

# BC Muons in Classrooms

## The BC “ $\mu$ siC” Project

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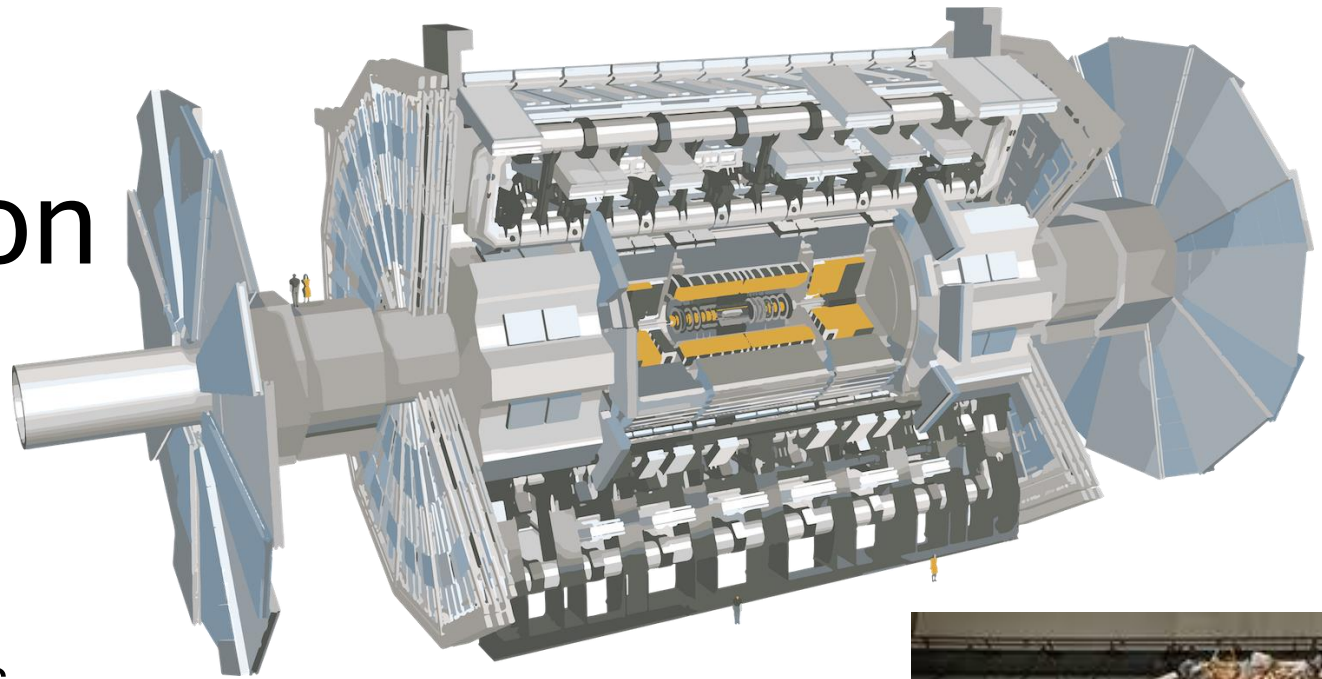
# Who are we?

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- We are a group of **particle physicists** from Simon Fraser University and TRIUMF
- We work on experiments which help us learn about how the basic building blocks of our universe behave

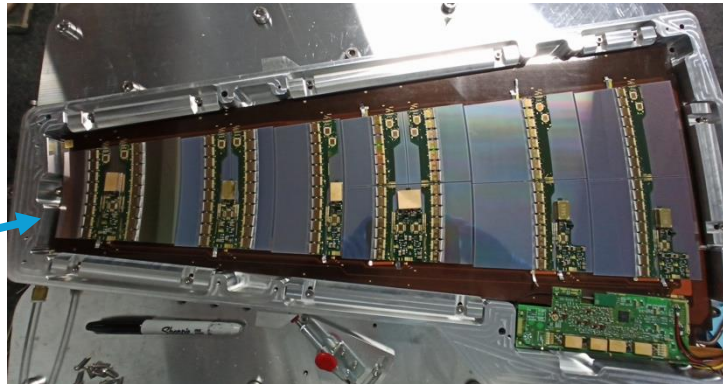
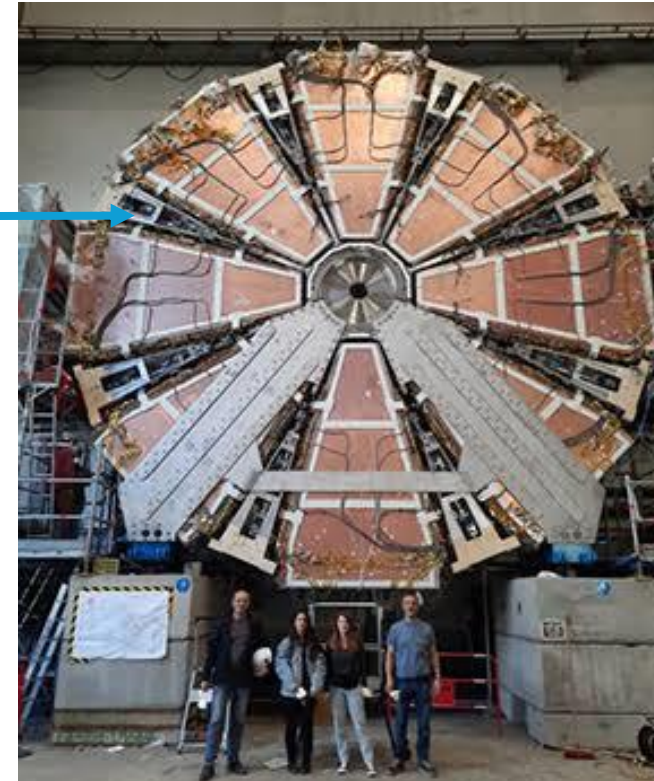


# Particle detection abroad: ATLAS



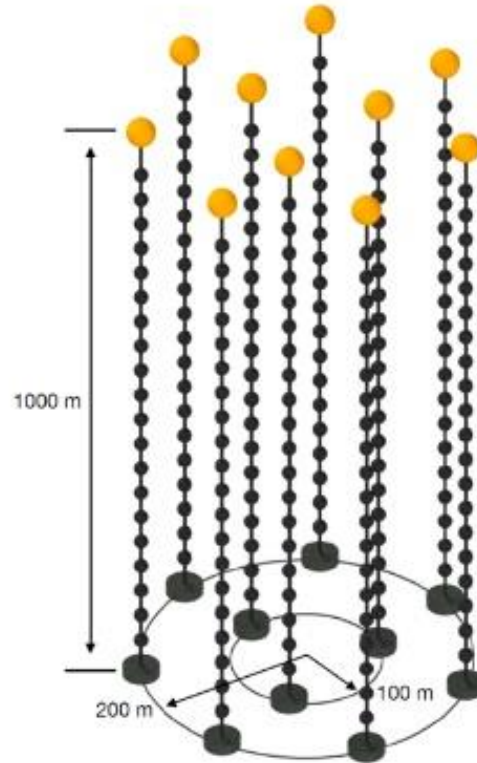
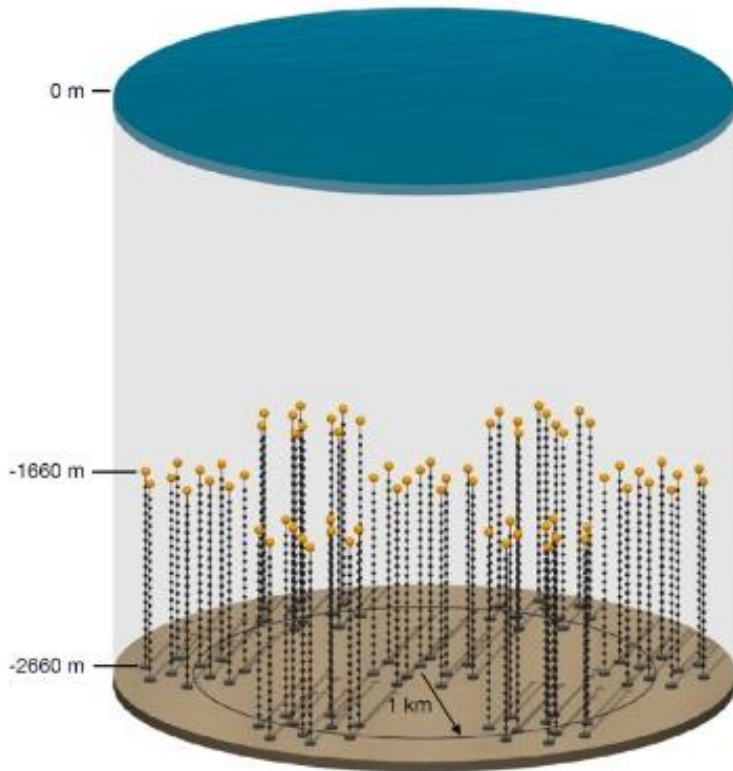
- A large particle detector underground at the French-Swiss border on the Large Hadron Collider at CERN
- About 50m long and 25m tall
- About 6000 people work on this experiment, from all over the world!
- At TRIUMF we are building the next generation of detector

TRIUMF helped build the New Small Wheel in the 2010s



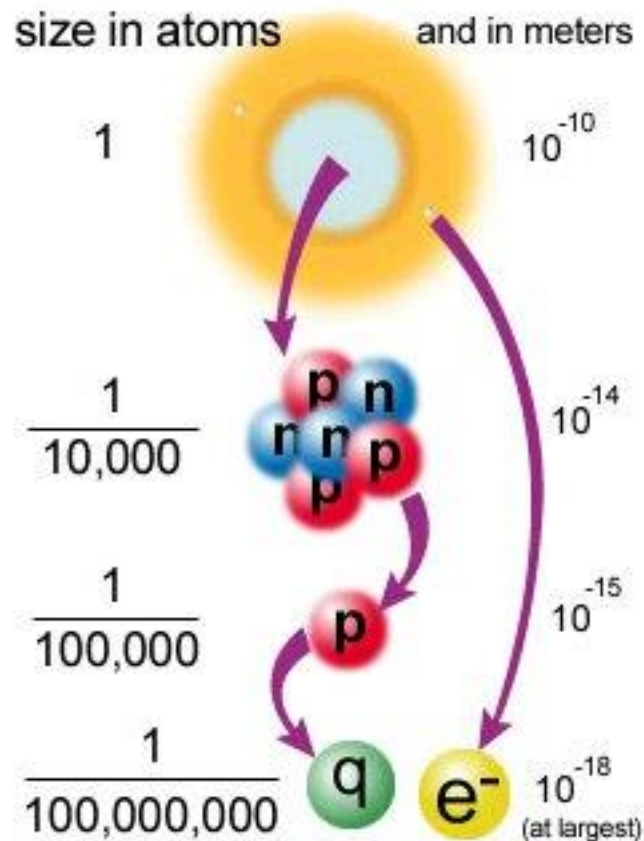
## Closer to home: P-ONE

- The Pacific Ocean Neutrino Experiment (P-ONE) was built in Vancouver and will be deployed underwater off the coast of Vancouver Island
- It will look for high energy particles from space, including muons!



# What is particle physics?

Particle physics is the study of the universe at the smallest scale.



Properties of atoms → atomic physics/physical chemistry

Properties of nuclei → nuclear physics

Properties of proton → nuclear & particle physics

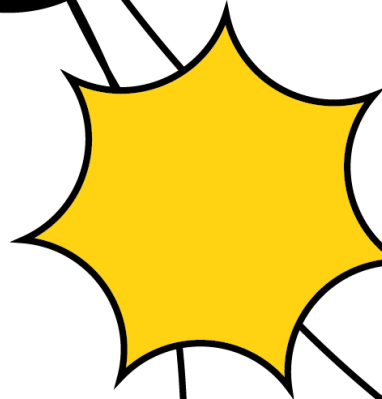
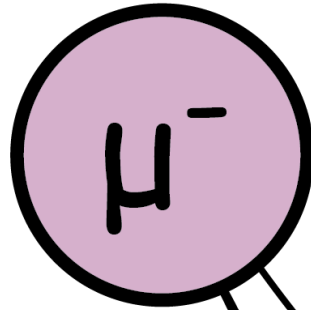
Properties of quarks → particle physics

# What is a muon?

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- Fundamental particle
- Heavier cousin of the electron (200x)
- Unstable – will decay into lighter particles

muon

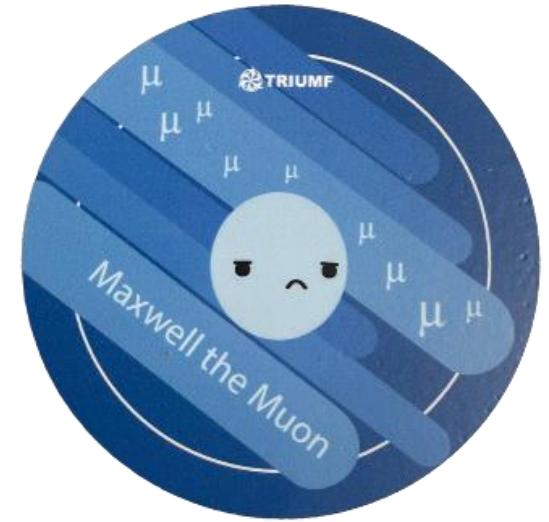


electron

muon neutrino



electron antineutrino



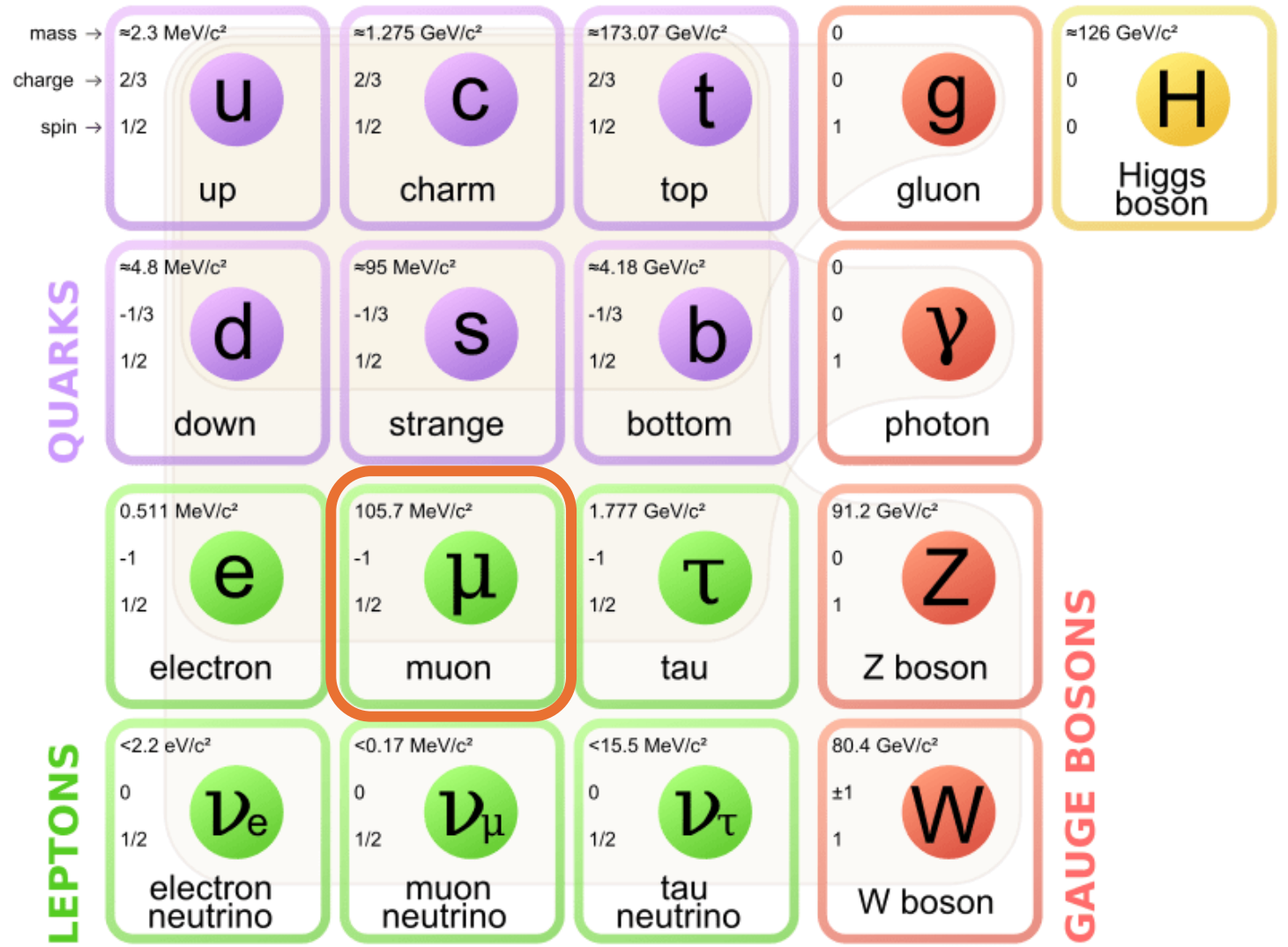
# What is a muon?

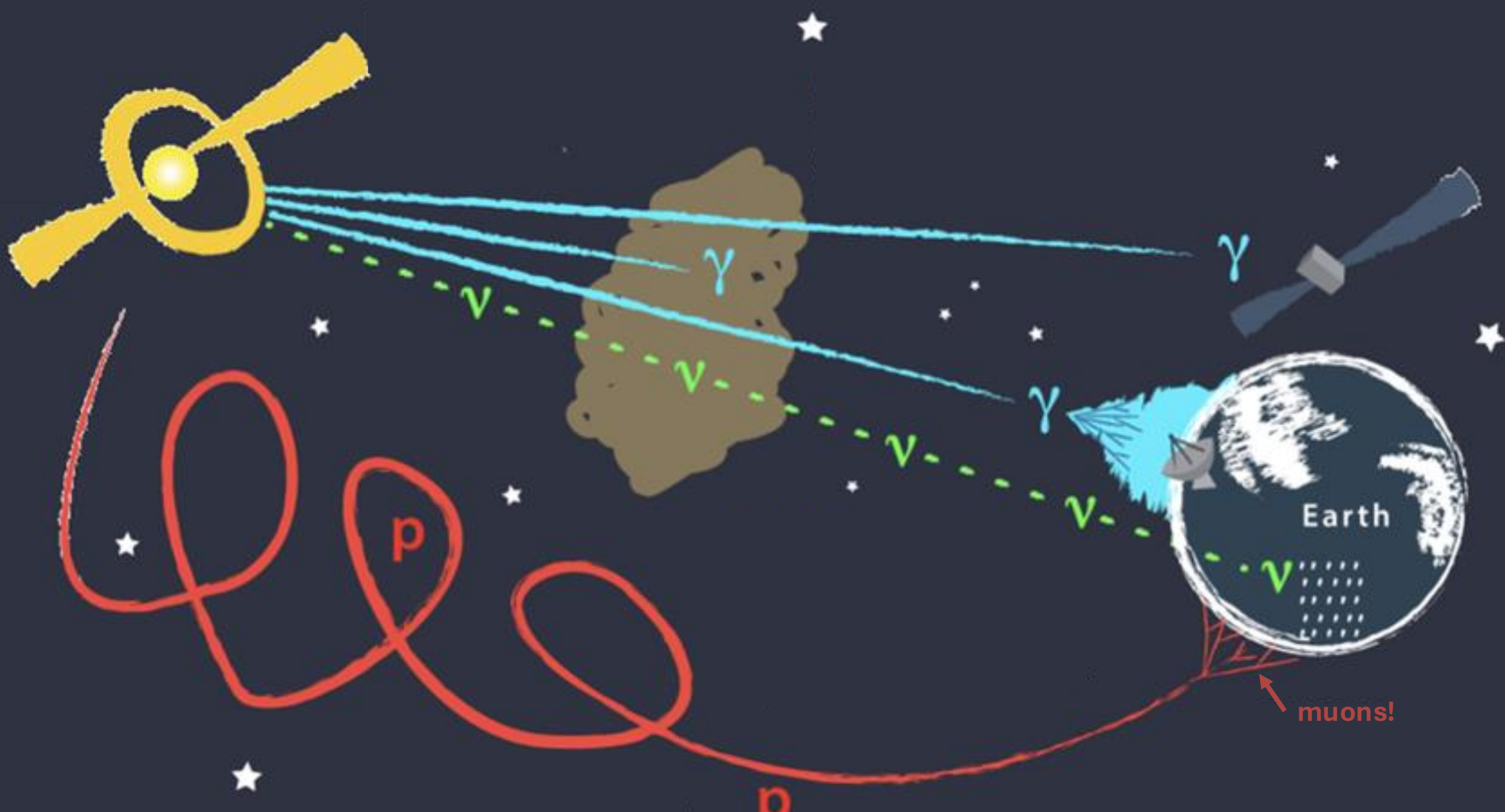
- Particles we interact with every day are light
- Smaller mass means more stable (they can live forever)
- We find these naturally on Earth

mass	$\approx 2.3 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 173.07 \text{ GeV}/c^2$	0	$\approx 126 \text{ GeV}/c^2$
charge	$2/3$	$2/3$	$2/3$	0	0
spin	$1/2$	$1/2$	$1/2$	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> Higgs boson
	$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
	$-1/3$	$-1/3$	$-1/3$	0	
	$1/2$	$1/2$	$1/2$	1	
<b>QUARKS</b>	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\gamma</math></b> photon	
	$0.511 \text{ MeV}/c^2$	$105.7 \text{ MeV}/c^2$	$1.777 \text{ GeV}/c^2$	$91.2 \text{ GeV}/c^2$	
	-1	-1	-1	0	
	$1/2$	$1/2$	$1/2$	1	
	<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b>Z</b> Z boson	
	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$80.4 \text{ GeV}/c^2$	
	0	0	0	$\pm 1$	
	$1/2$	$1/2$	$1/2$	1	
<b>LEPTONS</b>	<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b>W</b> W boson	<b>GAUGE BOSONS</b>

# What is a muon?

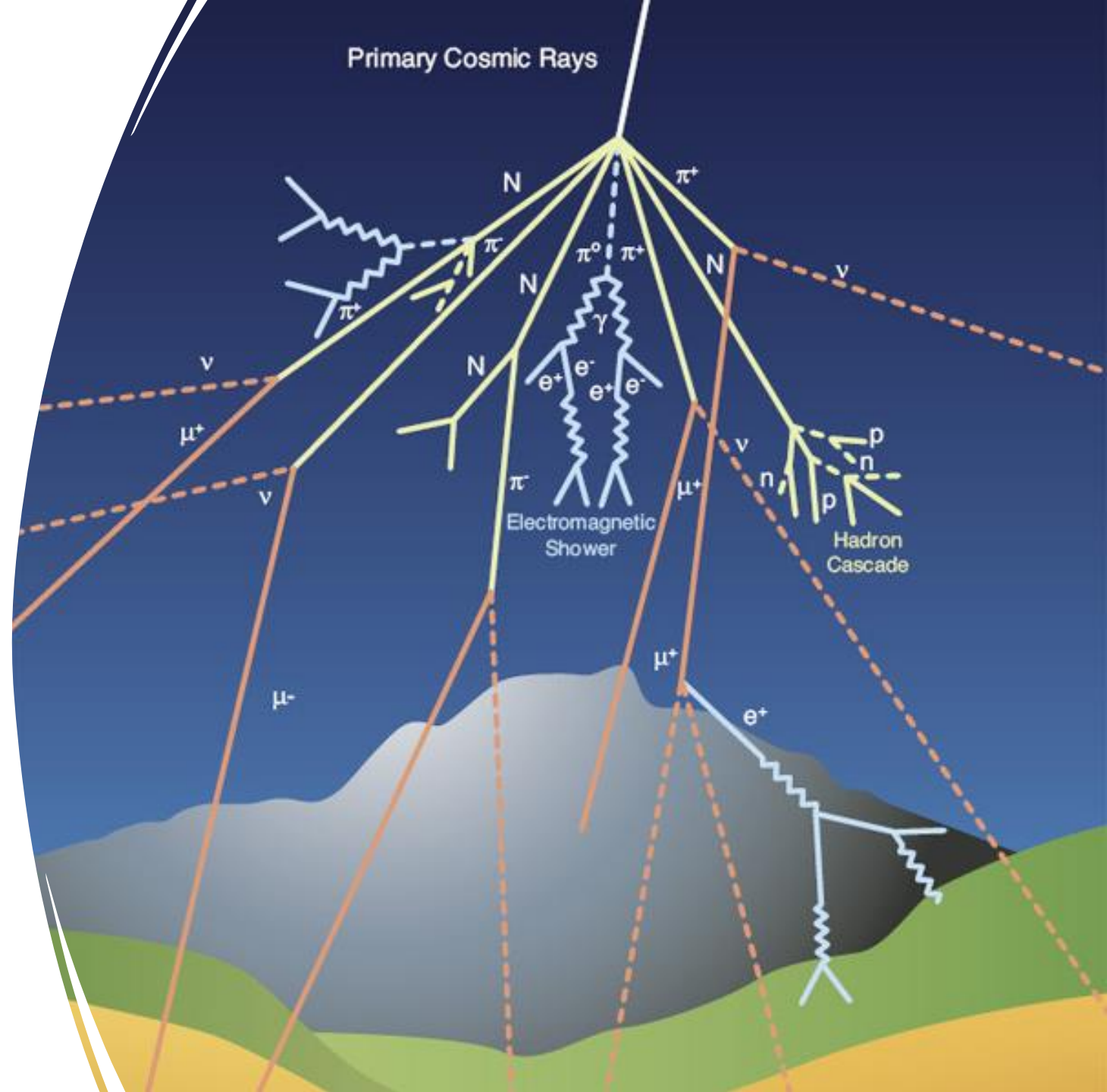
- Heavier particles need to come from places that have higher energy
- Made in galaxies or particle colliders





# Cosmic Muons

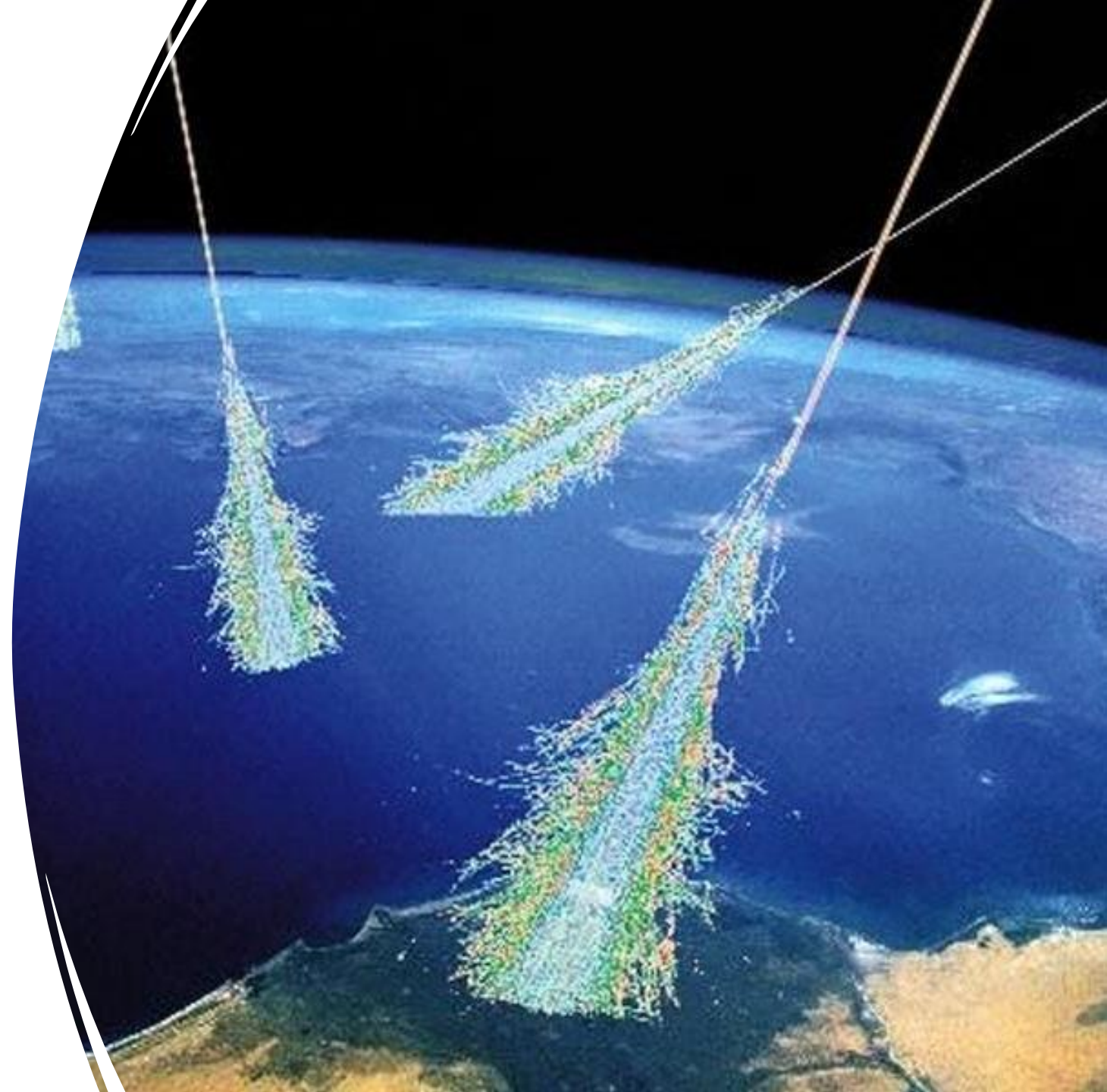
- Primary source from cosmic rays
- Particles from space interacting with our atmosphere
- Same energy as a baseball travelling 160 km/h!
- Cause a shower of particles
- Can be detected at ground level
- Ongoing area of study
- From our sun and extra-galactic sources such as nebulae



# Why are muons so interesting?

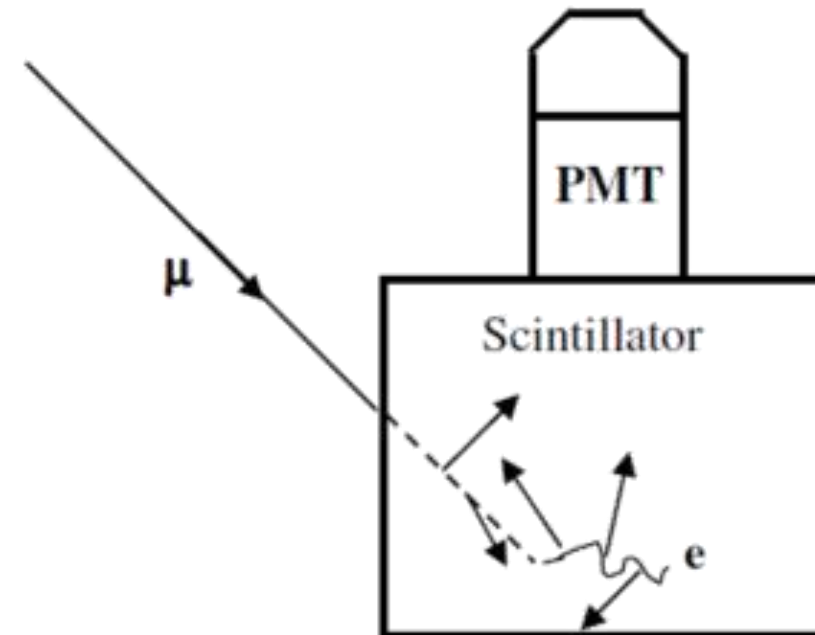
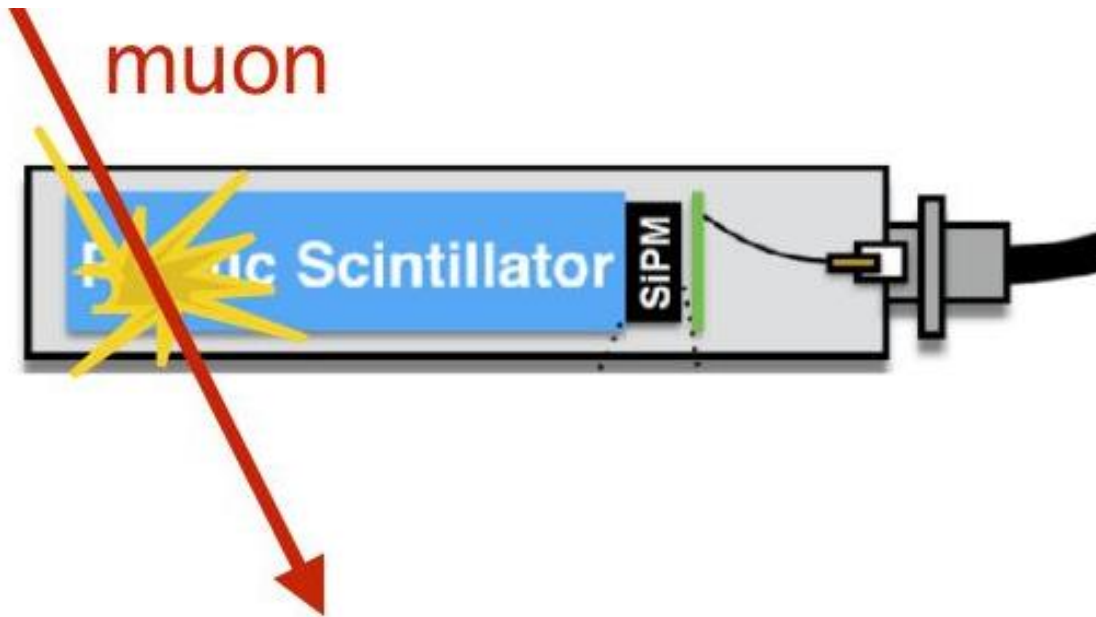
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- Very short lifetime,  $2.2 \mu\text{s}$ 
  - At the speed of light, that's 660m
- They travel so close to the speed of light that they experience **time dilation** which means they can travel 10km through the atmosphere to Earth and be detected!
- At sea level, we get a muons through a square centimeter every minute
  - Lots for us to measure!



# Scintillators: one kind of detector

- Atmospheric particle hits the scintillator (plastic) material in the detector
- Little flash of light
- Picked up by a photomultiplier
  - Converted to electricity
- Counted as an “event” by the circuit
  - LED flash



- +
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- But... you don't need a giant machine or a PhD to do particle physics!






# Cosmic Watch Project


- Developed by Spencer Axani, U Delaware
- Pocket sized muon detector
- Can work alone or with other detectors to record cosmic events
- Allows us to see muons that would otherwise be invisible!

# What does it do?

Every time the detector sees an event, it is recorded to a text file



You will see what the time the event happened, and how much energy went into the scintillator



You can use the collected data to find out how many events you record per second, and to see what energies they are.

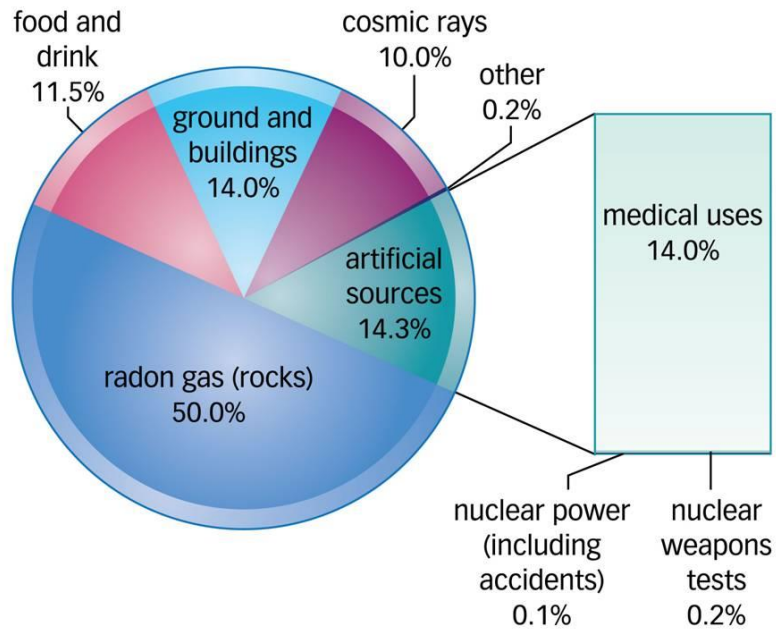
# The detector

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- You can watch events come in as the LED flashes
- You can upload your events to the cloud and see what other schools around Vancouver are recording;
  - Do you see them at the same rate?
  - The same energies?
  - Can you match your muon rate to big solar events?

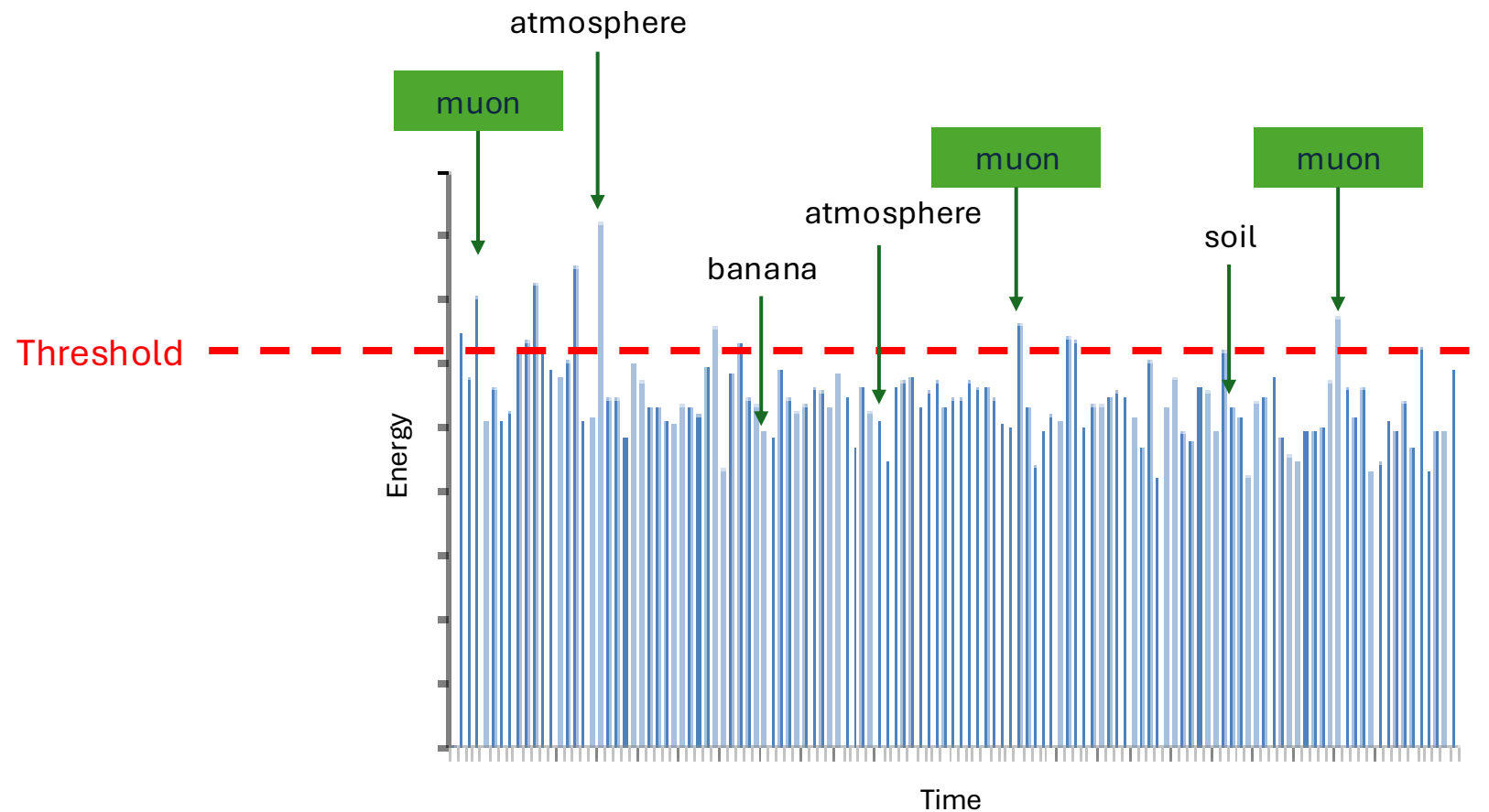


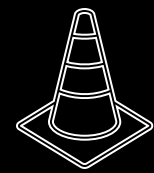
# Muon detection



Background radiation is all around us!

- Not every event we see will be a muon, there's lots of energetic particles flying about!
  - Can use **thresholds** to find out which events are likely muon candidates
  - Record over time in many locations





Website: under construction!

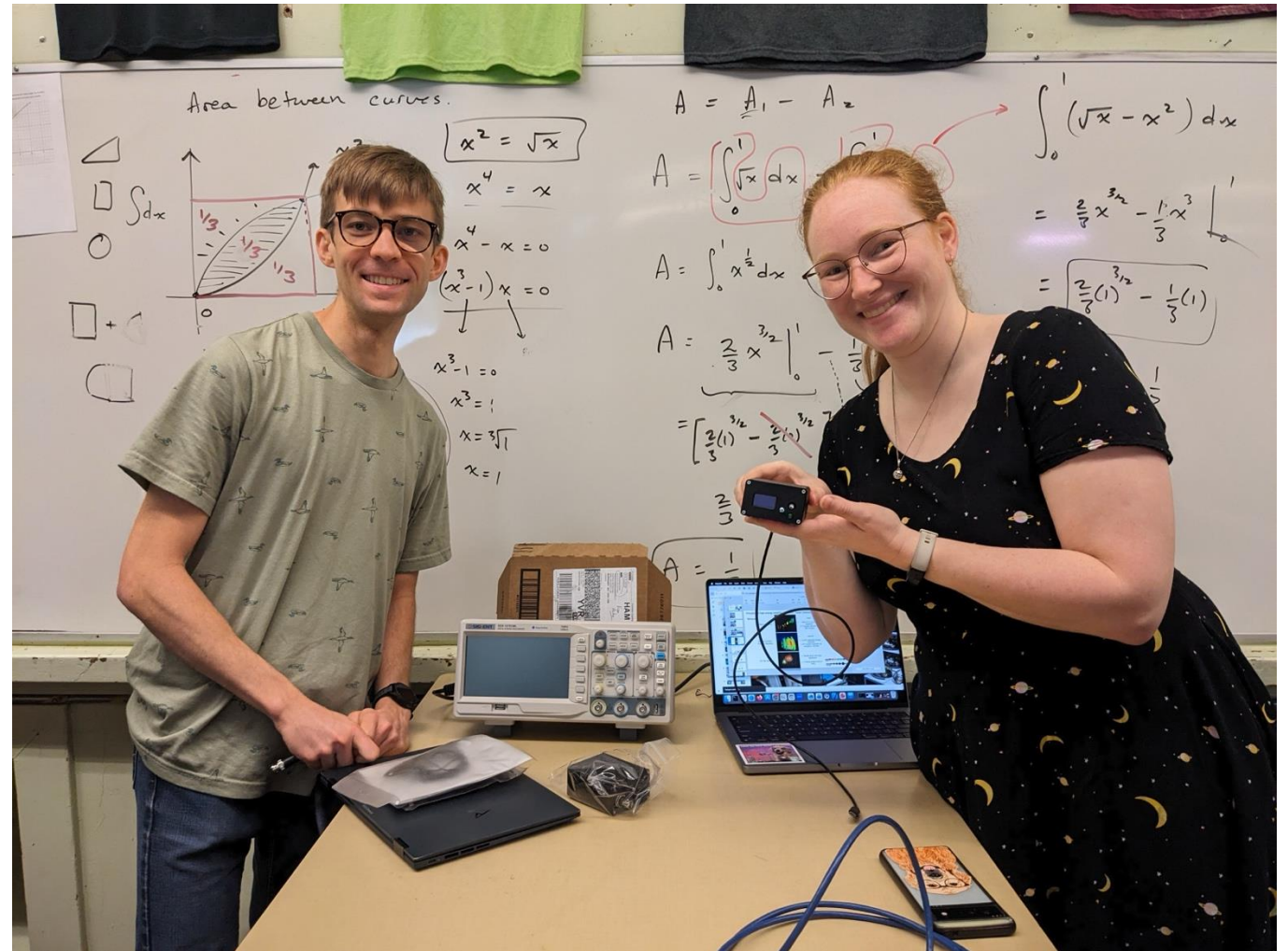


MusIC detector deployment locations



# Pilot Program

- One detector deployed in a high school so far – more planned for September 2026
- Demonstrated data collection, including coincidence between two detectors
- Class will collect data for upload to our website
- Data from many detectors and schools will be combined to reconstruct particle showers!



Matt Basso and Emily Filmer with the Cosmic Watch setup



Cosmic rays

Vancouver

Burnaby

Richmond

Surrey

Cosmic Watch

Cosmic Watch

# Interested? Contact us!

- In BC? Sign up here!
  - We are setting up school visits for the 26/27 year, and can travel anywhere within BC
- Elsewhere? We can still help!
  - Reach out by email and we can help you set up something in your area!



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