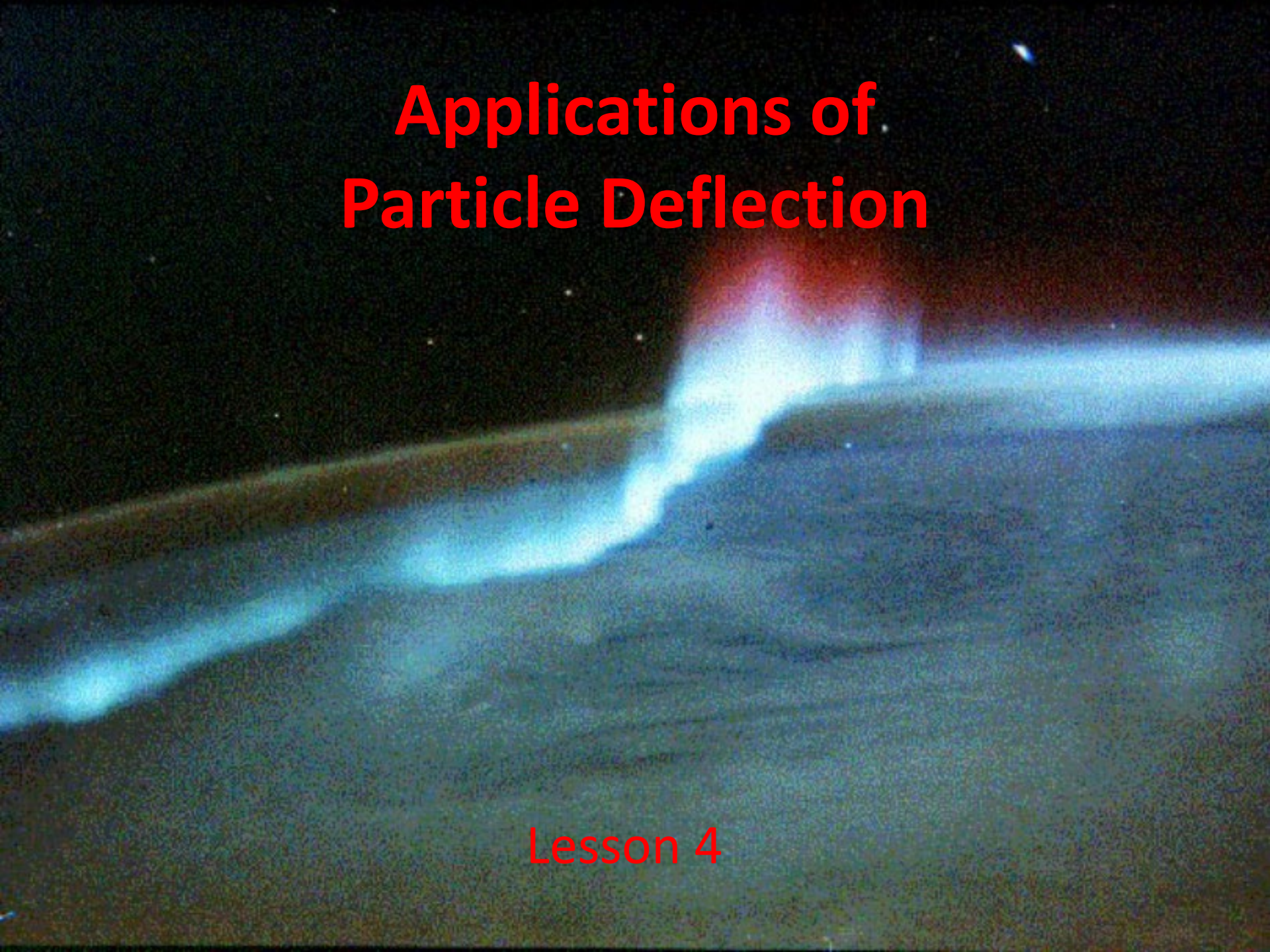


Applications of Particle Deflection

Lesson 4

Objectives

- explain, quantitatively, how uniform magnetic and electric fields affect a moving electric charge, using the relationships among charge, motion, field direction and strength, when motion and field directions are mutually perpendicular.

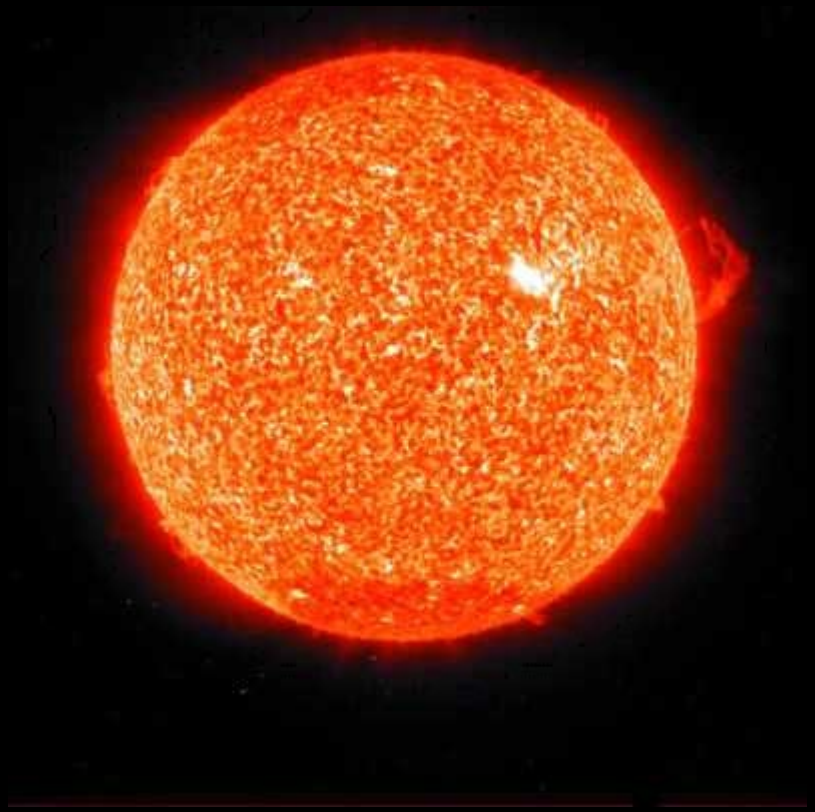
Today, we look at some important applications of particle deflection:

1. The Aurora Borealis (Northern Lights)

2. Mass Spectrometers

1. The Aurora

- Occurs at both poles: called "borealis" in the north and "australus" in the south.
- This natural phenomenon all starts (like most things) at the sun...



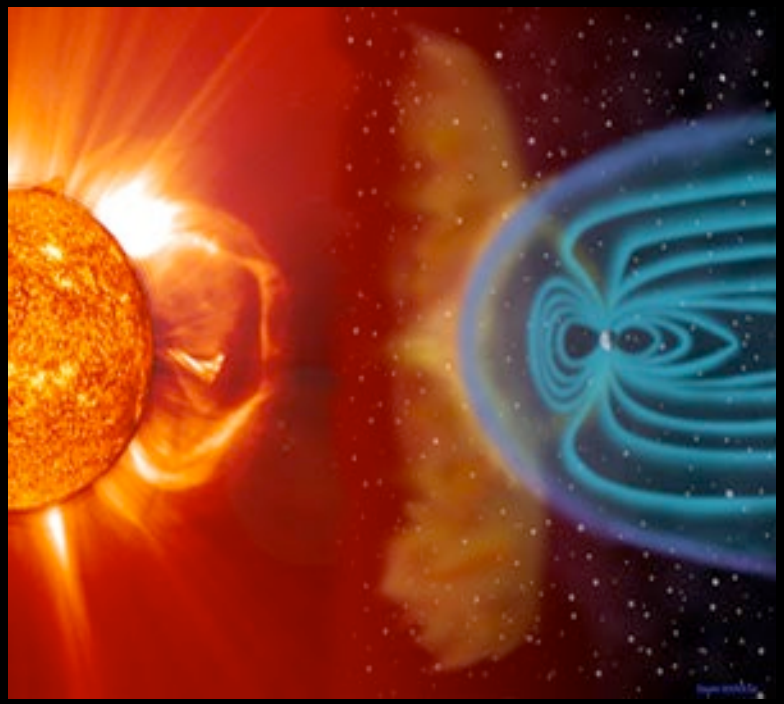
- The sun's surface (millions of degrees hot) produces large amounts of plasma: hot, charged particles (mostly electrons and small ions)
- This plasma is thrown off the sun via huge magnetic solar flares, scattering particles throughout the solar system

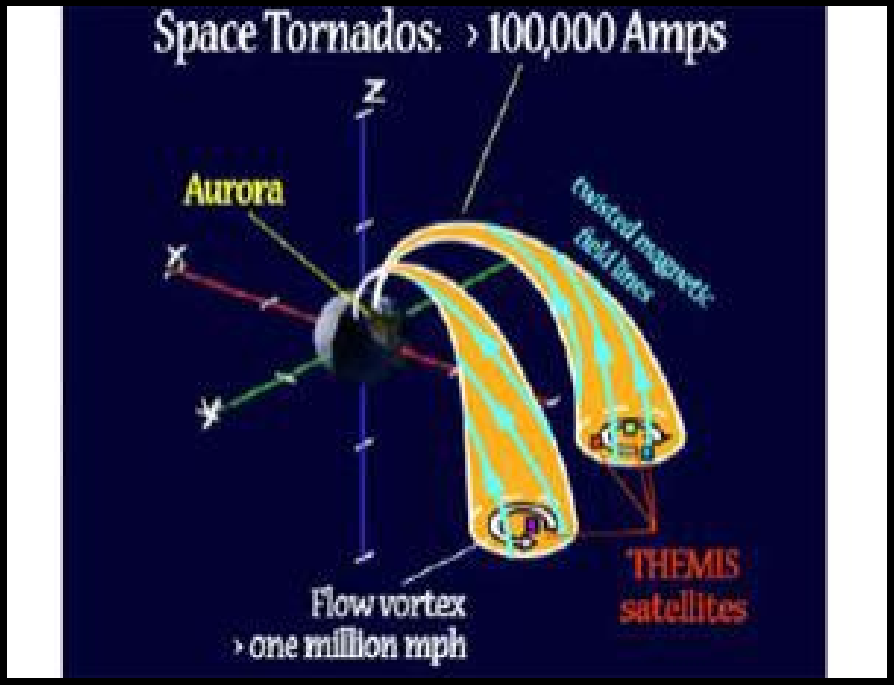
- These particles form solar winds, eventually transporting some of the charged particles to the Earth
- The charged particles are deflected into our atmosphere by the Earth's B-field

As the fields are strongest at the poles, most of the particles are drawn in here

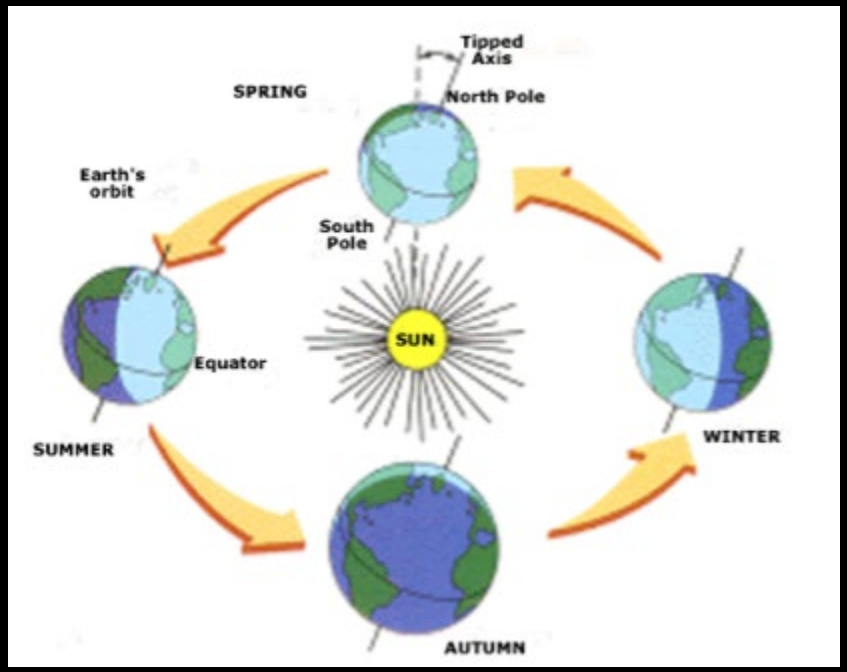
Space Tornadoes!

- **When the particle's velocity is at an angle to the field, the particles spiral down in a helical pattern.**





- The direction the particles make with the Earth's B-field is quite important:
- The B-field is perpendicular in April and October, making the effect most noticeable at these times
- The effect is less noticeable when the field and solar wind are not aligned, in winter and summer



- **When these high energy molecules hit air molecules in the atmosphere, they cause the molecules to excite and emit light.**
- **Nitrogen = blue and violet**
- **Oxygen = green and red**

- The non-uniform field at the poles causes some particles to be deflected to the other pole. This causes a cycle of particles called **The Van Allen Belt**

Diploma Question Alert!

20. Charged particles moving toward Earth are trapped within a field near Earth, where they cause the aurora borealis (northern lights) and aurora australis (southern lights). The field in which the particles are trapped is

A. a gravitational field

B. an induction field

C. a magnetic field

D. an electric field

Diploma Question Alert!

- **The Earth is under continual bombardment from energetic, charged particles. The magnetic field of the Earth influences the path of these particles. Make a statement about whether these particles are more strongly deflected by the Earth's magnetic field as they approach along the poles or along the equator. In a few sentences, explain the reason for your statement. Use this to explain why Northern lights occur and why they usually only occur in the far southern or northern regions during certain times of the year.**

2. Mass Spectrometers

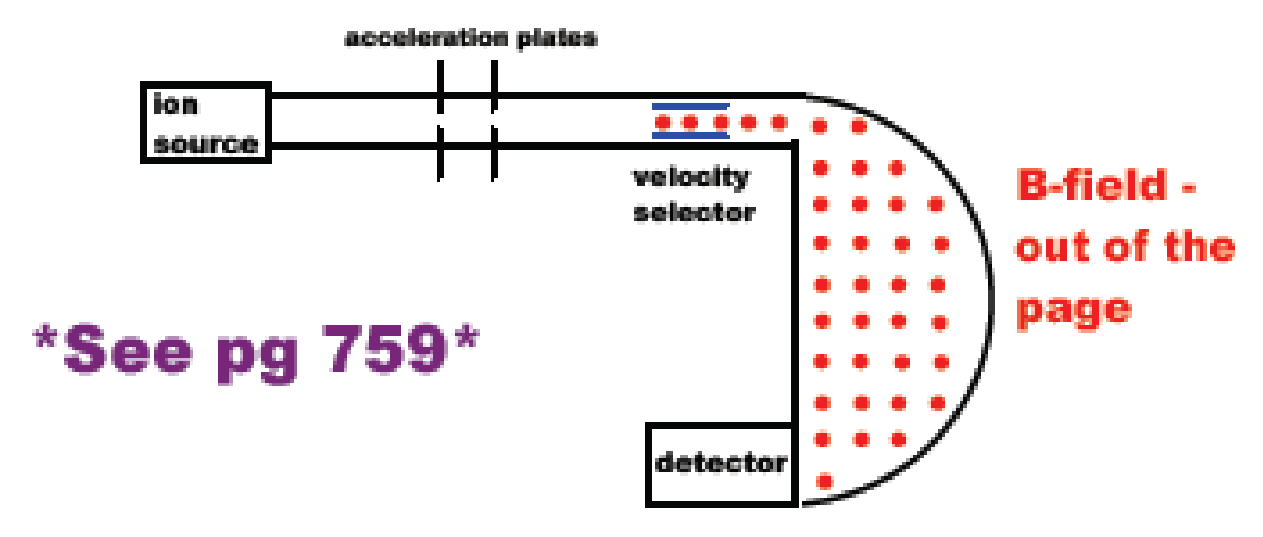
- On CSI, Grissom sometimes puts a material into a computer and BOOM!!! He instantly knows what elements it is made up of!
- THAT'S a Mass Spec.

Purpose of a Mass Spec.

- To determine the identity of an unknown matter sample, the machine determines the mass using concepts of electromagnetism, especially particle deflection

Inner Workings of a Mass Spec.

- Consists of five main parts:
- i) an ion source (the sample which has been ionized)
- ii) acceleration plates
- iii) a velocity selector
- iv) a deflector array
- v) an ion detector/counter



See pg 759

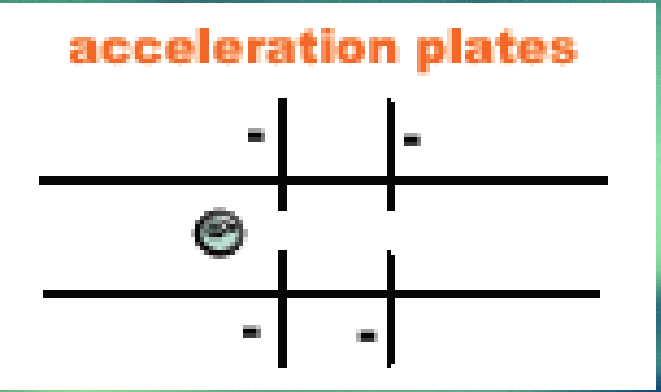
i) ion source

- The sample is heated and turned to a gas one or more electrons are removed to produce an ion

- Question: why is it necessary for an ion, not an atom, to be used?

ii) acceleration plates

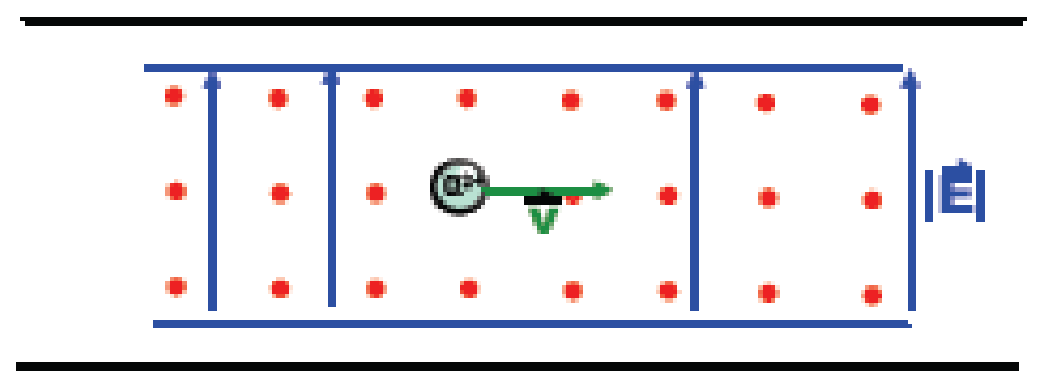
- The ions move through a set of parallel plates with a potential difference between them



- there is a hole in the plates for the ions to pass through
- the ions are sped up to move into the velocity selector

iii) velocity selector

- Particle enters into an area of perpendicular magnetic and electric fields



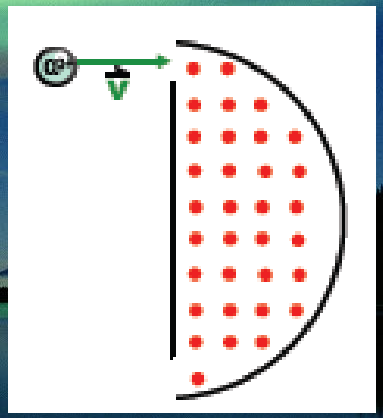
- These fields are set so that particles do not deflect: if this happens, we can calculate the particle's velocity

Example

- **What is the velocity of the particle if the E-field is 500 N/C and the B-field is 0.75 T?**

iv) deflector array

- When the particle enters the uniform B-field of the deflector, it travels in a circular pattern with a radius, r
- Given this radius, the velocity and the B-field, the charge to mass ratio of the particle can be determined



Example

- **Determine the charge-to-mass ratio of the particle using the data from previous examples and given the particle deflects with $r = 1.85 \times 10^{-5}$ m.**
- **Step 1: Set $F_M = F_c$**
- **Step 2: Solve for q/m.**

v) detector/collector

- Particles have distinct charge-to-mass ratios: like a fingerprint
- By determining the q/m ratio, the particle can be identified

- ex) What is the particle we ran through our mass spec?