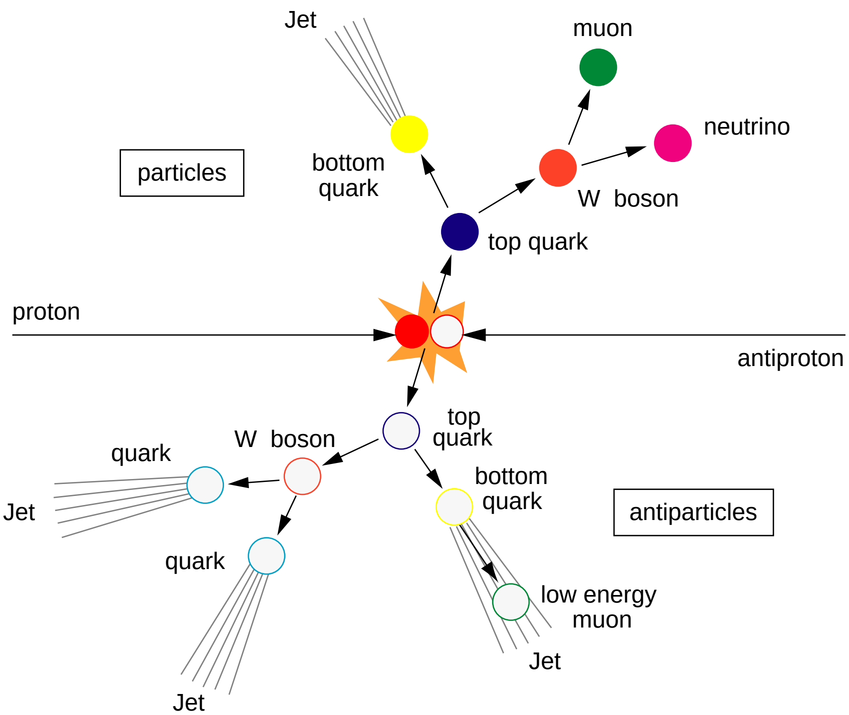
MASS OF THE TOP QUARK

☞ The purpose of this activity is to determine the mass of the top quark from proton–antiproton collision data gathered at Fermi National Accelerator Laboratory in 1995.

☞ When a proton meets an antiproton with just the right energy in a head on collision, a top–antitop quark pair may form. These decay after 10^{-24} s into particles that themselves decay finally into a muon, an antimuon, a neutrino, and four jets of mixed particles called hadrons. (See the diagram to the right.) The top quark is so exotic that in the billions of collisions performed at Fermilab only about a dozen events fit this profile. Four of the best candidate events were selected for this activity. You have been assigned one of them at random. Find three other students so that you form a group with all four events. You will work together on this project, but each of you will be responsible for processing the data from one event.

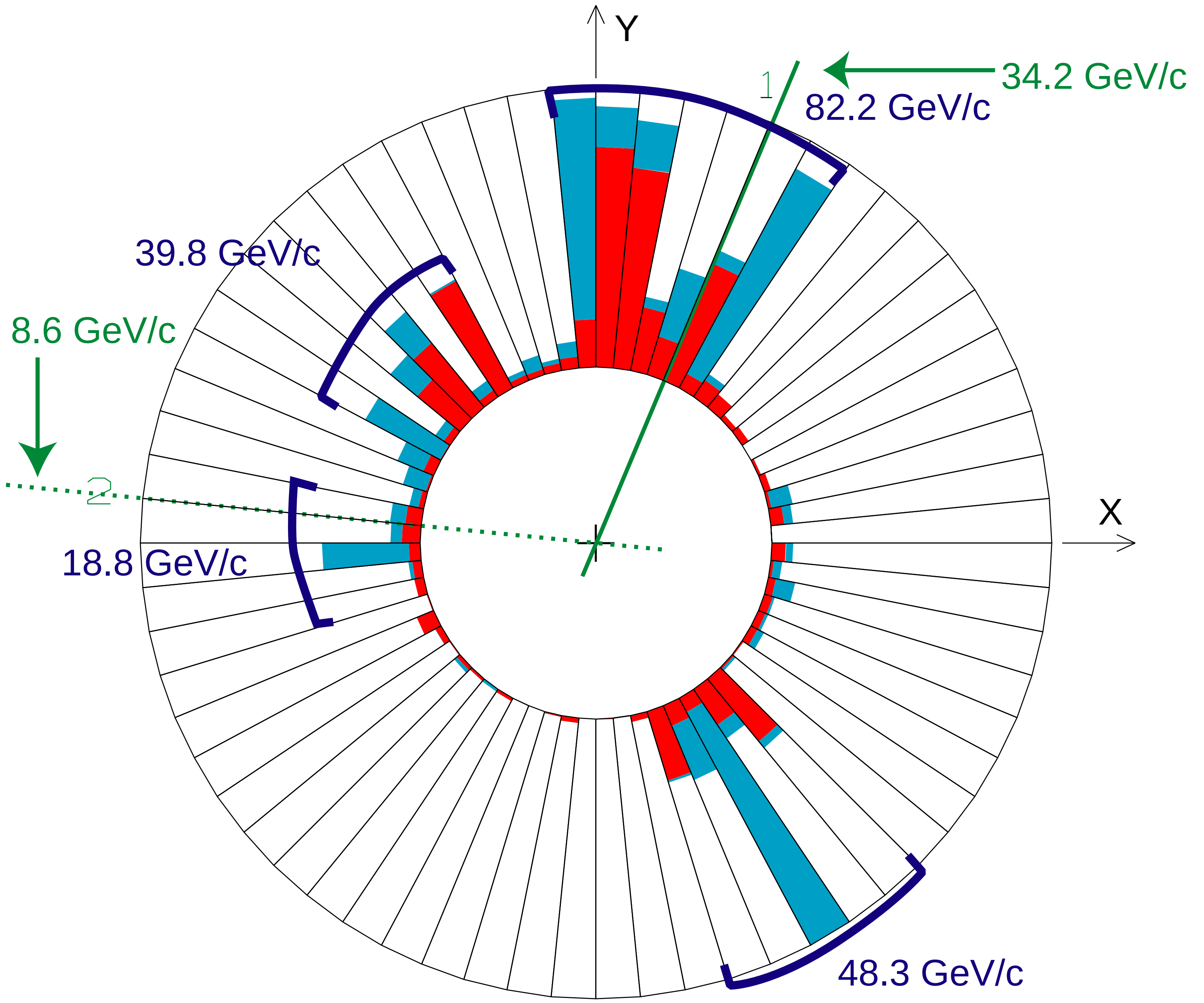


1. Since protons have the same mass as antiprotons and since they enter the target chamber from opposite sides with the same speed, their total momentum before annihilation is zero. By conservation of momentum, then, the total momentum of all the decay products must also be zero You will use this fact to begin your analysis. Each data set shows the momentum of the annihilation products in GeV/c (a convenient unit for high energy physics). The momentum of the muon and antimuon are represented with solid green and dashed green lines, respectively. The total momentum of the hadron jets are represented with solid blue brackets. The momentum of the neutrino is not shown. (Neutrinos are extremely difficult to detect.)

   Since the total momentum must equal zero, the momentum of the neutrino will be equal and opposite the sum of the momenta of the other decay products. Determine the x and y components of these momenta using a protractor and calculator. (The direction of the muon and antimuon are quite definite, but the direction of the momentum of the jets is subjective. Choose a mean direction for these clusters of particles.) Find the vector sum of the components along each axis; that is, the total momentum in the x direction and the total momentum in the y direction. Combine these two numbers using Pythagorean Theorem to find the resultant momentum of the decay products. The momentum of the neutrino will be equal and opposite this vector sum. State it.

2. The units in this experiment were chosen to eliminate the need for conversions. In high energy collisions, the magnitude of the momentum of a particle in GeV/c is the same as its energy in GeV and the energy of the decay products in GeV is also equal to the mass of the pair produced in GeV/c^2. Energy is a scalar quantity. Add the energies of the decay products: muon, antimuon, the four jets, and the elusive neutrino (which you determined in step one). Take this number and divide by two (since this reaction produced a top–antitop pair). This is the mass of the top quark in GeV/c^2. State it.

3. Your group should now have four pages of data and analysis, one for each of the four data sets. Be sure that the name of the student responsible appears at the top of the page and that the results from steps one and two are circled. Now prepare a cover sheet. Write the title of this activity, the names of the group members, a purpose statement, and a conclusion (that is, the average of the four calculations). Staple all five pages together and submit them before the end of the second period.



Run 00001 Event 00026

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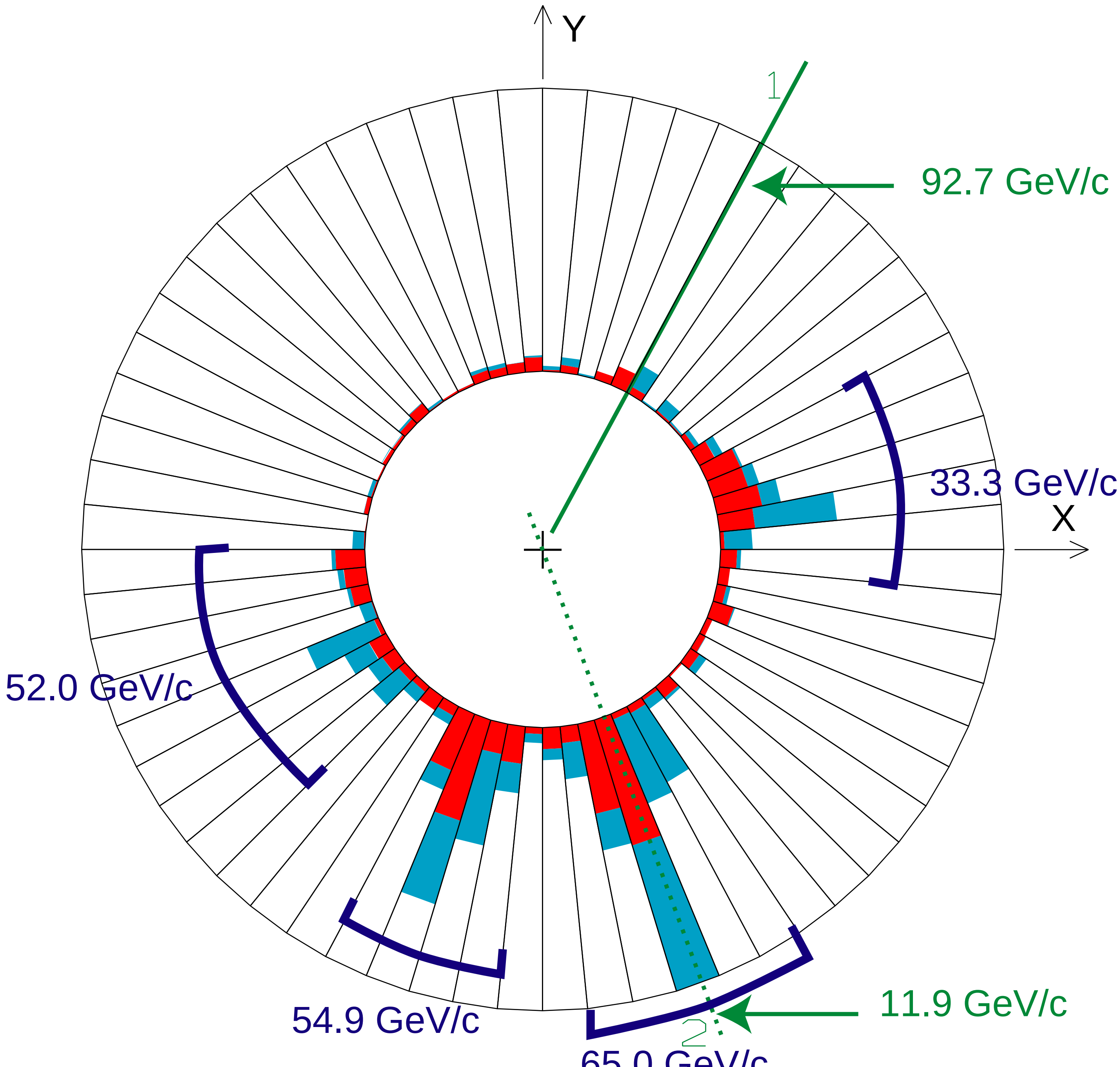

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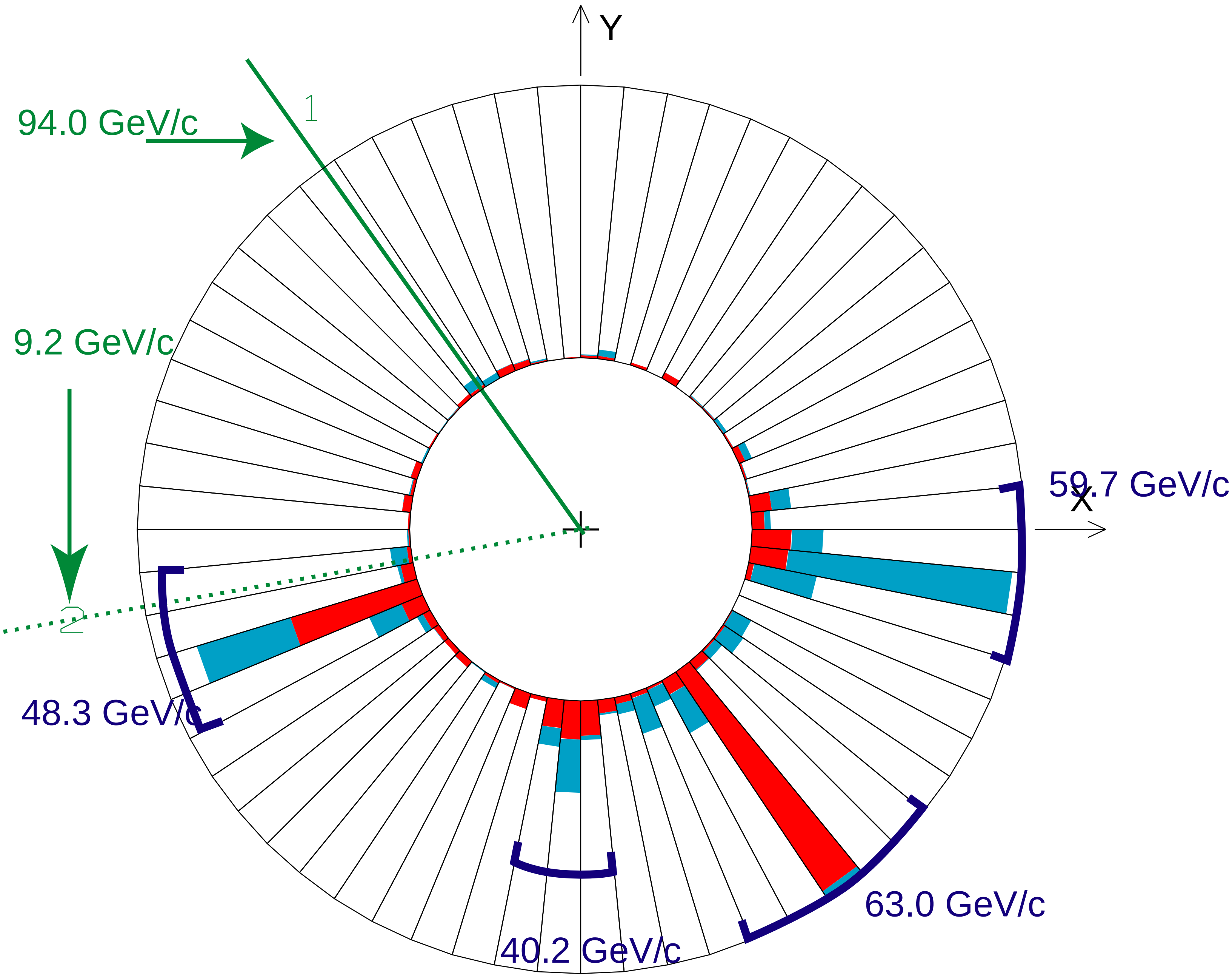

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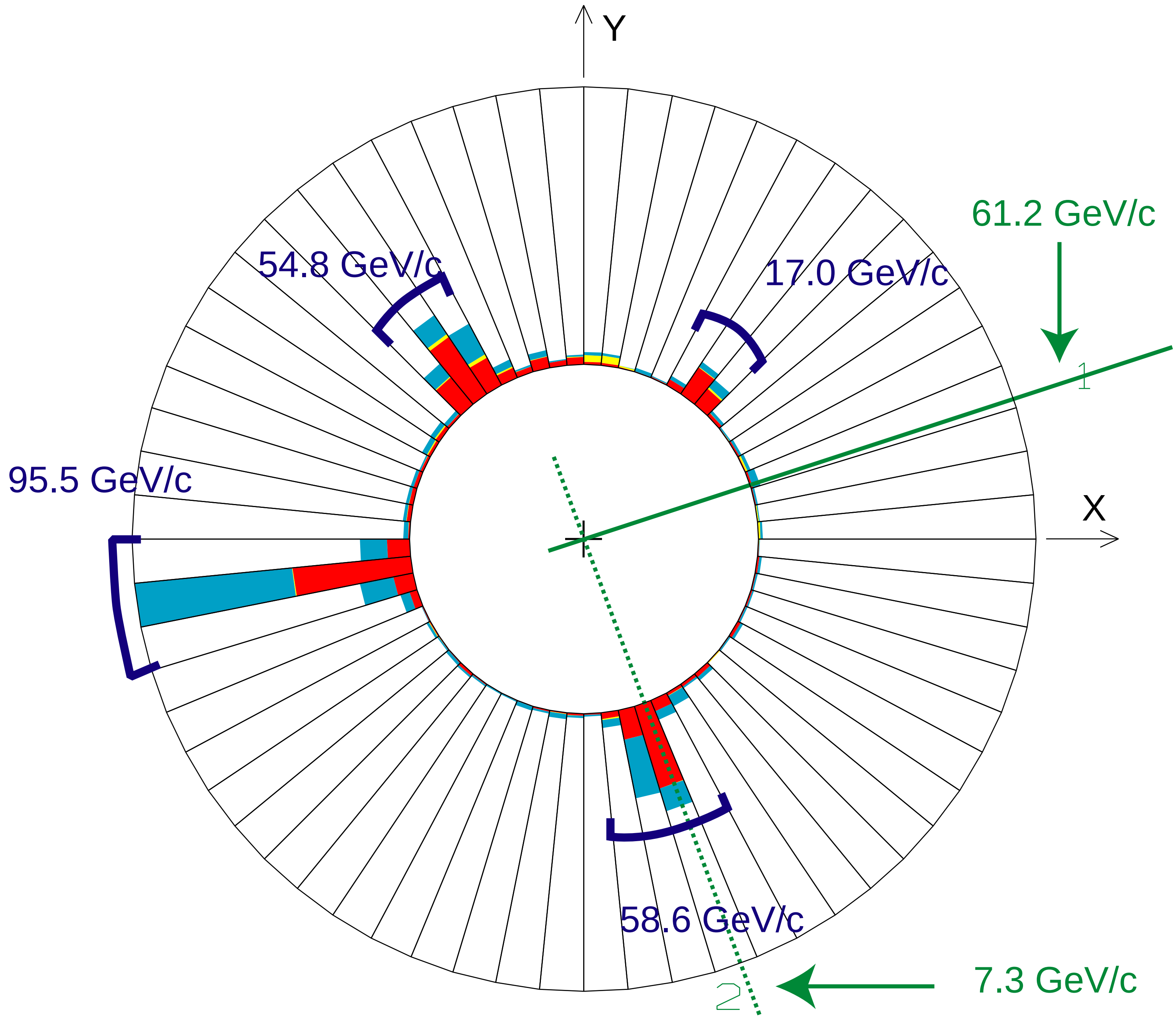

Run 92704 Event 14022

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