ELECTRON TUBES

STUDENT WORKSHEETS

Version 3.1

en

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Warning

When working with electron tubes you have to follow important safety instructions:

Attention High Voltage!

- **Don’t switch on the power supply until your tutor has checked your setup.**
- Changes in the wiring must be performed only when switched off.
- Use touch-proof security cable only.
- **Before switching on, all controls and knobs have to be turned to zero.**

Attention evacuated glass tube – Implosion hazards!

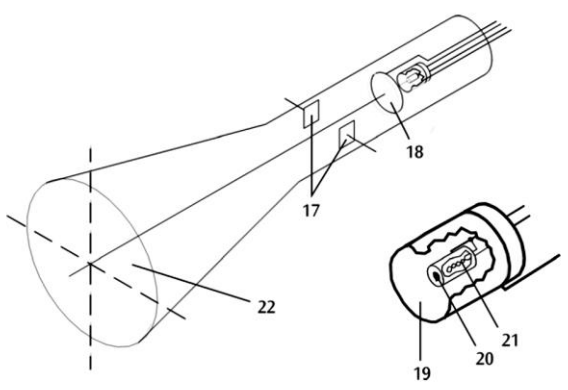
- Be very careful with the tube.
- Protect your eyes with safety goggles!

Introduction

Your tutor will introduce you to the operation of the electron tube.

Knowledge

a) Where are the electrons produced?
b) How are the electrons accelerated?
c) How are the electrons focused?
d) How can we make the electrons visible?



17	(Deflection plates)
18	Anode (-)
19	Focusing cylinder
20	Cathode (+)
21	Heater
22	Fluorescent screen

Figure 1 - Electron source and acceleration, source: 3Bscientific.de

Technology

a) How to switch on/off the device?
b) What is the meaning of the knobs at the power supply (figure 2)?
c) Where is the “ring magnet” and what is its function?
d) Where to find the additional equipment?

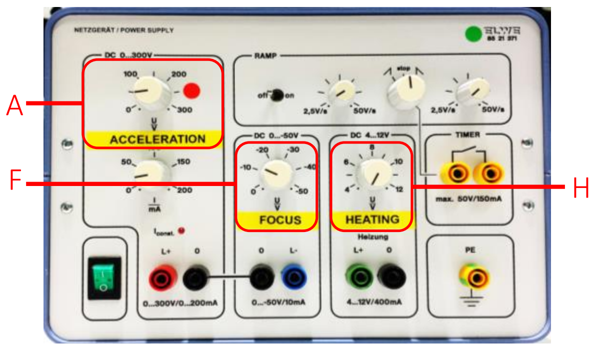


Figure 2 - power supply with different knobs

A Acceleration voltage
F Focusing voltage
H Heating voltage

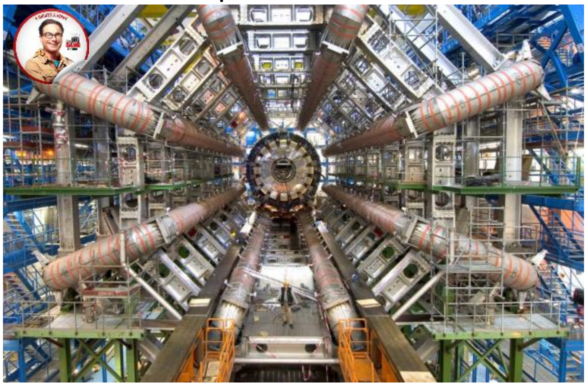
> **Limits:**
> **Attention: The following values shall not be exceeded during the measurements:**
> - Anode voltage = Acceleration voltage: **max. 250 V DC**
> - Heating voltage: 6...10 V DC depending on the device

Other
What is the difference between theorists and experimentalists and why is it so important, that they work together?

Theorists

☞ Remember what you already know and make predictions for the following measurements! Explain your predictions!

Experimentalists



☞ Perform precise measurements, note your observations and prove the theoretical predictions right or wrong!

☞ **Try to find explanations if the measurements differ from the predictions!**

Setup and cabling

Connect the electron tube with the power supply according to the following map. Ask your tutor to check the setup before switching on the device!

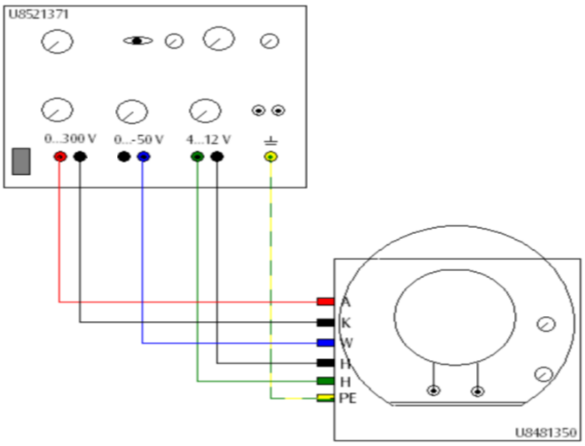


Figure 4 - cabling diagram

Part 1 – Control an electron beam

Become familiar with the equipment.

Make sure, that all knobs are at the zero position.

- Switch on the device (green main switch).
- Turn on the heating voltage: Start with 6 V. If you don't see a faint glow at the heating wire after 10 seconds, increase the voltage in 1V steps, always wait for 10 s between the steps.
- Switch on the acceleration voltage, raise the voltage slowly to 200 V.
- Ask your tutor to switch off the lights by your workplace.
- Watch the fluorescent screen. Are you able to find a bright green spot?
- Use the ring magnet to calibrate the electron beam so that it hits the centre of the fluorescent screen.

Experiment 1:
Increase the acceleration voltage slowly to 250 V and observe the electron beam. Which changes in brightness, size, colour and point of impact for the beam do you expect? What do you observe? Explain!

Time:

Prediction

Brightness of the beam spot	**Student 1**	**Student 2**	**Student 3**	**Student 4**
Namen:				
It becomes brighter.	☐	☐	☐	☐
It becomes darker.	☐	☐	☐	☐
It disappears completely.	☐	☐	☐	☐
There is no visible change.	☐	☐	☐	☐
Size of the beam spot				
It becomes bigger.	☐	☐	☐	☐
It becomes smaller.	☐	☐	☐	☐
There is no visible change.	☐	☐	☐	☐
Colour of the beam spot.				
The colour of the beam spot changes.	☐	☐	☐	☐
There is no visible change.	☐	☐	☐	☐
Impact point				
The position of the beam spot changes.	☐	☐	☐	☐
There is no visible change.	☐	☐	☐	☐

Explanation of your prediction:

Experiment 1:

Time:

Observation and comments

Brightness of the beam spot	Observation	comments
It becomes brighter.	☐	
It becomes darker.	☐	
It disappears completely.	☐	
There is no visible change.	☐	
Size of the beam spot		
It becomes bigger.	☐	
It becomes smaller.	☐	
There is no visible change.	☐	
Colour of the beam spot.		
The colour of the beam spot	☐	
There is no visible change.	☐	
Impact point		
The position of the beam spot	☐	
There is no visible change.	☐	


Ideas for the differences between prediction and observation:

Experiment 2:
Increase gradually the focusing voltage and observed the electron beam. What changes in the brightness, size, colour and point of impact for the beam do you expect? What do you observe it? Explain!

Time:

Prediction

Brightness of the beam spot	**Student 1**	**Student 2**	**Student 3**	**Student 4**
Namen:				
It becomes brighter.	☐	☐	☐	☐
It becomes darker.	☐	☐	☐	☐
It disappears completely.	☐	☐	☐	☐
There is no visible change.	☐	☐	☐	☐
Size of the beam spot				
It becomes bigger.	☐	☐	☐	☐
It becomes smaller.	☐	☐	☐	☐
There is no visible change.	☐	☐	☐	☐
Colour of the beam spot.				
The colour of the beam spot changes.	☐	☐	☐	☐
There is no visible change.	☐	☐	☐	☐
Impact point				
The position of the beam spot changes.	☐	☐	☐	☐
There is no visible change.	☐	☐	☐	☐

Explanation of your prediction:

Experiment 2:

Time:

Observation and comments

Brightness of the beam spot	Observation	comments
It becomes brighter.	☐	
It becomes darker.	☐	
It disappears completely.	☐	
There is no visible change.	☐	
Size of the beam spot		
It becomes bigger.	☐	
It becomes smaller.	☐	
There is no visible change.	☐	
Colour of the beam spot.		
The colour of the beam spot	☐	
There is no visible change.	☐	
Impact point		
The position of the beam spot	☐	
There is no visible change.	☐	

Ideas for the differences between prediction and observation:

☞ Now focuse the electron beam as much as possible!

Free experimenting

Examine the effect of a bar magnet on the electron beam.

Did you observe a change in the brightness of the beam and beam spot?

Systematic experimenting

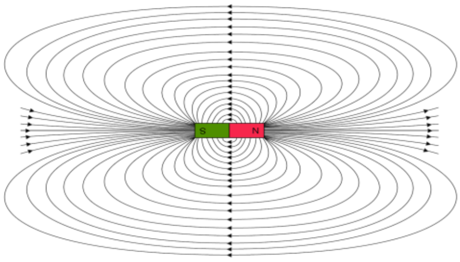
What effect have different magnet positions on the electron beam?

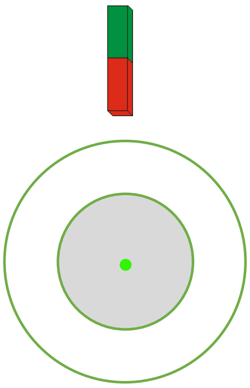
Prediction: Mark your prediction for the position of the beam spot with a **circle** O.

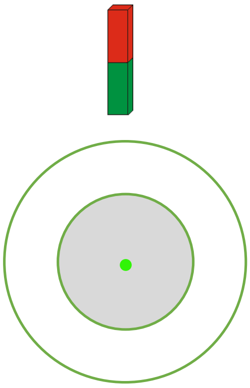
Observation: Mark the real position with a **cross** ×.

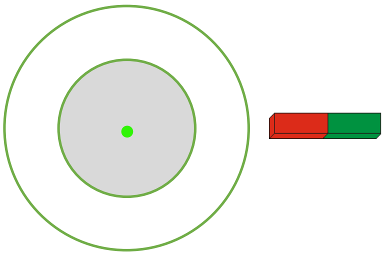
Repetition:

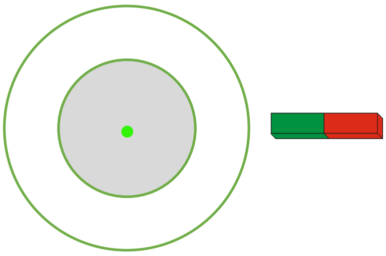
The poles of a bar magnet are defined as follows: RED = magnetic north pole, GREEN = south magnetic pole. The agreement on the direction of the magnetic field: NORTH → SOUTH







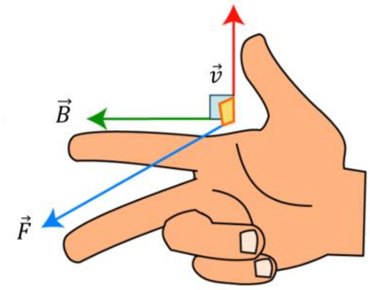




Describe the general relation for the angle between the **direction of the magnetic field** and the **force on the electrons**!

Describe the general relation for the angle between the **flight direction of the electrons** and the **force on the electrons**!

INFOBOX: The summary of these rules is described by the Lorentz force $\overrightarrow{F_L} = e \cdot (\vec{v} \times \vec{B})$ which is visualised in figure 5 and 6.



$\vec{v}$ … Velocity of the electrically (positively) charged particle

$\vec{B}$ … Magnetic field

$\overrightarrow{F_L}$ … Force on the electrically (positively) charged particle

Figure 5 – right hand rule of the Lorentz force for electrically positively charged particles

$\vec{v}$ … Velocity of the electrically (negatively) charged particle

$\vec{B}$ … Magnetic field

$\overrightarrow{F_L}$ … Force on the electrically (negatively) charged particle

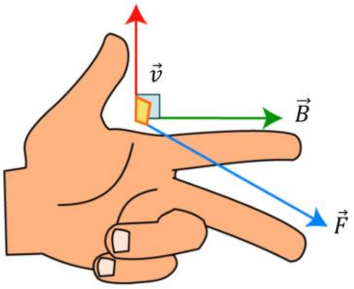


Figure 6 – “left hand rule” of the Lorentz force for electrically negatively charged particles

Why is this rule important for almost all physicists at CERN?

Insider knowledge: Since the Lorentz force is so important at CERN, there is a secret CERN greeting using three “perpendicular” fingers as symbol for this force. Try it out!

Accelerating particles

How do you have to hold the bar magnet to accelerate the electrons (increase their kinetic energy) without changing their direction?

Why do we need strong magnetic fields in the LHC?

Back to the acceleration voltage:

Hold the bar magnet as shown in the picture. Now change the accelerating voltage.

What do you observe?

How can you explain this behaviour?

Observation:

Explanation:

Can you imagine why scientists at CERN think about an even larger particle accelerator of 100 km in circumference at the moment?

Part 3 (optional) – Electromagnets

You have studied the influence of the magnetic field of a bar magnet on electrically charged particles such as electrons. Due to the Lorentz force, electrically charged particles are deflected in a magnetic field. This is exactly how we manage to keep particles on a circular path. In the LHC we installed 1232 electromagnets, which are responsible for the deflection of the particles on a circular path.

Now, you will use your own electromagnet and examine its effect on the electrons.

☞ Use one of the coils and connect it to the external power supply as shown in figure 5 & 6.

☞ Make sure you use an ampere meter to monitor the current through the coil.

The current shall not exceed 0.5 Ampere!

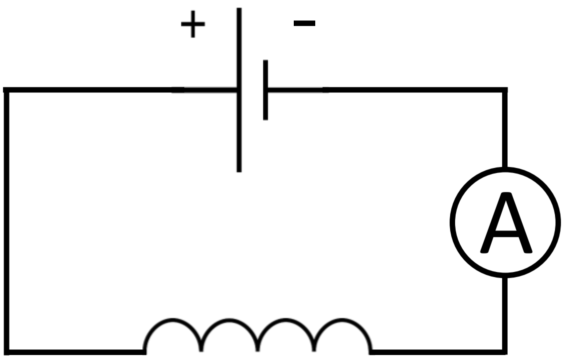


Figure 5 – circuit diagram with power supply, one coil and ampere meter

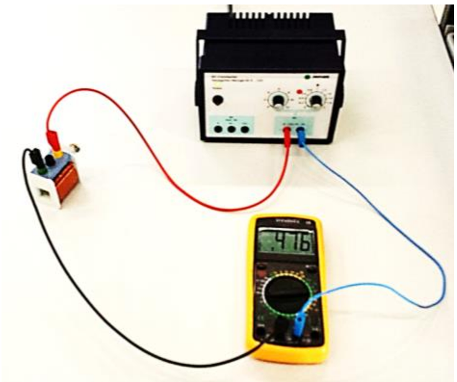
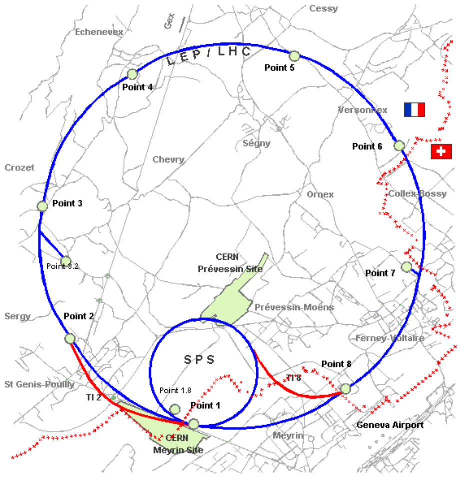


Figure 6 – picture of the circuit, one coil attached to power supply



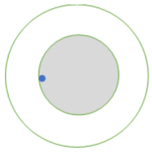
Map of CERN sites and LHC access points

Imagine you are now the operators of a professional electron accelerator. It is your task to make sure, that the electrons follow a circular path like the one you can see on the map of the LHC on the left.

☞ Discuss in the group, where to attach the electromagnet to the metal strip around the electron tube, so that the electrons follow the circular path indicated on the map.

☞ Attach the coil and try to hit the blue dot on the fluorescent screen of the tube.

☞ Note down the current that is needed for this deflection:



Current in Ampere:

In the LHC, a much higher current of up to **13 000 Ampere** is needed to bend the particles to a ring of 27 km in circumference. Try to explain why!

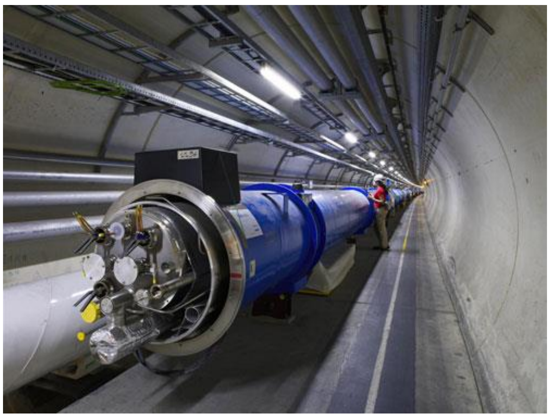


Figure 8 – electromagnet in the LHC, source: CERN