# Density enhancement of energetic charged particles with tapered glass capillary

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When a charged particle beam (slow highly charged ions as well as fast light ions) is injected in a macroscopic tapered capillary, it is effectively guided either via local charge up or via small angle scattering along the capillary wall and eventually extracted from the other side of the capillary even with considerable density enhancement as discussed during this Workshop (see e.g., talks by Ikeda, Kojima, Kobayashi, Meissl and Kanai), where a single tapered glass tube and a micro multi-capillary are used as targets. Although insulating materials were not favored for a long time because of unpredictable charge-up behaviors, the situation has changed recently, and various interesting and "rational" phenomena in charging and discharging processes of insulators have been observed. Here such guiding and density enhancement effects with tapered capillaries are briefly summarized with some emphasis on fast muon beams.

The guiding effect was first reported by N. Stolterfoht in 2002 [1] for micro multi-capillaries as targets with slow highly charged ions (3keV $Ne^{7+}$). We have extended the investigation to (1) single tapered glass capillaries[2] and teflon tubes, which show not only a guiding effect but also a density enhancement effect, (2) a pair of glass plates separated by ~0.1mm, which again show a similar guiding effect even in the direction parallel to the plate surface [3]. It is expected that these phenomena are the result of self-organized charging and discharging of the insulator surfaces.

A similar effect was also observed for a MeV ions transmitted through tapered glass capillaries [4] as well as fast muons [5], where multiple small-angle scattering would play a decisive role. As an application of the tapered glass capillary technique, we have prepared a single tapered glass capillary with a thin window at the tip so that the fine ion beam can be introduced in a microscopic volume of an arbitrary point in a macroscopic target. Some applications of this technique to various biological targets are also discussed during the workshop [6].

[1] N. Stolterfoht, J.-H. Bremer, V. Hoffmann, R. Hellhammer, D. Fink, A.Petrov, and B. Sulik, Phys. Rev. Lett. **88** (2002)133201.

[2] T. Ikeda, Y. Kanai, T. M. Kojima, Y. Iwai, T. Kambara, Y. Yamazaki, M. Hoshino, T. Nebiki, and T. Narusawa, Appl. Phys. Lett. **89**(2006) 163502.

[3] G.Pokhil, et al., private communications

[4] T. Nebiki et al., J. Vac. Sci. Technol. A 21 (2003) 1671.

[5] T.M.Kojima et al., J.Phys.Soc.Jpn 76(2006)093501, D.Tomono et al., *ibid* 80 (2011)044501.

[6] Y.Iwai et al., Appl. Phys. Lett. 92 (2007) 023509.