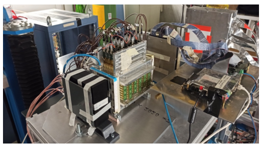
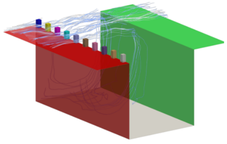
DEPARTMENT OF PHYSICS AND ASTRONOMY "AUGUSTO RIGHI"

Open Physics Hub



ADVANCED SENSING LABORATORY



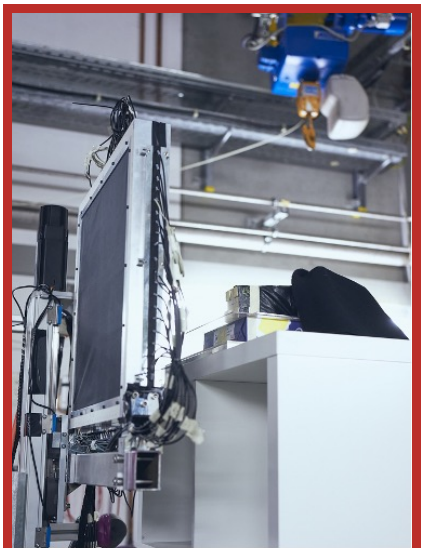
HIGH PERFORMANCE COMPUTING CLUSTER

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

OPH NEWSLETTER

FOCUS: OPH equipment for challenging nuclear physics experiments at GSI

The Data AcQuisition (DAQ) tools developed in the OPH laboratories are currently employed in different experiments. For instance by the FOOT (FragmentatiOn Of Target) collaboration, which aims at measuring the double differential cross section of nuclear fragmentation reactions of interest in hadrontherapy and radioprotection in Space. The accurate knowledge of nuclear fragmentation is in fact fundamental for a correct assessment of radiation-induced risks in cancer treatment sessions and long-term human space missions.



Downstream detectors of FOOT. The plastic scintillator in the front measures the time-of-flight of nuclear fragments, while the module of the calorimeter in the back measures their energy.

To achieve its goal, FOOT is conceived to accurately measure the kinematic properties of nuclear fragments produced when C and O beams interact with human tissue-like targets. The apparatus is currently under development and will consist of three main regions: an upstream region, dedicated to primary beam characterisation, a silicon magnetic spectrometer, which performs particle tracking, and a downstream region, dedicated to fragment charge and mass identification. Each detector has been studied to give the best possible resolution with the aim of performing measurements in inverse kinematics and with composite targets.

In July 2021, the FOOT collaboration carried out a measurement campaign at GSI, the laboratory of the Helmoltz Centre for Heavy

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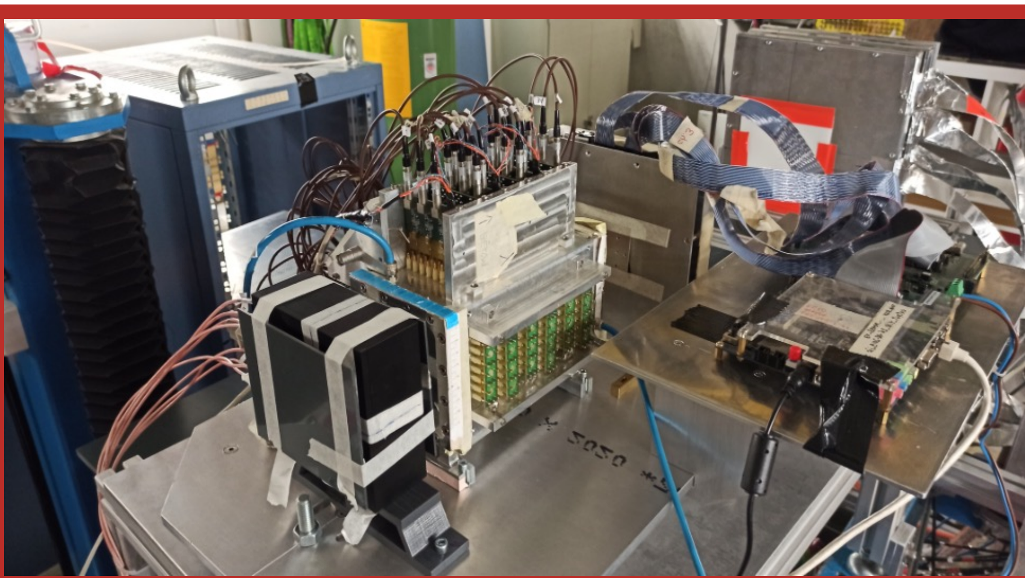
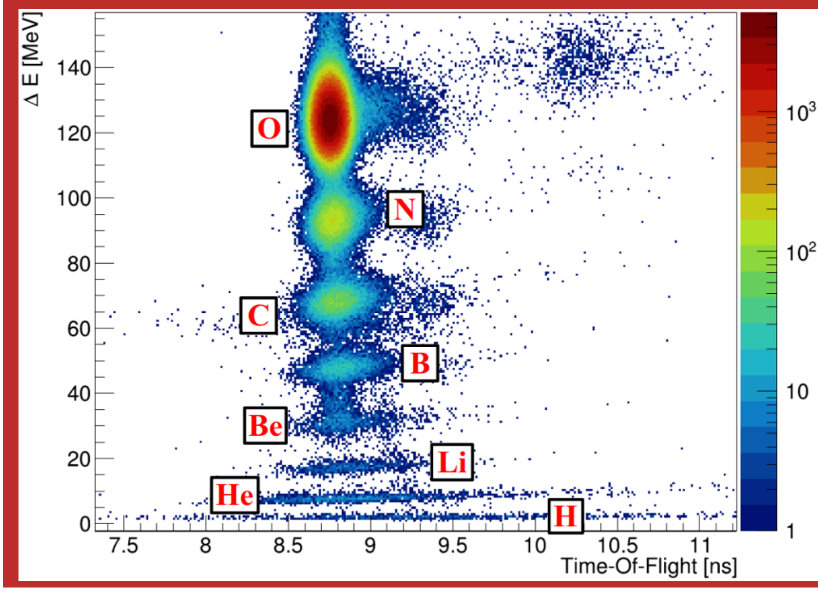


FOOT upstream region and tracking detectors used for the GSI campaign. The blue rack in the background contains the global DAQ system with the components developed at OPH.

Ion Research (Darmstadt, Germany). Measurements were performed with ^{16}O beams at 200 and 400 MeV per nucleon, respectively, impinging on graphite (C) and polyethylene (CH_2) targets. The detection setup consisted of a beam monitor, part of a tracker device, a "wall" of fast plastic scintillators for the measurement of the time of flight and, finally, a module of a calorimeter made of BGO scintillators. During the two days of acquisition, the FOOT DAQ system was able to run continuously and acquire a total of over 41 million events with a maximum rate of 1.2 kHz. These performances allowed the collaboration to collect the needed statistics for each beam and target employed in the limited time available. The preliminary results obtained from the GSI campaign seem very promising in terms of particle identification.

Charge identification of nuclear fragments based on energy loss and time-of-flight information. The graph shows the different fragments produced by an Oxygen beam at 400 MeV per nucleon on a 5-mm graphite target.



As an example, the very good resolution obtained on energy loss (4%) and Time-Of-Flight (<70 ps) measurements in the plastic scintillators of FOOT enables a very precise charge identification of the nuclear fragments produced in the nuclear reactions. The analysis of the acquired data is ongoing and more results will be available in the near future, such as the first fragmentation cross section measurements.

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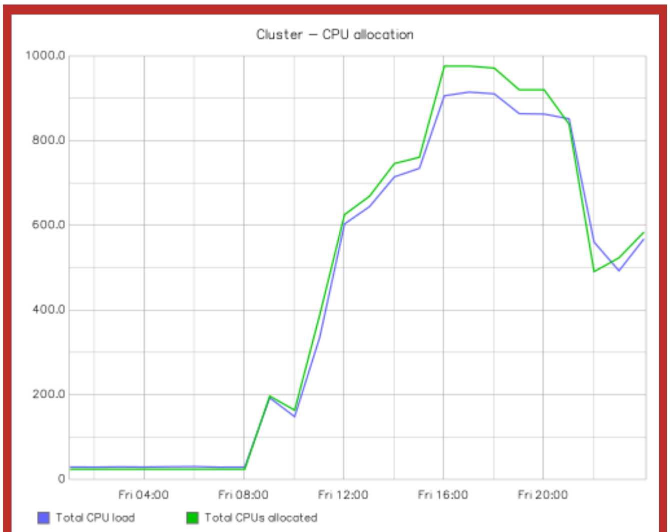
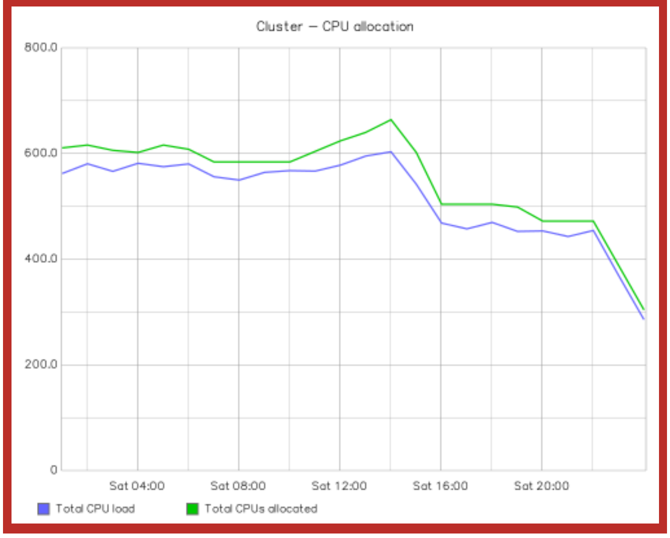
High Performance computing cluster

CLUSTER STATUS (HOW IS IT RUNNING?)

The OPH parallel computing cluster has reached its full computational power during the past year and is currently employed by about 90 research users (PhD students, post-docs, and faculty members) and by about 120 undergraduate students for various teaching activities within Bachelor and Master courses offered by DIFA. The initial setup of the Matrix partition, consisting of 896 virtual cores over 16 symmetric compute nodes, has been extended in September 2021 to 1584 virtual cores through the contributions provided by individual European and National project fundings, and will be soon further extended to 1920 virtual CPUs by two additional (already approved) hardware purchases. This shows the strong attractiveness of the OPH computing infrastructure in terms of co-funding, that will allow us to reach at the beginning of 2022 more than twice the computational power originally funded through OPH resources. Together with the 264 virtual cores of the data analysis cluster BladeRunner, the infrastructure will then feature a total of 2184 vCPUs. Also the storage capacity of the cluster has been substantially extended through individual fundings with the purchase of 48 additional disks that bring the available storage space to about half a Petabyte, more than twice the initial data volume.



The figures show the average CPU allocation per week in the months of August (top) and September (bottom) 2021: the vanishing allocation in the first two weeks of August (due to a hardware maintenance of the cluster) is followed by a peak of about 65% allocation, while in September 2021 the situation appears more stable at around 40% of the full capacity.



The machine is currently used at a roughly constant rate, with about 40-50% of the resources always allocated, which ensures relatively short queueing times for newly-submitted intermediate-size jobs, with peaks of 60-70% allocation. At the beginning of 2022 the cluster will close its first allocation period and a full analysis of the allocation shares will be performed in order to define the new shares for the second allocation period starting in March 2022.

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OPH PhD students

OPH offered **three Ph.D. fellowships** in the XXXV and XXXVI cycle, respectively, one for each of the Ph.D. programs hosted by DIFA. In the following, the three students attending the XXXVI cycle (second year of activity) are accounted.

GIORGIO LESCI

Giorgio Lesci is enrolled in the PhD programme in Astrophysics. He carries out his research in the field of observational cosmology, with a focus on the role of galaxy clusters. Indeed, such objects are fundamental tools for the understanding of our universe, providing information on the content of dark matter and on the nature of dark energy. Giorgio's research, based on the data collected by state-of-the-art telescopes, benefits from the high-performance OPH cluster “Blade/Matrix”, which is indispensable for performing Markov chain Monte Carlo analyses.

The Antarctic Ice Sheet (AIS) is an important indicator of climate change and the engine of sea level rise. Despite significant efforts over the past few decades, knowledge of the contribution of polar sheets to past, present and future sea level rise is still under discussion. The main objectives of **Fernando Linsalata**'s project are: (i) improve knowledge about the sea level trend along the Antarctic coasts in the past and provide estimates for regional and global future contributions and (ii) provide plausible interpretations of the geodetic-data currently available, improving, if necessary, the GIA modelling. For the project FL will execute a set of high-resolution simulations on the OPH computing cluster BladeRunner (in Fortran language) to investigate GIA effects more closely.

ROBERTO ZARRELLA

Roberto Zarrella is enrolled in the FOOT experiment, which studies nuclear fragmentation processes of interest in hadrontherapy and space radioprotection. His research activity focuses on the implementation of a particle tracking algorithm able to perform the reconstruction of fragmentation events. In parallel with this analysis, he is working in the OPH laboratories at the development and characterisation of the neutron detectors that will be added to the experimental setup, as well as their inclusion in the global DAQ system developed in Bologna.

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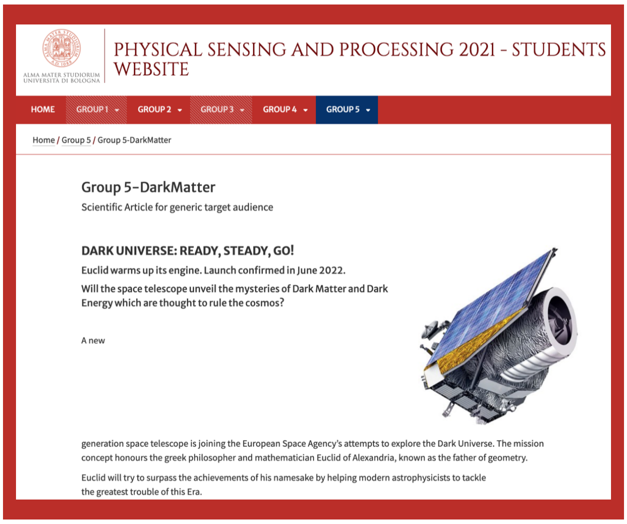
Teaching and outreach

THE 3RD EDITION OF THE DIFA INTERNATIONAL SUMMER SCHOOL ON PHYSICAL SENSING AND PROCESSING

The third edition of the Physical Sensing and Processing summer school yearly organised by DIFA took place from 5 through 9 July 2021, with a purely online format (hopefully for the last time) due to the persisting COVID-19 emergency. The topics of this year's school have been structured around the idea of presenting how the two methodological approaches that characterise the OPH mission (advanced physical sensing and parallel computing) are currently employed to develop cutting-edge research within a wide range of specific fields in Physics, with the aim to provide an interdisciplinary overview of the possible applications of the OPH strategic activities. More specifically, four very diverse research topics (ranging from Climatology, to Astroparticle Physics, Epidemiology, and X-ray tomography) have been presented to our students through a set of lectures providing for each topic a general introduction to the field, and two focused presentations of its current developments in terms of process detection and data analysis/modelling, respectively. The panel of lecturers has been designed to include both local and international speakers among highly-recognised experts for each specific field, namely Susanna Corti (CNR), Tiziano Maestri and Daniel Remondini (DIFA-UniBo), Egon Perilli and Saulo Martelli (Flinders University), Venkatramani Balaji (Princeton), Samantha Lycett (Edinburgh University), Marco Puts (CBS Netherlands), Tommaso Treu (UCLA), Sergio Navas (Granada University), and Mark Vogelsberger (MIT), who delivered very stimulating and highly participated presentations during the main teaching blocks of the school. Besides these twelve topical lectures, the school has also provided additional trainings in the form of three special talks — delivered by Massimiliano Guarrasi (Cineca), Federico Boscherini and Daniele Bonacorsi (DIFA-UniBo) — aimed at providing the "vision" for the possible future developments of some of the techniques presented by the different lecturers, and of a collaborative activity carried out by the students under the guidance of a science communication expert (Marco Boscolo, from the communication agency Formicablu). The latter activity has led the students to develop a series of web pages hosting their essays aiming to communicate some of the scientific contents of the school to different hypothetical target audiences (see Figure).

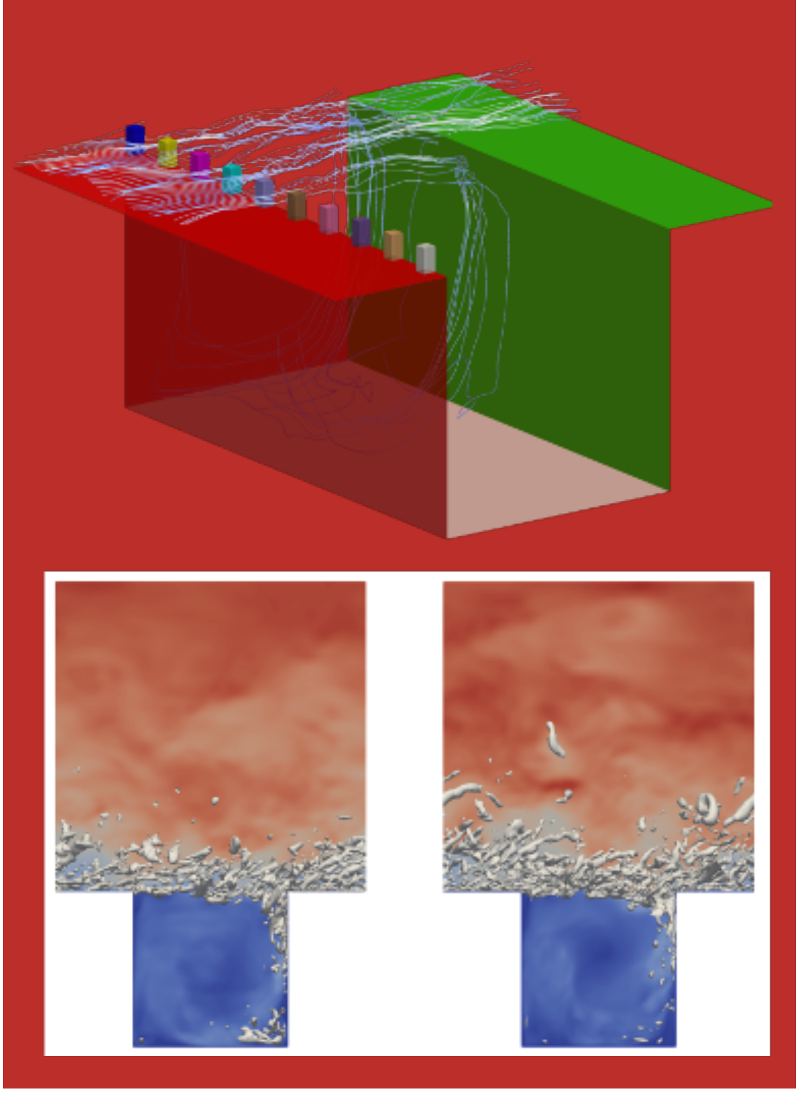


The school has been attended by 45 students from both UniBo bachelor, master, and PhD degree programmes, as well as from other national and international universities and other public and private research bodies, with a very active and diligent participation to the school activities as witnessed by the participation reports provided by the Teams videoconferencing application.

Publications related to OPH

NUMERICAL ANALYSES OF POLLUTANT REMOVAL IN URBAN AREAS

The problem of air quality in cities is a highly topical issue, where one of the fundamental aspects is the permanence of pollutants produced by traffic, but also by other human activities, in areas that are highly frequented by citizens. The research group in atmospheric physics, led by Prof. S. Di Sabatino, utilised experimental techniques and high-resolution numerical simulation to investigate the effects of natural-based solutions (NBS) with low environmental impact and high sustainability, that allow better dispersion of pollutants from the fabric of the city. The ability to numerically reproduce the determining action of atmospheric turbulence [1], the complex interactions with heat exchange processes [2] and the additional action of phenomena such as evaporation and condensation of water, is a formidable tool to provide concrete indications on the effective use of NBS, redevelopment and development of healthier urban areas.



Turbulent structures in a simplified urban canyon with rooftop obstacles

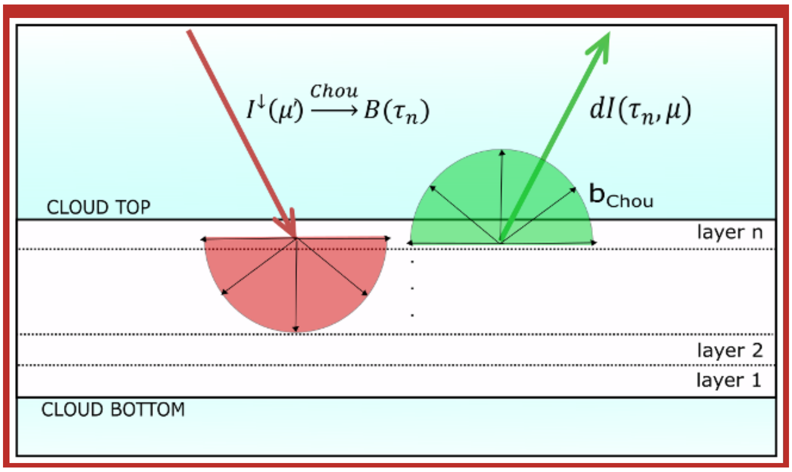
References

[1] Cintolesi C.; Pulvirenti B.; Di Sabatino S., Large-Eddy Simulations of Pollutant Removal Enhancement from Urban Canyons, «BOUNDARY-LAYER METEOROLOGY», 2021, 180, pp. 79 - 104

[2] Cintolesi C.; Barbano F.; Di Sabatino S., Large-eddy simulation analyses of heated urban canyon facades, «ENERGIES», 2021, 14, pp. 1 – 22

Publications related to OPH

STUDY OF RADIATIVE TRANSFER



The simulation of synthetic spectral radiances in presence of clouds plays a crucial role in the characterisation of the Earth outgoing longwave energy which is a fundamental quantity in weather and climate studies [1]. However, the solution of the full radiative transfer (RT) equation in a multiple scattering environment is computationally expensive. Thus, approximations and parameterisations are introduced to simplify and speed up the computation of the RT problem. The study, carried out at DIFA by a research team led by prof. T. Maestri, aims at investigating the level of accuracy of scaling methods and analytical approximations commonly used in radiative transfer codes to avoid the application of advanced and time-consuming numerical solutions. Specifically, it focuses on the Chou's approximation [2], and a simple scaling method based on the similarity principle [3]. Accurate computations of the parameterisation methodologies are provided accounting for updated characterisation of ice and liquid water cloud properties. The level of accuracy of the fast methodologies is then assessed. In case of both water and ice cloud scenarios, the approximate solutions perform well in the mid infrared (4-15 microns) for most of the cases studied. When the far infrared region (15-100 microns) is considered, not negligible inaccuracies are observed. Results are obtained by exploiting the computing cluster of the OPH and presented in a paper by Martinazzo et al. [4] which explores our ability to simulate radiance fields in presence of clouds in the far infrared band that will be observed by future ESA and NASA satellite missions.

References

[1] ESA-EOPSM-FORM-RP-3549. Earth Explorer 9 Candidate Mission FORUM — Report for Mission Selection. 1nd. ESA, (2019).

[2] Chou, M. D. et al., "Parameterization for Cloud Longwave Scattering for Use in Atmospheric Models." In: American Meteorological Society (1999).

[3] Tang G. et al., "Improvement of the Simulation of Cloud Longwave Scattering in Broadband Radiative Transfer Models" (2018)

[4] Martinazzo, M. et al., "Assessment of the accuracy of scaling methods for radiance simulations at far and mid infrared wavelengths", Journal of Quantitative Spectroscopy- and Radiative Transfer, (2021).

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Useful links

OPH website
https://site.unibo.it/openphysicshub/en/

Department of Physics and Astronomy
https://fisica-astronomia.unibo.it/it

INFN
http://www.bo.infn.it/

CNAF
https://www.cnaf.infn.it/en/

OPH Computing Cluster user guide
https://site.unibo.it/openphysicshub/en/internal

OPH Newsletter: previous numbers
#1_ OPH_Newsletter_01_May2020.pdf
#2_ OPH_Newsletter_02_Feb2021.pdf
#3_ OPH_Newsletter_03_May2021.pdf

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