

Erratum: Materials adopted for particle beam windows in relevant experimental facilities [Phys. Rev. Accel. Beams **27**, 024801 (2024)]

Lorenzo Notari[✉], Michele Pasquali[✉], Federico Carra[✉],
Marcello Losasso[✉], and Marilena Tomut[✉]



(Received 23 November 2025; published 27 January 2026)

DOI: [10.1103/zhcy-yqqr](https://doi.org/10.1103/zhcy-yqqr)

Several clarifications are provided regarding the description, historical use, and configuration of various beam windows across the CERN accelerator complex. These clarifications concern the operational status of specific components, the correct identification of materials and layouts, and the upgraded designs introduced for LHC Run 3 and the high-luminosity LHC. The main points are summarized below.

(i) The proton beam exit window of the CERN Neutrinos to Gran Sasso (CNGS) experiment, previously cited as an example of a beryllium thin metallic foil applied onto C–C layers, is no longer in operation. The CNGS facility ended its physics program in 2012, and the corresponding proton transfer line was subsequently repurposed for the AWAKE experiment [1]. It is interesting to note that a 120 mm-diameter, 6 mm-thick glassy carbon window is in operation on the proton beam diagnostics line of the AWAKE experimental area, demonstrating the suitability of glassy carbon for beam dump applications [2].

(ii) The Study of beryllium MAterials Under vacuum and Glassy carbon (SMAUG) activities were previously associated with a private internal reference. This should be replaced with the publicly accessible work of Solieri *et al.* [3]. Within this framework, thick beryllium plates of grades S-200F and S-200FH have successfully withstood all high-intensity proton beam experiments performed at HiRadMat to date, providing strong evidence supporting their suitability for beam window applications. Silicon nitride (Si_3N_4) and silicon carbide (SiC) have also been considered for the final beam window of the ionizing-cooling stage of the proposed Muon Collider, as reported in Ref. [4]. Si_3N_4 is currently regarded as the leading candidate material. Further characterization—covering cryogenic to high temperatures and including irradiation tests under high-brightness proton beams—will be carried out in upcoming phases of the SMAUG experiment at HiRadMat, as detailed in Ref. [4].

(iii) It is considered appropriate to clarify the section describing the use of Ti–6Al–4V alloy for beam windows at CERN. This alloy has historically been employed in single-layer configurations, such as in the PS injection lines to the Antiproton Decelerator and in the mobile windows installed in the TT20 transfer line between the SPS and the North Area. When used instead as a thin foil bonded to a C–C plate, Ti–6Al–4V has been employed for the target extraction dump (TDE) windows located in the TT60/TI2 and TT40/TI8 transfer lines between the SPS and the LHC [5,6], as illustrated in Fig. 1.

(iv) Additional clarification is provided regarding the upgraded LHC target dump external (TDE) windows. In preparation for Run 3 and the HL-LHC upgrade, the entire TDE was redesigned to cope with significantly higher beam intensities and energy deposition—up to 539 MJ per dump released in just 89 μs —which imposed stricter mechanical and operational requirements. Among the upgrades, the original grade 2 titanium windows were replaced with Ti–6Al–4V alloy to improve strength and reliability under these extreme thermo-mechanical conditions. The upstream window features a thickness increasing from 10 mm at the center to nearly 40 mm at the edge, providing the necessary stiffness and allowing integration of the nitrogen pressurization system and monitoring instrumentation. The downstream window retains a uniform 10 mm thickness, optimized for the broader beam footprint resulting from particle showering inside the dump core [8]. Their geometries are shown in Fig. 2.

(v) It is considered appropriate to clarify the role and configuration of the entrance windows displayed in Figs. 7–9 of the original article. These figures refer to the ultrahigh-vacuum (UHV) window separating the LHC extraction line from the beam dump cavern, but the captions did not explicitly specify the function of this component nor indicate that the window shown in Figs. 7 and 8 was removed in 2021. At the end of 2021, this UHV entrance window—originally consisting of a carbon–carbon (C–C) plate combined with a 316L stainless steel foil—was replaced to withstand the higher beam intensities foreseen for LHC Run 3 and the future high-luminosity LHC, and to mitigate the increased risk of vacuum leaks caused by

Published by the American Physical Society under the terms of the [Creative Commons Attribution 4.0 International](https://creativecommons.org/licenses/by/4.0/) license. Further distribution of this work must maintain attribution to the author(s) and the published articles title, journal citation, and DOI.

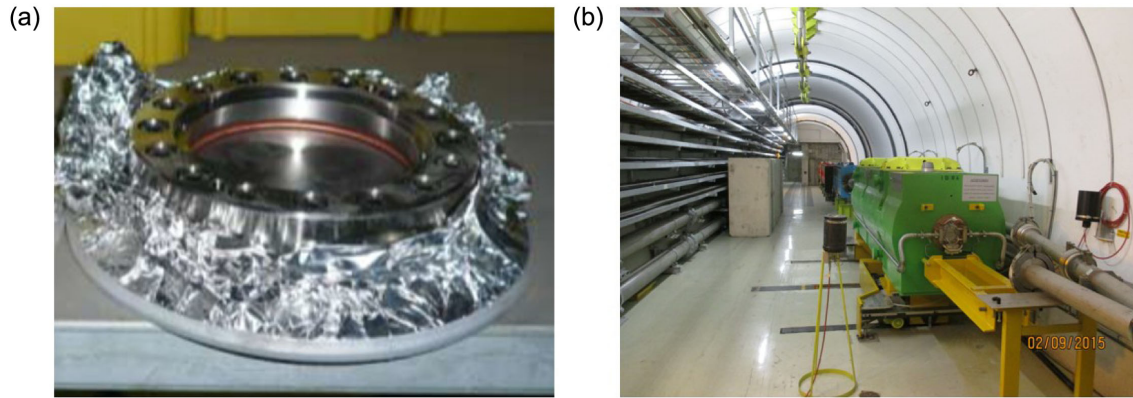


FIG. 1. (a) Picture of the target dump external window located at the beginning of the TI2 transfer line. (b) Image showing the TED installed in the LHC transfer line TT40, with a clear view of the Ti window on the front face of the graphite core [5,7].

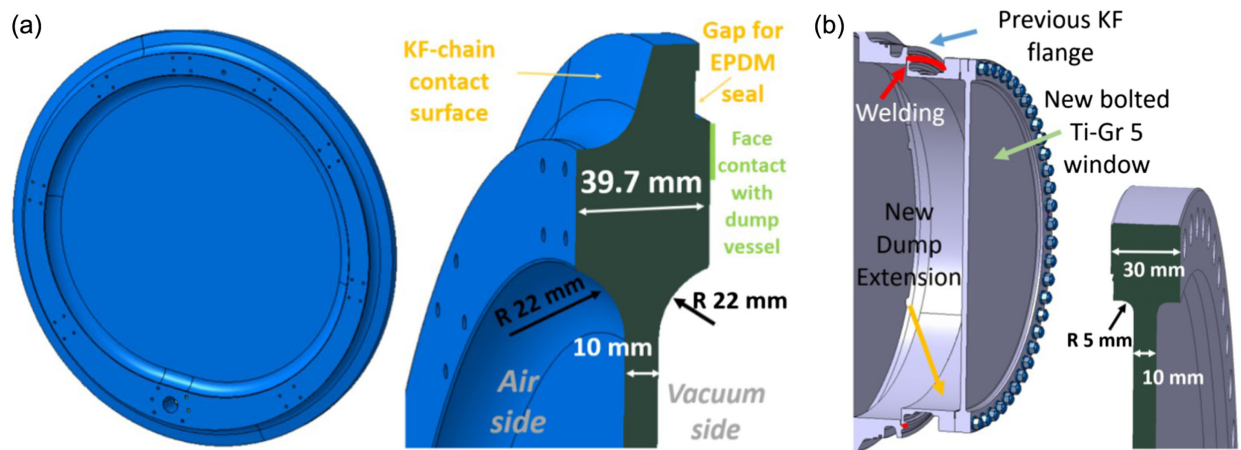


FIG. 2. Geometry of the upgraded TDE dump windows: (a) upstream window with variable thickness; (b) downstream window, bolted with a CF flange to an extension welded to the vessel [8].

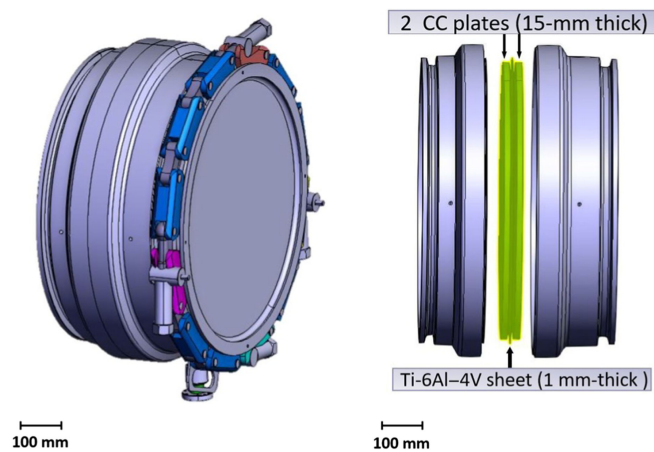


FIG. 3. CAD drawings of the redesigned UHV window separating the LHC extraction line from the beam dump cavern air, implemented for Run 3 and foreseen for HL-LHC at CERN [10].

gasket deformation under more energetic beams. The new dump-cavern layout also required a dismountable configuration, allowing replacement without venting the target dump vacuum line [9,10]. The redesigned window assembly consists of a 1 mm-thick Ti-6Al-4V sheet sandwiched between two 15 mm-thick C-C plates, as illustrated in Fig. 3, which provides the correct CAD representation of the window implemented for Run 3.

These clarifications were prepared in consultation with the Vacuum, Surfaces, and Coatings (TE-VSC) Group and the Sources, Targets, and Interactions (SY-STI) Group at CERN. Their careful review of the original manuscript helped identify several points that required further precision or contextualization, and we gratefully acknowledge their contribution to improving the technical accuracy of this work.

These clarifications do not affect the results or conclusions of the paper.

DATA AVAILABILITY

No data were created or analyzed in this study.

- [1] E. Gschwendtner *et al.*, The advanced proton driven plasma wakefield acceleration experiment at CERN, *Nucl. Instrum. Methods Phys. Res., Sect. A* **829**, 76 (2016).
- [2] F. Salveter, AWAKE project: Vacuum system, in *Vacuum, Surfaces and Coatings Group Seminar* (2015), p. 22, <https://indico.cern.ch/event/390486/>.
- [3] N. Solieri, Developments on RaDIATE-related R&D for CERN's beam intercepting devices, in *2023 RaDIATE Collaboration Meeting* (2023), p. 56, <https://indico.bnl.gov/event/18882/contributions/77843/>.
- [4] J. A. F. Somoza, Cooling windows/absorber impact of radiation load, in *IMCC Annual Meeting 2022* (2022), p. 26, <https://indico.cern.ch/event/1175126/timetable/?view=standard>.
- [5] V. Kain, R. Esposito, M. Fraser, B. Goddard, and M. Meddahi, Upgrades to the SPS-to-LHC transfer line beam stoppers for the LHC high-luminosity era, in *Proceedings of the 7th International Particle Accelerator Conference (IPAC 2016), Busan, Korea (JACoW, Geneva, Switzerland, 2016)*, p. 4, <https://accelconf.web.cern.ch/ipac2016/papers/tupmr050.pdf>.
- [6] M. Monteil, Inventory of windows for CERN accelerators, Technical Report No. 1074871(v.1), CERN, 2014.
- [7] M. Monteil, Vacuum windows, Technical Report, CERN, 2010, <https://indico.cern.ch/event/114535/attachments/47147/67804/Monteil-26-Nov-2010.pdf>.
- [8] J. Maestre, C. Torregrosa, K. Kershaw, C. Bracco, T. Coiffet, M. Ferrari, R. Franqueira Ximenes, S. Gilardoni, D. Grenier, A. Lechner, V. Maire, J. Martin Ruiz, E. Matheson, N. Solieri, A. Perillo-Marcone, T. Polzin, V. Rizzoglio, D. Senajova, C. Sharp, M. Timmins, and M. Calviani, Design and behaviour of the Large Hadron Collider external beam dumps capable of receiving 539 MJ/dump, *J. Instrum.* **16**, P11019 (2021).
- [9] M. Brice and C. Marcelloni, One of the beam dump of the LHC machine at point 6, Report No. CERN-AC-0807025-04, 2008, <https://cds.cern.ch/record/1141513>.
- [10] G. Bregliozzi, New LHC beam dump entrance window, in *Proceedings of the 10th LHC Operations "Evian" Workshop* (CERN, Geneva, Switzerland, 2021), p. 16, <https://indico.cern.ch/event/1077835/contributions/4615043/>.