2024/02/08

Oscura (DAMIC and SENSEI)

Juan Estrada
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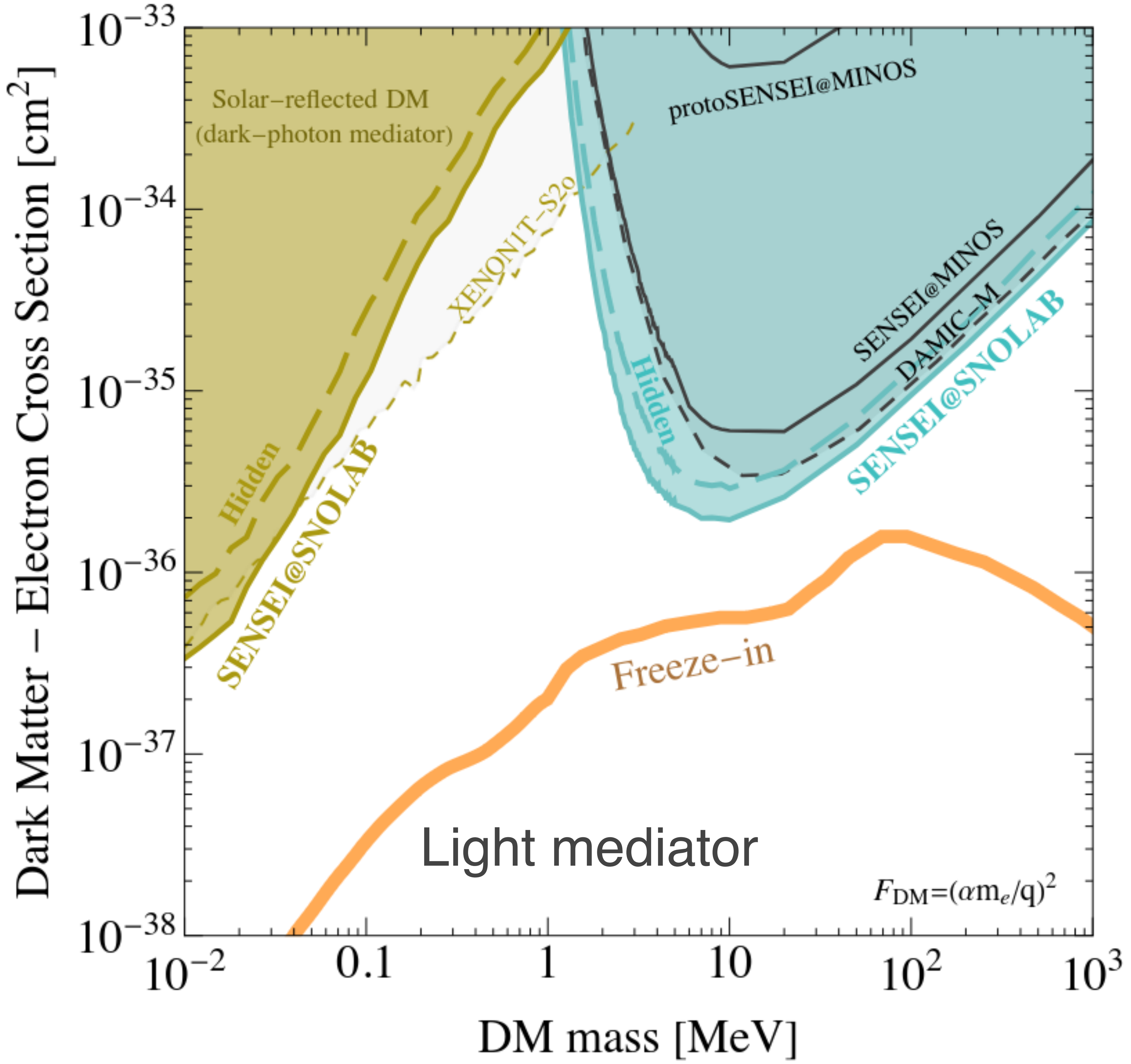
DAMIC and SENSEI Collaborator

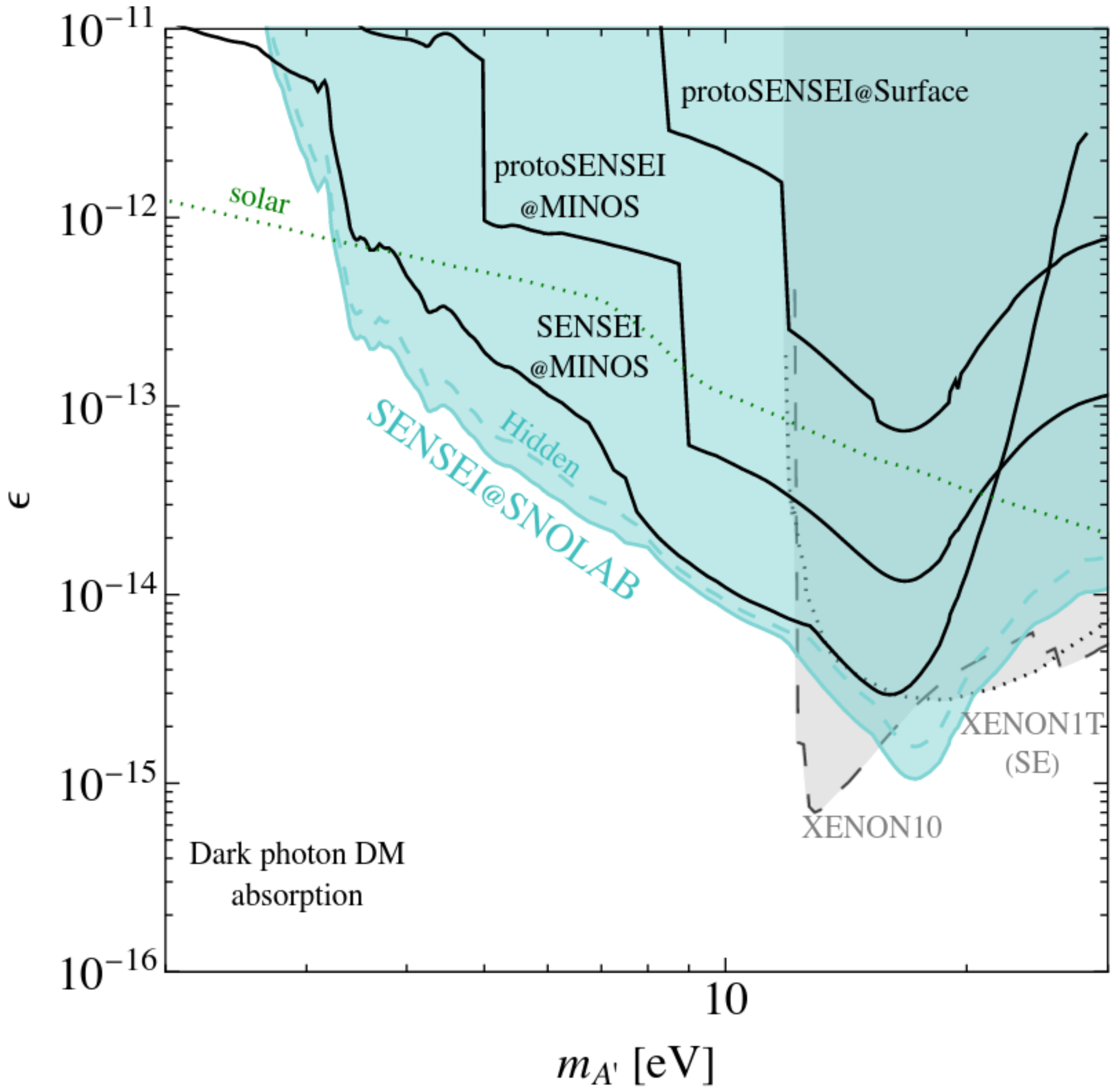
SNOLAB

This talk

- SENSEI Experiment (Results and plans) – from Javier Tiffenberg
- DAMIC Experiment (Results and plans) – from Alvaro Chavarria
- Oscura
  - R&D done
  -

First results from SENSEI @ SNOLAB:



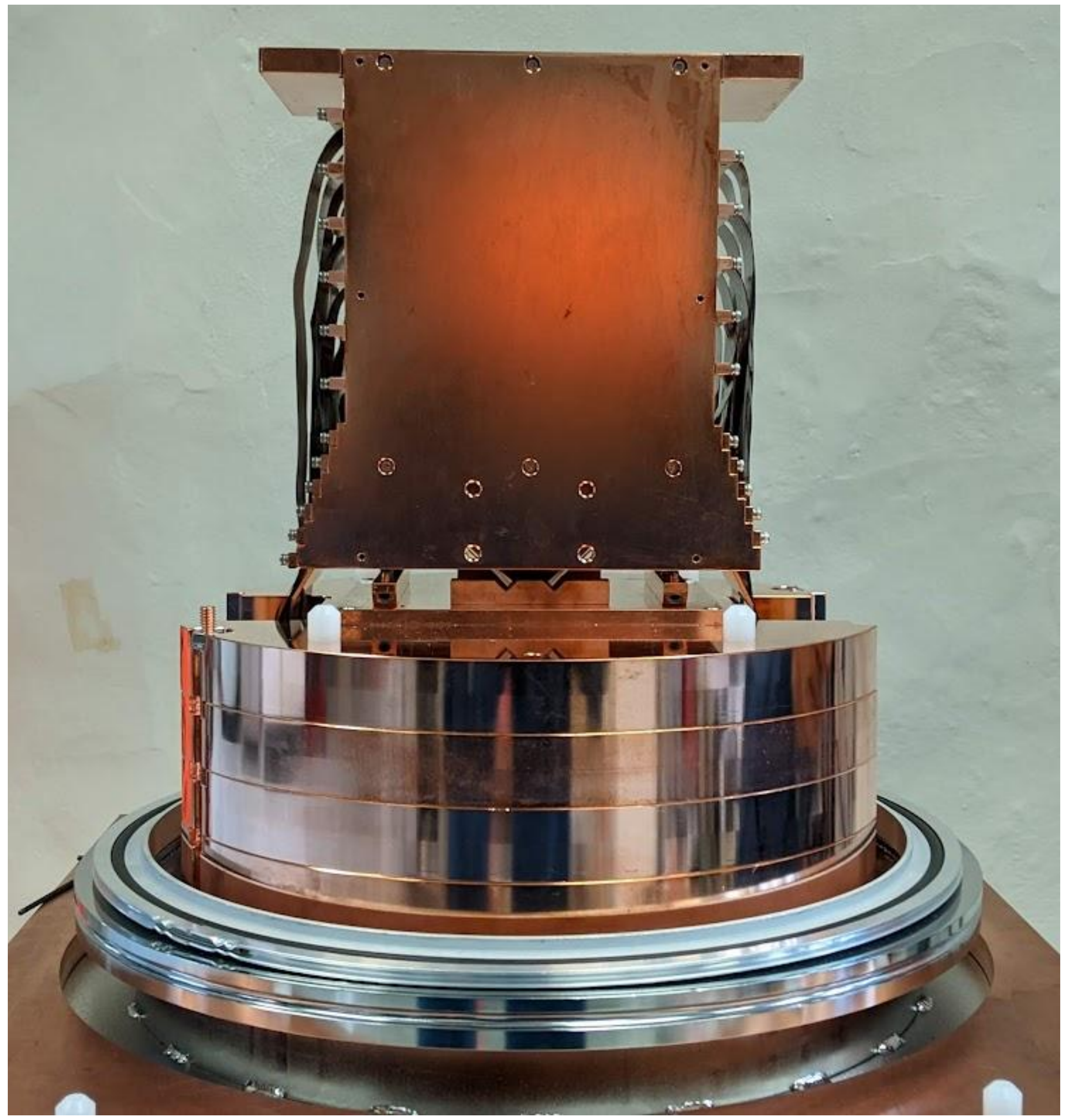


World-leading result using Snolab Run-1 data: arXiv:2312.13342 (Paper submitted on Dec-2023)

SENSEI @ SNOLAB: Second science run

Setup and **operations:**

- 19 CCDs (~**40 g**)
- **Commissioning**: **DONE!**
- **Science**: 11/2023 - present
- **Dark current** measurement: **DONE!**
- Data acquisition for **new DM limit** in progress



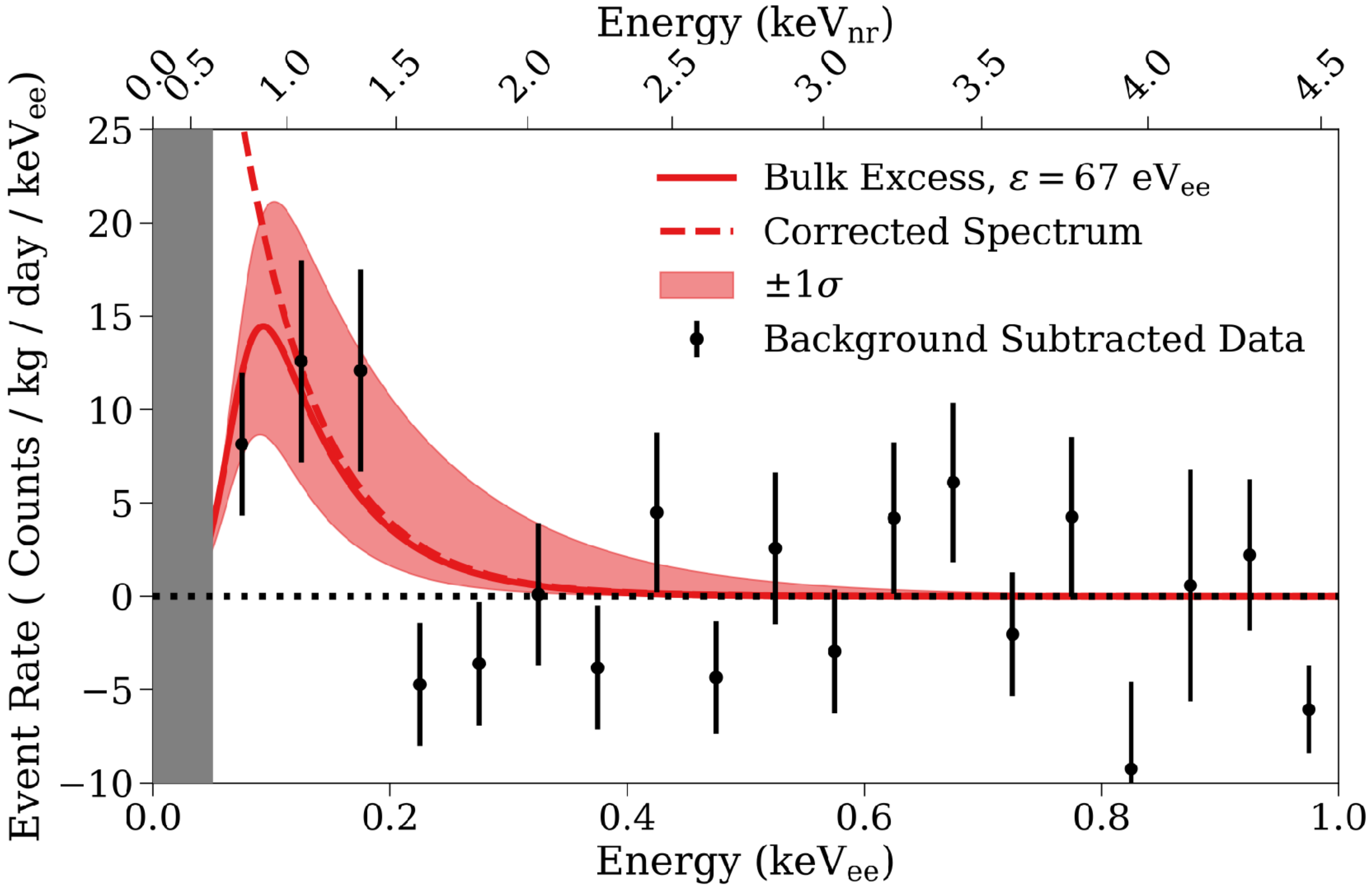
Thanks to Snolab for all the support!

DAMIC

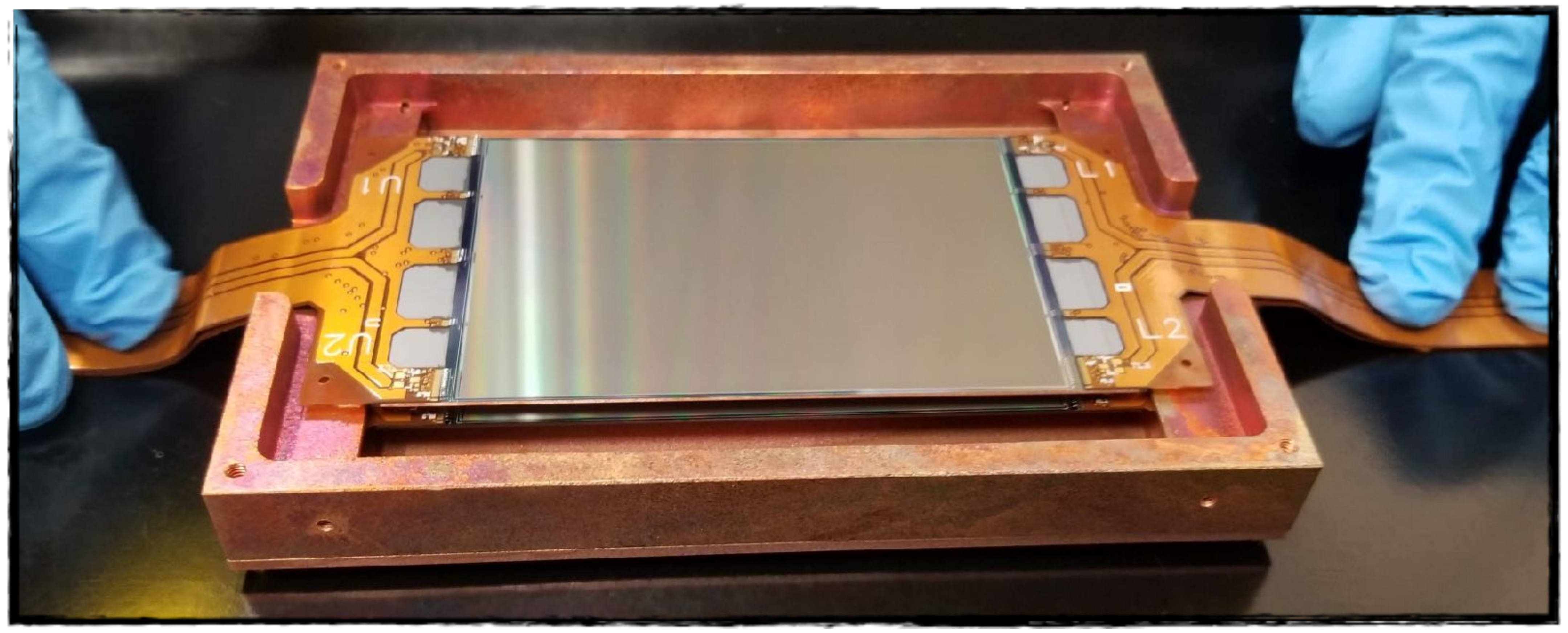
PRL **125** 241803 (2020)

PRD **105** 062003 (2022)

In 2020, we observed 17±8 excess bulk events with E~100 eV_{ee}.
Critical for DAMIC-M and Oscura



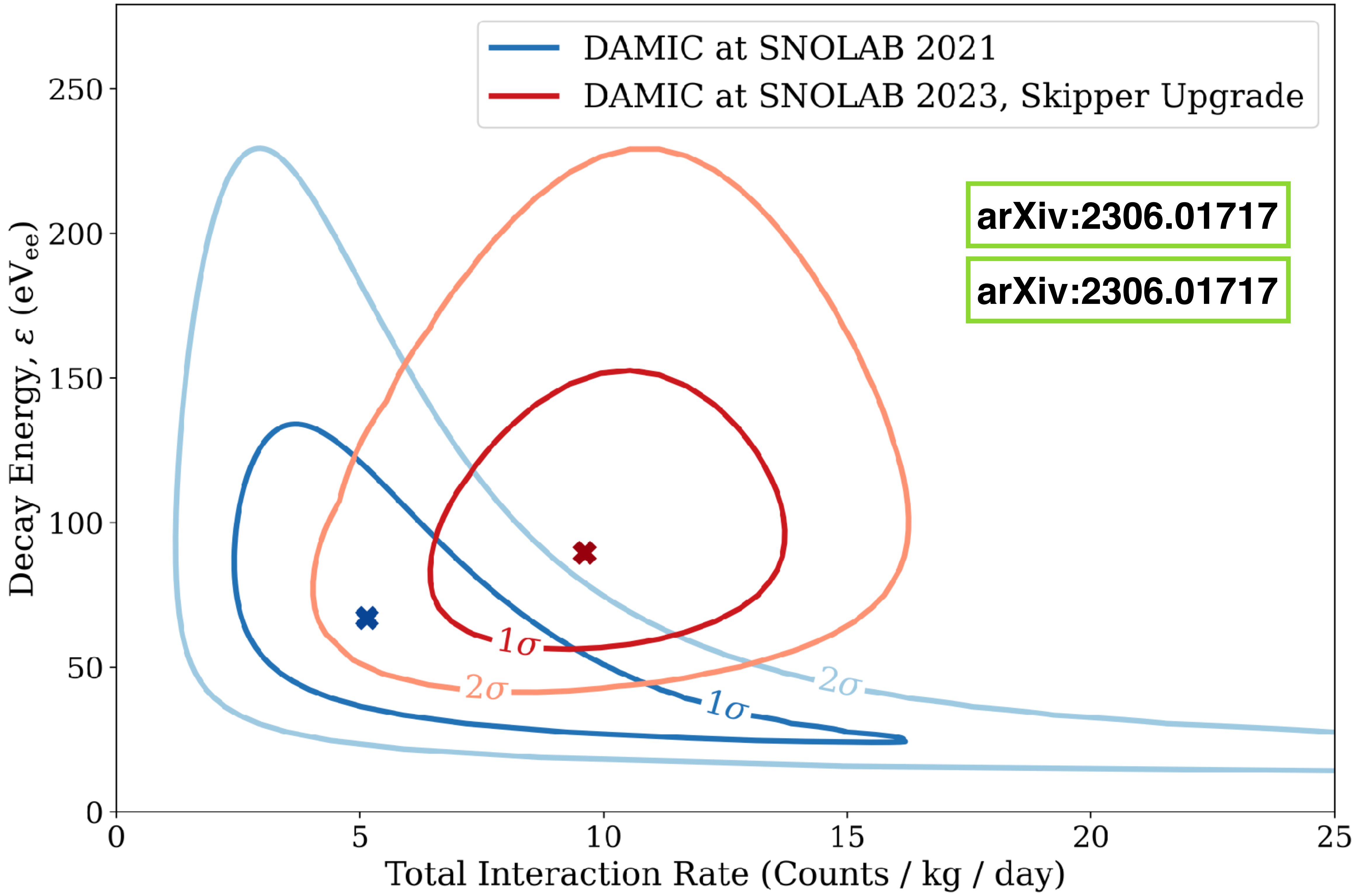
2022 Upgraded to skipper-CCDs



- Two 24 Mpix DAMIC-M skipper CCDs (18 g Si target) installed in Oct-Nov 2021.
- Single-e^- resolution, 2 x 10^{-3} e^-/pix/day, 10 d.r.u., 18 g.
- Nominally the same detector components, *i.e.*, very similar background environment.
- Science run from March 2022 to January 2023 (4.8 kg-day).

Results (June 2023)

- Excess measured again with 5.4 σ statistical significance.
- Results from skipper upgrade consistent with 11 kg-day analysis.
- Disfavors most (all?) possible “instrumental” origins of the excess.
- However, radiation environment of the detector remains the same.



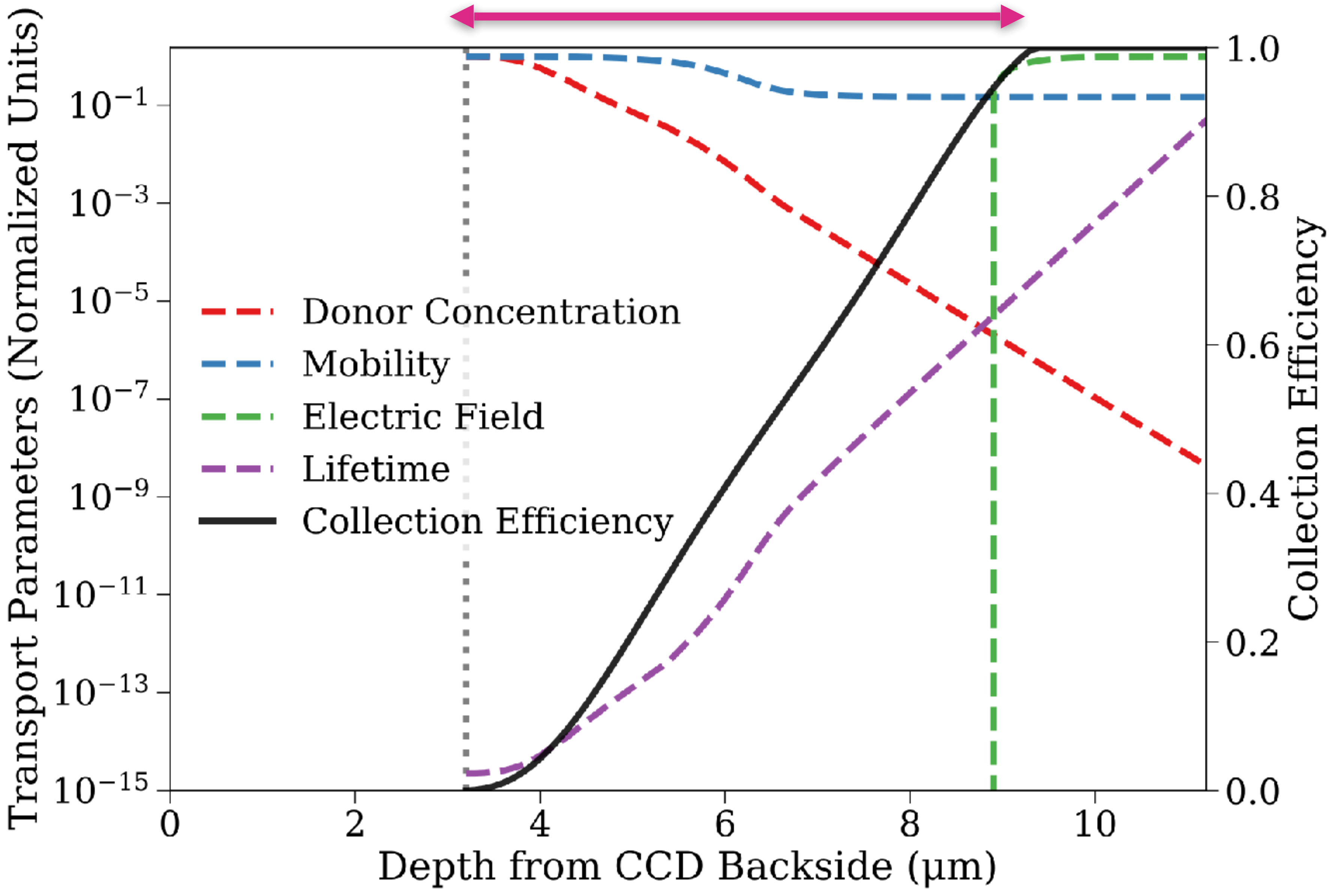
Most likely from a source of radiation in the DAMIC detector that is not included in our background model

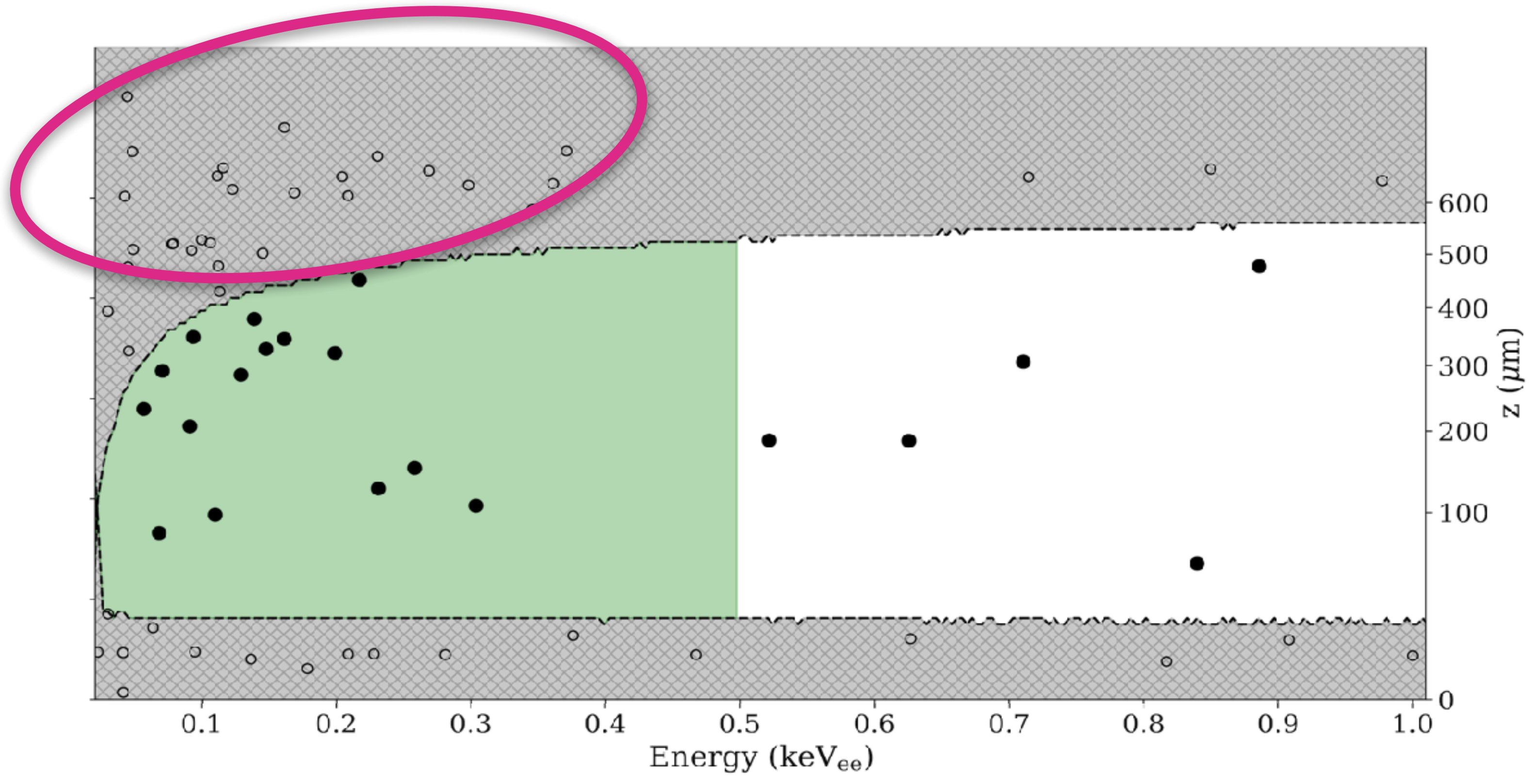
Hard to reconcile with results from liquid argon arXiv:2308.12176

Back-thinned CCDs

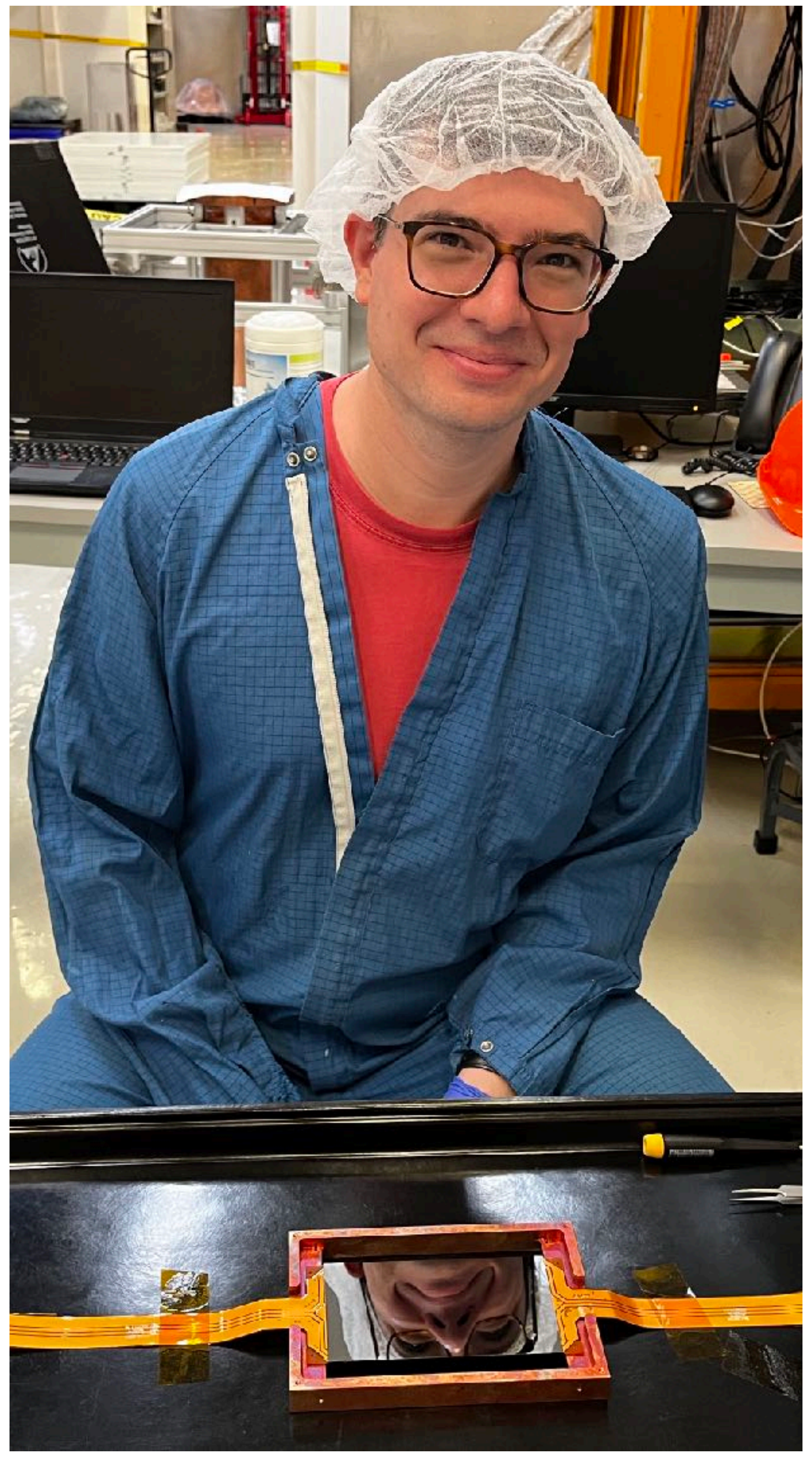
- Back-thinning removes the region of partial charge collection (PCC) on the back of the CCDs.
- PCC degrades the ionization signal from surface events so they populate the low-energy region where the DM signal is expected.
- These events are not the cause of the excess but could be an important background for Oscura.

Partial charge collection





- Two back-thinned CCDs of the same 24 Mpix format as before deployed in July 2023.
- We are acquiring data since July to study the backgrounds in back-thinned CCDs. Analysis underway.
- Expect results throughout 2024.



Oscura

Skipper-CCD DM program

Experiment	Mass [kg]	#CCDs	Radiation bkgd [dru]	Instrumental bkgd [e-/pix/day]	Commissioning
SENSEI @ MINOS	~0.002	1	3400	1.6×10^{-4}	late-2019
DAMIC @ SNOLAB	~0.02	2	~10	3×10^{-3}	late-2021
DAMIC-M LBC	~0.02	2	10	3×10^{-3}	late-2021
SENSEI-100	~0.1	50	10 (goal)		mid-2022
DAMIC-M	~1	200	0.1 (goal)		~2023
OSCURA	~10	20,000	0.01 (goal)	1×10^{-6} (goal)	~2028

Oscura is an ambitious program that brings together the DAMIC, SENSEI and DAMIC-M teams for the development of ultimate DM experiment with skipper-CCDs.

Skipper-CCD DM program

Experiment	Mass [kg]	#CCDs	Radiation bkgd [dru]	Instrumental bkgd [e-/pix/day]	Commissioning
DAMIC @ SNOLAB	~0.02	2	~10	3×10^{-3}	late-2021
SENSEI-100	~0.1	50	10 (goal)		mid-2022
OSCURA	~10	20,000	0.01 (goal)	1×10^{-6} (goal)	~2028

THIS IS A SNOLAB PROGRAM!

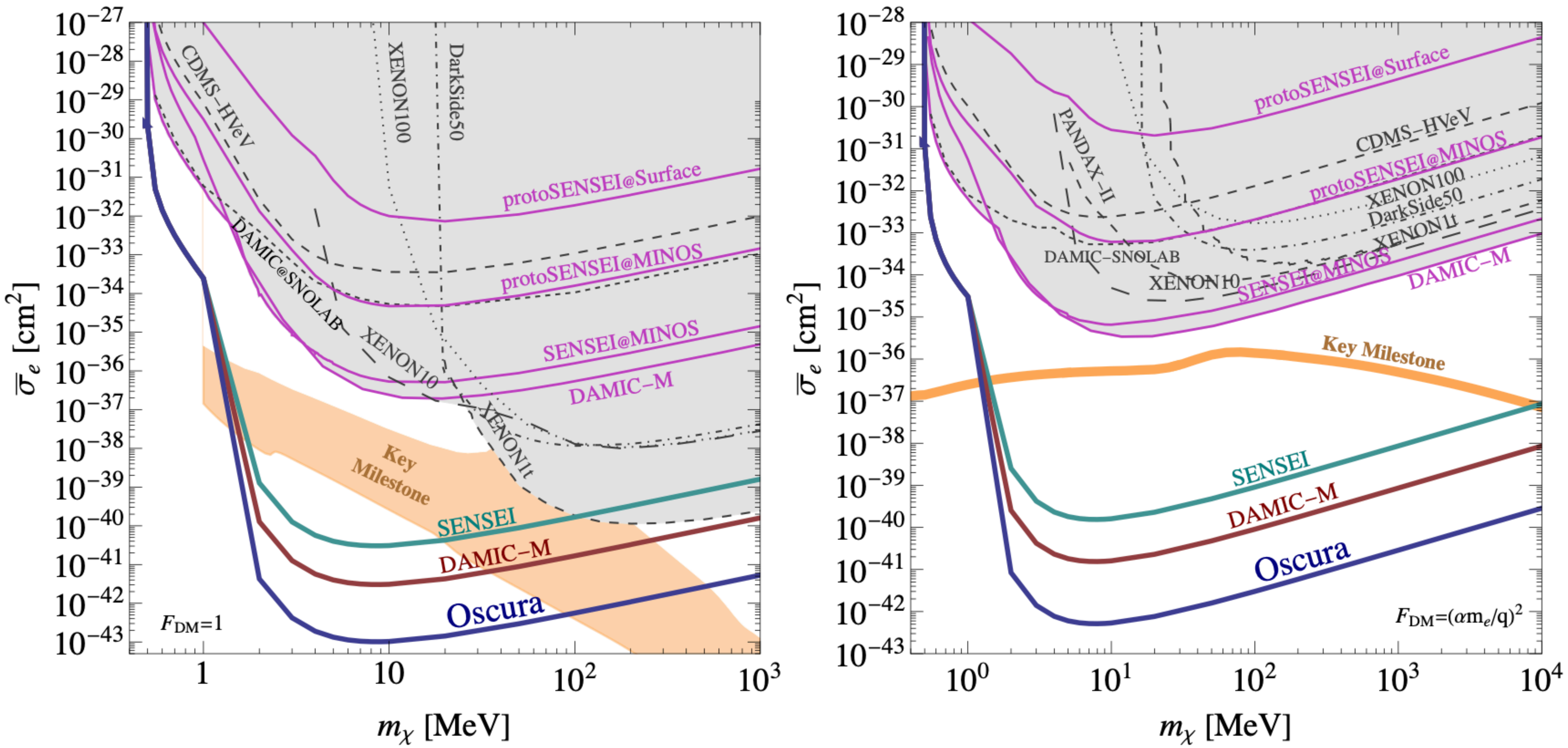


Figure 1. Approximate projected sensitivity for Oscura to DM-electron scattering at 90% C.L. assuming a 30 kg-year exposure, zero background events with $2e^-$ or more, a $1e^-$ threshold and a fixed $1e^-$ event rate of $10^{-6}e^-$/pix/day (blue). To build this curve, 100% efficiency was assumed for the reconstruction of events above $2e^-$. The left (right) plot assumes a heavy (light) mediator in the DM-electron interaction. Approximate projected sensitivities for SENSEI (DAMIC-M) are shown in cyan (red) [1, 5, 12, 18, 21, 22]. Existing constraints from skipper-CCDs from SENSEI [13–15] and DAMIC-M [16] are shaded in pink. Shaded gray regions are constrained by several other experiments (some shown explicitly) [19, 23–33]. Existing limits come directly from publications; reader should look at them for specific assumptions. Orange regions labeled "Key Milestone" represent well-motivated sub-GeV DM models, highlighted in the recommendations of the Basic Research Needs report [5].

R&D Milestones : 3 high priorities (done)

- SENSOR: Before Oscura skipper-CCDs were fabricated at DALSA. DALSA will discontinue this production line. The highest priority for Oscura R&D was developing a new fabrication process with more modern technology. We tested new sensors and these work (2 vendors) [arXiv:2304.04401].

- READOUT: Oscura will have ~20,000 CCDs. Developed new cold front end electronics for this. Solution designed and tested [arXiv:2304.13088, Sensors 2022, 22(11), 4308].

- BACKGROUND: SENSEI is designed for background of 5 d.r.u. (events/kg/day/keV), DAMIC-M 0.1 dru, Oscura has a goal of 0.01 dru. Major effort in background control material selection. Module simulations completed (Geant4), initial material budgets produced, established the cosmogenic activation limits. [arXiv:2007.10584, Phys. Rev. D 102, 102006 (2020), arXiv:2303.10862 , arXiv:2306.01717]

Completed R&D : sensors

PAPER • OPEN ACCESS

Skipper-CCD sensors for the Oscura experiment: requirements and preliminary tests

Brenda A. Cervantes-Vergara[1], Santiago Perez[15], Juan Estrada[4], Ana Botti[4], Claudio R. Chavez[4,8], Fernando Chierchie[8], Nathan Saffold[4], Alexis Aguilar-Arevalo[1], Fabricio Alcalde-Bessia[2], Nicolás Avalos[2] + Show full author list

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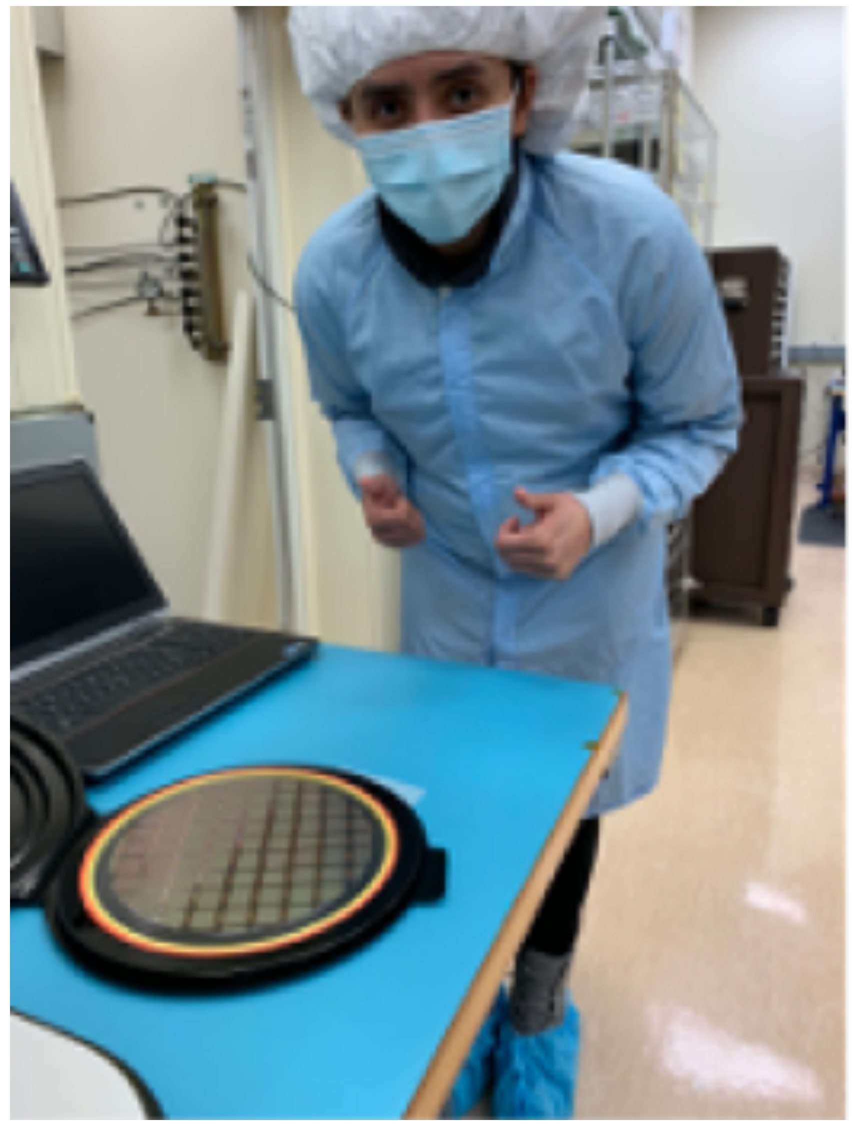
Journal of Instrumentation, Volume 18, August 2023

Citation Brenda A. Cervantes-Vergara *et al* 2023 *JINST* **18** P08016

DOI 10.1088/1748-0221/18/08/P08016



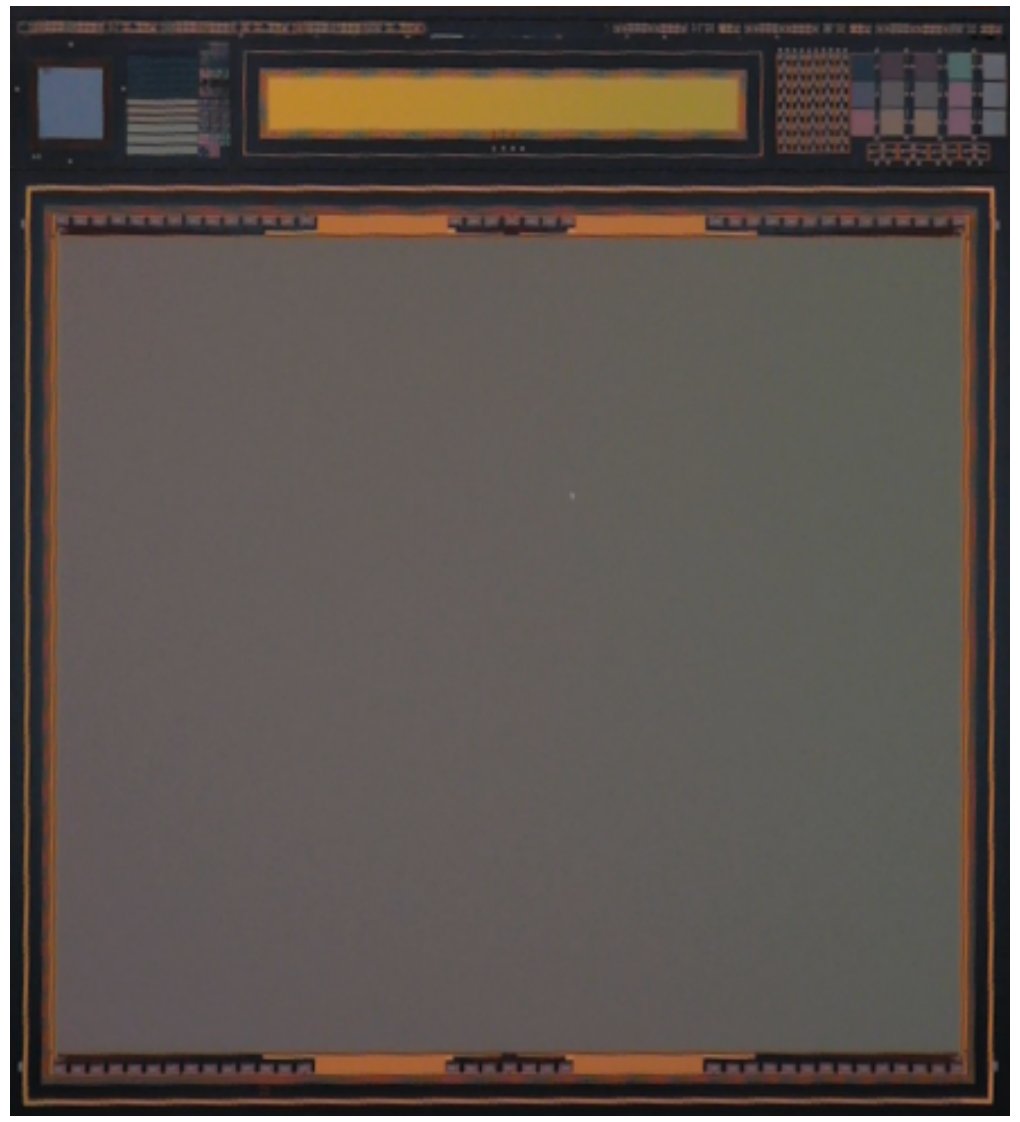


Table 2. Sensors performance parameters constraints to achieve the Oscura background goal/requirement and demonstrated performance of prototype sensors. The "Best achieved" column contains the best values achieved with skipper-CCDs and the checkmarks (✓) indicate that the constraints for meeting the Oscura background requirement have been met.

Parameter	Goal	Requirement	Prototype	Best achieved	Units
Dark current	1×10^{-6}	1.6×10^{-4}	3×10^{-2}	1.6×10^{-4} ✓	e^-/pix/day
Readout time (full array)	< 2	< 5	3.4 (4.2)	3.4 ✓	hours
Pixel readout rate	> 188	> 76	111 (89)	111 ✓	pix/s
Readout noise	< 0.16	< 0.20	0.19 (0.20)	0.19 ✓	e^- RMS
Spurious charge	$< 4 \times 10^{-11}$	$< 6 \times 10^{-9}$	7.2×10^{-7}	1.4×10^{-8}	e^-/pix/transfer
Trap density ($\tau > 5.3$ ms)	< 0.12		< 0.015	< 0.0003 ✓	traps/pix
Charge transfer inefficiency	$< 10^{-5}$		$< 5 \times 10^{-5}$	$< 10^{-5}$ ✓	1/transfer
VIS/NIR light blocking	$> 90\%$		95%	95% ✓	

Completed R&D : sensors

PAPER • OPEN ACCESS

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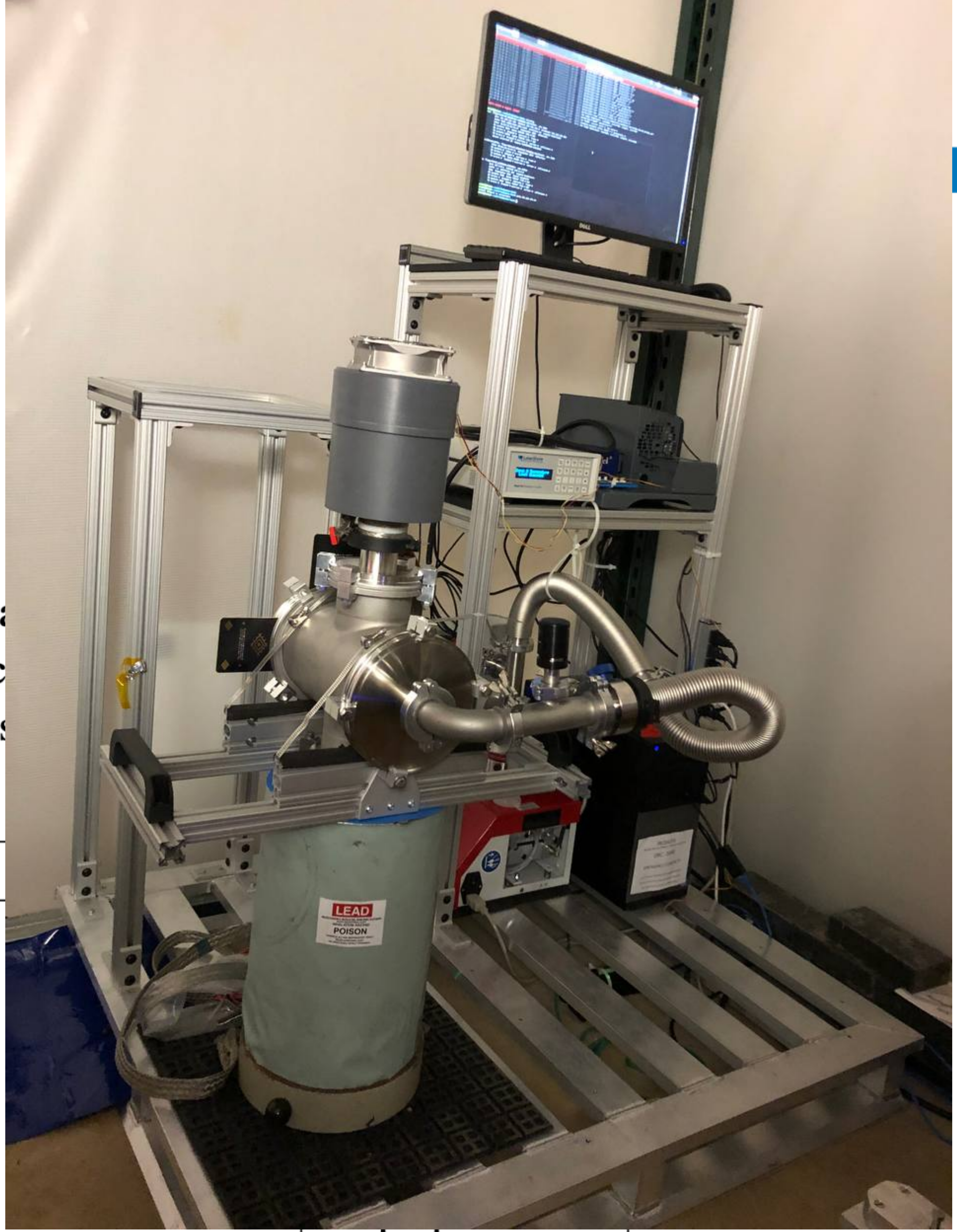
Table 2. Sensors performance parameters constraints to achieve the Oscur[a] and demonstrated performance of prototype sensors. The "Best achieved" c[…] achieved with skipper-CCDs and the checkmarks (✓) indicate that the cons[…] background requirement have been met.

News 2024!

Parameter	Goal	Requirement	Prototype			
Dark current	1×10^{-6}	1.6×10^{-4}	1x10^{-3}			
Readout time (full array)	< 2	< 5	3.4 (4.2)			
Pixel readout rate	> 188	> 76	111 (89)			
Readout noise	< 0.16	< 0.20	0.19 (0.20)			
Spurious charge	$< 4 \times 10^{-11}$	$< 6 \times 10^{-9}$	7.2×10^{-7}			
Trap density ($\tau > 5.3$ ms)	< 0.12		< 0.015			
Charge transfer inefficiency	$< 10^{-5}$		$< 5 \times 10^{-5}$	$< 10^{-5}$	✓	1/transfer
VIS/NIR light blocking	$> 90\%$		95%	95%	✓	



Moskita@MINOS

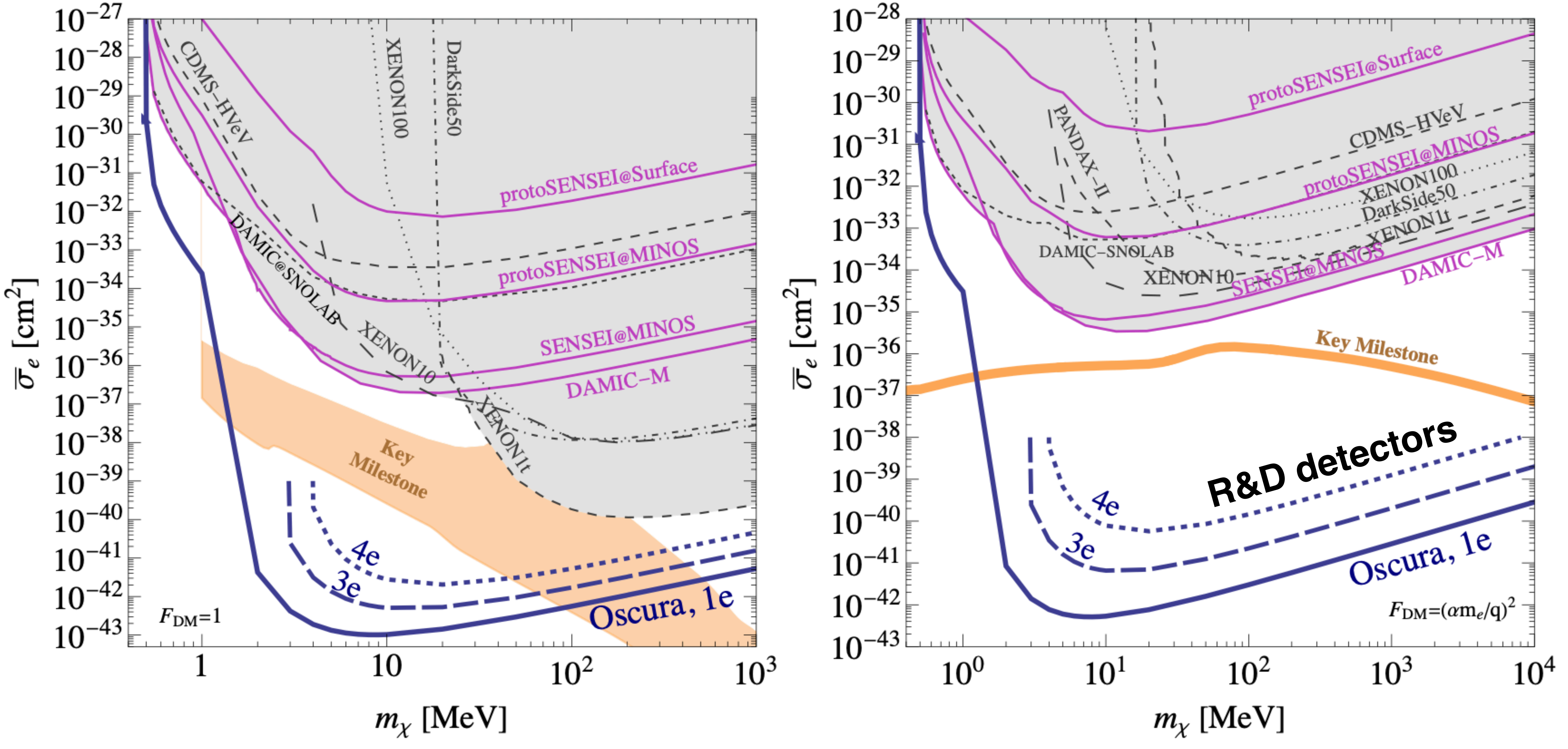
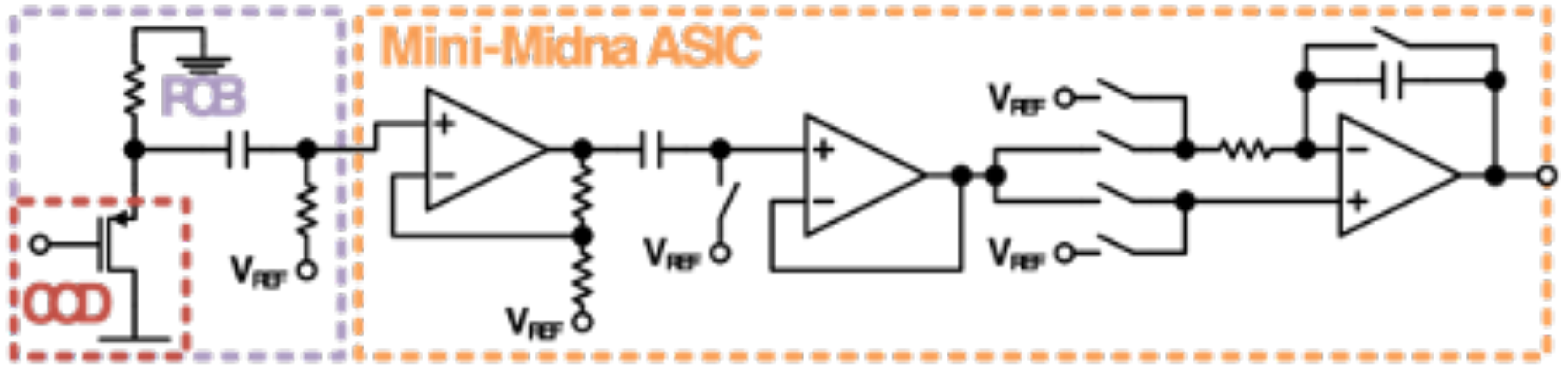


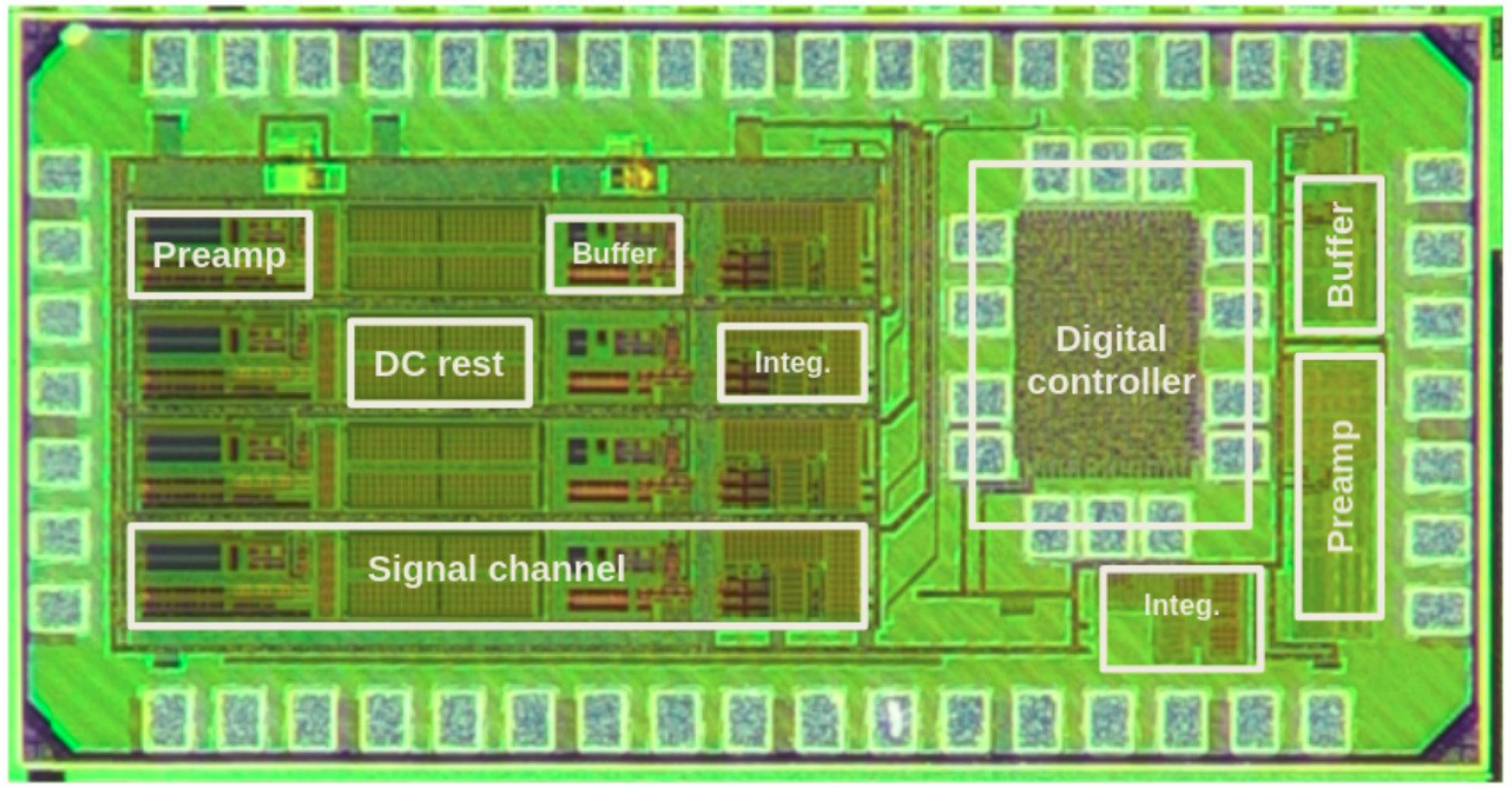
Figure 13. Approximate projected sensitivity for Oscura to DM-electron scattering at 90% C.L. assuming a 30-kg year exposure and: 1) a $3e^-$ threshold and zero background events with $3e^-$ or more (dashed blue); 2) a $4e^-$ threshold and zero background events with $4e^-$ or more (dotted blue). To build these curves, 100% efficiency was assumed for the reconstruction of events above the threshold. The left (right) plot assumes a heavy (light) mediator in the DM-electron interaction. The blue solid line and the other curves are as in Fig. 1.

Completed R&D : electronics

Cold front end:



16



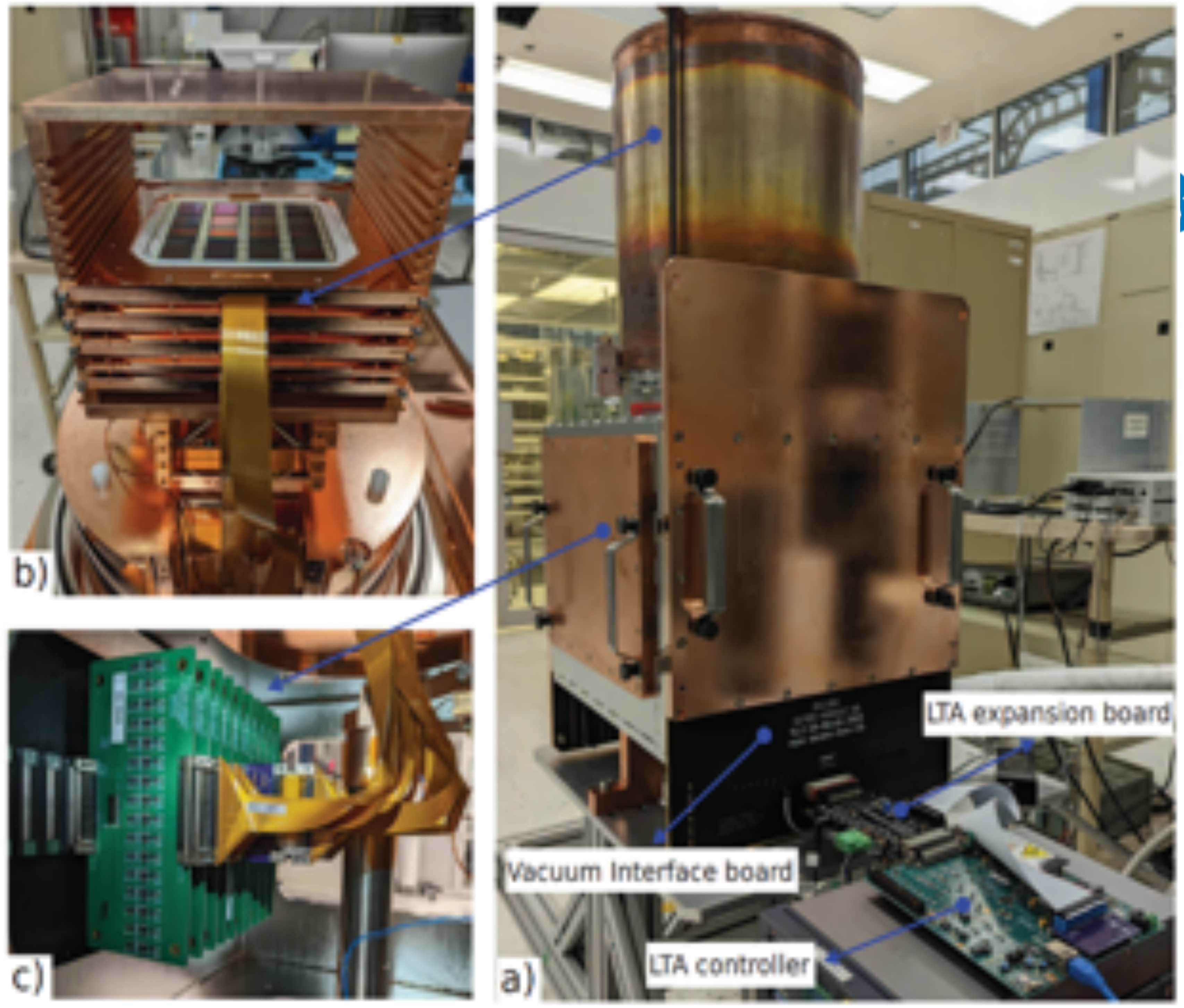
Designed, Fabricated and Tested the MIDNA ASIC. Cold front end electronics for skipper-CCD. 4-channel.

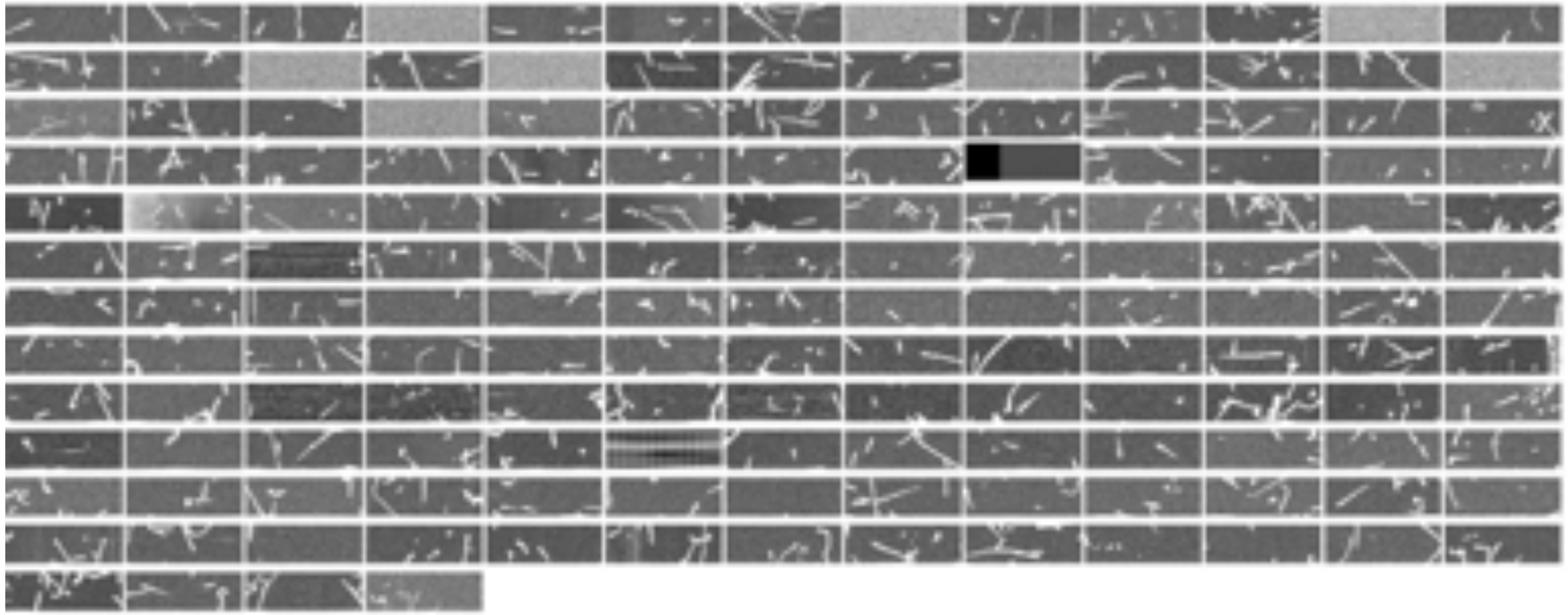
https://arxiv.org/abs/2304.13088

Back end :

Designed and tested a multiplexer solution for the back end. Operated 160 CCDs with single readout channel.

Sensors 2022, 22(11), 4308

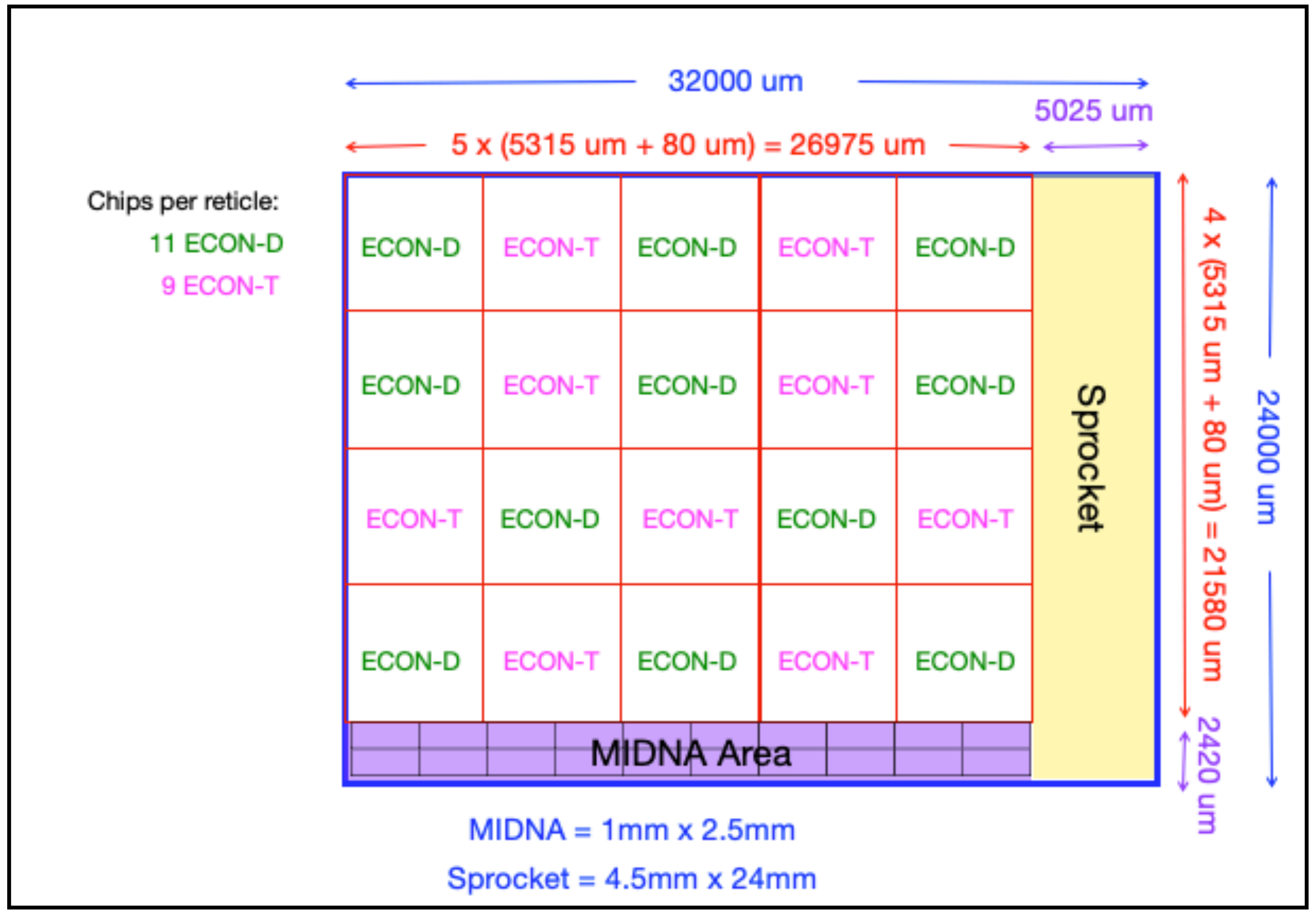




MIDNA ASICs

We designed, build and tested the MINDA2 ASIC for our readout.

We need 6,000 MIDNAs. This was a big part of our cost.



https://arxiv.org/abs/2304.13088

It turns out that the MIDNA is so small that we can use some space that is available for free on a large scale fabrication process at FNAL.
(CMS+microelectronics)

So will have **all our MIDNA done before we start the project.** This will cover all the ASIC needs for Oscura, with parts for other skipper-CCD efforts:

- MIDNA 2 (fully tested)
- MIDNA 2.1 (lower gain for better dynamic range)
- **MIDNA 3 (16 channel + multiplexer)**

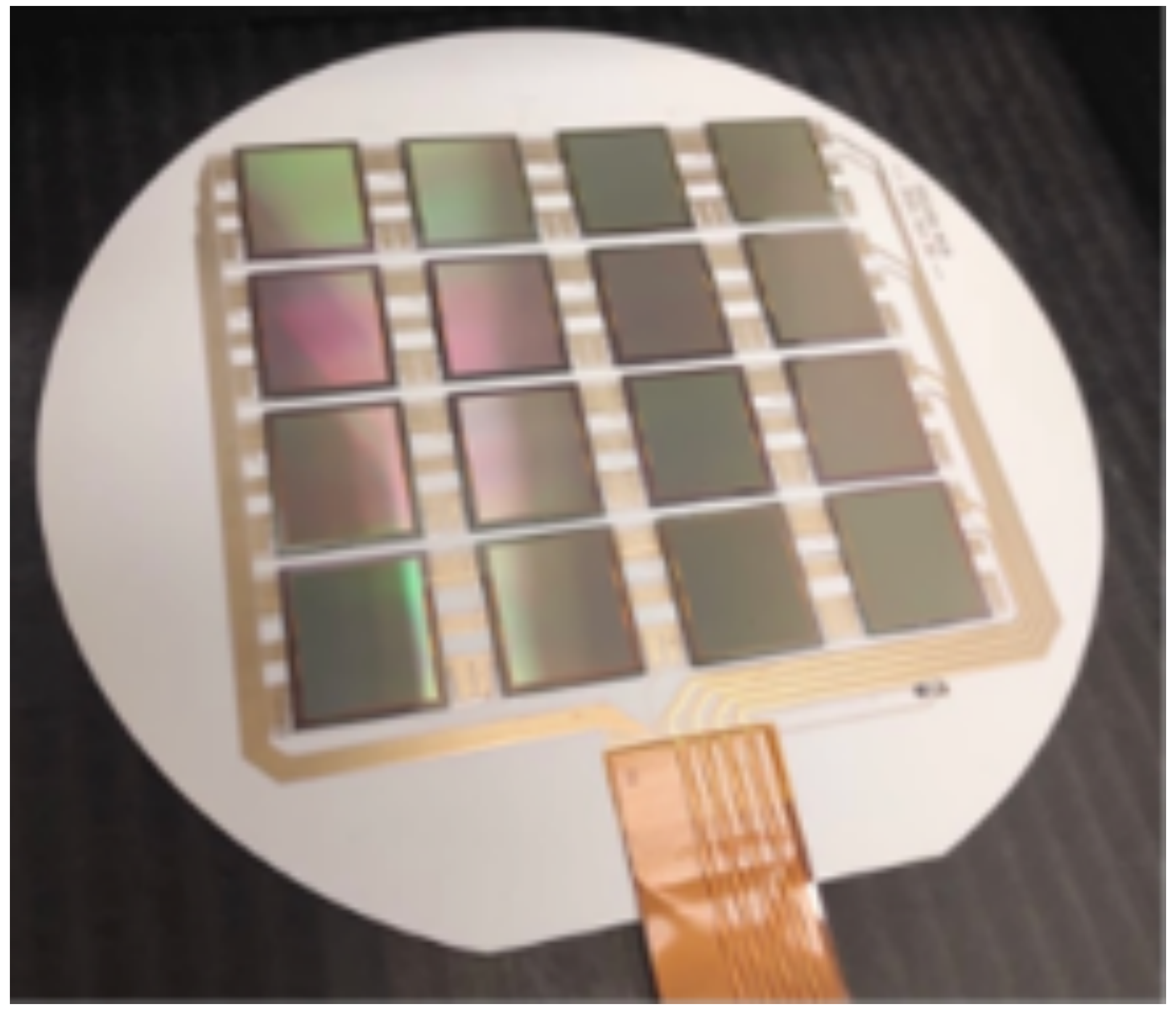
4MIDNA board for 1 MCM

Completed R&D : electronics/packaging Multi Chip Module

Circuit layout

MCM concept 2021

Functional test cold

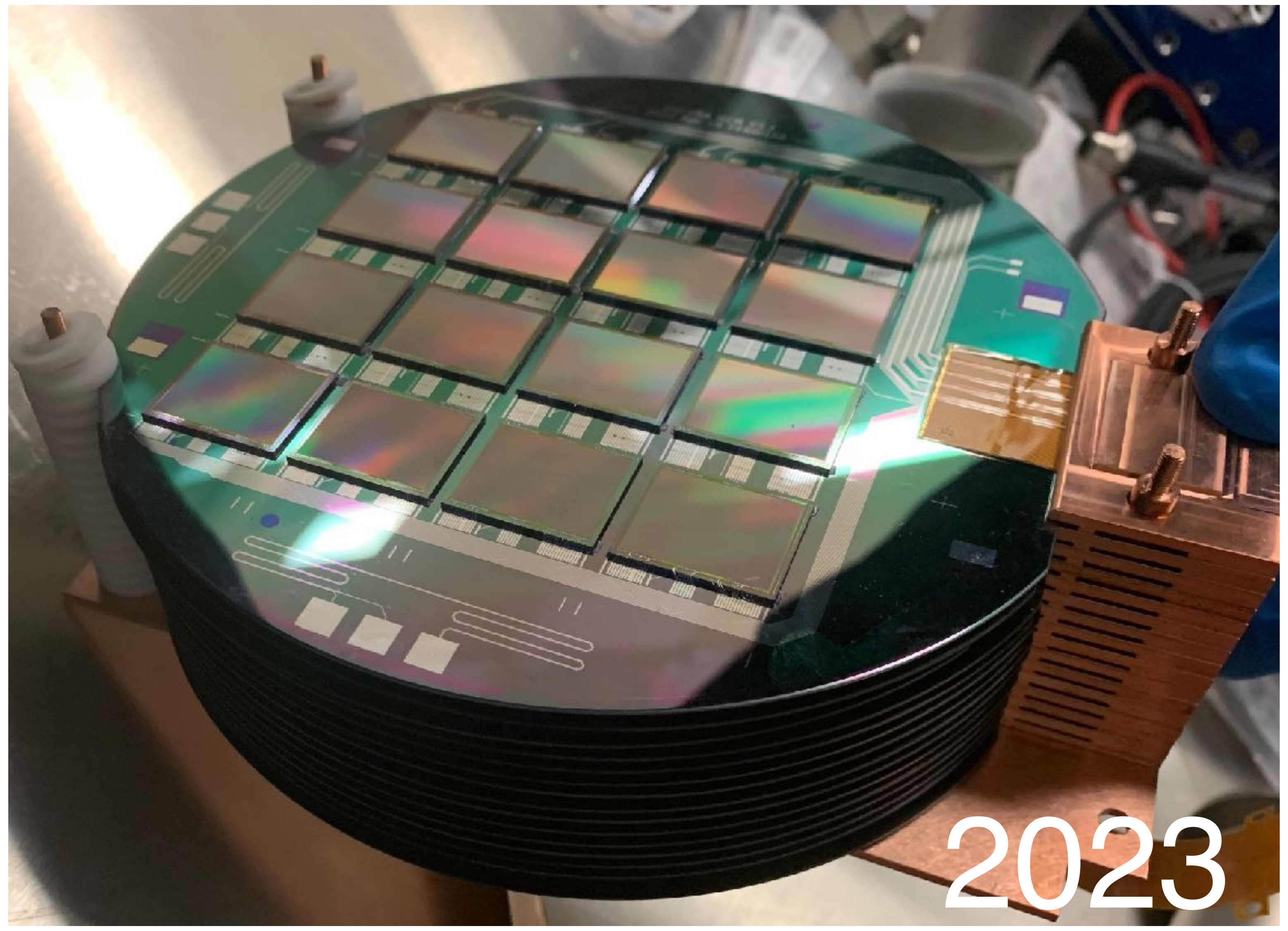


6” ceramic MCM 2022

Low background solution (Silicon)

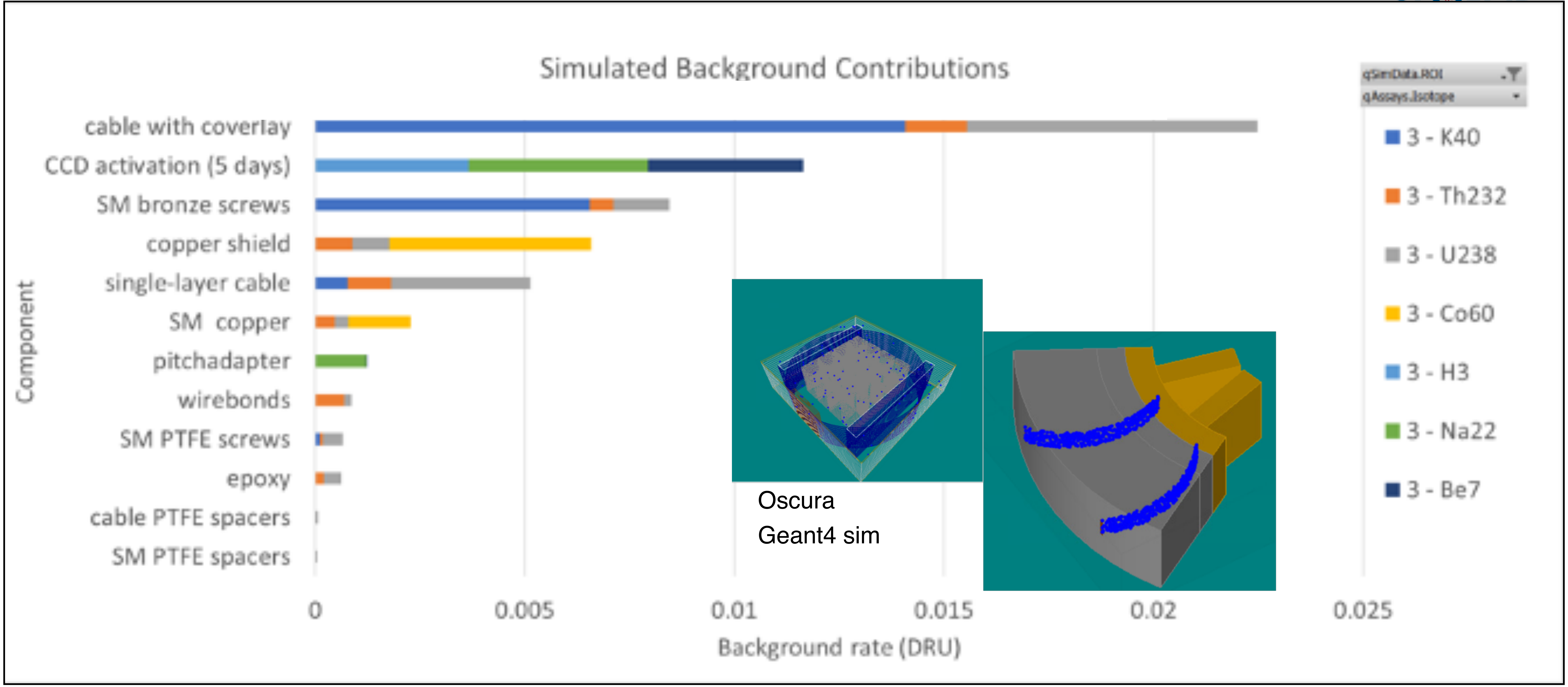
6” Si MCM 2022 : fabs and ANL + FNAL

Mechanical prototype of the Oscura Supermodule with 130g of CCDs (16 MCMs)



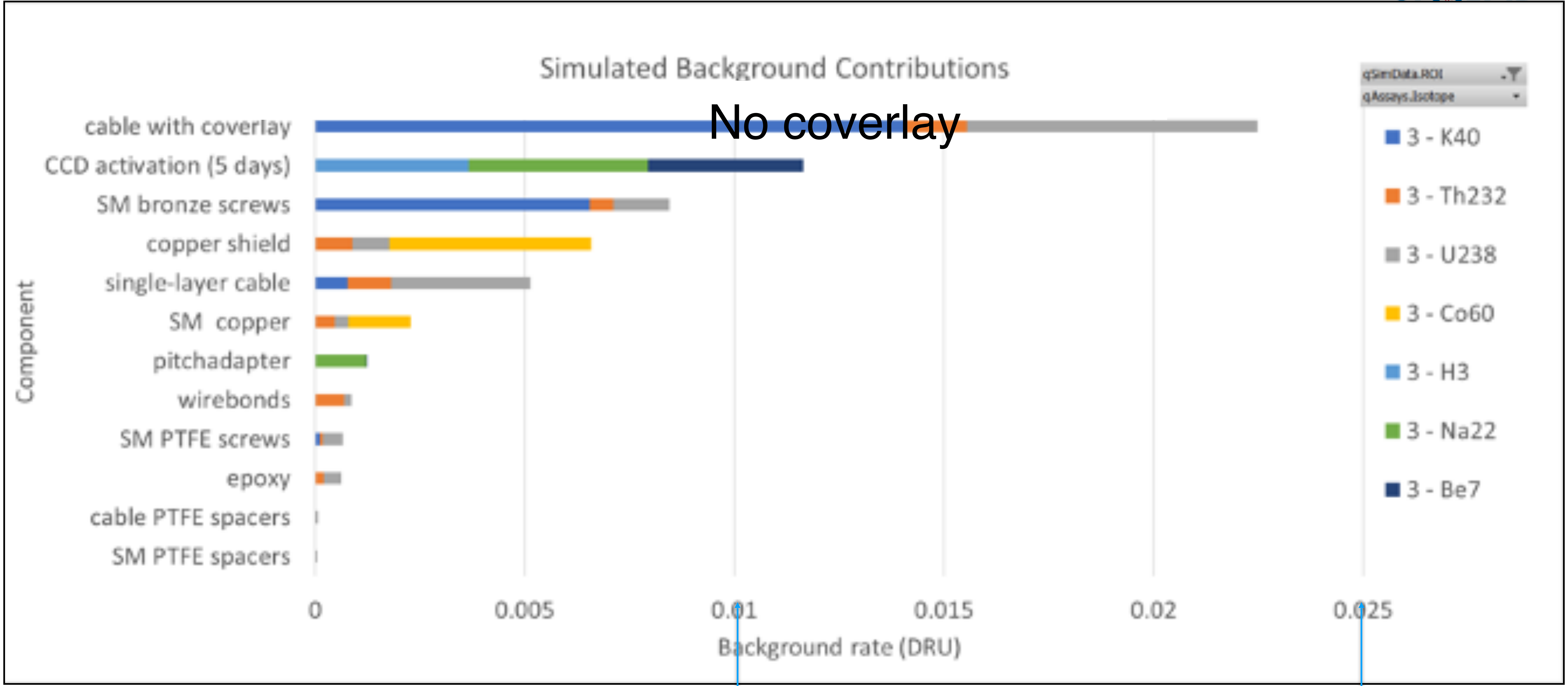
After a few iterations on the design of the Si-MCM we have now tested it, and are confident we can achieve the Oscura specs.

Background Control



Simularions by B.Loer (PNNL)

Background Control



Simularions by B.Loer (PNNL)

Goal

Used for forecast

Current status

Duration [d]	Step	Location	Latitude	Longitude	Altitude [km]	Neutron Flux [n/cm2/sec]	Sea Level Factor	Shielding	Shielding Factor	Sea-level days	NOTES
3	Ingot growing	TOPSIL, Frederikssund, Denmark	55.83	12.11	0.015	3.41E-03	1.16	None	1	3.48	Special request to grow quickly. If longer time needed for full mass, can we request multiple boules?
14	Ingot storage	Hospital basement, Copenhagen, Denmark	55.68	12.56	0.045	3.51E-03	1.19	Basement	50	0.33	Don't actually know duration or shielding factor
28	Transport to Montreal		55.68	12.56	0	3.36E-03	1.14	Shielded Container	20	1.60	Transportation time based on searates.com. Used Copenhagen as location
3	Transport to Phoenix		45.51	-73.55	0.864	7.74E-03	2.63	Shielded Container	20	0.39	Transportation time based on Google Maps. Used Montreal as location. Used Liberal, KA as altitude
4	Wafering	SUMCO, Phoenix, AZ	33.41	-111.94	0.36	4.24E-03	1.44	Shielded Box	2.25	2.56	Picked random place from Google. 26 min away from Microchip. Used Microchip as location.
14	Storage	San Xavier, AZ	31.97	-111.09	1.08	7.89E-03	2.68	Shallow Underground	400	0.09	Shielding based on assumed 100 m.w.e.
66	**PRE-FAB TOTAL**									**8.47**	
32	CCD processing	Microchip, Tempe, AZ	33.41	-111.94	0.36	4.24E-03	1.44	Shielded Box	2.25	20.51	Estimate 66% time in shielding box, rest outside during fab
30	Storage	San Xavier, AZ	31.97	-111.09	1.08	7.89E-03	2.68	Shallow Underground	400	0.20	Shielding based on assumed 100 m.w.e.
2	Transport to Fermilab	Fermilab, IL	31.97	-111.09	0.864	6.56E-03	2.23	Shielded Container	20	0.22	Transportation time based on Google Maps. Used Tempe as location. Used Liberal, KA as altitude
60	Packaging	MINOS tunnel	41.83	-88.26	0.216	1.50E-06	5.10E-04	None (already applied)	1	0.03	Neutron flux taken from Garrison thesis for neutrons > 15 MeV in SciBath at MINOS near detector
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1	Transport to SNOLAB		41.83	-88.26	0.216	4.16E-03	1.41	Shielded Container	20	0.07	Used Fermilab as location
185	**POST-FAB TOTAL**									**21.07**	
251	**TOTAL**									**29.53**	

R.Saldanha (PNNL)

Current status

Duration [d]	Step	Location	Latitude	Longitude	Altitude [km]	Neutron Flux [n/cm2/sec]	Sea Level Factor	Shielding	Shielding Factor	Sea-level days	NOTES
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251	**TOTAL**									**29.53**	
251	**TOTAL WITH BAKING**									**21.49**	

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32	CCD processing	Microchip, Tempe, AZ	33.41	-111.94	0.36	4.24E-03	1.44	Shielded Box	2.25	20.51	Estimate 66% time in shielding box, rest outside during fab
30	Storage	San Xavier, AZ	31.97	-111.09	1.08	7.89E-03	2.68	Shallow Underground	400	0.20	Shielding based on assumed 100 m.w.e.
2	Transport to Fermilab	Fermilab, IL	31.97	-111.09	0.864	6.56E-03	2.23	Shielded Container	20	0.22	Transportation time based on Google Maps. Used Tempe as location. Used Liberal, KA as altitude
60	Packaging	MINOS tunnel	41.83	-88.26	0.216	1.50E-06	5.10E-04	None (already applied)	1	0.03	Neutron flux taken from Garrison thesis for neutrons > 15 MeV in SciBath at MINOS near detector
60	Testing	MINOS tunnel	41.83	-88.26	0.216	1.50E-06	5.10E-04	None (already applied)	1	0.03	Neutron flux taken from Garrison thesis for neutrons > 15 MeV in SciBath at MINOS near detector
1	Transport to SNOLAB		41.83	-88.26	0.216	4.16E-03	1.41	Shielded Container	20	0.07	Used Fermilab as location
185	**POST-FAB TOTAL**									**21.07**	
251	**TOTAL**									**29.53**	
251	**TOTAL WITH BAKING**									**21.49**	

Very close… but need to understand cost

10.75

~0.026 DRU (scaling from 5 days)

Post fab baking (50%)

Another small advantage

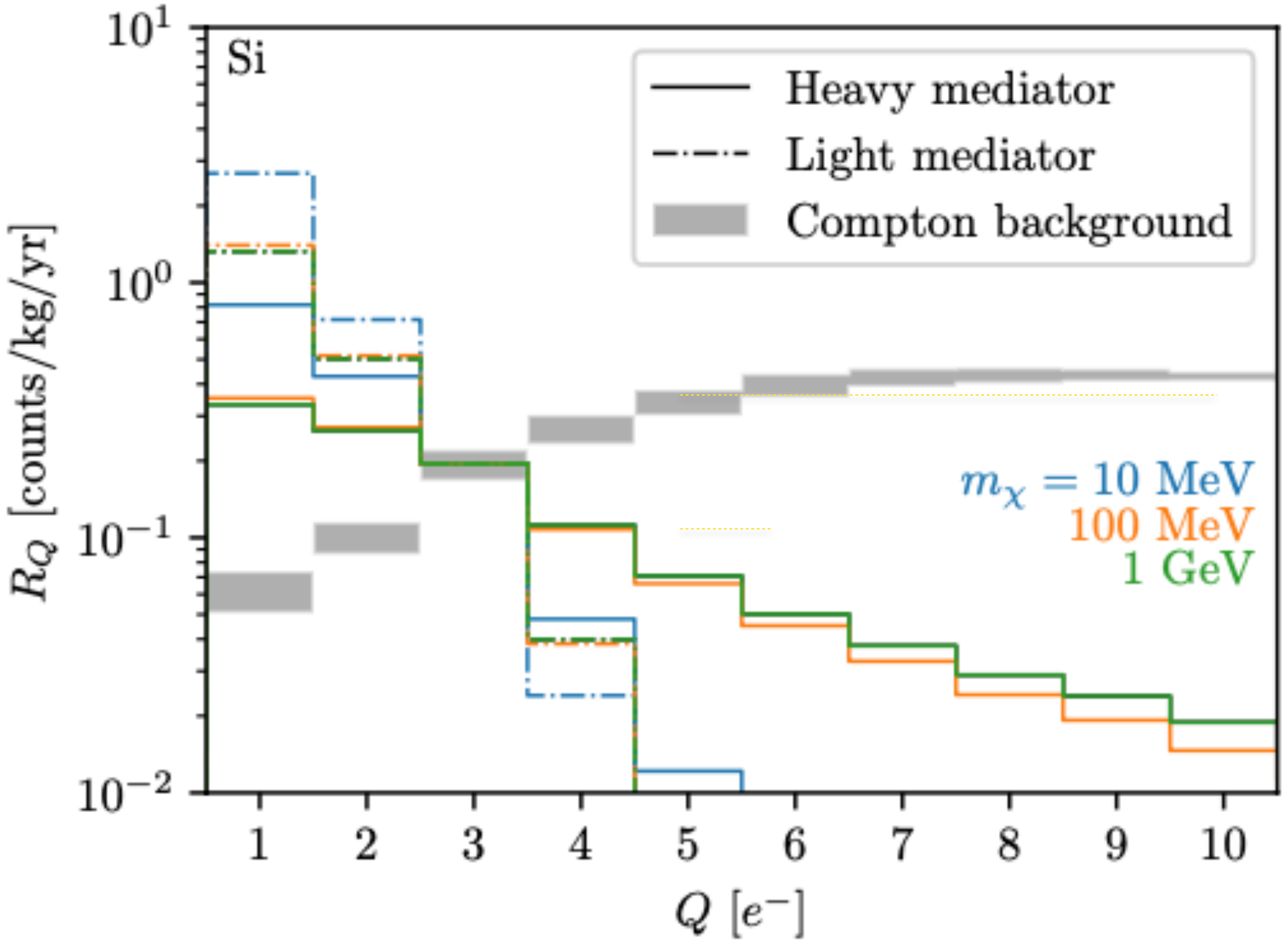


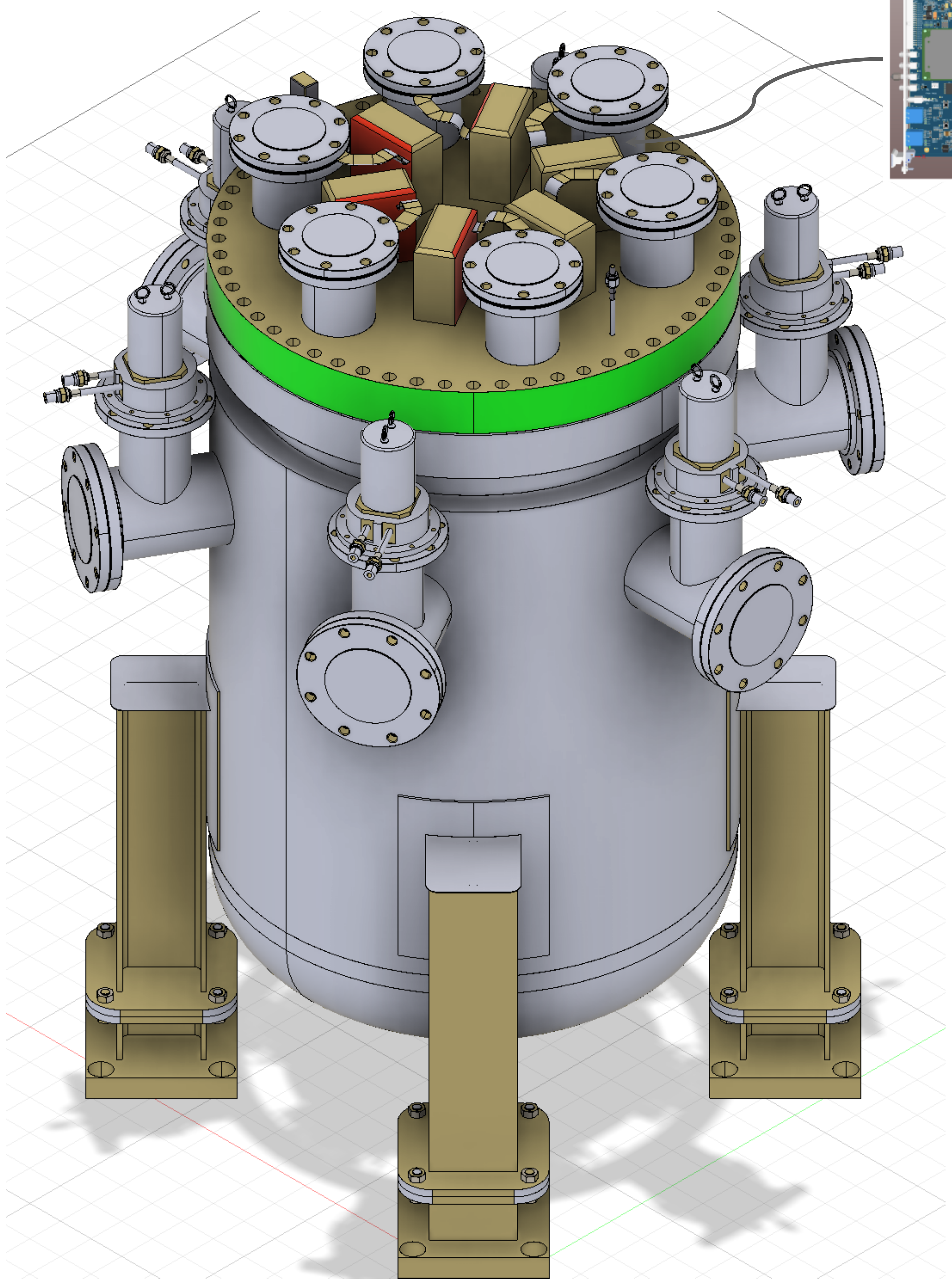
FIG. 3. **Rates as a function of charge for Si.** A comparison of the Compton scattering rates (*gray* bands) as a function of the charge ionized, Q, in a Si crystal with a background rate of 1 DRU at $\Delta E = 1$ keV using RIA. The lines show the DM–electron scattering rates computed with `QCDark` [28] for DM–electron cross-sections listed in Table II. We use the secondary ionization model at 100 K from Ref. [36].

Our forecasts assume flat background, but the Compton background dominating at low energies is not really flat. Ongoing effort to measure and model this background for skipper-CCDs show that a background at lower e-bins will benefit from this shape (x5 in 2e-bin).

R.Essig (SBU) et al arXiv: 2310:02316

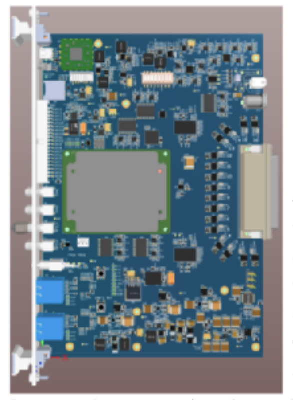
R&D done. Now get final design!

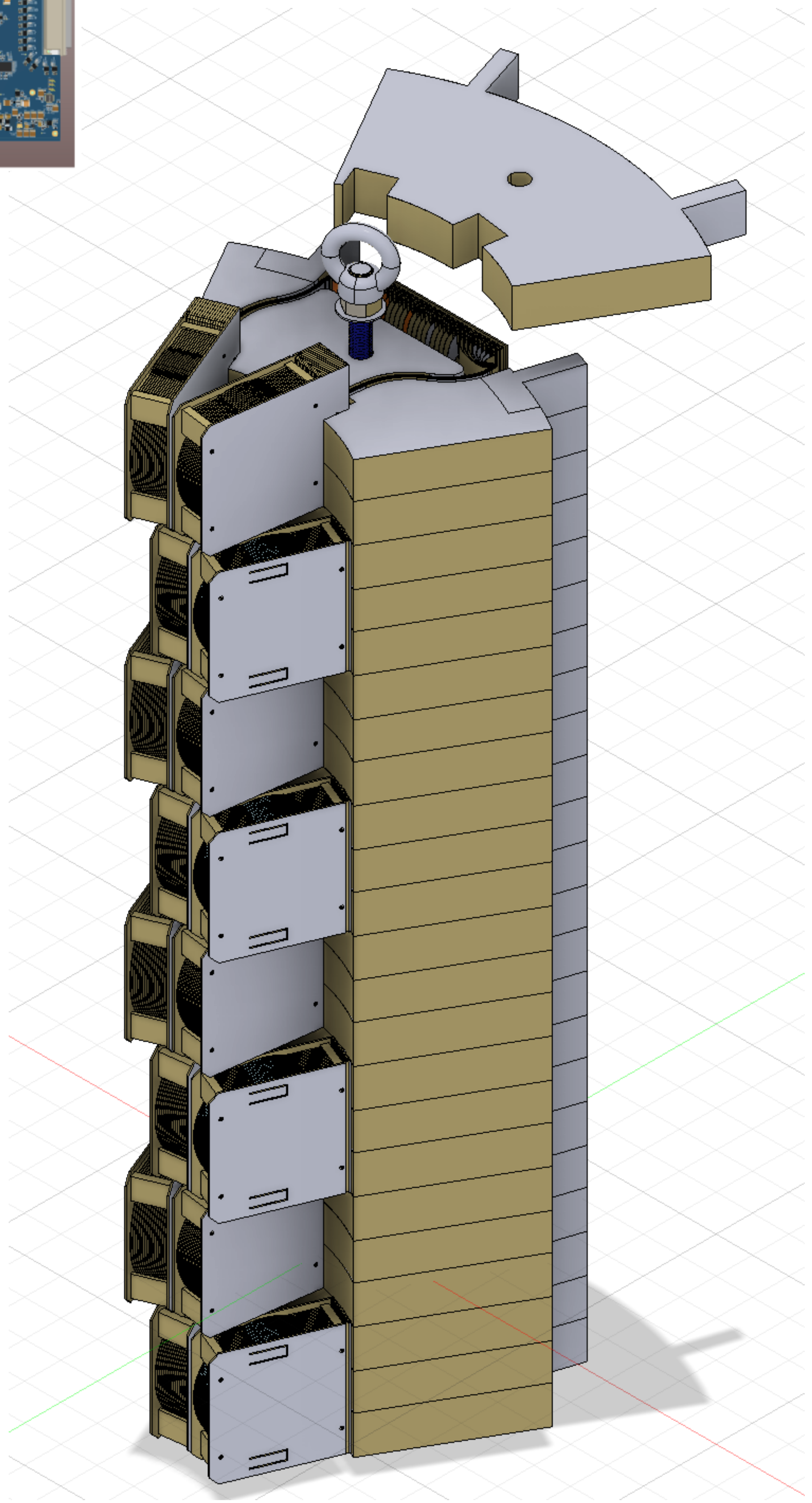
Some more details of the design



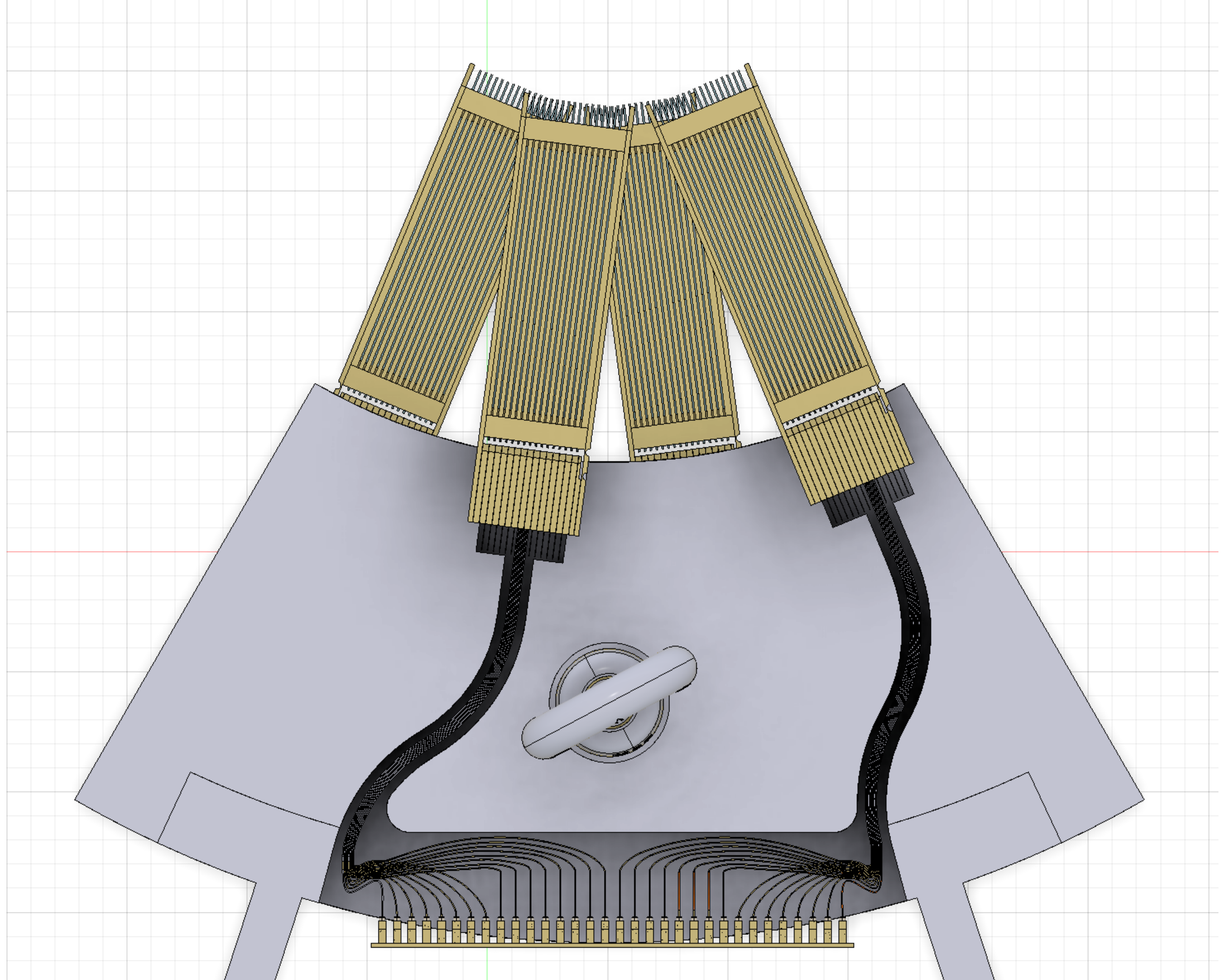
Vessel with mods to fit into cage and rail.

Slide of 16 SM with inner shield





We have a budgetary quote now…

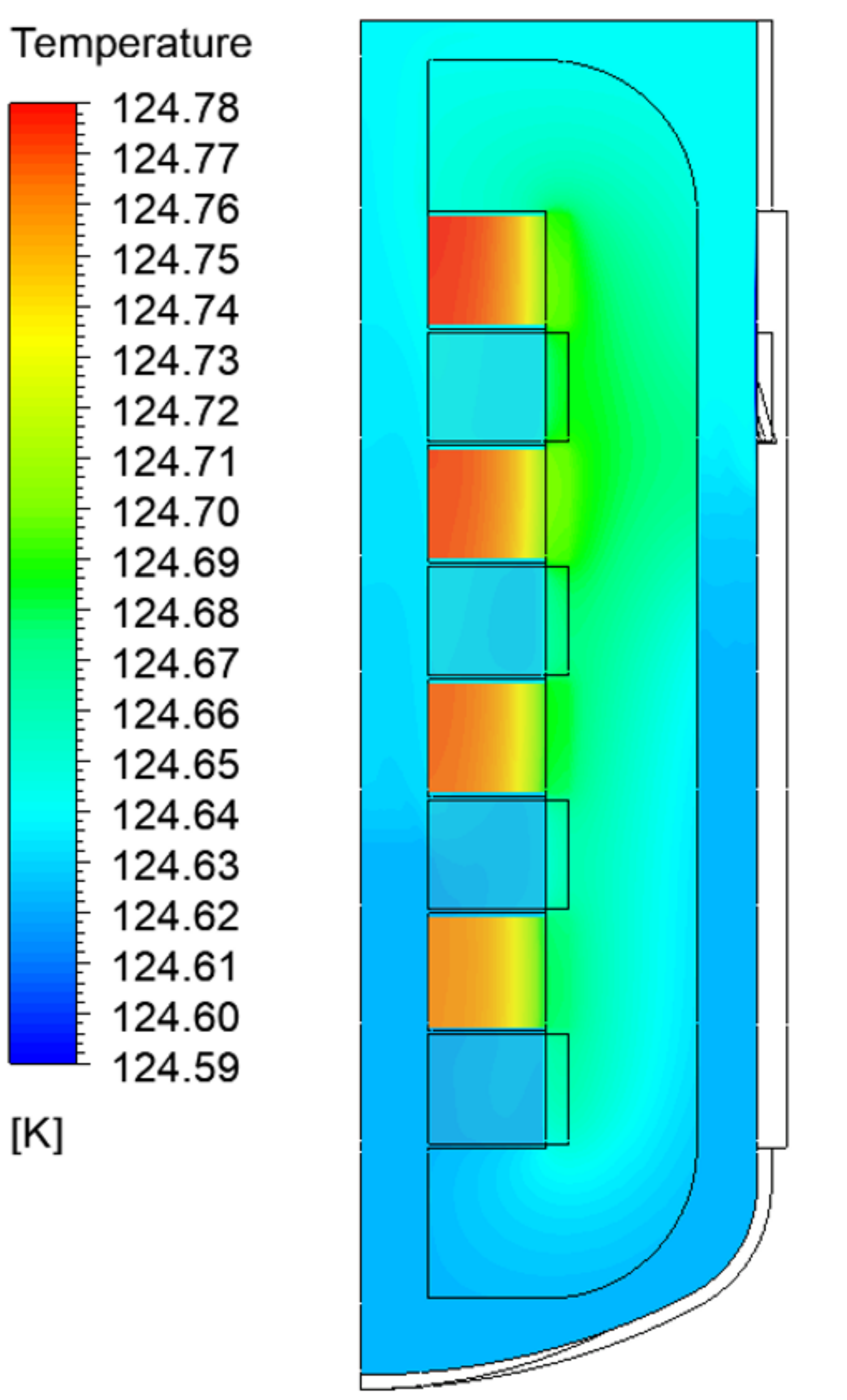


Preliminary proposed routing of flex cables including connectors.

26

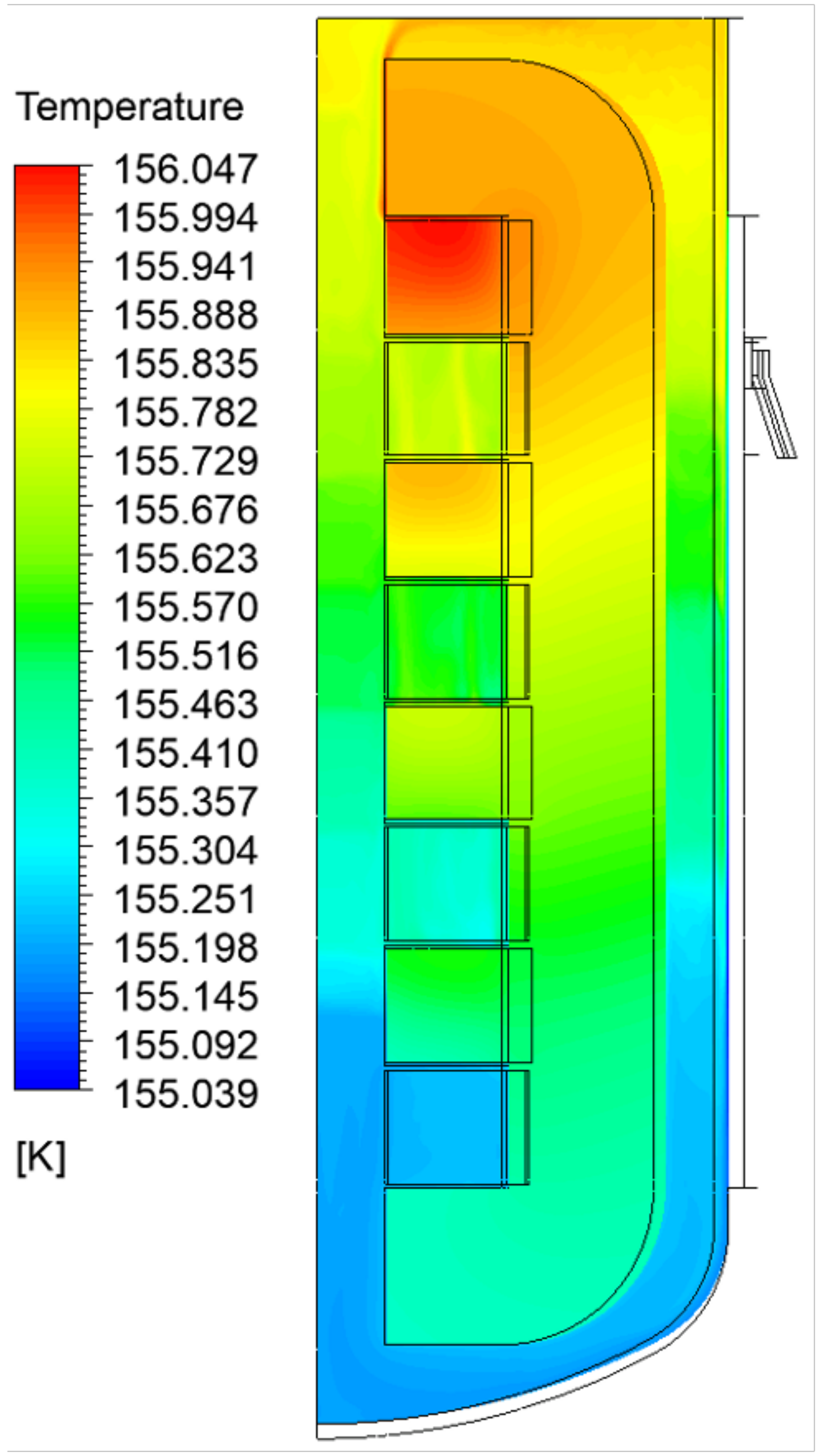
Pressure vessel fluid/thermal simulation

BEST (baseline)



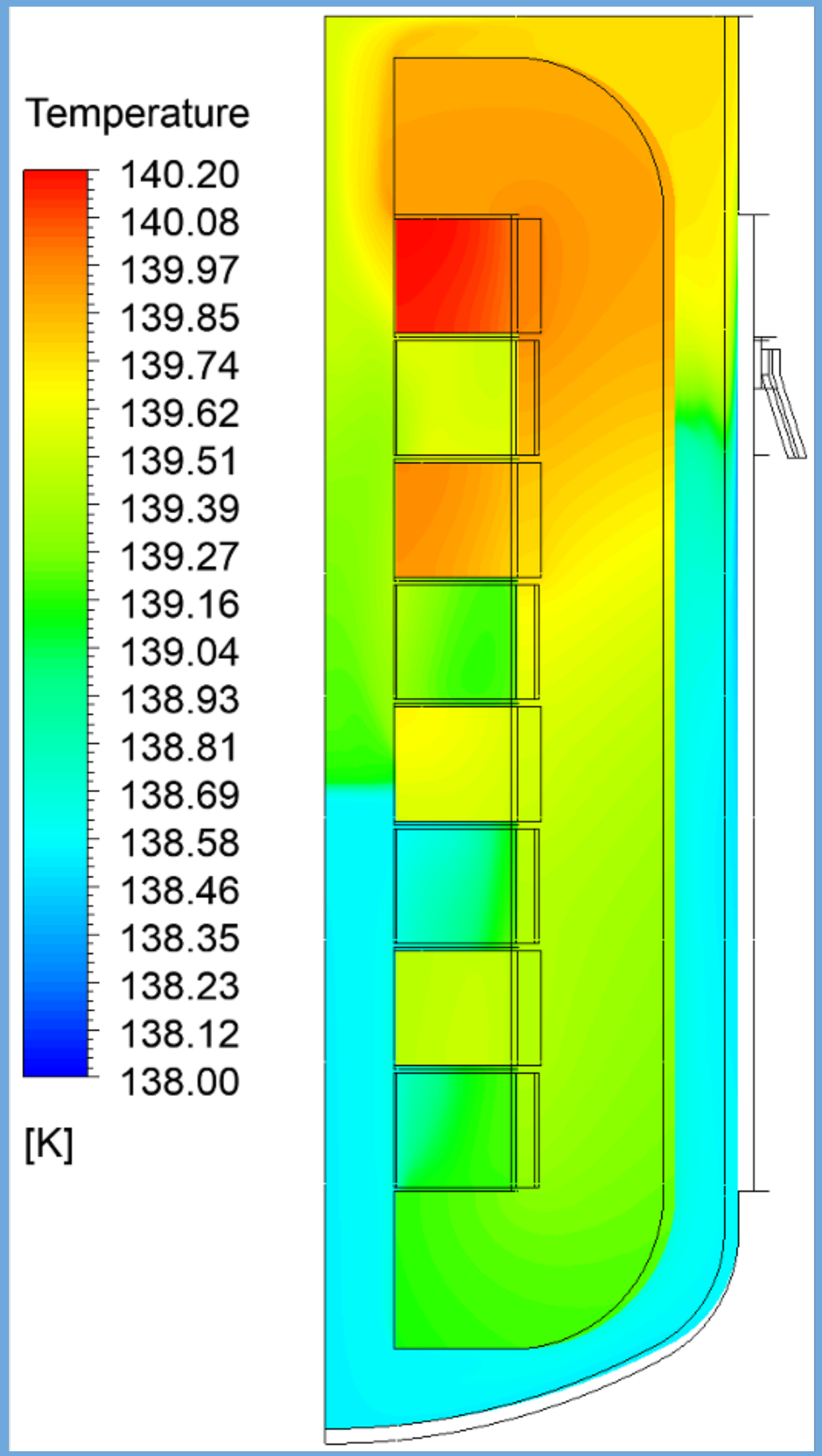
LN2@450 PSI

Too much backg.



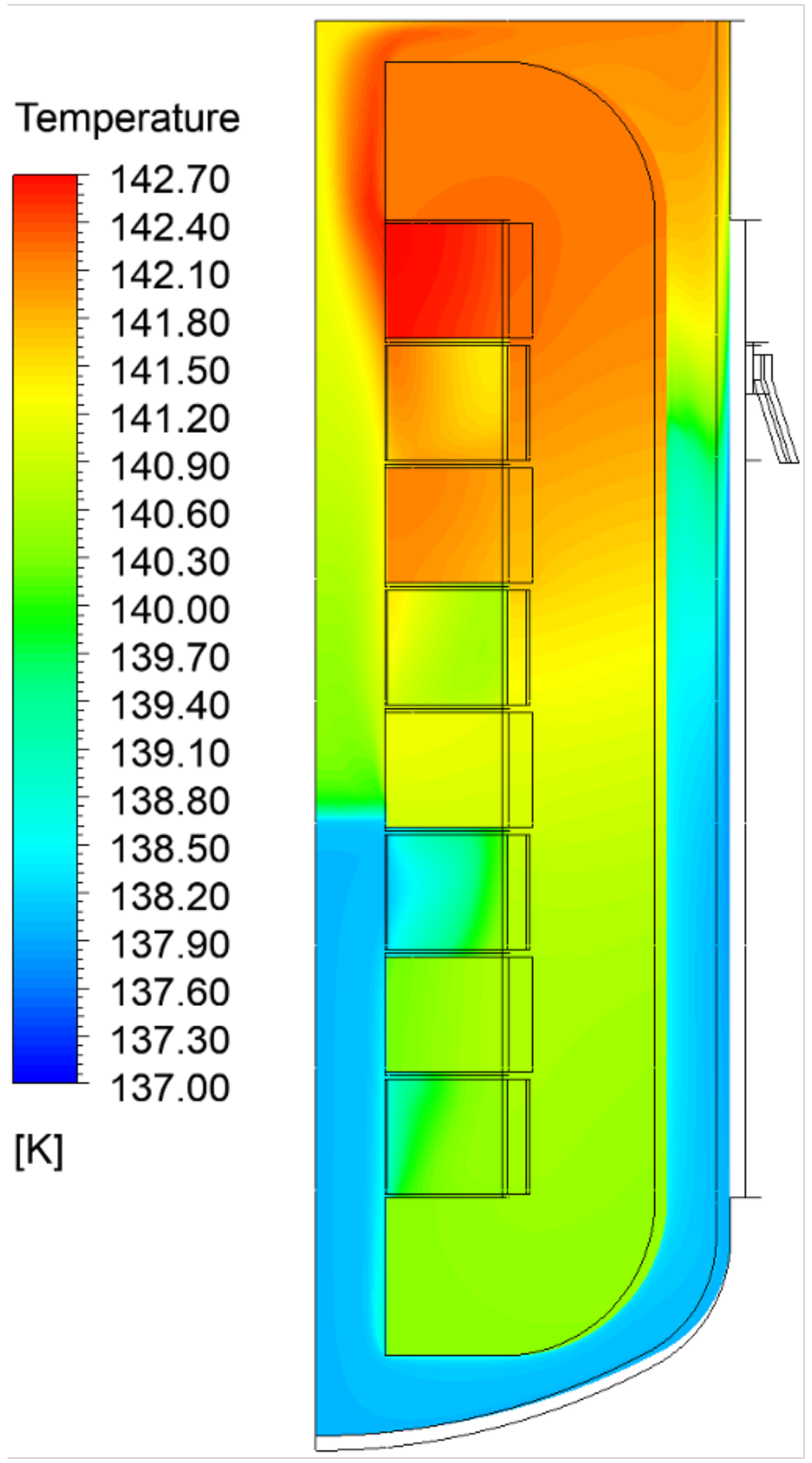
NOVEC 700

works (lower cost)



N2 gas 100 PSI

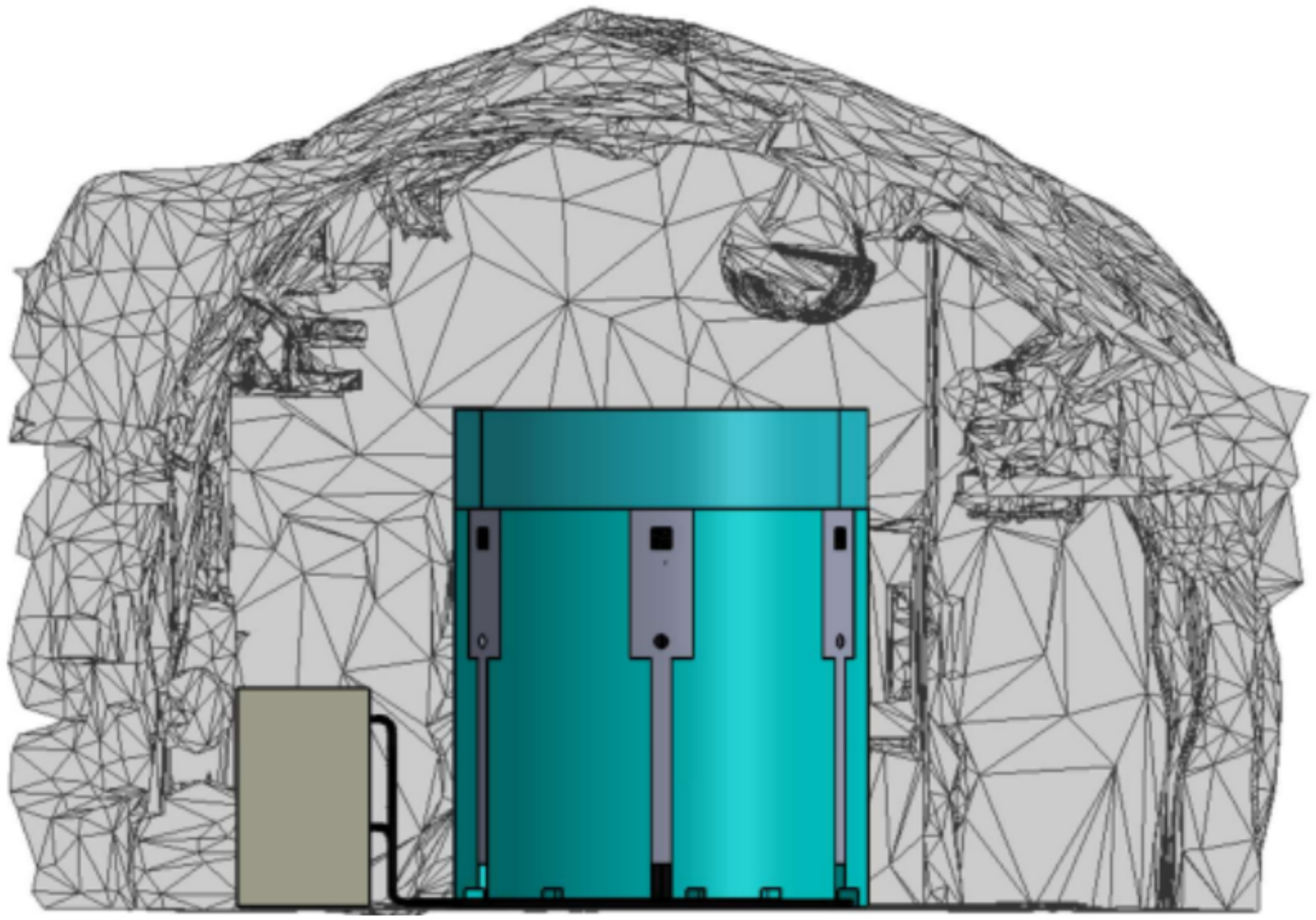
works (lower cost)



N2 gas 15 PSI

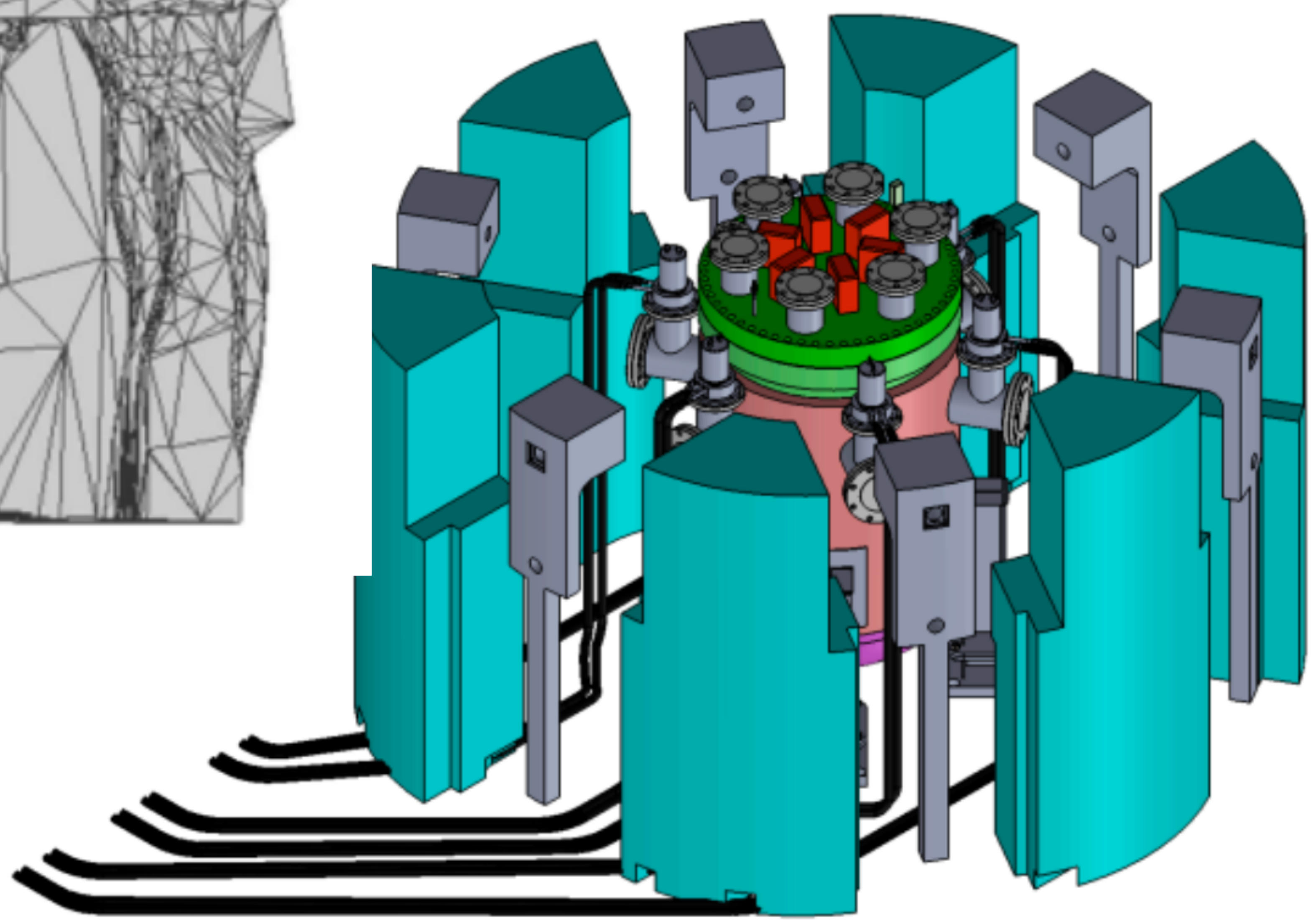
Pushing towards lower pressure

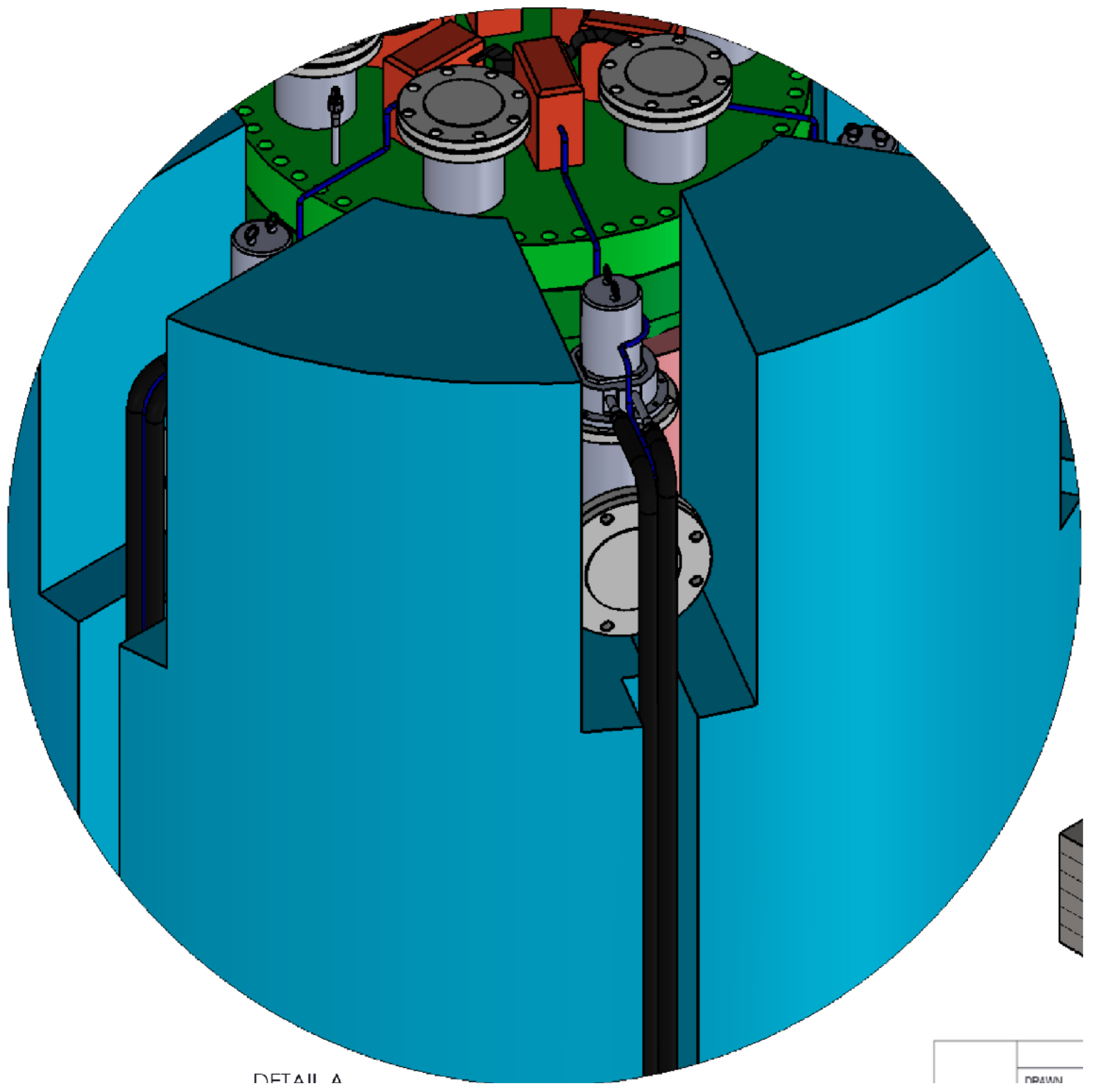
Design: outer shield and installation inside SNOLAB



In the SNOLAB drift

Outer shield assembly



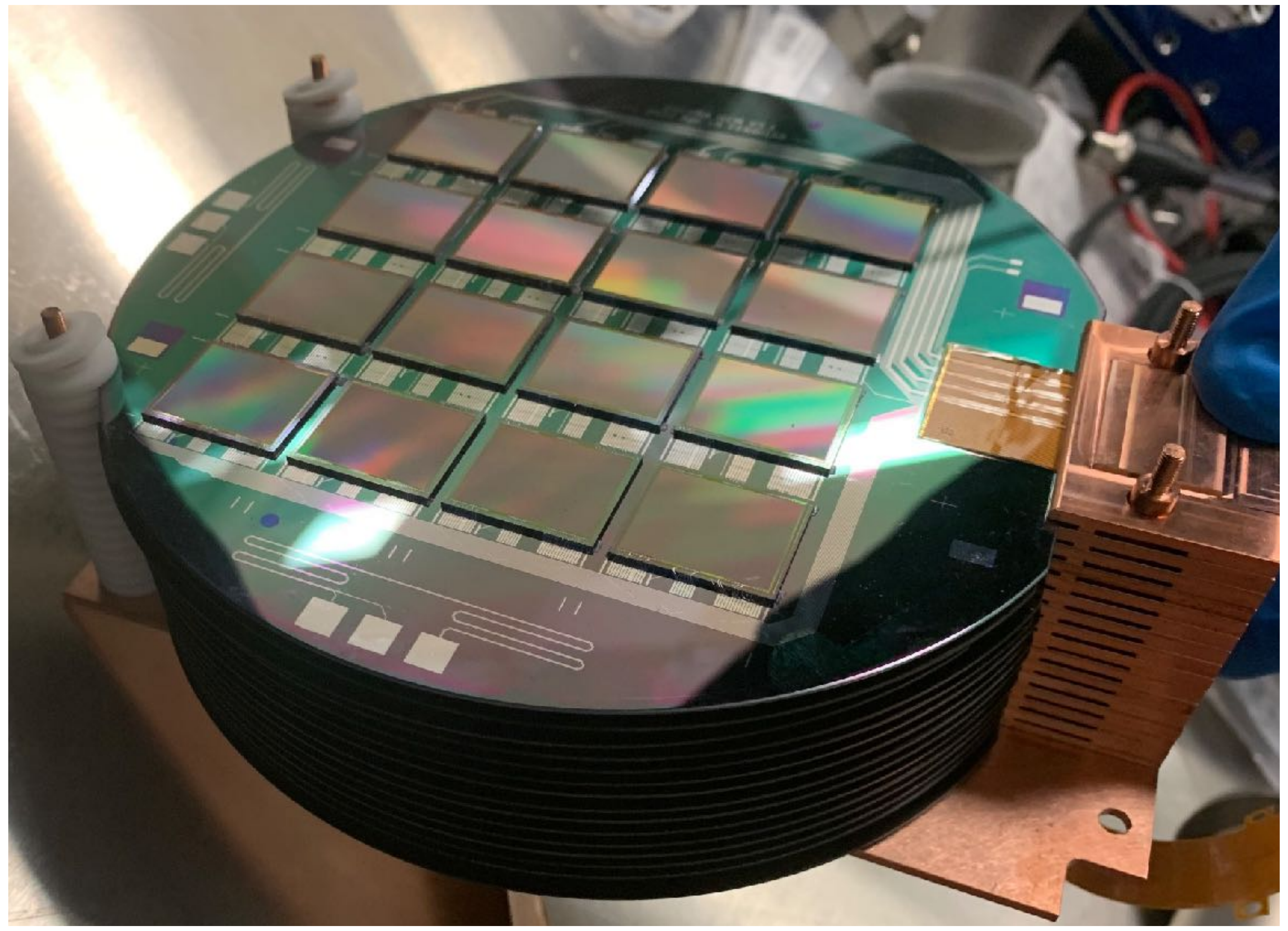


Detail of helium lines

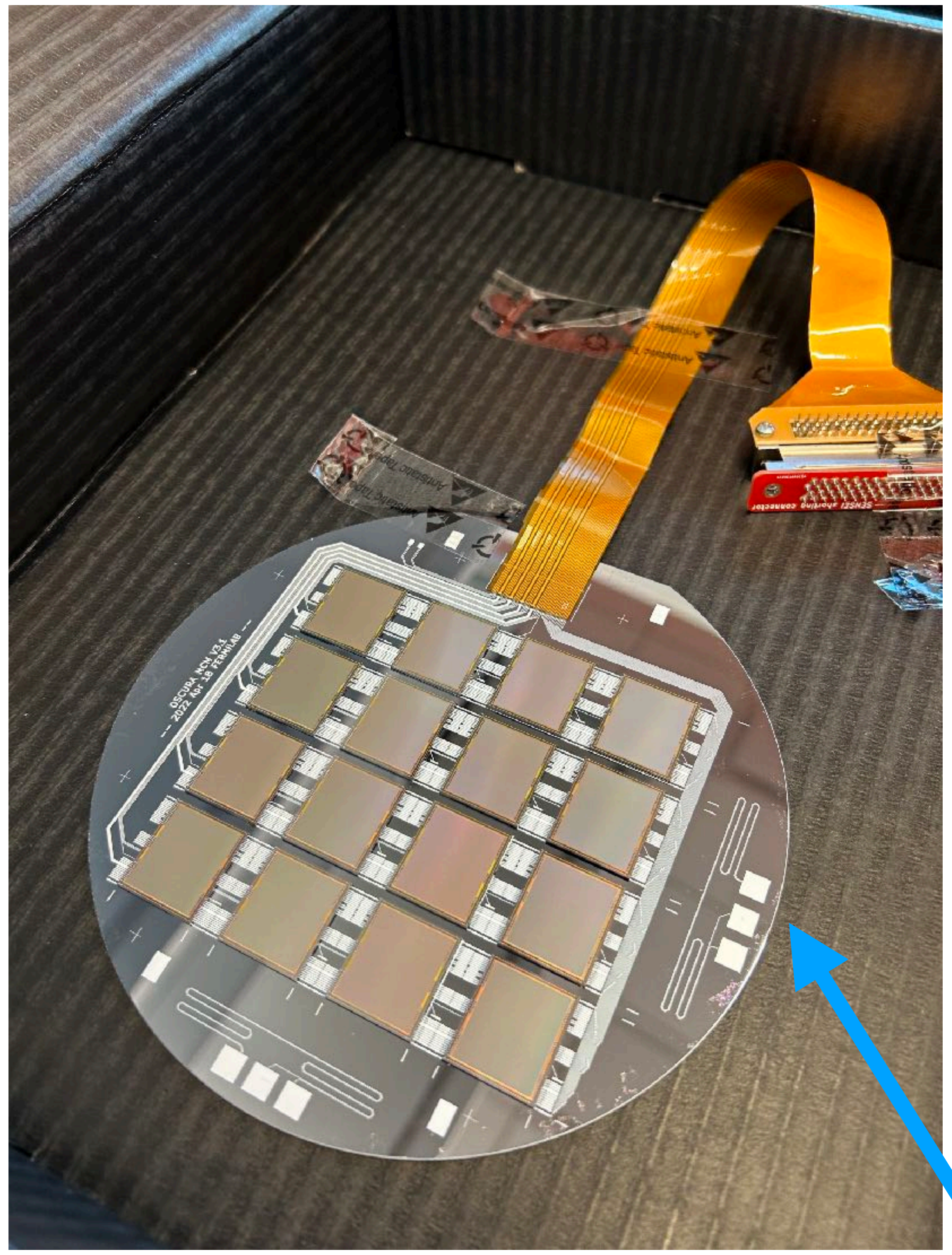
We know what do to, it is a matter of cost now…

10kg ~ $15M

Cost Drivers : MCM interconects

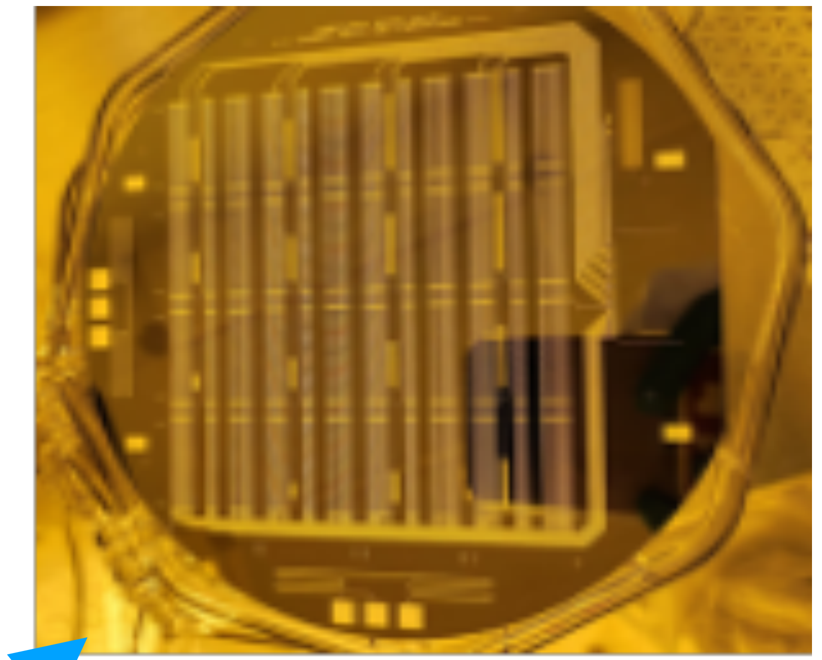


Need ~100 of these (Supermodule)



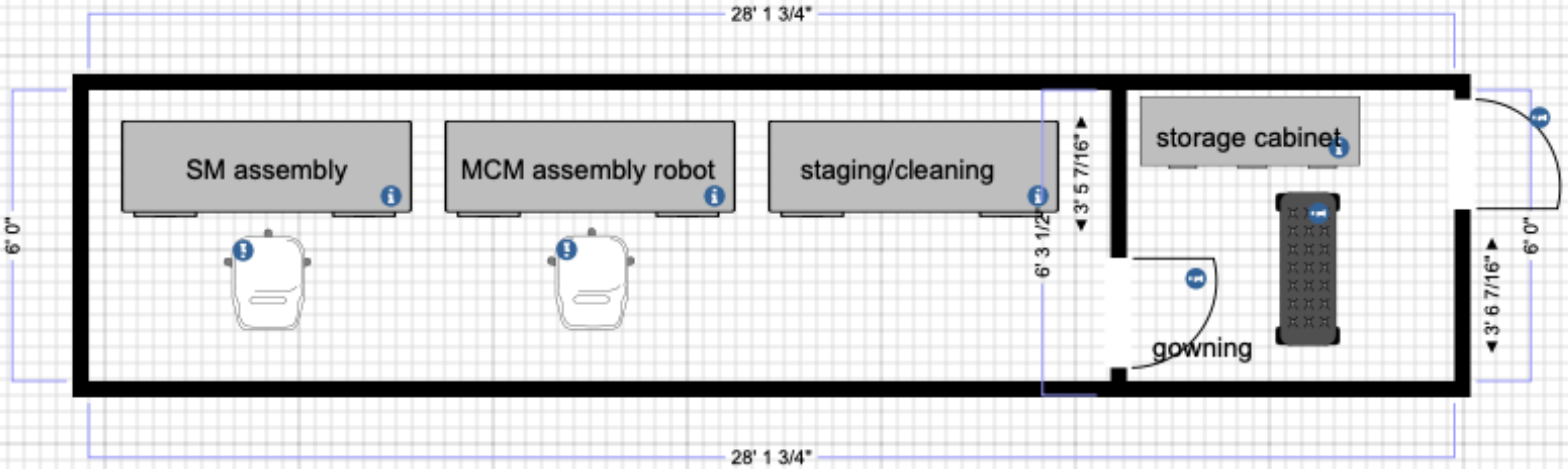
Need ~1600 of these (MCM)

High density cryogenic connectors



The MCM interconnects are expensive, but recently was able to find another vendor that could mean big savings ($1M).

Cost Drivers : MCM factory
(clean room with no cosmics, sounds familiar?)



There is a balance here between **buying new ideal equipment** vs **building facility** and using less expensive equipment…

MCM Assembly Robot

Micro-bonding

Estimated Uncertainty

Still need final design.

We have quotes for most things:
Sensors, connectors, Si circuits, electronics, packaging robot.

	10kg	Uncertainty %	EU
123.2 Project Controls	$174,154.22	0.1	$17,415.42
123.3.10 Sensor Production	$2,235,000.00	0.2	$447,000.00
123.3.9 Sensor Packaging	$2,624,720.74	0.2	$524,944.15
123.3.8 Readout Electronics	$2,664,342.91	0.25	$666,085.73
123.3.7 Data Aquisition System	$50,000.00	0.3	$15,000.00
123.3.6 Cryostat	$768,764.04	0.4	$307,505.62
123.3.11 Sensor Testing	$39,025.98	0.5	$19,512.99
123.3.5 Background Control	$200,000.00	0.3	$60,000.00
123.3.3 Shielding	$1,500,000.00	0.3	$450,000.00
123.3.2 Installation Planning	$93,739.90	0.3	$28,121.97
Total	$10,349,747.79		$2,535,585.87

OSCURA Risk Register

- OSCURA risks have been identified, analyzed and documented in the risk register in the Fermilab-standard format. Risk data were recently reviewed and updated by the project.
- Risks are being actively managed; four significant risks have already been closed:

Risk Register data																	
Risk ID	**Risk Title**	**Risk Summary**	**Risk Type**	**Risk Owner**	**Risk Status (6/2022)**	**Risk Mitigations**	**Risk Responses**	**Conditions for closing risk**	**Probability**	**Technical Impact**	**Cost Impact - Min (k$)**	**Cost Impact - Likely (k$)**	**Cost Impact - Max (k$)**	**Schedule Impact - Min (months)**	**Schedule Impact - Likely (months)**	**Schedule Impact - Max (months)**	**Explanation of Estimate**
Osc-risk-001	Microchip R&D sensors not adequate for Oscura.	If the Microchip CCDs do not meet Oscura needs THEN we cannot start construction of Oscura.	Threat	Steve Holland	Closed	The process control monitoring (PCM) test structures tested at LBNL.R&D sensors a to be ttested in 2021. Pre-production run is planned for 2023.	If risk occurs then we will need to have another design and fabrication cycle	This risk can be closed after the evaluation of the prototype sensors during 2021.	30%	High	150	200	300	4	7	12	Microhip CCD worked on the first fabrication run. Some optimization is till going on. **(REDUCED with respect to 2021)**
Osc-risk-003	Cost of readout for Oscura	IF we cannot design an affordable 24,000 channels readout system THEN cannot start construction of Oscura.	Threat	Juan Estrada	Closed	Tested in 2021 a discrete low cost solution for the front end.	If risk occurs more electronics R&D would be needed, or the electronics cost becomes very high	This has been retired during 2021.	0%	High	3000	4000	5000	4	6	12	This risk has been retired with the CDS tests done early 2021.
Osc-risk-004	ASIC readout meets noise requirements	IF ASIC demonstrates the noise performance needed for Oscura THEN front end electronics becomes less expensive, and lower background	Opportunity	Juan Estrada	Closed	MIDNA CCD demonstrated in 2022.	If risk occurs we will consider using ASIC in the front end electronics.	This risk will be closed when the readout decision is done (2/2022)	100%	High	-100	-300	-450	0	0	0	**The results indicate the MIDNA works, and we were able to reduce the cost of the experiment significantly (~$1M).**
Osc-risk-007	No agreement with SNOLAB	IF agreement with SNOLAB is not done THEN need to find new underground location.	Threat	Paul Grylls	Closed	Started conversations with SNOLAB at R&D phase. First step GW0 done. Now	If the risk occurs we have to look for other underground labs (Modane, SURF, other)	The risk will be closed when GW1 is reach with SNOLAB.	10%	High	300	1000	1500	4	12	24	**Oscura is now a SNOLAB project (GW0) and regular meetings are schedule to plan infrastructure and installation.**

MC model results: **Cost contingency**

- MC model aggregates stochastic risk costs
  - **Direct risk costs** (triangle impact functions)
  - **Burn rate costs** of (triangular) delays

    = $44k / month x stochastic delay
  - Note: *risk opportunties save money*

- Risk cost = $ 697k   (mean)
- Risk cost = $2,172k   (at 90% CL)

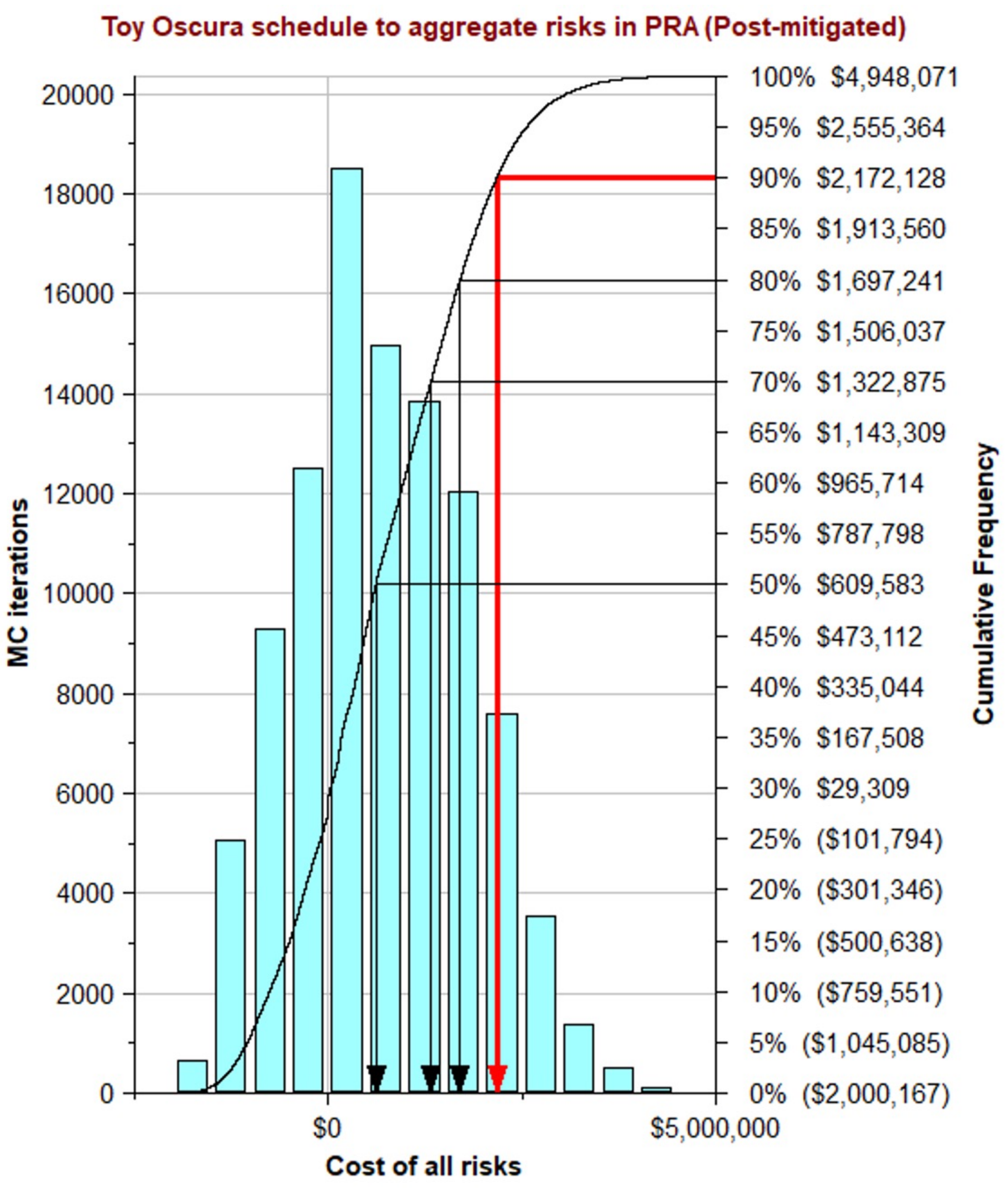
- Total cost contingency = $4.7M

  = $2.5M Estimate Uncertainty + $2.2M risk

  This is 47% or the $10M total base cost

  ~ 40% is typical for Fermilab projects

- Burn rate cost contribution will decrease if the schedule risk impacts are reduced



Analysis	
Iterations:	100000
Statistics	
Minimum:	($2,000,167)
Maximum:	$4,948,071
Mean:	$696,867
Bar Width:	$500,000
Highlighters	
50%	$609,583
70%	$1,322,875
80%	$1,697,241
90%	$2,172,128

Estimated Uncertainty

	10kg	Uncertainty %	EU
123.2 Project Controls	$174,154.22	0.1	$17,415.42
123.3.10 Sensor Production	$2,235,000.00	0.2	$447,000.00
123.3.9 Sensor Packaging	$2,624,720.74	0.2	$524,944.15
123.3.8 Readout Electronics	$2,664,342.91	0.25	$666,085.73
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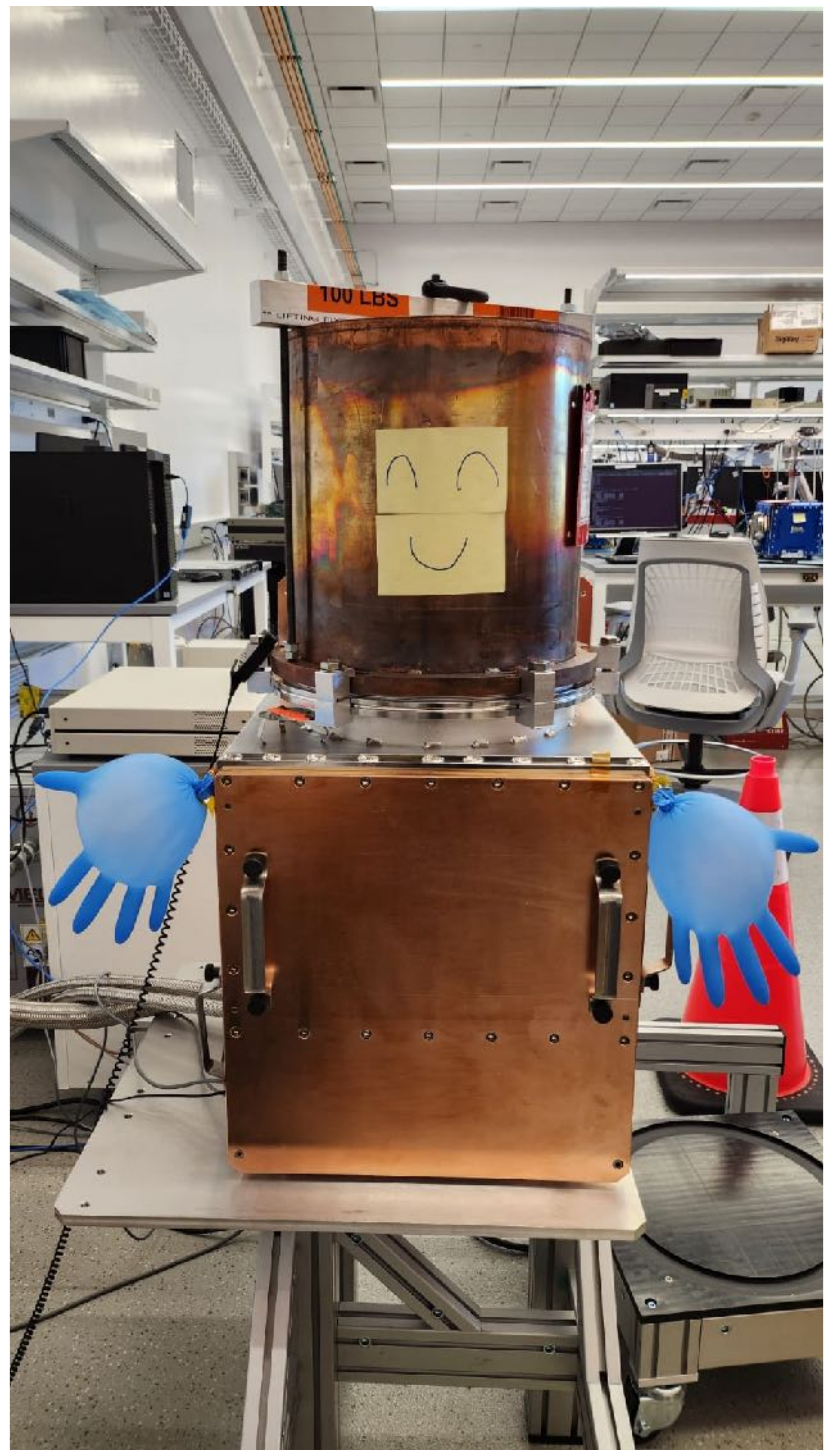
123.3.3 Shielding	$1,500,000.00	0.3	$450,000.00
123.3.2 Installation Planning	$93,739.90	0.3	$28,121.97
Total	$10,349,747.79		$2,535,585.87

Risk = $2.2M

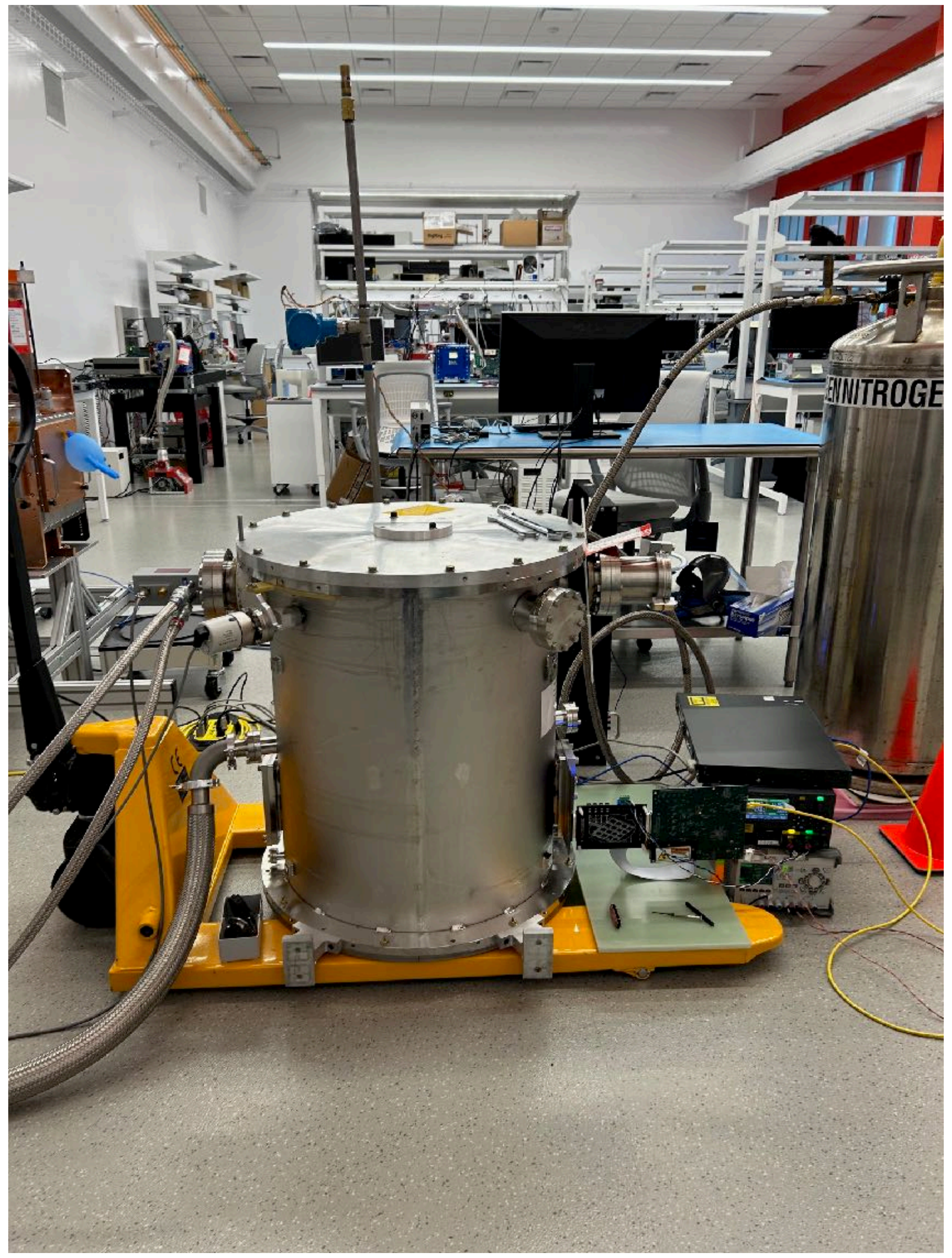
Total contingency (EU+Risk) = $4.7M

Oscura testing vessels at FNAL

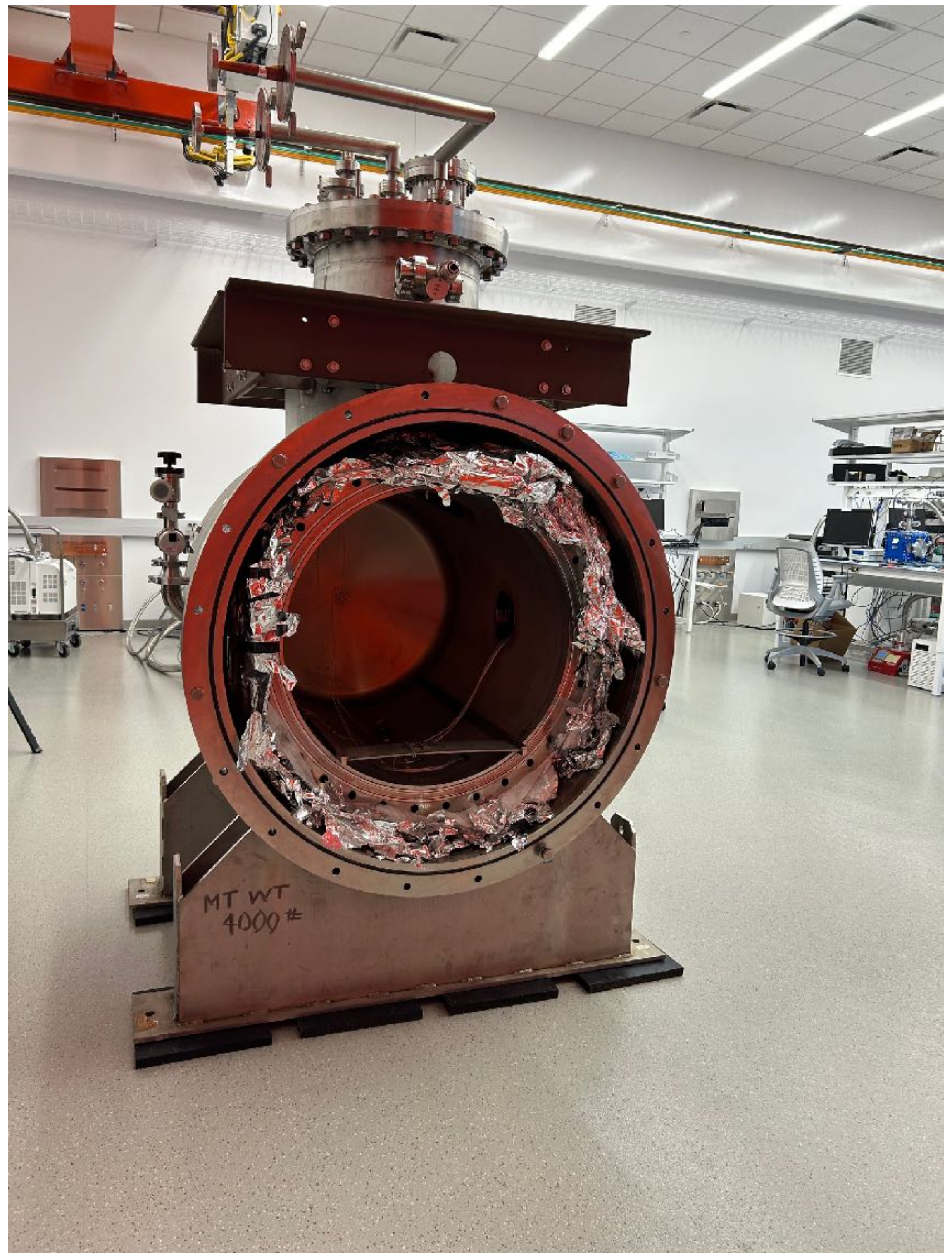
Moskita
Single Detector test at
MINOS to measure DC.



SENSEI Copy
(AKA : Dark Beats)
~160 CCDs (10 MCMs)
in vacuum. Electronics
test. Future beam
experiments.

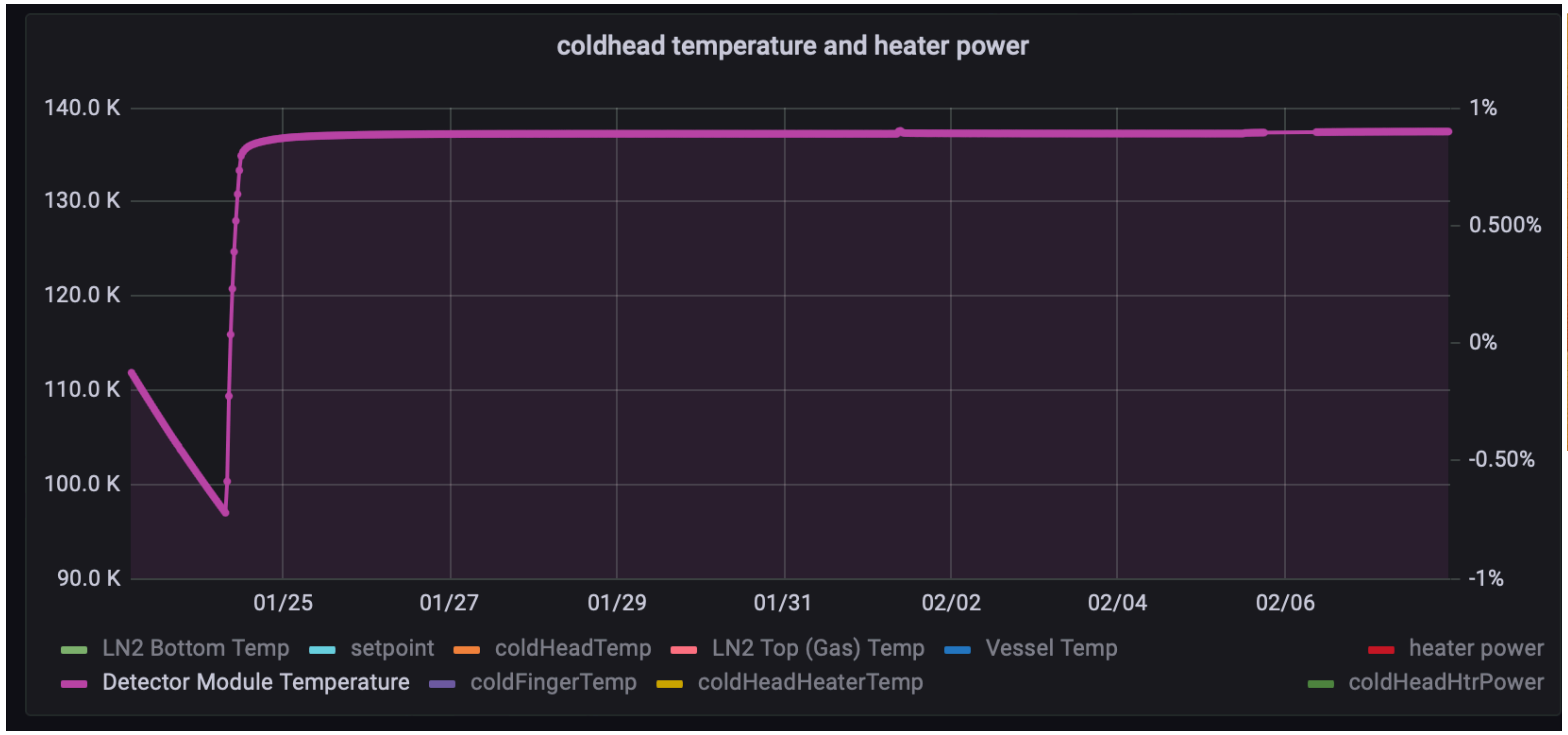


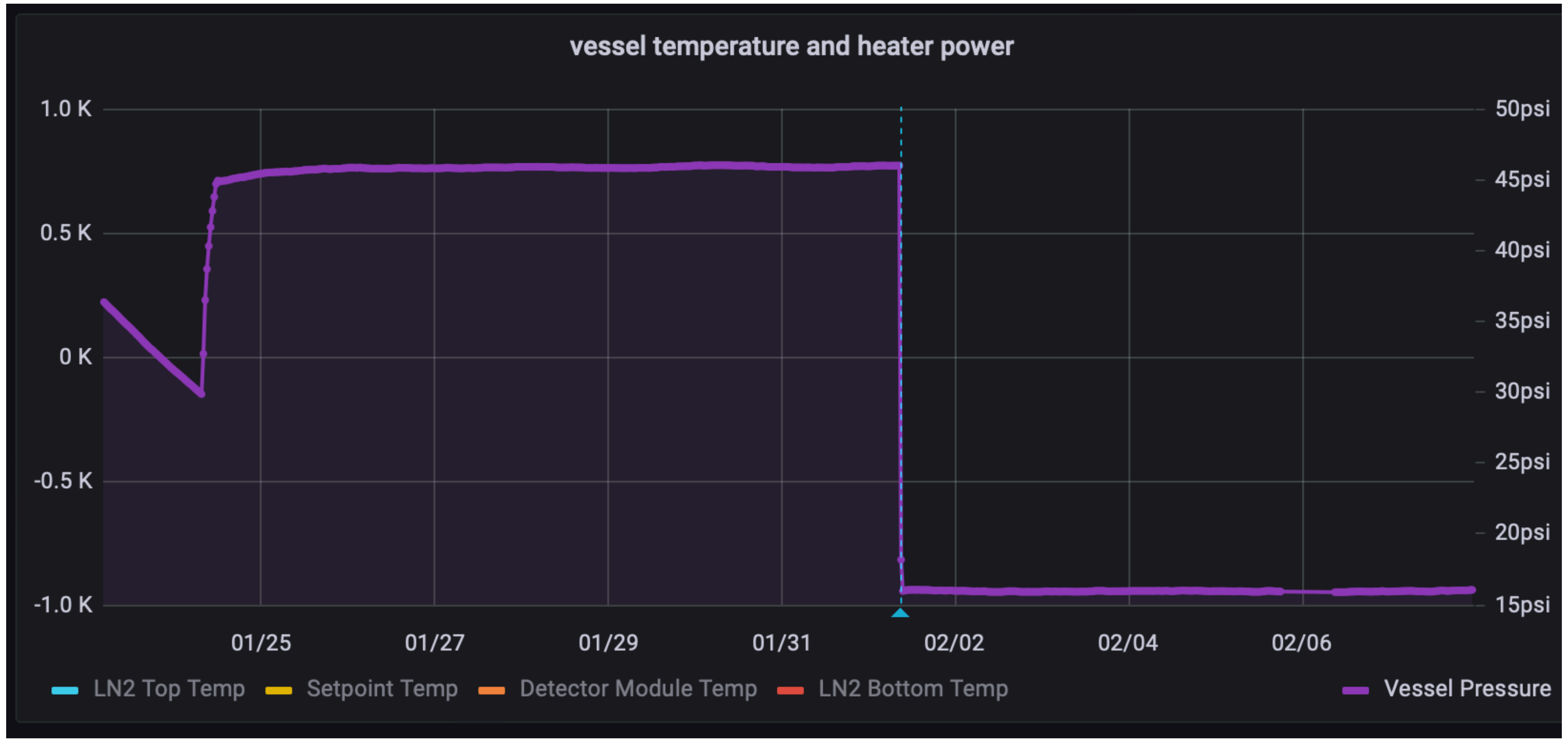
3 MCMs operating in nitrogen
gas (15 PSI). This is a test of the
MIDNAs + operations in gas.
Can have up to ~200 CCDs

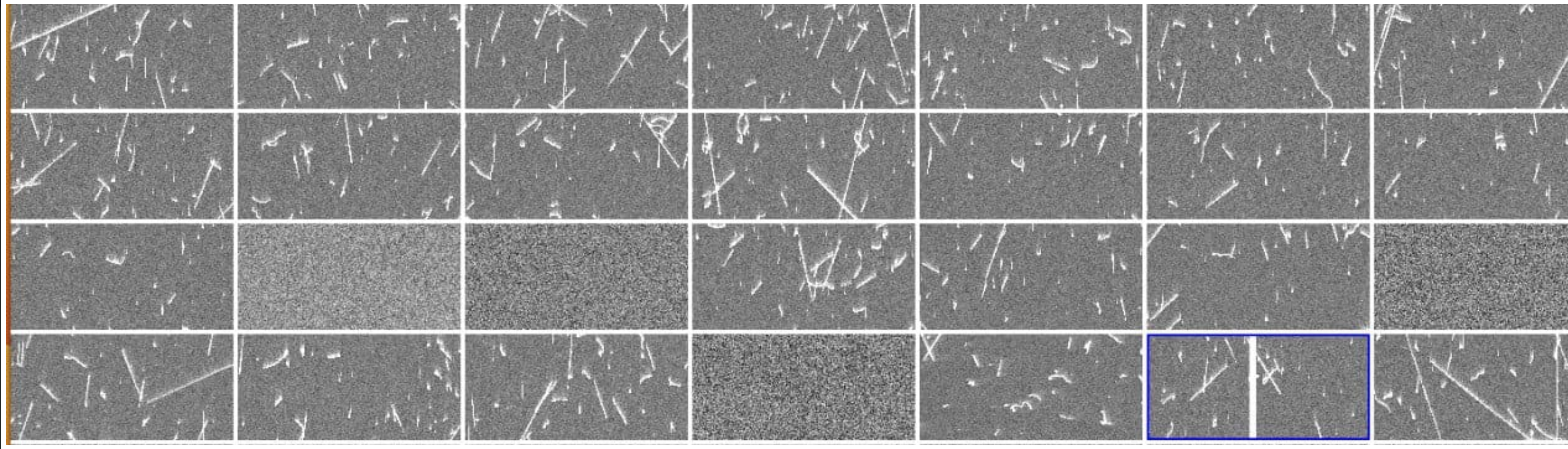


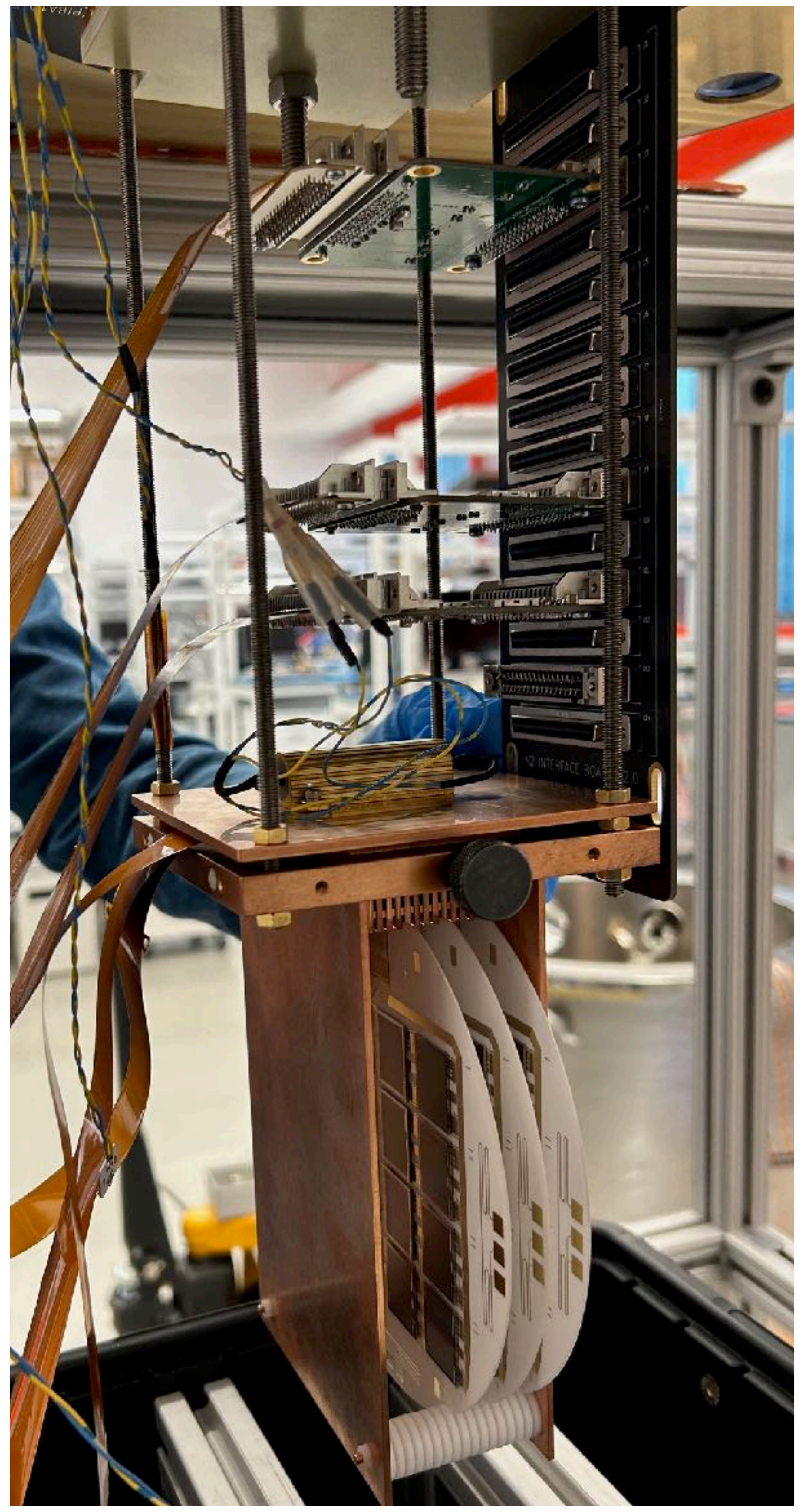
Future integration test (~1kg)
Lower background and to be use
to test SM before installation.
(Up to 1500 CCDs)

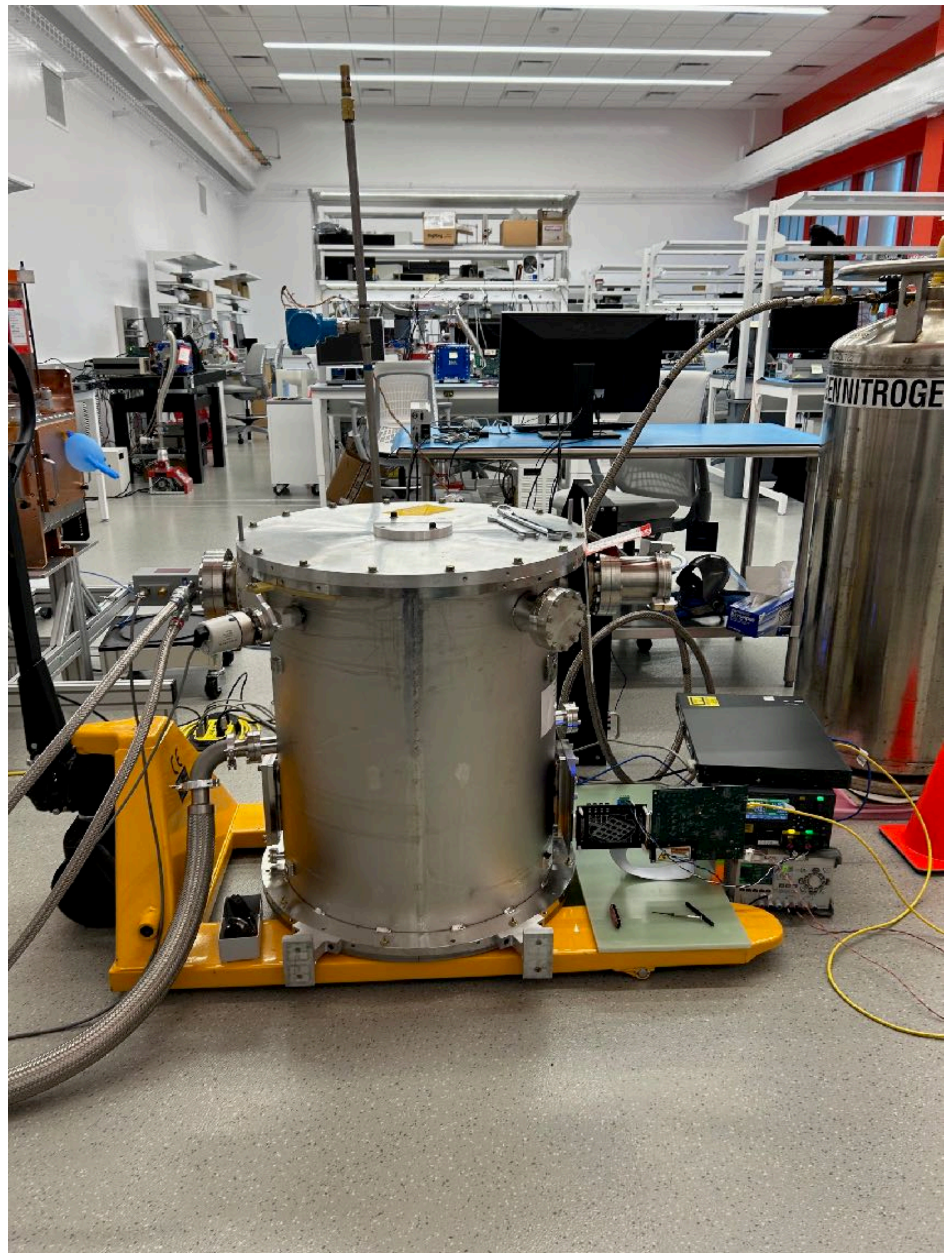
Low pressure (15 psi) operations of 3 MCMs



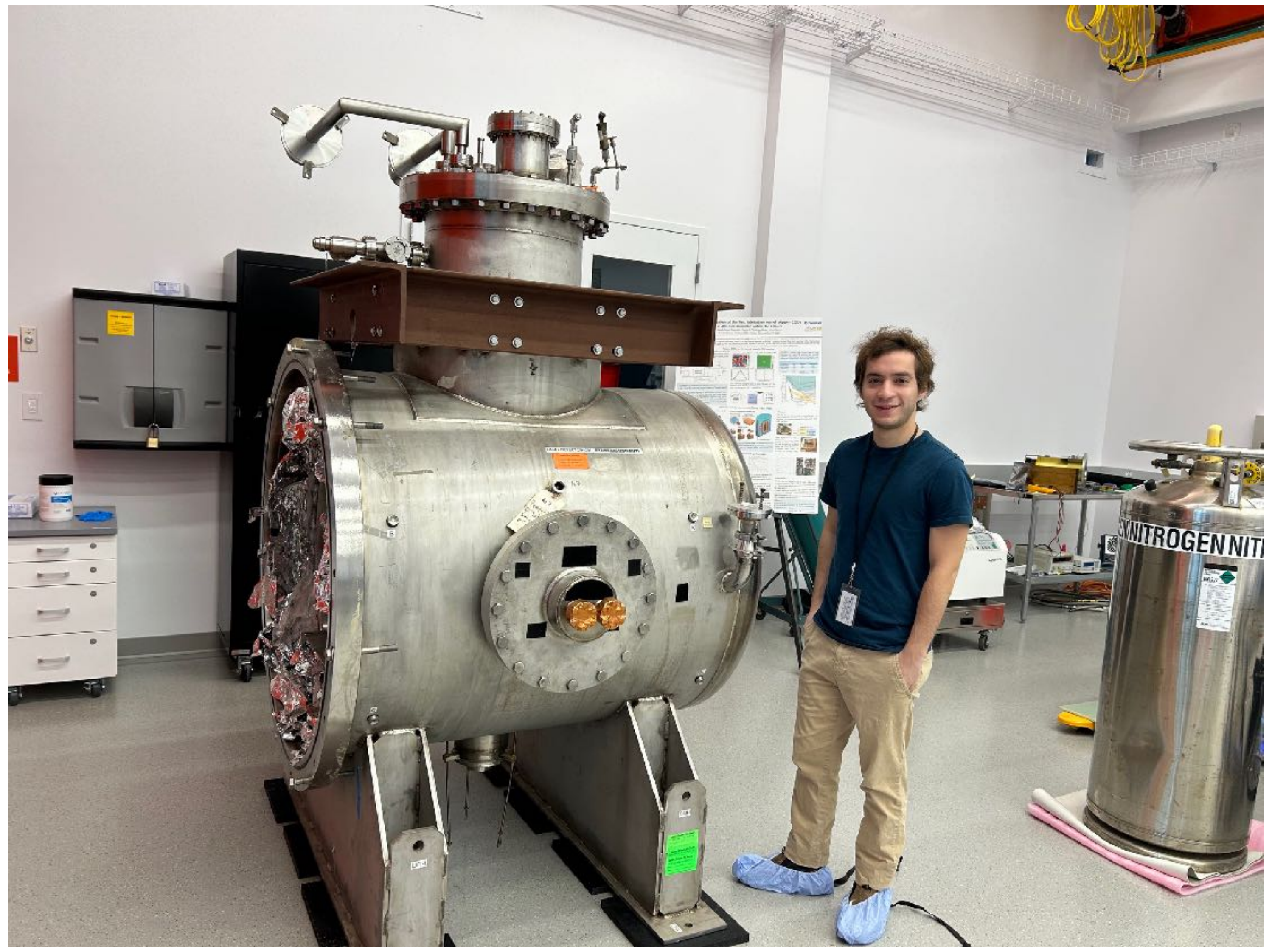


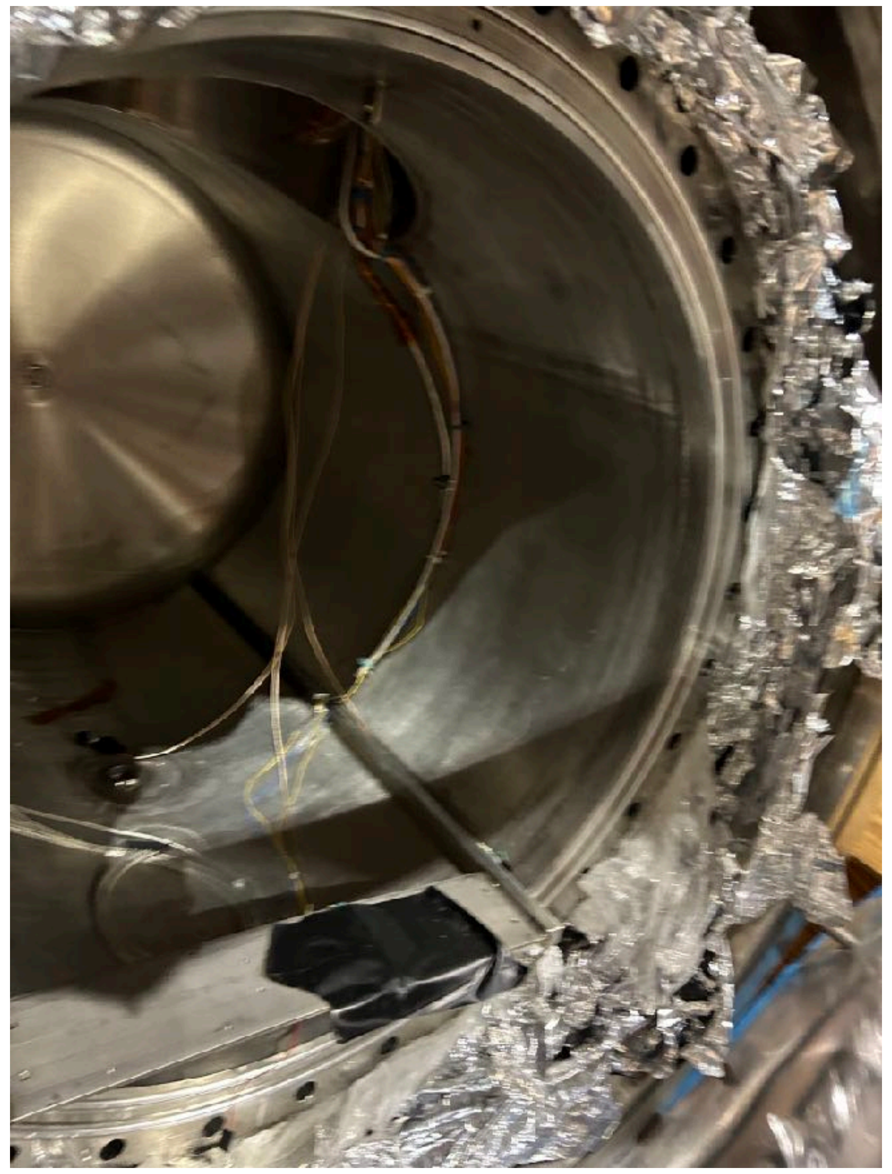






Getting ready for the 6 SM (1,500 CCD test)

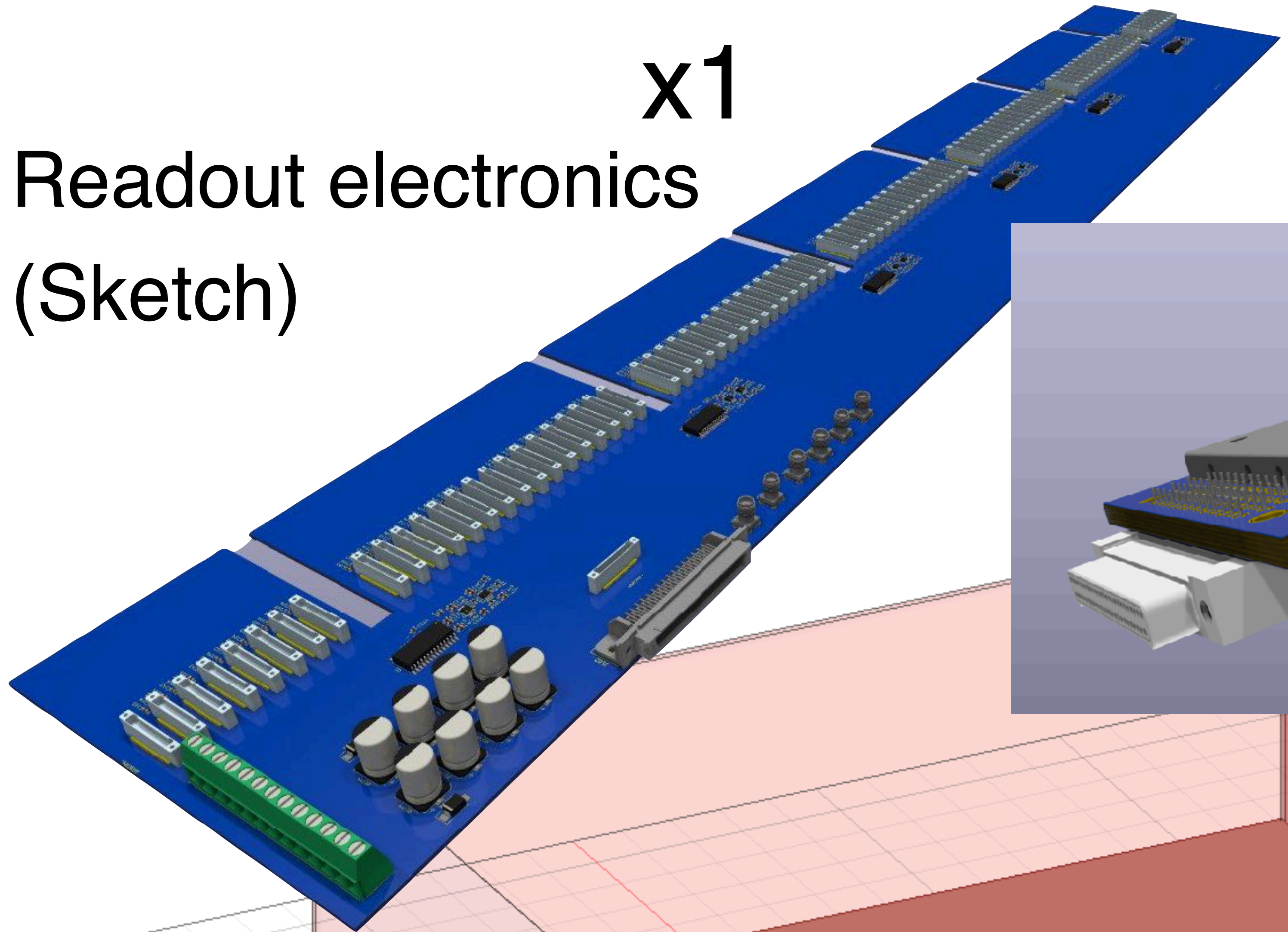




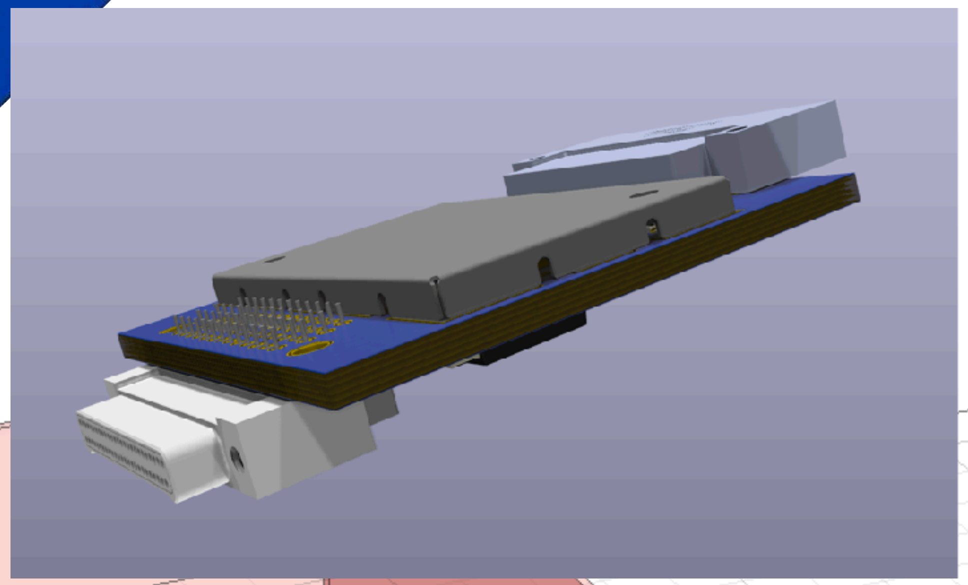
x1

Readout electronics

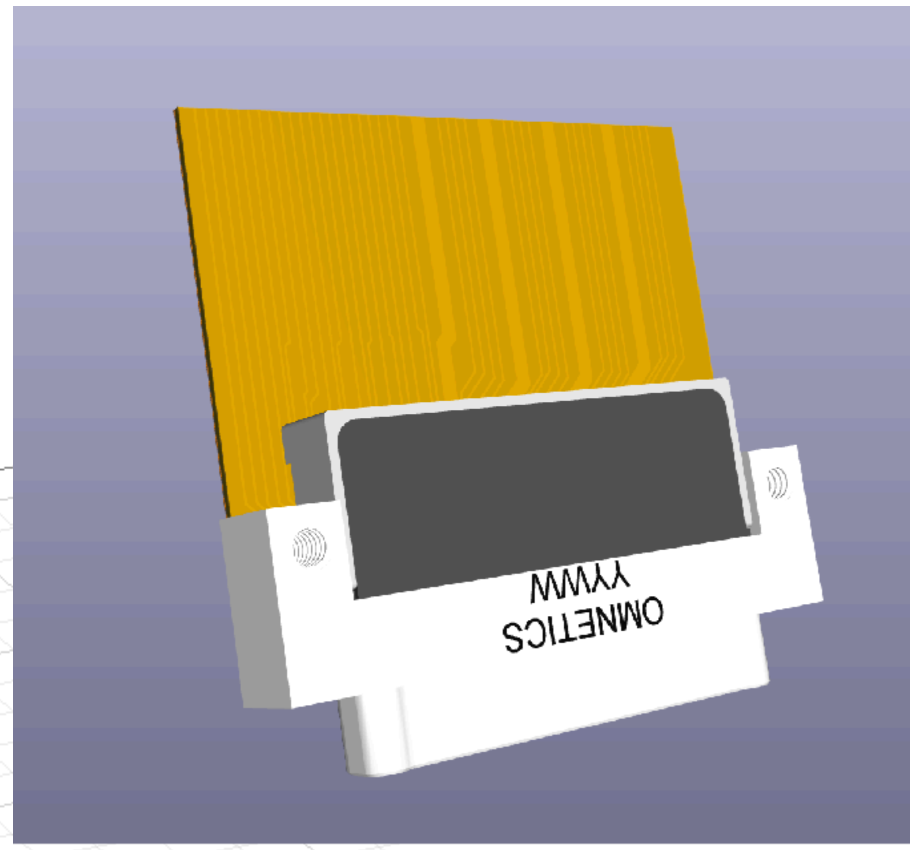
(Sketch)

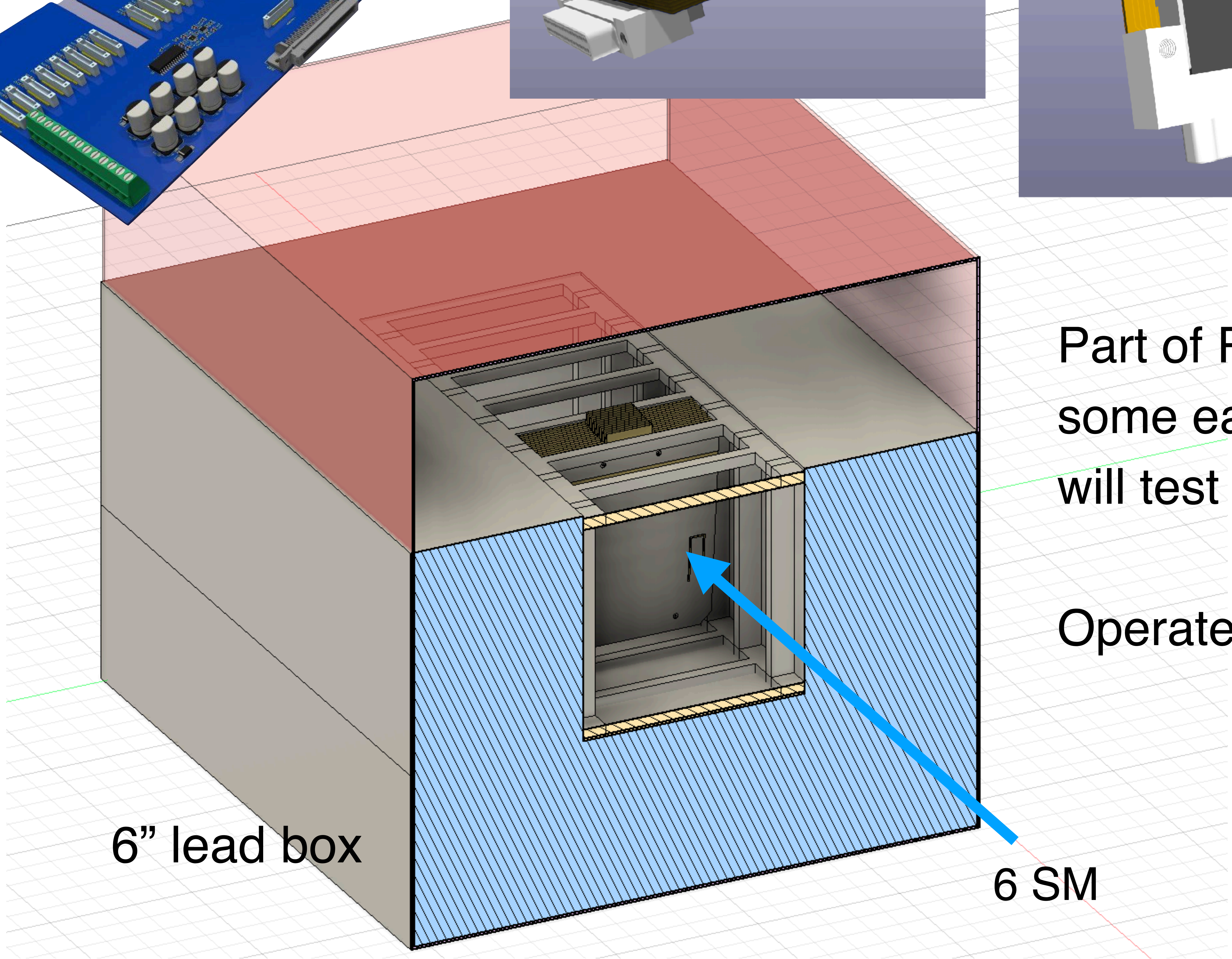


x96



X96





Part of R&D, could do some early science, and will test all the SM.

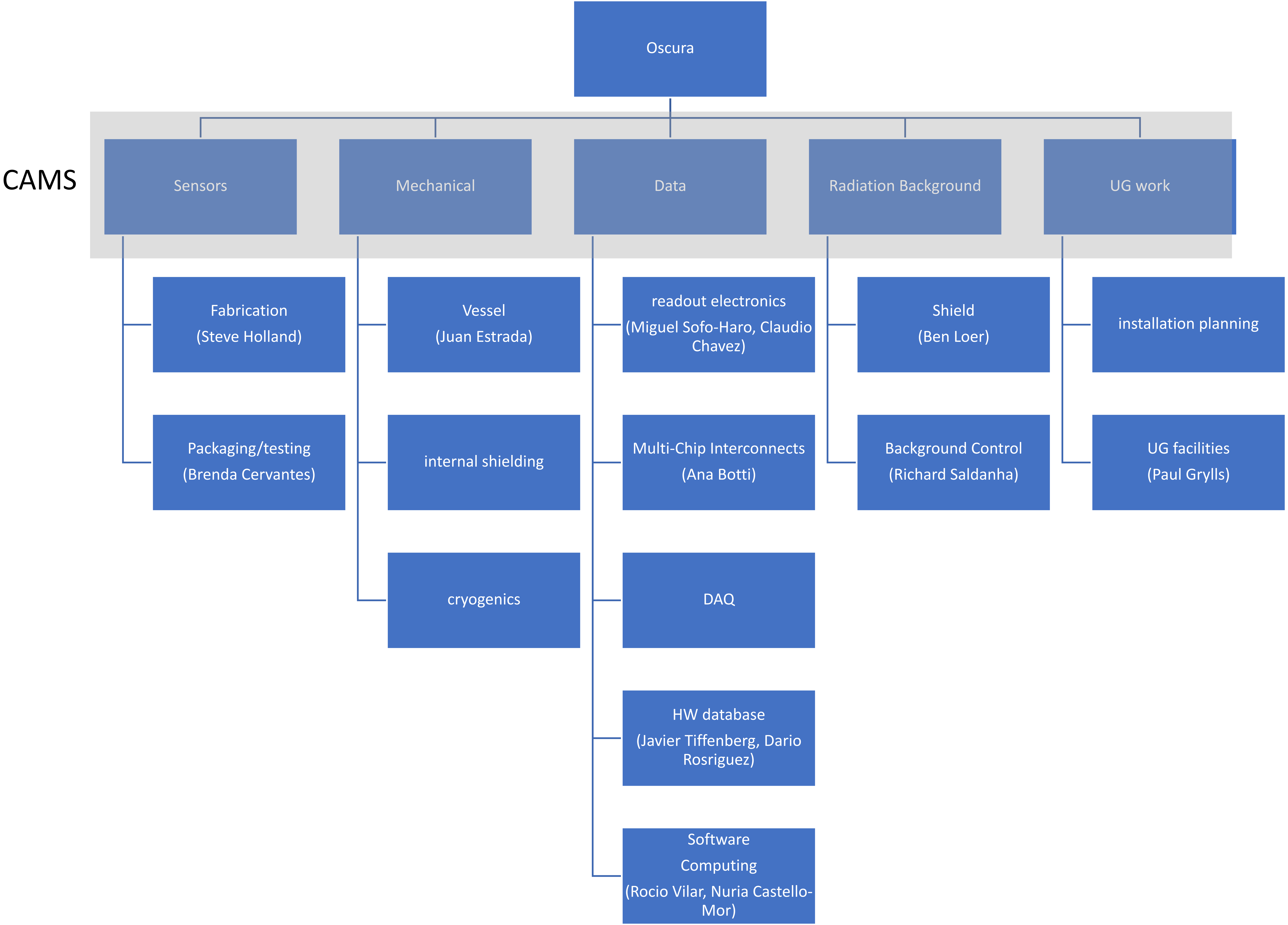
Operated underground.

What’s next for Oscura

- April 5th review:
  - Preliminary Project Execution Plan (FNAL)
  - Preliminary Design (SNOLAB/FNAL)

- End of 2024:
  - Ready to start construction

- This is part of the DMNI effort at DOE, good support from P5 report.


Oscura
CAMS
Sensors
Mechanical
Data
Radiation Background
UG work
Fabrication
(Steve Holland)
Packaging/testing
(Brenda Cervantes)
Vessel
(Juan Estrada)
internal shielding
cryogenics
readout electronics
(Miguel Sofo-Haro, Claudio Chavez)
Multi-Chip Interconnects
(Ana Botti)
DAQ
HW database
(Javier Tiffenberg, Dario Rosriguez)
Software
Computing
(Rocio Vilar, Nuria Castello-Mor)
Shield
(Ben Loer)
Background Control
(Richard Saldanha)
installation planning
UG facilities
(Paul Grylls)

Risk Register

- OSCURA has the 8 Open risks: 6 Threats and 2 Opportunities

Risk Register data

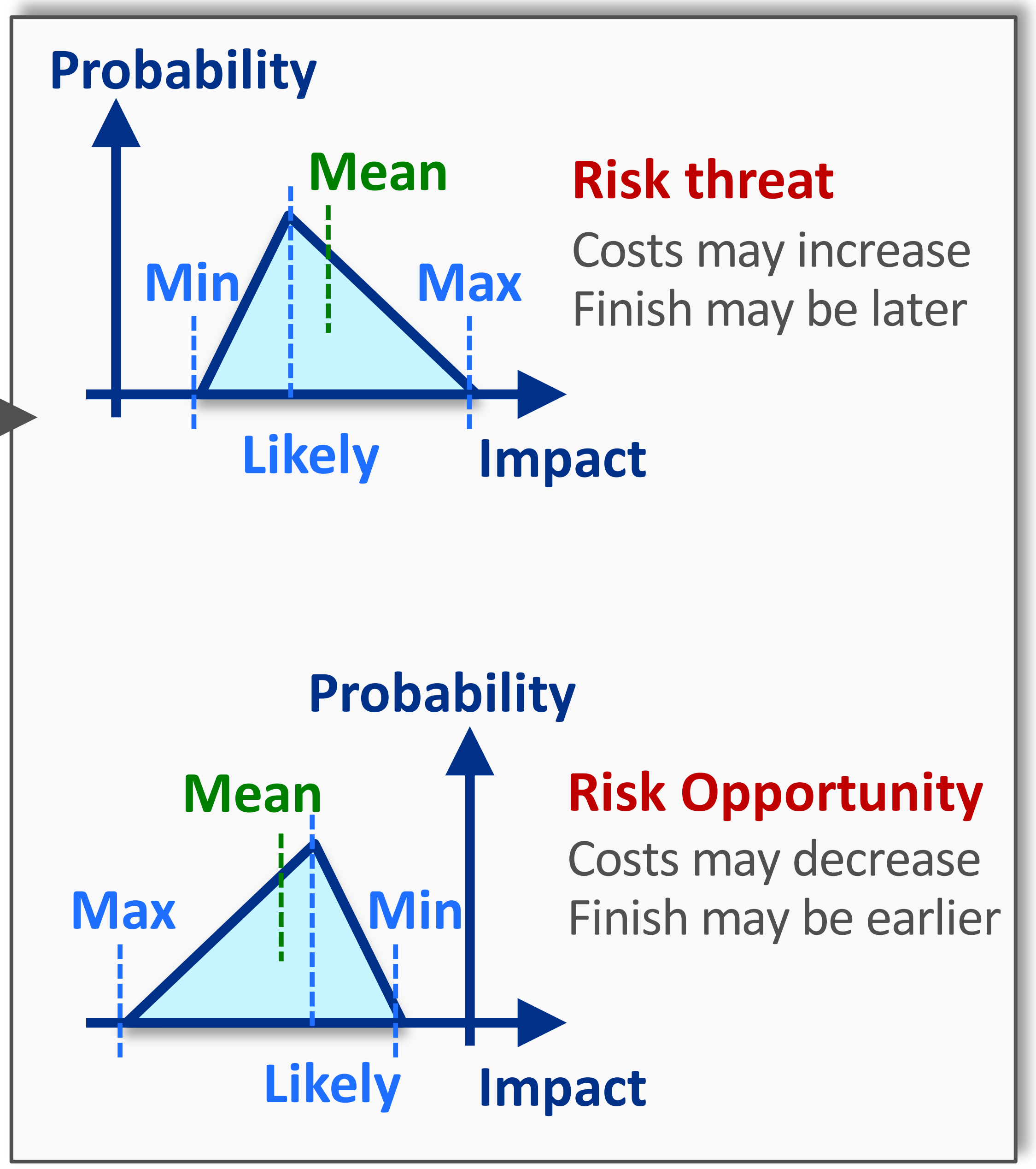
Risk ID	Risk Title	Risk Summary	Risk Type	Risk Owner	Risk Status (6/2022)	Risk Mitigations	Risk Responses	Conditions for closing risk	Probability	Technical Impact	Cost Impact - Min (k$)	Cost Impact - Likely (k$)	Cost Impact - Max (k$)	Schedule Impact - Min (months)	Schedule Impact - Likely (months)	Schedule Impact - Max (months)	Explanation of Estimate
Osc-risk-002	MIT-LL sensors part of Oscura	IF we include MIT-LL sensors in Oscura THEN project could address any issues during fab at microchip.	Opportunity	Javier Tiffenberg	Open	MIT-LL sensors being characterized continuously.	If risk occurs we could improve Oscura construction schedule, or detector performance.	This risk can be closed once we have most detectors in hand.	50%	High	150	400	600	0	0	0	The sensors work. Maybe they could have better performance (dark current)?
Osc-risk-005	Cosmic activation of CCDs produce unmanageable background.	IF cosmic activation of CCDs are not manageable THEN detectors need to be fabricated in a shielded area or underground.	Threat	Richard Saldanha	Open	Cosmic activation was quantified using neutrons. A process of removing tritium from CCDs is being developed. A shipping strategy is planned.	If risk occurs we have very high costs to control the cosmic activations.	This risk will be closed when a final CCD handling plan from foundry to SNOLAB is established.	20%	High	50	200	1000	0	0	0	Previous results in the literature and early tests show that tritium can be removed from pure silicon wafers. **This is still under investigation.**
Osc-risk-006	Background from CCD packaging materials above spec.	IF background from standard CCD packaging materials is too high THEN detector packaging cost will increase.	Threat	Ben Loer	Open	Assays on materials are being done, and simulations performed to evaluate this risk.	If the risk occurs we have to go into more expensive solutions for packaging (for example all silicon components)	This risk will be closed when a design for the packaging has been fully evaluated in simulations.	30%	High	50	200	2000	0	0	0	**Preliminary design works in early simulation. Full simulations ongoing.**
Osc-risk-008	Early science with partial detector load	IF we deploy partial load of detectors underground THEN Oscura could produce science before construction is completed.	Opportunity	Juan Estrada	Open	Collaboration need to make a plan for this option, is early since possible at SNOLAB?	If the risk occurs we have to plan early science run with partial detector load.	The risk will be closed when a plan for early science is ready.	50%	High	300	1000	1500	0	0	0	Early science is now part of the program, but still need to discuss details with SNOLAB.
Osc-risk-009	Unaccounted source of low energy background	IF there is an unknown background at 2e- THEN we will not be able to have a 0 background experiment	Threat	Juan Estrada	Open	Investigation into CCD backside layers as potential source of background and R&D into possible mitigation strategies. Evaluate science potential of Oscura with 3e- threshold	If the risk occurs we will have to increase the threshold of the experiment	The risk will be closed after the end of the run.	50%	Medium	0	0	0	0	0	0	Probability is currently unknown. Studies with pathfinder experiments are underway that will provide significant further input within the next year.
Osc-risk-010	Delays in distribution chain due o to covid-19	If problems with the electronics distribution chain continue after FY24, the fabrication of electronics will be delayed and cost more.	Threat	Juan Estrada	Open	Project has purchases most of the parts needed for testing (integration testing) of components before construction.	If the risk occurs we will have to purchase parts at a higher cost, with extra delay.	The risk will be closed when distribution chain becomes normal.	50%	High	300	1000	1500	6	12	24	Oscura is trying to design electronics with some flexibility to change components if they become unavaialble. No issue now for R&D or design stage because of early procurement of critical parts.
Osc-risk-011	Delays in procurement process.	Delays in the procurement process for: CCDs fab, MCM fab.	Threat	Juan Estrada	Open	Start the CCD fab and the MCM fab as soon as the Oscura projects starts starts.	If the risk occurs we will suffer a delay.	The risk will be closed when POs for MCMs and sensors are placed.	50%	High	0	0	0	6	9	12	We have places smaller order for sensor fabrications, and have seen delays of up to 9 months. We expect to do better, based on the experience.
Osc-risk-012	Availability of copper electroforming facility	Oscura is planning to use the electroforming facility at PNNL, but its use has to be scheduled with time.	Threat	Richard Saldanha	Open	Schedule the use of the facility as soon as possible, and start electroformic as soon as possible. An option will be to use commercial copper in the earlier stages of the project.	if the risk occurs we will have higher background during the ealier stages of the experiment.	The risk will be closed when electroforming is scheduled (SOW).	50%	Medium	100	150	200	0	0	0	We are estimating the cost of building the copper parts for the SM using commercial supplier, while we wait for the PNNL cooper.

Impacts are all zero !?

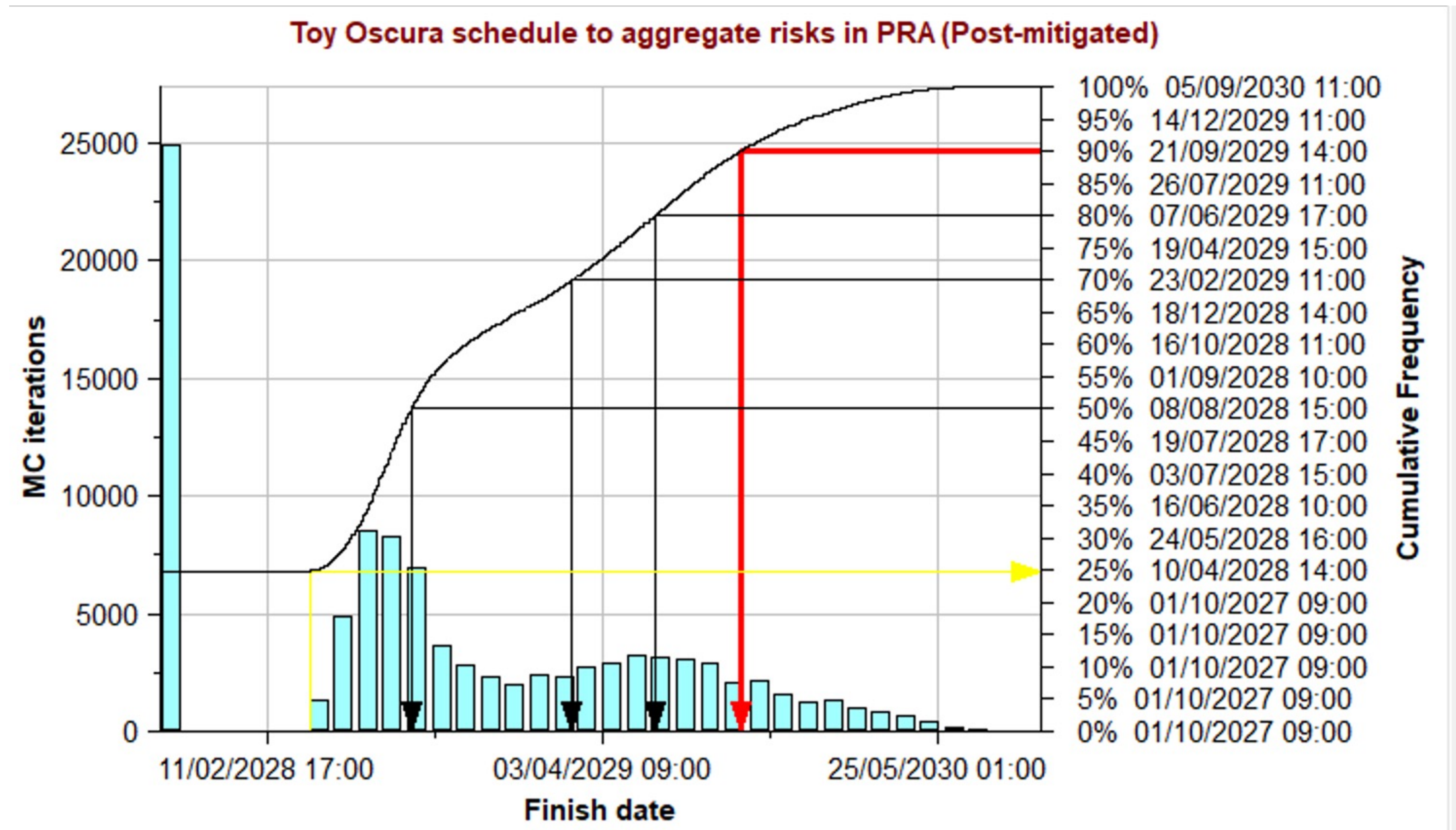
MC model to determine cost and schedule contingency

- Made summary (toy) schedule in Primavera P6, with a project duration of 3 years: Oct 2024 – Sep 2027

- Built risk MC model using the standard Fermilab risk framework: Oracle's *Primavera Risk Analysis (PRA)*
  - Modeled min/likely/max cost and schedule impacts using triangle probability distribution functions
  - Assumed risk delays are all on critical path (conservative)
  - Assumed risk delays occur in series (conservative)
  - Burn rate cost of risk delays = $44k / month
    - Marching army labor and increased escalation due to delays
    - In the MC model, burn rate costs are proportional to the stochastic risk delays



MC model results:
Schedule contingency



Analysis	
Iterations:	100000
Statistics	
Minimum:	01/10/2027
Maximum:	05/09/2030
Mean:	15/09/2028
Bar Width:	month
Highlighters	
Deterministic (01/10/2027...	25%
50%	08/08/2028
70%	23/02/2029
80%	07/06/2029
90%	21/09/2029

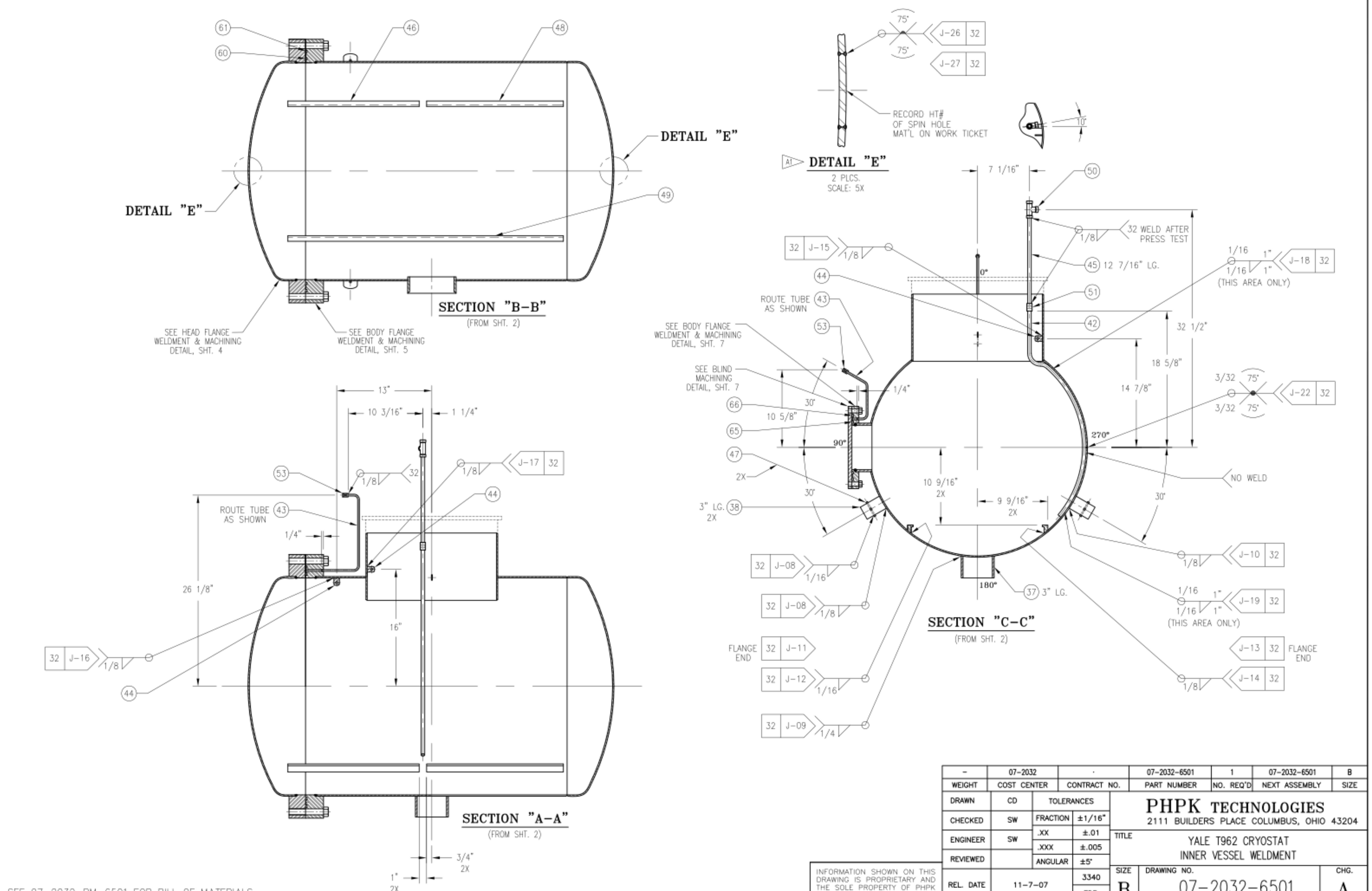
- Project finish without any risks
  - Project finish: 30 Sep 2027
- Allowing for stochastic risks
  - Mean finish: 15 Sep 2028 → Mean delay is 11.5 months
  - 90% CL finish: 21 Sep 2029 → Schedule contingency need is 23.7 months (at 90% CL)
- 2 years of schedule contingency for a 3 year project seems to be excessive
- Suggest revisiting the assessments for the schedule risk drivers :
  - Supply chain delays: P = 50% min / likely / max = 6 / 12 / 24 months (P*mean = 7.0 months)
  - Procurement delays: P = 50% min / likely / max = 6 / 9 / 12 months (P*mean = 4.5 months)

Phase-1

Cost reduction.

	10kg	5kg
123.2 Project Controls	$174,154.22	$174,154.22
123.3.10 Sensor Production	$2,235,000.00	$1,425,000.00
123.3.9 Sensor Packaging	$2,624,720.74	$1,443,764.64
123.3.8 Readout Electronics	$2,664,342.91	$1,353,730.49
123.3.7 Data Aquisition System	$50,000.00	$50,000.00
123.3.6 Cryostat	$768,764.04	$768,764.04
123.3.11 Sensor Testing	$39,025.98	$19,141.85
123.3.5 Background Control	$200,000.00	$200,000.00
123.3.3 Shielding	$1,500,000.00	$1,500,000.00
123.3.2 Installation Planning	$93,739.90	$93,739.90
Total	$10,349,747.79	$7,028,295.14

- Build the vessel for 10kg, install 5kg.
- 3 years from now, maybe we could get better performance with some of the new sensors we are developing (sisero, skipper-cmos, double-sided-CCD,…).
- This could also accelerate the schedule ~6mo…



SEE 07-2032-BM-6501 FOR BILL OF MATERIALS.

REVISIONS

CHG.	DATE	EDR	DWN.	CH'KD.	APP'D.	REV'D.	DESCRIPTION
A	12-3-07	3368	CD	SW	SW	.	1) ADDED DETAIL "E" 2 PLCS.

WEIGHT	COST CENTER	CONTRACT NO.	PART NUMBER	NO. REQ'D	NEXT ASSEMBLY	SIZE
–	07-2032	.	07-2032-6501	1	07-2032-6501	B

DRAWN	CD	TOLERANCES	
CHECKED	SW	FRACTION	±1/16"
ENGINEER	SW	.XX	±.01
		.XXX	±.005
REVIEWED		ANGULAR	±5°
REL. DATE	11-7-07	3340	EDR

DIMENSIONS ARE PROVIDED PRIOR TO SURFACE TREATMENTS UNLESS NOTED.

PHPK TECHNOLOGIES
2111 BUILDERS PLACE COLUMBUS, OHIO 43204

TITLE: YALE T962 CRYOSTAT INNER VESSEL WELDMENT

SIZE	DRAWING NO.	CHG.
B	07-2032-6501	A

SCALE 1=12 SHEET 3 OF 9

Collaboration Health

Oscura is an emerging Science Collaboration (not fully formed).

Oscura has a “Statement of Collaboration Culture”. We have named two ombudspersons to address any internal issues.

Soon, we will establish spokespeople, science collaboration groups, a publication board, and a speakers bureau. Science Collaboration Constitution.