5.2. A fast mercury jet entering a 20 T field

The purpose of these measurements is to provide benchmarks for simulation tools of a realistic free mercury jet target such as the one foreseen in neutrino factories [1]. These measurements, started in 2001 [2], were completed in June 2002 with an improved setup. A detailed description and analysis is presented in [3].
The test setup consists of a compressed air driven double piston pump feeding a 4 mm inner diameter cylindrical nozzle generating a pulsed mercury jet (~ 200 ms duration). The read-out is based on observation with a high speed camera. The injection of an 11 m/s mercury jet at an angle of 0 and 6 degree into a 20 Tesla field (M9, 130 mm bore) was observed. The velocity, the width and the deflection angle of the jet were measured as a function of the magnetic field strength.

With increasing field, the smoothness of the jet envelope is clearly improved thus demonstrating the expected damping of the surface oscillations. This can be clearly seen in Figure 5.3 where the larger and faster fluctuations of the diameter of the field free jet are suppressed by one order of manitude at 20 Tesla. The amplitude is then of the order of the spatial resolution of the camera system (~ 0.33 mm/pixel). The damping of disrupted jets, simulated with highly turbulent jets, could not be observed.
A 4 mm diameter jet injected in a 20 Tesla field stabilised at the desired injection angle within 10 ms (Figure 5.3). Minor misalignments or oscillation around the axis of the jet cannot be excluded. A larger jet such as the one proposed in neutrino factories would under similar conditions take more time to stabilise. A delay of 20 ms are available between proton pulse induced disruptions.
With increasing field, the tip gets thinner. On injecting a mercury jet into a magnetic field, the acting repulsive force resulted in a shaping of the tip of the mercury jet towards a “rocket” geometry.
The injection of the inclined jet showed no deflection.
The pinching is illustrated in Figure 5.4 (left), for two different static driving pressures, resulting in different velocities of about 9 and 11 m/s. The width of the jet decreases with increasing magnetic field by ~15%.
Jet velocities are presented in Figure 5.4 (right) as a function of the magnetic field strength. The expected tendency for the velocity of the jet to be reduced with increasing field is observed. Independent of the injection angle the velocity is about 25 % less at highest magnetic field.

The observed reduction of velocities by about 25 % in a 20 Tesla field is significantly larger when compared to the predictions of free jets. Thus underlining the importance of MHD effects occurring in the piping and in the valve specific to our experimental setup.
The welcome damping of jet instabilities is an asset for the final scheme of the target area. The narrowing of the jet by 15 % requires a full simulation of the injection circuit.

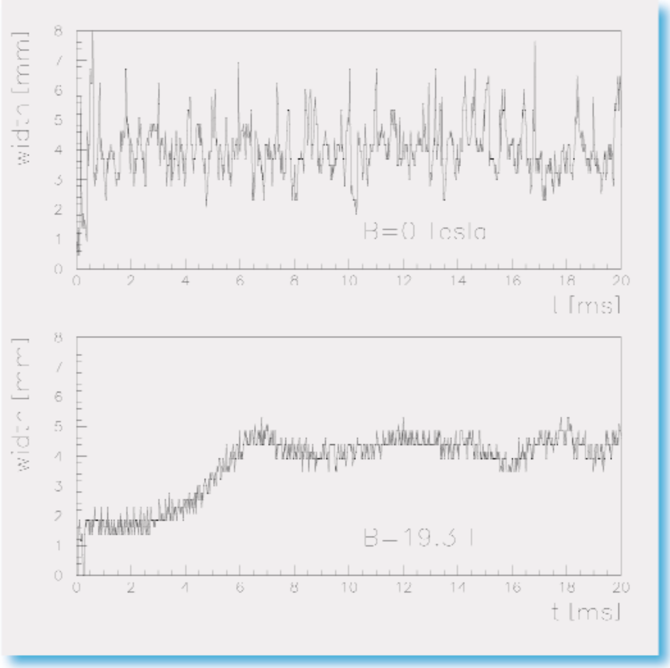

Figure 5.3: The width of the jet as a function of time at no magnetic field and at B = 19 Tesla. A clear smoothing of the jet shape at 19.3 Tesla is visible.

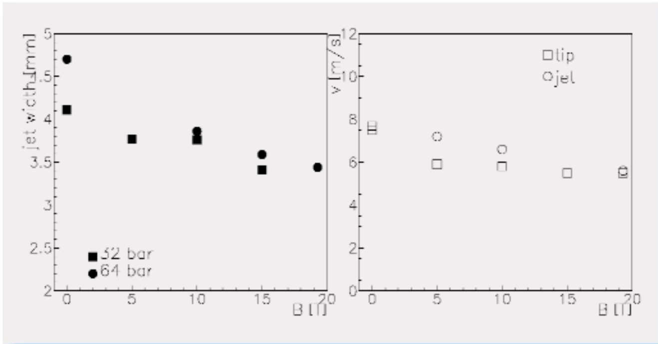

Figure 5.4: The pinching (left) and the velocity (right) of the jet as a function of the magnetic field strength. The decrease in the width is shown for two different driving pressures.

References and authors:

[1] http://www.cap.bnl.gov/mumu/studyii/
[2] GHMFL, Annual Report 2001
[3] A. Fabich, High Power Proton Beam Shocks and Magnetohydrodynamics in a Mercury Jet Target for a Neutrino Factory, CERN-THESIS-2002-038

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