# Review recap

Laura Gonella (U. of Birmingham) & Ernst Sichtermann (LBNL)

ePIC SVT DSC meeting
September 5, 2023

Selected R&D close-out slides

Shamelessly reproduced from Ed Kinney's close-out,
c.f. https://indico.bnl.gov/event/20113/

# Closeout Presentation of Detector Advisory Committee R&D Review
# August 28,31, 2023

Participating Members: *E. Auffray, , E. Kinney, P. Merkel, S. Miscetti, A. Papanestis, H. Schellman, B. Vachon, A. White, K. Wyllie, C. Yang*

Thanks to Elke Aschenauer, Rolf Ent, Thomas Ullrich, and Anna Mendez!

Thanks to EIC Project Team, ePIC Collaboration, and all the presenters!

# Charge to DAC

For the August 2023 DAC meeting dedicated to R&D we welcome your guidance and advice on:

- The status and progress from all ongoing projects eRD101 to eRD113. What milestones
- were achieved. How did our understanding improve. What is left to do?
- If applicable, the plans for remaining EIC project detector R&D for eRD102, eRD103, eRD104, eRD106, eRD107, eRD108, eRD109, eRD110, eRD111, eRD112, and eRD113.
- These may submit continuation proposals if and only if technical risk milestones remain. eRD101 and eRD105 are concluded as the ePIC collaboration has recently made the decision for a technology change for the backward RICH and the barrel ECal.
- The request for EIC project detector R&D for eRD114 and eRD115 that follow these two final detector technology selections for the ePIC detector.
- Further planning for the outyears of the EIC Project detector R&D as documented in the “Assessment of R&D Needs for an EIC Detector” (EIC Detector R&D) document.
- What do you see as priorities?

# eRD104 –Silicon Services Reduction

- The community proposes RnD towards a serial-powering scheme to reduce the material contribution from power-cabling. They have studied this, based on their experience of a similar approach in ATLAS, and have started the design of an integrated shunt-LDO circuit together with architectural studies. They have also studied a standalone alternative for the shunt-LDO.
- They also propose an electrical-optical conversion on detector to reduce the material contribution from data cabling and have identified options for the electrical and optical parts. Funding/procurements delays hindered the progress so far. They have also studied the readout implementation for ALICE-ITS3.
- How is the shunt-LDO prototyping planned and funded? The ‘standalone’ option allows flexibility to use MPW submission on TJ180 (or similar) while the integrated shunt-LDO is a large deviation from the ‘baseline’ ITS3 design. So the standalone shunt-LDO is a more promising route for the R&D.
- Two of the options for readout (PolarFire FPGA and Firefly Transceiver) are off-the-shelf and would likely require radiation testing. Is this part of the planned characterisation? If yes, are radiation facilities available, and is funding available?
- The switch to serial-powering is a significant change and is a large R&D effort requiring both ASIC and system design. Hardware prototyping is essential to prove its viability and the community should strive to advance with this as quickly as possible. The planned submission of the LAS v1 chip in Q1-2025 requires rapid closure of the R&D in 2024.
- There is potential synergy with ALICE-ITS3 on the readout links and this should be investigated thoroughly for the ePIC case. The ALICE system will use radiation-proven parts so requirements on radiation testing would be minimised. Access to these parts would likely require a request to CERN.

# eRD111 –Modules, Mechanics, Cooling and Integration

- The community has made good use of the close contacts to the ALICE community, in particular for the successful demonstration of bending dummy-ALPIDE chips to the ITS3 innermost radius and connecting them with FPCs. This has allowed the construction of a prototype tracker layer using dummy components.
- Air-cooling studies have advanced with carbon fibre + foam structures. The benchmark of a deltaT of 10C has been achieved with conducting carbon foam, which is encouraging for the prospect of air cooling.
- Simulations have been made to evaluate the presence of the air-flow on the beam-pipe bakeout, indicating that further study is required.
- The restrictions on the sensor-length variations imposed by the foundry triggered new layout considerations and CAD modelling.
- Is there a possibility to access prototype parts from ER1 for integration tests?
- Are the R&D concepts from eRD104 included in the integration modelling here? For example, the concept of the 'Data Management Board' borrowed from ALICE and the FPC.
- Proceed as fast as possible to prototyping bent structures using active ALPIDE parts or, even better, parts from ER1.
- Build strong communication with eRD104 for FPC and readout concept and design.

# eRD113 –Sensor Development and Characterization

- Together with the ALICE community, there has been significant progress on the validation of the TJ65 process with MLR1, then ER1. Multiple building blocks were submitted and many from MLR1 have been tested, including some radiation testing.
- Designs of other blocks customized for the EIC application were delayed waiting for funding approval and are carried forward to FY24.
- First discussions on a collaboration agreement with ALICE were held, paving the way for contact between designers.
- EIC institutes became more and more active in testing of structures from TJ65, including calibration with radioactive sources. A telescope was developed for testbeam activities and is available for EIC use.
- Is access to ALICE designs now granted and a collaboration agreement in place? This is vital for a EIC outer-barrel design submission targetting Q1-2025.
- The detector construction relies on stitching. Has there been a study on what yield is acceptable?
- Advance as quickly as possible to finalise the collaboration agreement with ALICE and integrate designers in the team at CERN.
- Foster strong ties with eRD104 to ensure the correct consideration in the MAPS design of the systems aspects of both serial-powering and readout links.

# Global Recommendations

- Again, congratulations to all on enormous progress in short time!
- Aggressive effort needed to keep to project timeline
- Important to expand manpower as soon as possible to keep on track
- Recommend continued direction of effort towards final detector development for CD2/3
- Silicon tracker, Imaging barrel calorimeter are critical complex components and should be a high priority; the choice of the HRPPD must be made relatively soon (in some cases already). ASICS development is also of high priority and will need a large, experienced manpower support to remain on timeline after CD2/3.

eRD104, 111, 113 talk — reproduced here

c.f. https://indico.bnl.gov/event/20113/

# ePIC Silicon Vertex Tracker Project R&D

Status Report and Proposal

eRD104: Services Reduction
eRD111: Modules, Mechanics, Cooling and Integration
eRD113: Sensor Development and Characterization

Ernst Sichtermann (LBNL)
for the ePIC SVT Detector Subsystem Collaboration

EIC Project R&D — Detector Advisory Committee Meeting (August 2023)
https://indico.bnl.gov/event/20113/

# Outline

- **Introduction**
- Status of R&D for the ePIC SVT
- Proposal and request for FY24
- Outlook

# ePIC Silicon Vertex Tracker Collaboration















# ePIC Silicon Vertex Tracker Collaboration

- The overarching goal is the development and construction of a full tracking and vertexing detector subsystem for the ePIC project detector based on 65nm MAPS sensors
- ePIC SVT DSC has its origins in the EIC Silicon Consortium,
- MIT, Oxford, and Purdue have joined during the past period,
- Productive work with the EIC project in areas ranging from agreements with ALICE/CERN on sensor development to service estimates and routing, work package structure, etc.
- Kickoff meeting provides an overview — https://indico.bnl.gov/event/19823/

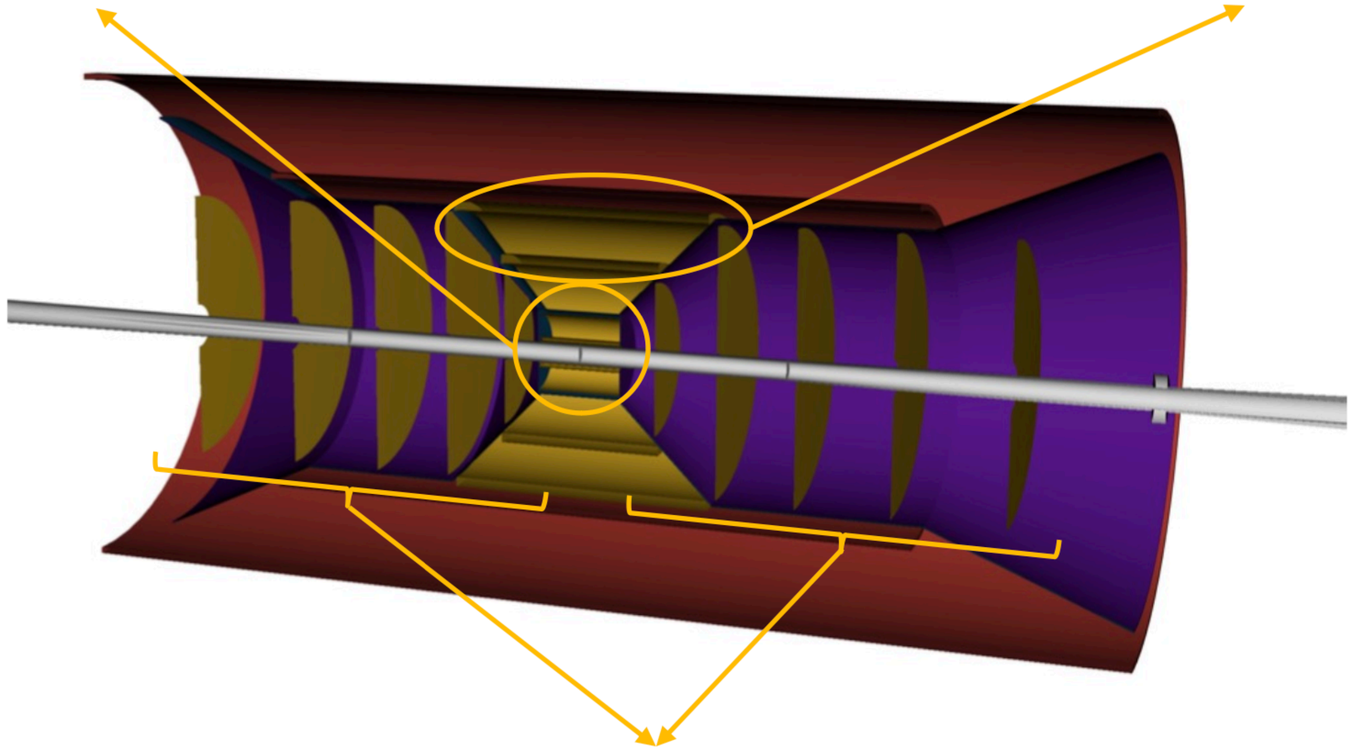
# ePIC Silicon Vertex Tracker

**Inner Barrel (IB)**

- Two curved silicon vertex layers,
- One curved dual-purpose layer,

**Outer Barrel (OB)**

- One stave-based sagitta layer,
- One stave-based outer layer,



**Electron/Hadron Endcaps (EE, HE)**

- Five disks on either side of the Interaction Region,

**Total active area ~ 8.5 m$^2$**
**Radius ~ 0.45 m**
**Length ~ 2.5 m**

**Well integrated, large acceptance, high granularity, and low-mass subsystem,**

**New generation MAPS technology to satisfy the requirements — based off the ALICE-ITS3 development.**

Note that the ePIC SVT concept and geometrical configuration is largely unchanged; there are, however, changes e.g. because of sensor development.
The surrounding ePIC tracking configuration has evolved; MPGDs are the topic of eRD108 and are outside the scope of eRD104, eRD111, and eRD113.

# ePIC Silicon Vertex Tracker R&D

Project R&D for the ePIC SVT is organized in three areas:

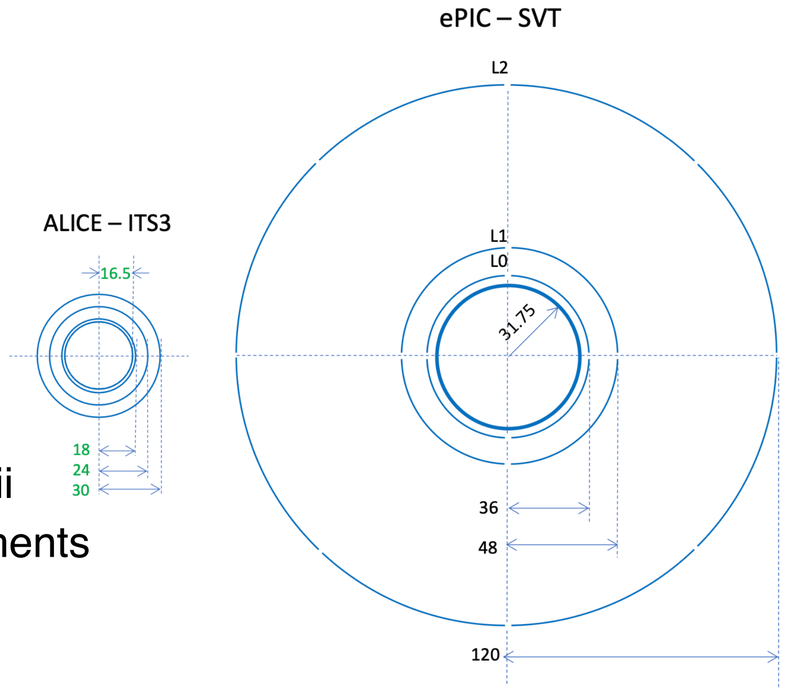
- **eRD104** — services reduction
  - Investigates methods to significantly reduce the services load;
  - Powering system
  - Readout system
- **eRD111** — modules, mechanics, cooling, and integration
  - Development of a full tracking detector solution composed of next-generation 65 nm MAPS;
  - Forming modules from stitched sensors
  - Barrel and Disks
  - Cooling
  - Mechanics and integration
- **eRD113** — sensor development and characterization (started in FY23)
  - Development of the EIC MAPS;
  - Sensor design
  - Sensor Characterization

In addition, the SVT relies on Project Engineering and Design support and in-kind contributions.

The SVT does *not* rely on the Generic EIC-related R&D Program, c.f. https://www.jlab.org/research/eic_rd_prgm. However, several members of the ePIC SVT DSC are part of submitted proposals to that program.

# ePIC SVT

At a high level, the ePIC SVT thus requires us to develop:




**1. ITS3-like Inner-Barrel layers**

- Re-use the ITS3 sensor as is
- Adapt the ITS3 detector concept to the EIC:
  - Mechanics of bent layers — sensor and support — for the larger EIC radii
  - Services and cooling design and routing for the EIC acceptance requirements
  - Considerations related to in-situ beam-pipe bake-out at the EIC

**2. EIC variant for the staves in the Outer Barrel and the Endcap Disks**

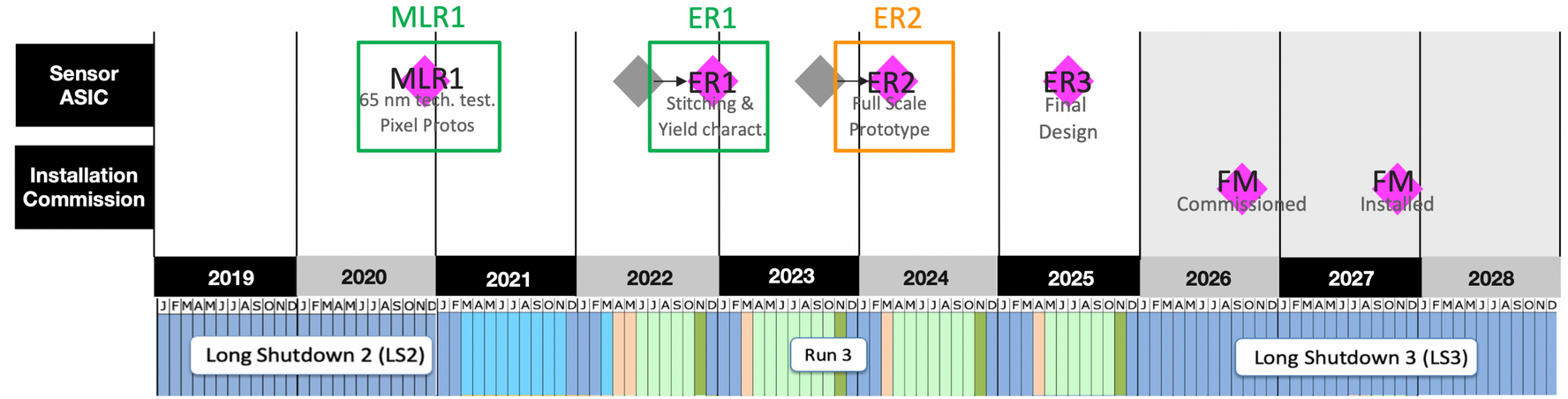
- EIC Large Area Sensor (LAS), i.e. ITS3 sensor size optimized for large-area coverage, yield, and cost
  - EIC LAS will be stitched, but not to wafer scale; functionality and interfaces stay largely unchanged
  - Size(s) of the EIC LAS to be defined by requirements for full coverage and yields, cost
- More conventional carbon composite mechanical support structures with integrated cooling

# ePIC SVT Sensor — ITS3

Management of the relationship with ITS3 is critical to eRD113 and the success of the ePIC SVT.

EIC project / ePIC and CERN / ALICE met in April 2023 at CERN — **agreement to share sensor.**

ITS3 development timeline:




Source: Gianluca Aglieri Rinella, Walter Snoeys — https://indico.cern.ch/event/1280150/

ePIC SVT sensor timeline: the EIC LAS will be based off the ER2 and ER3 designs.

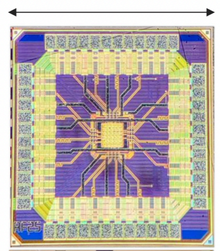
# Intermezzo — MLR1, ER1, ER2, …

- MLR1 — Q4 2020
  - Technology exploration — first submission in 65 nm CMOS imaging
  - Prototype circuit blocks for future sensors
  - Includes Analog and Digital Pixel Test Structures (APTS, DPTS)

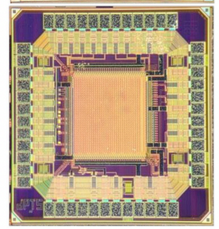
- ER1 — Q4 2022
  - MOSS and MOST sensors; exploratory designs to learn and prove stitching, methodology, constraints, yield
  - First, single unit MOSS was powered and responded correctly to slow control commands

- ER2 — Q1 2024
  - Sensor design aims to satisfy ITS3 requirements
  - *Not* a direct evolution of MOSS / MOST; substantial redesign of existing circuits, new features

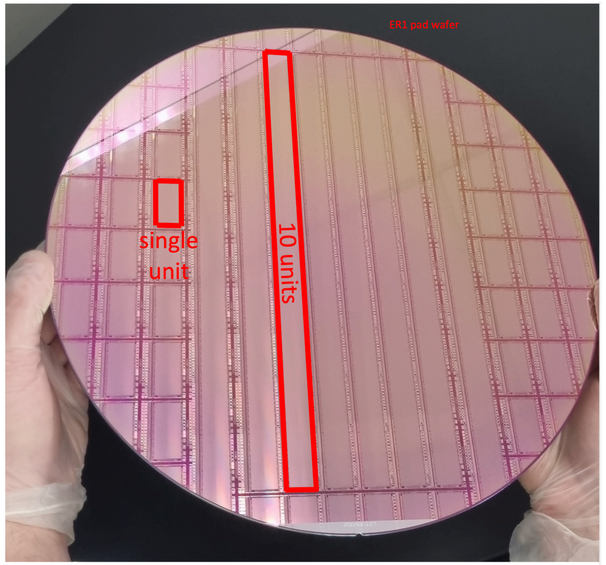
- ER3 — Q2 2025
  - Final ITS3 design / production




APTS
4x4 pixel matrix
10, 15, 20, 25 µm pitches
Pixel variants
Direct analogue readout



DPTS
32 × 32 pixels
15 µm pitch
Asynchronous digital readout
ToT information



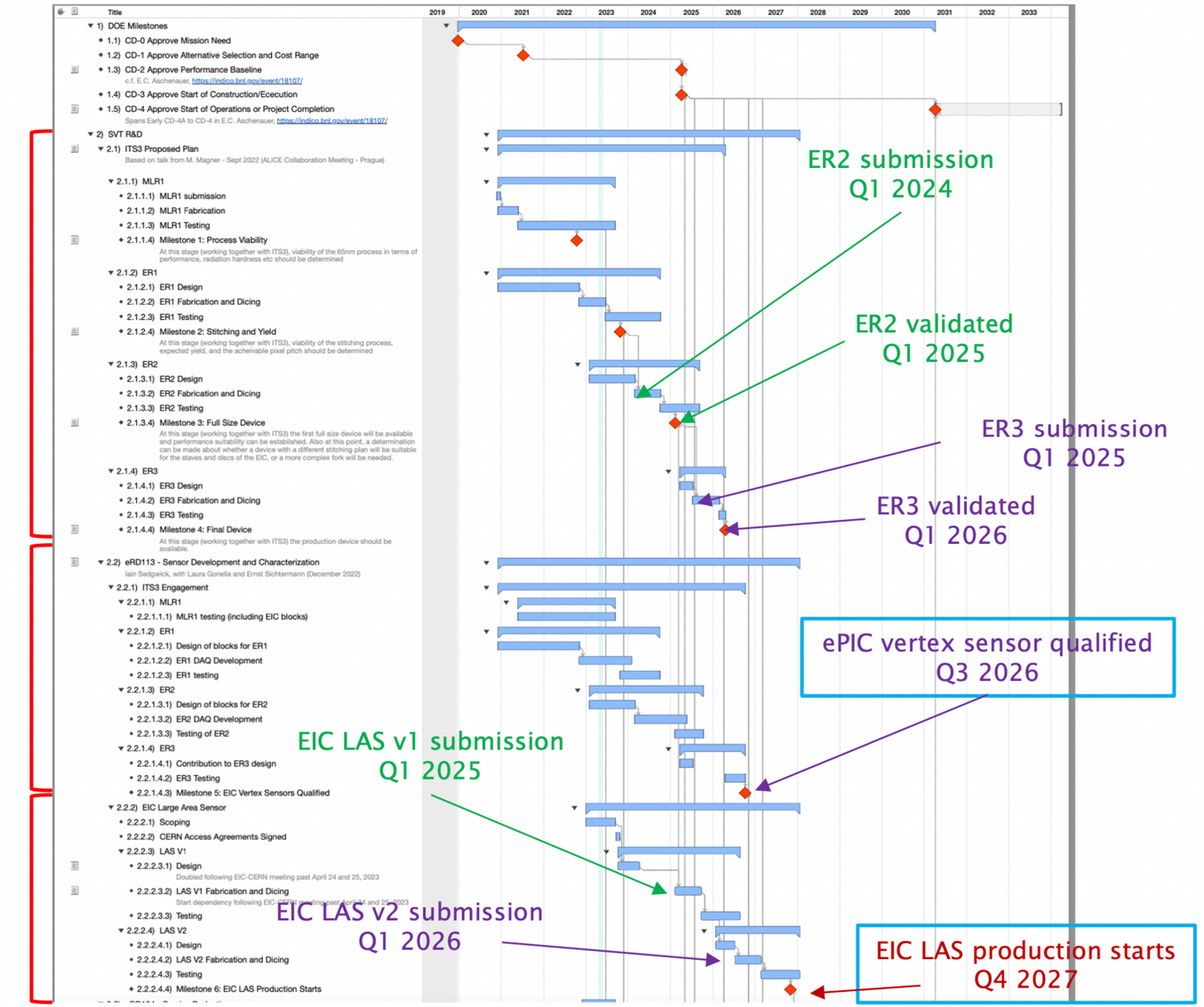

Source: Gianluca Aglieri Rinella, Walter Snoeys — https://indico.cern.ch/event/1280150/

# ePIC SVT Sensor — development schedule

ITS3 schedule

EIC contributions to ITS3 submissions

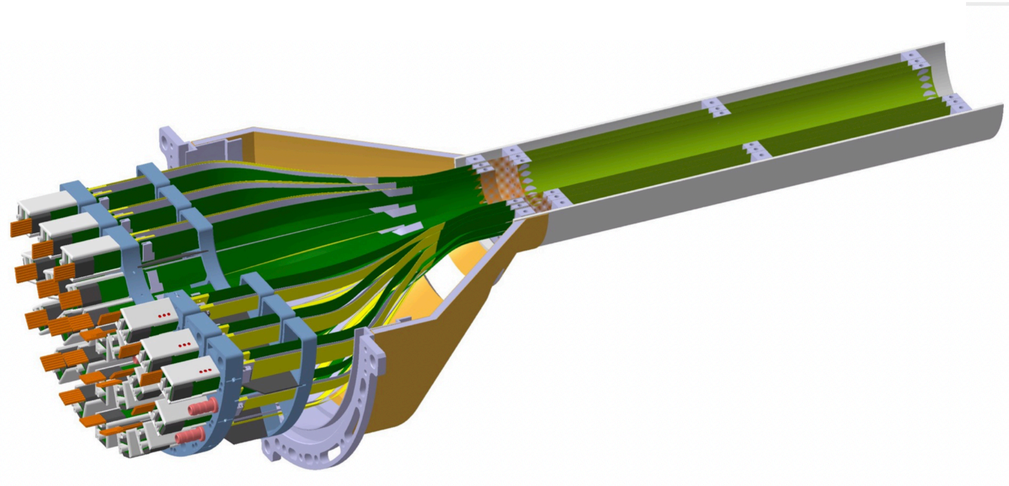
EIC LAS design



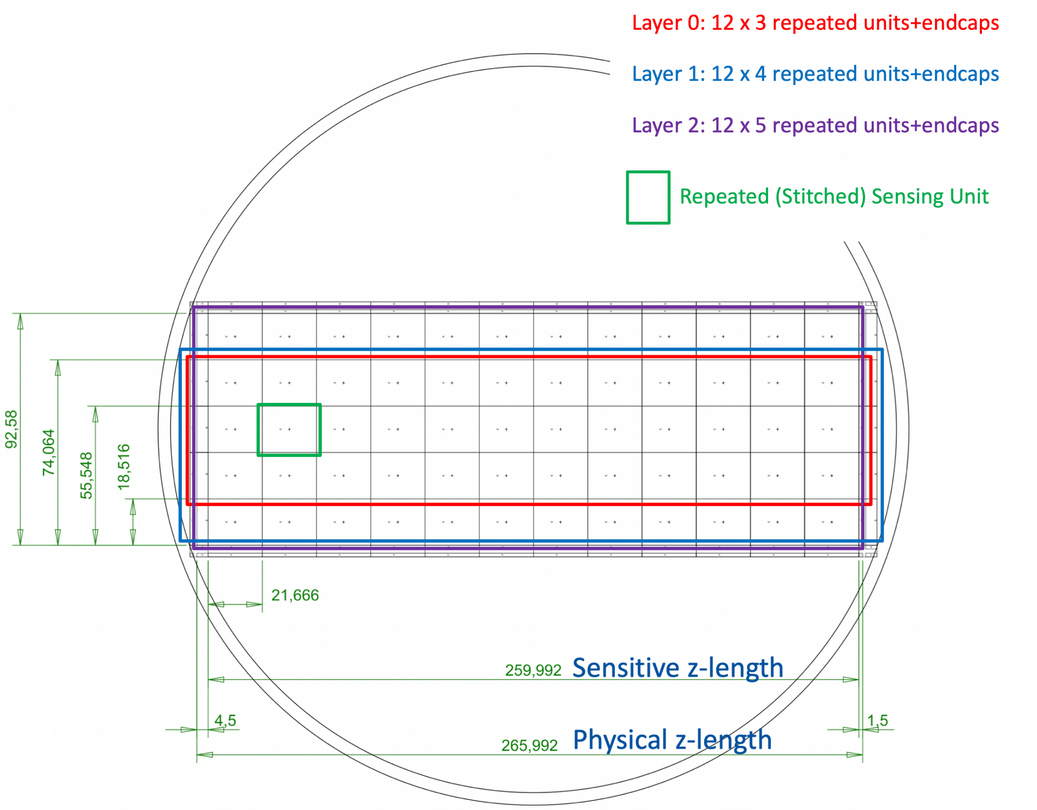
# ITS3 implications — ePIC SVT Sensor

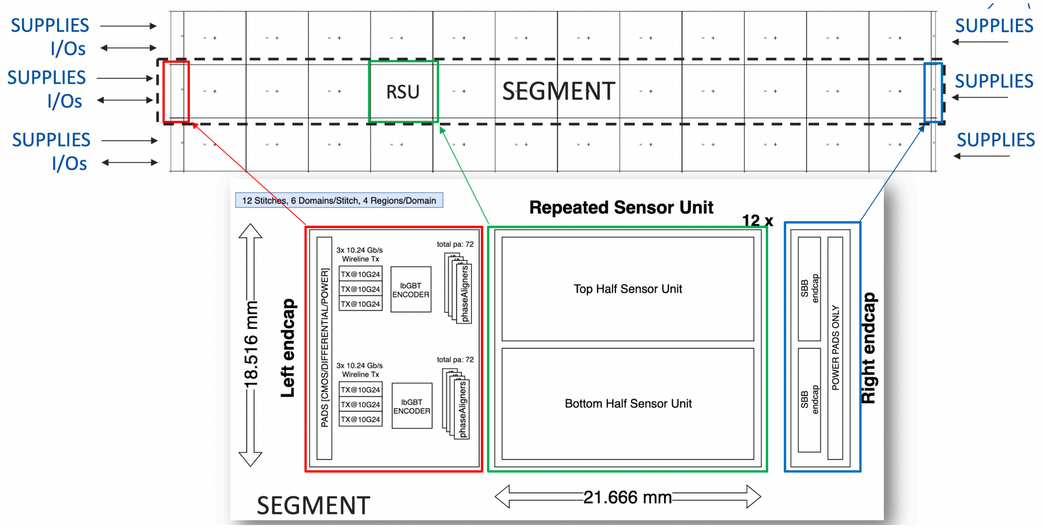
ITS3 in a nutshell:

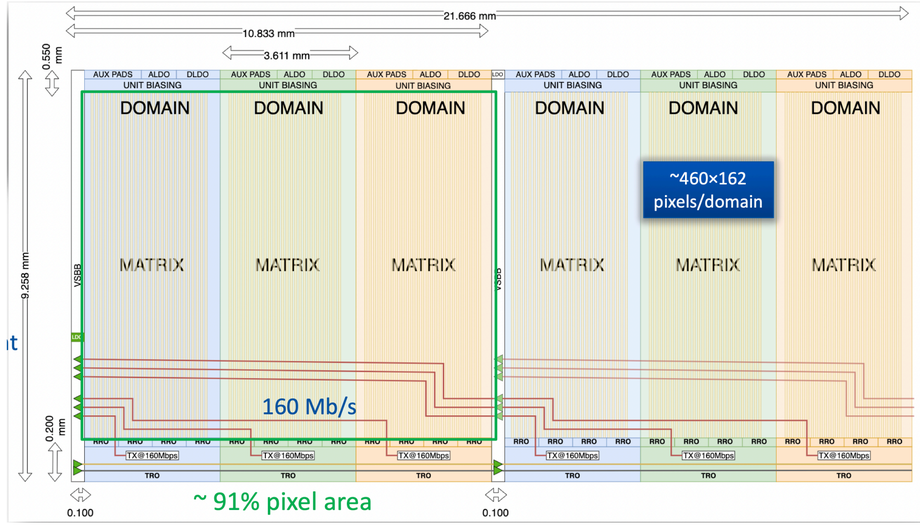
- Made with 6 curved wafer-scale single-die Monolithic Active Pixel Sensors
- No flex circuits in the active area; power and data transfer on the chip to/from the short edge
- Cooled by air flow; dissipate less than 20 mW/cm$^2$ (in the sensitive area)
- LoI CERN-LHCC-2019-018 / LHCC-I-034



# ITS3 ER2 implications — ePIC SVT Sensor




Rapidly evolving ER2 design,

Foundry rules will limit the EIC LAS to 2 or 3 variants,

Likely, limit EIC LAS variant(s) to six RSUs or fewer,

Serial powering, data multiplexing.

# Outline

- Introduction
- **Status of R&D for the ePIC SVT**
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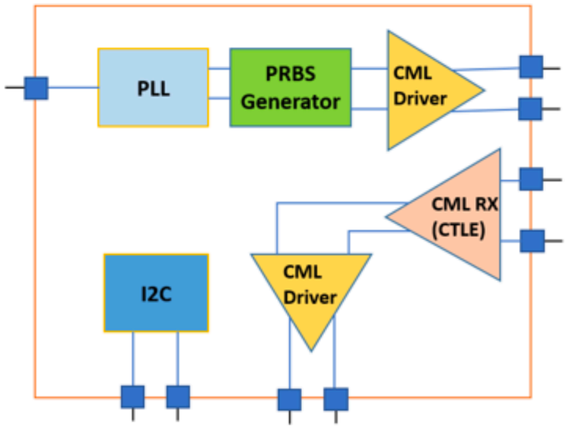
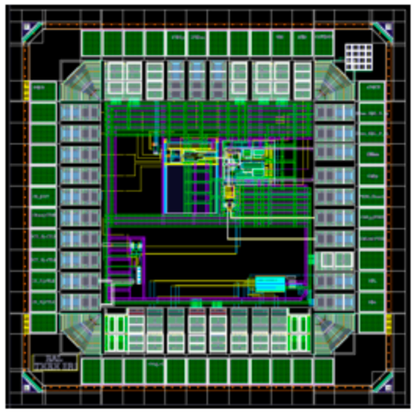
# ePIC SVT — Sensor Design

- RAL, BNL, and LBNL are involved in the design of the ePIC SVT sensor,

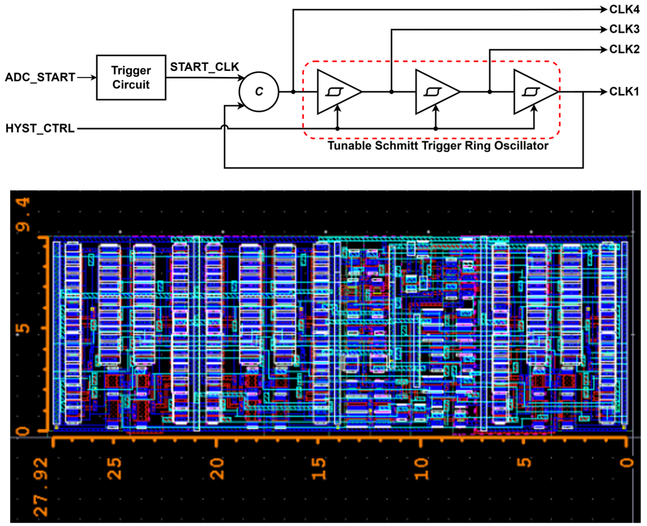
- RAL has contributed structures to the past ITS3 submissions — made possible with resources from the former eRD18/25 project and the UKRI-STFC Infrastructure fund,
    - MLR1 — circuit blocks for high-speed off-sensor data transmission up to 2 Gbps
    - ER1 (FY23) — continuation of high-speed off-sensor data transmission (PLL, CML receiver); design of low speed on-sensor data transmission (I2C); redesign of standard cells for DFM



# ePIC SVT — Sensor Design

- RAL, BNL, and LBNL are involved in the design of the ePIC SVT sensor,
- ePIC contributions to ER2 design under discussion with ITS3 designers
  - DFM / low power standard cells — RAL, BNL, LBNL
  - Monitoring Analog-to-Digital Converter — BNL
  - SRAM design — LBNL
  - Voltage regulation — RAL, BNL
- Design ongoing or starting on ePIC specific developments for EIC LAS
  - Shunt LDO regulator development for current-based serial powering scheme underway at RAL
  - Generation of sensor bias voltage from sensor low voltage — BNL
  - Integrated data multiplexing — BNL
- Early to late Q2 timeline of eRD113 project funding and PED has affected start on FY23 goals at BNL and LBNL; goals will carry over into FY24.

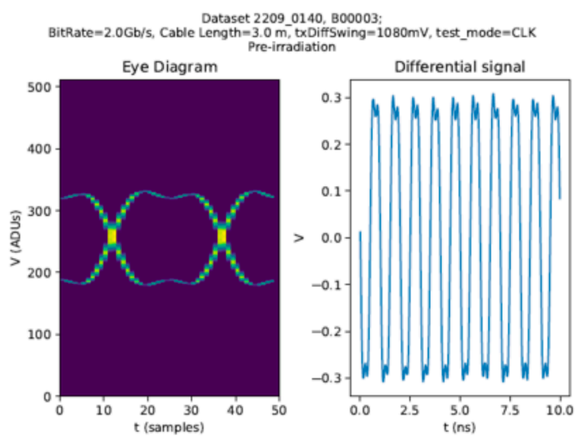


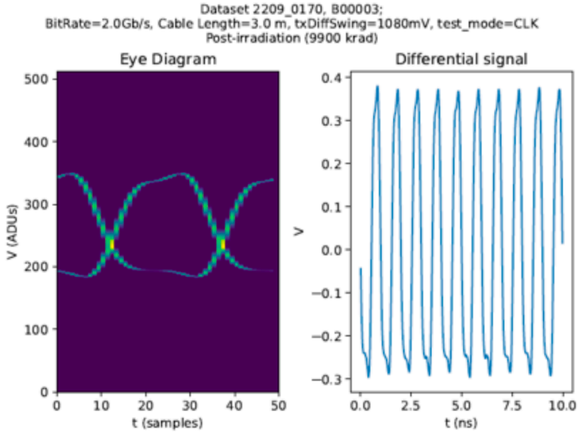

Monitoring ADC: on-demand clock component

# ePIC SVT — Sensor Characterization

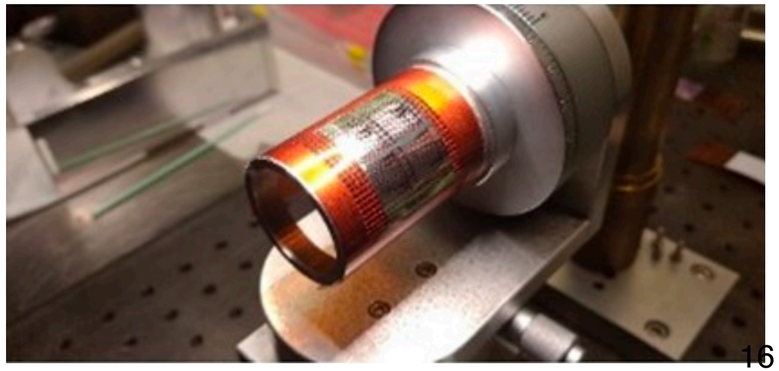
- INFN groups, UK groups, ORNL and LBNL are involved in characterization of ITS3 submissions,

- UK groups have characterized MLR1 RAL blocks; involved in testing of APTS and DPTS



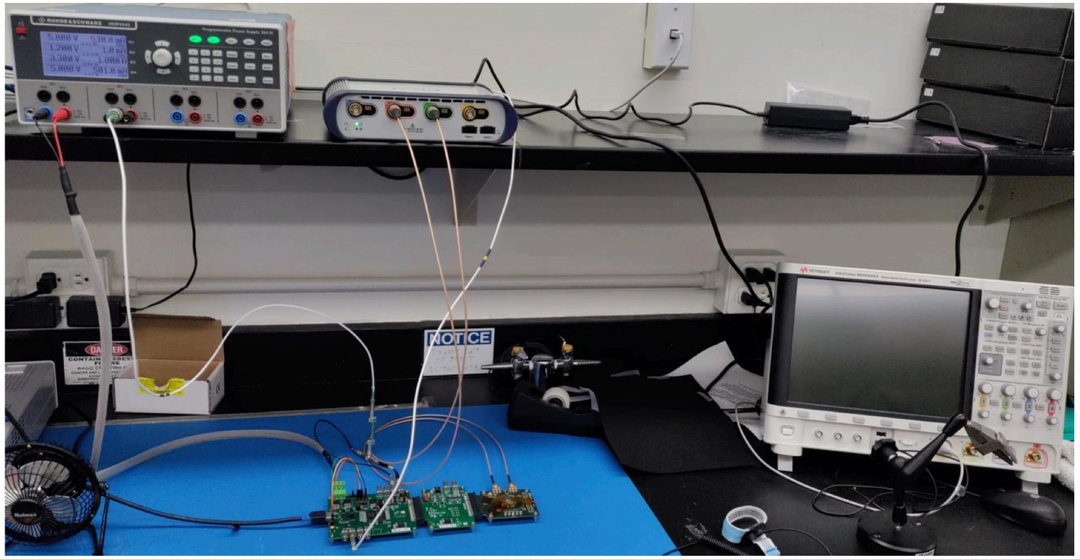



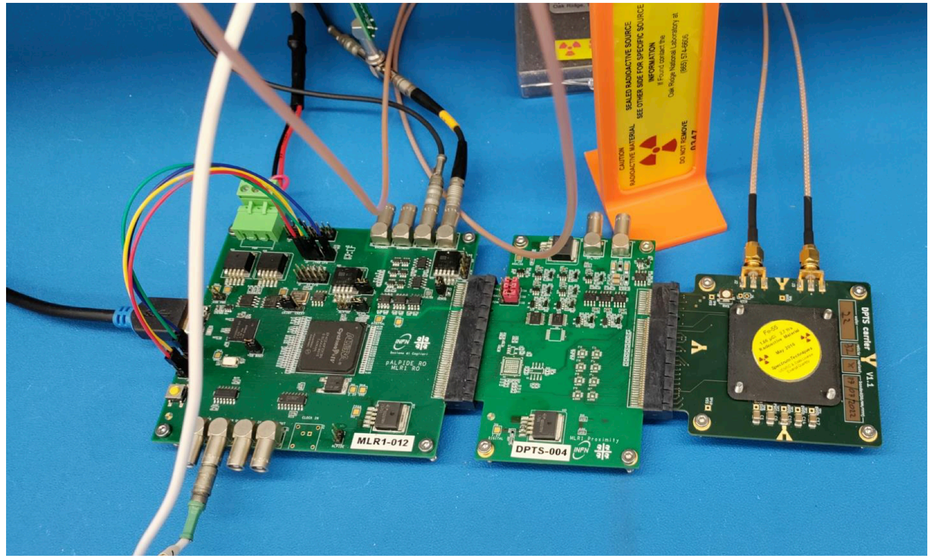

- INFN carrying out APTS and DPTS characterization, including curved geometry structures; trained ORNL and LBNL staff in DPTS characterization,



# ePIC SVT — Sensor Characterization

- INFN groups, UK groups, ORNL, LBNL, and MIT are involved in characterization of ITS3 submissions,
- ORNL established a DPTS test setup; ongoing effort towards energy calibration with Fe-55 source, CML buffer parameter scan, time-over-threshold studies, pixel-per-pixel variations



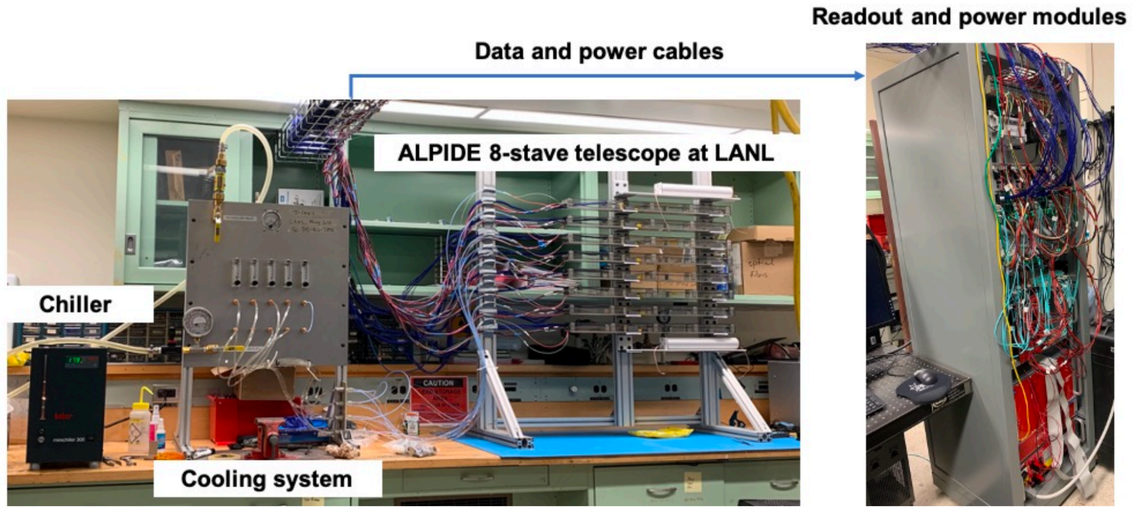




- LBNL established a DPTS test setup; multiple studies including ToT; produced and tested 20 DAQ boards to help overcome supply-chain shortages; participated in test-beam effort

# ePIC SVT — Sensor Characterization

- MIT is setting up a PIXEL laboratory at CERN and establishing close collaboration with ITS3; participated in ER1 MOSS test beam and analyzing its data

- LANL has set up an 8-stave ALPIDE (ITS2) telescope for precision tracking with test beams and is making it available for new EIC sensor characterization with test beams in late 2023 and 2024,



# ePIC SVT — Services Reduction

- UK groups and ORNL are involved in Services Reduction

- In a traditional approach, the largest components of services would be the powering system cabling followed by the readout cabling,

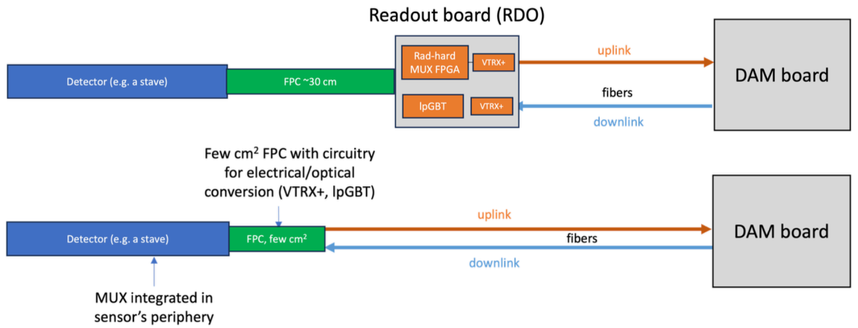
- FY23 aims were for a conceptual design of powering and readout schemes for the ePIC SVT and an initial assessment of components to inform selection,

- Powering:
  - Constant-current powering scheme is chosen for the Outer Barrel and Endcap Disks
    - EIC LAS sensors are powered in series,
    - Regulators convert the input current into the (analog and digital) voltage needed by the EIC LAS
  - Regulator architecture: Shunt-LDO
    - Regulator concept developed for the serial powering scheme of the ATLAS and CMS pixel systems at the HL-LHC,
  - Shunt-LDO design is in progress — aim for prototype submissions in early 2024,

# ePIC SVT — Services Reduction

- UK groups and ORNL are involved in Services Reduction

- Readout:
  - Develop a multiplexing strategy for the output links of the EIC LAS and thereby reduce the multiple 10 Gbps links in the ITS3 sensor that will not be required at the EIC in view of the much lower data rates at ePIC,
  - Two options under consideration:
    - External multiplexing using commercial FPGAs
    - Multiplexing integrated on the sensorReadout:

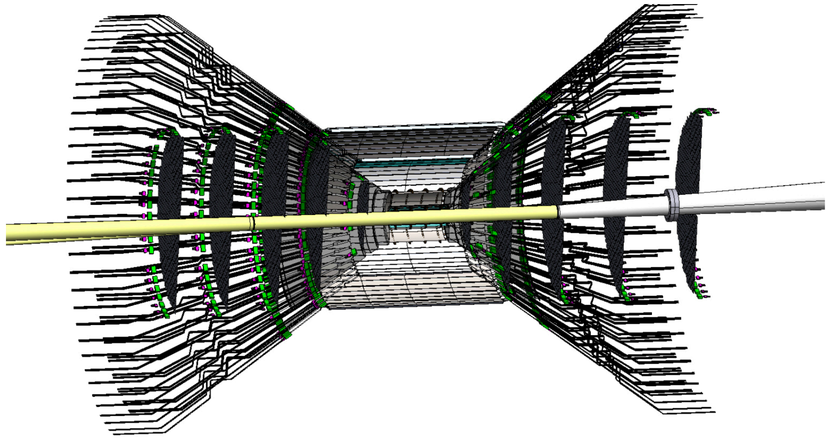



- Work with the project to inform service estimates in both areas,

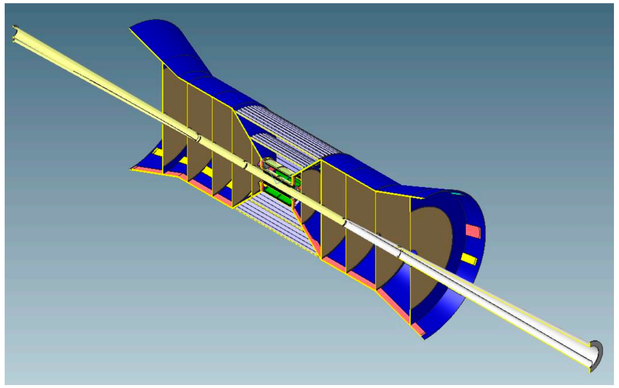
- Q2 timeline of eRD104 project funding has delayed planned ordering for various evaluation boards so that some of the FY23 goals for readout will carry over into FY24.

# ePIC SVT — Mechanics

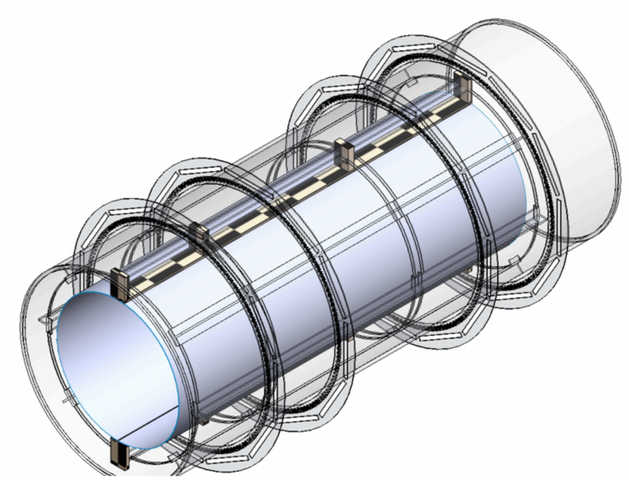
- UK groups, LANL, LBNL, and Purdue are involved in CAD modeling efforts — MIT starting up



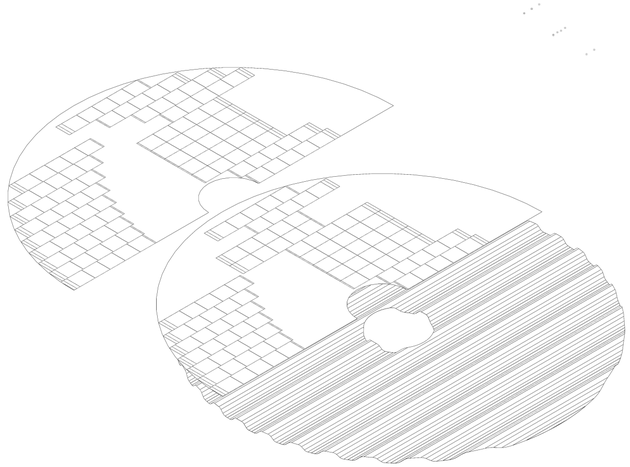
ePIC SVT overall layout - LANL



Emphasis on Outer Barrel layers - UK groups



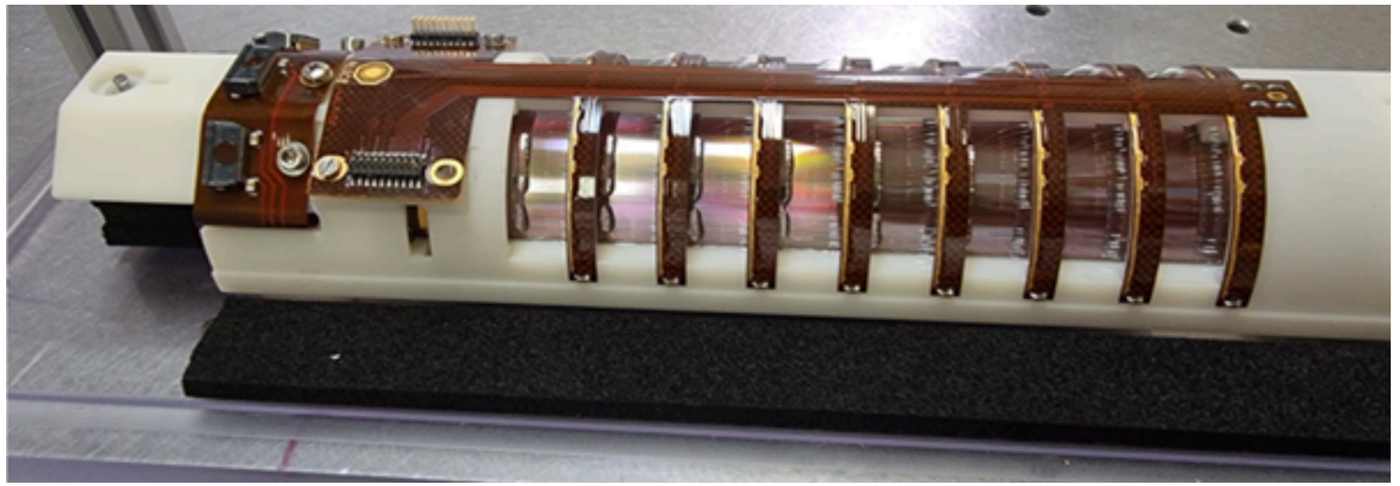
Sketch for ePIC Global support - Purdue



Disk concept with tiled EIC LAS — LBNL

# ePIC SVT — Mechanics

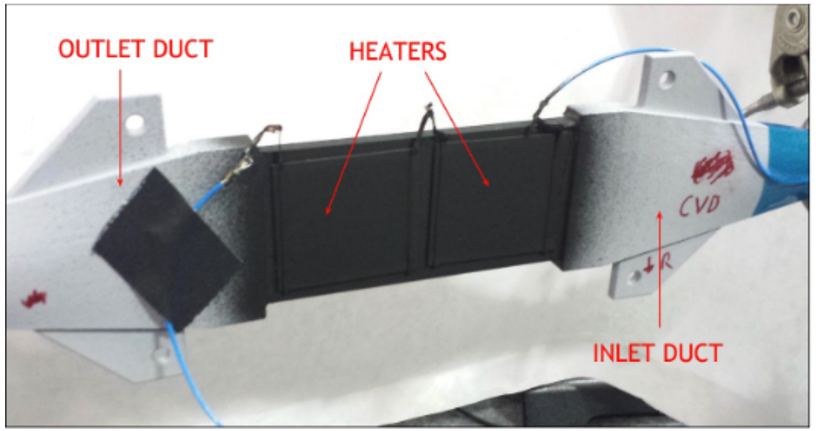
- INFN developed tooling and procedures for handling and bending thin wafer-scale silicon sensors,
- Successfully assembled two curved prototypes, based on blank silicon (no electronics) with the dimensions of the super-ALPIDE (ITS2 based) prototype layer

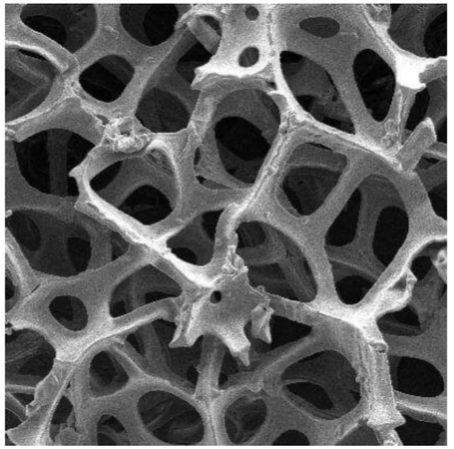


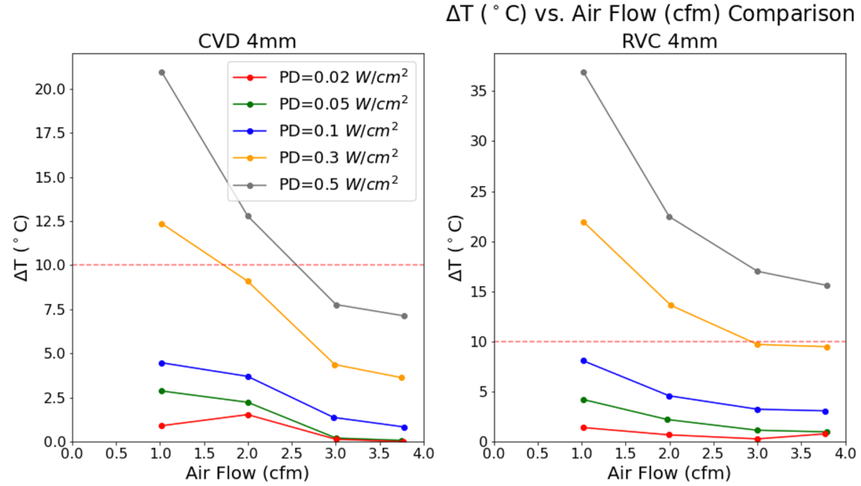
- INFN Pavia will be joining the effort and make their climate chamber available for stability tests.

# ePIC SVT — Cooling

- LBNL is performing studies to find out if internal air cooling is a viable option for the ePIC SVT
  - Current estimates are that the sensor main periphery will dissipate 1—2 W/cm$^2$ and the pixel matrix ~10 mW/cm$^2$






  - ePIC SVT specific structures and heating elements in progress


# Outline

- Introduction
- Status of R&D for the ePIC SVT
- **Proposal and request for FY24**
- Outlook

# ePIC SVT R&D — eRD104

- Contact person: Laura Gonella (University of Birmingham)

- UK groups propose continued collaboration on **services reduction for powering**:
  - Engineering Review of Serial Powering schemes
  - Electrical Testing of shunt-LDO regulators, mock-up SP powering schemes, shunt-LDO performance evaluation
  - Radiation testing (X-rays, electrons, hadrons) of regulators
  - Aluminum flex circuits
- Contributions are predominantly in-kind on a best effort basis; PED request for effort not (yet) supported by UK grant

- ORNL focuses on **readout services reduction** and proposes:
  - Characterization of the radiation tolerant FPGA utilizing the Microchip PolarFire evaluation board,
  - Characterization of the lpGBT environment as a means for electrical / optical conversion utilizing the CERN VLDB+ evaluation kit,
  - Characterization of the Samtec optical FireFly components utilizing a Samtec evaluation board, interfaced to the PolarFire evaluation board,
  - Design and implementation of the multiplexing firmware on both the PolarFire evaluation board as well as the FELIX board as the back-end DAM board
  - Design and fabrication of a test system as well as FPCs for the characterization of the ER-1 NIKHEF serializer chip
  - Radiation testing of fault tolerance of FPGA evaluation board multiplexing with fiber optic transmission at a test beam facility

# ePIC SVT R&D — eRD104

- MIT has recently joined the ePIC SVT effort and proposes contributions with postdoc effort stationed at CERN on the readout chain to transition to fiber links close to the sensor, thereby reducing the readout services load. This work will pursued in collaboration with ORNL.

Table 1: Institutions involved and institutional contacts

| **Topic** | **Institute** | **Institutional contact** |
|---|---|---|
| Powering system | Birmingham | Laura Gonella |
| | Oxford | B. Todd Huffman |
| | RAL | Fergus Wilson |
| Readout System | ORNL | Jo Schambach |
| | MIT | Gian Michele Innocenti |

Table 2: R&D funding request in k$ and breakdown by institution.

| **Institute** | **EE** | **ME** | **PD** | **M&S** | **travel** | **total FY24** |
|---|---|---|---|---|---|---|
| ORNL | 44.5 | 15.0 | | 15.0 | 7.0 | 81.5 |
| MIT | | | 21.0 | | | 21.0 |
| **Total** | **44.5** | **15.0** | **21.0** | **15.0** | **7.0** | **102.5** |

- The need for R&D is likely to continue beyond FY24 into FY25 in view of the still rapidly evolving sensor design.

# ePIC SVT R&D — eRD111

- Contact person: Nicole Apadula (Lawrence Berkeley National Laboratory)

- UK groups are proposing:
  - Development of FPC concepts for the inner barrel and exploration of wire bonding and interconnection
  - Study of FPC and module possibilities based on the number of RSU variations for the Outer Barrel. Implications of the study will be used for disk FPC and module design
- Contributions are predominantly in-kind on a best effort basis; project R&D request for effort not (yet) supported by UK grant

- INFN groups are proposing:
  - Climate chamber tests of long term mechanical stability of wafer-scale size sensors at inner barrel bending radii

- Purdue is proposing investigating if cooling options being considered for other detectors can be carried over to the ePIC SVT and explore options for low-mass two-phase $CO_2$. Careful attention will be paid to material budget.

# ePIC SVT R&D — eRD111

- Contact person: Nicole Apadula (Lawrence Berkeley National Laboratory)

| Topic | institute involved | institute contact |
|---|---|---|
| modules & interconnections | INFN institutes<br>UK institutes | Domenico Elia<br>Georg Viehhauser |
| barrel & discs | INFN institutes<br>LANL<br>LBNL<br>MIT<br>Purdue<br>UK institutes | Domenico Elia<br>Walter Sondheim<br>Nicole Apadula<br>Gian Michele Innocenti<br>Andy Jung<br>Georg Viehhauser |
| mechanics, cooling, & integration | LANL<br>LBNL<br>MIT<br>Purdue<br>UK institutes | Walter Sondheim<br>Nicole Apadula<br>Gian Michele Innocenti<br>Andy Jung<br>Georg Viehhauser |

| Institute | Request ($k) |
|---|---|
| INFN institutes | 45 |
| Purdue | 25 |
| UK institutes | 40 |
| **Total** | **110** |

- Proposed R&D efforts focus on reducing project risk only. Further efforts are needed to bring the ePIC SVT to construction readiness and will be part of a separate PED request.

# ePIC SVT R&D — eRD113

- Contact person: Grzegorz Deptuch (Brookhaven National Laboratory)

- Note: The eRD113 proposal currently contains both proposed R&D efforts and PED efforts.

- **Sensor design**
  - The UK groups are proposing:
    - Design and coordination of further development of the DFM standard cell library for the ITS3 ER2 submission
    - Shunt LDO implementation and circuit simulation
    - Simulation and verification of the serial powering scheme using the Shunt LDO
    - Prototyping of serial powering using the Shunt LDO
    - The contributions will be in-kind and on a best-effort basis

  - BNL proposes (in short):
    - Contributions to the DFM standard cells library
    - Continued development of a small-footprint ADC for Vital Functions Monitoring
    - Development of Long-Distance-on-Chip Ultra-Low-Voltage Signaling data transmission
    - New R&D for a Negative Voltage Bias Generator / Regulator compatible with LAS serial powering
    - New R&D for Time Division Multiple Access interface connects for aggregation of high-speed links for data transfer off the MAPS sensors
    - New R&D for TMDA multiplexer design to congregate LAS data to efficiently fill the lpGBT (up-)links

  - LBNL can take on additional design contributions to the DFM standard cells library

# ePIC SVT R&D — eRD113

- Contact person: Grzegorz Deptuch (Brookhaven National Laboratory)

- Note: The eRD113 proposal currently contains both proposed R&D efforts and PED efforts.

- **Sensor characterization**
  - INFN proposes:
    - EIC specific optimization of the MLR1 test structure configuration
    - Stitched sensor characterization

  - UK groups:
    - Propose continued characterization of devices fabricated on MLR1 and ER1
    - Seek to contribute to the texting of ER1 MOSS or baby-MOSS sensors (in discussion with ITS3 WP3)
    - The UK contributions will be in-kind and on a best-effort basis

  - ORNL proposes:
    - Characterization and calibration of sensors
    - Proof of principle laser stimulation of sensors
    - Gantry tooling development for sensor and flex circuit handling and assembly

# ePIC SVT R&D — eRD113

- Contact person: Grzegorz Deptuch (Brookhaven National Laboratory)
- Note: The eRD113 proposal currently contains both proposed R&D efforts and PED efforts.
- **Sensor characterization**
  - LBNL proposes:
    - Continued characterization effort of sensors
    - Modeling efforts to reduce risk associated with tiling, uncertainties from yields and power specifically for the ePIC SVT
  - LANL proposes:
    - Participation in ITS3 prototype sensor beam tests
    - Contributing to EIC-LAS back-end readout integration in collaboration
    - Irradiation tests for ITS3 sensors using the LANSCE facility at LANL
  - MIT is equipping a pixel lab at CERN and proposes:
    - Characterization effort of ER2 sensors “on the bench” at CERN once these sensors become available,
    - Characterization with test beams of the ER2 sensor and of the ePIC
    - Software integration and DAQ tool development for ER2

# ePIC SVT R&D — eRD113

- Contact person: Grzegorz Deptuch (Brookhaven National Laboratory)
- Note: The eRD113 proposal currently contains both proposed R&D efforts and PED efforts.

| Topic | Institution | Institutional contact |
|---|---|---|
| Sensor Development | RAL | Iain Sedgwick |
| | BNL | Grzegorz Deptuch |
| | LBNL | Carl Grace |
| Sensor Characterization | INFN | Rosario Turrisi |
| | UK institutes | Laura Gonella |
| | LBNL | Yuan Mei |
| | ORNL | Jo Schambach |
| | LANL | Xuan Li |
| | MIT (new in FY24) | Gian Michele Innocenti |

| Institution | PD Staff | Design Eng. | Electrical Eng. | Tech. |
|---|---|---|---|---|
| UK Institutes | | | | |
| INFN Institutes | 0.35 | | | |
| BNL | | 2.3 | 0.5 | 0.2 |
| LBNL | 0.5 | 0.2 | | |
| ORNL | | 0.05 | | 0.05 |
| LANL | | | 0.5 | |
| MIT | 0.7 | | | |

| Institution | effort | travel | M&S | Total |
|---|---|---|---|---|
| UK Institutes | | | | in kind |
| INFN | 30 | | 15 | 45 |
| BNL | 1,500 | 15 | 90 | 1,605 |
| LBNL | 180 | | | 180 |
| ORNL | 40 | | 35 | 75 |
| LANL | 250 | 15 | 10 | 275 |
| MIT | 100 | | | 100 |
| **Total** | 2,100 | 30 | 150 | 2,280 |

- The need for R&D on sensor design and characterization is likely to continue beyond FY24.

# Outline

- Introduction
- Status of R&D for the ePIC SVT
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- **Outlook**

- Progress on many aspects of the ePIC SVT detector
- ePIC SVT Detector Subsystem Collaboration has grown
- EIC / ePIC — CERN/ALICE agreement to share sensor is key
- Finalization of the ITS3 ER2 design in the next few months will fix crucial parameters for the ePIC SVT development
- Aim to advance designs to converge towards final design choices and scale up prototypes in preparation for the TDR

# EIC-related Generic Detector R&D

Per Thomas Ullrich: “Should you also have submitted a generic R&D proposal please indicate this on your slides”

The SVT does *not* rely on the Generic EIC-related R&D Program, c.f. https://www.jlab.org/research/eic_rd_prgm. However, several members of the ePIC SVT DSC are part of submitted proposals to that program:

- Yuan Mei (LBNL) — Industrial aluminum flexible circuit manufacturing
- Nicole Apadula (LBNL), Nicholas Schmidt (ORNL), Giacomo Contin (INFN) — Kapton embedded Monolithic Active Pixel Sensor R&D

- Xuan Li (LANL) — A Fast Timing MAPS Detector for the EIC
- Soumyajit Mandal (BNL) — Photonics-based Readout and Power Delivery by Light for Large-Area MAPS
- Dominik Gorni (BNL) — Large-Area MAPS Combining High Spatial and Temporal Resolution