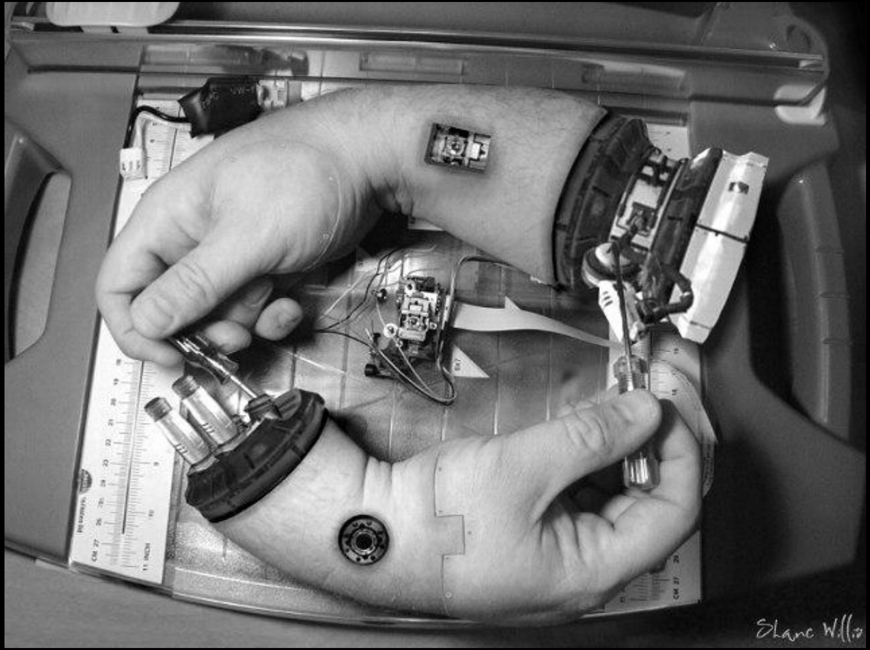
Dual Radiator RICH Design



C. Fanelli

E. Cisbani, A. Del Dotto, C. Fanelli, M. Williams et al
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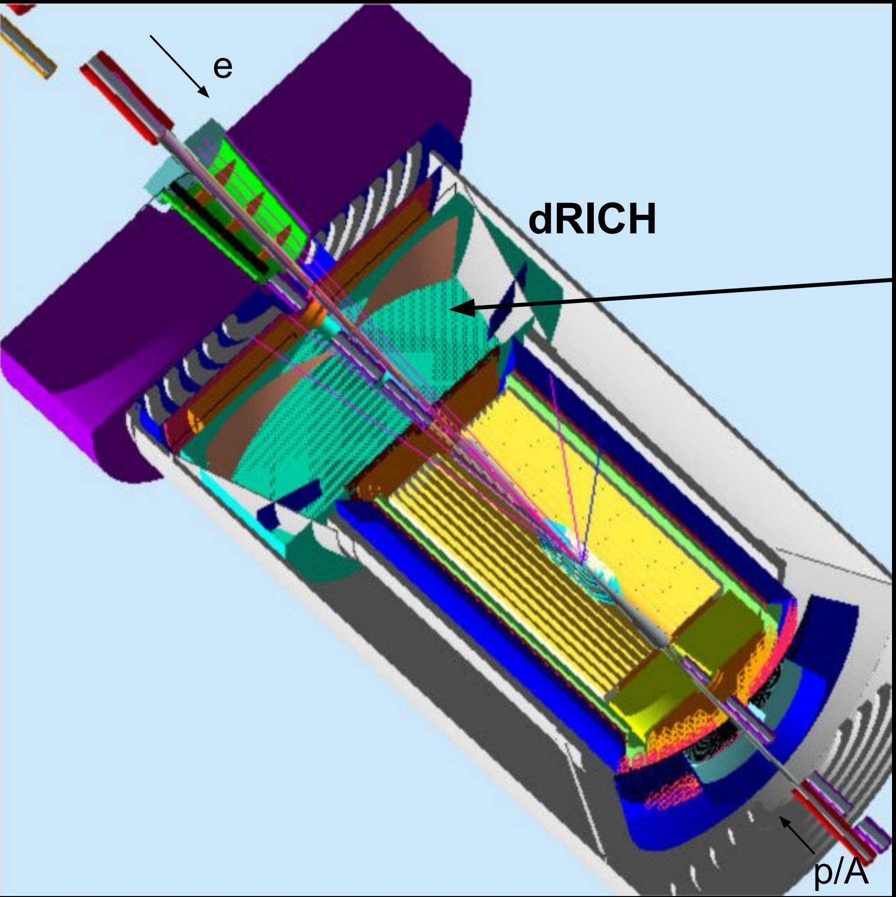
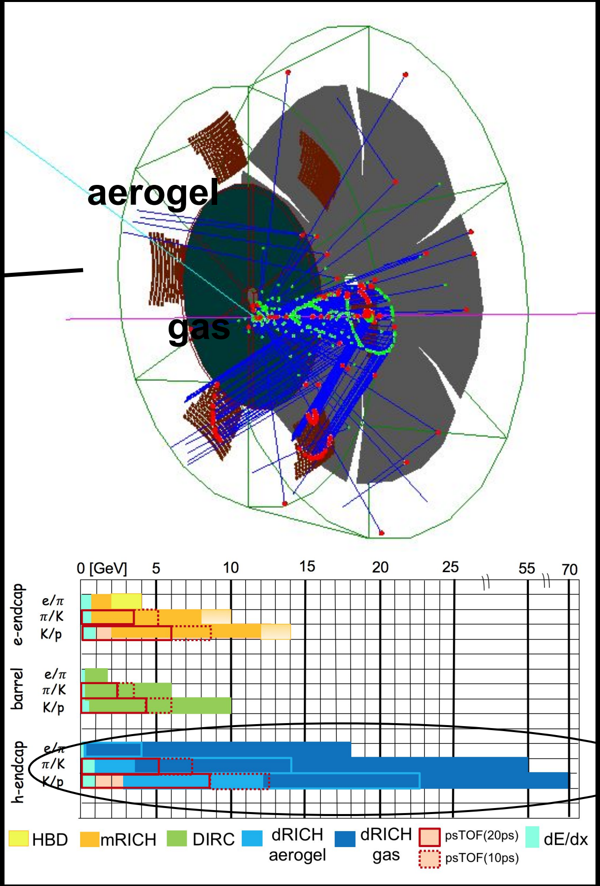
Motivation

EIC is in its design phase... can AI help?





aerogel
4 cm, n(400 nm) 1.02
+ 3 mm acrylic filter

gas
1.6 m, nC_2F_6 1.0008

A dual-radiator RICH needed to cover continuously momenta up to 50 GeV/c in the h-endcap

Construction Constraints

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]
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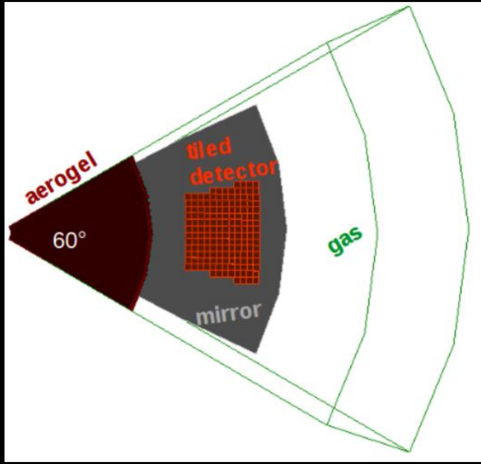
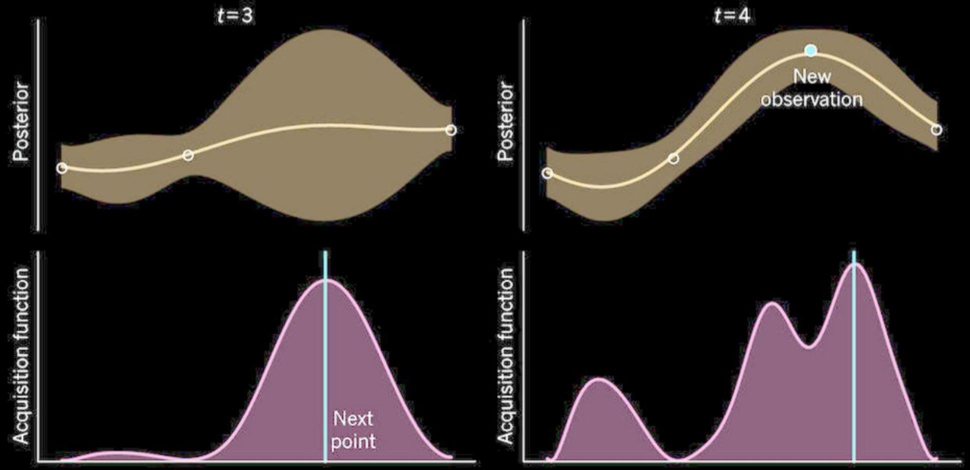
$n_{aerogel}$	aerogel refractive index	[1.015,1.030]	0.2%
$t_{aerogel}$	aerogel thickness	[3.0,6.0] [cm]	1 [mm]

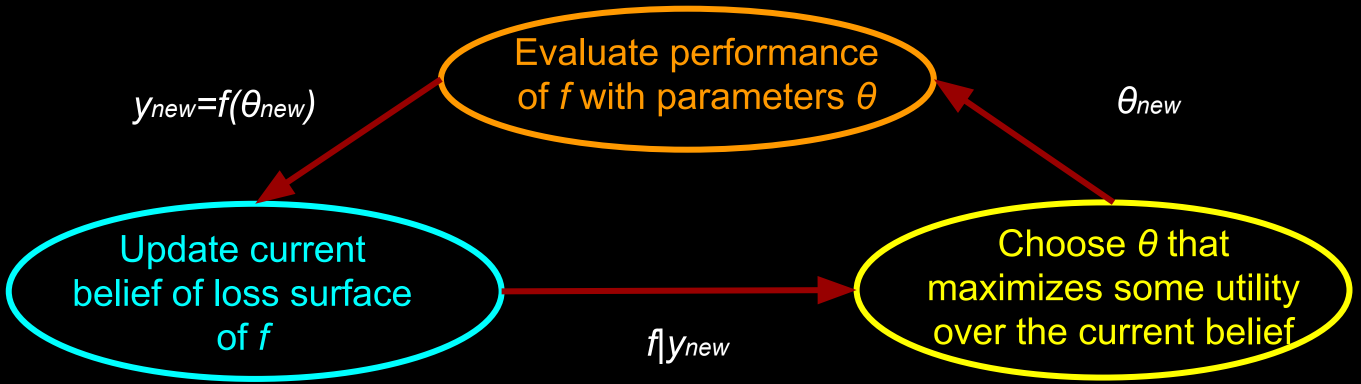


Ranges depend mainly on mechanical constraints and optics requirements.
These requirements can change in the next future based on inputs from prototyping.

Bayesian Optimization

- BO is a strategy developed for global optimization.
- After gathering evaluations BO builds a posterior distribution (different regression techniques) used to construct an **acquisition function**.
- This cheap function determines what is **next query point**.

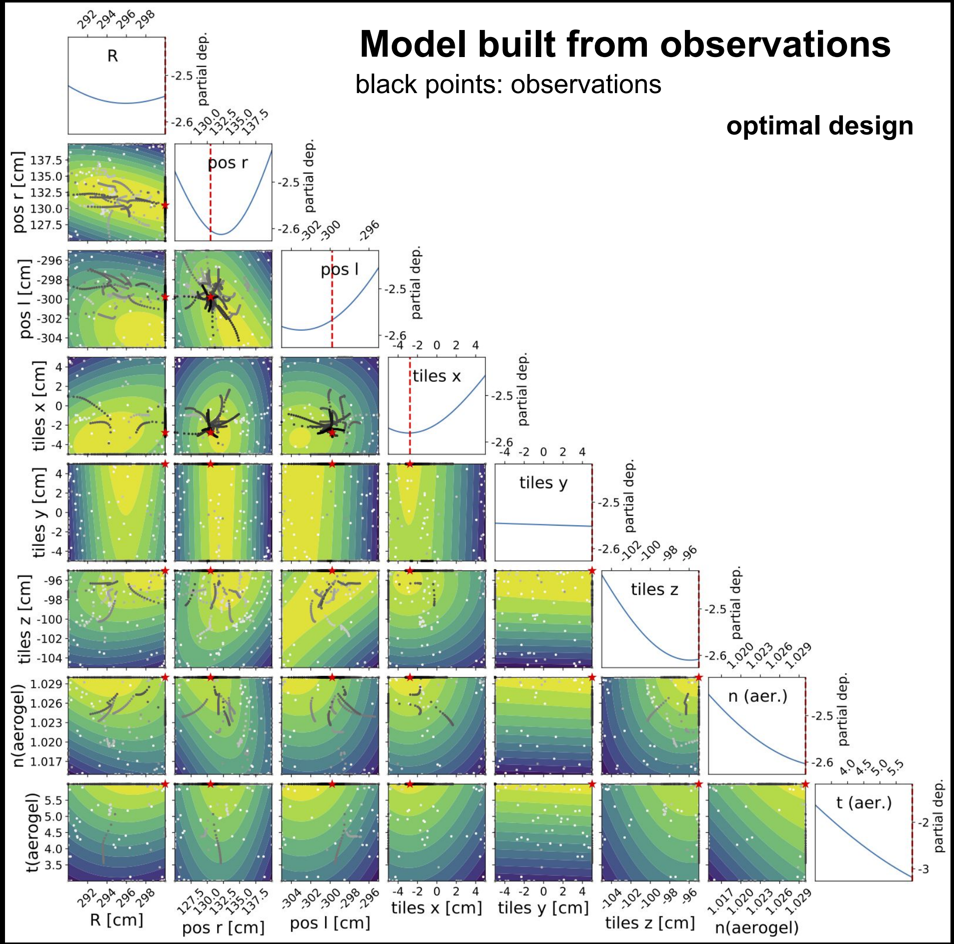


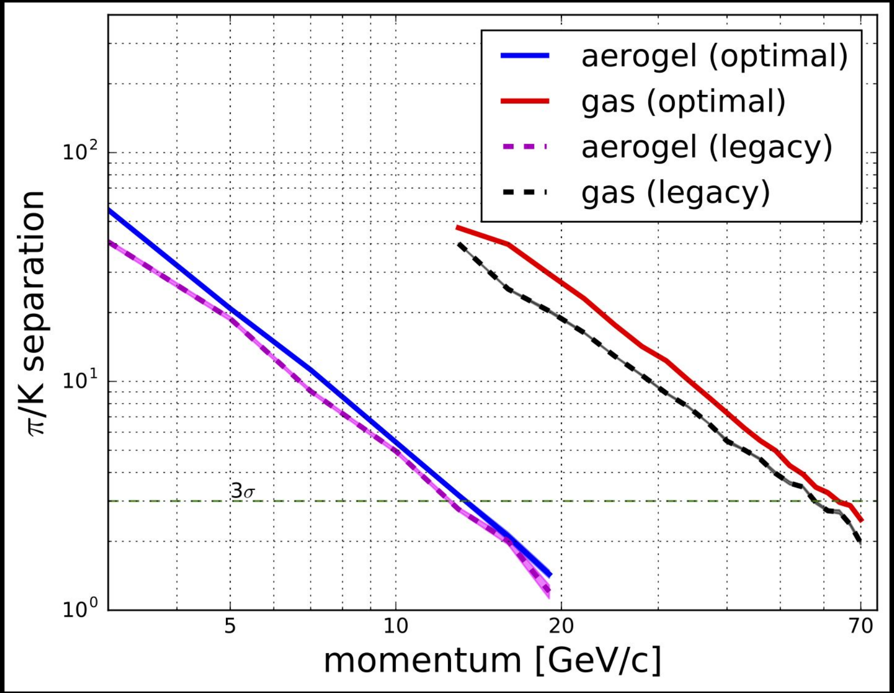


Model and FoM

$$N\sigma = \frac{||\langle\theta_K\rangle - \langle\theta_\pi\rangle||\sqrt{N_\gamma}}{\sigma_\theta^{1p.e.}} \qquad N_\gamma = (N_\gamma^\pi + N_\gamma^K)/2$$

$$h = 2 \cdot \left[\frac{1}{(N\sigma)|_1} + \frac{1}{(N\sigma)|_2}\right]^{-1}$$



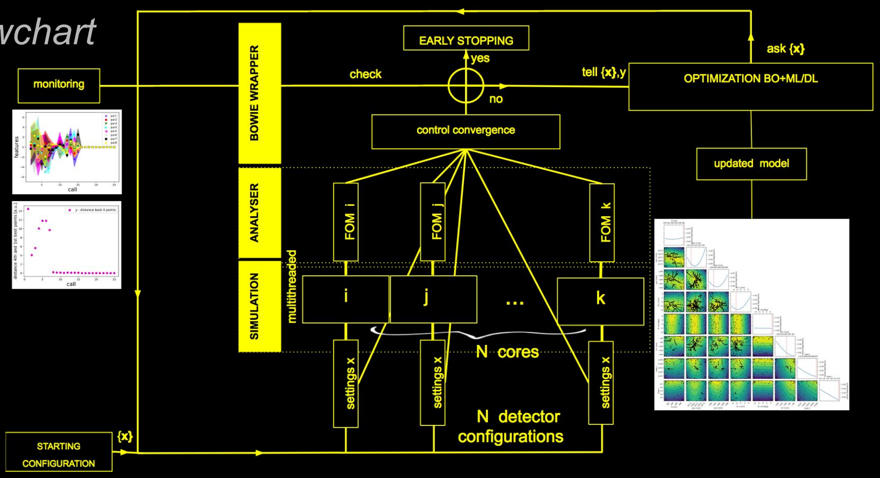


Summary

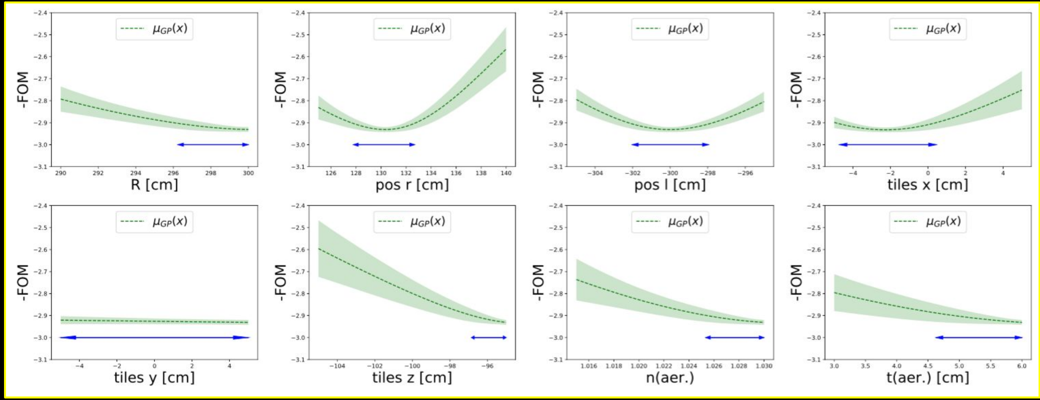
- automated, highly-parallelized, self-consistent.
- Possible to use the posterior to determine tolerances on parameters
- Can be extended and applied to other detectors and possibly to the entire experiment, making the EIC R&D one of the first programs to systematically exploit AI in the detector-design phase.

- AI can help coordinate the efforts of different groups developing different sub-detectors towards the final global detector design.

flowchart



tolerances



BACKUP

Vision Slide

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

Bayesian Optimization

DL-boosted

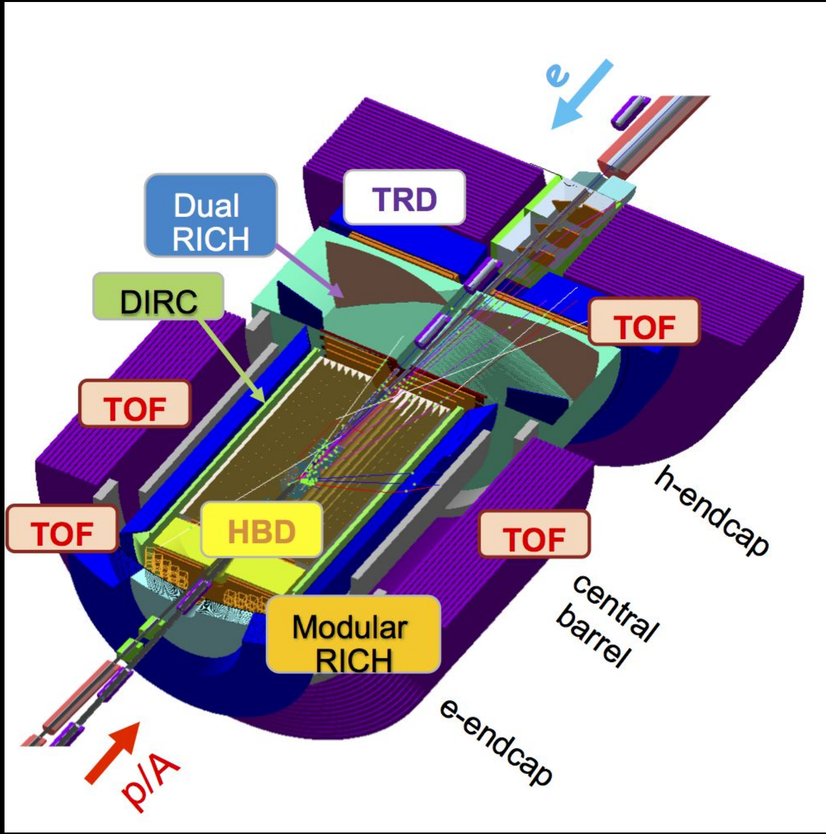
Evolutionary autoML

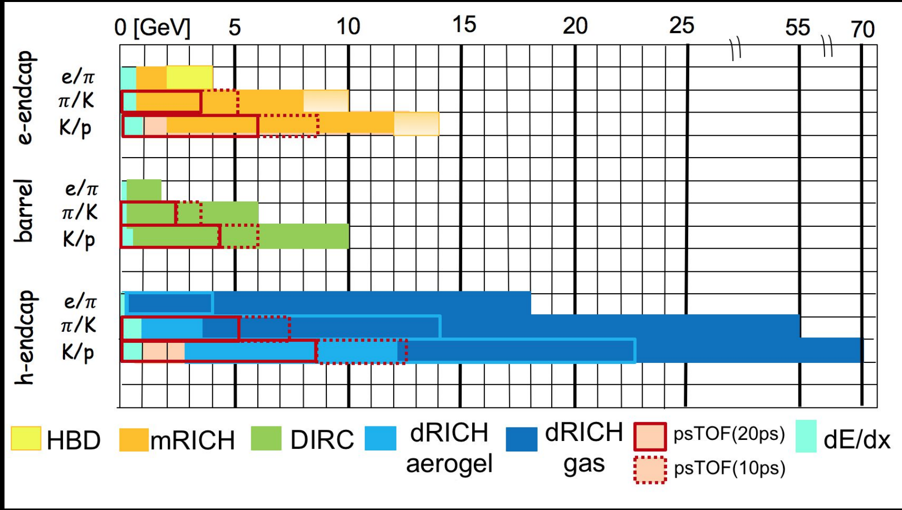
Meta-learning

Reinforcement Learning

- AI for detector design
- Intelligent detection systems able to self-calibrate/align
- etc

Detector Concepts





Different detector concepts…

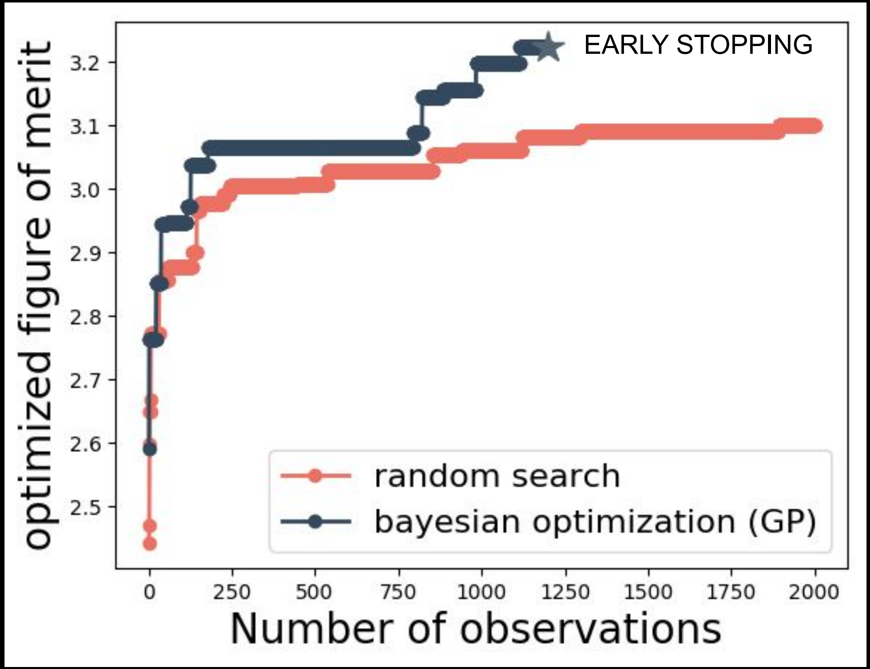
h-endcap: a dual-radiator RICH needed to cover continuously momenta up to 50 GeV/c

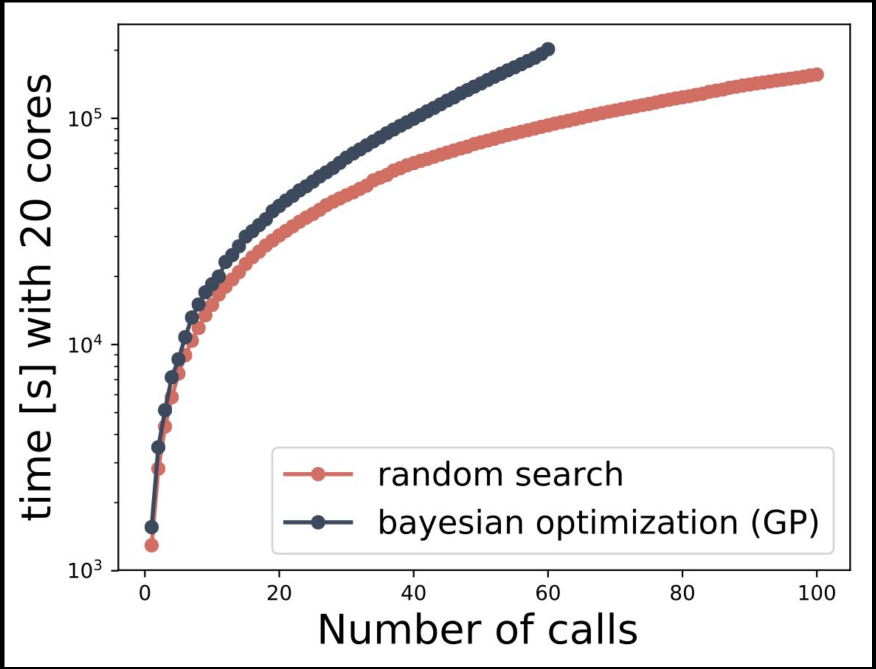
e-endcap: a small lens focused aerogel RICH for momenta up to 10 GeV/c

barrel: DIRC provide a compact and cost effective way to cover momenta up to 6 GeV/c

TOF (and or dE/dx in the TPC) can cover the low momenta region

Comparison with Random Search



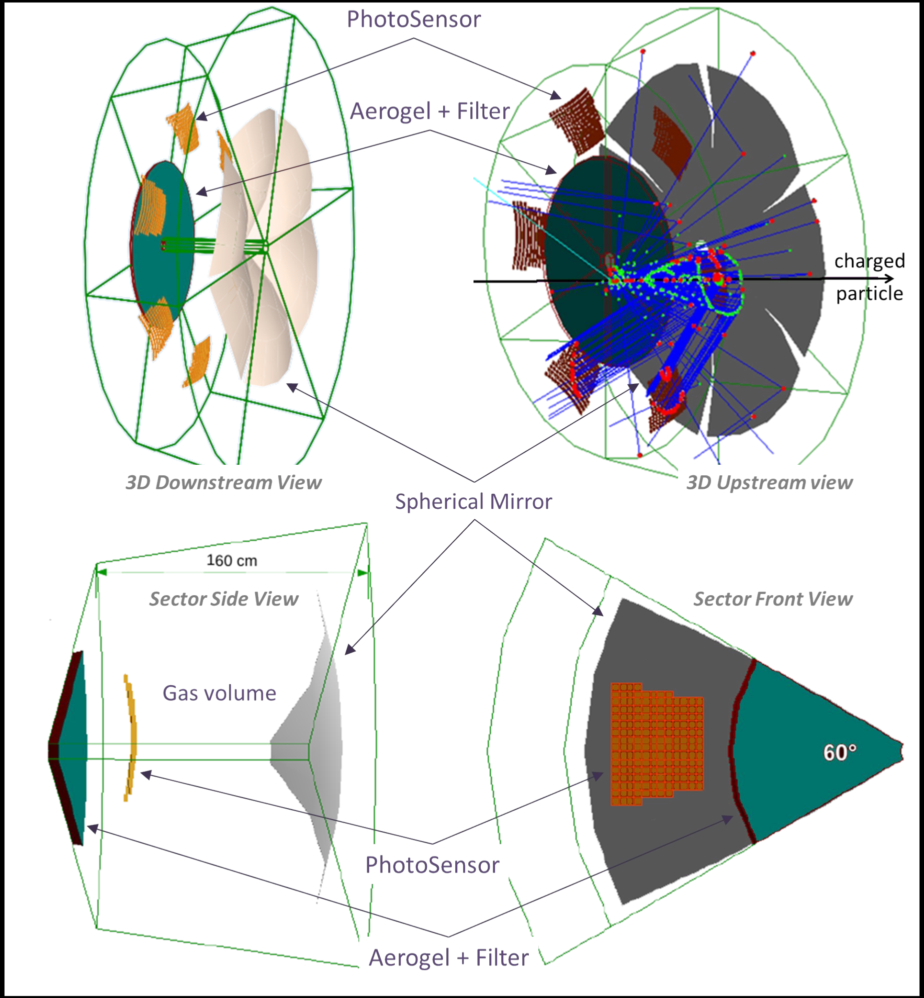


Case Study: dRICH

- 6 Identical open sectors (petals)
- Optical sensor elements:
  8500 cm^2/sector, 3 mm pixel
- Large focusing mirror

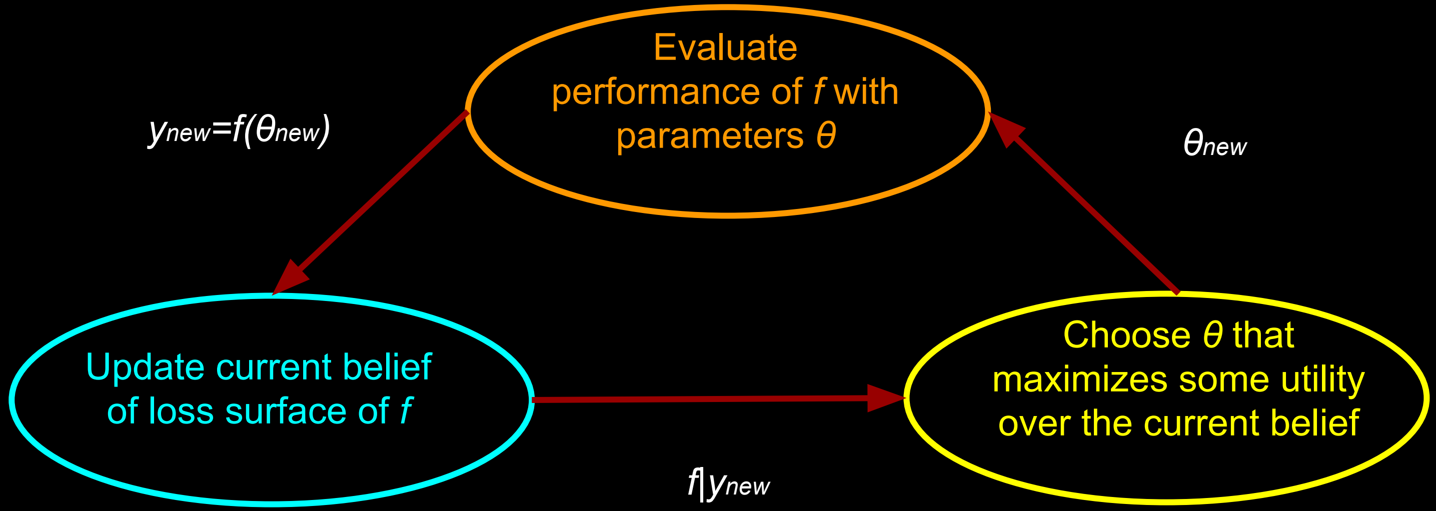
aerogel (4 cm, n(400 nm) 1.02)
+ 3 mm acrylic filter
+ gas (1.6 m, nC_2F_6 1.0008)

- Continuous momentum coverage.
  Simple geometry/optics,
  cost effective.
- Legacy design from [EICUG2017]



Bayesian Optimization

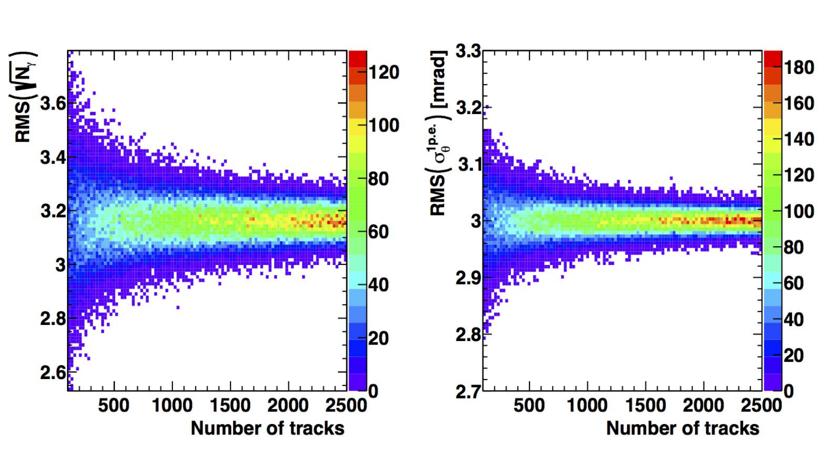
It basically consists of three steps

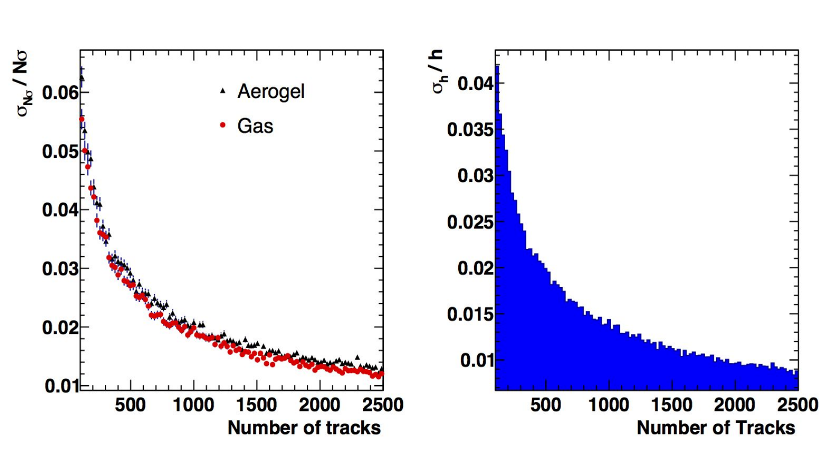


Noise Studies

CF et al. AI-optimized detector design for the future EIC *arXiv:1911.05797* (2019)

- Dedicated studies to characterize the noise as this is an optimization of a noisy function
- We choose N tracks = 400 based on the studies on noise to minimize as much as possible computing time during simulation.





symbol	description	value
T	maximum number of calls	100
M	points generated in parallel (GP)	20
N	pions (and kaons) per sample	200
kappa	controls variance in predicted values	1.96
xi	controls improvement over previous best values	0.01
noise	expected noise (relative)	2.5%

(list of hyperparameters)

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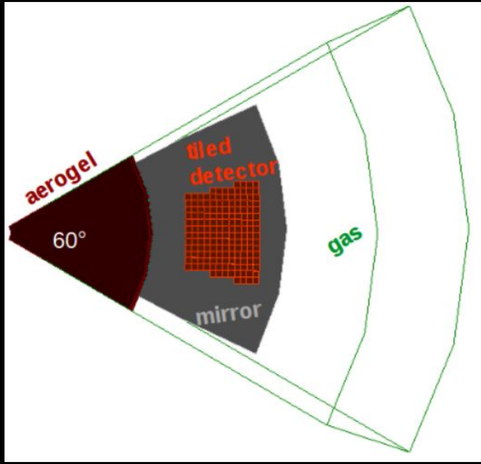

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Figure of Merit

CF et al. AI-optimized detector design for the future EIC *arXiv:1911.05797* (2019)

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$$N_\gamma = (N_\gamma^\pi + N_\gamma^K)/2$$

$$h = 2 \cdot \left[\frac{1}{(N\sigma)|_1} + \frac{1}{(N\sigma)|_2}\right]^{-1}$$

@ p_1 = 14 GeV/c (aerogel) and p_2 = 60 GeV/c (gas)

considering the two parts disentangled