7.1. Liquid metal jet into a high magnetic field

In the frame work of a ν-neutrino factory [1], 10^{21} high energy neutrinos are directed towards far located ν-detectors with the aim of measuring the parameters of their mixing matrix. The production chain starts with the interaction of high-energy protons on a target. Possibly the resulting pions are collected in a permanent 20 T magnetic field and lead into a decay tunnel were they decay into regular muons. The molten metal target foreseen in the collection schemes of future neutrino facilities are among the rare technical solutions able to cope with the very large energy densities of the proton beam and among them mercury was chosen as a test case. The question to be addressed concerns the behaviour of the molten metal within the 20 T magnetic field. Its most basic geometry namely a perfect mercury cylinder penetrating into a 20 T coaxial solenoid was addressed numerically and shows major deformations [2]. Therefore, experimental benchmarks are required.

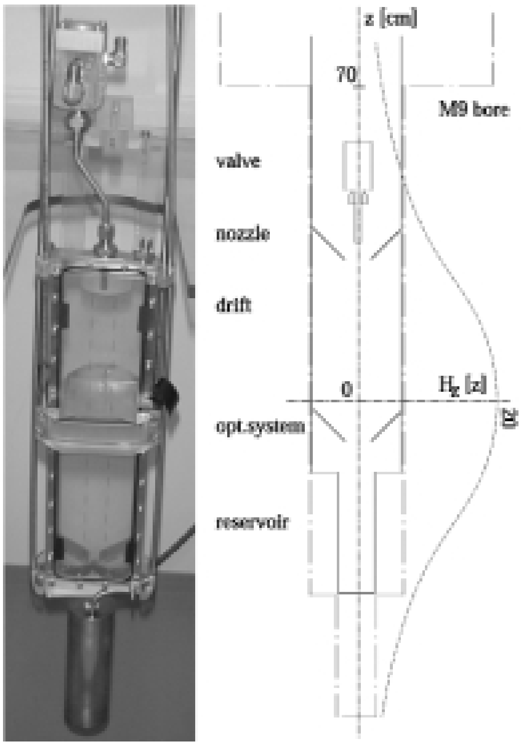

Figure 7.1: Left: jet chamber; right: schematic setup in the magnet bore M9.

The goal of the proposed experiment is to record by photographic methods the MHD effect on a pulsed mercury jet entering solenoidal field under an injection angle of 0° and 6°. The jet behaviour is monitored with a high-speed camera (up to 8000 frames per second).

- M5: 0-13 Tesla solenoid (vertical bore 13 cm): Collinear injection in a field gradient dB/dz of –60 to 60 T/m: At velocities of ≈ 5 m/s a modification of the tip of the jet was observed for the highest gradient. No other visible effects were observed at higher velocities. The turbulence of the jet is likely to hide effects leading to a deformation below 0.5 mm.

- M9: 0-20 Tesla collinear injection in the field gradient. Clear deflection and disruption of a Hg-jet pulsed through a cylindrical nozzle were recorded. The experimental chamber was kept under vacuum and the optics allowed the observation of a 4 cm diameter surface movable along the field axis over a distance of 20 cm. The Hg-jet experienced a deflection from the axis of the bore increasing with the field strength (figure 7.2). A major reduction of the jet velocity was observed, however analysis is underway to determinate its cause (friction of drops on the windows, MHD effects in the Nozzle or in free flight).

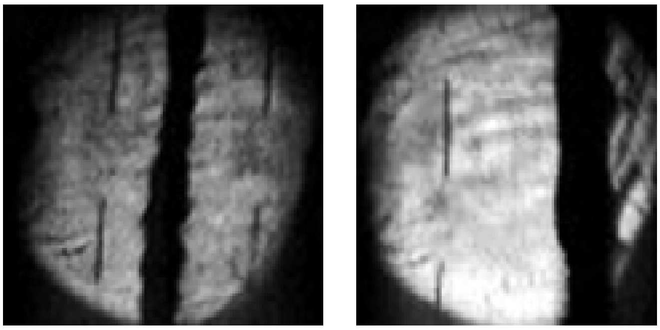

Figure 7.2: Displacement of the jet trajectory: left: B = 0 T, right: B = 15 T. The displacement of ≈ 1 cm can be clearly seen.

Two technical difficulties were encountered:
- the movement induced by the reactive force of the nozzle induced a displacement of the parallel laser beam away from the camera objective (solved in-situ by insertion of a wedge),
- the diameter of the mercury reservoir was designed for a 55 mm bore outlet not matching the equipment in place (50 mm) (figure 7.1). No attempt was made to modify the equipment, as the first problem required frequent adjustments and the only solution would have been against the double confinement that effectively prevents any mercury leakage.

The 20 data sets recorded during the third day contains sufficient information to characterise the case of collinear injection were the nozzle is out of the homogeneous field section and underlines the real challenging task of injecting a molten metal target in a high magnetic field. The apparatus has now overcome its youth disease and is ready for the production of the expected results.

References and authors:

[1] http://home.cern.ch/nfwg
[2] http://pubweb.bnl.gov/people/rosamu/MHD/

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