

Let's Smash The Proton!

Raghav Kunnawalkam Elayavalli
(they/them)

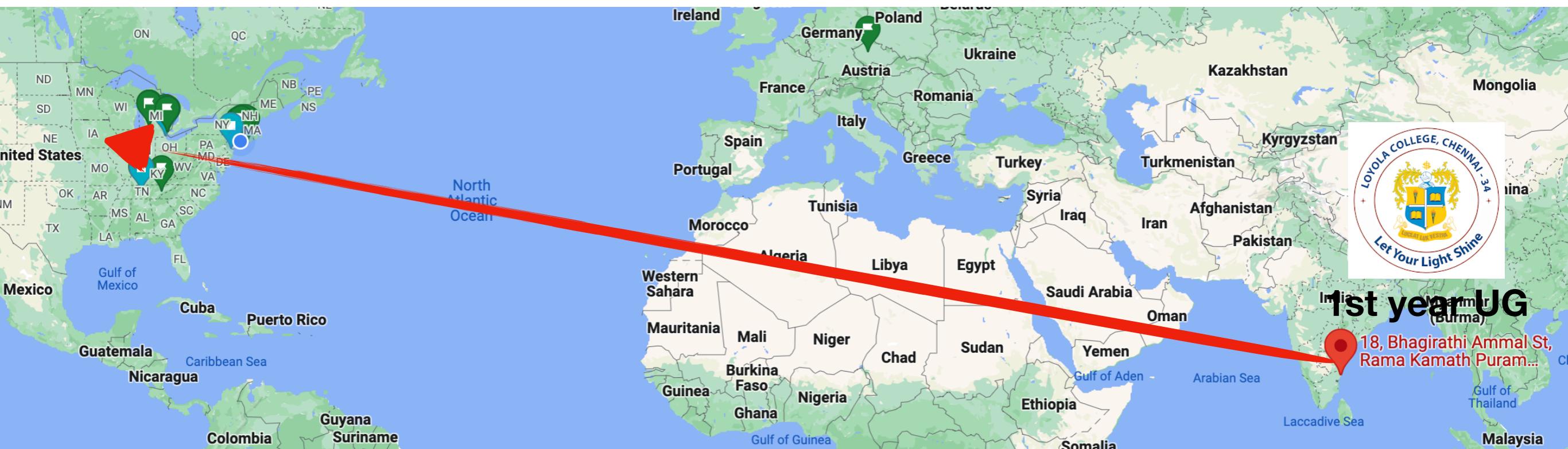
School of Science and Math at Vanderbilt
Summer 2023

Day 1 - Introduction to Colliders and the program

HELLO

My name is

My pathway to physics



Undergraduate



Masters



PhD



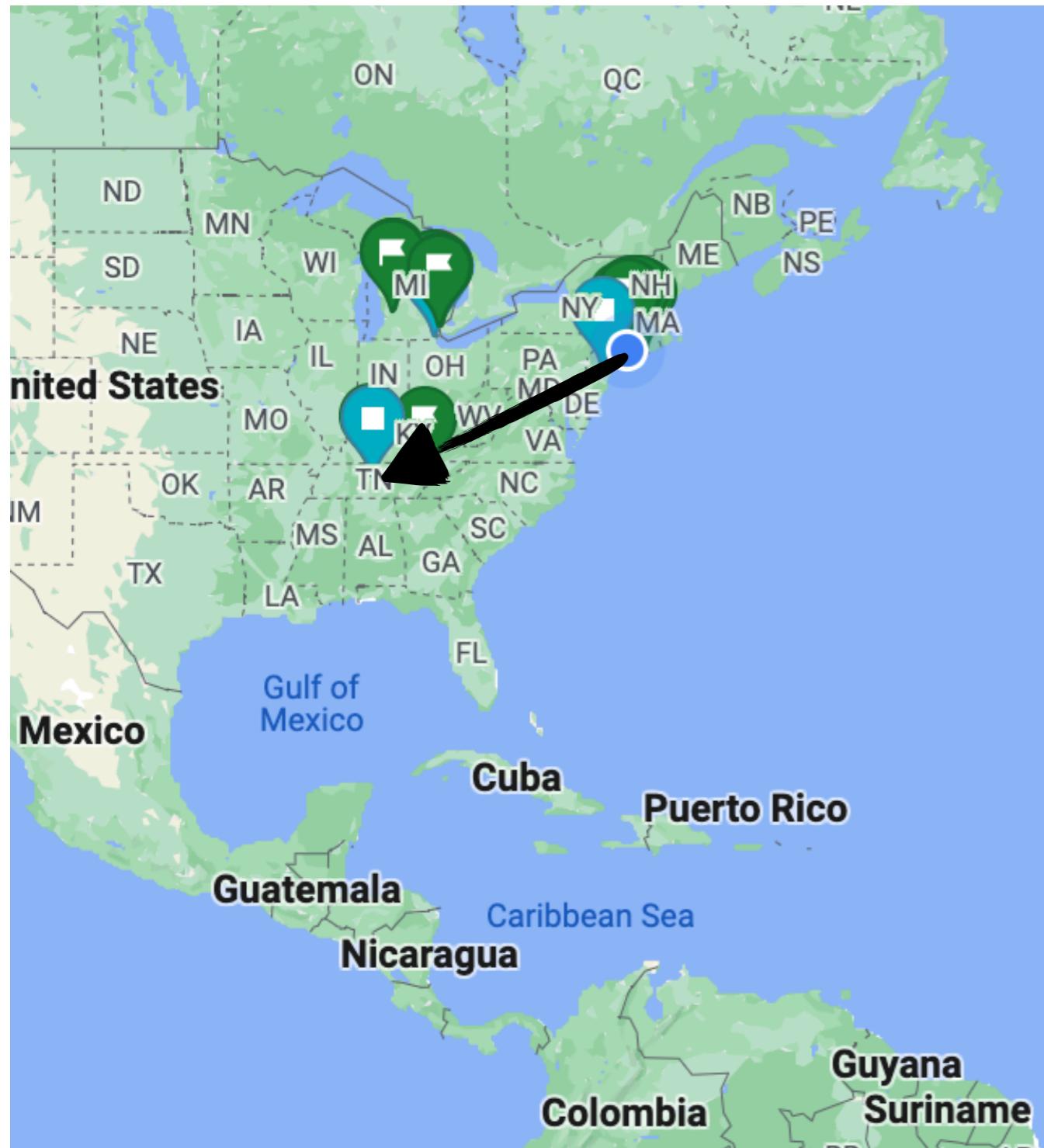
WAYNE STATE
UNIVERSITY



Post-doctoral
research fellow

Associate
Research
Scientist

My pathway to physics



VANDERBILT
UNIVERSITY

Assistant professor of physics
(Since fall 2022)

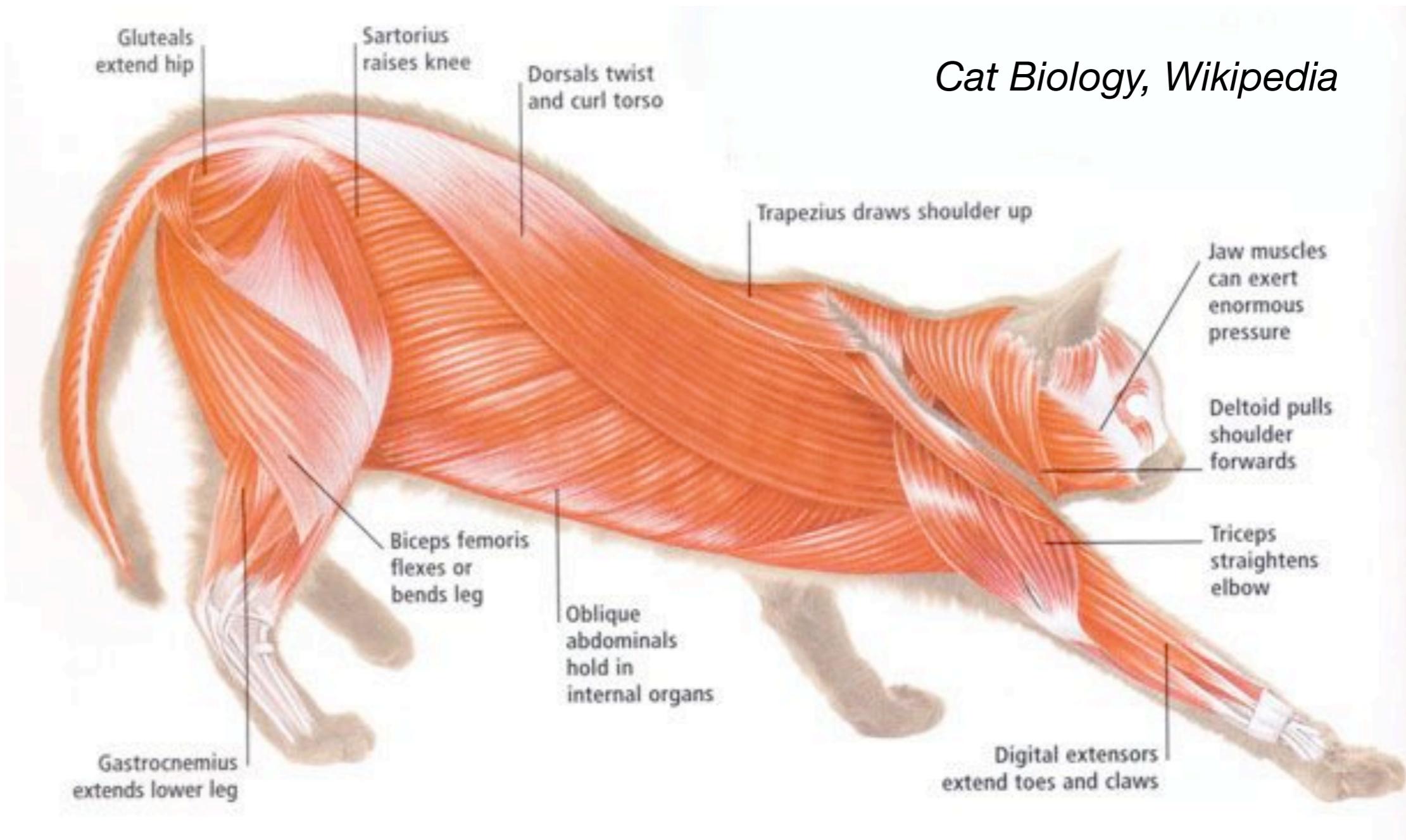


Lets ask a simple question

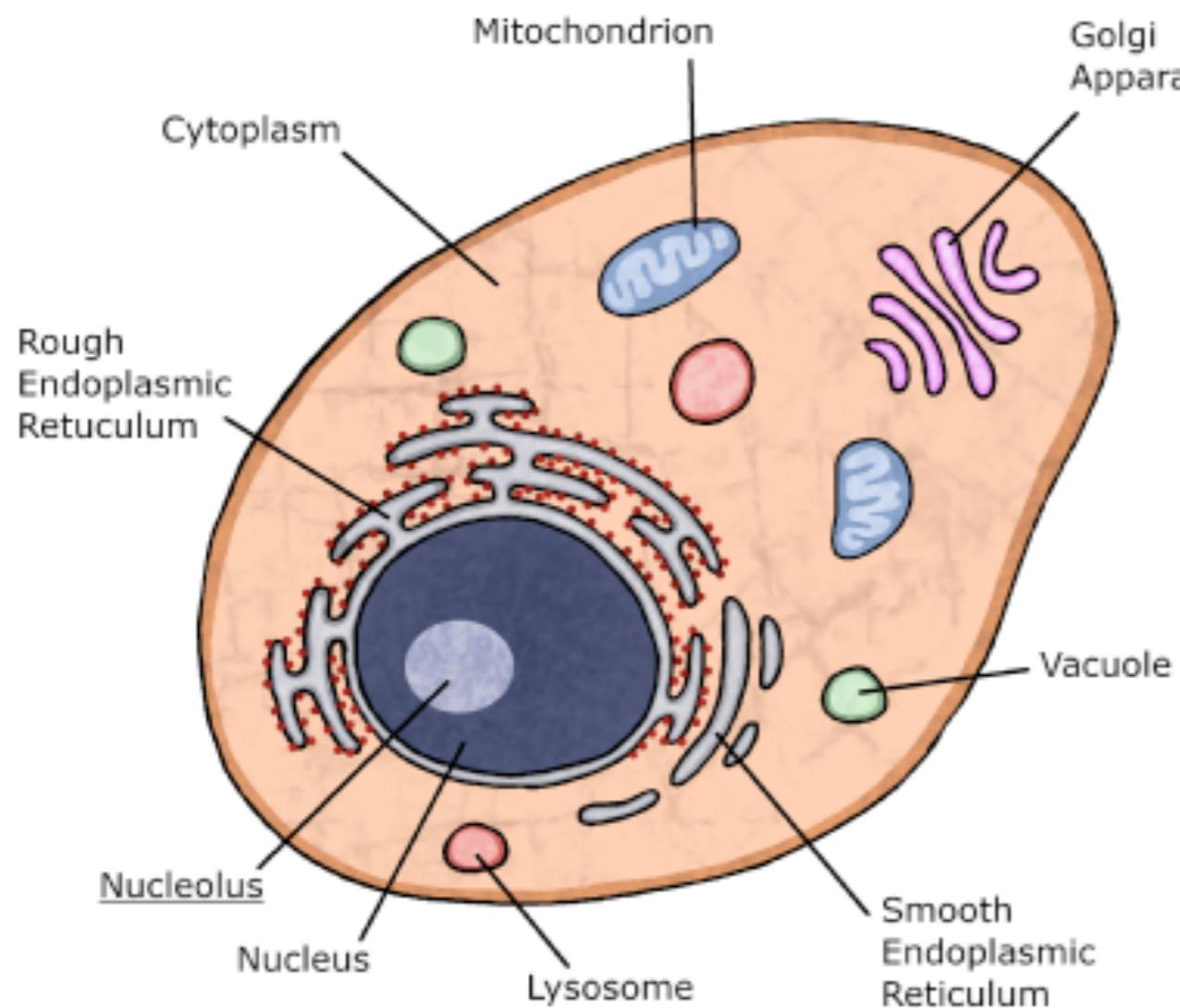


What are
Fili and Kili
made of?

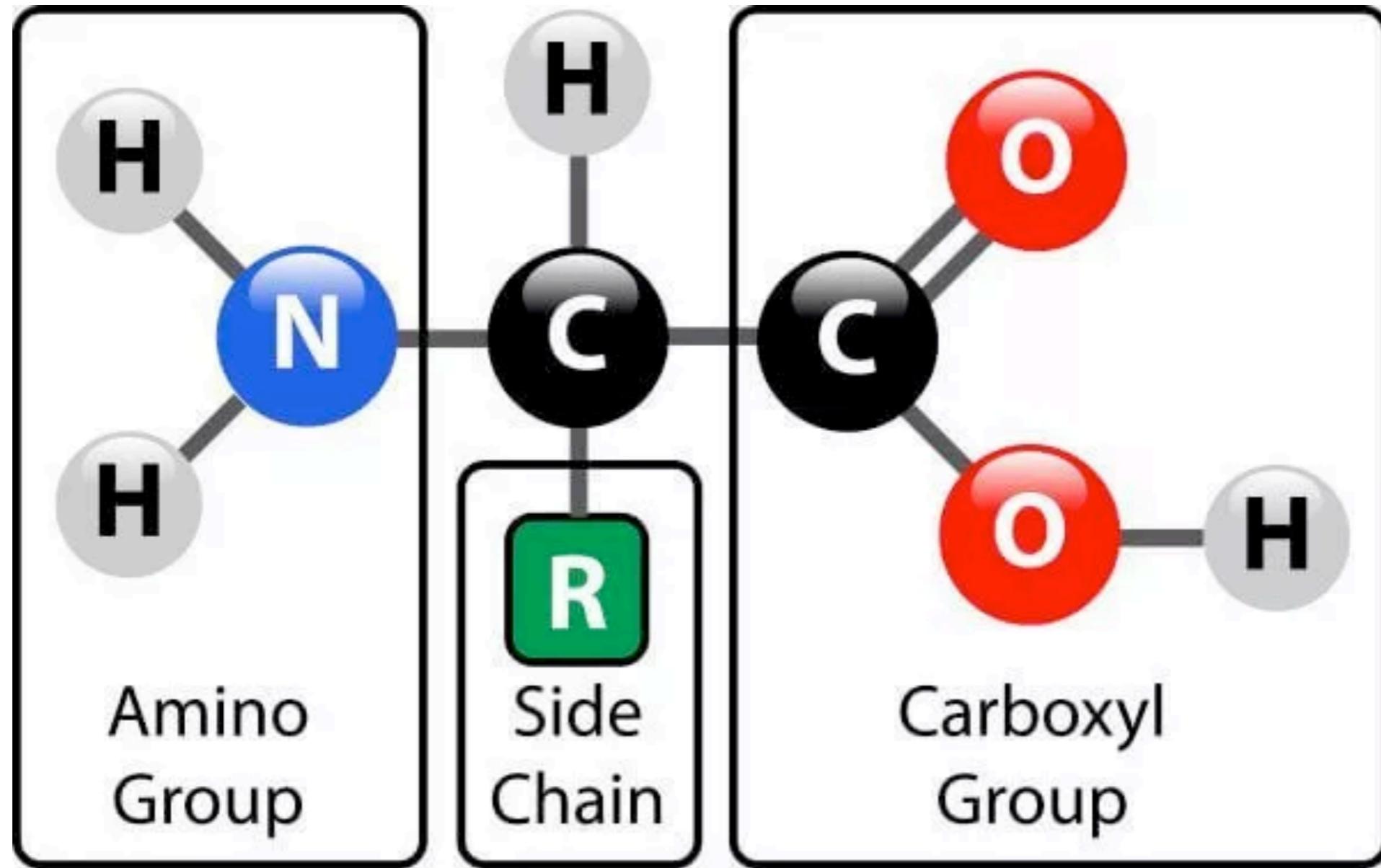
Cat Biology, Wikipedia



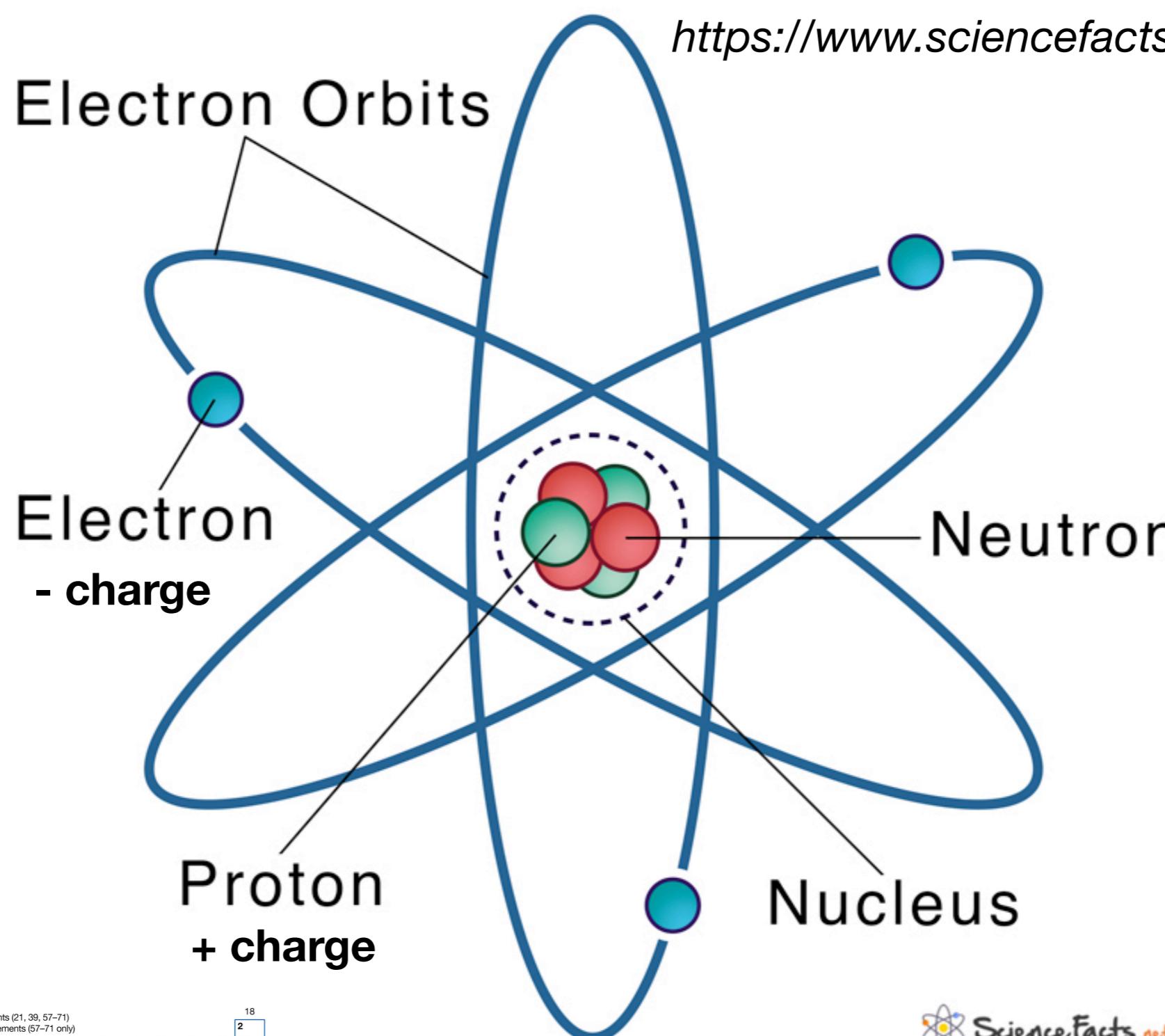
- They have hair, muscles, bones, tissues, fibers, blood, etc..
- What are those made of?



- Complicated structures which involve collections of smaller things...
- What makes up these structures?



- Proteins are made of chains of amino acids which are composite objects made from different atoms
- What are atoms made of?

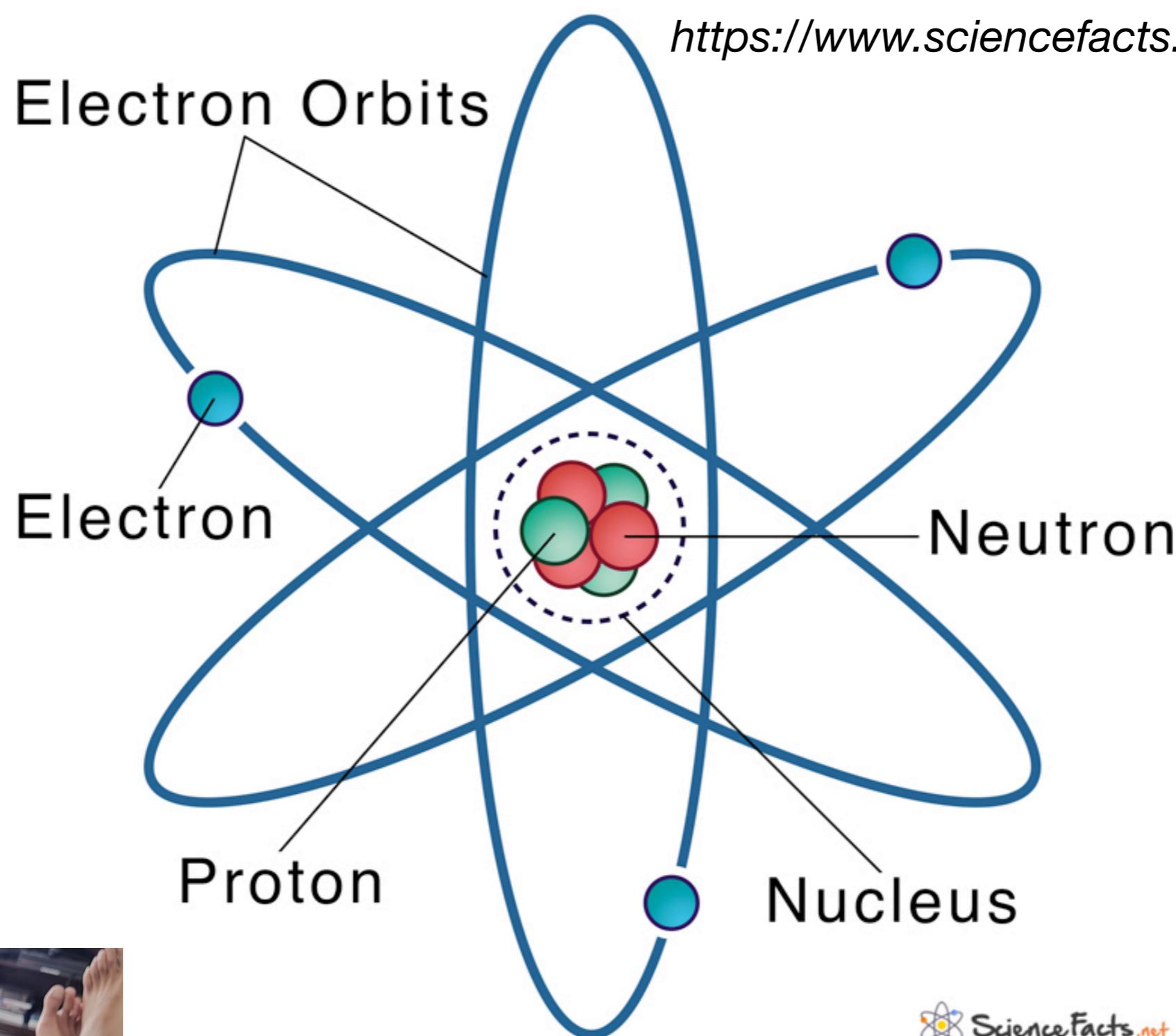


Neutral

Periodic table of the elements

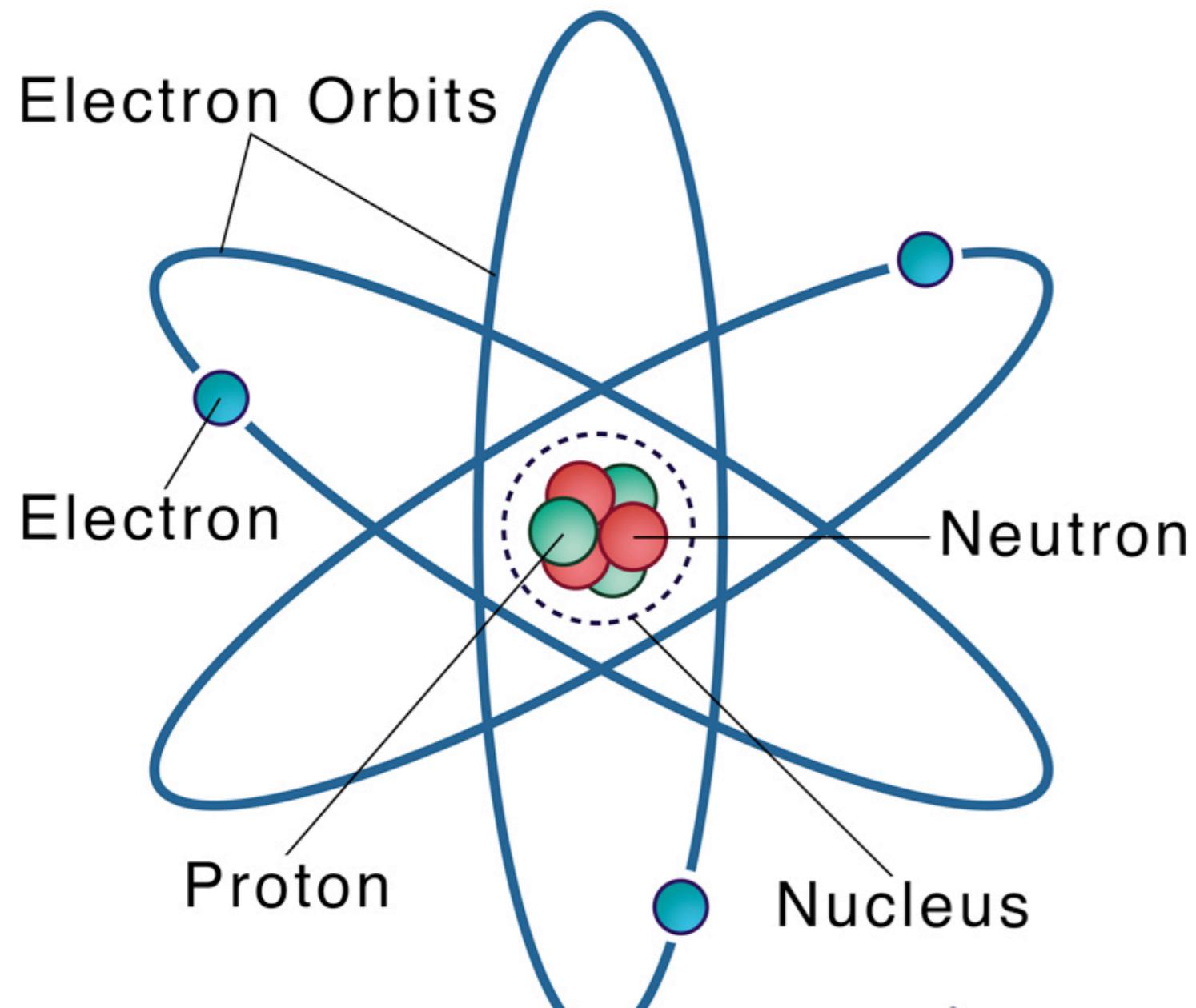
		Alkali metals		Alkaline-earth metals		Transition metals		Other metals		Other nonmetals		Halogens		Noble gases		Rare-earth elements (21, 39, 57–71) and lanthanoid elements (57–71 only)		Actinoid elements							
period	group	H	Li	Be	Na	Mg	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	He
1	1	H																					He		
2	3		Li	Be																				Ne	
3	11			12																				Ar	
4	19	20		21	22	23	24	25	26	27	28	29	30			31	32	33	34	35	36			Kr	
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54						Xe	
6	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I								
7	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86						Rn	
7	87	88	89	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118						Og	
Ianthanoid series																							Lu		
actinoid series																							Lr		
Numbering system adopted by the International Union of Pure and Applied Chemistry (IUPAC).																									

- Everything we see around us are made of these atoms!



- Can we keep going further?
Is there anything smaller?





**How to
see inside
the proton/
neutron?**

Question - 1



How to see
what's inside this
Apple Watch?

Apple Watch

How to see whats inside this Apple Watch?



Apple Watch

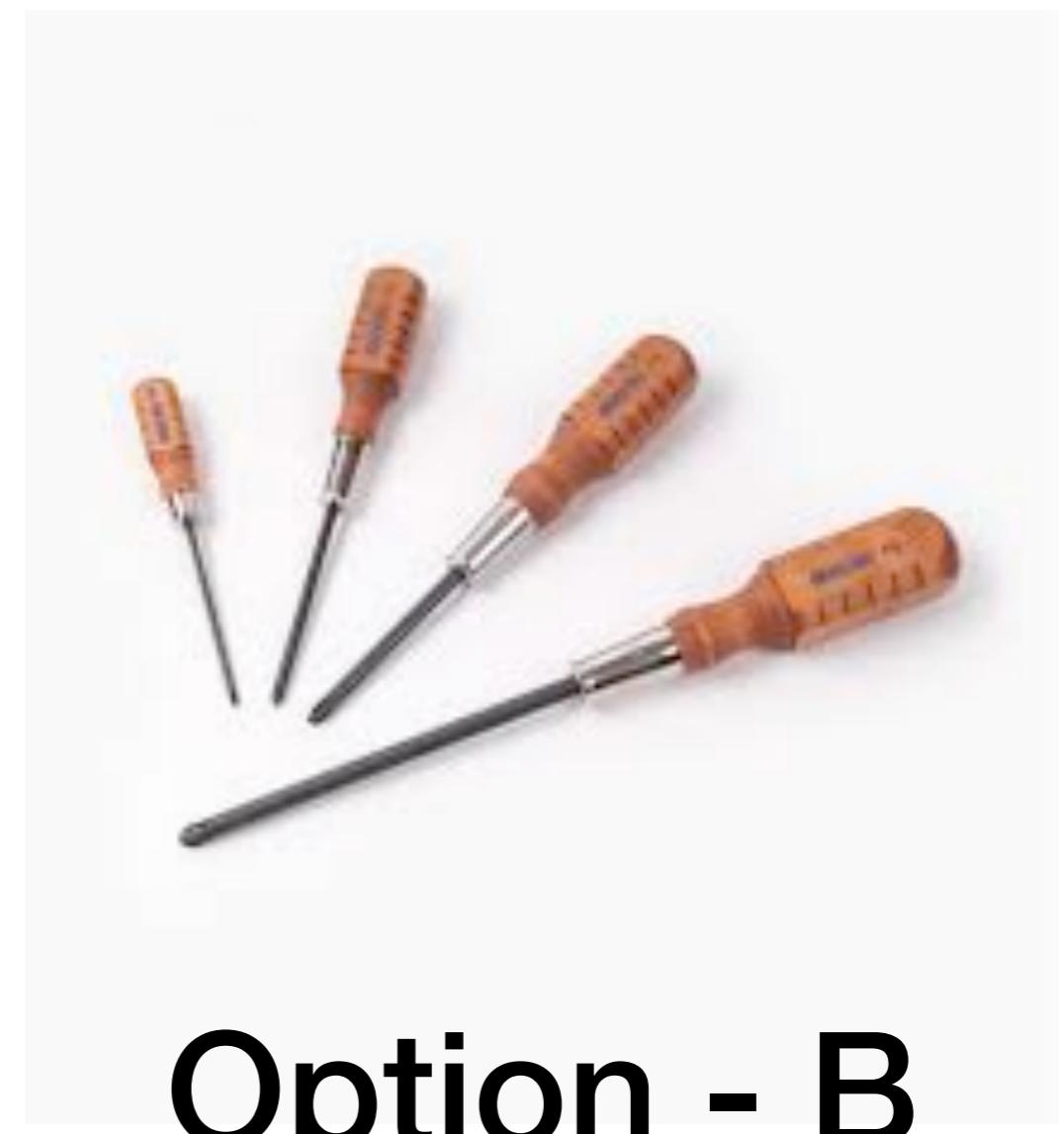


Option - A

How to see whats inside this Apple Watch?



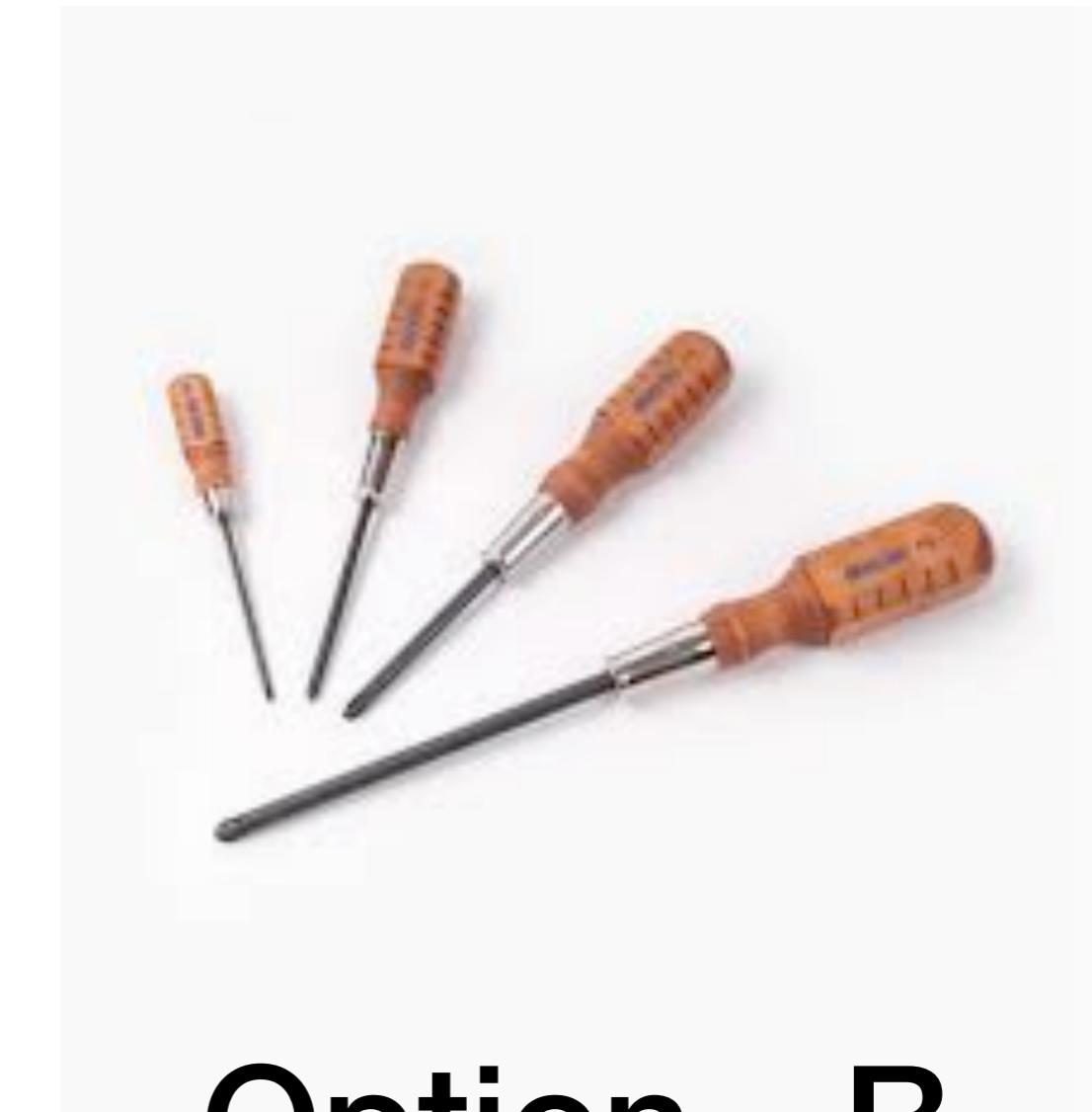
Apple Watch



Option - B



Option - A



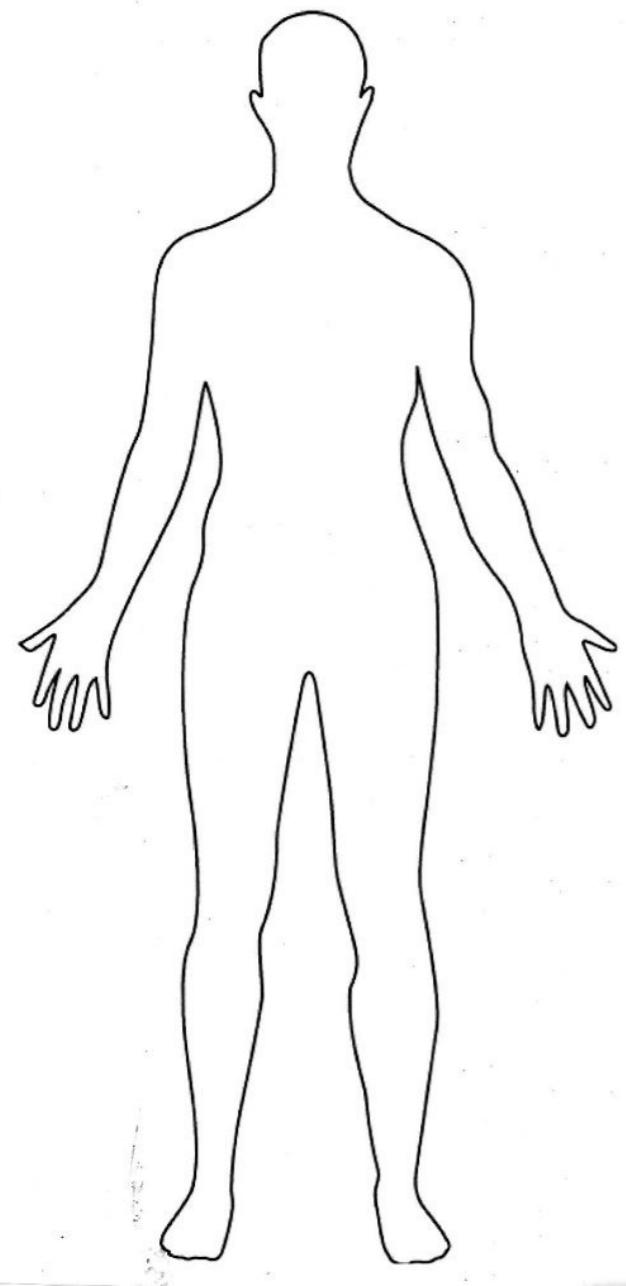
Option - B



Option - A



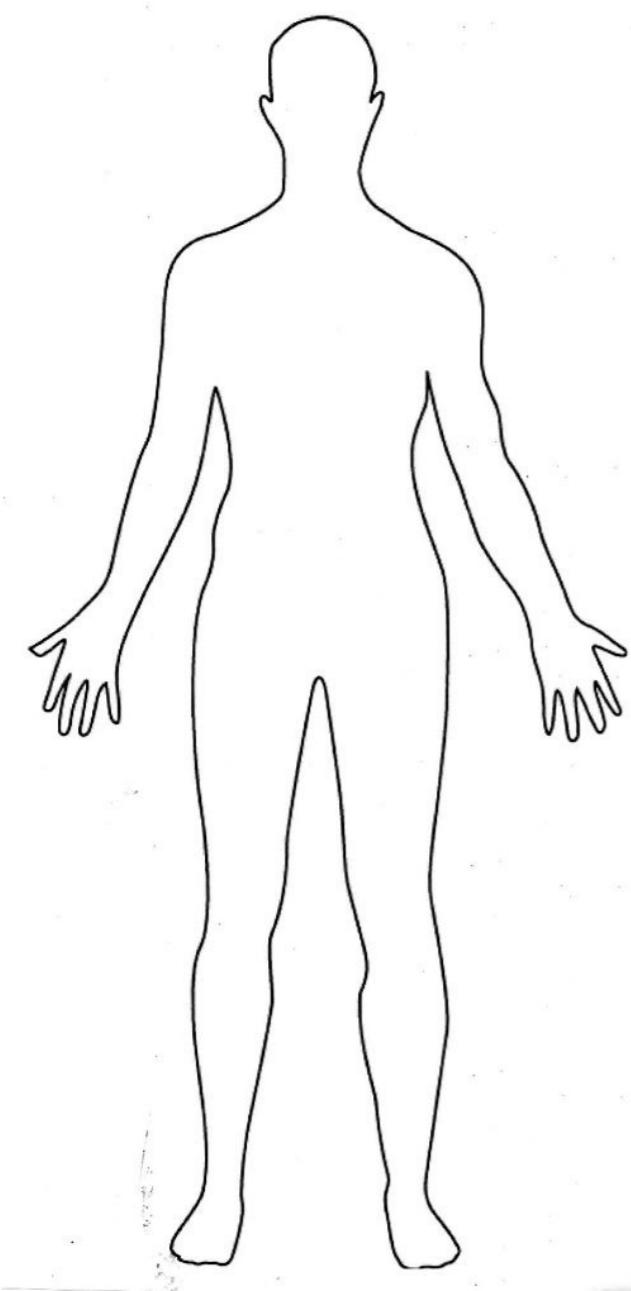
Option - B



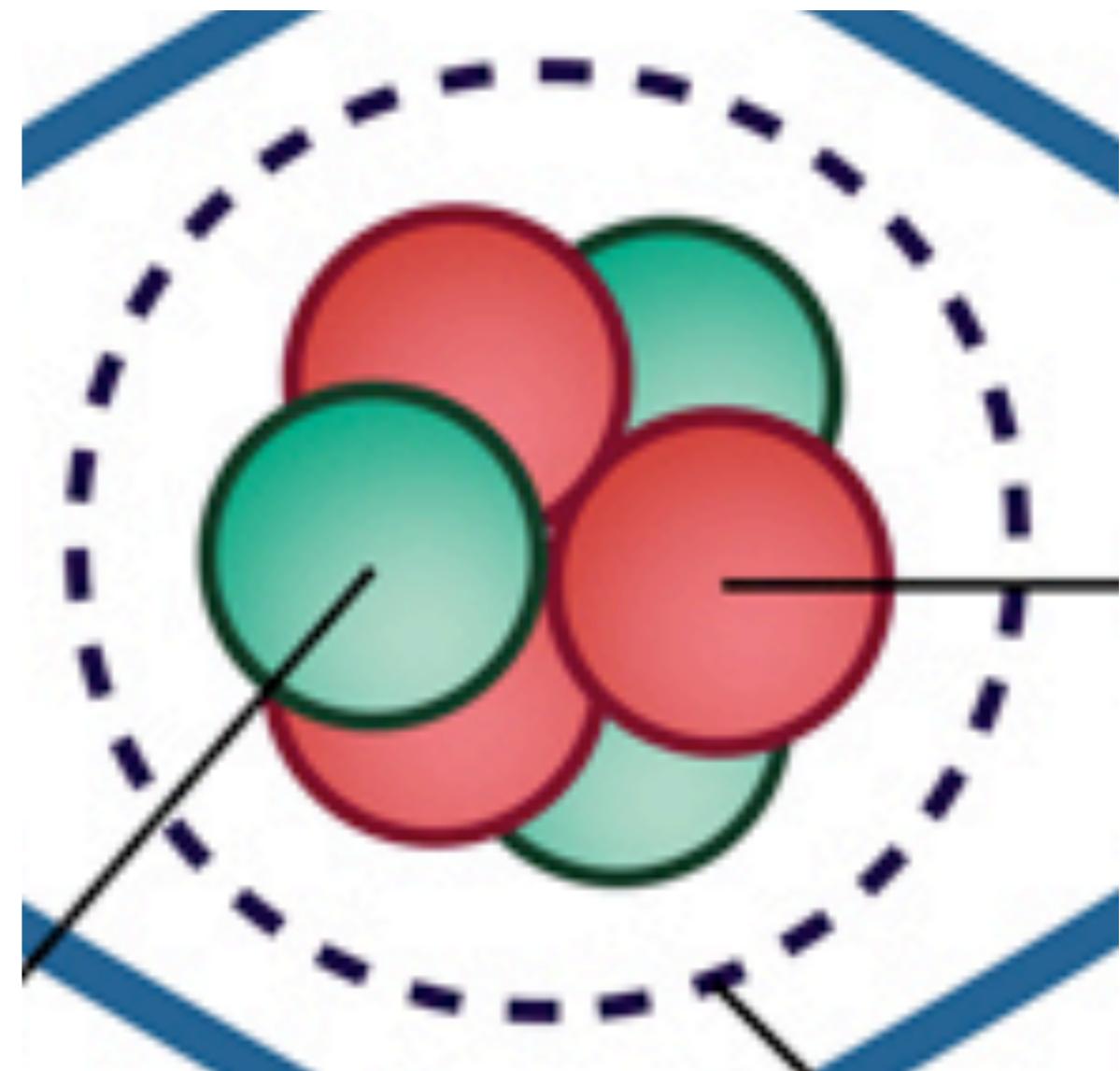
1 m



0.1 m



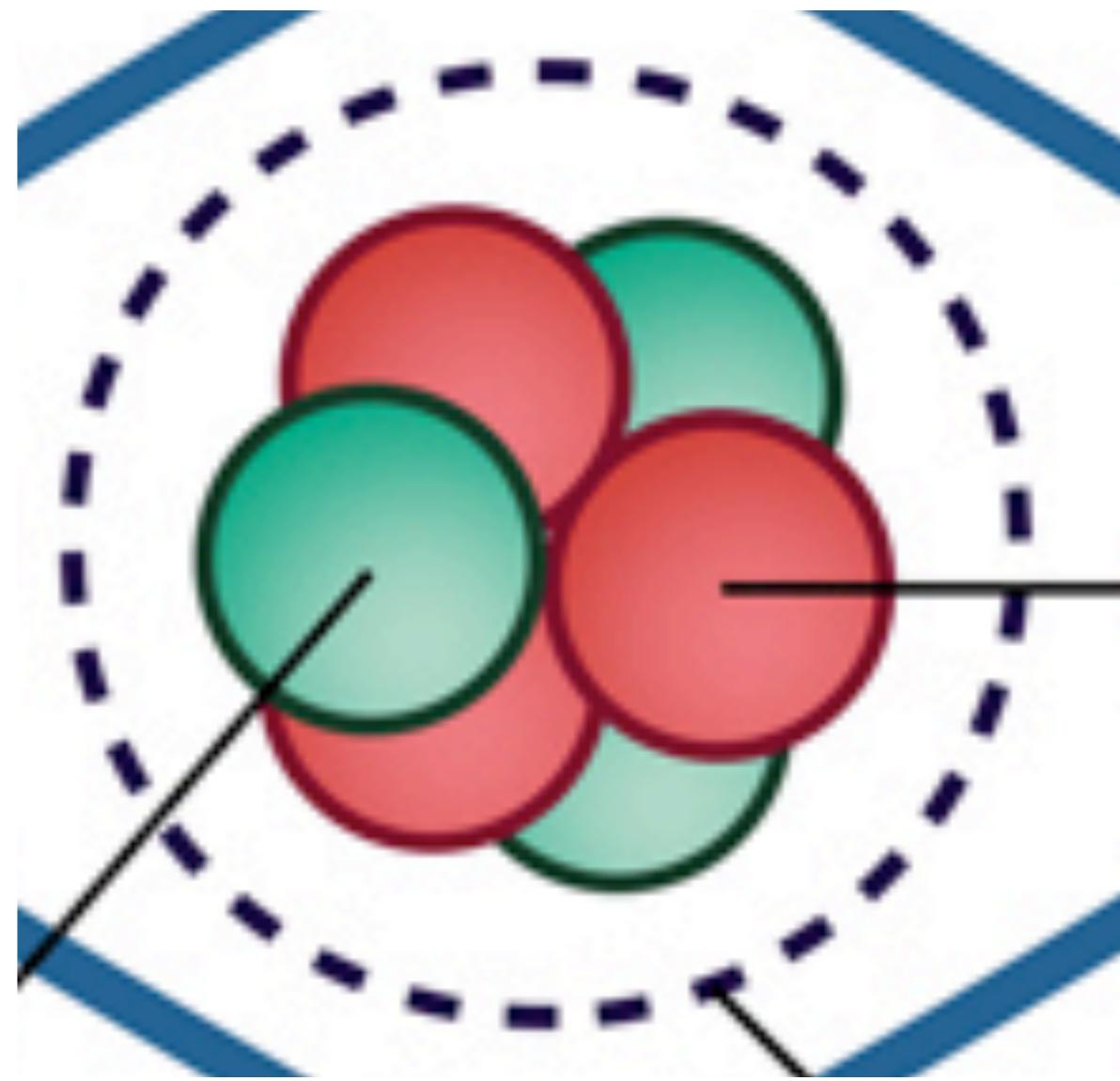
1 m



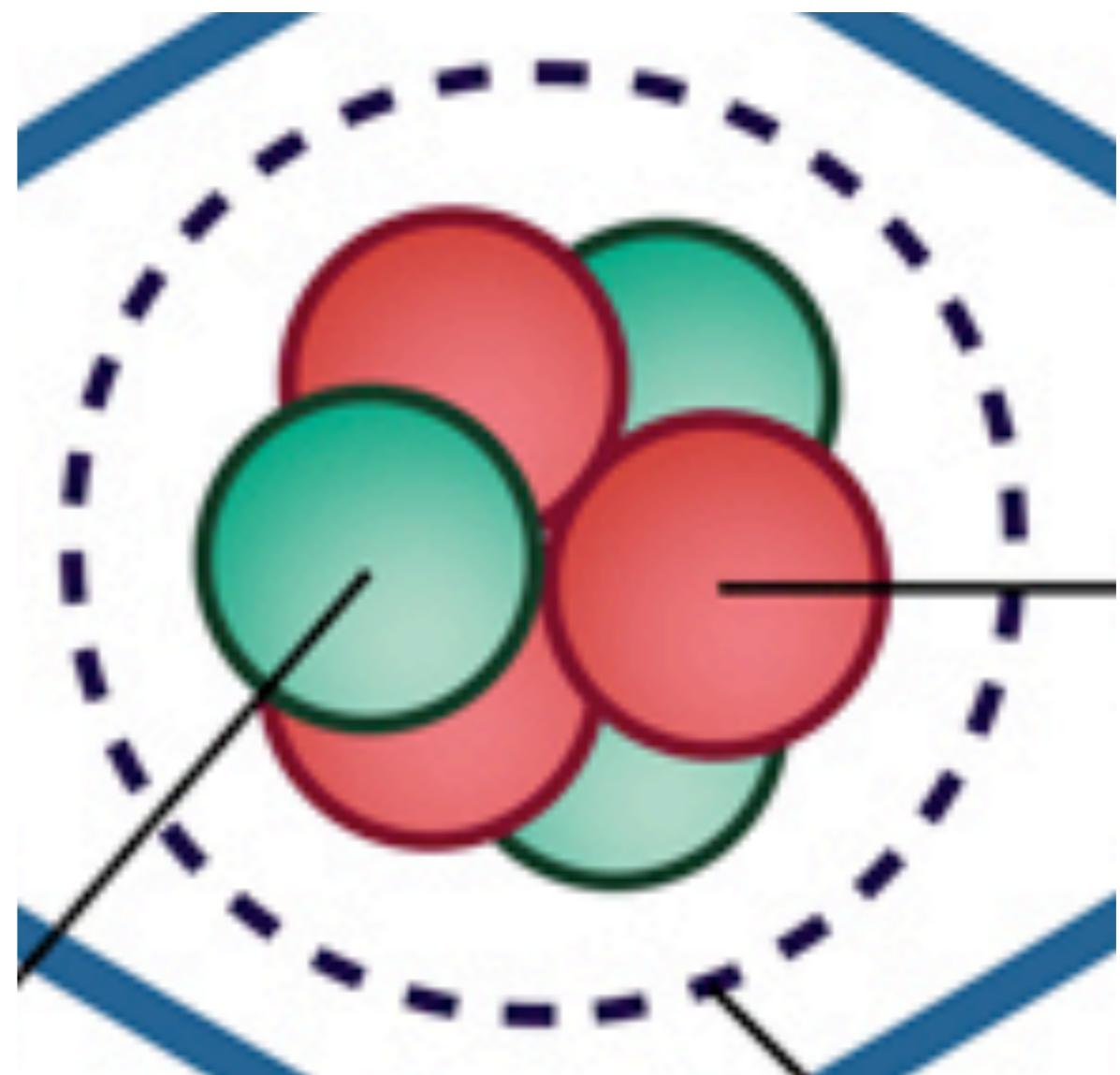
0.000000000000001 m



Is ‘Option B’
still feasible?



$0.000000000000001 \text{ m}$
 10^{-15} m



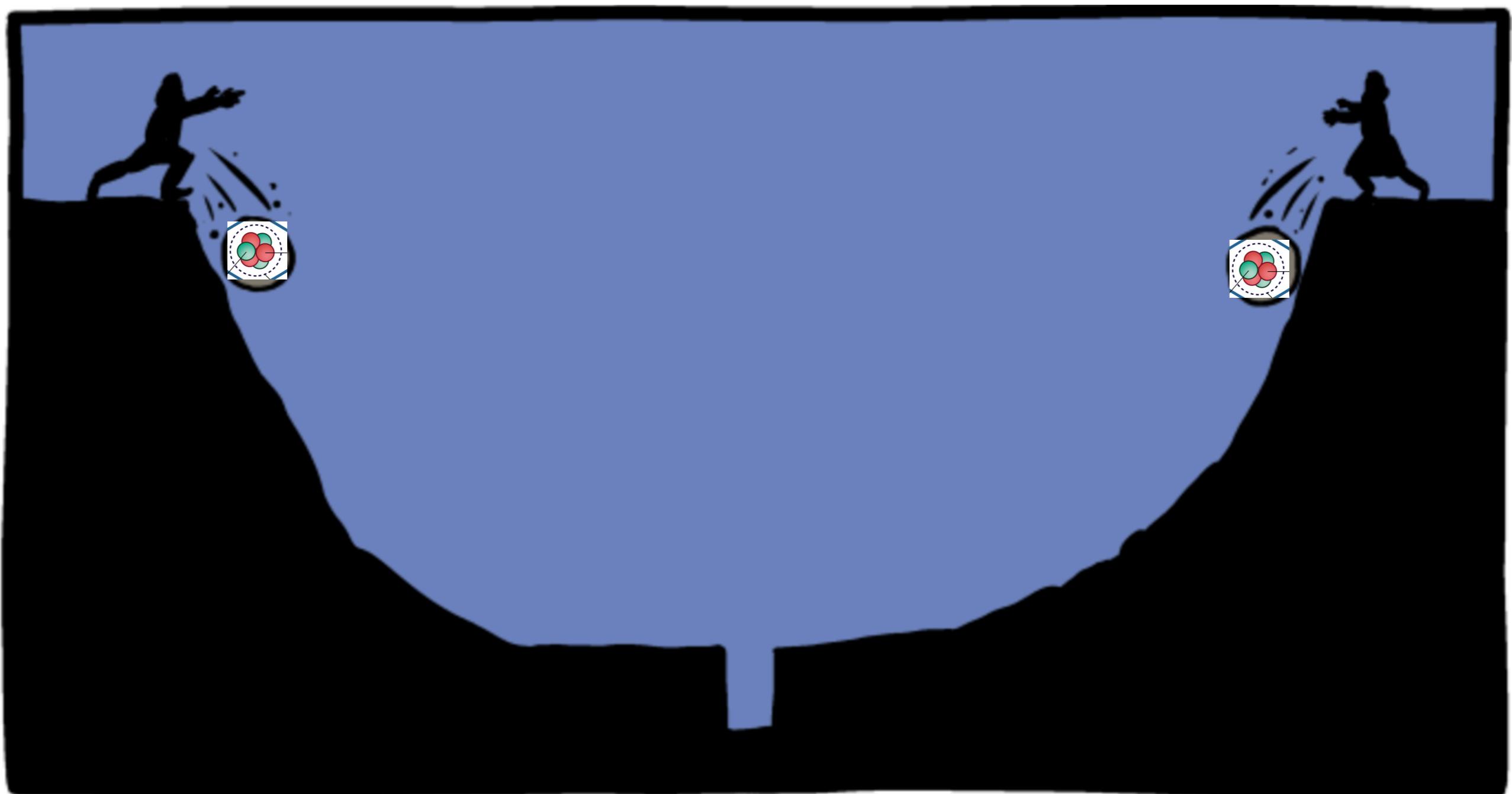
Option - A

$0.000000000000001 \text{ m}$

Option A our only choice!

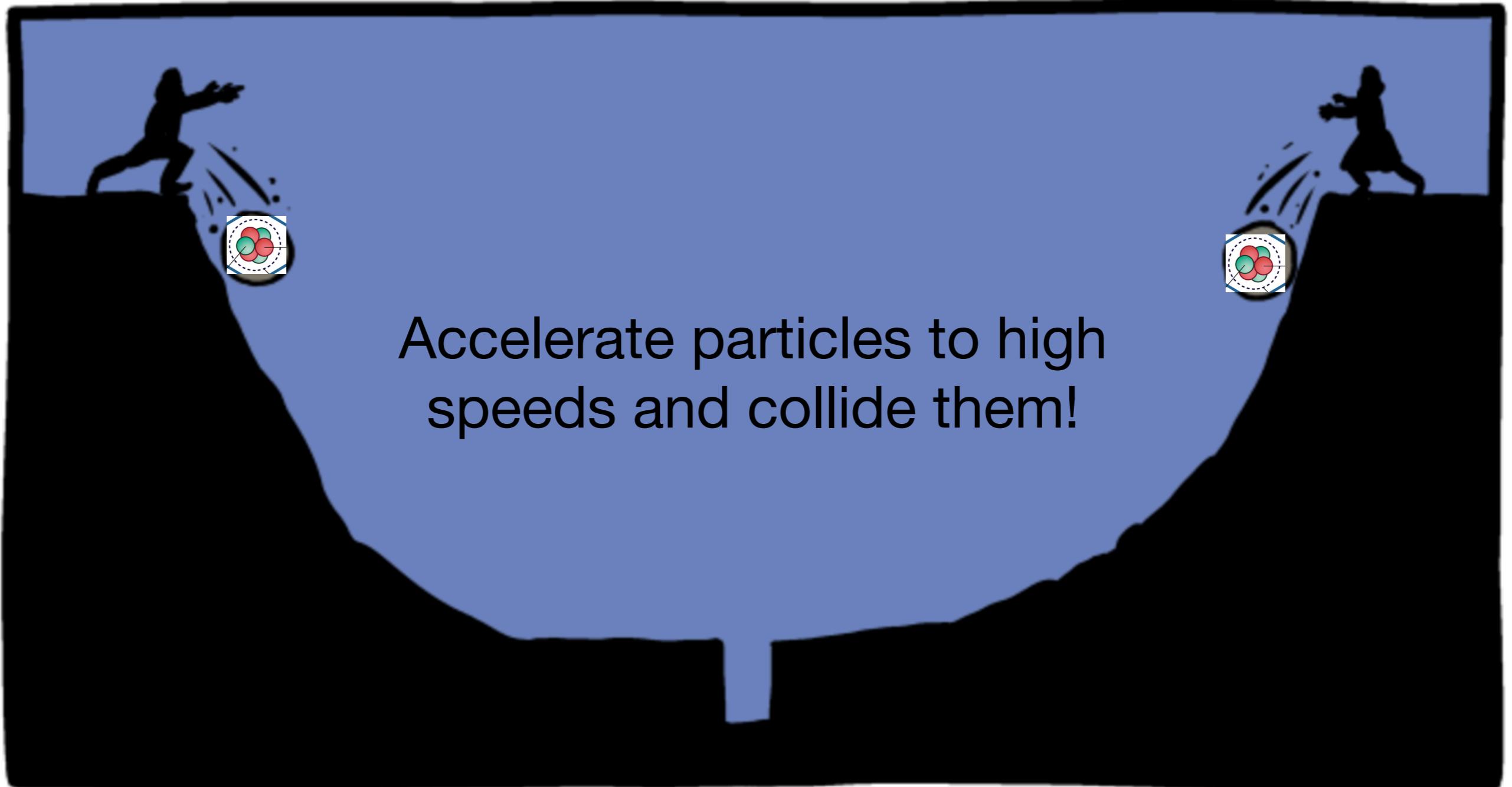
10^{-15} m

Particle Colliders



<https://www.smbc-comics.com/comic/2014-11-25>

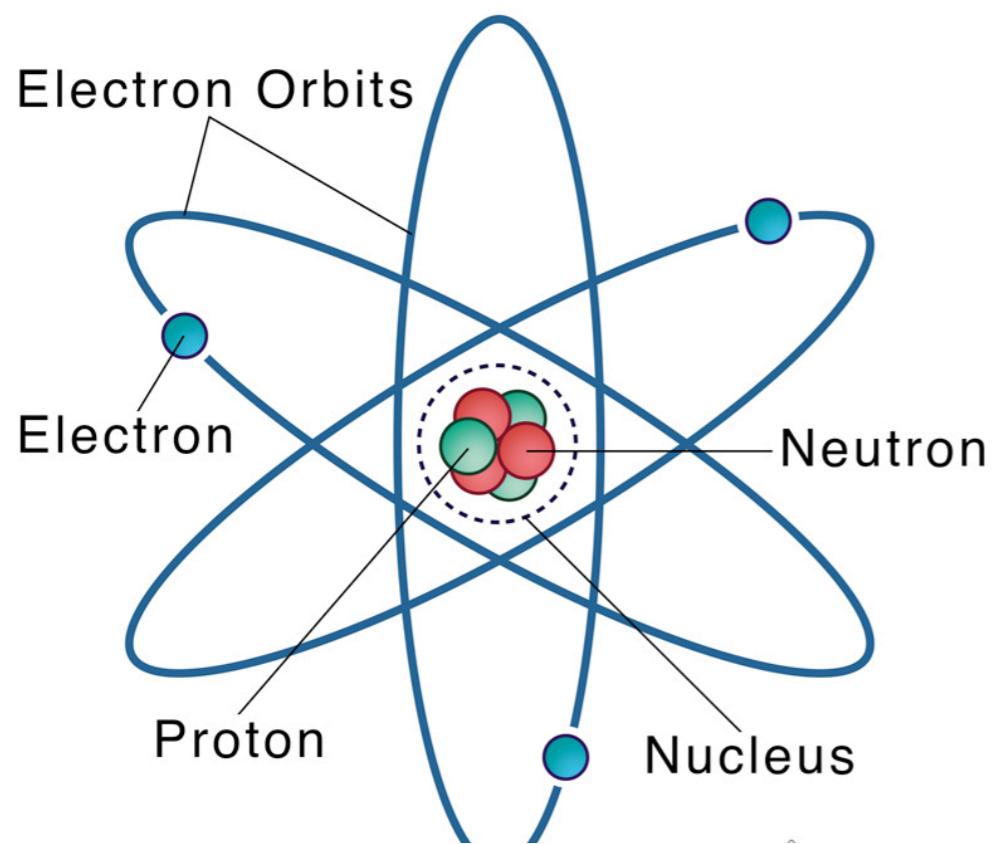
Particle Colliders



<https://www.smbc-comics.com/comic/2014-11-25>

Question - 2

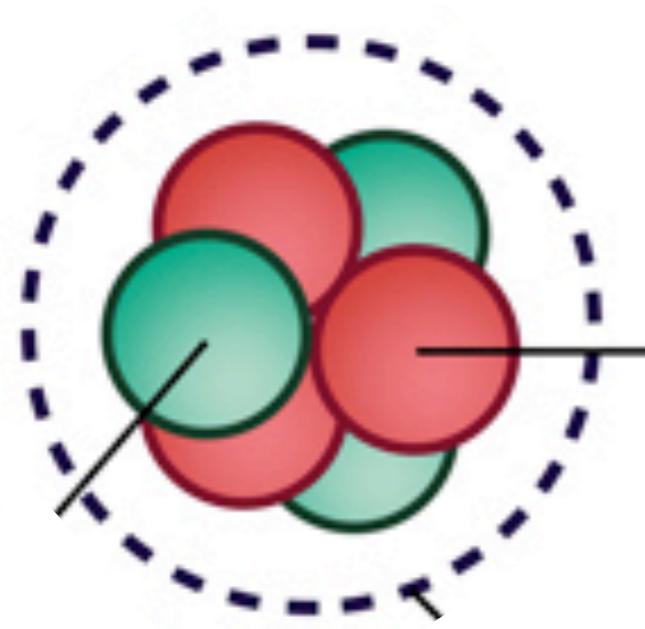
How do we accelerate these guys?



- Electron - negative charge
- Proton - positive charge
- Neutron - neutral
- Atom as a whole is neutral!

Question - 2

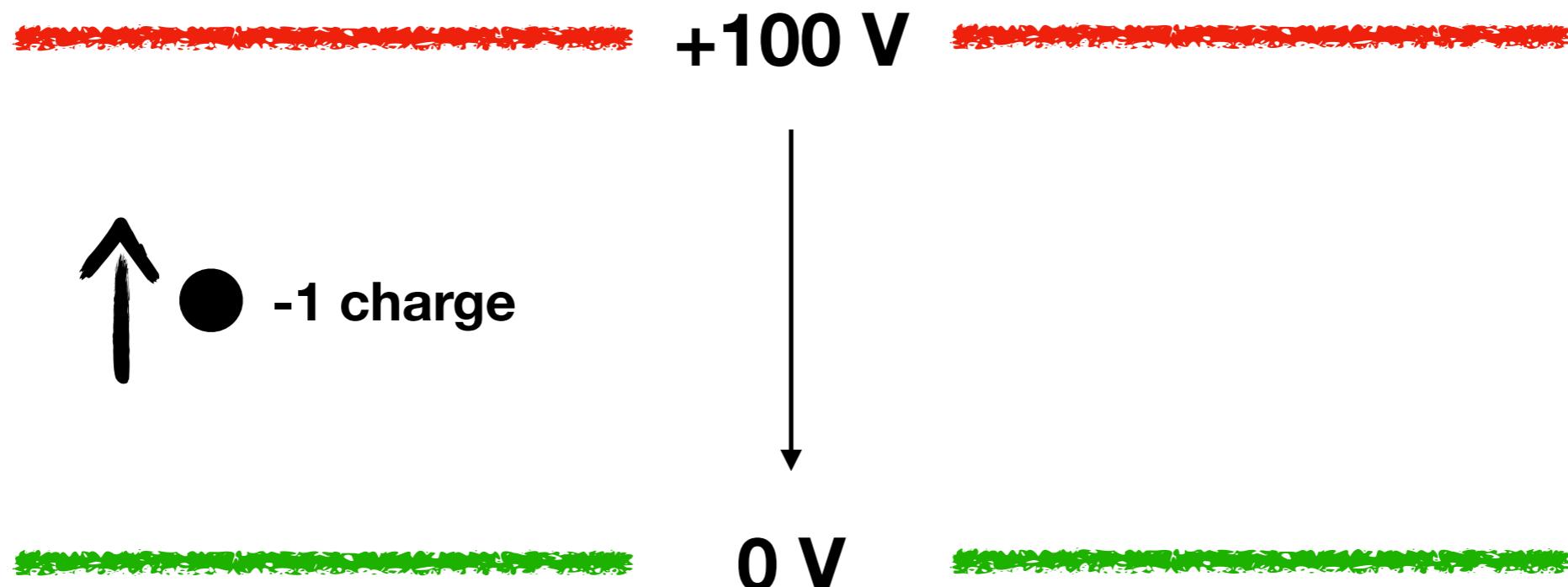
How do we accelerate these guys?



- Electron - negative charge
- Proton - positive charge
- Neutron - neutral
- Nucleus is positively charged!

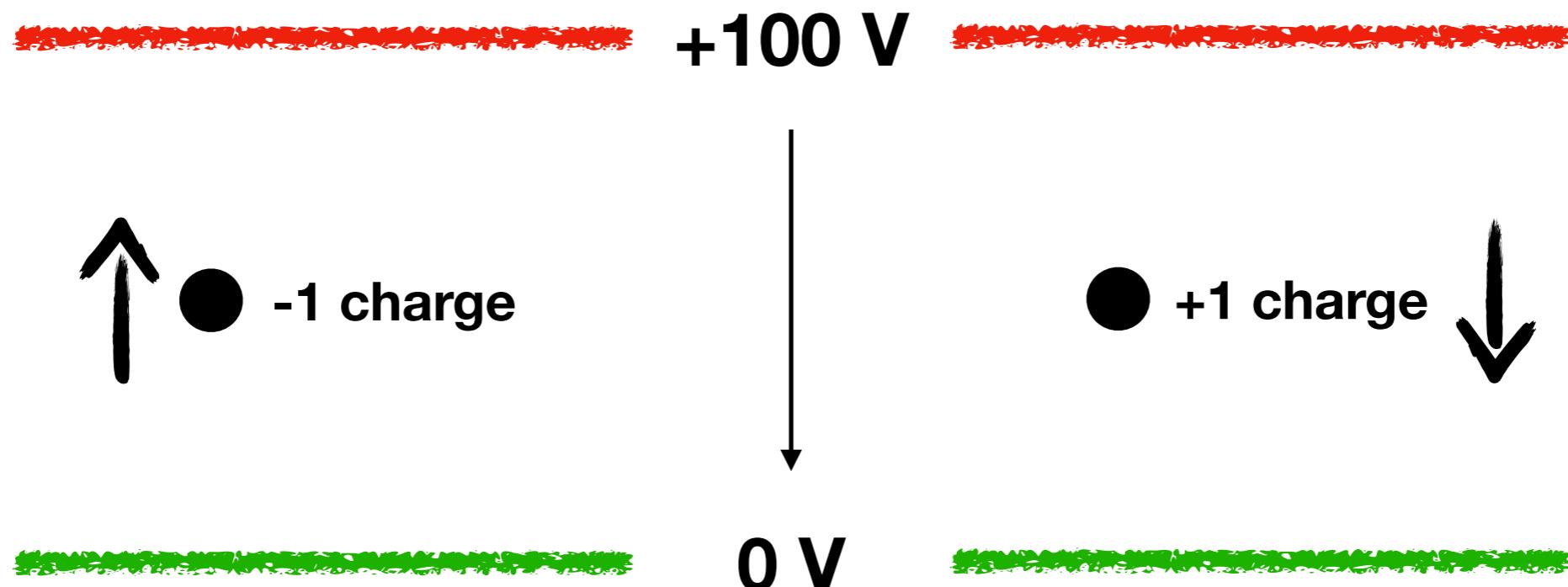
How to accelerate charged objects?

- We use the electric field!



How to accelerate charged objects?

- We use the electric field!

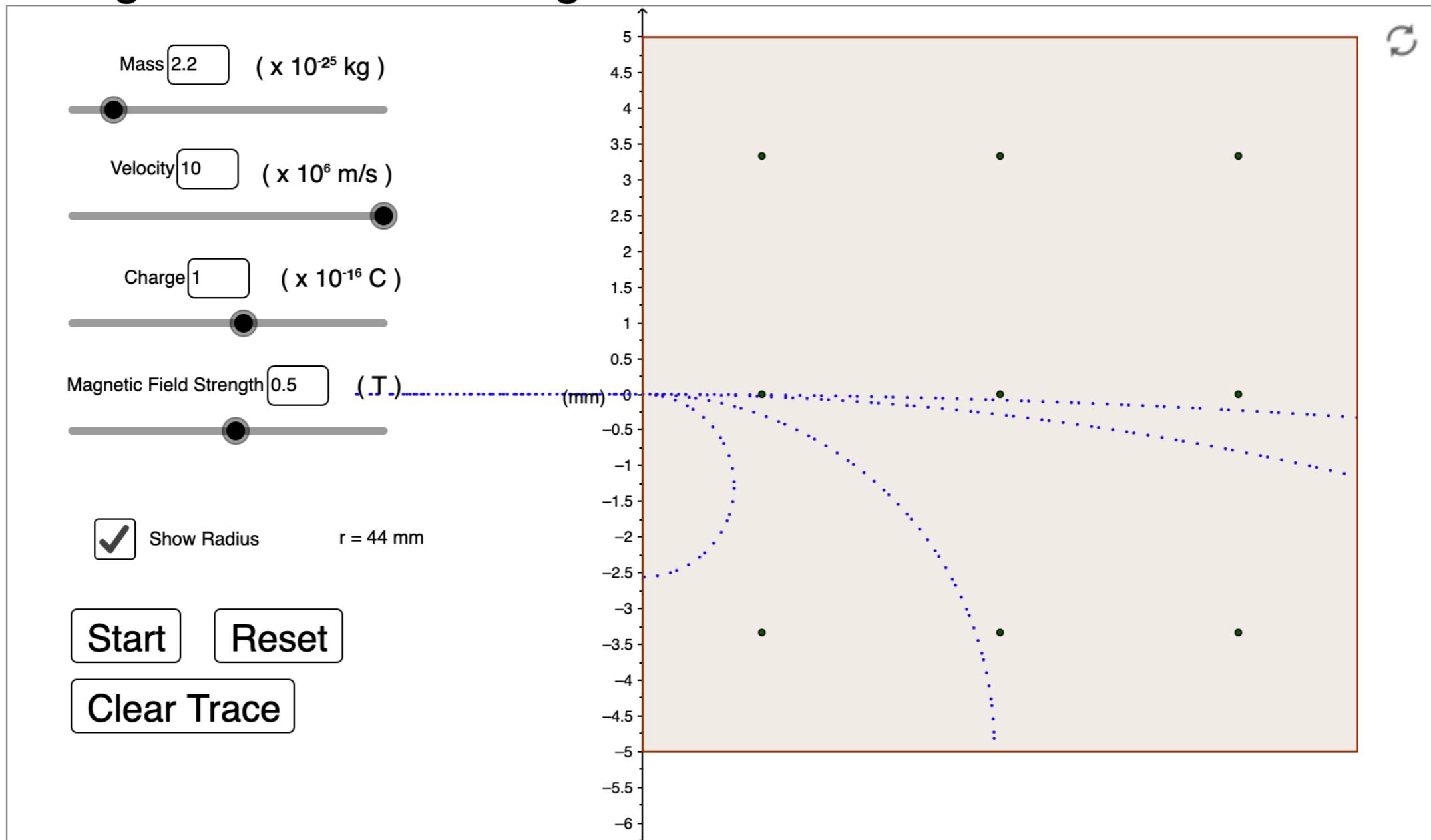


What if we want to turn?



How to turn particles?

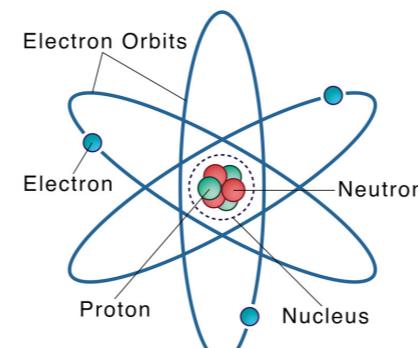
Charged Particle in a Magnetic Field



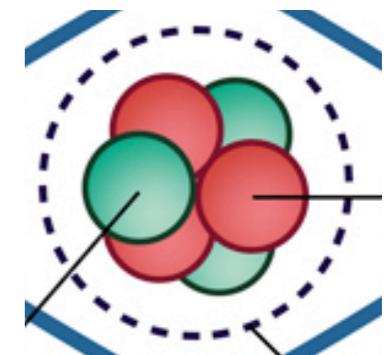
<https://ophysics.com/em7.html>

Recap

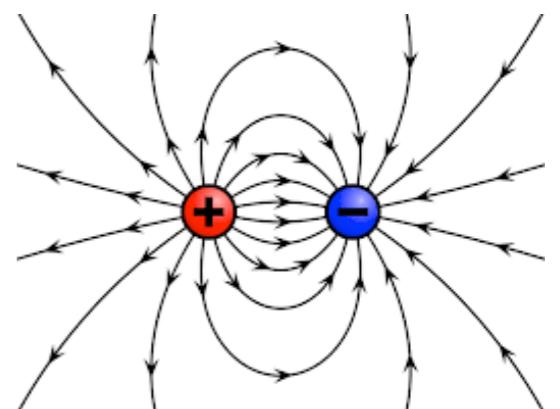
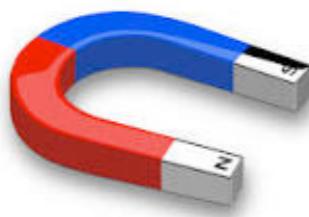
- We start with atoms



- Strip away the electrons - left with nucleus containing protons and neutrons

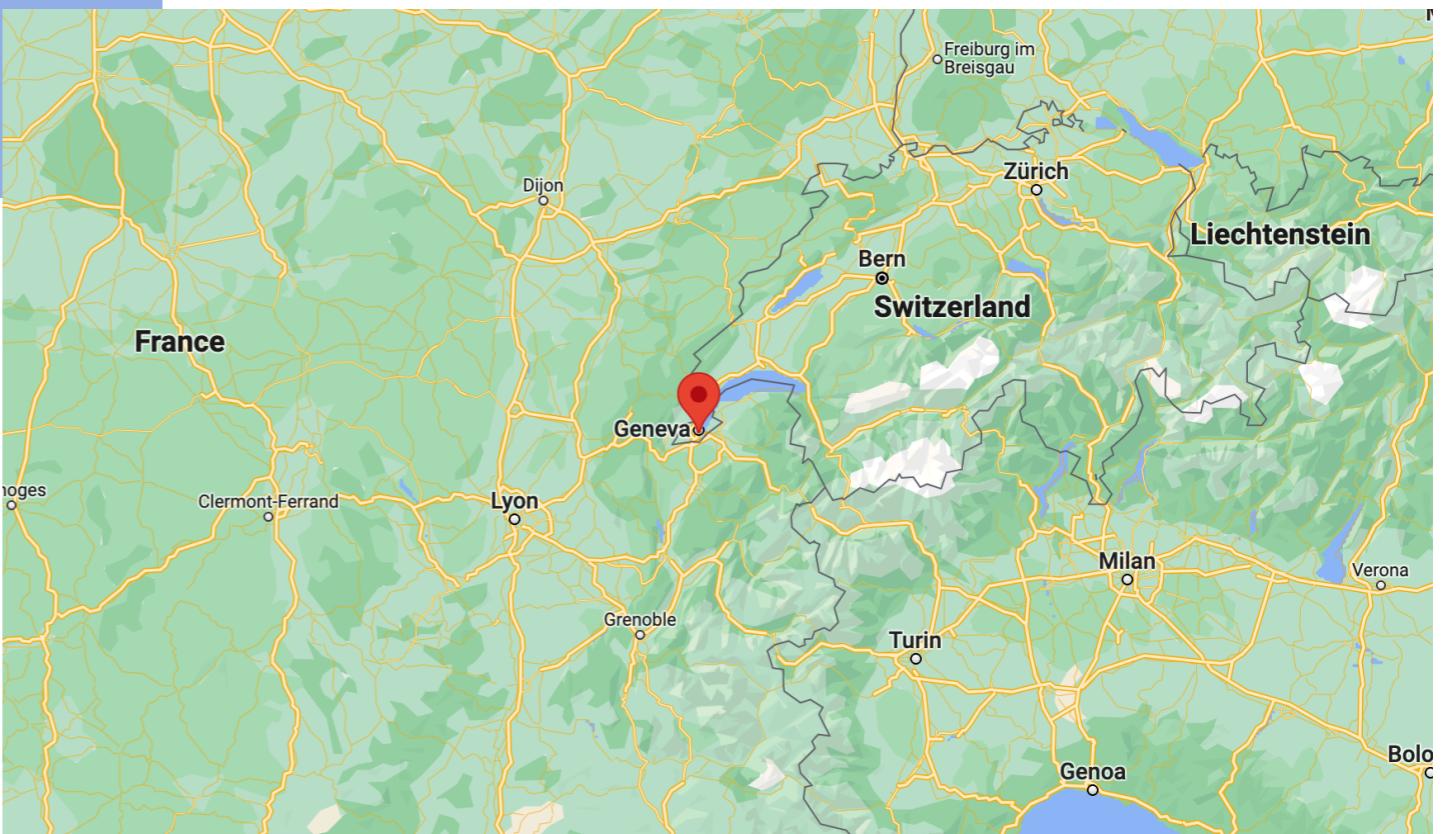
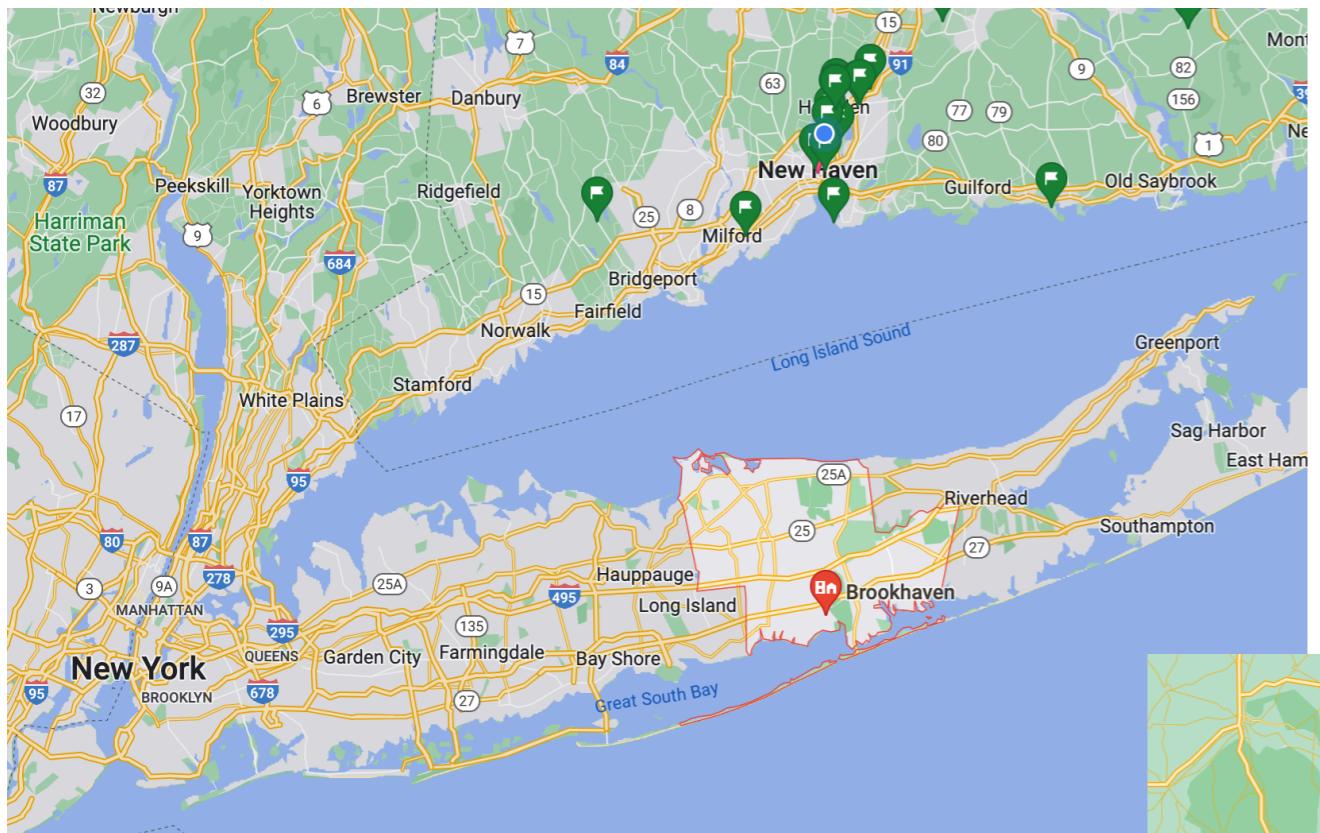


- Accelerate and turn them via electric and magnetic fields



- Onto our existing colliders!

Two biggest active particle accelerators in the world



Large Hadron Collider



Swiss Alps!



Facts about the LHC

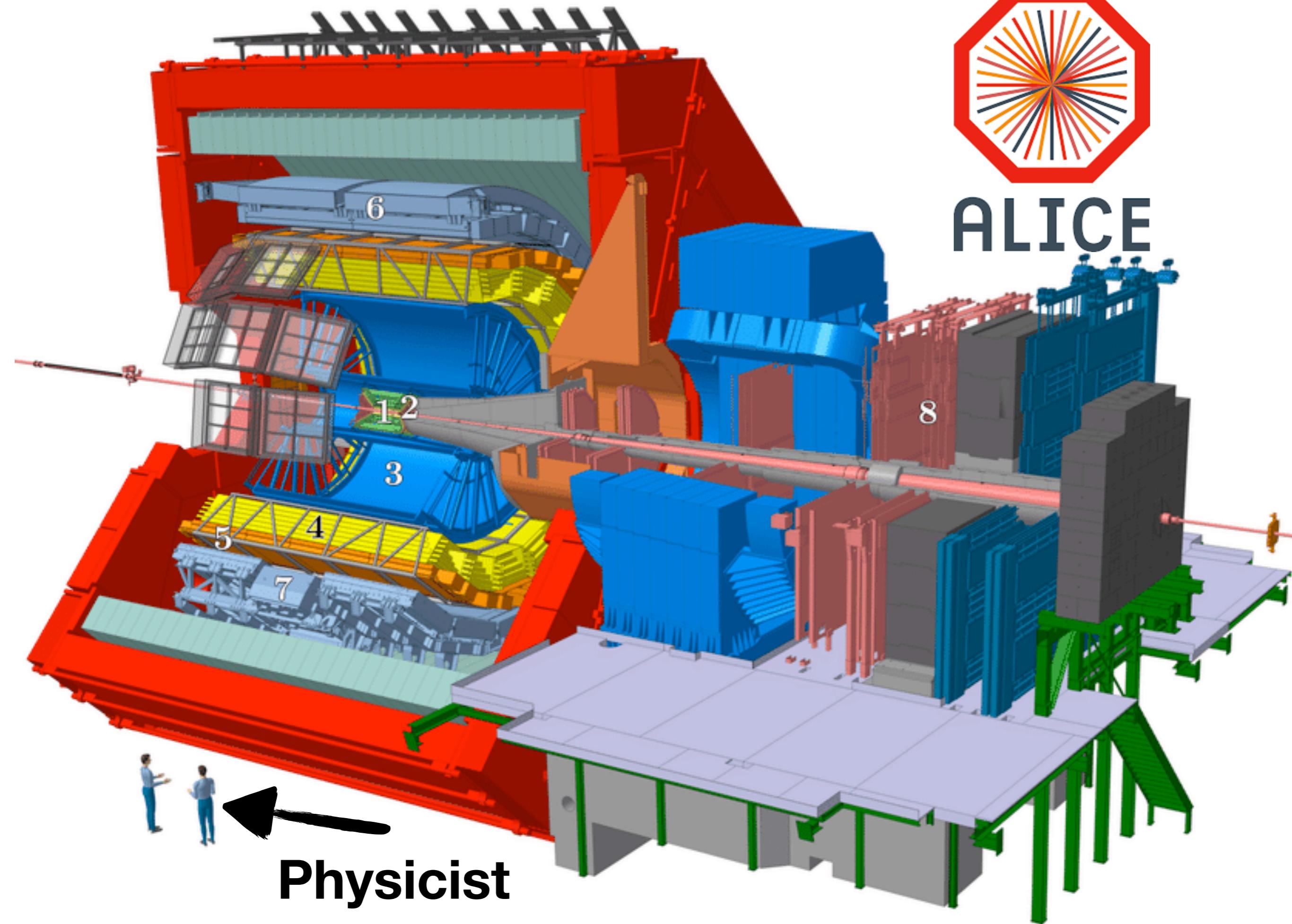
- circumference of 27 km (17 miles)
- Built underground! 100 meters below the surface
- protons race around the LHC ring 11,245 / second
- Speed of the protons is only 3.1m/s slower than light!
- Accelerates protons (p) and lead (Pb) and xenon (Xe) atoms

Collider in action

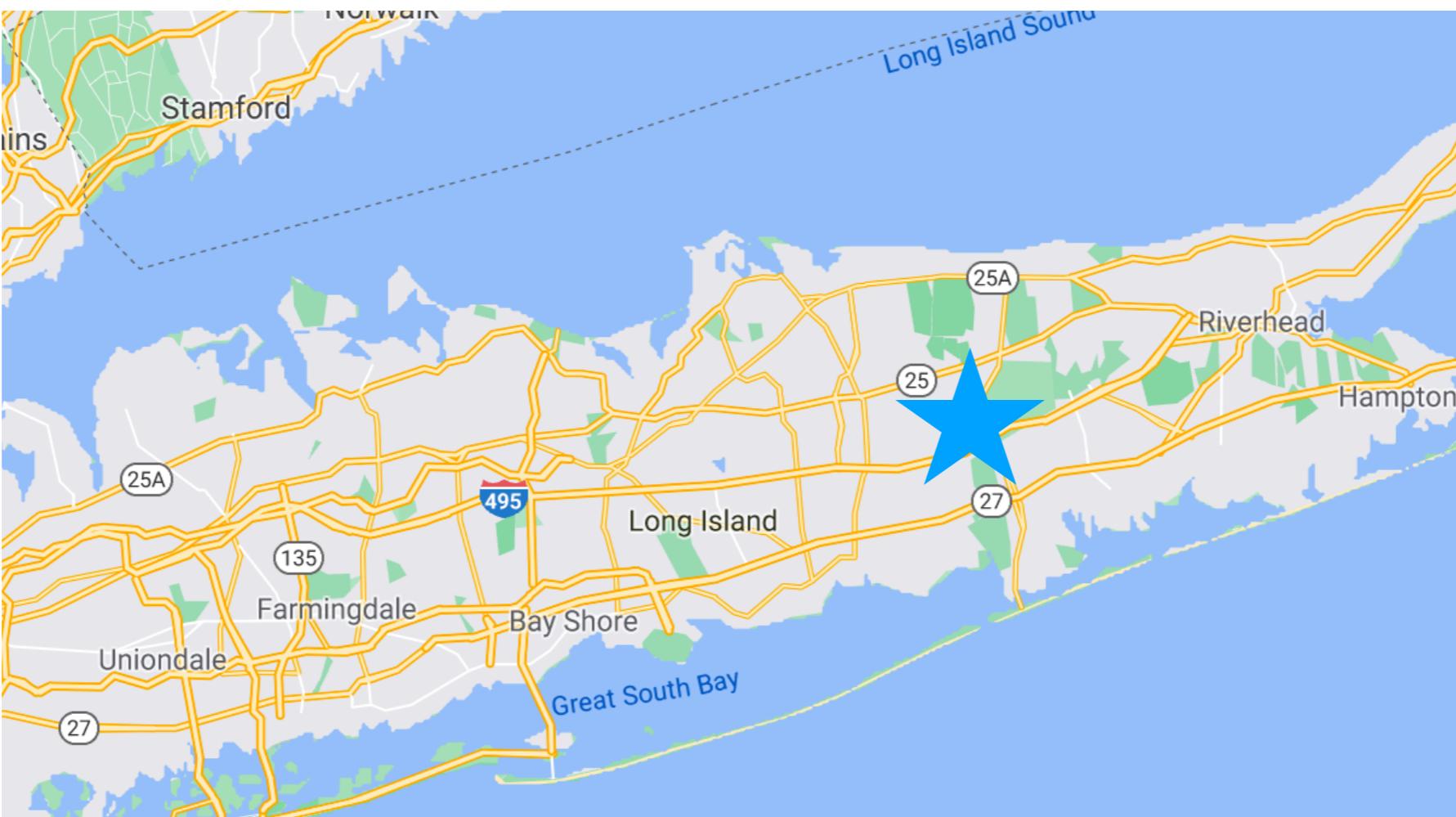


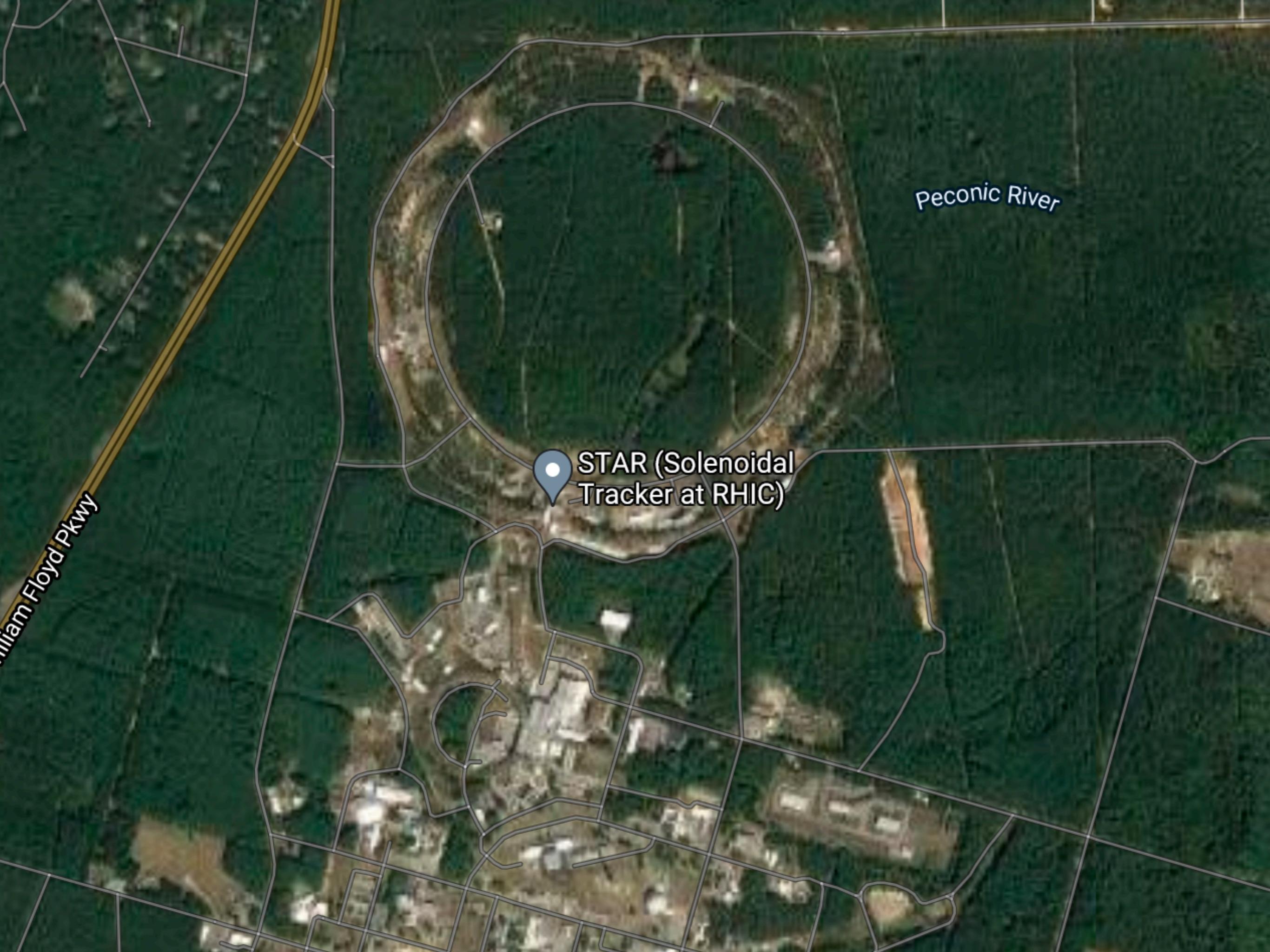


ALICE



Relativistic Heavy Ion Collider





STAR (Solenoidal
Tracker at RHIC)

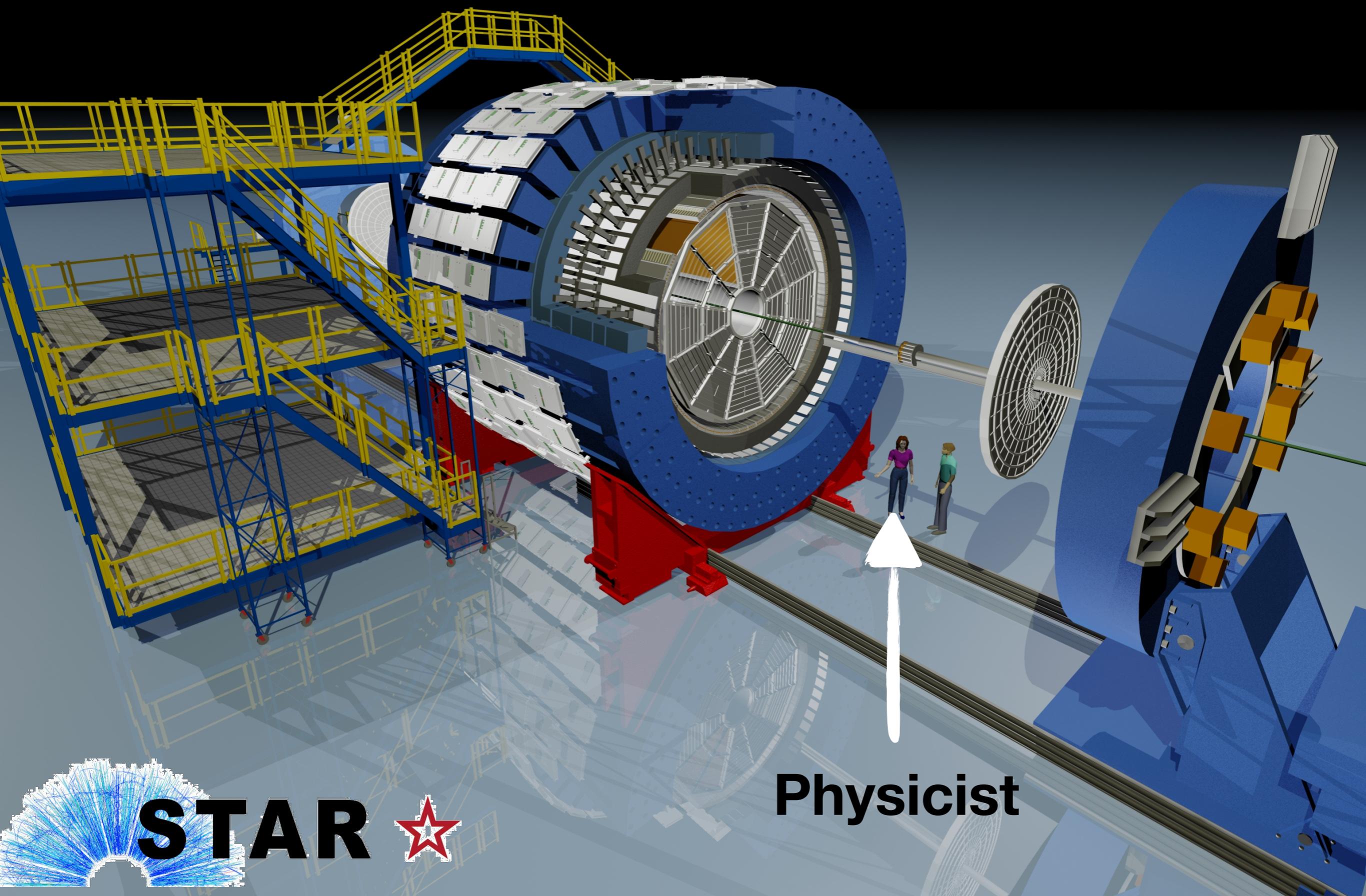
Peconic River

William Floyd Pkwy

Facts about RHIC

- circumference of 3.834 km (2.4 miles)
- Built at roughly ground level
- Speed of the protons is only 1653 m/s slower than light!
- Accelerates many different species - p, Deuteron, Helium, Oxygen, Copper, Aluminum, Zirconium, Ruthenium, Gold and Uranium

Current!

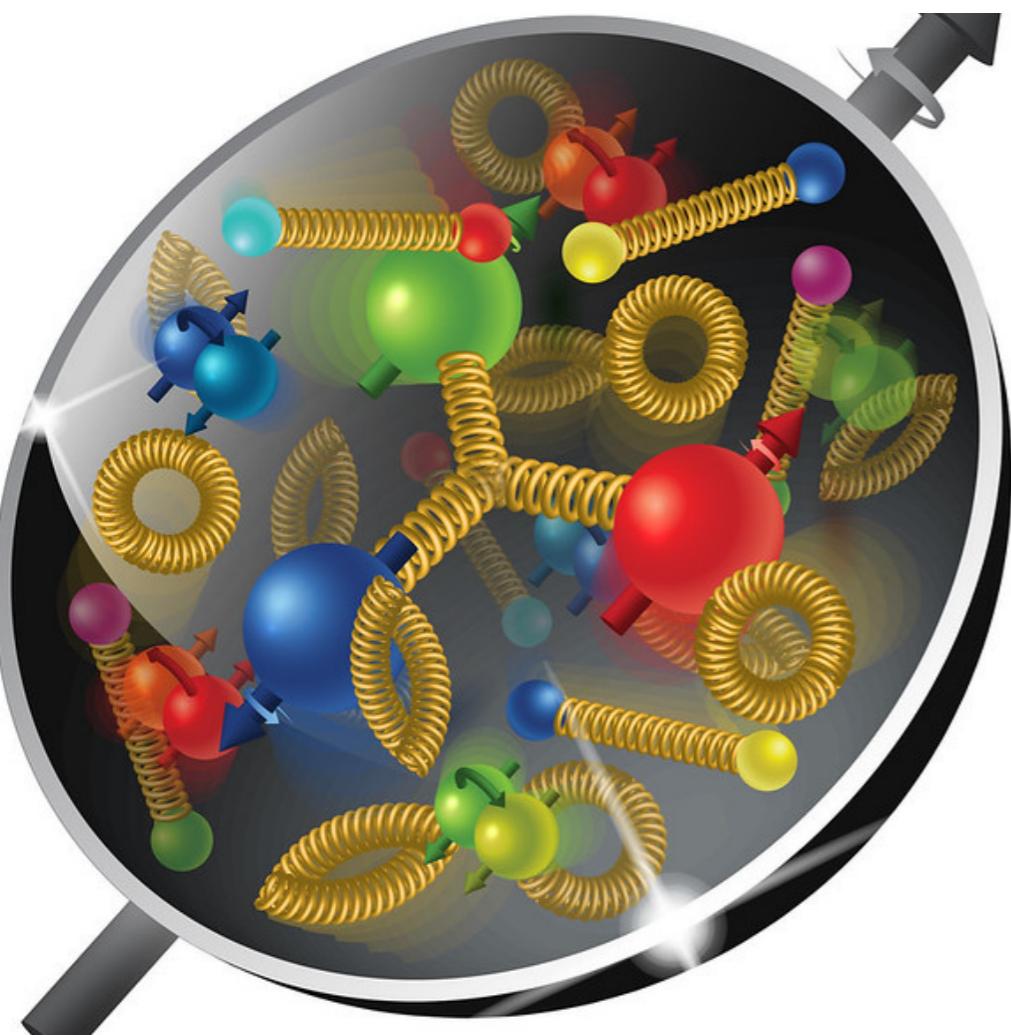


STAR ★

Physicist

Lets ‘now’ smash the proton!

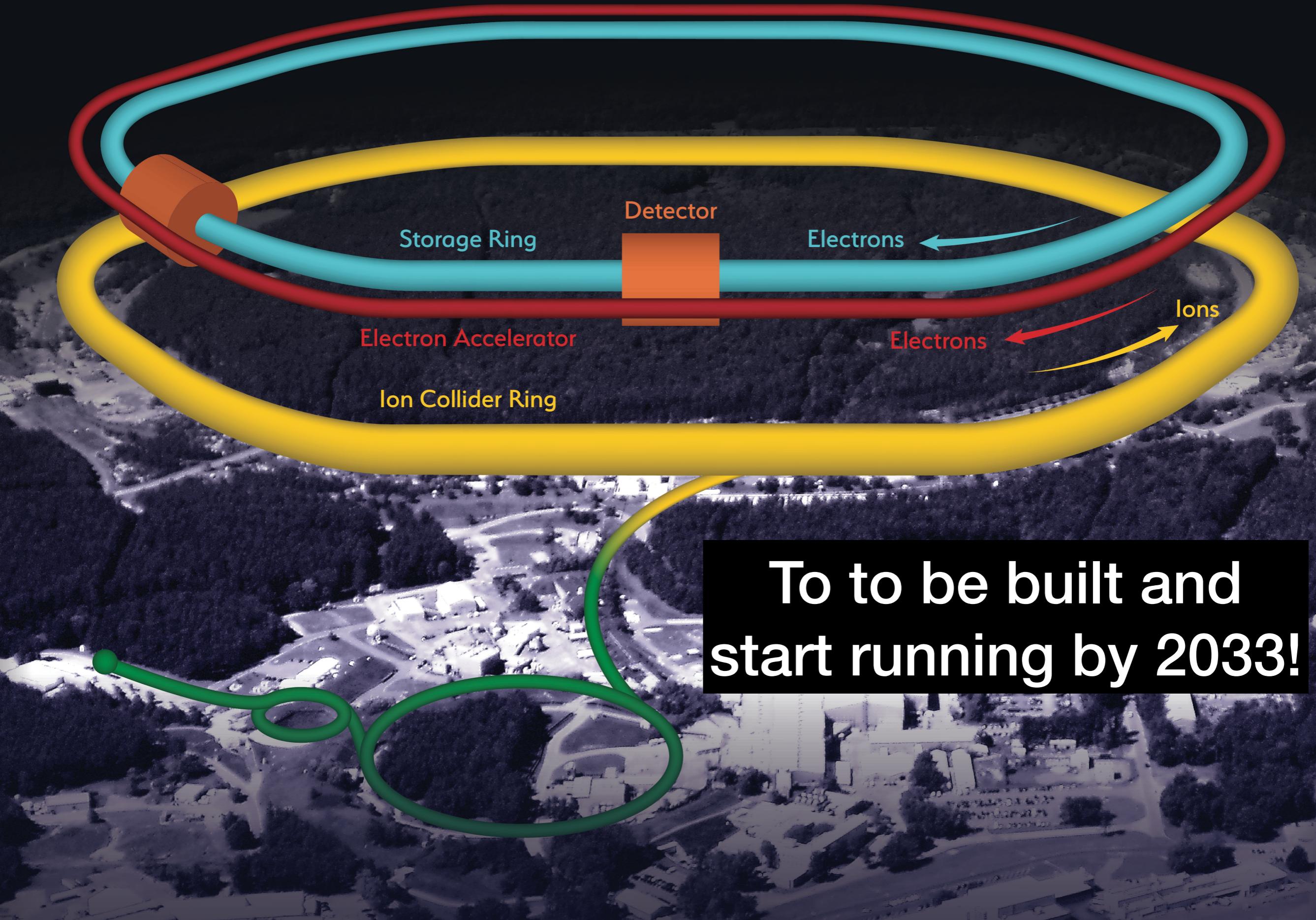
- Collide proton with the electron!



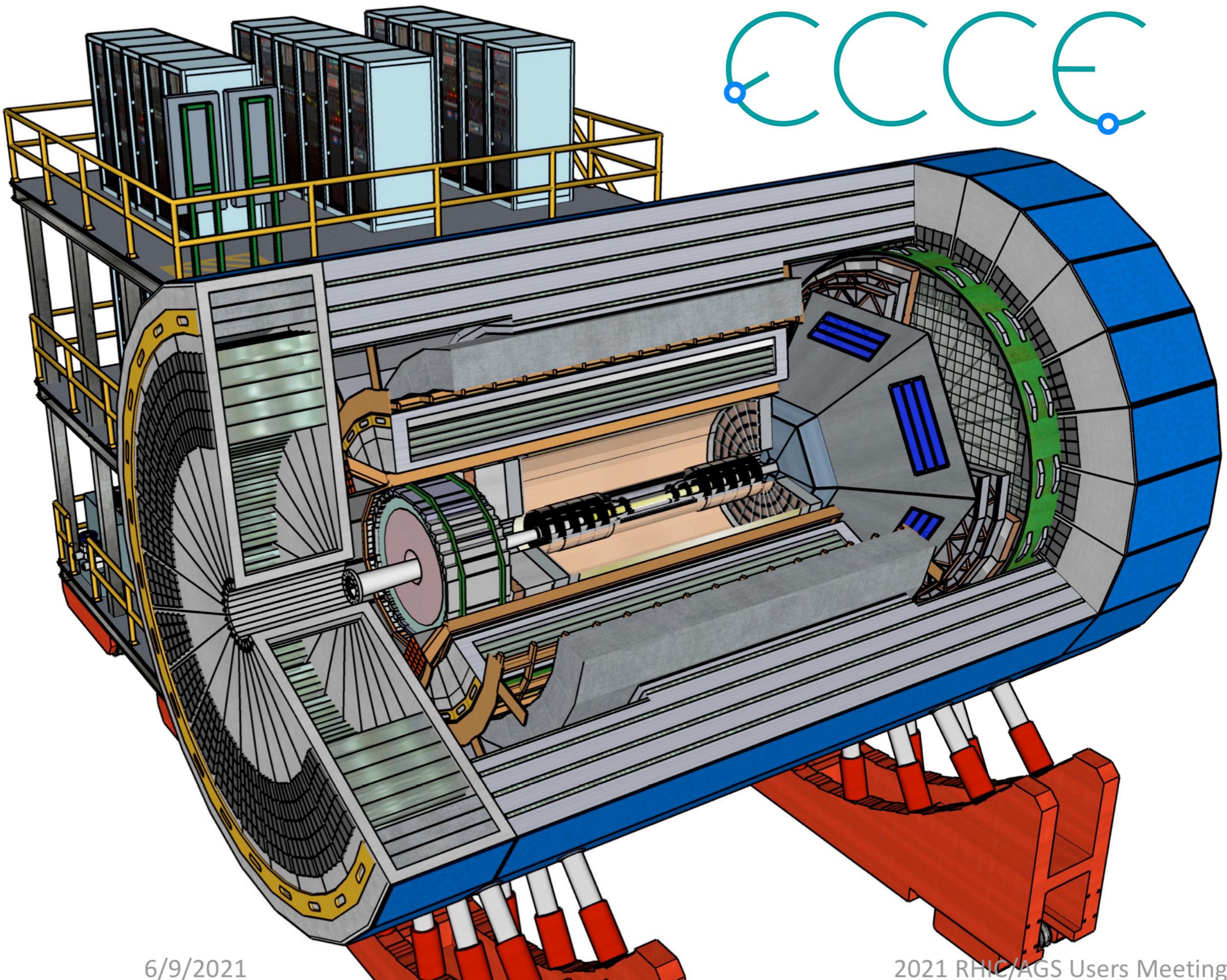
VS



- Head over to our collider!



To be built and
start running by 2033!





Lets run our own simulations! - to the jupyter notebooks