Momentum Conservation in the D0 experiment Instructions:

Use the events from the D0 experiment, found here:
https://quarknet.org/sites/default/files/content/portfolio/file/2024-01/DZero_events_0.pdf

Note that these events were chosen carefully: all of the decay products moved in the transverse plane, the plane perpendicular to the beam. This means you can analyze the events in two dimensions instead of three.

Let's define $\boldsymbol{p}_0$ to be the **initial total** momentum of the system and $\boldsymbol{p}_{obs}$ to be the **total observed** momentum after the collision.

Repeat the process below for at least 2 of the 4 events.

1. Draw lines through the centers of all jets (blobs of red and blue bars) to the origin of the coordinate system.
2. For each jet and muon track (solid green line), use a protractor to find the angle θ between the line you drew and the positive x-axis.
3. The magnitude of the momentum $\boldsymbol{p}$ for all of the jets and muons is given on the plot. Find $p_x = p\cos(\theta)$ and $p_y = p\sin(\theta)$ for all jets and muons.
4. Add up the individual components to find the components of the total observed momentum, $p_{x,obs}$ and $p_{y,obs}$. Then find the magnitude and direction of $\boldsymbol{p}_{obs}$.

Reflection questions:

- In particle collisions inside the D0 detector, what is the initial momentum $\boldsymbol{p}_0$ in the transverse plane?

- What did you calculate for the total visible momentum in the event, $\boldsymbol{p}_{obs}$? Is $\boldsymbol{p}_0$ equal to $\boldsymbol{p}_{obs}$? If not, then this could be evidence of neutrino production!

- Follow up question: Why would neutrinos lead to a momentum imbalance? What is the neutrino's energy? What is the neutrino's momentum?

Bonus: these events are all examples of top-antitop production (known as ttbar events). Look up the Feynman diagram for this process and explain how the diagram matches the observed events. Why is the previous question misleading?