



Photo-ionization measurements with a Time-of-Flight Coincidence Spectrometer

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Abstract

The aim of the project was the setup of an experiment for time resolved studies at the P04 variable Polarization XUV beamline at Petra III. Therefor a photoelectron – photoion Time-of-Flight coincidence spectrometer was placed in the optical path of the P04 beamline and a nearly collinear mobile laser system.

After adjusting parameters such as position of the spectrometer, electric fields for appropriate mass resolution or the optical path of the laser, the setup was tested in first photoionization measurements with Neon and Xenon.

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1. Introduction

This report is corresponding about the preparation and first photoionization measurements of a beamtime at the P04 variable Polarization XUV beamline at Petra III. Therefor a detector has been set up, that consists of an electron Time-of-Flight (eTOF) spectrometer and an ion Time-of-Flight (iTOF) spectrometer.

In Time-of-Flight mass spectrometry, ions are accelerated by an electrical field to the same kinetic energy with the velocity of the ion depending on the mass-to-charge ratio. Thus the Time-of-Flight is used to measure velocity, from which the mass-to-charge ratio can be determined. The Time-of-Flight spectroscopy for electrons is used to measure their kinetic energy.

In addition a mobile laser system has been installed at the P04 beamline for time-resolved measurements. Depending on proper adjustment of various parameters such as position, electric fields and the optical path the combination of eTOF and iTOF allows simultaneous measurement of electrons and ions from single ionization processes. This principle is called coincidence spectroscopy and is applied for investigation of dynamics in atoms and molecules after ionization. Because of its photon energy range of 250-3000 eV the P04 beamline is well suited for photoionization as the initial process in the work of the coincidence spectrometer.

An important requirement for coincidence spectroscopy is the efficiency of the detector, which means that measurement of all electrons and ions from a single ionization event is desirable. Therefor the spectrometer makes use of electric fields for efficient ion detection on a microchannel plate (MCP) detector. For the efficient measurement of electrons an additional magnetic bottle type field is needed that guides electrons to a second MCP detector.

2.1. Experimental Setup – The Coincidence Spectrometer

A Time-of-Flight (TOF) coincidence spectrometer consists of a short Time-of-Flight spectrometer for ion detection and a so called *magnetic-bottle* spectrometer for electron detection.

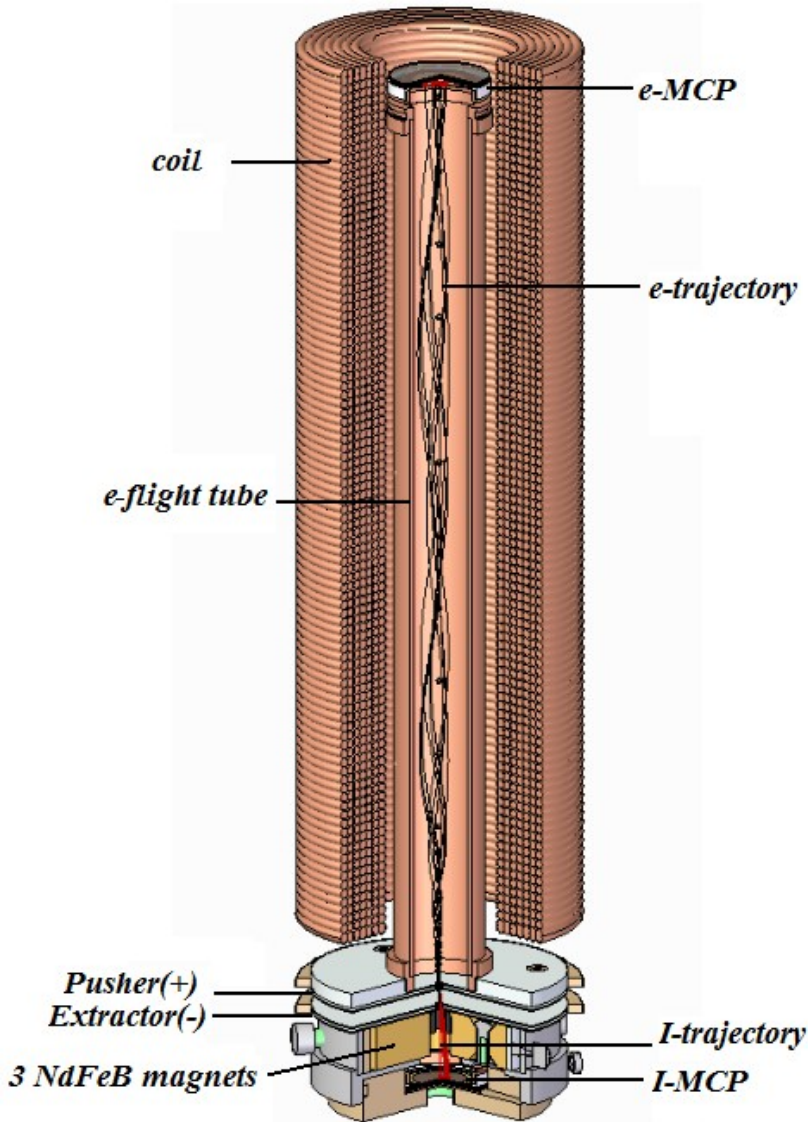


Fig.1. Setup of the TOF Coincidence Spectrometer

Pusher (+) has a positive charge; the lower plate called Extractor (-) has a negative charge. Therefore the relatively slow ions ($E_{\text{kin}} \sim 1/40$ eV) follow the electric field quite strictly towards the I-MCP, while fast electrons (E_{kin} up to several hundreds of eV) basically are emitted and fly under different angles. Therefore a magnetic bottle shaped field is used to guide electrons through the aperture of the pusher to the upper MCP-detector.

The iTOF spectrometer is based on the principles described by Wiley and McLaren [1]. The magnetic-bottle spectrometer is described by Kruit and Read [2]. Microchannelplates (MCPs) are used for the detection of electrons and ions.

The combination of both devices allows efficient investigation of photoionization processes [3].

The Wiley/McLaren spectrometer resolution depends on the length of the flight tube and the strength and ratio of E_1 & E_2 , where E_1 is the electric field in the ionization region and E_2 is used as additional ion acceleration (Fig.2).

Photoionization occurs between two titanium plates with different charges. The upper plate called

The magnetic bottle is formed by the superposed fields of three 1.4 Tesla NdFeB-magnets for the “bottle neck” that generates flux densities up to 600 mT near the interaction zone. A structure of the magnetic bottle is shown in figure 3.

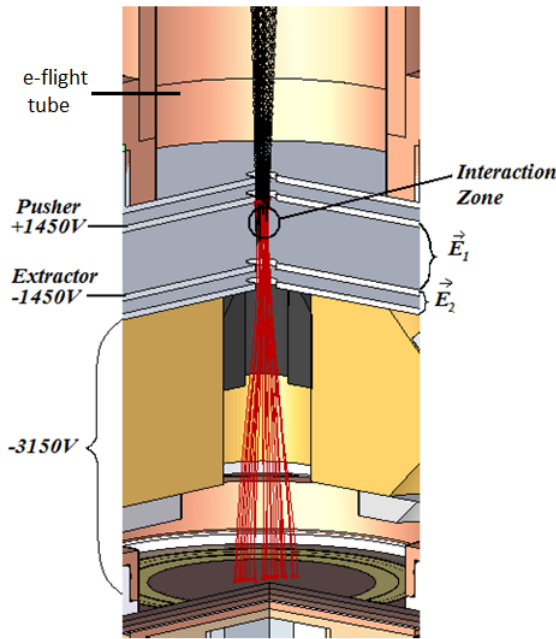


Fig.2. Interaction Zone between Pusher (+) and Extractor (-) and trajectories of electrons (black) and ions (red)

The magnetic bottle is able to collect up to 100% of the electrons and guides them to the detector at the end of the electron flight tube. This tube is located inside the coil.

A structure of the magnetic bottle is shown in figure 3. An electron initially emitted at an angle θ to the z direction, with an energy E and velocity v , undergoes helical motion in the field B because of Lorentz force.

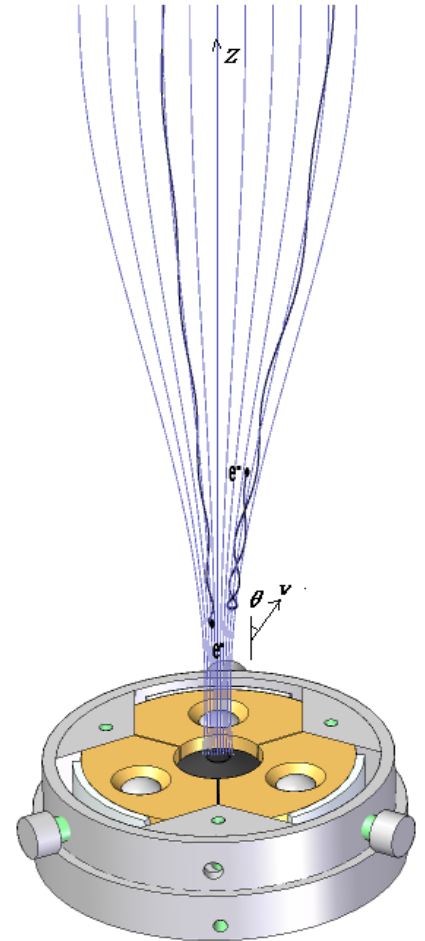


Fig.3. Three NdFeB magnets and schematic diagram showing the helical motion of an electron moving in a magnetic field that changes gradually from a strong field in the magnetic bottle neck to a weaker uniform field inside the coil

Depending on the electron energy the magnetic bottle is able to guide electrons through the hole in the pusher to the eTOF-MCP detector. The electric field helps to guide them almost along a one straight line.

The advantage of the inhomogeneous magnetic field is the conservation of momentum even when electron trajectories turned to the direction of the electron.

2.2. Experimental Setup – The Mobile Laser System

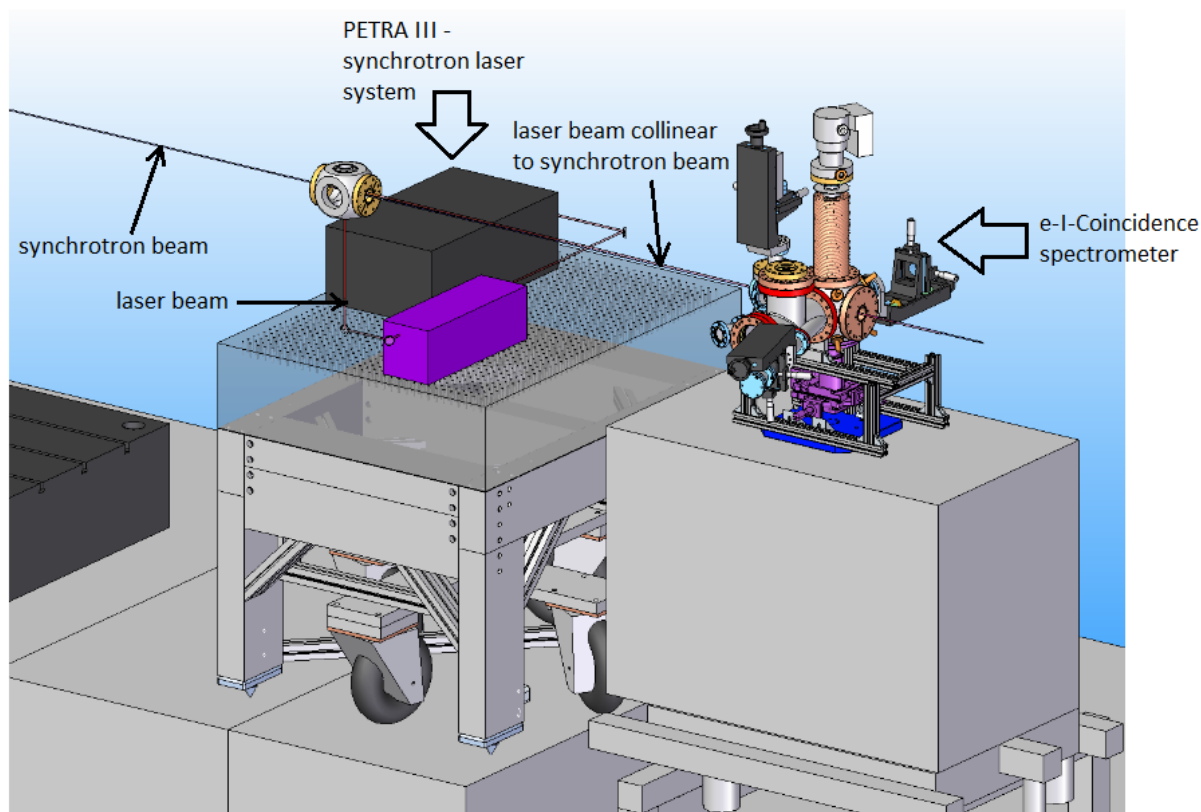


Fig.4. Schematic representation of the direction of beams of the laser and synchrotron

For the beamtime a mobile laser system from the Dynamix-Group of the University of Hamburg has been installed at the P04 beamline. As a laser wavelength of 343 nm is needed this is generated as the third harmonic of a 1030 nm fundamental.

The laser beam is coupled into the vacuum system nearly collinear to the synchrotron beam with various mirrors. Shortly before the laser reaches the spectrometer it is focused that the focus of the laser falls and the synchrotron beam fall together in the interaction zone of the spectrometer. This is controlled by a screen/camera system connected with spectrometer. Besides this spatial overlap of both beams, a temporal overlap with arbitrary delay is also available.

After adjustment of electric fields, positions and the optical path first calibration measurements with Xenon were made.

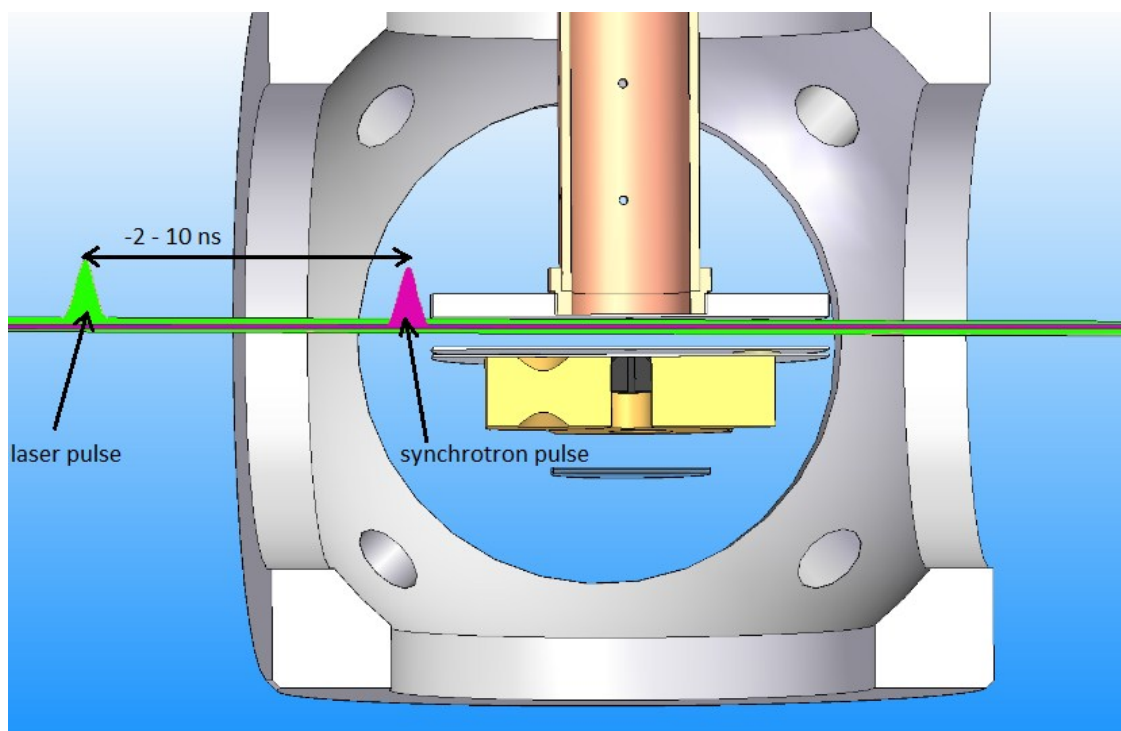


Fig.5. Schematic of delayed laser pulse and synchrotron pulse

4. Results

The known abundances of the xenon isotopes displayed are 128, 2%; 129, 26.4%; 130, 4.1%; 131, 21.2%; 132, 26.9%; 134, 10.4%; 136, 8.9%.

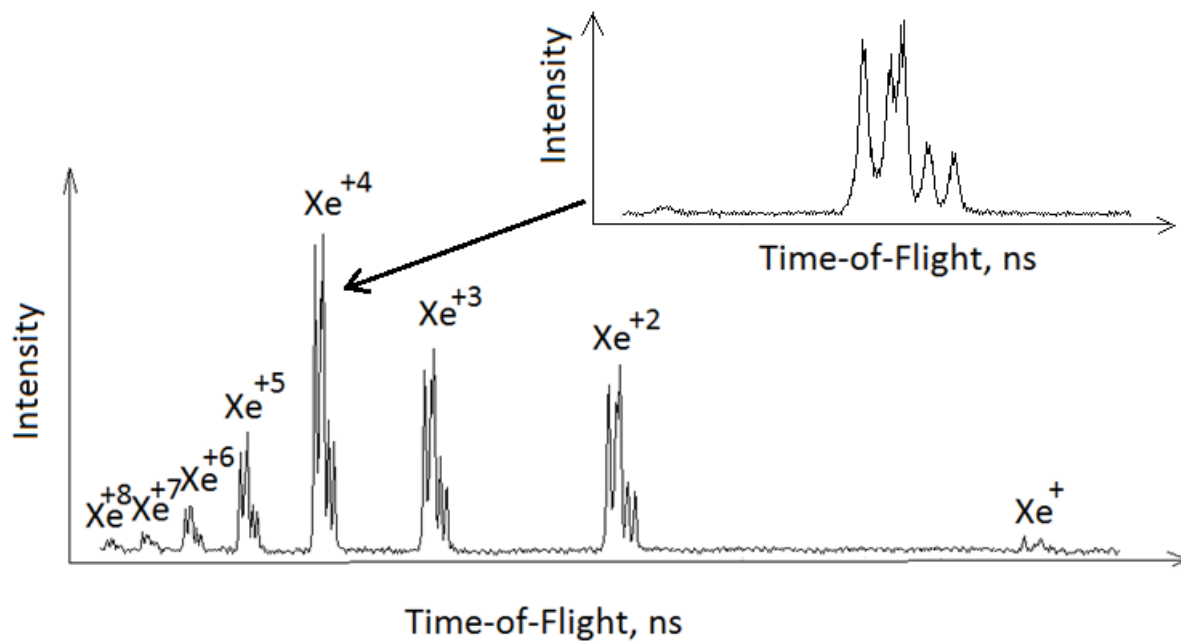


Fig.6. Photoion spectrum of Xenon and zoomed spectrum of Xe^{+4} ($E_{\text{phot}} = 674 \text{ eV}$)

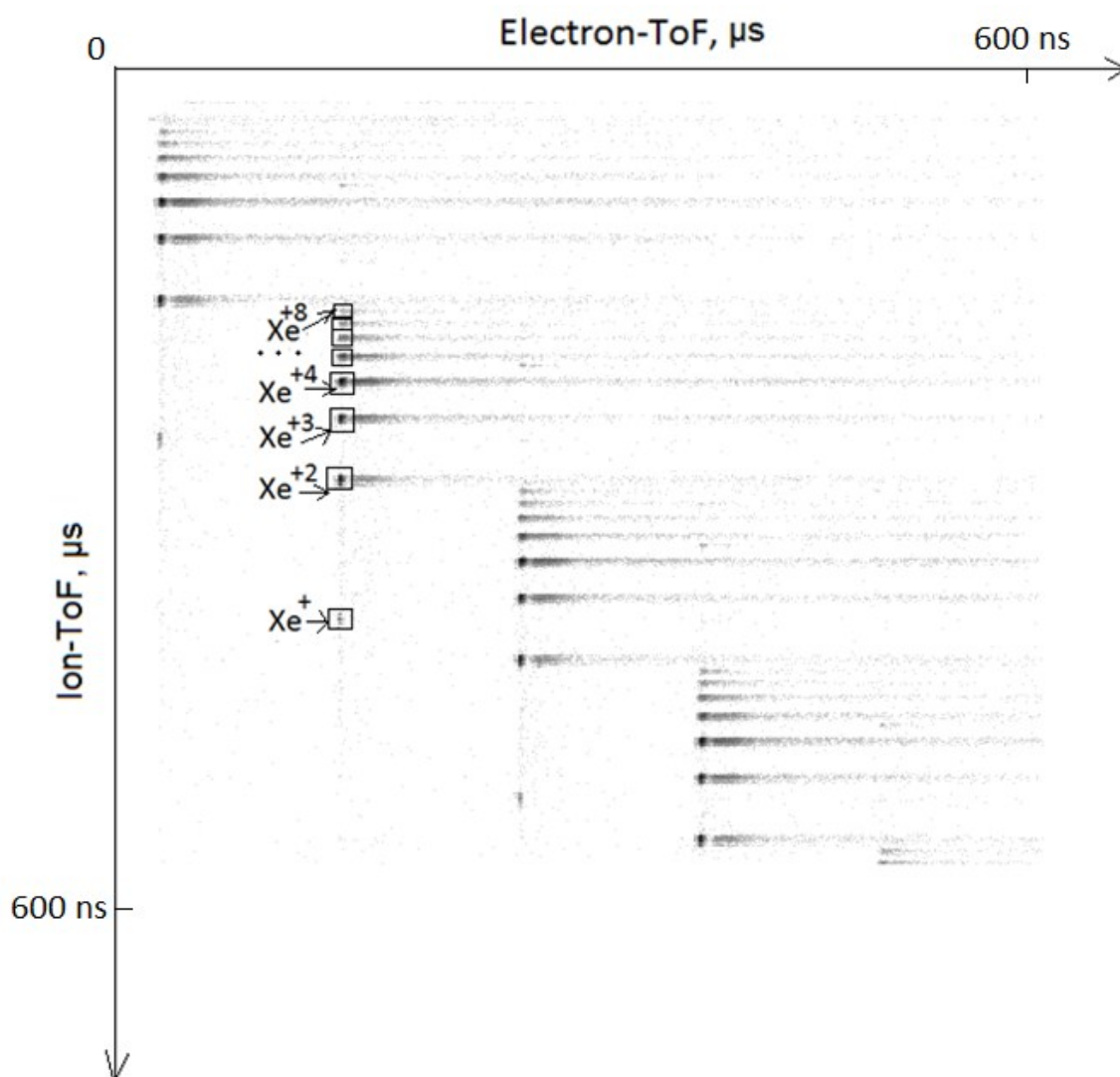


Fig.7. Xenon e^-I^+ -Coincidence map

Figure 7 presents a Xenon e^-I^+ -Coincidence map. In this experiment I^+ -resolution is increased which results in a reduced e^- -resolution. In addition to the different charge states - which can be measured also with simple photoion spectra - also the electron-TOF for electrons that belong to different charge states is measured. So coincidence measurements contain information about all possible decay paths after photoionization that lead to different charge states. This is even more interesting for measurements of molecules that decay to different ions.

Another feature of coincidence measurements is that nearly noise free spectra are generated.

5. Acknowledgements

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