X-ray spectroscopy as a tool to enlighten the growth of Van der Waals nanoparticles in a supersonic jet

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Since many decades, studies of collision processes of electrons, photons and heavy particles interacting with matter (from gaseous to solid) are an important tool in physics to understand the internal structure of matter at atomic level (or at nanoscale) as well as at very short time scale (down to fs). For example, recently, pump-probe experiments with IR and XFEL photons allowed probing the morphological structure of an isolated Van der Waals cluster by time resolved imaging [1]. Taking advantage of x-ray spectroscopy, which acts also as a very short time probe, we have investigated the μs temporal structure of the cluster condensation in high-density rare gas expansion (supersonic beams). Briefly summarized, we have previously demonstrated that the x-ray emission allows to determine: i) the absolute total atomic density when the cluster jet is submitted to keV electron impact; ii) the relative cluster density profile when interacting with an intense IR femtosecond laser pulse; iii) and finally the free atom density when irradiated by slow highly charged ions.

These first experiments led to the determination of a high degree of condensation (close to 100 %) of the clusters in the supersonic beam when using a skimmer [2]. These results have also paved the way towards new questions: what is the temporal evolution of the thermodynamic growing of clusters? What is the saturation time, needed for having stationary flow conditions in the beam?, etc. To obtain deeper information on the growth of Van der Waals nanoparticles in a supersonic jet, we are performing new experiments with our set-up at the SIMPA facility (French acronym for "Highly Charged Ion facility in Paris") using Ne^{9+} of 90 keV on argon. Figure 1 shows a comparison of the temporal x-ray signal when the supersonic jet interacts with 10 keV electrons and Ne^{9+} ions for a backing pressure of around 20 bar upstream a conical nozzle with a 300 μm aperture diameter and using a skimmer of 500 μm. Clearly, the x-ray signal starts before with HCIs compared to electron impact. It is a clear signature of the high sensitivity of HCIs to probe very low free atomic density when the cluster begins growing, i.e. at a time scale that is not reachable with "traditional" techniques (like optical measurements). More systematic measurements are under progress and a complete set of results varying the cluster size will be presented. They will provide new insights on the thermodynamics of a supersonic beam and on the cluster formation.

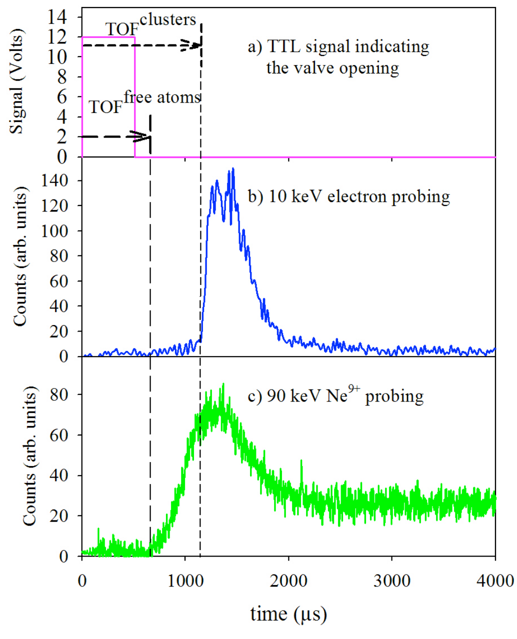

Figure 1: *Preliminary results of temporal clusters' x-ray emission in case of b) 10 keV electrons and c) 90 keV Ne^{9+} ions*

References

[1] T. Möller *et al.*, PRL **108** (2012) 245005

[2] M. Trassinelli *et al.*, J.Phys. Conf. Ser. **388** (2012) 082009