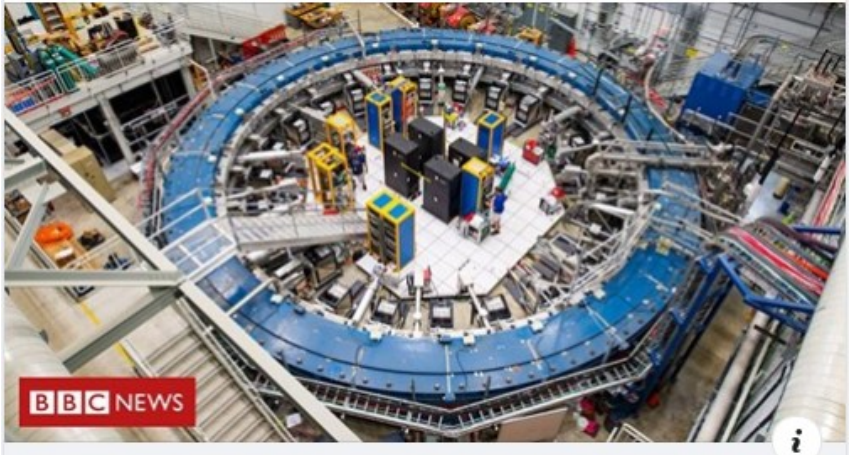
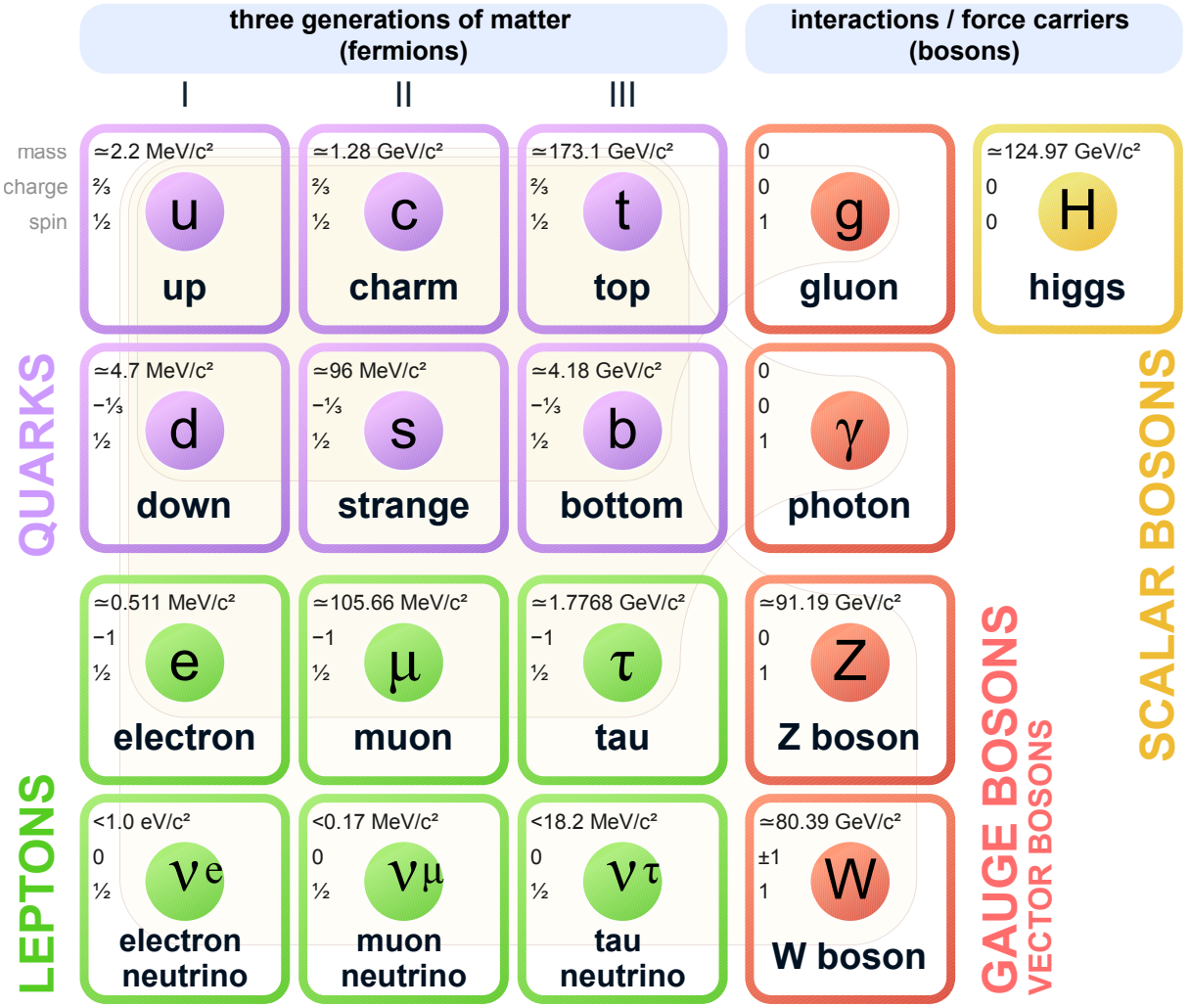
What's all the excitement about muons?

Tim Gershon
University of Warwick
Physics Virtual Offer Holder Open Day
May 5th 2021

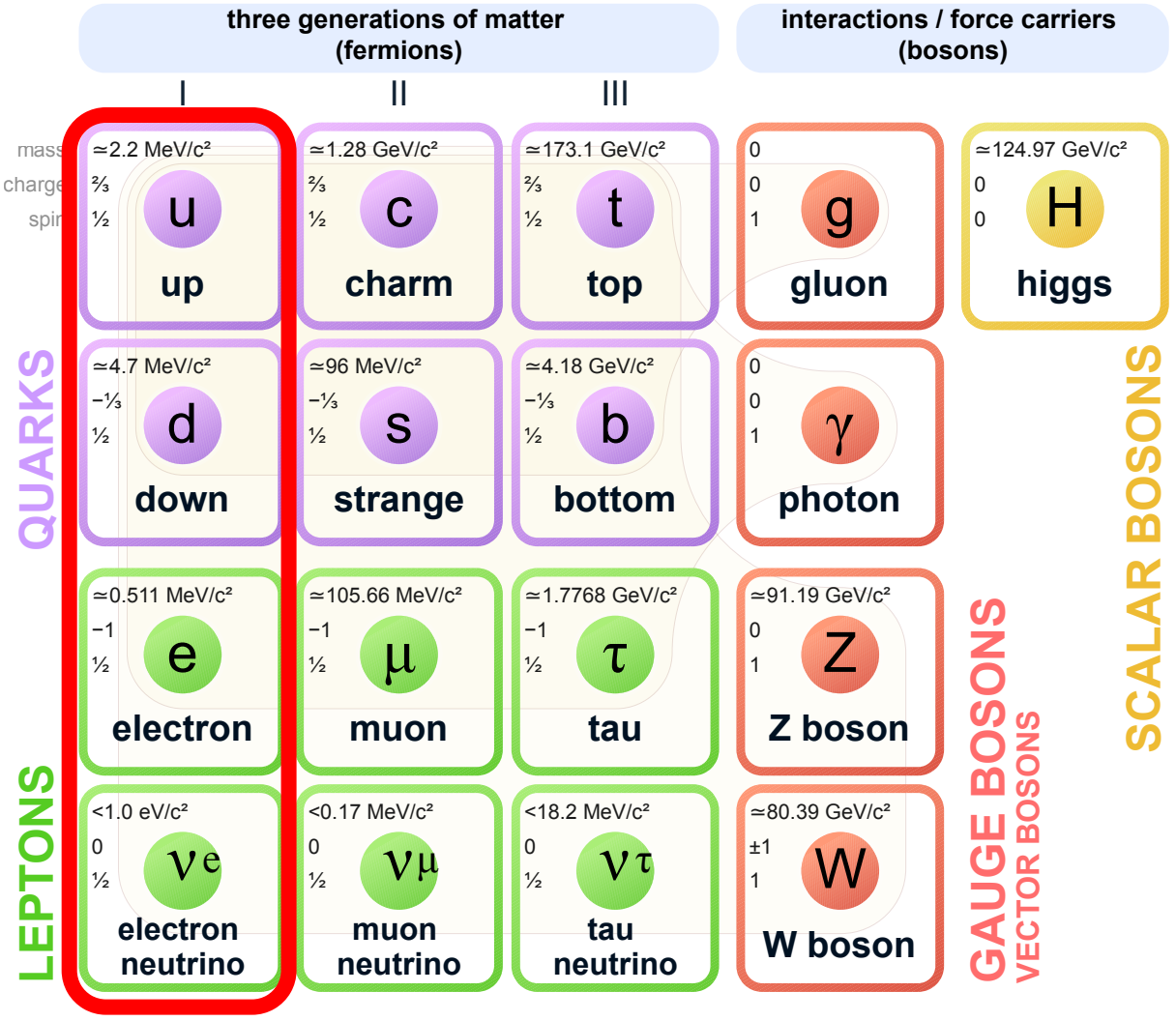


Standard Model of Elementary Particles

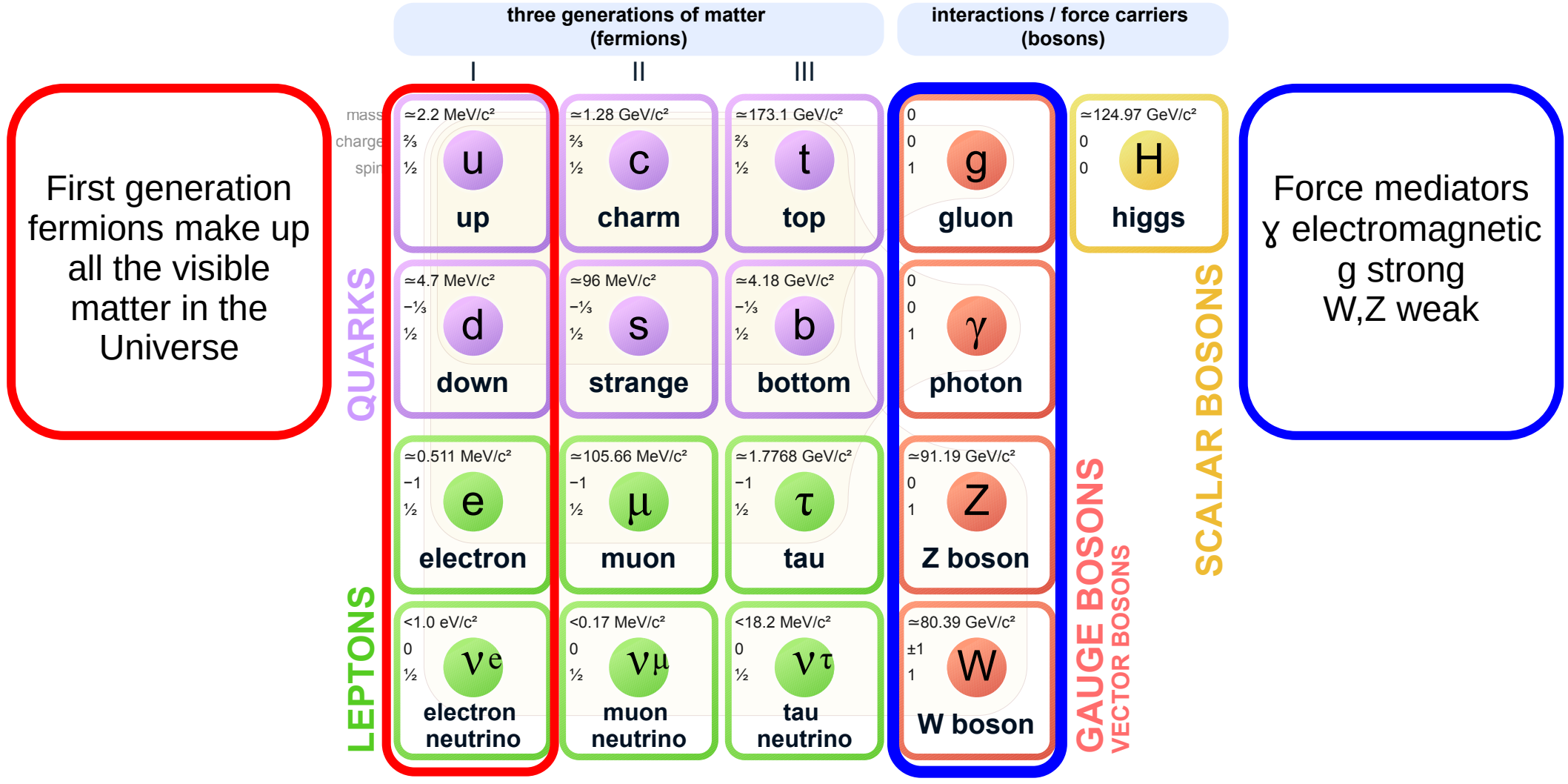


Standard Model of Elementary Particles

First generation fermions make up all the visible matter in the Universe



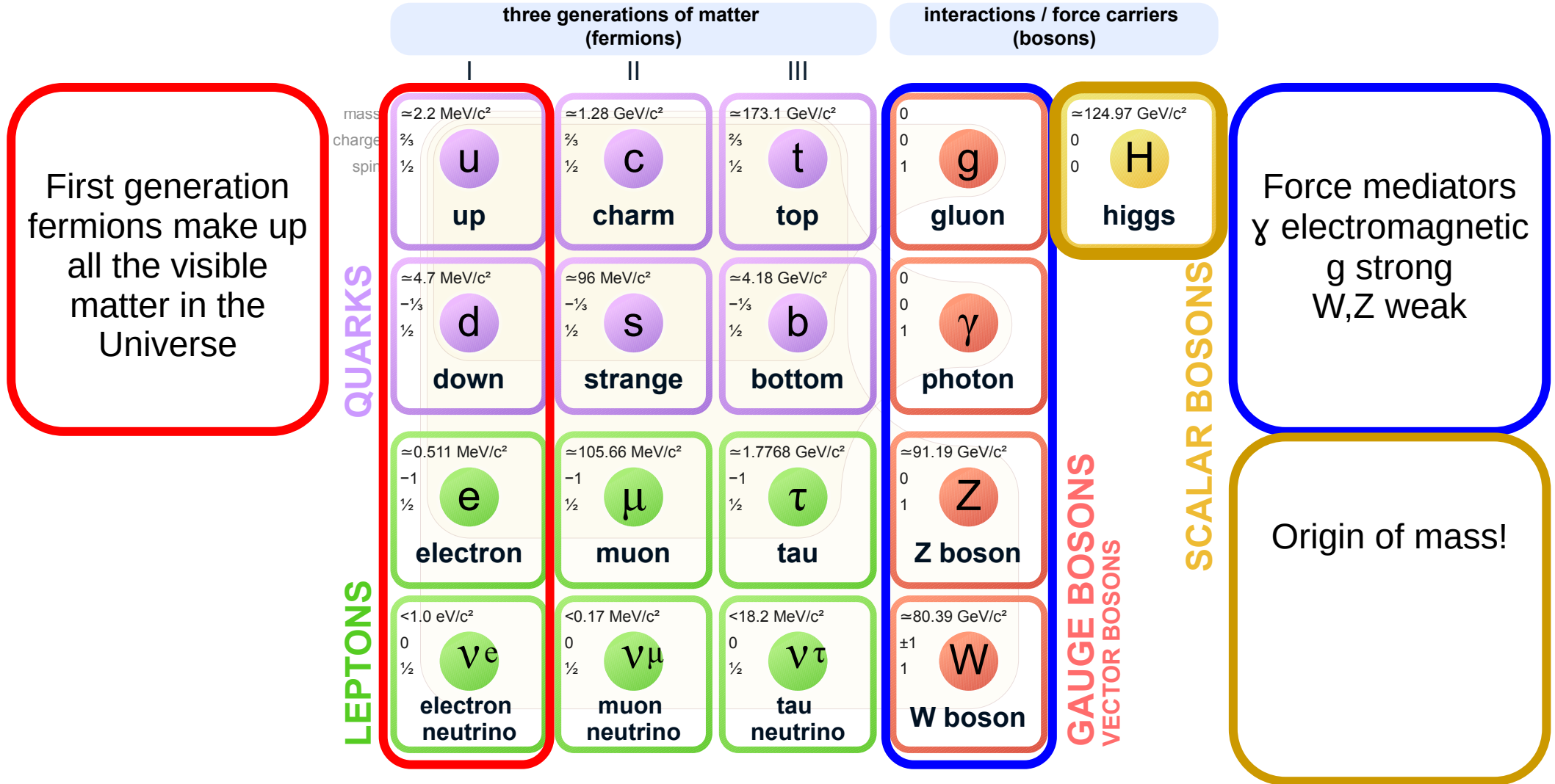
Standard Model of Elementary Particles



First generation fermions make up all the visible matter in the Universe

Force mediators
γ electromagnetic
g strong
W,Z weak

Standard Model of Elementary Particles

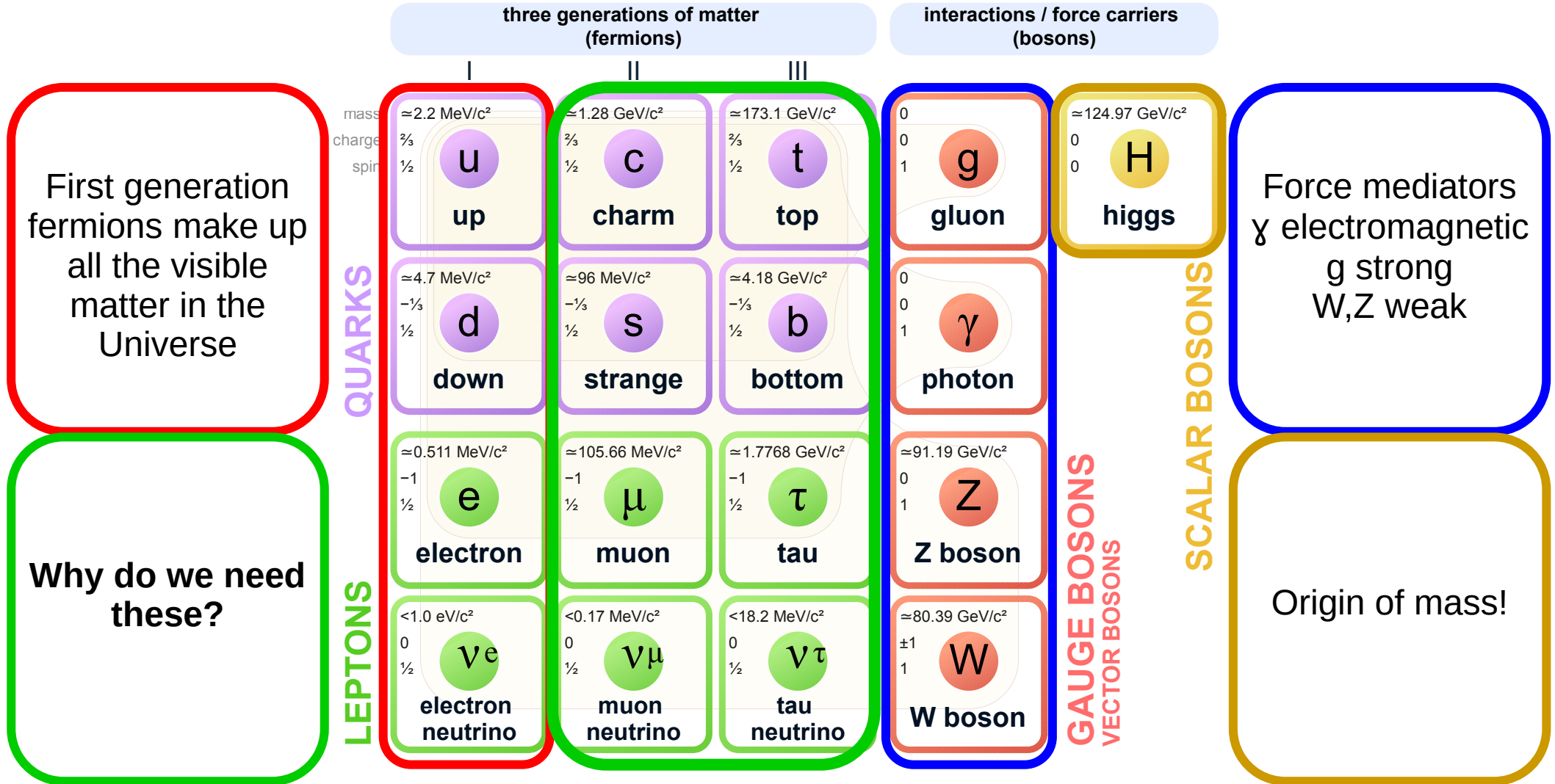


First generation fermions make up all the visible matter in the Universe

Force mediators
γ electromagnetic
g strong
W,Z weak

Origin of mass!

Standard Model of Elementary Particles



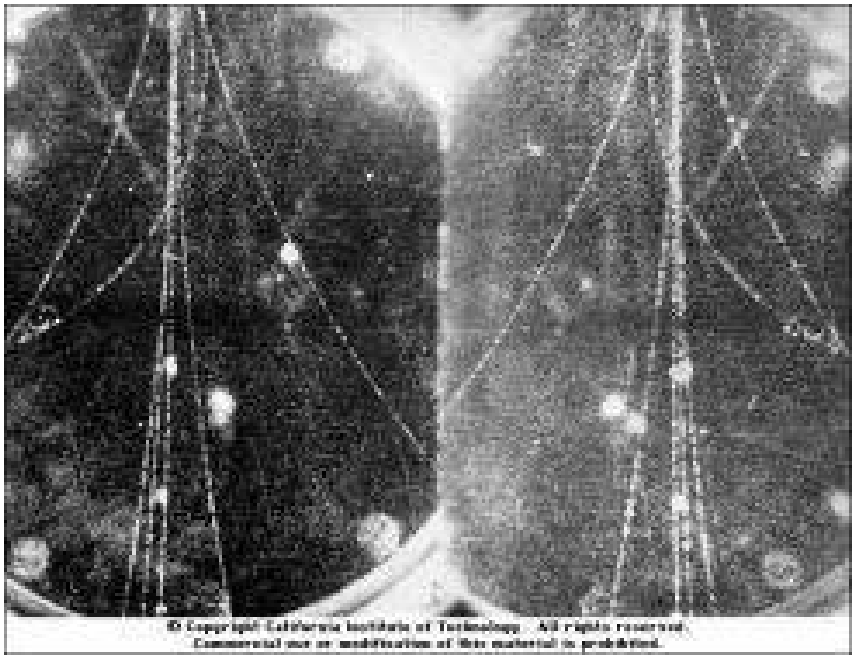
First generation fermions make up all the visible matter in the Universe

Why do we need these?

Force mediators
γ electromagnetic
g strong
W,Z weak

Origin of mass!

Muons were discovered in 1936 from studies of cosmic radiation

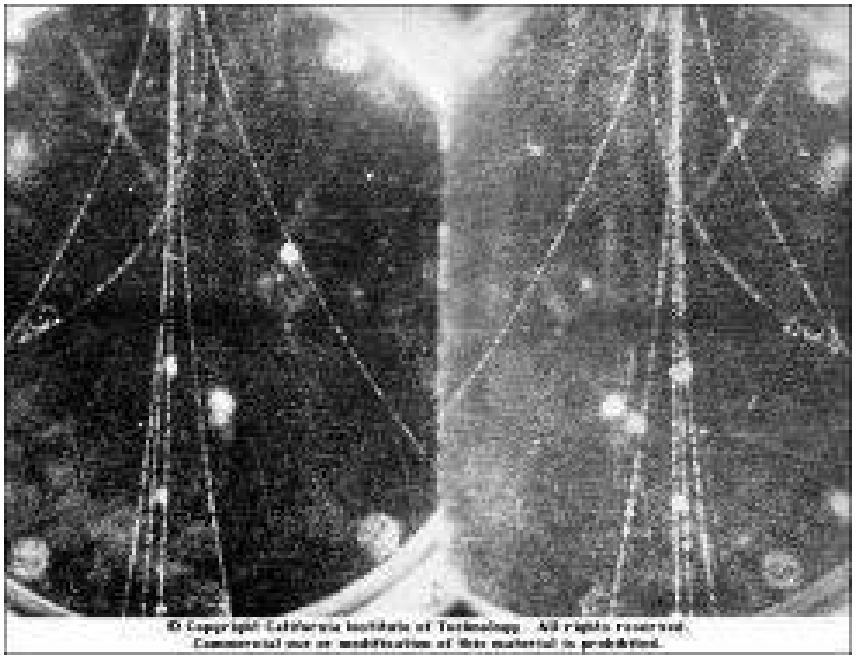


Radius of curvature of charged particle in magnetic field $\propto$ charge/mass

Who ordered that?

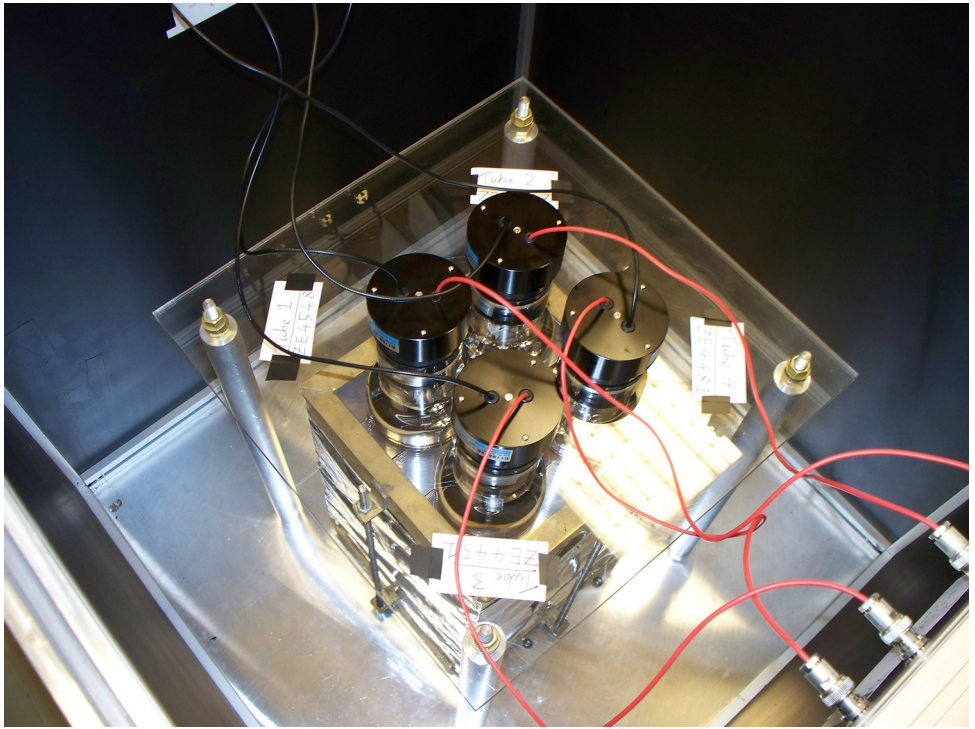
Isidor I Rabi

Muons were discovered in 1936 from studies of cosmic radiation



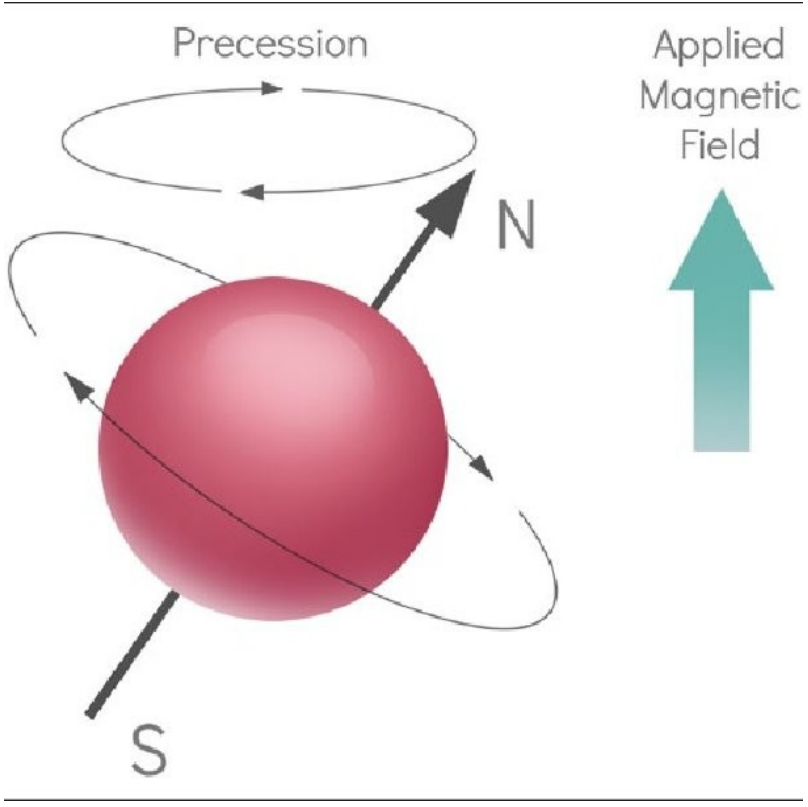
Radius of curvature of charged particle in magnetic field $\propto$ charge/mass

Apparatus used in (non-virtual) Warwick open days to detect cosmic radiation muons



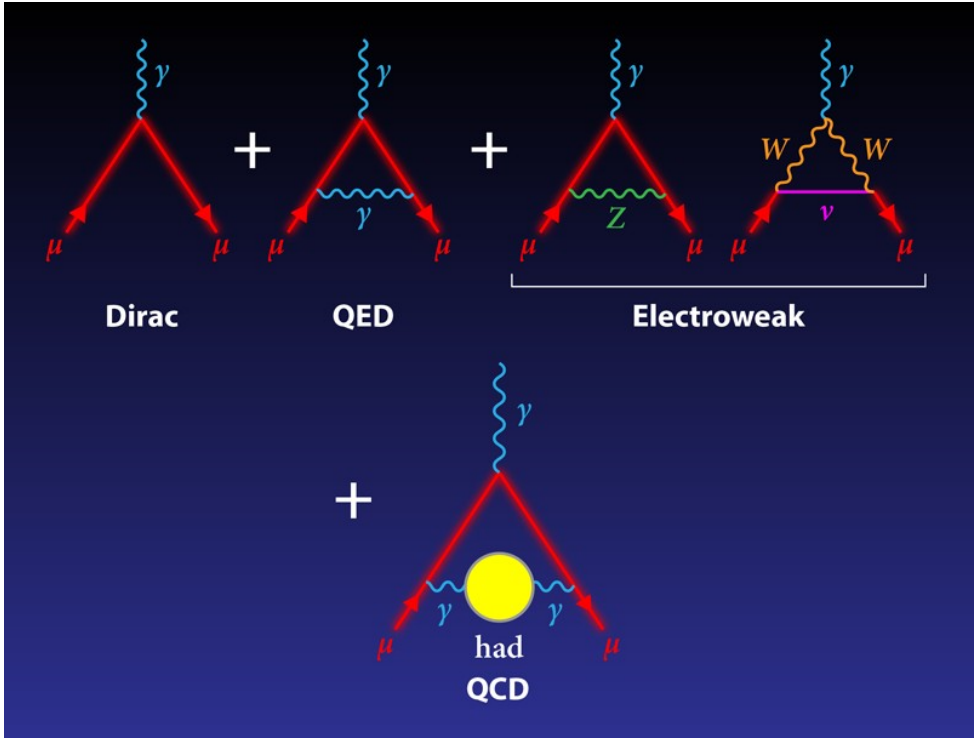
The muon magnetic moment

- The muon (like the electron) has intrinsic angular momentum (“spin”)
- Interaction strength between spin and magnetic field modified by factor denoted g

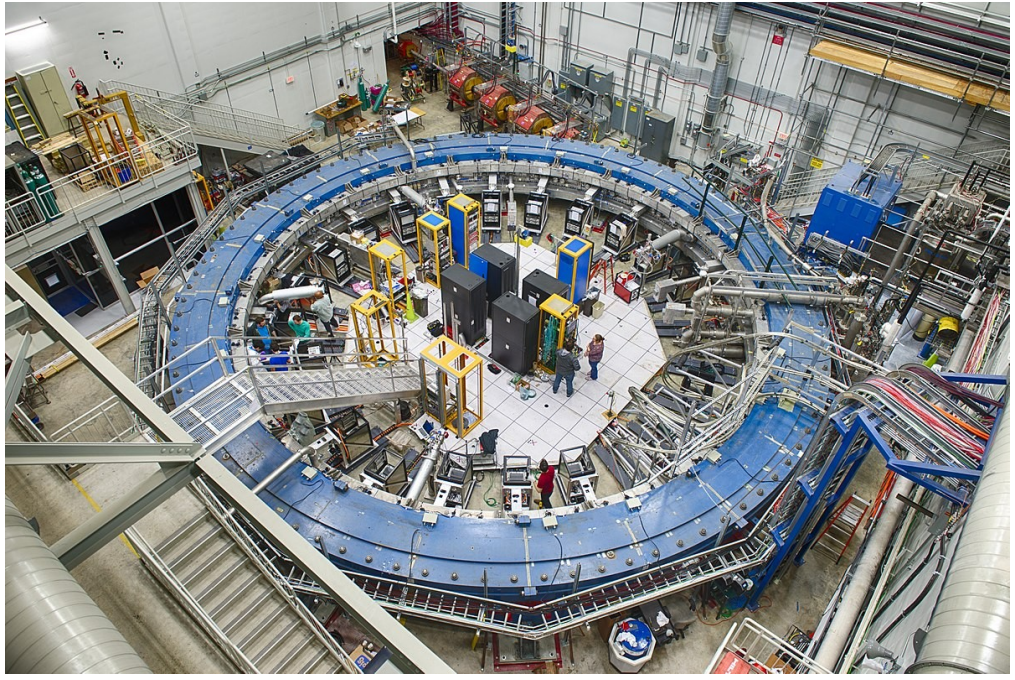


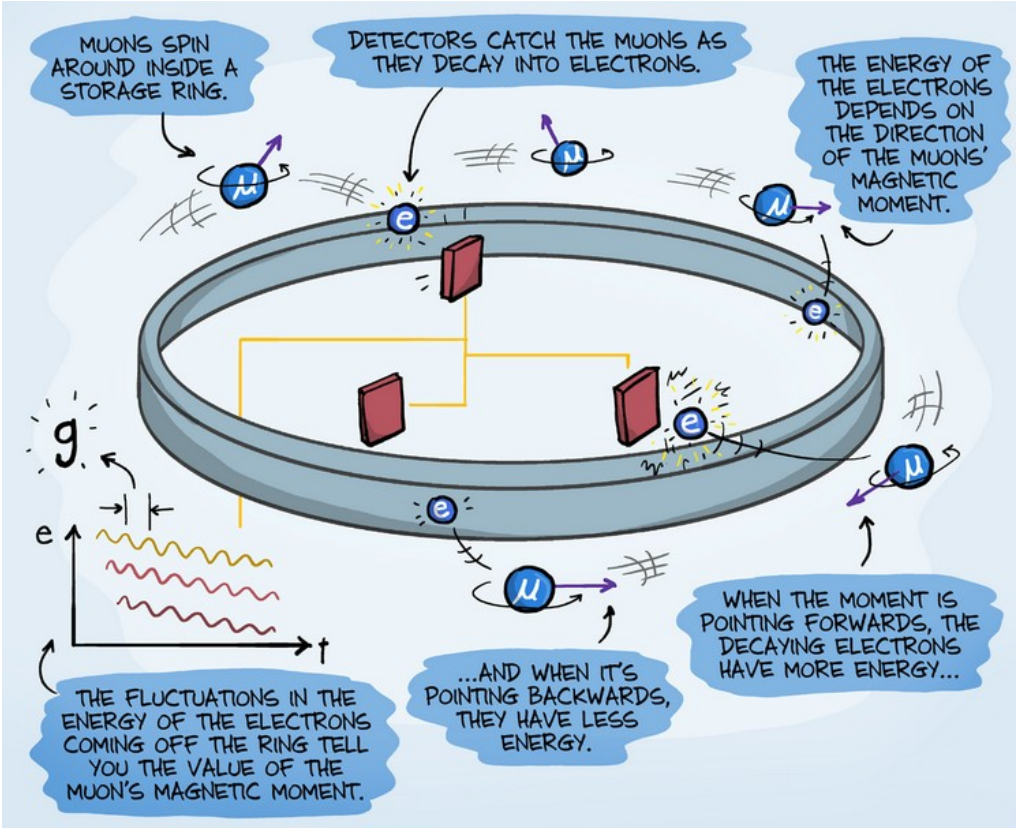
The muon magnetic moment

- The muon (like the electron) has intrinsic angular momentum (“spin”)
- Interaction strength between spin and magnetic field modified by factor denoted g
- Dirac (1928) predicted g=2
- Schwinger (1948) calculated small QED corrections to this
- Today, we know precisely the corrections due to all Standard Model particles

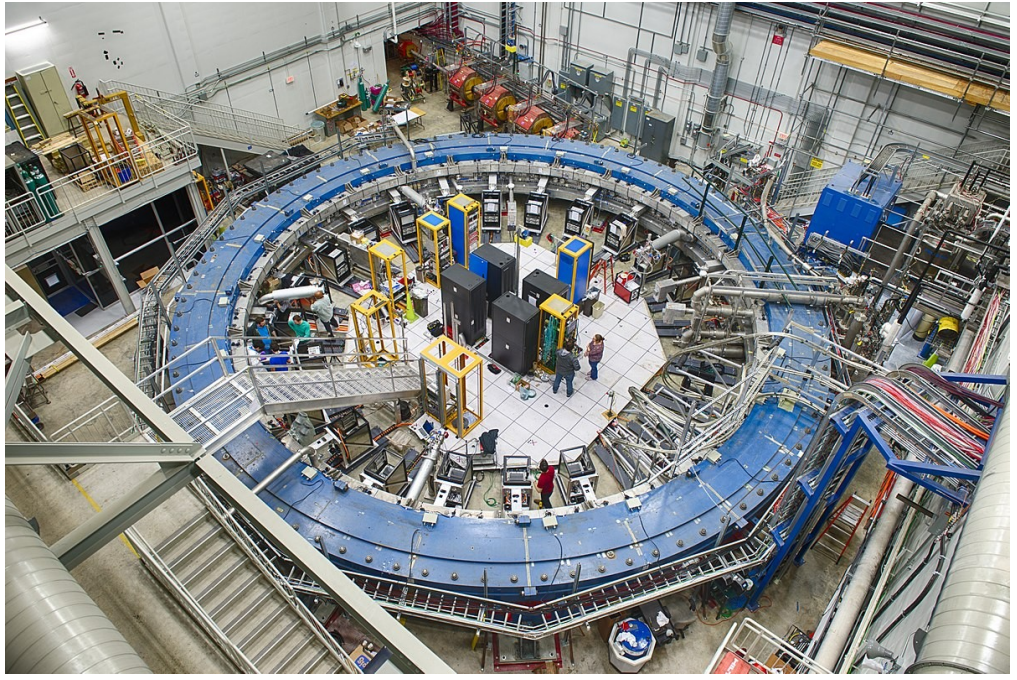


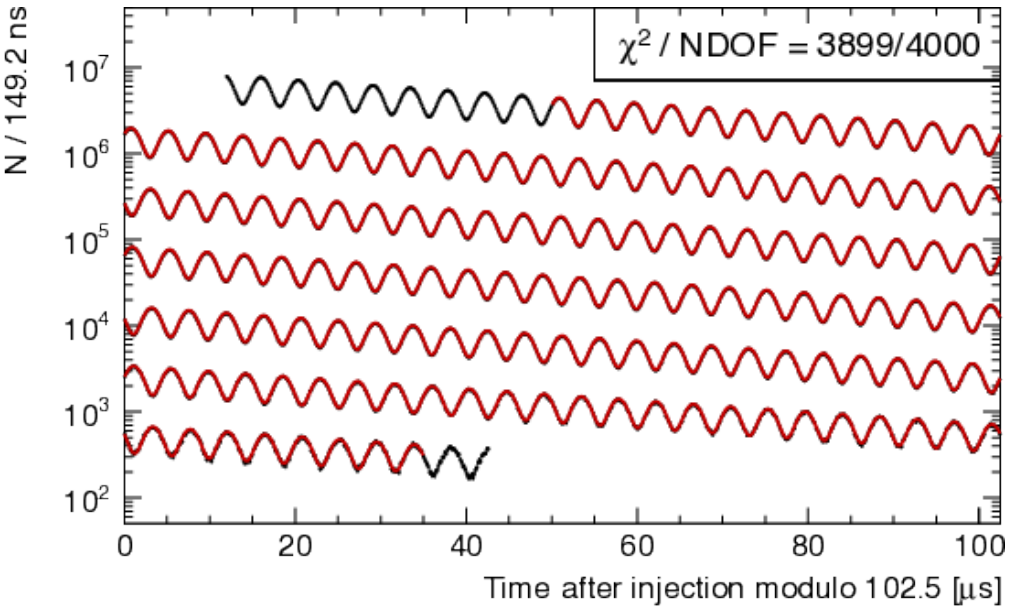
The muon magnetic moment
g-2 experiment at Fermilab, USA



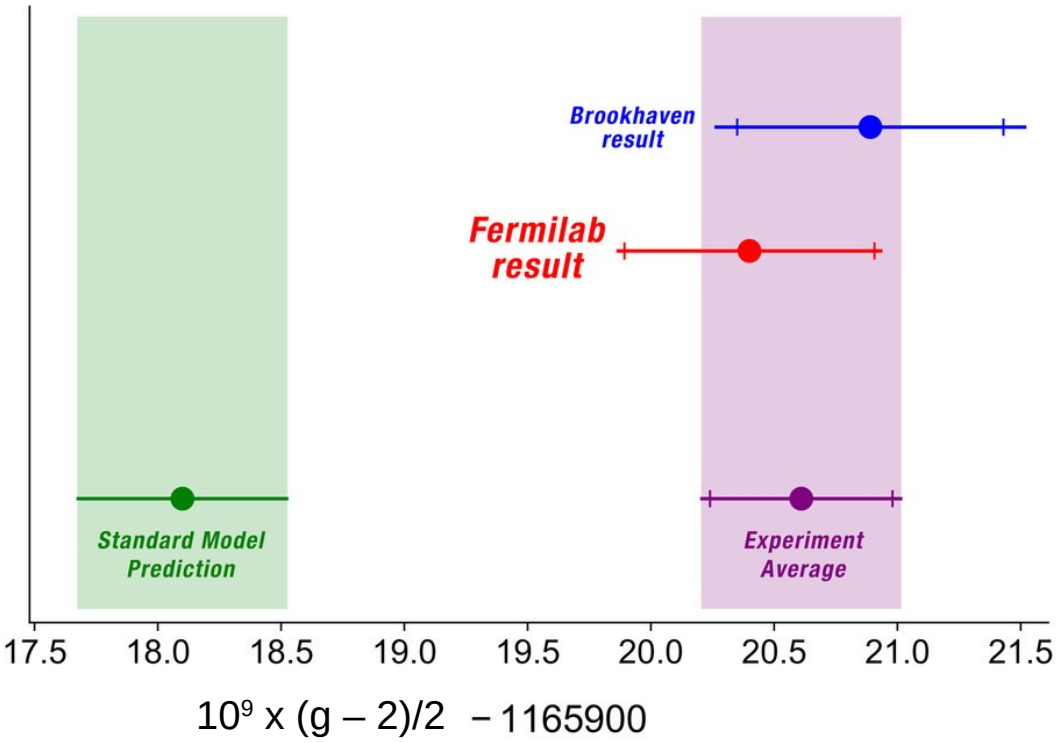


The muon magnetic moment
g-2 experiment at Fermilab, USA





The muon magnetic moment

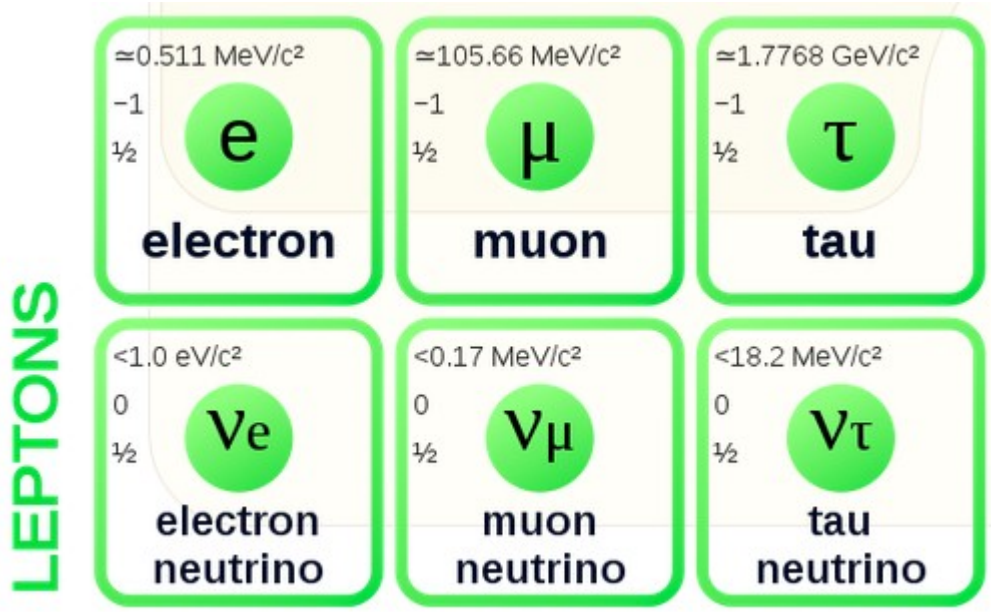


Experiment and theory don't seem to agree!

Could be due to some extra particle(s), not in the Standard Model, causing a small correction to g

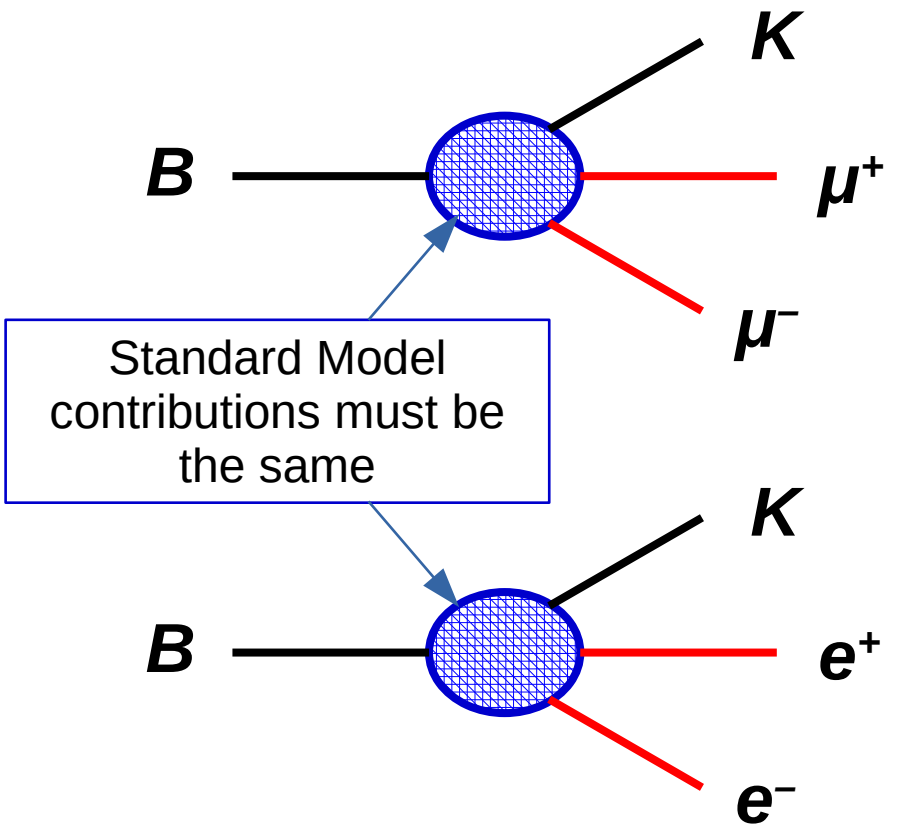
Lepton universality

- Electrons and muons (leptons) have same interaction strength in the Standard Model
  - Only difference between them is their mass
- No fundamental reason for this universality
  - “accidental symmetry”

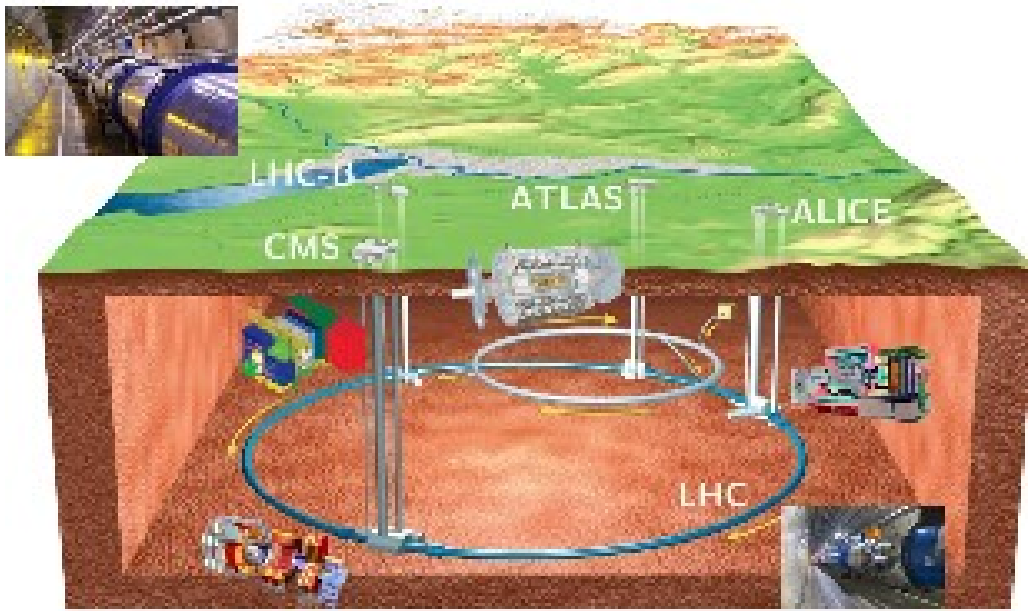


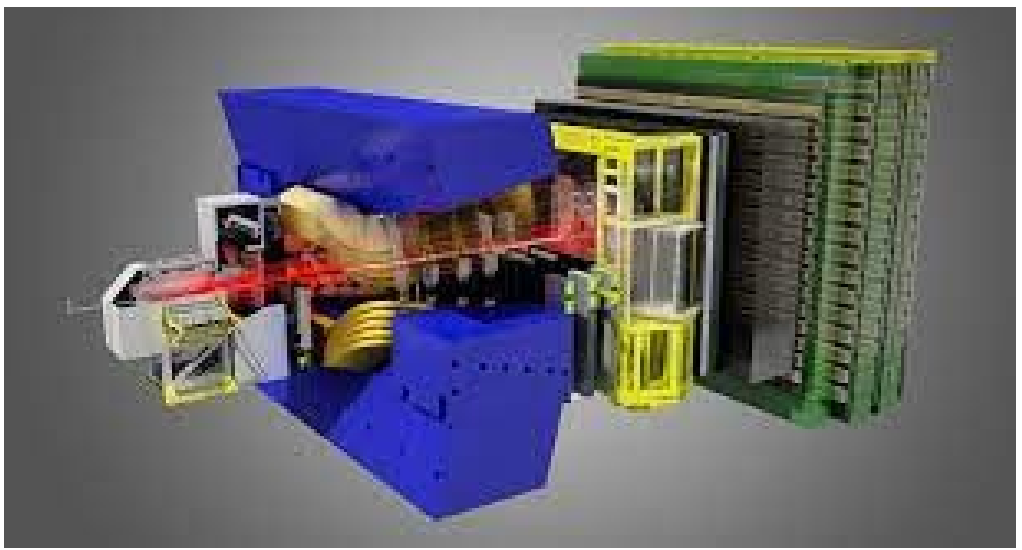
Lepton universality

- Electrons and muons (leptons) have same interaction strength in the Standard Model
  - Only difference between them is their mass
- No fundamental reason for this universality
  - “accidental symmetry”
- Can test if they are produced at same rates in various processes



Lepton universality
LHCb experiment at CERN





LHCb collaboration: about 1400 people representing 86 institutes from 18 countries

Warwick LHCb group: 5 academics, 7 PDRAs, 10 PhD students

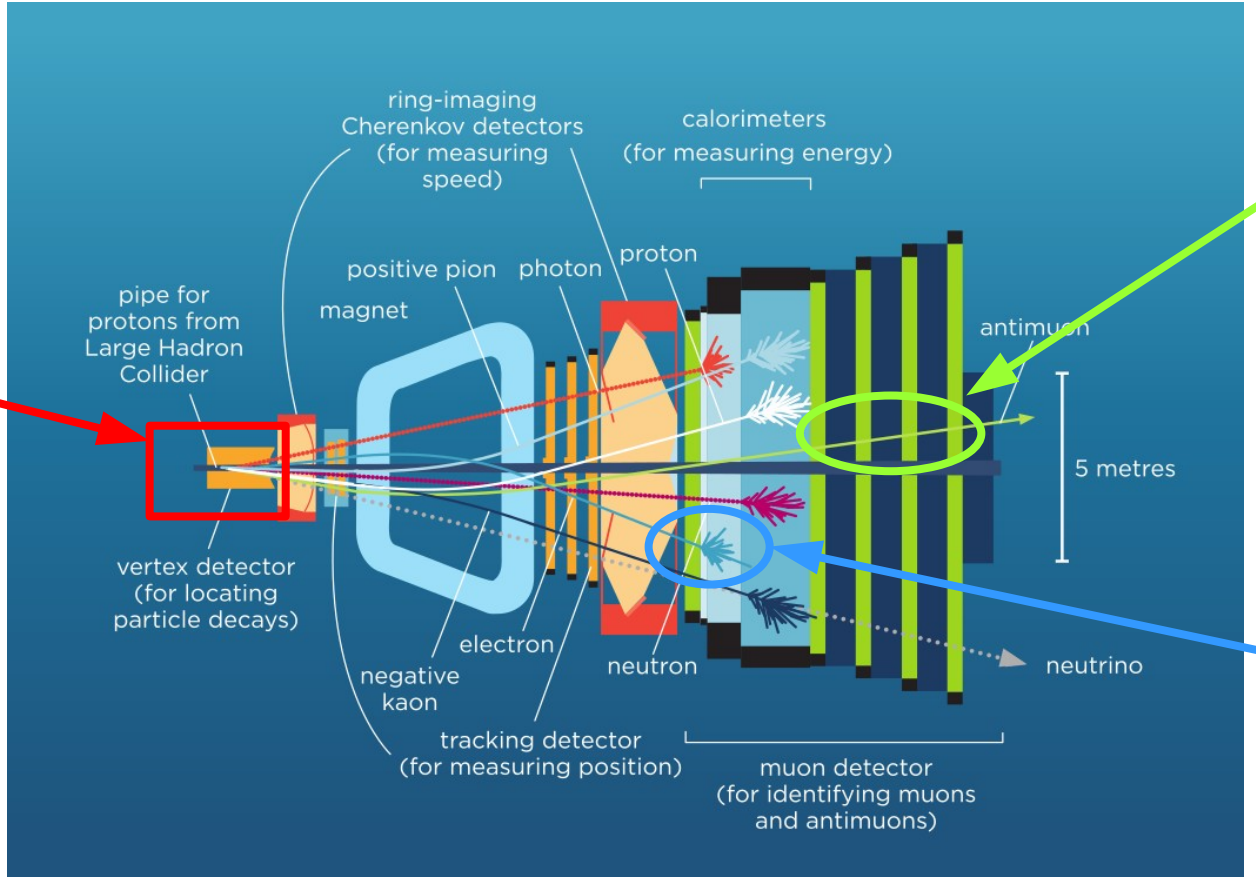
WARWICK

Lepton universality
LHCb experiment at CERN

Proton proton collisions occur inside vertex detector

B particles produced in forward direction

These decay rapidly to particles that traverse the detector



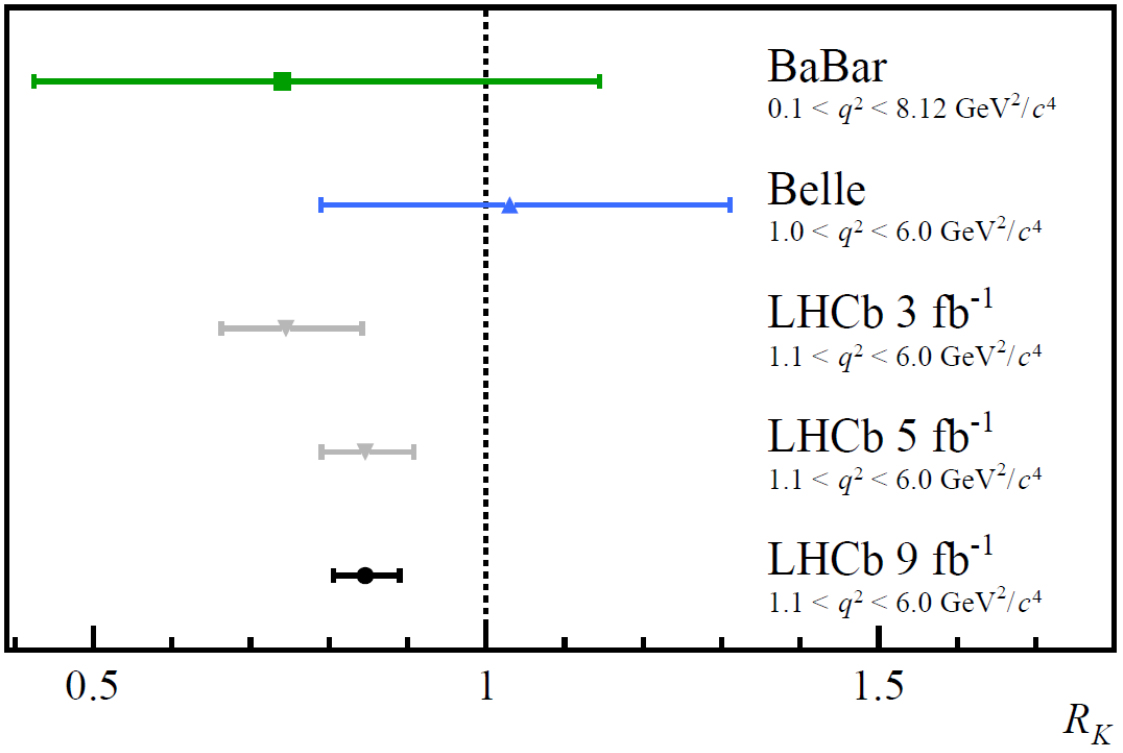
Muons penetrate detector & reach muon counters

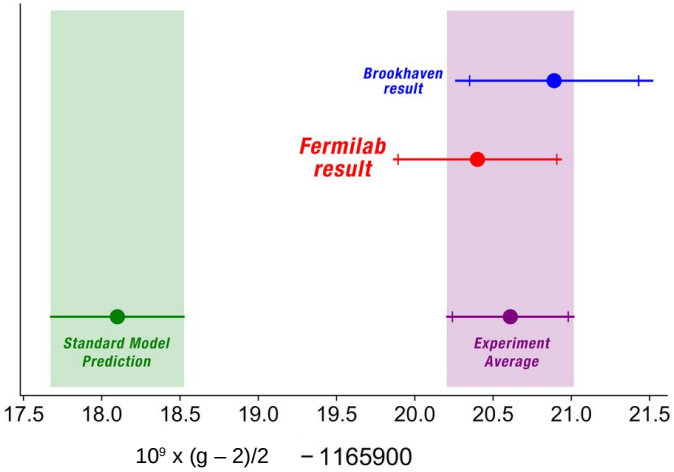
Electrons deposit all their energy in calorimeter

Lepton universality

Experiment and theory don't seem to agree!

Could be due to some extra particle(s), not in the Standard Model, interacting with muons but not electrons



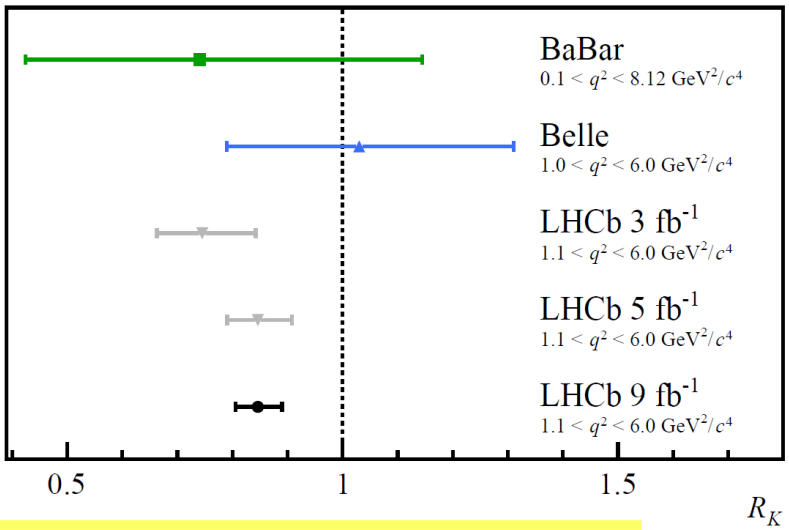


Experiment and theory don't seem to agree!

Could be due to some extra particle(s), not in the Standard Model, causing a small correction to g

Experiment and theory don't seem to agree!

Could be due to some extra particle(s), not in the Standard Model, interacting with muons but not electrons



Could these effects have a common origin?

Yes, potentially. But much more research is needed ...

Particle physics at Warwick

- Year 1
  - Quantum Phenomena + Introduction to Particle Physics
- Year 2
  - Quantum Mechanics and its Applications
- Year 3
  - Quantum Physics of Atoms
  - The Standard Model
- Year 4
  - Advanced Quantum Theory
  - Theoretical Particle Physics
  - Frontiers of Particle Physics

Final year project options
in both 3rd & 4th years (BSc or MPhys)

Opportunities for summer projects

WARWICK

Particle physics at Warwick

- Year 1
  - Quantum Phenomena + Introduction to Particle Physics
- Year 2
  - Quantum Mechanics and its Applications
- Year 3
  - Quantum Physics of Atoms
  - The Standard Model
- Year 4
  - Advanced Quantum Theory
  - Theoretical Particle Physics
  - Frontiers of Particle Physics

Final year project options
in both 3rd & 4th years (BSc or MPhys)

Opportunities for summer projects

… and then, if you are really keen,
opportunities for graduate study

WARWICK