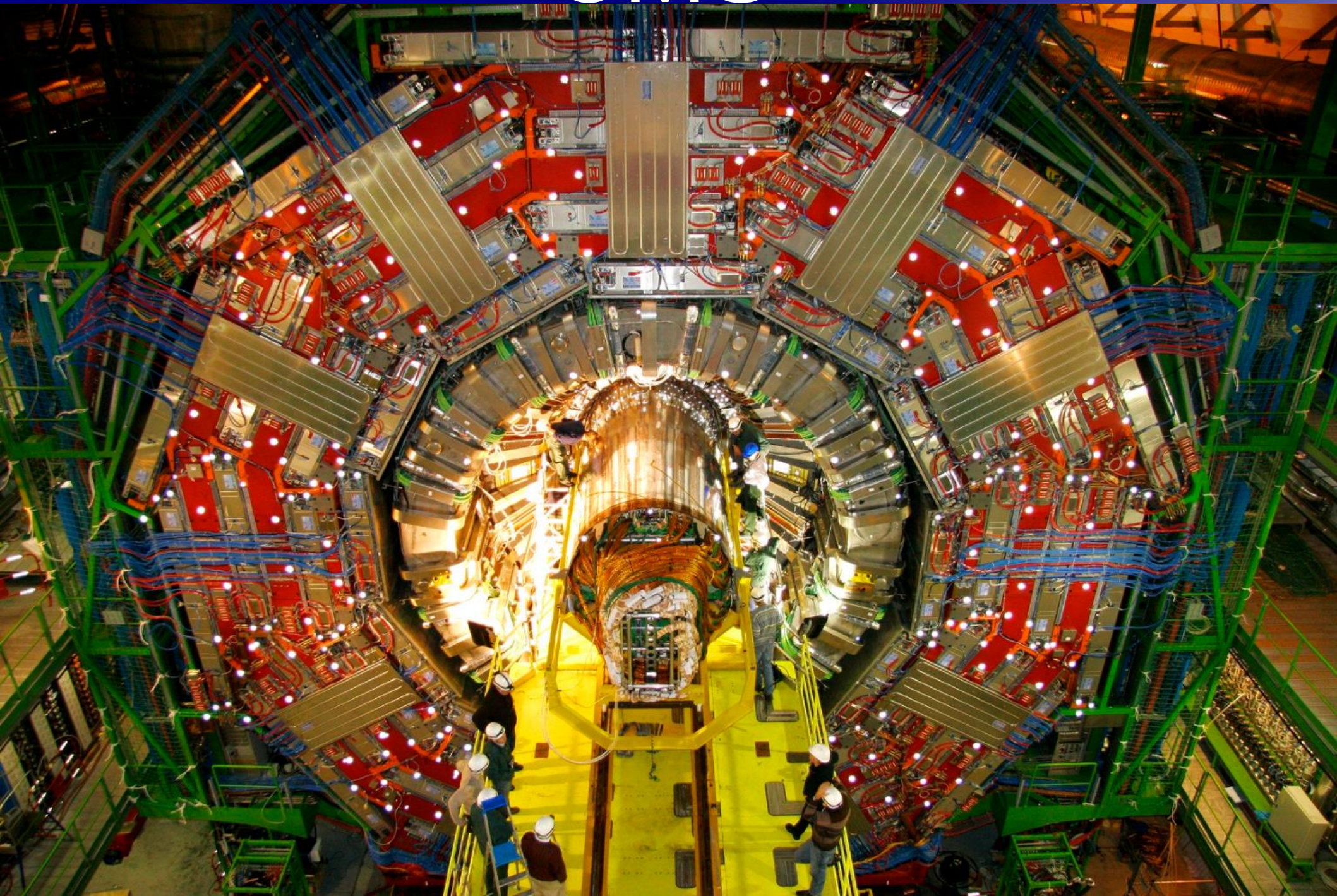




CMS

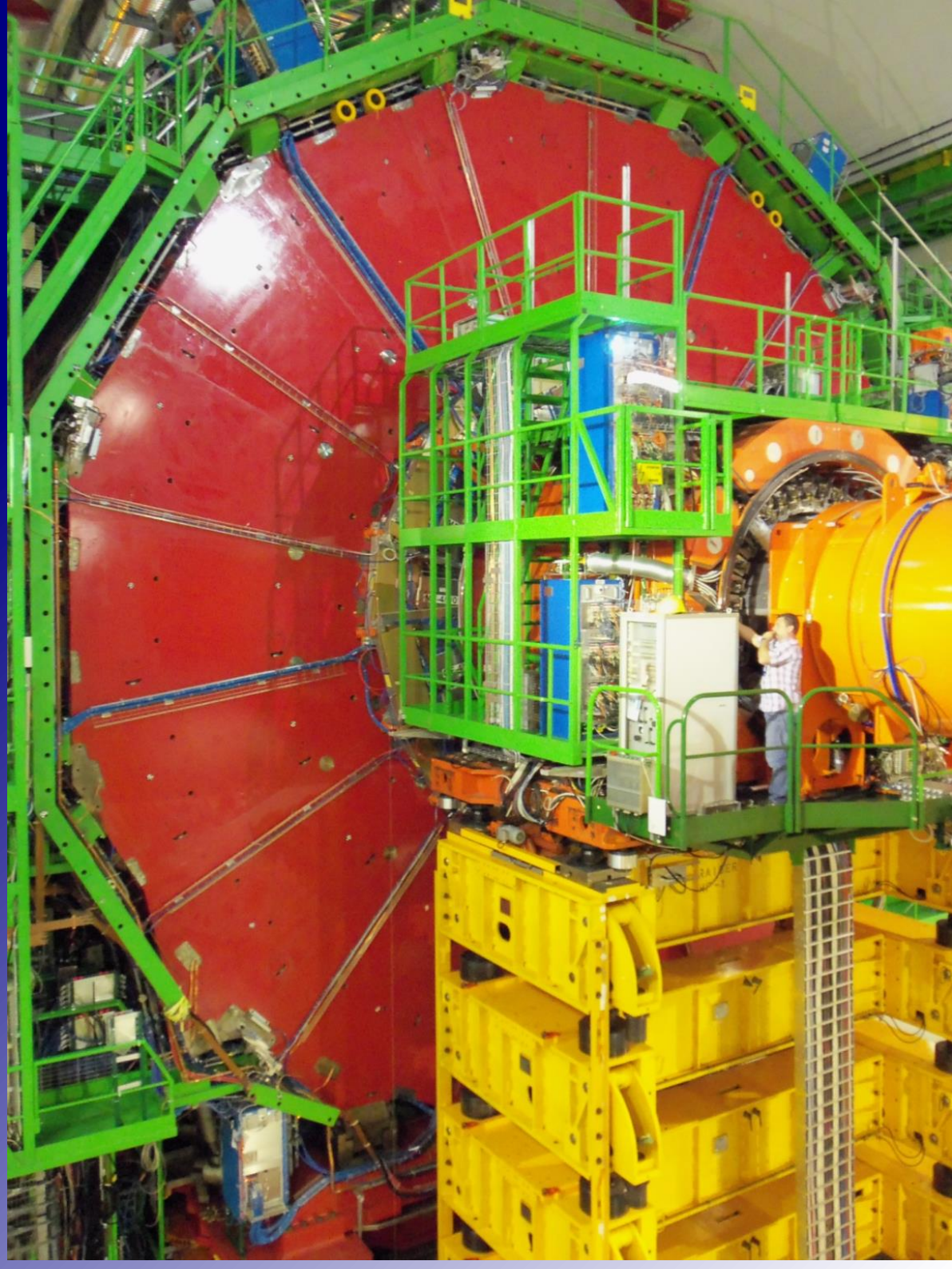


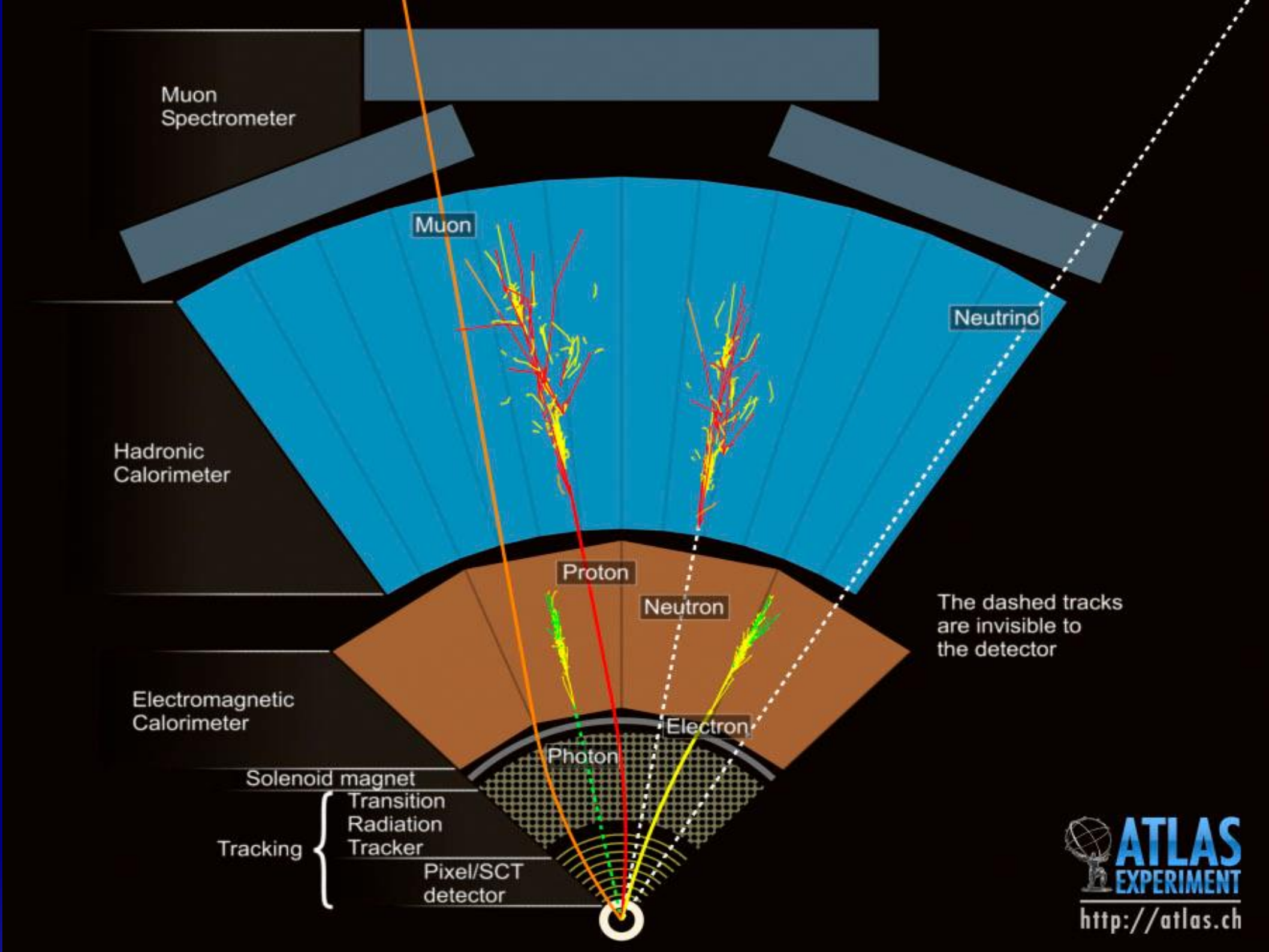
CMS

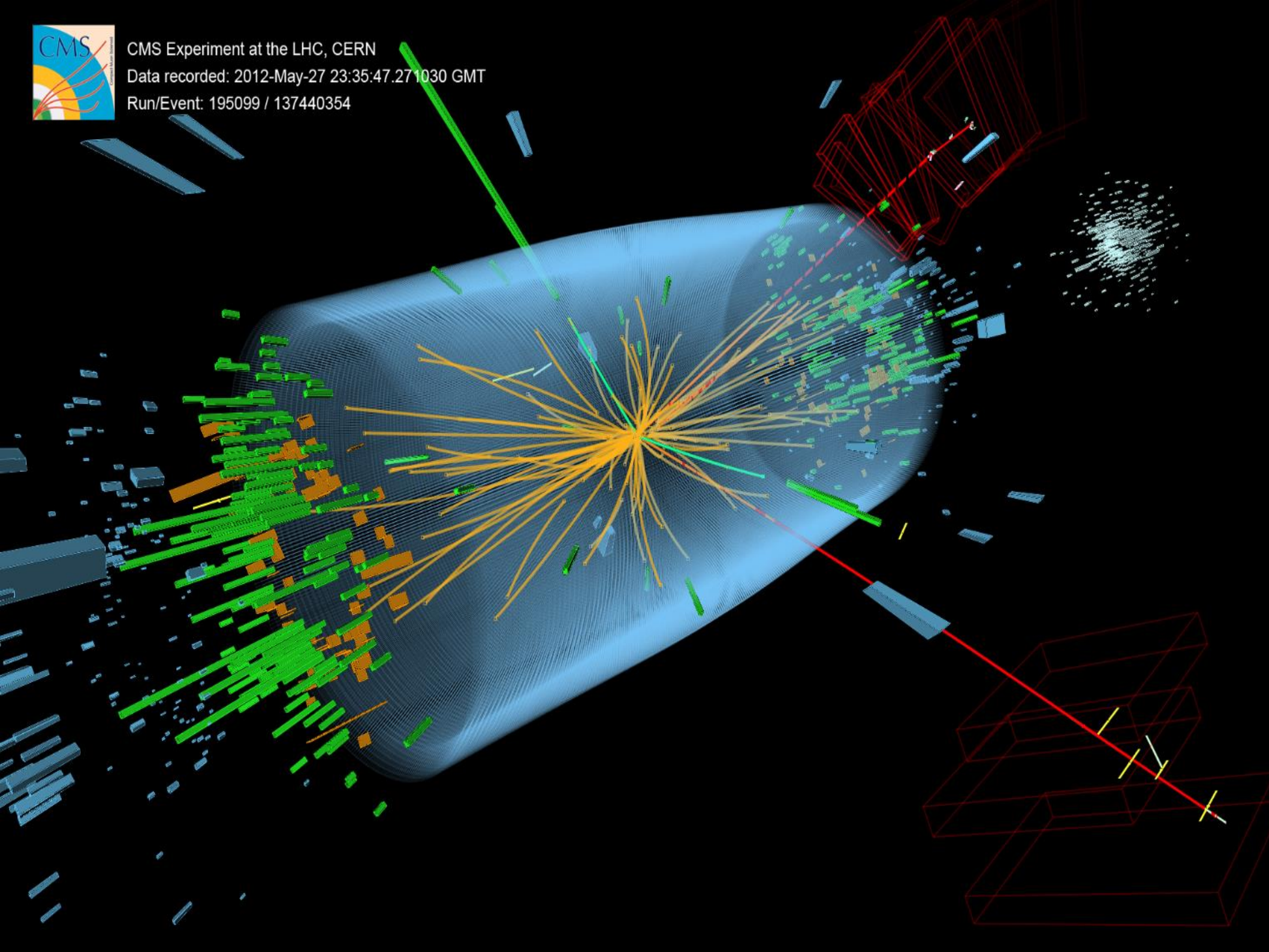


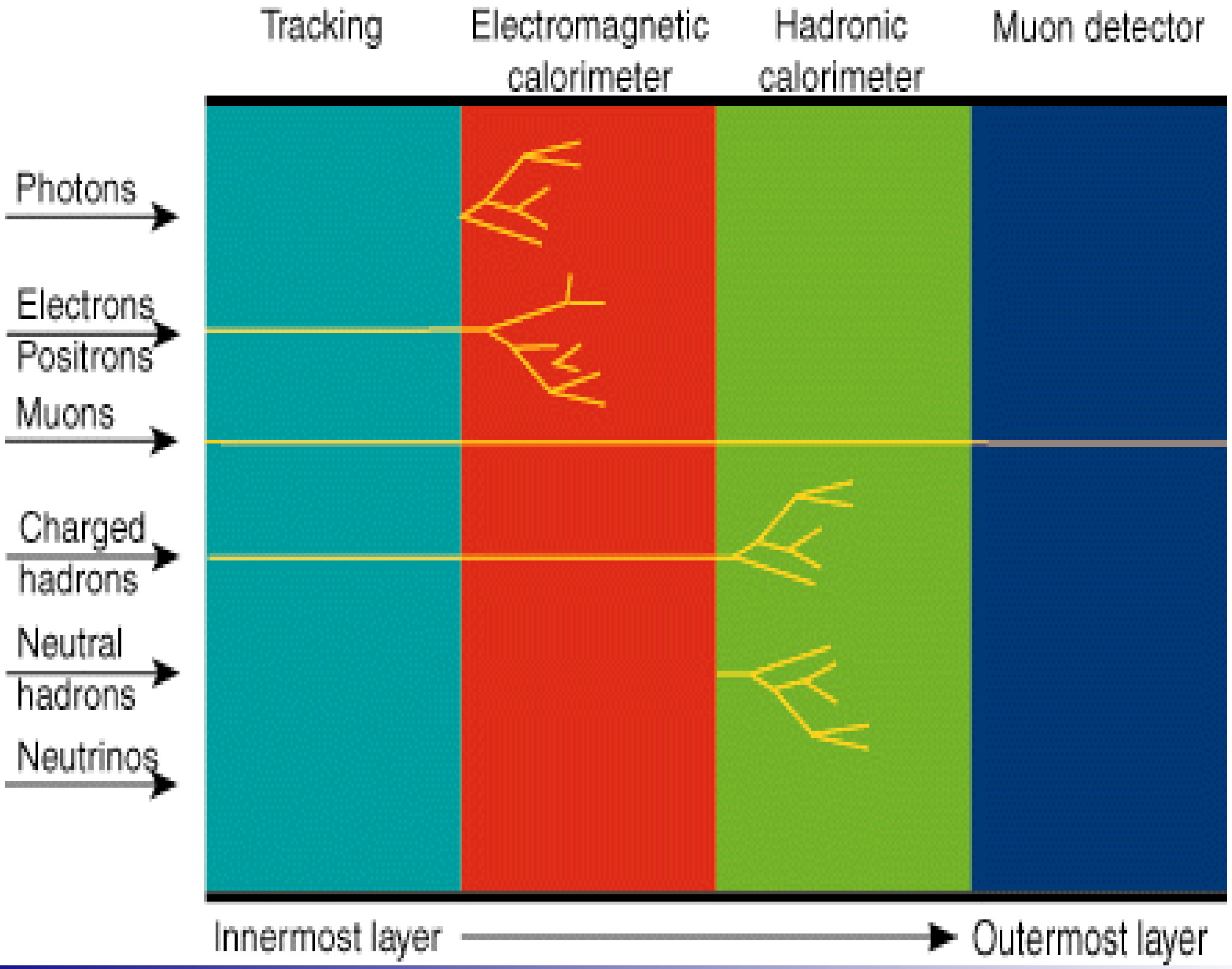
CMS

- My view of the CMS detector in July 2011
- Beam pipe is orange tube at far right



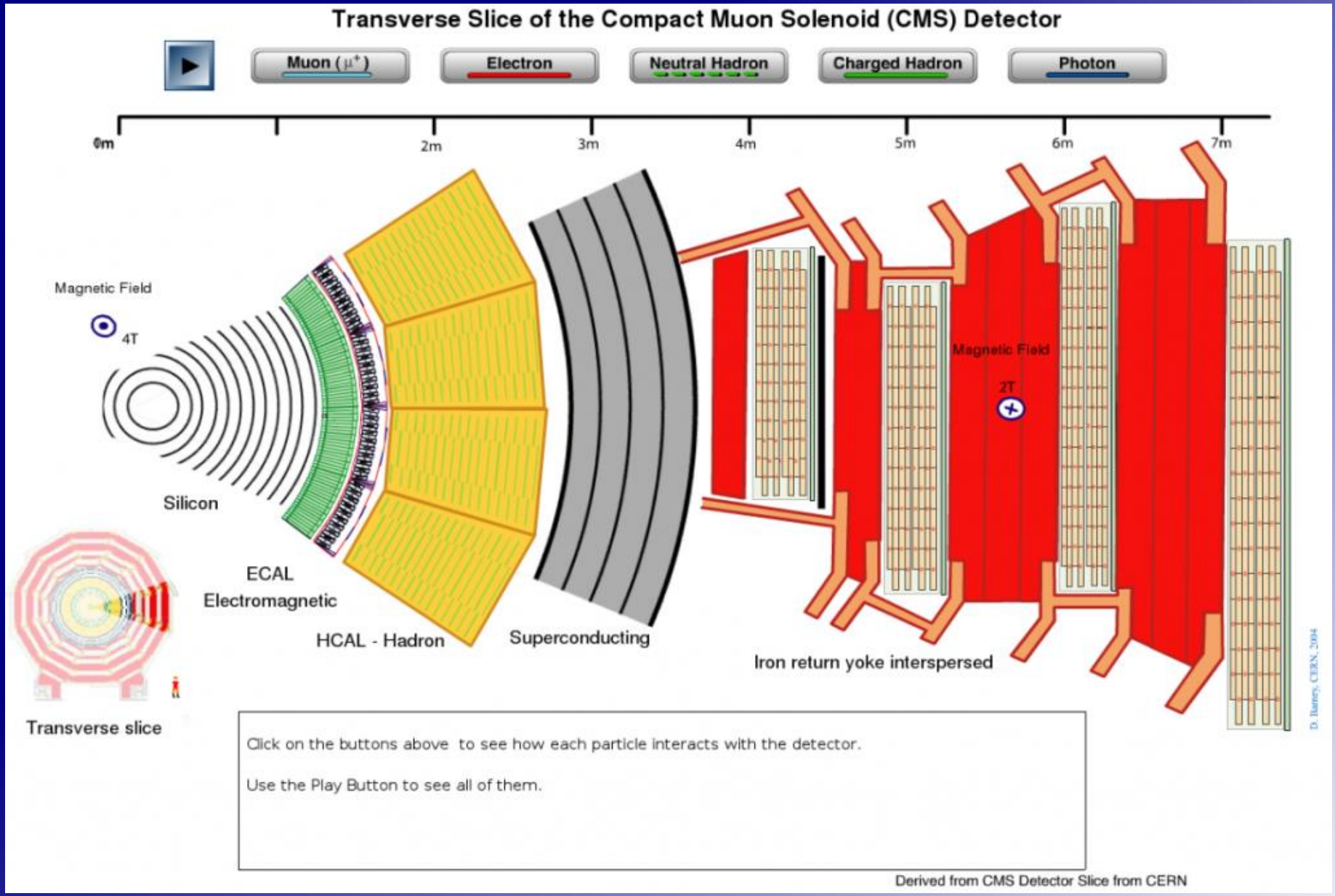

Muon
Spectrometer
Muon
Neutrino
Hadronic
Calorimeter
Proton
Neutron
The dashed tracks
are invisible to
the detector
Electromagnetic
Calorimeter
Electron
Photon
Solenoid magnet
Tracking
Transition
Radiation
Tracker
Pixel/SCT
detector
ATLAS
EXPERIMENT
http://atlas.ch


CMS Experiment at the LHC, CERN
Data recorded: 2012-May-27 23:35:47.271030 GMT
Run/Event: 195099 / 137440354

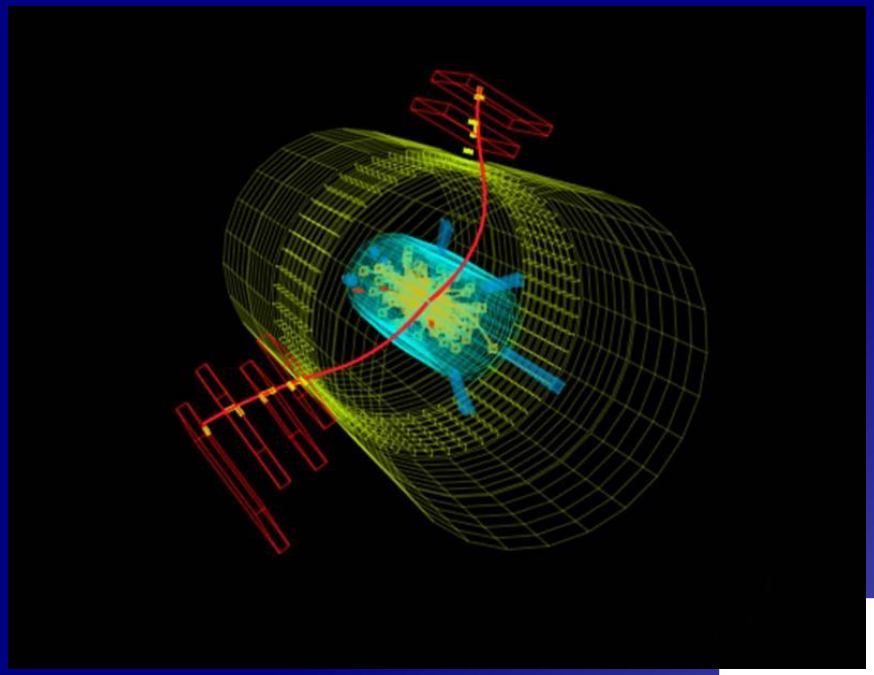

Tracking
Electromagnetic calorimeter
Hadronic calorimeter
Muon detector
Photons
Electrons
Positrons
Muons
Charged hadrons
Neutral hadrons
Neutrinos
Innermost layer
Outermost layer

CMS Interactive

B



Event Display

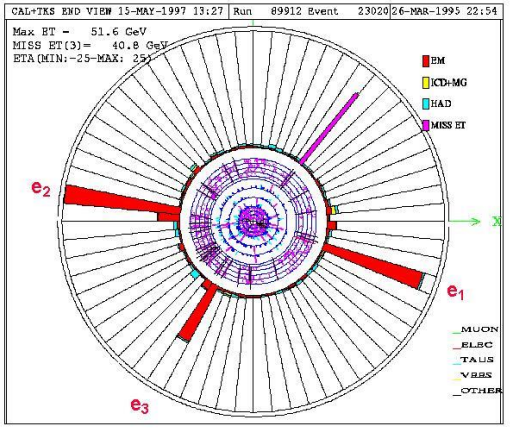


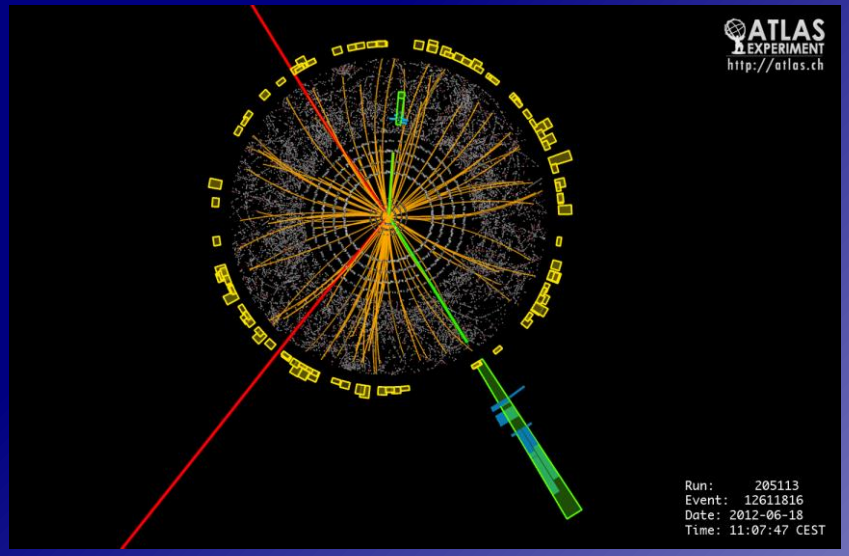
The Candidate WZ Event

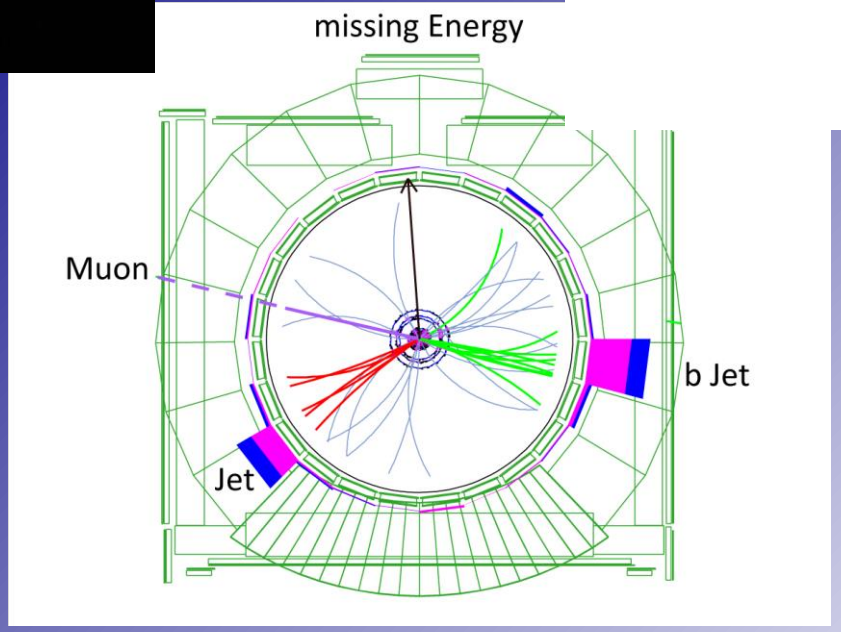
$W \rightarrow e\nu$

$Z \rightarrow e^+e^-$

$M_T(e_2, \nu)$=74.7 GeV/c²
$M(e_1, e_3)$=93.6 GeV/c²

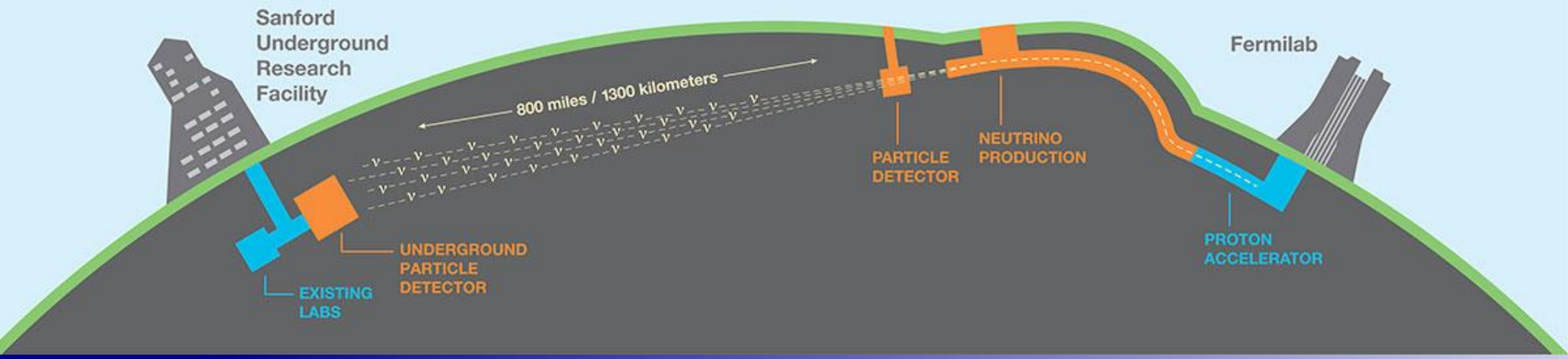




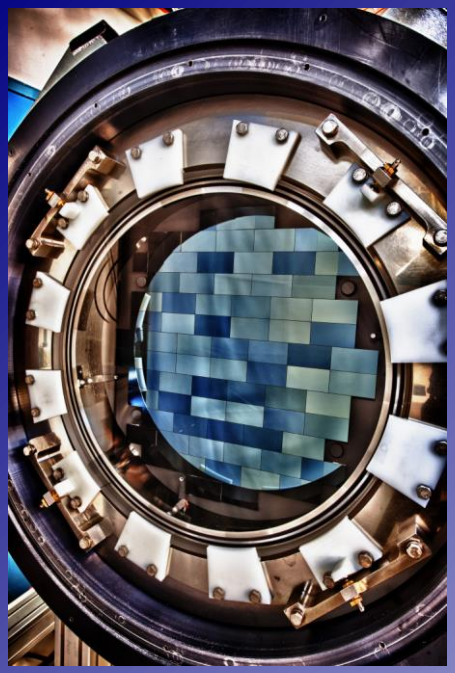


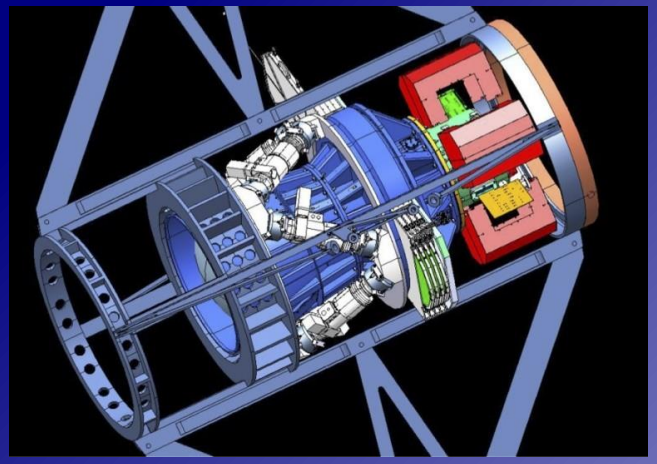
New on the Prairie

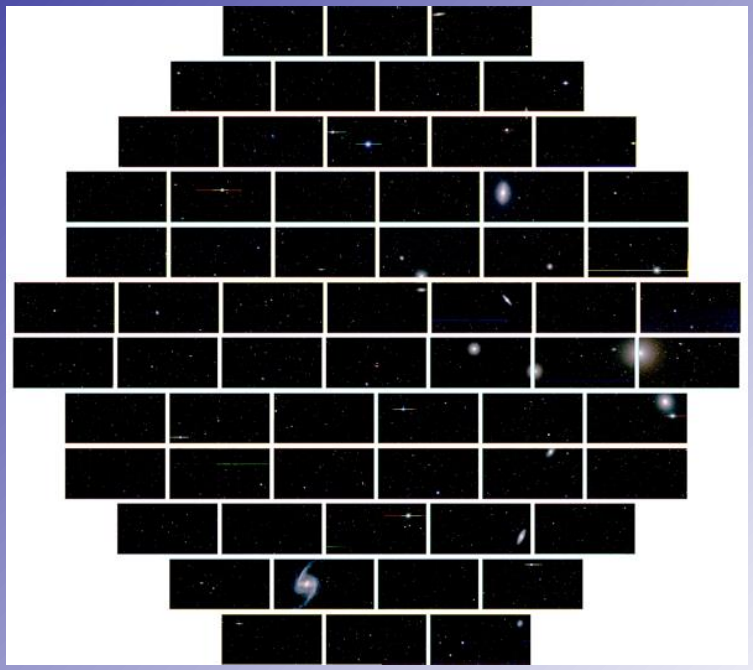
LBNF / DUNE


Sanford
Underground
Research
Facility
800 miles / 1300 kilometers
Fermilab
PARTICLE
DETECTOR
NEUTRINO
PRODUCTION
PROTON
ACCELERATOR
UNDERGROUND
PARTICLE
DETECTOR
EXISTING
LABS

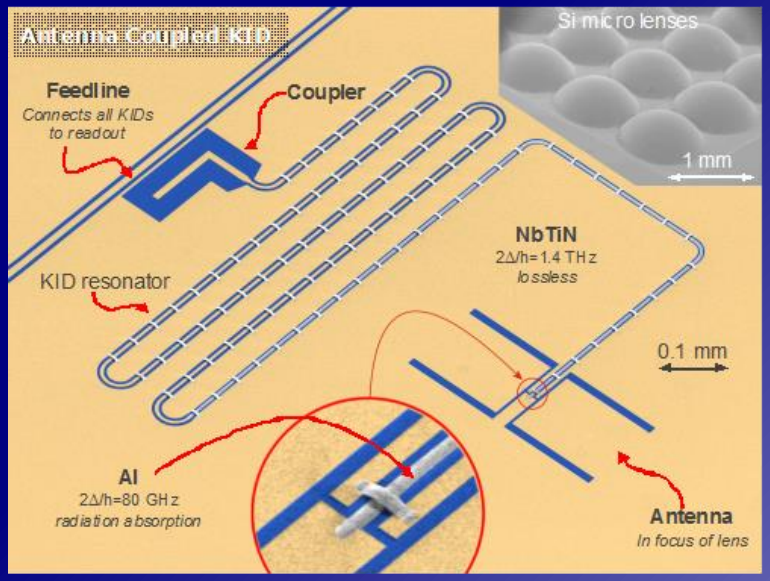
Dark Energy Survey

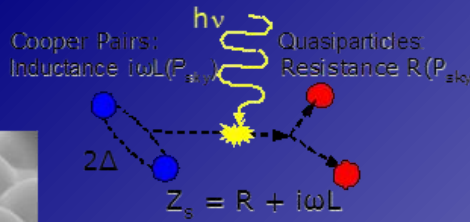


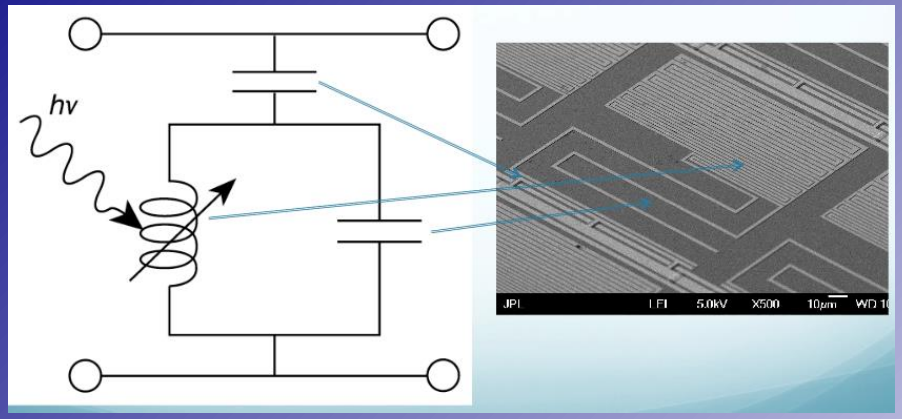




MKIDs for Astronomy



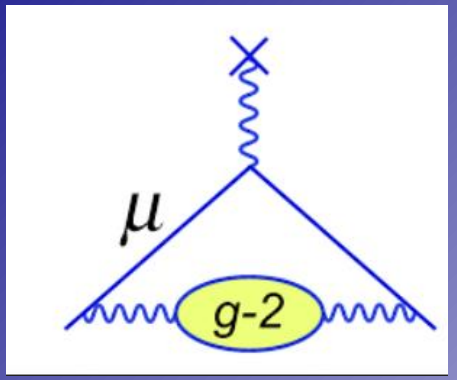


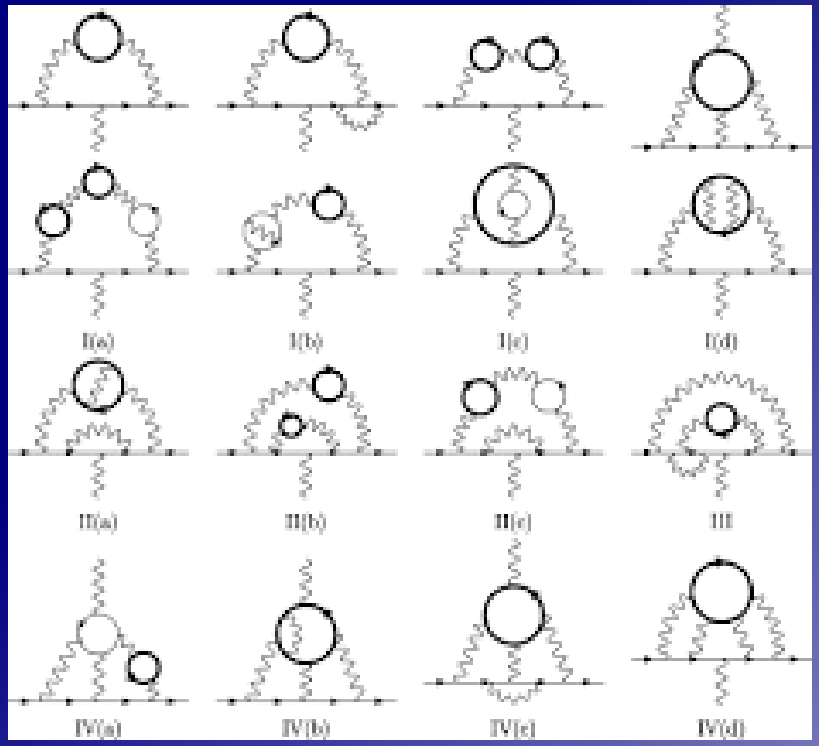


Muon g-2 Experiment

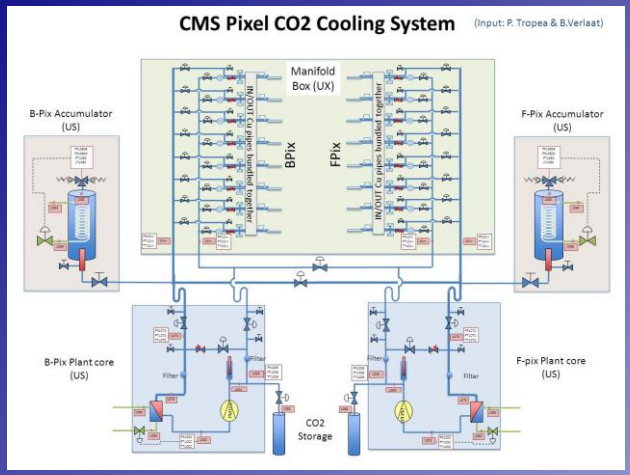
$$g_{exp} = 2.00233184178$$

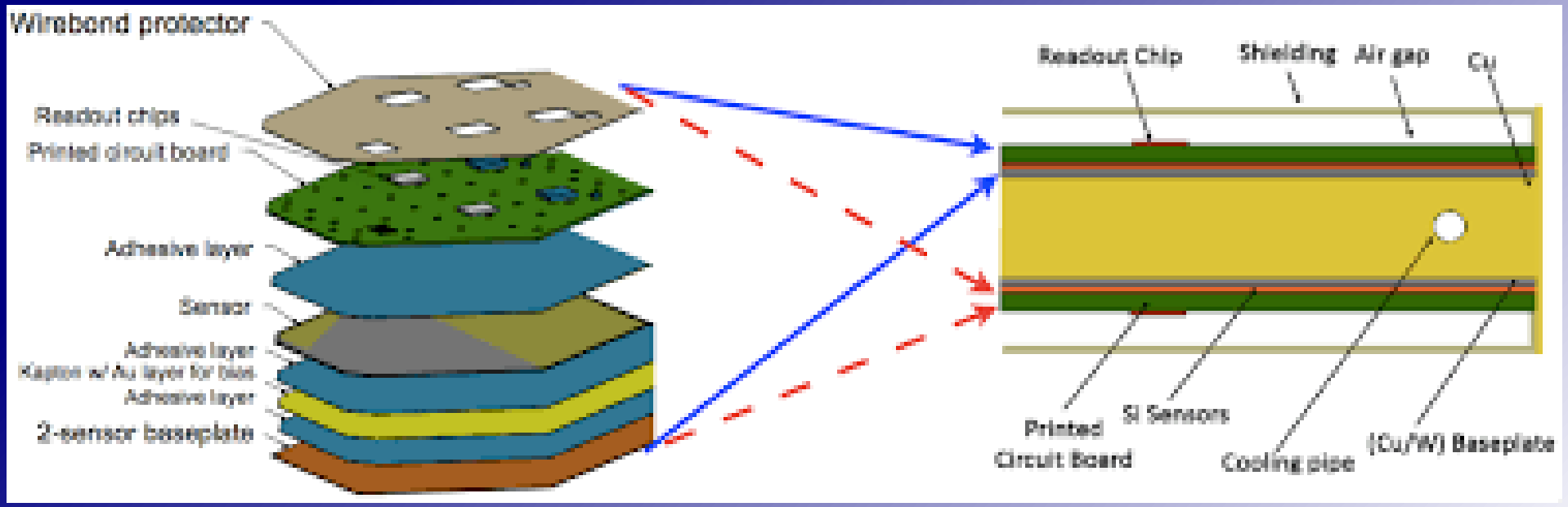
$$g_{theory} = 2.00233183630$$



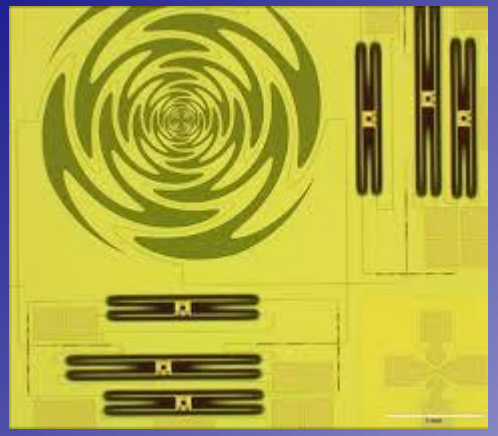


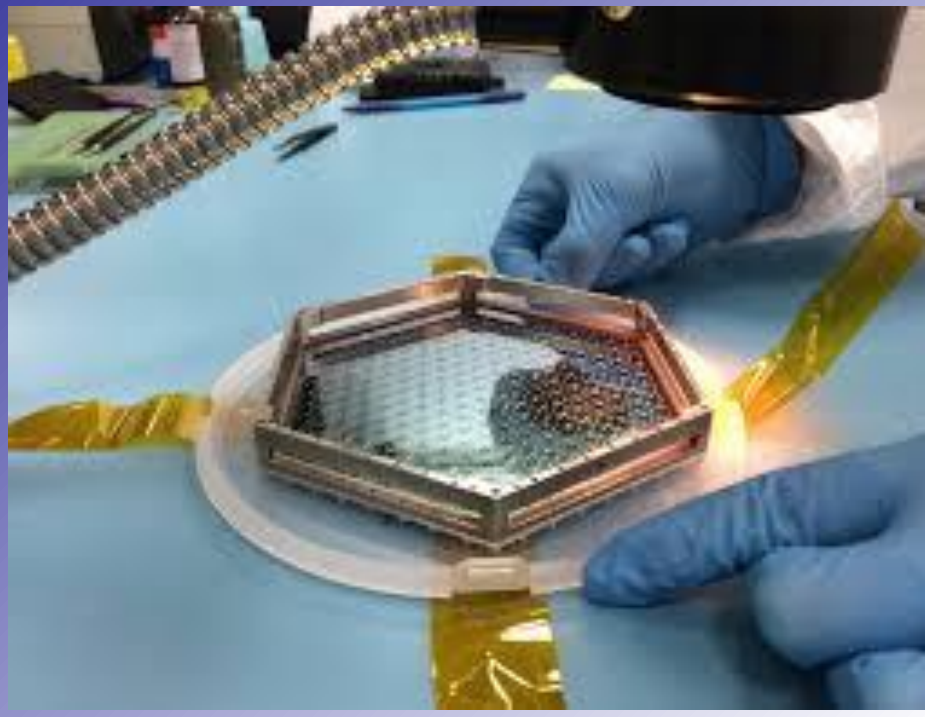
HGCal Upgrade to CMS





SPT-3G

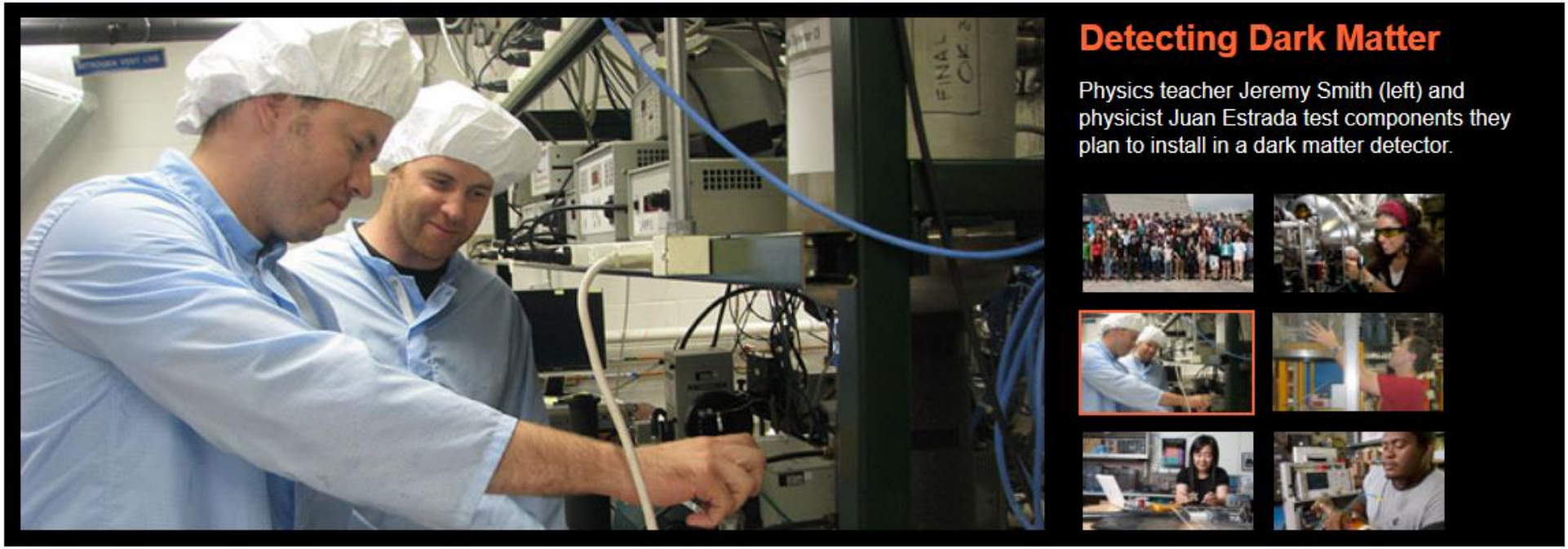




What Can QN Offer Teachers?

RET

Internships for Students and Teachers



Detecting Dark Matter

Physics teacher Jeremy Smith (left) and physicist Juan Estrada test components they plan to install in a dark matter detector.

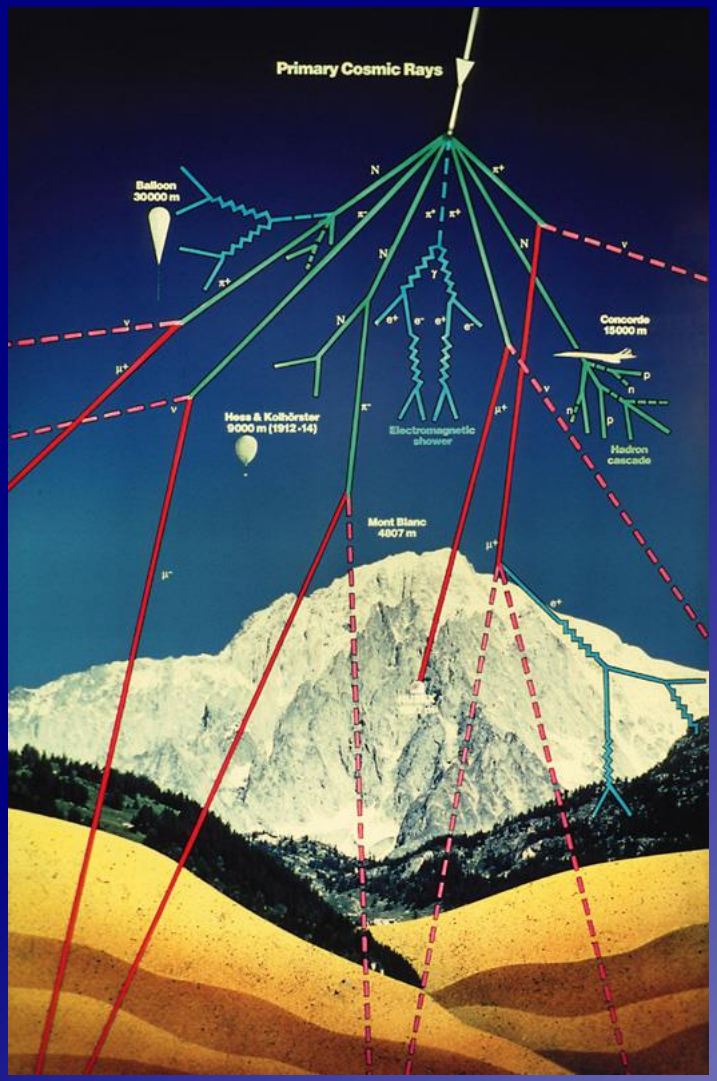
REU

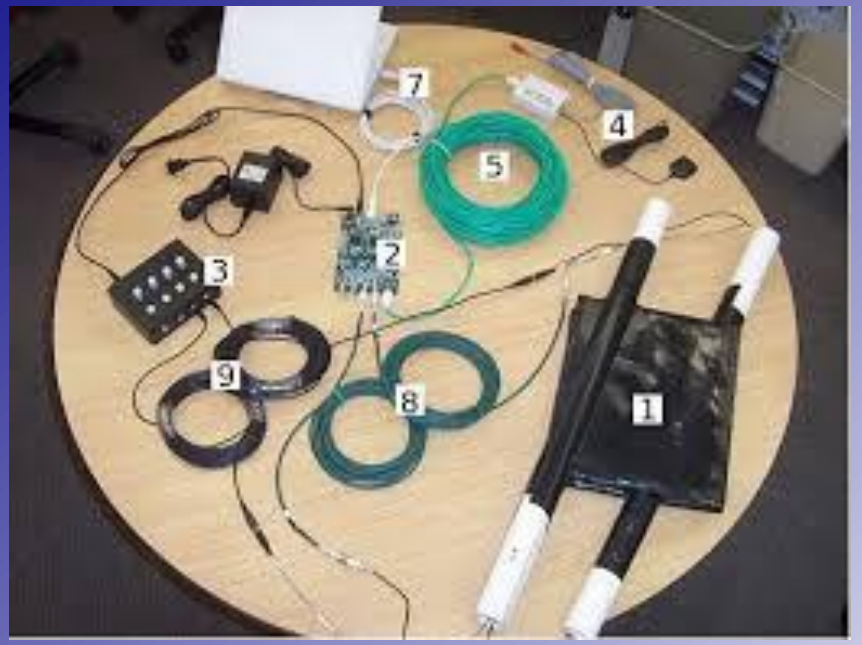
SRF Research and Development, Alex Juern,
CCI Program
Abstract

NIU
ROBOTICS

Data Camp

Cosmic Ray Detector





CERN

Miskova, Petra
(Slovakia)
Mpiana Mulamba, Florimond
(South Africa)
Mulder, Guus
(Netherlands)
Pisanic, John
(USA)
Restivo, Evelyn
(USA)
Rittner, James
(USA)