

ISP220 2017 Homework #14, paper portion
20 points

Due at or before the final exam day.

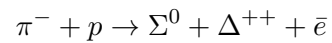
Notice that the MasteringPhysics portion is still due on Saturday, April 29

April 22, 2017

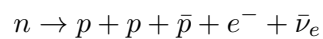
Your Name: _____

- un...**STAPLE** these pages!!
- This homework set is due on Thursday, April 29, which is Final Exam day.
- I need you to show all of your work—if you have comments about your reasoning, say them.

1. (2 points) **There are reasons why the following reaction cannot occur. Tell me three.** You might need to watch the Quantum Numbers video, if you haven't already.



2. (2 points) **This is almost a trick question: Why is it impossible for the following decay to occur? The neutron is at rest. (Remember relativity.)**



Let's warm up for the final exam by doing one of the calculations like I did on the video at <https://vimeo.com/64457879> . What collides at Fermilab and the LHC are pairs of quarks within protons (or antiprotons). In particular to produce the following reaction at Fermilab:

$$p\bar{p} \rightarrow Wg,$$

If this were the Final, the things that I would provide to you are the following:

- i) **Luminosity.** The Accelerator is the proton-antiproton collider at Fermilab with a luminosity of $L = 10^{32} \text{cm}^{-2}\text{s}^{-1}$.
- ii) **The production Feynman Diagram** is shown in Fig. 1.

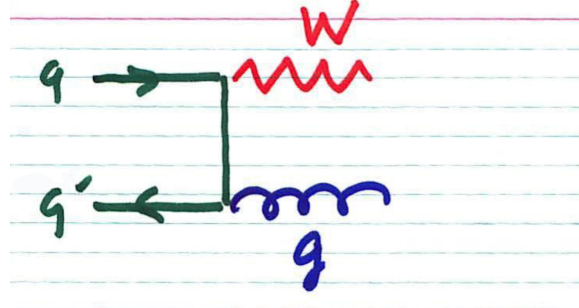


Figure 1: The production Feynman Diagram for the process.

- iii) **The cross section** for the process is $\sigma = 4 \times 10^2$ pb. (picobarn)
- iv) **The final state** for this problem is demands that the W boson decay into a muon and a muon neutrino, so the whole reaction is:

$$q\bar{q} \rightarrow W + g$$

$$\quad \quad \quad \downarrow$$

$$\quad \quad \quad \mu + \nu_\mu$$

- v) **The Branching Ratios** are: $BR(W \rightarrow qq') = 0.7$, $BR(W \rightarrow e\nu_e) = 0.1$, $BR(W \rightarrow \mu\nu_\mu) = 0.1$, and $BR(W \rightarrow \tau\nu_\tau) = 0.1$.

From the old lecture, you know two things that you need for the conversion of picobarns to cm^2 :

- a “barn” is a unit of area in which $1 \text{ barn} = 10^{-24} \text{ cm}^2$ and
- $1 \text{ pb} = 10^{-12} \text{ b}$.

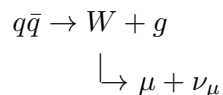
I also will remind you that a year has 3.15×10^7 seconds, which we playfully call “ $\pi \times 10^7$ seconds” in order to remember it.

So now the questions:

6. (2 points) Show that the number of square centimeters that corresponds to 1 pb is 10^{-36} by filling in the formula, canceling the dimensions, and getting the answer (see the example on the last page to see what I mean for you to do here):

$$1 \text{ pb, in } \text{cm}^2 = 1 \text{ pb} \left(\frac{\text{b}}{1 \text{ pb}} \right) \times \left(\frac{\text{cm}^2}{1 \text{ b}} \right) = 10^{(\quad)} \text{cm}^2$$

7. (3 points) From the familiar formula of $N = L\sigma\Delta t \cdot BR$ number of events in a year for



at this accelerator with the stated luminosity for this final state is about (circle your choice):

- (a) 12×10^5 events
- (b) 12×10^4 events
- (c) 12×10^3 events
- (d) 12×10^2 events

8. (4 points) Draw the Feynman Diagram for the whole process of

$$q\bar{q} \rightarrow W + g$$
$$\quad \quad \quad \downarrow$$
$$\quad \quad \quad \mu + \nu_\mu$$

Bubble Chamber Reactions

What follows refers to photographs at the end of the set. You don't have to print them out and turn them in if you don't want to.

I have three bubble chamber photographs of events which were exposed to a K^- beam in a liquid hydrogen bubble chamber. So, the target consists of protons. I'll work one as an example, and you work the other two. The Example refers to Figure 2 on page 10. See the letters imbedded in the photograph? That's what the questions will refer to in what follows and you need to circle the letter you think corresponds.

1. Which track shows a collision of beam particle with a proton:

a b c d e f g

2. Which track shows the decay of a neutral particle.

a b c d e f g

3. Which track shows a collision of a beam particle with an electron.

a b c d e f g

4. Which track shows a collision of a neutron with a proton.

a b c d e f g

5. Collision of a photon with an electron.

a b c d e f g

Here is my analysis:

1. A kaon hitting a proton will result in some strong interaction, so you're looking for a charged kaon coming in from the bottom and at some point multiple charged tracks

emerging from a point on a kaon track. That would be the production of pions and protons and at least some strange particle. It could also include production of neutral pions, which you'll remember decay into two photons, which you'd see convert into e^+e^- pairs. There's nothing like that. But, c does appear to be a beam-proton collision.

2. This will be one of the V's found in cosmic rays. That's apparent at point d.
3. This will be the collision of a kaon and an atomic electron, which will probably be a "glancing" blow and the electron will spiral quickly and the kaon will continue on its way since it's so much more massive than a stationary electron, it's momentum will be hardly affected. Look at a. Here is exactly this circumstance. Notice that this also shows you the direction of the magnetic field: negative particles will bend to the right. The kaon beam is moving pretty fast and it's hard to tell that they are negative.
4. A neutron hitting a proton is obviously not the consequence directly of the incoming kaon beam. But, neutrons are always a background in beams since they can be produced way up stream and then they're really hard to stop.¹ So, the occasional neutron will happen and it does here. The initial state would have a net positive charge of +1 since it's due to the target proton alone—the neutron hasn't any charge. So, that's why the V in the previous question doesn't qualify. That was a net zero charge in those two decaying particles. Point e has three tracks emerging, one negative (bends right) and two positive, as expected.
5. Photons could also come with a charged beam since they might be radiated from a beam particle. So, we expect to see nothing and then an electron suddenly spiraling to the right. Point b is exactly that.

Now it's your turn.

¹That's why the so-called "neutron bomb" is such a deadly battlefield weapon. There is no protection for people, even inside of tanks. The water in the body is a large amount of nearly free protons, so the neutrons elastically scatter from them and do terrible damage. Of course, it's indiscriminate and civilians and not just soldiers would be killed. I don't like the neutron bomb.

(Using Figure 3 on page 11), answer the following:

10. (2 points) Which track shows the decay of a neutral particle.

v w x

11. (1 point) Which track shows a collision of a beam particle with an electron.

v w x

12. (1 point) Which track shows a collision of a beam particle with a proton.

v w x

(Using Figure 4 on page 12), answer the following:

13. (1 point) Which track shows the decay of a neutral particle.

v w x y

14. (1 point) Which track shows a collision of a beam particle with an electron.

v w x y

15. (1 point) Which track shows a collision of beam particle with a proton:

v w x y

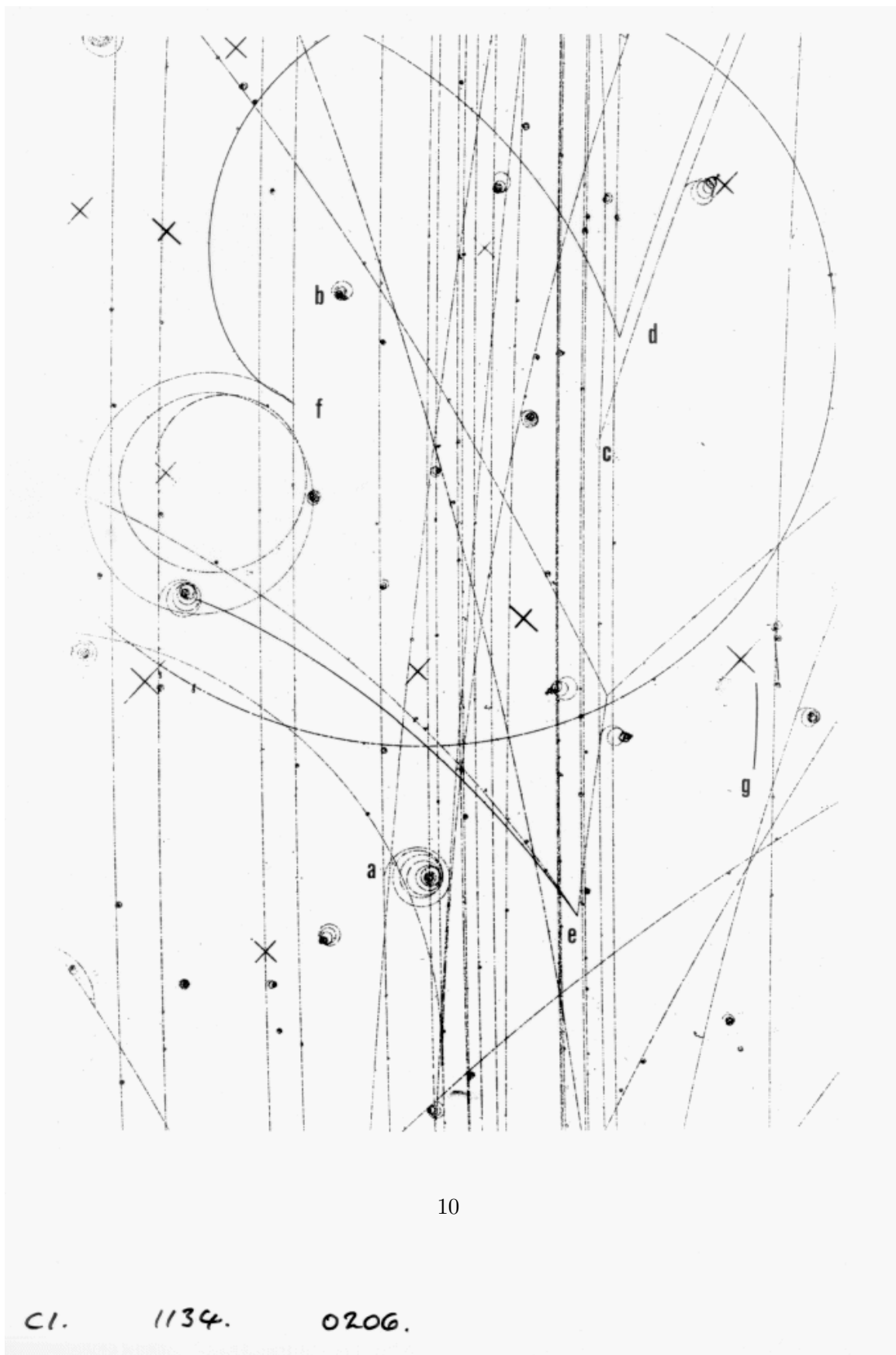


Figure 2: Example events in a negative Kaon beam.

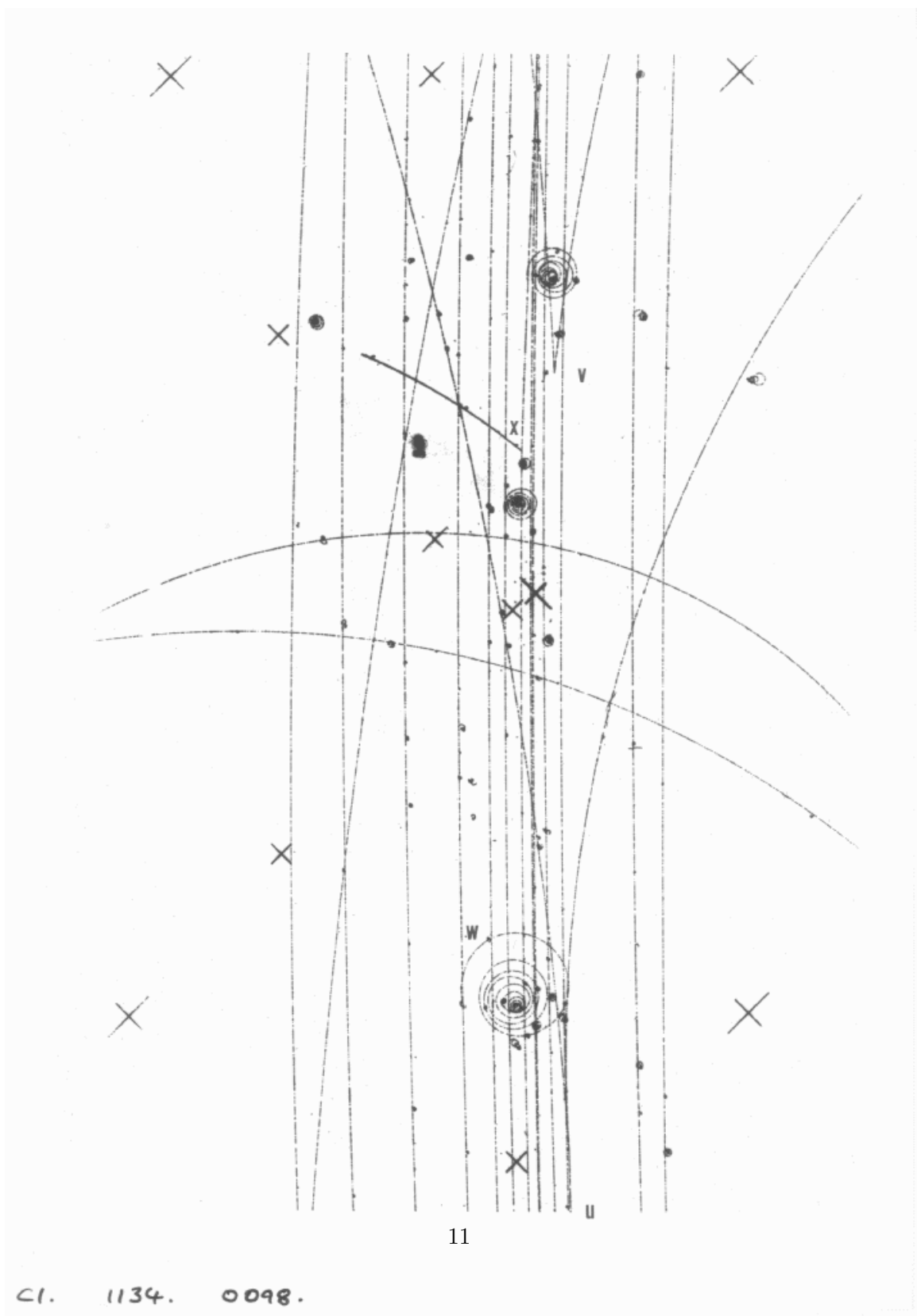


Figure 3: Problem 1 bubble chamber picture.

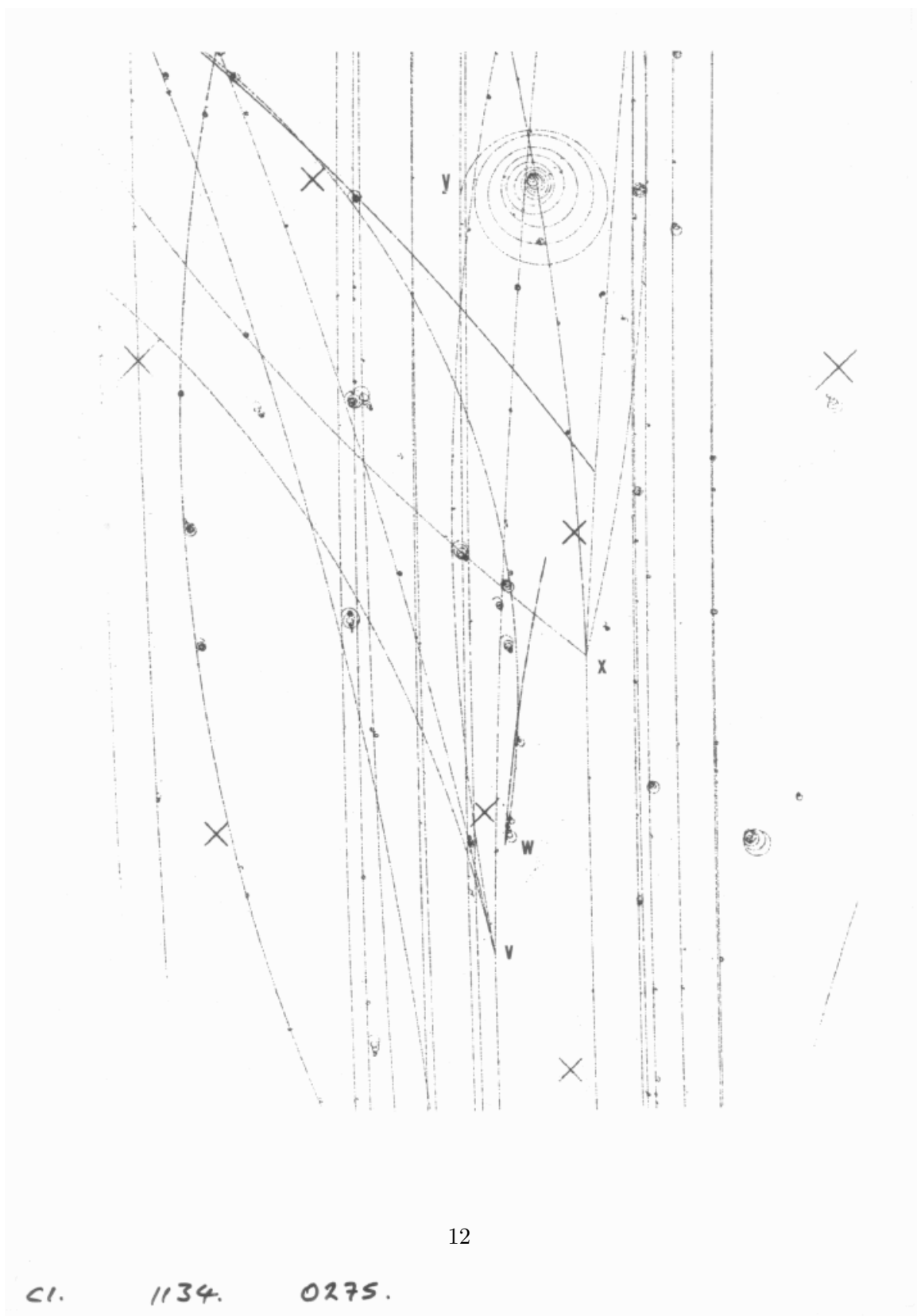


Figure 4: Problem 2 bubble chamber picture

I promised an example to go along with the formula in question 5. Suppose we want to calculate 1 millennium in years. You know:

- 100 years in a century (“cen”) and
- 10 centuries in a millennium (“mill”).

Then in the same spirit, I would fill in:

$$1 \text{ mill (in years)} = 1 \cancel{\text{mill}} \left(\frac{100 \text{ y}}{1 \cancel{\text{cen}}} \right) \times \left(\frac{10 \cancel{\text{cen}}}{1 \cancel{\text{mill}}} \right) = 10^3 \text{ y}$$