AID(2)E: AI-Assisted Detector Design for the EIC

2026 EIC UGM, AI Town Hall

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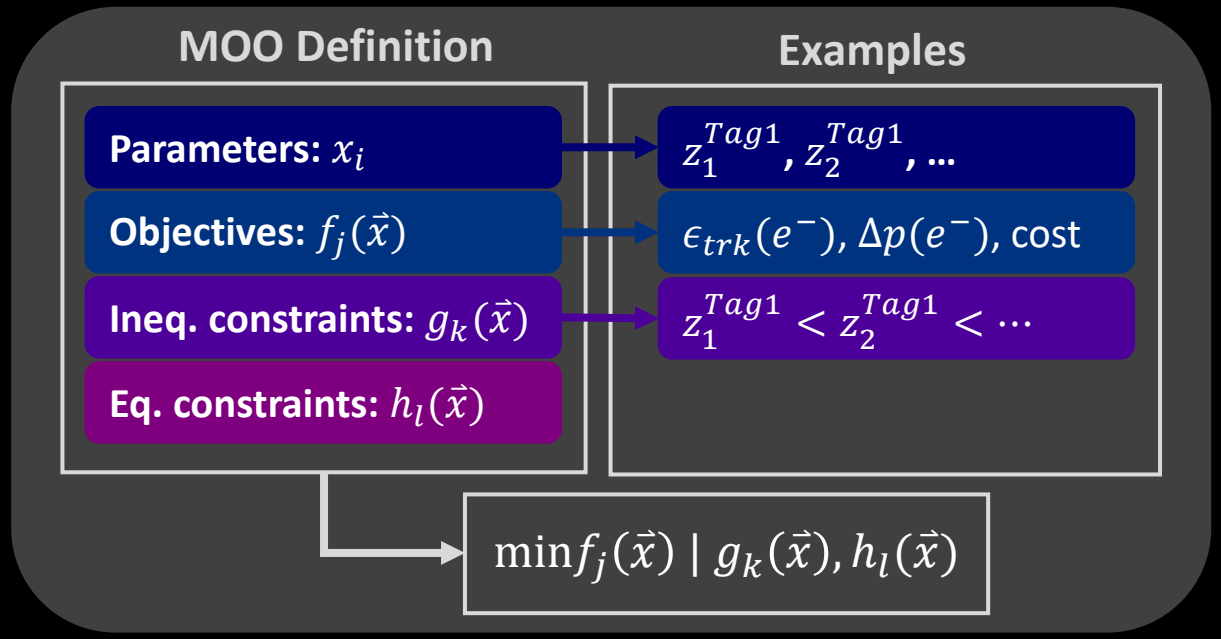
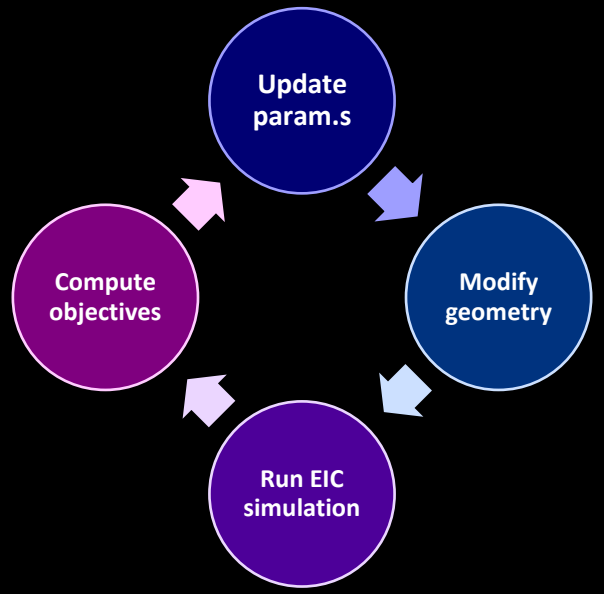
07.16.2026

Method | Detector Optimization as MOO





- Detector design can be formalized as a **Multi-Objective Optimization (MOO)** problem:
  - Have a set of objectives f_j that are functions of parameters $\vec{x}$ subject to constraints g_k and h_l
  - Map onto **physically-motivated observables (f_j)** and **parameters of detector ($\vec{x}$)**

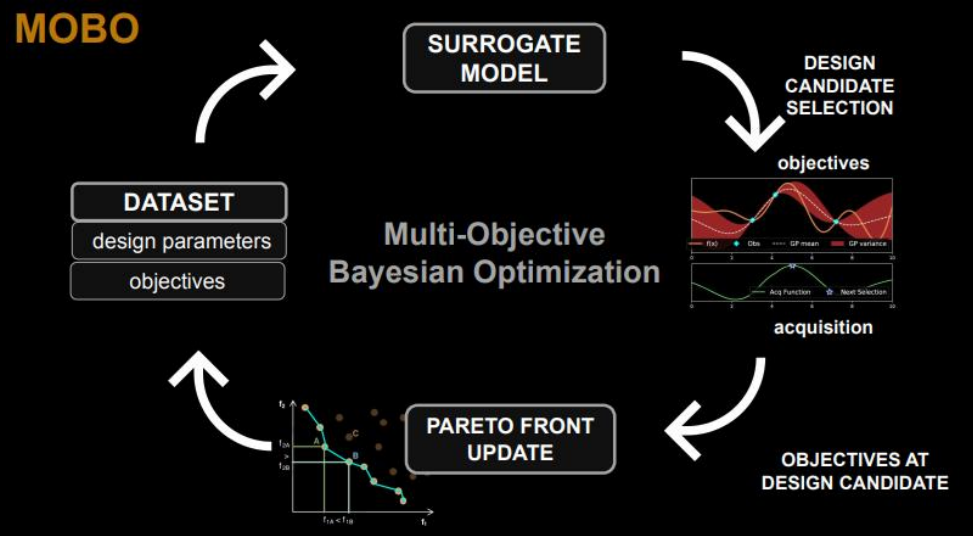
- Goal is to minimize (maximize) objectives
  - ☞ **But how do you do that *effectively*?**

- For (very) small no. of $\vec{x}$, could do grid search…
  But:
  1) EIC simulations can be *very* heavy;
  2) And what if you have *many* $\vec{x}$ and/or complex trade-offs b/n f_j?

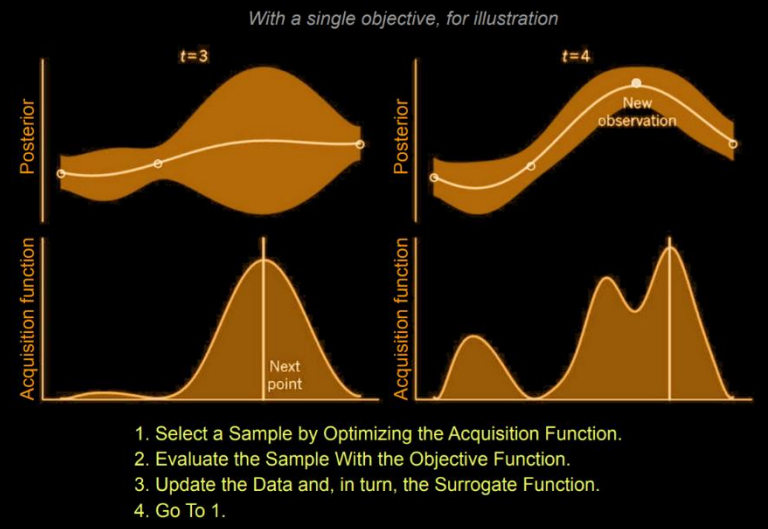
AI/ML | AID(2)E Project

- **AI/ML can help!** Specifically *Bayesian* optimization techniques (MOBO)
  - MOBO guides optimization by identifying most-promising areas of design space to focus on
    - ☞ **Right:** illustration of a typical MOBO algorithm
  - Frameworks like Ax and Pymoo offer robust libraries for MOBO and Genetic Algorithms (MOGA)

- **AID(2)E:** **AI**-Assisted **D**etector **D**esign for the **E**IC
  - Collaboration focused on applying and spreading AI-assisted MOO techniques to the EIC (and beyond)
  - See 2024 whitepaper [JINST 19 C07001 (2024)]



AID(2)E, JINST **19** C07001 (2024)



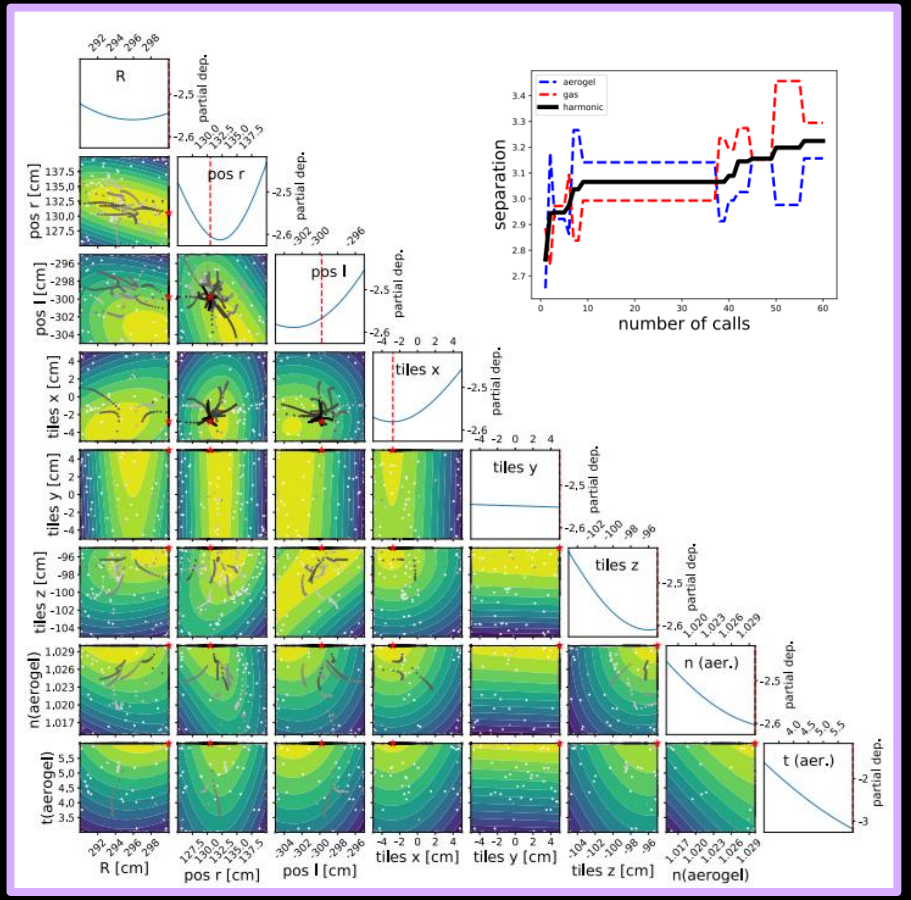
C Fanelli, RHIC/AGS AUM (2024)

Examples | dRICH, B0, and more MOBOs

- **dRICH-MOBO** [JINST **15** P05009 (2020)]
  - Simultaneous optimization of dRICH mirror radius/position, tile positions, and aerogel properties
  - Used harmonic mean $\pi/K/p$ separation in aerogel and gas
  - **Right:** posterior distributions of parameters (bottom left) and objectives vs. trial no. (upper right)
    - ☞ Points indicate values selected during trials

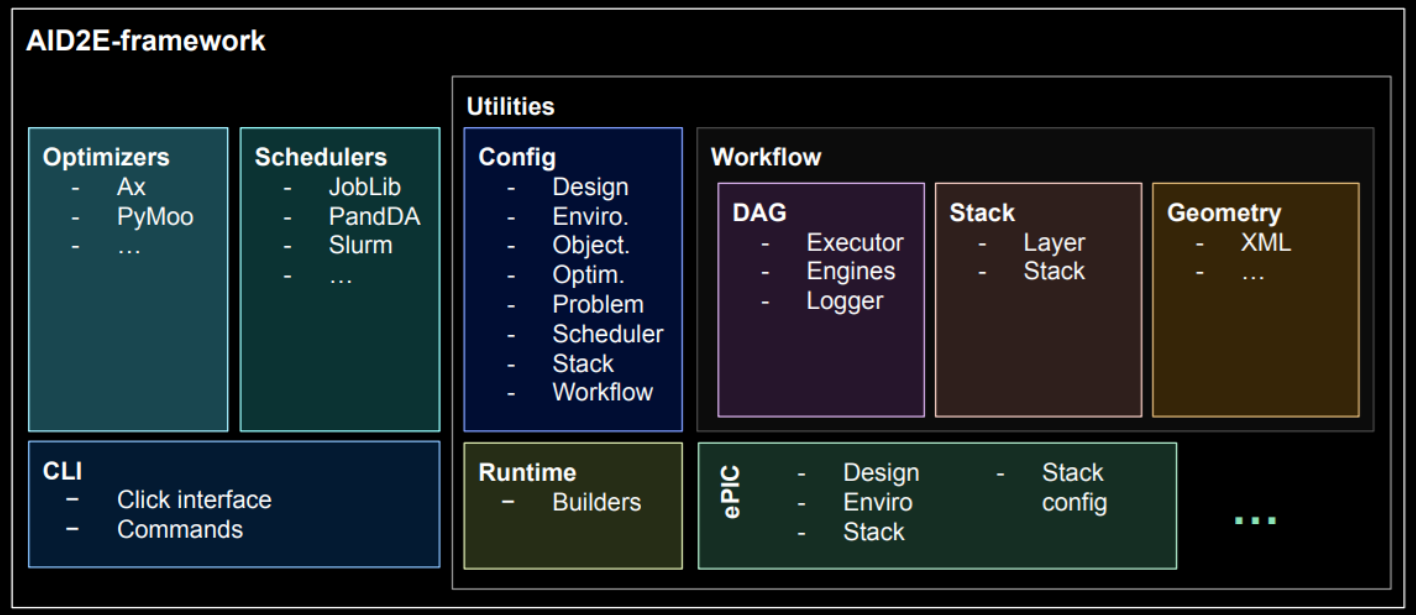
- **B0 geometry currently being optimized by Baptiste Fraisse et al**
  - Simultaneously optimizing tracker disc positions and active region for θ RMSE
  - ☞ See the recent technical note on Zenodo!

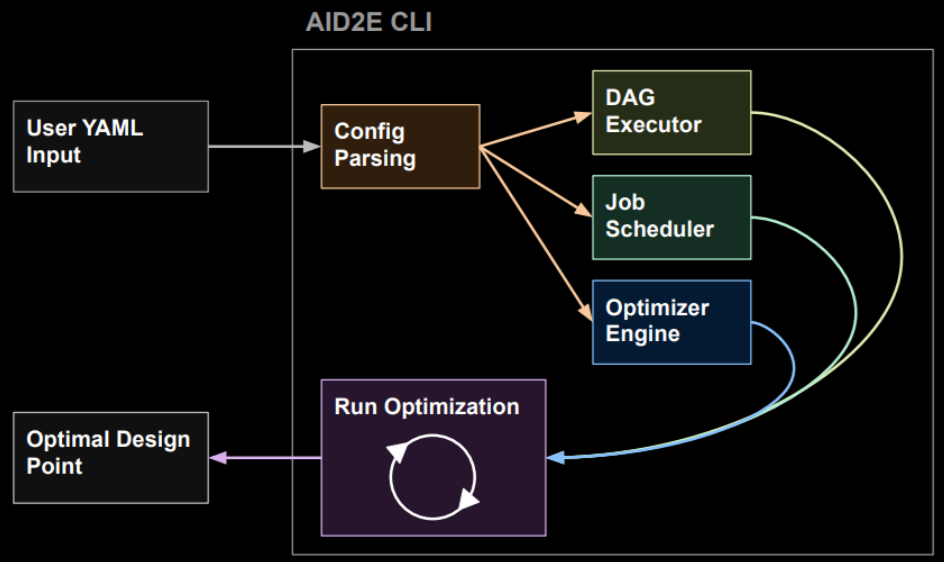
- **And:** Simon and I are exploring using MOBO techniques for optimizing the Low-Q^2 tagger



E. Cisbani et al, JINST **15** P05009 (2020)

Current Targets | Framework and Paperwork





- **A key AID(2)E deliverable:** *turnkey* framework to do optimizations
  - Provide a simple, unified interface to HPC/HTC resources, optimization engines, and experiment software
  - **Above:** resource diagram for framework **(left)** and intended workflow **(right)**
- **Two primary targets for this year:**
  a) 1st implementation of framework
  b) Paper illustrating computational performance of framework
- **Note:** subsequent framework release will *also* support optimization of *reconstruction* & *analysis* parameters

Thanks!

Questions/Comments?

Outlook

- Effectiveness of detector design as MOO demonstrated in several examples, closure tests
- **Still room for optimization at the EIC!**
  - Some designs are still pending, some will change
  - Reconstruction will continue to evolve
  - Detector 2 under active development
- Working towards 1st release of AID(2)E framework and accompanying computation paper
- Ongoing effort to explore use of LLMs and agentic techniques in AID(2)E context
  - [arXiv:2603.30014] Discussion on using agents with PanDA-iDDS for AID(2)E

AID(2)E

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- Cristiano Fanelli (W&M)
- Baptiste Fraisse (CUA)
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