JENAS GROUP meeting, Aug 26 2020

# *Machine Learning End-to-End Optimized Design of Particle Detectors for Future Scientific Experiments*

**T. Dorigo**[1], D. Boumediene[3], C. Delaere[2], D. Derkach[4], J. Donini[3], A. Giammanco[2], L. Layer[1], R. Rossin[1], G. Strong[1], M. Tosi[1], A. Ustyuzhanin[4], P. Vischia[2], H. Yarar[1]

1 INFN, Sezione di Padova (and associates from Padova and Naples Universities), Italy
2 Université Catholique de Louvain, Belgium
3 Université Clermont Auvergne, France
4 Laboratory for big data analysis of the Higher Shool of Economics, Russia

UNIVERSITÉ Clermont Auvergne

INFN Istituto Nazionale di Fisica Nucleare

UCL Université catholique de Louvain

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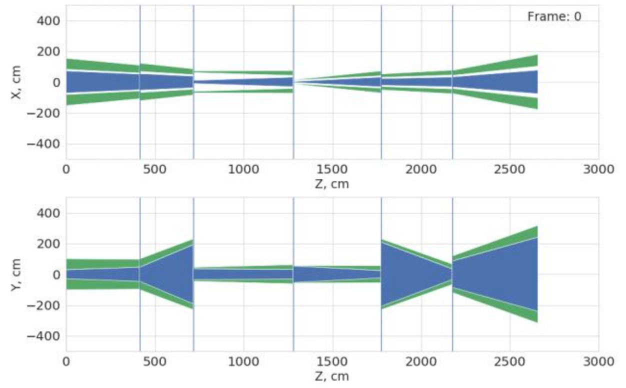
# Realigning design choices and ultimate goals for particle physics detectors

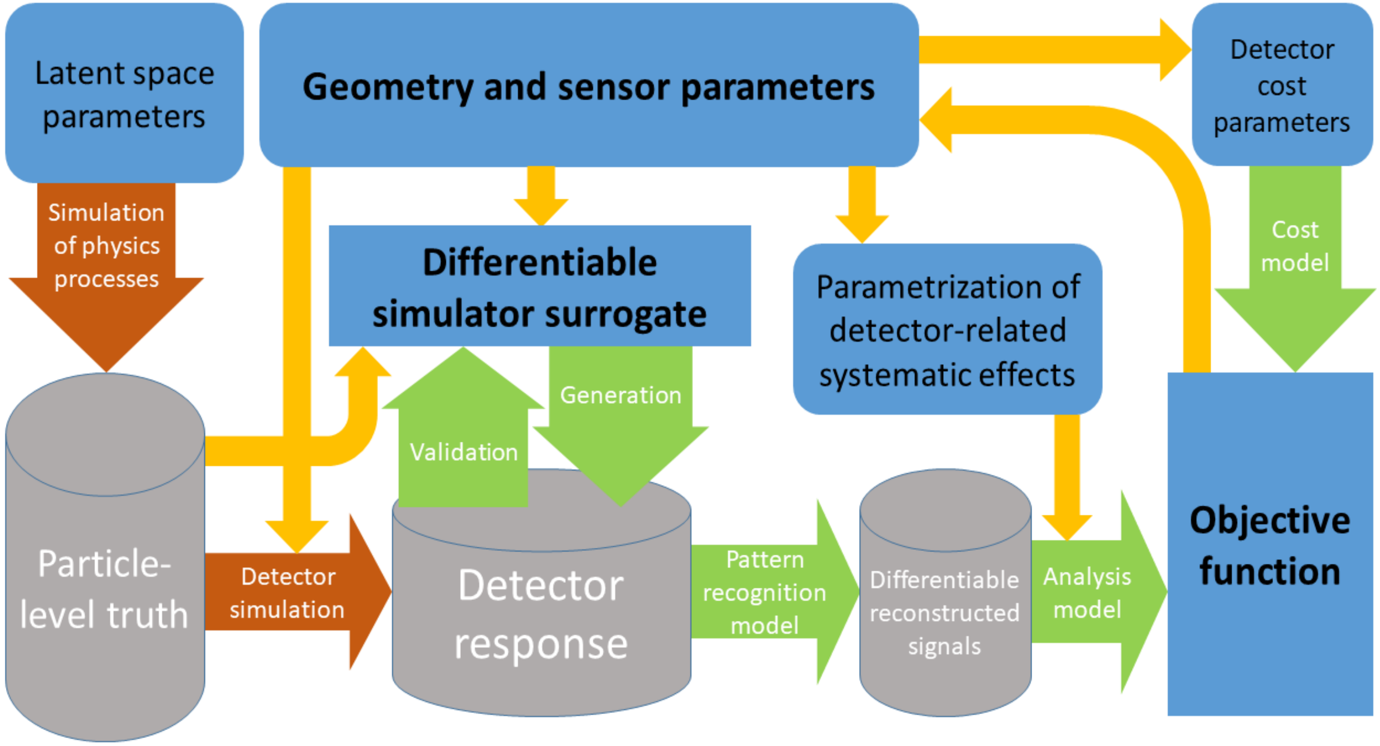



(Local generative surrogates of gradient of objective function Proved to allow minimization in SHIP muon shielding, See S. Shirobokov, **A. Ustyuzhanin** et al., [arXiv:2002.04632v1[cs.LG]](arXiv:2002.04632v1[cs.LG]))

Until today, we have been designing our instruments by targeting makeshift objectives of our real goals → this is highly ineffective!

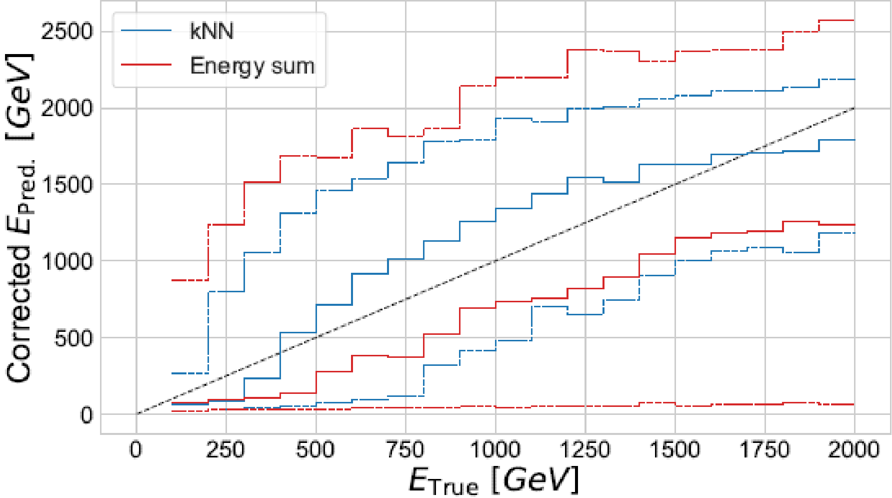
Differentiable programming allows us to incorporate all elements of the problem in a single structure and simultaneously optimize them through a recursive cycle

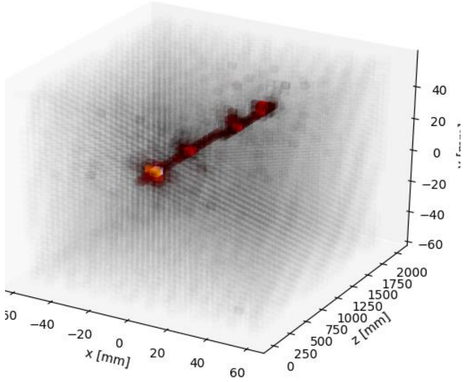
- **Huge potential gain** in utility function
- Modularity allows use in many different use cases and scalability
  - Proposed ones: muon tomography; hadrotheraphy; hybrid calorimeter for future collider; muon collider detector shielding

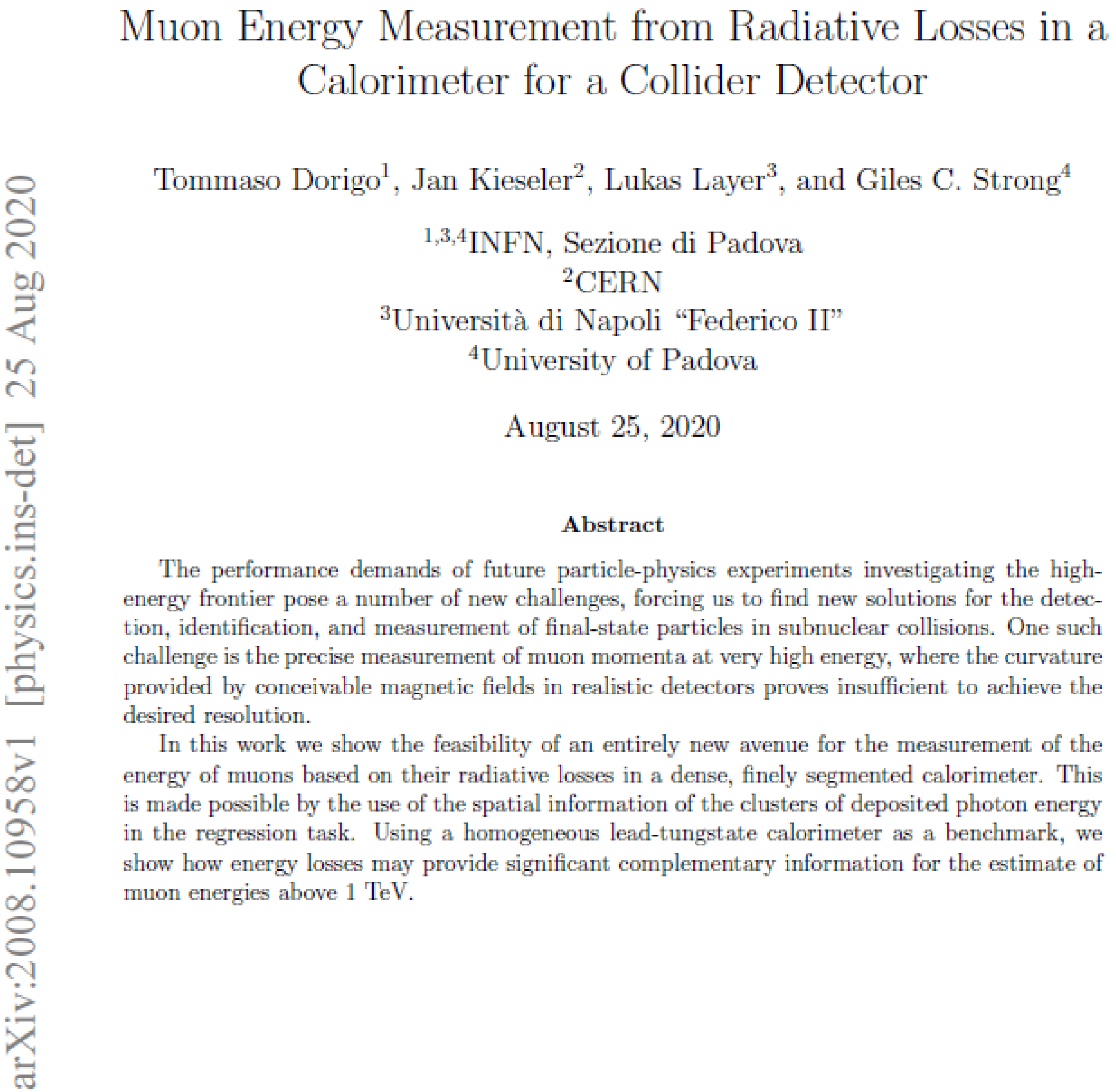


# Muon Energy Measurement in the Calorimeter

- One of the proposed deliverables of the expression of interest is becoming a reality
- Preprint submitted yesterday! https://arxiv.org/abs/2008.10958
- Resolutions of 30% may be achieved for 2 TeV muons in highly granular, homogeneous calorimeter
- Gradient-boosted kNN algorithm used for this study. We expect CNNs will further improve performance of regression
- Spatial information proven to be crucial (see below, left)




Muon Energy Measurement from Radiative Losses in a Calorimeter for a Collider Detector

Tommaso Dorigo[1], Jan Kieseler[2], Lukas Layer[3], and Giles C. Strong[4]

[1,3,4]INFN, Sezione di Padova
[2]CERN
[3]Università di Napoli "Federico II"
[4]University of Padova

August 25, 2020

**Abstract**

The performance demands of future particle-physics experiments investigating the high-energy frontier pose a number of new challenges, forcing us to find new solutions for the detection, identification, and measurement of final-state particles in subnuclear collisions. One such challenge is the precise measurement of muon momenta at very high energy, where the curvature provided by conceivable magnetic fields in realistic detectors proves insufficient to achieve the desired resolution.

In this work we show the feasibility of an entirely new avenue for the measurement of the energy of muons based on their radiative losses in a dense, finely segmented calorimeter. This is made possible by the use of the spatial information of the clusters of deposited photon energy in the regression task. Using a homogeneous lead-tungstate calorimeter as a benchmark, we show how energy losses may provide significant complementary information for the estimate of muon energies above 1 TeV.

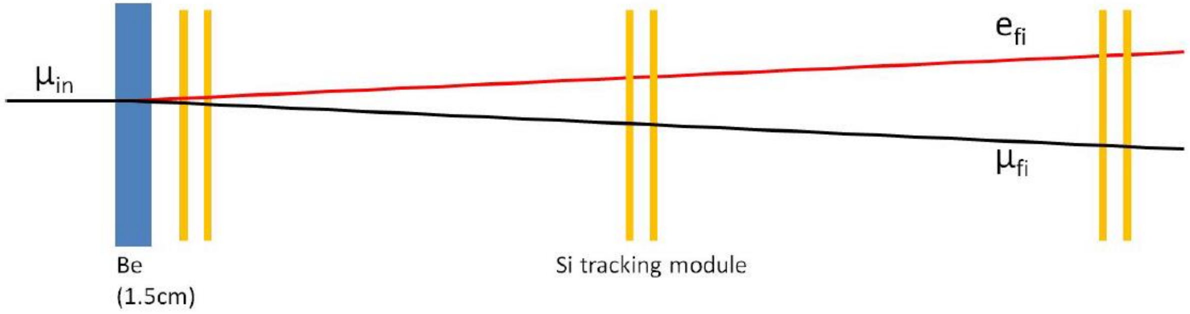
# A Proof Of Large Potential Gains

I recently provided a proof of the large potential gains that a systematic investigation of the large parameter space of geometry design by studying the proposed MUonE detector

https://doi.org/10.1016/j.physo.2020.100022

MUonE aims to determine with high precision the muon-electron elastic scattering differential cross section, to extract hadronic contributions and reduce the systematics of the g-2 muon anomaly

- By optimizing layout of active sensors and passive elements with a discrete sampling, I proved how an improvement of almost a factor of 2 in the relevant metric ($q^2$ resolution) could be achieved without increase in detector cost
- I also proved how dreaded systematic effects from positioning uncertainties could be nullified by software means





ELSEVIER
Physics Open
Volume 4, September 2020, 100022


## Geometry optimization of a muon-electron scattering detector


Tommaso Dorigo [1]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### Abstract

A high-statistics determination of the differential cross section of elastic muon-electron scattering as a function of the transferred four-momentum squared, $d\sigma_{el}(\mu e \to \mu e)/dq^2$, has been argued to provide an effective constraint to the hadronic contribution to the running of the fine-structure constant, $\Delta\alpha_{had}$, a crucial input for precise theoretical predictions of the anomalous magnetic moment of the muon. An experiment called "MUonE" is being planned at the north area of CERN for that purpose. We consider the geometry of the detector proposed by the MUonE collaboration and offer a few suggestions on the layout of the passive target material and on the placement of silicon strip sensors, based on a fast simulation of elastic muon-electron scattering events and the investigation of a number of possible solutions for the detector geometry. The employed methodology for detector

# Next steps

- We plan to organize a workshop on "*Detector Optimization with Deep Learning*" to allow interested scientists to join and discuss together the means and the possible applications
  - Support for this activity would clearly get us going in a more focused and collaborative effort, beyond what is already ongoing
- We would also be happy to have support for short visiting scientist rounds