ATHENA

A Totally Hermetic Electron–Nucleus Apparatus

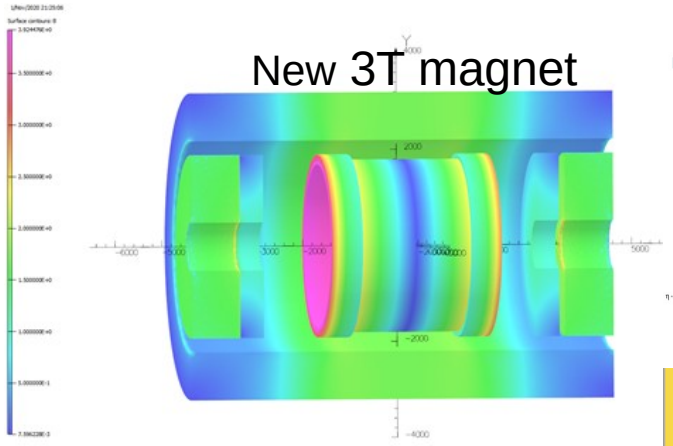
F.Bossù (CEA Saclay)
on behalf of the ATHENA collaboration

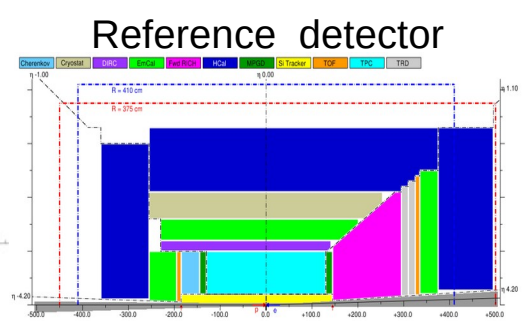
PSQ@EIC, 07/22/2021

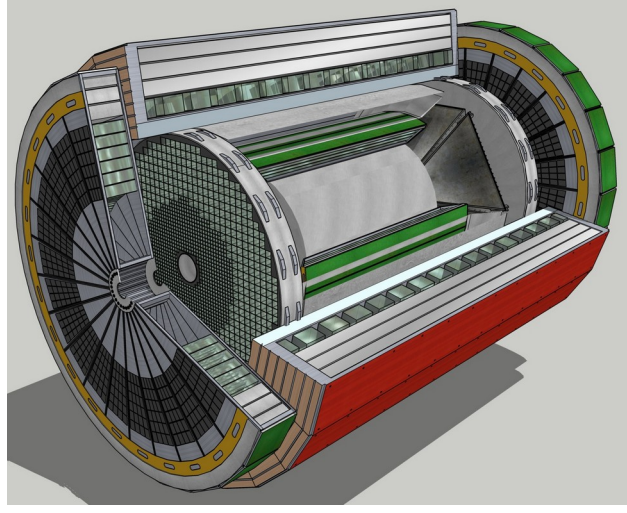
What is ATHENA?

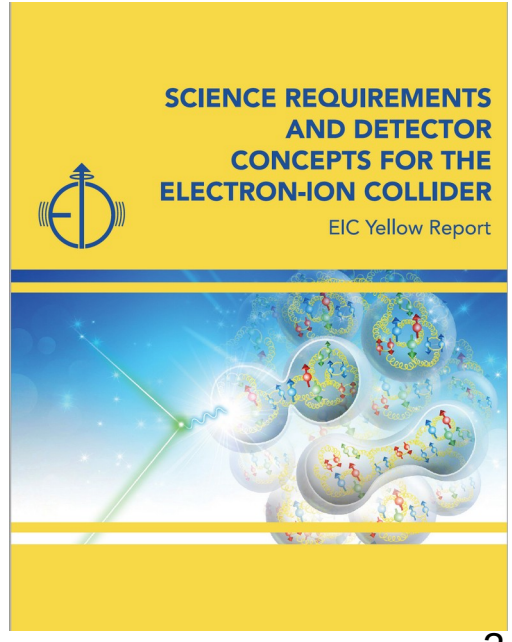
- Aiming at covering the whole physics program highlighted in the EIC White Paper, the NAS report and the Yellow Report
- Based on the YR/EIC-CDR reference detector
- Built around a new (up to) 3T magnet
- It will fulfill the Call for the Detector Proposal mandate for Detector 1

Contact to EIC Project Management: Elke Aschenauer







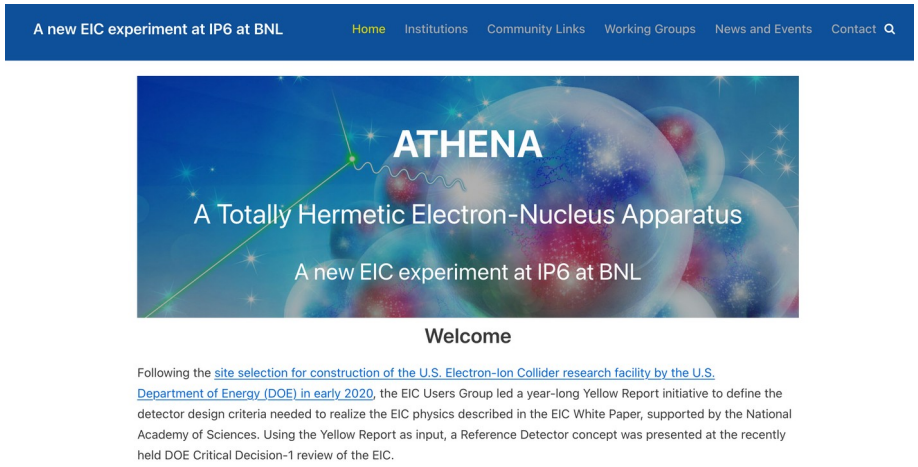


The ATHENA collaboration

- All started with the kick-off meeting in March (https://indico.bnl.gov/event/10825/)
- The **Coordination Committee** (namely the kick-off meeting organizers) leads the preliminary effort until the collaboration structure is established:
  S. Dalla Torre, A. Deshpande, O. Evdokimov, Y. Furletova , B. Jacak, A. Kiselev, F. Sabatié, B. Surrow
- The **Institution Board**: currently formed by 97 institutions
- A dedicated committee prepared the **ATHENA Charter:** overwhelmingly **approved by the IB**!
- The **Election Committee** has been established: soon elections for the key roles of the collaboration

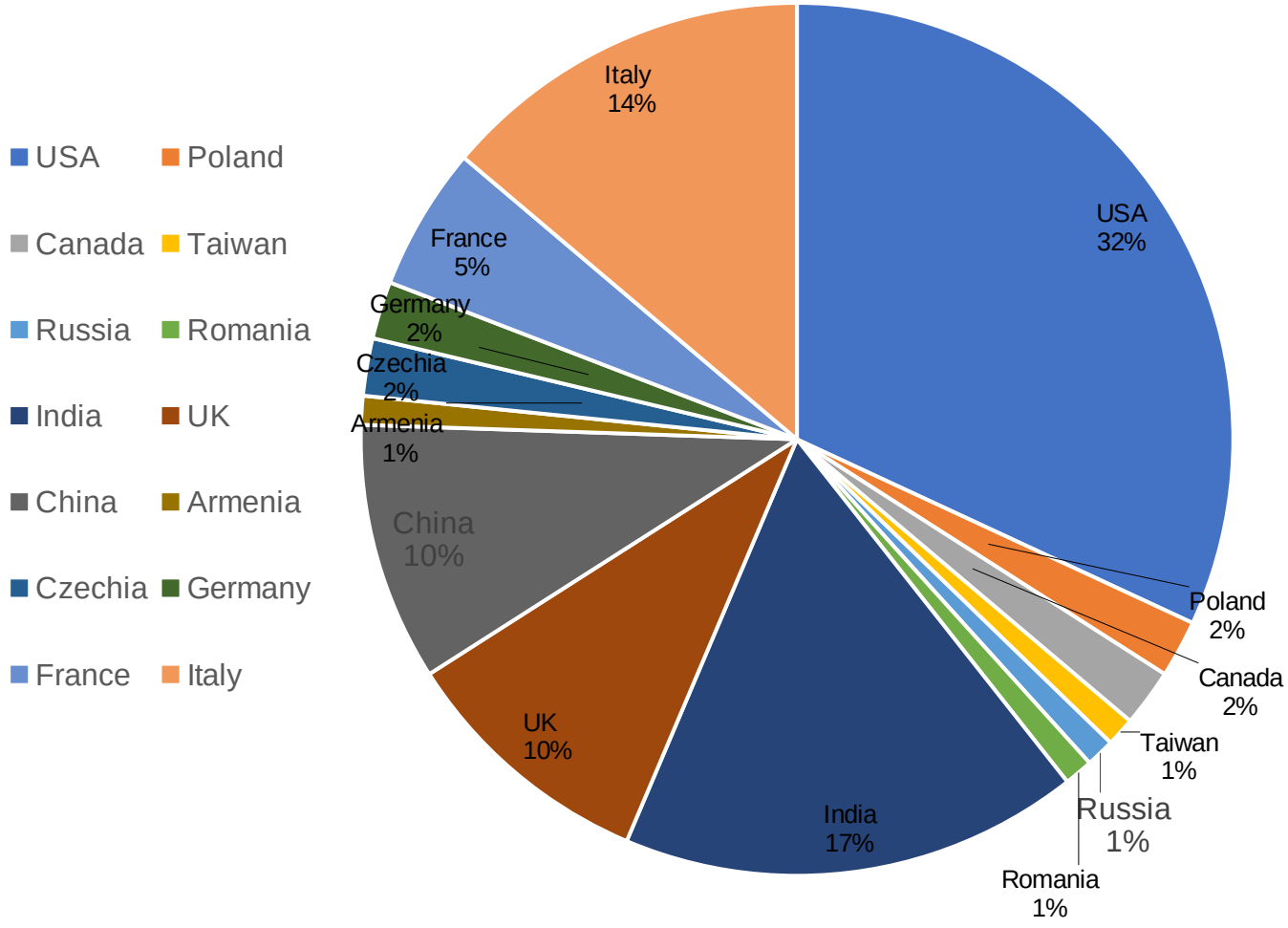
ATHENA welcomes new collaborators! More information on how to join and to contribute on:

- Website: https://sites.temple.edu/eicatip6/
- Mailing lists: https://lists.bnl.gov/mailman/listinfo/
- On Slack: link

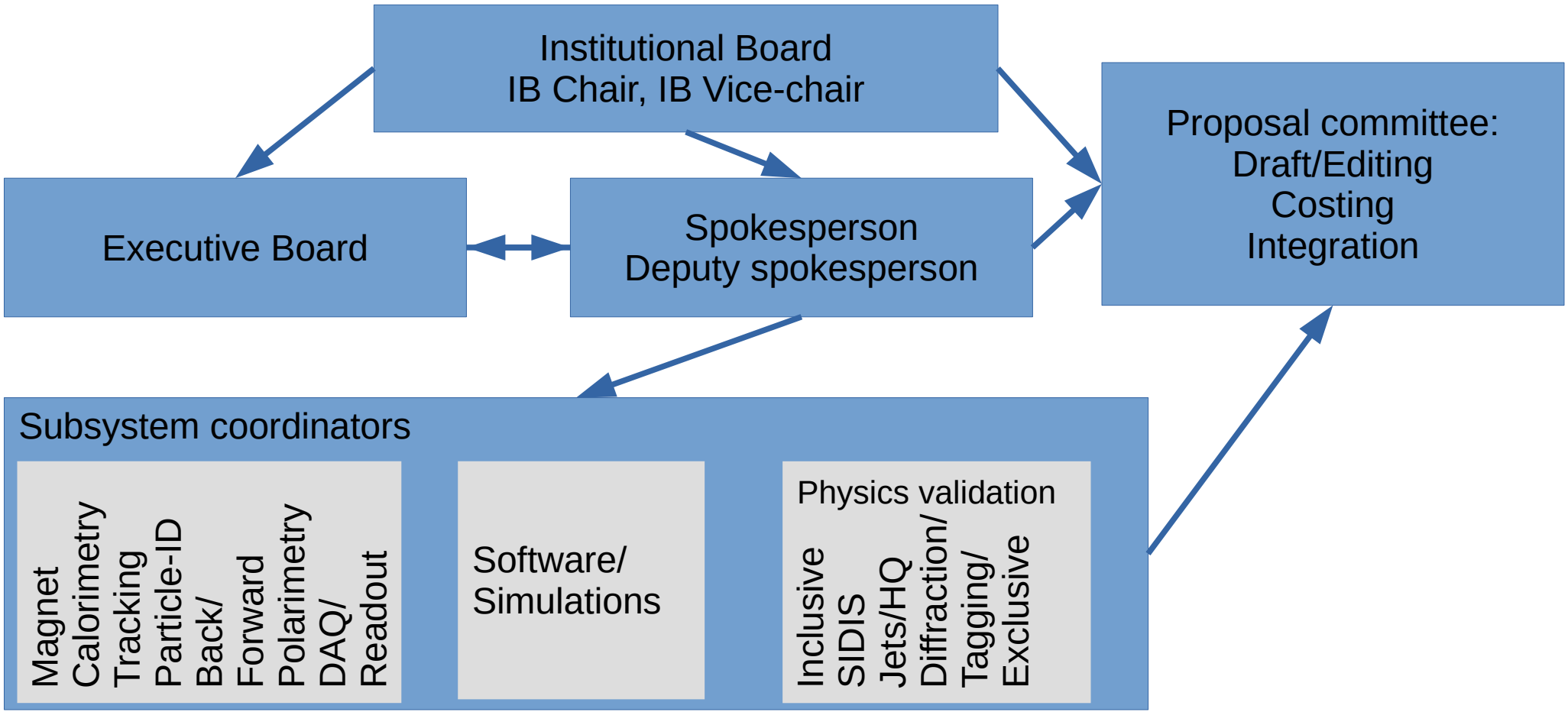


The ATHENA collaboration

The ATHENA IB formed by 97 institutions from all over the world



The ATHENA collaboration



Proposal committee

- **Integration / Global design:** Bedanga Mohanty, Franck Sabatié, Alexander Kiselev, Thomas Ullrich , Silvia Dalla Torre
  - Engage in a dialog between physics WGs concerning requirements and subsystem WGs concerning performance and help realize a global detector model based on performance, cost, maturity, and institutional commitment while
  - Keeping the ATHENA community fully informed about design considerations, ensuring opportunities for feedback from collaborators.
- **Costing:** Bernd Surrow, Olga Evdokimov, Zhangbu Xu, Yulia Furletova
  - Use cost template from EIC project team and EIC reference detector costing evaluation presented to the ICR in January 2021 as a starting point for completing detector costing.
  - Communicate with subsystem WGs about costing: Subsystem template, expected cost bracket, holding regular costing meetings with a “costing” representative for each subsystem WGs.
  - Prepare full costing of detector proposal with advice/input from the EIC project team and ATHENA community.
- **Draft/ Editing:** Abhay Deshpande, Barbara Jacak, Zein-Eddine Meziani, Peter Jones
  - Prepare a draft outline for the detector proposal and present it to the ATHENA community using shared overleaf document.
  - Writing of introductory material.
  - Solicit input from WGs specifying details for each section, including costing from the costing focus group.
  - Compiling the entire document, soliciting comments, and finalizing the document.

Ex-officio / Official EIC project contact: Elke Aschenauer

WG conveners and charge highlights

ATHENA

Subsystem detector WG Conveners:

Technology choices / Estimate of services, support + active materials / Implementation into global experimental model / Simulation of subsystem performance in the global experiment / Costing of each subsystem

- **Tracking**: Francesco Bossù, Domenico Elia, Laura Gonella, Matt Posik
- **PID**: Frank Geurts, Tom Hemmick, Roberto Preghenella
- **Calorimetry**: Vladimir Berdnikov, Paul Reimer, Oleg Tsai
- **Far Forward**: John Arrington, Alexander Jentsch
- **Far-Backward**: Jaroslaw Adam, Krzysztof Piotrzkowski
- **DAQ**: Alexandre Camsonne , Jeffery Landgraf
- **Polarimetry**: Oleg Eyser*, Ciprian Gal (joint group across EIC detectors)

Physics Validation WG Conveners:

Identify key observables described in YR / 2-3 plots which will illustrate the ability of ATHENA to address NAS report and YR / Additional physics performance plots that would give a competitive advantage for the proposal?

- **Inclusive**: Paul Newman, Barak Schmookler, Qinghua Xu
- **Semi-inclusive**: Marco Radici, Anselm Vossen
- **Jets/HF/EW-BSM**: Miguel Arratia, Brian Page, Stephen Sekula, Ernst Sichtermann
- **Exclusive**: Salvatore Fazio, Spencer Klein, Daria Sokhan

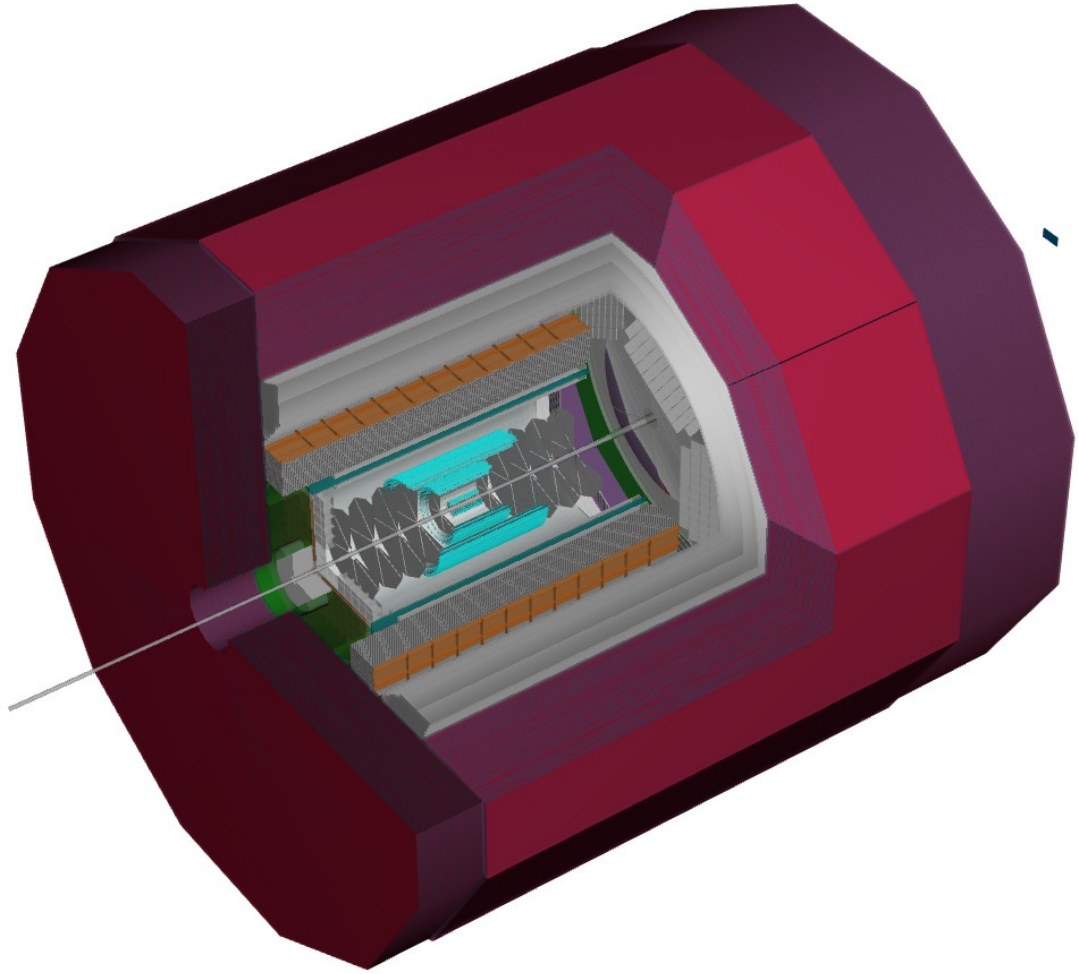
Software WG Conveners:

Full detector assembly / Assist detector and physics WG's to perform simulation and detector integration / Complete and improve reconstruction software

Whitney Armstrong, Andrea Bressan(*), Wouter Deconinck, Sylvester Joosten, Dmitry Romanov

(*)- liaison to EICUG software group

The ATHENA detector

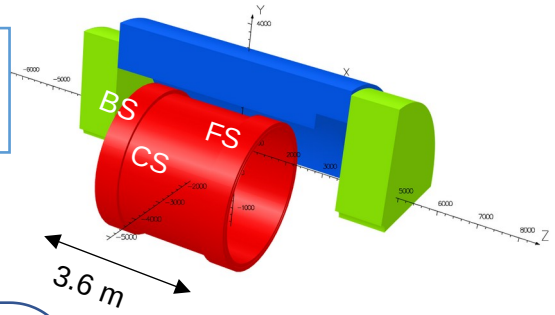


New (up to) 3T Magnet

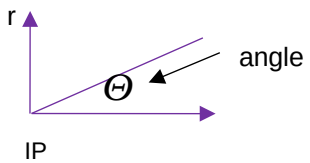
By: V. Calvelli (CEA), R. Rajput-Ghoshal (JLAB)

Solenoidal Configuration

Version for full analysis
Magnetic field map released 07/05/2021



On the Interaction Point plane



$$Proj = \frac{B_z \tan\Theta - B_r}{J_E}$$

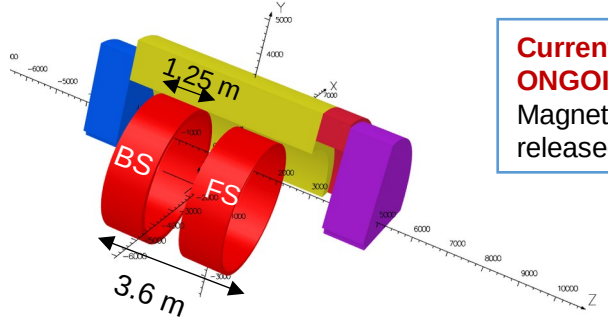
Parameter	Values
B_{IP} (T)	**3.15**
B_{peak} (T)	4.35
Coil thickness (mm)	200
Energy (MJ)	183.9
H TPC 2 (%)	**6.61**
H FLAT 1 (%)	**25.12**
Projectivity (T/Amm²)	**14.82**

Parameter	Goal
B_{IP} (T)	3.00
Bore diameter (mm)	1600
Coil length (mm)	3600
H TCP 2 (%)	5.0
H FL	10.0
	in

$$H^2_{TPC} = \left|\frac{B_r}{B_z}\right| < 5\,\%$$

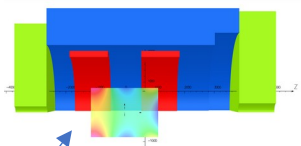
$$H^1_{FLAT} = \frac{B_{max} - B_{min}}{B_{IP}} < 10\,\%$$

Helmholtz Configuration

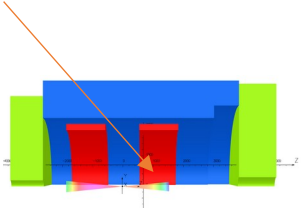


Current version ONGOING
Magnetic field map released 28/05/2021

Parameter	Values
B_{IP} (T)	**2.97**
B_{peak} (T)	4.84
Coil thickness (mm)	210
Energy (MJ)	235.7
H TPC 2 (%)	**4.83**
H FLAT 1 (%)	**16.37**
Projectivity (T/Amm²)	**17.51**



No problem here



Mostly difficult to reach before the RICH
Due to the short length of the magnet

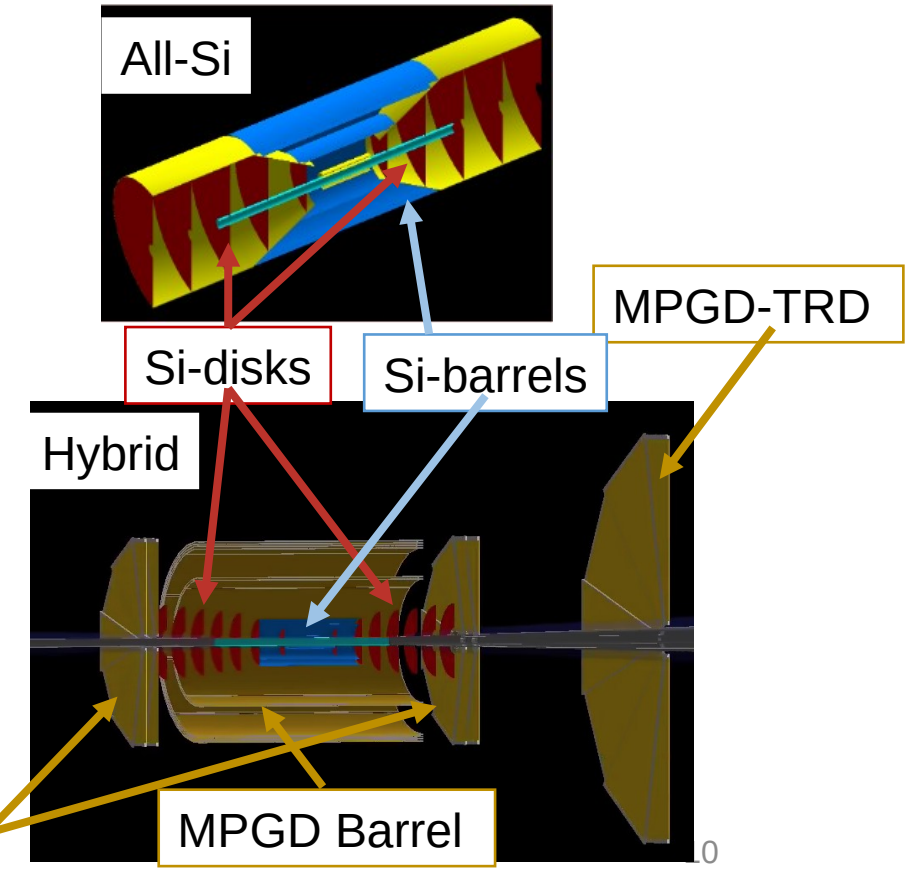
Tracking

https://indico.bnl.gov/category/363/

Two configurations under consideration:

- **All-Silicon concept**
  - Vertex/Barrels and disks based on ALICE ITS3 MAPS
    - *EIC Silicon consortium*

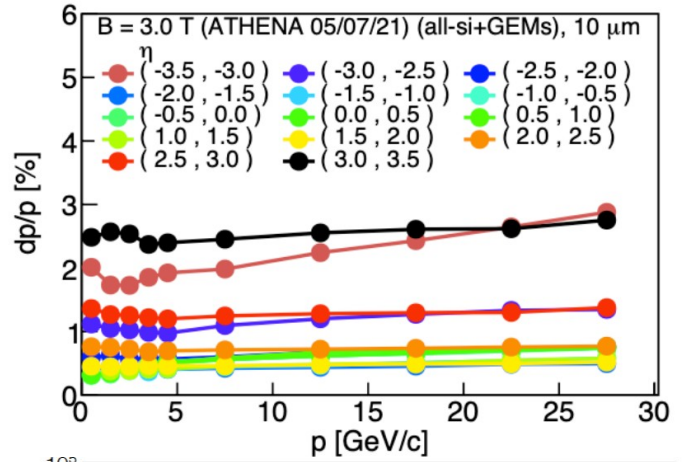
- **Hybrid concept**
  - Silicon vertex/barrels and disks (ALICE ITS3 MAPS)
    - *EIC Silicon consortium*
  - MPGD end cap: (GEMs or micro R-Wells)
    - *Florida Tech., Temple, UVa*
  - MPGD barrel
    - Micromegas – *CEA Saclay*
    - µRwelll – *Florida Tech, Temple, UVa*
  - Large z MPGD-TRD
    - *BNL, Florida Tech. Jlab, Temple, UVa, Vanderbilt*

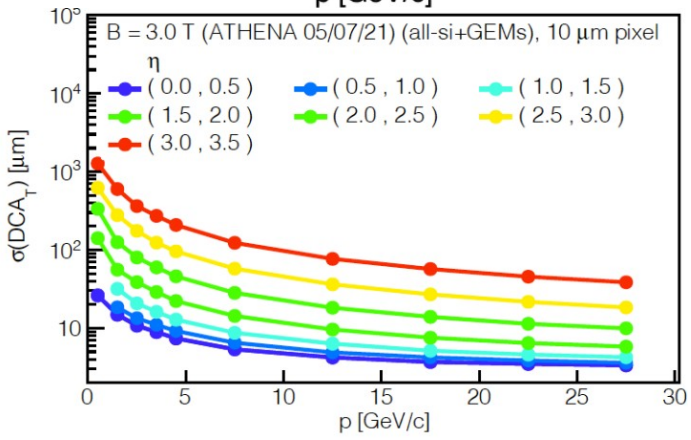


Tracking

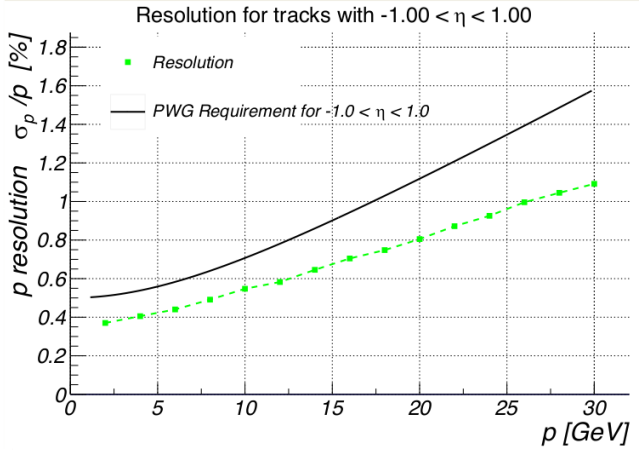
- YR PWG requirements are met by both configurations
- Performance studies with different magnetic field configurations
- Ongoing implementation and optimization studies with support materials
- Close connections with the PID WG

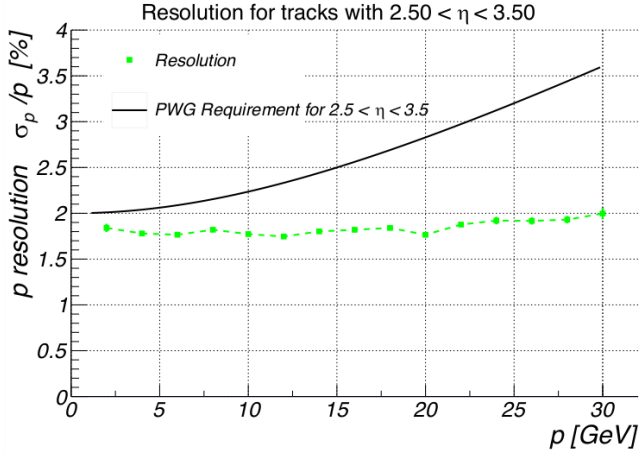
All silicon





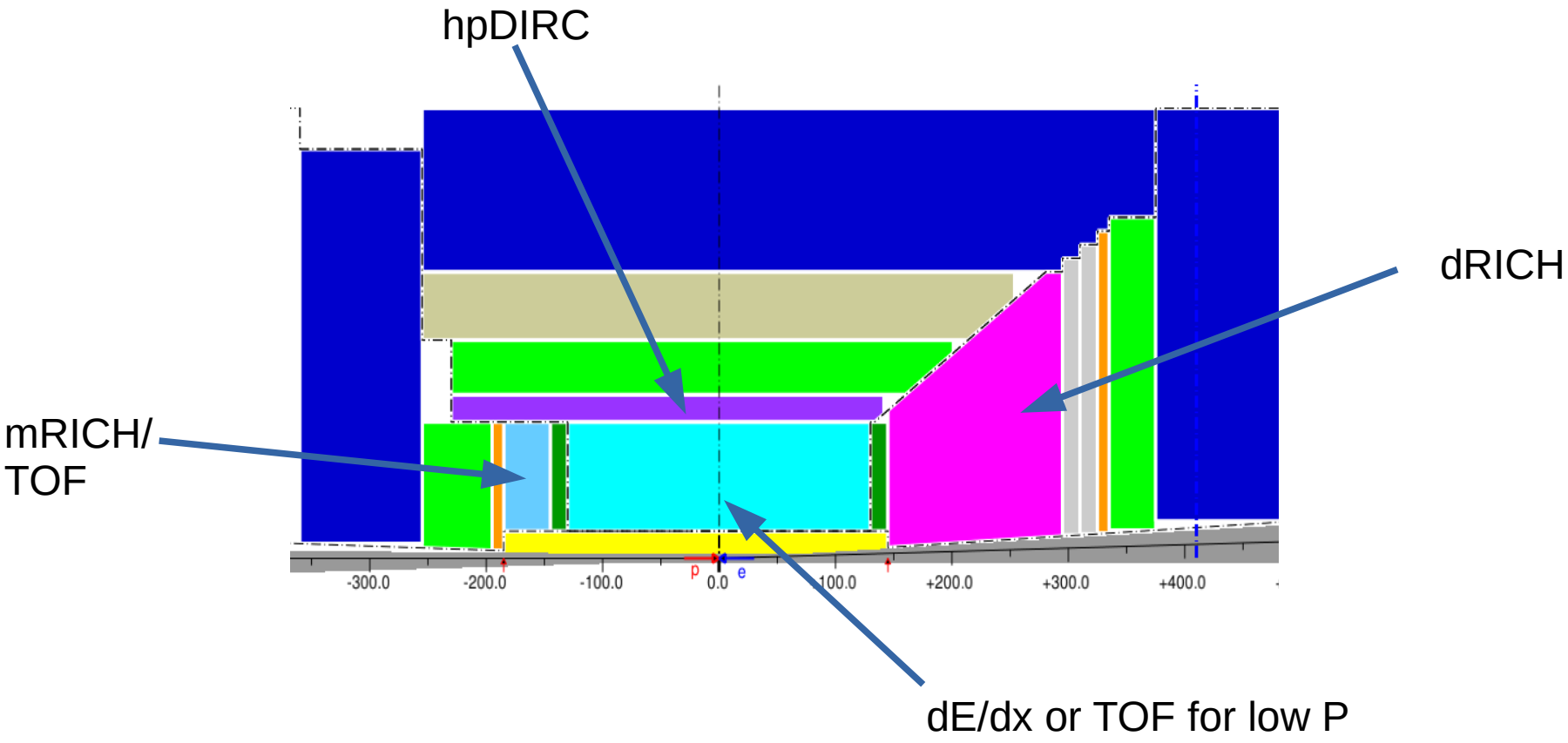
Hybrid





Particle-ID

Several technologies are being considered for particle identification



Particle-ID

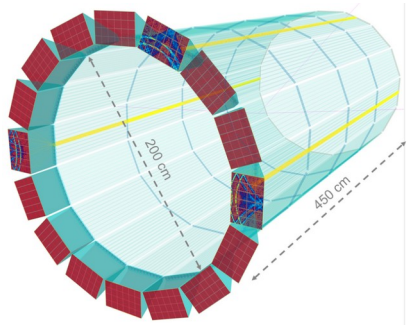
hpDIRC

- Fast focusing DIRC
- Innovative 3-layer spherical lenses, compact fused silica expansion volumes
- Fast photon detection using small-pixel MCP-PMTs *(eRD14)* and high-density readout electronics *(eRD14)*

Excellent performance over wide angular range:

- ≥ 3 s.d. π/K up to 6 GeV/c, ≥ 3 s.d. e/π up to ~1.2 GeV/c
- Low momentum π/K identification in “veto mode” down to 0.2-0.3 GeV/c

Involved institutions: CUA, GSI, BNL, W&M, USC, SBU, UH, JLab, ODU



dRICH

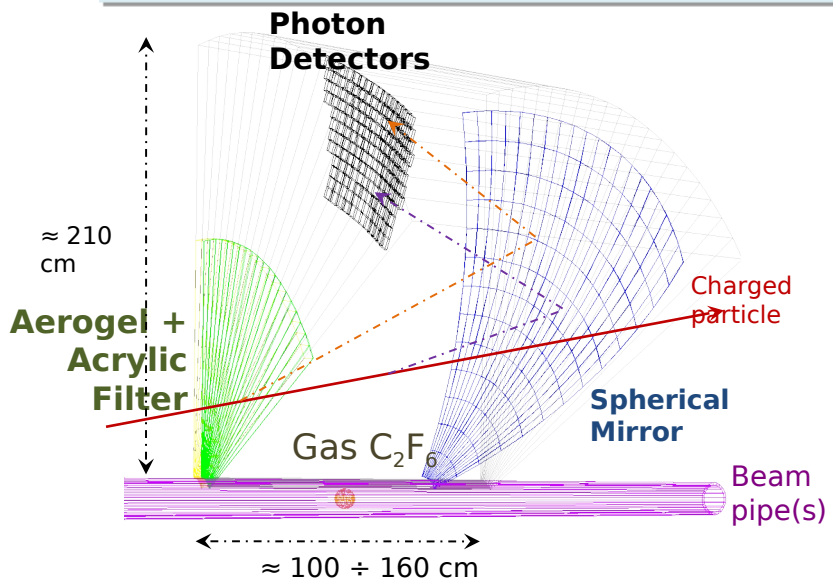
Radiators:

- Aerogel: 4 cm, $n_{(400nm)}$~1.02 + 3 mm acrylic filter
- Gas: 1.6m (1.1m ePHENIX), n_{C2F6}~1.0008

6 Identical Open Sectors (Petals):

- Large Focusing Mirror with R ~2.9m (~2.0m ePHENIX)
- Optical sensor elements: ~4500 cm²/sector, 3 mm pixel size, UV sensitive, out of charged particles acceptance

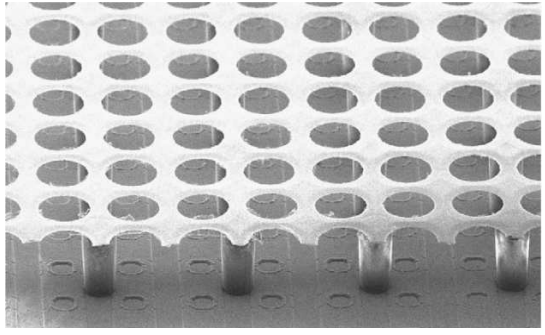
Optimized for JLEIC, preliminary implementation in ePHENIX

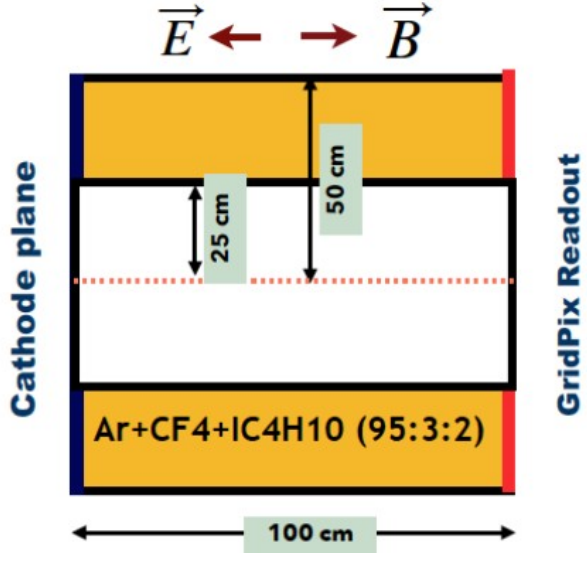


Particle-ID

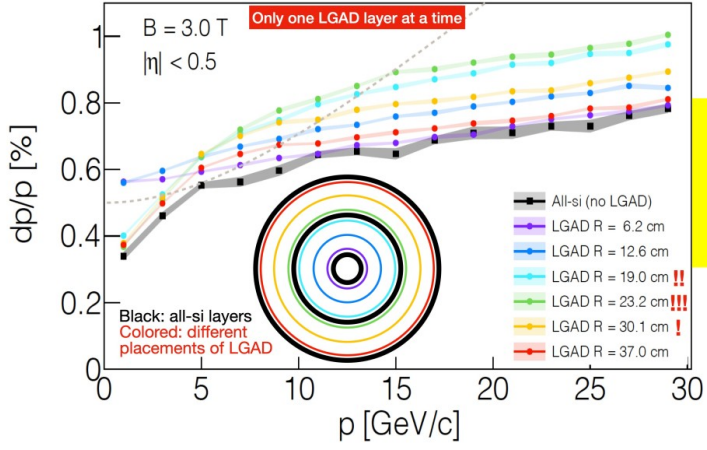
Options for low momentum PID at |η|<1:

- Compact TPC based on GridPix
  - 55x55μm^2 pixel, 90% single electron efficiency
  - dE/dx by counting “each” primary electron
  - Good position information useful for tracking
  - Ongoing implementation in simulation





- LGAD layer for TOF
  - Well developed technology (20ps resolution)
  - Ongoing simulations to study the impact on tracking performance

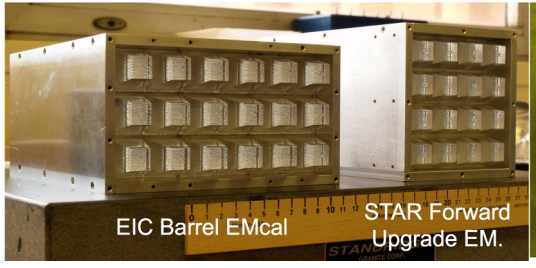


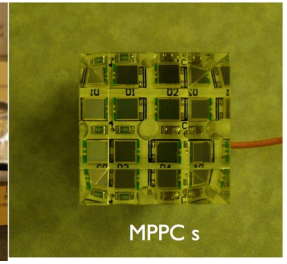
LGAD inside tracker

Calorimetry

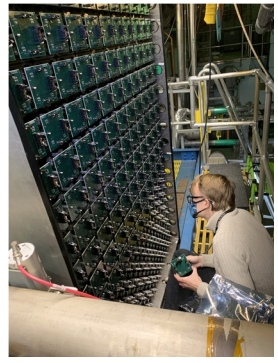
https://indico.bnl.gov/category/364/

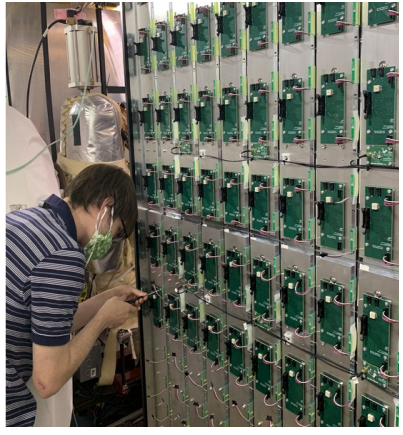
- High Resolution EndCaps.
- Technologies developed during EIC generic detector R&D. Well established and spread in the EIC users community.
- Barrel Calorimeters – being optimized, depends on design of the new SC magnet.





- WScFI EM section of Hadron EndCap.
- Technology pioneered at UCLA.
- Very Compact with good EM resolution.
- Similar technology as sPHENIX EMCal.

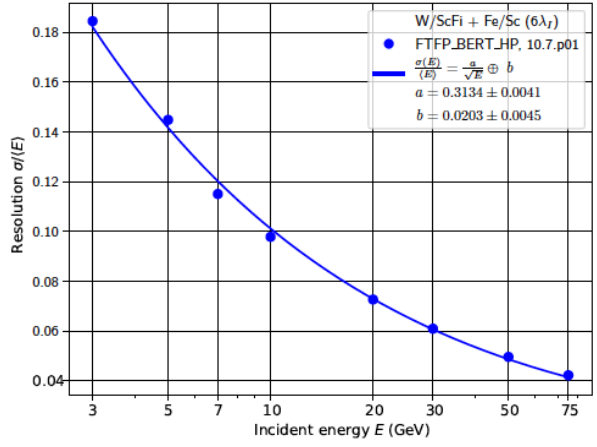




STAR Forward Calorimeter System.

Constructed in 2020 with new, very efficient method.

HCal Fe/Sc, similar technology for EIC reference detector.



Expected performance of ATHENA hadron endcap (improved version of STAR FCS)

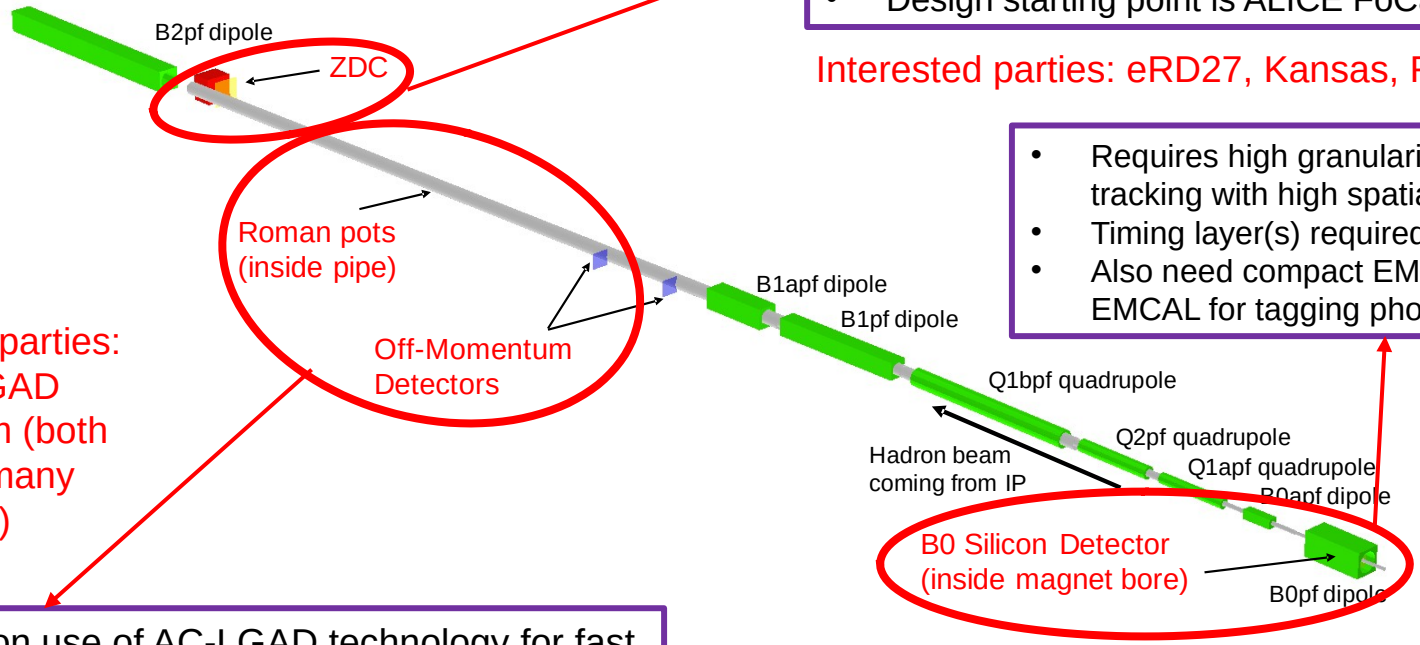
Interested institutes:
nECAL: EEEMCal consortium, (CUA, Lehigh U., MIT, U. Kentucky, AANL, FIU, Prague, IJCLab
bECAL: ANL
pECAL and **hCAL**: UCLA, UCR, Fudan U., Shandong U., Tsinghua U., South China Normal U.

Far-Forward Detectors

https://indico.bnl.gov/event/12290/

- Combination EMCAL and HCAL with high granularity and resolution.
- Design starting point is ALICE FoCal.

Interested parties: eRD27, Kansas, RIKEN



- Requires high granularity silicon tracking with high spatial resolution.
- Timing layer(s) required.
- Also need compact EM preshower or EMCAL for tagging photons.

Interested parties: LANL, and others

Interested parties: eRD24, LGAD Consortium (both comprise many institutions)

- Both can rely on use of AC-LGAD technology for fast (~20-30ps) timing and good spatial resolution.
- Roman Pots require special care since we plan to go with “potless” design to maximize acceptance.

Far-Backward Detectors

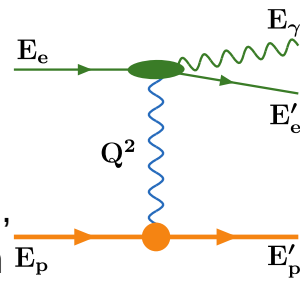
https://indico.bnl.gov/category/371/

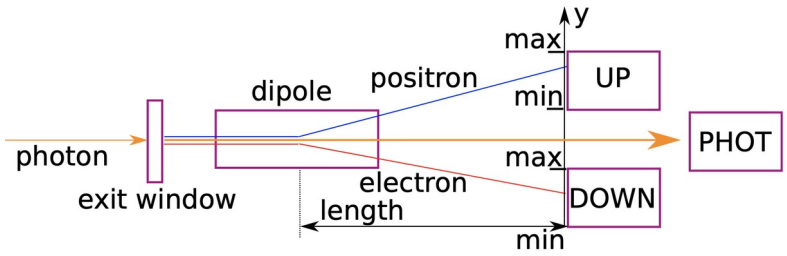
Aiming at measuring the EIC luminosity with a precision better than 1% using the electron-ion bremsstrahlung:

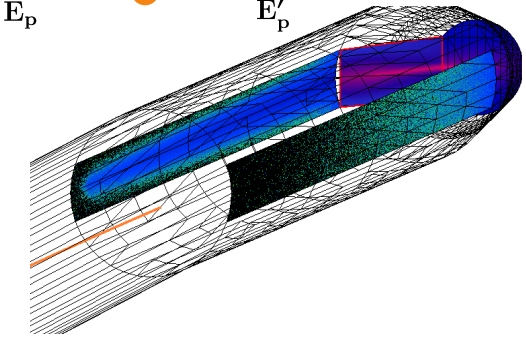
Dedicated detectors will measure “zero-degree” photons, and the design effort started from the challenging design of the photon exit window, hit by a SR fan.

A fraction of the scattered electrons in bremsstrahlung will be measured too, and the electron detectors will also be used to tag low-Q^2

Events (photoproduction) in ATHENA:

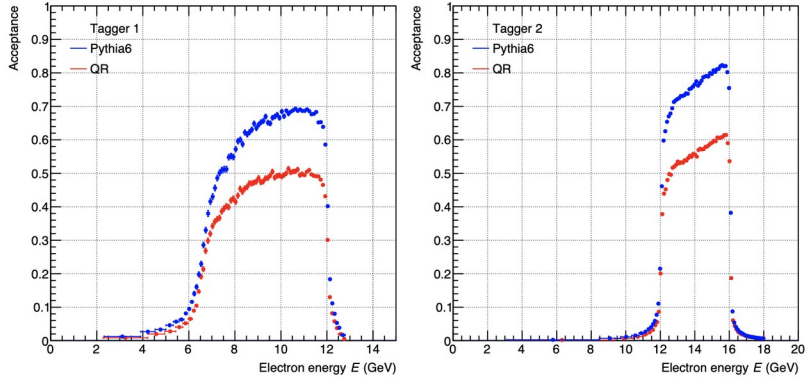






Interested groups in this ATHENA project:

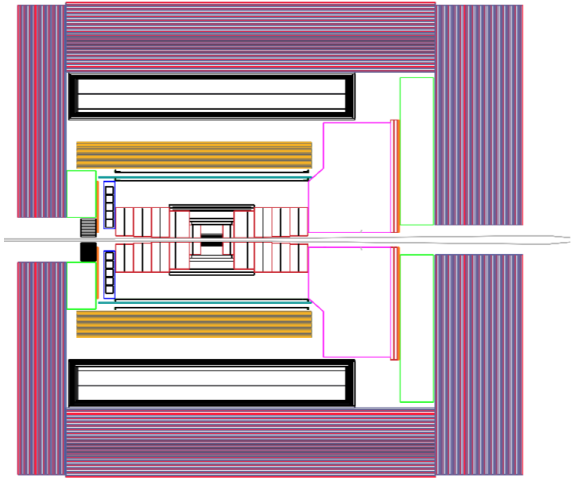
AGH UST (Kraków), BNL, Glasgow Univ., IFJ PAN (Kraków), Temple Univ.

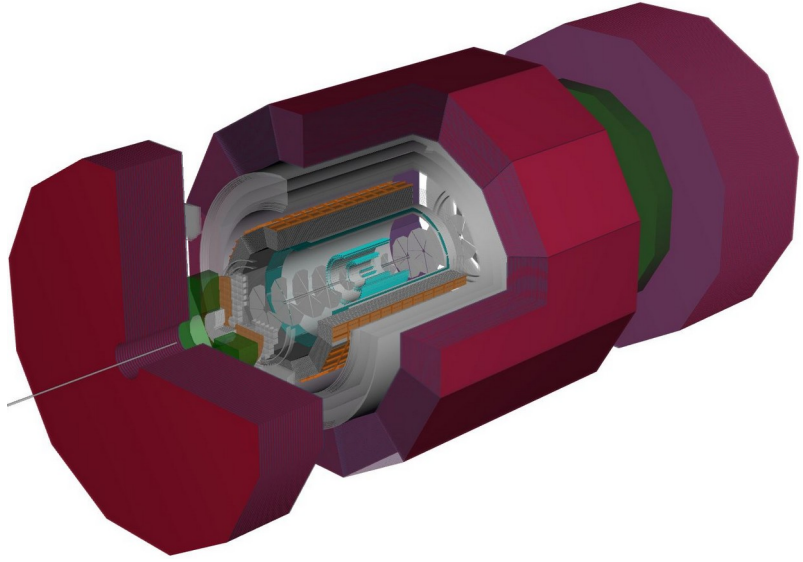


Software & computing

Software based on a state of the art HEP packages, such as DD4Hep, Gaudi, ACTS...

- Full geometry based on reference detector implemented in DD4hep
- Reasonable detail in central detector tracking
- Various ECAL and HCAL options with support structures
- Latest Solenoid geometry and beamline setup
- Working with PID working group to enhance implementations of dRICH, mRICH and DIRC systems.
- Working with Far Forward and Far Backward WGs to implement the full beamline and near-beamline detector system.





Summary

- ATHENA has now adopted a Charter that defines it as a collaboration
- Elections of the key collaboration roles will take place soon
- The ATHENA collaboration aims at proposing a detector:
  - built around a new 3T magnet
  - based on the EICUG Yellow Report reference detector
  - that will meet the physics requirements defined in the YR
  - that is leveraging the technologies developed by the EIC R&D program
- A preliminary configuration is being implemented for full simulation studies
- The final version will be the best of the efforts of all the Wgs, within the available cost range

- The ATHENA collaboration welcomes new institutions and collaborators to join:
  - To join: send email to eic-ip6-org-l@lists.bnl.gov
  - Stay connected: subscribe to public mail eic-ip6-public-l@lists.bnl.gov