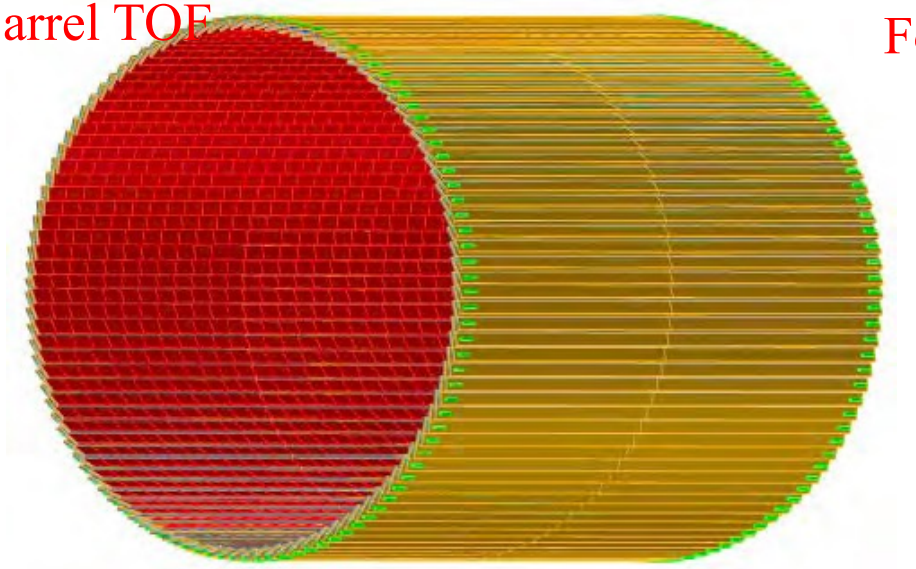
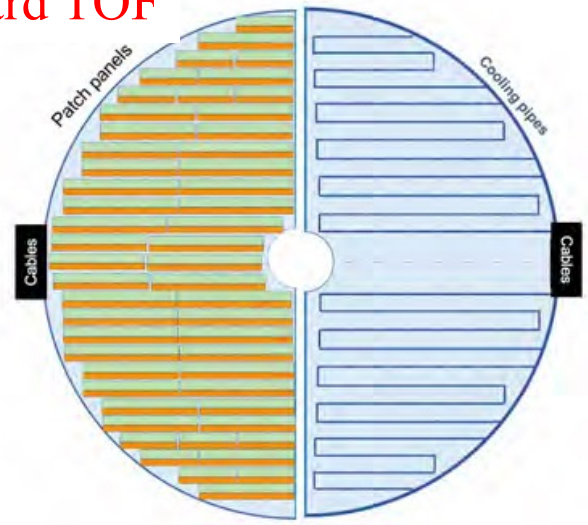
AC-LGAD Detectors for ePIC

Barrel TOF



Forward TOF



Roman Pots

	Area (m^2)	Channel size (mm^2)	# of Channels	Timing Resolution	Spatial resolution	Material budget
Barrel TOF	10	0.5*10	2.4M	30 ps	30 μm in $r \cdot \varphi$	0.01 X0
Forward TOF	2	0.5*0.5	8.8M	25 ps	30 μm in x and y	0.05 X0
B0 tracker	0.07	0.5*0.5	0.28M	30 ps	20 μm in x and y	0.01 X0
RPs/OMD	0.14/0.08	0.5*0.5	0.56M/0.32M	30 ps	140 μm in x and y	no strict req.

Requirements on timing and spatial resolutions and material budget are still being evaluated and are subject to change as the design matures, and we will continue to explore common designs for these detectors where possible to reduce cost and risk.

AC-LGAD R&D FY23 Deliverables

- Sensor prototype with 30 ps time and spatial resolution match RPs and Tracker;
  Sensor prototype with 20 ps time resolution for ToF.
- 1st sensor + ASIC demonstrator for EIC applications and testing with particle beam.
- 2nd ASIC prototype submissions with better performance and extended features.
- ~~Irradiation campaign for sensor and ASIC prototypes~~.
- Design and prototype of flexes, ~~interconnects and off-detector electronics~~.
- Design and prototype of light-weight structure with embedded cooling tubes.

eRD112
- Sensor R&D
  - TCAD simulation
  - BNL, HPK productions
  - Lab/beam/irradiation
- Sensor/ASIC integration
  - Interposer
- Module structure
  - Light-weight structure

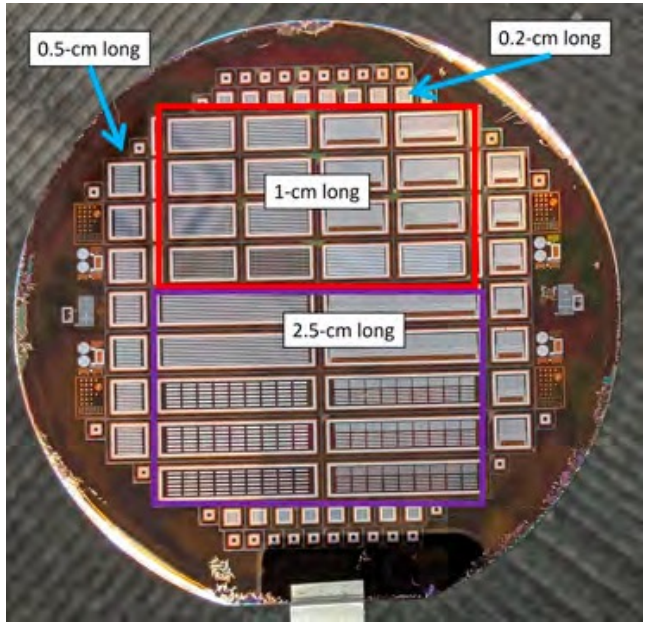
eRD109
- Frontend ASICs
  - EICROC
  - FCFD
  - SCIPP (FAST, ASROC, HP-SoC)
- Frontend electronics
  - Low-mass flexible PCB

Project Engineering Design
- Mechanical engineering
  - Mech. support, integration
  - Cooling system
- Electric engineering
  - Clock distribution system
  - Streaming readout
  - Service hybrid

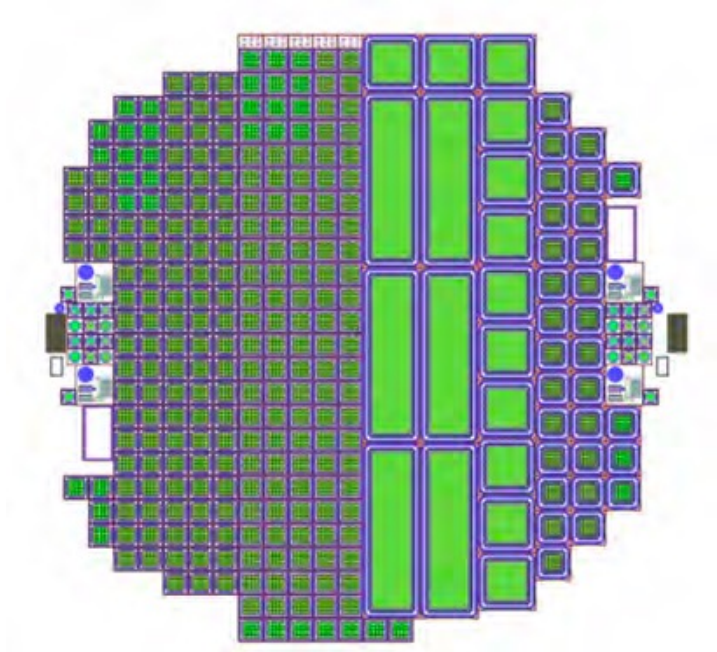
AC-LGAD Sensor R&D

- Production of medium/large area sensors with different doping concentration, pitch and gap sizes between electrodes and Si thickness to optimize performance by BNL IO and HPK.
  - 1st BNL (06/2021-11/2021): 5-25 mm strips with 500 μm pitch, 100-300 μm electrode width, 50 μm active Si
  - 2nd BNL (06/2022-11/2022): 5-25 mm strips with 500-700 μm pitch, 50-100 um electrode width, 20-50 μm Si
  - 3rd BNL (08/2022-12/2022): pixels with 500-700 μm pitch, various electrode shapes, 20-50 μm Si
  - 1st HPK (06/2022-04/2023): strip+pixel sensors with different electrode width, active thickness and n^+ doping
  - 4th BNL (02/2023-06/2023): deep gain layer to increase signal amplitudes

1st/2nd BNL Production



3rd BNL Production



Joint HPK Production

HPK Sensors for EIC

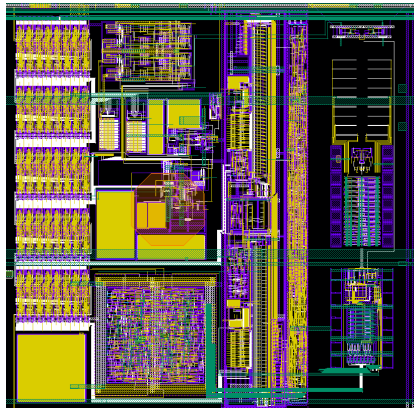
n+ resistivity	active thickness	AC capacitance
E-type	50um	240pF/mm2
C-type	50um	240pF/mm2
E-type	50um	600pF/mm2
C-type	50um	600pF/mm2
E-type	20um	600pF/mm2
C-type	20um	600pF/mm2

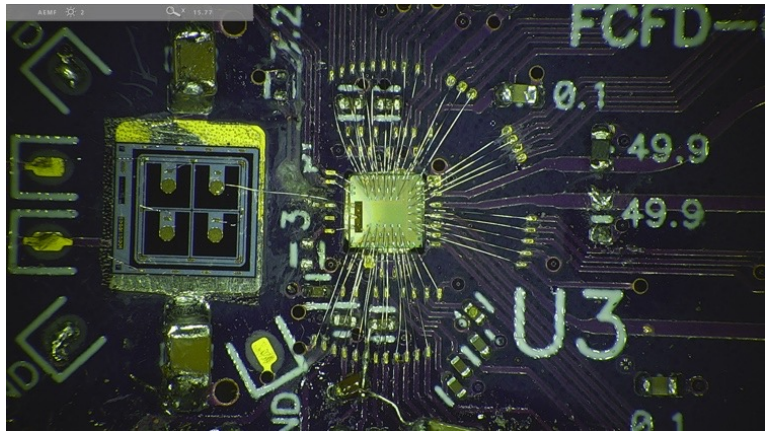
- 6 wafers with different n+ resistivity, active thickness and AC-coupling capacitance
- Each wafer has strip sensors with different length and electrode width, and pixel sensors with different electrode width

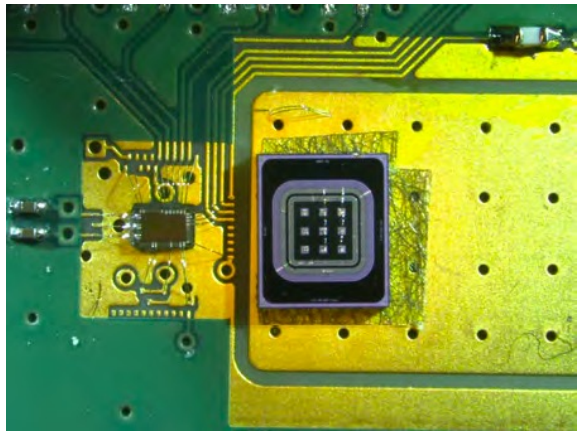
Sensor Name	Type	Electrode pitch		Electrode size	
		x [um]	y [um]	x [um]	y [um]
EIC 25mm strip wide	Strip	25000	500		100
EIC 25mm strip narrow	Strip	25000	500		50
EIC 20mm strip wide	Strip	20000	500		100
EIC 20mm strip narrow	Strip	20000	500		50
EIC 10mm strip wide	Strip	10000	500		100
EIC 10mm strip narrow	Strip	10000	500		50
EIC 5mm strip wide	Strip	5000	500		100
EIC 5mm strip narrow	Strip	5000	500		50
EIC 5x5 pixel	Pixel	500	500	450	450
EIC 4x4 pixel (450um elec)	Pixel	500	500	450	450
EIC 4x4 pixel (300um elec)	Pixel	500	500	300	300
EIC 4x4 pixel (150um elec)	Pixel	500	500	150	150

Frontend ASIC R&D

- **R&D Goals**
  - 15-20 ps jitter with minimal (1 mW/ch) power consumption, match AC LGAD sensors for EIC
- **Plan**
  - Continue the ASIC prototyping efforts and utilize the design and experience in ASICs for fast-timing detectors from ATLAS and CMS, and investigate common ASIC design and development for RP/B0 and ToF







EICROC by IJCLab/Omega/Irfu/AGH

- Preamp, discri. taken from ATLAS ALTIROC
- I2C slow control taken from CMS HGCROC
- TOA TDC adapted by IRFU Saclay
- ADC adapted to 8bits by AGH Krakow
- Digital readout: FIFO depth8 (200 ns)

FCFD by Fermilab

- Adapt the Constant Fraction Discriminator (CFD) principle in a pixel paired with a TDC, one time measurement gives the final answer.
- Charge injection consistent with simulations: ~30 ps at 5 fC, and <10 ps at 30 fC
- Tested with laser, beta source and beam

ASICs by SCIPP

Developer	ASIC	Technology
INFN Torino	FAST	110 nm CMOS
NALU Scientific	HPSoC	65 nm CMOS
Anadyne Inc	ASROC	Si-Ge BiCMOS

Upcoming Reviews

• **Preliminary Design Status Review ePIC PID detectors**	**July 5-6 or 6-7, 2023**
• **DAC Meeting(s): R&D (2 days) and technical design review (2 days)**	**July-August 2023 (TBD)**
• **Final Design Review for LLPs of Detector**	**September 2023**
• **CD-3A Director's Review**	**October 10-12, 2023**
• **DOE CD 3A OPA Review**	**November 2023**
• **DOE CD 3A ESAAB Approval**	**January 2024**
• **Final Design Reviews for all ePIC subsystems**	**April – October 2024**
• **DOE CD 2/3 OPA Review and ICR**	**January 2025 (TBC)**
• **DOE CD 2/3 ESAAB Approval**	**April 2025**

Call for FY24 R&D Proposals

Dear current and future R&D participants,

It is time to discuss the next steps in our path, i.e., the FY24 projects. We are trying to get the R&D program fully in sync with the FY boundaries.

Proposals

1. Please submit your proposals and progress reports (where applicable) to us by July 7, 2023. We aspire to have a DAC meeting well in time to prepare for contracts at the beginning of FY24.
2. We expect progress report from all ongoing projects eRD101 to eRD113. What milestones were achieved. How did our understanding improve. What is left to do?
3. eRD102, eRD103, eRD104, eRD106, eRD107, eRD108, eRD109, eRD110, eRD111, eRD112, and eRD113 may submit continuation proposals if and only if technical risk milestones remain.

These new proposals should be relatively straightforward to write. Keep them short and concise. List whatever technical risks remain, the milestones, deliverables, and two money matrices showing cost/item and funding/institution to close those remaining risks. Also list the representatives for each institution. List all participating members and institutions on the front page. Please also give, if applicable, an outlook for the years past FY24.

Be aware that R&D should not be mixed with PED. If you are not sure, talk to us. The proposals should concentrate on detector R&D tasks that mitigate project detector technical, risk.

DAC Review Meeting

With the project detector R&D expected to dwindle down at CD-2, we will limit the meeting to a two-day review meeting in the July-August period. The FY24 proposal goals of all continuation projects should be presented as well as a short status report of all FY22/FY23 proposals. More details on this meeting will be announced soon.

Best regards,
Elke, Rolf, and Thomas

Meeting Agenda – 5/16/2023

eRD112/LGAD Consortium Meeting

Tuesday 16 May 2023, 09:00 → 13:15 US/Eastern

Alessandro Tricoli (Brookhaven National Lab), Wei Li (Rice University), Zhenyu Ye (University of Illinois at Chicago)

Description This is a joint meeting of the eRD112 and the LGAD Consortium

Zoom Meeting
https://uic.zoom.us/j/82195681594?pwd=V3JXdHZQbE5vMVlKS045SHphSWdSdz09

Meeting ID: 821 9568 1594
Passcode: eRD112LGAD

09:00 → 09:10 **News** — 10m
Speakers: Alessandro Tricoli (Brookhaven National Lab), Wei Li (Rice University), Zhenyu Ye (University of Illinois at Chicago)

09:10 → 09:30 **Status and Plan on FCFD** ¶ — 20m
Speaker: Artur Apresyan (Fermi National Accelerator Laboratory)

09:30 → 09:50 **Report on Recent Sensor Beam Tests at Fermilab** — 20m
Speaker: Irene Dutta (Fermi National Accelerator Laboratory)

09:50 → 10:20 **Report on Recent Sensor Test at UCSC** — 30m
Speakers: Jennifer Ott (University of California, Santa Cruz (US)), Simone Mazza (University of California - Santa Cruz)

10:10 → 10:30 **Report on Recent Sensor Test at UIC** — 20m
Speaker: Shirsendu Nanda (University of Illinois at Chicago)

Meeting Agenda – 6/6/2023

eRD112/LGAD Consortium Meeting

Tuesday 6 Jun 2023, 09:00 → 13:15 US/Eastern

Alessandro Tricoli (Brookhaven National Lab), Wei Li (Rice University), Zhenyu Ye (University of Illinois at Chicago)

Description This is a joint meeting of the eRD112 and the LGAD Consortium

Zoom Meeting
https://uic.zoom.us/j/82195681594?pwd=V3JXdHZQbE5vMVlKS045SHphSWdSdz09

Meeting ID: 821 9568 1594
Passcode: eRD112LGAD

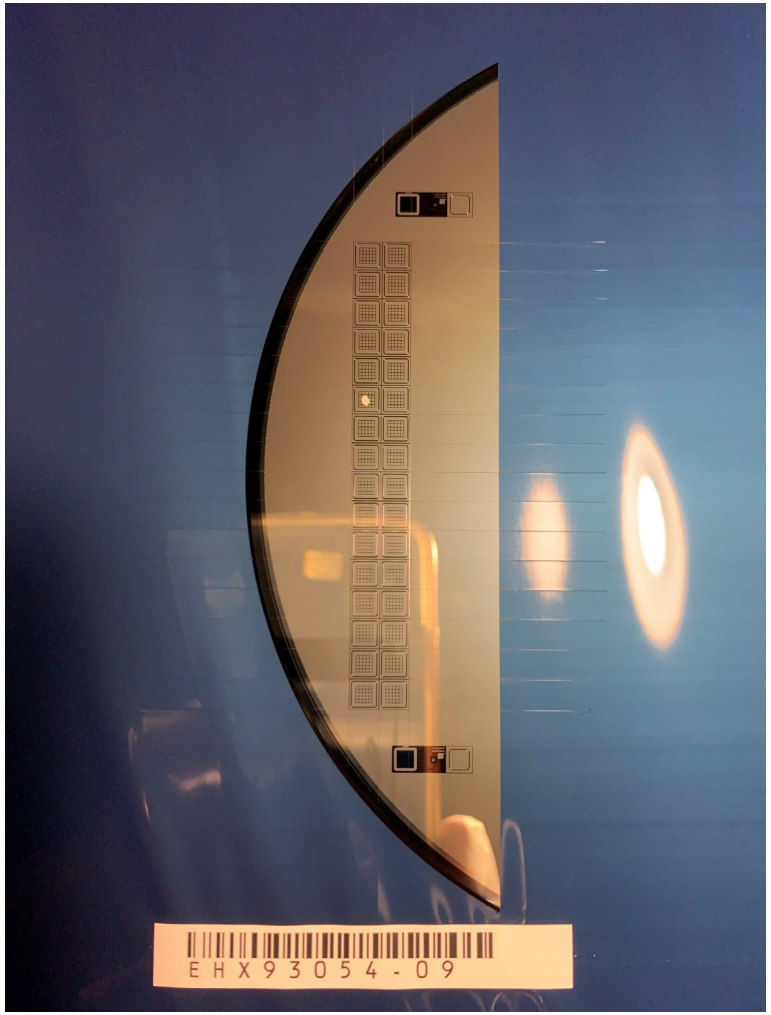
09:00 → 09:10 **News** — 10m
Speakers: Alessandro Tricoli (Brookhaven National Lab), Wei Li (Rice University), Zhenyu Ye (University of Illinois at Chicago)

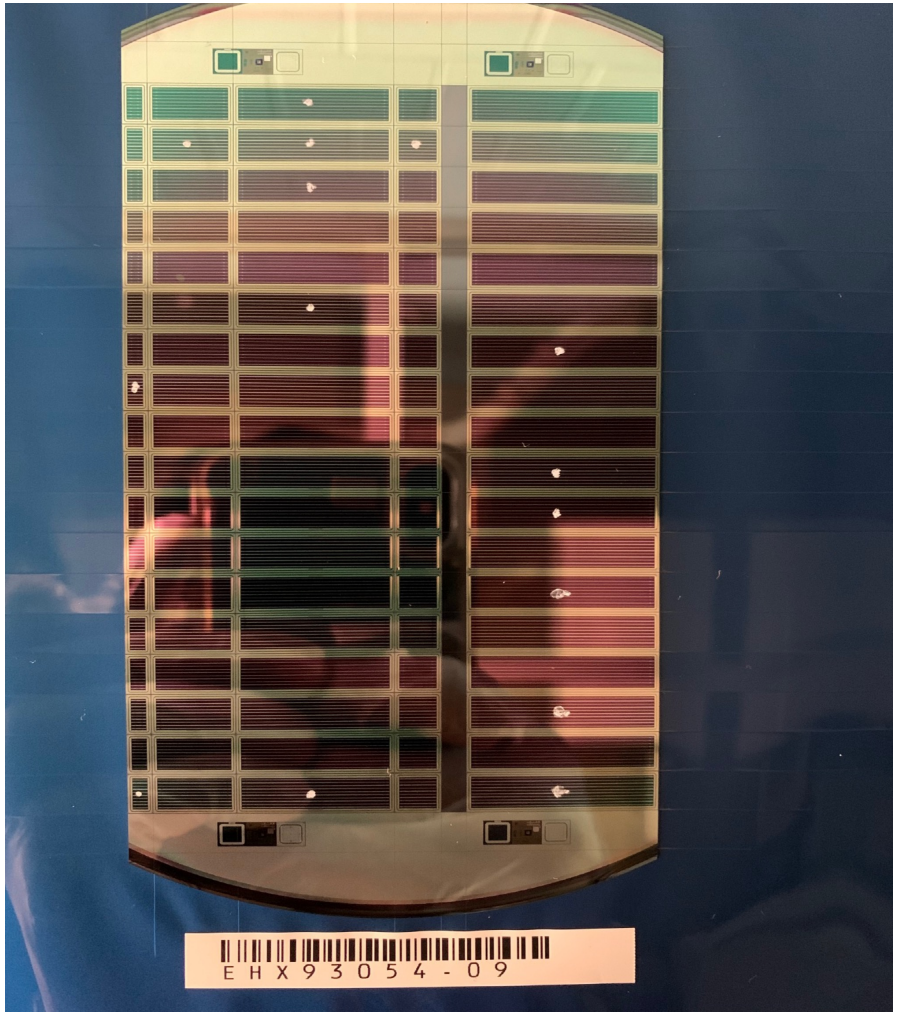
09:10 → 09:35 **Status and Plan on EICROC** ¶ — 25m
Speaker: Dominique Marchand (IJCLab Orsay)

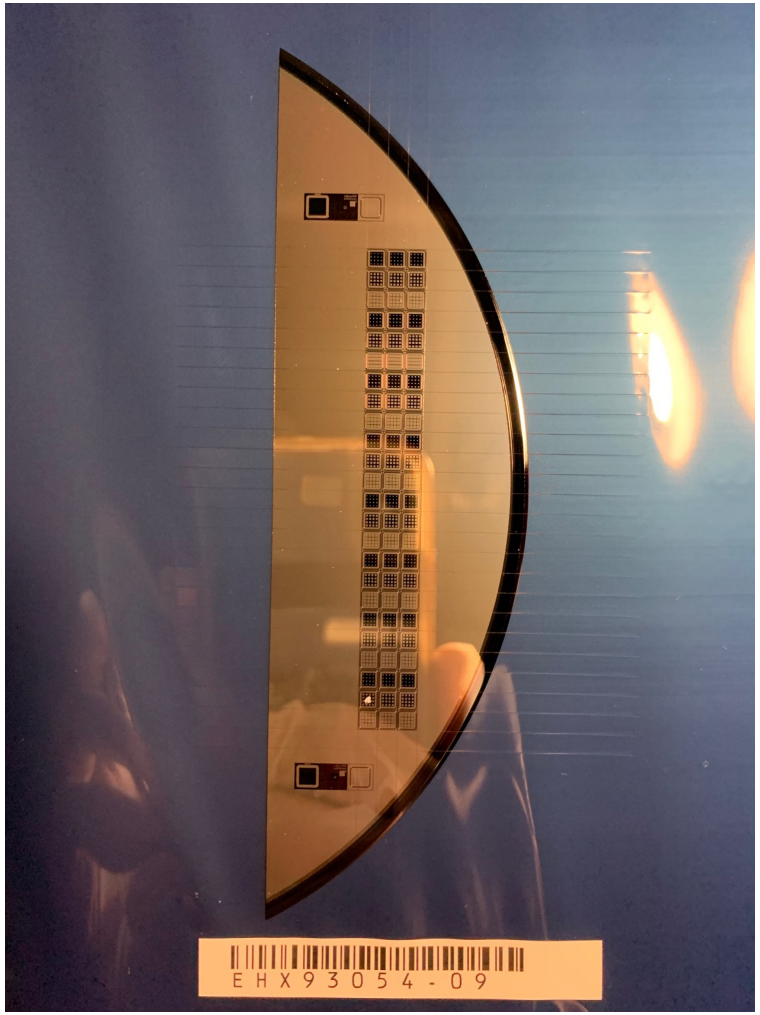
09:35 → 10:00 **Status and Plan on Light-Weight Module Structure** — 25m
Speakers: Andreas Werner Jung (Purdue University), Yi Yang (National Cheng Kung University)

10:00 → 10:25 **Status and Plan on Low Mass Hybrid (TBA)** — 25m
Speakers: Mathieu Benoit, Oskar Hartbrich (Oak Ridge National Lab)

HPK Sensors







FY23 Resource Requests by eRD112

Vendor/ Institute	M&S Item	Cost per Item (k$)	N. Items	Tot. Cost (k$)	
Sensor Production				**175**	
BNL IO	Sensor fabrication (incl. labor)	50 (10 wafers)	1.5	75	→ 75
HPK/FBK	Sensor fabrication	75+3-5/wafer	1	100	→ 80
Sensor Characterization				**13.7**	
UIC	M&S for test beam setup	-	-	5	→ 5
~~LANL~~	~~M&S for irradiation test~~	~~-~~	~~-~~	~~5~~	
~~SCIPP~~	~~Fermilab 16-channel boards~~	~~-~~	~~-~~	~~3.7~~	
Sensor/ASIC Integration				**30**	
~~UIC~~	~~Interposer fabrication and bump bonding~~	~~30~~	~~1~~	~~30~~	
Mechanical Structure				**15**	
NCKU	Material for light-weight support structure	-	-	10	→ 10
Purdue	Material for light-weight support structure	-	-	5	→ 5
Travel				**21**	
~~BNL~~	~~Trips to Fermilab testbeam~~	~~2~~	~~2~~	~~4~~	
UIC	Trips to Fermilab testbeam	1	5	5	→ 5
~~ORNL~~	~~Trips to Fermilab testbeam~~	~~3~~	~~2~~	~~6~~	
~~Rice~~	~~Trips to Fermilab testbeam~~	~~3~~	~~2~~	~~6~~	
TOT.				**254.7**	→ 180

Table 8: eRD112 resource request for M&S costs in FY23, excluding frontend ASIC and electronics.

FY23 Resource Requests by eRD112

Inst.	Task	Labor Type	FTE (%)	Tot. Cost (k$)	
Sensor R&D				**172.3**	
BNL	Sensor+ASIC and test board assembly	El. Tech.	10	20	→ 20
UIC	Sensor+ASIC and test board assembly	El. Tech.	10	15	→ 15
	~~lab/beam test for sensors and ASICs~~	~~Research Sp.~~	~~50~~	~~45~~	
LANL	~~Sensor irradiation test~~	~~Scientist~~	~~2.5~~	~~10~~	
	~~Sensor irradiation test~~	~~Student~~	~~5~~	~~5~~	
Rice	~~pixel sensor test~~	~~Postdoc~~	~~40~~	~~40~~	
SCIPP	~~Oversight and coordination~~	~~Project Scientist~~	~~5~~	~~9~~	
	TCAD sim. and sensor design	El. Design Specialist	10	16.5	→ 5
	Prototype Assembly	EM Engineer	5	11.8	→ 10
Sensor/ASIC Integration				**15**	
UIC	~~interposer design and testing~~	~~El. Engineer~~	~~10~~	~~15~~	
Mechanical Structure				**20**	
NCKU	light-weight support structure R&D	Mech. Engineer	10	5	→ 5
Purdue	light-weight support structure R&D	Mech. Engineer	10	15	→ 15
TOT.				**207.3**	→ 70

Table 9: eRD112 budget request for labor costs in FY23, excluding frontend ASIC and electronics.