# A FEASIBILITY EXPERIMENT OF A W-POWDER TARGET IN THE HIRADMAT FACILITY AT CERN

N. Charitonidis*, I. Efthymiopoulos, A. Fabich, CERN, Geneva, Switzerland
O. Caretta, T. Davenne, C. Densham, P. Loveridge, RAL - Chilton, OX110QX, United Kingdom
L. Rivkin, EPFL-LPAP, CH-1015, Lausanne, Switzerland

*Abstract*

Granular solid targets made of fluidized tungsten powder or a static pebble bed of tungsten spheres, have been proposed and are being studied as an alternative configuration for high-power (>1MW of beam power) target systems, suitable for a future Super Beam or Neutrino Factory. Due to the lack of experimental data on this field, a feasibility experiment was performed in HiRadMat facility of CERN to address the effect of the impact of the SPS beam (440 GeV/c) on a static tungsten powder target. Online instrumentation such as high-speed photography and laser-Doppler vibrometry was employed. Preliminary results show a powder disruption speed of less than 0.6 m/s at 3 $10^{11}$ protons/pulse while the disruption speed appears to scale with the beam intensity.

## INTRODUCTION

Following the validation in the proof-of-principle experiment MERIT at CERN [1], a free liquid mercury jet is considered as the present baseline for the Neutrino Factory target [2]. However, the technical challenges involved and in particular the safety constraints from the use of mercury, make its use less attractive should an alternative solution be found [3].

Granular targets of high-Z materials have been proposed as candidates for high-power targets [4] that offer several advantages and could be considered as valuable alternatives to mercury systems. Recent R&D work at Rutherford Appleton Laboratory in UK [5, 6] demonstrated that fluidized tungsten powder can be circulated in a loop to create a renewable target combining the advantages of a liquid target without the complexity from the use of mercury. The experiment HRMT10-WTHIMBLE at the HiRadMat facility of CERN/SPS [7] conducted a systematic evaluation of the proton beam induced disruption in a Tungsten powder target. The experimental run with beam took place on $31^{st}$ May 2012.

## EXPERIMENTAL SETUP & INSTRUMENTATION

The target consisted of Tungsten grains (typically diameter 60 $\mu$m) placed in a Titanium trough (length 300 mm). The trough cross-section is U-shaped with an inner width of 15 mm and a maximum height of 22.5 mm (Figure 1). The trough setup was surrounded by a double containment

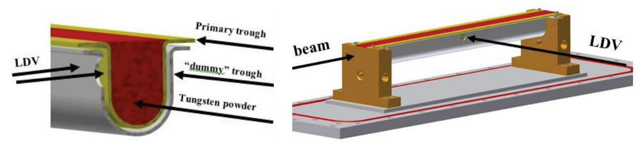


Figure 1: Detailed cut view (left) and full target trough indicating the measurment position of the laser-Doppler vibrometer

for safety reasons, where sapphire windows allowed a direct view onto the target trough (Figure 2). The target containment was filled with Helium gas at nominal 1 bar. The target setup was fixed to the standardized experimental table of HiRadMat, which allowed a fully remote installation (see Figure 3).

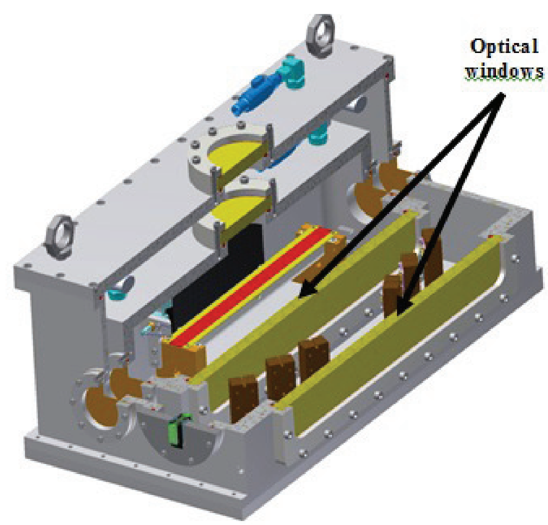


Figure 2: Section of the experimental sampler holder. The powder is depicted in red, the observation windows in yellow. 6 powerful LED-cluster stations placed inside the first container were used for the illumination of the target.

The proton beam intercepted the target horizontally aligned with the trough's long axis (see Figure 2), where the vertical position was 6 mm below the target top surface. The total pulse program consisted of 22 single pulses, where the intensity of the 440 GeV/c proton beam was varied from a few times $10^9$ to maximum 3 $10^{11}$ protons/pulse. The total beam on target accumulated to 3.3 $10^{12}$ protons.

* n.charitonidis@cern.ch, also at EPFL, Lausanne Switzerland

At maximum intensity the beam spot was about $\sigma$=1 mm in both planes.

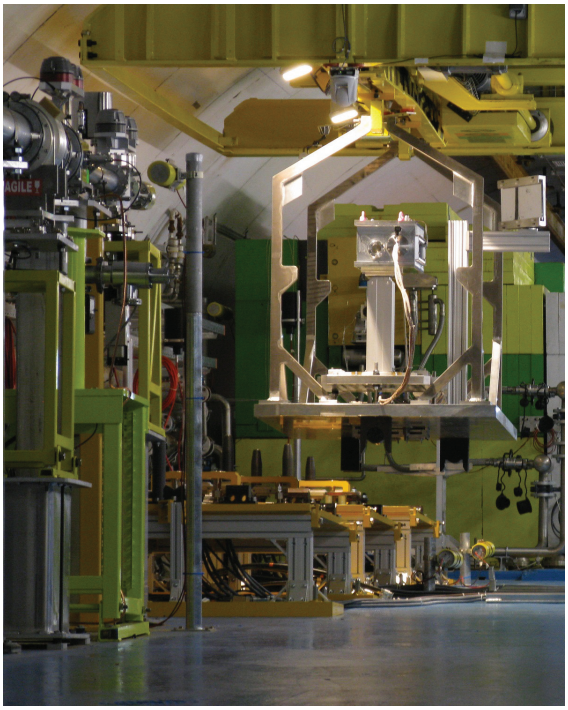

Figure 3: The remote installation of the HRMT10 experiment on the target position. In the left foreground the primary beam vacuum pipe is visible. The picture background shows the beam dump. On the right side of the trough setup one can see mirrors, which guided the light of the high-speed camera and the laser-Doppler vibrometer.

Two different observation concepts were applied quantifying the target reaction to the proton beam exposure: A high-speed camera for optical observation of the powder erruption and a laser-Doppler vibrometer (LDV) recording the beam induced shock waves. For avoiding prompt radiation induced damage to the electronic devices, both instruments were placed in a concrete housing at a distance of about 35 m from the target. A system of mirrors guided the optical view and the LDV laser to the target position. The high-speed camera had a total object view of 12 cm by 9 cm, where the resolution was 0.15 mm/pixel at a frame rate of 2 kHz. The Laser-Doppler vibrometer, with a maximum recording frequency of 10.24 MHz, was pointed at the longitudinal center of the target. Additionally, the primary sampler holder was surrounded by a "dummy" trough which, although having a similar geometry to the primary holder, was not directly in contact with the Tungsten powder. The dummy trough had a hole on the side in order to focus the LDV spot on the primary holder. A remotely controlled mirror allowed shifting the LDV spot from pointing to the primary powder holder to the outer dummy trough. This allows differing between shock waves directly induced in the trough material and the ones transmitted from the powder. Figure 1 highlights the impact point of the proton beam and the sampling point for the LDV.

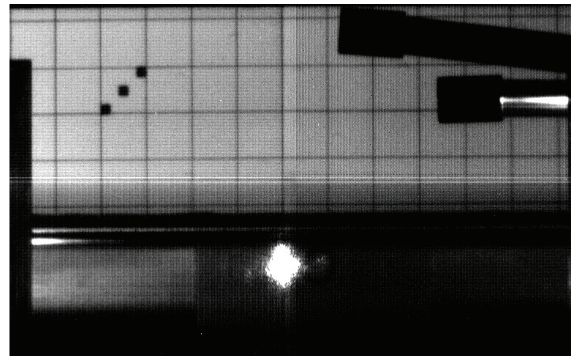

Figure 4: One frame as recorded by the optical observation system (before beam impact): The upper surface of the powder is located at the lower edge of the 1-cm grid. The beam direction is from the left. The bright spot in the lower part of the image is caused by the LDV laser beam, pointed at the trough.

## PRELIMINARY RESULTS

### *Optical Observations*

In Figure 5, the effect of 2 $10^{11}$ protons/pulse 37 ms after beam impact can be seen. In Figure 6 the disruption height as a function of time is shown for the same beam pulse, measured at a point near the theoretical shower maximum located at about 11 cm downstream the target entrance. Initially the powder is accelerated reaching a maximum velocity about 10 ms after beam impact. At this time the powder tip moved already a couple mm and the continuing acceleration cannot be explained by thermal expansion of the target anymore. On top of the initial, instantaneous acceleration by the thermal expansion, the expansion of the heated of the helium atmosphere has an additional accelerating effect on the target material. The movement beyond 10 ms is fully described by gravity and the drag force on the Tungsten grains.

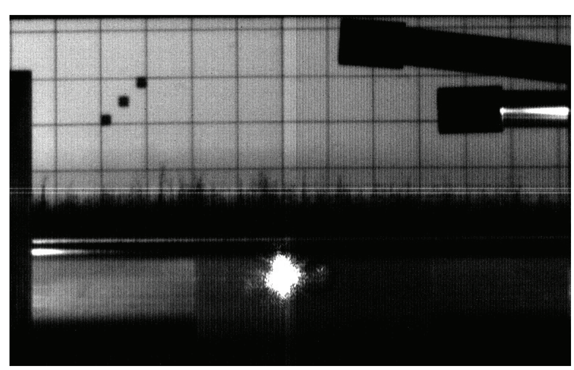

Figure 5: Powder erruption at 37 ms after beam impact: the powder has reached its peak position about 6 mm above the initial maximum position.

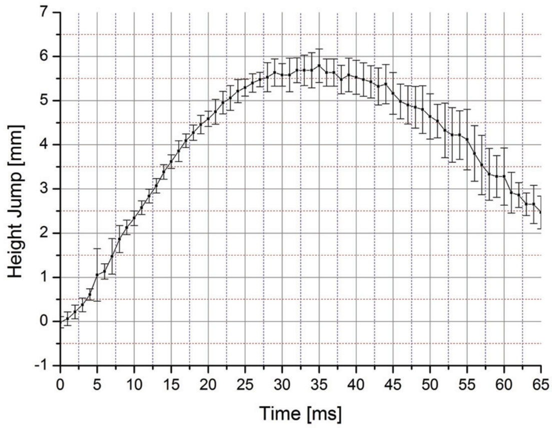


Figure 6: The disruption height as a function of time after beam impact of 2 $10^{11}$ protons/pulse.

Using pixel-by-pixel analysis of the high speed images of the powder movement, the maximum speed of the individuals events (22) was measured. A global analysis of all events shows that the initial disruption speed scales proportionally with the beam intensity as shown in Figure 7. The disruption speed does not exceed 0.55 m/s for a maximum intensity of $2.94 \times 10^{11}$ protons/pulse.

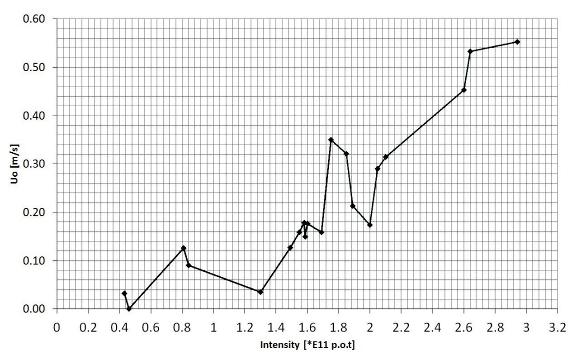


Figure 7: The speed of the target disruption is scaling with the intensity.

## *LDV Data Analysis*

Measured LDV data show a definite relationship to the physical events of the experiment although the experimental setup did not allow reference validation experiments before or after the irradiation. Despite some limitations on the LDV data analysis, such as the lack of absolute time stamp or the higher than expected amplitude of the trough vibrations, the frequency analysis up to today gives reasonable agreement with the simulations as far as the resonances of the containers are concerned. Additionally, the displacement velocity of the containers seems to correlate with the beam intensity (see Figure 8).

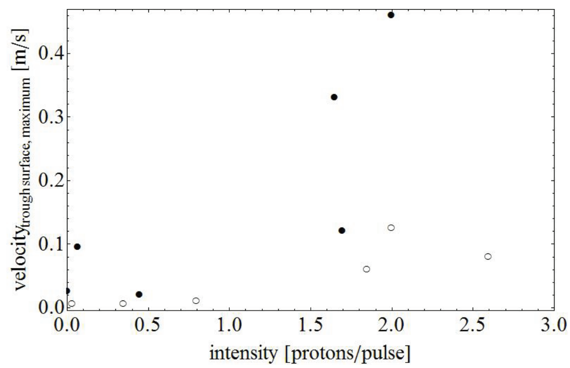


Figure 8: The containers displacement speed, as a function of the protons on target (p.o.t)

## SUMMARY

A feasibility experiment for a high-power tungsten powder target was performed in HiRadMat facility of CERN, using high-speed photography and laser-doppler vibrometry. Preliminary results show a disruption speed scaling with the beam intensity, which, at any case stays below 0.6 m/s at an intensity of 3 $10^{11}$ protons/pulse, and a displacement speed that scales with the beam intensity. It is envisaged continuing this experimental effort, e.g. repeating the experiment using an evacuated target chamber confirming the impact of gas expansion and collecting extended statistics on the influence of the beam spot size on the target disruption.

## REFERENCES

[1] I. Efthymiopoulos et al. The MERIT (nTOF-11) High Intensity Liquid Mercury Target Experiment at the CERN PS. EDMS No: 929446.

[2] IDS-CDR, https://www.ids-nf.org/

[3] J. Lettry. Review of target developments for a neutrino factory. London, UK : Proceedings of 4th NuFact'02 Workshop, 2002.

[4] P. Sievers, A stationary target for the CERN-neutrino factory. 2001. CERN-NuFact-Note-065 and Proceedings of NuFact-01 (Tsukuba).

[5] O.Caretta, C.J.Densham, T.W.Davies and R.Woods. Preliminary Experiments on a Fluidised Powder. Proceedings of EPAC 2008, Genoa, Italy,23-27 Jun 2008.

[6] O. Caretta et al., The potential of fluidised powder target technology in high power accelerator facilities. Proceedings of PAC09, Vancouver, BC, Canada.

[7] I. Efthymiopoulos et al., HiRadMat: A New Irradiation Facility for Material Testing at CERN, Proceedings of IPAC 2011, 4-9 September 2011, San Sebastien, Spain, reference:TUPS058