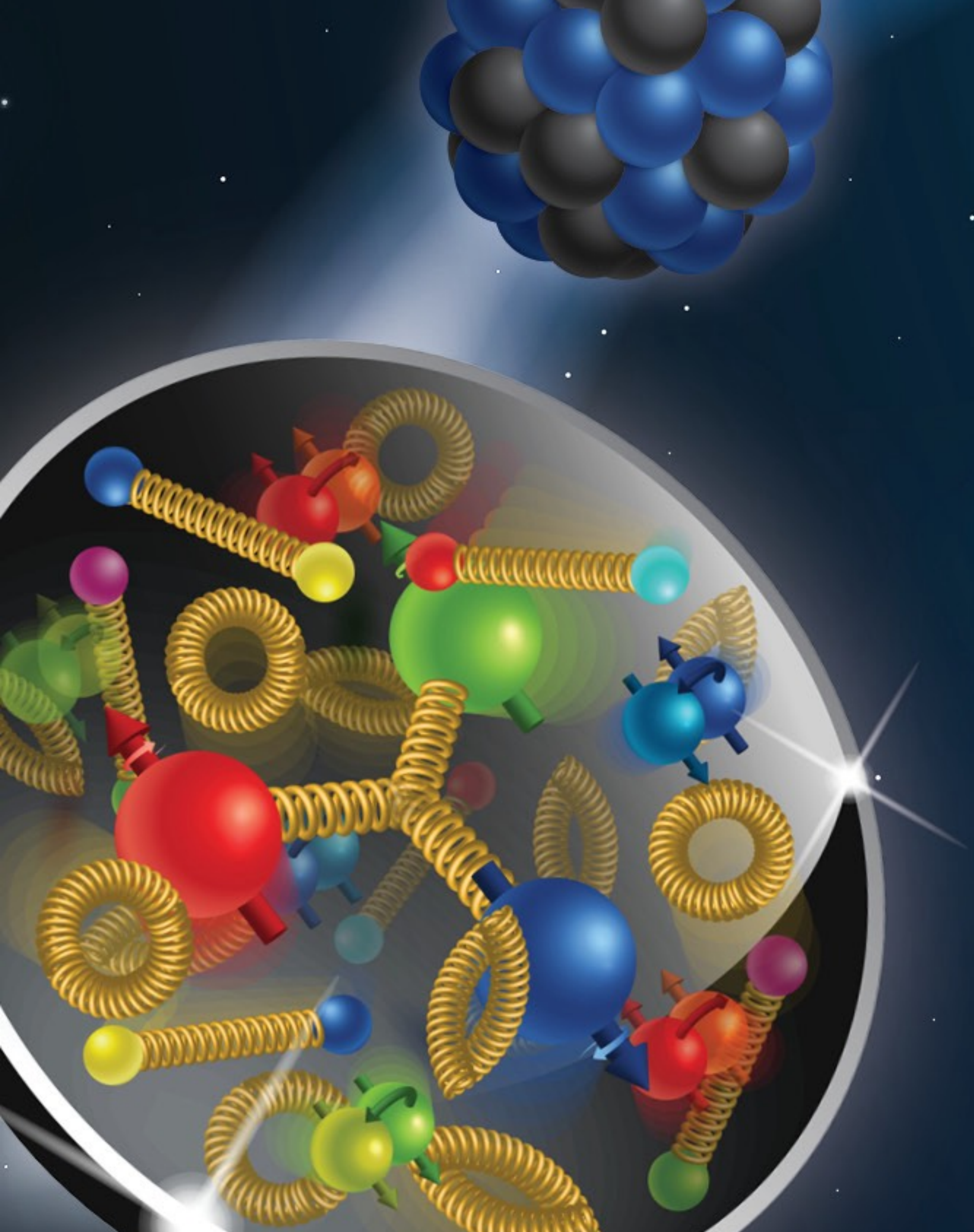


EIC@IP6 Efforts

Thomas Ullrich

April 27, 2021

BNL Seminar

Electron-Ion Collider

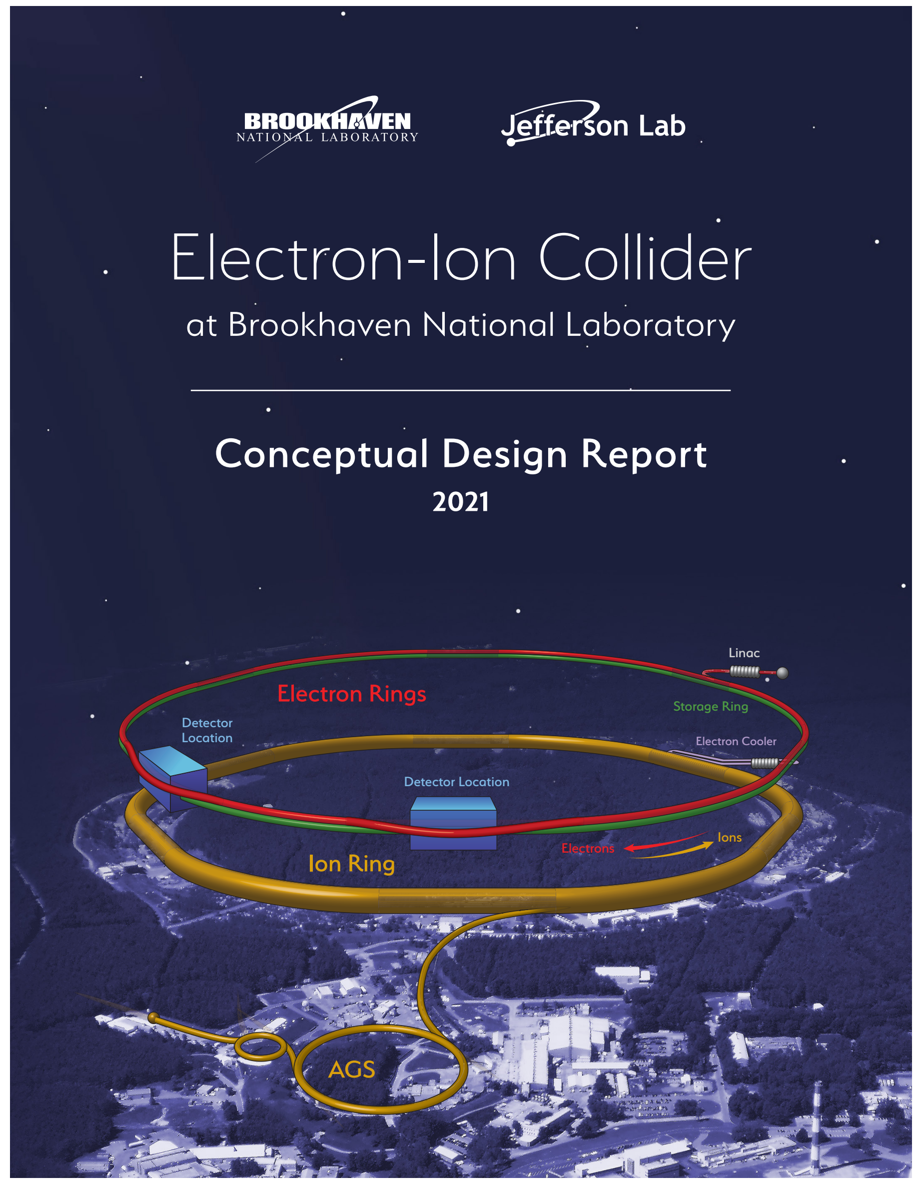
BROOKHAVEN NATIONAL LABORATORY
Jefferson Lab
U.S. DEPARTMENT OF ENERGY | Office of Science

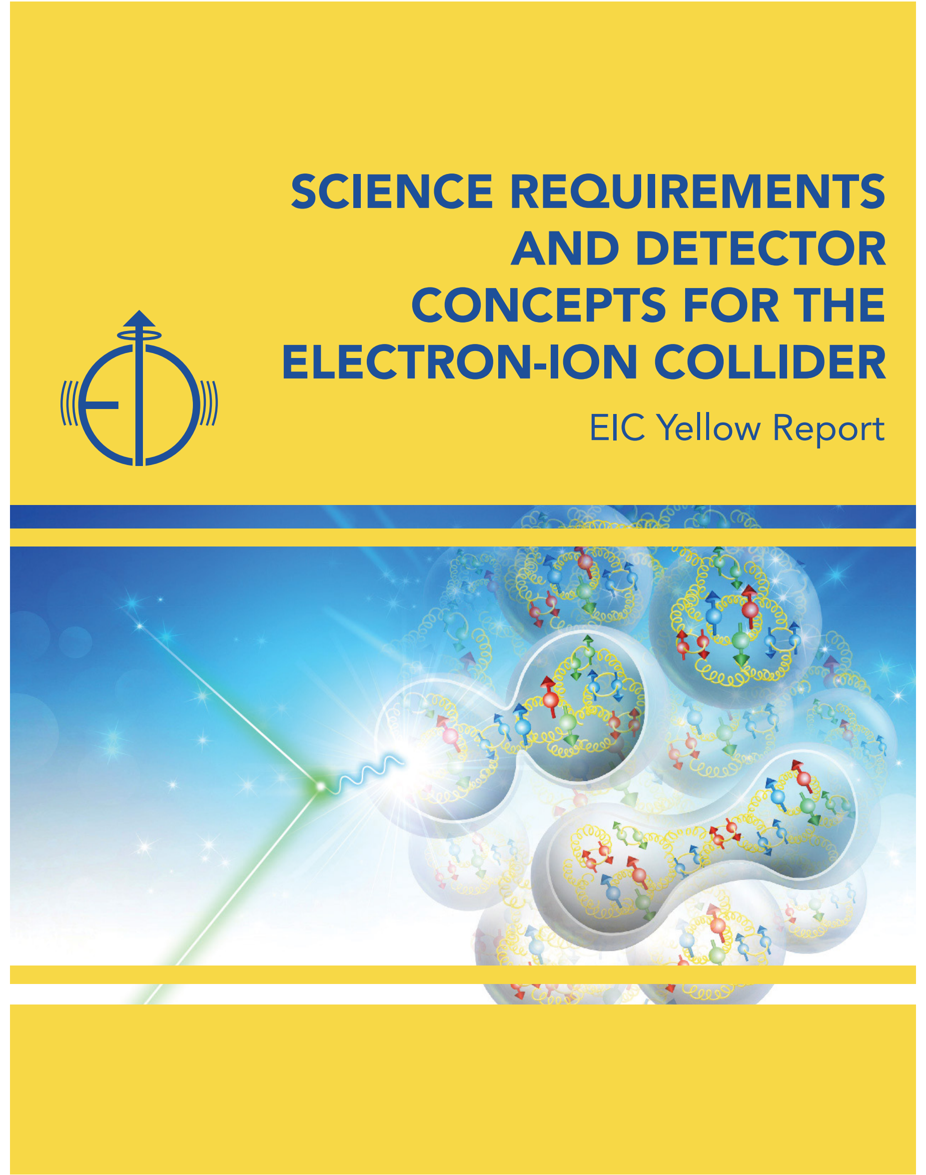
EIC@IP6 Context

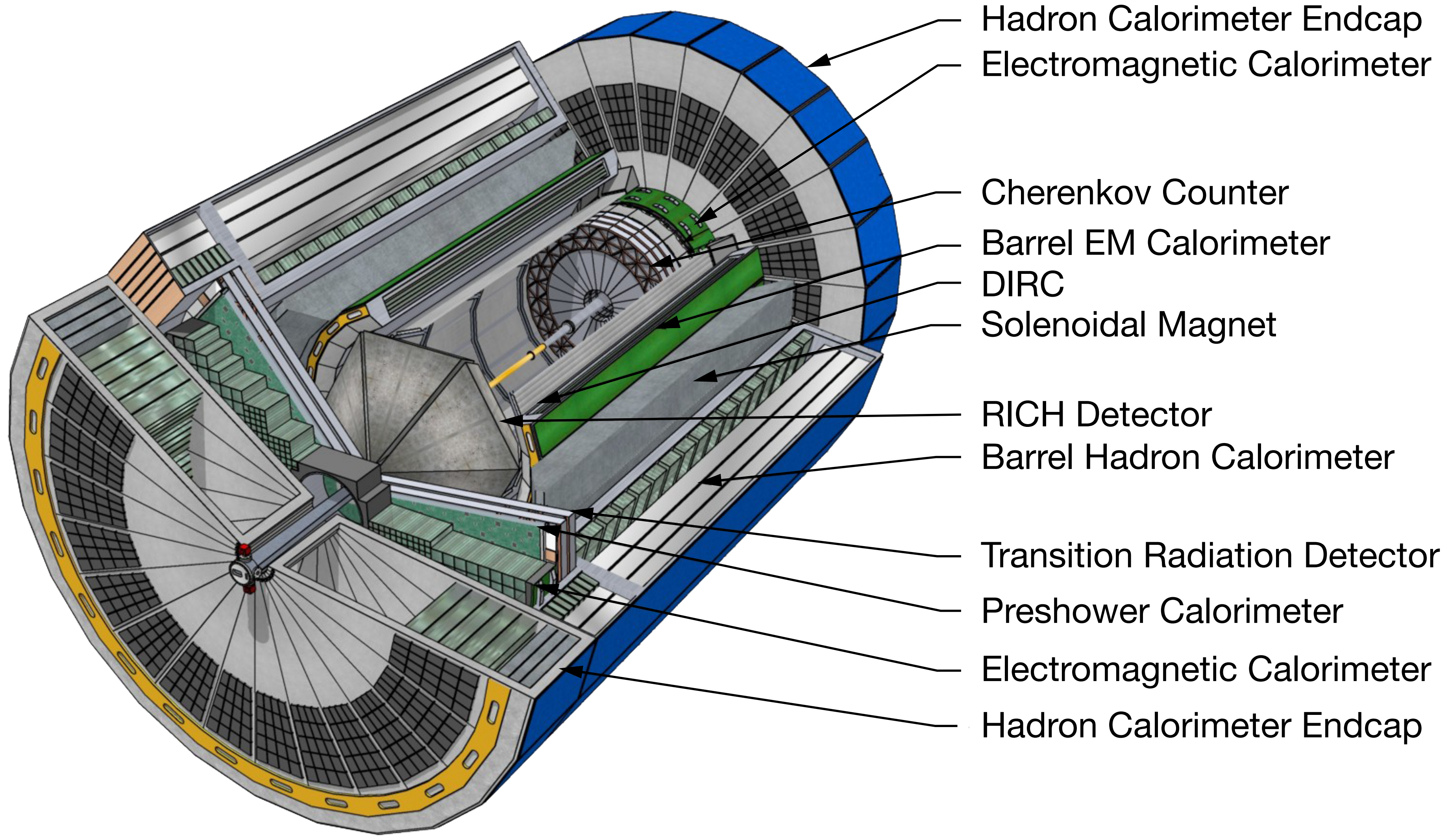
- The “Call for Detector” (`https://www.bnl.gov/eic/CFC.php`) with deadline on December 1st is now in front of the EIC community
  - Clear priority and clear timelines for detector sitting at IP6
- Detector at IP6 is integral part of the EIC approved project
- Availability of a large preparatory work for the Reference Detector within the EIC Yellow Report, now released: `https://arxiv.org/abs/2103.05419`
- The vitality of the overall EIC community and the strong preference for two detectors is demonstrated by the initiatives already started:
  - CORE
  - ECCE
  - EIC@IP6
  - IR2 Initiative

EIC@IP6 Goals

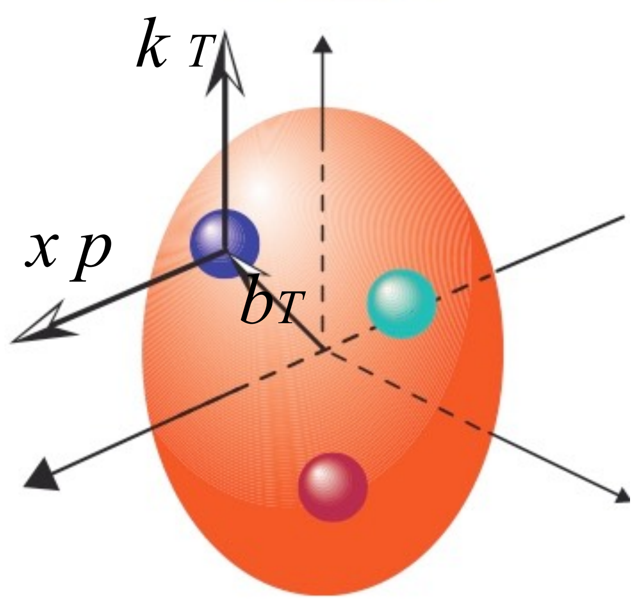
- An initial Reference Detector concept was presented at the recent CD-1 review of the EIC and is included in the EIC CDR (`https://www.bnl.gov/ec/files/EIC_CDR_Final.pdf`). It is similar to the reference detector discussed in the Yellow Report.
- EIC@IP6 aims to plan for a detector inspired by the Yellow Report detector concept based on a new central detector magnet of 3T, evolving into a concrete proposal and collaboration formation for IP6.

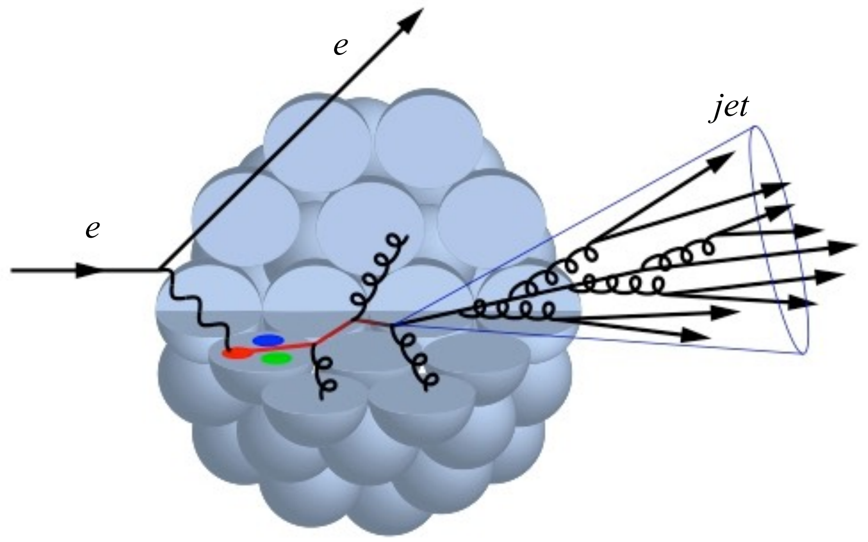


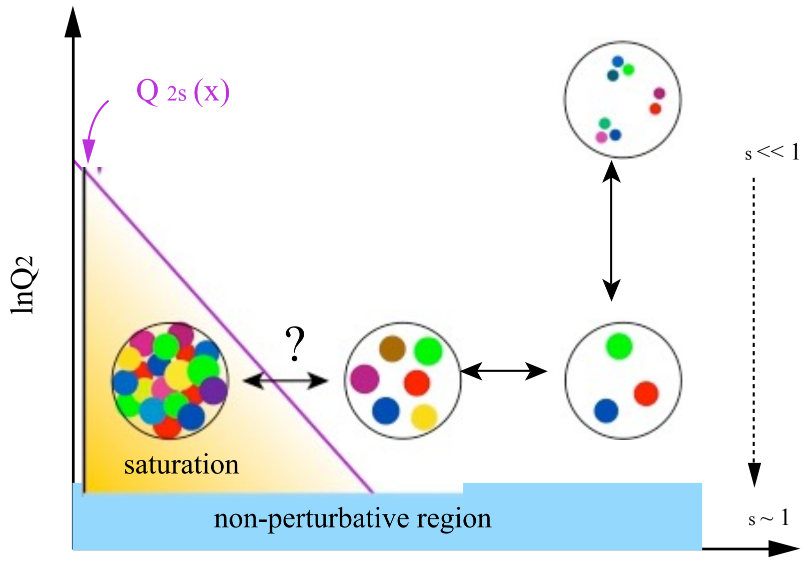




Physics





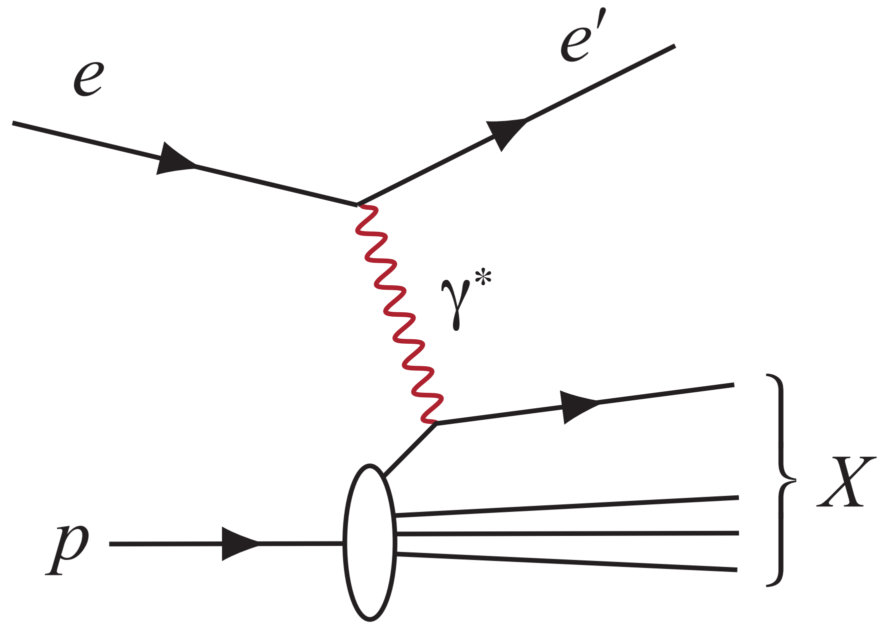


"Detector 1 Collaboration Proposals: Experiments must address the EIC White Paper and NAS Report science case. The collaboration should propose a system that meets the performance requirements described in the EIC CDR and EICUG YR"

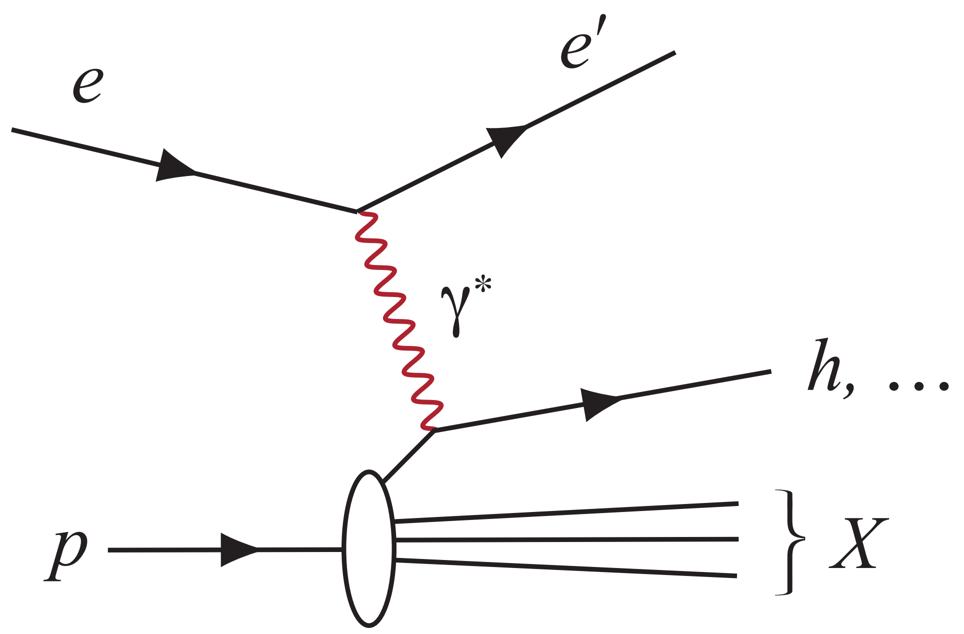
Central Themes:

- Imaging/Structure: How are sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleon?
- Hadronization: How do color-charged quarks and gluons, and colorless jets, interact with a nuclear medium? How do confined hadronic states emerge from these quarks and gluons?
- Saturation: What happens to the exploding gluon density at low-x in hadronic matter? Does it saturate at high energy, giving rise to a gluonic matter with universal properties?

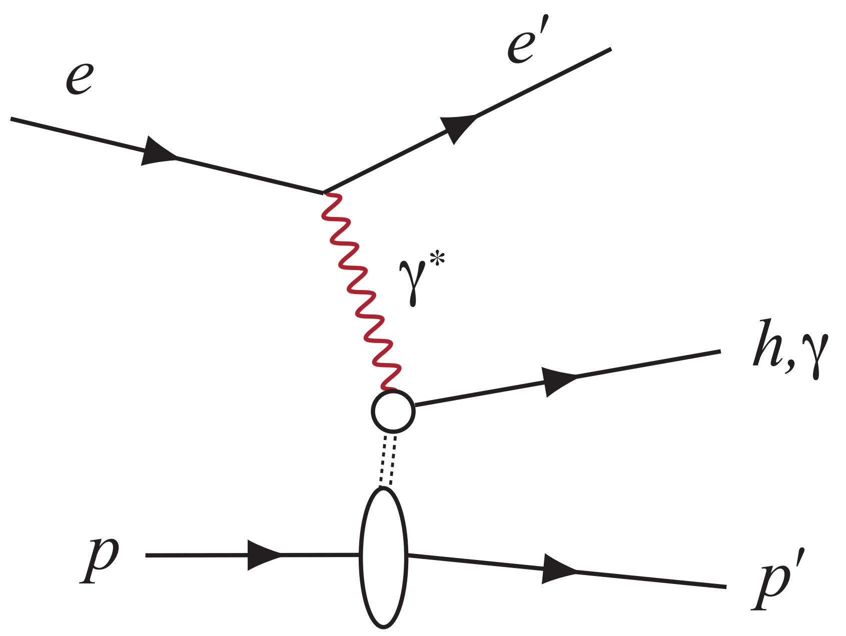
Physics



Inclusive Processes



Semi-Inclusive (SIDIS)



Exclusive Processes

- **Inclusive:** unpolarized $f_i(x,Q^2)$ and helicity $\Delta f_i(x,Q^2)$ distribution function through unpolarized and polarized structure function measurements (F_2, F_L, g_1)
  - Define kinematics (x, y, Q^2) with high precision
    - e-ID is critical
    - also through hadron final state or a combination of both
- **SIDIS:** flavor tagging through hadron identification studying FF (hadronization) and TMD's
  - Azimuthal asymmetry → full azimuthal acceptance
  - Heavy flavor → excellent vertex reconstruction
- **Exclusive:** Imaging & GPDs., …
  - tagging of final state proton using Roman Pots
- **eA:** Saturation, hadronization, medium response …
  - b-dependence → neutron tagging
  - incoherent vs. coherent diffraction → neutron & photon tagging

Requirements (Yellow Report)

arXiv:2103.05419

η	Nomenclature			Tracking				Electrons and Photons			π/K/p PID		HCAL		Muons
				Min p_T	Resolution	Allowed X/X_0	Si-Vertex	Min E	Resolution σ_E/E	PID	p-Range (GeV/c)	Separation	Min E	Resolution σ_E/E	
-6.9 — -5.8	↓ p/A	Auxiliary Detectors	low-Q^2 tagger		$\delta\theta/\theta < 1.5\%$; $10^{-6} < Q^2 < 10^{-2}$ GeV^2										
…															
-4.5 — -4.0			Instrumentation to separate charged particles from γ						$2\%/\sqrt{E}+(1\text{-}3)\%$						
-4.0 — -3.5				100 MeV π 135 MeV K				50 MeV						~$50\%/\sqrt{E}+6\%$	
-3.5 — -3.0		Central Detector	Backwards Detectors		$\sigma_p/p \sim 0.1\%\times p+2.0\%$	~5% or less				π suppression up to 1:10^4	≤ 7 GeV/c	≥ 3σ	~500 MeV	~$45\%/\sqrt{E}+6\%$	Useful for bkg, improve resolution
-3.0 — -2.5							σ_{xy}~30μm/p_T+40μm								
-2.5 — -2.0					$\sigma_p/p \sim 0.05\%\times p+1.0\%$		σ_{xy}~30μm/p_T+20μm								
-2.0 — -1.5									$7\%/\sqrt{E}+(1\text{-}3)\%$						
-1.5 — -1.0															
-1.0 — -0.5			Barrel		$\sigma_p/p \sim 0.05\%\times p+0.5\%$		σ_{xyz} ~ 20 μm, $d_0(z) \sim d_0(r\varphi) \sim 20/p_T$ GeV μm + 5 μm		$(10\text{-}12)\%/\sqrt{E}+(1\text{-}3)\%$		≤ 10 GeV/c			~$85\%/\sqrt{E}+7\%$	
-0.5 — 0.0															
0.0 — 0.5															
0.5 — 1.0											≤ 15 GeV/c				
1.0 — 1.5			Forward Detectors		$\sigma_p/p \sim 0.05\%\times p+1.0\%$		σ_{xy}~30μm/p_T+20μm			3σ e/π	≤ 30 GeV/c			~$35\%/\sqrt{E}$	
1.5 — 2.0											≤ 50 GeV/c				
2.0 — 2.5															
2.5 — 3.0					$\sigma_p/p \sim 0.1\%\times p+2.0\%$		σ_{xy}~30μm/p_T+40μm				≤ 30 GeV/c				
3.0 — 3.5							σ_{xy}~30μm/p_T+60μm				≤ 45 GeV/c				
3.5 — 4.0	↑e	Auxiliary Detectors	Instrumentation to separate charged particles from γ												
4.0 — 4.5															
…															
> 6.2			Proton Spectrometer		$\sigma_{intrinsic}(\|t\|)/\|t\| < 1\%$; Acceptance: $0.2 < p_T < 1.2$ GeV/c										

Requirement matrix: Attempt to summarize all on one slide. Devil is in the detail.

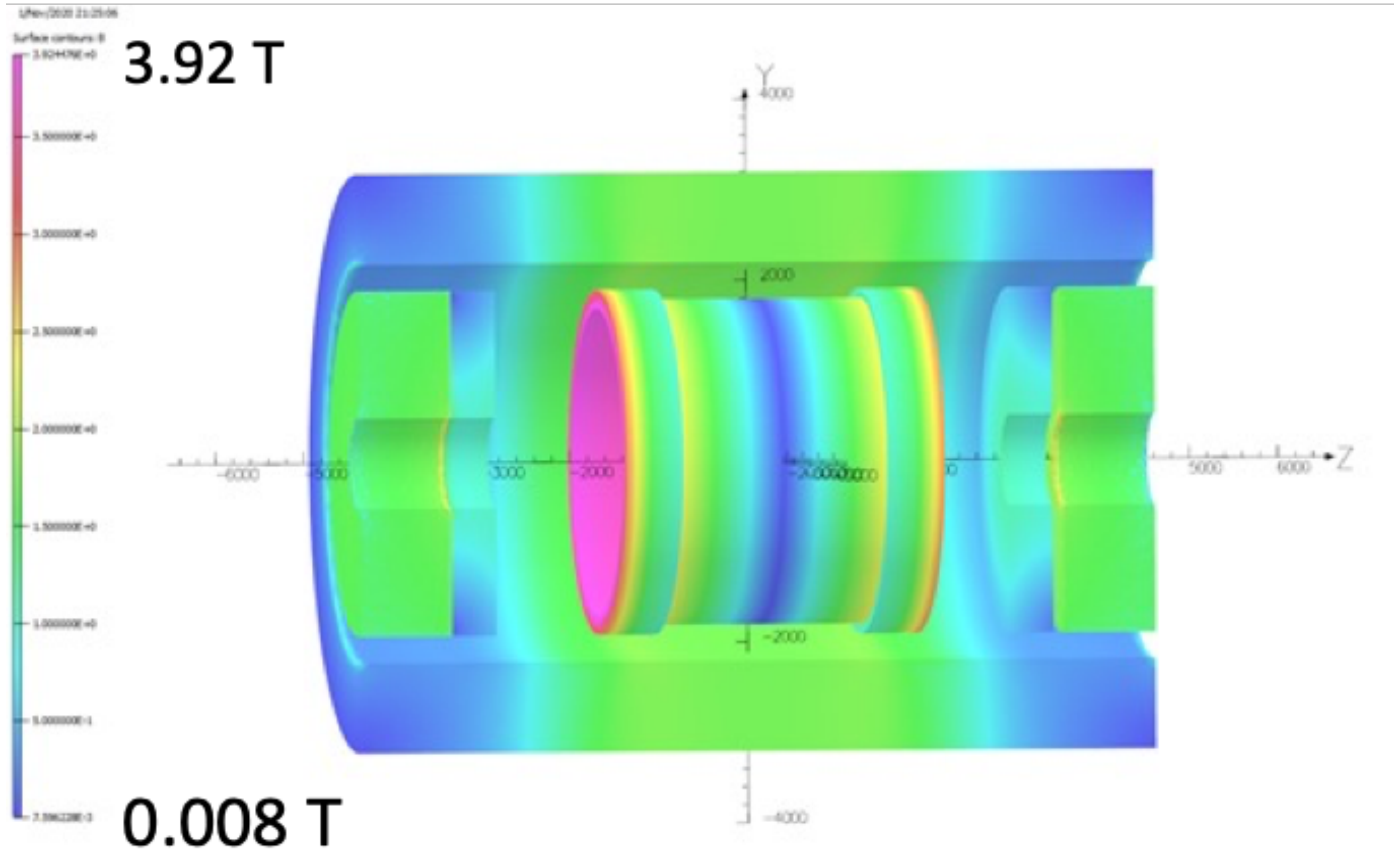
Detector Requirements

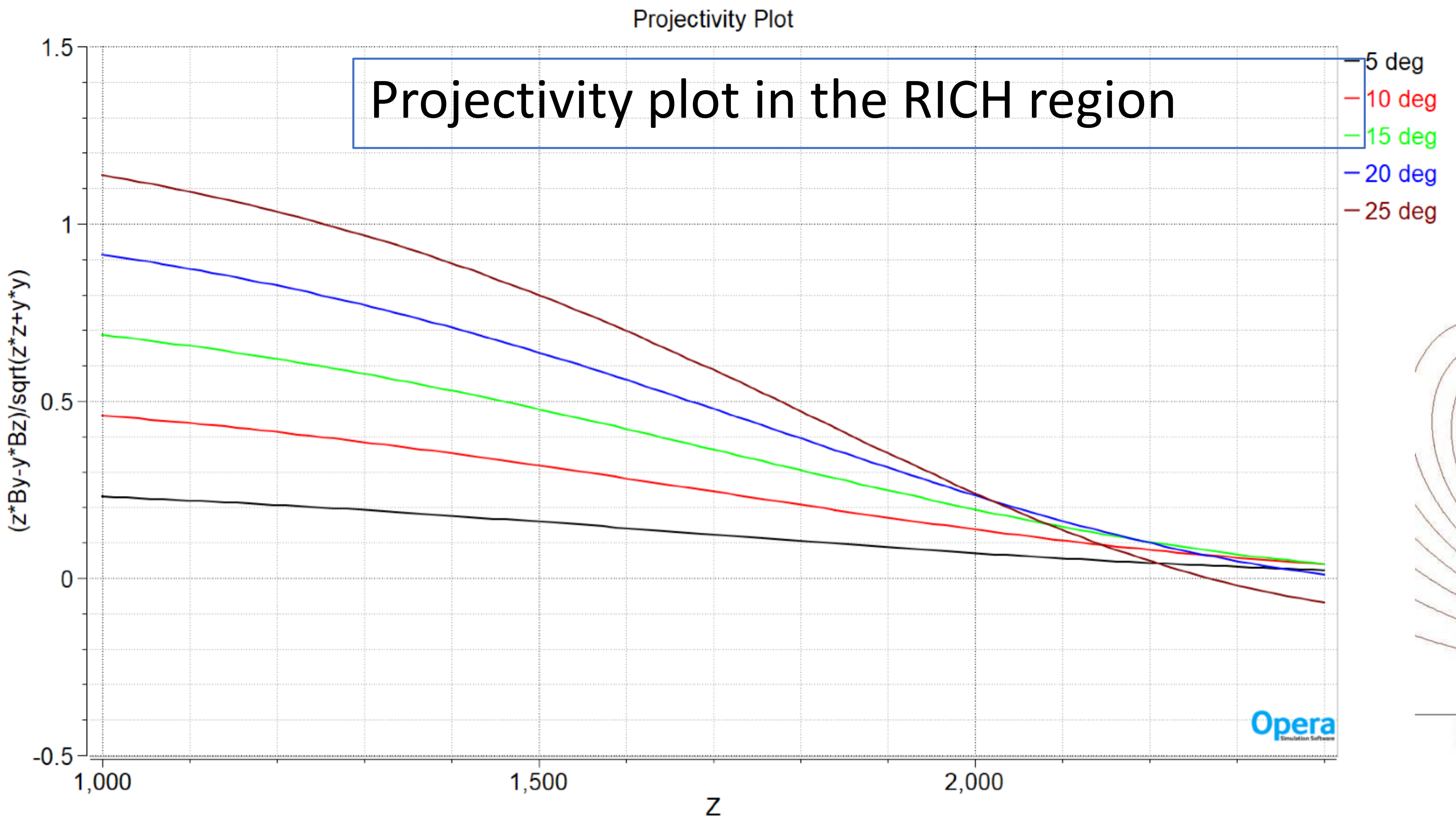
General purpose collider detector

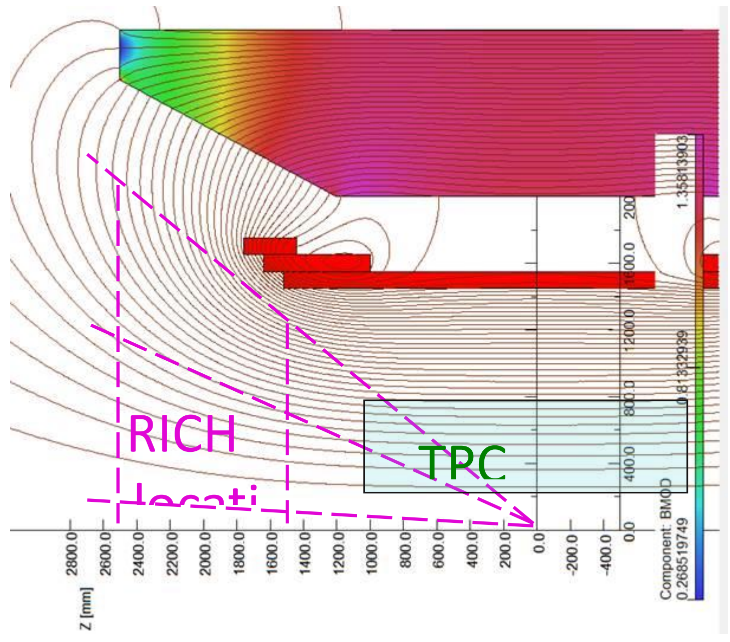
- Large rapidity ($-4 < \eta < 4$) coverage; and far beyond in the far-forward detector region
- High precision low mass tracking
  - $\sigma_{p_T}/p_T\Big|_{\mathrm{meas} \oplus \mathrm{MS}} \propto 1/B$
- Electromagnetic and Hadronic Calorimetry
  - equal coverage of tracking and EM-calorimetry
- High performance PID to separate π, K, p on track level
  - also need good e/p separation

- Large acceptance for diffraction, tagging, neutrons from nuclear breakup: critical for physics program
- Several ancillary detectors integrated in the beam line: low-Q2 tagger, Roman Pots, Zero-Degree Calorimeter, Off-momentum spectrometer
- Control of systematics
  - luminosity monitor, electron & hadron polarimetry
- Fit within tight boundary of IR -4.5 / +5.0 m machine-element-free region for central detector

New 3T Solenoidal Magnet





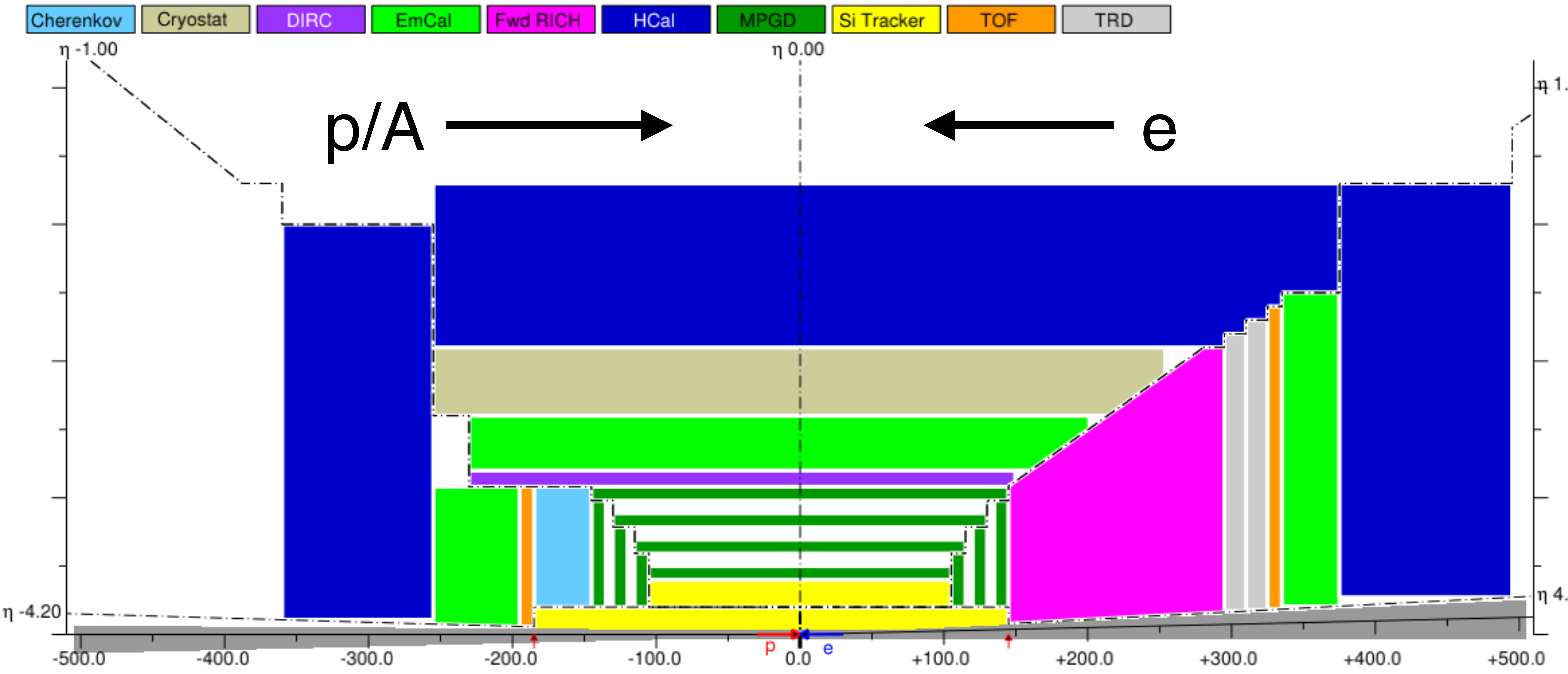


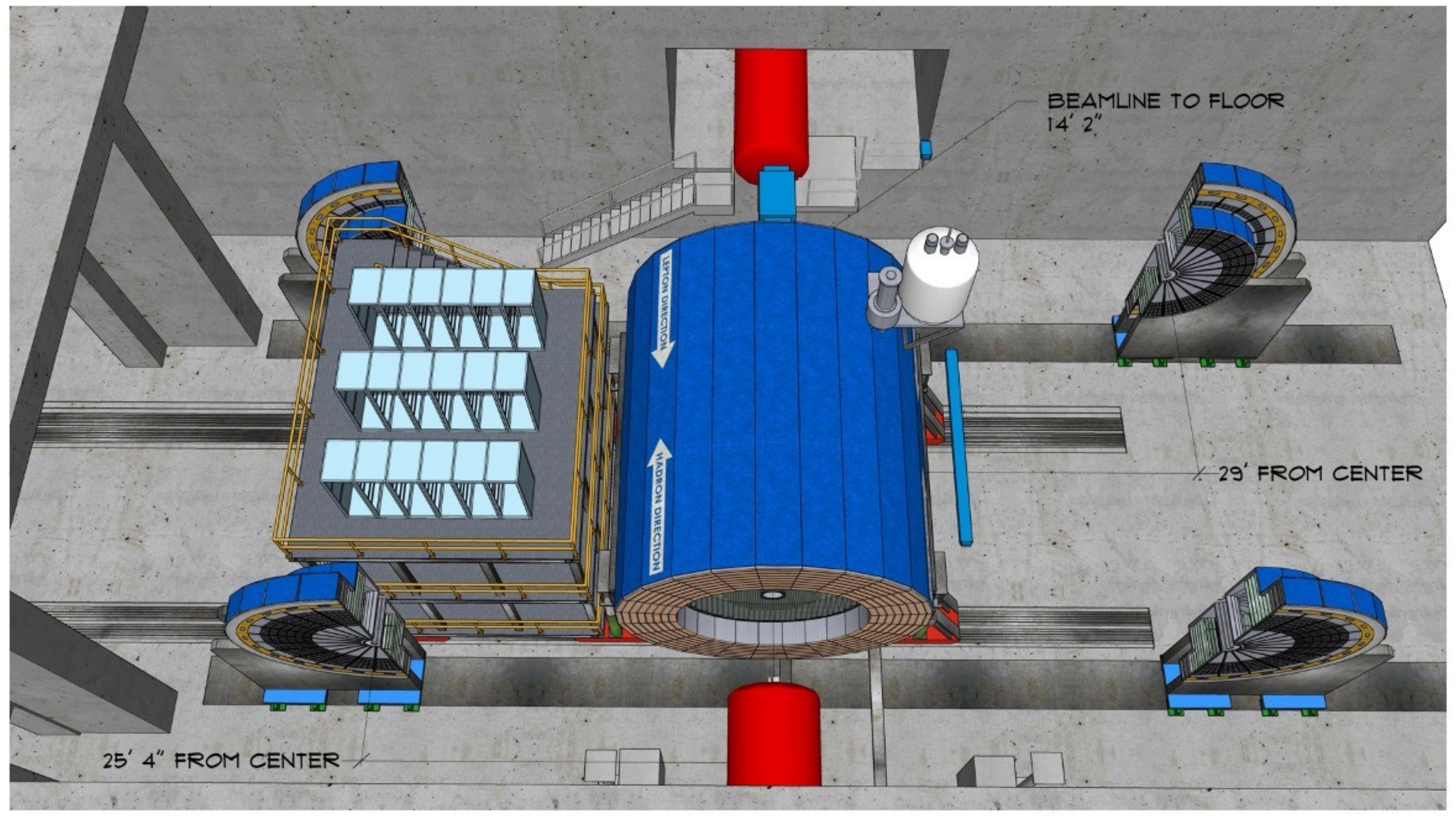
- Specification document is being finalized
  - Account for geometric constraints
  - Observe the projectivity requirement in the forward gaseous RICH volume
  - Optimize for tracking at large $|\eta|$
- A preliminary electric design will be available on a time scale of weeks
- Interface to GEANT is available
- flexible design 0.5 - 3T

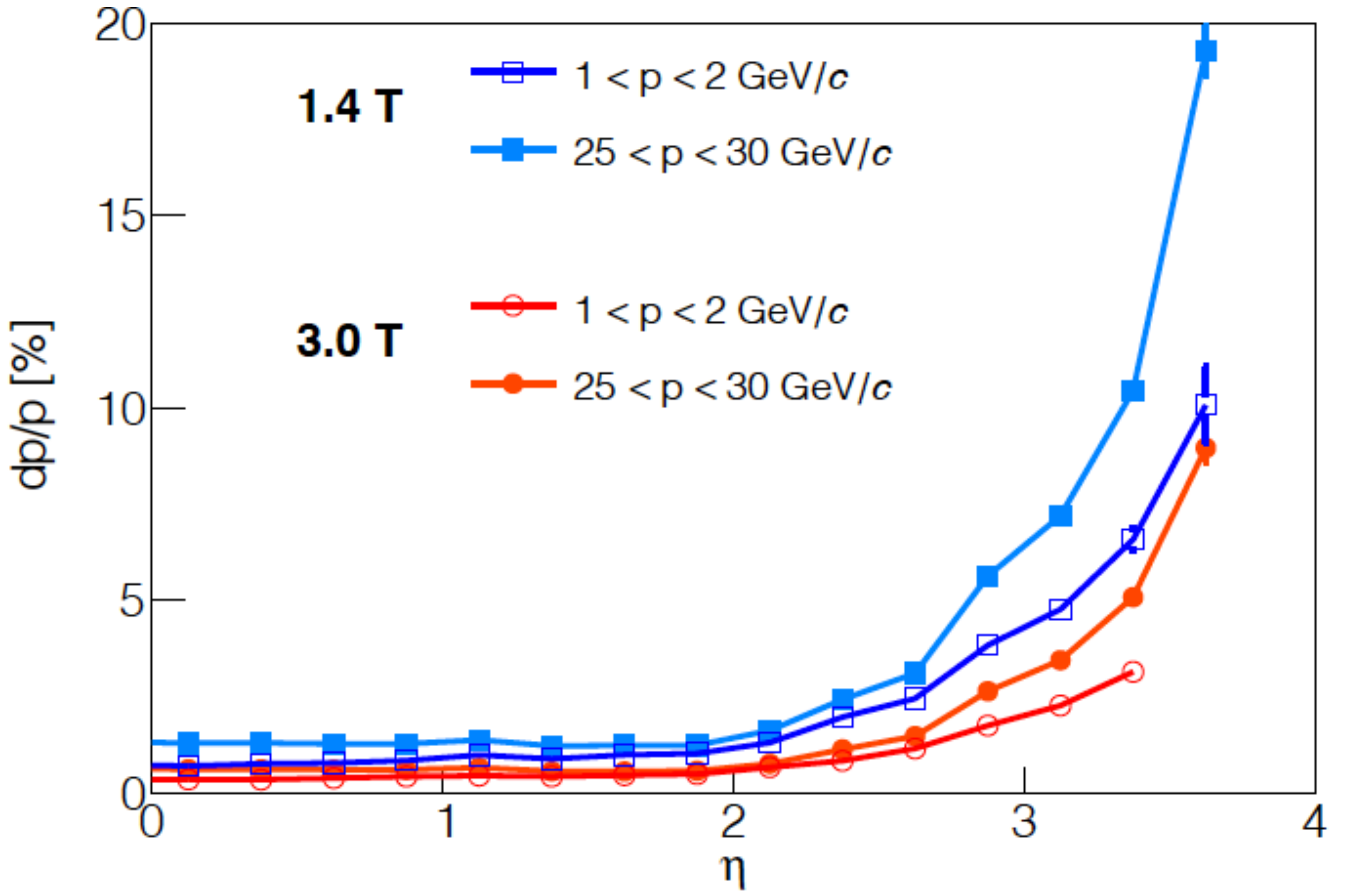
Parameter	New Magnet	BABAR/sPHENIX Magnet
Maximum Central Field (T)	3	1.5
Coil length (mm)	3600	3512
Warm bore diameter (m)	3.2	2.8
Uniformity in tracking region ($z = 0$, $r < 80$ cm) (%)	3	3
Conductor	NbTi in Cu Matrix	Al stabilized NbTi
Operating Temperature (K)	4.5	4.5

Table 11.1: Summary of some of the main requirements of the EIC detector solenoid magnet.

EIC Reference Detector







- Ref. detector is starting point for EIC@IP6 efforts
- Many options on table, many were evaluated in YR
- Main tracker: current favored solution is all-Si tracker (DMAPS) possibly augmented by MPGD layer - low material budget is key
- Barrel PID a challenge - ToF?

EIC@IP6 Pre-Collaboration (born March 12, 2021)

- Web site: `https://sites.temple.edu/eicatip6/` (temporary)
- Institutional Board in place
  - 94 confirmed their participation already
- Current governance through steering/organization committee
  - Silvia Dalla Torre (Trieste), Abhay Deshpande (SBU), Olga Evdokimov (UIC), Barbara Jacak (UCB), Franck Sabatié (Saclay), Bernd Surrow (Temple), *Alexander Kiselev (BNL), Yulia Furletova (JLAB)*
- Contact to EIC Project Management: Elke Aschenauer
- In place: Mailing lists, Indico, Slack channels, Wiki, …
  - General: eic-ip6-public-l@lists.bnl.gov

N.B. EIC@IP6 is a placeholder. Final name will be picked in competition.

EIC@IP6 Towards Collaboration

The Proposals should include […]:

"A collaboration roster and structure, timescale and cost (including potential sources of funding sources and assumptions), and potential upgrade paths."

- Charter committee in place (14 member, chair Olga Evdokimov (UIC), BNL member is T.U.)
- Membership confirmed by IB
- The goal of the Charter Committee is to develop the draft for the collaboration bylaws/charter
  - Membership, Governance, Boards, Election, Code of Conduct, …
- Goal is to have it finalized and approved by IB within 2 months

EIC@IP6 Towards Proposal

- Two biweekly EIC@IP6 wide meetings (US/Europe time one week, Asian time the other week)
- Proposal Drafting Group (tbd)
- Working Groups for Detector, Software and Physics Validation
  - at least 2 conveners each (announced this week and to be confirmed by IB)
  - regular meeting
  - usual collaborative tools
  - expected to provide input requested by the proposal drafting committee

- Collaboration/Proposal preparation timeline:

April	June	August	October	December
Pre-collaboration				**Proposal**
IB, Charter Committee Working groups	Charter adoption, IB chair, Spokespeople elections	Proposal draft is assembled by Proposal Committee	Preview and validation	
	formal **Collaboration**			

EIC@IP6 Working Groups

Detector

- Tracking/Vertex
- Calorimeter
- PID
- Far-forward/backward
- Magnet
- DAQ

Software & Computing

Event generator, fast simulations, full simulations (Geant4), batch processing, storage organization

Physics/Validation

- Inclusive
  - check x, y, Q2 resolutions
  - electron reconstruction/identification methods
  - check acceptance
- Semi-inclusive
  - Check tracking, PID
- Jets – Heavy Flavor
  - Check VTX
  - Check jet rec. and performance
- Exclusive & Diffraction/Tagging
  - Check Far –Forward performance
- EW/BSM (possibly merge into jets)
  - Check CC (hermicity)

EIC@IP6 at BNL

- 22 member of NP have so far joined EIC@IP6
  - All committed to spend fraction of their time on proposal effort
- Several are nominated for convenership
- IB representative: TU

- Hardware contributions are not decided yet.
- Possible projects to contribute to or take leadership of are:
  - DAQ + RO Electronics
  - Auxiliary detectors:
    - Roman Pots, B0, off-momentum
    - Luminosty monitor & Q2 tagger
  - Hadron polarimetry (must-do)
  - Barrel PID/ToF
    - LYSO+SiPM/LGAD/LAPPD

EIC@IP6 Software

ANL, INFN, …

- Requires consistent geometry across all the simulation efforts, including material distributions
- Long term
  - Green field design leveraging modern, modular CERN-supported software components
- Immediate concern: proposal
  - No disruption of WG simulation process after the DWGs and PGWs are formed
  - Provide computing resources and active support for fun4all/EICROOT and other legacy tools throughout the coming year. Successful detector proposal is main priority!
  - In parallel: Implement subsystems in new software toolkit to prepare for full simulation & reconstruction of a realistic candidate detector by early June.
  - Leveraging existing in house software stacks (Argonne and JLAB)
  - Gradual transition from old to new software tools
  - Computing resources available at large range of facilities (BNL, JLab, ANL, OSG)

Take Away Message

- EIC@IP6 is 6 weeks old and setup/organization is progressing well
- In place
  - Temporary steering committee
  - IB board
  - Charter Committee
  - WG formation and convenership assignment this week
  - Software group in place
- Strong contribution from BNL
  - dedicated manpower to work on proposal
  - hardware contributions still under discussion

If you are interested in joining/contributing please drop me an email

Backup Slides

EIC@IP6 Institutions (94 and growing)

AGH University of Science and Technology, Krakow
Akal University
ANL
Banaras Hindu University
BNL
Brunel University
CCNU Wuhan
Central University of Karnataka
Central University of Tamil Nadu
CIAE
CUA
A. Alikhanyan National Science Laboratory (Yerevan Physics Institute)
Czech Technical University in Prague
DA V College, Chandigrah
Daresbury Laboratory
Duke University
FIT
Florida International University
Florida State University
Fudan University
Goa University
GSI
GSU
IFJ PAN
IJCLab, Université Paris-Saclay, CNRS-IN2P3, Orsay
INFN Bari
INFN Bologna
INFN Catania
INFN Cosenza
INFN Ferrara
INFN Genova
INFN Laboratori Nazionali di Frascati
INFN Laboratori Nazionali del Sud
INFN Padova
INFN Roma1
INFN Roma2
INFN Torino
INFN Trieste
Indian Institute of Science Research and Education, Berhampur
Indian Institute of Science Research and Education, Tirupati
Indian Institute of Technology Bombay
Indian Institute of Technology Delhi
Indian Institute of Technology Indore
Indian Institute of Technology Madras
Indian Institute of Technology Patna
Institute of Modern Physics, Chinese Academy of Sciences
Institute of Physics
IPHC, Université de Strasbourg, CNRS-IN2P3, Strasbourg
JLab
LANL
LBNL
Lehigh University
LLNL
LLR, CNRS-IN2P3, Ecole Polytechnique, Institut Polytechnique de Paris, Paris
Malaviya National Institute of Technology Jaipur
Mount Allison University
National Cheng Kung University
National Institute of Science Education and Research
University of North Georgia
Nuclear Physics Institute of the Czech Academy of Sciences
ORNL
Panjab University
Polytechnical Univ. Bucharest
RAL CMOS Sensor Design Group (CSDG)
RAL Particle Physics Division (PPD)
Ramakrishna Mission Residential College, Kolkata
Rice University
Irfu, CEA-Saclay, Université Paris-Saclay, Saclay
South China Normal University (SCNU)
Shandong University
SMU
Stony Book University
Subatech, IMT Atlantique, Université de Nantes, CNRS-IN2P3, Nantes
Temple University
Tsinghua University
UC Berkeley
UC Davis
UCLA
UC Riverside
University of Illinois at Chicago
University of Birmingham
University of Massachusetts Amherst
University of Michigan
University of Tennessee
University of Virginia
University of Glasgow
University of Jammu
University of Kansas
University of Kentucky
University of Lancaster
University of Liverpool
University of York
University of Science and Technology of China
UT Austin