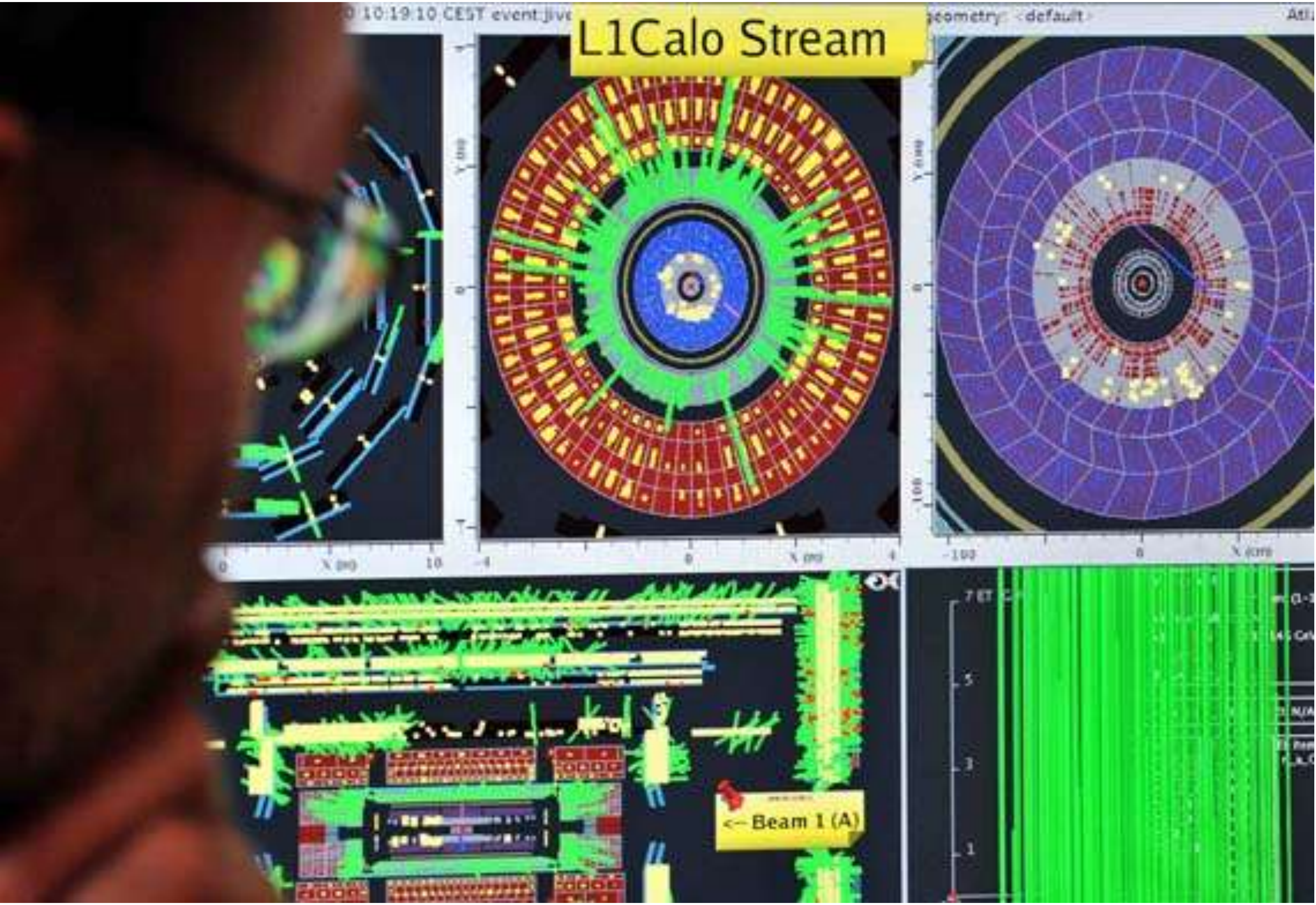
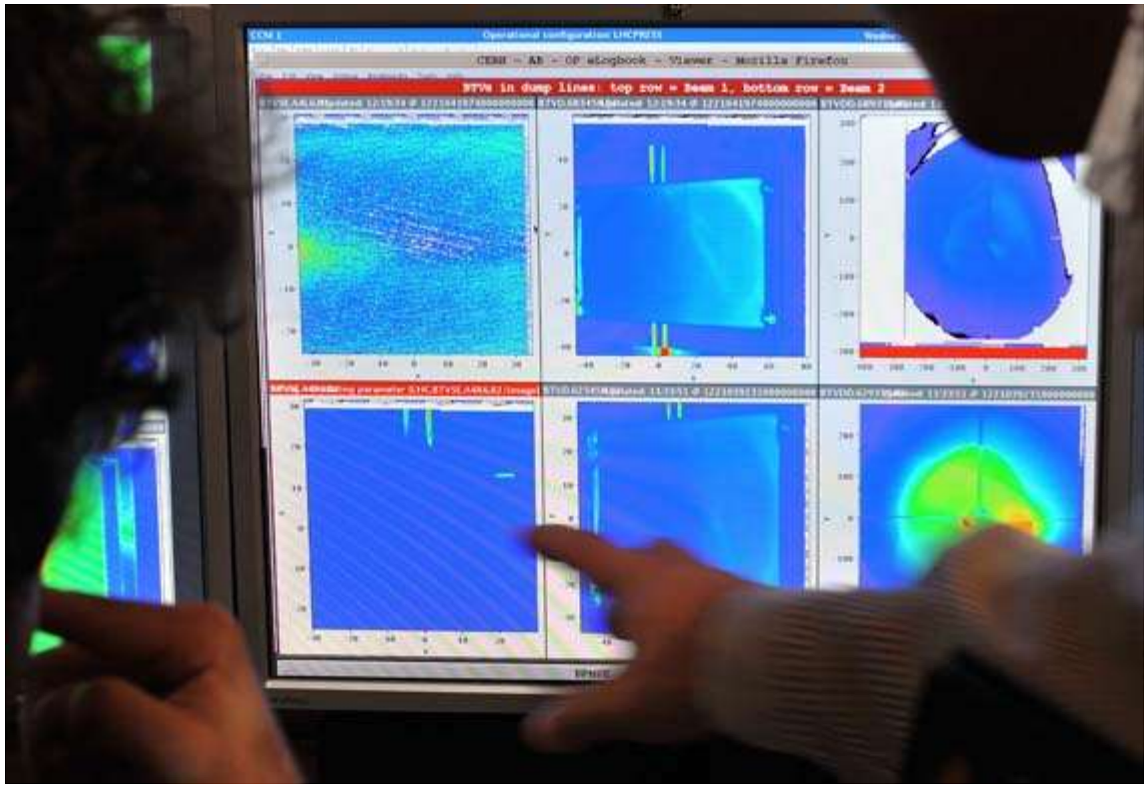
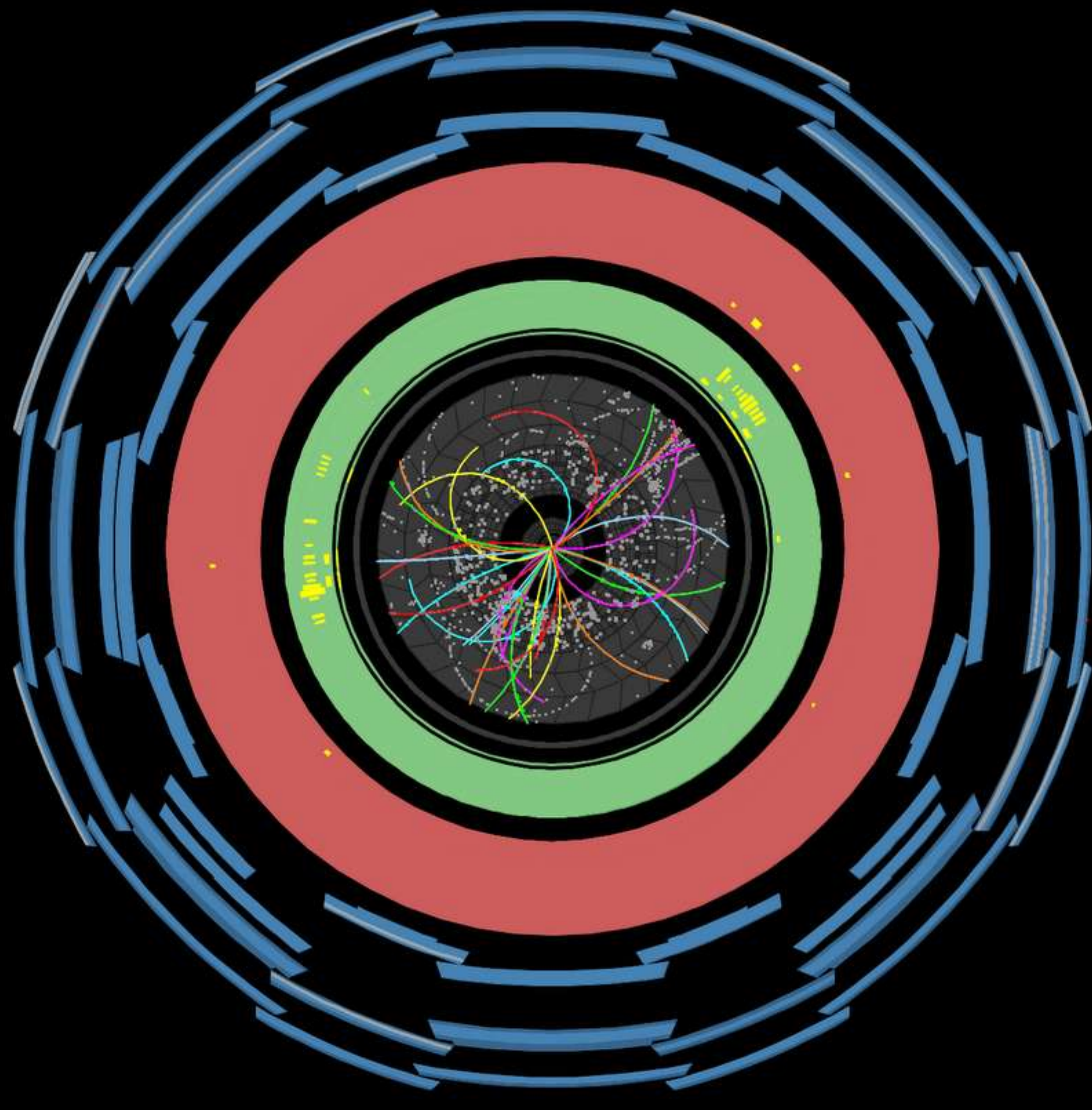
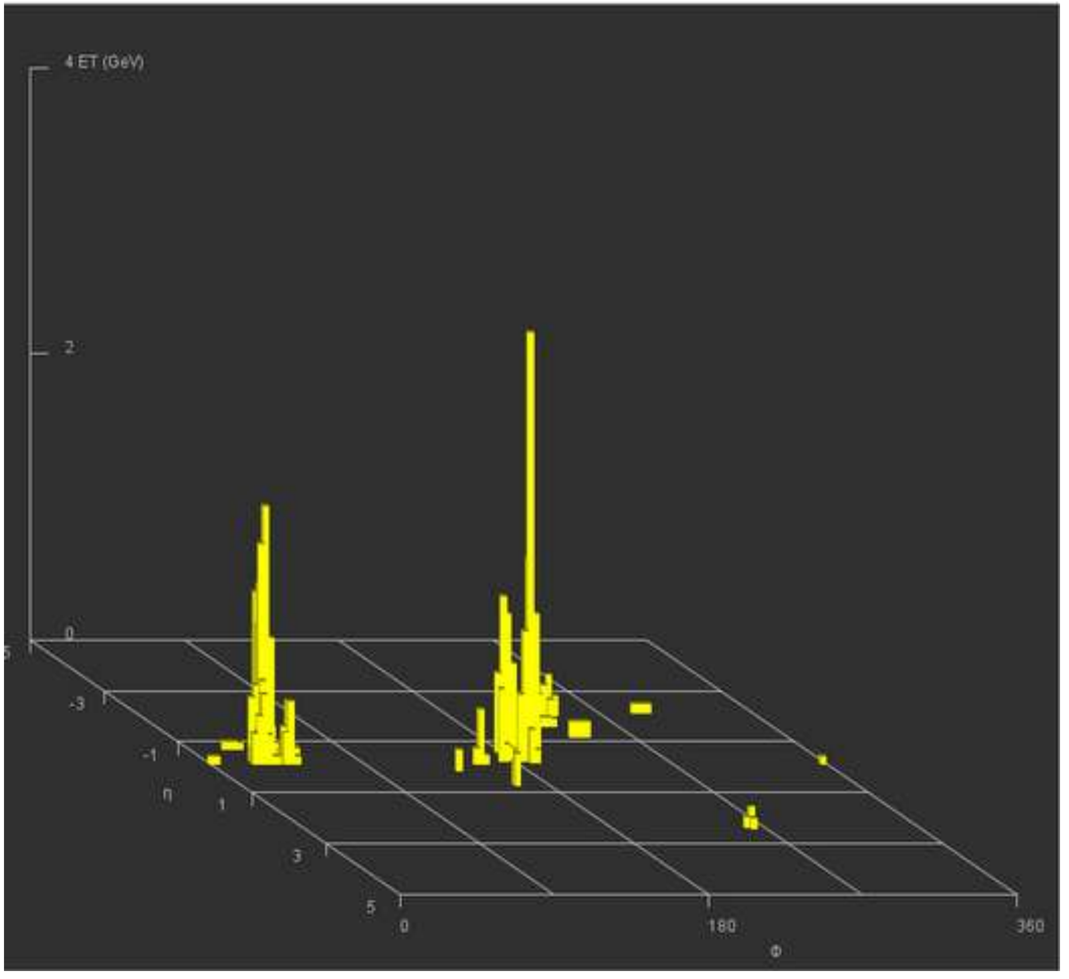


L1Calo Stream
<-- Beam 1 (A)

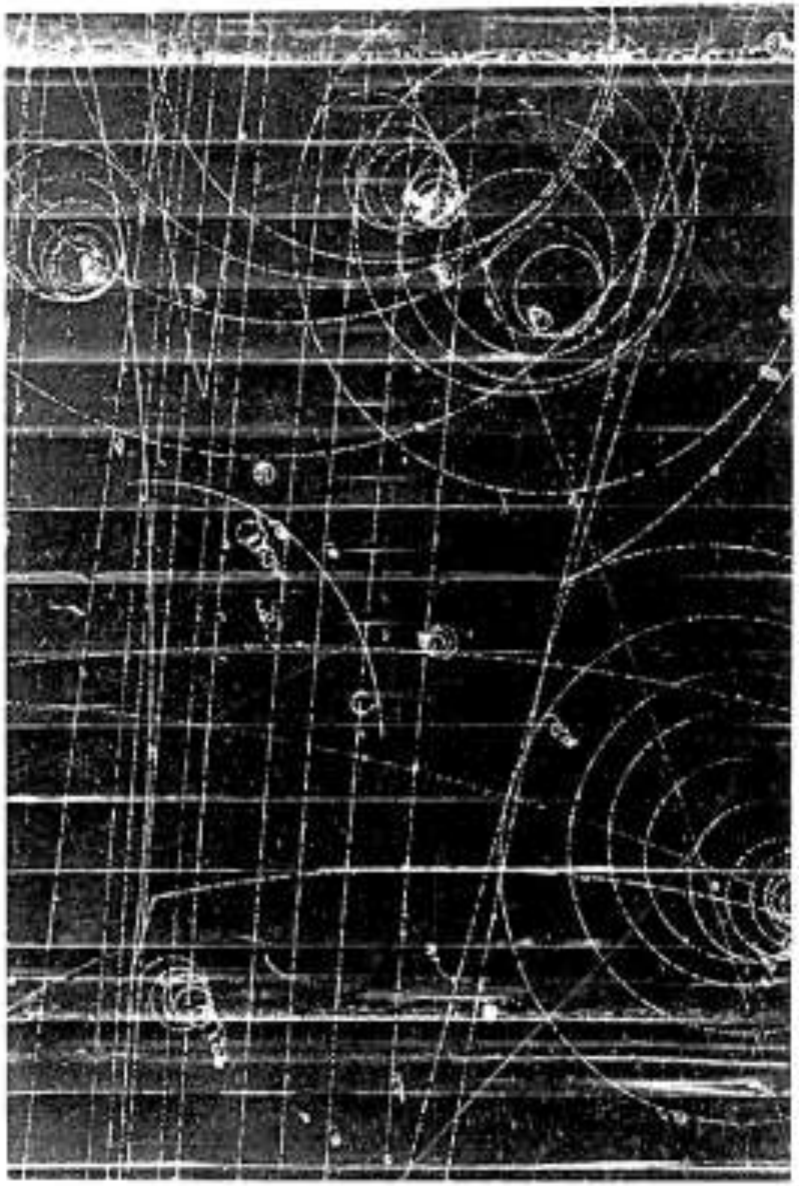

CERN - AB - OP eLogbook - Viewer - Mozilla Firefox
BTVs in dump lines: top row = Beam 1, bottom row = Beam 2

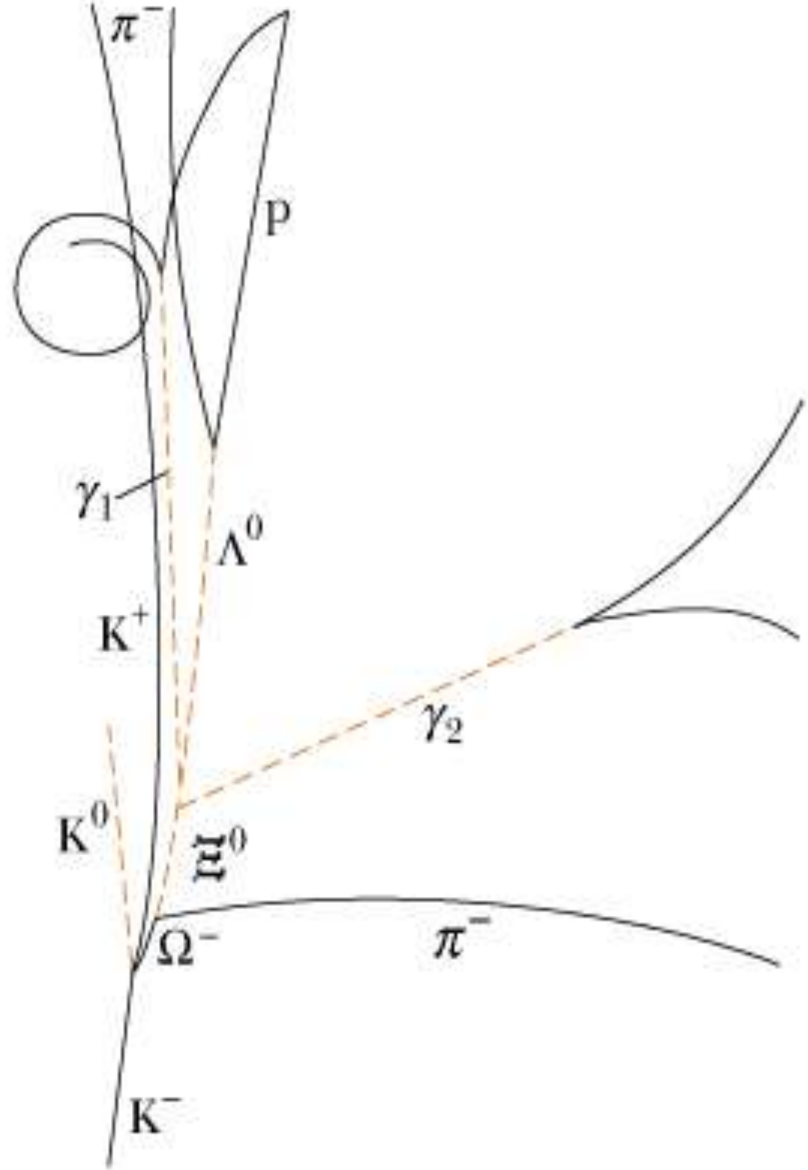
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

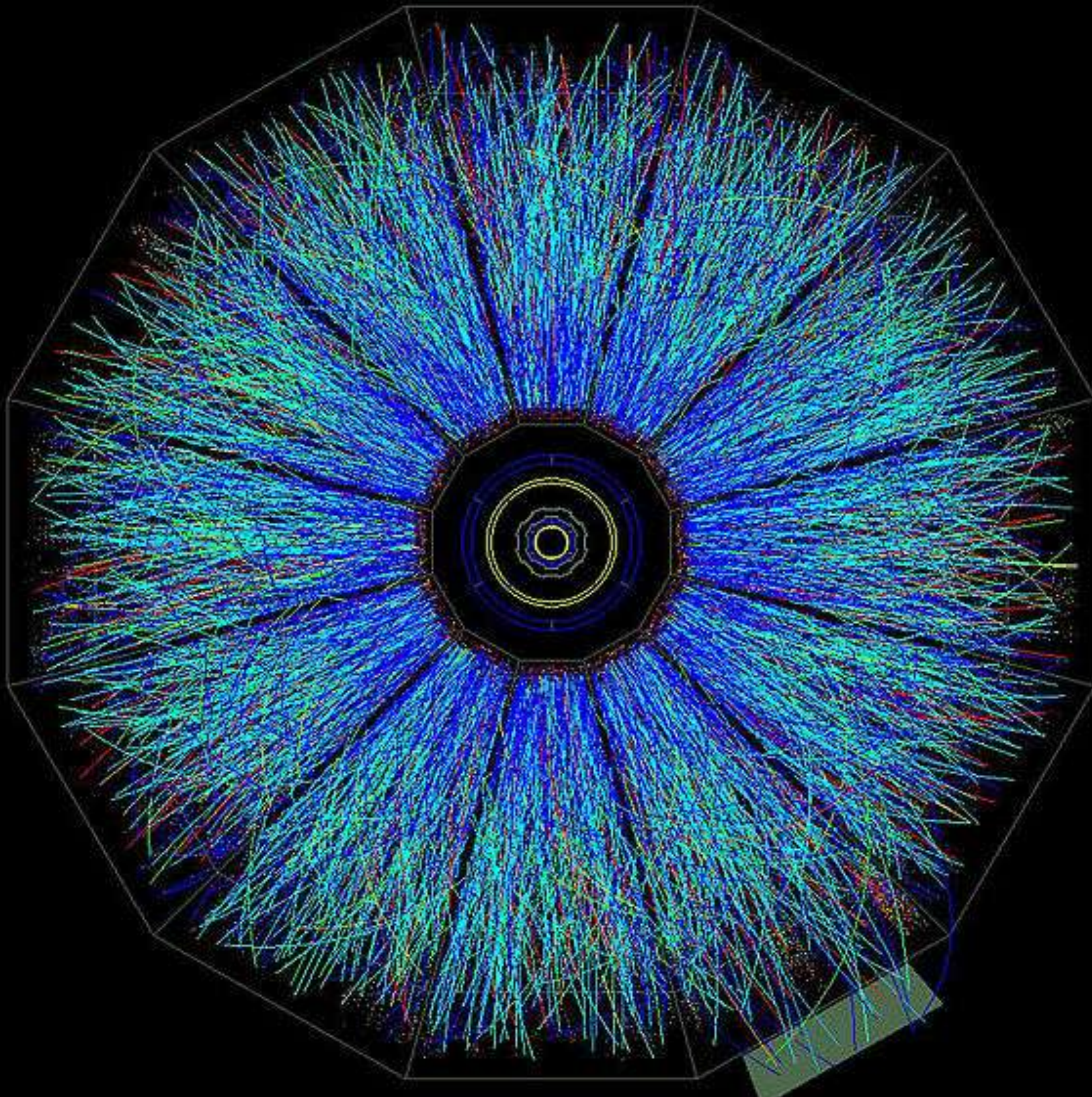




4 ET (GeV)
2
0
5
-3
-1
η
1
3
5
0
180
360
Φ

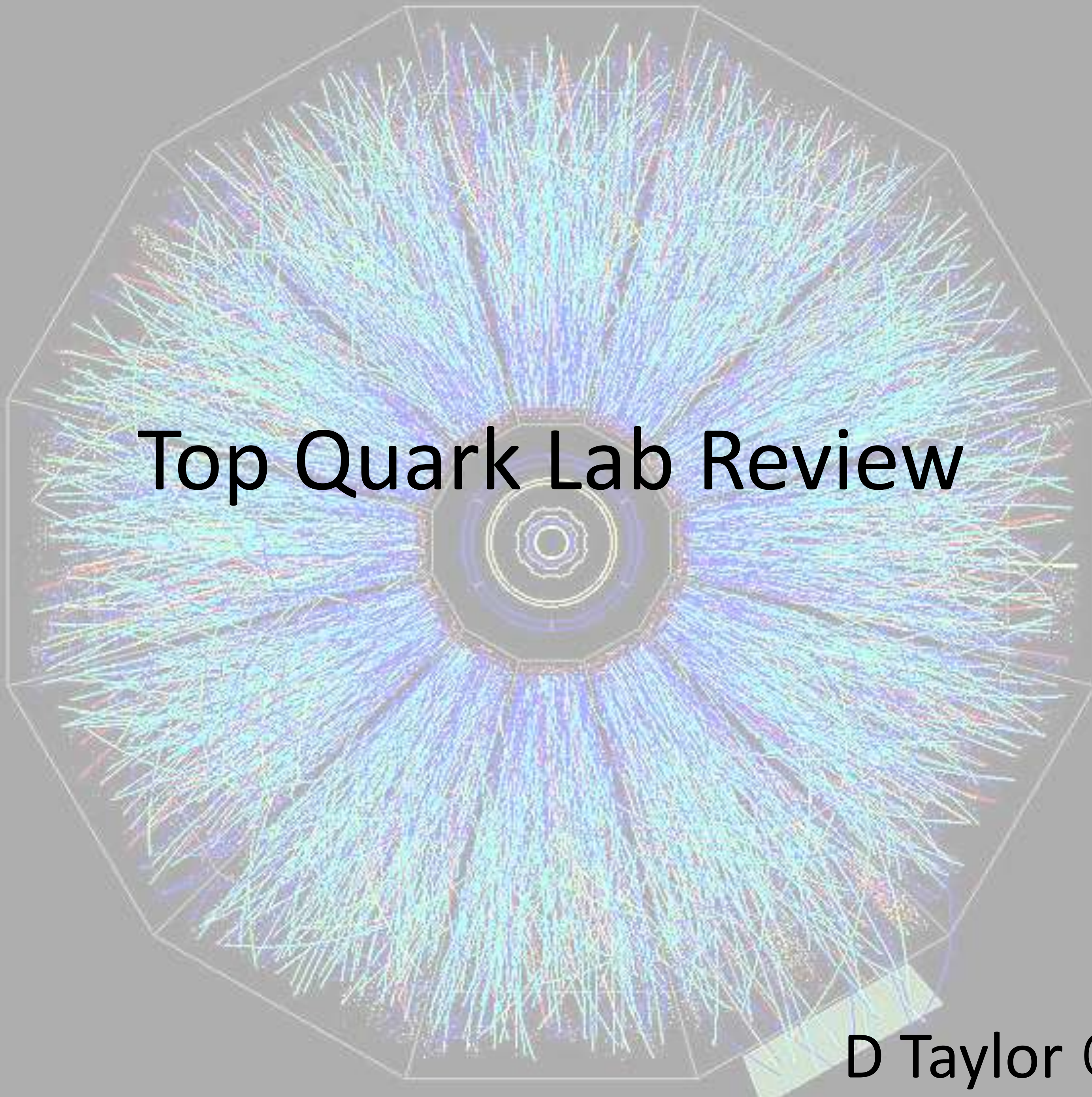



π^-
P
γ_1
Λ^0
K^+
γ_2
K^0
Ξ^0
Ω^-
π^-
K^-



Top Quark Lab

- ***15 min YOU***
- ***15 min ME***
- ***30 min YOU***
- ***15 min ME***
- ***Hand In***



Top Quark Lab Review

Top Quark Lab Review

- **Following Directions is a gift. Buy it for yourself.**
- *The idea that mass and energy are **interchangeable** is essential to those interested in understanding how two top quarks (actually a top and an antitop) are created from the collision of two protons (actually a proton and an antiproton).*

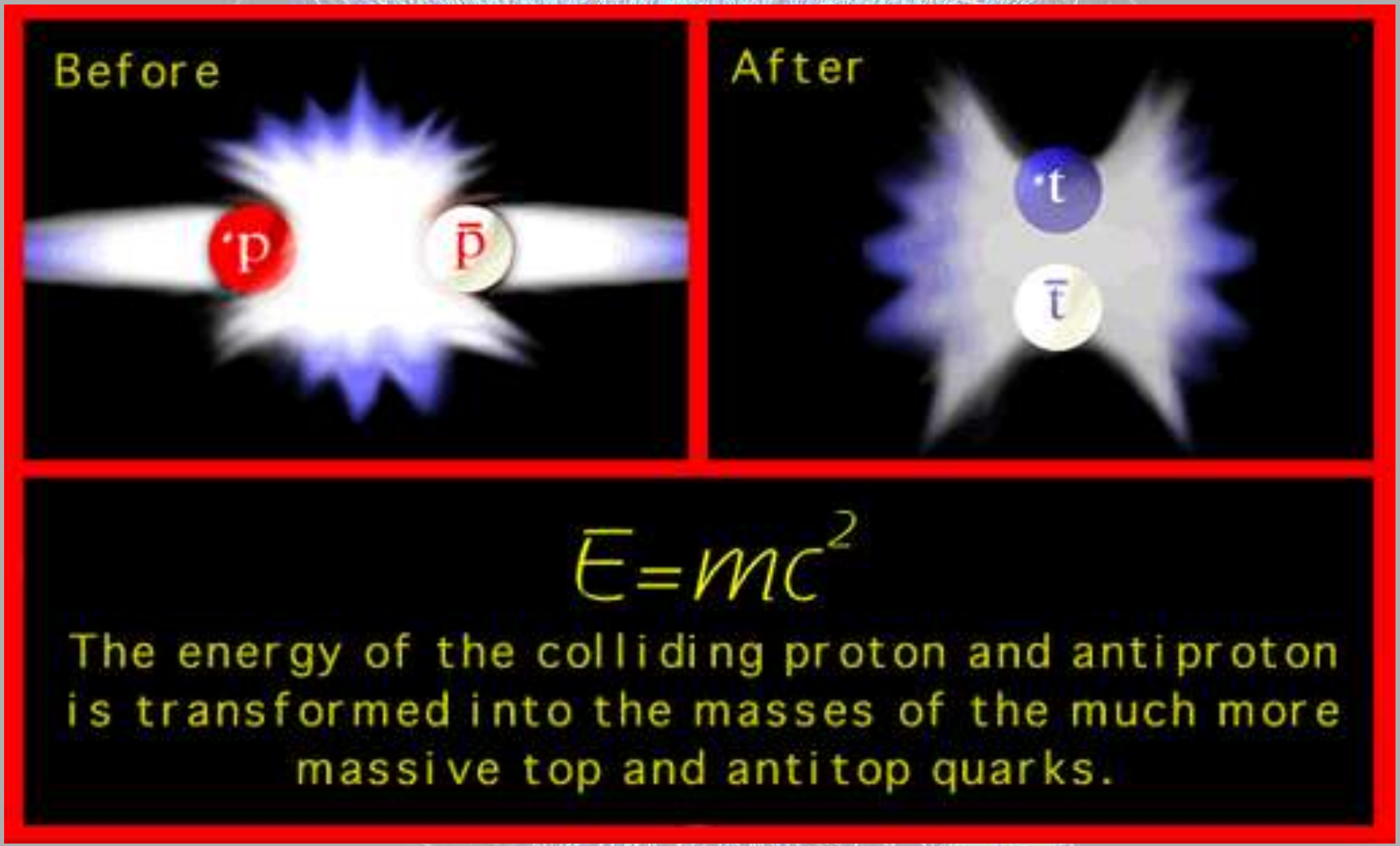
Top Quark Lab Review

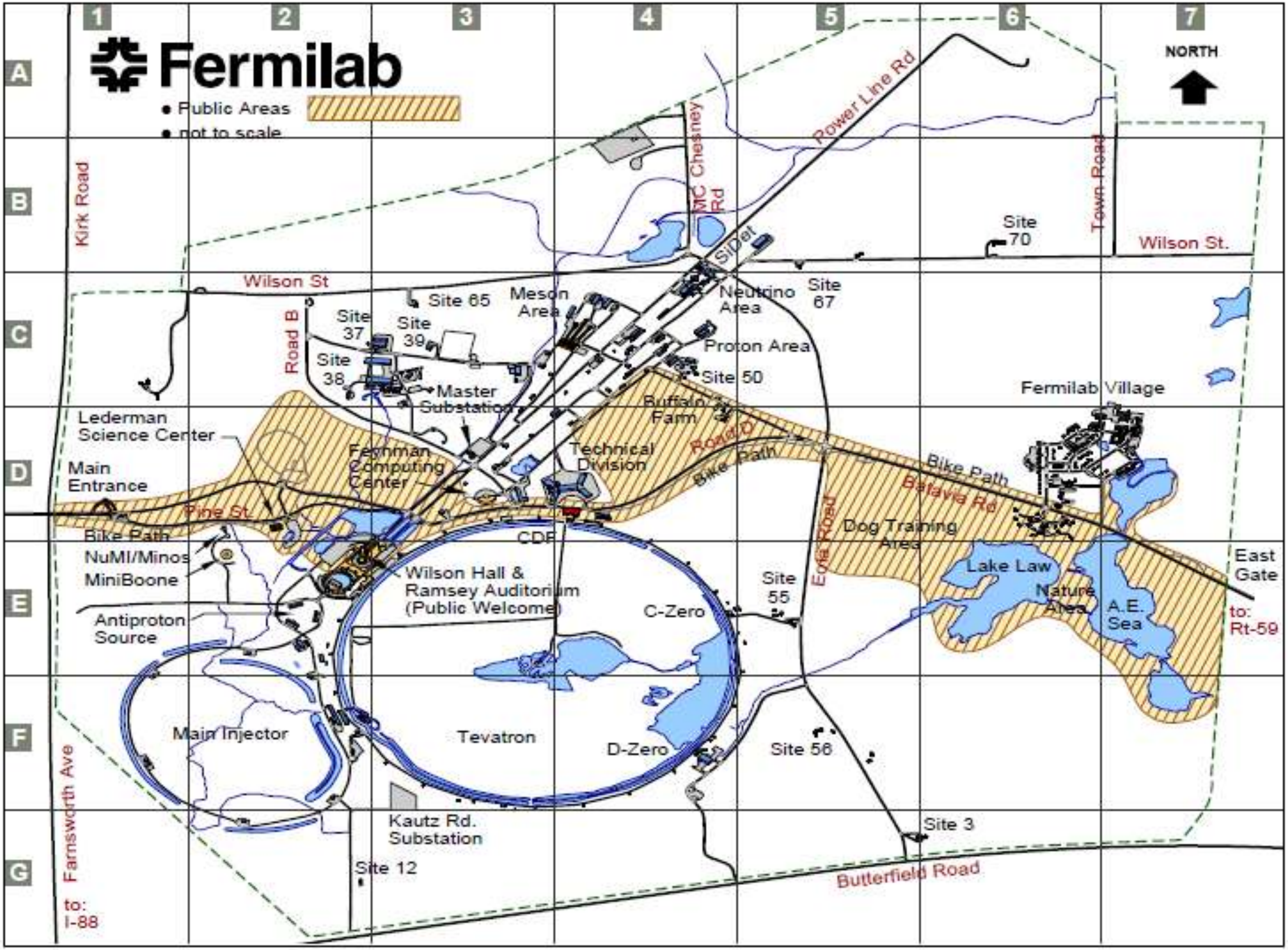
- *The highly energetic protons collide to create top quarks of about 180 times the mass of the protons. The* ***energy*** *of the less massive protons is converted into the huge* ***mass*** *of the resultant top quarks.*

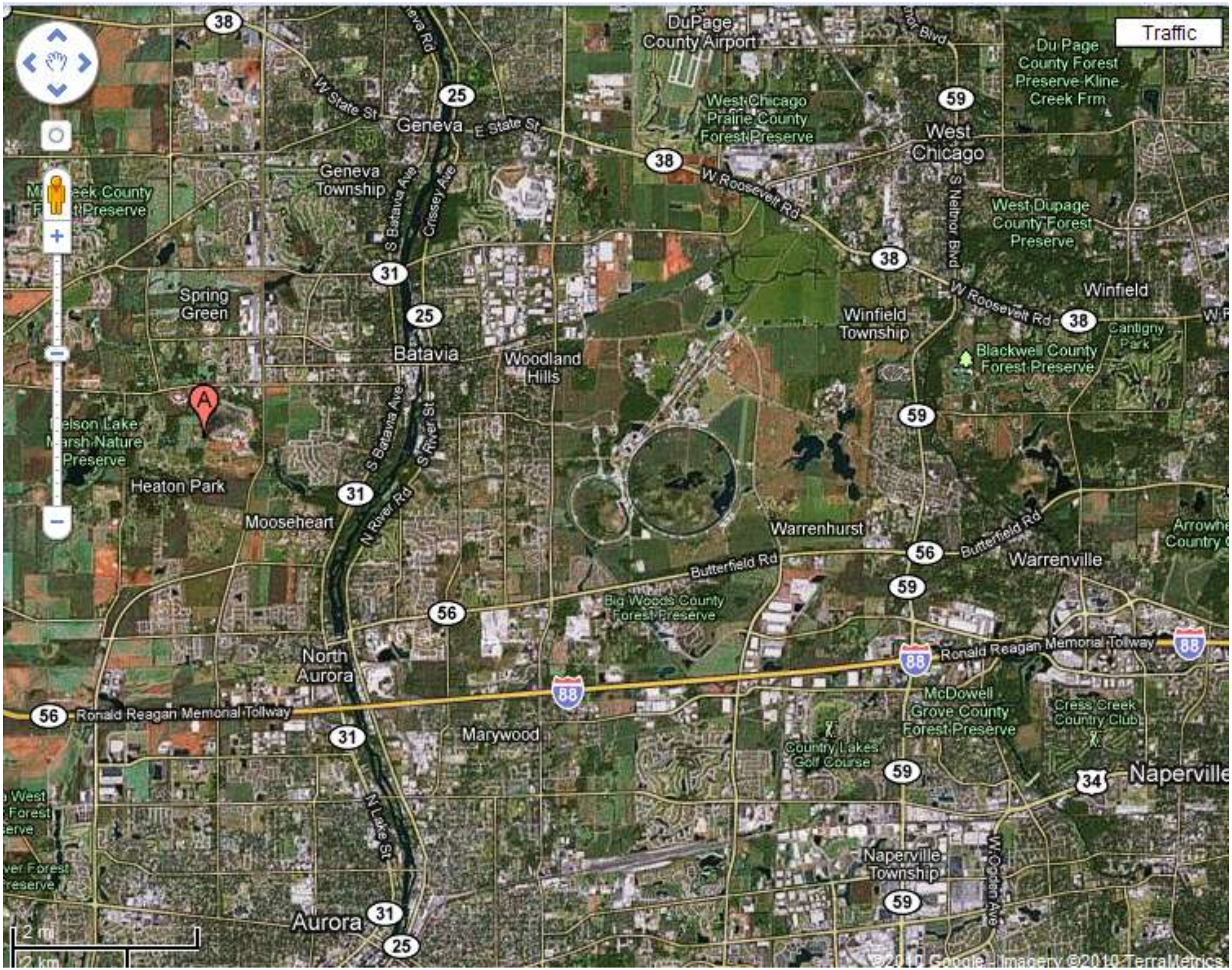
Top Quark Lab Review

- *…the proton and antiproton pair were traveling so close to the speed of light that together they had about **1.8×10^{12} eV** worth of energy to work with. This energy then **becomes** the mass of the newly discovered quarks as shown in this diagram of $E=mc^2$*

Top Quark Lab Review



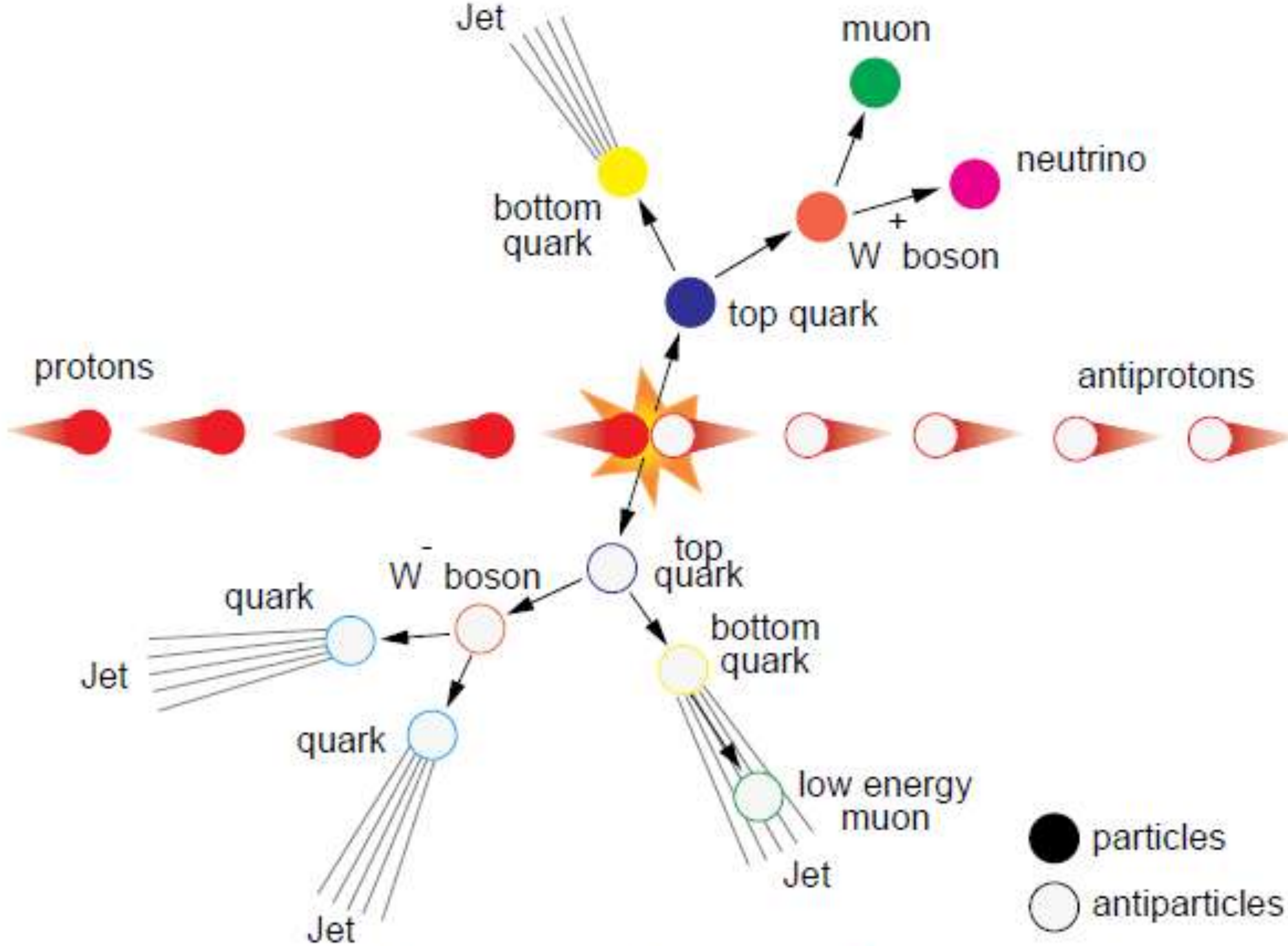

Fermilab
Public Areas
not to scale
NORTH
Kirk Road
Wilson St
Power Line Rd
MC Chesney Rd
SiDet
Town Road
Site 70
Wilson St.
Site 65
Meson Area
Neutrino Area
Site 67
Road B
Site 37
Site 39
Site 38
Proton Area
Site 50
Master Substation
Fermilab Village
Lederman Science Center
Buffalo Farm
Feynman Computing Center
Technical Division
Road D
Bike Path
Main Entrance
Batavia Rd
Pine St.
Eola Road
Dog Training Area
CDF
NuMI/Minos
MiniBoone
Wilson Hall &
Ramsey Auditorium
(Public Welcome)
Site 55
Lake Law
Nature Area
A.E. Sea
East Gate
to: Rt-59
C-Zero
Antiproton Source
Main Injector
Tevatron
D-Zero
Site 56
Kautz Rd. Substation
Site 3
Site 12
Butterfield Road
Farnsworth Ave
to: I-88


Traffic
DuPage County Airport
Du Page County Forest Preserve-Kline Creek Frm
West Chicago Prairie County Forest Preserve
West Chicago
Geneva
Geneva Township
W State St
E State St
W Roosevelt Rd
West Dupage County Forest Preserve
S Neltnor Blvd
Winfield
Winfield Township
Cantigny Park
Blackwell County Forest Preserve
Spring Green
Batavia
Woodland Hills
S Batavia Ave
Crissey Ave
S River St
N River Rd
Heaton Park
Mooseheart
Warrenhurst
Warrenville
Butterfield Rd
Big Woods County Forest Preserve
North Aurora
Ronald Reagan Memorial Tollway
McDowell Grove County Forest Preserve
Cress Creek Country Club
Country Lakes Golf Course
Marywood
Naperville
Naperville Township
W Ogden Ave
N Lake St
Aurora
2 mi
2 km
©2010 Google - Imagery ©2010 TerraMetrics

Traffic
2 miles
Kirk Rd
Kirk Rd
Kirk Rd
Lake Law
Butterfield Rd
56
56
2000 ft

Top Quark Lab Review

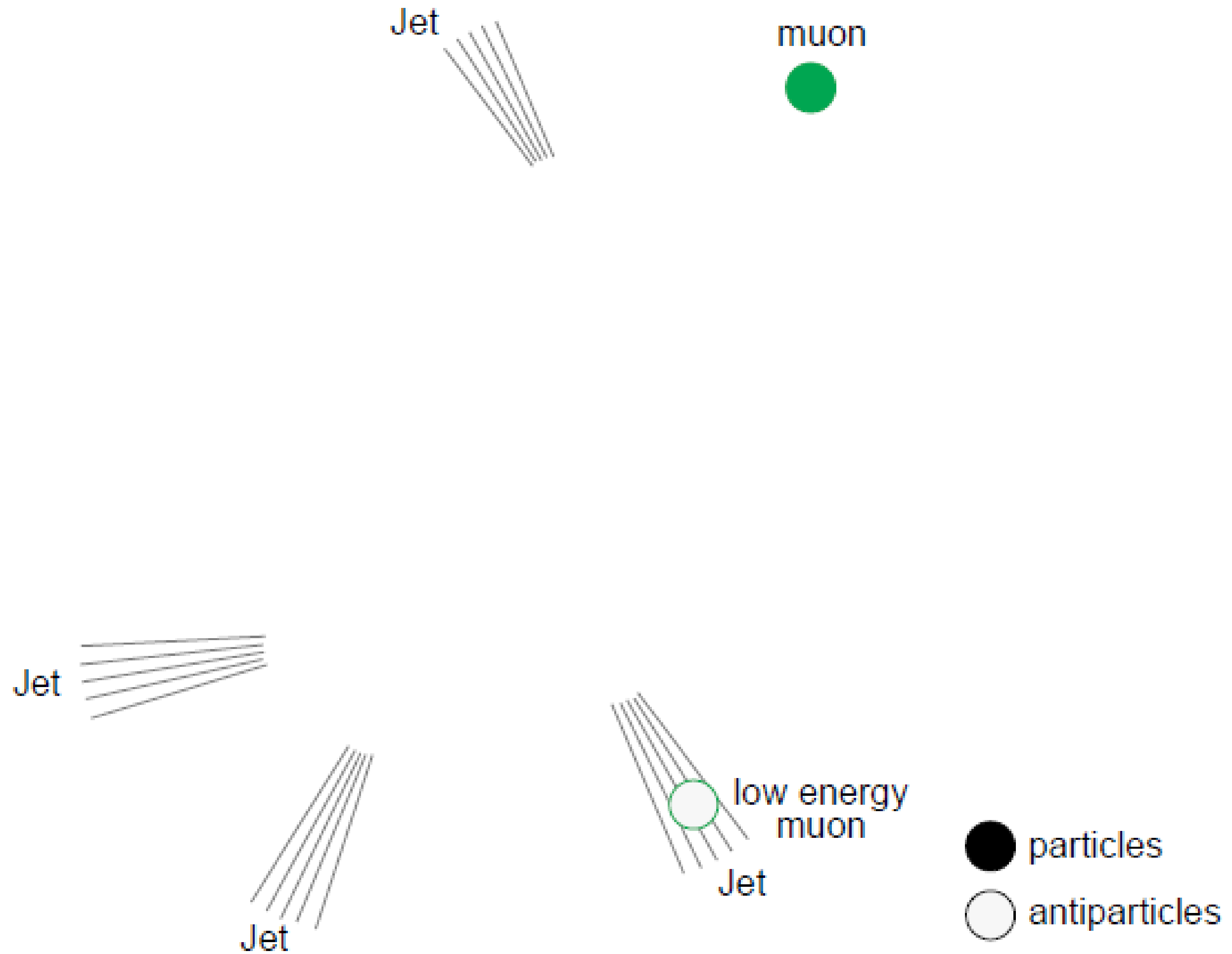
- *To help the students understand the idea that mass and energy are interchangeable, this activity examines the fingerprint of a top/antitop production that took place in the D-Zero Detector at Fermilab on July 9, 1995 and is shown in an artist's rendition of top/antitop production.*



A Top Antitop Quark Event from the D-Zero Detector at Fermilab

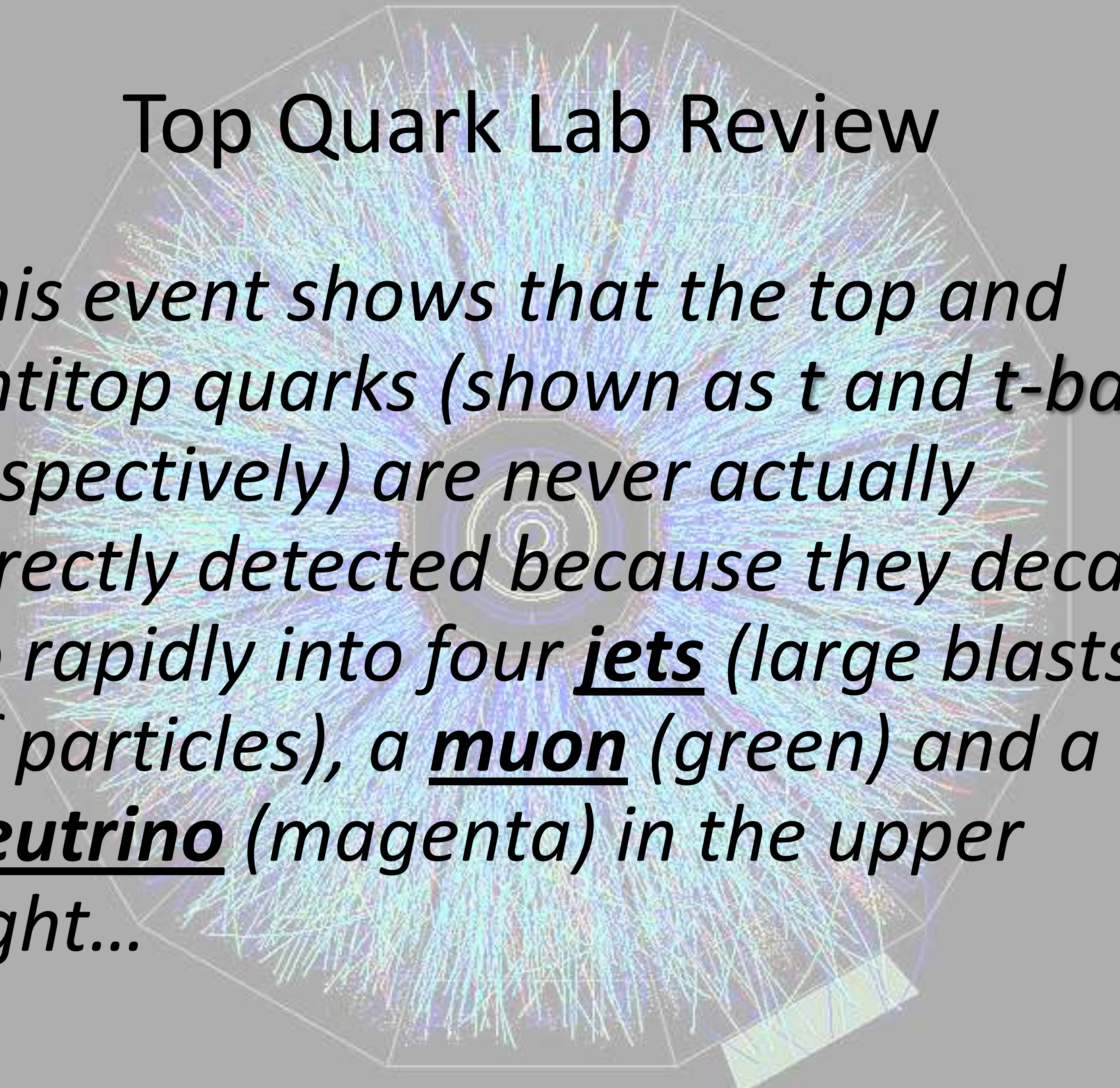
Top Quark Lab Review

- *It is important to point out that the top and antitop quarks are actually very short-lived particles. They quickly decay into daughter particles and then in turn into "granddaughter" and "great granddaughter" particles. It is these offspring that are actually detected by the scientists at Fermilab.*



Particles Seen by the D-Zero Detector at Fermilab
in a Top Antitop Quark Event.

Top Quark Lab Review

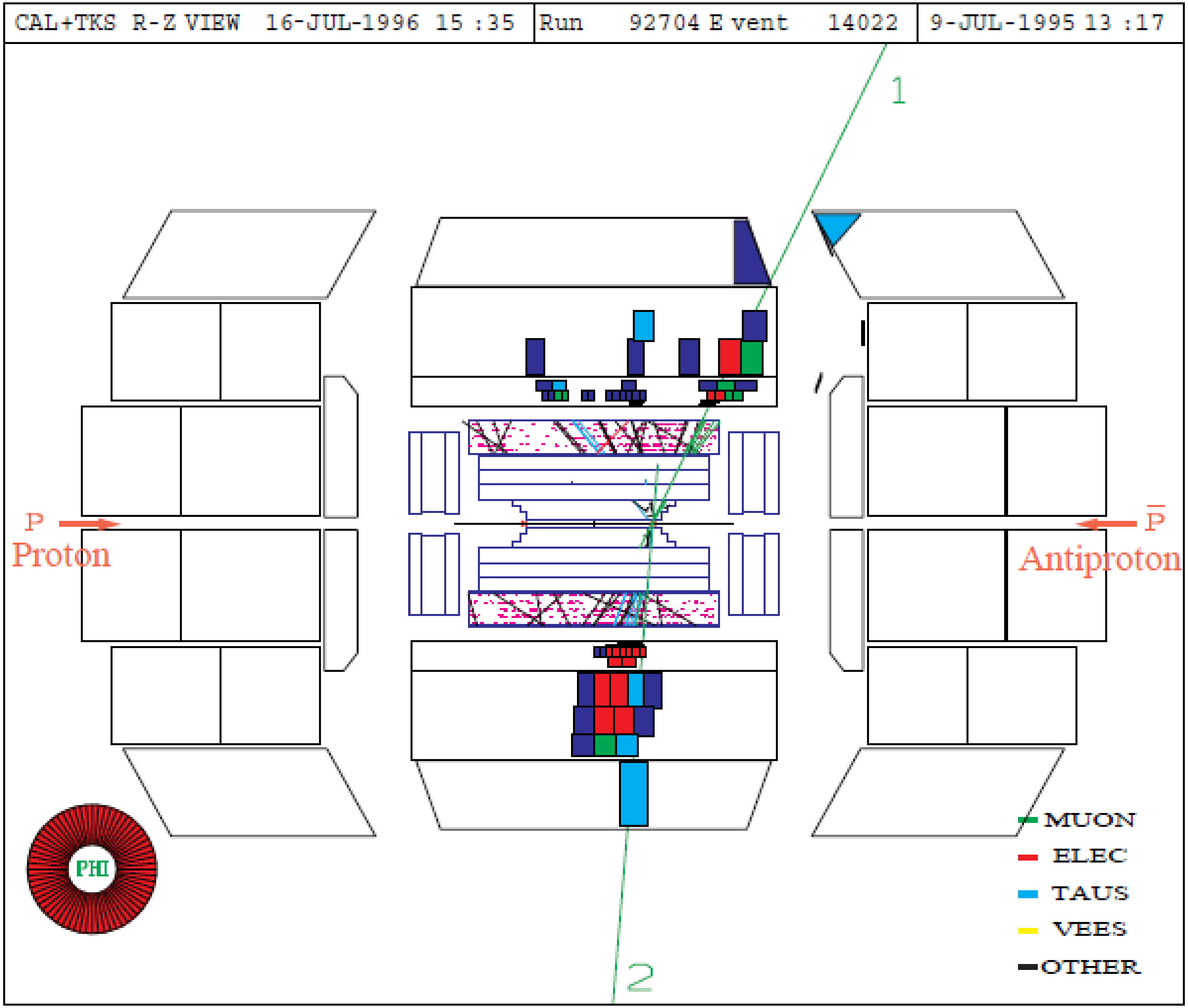


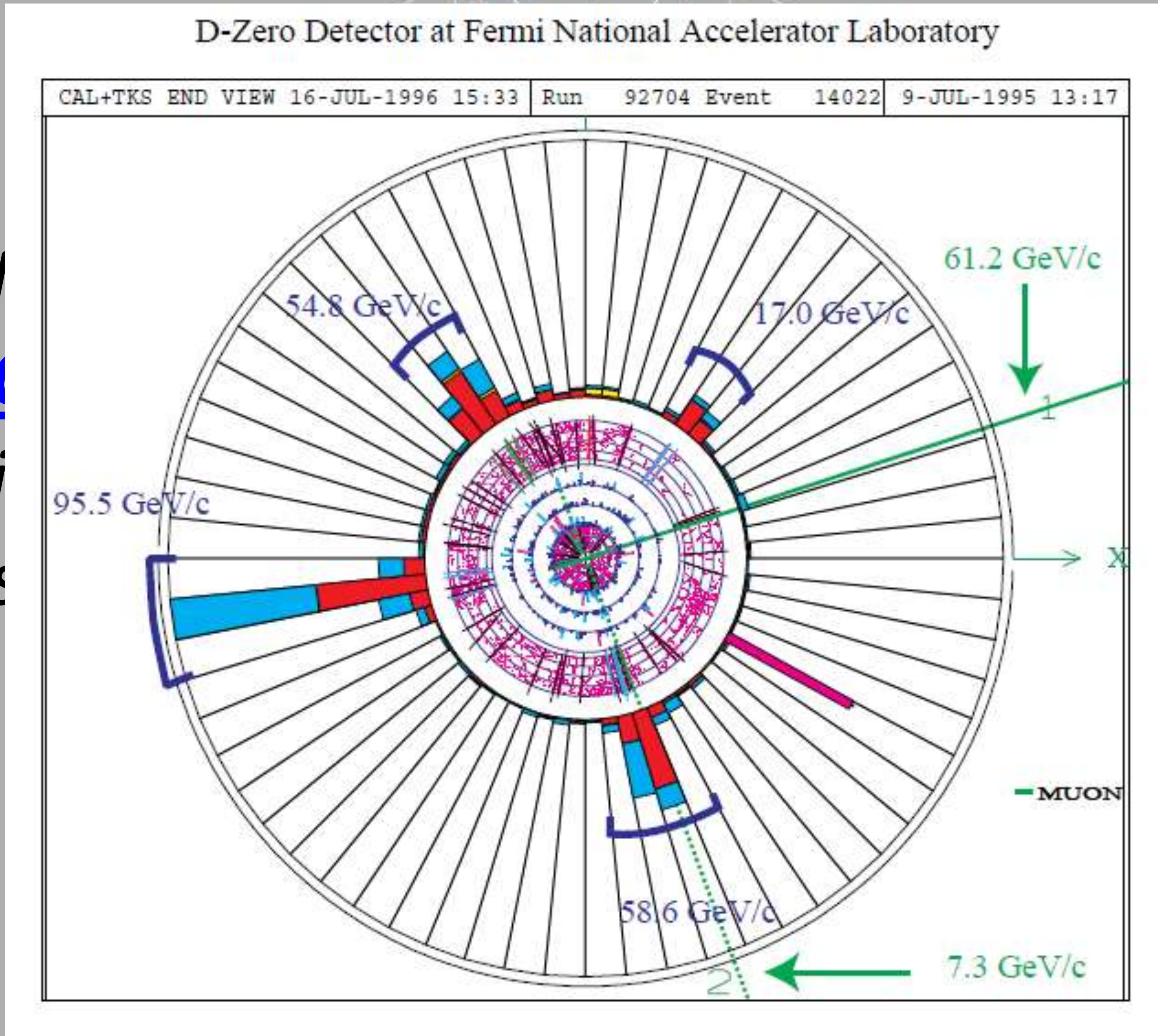
- *This event shows that the top and antitop quarks (shown as* ***t*** *and* ***t-bar*** *respectively) are never actually directly detected because they decay so rapidly into four* ***jets*** *(large blasts of particles), a* ***muon*** *(green) and a* ***neutrino*** *(magenta) in the upper right…*

Top Quark Lab Review

- *To help visualize the event, you may look more carefully at the first color plot labeled* ***CAL+TKS R-Z VIEW*** *which gives a perspective from the* ***side*** *of the detector.*

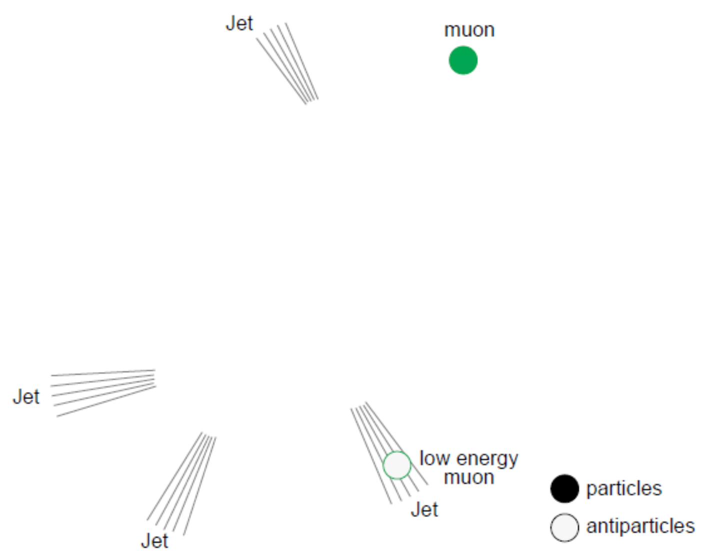
D-Zero Detector at Fermi National Accelerator Laboratory - Side View



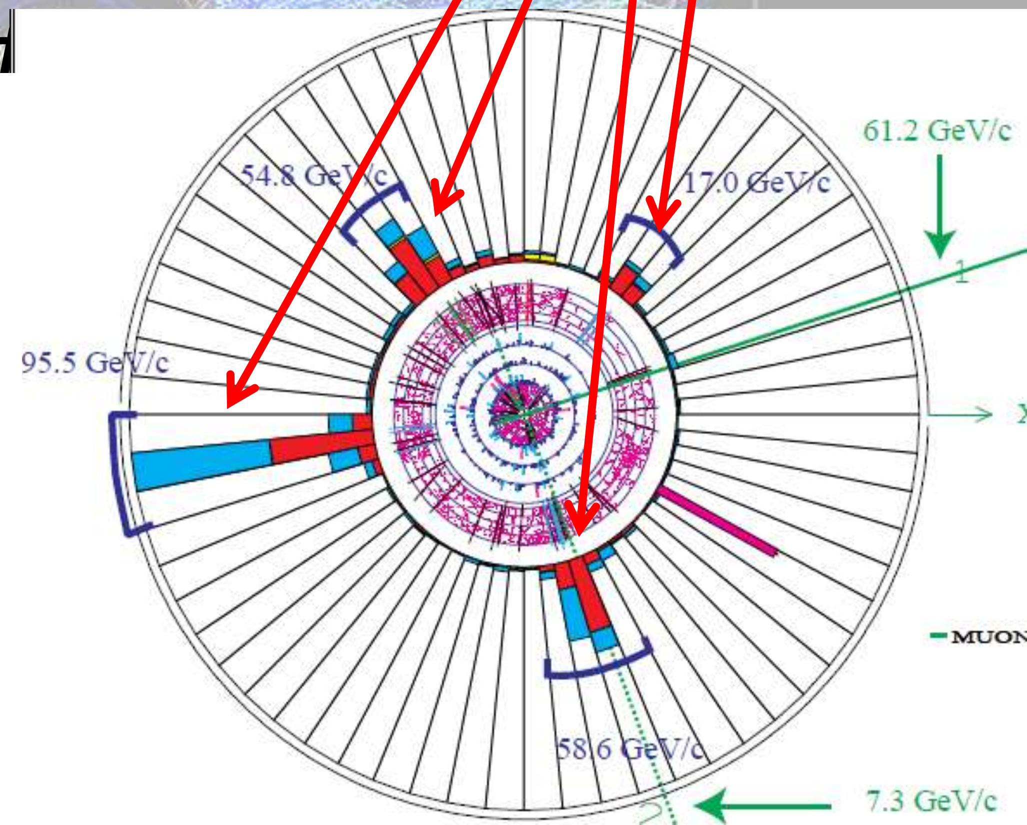

D-Zero Detector at Fermi National Accelerator Laboratory
CAL+TKS END VIEW 16-JUL-1996 15:33
Run 92704 Event 14022
9-JUL-1995 13:17
61.2 GeV/c
54.8 GeV/c
17.0 GeV/c
1
95.5 GeV/c
X
MUON
58.6 GeV/c
2
7.3 GeV/c

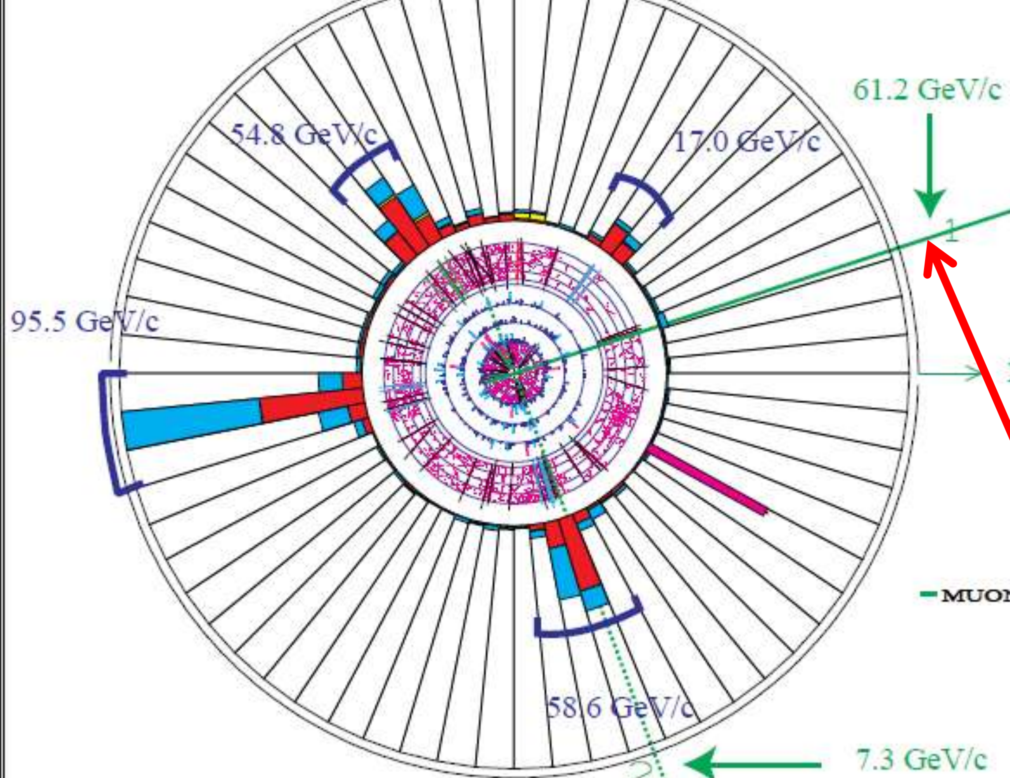
Top Quark Lab Review

- *Notice the four blue and red "jets" which are the four jets shown on the artist's picture o*



Particles Seen by the D-Zero Detector at Fermilab
in a Top Antitop Quark Event.



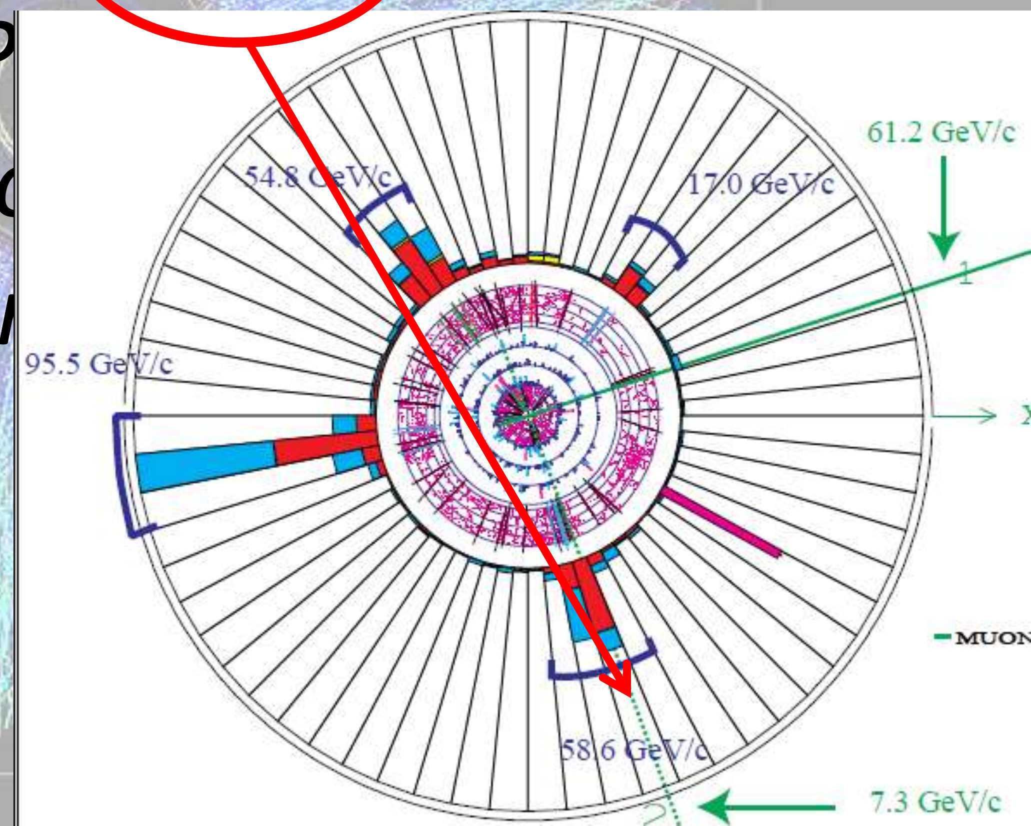


ab Review

e and red "jets"
jets shown on the
he event above.
You will also notice a solid green line
which represents the muon's track.

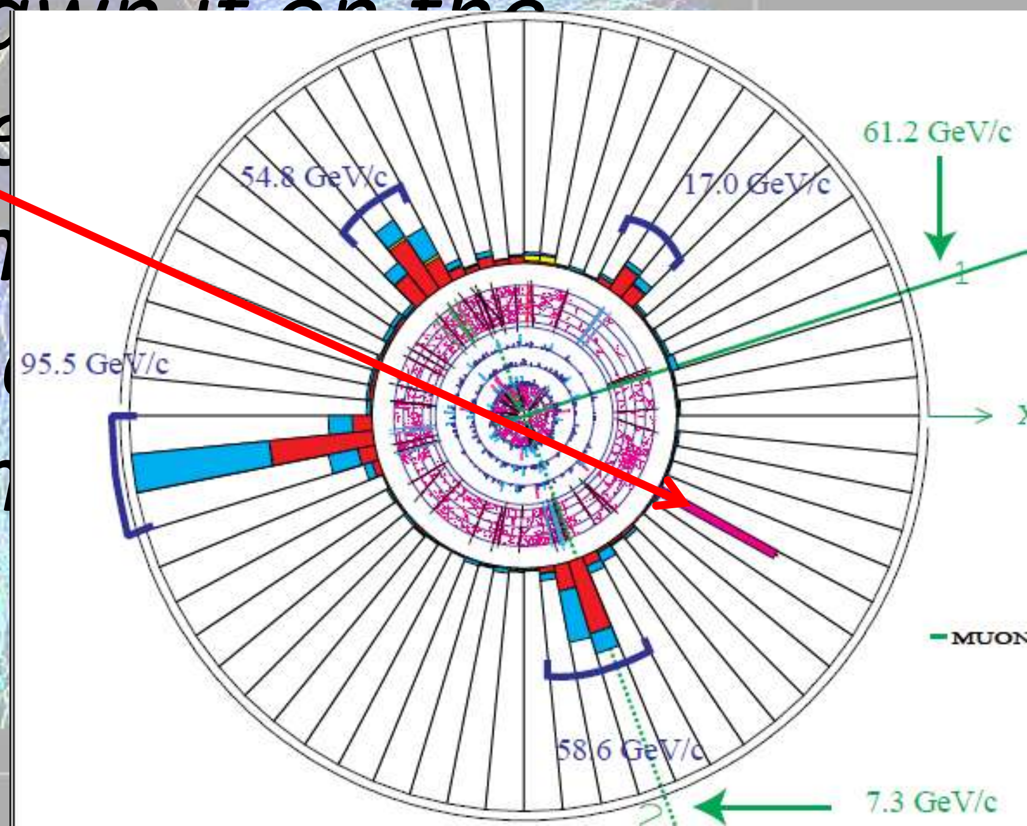
Top Quark Lab Review

- *…you will also see a green dotted line. This is a "soft* ***muon****" that is hidden in a jet. P*
  that all of the m
  measured and a
  plot.



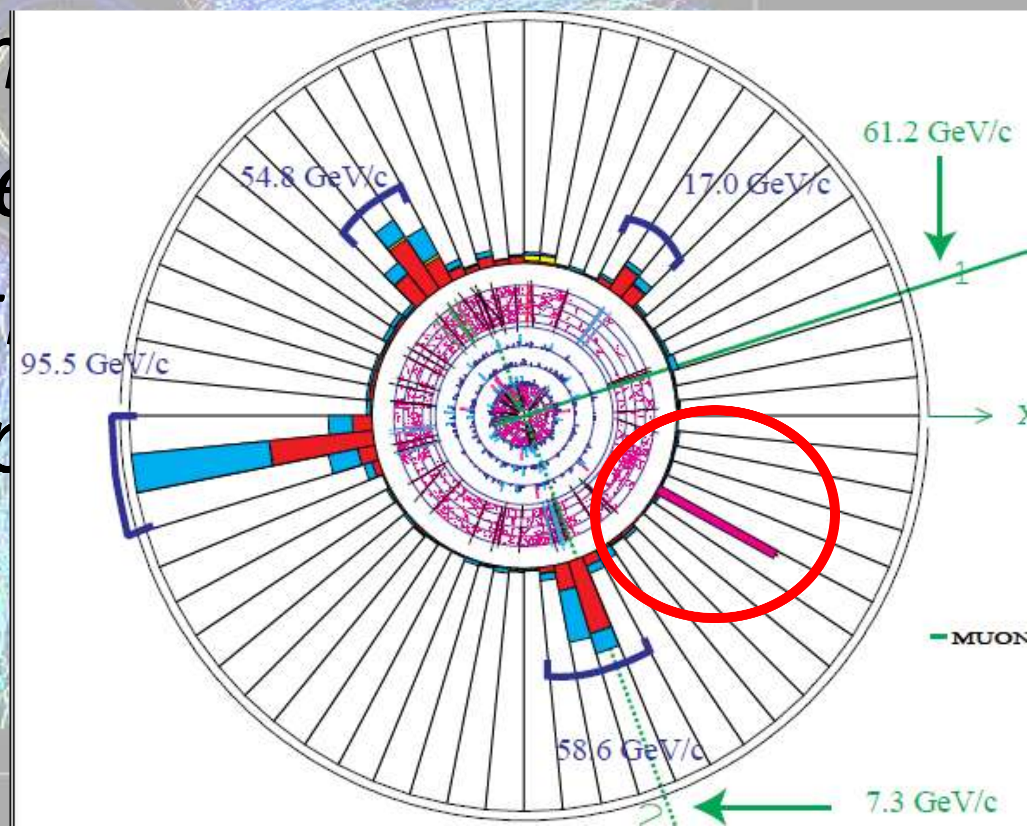
Top Quark Lab Review

- *You will also see that the computer has calculated the energy of the* ***neutrino*** *and dra*
  diagram in mage
  not detectable in
  existence is foun
  total momentum
  collision.



Top Quark Lab Review

- *The process of finding the missing momentum is what your students will do to determ*
top quark. Notice
momentum for t
included on the p

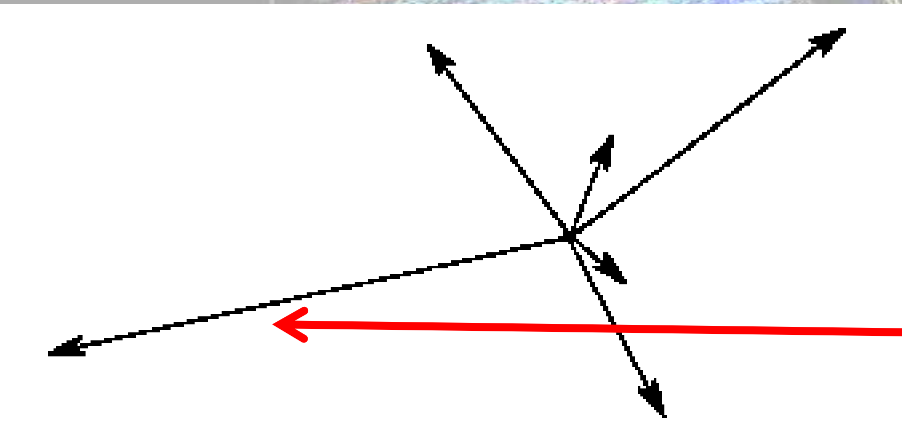
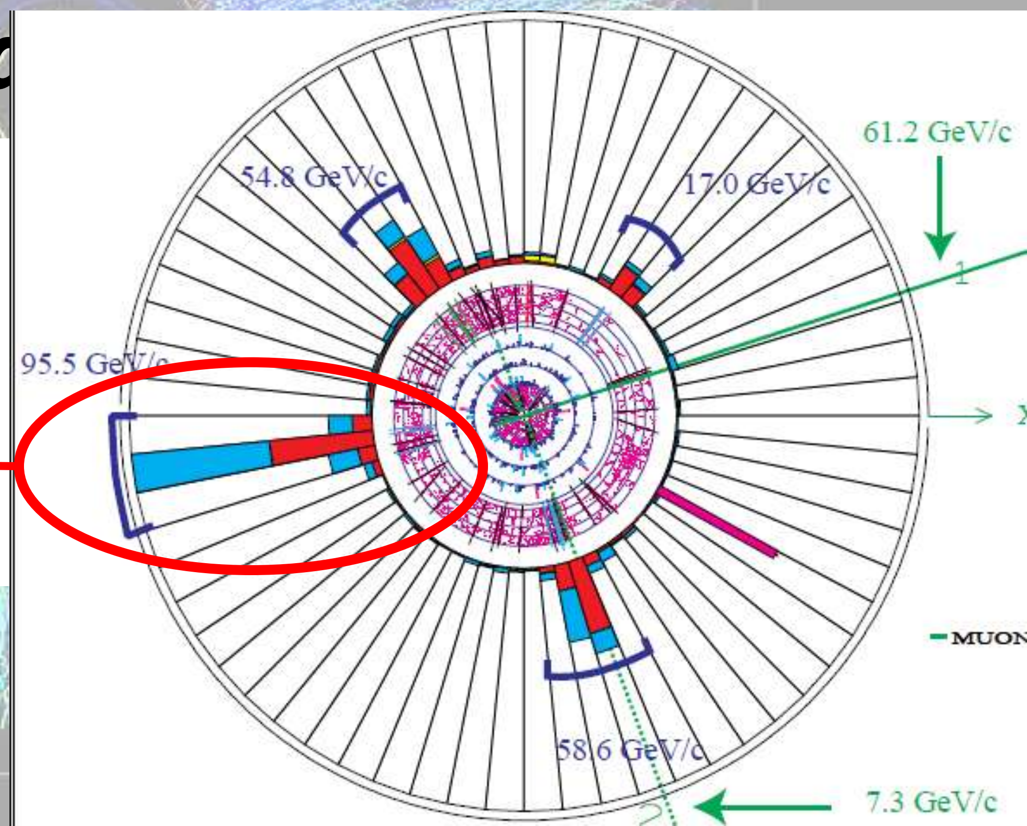


Top Quark Lab Review

- You *are to determine the momentum of the 'undetectable' neutrino by adding up the vectors with directions shown on the diagram and magnitudes indicated by the numbers listed.*

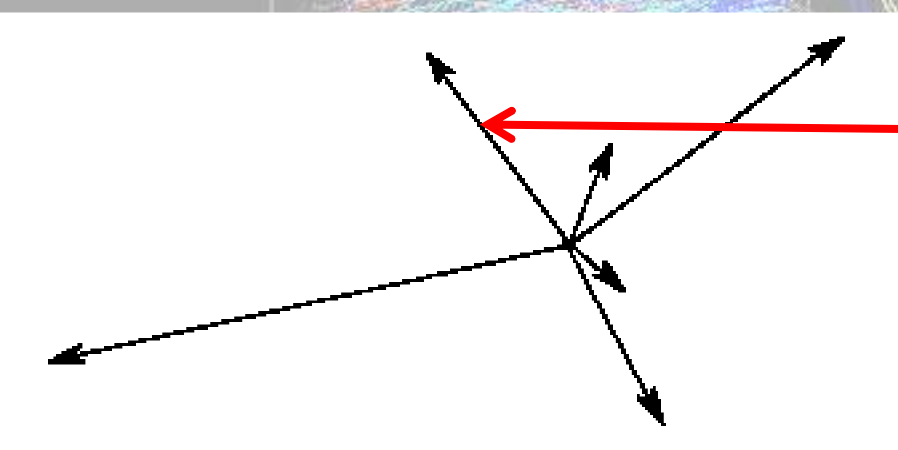
Top Quark Lab Review

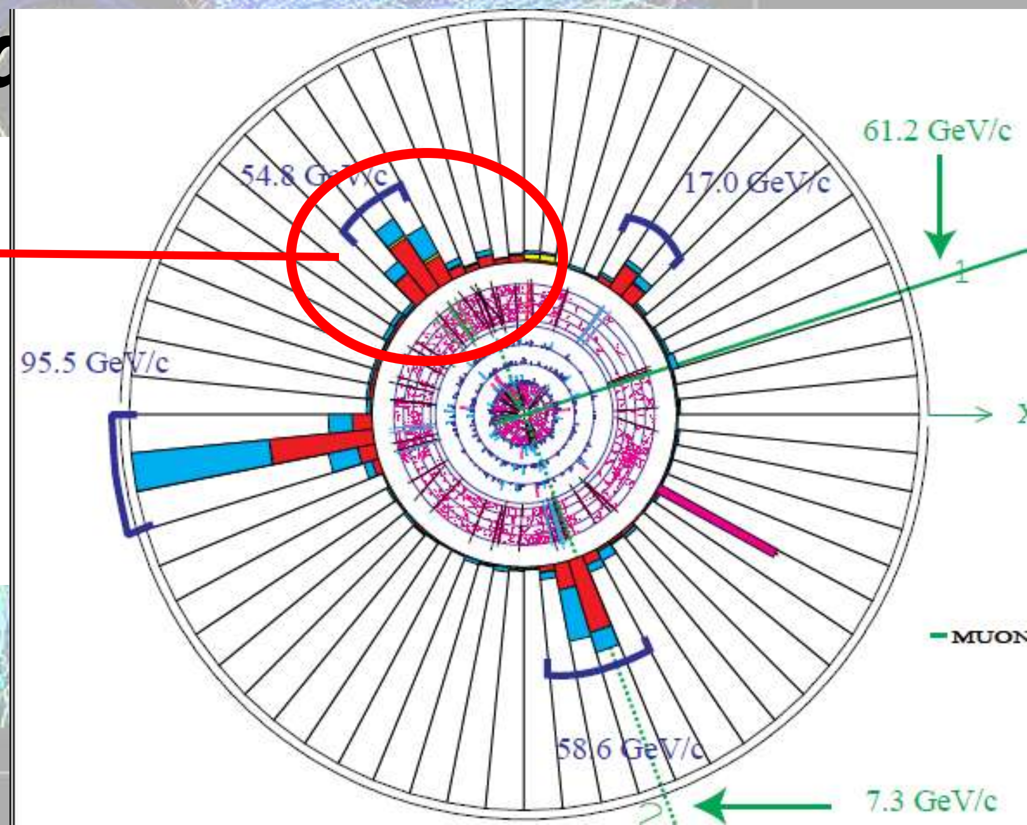
- *An example of a possible vector diagram for event 14022 is shown below for the* ***te***

Top Quark Lab Review

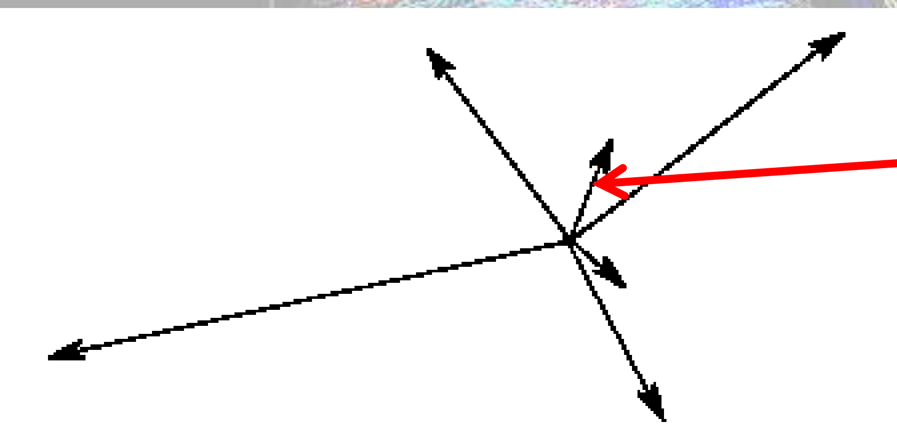
- *An example of a possible vector diagram for event 14022 is shown below for the* ***te***

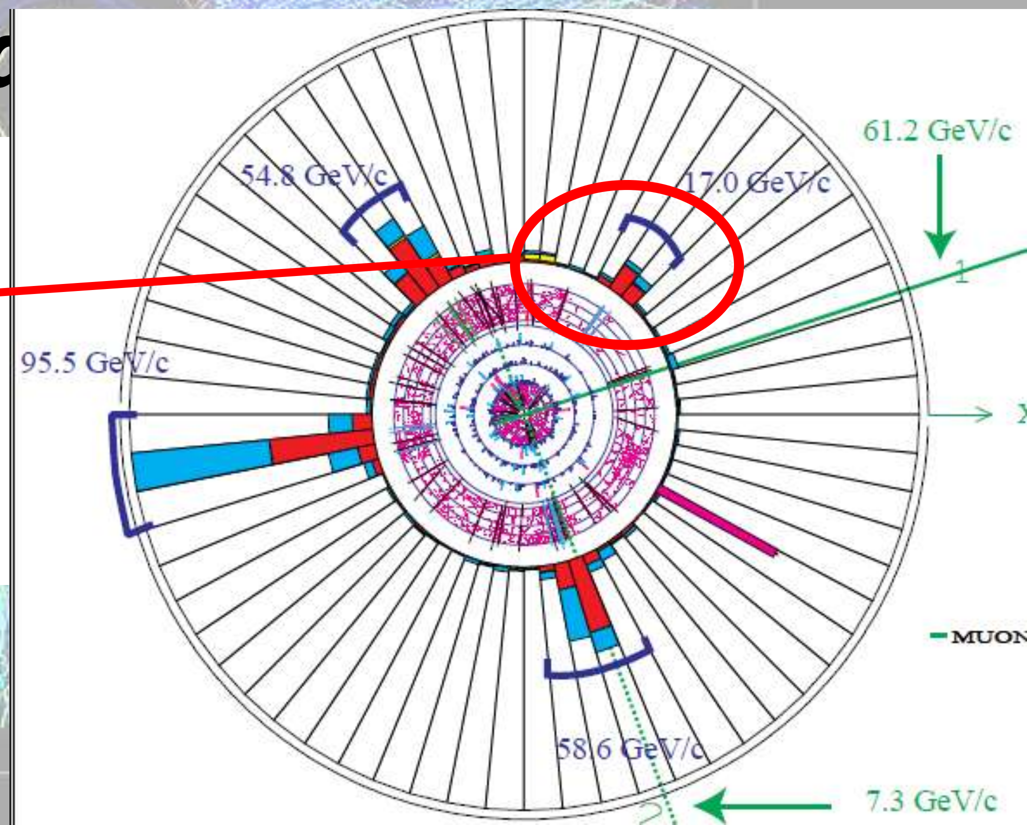




Top Quark Lab Review

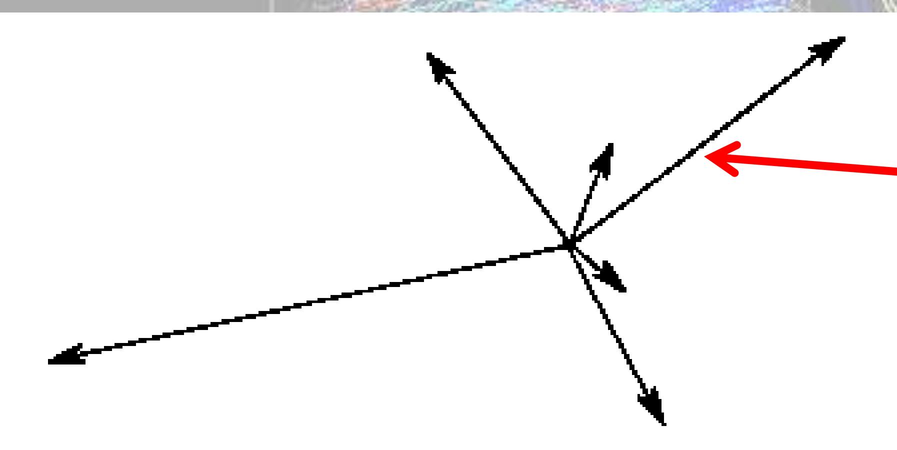
- *An example of a possible vector diagram for event 14022 is shown below for the **tec***

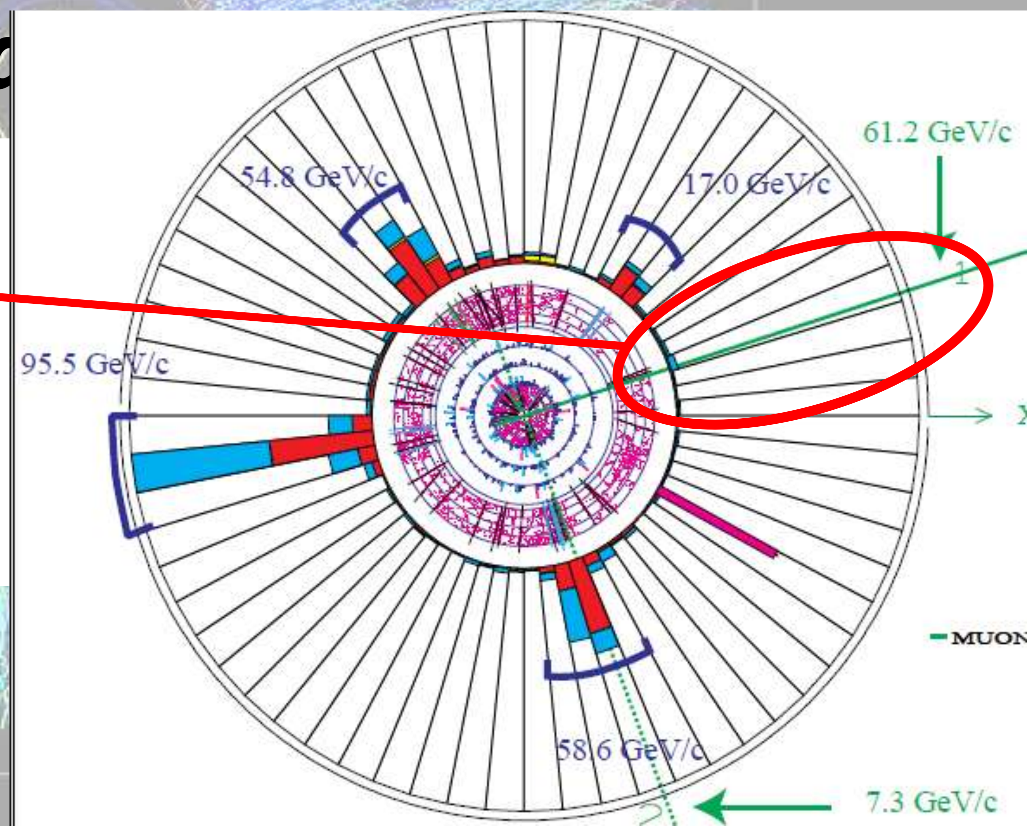




Top Quark Lab Review

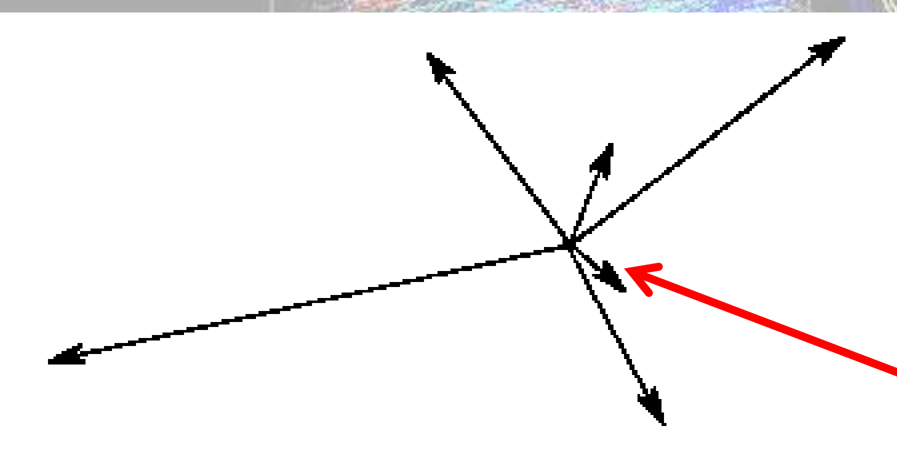
- *An example of a possible vector diagram for event 14022 is shown below for the* ***tec***

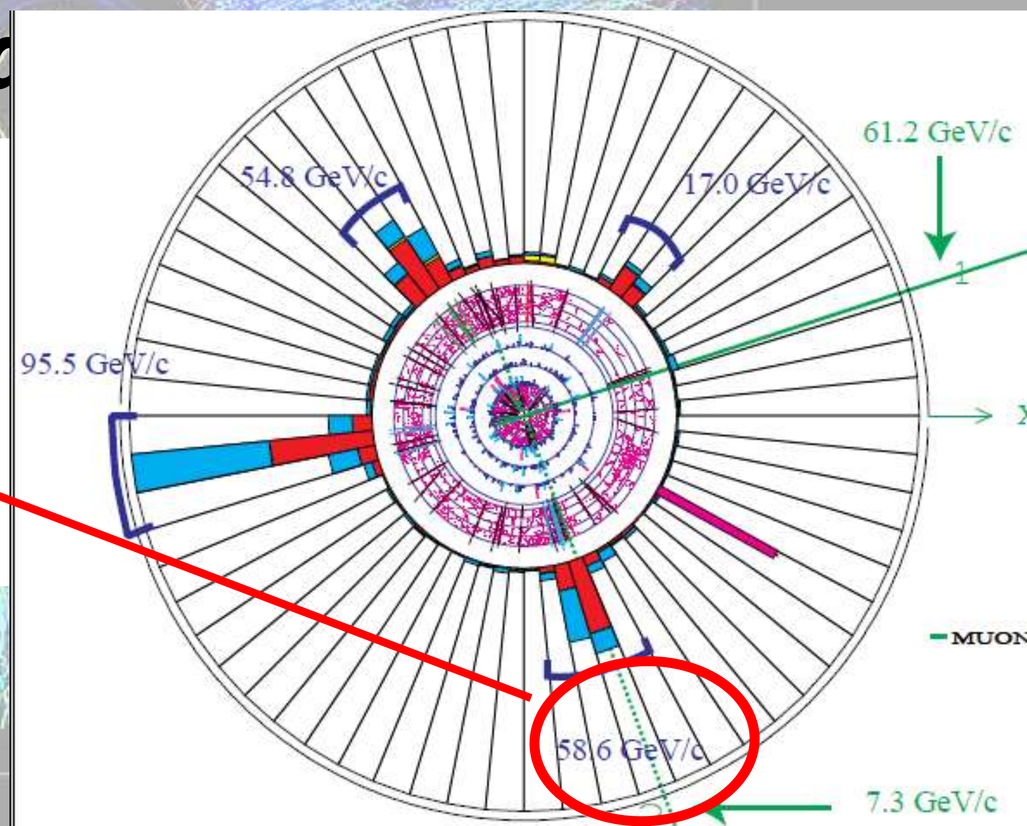




Top Quark Lab Review

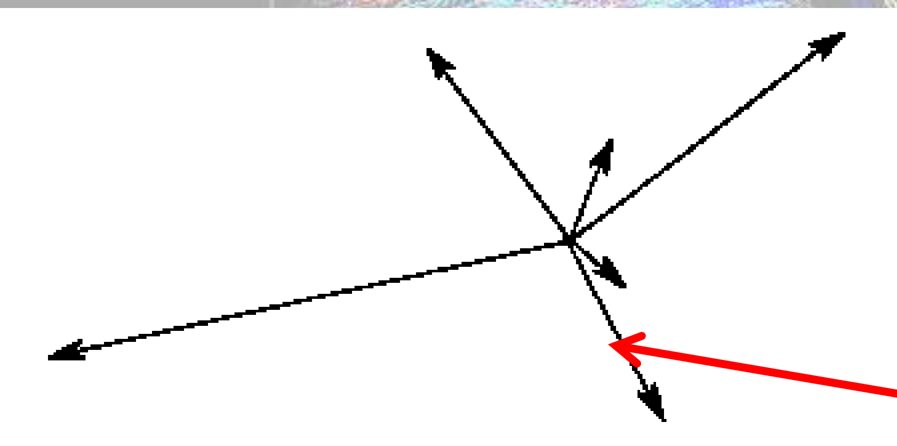
- *An example of a possible vector diagram for event 14022 is shown below for the* ***te***

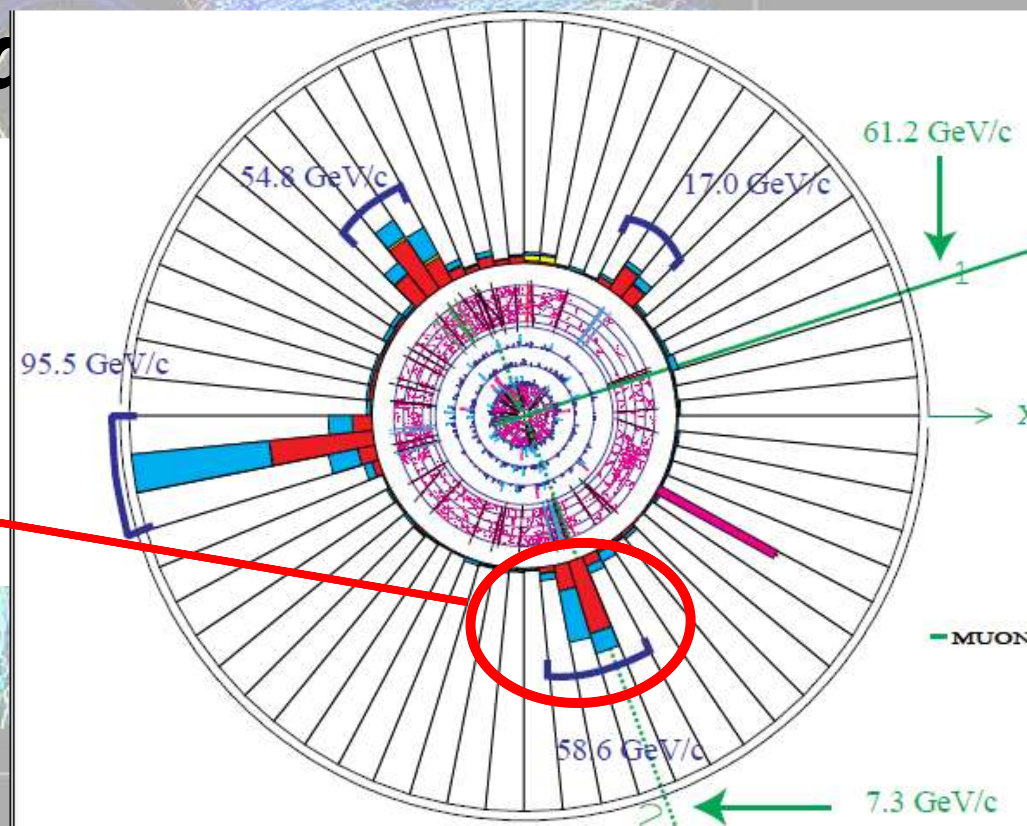




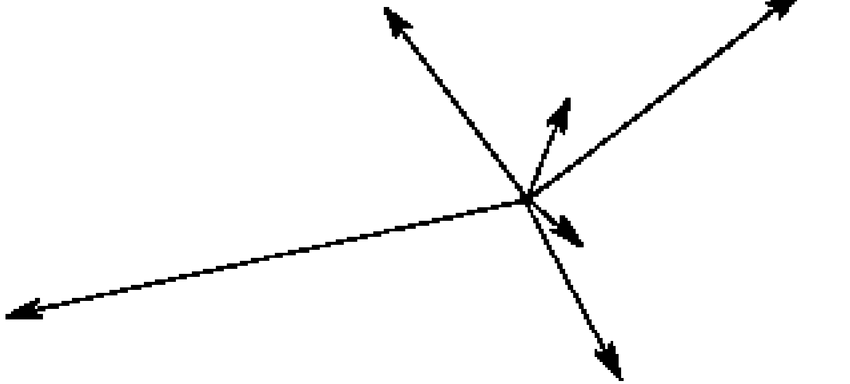
Top Quark Lab Review

- *An example of a possible vector diagram for event 14022 is shown below for the* ***te***

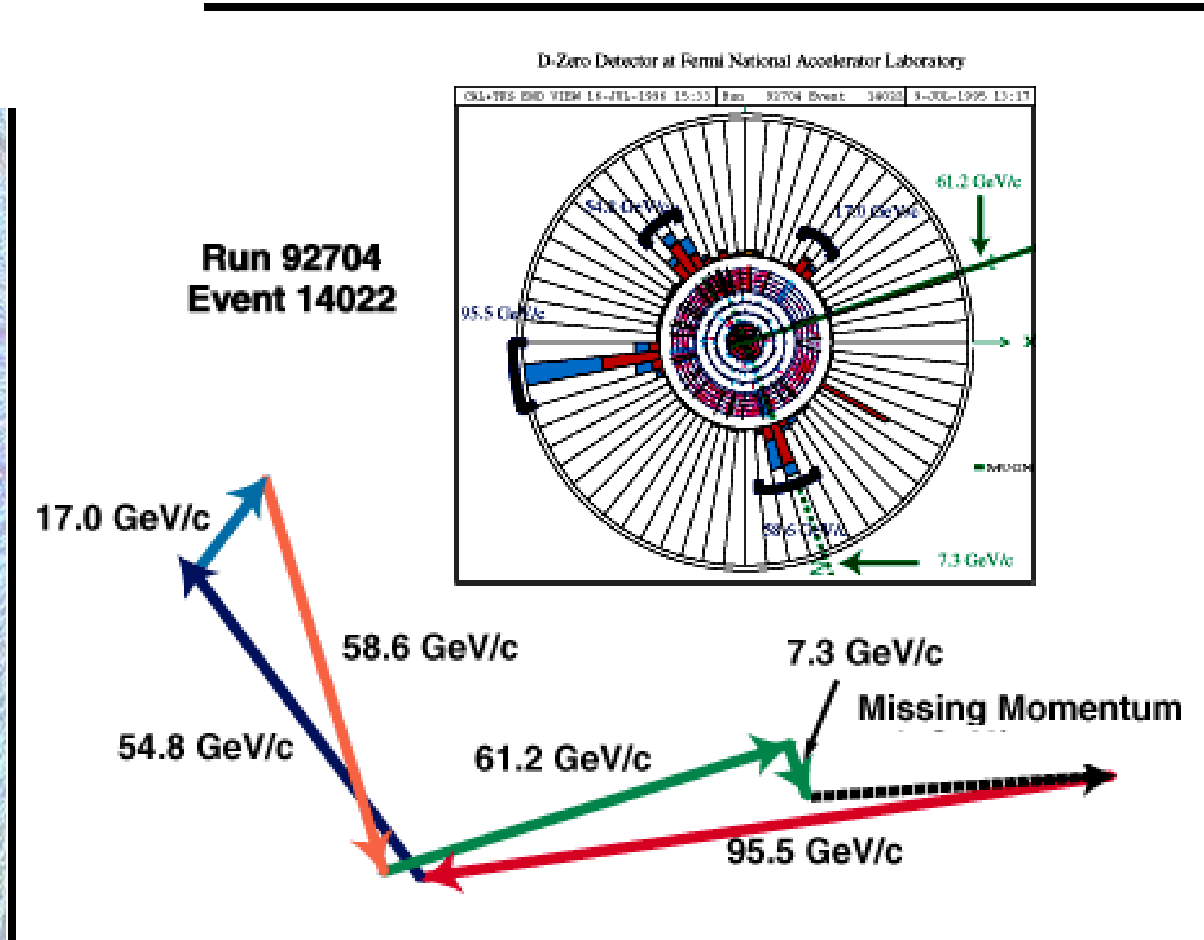




k Lab Review



STOP HERE!!!

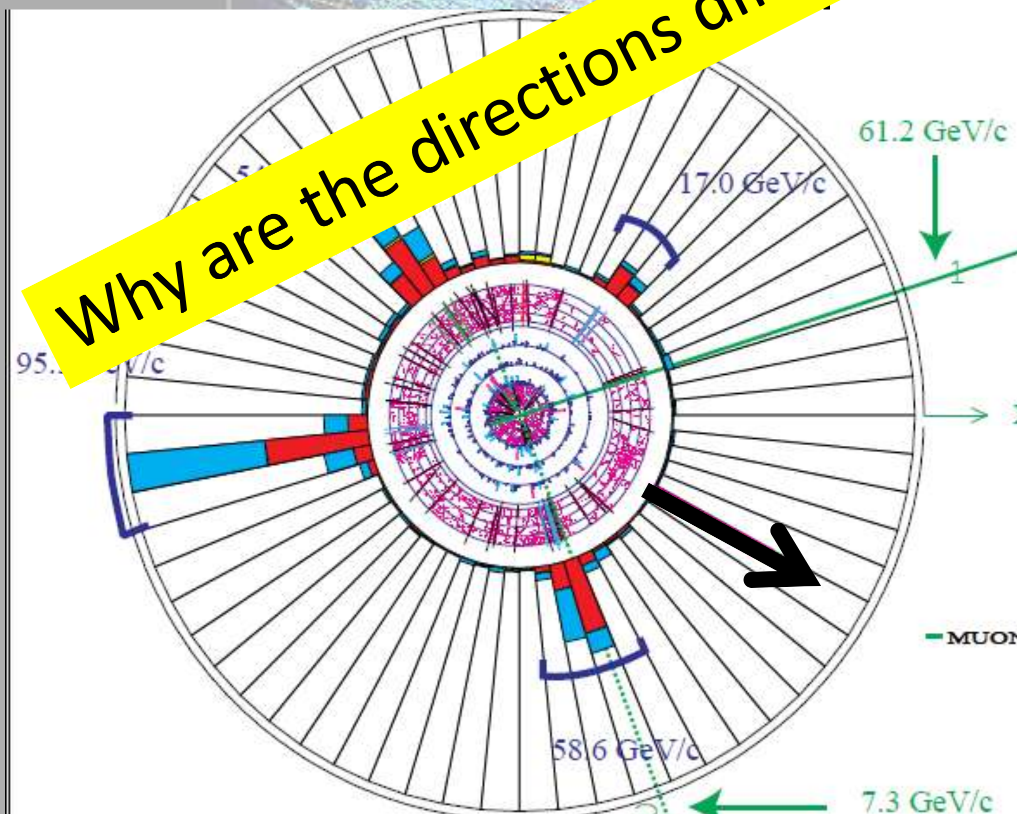


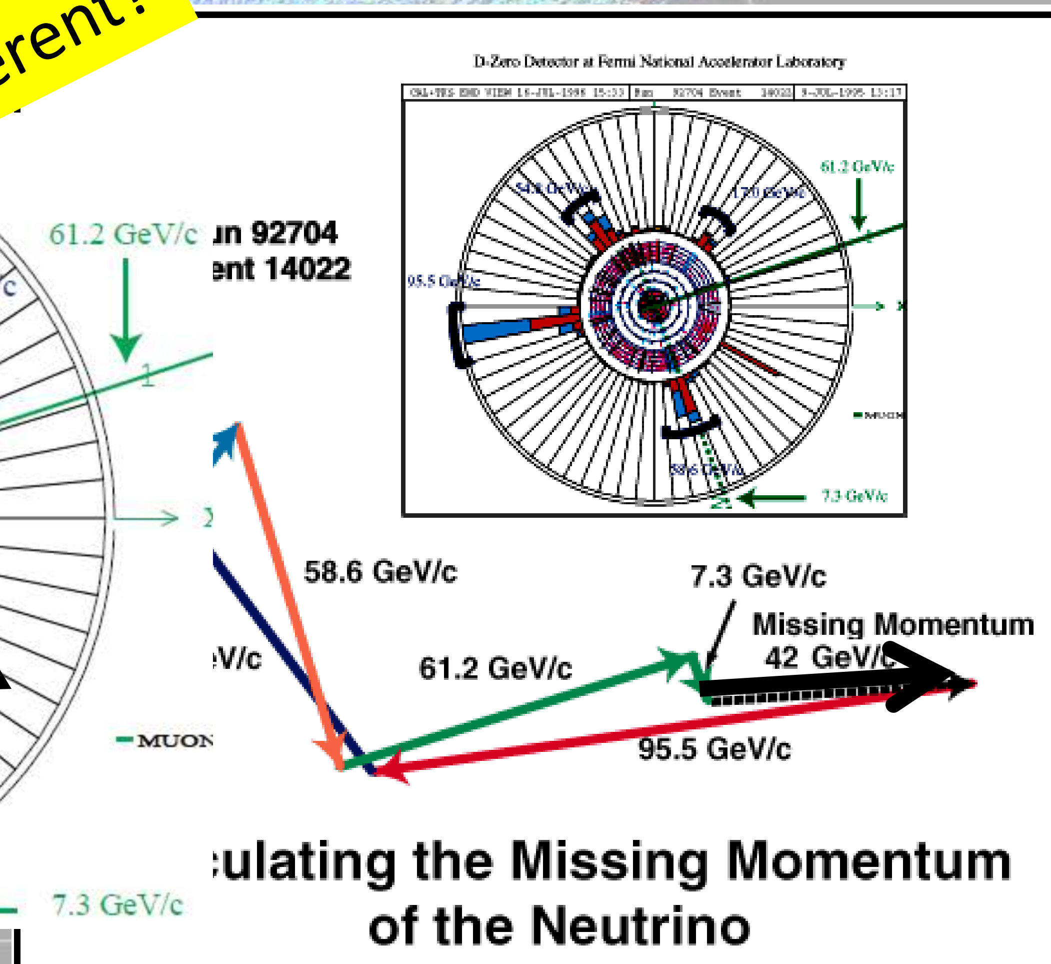
Calculating the Missing Momentum of the Neutrino

Top Quark Lab Review

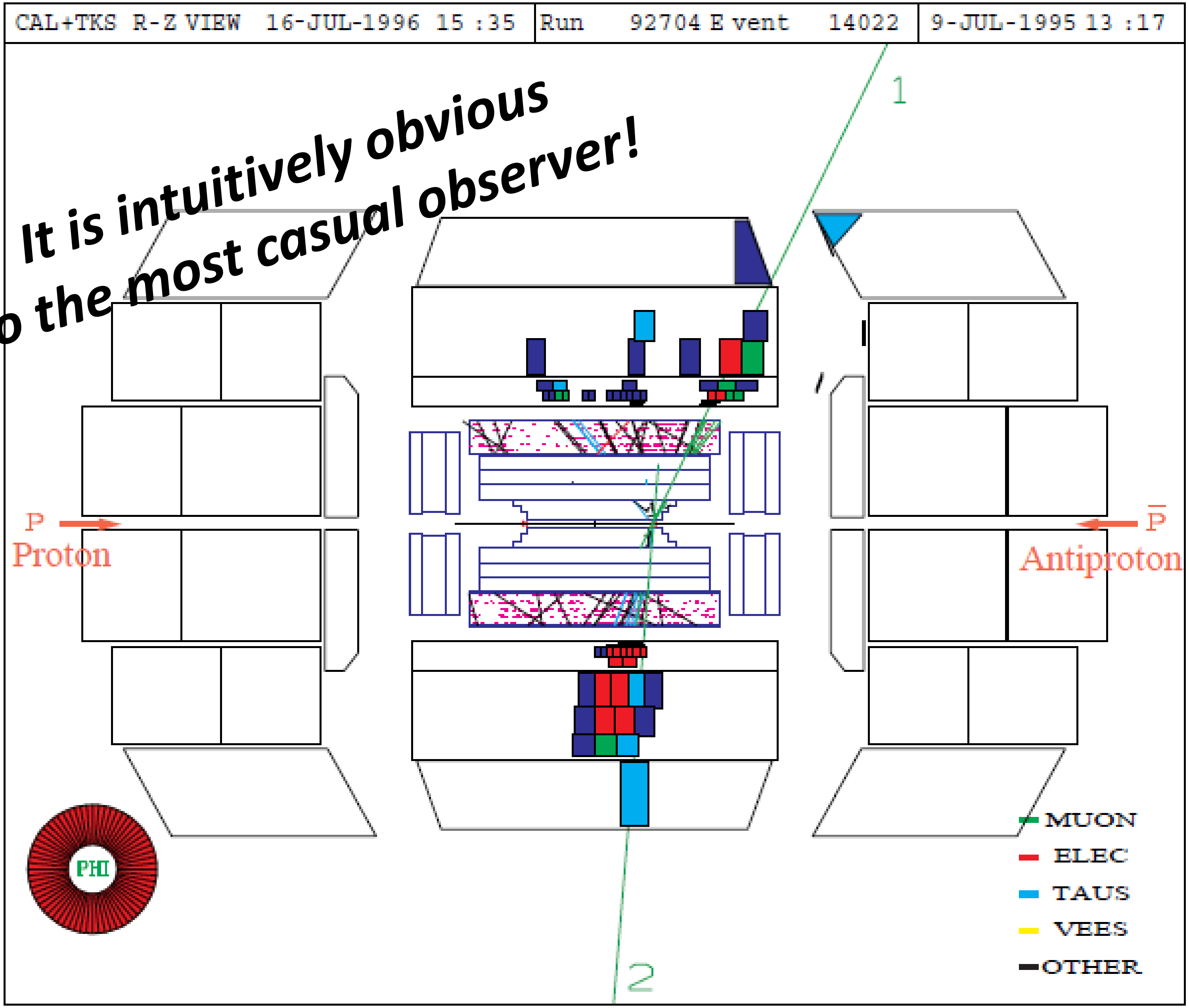
- Notice the direction of the momentum of the neutrino????

Why are the directions different?





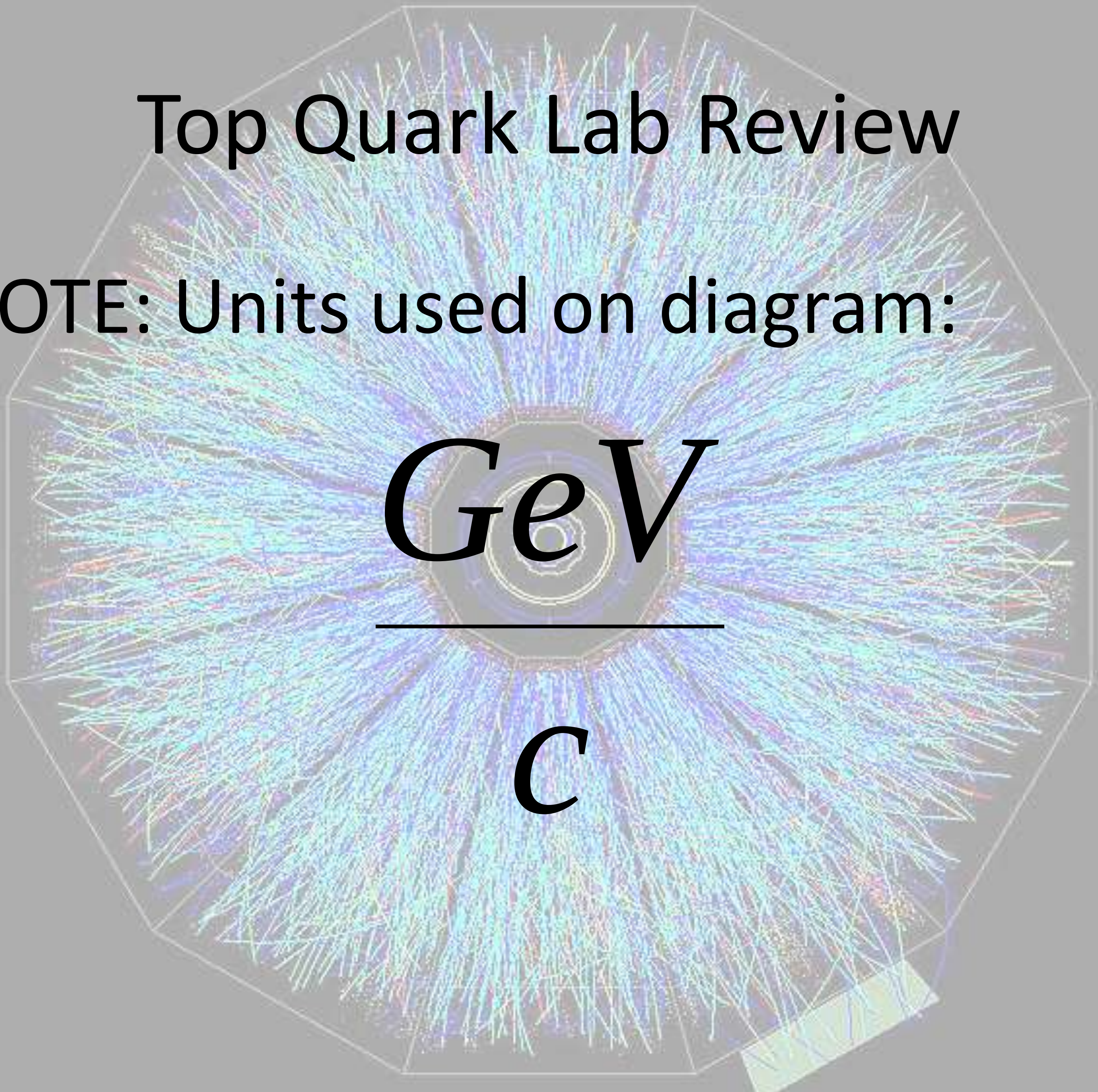
D-Zero Detector at Fermi National Accelerator Laboratory - Side View



•

It is intuitively obvious
To the most casual observer!

Top Quark Lab Review



- NOTE: Units used on diagram:

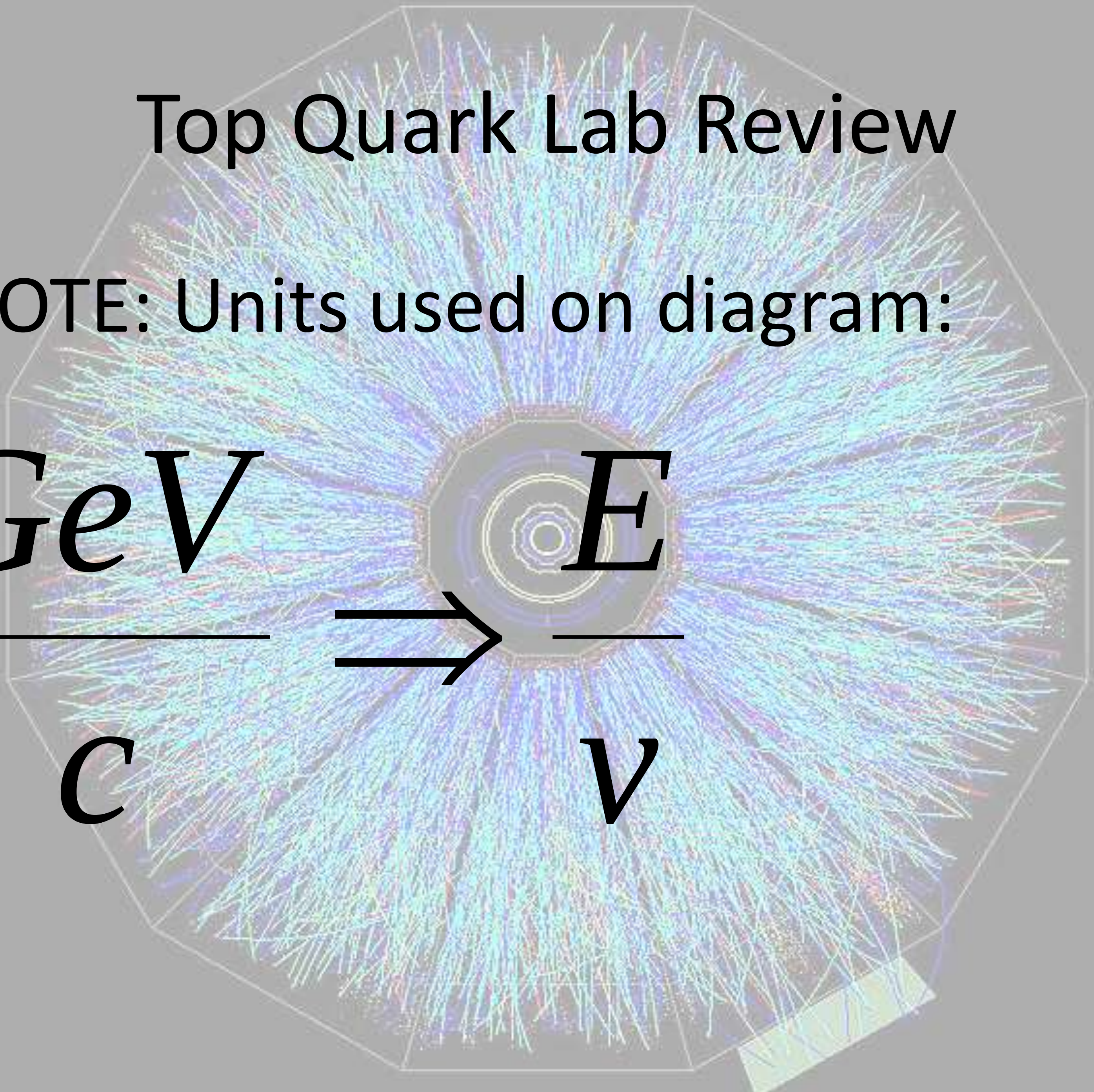
$$\frac{GeV}{c}$$

Top Quark Lab Review

- NOTE: Units used on diagram:

$$\frac{GeV}{c} \Rightarrow \frac{Energy}{Velocity}$$

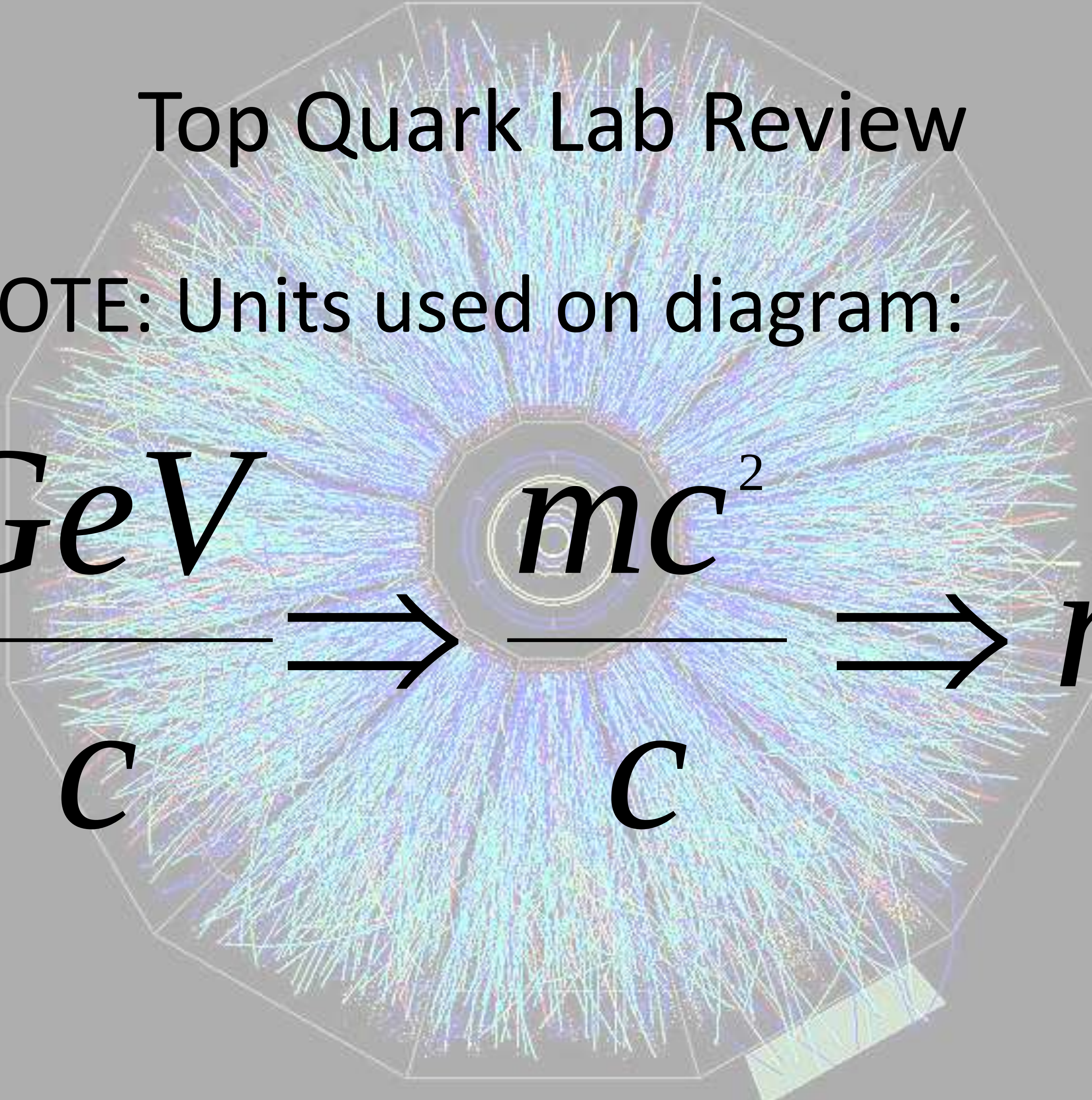
Top Quark Lab Review



- NOTE: Units used on diagram:

$$\frac{GeV}{c} \Rightarrow \frac{E}{v}$$

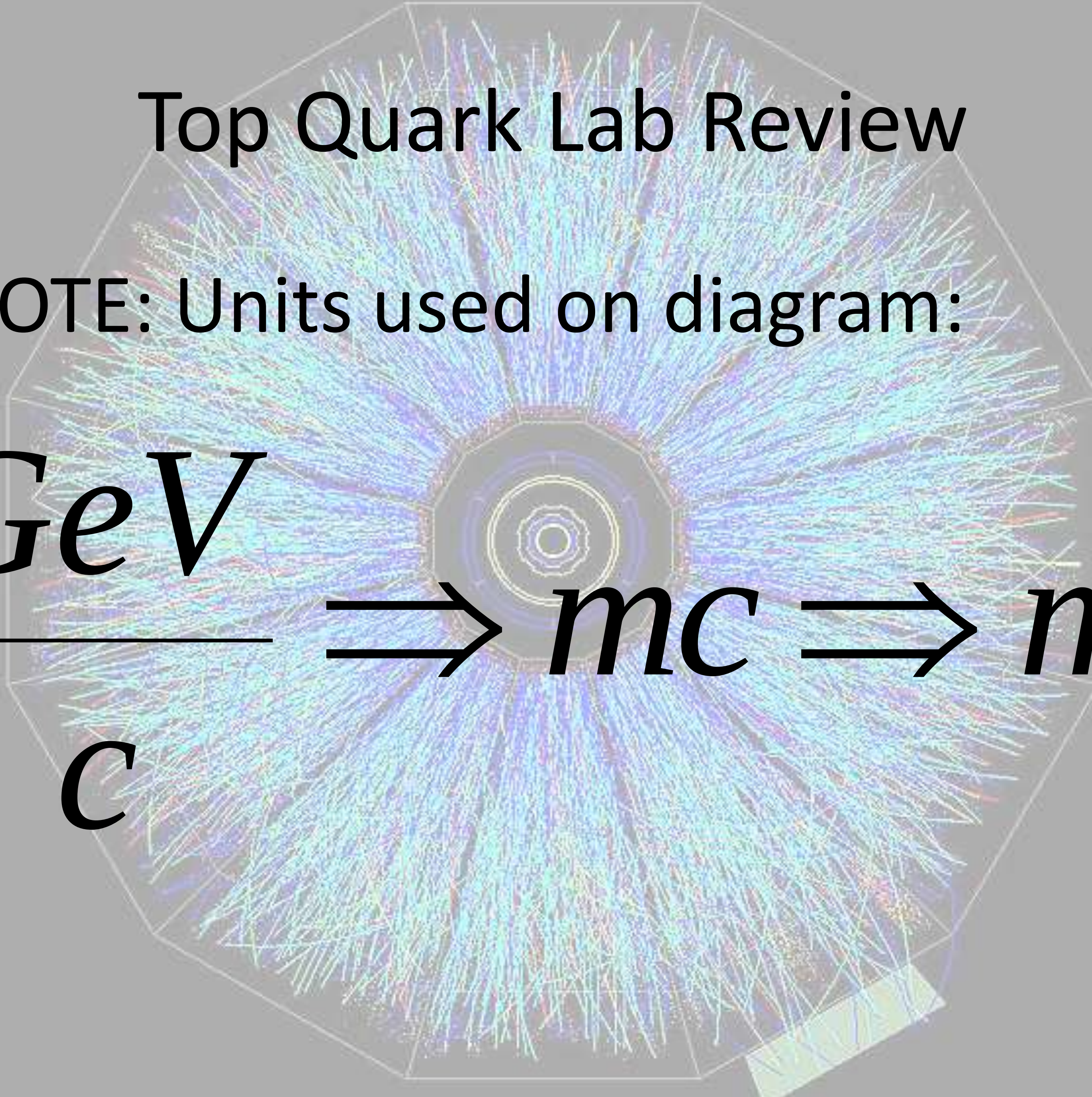
Top Quark Lab Review



- NOTE: Units used on diagram:

$$\frac{GeV}{c} \Rightarrow \frac{mc^2}{c} \Rightarrow mc$$

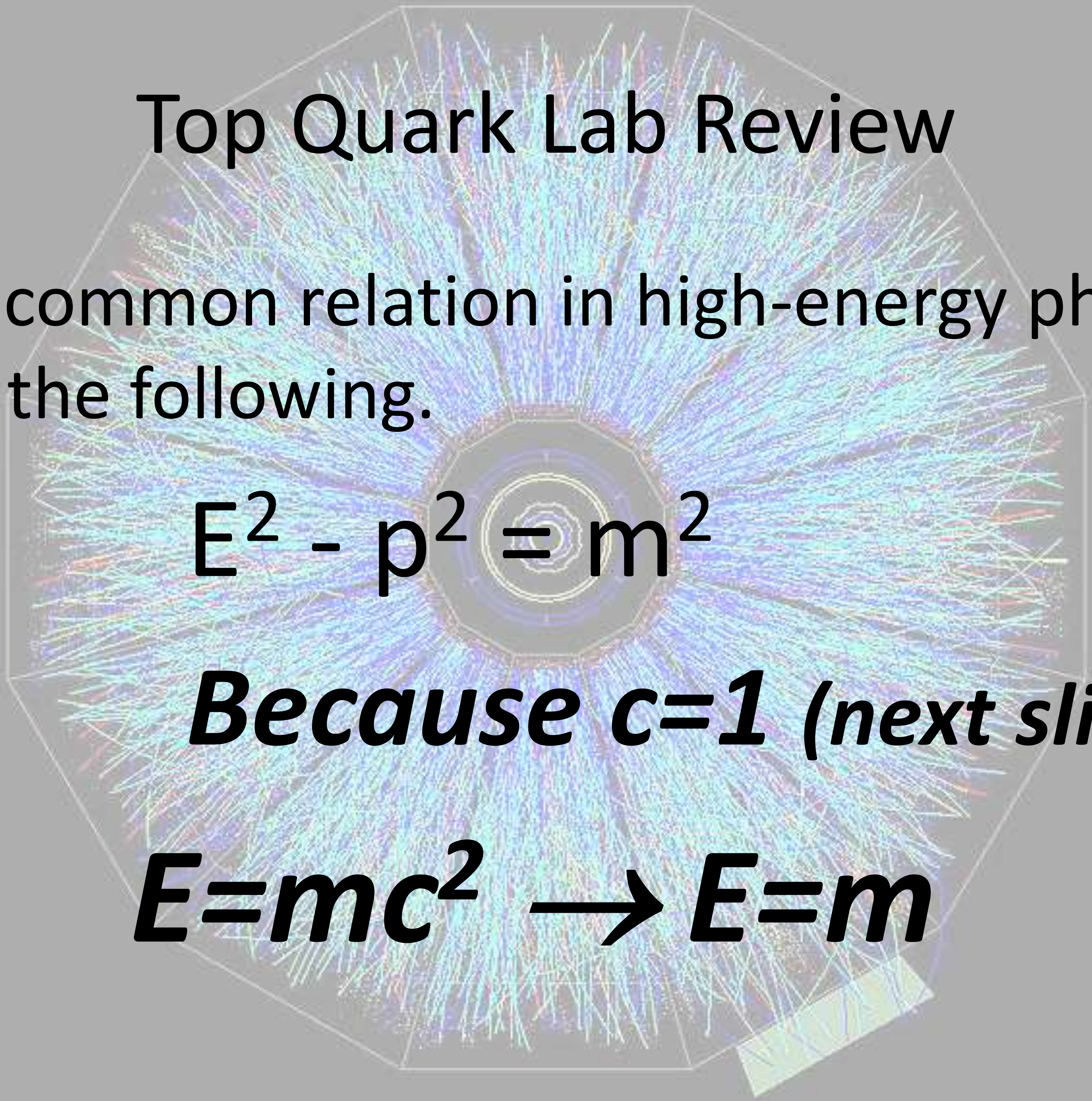
Top Quark Lab Review



- NOTE: Units used on diagram:

$$\frac{GeV}{c} \Rightarrow mc \Rightarrow mv$$

Top Quark Lab Review



- A common relation in high-energy physics is the following.

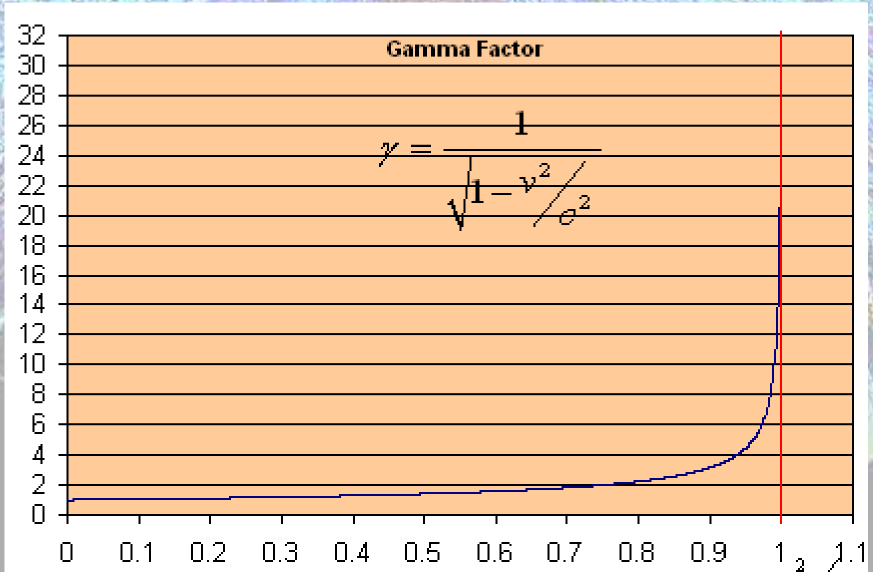
$$E^2 - p^2 = m^2$$

***Because c=1** (next slide)*

$$\boldsymbol{E=mc^2 \rightarrow E=m}$$

Top Quark Lab Review

- Why can c=1? Simple *relativity*, my friends.
  - As an object approaches the speed of light, its mass increases exponentially.



Top Quark Lab Review

- So, at relativistic speeds, ***m>>*** it makes ***c<<***.

$$M_{c^2} = M_c = M$$

Top Quark Lab Review

- A common relation in high-energy physics is the following.

$$E^2 - p^2 = m^2$$

Because c=1

$$\boldsymbol{P = mv \rightarrow p = mc \rightarrow p = m}$$

Top Quark Lab Review

- *In our particular case, it follows that one should write energy and momentum in terms of the mass of the top quark.*

$$E^2 - p^2 = (2m_t)^2$$

But *p=0* along collision axis…

Top Quark Lab Review

$$E^2 - p^2 = (2m_t)^2$$

Becomes

$$E^2 = (2m_t)^2$$

Which becomes

$$E = 2m_t$$

Top Quark Lab Review

- *Because almost all of the energy of the collision is the result of* ***top*** *and* ***antitop*** *decay, we simply add the energies of the* ***four jets****, the* ***soft muon,*** *the* ***muon*** *and the* ***neutrino*** *before dividing by the two tops (actually a top and an antitop quark) to obtain the mass of the most recently discovered quark.*

Top Quark Lab Review

- *So use the values you calculated for momentum (****now as energy values****) and incorporate your new value for the missing neutrino (42 GeV) before adding all the energies as* ***scalars*** *to find* $2m_t$.
- *If we use the 42 GeV we got with our vectors produced with protractor and straight edge, we get the equation:*

Top Quark Lab Review

61.2 + 7.3 + 95.5 + 58.6 + 54.8 + 17.0 + **42**

= **336.3 GeV**

348.2 GeV/2 = **168 GeV**

Top Quark Lab Review

*If we use the value of **53.0** GeV calculated by the computers used by the D0 collaboration, we would have the equation*:

61.2 GeV + 7.3 GeV + 95.5 GeV + 58.6 GeV +

54.8 GeV + 17.0 GeV + **53.9 GeV** = 348.2 GeV

- 348.2 GeV/2 = **174.2 GeV**

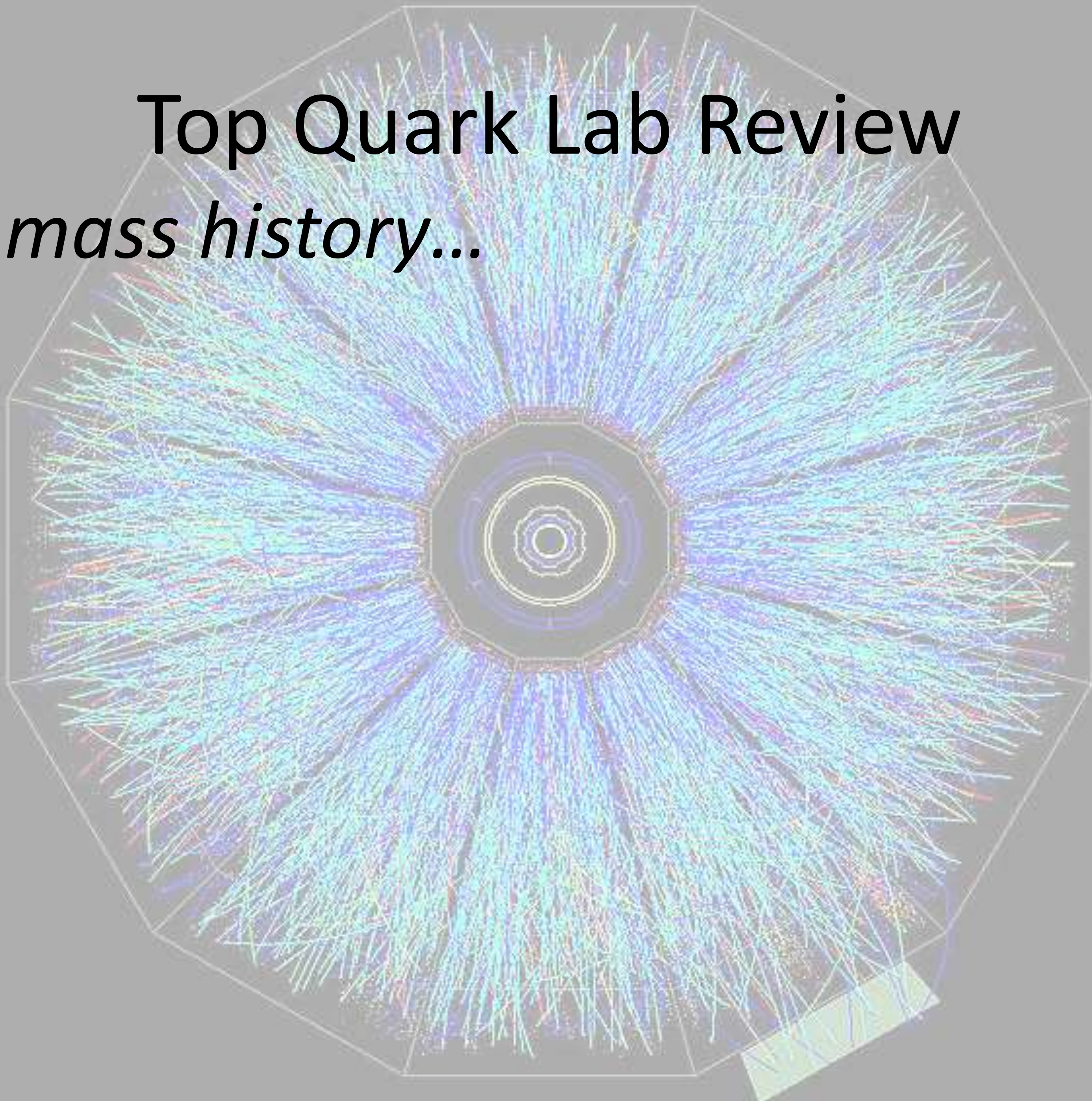
which is even closer to the currently accepted value of **172 $\pm$ 2.2 GeV**.

Top Quark Lab Review

- *Note:*
  - *a mass of 174 Gev/c is heavier than a Tungsten ATOM (Z=74, M=184)*
  - *$T_{1/2}$ = 5 x 10^{-25} sec*
    - *Not enough time to form hadrons like the other quarks*
    - Decays into
      - bottom quark (99.8%)
        strange quark (0.17%)
        down quark (0.007%)

Top Quark Lab Review

- *Top mass history…*



Top Quark Lab Review