Spatial characterisation of the internal gas target at the ESR for the FOCAL experiment

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The FOCAL experiment involves a highly accurate twin crystal spectrometer, designed to measure the Lamb shift of stored highly charged ions, like hydrogen-like Au^{78+}, with an accuracy down to the few-eV level where higher-order QED contributions become accessible [1]. Since the geometrical configuration of the whole apparatus is of crucial importance, all parameters influencing the final value have to be known as accurately as possible. In this annual report we present our efforts to characterise the internal gas target [2, 3] at the ESR at GSI Darmstadt were in 2012 the FOCAL experiment was conducted.

In the accurate spectroscopy of fast moving ions a recurring task is the transformation of the measured wavelength in the laboratory frame back to the wavelength in the emitter frame. The according relation between the laboratory wavelength λ_{lab} and the emitter wavelength λ_{emitter} is the relativistic Doppler formula

$$\lambda_{\text{lab}} = \lambda_{\text{emitter}}\,\gamma\,(1-\beta\cos(\theta_{\text{lab}})) \qquad (1)$$

with two main unknown: The first unknown is the velocity of the ions hidden in the Lorentz parameters β and γ, the second one is the observation angle θ_{lab} under which the x-ray emission is measured. The velocity can be determined (in case of the ESR) with very high accuracy with the electron-cooler voltage. For determining the observation angle θ_{lab} one has to know the position of (i) the detector and (ii) the position of the emitter. In the FOCAL experiment conducted in 2012 as in many other experiments the position of the x-ray emitter is the volume defined by the intersection of the stored ion beam and the internal gas-jet target of the ESR. Since the detectors where accurately aligned with the help of optical telescopes just before the beam time the remaining unknown is the position and the density distribution of the gas target. Therefore the experiment presented in this report was conducted.

To measure the position, the diameter and the density distribution of the internal gas target of the ESR we decided to use a mechanical gas-scatter approach. At the low particle density of the gas target of only 10^{11} particles/cm^3 encountered other methods considered such as photon scattering or photo absorption/re-emission suffer from prohibitively low event rates. The probe used consisted of an aluminium body on which a Constantan wire of 0.6 mm diameter is tensed. If the gas jet hits the wire the pressure in the target chamber will rise which can easily be detected by standard methods. In order to scan the frame over a suitable position range it was mount on a linear actuator installed under 35° with respect to the ion-beam direction. All anchors for the wire are placed in a way that the wire runs parallel or perpendicular with respect to the ion-beam axis. Therefore it is possible to measure the density profile of the gas target in north-south (longitudinal) and east-west (transversal) direction and to determine a position centroid. In addition to the wire anchors there are also three fiducial marks used by the telescopes located left and right of the ion axis and in-line with the vertical gas-jet, respectively. This alignment is needed to relate our probe and hence the measured gas target position with the reference frame of the ESR.

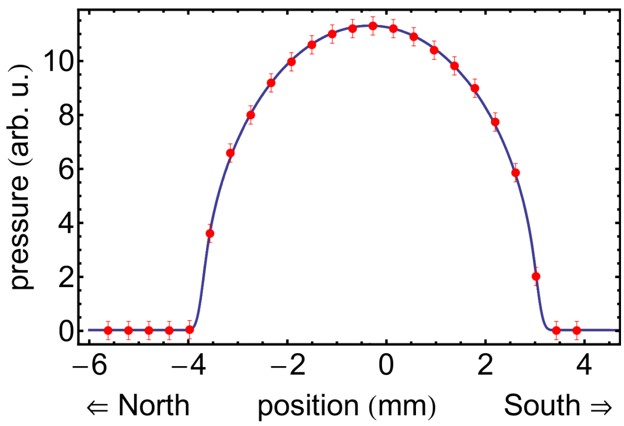

Figure 1: Measured pressure in the target chamber (red dots) as a function of the wire position. The blue curve is the best fit of our model which assumes a round gas-jet, with constant particle density in the center.

Figures 1 shows the measured pressure rise in the target chamber (red dots) and the best fit of our model (blue curve) assuming constant density in the central region of the round gas target. The measurement values are in good agreement with the model enabling us to determine the position and the diameter with an estimated uncertainty of ±0.3 mm dominated by small telescope imperfections leading to a significant reduction of systematic uncertainties.

References

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