Photoelectron-Photoion-Coincidence Measurements with a new developed Spectrometer

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A new Time-of-Flight coincidence spectrometer was developed for photo-ionization experiments in the first instance for the P04 Polarization XUV Beamline at PETRA III. The device consists of a short Time-of-Flight spectrometer for ion detection, using electrostatic fields according to the principle of Wiley and McLaren [1], and a so called *magnetic-bottle* spectrometer for electron detection, that is described by Kruit and Read [2].

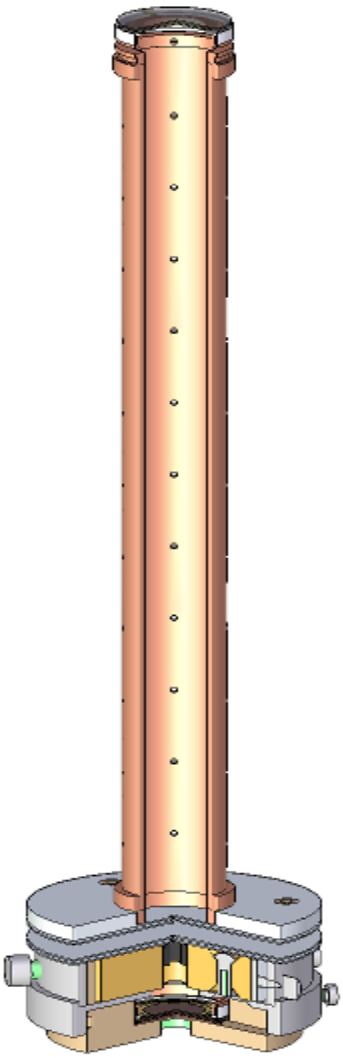

Fig 1:
Setup of the coincidence spectrometer. The upper end of the electron flight tube is closed with a MCP-detector. The ion flight tube is built by the gold colored magnets, that form the "bottle neck".

The magnetic bottle collects up to 100 % of the photoelectrons and guides them to the detector at the end of the electron flight tube (copper colored tube in fig. 1). The magnetic bottle is formed by the superposed fields of three magnets (NdFeB, 1.4 T) that generate the „bottle neck“ with flux densities up to 600 mT and the homogeneous field of a coil of about 10 mT in the electron flight tube. This configuration allows to bend up to 100 % of the electron trajectories towards the MCP-detector, that is placed at the end of the flight tube (s. fig 2).

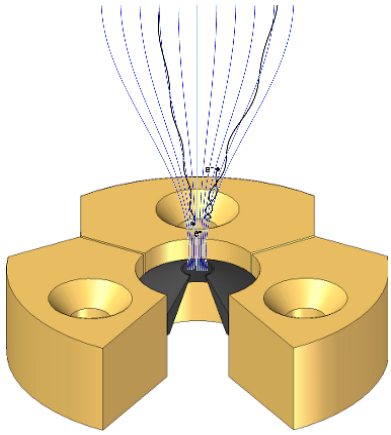

Fig. 3:
Three NdFeB-magnets with magnetization towards the softiron polecap forming the magnetic bottle neck.

For electron-ion coincidence measurements it is reasonable to place the ion-Time-of-Flight spectrometer opposite to the electron-spectrometer. Therefor a hole is in the center of the magnets, that serves as an ion flight tube. Because of the longer flight times of heavy ions compared to electrons, the ion flight tube is as short as possible. For more details and performance see [3].

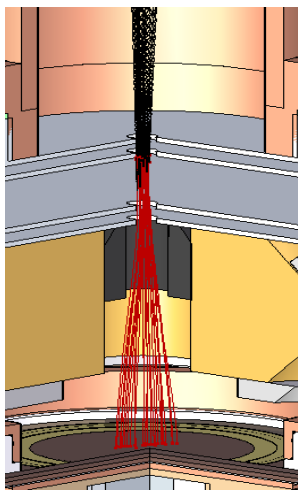

Fig. 2:
Photoionization takes place between two plates of aluminum with positive (upper plate) and negative voltage (lower plate). Ions (black trajectories) are pulled to the MCP-detector below the gold colored magnets. The influence of the magnetic field to the heavy ions is negligible while it is needed to guide higher energy electrons through the electron flight tube to the detector.

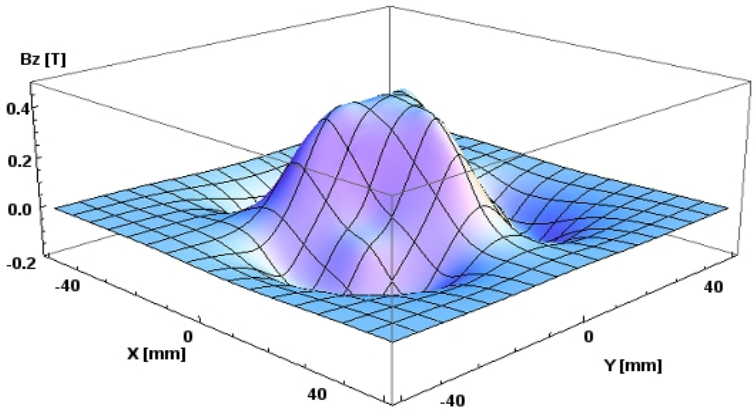

Fig. 4:
Simulation of the vertical magnetic field component, 5 mm above the magnets surface (fig.3). Measurements at the HASYLAB undulator lab differed up to only 5 % from simulation what lies within hoped expectations.

Various magnetic assemblies have been characterized in the HASYLAB undulator lab with the help of the FS-US group. We gratefully acknowledge their support in particular by Paul Neumann, Sumit Tripathi, Orkidia Zeneli, and Markus Tischer.

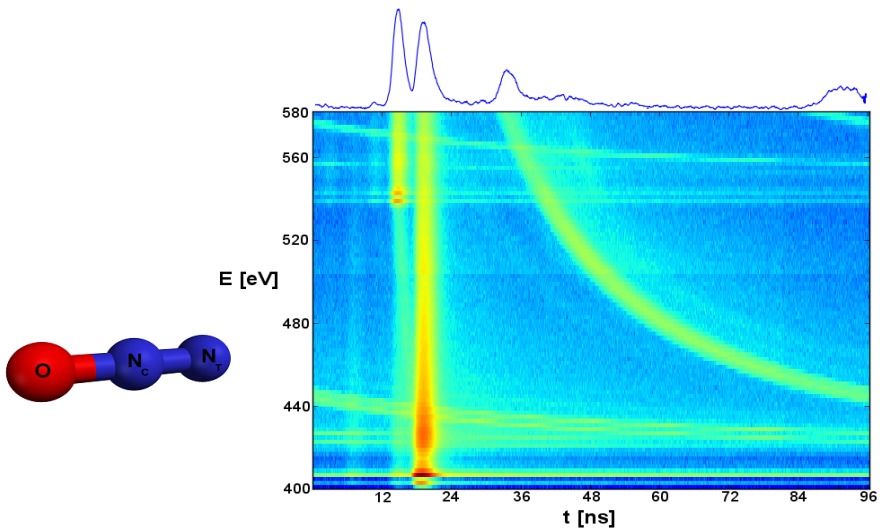

Fig 5:
Series of Electron-Time-of-Flight spectra for N_2O taken at the BW3-Beamline at DORIS III. Intensities of single Time-of-Flight spectra were color coded and stacked for an overview at different photon energies (vertical axis). As an example the photoelectron spectrum at 580 eV is placed on top.Amongst others the resolution of the electron was tested with photoionization of the N_2O molecule, where binding energies of the both 1s-electrons of the Nitrogen differ by ~4 eV (408.5 eV & 412.5 eV). Both lines can be resolved up to at least 490 eV.

References

[1] P. Kruit, F.H. Read, J. Phys. E 16 (1983) 313
[2] W.C. Wiley, I. H. McLaren, Rev. Sci. Instrum. 26 (1955) 1150
[3] S. Deinert, et al., HASYLAB Annual Report 2010, Development of a Highly Efficient Electron-Ion-Coincidence-Spectrometer