# Manual for Compton scattering set

11.08.14 5190.00 AE

**The Compton Effect**

This equipment allows you to study the energy of Compton scattered gamma radiation. Gamma quanta (photons) can lose energy in collisions with loosely bound electrons. The remaining energy of the scattered quanta depends on the deflection angle.

The equation that describes the relationship can be found at the end of this guide.

**Description**

The kit consists of a central holder with a lead absorber which prevents direct radiation from the source from reaching the detector. The holder has a platform with adjustment screws which carries two aluminium shells. These shells are designed so that the scattering angles of the gamma quanta which are scattered in the direction of the detector are approximately the same. There is no focusing involved, but quanta that are scattered in other angles will miss the detector. The two sets of shells provide for a scattering angle θ around 60°, resp. 90°.

The equipment utilizes a well-known geometric theorem about central and inscribed angles of a circle.

Applied to this equipment the theorem states that if the source and detector are placed as two points S and D on the circumference of a circle, then all points on the arc between them will ”see” the same angle from S to D. Rotating the arc around an axis through S and D will form an infinitely thin version of the shells in the set.

In order to get more than infinitely small count rates, the shells are made a little thicker – the cost of this is a slightly poorer definition of the angle.

In addition to this set (5190.00) the following equipment is required:

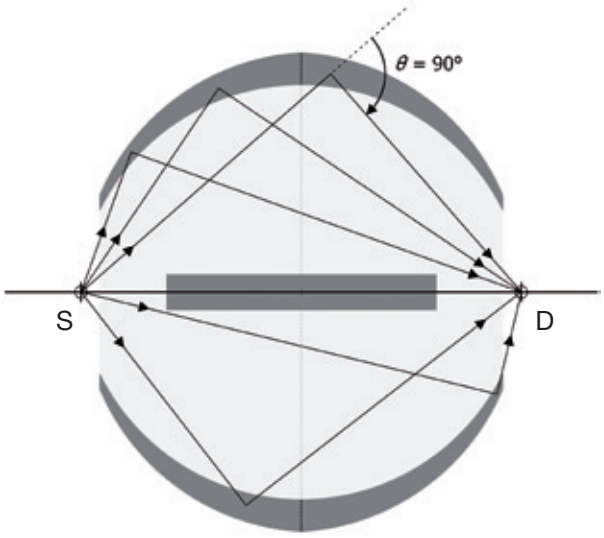
- 5180.00 Multichannel analyzer
- 5185.00 Scintillation detector
- 5141.80 Source holder for exp. bench, simple *)
- 5141.02 Rail for mounting bench, 40 cm
- 2946.10 Sliding saddle (2 pcs.)
- 5100.30 Gamma source; Cs-137 *)

*) Please consult the hardware compatibility section below when other sources are to be used.

The connection to the detector must not be changed when multichannel analyzer is powered:

**First** connect the detector to the MCA – **then** plug the USB cable into the PC.

When you are finished, you must **first** disconnect the USB connection – **then** remove the cables to the detector

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**Basis**

For the sake of clarity, this guide for the Compton Scattering set will not describe the use of the program GaSp on a "click-by-click level".

The guide to the multichannel analyzer should be at hand during the work!

A gamma peak should be fitted in GaSp by creating a ROI (Region Of Interest). Calibration is performed in the panel by the same name. Both are described in detail in the manual.

## PROCEDURE

### 1 – Energy calibration

To calibrate the equipment, it is preferred to have sources of gamma energies in the area to be examined. With a Cs-137 source you get the extremes covered: 662 keV (gamma) and 32 keV (x-ray). If you have a radioactive mineral sample, there is a good chance that you can use the three distinct peaks from Pb-214 at resp. 242, 295 and 352 keV and the Bi-214 peak at 609 keV.

Place the Cs-137 source close to the detector and set the detector parameters so that the spectrum extends significantly on the x-axis, but with adequate room for the whole spectrum.

Let the program run until sufficient statistics for a precise determination of the photo peak location is achieved. Use the program's fitting facility and note the channel number.

Repeat for the remaining energies to be used. Enter the data in the calibration panel.

The calibration can be saved to a file.

NB! Be sure **not** to change the hardware parameters for the rest of the experiment!

### 2 – Setup

The fastening screws at the base of the source holder and the sliding saddles must face the same way.

Adjust the lead absorber and the detector height to match the source height above the rail. The absorber must be carefully lined up parallel to the longitudinal direction of the rail.

Some useful measurements in the longitudinal direction:

The radioactive substance in the gamma source 5100.30 is positioned approx. 2.5 mm from its tip – i.e. 3.5 mm behind the front of the source holder when the source is fully screwed in. When using other sources: obtain relevant information from your supplier and correct the geometry parameters below accordingly.

There is approx. 1 mm from the front of the detector housing to the surface of the CsI crystal in the detector. The crystal itself is 15 mm long – there is thus 8.5 mm from the detector front to the centre of the crystal.

The distance from the centre of the setup to the two peripheral points (resp. source and detector) is for 90° scattering: 36.7 mm. For 60° scattering: 62.7 mm.

The tape measure on the rail can be a good help! There is a centre mark on the sliding saddles; for the source holder, you must use the edge of the base.

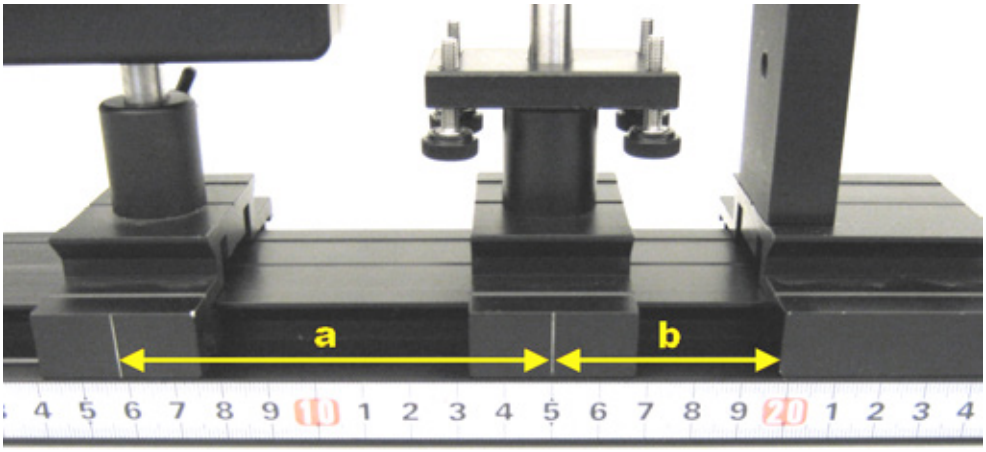
In practice, you can rely on these distances:

| | (a) | (b) |
|---|---|---|
| Angle | From saddle, centre to saddle, detector | From saddle, centre to edge, source holder |
| 90° | 91 mm | 48.5 mm |
| 60° | 117 mm | 74.5 mm |

At least for 90°, you must move the source and detector away while installing and removing the shells. If you make a note of all the positions it is easy to return to the correct conditions.

The screws must be adjusted so that the edges of the shells are vertical and fit together. The circular parts of the source holder and the detector should be concentric with the holes in the shells. (The adjustment is different for the two sets of shells – finish working with one scattering angle before starting on the other.)

Please also see page 4.

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### 3 – Reference Spectrum

When the screws are adjusted, remove the shells, and the setup is ready to record a reference spectrum. This spectrum comes not only from the background radiation, but includes also radiation from the source that is Compton scattered on the table top, etc. – and a small contribution that penetrated the lead absorber.

The reference spectrum is to be loaded into the program as a background spectrum, enabling us to subtract it from the spectrum we later collect with the shells in place. The uncertainties of the counts in the reference spectrum propagate to the result, so it should be measured over as long time as you want to use for the ”real” spectrum. With a 370 kBq Cs-137 source, 10 minutes will typically be enough to be able to fit the photo peak precisely.

The reference spectrum is dependent on the geometry of the setup. When you later change it to measure the other scattering angle, you need to make a new reference spectrum.

Include the angle in the name of your reference spectrum files to avoid confusion!

### 4 – The spectrum of the Compton scattered radiation

Now place the shells in the centre holder. It may be necessary to move the source and the detector a little away; make sure that they return to exactly the same position.

Record the spectrum for about the same time as was used for the reference spectrum. The gross spectrum now collected shows the Compton scattered radiation and roughly the same contribution from background radiation and scattered quanta from the tabletop as was collected in the reference spectrum. (Although the radiation that is reflected in the shells can now no longer reach the table.)

Specify the reference spectrum as the background spectrum in the program. The desired difference spectrum can then be observed along the way. The program takes differences in live time into account.

Save the spectrum as a spectrum experiment. This way, the file contains both the gross spectrum and the reference spectrum (as background spectrum).

### Theory

Compton discovered originally that the wavelength of X-ray radiation that is scattered on loosely bound electrons is changed by an amount that depends only on the scattering angle. In connection with gamma radiation, it is more natural to work with energy than the wavelength. The result can be formulated as follows:

$$E' = \frac{E}{1 + \frac{E}{m_0 \cdot c^2} \cdot (1 - \cos\ \theta)}$$

Here, *E'* is the energy of the scattered gamma quantum, *E* is the energy of the original gamma quantum, $\theta$ is the scattering angle, $m_0$ is the electron rest mass, and *c* is the speed of light.

The above formula is derived from energy and momentum conservation (in relativistic formulation).

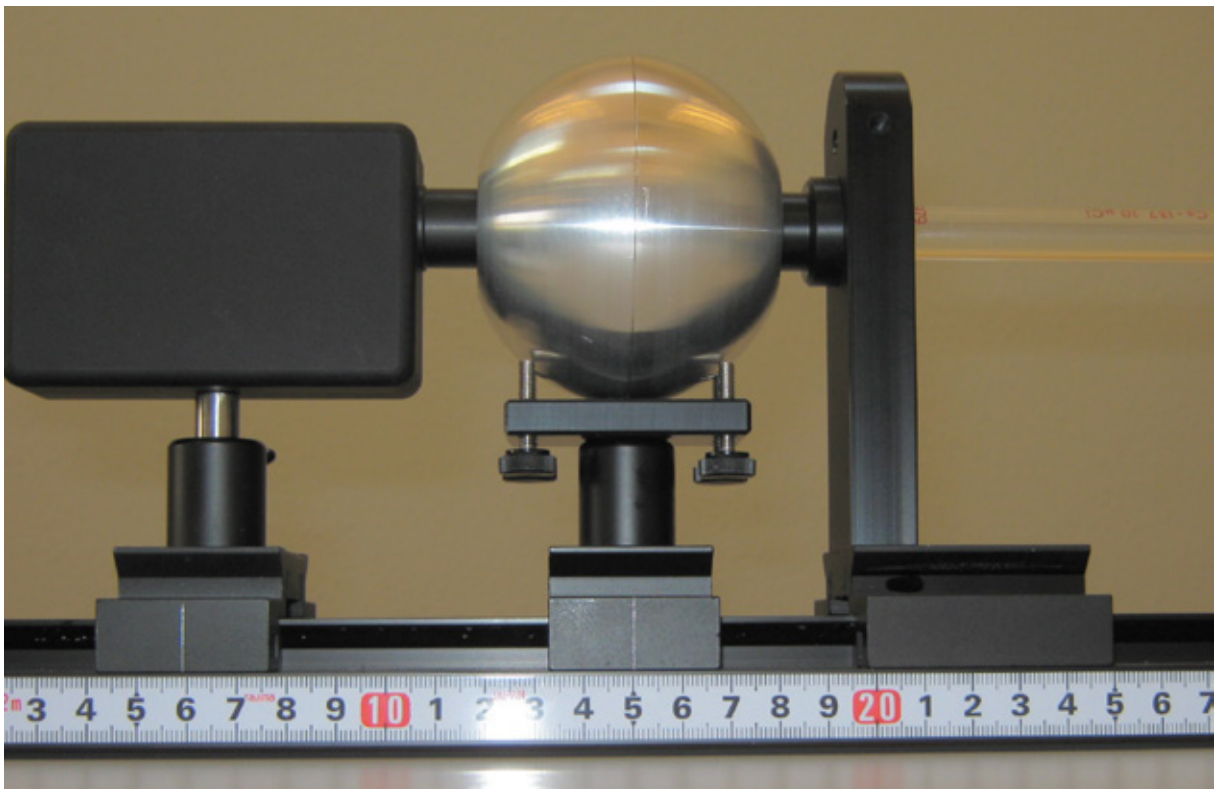
### Hardware compatibility

The gamma source provided by Frederiksen (5100.30) fits the source holder (5141.80).

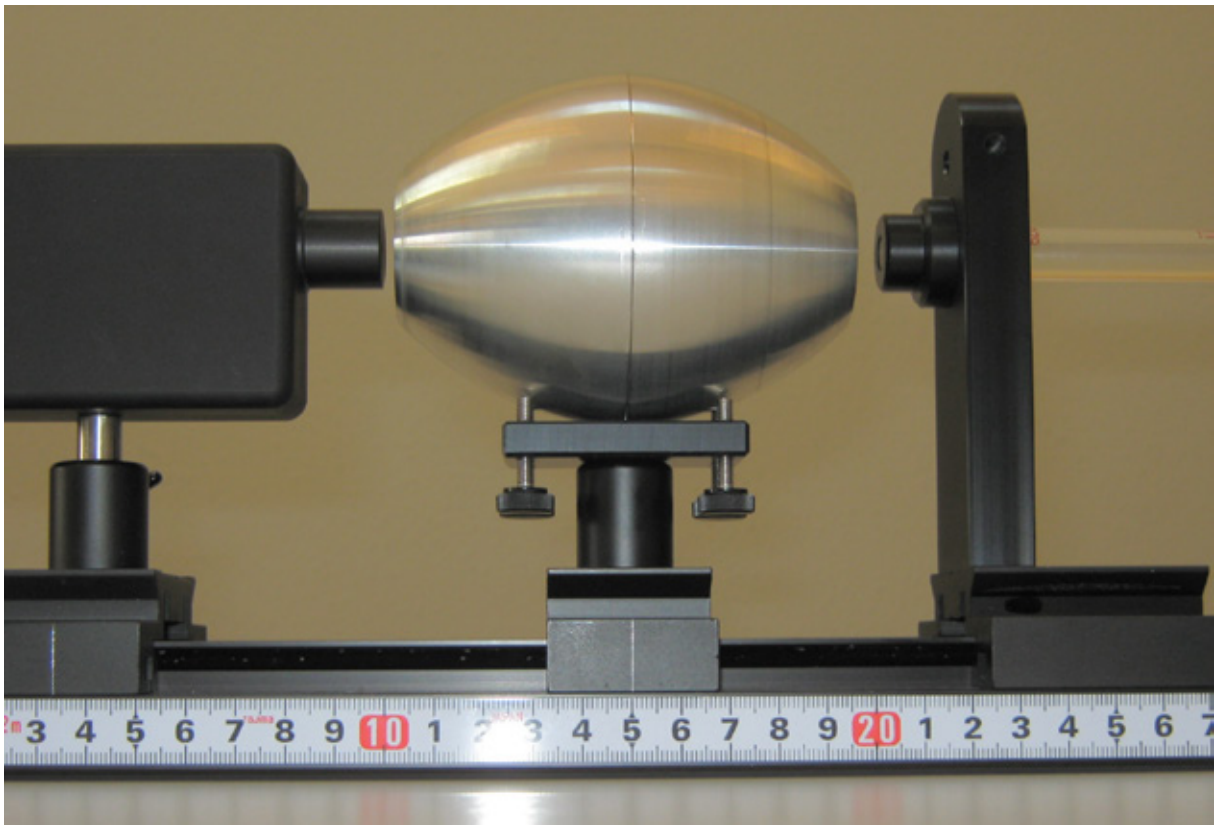
Other types of sources can be used with the Compton scattering set, as long as they can be positioned as described. We make holders for two more types of sources, which can be used instead of 5141.80:

- 5141.85 Source holder for exp. bench, simple. For disc source Ø 25 mm
- 5141.87 Source holder for exp. bench, simple. For cylindrical sources Ø 12 mm

If in doubt, consult your local Frederiksen distributor.



Complete setup for 90°



Complete setup for 60°

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