

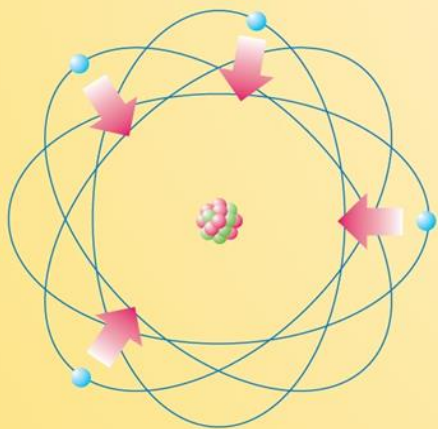


MERTON  
COLLEGE  
OXFORD



# The Four Fundamental Forces of Nature

**Electro-  
magnetism**



**Weak  
Interaction**

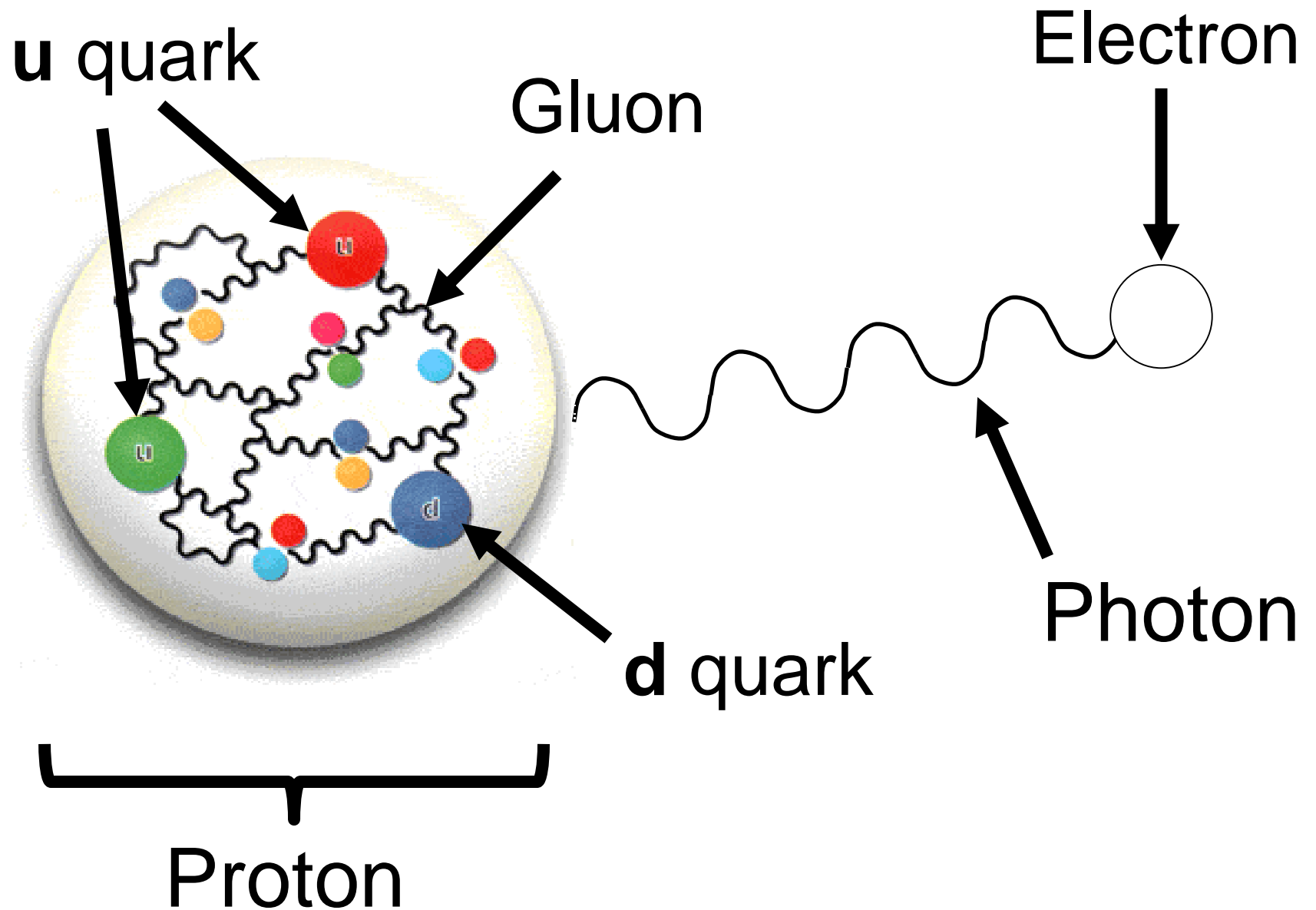


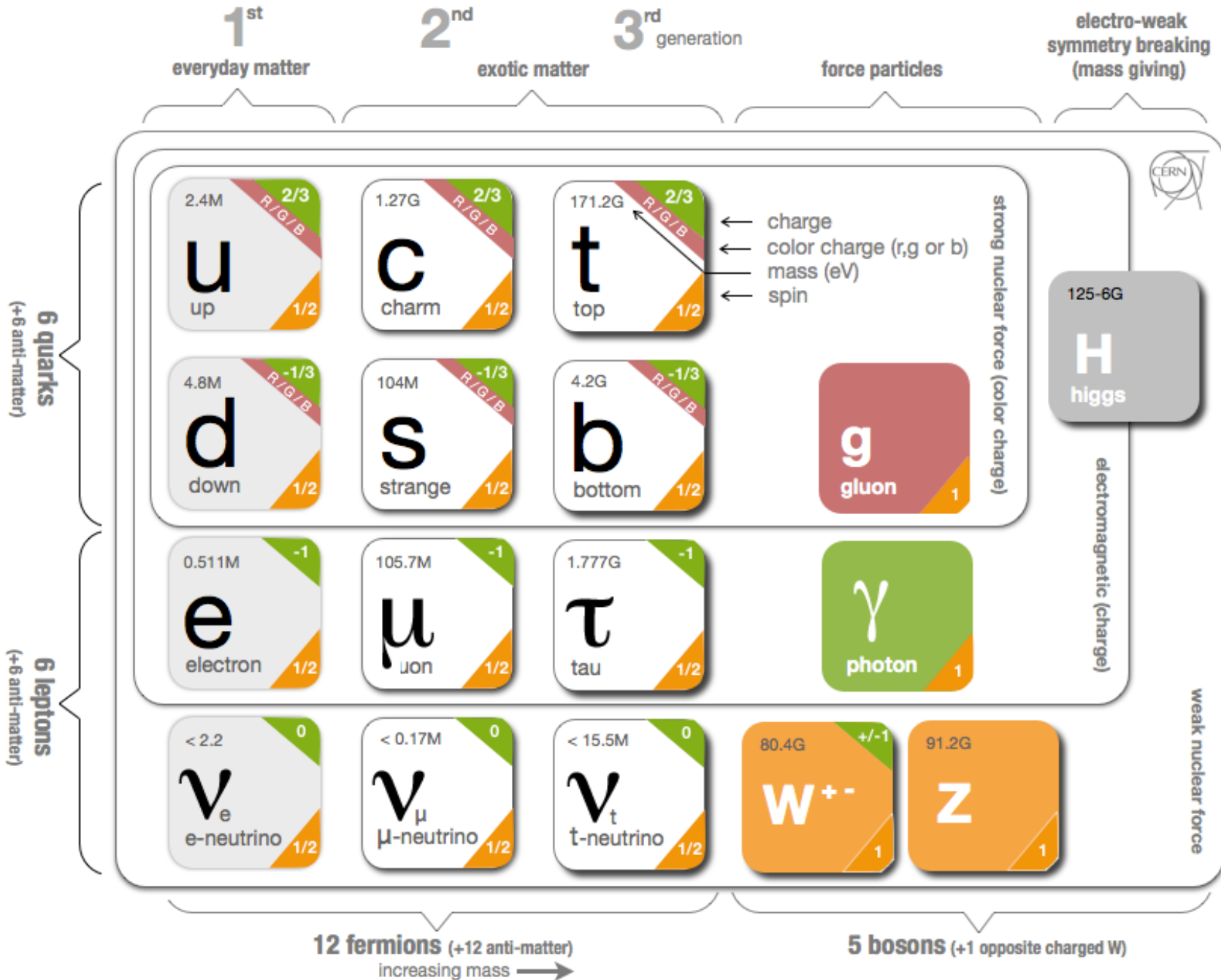
**Strong  
Interaction**



**Gravitation**







# A very precise theory



Electrons behave like gyroscopes

Experiment:

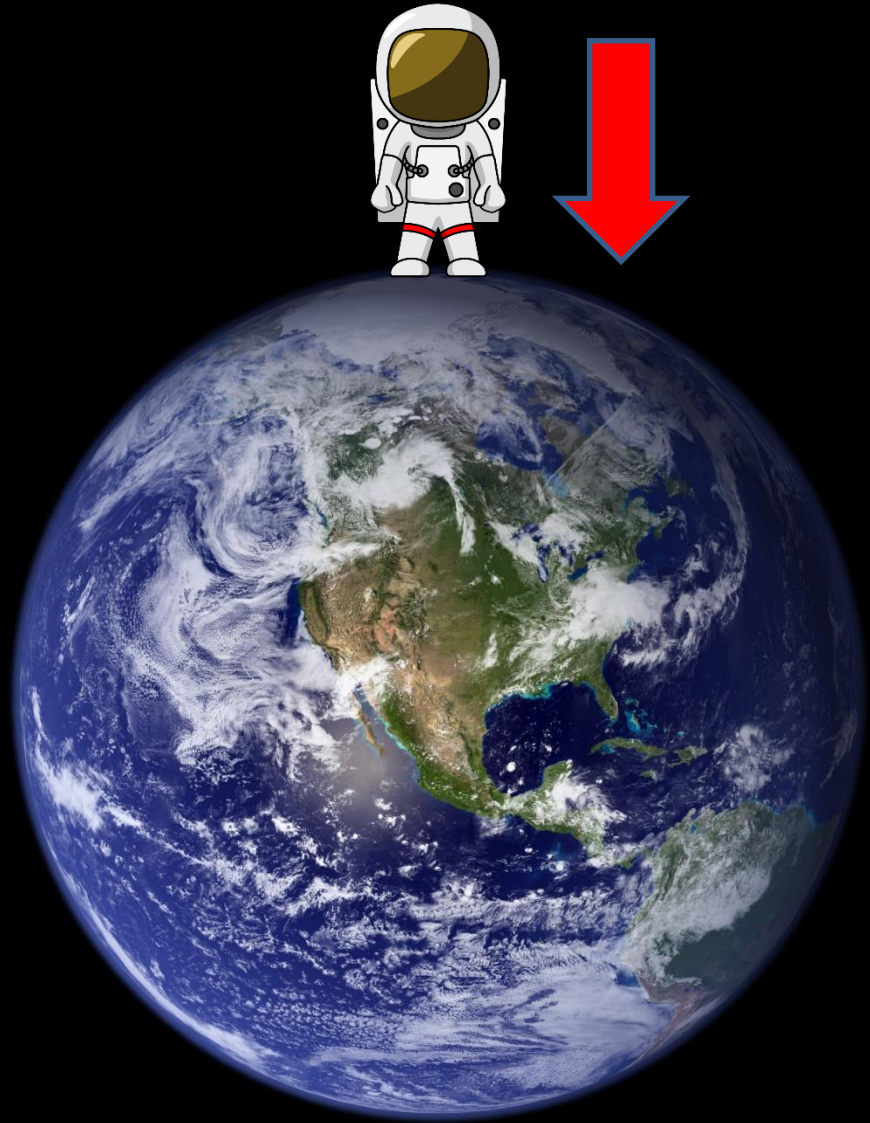
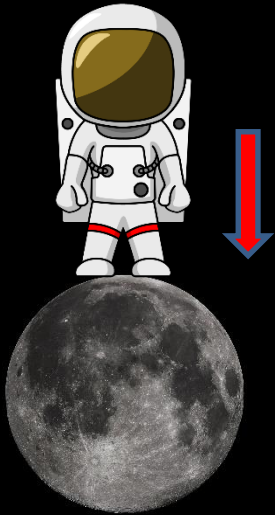
$$g/2 = 1.001\ 159\ 652\ 180\ 7\ (3)$$

Theory:

$$g/2 = 1.001\ 159\ 652\ 181\ 8\ (8)$$

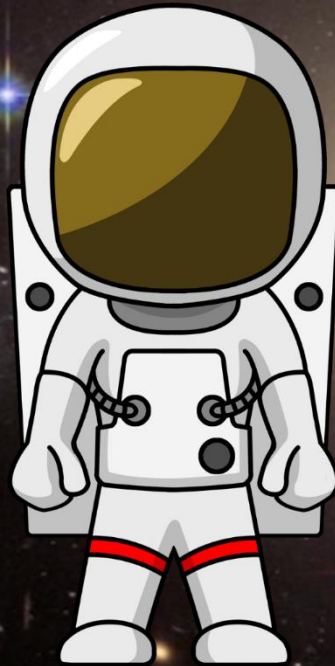


# Weight





# Mass



$$E = mc^2$$



$$\mathcal{L} = (D_\mu \phi)^\dagger D^\mu \phi - V(\phi) - \frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$

$$D_\mu \phi = \partial_\mu \phi - ie A_\mu \phi$$

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$$

$$V(\phi) = \lambda \phi^\dagger \phi + \beta (\phi^\dagger \phi)^2$$

$$\lambda < 0, \quad \beta \geq 0$$

# A theory of mass

Ingredients:

1. Field
2. Interaction
3. Excitation

1964: Englert–Brout–Higgs–Guralnik–Hagen–Kibble







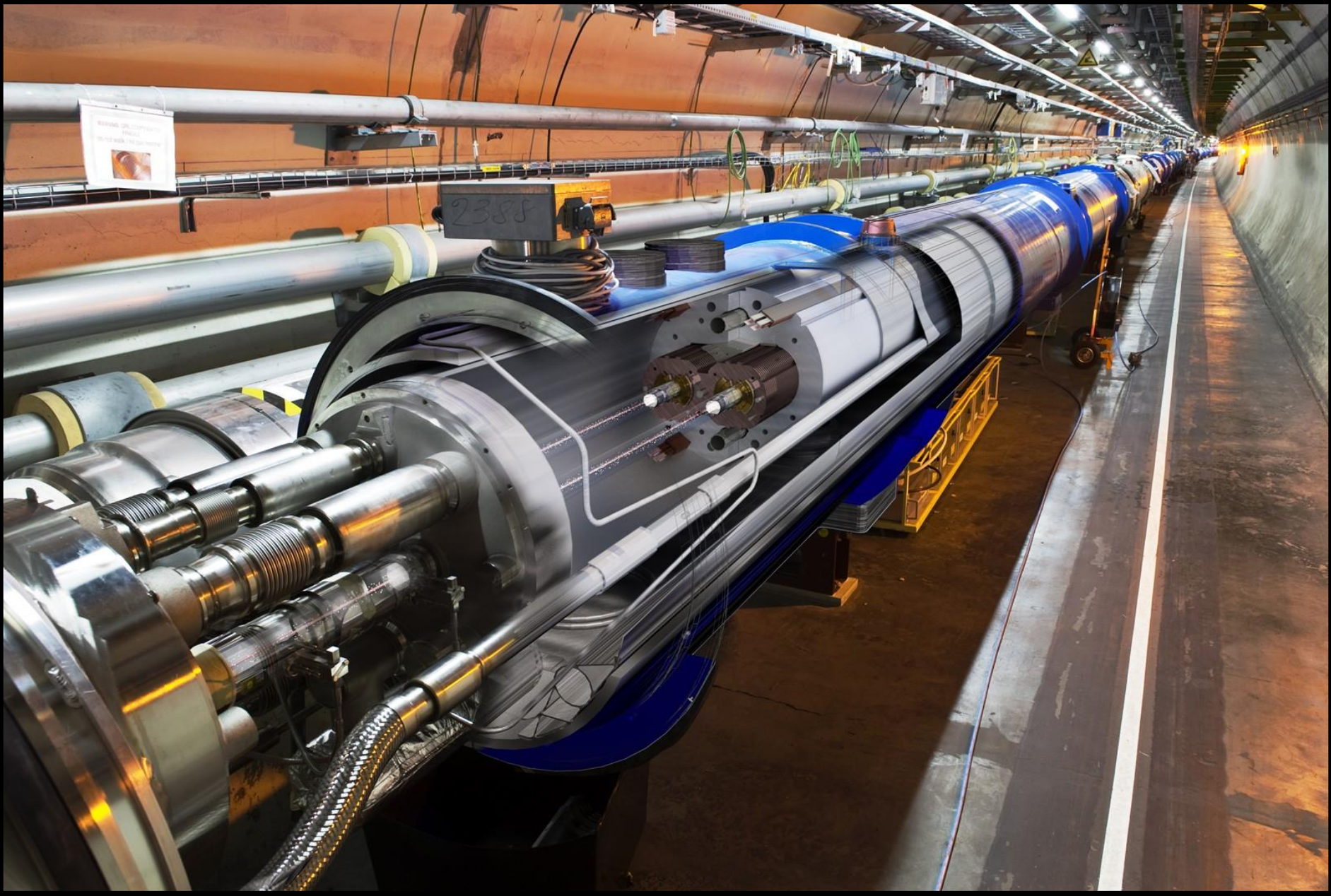










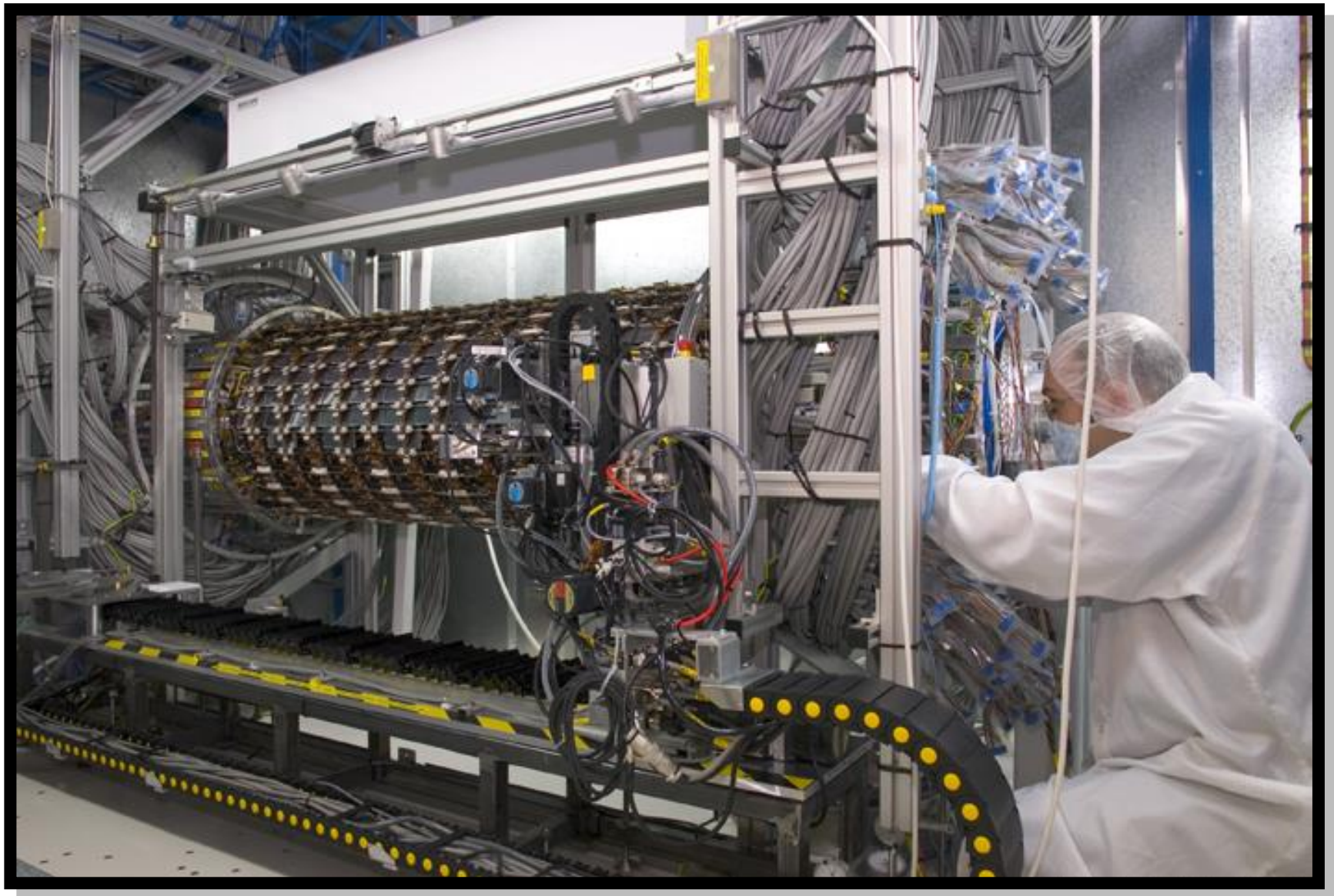


Note concerning “high energy”

**FOURTEEN THOUSAND  
BILLION VOLTS**

Spark could jump 5000 km in air  
(~radius of The Earth)



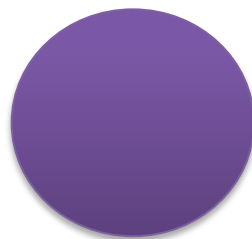




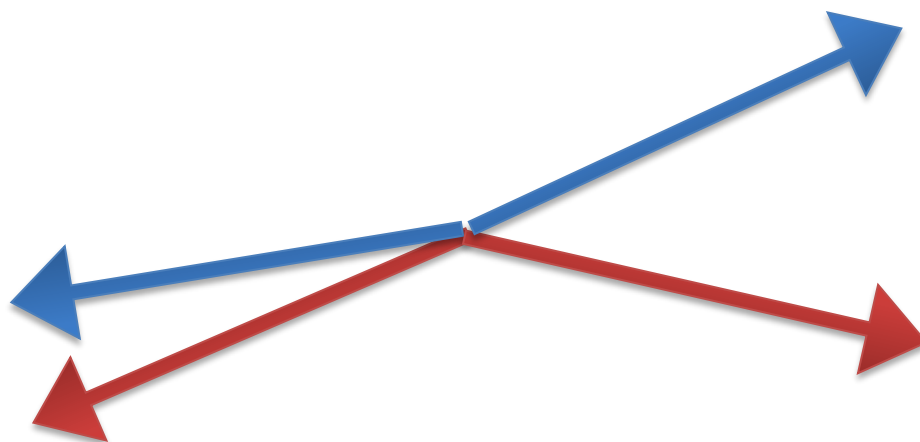
**Proton**



**Proton**



**Higgs boson**



**Decay  
products**

**Decay  
products**





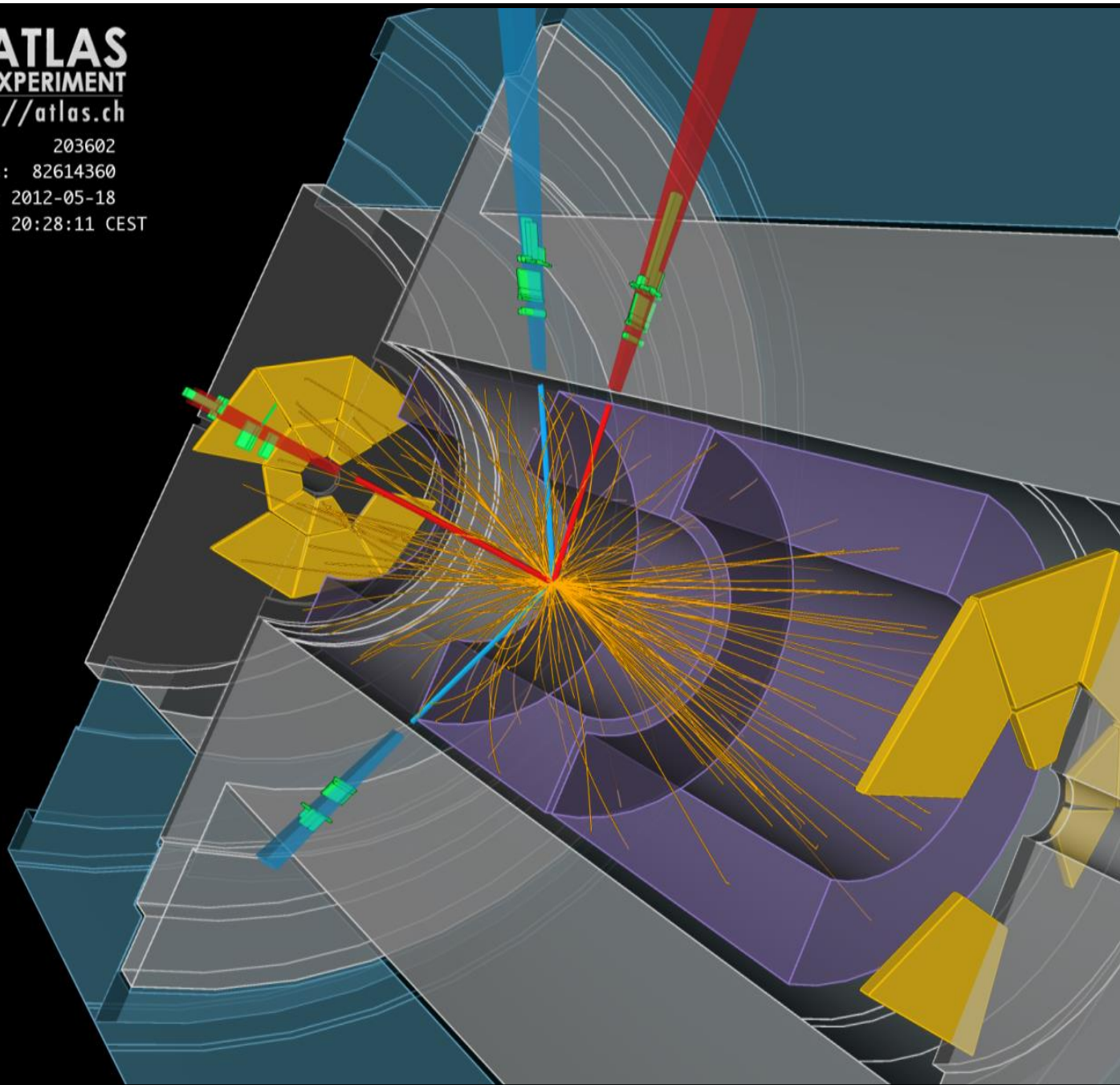
<http://atlas.ch>

Run: 203602

Event: 82614360

Date: 2012-05-18

Time: 20:28:11 CEST

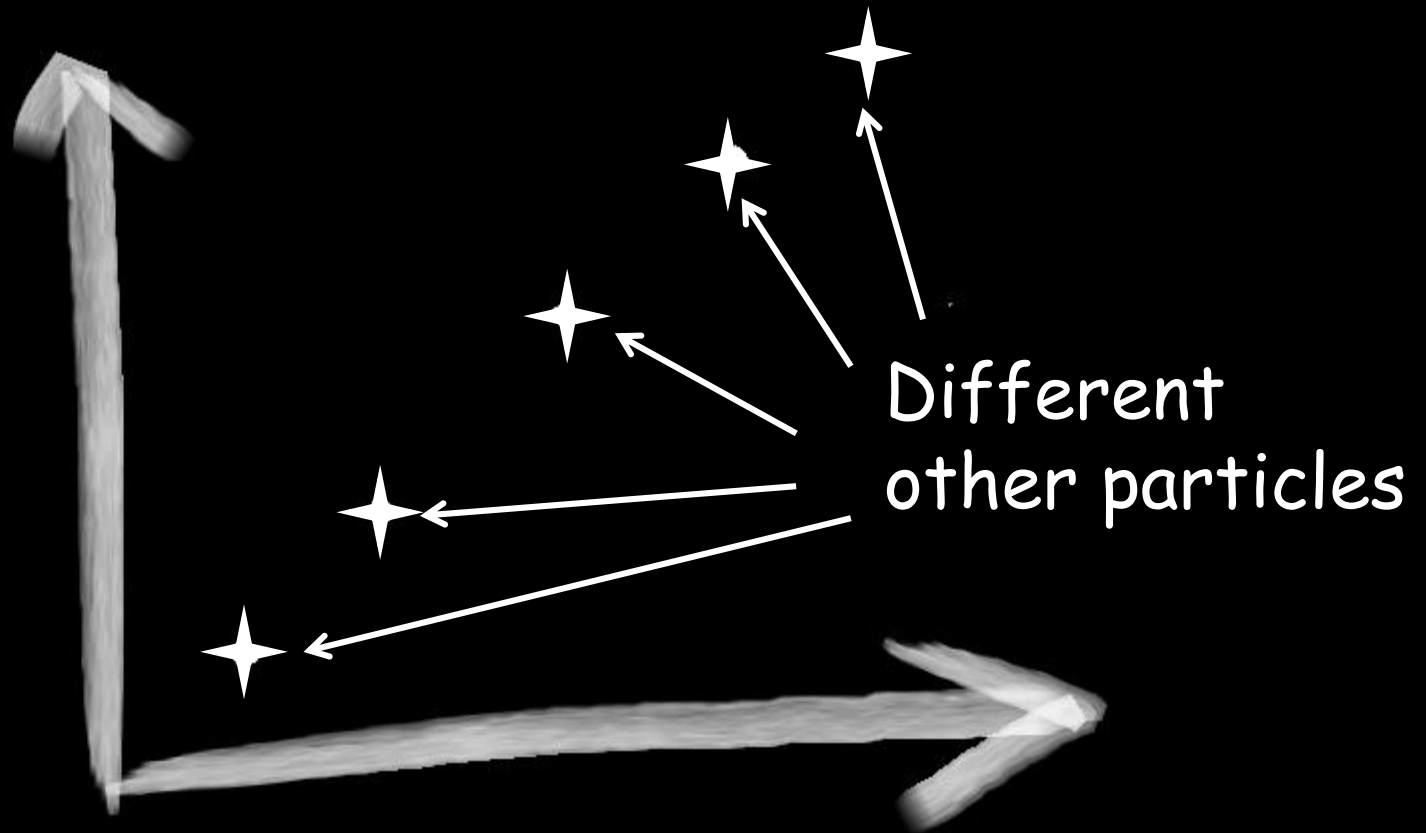


# Discovery!



# Fingerprinting the Higgs boson

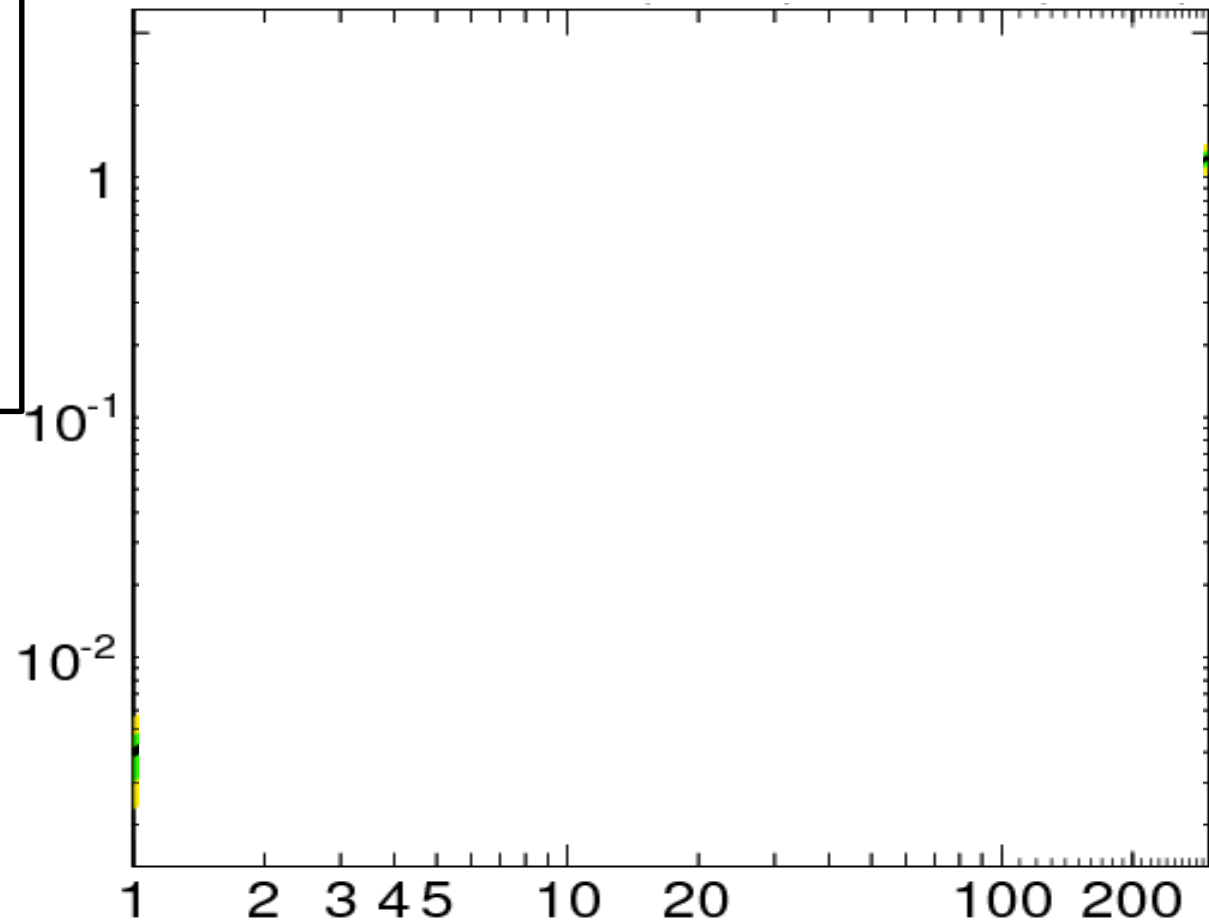
Interaction with  
other particle



Mass of other particle

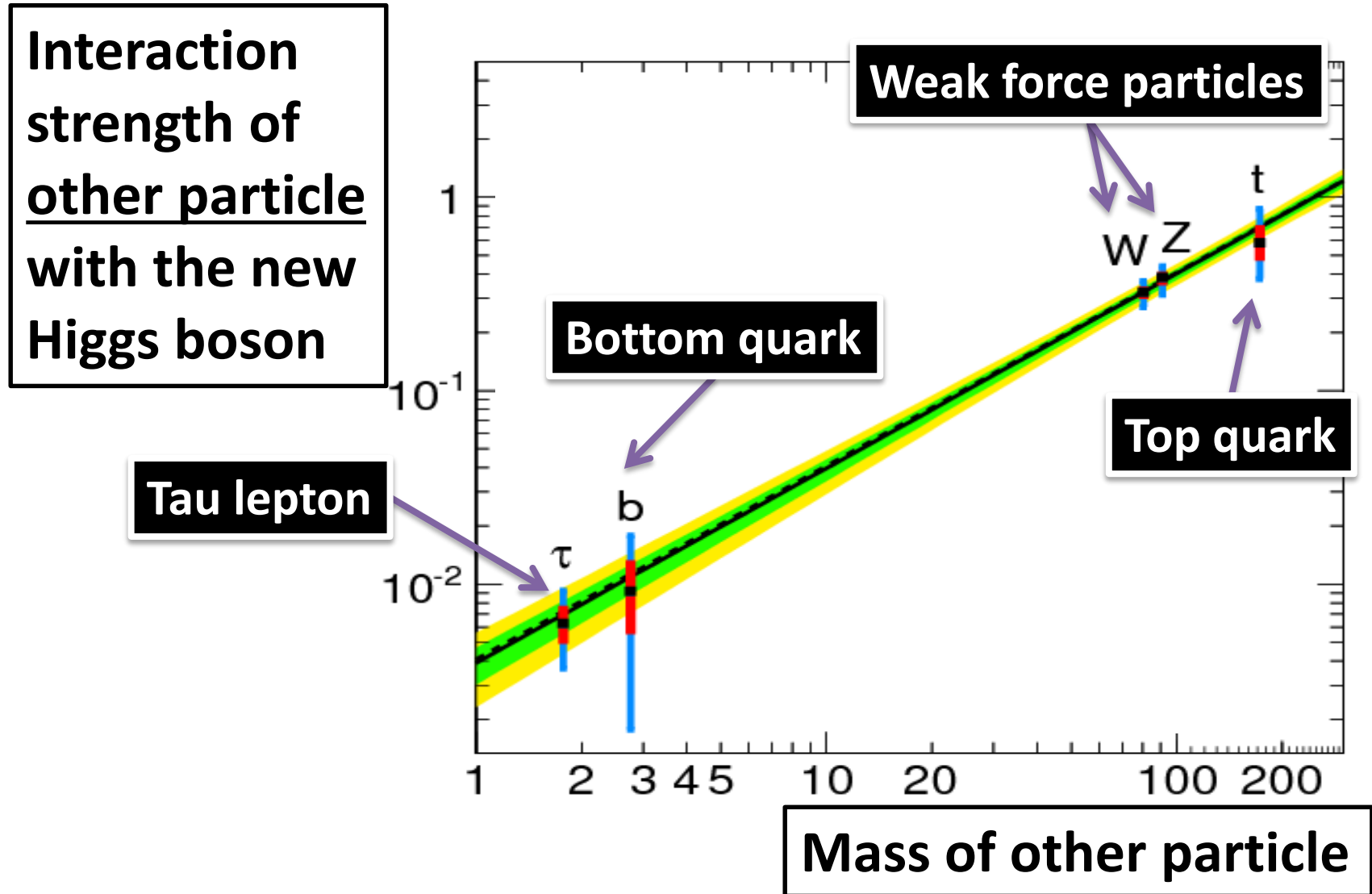
# Fingerprinting the Higgs boson

Interaction  
strength of  
other particle  
with the new  
Higgs boson



Mass of other particle

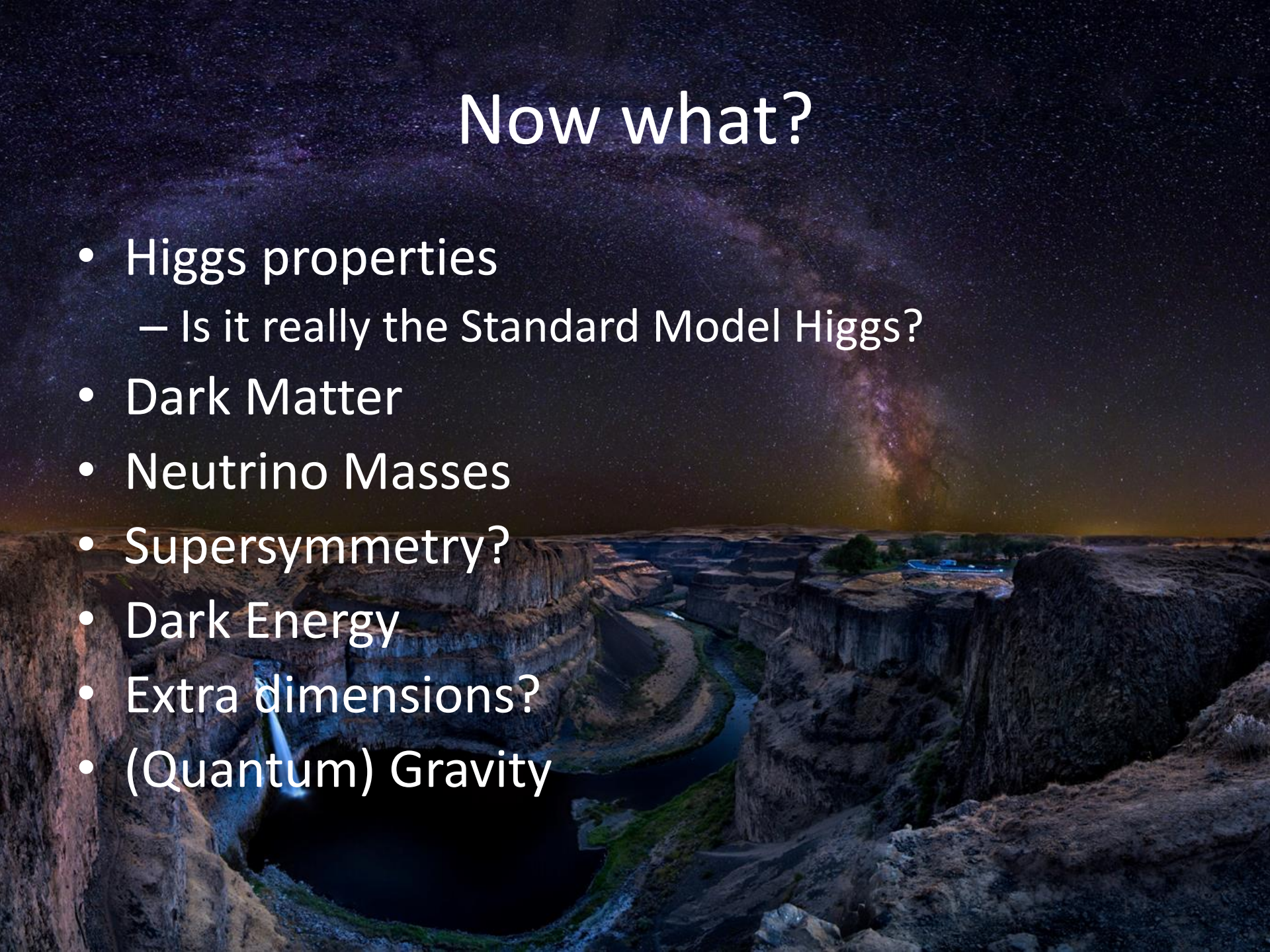
# Fingerprinting the Higgs boson



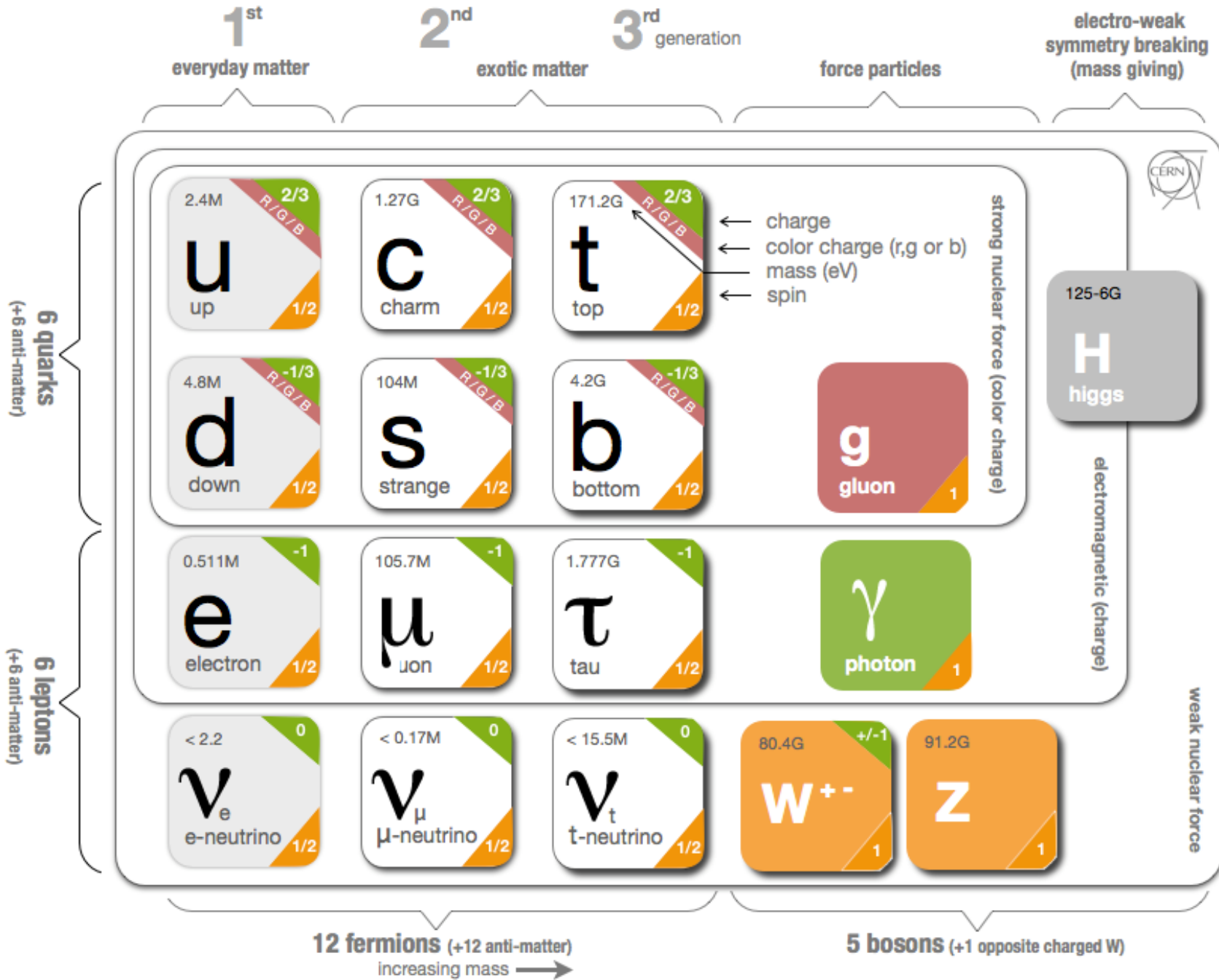


# Now what?

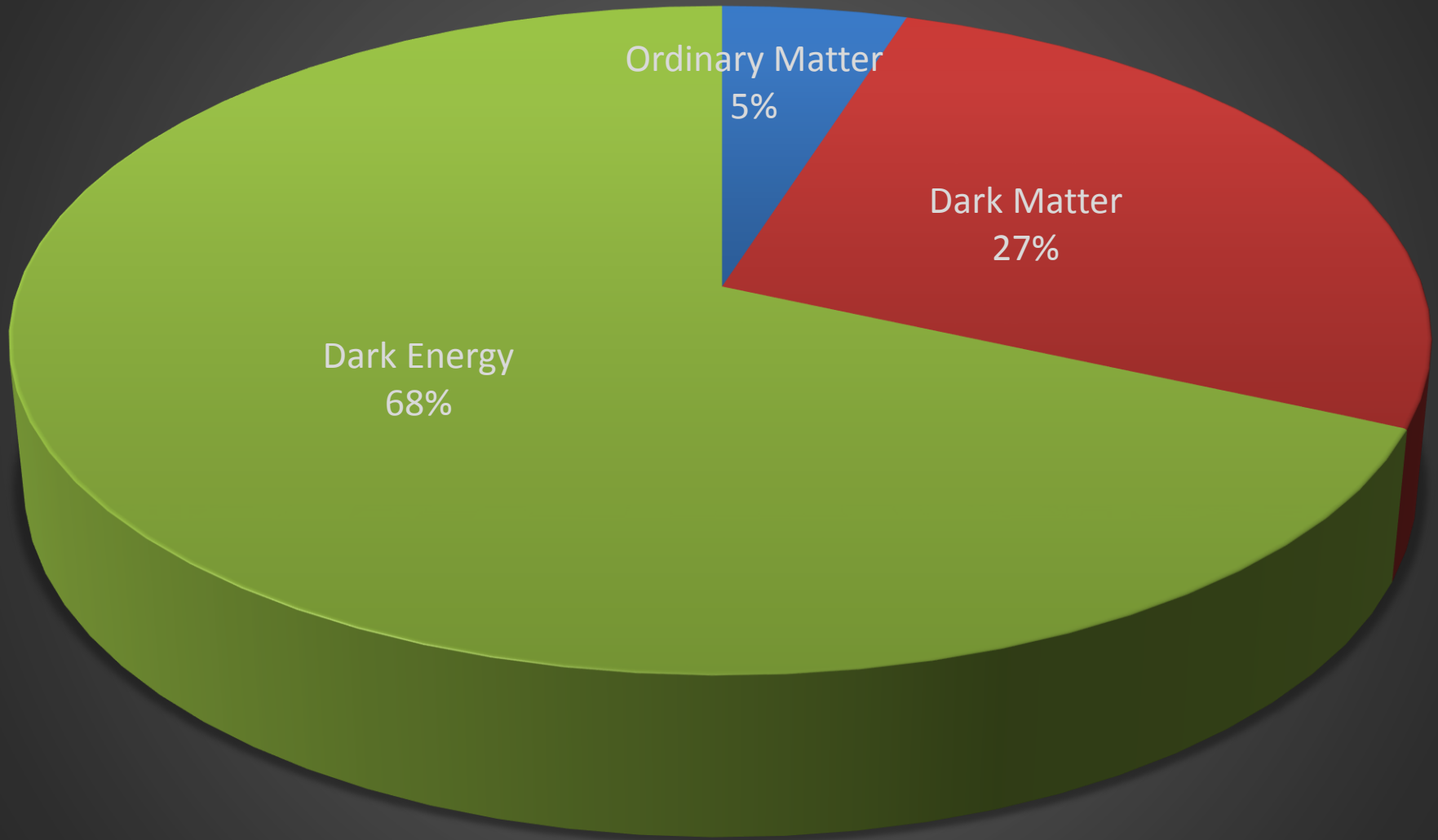
- Higgs properties
  - Is it really the Standard Model Higgs?
- Dark Matter
- Neutrino Masses
- Supersymmetry?
- Dark Energy
- Extra dimensions?
- (Quantum) Gravity



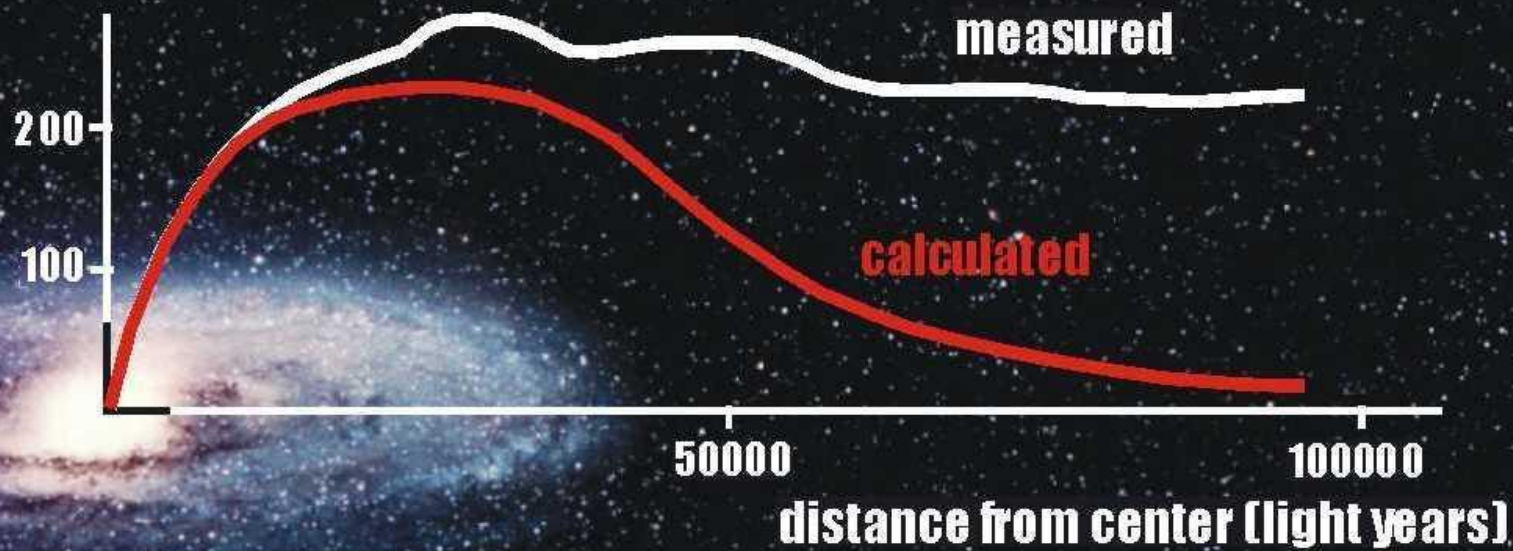




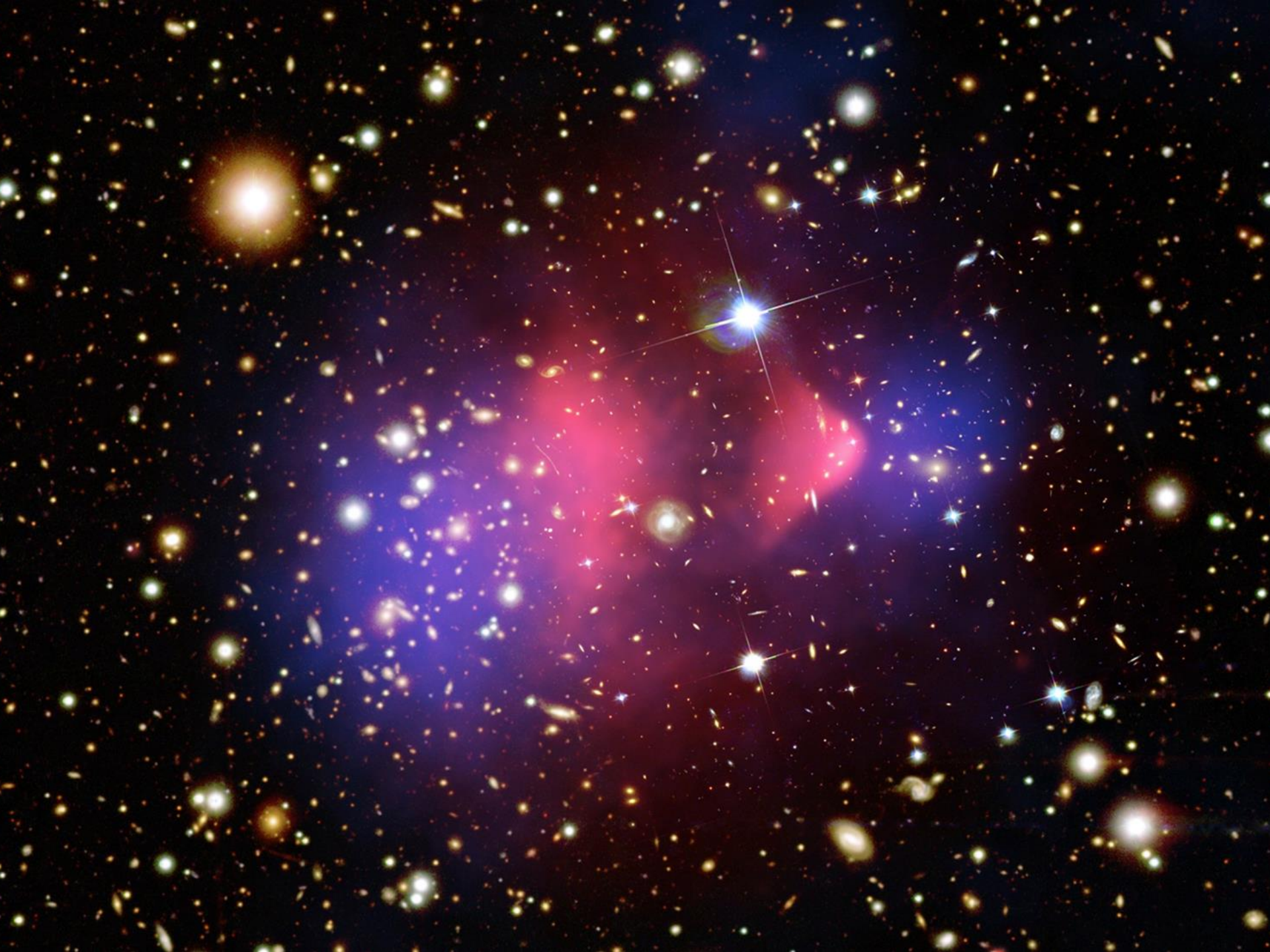
# Far from the full story



**rotational velocity  
(km/s)**







# Spin offs...

- **World Wide Web**
- **Medical imaging scanners**
- **Airport scanners**
- **Climate change modelling**
- **Drug development**
- **Radiotherapy**

**... and who knows what else?**



Support gratefully acknowledged