

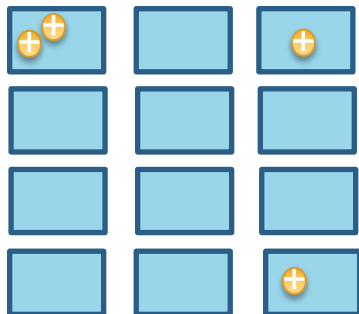


Towards a 10 kg Skipper-CCD detector: the multiplexing analog electronics for the OSCURA experiment

Claudio Chavez (Presenter), Fernando Chierchie, Miguel Sofo-Haro and FNAL CCD group

Coordinating Panel for Advanced Detectors Workshop
30th November 2022

CCDs, Skipper-CCDs and the OSCURA project



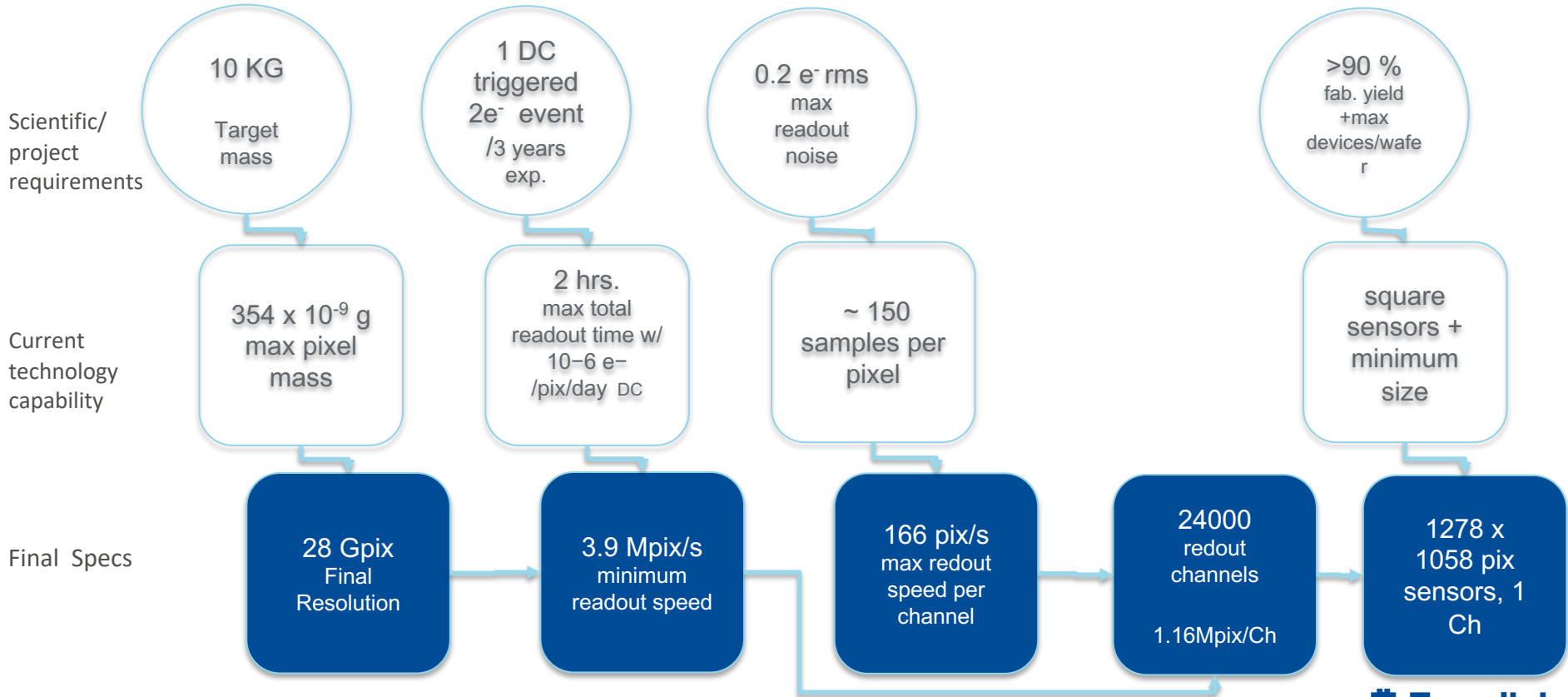
The Skipper-CCD

-> *Non Destructive Readout Image Sensors (NDRIS)*

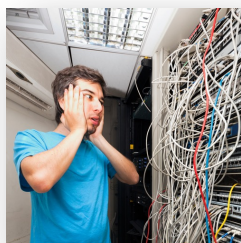
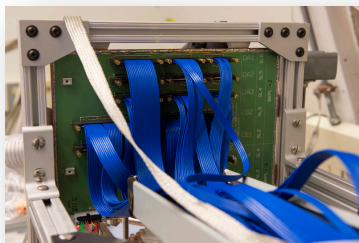
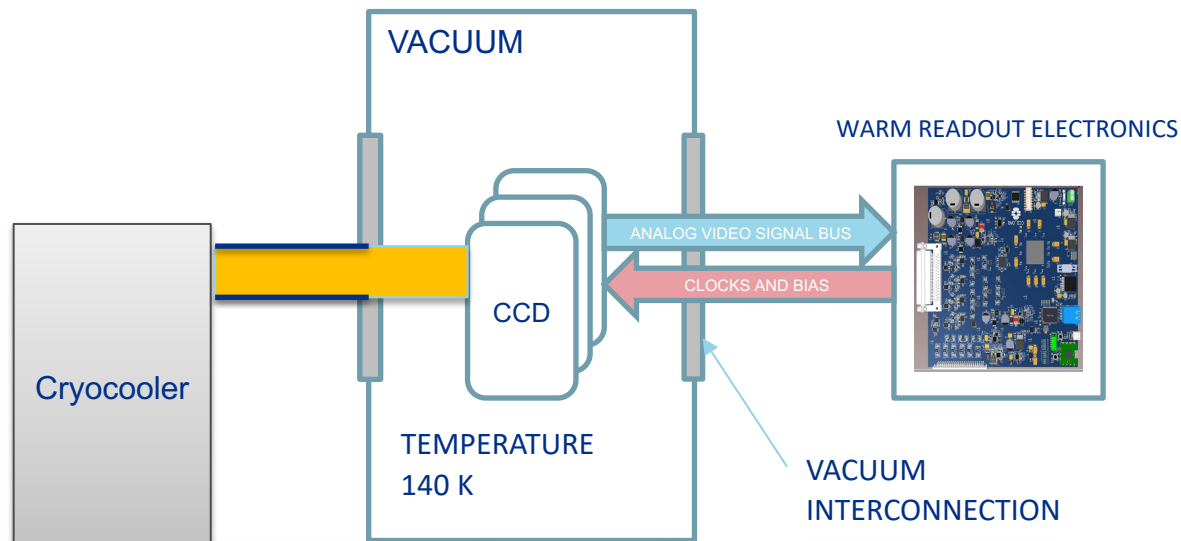
OSCURA ultimate DM limit relies on:

- 10 Kg silicon
- Dark Current contribution mitigation
- Strict background mitigation/control
- 0.2 e^- rms noise

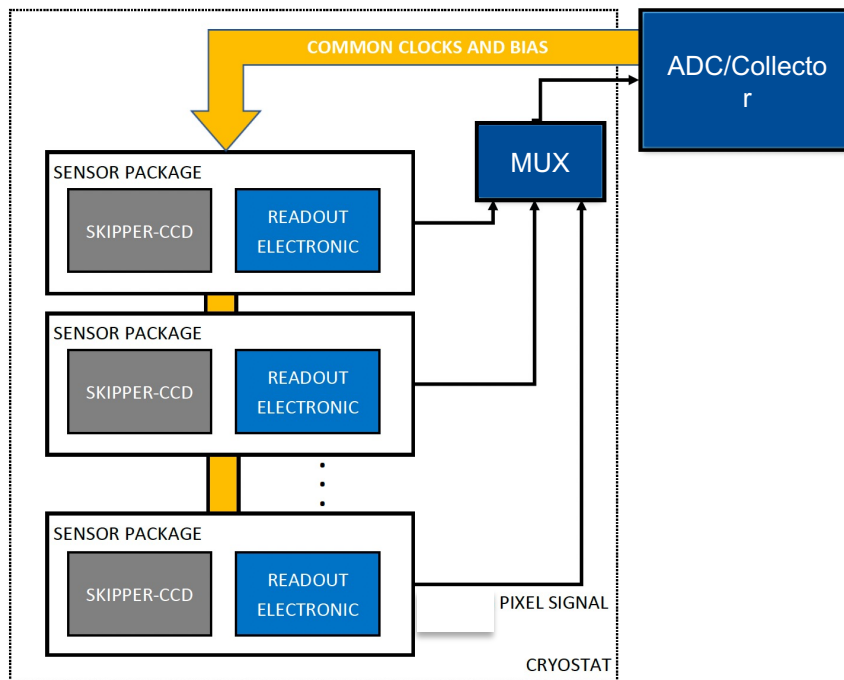
Requirements



Readout systems for few sensors

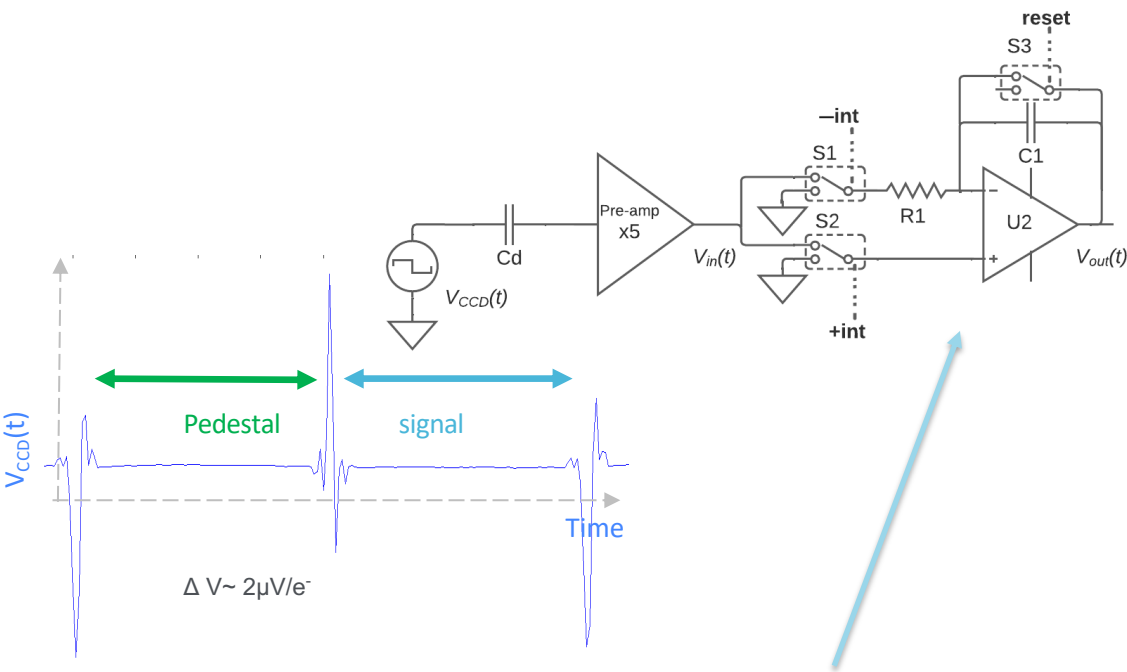


Distributed/multiplexed readout system?

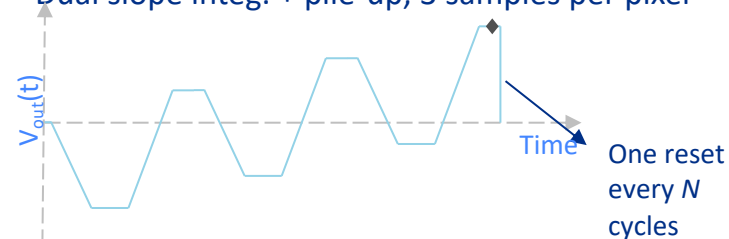


28 Gpix ✓

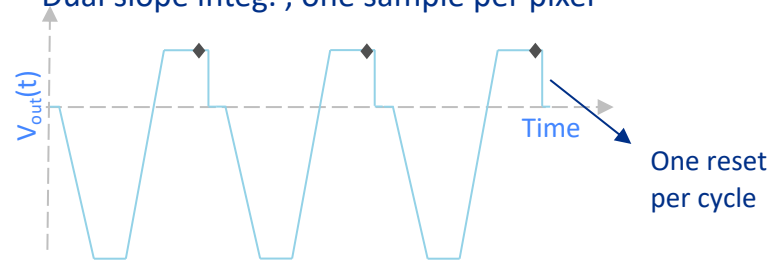
The analog pile-up concept



Dual slope integ. + pile-up, 3 samples per pixel



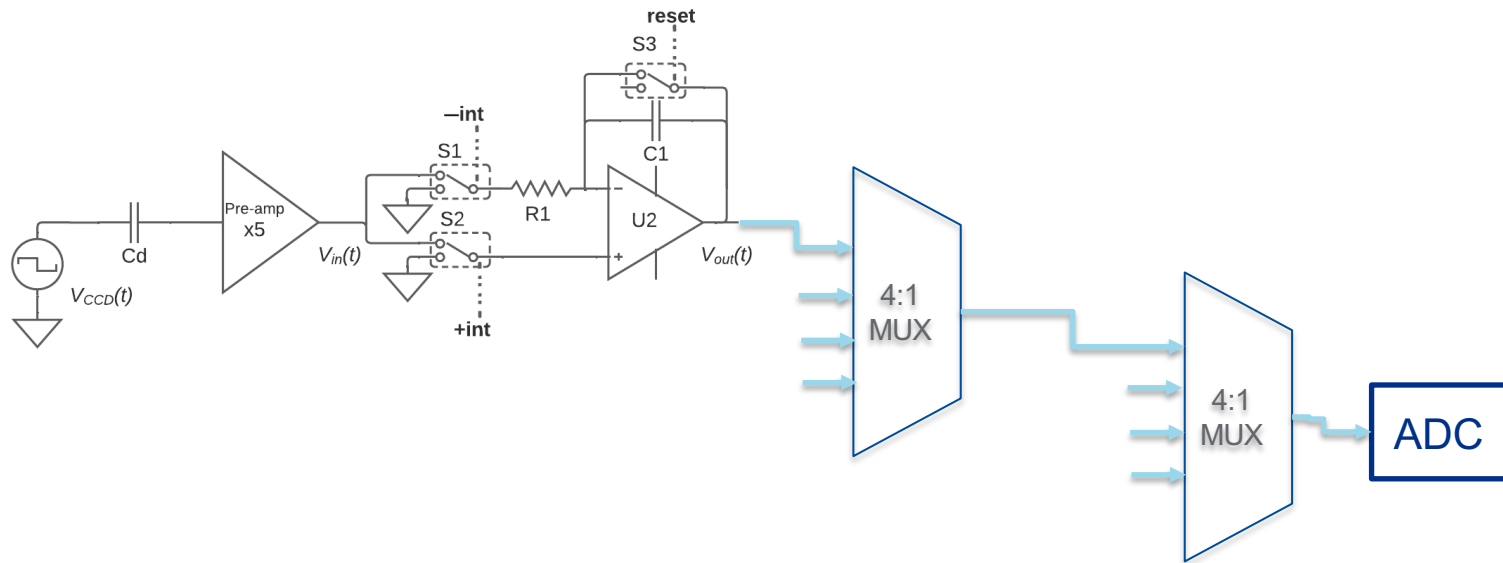
Dual slope integ. , one sample per pixel



$$P_i = \frac{1}{N} \sum_{j=0}^{N-1} \left(\int_{t_i+\tau+t_j}^{2t_i+\tau+t_j} V_{CCD}(t) dt - \int_{t_j}^{t_i+t_j} V_{CCD}(t) dt \right)$$

◆ Pixel value digital conversion

The analog pile-up concept



Timeline

Jun 2020

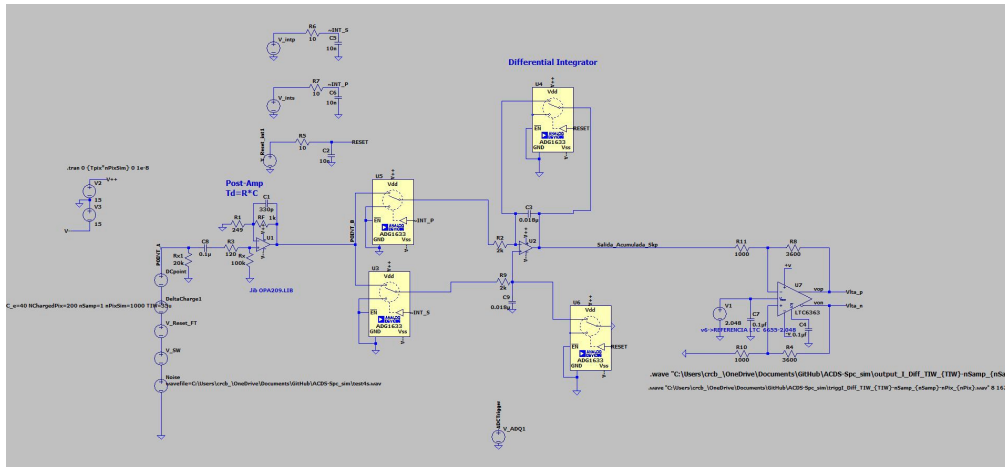
July 2020

Aug 2020

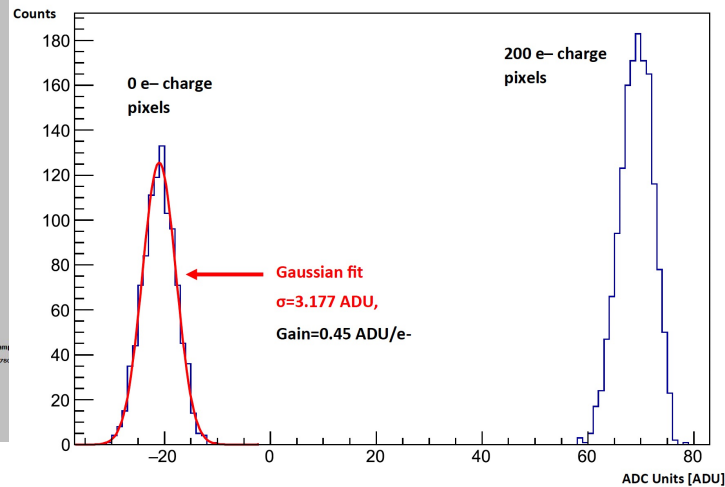
Sept 2020

Oct 2020

Simulations using CCD signal synthesis and advanced spice models



2500 pixels simulation. Output histogram at 16 bits simulated digital conversion.



Timeline

Jun 2020

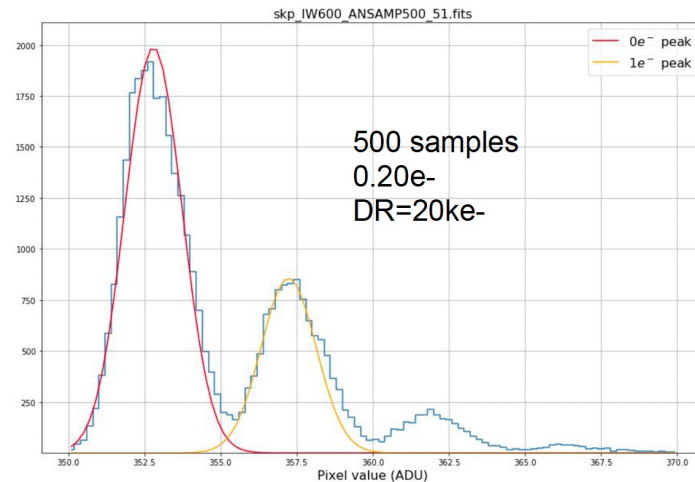
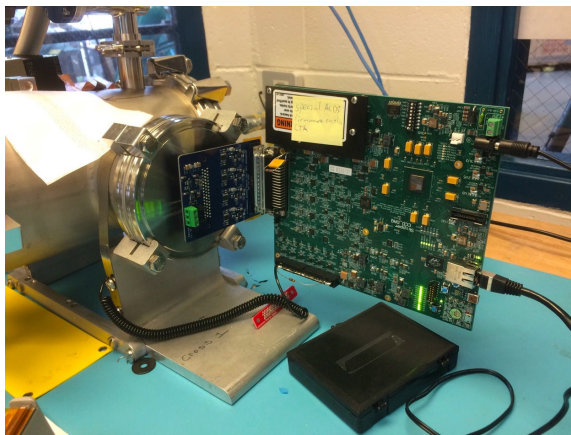
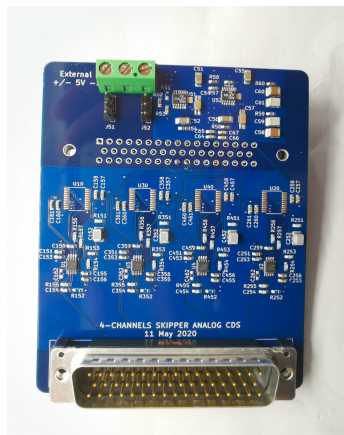
July 2020

Aug 2020

Sept 2020

Oct 2020

First real circuit test. Single-electron resolution reached with 500 samples



Timeline

Jun 2020

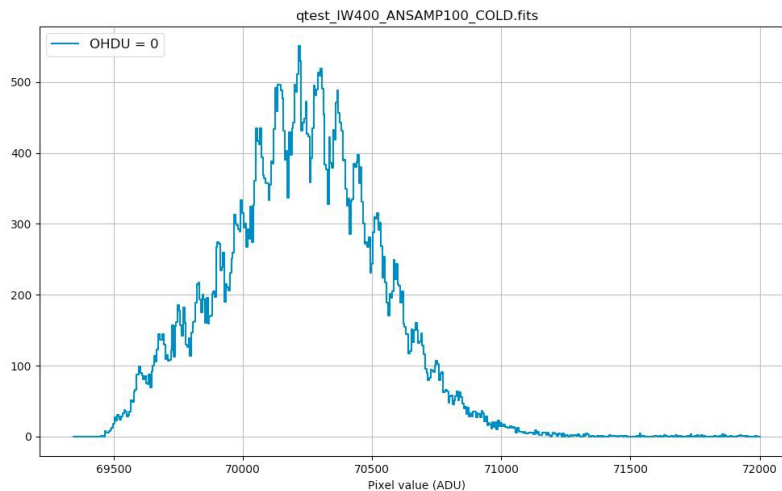
July 2020

Aug 2020

Sept 2020

Oct 2020

Test at LN2
temperature



Timeline

Jan 2021

Concept design start

Feb 2021

Crazy Ideas
acceptance and
analysis

Mar 2021

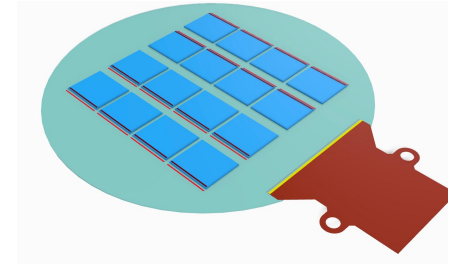
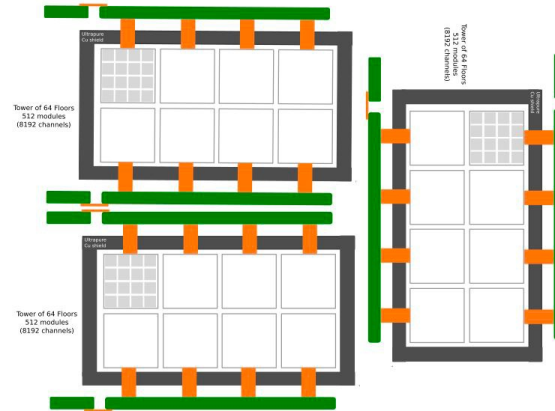
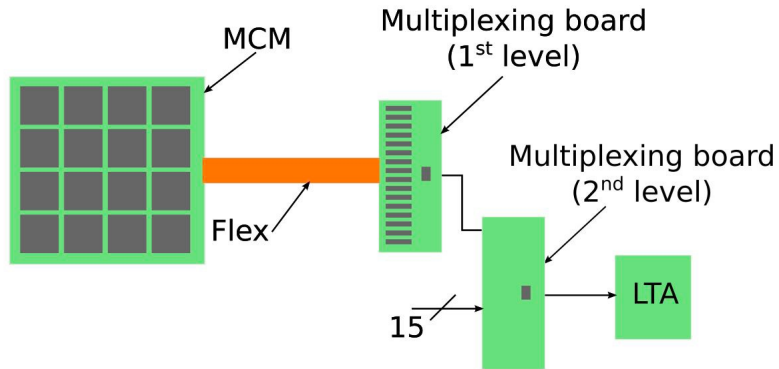
Engineering teams
fights

Apr 2021

Multi CCD module
concept was born

May 2021

Super module
concept was born



Timeline

Jun 2021

Jul 2021

Aug 2021

Sept 2021

Oct 2021

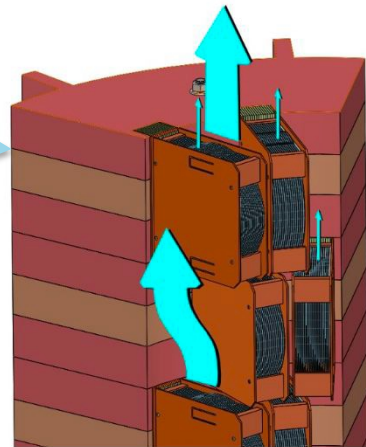
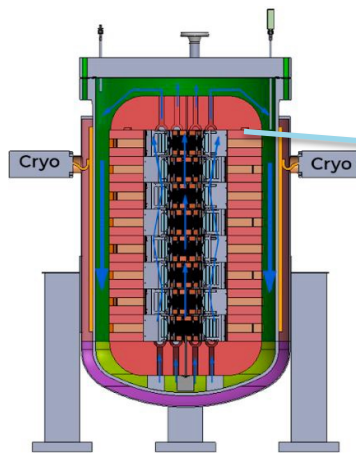
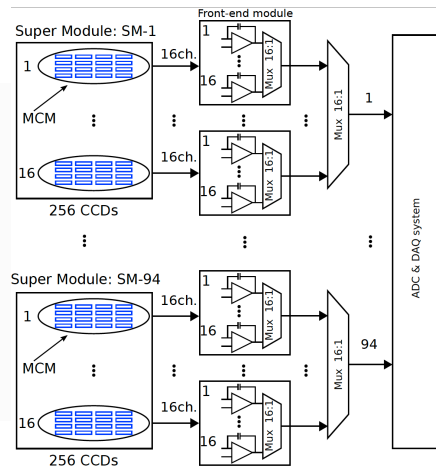
Cooling down using pressurized LN2

Multiplexing
scheme/ electronics
distribution

Engineering teams
fights 2nd round

Vessel design considering LN2 flow

Prototype vessel for SM testing



Timeline

Dec 2021

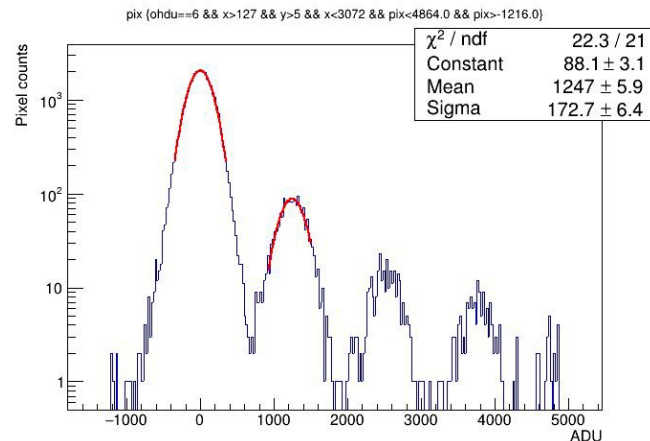
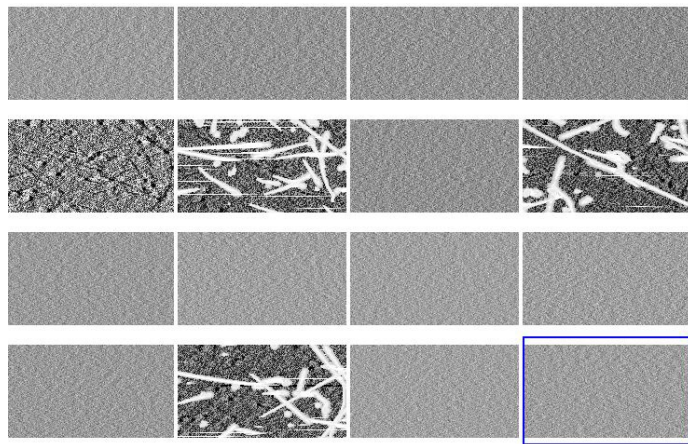
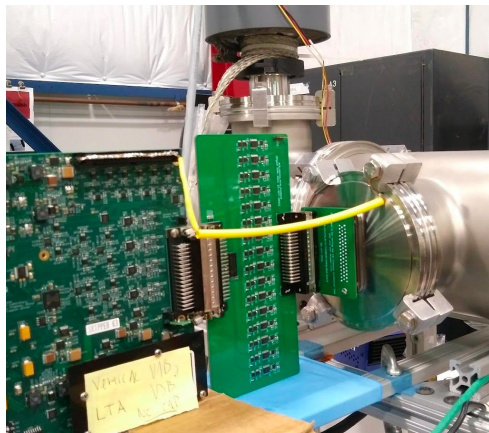
Jan 2022

Feb 2022

Mach 2022

Apr 2022

First Images using
multiplexed readout
and a 3ch Skipper-
CCD



Timeline

Dec 2021

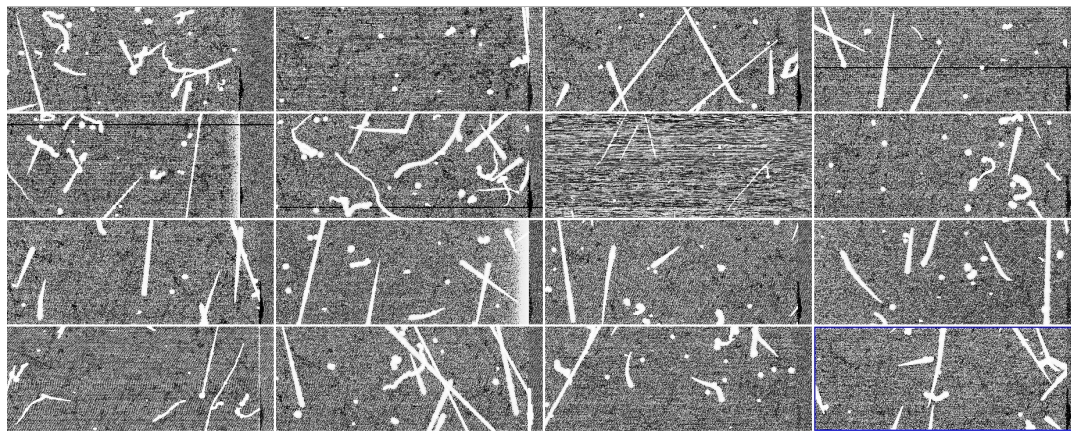
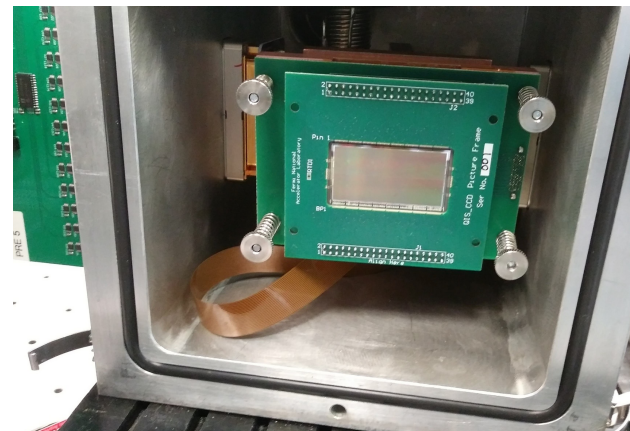
Jan 2022

Feb 2022

Mach 2022

Apr 2022

First Images using
multiplexed readout
and a 16ch Skipper-
CCD, still with single
 e^- resolution



Timeline

Dec 2021

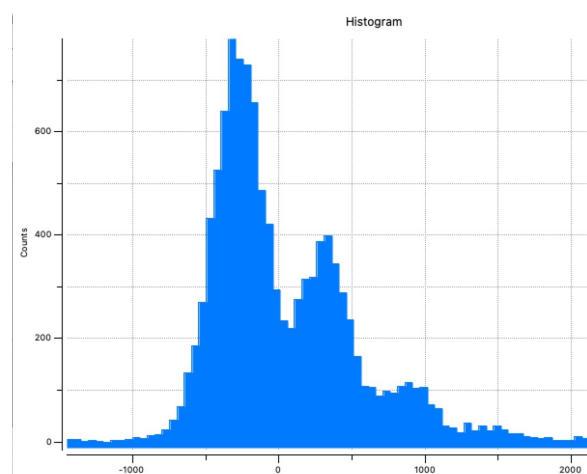
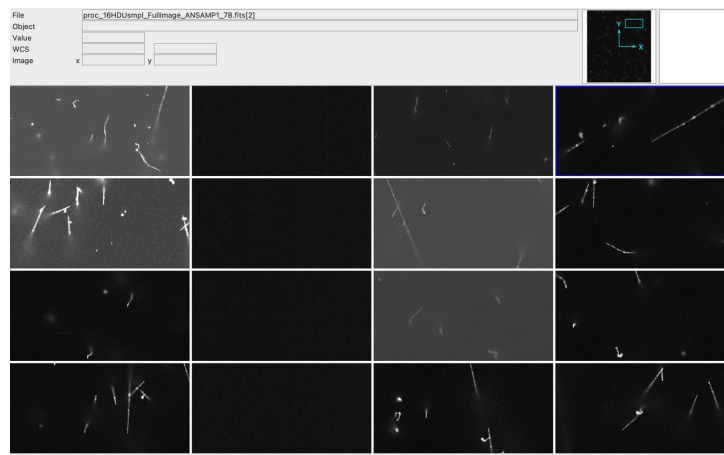
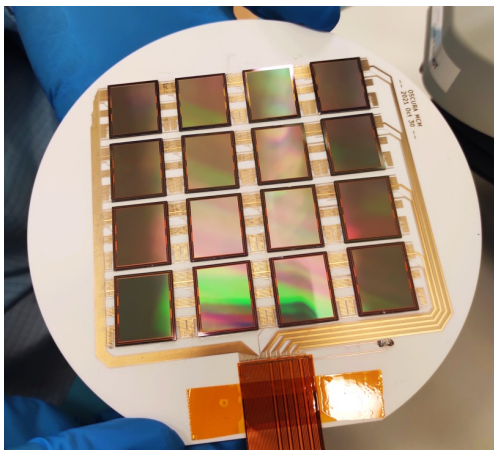
Jan 2022

Feb 2022

Mach 2022

Apr 2022

First images using an MCM prototype and the new sensors



Timeline

Jun 2022

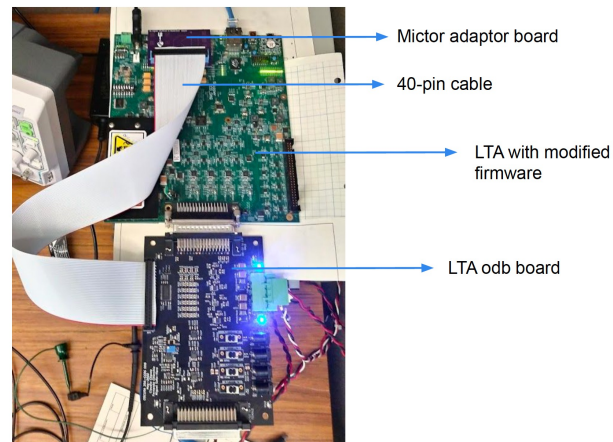
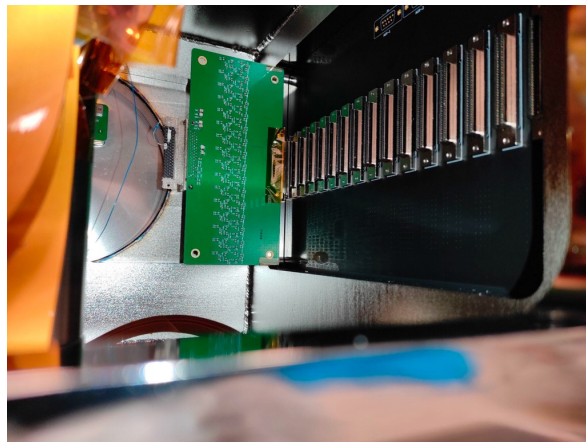
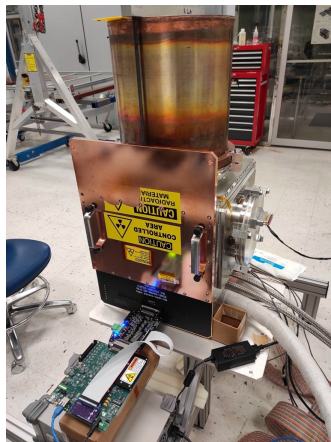
Jan 2022

Feb 2022

Mach 2022

Apr 2022

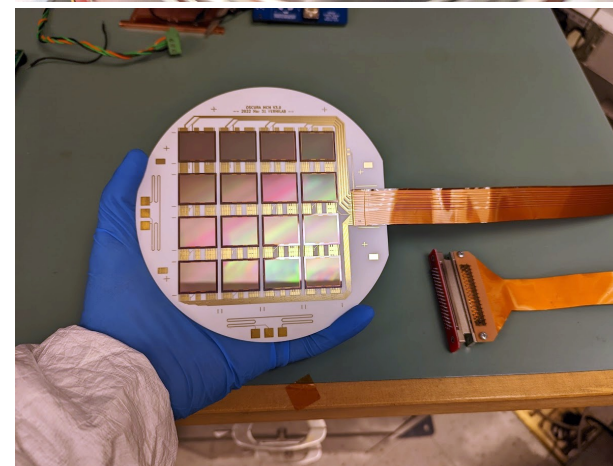
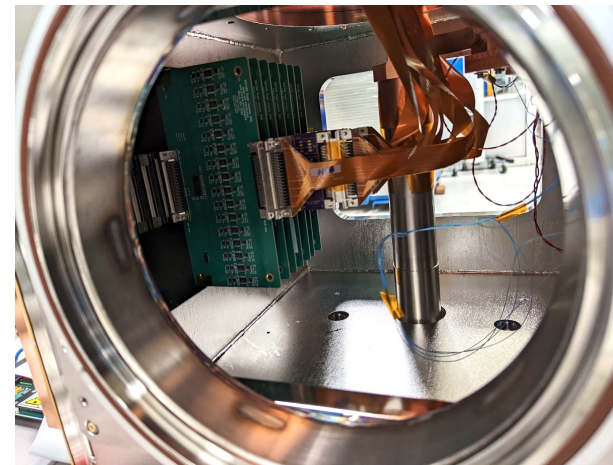
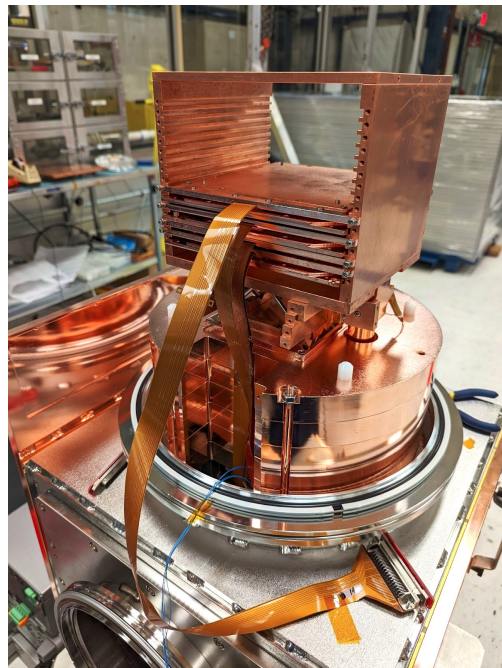
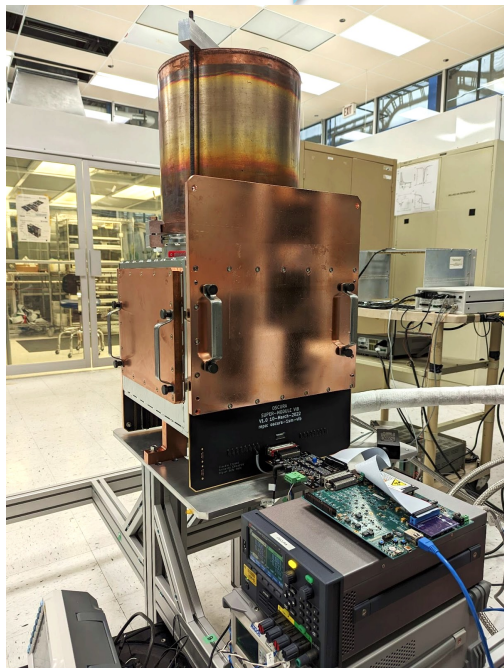
First images using an
MCM prototypes
and 2 stages
multiplexing



Timeline

Sept 2022

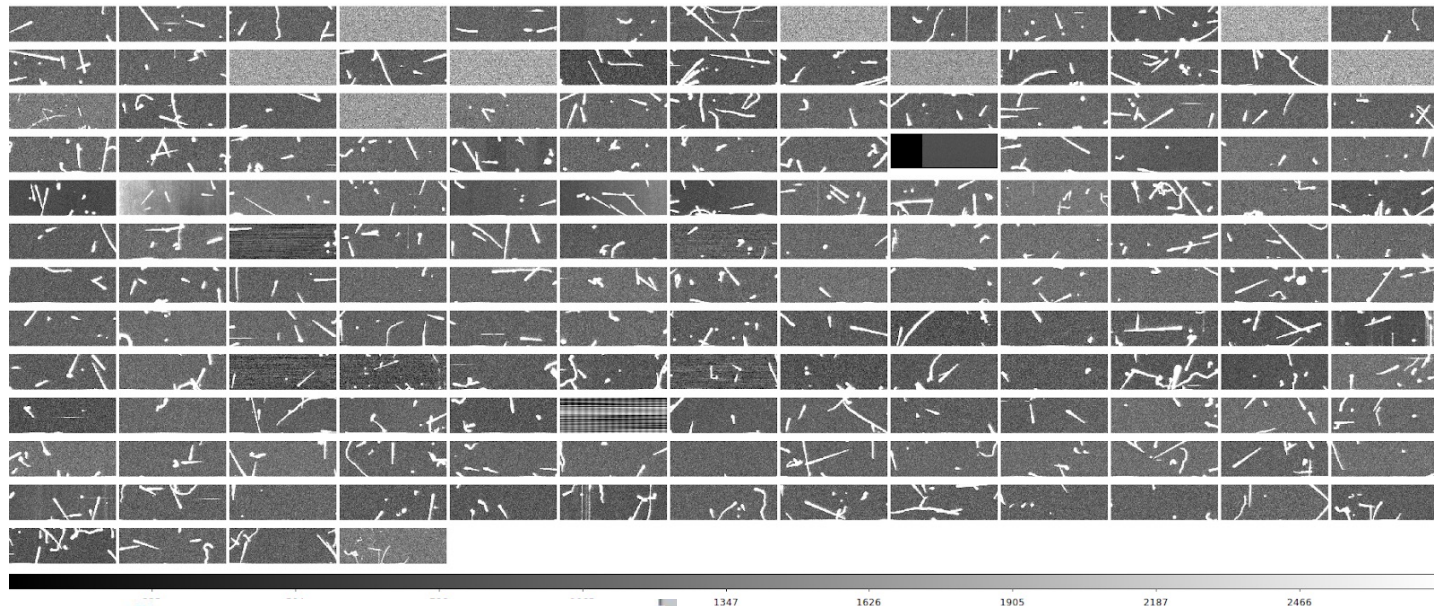
- 1% of OSCURA
- 10 MCM, 160 Channels (largest SCA)
- 84 grams of sensitive mass
- Multiplexed redout with only 1 ADC



Timeline

Sept 2022

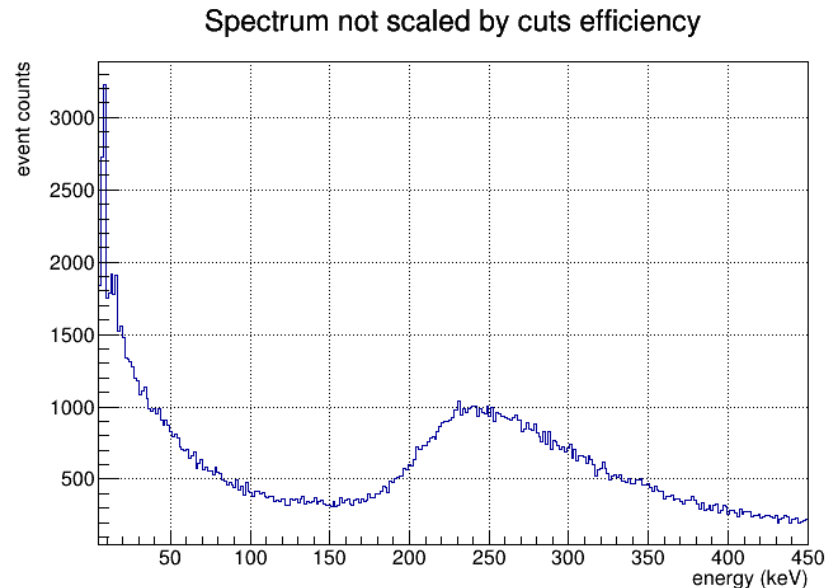
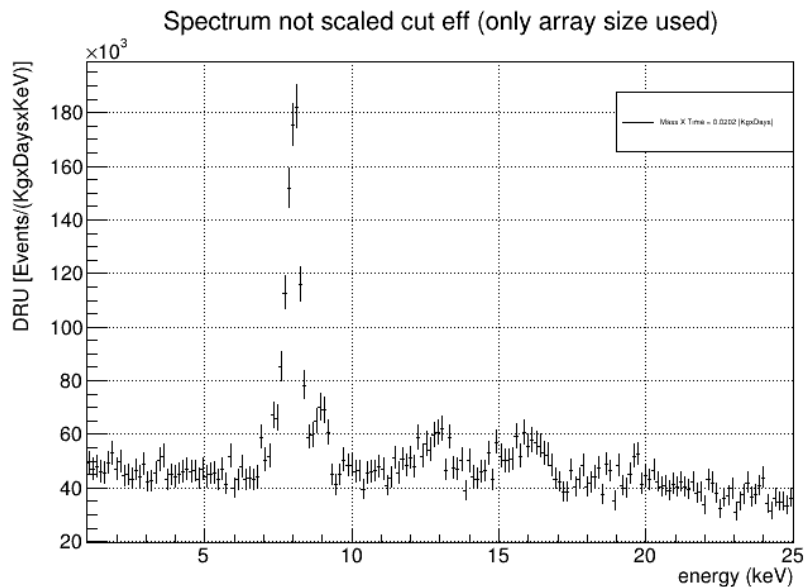
- 160 channels, ~216 Mpix!. Designed for up to 256 channels



Timeline

Sept 2022

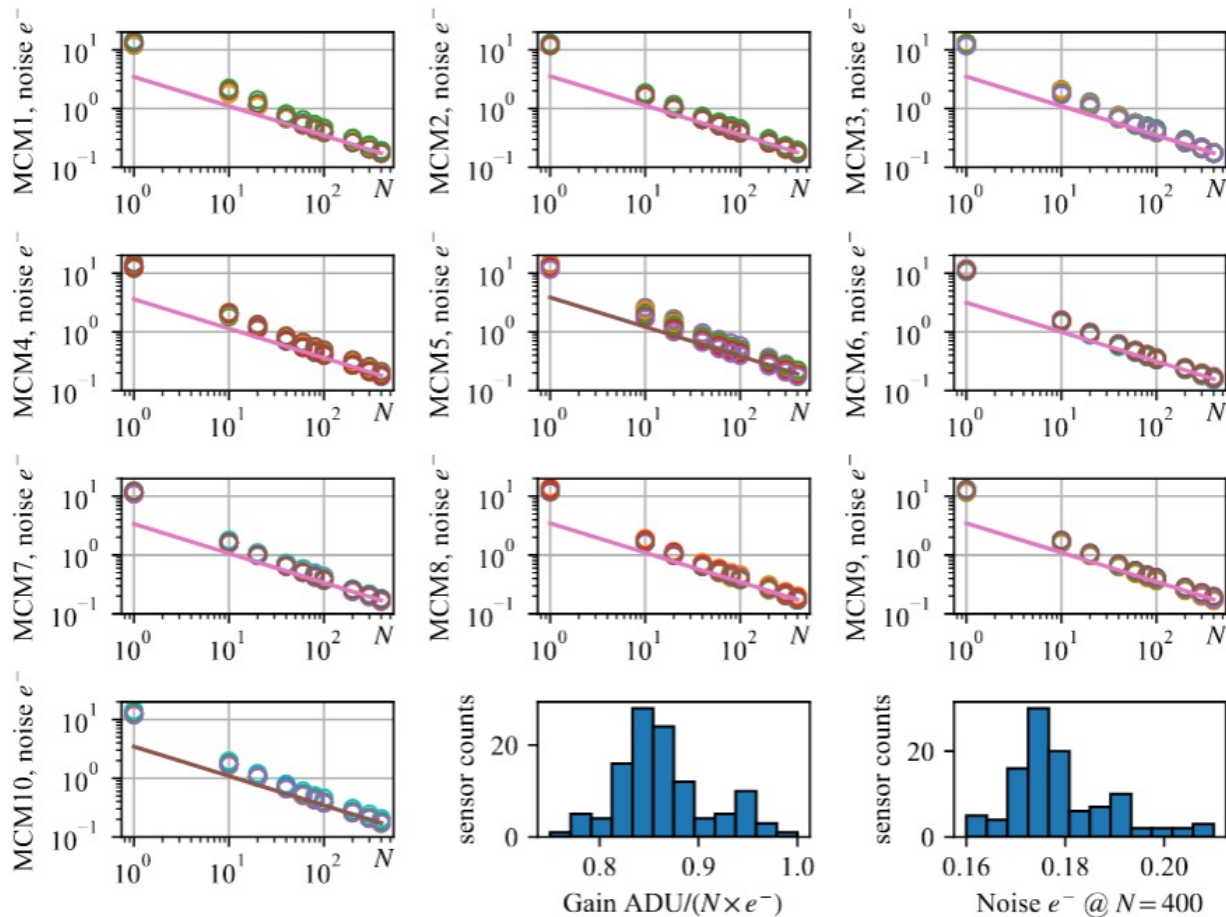
- Energy Spectrum in one single run.



Timeline

Sept 2022

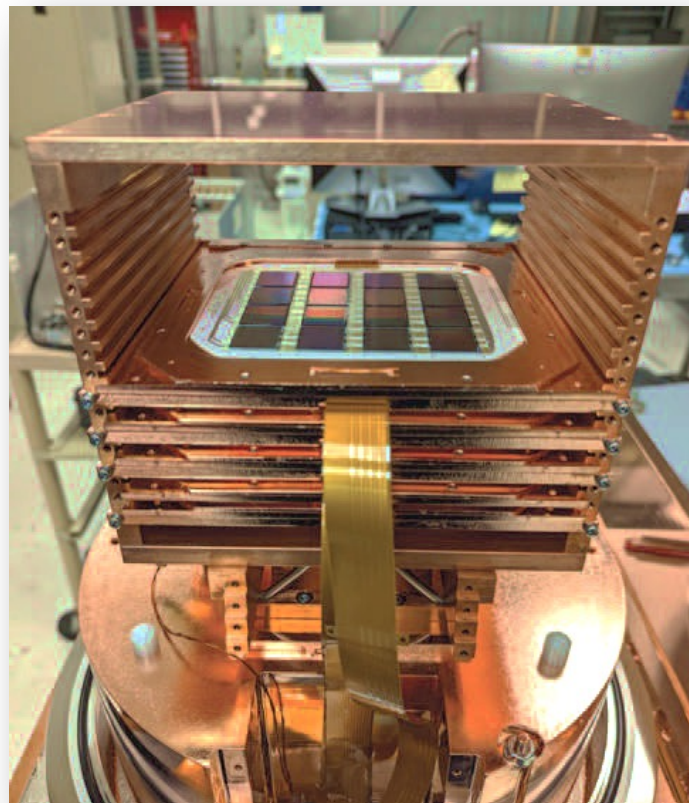
- Low noise mode!.



Highlights

Only 1% OSCURA??, Does it help?

- The storage and data management problem!
- Tools optimization.
- Suppression/compression
- Supports packaging development
- A platform for volume sensor testing
- Readout system demonstration.
- Design testing procedures

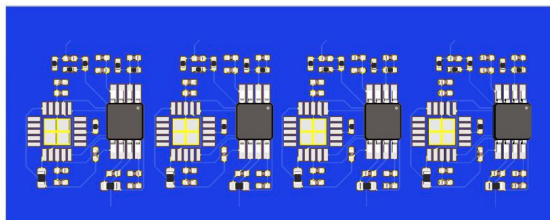


Highlights

- This readout system could instrument the SENSEI experiment(100g, ~ 200 channels) with one channel, or DAMIC-M (1kg, few hundred channels) with minimal or no modifications.

What's next?

- Make it small!!!



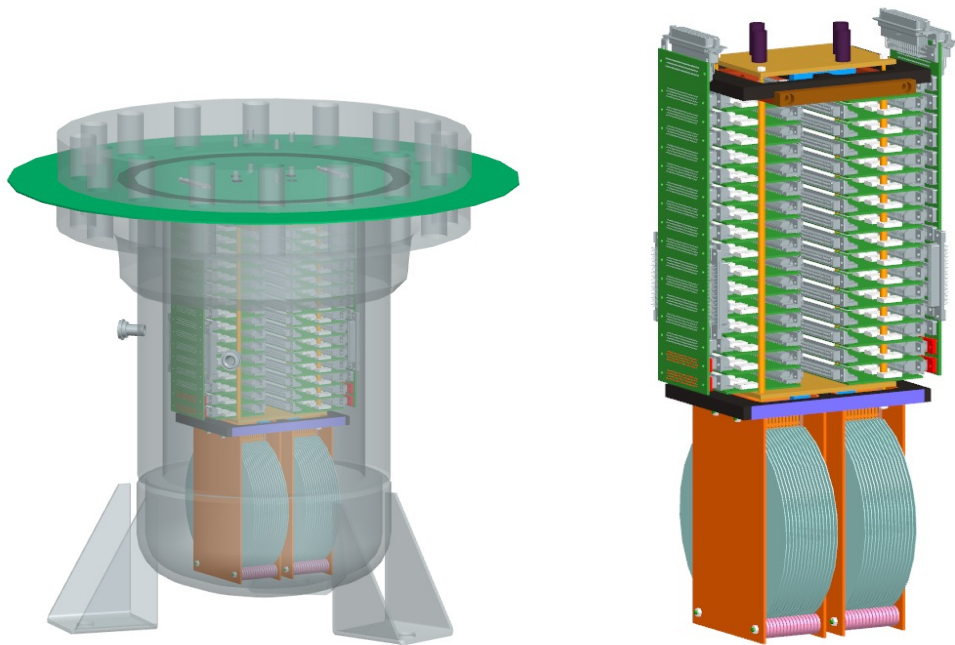
- Minimum size analog processing chain, 4ch

- That small???



- MIDNA ASIC

What's next?



- 2 super modules in pressurized LN2, ~260 grams (another record), with MIDNA ASICS and silicon substrates.

Thanks!

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