ESRF	**Experiment title:** Investigating the differential electron-electron correlation in Helium with Compton scattering	**Experiment number**: CH-5345
Beamline: ID31	**Date of experiment**: from: 27 Apr 2018 to: 09 May 2018	**Date of report**: 18/02/2020
Shifts: 18	**Local contact(s)**: Veijo Honkimäki	*Received at ESRF:*

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Report:

The goal of this beamtime was to for the first time bring a modern COLTRIMS reaction microscope for gas-phase studies of Compton scattering to ESRF. We aim to set-up a long-term program for atomic and molecular physics utilizing Compton scattering. Meanwhile we have received funding from DFG for this line of research. For this beamtime with a transportable COLTRIMS end-station, we brought in a large amount of equipment from Frankfurt and installed it for one week in the ID31 hutch. Fig. 1 and caption show the report in the ESRF News on this experiment:

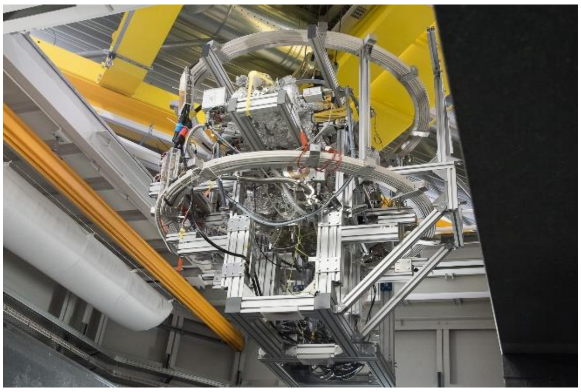

Fig.1 – From ESRF News 01.06.2018: Big logistic effort bringing a COLTRIMS Reaction Microscope from Frankfurt to ID31 for a one-week beamtime. Text from ESRF News: “This is no ordinary experiment. With a huge detector in tow and a team of 15 scientists from Goethe University in Frankfurt (Germany), it is probably as big as science gets -literally.” (*Text by Montserrat Capellas Espuny, ESRF).*

With this major logistic effort and the very unusual gas-phase detector setup in ID31 already this exploratory experiment was successful and paved the road for a second beamtime in the following period from which already two papers in Phys. Rev. Lett. have been published (see experimental report on CH-5524, Kircher, period 8/2018).

In the experiment covered by the present report, we investigated the electron-electron correlations in helium, probing the system via Compton scattering. The incoming photon scatters at one of the two electrons in the helium atom, which is then ionized. In about 1% of all cases, due to shake-off the second electron will be emitted as well, a process solely depending on electron-electron correlations. With our COLTRIMS reaction microscope we are able to measure the initial-state momentum of the first (Compton) electron in coincidence with the momentum of the shake-off electron. Thus, we gain access to the correlated wave function $|\psi(\vec{p}_{e1}\vec{p}_{e2})|$, where $\vec{p}_{e1,e2}$ are the bound-state momenta of the two electrons.

With the COLTRIMS technique, we guide the charged reaction particles with electric and magnetic fields towards two position- and time-sensitive detectors. With the times-of-flights and positions-of-impacts, we are able to reconstruct the momenta at reaction time. We are not able to detect the final momentum of the high-energy Compton electron directly. But, detecting the final momenta of the He^{++} ion and the shake-off electron, we can infer the initial momentum of the Compton electron using momentum conservation (see Fig. 2).

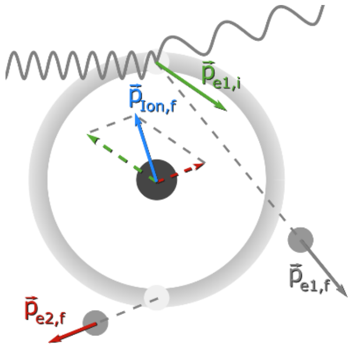

Fig. 2 – Sketch of the momentum configuration.

Performing and analyzing this experiment is very challenging for multiple reasons:

- The calibration of the spectrometer at the available photon energies at ID31 required an ion-collision process, where a doubly charged projectile captures one or more electrons of a neutral target, resulting in definite momenta of the target in beam direction. These can be used to calibrate the setup.
- The low cross section for Compton scattering double ionization of He and the highly differential nature of our experiment requires high photon flux and long data acquisition times. However, we were able to detect He^{+} and He^{++} events successfully.

These preliminary results show that, in principle, our measurement was successful. This proves that utilizing a COLTRIMS spectrometer at the available high energies at ID31 is possible and that the available maximum beamtime of 18 shifts is sufficient to collect enough statistics to get meaningful results. However, the results are not final, the analysis is not finalized yet. We so far can demonstrate that we detected low-energy electrons from shake-off in coincidence with ions (Fig. 3) and we could measure the Compton profile of He^{+} ions with high resolution (Fig. 4).

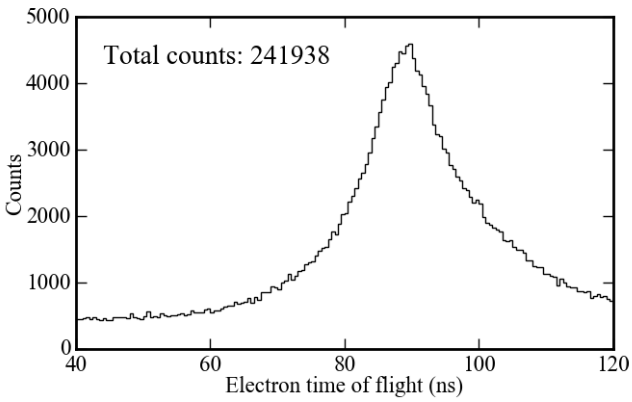

Fig. 3 – Electron time of flight spectrum.

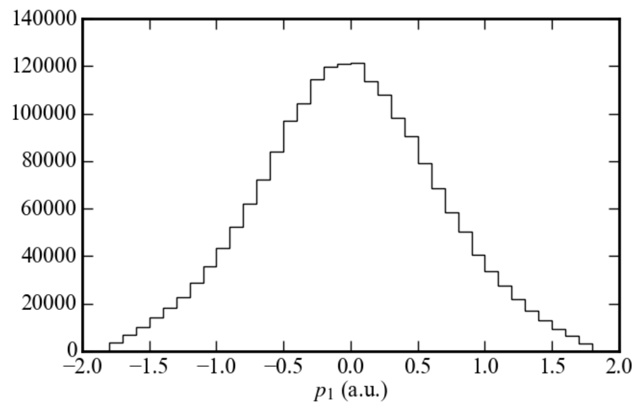

Fig. 4 – Compton profile of He^{+} ions.

Measuring the Compton profile in gas-phase coincidence experiments opens a wide variety of new studies, e.g. measuring the Compton profile of molecular systems relative to molecular orientations or the Compton profile of different final states. This measurement is a proof-of-principle that COLTRIMS is a viable instrument to do such experiments. We are confident that one publication will be gained from this run. From the following experimental run, the data were more straightforward to analyze and the corresponding papers (two Phys. Rev. Lett.) are already published (see report on CH-5524).