

A large, glowing, spiral galaxy with a bright yellow core, set against a dark blue background. The galaxy's spiral arms are composed of numerous small, bright blue and white stars, creating a dense, swirling pattern. The central core is a bright, yellowish-white glow, indicating a high concentration of stars and possibly a supermassive black hole. The overall appearance is that of a classic spiral galaxy, possibly a barred spiral galaxy, viewed from an angle that shows its three-dimensional structure.

Particles and the Universe

Particle Physicists

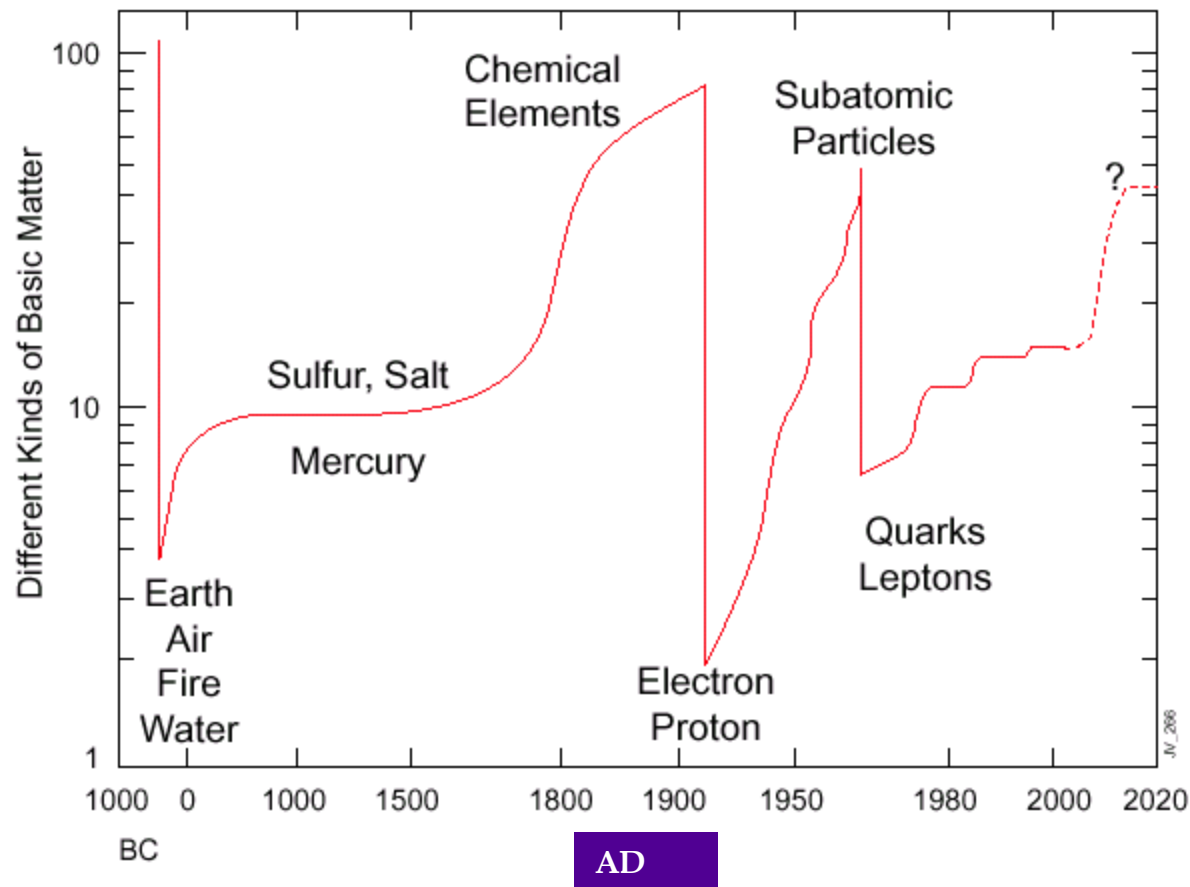
which to understand:

What are the
fundamental
constituents of
matter?

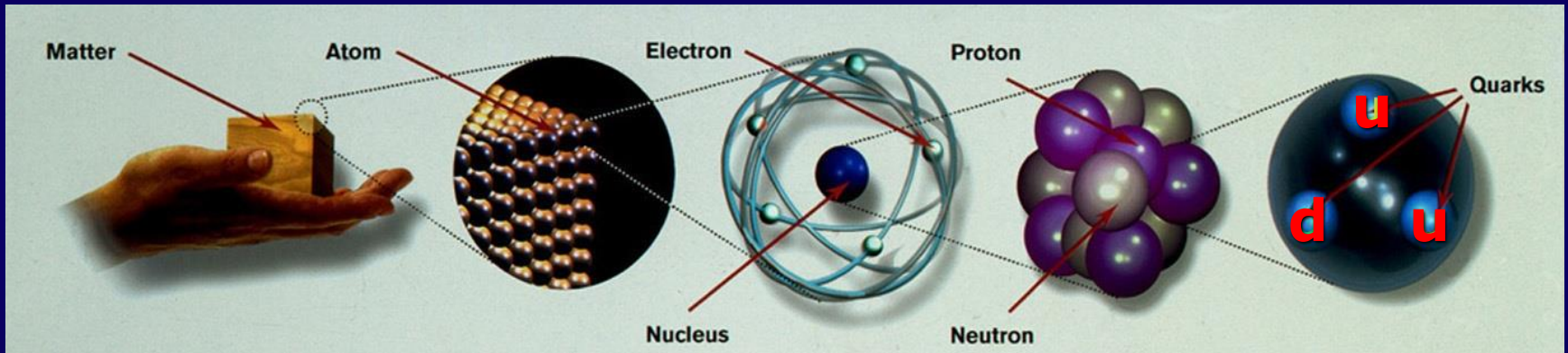
Which are the fundament
interactions among particles?
How does the world function?



“Elementary” particles as a function of time...



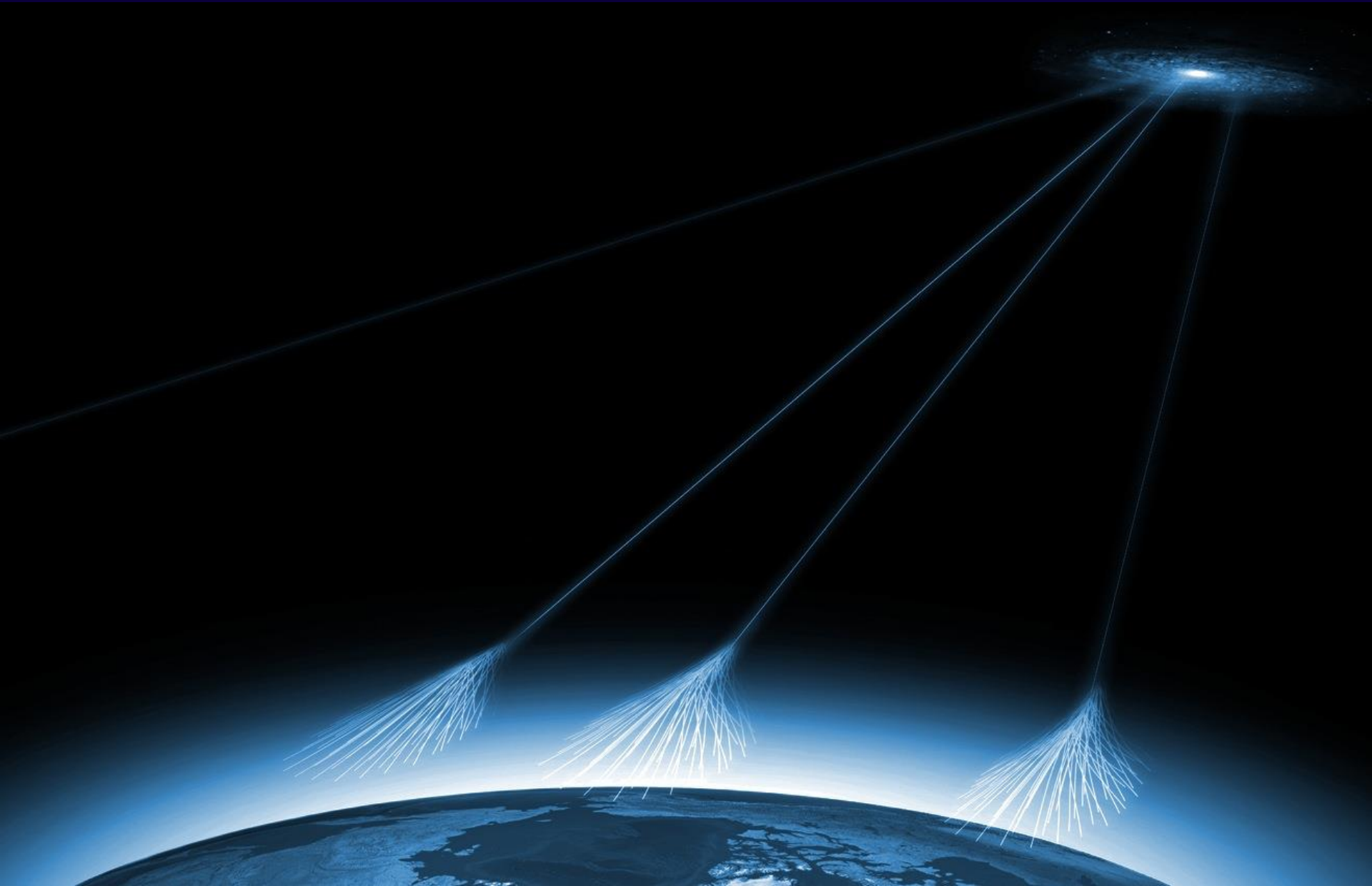
Constituents of matter



Bound State of **3 quark** = Baryon

Bound State **quark anti-quark** = Meson

Cosmic Rays

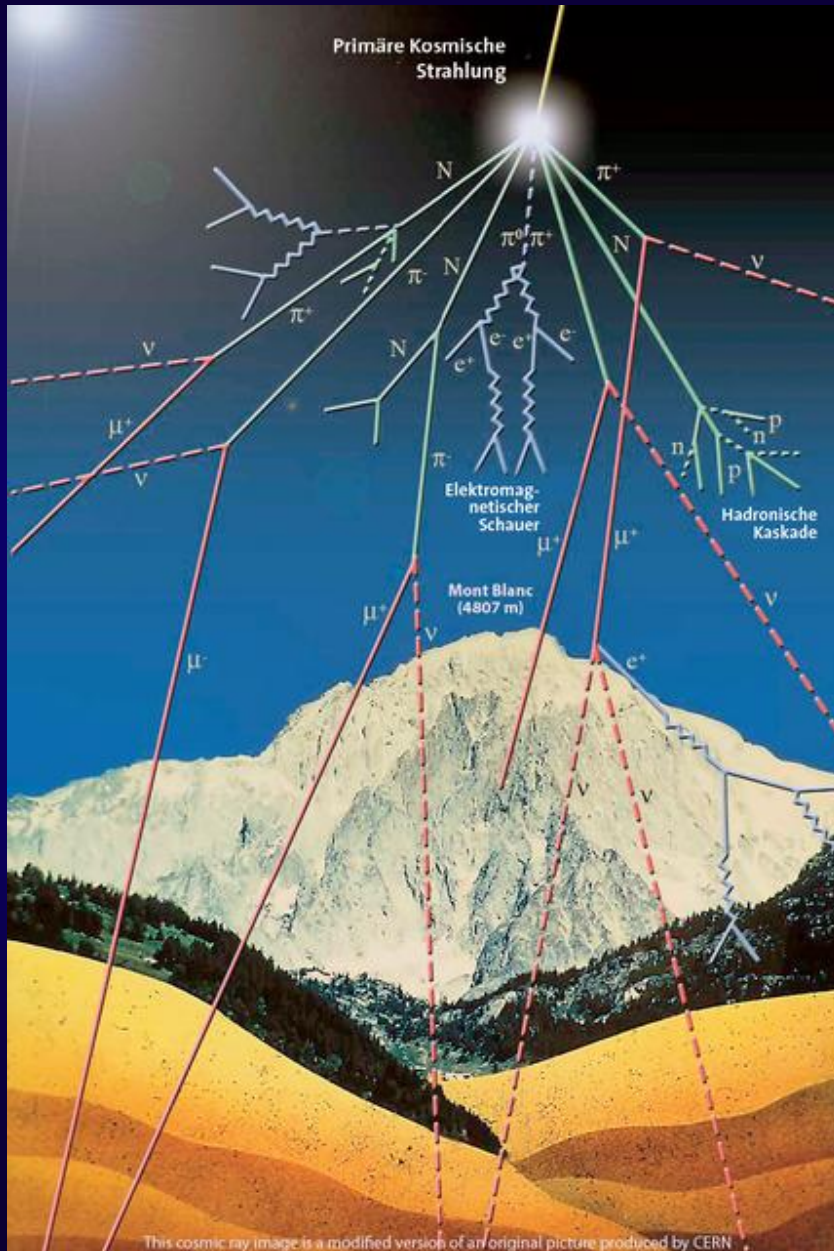


What does it come from the sky?



Nice

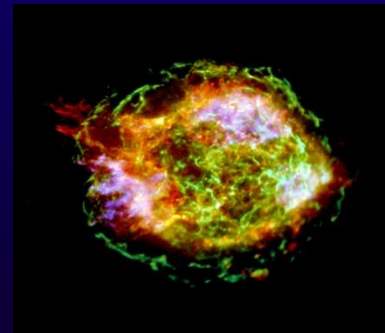
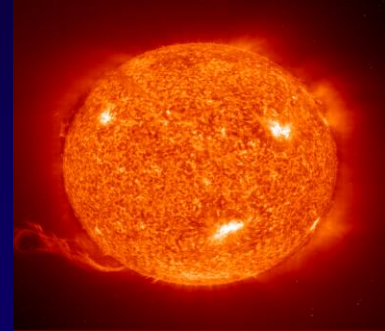
How do we measure cosmic rays?



200 particles / m^2 / s

From where?

- From our Sun
- From Galaxies
- From Supernovae



Spark Chamber



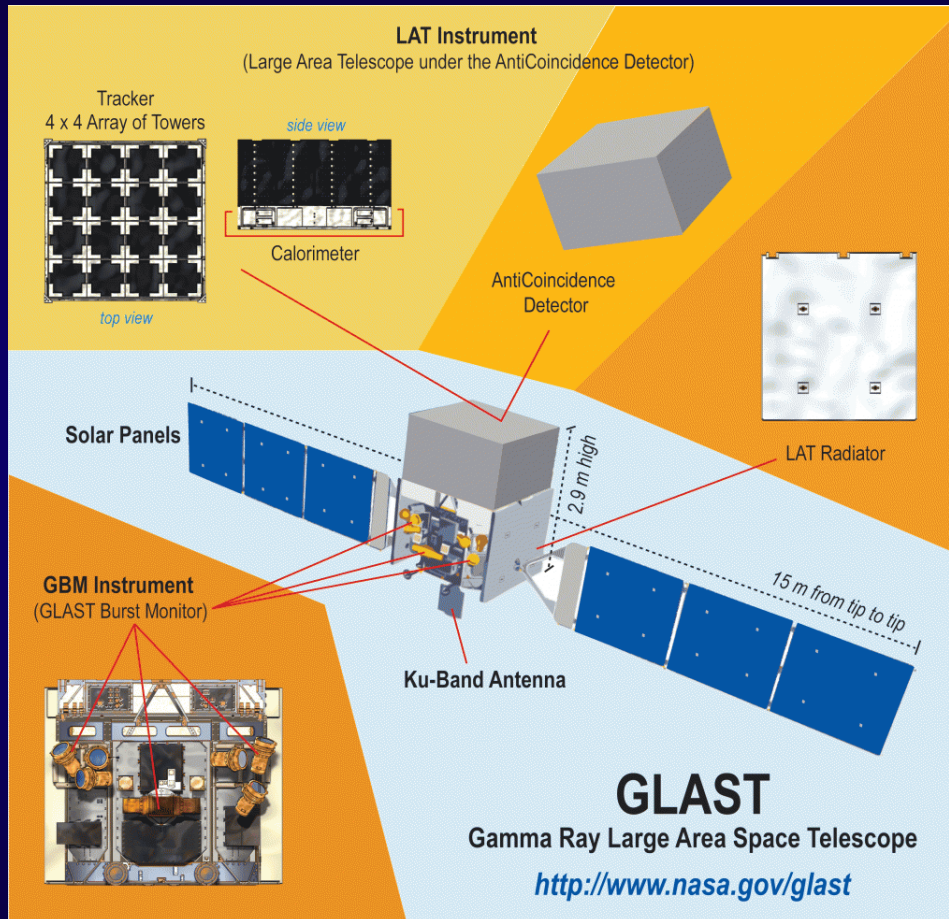
Nice

Cloud Chamber

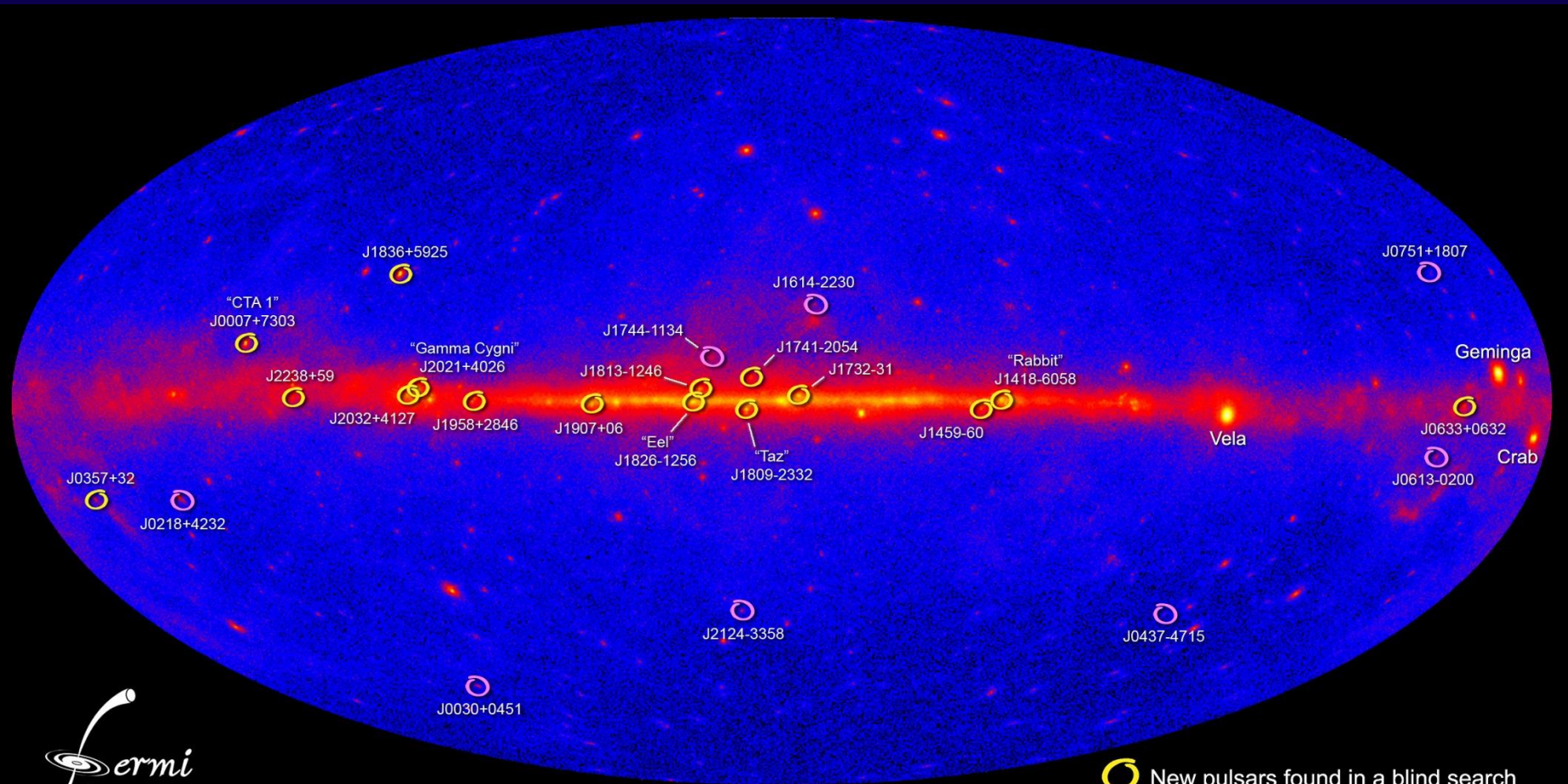


Nice

Fermi Telescope



Map of gamma rays from Fermi



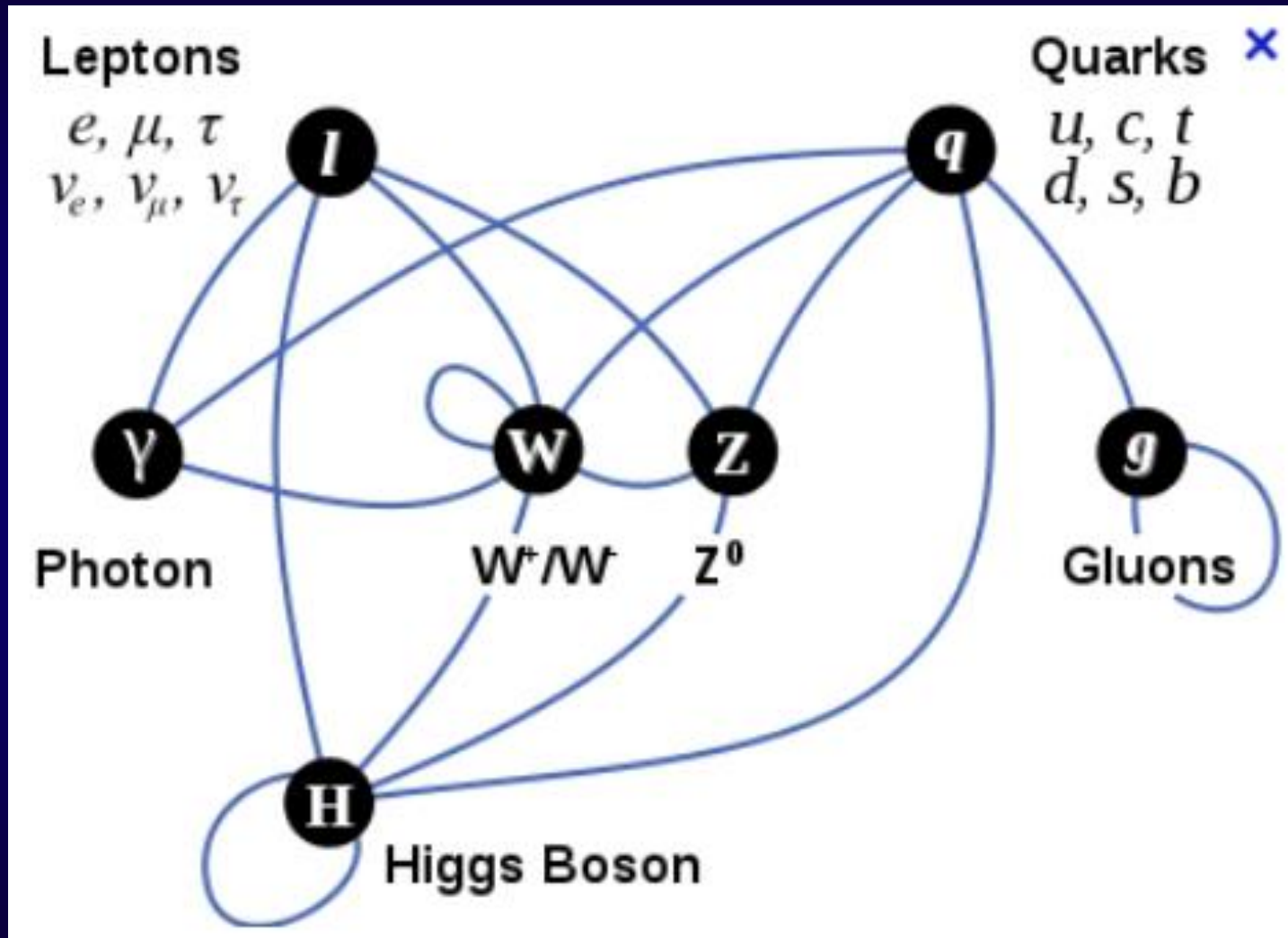
The "Standard Model"

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

		Fermions (Matter)			Bosons			
<p>$Q = +2/3 q_e$</p> <p>$Q = -1/3 q_e$</p> <p>$Q = 0$</p> <p>$Q = - q_e$</p>	Quarks	$\sim 3 \text{ MeV}$	1.3 GeV	173 GeV	elettromagnetiche		Interactions	<p>$1 \text{ keV} = 10^3 \text{ eV}$</p> <p>$1 \text{ MeV} = 10^6 \text{ eV}$</p> <p>$1 \text{ GeV} = 10^9 \text{ eV}$</p> <p>$m_p \sim 938 \text{ MeV}$</p>
		u up	c Charm	t top	γ photon			
		d down	s strange	b bottom	strong			
					g gluon			
	Leptons	$\sim 5 \text{ MeV}$	$\sim 100 \text{ MeV}$	4.2 GeV	Weak (charged)			
		ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson			
	511 keV	105 MeV	1.8 GeV	Weak (neutral)				
	e electron	μ muon	τ tau	Z Z boson				
				Higgs boson				
Generation		I	II	III				

Nice

Particle Interactions



CERN: European Organization for Nuclear Research

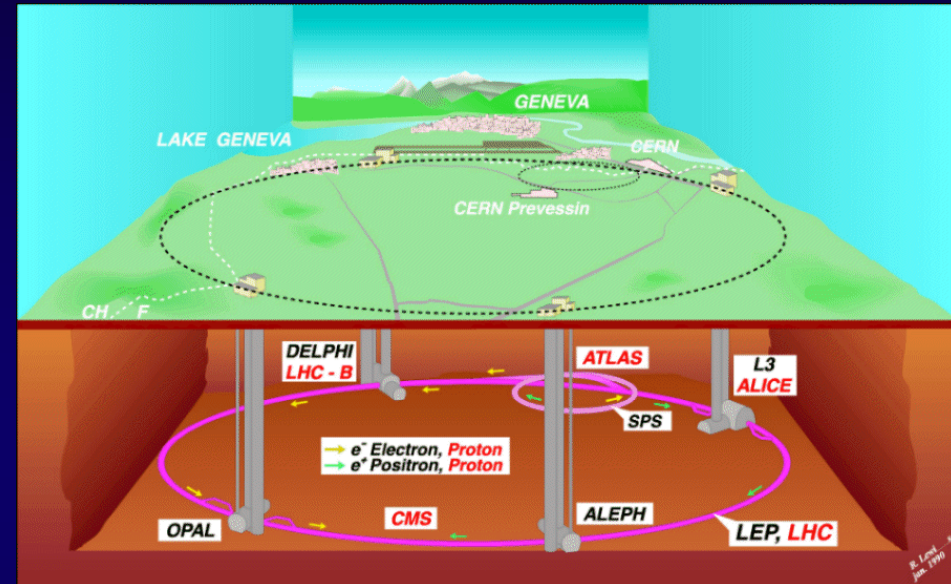
The Twenty Member States of CERN



Member States (Dates of Accession)

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

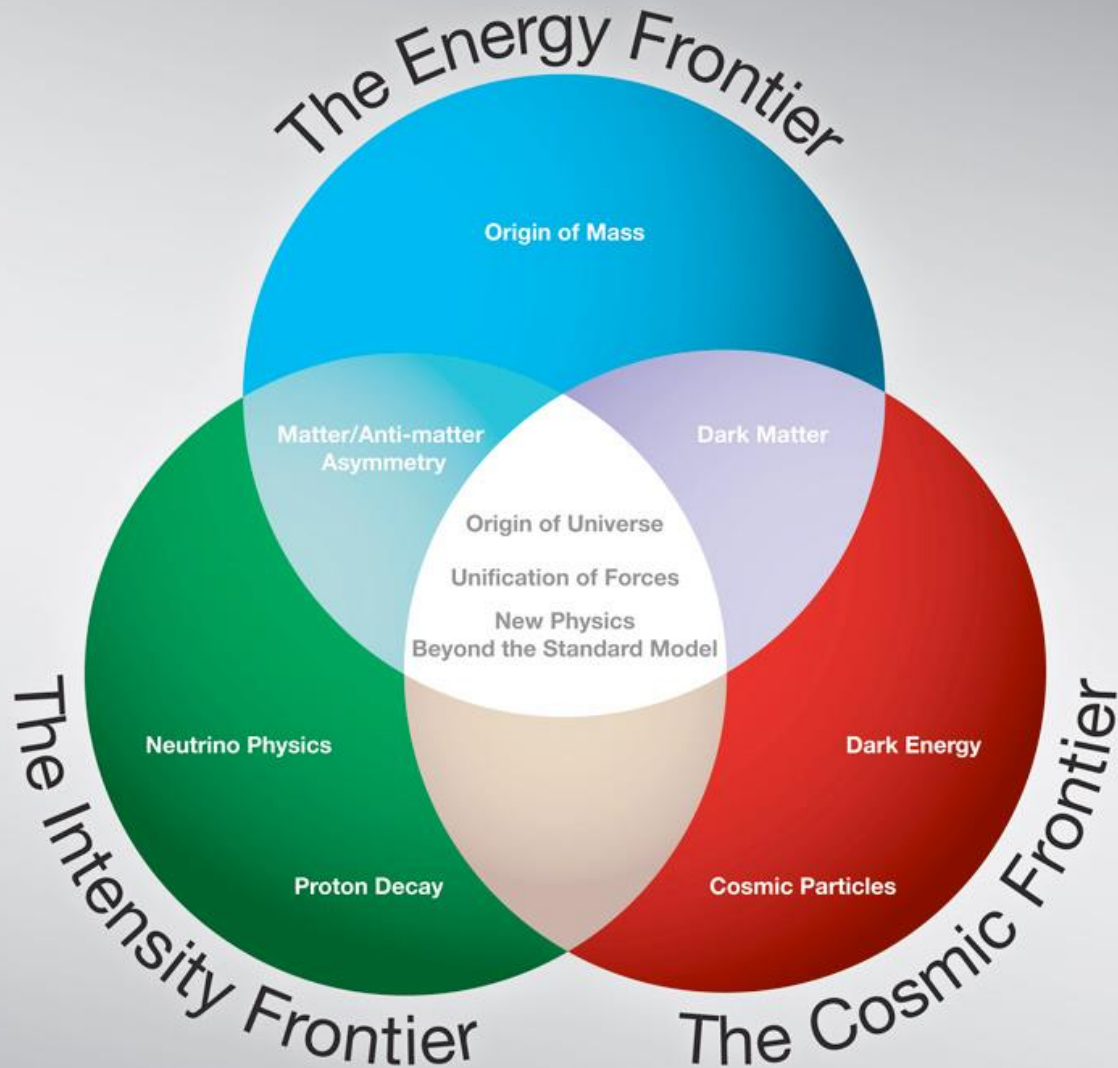
21 Stati membri



Presso Ginevra a cavallo fra Svizzera e Francia

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

Three Frontiers



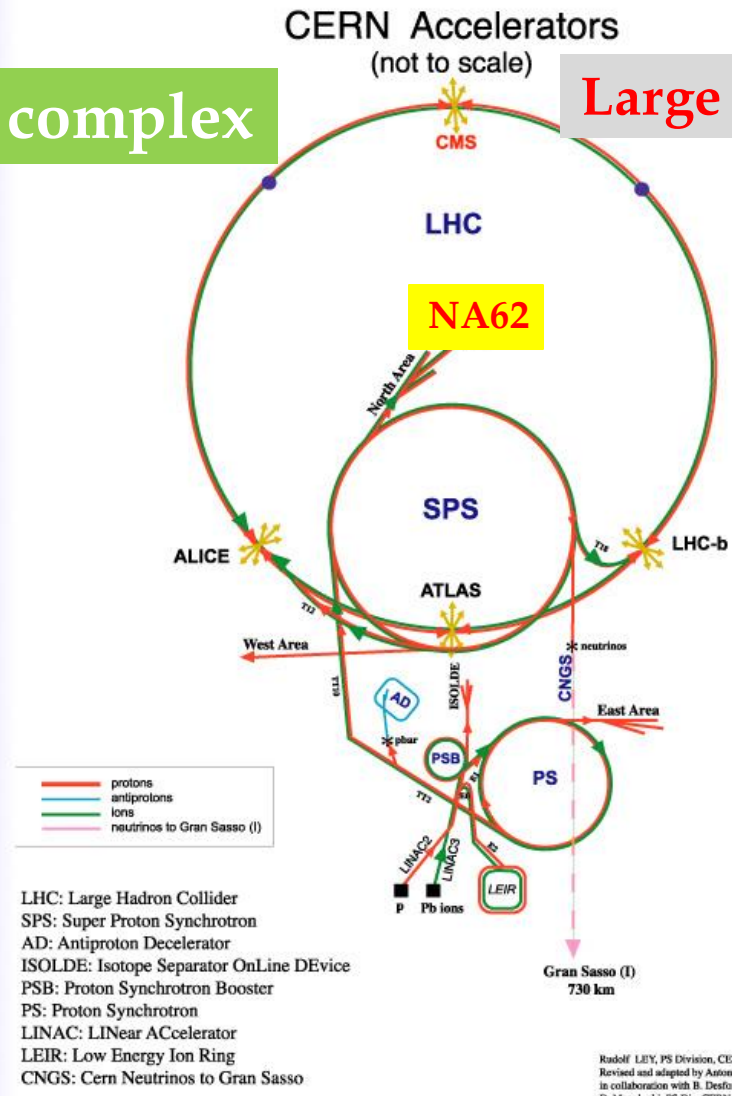
CERN Accelerators

A unique complex

Large Hadron Collider

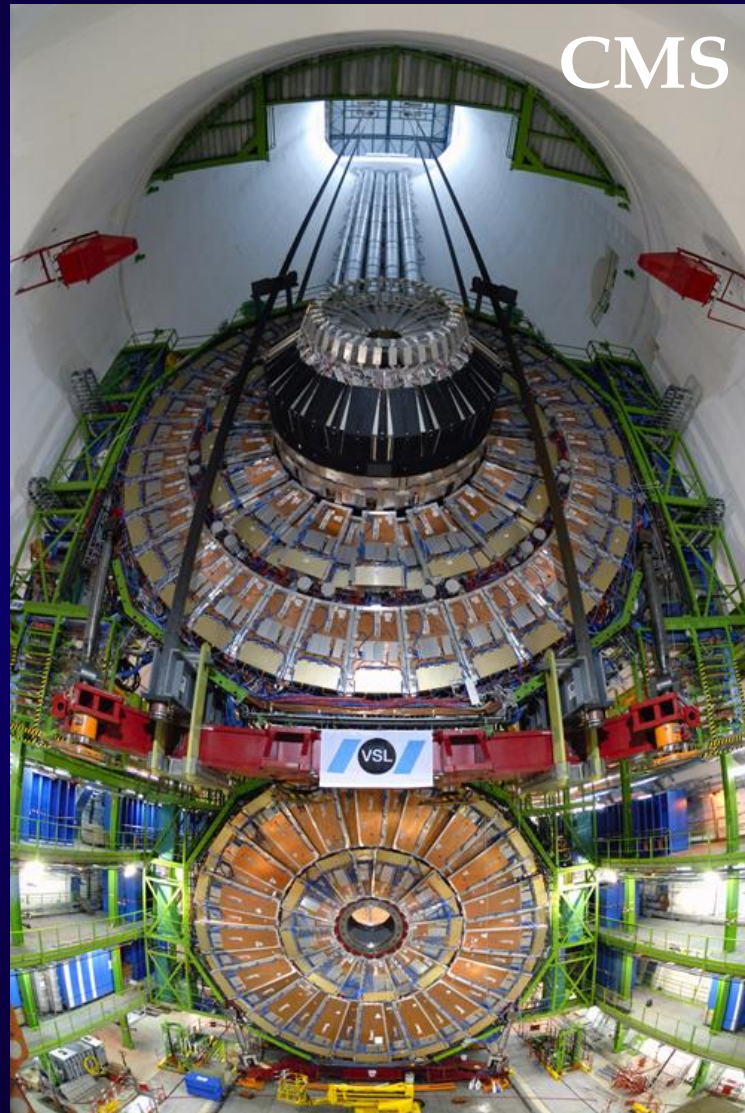
Extracted beams:
Muon, K, Ions, p

Neutrinos to
Gran Sasso
(until 2012)



Rudolf LEY, PS Division, CERN, 02.09.96
Revised and adapted by Antonella Del Rosso, ETT Div
in collaboration with B. Desforges, SI, Div., and
D. Manglinski, PS Div. CERN, 23.05.01

Example of LHC Detector: CMS

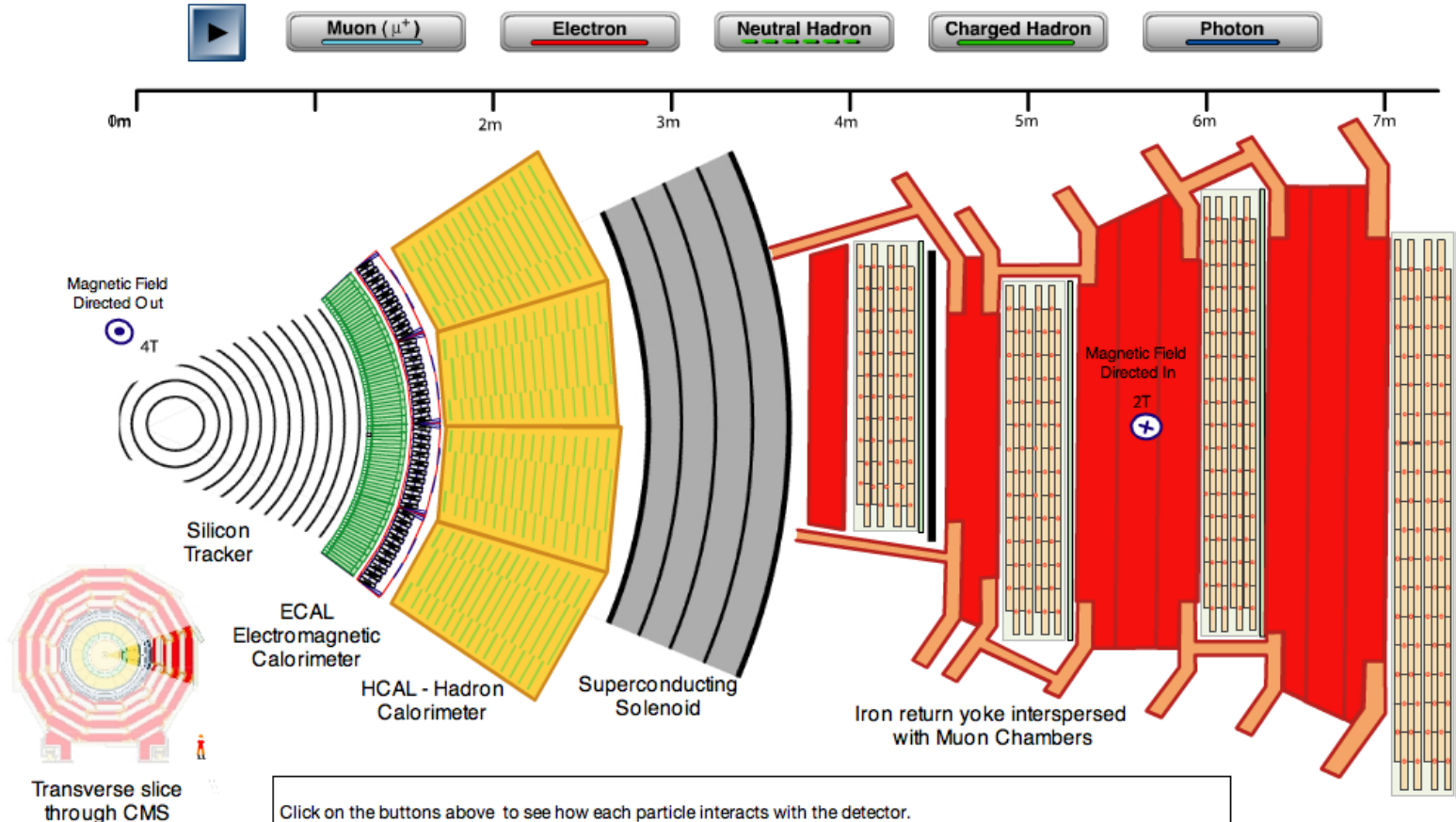


**Detectors are instruments
That enable us to record the
Results of the collisions**

Nice

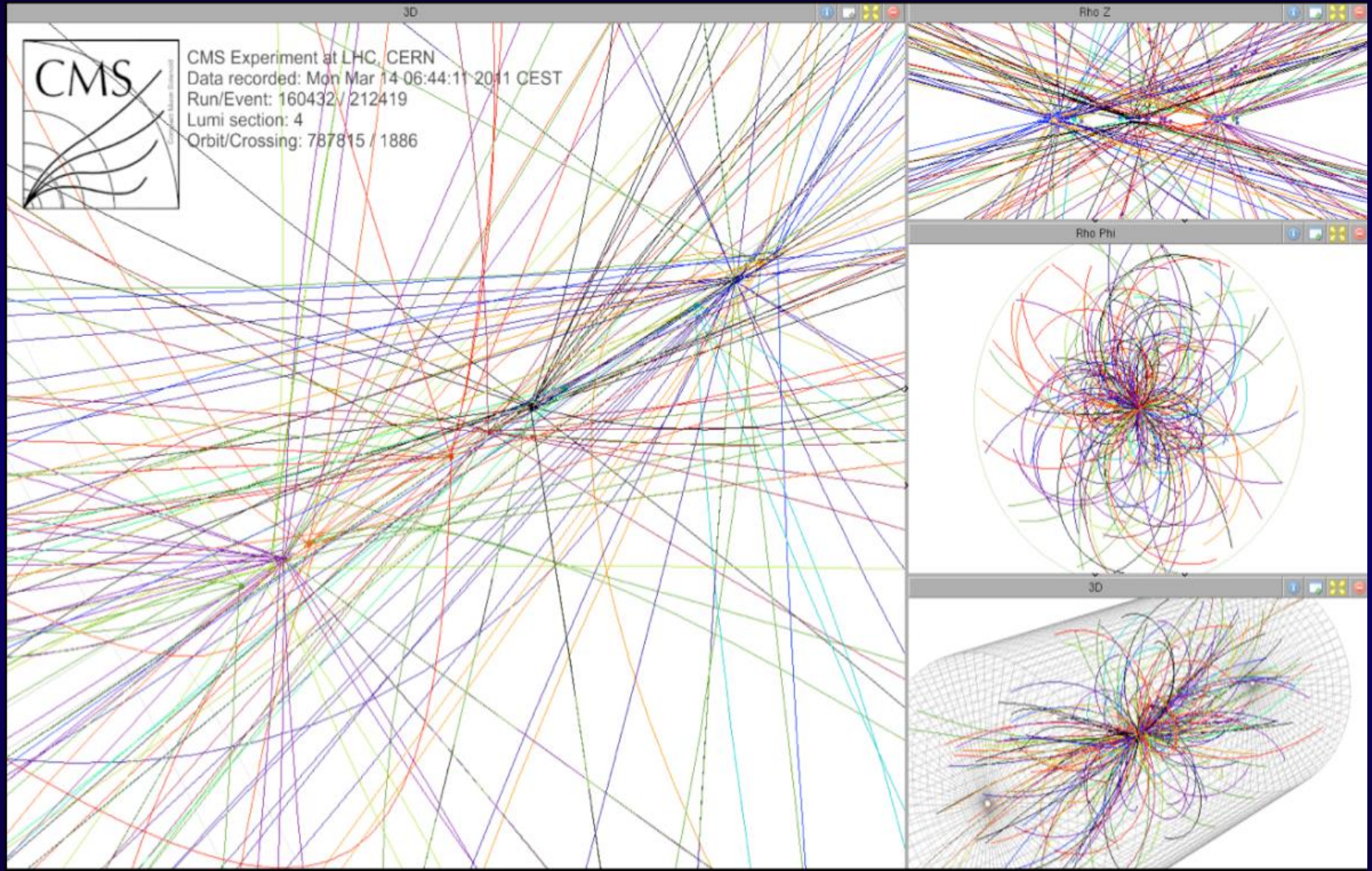
Compact Muon Solenoid (CMS)

Transverse Slice of the Compact Muon Solenoid (CMS)



D. Barney, CERN, 2004

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.....

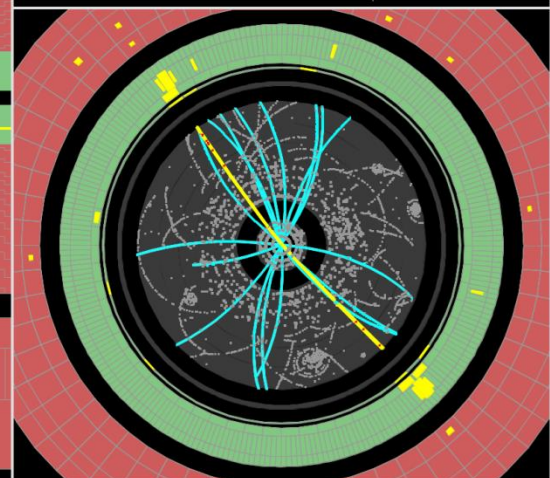
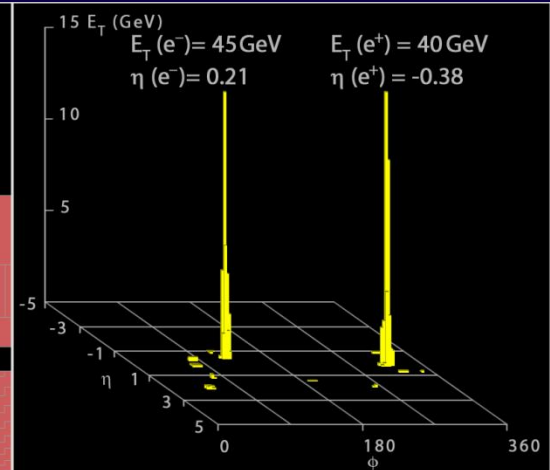
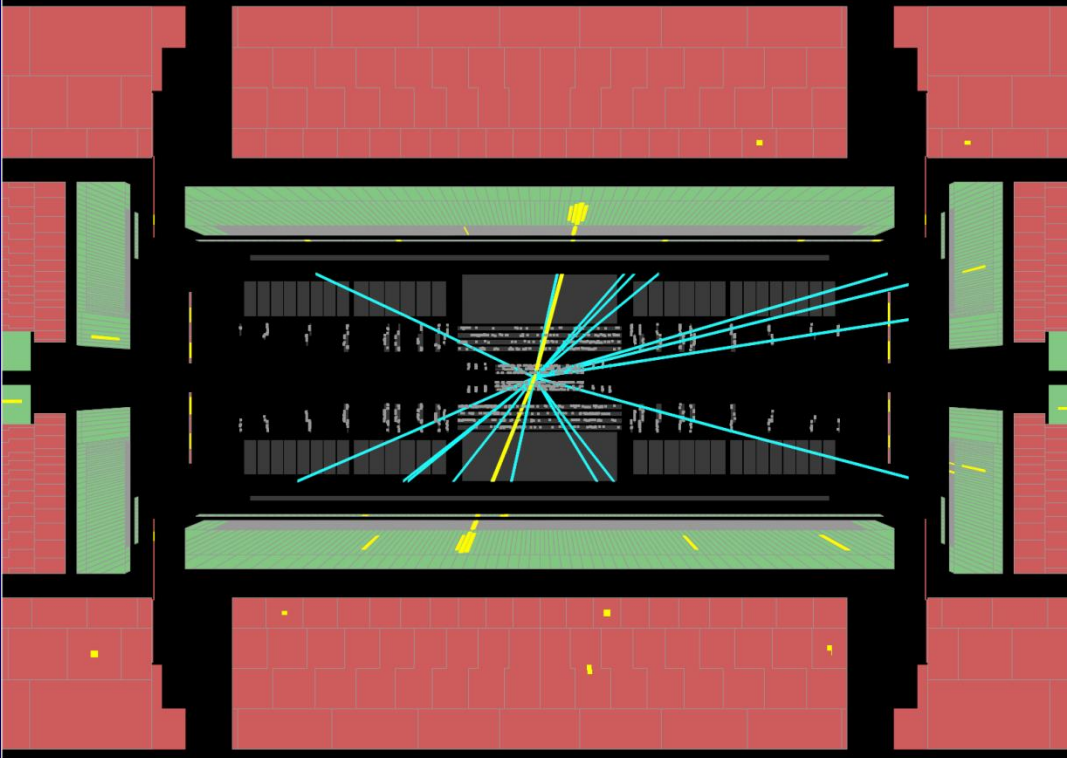


Run Number: 154817, Event Number: 968871

Date: 2010-05-09 09:41:40 CEST

$M_{ee} = 89 \text{ GeV}$

$Z \rightarrow ee$ candidate in 7 TeV collisions

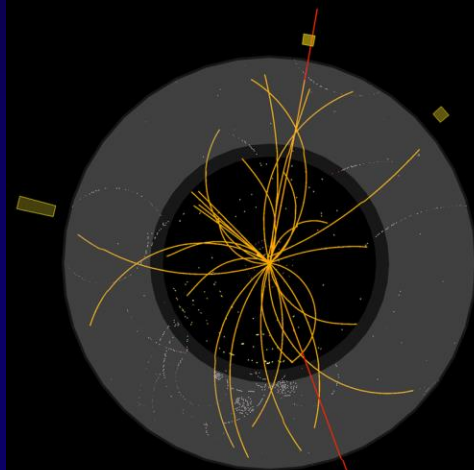


Can you find the electron pair?

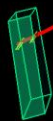
Nice

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

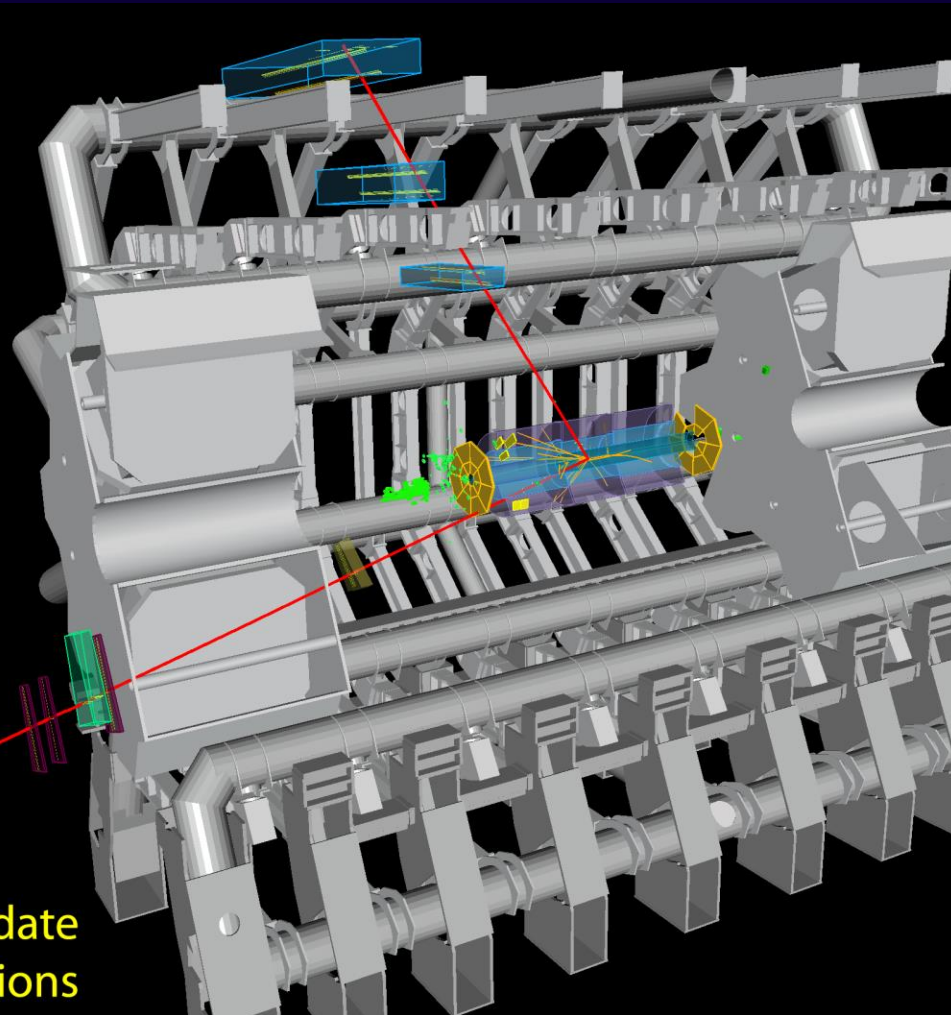
 **ATLAS**
EXPERIMENT
Run: 154822, Event: 14321500
Date: 2010-05-10 02:07:22 CEST



$p_T(\mu^-) = 27 \text{ GeV}$ $\eta(\mu^-) = 0.7$
 $p_T(\mu^+) = 45 \text{ GeV}$ $\eta(\mu^+) = 2.2$
 $M_{\mu\mu} = 87 \text{ GeV}$



$Z \rightarrow \mu\mu$ candidate
in 7 TeV collisions

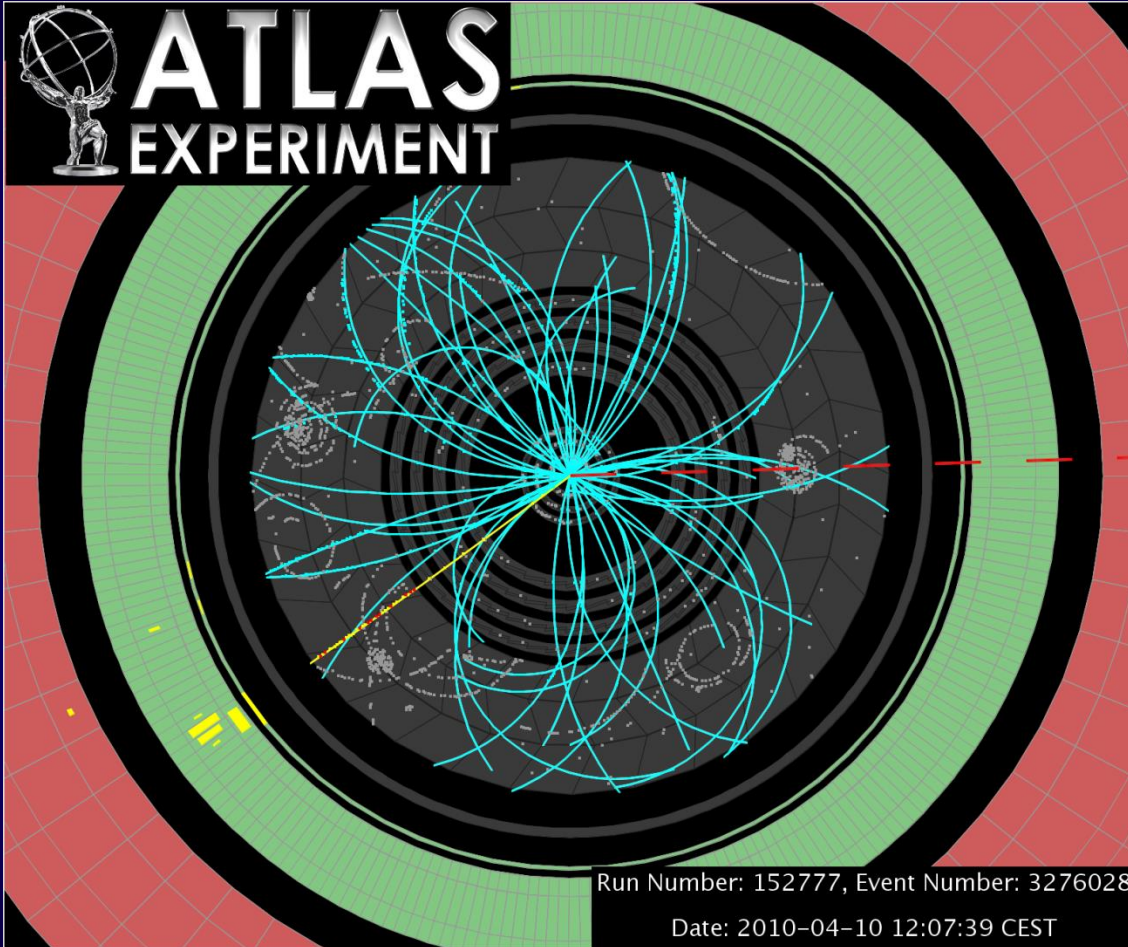


Muons (μ) are like electrons..but ~ 200 times heavier...
Can you explain why they escape from the inner detectors?

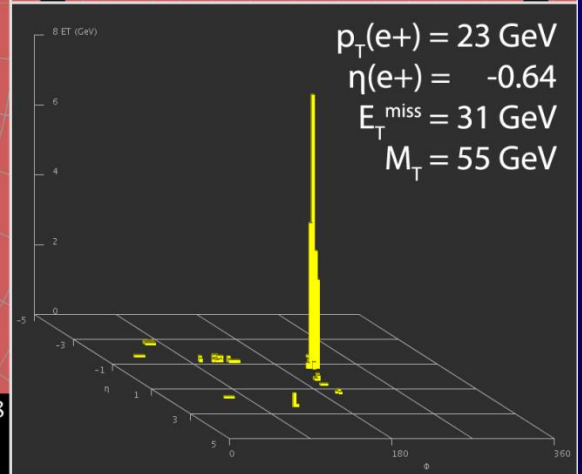
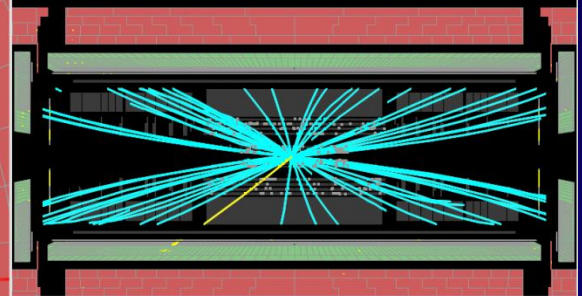
Nice

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

 **ATLAS**
EXPERIMENT



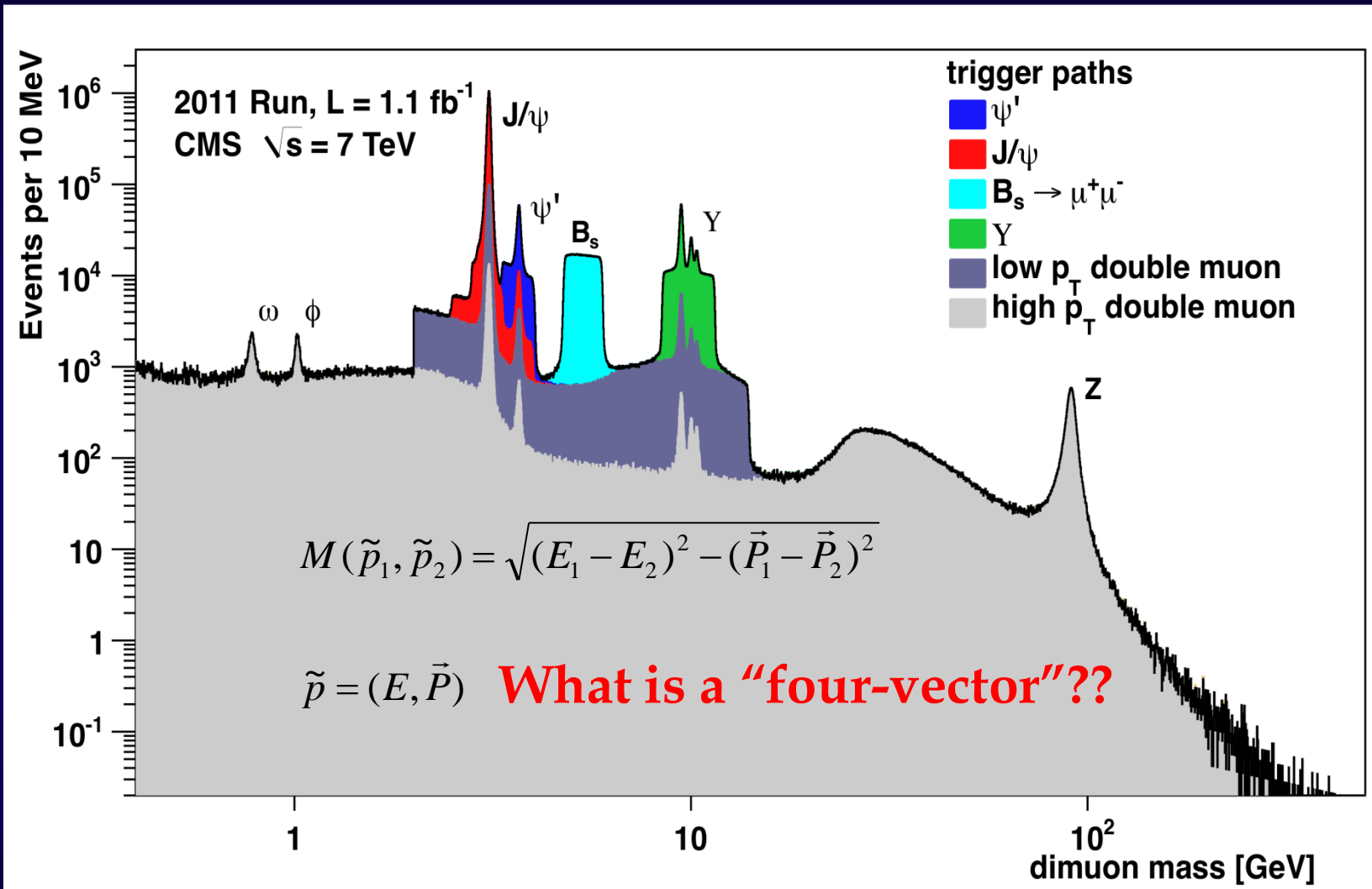
$W \rightarrow e\nu$ candidate in
7 TeV collisions



Can you see the neutrino (ν)???

Nice

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



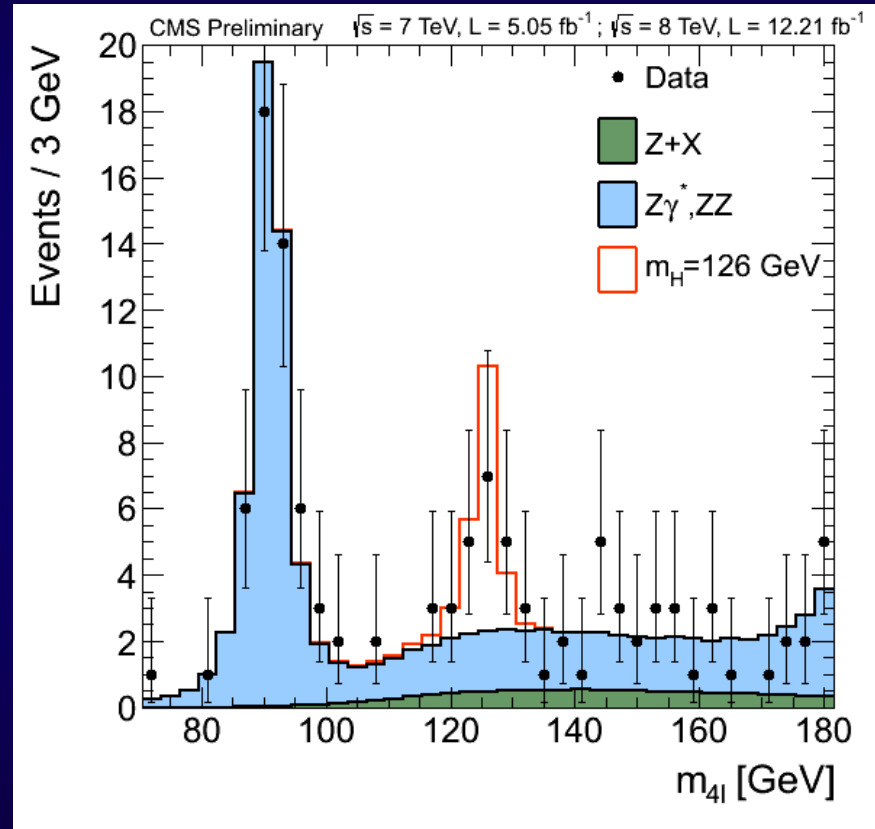
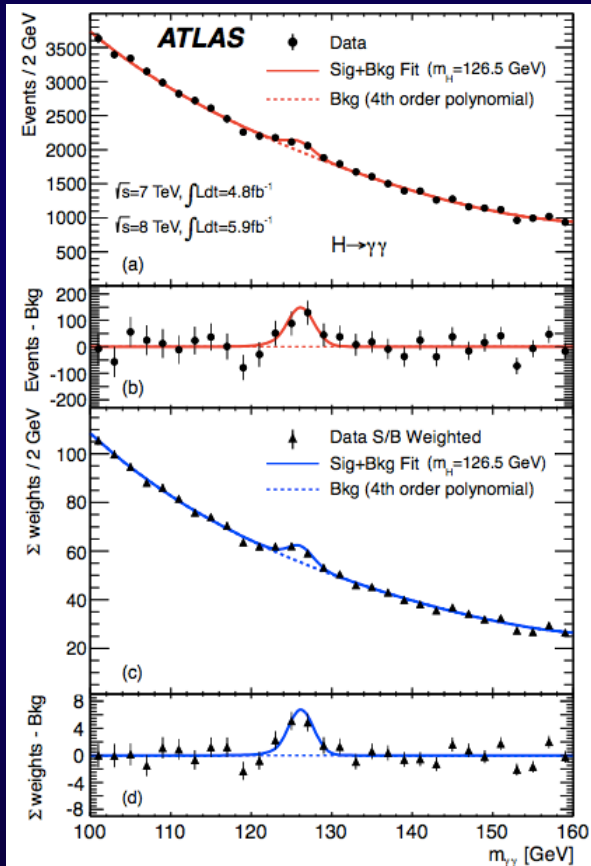
The invariant mass M is a Lorentz scalar: what does it mean?
How many "resonances" can you find?

Nice

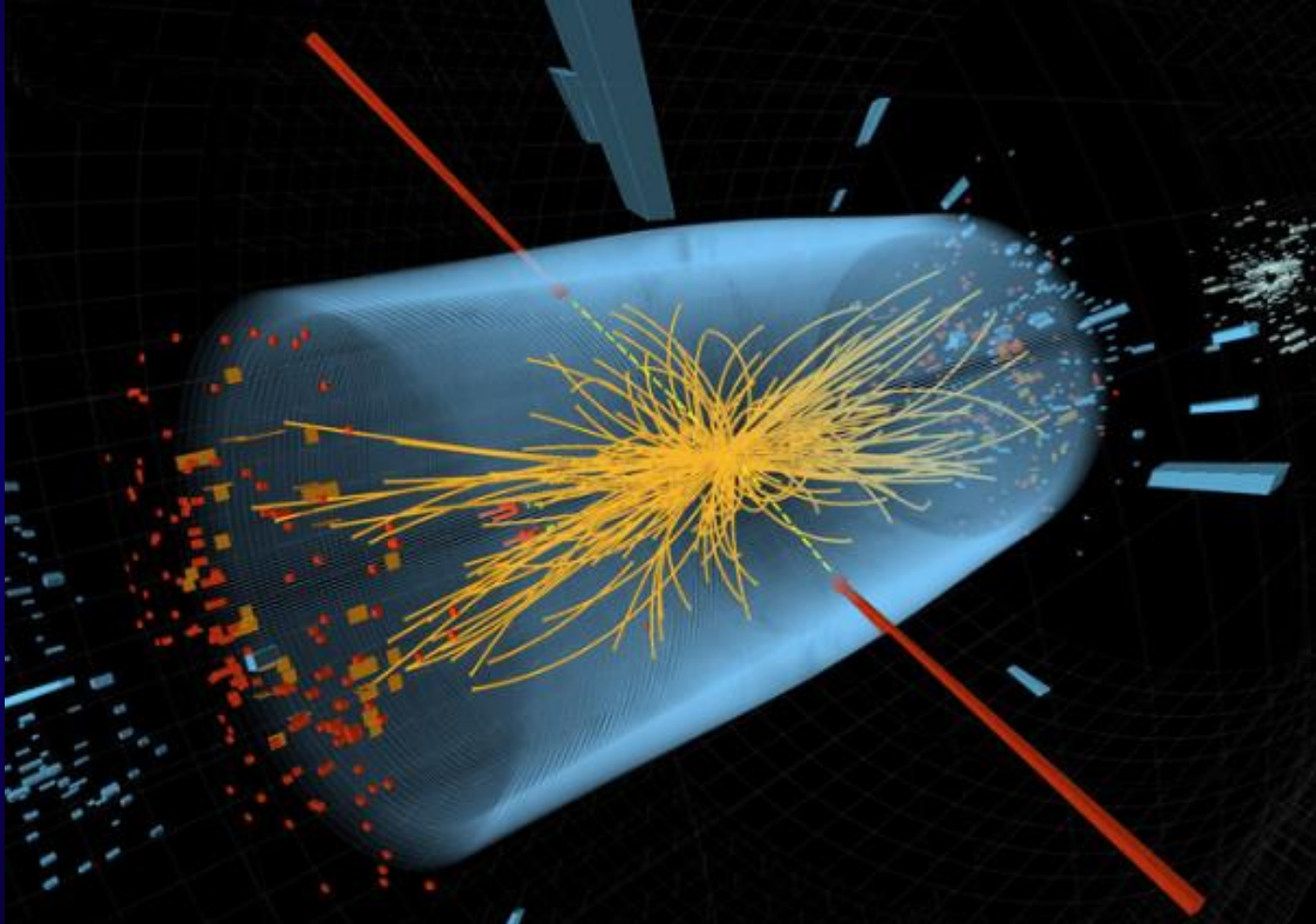
DISCOVERY OF THE HIGGGS

ATLAS

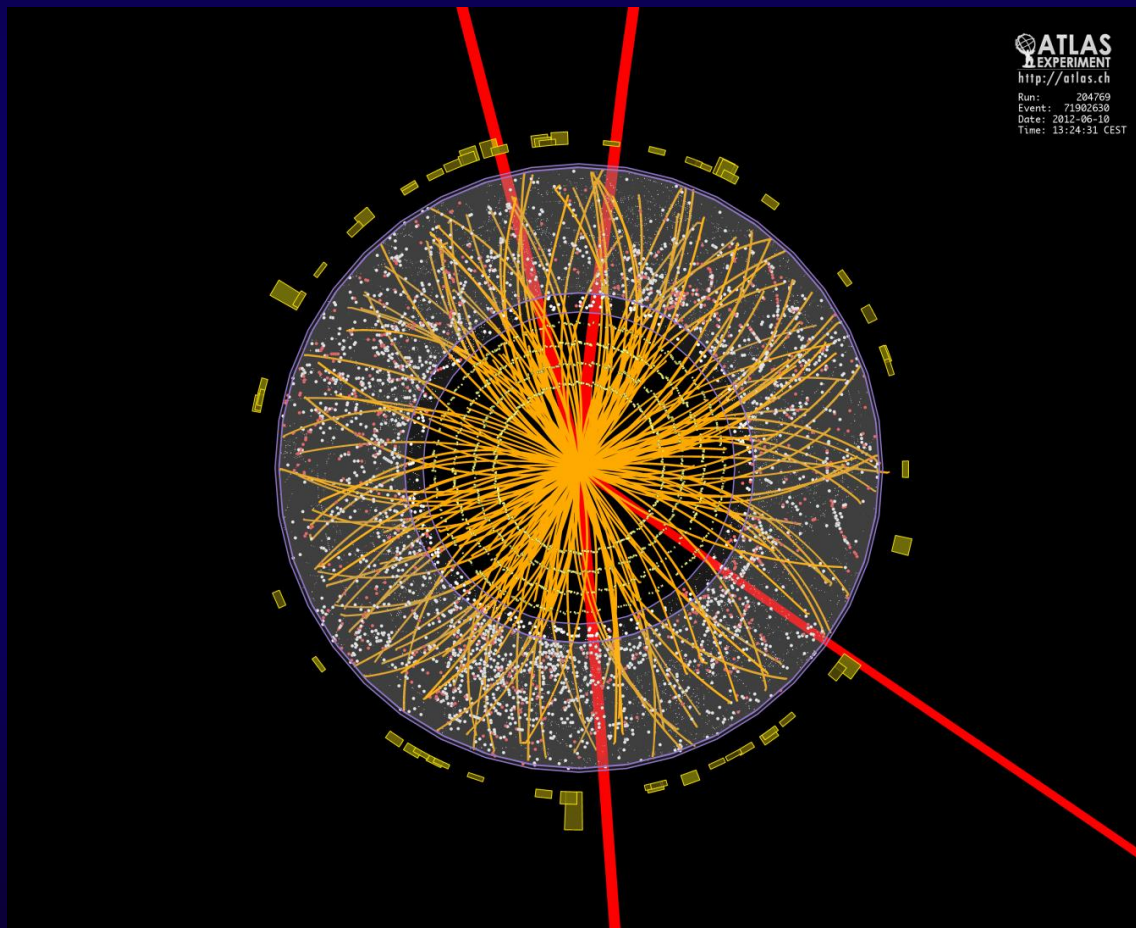
CMS



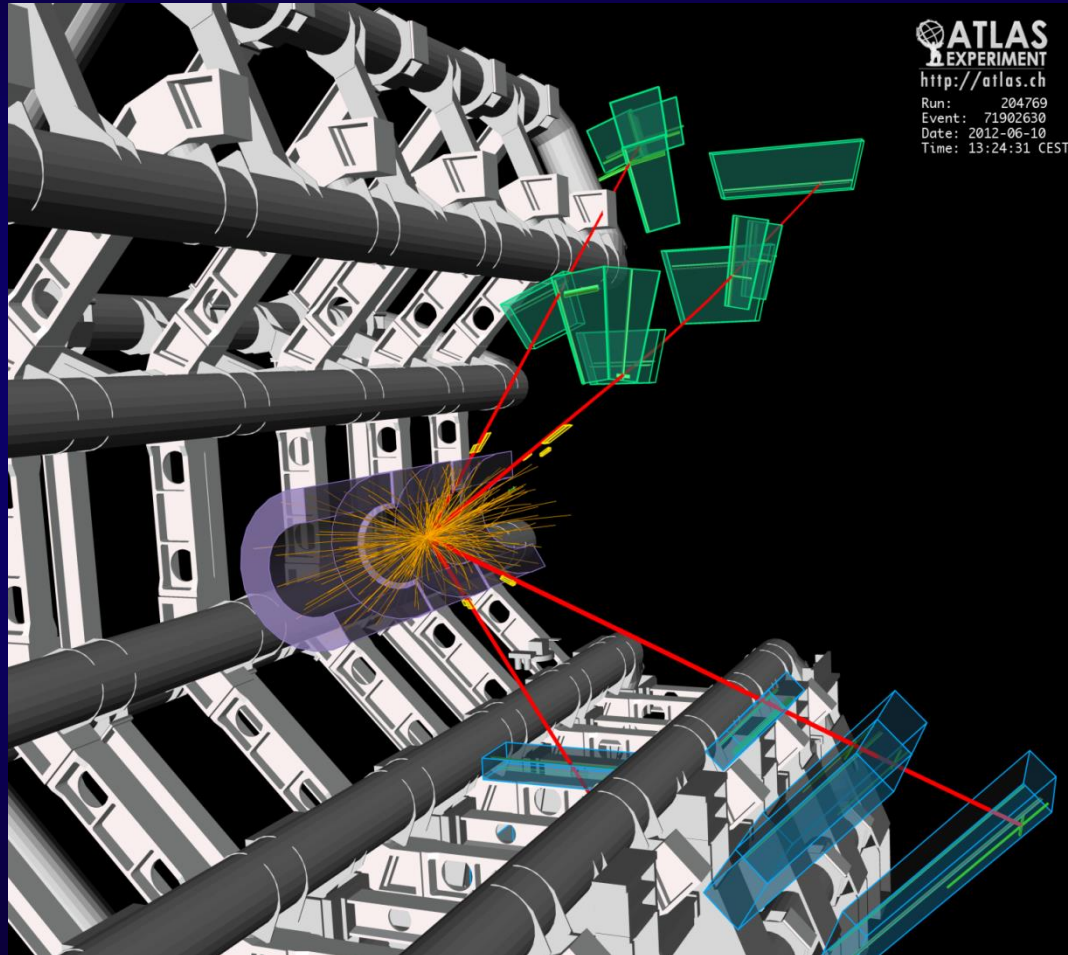
CMS: $H \rightarrow \gamma\gamma$



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

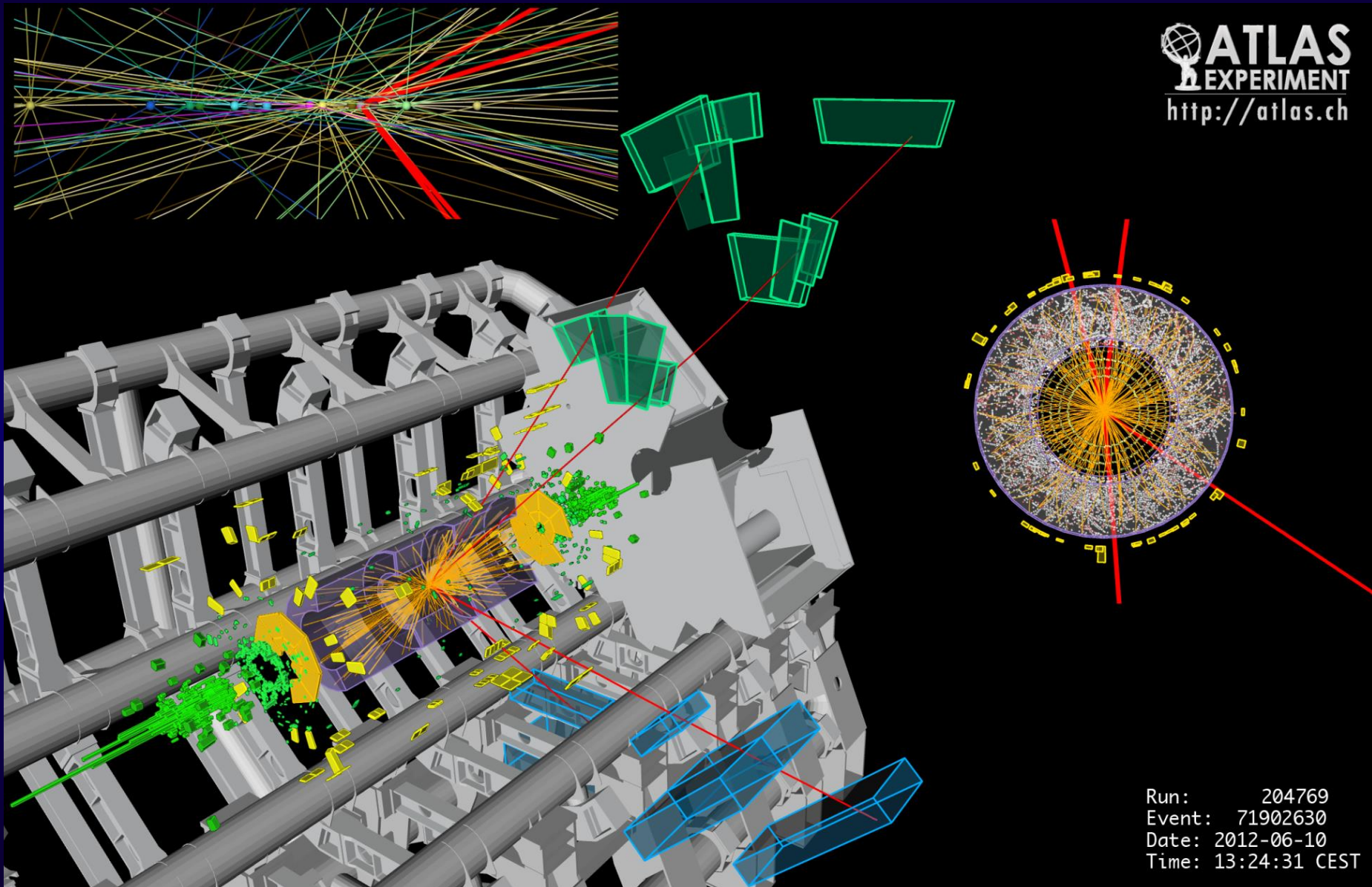


$$H \rightarrow Z Z^* \rightarrow \mu^+ \mu^- \mu^+ \mu^-$$

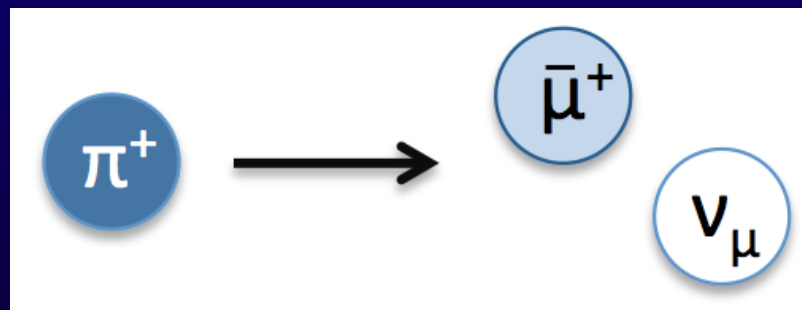
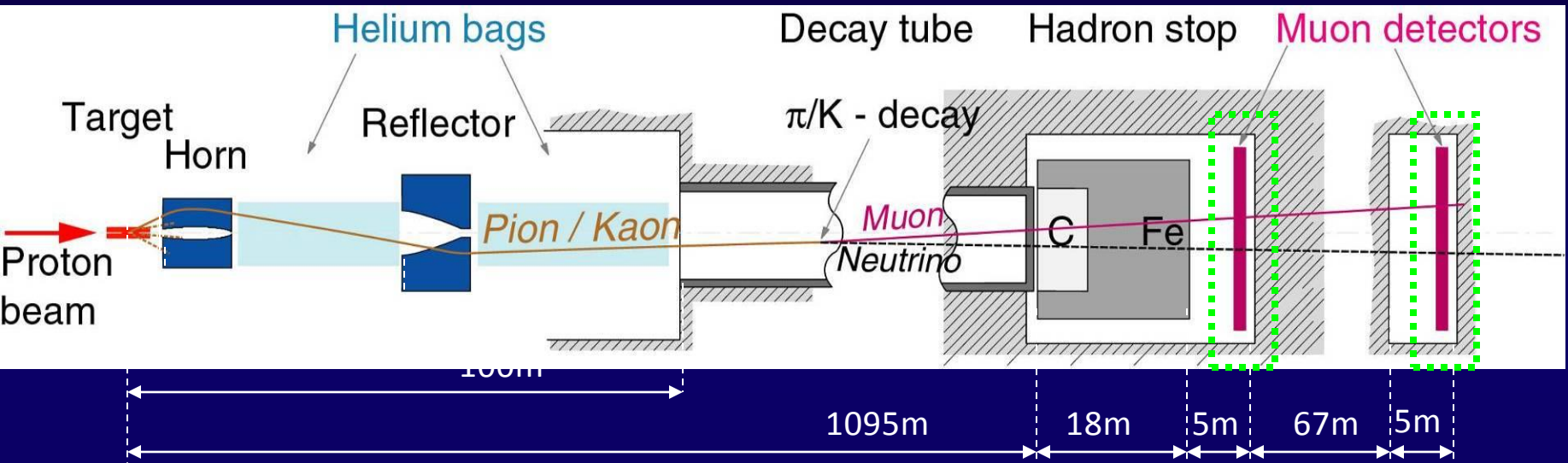


$$H \rightarrow Z Z^* \rightarrow \mu^+ \mu^- \mu^+ \mu^-$$

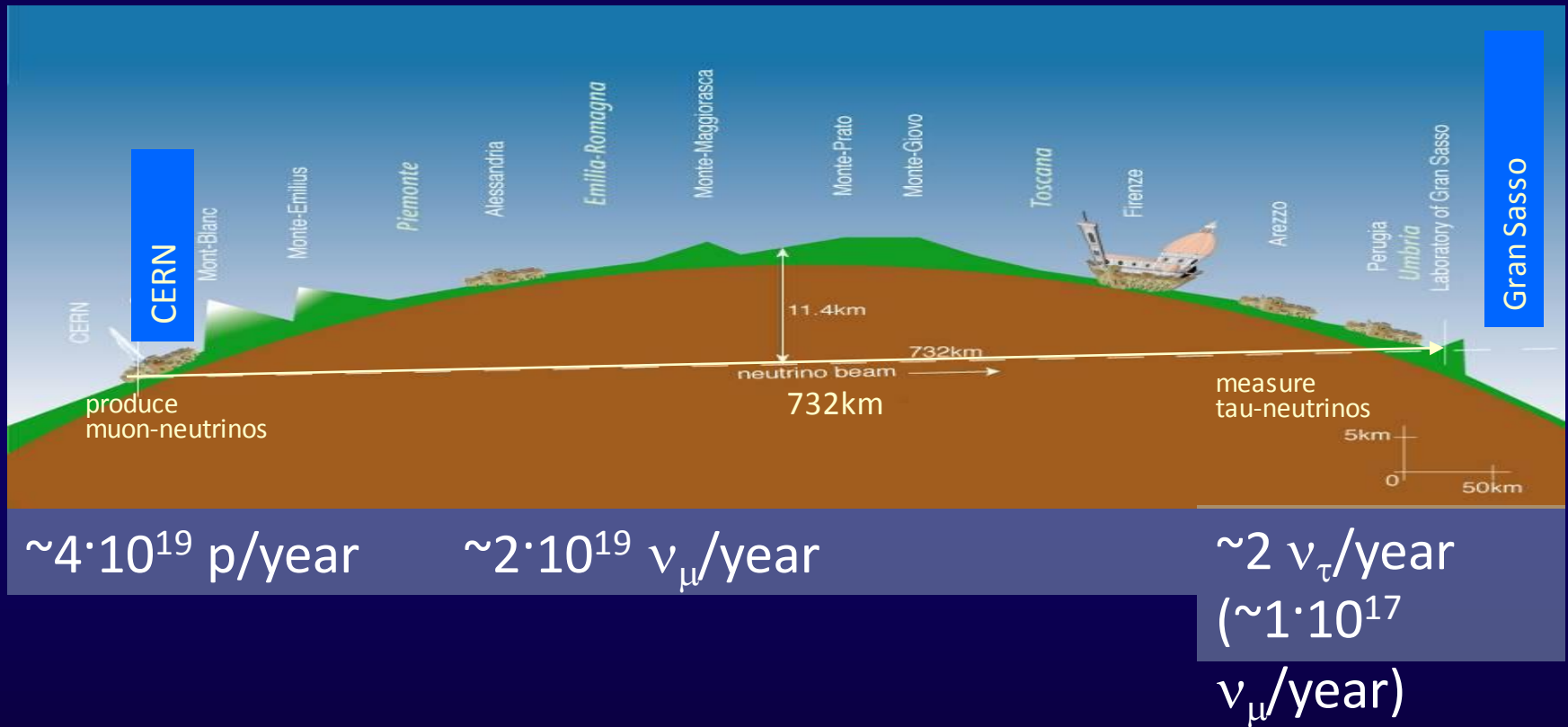

ATLAS
EXPERIMENT
<http://atlas.ch>



How to make a neutrino beam

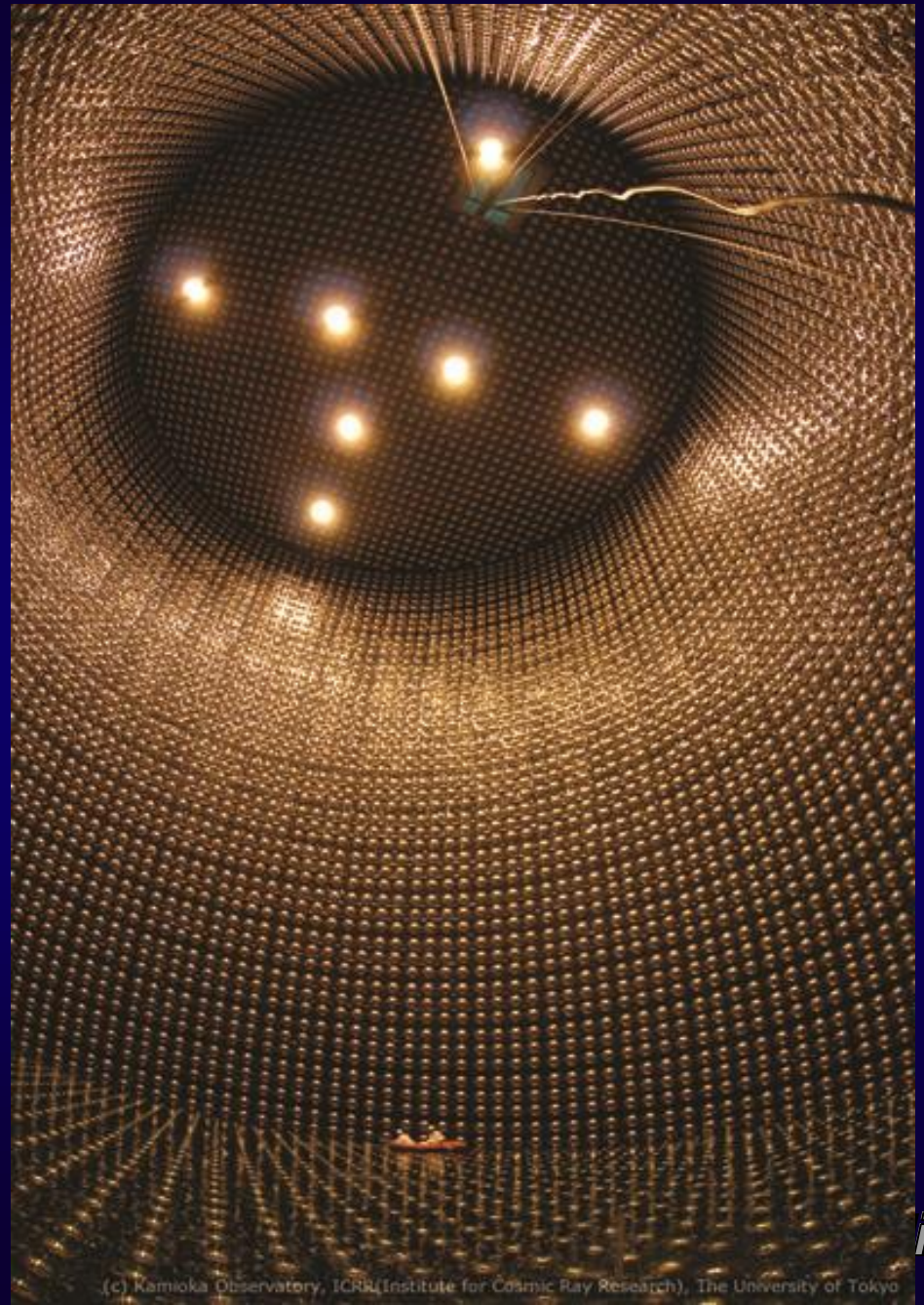


Long Baseline neutrino beam



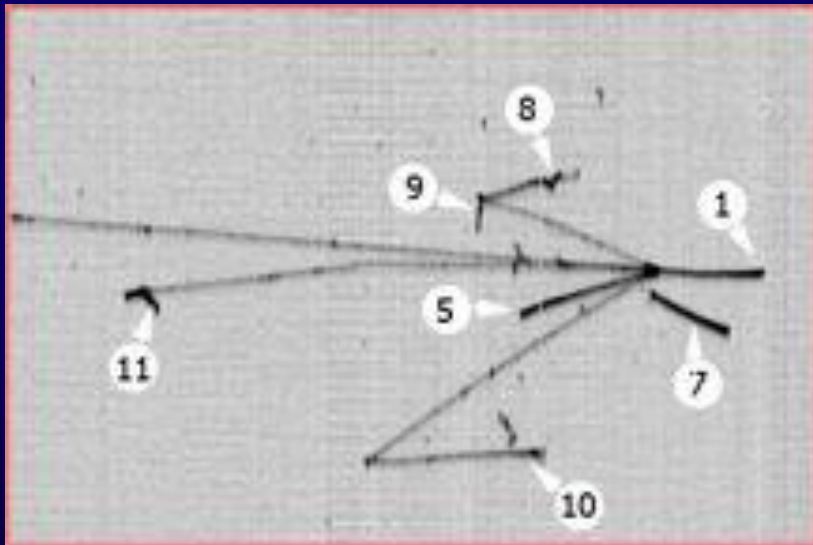
Superkamiokande Neutrino Detector (Japan)

Do you know what the
Detector is made of?



ice

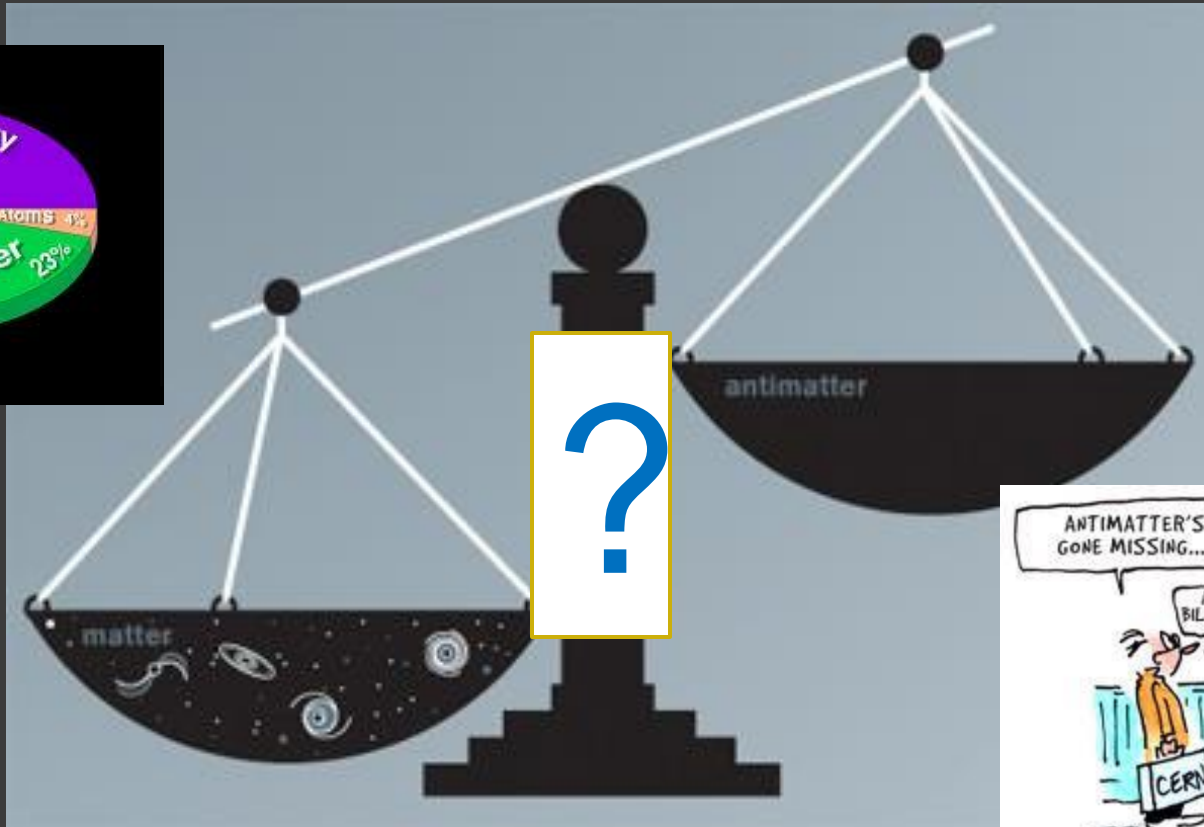
ICARUS Bubble Chamber



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

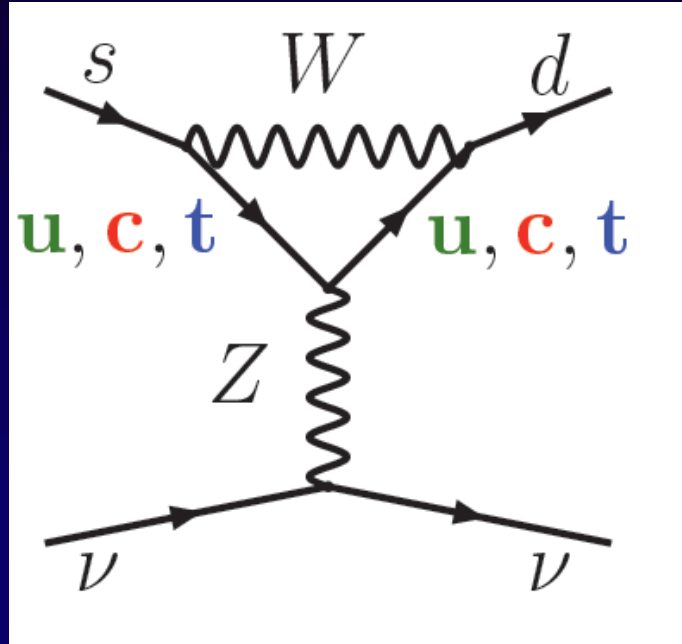
Baryon Asymmetry of the Universe (BAU)



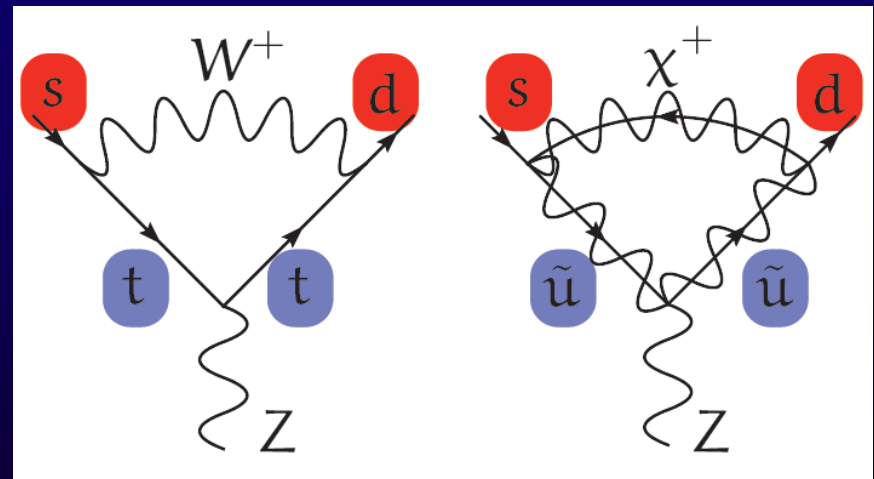
$$n_{\text{quark}} - n_{\text{antiquark}} / n_{\text{quark}} \text{ (Proto Universe)} \sim n_{\text{baryon}} / n_{\text{photon}} \text{ (Today)} \sim 5 \times 10^{-10}$$

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** ($\sim\%$)
- ◆ They are very sensitive to possible contributions from **New Physics**



Ultra-Rare K decay experiment



CERN-SPS



Nice

Dark Matter? Dark Energy

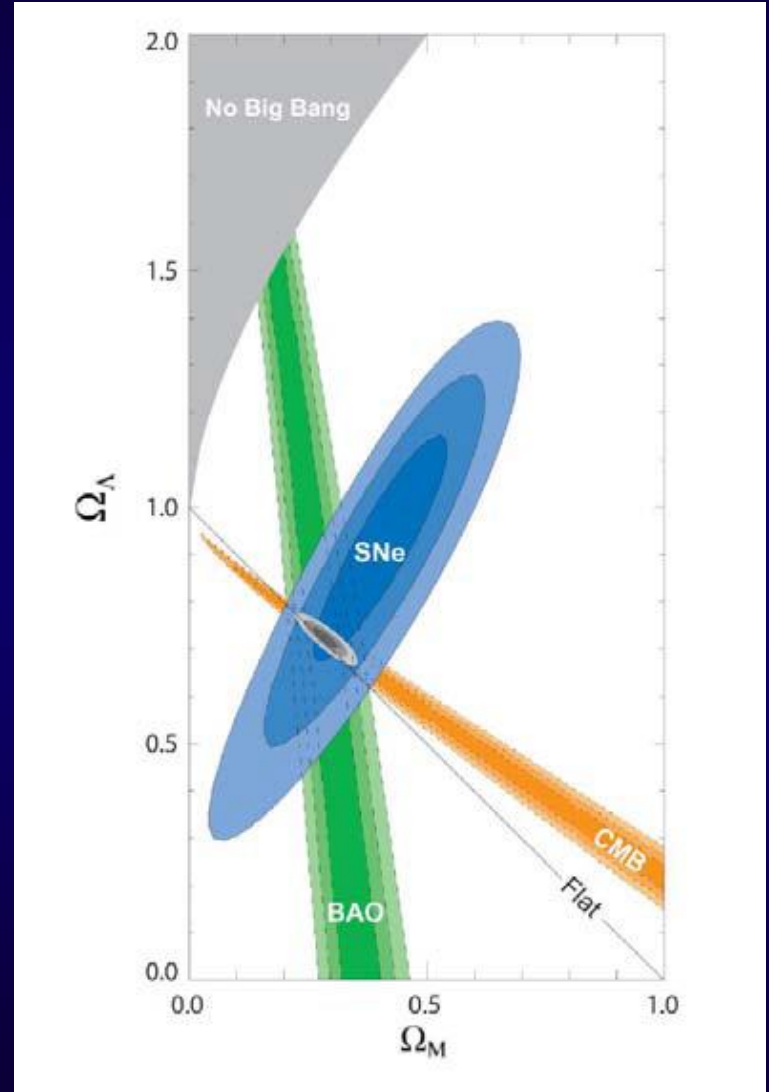
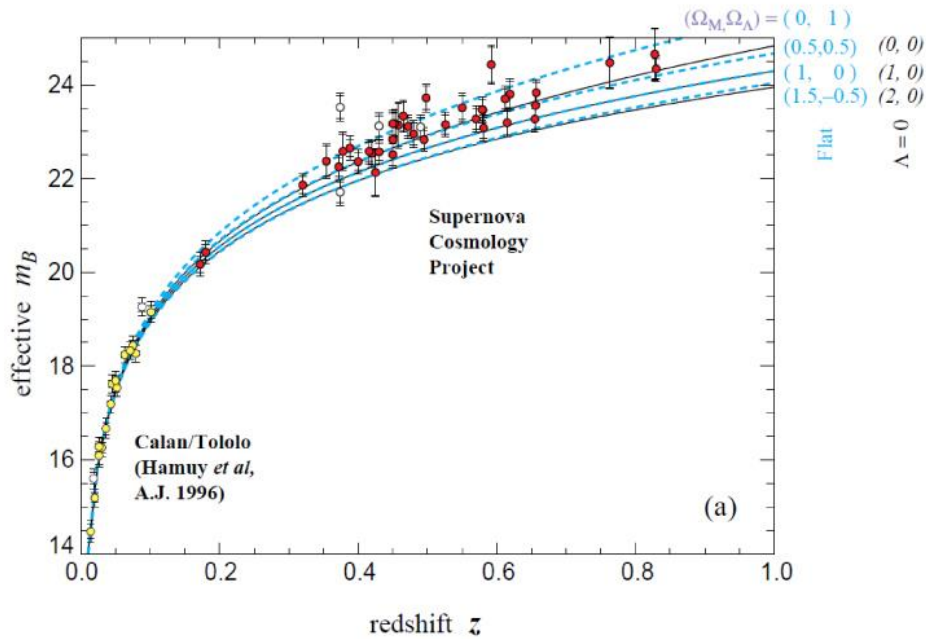


- ◆ **Dark Matter** is matter that emits minimal to no light. Its evidence comes, for instance, from the orbits of galaxies in galaxy clusters
- ◆ **Dark Energy** is the term used to explain the accelerating expansion of the Universe (Cosmological Constant?)



2011 Nobel Prize in Physics

Accelerating Universe



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

Nice

Dark Matter and Gravitational Lensing

