The Costanera controller: a modular open-hardware project for and by undergrads

Image: Students, supervisors and board at LAMBDA laboratory

G. Alvarez[1], A. M. Botti[2], F. Pietra[1], D. Rodrigues[1], G. Schialchi[1], G. Sierra[1], M. Obst[1], M. Sofo Haro[3], J. Tiffenberg[1]

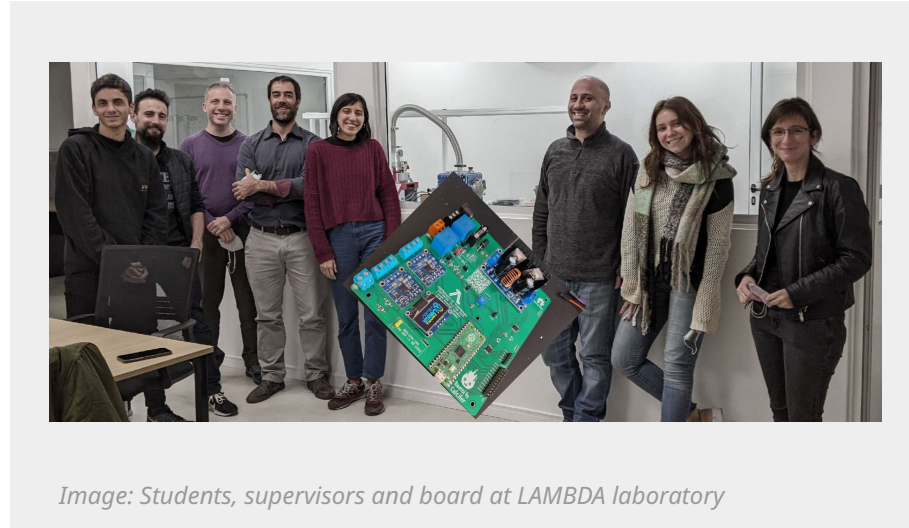18th International Conference on Topics in Astroparticle and Underground Physics, Vienna

August 31, 2023

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2 Fermi National Accelerator Laboratory · abotti@fnal.gov
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Skipper-CCDs

➢ Pixeled **silicon** detector with **ultra low** read out **noise**

➢ Designed at **LBNL**, first integration at **FNAL** @ 2017

➢ Many science applications: **dark matter, neutrinos, quantum imaging, sky surveys, x-ray detection**, etc.

➢ **8 experiments** in TAUP@2023 showing skipper data

➢ **~ 20 institutions** world wide using this technology
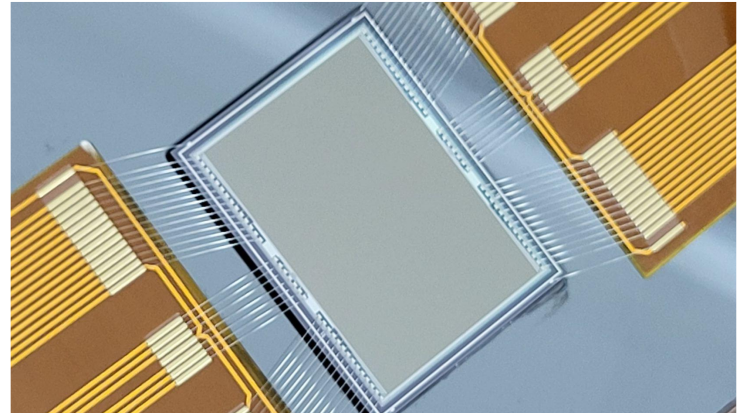
El laboratorio LAMBDA*

- ➤ Joint laboratory **Buenos Aires University** & **Fermilab**
- ➤ Directors:
  - ○ Darío Rodrigues (UBA)
  - ○ Javier Tiffenberg (FNAL)
- ➤ Main research topics:
  - ○ **Quantum Optics** with Skipper-CCD
  - ○ **Dark Matter** searches
  - ○ **Reactor-neutrino** physics experiments using Skipper-CCDs
  - ○ CCD **R&D** and characterization
- ➤ After 1 year anniversary:
  - ○ **2 full** Skipper-CCD systems producing papers
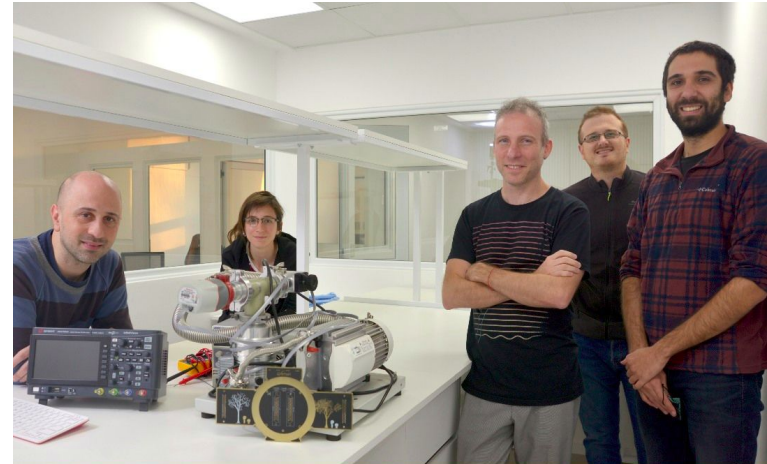 - ○ 1 more to build
  - ○ 7 publications

Image: photo taken before the inauguration of the laboratory on June 2022

* Laboratorio Argentino de Mediciones de Bajo umbral de Detección y sus Aplicaciones

http://lambda.df.uba.ar
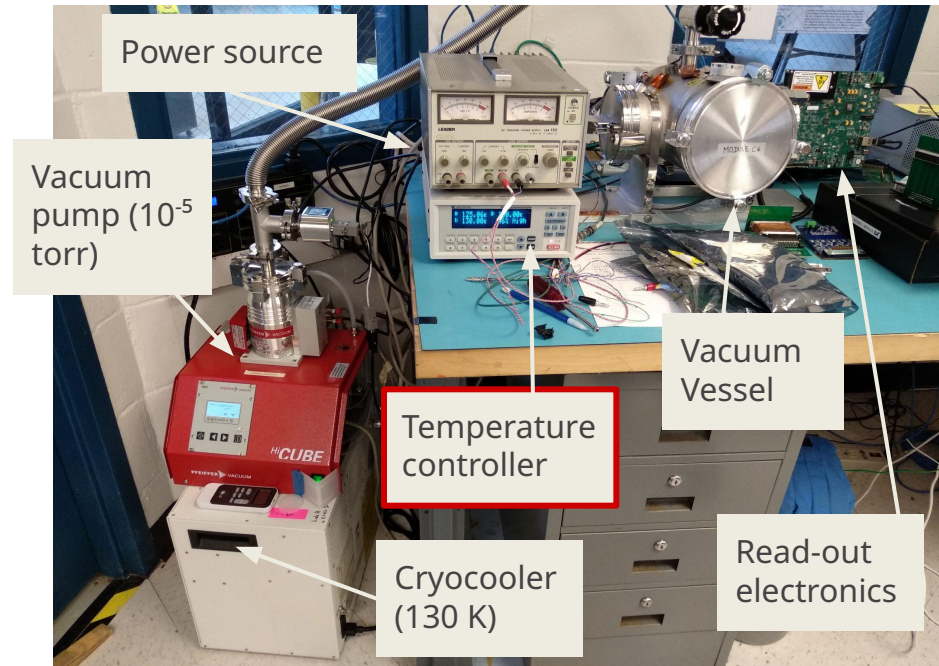
Buenos Aires University

➢ It's a big school:

- ○ 13 Faculties with 87 degrees (undergrad)

- ○ Public with no admission fees

- ○ Students (2011): **308 748** (the second most populated city in Austria, Graz, has 292,630 people)

➢ **Physics program:**

- ○ **6** year undergrad diploma (average **7~8 years**)

- ○ Same program for theoretical and experimental

- ○ **1** year **experimental** research project (~ BSc thesis)

- ○ **1** year thesis (~ MSc level).

- ○ Research project in other institutions allowed (we have many students coming to Fermilab).

- ○ **5** year **Ph.D.**

*Image: EHT seminar at UBA (2019). Credits: Exactas UBA comunicación*

Skipper-CCD setup

➢ Vacuum vessel

➢ Vacuum pump (10^{-5} torr)

➢ Cryocooler

➢ Power source

➢ Low-threshold acquisition board

➢ **PID temperature controller**

   ○ ~ U\$S 20k

   ○ ~ 6 months purchase delay

Power source

Vacuum pump (10^{-5} torr)

Vacuum Vessel

Temperature controller

Read-out electronics

Cryocooler (130 K)

New PID temperature controller

➤ **Open hardware**

➤ **Scalable** modular design

➤ Commercial available components

➤ **Generic** components

➤ Raspberry pi pico

➤ Firmware in **microPython**

➤ PCB on **kiCAD**

➤ Multi platform client

➤ **< U$S 100** (commercial PID costs 20k)

➤ **40 W** with low electrical noise and 0.1 K stability
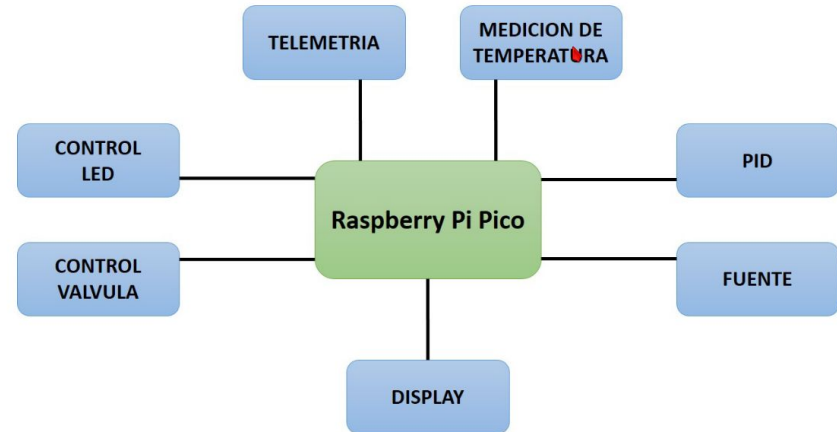
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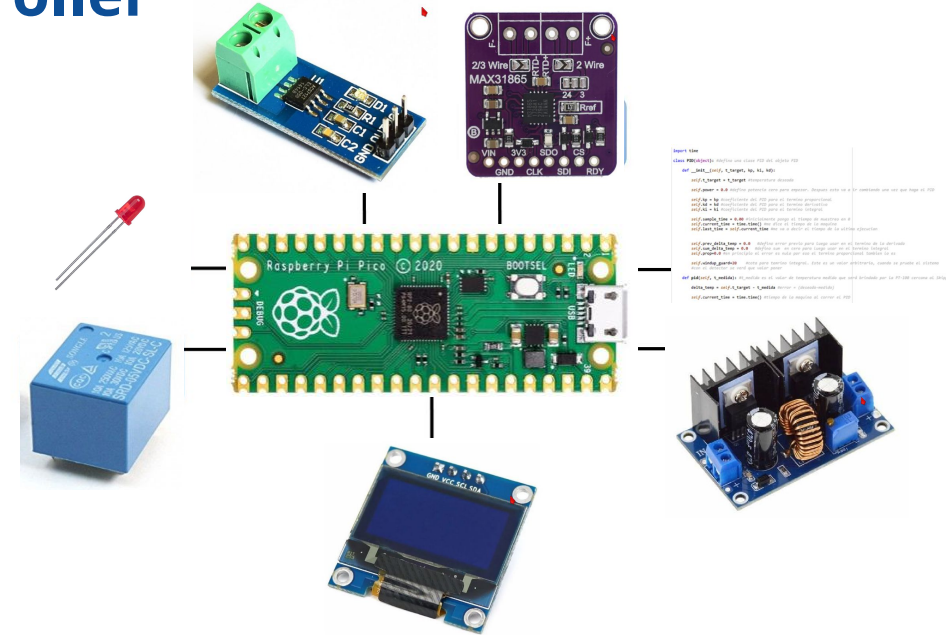
Methodology

➢ **5 students at LAMBDA**

➢ 4 ~ BSc

➢ 1 ~ MSc

➢ First semester during the **pandemic** (no access to labs)

➢ Few months understanding **thermodynamics** and **skipper** sensors (DM, neutrinos, xray)

➢ Define **common** and **individual** tasks

➢ **Individual** and **general** meetings (mostly remote)

➢ Individual progress **implemented** and **tested** by other groups

➢ **Rough** at the beginning, but **great synergy** between groups after a little while

➢ **Final reports** with results and **physics** impact

Commons tasks

➢ Programmer
➢ Micro controller
➢ SPI/IC communications
➢ Client communication
➢ Version control
➢ Instrument Calibration

Individual tasks

➢ Module implementation
➢ Simulations
➢ Framework development and testing
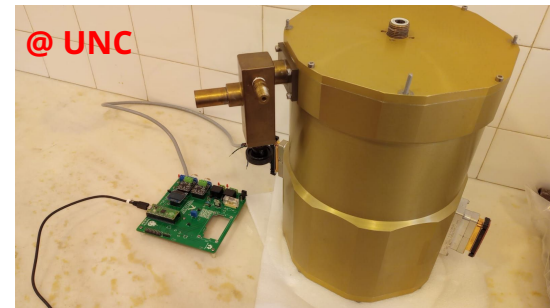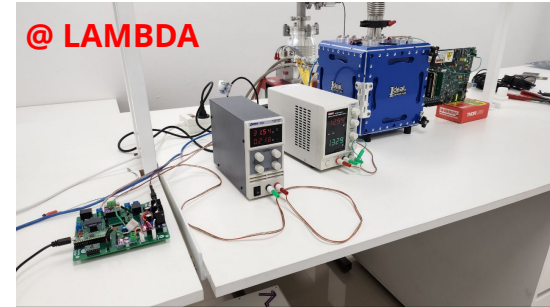➢ Calibration
➢ Client software
➢ PID algorithm
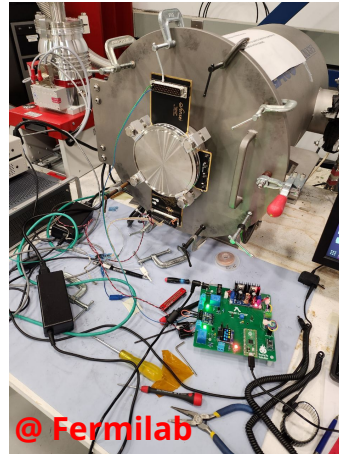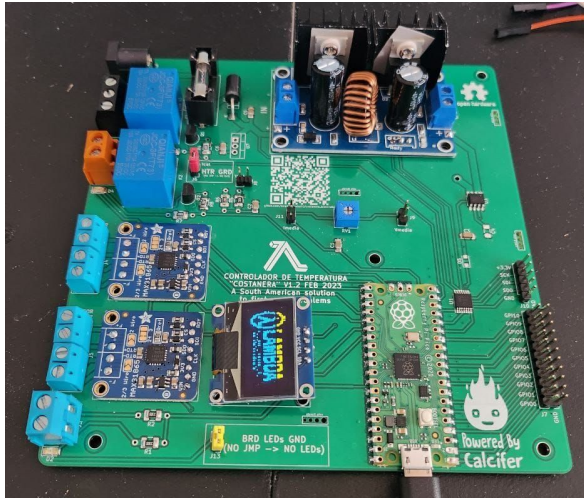➢ PCB Design
➢ Component selection and purchase

And the design
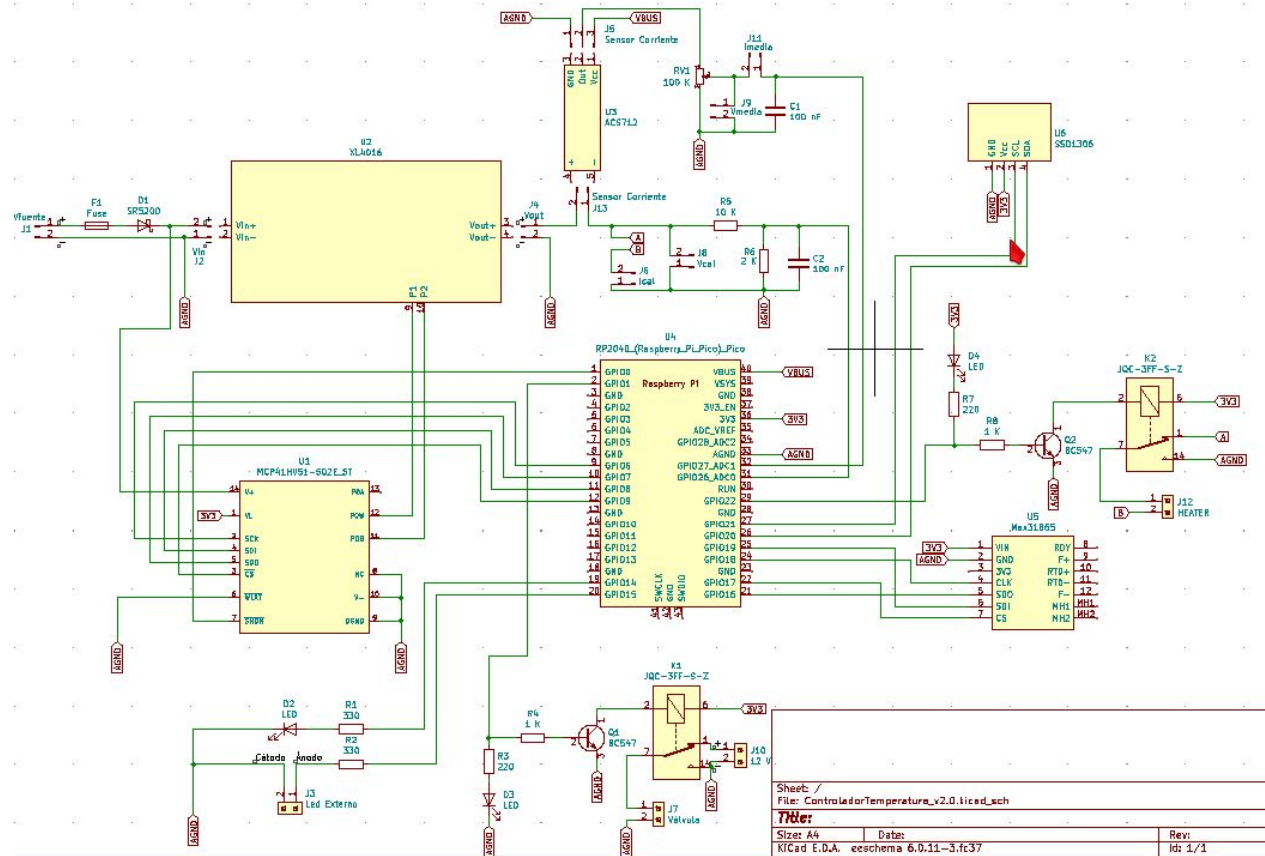
Implementation
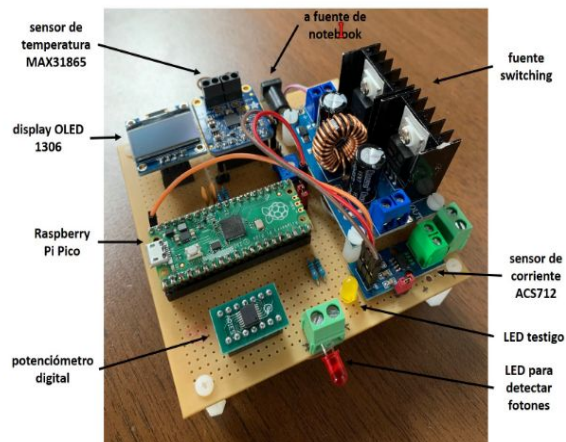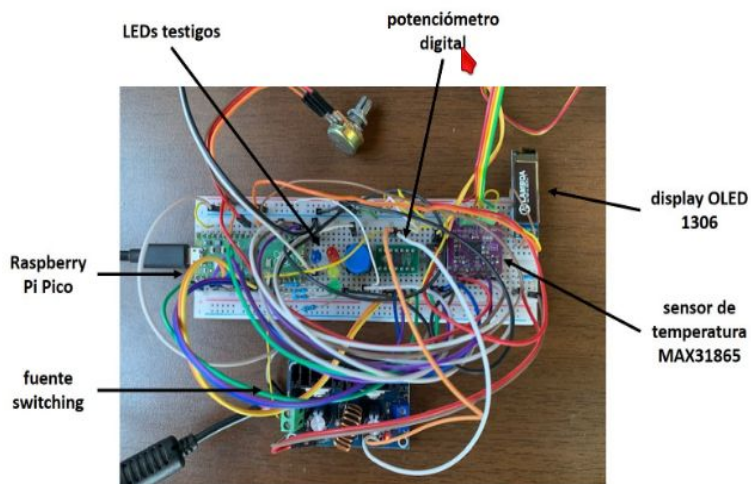
And... with a little help from the supervisors :)

@ LAMBDA

@ Fermilab
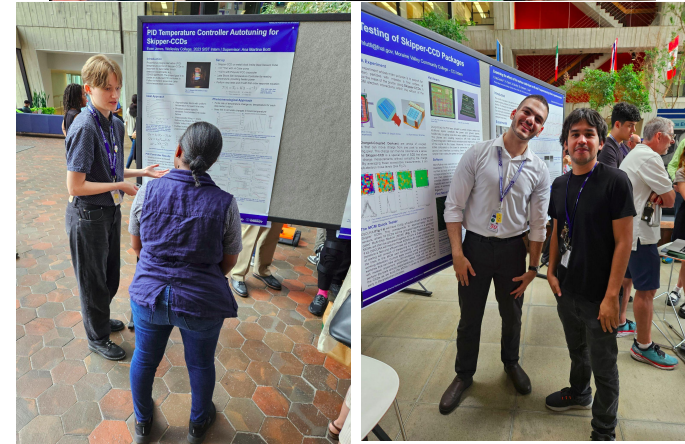
@ UNC

Outcome

➢ Working PID temperature controller

➢ Open hardware / open software system ready to download

➢ Repository with hardware and software available

➢ Tested in 5 setups at 3 institutions

➢ 5 1-year undergrad research project completed

➢ Scalable device

➢ Many new projects from this initial experience

➢ Improvements on this board

➢ New hardware to replace commercial tools
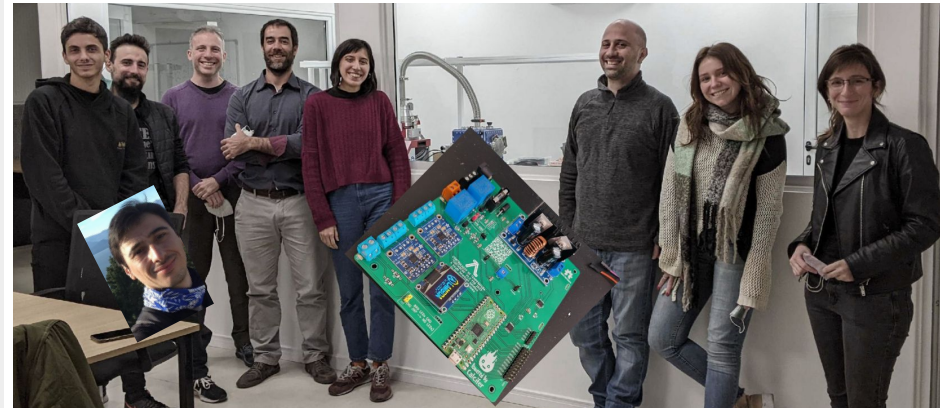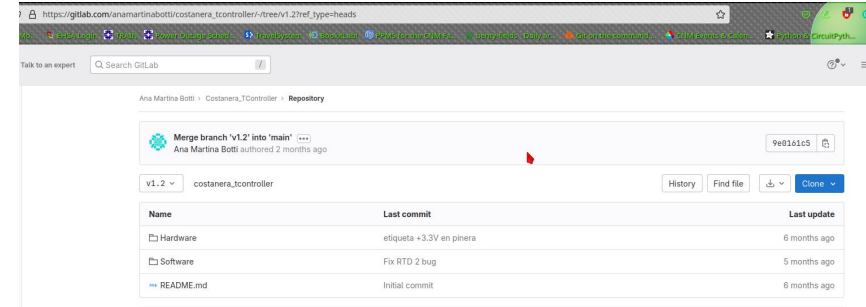
Lessons learnt

➢ Open hardware is actually useful

➢ Students projects can be broad (hardware, software, data analysis, etc.)

➢ Collaborative work at an early stage works!

➢ These projects can be adapted to students interests and needs: electronics, physics, computing, etc.

➢ New projects for summer interns or thesis (physics/engineering):

 ○ 6 new students from LAMBDA

 ○ 2 students from Paraguay

 ○ 2 summer interns at Fermilab

 ○ 8 PIs/Postdocs/Engineers supervising

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Student projects are a little bit too fun. Hard to stop senior scientists from doing them.

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Lessons learnt

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➢ Students projects can be broad (hardware, software, data analysis, etc.)

➢ Collaborative work at an early stage works!

➢ **These projects can be adapted to students interests and needs: electronics, physics, computing, etc.**

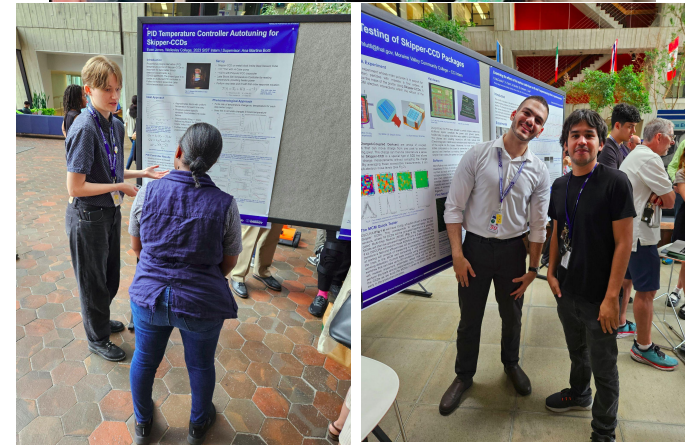➢ New projects for summer interns or thesis (physics/engineering):

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Ideas for the future

- ➢ We started at **LAMBDA** with **5 students** 3 Scientist and 1 postdoc on August 2021
- ➢ Now we added up to **15 students** and 9 collaborators from 8 different institutions in **3 countries**
- ➢ Build a **network** for **collaborative** student **projects** on instrumentation, open hardware and software
- ➢ Provide **ideas** to the community for **undergrads** interested in electronics, instrumentation, hardware, software, etc.
- ➢ **Deliver** instrumentation **solutions** to laboratory needs

Thanks to all the people involved

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Q. Pears Stefano (DF - Argentina)

A. Pereyra (LAMBDA - Argentina)

S. Perez (LAMBDA - Argentina)

F. Pietra (LAMDA - Argentina)

D. Rodrigues (LAMDA - Argentina)

G. Schialchi (LAMDA - Argentina)

G. Sierra (LAMDA - Argentina)

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