Developing the first astronomical and quantum imaging instrument using the Smart Skipper-CCD techniques

July 4, 2020

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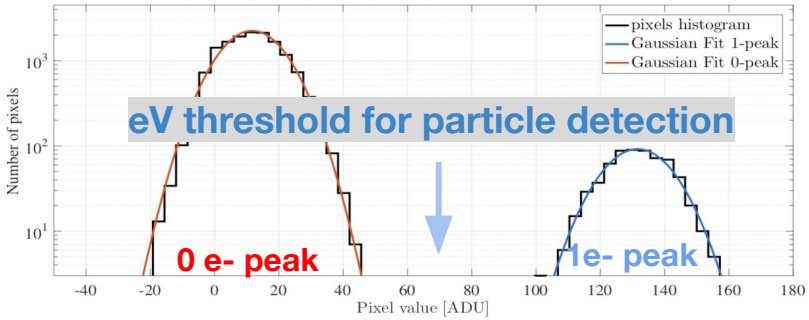
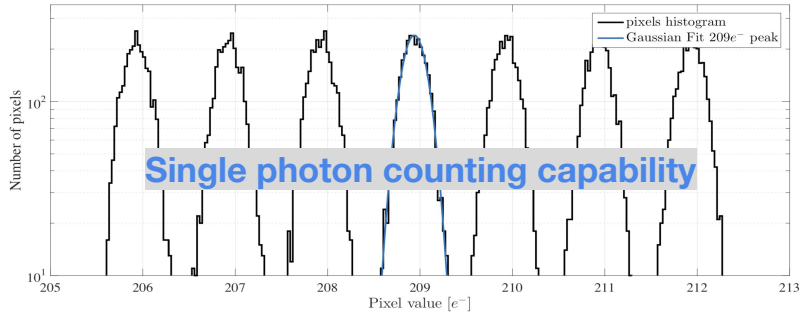
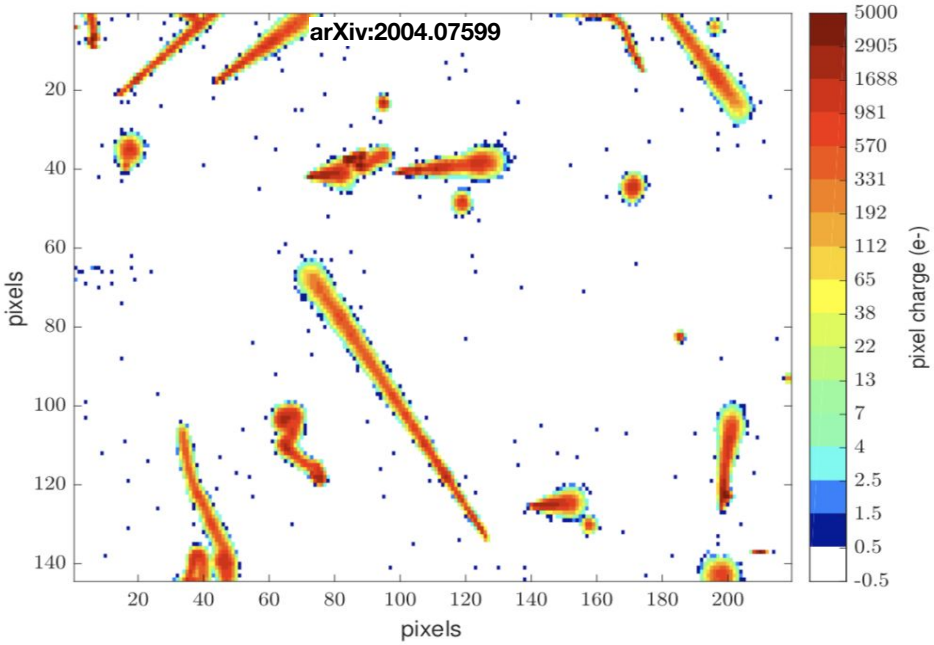
We should prioritize Skipper CCD as a new technology for Latin America







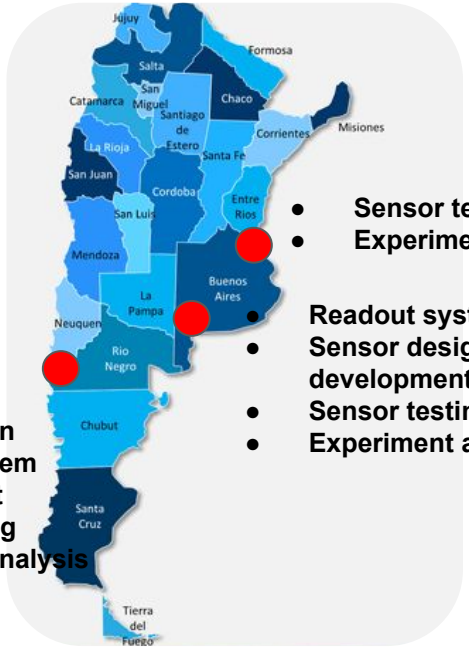
Summary

- eV interaction threshold
- Single charge/single photon counting capability from 0 to 100.000 e-.
- It allows to scale system of thousands of these devices.

A lot of sinnergy between Argentina and Fermilab in the development of Skipper CCD

Fermilab

- Sensor design
- Readout system development
- Sensor testing
- Experiment analysis



- Sensor testing
- Experiment analysis

- Readout system
- Sensor design development
- Sensor testing
- Experiment analysis

Bahia Blanca Laboratory for CCD instrumentation developing and testing

- Belongs to the Instituto de Investigación en ingeniería electrónica “Alfredo desages”.

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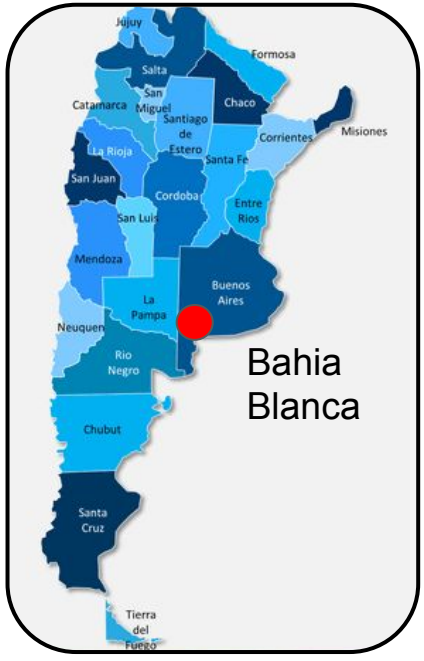
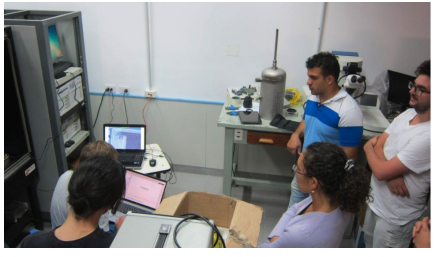


- Facilities and instrumentation

- Ongoing project: Fabrication of the first Skipper CCD readout electronics.

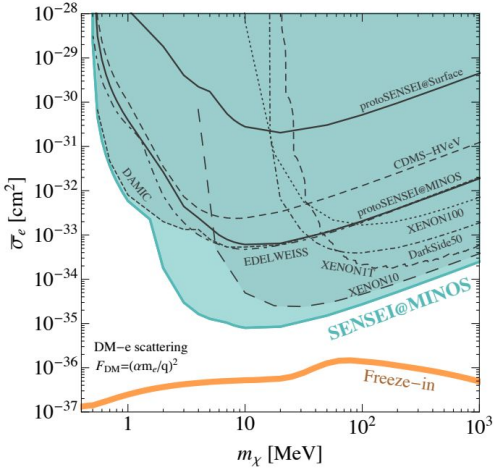
- Lab located in the University campus (Universidad Nacional del Sur, Bahía Blanca)

UNS



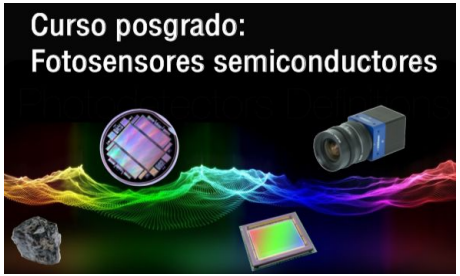
Bahia Blanca has a large history in the development of CCD instrumentation

- Development of the first readout electronics and data acquisition system for Skipper CCD (**arXiv:2004.07599**).
- Now being the new standard for Skipper CCDs.
- Used for Dark matter search (**SENSEI, DAMIC, OSCURA**), neutrino search (**vIOLETA, MINER, CONNIE**), Astronomy (**new spectrograph instrument at FNAL**), quantum imaging (**New quantum camera**), satellite missions (**Darkness**).



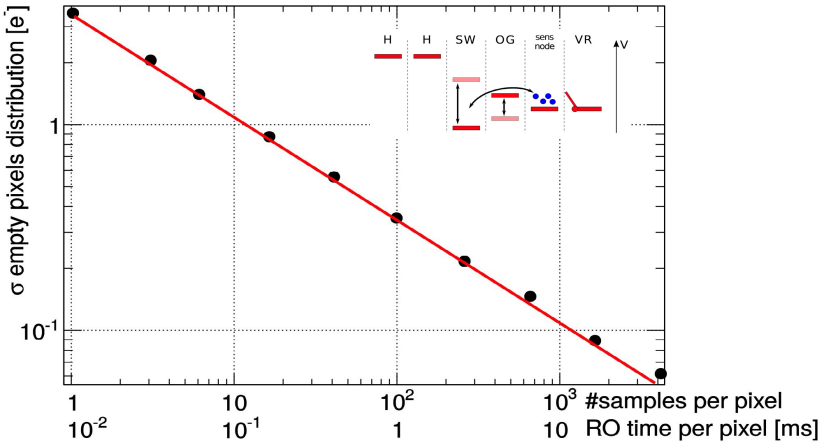
- Strong participation on particle detection CCD projects. Neutrinos: CONNIE, vIOLETA. Dark Matter: SENSEI, OSCURA.

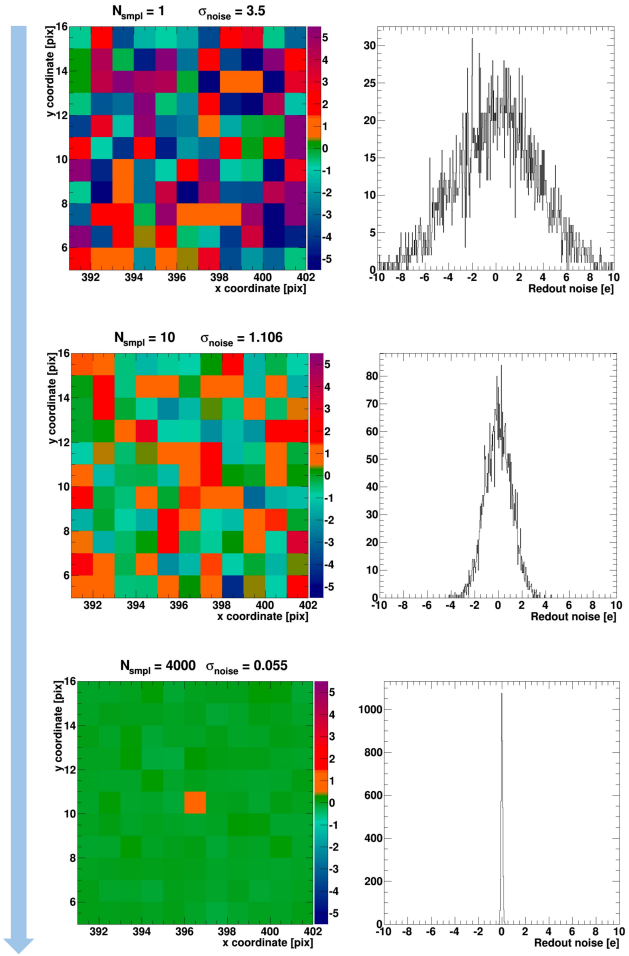
- Creation of human resources. Incorporation of undergraduate, graduate students to the CCD projects. Dictation of postgraduate courses semiconductor sensors for students nationwide.



Skipper CCD is a slow sensor

- CCD is read out sequentially. Readout noise is a function of pixel readout time.
- The sensor takes several samples of the same charge packet in the output sense node. Sub-electron noise is achieve after many measurements of the same charge packet. This makes the sensor very slow.
- Readout time for several million pixels takes hours.
- This prohibits its use for Astronomy, quantum imaging and other fast applications.
- Readout time should be 100 times smaller to exploit the full single photon/charge counting.



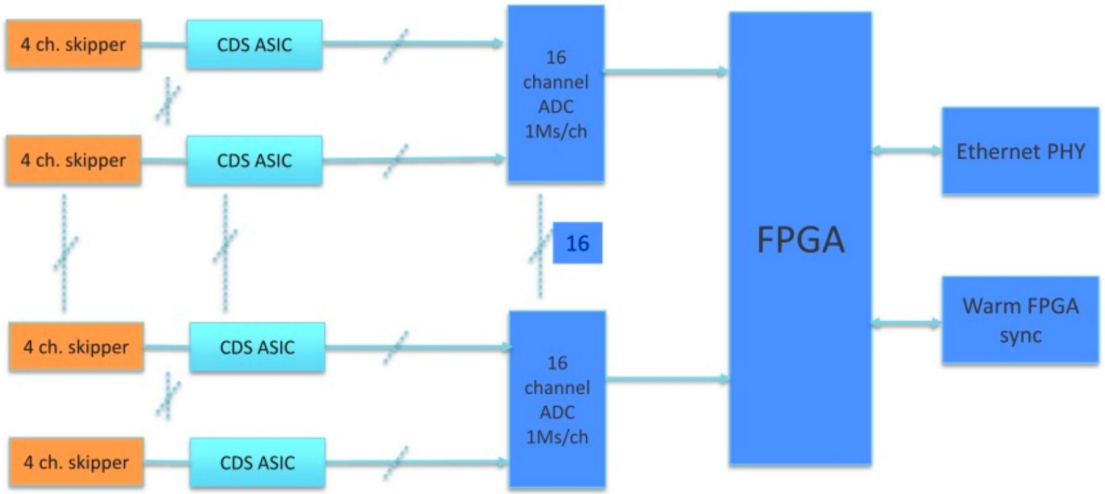


Time (~milliseconds per pixel to get photon counting capability)

Two approaches being followed to speed up the sensor

First approach: Development of parallel multichannel readout systems of thousands of channels.

- Enables readout speed for Astronomy and Quantum Imaging.
- This will be the readout electronic approach to follow for particle large arrays for Dark matter Neutrino detection (OSCURA and vIOLETA).

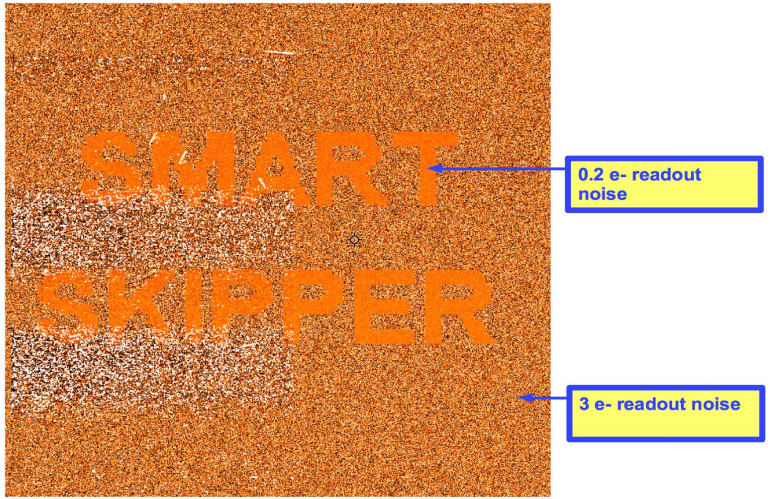


Two approaches being followed to speed up the sensor

Second approach: Smart Skipper. Adjust the speed of readout of each pixel depending on the pixel information or known information from the physical source. Add intelligence to the readout system (create smart sensor).

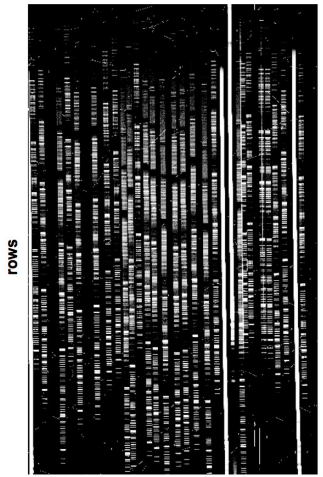
- Enables readout speed for Astronomy and Quantum Imaging.
- Allows to speed up all the current systems for particle detection.

CCD exposed to X-ray in a setup at FNAL

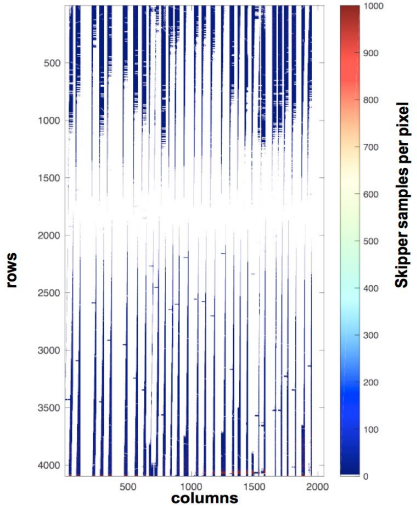


Example of online processing using region of interest scheme.

Original spect. image



Optimum number of samples per pixel



Example of offline processing of a real spectrograph image using pixel information. 100 times faster readout.

Conclusions

- **We should support the development of Skipper CCD technology in Latin America.**
- **We should support the labs and groups in Latin America doing R&D development on Skipper CCD.**
- **Bahia Blanca's CCD lab has made significant contribution in the Skipper technology.**
- **The next step for the Skipper CCD is to speed up its readout while keeping the single charge counting capability.**
- **Smart skipper techniques will be a solution for existing and future Skipper CCD sensors.**