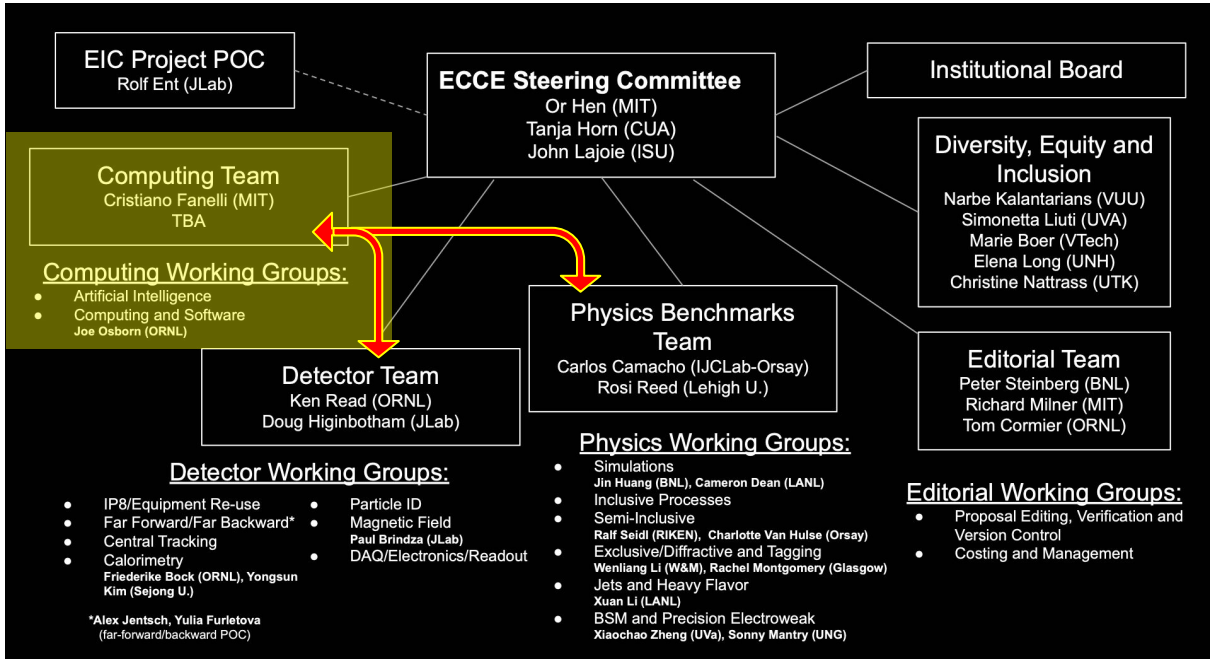
C. Fanelli for the Computing Team

Outline

- Structure and Role of the Computing Team
- Initial Documentation and Communications
- Planned Activities and Artificial Intelligence
- Action Items and Summary

Computing Team

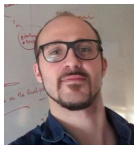
- The Computing Team more recently created to support and work synergistically with the Detector and Physics Teams and act as “liaison” with computing centers.
- CT Co-convener (TBD)
- CT is currently divided into two main working groups:
  - **Computing and Software** (**Joe Osborn**, ORNL)
  - **Artificial Intelligence** (TBD)
- CT coordinates aspects related to: Resources / Software / Repositories / Data storage / Artificial Intelligence



contacts:

cfanelli@mit.edu (Computing Team)

osbornjd@ornl.gov (Computing & Software WG)



(C.F.)

(J.O.)

Activities: Documentation and Communications

- To help with simulation and software production, ECCE (recent email from C. Dean on behalf of the simulations and computing teams) put together a documentation webpage here:
  - ECCE@EIC Software Documentation https://ecce-eic.github.io/
  - Fast tutorial on macros: https://github.com/ECCE-EIC/macros.
  - mattermost channel (https://chat.sdcc.bnl.gov/eic/channels/fun4all-ecce)
- Storage place to get started, https://eic.github.io/resources/overview.html;
- ECCE Simulation Workshop, https://indico.bnl.gov/event/11112/
  - Tutorial sessions, e.g, Joe Osborn: From Simulation to Reconstruction to Analysis
- Will show few slides on AI in this presentation

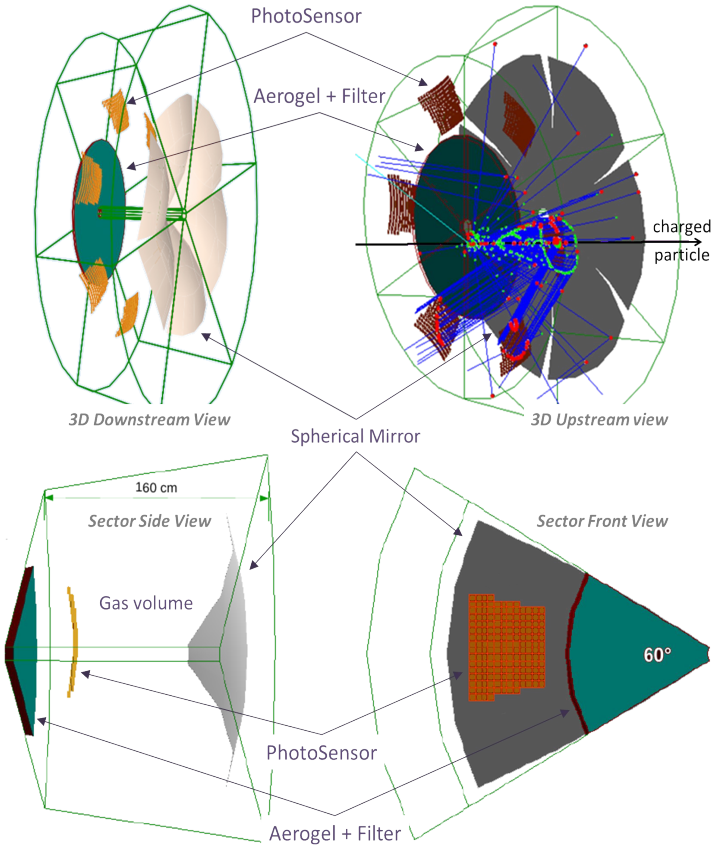
Artificial Intelligence

- ECCE with the creation of a WG dedicated to Artificial Intelligence recognizes the key-role that AI can play in the realization of the future Electron Ion Collider.
- The EIC R&D will be one of the first experimental programs in NP to systematically exploit AI since the detector-design phase.
- For the realization of EIC (~10 years) it is anticipated that AI can contribute to, e.g., Detector Design, PID, Reconstruction, Streaming RO, etc.

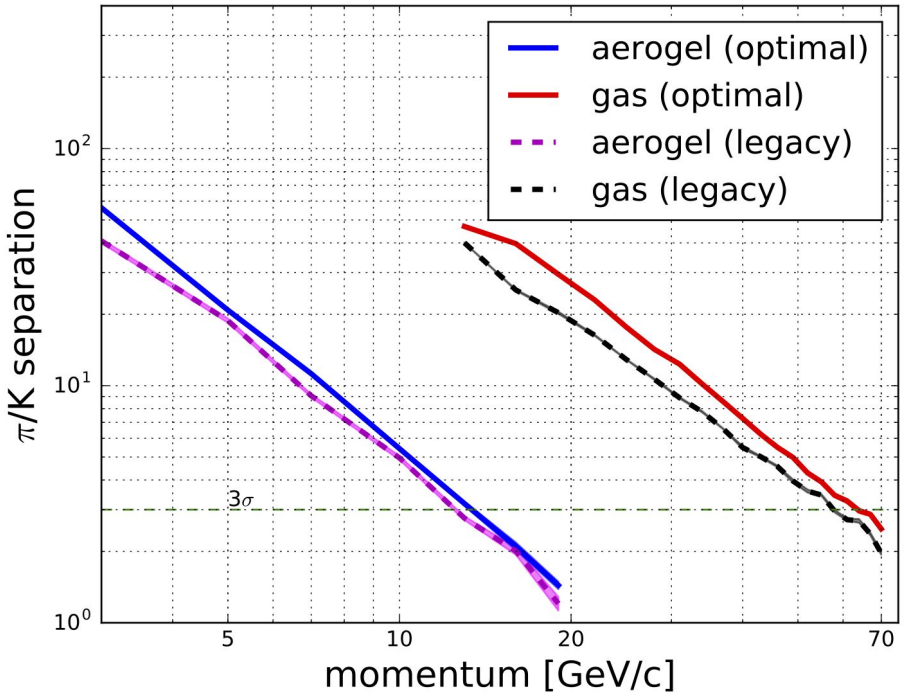
Yellow Report
arXiv:2103.05419v2

The YR already contains the first application of AI for EIC (for the dRICH design)

AI-optimized detector design: The dRICh example in the YR



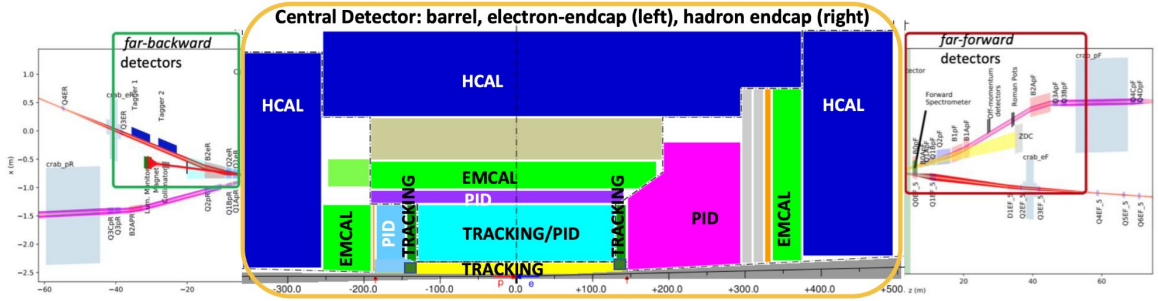
aerogel (4 cm, n(400 nm): 1.02)
+ 3 mm acrylic filter
+ gas (1.6 m, n(C_2F_6): 1.0008)



E. Cisbani, A. Del Dotto, CF*, M. Williams et al.
JINST 15.05 (2020): P05009.

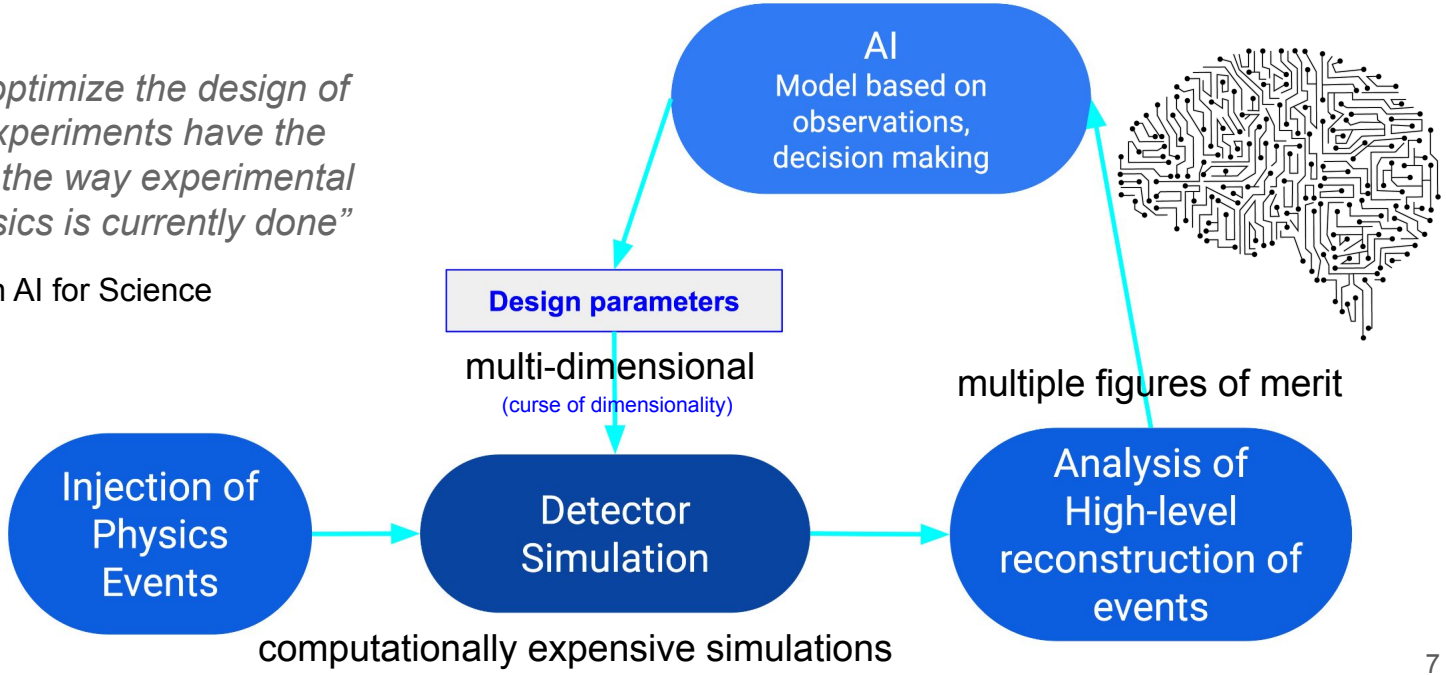
Detector Optimization Workflow

EIC Central Features Detector 2D: 3 integrated regions: Far-backward, Central, Far-forward



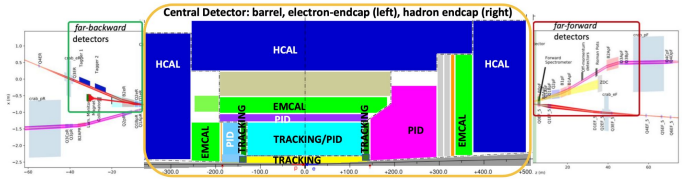
"AI techniques that can optimize the design of complex, large-scale experiments have the potential to revolutionize the way experimental nuclear and particle physics is currently done"

DOE Town Halls on AI for Science



Planned Activities

EIC Central Features Detector 2D: 3 integrated regions: Far-backward, Central, Far-forward

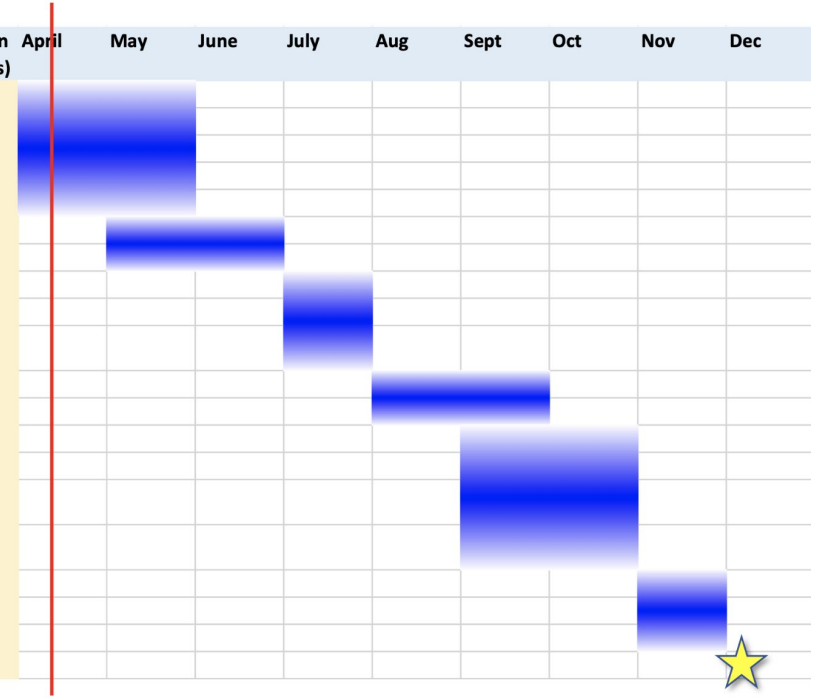


- CT aligned with ECCE timeline: AI for optimization from the first simulation campaign
- More details on how to coordinate these efforts (problems/tasks/priorities, workforce, resources etc) discussed in dedicated meetings (see next slides)
- Interested people (ideally with some prior knowledge of AI) welcome to contribute to this “task force”!
- Considering the possibility of office hours.

ECCE Timeline

Today, 12 April

Tasks	Duration (months)
Startup	1.5
Implement ECCE setup in Fun4All	
Agree on technology alternatives to study	
Agree on main physics studies	
Arrange required event generators	
First simulation campain & initial analysis	1.5
Optimize	
Midterm activities	1
Large scale simulations production	
Drafting Collaboration Structure part of the proposal	
Analysis of simulation data	1.5
demonstrate physics extraction	
Start of Proposal Writing	1.5
All physics plots are done	
Agree on technology selection based on physics studies	
Compose narrative around simulation results and selected technologies	
Proposal Review and final edits	1
Review by external colleagues	
Final edits	
Proposal Submission (1 Dec. 2021)	



Contact: cfanelli@mit.edu

AI4EIC Workshop

[1] AI4NP Wokshop, JLab, Report from the AI For Nuclear Physics Workshop, arXiv:2006.05422 (2020)
[2] Joint Machine Learning Workshop, GlueX Panda EIC, 2020.
[3] AI4NP Winter School (11-15 January 2021)

- Strategic moment to discuss how to fully take advantage of the new opportunities offered by AI to advance research, design, and operation of EIC.
- Growing convergence of AI, Data, and HPC provides a once in a generation opportunity to profoundly accelerate scientific discovery, create synergies across scientific areas.
- The interest of the community evidenced by the number of contributions and attendance of workshops/schools dedicated to AI in Nuclear Physics, e.g. the [1, 2, 3]
- The **AI4EIC** workshop will bring together the communities directly using AI technologies and provide a venue for discussion and identifying the specific needs and priorities for EIC.
- This will be a series of workshops. The first one will have a focus on experimental applications, therefore **AI4EIC-exp.**

- Detector Optimization
- Fast Simulations / Digital-twins / Surrogate
- Reconstruction / PID
- Autonomous control / Intelligent Systems
- DAQ / event filtering / near real-time
- Computing frontiers

Action Items

✅ Software up and running

✅ AI framework allowing for design optimization

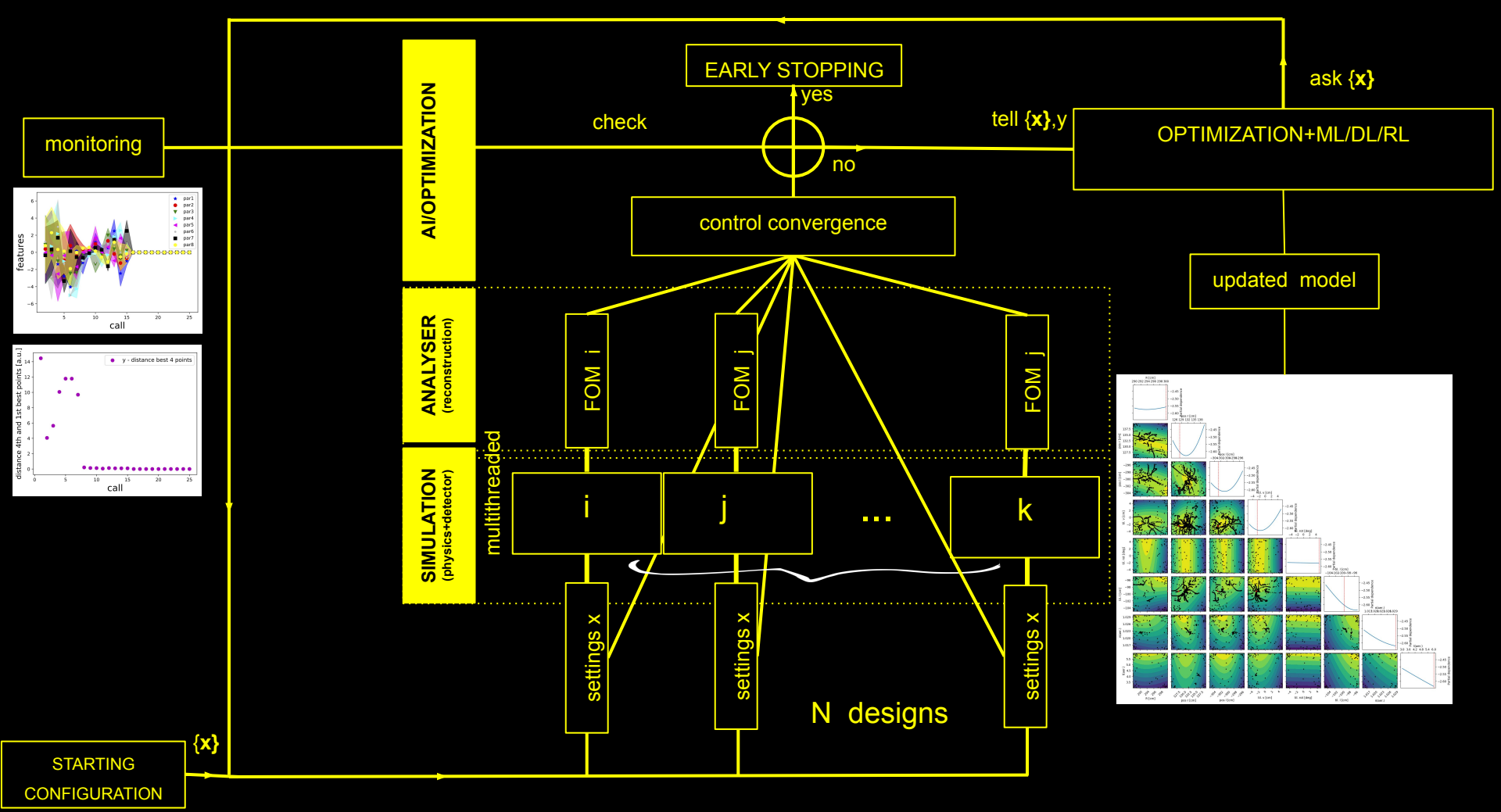
- Create mailing list for ECCE-CT (this week)
- CT co-convener and AI WG convener (expected in << 2 weeks)
- Future ECCE workshops; Office hours and meeting schedule (bi-weekly?) (TBD)
- **Initial Steps**:
  - topics above / resources, address computing space to store MC in conjunction with simulations WG; meeting ~ a week from now
  - consolidate list of optimization tasks; ~ 2 weeks
  - build prototype simulation pipeline (from simulation to analysis) and optimize with AI - in order to generalize/extend to other sub-detectors / more sub-detectors together for the simulation campaign; (expected by end of April)

Summary

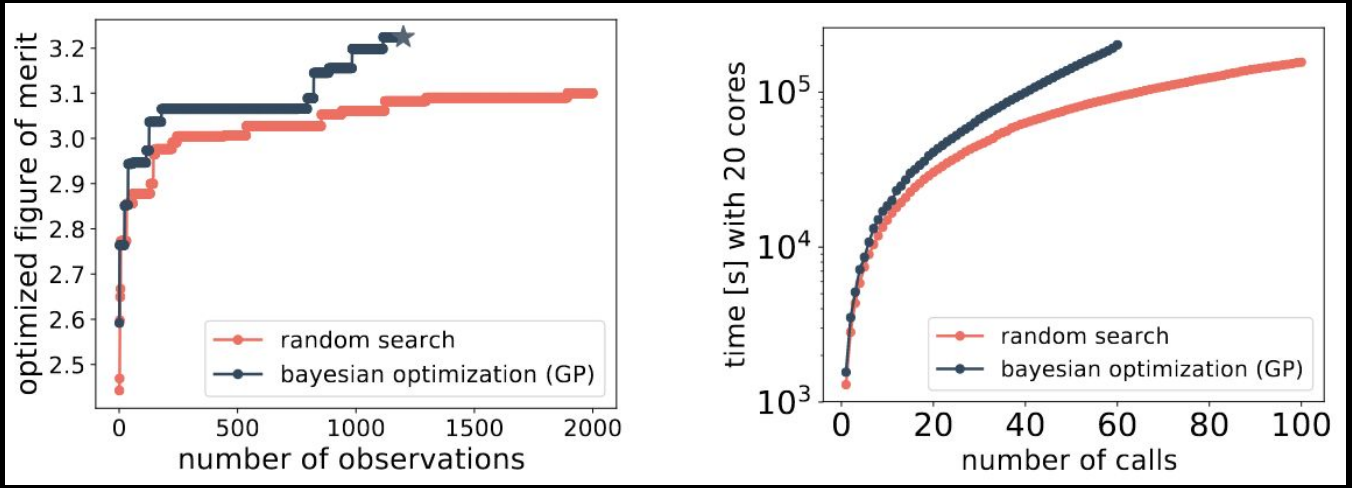
- The Computing Team will provide:
  - Computing & Software support to the other teams
  - AI-support for the optimization of the ECCE design (CT will coordinate tasks/resources, implementation, prioritize parts to optimize, etc)
  - Support/coordination of technical aspects (how to/where to, wiki/indico, repos, resources, etc)
- Get started with simulations! Reach out to us and simulation team for any issues.
- People willing to get involved in detector design with AI (possibly with prior knowledge of AI) or for any ideas/suggestions, please contact: cfanelli@mit.edu.

  - ECCE wiki (under construction) https://wiki.bnl.gov/eicug/index.php/ECCE
  - Lectures on Detector Design Optimization, C. Fanelli, AI4NP Winter School https://github.com/cfteach/AI4NP_detector_opt
  - Computing resources:
    - available at BNL and JLab, https://eic.github.io/resources/overview.html
    - SDDC@BNL, https://wiki.bnl.gov/eic/index.php/Computing

SPARES


monitoring
AI/OPTIMIZATION
EARLY STOPPING
yes
check
tell {x},y
ask {x}
OPTIMIZATION+ML/DL/RL
no
control convergence
updated model
ANALYSER
(reconstruction)
SIMULATION
(physics+detector)
multithreaded
FOM i
FOM j
FOM j
i
j
...
k
settings x
settings x
settings x
N designs
{x}
STARTING
CONFIGURATION
features
call
distance 4th and 1st best points [a.u.]
y - distance best 4 points
call

Comparison with Random Search



Each call:
400 tracks generated/core
20 cores

1 design point ~ 10 mins/CPU

Budget: 100 calls

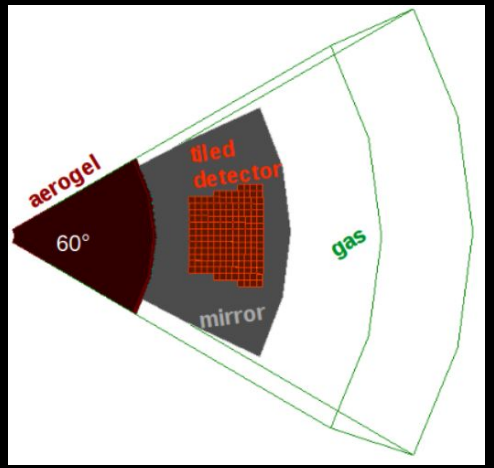
- BO with GP scales cubically with number of observations.
- Bayesian optimization methods are more promising because they offer principled approaches to weighting the importance of each dimension.
- For this 8D problem - even with 50 cores, RS looks unfeasible due to the curse of dimensionality.
  - Recall that the probability of finding the target with RS is $1-(1-v/V)^T$, where T is trials, v/V is the volume of target relative to the unit hypercube

Bergstra, Bengio, “Random search for hyper-parameter optimization”, J. Mach. Learn. Res.13 (Feb) (2012) 281–305.

Construction Constraints on Design Parameters

The idea is that we have a bunch of parameters to optimize that characterize the detector design.
We know from previous studies their ranges and the construction tolerances.

parameter	**description**	**range** [units]	**tolerance** [units]
R	mirror radius	[290,300] [cm]	100 [μm]
pos r	radial position of mirror center	[125,140] [cm]	100 [μm]
pos l	longitudinal position of mirror center	[-305,-295] [cm]	100 [μm]
tiles x	shift along x of tiles center	[-5,5] [cm]	100 [μm]
tiles y	shift along y of tiles center	[-5,5] [cm]	100 [μm]
tiles z	shift along z of tiles center	[-105,-95] [cm]	100 [μm]
$n_{aerogel}$	aerogel refractive index	[1.015,1.030]	0.2%
$t_{aerogel}$	aerogel thickness	[3.0,6.0] [cm]	1 [mm]



Ranges depend mainly on mechanical constraints and optics requirements.
These requirements can change in the next future based on inputs from prototyping.

The Model and the Optimized FoM

$$N\sigma = \frac{||\langle\theta_K\rangle - \langle\theta_\pi\rangle||\sqrt{N_\gamma}}{\sigma_\theta^{1p.e.}}$$