The ECCE Experiment

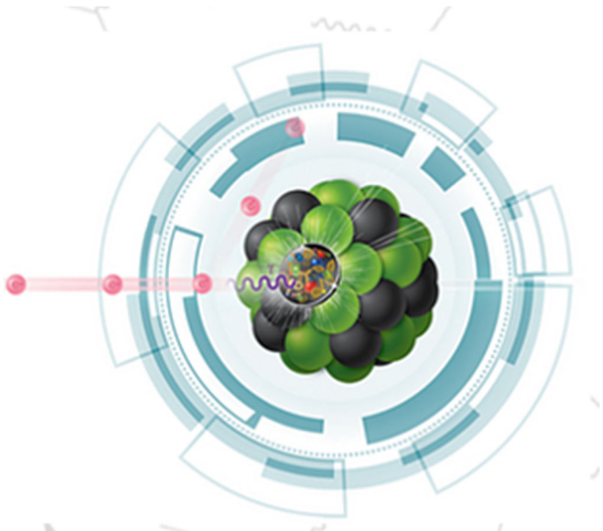
John Lajoie

Iowa State University

for the ECCE Consortium

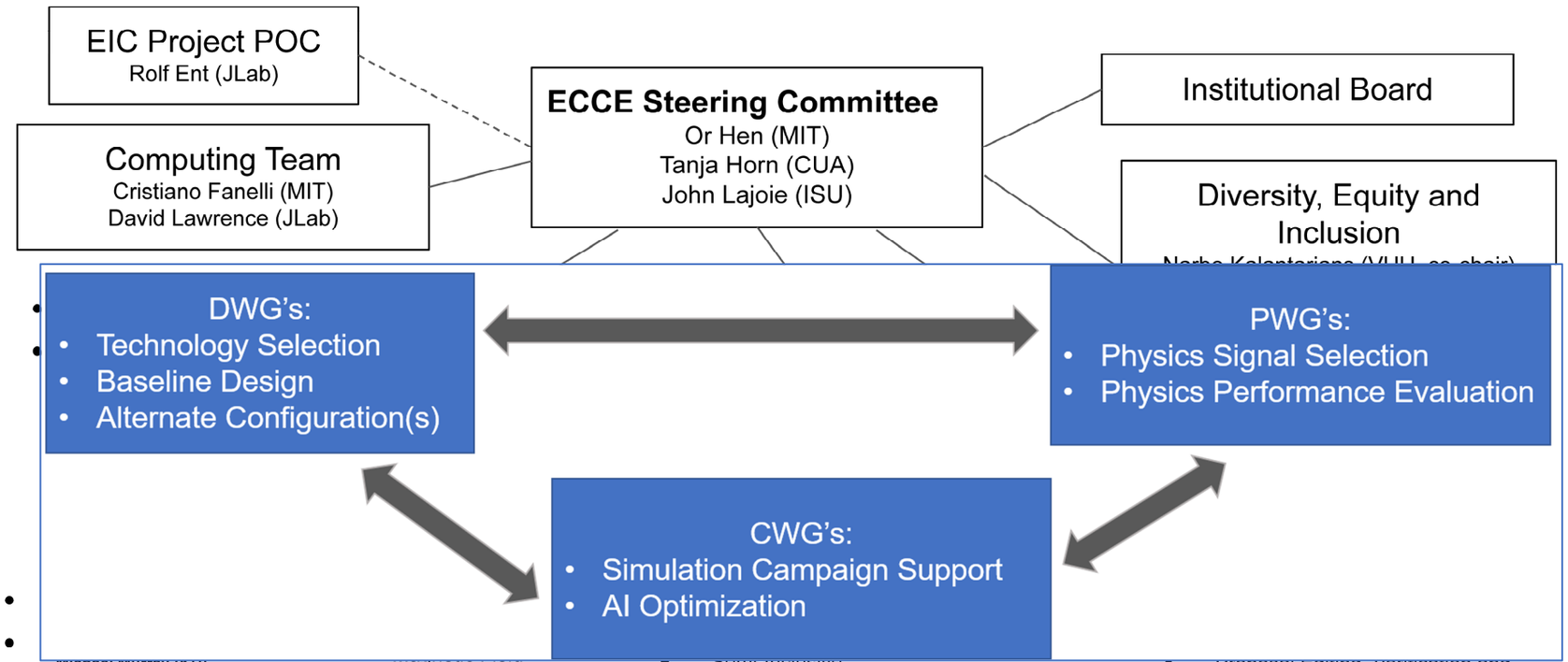
ECCE 101

EIC Comprehensive Chromodynamics Experiment



- ECCE is 77 institutions (& counting) collaborating to design an EIC detector offering full kinematic coverage and an optimized far forward detector system
- ECCE is investigating a design which incorporates the existing 1.5T BaBar magnet, which will help reduce cost and risk, to allow it to be ready for first EIC detector operations (CD4a)
- ECCE is also investigating the costs and benefits associated with using either IP6 with 25 mrad crossing angle, or IP8 with 35 mrad
- ECCE is planning to submit a proposal to be the EIC project detector ("Detector 1"), which will address the complete science program outlined in the NAS report and Yellow Report
- ECCE is fully supportive of two detectors at the EIC, in both IR8 and IR6, to maximize the scientific output of the EIC
- ECCE is open to everyone in the community to participate, even if they wish to contribute to other proposals.

ECCE Consortium Structure



Michael Murray (KU),
Yuji Goto (RIKEN), Igor Korover (MIT)

- Tracking
  Xuan Li (LANL),
  Nilanga Liyanage (UVA)
- Calorimetry
  Friederike Bock (ORNL), Yongsun Kim (Sejong U.)

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

Paul Brindza (JLab),
Renuka Rajput-Ghoshal (JLab)

- DAQ/Electronics/Readout
  Chris Cuevas (JLab),
  Martin Purschke (BNL)

- 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)

- Proposal Editing, Verification and Version Control
- Costing and Management

Website:
https://www.ecce-eic.org/

Mailing Lists:
https://lists.bnl.gov

- ecce-eic-public-l
- ecce-eic-ib-l
- ecce-eic-comp-l
- ecce-eic-dei-l
- ecce-eic-det-l
- ecce-eic-phys-l
- ecce-eic-prop-l

Indico:
https://indico.bnl.gov/category/339/

ECCE is Growing…

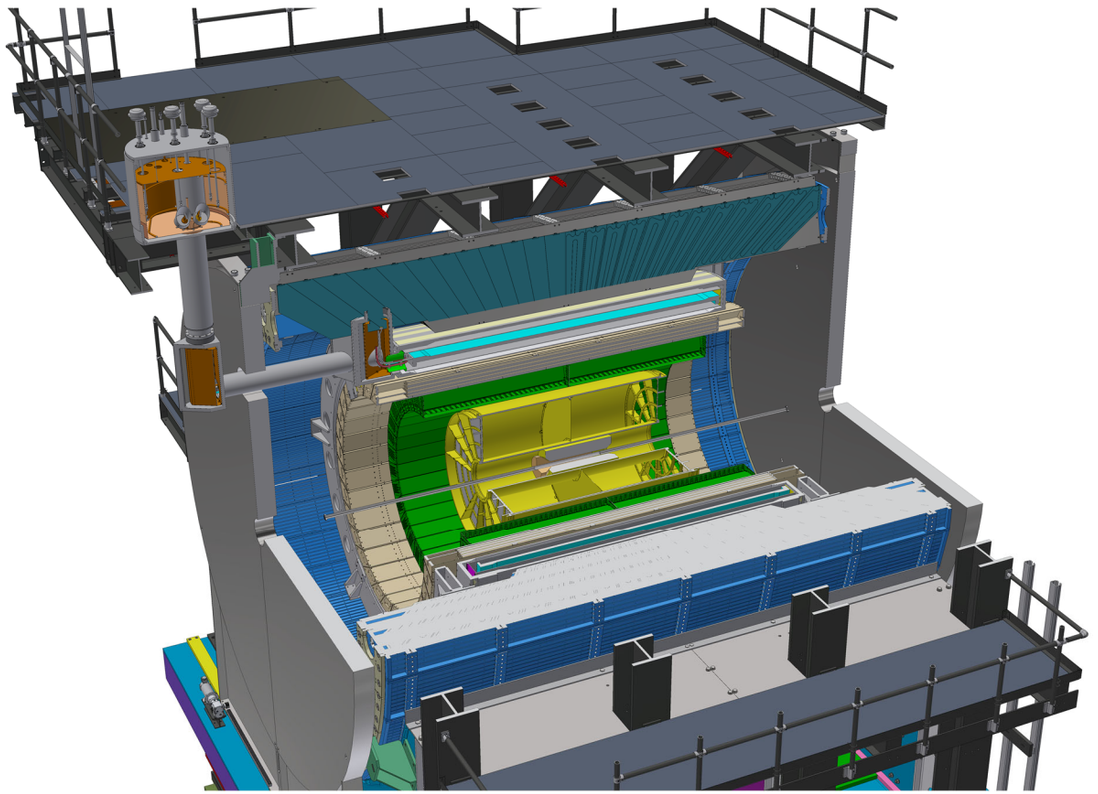
1. AANL/Armenia*
2. AUGIE
3. BGU/Israel*
4. BNL
5. Brunel University*
6. Canisius College
7. CCNU/China*
8. Charles U./Prague*
9. CIAE
10. CNU
11. Columbia
12. CUA
13. Czech. Tech. Univ.
14. Duquesne U.
15. Duke
16. FIU
17. Georgia State
18. Glasgow/Scotland*
19. GSI/Germany*
20. GWU
21. Hampton
22. HUJI
23. IJCLab-Orsay/France*
24. IMP/China*
25. Iowa State
26. IPAS/Taiwan*
27. JLab
28. Kyungpook Natl. Univ./Taiwan*
29. LANL
30. LBNL/Berkeley
31. Lehigh University
32. LLNL
33. Morehead State
34. MIT
35. MSU
36. NCKU/Taiwan*
37. NCU/Taiwan*
38. NMSU
39. NRNU MEPhI/Russia*
40. NTHU/Taiwan*
41. NTU/Taiwan*
42. ODU
43. Ohio U
44. ORNL
45. PNNL
46. Pusan Natl. Univ.*
47. Rice
48. RIKEN/Japan*
49. Rutgers
50. Saha / India*
51. SBU
52. SCNU/China*
53. Sejong U.
54. TAU/Israel*
55. Tsinghua U./China*
56. Tsukuba U./Japan*
57. CU Boulder
58. UConn
59. UH
60. UIUC
61. UKY
62. U. Ljubljana/Slovenia*
63. UNH
64. USTC/China*
65. UT Austin
66. UTK
67. UTSM/Chile*
68. UVA
69. Vanderbilt
70. Virginia Tech
71. Virginia Union
72. Wayne State
73. WI/Israel*
74. WM
75. Yonsei Univ.*
76. York/UK*
77. Zagreb U./Croatia*

*Non-US institutions (36%)

Existing Infrastructure

- Existing BaBar solenoid (1.5T), flux return and cradle
  - Substantial investment/risk reduction
- IP8 infrastructure
  - Cryogenic connection to RHIC
  - Racks, mechanical, safety, electrical, etc.
- Potential re-use/refurbish existing sPHENIX detectors as appropriate
- ECCE consortium has considerable recent DOE project experience

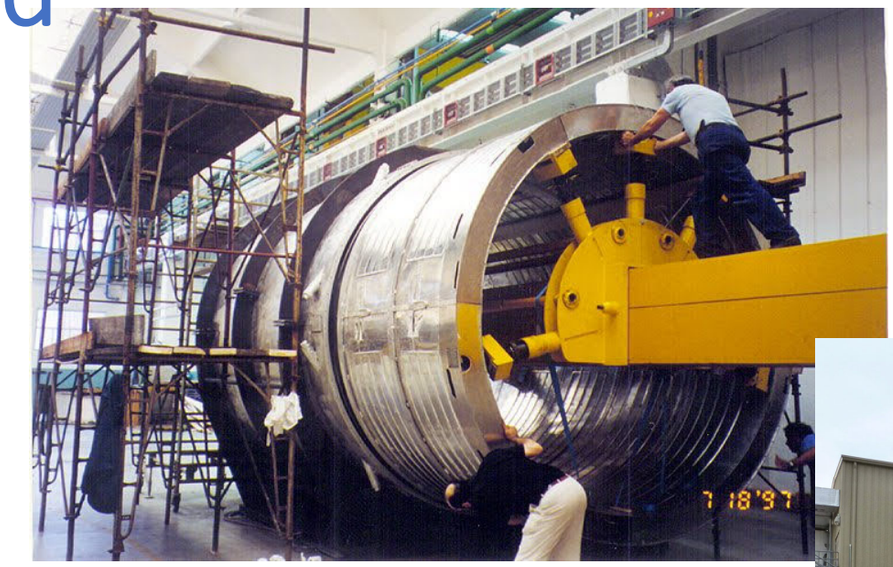
Currently under construction, sPHENIX represents a $27M investment by DOE (MIE)



1.5T BaBar Solenoid

- Built in 1997 (Ansaldo)
- Very conservative design
- 3.7m long,
  1.4m bore radius
- Designed for 1.5T @ 5kA
  - 20MJ stored energy
- Transported to BNL 2015
  - Successful low and high field tests
- Extensive risk analysis shows that the magnet is in excellent shape
  - Some refurbishment required

under construction



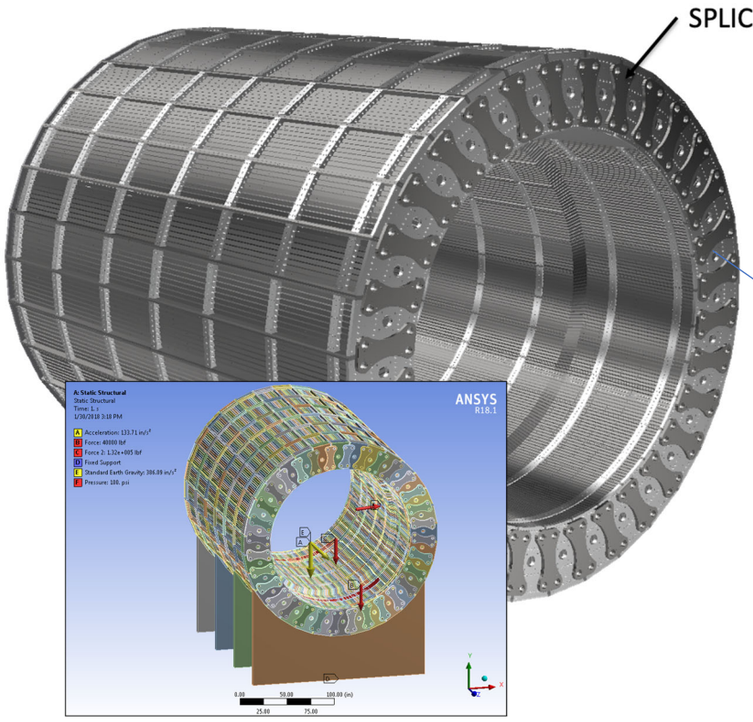
shipping to BNL

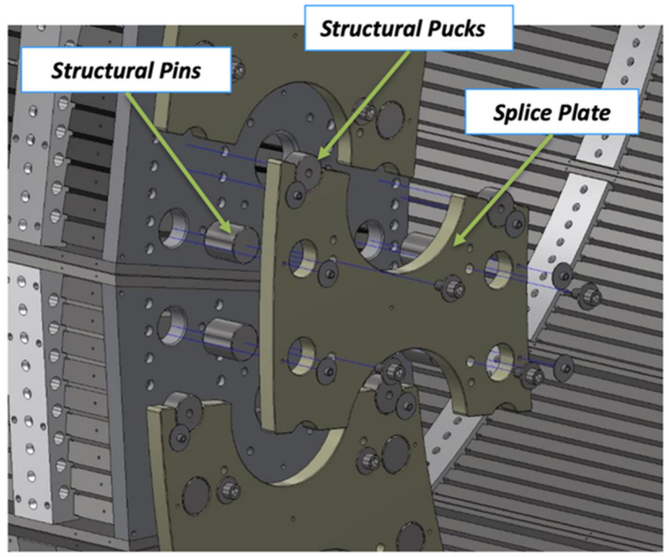
Pasquale Fabbricatore

Designed BaBar and CMS 4T superconducting magnets

Recipient of IEEE Award for Continuing and Significant Contributions in the Field of Applied Superconductivity (2020)

Other Infrastructure…

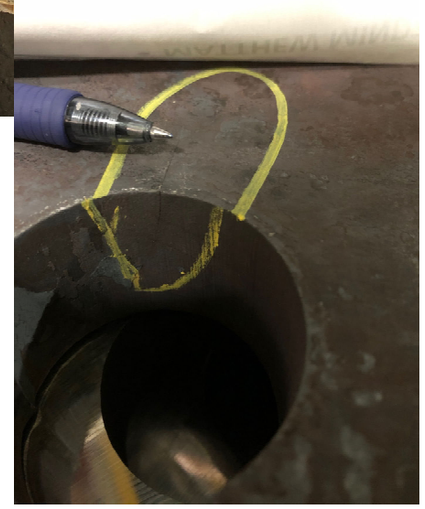




The splice plates, pucks and pins are fabricated from high strength steel (AISI 4140 HT) to ensure there is a high safety factor for the oHCAL arch ring structure

Multiple rounds of prototyping to adapt 4140 HT process to thick material:

Initial attempt cracked when machined, required modified treatment and machining



engineering, FEA, reviews, prototyping, material choice, vendor selection, test fitting, and so on

8+ months to engineer and certify “dogbone” plates: reuse brings time and cost savings

ECCE Highlights from Past Few Months

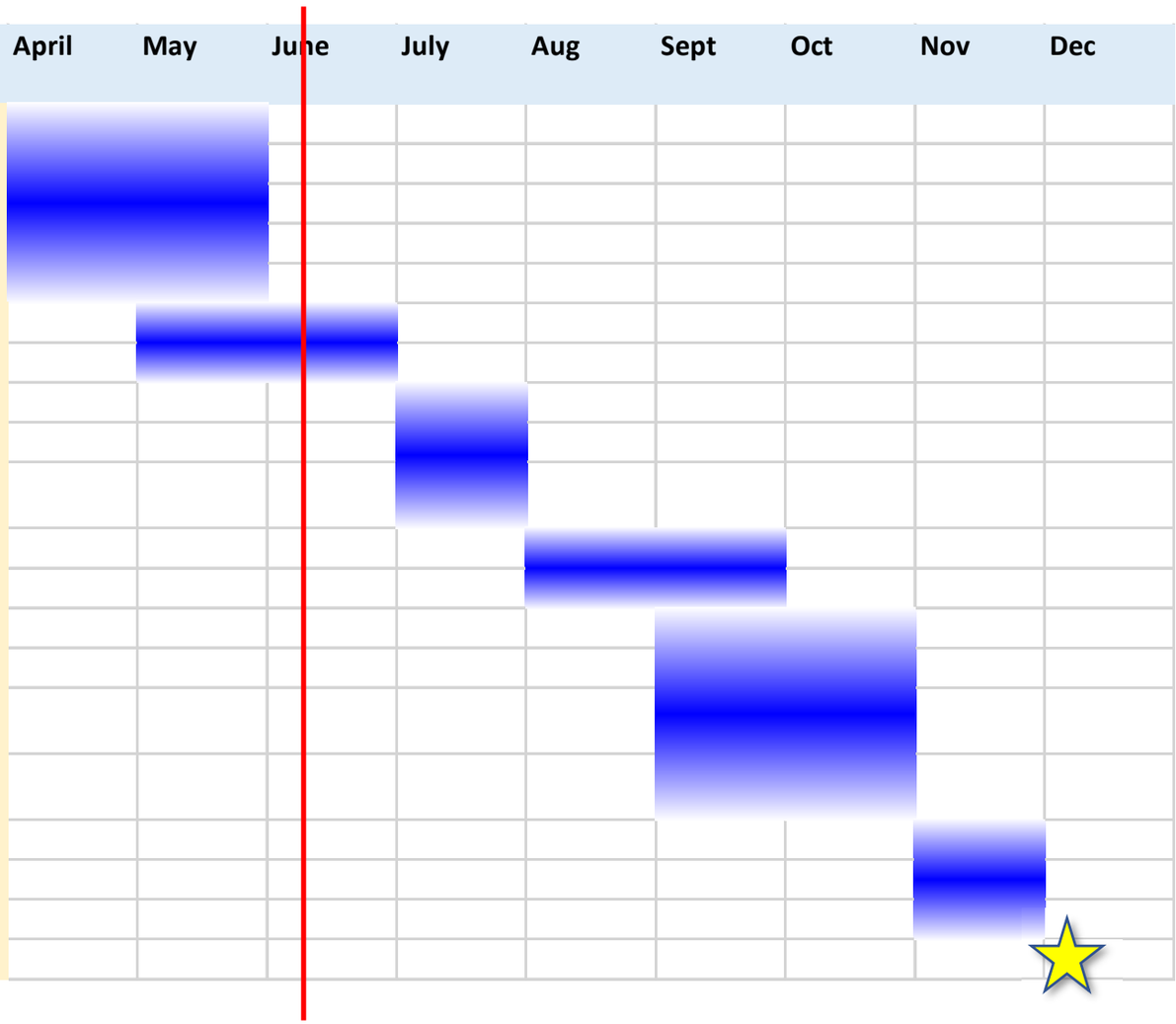
Much activity – moving at a rapid pace to meet the global timeline

- ✓ 26 February: first IB meeting
- ✓ 5 March: IB approves the Consortium Structure
- March 2021
  - ✓ Team Conveners were selected
  - ✓ Additional institutions joined the effort
  - ✓ Team Conveners added WG co-conveners
  - ✓ Mailing lists were set up
  - ✓ Indico pages were set up
- ✓ 2 April: 1st Simulations Workshop was held
- ✓ 9 April: Start of PWG/DWG meetings
- April 1st - ~June 7th: Start up activities
  - ✓ Finish implementing initial ECCE setup in Fun4All.
  - ✓ Identify technology alternatives to study with Fun4All.
  - ✓ Identify key physics processes to address physics of NAS/YR
  - ✓ Collected required event generators
  - ✓ Wiki was setup to collect information
  - ✓ 21 May: 2nd Simulation Workshop
  - ✓ Demonstration of pipeline for AI detector optimization
- Mid-June: ECCE Baseline
  - Finish implementing initial ECCE baseline setup in Fun4All.
  - First simulation campaign

ECCE Timeline

Today, 9 June 2021

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)	

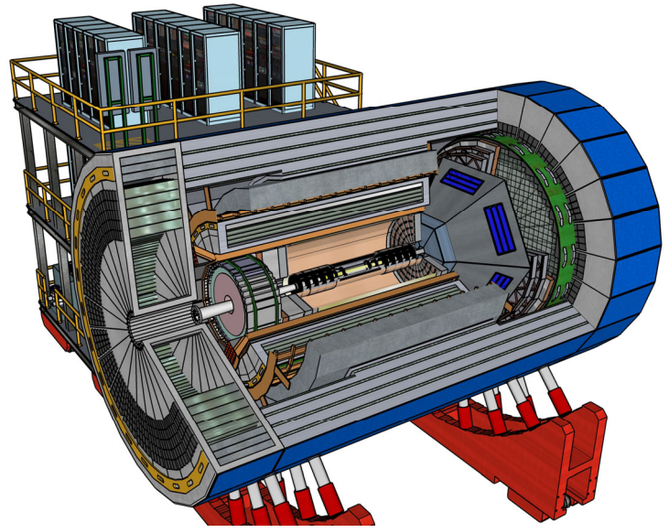


ECCE Detector Team – Detailed Studies Ongoing

Team Leaders: Ken Read (ORNL) and Doug Higinbotham (JLab)

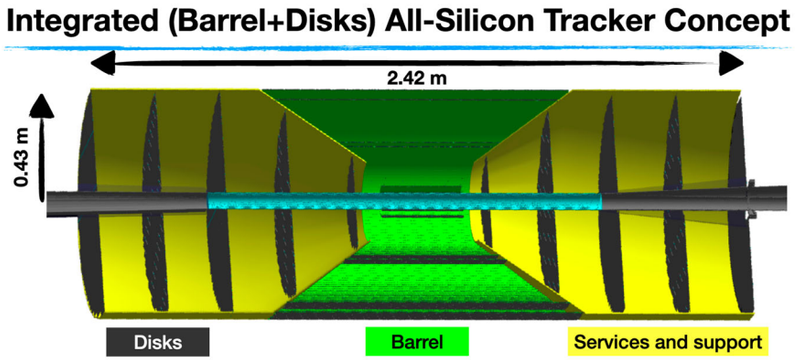
Topic and Conveners

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



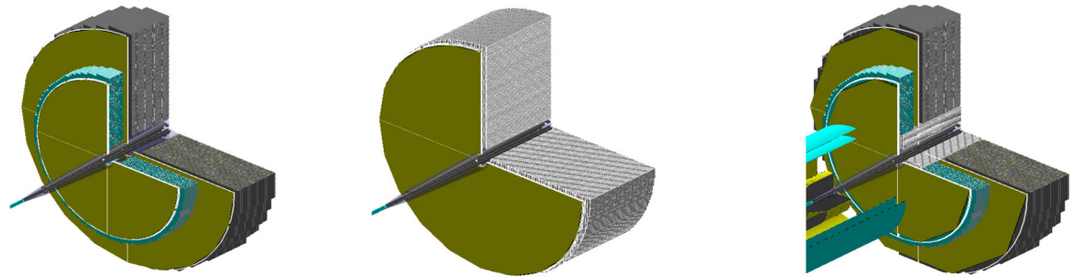
Sketchup of ECCE

Calendar of meetings can be found at: https://indico.bnl.gov/category/345/



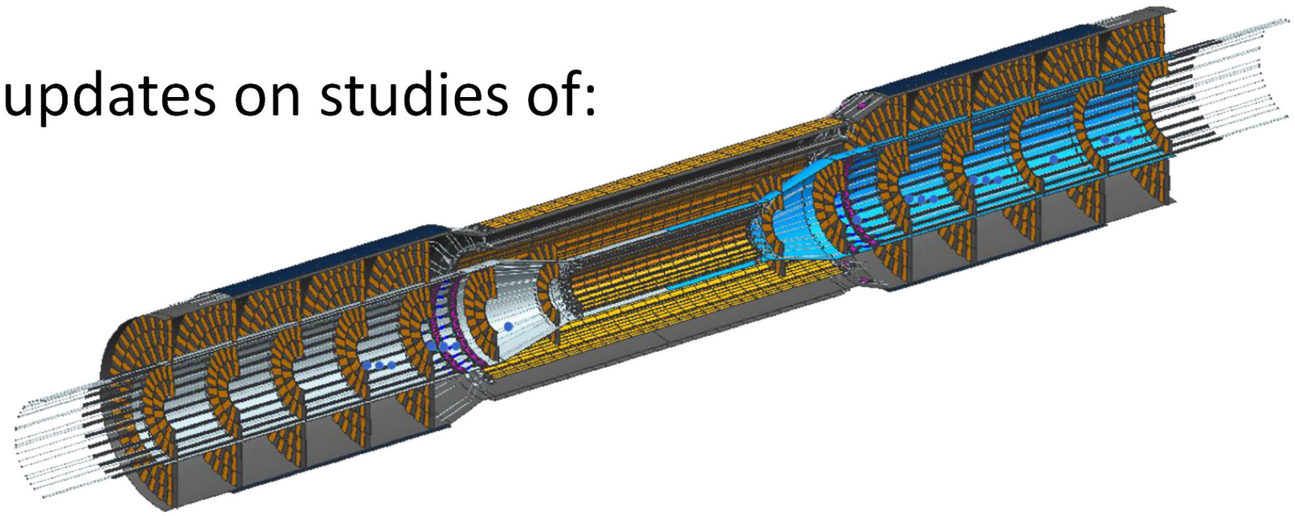
Presented at May 11th ECCE Tracking Meeting

Detailed review of Calorimetry options (far forward shown)



Presented at May 4th Calorimetry meeting

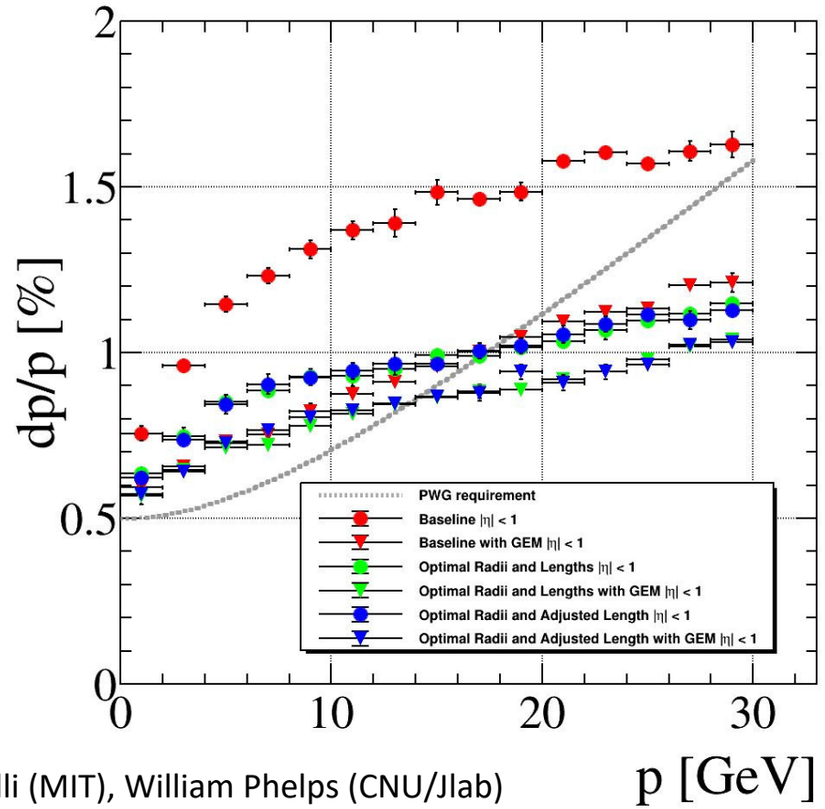
Tracking DWG Progress



- Tracking DWG has recently presented updates on studies of:
  - MAPS Silicon tracker barrel performance
  - Forward silicon tracker performance
  - µRWell (MPGD) end-cap tracking
  - Further recent details here:
    - https://indico.bnl.gov/event/11654/
    - https://indico.bnl.gov/event/11659/
- Details of how the central tracker can be built (drawing in Siemens NX)
  - Will need to clam shell around the beamline
  - Details like the cooling lines and cables shown & add to the material budget.
- Development of AI pipeline for optimizing tracker design:
  - https://indico.bnl.gov/event/12052/

AI Detector Optimization

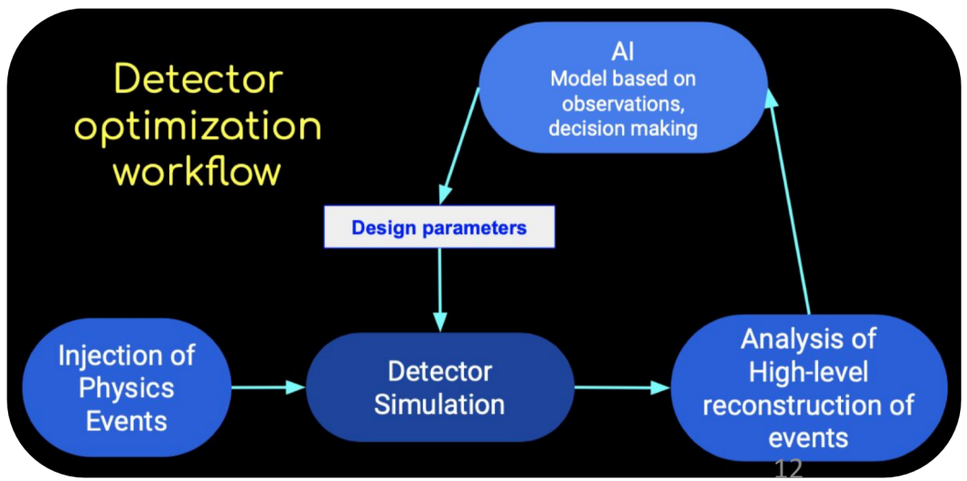
- AI WG is starting to optimize ECCE
- Building on existing experience (e.g. dRICH)
- Working from the inside out
- First ECCE-specific example: Tracker layer radii
- Pushing to optimize for PHYSICS as opposed to single detector element performance



Cristiano Fanelli (MIT), William Phelps (CNU/Jlab)

EXCELLENT Opportunities:

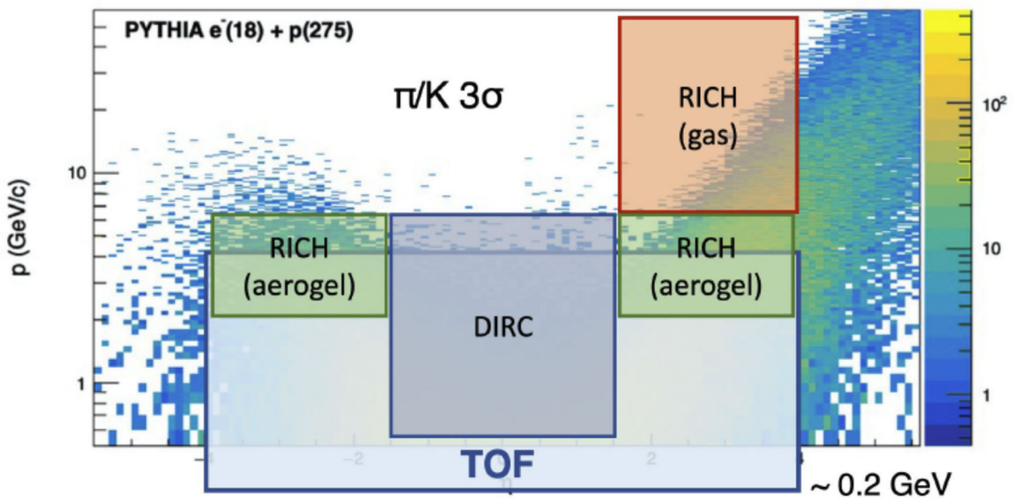
A. For collaborators to contribute and gain experience in AI
B. For ECCE to integrate AI starting from its early design stage

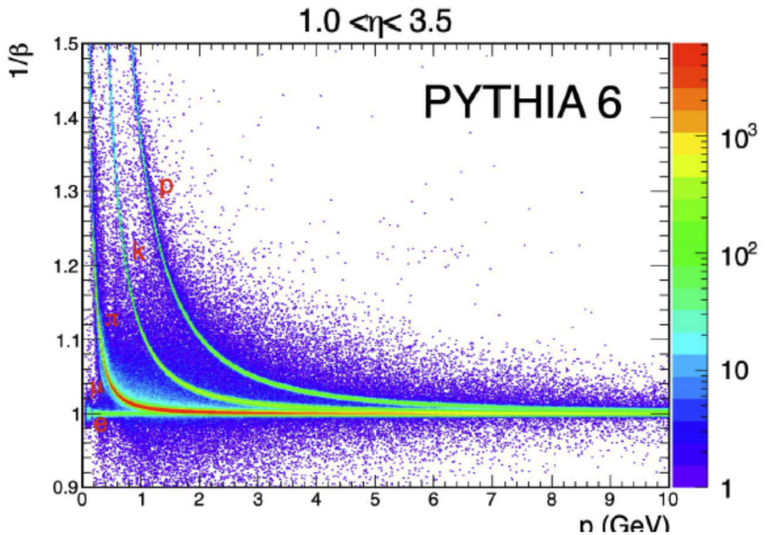


https://indico.bnl.gov/event/11517/

PID DWG Progress

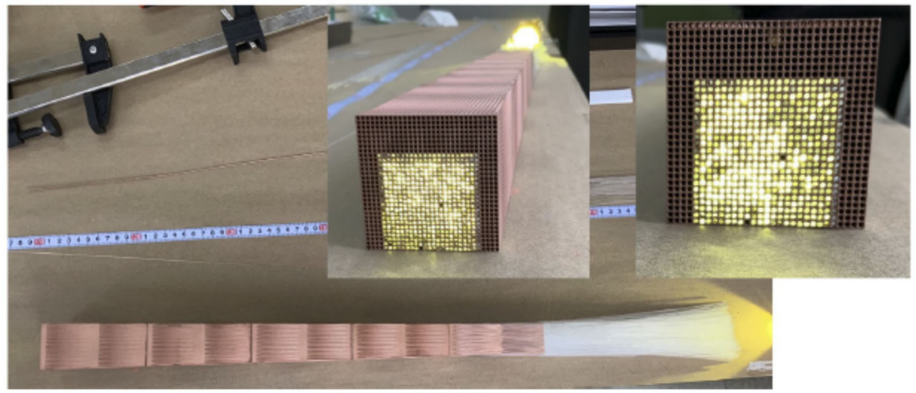
- PID DWG has recently presented updates on progress towards Fun4All performance studies:
  - **LGAD** TOF available for evaluation in Fun4All
  - Progress implementing **dRICH** and **hpDIRC** in Fun4All
  - Optimizing **mRICH** in Fun4All
- Recognize need to properly pass PID info within Fun4All
- Visualization of ECCE PID concept from talk with Wei Li (Rice)
- PID from TOF using LGAD detectors (shown with electron, muon, pion, kaon, & proton).





Calorimetry DWG Progress

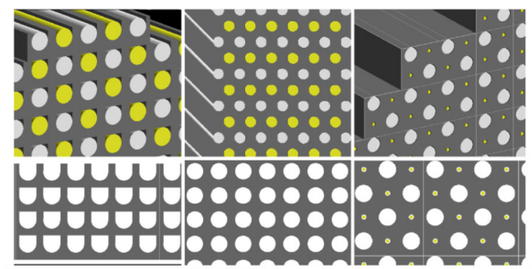
- Calorimetry DWG has recently presented updates on emerging primary options:
  - Insert Dual Readout with 3D printing for forward calorimetry, surrounded by standard ECAL and longitudinally-segmented HCAL
  - Re-use for Backward HCAL and Barrel HCAL
  - SciGlass for Barrel ECAL
  - Hybrid SciGlass/PbWO for Backward ECAL
  - Further details available here:
    - https://indico.bnl.gov/event/11915/
    - https://indico.bnl.gov/event/11917/

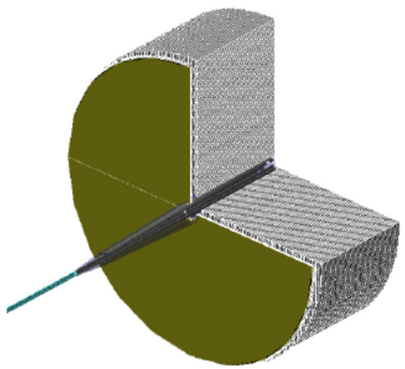


Example 3D printed Dual Readout Calorimeter

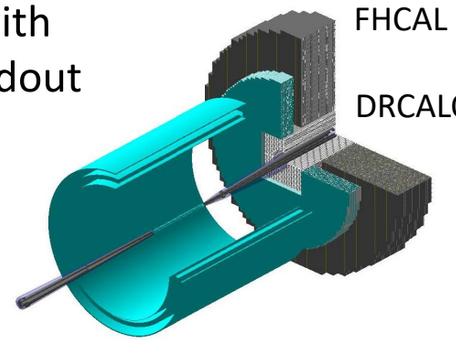
- Working on arranging mechanical engineering help at ORNL for some aspects.

G4 Implementation of Dual Readout





Option with Dual Readout Insert

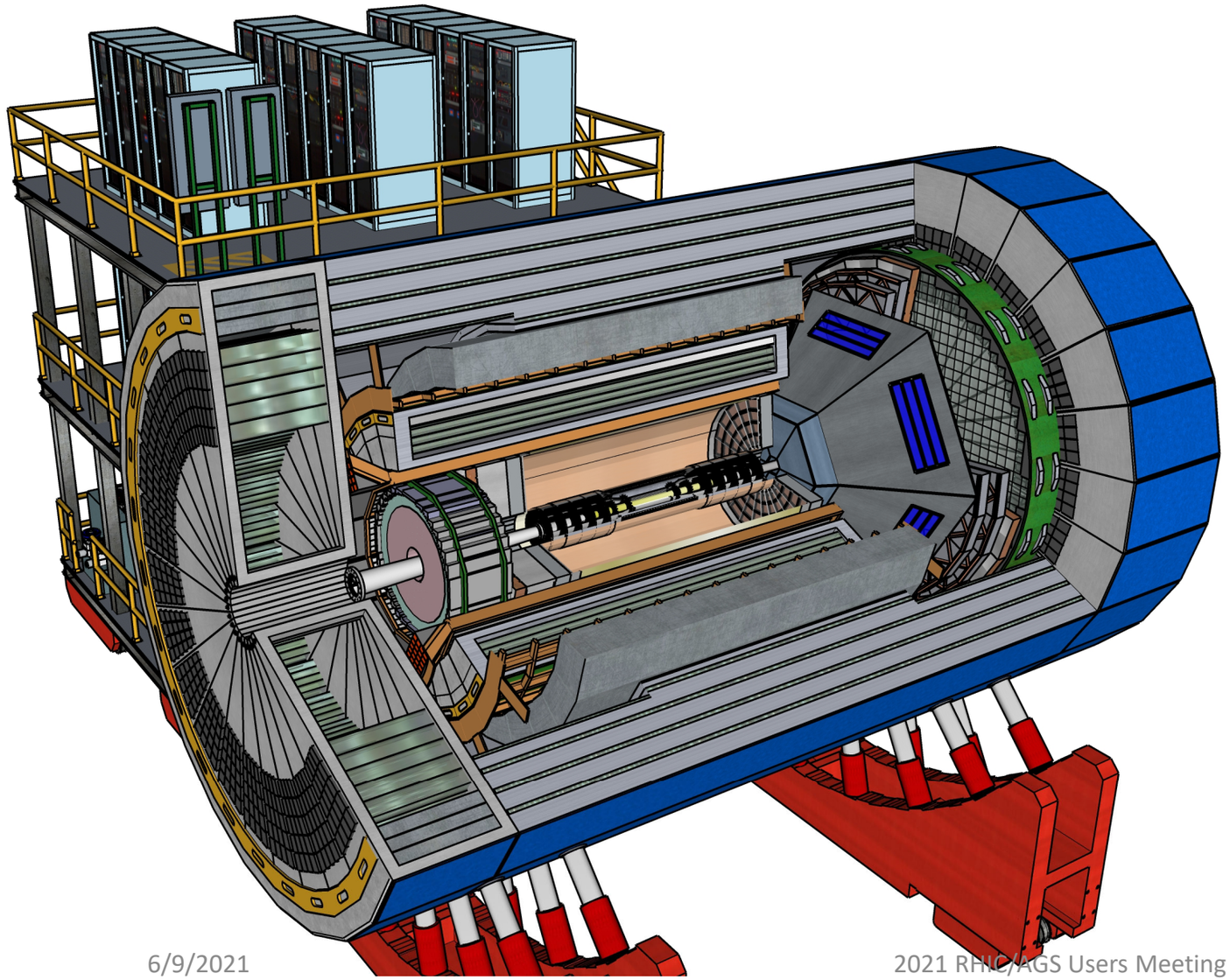


ECCE Design Status

- DWGs proceeding with evaluation of leading technology alternatives.
- **Converging on initial setup for first IP6 simulations campaign starting next week!**
- Detector Team Group Meeting June 10th 11am to 2pm:
  - co-conveners will present latest evaluated technology options,
  - Focus on detectors choices to move forward with DAQ and determining optimal re-use,
  - https://indico.bnl.gov/event/12079/
- Still need to optimize performance / cost / risk with inputs from simulations.

ECCE Detector (W.I.P.)

Red = preferred technology
Blue = preferred technology with some open questions
Black = still being discussed



ELECTRON ENDCAP

Tracking: GEM / MPGD
Electron Detection:
- Inner part: PWO crystals (reuse some)
- Outer part: SciGlass (backup PbGl)

h-PID: mRICH & AC-LGAD
HCAL: Steel from magnet or Fe/Sc
- Not instrumented and only serve as flux return?
- Instrumented \w reduced thickness (lower energies)

CENTRAL BARREL

Tracking: Silicon barrel + forward tracker (optional Si/GEM hybrid)
Electron PID: SciGlass (backup: PbGl or W(Pb)/Sc shashlik)
h-PID: hpDIRC & AC-LGAD/LYSO [progress: DIRC orientation]
HCAL: magnet steel (**reuse**) - Fe/Sc

HADRON ENDCAP

Tracking: GEM / MPGD
PID: dual-RICH & AC-LGAD
Calorimetry: standard W/ScFi + Fe/Sc
Upgrade: Dual Readout EM+Had Cal?

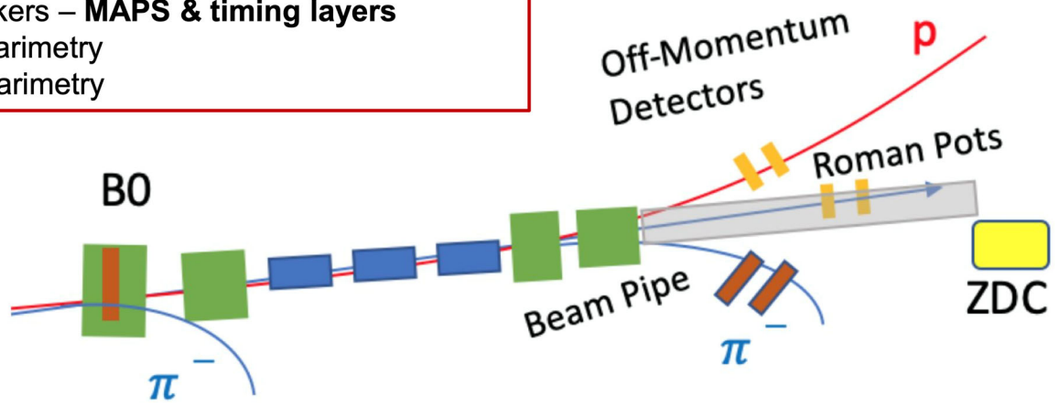
Example discussions:
- Backup for AC-LGAD in barrel
- SciGlass ongoing R&D timeline
- Hadron Endcap calorimetry

ECCE Far Forward / Back

FAR FORWARD DETECTORS

- ZDC – **Si/W & PWO (SciGlass)**
- Roman Pots – **Silicon sensors, AC-LGADs**
- Off-momentum det. – **Silicon sensors**
- B0-trackers – **MAPS & timing layers**

Lepton polarimetry
hadron polarimetry

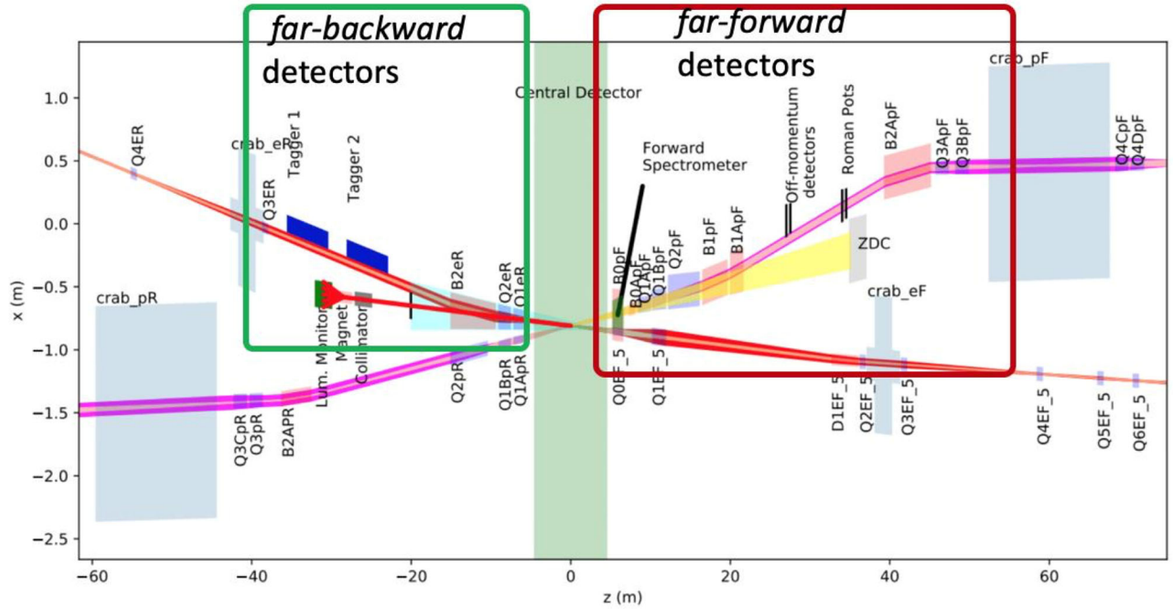


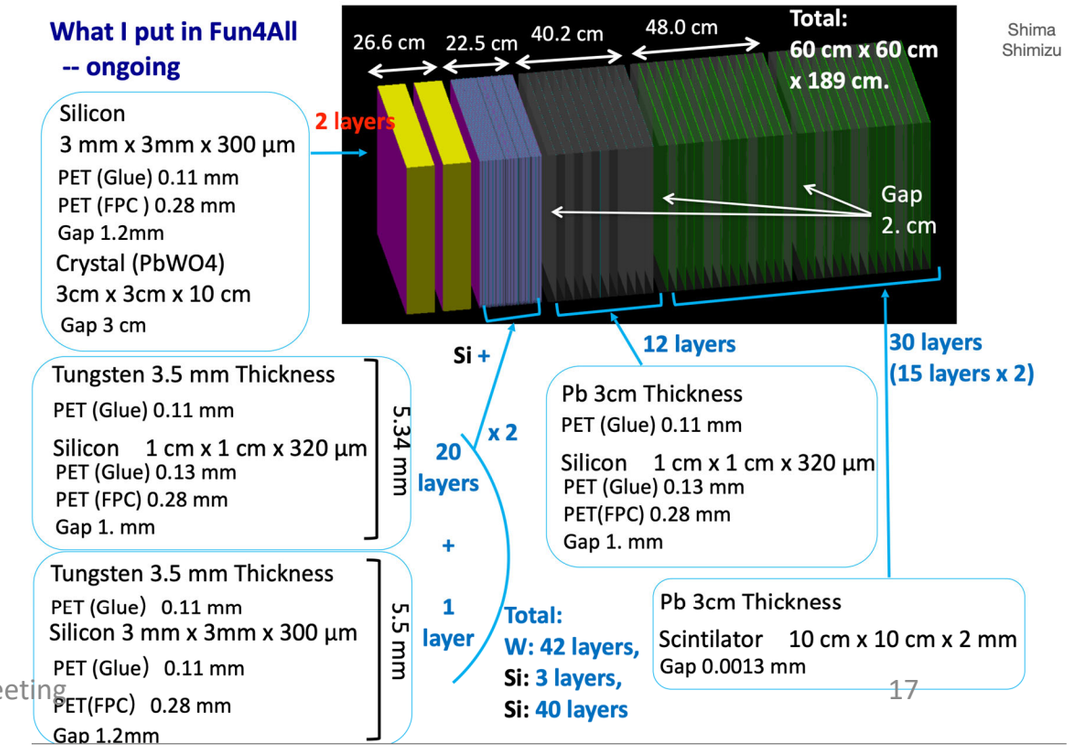
FAR BACKWARD DETECTORS

- low-Q2 tagger
- Lumi-detector

Lepton polarimetry
hadron polarimetry

Participating in coordinated meetings between all proto-collaborations, organized by EIC PM.

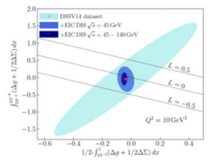




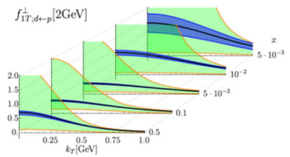
ECCE Physics Studies Focus: A First Look

Studies to demonstrate EIC NAS Study, Yellow Report physics

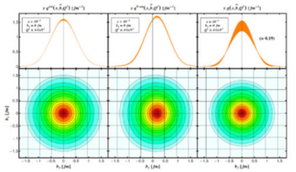
- Origin of Nucleon Spin



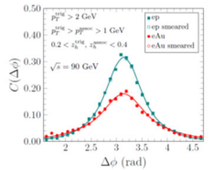
- Confined motion of partons



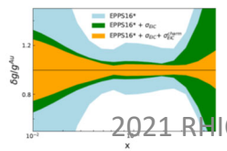
- 3D imaging quarks and gluons



- Nucleon mass
- High gluon densities in nuclei

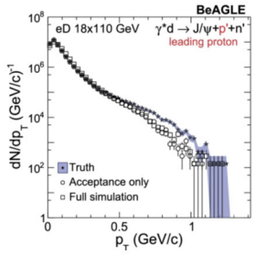


- Quarks and gluons in the nucleus

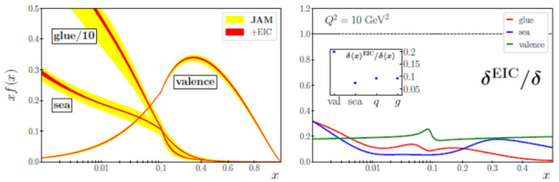


Studies to show unique ECCE strengths

- Light-ion tagging

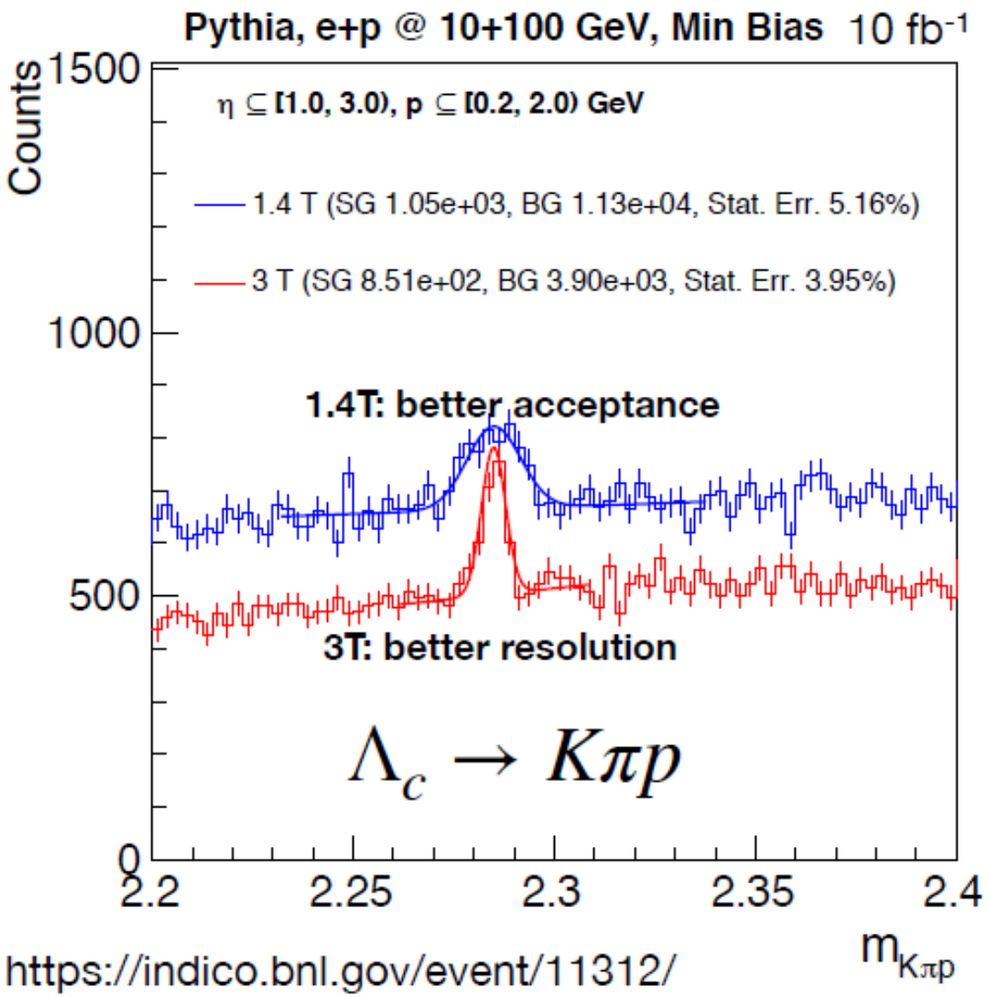


- Pion/Kaon structure



- Diffractive jets?
- Nuclear modifications and in-medium evolution
  - D/D* reconstruction and heavy-flavor in jets.

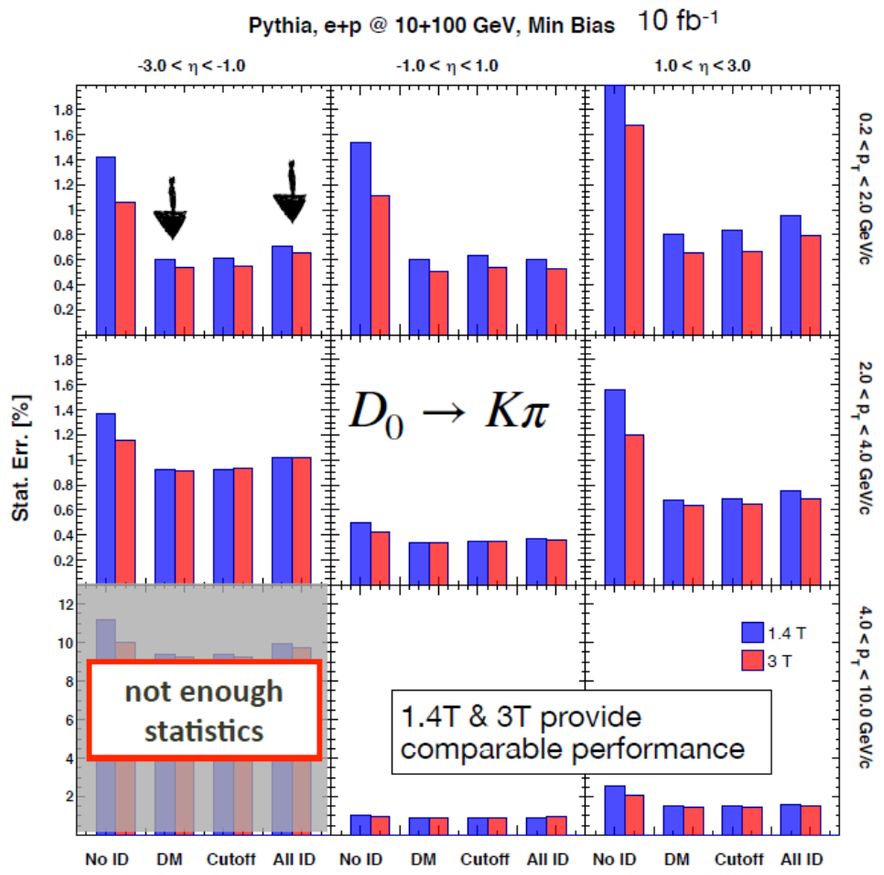
Heavy Flavor in ECCE



https://indico.bnl.gov/event/11312/

Recent Study by Wenqing Fan (LBNL)

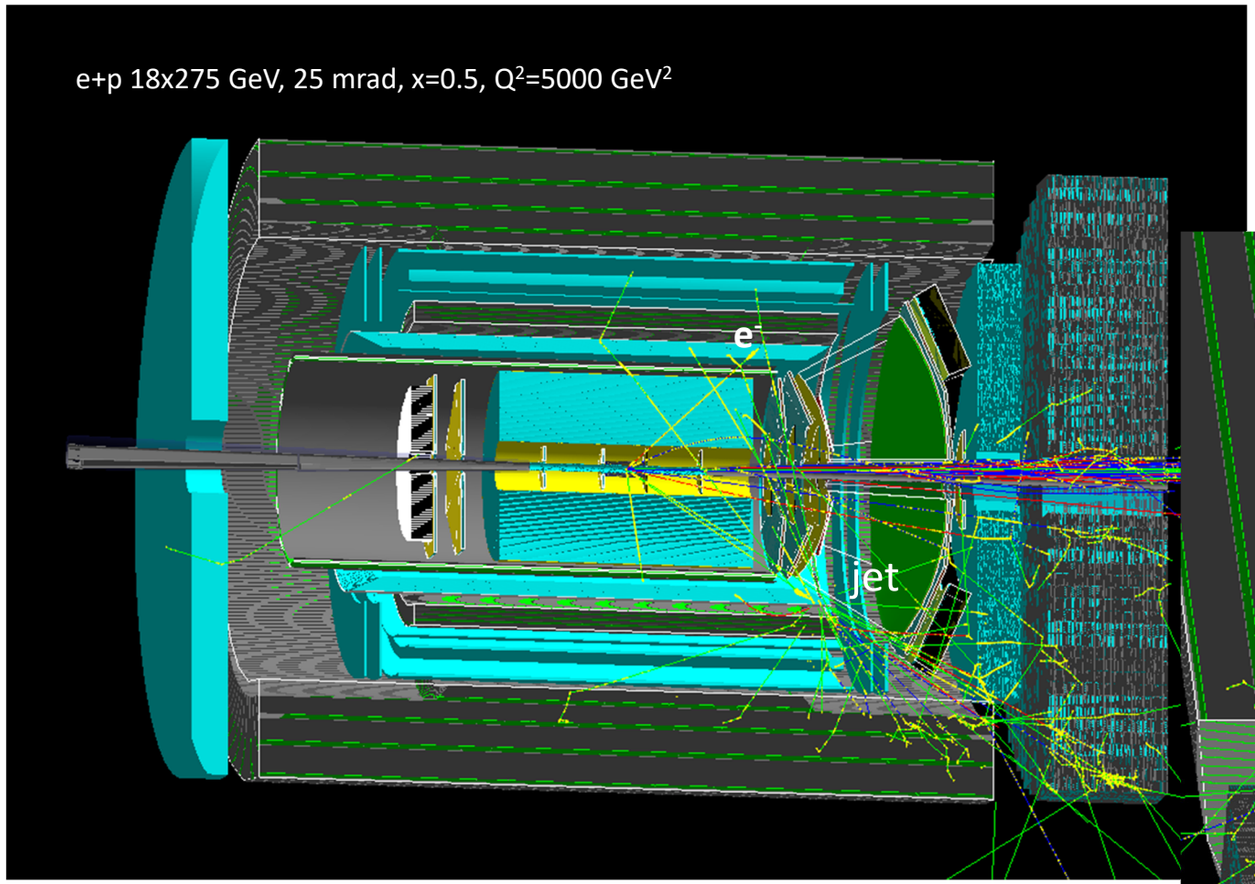
- *Fast simulation of PID, based on YR specifications*
- *Parallel effort ongoing with full detector G4 simulations*

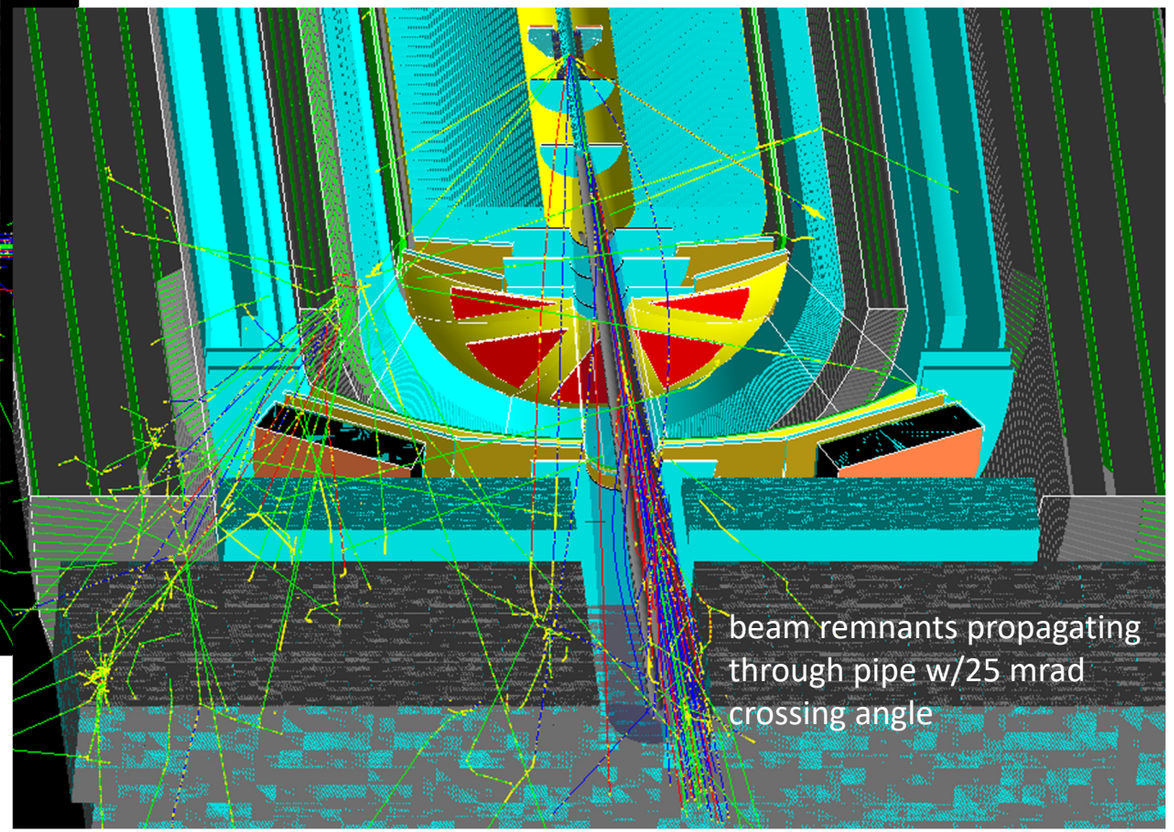


G4 Simulations

https://ecce-eic.github.io

ECCE leverages the fun4all framework already used extensively for sPHENIX





First simulation campaign starting soon!

ECCE Future Highlights

- May 20th - July 1st [~1.5 months]:
  - First simulation campaign with a few detector configurations & initial analysis.
  - Detector baseline set ~June 14th, first 10M event simulation campaign
  - Debug the many things that won't go right the first time :)
- July 1st - Aug. 1st [1 month]:
  - Large scale simulations production
  - Drafting 'collaboration structure' part of the proposal by writing team.
- Aug. 1st - Sep. 15th [1.5 months]:
  - Analysis of simulation data to demonstrate physics extraction.
  - Presentation at August 2-6 EIC UG meeting
- Sep. 15th - Nov. 1st [1.5 months]:
  - All physics 'plots' are done.
  - Final evaluation of technology selection based on physics studies results.
  - Compose narrative around simulation results and selected technologies.
- Nov. 1st - Nov. 30th [1 month]:
  - Proposal review by external colleagues.
  - Final edits

Conclusions

- The ECCE consortium is 77 institutions (& growing) working to design the EIC project detector based around the BaBar solenoid
- By reducing cost and risk, ECCE plans to be ready for physics by EIC CD4a, as soon as possible at the start of machine operations.
- The physics program spans the entirety of that outlined in the NAS study and the Yellow Report
- The detector design process is fully underway, in tandem with a wide range of full physics simulations

https://ecce-eic.org