

Assisting detector design with machine learning

Tobias Golling, University of Geneva

FCC Zurich workshop, August 25-26, 2022

The detector design challenge

- Very high-dimensional
- Many trade-offs not obvious at detector level
- But dictated by downstream physics goals
- Slow design cycles, hard to automate (*non-differentiable*)
- Paradigm-based, no guarantee of optimality

Many challenges !

- Optimal design needs to include ALL aspects of the simulation-reconstruction chain
 - Making software like GEANT differentiable: colossal task !
 - Also tracking, clustering, P-flow, object ID,...
- What to optimize for?
 - *Factorization* approach: particle resolution, classification,...
 - Vs. final physics goals: Higgs coupling, NP discovery potential,...
 - Unconventional signatures
 - Cost, redundancy, robustness, “general-purpose”, *buildability*,...
- Multi-objective optimisation (Pareto optimality)
 - Optimal sub-manifolds (see ATLAS & CMS)
 - Future-proof: new tech, new AI, new reco (boosted-object tagging @LHC)

A
superhuman
task !

“New directions in science are launched by new tools much more often than by new concepts.”

- Freeman Dyson



The pitch: ML to assist in designing better detectors

- Machine learning* to assist in end-to-end optimisation
 - ML is *differentiable*
 - Evaluation is fast (function call)
- Facilitates automation:
 - (Stochastic) gradient descent
 - Generative surrogate models to replace (locally) Sim+Reco
 - Reinforcement learning (explore vs. exploit)
 - From “hits-to-Higgs” (graph-based models)

*Rise of deep learning in HEP in last 10 years going beyond classification and regression [[LivingReview](#)]

Growing area of active research

- Recent success on Chip design [[Nature](#)], sensor design etc.
- Overview on surrogate models in HEP [[2203.08806](#)]
- Proofs of concept in HEP [[2002.04632](#), [MODE](#)]

- TG: plan for magnet design with Carmine Senatore (new PI@DPNC-UNIGE-CHIPP)
- Keen to hear about your interest / brainstorm / benchmarks / collaborate

- Reminder:
 - Intended to assist detector design **not** to replace experts
 - Goal: guidelines for design, novelty, symbiosis: AI-empowered HEP