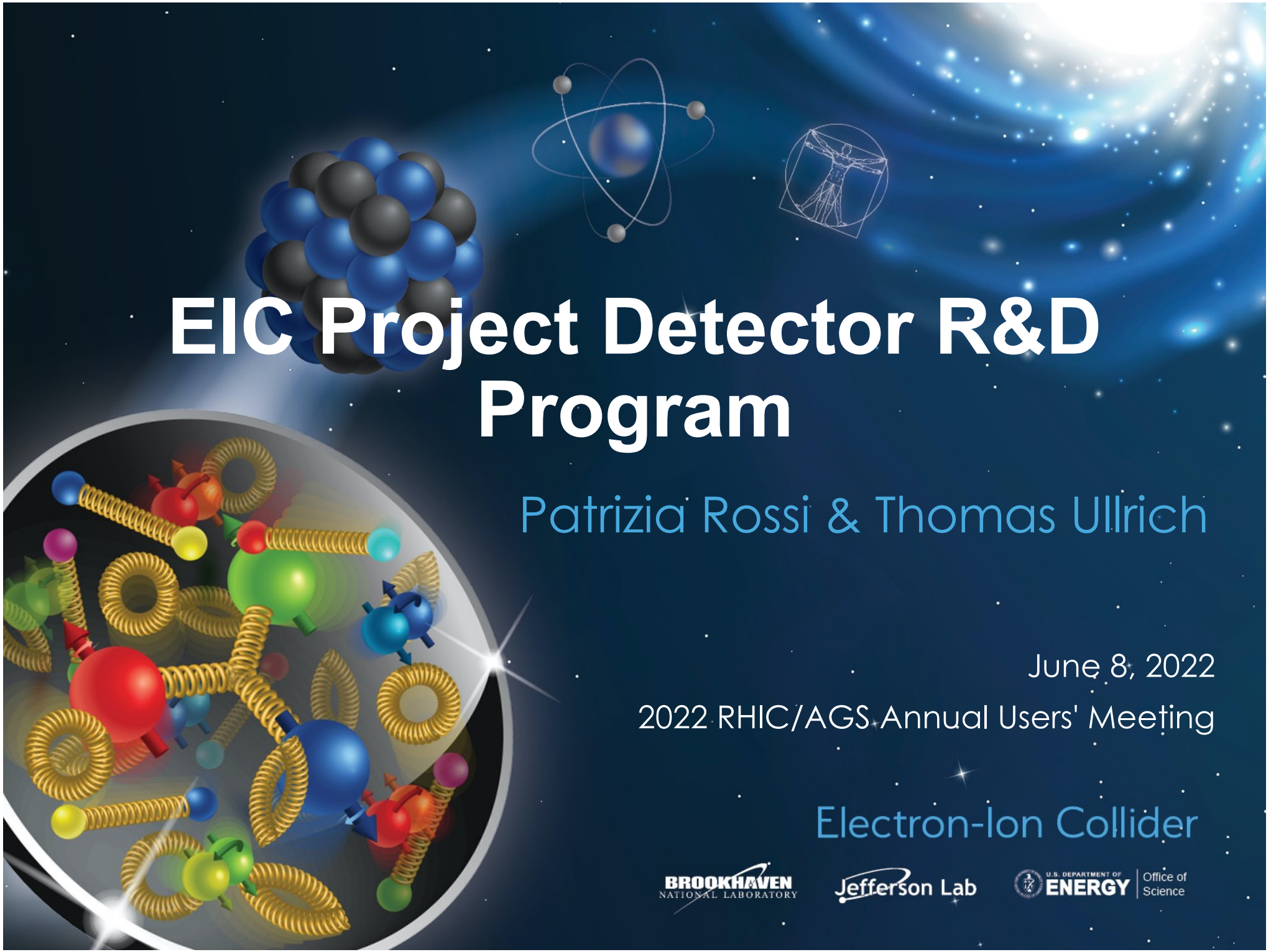

EIC Project Detector R&D Program
Patrizia Rossi & Thomas Ullrich
June 8, 2022
2022 RHIC/AGS Annual Users' Meeting
Electron-Ion Collider
BROOKHAVEN NATIONAL LABORATORY
Jefferson Lab
U.S. DEPARTMENT OF ENERGY
Office of Science

EIC Project R&D: context

wiki page: https://wiki.bnl.gov/conferences/index.php/General_Info

- Efforts on EIC Detector R&D focus:
  - to demonstrate a solution to the fundamental challenges
  - to reduce the risk for individual subdetectors.

- Detector R&D project started before the selection of the reference detector since several subsystems turned out to be quite generic and of priority for all or most detector concepts under consideration .
  - Strategy memo released on August 2021 ➞ 12 R&D projects identified.
  - Groups asked to write a short and concise document laying out:
    - For FY22: R&D plan, Manpower required and available, milestones and timeline, suggested funding profile including funding split among the participating institutions.
    - Preview of remaining R&D after FY22 until completion.

- Plans, milestones and funding profiles were adjusted after meeting with the groups individually. Process completed in October 2021 and presented in DOE OPA review.

EIC Project R&D: context

- The start of project R&D was unexpectedly difficult due the US budget delays (6 months) because of the long Continuing Resolution and the funding being far from ideal.

- All proposals were reviewed carefully and funds were awarded in accordance with the project's priorities and the overall planning status. Milestone timelines were adjusted to accommodate the delayed start of the R&D program (+6 months).

- The project R&D funding was transmitted to the PIs of each R&D project via asking One-page Statement-of-Work (SOW) and associated milestones to establish the contract.

R&D Projects: FY22 Funding

ID	Subject	Contacts	Institutes	Contract	Funding
eRD101	mRICH	Prof. Xiaochun He (Georgia State University),	Georgia State University	BNL	yes
eRD102	dRICH	Dr. Evaristo Cisbani, (INFN Roma), Dr. Marco Contalbrigo (INFN Ferrara)	BNL, Duke University, INFN Ferrara	JLAB	yes
eRD103	hpDIRC	Dr. Gregor Kalicy (Catholic University of America),	Catholic University of America, Old Dominion University, Stony Brook	BNL	yes
eRD104	Service reduction	Dr. Giacomo Contin (INFN, Trieste), Dr. Grzegorz Deptuch (Brookhaven National Laboratory)	Oak Ridge National Laboratory, BNL	BNL	yes
eRD105	SciGlass	Prof. Tanja Horn (Catholic University of America)	Catholic University of America, IJCLab-Orsay, INFN-Genova, Kansas	JLab	yes
eRD106	Forward EMCAL	Prof. Huan Z. Huang, Dr. Oleg Tsai (UCLA)	N/A	BNL	no/delayed
eRD107	Forward HCAL	Prof. Huan Z. Huang, Dr. Oleg Tsai (UCLA)	N/A	BNL	no/delayed
eRD108	Cylindrical & Planar MPGD	Dr. Kondo Gnanvo (Thomas Jefferson National Accelerator Facility)	BNL, Florida Institute of Technology, University of Virginia, Saclay, Temple University	JLAB	yes
eRD109	ASICs/Electronics	Fernando Barbosa (Thomas Jefferson	N/A		no/delayed
eRD110	Photosensors	Dr. Pietro Antonioli (INFN),	Argonne National Laboratory, BNL, INFN, Mississippi State University,	JLab	yes
eRD111	Si-Tracker/no sensors	Same as eRD104	Los Alamos National Laboratory, Lawrence Berkeley Laboratory	BNL	yes
eRD112	AC-LGAD	Prof. Zhenyu Ye (University of Illinois Chicago)	BNL, University of Illinois Chicago, Rice University, UC Santa Clara, Los	BNL	yes
					$1,280,800.00

- Funding requested in general close to our early estimates
- Funding adjusted in accordance with the project's priorities and the overall planning status

Put on hold, until technology choices become clearer

Put on hold, not enough details to start ASIC development yet

3

- ~ $1,300K critical for FY22
- This does not include or has a large reduction of several crucial items which we have to delay (ASICs, forward calorimetry, LAPPDs, AC-LGAD). That would roughly need another ~$900K

EIC Project R&D: where we are

- Decision was made to handle the contracts through the procurement office of both BNL and Jlab
  - If US contracts only -> BNL. If at least one non-US inst. -> JLab

- Points of Contacts have been identified in both laboratories: Anna Mendez (BNL), Sherry Thomas (JLab). They will be the interface between the procurement office and the Institution Representatives.

- We are presently working on setting up the contracts. It's a new program so some patience and collaboration will be needed to get all going at the beginning. Also the rules at BNL and JLAB are slightly different.

- Contracts will be signed with each Institution upon receipt of a Statement-of-Work (SOW) and associated milestones.

Contract Map Projects

Institution	PI	Project R&D	Topic (short)	Contract Lab
Georgia State University	Prof. Xiaochun He	eRD101	modular RICH (mRICH)	BNL
INFN Roma	Dr. Evaristo Cisbani	eRD102	dual RICH (dRICH)	JLAB
INFN Ferrara	Dr. Marco Contalbrigo	eRD102	dual RICH (dRICH)	JLAB
Duke University	Prof. Anselm Vossen	eRD102	dual RICH (dRICH)	JLAB
Catholic University of America	Dr. Gregor Kalicy	eRD103	high performance DIRC (hpDIRC)	BNL
Old Dominion University	Prof. Charles Hyde	eRD103	high performance DIRC (hpDIRC)	BNL
Stony Brook University	Prof. Tom Hemmick	eRD103	high performance DIRC (hpDIRC)	BNL
Oak Ridge National Laboratory	Jo Schambach	eRD104	Service Reduction	BNL
BNL	Dr. Grzegorz Deptuch	eRD104	Service Reduction	direct charging to BNL
Catholic University of America	Prof. Tanja Horn	eRD105	Scintillating Glasses	JLAB
IJCLab-Orsay	Dr. Carlos. Munoz-Camacho	eRD105	Scintillating Glasses	JLAB
INFN-Genova	Dr. M. Battaglieri	eRD105	Scintillating Glasses	JLAB
Kansas University	Prof. Michael Murray	eRD105	Scintillating Glasses	JLAB
AANL/Armenia	Dr. Hamlet Mkrtchyan	eRD105	Scintillating Glasses	JLAB
Florida Institute of Technology	Prof. Marcus Hohlmann	eRD108	Micro Patter Gaseous Detectors (MPGDs)	JLAB
University of Virginia	Kondo Gnanvo	eRD108	Micro Patter Gaseous Detectors (MPGDs)	JLAB
BNL	Dr. Craig Woody	eRD108	Micro Patter Gaseous Detectors (MPGDs)	direct charging to BNL
Saclay, France	Dr. Maxence Vandenbroucke	eRD108	Micro Patter Gaseous Detectors (MPGDs)	JLAB
Temple University	Prof. Bernd Surrow	eRD108	Micro Patter Gaseous Detectors (MPGDs)	JLAB
Argonne National Laboratory	Dr. Junqi Xie	eRD110	Photosensors	JLAB
BNL	Dr. Alexander Kiselev	eRD110	Photosensors	direct charging to BNL
INFN Trieste	Dr. Silvia Dalla Torre	eRD110	Photosensors	JLAB
INFN Bologna	Dr. Pietro Antonioli	eRD110	Photosensors	JLAB
Mississippi State University	Prof. Sanghwa Park	eRD110	Photosensors	handled through BNL
Los Alamos National Laboratory	Xuan Li	eRD111	Si-Tracker	BNL
Lawrence Berkeley Laboratory	Dr. Ernst Sichtermann	eRD111	Si-Tracker	BNL
University of Illinois Chicago	Prof. Zhenyu Ye	eRD112	AC-LGAD sensor and ASICs	BNL
BNL	Dr. Zhangbu Xu	eRD112	AC-LGAD sensor and ASICs	direct charging to BNL
Rice University	Prof. Frank Geurts	eRD112	AC-LGAD sensor and ASICs	BNL
UC Santa Cruz	Prof. Abraham Seiden	eRD112	AC-LGAD sensor and ASICs	BNL
Los Alamos National Laboratory	Dr. Xuan Li	eRD112	AC-LGAD sensor and ASICs	BNL

BNL	11
JLab	15
Habdled through BNL	1
Direct charging to BNL	4
TOTAL	31

EIC Project R&D: where we are

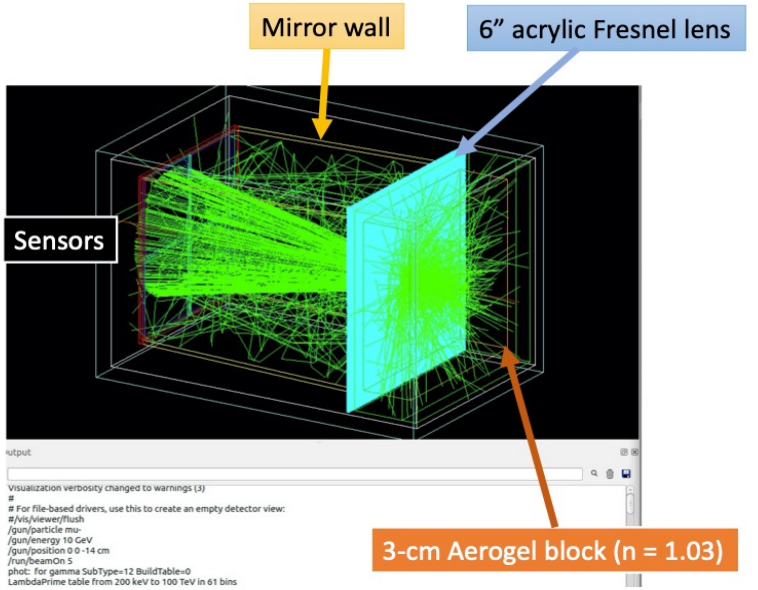
- Preliminary assessment of the milestones in the submitted SOWs:
  - Few milestones kept the original schedule + 6-month shift.
  - Some milestones have been removed because of the funding cut.
  - Few milestones will be completed by the end of FY22.

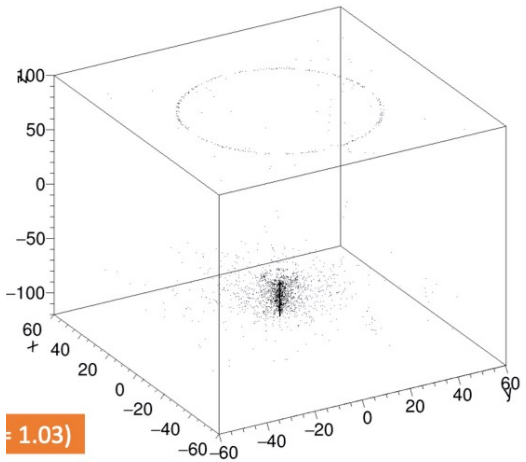
- Deliberation
  - A 9-month shift in the milestones is acceptable because realistically the contracts will be awarded not before the end of this month.
  - Funds should be obligated by FY22 but we can use them to complete the milestones in 2023.

eRD101: mRICH

Goal: Develop sharper and small ring imaging RICH for K/π separation in a momentum range of 3 to 10 GeV/c and e/π separation below 2 GeV/c

- R&D: Validate the concept

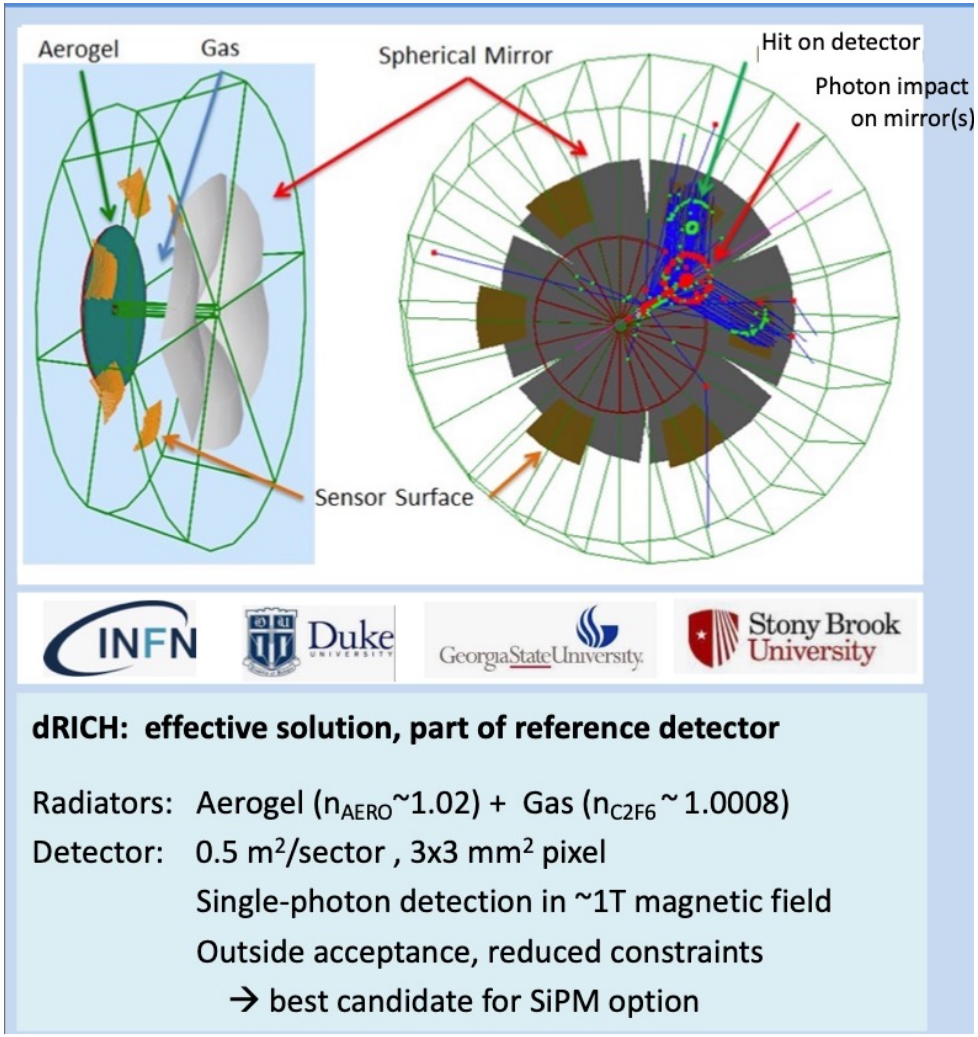




Milestones and Timeline for FY22

- Analyzing the mRICH beam test data taken at JLab and finishing up the data analysis from the 2nd mRICH beam test at Fermilab. Obtain the single photon characterization of the mRICH by the end of **9/2022.**

eRD102: dRICH



Goal: Develop a dual-radiator Ring Imaging Cherenkov detector to provide continuous full hadron identification (π/K/p) separation better than 3σ in the range 3 -50 GeV/c in the forward range. It also offers a e/π separation from few hundred MeV up to about 15 GeV/c.

- Main Technical risk:
- Greenhouse gas: potential procurement issue -> Search for alternatives (not part of the eRD102)
- Photon detectors

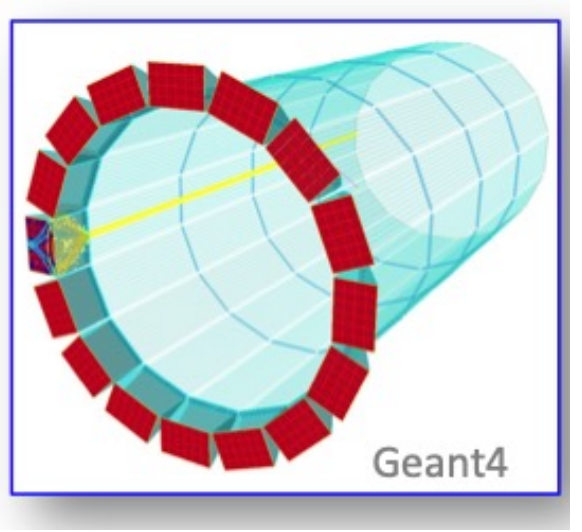
- Commissioning of dRICH prototype to assess:
  - dRICH concept
  - aerogel (and gas) optical performance
  - SiPM usage in realistic experimental conditions

Milestones & Timeline for FY22 - Updated

- Realistic implementation of dRICH into the EIC detector - **10/22**
- Initial assessment based on the first test beams - **12/22**
- Realization of a suitable detector plane for the dRICH prototype - **3/23**

eRD103: hpDIRC

Goal: Develop fast focusing compact DIRC with coverage reaching 6 GeV/c for π/K, pushing the performance well beyond the state-of-the-art for DIRC counters.



- Based on BaBar DIRC, *PANDA Barrel DIRC*
- Technical risk:
  - Small pixel photon sensor and fast readout electronics performance
  - (risk/opportunity): Reuse of BaBar DIRC bars
- R&D Priorities:
  - Baseline design validation
  - Cost/performance optimization

Milestones & Timeline for CY22

- Assembly of Cosmic Ray Telescope (CRT) in SBU DIRC lab complete - **12/2022**
- Mechanical integration of initial hpDIRC prototype into CRT achieved **-12/2022**

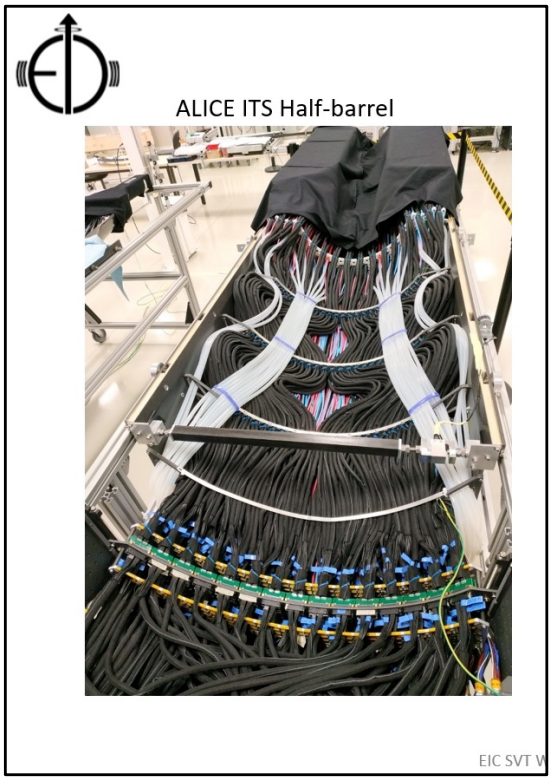
Shifted to Jlab

- Optical DIRC lab for BaBar DIRC bar
  New space (EEL-108A) is ready, items have been bought (clean room, laser, table).
  We delayed construction of the clean room that needs about 2-3 days as the techs were busy with preparing for the experiments.

- Complete QA of bars from first disassembled BaBar DIRC bar box, decision about further disassembly strategy
  We have ok from SLAC for a two stage plan for DIRC bars disassembly and QA, first a test module then the real bars (two separate contracts). But they have not given us the info (costs) to set to an IEWO contract yet to start it.

eRD104: Service Reduction

- **Goal**: investigate methods to significantly reduce the services load for an EIC MAPS based tracking detector (but many systems will potentially benefit from this)



- Starting Point - ALICE ITS-2 Current state of the art for MAPS
- The vast majority of the services for the ITS-2 consist of the powering and readout cables
  - Powering: radiation tolerant DC-DC converter, serial powering architectures
  - Data: data aggregation on detector using radiation tolerant FPGAs

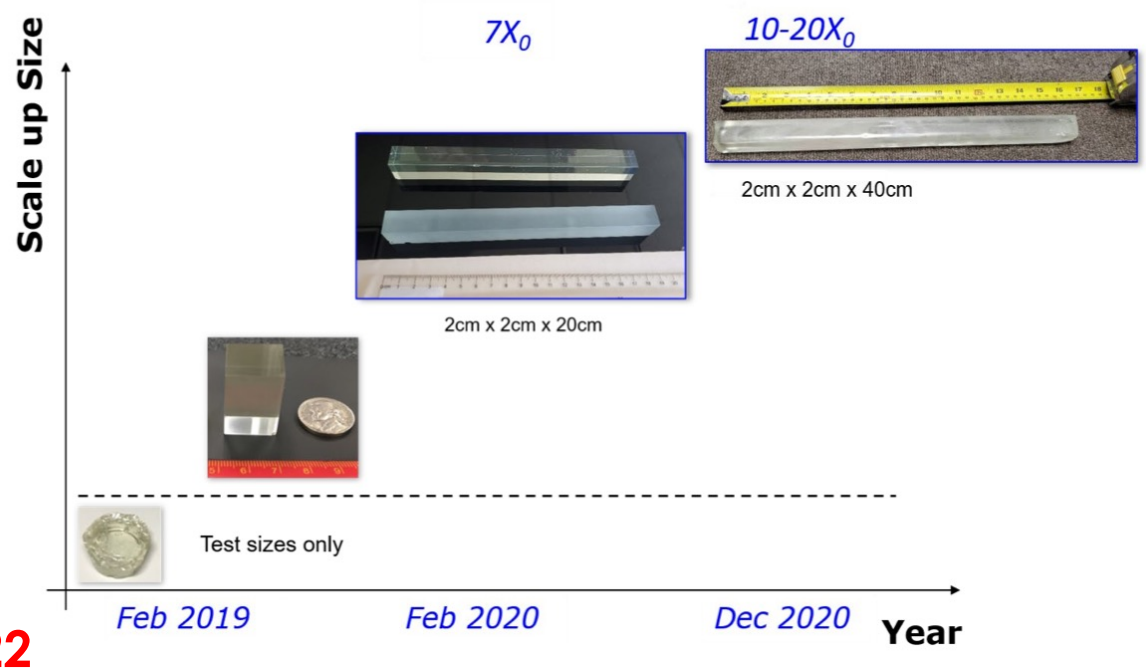
Milestones and Timeline for FY22

- Report on serial powering - **8/2022**
- Report on DC-DC powering - **10/2022**

eRD105: Scintillating Glasses

- **Goal**: Demonstrate that SciGlass is a viable solution as precision calorimeter technology.
- Radiation hard material, developed by Scintilex, LLC in collaboration with the Vitreous State Lab at CUA, and optimized to provide characteristics similar to or better than PbWO4.
  - o Fabrication is expected to be cheaper, faster, and more flexible than PbWO4 crystals.

- Tremendous progress made in the formulation and production of SciGlass to improve material properties
- Successful scaleup method demonstrated -> now reliably production of glass samples of sizes up to ~10 radiation lengths.



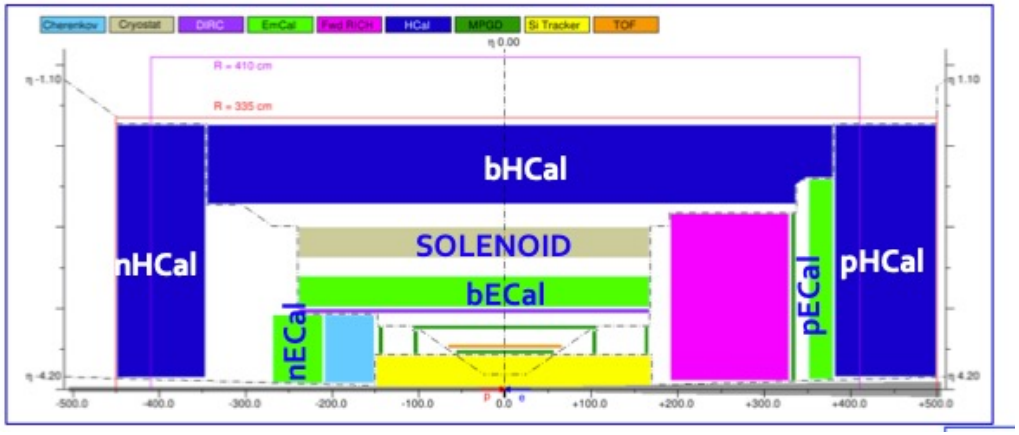
Milestones and Timeline for FY22

- Receive ~25-50 test samples; initially 20 cm and 40 cm - **9/2022**
- Construct a small 3x3 prototype and finalize readout infrastructure - **7/2022**
- Commission the 3x3 prototype - **9/2022**

eRD106_107: Forward EMCal+HCal

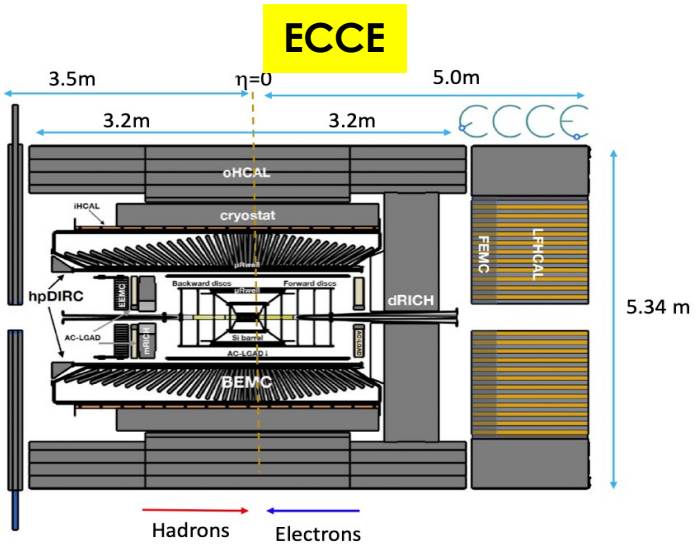
- The endcap calorimeters (EMCal and Hcal) require substantial efforts to merge the projects of the two collaborations, ATHENA and ECCE

ATHENA



- Compensated electromagnetic calorimeter (pECal)
- Fe/Scint (20 mm / 3 mm) sandwich hadronic calorimeter (pHCal)

ECCE



- Electromagnetic calorimeter Pb/ScFi shashlik (FEMC)
- Longitudinally separated hadronic calorimeter (LHFCAL)

- A decision on the submitted proposals is postponed until a selection on what the project detector's technology with be ultimately used for the forward calorimeters will be made.

eRD109: ASICs/Electronics

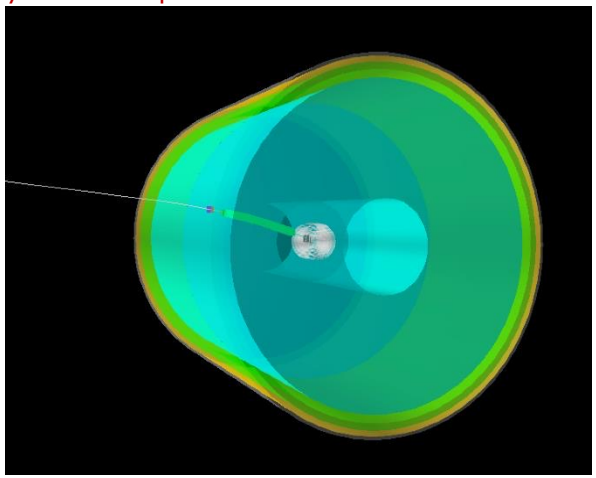
- Substantial R&D will be need for the development of Front-End Electronics: ASIC, Front-End Board (FEB), and Front-End Processor (FEP)
- The choice of using streaming read-out for the EIC excludes several existing ASIC chips.
- ASICs exist for the Si-Vertex detector (the current ALICE ITS chips meet EIC requirements).
- ASICs for the readout of LGADs/AC-LGADS is contained in the LGAD R&D.
- Estimate the need for 3 ASICs : (i) SiPM (calorimetry), (ii) MCP-PMT/PMT (PID), and MMG/GEM2/μRWell (tracking). This will require 3 FEB and likely 1-2 FEP.
- Timeline: ASIC development takes 4-5 years. Developments of the various parts will likely have to occur concurrently. Final requirements can only be established once the detector technologies are finalized
- eRD109: Put on hold since we don't have enough details to start ASIC development yet

eRD108: MPGDs

Goal: develop EIC tracking for different systems

- R&D on three Micro-Pattern Gaseous Detectors (MPGDs)
  - micro-Resistive-Well (µRWELL)
  - micromegas (MM)
  - Gas Electron Multiplier (GEM)
- Applications:
  - µRWELL Layer for seeding DIRC reconstruction
  - Micromegas Barrel Tracker
  - Planar GEM/µRWELL Endcap Tracker (removed)
    - ➥ the initial challenges (ultra-low mass planar detectors) are no longer relevant in the end cap regions of the current EIC detector 1

Cylindrical µRWELL Tracker for the DIRC



Milestones and Timeline for CY22 - Updated

Cylindrical Micromegas Barrel Tracker:

Readout designs (Saclay & BNL) – **9/2022**
Readout foils received (Saclay & BNL) – **12/2022**
Bulk and assembly of prototypes (Saclay) – **4/2023**
Cosmic ray data taking completed (Saclay) – **6/2023**
Analysis and results (Saclay & BNL) – **8/2023**

Cylindrical µRWell:

- Major Milestone: Design completed
  - Mechanical design completed (FIT) – **10/30/2022**
  - Front-end electronics & DAQ design completed (TU) - **9/30/2022**
  - Readout foil design completed (UVa & BNL) – **9/30/2022**
- Major Milestone: Detector Assembled
  - Mechanical assembly completed (FIT) - **4/30/23**
  - Existing (VMM-SRS) front-end electronics & DAQ tested (TU) - **4/30/23**
  - Readout foil produced at CERN (UVa & BNL) - **4/30/23**
- Major Milestone: Detector ready for beam test
  - Integration of detector & electronics and benchtop testing (All) - **6/30/2023**

eRD110: Photosensors

Goal: Reduce current risk associated with lack of reliable highly pixilated photodetectors working at 1.5-3 T.

- On the market (or in development by manufacturer)
  - SiPMs - radiation hardness
  - LAPPD/HRPPD - pixelation
  - MCP PMT – magnetic tolerance
- At the moment no funding available for the characterization of MCP-PMTs

Milestones and Timeline for CY22 – Updated

LAPPD:

- Full evaluation of up to four different LAPPD and HRPPD tiles in the lab and under beam conditions. Evaluation includes determination of quantum efficiency, gain uniformity, operation under high rate, timing and position resolution measurements in a finely pixelated configuration.

BNL

	08/2021 proposal	05/2022 SOW
Readout board design and procurement	March-April 2022	May-June 2022
Fermilab beam test	May 2022	June 2022
Spatial resolution report	July 2022	September 2022
Beam test data analysis and report	by October 2022	December 2022
Preliminary LAPPD-for-EIC assessment	by October 2022	December 2022

Few months shift towards the later dates, due to several substantial modifications to the experimental setup for both benchtop and beam test studies made over the Fall 2021

INFN

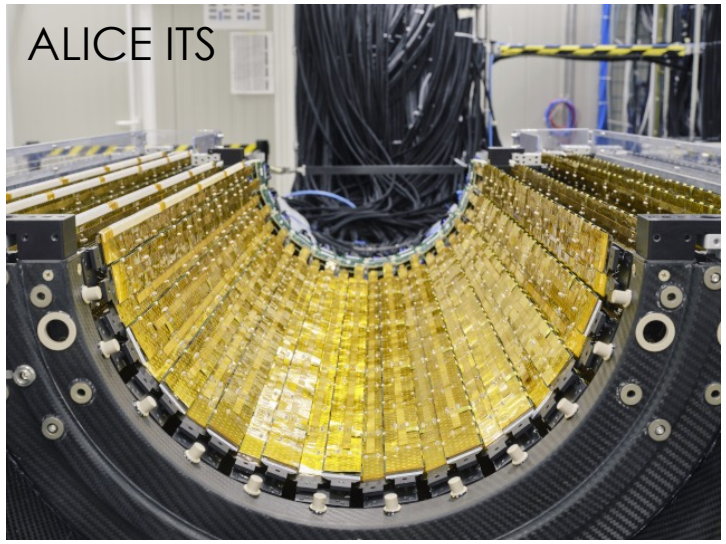
- Completion of the lab equipment for LAPPD characterization at INFN - 6/2022
- Timing characterization - 9/2022

SiPM:

- Comparative assessment of commercial (and prototypes not yet available on the market) of SiPM performance after irradiation - **2/2023** (interim results available at 9/2022)
- Definition of an annealing protocol - **2/2023**

eRD111: Si-Vertex

Goal: Development of a full tracking detector solution composed of next generation MAPS sensors and based on the *developments ongoing at CERN for the ALICE ITS*



- Identified areas of R&D that require development that are particularly challenging and/or extend beyond the existing MAPS implementations
  - Forming modules from stitched sensors
  - Stave/disc construction
  - Additional infrastructure including mechanics and cooling

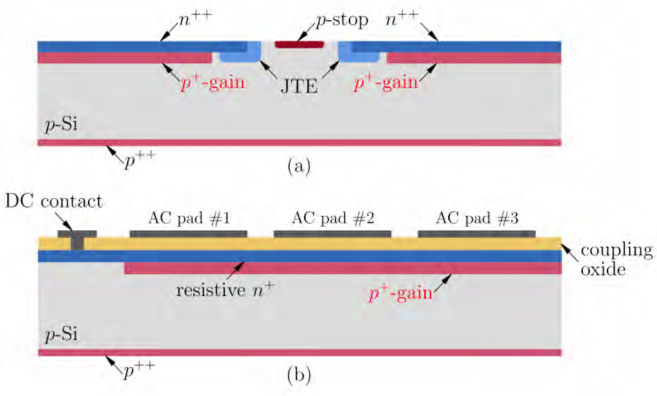
Milestones and Timeline for CY22

- Report on baseline stave design – **10/2022**
- Report on baseline disc designs – **12/2022**
- Up-to-date silicon tracking CAD models – **12/2022**

eRD112: AC-LGAD

Goal: Develop AC-LGAD based systems including sensors, ASIC, and Services for auxiliary detectors (Roman Pots, B0)

AC-LGAD improves on LGAD in terms of timing and position resolution.Substantial synergy with AC-LGAD efforts in HEP



- Could be also used for
  - low-p,p_T ToF
  - Polarimetry
  - Common designs in sensor, ASIC where possible, combine R&D efforts

Milestones and Timeline for CY22

- Small sensor prototypes that meet space resolution specifications with a time resolution of 20-30 ps, -**12/2022.**
- Production of medium/large-area sensors with different doping concentration, pitch, and gap sizes between electrodes to optimize performance by BNL IO and Hamamatsu. BNL expected - **12/2022**

} sensors

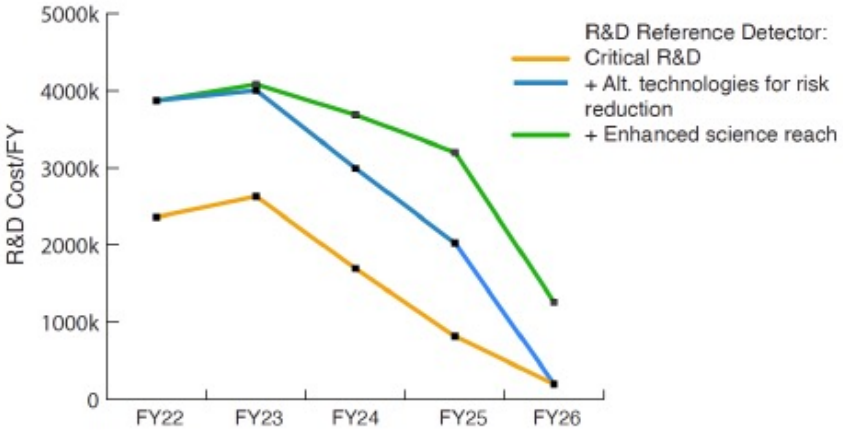
- A prototype ASIC design to readout AC LGADs using signal sharing across neighboring electrodes and has 30 ps time resolution with low power consumption - **9/2022.**

} ASIC

Generic R&D Program

- DOE NP is restarting the EIC generic R&D program in FY22 of scale 1-2M$.
- Such a program would look at new cost-effective detector capabilities for either the detector-1 in the project scope or of use for a detector-2.
- This may well be aligned with a detector R&D white paper that was submitted to DOE/NP in Summer 2020 (Elke & Rolf) and with information in the EIC detector R&D plan document (Thomas & Patrizia).

"Generic EIC-related detector R&D is driven both by pursuing alternate detector technologies for a complementary second EIC detector and to prepare for future cost-effective detector upgrades to enhance capabilities addressing new nuclear physics opportunities. The goals of such generic EIC-related detector R&D can best be considered in detector functionality areas such as particle identification, calorimetry, tracking, and readout electronics, to address how one can enhance the performance of the plausible scenario reference EIC detector with target R&D projects in a year or more. "



- The generic detector R&D program is expected to be governed similar as the successful generic EIC-related detector R&D program that ran through BNL from 2011-2021.
- It will be managed by Jefferson Lab, drawing deeply on BNL's extensive experience managing the previous version of the program.
- The PI will be David Mack (TJNAF). The Program Manager is David Dean (TJNAF).
- The call for proposals will go out before the end of June.

Conclusions

- Project R&D program started.
- R&D plan for detector 1 is in place.
- Selection of R&D projects concluded. Timelines and milestones defined for all projects but three which are on hold (ASICs/electronics, Forward EMCal & Hcal).
- Contracts with Institutions are being prepared.
- A generic EIC-related detector R&D program of scale 1-2M$ is going to start in FY22.