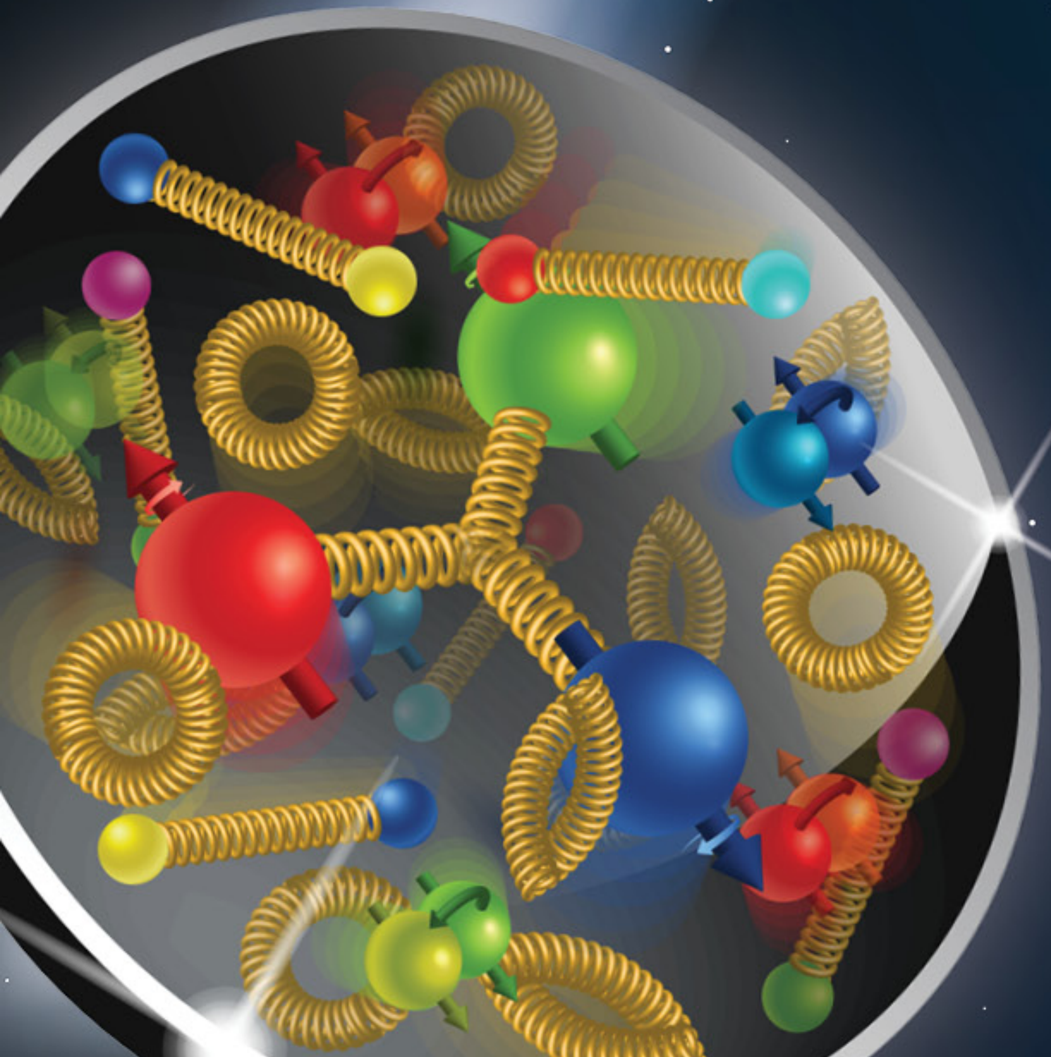
EIC Detector R&D



Patrizia Rossi & Thomas Ullrich
Detector 1 General Meeting
April 29, 2022

Electron-Ion Collider

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

EIC Project R&D: Context

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

- Project Detector R&D
  - 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
  - Plans, milestones and funding profiles laid out by the groups were adjusted after meeting with them individually. Process completed in October 2021 and presented in DOE OPA Review.
- The start of project R&D was unexpectedly difficult due the US budget delays 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. *The timelines were adjusted to accommodate the delayed start of the R&D program.*
- The project R&D funding will be transmitted via one or more R&D subcontracts with BNL/JLab. One-page Statement-of-Work (SOW), Milestones, and cost details will be needed 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

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eRD104	Service rec				yes
eRD105	SciGlass				yes
eRD106	Forward El				no/delayed
eRD107	Forward H				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
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					$1,280,800.00

- $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, …). That would roughly need another ~$900K

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

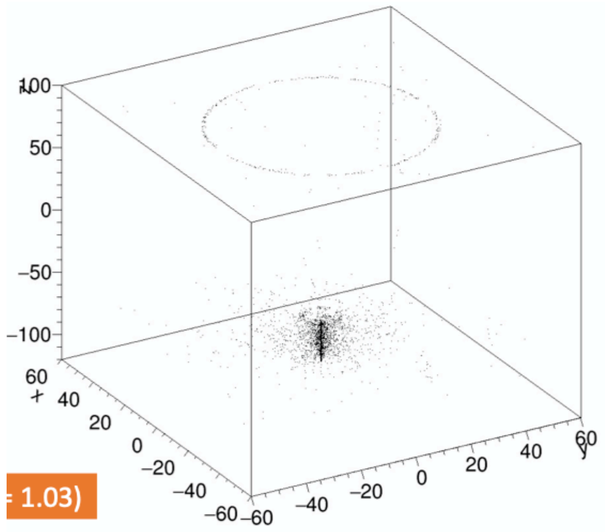
Put on hold, until technology choices become clearer

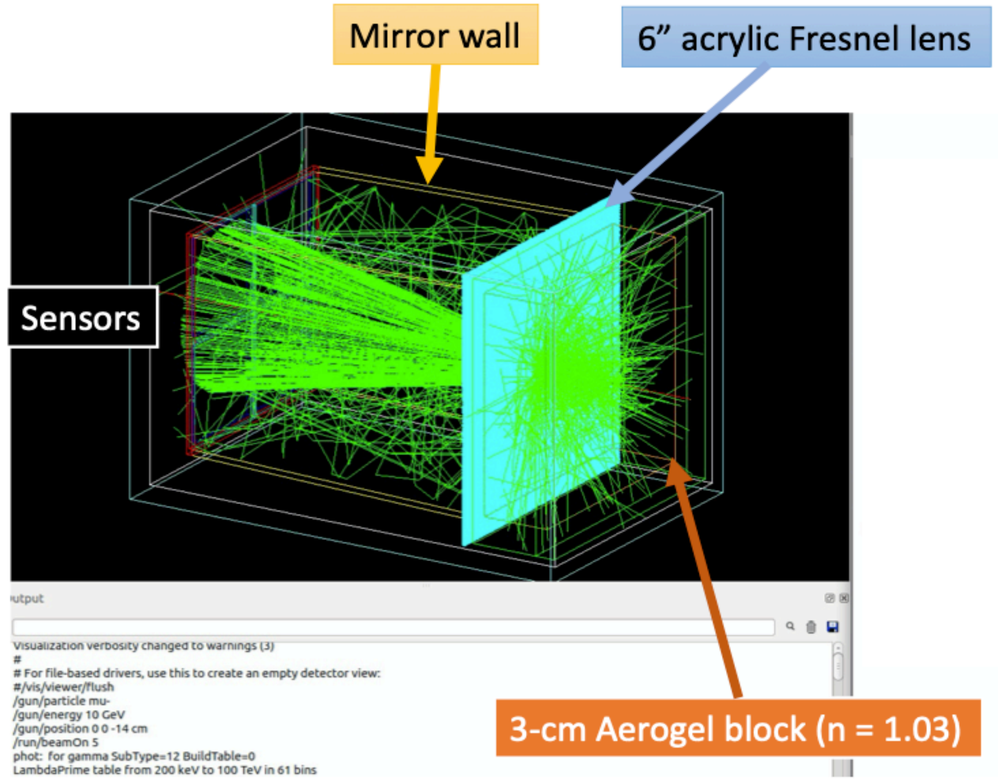
Put on hold, not enough details to start ASIC development yet

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

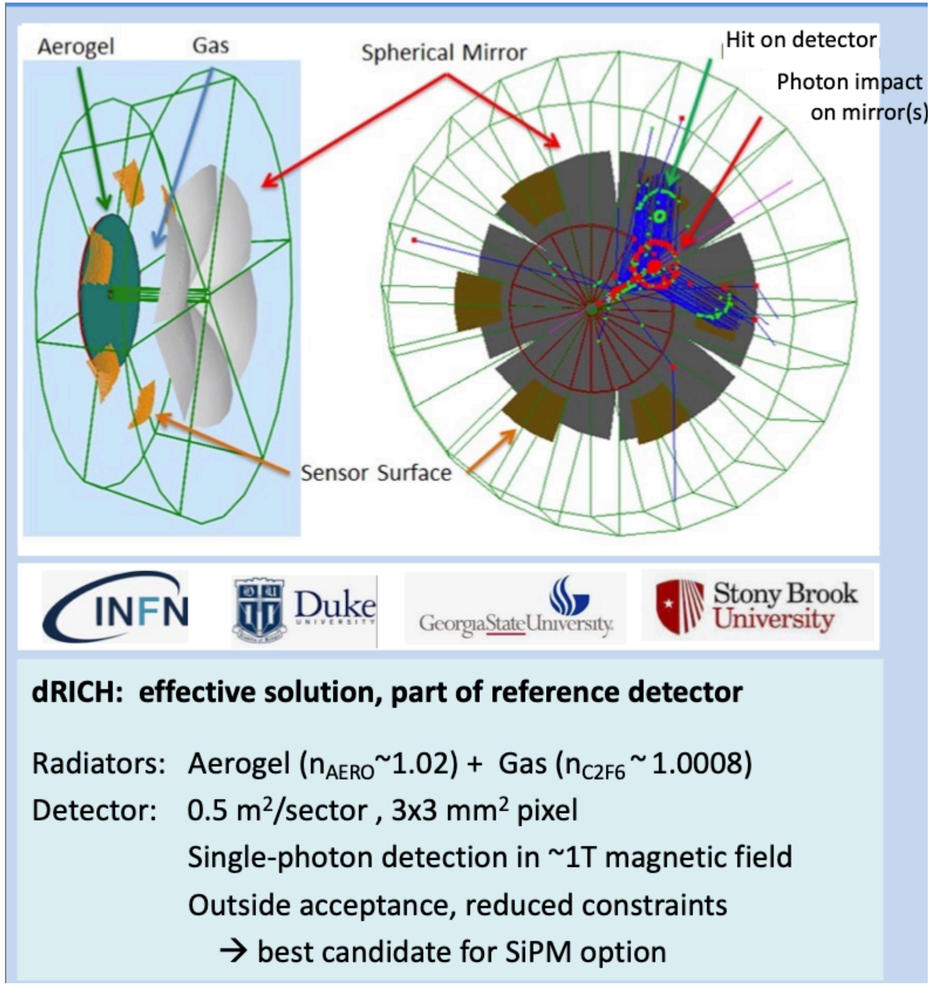




Milestones and Timeline for FY22

- 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.

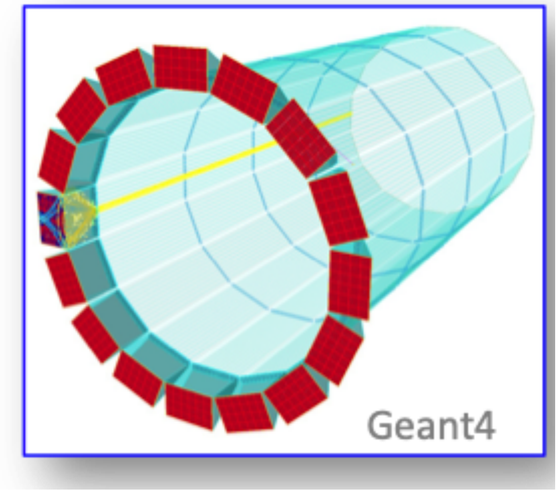
- Main Technical risk:
  - Greenhouse gas: potential procurement issue Search for alternatives (not part of eRD102 -> Project)
  - Photon detectors
- Commissioning of dRICH prototype to assess:
  - dRICH concept
  - aerogel (and gas) optical performance
  - SiPM usage in realistic experimental conditions

Milestones & Timeline for FY22

- Assessment of the basic prototype performance based on the 2021 test beams **(7/2022)**
- Realization of a suitable photon detection plane for the dRICH prototype **(9/2022)**

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

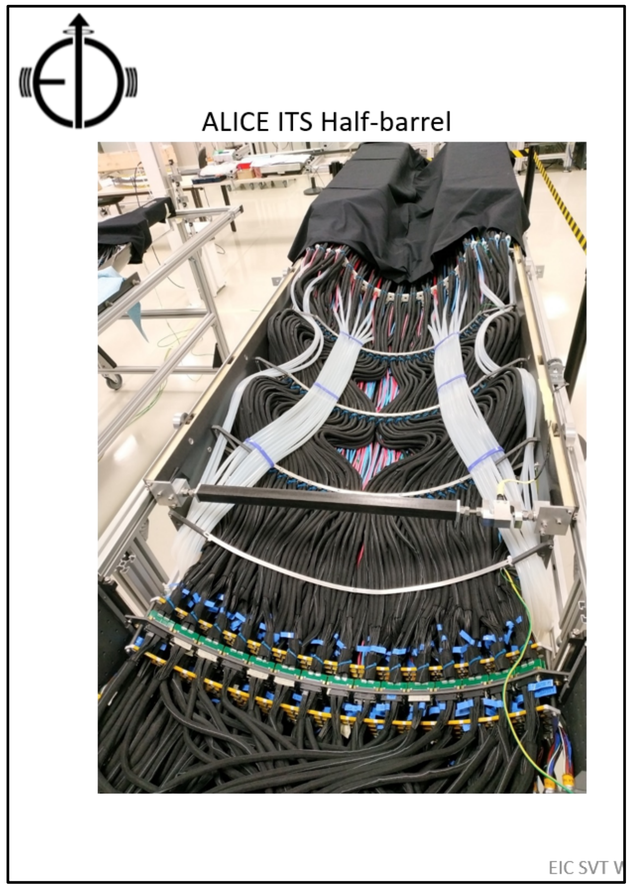
- Assembly of Cosmic Ray Telescope (CRT) in SBU DIRC lab complete, **(12/2022)**
- Mechanical integration of initial hpDIRC prototype into CRT achieved **(12/2022)**

Shifted to Jefferson Lab

- Optical DIRC lab for BaBar DIRC bar
- Complete QA of bars from first disassembled BaBar DIRC bar box, decision about further disassembly strategy

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

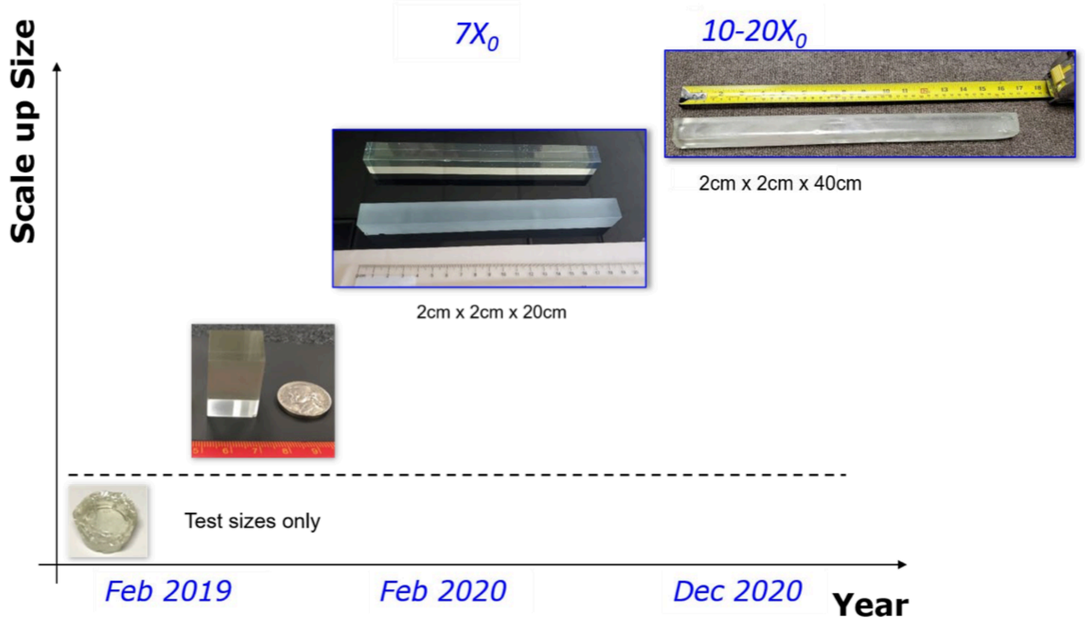
- Report on serial powering, **8/2022**
- Report on DC-DC powering, **10/2022**

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 $PbWO_4$.
  ➡ 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.



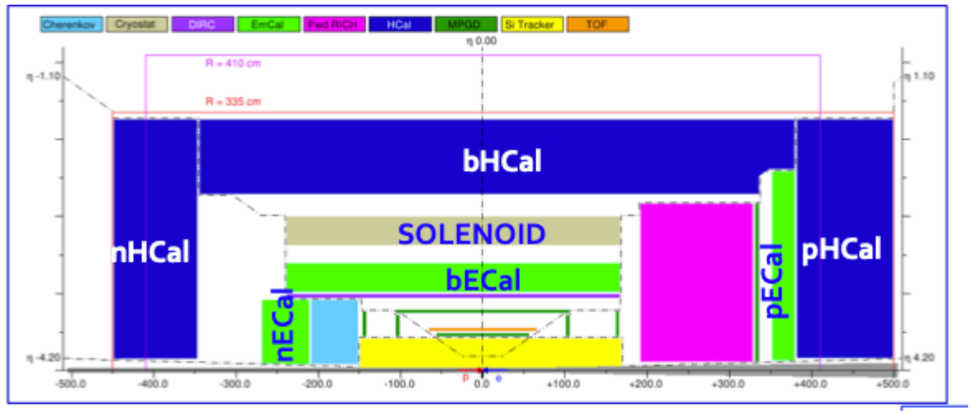
Milestones and Timeline for FY22

- 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/eRD107: Forward EMCal+HCal

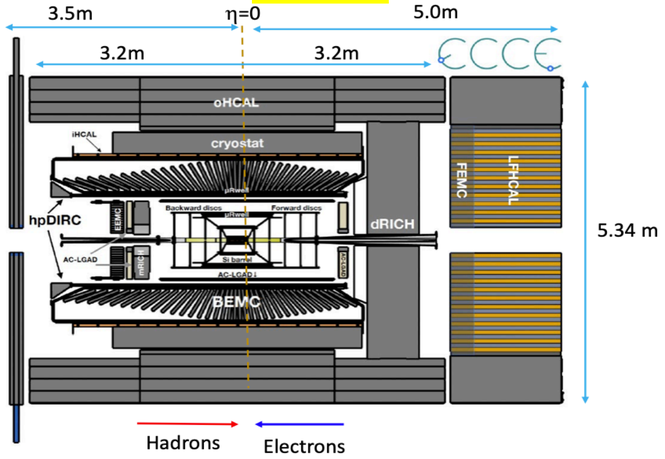
- The endcap calorimeters (EMCal and Hcal) require substantial efforts to merge the projects of the two collaborations, ATHENA and ECCE

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

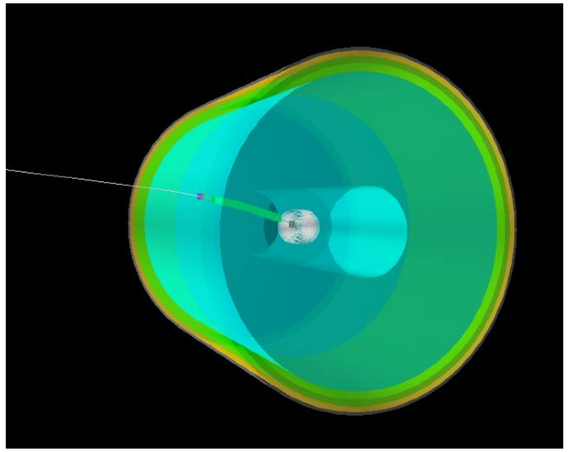
eRD108: MPGDs

Goal: develop EIC tracking for different systems

- R&D on three Micro-Pattern Gaseous Detectors (MPGDs)
  - micro-Resistive-Well (μRWELL)
  - Micromegas (MMG)
  - Gas Electron Multiplier (GEM)

- Applications:
  - μRWELL Layer for seeding DIRC reconstruction
  - Micromegas Barrel Tracker
  - Planar GEM/μRWELL Endcap Tracker

Cylindrical μRWELL Tracker for the DIRC



Milestones and Timeline for CY22

- Cylindrical μRWell:
  - Major Milestone: Design completed – 10/2022
  - Mechanical design completed (FIT) – 9/2022
  - Front-end electronics & DAQ design completed (TU) - 9/2022
  - Readout foil design completed (UVa & BNL) - 10/2022
- Cylindrical Micromegas Barrel Tracker:
  - Readout designs (Saclay & BNL) – 7/2022
  - Readout foils received (Saclay & BNL) – 10/2022
  - Bulk and assembly of prototypes (Saclay) – 12/2022
- Planar GEM/μRWell Endcap Tracker:
  - Realistic endcap detector simulation completed (FIT) – 11/2022
  - New frame designs completed (FIT & UVa & TU) – 10/2022

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

LAPPD:

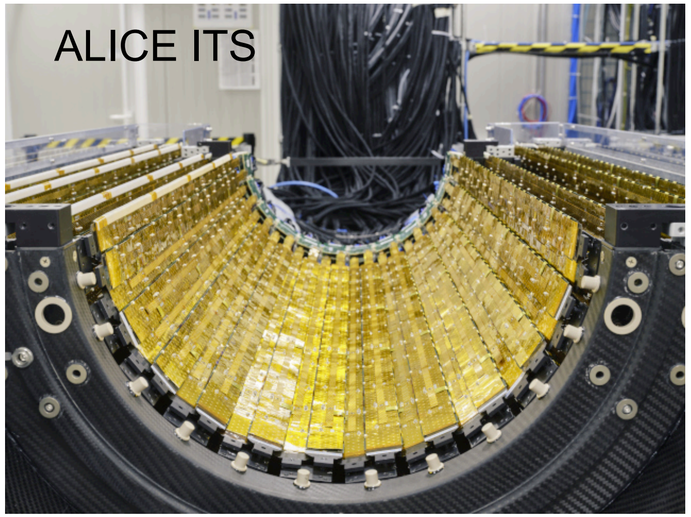
- Full evaluation of up to four different LAPPD and HRPPD tiles in the lab and under beam conditions. Evaluation includes determination of quantum efficiency, gain uniformity, operation under high rate, timing and position resolution measurements in a finely pixelated configuration.
  - Magnetic field test facility at Argonne ready for 20 cm tiles – **7/2022**
  - Various Gen II readout boards designed and delivered to BNL – **9/2022**
  - Fermilab beam test with the capacitively coupled LAPPDs / HRPPD – **10/2022**
  - Single photon position resolution report (bench tests with pixelated boards) by BNL – **12/2022**
  - Magnetic field tolerance report by Argonne – **2/2022**
  - Beam test data analysis and report - by **3/2022**
  - Preliminary assessment of the LAPPD / HRPPD feasibility for the EIC detector - by **3/2022**

SiPM:

- Comparative assessment of the performance after irradiation of commercial SiPM as well as prototypes not yet available on the market (but to INFN) of SiPM performance after irradiation, **8/2022**
- Definition of an annealing protocol, **9/2022**

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

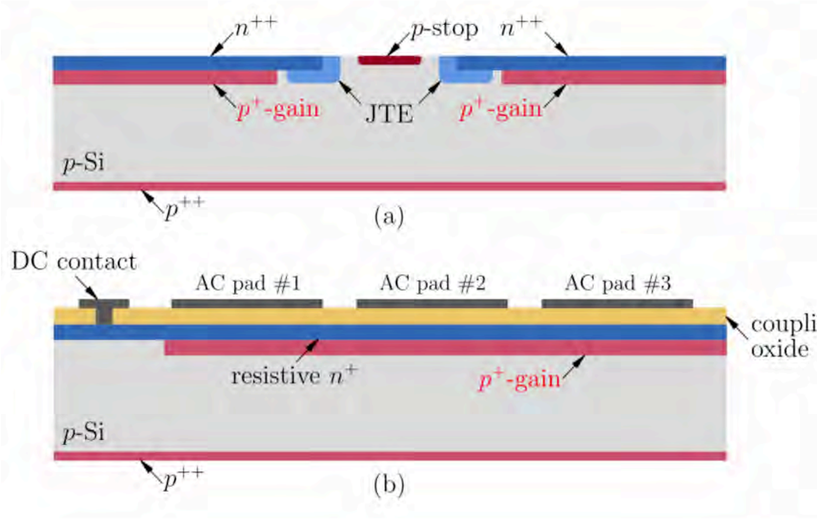
Milestones and Timeline for CY22

- 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)

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



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

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

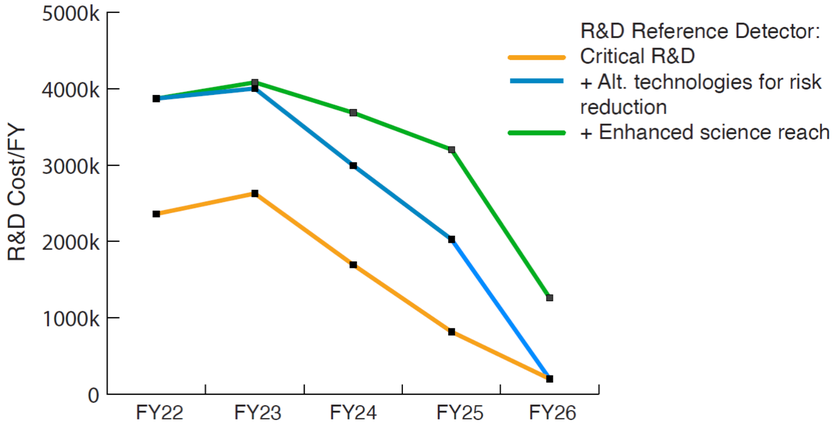
- A prototype ASIC design to readout AC LGADs using signal sharing across neighboring electrodes and has 30 ps time resolution with low power consumption, **9/2022.**

ASIC

Generic R&D Program

- In the remote quarterly EICUG meeting of March 29, 2022, Tim Hallman indicated an intent of the DOE Office of Nuclear Physics to start a generic EIC-related detector 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.

Take Away Message

- Project R&D program started
- R&D plan for reference detector 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)
- Indication from the DOE Office of Nuclear Physics to start a generic EIC-related detector R&D program in FY22 of scale 1-2M$.