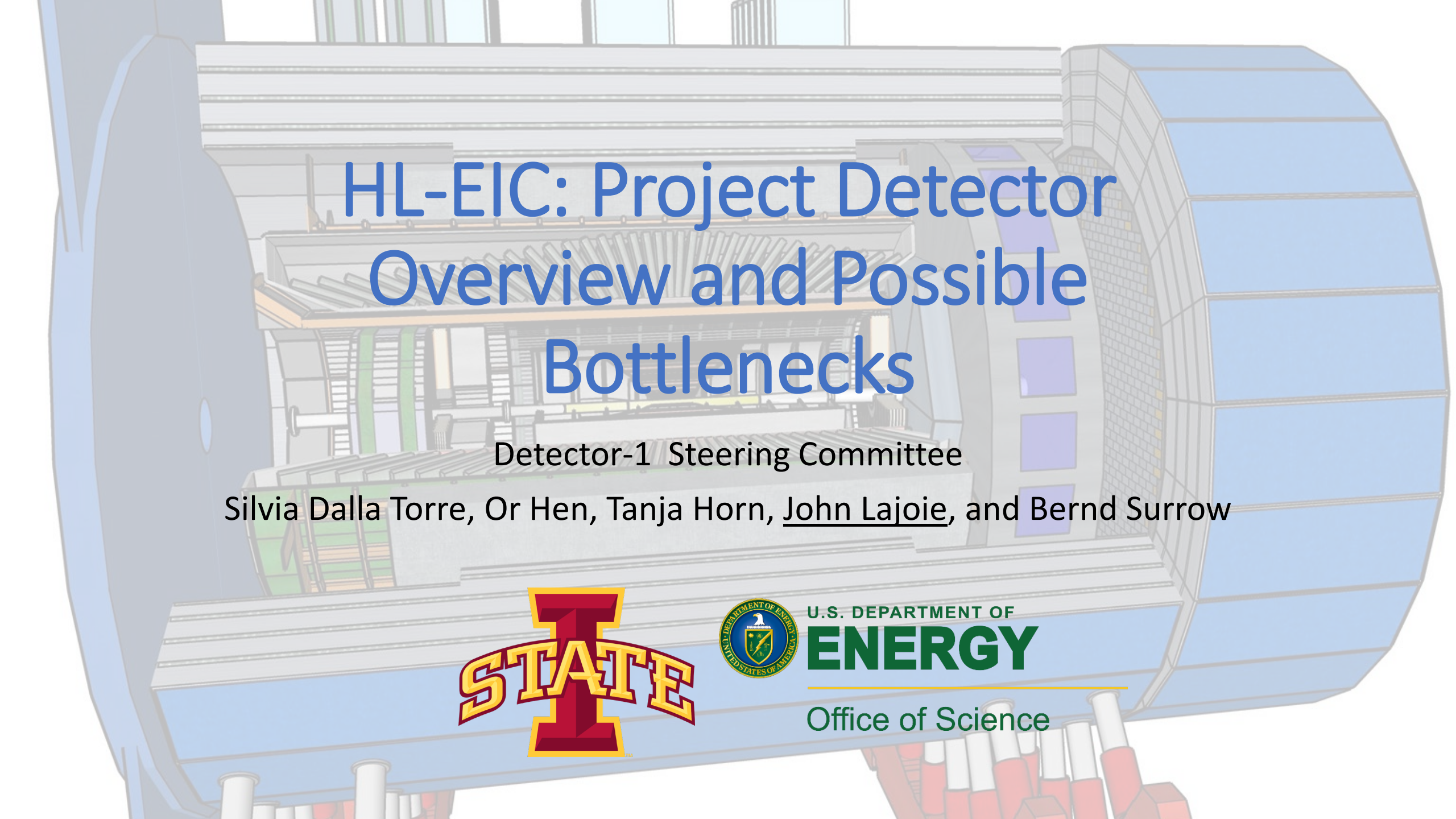


HL-EIC: Project Detector Overview and Possible Bottlenecks

Detector-1 Steering Committee

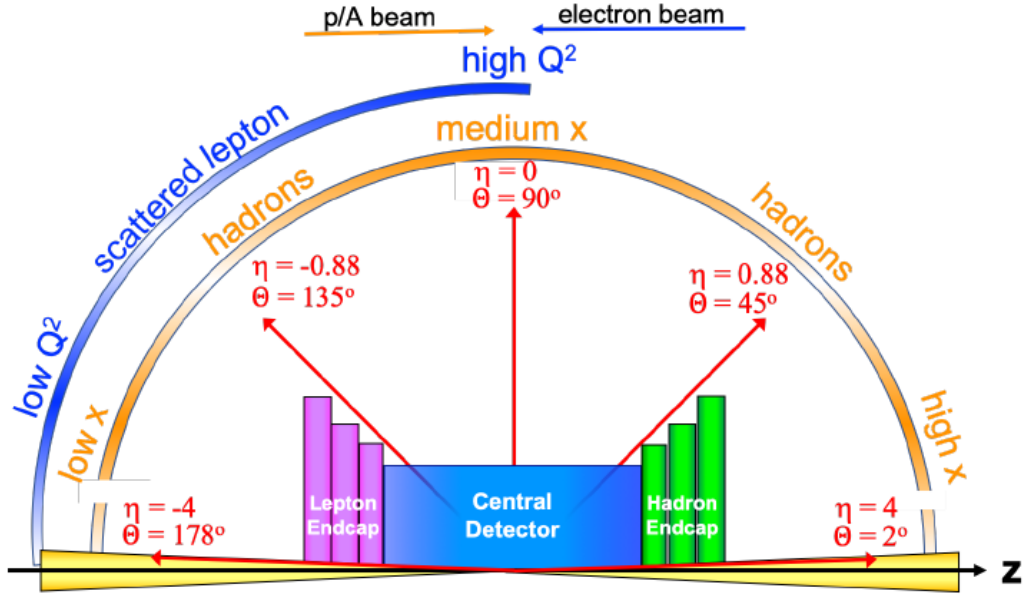
Silvia Dalla Torre, Or Hen, Tanja Horn, John Lajoie, and Bernd Surrow

U.S. DEPARTMENT OF ENERGY

Office of Science

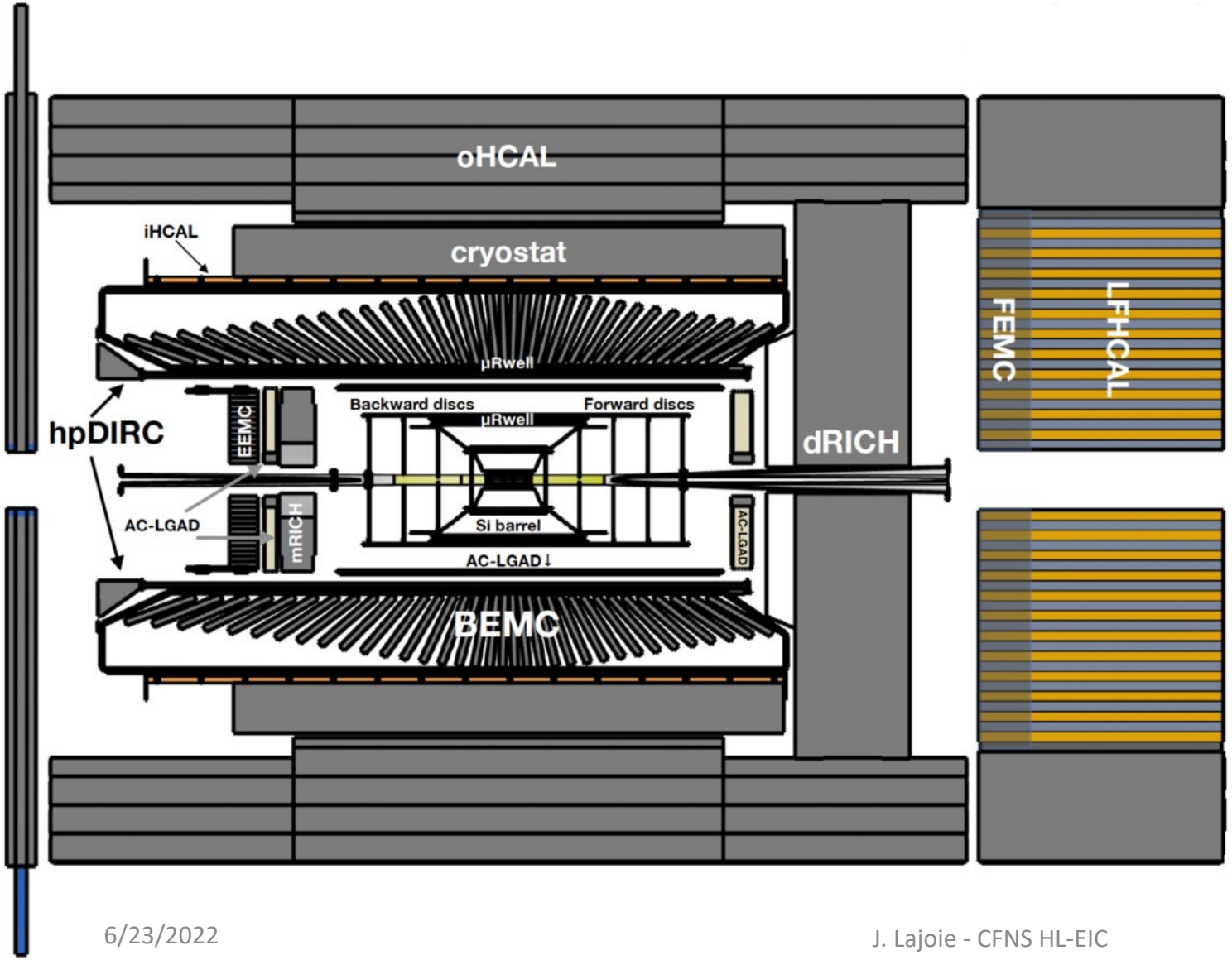
EIC Detectors

- Detector-1 (EIC Project Detector)
  - To be sited at IP6 (25mr crossing angle)
  - Addresses EIC science program as outlined in the EIC white paper and NAS report
  - Must be ready for Day-1 EIC operations
  - DPAP proposal process
  - Working towards pre-TDR/CD-2



- Detector-2
  - To be sited at IP8 (35mr crossing angle, secondary focus)
    - Requires development of 2nd IR
  - Physics program complementary to Detector-1
  - Ready 2-5 years after Detector-1
  - Development activity at the EICUG WG level

Detector-1 Reference Design (Current)



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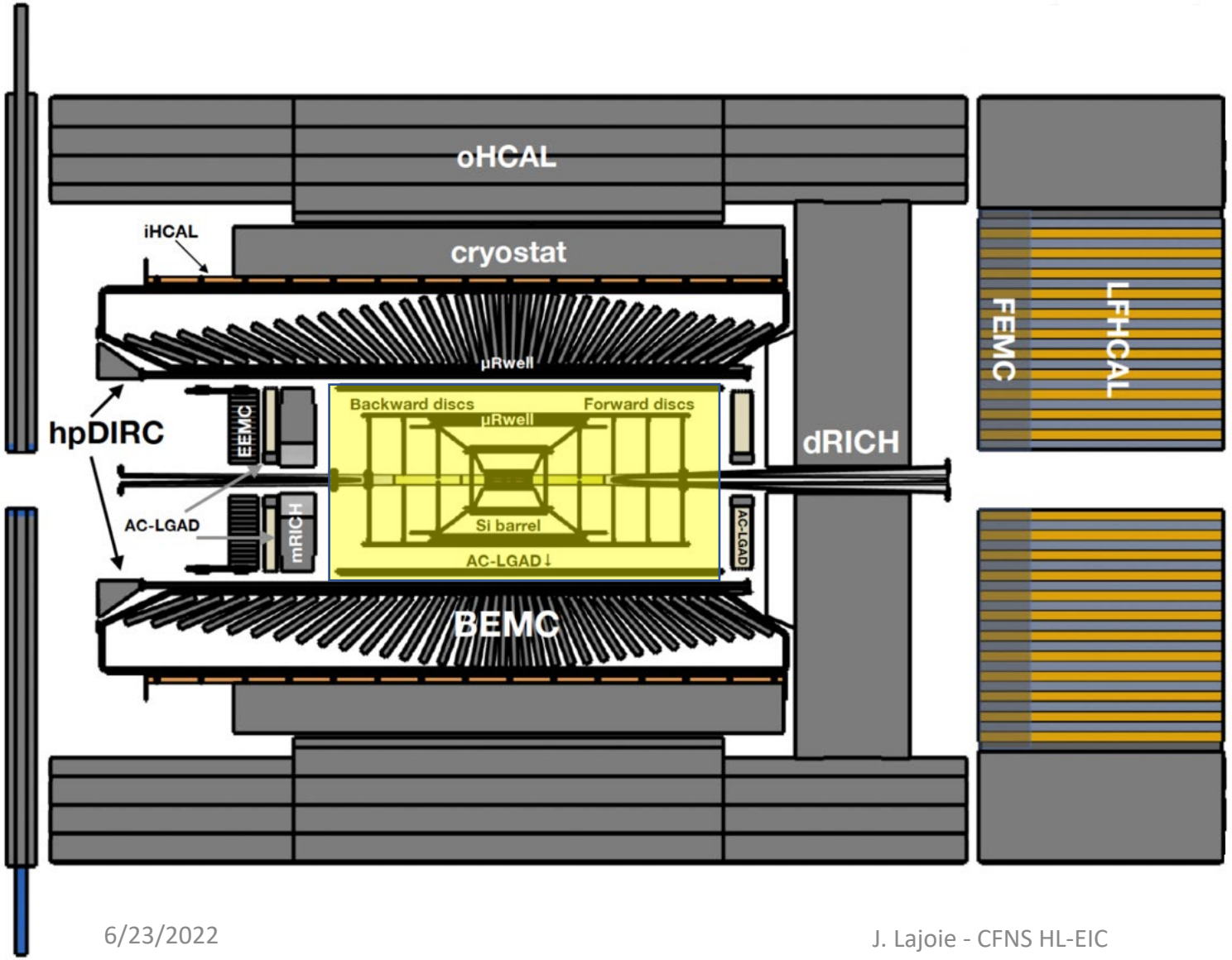

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- Si MAPS (65nm)
- AC-LGAD
- µRWELL

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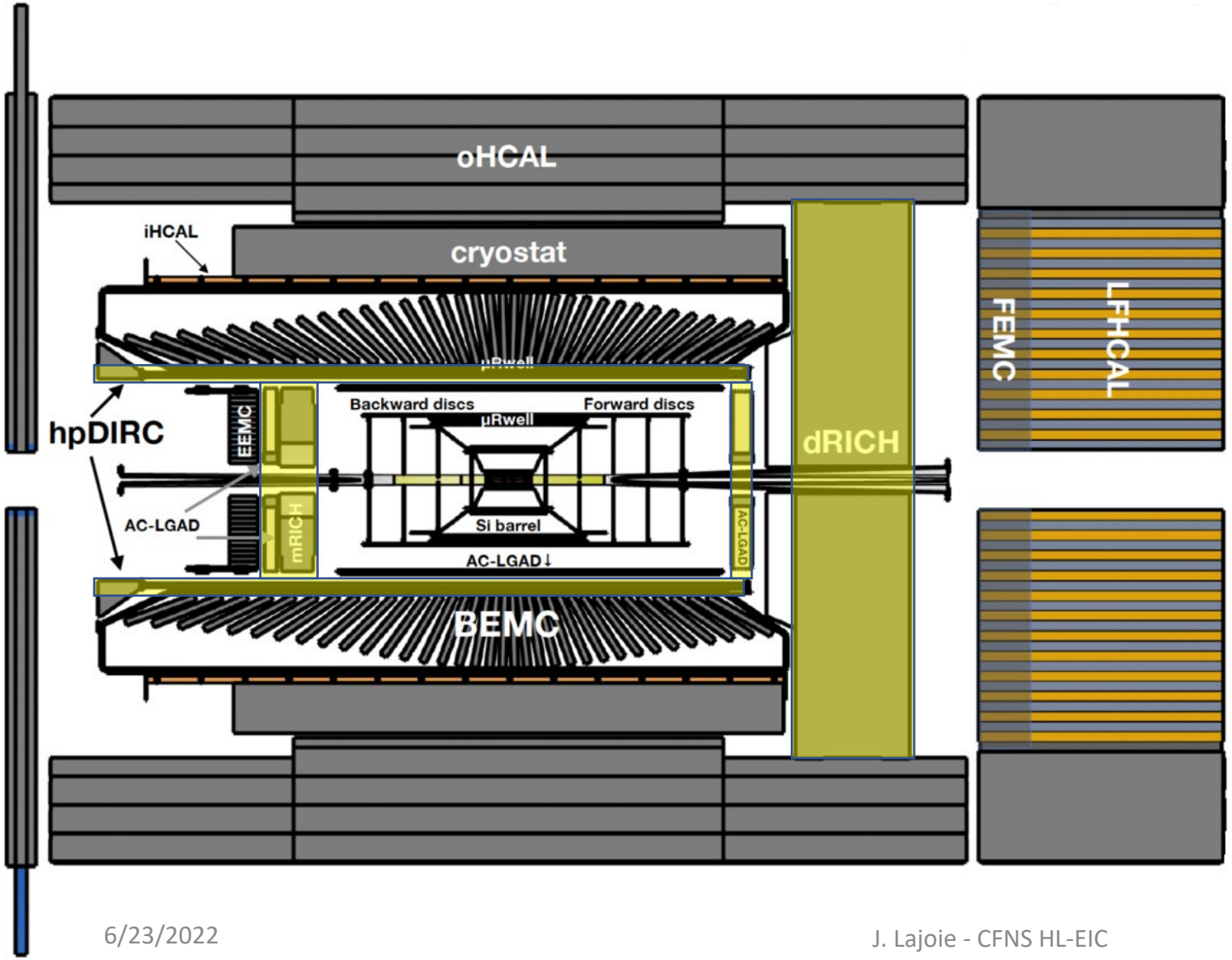

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- mRICH
- dRICH
- AC-LGAD (~30ps TOF)

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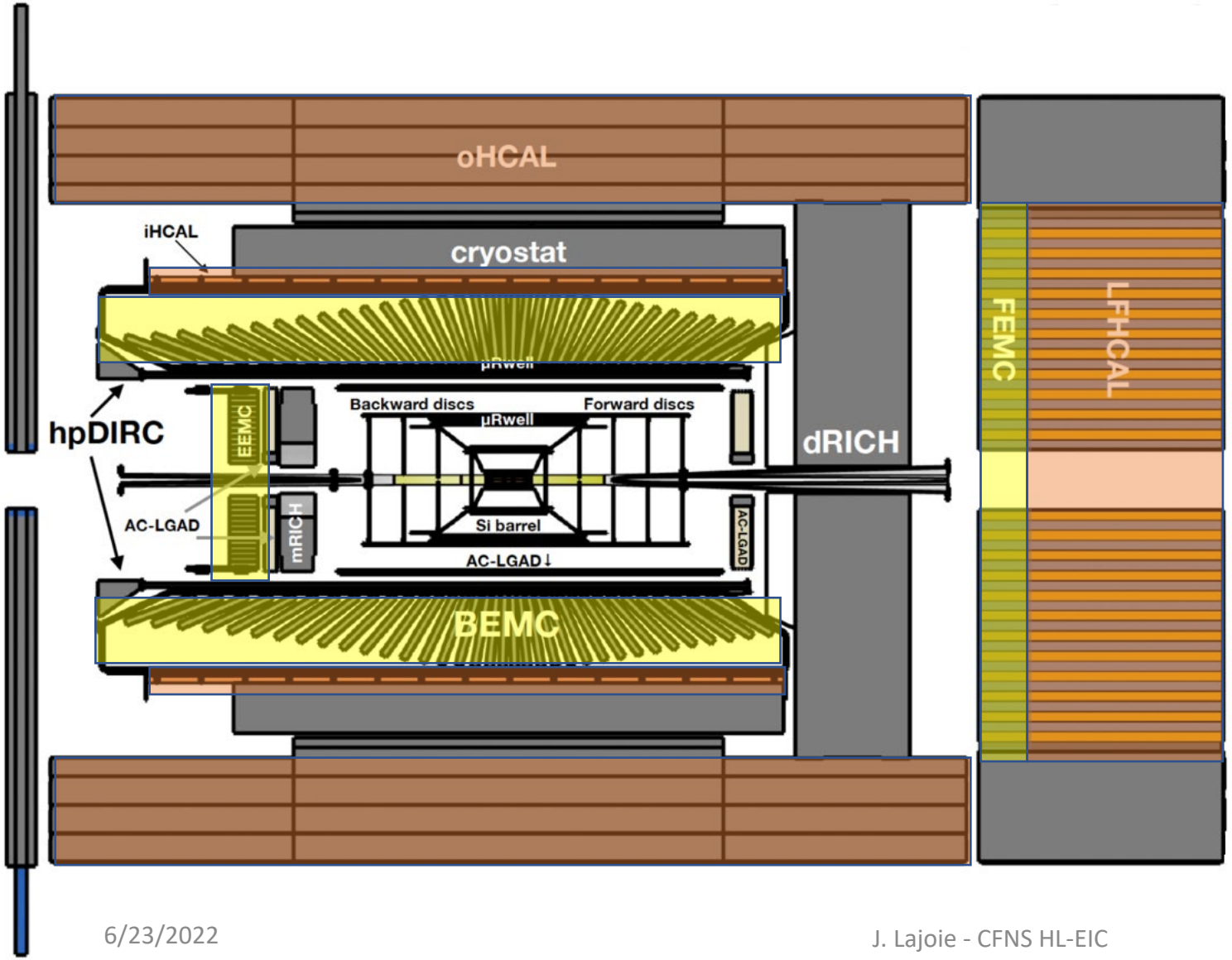

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- AC-LGAD (~30ps TOF)

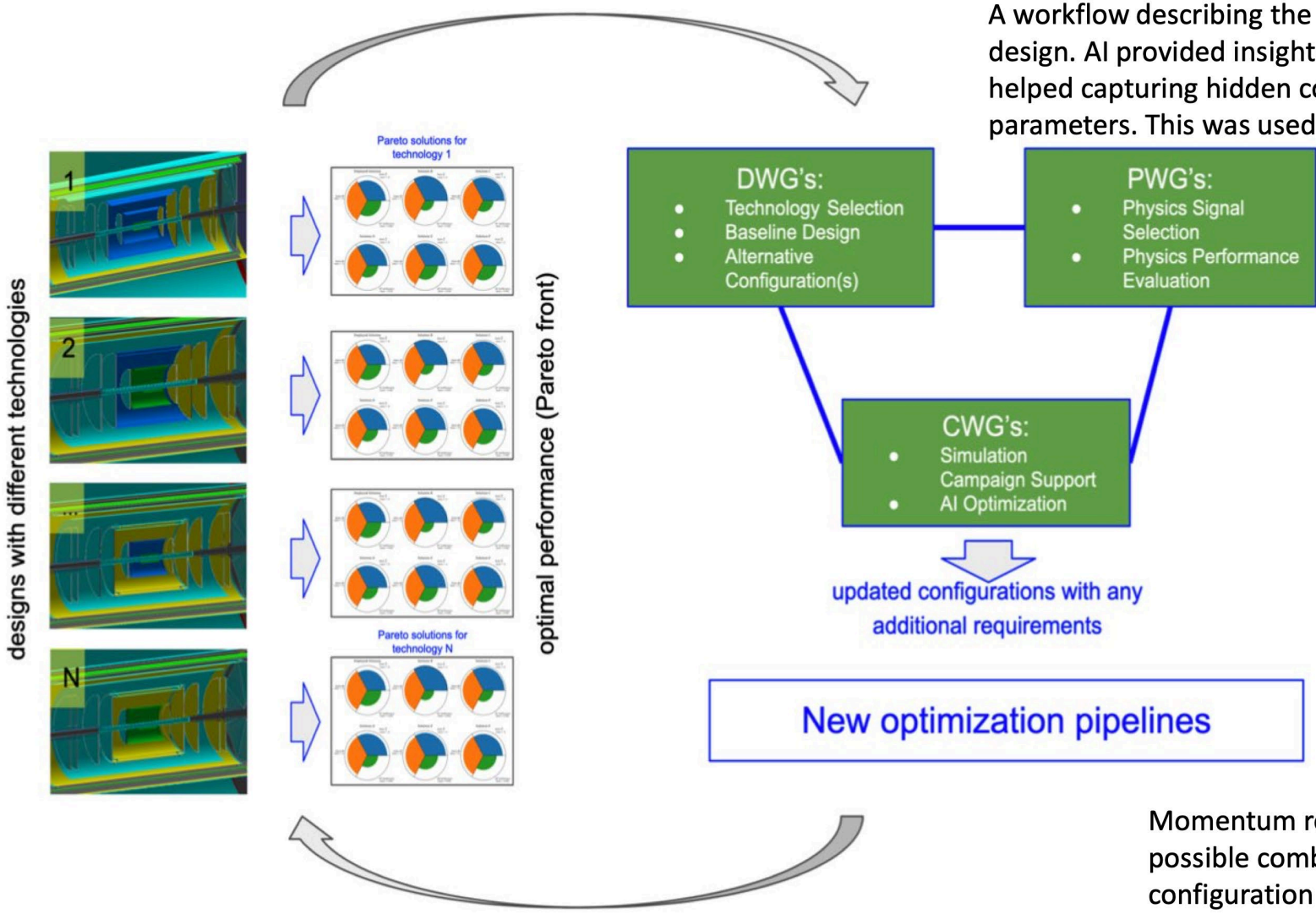
Calorimetry:

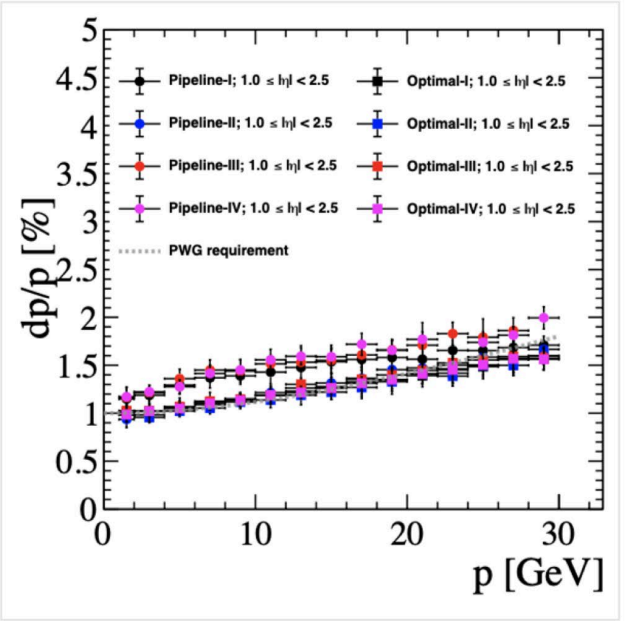
- SciGlass Barrel EMCal
- PbWO EEEMCal
- Longitudinally separated EM+Hcal
- Inner HCal (instrumented frame)
- Outer HCal (sPHENIX re-use)

AI Assisted Detector Design

AI is a key part of EIC detector design!

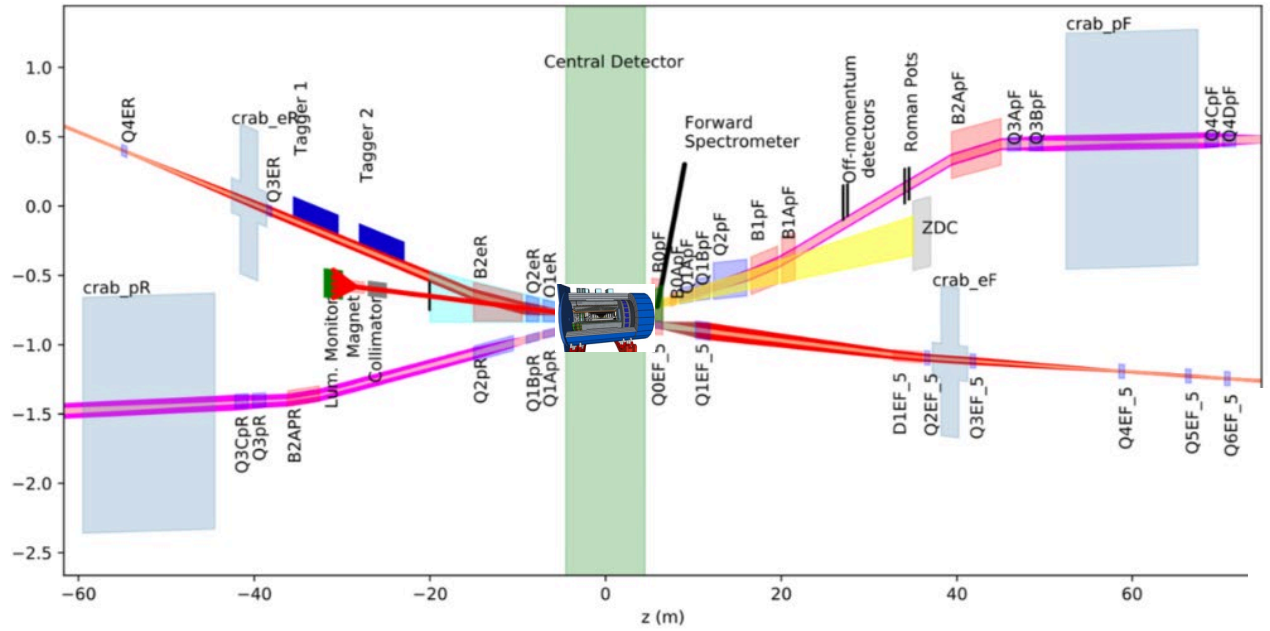
A workflow describing the iterative process of detector design. AI provided insights for technology choices and helped capturing hidden correlations among the design parameters. This was used to steer the design





Momentum resolution of different pipelines corresponding to different possible combinations of technology optimized with AI. The AI-optimized configuration outperformed the original designs in all η bins.

Far-Forward / Backward Instrumentation



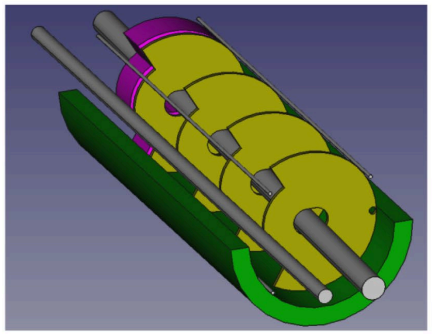
EIC detectors are highly integrated with the accelerator – extensive cooperation required to achieve science goals!

Far-Backwards

- Low-Q^2 tagger
- Luminosity monitor

See talk from Michael Murray (Thurs)

Far-Forward Instrumentation



B0 Trackers + Calorimeter

Roman Pots

ZDC

Off Momentum

Hadron Beam after IP

B1apf Dipole

B1pf Dipole

Q2bpf quadrupole

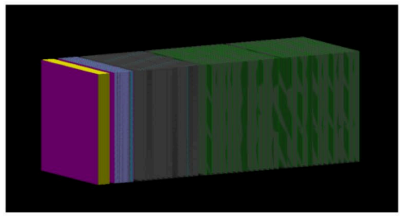
Q1pf quadrupole

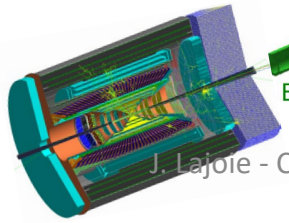
Q1apf quadrupole

B0apf Diople

B0pf Diople

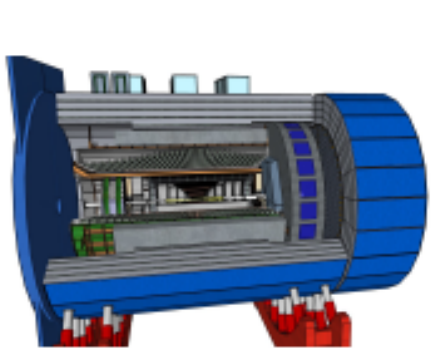
ZDC

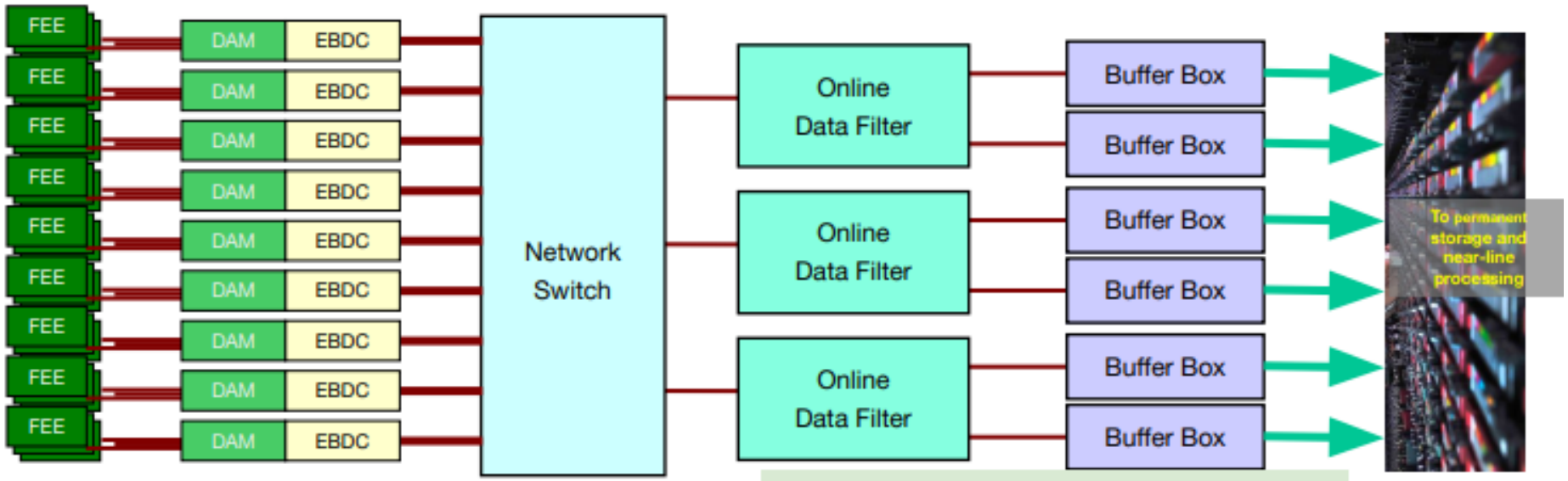




Streaming DAQ

See talk from Jin Huang (Thurs)





- No External trigger
- All collision data digitized but aggressively zero suppressed at FEE
- Low / zero deadtime
- Event selection can be based upon full data from all detectors (in real time, or later)
- Collision data flow is independent and unidirectional-> no global latency requirements
- Avoiding hardware trigger avoids complex custom hardware and firmware
- The “Front End Processing”, programmable hardware between the FEEs and the DAQ computers, is deemphasized relative to the yellow report, but should not be precluded.
- Data volume is reduced as much as possible at each stage

Reference Detector Consolidation

- Return to the guidance from the EIC project:

> *"The EIC Project recognizes that the panel recommended ECCE as the Project Detector. As described in the panel report, we will urge the proto-collaboration to: (1)* ***integrate new collaborators*** *in a manner that enables them to make contributions that impact the capabilities and success of the experiment in significant ways, including new collaborating individuals and groups into positions of responsibility and leadership; and (2)* ***integrate new experimental concepts*** *and technologies that improve physics capabilities without introducing inappropriate risk.* ***ECCE is the reference design for this optimization and consolidation so that the Project Detector can advance to CD2/3a in a timely way****"* – email communication from the EIC Project Team on 13 March 2022.

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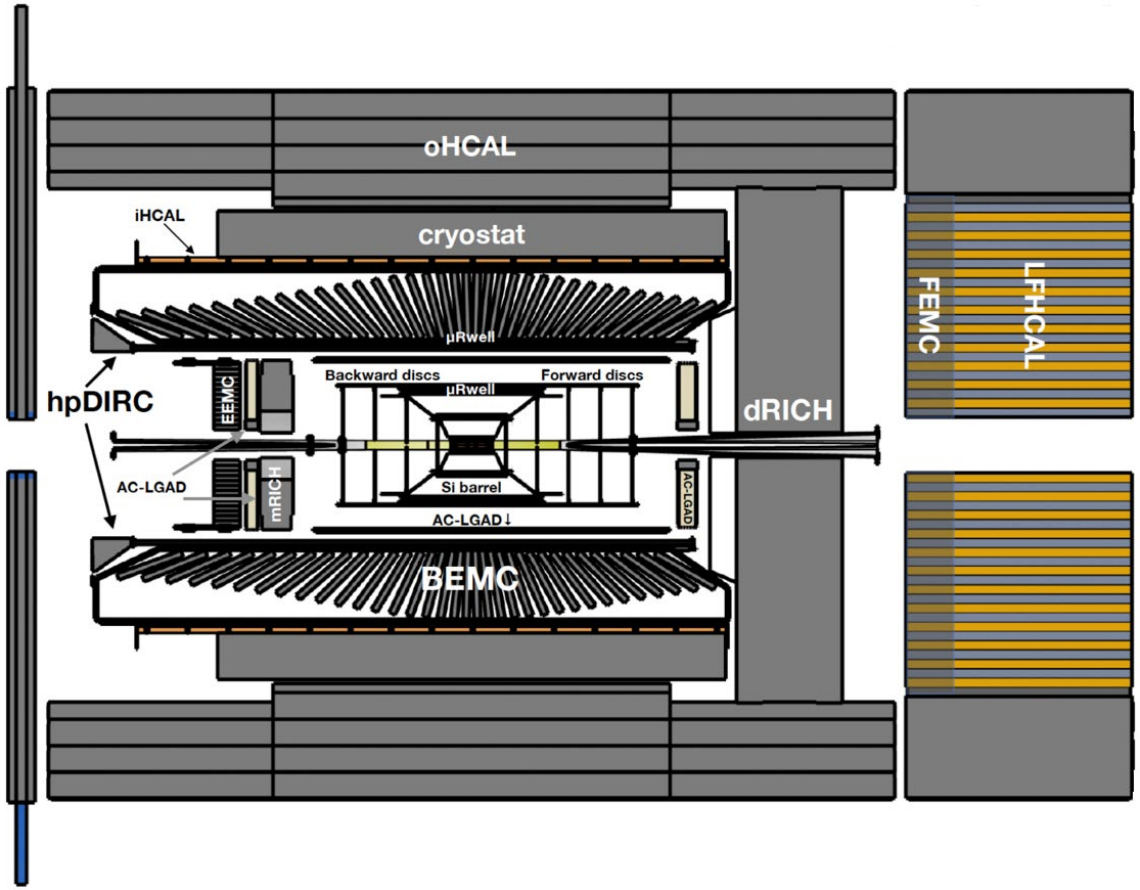
This process must be driven by physics performance!

Key items under consideration by Det1 WG's



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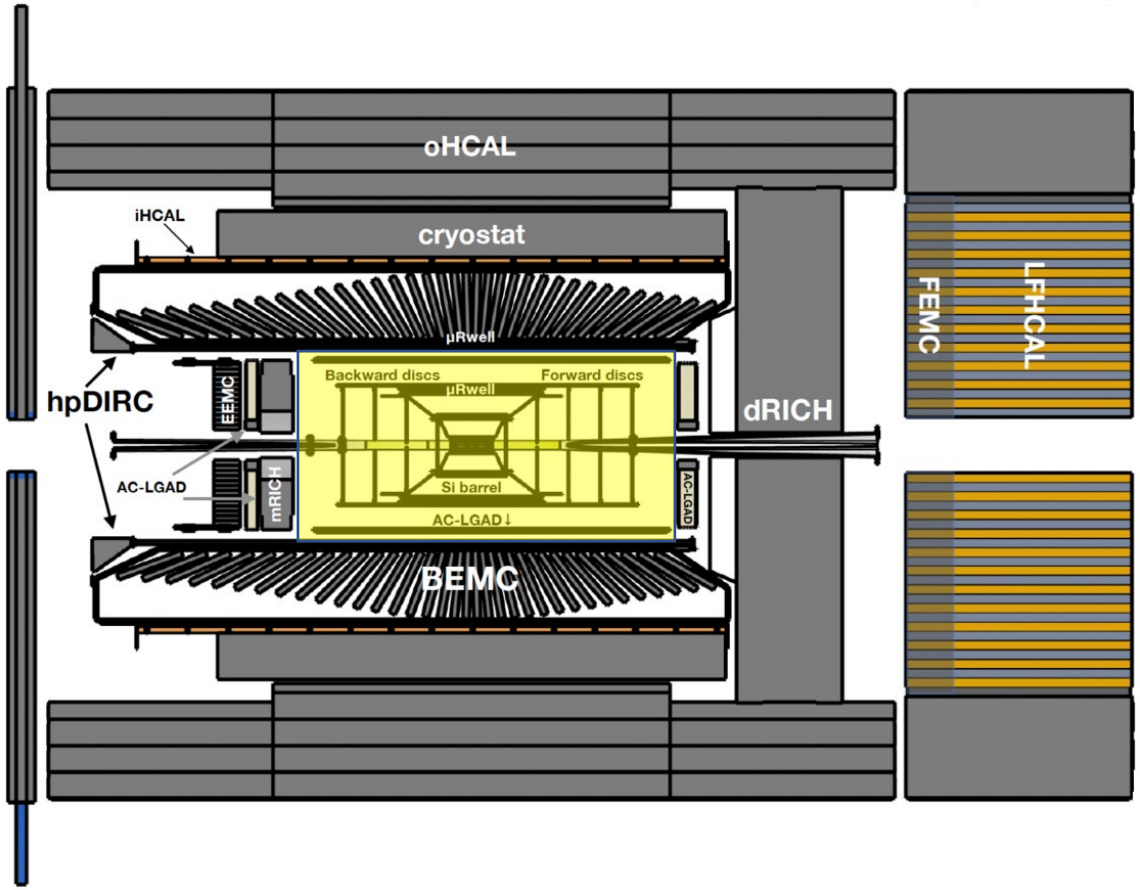

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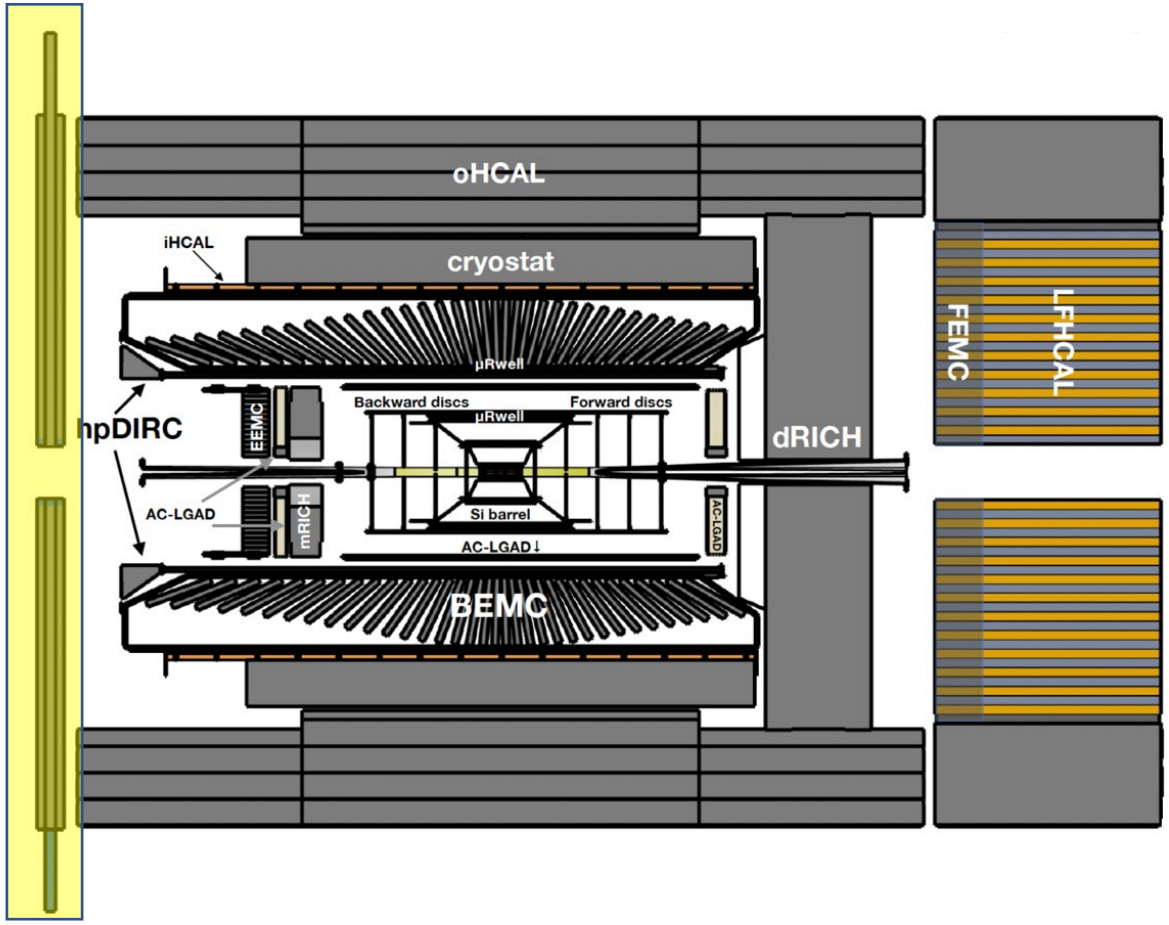

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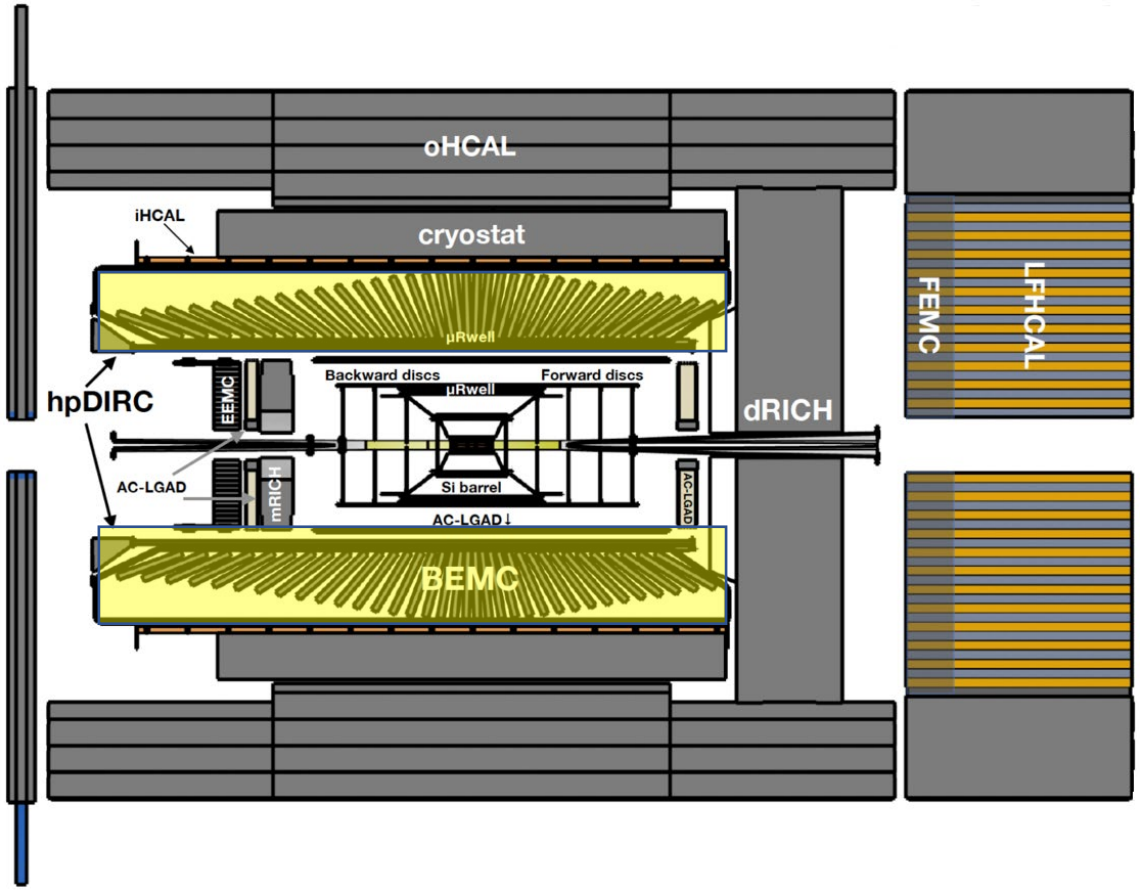

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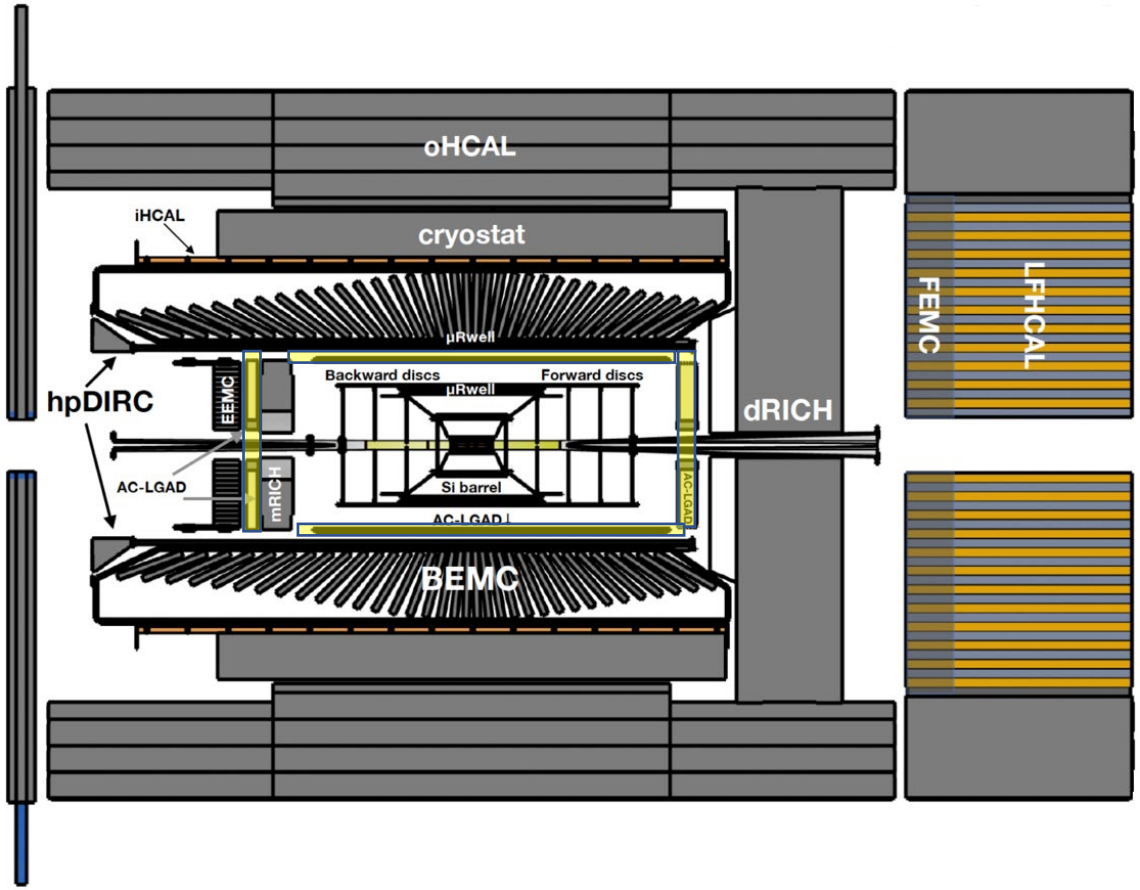

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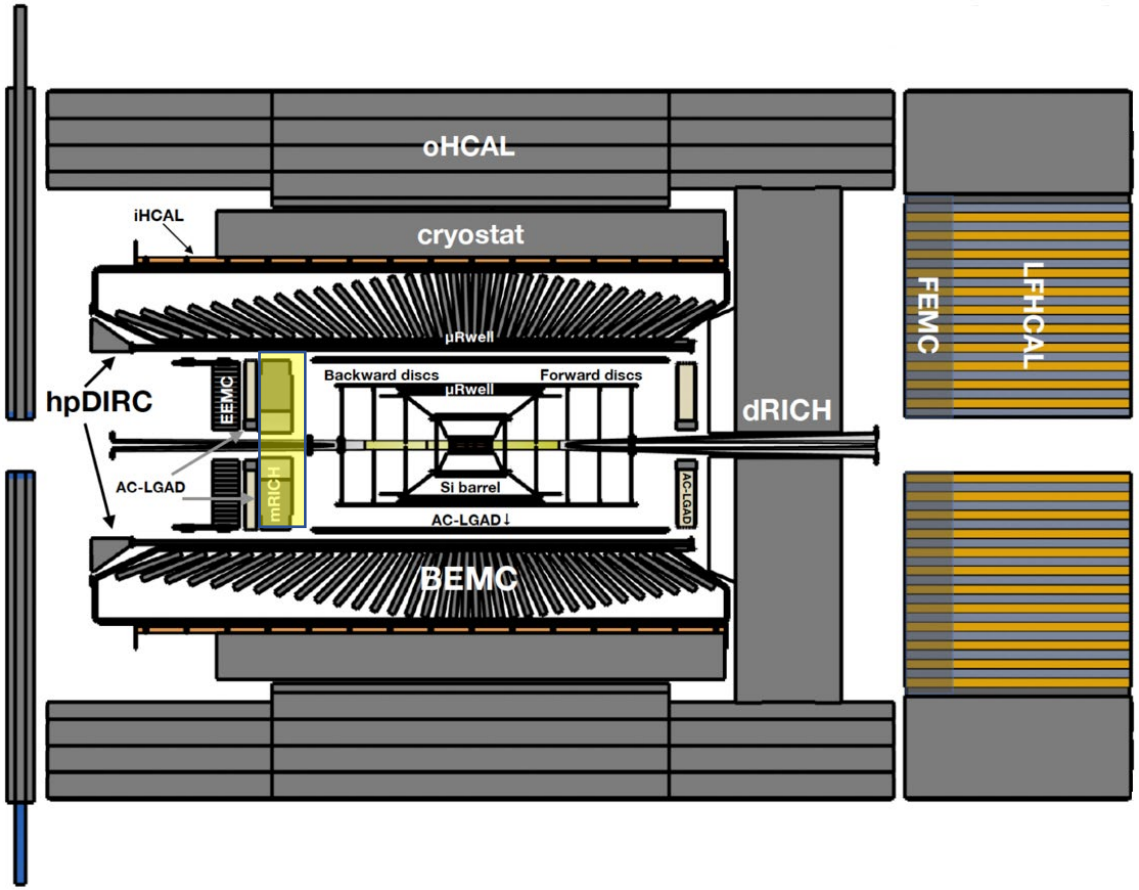

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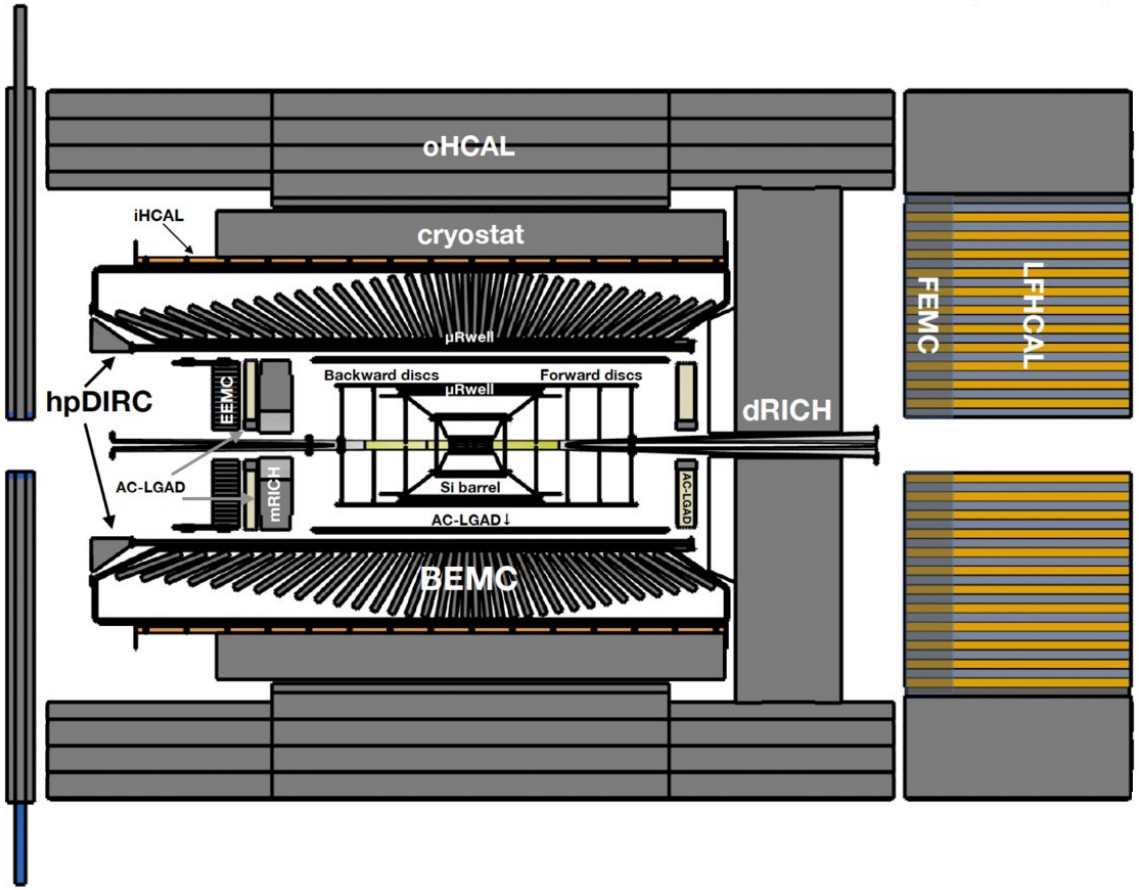

This process must be driven by the physics performance!

Iterative process between DWG's, PWG's and GD/I WG

Vision of Collaboration Forming Process

- Vision for a collaboration forming process:
  - Institutional Survey: Next slide!
  - Formation of a ~~prelim. IB~~ (inst. representatives)
  - Nomination & Formation of Bylaws/Charter Committee
  - Formulation & Adoption of Bylaws/Charter
  - Nomination & Election Process of Detector 1 Leadership
  - Finalization of IB and Election of IB Chair
  - Election of Spokesperson(s)

Elected at the same time!

EIC Detector 1 Institutional Survey Form

Timescale:

Done

ASAP

Now -> JULY

EICUG Meeting Discussion (approval in months following mtg)

Set by adoption of bylaws – perhaps Sept/Oct?

EIC Detector 1 General Meeting
Philadelphia, PA, May 13, 2022

From 5/13 – B. Surrow presentation

Goal is to expedite the formation of the collaboration with elected leadership!

Vision of Collaboration Forming Process

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Elected at the same time!

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Many more details to follow at June 24th Det1 General Meeting

https://indico.bnl.gov/event/16017/

EIC Detector 1 Institutional Survey Form

Timescale:

Done

g

onths

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row

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Detector-1 Collaboration Formation

- EICUG Annual Meeting
  July 26-30, 2022
  - Early Career meeting July 24-25th
- Detector 1 Dedicated Meeting:
  - July 27th (half day), 28th
  - Scientific program focused on Det1
  - Collaboration formation:
    - IB Meeting Session
    - Open discussion on bylaws/charter

The July meeting will kick off the start of the official Detector-1 collaboration. Following this meeting the Det1 institutions will continue in the fall with the approval of the charter and elections for leadership positions.

What creates systematic limitations?

- Things you need to correct for, but can't directly measure or can't measure as well as you would like:
  - PID unfolding for flavor separated measurements
    - … across multiple detector systems!
  - MCEG Tune dependence
  - Radiative corrections
  - Finer statistics allow for finer binning, which then requires much higher MC statistics for unfolding detector effects
  - Luminosity/Relative luminosity
  - Polarization
  - Backgrounds/Radiation in detector
  - … (lots of additional items on this list)

See Tues afternoon/
Wed morning talks

EIC, Det1 and BSM Physics

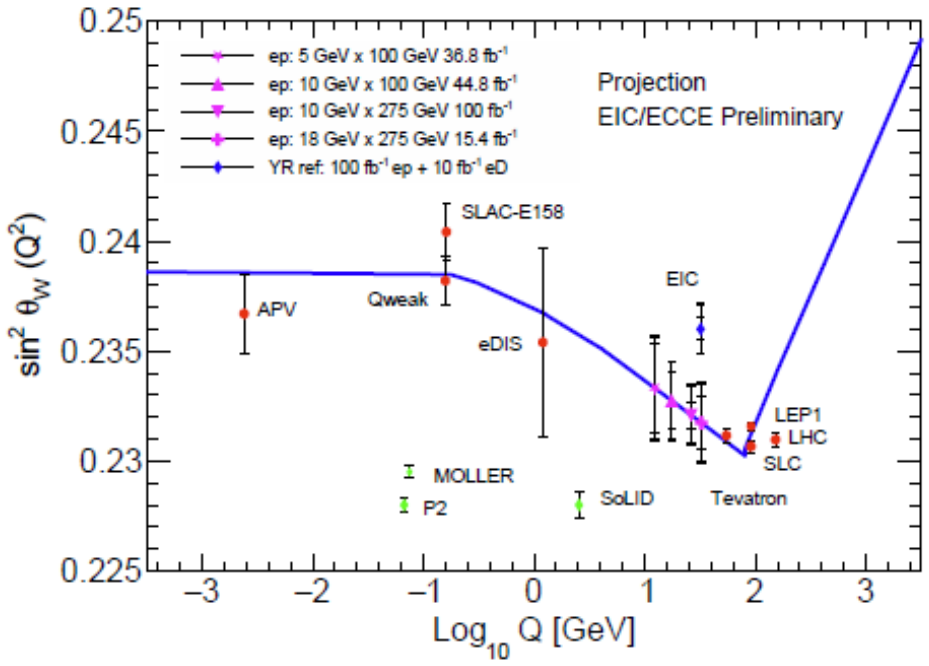
arXiv:2204.07557v2

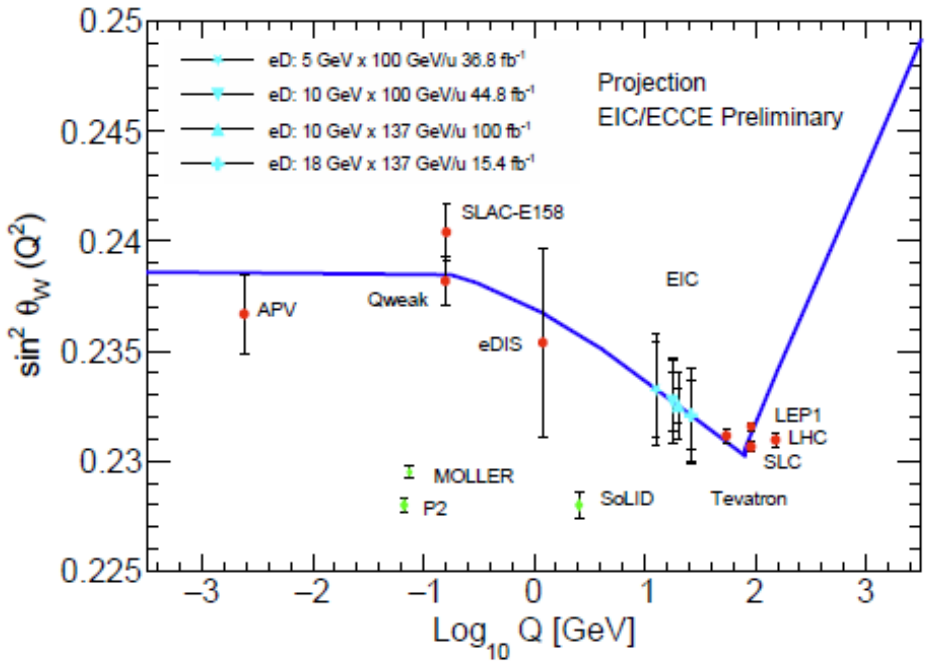
Neutral-Current Electroweak Physics and SMEFT Studies at the EIC

Radja Boughezal[1], Alexander Emmert[2], Tyler Kutz[3], Sonny Mantry[4], Michael Nycz[2], Frank Petriello[1,5], Kağan Şimşek[5], Daniel Wiegand[5], Xiaochao Zheng[2]

[1] *Argonne National Laboratory, Lemont, IL, USA*
[2] *University of Virginia, Charlottesville, VA, USA*
[3] *Massachusetts Institute of Technology, Cambridge, MA, USA*
[4] *University of North Georgia, Dahlonega, GA, USA*
[5] *Northwestern University, Evanston, IL, USA*

We study the potential for precision electroweak (EW) measurements and beyond-the-Standard Model (BSM) searches using cross-section asymmetries in neutral-current (NC) deep inelastic scattering at the electron-ion collider (EIC). Our analysis uses a complete and realistic accounting of systematic errors from both theory and experiment and considers the potential of both proton and deuteron beams for a wide range of energies and luminosities. We also consider what can be learned from a possible future positron beam and a potential ten-fold luminosity upgrade of the EIC beyond its initial decade of running. We use the SM effective field theory (SMEFT) framework to parameterize BSM effects and focus on semi-leptonic four-fermion operators, whereas for our precision EW study, we determine how well the EIC can measure the weak mixing angle. New features of our study include the use of an up-to-date detector design of EIC Comprehensive Chromodynamics Experiment (ECCE) and accurate running conditions of the EIC, the simultaneous fitting of beam polarization uncertainties and Wilson coefficients to improve the sensitivity to SMEFT operators, and the inclusion of the weak mixing angle running in our fit template. We find that the EIC can probe BSM operators at scales competitive with and in many cases exceeding LHC Drell-Yan bounds while simultaneously not suffering from degeneracies between Wilson coefficients.





See also:
Michael Nycz (Tues)
Jinlong Zhang (Wed)

Extraction of $sin^2\theta_w$ already limited by ~1% electron polarization scale error!

HL-EIC, Det1 and BSM Physics

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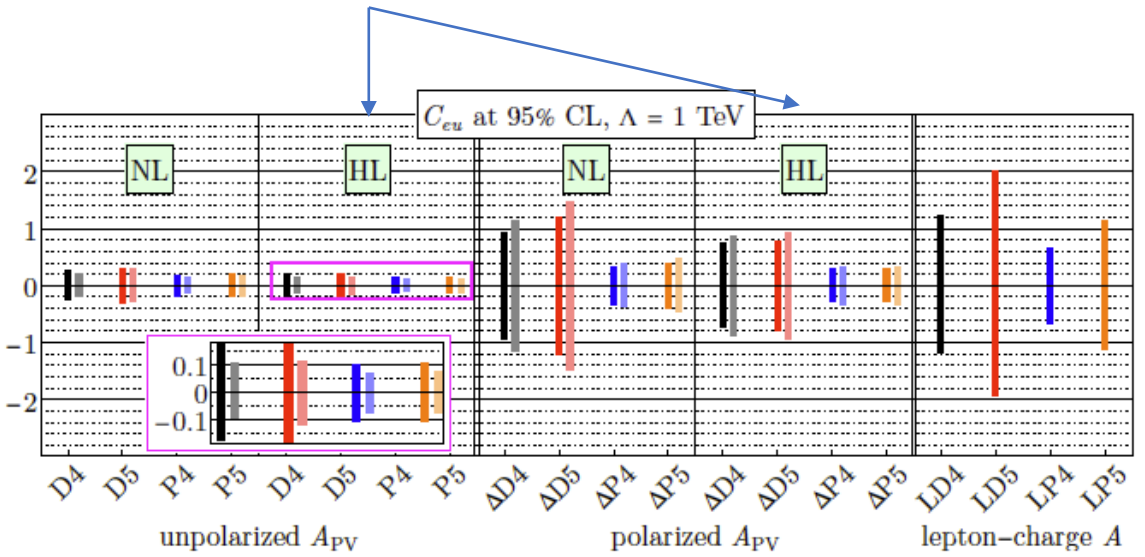
HL = 10 x EIC

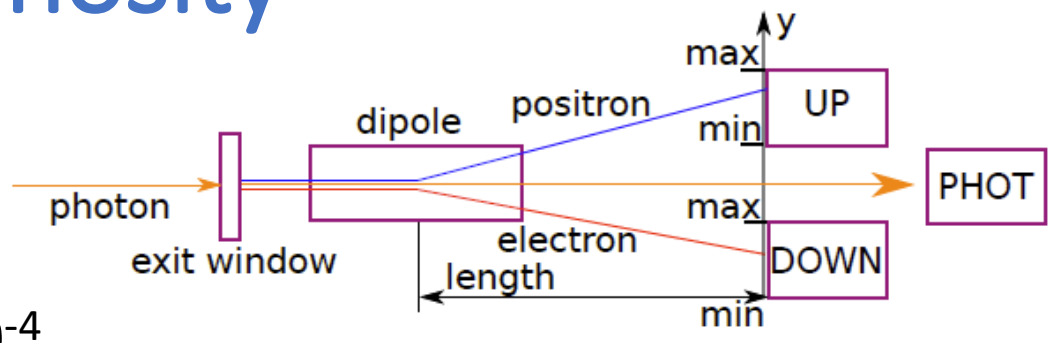


Attempt to reduce effect of P_e systematic error by simultaneously fitting P_e and Wilson coefficients – but this introduces correlations between the two!

See also:
Kagan Simsek (Tues)

Luminosity/Relative Luminosity

EIC YR Fig 11.112



- Builds on HERA experience
  - Achieved 1.7% scale uncertainty, EIC goal is ~1%
- Precision required for relative lumi. ~10^{-4}
  - Set by asymmetry measurement requirements
  - As both beams are polarized, bremsstrahlung rate depends on spin state:

$$\sigma_{brems} = \sigma_0(1 + aP_eP_h)$$

  - This couples the P_e, P_h and luminosity measurements (!)
  - Goal for $P_{e,h}$ systematic ~ 1%

See Thurs talks from:
Dave Gaskell
Jaroslav Adam

- It will be a challenge to improve the relative luminosity measurement to a level that allows statistical improvement in the asymmetry measurements at an HL-EIC

Detector Backgrounds/Radiation

- Three types of background/radiation sources we need to worry about:
  - Primary collisions
  - Synchrotron radiation
  - Beam-gas induced
- All of these couple with the beam parameters
  - Divergence, energy spread, crossing angle, bunch length

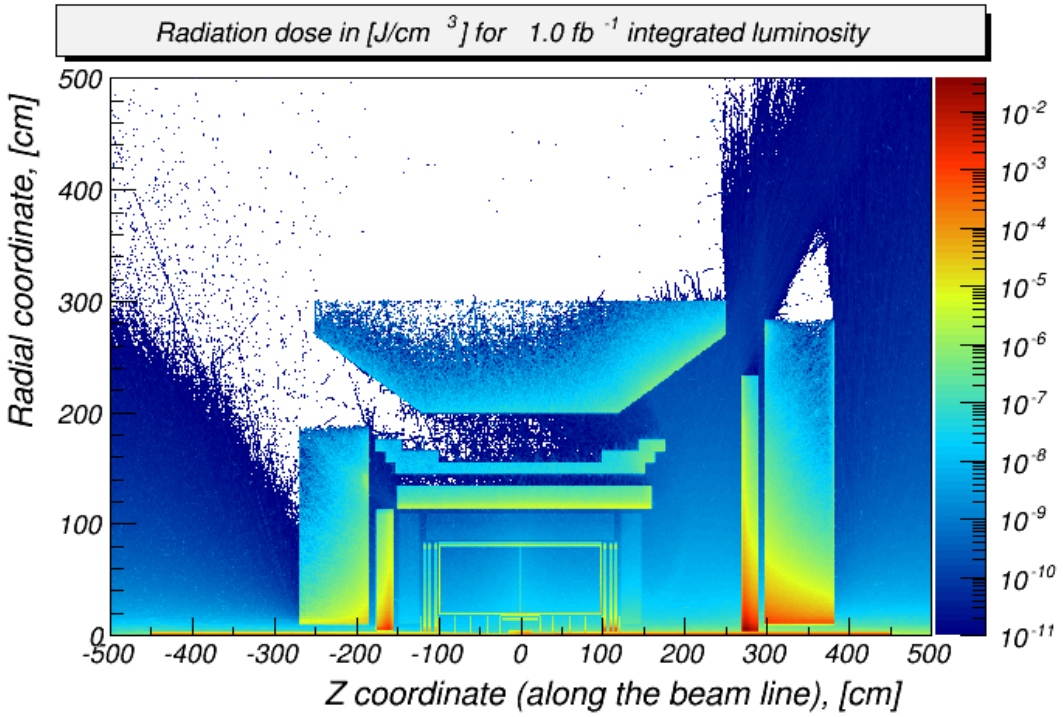
Excellent set of talks in Jun 16 Det1 Tracking WG meeting: https://indico.bnl.gov/event/15821/

- Why are these “bad”?
  - Detector occupancy
    - Additional hits in detectors (especially for the tracker vertexing layers)
    - Affects PID detectors due to scattering and secondary interactions
  - Detector lifetime (radiation damage)

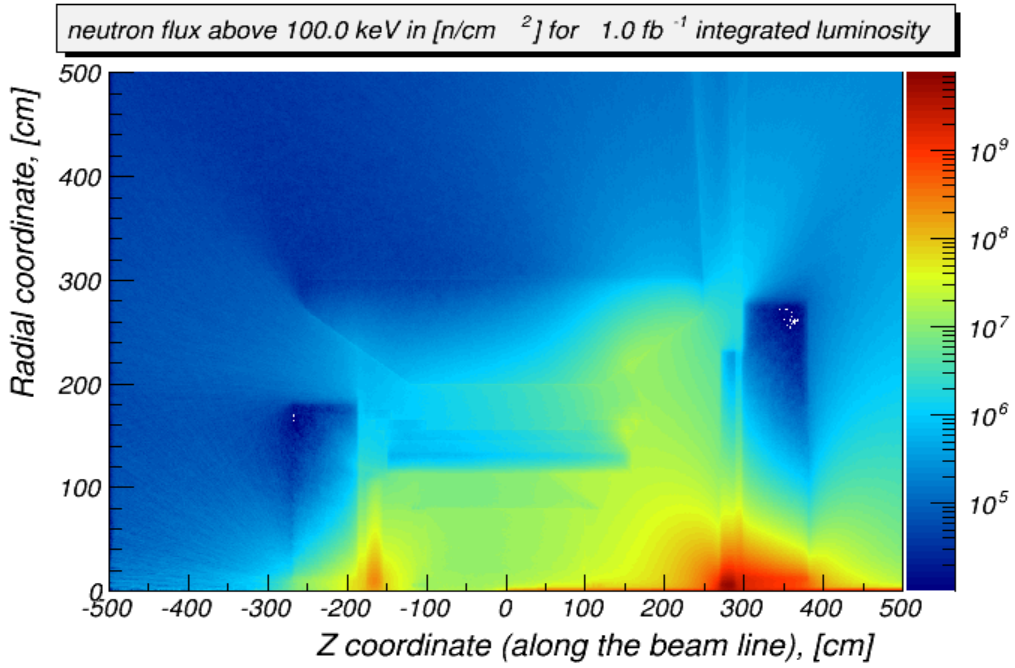
Primary Collisions

Neutron fluence studies require validation and are sensitive to the simulation framework and the detector design!

- Primary source of *ionizing radiation* and *low energy neutrons*



→ backward EmCal: ~250 rad/year (at a luminosity ~10^{33} cm^{-2} s^{-1})

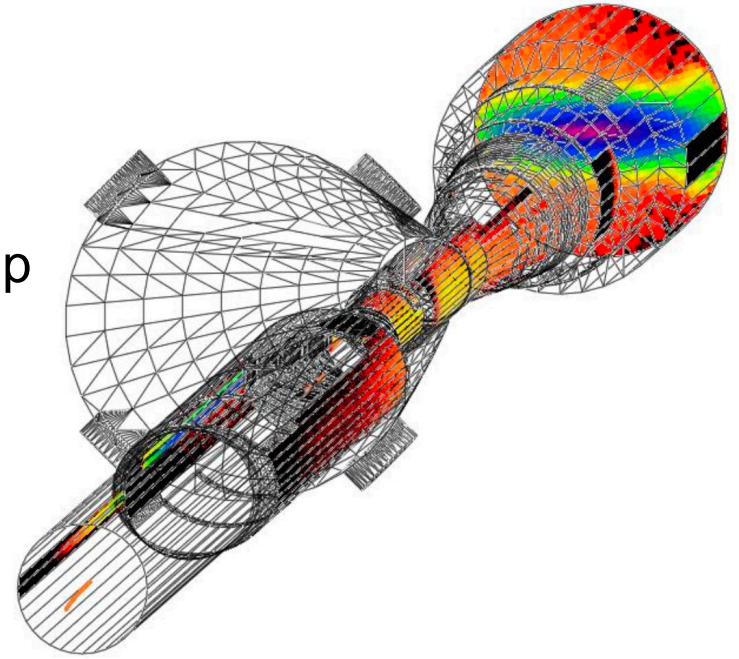


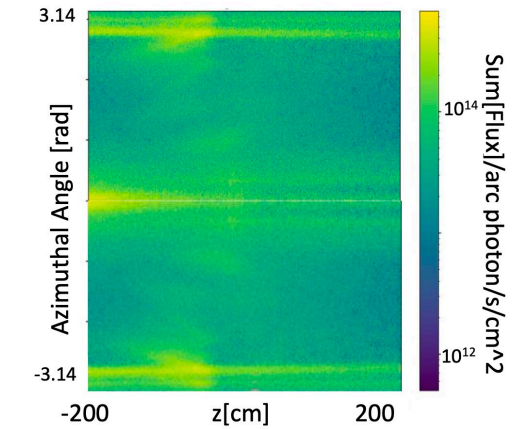
→ forward EmCal: up to ~5*10^9 n/cm^2 per fb^{-1} (*inside the towers*); perhaps ~5 less at the SiPM location

(figures from E. Aschenauer)

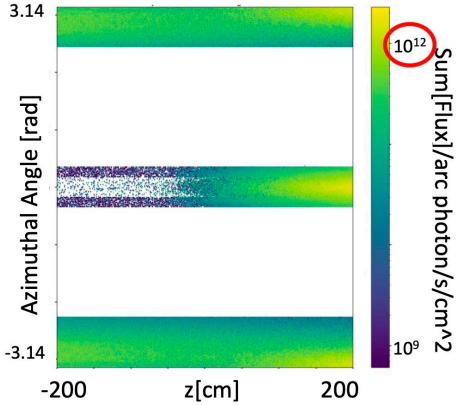
Synchrotron Radiation

- Extensive simulations by of SR by accelerator background WG group
  - SynRad+ modeling software
  - Input:
    - 3D model of beampipe
    - Beam emittance, current Magnet locations and fields
  - Output:
    - Synchrotron Radiation – Position, Flux, Energy, Direction
- Synchrotron Radiation Mitigation
  - Photon absorber configuration:
  - Wider beam pipe for
    - 13.5 σ clearance in x
    - 23 σ clearance in y
  - Beampipe material/structure
    - 2-5 μm Au coating
    - Sawtooth/ridge texture for photon absorption





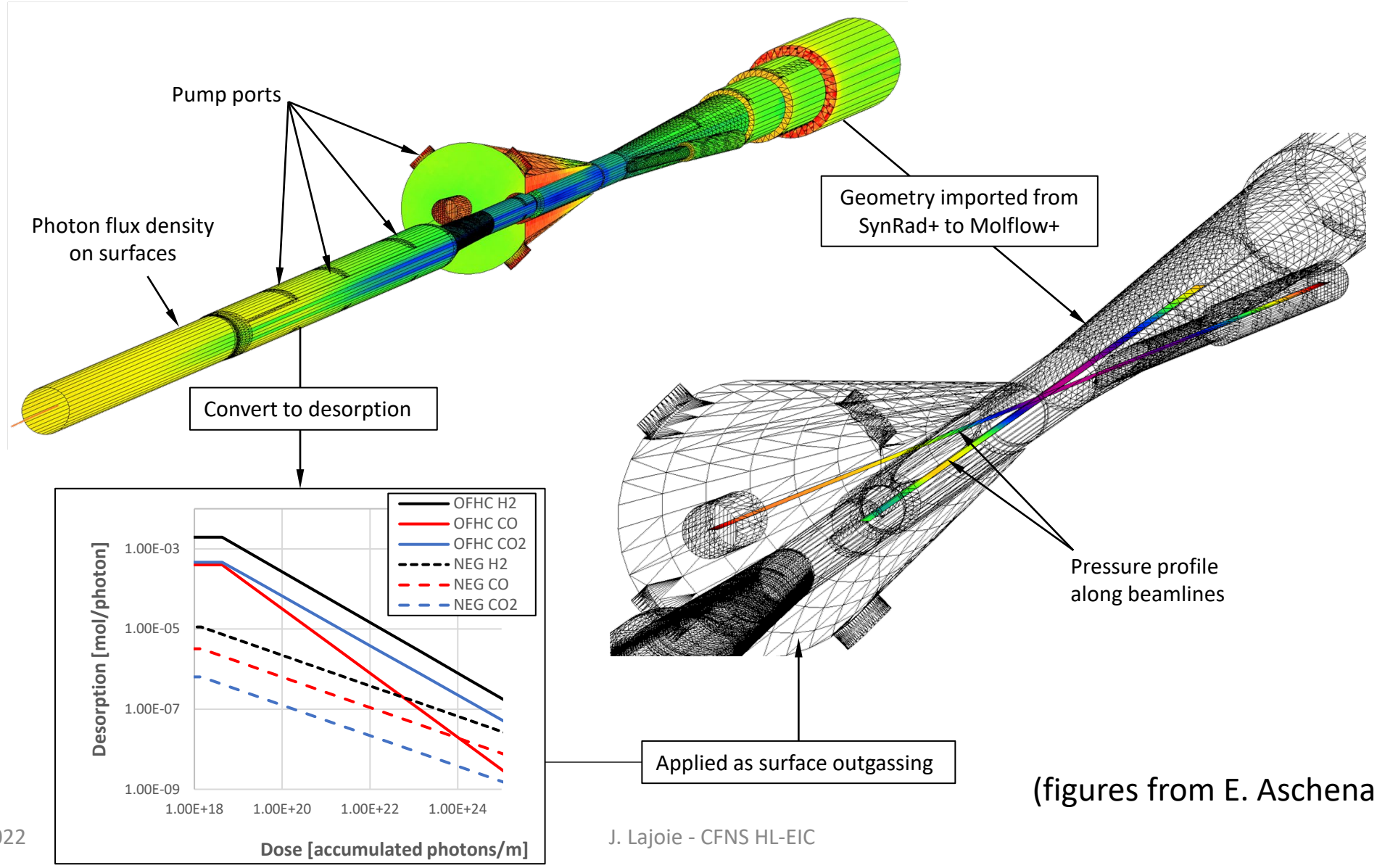
Photon flux incident on vacuum chamber
10 GeV, photons > **10 eV**



Photon flux incident on vacuum chamber
10 GeV, Photons > **5 keV**
which can penetrate gold
Flux drops by ~1000x

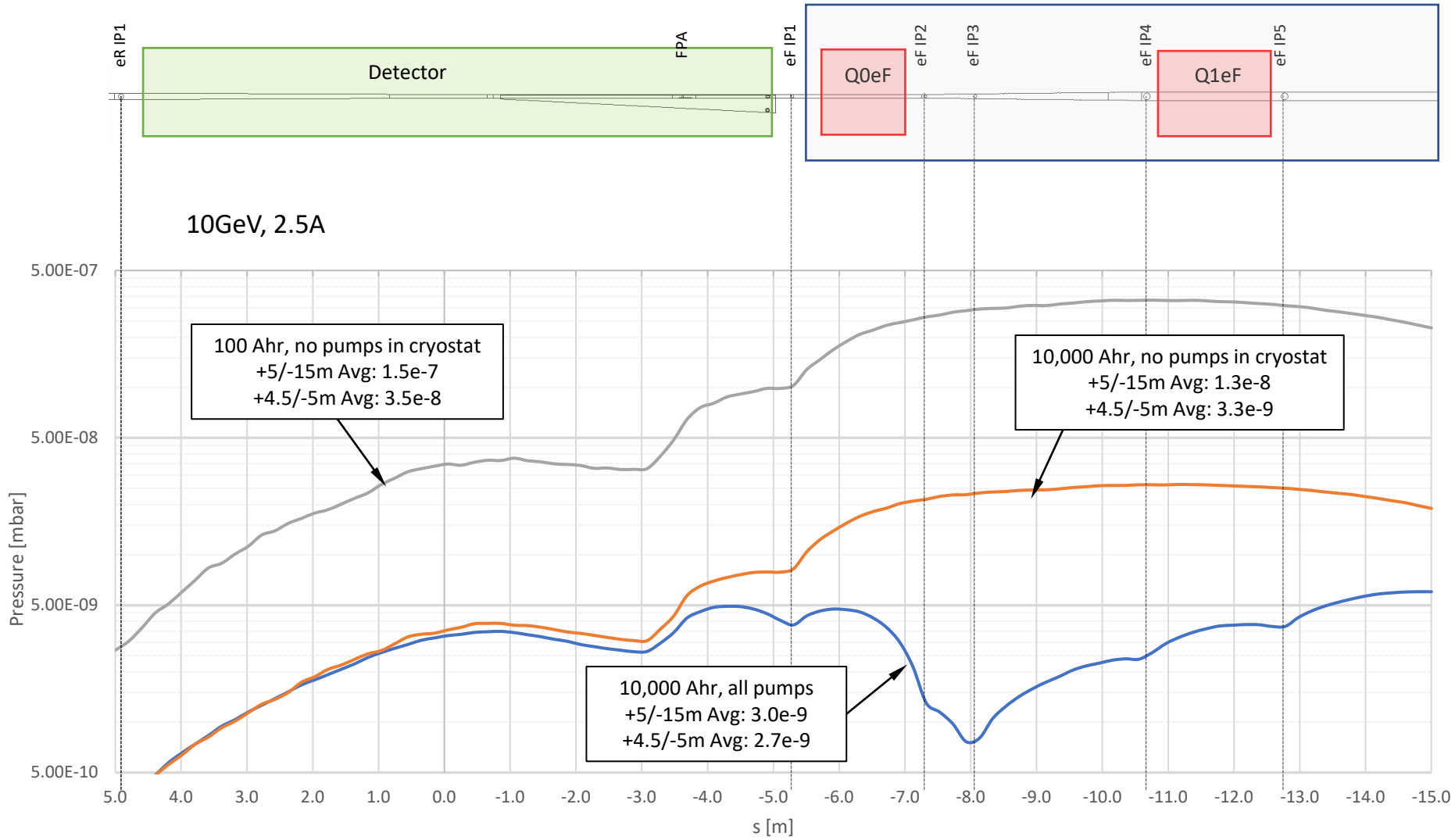
(figures from E. Aschenauer)

Synchrotron Radiation and Desorption



(figures from E. Aschenauer)

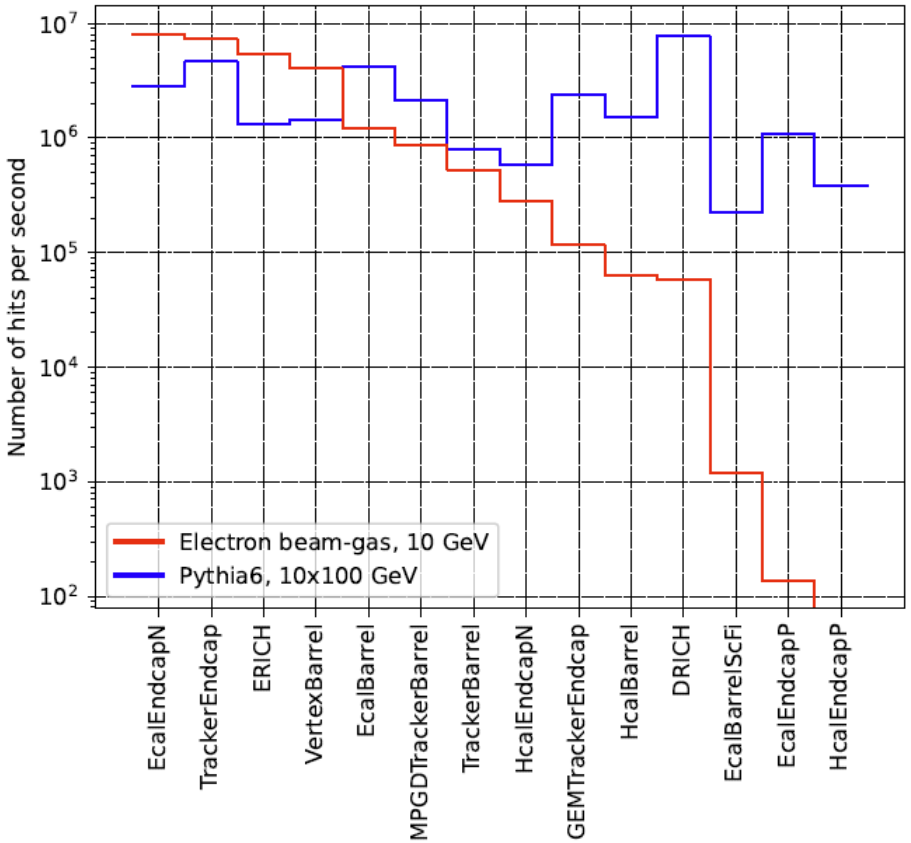
Pressure in Forward Cryostat



(figures from E. Aschenauer)

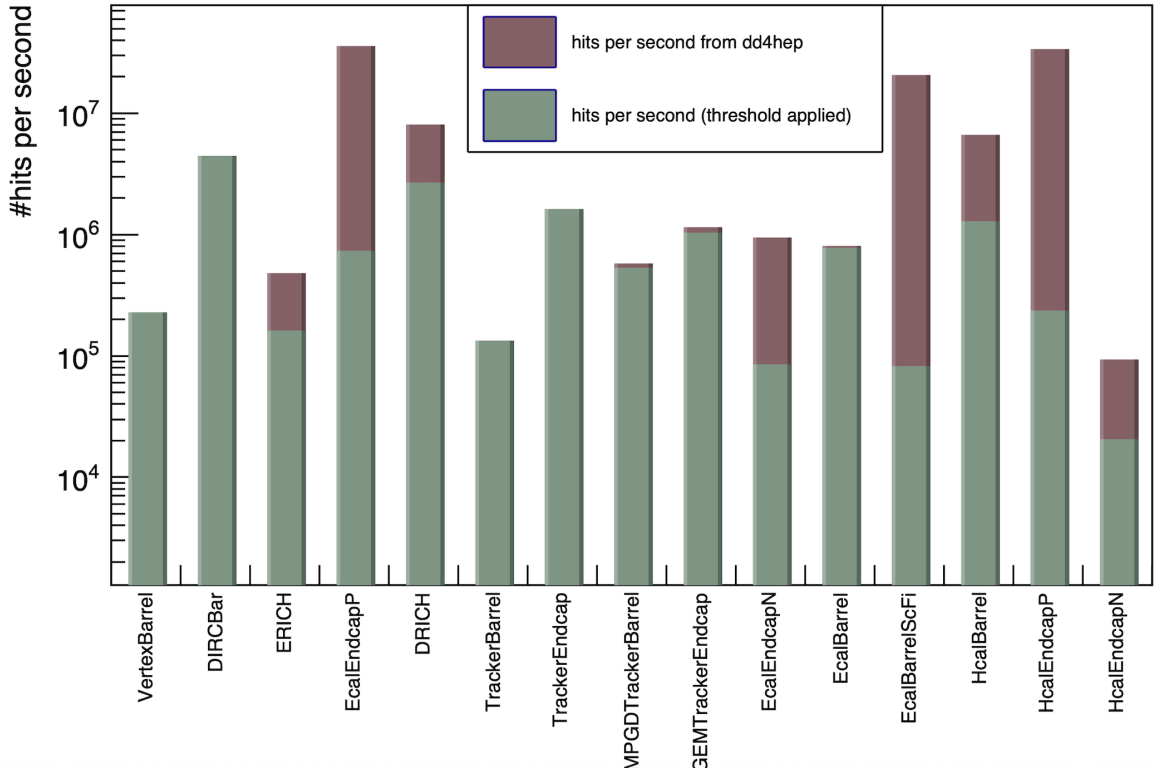
Beam-Gas Consequences

Electron Beam: $\mathrm{e} + H^2 \rightarrow e' + \gamma + H^2$



ATHENA study by Jaroslav Adam (BNL)

Proton Beam: $\mathrm{p/A} + H^2 \rightarrow stuff$



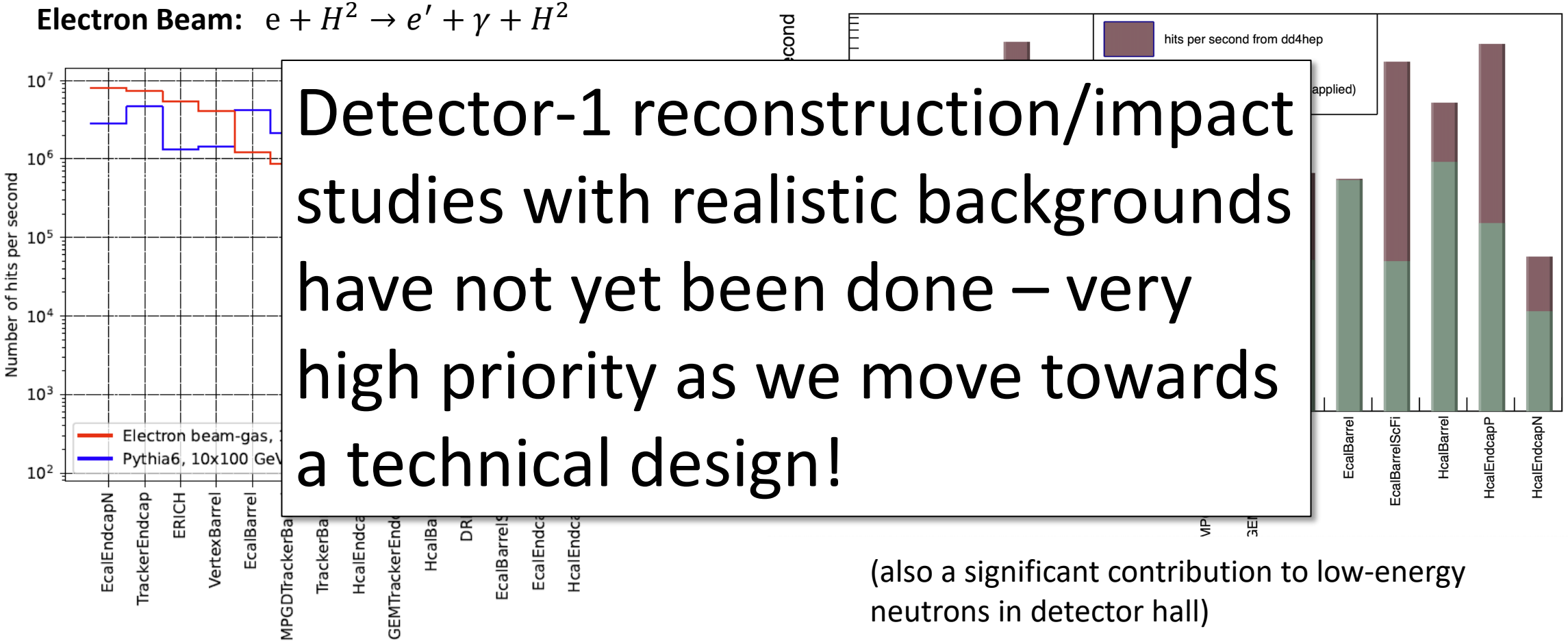
(also a significant contribution to low-energy neutrons in detector hall)

ATHENA study by Zhengqiao Zhang (BNL)

Beam-Gas Consequences

Proton Beam: $\mathrm{p/A} + H^2 \rightarrow stuff$

Electron Beam: $\mathrm{e} + H^2 \rightarrow e' + \gamma + H^2$



Detector-1 reconstruction/impact studies with realistic backgrounds have not yet been done – very high priority as we move towards a technical design!

(also a significant contribution to low-energy neutrons in detector hall)

ATHENA study by Jaroslav Adam (BNL)

ATHENA study by Zhengqiao Zhang (BNL)

Conclusions

- The process of developing the EIC Det1 is really just maturing
  - EIC detectors are an enormous undertaking that will require participation and expertise from both the RHIC and JLab communities, as well as key international contributions!
  - Currently wrestling with EIC luminosity requirements, 10xEIC will require a lot of thought and work
- The “Detector-1” Collaboration effort has kicked-off:
  - Collaboration formation meeting July 27-28th , preparatory work ongoing
- A detector at the HL-EIC will have to contend with a number of issues:
  - Need for improved polarization systematic (P_e)
  - Luminosity/Rel. Luminosity measurement requirements
  - Increased radiation dose, esp. neutrons (SiPMs)
  - Increased synchrotron radiation
  - Need for very high-quality vacuum in the machine
    - …and need for stability across runs, detector maintenance, etc.

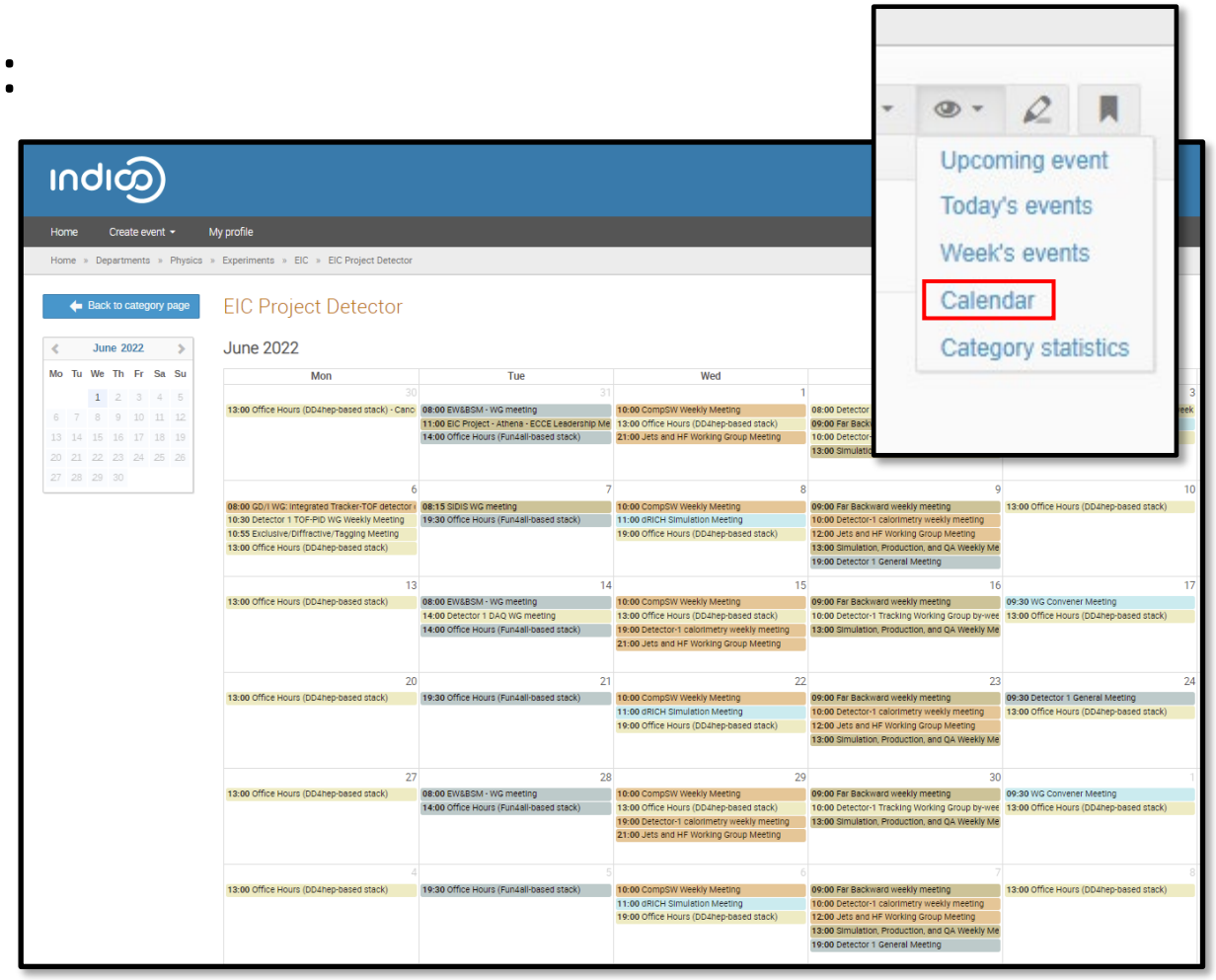

BACK UP

Detector-1 Resources

Indico calendar for all Detector-1 meetings can be connected to your calendar (View->Calendar)

- New Indico section for Detector-1 WG's:
  - https://indico.bnl.gov/category/402/
- New mailing lists (lists.bnl.gov)

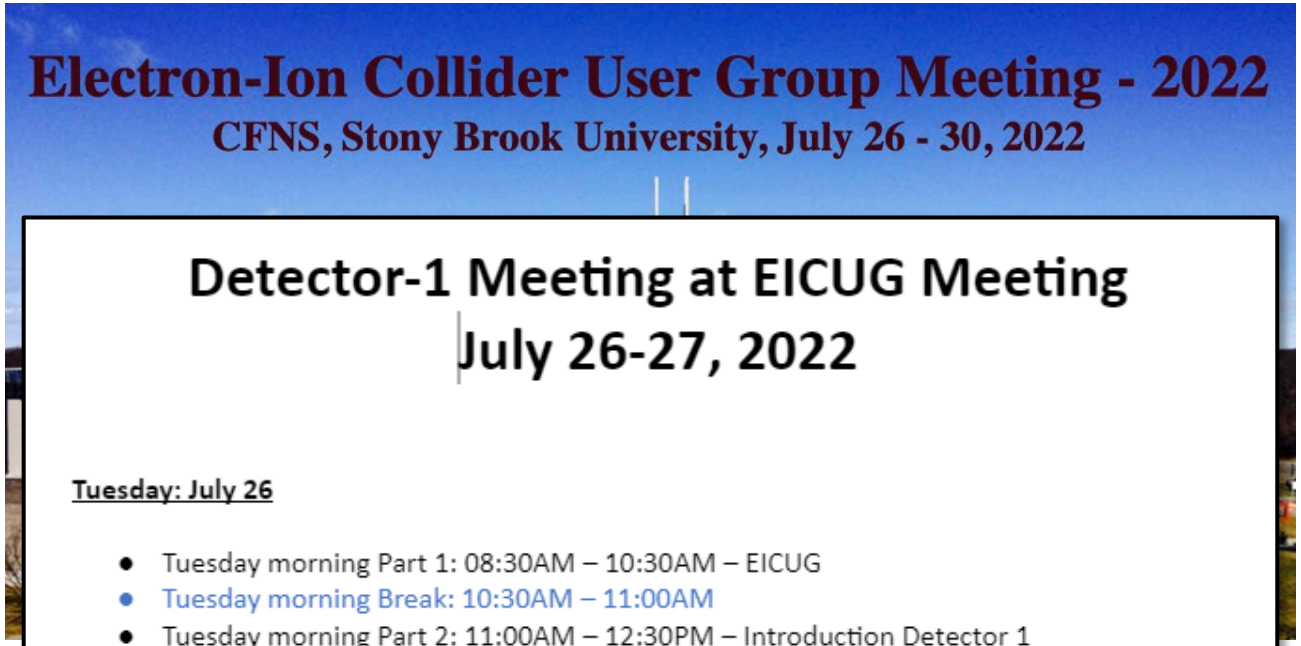
eic-projdet-SimQA-l@lists.bnl.gov
eic-projdet-FarBack-l@lists.bnl.gov
eic-projdet-daq-l@lists.bnl.gov
eic-projdet-FarForw-l@lists.bnl.gov
eic-projdet-CompSW-l@lists.bnl.gov
eic-projdet-Inclusive-l@lists.bnl.gov
eic-projdet-JetHF-l@lists.bnl.gov
eic-projdet-GlobalInt-l@lists.bnl.gov
eic-projdet-TOFPID-l@lists.bnl.gov
eic-projdet-calo-l@lists.bnl.gov
eic-projdet-ExclDiff-l@lists.bnl.gov
eic-projdet-SemiIncl-l@lists.bnl.gov
eic-projdet-BSMEW-l@lists.bnl.gov
eic-projdet-CPID-l@lists.bnl.gov
eic-projdet-tracking-l@lists.bnl.gov



- Additional Collaboration resources available:
  - Wiki, Mattermost, etc.

EICUG Det1. Agenda

- EICUG Annual Meeting
  July 26-30, 2022
  - Early Career meeting July 25th
- Detector 1 Dedicated sessions:
  - July 26th (half day), 27th
  - Scientific program focused on Det1
    - Be prepared for WG presentations
    - WG conveners are encouraged to attend in-person if possible
  - Collaboration formation:
    - IB Meeting Session
    - Open discussion on bylaws/charter



Electron-Ion Collider User Group Meeting - 2022
CFNS, Stony Brook University, July 26 - 30, 2022

Detector-1 Meeting at EICUG Meeting
July 26-27, 2022

Tuesday: July 26

- Tuesday morning Part 1: 08:30AM – 10:30AM – EICUG
- Tuesday morning Break: 10:30AM – 11:00AM
- Tuesday morning Part 2: 11:00AM – 12:30PM – Introduction Detector 1
- Tuesday Lunch: 12:30PM – 02:00PM
- Tuesday afternoon: 02:00PM – 03:30PM WG part 1 (Detector)
- Tuesday afternoon Break: 03:30AM – 04:00PM
- Tuesday afternoon: 04:00PM – 05:30PM WG part 2 (Detector)

Wednesday: July 27

- Wednesday morning Part 1: 09:30 AM – 10:30 AM – IB meeting
- Wednesday morning Break: 10:30 AM – 11:00 AM
- Wednesday morning Part 2: 11:00 AM – 12:30 PM – IB meeting
- Wednesday Lunch: 12:30 PM – 02:00 PM
- Wednesday afternoon: 02:00 PM – 03:30 PM WG part 3 (Physics)
- Wednesday afternoon Break: 03:30 PM – 04:00 PM
- Wednesday afternoon Part 2: 04:00PM – 05:30PM GD/I Detector-1 Summary & Discussion

Note: No parallel session since the focus of the meeting is the formation of a new collaboration!