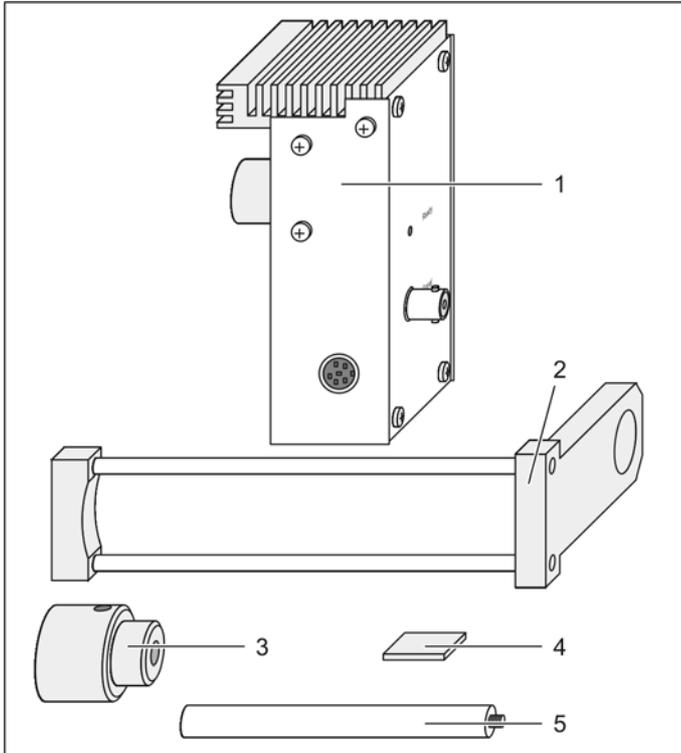


06/05-W97-Iv/Sel



## Instruction sheet 559 938

### X-ray energy detector (559 938)

- 1 X-ray energy detector
- 2 Sensor holder
- 3 Absorption screen
- 4 Calibration target
- 5 Stand rod with thread

## 1 Description

The X-ray detector enables energy spectra of X-rays or  $\gamma$  radiation in the energy range of approx. 2keV to 60 keV to be recorded. It consists of a Si-PIN photodiode, which is cooled by a Peltier element. A charge sensitive preamplifier and a linear main amplifier with pulse-shaping electronics are integrated in the detector housing. The detector is particularly suited for installation in the X-ray apparatus (554 811).

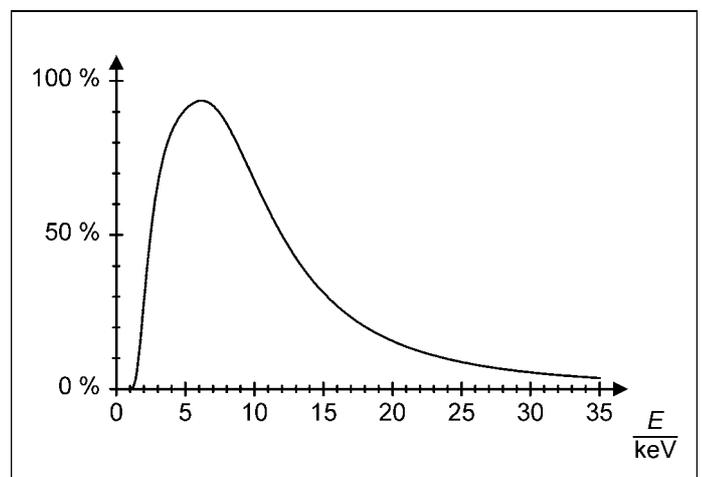
## 2 Scope of delivery

- 1 X-ray energy detector
- 1 table power supply, 100-240 VAC
- 1 BNC cable, 50 cm
- 1 sensor holder
- 1 stand rod with thread
- 1 absorption screen
- 1 calibration target (galvanized steel)
- 1 test certificate
- 1 Allen key, 1.5 mm

## 3 Detection probability

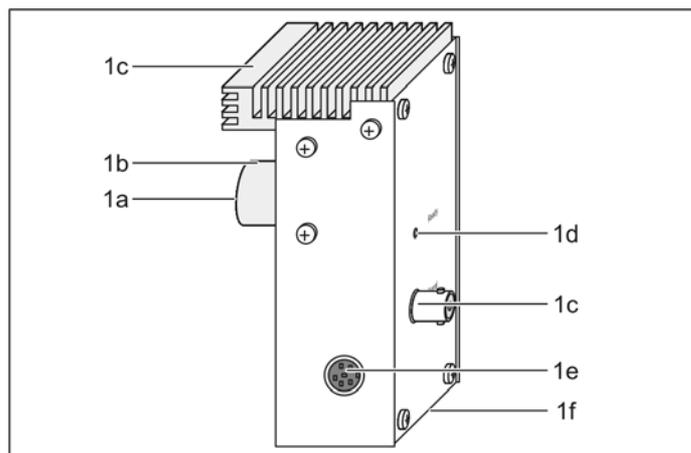
The detection probability of an X-ray photon entering the Si-PIN photodiode depends on its energy  $E$ .

The figure shows the dependence up to the maximum energy of the X-ray apparatus (554 811). At higher energies, the detection probability drops further and further.



## 4 Components

### 4.1 X-ray energy detector



- 1a Entrance window
- 1b Tube
- 1c Heat sink
- 1d Indicator LED
- 1c Signal output
- 1e Supply voltage input
- 1f Threaded bush M6

**Tube:**  
for holding the detector in the sensor holder contained in the scope of delivery

**Indicator LED:**  
red: supply voltage is applied  
green: Si-PIN photodiode cooled down, detector ready for operation

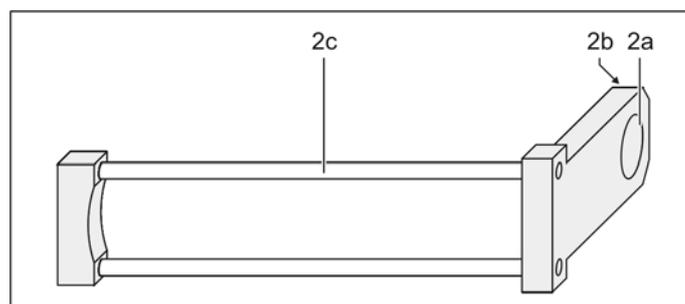
**Signal output:**  
for connecting the detector to the MCA box (524 058)

**Supply voltage input:**  
for connecting the detector to the table power supply contained in the scope of delivery

**Threaded bush M6:**  
for fastening the stand rod with thread contained in the scope of delivery

### 4.2 Sensor holder:

for holding the X-ray energy in the goniometer of the X-ray apparatus (554 811)



- 2a Bore
- 2b Allen screws, 1.5 mm
- 2c Guide rods

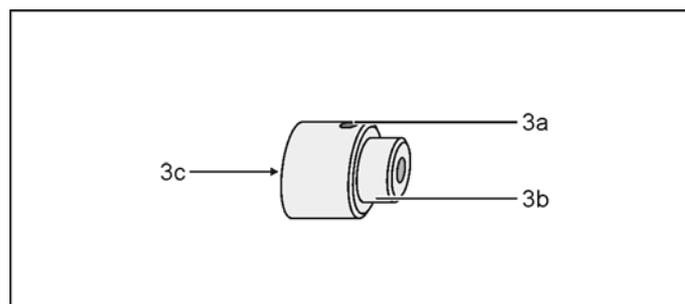
**Bore:**  
fitting the tube of the X-ray energy detector

**Allen screws, 1.5 mm:**  
for fixing the X-ray energy detector

**Guide rods:**  
fitting the sensor arm of the goniometer in the X-ray apparatus (554 811)

### 4.3 Absorption screen:

for attenuating the X-ray beam for direct measurements with the X-ray energy detector in the primary beam of the X-ray apparatus. Between the two screws, which are secured by means of lacquer, there is a fine slit of 10  $\mu\text{m}$  width through which the primary beam can pass.



- 3a Screws (secured)
- 3b Projection for filter
- 3c Mating bore

**Projection for filter:**  
for mounting the filters (554 832 und 554 833)

**Mating bore:**  
fitting the slit collimator of the X-ray apparatus (554 811) and the circular collimator from the scope of delivery of the set Compton accessory II X-ray (554 837)

## 5 Technical data

### X-ray energy detector:

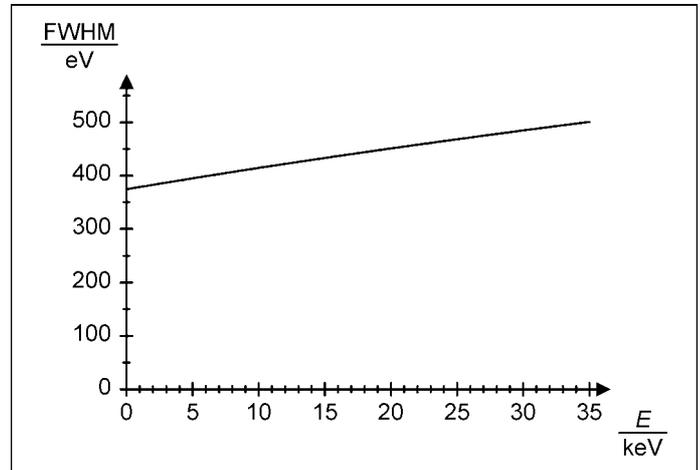
Energy range:	approx. 2 keV to 60 keV
Energy resolution:	0.4 keV (FWHM) at $E_{\text{FeK}\alpha} = 6.40 \text{ keV}$
Non-linearity (including MCA box):	< 1 % at $E = 3\text{-}35 \text{ keV}$
Long-term energy drift:	< 3 % (after 4 h of continuous operation in the X-ray apparatus at $\vartheta_{\text{lab}} = 25 \text{ }^\circ\text{C}$ )
Entrance window:	plastic (absorption equivalent to graph- ite with $d = 40 \text{ }\mu\text{m}$ )
Detector:	Si-PIN photodiode
Active area of the detector:	0.8 mm dia.
Thickness of the detector:	approx. $150 \text{ }\mu\text{m}$
Detector housing:	iron alloy, plated with gold alloy
Rise time of the output signals:	approx. $0.5 \text{ }\mu\text{s}$
Fall time of the output signals:	approx. $5 \text{ }\mu\text{s}$
Dead time per pulse:	approx. $250 \text{ }\mu\text{s}$
Working temperature of the Si-PIN photodiode:	approx. $-15^\circ\text{C}$
Cooling of the detector:	thermoelectric (Peltier element)
Supply voltages:	$\pm 15 \text{ V}$ , $+5 \text{ V}$ (from table power supply, 100-240 VAC)
Input supply voltages:	Mini DIN socket
Signal output:	BNC socket
Dimensions:	$60 \text{ mm} \times 120 \text{ mm} \times 60 \text{ mm}$
Weight:	450 g
<b>Absorption screen:</b>	
Slit width:	approx. $10 \text{ }\mu\text{m}$
<b>Calibration target:</b>	
Material:	galvanized steel
Fe $K\alpha$ line:	6.40 keV (weighted mean value)
Zn $K\alpha$ line:	8.63 keV (weighted mean value)
Dimensions:	$25 \text{ mm} \times 25 \text{ mm}$

## 6 Energy resolution

The full width at half maximum (FWHM) depends on the energy  $E$  of the X-ray:

$$\text{FWHM}(E) = 2 \cdot \sqrt{2 \cdot \ln 2} \cdot \sqrt{\sigma_{\text{el}}^2 + F \cdot \varepsilon \cdot E}$$

with  $\sigma_{\text{el}} \approx 160 \text{ eV}$ ,  $F \approx 0.15$ ,  $\varepsilon = 3.8 \text{ eV}$



## 7 Remark concerning the operability

It cannot be excluded that water vapour from the ambient air penetrates through the thin entrance window of the detector in the course of several years. This may impair the operability of the Si-PIN photodiode.

If the X-ray energy detector should become inoperative after some time for this reason, this can be fixed by the manufacturer, LD Didactic GmbH.

## 8 Accessories

*for energy spectroscopy:*

1 BNC lead, 1 m long	501 02
1 MCA box	524 058
1 Sensor-CASSY	524 010
or	
1 Pocket-CASSY	524 006
1 CASSY Lab	524 200
1 PC with Windows 98/NT or higher version	

*for demonstrating the Compton effect on X-rays:*

Compton accessory II Xray	554 837
X-ray apparatus with X-ray tube Mo and goniometer	554 811

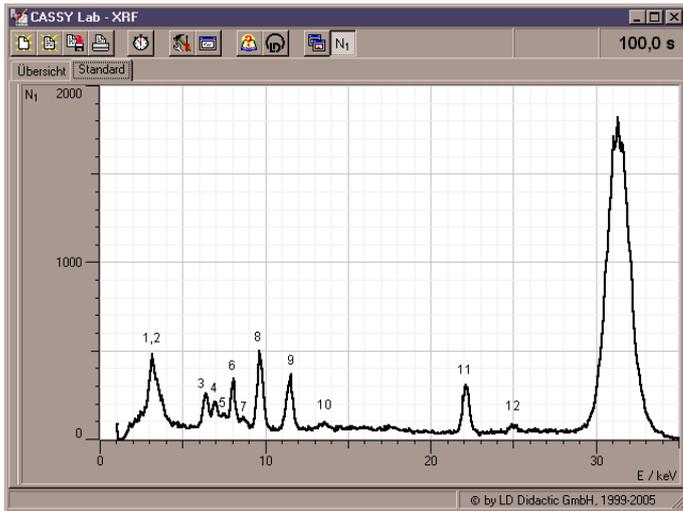
*for X-ray fluorescence spectroscopy:*

Set of targets K-line fluorescence	554 844
Set of targets L-line fluorescence	554 846
X-ray apparatus with X-ray tube Mo and goniometer	554 811
or	
with X-ray tube Cu and goniometer	

### 9 Fluorescence of the housing material

Part of the incoming X-rays penetrates through the Si-PIN photodiode into the wall of its housing and there excites X-ray fluorescence in atoms. The characteristic radiation of these atoms partially gets into the photodiode and is detected together with primary X-rays. Therefore it is always possible that the measured spectrum contains the characteristic lines of the elements Fe, Co, Ni, Cu, Zn, Au and Ag.

The excitation of individual characteristic lines depends on the energy of the primary radiation. Most frequently the L-lines of gold are observed.



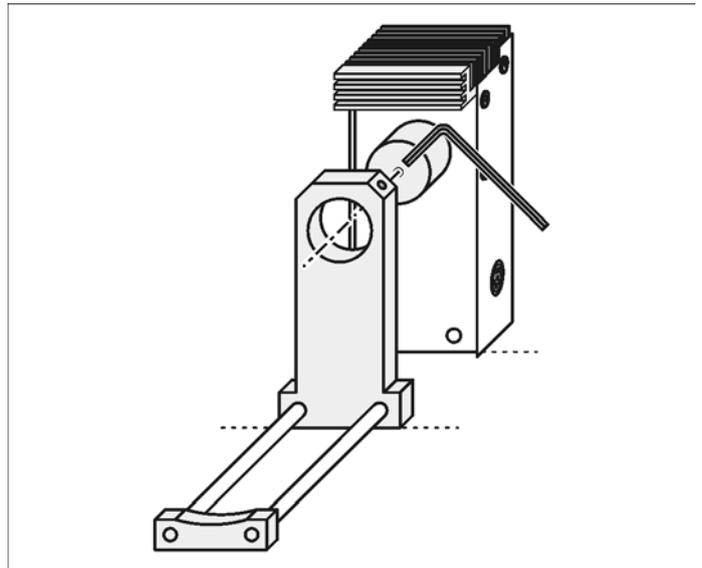
Resonance fluorescence of the housing of the Si-PIN photodiode excited by X-rays with  $E = 31 \text{ keV}$  that are made monochromatic (Bragg reflection).

No.	Line	$\frac{E}{\text{keV}}$	No.	Line	$\frac{E}{\text{keV}}$
1	Ag $L\alpha$	2.98	7	Zn $K\alpha$	8.64
2	Ag $L\beta$	3.15	8	Au $L\alpha$	9.71
3	Fe $K\alpha$	6.40	9	Au $L\beta$	11.44*
4	Co $K\alpha$	6.93	10	Au $L\gamma$	13.38*
5	Ni $K\alpha$	7.48	11	Ag $K\alpha$	22.16*
6	Cu $K\alpha$	8.05	12	Ag $K\beta$	24.94*

\* Energy of the  $K\alpha_1$  line

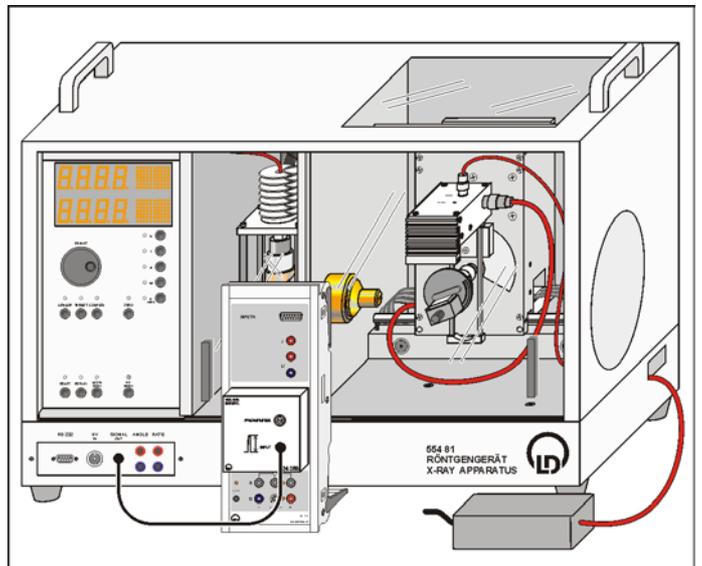
### 10 Operation in the X-ray apparatus (554 811)

#### 10.1 Installation in the sensor holder:



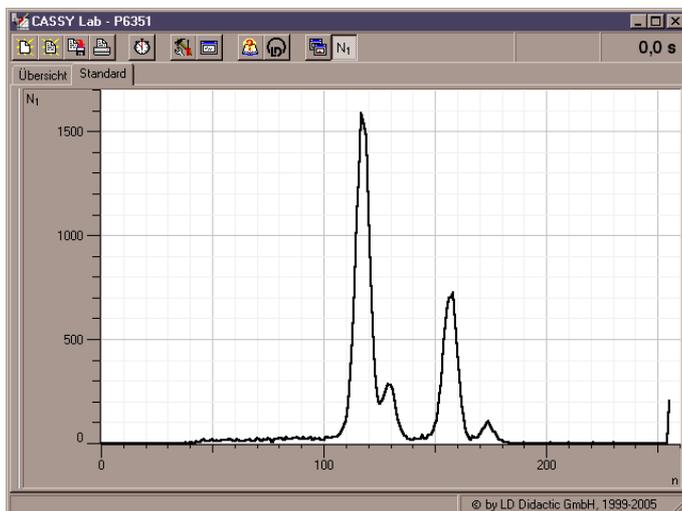
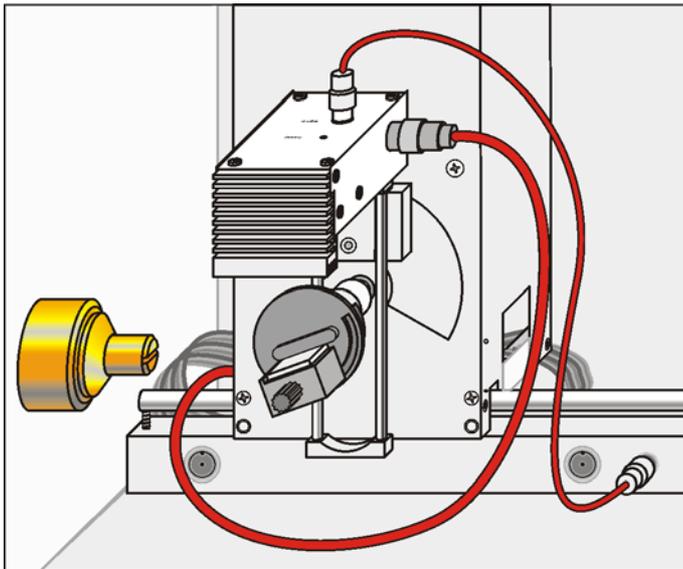
- Insert the tube of the X-ray energy detector in the sensor holder until it abuts.
- Align the X-ray energy detector, and fix it with the Allen screws.

#### 10.2 Installation in the X-ray apparatus (554 811) and connection to the MCA box (524 058):



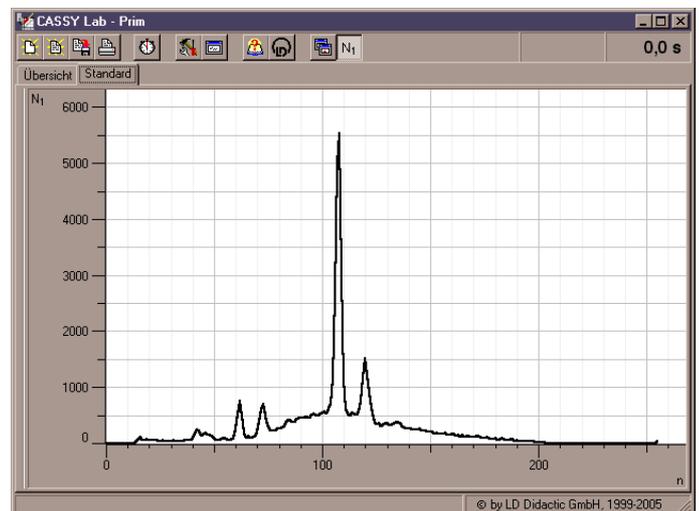
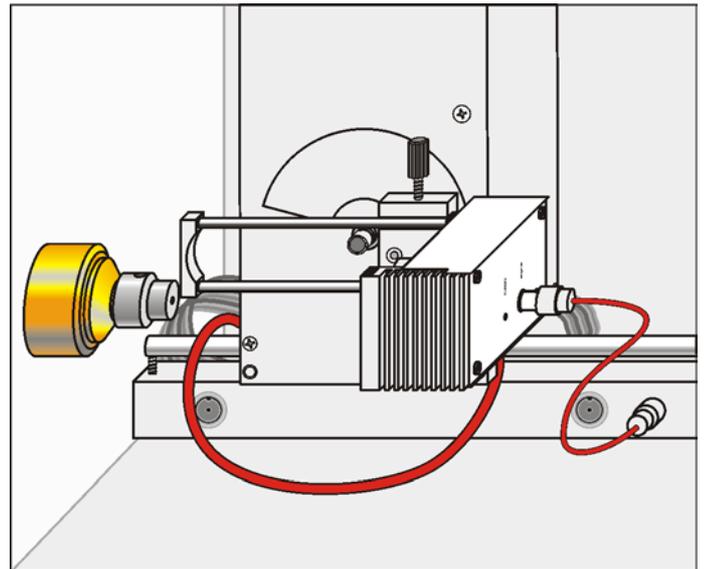
- Guide the connection cable of the table power supply through the empty duct of the X-ray apparatus (554 811), and connect it to the supply voltage input of the X-ray energy detector.
- Mount the sensor holder with the X-ray energy detector in the sensor arm of the goniometer, and push a sufficient length of the connection cable into the duct so that the sensor arm can perform a complete rotation.
- Using the BNC cable from the scope of delivery, connect the signal output of the X-ray energy detector to the BNC socket SIGNAL IN in the experiment chamber.
- Connect the output Signal Out on the terminal panel of the X-ray apparatus to the MCA box, using a BNC cable.

### 10.3 Measurement with the calibration target:



- Fix the calibration target on the target stage of the goniometer.
- Close the experiment chamber of the X-ray apparatus, and adjust the sensor angle  $90^\circ$  and the target angle  $45^\circ$ .
- Connect the table power supply to the mains, and wait approx. 2 minutes until the LED of the X-ray energy detector shines green (change from red to green).
- Select the tube high voltage  $U = 35 \text{ kV}$  and the emission current  $I = 1.00 \text{ mA}$ , and switch the tube high voltage on.
- Select the measuring parameters "Multichannel Measurement, 256 Channels, Negative Pulses, Gain -6, Measuring Time 300 s" in CASSY Lab.
- Start recording the spectrum with  or with the F9 key (the spectrum shown above is recorded if the measurement will be performed with a Mo anode or a Cu anode).

### 10.4 Measurement of the primary beam:



- Remove the target holder with the target stage, and take the sensor to the  $0^\circ$  position.
- Put the absorption screen on the collimator until it abuts, and align it carefully (with the screws pointing upwards and downwards).
- Connect the table power supply to the mains, and wait approx. 2 minutes until the LED of the X-ray energy detector shines green (change from red to green).
- Select the tube high voltage  $U = 35 \text{ kV}$  and the emission current  $I = 0.10 \text{ mA}$ , and switch the tube high voltage on.
- Select the measuring parameters "Multichannel Measurement, 256 Channels, Negative Pulses, Gain -2, Measuring Time 300 s" in CASSY Lab.
- Start recording the spectrum with  or with the F9 key (the spectrum shown above will be recorded if the measurement is performed with a Mo anode).
- Look for the sensor angle at which the total counting rate is about 200 1/s in steps of  $0.1^\circ$ .

If none or only a few events are counted:

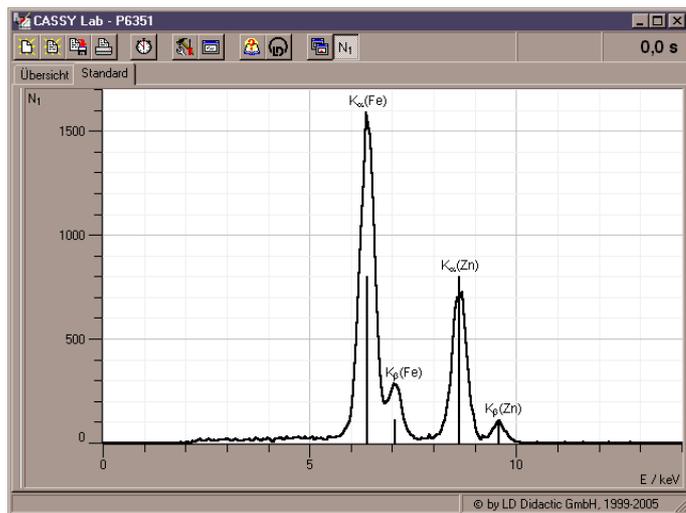
- Rotate the absorption screen by  $180^\circ$ , put it on again and look for the optimal sensor angle anew.

### 11 Energy calibration

- Open the "Energy Calibration" dialog window in CASSY Lab with the shortcut Alt+E, and select "Global Energy Calibration".
- Enter the energies of two measured lines.
- Select the menu item "Other Evaluations" → "Calculate Peak Center" in the pop-up menu of the diagram window, and mark the region of the first line.
- Enter the result in the "Energy Calibration" dialog window.
- Then determine and enter the peak center of the second line.
- Close the "Energy Calibration" dialog window with OK.

### 12 Measuring ranges

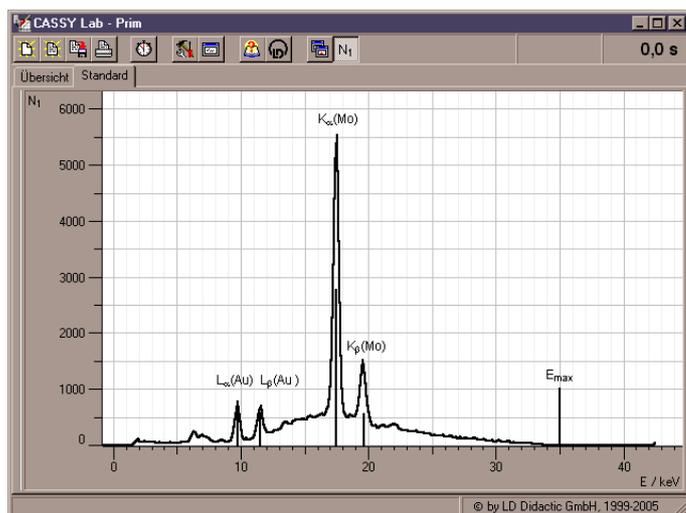
Gain of the MCA box	Maximum measurable energy
1	approx. 84 keV
2	approx. 42 keV
3	approx. 28 keV
4	approx. 21 keV
5	approx. 17 keV
6	approx. 14 keV



Energy calibrated fluorescence spectrum of the calibration target, lines used for the calibration: Fe  $K\alpha$  ( $E = 6.40$  keV) and Zn  $K\alpha$  ( $E = 8.63$  keV)

### 13 Operation in a stand setup

- Screw the stand rod with thread into the threaded bush of the X-ray energy detector, and mount it on stand material.
- Connect the connecting cable of the table power supply to the supply voltage input of the X-ray energy detector.
- Connect the signal output of the X-ray energy detector to the MCA box via the BNC cable.
- Select the measuring parameters "Multichannel Measurement, negative pulses, Gain -1" in CASSY Lab.



Energy calibrated spectrum of the primary beam of a Mo anode at the tube high voltage  $U = 35$  kV lines used for the calibration: Mo  $K\alpha$  ( $E = 17.44$  keV) and Au  $L\alpha$  (9.71 keV)