# **Caribou:** A Versatile Data Acquisition System for Silicon Pixel Detector Characterization

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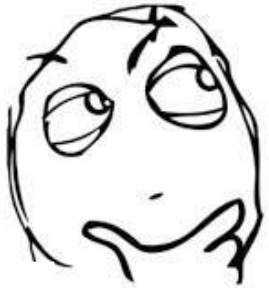
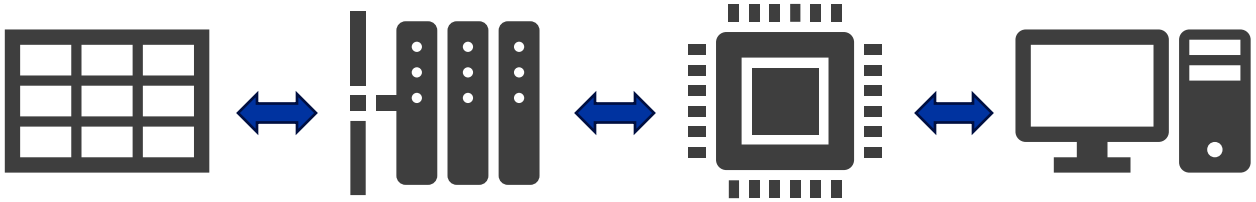
**EP R&D Seminar – 14 October 2024**

# What is it and why is it ?

# A particular solution to a particular need

Most silicon pixel detectors share the same power, control and readout concepts
(voltage/current supply, high speed data, communication protocols)





Pixel device | Interface electronics | FPGA processing | Software processing

# A particular solution to a particular need

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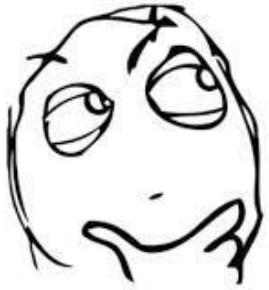
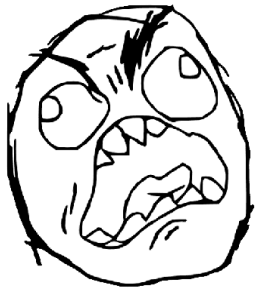
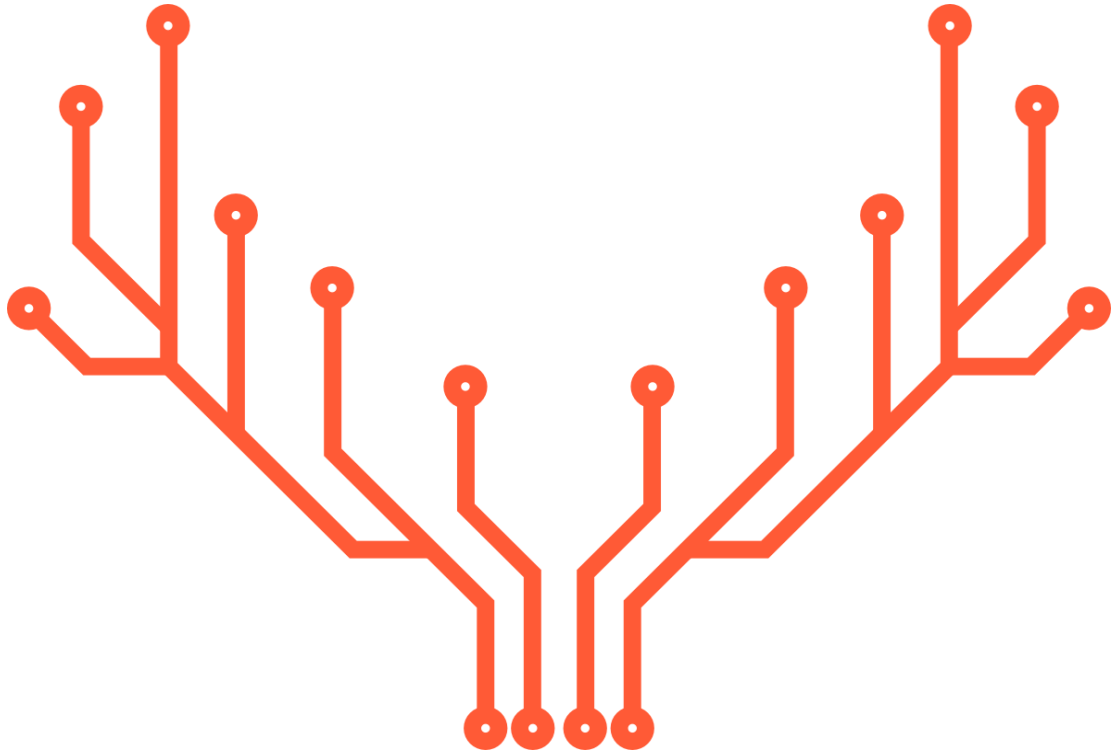




Every new prototype drives the development of a new DAQ system or modification of an exisiting one
(time consuming, not very efficient)

Why not a common versatile DAQ system ?
(Common hardware, firmware and software suit, keeping the focus of users on detector integration)

# A particular solution to a particular need

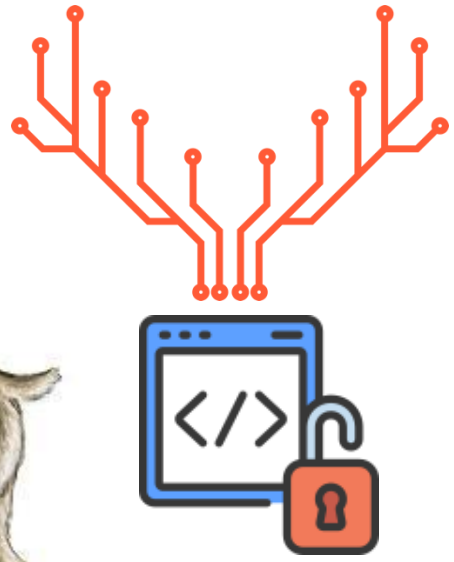


Caribou

# Collaborating towards the open

Open source hardware, firmware and software for laboratory and beam tests

Publications

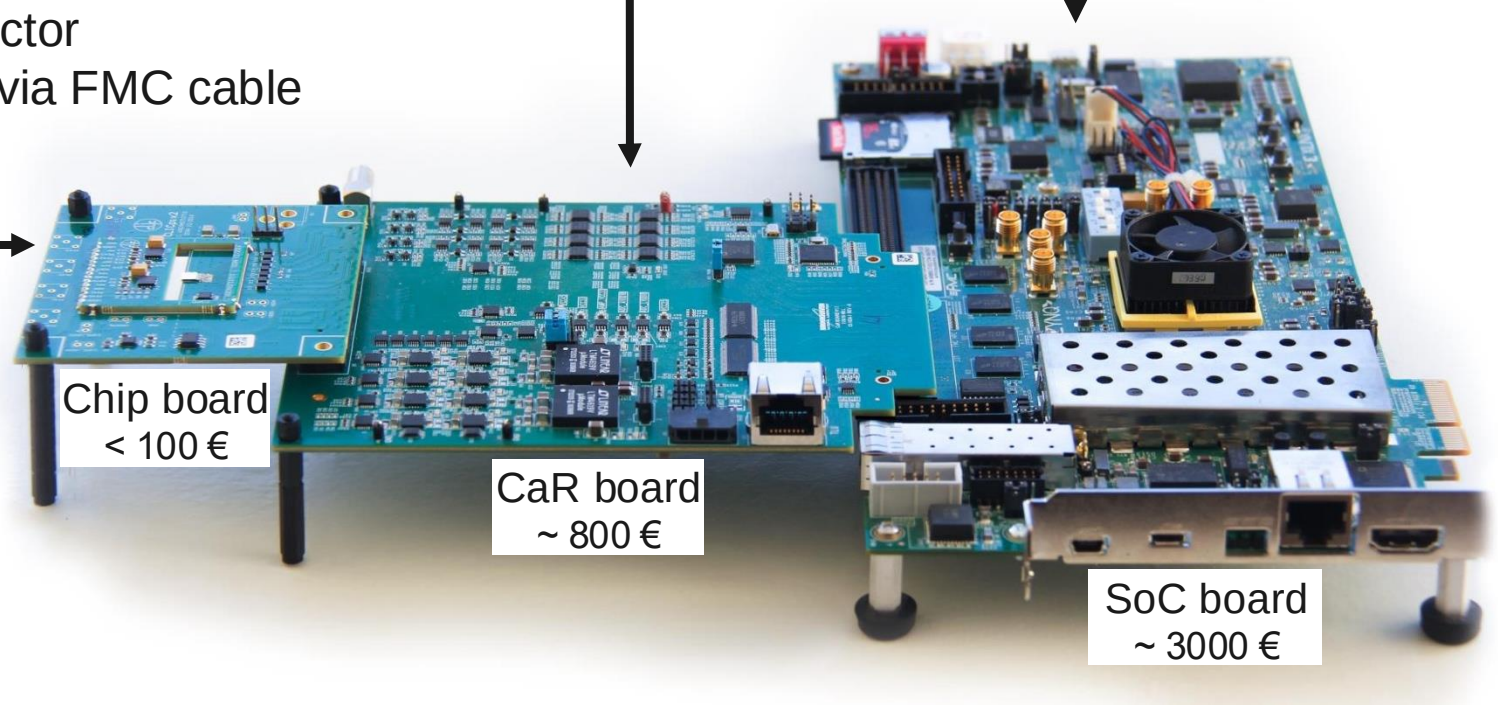


Gitlab

Developped by a collective effort of hardware, firmware and software developers

# A simple system architecture

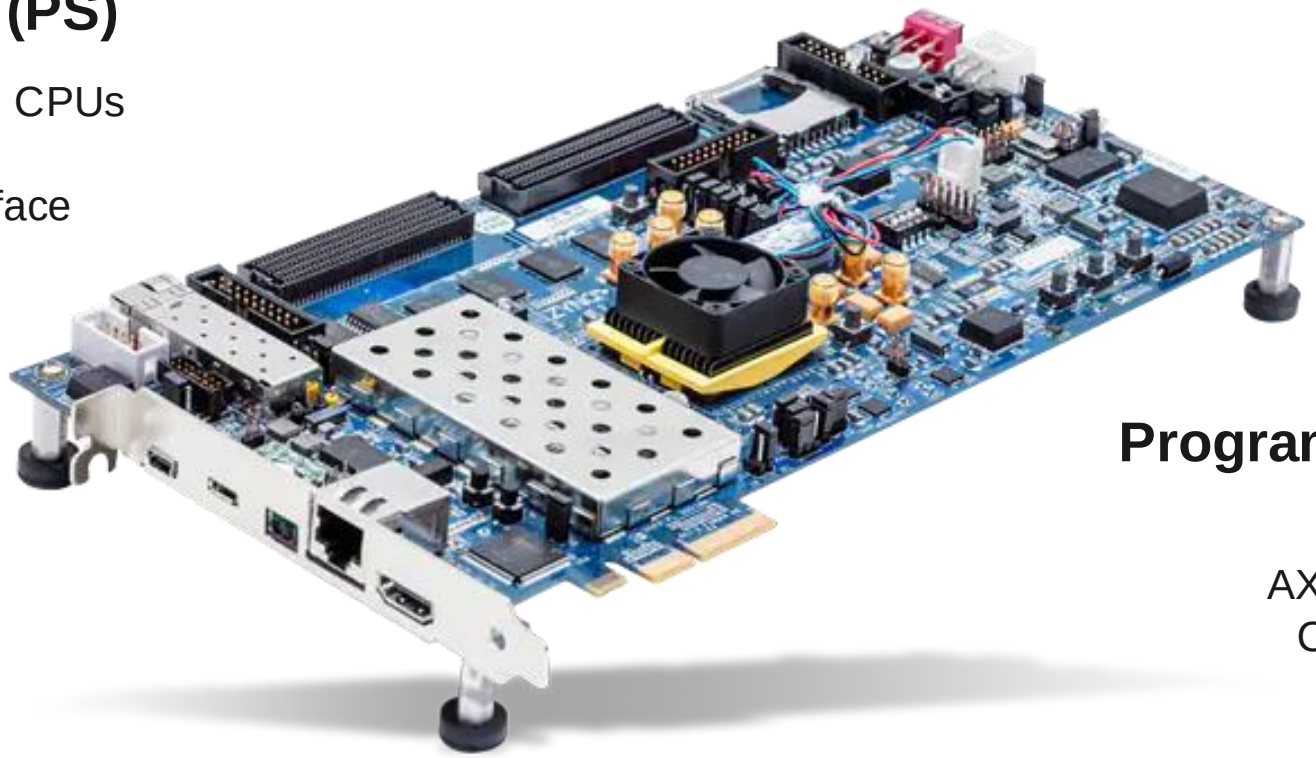
- **System-on-Chip (SoC) board**
  - ie: Xilinx ZC706 evaluation board
  - Embedded CPU runs DAQ and control software
  - FPGA runs custom firmware for detector control and readout
- **Control and Readout (CaR) interface board**
  - Physical interface from SoC to detector
  - CaR – SoC connection extendable via FMC cable
- **Detector (chip) carrier board**
  - Custom low-cost PCB
  - Designed by users



# A commercial System-on-Chip board

## Processing System (PS)

2 x ARM Cortex-A9 MPCore CPUs
Petalinux image
Network/ssh control interface
Caribou software



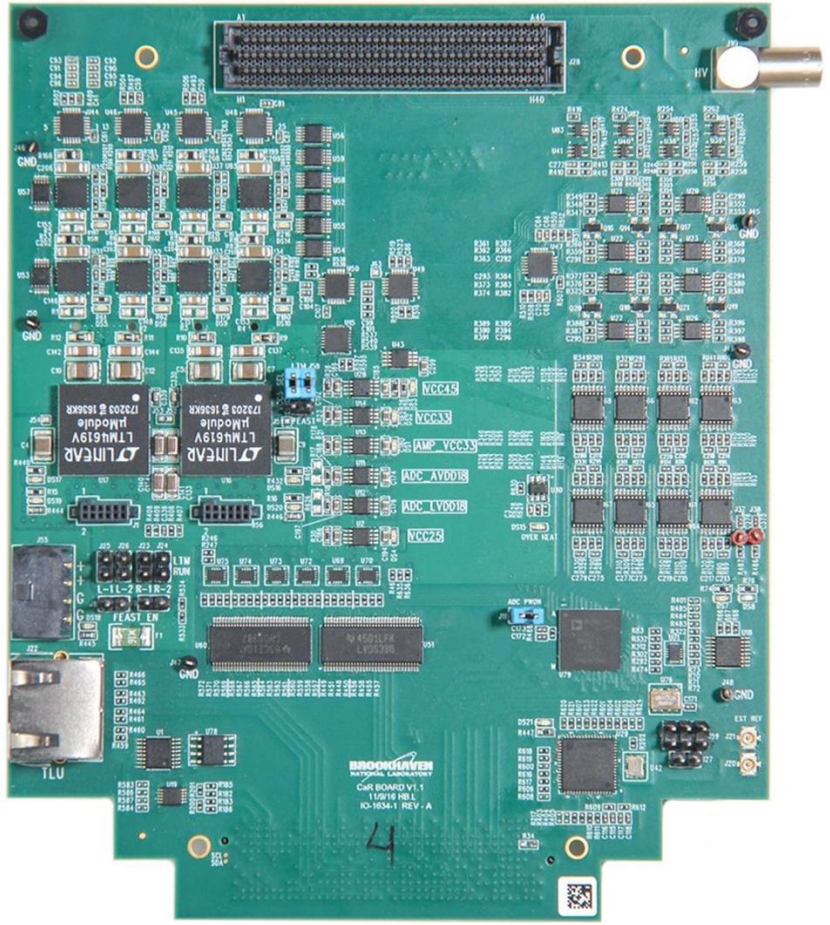
Xilinx ZC706 evaluation board

## Programmable Logic (PL)

Kintex-7 FPGA
AXI control interface
Caribou firmware

# A multifeature CaR board

| Feature | Description |
|---|---|
| Adjustable Power Supplies | 8 units, 0.8 – 3.6 V, 3 A |
| Adjustable Voltage References | 32 units, 0 – 4 V |
| Adjustable Current References | 8 units, 0 – 1 mA |
| Voltage Inputs to Slow ADC | 8 channels, 50 kSPS, 12-bit, 0 – 4 V |
| Analog Inputs to Fast ADC | 16 channels, 65 MSPS, 14-bit, 0 – 1 V |
| Programmable Injection Pulsers | 4 units |
| Full-Duplex High-Speed GTx Links | 8 links, <12 Gbps |
| LVDS Links | 17 bidirectional links |
| Input/Output Links | 10 output links, 14 input links, 0.8 – 3.6 V |
| Programmable Clock Generator | Included |
| External TLU Clock Reference | Included |
| External High-Voltage (HV) Input | Included |
| FEAST Module Compatibility | Supported |
| FMC Interface to FPGA | Included |
| SEARAY Interface to Detector Chip | 320-pin connector |



Resources for various target applications

**More than 50 CaR boards to 14 institutes**

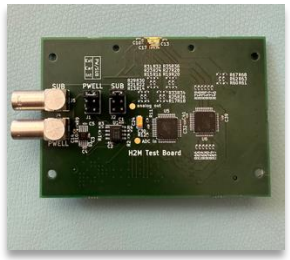
Production and distribution coordinated by WP-1.4

# A custom detector chip board

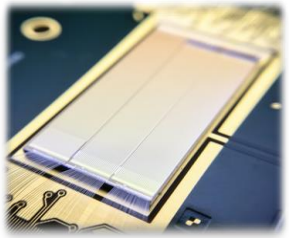
- **Detector-specific**
  - Physical hardware hosting the detector
  - Only provide passives and detector-specific components

- **Multiple detectors already integrated and tested:**

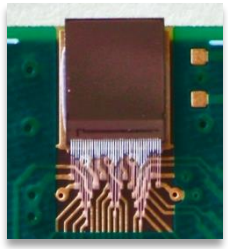
H2M



ATLASpix



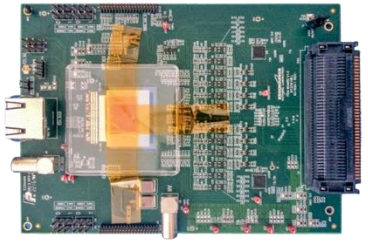
CLICpix2



CLICTD

FASTPIX

H35Demo/FEI4

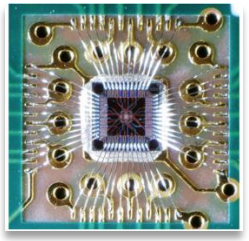


RD50-MPW1

RD50-MPW2

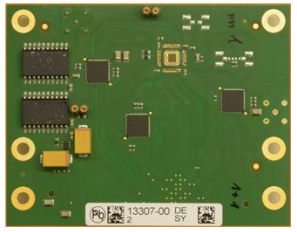
RD50-MPW3

APTS

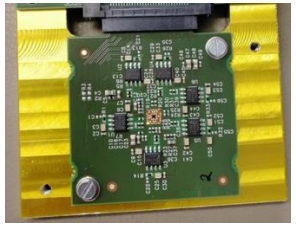


DPTS

dSiPM



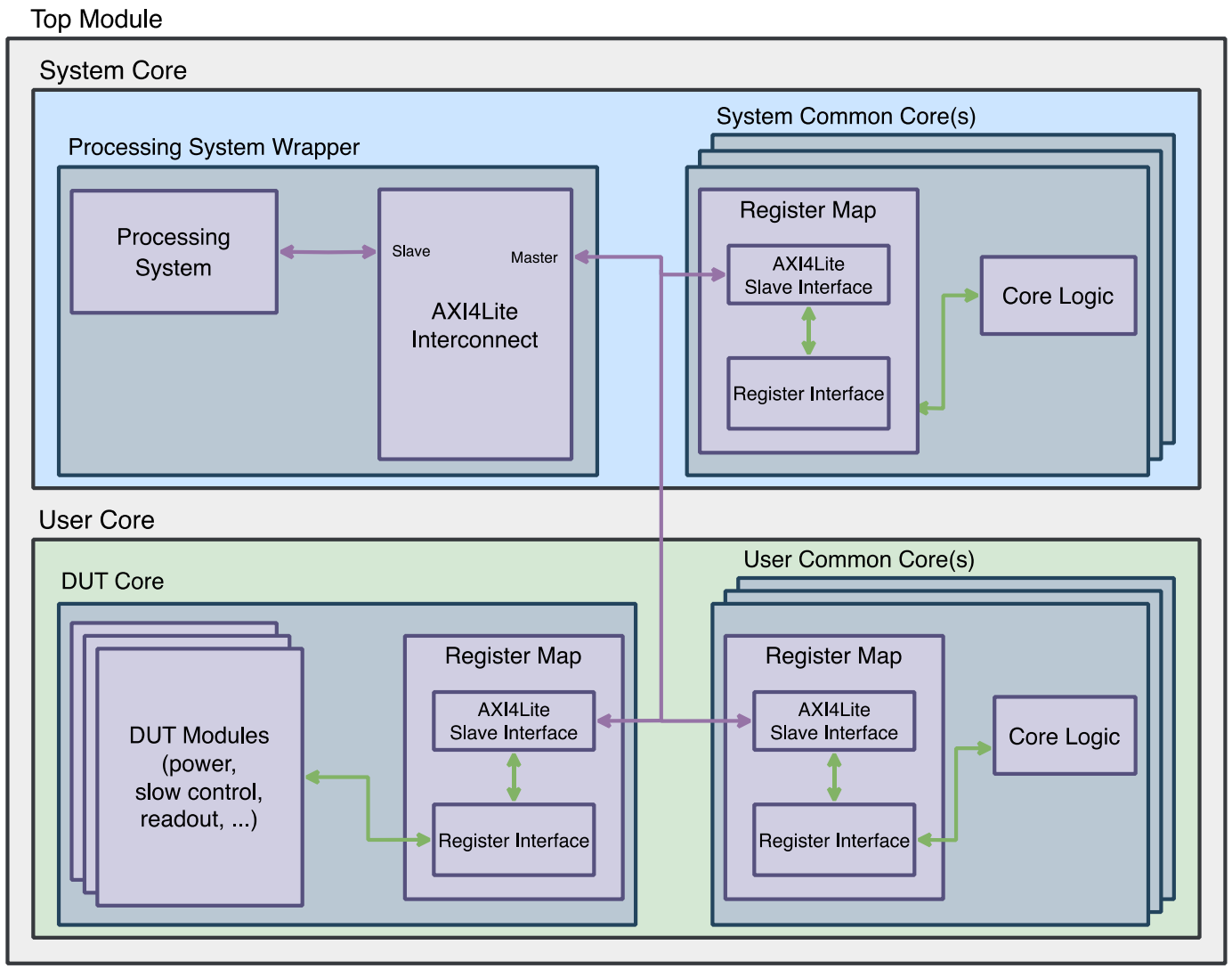
MLR1

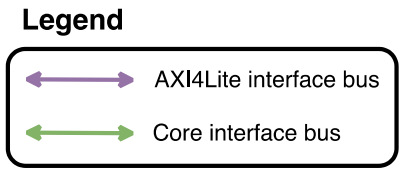


CoRDIA

# What else ?

# Caribou Boreal firmware




## Unified, modular and configurable

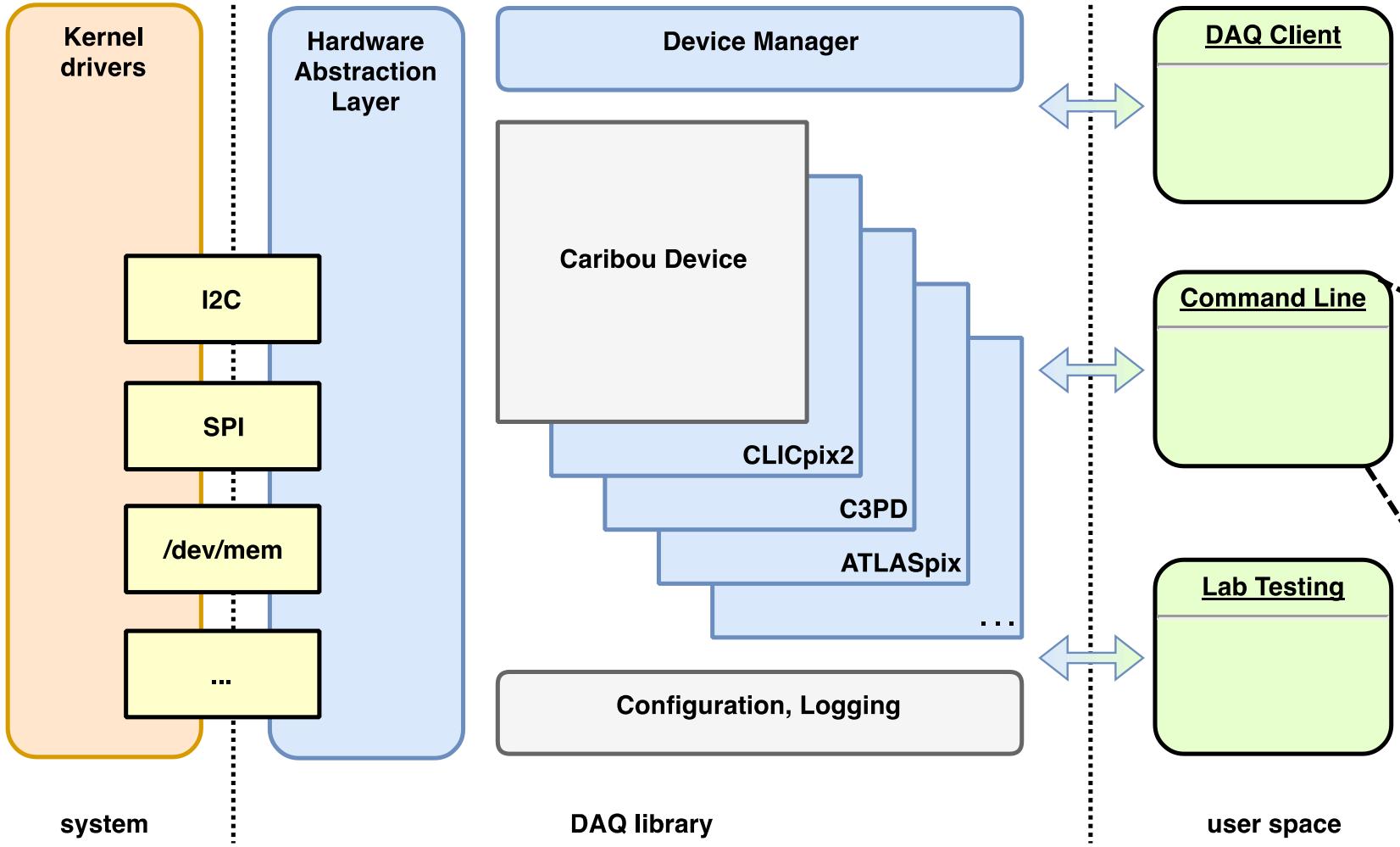
## Streamlined CI/CD workflow

Linting, simulation, building


## Integration pilot projects:

- *H2M* : DESY, CERN
- *MPW4* : Sevilla University

# Caribou Peary software



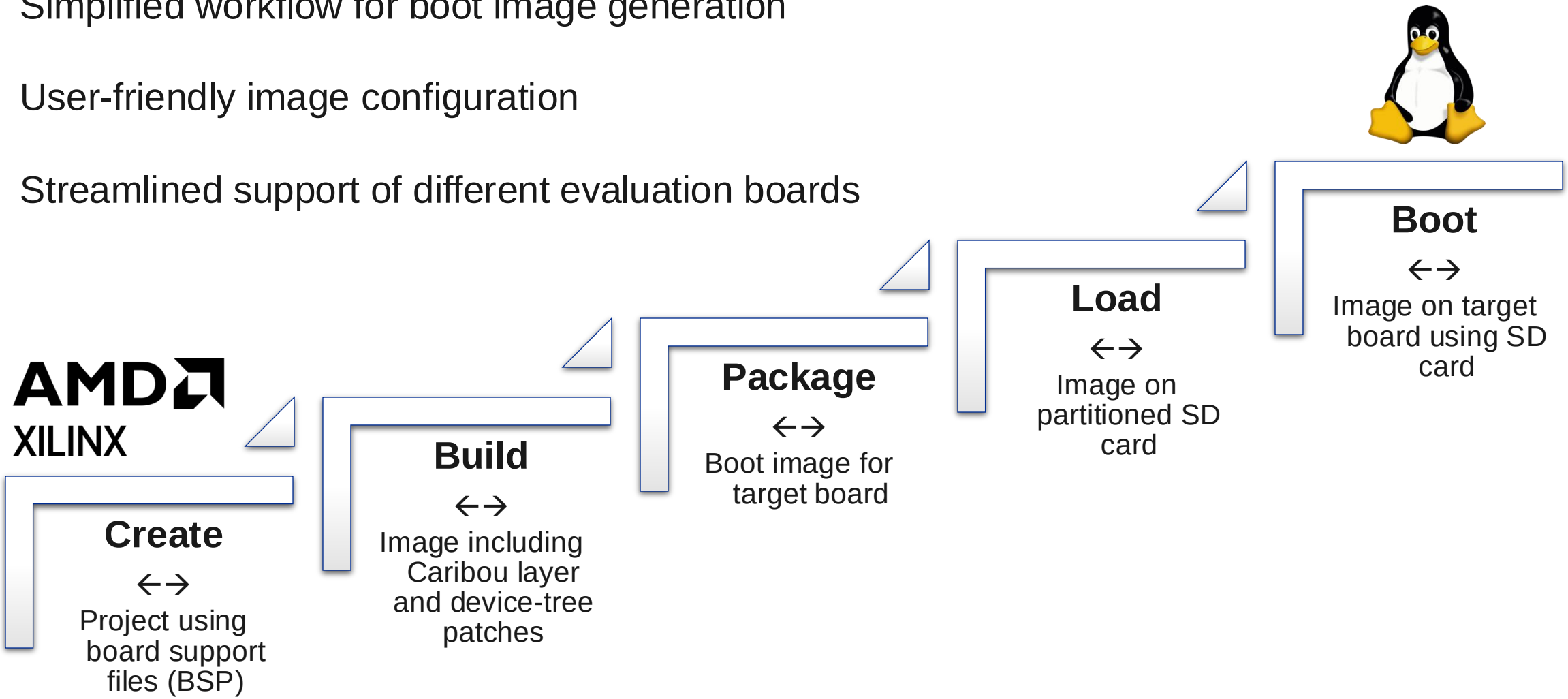

**Unified, modular**

Provides many features needed in laboratory and test-beam

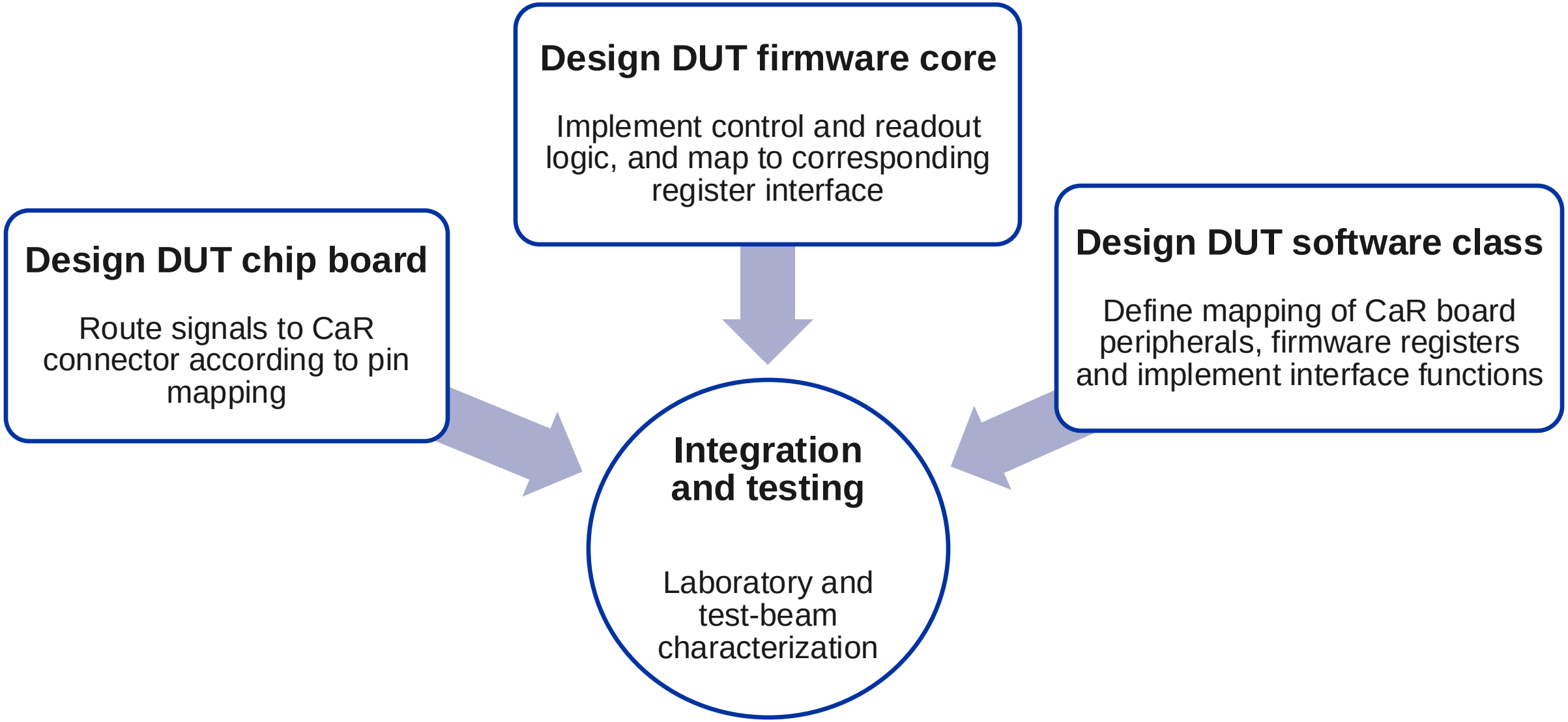
```
root@caribou:~# pearycli
|10:52:16.360| (WARNING) No configuration file provided, all devices will use defaults!
|10:52:16.361|    (INFO) Welcome to pearyCLI.
|10:52:16.361|    (INFO) Currently 0 devices configured.
|10:52:16.361|    (INFO) To add new devices use the "add_device" command.
# add_device H2M
|10:52:22.536|    (INFO) Creating new instance of device "H2M".
|10:52:22.536|  (STATUS) New Caribou device instance, version peary v0.11.0+447^g638de98f
|10:52:22.536|  (STATUS) This device is managed through the device manager.
|10:52:22.537|  (STATUS) Firmware version: 0x00000000 (0/0/2000 0:0:0)
|10:52:22.537|  (STATUS) Board ID: 19 Board Revision: 0x01
|10:52:22.546|    (INFO) Appending instance to device list, device ID 0
|10:52:22.546|    (INFO) Manager returned device ID 0.
# powerOn 0
|10:52:28.500|    (INFO) [H2M] Powering up
```

# Petalinux image builder

- Simplified workflow for boot image generation
- User-friendly image configuration
- Streamlined support of different evaluation boards



# Device integration workflow



# Application examples

- Support for various readout schemes
  - Digital interface via GTx or LVDS
  - Analogue waveforms (ADC or oscilloscope)

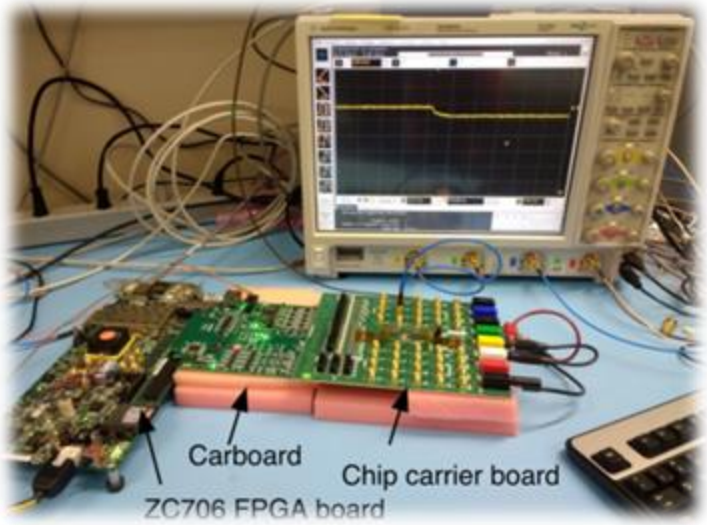
- Integration in beam telescope setups
  - Timepix3/SPIDR, Mimosa/EUDAQ, ALPIDE

Telescope integration

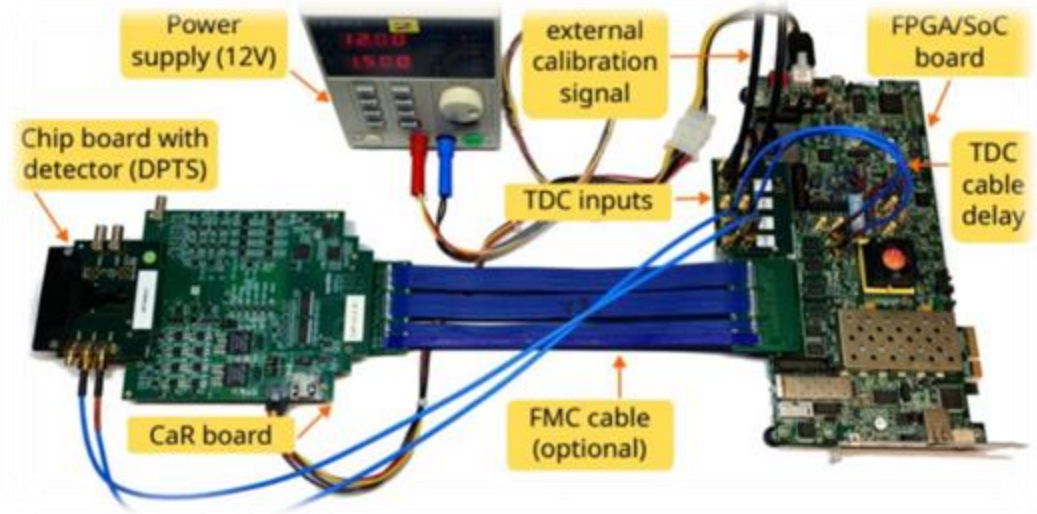
CLICdp Timepix3 @ CERN

MIMOSA @ DESY

FASTpix with oscilloscope readout



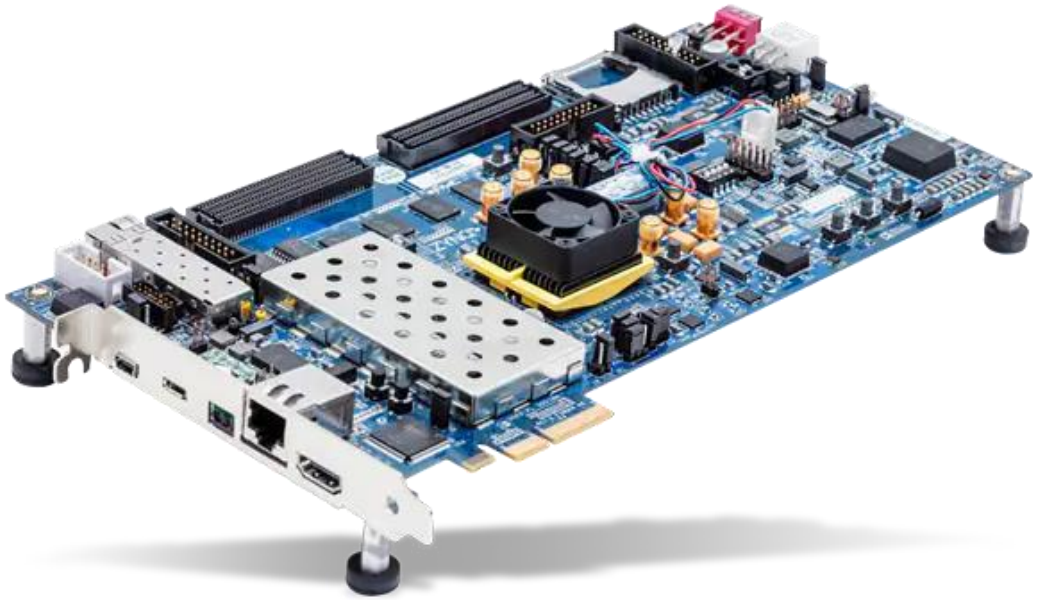

DPTS with TDC in FPGA readout




ALPIDE @ MAMI

# What’s next ?

# Support of UltraScale+ MPSoC boards



Xilinx ZC706 evaluation board

**Supported**

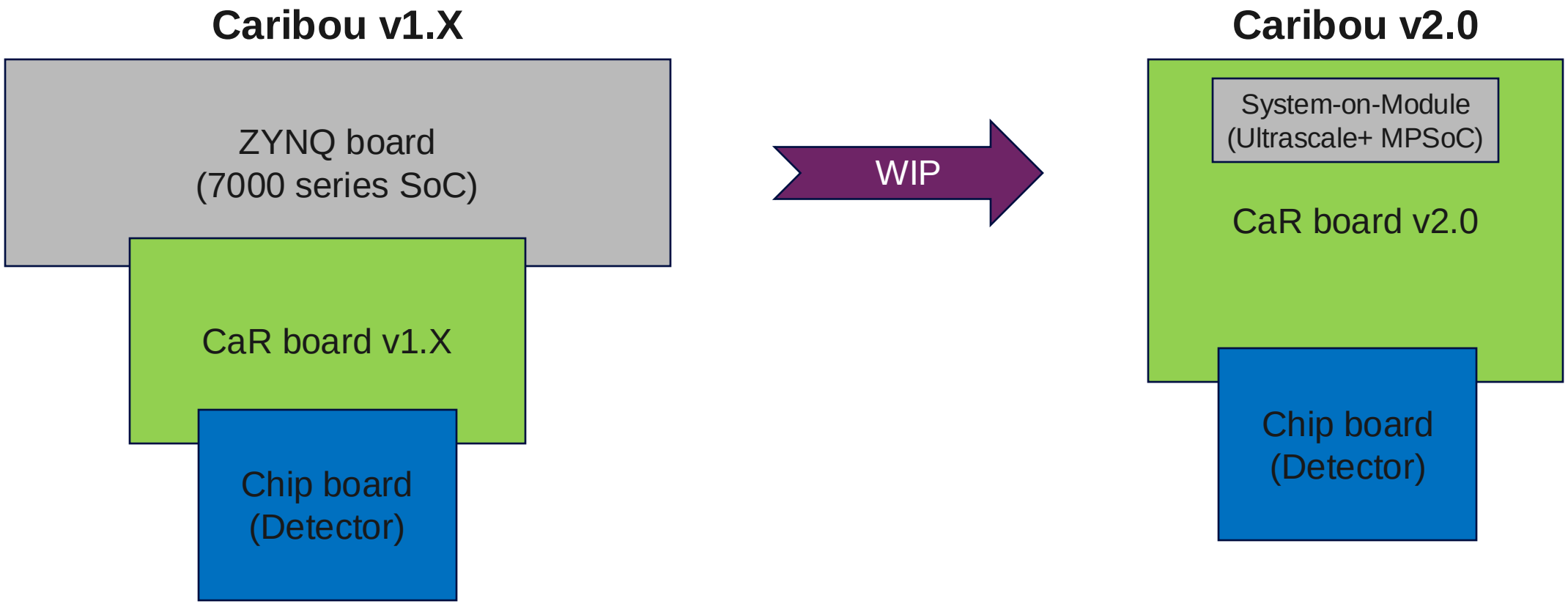
**Not available anymore**

Xilinx ZCU102 evaluation board

**Supported**

**Intermediate step towards Caribou v2.0**

# Caribou v2.0


Caribou v1.X
ZYNQ board
(7000 series SoC)
CaR board v1.X
Chip board
(Detector)
WIP
Caribou v2.0
System-on-Module
(Ultrascale+ MPSoC)
CaR board v2.0
Chip board
(Detector)

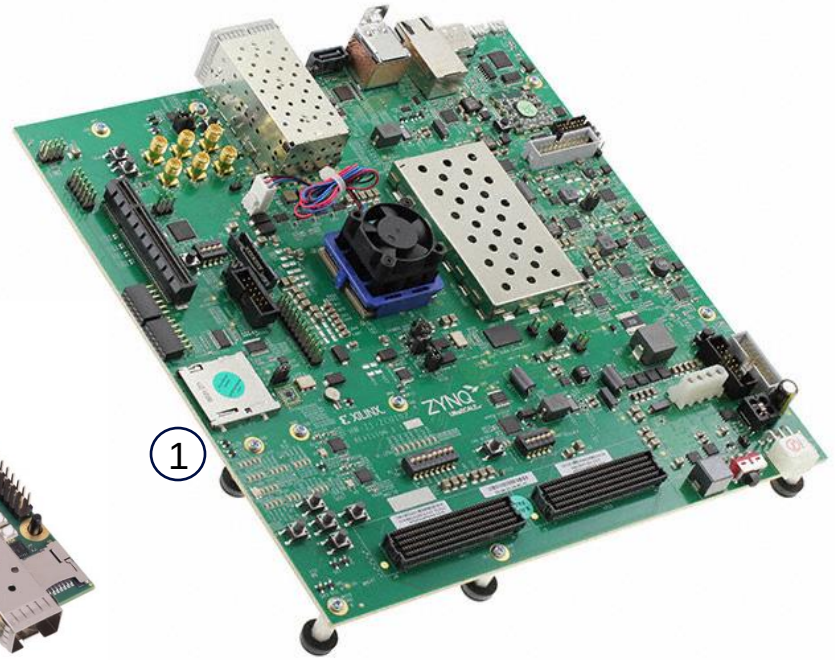
# Caribou v2.0

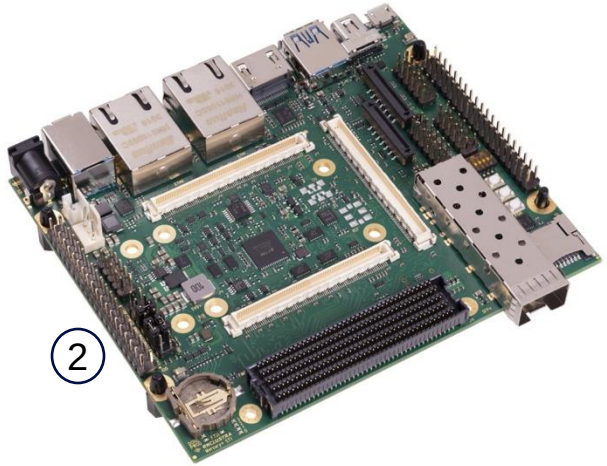
- Based on commercial **System-on-Module** (SoM)
  - Merge CaR board and ZYNQ board into a single board
  - Optimize system cost, increase flexibility and performance

- Mercury+ XU1 System-on-Chip
  - ZYNQ Ultrascale+ MPSoC
  - More resources and processing power

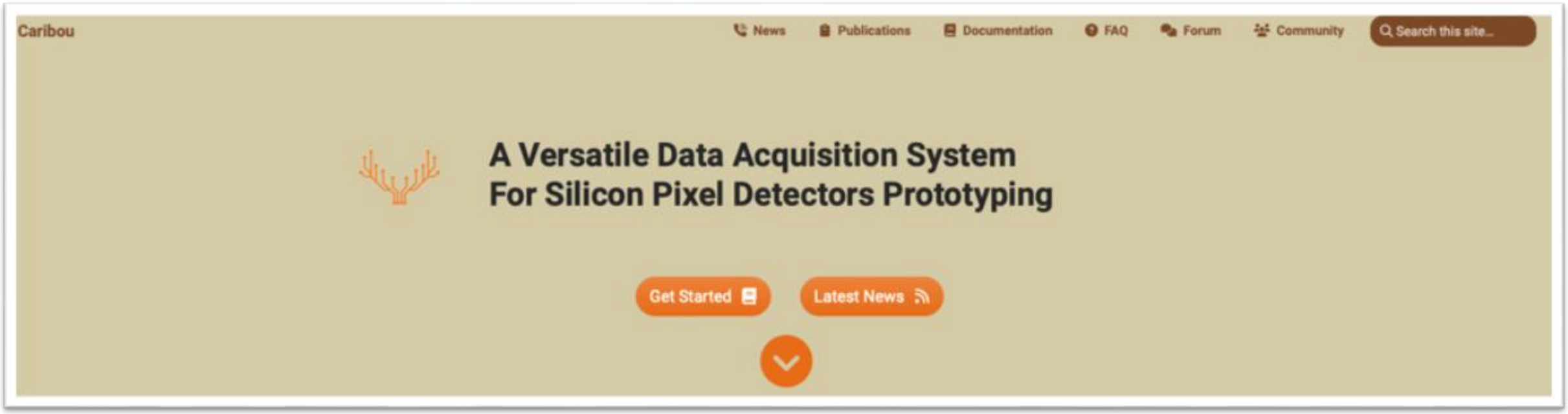
- CaR board hardware specifications and design in progress

- Software/Firmware development phase
  - Support of compatible boards
  - 1) Xilinx ZCU102
  - 2) Mercury+ ST1



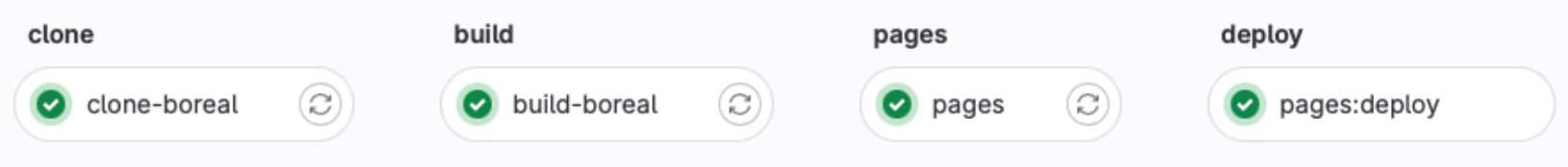
# Documentation website



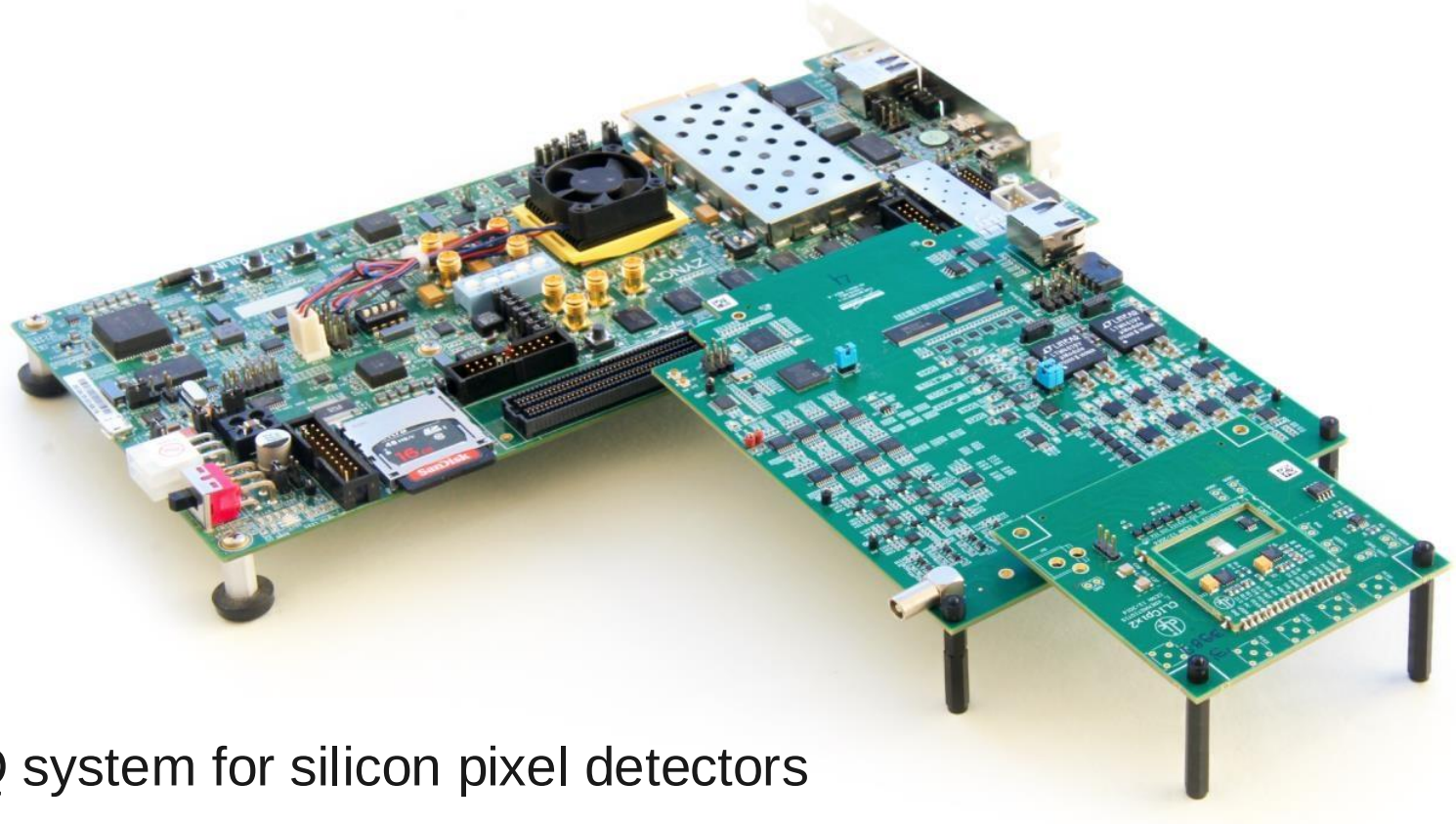

**Project website**

- Documentation
- Mattermost channel
- Publications
- Forum
- …

Automatic documentation builds and website deployments

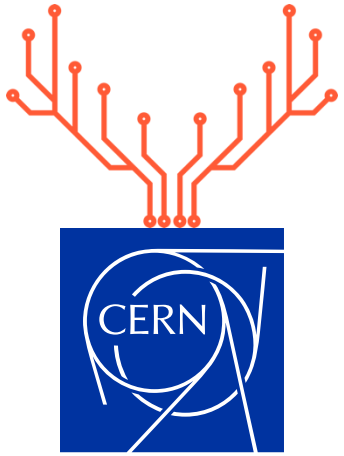


# Summary



- Caribou is:
  - A versatile DAQ system for silicon pixel detectors
  - Open source, standalone
  - Proved excellent operation on many detector prototypes
  - Large community of users (including DRD3)
  - Ongoing upgrade phase with many improvements to come

# Thank you

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# Caribou system architecture