Current HEP-IC projects

Other IC projects

Future projects

Devices and Sensors Division, Bariloche Atomic Center

High Energy Physics - Integrated Circuits Workshop 2022

Fabricio Alcalde Bessia

Nano-science and Nano-technology Institute (INN) National Atomic Energy Comission (CNEA) National Scientific and Technical Research Council (CONICET) Balseiro Institute, National University of Cuyo (UNCuyo)



May 18th, 2022



About	us
0000	
00	

Other IC projects

Future projects

▲□▶▲□▶▲□▶▲□▶ □ のQ@

Content



• The research group

Current HEP-IC projects

- MIDNA: A multi-channel cryogenic low-noise skipper-CCD readout ASIC
- Skipper-CCD in CMOS technology

Other IC projects

BUSARD: A monolithic HV-SOI particle detector

Near future developments

Moun detector using a hybrid SiPM-HBT IC

About	u
0000	
00	

Other IC projects

Future projects

Where are we?



(ロ) (国) (E) (E) (E) (O)(C)

About	u
0000	
00	

Other IC projects

Future projects

San Carlos de Bariloche



Current HEP-IC projects

Other IC projects

Future projects

San Carlos de Bariloche



900

Other IC projects

Future projects

Most relevant facilities at the Bariloche Atomic Center





National Atomic Energy Commission

- Campus size: 460,000 m².
- RA-6 Nuclear Research Reactor (1 MW thermal)
 - Neutron Radiography, BNCT, activation analysis and radiation sources.
- Radiotherapy Center
 - 15MV LINACs, PET/CT/MR, Cyclotron.
- Micro-Nano Technology Clean room
 - PhotoLithography, Sputtering, RIE, SEM/TEM, Molecular Beam Epitaxy.
- 1.7 MV tandem accelerator
 - PIXE, RBS, NRA, ERDA, etc.

About	u
0000	
•0	

Other IC projects

Future projects

▲□▶▲□▶▲□▶▲□▶ □ のQ@

Outline

Location and facilities in the Bariloche Atomic Center
 The research group

Current HEP-IC projects

- MIDNA: A multi-channel cryogenic low-noise skipper-CCD readout ASIC
- Skipper-CCD in CMOS technology

3 Other IC projects

BUSARD: A monolithic HV-SOI particle detector

Near future developments

• Moun detector using a hybrid SiPM-HBT IC

Current HEP-IC project

Other IC projects

Future projects

The research group



Dr. J. Lipovetzky, Dr. M. Gómez Berisso, Dr. J. Blostein,

Dr. I. Sidelnik, Dr. M. Sofo Haro, Dr. M. Pérez

A group formed by Nuclear Engineers, Physicist and Electronics Engineers.

Research topics:

- Radiation monitoring, X-ray radiography/densitometry using CIS.
- Neutron detectors and neutron imaging.
- Neutron conversion materials and deposition.
- Detectors for high-energy physics and astrophysics: CCD, Cherenkov, hybrid, monolithic.

About	us
0000	
00	

Other IC projects

Future projects

▲□▶▲□▶▲□▶▲□▶ □ のQ@

Outline

Location and facilities in the Bariloche Atomic Center
 The research group

Current HEP-IC projects

- MIDNA: A multi-channel cryogenic low-noise skipper-CCD readout ASIC
- Skipper-CCD in CMOS technology

3 Other IC projects

• BUSARD: A monolithic HV-SOI particle detector

Near future developments

• Moun detector using a hybrid SiPM-HBT IC

Current HEP-IC projects

Other IC projects

Future projects

The OSCURA experiment

Motivation

- Identify the nature of dark matter by direct detection of sub-GeV particle interactions.
- OSCURA aims at reading out 10 kg of skipper-CCDs working at low temperature (120 K). → ≈ 24000 CCDs.
- Single electron sensitivity is required.
- Skipper CCDs enable the non-destructive readout of the same charge packet many times.
- By averaging short reads the readout noise can be lowered.
- This technique avoids the 1/f noise limitation.



The OSCURA Experiment. arXiv:2202.10518

Other IC projects

Future projects

MIDNA: A multi-channel cryogenic low-noise skipper-CCD readout ASIC

- Designed in collaboration with Fermilab ASIC group.
- Fabricated in a 65 nm CMOS process.
- Designed to work at 120 K.
- ¹/₃ of CCD noise at 120 K (not guaranteed at room temperature).
- Uses 2.5 V transistors for voltage headroom (3000 e⁻ of dynamic range).
- Analog CDS using a Dual-Slope Integrator.
- 4 full readout channels in single chip.
- Replaces several costly PCB components.
- pprox 6000 chips will be used in OSCURA.



1 mm

Current HEP-IC projects

Other IC projects

Future projects

MIDNA: Testing of the first prototype

- Low-activity Fe-55 X-ray source:



Readout gain and noise:



Noise limited by CCD. Same performance as the discrete electronics solution!

- Noise reduction by averaging skipper samples:



Readout noise follows the 1/sqrt(N) reduction.
Piling-up samples in MIDNA's integrator enables single electron resolution:



About	US
0000	
00	

Other IC projects

Future projects

▲□▶▲□▶▲□▶▲□▶ □ のQ@

Outline

- Location and facilities in the Bariloche Atomic Center
 The research group
- Current HEP-IC projects
 - MIDNA: A multi-channel cryogenic low-noise skipper-CCD readout ASIC
 - Skipper-CCD in CMOS technology

Other IC projects

• BUSARD: A monolithic HV-SOI particle detector

Near future developments

• Moun detector using a hybrid SiPM-HBT IC

Other IC projects

Future projects

Skipper-CCD in CMOS technology testchip

- Development effort between SLAC, Fermilab and CAB.
- Fabricated in a 180 nm CMOS process.
- Sub-micrometer technology → Small gap between CCD gates & small sense-node.
- Pinned photodiode → Low dark current & high QE.
- Image sensor tech. \rightarrow BSI.
- The testchip includes several pixel flavors with variations in PPD and CCD sizes.



About us	
0000	

Other IC projects

Future projects

▲□▶▲□▶▲□▶▲□▶ □ のQ@

Outline

- Location and facilities in the Bariloche Atomic Center
 The research group
- 2 Current HEP-IC projects
 - MIDNA: A multi-channel cryogenic low-noise skipper-CCD readout ASIC
 - Skipper-CCD in CMOS technology
- Other IC projects
 BUSARD: A monolithic HV-SOI particle detector
- Near future developments
 - Moun detector using a hybrid SiPM-HBT IC

Other IC projects ○●○

BUSARD: A monolithic HV-SOI particle detector

- Developed in collaboration between Karlsruhe Institute of Technology (Germany) and Instituto Balseiro (Argentina).
- 180 nm High-Voltage Low-Power SOI-CMOS technology which includes N-Buried Diffusion and Handle Wafer Contacts.
- Depletion region depth around 30 to 50 μ m.



- Analog pixel design:



- In-pixel hit counter, Time-over-Threshold and charge-sharing mode.
- Tune DACs for threshold equalization across matrix.

▲□▶▲□▶▲□▶▲□▶ □ のQ@

• Synthesized digital controller with conf. registers.

BUSARD particle detector. arXiv:2112.03166

Other IC projects

Future projects

BUSARD: A monolithic HV-SOI particle detector

- The IC contains a matrix of 13×13 pixels.
- Pixel size $80\mu m \times 80\mu m$.
- Digital communication with LVDS I/Os.
- Charge injection input and analog test output.



BUSARD particle detector, arXiv:2112.03166





- Electronics noise: 100 e⁻_{rms}
- Slightly non-linear response from 8 keV to 30 keV.

About	us
0000	

Other IC projects

Future projects

Outline

- Location and facilities in the Bariloche Atomic Center
 The research group
- 2) Current HEP-IC projects
 - MIDNA: A multi-channel cryogenic low-noise skipper-CCD readout ASIC
 - Skipper-CCD in CMOS technology
- 3 Other IC projects
 - BUSARD: A monolithic HV-SOI particle detector
 - Near future developments
 - Moun detector using a hybrid SiPM-HBT IC

Other IC projects

Future projects

Moun detector using a hybrid SiPM-HBT IC

- Improve time resolution of muon detectors used in AMIGA (Auger Observatory) and MuTe (Muon Telescope).
- Replace the current electronics with a hybrid SiPM-BiCMOS approach.
- Targeting IHP 130 nm SiGe BiCMOS process.
- Take advantage of the very high f_t and high gm of Heterojunction Bipolar Transistors (HBT) to reach picosecond time resolution.
- Currently in the process of establishing the collaboration.





Current HEP-IC projects

Other IC projects

Future projects



Comisión Nacional de Energía Atómica

Thank you

falcalde@ib.edu.ar





