Recent experimental developments for the Lamb shift investigation in heavy ions

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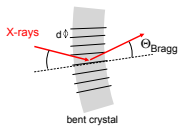
Crystal Spectroscopy

Bragg-Laue Relation

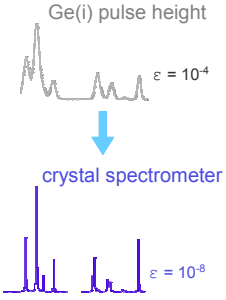
$$\lambda = 2 \cdot d \cdot \sin\Theta$$

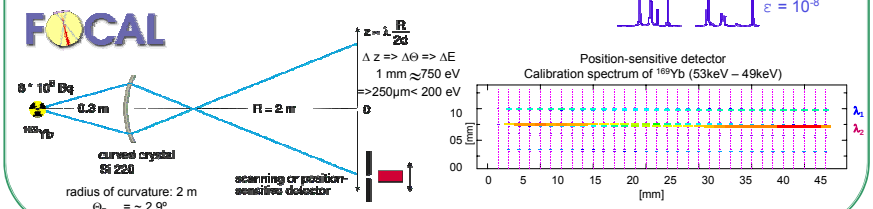


- measurement of angles
- ⇒ measurement of wavelength
- resolution: ~ 75 eV @ 60 keV

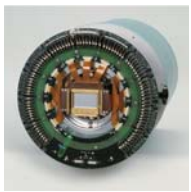
Lacking in the efficiency crystal spectrometers provide high spectral resolution.

Promising for high-precision experiments are combinations of the crystal spectrometers resolution with position-sensitive Germanium detectors [1,2].

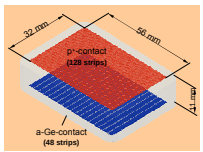




Two-dimensional Microstrip Germanium Detector



- 128 strips on an area of 32 mm x 56 mm with a pitch of 250µm on the front-side
- 48 strips with a pitch of 1167 µm on the rear-side [3]



- resolution: ~2.15 keV @ 60 keV

Extension of the Dirac Theory - Lamb Shift

Self energy **Vacuum polarization**

current status for the 1s Lamb shift in uranium [4]:

Experiment: 459.8 eV ± 4.6 eV
Theory: 463.95 eV

SE	VP	NS
355.0 eV	-88.6 eV	198.7 eV

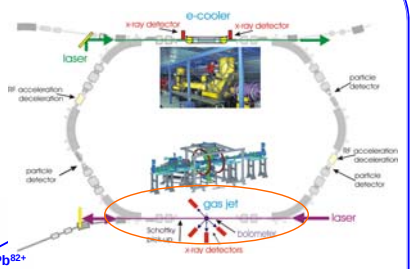
Novel experimental techniques are aiming at a precision of 1 eV!

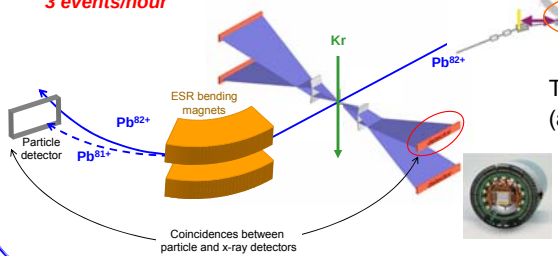
Experimental Storage Ring

Ion beam:
$^{208}Pb^{81+}$ ion beam
energy: 210 MeV/u
β = 0.586

Jet target:
supersonic krypton jet
density: ~7*10^{11} atoms/cm^3
width: ~5 mm

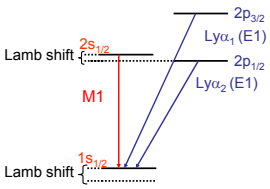
3 events/hour

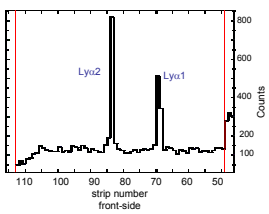




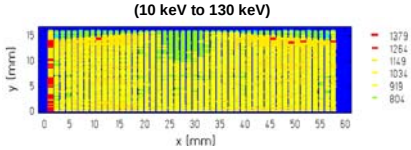
The **FOCAL** set-up (at the gas target)

2D – spectra obtained in the experiment

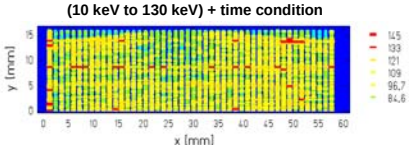




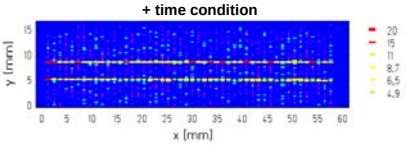
(10 keV to 130 keV)



(10 keV to 130 keV) + time condition



energy condition (58 keV to 65 keV)
+ time condition

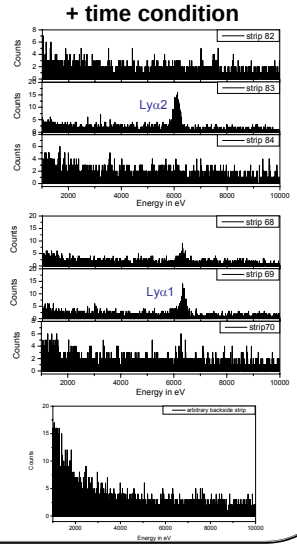


The spectra shown on the left are 2D images recorded during a commissioning experiment in march 2006. The x-axis consists out of the strips from the rear-side of the detector whereas the y-axis depicts the strips of the front-side. On the right, single strip energy-spectra of the relevant front-side strips are shown.

Different conditions were applied to the energy-spectrum of the individual strips. The influence of the Doppler effect was compensated already during the experiment by tilting the detector.

Only by applying a proper energy- and time-condition we are able to see the desired Ly-α transitions with high spectral resolution. This underlines the necessity of position-sensitive detectors having a good time- and energy-resolution for such high precision measurements. This holds true in particular for the rear-side strips (spectrum on the lower right), which detect all incoming energies.

selected single strip spectra + time condition



References:

[1] H. F. Beyer et al., Spectrochim. Acta Part B 59, 1535 (2004)
[2] Th. Stöhlker et al., Nucl. Instr. Meth. B 205, 210 (2003)
[3] D. Protic et al., IEEE Trans. Nucl. Sci. 52, 3194 (2005)
[4] A. Gumberidze et al., Phys. Rev. Lett. 94, 223001 (2005)