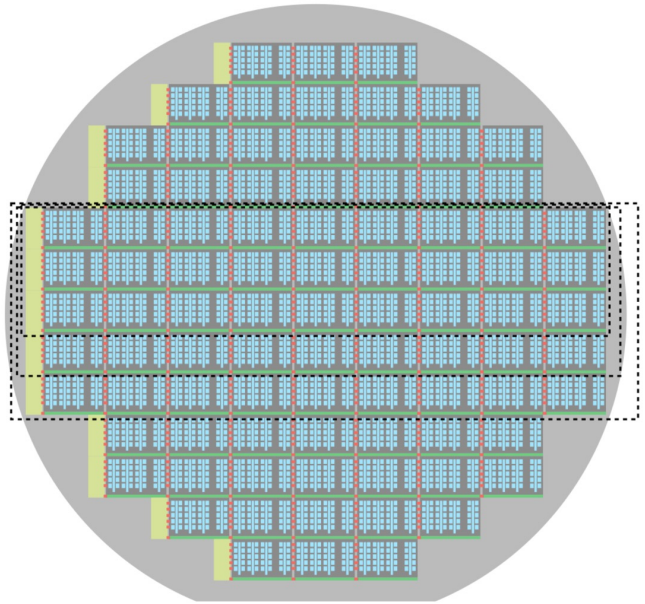
Silicon Tracking Generic R&D

Nikki Apadula

LBNL EIC Meeting

12/20/22

65 nm MAPS



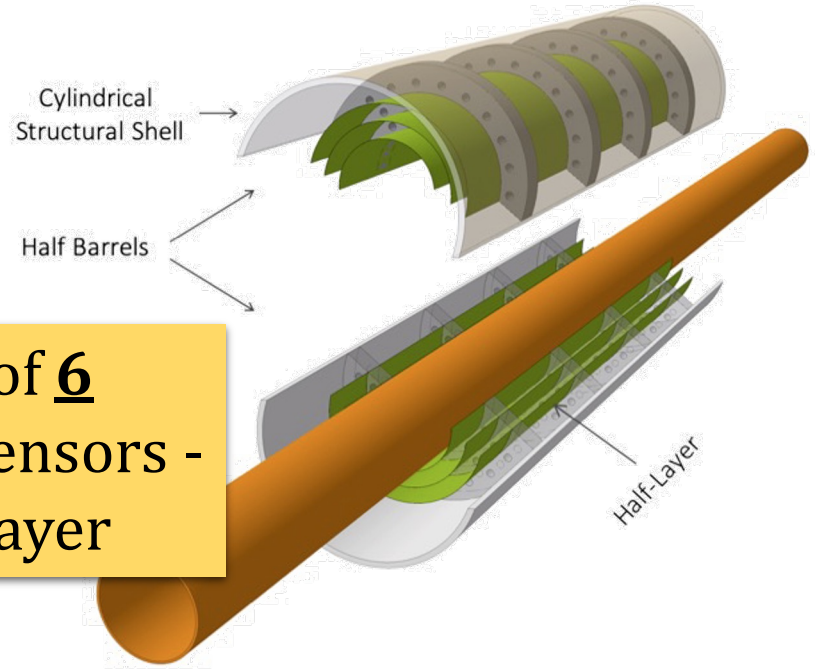
- ALICE ITS3 MLR1: 2021+
  - 65 nm process verified
- ALICE ITS3 ER1: submission end of 2022
  - Stitching verification & first yield information

Big unknown!

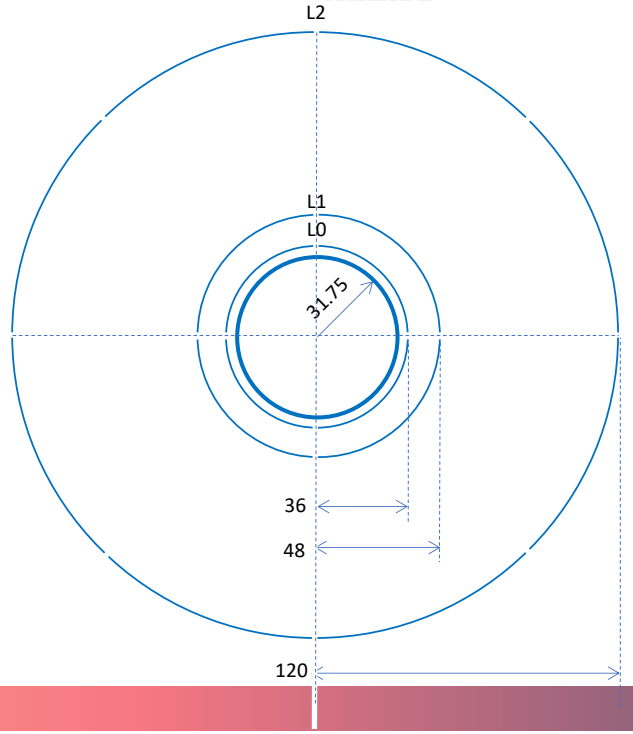
- Open questions:
  - What changes need to be made if yield is low?
  - Power distribution over the stitched sensor

From ALICE ITS3 to EIC

- ITS3 sensor reticle size will be optimized for ALICE radii
- EIC radii larger → geometry needs to be adapted
- Some mechanical challenges still to be thought out
  - Lose some of the structural support from curvature
  - What is the stress/strain on silicon?



Total of **6** stitched sensors - 2 per layer

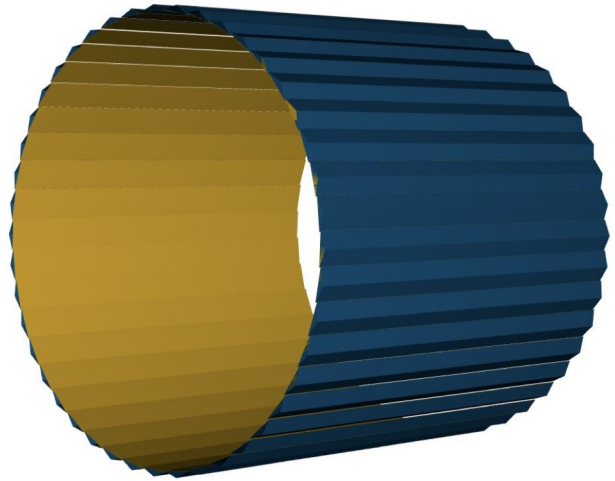


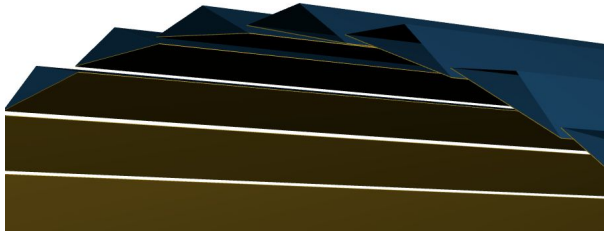
Option for EPIC layers 0-2

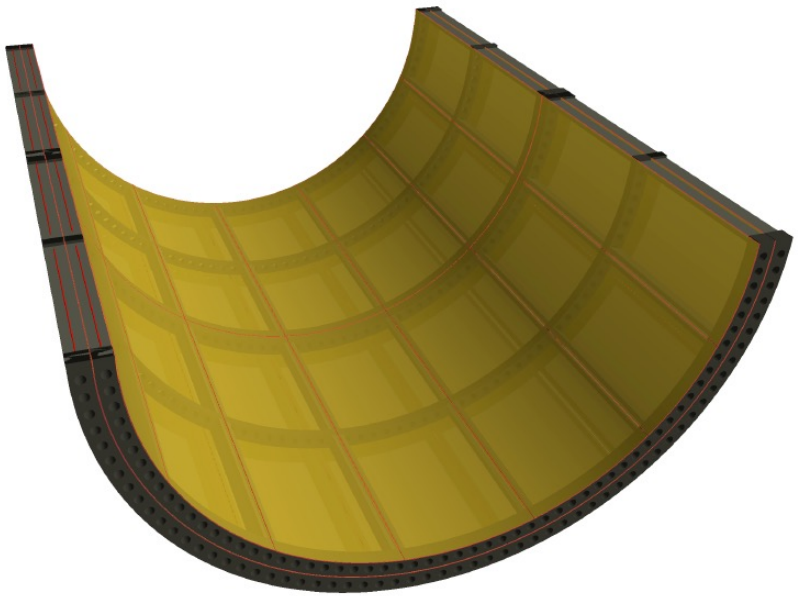
Total of **16** stitched sensors
Layers 0, 1: 4
Layer 2: 8

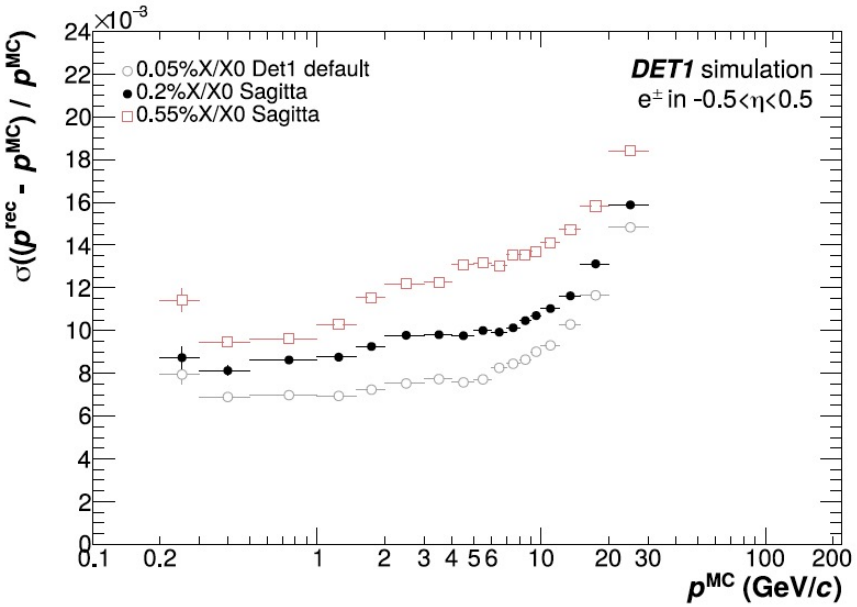
Staves & discs

- Material budget an issue for tracking
  - Longer sensors mean more material (power, support)

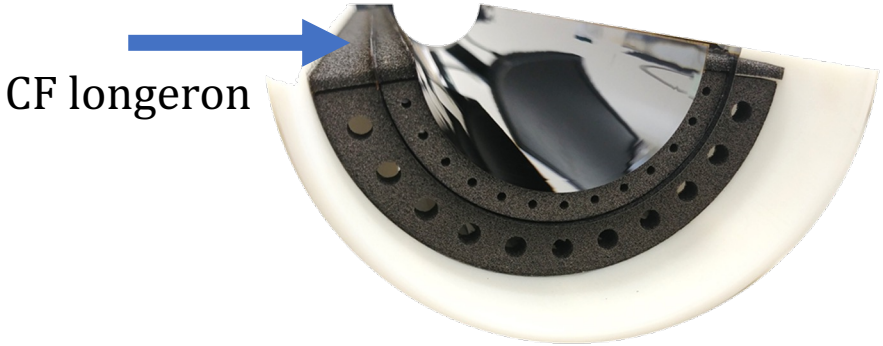








R&D Motivation



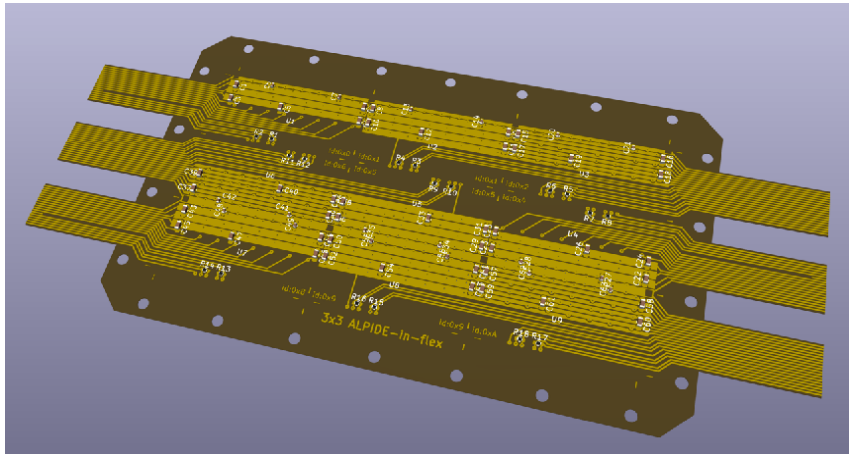
- Alleviate deformation expected from carbon foam longerons
- Reduce mechanical strain to the bare silicon
- Sagitta/Outer layers: Planar staves → larger, more cylindrical barrel structures
- Overcome possible weakness in power distribution network in 65 nm process

Risk reduction for detector 1, options for detector 2

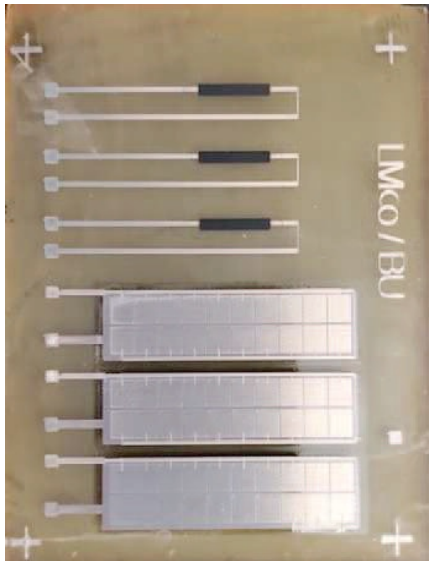
Additive manufacturing

- Power distribution from edge along entire stitched sensor not yet verified
- Printing of dielectric & metal patterns directly on the silicon
  - **Risk reduction for vertex layers**
- Would be a simpler, lighter, & more adaptable layout than separate power bus or FPC

Aerosol-Printed Highly Conductive Ag Transmission Lines for Flexible Electronic Devices



Example of ~ 10 x 5 cm sensor matrix connection trace layout



Fully Additive Manufacturing of Passive Circuit Elements using Aerosol Jet Printing

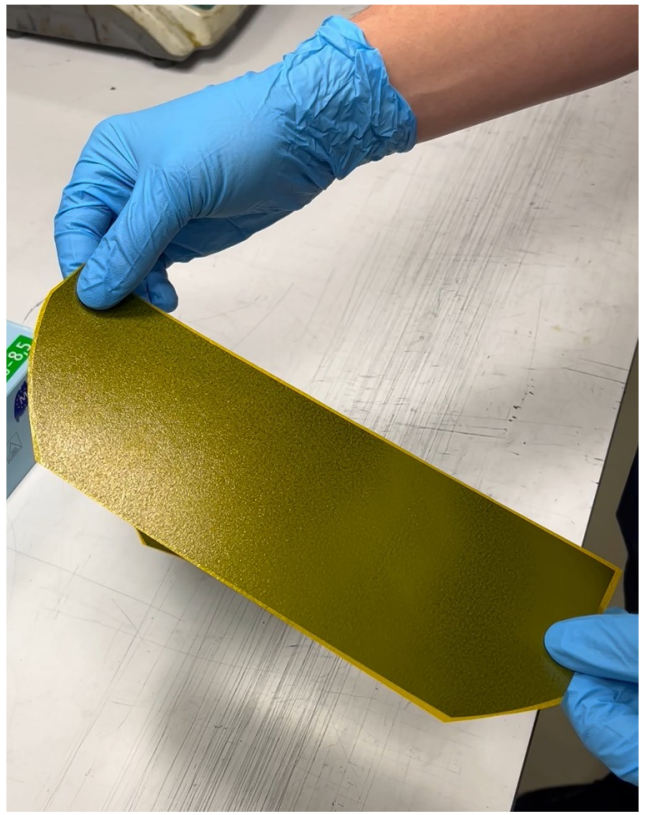
Additive manufacturing: vendors

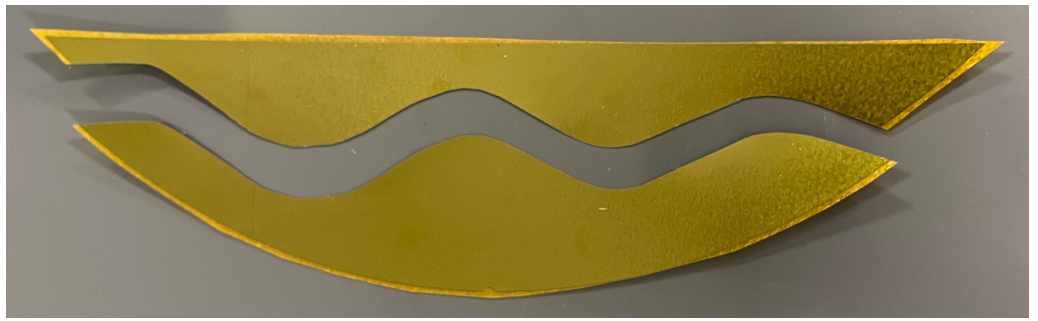
- CNR-IOR Nano- and Micro-fabrication Laboratory in Trieste
  - Active collaborators of the University of Trieste, INFN Trieste proponent institute on different R&D
  - Experienced in evaporation and deposition of conductive materials on different substrates
- Printed and Flexible Electronics lab at the Silicon Austria Labs (SAL) research center in Villach (Austria)
  - Established first exploration of capabilities
  - A series of printers based on ink-jet and aerosol-jet techniques are being commissioned for the development of deposited re-distribution layers on a wide variety of substrates
- Aerosol Printing & Photonic Curing Laboratory at the University of Brescia (Italy)
  - Established first contacts for possible collaboration
  - Offers similar capabilities in the field of 3D additive manufacturing based on aerosol-jet printing

Silicon lamination

- ORNL Manufacturing Demonstration Facility
  - ORNL on-site facility
    - Have been used by the ORNL group members previously
  - Conversations with staff are ongoing

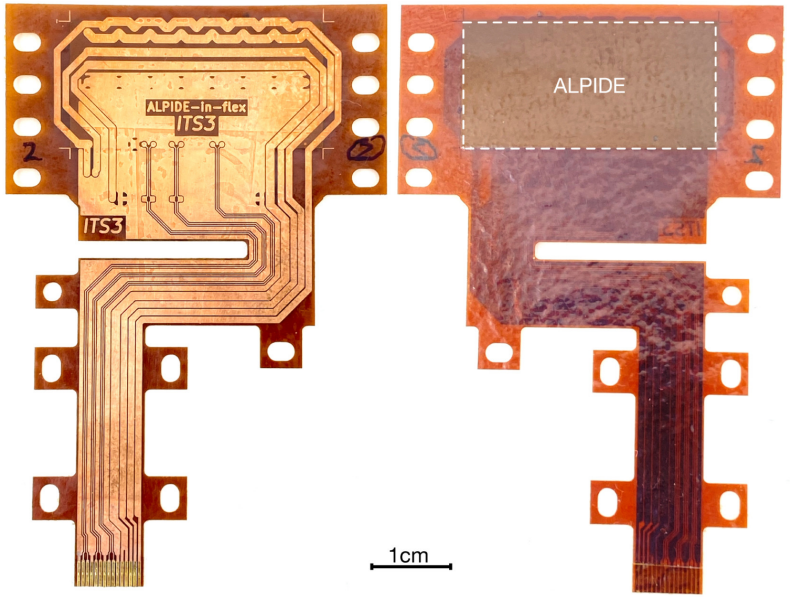
- Similar process ongoing at CERN

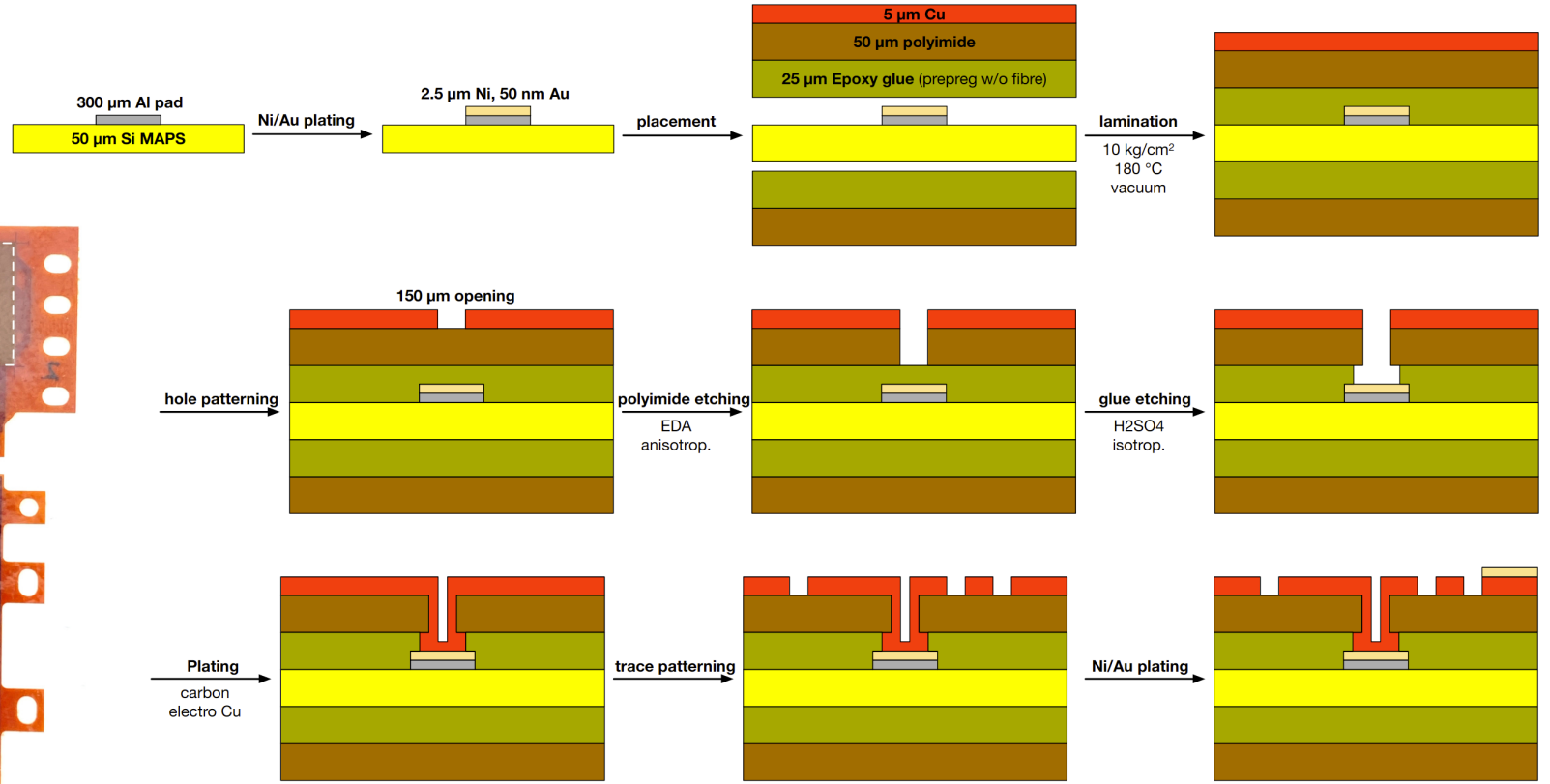




Improved mechanical resistance with low material: 0.1% X/X_0 silicon + kapton

“MAPS foil”

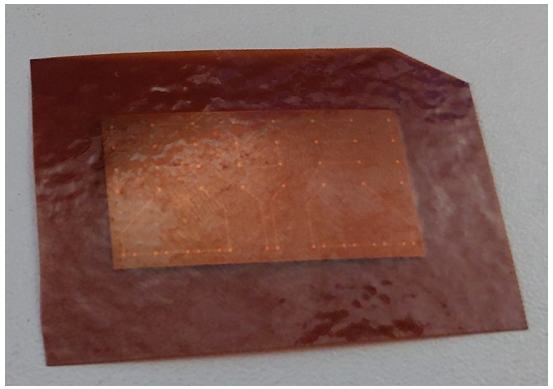




https://doi.org/10.1016/j.nima.2022.167673

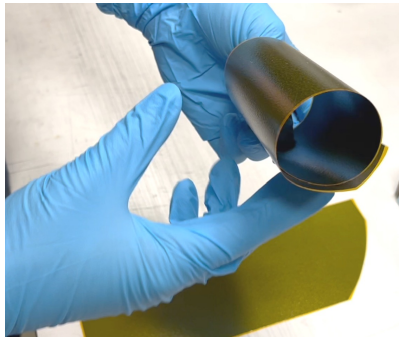
- Kapton foil lamination process developed for thinned MAPS
- Demonstrated successfully on single ALPIDE sensors (ITS2)

FY23: Single reticle size lamination



- Validation of the lamination process
- Glue variations
- Variations of thickness?
- **FY23 deliverables: Embedding small, ALIPDE-sized silicon mock-ups**
  - **Production of test pieces to be used in mechanical & cooling tests**
  - **Written report (in conjunction with large area mock-ups)**

FY23: Large scale lamination



- Thickness, glue, etc. based on validation from single reticle
- Large, stitched size sensors
- Staves made from multiple single or stitched sensors
  - How to align & place them
  - Additional mechanical stress?
- **FY23 deliverables: Embedding large scale silicon mock-ups**
  - **Production of large scale (stave size) test pieces to be used in mechanical & thermal tests**
  - **Written report (in conjunction with single reticle mock-ups)**

FY23: Laminated sensors: mech & thermal

- Thermal studies of the laminated sensor – with & without cooling
- How does the material deform under air flow?
- Laminate a sensor to hold a curved shape
- **FY23 deliverables: Mechanical and thermal properties of laminated sensors**
  - **Written report detailing the mechanical and thermal properties of the laminated sensor**

FY23: Additive manufacturing

- Evaluate dielectric & conductive aerosol/ink material properties & optimization of electrical characteristics
- Fabricate small size prototypes to study mechanical properties on curved silicon
- Extend to large-area prototypes to evaluate & improve process
- **FY23 deliverables: Additive manufacturing of power & data redistribution layers on thin large-area silicon**
  - **Written report detailing the electrical properties of the different additive manufacturing technologies**

Aluminium Flex PCB (cable)

Radiation length:

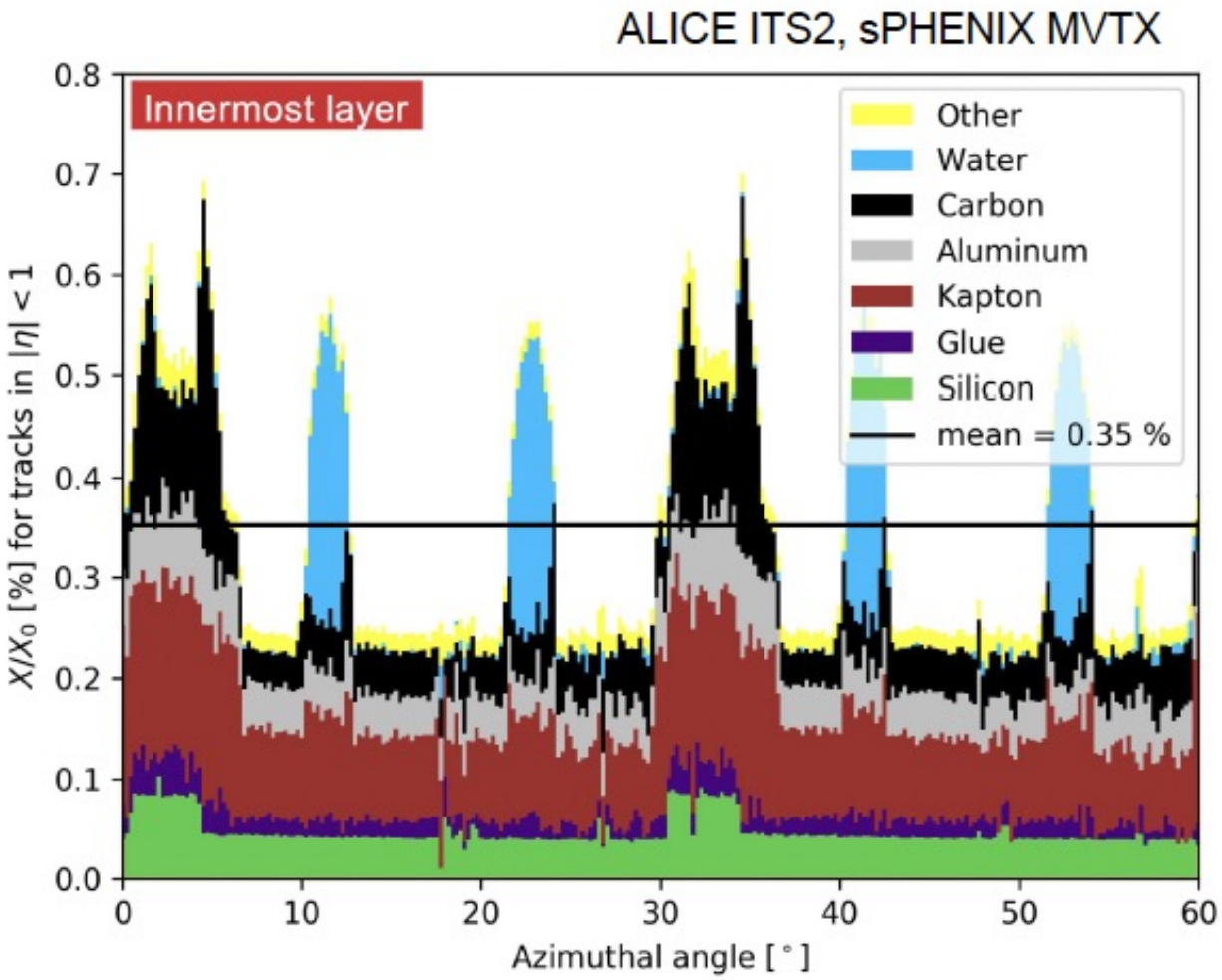
$X_{0\ Cu} \sim 1.4cm$
$X_{0\ Al} \sim 8.9cm$
} factor 6

CERN

Kharkiv Institute

Explore companies:

- Hughes Circuit Inc. (CA)
- Qflex Inc. (CA)
- Omni Circuit Boards Ltd. (BC, Canada)



From Yuan's Generic R&D presentation

Aluminium Flex PCB (cable)

Aluminum conductors for existing vertexing instruments came from:

- CERN
- Kharkiv Institute

Commercial sector is developing closely related capabilities driven by applications in Quantum Computing and other interests; explore possibility to commercially manufacture flex PCB for EIC tracking / vertexing subsystem and reduce risk(s),

Request: 15 k$ in seed funds (12.5k$ material + 2.5k$ travel)

Deliverables: manufacturability & accurate cost estimate at scale

From Yuan's Generic R&D presentation

FY23 award

- Silicon embedding: awarded $172.5k (60% of request)
  - Likely impact is to forgo alternate embedding techniques and reduce the number of prototype pieces
  - Will work with ORNL to figure out what can be done and what is required to produce the pieces
- Aluminum flex: awarded $16k (100%)