MIT Bates for ultra-light silicon pixel detectors

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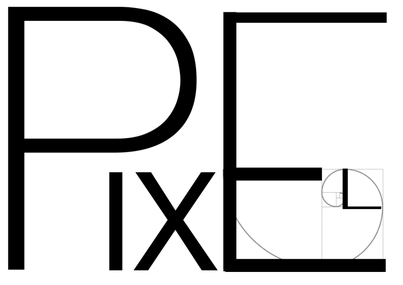
MIT Heavy-ion Group

DOE review of Bates Laboratory

MIT, July 09-10, 2024

https://pixelphilab.mit.edu



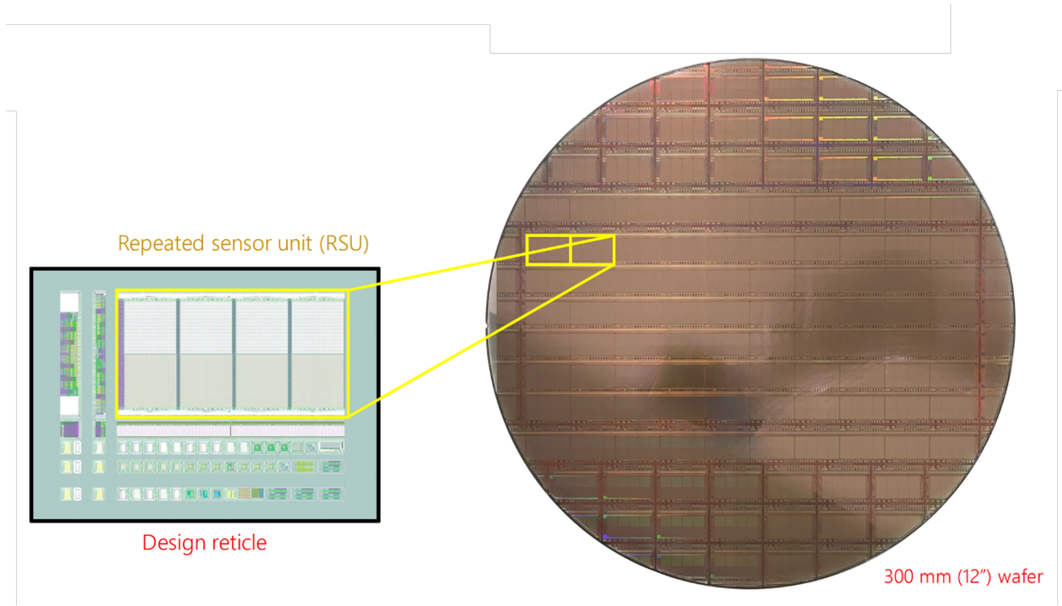
Next generation silicon detectors

MIT PixELφ : a new laboratory to exploit a new cutting-edge silicon pixel technology:

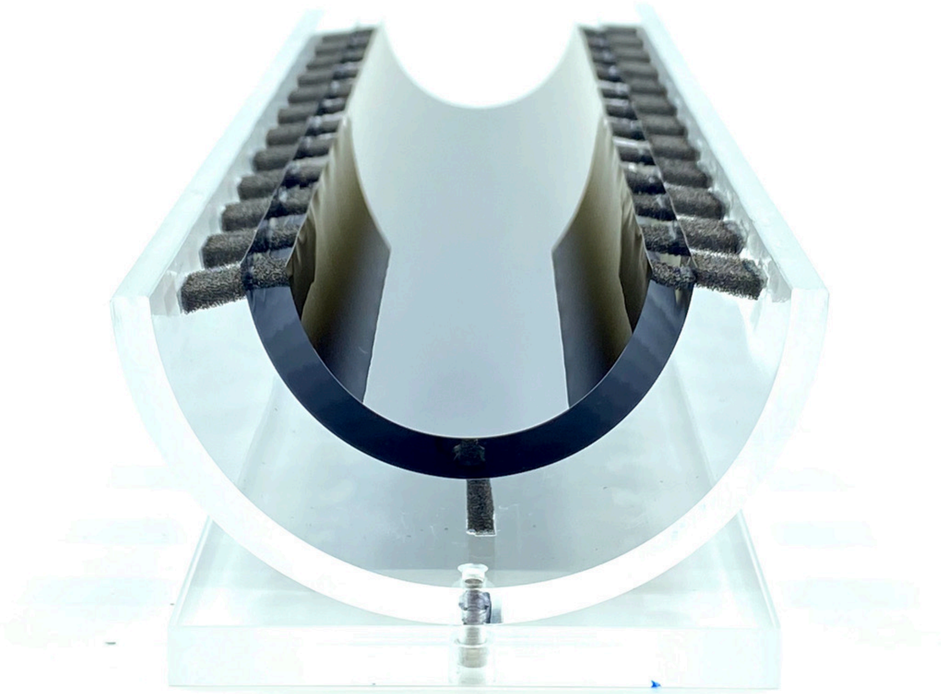
→ Ultra-light (“massless”) Bendable Monolithic Active Pixels

→ **most-accurate tracking detector ever built (~ micron spatial resolution)**

• large sensors **with “stitching” techniques**



• **“bendable” when thinned** below ~20-40 µm

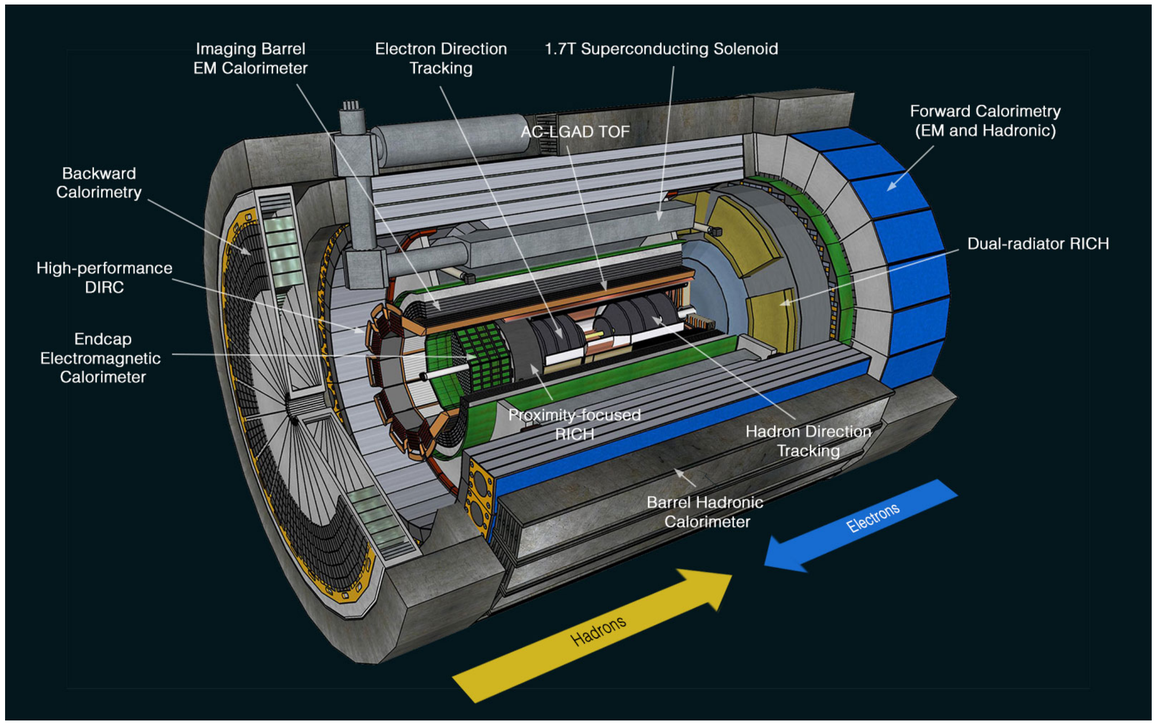


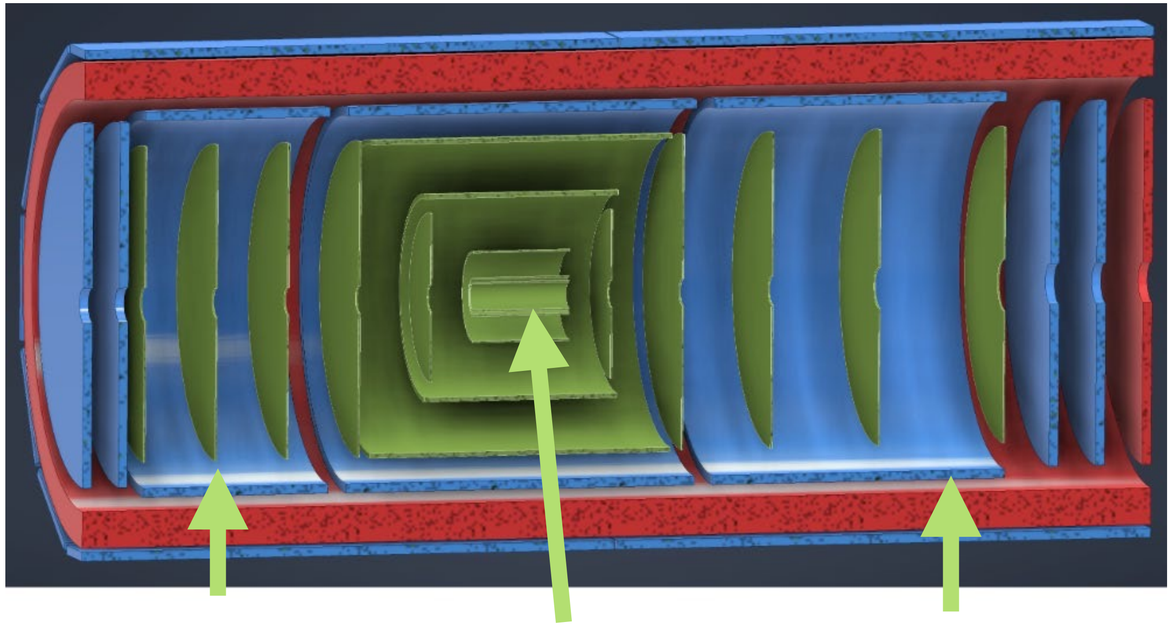
The Silicon Vertex Tracker (SVT) for ePIC@EIC is the most advanced application of stitched MAPS sensors for large-area wide-acceptance detectors

SVT for ePIC at the Electron-Ion Collider

SVT is paving the way for future large-area application of this new technology

→ unique technological challanges in terms of sensor R&D, cooling, mechanical design and integration





SVT disks **SVT inner barrel (IB)** **SVT disks**

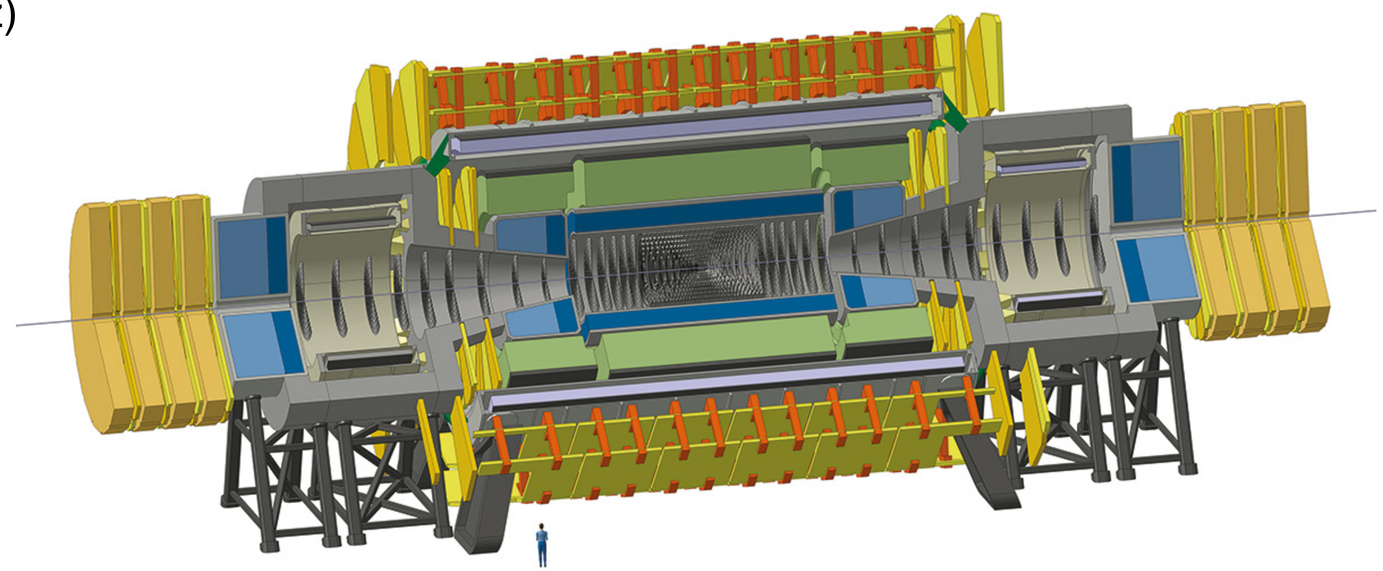
Large-area stitched-MAPS sensors

PixELφ at Bates: prospects beyond SVT

On-sensor AI for MAPS with hls4ml:
- **noise-tagging, fast trigger and data reduction** on MAPS for future HEP experiments (focus on e^+e^- for FCC and eA for EIC)

Applications in atomic physics:
e.g. detection of low-energy electrons
for cold-atom physics (in collaboration with Prof. Garcia Ruiz)

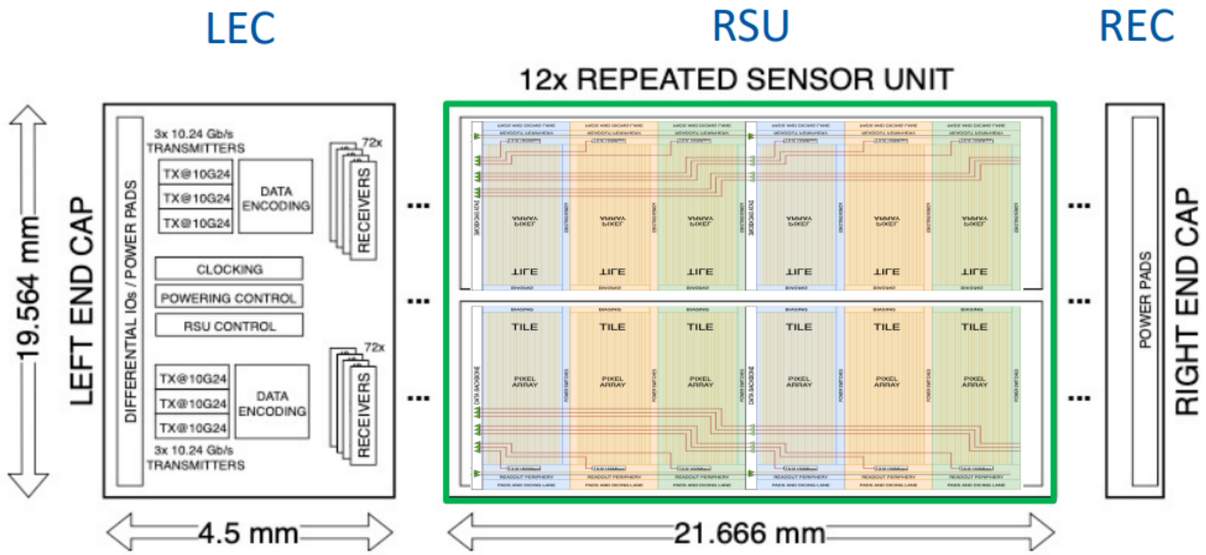
Medical imaging:
online calibration of proton/ion beams for Carbon therapy



MAPS-based tracker for the Future-Collider Collider at CERN:
→ MAPS is at the core of the detector design of the future FCC detectors (2040/2050 -)

MIT PixELφ: SVT contributions

- **Major contributions to the sensor design and testing**



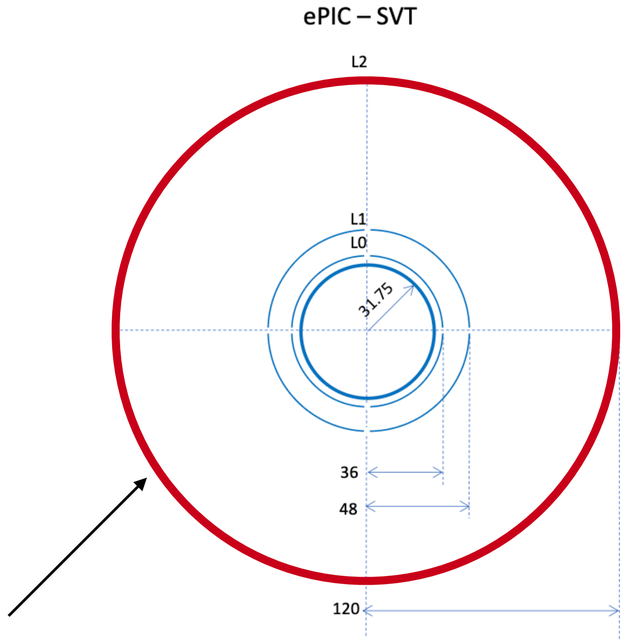
- **Developing a brand new high-frequency testing strategy for large-area sensors**
  → **MIT is leading the testing, characterization working group of the SVT collaboration**
- **Design and optimize the SVT readout strategy for service reduction**

The sensor and **testing activities are currently carried out at CERN** to maximize the synergies with CERN MAPS experts:
→ **Our plan is to move and expand the testing lab to Bates over the course of the next 2-3 years**

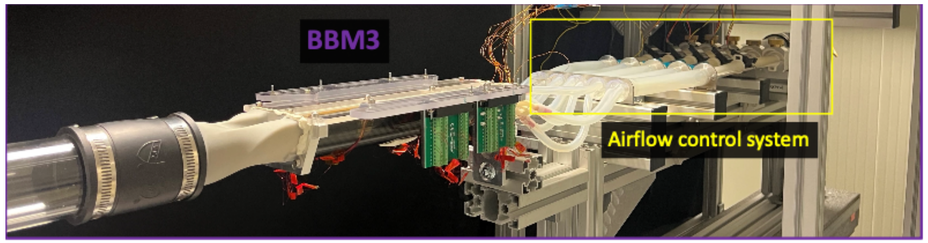
PixELφ at Bates: **planned** contributions to SVT mechanics

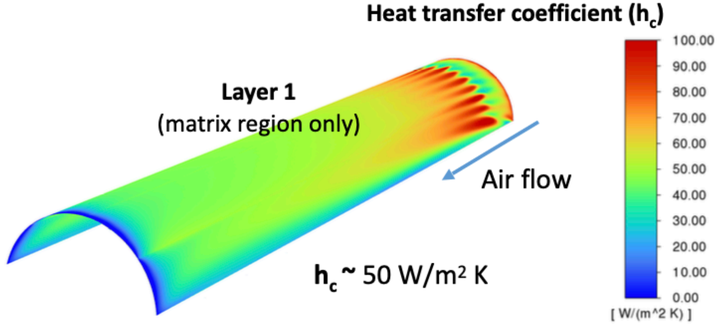
- **Simulation studies to characterize the mechanical properties of the SVT IB layers (ongoing)**
  - implement SVT geometry in ANSYS, heat-dissipation studies
  - test the impact of vibrations in the presence of air flows at different speeds
  - define the specifications of a wind tunnel to test the IB mechanical design, cooling, ..

- **Design of the inner-barrel geometry, support structure, and cooling**
  - **MIT is in charge of the design and construction of the Layer2**



C. Gargiulo, ITS3 Plenary 30 June 2023

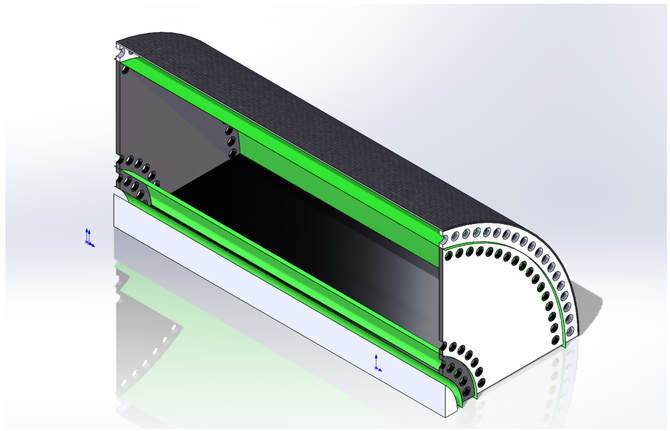


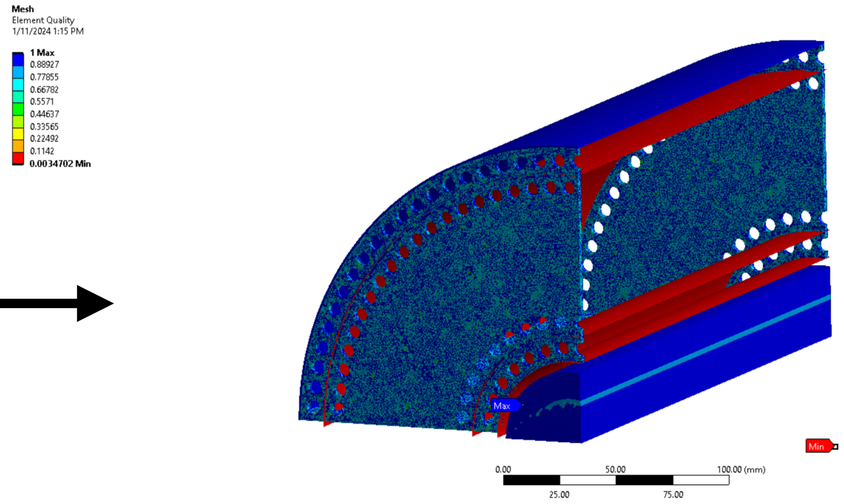


Layer2: the largest-R layer of bent MAPS sensor ever designed and constructed → **a fundamental technological step towards large-area MAPS-based detectors**

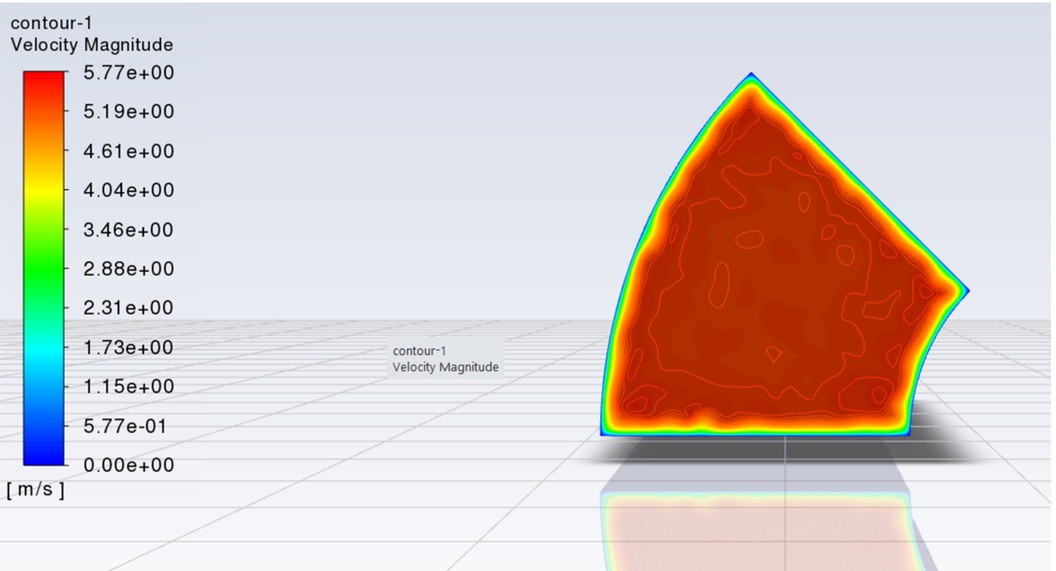
- **Design and construction of a wind-tunnel setup** to test the cooling, dissipation and mechanical properties of the SVT

PixELφ at Bates: **status** of R&D activities to SVT mechanics





- **Implemented the current mechanical design for the SVT in** SolidWorks
-



- **Develop a fluido-dynamic simulation to model the air-based cooling of the SVT**
- **Currently performing a thermal study to characterize the cooling performance in presence of a realistic heat dissipation**

→ preliminary studies are currently supported with in-kind Bates resources **(Tricia Smith, Jim Kelsey)**

→ **SVT relies on Bates for the design and construction of the SVT L2!**

PixELφ at Bates: our vision

- **Bates as a centre of excellence for the R&D, design, construction and assembly of large-area sensor detectors:**
→ one of the key R&D, construction, assembly sites for the EIC Silicon Vertex Tracker

- **Requirements:**
  - Cutting-edge equipments for mechanics and electronics (bending, assembly, gluing..)
  - Wind tunnels for large-area sensors
  - Electronic equipment for testing (wafer probe machines, DAQ setups), bonding machine
  - Spaces (clean room with vacuum systems)

- **Timescale**
  - **Next 6 months:**
    - clean room to be refurnished
    - purchase of the bending tools
  - **Next year**
    - development of a wind tunnel
    - purchase of mechanical equipment (e.g. Mitutoyo machine w/ alignment vacuum tools)
  - **Next two/three years:**
    - **→ Move the now CERN-based test laboratory to MIT/Bates**
    - **→ Equip the Bates-based lab for the assembly of the SVT inner tracking layers**

<u>Bates is a unique asset to expand and mantain a long-term leadership in this new technology</u>

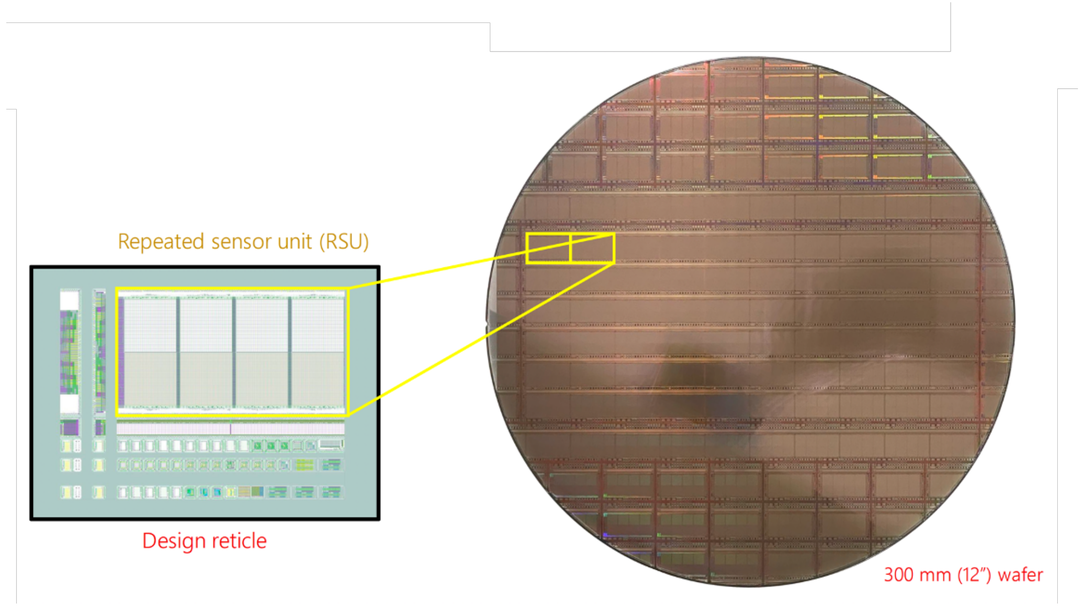
BACKUP

MIT PixELφ: a Silicon Pixel Lab for ELementary physics at MIT

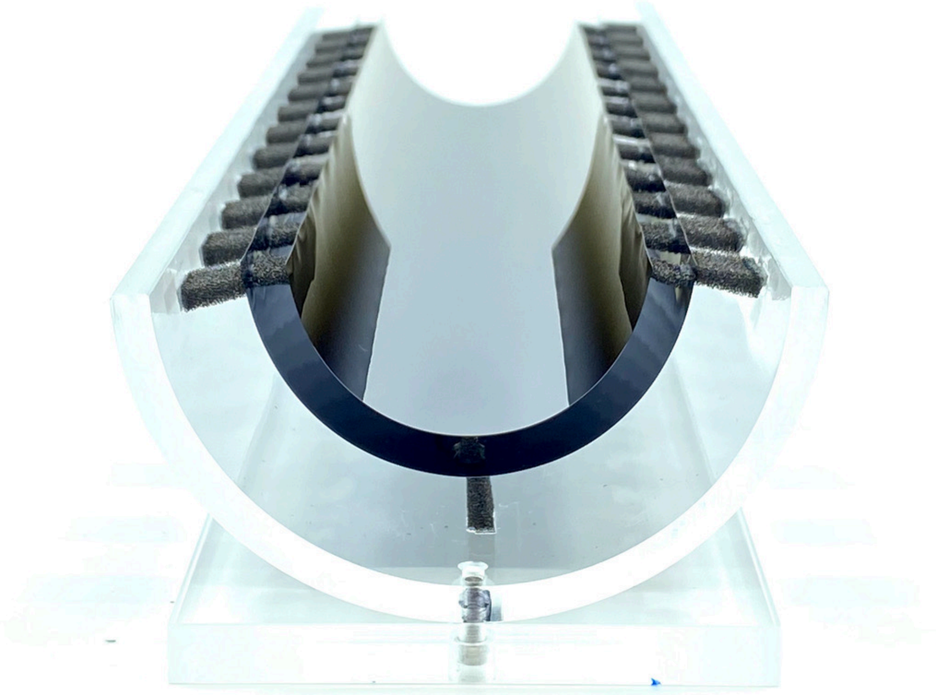
A new laboratory built at MIT to exploit a new cutting-edge silicon pixel technology:

→ Ultra-light (“massless”) Bendable Monolithic Active Pixels

- large sensors **with “stitching” techniques**

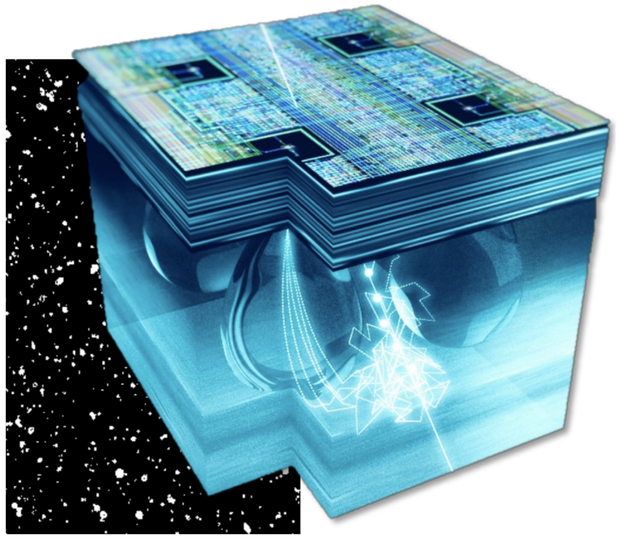


- **“bendable” when thinned** below ~20-40 µm

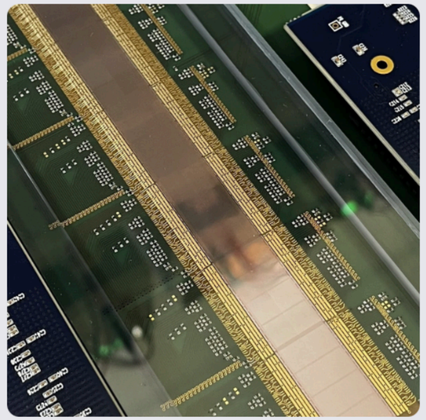


MIT PixELφ : a Silicon Pixel Lab for ELementary physics at MIT

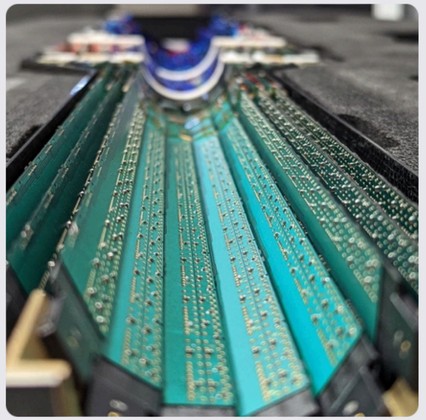
→ **Next generation "stitched" MAPS technology** for high-accuracy detectors for high-energy and nuclear physics



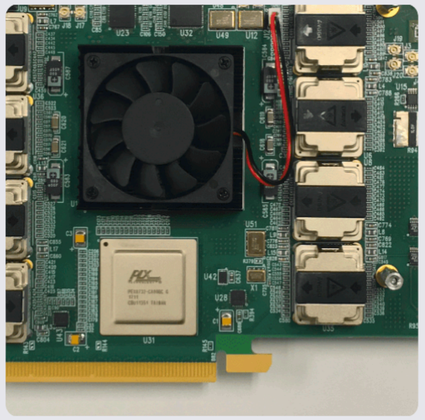
Ongoing projects



Silicon Vertex Tracker (SVT) for the ePIC experiment at the Electron-Ion Collider



MVTX for the sPHENIX experiment



Artificial intelligence with FPGA for MAPS detectors

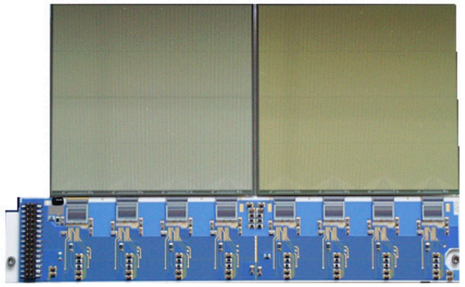
→**CERN-based MIT laboratory**

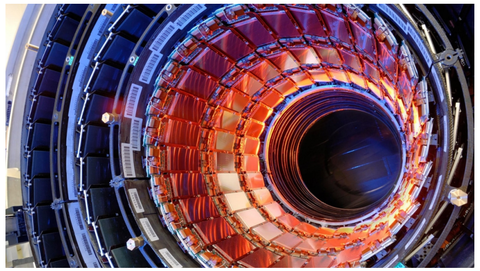
Silicon detectors in the MIT heavy-ion group

R. Nouicer, B. Wislouch et al., Nucl. Instrum. Meth. A461:143-149, 2001

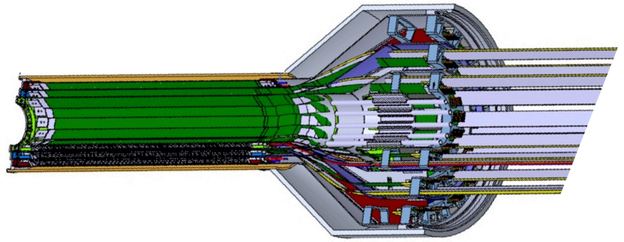
→ Almost 30 years of experience in pixels detector design, construction, commissioning

PHOBOS experiment at RHIC
AC-coupled, single-sided, silicon pad for tracking, vertexing, and multiplicity





CMS tracker ("hybrid pixels")
commissioning pixel and strip detectors for heavy-ion runs



Monolithic Active Vertex Tracker (MVTX) for sPHENIX with ALICE ITS2 technology
- mechanical design, cooling, and integration
- module characterization
- DCS design, installation and commissioning

Ultra-fast silicon timing detector for CMS in Run 4

IST for STAR at RHIC

IST for STAR at RHIC

1990 2000 2010 2020 2030

SVT at the ePIC: timescale and synergies with the ITS3 project