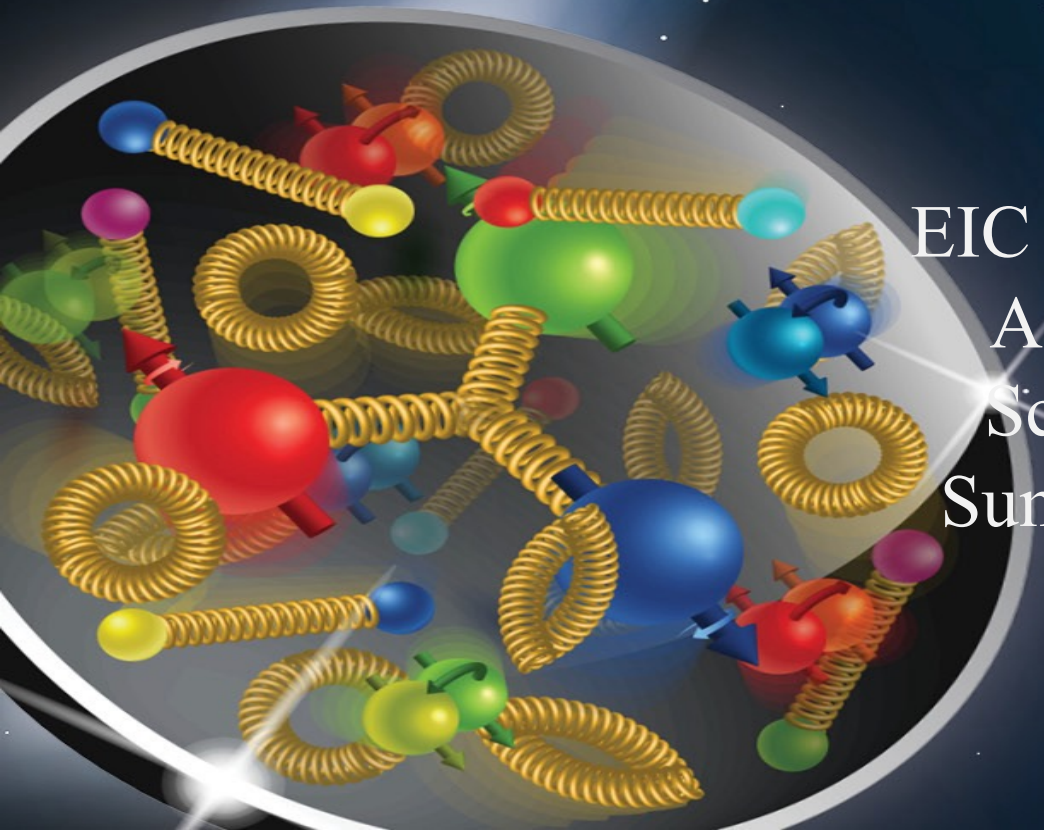
AC-LGAD R&D for EIC – eRD112



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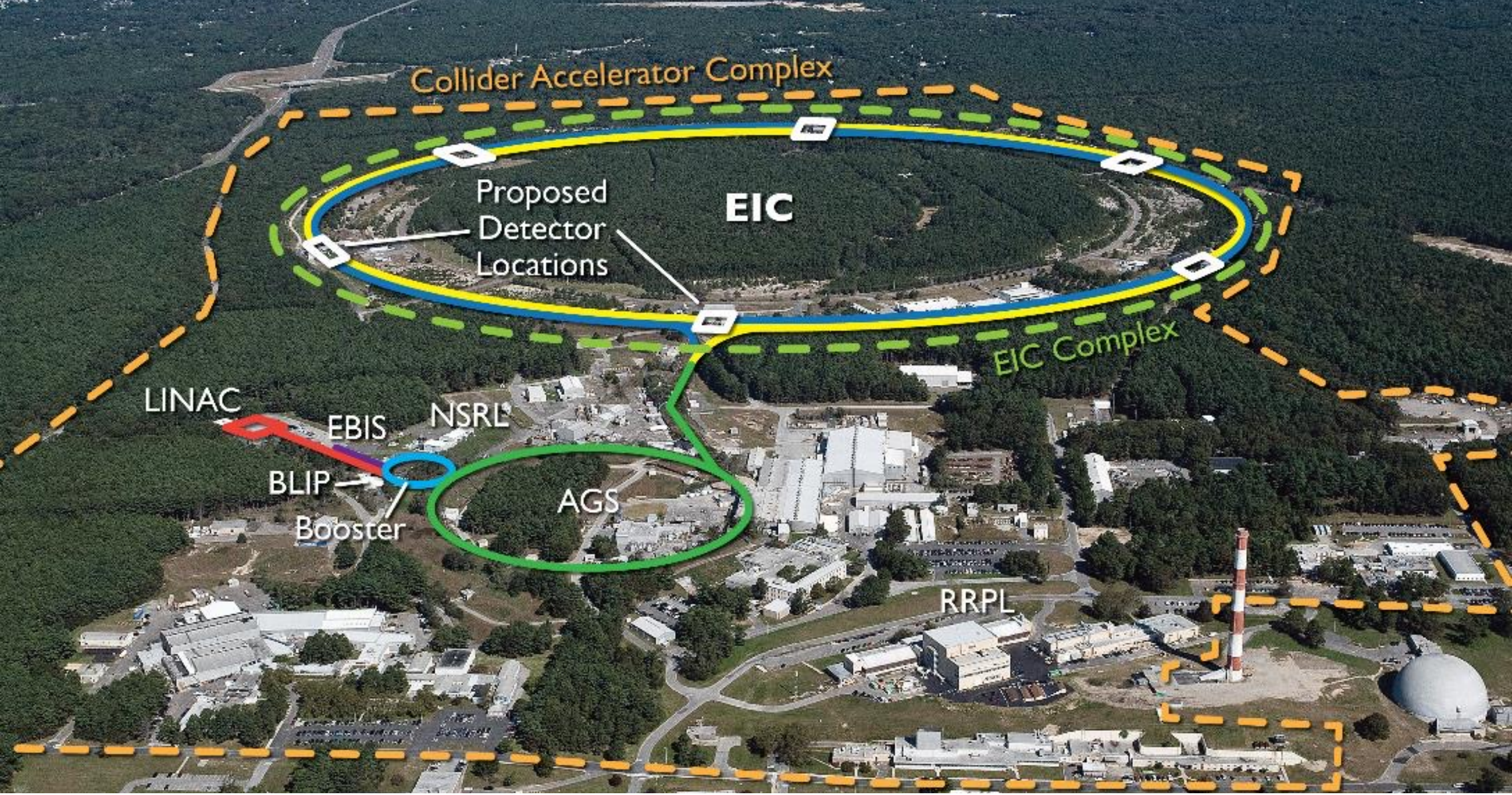
Electron-Ion Collider

BROOKHAVEN NATIONAL LABORATORY

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

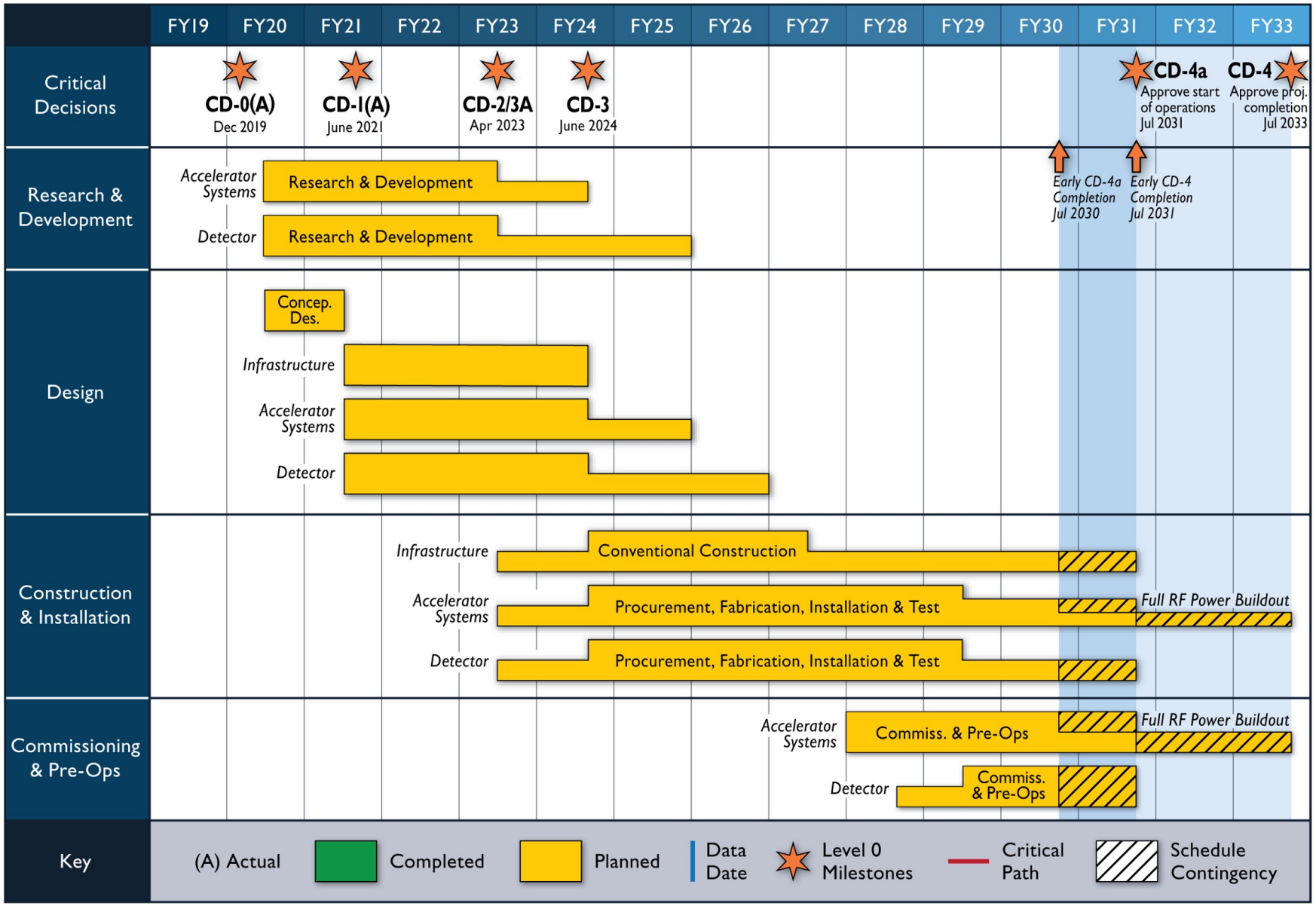


RHIC will conclude operations in 2025. EIC installation will begin after RHIC ops conclude

Total Project Cost @ CD-1 (Approved June 29, 2021)

WBS	Description	WBS Manager	Total M$	DOE M$
6	**Electron-Ion Collider**	**J. Yeck**	**$ 1,751**	**$ 1,509**
6.01	Project Management	D. Hatton	$ 97	$ 97
6.02	Accelerator Dev & R&D	M. Blaskiewicz	$ 66	$ 66
6.03	Electron Injector	V. Ranjbar	$ 186	$ 161
6.04	Electron Storage Ring	C. Montag	$ 293	$ 268
6.05	Hadron Ring	V. Ptitsyn	$ 187	$ 187
6.06	Interaction Regions & Detector Interface	G. McIntyre	$ 183	$ 183
6.07	Accelerator Support Systems	J. Tuozzolo	$ 216	$ 216
6.08	Infrastructure	C. Folz	$ 203	$ 103
6.09	Pre-Operations	W. Fischer	$ 75	$ 75
6.10	EIC Detector	R. Ent	$ 245	$ 152

Reference Schedule for EIC



CD-2 – Approve Performance Baseline: Approval of the preliminary design of the project and the baseline scope, cost, and schedule. What is most relevant is that CD-2 means there is now a definitive plan that the project will be measured against in cost, schedule and technical performance.

CD-3 – Approve Start of Construction: Approval of the project's final design and authorizes release of funds for construction. What is most relevant is that projects can now proceed with construction related procurements and activities.

CD-4 – Approve Start of Operations or Project Completion: provide recognition that the project's objectives have been met. CD-4 is sometimes split in CD-4A that allows, after agreed-upon criteria for technical success have been met, for transition into operations, and CD-4B that provides the formal closeout of the project.

On Aug 18, 2021, at 12:53 PM, 'Thomas Ullrich' via EICUG Users <eicug-users@eicug.org> wrote:

Dear EIC User Group Members,

We are happy to announce that Detector R&D efforts by the EIC project for subsystems and components that are within the scope of the project to mitigate technical, cost, and schedule risk will be started for FY22.

While no detector design was selected yet and the three proto-collaborations are still working intensively on their proposals, several subsystems are of common interest and of priority for all or most detector concepts under development. R&D efforts for those subdetector technologies can start beginning of FY22. The current EIC project R&D plan for the experimental equipment can be found at: https://indico.bnl.gov/event/10974/contributions/53172.

To kick-off these efforts we selected projects that meet the criteria mentioned above:

- eRD104 Silicon Service reduction
- eRD105 SciGlass
- eRD106 Forward EMCAL
- eRD107 Forward HCAL
- eRD108 Cylindrical MPGD
- eRD110 Photosensors
- eRD111 Si-Vertex (excl. sensors)
- **eRD112 AC-LGAD**

These projects got strong endorsement from the Detector Advisory Committee and are well aligned with the R&D priorities presented at the CD-1 review. We want to emphasize that these efforts are not tied to a specific proto-collaborations but should and will include all interested in a respective subsystem technology.

To get the ball rolling we contacted several colleagues(*), mostly based on membership of the generic R&D program. We expect and request that they will invite the relevant personnel to join the effort and that they will appoint a contact person with whom we can communicate all matters concerning a specific R&D effort, and to verify the EIC project milestones are met. If you are interested in joining one of the R&D efforts listed above, please see the contact list at the end of this email.

We have asked each group to develop a short document that will detail milestones, timelines, workforce, and other needs of their efforts in FY22. Deadline for this report is no later than August 31.

Elke, Patrizia, Rolf, and Thomas

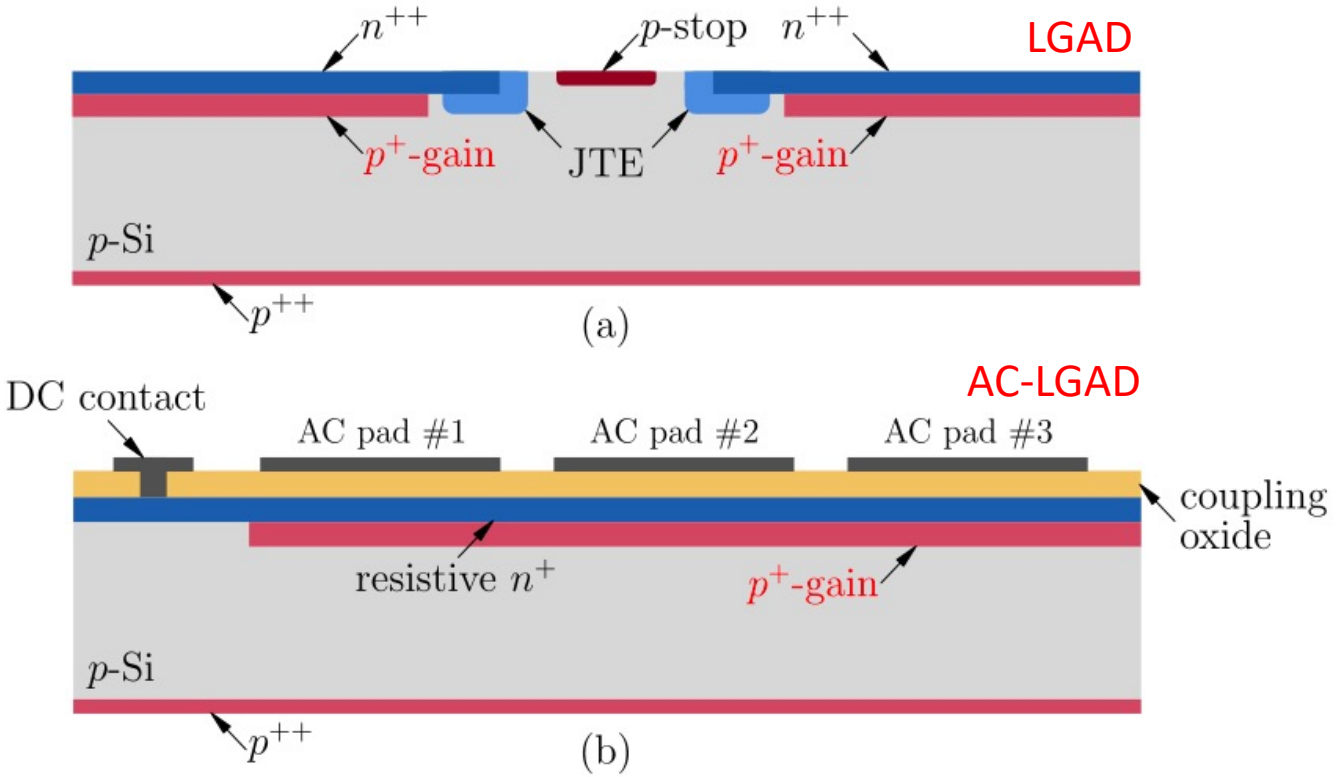
*AC-LGAD: Alessandro Tricoli (BNL), Wei Li (Rice), Frank Geurts (Rice), Zhangbu Xu (BNL), Zhenyu Ye (UIC)

AC LGAD for EIC

- Large area LGAD detectors are being built by ATLAS (6.4 m^2) and CMS (14 m^2) for data taking starting in 2026.

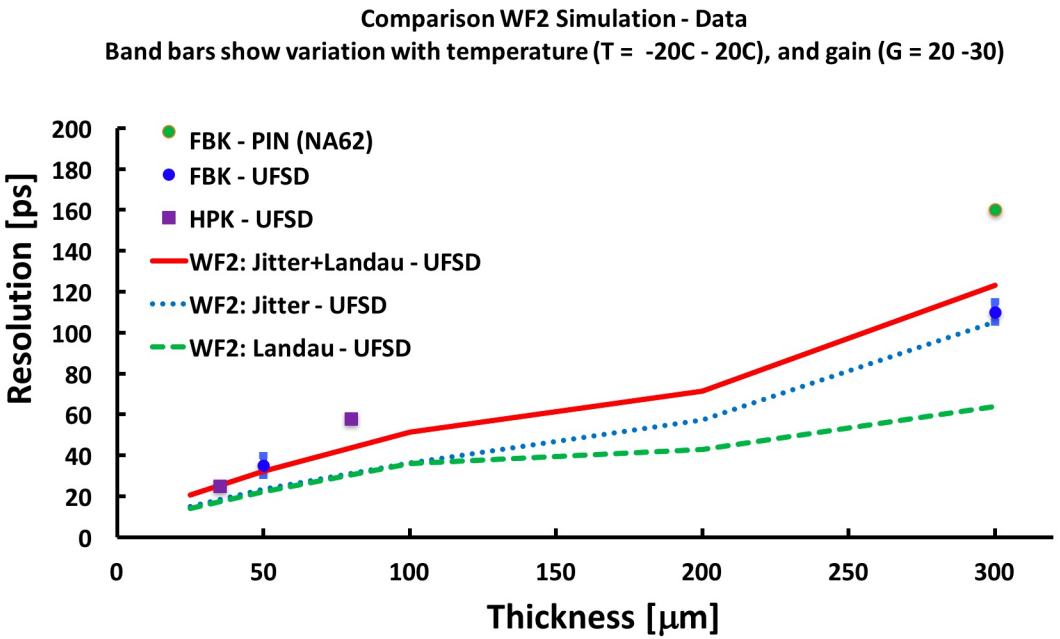
- AC LGAD detectors proposed for EIC
  - Roman Pots and B0
  - TOF for PID (and tracking)

- Have common designs in sensor, ASIC etc. when possible, combine R&D efforts

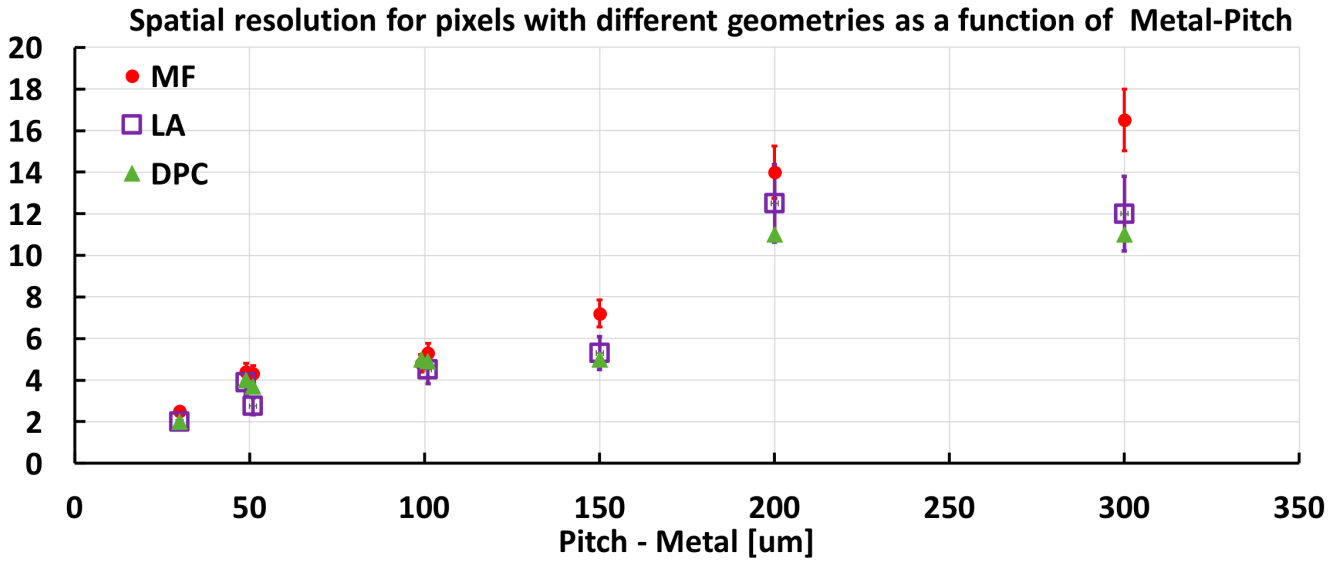


	Time resolution / hit	Position resolution / hit	Material budget / layer
Barrel ToF (Tracker)	<30 ps	(3-30 μm for Tracker)	$< 0.01\ X_0$
Endcap ToF (Tracker)	<25 ps	(30-50 μm for Tracker)	e-direction $< 0.05 X_0$ h-direction $< 0.15 X_0$
Roman Pots	<50 ps	$< 500/\sqrt{12}\ \mu m$	N/A
B0	<50 ps	$O(50)\ \mu m$	$< 0.01\ X_0$

Sensor

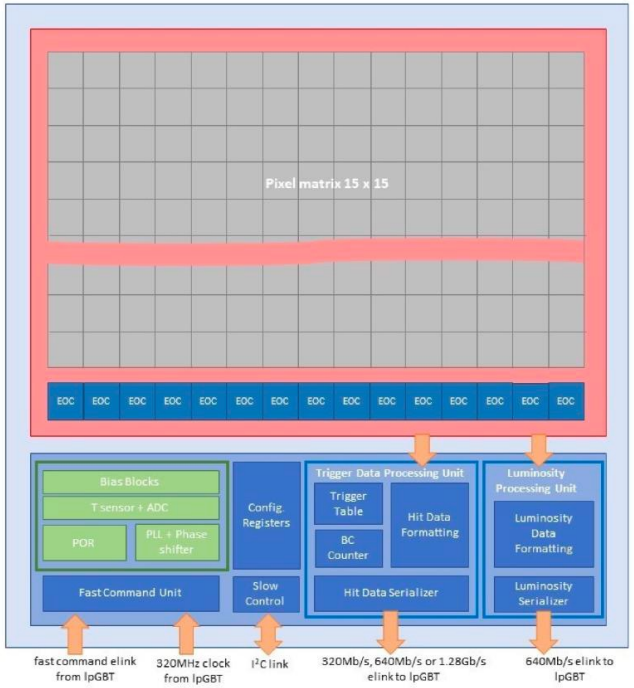


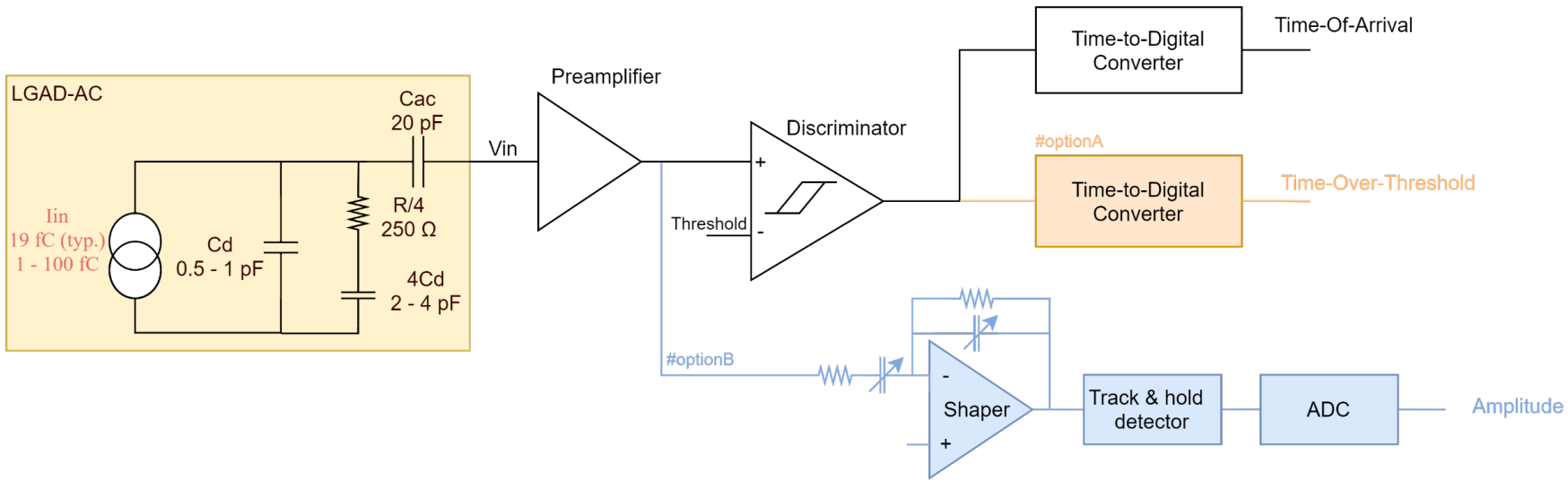
Nicolo Cartiglia



- **R&D Goals**
  - 15-20 ps timing resolution, O(3-50μm) position resolution where needed
  - Minimal readout channel density (long strip, rectangular pixel) for reduced power, material and cost
- **Plan**
  - Produce and test sensors with thinner active volume to achieve the desired timing resolution
  - Optimize implantation parameters and AC-pad segmentation through simulation and real device studies
  - Engage commercial vendors to improve fabrication process and yield

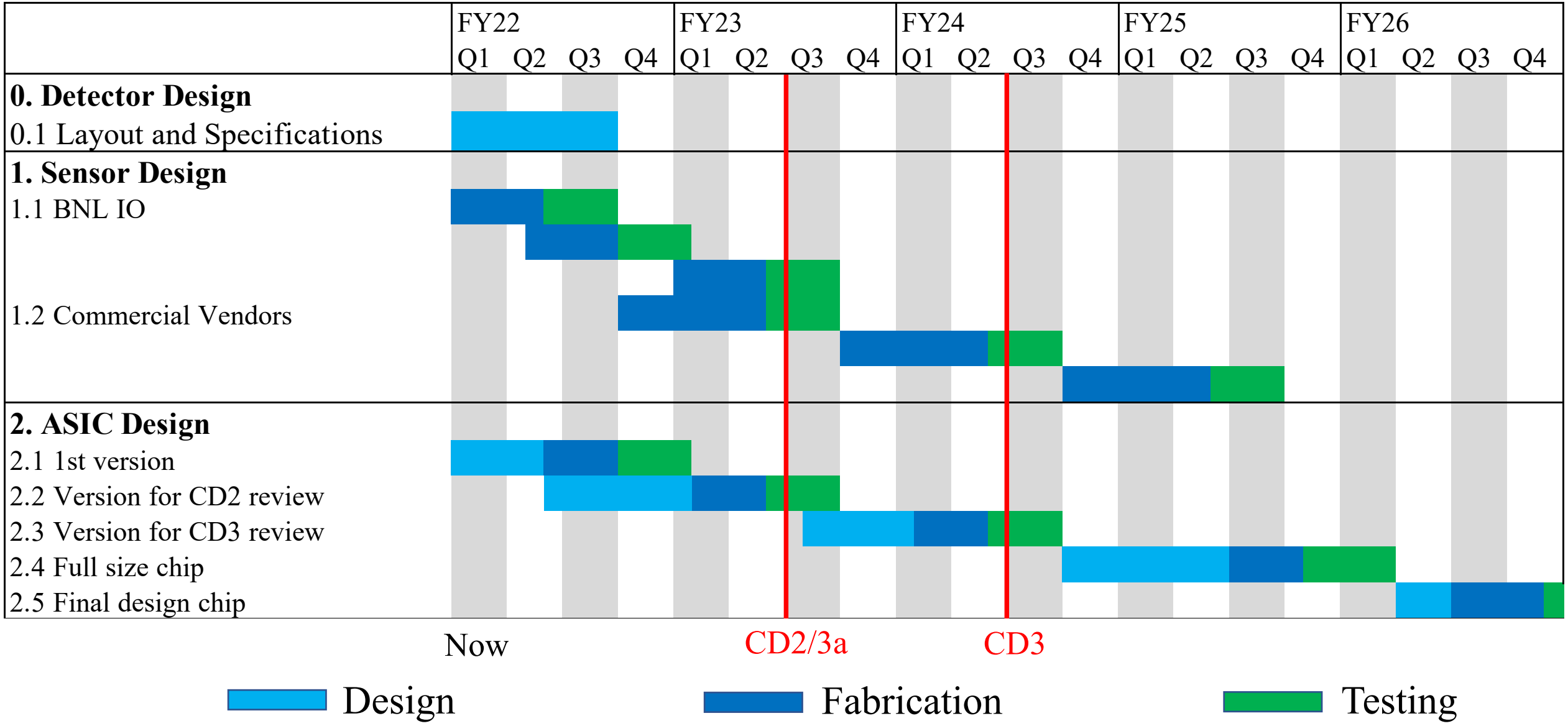
ASIC





- **R&D Goals**
  - 15-20 ps jitter with minimal (1-2 mW/ch) power consumption, match AC LGAD sensors for EIC
- **Plan**
  - Continue the ASIC prototyping effort for RPs by IJCLAB/Omega (1st submission in FY22 funded externally)
  - Utilize the design and experience in ASICs for fast-timing detectors from ATLAS and CMS, and investigate common ASIC design and development for RP/B0 and ToF

eRD112 Timeline – Sensor & ASIC



Other Components

- Detector overall design
  - **June 2022:** Definition of physics and performance specifications for different sub-systems, with a focus on detector layout, material budget requirement, timing, and space resolution targets.

- **Light-weight mechanical structure and Cooling**
  - **May 2022**: Formation of a team of experts to start developing the cooling strategy and identifying mechanical requirement.
  - **FY23 Q1**: Development of a general cooling strategy and mechanical requirements to be used as baseline for CD2 review.
  - **FY24 Q2**: Cooling demonstrator and building of a mechanical module. This will be used as baseline for the CD3 review.
  - **FY25**: Development of final cooling system.

- **Flex, Interconnects and off-detector electronics**
  - **July 2022**: Formation of a team of experts to start developing strategy for exes, interconnects, and off-detector electronics.
  - **FY23 Q1**: Development of a general layout of exes and off-detector electronics to be used as baseline for the CD2 review.
  - **FY24 Q2**: Advanced design and prototyping of exes, interconnects, and off-detector electronics. This will be used as baseline for the CD3 review.
  - **FY25**: Production of exes, interconnects, and off-detector electronics with fin design.

Summary and Outlook

- AC-LGAD is the selected technology for TOF and far-forward detectors (RPs/B0) at EIC.
  - Opportunity: new detector technology development; multi-million and multi-year projects.
  - Challenge: strict detector performance requirements; very tight schedule.

- eRD112: develop sensor, ASIC, and other key components for AC-LGAD detectors at EIC
  - Approach: having common design and with combined R&D efforts for different detectors when possible.

- **If you are interested to join eRD112 for EIC or to collaborate on the development of some components, please let us know. We are eager to have your expertise and contribution.**

eRD112:

Brookhaven National Lab: E.C. Aschenauer, A. Jentsch, A. Kiselev, T. Ljubicic, A. Tricolli, G. Giacomini, Z. Xu
IJCLAB/Oemga, FR: R. Dupré, D. Marchand, C. Munoz Camacho, L. Serin, C. de La Taille, M. Morenas
Los Alamos National Lab: X. Li
Rice University: F. Geurts, W. Li
University of California, Santa Cruz: A. Seiden, H. Sadrozinski, B. Schumm
University of Illinois at Chicago: O. Evdokimov, Z. Ye

Backup

FY22 Deliverables

- High-level strawman layout design and requirements for sub-systems using AC LGADs.
- Production of medium/large area sensors with different doping concentration, pitch and gap sizes between electrodes to optimize performance by BNL Instrumentation and HPK.
- Start production of sensors of small thickness (20, and 30 microns) for ToF applications with time resolution 20 ps by BNL Instrumentation.
- A first ASIC prototype that is compatible with EIC Roman Pot requirements and can read out an AC-LGAD with 500 micron pitch and 20 ps time resolution.

eRD112 Timeline and Deliverables