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Future missions of the former LHCb Outer Tracker gaseous detector in PANDA at FAIR

A. Belias,[a,*] **R. Böhm**,[a] **D. Glaab**,[a,1] **N. Ibrišimović**,[b] **R. Karabowicz**,[a] **C. Kobdaj**,[e] **S. Koch**,[a] **U. Kurilla**,[a] **J. Lancione**,[c] **J. Lühning**,[a] **K. Manasatitpong**,[f] **K. Peters**,[a,d] **S. Pongampai**,[f] **L. Schmitt**,[a] **L. Schramm**[a] **and M. Traxler**[a] **on behalf of the PANDA collaboration**

[a] *GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany*
[b] *University of Sarajevo, Obala Kulina bana 7, 71000 Sarajevo, Bosnia and Herzegovina*
[c] *University of Turin, Via Pietro Giuria 1, 10125 Torino, Italy*
[d] *Goethe University Frankfurt, Max-von-Laue-Straße 1, 60438 Frankfurt am Main, Germany*
[e] *Suranaree University of Technology, 111 Thanon Maha Witthayalai, Nakhon Ratchasima 30000, Thailand*
[f] *Synchrotron Light Research Institute, 111 University Avenue, Nakhon Ratchasima District 3000, Thailand*

E-mail: a.belias@gsi.de

Abstract: The former Outer Tracker of LHCb/CERN based on gas-filled straw tubes has been kindly donated to GSI for further use in experiments at GSI and FAIR and predominantly in PANDA. This formidable gaseous tracking detector of LHCb employed in LHC Run 1 and Run 2 performed continuously and above expectations until its replacement by a Scintillating Fibre Tracker to address the challenges after upgrades to the LHC. Upon arrival at GSI, the whole straw tube detector is being stored and gradually prepared for various use cases.

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[*] Corresponding author.
[1] Now at Goethe University Frankfurt, Germany.

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1 The LHCb gaseous Outer Tracker

The LHCb (Large Hadron Collider beauty) experiment at CERN [1] is designed to perform precise heavy flavour physics measurements and search for New Physics at the LHC [2]. The LHCb detector is a single arm forward spectrometer, with several charged particle tracking devices, of which the large gaseous tracking detector, Outer Tracker (OT) [3], covered the outer region downstream of the magnet. The LHCb gaseous OT operated superbly [4], surpassing expectations during Run1 [5] with further performance improvements in Run2 [6], yet with further LHC upgrades it is replaced by the new Scintillating Fibre Tracker [7].

The OT consists of 53,780 straw tubes of approximately 5 mm diameter and 2.5 m length. Two mono-layers of 64 tubes each, staggered on top of each other, make up an assembly of 128 tubes which is read out on one side while terminated at the other side. Two assemblies with their readout at the upper and lower side are enclosed within a gas-tight module of 5 m length. The modules close to the beam pipe have a wider spacing between the assemblies and a few modules are narrower with 32 tubes per mono-layer. The complete detector with fully equipped infrastructure is placed within its transport frame specially designed for safe handling during transport and storage.

During the OT decommissioning the interest expressed by members of the PANDA collaboration led to the preparation of the donation agreement between LHCb/CERN and GSI/FAIR. After clearance by the Radiation Protection group at CERN, the donation was enacted on Decmber 2023, and in close cooperation between CERN (Transport services, LHCb gaseous OT members) and GSI/FAIR (Transport and Installation, PANDA Technical Coordination), the whole gaseous OT was transported from CERN, within 5 days to GSI, arriving 24-Aug-2024, see figure 1.

Figure 1. (Left) Single C-frame with 9 straw modules attached on each side, at LHCb/CERN. (Right) Whole OT gaseous tracker in its transport frame, $(13.5 \times 5.2 \times 7)$ m^3, 24 t, arriving at GSI.

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2 Scopes of reuse in PANDA at FAIR

The international Facility for Antiproton and Ion Research in Europe (FAIR) is currently under construction next to GSI, in Darmstadt, Germany. FAIR consists of a new superconducting ring accelerator, SIS100 GSI accelerators will serve as the first acceleration stage providing beams to SIS100 for further acceleration to serve several new beams lines and target areas and storage rings, including the production of antiproton beams for experiments at the High Energy Storage Ring (HESR). The versatile research capabilities at FAIR are exploited by four pillars [8] (in alphabetical order):

- APPA — Atomic, Plasma Physics and Applications,
- CBM — Compressed Baryonic Matter,
- NUSTAR — Nuclear Structure, Astrophysics and Reactions
- and PANDA — Physics with High Energy Antiprotons.

PANDA, anti-Proton ANnihilation in DArmstadt, is the unique experiment at the HESR, using antiprotons beams, up to 15 GeV/c interacting with proton- or nuclear- targets. This exciting hadron physics research is recognized as a future flagship experiment by NuPECC [9]. PANDA features two spectrometers, one for the target region with a solenoid magnet and another for the downstream region with a dipole magnet. Both spectrometers will be equipped with sub-detectors for charged particle tracking, particle identification (PID), time-of-flight measurements, and calorimetry with several crystal calorimeter and a shashlyk type calorimeter and muon detection [10].

Due to the planar geometry of the OT modules, their reuse is considered in the PANDA Forward spectrometer, as two different use cases, (a) as a forward tracking detector similar to their set-up at LHCb and (b) as part of a muon range system. In the case of forward tracking in PANDA we envisage to reuse those OT modules originally located close to the beam pipe at LHCb. Since these modules have a gap in-between a safe separation is technically feasible. By arranging the separated modules next to each other it is possible to instrument the required fiducial volume with the small number available of these modules. To use modules as two separate halves require their dismounting from the original structural support (C-frame) and after separation their attachment to new mechanical supports and supply chains. First designs of new structural support and supply infrastructure are in progress.

The majority of the OT modules cannot be separated, and yet another use case involves their installation without any alteration in PANDA. In the PANDA forward region a Muon Range System is foreseen and this is the use case for the remaining modules. The already designed platform for the forward spectrometer requires little alterations in order to host the OT layers horizontally and interspersed with passive absorber material, in order to distinguish muons from hadrons.

Central to all use cases is the development of new Front-End Electronics to interconnect with modern DAQ systems, while retaining the original ASICs. The developments at GSI include an adapter board to interface the ASICs with FPGA based TDC systems designed at GSI. Prototypes produced so far are being validated in test stands [11].

In addition to use cases in experiments, PANDA has started to use single modules for pedagogical purposes [12, 13].

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3 Outlook

Two use cases are under investigation to deploy parts of the LHCb gaseous OT in the PANDA forward spectrometer (a) for charged particle tracking using halved modules and (b) as a muon range system with the large modules interspersed with passive absorber layers. First developments to interface the on-detector ASICs with new FPGA TDC and modern readout systems are in progress. By virtue of reusing the LHCb gaseous OT we contribute to the Sustainable Development Goals of the United Nations [14].

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