EUCAIF WG2 kick-off meeting minutes

December 19, 2024

Present at the meeting:
T. Dorigo, F. Stummer, I.S.Heng, M.Koppel, F. Nardi, Ch. Glaser, R. Ruiz, K. Potamianos, P. Vischia, T. Golling, M. Tosi, S. Caron, M. Kagan

Indico page of the meeting, with presentation slides and these minutes:
https://indico.cern.ch/event/1492195/

At the beginning of the meeting there was a round of introductions of WG2 members present in the video call:

- Florian Stummer is a post-doctoral scientist at CERN. He works on beamlines and accelerator optimization.
- Ik Siong Heng is staff at Glasgow. He is mainly interested in research with gravitational waves. He is an observer here, interested to see what technology emerges from our studies.
- Marius Koppel, post-doc at ETH. Does research at PSI on neutron decays. Small experiments, lots of potential for optimization.
- Federico Nardi, UNIPD/UCA grad. student. Working in MODE for differentiable programming optimization and finishing a thesis on muon collider EM calorimeter optimization.
- Christian Glaser is staff at Uppsala. He works on neutrino detectors and optimization tasks.
- Roberto Ruiz is staff at Univ. Valencia. Background in theory HEP and astro-HEP. Main interest within this WG is on building differentiable simulators.
- Karolos Potamianos, staff at Univ. Warwick. Member of ATLAS, working on tracker upgrade and HEP. Interested in the co-design for future colliders.
- Pietro Vischia, staff at U.Oviedo. Coordinator of MODE, works in HEP, optimization of experiment design in muography, neutron tomography, calorimetry.

- Tobias Golling, staff at U. Geneva. ATLAS, background in design and construction, pixels. ITK upgrade. Searches, top quark measurements.
- Mia Tosi, staff at UNIPD. CMS physics, trigger coordinator, main interest SM and searches, reconstruction
- Sascha Caron, staff at Nikhef. Interested in detector development and design at all levels.
- Michael Kagan, staff at SLAC. Technology and methods to do AI-assisted detector design, surrogate methods. Future colliders.
- Tommaso Dorigo is staff at INFN and at Lulea University. He works in HEP and astro-HEP, and is developing optimization strategies for experiments as well as innovative calorimetry.
- Max Aehle, Postdoctoral scientist at RPTU. Automatic differentiation, looking at Geant4.

T. Dorigo presented some slides (see indico page, link at the top) to describe finalities of the working group as stated in initial definition, and the goals of the kick-off meeting. The finalities of WG2 were initially stated as:

- 1) Identify existing design paradigms for particle and astroparticle physics instruments which have become obsolete in the AI era, and assemble software strategies and research paths to overtake them
- 2) Support the development of simulation tools that constitute enablers of co-design approaches to holistic optimization for detector use cases in HEP, astro-HEP, nuclear and neutrino physics.
- 3) Understand physical limits of information generated by particle interactions in granular calorimeters and conditions for its lossless extraction, as a preliminary step toward the AI-assisted hybridization of calorimeters and tracking detectors into optimized variable-density systems.

T.Dorigo introduced the topic of co-design and explained how large gains can be made on final utility of experiments by considering the hardware and software design together (Muone example: gain of a factor of 2 in sensitivity, see also T. Dorigo, *Geometry Optimization of a Muon-Electron Scattering Experiment*,Physics Open 4 (2020) 100022.) He highlighted how common problems in fundamental physics have of the order of 10,000 parameters, which is not any longer a show-stopper. But we need new competences, engage computer scientists, and to pursue a “human in the middle” approach to avoid hostility from the detector builders community.

A few analysis efforts were then described (see slides at https://indico.cern.ch/event/1492195/ for detail) to test the limits of particle ID in granular calorimeters; to exploit nanophotonics to develop fast, energy-efficient readout of calorimeters with neuromorphic computing; to use diffusion models to learn best geometry of sampling calorimeters; to produce derivatives of energy deposition simulated by Geant4; and to hybridize tracking and calorimetry.

Two ideas of possible co-design studies that T. Dorigo presented at the end were:

- Expand studies of neuromorphic computing application to calorimetry readout, where nanophotonics can remove the need to segment calorimeters as it can exploit the native time-encoding of information on the location of the energy release. Here, the co-design aspect

involves the tight coupling of the detection end (nanowires as photon receptors) with the computing architecture (arrays of nanowires in 3d geometrical layouts perform as a network).
- Study use of drones to study atmospheric showers. Here, the idea is to couple a ground-based array of detectors for cosmic rays with high-altitude drones carrying particle detectors. Drones can today fly for weeks at 15-20km altitude, carrying payloads in excess of 300kg. They can help substantially in reducing systematics on energy determination due to unknown Xmax of showers, as well as improve ID of primary particle, strongly improve angular resolution of array, fast pointing to transients, and studies of particle composition in showers, refining models.

The survey was quickly touched on, noting that it collected only 12 responses so far (with a WG including 36 members). Interim results highlight that many participants belong to HEP, but significant interest in detector physics, astroparticle physics, and calorimeter developments. Overall it is possible to extrapolate that the personpower we can potentially deploy is of the order of 12PM/year, with some additional 40-50 PM/years from collaborators/students. However, for that to happen we need to identify areas of interest where co-design is crucial.

The idea of a bottom-up approach to identify ideas that may be aggregators of common WG2 activities was agreed upon. For every application it would be proficuous to interrogate ourselves on the open research questions, the bottlenecks and hindrances, and plans to overcome them; as well as what can be suitable medium- and long-term goals of our group's activities.

Application for funding must be one of our goals, as are publications. However it was pointed out how the latter may sometimes be a precondition of the former. Publications may come naturally if we aggregate researchers on a few topic of common interest.

We agreed on the following action items:

- Push to complete snapshot of WG2 personpower, interests, commitment with a fully completed survey and analysis of results (Tommaso, Pietro, + all those who did not yet filled survey)
- Engagement of colleagues who can be interested in our activities (All)
- Create google doc where we can organize our thoughts concerning possible projects, and define short-term "proto-studies" aimed at understanding feasibility and literature on topic (Tommaso, Pietro)
- Fill above document with ideas on co-design tasks and volunteering for deep thinking on those topics (All)
- Meet again at beginning of February (All)

For WG2,

Tommaso and Pietro, Dec 19 2024