Particles and the Universe

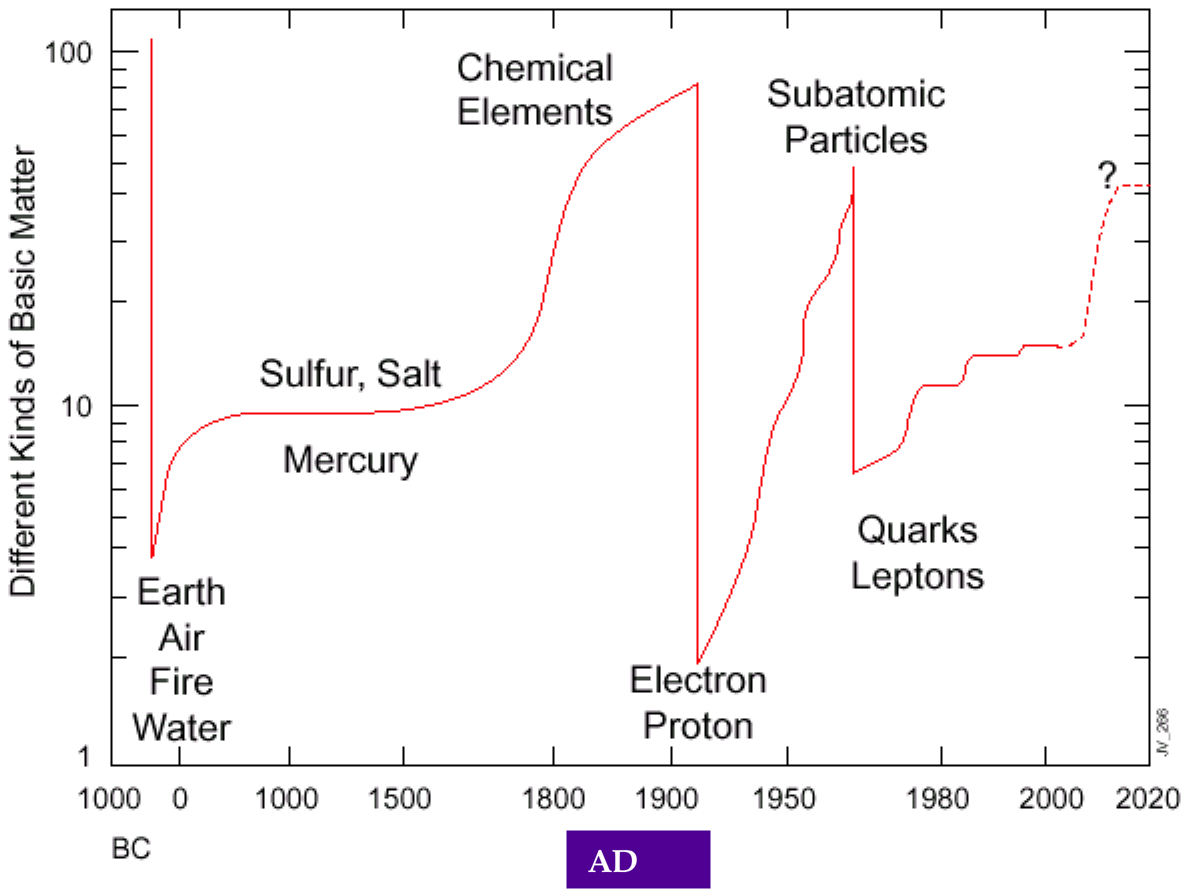
Particle Physicists whish to understand:

What are the fundamental constituents of matter?

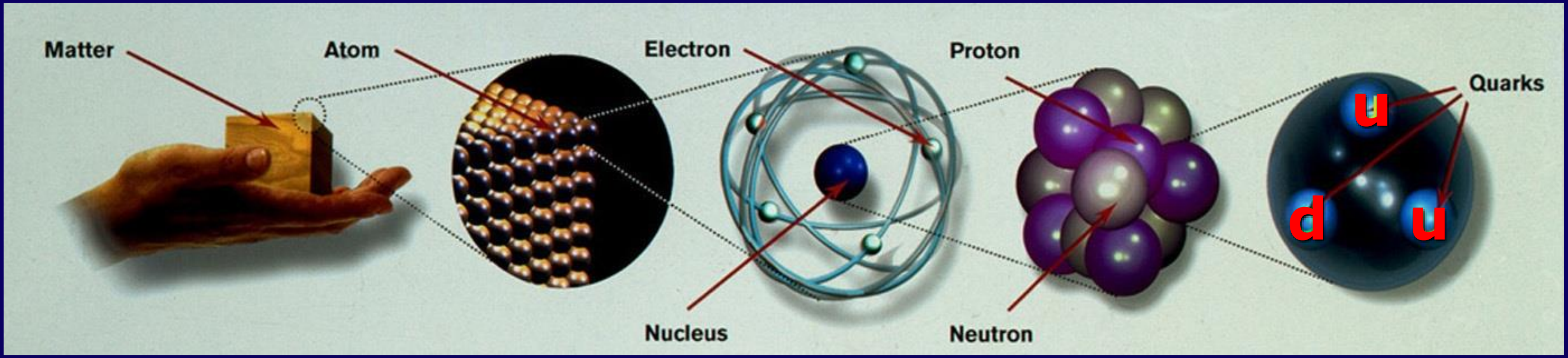
Which are the fundament interactions among particles?

How does the world function?

"Elementary" particles as a function of time...



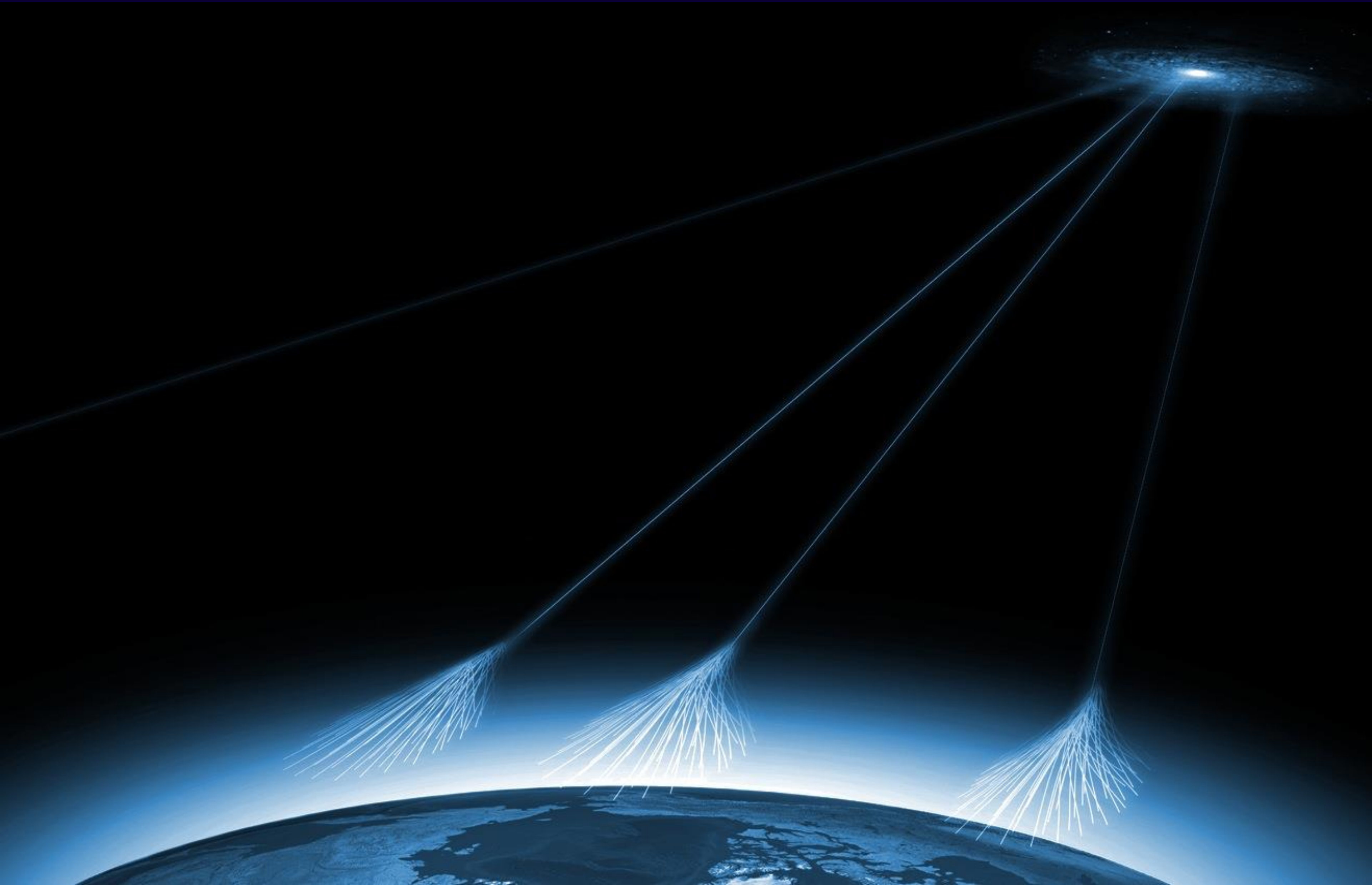
Constituents of matter



Bound State of 3 quark = Baryon
Bound State quark anti-quark = Meson

Nice

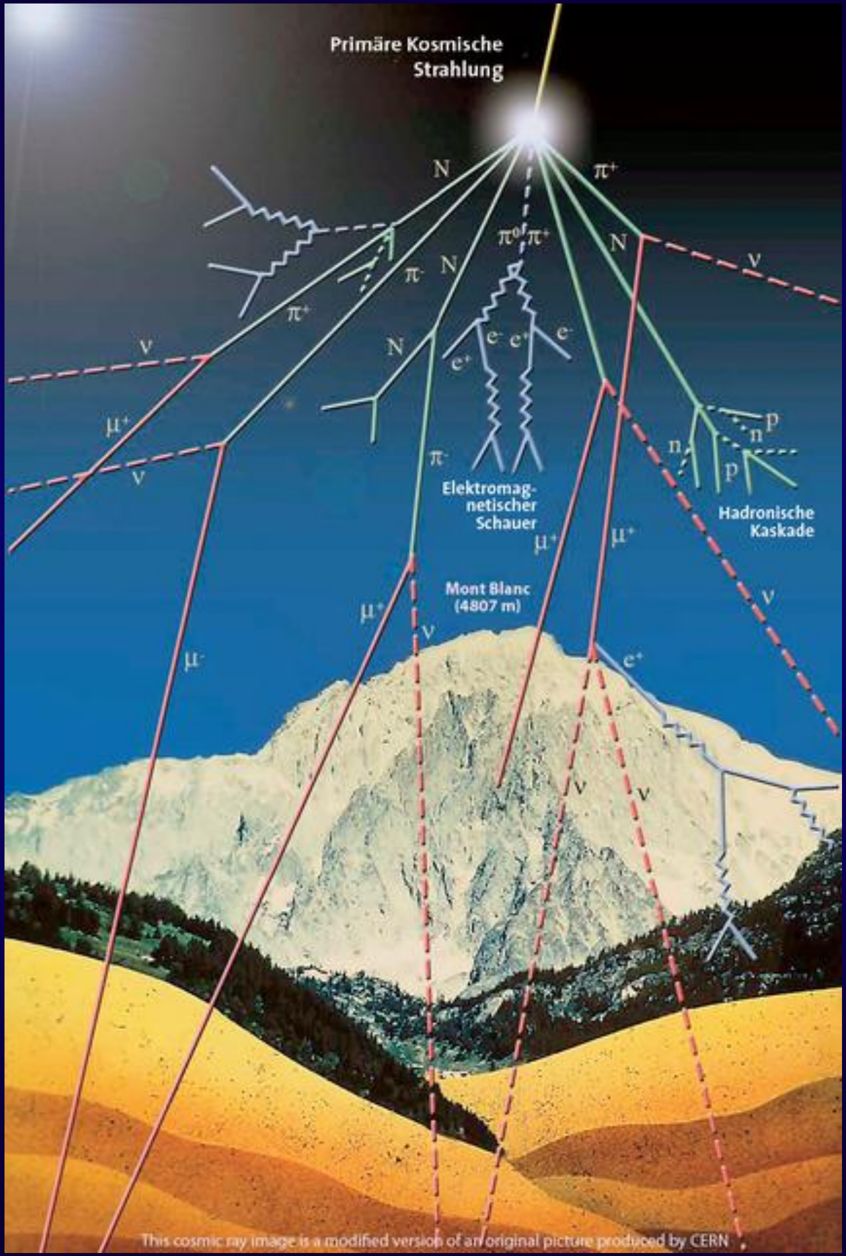
Cosmic Rays



What does it come from the sky?

Nice

How do we measure cosmic rays?

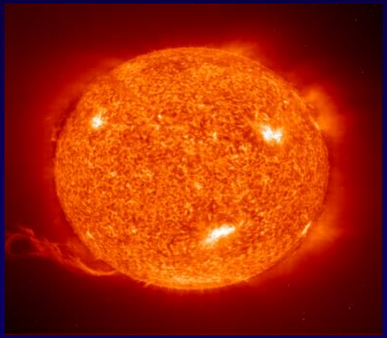


200 particles / m^2 / s

Nice

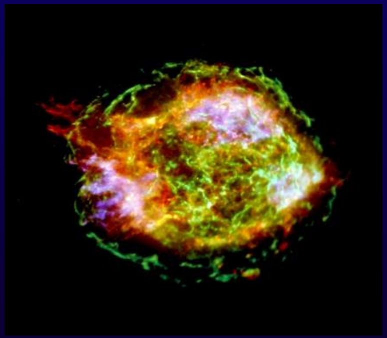
From where?

- From our Sun



- From Galaxies

- From Supernovae



Nice

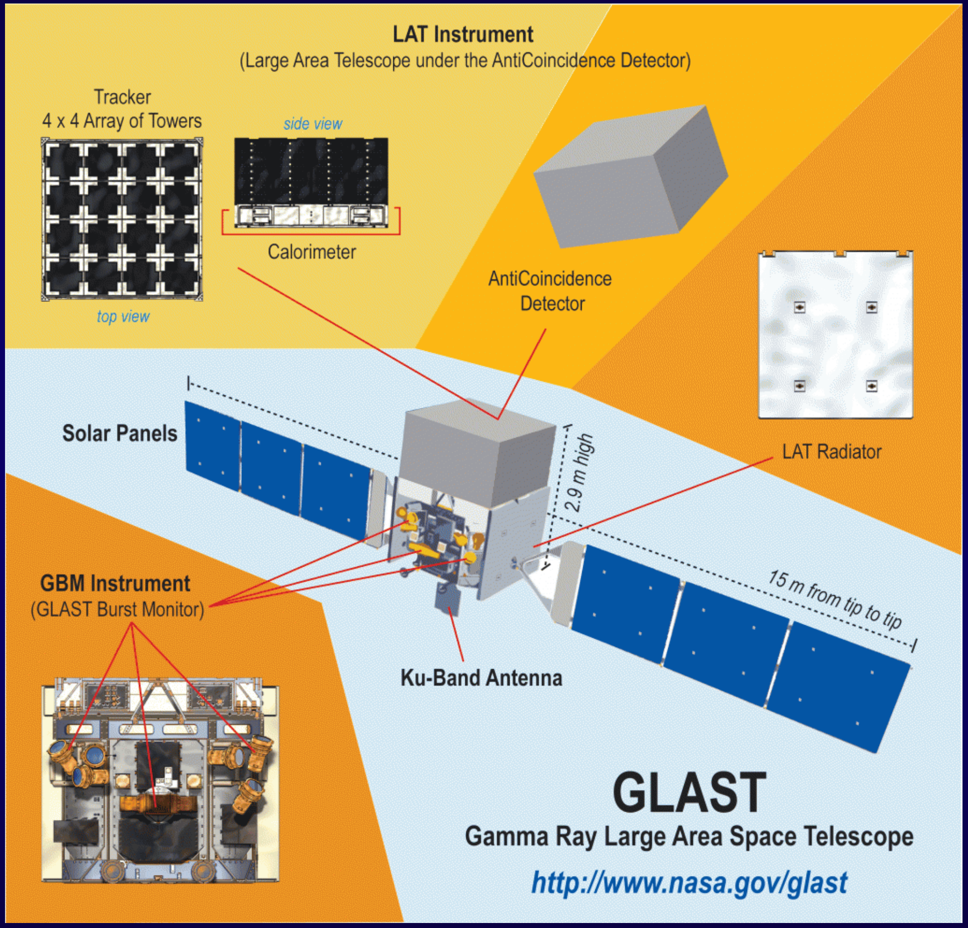
Spark Chamber

Nice

Cloud Chamber

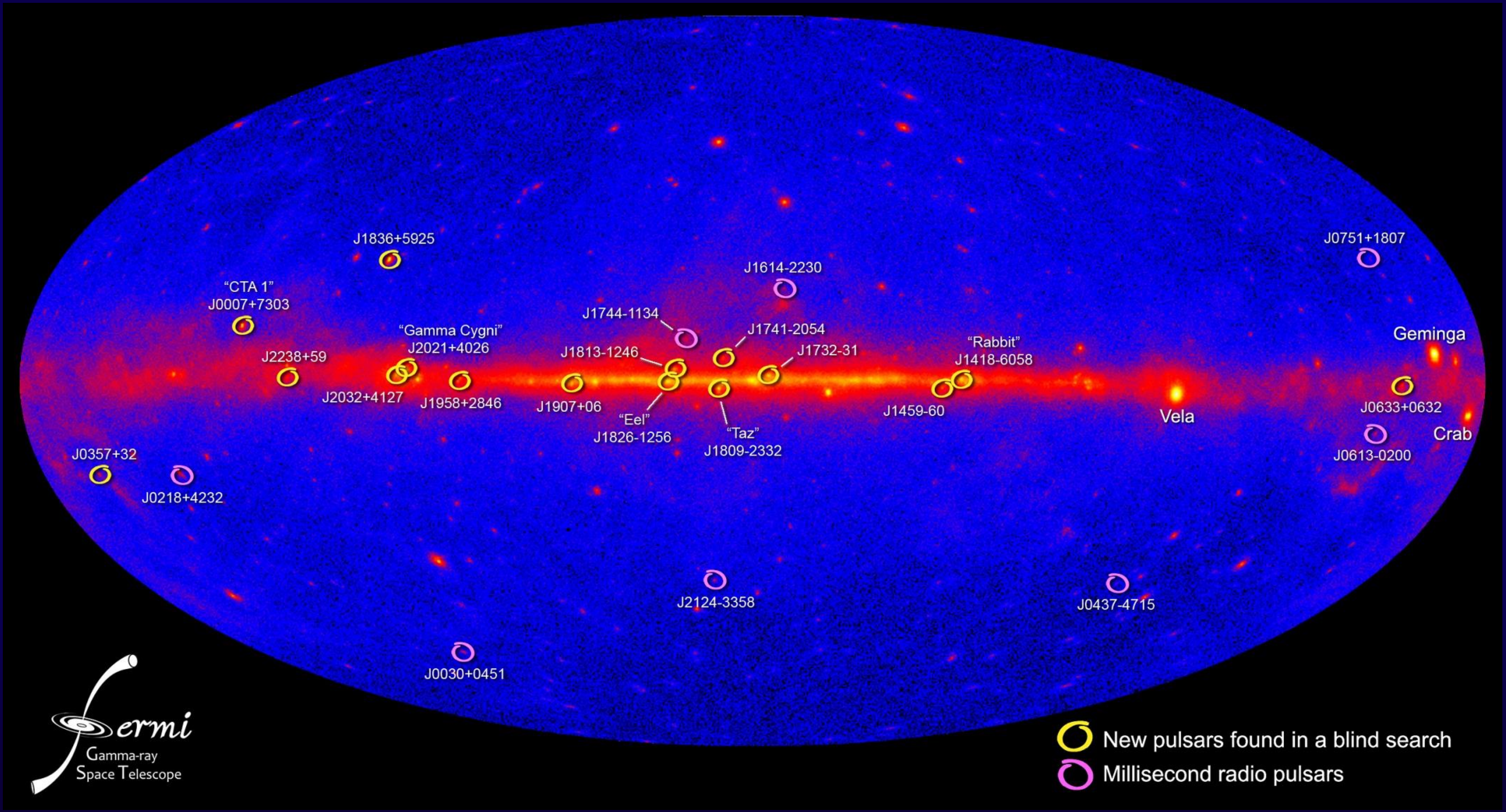
Nice

Fermi Telecope



Nice

Map of gamma rays from Fermi



Nice

The "Standard Model"

$1\ eV \sim 1.6\ 10^{-19}\ J$

Charge		Fermions (Matter) – I	II	III	Bosons
Q= +2/3 | q_e |	Quarks	~3 MeV *u* up	1.3 GeV *c* Charm	173 GeV *t* top	elettromagnetiche γ photon
Q= -1/3 | q_e |	Quarks	~5 MeV *d* down	~100 MeV *s* strange	4.2 GeV *b* bottom	strong *g* gluon
Q=0	Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Weak (charged) *W* W boson
Q= - | q_e |	Leptons	511 keV *e* electron	105 MeV μ muon	1.8 GeV τ tau	Weak (neutral) *Z* Z boson
	Generation	I	II	III	

Interactions

Higgs boson

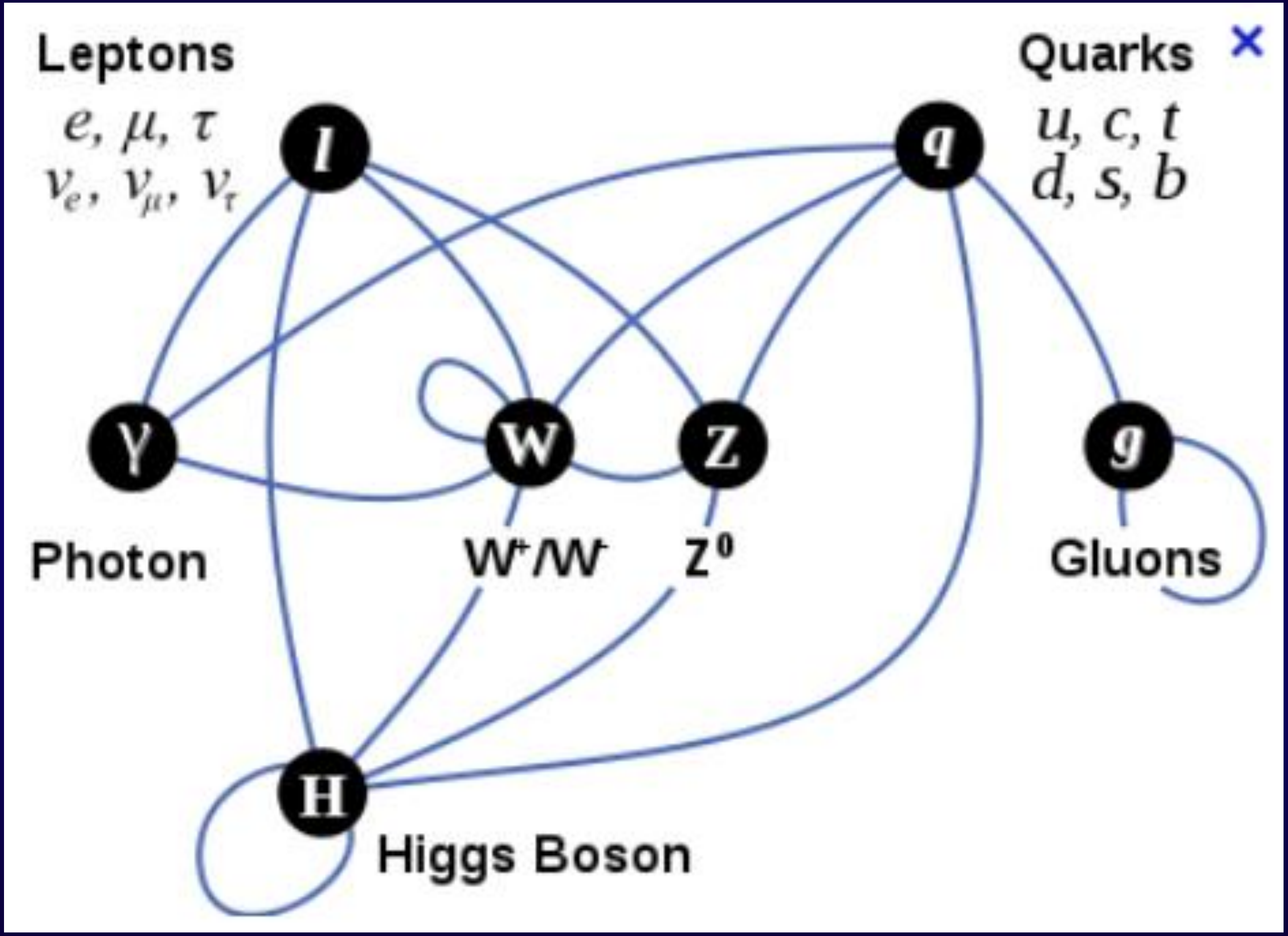
$1 keV = 10^3\ eV$

$1 MeV = 10^6\ eV$

$1 GeV = 10^9\ eV$

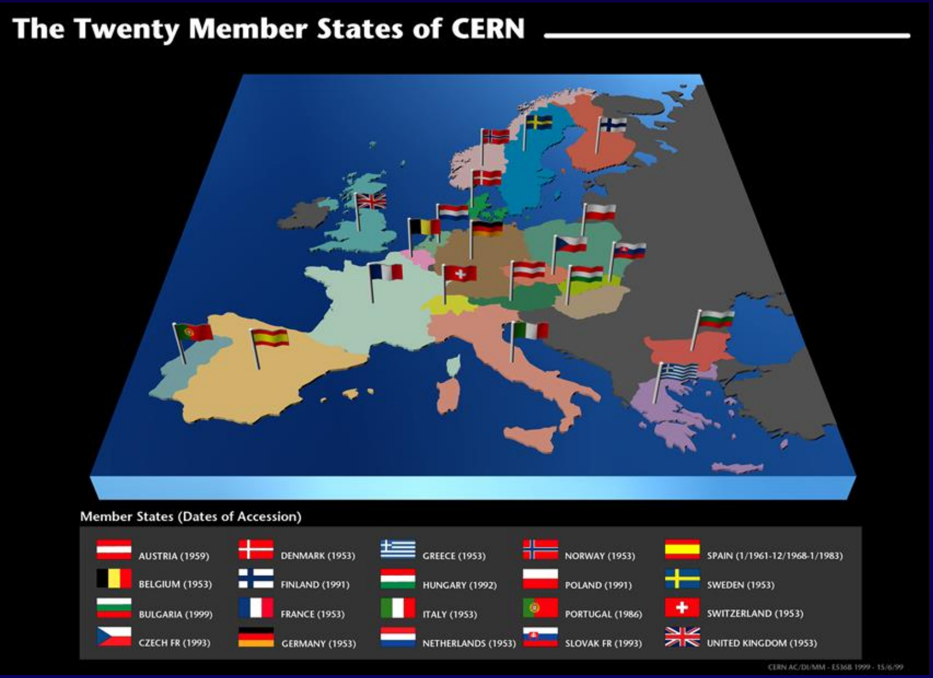
$m_P \sim 938\ MeV$

Particle Interactions

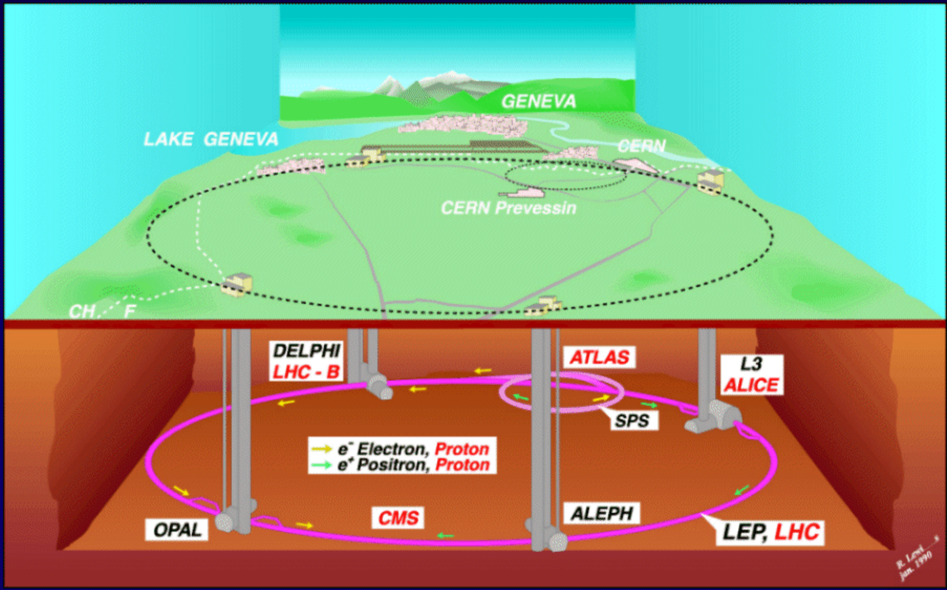


Nice

CERN: European Organization for Nuclear Research



21 Stati membri

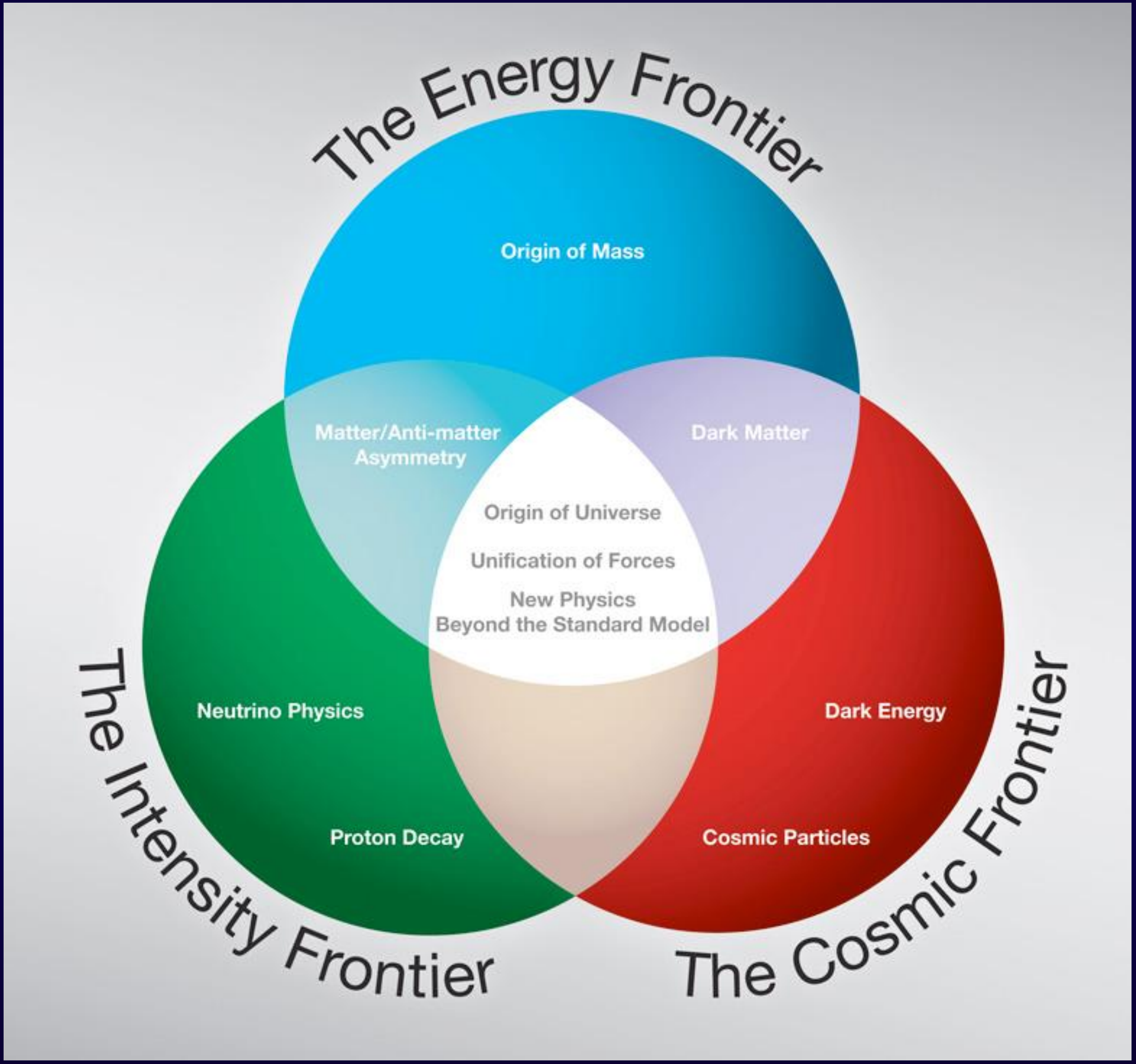


Presso Ginevra a cavallo fra Svizzera e Francia

Le missioni del CERN: Ricerca, Tecnologia, Collaborazione, Educazione

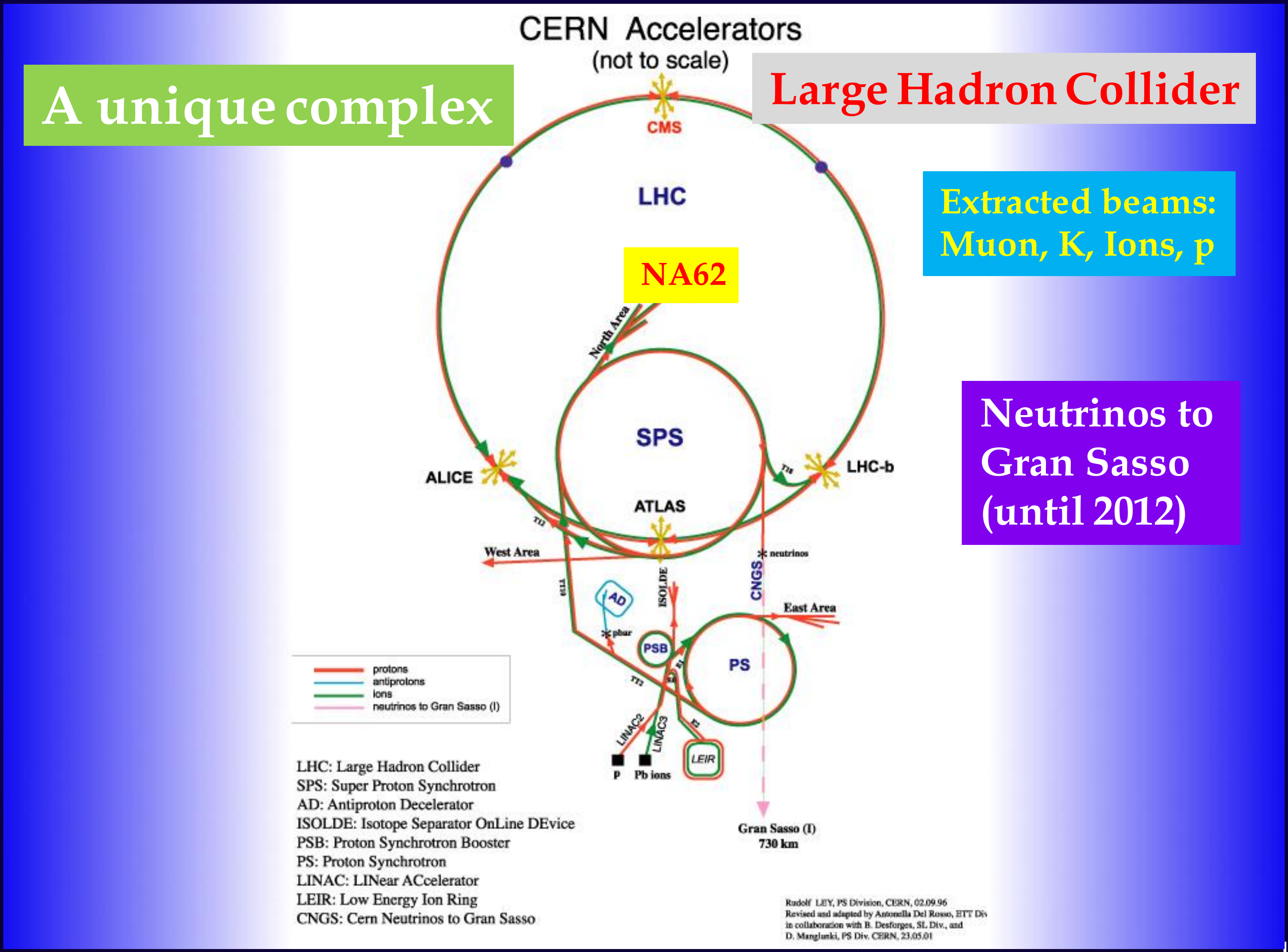
Nice

Three Frontiers

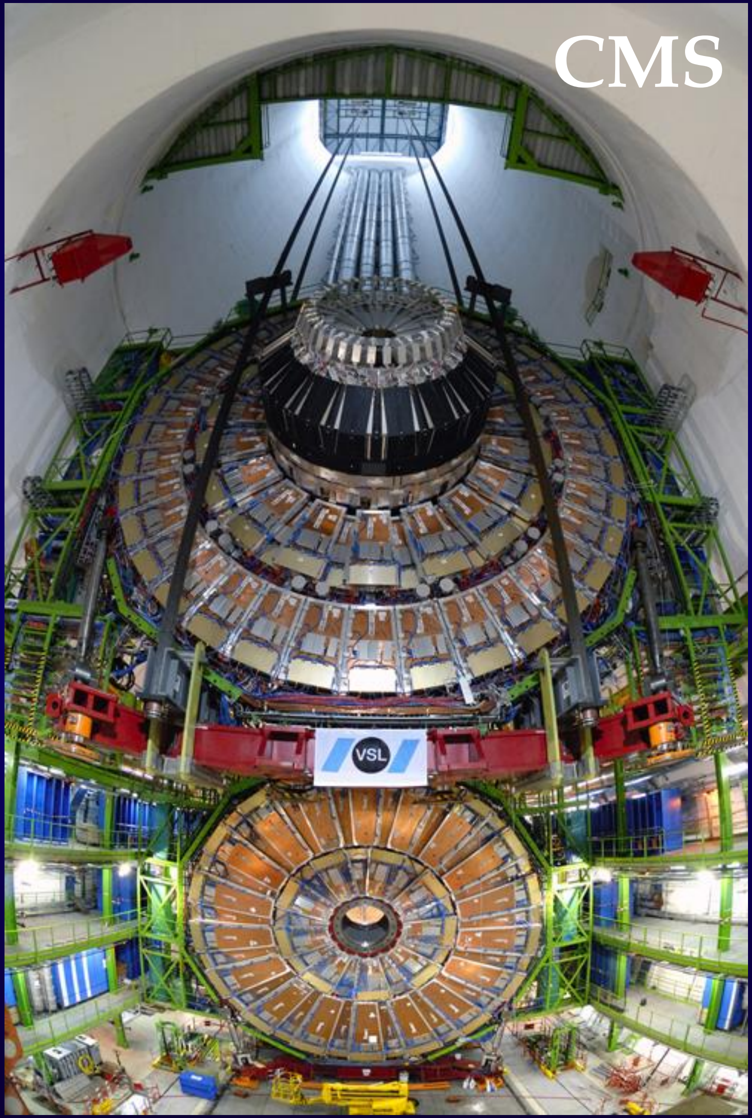


Nice

CERN Accelerators



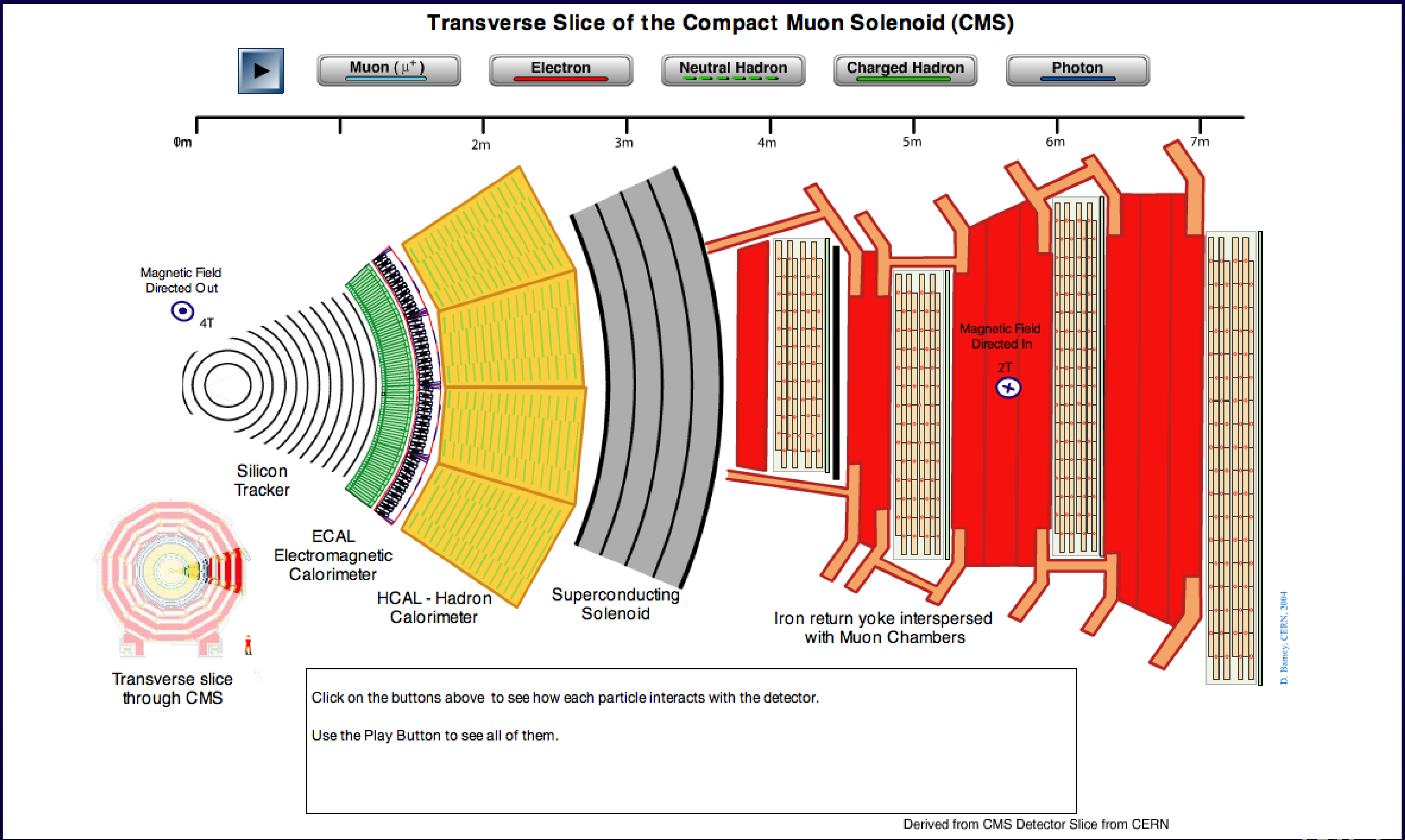
Example of LHC Detector: CMS



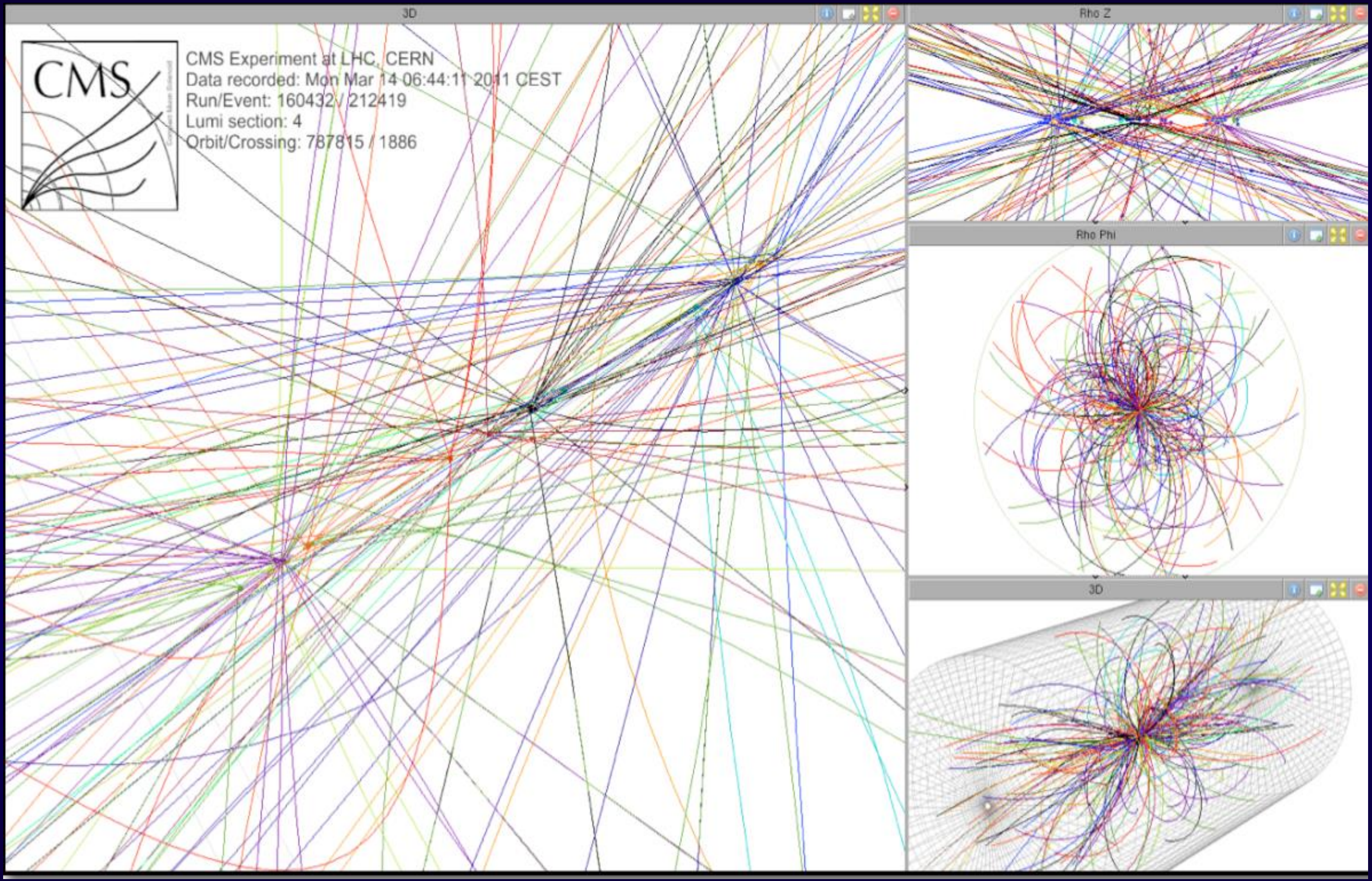
Detectors are instruments
That enable us to record the
Results of the collisions

Nice

Compact Muon Solenoid (CMS)



The challenge of data taking at LHC

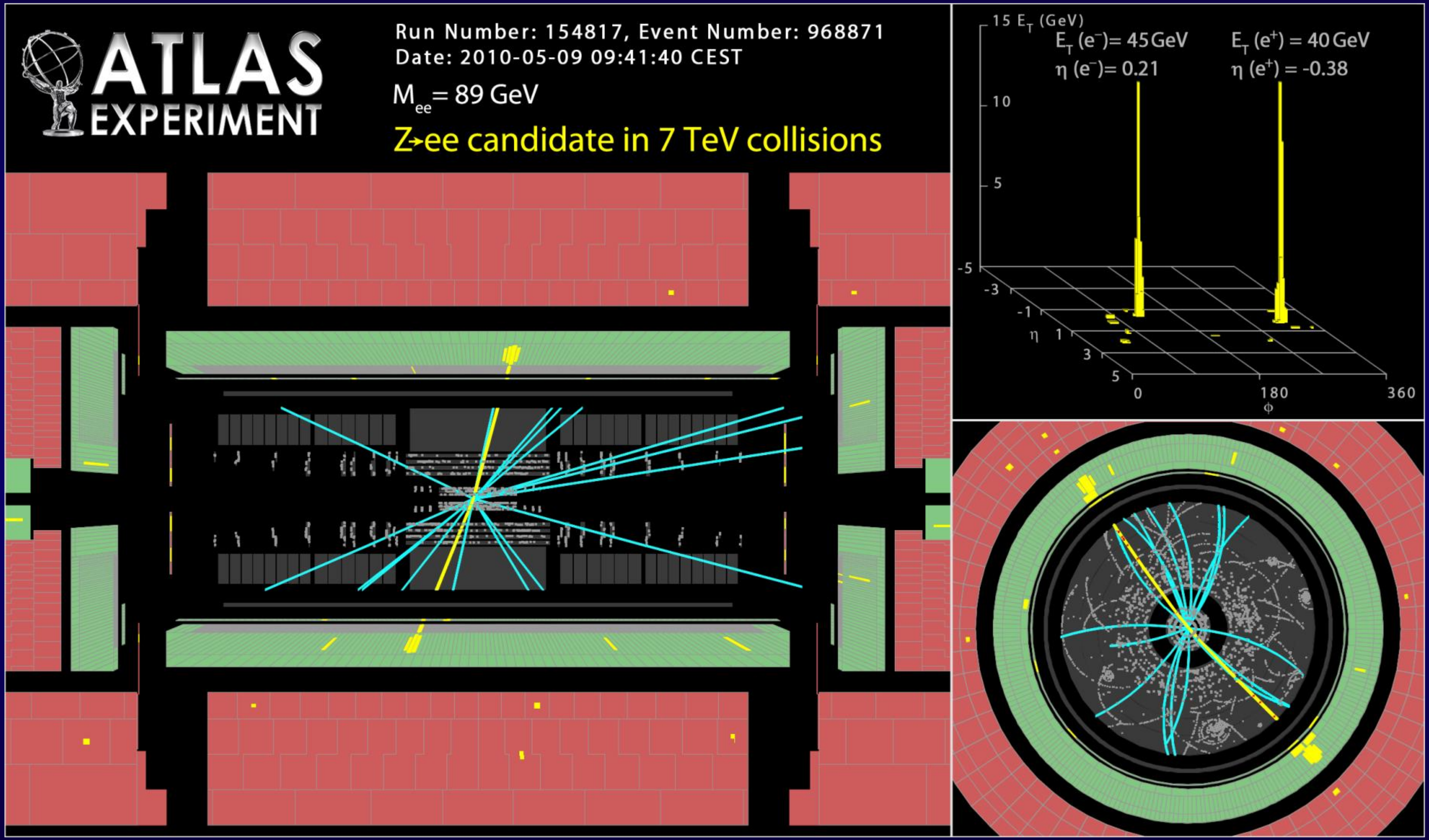


How many p-p interactions can you find ?

Nice

$Z \rightarrow e^+e^-$

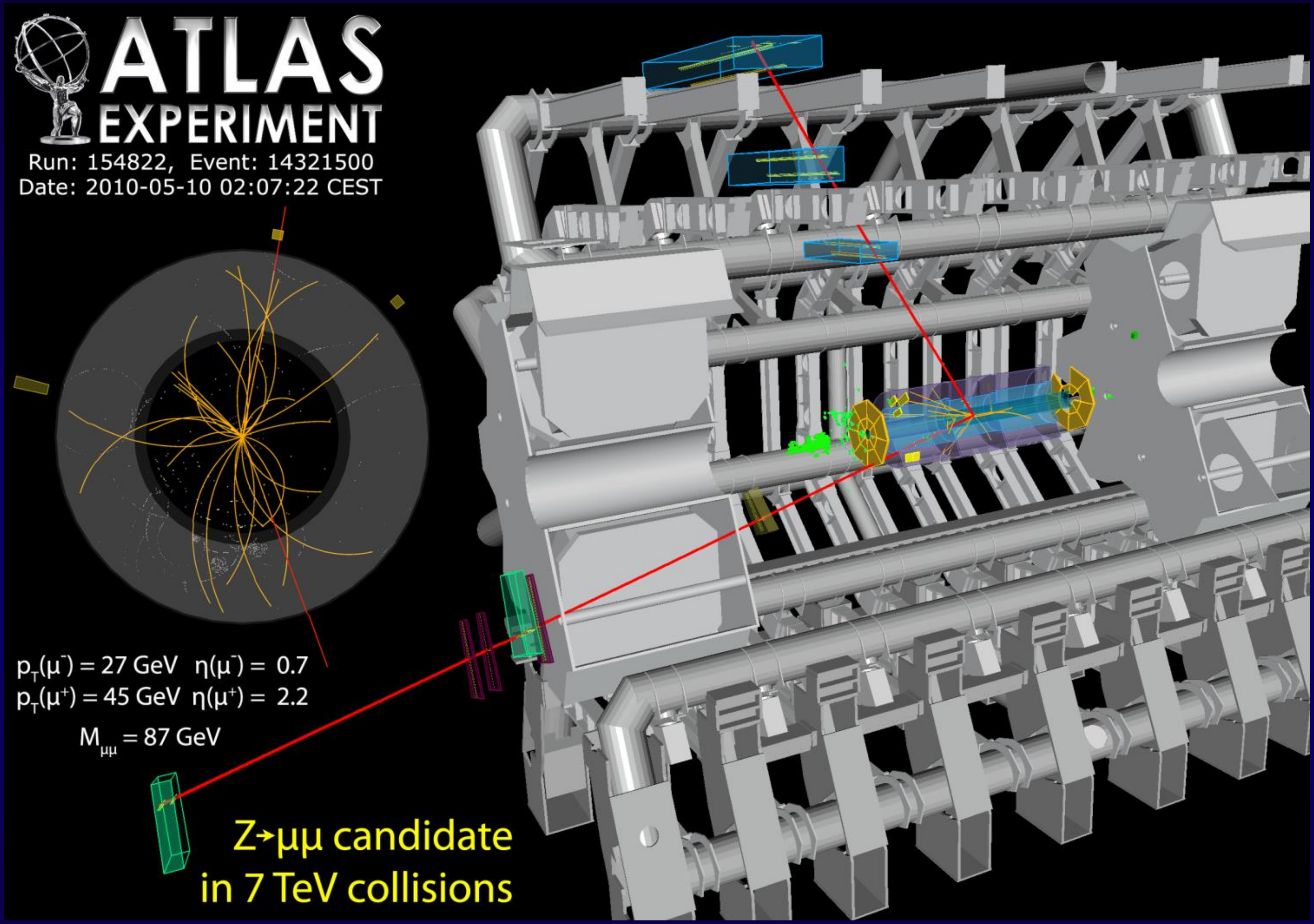
A few examples of nice Collider events…….



Can you find the electron pair?

Nice

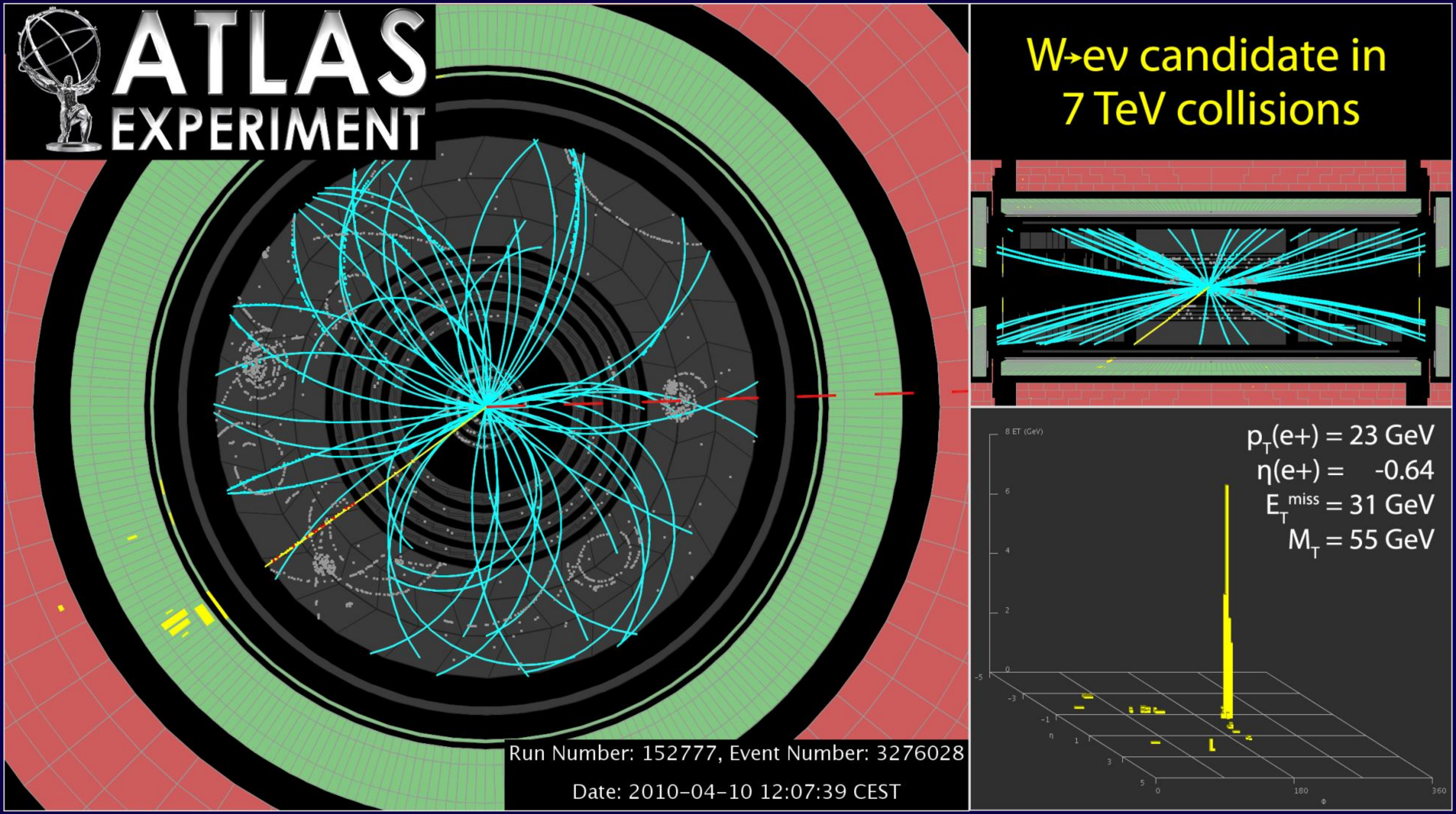
Z → $\mu^+\mu^-$



Muons (μ) are like electrons..but ~200 times heavier…
Can you explain why they escape from the inner detectors?

Nice

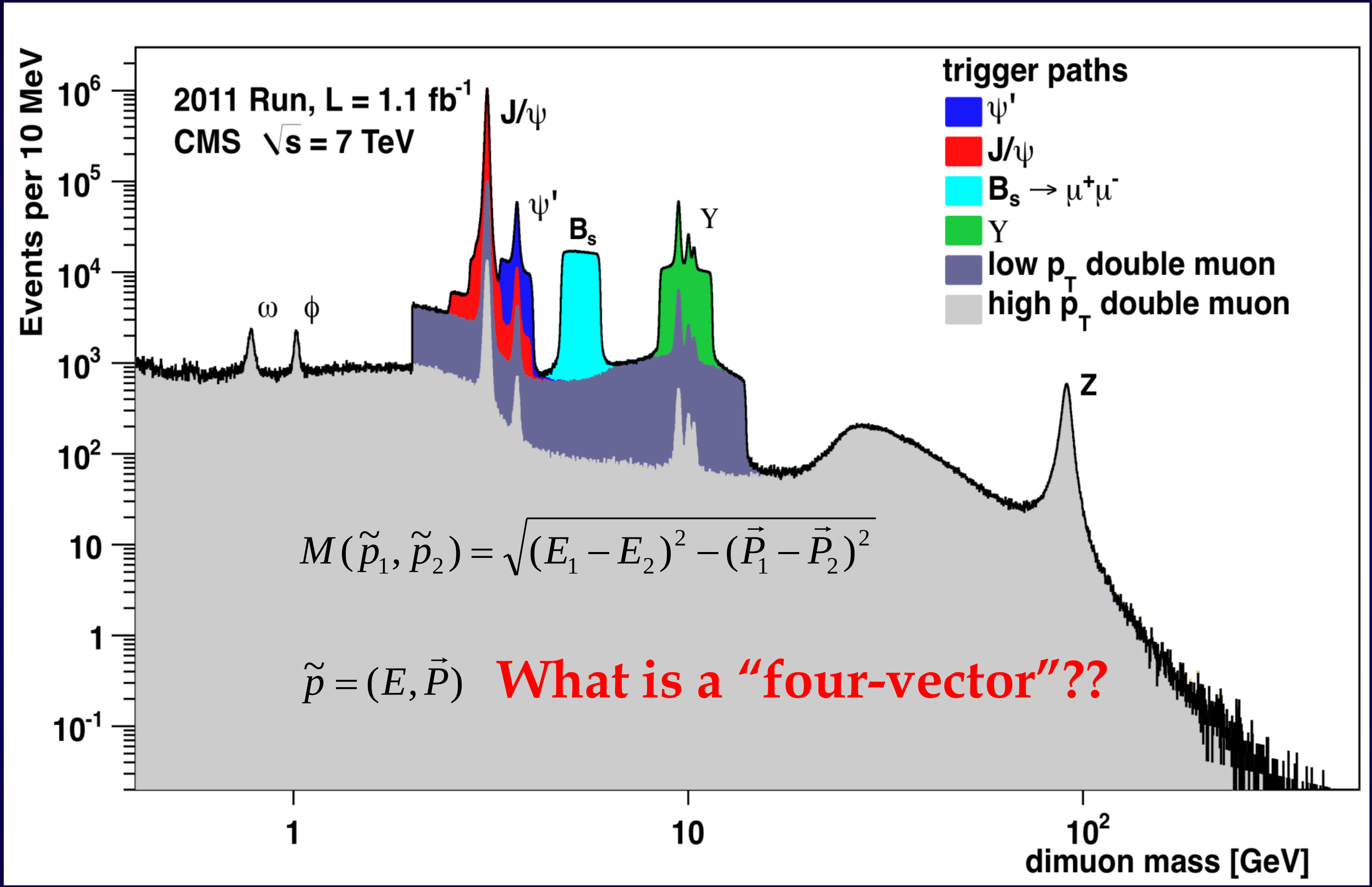
$W^+ \rightarrow e^+ \nu$



Can you see the neutrino (ν)???

Nice

Triggering on di-muons at 10^{32}-10^{33} with CMS



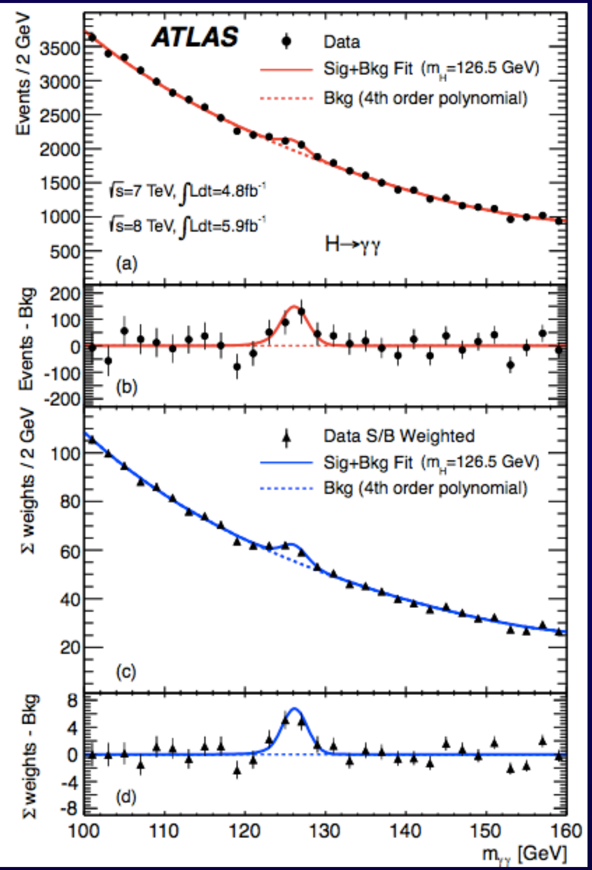
The invariant mass M is a Lorentz scalar: what does it mean?

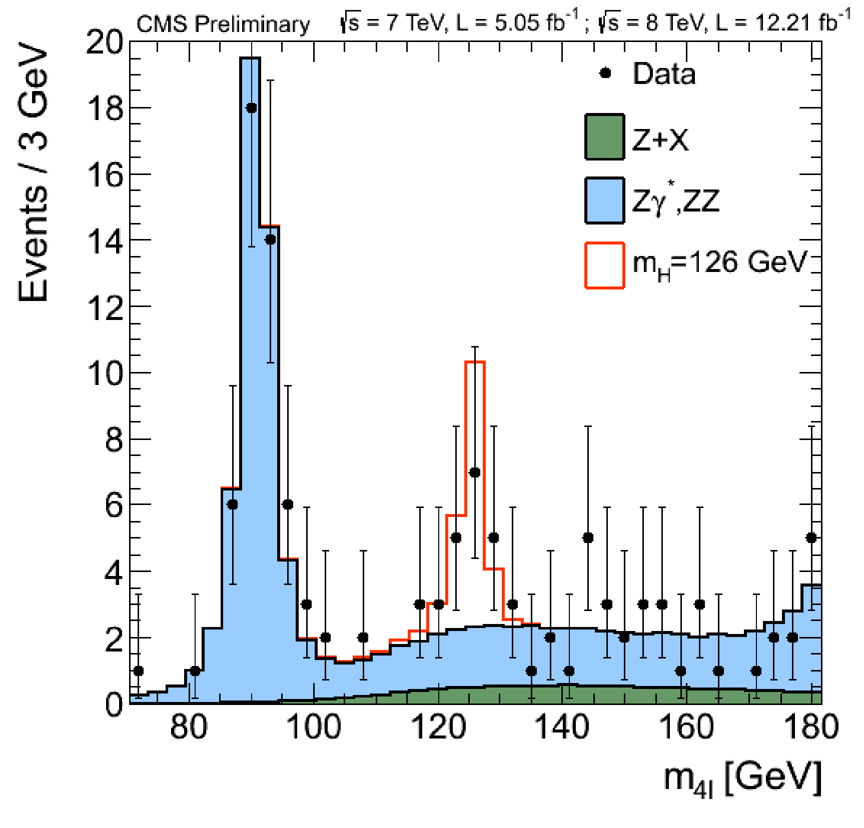
How many "resonances" can you find?

Nice

DISCOVERY OF THE HIGGS

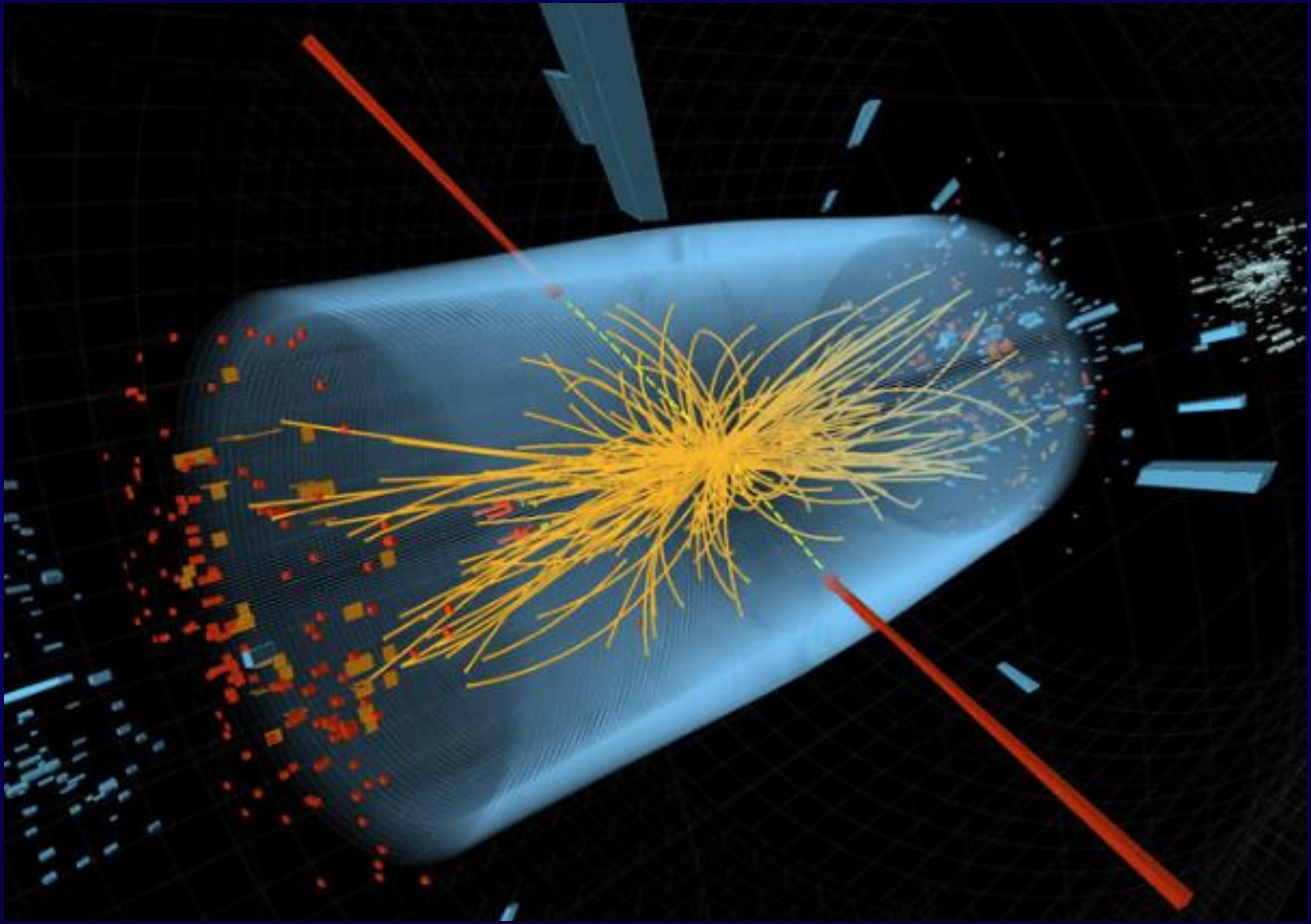
ATLAS CMS



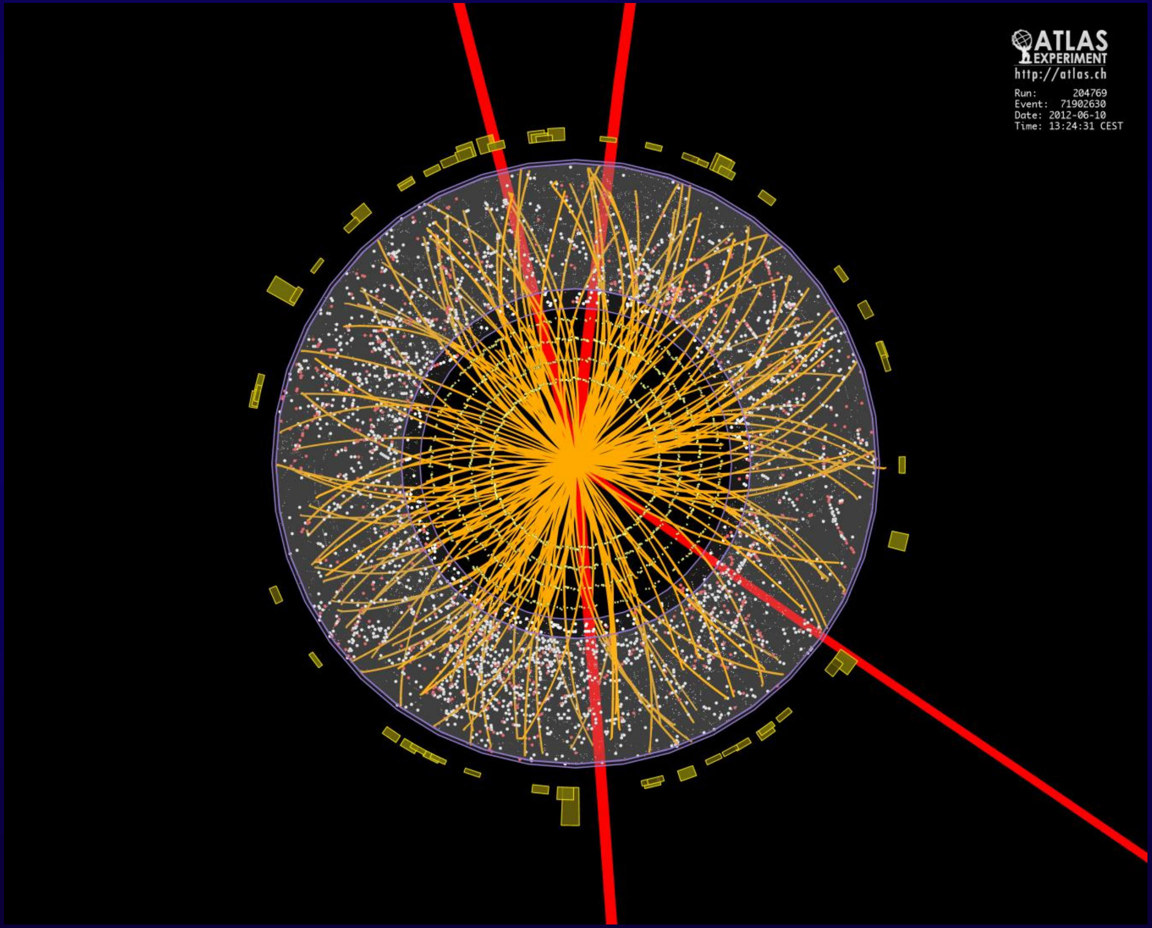


Nice

CMS: H→γγ

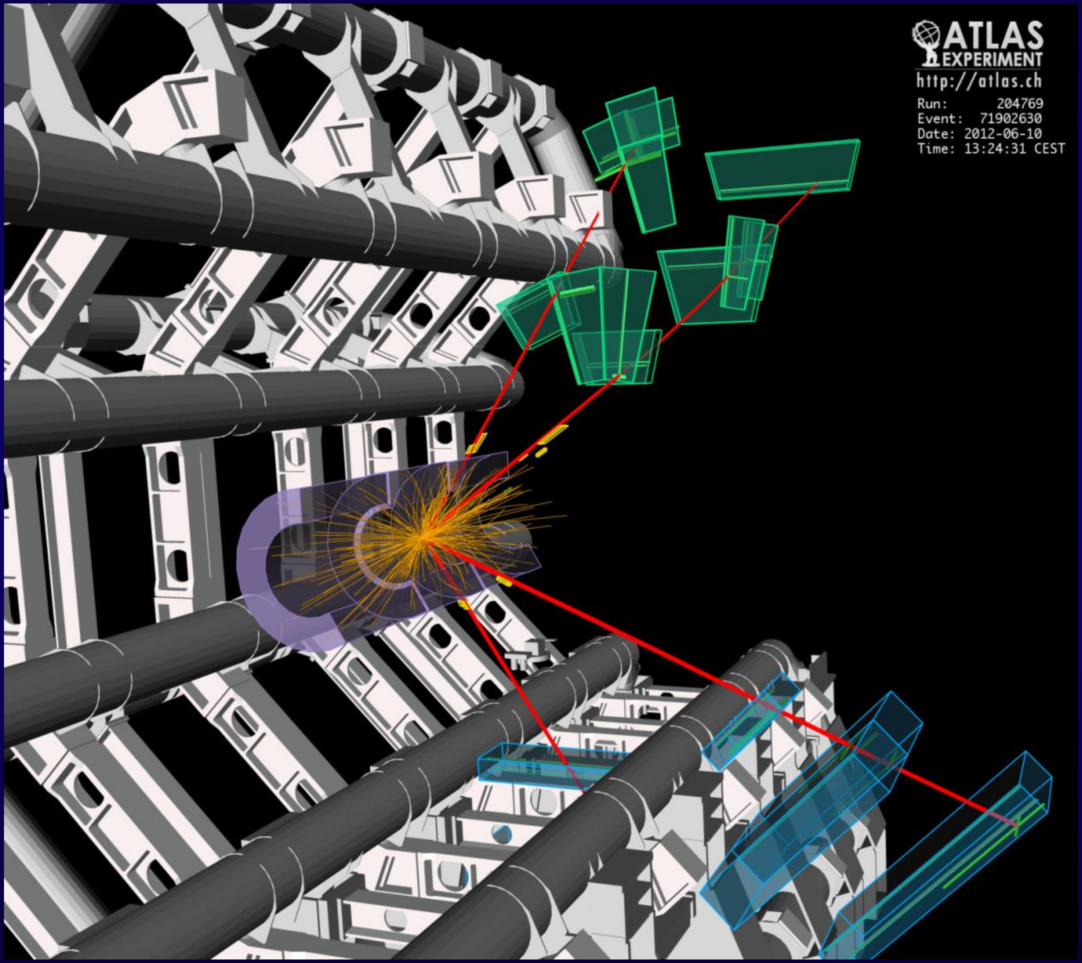


$H \rightarrow Z Z^* \rightarrow \mu^+ \mu^- \mu^+ \mu^-$



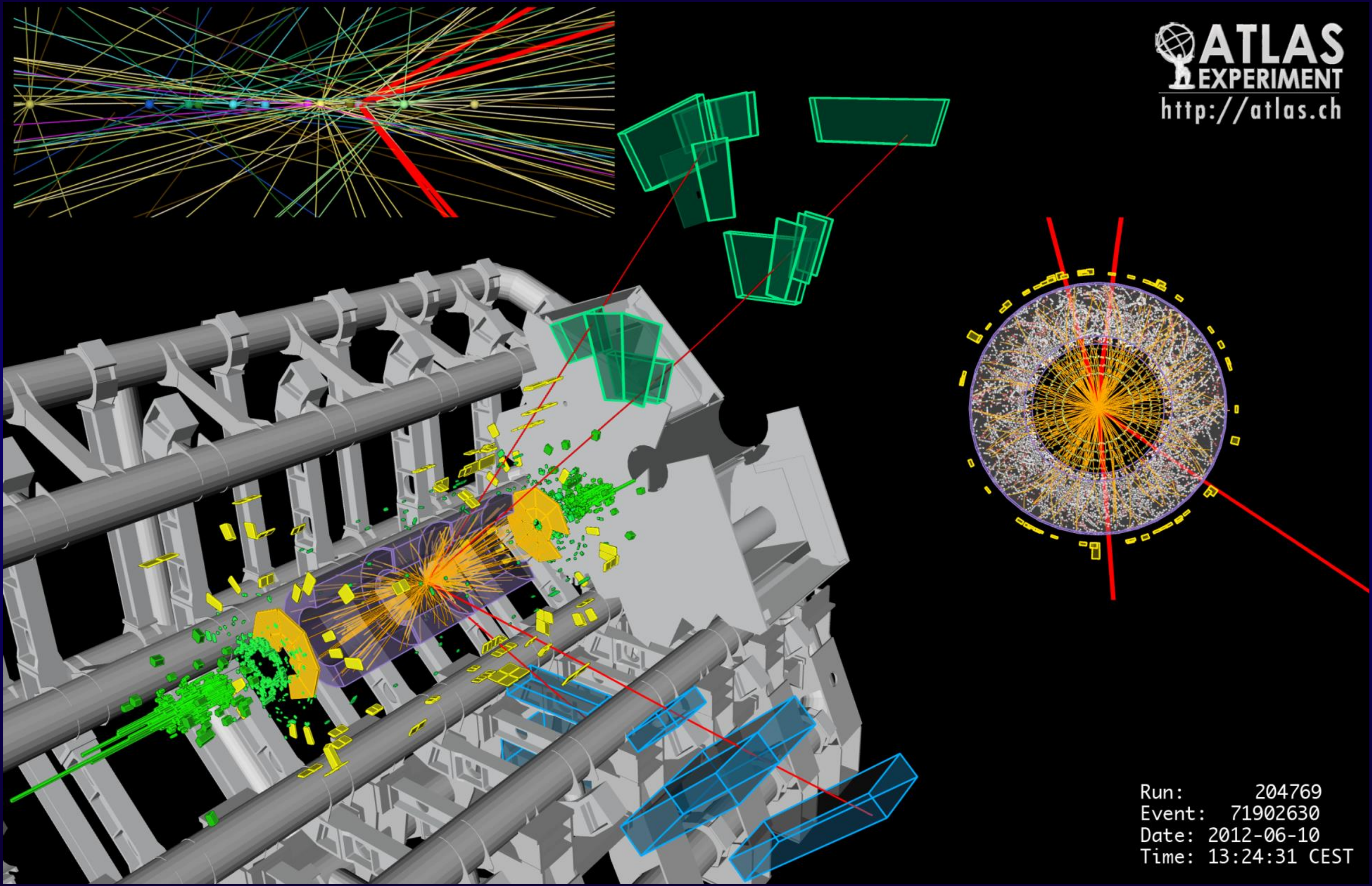
Nice

H→ Z Z* →$\mu^+ \mu^- \mu^+ \mu^-$

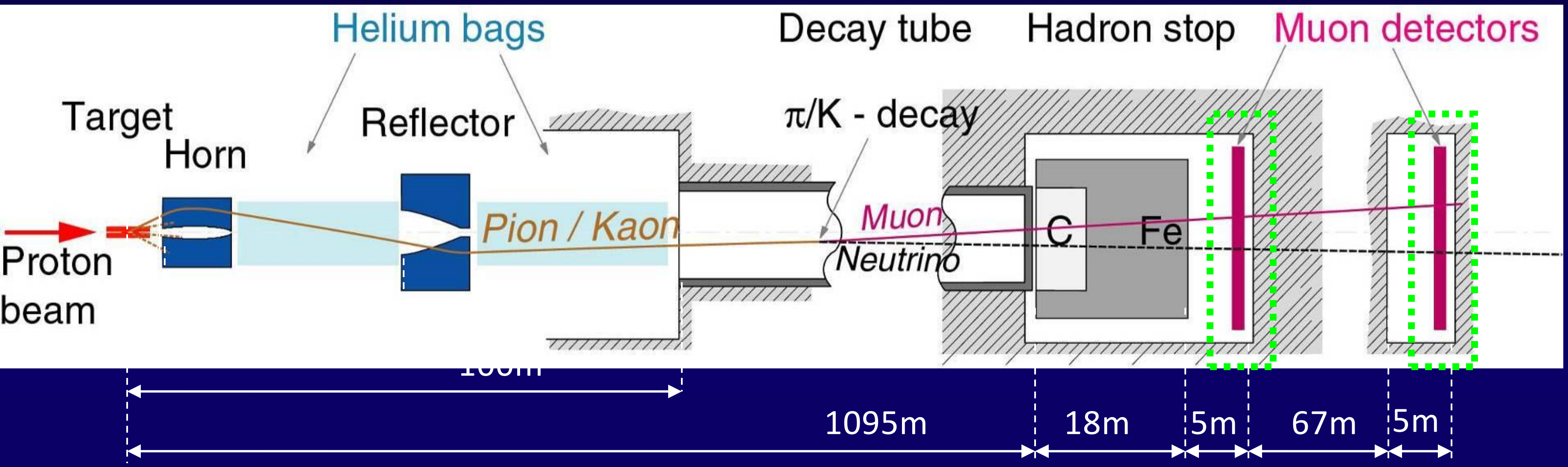


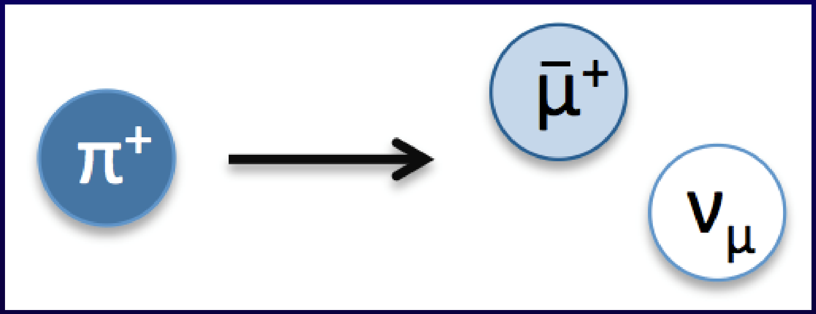
Nice

H→ Z Z* →μ⁺ μ⁻ μ⁺ μ⁻

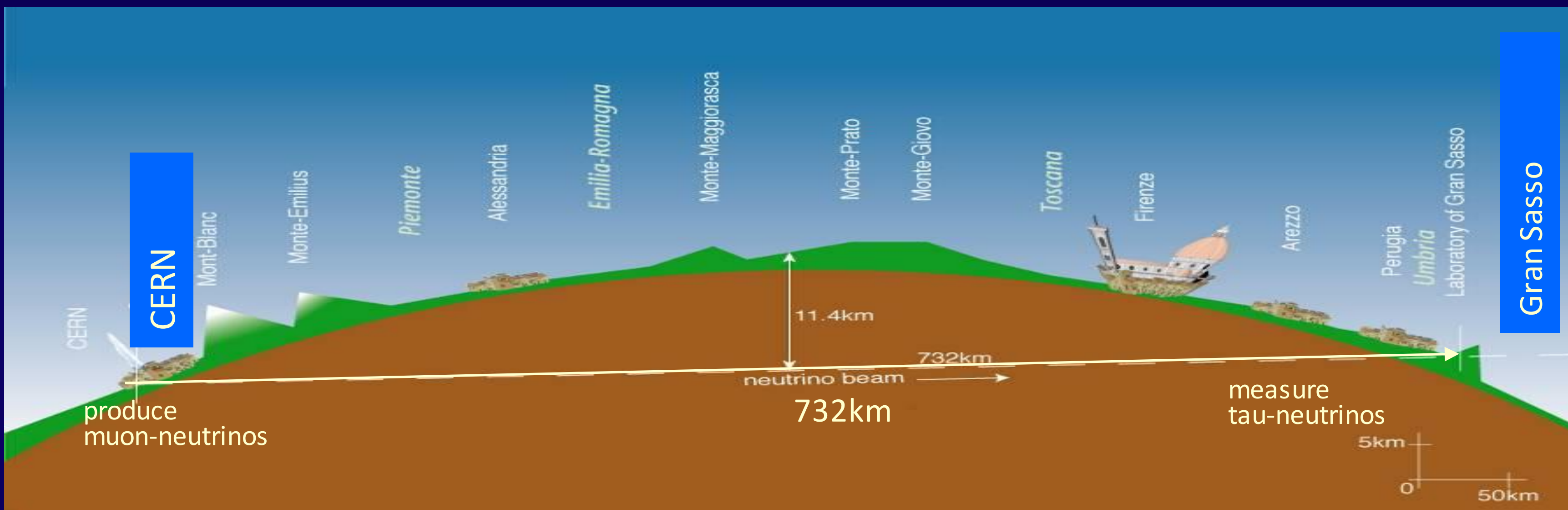

ATLAS EXPERIMENT
http://atlas.ch
Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

How to make a neutrino beam





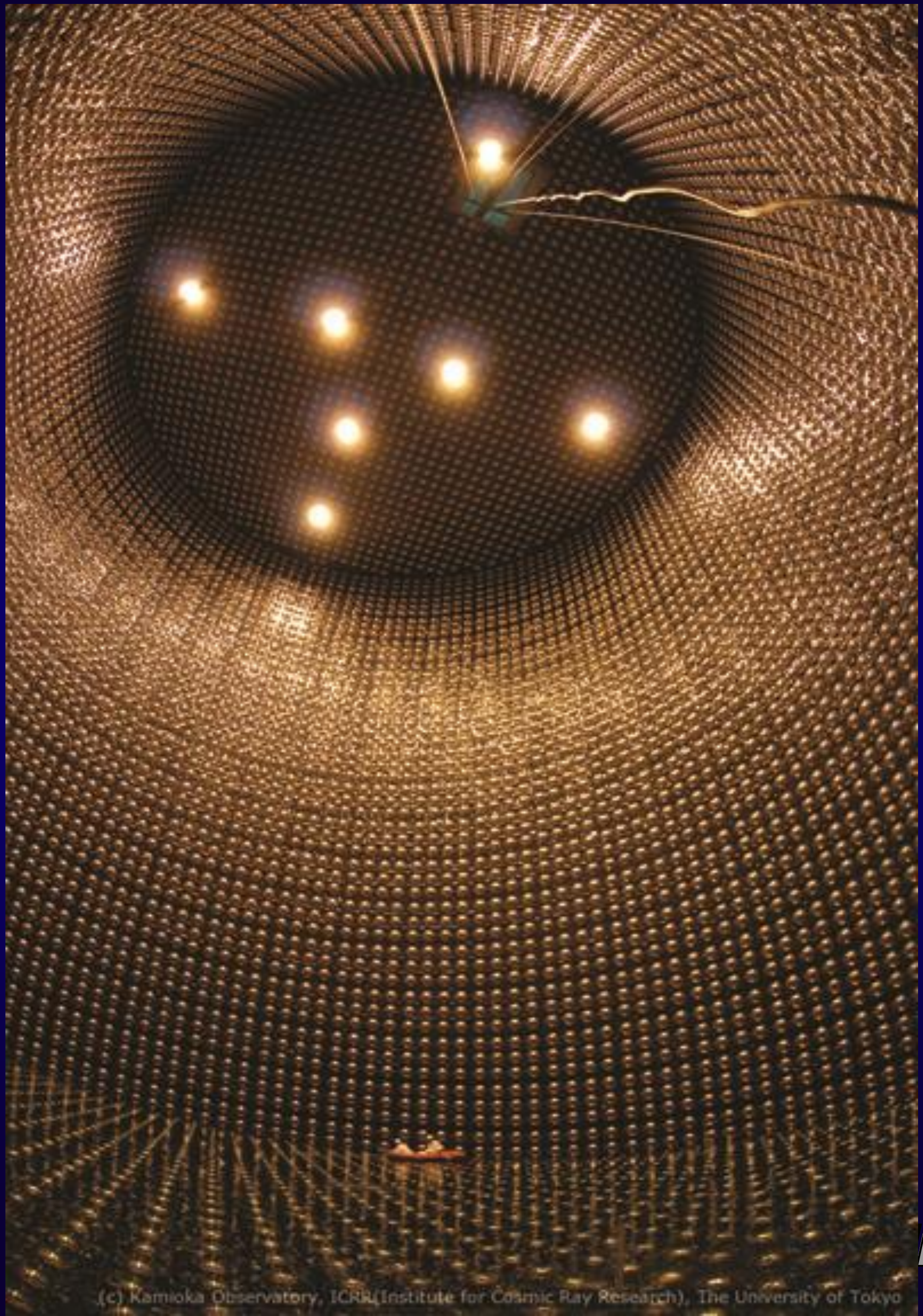
Long Baseline neutrino beam



~4·10^{19} p/year ~2·10^{19} ν_μ/year

~2 ν_τ/year (~1·10^{17} ν_μ/year)

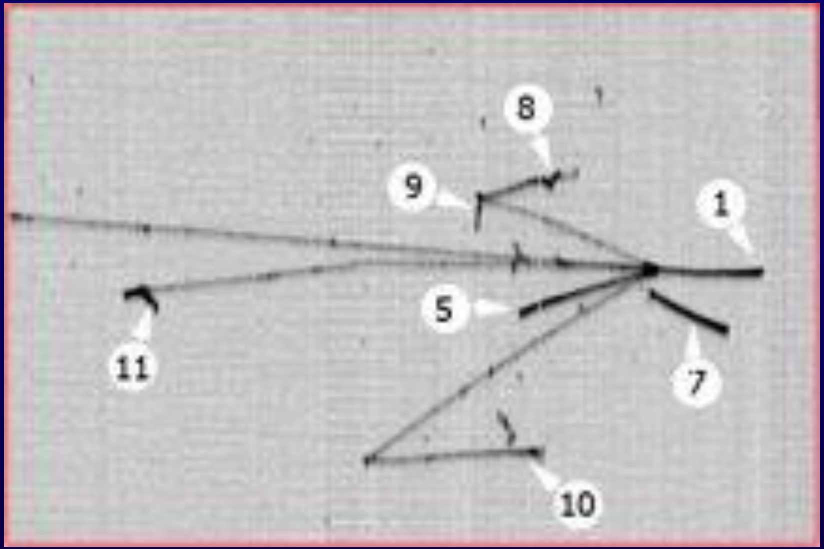
Superkamiokande Neutrino Detector (Japan)



Do you know what the Detector is made of?

ice

ICARUS Bubble Chamber

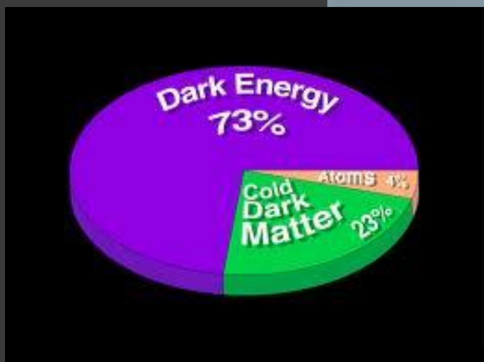


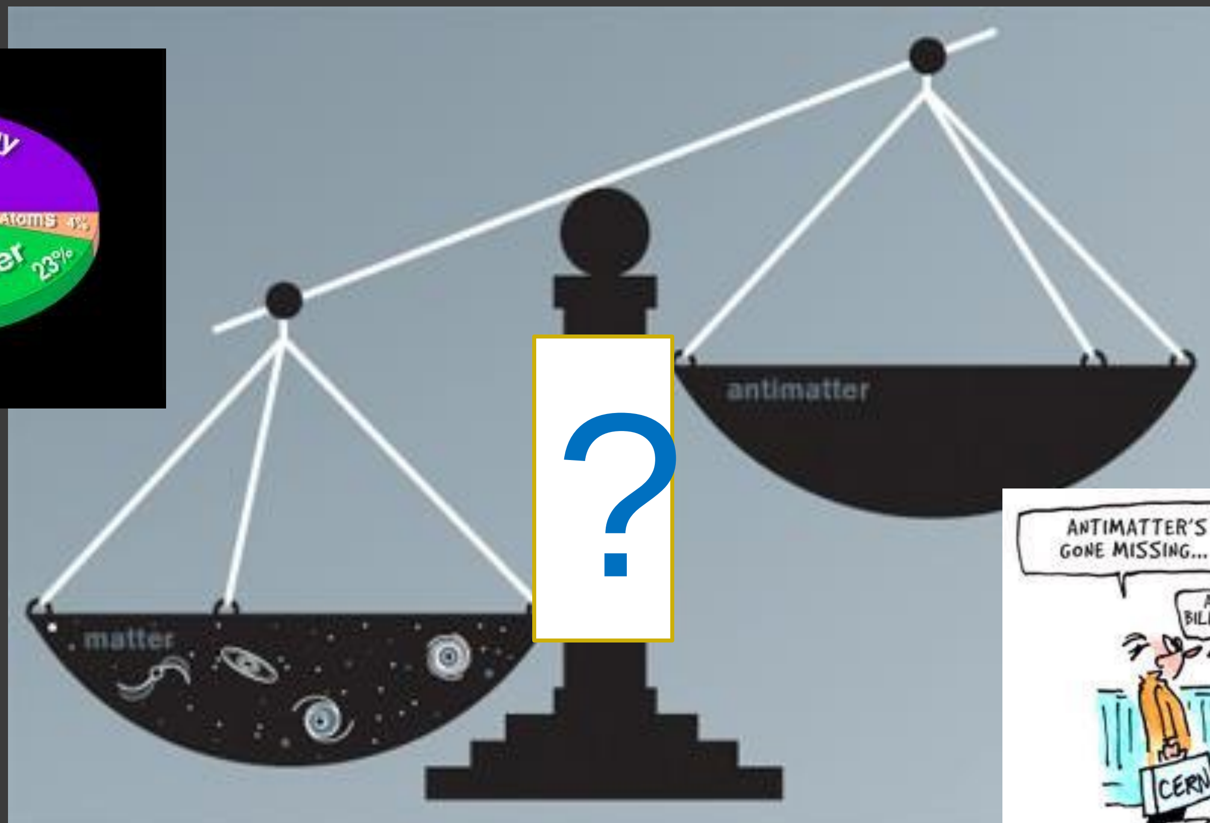
Track	E_{dep} [MeV]	range [cm]
1(p)	185±16	15
5(p)	192±16	20
7(p)	142±12	17
8(π)	94±8	12
9(p)	26±2	4
10(p)	141±12	23
11(p)	123±10	6

Shown at NEUTRINO-2012
In Kyoto by F. Pietropaolo

Nice

Baryon Asymmetry of the Universe (BAU)

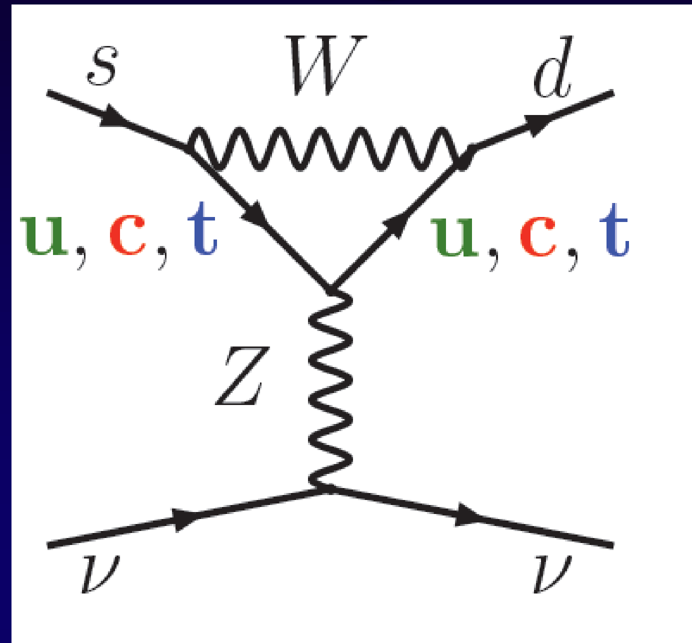




$n_{quark}-n_{antiquark}/n_{quark}$ (Proto Universe) ~n_{baryon}/n_{photon} (Today)~**5×10^{-10}**

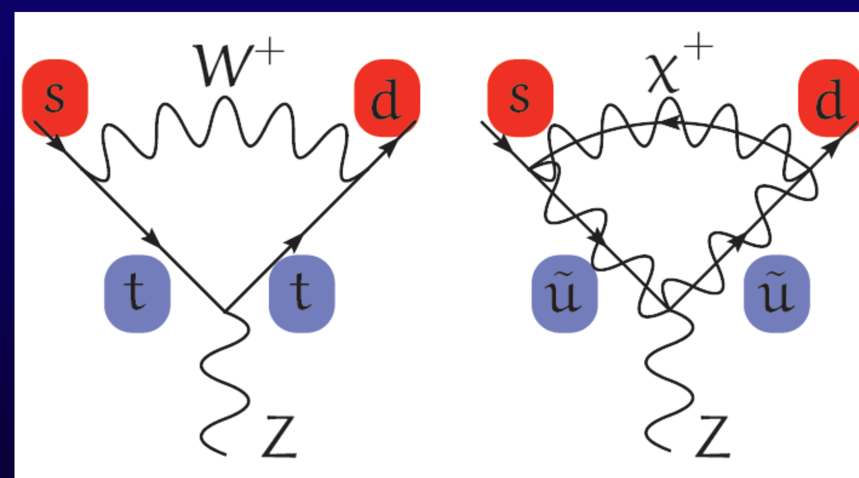
Ultra-rare K Decays

$$K \rightarrow \pi \nu \bar{\nu}$$



- The contribution to these processes due to the Standard Theory is **strongly suppressed (<10^{-10})** and **calculable with excellent precision (~%)**

- They are very sensitive to possible contributions from **New Physics**



Ultra-Rare *K* decay experiment

CERN-SPS

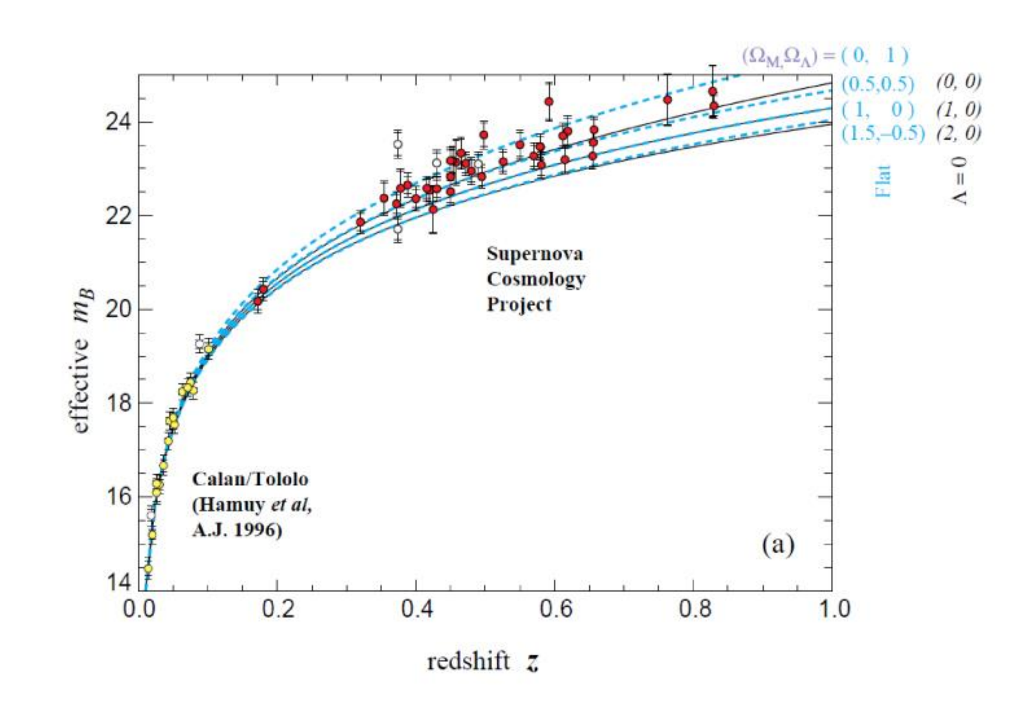
Nice

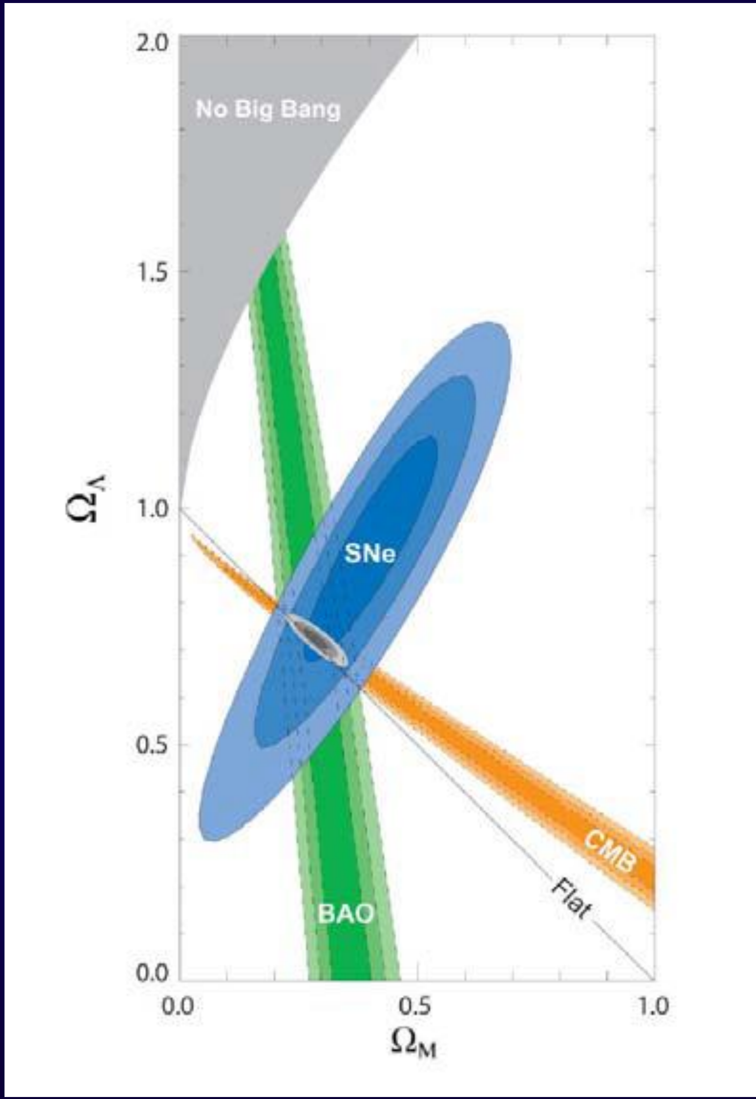
Dark Matter? Dark Energy

- **Dark Matter** is matter that emits minimal to no light. Its evidence comes, for instance, from the orbits of galaxies in galaxy clusters
- **Dark Energy** is the term used to explain the accelerating expansion of the Universe (Cosmological Constant?)

2011 Nobel Prize in Physics

Accelerating Universe





S. Perlmutter, B.P. Schmidt, A.G. Riess

Nice

Dark Matter and Gravitational Lensing