

TEACHING MODULES IN PARTICLE PHYSICS FOR STUDENTS AGED 14-15 YEARS

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CERN Education Group

*EIROforum Teacher School
CERN, Geneva
Thursday, November 19, 2009*



What we are attempting to do:



What we are attempting to do:

Make modern physics

(in particular, particle physics)

interesting and exciting to students

and...

What we are attempting to do:

Make modern physics

(in particular, particle physics)

interesting and *exciting* to students

and...

do so at *earlier* stages in their
science curriculum.



How we are attempting to do it:



How we are attempting to do it:

Develop Teaching Modules that:

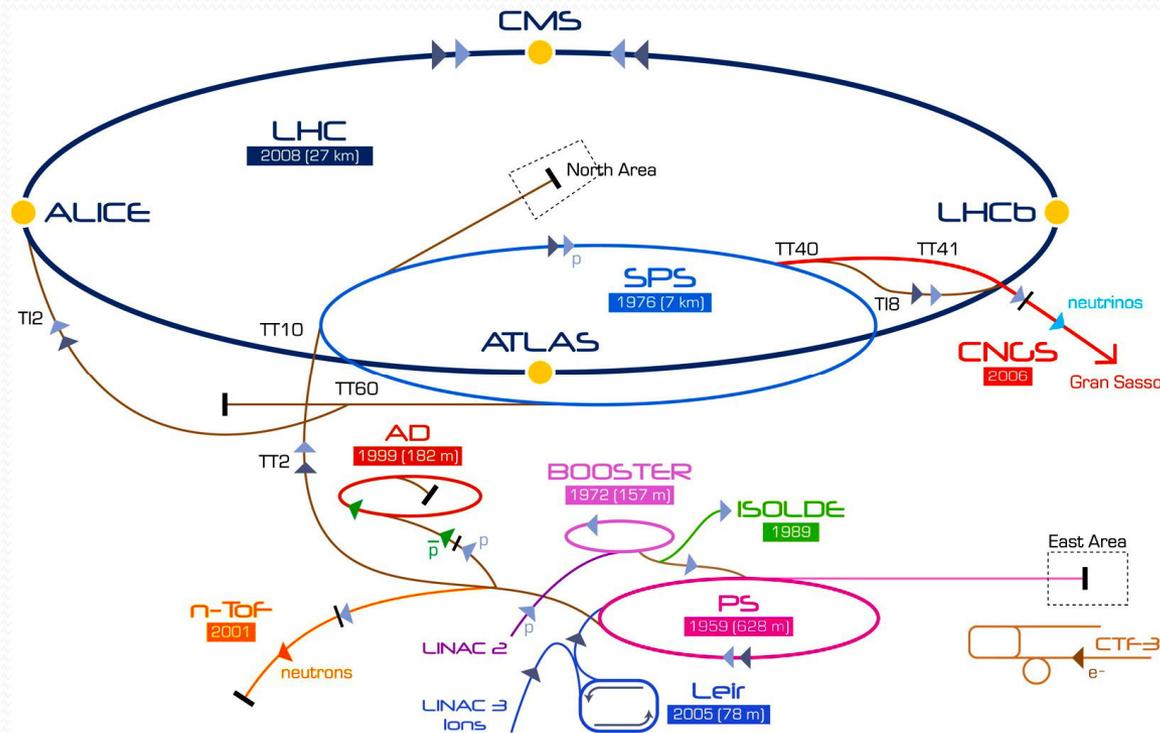
How we are attempting to do it:

Use as a target group 14-15 year olds



How we are attempting to do it:

Use topics that are related to the experiments being done at CERN...





How we are attempting to do it:

...AND...



How we are attempting to do it:

...AND...

...have a built-in “WOW” factor



How we are attempting to do it:

...AND...

...have a built-in “WOW” factor

such as...



ANTIMATTER

STAR TREK

05.08.09

A dramatic image of Darth Vader from Star Wars, shown from the chest up. He is wearing his iconic black helmet and armor, and is holding a glowing yellow lightsaber in his right hand. The background is a fiery, orange and red landscape, possibly a volcanic planet, with a bright light source on the right side. The overall mood is intense and menacing.

DARK MATTER

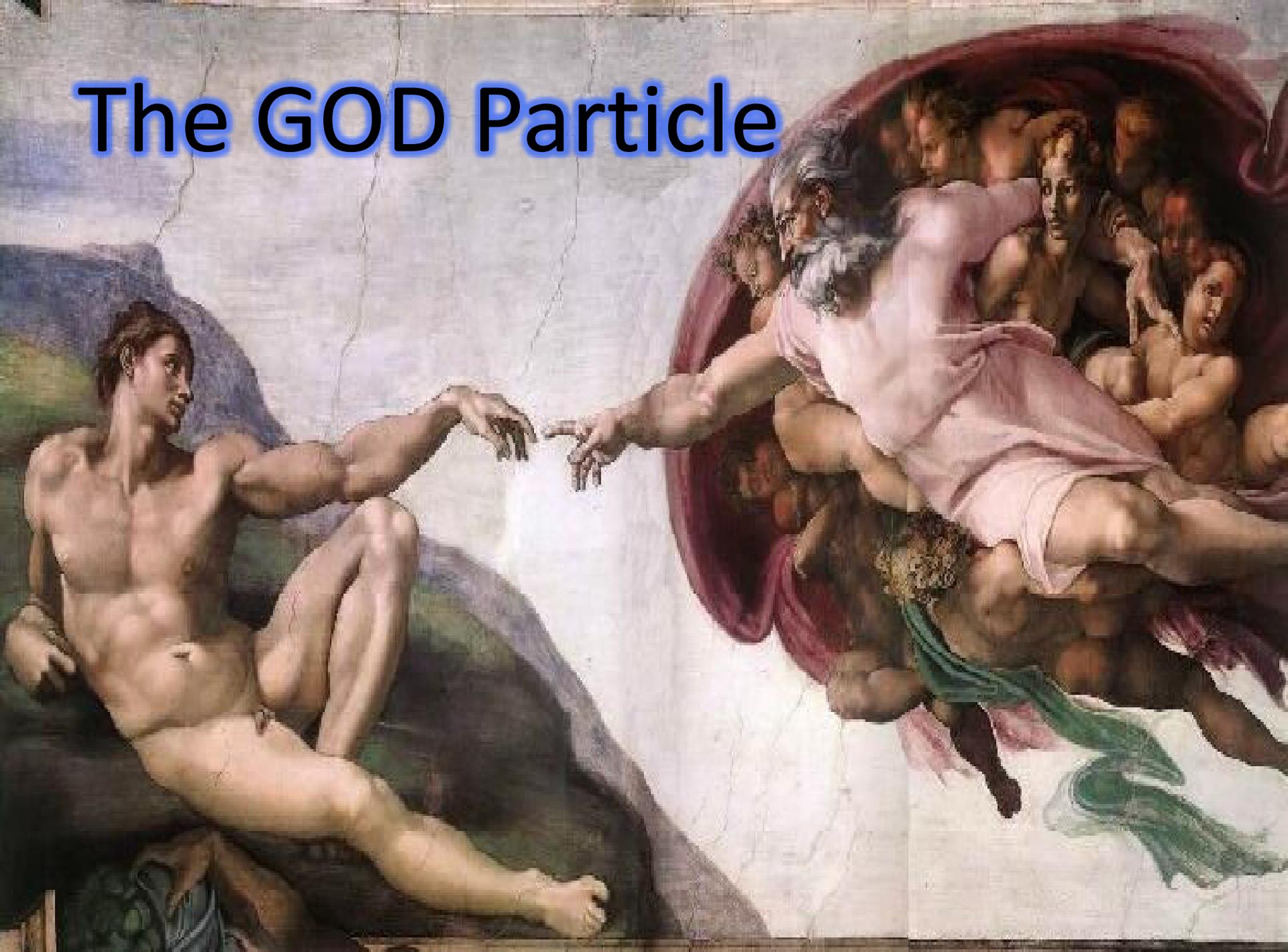
&

DARK ENERGY

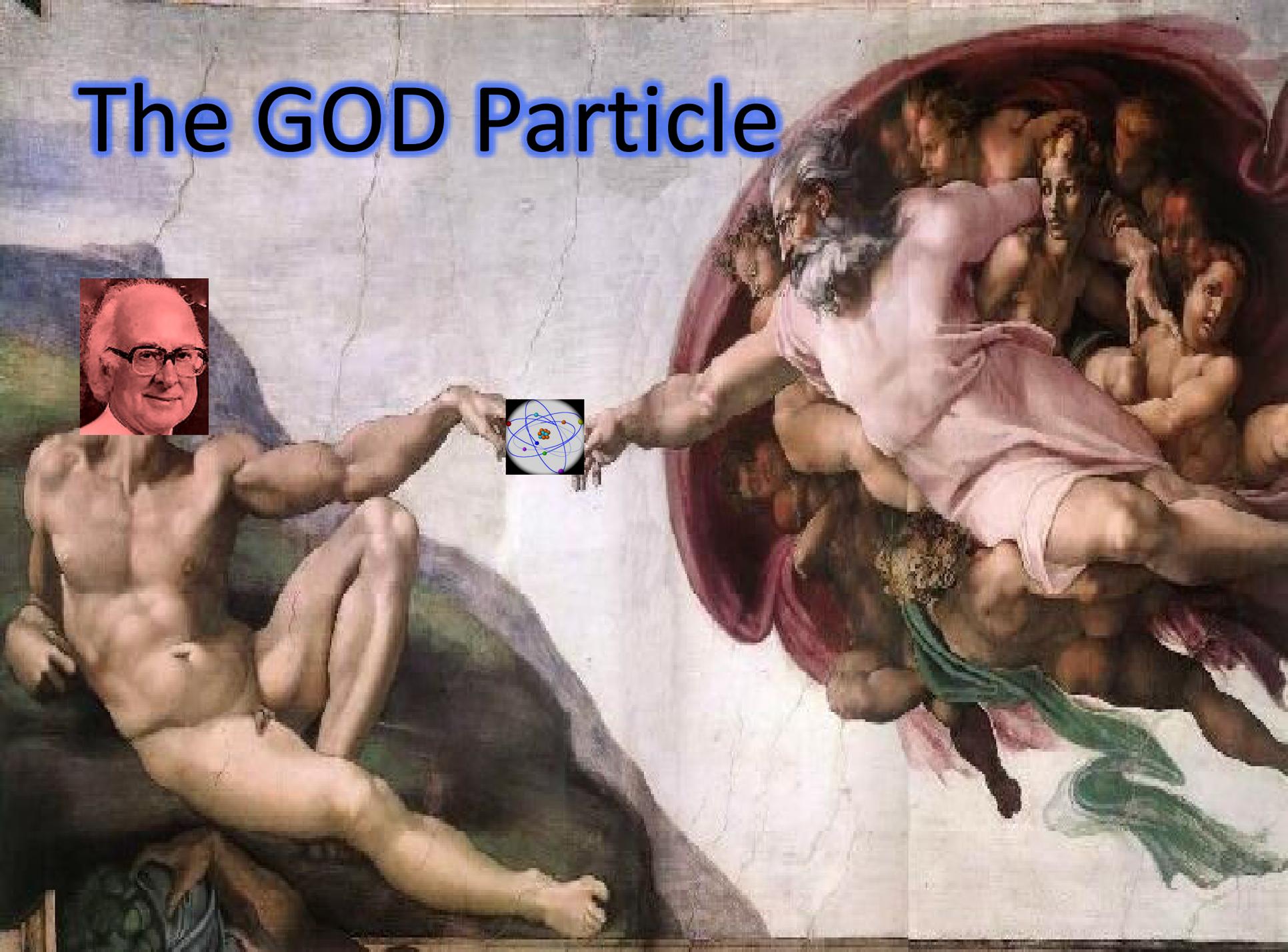
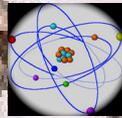
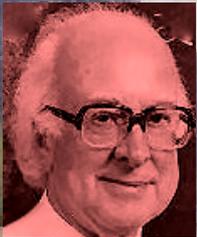
The Higgs Boson

The Higgs Boson, also known as

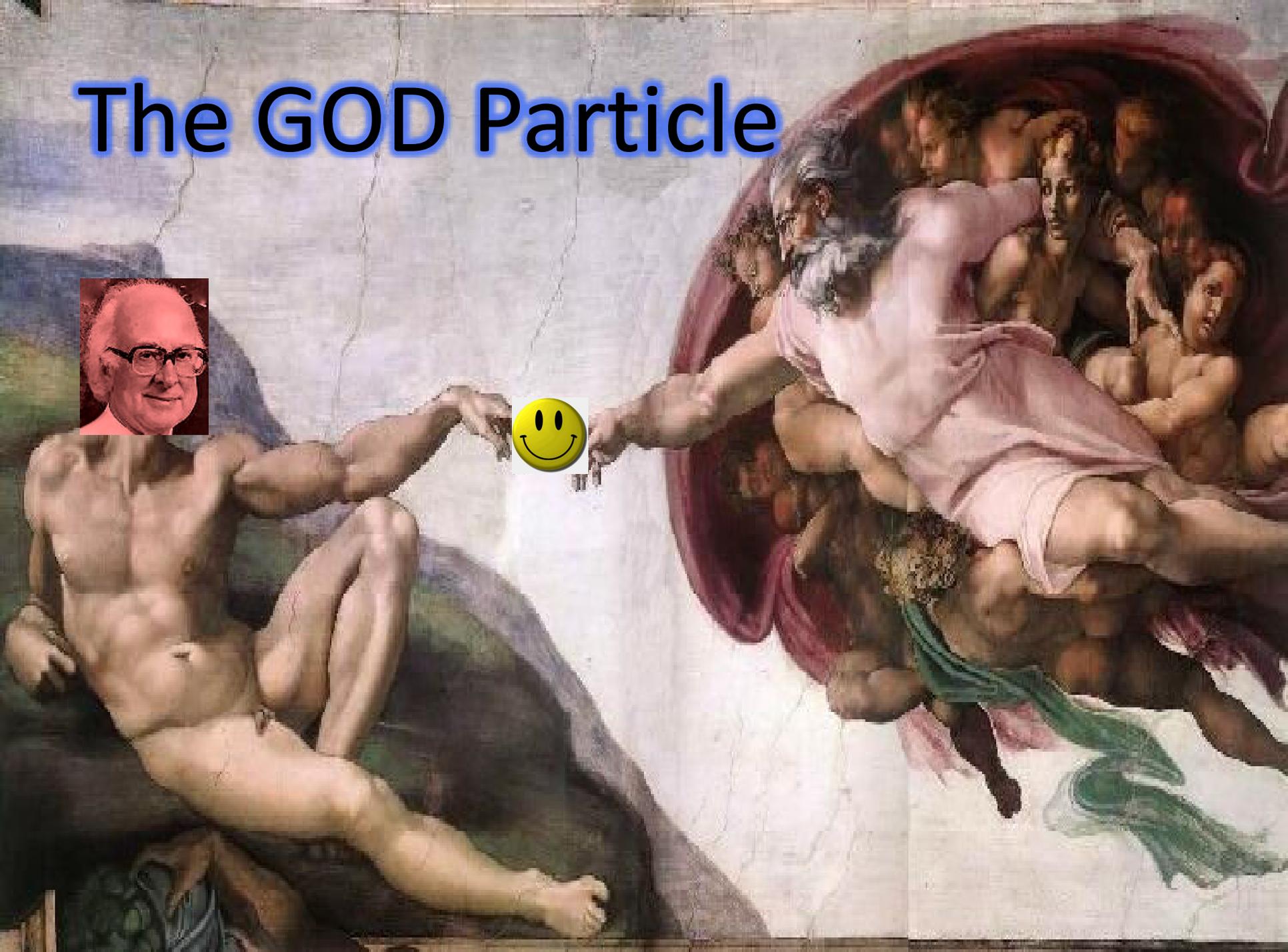
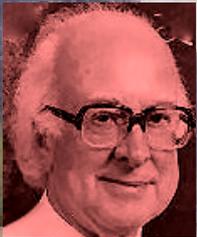
The GOD Particle



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- ✓ *Lesson plans that can be easily integrated into national science curricula.*

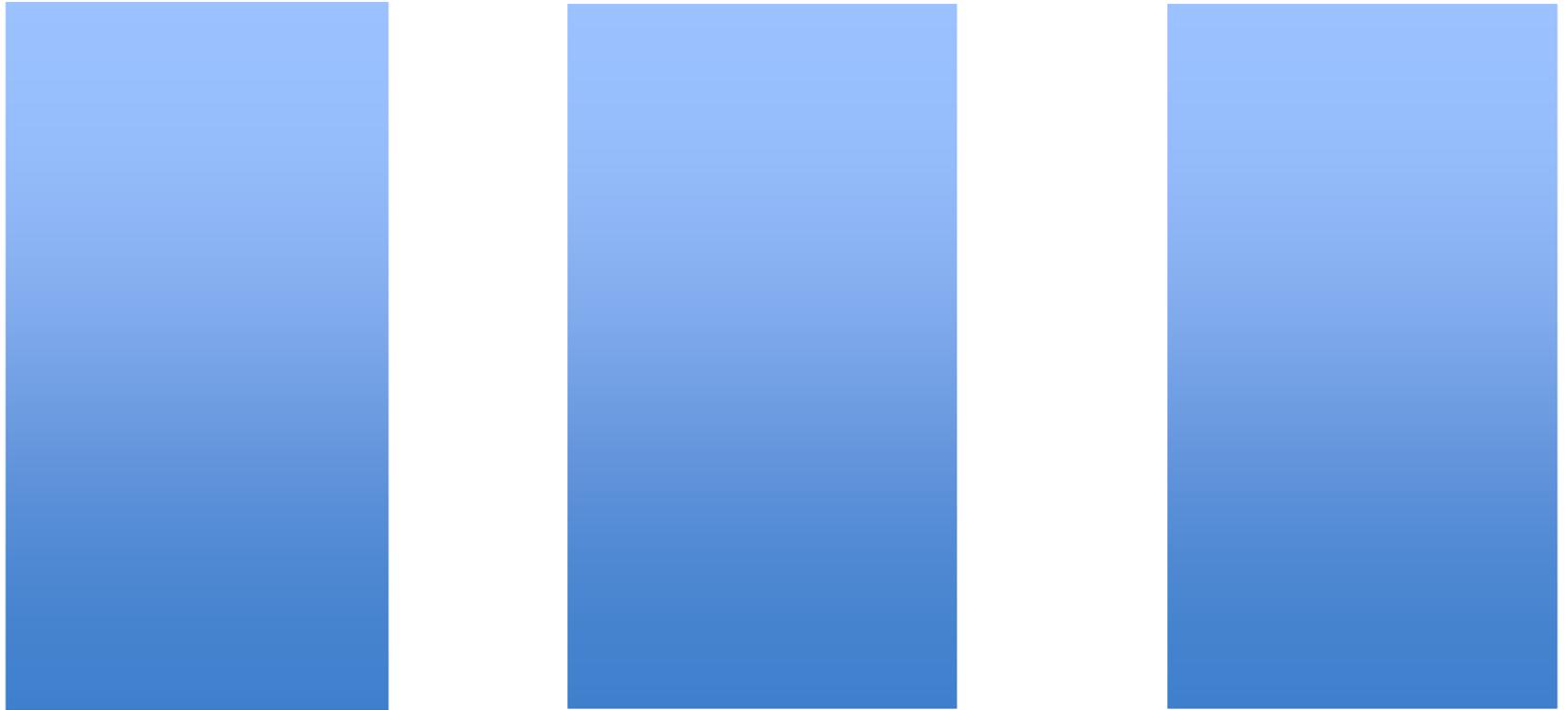
The following slides use curricula from Ontario (Canada), Norway and The International Baccalaureate Middle Years Programme. For more information, please consult the following links:

<http://www.edu.gov.on.ca/eng/>

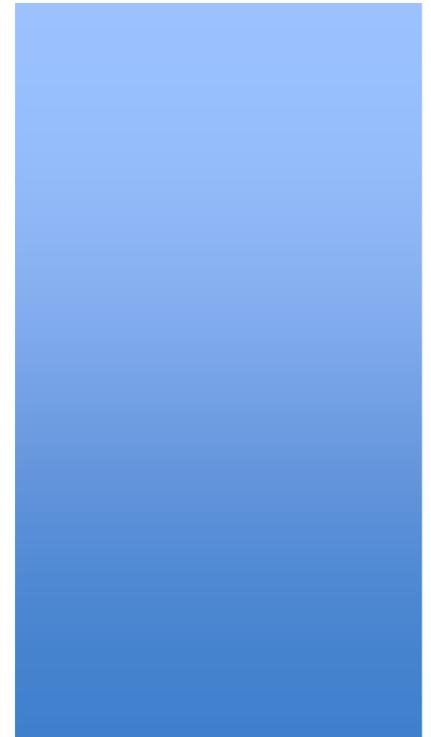
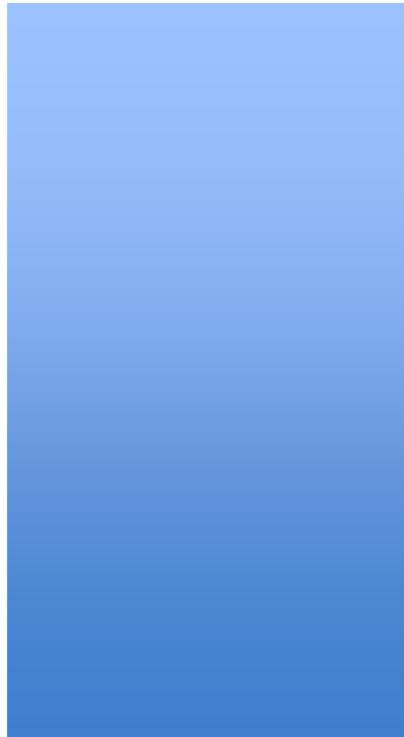
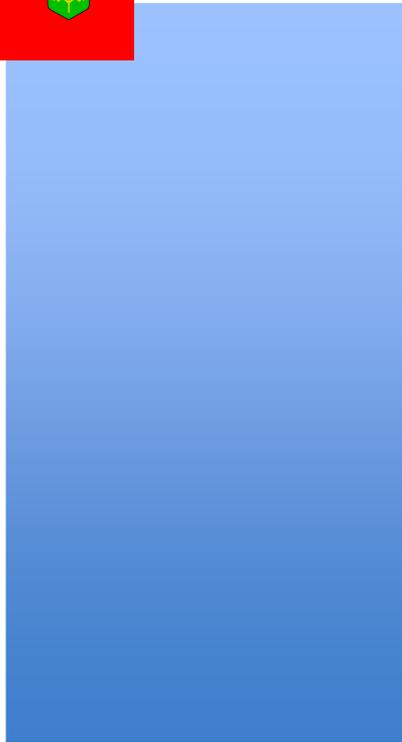
<http://www.udir.no/Tema/In-English/>

<http://www.ibo.org/myp/>

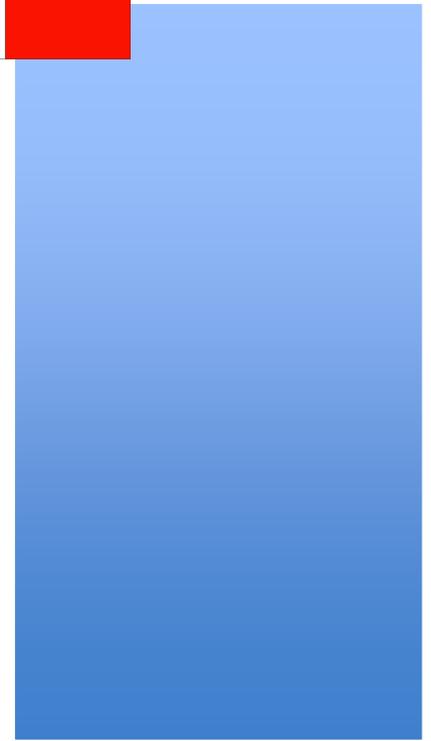
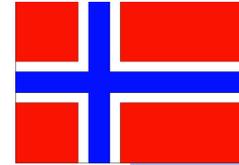
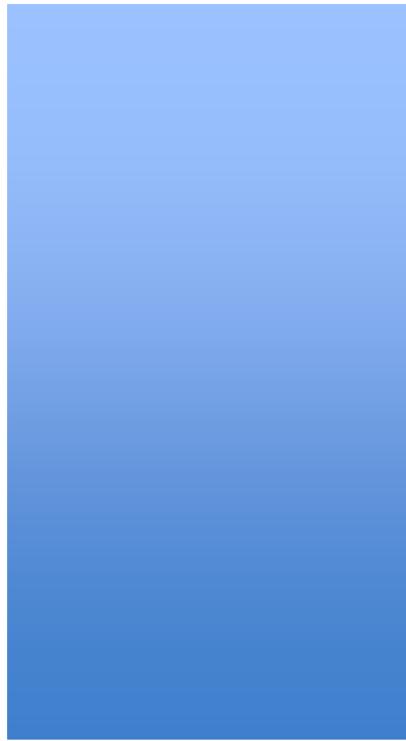
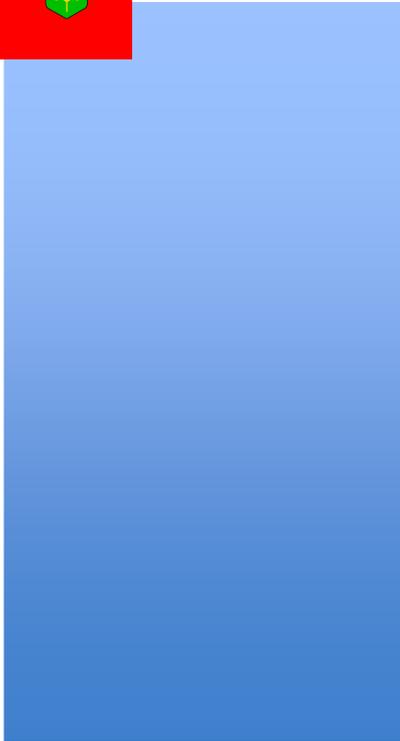
Transnational Sample of Lower Secondary Science Curriculum Objectives



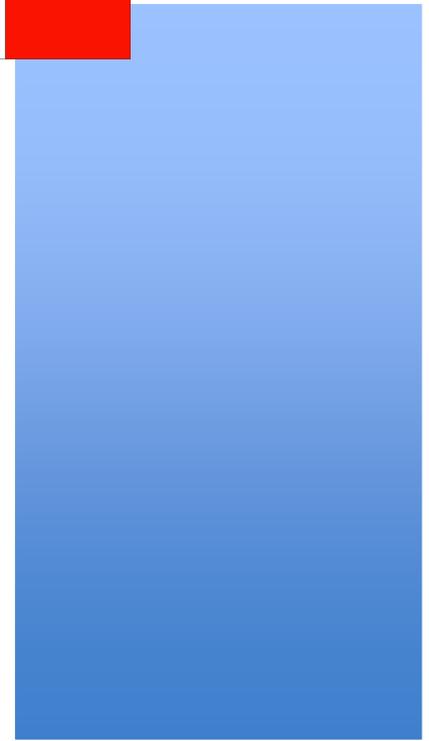
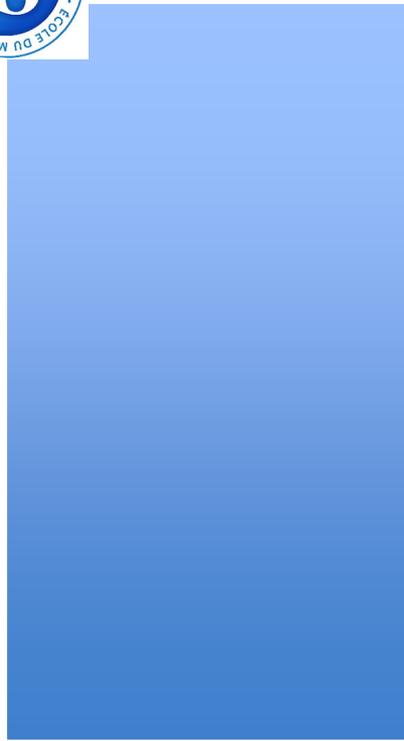
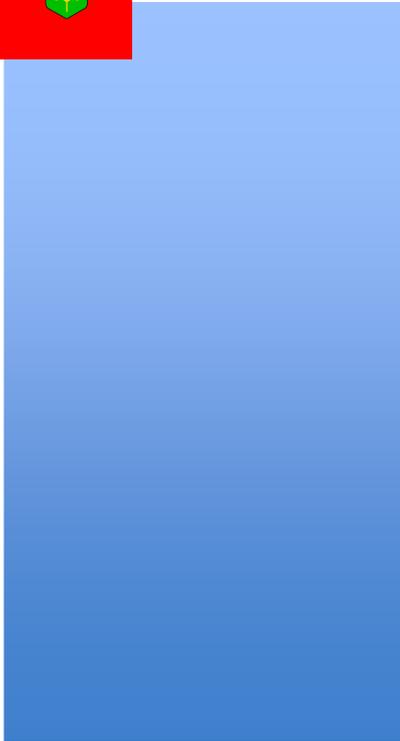
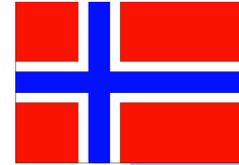
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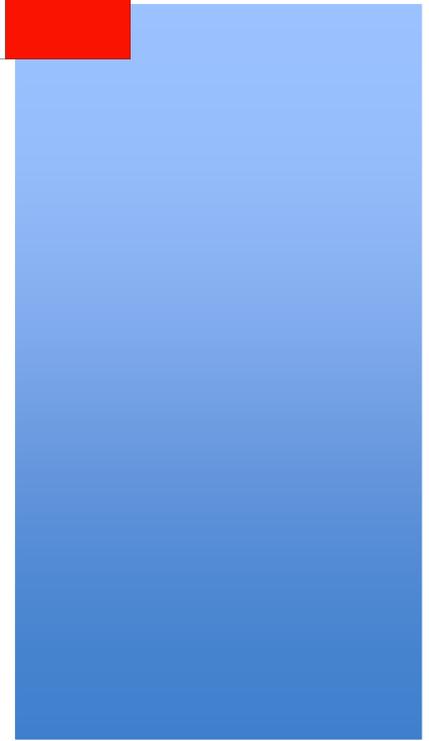
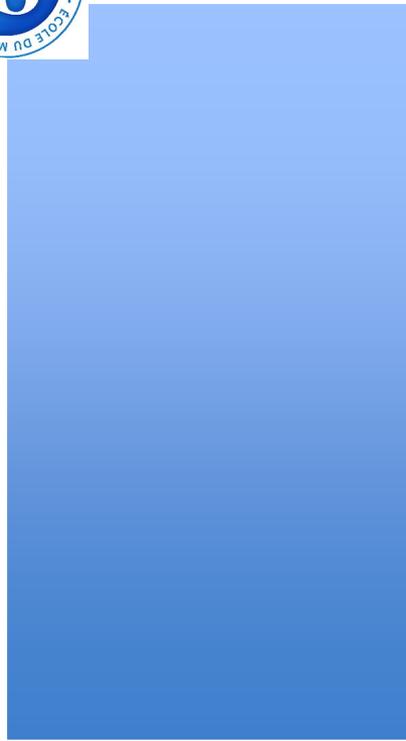
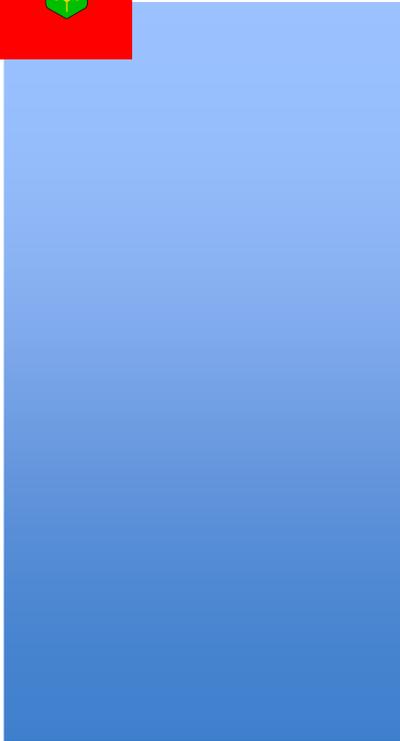
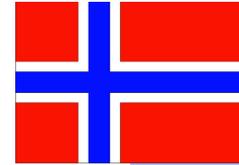
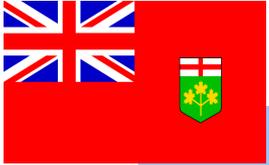
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Evolution of the Universe

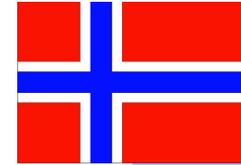


Evolution of the Universe



- **Earth and Space Science: The Study of the Universe**
(Grade 9 of 12)

- *“describe observational and theoretical evidence relating to the origin and evolution of the universe (e.g., evidence supporting the big bang theory)”.*

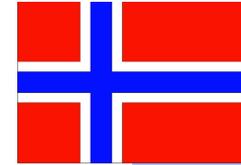


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- Space (by the end of Grade 10 of 13)

• *“describe the universe and the various theories for how the universe has evolved”.*

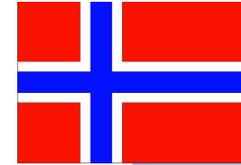
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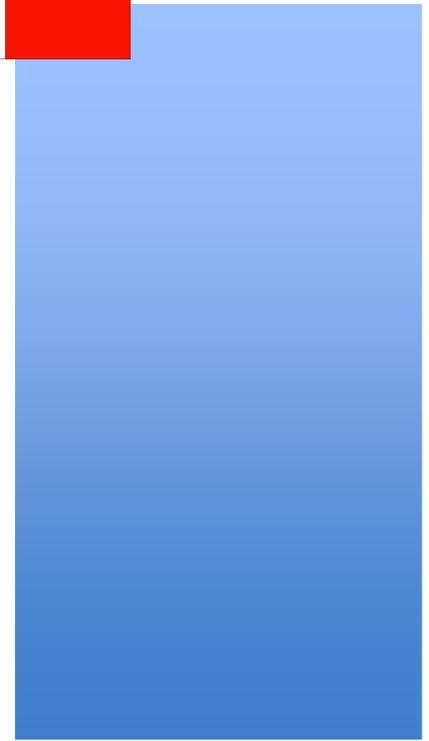
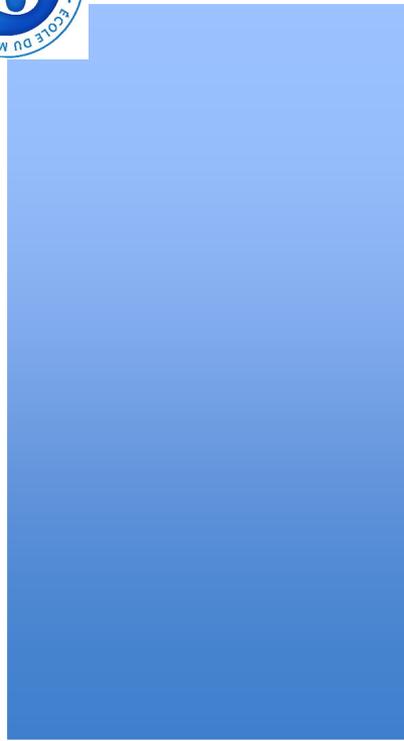
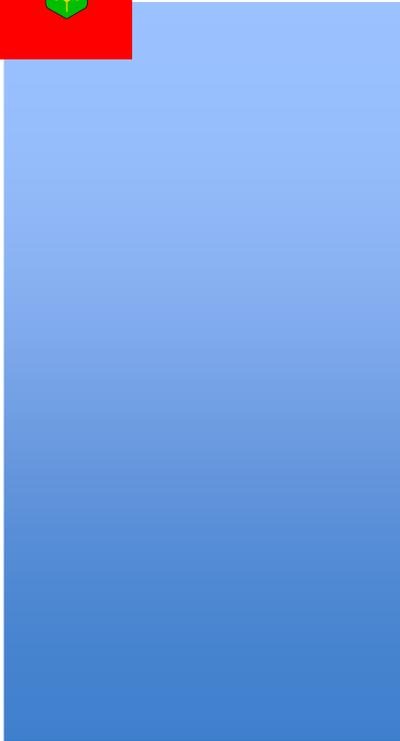
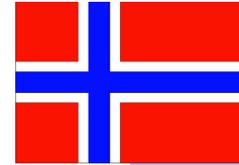


- **Earth and space** (by the end of MYP = Grade 11 of 13)
- *“develop an understanding of the architecture of the universe, become aware of the scientific aspects of the origin and structure of the universe (and) the theories about (its) origin”.*

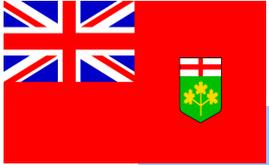


- **Space** (by the end of Grade 10 of 13)
- *“describe the universe and the various theories for how the universe has evolved”.*

Fundamental Particles

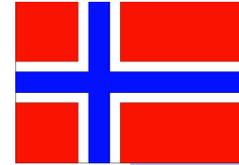


Fundamental Particles

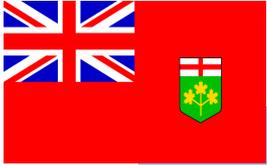


- Chemistry: Atoms, Elements, and Compounds (Grade 9 of 12)

• *“Describe the characteristics of neutrons, protons, and electrons, including charge, location, and relative mass”.*

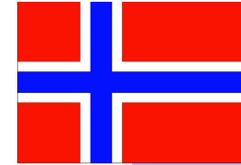


Fundamental Particles



- Chemistry: Atoms, Elements, and Compounds (Grade 9 of 12)

• *“Describe the characteristics of neutrons, protons, and electrons, including charge, location, and relative mass”.*



- Phenomena and Matter (by the end of Grade 7 of 13)

• *“Explain how matter is built up, and how matter can be transformed by using the concepts atoms and molecules”.*

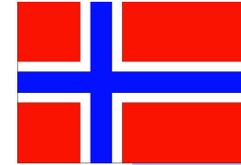
Fundamental Particles



- **Chemistry: Atoms, Elements, and Compounds** (Grade 9 of 12)
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- **Structure of matter** (by the end of MYP = Grade 11 of 13)
- *Some of the content areas are suggested are the “atomic model and the concept of particulate nature of matter, the Idea of conservation of mass”.*



- **Phenomena and Matter** (by the end of Grade 7 of 13)
- *“Explain how matter is built up, and how matter can be transformed by using the concepts atoms and molecules”.*

Some features of the modules:

- ✓ *Lesson plans that can be easily integrated into national science curricula.*

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Cloud Chamber Experiment



<http://teachers.web.cern.ch/teachers/document/cloud-final.pdf>

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- ✓ *Incorporation of an experimental component.*
- ✓ *Videoconferencing possibilities.*

Photos are from a videoconference held between CERN and physics students at Berg videregående skole in Oslo, Norway on September 10th, 2008. Participating physicists were Erik Adli (University of Oslo) and Mick Storr (CERN)



Possible Format for a Lesson:

Possible Format for a Lesson:
The "Cinematic" Approach

Possible Format for a Lesson: *The "Cinematic" Approach*

- + The Teaser
- + Opening Credits
- + The Story
- + The End Credits
- + Post-Credits

Possible Format for a Lesson: *The "Cinematic" Approach*

- + **The Teaser** *Thought-provoking question*
- + **Opening Credits**
- + **The Story**
- + **The End Credits**
- + **Post-Credits**

Possible Format for a Lesson: *The "Cinematic" Approach*

- + **The Teaser** *Thought-provoking question (with a "WOW")*
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Possible Format for a Lesson: *The "Cinematic" Approach*

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- + **Post-Credits**

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Special Effects:

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Special Effects:

Interactive materials

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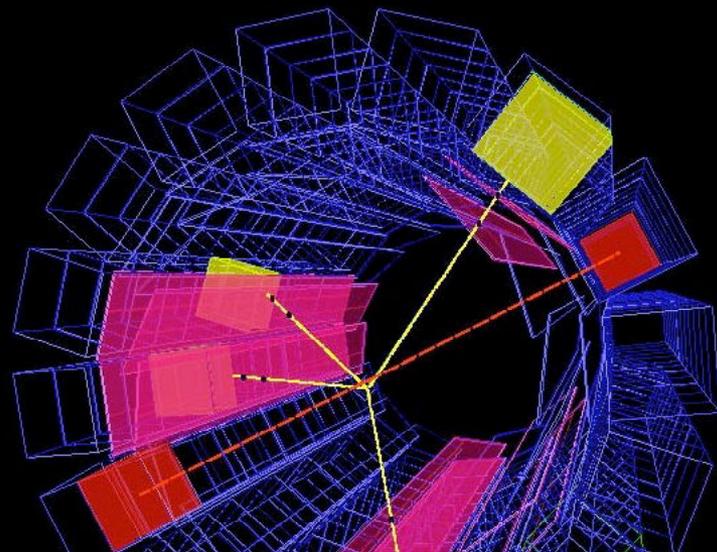
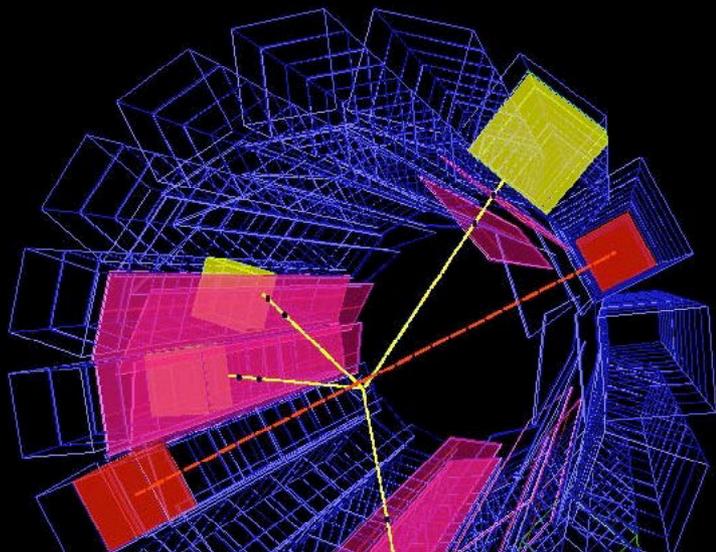
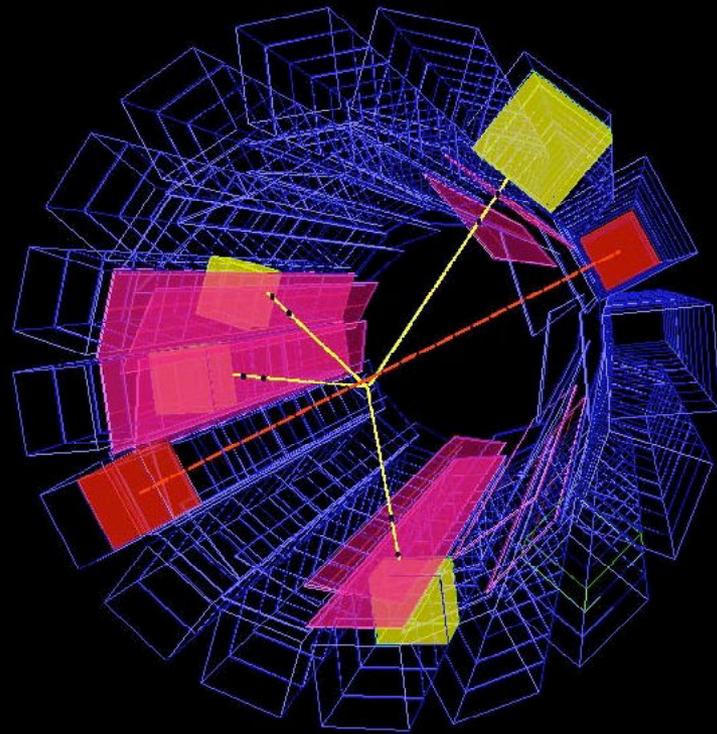
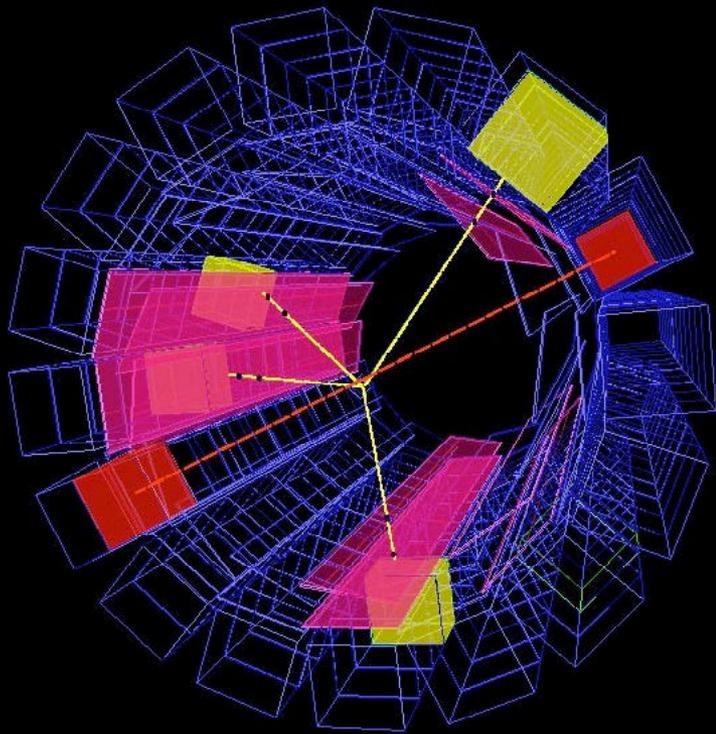
Interactive materials, hands-on experiments

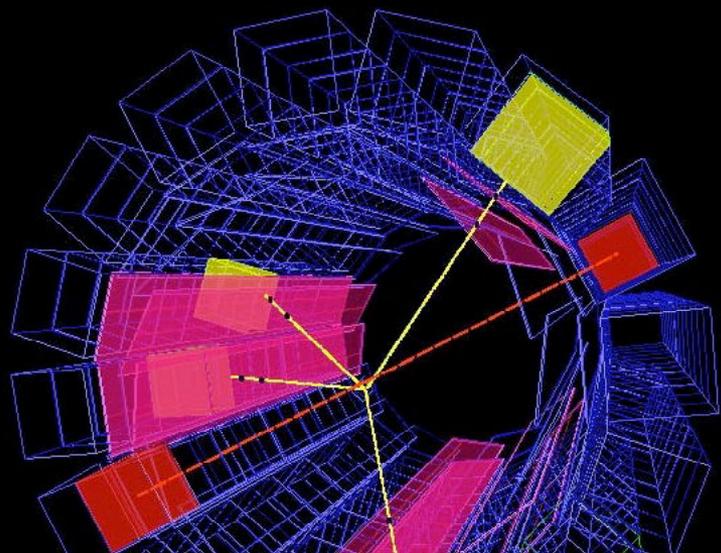
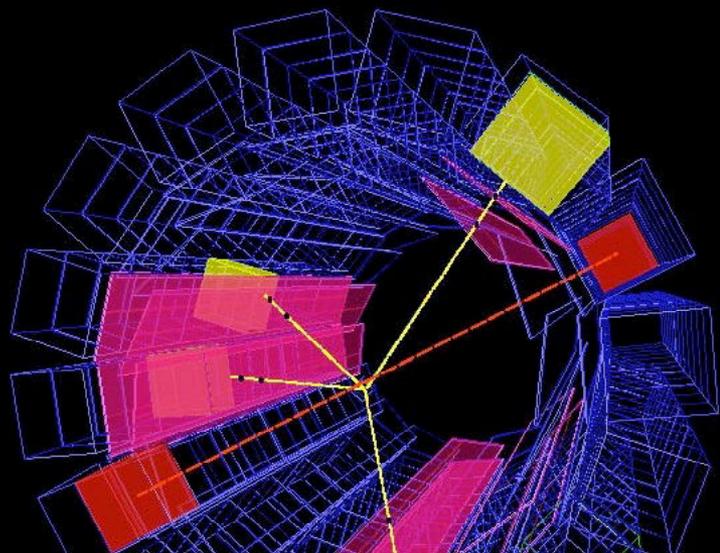
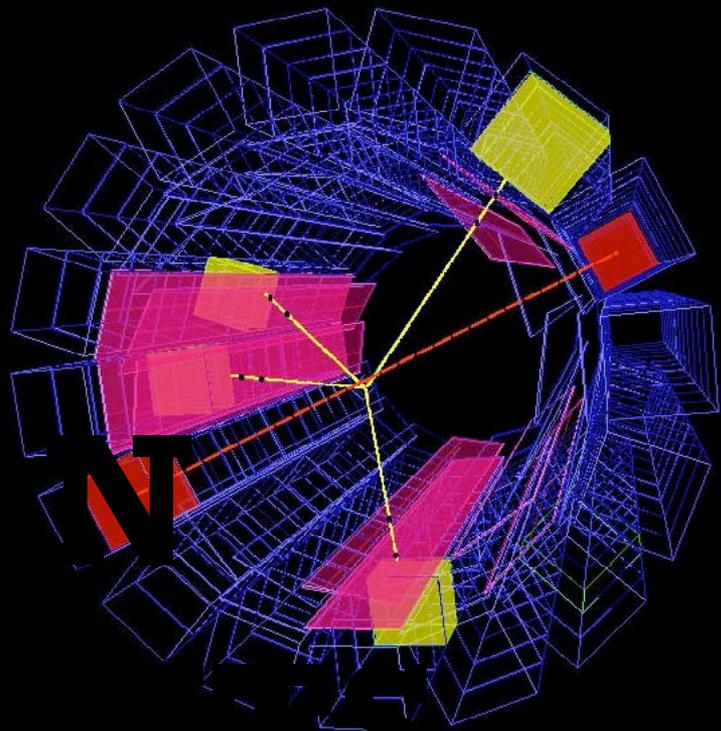
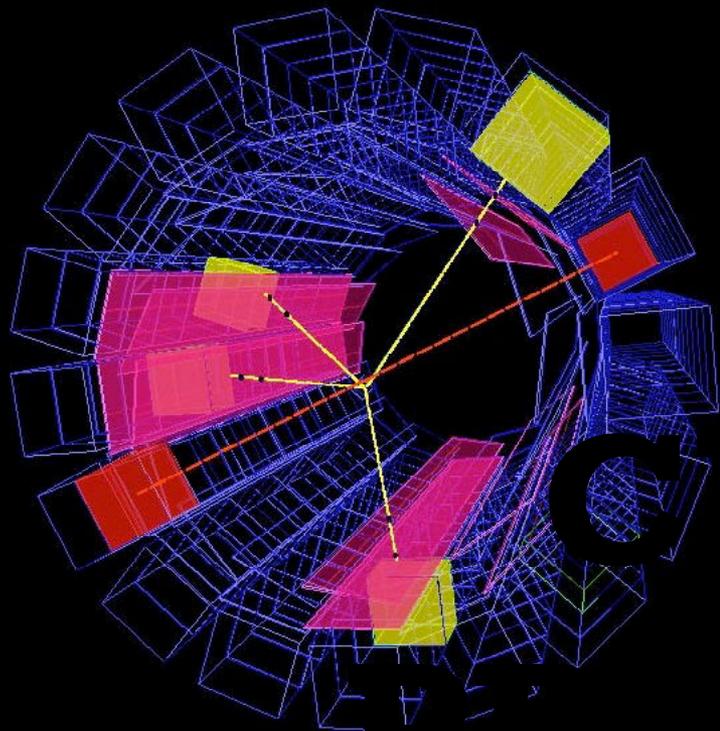
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- + Post-Credits** *Exercises, including problem-solving*

Special Effects:

Interactive materials, hands-on experiments, possible extension material



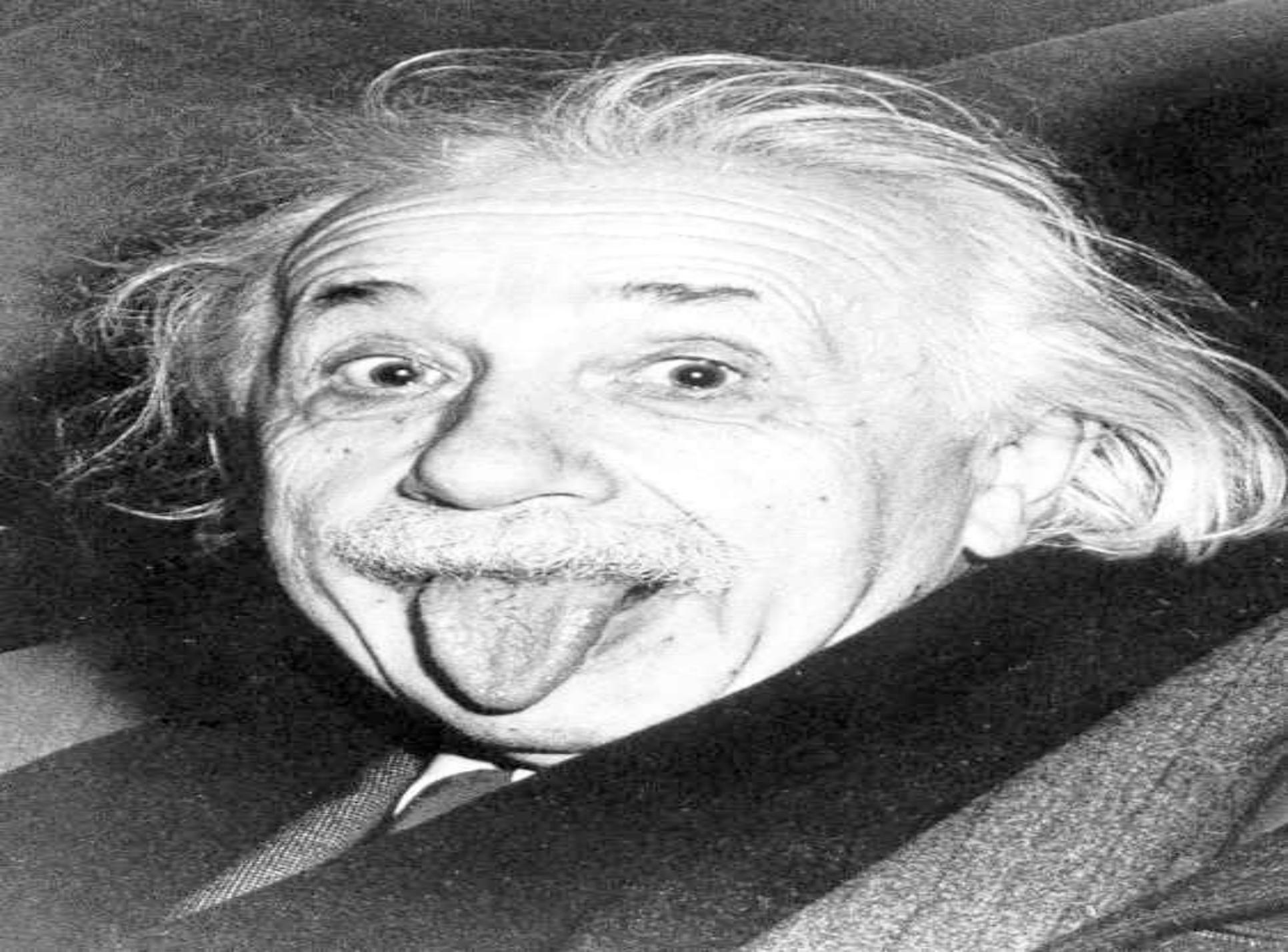












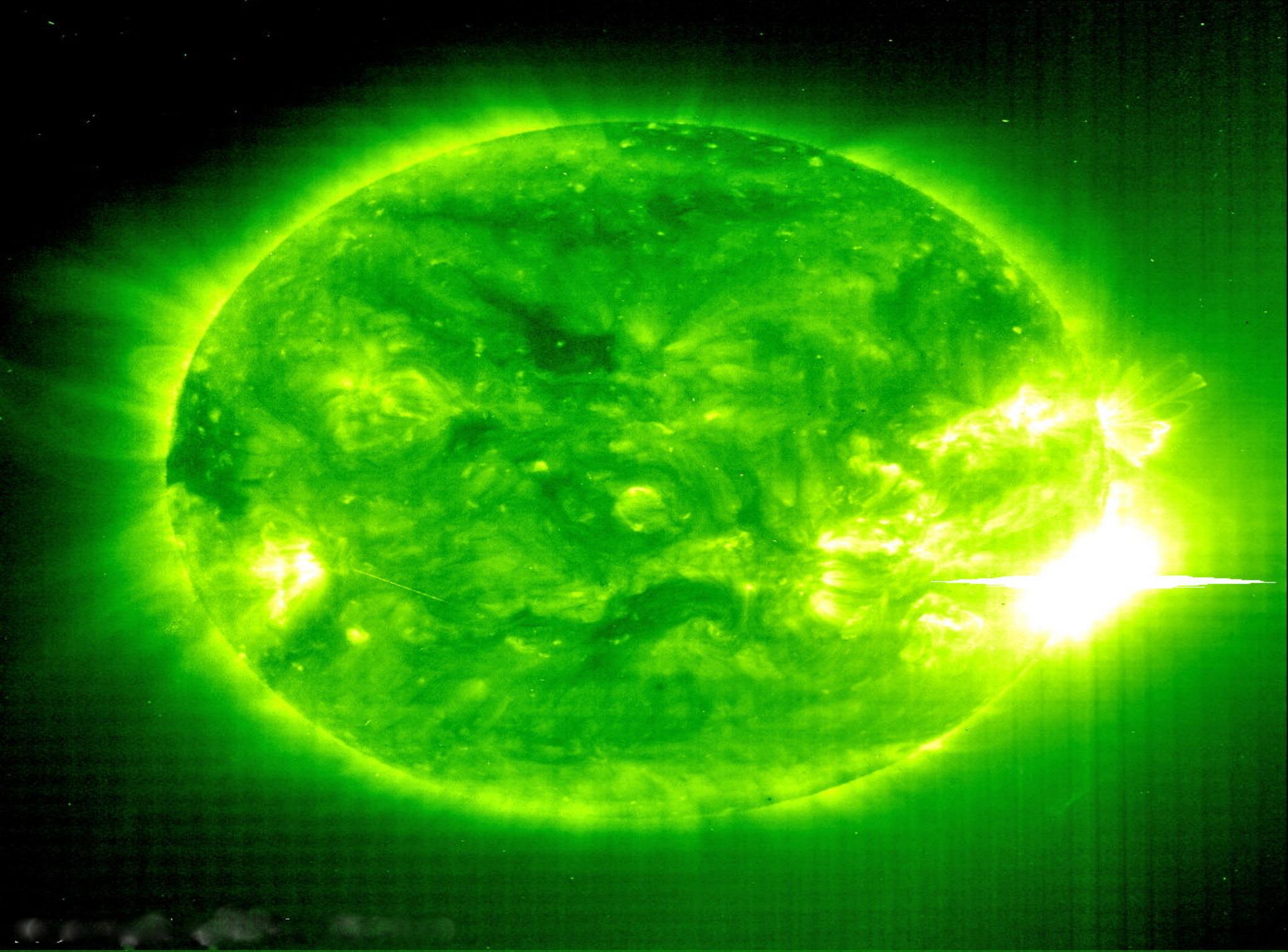


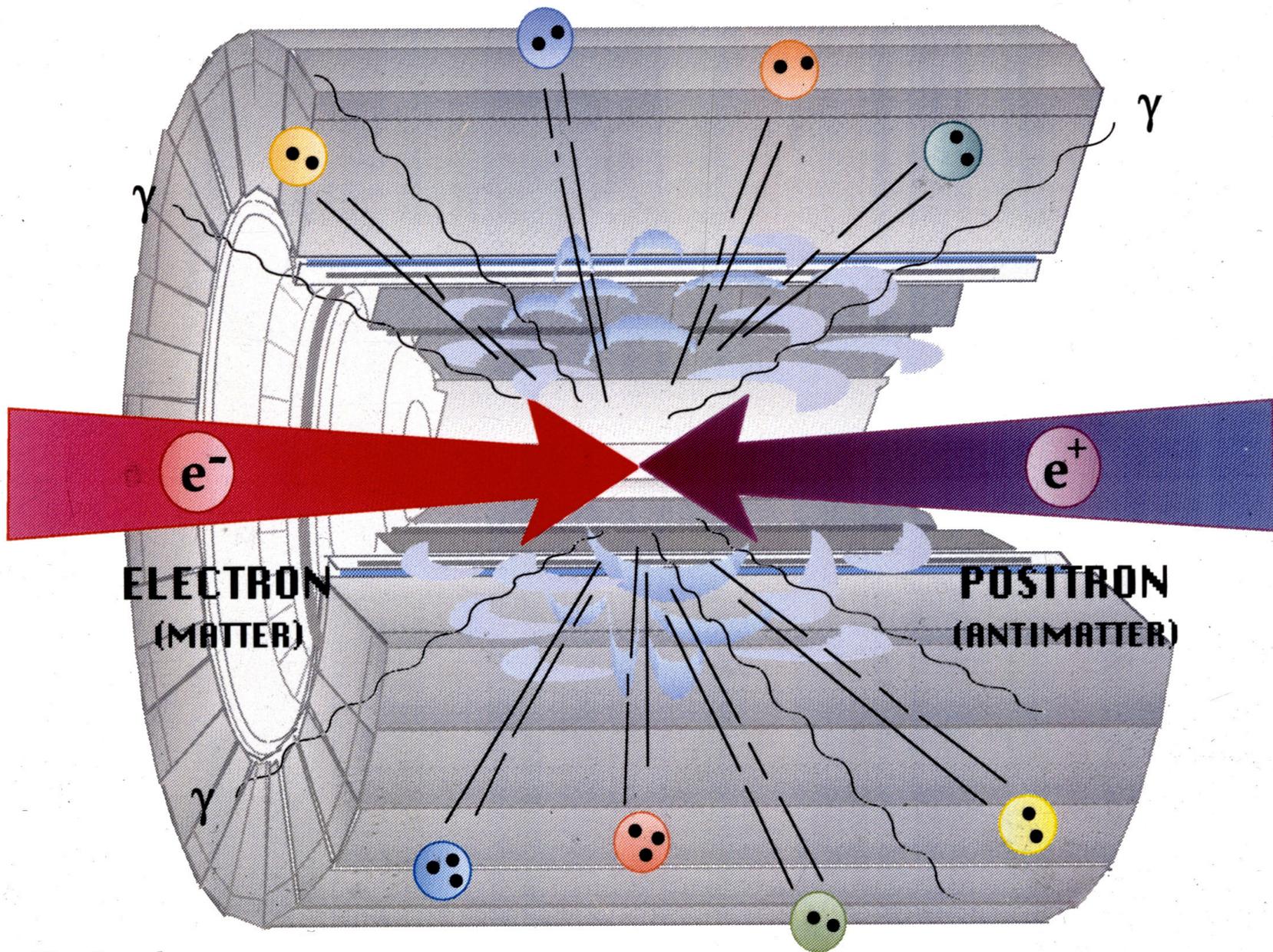
ANGELS & DEMONS

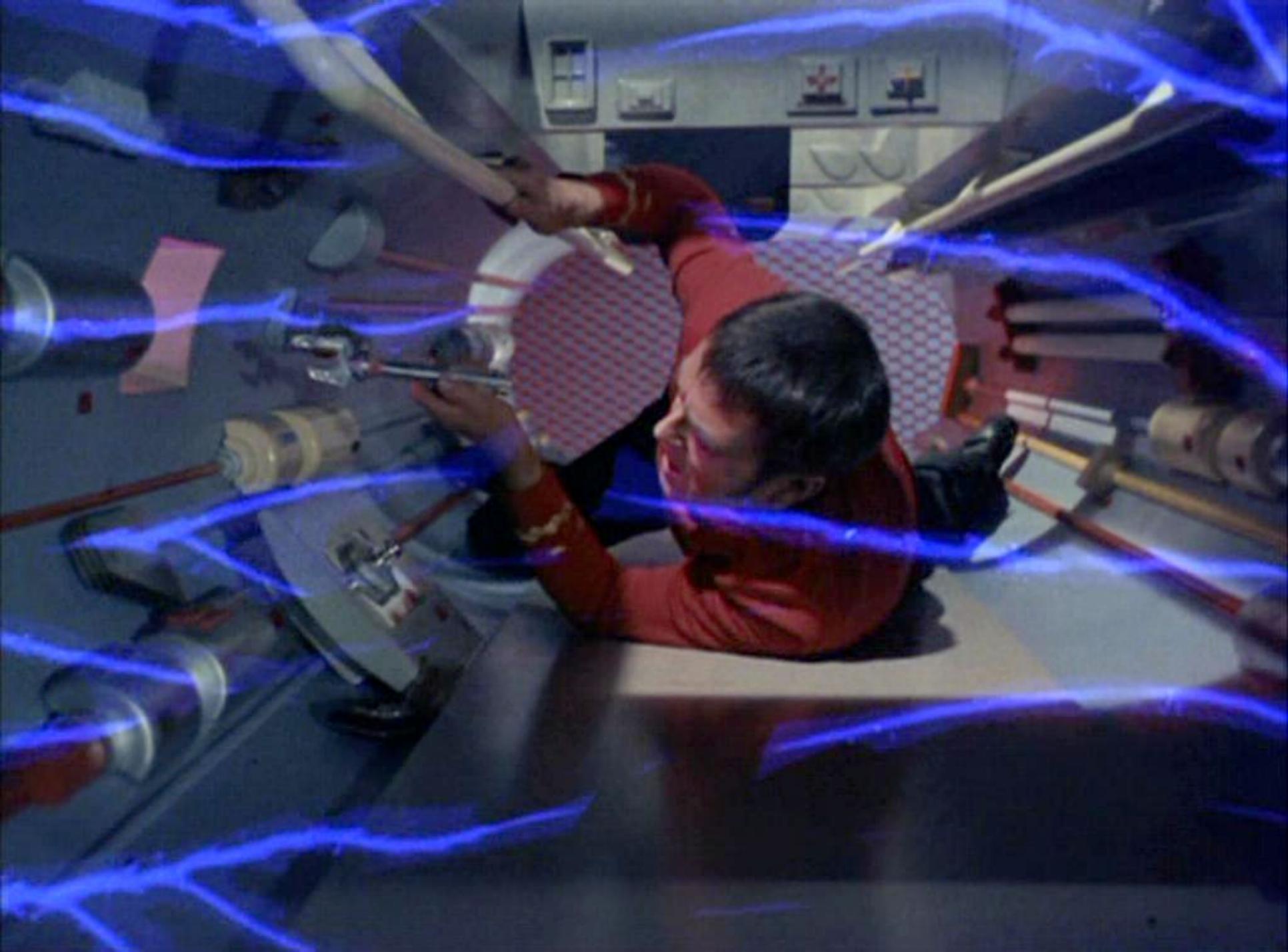
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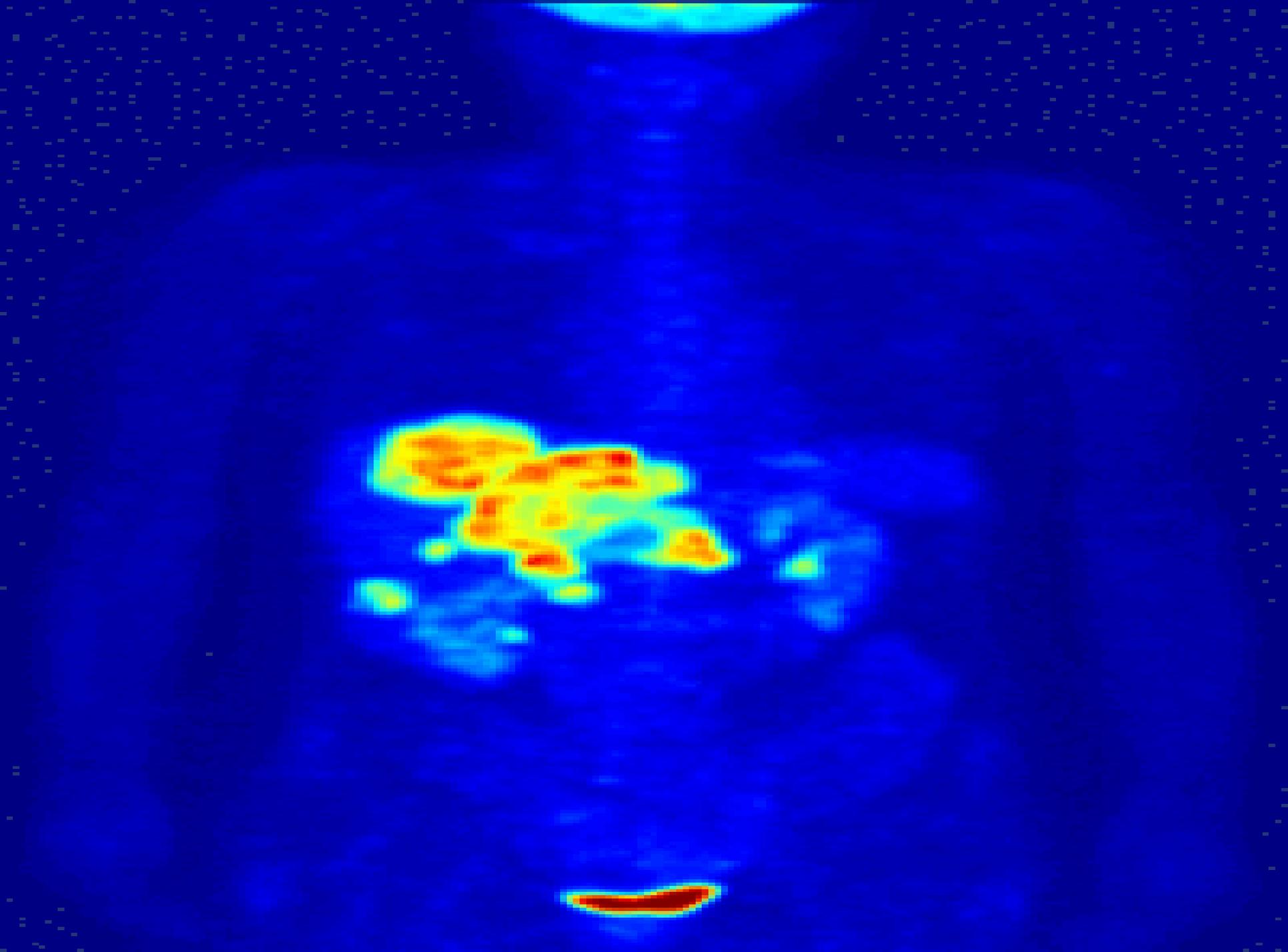




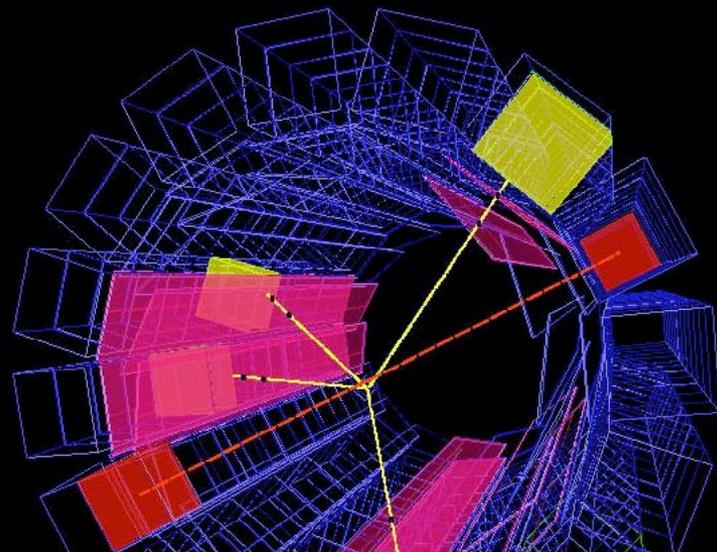
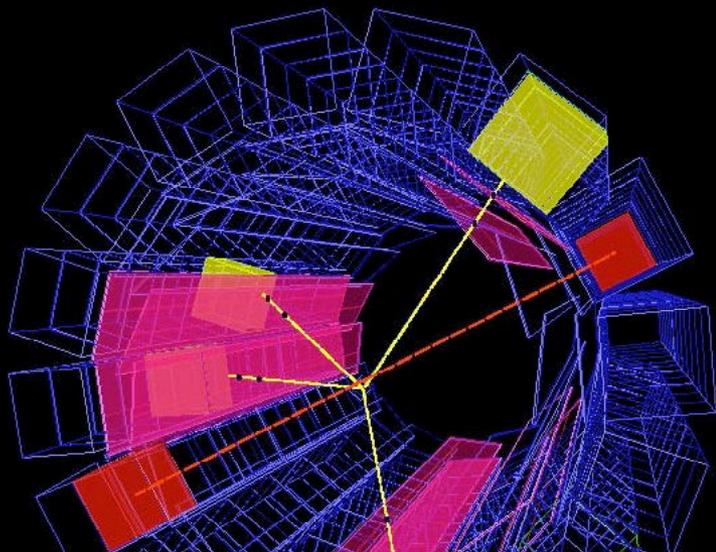
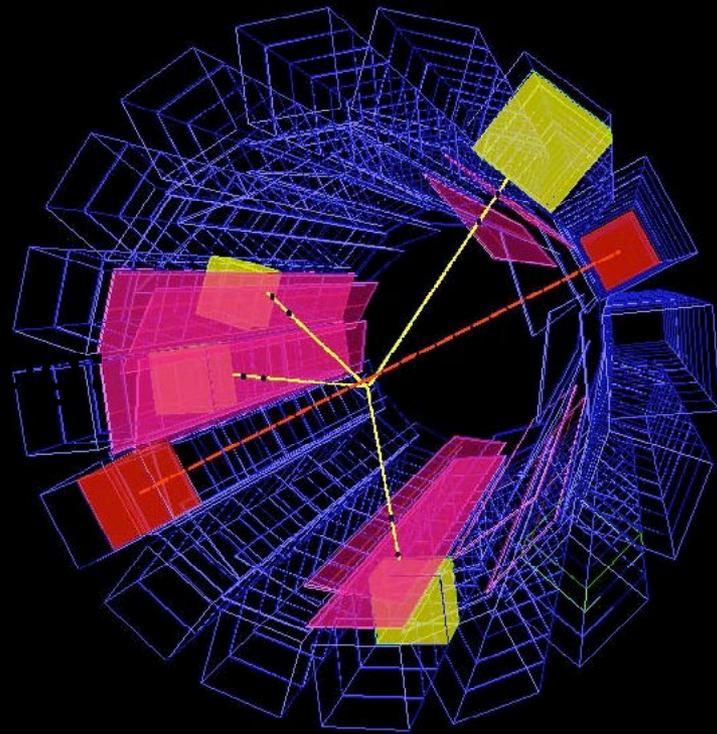
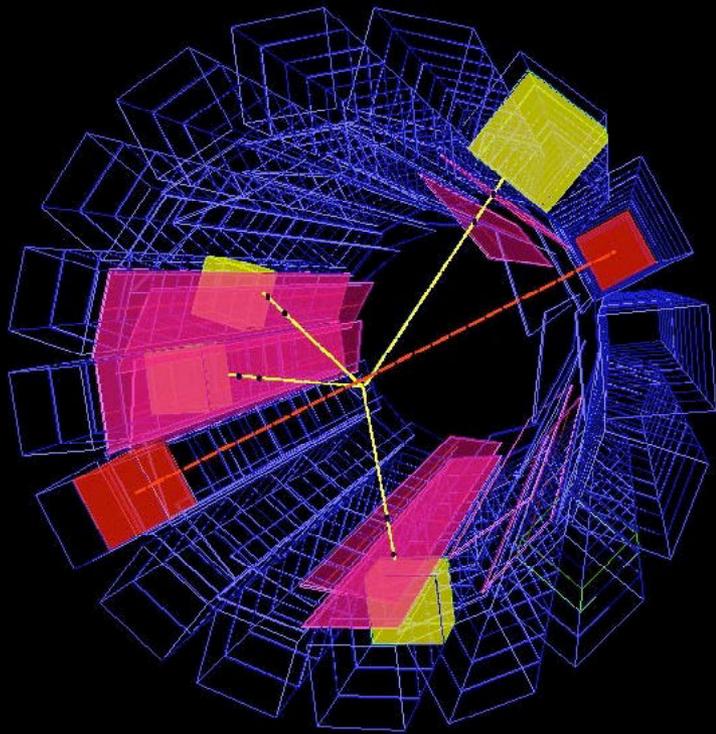


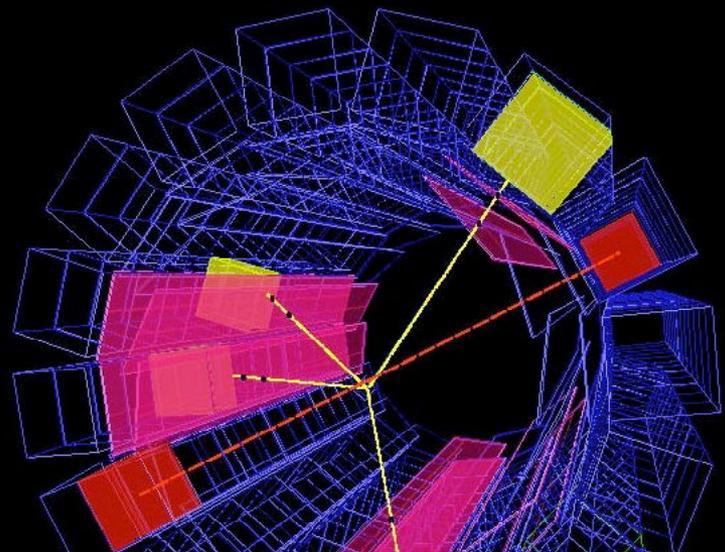
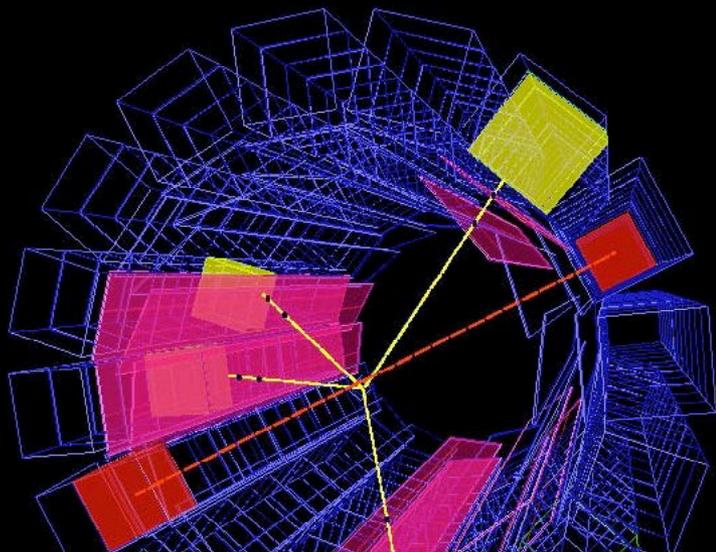
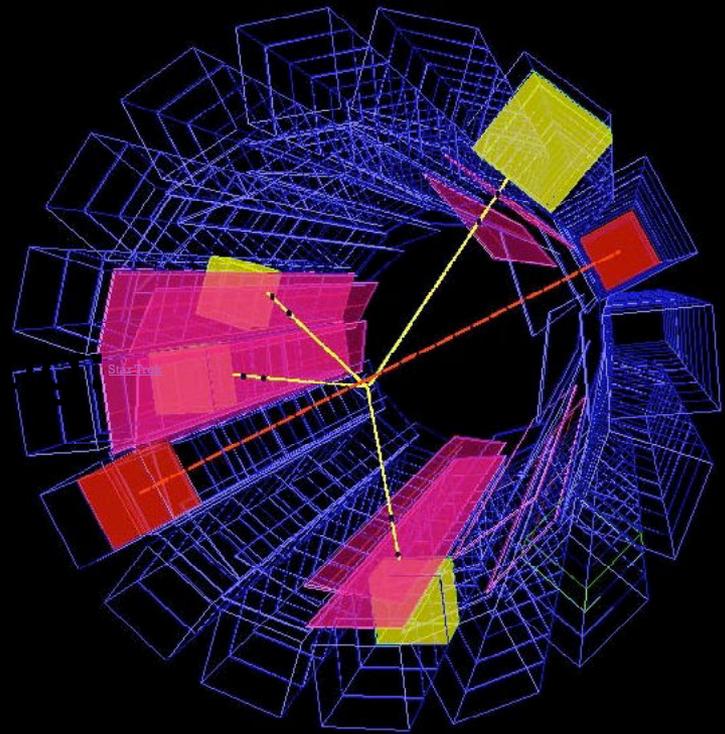
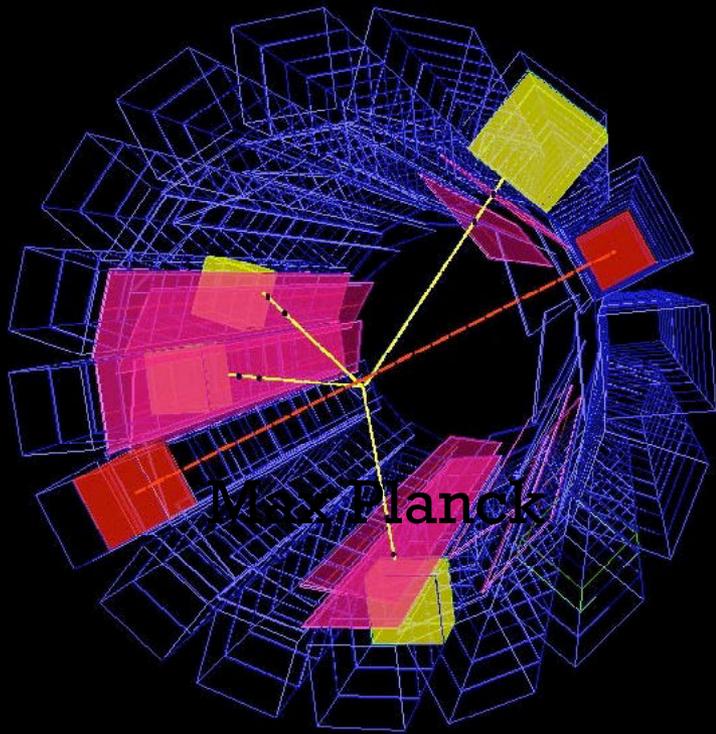


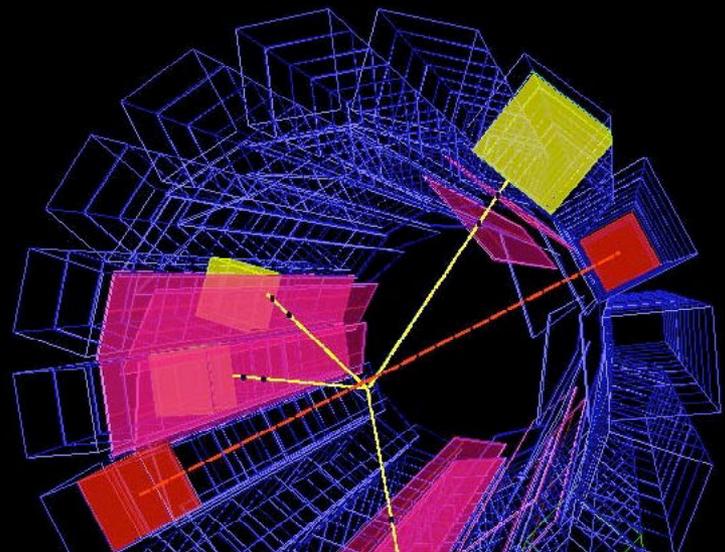
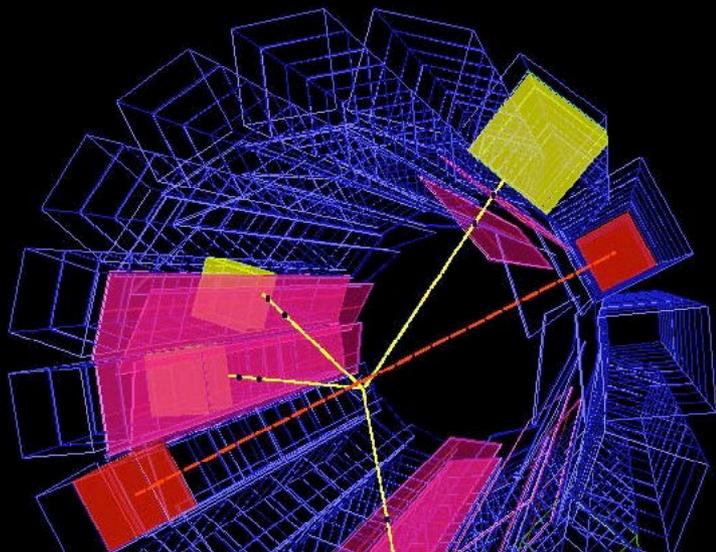
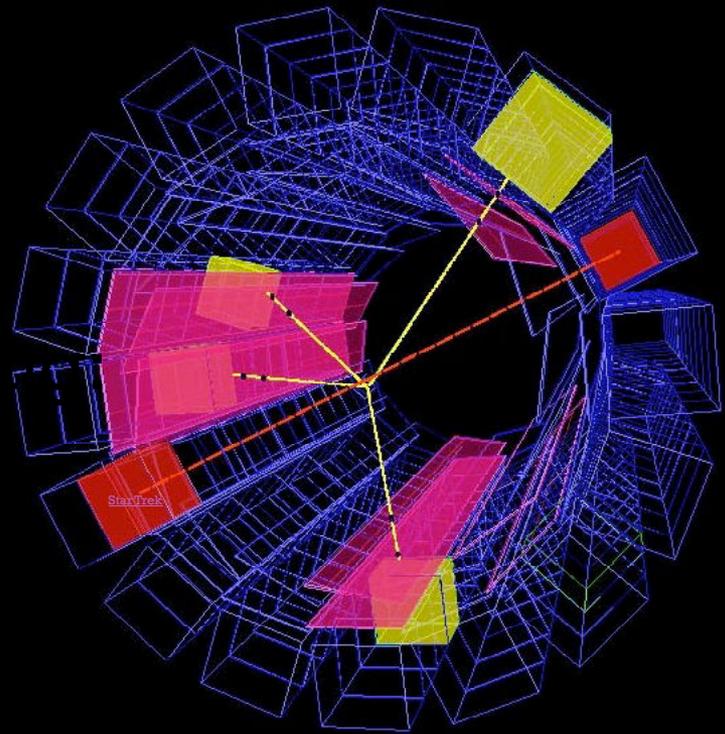
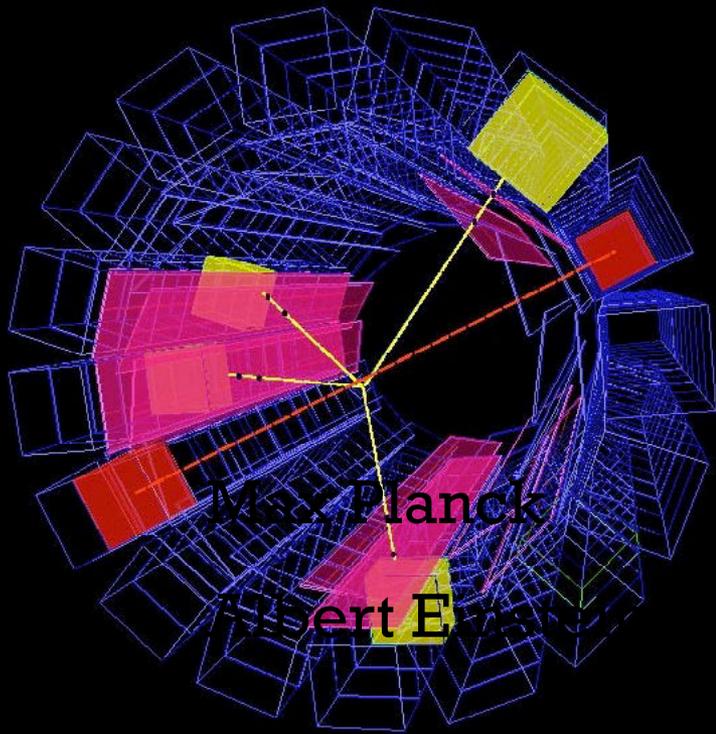


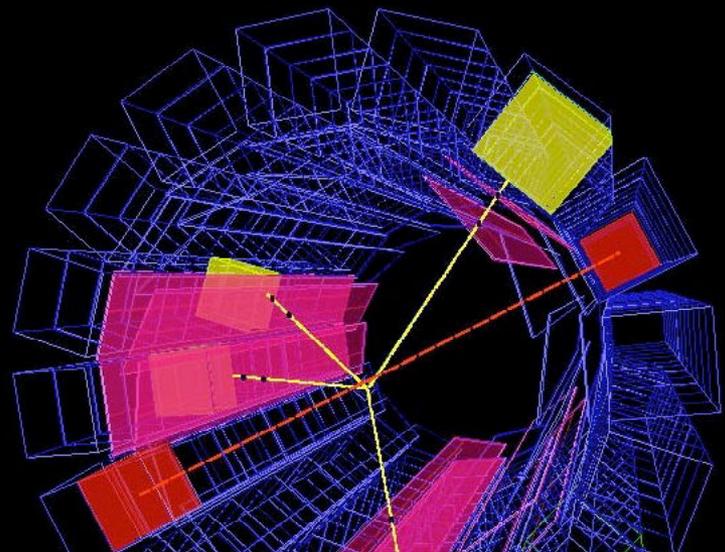
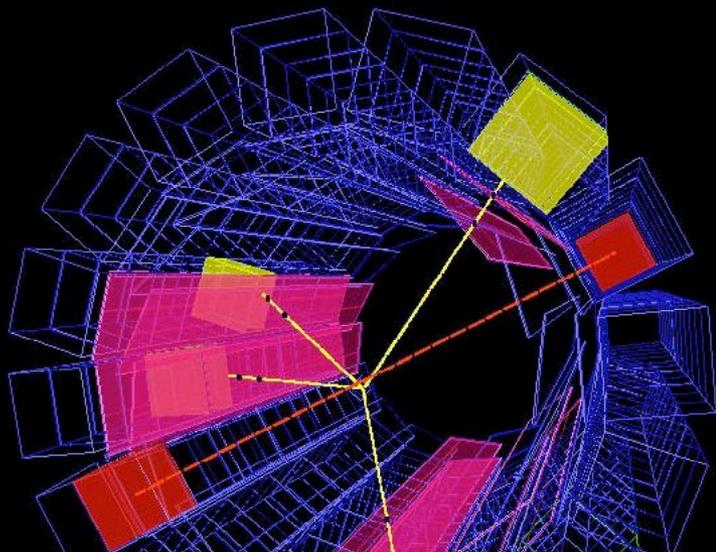
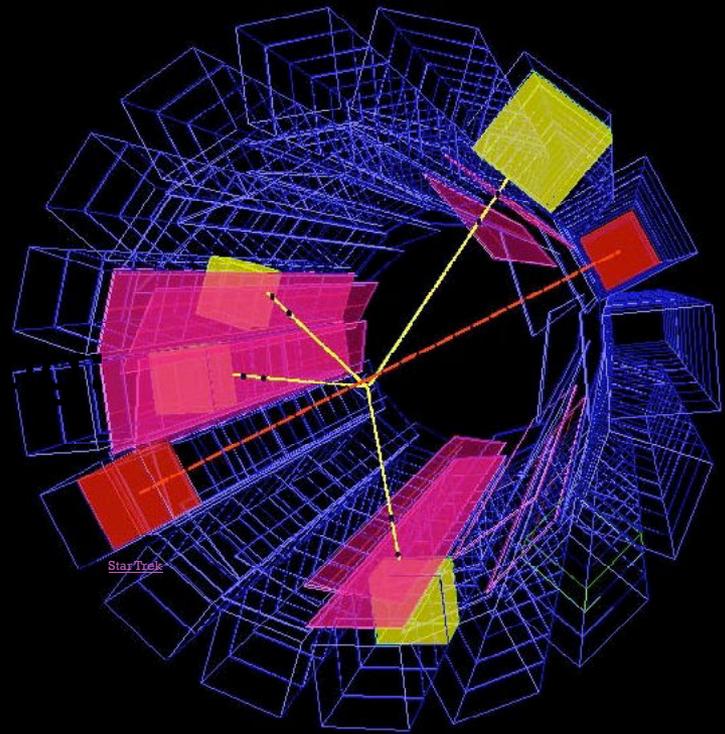
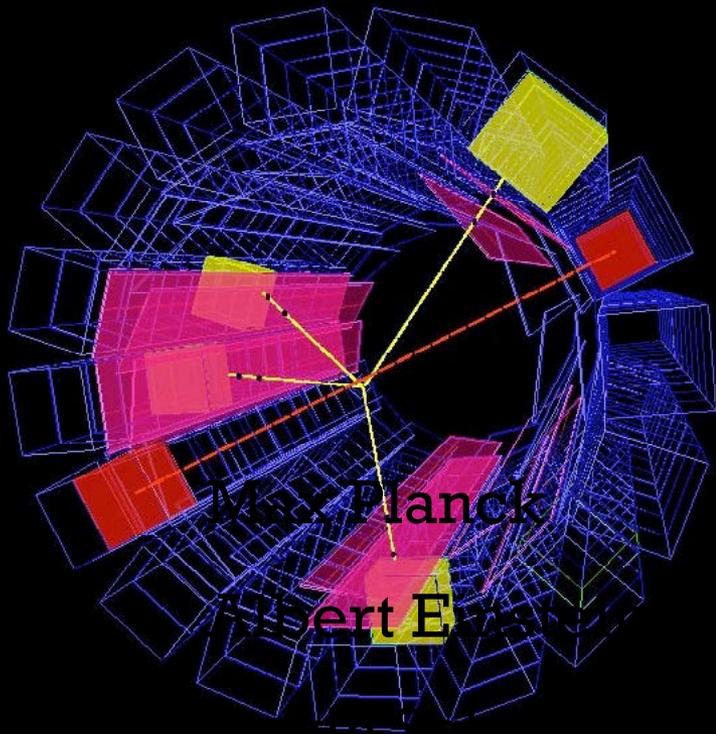


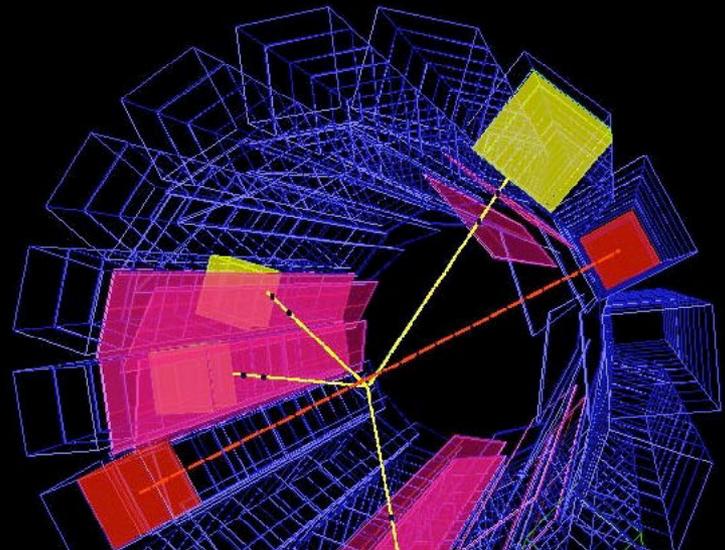
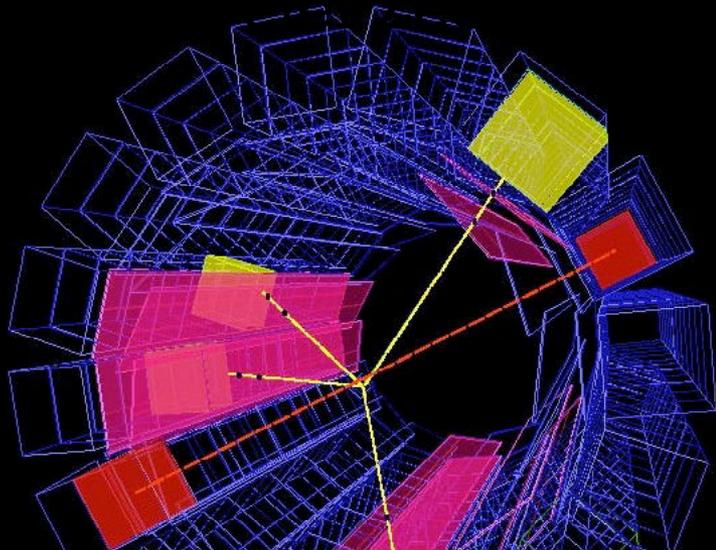
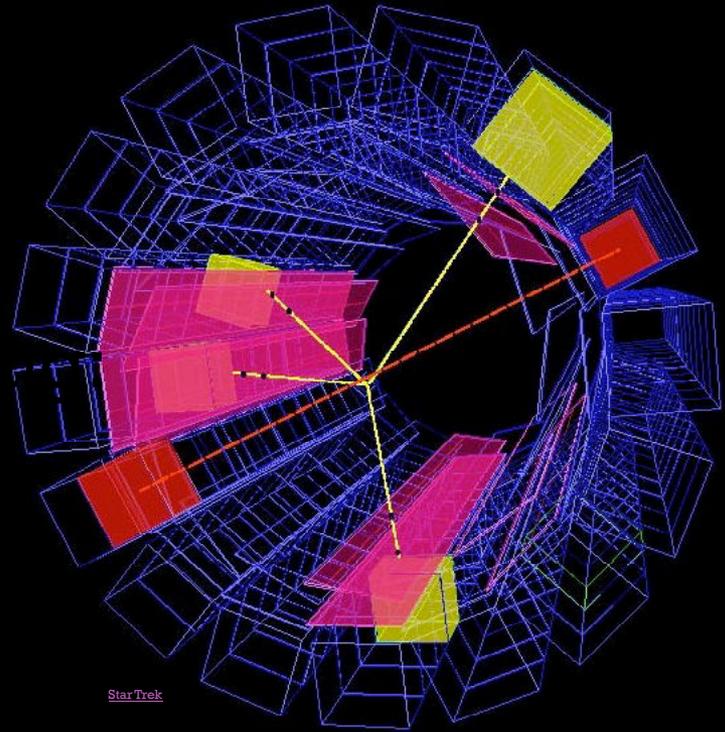
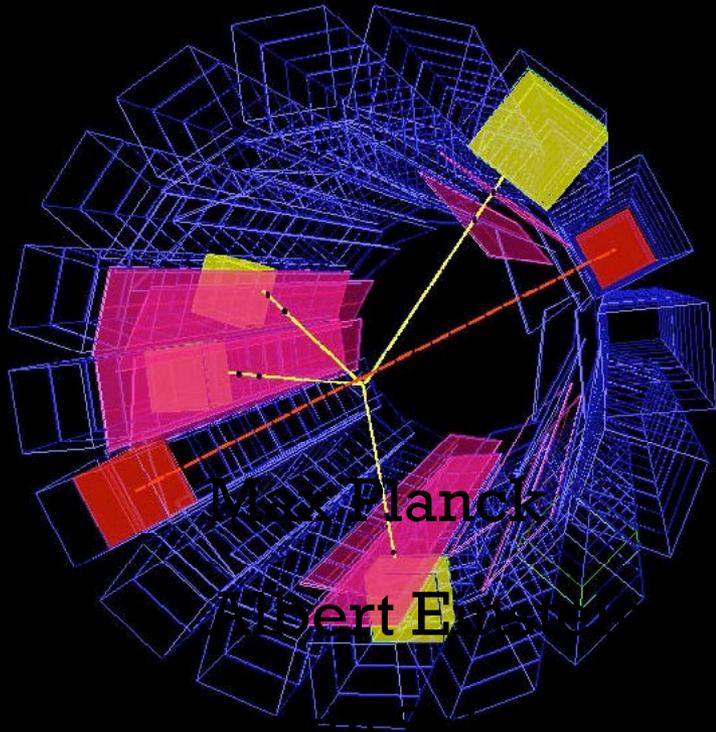
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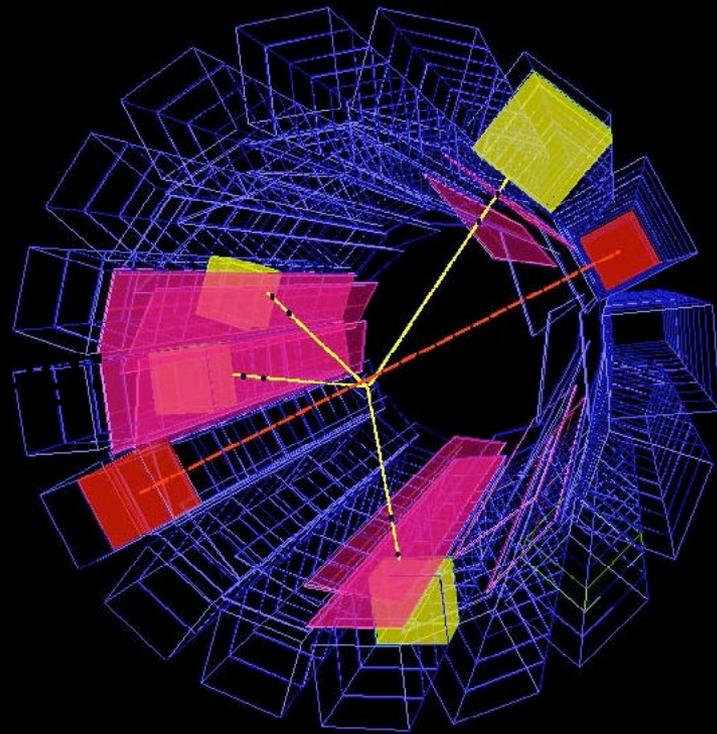
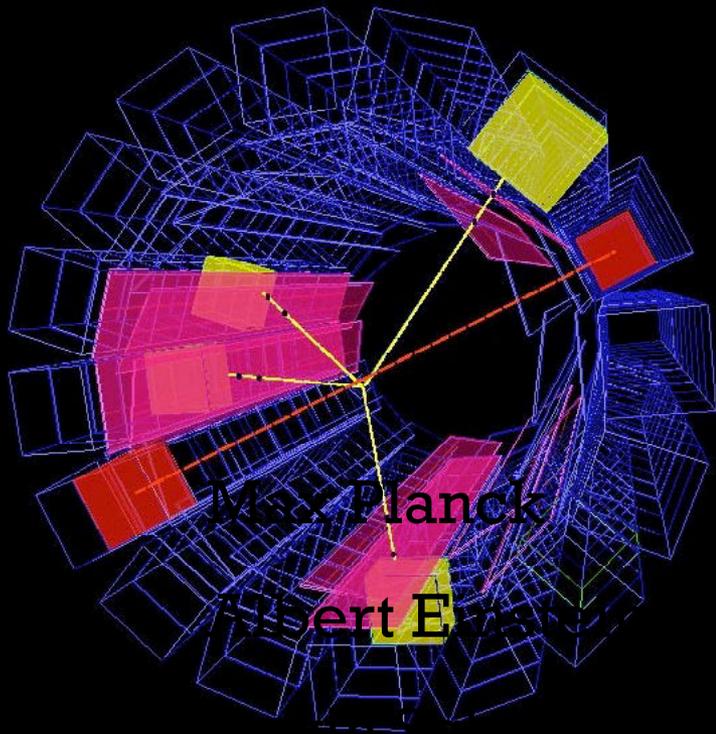




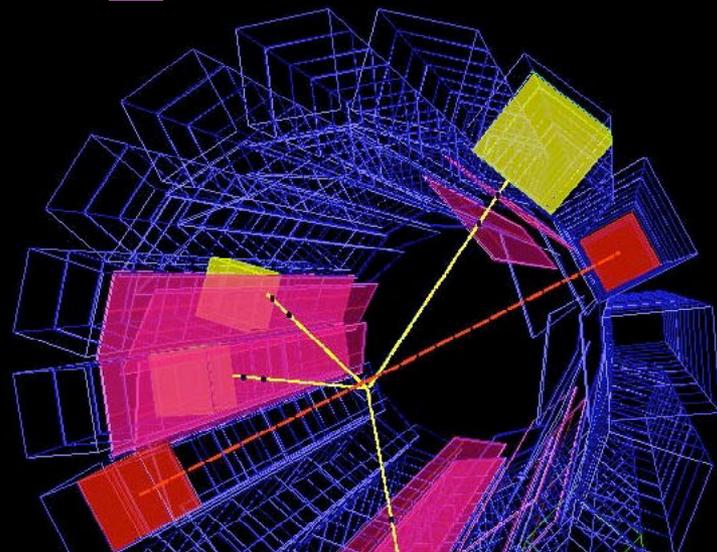
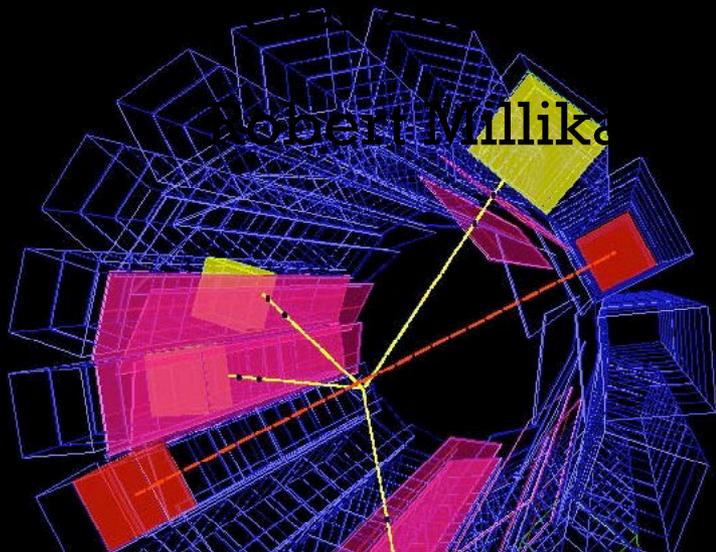


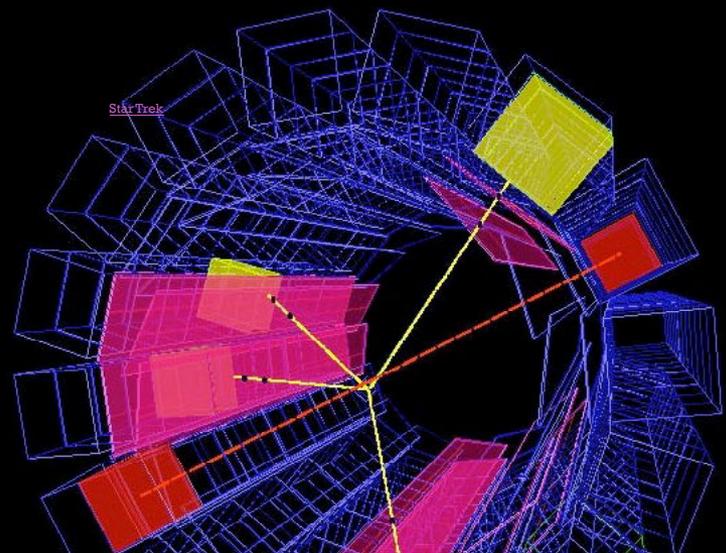
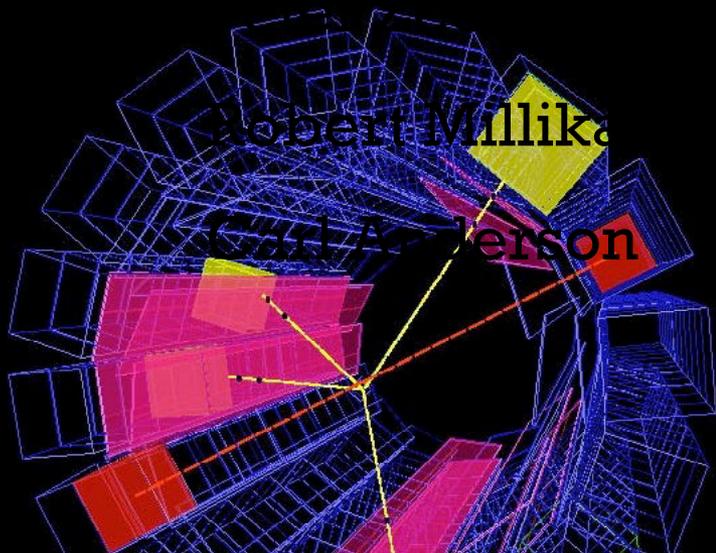
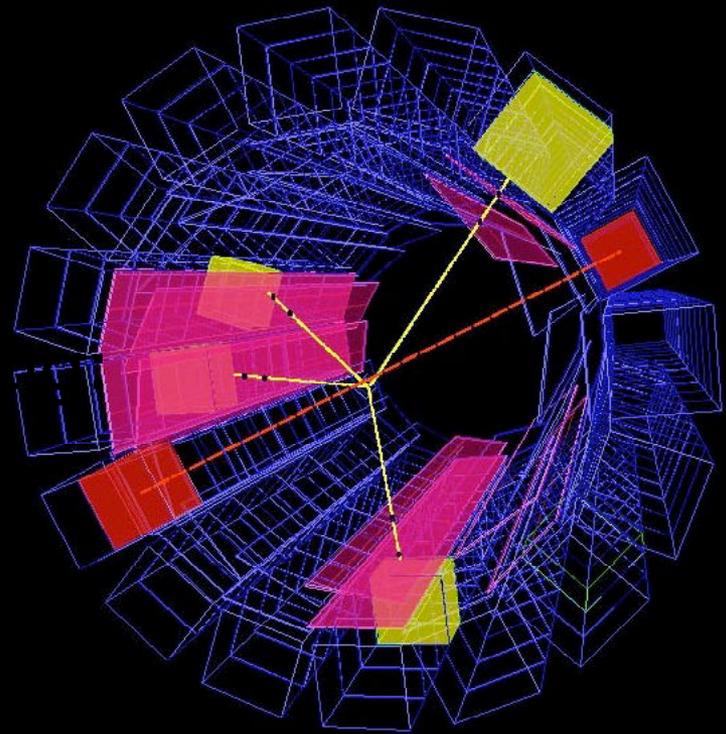
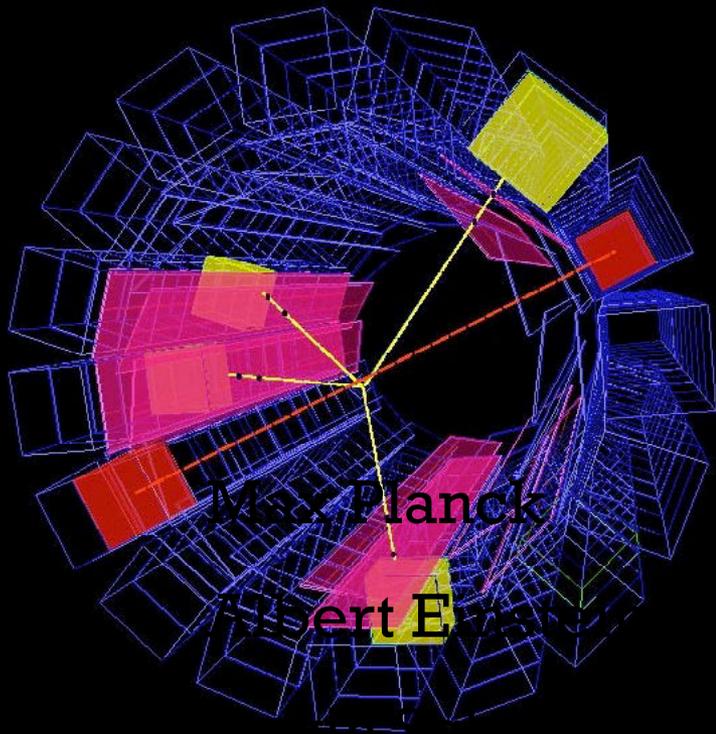


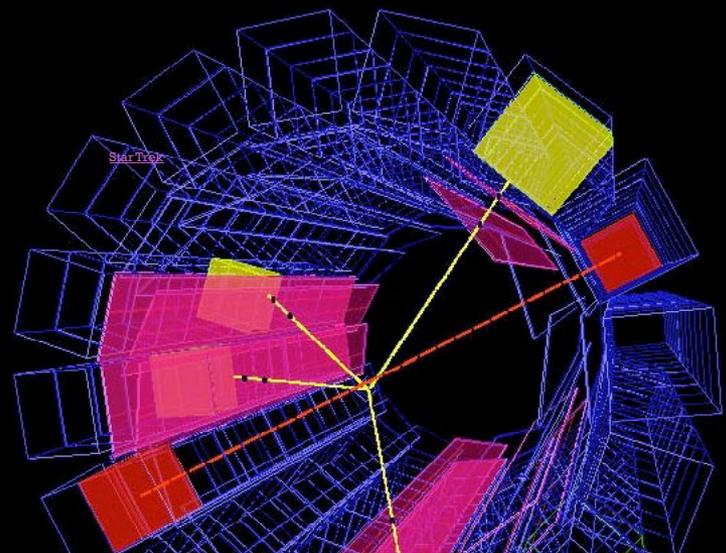
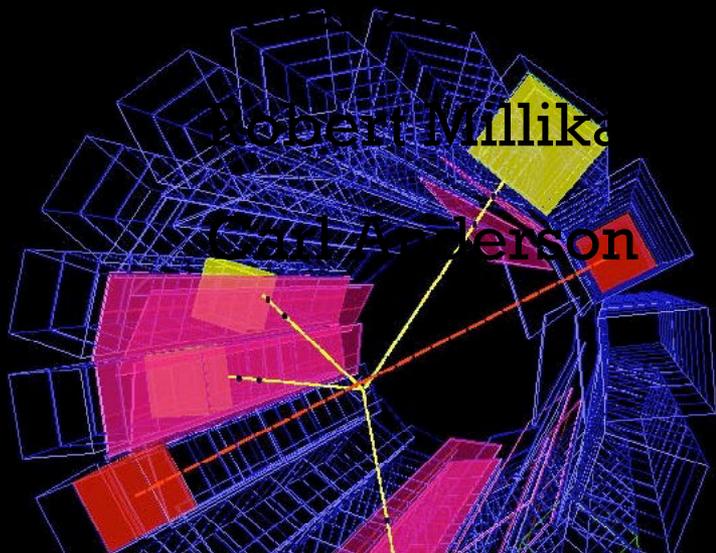
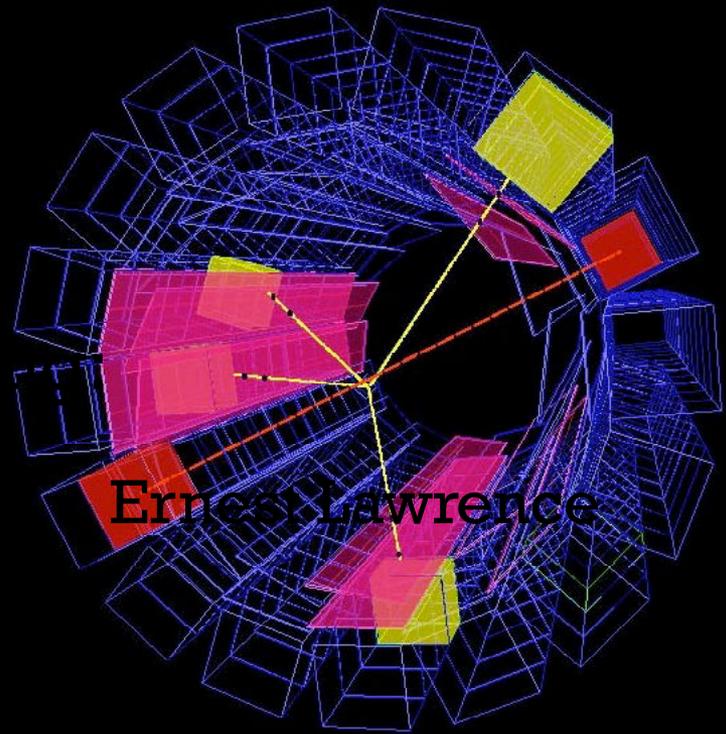
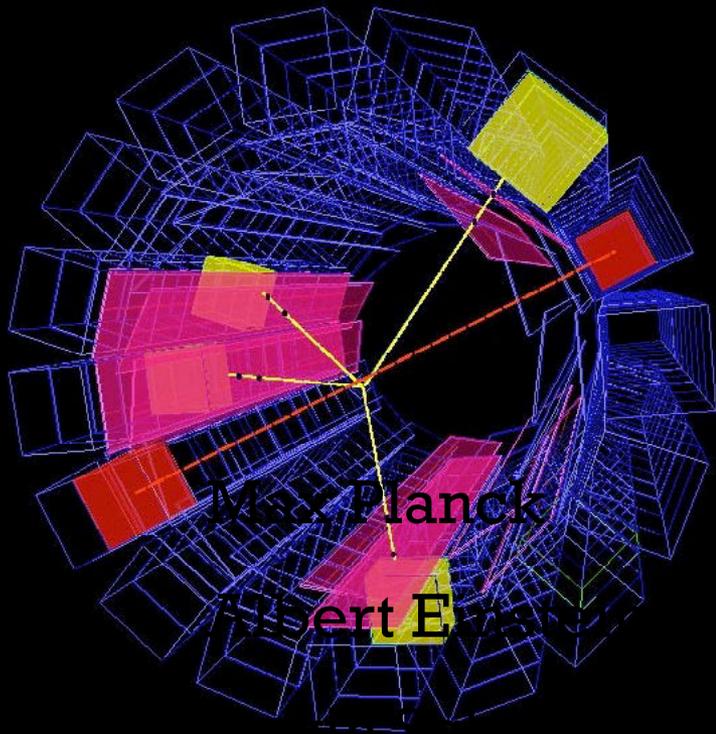


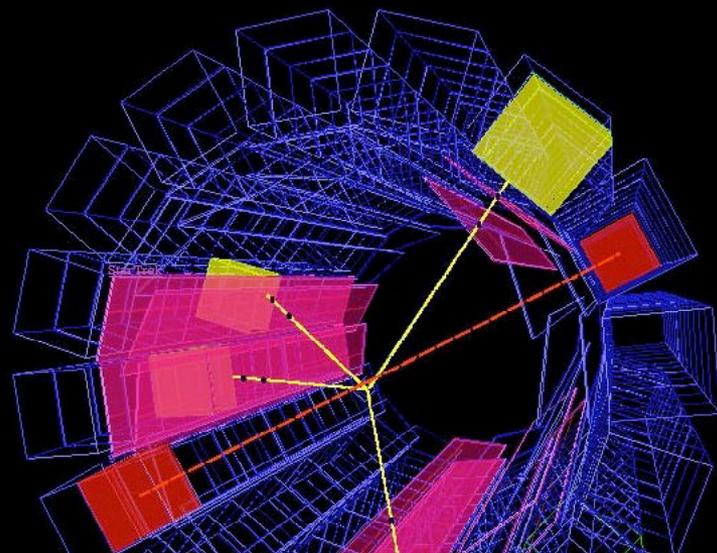
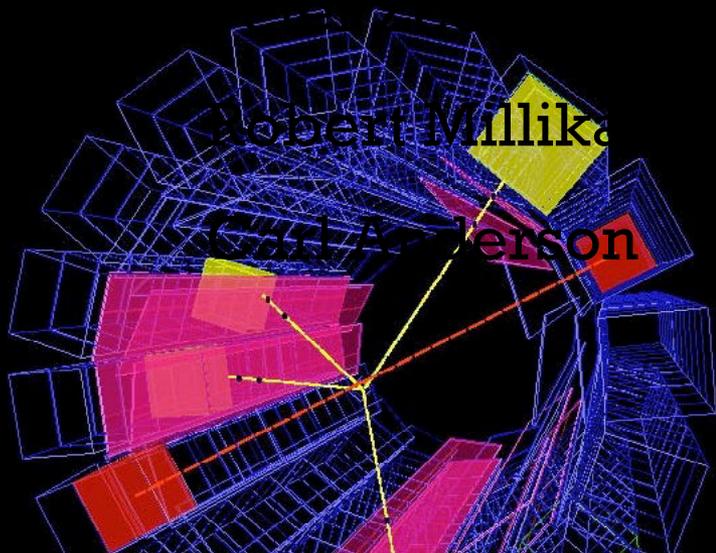
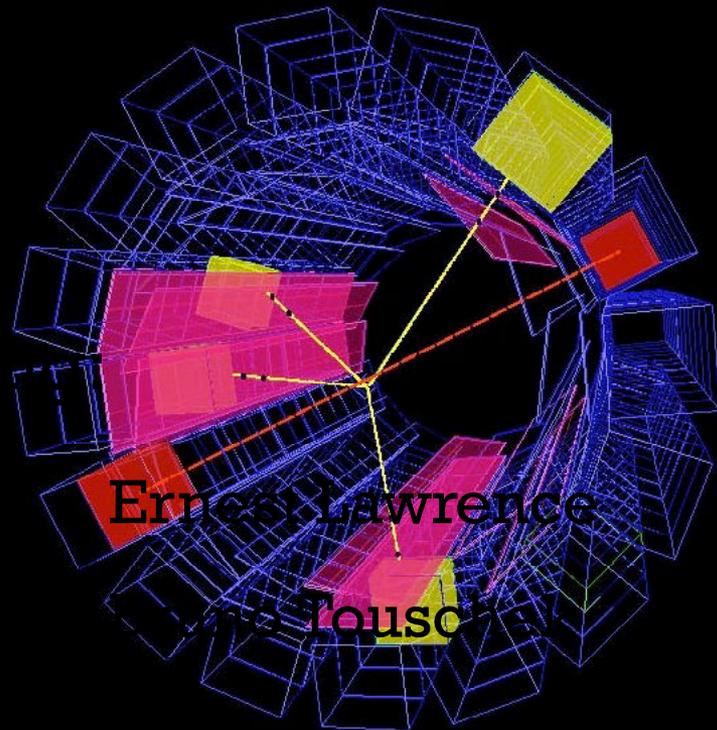
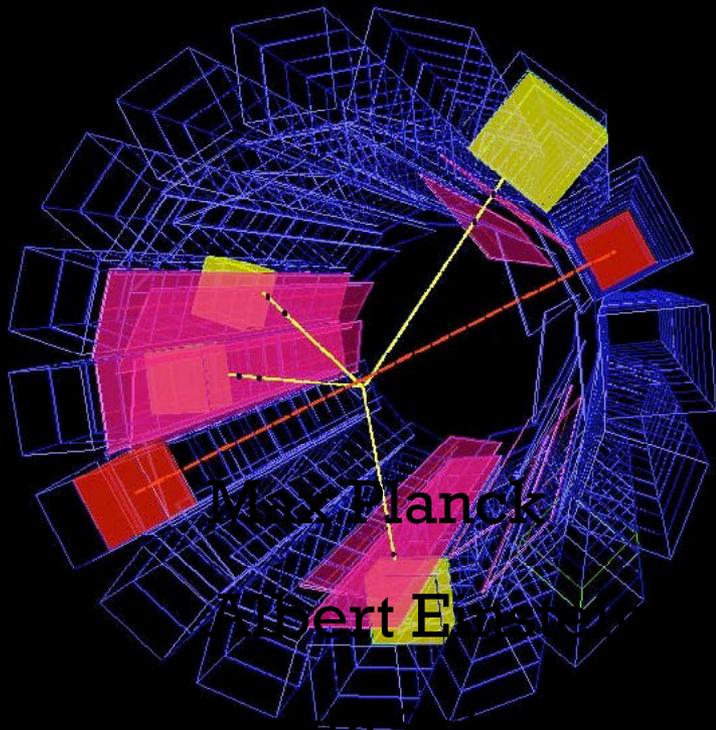


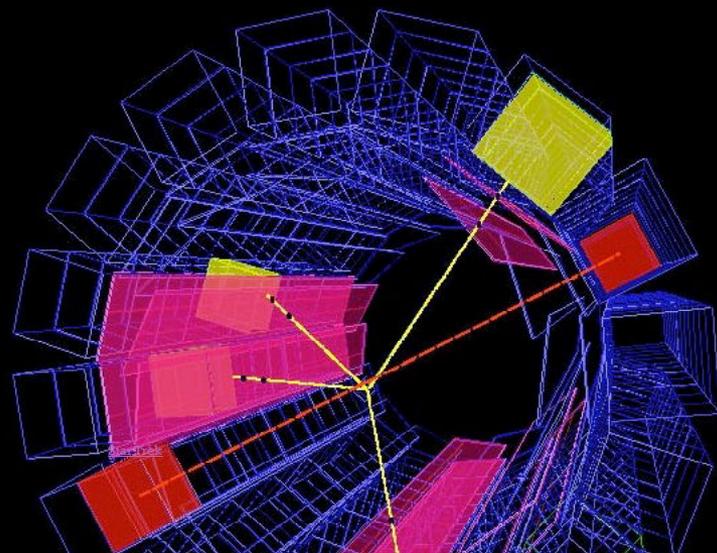
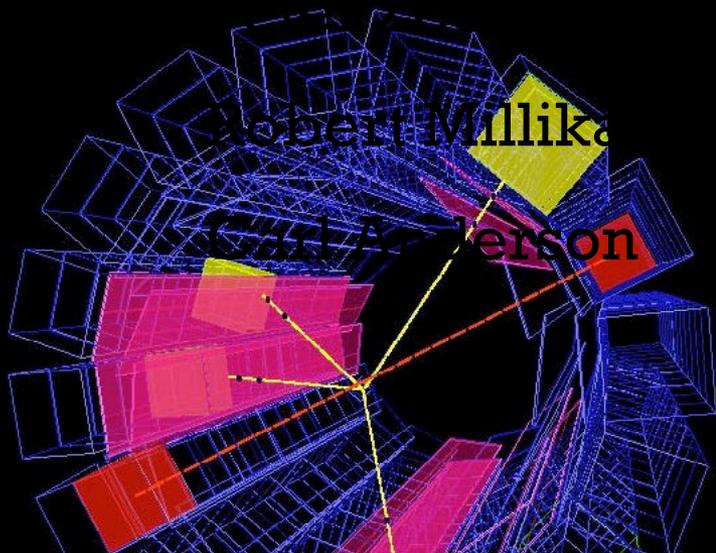
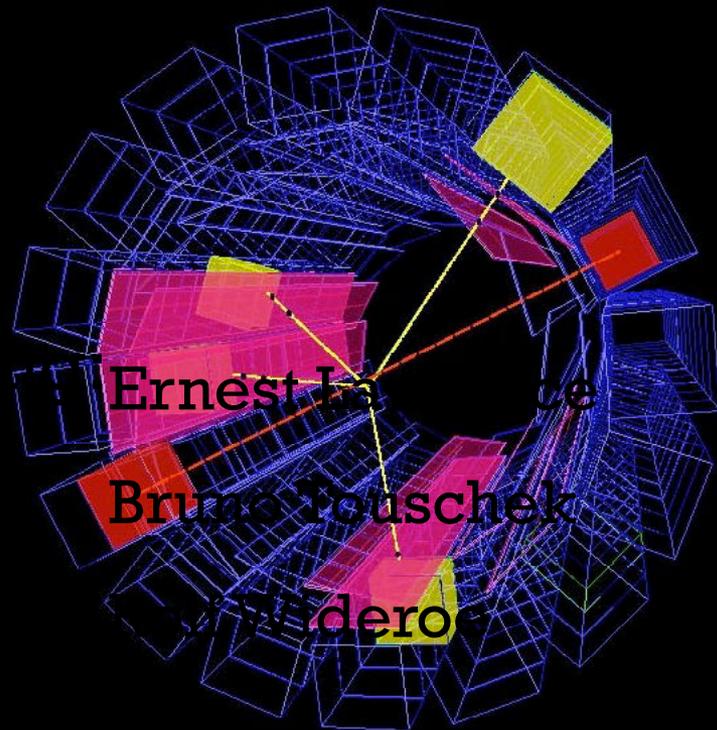
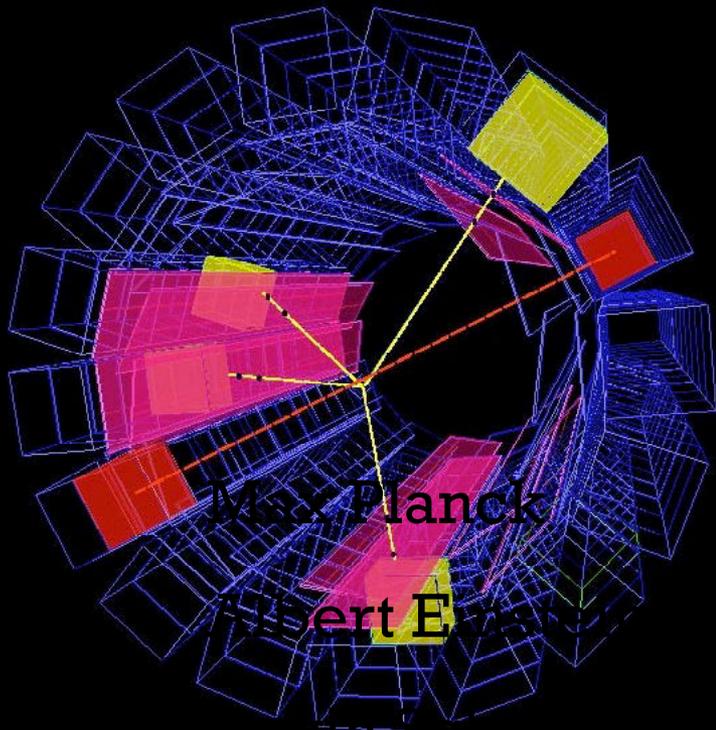
[Star Trek](#)

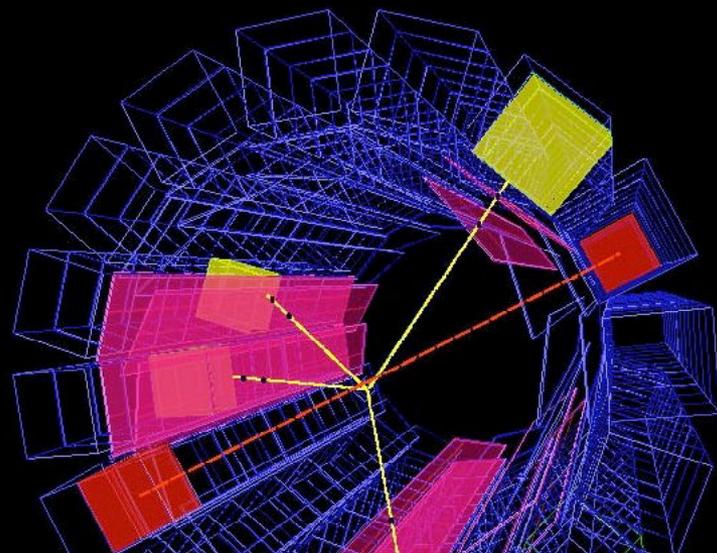
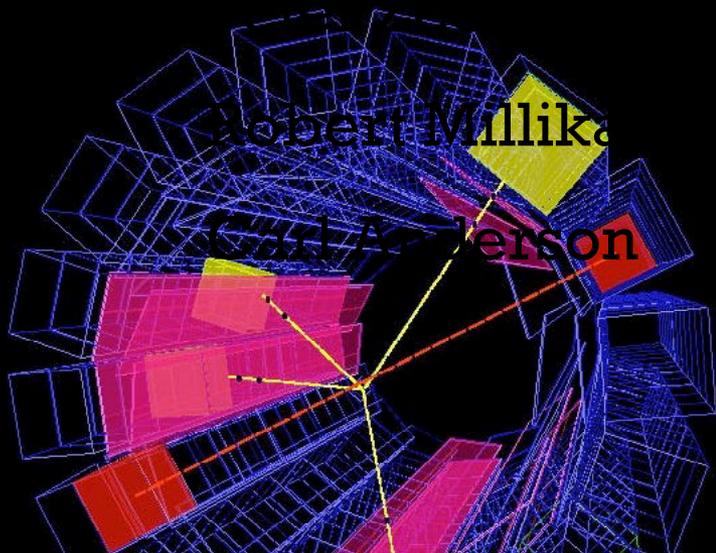
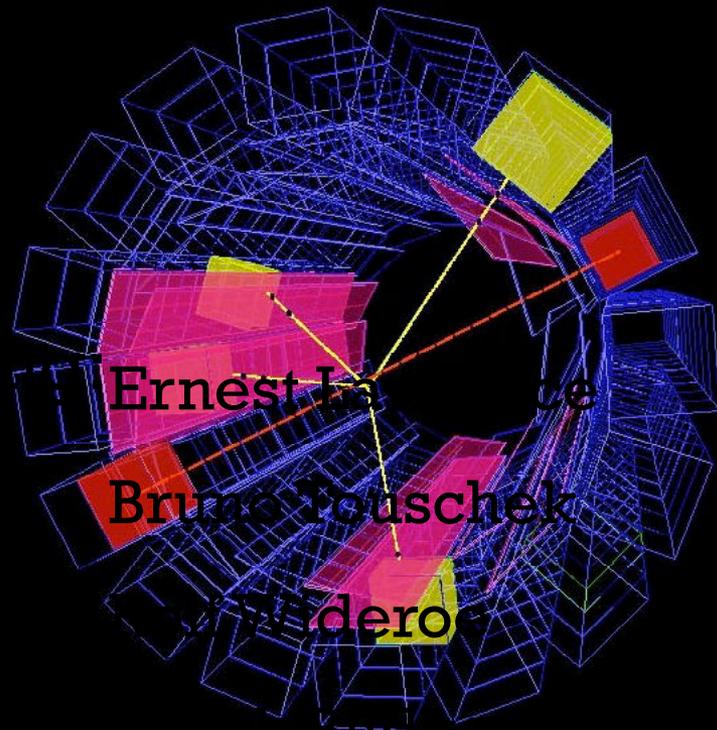
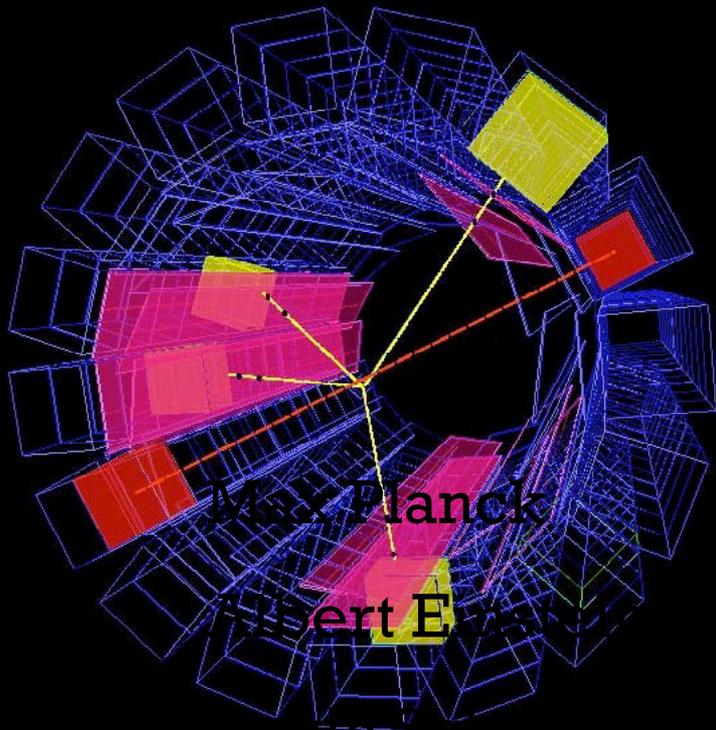


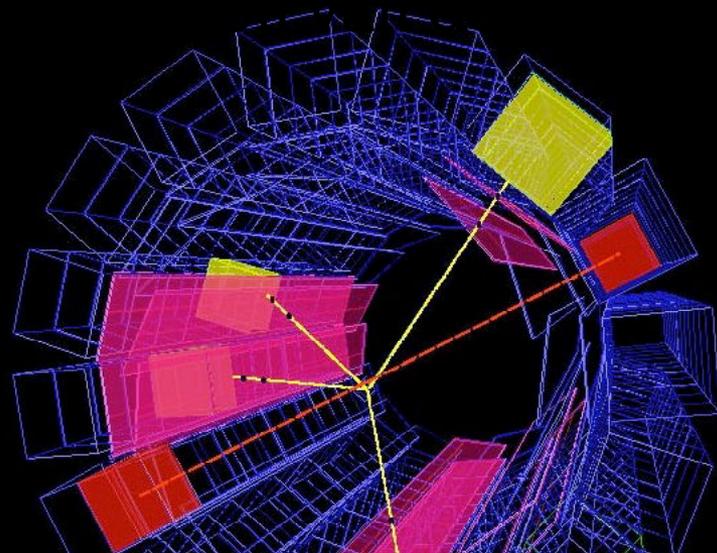
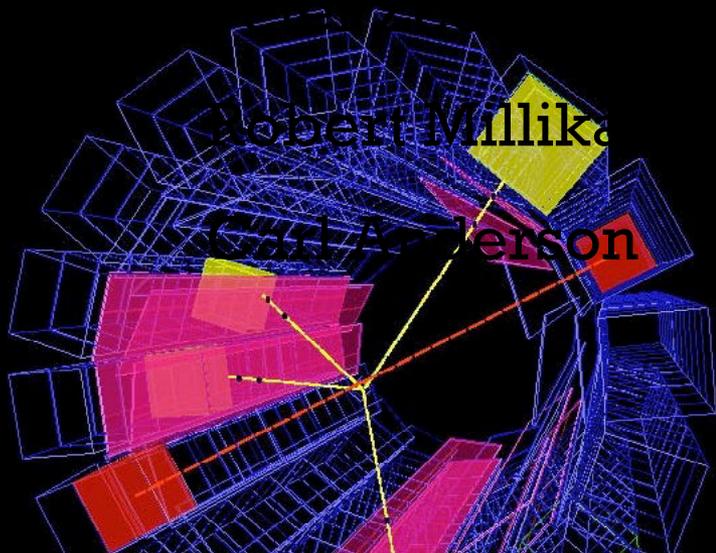
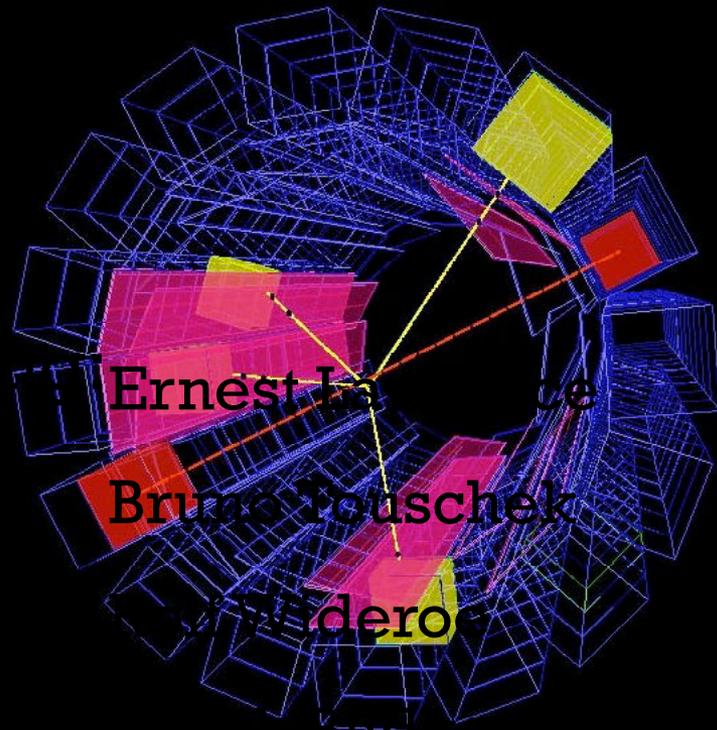
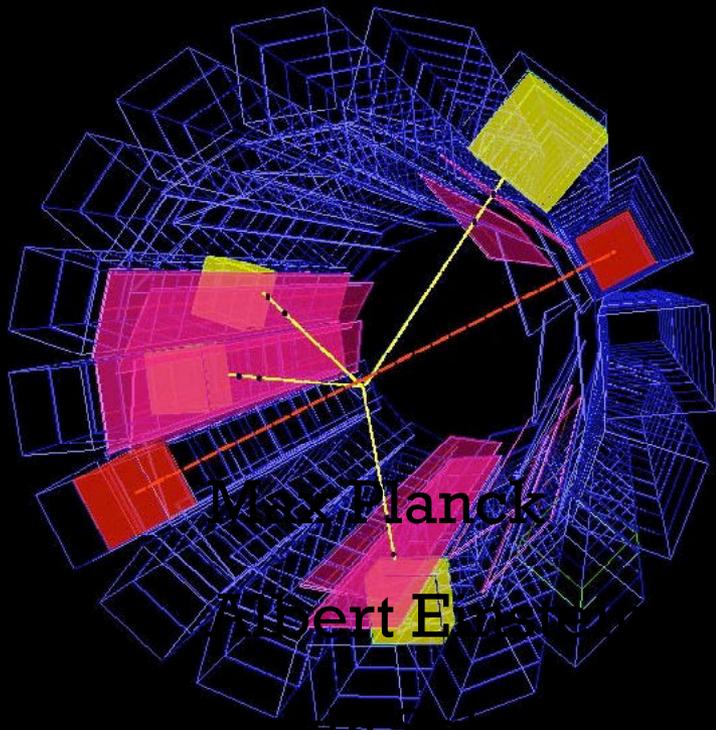


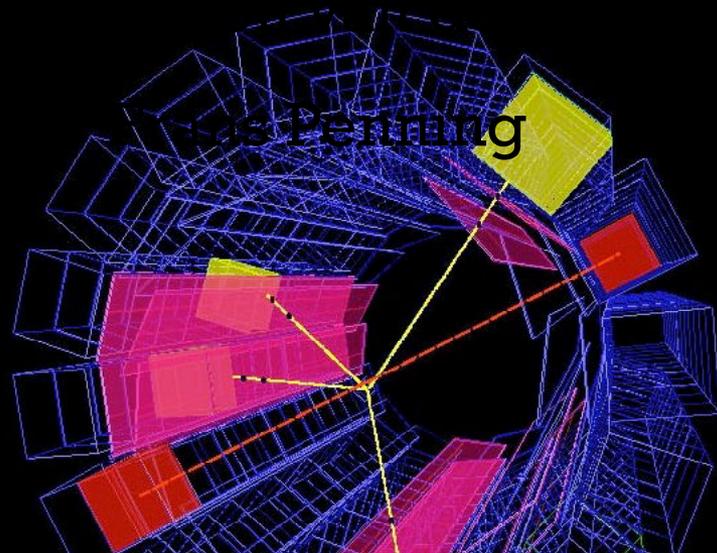
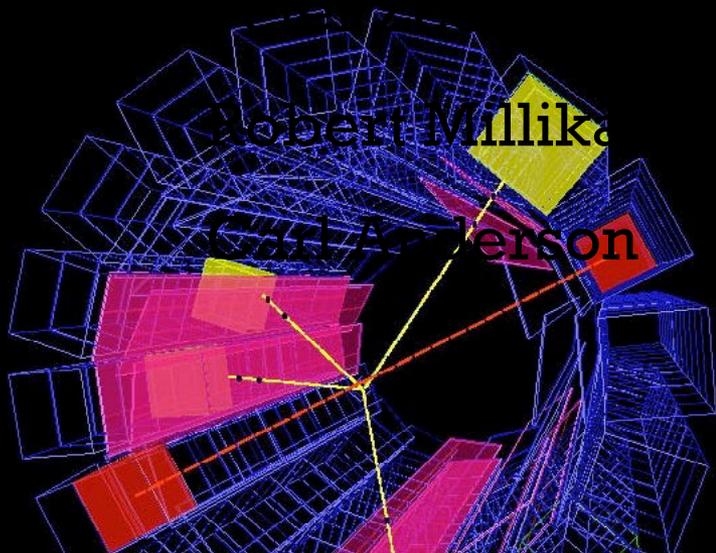
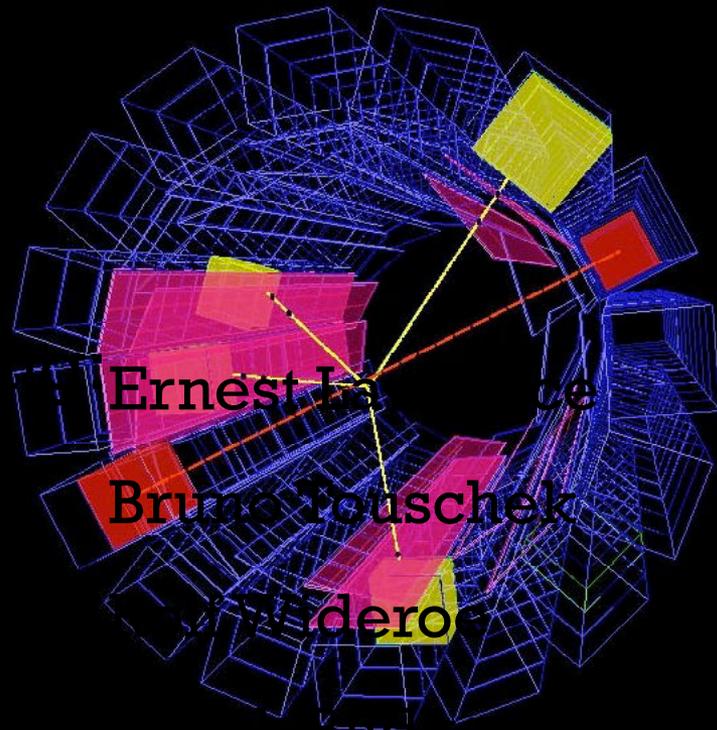
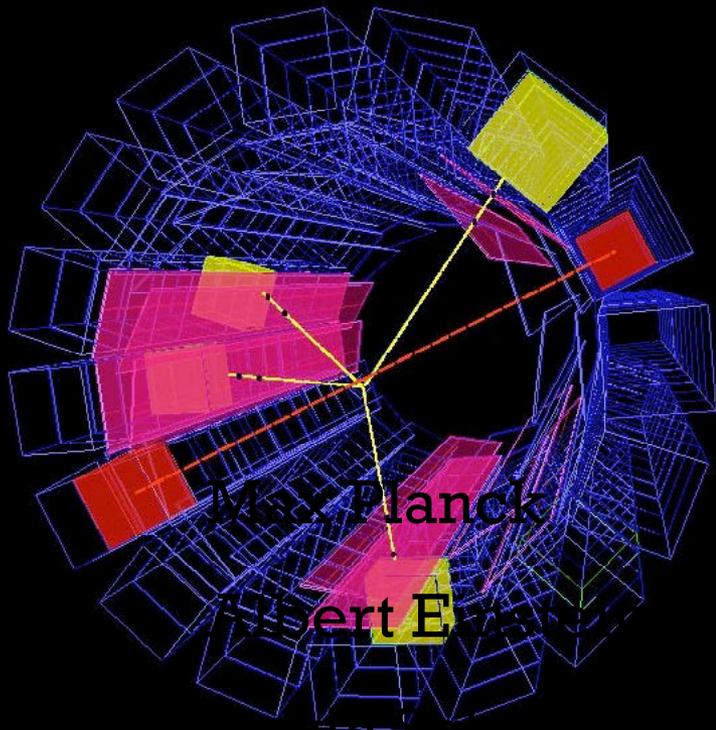


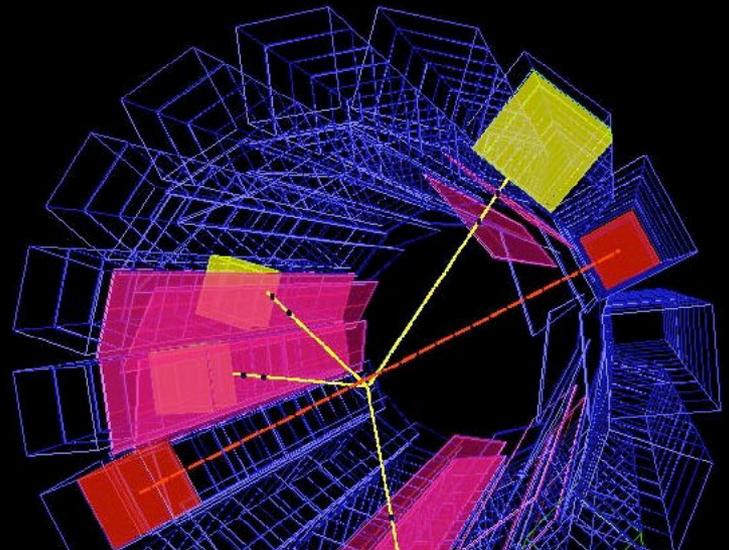
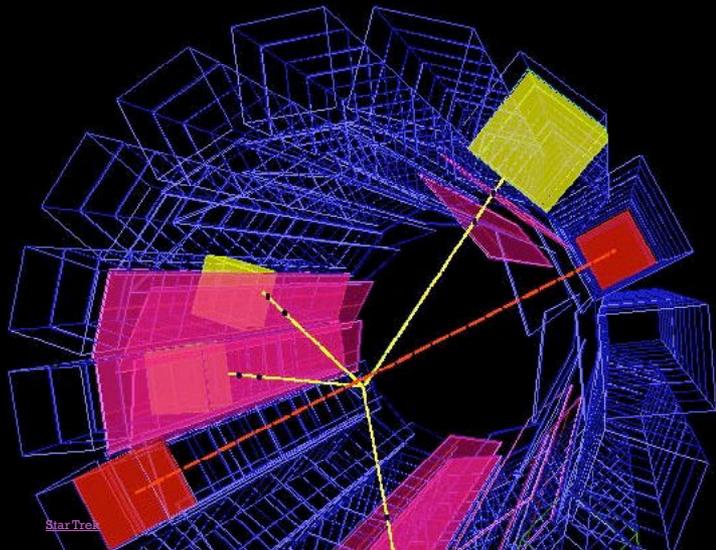
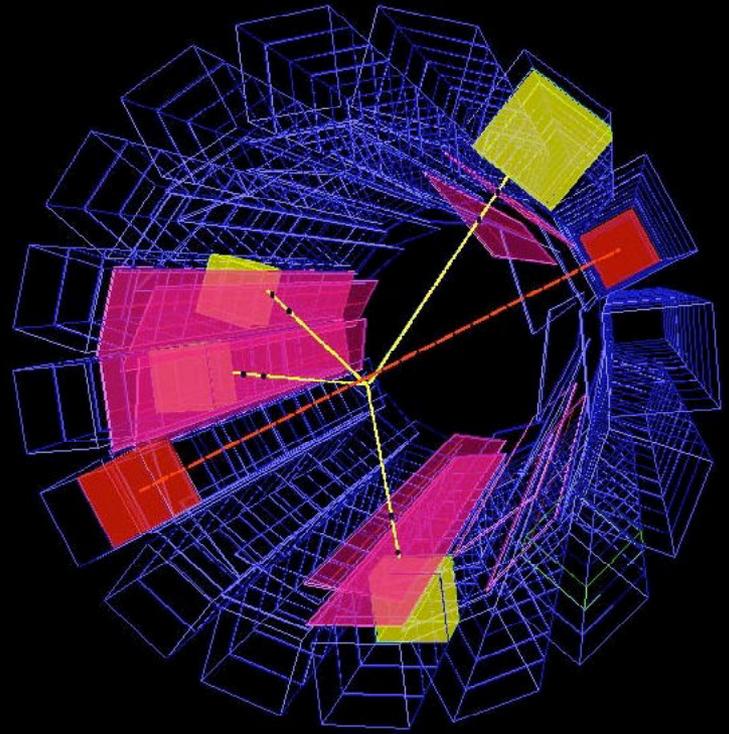
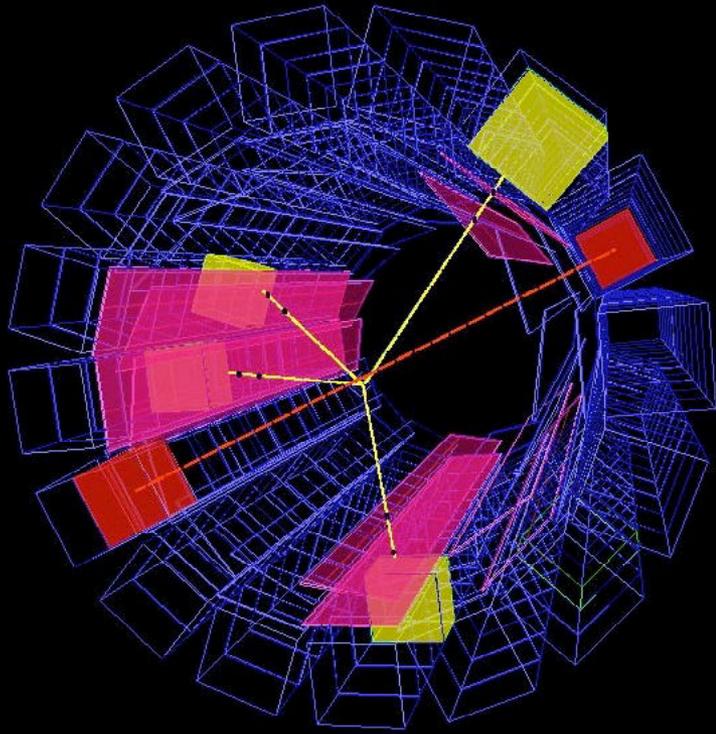


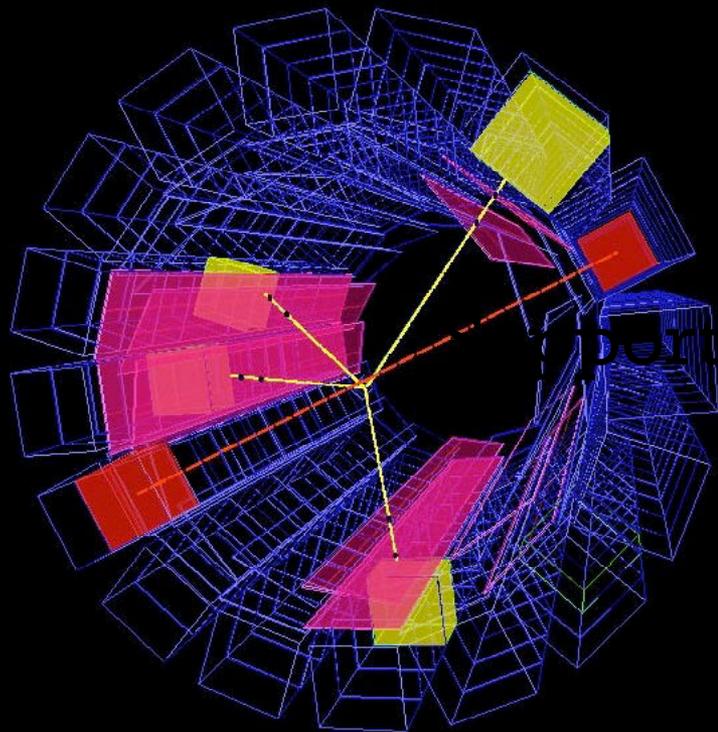




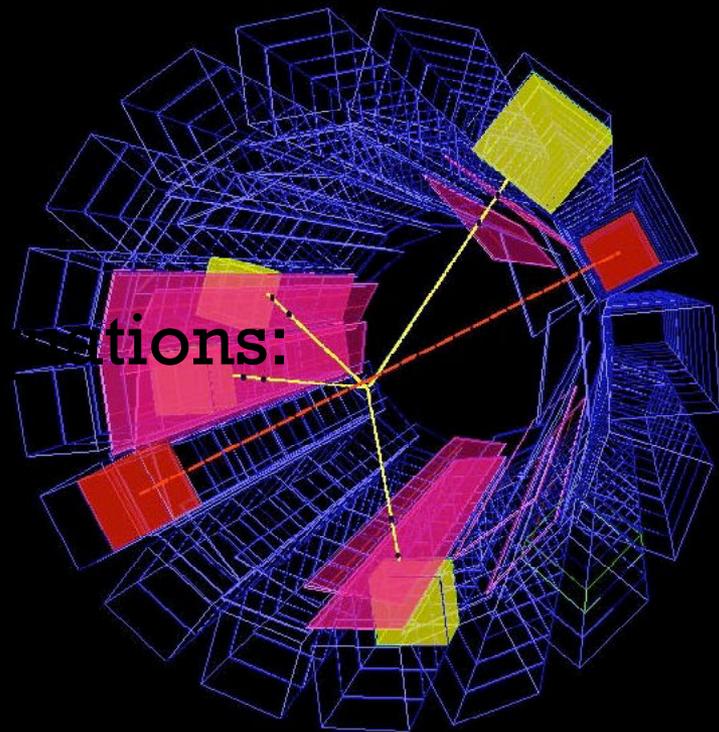




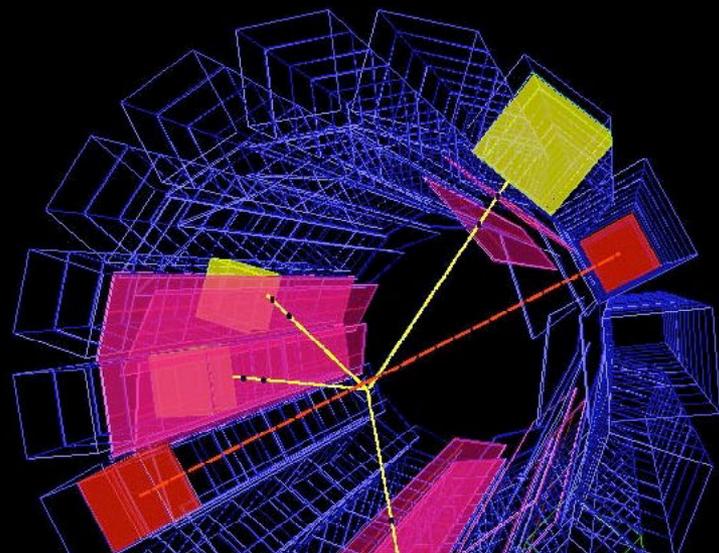
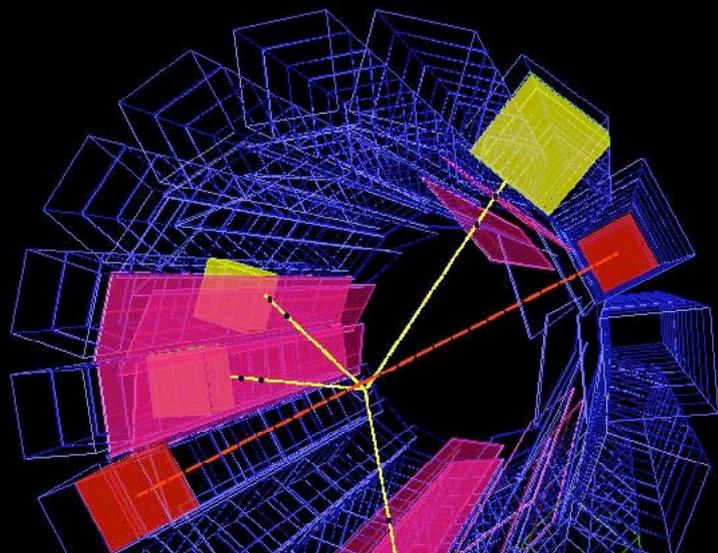


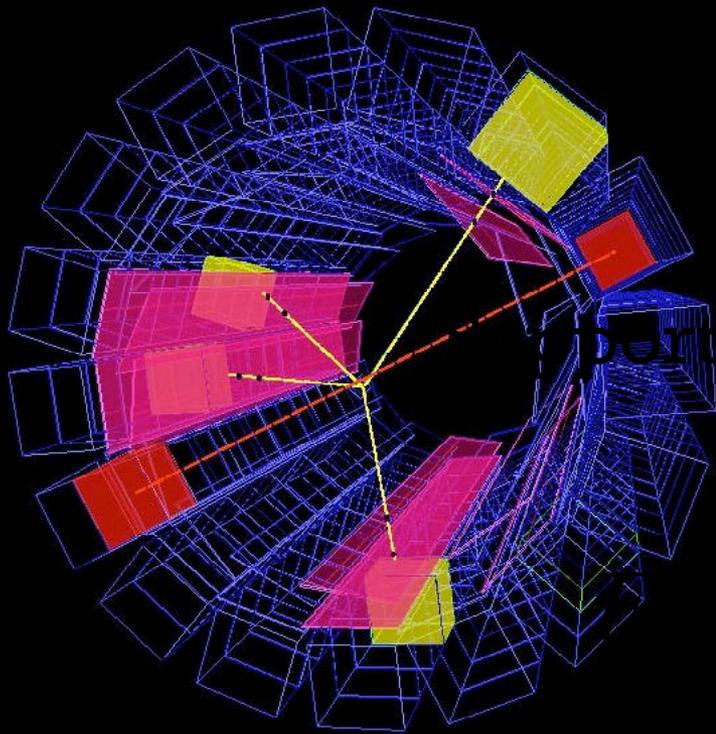


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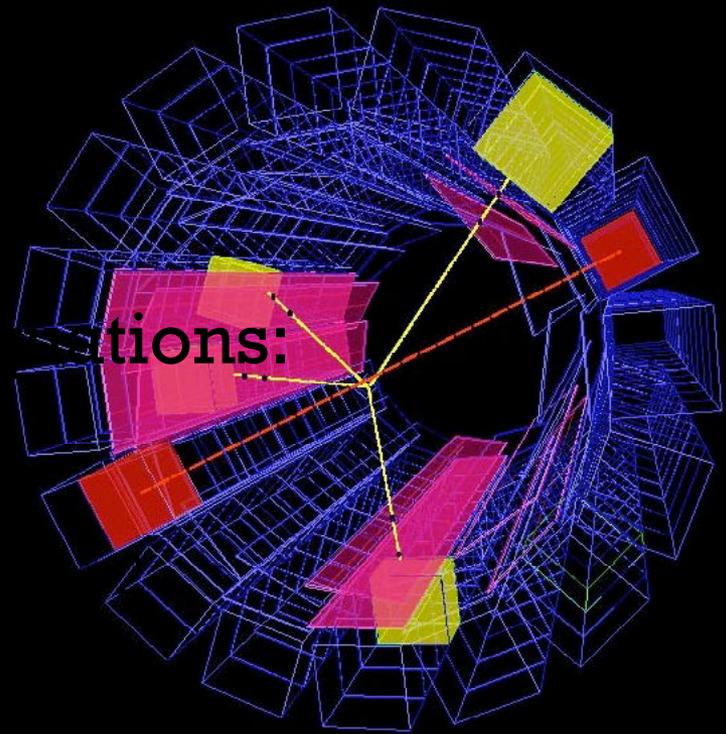


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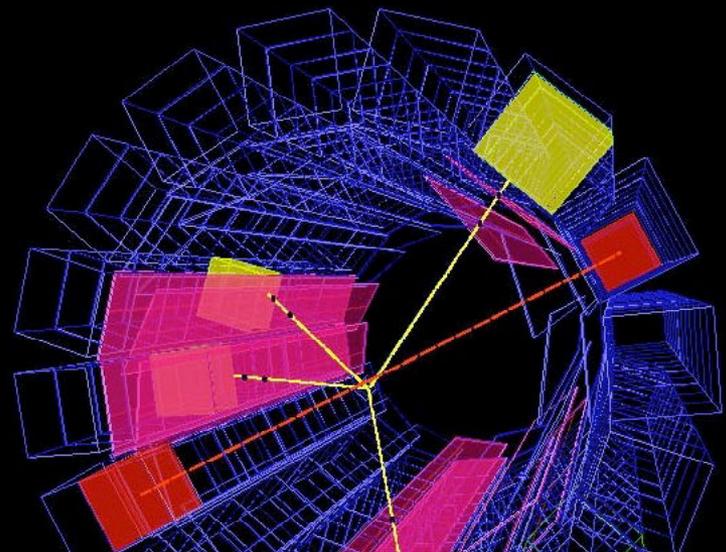
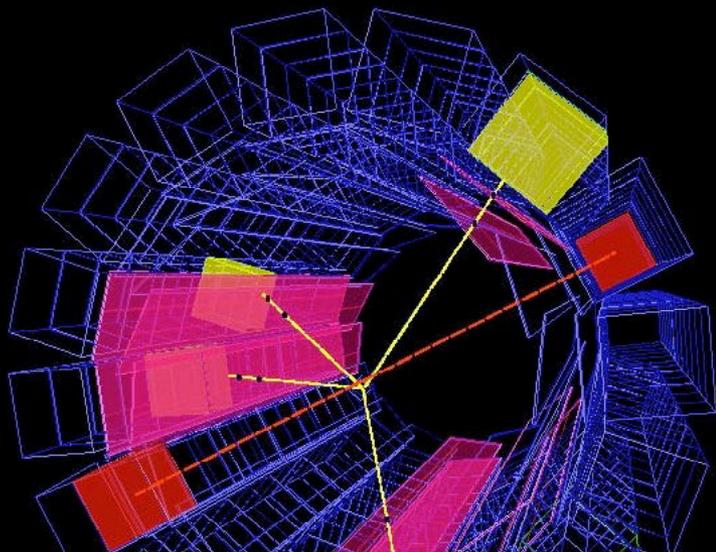


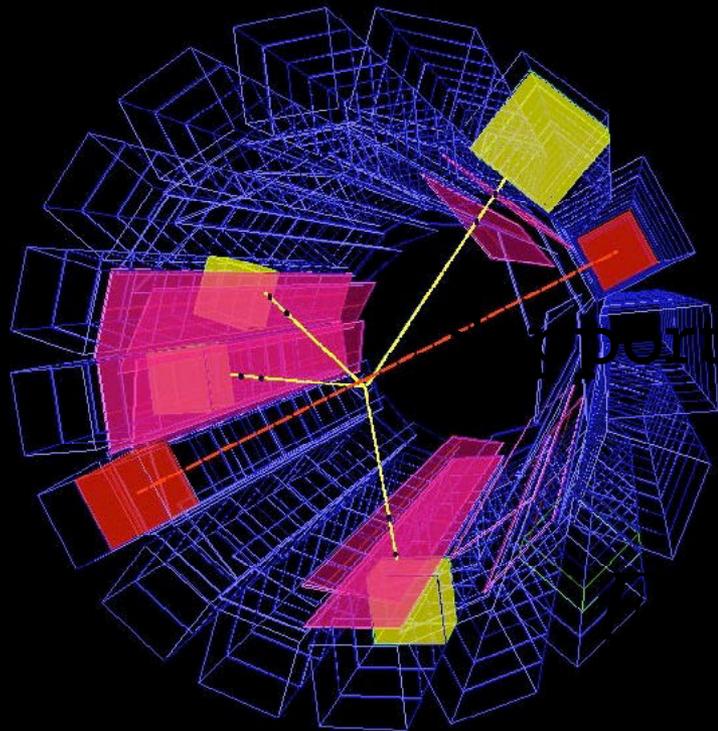


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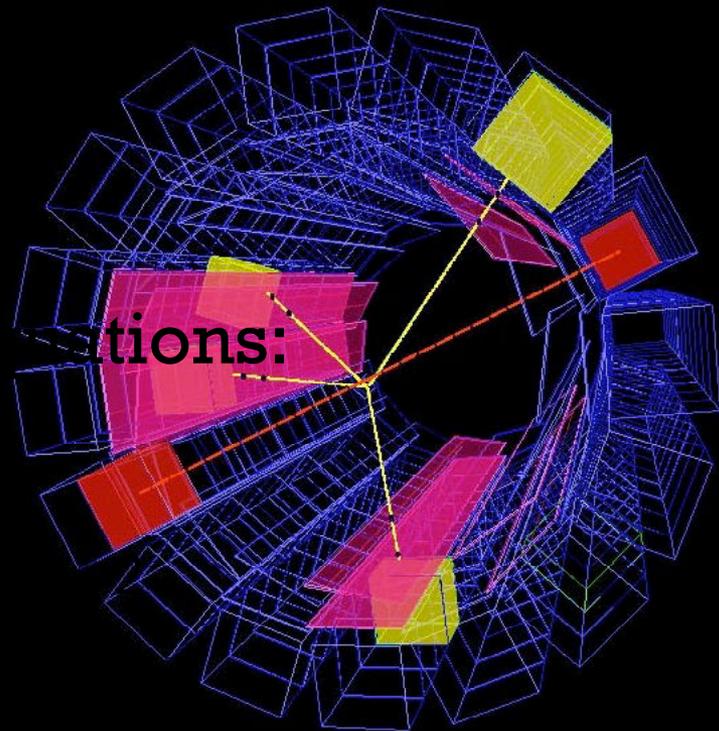


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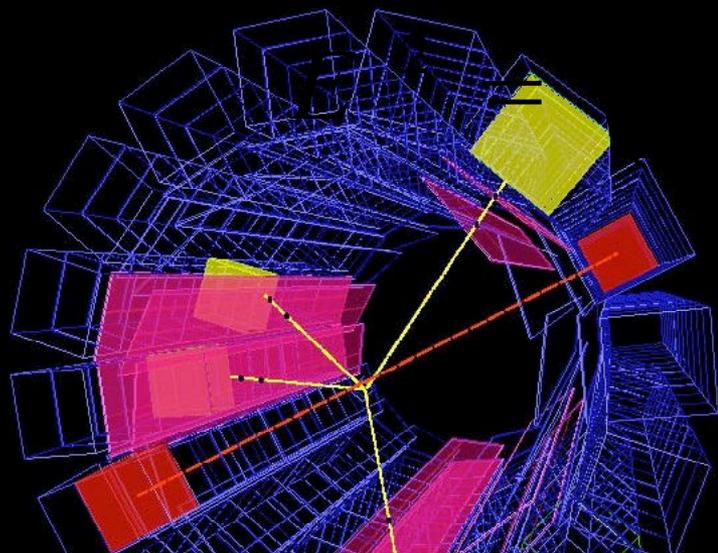




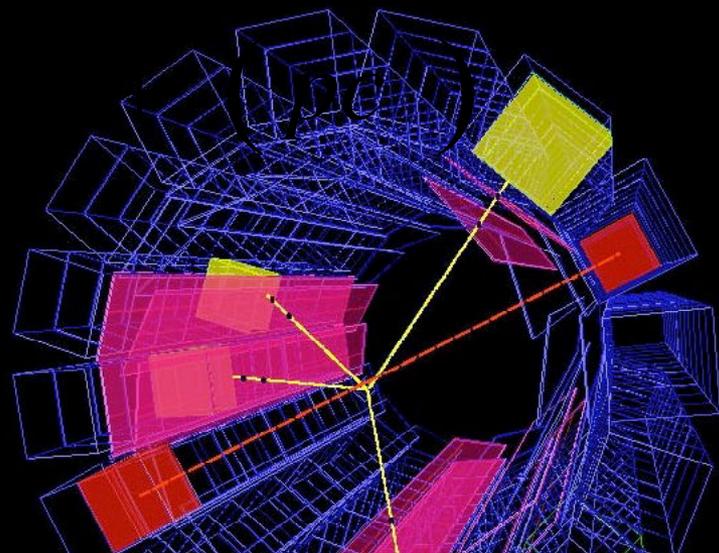
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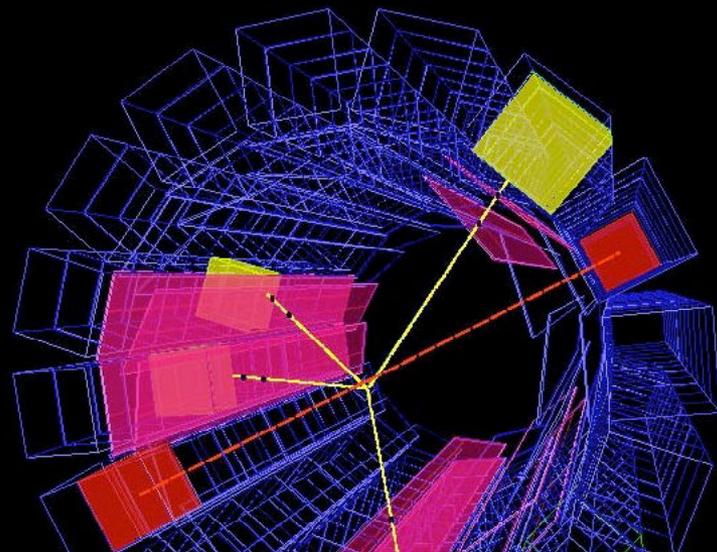
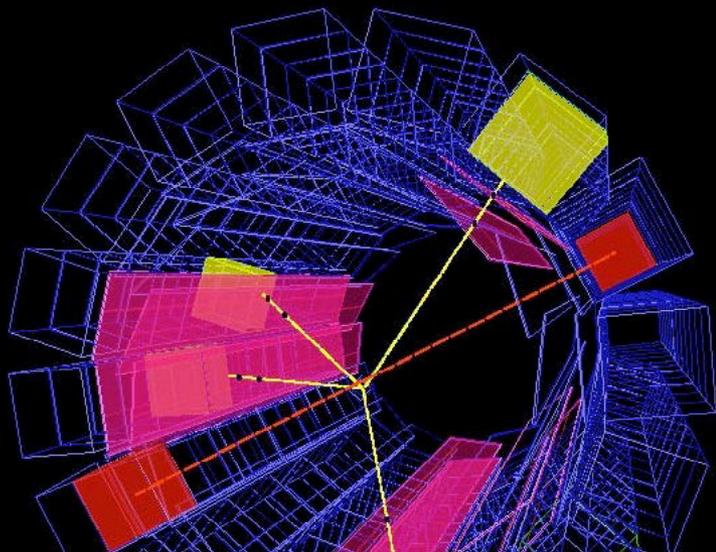
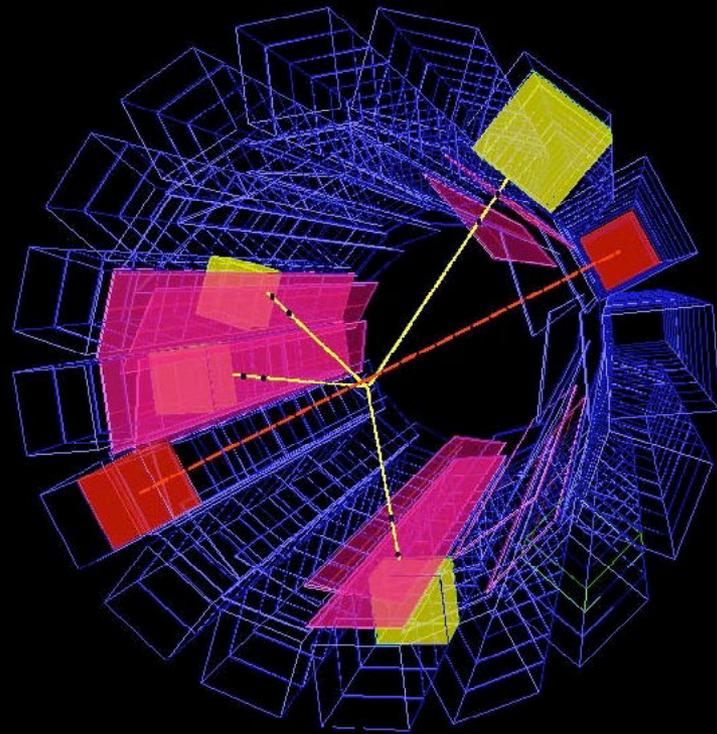
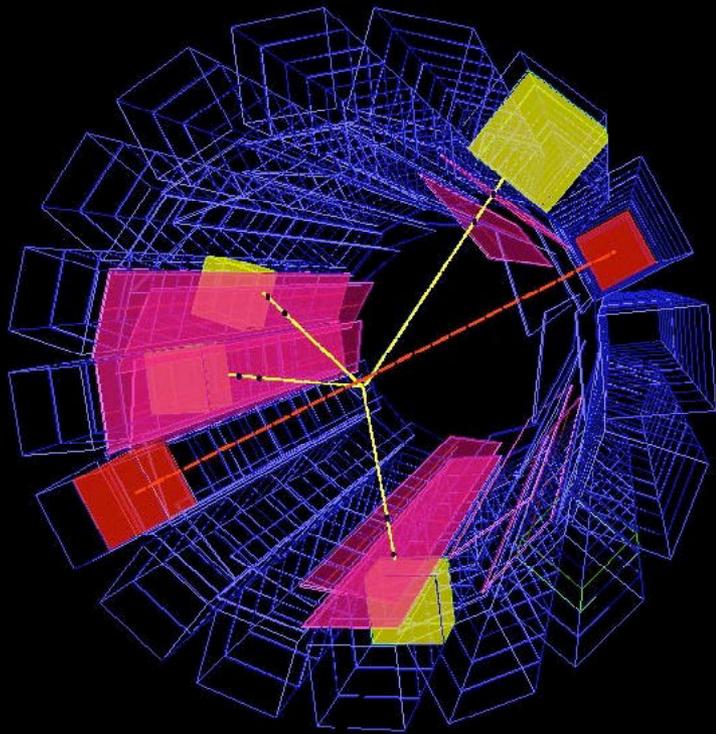
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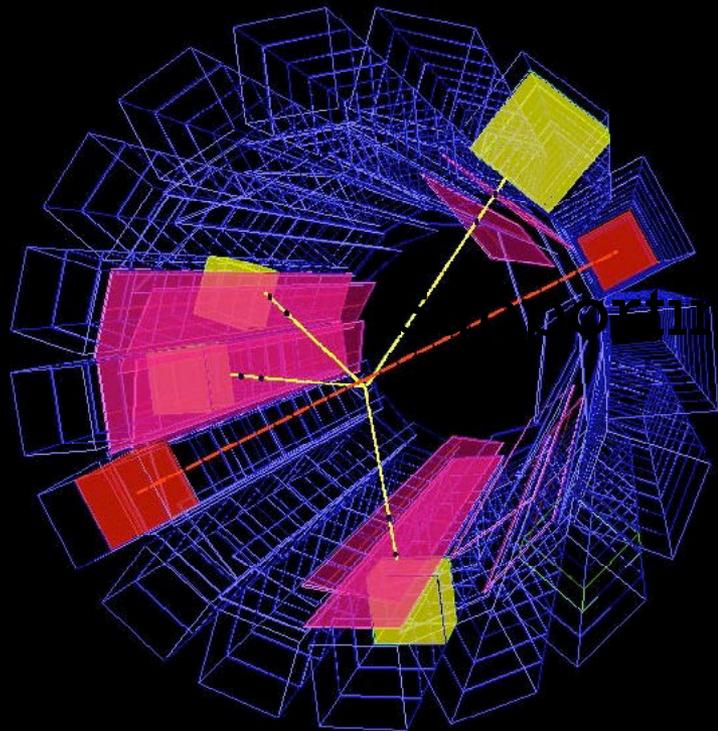


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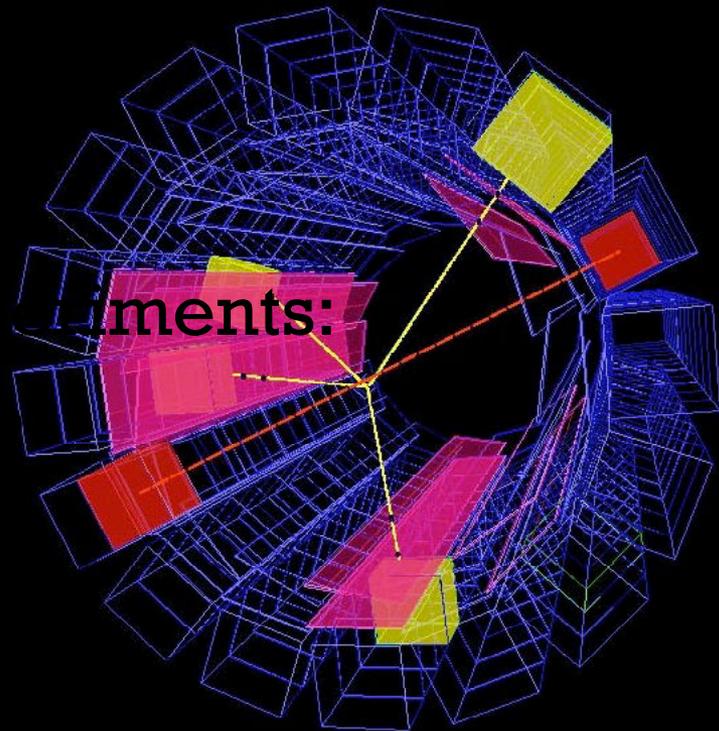


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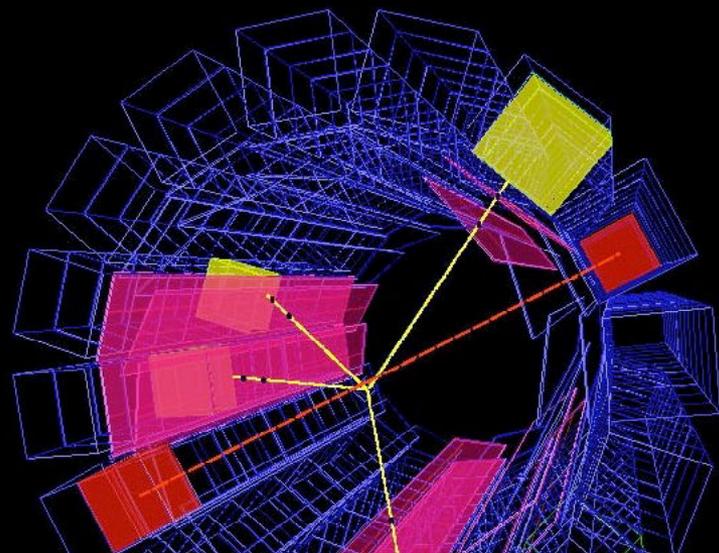
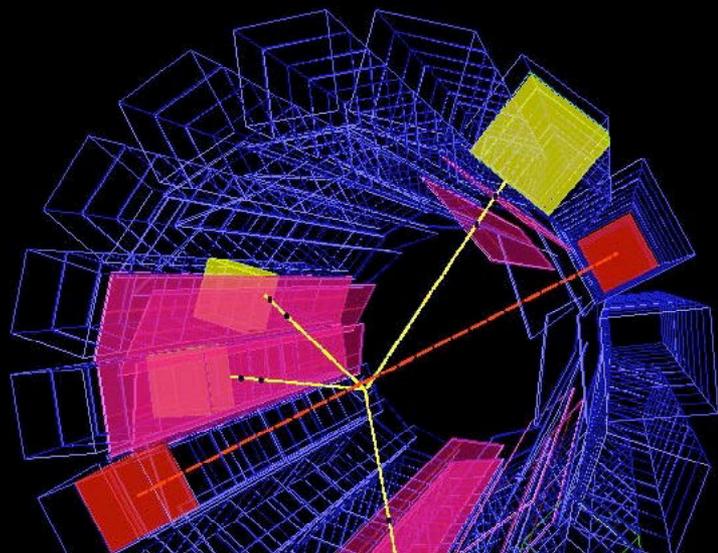


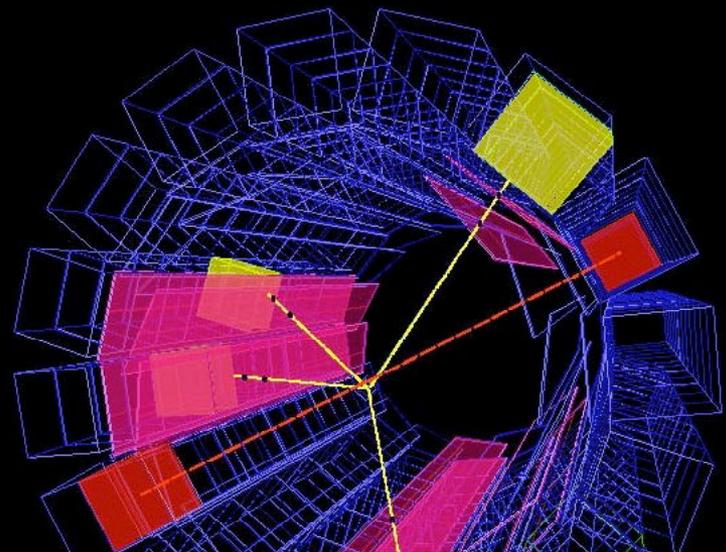
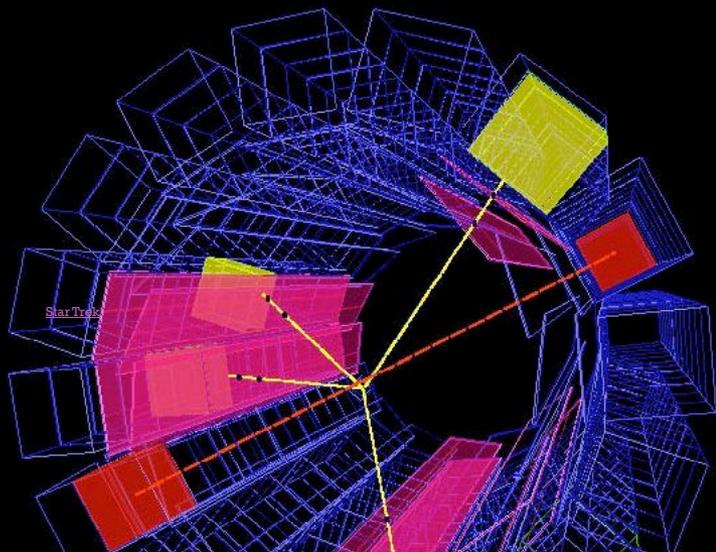
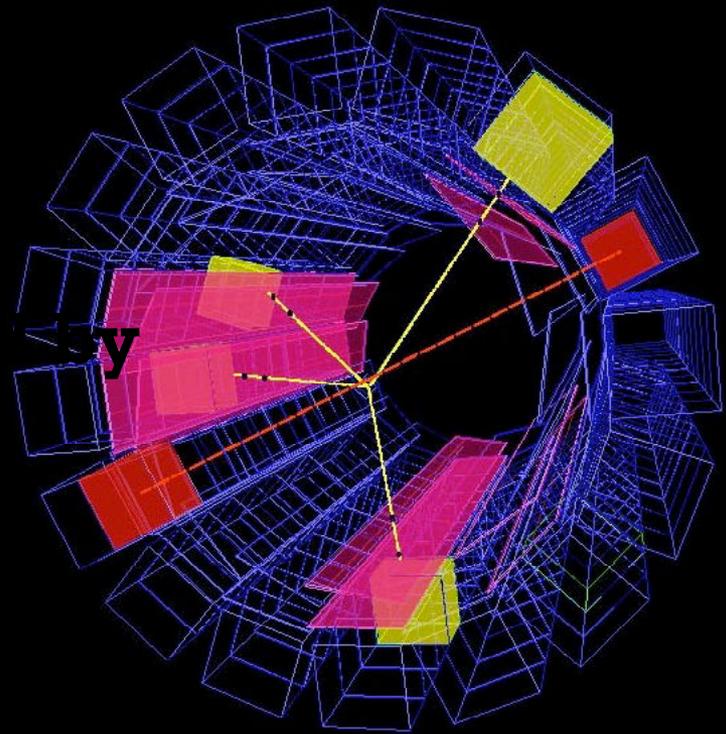
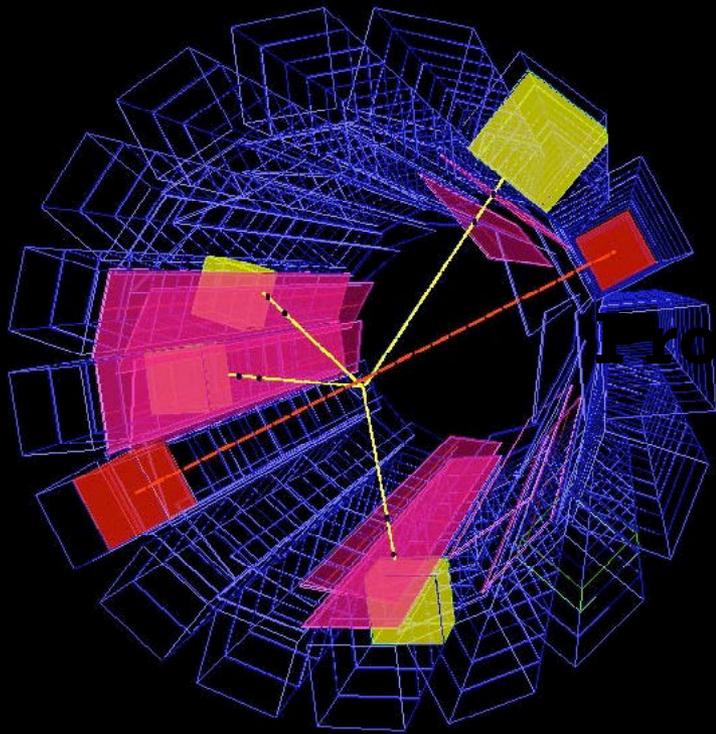


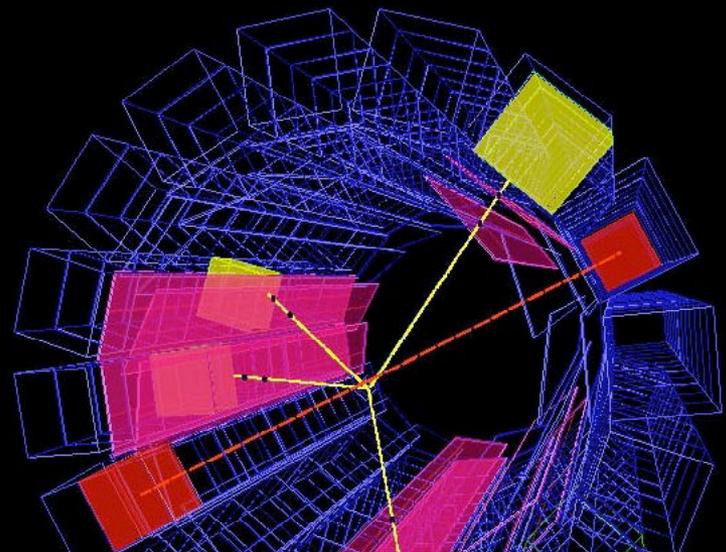
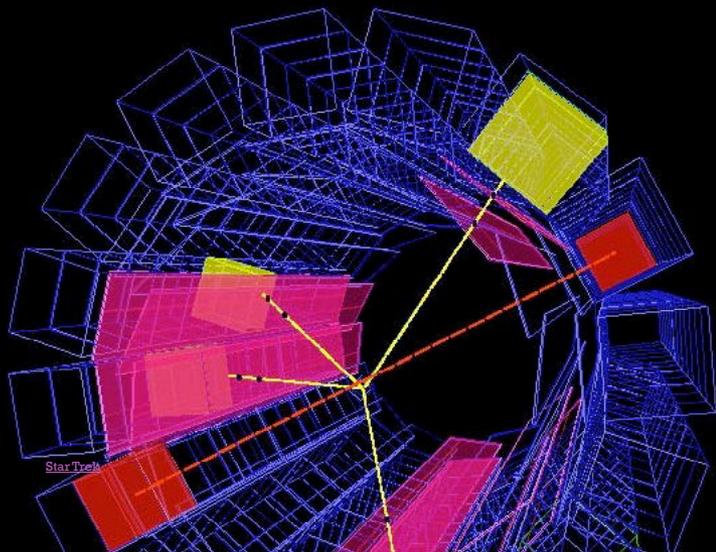
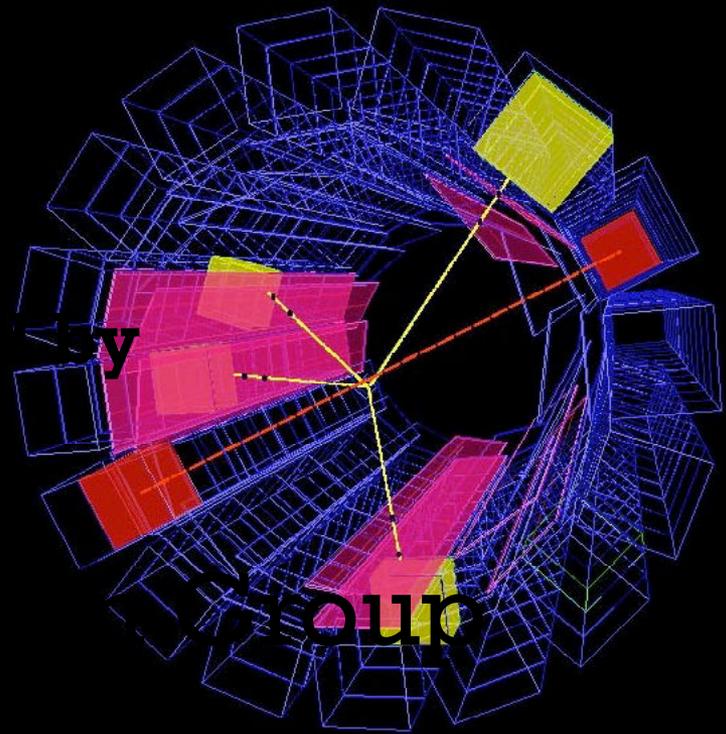
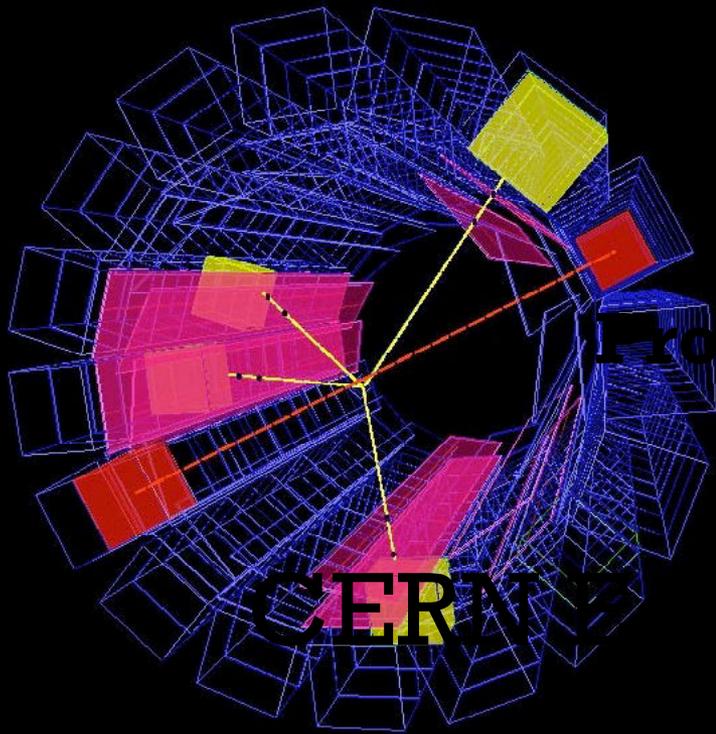
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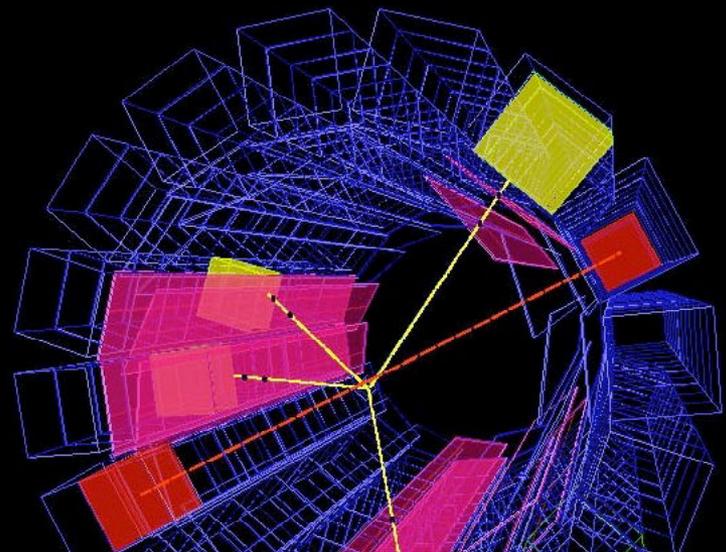
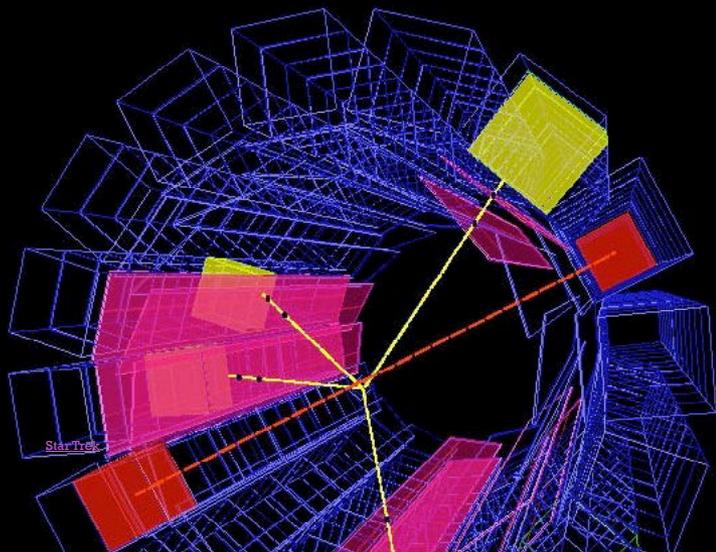
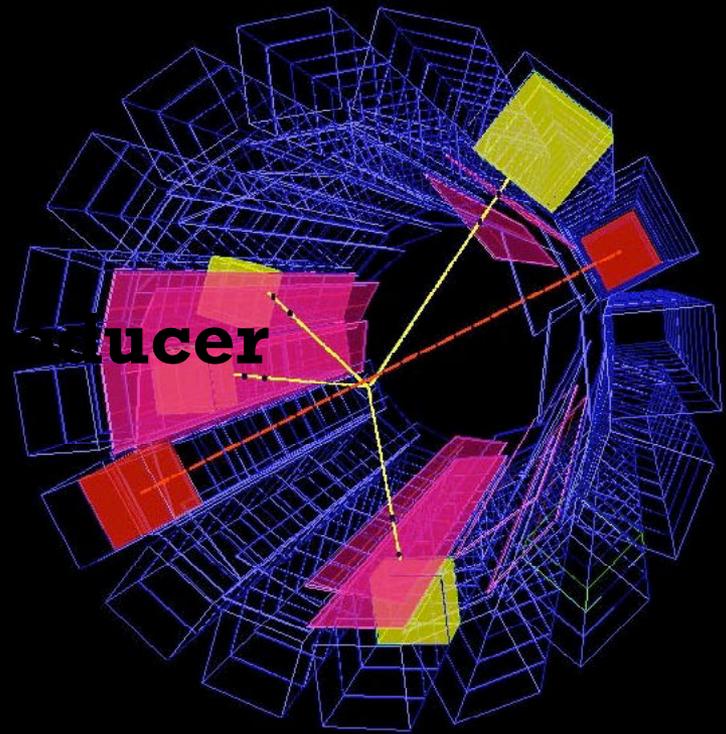
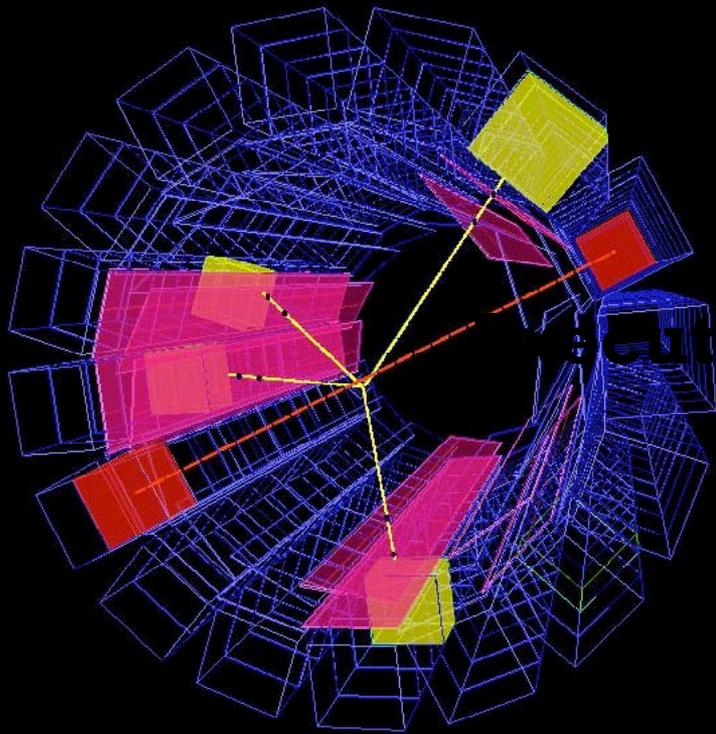


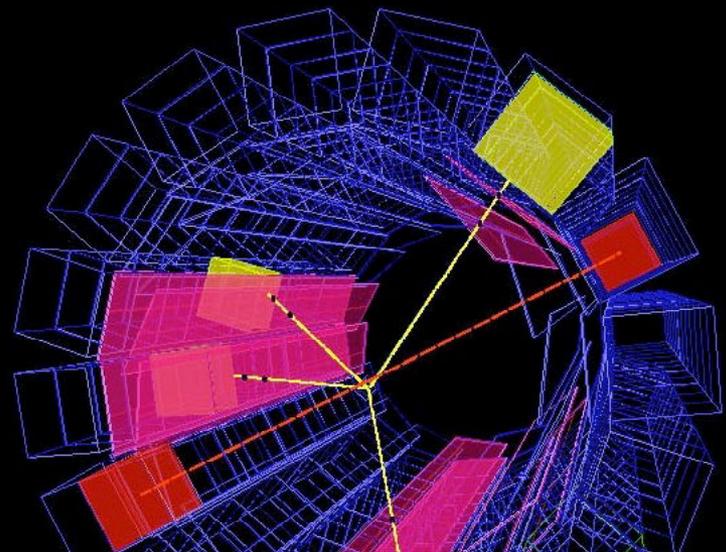
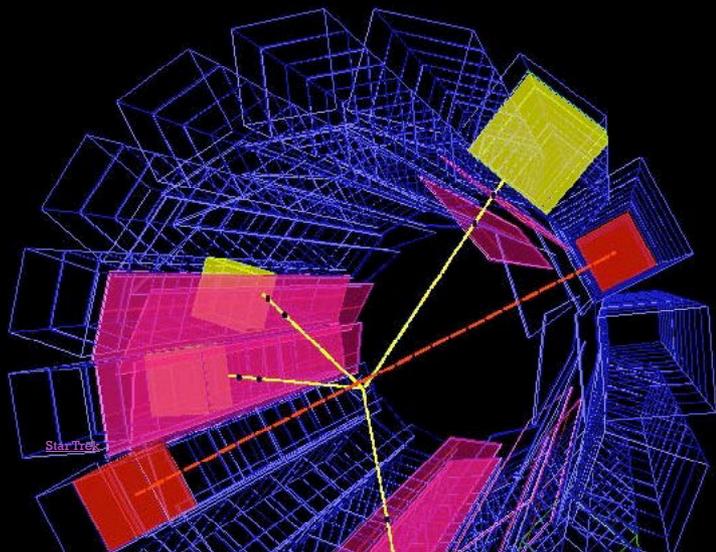
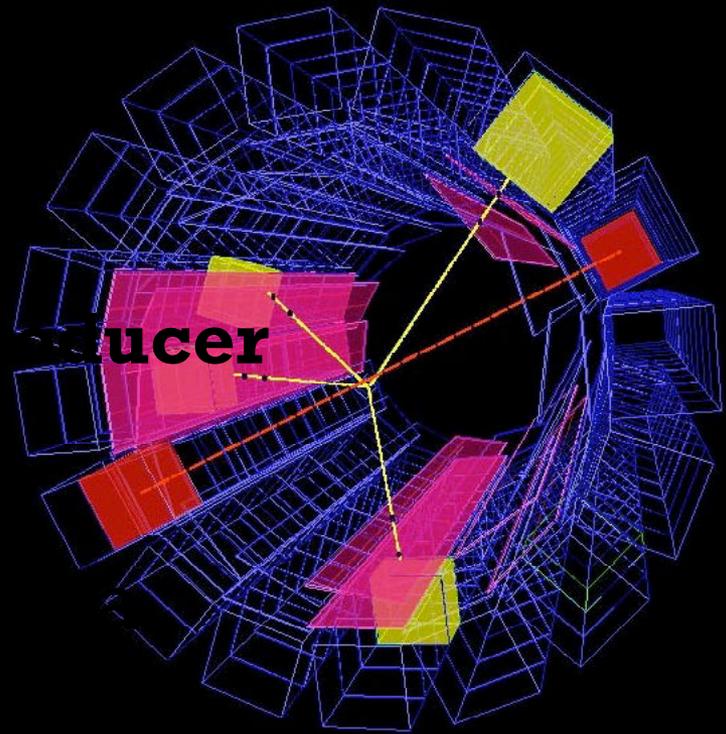
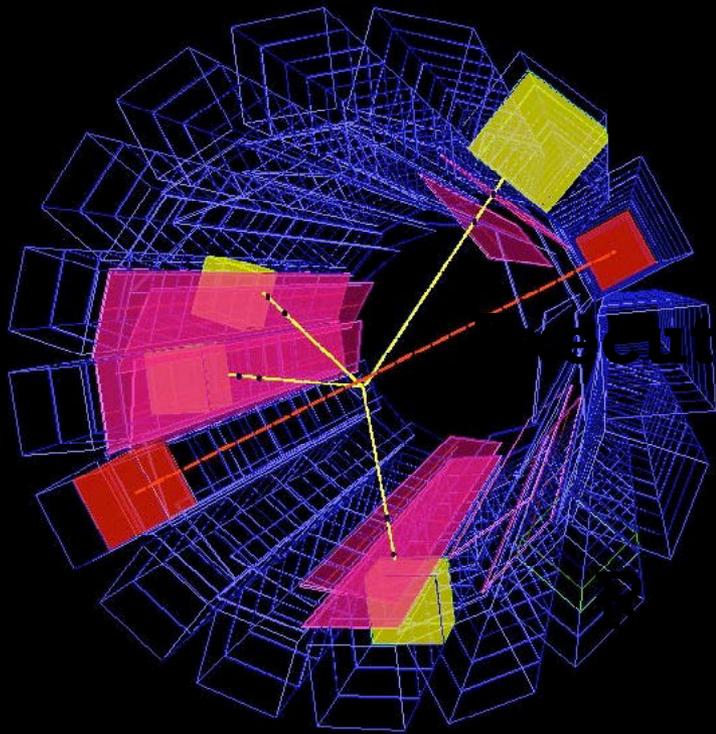
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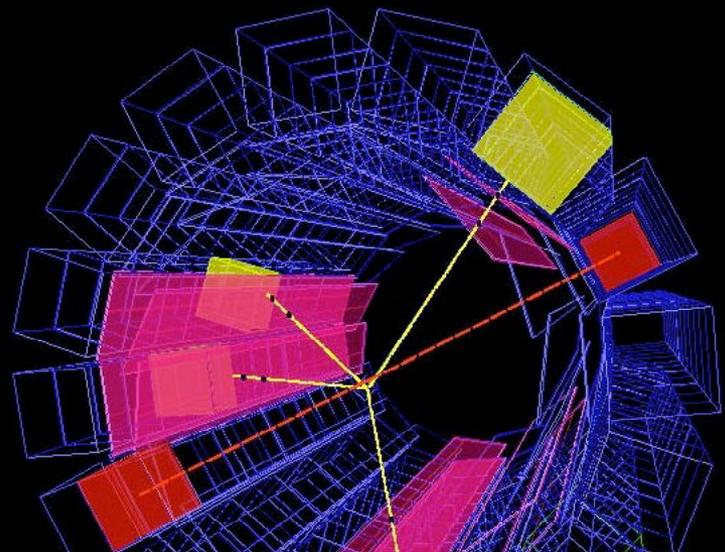
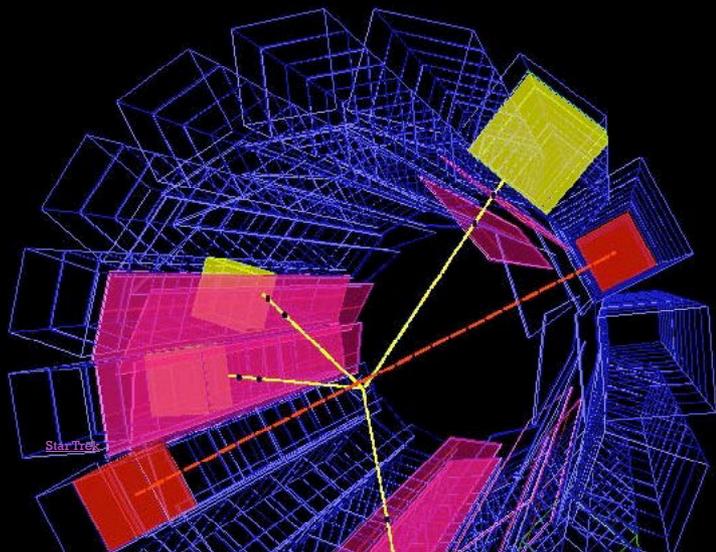
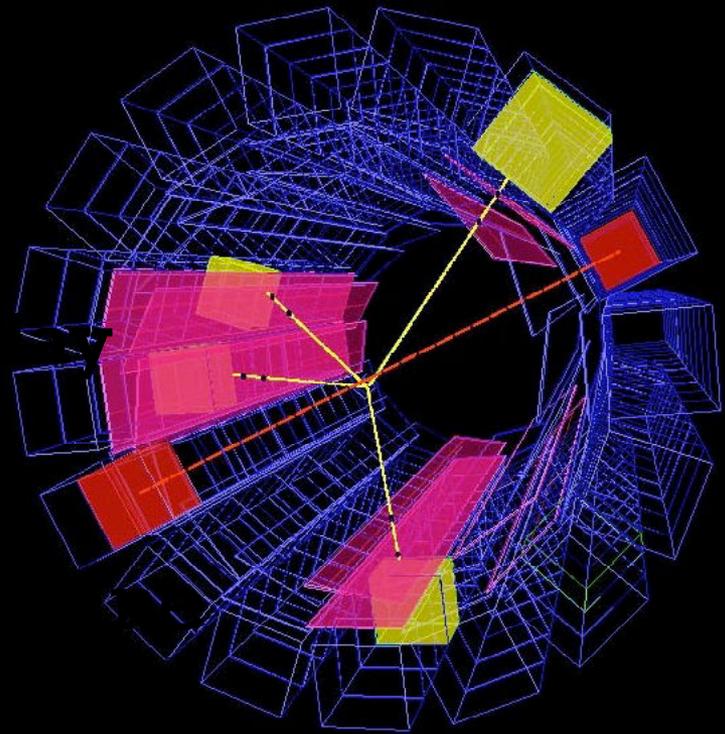
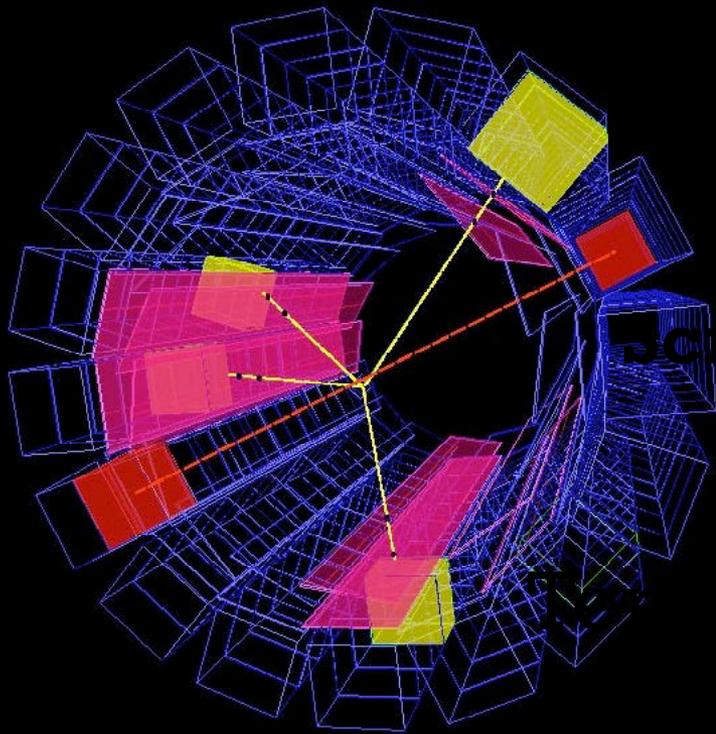


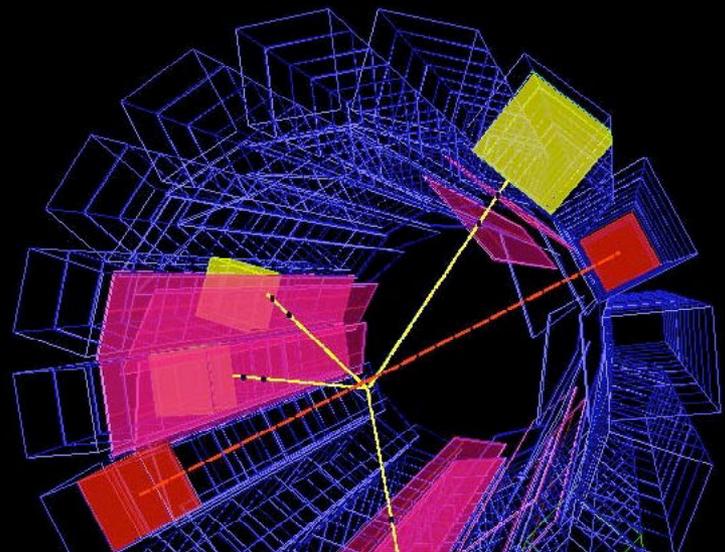
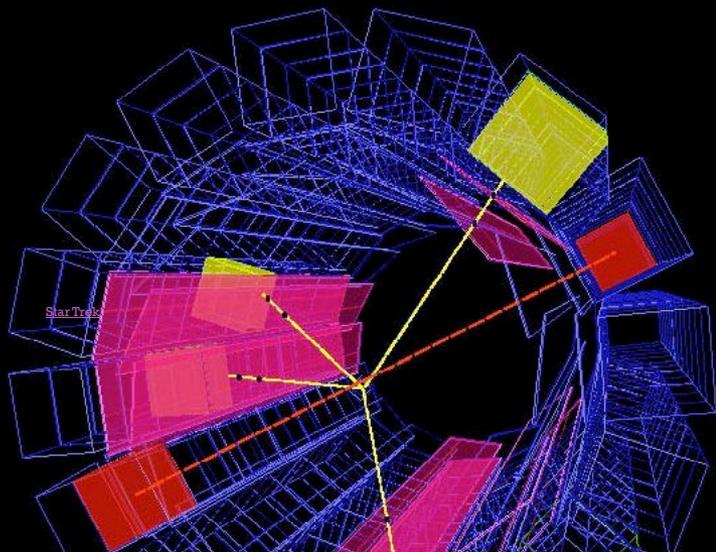
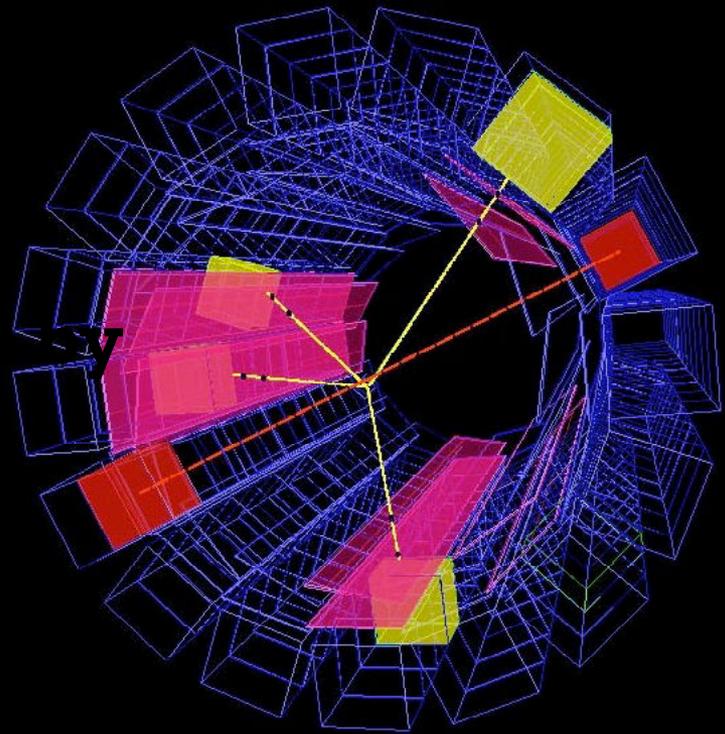
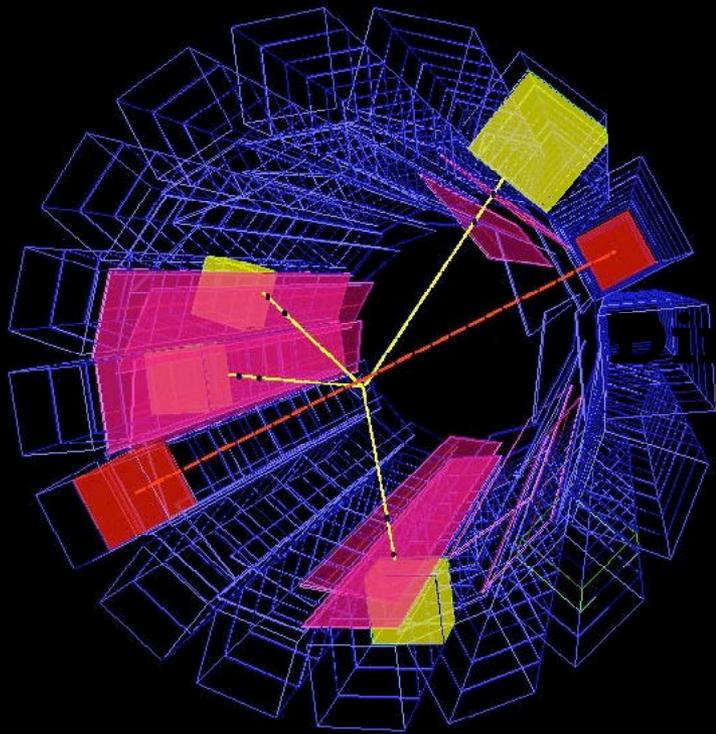


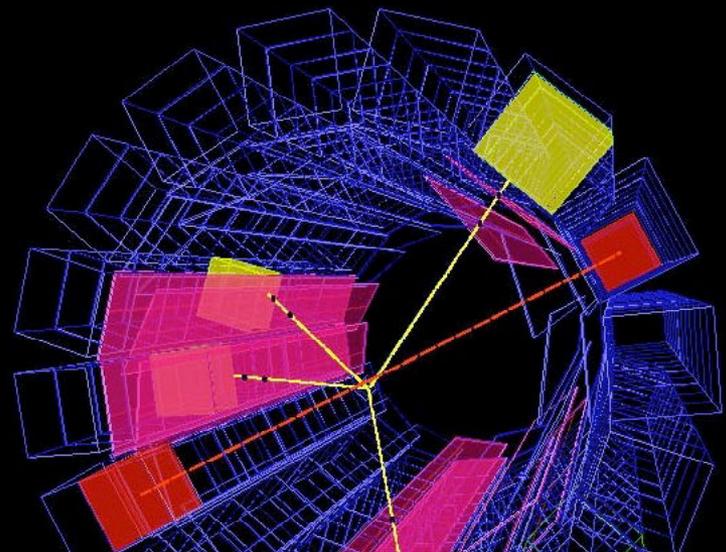
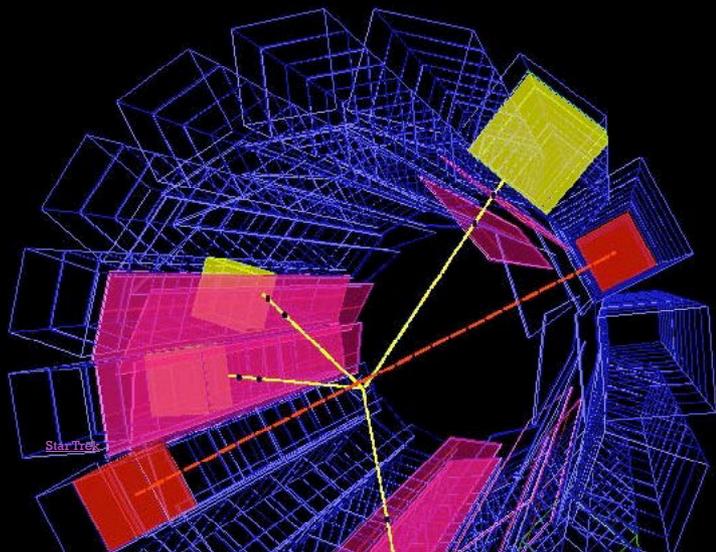
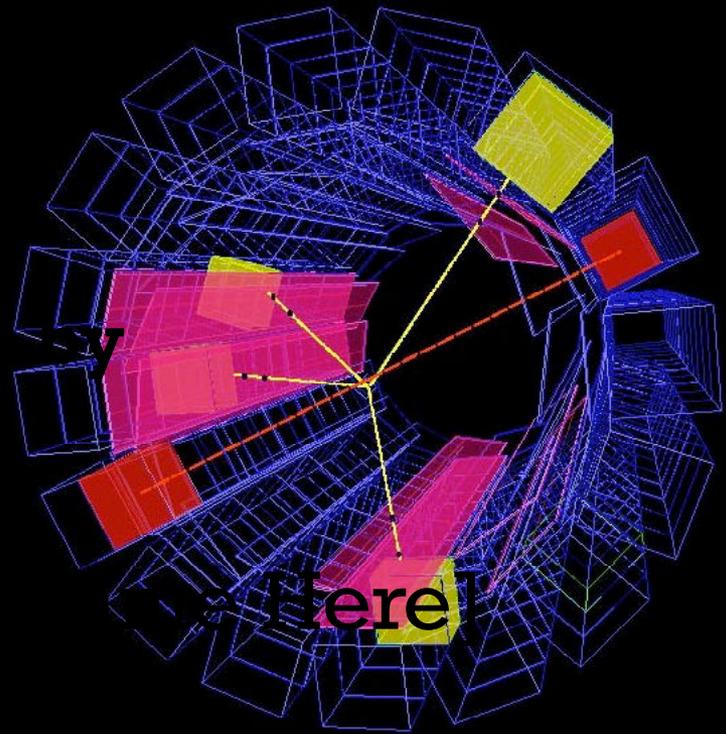
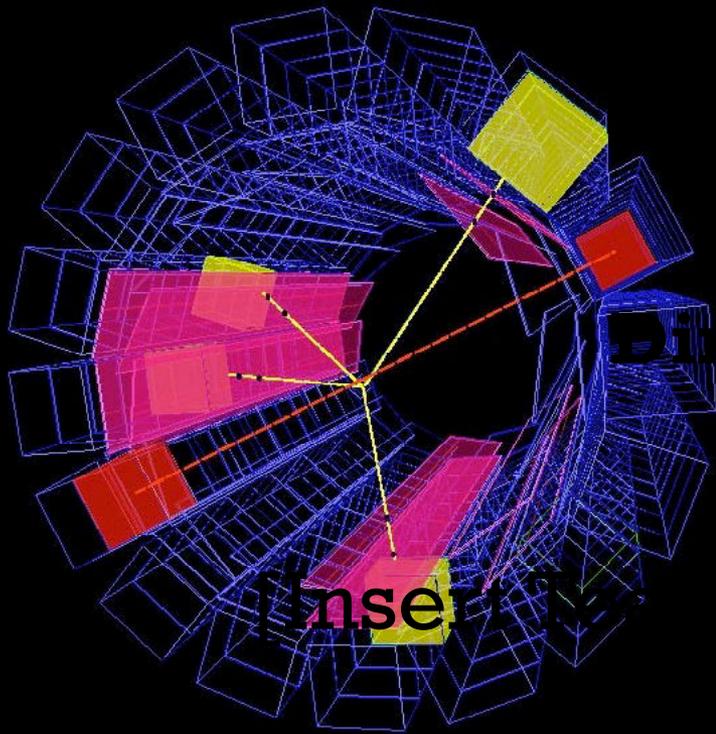














Some thought-provoking questions...



...motivated by Science Fiction



...motivated by Science Fiction

Can antimatter be used to fuel spacecraft
as in Star Trek?

*From the Star Trek (Original Series) Season 3 episode "That Which Survives".
First aired On North American television on January 24, 1969.*

Spock: *As I recall the pattern of our fuel flow, there is an access tube leading to the matter-antimatter reaction chamber.*

Scotty: *Aye, there's a service crawlway, but it's not meant to be used when the integrator operates.*

Spock: *Still, it is there and it may be possible to shut off the flow of fuel at that point.*

Scotty: *What with? Bare hands?*

Spock: *A magnetic probe.*





Scotty: *Any matter that comes in contact with antimatter triggers the explosion. And I'm not even sure a man can live in a crawlway in the energy stream of the magnetic field that bottles up the antimatter!*

Spock: *I shall try.*



...motivated by Science Fiction

What amount of antimatter is needed to
reach another star?

*Clip is from the Star Trek (The Next Generation) Season 1 episode "Coming of Age".
First aired On North American television on March 14, 1988.*

Computer voice: *"Last question on the hyperspace physics test: If the matter and antimatter tanks on a galaxy class starship are nine-tenths depleted, calculate the intermix ratio necessary to reach a star base 100 light years away at warp factor 8".*





Mordock: *I must admit, Wesley, you have a very fast mind.*

Wesley: *Once I realized it was a trick question, there was only one answer.*

Mordock: *Yes. There is only one ratio with matter-antimatter—1:1.*



...motivated by Science Fiction

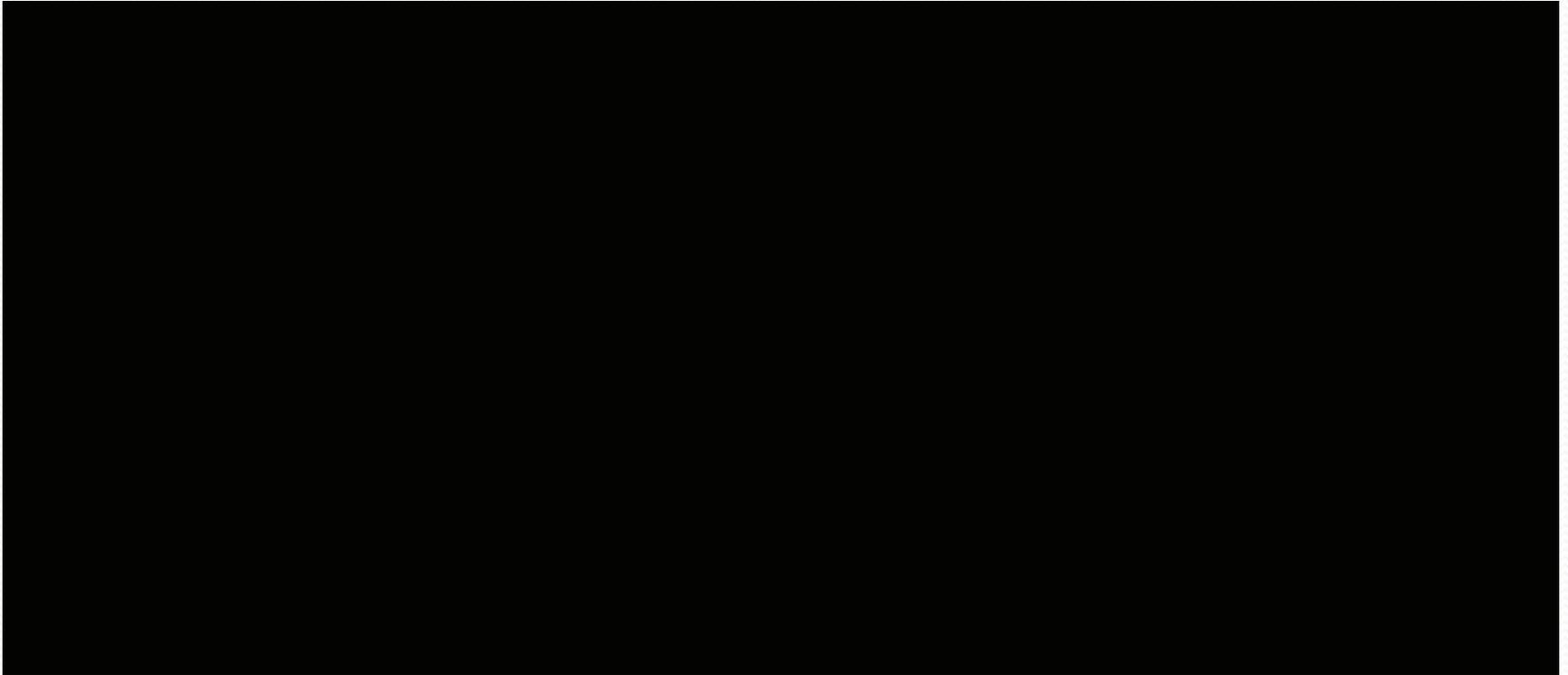
Should we be worried about
antimatter weapons?

Clip is from the film “Angels and Demons”.

Released worldwide May, 2009.



...motivated by Science Fiction





...motivated by Science Fiction



...motivated by Science Fact



...motivated by Science Fact

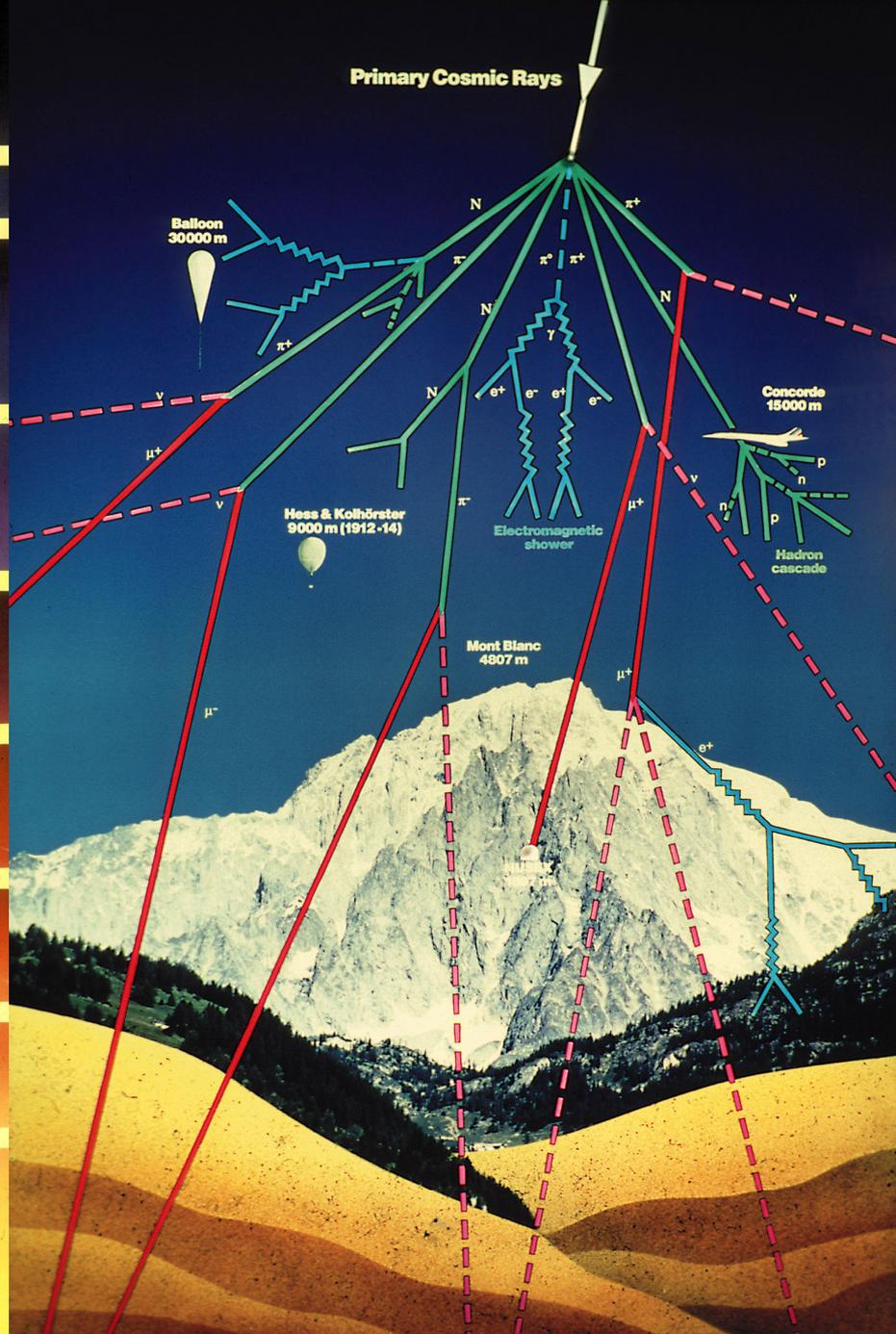
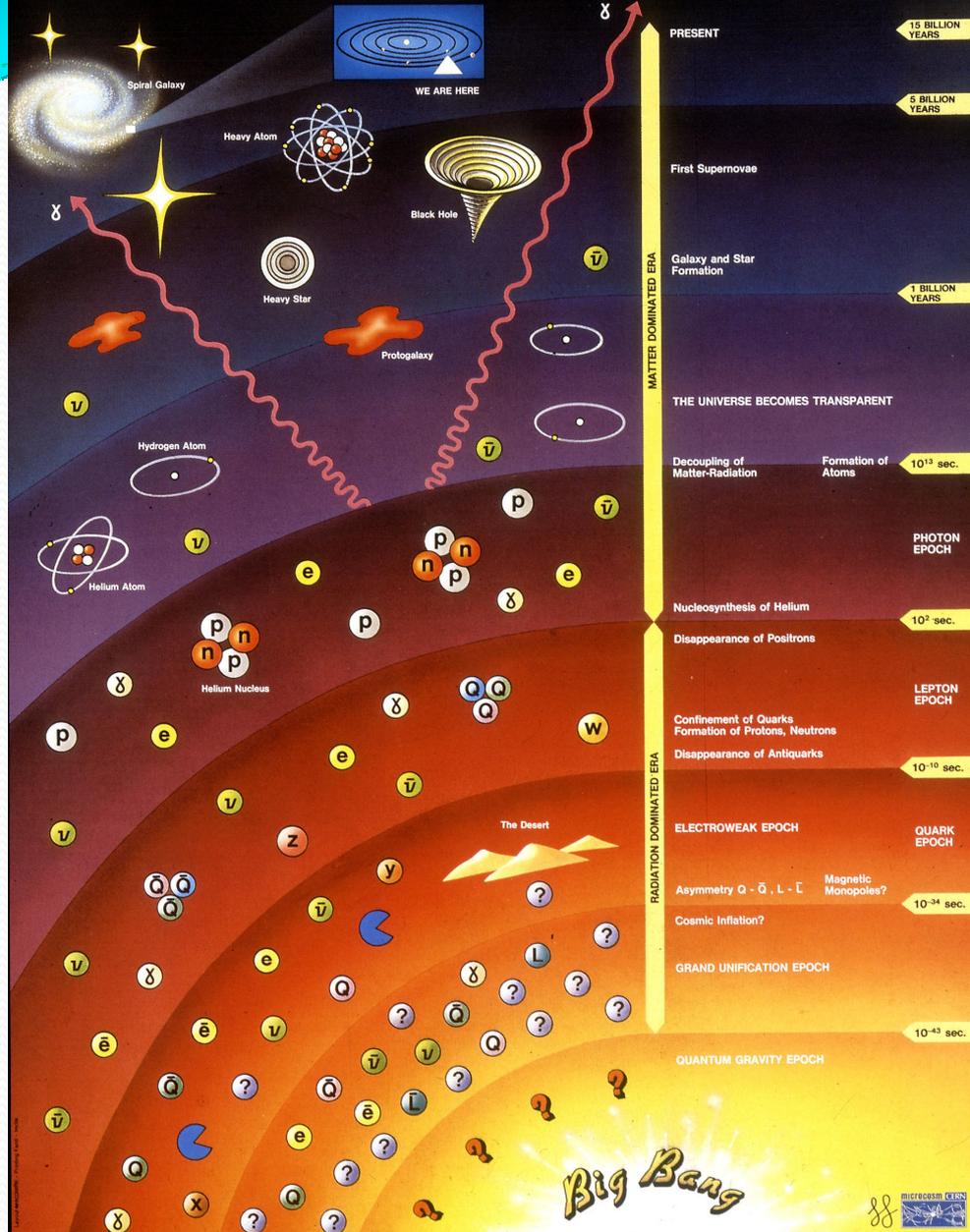
Where does antimatter come from?



...motivated by Science Fact

And where did it all go?

History of the Universe

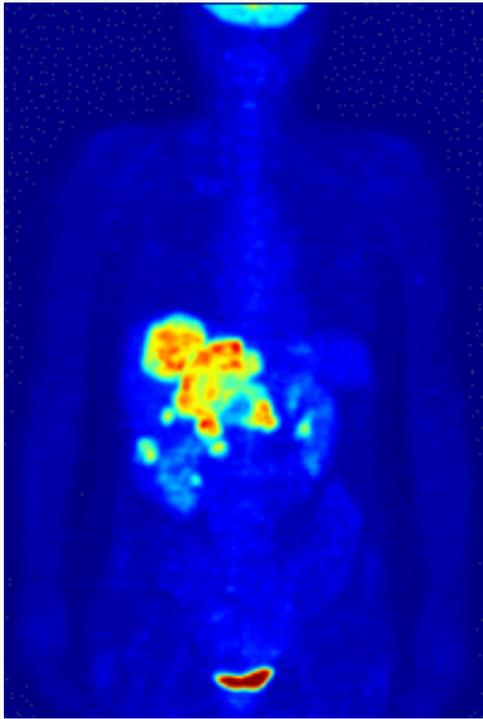




...motivated by Science Fact

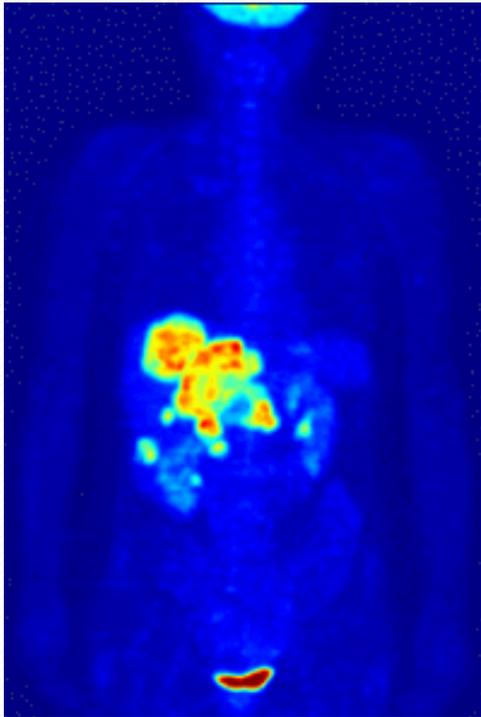
What can antimatter
practically be used for?

...motivated by Science Fact



Positron
Emission
Tomography

...motivated by Science Fact



Positron
Emission
Tomography

Antiproton Annihilation Therapy?

- Energy from annihilation : $2x m_p \sim 1.88 \text{ GeV}$
- Most of the energy is carried away by pions and gammas.
- Recoiling nuclei do the local damage, "only" about 30 MeV

Michael H. Holzschelner FIAS 19. October 2006





“The only way of discovering the limits of the possible is to venture a little way past them into the impossible.”

(Arthur C. Clarke)

“The only way of discovering the limits of the possible is to venture a little way past them into the impossible.”

(Arthur C. Clarke)

Is there an anti-universe? An anti-planet?

“The only way of discovering the limits of the possible is to venture a little way past them into the impossible.”

(Arthur C. Clarke)

Is there an anti-you?

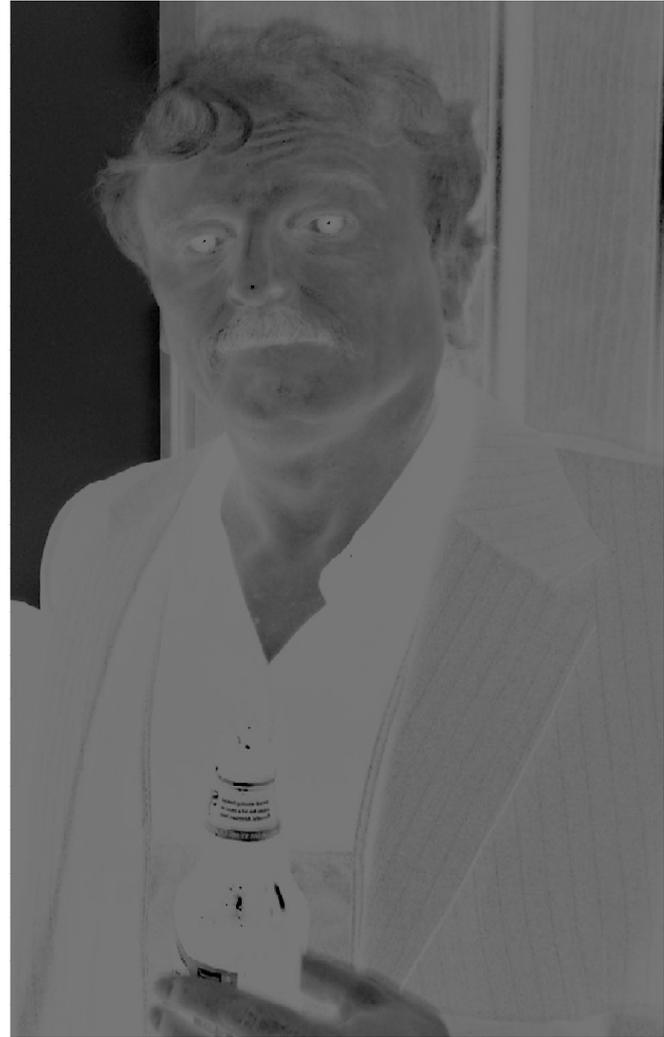
Me



Me



Anti-me



Me



Anti-me



Anti-Beer

Merkel/Stoltenberg



Merkel/Stoltenberg



AntiMerkel/Stoltenberg



Relevant Prior Knowledge in Science

**The following
example uses the
Ontario (Canada)
Science Curriculum
(2008).**

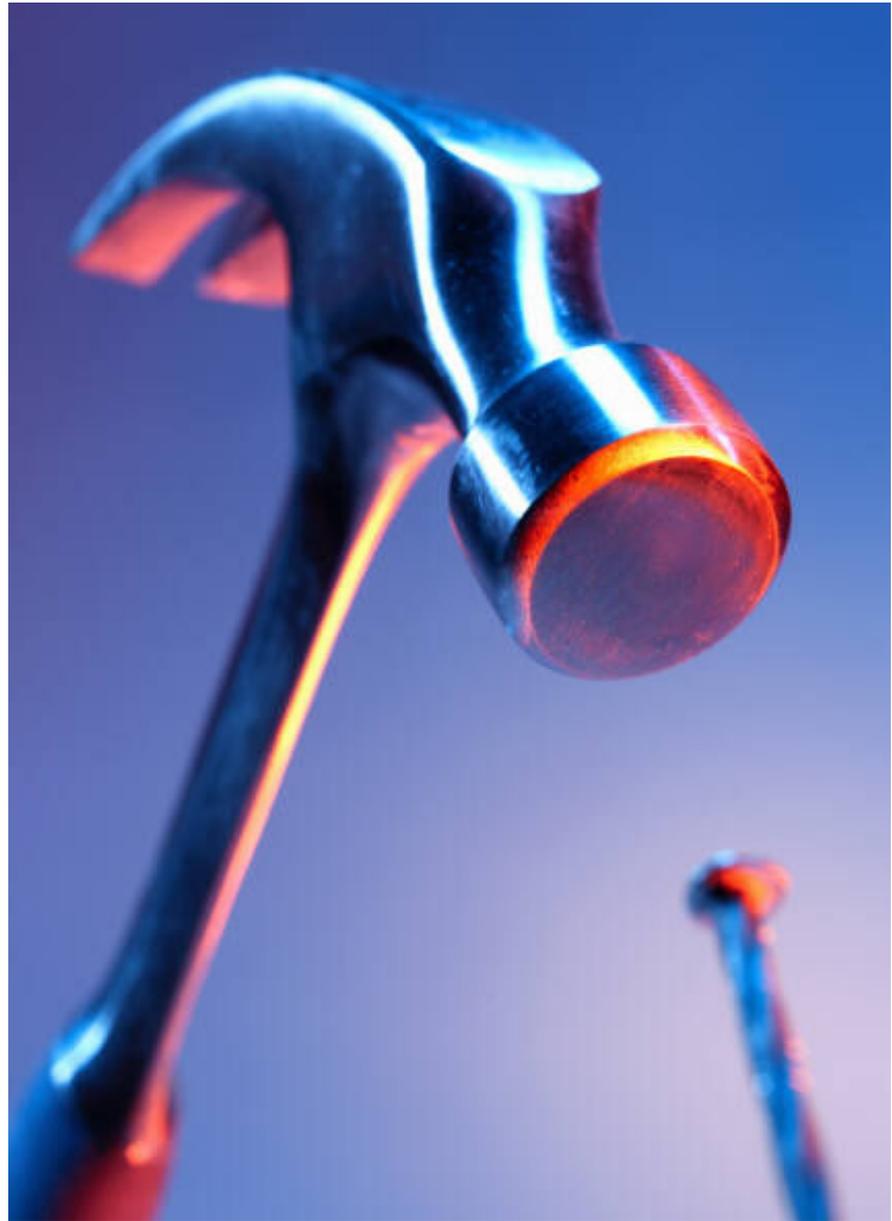
[http://www.edu.gov.
on.ca/eng/](http://www.edu.gov.on.ca/eng/)

Relevant Prior Knowledge in Science

Relevant Prior
Knowledge in Science

Grade 3

*“Identify a
force as a push
or a pull that
causes an
object to
move.”*

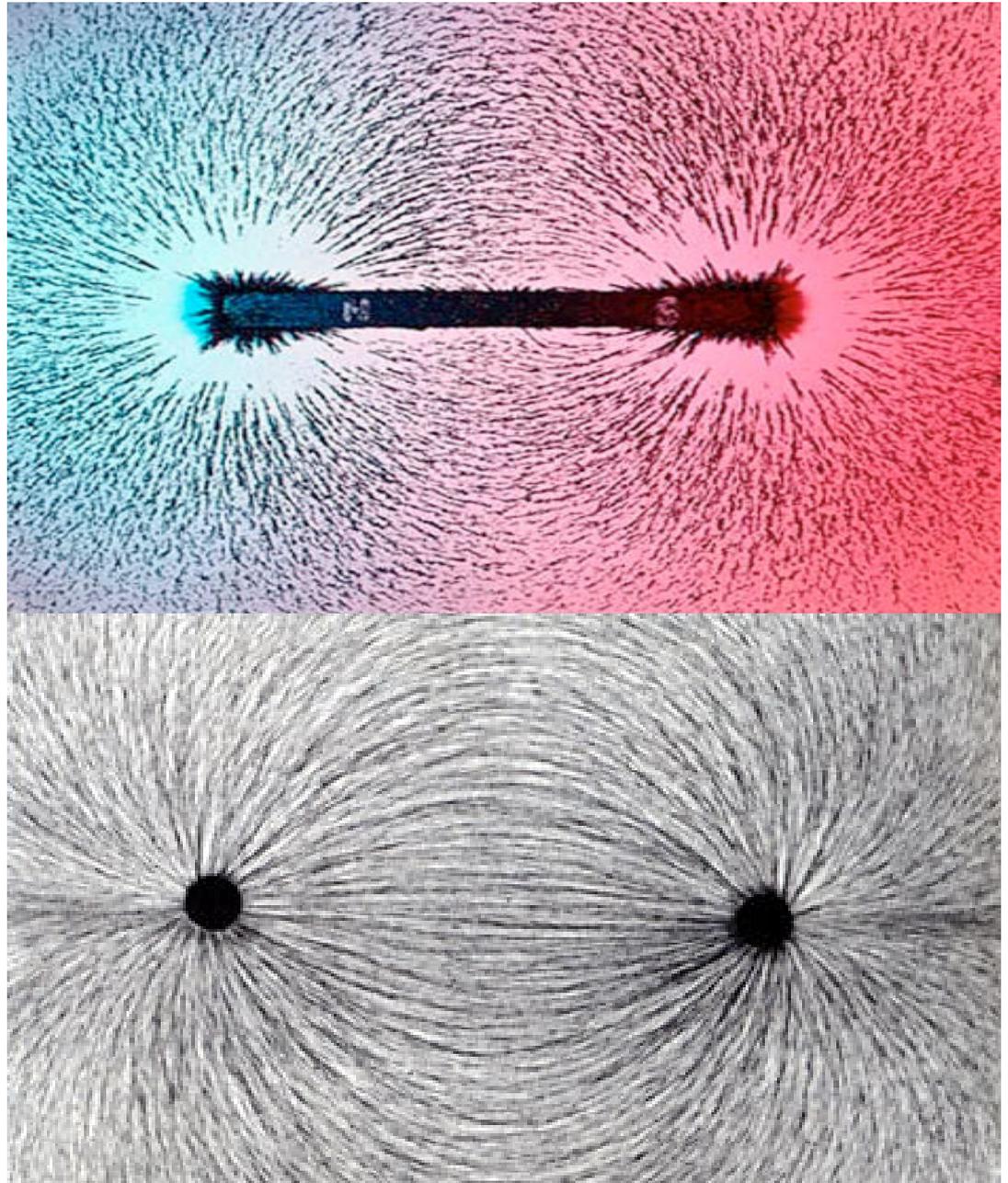


Relevant Prior Knowledge in Science

Grade 3

“Identify a force as a push or a pull that causes an object to move.”

“Identify different kinds of forces (e.g., gravity, the electrostatic force, and the magnetic force).”



Relevant Prior Knowledge in Science

Grade 3

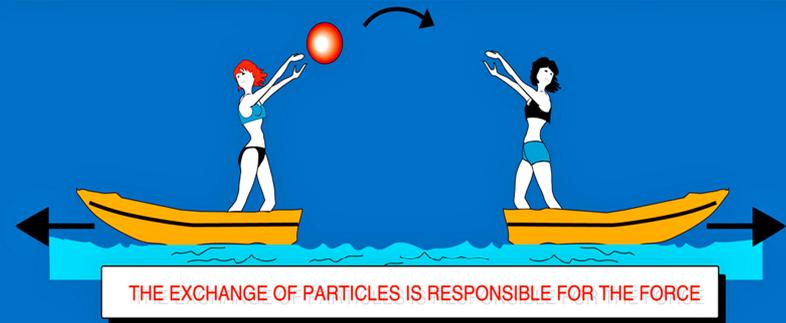
“Identify a force as a push or a pull that causes an object to move.”

“Identify different kinds of forces (e.g., gravity, the electrostatic force, and the magnetic force).”

“Explain how forces are exerted through direct contact (e.g., pushing a door, pulling a toy) or through interaction at a distance (e.g., magnetism, gravity).”

The forces in Nature

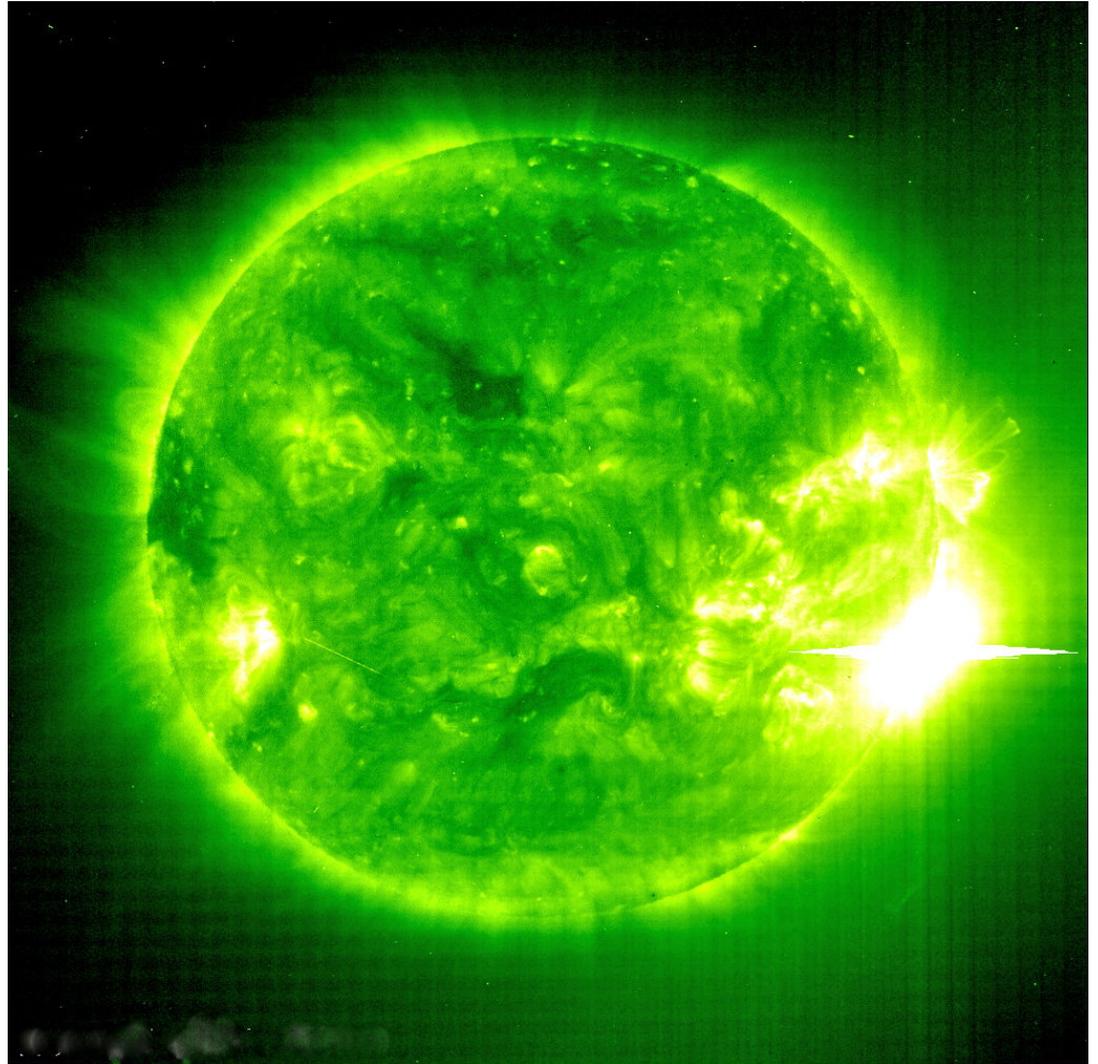
TYPE	INTENSITY OF FORCES (DECREASING ORDER)	BINDING PARTICLE (FIELD QUANTUM)	OCCURS IN :
STRONG NUCLEAR FORCE	~ 1	GLUONS (NO MASS)	ATOMIC NUCLEUS
ELECTRO -MAGNETIC FORCE	$\sim 10^{-3}$	PHOTONS (NO MASS)	ATOMIC SHELL ELECTROTECHNIQUE
WEAK NUCLEAR FORCE	$\sim 10^{-5}$	BOSONS Z^0, W^+, W^- (HEAVY)	RADIOACTIVE BETA DESINTEGRATION
GRAVITATION	$\sim 10^{-38}$	GRAVITONS (?)	HEAVENLY BODIES



Relevant Prior
Knowledge in Science

Grade 4

“Demonstrate an understanding of light and sound as forms of energy that have specific characteristics and properties.”



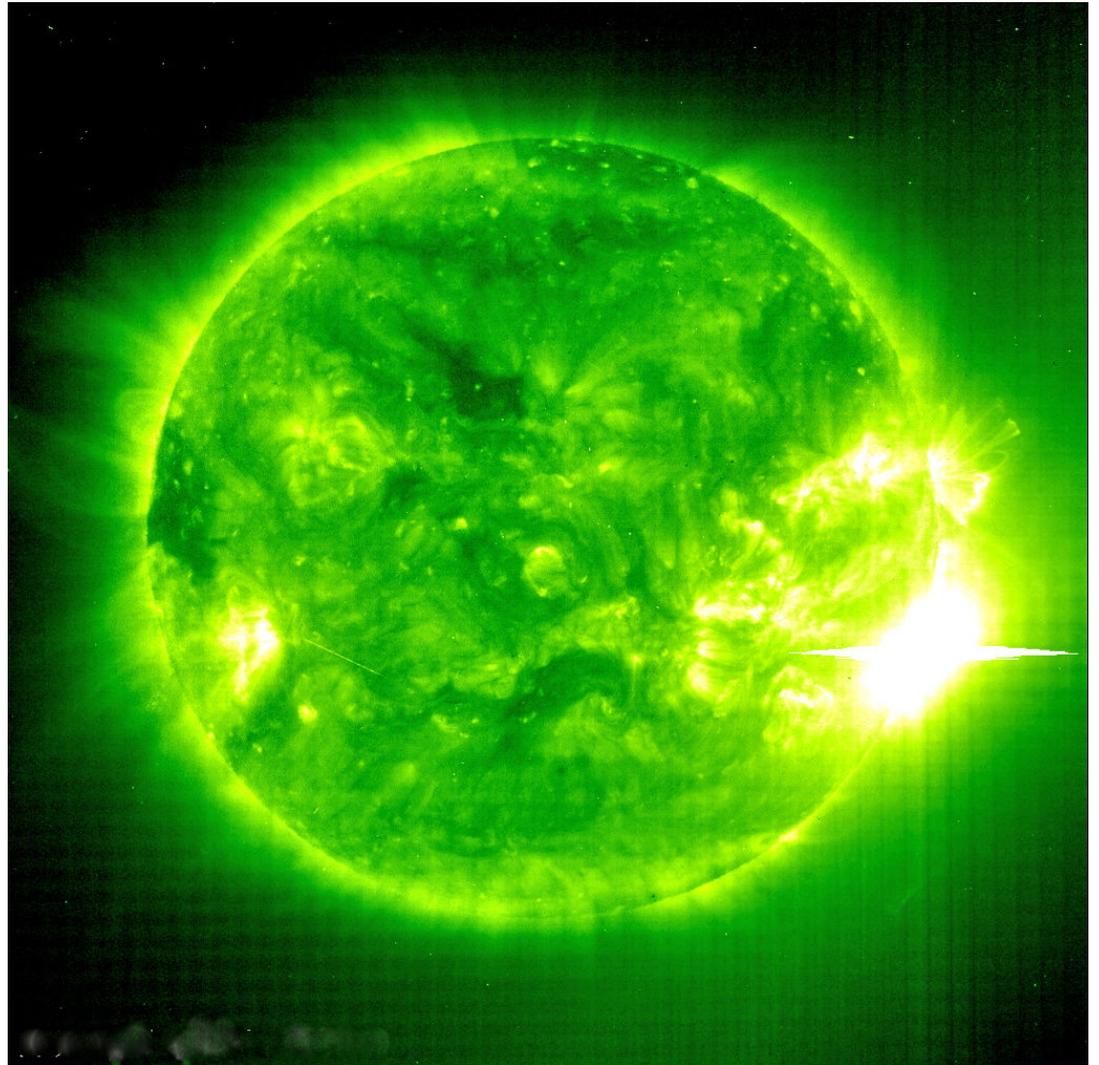
Relevant Prior Knowledge in Science

Grade 4

“Demonstrate an understanding of light and sound as forms of energy that have specific characteristics and properties.”

Grade 5

“Demonstrate an understanding of the various forms and sources of energy and the ways in which energy can be transformed and conserved.”

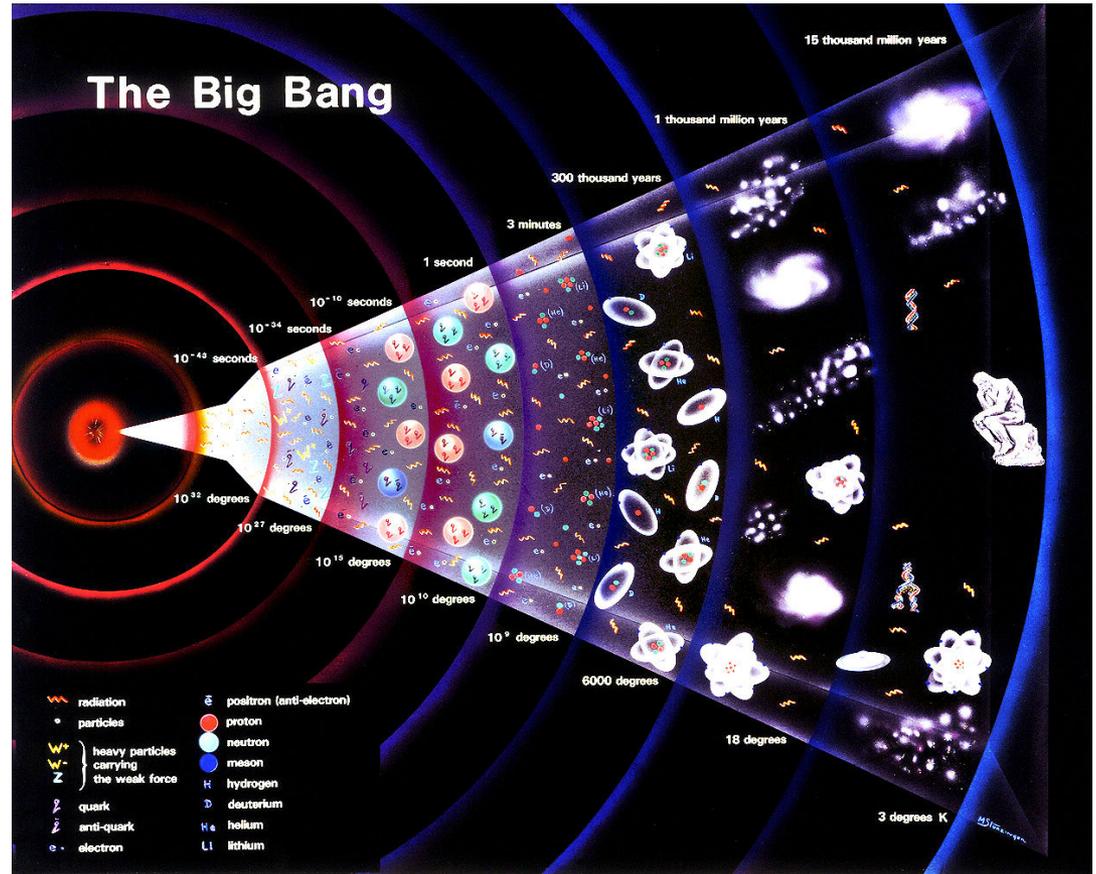


Relevant Curriculum Objectives

Relevant Curriculum Objectives

Grade 9

“Describe observational and theoretical evidence relating to the origin and evolution of the universe (e.g., evidence supporting the big bang theory).”

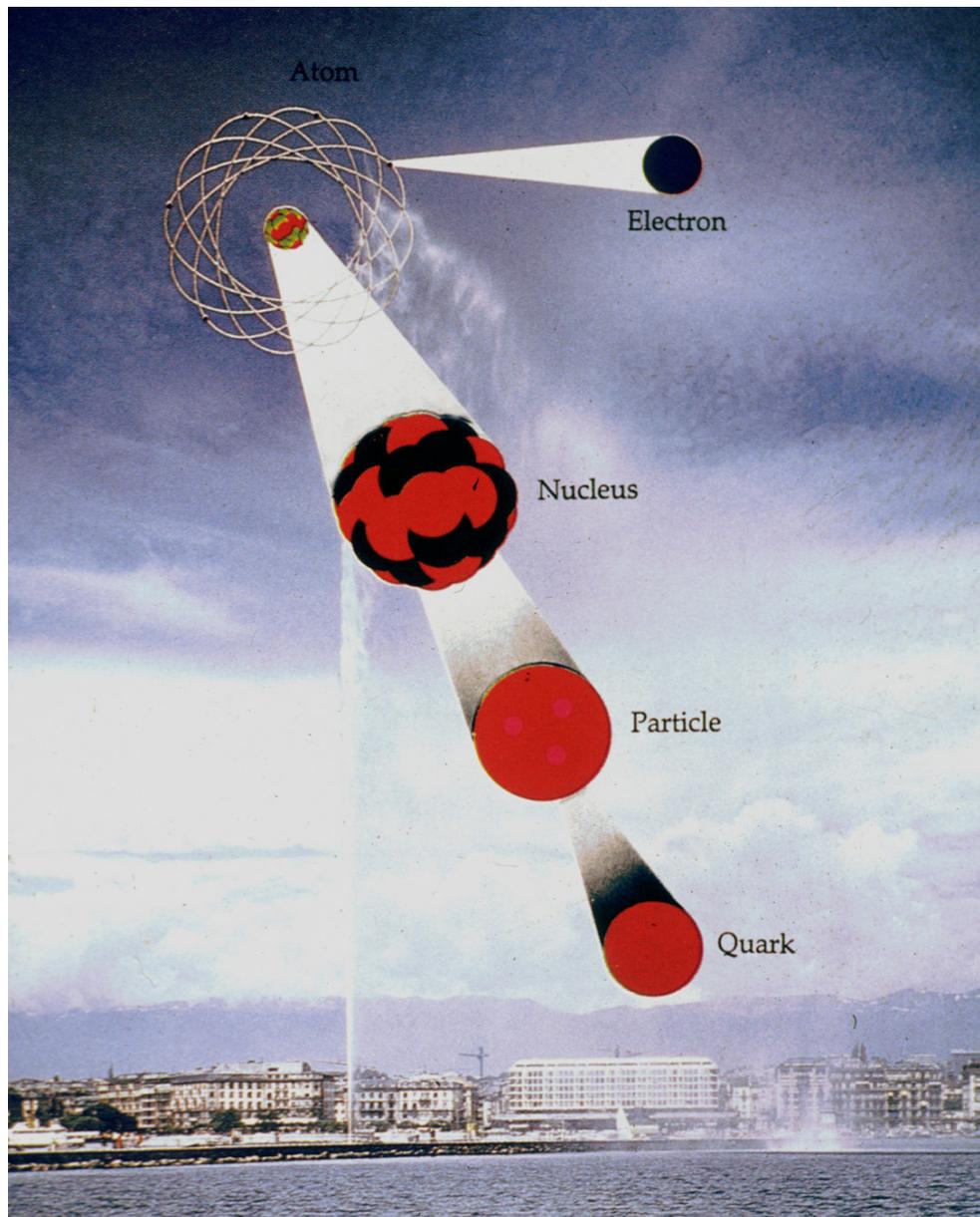


Relevant Curriculum Objectives

Grade 9

“Explain how different atomic models evolved as a result of experimental evidence.”

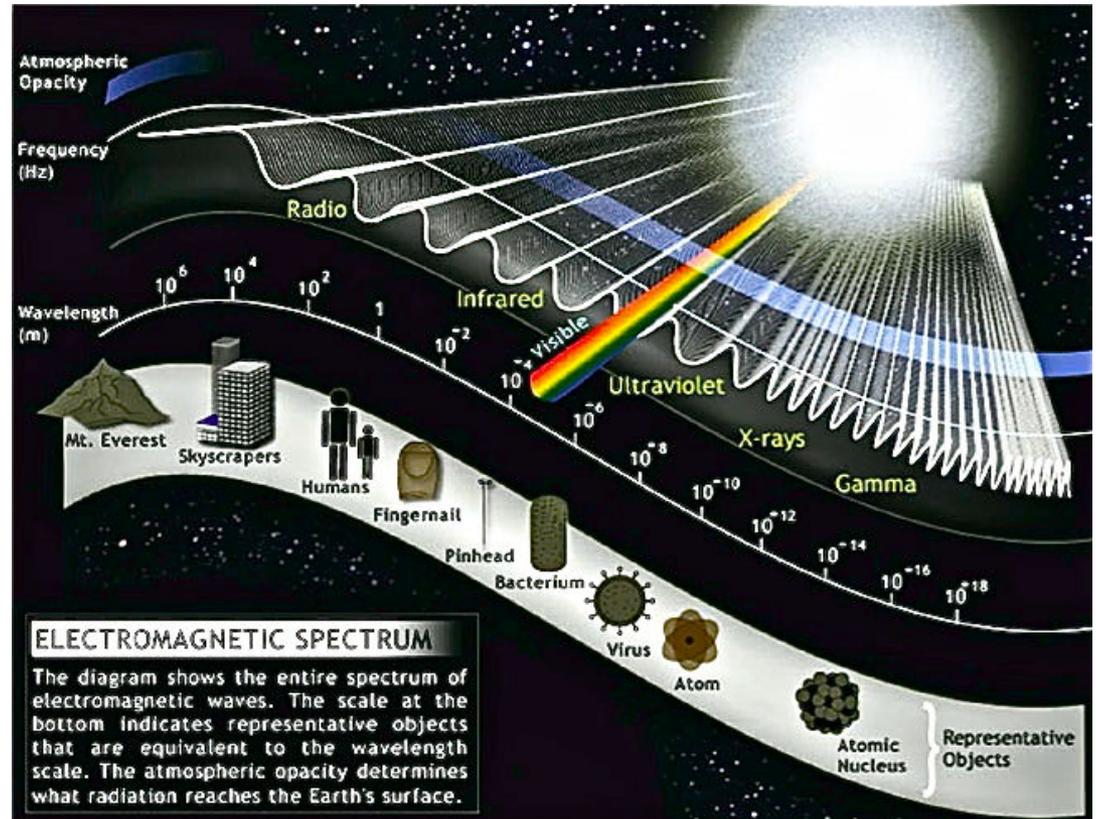
“Describe the characteristics of neutrons, protons, and electrons, including charge, location, and relative mass.”



Relevant Curriculum Objectives

Grade 10

“Identify and label the regions of the electromagnetic spectrum.”





Another thought-provoking question:



Another thought-provoking question:

What happens if you meet your
anti-you?

Me



Anti-me



1535400000000000000

Joules of energy!

$$E = mc^2$$

$$m = (85\text{kg} + 0.300\text{ kg}) \times 2$$

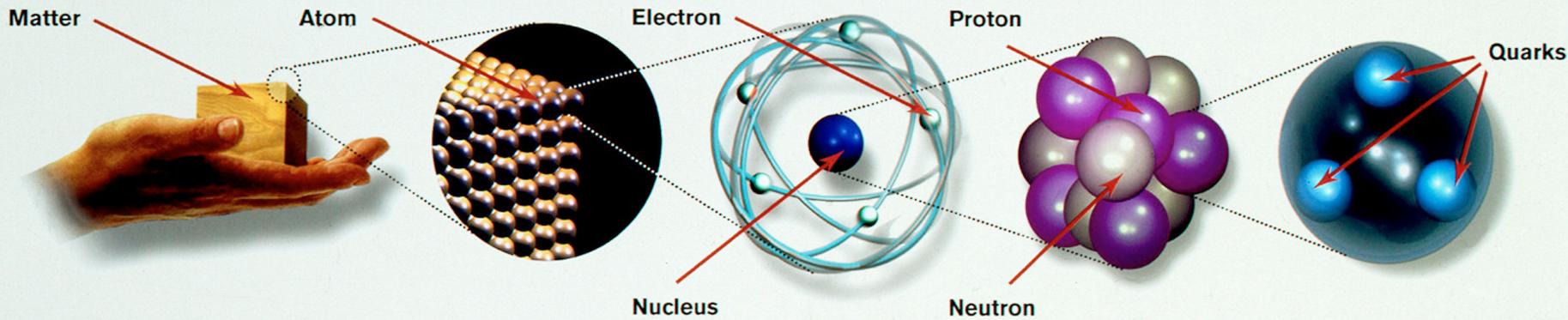
$$c = 3.0 \times 10^8 \text{ ms}^{-1}$$

$$E = ((85.300 \times 2))(3.0 \times 10^8)^2$$

Joules of energy!
 $E =$



What should *minimally* be done?



Matter particles

All ordinary particles belong to this group

These particles existed just after the Big Bang. Now they are found only in cosmic rays and accelerators

LEPTONS				
FIRST FAMILY	Electron Responsible for electricity and chemical reactions; it has a charge of -1		Electron neutrino Particle with no electric charge, and possibly no mass; billions fly through your body every second	
SECOND FAMILY	Muon A heavier relative of the electron; it lives for two-millionths of a second		Muon neutrino Created along with muons when some particles decay	
THIRD FAMILY	Tau Heavier still; it is extremely unstable. It was discovered in 1975		Tau neutrino not yet discovered but believed to exist	

QUARKS				
Up	Has an electric charge of plus two-thirds; protons contain two, neutrons contain one		Down Has an electric charge of minus one-third; protons contain one, neutrons contain two	
Charm	A heavier relative of the up; found in 1974		Strange A heavier relative of the down; found in 1964	
Top	Heavier still		Bottom Heavier still; measuring bottom quarks is an important test of electroweak theory	

Force particles

These particles transmit the four fundamental forces of nature although gravitons have so far not been discovered

Gluons
Carriers of the **strong force** between quarks

Felt by: quarks

The explosive release of nuclear energy is the result of the **strong force**

Photons
Particles that make up light; they carry the **electromagnetic force**

Felt by: quarks and charged leptons

Electricity, magnetism and chemistry are all the results of **electro-magnetic force**

Intermediate vector bosons
Carriers of the **weak force**

Felt by: quarks and leptons

Some forms of radio-activity are the result of the **weak force**

Gravitons
Carriers of **gravity**

Felt by: all particles with mass

All the weight we experience is the result of the **gravitational force**

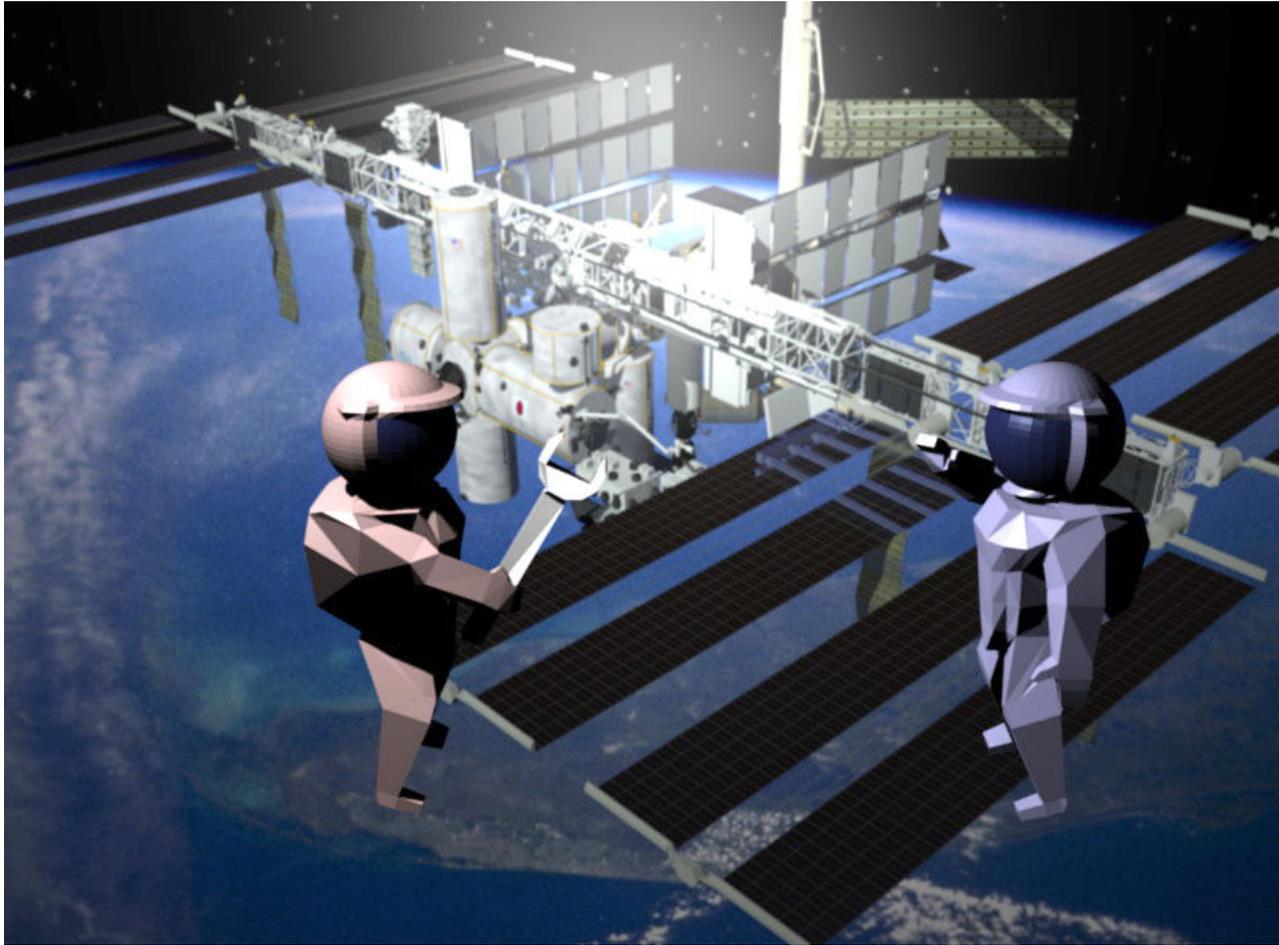


And if your students want to know
more...?

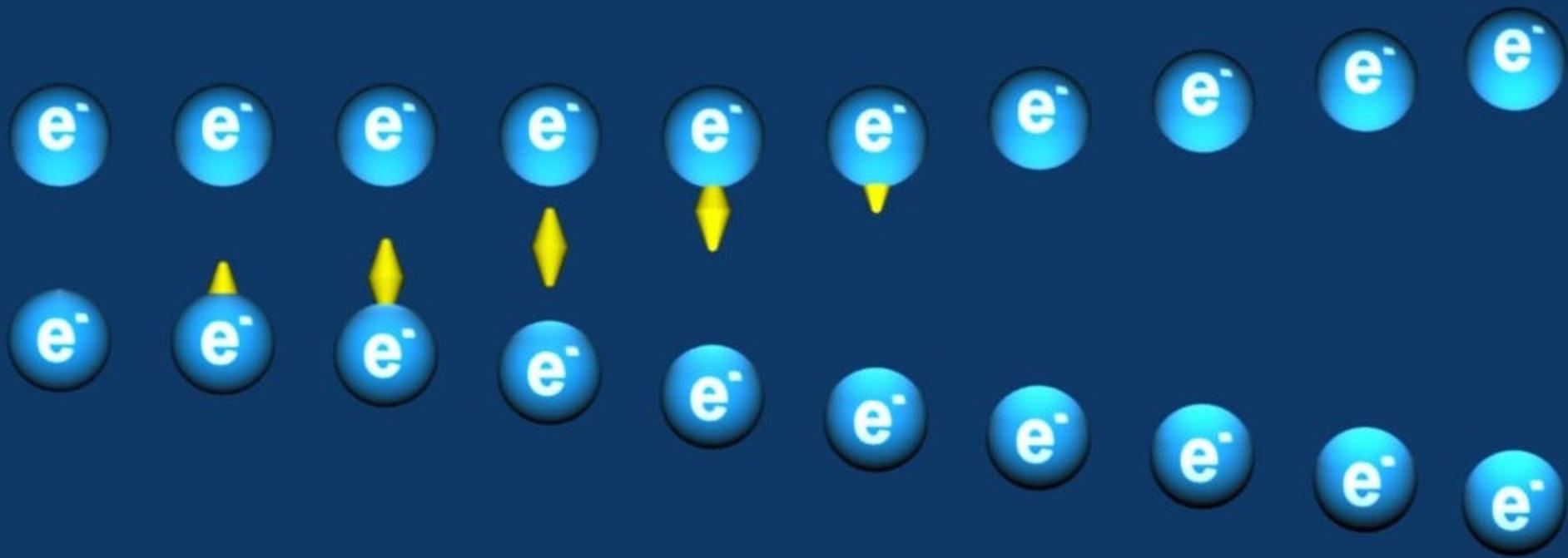


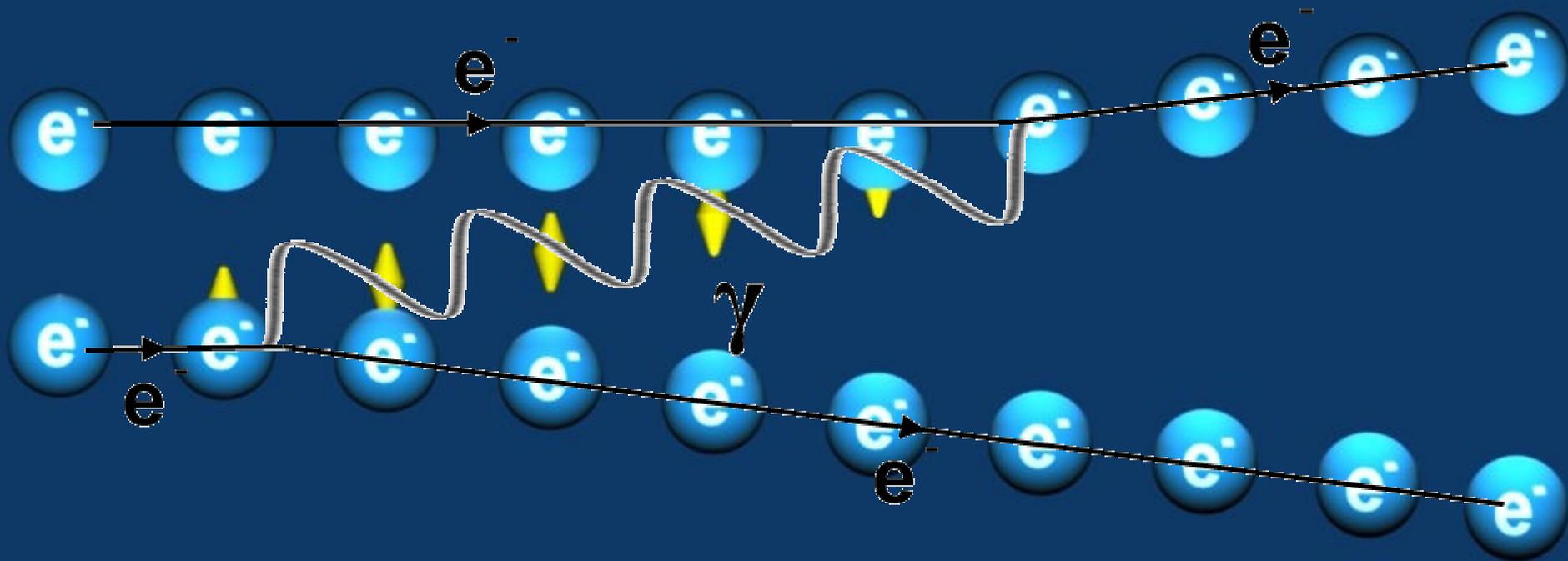
And if your students want to know
more...?

Consider the following...

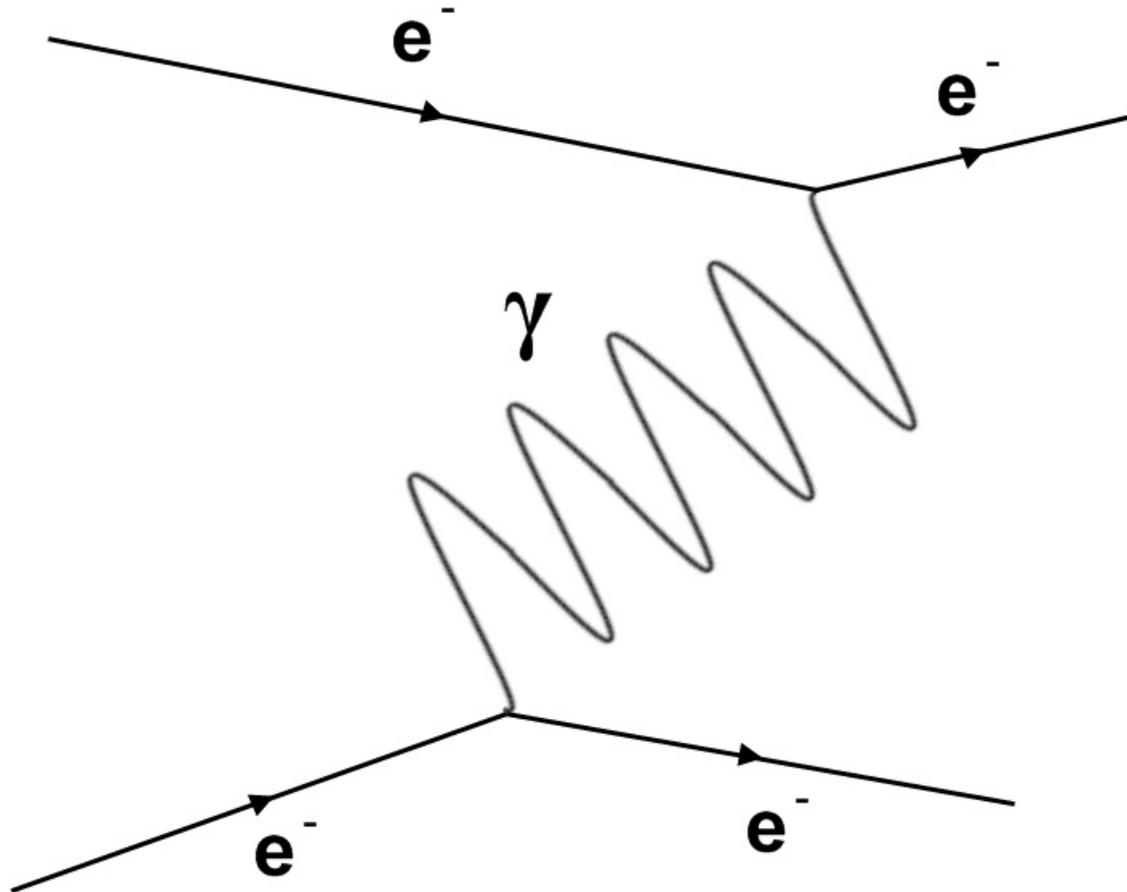


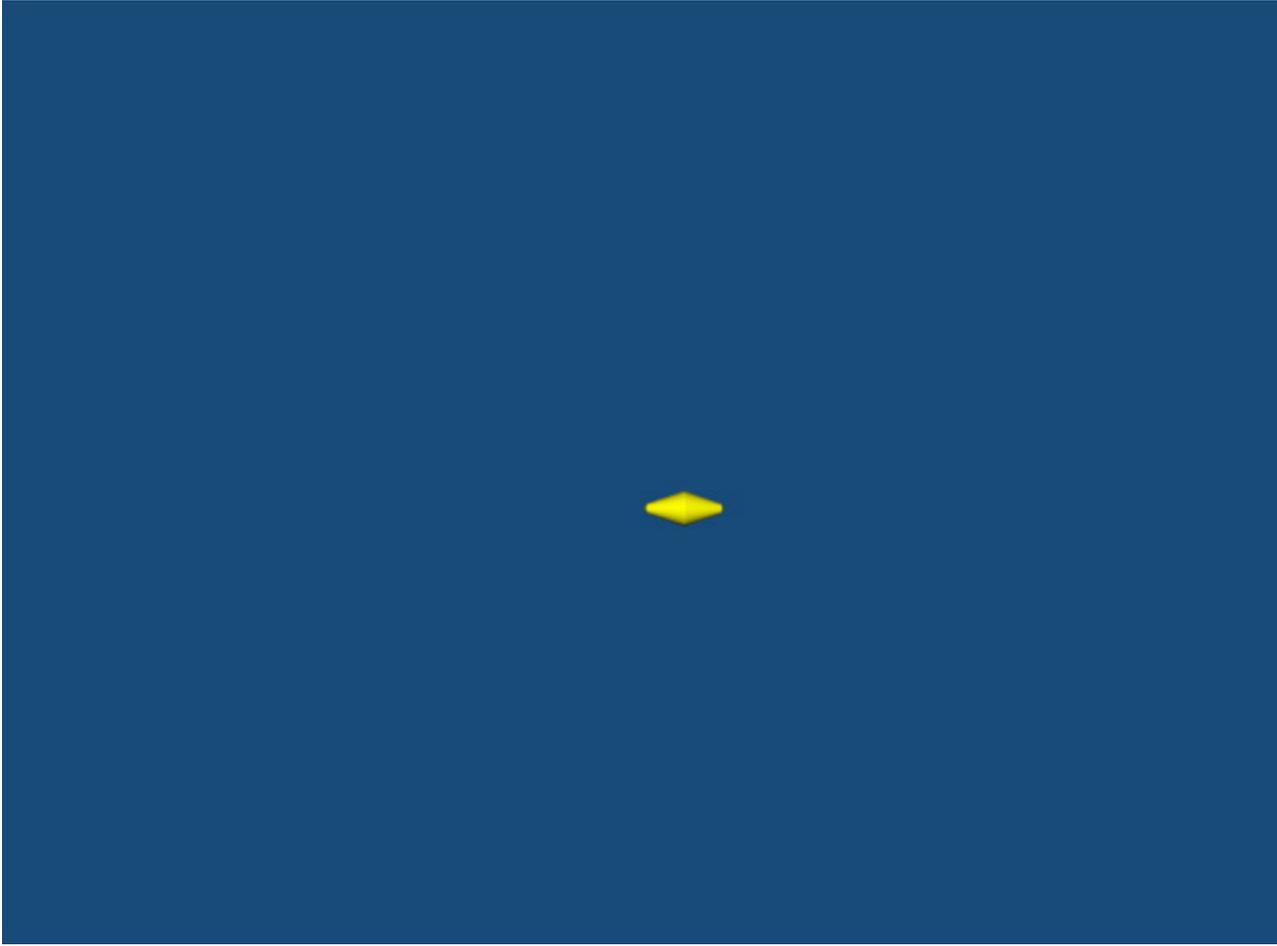


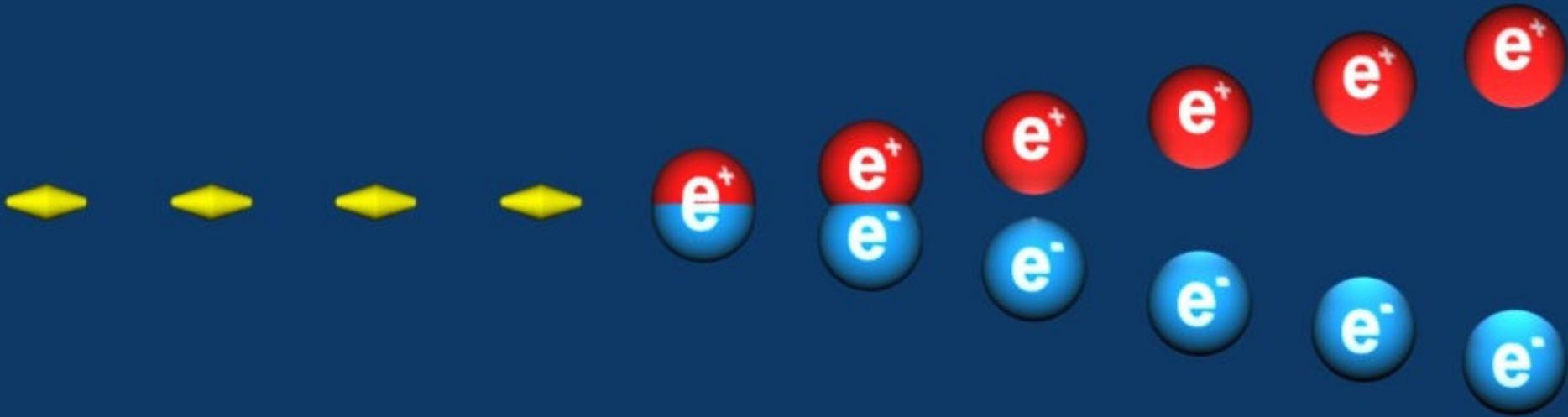


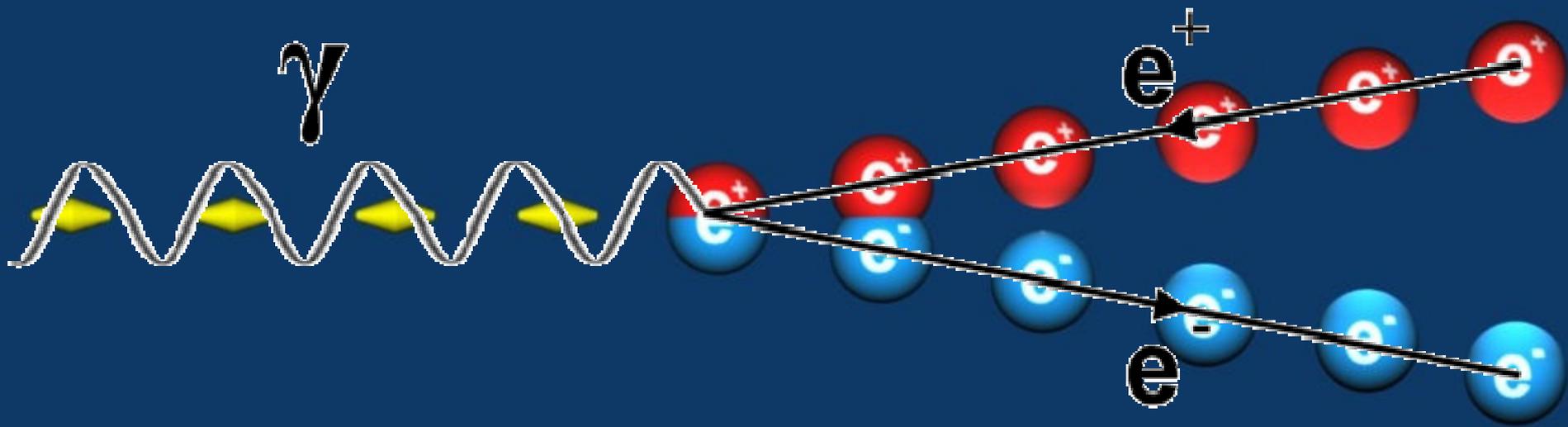


Feynman diagram for electron-electron scattering

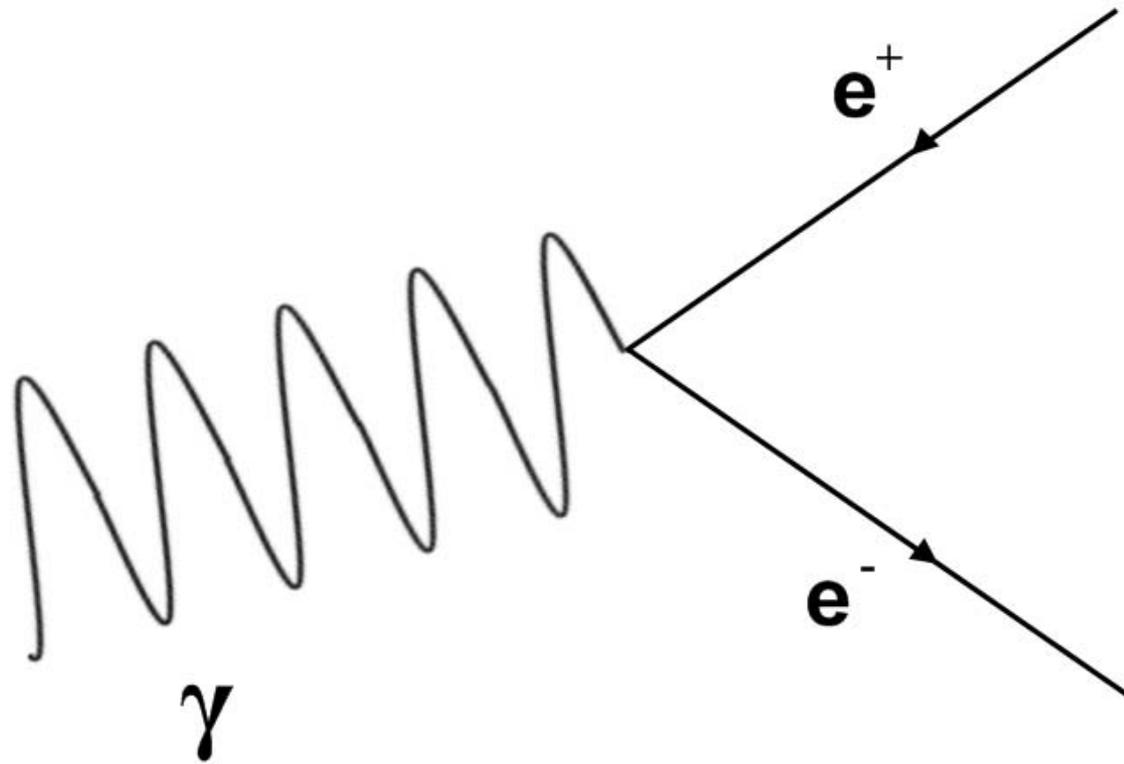


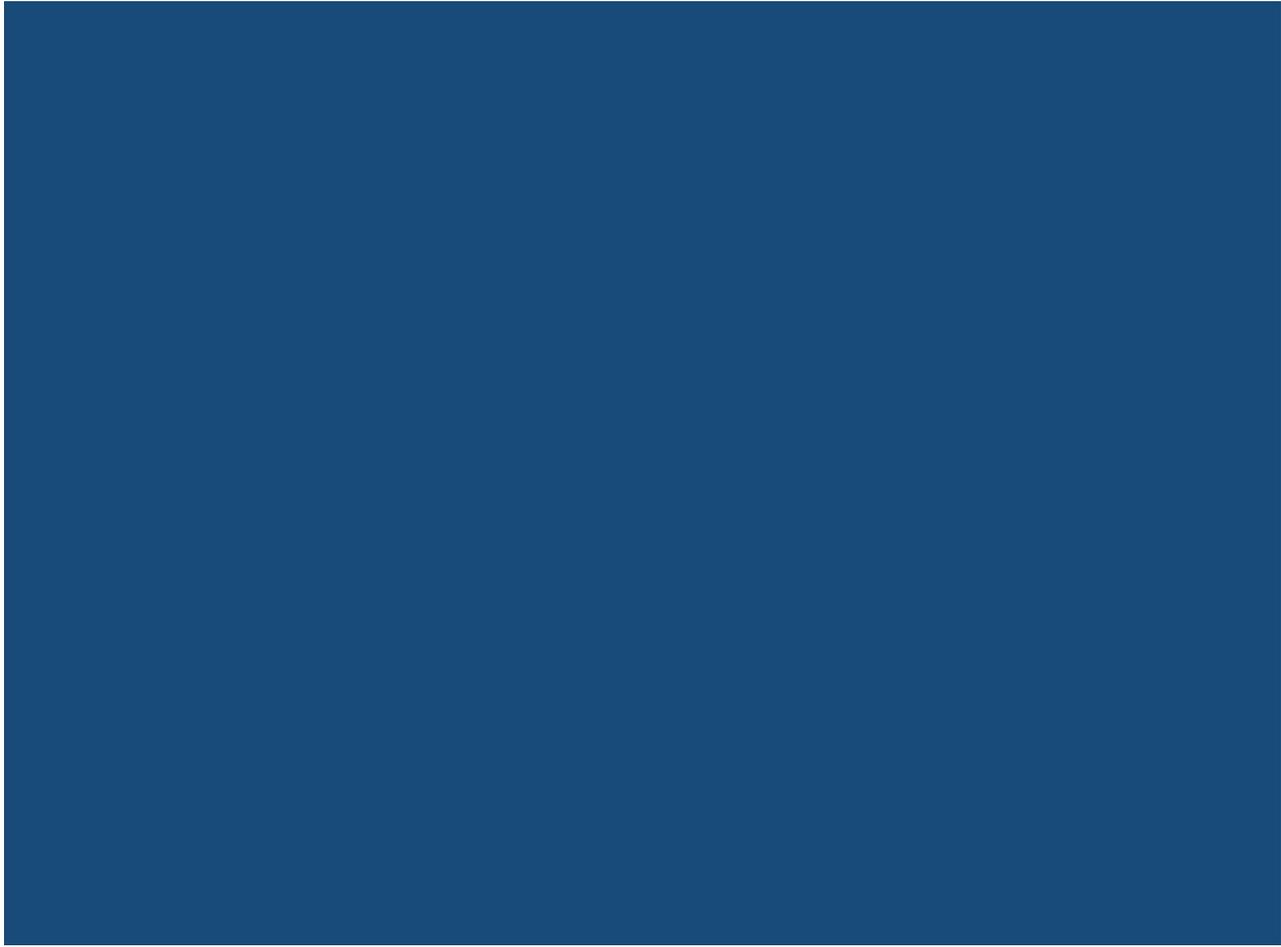


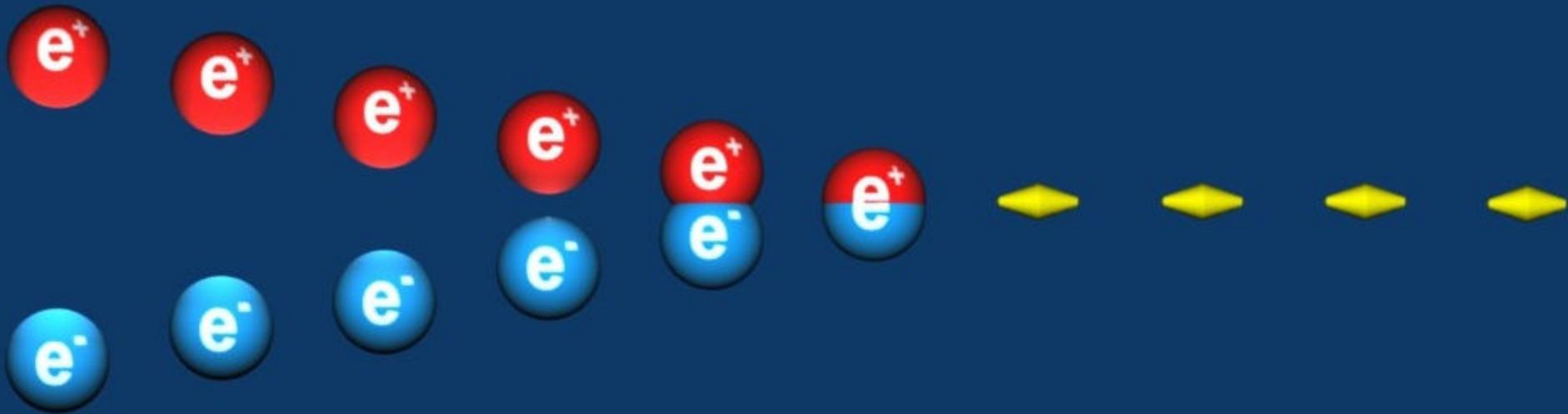


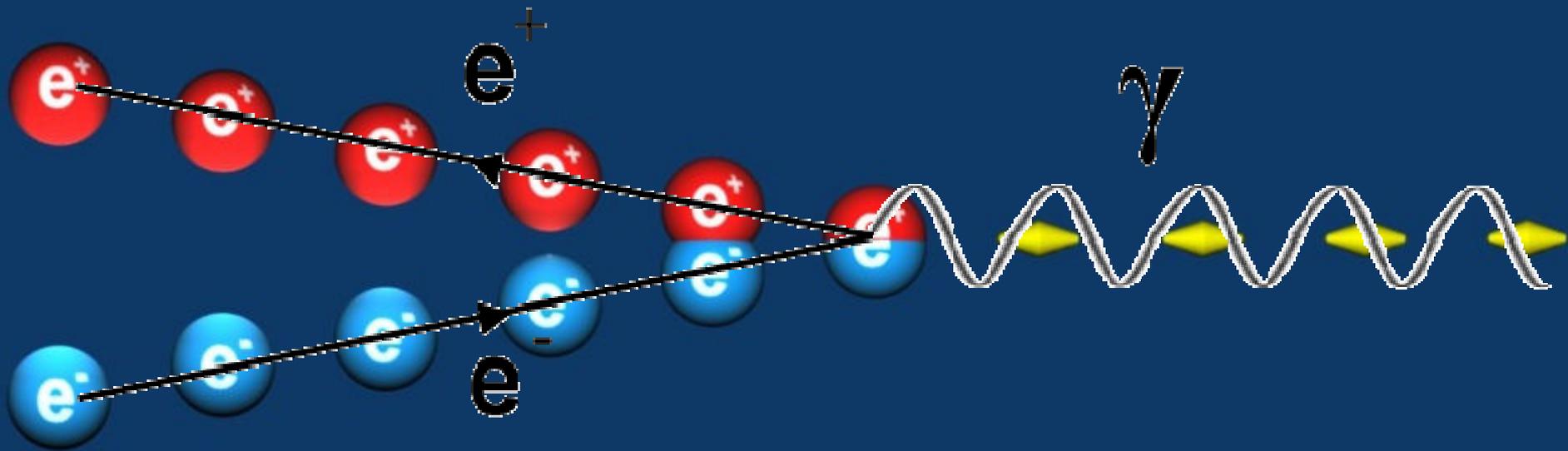


Feynman diagram for pair-production

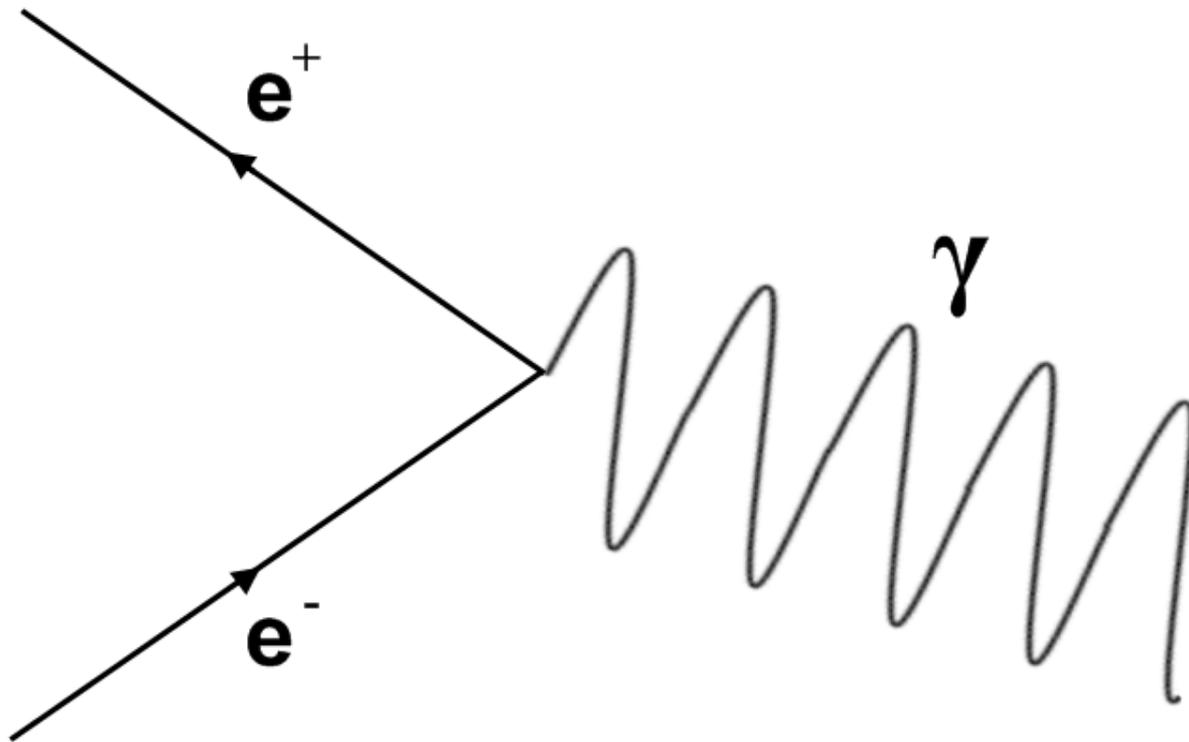








Feynman diagram for annihilation





Why do we want to do this?



Why do we want to do this?

“A little learning is a dangerous thing”.

Alexander Pope

Why do we want to do this?

“A little learning is a dangerous thing”.

Alexander Pope

“Two things are infinite:

the universe and human stupidity.

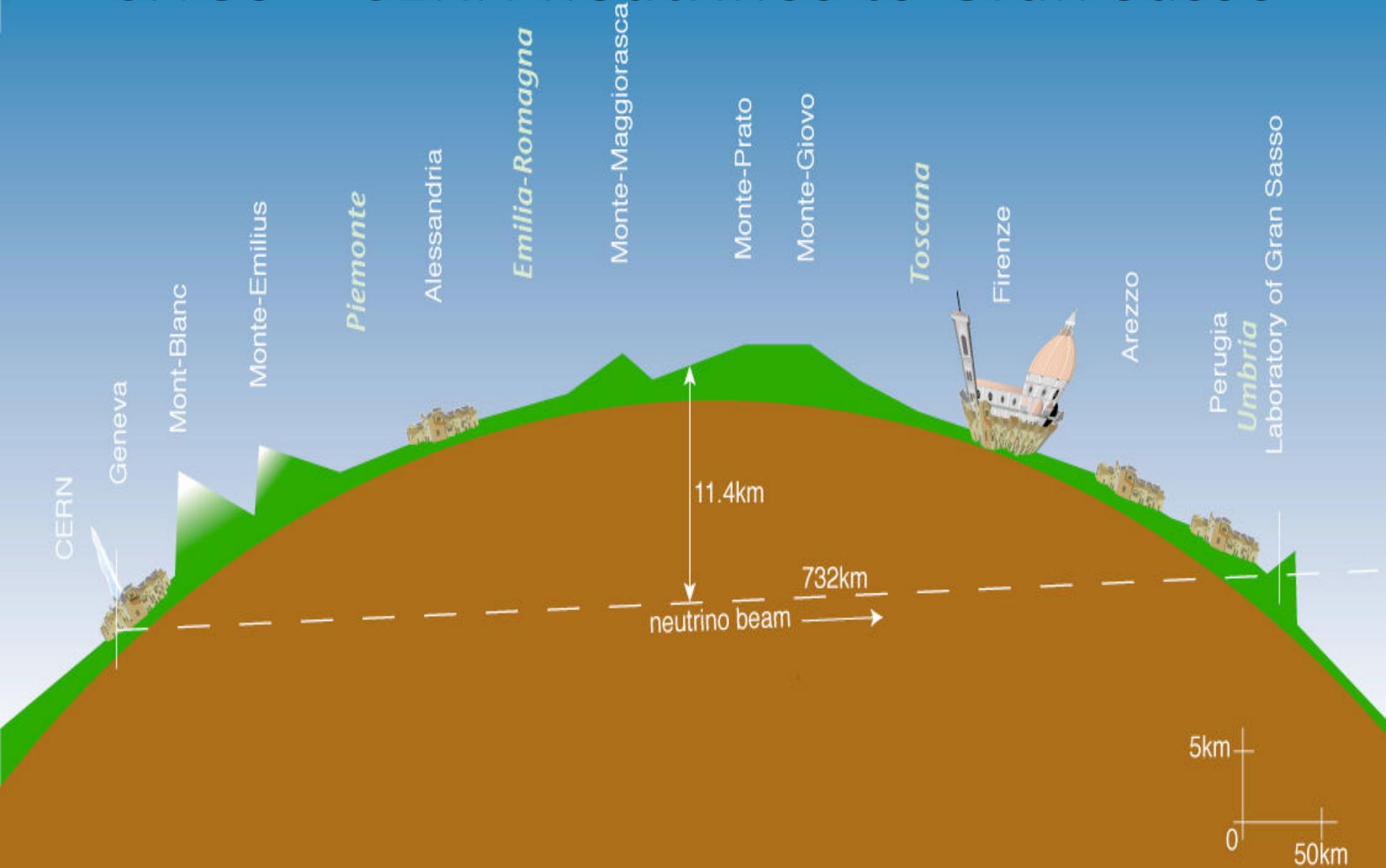
And I’m not sure about the universe”.

Albert Einstein

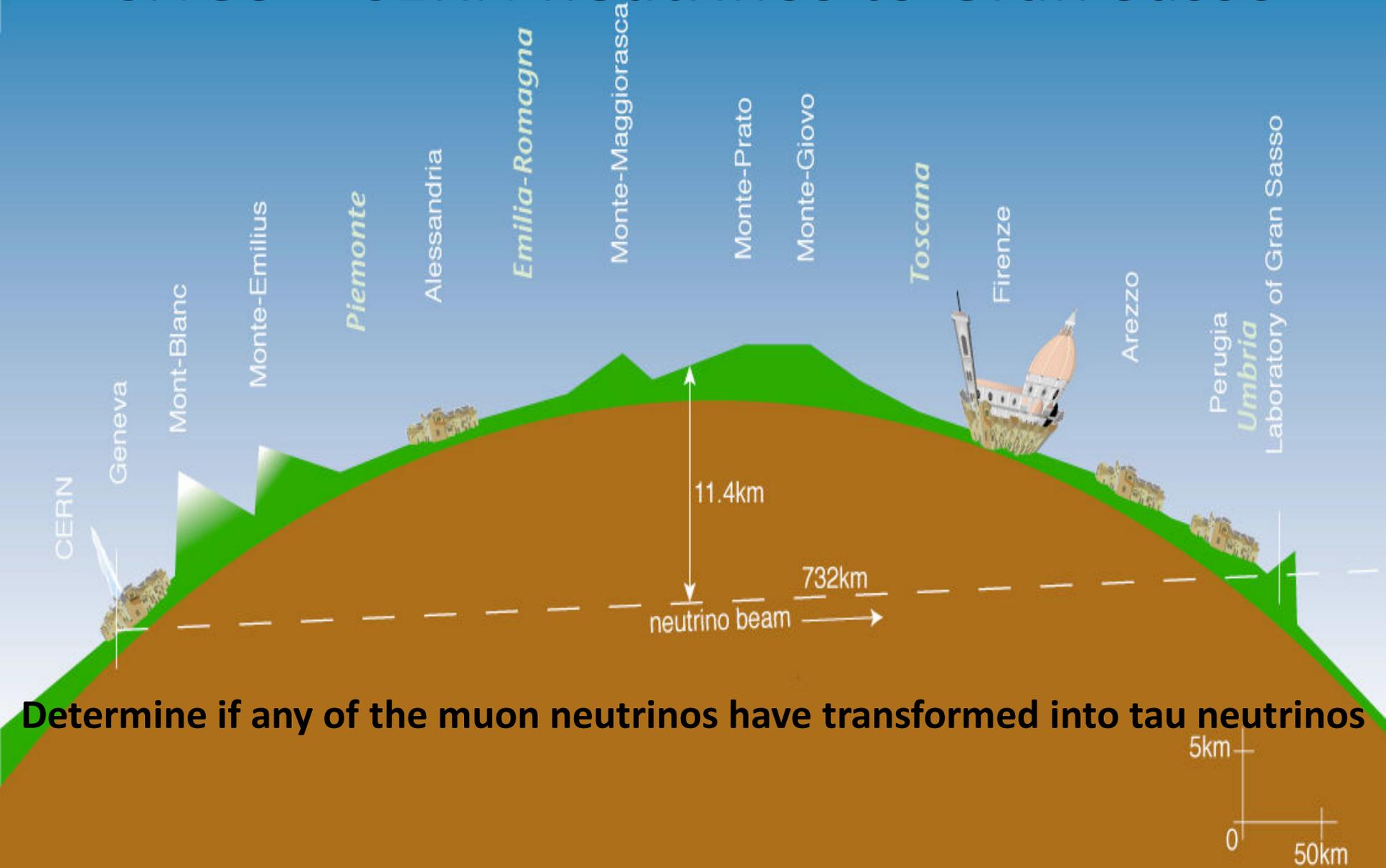


...and one more thing...

CNGS – CERN neutrinos to Gran Sasso

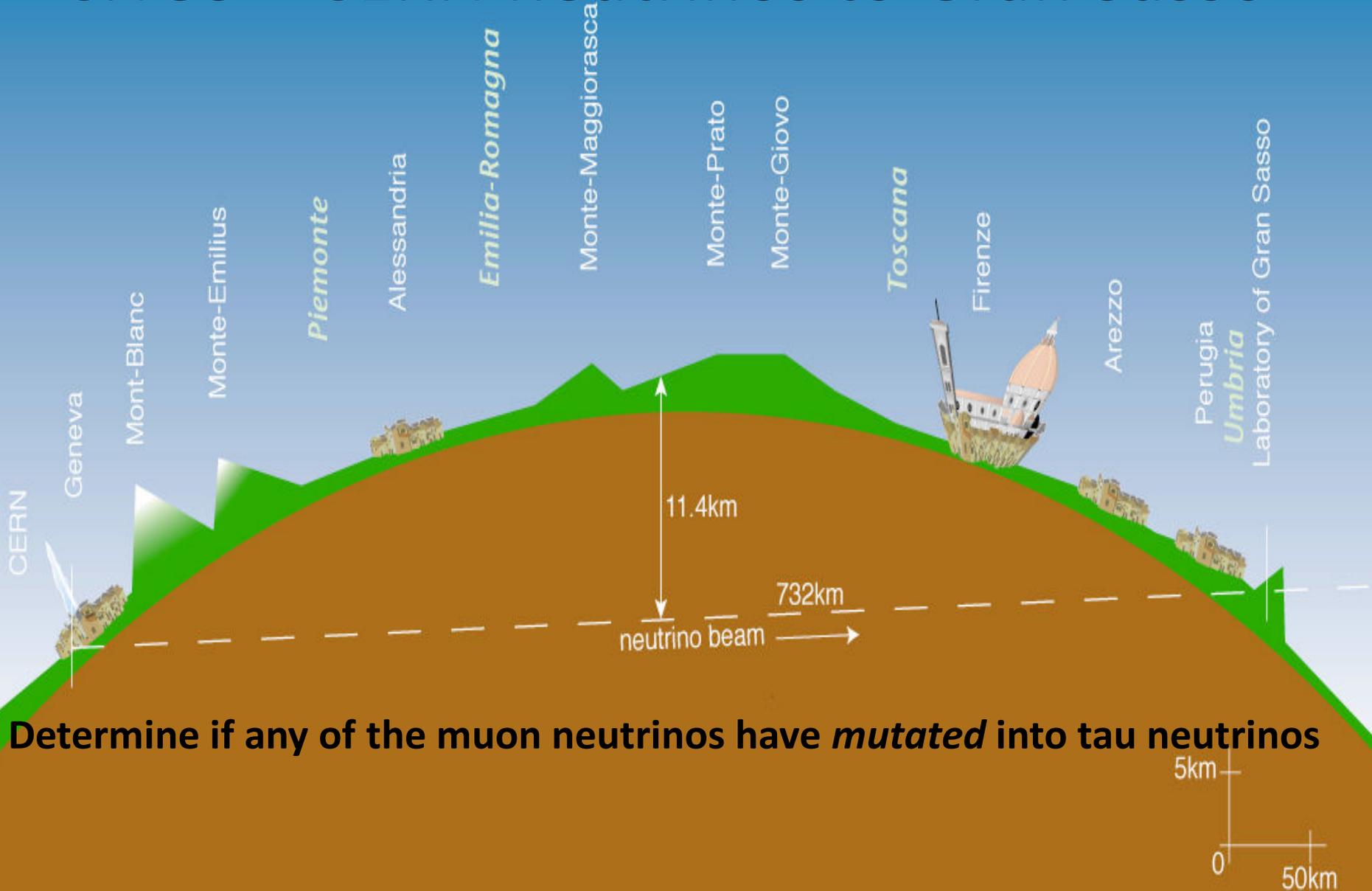


CNGS – CERN neutrinos to Gran Sasso



Determine if any of the muon neutrinos have transformed into tau neutrinos

CNGS – CERN neutrinos to Gran Sasso



Determine if any of the muon neutrinos have *mutated* into tau neutrinos

2012

Earth's core is superheated by...

2012

Earth's core is superheated by...

2012

... "mutant neutrinos"

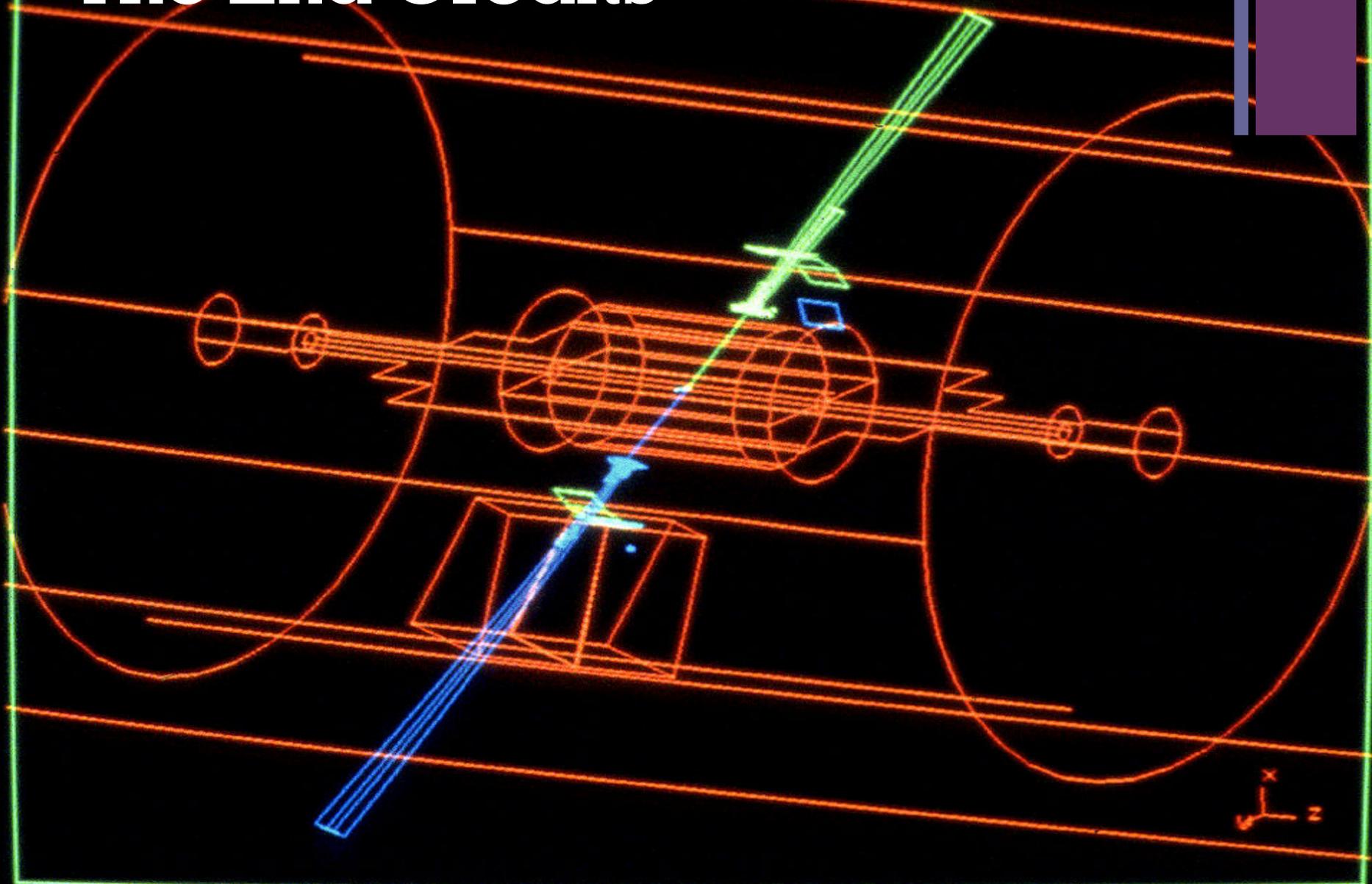
<http://www.whowillsurvive2012.com/>

2012

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EVENT NR 218

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21

The End Credits



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EVENT NR 218

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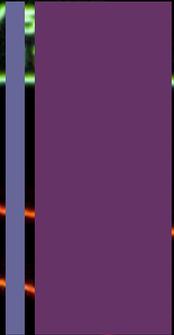
*Thanks to Christian Cheung
NTNU(Norwegian University of Science
and Technology) for help with the
animations.*



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and

THANKS TO YOU!

