Sustainable HEP 2024 —3rd Edition

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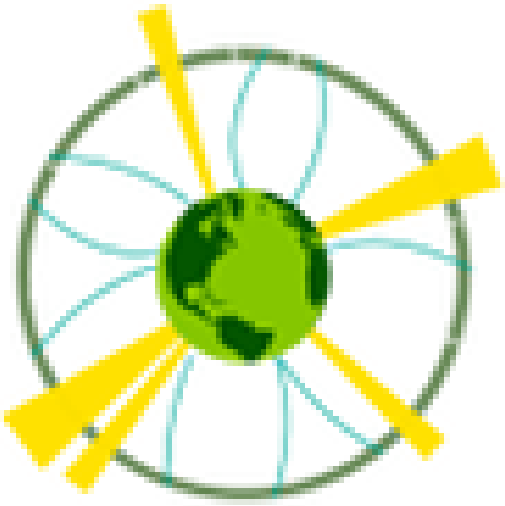

Book of Abstracts

Contents

Invited Talks / **1**

Impact of Climate Change on Energy System and Technology Choices (Keynote speech)

Global climate change has shaken up our energy and economic systems. The fossil fuels, which helped us through the last century , starting with coal and followed by oil and gas have led to accumulation of 1500 billion tons of CO2 in the atmosphere and disturbed the earth's ecosystem balance significantly. It includes hydro cycle, temperature rise, oceans warming and hence ocean currents, disturbances in forests, arctic and antarctic ecosystems, mountain systems and also human habitats. Thus, transition to renewable energy has become imperative. However, sun, wind , hydro power are relatively low energy density energy sources compared to fossil fuels and nuclear power which can give us high density source to reach 600 C degrees and beyond, needed for generating high voltage electricity in a continuous manner so as to ensure 24 hour reliability. It is also indispensable for manufacturing steel, aluminum, cement, chemicals, fertilisers etc Moreover, lightweight energy carriers such as liquid and gaseous fuels are needed to run cars, trains, ships and planes.
The fossil fuels provided a high intensity energy source to produce electricity in a predictable manner and meet our fluctuating demand throughout the 24 hours. as needed.
On the other hand, solar, wind and hydro energy are low density, unpredictable and intermittent energy sources.Yet, through ingenious ways, it is possible to combine technologies such as solar, wind, hydro, batteries, nuclear, pumped hydro and hydrogen as carriers of energy and digital technologies to ensure the same services and functions.
This is the challenge that we have to meet as we chart out a new course, taking net zero emissions pathway
The lecture will cover the techno socio economic challenges associated with this transition.

Invited Talks / **2**

Tackling the hidden costs of computational science: GREENER principles for environmentally sustainable research

From genetic studies and astrophysics simulations to AI, scientific computing has enabled amazing discoveries and there is no doubt it will continue to do so. However, the corresponding environmental impact is a growing concern in light of the urgency of the climate crisis, so what can we all do about it? Tackling this issue and making it easier for scientists to engage with sustainable computing is what motivated the Green Algorithms project. Through the prism of the GREENER principles for environmentally sustainable science, we will discuss what we learned along the way, how to estimate the impact of our work and what levers scientists and institutions have to make their research more sustainable. We will also debate what hurdles exist and what is still needed moving forward.

Invited Talks / **3**

ARUP Life Cycle Assessment of the tunnelling of CLIC and ILC

Corresponding Author: suzanne.evans@arup.com

Arup worked with CERN and KEK to evaluate and understand the environmental and embodied carbon impact of three linear collider options, the Compact Linear Collider (CLIC) Drive Beam and Klystron, and the International Linear Collider (ILC). Suzanne will present the results of the Life Cycle Assessment and the embodied carbon reduction opportunities identified. She will also highlight

next steps including a Whole Life Cycle Assessment for CLIC and ILC machine componentry, and further opportunities for carbon reduction and carbon management using PAS2080:2023.

Invited Talks / 4

The Climate Emergency: can Particle Physics ever be sustainable?

Corresponding Author: veronique.boisvert@cern.ch

We live in a climate emergency and consequently all countries are putting in place measures to reduce their carbon emissions in order to reach a so-called "net zero emissions"by 2050. All aspects of economic life will be affected by such measures, including particle physics research. I will present some examples of sources of carbon emissions within the field of particle physics. This will include emissions associated with building and running accelerators, detector operations, high-performance computing and activities associated with our research life like travel. I will also present solutions being developed for addressing this in the near and long term as well as recommendations for the field.

Invited Talks / 6

On the environmental footprint of supercharged science

Corresponding Author: ayan.paul@desy.de

Since the dawn of human social organization, the practice of science and engineering has been the primary defense against the forces of Nature that has allowed for the progress of civilizations. Yet the same progress has allowed for the unchecked growth of the burden on natural resources and the destabilization of the fragile balance on which the continuation of living forms, as we know them today, depends. Climate change is a direct consequence of the choices we have made over several millennia and, especially, the era past the industrial revolution. To attenuate the existential threat that climate change poses to our society a paradigm shift is necessary in the way we do science and the core objectives that we aspire for from its practice. We will discuss how supercharged science can be better optimized to mitigate climate change rather than be a determinant of climate change.

Parallel Session A / 7

"Green"use of fluorocarbons in Cherenkov detectors and detector cooling systems - challenges and opportunities.

Author: Gregory Hallewell[1]

[1] *Centre National de la Recherche Scientifique (FR)*

Corresponding Author: gregory.hallewell@cern.ch

Saturated fluorocarbons (SFCs: CnF(2n+2)) are chosen for their optical properties as Cherenkov radiators, with C4F10 and CF4 used at CERN in the COMPASS and LHCb RICH detectors. Non-conductivity, non-flammability and radiation resistance also make SFCs ideal coolants: C6F14 liquid cooling is used in all LHC experiments, while C3F8 is used for the evaporative cooling of TOTEM and

the ATLAS silicon tracker. These fluids, however, have high GWPs (5000–10000*CO2), and represented around 36% of CERN's CO2-equivalent emissions in 2018. There is thus an impetus to reduce their use through improved monitoring and circulation system design.
Newer spur-oxygenated fluoro-ketones, for example from the 3M NOVEC® range, with CnF2nO structures, can offer similar performance to SFCs with but with very low, or zero GWP. Although these fluids do not yet exist in large quantities over the full CnF2n "matrix"the radiation tolerance and thermal performance of NOVEC 649 (C6F12O) was sufficiently promising for it to be chosen as a C6F14 replacement for cooling silicon photomultipliers. Additionally, subject to optical testing, NOVEC 5110 (C5F10O) could (if blended with nitrogen) replace both C4F10 and CF4 in Cherenkov detectors. Lighter molecules (for example C2F4O, with similar thermodynamics to C2F6) - if and when available in industrial quantities—might allow lower temperature operation than evaporative CO2 in future silicon trackers operated at very high luminosity.
Ultrasonic gas mixture analysis is very sensitive to concentration changes of a heavy vapour in a light carrier, and is used - in the only such fluorocarbon coolant leak monitoring system operating at LHC - for real-time monitoring of C3F8 coolant leaks from the ATLAS pixel and SCT silicon trackers into their nitrogen-flushed environmental volumes. A typical C3F8 sensitivity of better than 10–5 is achieved.
Advanced new ultrasonic algorithms allow measurement of the concentrations of a pair of gases of particular interest on top of a varying known baseline of other gases. The technique is thus of considerable value in leak monitoring and could be used to blend fluoro-ketones with nitrogen or argon to reduce the GWP "load"of large volume atmospheric pressure gas Cherenkov radiators without the recourse to higher-pressure noble gas approaches.
This presentation outlines an approach to GWP reduction with fluoro-ketone fluids and the blending of heritage SFCs or fluoro-ketones with lighter gases using ultrasonic monitoring and control. Possible avenues for the use of fluoro-ketones in liquid phase and evaporative cooling of silicon trackers are discussed.

Invited Talks / **8**

Overview on the sustainability of future accelerators

Corresponding Author: masakazu.yoshioka@kek.jp

Future accelerators must be assessed for sustainability during their life cycle, including construction, operation, and decommissioning, to meet the global goal of carbon neutrality by 2050. Accelerator scientists should strive to achieve performance with less electric power in the optical design phase of accelerators, and to improve power efficiency during the design and manufacture of accelerator components. Furthermore, we should understand CO2 emissions during the manufacturing of concrete, steel frame, and reinforcing bars, which are the main causes of CO2 emissions during construction, and cooperate in efforts with industries to reduce these emissions. The main source of CO2 emissions during accelerator operation is the electricity generated in the region where the accelerator is located. Therefore, we should understand the power composition of the region and ensure that accelerator operations are powered by "green (sustainable) power". The low-grade waste heat emitted from accelerators should also be recovered as much as possible and returned to society. In addition, to reduce CO2 emissions in the entire region where the accelerator is located, efforts should be made to increase CO2 absorption throughout the agriculture, forestry, fisheries, and livestock industries, as well as to increase long-term CO2 fixation by incorporating more wooden structures in local housing and large public buildings, including accelerator-related facilities. As described above, there are not only issues that accelerator researchers should address, but also many items that can be accomplished in cooperation with communities and companies where accelerators are located. I will discuss these items that should be addressed in these various areas.

Parallel Session B / **9**

Reducing the RF power demands for future colliders

Authors: Alick Macpherson[1]; Graeme Campbell Burt[2]; Igor Syratchev[1]; Nicholas Shipman[2]; Oleg Malyshev[3]; Reza Valizadeh[4]

[1] *CERN*

[2] *Lancaster University (GB)*

[3] *ASTeC, Daresbury Laboratory*

[4] *STFC Daresbury Laboratory*

Corresponding Authors: reza.valizadeh@stfc.ac.uk, nicholas.shipman@cern.ch, alick.macpherson@cern.ch, graeme.burt@cockcroft igor.syratchev@cern.ch, o.b.malyshev@dl.ac.uk

The largest power demands of most future colliders, particularly Higgs factories and muon colliders, is dominated by the wall-plug-power required to run the RF systems and its cooling. Most of this power does not end up in the beam but is power lost as heat in the RF amplifiers, cavities and RF loads. This power lost is not a fundamental limit and there has been recent progress in addressing each to increase the efficiency of the RF system (and its associated cryo-plants in the case of superconducting machines) by a factor of 2 to 10 depending on the machine.

This talk will provide an overview of those recent advances covering high efficiency klystrons and SSPA, novel materials for superconducting RF and fast reactive tuners and discuss each in the context of future colliders.

Parallel Session B / 10

Physics to address global challenges to achieve the SDG by 2030

Author: Kate Shaw[1]

[1] *University of Sussex (GB)*

Corresponding Author: kate.shaw@cern.ch

Physics brings technological, economic and educational development, and investment is necessary to achieve the Sustainable Development Goals (SDGs). An key ingredient needed to build a more peaceful and sustainable future is from the soft diplomacy achieved through international scientific cooperation. Important pathways towards the SDGs must embrace Open Science and Open Data, expanding outreach and education programmes to improve scientific literacy worldwide, and improve diversity and inclusion in physics for people from all countries, genders, ethnicities and economic backgrounds.

Parallel Session A / 11

Sustainability Strategy for the Cool Copper Collider

Authors: Brendon Bullard[1]; Caterina Vernieri[2]; Dimitris Ntounis[2]; Emilio Alessandro Nanni[None]; Martin Breidenbach[3]

[1] *SLAC National Accelerator Laboratory (US)*

[2] *SLAC National Accelerator Laboratory (US)*

[3] *SLAC*

Corresponding Authors: dimitrios.ntounis@cern.ch, enanni@stanford.edu, brendon.aurele.bullard@cern.ch, caterina.vernieri@cern.ch, mib@slac.stanford.edu

In this talk, we will discuss the studies presented in PRX ENERGY 2, 047001, where the carbon impact of the Cool Copper Collider (C^3), a proposed e^+e^- linear collider operated at 250 and 550 GeV center-of-mass energies, is evaluated. We will introduce several strategies that could be utilized to reduce the power needs for C^3 without modifications in the ultimate physics reach. We will also propose a metric to evaluate the carbon costs of Higgs factories, balancing physics output, energy needs, and carbon footprint for both construction and operation, and we will present a comparison of C^3 with other Higgs factory proposals –ILC, CLIC, FCC-ee and CEPC –within this framework. We conclude that the compact 8 km footprint and the possibility for cut-and-cover construction make C^3 a compelling option for a sustainable Higgs factory. More broadly, the developed methodology serves as a starting point for evaluating and minimizing the environmental impact of future colliders without compromising their physics potential.

Parallel Session A / **12**

Innovate for Sustainable Accelerating Systems (iSAS)

Authors: Giovanni Bisoffi[None]; Jens Knobloch[1]; Jorgen D'Hondt[2]; Maud Baylac[3]; achille stocchi[4]

[1] *Helmholtz-Zentrum Berlin & Universität Siegen*

[2] *Vrije Universiteit Brussel (BE)*

[3] *LPSC*

[4] *IJCLab , UNiversite Paris-Saclay, CNRS*

Corresponding Authors: giovanni.bisoffi@lnl.infn.it, jorgen.dhondt@cern.ch, baylac@lpsc.in2p3.fr, achille.stocchi@ijclab.in2p3.fr, jens.knobloch@helmholtz-berlin.de

With the ambition to maintain competitiveness of European accelerator-based research infrastructures, the Horizon Europe project Innovate for Sustainable Accelerating Systems (iSAS) has been approved. Within total 17 academic and industrial partners, the objective of iSAS is to develop, prototype and validate new impactful energy-saving technologies so that SRF accelerators use significantly less energy while providing the same, or even improved, performance. Aligned with the European accelerator R&D roadmap, the project focusses on three key technology areas connected to SRF cryomodules: the generation and efficient use of RF power, the improved cryogenic efficiency to operate superconductive cavities and optimal beam-energy recovery. The most promising and impactful technologies will be further developed to increase their TRL and facilitate their integration into cryomodules at existing research infrastructures and/or in the design of future accelerators.

Parallel Session B / **13**

Scientists as climate activists

Author: Sophie Alice Renner[1]

[1] *University of Glasgow (GB)*

Corresponding Author: sophie.renner@cern.ch

The HEP community's exciting plans for the physics we will do over the next decades stand in stark contrast to the reality of what the world will look like if action is not taken against disastrous climate change. No matter what we do within our own community, if our governments allow the fossil fuel era to continue, then within our lifetimes fundamental science will become a luxury that a desperate world cannot afford. In this talk, I will discuss the growing movement of scientists as climate and ecology activists, holding governments and corporations to account. Action is the antidote to despair, and by standing up for a liveable planet, scientists can ensure that curiosity remains possible for the next generation.

Parallel Session A / 14

Sustainability at Belle II

Author: Thomas Kuhr[1]

[1] *Ludwig Maximilians Universitat (DE)*

Corresponding Author: thomas.kuhr@lmu.de

In the Belle II collaboration, a discussion of the sustainability topic began in 2023. A survey showed that many Belle II members care about the topic. We will report about the status of a grassroots initiative to address the sustainability challenge of research at Belle II.

Parallel Session B / 15

The future of meetings in the particle astrophysics community

Authors: Deirdre HORAN[1]; Elisa Prandini[2]; Gert Kluge[3]; Jonathan BITEAU[4]; Luigi TIBALDO[5]

[1] *Laboratoire Leprince-Ringuet, CNRS/IN2P3, École polytechnique, Institut Polytechnique de Paris, 91120 Palaiseau, France*

[2] *Padova University and INFN Padova, Italy*

[3] *University of Oslo, Department of Physics*

[4] *Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France*

[5] *IRAP, Université de Toulouse*

Corresponding Authors: elisa.prandini@pd.infn.it, gertwkl@gmail.com, deirdre.horan@llr.in2p3.fr, luigi.tibaldo@irap.omp.eu, biteau@ipno.in2p3.fr

A recent survey within the particle astrophysics community suggests that reducing the number of meetings and conferences is a viable way to address concerns about the effectiveness of the modern scientific collaboration process, its effects on the environment and the well-being of researchers. The results of the survey were published in a Comment in Nature Astronomy. In this presentation we will discuss the context in which the survey took place, the results obtained and possibilities for how to best serve the particle astrophysics community and beyond moving forward.

Parallel Session B / 16

Evaluating the environmental impact of the ISIS-II Neutron and Muon Source

Author: Hannah Wakeling[1]

[1] *John Adams Institute, Oxford University*

Corresponding Author: hannah.wakeling@stfc.ac.uk

The ISIS-II Neutron and Muon source is the proposed next generation of, and successor to, the ISIS Neutron and Muon Source based at the Rutherford Appleton Laboratory in the United Kingdom. Anticipated to start construction in 2032, the ISIS-II project presents a unique opportunity to incorporate environmental sustainability practices from its inception.
As part of the optioneering and design process of ISIS-II, I am examining the environmental impact of the facility through carbon impact estimation and through a (simplified) Life Cycle Assessment

(LCA). I will present these efforts and discuss the methodology, including how we are overcoming some of the difficulties in performing such an analysis.

Invited Talks / 17

Sustainable Accelerator R&D in the UK (Contribution from the IOP PABG)

Corresponding Author: ben.shepherd@stfc.ac.uk

This talk describes some of the work on sustainable accelerators carried out within the ASTeC department of STFC. We are developing a portfolio of sustainable accelerator technologies, including permanent magnets and thin film superconducting cavities. We have carried out a carbon inventory of RUEDI, a future electron diffraction facility to be built at the Daresbury site, and we plan to invest significantly in this area in the coming years with the creation of a new Centre of Excellence in Sustainable Accelerators (CESA).

Parallel Session A / 18

Green transition of Resistive Plate Chamber detectors for HEP applications

Authors: Luca Quaglia[1]; RPC ECOgas@GIF++ collaboration[None]

[1] *Universita e INFN Torino (IT)*

Corresponding Author: luca.quaglia@cern.ch

Resistive Plate Chamber (RPC) are gaseous detectors widely employed in High Energy Physics experiments. Thanks to their comparatively low cost and excellent timing and positioning performance, they are used to cover large detection areas, such as those needed by the muon trigger systems of the LHC experiments (RPCs are currently employed in ALICE, ATLAS and CMS and they are also being considered for the LHCb upgrade II).

The gas mixture employed in RPCs plays a crucial role in their correct operation. Currently the gas mixture mainly in use consists of 95.2% C2H2F4, 4.5% i-C4H10 and 0.3% SF6. While this grants an optimal detector response, it also poses environmental issues. Indeeed C2H2F4 and SF6 are classified as fluorinated greenhouse gases (GHGs) with a high Global Warming Potential: on a 100 year timescale, they are around 1400 and 22800 times that of CO2 respectively.

Starting from 2015, new European Union regulations ((EU) 517/2014) have imposed a progressive phase-down of GHGs production and usage, aiming at singnificantly reducing the amount of GHGs placed on the market by the year 2030. This will inevitably lead to a price increase and a reduction in the availability of those gases. CERN has adopted a GHGs usage reduction policy and RPC detectors are especially affected, since their operation contributes to roughly 80% of the total GHGs consumption at CERN.

This talk will give an overview of the second CERN environment report, especially for what concerns RPC operations during LHC Run 1 and 2. It will also discuss the strategies that have been adopted so far to reduce GHGs emission at CERN, focusing on the efforts of the RPC ECOgas@GIF++ collaboration, born in 2019 as a joint effort among RPC experts of the LHC experiments and the CERN detector technology (EP-DT) group. Indeed, all these groups have started to separately look for suitable eco-friendly gas mixtures where C2H2F4 has been substituted with one of its industrial alternative, namely HFO-1234ze, and CO2 in different concentrations. The work of the collaboration is focused on performing in-depth gas mixture characterization as well as the study of the long-term stability of detector operation. The main results obtained from these studies will also be summarized.

Parallel Session B / 20

Sustainability approach at DESY

Author: Andrea Klumpp[None]

Co-author: Denise Völker [1]

[1] *D6 DESY*

Corresponding Authors: denise.voelker@desy.de, andrea.klumpp@desy.de

DESY is an accelerator facility with an evolving history. Having started as a collider, we now provide the platform for a wide range of applications. Our expertise ranges from detector development and testing to dark matter experiments and photon science.
As a large research institute with an enormous consumption of resources, we also have a great responsibility to use these resources wisely. In order to fulfil this responsibility, the staff unit for sustainability was established at DESY in 2019. We are currently facing the challenge of upgrading our PETRA accelerator. This involves the use of large quantities of materials, such as concrete for new buildings, copper for cables and much more. Energy consumption also needs to be minimised. In this presentation, the sustainability strategy of DESY will be briefly presented with some examples. Our experiences, processes, problems and ideas will be discussed. And an outlook will be given.

Parallel Session B / 21

Sustainability Studies for Future Linear Colliders

Authors: Benno List[1]; Maksym Titov[2]; Steffen Doebert[3]; Steinar Stapnes[3]

[1] *Deutsches Elektronen-Synchrotron (DE)*

[2] *IRFU, CEA Saclay, Université Paris-Saclay (FR)*

[3] *CERN*

Corresponding Authors: benno.list@desy.de, maxim.titov@cea.fr, steinar.stapnes@cern.ch, steffen.doebert@cern.ch

Sustainability has become a prioritized goal in the design, planning and implementation of future accelerators; approaches to improved sustainability include overall system design, optimization of subsystems, and operational concepts. A direct quantification of the ecological footprint, is currently performed only sporadically, with Lifecycle Assessments (LCA) emerging as a more comprehensive approach.

Two large electron-positron linear colliders are currently being studied as potential future Higgs-factories, CLIC at CERN and ILC in Japan. These projects are closely collaborating on methods to reduce the power consumption of accelerator components and systems, and smart integration of future accelerator infrastructure with the surrounding site and society. In a recent, common study an LCA of the construction of tunnels, caverns and shaft of both accelerators was conducted. This contribution will present this and other current results and future activities.

Invited Talks / 22

The Psychology behind Sustainable Energy Transitions

Corresponding Author: t.bouman@rug.nl

Whereas Energy and Energy Transitions are typically approached from a Technological Science and Physics perspective, it is increasingly acknowledged that these topics have a very strong Social Science component as well. For instance, in many cases developments in energy and energy transitions have consequences for people and society, and people's perceptions of these developments have a substantial impact on the implementation, adoption and use of energy sources and technologies. In addition, many developments require people to change as well, such as using energy differently or at different times, or even involving them in the energy production and storage. In his talk, Bouman will briefly present the field of Environmental Psychology and its relevance for energy research. He will share some key insights from the field and how these could be incorporated in your work.

Parallel Session B / 23

ICFA Strategy on Sustainable Accelerators and Colliders

Author: Thomas Roser[1]

[1] *BNL*

Corresponding Author: roser@bnl.gov

The ICFA Panel on Sustainable Accelerators and Colliders assesses and promotes developments on energy efficient and sustainable accelerator concepts, technologies, and strategies for operation, and assesses and promotes the use of accelerators for the development of Carbon-neutral energy sources. In this talk I will start with describing why energy efficiency and reduced energy consumption are a critical part of sustainability and addressing Global Warming and then give an overview of the world-wide efforts towards sustainable accelerators and colliders.

Parallel Session A / 24

Efforts to make CEPC a green machine

Author: yuhui li[1]

[1] *Institute of High Energy Physics*

Corresponding Author: liyuhui@ihep.ac.cn

The Circular Electron-Positron Collider (CEPC) aims to construct a top-performing Higgs factory to tackle pressing issues in particle physics. The baseline design includes three operation modes: Higgs, W, and Z, followed by an energy upgrade plan for ttbar collision. The operations plan adheres to a "10-2-1-5" scheme: 10 years as a Higgs factory, 2 years as a Z factory, 1 year as a W factory, and 5 years as a ttbar operation.
The baseline design for synchrotron radiation power is 30 MW, with a potential upgrade to 50 MW for higher luminosity. The required electrical powers are 262 MW and 340 MW, respectively. Given the considerable energy consumption, it's crucial to incorporate green designs into key technologies and improve their efficiency. Utilizing renewable energies, like solar power, is another important area for investigation. Additionally, a lifecycle assessment of carbon dioxide emissions is essential. These issues have been considered in the studies for the CEPC, some of which have been years of endeavors, while others are still in early stages. The current research status will be presented in the upcoming talk.

Parallel Session A / 25

Energy Recovery and Reuse Technology Studies for Large Green Accelerators

Authors: Rui Ge[None]; mei li[1]

[1] *Institute of High Energy Physics, China Academy Sciences*

Corresponding Author: gerui@ihep.ac.cn

Large particle accelerators, such as the LHC, ILC, and proposed CEPC, face significant challenges, including the massive energy consumption due to their high energy demands, while China strives to reduce energy pollution and promote the carbon neutrality by 2060. In this study, we conducted extensive research on waste heat recovery and reuse for CEPC. The first step is to comprehend the particular requirements for waste heat recovery and utilization in CEPC. The basics of Absorption Heat Pumps (AHP), a technology that enables the conversion of low-grade waste heat into usable high-grade energy, are then investigated. Based on this technology, a photovoltaic (PV) to heat → absorption heat pumps (AHP) scheme is proposed and the economic analysis is provided for reusing CEPC waste heat, which offers a cost-effective solution with a relatively small initial investment for substantial long-term gains. In summary, the energy recovery and reuse technology studies for large green accelerators are relatively new but crucial topic in this field. This project aims to develop the waste heat recovery technologies of the accelerator, and provide fundamental research assistance for the "green" energy-saving transformation of China's particle accelerator. Further green accelerator development & research works are still going on.

Parallel Session B / 26

Changing the world of research based on solid measurements

Authors: Melissa Ridel[1]; Samuel Calvet[2]; Yann Coadou[3]

[1] *LPNHE / Sorbonne Université / Centre National de la Recherche Scientifique / Paris (FR)*

[2] *LPC Clermont-Ferrand, IN2P3 / UCA (FR)*

[3] *CPPM, Aix-Marseille Université, CNRS/IN2P3 (FR)*

Corresponding Authors: samuel.pierre.jean.calvet@cern.ch, melissa.ridel@cern.ch, coadou@cppm.in2p3.fr

Scientists are becoming more aware of the impact of their activities on the environment. They also want to base their analysis of the situation on measurements, leading to decisions to minimise their contribution to climate change and pollution. With this in mind, scientists in French labs started the Labos 1point5 initiative in 2019, to collect what is already being done, study how research is being carried out, think about changes to promote in our teaching and research approaches, and provide tools to measure our labs greenhouse gases emissions in a standardised way. With GES 1point5, hundreds of labs are reporting their yearly emissions from buildings, electricity, duty travel, commute and procurement. The latest addition includes emissions linked to the usage of large infrastructures such as CERN, large computing centres and astronomical observatories. The aims of these evaluations are to increase awareness among scientists that our activities are far from neutral from an environmental point of view, and to help trigger actions in our labs and bigger structures to reduce the impact of research. The kit 1point5 and scenario 1point5 tools suggest measures and model their impact by 2030, aiming at a 55% reduction in GHG emissions with respect to 2019.

Parallel Session A / 27

Energy Efficient Cooling Infrastructure for CERN Accelerators

Author: Nikolina Bunijevac[None]

Co-author: Diogo Monteiro [1]

[1] *CERN*

Corresponding Authors: nikolina.bunijevac@cern.ch, diogo.monteiro@cern.ch

Following global sustainability concerns, "pursuing actions and technologies aiming at energy savings and reuse"is listed as one of the main objectives for 2021-2025 at the European Organization for Nuclear Research (CERN). This objective extends to the Cooling and Ventilation group, within the Engineering department, who oversees the operation of CERN's cooling infrastructure. This large, energy intensive infrastructure ensures a stable thermodynamic condition for critical accelerator machinery. Over recent years, several actions regarding energy savings have been implemented. Algorithms, mostly based on classical controls, have been developed, leading to energy savings up to 50%. One notable example is the new controller design for the cooling tower plants of the LHC (CERN's largest accelerator), with more than 2700MWh yearly saved. Another recent initiative was a study supported by the digital twin technology concerning efficiency improvements in water distribution systems. The study concluded with the discovery of significant potential for electricity savings. Ongoing research includes further development of methods for energy savings, including more advanced control algorithms which rely on artificial intelligence, as well as simpler ones, with the common goal to utilize available resources in the most efficient way, without compromising performance.

Parallel Session A / **28**

Sustainability of real time analysis at 5 TB/s data rate

Authors: Arantza De Oyanguren Campos[1]; Brij Kishor Jashal[2]; Jiahui Zhuo[1]; Valerii Kholoimov[3]; Volodymyr Svintozelskyi[1]

[1] *Univ. of Valencia and CSIC (ES)*

[2] *RAL, TIFR and IFIC*

[3] *Instituto de Física Corpuscular (Univ. of Valencia)*

Corresponding Authors: jiahui.zhuo@cern.ch, valerii.kholoimov@cern.ch, arantza.de.oyanguren.campos@cern.ch, brij.kishor.jashal@cern.ch, volodymyr.svintozelskyi@cern.ch

The LHCb collaboration is currently using a pioneer system of data filtering in the trigger system, based on real time particle reconstruction in Graphics Processing Units (GPUs). This corresponds to processing 5 TB/s of information and has required a huge amount of hardware and software developments. Among them, the corresponding power consumption and sustainability is an imperative matter in view of the next high luminosity era for the LHC collider, which will largely increase the output data rate. In this talk we show some of the proposals which can be considered to optimize the energy usage in terms of the computing architectures and the efficiency of the algorithms which are running on them.

Parallel Session B / **29**

Synergies between Astronomers for Planet Earth and Sustainable HEP

Authors: Adrienne Cool[None]; Beatriz Mingo[None]; Leonard Burtscher[1]; Sarah Wagner[None]; Sebastian Jester[None]; Tobi Beuchert[None]

[1] *University Würzburg*

Corresponding Authors: burtscher@astro.uni-wuerzburg.de, sarah.wagner1@stud-mail.uni-wuerzburg.de

Founded in 2019, Astronomers for Planet Earth (A4E) is a volunteer, global network of nearly 2000 astronomers, with a common goal: addressing the climate crisis from an astronomical perspective. In the last year we registered an official NGO for this organization in Germany such that we will be able to receive financial support in the future. In this presentation, I want to illustrate how we got here and where we are at. As astronomers, we have a unique perspective on our planet and we have the ability to convey these concepts effectively and engage large audiences. On the other hand, professional astronomy carries a large carbon footprint, which we must urgently measure and reduce. With A4E we take action for a sustainability movement in astronomy while at the same time sharing the astronomy perspective in the sustainability movement. Since there are natural overlaps with the areas of HEP, we want to use our common ground for joint activities and coordination of our efforts.

Parallel Session A / 30

Resource-aware Research on Universe and Matter: Call-to-Action in Digital Transformation

Author: Ben Bruers[1]

[1] *Deutsches Elektronen-Synchrotron (DE)*

Corresponding Author: ben.brueers@cern.ch

Given the urgency to reduce fossil fuel energy production to make climate tipping points less likely, we call for resource-aware knowledge gain in the research areas on Universe and Matter with emphasis on the digital transformation. A portfolio of measures is described in detail and then summarized according to the timescales required for their implementation. The measures will both contribute to sustainable research and accelerate scientific progress through increased awareness of resource usage. This talk is based on the publication arXiv:2311.01169, which is the result of a three-days workshop on sustainability in digital transformation held in May 2023.

Parallel Session A / 31

Eco-friendly gas mixtures for gaseous detectors at CERN and beyond

Author: Aashaq Shah[1]

Co-author: Oleg Brandt [1]

[1] *University of Cambridge (GB)*

Corresponding Authors: aashaq.shah@cern.ch, oleg.brandt@cern.ch

Gaseous detectors are indispensable as they serve a multitude of diverse applications in particle and nuclear physics, but also in industry, e.g., in the national security domain. To stay at the forefront of rapidly changing particle detector technologies for future detector applications, gaseous detectors must face a critical global challenge: sustainability. Today's RPC detectors utilise highly potent greenhouse gas mixtures including CF4, SF6, and C2H2F4 with Global Warming Potentials (GWP) of 6630, 23500, and 1300 that of CO2. Current gases used for particle detectors, detector cooling, etc., are the highest source of emissions from CERN (https://hse.cern/environment-report-2021-2022). The key to enabling the continued operation of current detectors and installation of future detectors, especially large-scale ones like ANUBIS, is identifying a viable strategy to replace the current

detector gas mixture by an alternative eco-friendly gas mixture while not compromising the detector performance, which is a prominent part of the DRD1 research agenda. The talk will review the challenges to identify a suitable eco-gas mixture and provide an overview of previous work in the context of RPC detectors. The talk will close by outlining possible future avenues.

Parallel Session B / 32

ScanMu: Muon Tomography using RPC detectors to reduce the human carbon footprint

Author: Oleg Brandt[1]

[1] *University of Cambridge (GB)*

Corresponding Author: oleg.brandt@cern.ch

Global warming is one of the biggest challenges of mankind due to non-linear, self-enhancing (exponential) dependencies of the climate on human-made factors. The production of concrete for the construction industry is responsible for 5-8% of the global carbon footprint. A solution could be extending the lifetime of buildings and civil infrastructure. A key requirement for this is the ability to scan reinforced concrete to determine its structural integrity and remaining life span. After a brief overview of muon tomography as a novel, destruction-free method to scan reinforced concrete and other sealed large objects using cosmic ray muons, the talk will focus on our idea to adapt the tracking stations similar to those of the ANUBIS detector for the purpose of muon tomography, and outline some key performance parameters and challenges towards the realisation of a real-life demonstrator.

Parallel Session B / 33

Techno-economic analysis of renewable energy generation at the South Pole

Author: Amy Bender[1]

[1] *Argonne National Laboratory*

Corresponding Author: abender@anl.gov

Renewable energy sources are widely recognized for their ability to provide affordable, reliable energy with reduced environmental impact. The South Pole is the site of the both current and future HEP experiments and presents singular conditions for a transition to renewables. South Pole power is currently supplied by diesel generators and the associated complex and costly transport of the required fuel. Transitioning to locally-available renewable energy sources presents an opportunity to reduce both negative economic and environmental impacts. We present here a techno-economic analysis for implementation of a hybrid renewable energy system at the South Pole. We explore a tailored model of resource availability and economics at this site for solar photovoltaics, wind turbine generators, lithium-ion energy storage, and long-duration energy storage in different combinations with and without existing diesel generation. We describe the results of this study as well as ongoing work to move towards a conceptual design of a hybrid renewable energy system.

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Informal Meet and Greet (and videoconference setup)

Corresponding Authors: brendon.aurele.bullard@cern.ch, shreyasi.acharya@cern.ch, shreya.saha@cern.ch, juliette.alimena@cern.ch, hannah.wakeling@stfc.ac.uk, daniel.britzger@cern.ch

In this informal session all speakers are invited to meet the organizing committee and other speakers of the Sustainable HEP 2024 workshop. This session also serves to test your connection to the zoom room, your microphone, camera and speaker and your ability to share your slides. We hope to see many of you there…

You can also connect at any other time to the zoom rooms and test your technical setup.

The Sustainable HEP 2024 organizers.

Workshop / **50**

Know Your footprint

Corresponding Author: naman.kumar.bhalla@cern.ch

With the ever-increasing requirement for sustainability in the modern age, it is crucial to understand the environmental impact of High Energy Physics (HEP) and related fields, especially considering the field's high resource consumption. This workshop provides details on the quantification made to estimate the carbon footprints associated with four categories: Experiment, corresponding to the large infrastructure within HEP collaborations; Institute, accounting for the emissions from research institutes and universities; Computing, covering the resource consumption for data analysis and running simulations; and Travel, accommodating business trips for conferences, workshops, and meetings. A survey for self-evaluation was devised based on these studies, enabling you to estimate your professional footprint. The workshop also offers a hands-on session to engage with the Know your footprint survey and estimate the individual professional footprint. The Know your footprint campaign aims to raise awareness, identify the dominant contributing factors to the HEP-related footprint, and motivate the community to move towards more sustainable research practices.

Parallel Session A / **51**

session A recording (Monday part 1)

Parallel Session A / **52**

session A recording (Monday part 2)

Parallel Session A / **53**

session A recording (Tuesday)

Parallel Session B / **54**

session recording (Monday)

Parallel Session B / 55

session B recording (Tuesday part 1)

Parallel Session B / 56

session B recording (Tuesday part 2)