at the EIC

Peter Steinberg, BNL / BNL special seminar / 27 April 2021

Special thanks to ECCE teams, Jin Huang, Dave Morrison

What is ECCE ?

https://www.ecce-eic.org

- **ECCE is 64 institutes (& counting) collaborating to design an EIC detector offering full kinematic coverage and an optimized far forward detector system**

- **Investigating a design which incorporates the existing 1.5T BaBar magnet, which will help manage cost, risk and schedule - to allow it to be ready for first EIC detector operation (CD4a)**

- **Also investigating the costs and benefits associated with using either IP6 or IP8**

- **Will 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**

- **Fully supportive of the use of two detectors, 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: Feb. 26

1. AANL*
2. AUGIE
3. BGU*
4. BNL
5. Charles U*
6. Columbia
7. CUA
8. FIU
9. Georgia State
10. Glasgow*
11. GWU
12. IJCLab-Orsay*
13. Iowa State
14. IPAS*
15. JLab
16. LANL
17. Lehigh University
18. LLNL
19. MIT
20. NCKU*
21. NCU*
22. NRNU MEPhI*
23. NTHU*
24. NTU*
25. ODU
26. Ohio U
27. ORNL
28. PNNL
29. Rice
30. Rutgers
31. Saha*
32. SBU
33. TAU
34. CU Boulder
35. UConn
36. UIUC
37. UKY
38. UNH
39. UTSM*
40. UVA
41. Vanderbilt
42. Virginia Tech
43. Virginia Union
44. Wayne State
45. Weizmann*
46. Zagreb University*

*Non-US institutions (33%)

1

ECCE Consortium: April 26

Up by 40%!

1. AANL*
2. AUGIE
3. BGU*
4. BNL
5. CCNU*
6. Charles U.*
7. CNU
8. Columbia
9. CUA
10. Czech. Tech. Univ.*
11. Duke
12. FIU
13. Georgia State
14. Glasgow*
15. GSI*
16. GWU
17. HUJI*
18. IJCLab-Orsay*
19. IMP*
20. Iowa State
21. IPAS*
22. JLab
23. LANL
24. LBNL/Berkeley
25. Lehigh University
26. LLNL
27. Morehead State
28. MIT
29. MSU
30. NCKU*
31. NCU*
32. NMSU
33. NRNU MEPhI*
34. NTHU*
35. NTU*
36. ODU
37. Ohio U
38. ORNL
39. PNNL
40. Rice
41. RIKEN*
42. Rutgers
43. Saha*
44. SBU
45. SCNU*
46. TAU*
47. Tsukuba U.*
48. CU Boulder
49. UConn
50. UH
51. UIUC
52. UKY
53. UNH
54. USTC*
55. UTK
56. UTSM*
57. UVA
58. Vanderbilt
59. Virginia Tech
60. Virginia Union
61. Wayne State
62. WI*
63. York*
64. Zagreb U.*

*Non-US institutions (40%)

ECCE consortium (current)

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)
TBA

Diversity, Equity and Inclusion
Narbe Kalantarians (VUU)
Simonetta Liuti (UVA)
Elena Long (UNH)
Christine Nattrass (UTK)

Computing Working Groups:

- Artificial Intelligence
- Computing and Software
  Joe Osborn (ORNL)

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

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

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

Physics Working Groups:

- Simulations
  Cameron Dean (LANL), Jin Huang (BNL)
- Inclusive Processes
- 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)
- BSM and Precision Electroweak
  Sonny Mantry (UNG), Xiaochao Zheng (UVa)

Editorial Working Groups:

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

Detector Working Groups:

- IP8/Equipment Re-use
  John Haggerty (BNL)
- Far Forward/Far Backward*
  Michael Murray (KU)
- Tracking
  Xuan Li (LANL)
- Calorimetry
  Friederike Bock (ORNL), Yongsun Kim (Sejong U.)
- Particle ID
  Greg Kalicy (CUA)
- Magnetic Field
  Paul Brindza (JLab)
- DAQ/Electronics/Readout
  Chris Cuevas (JLab)

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

Structure developing for proposal evolving towards full collaboration.
Strong representation from BNL & JLab. Good communication with project.

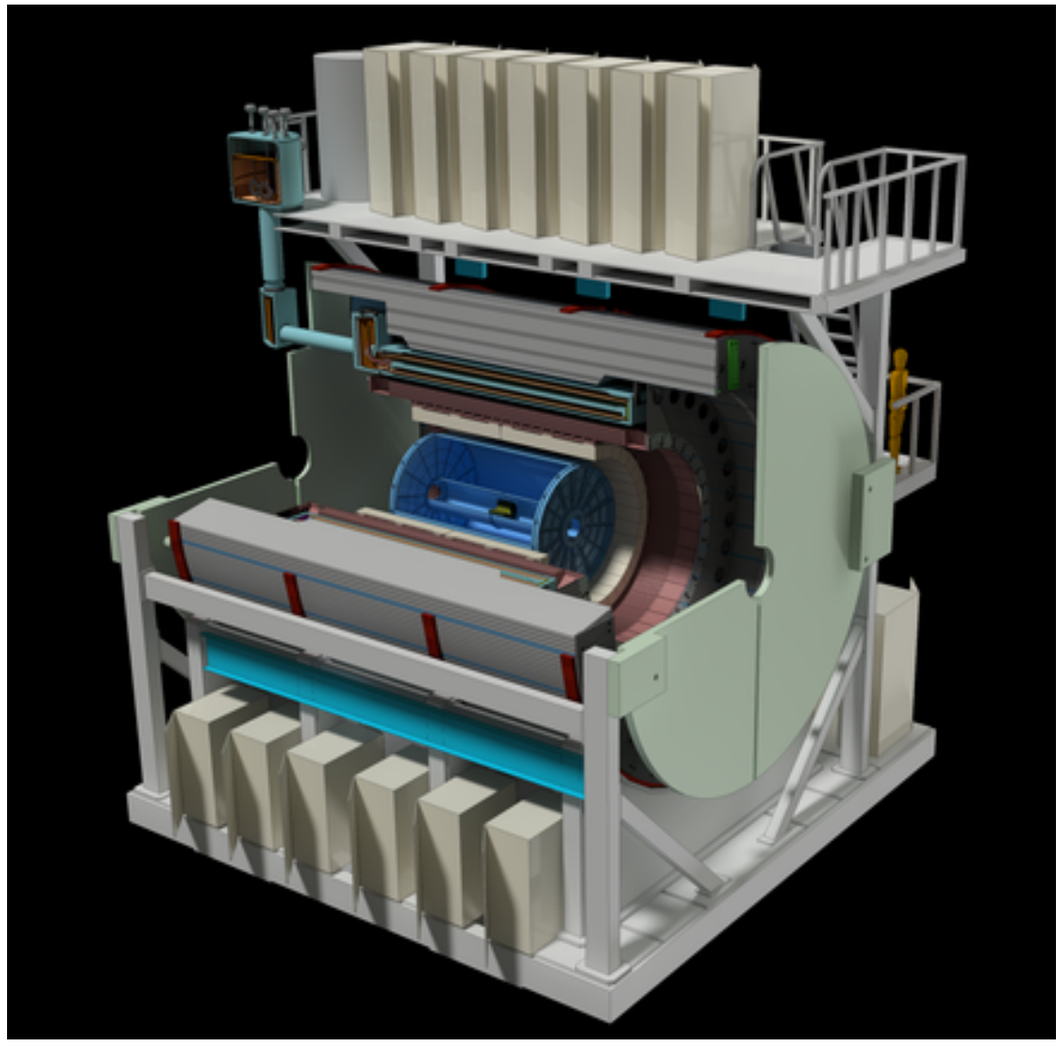
Existing BNL resources

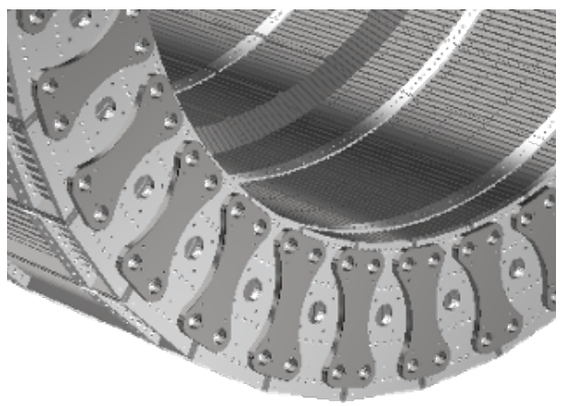
- **1.5T BaBar solenoid, flux return and cradle**
  - Used in sPHENIX MIE ($27.5M)
    - *MVTX $5M, iHCal $1.5M, INTT $3M*
  - Reuse of even some components contributes to management of cost, schedule and risk

- **IP8 infrastructure**
  - Cyrogenic connections to RHIC
  - Racks, electrical, mechanical, HVAC, safety, etc.
  - $33.4M investment to refurbish IR for sPHENIX

- **sPHENIX subsystems**
  - Benefit from substantial investment in engineering
    - *An illustrative example: 8+ months spent developing “dogbones” for HCal*
    - *engineering, FEA, reviews, prototyping, material choice, vendor selection, test fitting…*

- **DOE project experience**
  - Expertise in CD and PD process (sPHENIX CD-0 in Fall 2016)





BaBar 1.5T solenoid

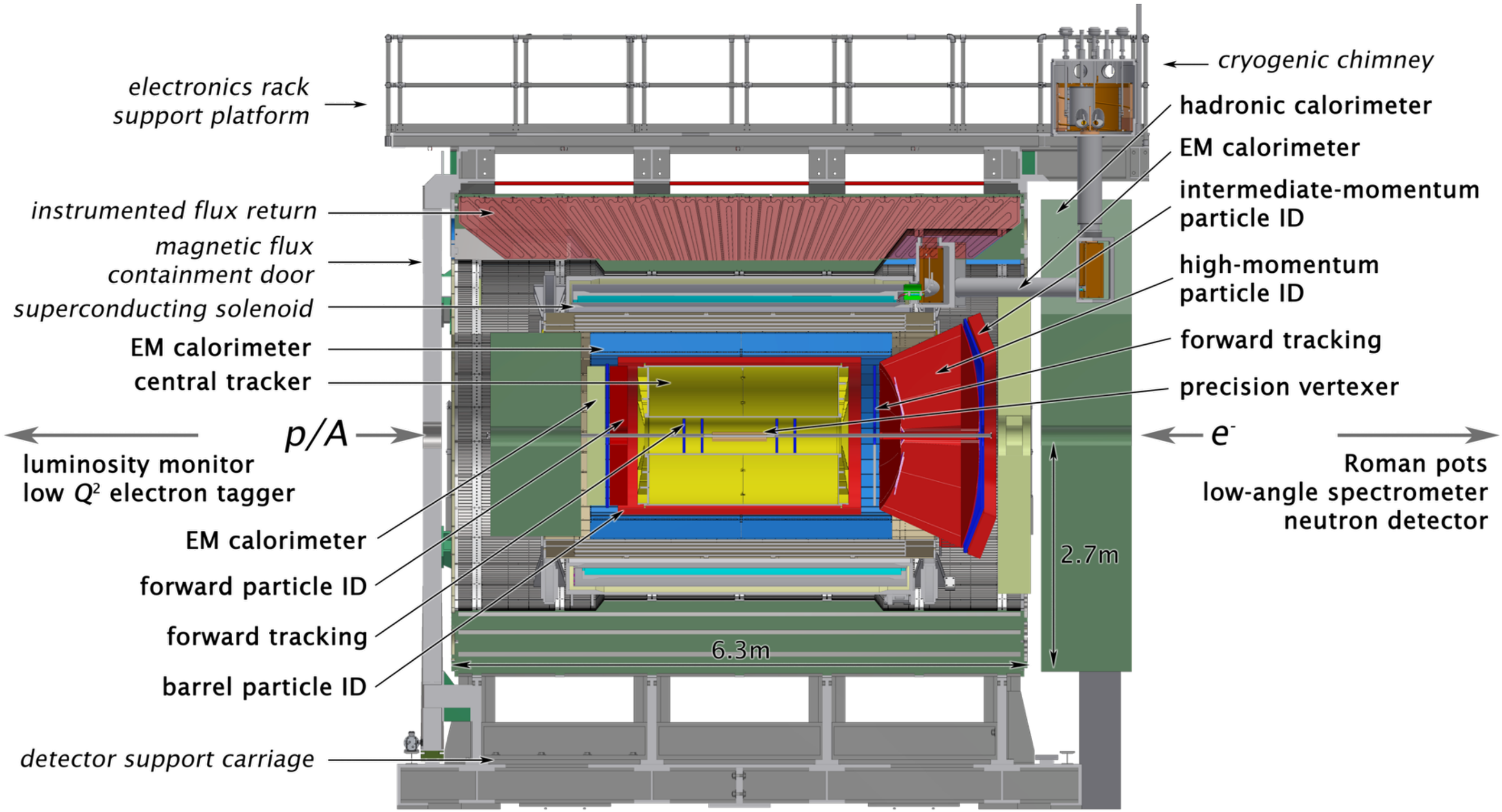
- **Built in 1997 (Ansaldo)**
- **3.7m long, 1.4m bore radius**
- **1.4T in sPHENIX configuration**
- **Transported to BNL in 2015**
  - Low and high field tests
- **Magnet mapping planned for 2022**
- **Extensive risk analysis shows that the magnet is in excellent shape**

Pasquale Fabbricatore

Designed BaBar and CMS 4T superconducting magnets

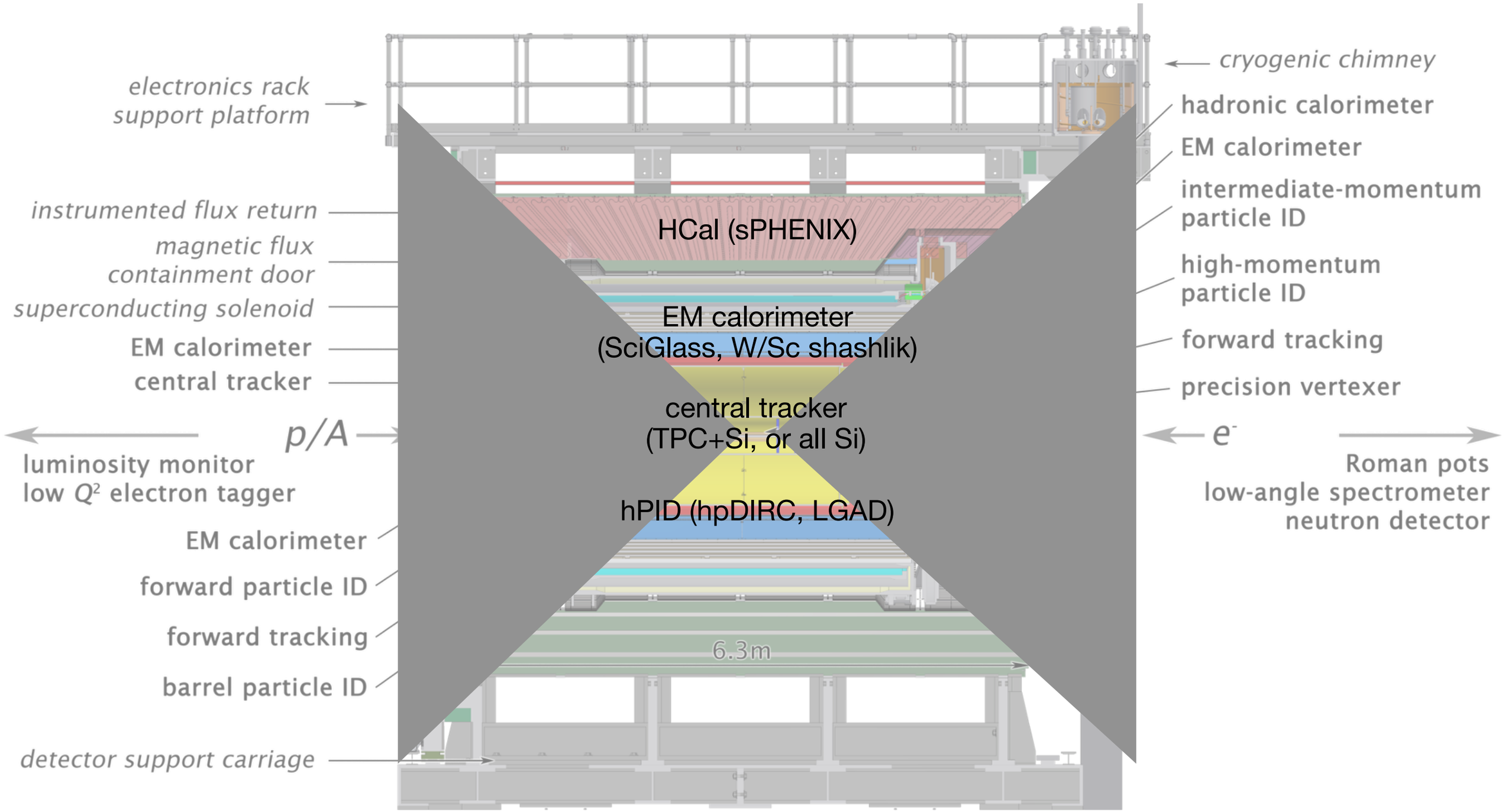
Recipient of IEEE Award for Continuing and Significant Contributions in the Field of Applied Superconductivity

A first look at a possible ECCE

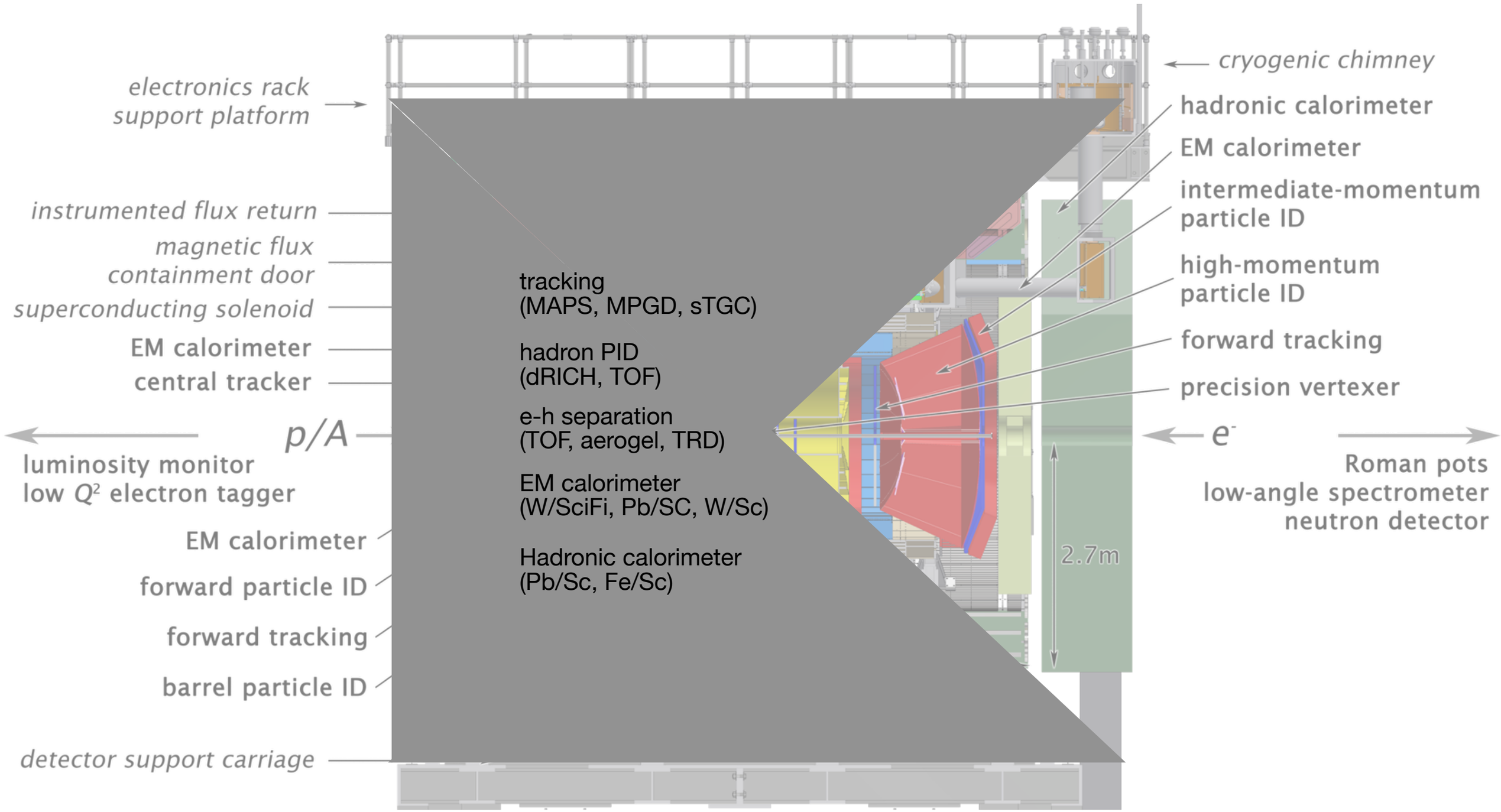


sPHENIX experience will be invaluable

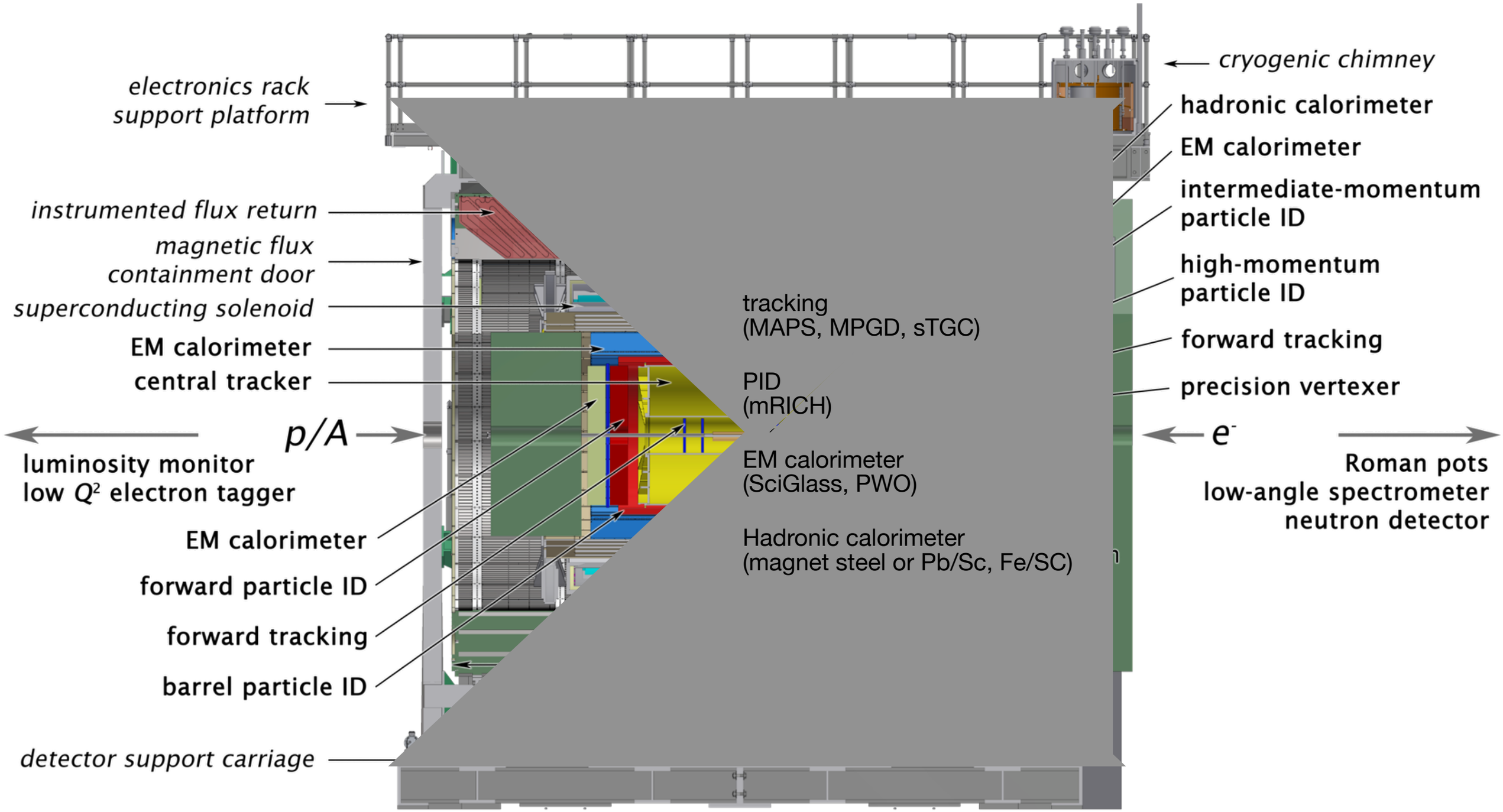
Central barrel



Hadron endcap



Electron endcap

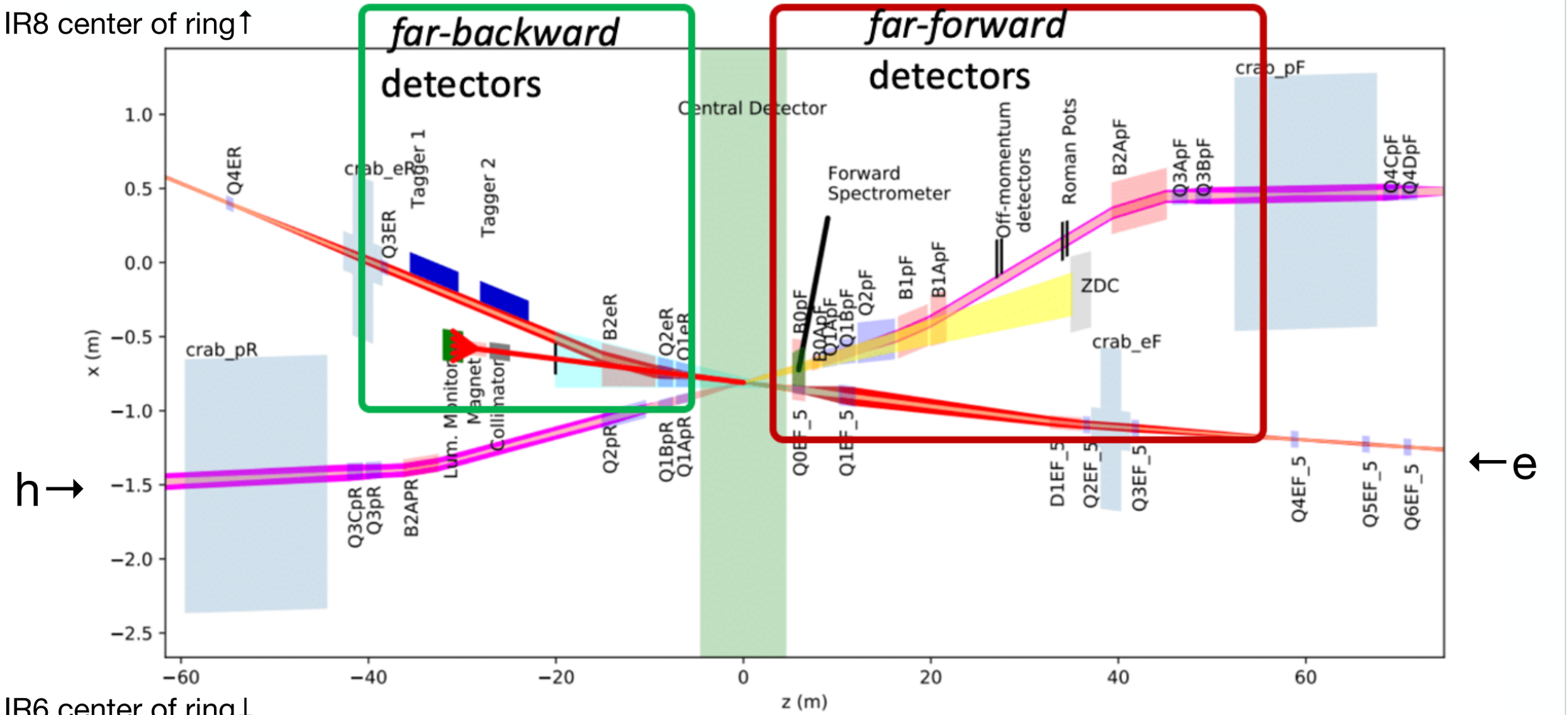


Far forward & backward regions

Glasgow
ODU

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

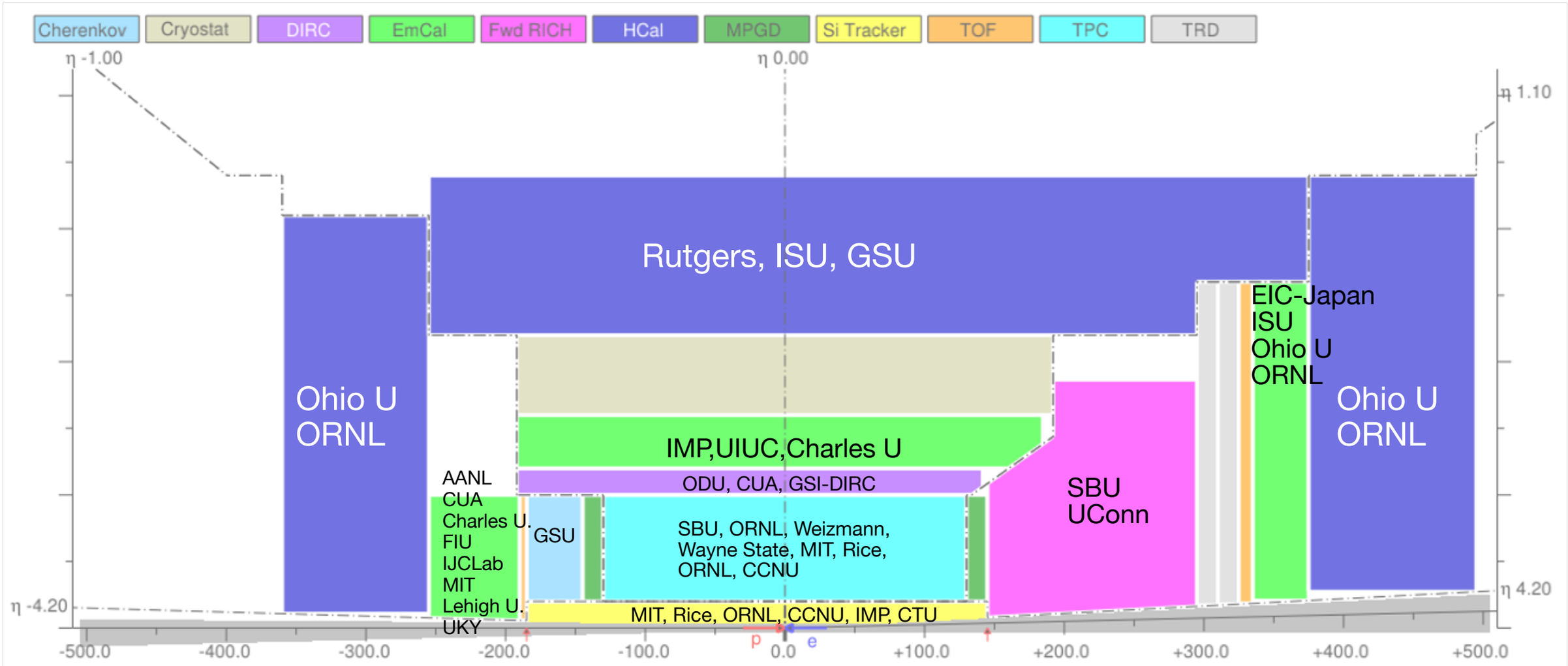
IR8 center of ring↑



IR6 center of ring↓

IR6/25mrad shown here, to be used for initial simulations.
Eagerly awaiting revised IR8/35mrad design to explore increased far-forward acceptance!

Institutional interest from EoI & beyond



Polarized Beam and polarimetry: MIT, UNH, SBU

Electronics: Columbia, ORNL, IMP

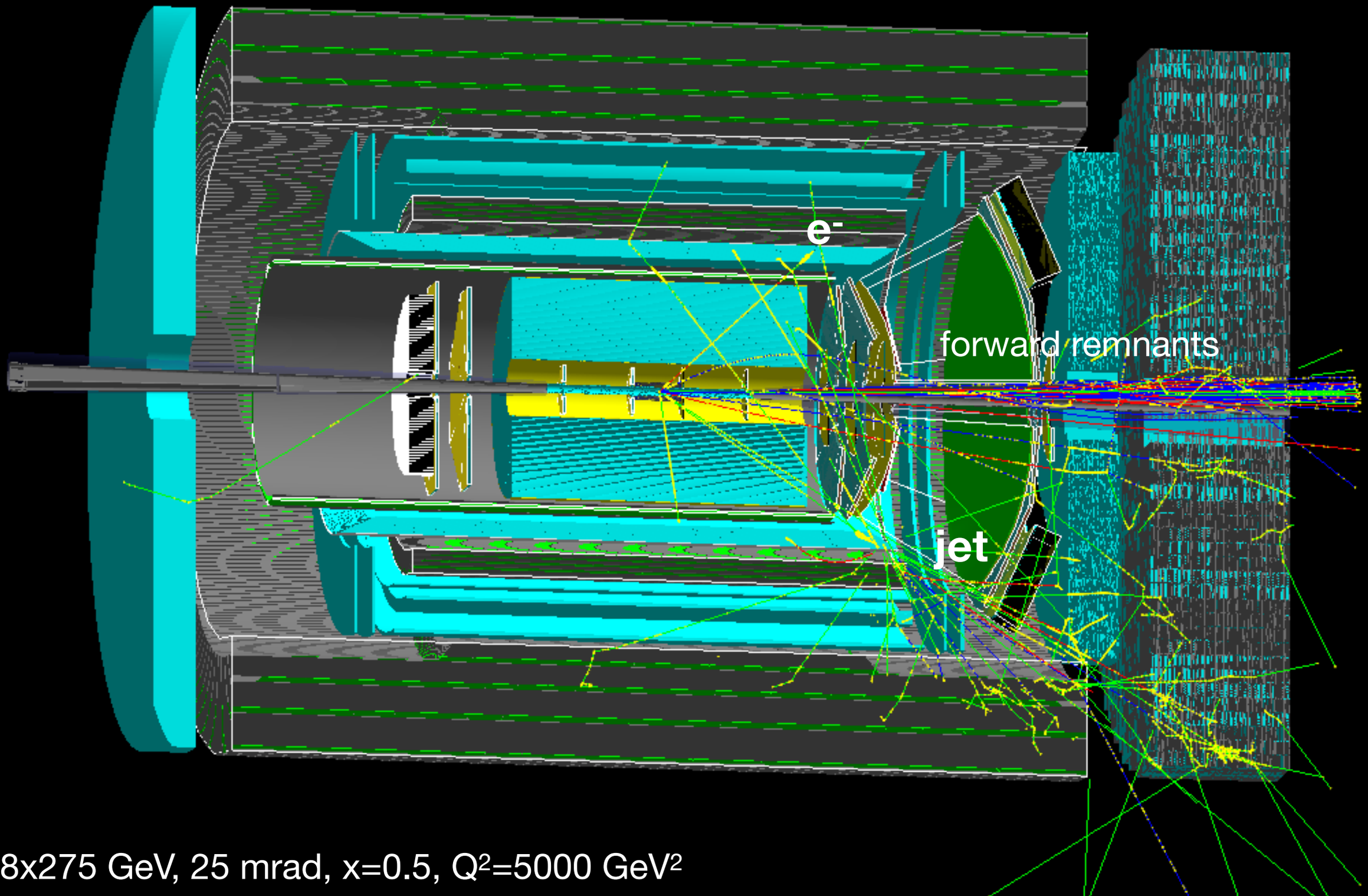
DAQ/Trigger: ISU, CU Boulder, OU, ORNL, SBU, UConn, LLNL

Reflects situation at time of EoI, and recently-joined institutes:
Many areas where BNL (PO, ATRO, CSI, SDCC) can contribute:
calorimetry, tracking, PID, electronics, computing…

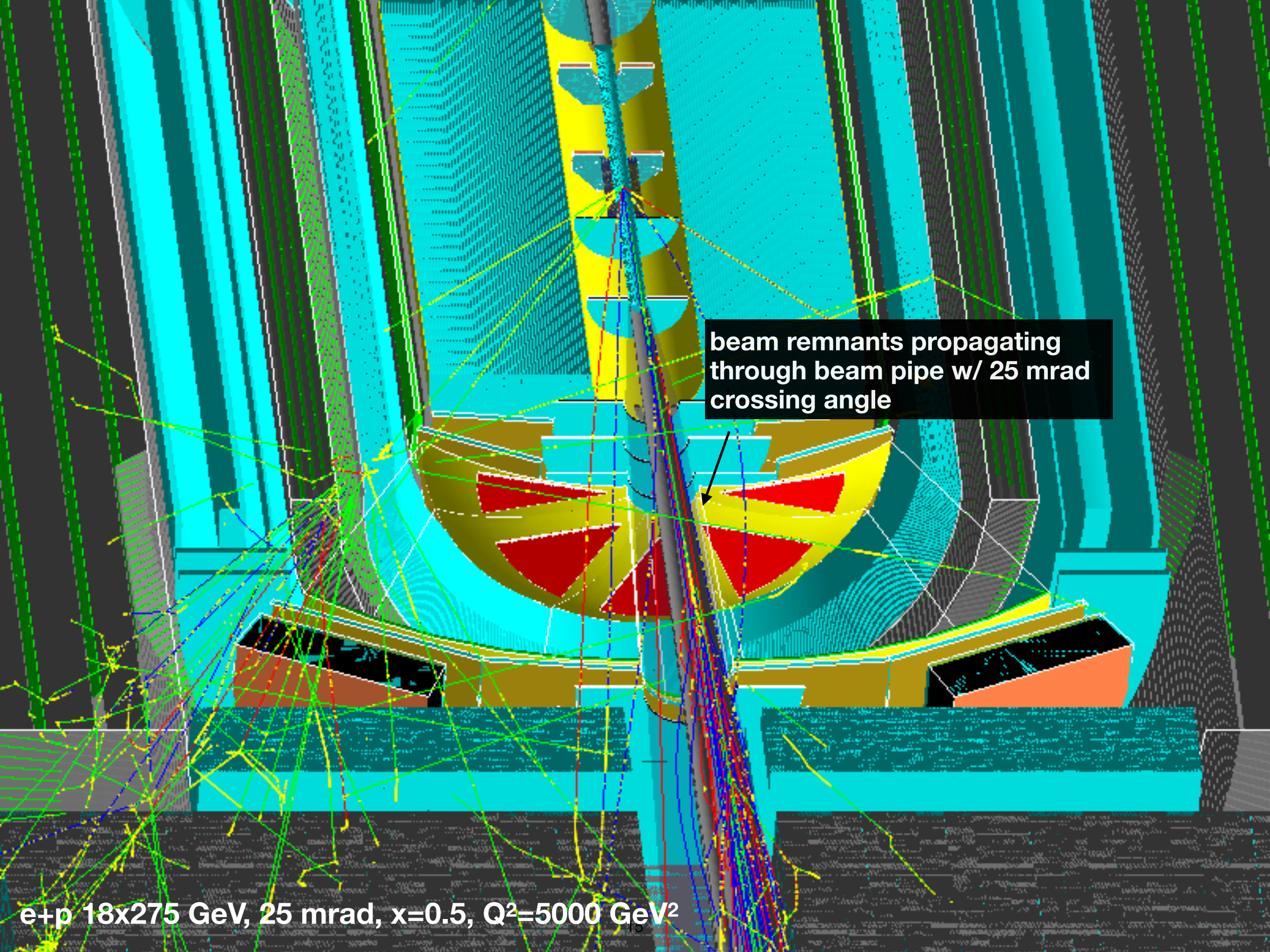
Simulation framework

https://ecce-eic.github.io

- **ECCE leverages the fun4all framework already used extensively for sPHENIX**
- **Includes realistic IRs and crossing angle**



e+p 18x275 GeV, 25 mrad, x=0.5, Q^2=5000 GeV^2


beam remnants propagating through beam pipe w/ 25 mrad crossing angle
e+p 18x275 GeV, 25 mrad, x=0.5, Q²=5000 GeV²

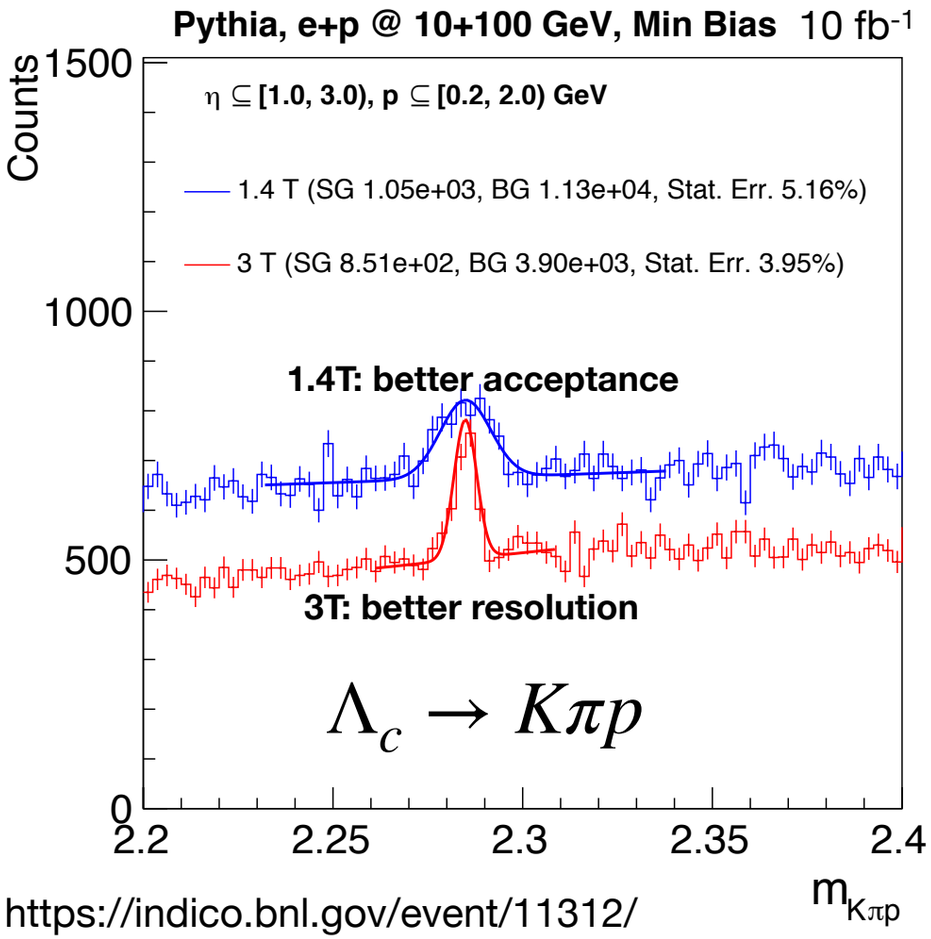
ECCE physics program

- **ECCE will address the full spectrum of the EIC physics program with a capable detector**

- **Scope of the program reflected in physics subgroups**
  - Inclusive processes (nucleon and nuclear parton structure)
  - Semi-inclusive processes (imaging via GPD & TMD)
  - Exclusive processes (DVCS, DVMP)
  - Diffraction and tagging (vector mesons, meson structure, neutron structure)
  - Jets & heavy flavor - precision q & g (n)PDF measurements, jet substructure
  - BSM & precision electroweak

- **NPP strategy from 2020 emphasizes BNL taking strong role in EIC physics program, starting with first EIC data**
  - e.g. inclusive nuclear diffraction might provide insight into the role of saturation at the EIC, as it did in early days of HERA

Heavy flavor in ECCE



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

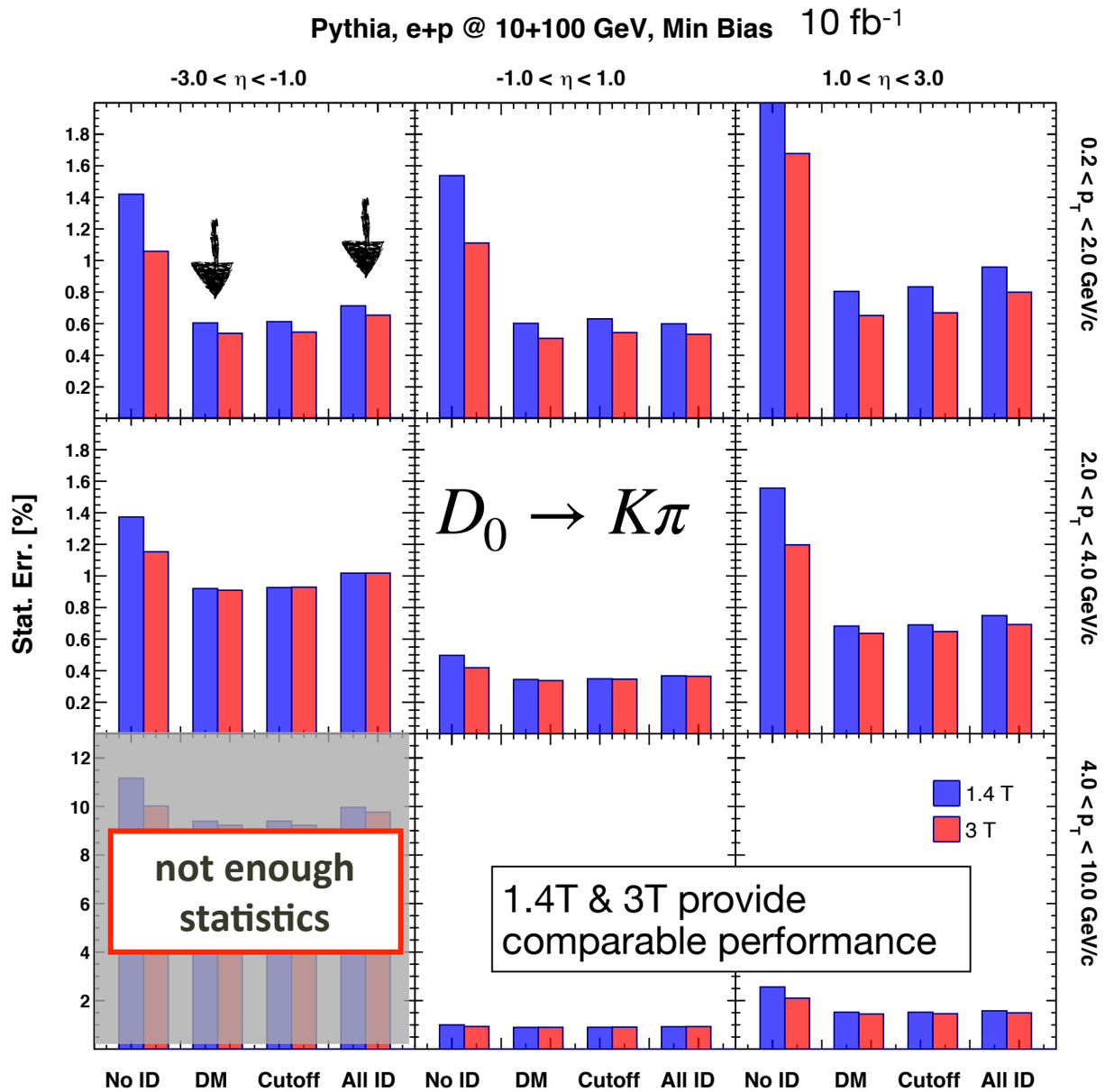
EICUG YR

radiator	index	Threshold (GeV/c) e	π	K	p
quartz (DIRC)	1.473	0.00048	0.13	0.47	0.88
aerogel (mRICH)	1.03	0.00207	0.57	2.00	3.80
aerogel (dRICH)	1.02	0.00245	0.69	2.46	4.67
C_2F_6 (dRICH)	1.0008	0.01277	3.49	12.34	23.45
CF_4 (gRICH)	1.00056	0.01527	4.17	14.75	28.03

Table 11.23: Table of Cherenkov thresholds for various media.

Recent study by Wenqing Fan, LBNL

- *Fast simulation of PID, based on YR specifications*
- *Parallel effort ongoing with full detector geant4 sim*



BNL Opportunties in ECCE

- **Detector**
  - Mature detector concept exists, but technology options not yet finalized
  - Opportunities for BNL groups
    - *forward tracking (e.g. sTGC)*
    - *particle ID (e.g. LGADs for PID)*
    - *Forward calorimetry (e.g. hadron direction)*
    - *Far forward detector integration into IR*
    - *Optimizing reuse of sPHENIX components, DAQ & computing*
  - BNL experience valuable and very welcome
    - *STAR, PHENIX, LHC, ATRO, CSI, SDCC*

- **Physics**
  - ECCE has a vast physics program, with many places to contribute
  - Again, experience from STAR and PHENIX groups will strengthen ECCE's core "NAS/YR" program and also expand it
    - *e.g. BNL is a center for saturation physics, both on experiment and theory*

Summary and Outlook

- **ECCE consortium is 64 institutions (& growing) planning to design the EIC project detector based around the BaBar solenoid, ideally (but not necessarily) in IP8**

- **By managing cost, risk, and schedule, ECCE will be ready for physics by EIC CD4a, at the start of machine operation**

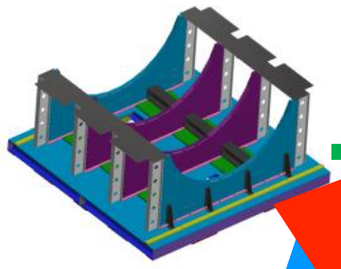
- **Physics program spans the entirety of that outlined in the NAS report and Yellow Report/White Paper, and beyond**

- **Detector design process has begun, in tandem with a wide range of full physics simulations**

- **BNL staff already plays important roles, but please contact me (ECCE BNL IB rep.) if you wish to join ECCE to help!**
  - Please attend ECCE kickoff meeting next Weds., May 5, 2pm

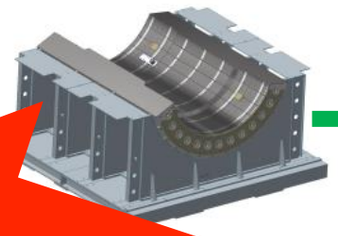
sPHENIX Construction Sequence

(1) Cradle Base, AH



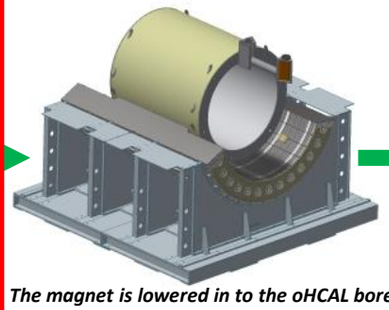
The base will be built on top of the

(2) oHCAL Sector 1-13, AH



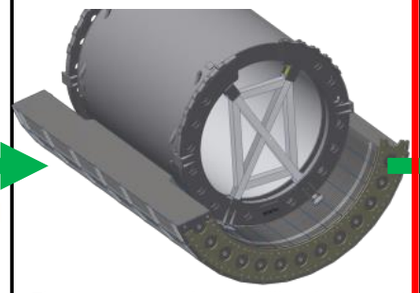
attached

(3) Magnet mount, AH



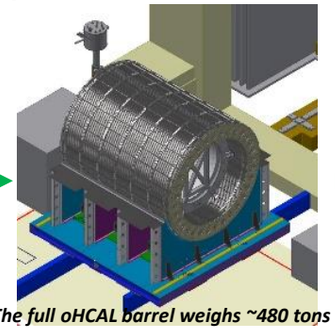
The magnet is lowered in to the oHCAL bore

(4) Inner Rings, AH



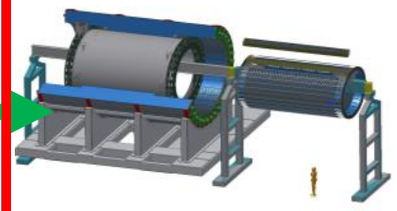
The rings also work to stabilize the magnet

(5) oHCAL Sector 14-32, AH



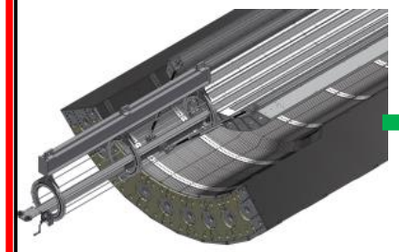
The full oHCAL barrel weighs ~480 tons

(6) Inner HCAL structure



The iHCAL barrel slides in from the North

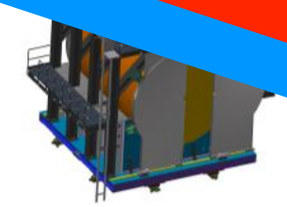
(7) EMCAL



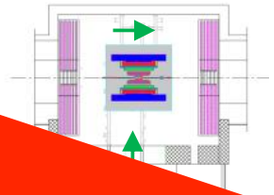
There are 64 EMCAL sectors each installed one at a time with a special tool

Work on sPHENIX will stop for the time needed to remove the shield wall

(9) Carriage, platforms, AH

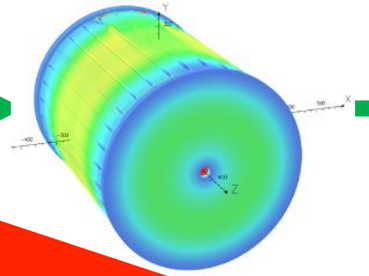


(10) Move sPHENIX to IR



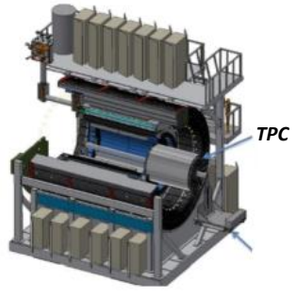
There is a 5-foo

(11) Connect, Map Magnet



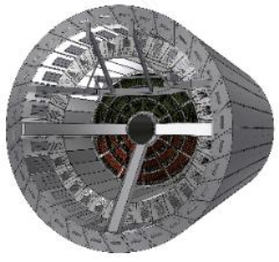
IX OPERA EM FEA

(12) TPC, IR

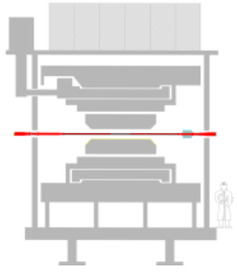


TPC slides in the EMCAL bore from North

(13) INTT Supports, IR

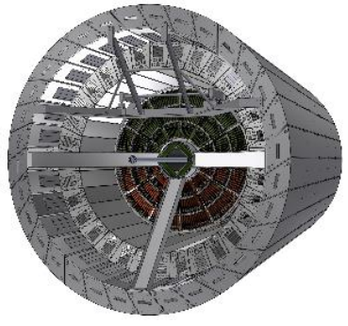


(14) Beam Pipe Install. IR



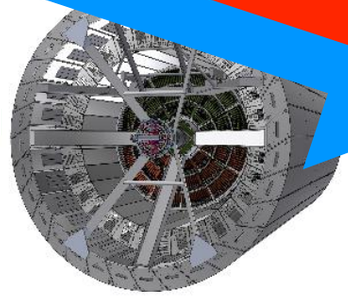
Beam pipe is supported temporarily

(15) INTT Device, IR

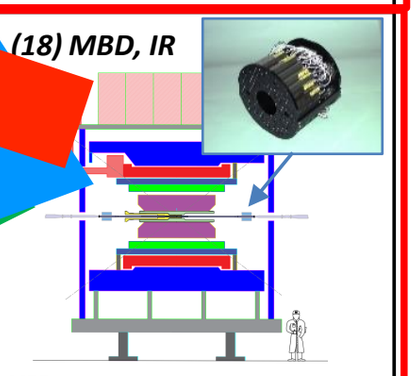


(16) MVTX and Supports, IR

MVTX has a 2mm clearance to the beam pipe



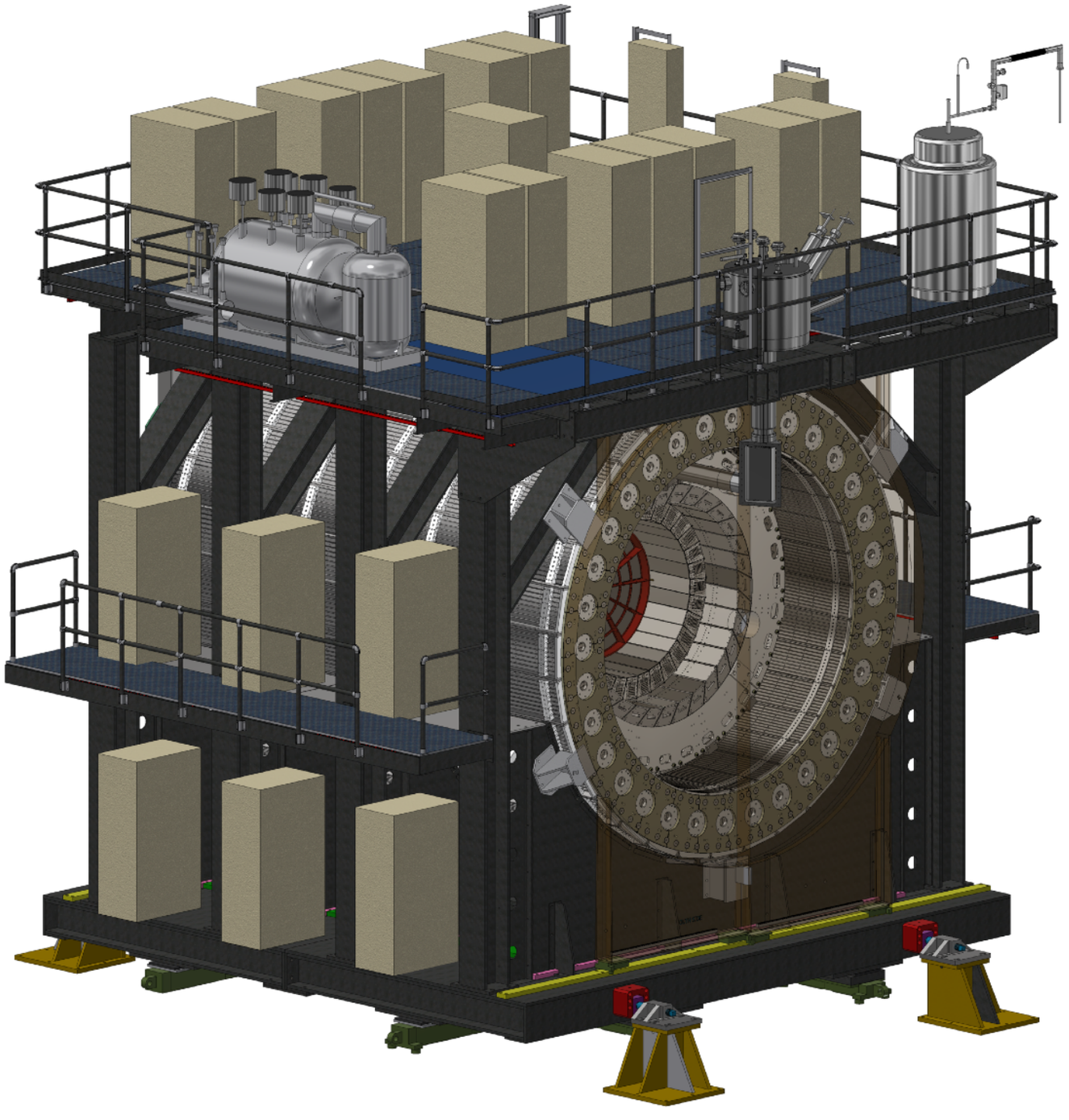
(18) MBD, IR

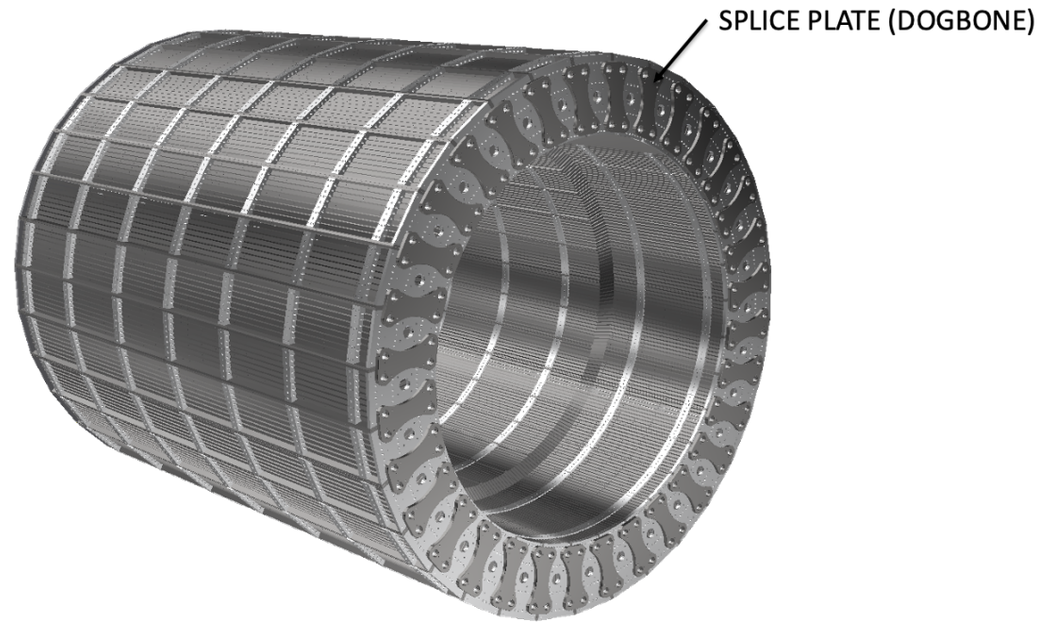


+MBD supports

If we know how it is put together, we know how to take it apart and move it

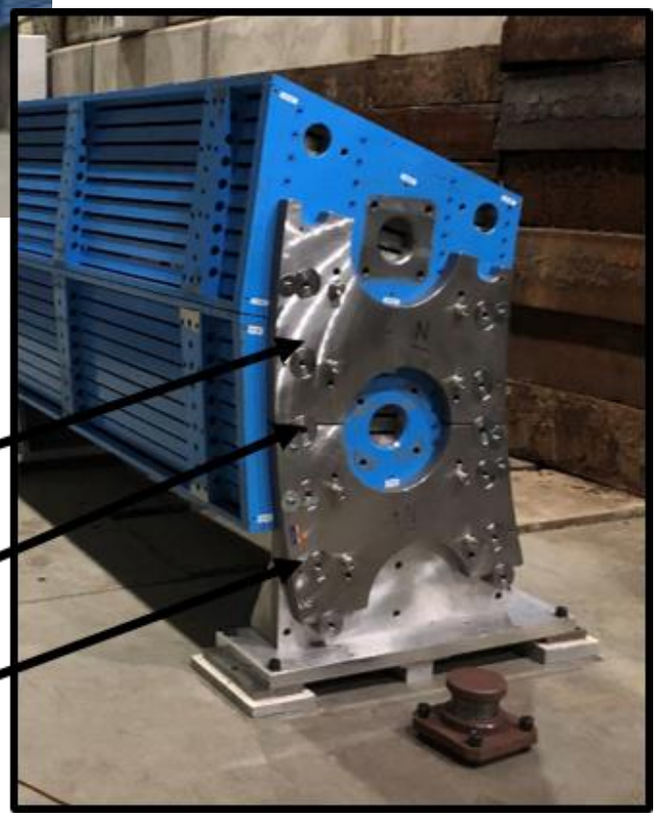
Structural studies for sPHENIX “dogbones”

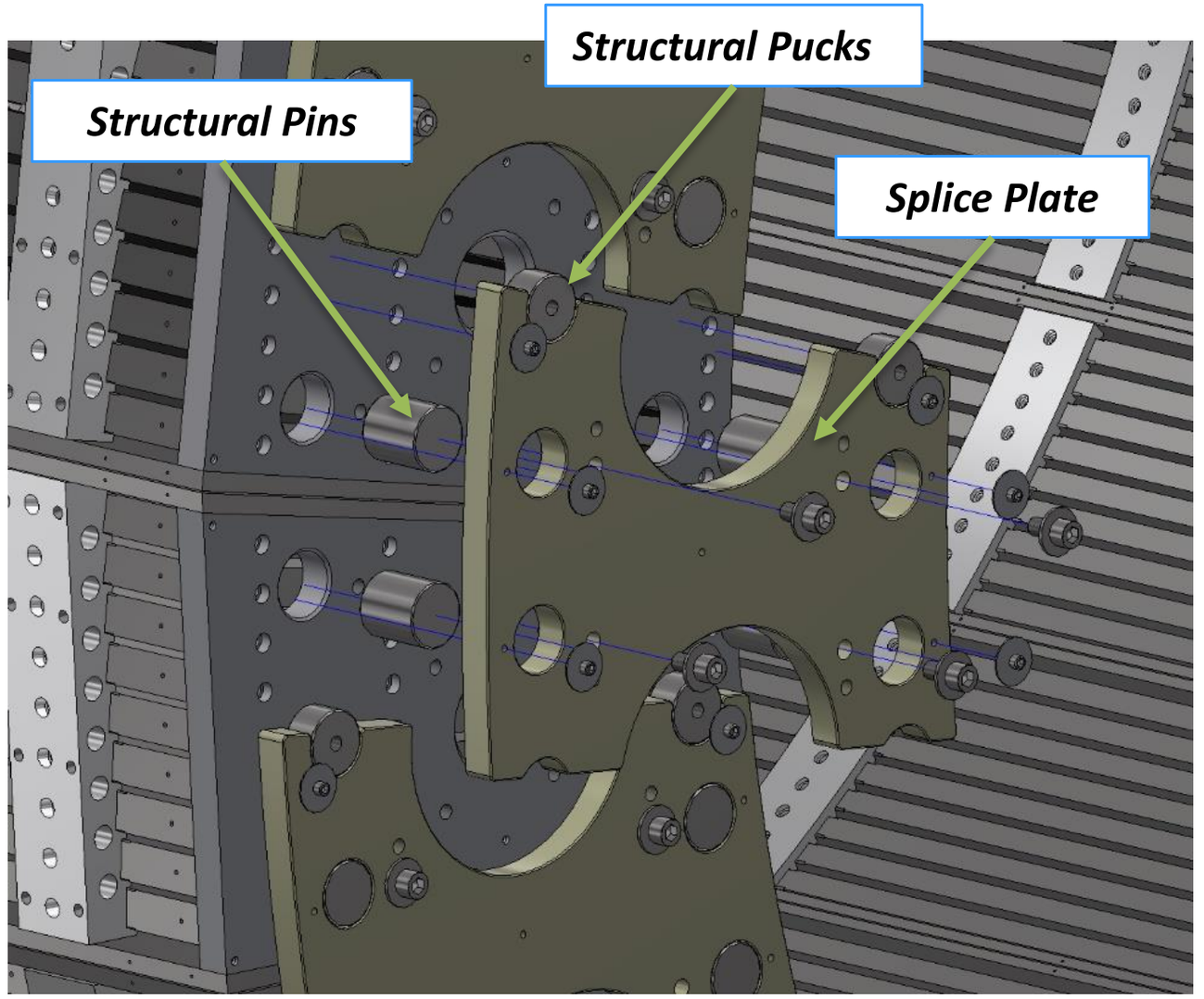




Structural studies for sPHENIX “dogbones”

oHCAL sectors staged for installation of oHCAL tiles and wiring on the oHCAL factory floor

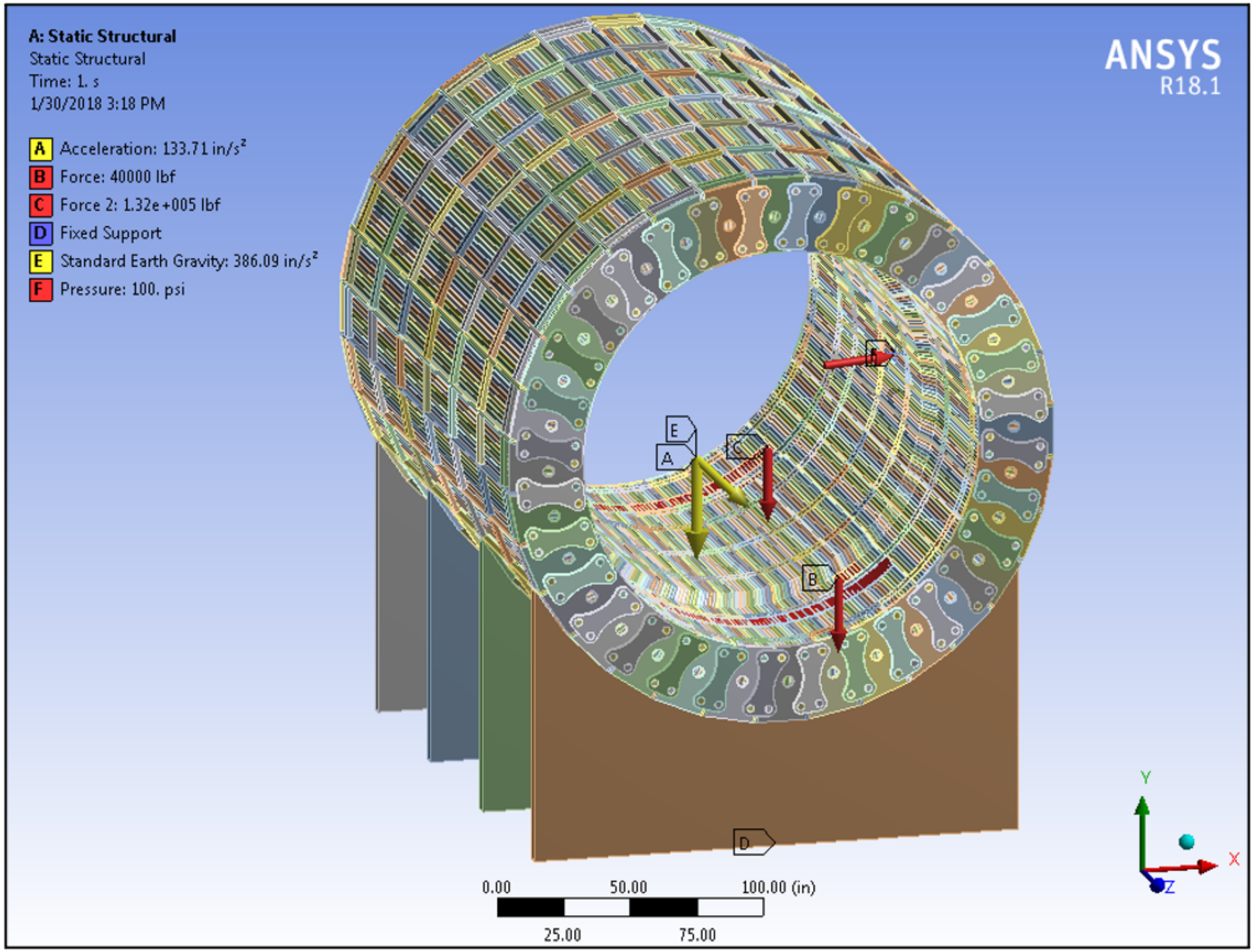




The splice plates, pucks and pins are fabricated from high strength steel (AISI 4140 HT) to ensure there is a high safety factor for the oHCAL arch ring structure

Structural studies for sPHENIX “dogbones”

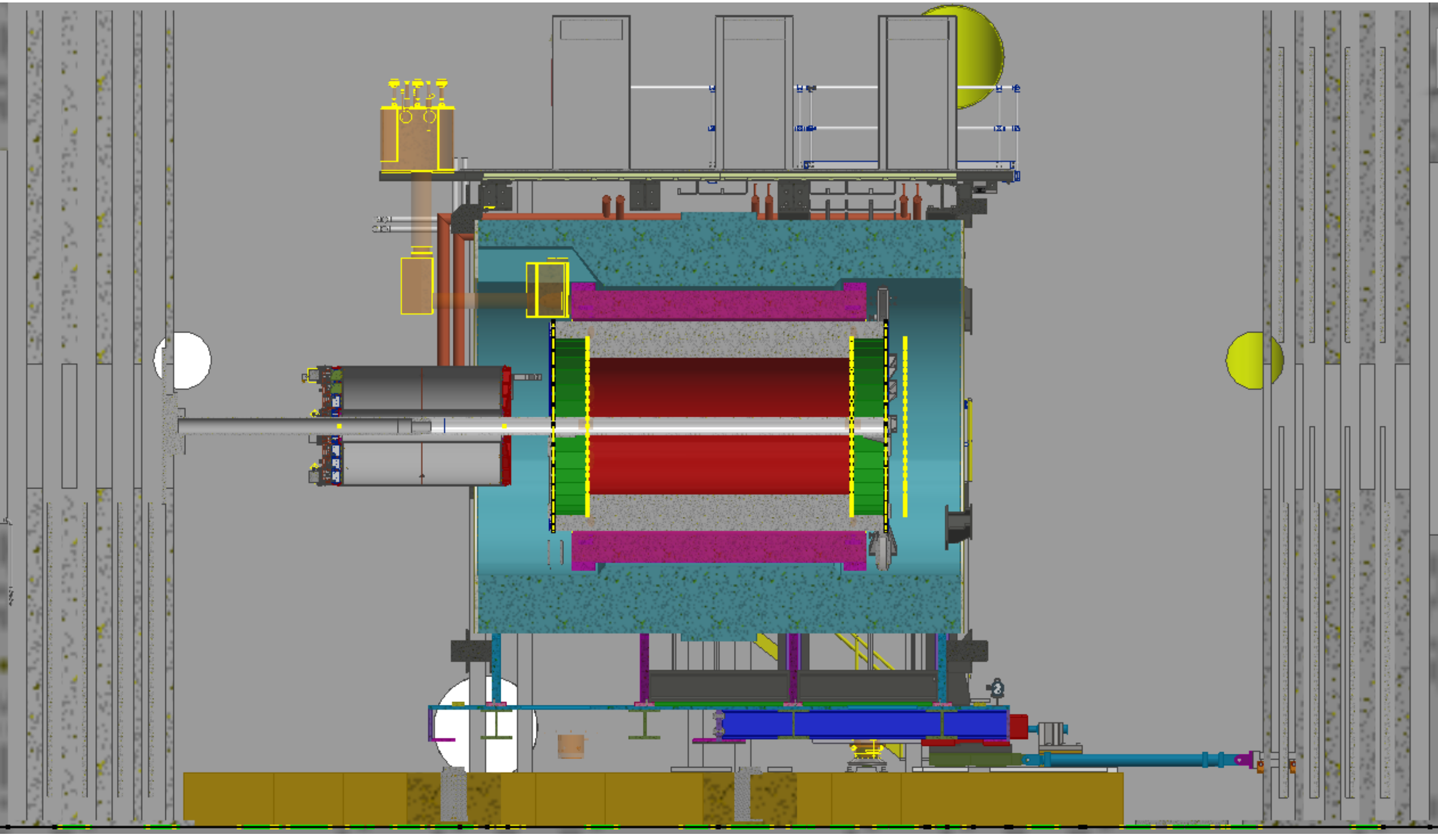
engineering, FEA, reviews, prototyping, material choice, vendor selection, test fitting, and so on



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

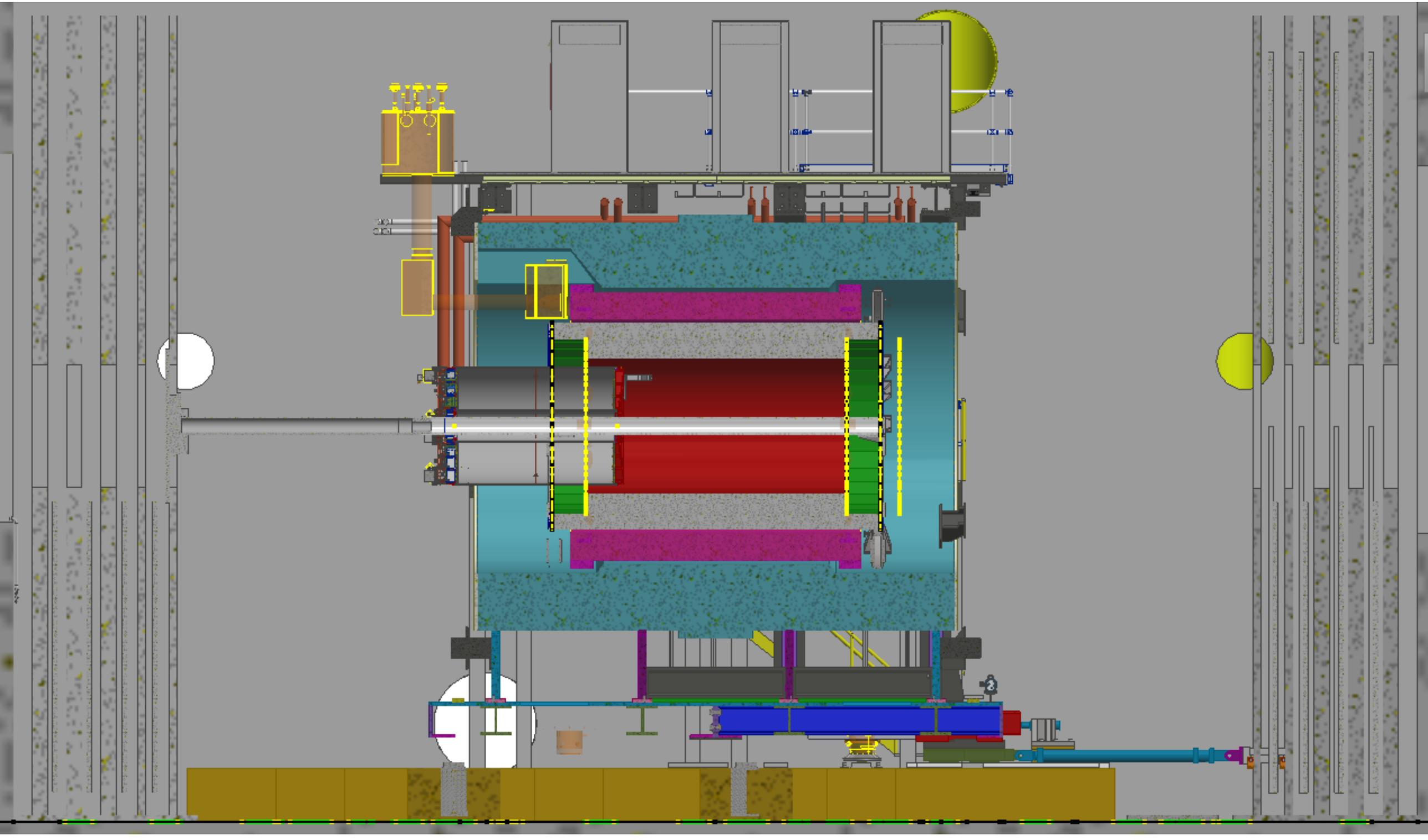
TPC installation in IP8

C. Miraval



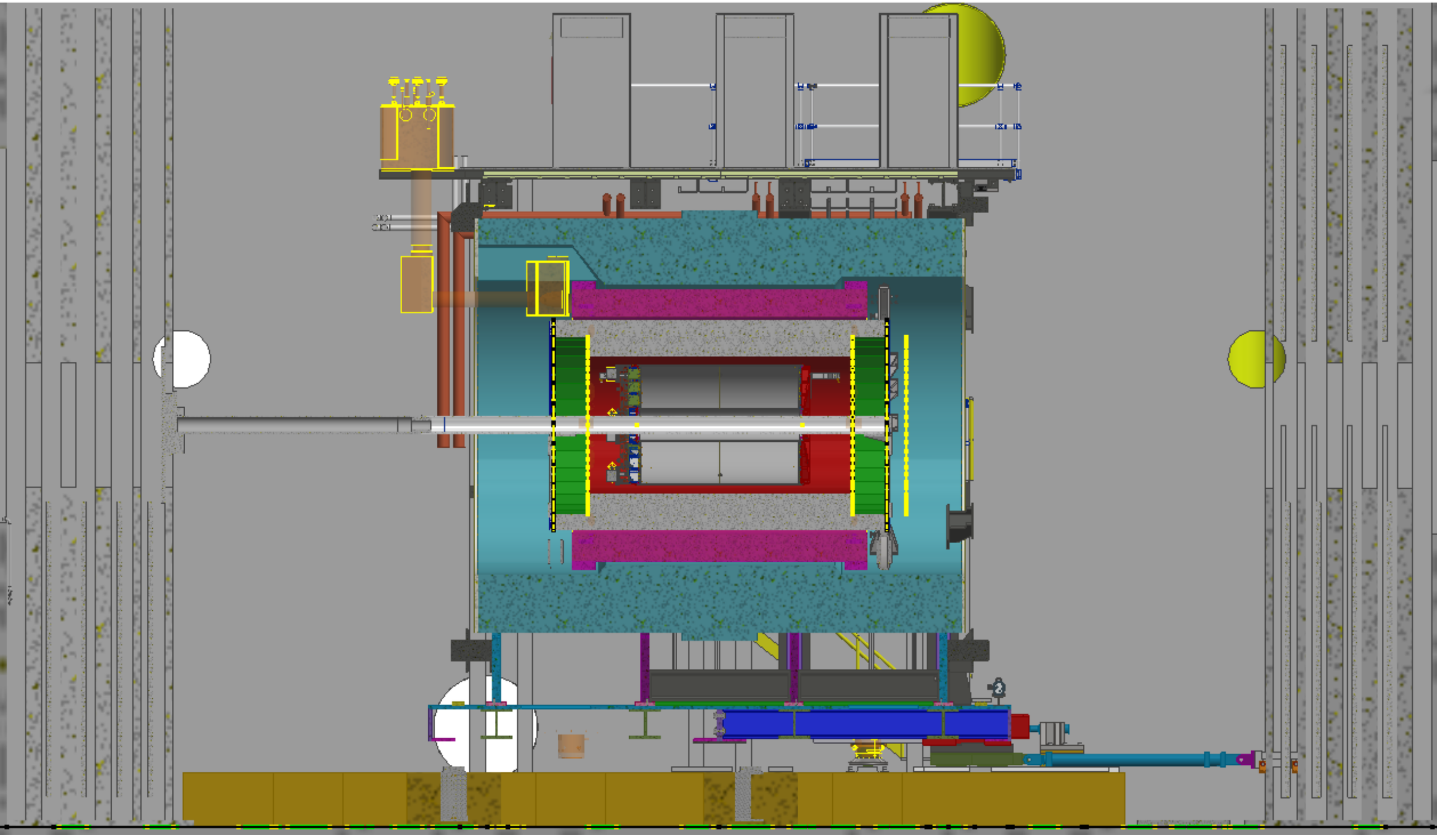
TPC installation in IP8

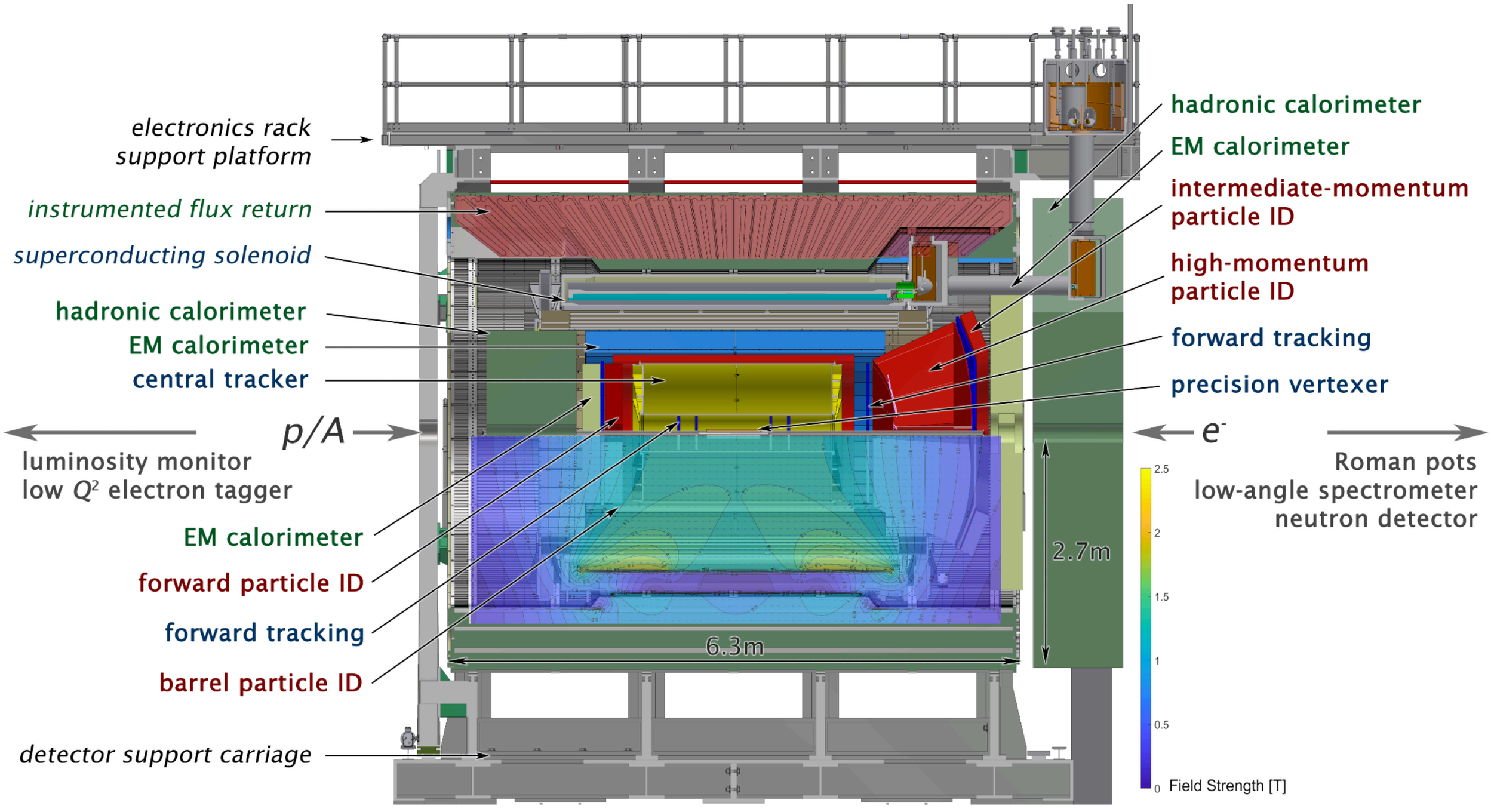
C. Miraval



TPC installation in IP8

C. Miraval




electronics rack
support platform
instrumented flux return
superconducting solenoid
hadronic calorimeter
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
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
2.5
2
1.5
1
0.5
0
Field Strength [T]