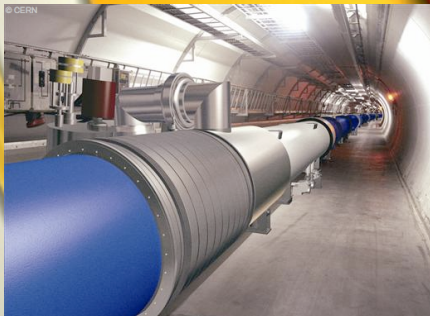
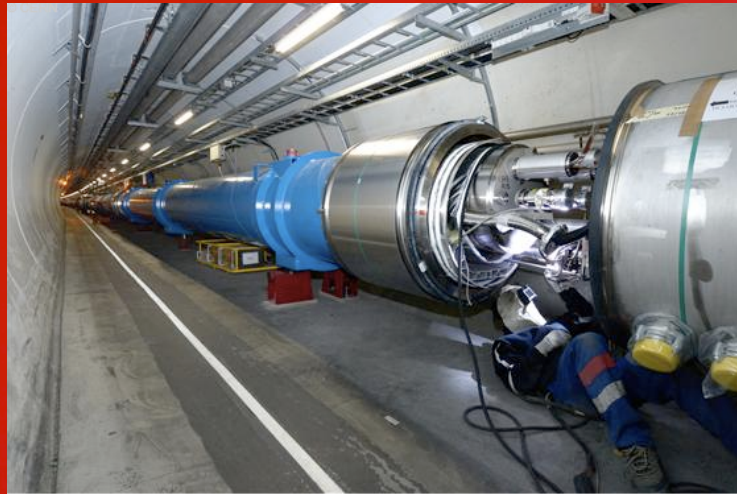


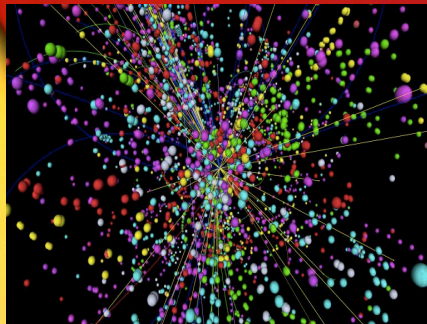
Particle Physics in the Age of the Large Hadron Collider

Based on the Teachers' Conference given at the Kavli Institute for Theoretical Physics at UCSB in May 2008.

By
Nick Nicastro



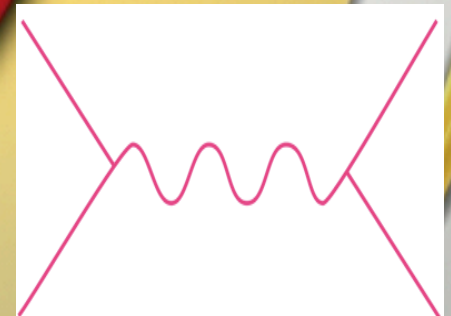
1. What IS the LHC and How Will We Use It?



2. LHC and the World of Extra Dimensions



3. Exploring the Cosmos with the LHC



4. Frontiers of Particle Physics

What IS the LHC and How Will We Use It?



Since the beginning of time, man has relied upon his SENSES to explore the world around him.

To “SEE” the world, we use our eyes.

What IS the LHC and How Will We Use It?



Since the beginning of time, man has relied upon his SENSES to explore the world around him.

To “SEE” the world, we use our eyes.
(sometimes with help from eyeglasses)



What IS the LHC and How Will We Use It?



Since the beginning of time, man has relied upon his SENSES to explore the world around him.

To “SEE” the world, we use our eyes.

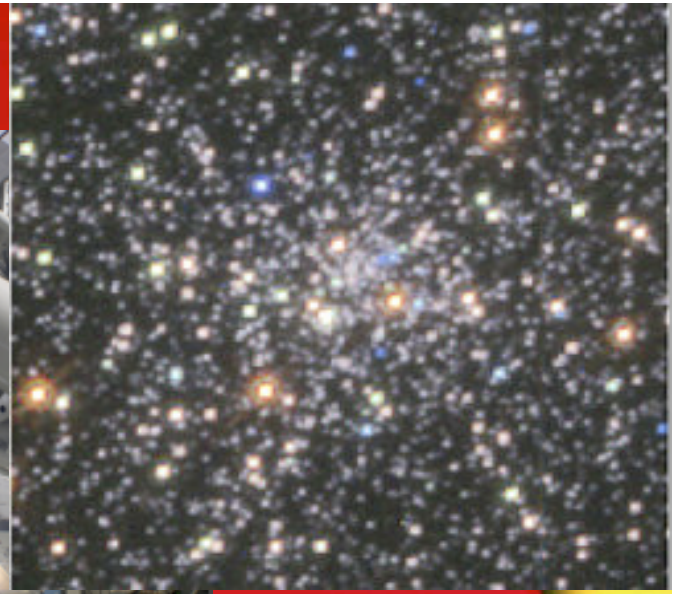
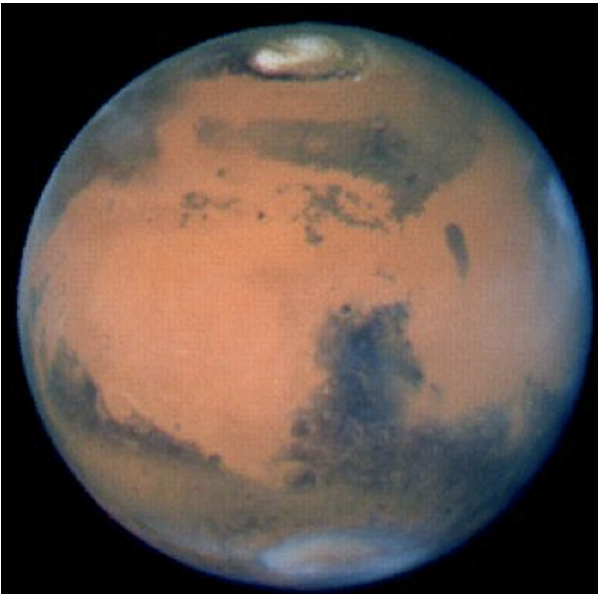
But our eyes are very limited in our ability to “SEE” the universe.



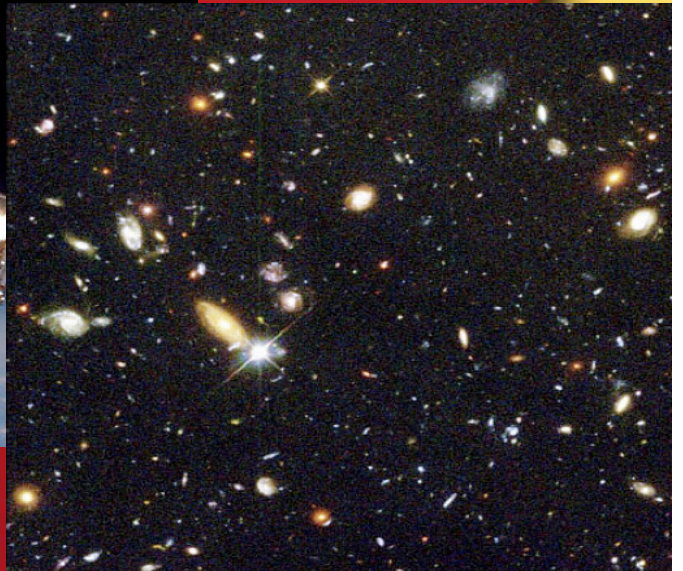
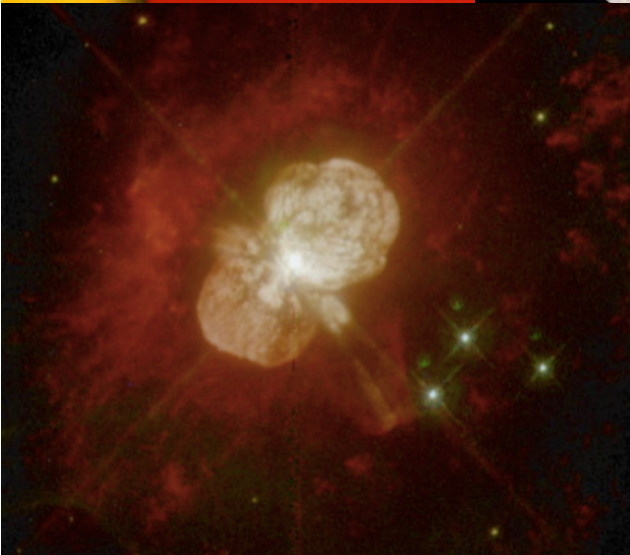
So, we have to

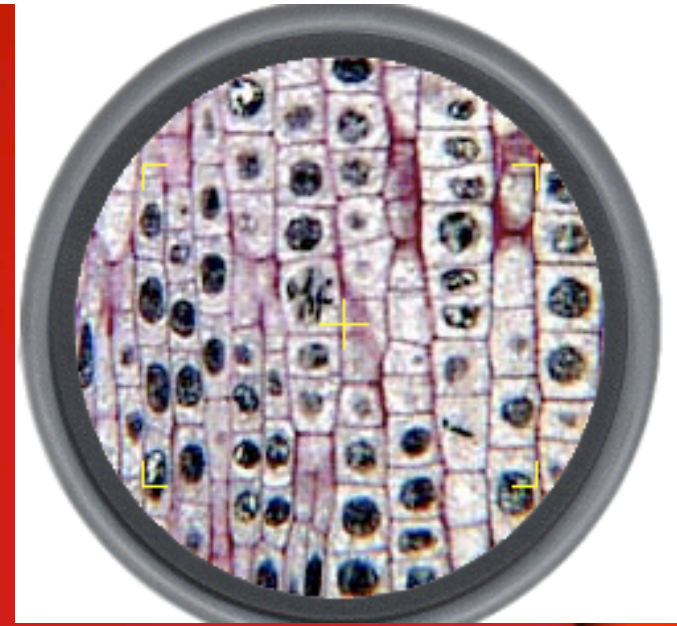
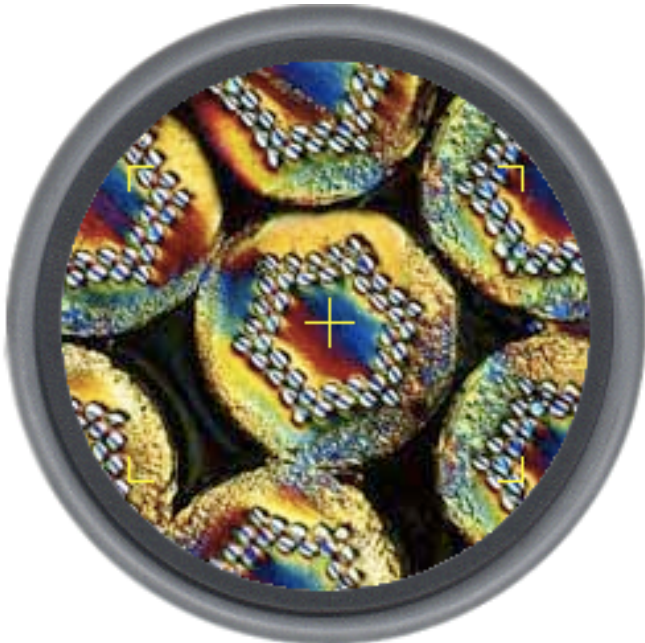
EXTEND

our vision.

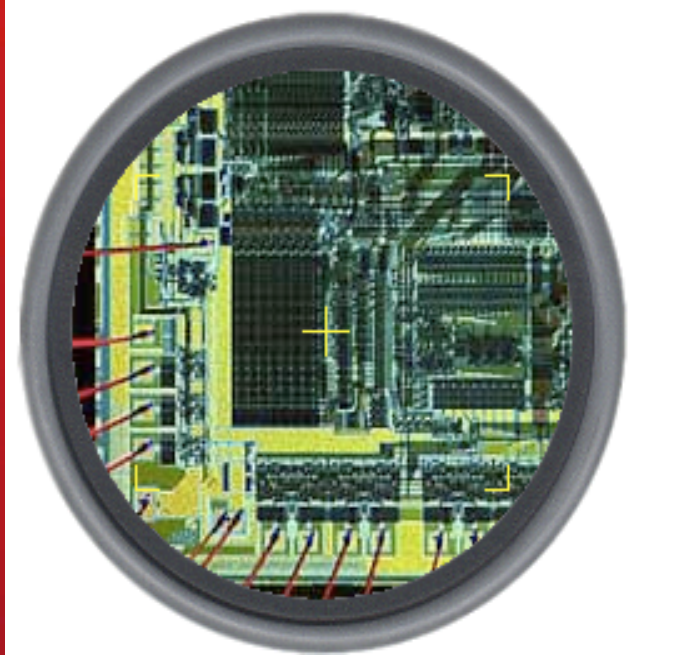


We use ground-based and satellite-based telescopes to observe the visible universe.



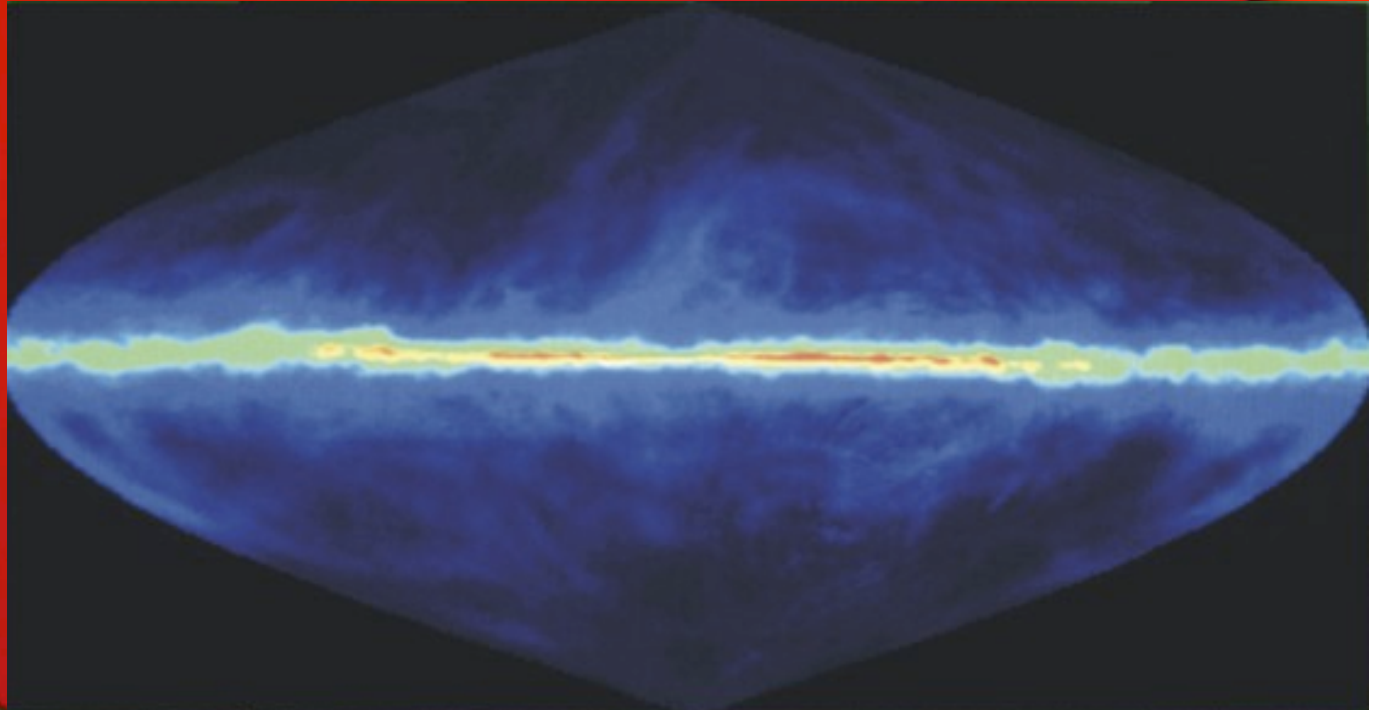


We use microscopes to look deep into tiny structures.





We use electromagnetic detectors to probe the “invisible”.



But, in order to “see” the world of *subatomic particles*,

we need **GIGANTIC** MACHINES

to accelerate particles to VERY high speeds,

in order to “SMASH” them into each other with

EXTREMELY HIGH ENERGY!!!!!!

It's a bit like firing a bullet . . .



. . . into a pocket watch

And carefully observing the pieces flying out!!!!

NOT VERY ELEGANT, IS IT?

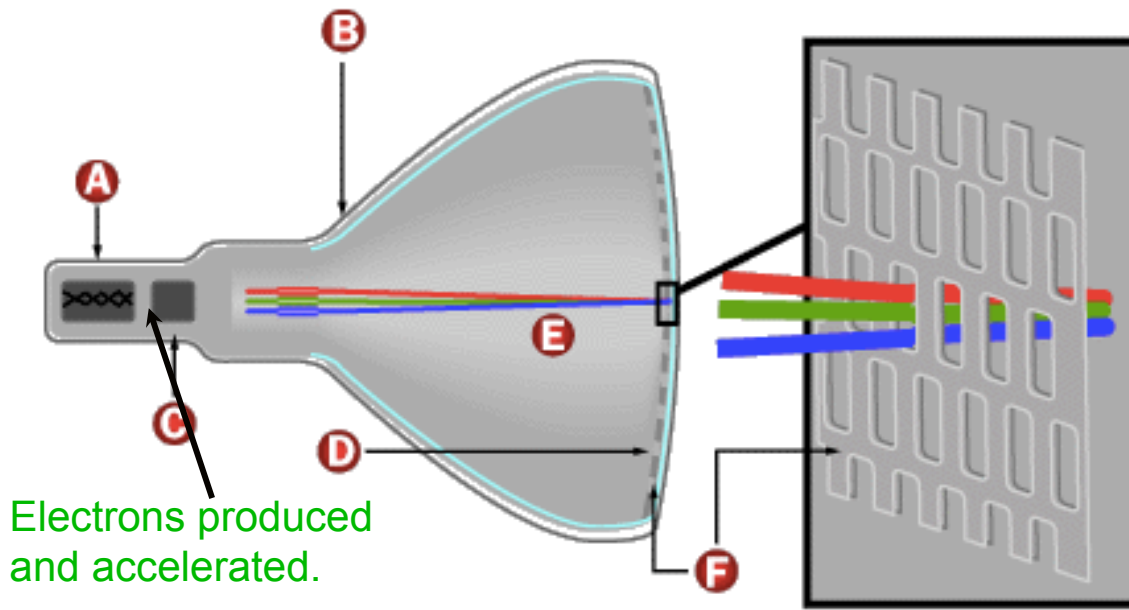
These machines are called

PARTICLE ACCELERATORS

OR,

COLLIDERS

An older television set is a type of
“particle accelerator” since it has a
CATHODE RAY TUBE



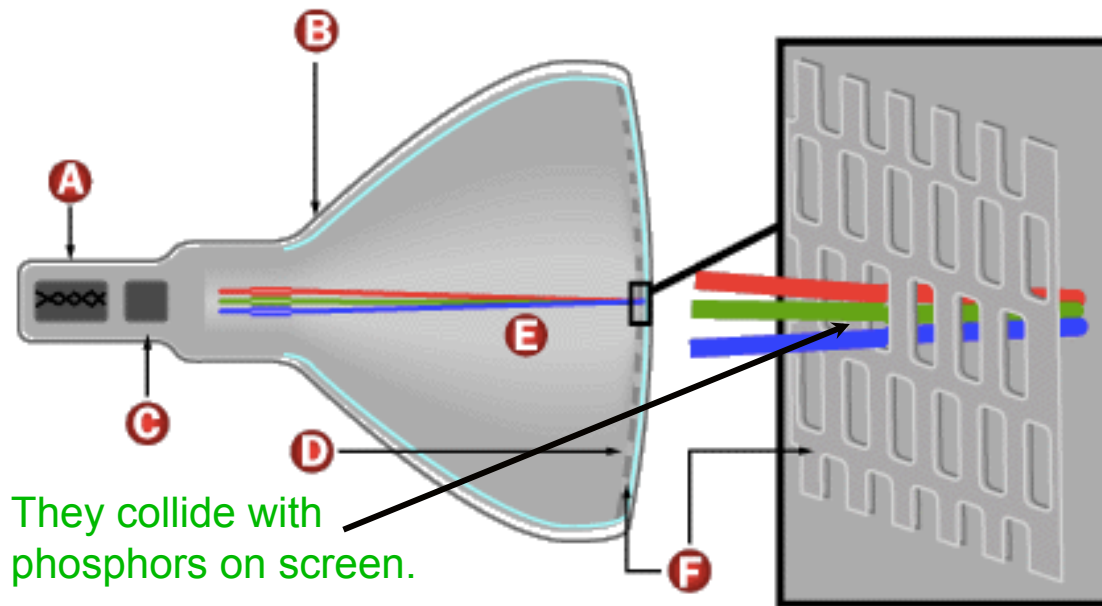
Electrons produced
and accelerated.

©2000 How Stuff Works

- A** Cathode
- B** Conductive coating
- C** Anode

- D** Phosphor-coated screen
- E** Electron beams
- F** Shadow mask

An older television set is a type of
“particle accelerator” since it has a
CATHODE RAY TUBE



©2000 How Stuff Works

- | | |
|-----------------------------|---------------------------------|
| A Cathode | D Phosphor-coated screen |
| B Conductive coating | E Electron beams |
| C Anode | F Shadow mask |

(A cathode ray is a beam of electrons)

BUT, in order to give particles
higher speeds (more kinetic energy),
much larger machines must be used!



VERY POWERFUL ELECTRIC FIELDS PRODUCE AND ACCELERATE THE PARTICLES,

AND VERY POWERFUL MAGNETIC FIELDS GUIDE THE PARTICLES.

WHERE THEY EITHER HIT A “TARGET”, OR COLLIDE WITH OTHER PARTICLES MOVING IN THE OPPOSITE DIRECTION.

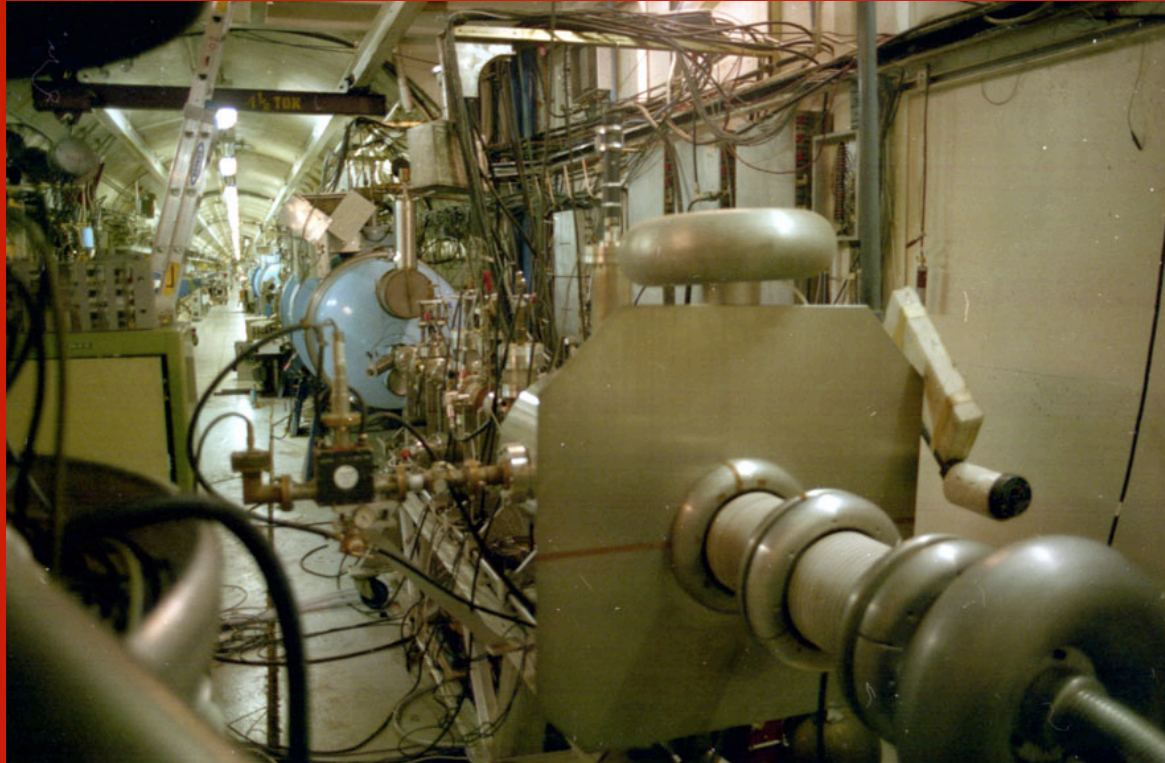
AND THE “REMNANTS” OF THE COLLISION ARE OBSERVED BY VERY SENSITIVE DETECTORS.



FORCES MUST BE CONTINUOUSLY SUPPLIED TO KEEP THE PARTICLES ACCELERATING.

(Newton's Second Law!)

Some accelerate particles in a
straight *line* . . .



Like the STANFORD *LINEAR* PARTICLE
ACCELERATOR (SLAC)

... And some accelerate particles
in a CIRCULAR PATH
(“synchrotron”)



like

FERMILAB (outside of Chicago)

The most powerful accelerator in the United States.

A large red circle is centered on a yellow background. A horizontal red band passes behind the circle, creating a ring effect. The word "BUT," is written in a bold, yellow, sans-serif font in the center of the red circle.

BUT,



**Just outside of Geneva, Switzerland,
located on the France-Switzerland border,**

**The MOST POWERFUL ACCELERATOR
ever built has just been constructed!!!**

A large red circle is centered on a yellow background. A horizontal red band passes through the middle of the circle. The text "At a facility called" is written in yellow inside the top part of the red circle.

At a facility called

An aerial photograph of the CERN facility in Geneva, Switzerland. The image shows a large complex of buildings, roads, and green spaces, surrounded by rolling green hills and mountains in the distance. The sky is clear and blue. The word "CERN" is overlaid in large, bold, yellow letters across the center of the image. Below it, the text "THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH" is also overlaid in yellow, bold letters.

CERN

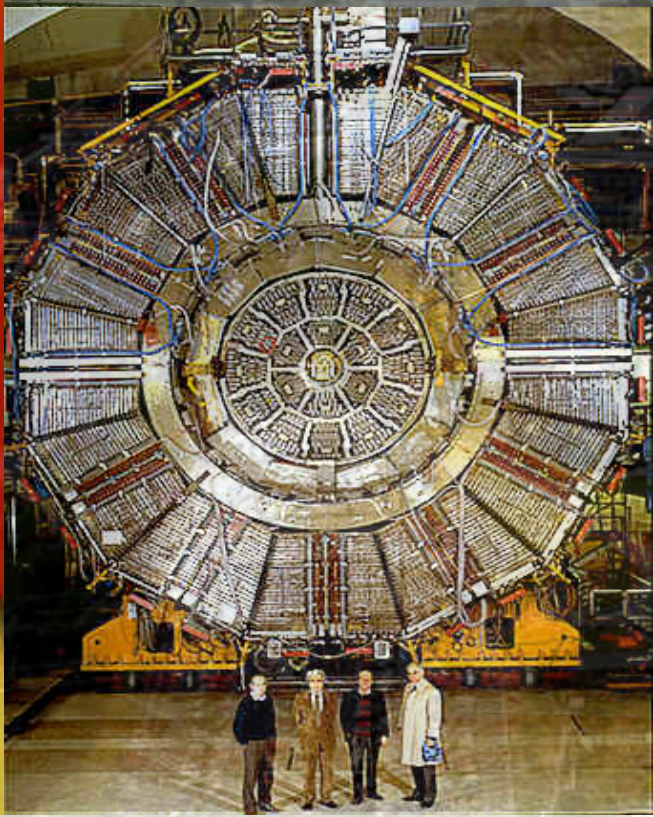
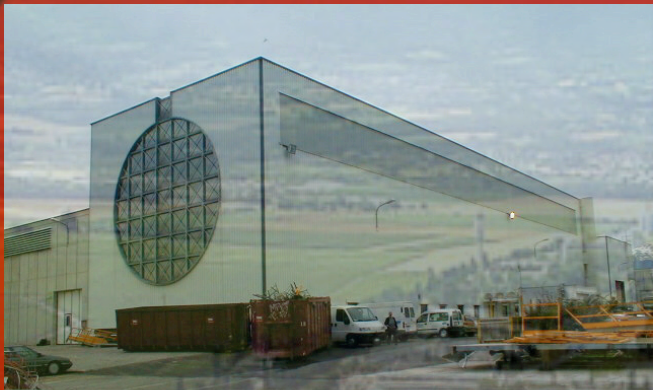
**THE EUROPEAN ORGANIZATION FOR
NUCLEAR RESEARCH**



Founded in 1954 by 12 countries, CERN is a collaborative effort that brings together thousands of scientists, engineers, and technicians from 20 member countries as well as other contributing countries from around the world.



CERN is not just a single building, but a self-contained “city” covering several square miles of laboratories, research facilities, particle accelerators, detectors, massive assembly buildings, office buildings, a science “museum”, dormitories, even restaurants, its own police and fire stations, and hospital!









BUT, most of the action takes place
deep underground. . .

in a maze of caverns and tunnels
100 meters below the surface,

extending from Switzerland into France.

IT IS HERE WHERE
PARTICLES ARE
PRODUCED,
ACCELERATED,

COLLIDED, AND
DETECTED!!!

SO, WHAT IS THE L.H.C.??

LET'S BREAK IT DOWN . . .



THE

L.

H.

C.

STANDS FOR

THE
LARGE

HADRON

COLLIDER

So, what does THAT mean???

Let's break it down some more:

LARGE:

THIS IS DUE TO ITS LARGE SIZE!!!



THIS IS JUST ONE OF MANY
SURFACE BUILDINGS,
(HOUSING THE LHCb).

LHC / POINT 8 - SURFACE AREA - SX BUILDING FOR LHCb

LHCb Expt Area 8 February 2001

LARGE:

THIS IS DUE TO ITS LARGE SIZE!!!

BUT MOST OF THE LHC LIES **100 METERS**

BELOW THE GROUND, WHERE PARTICLES

ARE ACCELERATED IN OPPOSITE DIRECTIONS

IN A TUNNEL **27 KM (ALMOST 17 MILES)** IN

CIRCUMFERENCE!!!

LARGE:

THIS IS DUE TO ITS LARGE SIZE!!!



HERE IS AN ARIAL VIEW OF THE OUTSKIRTS OF GENEVA.
SWITZERLAND WITH FRANCE IN THE BACKGROUND.

LARGE:



THIS IS DUE TO ITS LARGE SIZE!!!

LHC TUNNEL
(27km CIRCUMFERENCE,
100 m BELOW GROUND!)

HERE IS A SHOT OF CERN SHOWING THE SIZE
AND LOCATION OF THE LHC TUNNEL UNDERGROUND

LARGE:



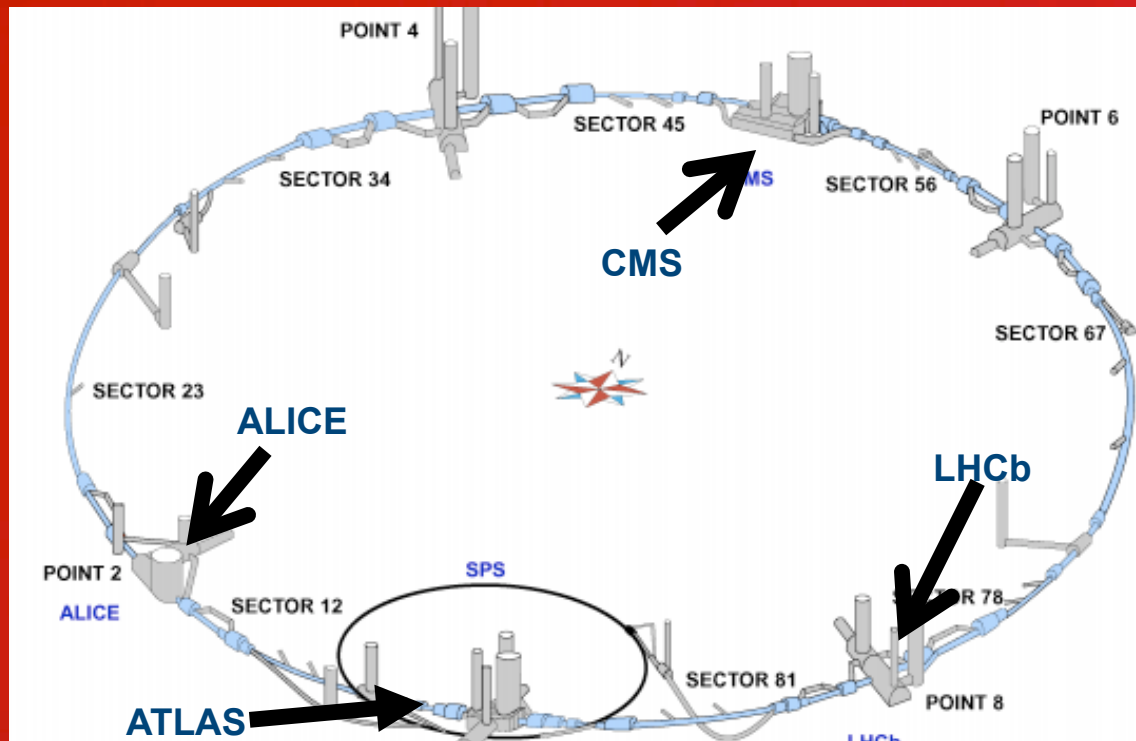
ENGINEERS INSPECT A SMALL SECTION OF THE TUNNEL THAT HOUSES MORE THAN 1600 MAGNETS, MOST ABOUT HALF THE SIZE OF A BASKETBALL COURT, EACH WEIGHING OVER 30 TONS!

LARGE:



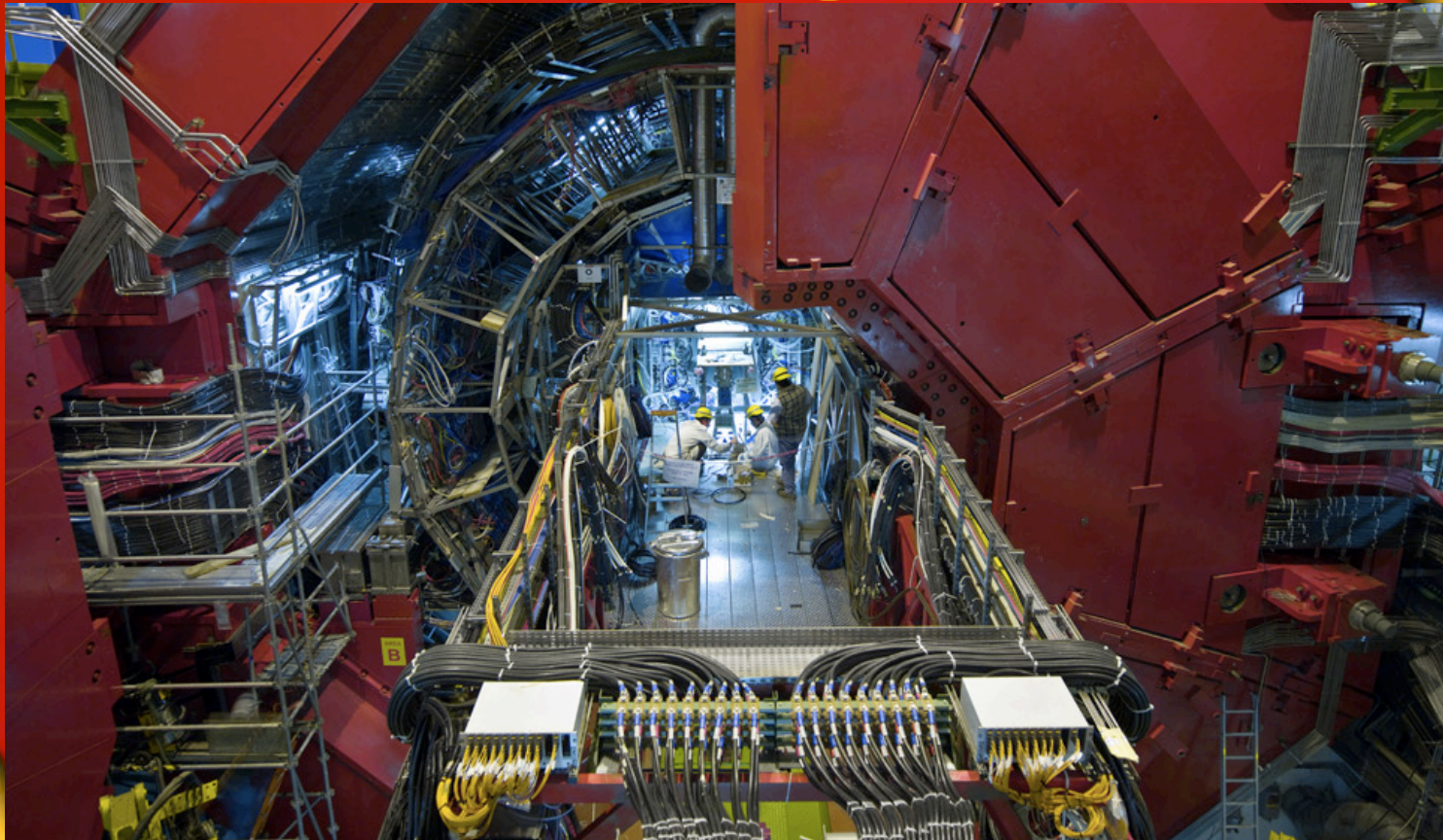
THE BEAMS OF PROTONS WILL BE STEERED BY THESE POWERFUL MAGNETS ALONGSIDE PIPES OF LIQUID HELIUM, COOLED TO -456 DEGREES F, MAKING IT ONE OF, IF NOT THE, COLDEST PLACES IN THE UNIVERSE!

LARGE:



AT FOUR LOCATIONS IN THE TUNNEL, THE BEAM PIPE IS BROKEN WHERE COLLISIONS MAY OCCUR, WITH A MASSIVE DETECTOR AT EACH LOCATION, LOOKING FOR SPECIFIC TYPES OF PARTICLES THAT MAY EMERGE FROM THE COLLISION. HERE THEY ARE:

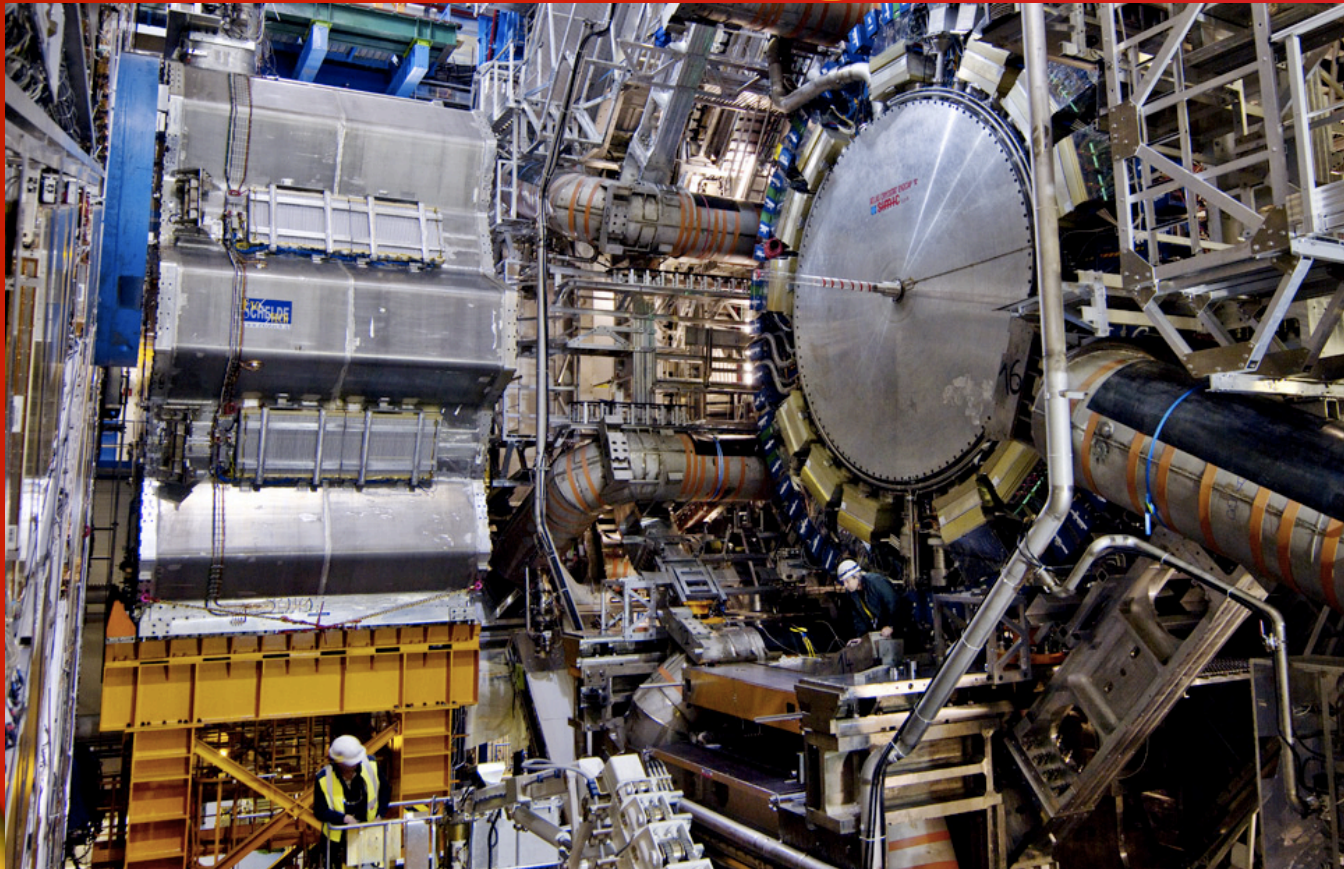
LARGE:



“ALICE”

A Large Ion Collider Experiment

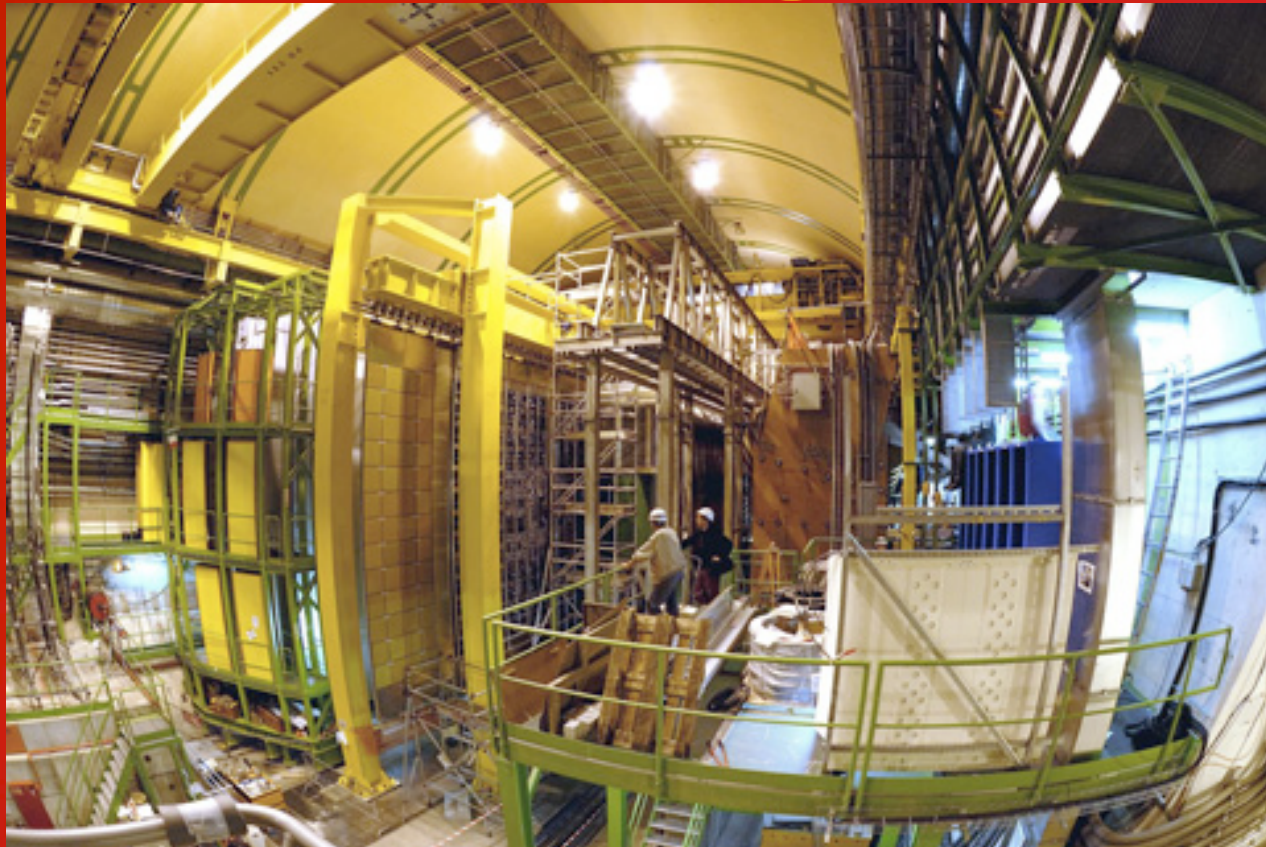
LARGE:



“ATLAS”

A Toroidal LHC ApparatuS

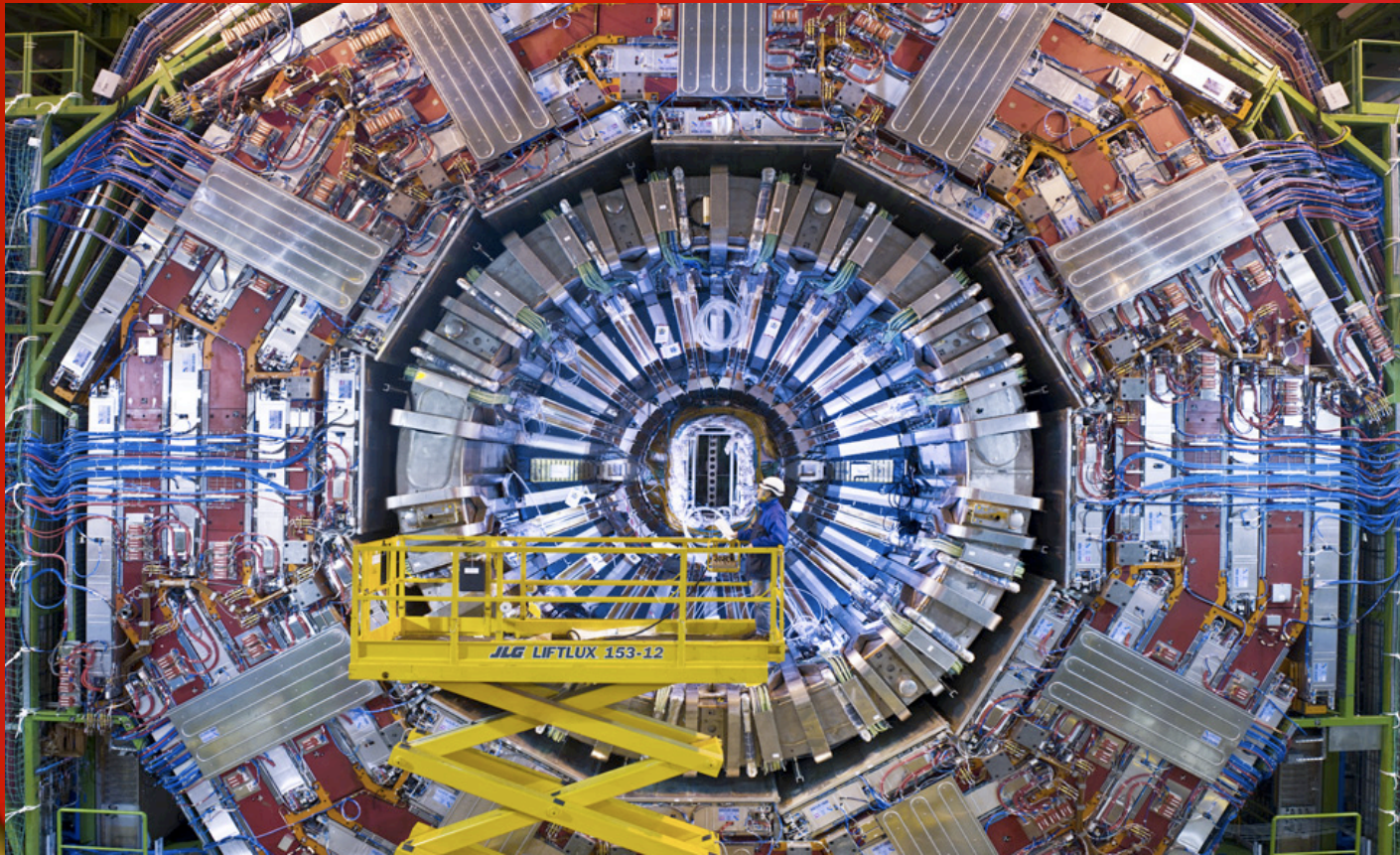
LARGE:



“LHCb”

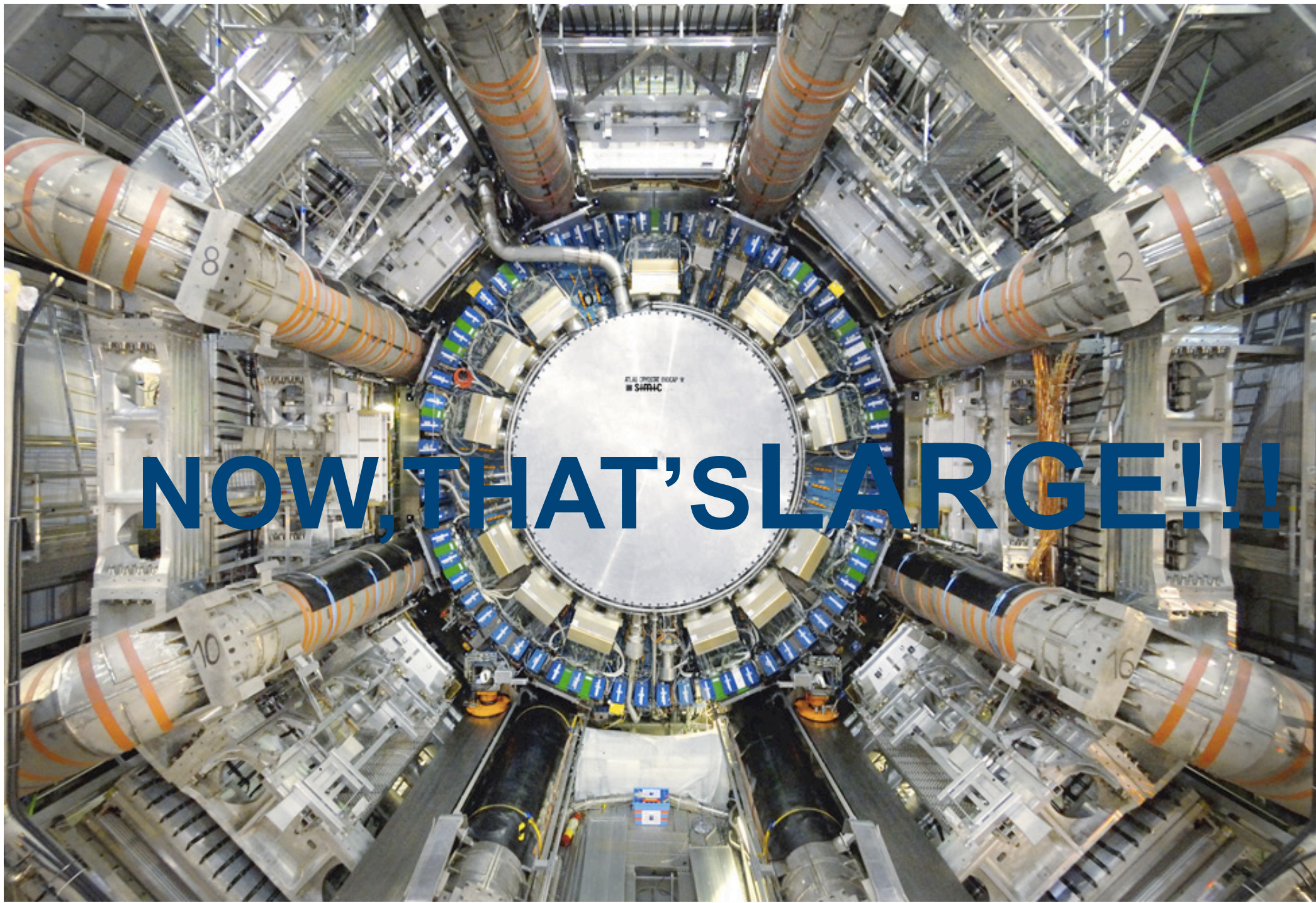
The Large Hadron Collider Beauty Experiment

LARGE:



“CMS”

Compact Muon Solenoid



NOW, THAT'S LARGE!!!

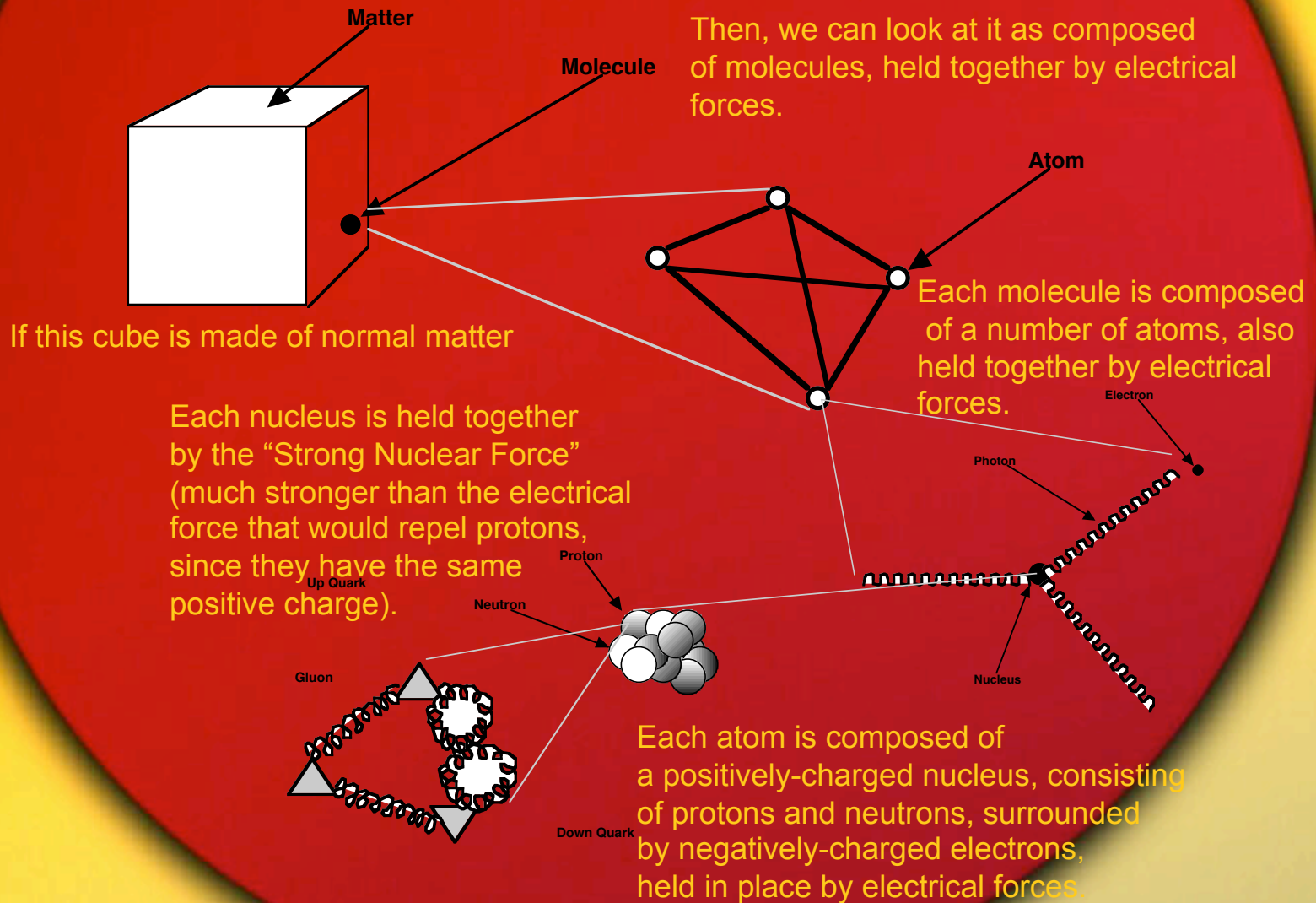
HADRON:

THESE ARE PARTICLES AFFECTED BY THE
STRONG NUCLEAR FORCE

WHAT KIND OF PARTICLES ARE THESE, AND
WHAT IS THE STRONG NUCLEAR FORCE?

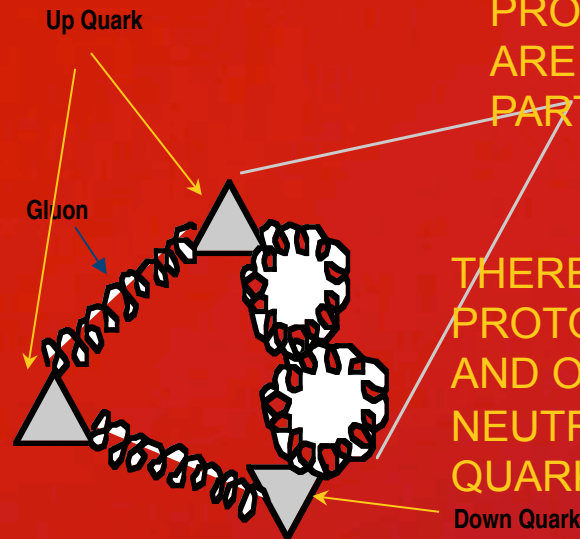
LET'S DO A SIMPLE BREAKDOWN
OF WHAT WE CALL
"NORMAL MATTER":

HADRON:



HADRON:

PROTONS AND NEUTRONS ARE EACH MADE UP OF THREE PARTICLES CALLED "QUARKS".



THERE ARE SIX TYPES OF QUARKS - PROTONS HAVE TWO "UP" QUARKS AND ONE "DOWN" QUARK, WHILE NEUTRONS HAVE TWO "DOWN" QUARKS AND ONE "UP" QUARK EACH.

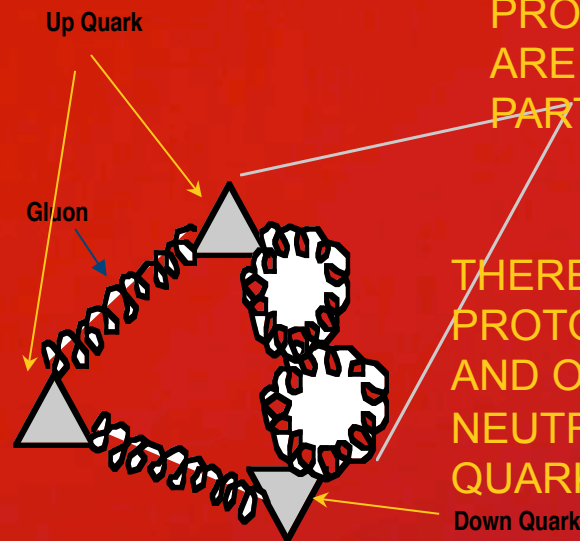
(According to the STANDARD MODEL of particle physics.)

Elementary Particles

Quarks	u up	c charm	t top	Force Carriers
	d down	s strange	b bottom	
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z Z boson
	e electron	μ muon	τ tau	W W boson
I II III				
Three Families of Matter				

HADRON:

So, what type of particle would this be????

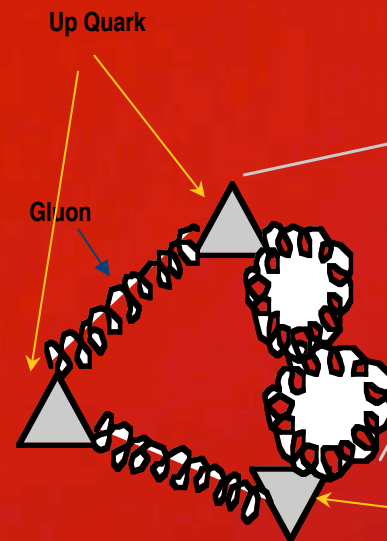


PROTONS AND NEUTRONS ARE EACH MADE UP OF THREE PARTICLES CALLED "QUARKS".

THERE ARE SIX TYPES OF QUARKS - PROTONS HAVE TWO "UP" QUARKS AND ONE "DOWN" QUARK, WHILE NEUTRONS HAVE TWO "DOWN" QUARKS AND ONE "UP" QUARK EACH.

THE QUARKS ARE HELD TOGETHER BY FORCE-CARRYING PARTICLES CALLED "GLUONS".

HADRONS:



PROTONS AND NEUTRONS ARE EACH MADE UP OF THREE PARTICLES CALLED "QUARKS".

THERE ARE SIX TYPES OF QUARKS - PROTONS HAVE TWO "UP" QUARKS AND ONE "DOWN" QUARK, WHILE NEUTRONS HAVE TWO "DOWN" QUARKS AND ONE "UP" QUARK EACH.

Down Quark

THE QUARKS ARE HELD TOGETHER BY FORCE-CARRYING PARTICLES CALLED "GLUONS".

PARTICLES THAT CONSIST OF THREE QUARKS ARE CLASSIFIED AS

"HADRONS" . . . SO

PROTONS AND NEUTRONS ARE ALSO KNOWN AS

HADRONS*

*MORE SPECIFICALLY, THEY ARE CLASSIFIED AS “BARYONS.”

HADRONS THAT CONSIST OF EXACTLY **TWO** QUARKS
(ONE QUARK AND ONE “ANTIQUARK”) ARE CLASSIFIED AS
“MESONS.”

THE TITLE *MIGHT* ALSO BE INTERPRETED AS “LARGE
HADRON. . .” (BARYONS), AS OPPOSED TO “SMALL
HADRON” (MESONS)

PROTONS AND NEUTRONS ARE ALSO KNOWN AS

HADRONS

BUT, ONLY BEAMS OF PROTONS
WILL BE USED IN THE LHC, SINCE THEY
HAVE A POSITIVE CHARGE, AND CAN BE
ACCELERATED BY AN ELECTROMAGNETIC
FIELD.

(NEUTRONS HAVE NO CHARGE, SO
THEY WOULD NOT BE AFFECTED.)

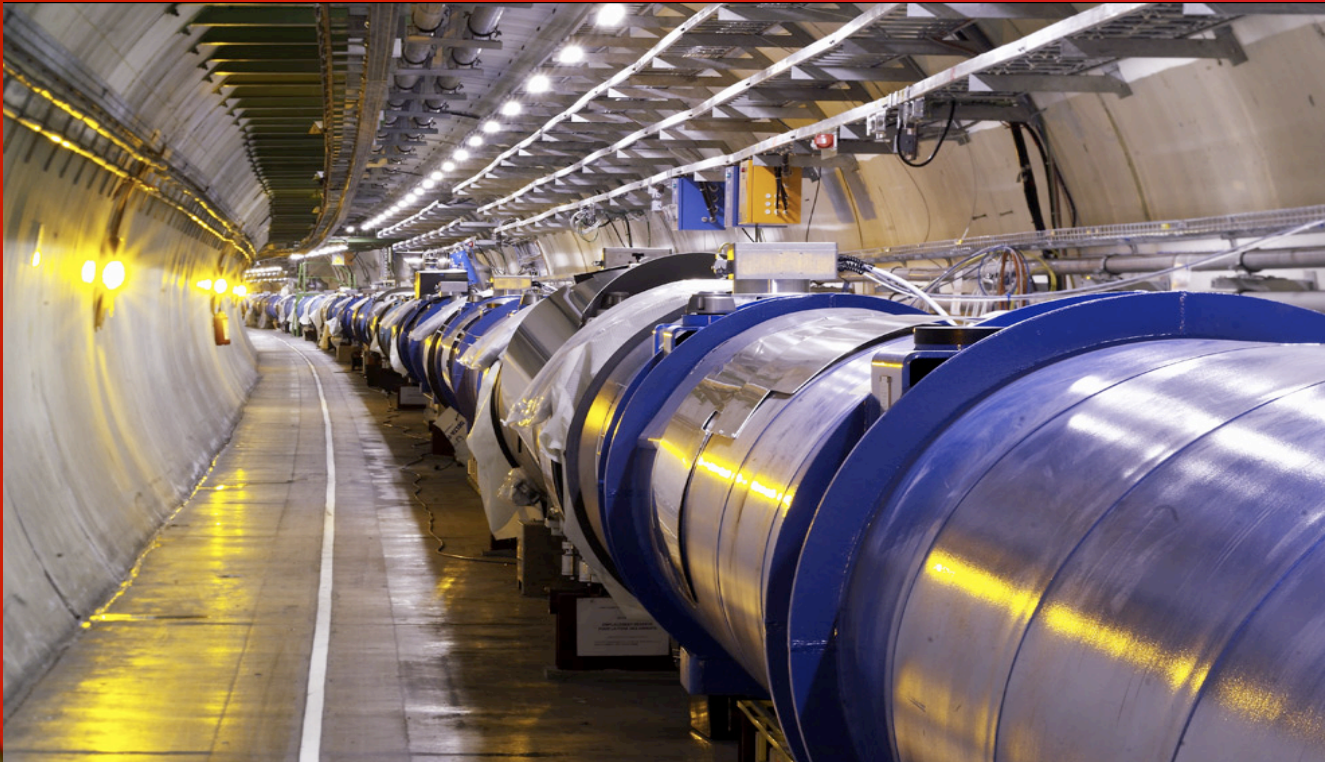
And now, a word about

THE

LARGE

HADRON

COLLIDER!

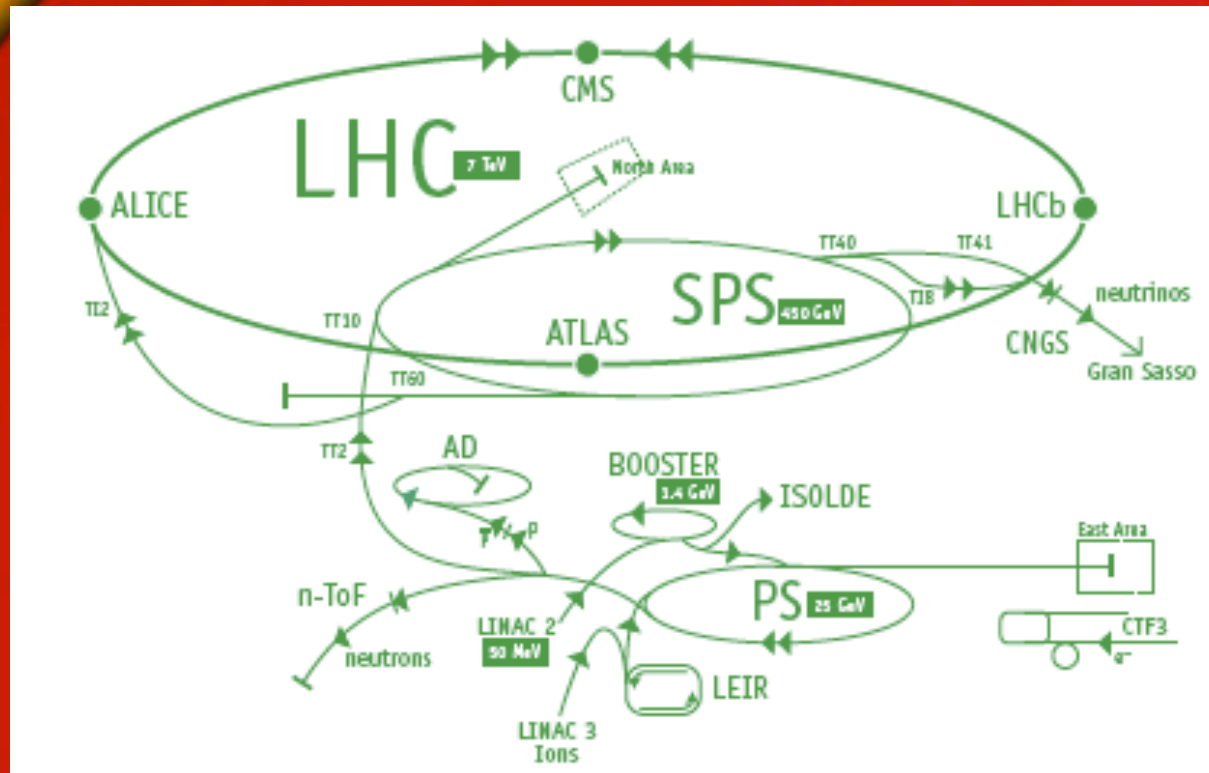


But, first, did you know that. . .

THE LHC IS NOT THE *ONLY*
PARTICLE ACCELERATOR AT CERN



OTHER LINEAR AND CIRCULAR ACCELERATORS
ALREADY CONSTRUCTED WILL BE USED TO INITIALLY
ACCELERATE THE PROTONS BEFORE THEY ENTER
THE LHC TUNNEL. HERE'S A DIAGRAM:

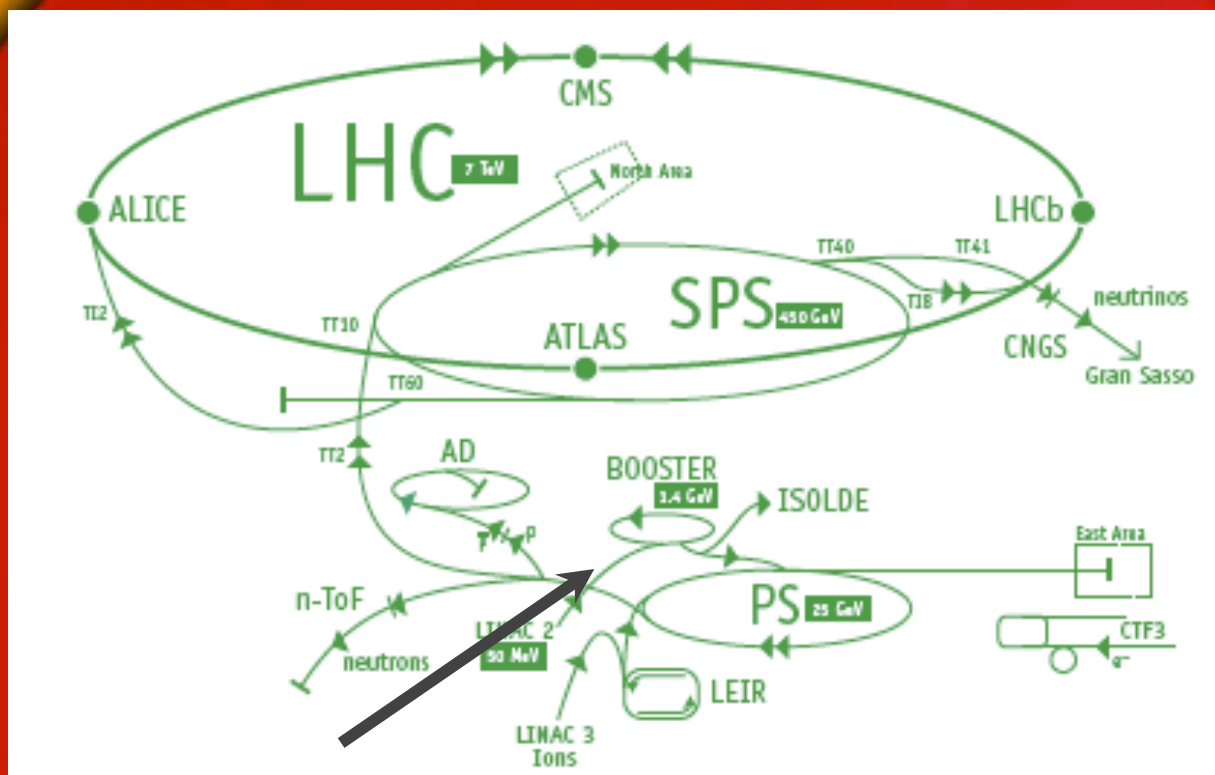


There are a series of accelerators at CERN, each with increasing energies. The LHC is the final link in this chain, accelerating protons to a record energy of 7 TeV!

(An eV stands for “electron-Volt” and is used to measure the energy of very small particles. A “TeV” is a terra electron-Volt, which is one thousand BILLION electron-Volts!!!!)

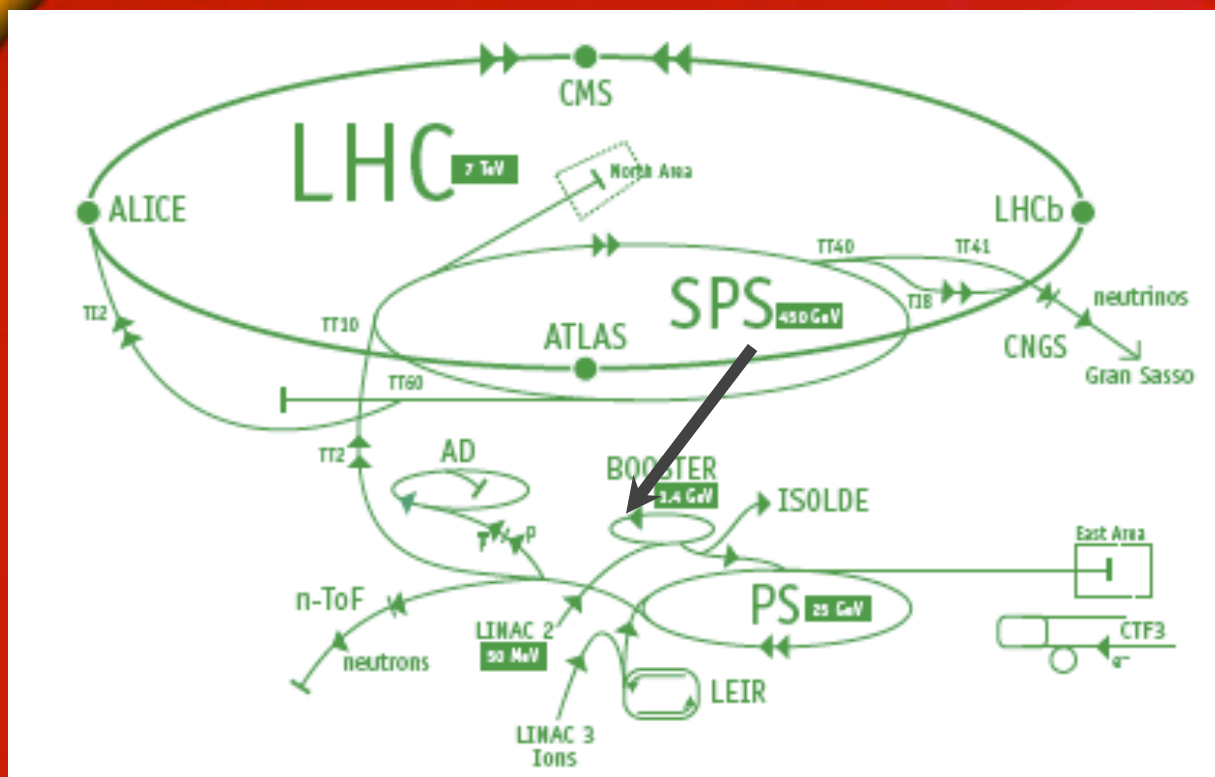
$$1 \text{ TeV} = 1,000,000,000,000 \text{ eV}$$

STEP 1:



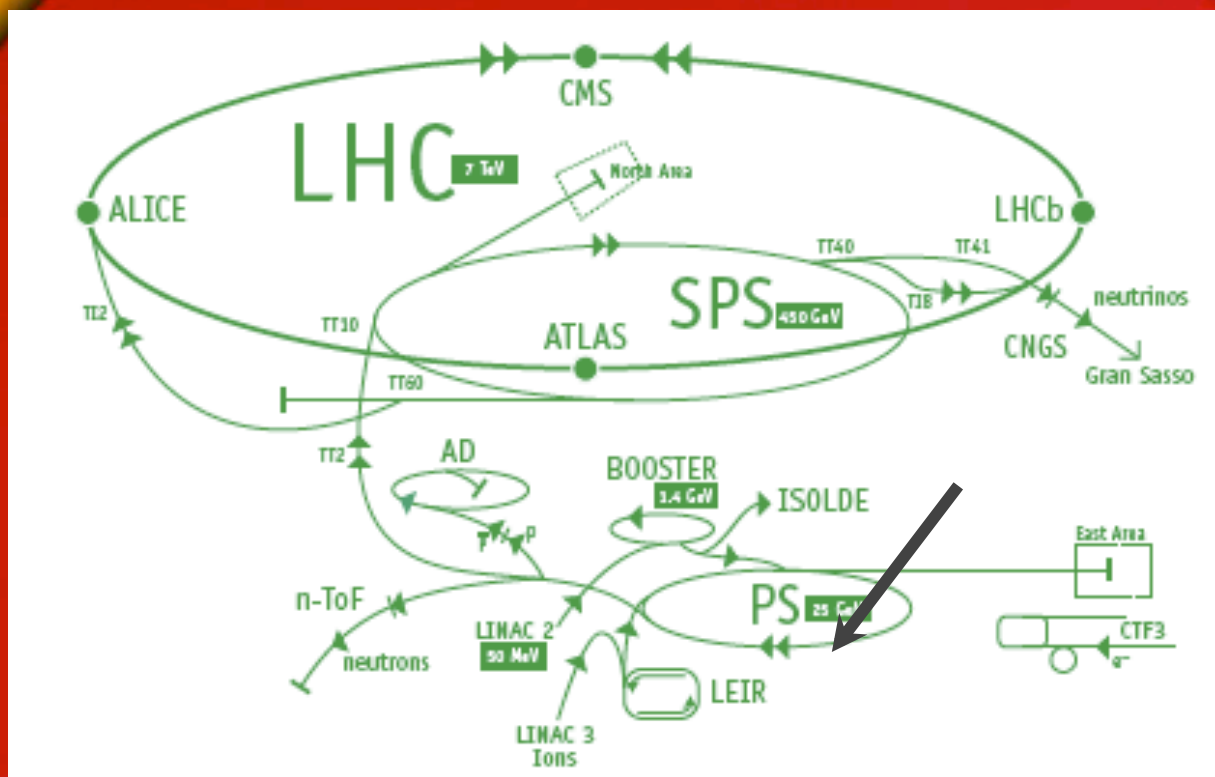
Hydrogen ions (hydrogen atoms stripped of their electrons, leaving just the protons) are injected into the PS Booster (PS) at an energy of 50 MeV (50 million eV) from “Linac 2” (linear accelerator).

STEP 2:



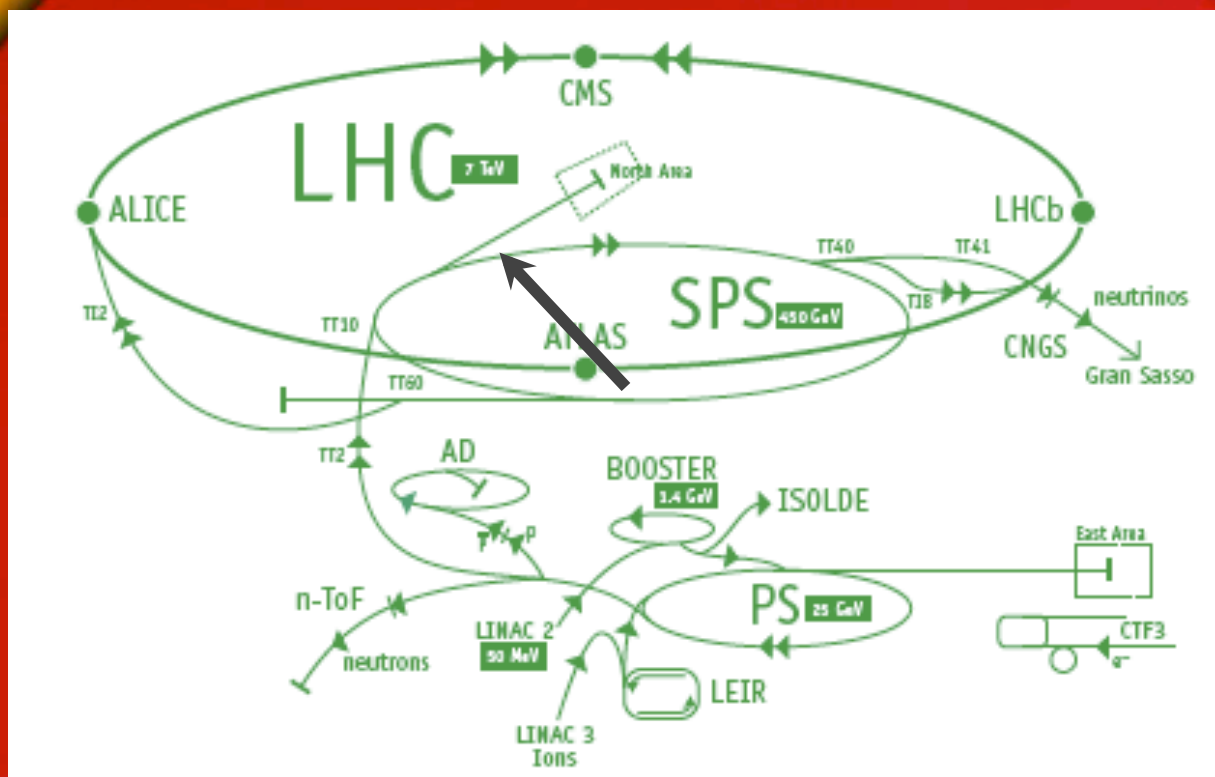
The booster accelerates them to 1.4 GeV (giga eV, 1.4 billion eV).

STEP 3:



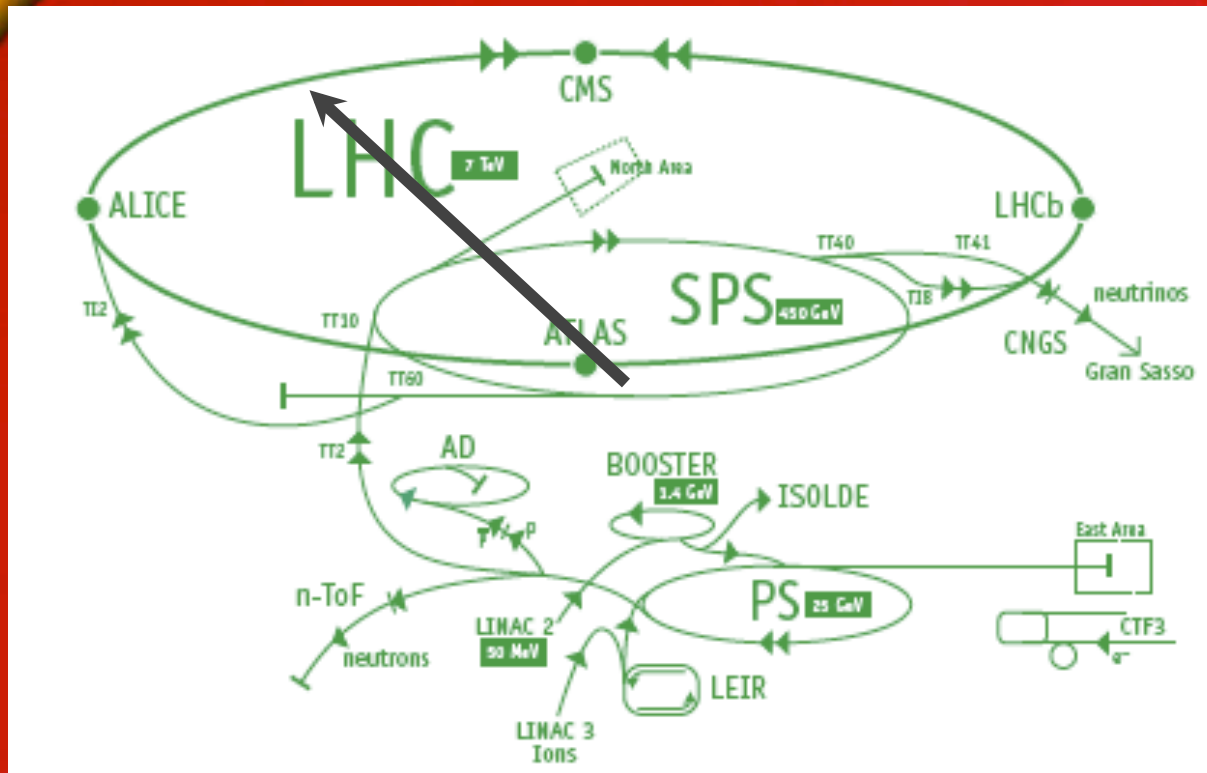
The beam is then fed into the Proton Synchrotron (PS), where it is accelerated to 25 GeV.

STEP 4:



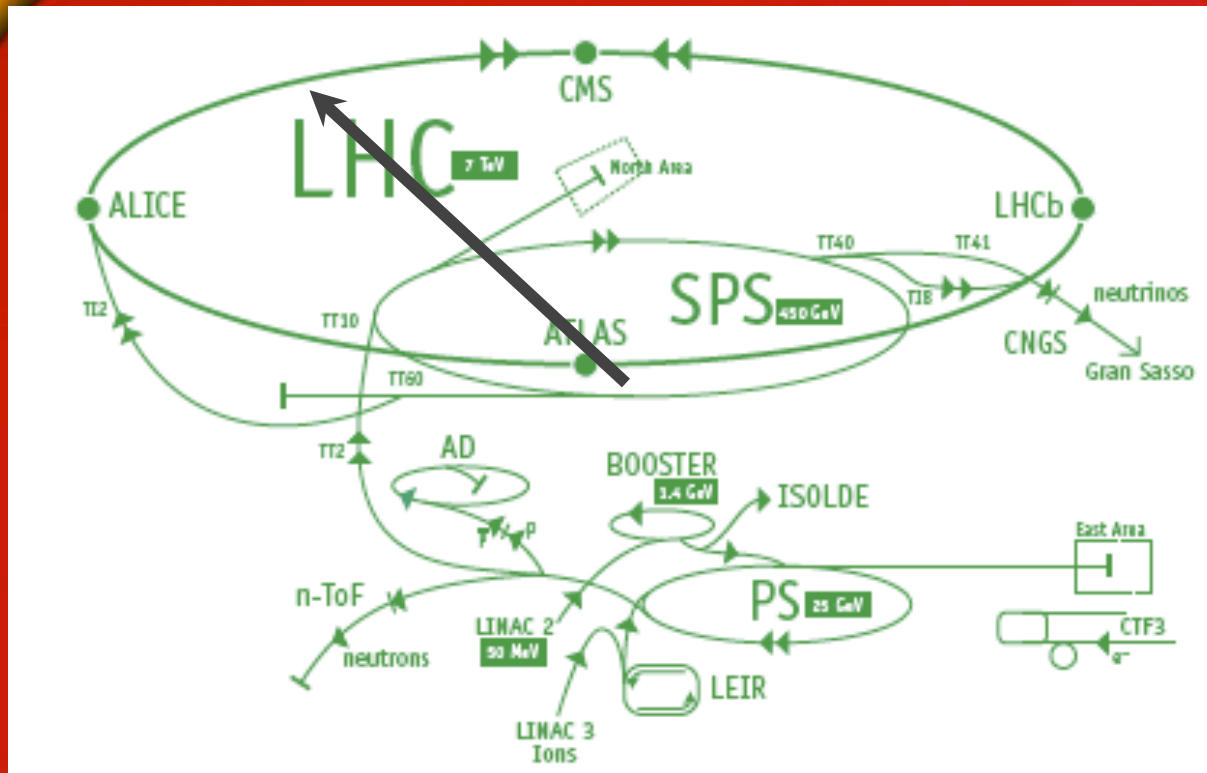
Protons are then fed into the Super Proton Synchrotron (SPS), where they are accelerated to 450 GeV.

STEP 5:



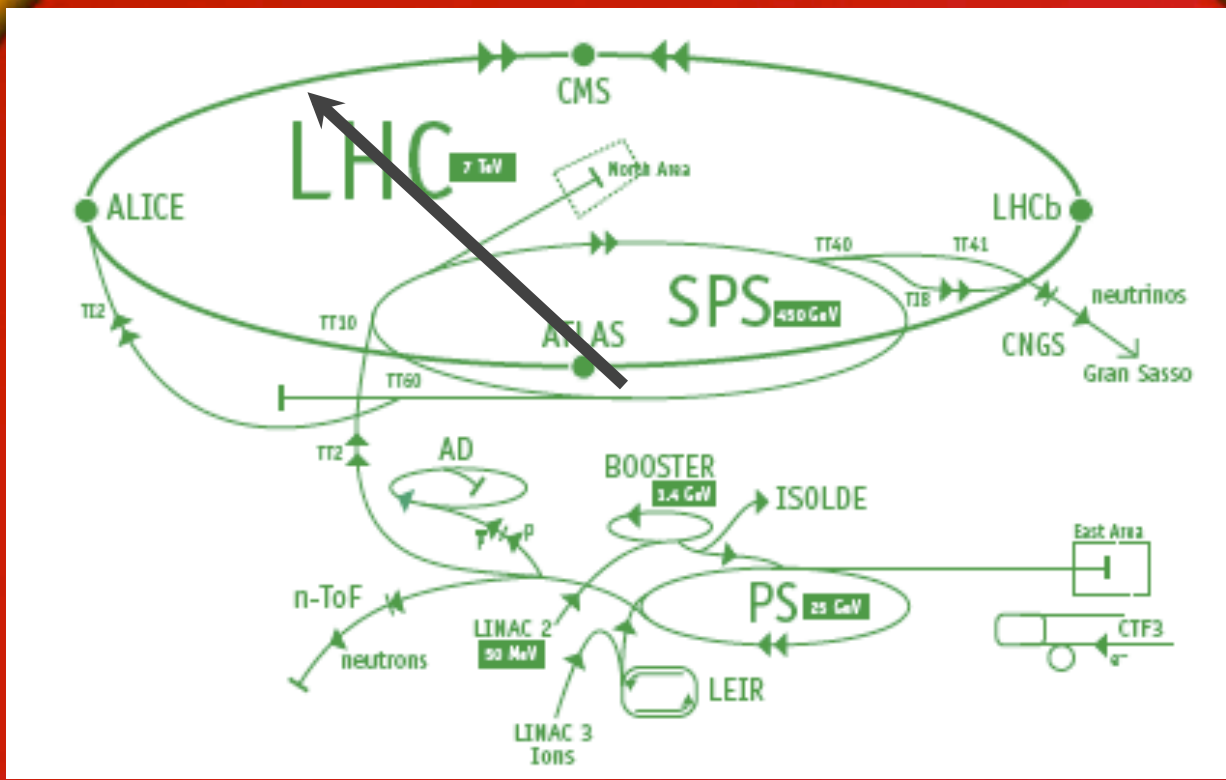
They are finally transferred to the LHC tunnel, where they are injected in “bunches” (2808) of billions of protons, some going clockwise, some going counterclockwise. It takes about four hours and twenty minutes to fill these two rings. The beams of protons are actually 40 microns in diameter. (About one-third the size of a human hair)!

STEP 5:



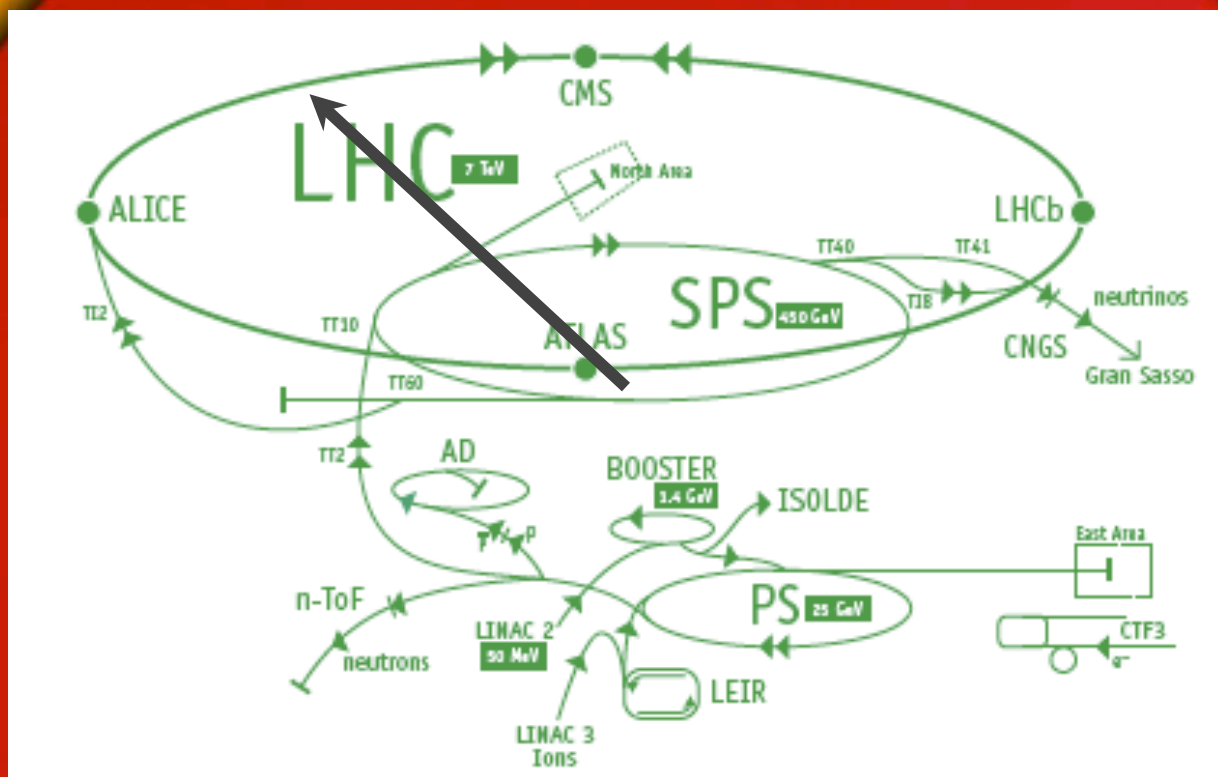
After about 20 minutes, they reach the target energy of 7 TeV. When they collide, it's like a **head-on collision between two cars going in opposite directions, they will have a combined energy of 14 TeV!!!** Even with so many bunches of protons crossing paths, an average of 20 actual collisions may occur in one bunch. This is the most energetic (man-made) collision between particles ever produced!

STEP 5:



JUST HOW MUCH ENERGY IS 14 TeV??

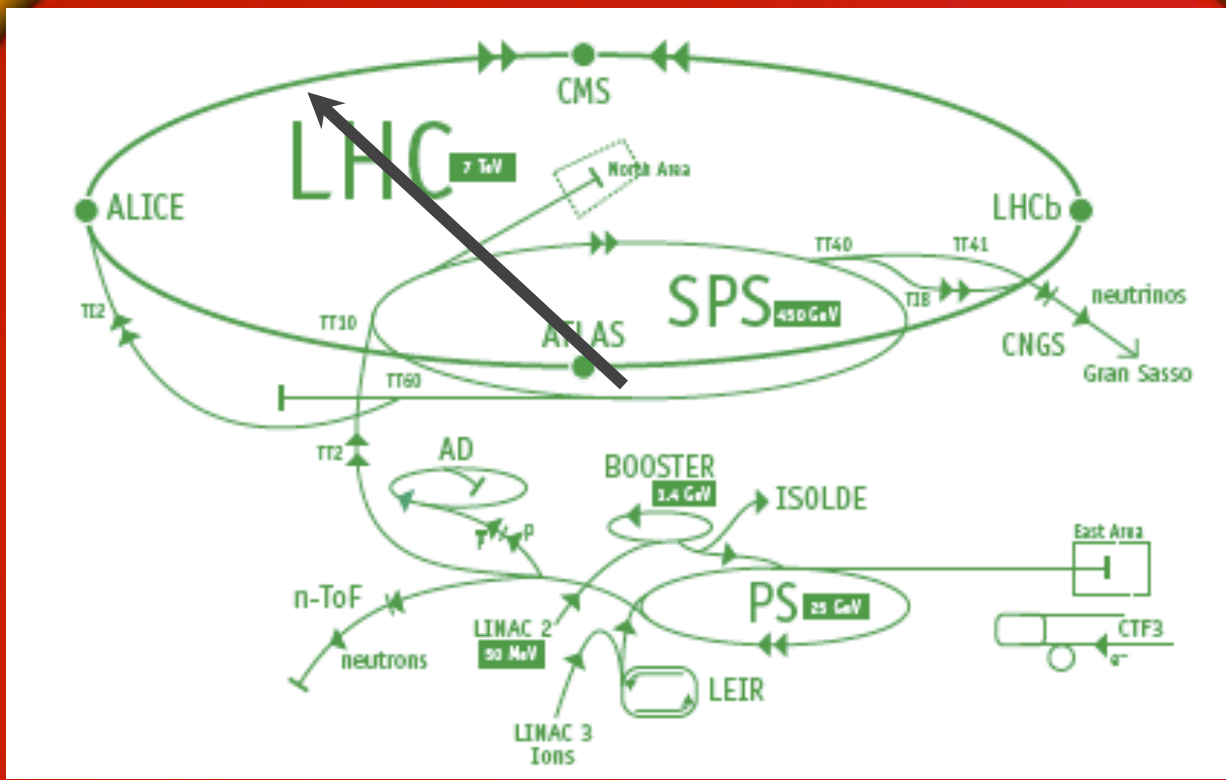
STEP 5:



JUST HOW MUCH ENERGY IS 14 TeV??

MORE THAN A NUCLEAR BOMB?

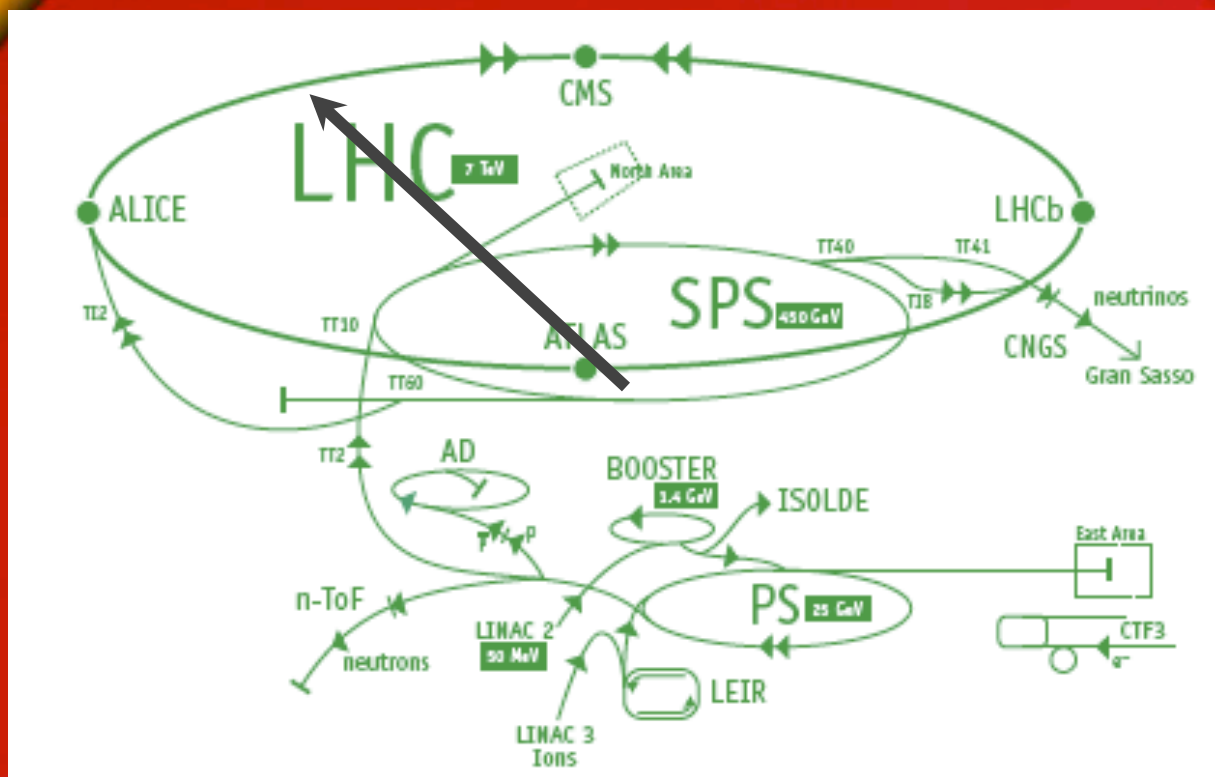
STEP 5:



JUST HOW MUCH ENERGY IS 14 TeV??

ENOUGH TO DESTROY THE EARTH?

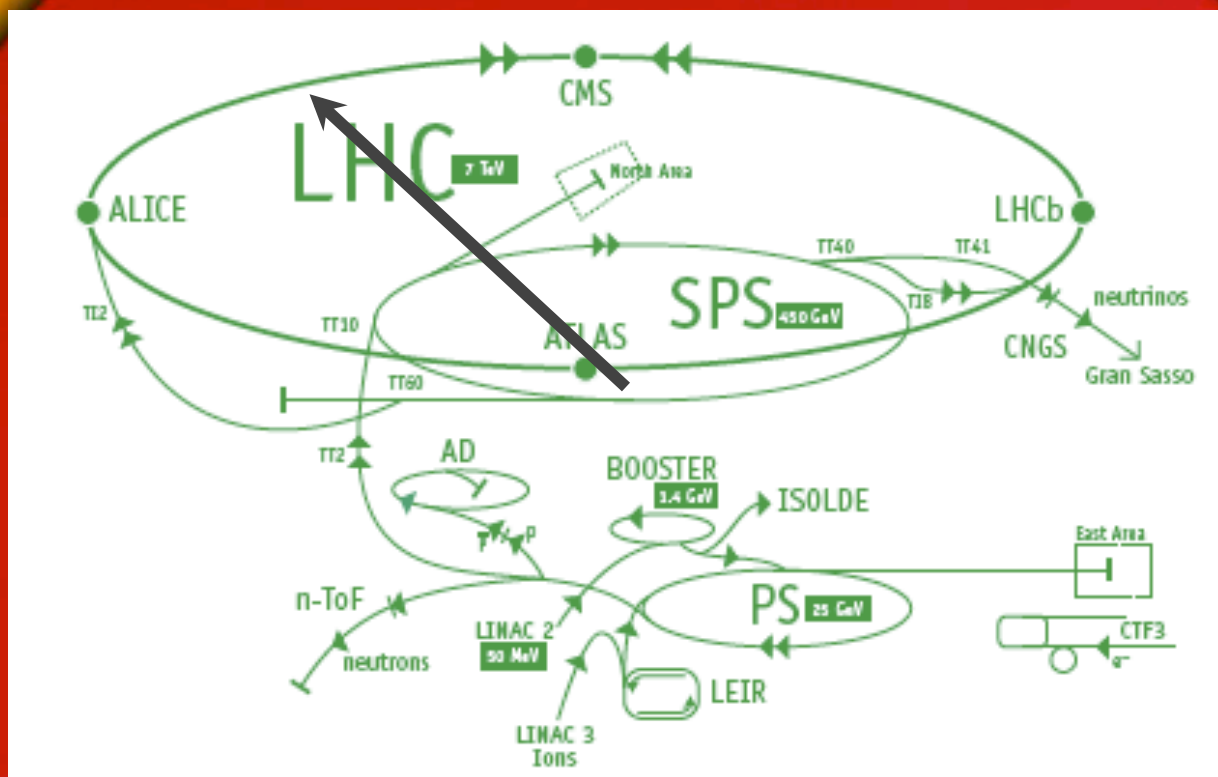
STEP 5:



JUST HOW MUCH ENERGY IS 14 TeV??

ENOUGH TO CREATE A MASSIVE
BLACK HOLE???

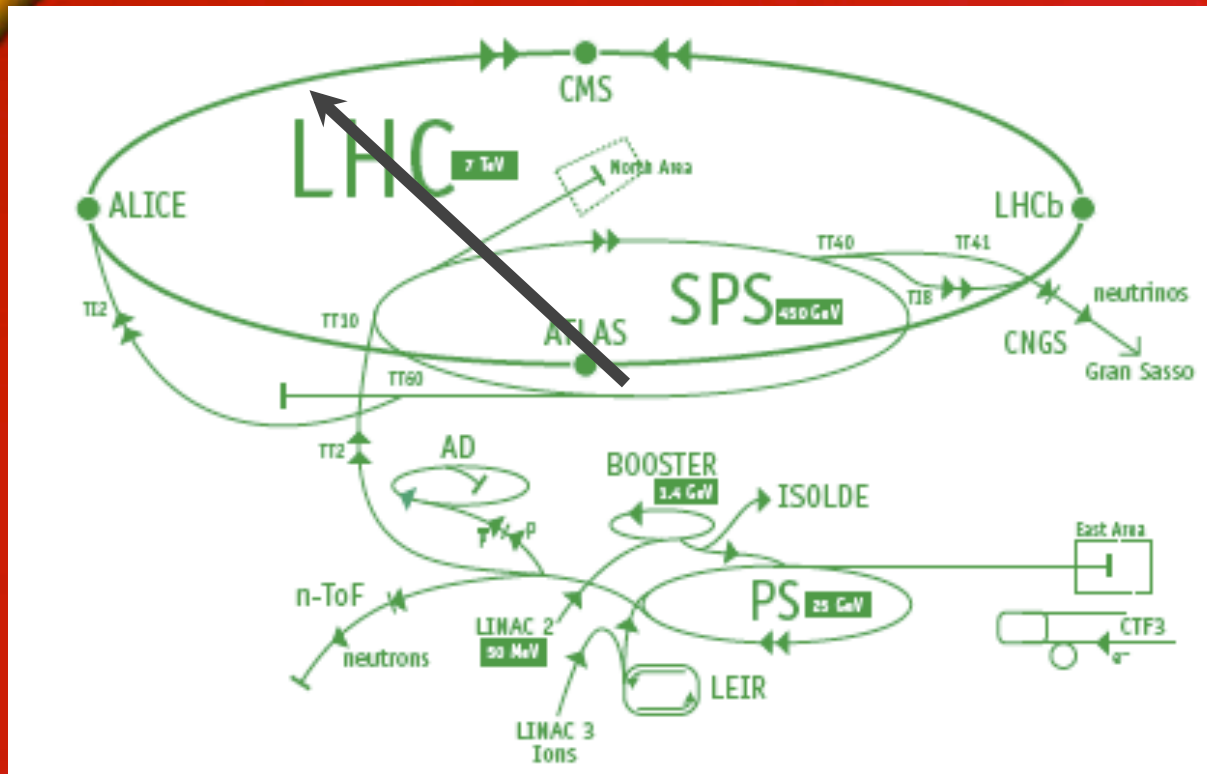
STEP 5:



JUST HOW MUCH ENERGY IS 14 TeV??

NO!!!

STEP 5:

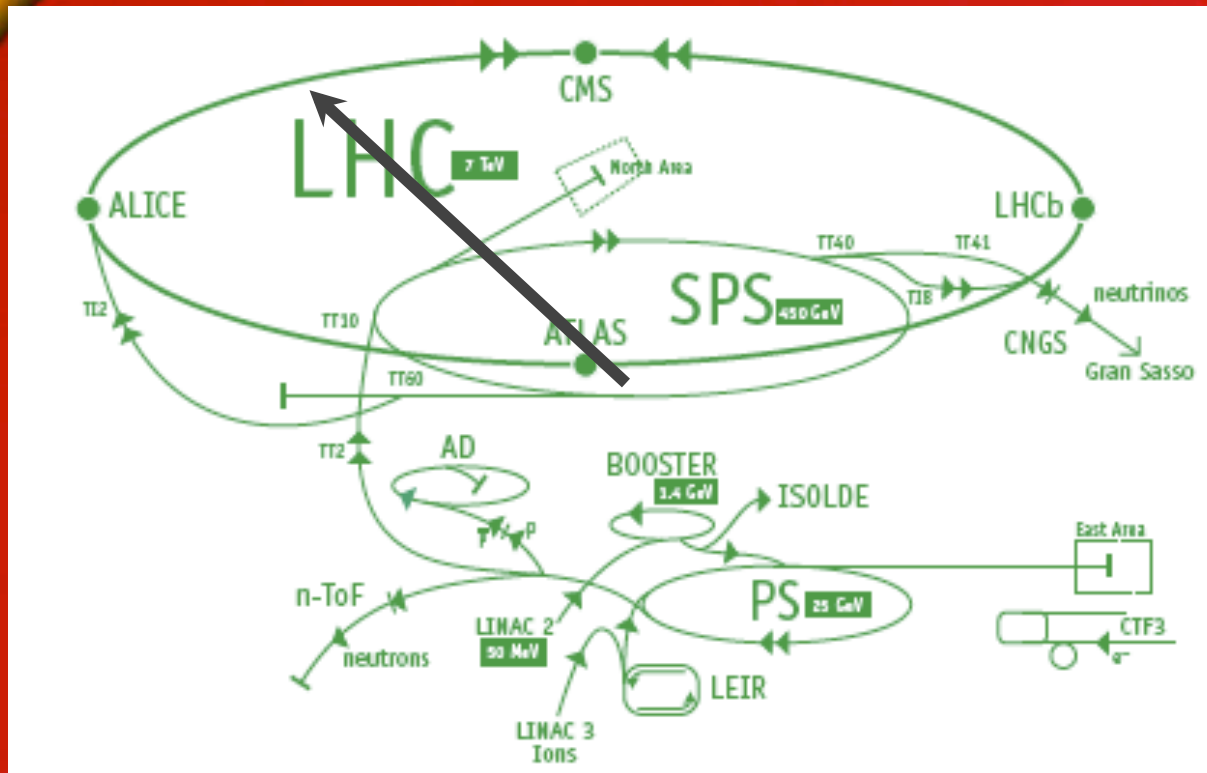


JUST HOW MUCH ENERGY IS 14 TeV??

ONE TeV IS ABOUT THE AMOUNT OF ENERGY GENERATED BY THE FLAPPING WINGS OF A MOSQUITO!!!!!!!



STEP 5:



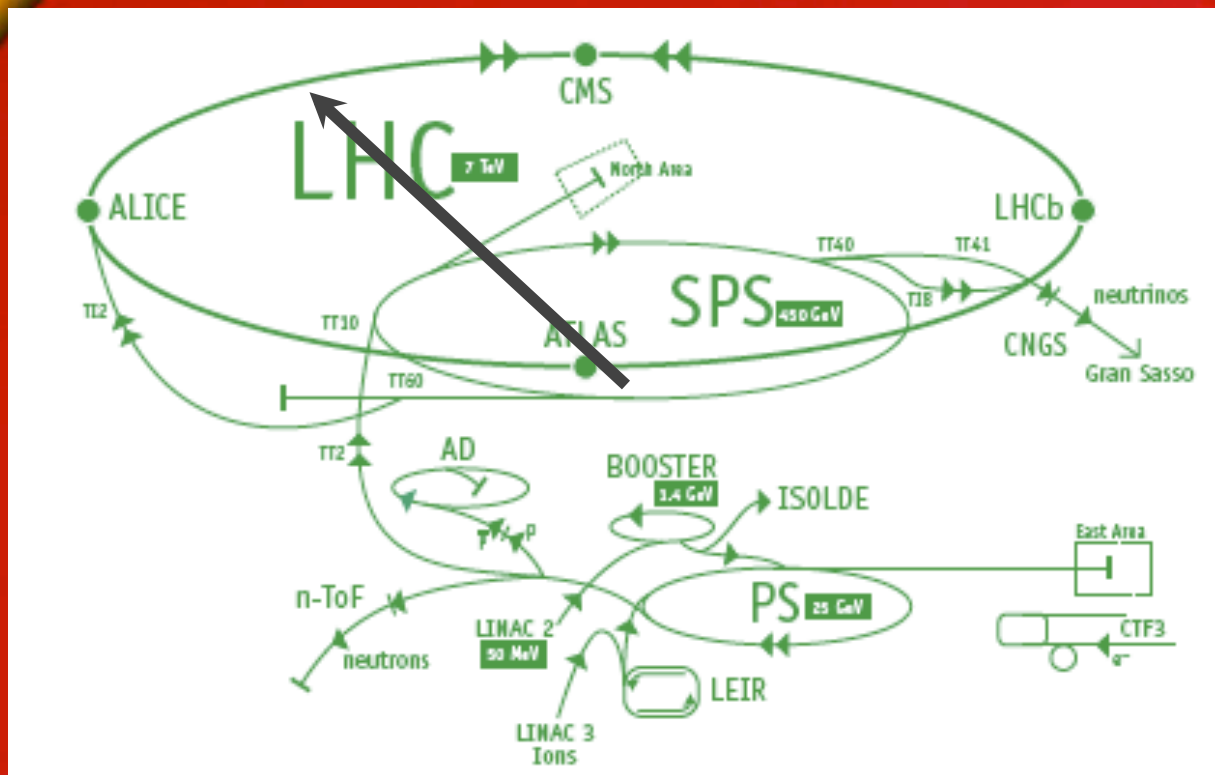
JUST HOW MUCH ENERGY IS 14 TeV??

ONE TeV IS ABOUT THE AMOUNT OF ENERGY GENERATED BY THE FLAPPING WINGS OF A MOSQUITO!!!!!!!

YOU PRODUCE MORE ENERGY WHEN YOU CLAP YOUR HANDS!

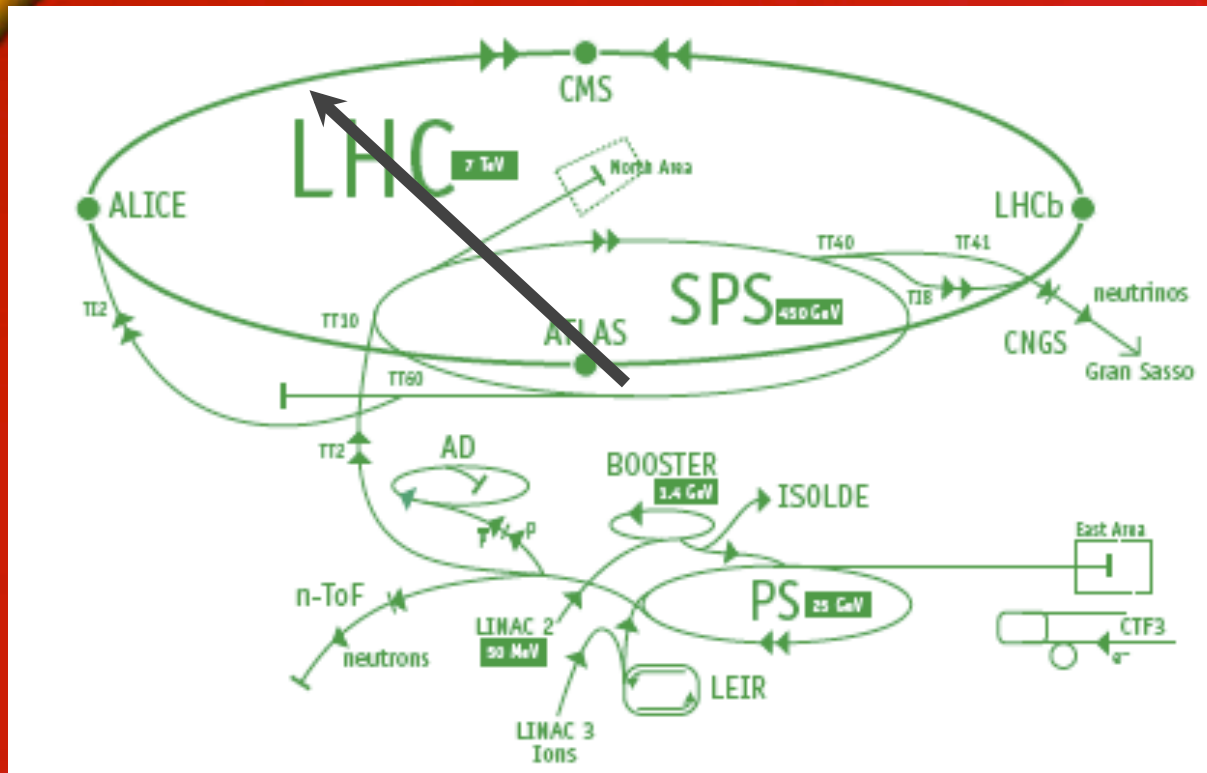


STEP 5:



THE KEY IS HOW THIS ENERGY IS
CONCENTRATED!!

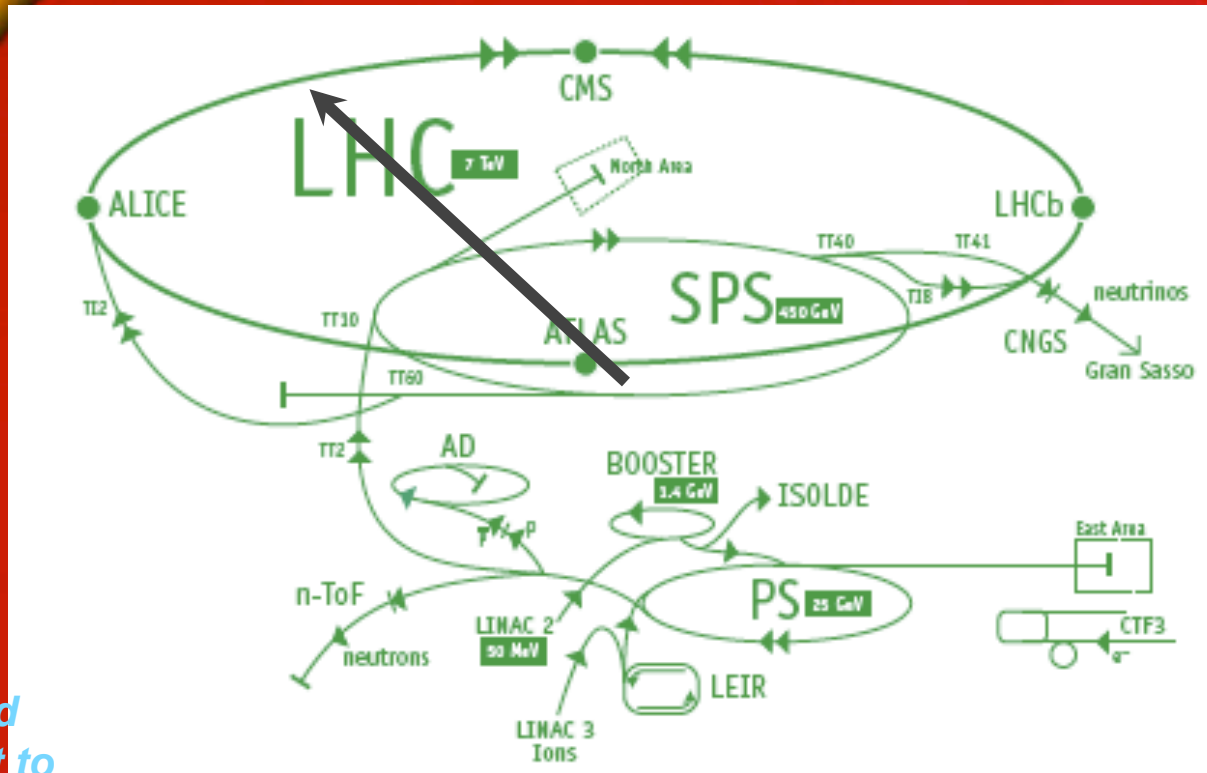
STEP 5:



THE ENERGY IS SQUEEZED INTO
A SPACE THAT IS ONE MILLION
MILLIONTH THE SIZE OF A
MOSQUITO!
(1/100000000000000)



STEP 5:

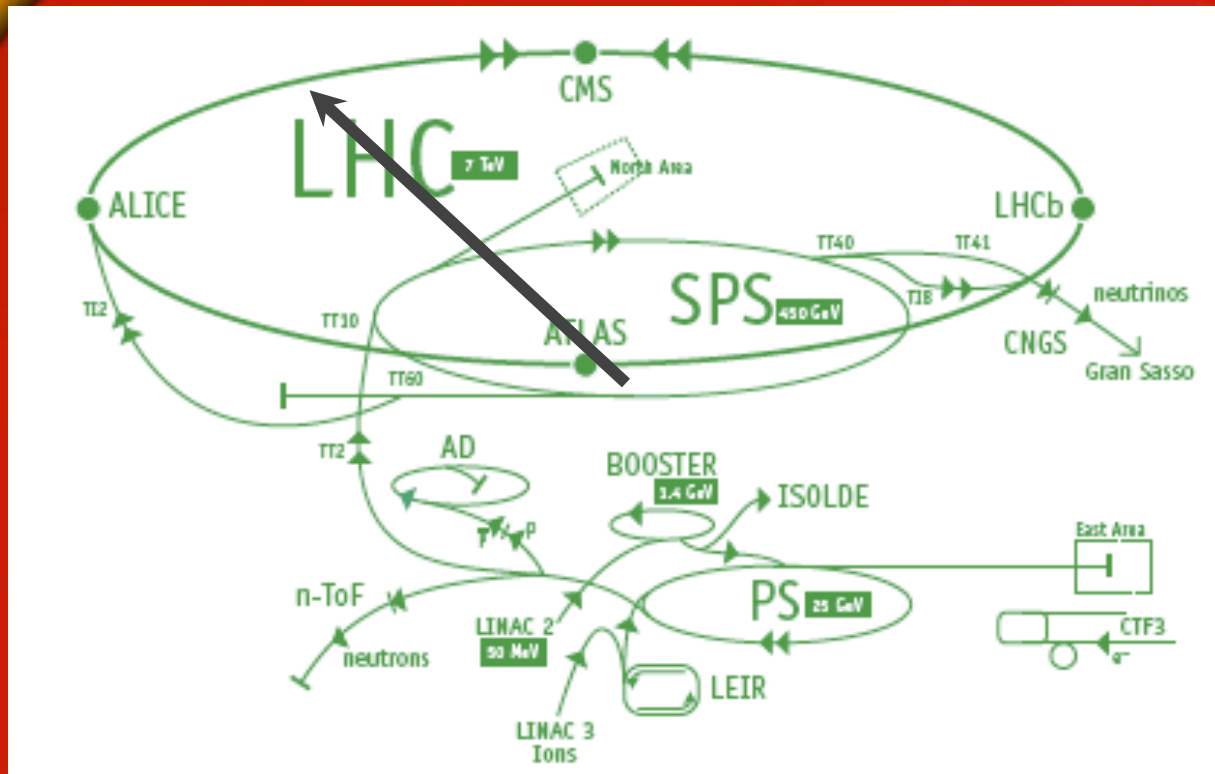


You would NOT want to clap your hands if you were holding a needle pointed towards one hand!

**THE ENERGY IS SQUEEZED INTO A SPACE THAT IS ONE MILLION MILLIONTH THE SIZE OF A MOSQUITO!
(1/100000000000000)**

THIS IS CONCENTRATED!

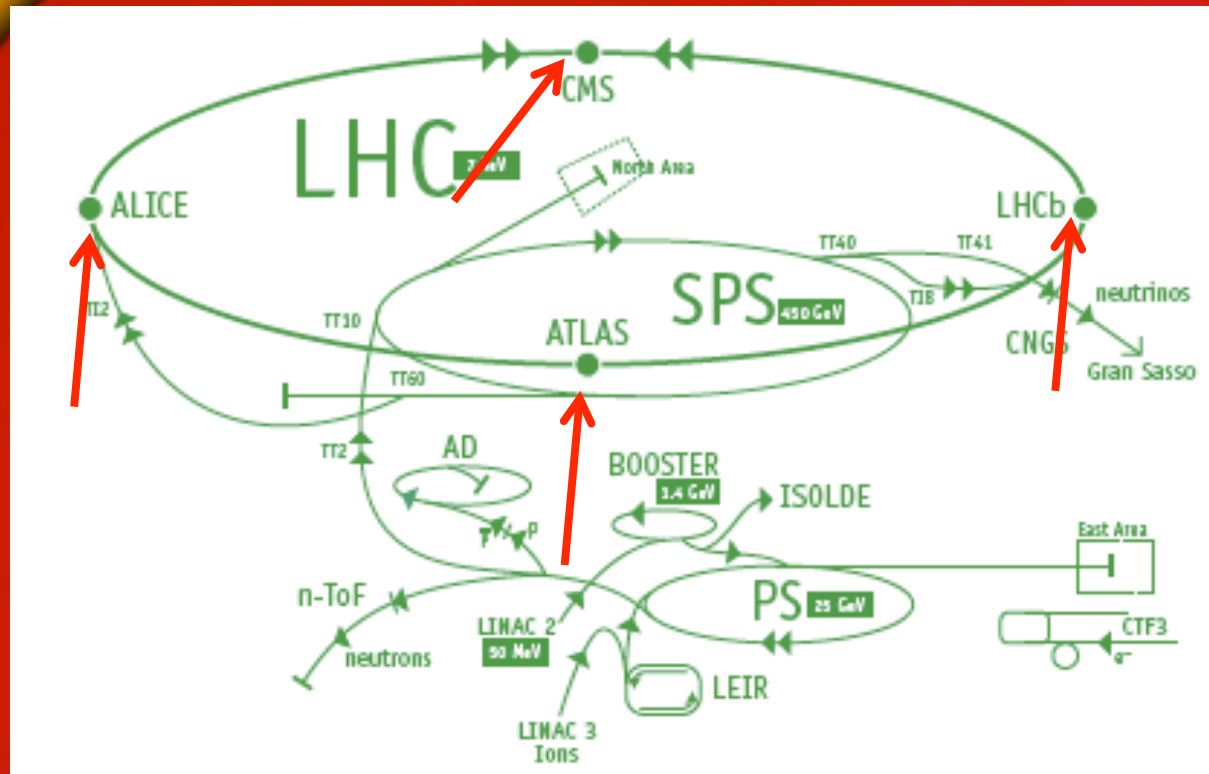
STEP 5:



BUT *THIS* AMOUNT OF CONCENTRATED ENERGY IS EQUIVALENT TO A 400 TON TRAIN TRAVELING OVER 100 MILES/HR!



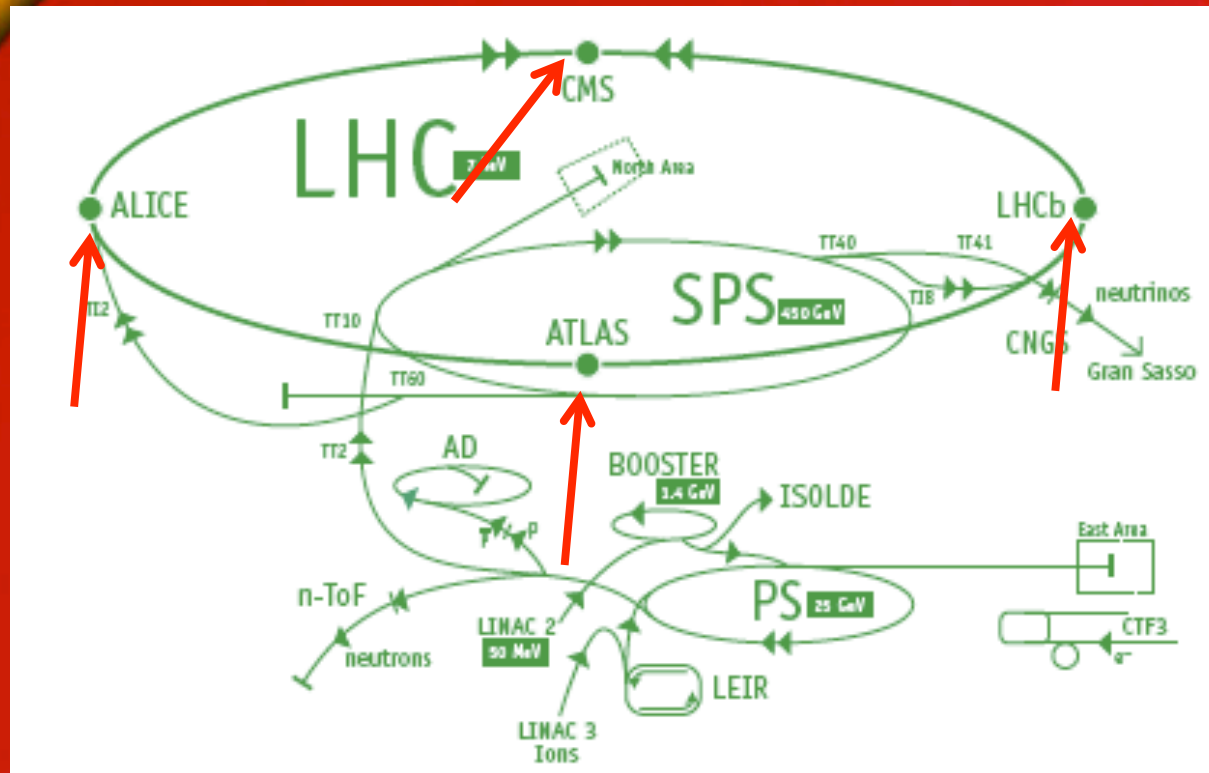
STEP 6:



These protons will be traveling at 0.999999991 the speed of light, making more than 11,000 trips around the 27 km tunnel every second!

Collisions are allowed to take place in any or all of the four “experiment” detectors.

STEP 6:

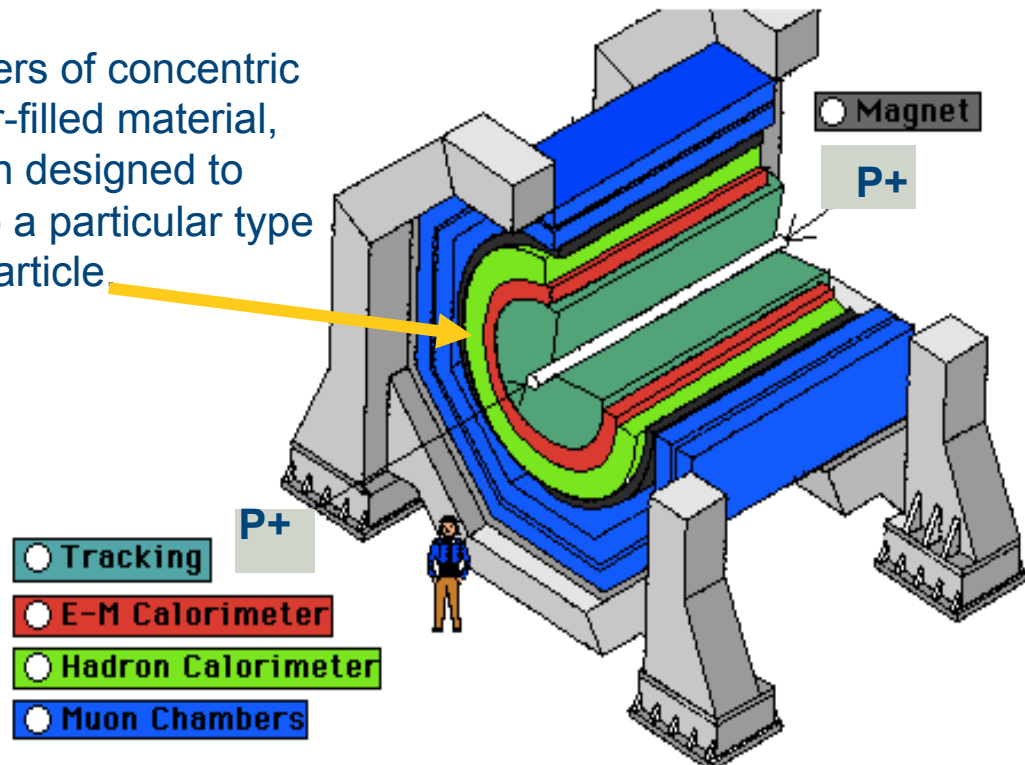


When a collision occurs, the detectors are designed to trace the paths of emerging particles if they are **charged**. In this way, they can be identified by the ion trail they leave behind.

If they are **not** charged, the particles will be “stopped” by specialized targets, where their energy can be absorbed and measured. These are called

STEP 6:

Layers of concentric fiber-filled material, each designed to stop a particular type of particle



When a collision occurs, the detectors are designed to trace the paths of emerging particles if they are **charged**. In this way, they can be identified by the ion trail they leave behind.

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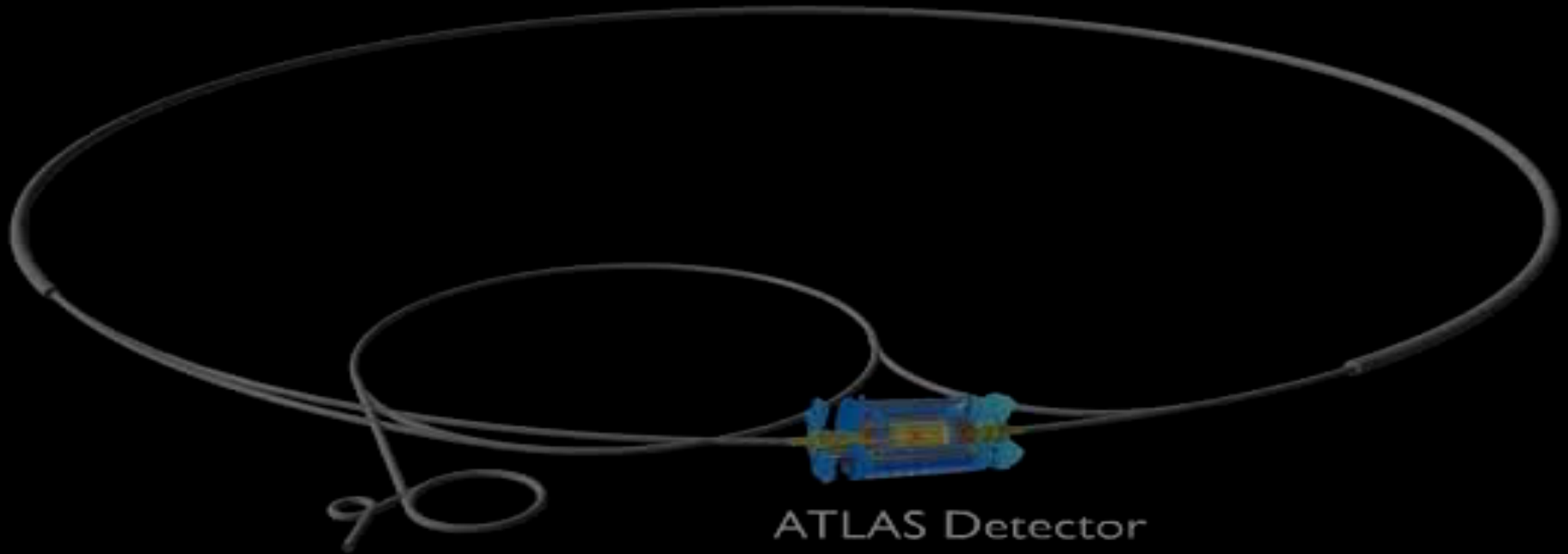
A large red circle is centered on a yellow background. A horizontal red band passes through the middle of the circle. The text "HERE IS WHAT THIS PROCESS LOOKS LIKE:" is written in yellow capital letters across the center of the red circle.

HERE IS WHAT THIS PROCESS LOOKS LIKE:

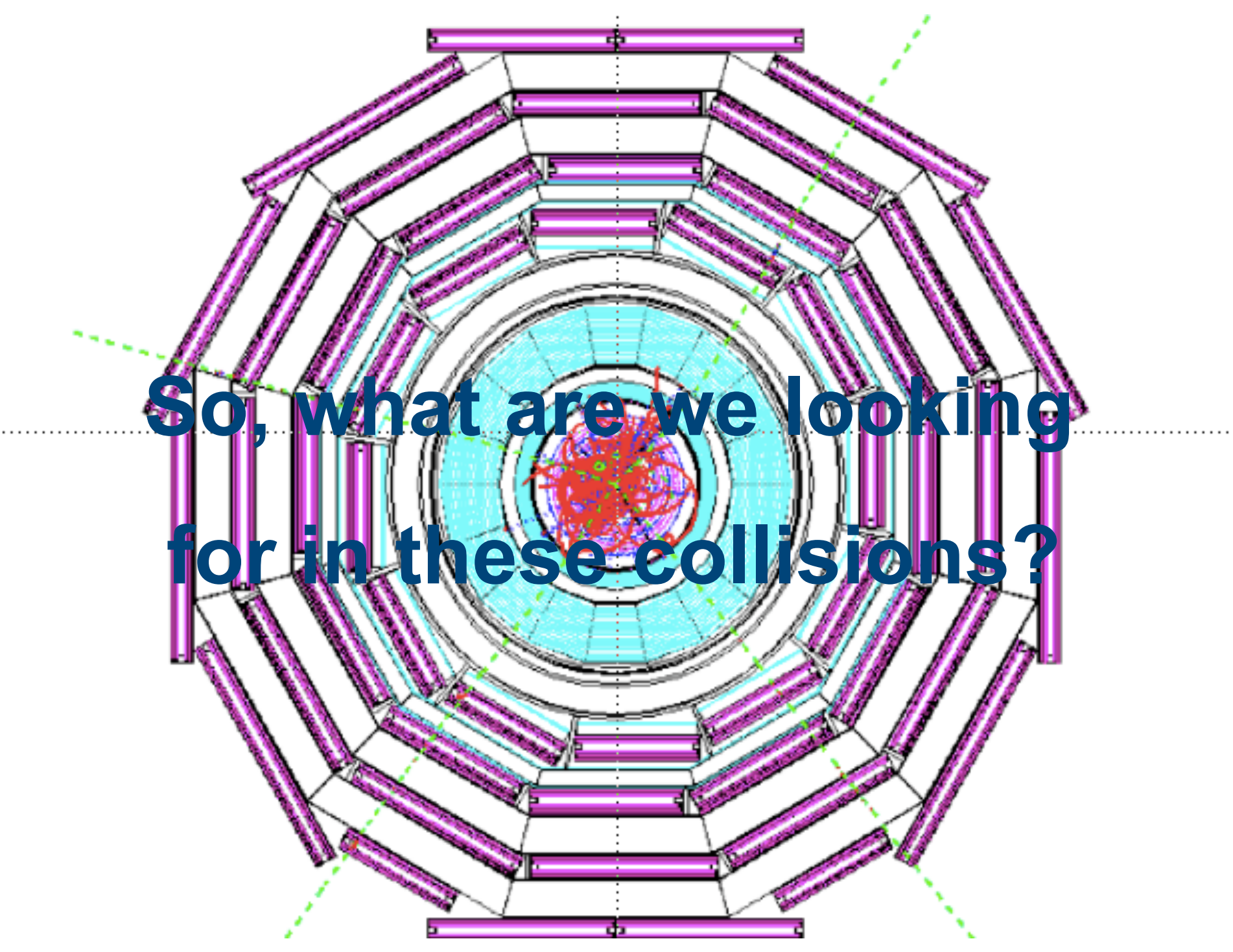
PLAY ▶

<http://www.youtube.com/watch?v=AHT9RTICqjQ>

Large Hadron Collider



ATLAS Detector



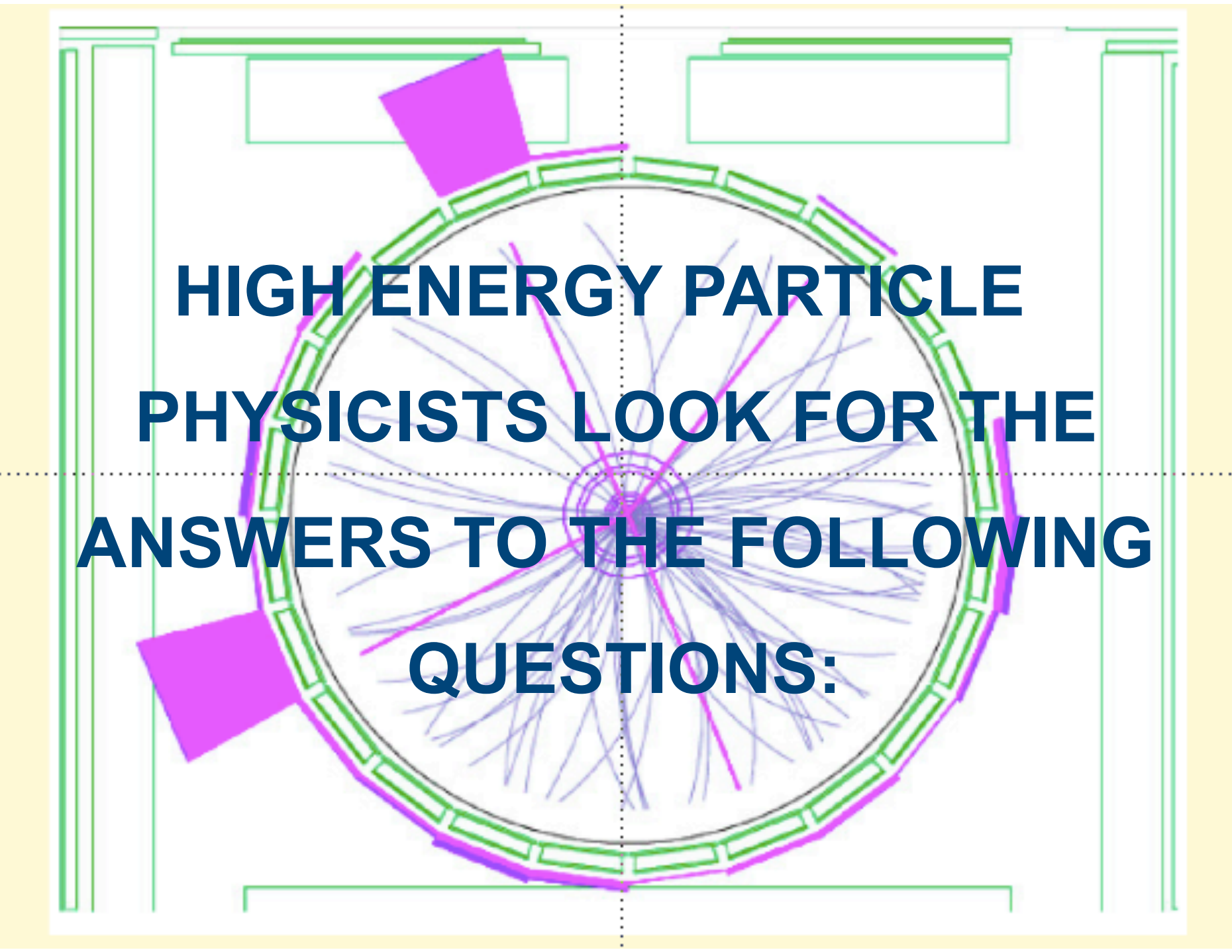
**So, what are we looking
for in these collisions?**



**What do we hope to learn
from all this????**

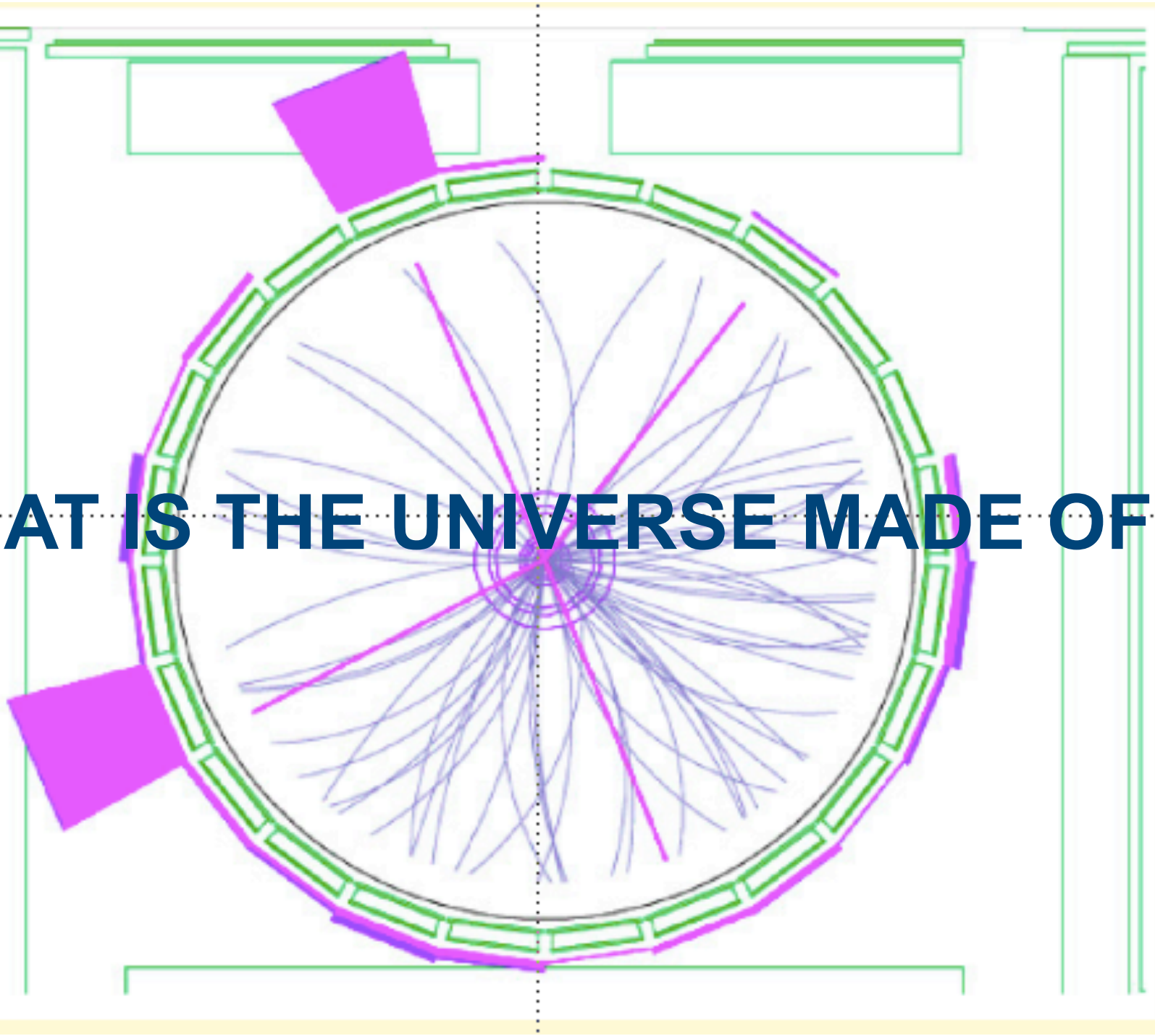
The image features a central circular diagram with a complex internal structure of blue and purple lines radiating from a central point. This diagram is overlaid on a green grid-like structure that includes rectangular boxes at the top and bottom. The entire composition is set against a yellow background. The text is centered over the diagram.

**AND *HOW* WILL IT
ADVANCE SCIENCE
AND TECHNOLOGY????**

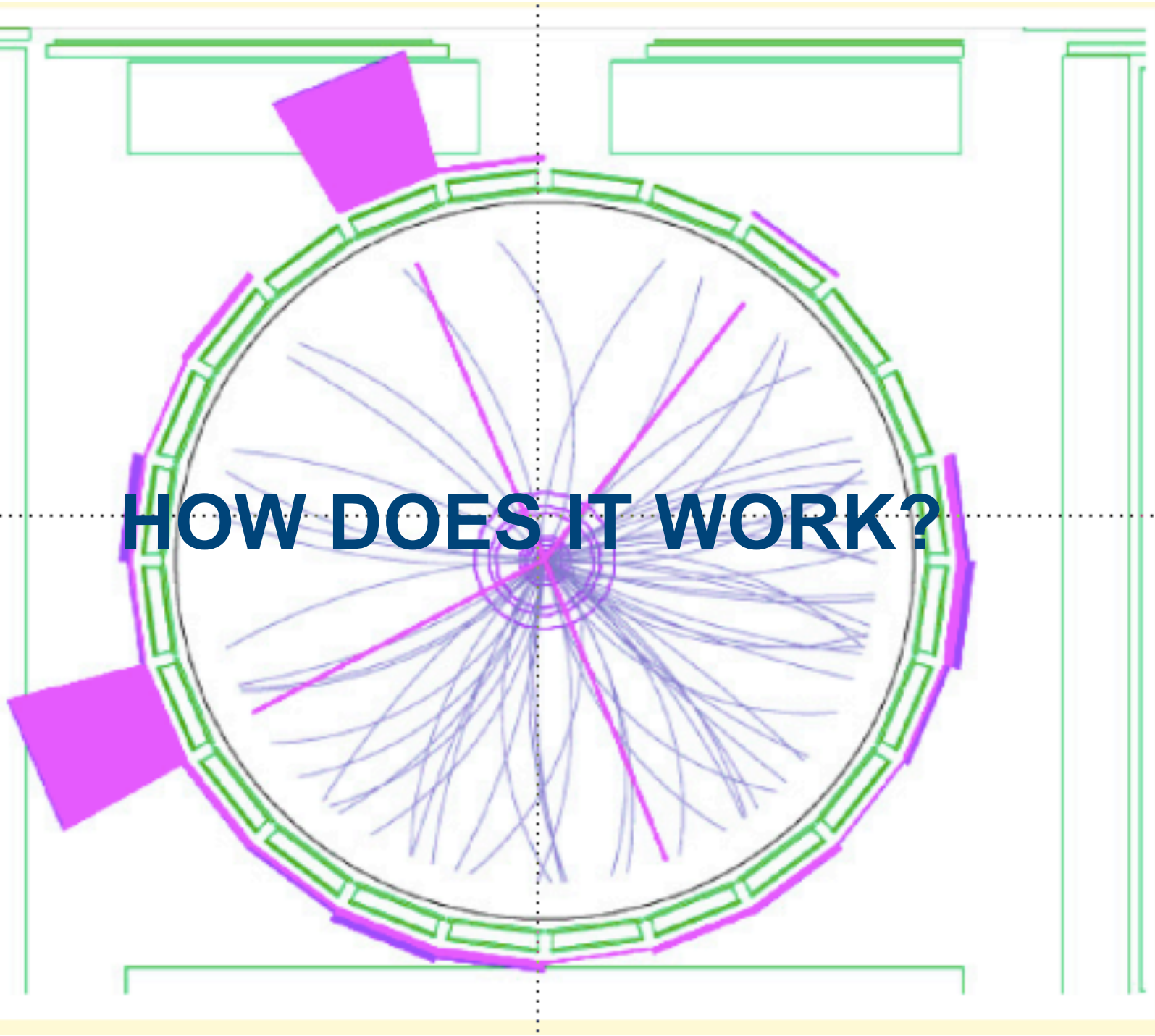


**HIGH ENERGY PARTICLE
PHYSICISTS LOOK FOR THE
ANSWERS TO THE FOLLOWING
QUESTIONS:**

WHAT IS THE UNIVERSE MADE OF?



HOW DOES IT WORK?



A diagram of a circular structure, possibly a cross-section of a dome or a similar architectural element. The structure is composed of a central hub with numerous thin, blue, radiating lines extending to the outer edge. The outer edge is defined by a thick green border, which is further outlined by a thin black line. Two magenta rectangular shapes are attached to the outer edge, one at the top and one at the bottom. The entire diagram is overlaid on a grid of dashed lines, with a vertical dashed line passing through the center and a horizontal dashed line passing through the middle. The background is a light yellow color.

WHY?



ARE THERE *FUNDAMENTAL* BUILDING BLOCKS?

IF SO, WHAT ARE THEY?

**ARE QUARKS MADE UP OF EVEN *SMALLER*
PARTICLES?**

ACCORDING TO THE STANDARD MODEL,
ALL "NORMAL MATTER" IS MADE UP OF
QUARKS AND "LEPTONS"

ARE THERE *FUNDAMENTAL BUILDING BLOCKS*?

IF SO, WHAT ARE THEY?

Elementary Particles

Quarks	u up	c charm	t top	Force Carriers	γ photon
	d down	s strange	b bottom		g gluon
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Force Carriers	Z Z boson
	e electron	μ muon	τ tau		W W boson

I II III
Three Families of Matter

The STANDARD MODEL does *not* explain why some particles are more massive than others, and why some particles are even massless!

ARE THERE *FUNDAMENTAL* BUILDING BLOCKS?

IF SO, WHAT ARE THEY?

Elementary Particles

Quarks	u up	c charm	t top	Force Carriers	γ photon
	d down	s strange	b bottom		g gluon
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Force Carriers	Z Z boson
	e electron	μ muon	τ tau		W W boson

I II III
Three Families of Matter

IT DOES NOT OFFER AN EXPLANATION AS TO EVEN WHY
PARTICLES HAVE MASS AT ALL!! *WHAT EXACTLY IS MASS?*



ARE THERE *FUNDAMENTAL* BUILDING BLOCKS?

IF SO, WHAT ARE THEY?

HOW DO THEY INTERACT?

One theory that physicists are pursuing is that particles acquire mass from interacting with force-carrying particles known as **HIGGS BOSONS**, (bosons are force-carrying particles) named after the British physicist Peter Higgs in the 1960's.

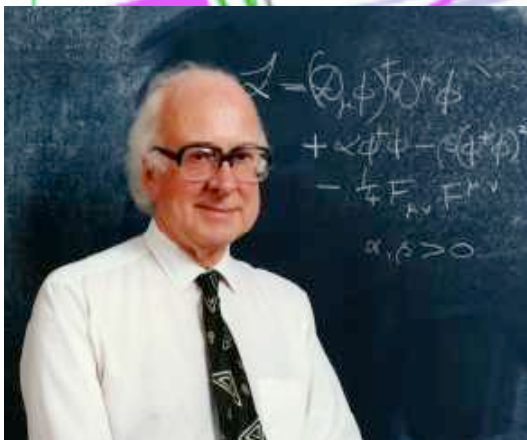


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One theory that physicists are pursuing is that particles acquire mass from interacting with force-carrying particles known as **HIGGS BOSONS**, (bosons are force-carrying particles) named after the British physicist Peter Higgs in the 1960's.



A simplified diagram of a particle detector, likely a circular collider. It features a central circular track with a dashed line indicating the path. The track is surrounded by a green rectangular structure, possibly representing the detector's outer shell. Two purple rectangular shapes are positioned at the top and bottom of the track, representing detectors. Numerous blue lines radiate from the center, representing particle tracks. The background is a light yellow gradient.

ARE THERE *FUNDAMENTAL* BUILDING BLOCKS?

IF SO, WHAT ARE THEY?

HOW DO THEY INTERACT?

One theory that physicists are pursuing is that particles acquire mass from interacting with force-carrying particles known as **HIGGS BOSONS**, (bosons are force-carrying particles) named after the British physicist Peter Higgs in the 1960's.

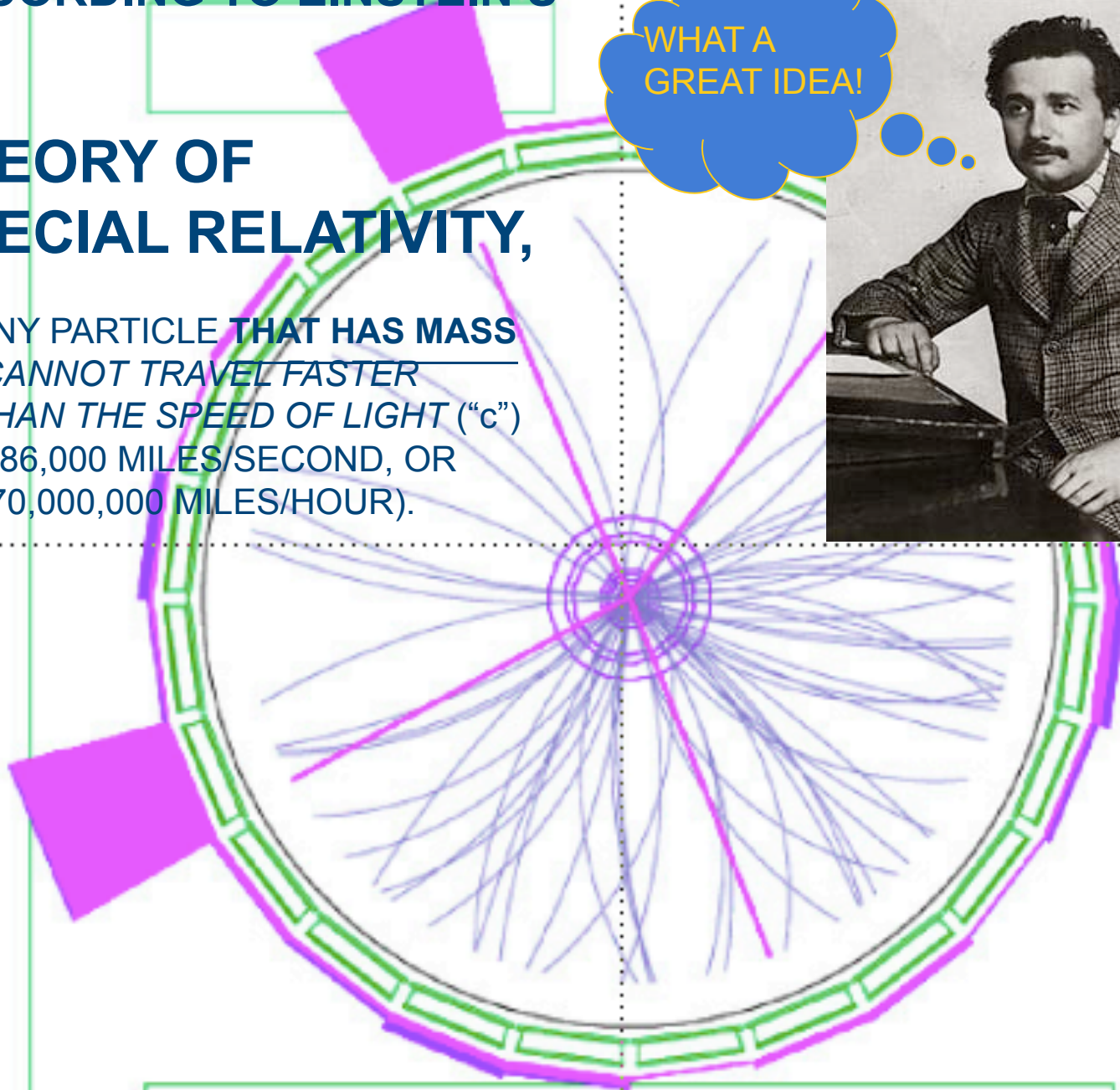
**HERE'S A VERY SIMPLIFIED EXAMPLE
OF HOW THE THEORY WORKS:**

ACCORDING TO EINSTEIN'S

THEORY OF SPECIAL RELATIVITY,

ANY PARTICLE THAT HAS MASS
CANNOT TRAVEL FASTER
THAN THE SPEED OF LIGHT ("c")
(186,000 MILES/SECOND, OR
670,000,000 MILES/HOUR).

WHAT A
GREAT IDEA!



ACCORDING TO EINSTEIN'S

THEORY OF SPECIAL RELATIVITY,

ANY PARTICLE THAT HAS MASS
CANNOT TRAVEL FASTER
THAN THE SPEED OF LIGHT ("c")
(186,000 MILES/SECOND, OR
670,000,000 MILES/HOUR).

SPEED
LIMIT
"c"

..and my teachers
said I would never
amount to anything!



ACCORDING TO EINSTEIN'S

THEORY OF SPECIAL RELATIVITY,

ANY PARTICLE THAT HAS MASS
CANNOT TRAVEL FASTER
THAN THE SPEED OF LIGHT ("c")
(186,000 MILES/SECOND, OR
670,000,000 MILES/HOUR).

EVERYTHING
MUST FOLLOW
THE SPEED LIMIT!



SPEED
LIMIT
"c"

NOT GALAXIES.

ACCORDING TO EINSTEIN'S

THEORY OF SPECIAL RELATIVITY,

ANY PARTICLE THAT HAS MASS
CANNOT TRAVEL FASTER
THAN THE SPEED OF LIGHT ("c")
(186,000 MILES/SECOND, OR
670,000,000 MILES/HOUR).

YOU WILL
NEVER MAKE
THEM GO FAST
ENOUGH!



SPEED
LIMIT
"c"

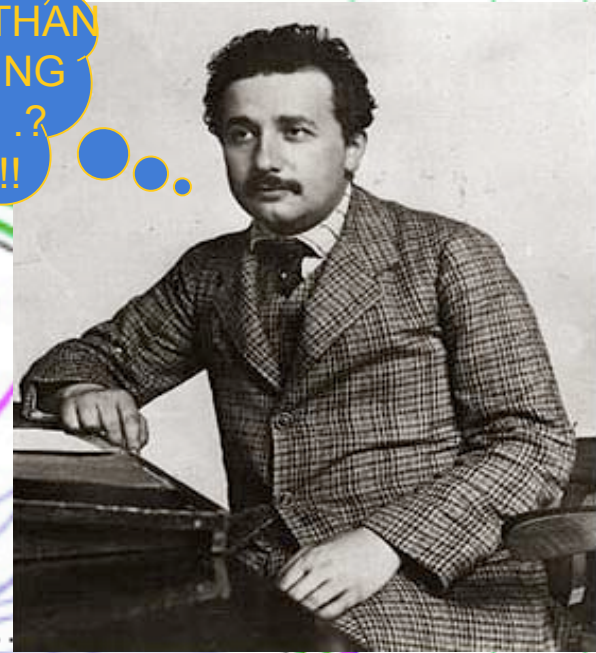
NOT ROCKETS.

ACCORDING TO EINSTEIN'S

THEORY OF SPECIAL RELATIVITY,

ANY PARTICLE THAT HAS MASS
CANNOT TRAVEL FASTER
THAN THE SPEED OF LIGHT ("c")
(186,000 MILES/SECOND, OR
670,000,000 MILES/HOUR).

FASTER THAN
A SPEEDING
BULLET...?
HA!!!!!!!



SPEED
LIMIT
"c"

NOT SUPERMAN.



ACCORDING TO EINSTEIN'S

THEORY OF SPECIAL RELATIVITY,

ANY PARTICLE THAT HAS MASS
CANNOT TRAVEL FASTER
THAN THE SPEED OF LIGHT ("c")
(186,000 MILES/SECOND, OR
670,000,000 MILES/HOUR).

BUT,
They can come
CLOSE if they
Have enough
ENERGY!



SPEED
LIMIT
"c"

NOT EVEN AN
ELECTRON OR PROTON!

ACCORDING TO EINSTEIN'S

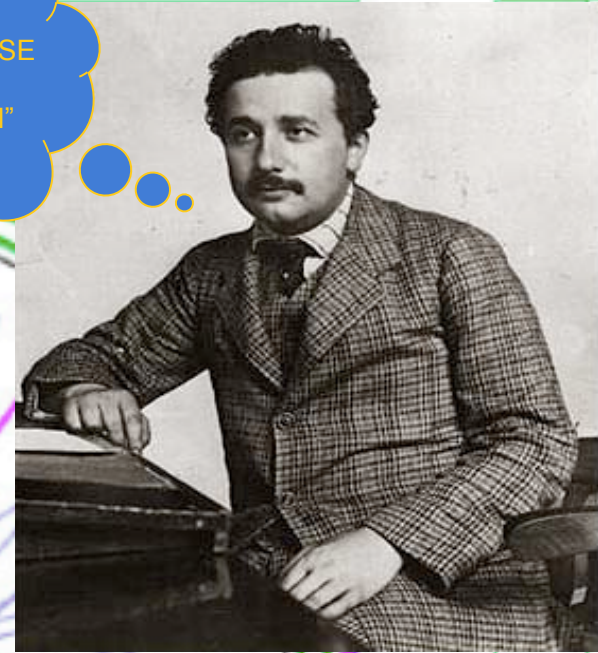
THEORY OF SPECIAL RELATIVITY,

ANY PARTICLE THAT HAS MASS
CANNOT TRAVEL FASTER
THAN THE SPEED OF LIGHT ("c")
(186,000 MILES/SECOND, OR
670,000,000 MILES/HOUR).

SPEED
LIMIT
"c"

PARTICLES THAT ARE
MASSLESS
(PHOTONS OF LIGHT, RADIO,
UV, X-RAY, GAMMA, ETC.) CAN
TRAVEL AT THE SPEED OF
LIGHT
(IN A VACUUM).

THAT'S BECAUSE
THEY ARE ALL
FORMS OF "EM"
RADIATION!



ACCORDING TO EINSTEIN'S

THEORY OF SPECIAL RELATIVITY,

ANY PARTICLE THAT HAS MASS
CANNOT TRAVEL FASTER
THAN THE SPEED OF LIGHT ("c")
(186,000 MILES/SECOND, OR
670,000,000 MILES/HOUR).

SPEED
LIMIT
"c"

So, Higgs theorized a field of particles permeating all of space (a "**HIGGS FIELD**"), and that *ALL particles actually travel at the speed of light*, but some interact with these Higgs Particles, or (BOSONS), giving them MASS, the amount of mass they have depending on how much they interact.

Massless particles do NOT interact at all with the Higgs Particles, which explains why they can travel at the speed of light.

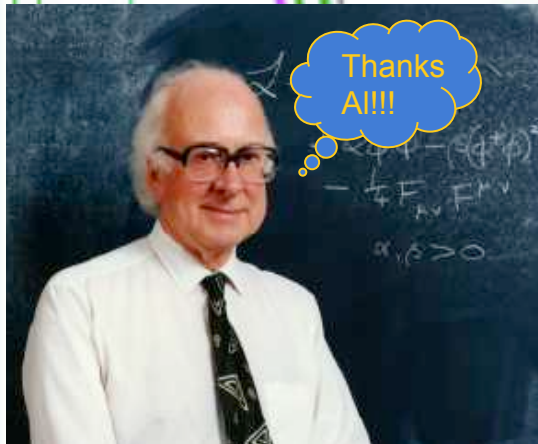


ACCORDING TO EINSTEIN'S

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ANY PARTICLE THAT HAS MASS
CANNOT TRAVEL FASTER
THAN THE SPEED OF LIGHT ("c")
(186,000 MILES/SECOND, OR
670,000,000 MILES/HOUR).

SMART MAN,
THAT HIGGS!



Thanks
A!!!!

So, Higgs theorized a field of particles permeating all of space (a "**HIGGS FIELD**"), and that *ALL particles actually travel at the speed of light*, but some interact with these Higgs Particles, or (BOSONS), giving them MASS, the amount of mass they have depending on how much they interact.

Massless particles do NOT interact at all with the Higgs Particles, which explains why they can travel at the speed of light.

HERE'S AN EXAMPLE:

LET'S SAY THAT THIS
IS A HIGGS BOSON



NOW, LET'S MAKE A HIGGS FIELD:



THIS IS A SAMPLE OF A HIGGS FIELD:

IMAGINE THESE GUYS FILLING ALL OF SPACE!!!

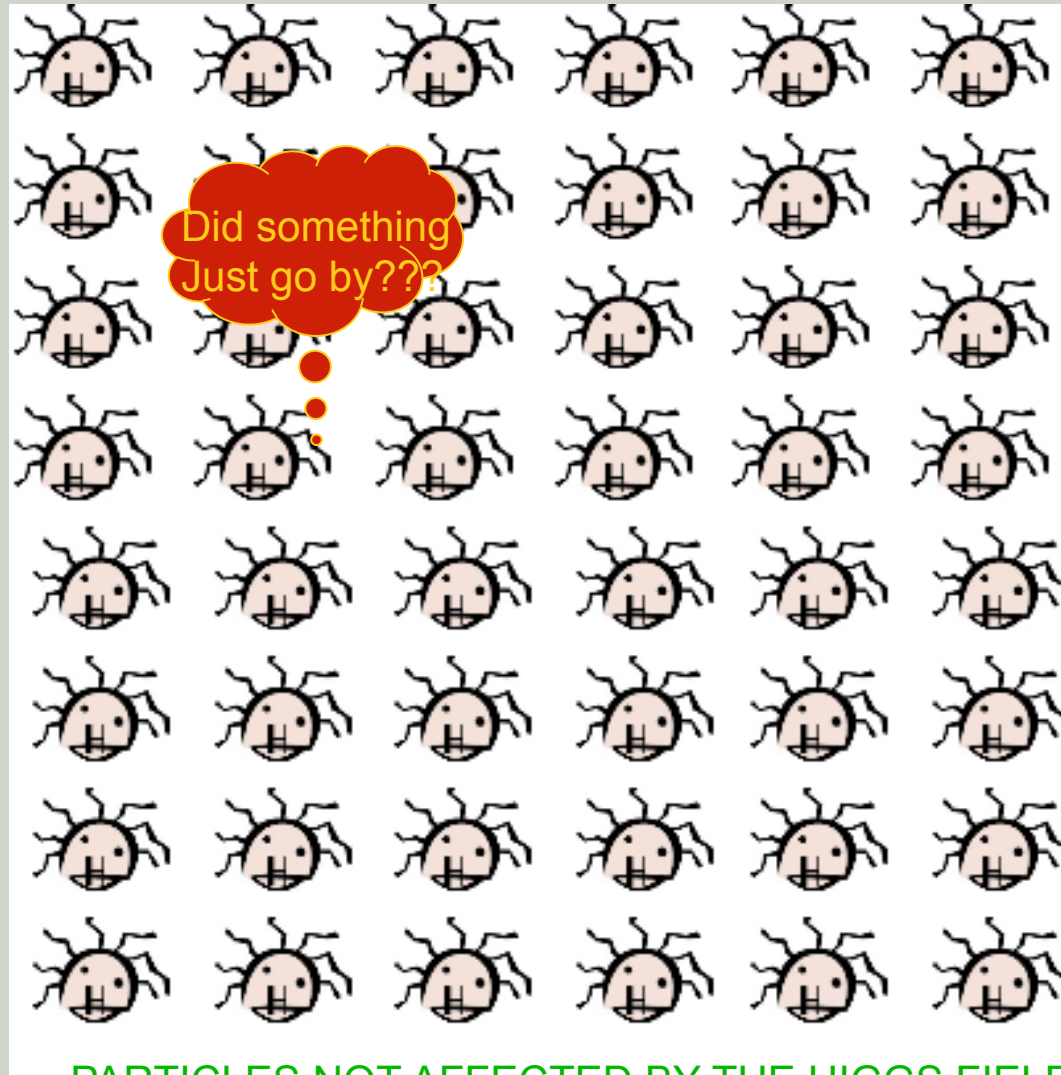
THERE GOES A PHOTON:



THERE GOES A PHOTON:



THERE GOES A PHOTON . . .



Did something
Just go by???

HA!
Didn't even
touch me!!

I MUST NOT
HAVE ANY
MASS!!

PARTICLES NOT AFFECTED BY THE HIGGS FIELD
DO NOT HAVE MASS!!!

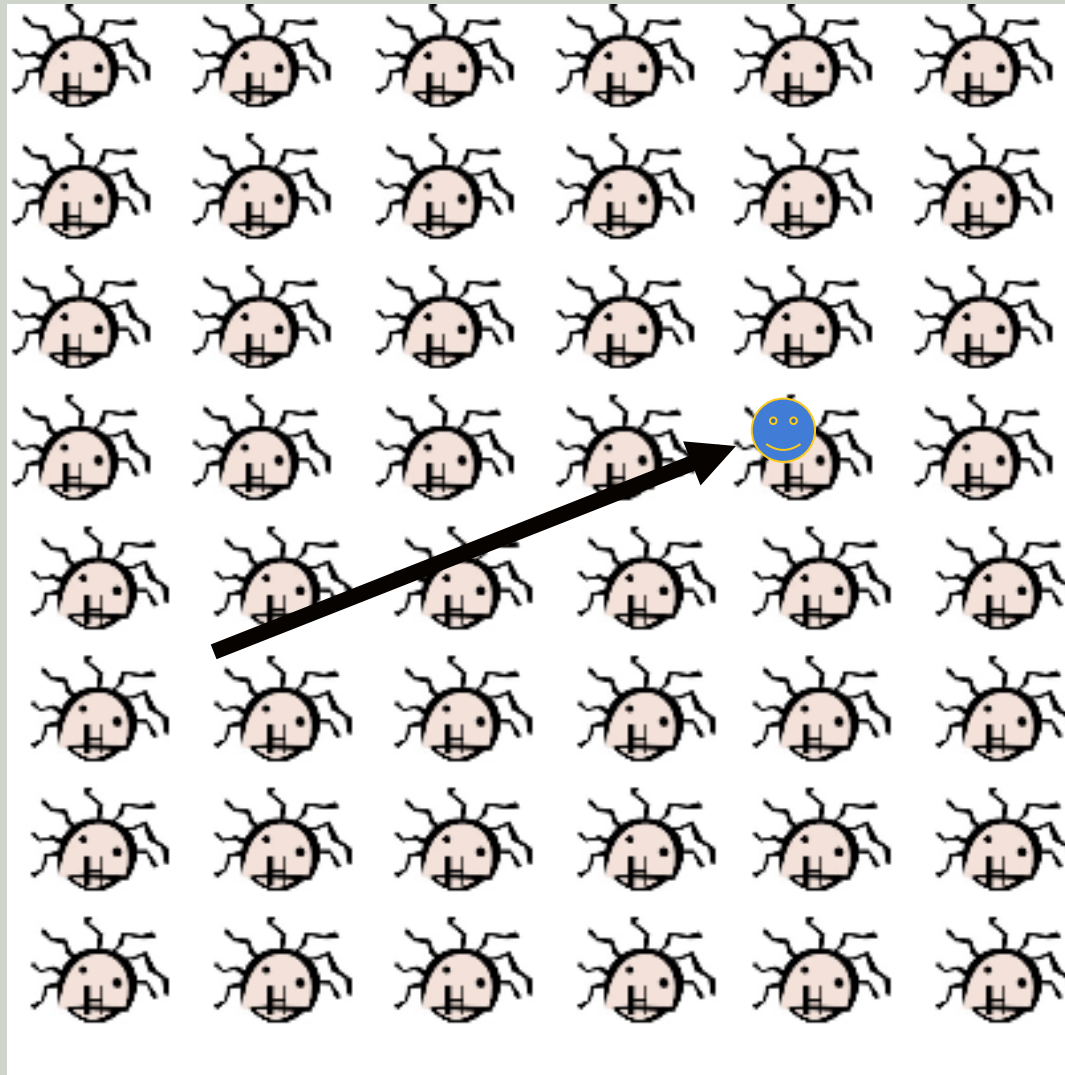
HERE COMES AN ELECTRON: . . .



HERE COMES AN ELECTRON: . . .



HERE COMES AN ELECTRON: . . .



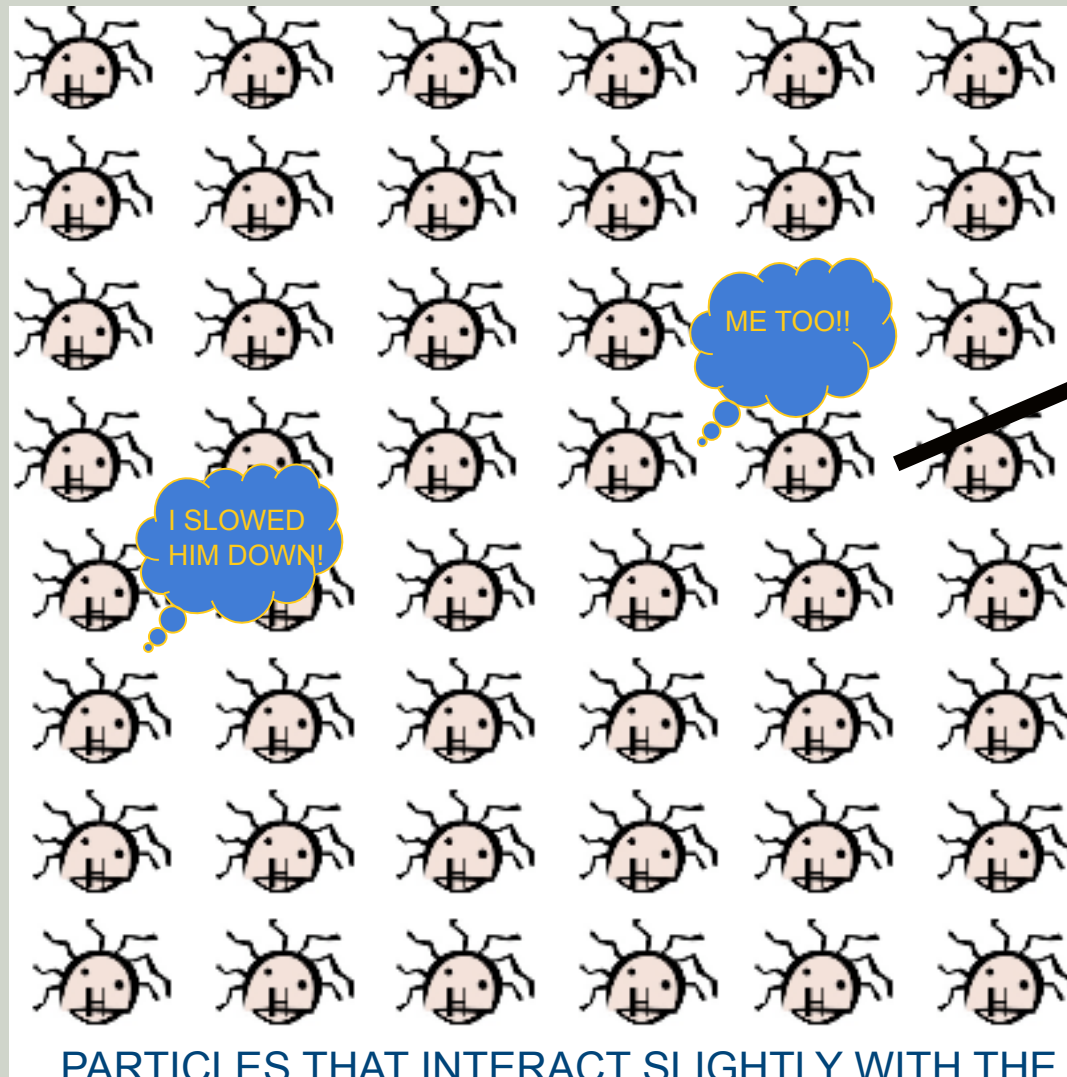
HERE COMES AN ELECTRON: . . .



THAT WAS
PRETTY EASY!



THERE GOES AN ELECTRON: . . .



PARTICLES THAT INTERACT SLIGHTLY WITH THE HIGGS FIELD HAVE A SMALL MASS.
(This is why they travel slower than light.)

HERE COMES A TOP QUARK . . .



HERE I COME!



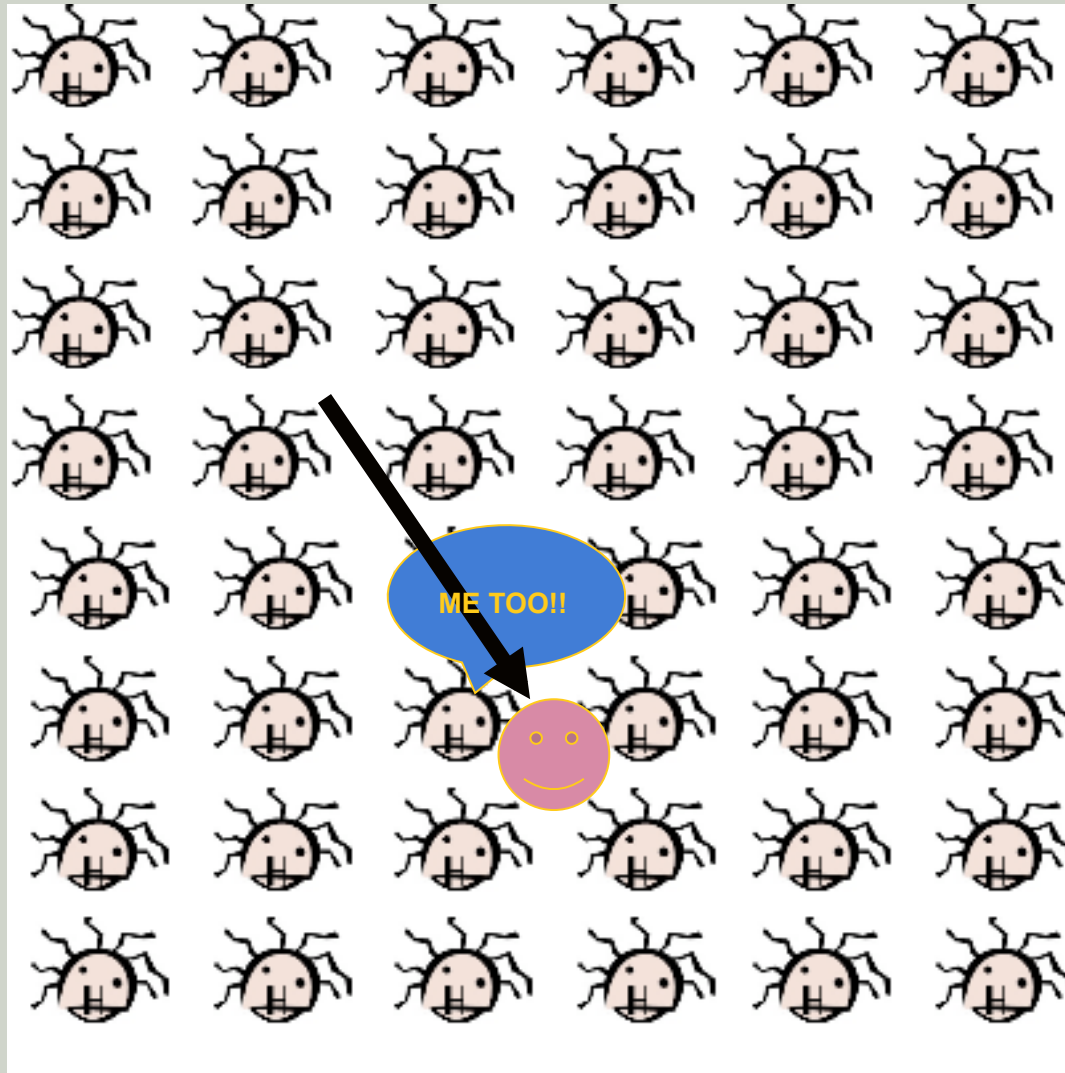
HERE COMES A TOP QUARK . . .



HERE COMES A TOP QUARK . . .

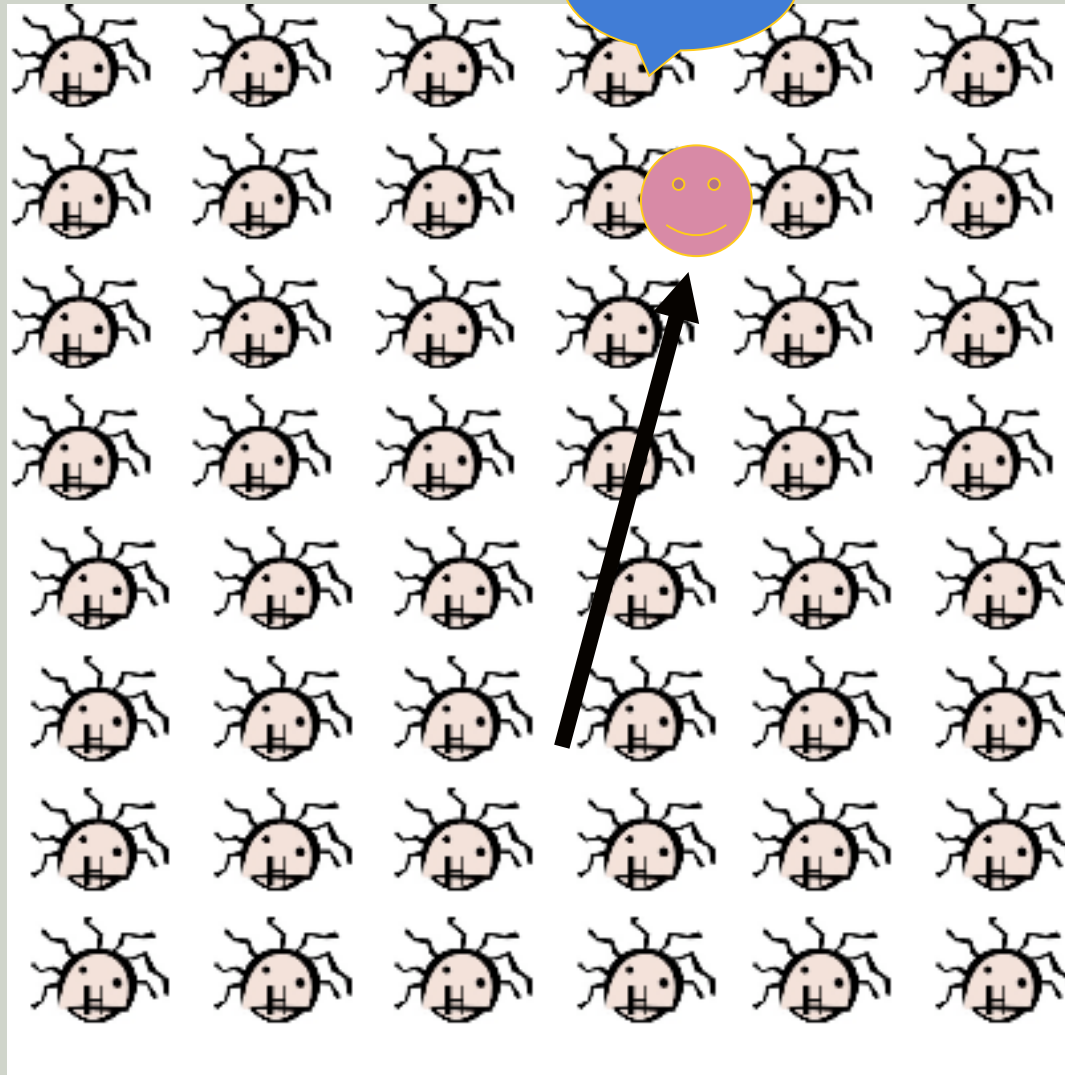


HERE COMES A TOP QUARK . . .

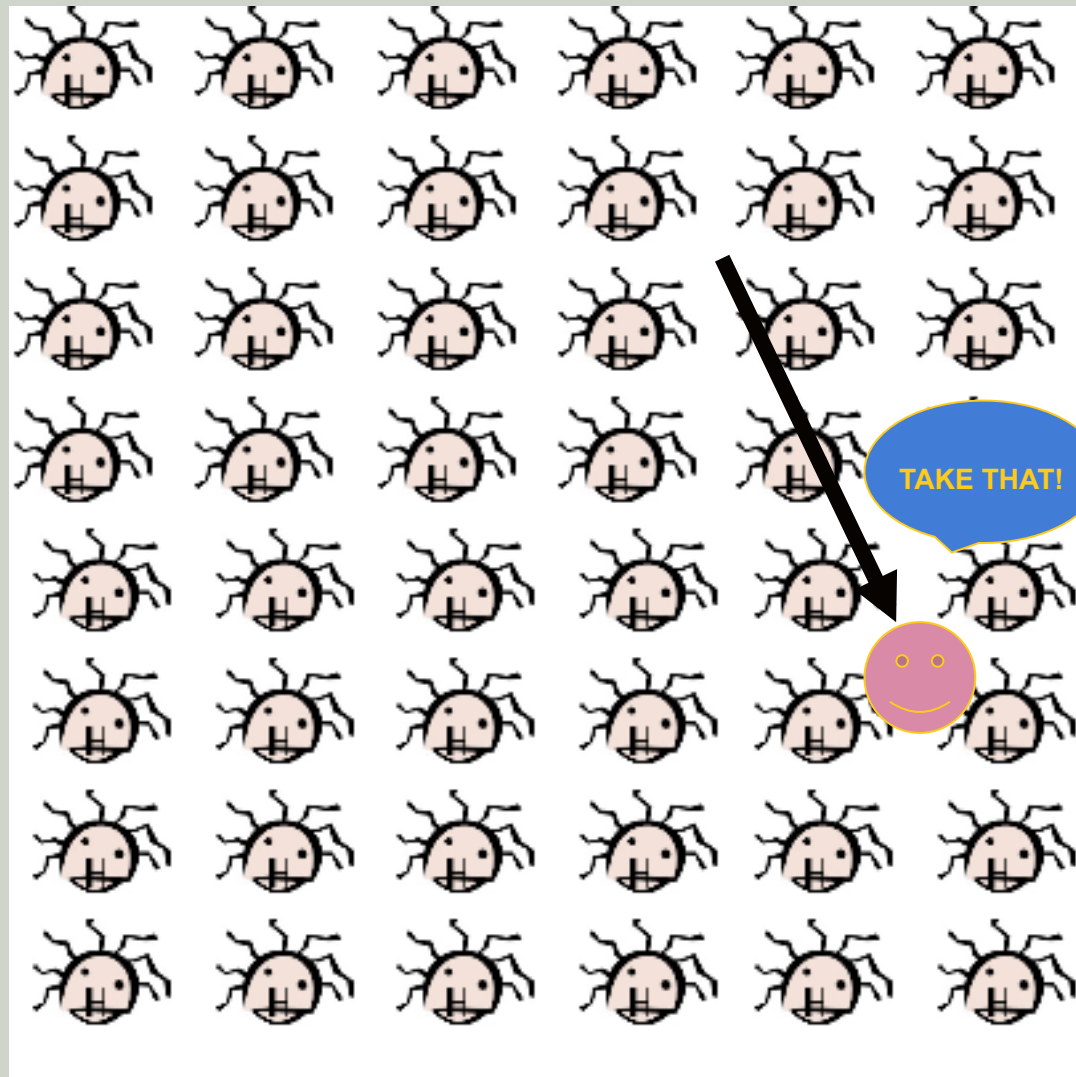


HERE COMES A TOP QUARK . . .

I GOT HIM!



HERE COMES A TOP QUARK . . .



HERE COMES A TOP QUARK . . .

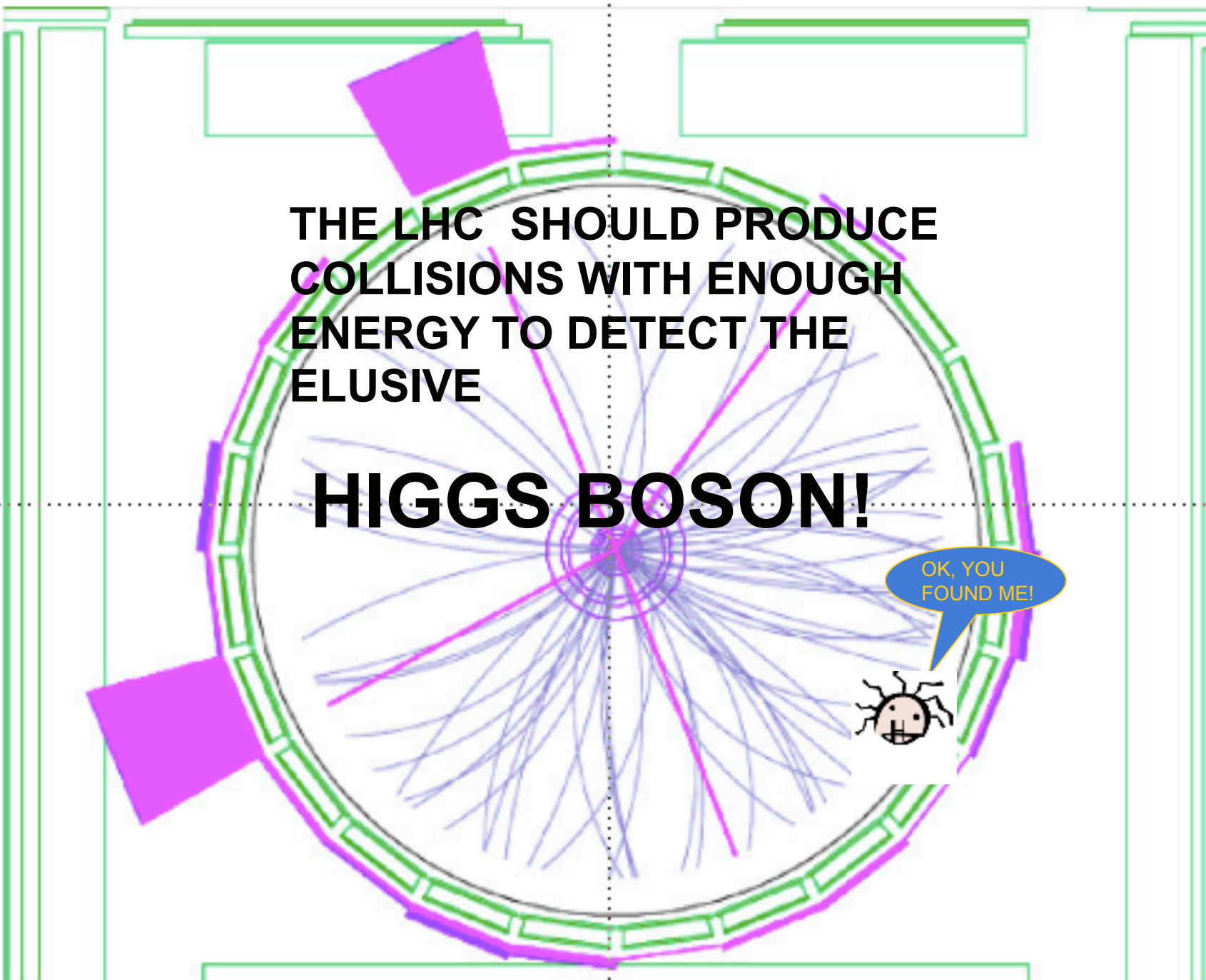


THAT' NOT SO EASY!




I HAVE MORE MASS THAN THE ELECTRON!

PARTICLES THAT INTERACT MORE WITH THE HIGGS FIELD HAVE A *LARGER* MASS.
(This is why they travel even slower than light.)

The diagram shows a top-down view of a particle detector. A central circular region represents the collision point, with numerous blue lines radiating outwards, representing particle tracks. This central region is enclosed by a ring of green rectangular segments, likely representing the calorimeter. Outside this ring are several purple trapezoidal shapes, representing the muon spectrometers. The entire detector is contained within a larger rectangular frame with a yellow background.

**THE LHC SHOULD PRODUCE
COLLISIONS WITH ENOUGH
ENERGY TO DETECT THE
ELUSIVE**

HIGGS BOSON!

A small, black, cartoonish bug character with a smiling face and six legs. It is positioned in the lower right quadrant of the detector diagram. A blue speech bubble with a yellow border points to the bug, containing the text 'OK, YOU FOUND ME!'.

OK, YOU
FOUND ME!

THIS WOULD EXPLAIN
HOW AND WHY
PARTICLES HAVE MASS!



PHOTONS

(light, radio, infrared, etc.)
(no mass)

Travel at "c" in a vacuum.



PROTONS

(positively charged HADRONS)

Travel \ll "c" in a vacuum.



ELECTRONS

(negatively charged particles
known as "LEPTONS")

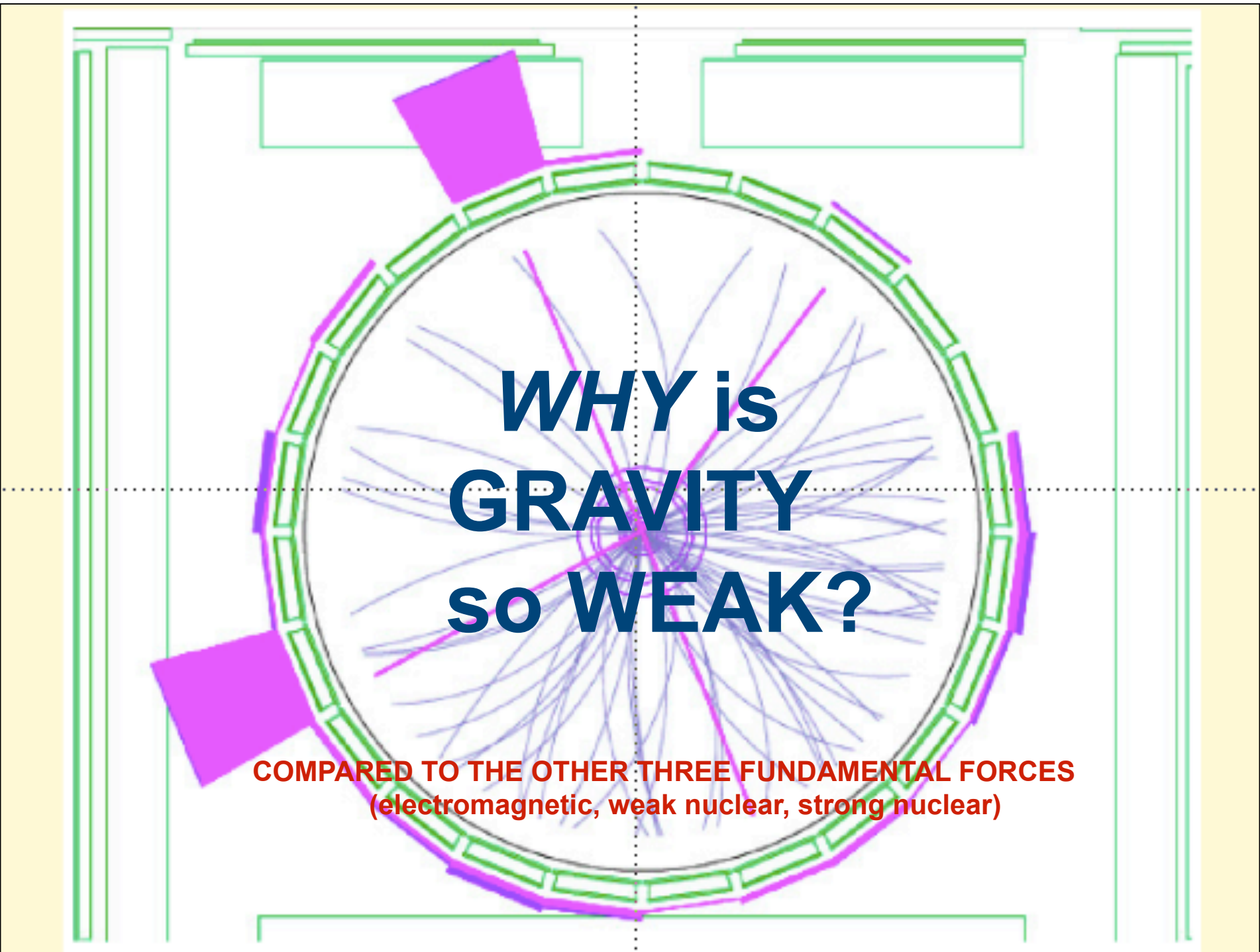
Travel $<$ "c" in a vacuum.

A diagram of a circular structure, possibly a cross-section of a planet or a ringed planet like Saturn. The center is a point from which numerous thin blue lines radiate outwards, representing gravitational pull or field lines. The lines are denser and longer closer to the center. The circular structure is outlined by a thick green border, which is further defined by a purple border. Two purple rectangular shapes are attached to the outer edge of the circle, one at the top and one at the bottom. The entire diagram is set against a light yellow background with a white grid. A vertical dotted line and a horizontal dotted line intersect at the center of the circle.

IT MAY ALSO LEAD TO TELL US SOMETHING ABOUT

GRAVITY

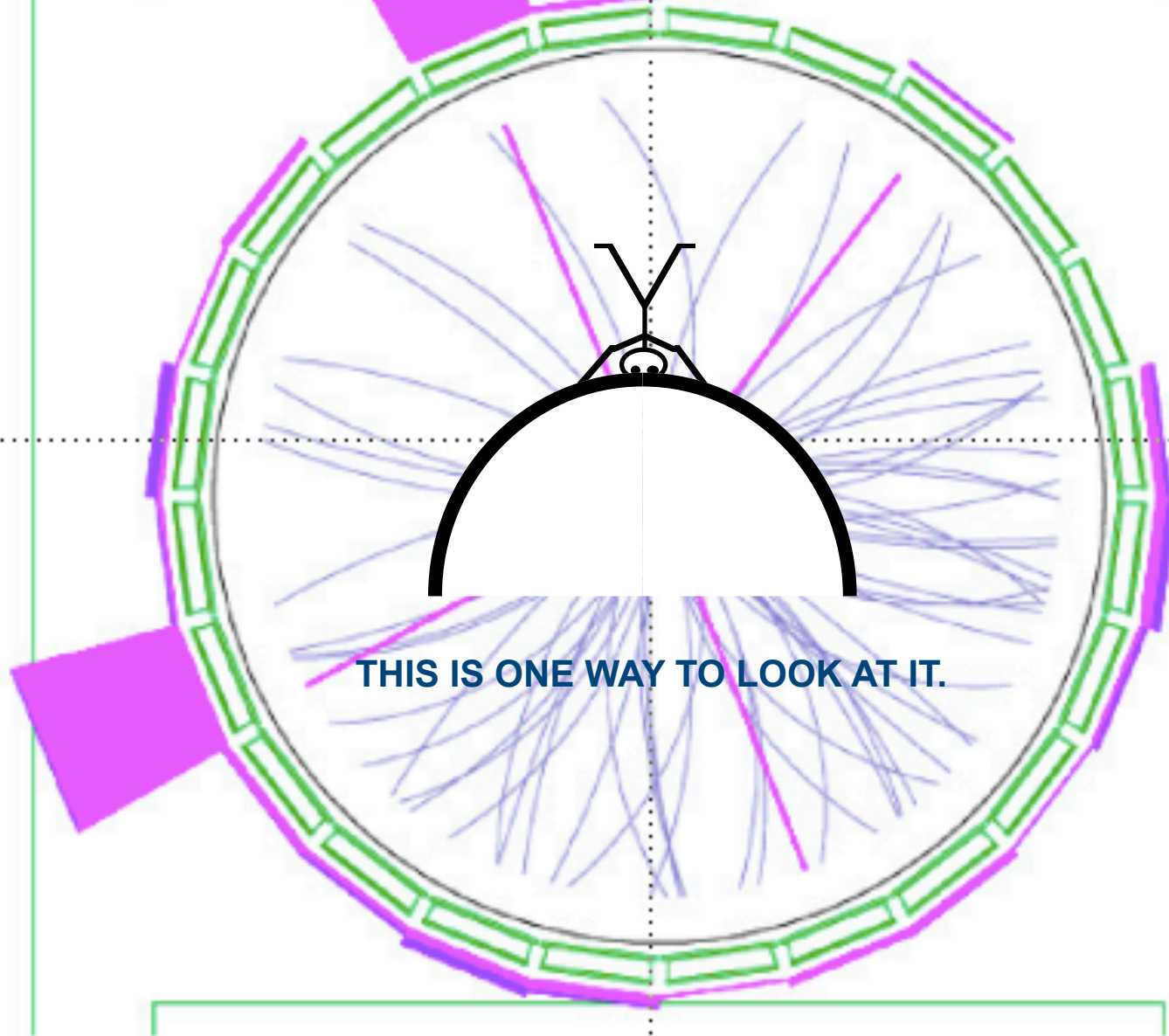
The *WEAKEST* FORCE in the UNIVERSE!!!



WHY is GRAVITY so WEAK?

**COMPARED TO THE OTHER THREE FUNDAMENTAL FORCES
(electromagnetic, weak nuclear, strong nuclear)**

DOESN'T GRAVITY KEEP US ON EARTH??



THIS IS ONE WAY TO LOOK AT IT.

DOESN'T GRAVITY KEEP US ON EARTH??



I'm
ATLAS!

THIS IS ANOTHER WAY.

MAYBE GRAVITY IS STRONGER THAN WE THINK!

NOT REALLY!!!

(except in black holes, or at quantum distances)

DOESN'T GRAVITY KEEP US ON EARTH??



I'm
ATLAS!

THIS IS ANOTHER WAY.

MAYBE GRAVITY IS STRONGER THAN WE THINK!

NOT REALLY!!!

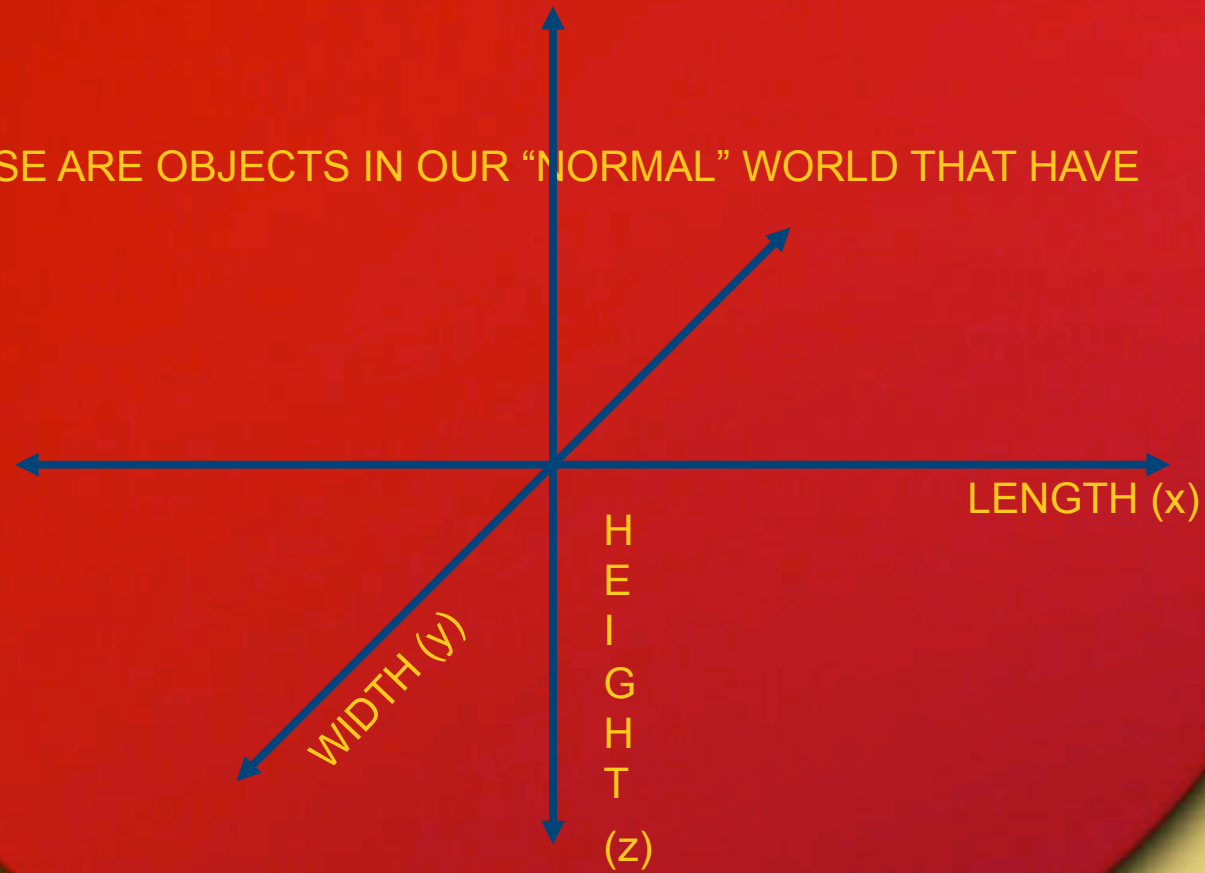
THIS LEADS US TO

THE SEARCH FOR EXTRA DIMENSIONS AT THE LHC

(extra *what?*)

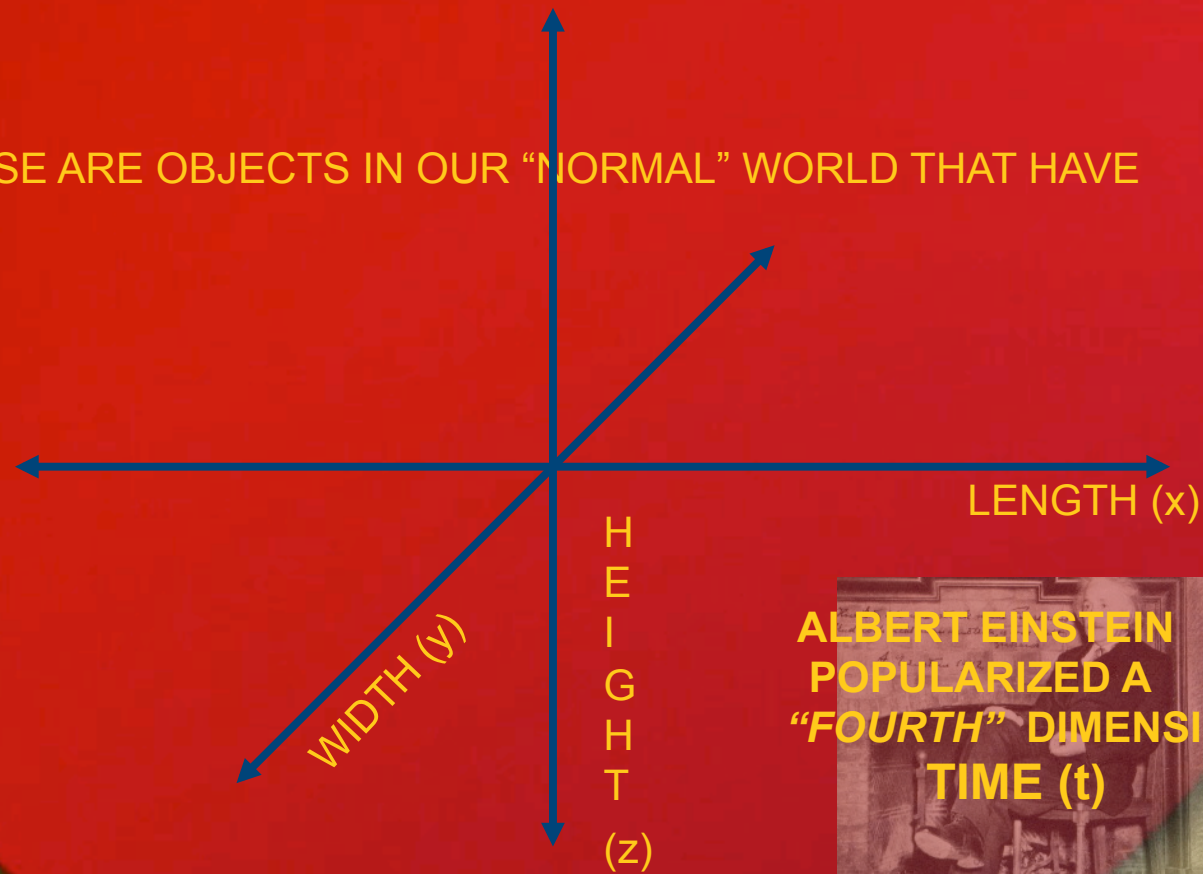
WE ARE ALL FAMILIAR WITH 3-DIMENSIONAL OBJECTS.

THESE ARE OBJECTS IN OUR "NORMAL" WORLD THAT HAVE

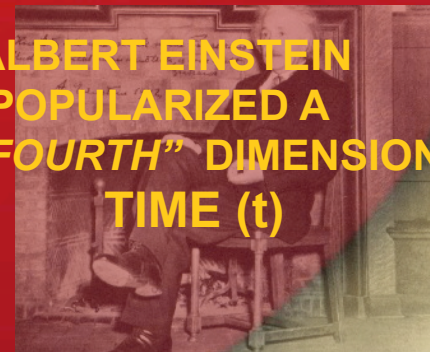


WE ARE ALL FAMILIAR WITH 3-DIMENSIONAL OBJECTS.

THESE ARE OBJECTS IN OUR "NORMAL" WORLD THAT HAVE



ALBERT EINSTEIN
POPULARIZED A
"FOURTH" DIMENSION:
TIME (t)

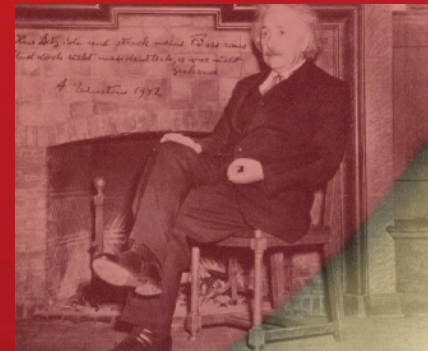
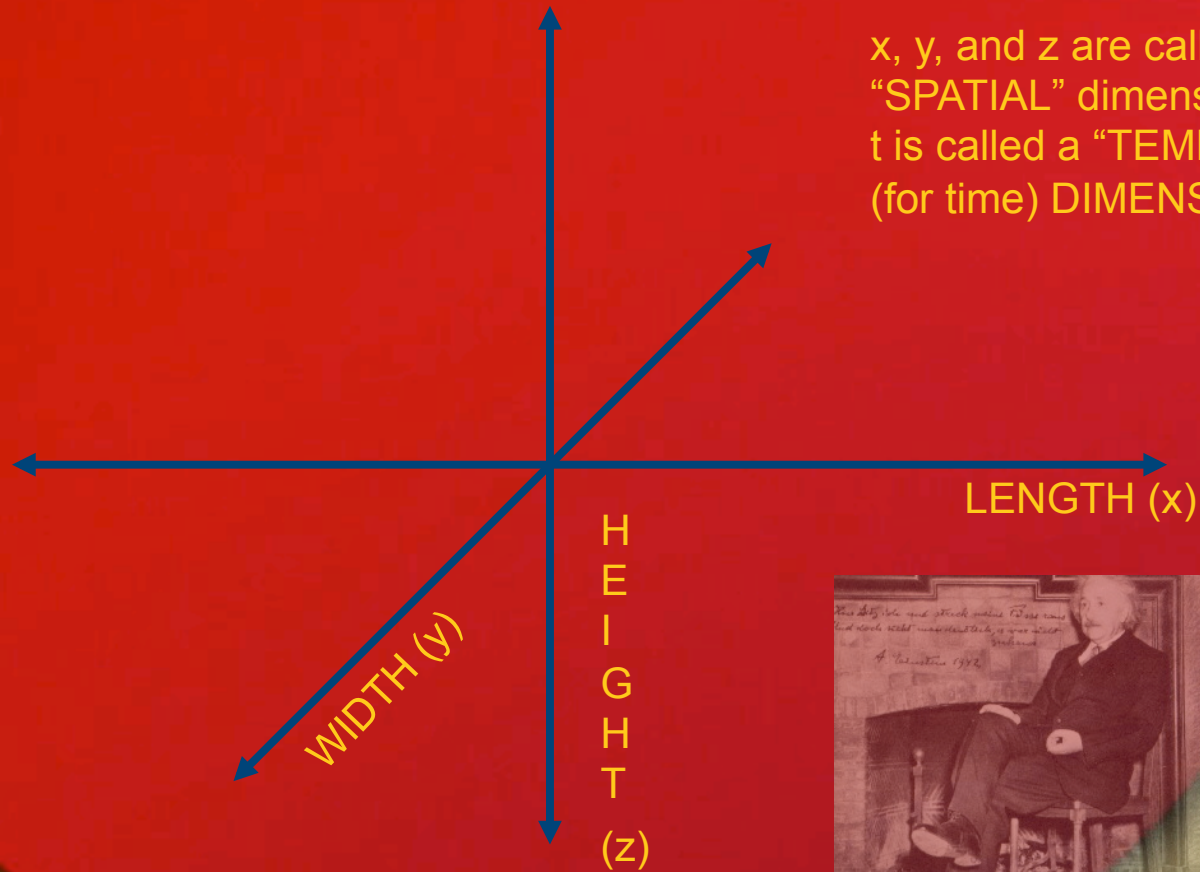


So, we actually live in a FOUR-DIMENSIONAL WORLD of

SPACETIME

(x, y, z, t)

x, y, and z are called
"SPATIAL" dimensions,
t is called a "TEMPORAL"
(for time) DIMENSION.



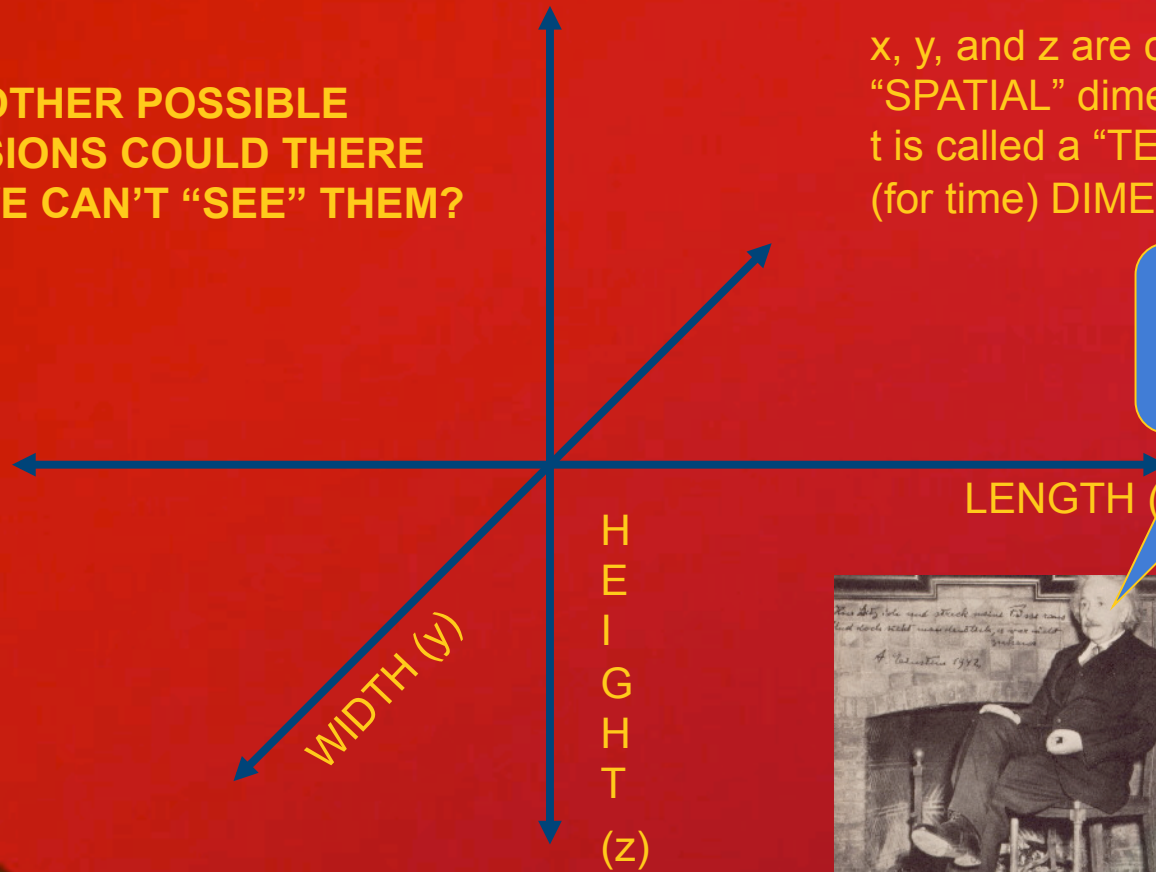
So, we actually live in a FOUR-DIMENSIONAL WORLD of

SPACETIME

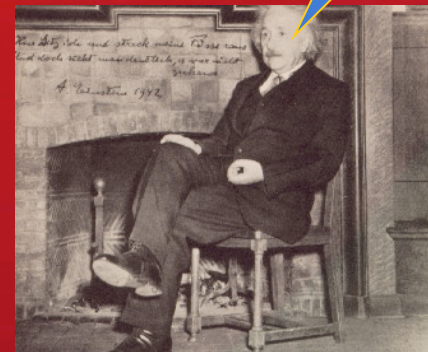
(x, y, z, t)

x, y, and z are called
“SPATIAL” dimensions,
t is called a “TEMPORAL”
(for time) DIMENSION.

WHAT OTHER POSSIBLE
DIMENSIONS COULD THERE
BE IF WE CAN'T “SEE” THEM?



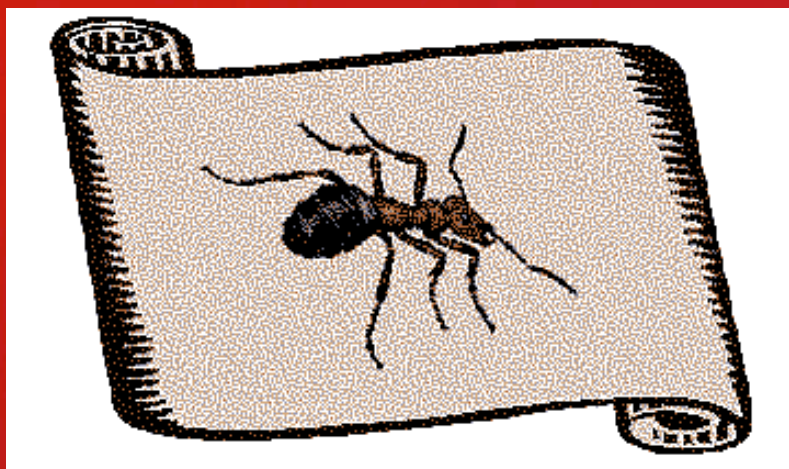
“Imagination is
more important
than knowledge!”



SCIENTISTS BELIEVE THAT THERE MAY BE MORE DIMENSIONS

THAT WE CANNOT SEE!!!

IMAGINE A “FLAT” ANT CRAWLING ALONG A ROLL OF PAPER



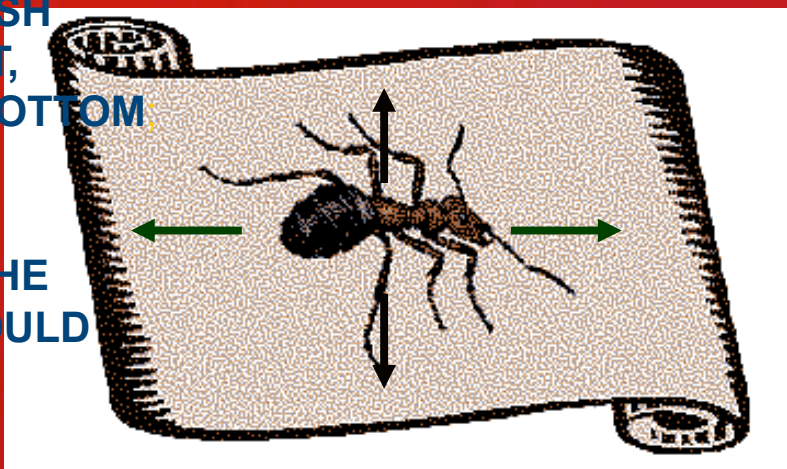
SCIENTISTS BELIEVE THAT THERE MAY BE MORE DIMENSIONS

THAT WE CANNOT SEE!!!

IMAGINE A “FLAT” ANT CRAWLING ALONG A ROLL OF PAPER

IT CAN DISTINGUISH
LEFT FROM RIGHT,
AND TOP FROM BOTTOM

BUT IT IS
RESTRICTED TO
THE PLANE OF THE
PAPER, SO IT WOULD
NOT BE ABLE TO
DISTINGUISH

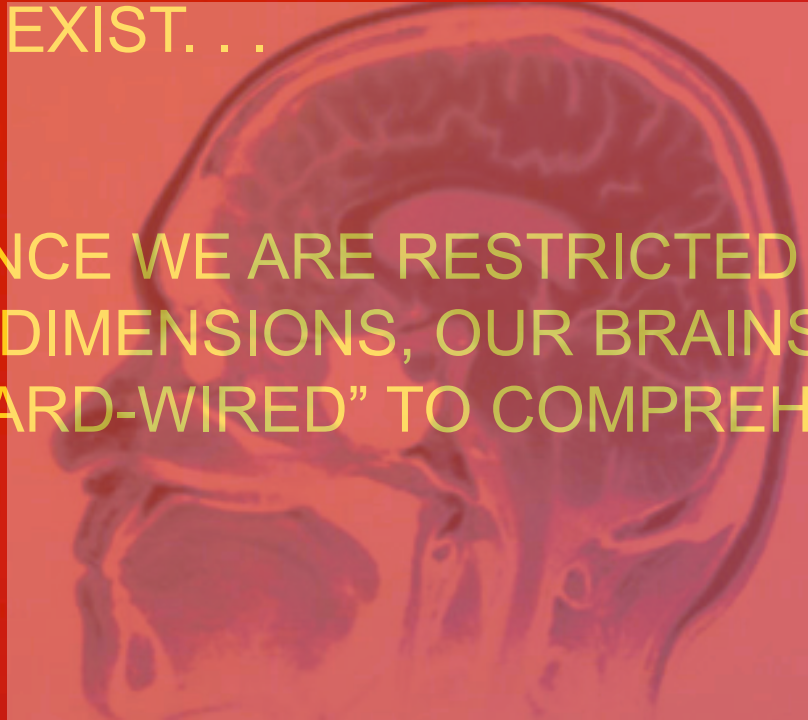


“UP”
FROM
“DOWN”

*IT WOULD BE
IMPOSSIBLE
FOR THE
ANT TO
HAVE ANY SENSE
OF IT AT ALL!*

JUST LIKE THAT ANT, IT IS POSSIBLE THAT
MORE THAN THREE SPATIAL DIMENSIONS
COULD EXIST. . .

BUT, SINCE WE ARE RESTRICTED TO
THREE DIMENSIONS, OUR BRAINS ARE
NOT “HARD-WIRED” TO COMPREHEND IT.

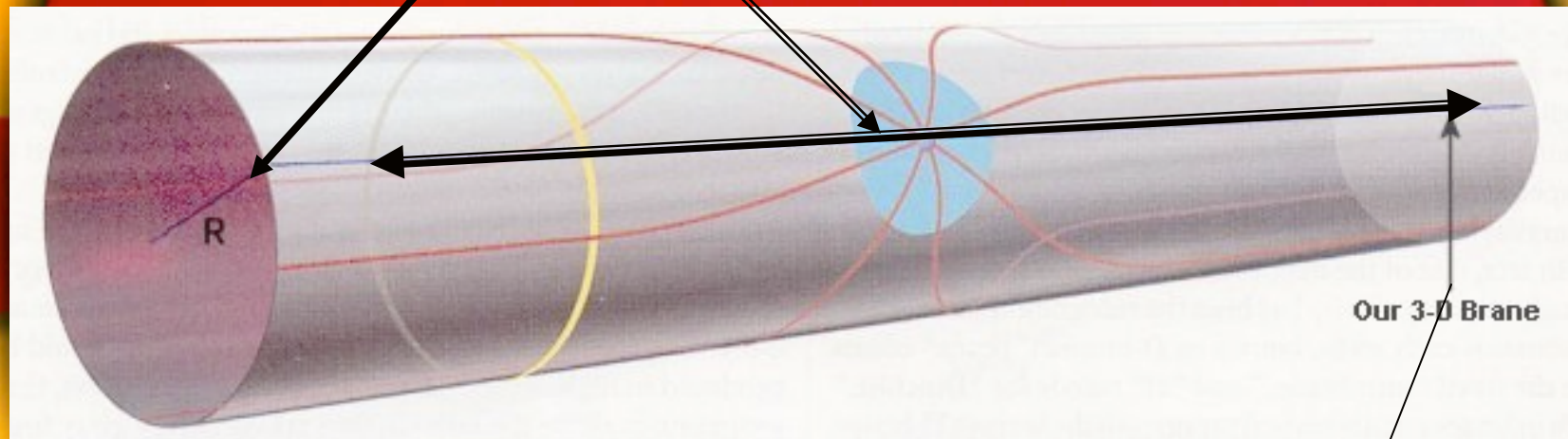


JUST LIKE THAT ANT, IT IS POSSIBLE THAT MORE THAN THREE SPATIAL DIMENSIONS *COULD* EXIST. . .

BUT, SINCE WE ARE RESTRICTED TO THREE DIMENSIONS, OUR BRAINS ARE NOT “HARD-WIRED” TO COMPREHEND IT.

ONE POSSIBLE EXPLANATION IS THAT THESE “EXTRA DIMENSIONS” ARE VERY SMALL, AND CURL UP ON EACH OTHER. . .

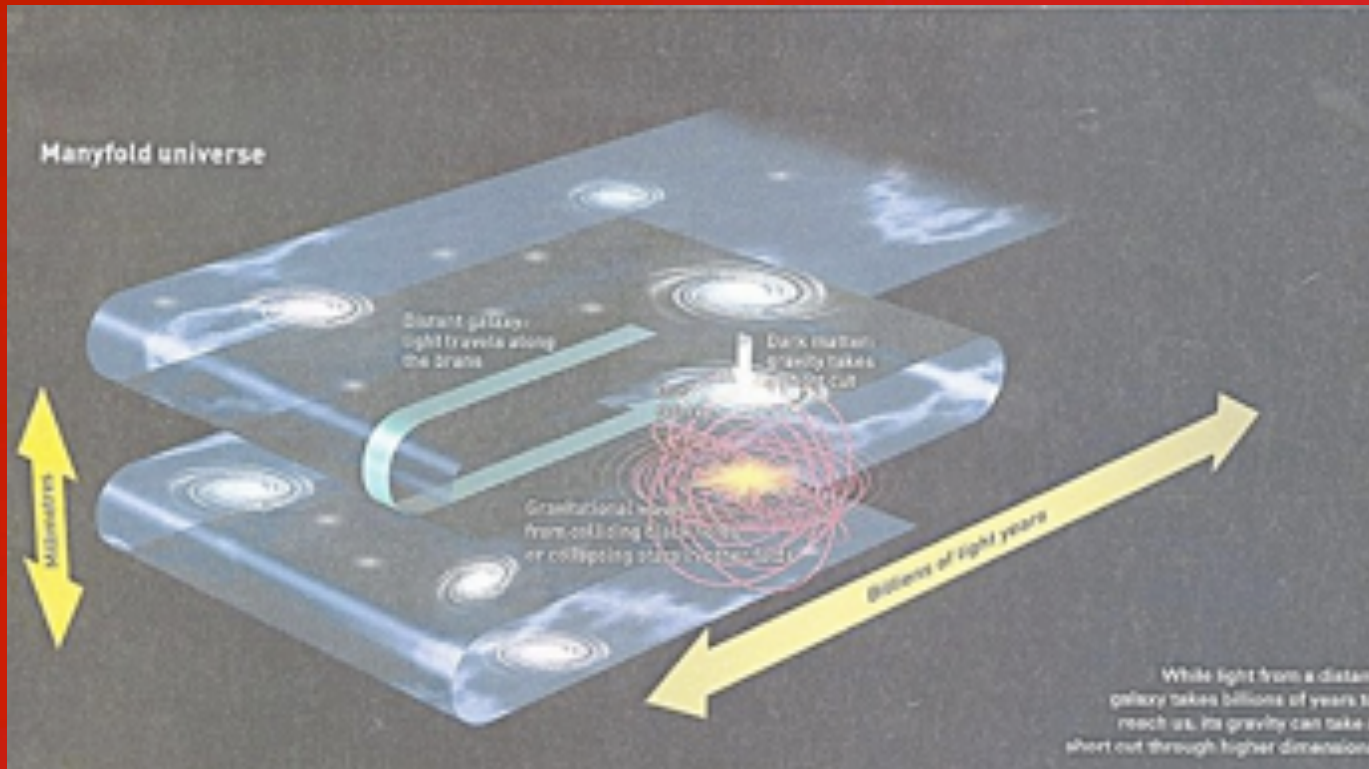
THESE EXTRA DIMENSIONAL “CYLINDERS” WOULD HAVE
A VERY TINY RADIUS, BUT COULD STRETCH INFINITELY
IN ITS LENGTH.



IF THIS IS TRUE, THEN ITS RESTRICTED RADIUS MIGHT ALSO
RESTRICT THE AMOUNT OF INFORMATION (IN THE FORM OF
RADIATION) IT COULD CARRY.

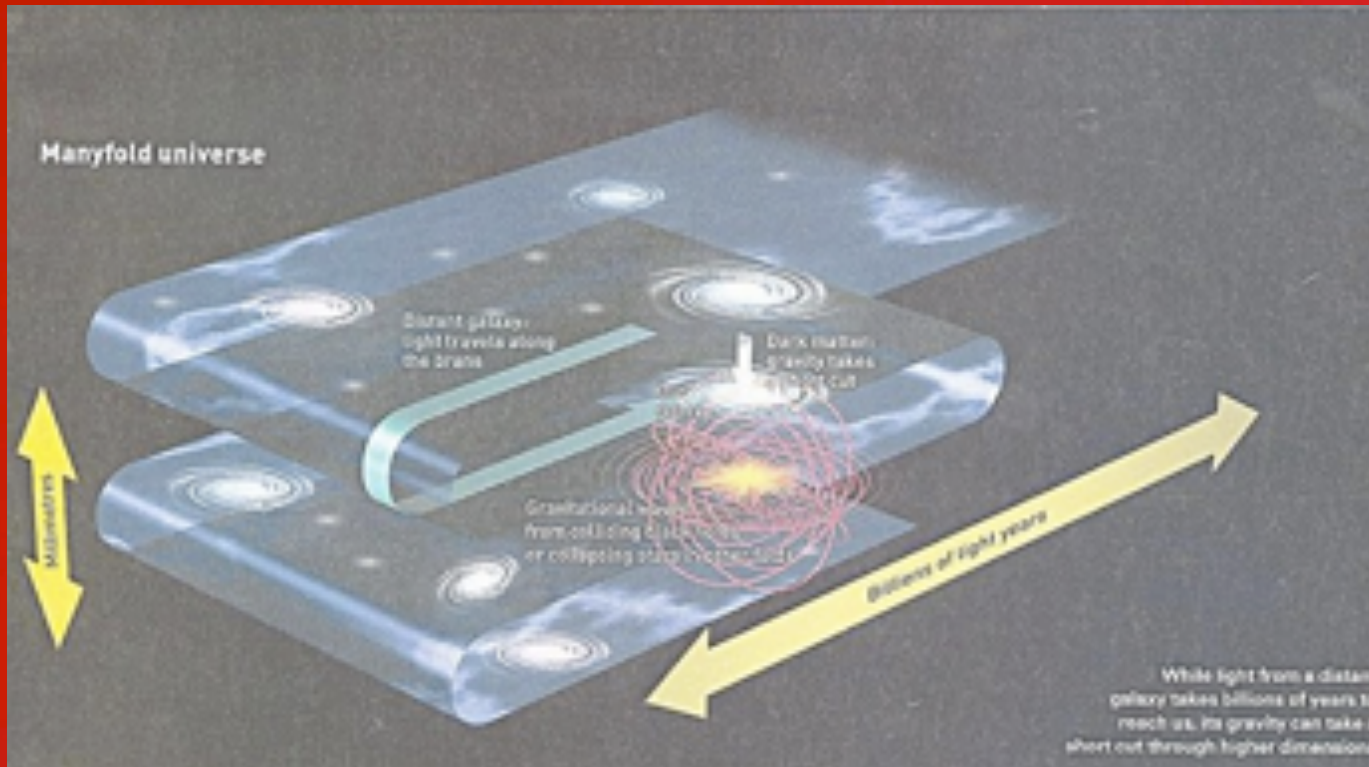
IN FACT, OUR UNIVERSE MAY BE CONFINED TO A “BRANE”
(SHORT FOR “MEMBRANE”) FLOATING IN A SPACE OF
3, 4, 5 , . . . , DIMENSIONS!!

THIS WOULD GREATLY CHANGE OUR CURRENT VIEW OF THE “UNIVERSE” AND OPEN UP THE POSSIBILITY OF A “*MANYFOLD UNIVERSE*”, OR EVEN A



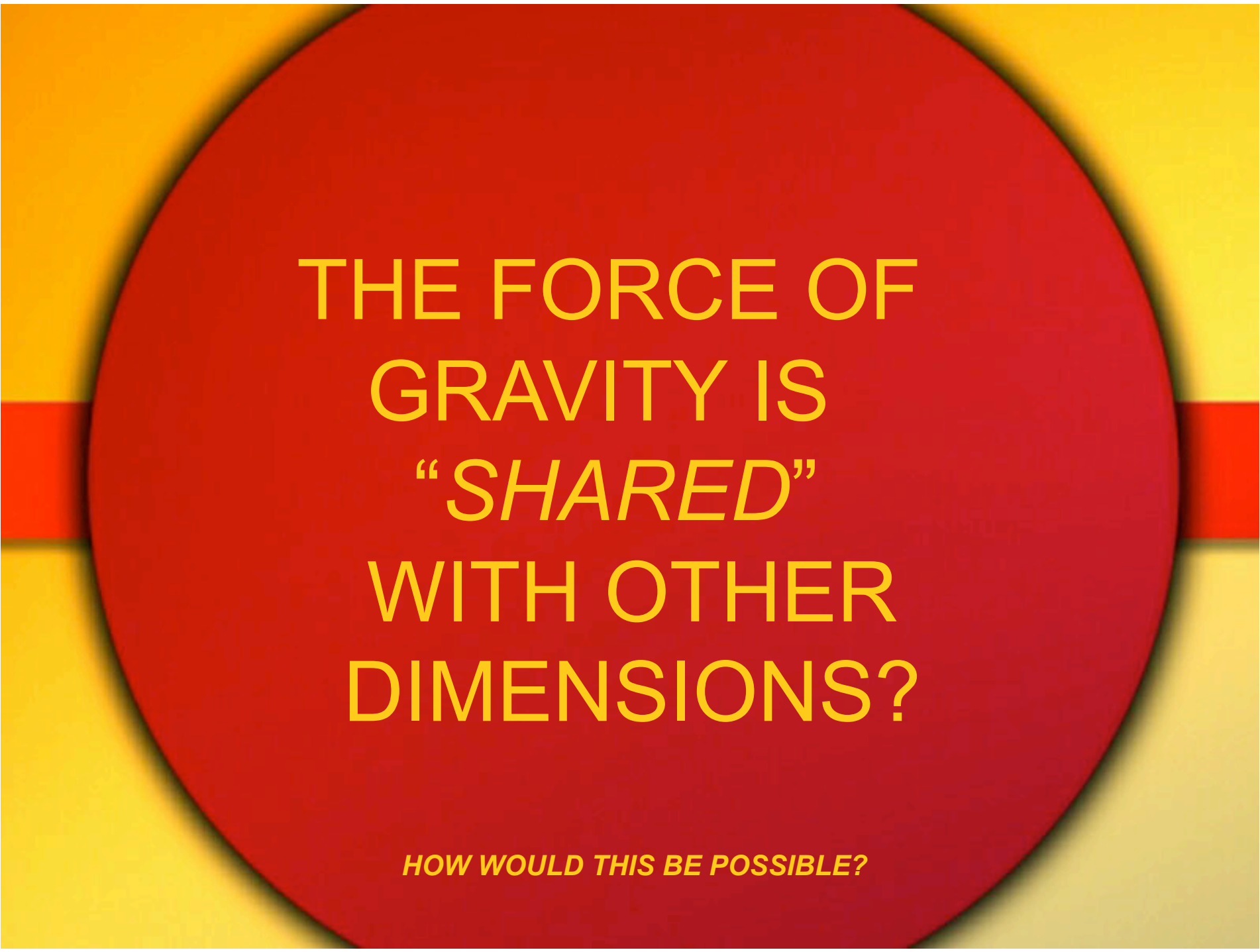
“MEGAVERSE”!

OUR UNIVERSE WOULD BE ON ONE OF THESE “FOLDS”, AND THREE FUNDAMENTAL FORCES (ELECTROMAGNETIC, WEAK AND STRONG NUCLEAR) WOULD BE RESTRICTED,



AS WOULD PARTICLES OF “NORMAL MATTER”.

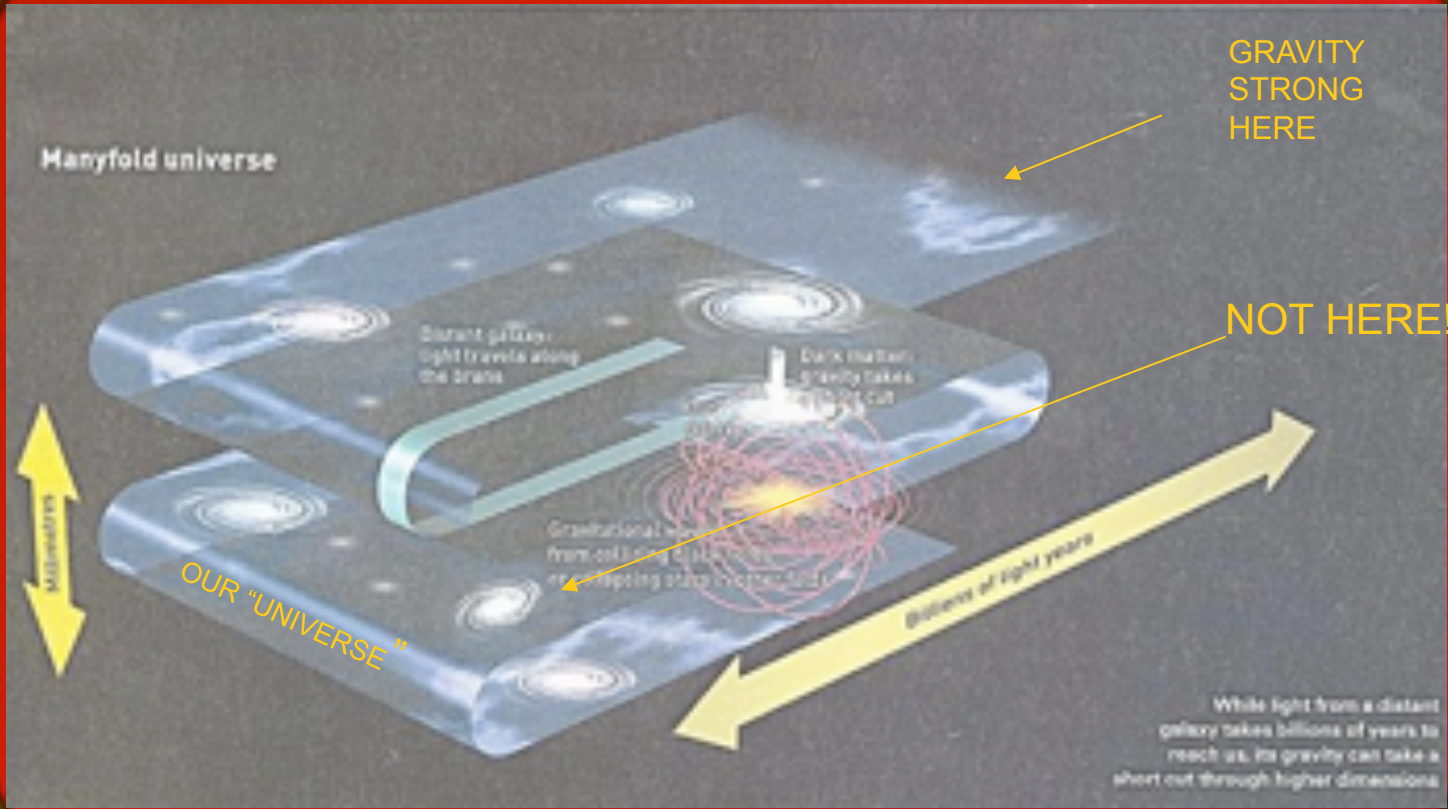
BUT WHAT IF...



THE FORCE OF
GRAVITY IS
“SHARED”
WITH OTHER
DIMENSIONS?

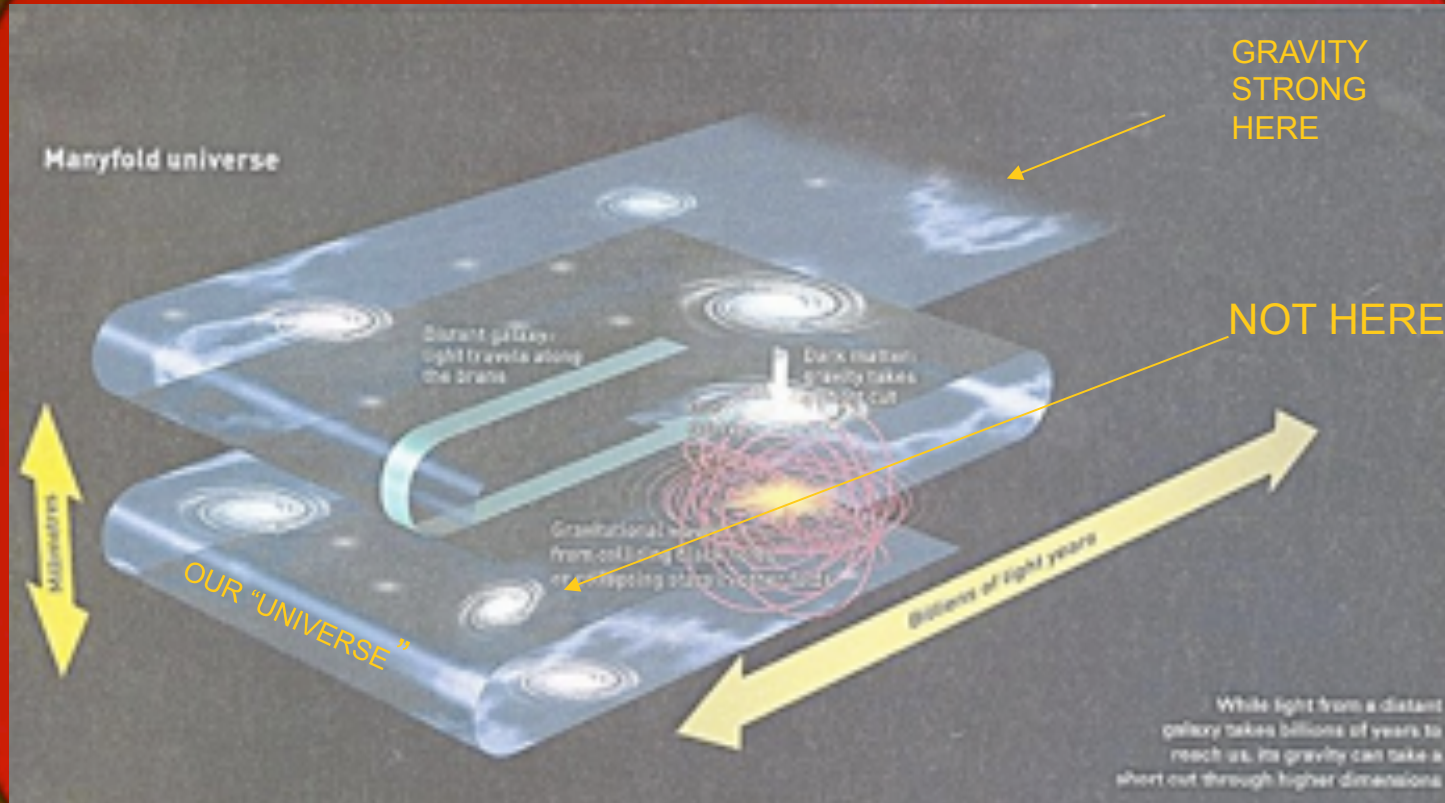
HOW WOULD THIS BE POSSIBLE?

ACCORDING TO THE *STANDARD MODEL OF PARTICLE PHYSICS*, THE PARTICLE THAT "CARRIES" THE GRAVITATIONAL FORCE IS CALLED THE

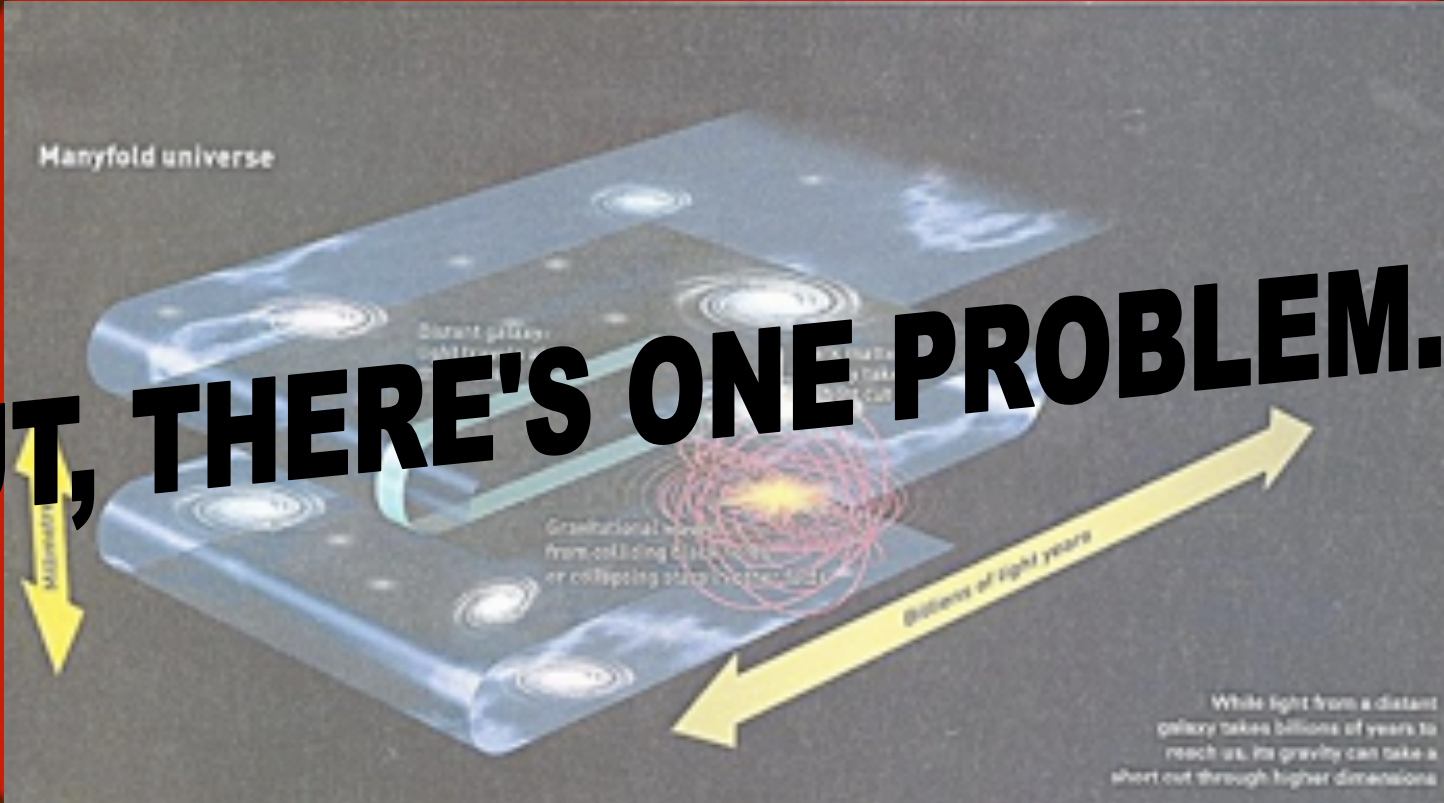


GRAVITON

WHAT IF GRAVITONS ARE ABLE TO “JUMP”
FROM ONE DIMENSION (OR UNIVERSE)
TO ANOTHER, *UNLIKE* OTHER
FORCE-CARRYING PARTICLES?



A THEORY CALLED “**STRING THEORY**”
PREDICTS THAT THIS *COULD* HAPPEN!



BUT, THERE'S ONE PROBLEM. . .

SINCE GRAVITY IS **SO WEAK,**
THE GRAVITON WOULD BE
VERY, VERY WEAK,
AND VIRTUALLY **UNDETECTABLE**
WITH OUR CURRENT TECHNOLOGY

IF THE STRENGTH OF GRAVITY IS = 1;

THE RELATIVE STRENGTH OF THE WEAK NUCLEAR FORCE IS
10,000,000,000,000,000,000,000

THE RELATIVE STRENGTH OF THE ELECTROMAGNETIC FORCE IS
100,000,000,000,000,000,000,000,000,000,000,000 AND

THE RELATIVE STRENGTH OF THE STRONG NUCLEAR FORCE IS
100,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 !!!!!!!


THE QUESTION OF THE RELATIVE WEAKNESS
OF GRAVITY COMPARED TO THE OTHER
FUNDAMENTAL FORCES IS KNOWN AS
“THE HIERARCHY PROBLEM.”

THE LHC WILL BE SO

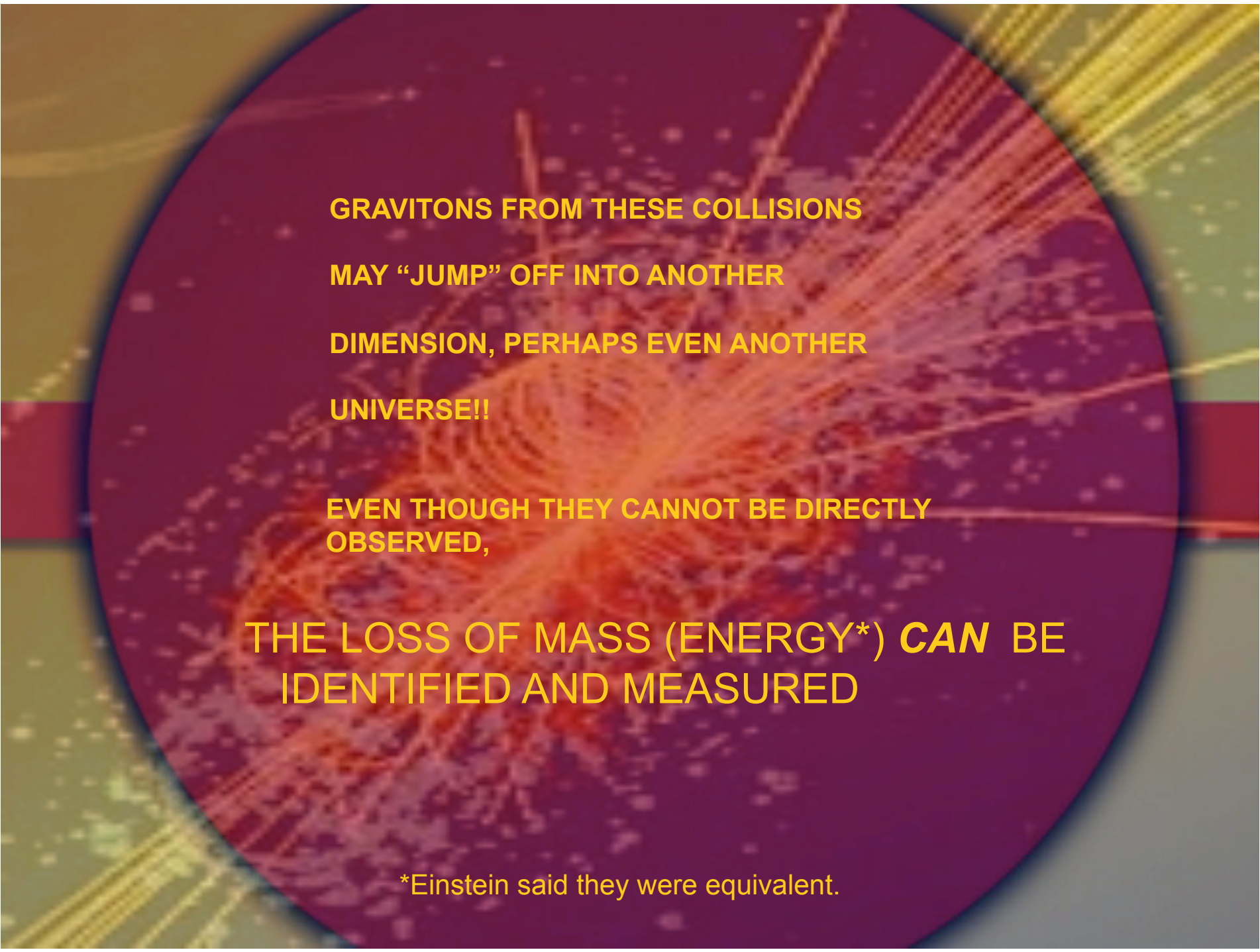
POWERFUL

(REMEMBER, 14 TeV!)

THAT THE COLLISIONS IT PRODUCES
WHEN PROTONS COLLIDE MAY REVEAL
PARTICLES THAT MAY HAVE ONCE BEEN
PRODUCED IN THE "BIG BANG"
AND HAVE NOT BE SEEN SINCE.



**GRAVITONS FROM THESE COLLISIONS
MAY “JUMP” OFF INTO ANOTHER
DIMENSION, PERHAPS EVEN ANOTHER
UNIVERSE!!**

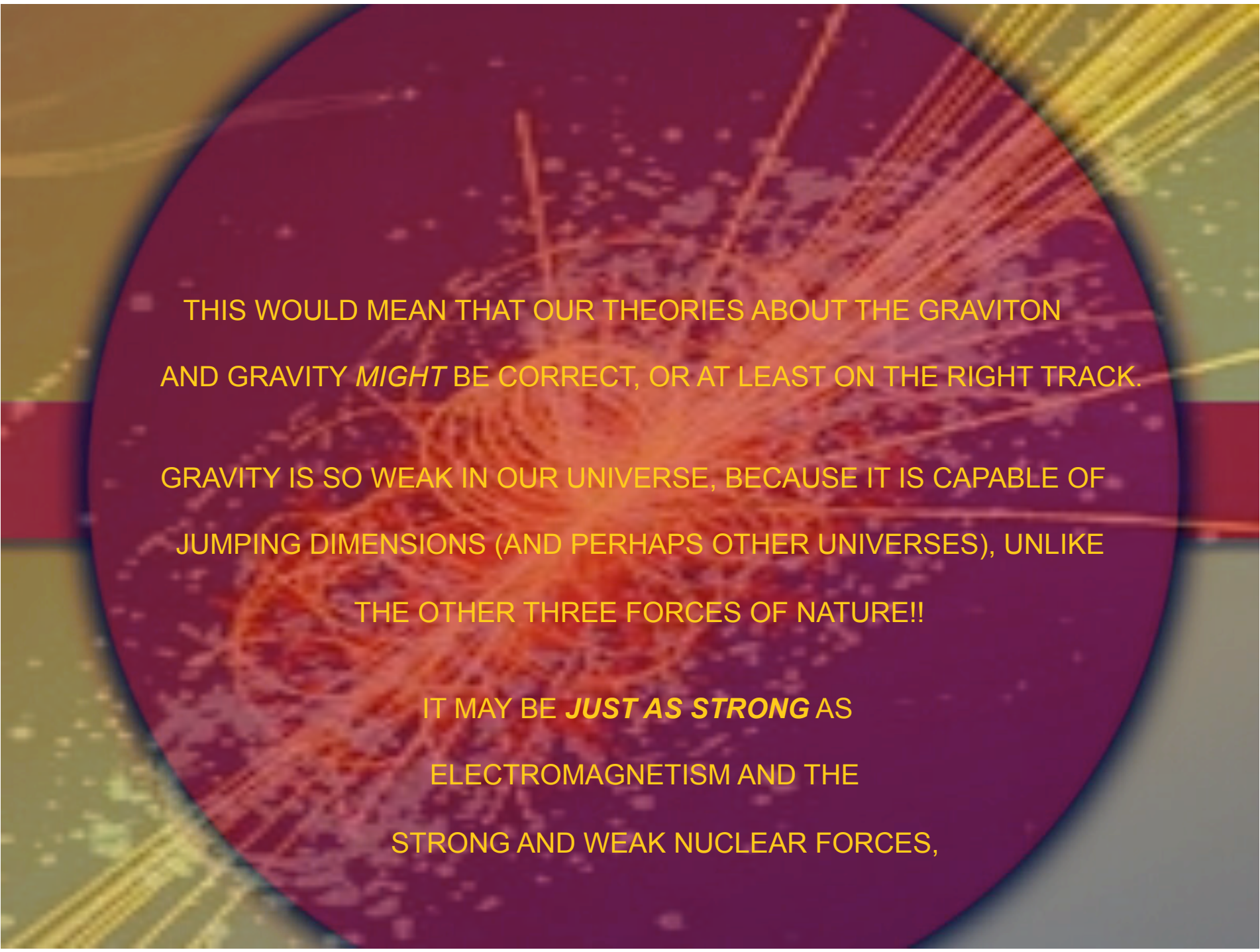


GRAVITONS FROM THESE COLLISIONS
MAY “JUMP” OFF INTO ANOTHER
DIMENSION, PERHAPS EVEN ANOTHER
UNIVERSE!!

EVEN THOUGH THEY CANNOT BE DIRECTLY
OBSERVED,

THE LOSS OF MASS (ENERGY*) **CAN** BE
IDENTIFIED AND MEASURED

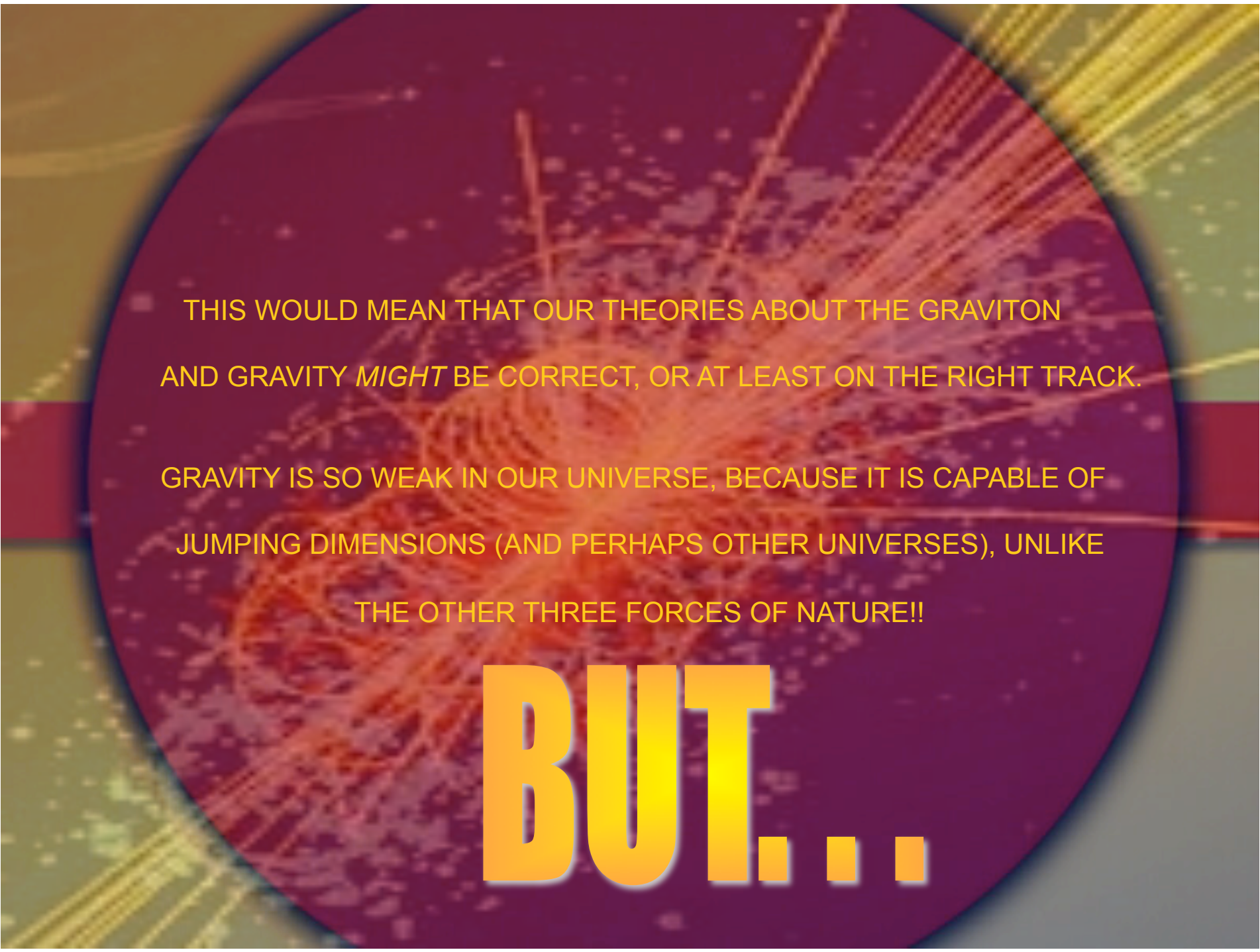
*Einstein said they were equivalent.



THIS WOULD MEAN THAT OUR THEORIES ABOUT THE GRAVITON
AND GRAVITY *MIGHT* BE CORRECT, OR AT LEAST ON THE RIGHT TRACK.

GRAVITY IS SO WEAK IN OUR UNIVERSE, BECAUSE IT IS CAPABLE OF
JUMPING DIMENSIONS (AND PERHAPS OTHER UNIVERSES), UNLIKE
THE OTHER THREE FORCES OF NATURE!!

IT MAY BE ***JUST AS STRONG*** AS
ELECTROMAGNETISM AND THE
STRONG AND WEAK NUCLEAR FORCES,



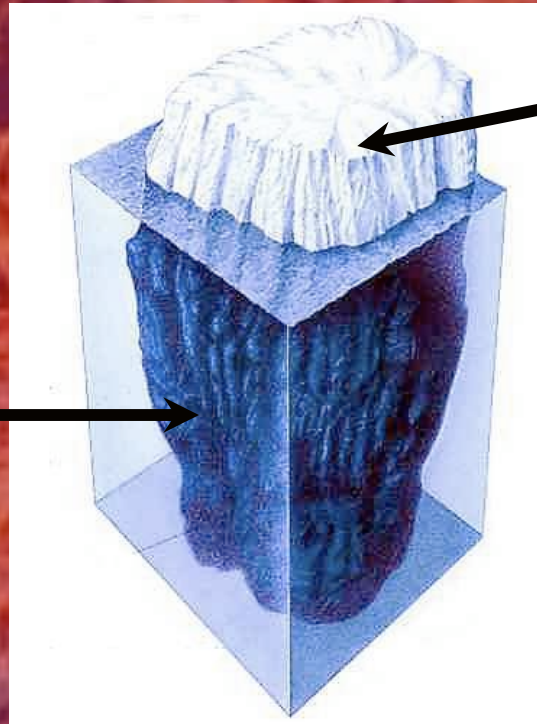
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JUMPING DIMENSIONS (AND PERHAPS OTHER UNIVERSES), UNLIKE
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BUT...

IT WOULD BE LIKE AN

ICEBERG



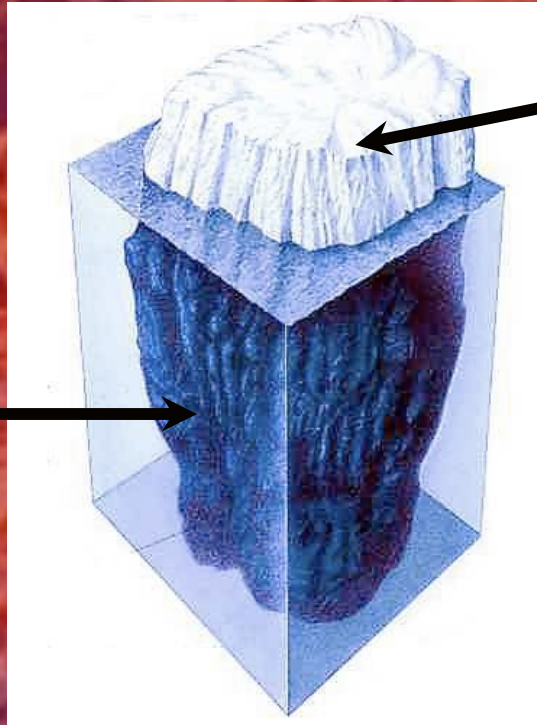
GRAVITY IN *OUR*
UNIVERSE

GRAVITY IN
OTHER UNIVERSES

WE ONLY SEE THE TIP, BUT MOST OF IT IS HIDDEN UNDERWATER!

IT WOULD BE LIKE AN

ICEBERG



GRAVITY IN *OUR*
UNIVERSE

GRAVITY IN
OTHER UNIVERSES

BUT, WHAT'S EVEN MORE AMAZING...



ESTABLISH COMMUNICATION
WITH OTHER DIMENSIONS
OR UNIVERSES!

USING GRAVITONS, WE MIGHT
ACTUALLY BE ABLE TO...

...GRAVITONS...





UNLOCK THE
MYSTERY

OF

DARK MATTER!!!

WHAT IS ***DARK MATTER???***

THE SIMPLE ANSWER IS. . .

WE DON'T KNOW!

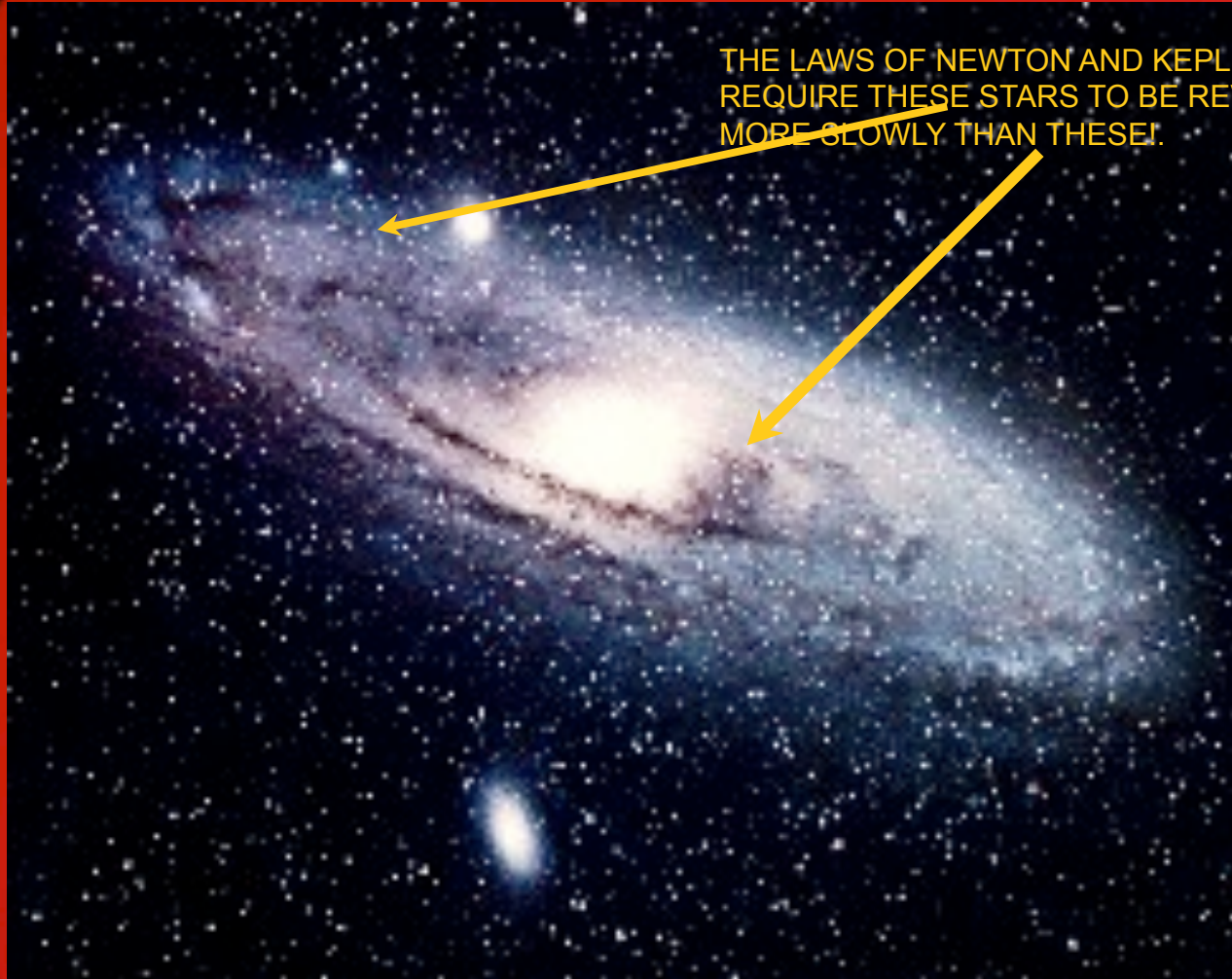
WHAT IS ***DARK MATTER???***

THE SIMPLE ANSWER IS. . .

WE DON'T KNOW!

BUT, WHAT WE ***DO*** KNOW IS

STARS THAT WE OBSERVE IN DISTANT GALAXIES



THE LAWS OF NEWTON AND KEPLER
REQUIRE THESE STARS TO BE REVOLVING
MORE SLOWLY THAN THESE!

ARE **NOT** FOLLOWING LAWS OF NEWTONIAN PHYSICS

STARS REVOLVING AROUND THE GALACTIC NUCLEI



ARE GOING *MUCH TOO FAST!*



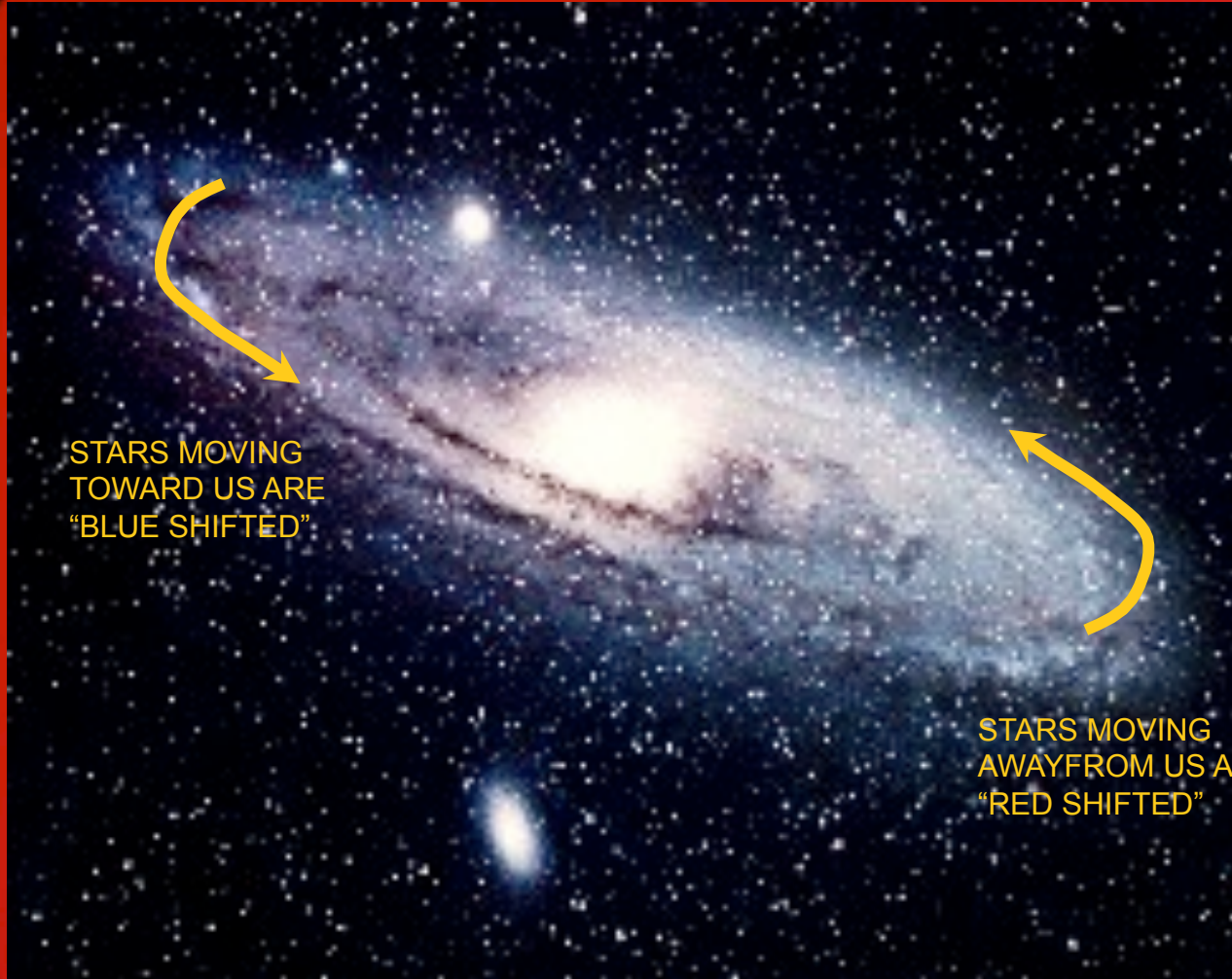
HOW DO WE KNOW THIS?

BY OBSERVING AND MEASURING
THE

"DOPPLER SHIFT"

OF STARS IN THE
GALAXY:

ARE GOING *MUCH TOO FAST!*



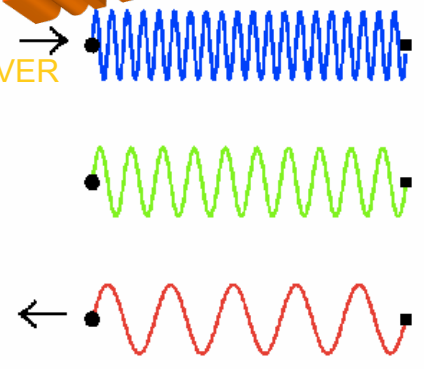
STARS MOVING
TOWARD US ARE
"BLUE SHIFTED"

STARS MOVING
AWAY FROM US ARE
"RED SHIFTED"

ARE GOING *MUCH TOO FAST!*

"DOPPLER SHIFT"

BLUE SHIFT:
LIGHT MOVING
TOWARD OBSERVER



LIGHT OBSERVED
WHEN THERE IS
NO RELATIVE MOTION.

RED SHIFT:
LIGHT MOVING
AWAY FROM
OBSERVER

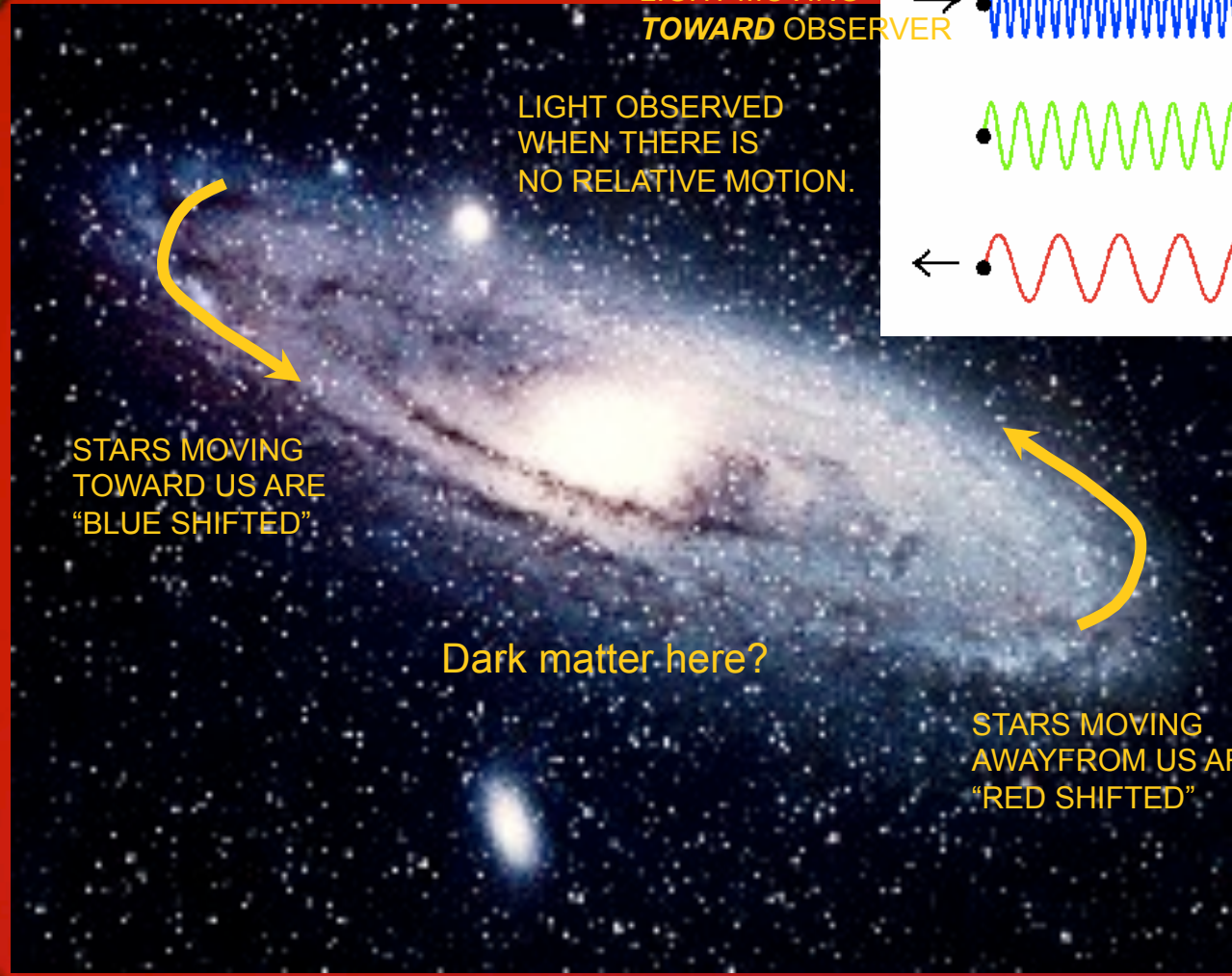
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TOWARD US ARE
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STARS MOVING
AWAY FROM US ARE
"RED SHIFTED"

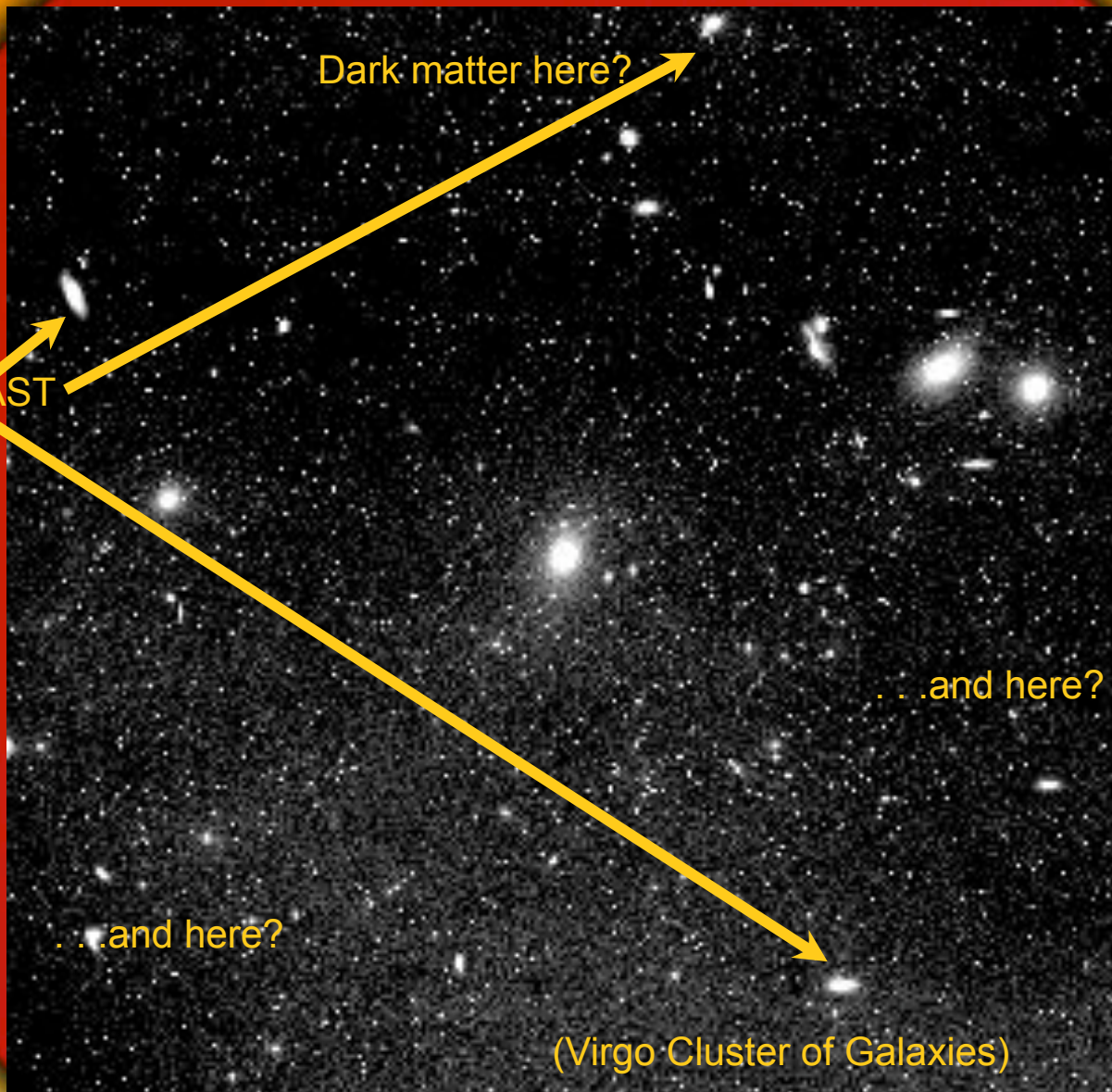
Dark matter here?

ARE GOING **MUCH TOO FAST!**

AS ARE...



ENTIRE *CLUSTERS* OF GALAXIES!!



Dark matter here?

TOO FAST

...and here?

...and here?

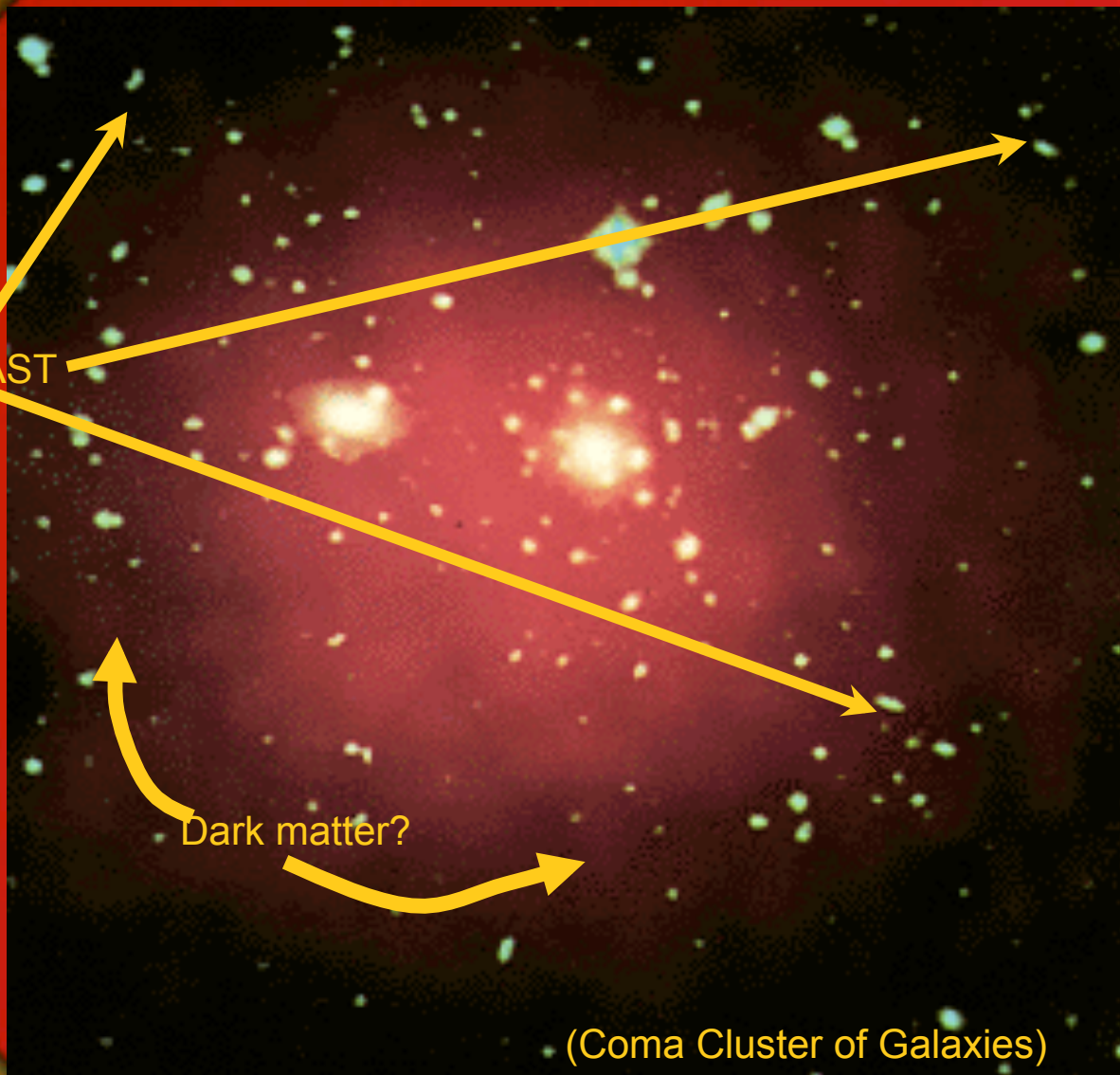
(Virgo Cluster of Galaxies)

ENTIRE *CLUSTERS* OF GALAXIES!!

TOO FAST

Dark matter?

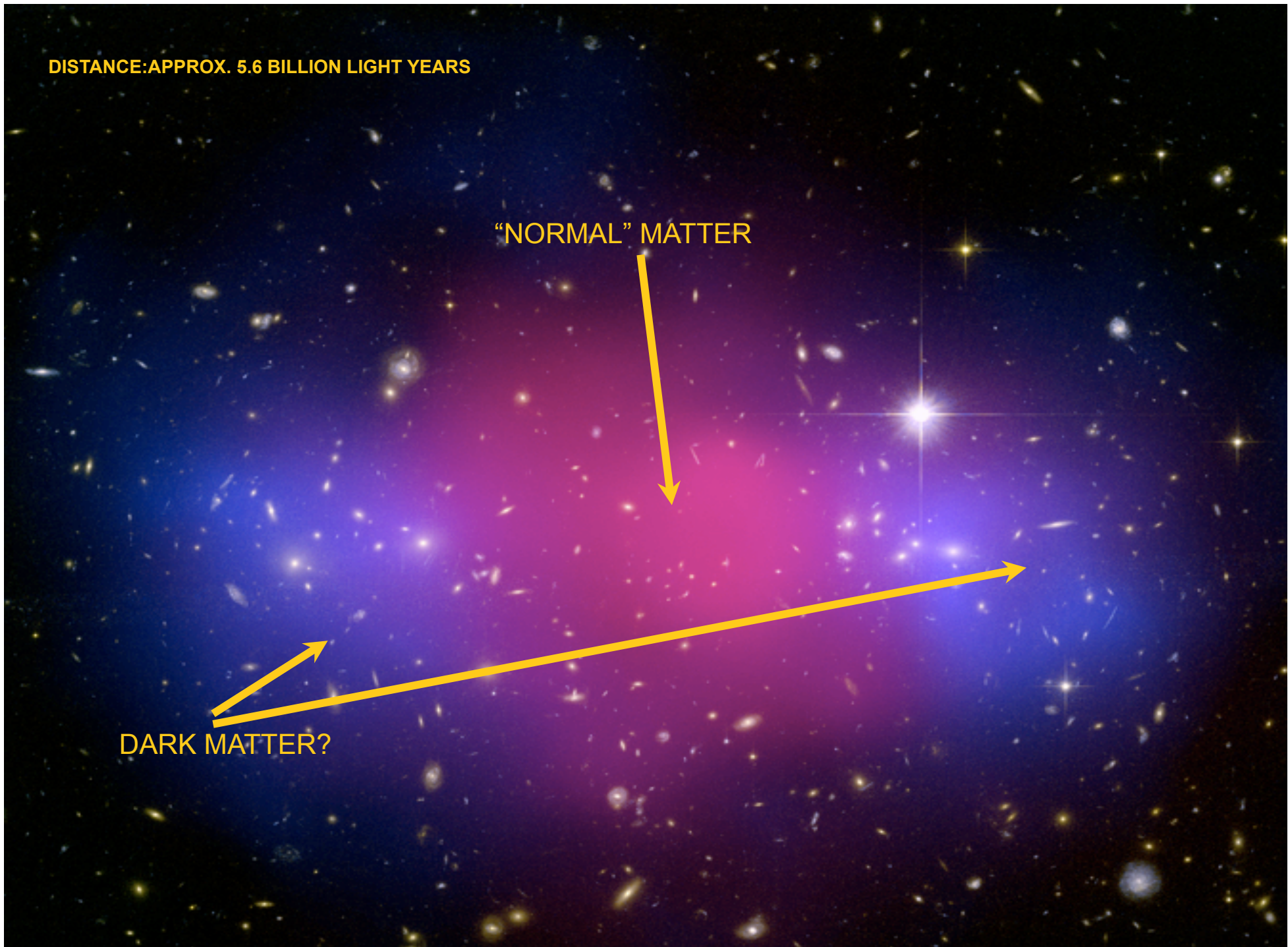
(Coma Cluster of Galaxies)



DISTANCE: APPROX. 5.6 BILLION LIGHT YEARS

“NORMAL” MATTER

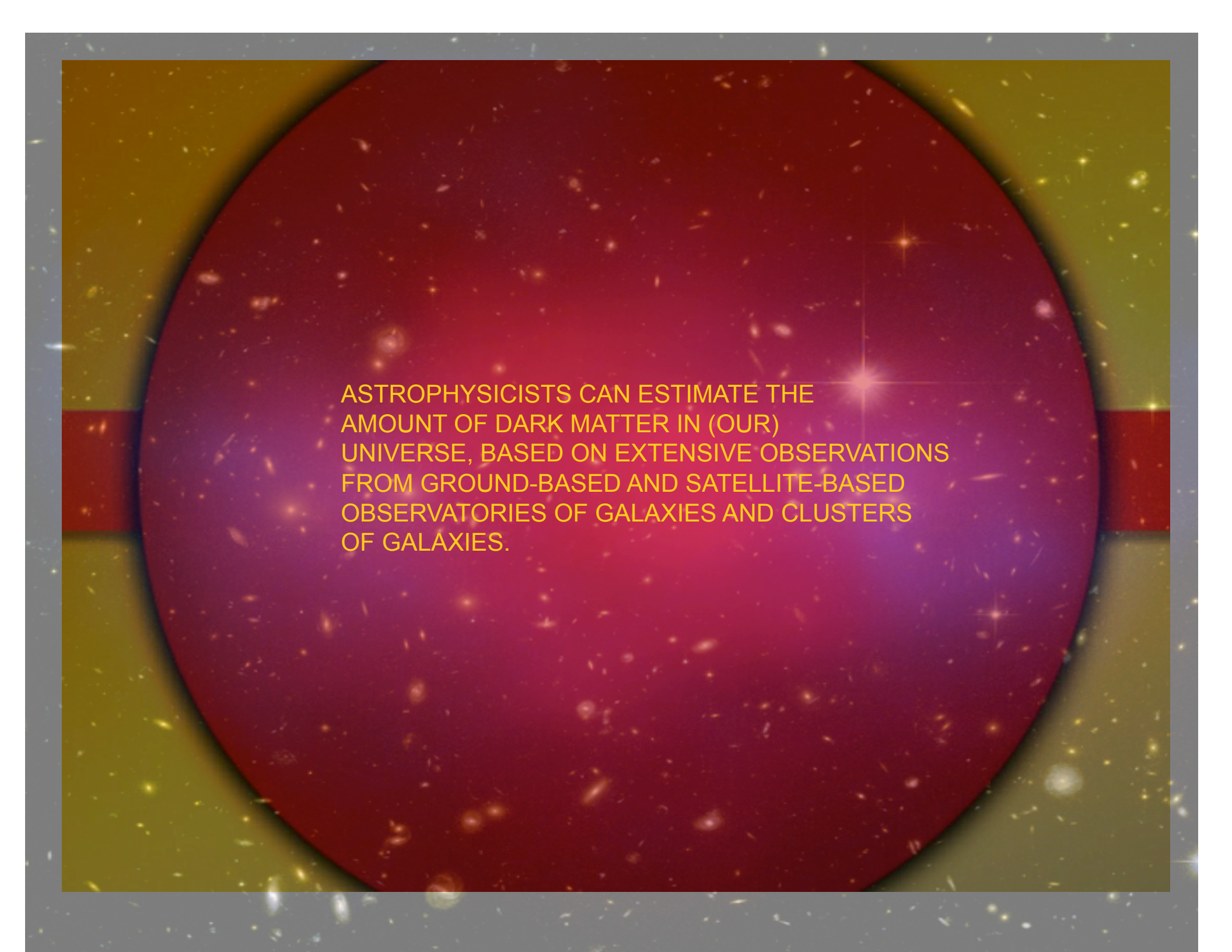
DARK MATTER?



THIS FACT IMPLIES THAT
THERE MUST BE A ***SUBSTANTIAL AMOUNT
OF MATTER*** CAUSING THIS THAT WE CANNOT
“SEE”!

HENCE,

DARK MATTER!



ASTROPHYSICISTS CAN ESTIMATE THE AMOUNT OF DARK MATTER IN (OUR) UNIVERSE, BASED ON EXTENSIVE OBSERVATIONS FROM GROUND-BASED AND SATELLITE-BASED OBSERVATORIES OF GALAXIES AND CLUSTERS OF GALAXIES.



ASTROPHYSICISTS CAN ESTIMATE THE AMOUNT OF DARK MATTER IN (OUR) UNIVERSE, BASED ON THE TRENDS / CORRELATIONS FROM GR (UNIT-BASED) AND AT (LIN)-BASED CORRELATIONS OF GALAXIES AND CLUSTERS OF GALAXIES.

BUT THERE'S ANOTHER PROBLEM!

WE HAVE KNOWN THAT OUR UNIVERSE IS **EXPANDING**
THANKS TO THE OBSERVATIONS OF EDWIN HUBBLE IN
THE EARLY 20TH CENTURY.



WE HAVE KNOWN THAT OUR UNIVERSE IS **EXPANDING**
THANKS TO THE OBSERVATIONS OF EDWIN HUBBLE IN
THE EARLY 20TH CENTURY.

BUT, IS ITS ***RATE OF EXPANSION:***

- A) SPEEDING UP?
- B) SLOWING DOWN?
- C) REMAINING CONSTANT?



THE ANSWER TO THIS QUESTION MAY
DECIDE THE FATE OF OUR UNIVERSE!

THE ANSWER:



A) SPEEDING UP!!!

SHOULDN'T THE PRESENCE OF ALL THIS MATTER
AND DARK MATTER CAUSE EXPANSION TO SLOW
DOWN, OR AT LEAST REMAIN CONSTANT???????



EXPANDING
UNIVERSE

SOMETHING ELSE IS GOING ON HERE!!

SHOULDN'T THE PRESENCE OF ALL THIS MATTER
AND DARK MATTER CAUSE EXPANSION TO SLOW
DOWN, OR AT LEAST REMAIN CONSTANT???????



SCIENTISTS BELIEVE THAT SOME "MYSTERIOUS"
FORM OF **ENERGY** IN OUR UNIVERSE MUST BE
DOING THIS!!!!

THIS ENERGY IS GIVEN THE NAME. . .

DARK ENERGY

EX
UN





EXPANDING UNIVERSE

Actually, Albert Einstein, in his THEORY OF GENERAL RELATIVITY, inserted a term in his equation to account for such an occurrence - he called it the



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$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

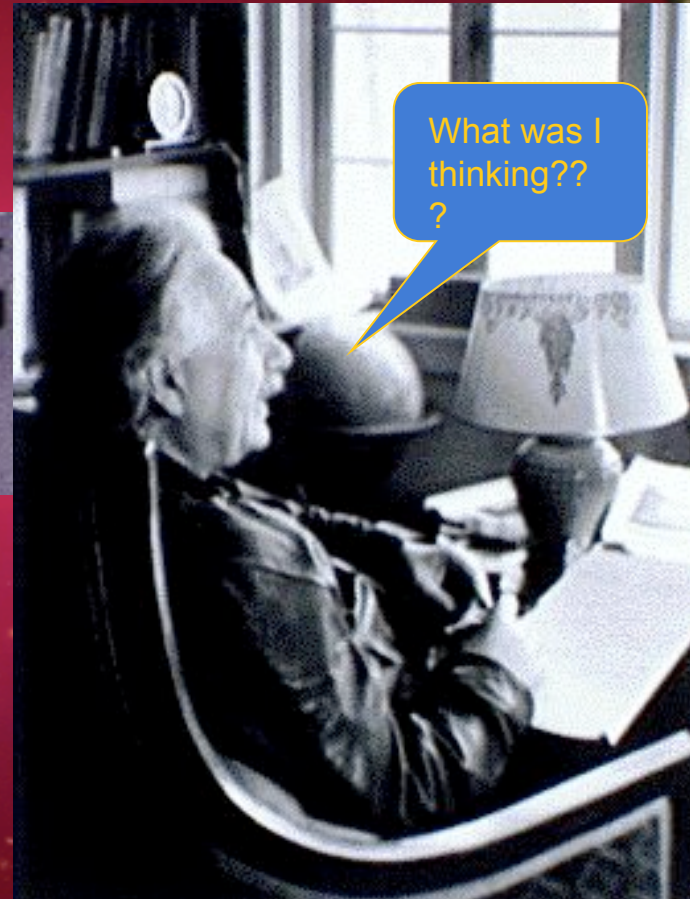
COSMOLOGICAL CONSTANT

EINSTEIN AND THE "COSMOLOGICAL CONSTANT"

AFTER HUBBLE'S DISCOVERY,
HE THOUGHT HE WAS WRONG
IN MODIFYING HIS EQUATION,
CALLING THE ADDITIONAL TERM
". . . THE GREATEST MISTAKE OF
MY LIFE."

EXPANDING
UNIVERSE

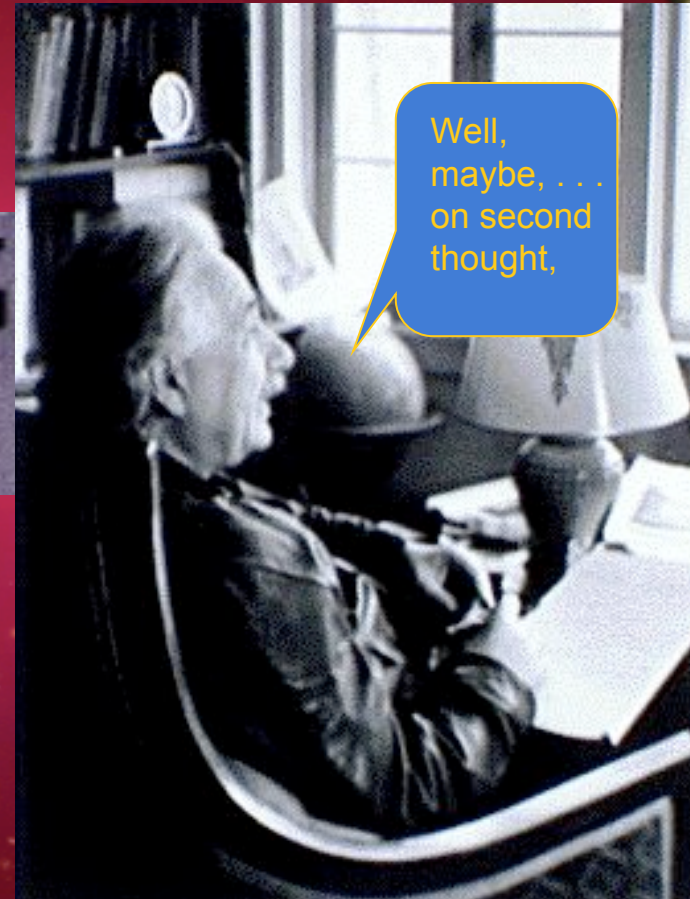
$$G_{\mu\nu} + \cancel{\Lambda g_{\mu\nu}} = \frac{8\pi G}{c^4} T_{\mu\nu}$$



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EXPANDING
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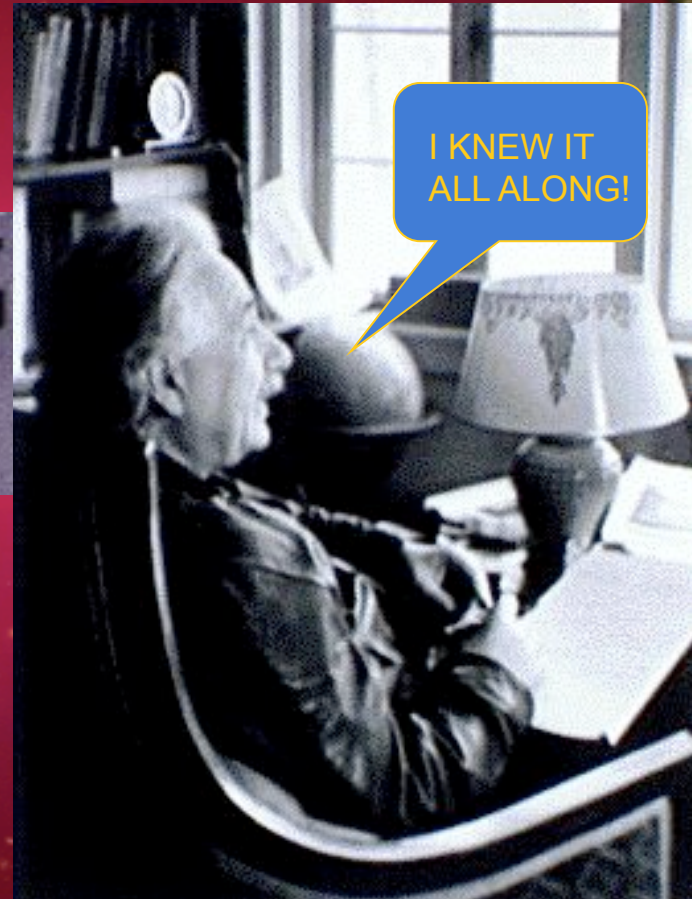
BUT OUR OBSERVATIONS
TODAY OF ACCELERATING
EXPANSION MAY BE DUE TO
THE PRESENCE OF DARK
ENERGY (DESCRIBED BY
THIS TERM)!



AFTER HUBBLE'S DISCOVERY,
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CALLING THE ADDITIONAL TERM
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EXPANDING
UNIVERSE

BUT OUR OBSERVATIONS
TODAY OF ACCELERATING
EXPANSION MAY BE DUE TO
THE PRESENCE OF DARK
ENERGY (DESCRIBED BY
THIS TERM)!



EINSTEIN WAS ACTUALLY CORRECT!



IN FACT, BASED ON OUR
CURRENT MEASUREMENTS
OF THE BEHAVIOR OF
GALACTIC CLUSTERS, AND
THE ACCELERATING EXPANSION
OF THE UNIVERSE,

THE BREAKDOWN OF ALL THE “STUFF”
IN OUR UNIVERSE GOES SOMETHING LIKE
THIS:

THIS REPRESENTS EVERYTHING WE CAN "SEE" OR DIRECTLY DETECT TODAY!!!

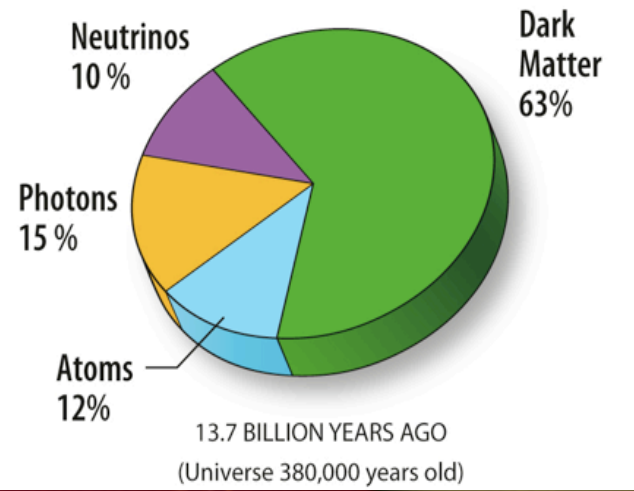
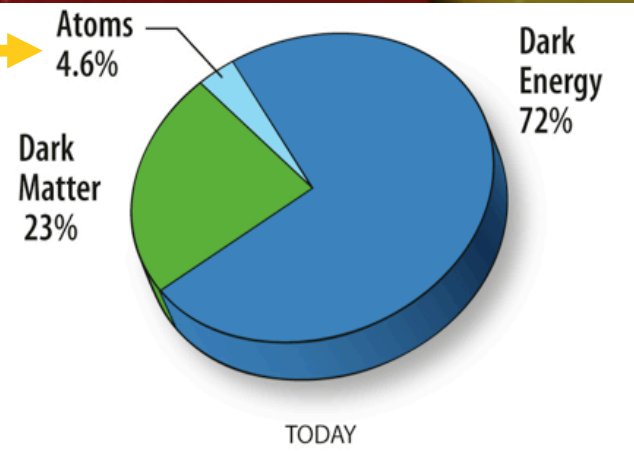
THIS ACCOUNTS FOR OUR ENTIRE "OBSERVABLE" UNIVERSE!!

????????????????

IN FACT, BASED ON OUR CURRENT MEASUREMENTS OF THE BEHAVIOR OF GALACTIC CLUSTERS, AND THE ACCELERATING EXPANSION OF THE UNIVERSE,

THE BREAKDOWN OF ALL THE "STUFF" IN OUR UNIVERSE GOES SOMETHING LIKE THIS:

BREAKDOWN OF ALL "MATTER" IN THE UNIVERSE SHORTLY AFTER THE BIG BANG.



THIS REPRESENTS EVERYTHING WE CAN "SEE" OR DIRECTLY DETECT TODAY!!!

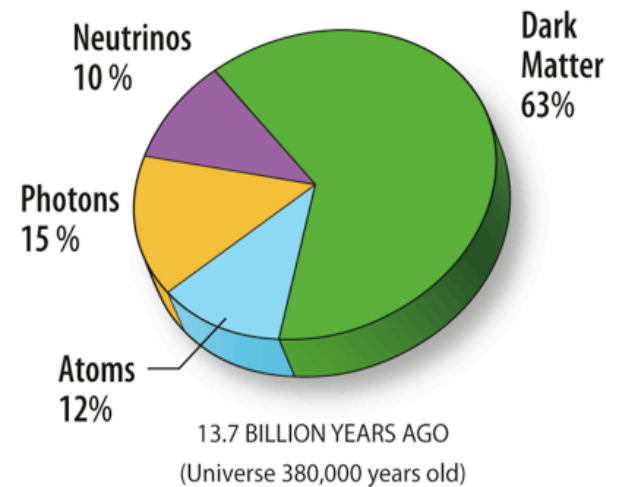
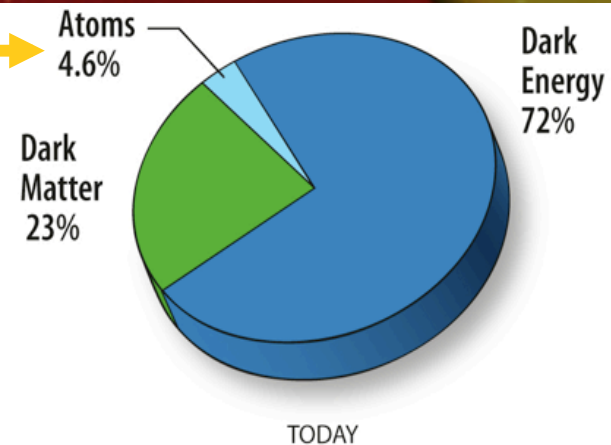
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IN FACT, BASED ON OUR CURRENT MEASUREMENTS OF THE BEHAVIOR OF GALACTIC CLUSTERS, AND THE ACCELERATING EXPANSION OF THE UNIVERSE,

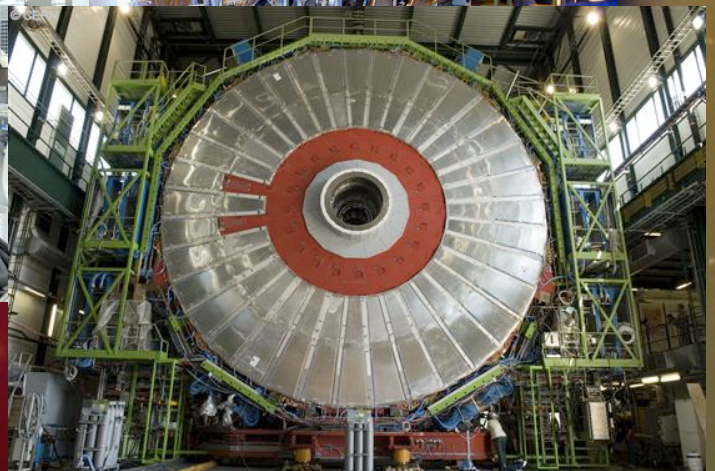
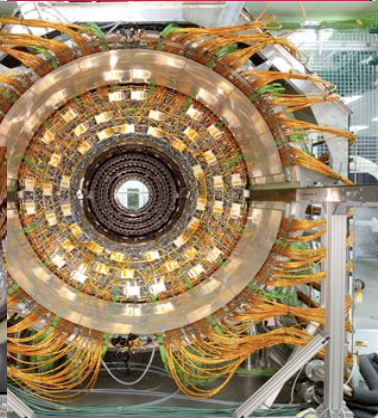
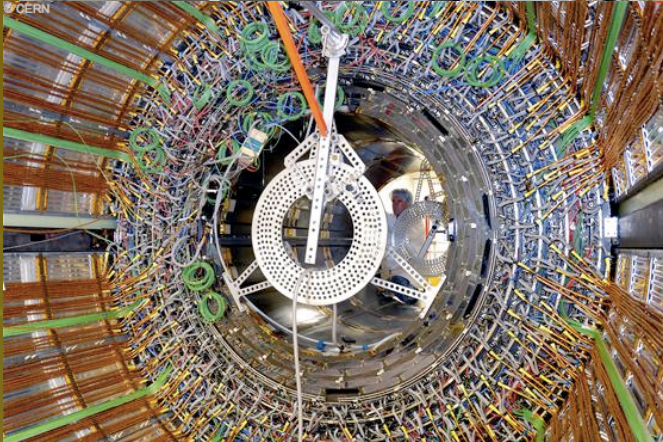
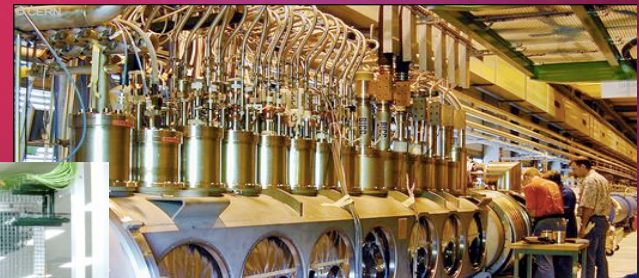
THE BREAKDOWN OF ALL THE "STUFF" IN OUR UNIVERSE GOES SOMETHING LIKE THIS:

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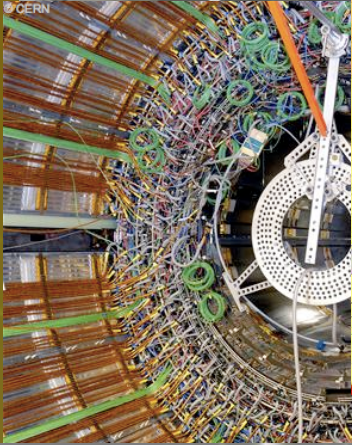
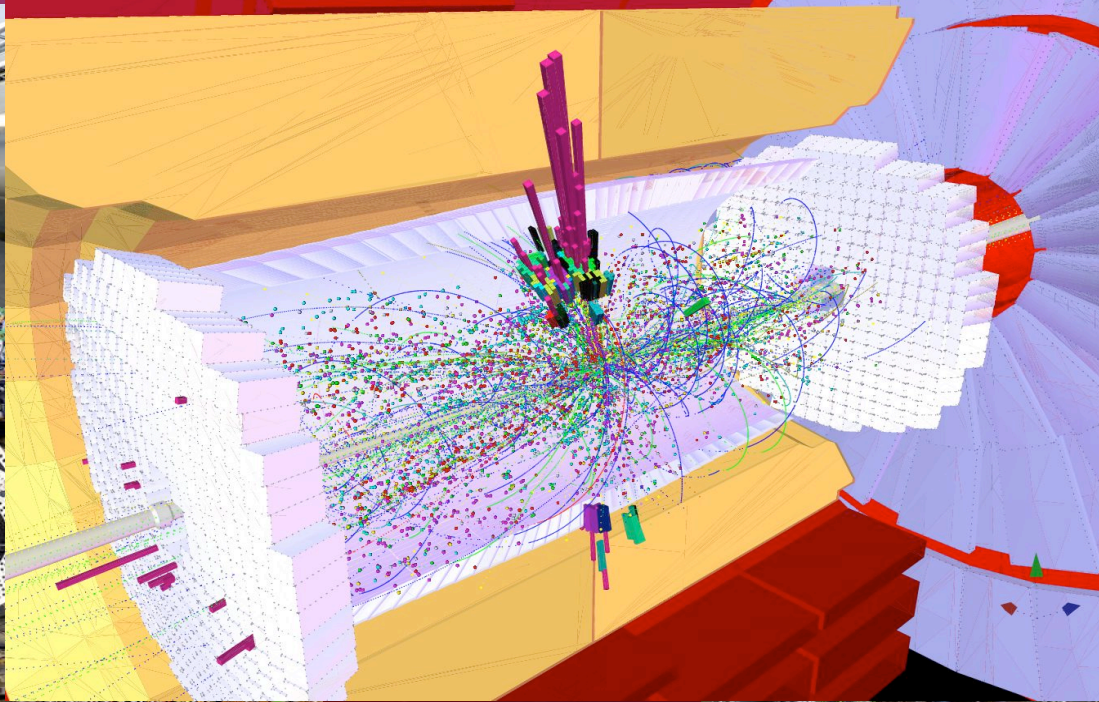


THIS REALLY DOESN'T MAKE SENSE!!!

THE LHC MAY HELP US UNDERSTAND DARK



THE LHC MAY HELP US UNDERSTAND WHY





**AS WE HAVE SEEN,
THE LHC MAY HELP US FIND THE ANSWER
TO THE FOLLOWING QUESTIONS:**

- o **What happened during the first instants after the “BIG BANG”?**
- o Were the Fundamental Forces (gravity, EM, strong and weak nuclear) **EQUALLY** strong at that time?
- o **CAN** we detect the **GRAVITON**?
- o Are the observable predictions of **STRING THEORY** accurate?
- o Is the **HIGGS MECHANISM** a valid hypothesis in determining what **MASS** actually is, and why particles differ in mass?
- o Do **EXTRA DIMENSIONS** actually exist, and can we detect them?

The image features a central hub-and-spoke network diagram with numerous thin, multi-colored lines radiating from a central point. This network is superimposed on a background of a large, dark red circular area with a greenish-yellow outer ring. Scattered throughout the scene are many small, colorful spheres in shades of red, blue, green, yellow, and purple, some appearing to be connected to the network lines. The overall aesthetic is that of a complex, interconnected system, possibly representing a particle collision event or a data network.

IN ADDITION TO THESE QUESTIONS,
THE LHC MAY ALSO HELP US SOLVE
THE FOLLOWING MYSTERIES:



**WHAT IS THE NATURE OF
DARK MATTER AND DARK ENERGY???**

**WHY DOES EVERYTHING WE SEE IN THE UNIVERSE
ACCOUNT FOR ONLY 4.6% OF ALL THAT IS OUT THERE?**

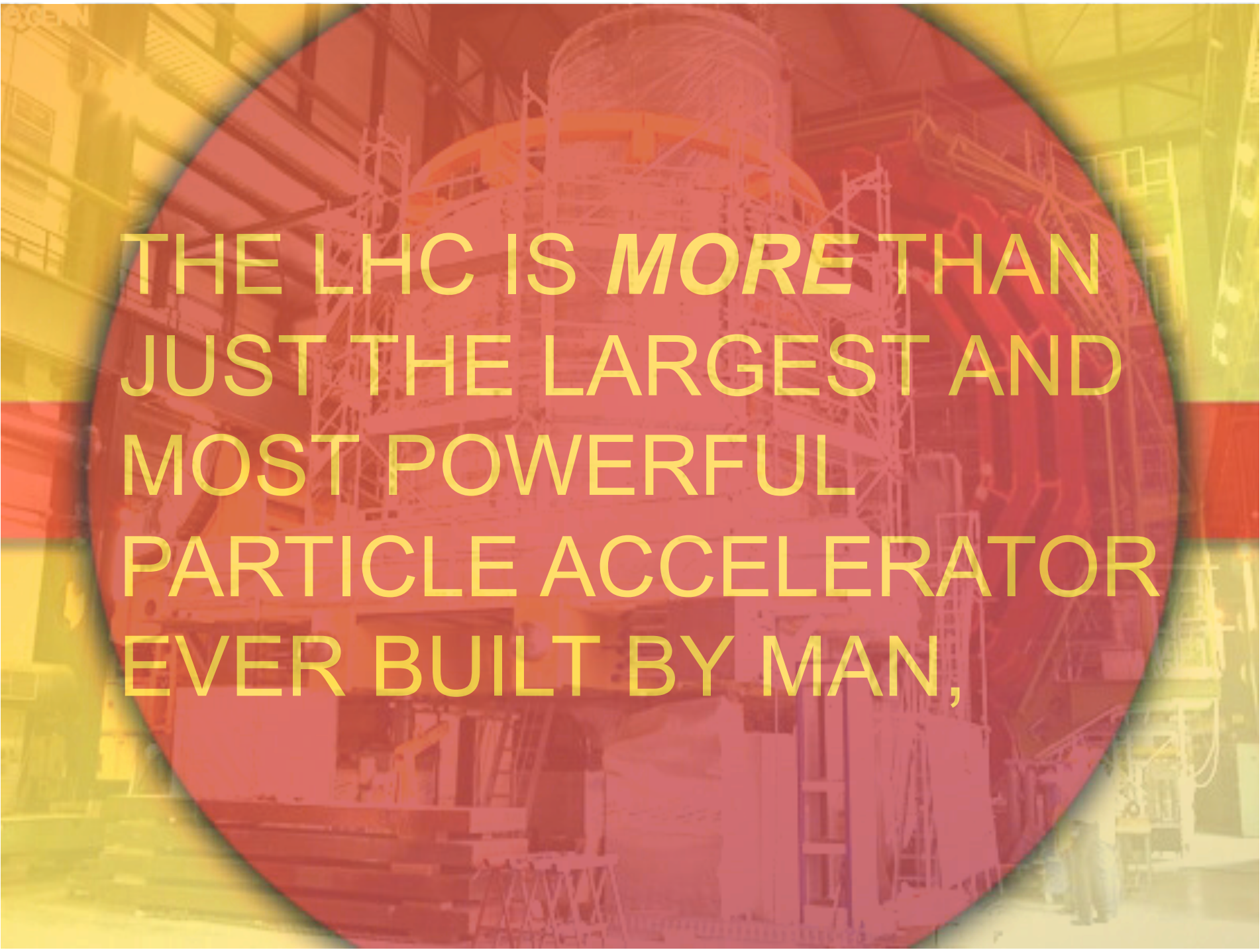
**WHY DOES OUR UNIVERSE HAVE SUCH AN IMBALANCE
OF MATTER OVER “ANTIMATTER”?**

**DO AN INFINITE NUMBER OF “PARALLEL
UNIVERSES” EXIST ALL AROUND US?**

**WILL WE EVER FIND THE KEY TO QUANTUM
GRAVITY AND A “THEORY OF EVERYTHING”?**

A complex network diagram with a central hub and many radiating lines connecting to numerous colorful nodes. The nodes are small spheres in various colors (red, blue, green, yellow, purple, cyan) and are connected by thin, multi-colored lines. The background is dark with a large, faint circular pattern. The text "WHAT IS THE FUTURE OF OUR UNIVERSE?" is overlaid in the center in a bold, yellow font.

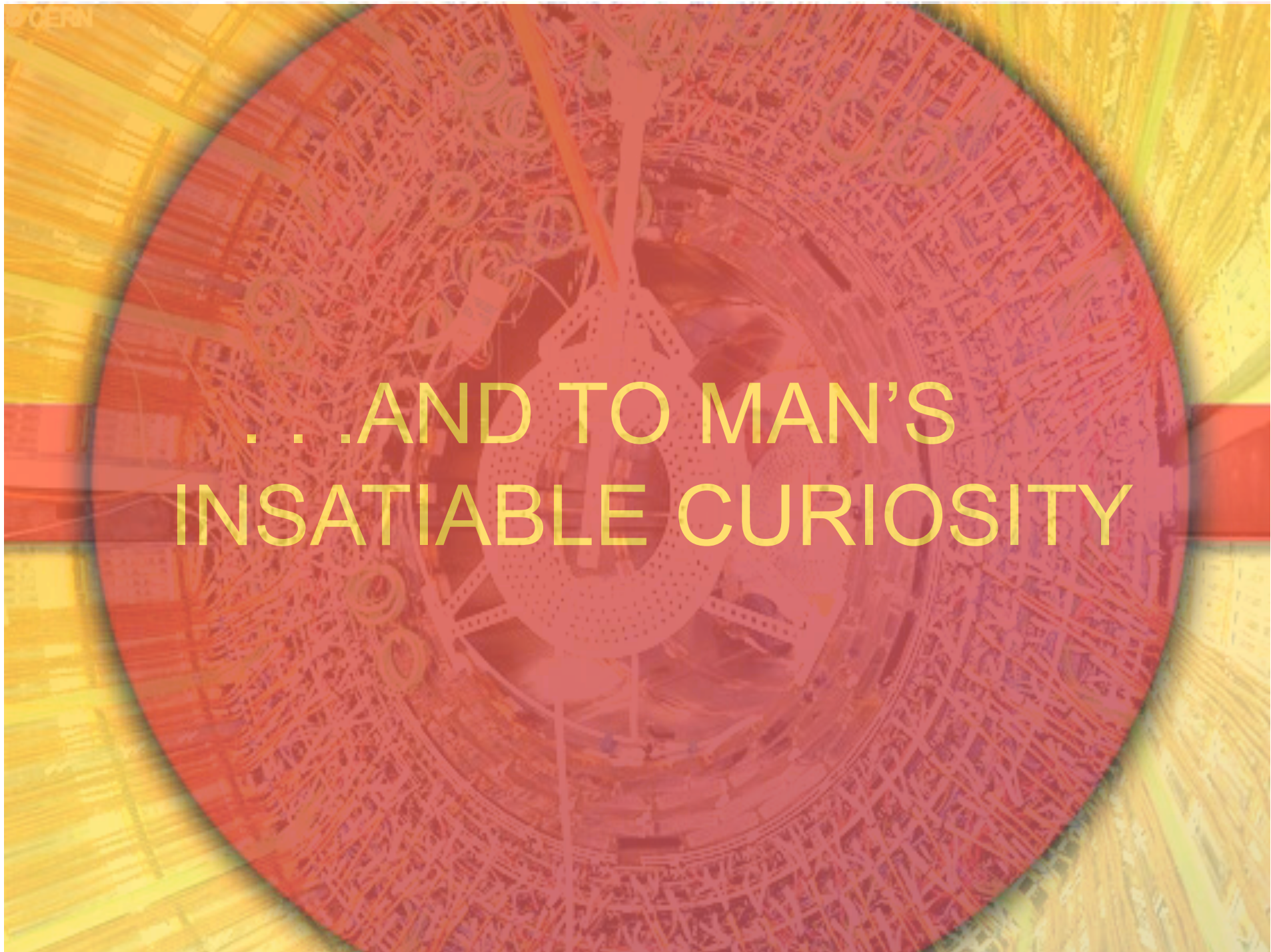
WHAT IS THE FUTURE OF OUR UNIVERSE?



THE LHC IS *MORE* THAN
JUST THE LARGEST AND
MOST POWERFUL
PARTICLE ACCELERATOR
EVER BUILT BY MAN,

IT IS A TESTIMONY TO
THE HUMAN SPIRIT,
THE STRENGTH OF
COOPERATION
AND INGENUITY,

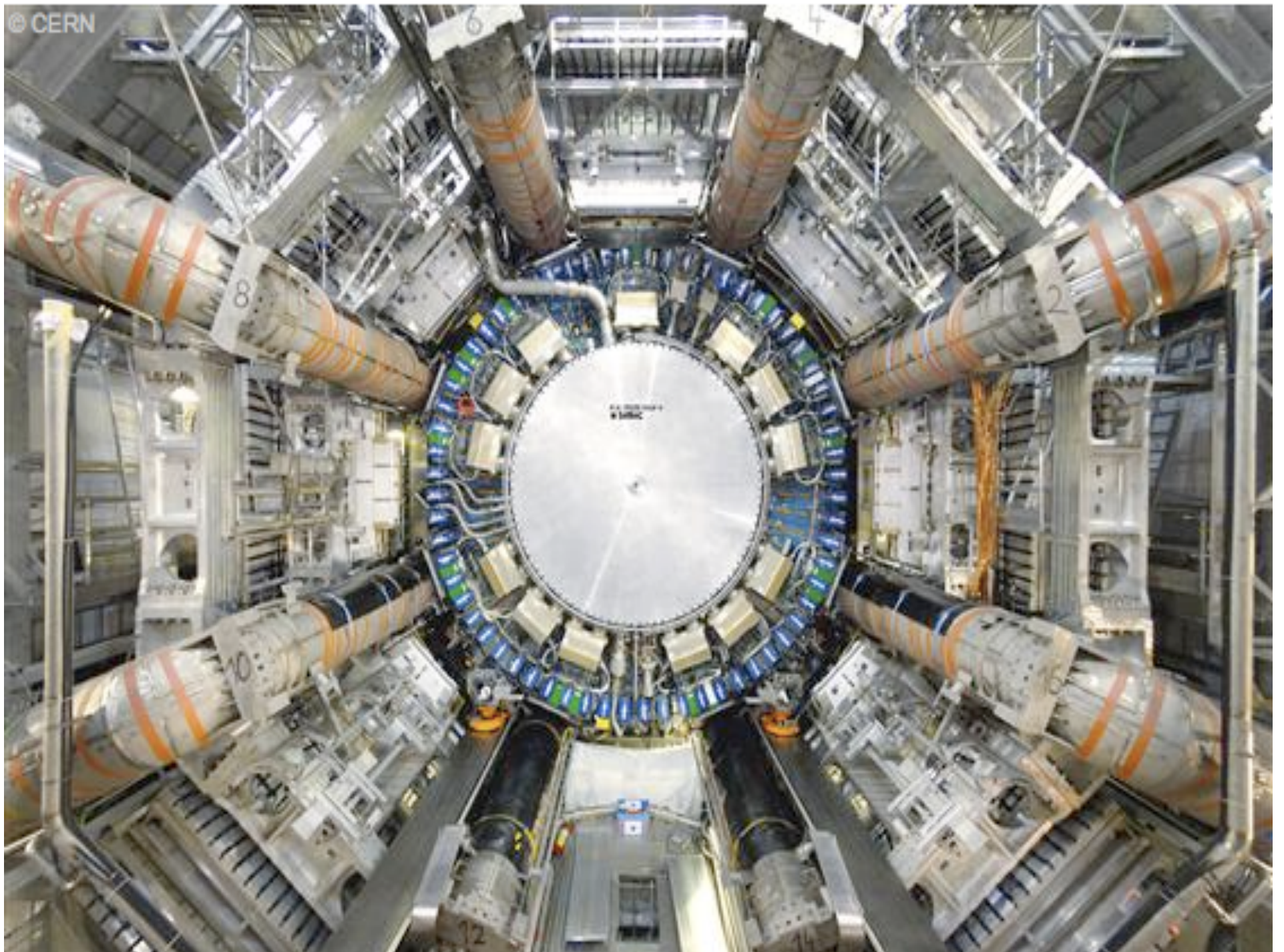
...AND TO MAN'S
INSATIABLE CURIOSITY



TO BETTER UNDERSTAND
THE WORLD AROUND
HIM AND HIS PLACE
IN IT.

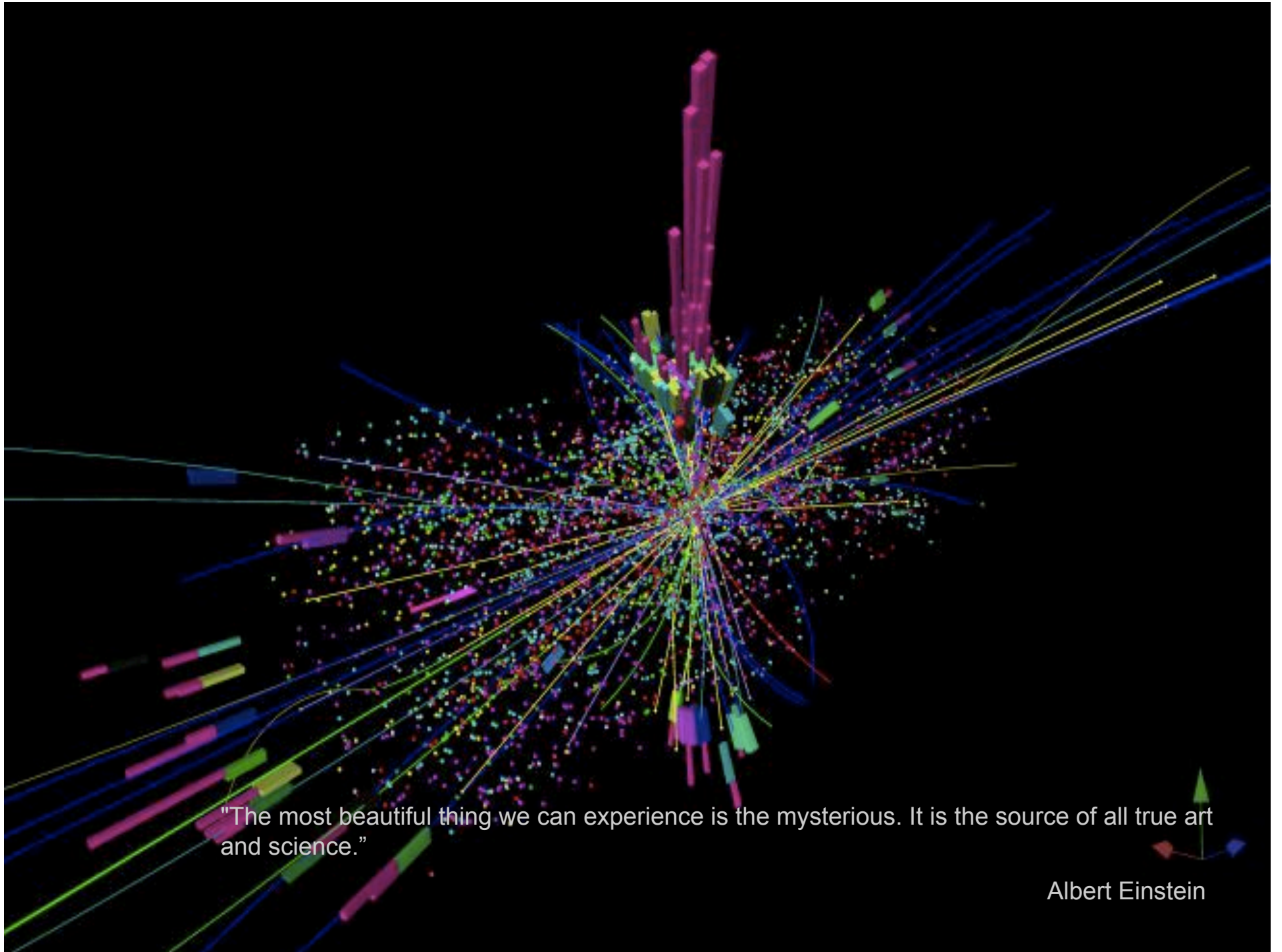












"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science."

Albert Einstein

REFERENCES AND SOURCES

This presentation could not have been made without the following sources:

The CERN Publication Office, including the ATLAS, CMS,
LHCb AND ALICE sites

Maximillien Brice, Mona Schweizer

The Keynote Presenters at the Teachers' Conference at the
Kavli Institute for Theoretical Physics at UCSB (Director Dr. David Gross):

Ayana Holloway Arce

Raman Sundrum

Kevin McFarland

James Wells

NASA - The CHANDRA PROJECT and The HUBBLE SPACE TELESCOPE

The Einstein Archives

SLAC

FERMILAB

The American Institute of Physics

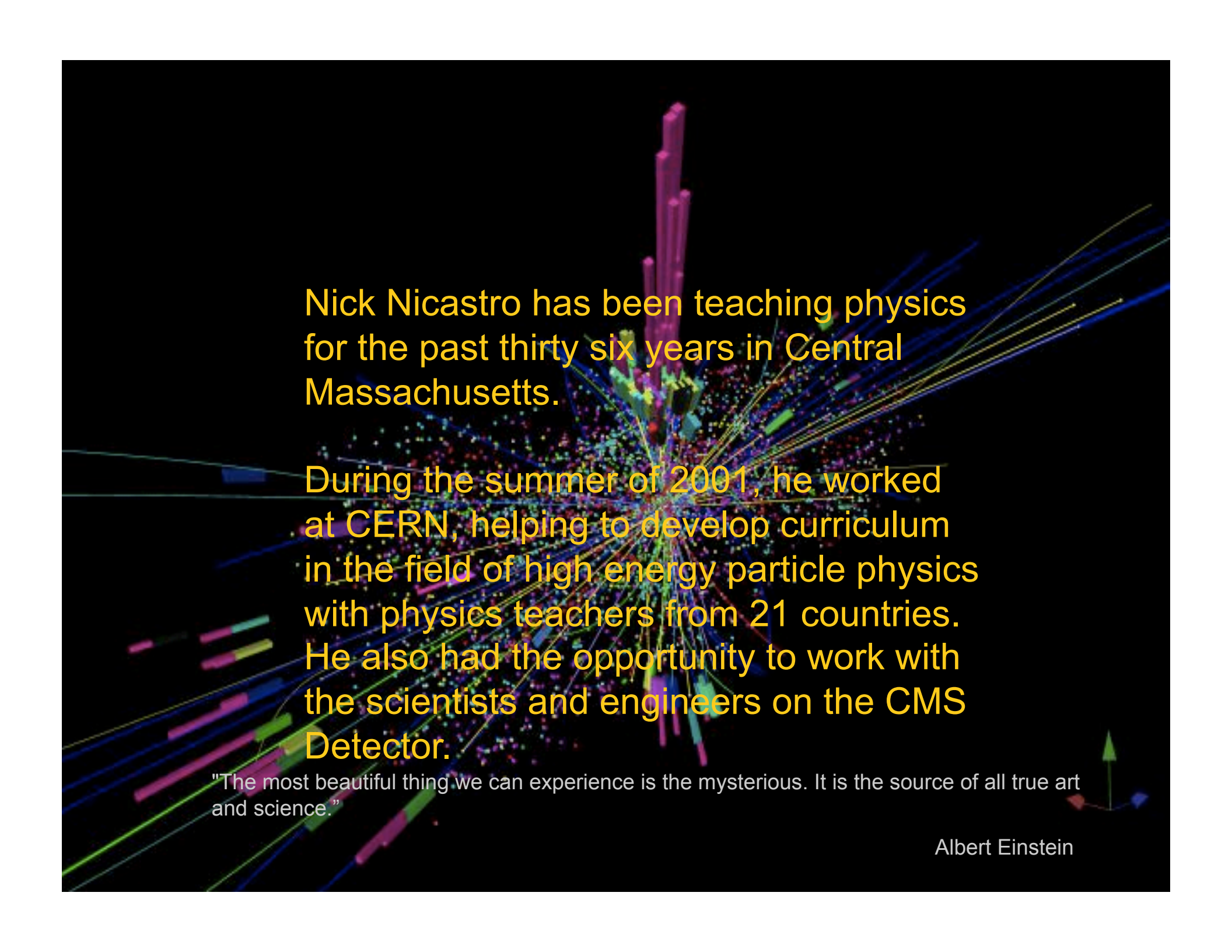
The American Physical Society

The American Association of Physics Teachers

PhysicsWorld.com

"The most beautiful thing we can experience is the mysterious. It is the source of all true art
and science."

Albert Einstein

A complex visualization of particle tracks, likely from a detector like CMS. The image shows a central point from which numerous tracks radiate outwards. The tracks are composed of many small segments in various colors, including purple, blue, green, and yellow. Some tracks are straight, while others are curved or branched. The background is black, making the colorful tracks stand out.

Nick Nicaastro has been teaching physics for the past thirty six years in Central Massachusetts.

During the summer of 2001, he worked at CERN, helping to develop curriculum in the field of high energy particle physics with physics teachers from 21 countries. He also had the opportunity to work with the scientists and engineers on the CMS Detector.

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