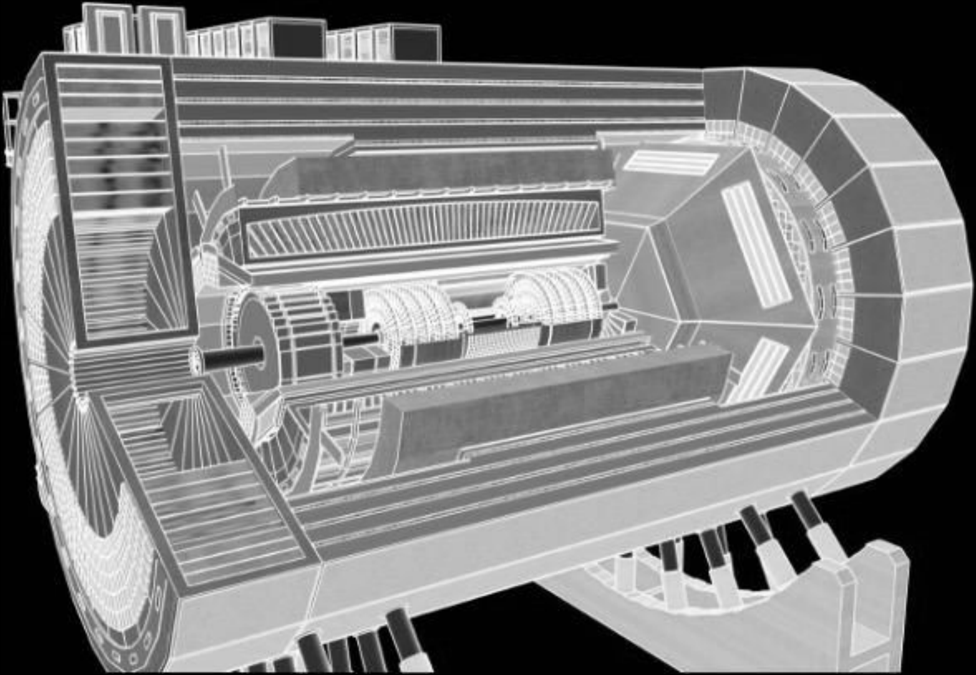
Detector Design Optimization for ECCE



ECCE detector concept

Cristiano Fanelli

On behalf of the
ECCE AI WG

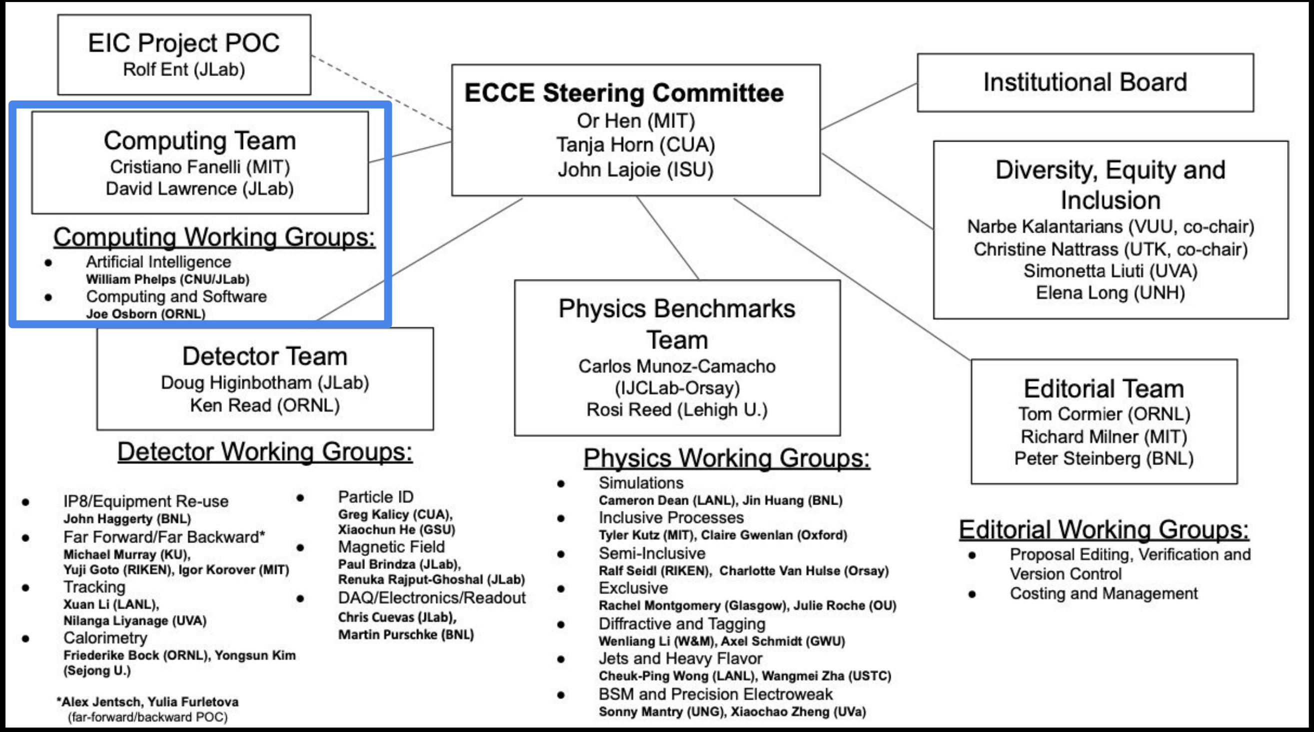
AI within ECCE

EIC Comprehensive Chromodynamics Experiment

https://www.ecce-eic.org

ECCE shares the vision of the NP community that the EIC science mission is best served by two complementary detectors, and is investigating a design based on a 1.5T solenoid in both EIC interaction regions.

ECCE recognizes the important role that AI can play in a future experiment like EIC, and includes in its structure a working group dedicated to AI (March 2021)



EIC Project POC
Rolf Ent (JLab)

ECCE Steering Committee
Or Hen (MIT)
Tanja Horn (CUA)
John Lajoie (ISU)

Institutional Board

Computing Team
Cristiano Fanelli (MIT)
David Lawrence (JLab)

Computing Working Groups:
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  William Phelps (CNU/JLab)
- Computing and Software
  Joe Osborn (ORNL)

Diversity, Equity and Inclusion
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Christine Nattrass (UTK, co-chair)
Simonetta Liuti (UVA)
Elena Long (UNH)

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Doug Higinbotham (JLab)
Ken Read (ORNL)

Physics Benchmarks Team
Carlos Munoz-Camacho (IJCLab-Orsay)
Rosi Reed (Lehigh U.)

Editorial Team
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Richard Milner (MIT)
Peter Steinberg (BNL)

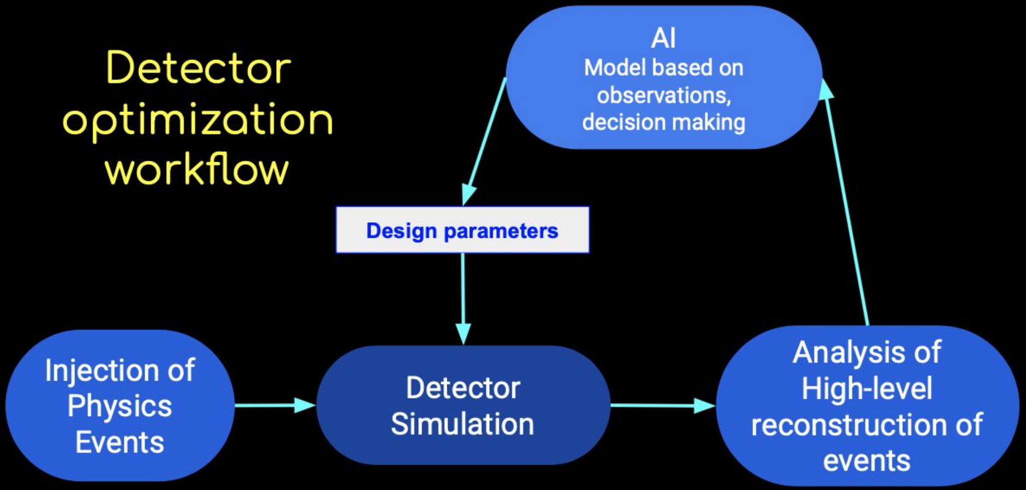
Detector Working Groups:
- IP8/Equipment Re-use
  John Haggerty (BNL)
- Far Forward/Far Backward*
  Michael Murray (KU), Yuji Goto (RIKEN), Igor Korover (MIT)
- Tracking
  Xuan Li (LANL), Nilanga Liyanage (UVA)
- Calorimetry
  Friederike Bock (ORNL), Yongsun Kim (Sejong U.)
- Particle ID
  Greg Kalicy (CUA), Xiaochun He (GSU)
- Magnetic Field
  Paul Brindza (JLab), Renuka Rajput-Ghoshal (JLab)
- DAQ/Electronics/Readout
  Chris Cuevas (JLab), Martin Purschke (BNL)

***Alex Jentsch, Yulia Furletova**
(far-forward/backward POC)

Physics Working Groups:
- Simulations
  Cameron Dean (LANL), Jin Huang (BNL)
- Inclusive Processes
  Tyler Kutz (MIT), Claire Gwenlan (Oxford)
- Semi-Inclusive
  Ralf Seidl (RIKEN), Charlotte Van Hulse (Orsay)
- Exclusive
  Rachel Montgomery (Glasgow), Julie Roche (OU)
- Diffractive and Tagging
  Wenliang Li (W&M), Axel Schmidt (GWU)
- Jets and Heavy Flavor
  Cheuk-Ping Wong (LANL), Wangmei Zha (USTC)
- BSM and Precision Electroweak
  Sonny Mantry (UNG), Xiaochao Zheng (UVa)

Editorial Working Groups:
- Proposal Editing, Verification and Version Control
- Costing and Management

AI WG Activities



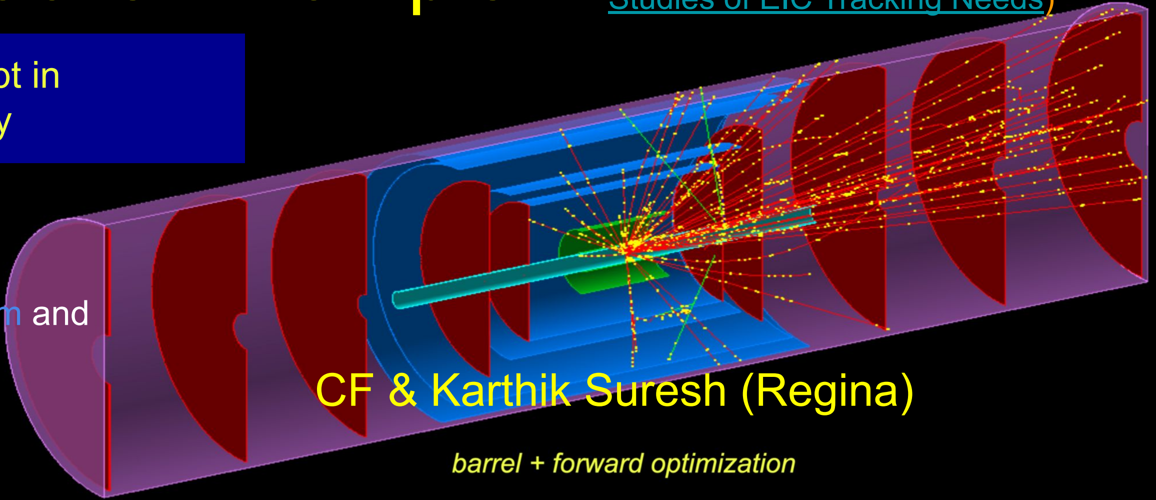
- Identified activities in the AI Working Group (regarding design and reconstruction algorithms):
  - Tracking (Brunel, MIT, Regina, work in progress)
  - PID --- DIRC (CNU, MIT), d-RICH (MIT d-RICH paper)
  - Calorimetry (CUA, MIT, Regina, work started within eRD1, link to presentation)
  - (Far Forward --- ZDC (Duquense))

The ECCE Inner Tracker Example

Baseline (see talk of R. Cruz-Torres, Studies of EIC Tracking Needs)

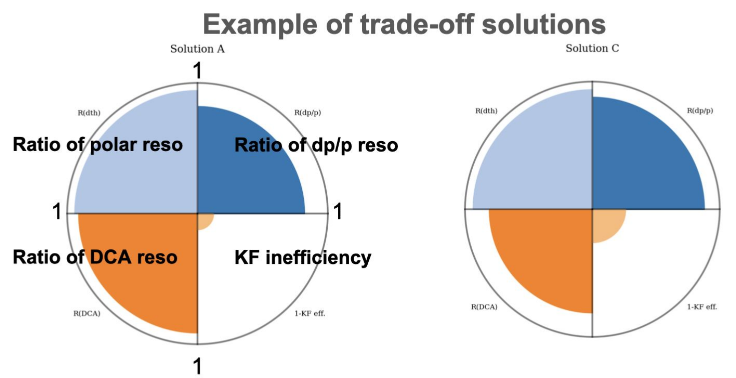
This is an unprecedented attempt in detector design for complexity

- Extended the design criteria to include simultaneously Kalman filter efficiency, pointing resolution, along with momentum and angular resolutions.
- Mechanical constraints



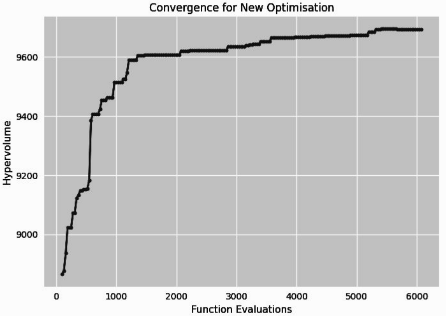
CF & Karthik Suresh (Regina)

barrel + forward optimization



11 parameters
4 objectives
Population size 100
Offspring distributed over 30 cores

Each proposed design is consistent with baseline Aluminum support shell (not displayed)

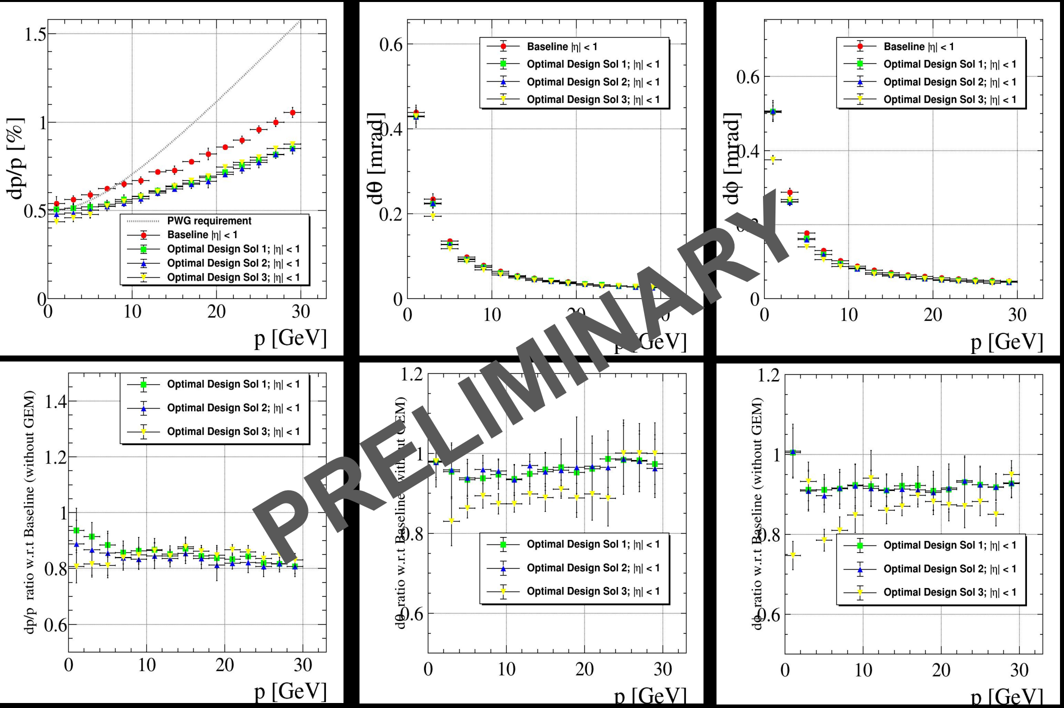


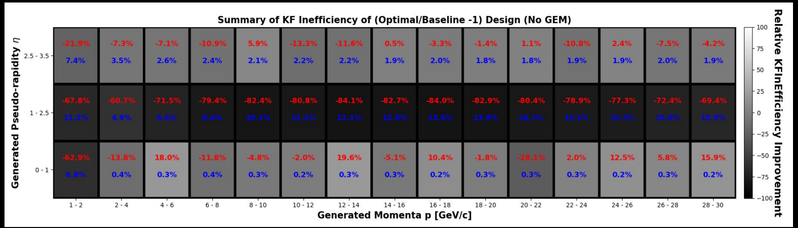
Ratios are with respect the LBNL all Si baseline

Inner Tracker

For each design solution in the front one can study the corresponding detector performance.

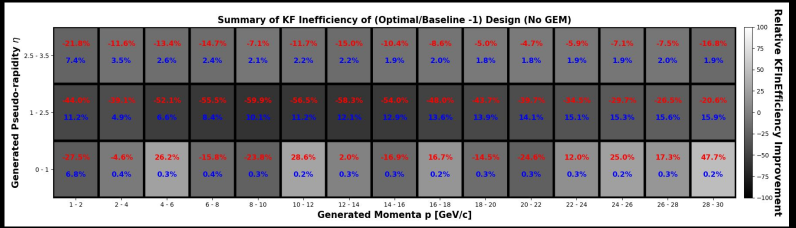
- The decision making process on the design can happen after the optimization, exploring the performance of the trade-off solutions.
- On left are displayed momentum, angular resolutions) for one solution. Below the Kalman Filter inefficiency.
- Performance not included as objectives can be used for validation. For example, pattern recognition and fake tracks rejection studies eventually studied to validate designs.




Summary of KF Inefficiency of (Optimal/Baseline -1) Design (No GEM)

Generated Pseudo-rapidity η	1 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20	20 - 22	22 - 24	24 - 26	26 - 28	28 - 30
2.5 - 3.5	-21.9% 7.4%	-7.3% 3.5%	-7.1% 2.6%	-10.9% 2.4%	5.9% 2.1%	-13.3% 2.2%	-11.6% 2.2%	0.5% 1.9%	-3.3% 2.0%	-1.4% 1.8%	1.1% 1.8%	-10.8% 1.9%	2.4% 1.9%	-7.5% 2.0%	-4.2% 1.9%
1 - 2.5	-67.8% 11.2%	-60.7% 4.9%	-71.5% 6.6%	-79.4% 8.4%	-82.4% 10.1%	-80.8% 11.2%	-84.1% 12.1%	-82.7% 12.9%	-84.0% 13.6%	-82.9% 13.9%	-80.4% 14.1%	-78.9% 15.1%	-77.3% 15.3%	-72.4% 15.6%	-69.4% 15.9%
0 - 1	-62.9% 6.8%	-13.8% 0.4%	18.0% 0.3%	-11.8% 0.4%	-4.8% 0.3%	-2.0% 0.2%	19.6% 0.3%	-5.1% 0.3%	10.4% 0.2%	-1.8% 0.3%	-28.1% 0.3%	2.0% 0.3%	12.5% 0.2%	5.8% 0.3%	15.9% 0.2%

Generated Momenta p [GeV/c]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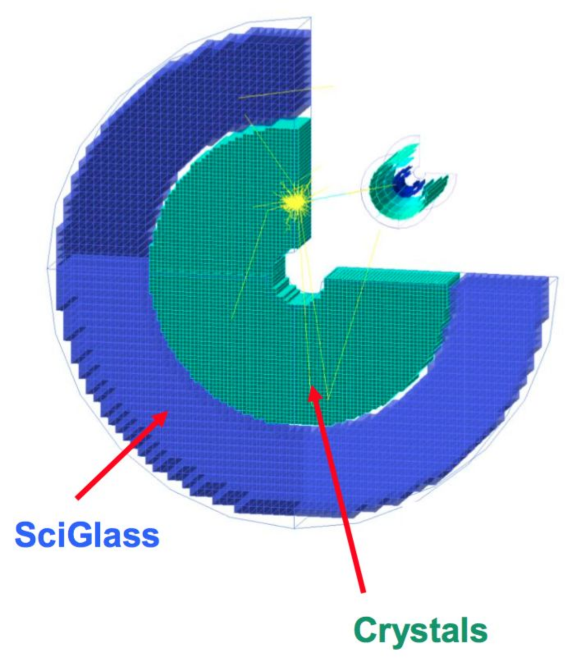
2.5 - 3.5	-21.8% 7.4%	-11.6% 3.5%	-13.4% 2.6%	-14.7% 2.4%	-7.1% 2.1%	-11.7% 2.2%	-15.0% 2.2%	-10.4% 1.9%	-8.6% 2.0%	-5.0% 1.8%	-4.7% 1.8%	-5.9% 1.9%	-7.1% 1.9%	-7.5% 2.0%	-16.8% 1.9%
1 - 2.5	-44.0% 11.2%	-39.1% 4.9%	-52.1% 6.6%	-55.5% 8.4%	-59.9% 10.1%	-56.5% 11.2%	-58.3% 12.1%	-54.0% 12.9%	-48.0% 13.6%	-43.7% 13.9%	-39.7% 14.1%	-34.5% 15.1%	-29.7% 15.3%	-26.5% 15.6%	-20.6% 15.9%
0 - 1	-27.5% 6.8%	-4.6% 0.4%	26.2% 0.3%	-15.8% 0.4%	-23.8% 0.3%	28.6% 0.2%	2.0% 0.3%	-16.9% 0.3%	16.7% 0.2%	-14.5% 0.3%	-24.6% 0.3%	12.0% 0.3%	25.0% 0.2%	17.3% 0.3%	47.7% 0.2%

Generated Momenta p [GeV/c]

EIC Electron Endcap EMCal

The team: V. Berdnikov, M. Bondi', CF, Y. Furletova, T. Horn, I. Larin, D. Romanov, R. Trotta

- We want to optimize glass/crystal material selection in shared rapidity regions including mechanical constraints.
- Like in the Hall B SRO project, we can explore implementation of AI for clustering/reconstruction.



Goal: maintain the resolution needed by the physics processes while reducing the number of crystals/cost, taking into account constraints.

More details on this project can be found here:

https://wiki.jlab.org/cuawiki/images/f/ff/EEEmCal_AI_Fanelli.pdf

EIC Electron Endcap require an inner part (crystal) with high resolution and an outer part (glass) with less stringent requirements

Crystals have been used in homogeneous calorimeters but their production is slow and expensive.

As an alternative Scintilex develops SciGlass that is much simpler and less expensive to produce and thus offers great potential for both cost reduction and wider application if competitive performance parameters can be achieved.

Summary

https://indico.bnl.gov/event/10699/

- AI will likely play a major role in multiple aspects of the Electron Ion Collider experiment. We will have a dedicated workshop on AI4EIC on September 7-10 2021.
- AI is at present already contributing to the ECCE design. We welcome everyone to contribute to ECCE, if interested please contact the AI WG convener Will Phelps wphelps@jlab.org or me cfanelli@mit.edu
- In NP we started exploring AI for optimal design in multidimensional space with single objectives. Most of the problems are multi-objectives though. None ever accomplished a multi-dimensional / multi-objective optimization of the performance of detectors when operating together. This is a high-dimensional combinatorial problem (with many parameters) that can be solved with AI.
- One of the conclusions from the DOE Town Halls on AI for Science on 2019 was that "*AI techniques that can optimize the design of complex, large-scale experiments have the potential to revolutionize the way experimental nuclear physics is currently done*".