



X-RAY UNITS  
STUDENT WORKSHEETS  
Version 3.2 student  
en  
01/06/15  
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## Warning

The X-ray units in S'Cool LAB are fully protected devices and specially designed for use in schools. They present no danger from ionising radiation. However, the follow rules apply:

- Be careful with the doors of the X-Ray units, there are 2 locking systems.
- Be very careful with the pixel detectors! Although they don't look fragile, any mechanical stress will seriously damage the sensible detectors.
- Obey the instructions of your tutor and follow the instruction in this manual.



## Introduction

Your tutor will introduce you to the operation of the X-Ray units.

## Knowledge

- a) What are X-rays?
- b) How are the high-energy photons produced in X-ray machines?
- c) How can we make high-energy photons visible?

## Technology

- d) How can you switch the device on/off?
- e) What is the meaning of the values on the display and how can I change these? (Light, locks, X-Rays ON/OFF, menu and X-Ray parameters)
- f) How can you open the experiment chamber?
- g) Where can you find the additional equipment (fluorescent screen + holder, tape, cover...)?

## Other

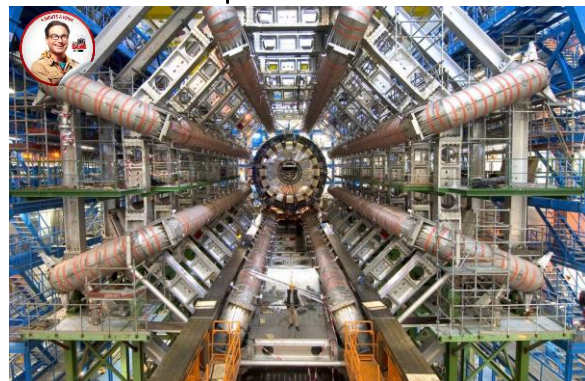
- h) What is the difference between theorists and experimentalists and why is it so important that they work together?

### Theorists



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### Experimentalists




ATLAS Experiment © 2014 CERN

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

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

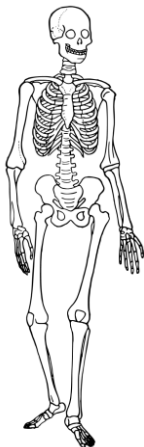
☞ Try to find explanations if the measurements differ from the predictions!


## Make high-energy photons visible

- Become familiar with the equipment.
- Place the fluorescent screen in the middle of the experiment chamber.
- Attention: This screen has two different sides, the side labelled “back” must be facing away from the X-Ray source.
- Use the black cover to cover the device. Make sure the ventilation is not covered.
- Switch on the device (main switch)
- **Set the following values:**
  - o Emission Current (CURRENT) **1 mA**
  - o Voltage (HIGH VOLTAGE) **25 kV**
- Ask your tutor to switch off the light by your workplace.
- Start the X-Radiation with this button 
- Watch the fluorescent screen from behind. Do you see a bright greenish spot?

## Broken Bones

High energy photons from X-Ray machines are used in hospital, to make e.g. bone fractures visible.



 Examine the model human (pink foil) with the X-Ray machine and the fluorescent screen. What can you diagnose?

**Diagnosis:**

What are the **differences** between the image on the fluorescent screen and a „real“ X-Ray image like in the picture at the right?

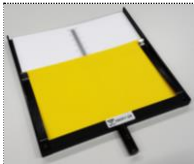
What are the **similarities**?



The goal for this experiment is, to learn more about X-Ray images!

**Time:**

Photons in matter



**Experiment 1:**

Place a **yellow sheet of paper** between the X-Ray source and the fluorescent screen.

Predict how **brightness and colour** of the greenish spot will change. Conduct the experiment and note your observations. Explain!



**Prediction**

**Brightness**

names:

Student 1	Student 2	Student 3	Student 4

- |  |                          |                          |                          |                          |
|--|--------------------------|--------------------------|--------------------------|--------------------------|
| - The greenish spot becomes brighter.      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| - The greenish spot becomes darker.        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| - The greenish spot disappears completely. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| - There is no visual change.               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Explain:

**Colour**

Student 1	Student 2	Student 3	Student 4

- |  |                          |                          |                          |                          |
|--|--------------------------|--------------------------|--------------------------|--------------------------|
| - The colour of the greenish spot changes. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| - There is no visual change.               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Explain:



**Observation**

**Brightness**

- The greenish spot becomes brighter.
- The greenish spot becomes darker.
- The greenish spot disappears completely.
- There is no visual change.

**Colour**

- The colour of the greenish spot changes.
- There is no visual change.

comments:




**Explanation ideas of differences between prediction and observation:**

**Time:**

**Experiment 2:**

Now, place a combination of **black and yellow paper of the same thickness** between the X-Ray source and the fluorescent screen. Observe how **brightness and colour** of the greenish spot change behind the **black paper compared to the yellow paper!**

 **Prediction**

**Brightness**

**Compared to the yellow paper ...**

- The greenish spot becomes brighter.
- The greenish spot becomes darker.
- The greenish spot disappears completely.
- There is no visual change.

Explain:

**Colour**

**Compared to the yellow paper ...**

- The colour of the greenish spot changes.
- There is no visual change.

Explain:

 **Observation**



**Brightness**

- The greenish spot becomes brighter.
- The greenish spot becomes darker.
- The greenish spot disappears completely.
- There is no visual change.

comments:

**Colour**


- The colour of the greenish spot changes.
- There is no visual change.

  **Explanation ideas of differences between prediction and observation:**

**Time:**

**Experiment 3:**

Now, place an **aluminium foil** of the same thickness as the paper between the X-Ray source and the fluorescent screen. Observe how **brightness and colour** of the greenish spot changes **compared to the black paper!**

 **Prediction**

**Brightness**

**In comparison with black paper ...**

- The greenish spot becomes brighter.
- The greenish spot becomes darker.
- The greenish spot disappears completely.
- There is no visual change.

Explain:

**Colour**

- The colour of the greenish spot changes.
- There is no visual change.

Explain:

 **Observation**



**Brightness**

- The greenish spot becomes brighter.
- The greenish spot becomes darker.
- The greenish spot disappears completely.
- There is no visual change.

**Colour**

- The colour of the greenish spot changes.
- There is no visual change.

comments:

  **Explanation ideas of differences between prediction and observation:**

**Summary of experiments 1 - 4:**

What happens to the photons if they fly through matter?

What is the best way to shield high-energy photons?

Why can we distinguish bones and soft tissue like muscles in X-Ray images?

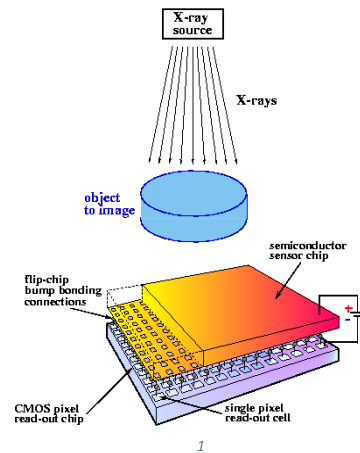
Discuss and compare your summary with other teams or you tutor!

## Pixel detector

## Time:

Instead of a fluorescent screen, you can also make use of particle detectors, such as pixel detectors to make high-energy photons visible. In this detector (MX-10) a silicon detector chip (256 x 256 Pixel of  $1,4 \times 1,4 \text{ cm}^2$ ) is used, which was originally developed by the Medipix2 Collaboration at CERN and is used in medical imaging.

Detectors with semiconductor materials such as silicon are based on the following principle: High-energy particles fly through the semiconductor material and liberate charge carriers such as electrons, which migrate to electrodes made of metal. This current is amplified and evaluated. By dividing the whole detector surface into small parts (pixels), you can measure the location of a detected particle.



## Warning

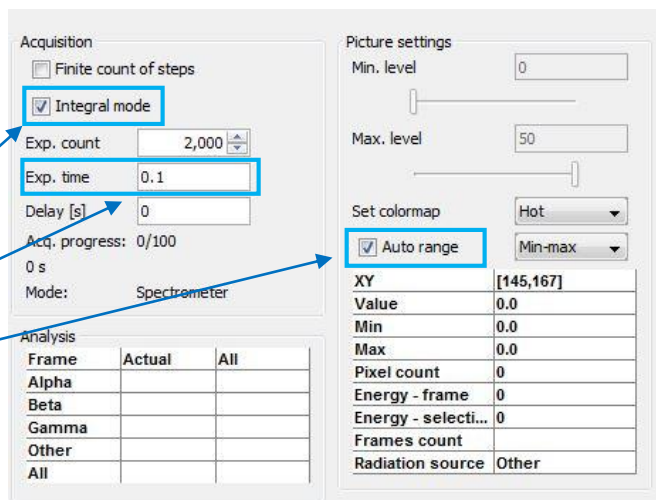
The detector chips are very fragile and expensive.

- Never touch the silicon surface!
- Don't remove the protective cover when working with X-Rays!
- **Follow exactly the written procedure!**
- **Be very careful when handling the device!!!**

## How does a pixel detector work?

Procedure:

1. Place the detector inside the experiment chamber. Use a pin to mount the device carefully on a holder on the rail.
2. Connect the USB cable to the detector and guide it through the **cable channel** to the outside.
3. Connect the outer end of the USB cable to the PC (USB port in the socket panel).
4. Switch on the PC, keyboard and mouse.
5. Login with
  - User: SCOOLX1\ScoolStudent
  - Password: **Einstein1879**
6. Start the Software Pixelman from the desktop
7. Check the settings (see picture at the right, blue frame: important).
  - Integral mode
  - Exp. Time 0.1 s
  - Auto range



<sup>1</sup> Pixeldetector, source: medipix.web.cern.ch



### First Measurement – NO X-Rays

8. Click on the „Start“ button to start the measurement.
9. Observe the measurement of the detector for 30 seconds.

Observation:

Explanation:

What is the meaning of the different colours in the detector image in the software?

### Pixel detector with high-energy photons

10. Set the **emission current to 0,01 mA**.
11. Start a new measurement in Pixelman.
12. Start the X-radiation.

Observation:

Explanation:

### Take radiographs of different objects!

If you bring objects between the X-ray source and the detector you can record radiographs of these objects!

#### Airport security

Imagine you work for the airport security and you have to check radiographs of bags for dangerous material. You will find in the trolley a box with small “suitcases” which contain different objects. Can you find the dangerous suitcase? (If you need clues: Have a look at the last line of this page!)

#### More radiographs

In addition to the suitcases you can x-ray anything you want to. Look for small objects (no living animals!!), such as pens, USB flash drive, SD memory card, plug, leaves, dead bugs, ... and take a radiograph!