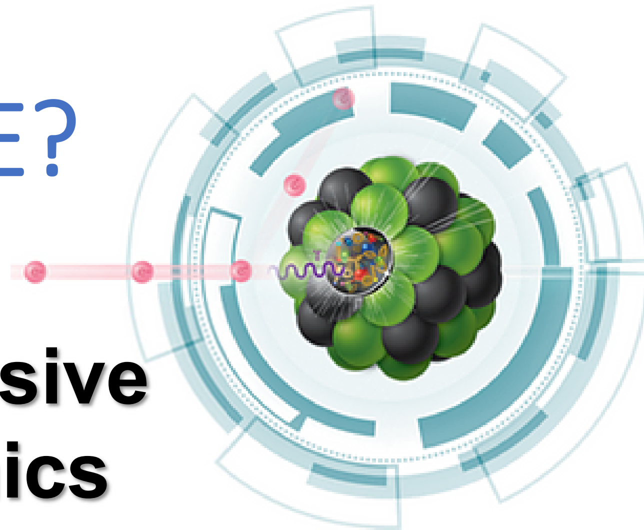
Introduction to ECCE

John Lajoie

Iowa State University

What is ECCE?



EIC Comprehensive Chromodynamics Experiment

The EIC Comprehensive Chromodynamics Experiment (ECCE) consortium comprises 54 institutions assembled around the idea of developing an EIC detector envisioned to offer full energy coverage and an optimized far forward detection region. The consortium includes institutions with wide-ranging world-class detector expertise, strong involvement with EIC physics, and an understanding of the DOE approach to project management. Our foundational principles are outlined in this talk from the first ECCE workshop.

ECCE shares the vision of the Nuclear Physics community that the EIC science mission is best served by two complementary detectors. In pursuit of that goal, ECCE is investigating the complementarity of a detector based on a 1.5T solenoid in both EIC interaction regions.

The ECCE consortium will thus respond to the EIC call for detector proposals with a plan to address the full range of EIC physics outlined in the NAS study and the Yellow Report, as the EIC project detector. To achieve complementarity we will investigate both IRs with the existing BABAR 1.5T solenoid and will show how ECCE will perform at either RHIC IP6 with its 25 mrad crossing angle or at IP8 with its ~35 mrad crossing angle.

We invite all interested institutions to join our effort!

ECCE Consortium Structure

EIC Project POC
Rolf Ent

ECCE Steering Committee
Or Hen
Tanja Horn
John Lajoie

Institutional Board

Computing Team
Cristiano Fanelli (MIT)
TBA

Computing Working Groups:
- Artificial Intelligence
- Computing and Software
  (Joe Osborn)

Diversity, Equity and Inclusion
Narbe Kalantarians (VUU)
Simonetta Liuti (VA)
Marie Boer (VTech)
Elena Long (UNH)
Christine Nattrass (UTK)

Detector Team
Ken Read (ORNL)
Doug Higinbotham (JLab)

Detector Working Groups:
- IP8/Equipment Re-use
- Far Forward/Far Backward
- Central Tracking
- Calorimetry
  (Friederike Bock, Yongsun Kim)
- Particle ID
- Magnetic Field
  (Paul Brindza)
- DAQ/Electronics/Readout

Physics Benchmarks Team
Carlos Camacho (Orsay)
Rosi Reed (Lehigh)

Physics Working Groups:
- Simulations
  (Jin Huang, Cameron Dean)
- Inclusive Processes
- Semi-Inclusive
  (Ralf Seidl, Charlotte Van Hulse)
- Exclusive/Diffractive and Tagging
- Jets and Heavy Flavor
- BSM and Precision Electroweak

Editorial Team
Peter Steinberg (BNL)
Richard Milner (MIT)
Tom Cormier (ORNL)

Editorial Working Groups:
- 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-dei-l
- ecce-eic-det-l
- ecce-eic-phys-l
- ecce-eic-prop-l

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

ECCE Foundation

- Develop a detector capable of delivering the full EIC science mission
  - As outlined in the Yellow Report
- Appropriate utilization and/or upgrades of existing detectors and infrastructure
  - Reduce technical and schedule risks
  - Reinvest savings in detectors

Expression of Interest (EOI) for the EIC Collider Detector ("ECCE") Consortium

Contact persons for this submission:

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John Lajoie (lajoie@iastate.edu)

Institutions collectively involved in this submission of interest:
AANL/Armenia, Academia Sinica/Taiwan, BGU/Israel, BNL, CU Boulder, CUA, Charles U./Prague, Columbia, FIU, GWU, GSU, IJCLab-Orsay/France, ISU, JLab, Kentucky, LANL, LLNL, Lehigh, MIT, National Cheng Kung University/Taiwan, National Central University/Taiwan, National Taiwan University/Taiwan, National Tsing Hua University/Taiwan, ODU, Ohio University, ORNL, Rice, Rutgers, SBU, TAU/Israel, UConn, UIUC, UNH, UVA, Vanderbilt, Wayne State, and WI/Israel.

Items of interest for potential equipment cooperation:
The EIC enables an exciting research program which will advance our understanding of the structure of hadronic matter. A state-of-the-art collider detector for the EIC, which is needed to realize its physics program, will be extremely complex. It will require extensive infrastructure, and will need to be integrated into the operation of the accelerator to a very high degree. The technically driven reference schedule for the EIC project is aggressive and presents a significant challenge for an EIC detector to be designed, built, commissioned, and ready to start delivering science when the machine begins to deliver collisions. The substantial resources needed to construct a state-of-the-art detector for the EIC present an additional challenge. Time-tested strategies for addressing such challenges include the reuse of existing infrastructure where suitable and leveraging the hard-won expertise gained through previous successful projects.

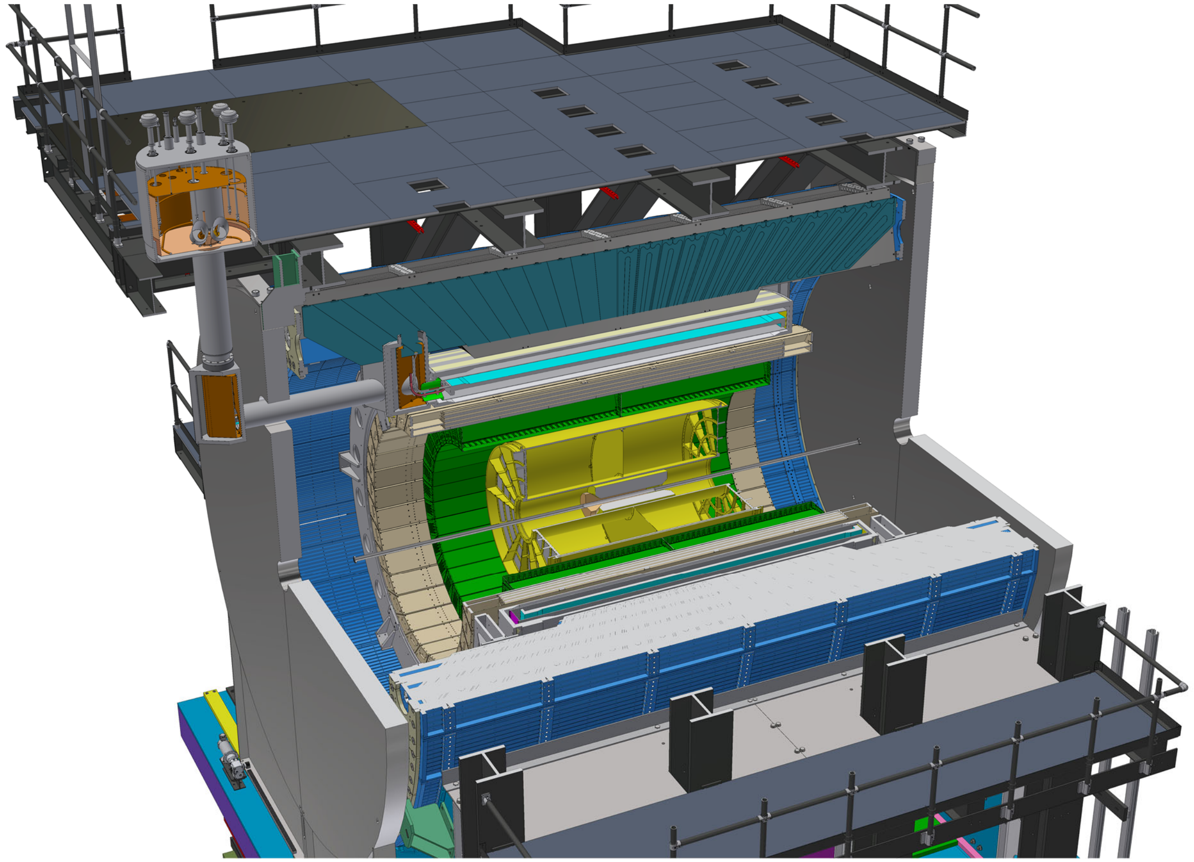
The EIC Collider dEtector (ECCE) consortium comprises 36 institutions assembled around the idea of building on the foundation of existing infrastructure available at RHIC IP8 and experimental equipment available there and elsewhere at JLab and RHIC. The consortium includes institutions with wide-ranging world-class detector expertise, strong familiarity with the EIC-suitable characteristics of IP8, and an understanding of the approach to DOE project management. Appropriate use of existing infrastructure will help mitigate several technical and schedule risks of an EIC detector project. The technical expertise in the consortium can build on and extend upon the base provided by existing equipment to provide a complete detector with capabilities mandated by the EIC science requirements as defined by the recent EIC Yellow-Report community effort. The substantial project management experience of the involved institutions provides credible "out of the box" know-how for realizing such a sophisticated detector.

Our working principles in developing this consortium have been:
- To follow the guidance provided by the Yellow Report detector design study.

Existing Infrastructure

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

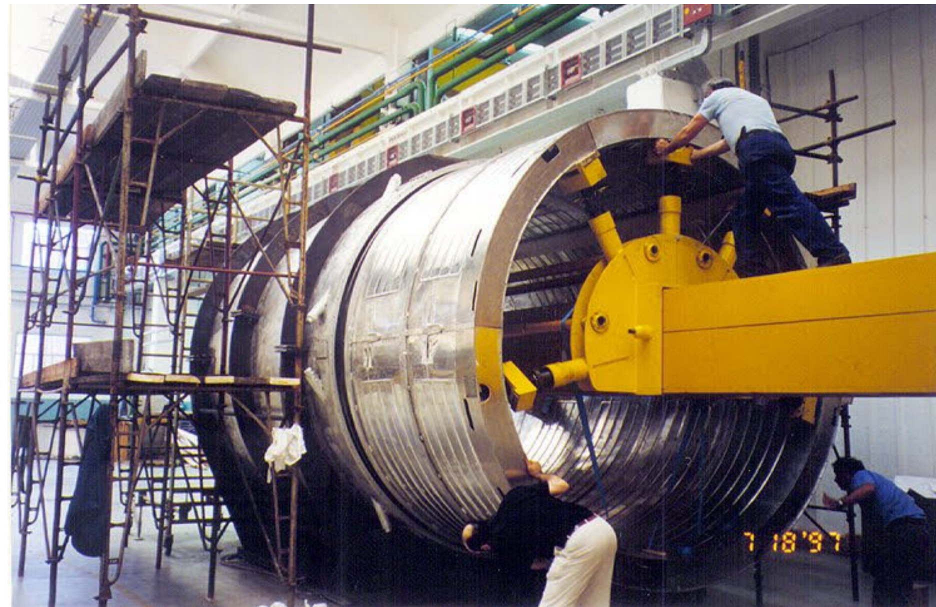
- Existing BaBar solenoid (1.5T), flux return and cradle
  - Substantial investment/risk reduction
- IP8 infrastructure
  - Cryogenic connection to RHIC
  - Racks, mechanical, safety, electrical, etc.
- Potential re-use/refurbish existing sPHENIX detectors as appropriate
- ECCE consortium has considerable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



1.5T BaBar Solenoid

- Built in 1997 (Ansaldo)
- Very conservative design
- 3.7m long,
  1.4m bore radius
- 1.4T in sPHENIX configuration
  - Designed for 1.5T @ 5kA
  - 20MJ stored energy
- Transported to BNL 2015
  - Successful low and high field tests
- Mapping in 2022

under construction



shipping to BNL

high field test @BNL

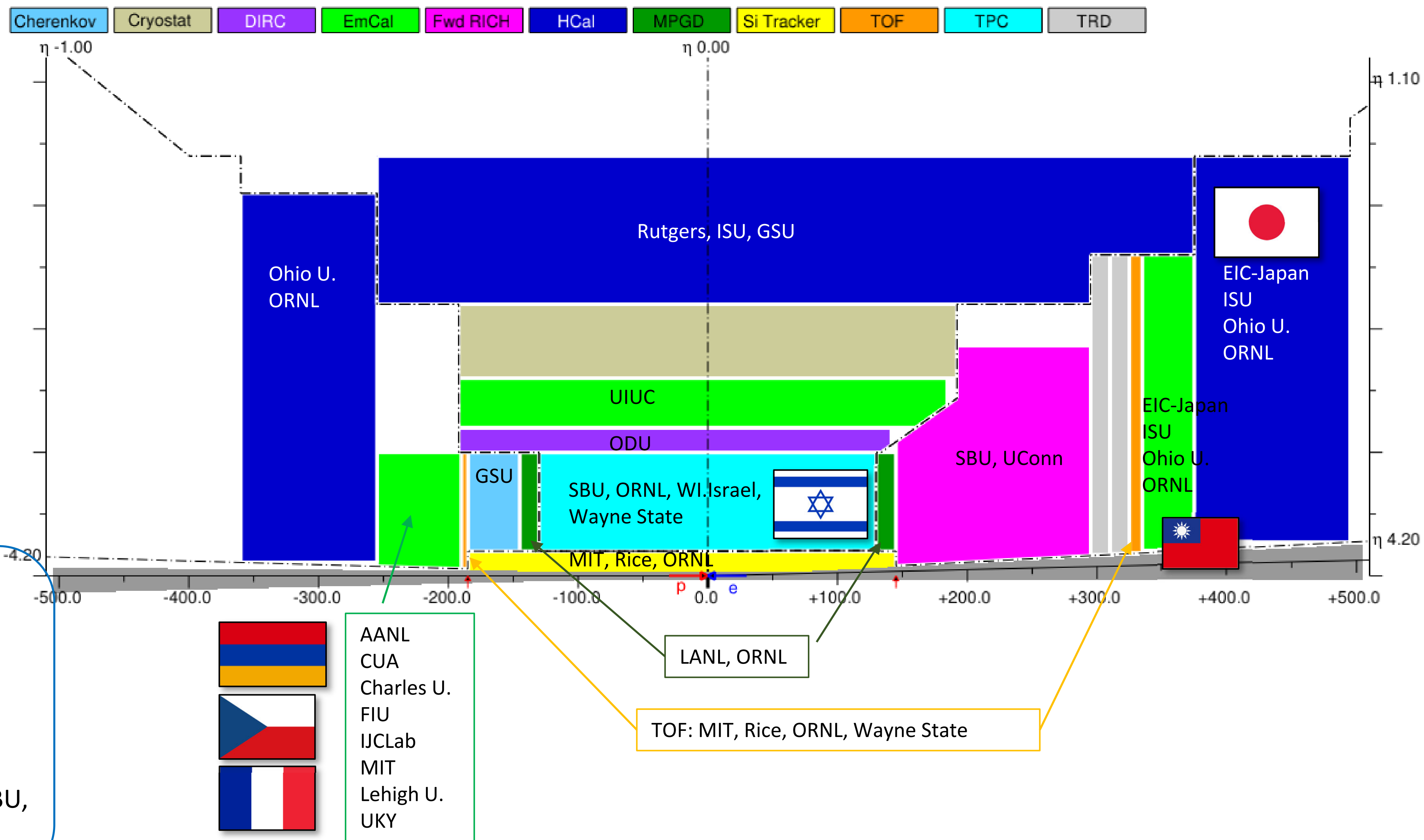
The EIC Call for Proposals

- A joint BNL/JLab call for Collaboration Proposals for Detectors at the EIC has been issued, deadline December 1, 2021 Call Collaboration Proposals
  - With input from DOE and EIC User's Group
- Detector 1 is within the scope of the project. US Federal funds are expected to support most but not all of the acquisition of Detector 1
- Detector 2 is not within the Project scope. Routes to make Detector 2 and a second interaction region possible are being explored
- Proposals should consider the siting scenario for the detectors described in the CDR.
  - Detector 1 is currently planned to be located at Interaction Point 6 (IP6) on the Relativistic Heavy-Ion Collider.
  - Other siting options are welcome but proposals that deviate from the CDR will need to address the implications to the EIC project.

The Science

- Detector 1 should be based on the “reference” detector described by the EIC User Group (EICUG) in the Yellow Report (YR) and CDR
  - Must address the EIC White Paper and NAS Report science case
  - The collaboration should propose a system that meets the performance requirements described in the EIC CDR and EICUG YR
  - The design should be compatible with that of the accelerator and interaction region layout of the CDR
  - Completion of detector construction must be achieved by Critical Decision (CD)-4A, the start of EIC accelerator operations.
- Detector 2 could be a complementary detector that may focus on optimizing particular science topics or address science topics beyond those described in the White Paper and the National Academies of Science (NAS) 2018 report
  - Completion at Critical Decision (CD)-4

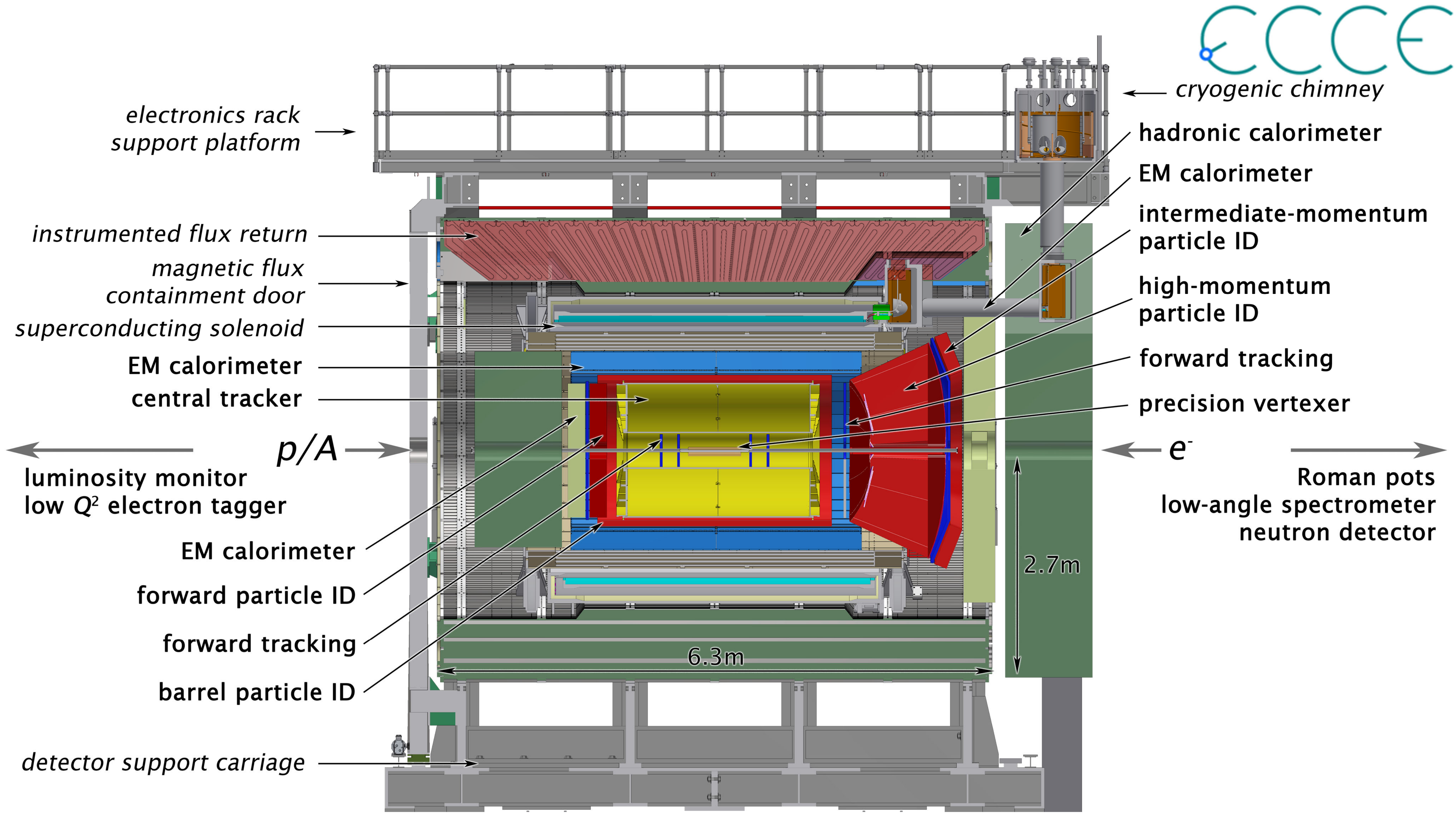
ECCE Concept - Barrel



Polarized Beam and polarimetry: MIT, UNH, SBU

Electronics: Columbia, ORNL

DAQ/Trigger: ISU, CU Boulder, OU, ORNL, SBU, UConn, LLNL

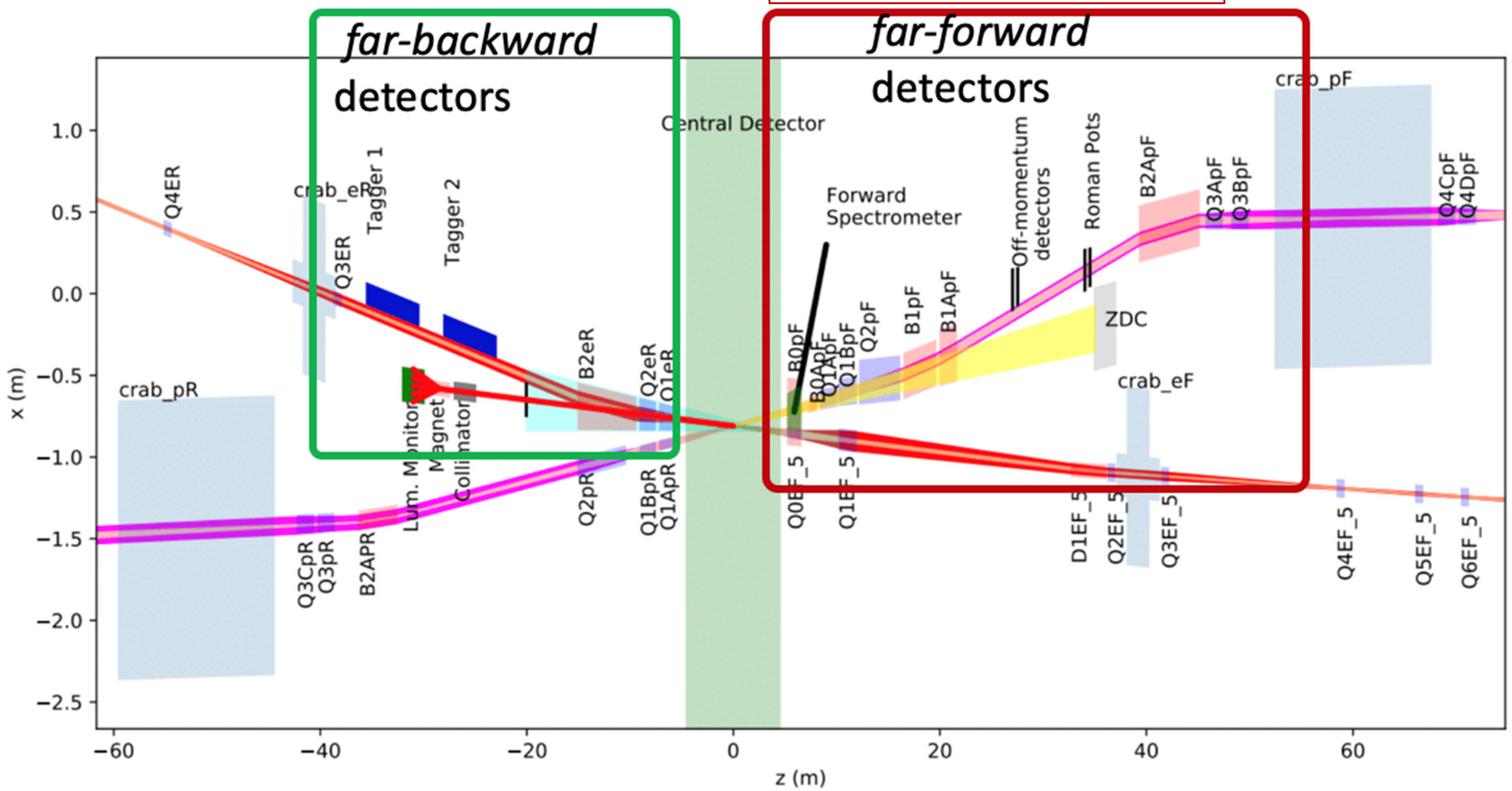


electronics rack
support platform
instrumented flux return
magnetic flux
containment door
superconducting solenoid
EM calorimeter
central tracker
p/A
luminosity monitor
low Q² electron tagger
EM calorimeter
forward particle ID
forward tracking
barrel particle ID
detector support carriage
cryogenic chimney
hadronic calorimeter
EM calorimeter
intermediate-momentum
particle ID
high-momentum
particle ID
forward tracking
precision vertexer
e⁻
Roman pots
low-angle spectrometer
neutron detector
2.7m
6.3m

ECCE Concept - Far Forward/Backward

Glasgow U., ODU

BGU/Israel, MIT, ORNL, UIUC, IJCLab-Orsay, EIC-Japan, TAU/Israel, UVA, GWU, MIT-BATES, HUIJ/Israel



Example of ECCE Physics : Spin

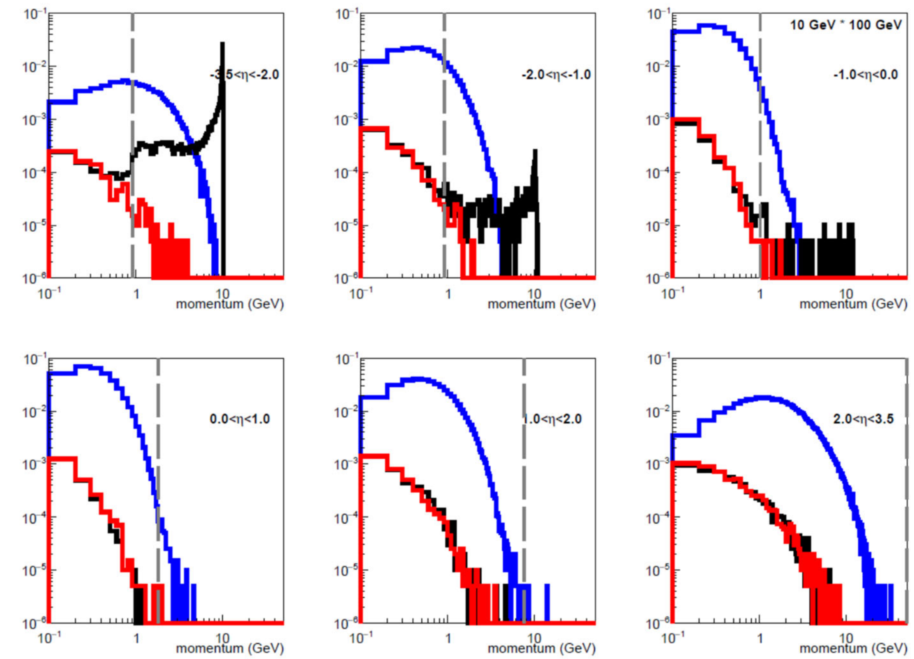
Major requirements:

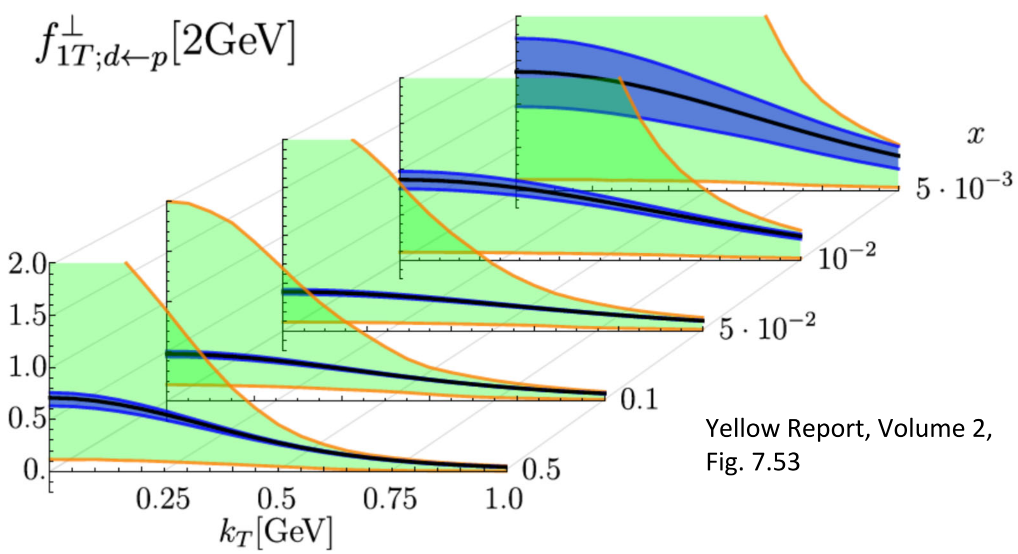
- ❑ Precision calorimetry in lepton endcap
- ❑ PID in barrel

ECCE:

- ❑ High resolution calorimetry in lepton endcap
- ❑ PID in barrel
- ❑ PID in forward endcap enables also TMDs

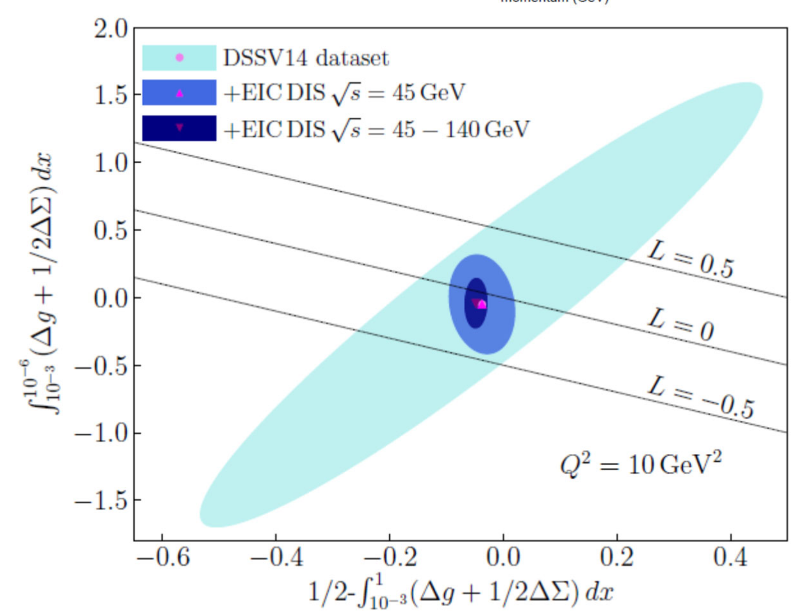
Scattered Electron Backgrounds





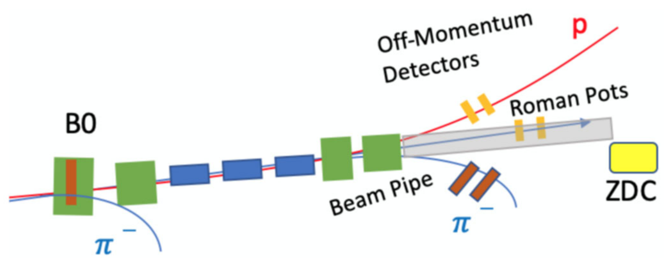
Yellow Report, Volume 2, Fig. 7.53

Yellow Report, Volume 2, Chapter 7



Yellow Report, Volume 2, Fig. 7.17 and 8.11

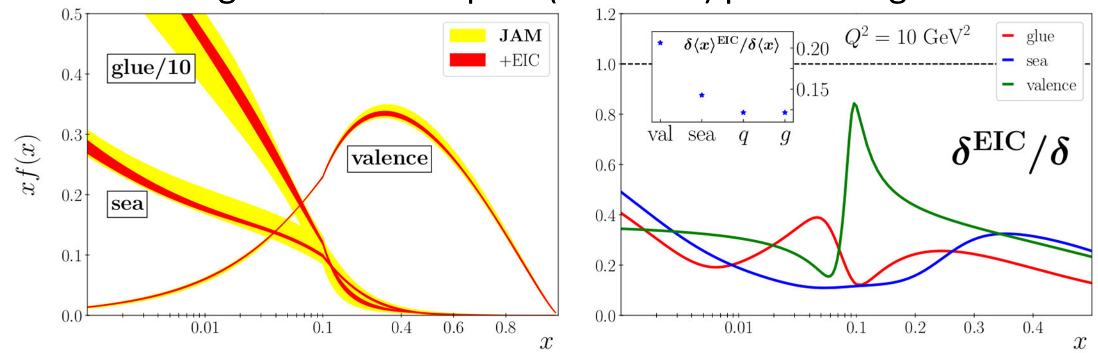
Example of ECCE Physics : Origin of Hadron Mass



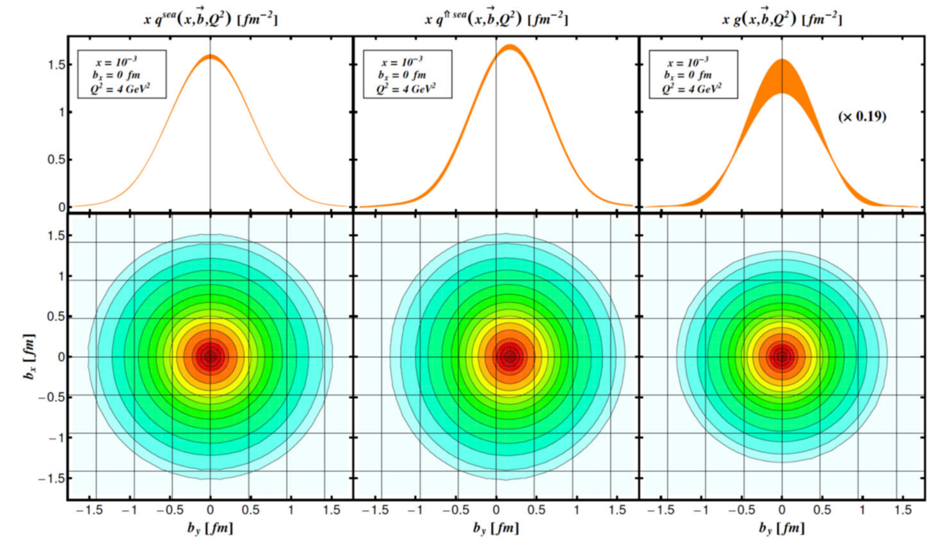
Major requirements

- ❑ Far-forward detection to tag n and Λ (or Σ^o) (meson structure) and to tag p (for DVCS/3D).
- ❑ Scattered electron detection in electron endcap
- ❑ Good hadron endcap and far-forward calorimetry (goal: 35%/E, <50%/E acceptable)
- ❑ For pion form factor: pion in hadron endcap

Large reduction in pion (structure) pdfs through EIC



Yellow Report, Volume 2, Fig. 7.24



Yellow Report, Volume 2,Fig. 7.46

ECCE – physics reach enhanced in x_L and x_B with beam focus with dispersion – relevant for diffraction (e-p, e-A) and tagging (e-d, e-^{3}He, etc), and exclusive measurements

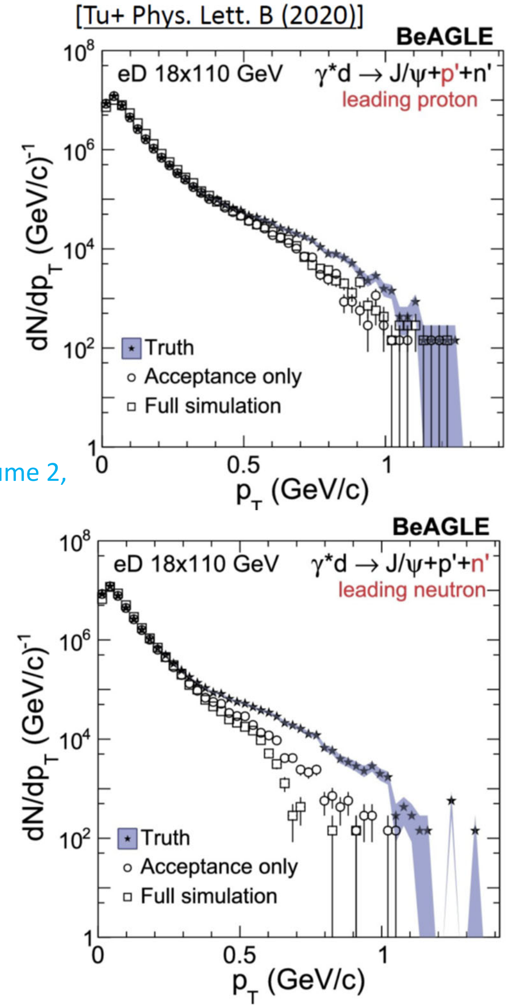
#	Parameter	EIC IR #1	EIC IR #2	Impact
8	Minimum $\Delta(B\rho)/(B\rho)$ allowing for detection of $p_T = 0$ fragments	0.1	0.003 – 0.01	Beam focus with dispersion, reach in x_L and p_T resolution, reach in x_B for exclusive processes

From 4th YR Workshop – talks on complementarity (Y. Zhang, V. Morozov)

Example of ECCE Physics : Nuclei

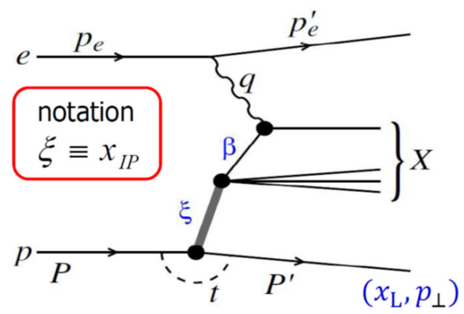
Incoherent diffractive J/Ψ production in e-d tagging

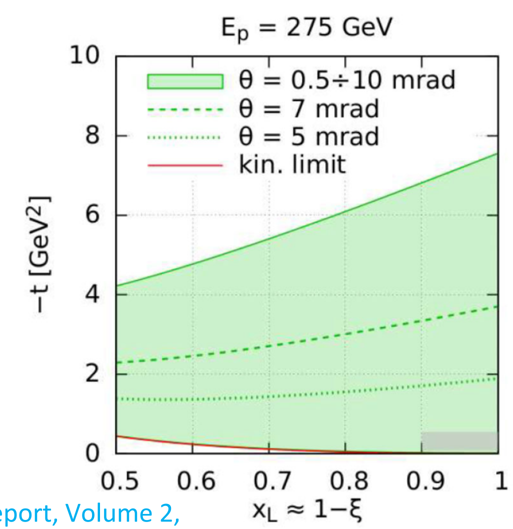
[Tu+ Phys. Lett. B (2020)]



Yellow Report, Volume 2, Fig. 7.73

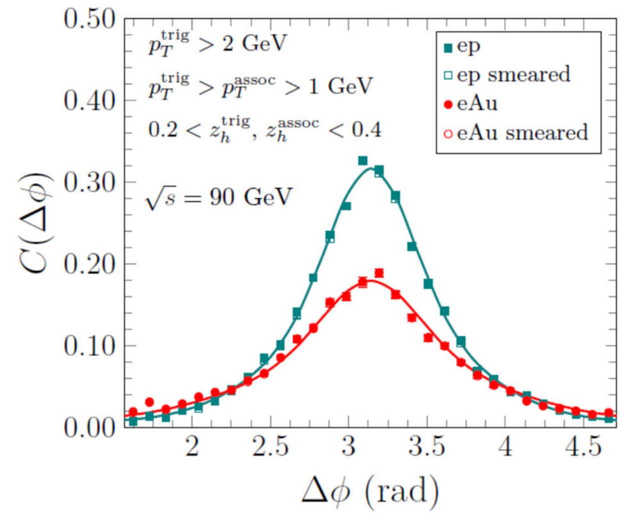
Inclusive diffraction in e-A



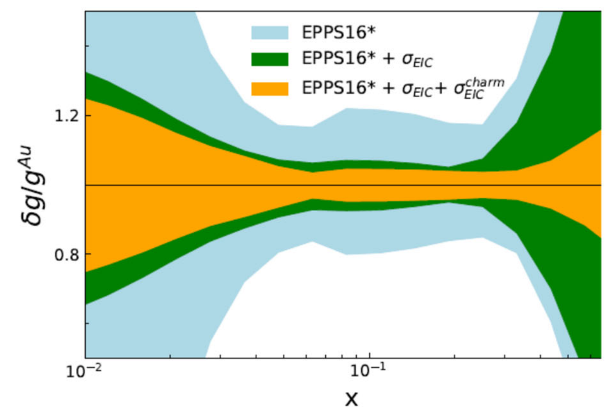


Yellow Report, Volume 2, Fig. 7.30

di-hadron azimuthal angle correlation, nuclear glue ratio through inclusive and open charm



Yellow Report, Volume 2, Fig. 7.63



Yellow Report, Volume 2, Fig. 7.69

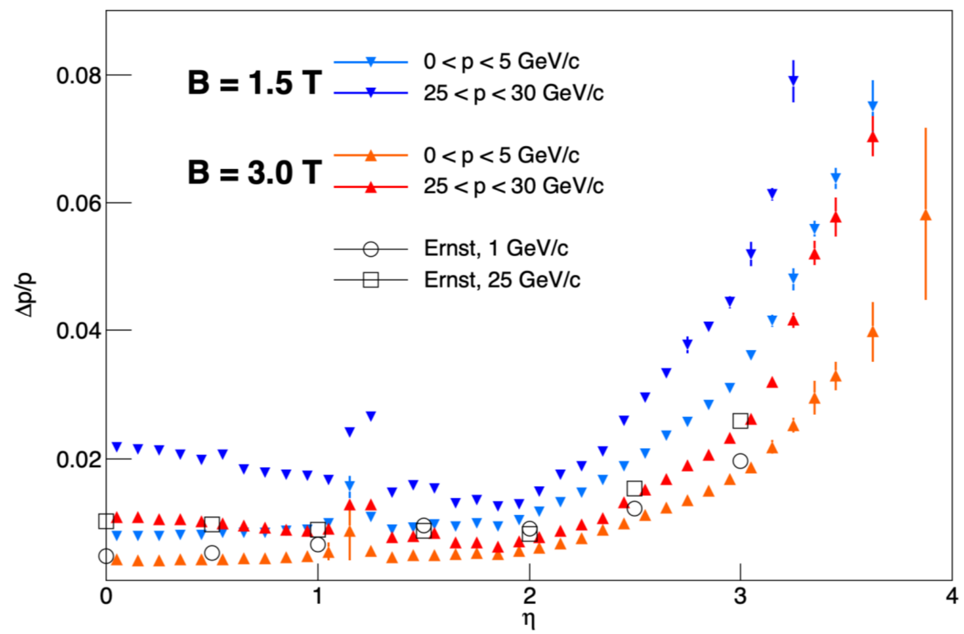
ECCE – physics reach enhanced in x_L and x_B with beam focus with dispersion – relevant for diffraction (e-p, e-A) and tagging (e-d, e-^{3}He, etc), and exclusive measurements

Challenges with B=1.5T

Resolution in forward region η > 2.5

- ❑ Jets and heavy flavor group requires higher resolution in forward hadron region.

Jets/HF WG (https://wiki.bnl.gov/eicug/index.php/Yellow_Report_Physics_Jets-HF)



Track Momentum Resolution

Eta Range	Default Resolution (σP/P)%	Requested (σP/P)%
-3.5 < η < -2.5	0.1%*P + 0.5%	Same
-2.5 < η < -2.0	0.1%*P + 0.5%	Same
-2.0 < η < -1.0	0.05%*P + 0.5%	Same
-1.0 < η < 1.0	0.05%*P + 0.5%	Same
1.0 < η < 2.5	0.05%*P + 1.0%	Same
2.5 < η < 3.5	0.1%*P + 2.0%	Same

Investigating options for field shaping.

- ❑ However, lower field can also be useful in tagging and reconstruction of certain heavy mesons (D*) – resolution vs. acceptance/efficiency balance

Pseudorapidity Range	Min p_T (3T) [MeV/c]	Min p_T (1.5T) [MeV/c]
$0.0 < \eta < 1.0$	400	200
$1.0 < \eta < 1.5$	300	150
$1.5 < \eta < 2.0$	160	70
$2.0 < \eta < 2.5$	220	130
$2.5 < \eta < 3.5$	150	100

Central Barrel Space Constraints

Tracking	all-Si maybe down to 50-60 cm, Si + TPC = 80 cm
Tracking support structure	5 cm
Hadron particle identification	DIRC only needs 10 cm, RICH 50 cm but better for uniformity
EM Calorimetry	50 cm for high-resolution, 30 cm for less-resolution (or costly)
PID & EMCal support structure	10-15 cm likely enough

Function	Minimum [cm]	Maximum [cm]	Minimum [cm]	Maximum [cm]
Tracking (includes 5 cm support)	All-Si		Si + TPC	
	65		85	
Hadron particle identification	RICH		DIRC	
	50		10	
EM Calorimetry	30	50	High-Resolution to achieve P < 2 GeV	
			50	
PID & EMCal support structure	10	15	10	15
Total	145	165	155	160

Need to discuss the fit of all detectors in the existing magnet with bore 2.8 meter - will be a tour de force and will require optimization.

From 4th YR Workshop – talk on magnet

Goals of this Workshop

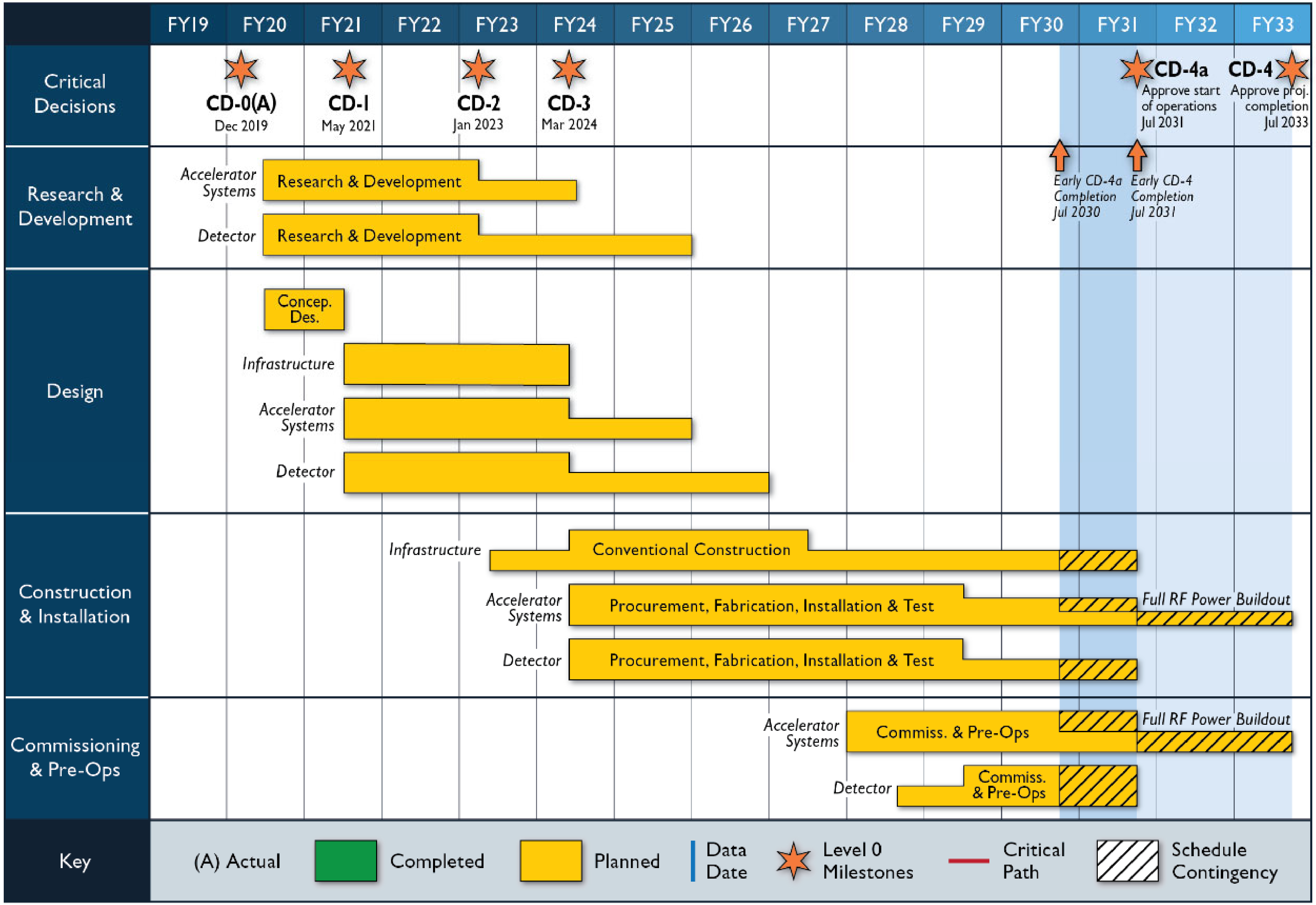
- Meet your fellow ECCE collaborators!
- Gain familiarity with the tools we will use to develop the simulation case for the ECCE proposal
- Discussions to begin the process of:
  - Organizing the work to be done on the simulation framework
    - Most importantly - detector implementations (working with Detector Team DWG's)
  - Designing the ECCE detector
    - Technology choices based on *integrated* physics performance
    - How do we design an *optimal* detector?
  - Evaluation of the physics performance
    - Focus to be determined working with Physics Team PWG's

You can make ECCE happen!

- ECCE offers a great start to realizing the EIC science program!
- This workshop is the first step in designing ECCE and evaluating its ability to address the EIC science mission
- Nothing is set in stone - your participation <u>defines</u> ECCE
  - We need your input and creativity!
  - This is a once in a lifetime opportunity!

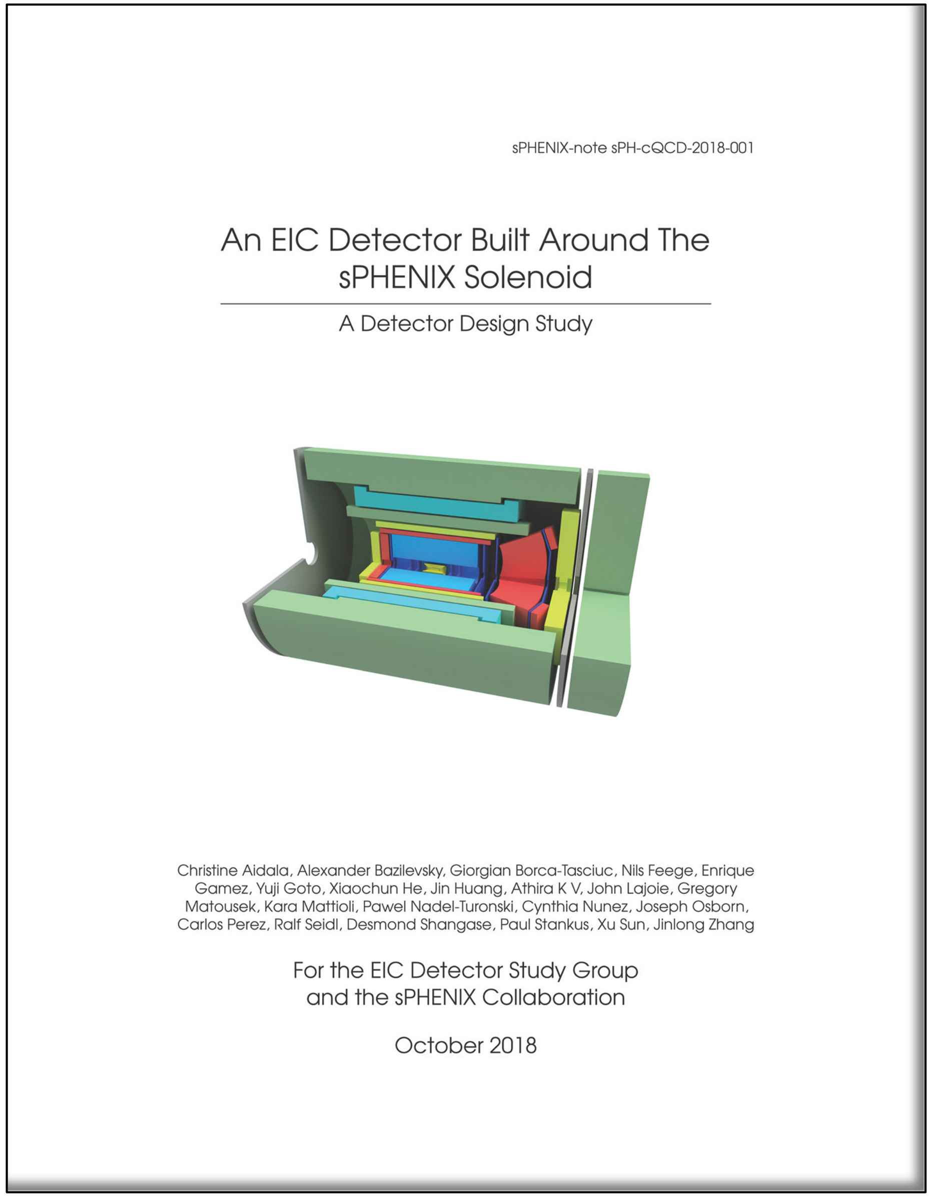
- Enjoy the workshop!

BACKUP



From Jim Yeck
3/30/21

Prior Design Studies


sPHENIX-note sPH-cQCD-2018-001

An EIC Detector Built Around The sPHENIX Solenoid

A Detector Design Study

Christine Aidala, Alexander Bazilevsky, Giorgian Borca-Tasciuc, Nils Feege, Enrique Gamez, Yuji Goto, Xiaochun He, Jin Huang, Athira K V, John Lajoie, Gregory Matousek, Kara Mattioli, Pawel Nadel-Turonski, Cynthia Nunez, Joseph Osborn, Carlos Perez, Ralf Seidl, Desmond Shangase, Paul Stankus, Xu Sun, Jinlong Zhang

For the EIC Detector Study Group and the sPHENIX Collaboration

October 2018

- Previous 2014/18 studies centered on BaBar solenoid
  - 2018 study in response to charge by BNL ALD
    (see talk by Christine Aidala)
  - Flexible, complete G4 simulation framework already exists for ECCE studies
    - Foundation for ECCE proposal work

arXiv:1402.1209
https://indico.bnl.gov/event/5283/