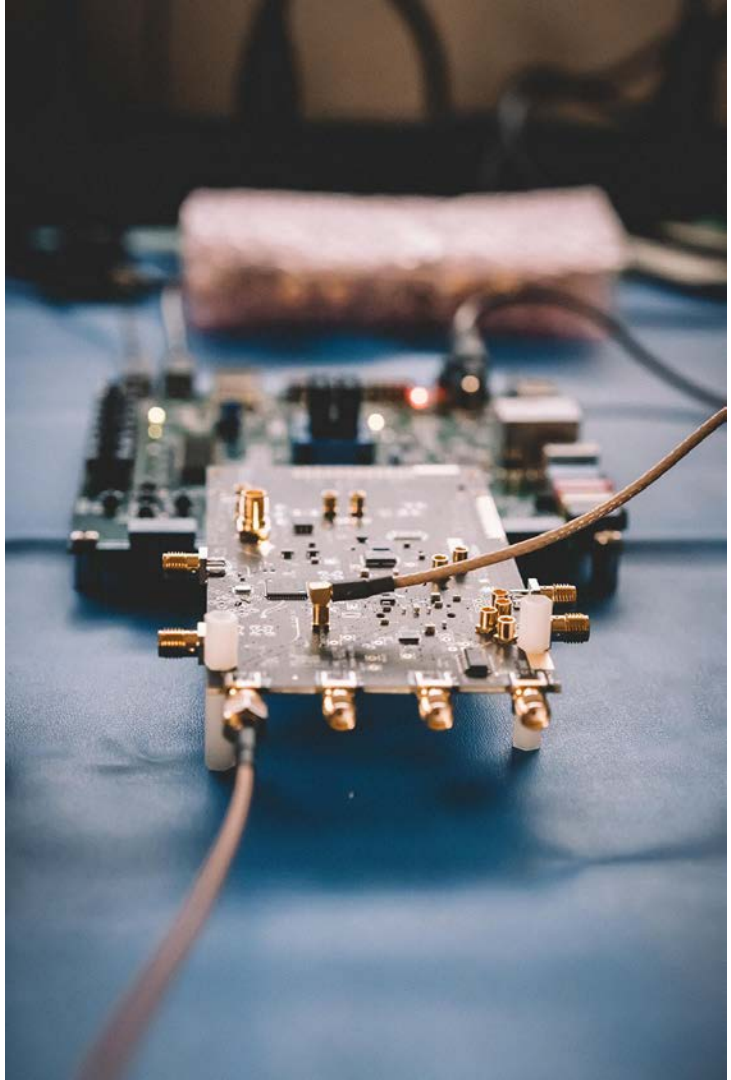


NALU SCIENTIFIC
ENABLING INNOVATION

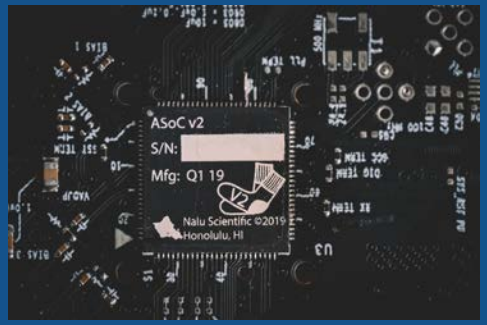
Waveform Digitizing and Processing Front-end Microelectronics for Particle Physics Experiments

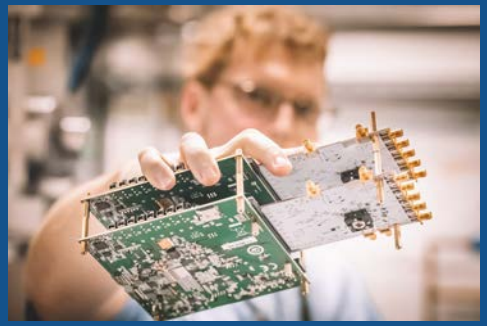
July 12, 2021
Isar Mostafanezhad, Ph.D.
Founder and CEO at Nalu Scientific LLC

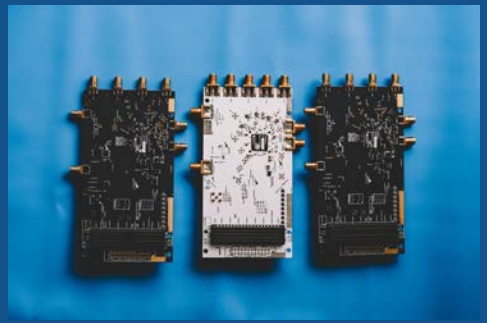
Work partially funded by US DOE SBIR Grants:

DE-SC0015231, DE-SC0017833, DE-SC0020457

HTDC- UH OIC, Hawaii SBIR Lessons Learned. July 12, 2021







ABOUT NALU SCIENTIFIC

Fast Growing Startup in Honolulu, Hawai'i

- Located at the Manoa Innovation Center
- Over $11M in committed funding, 18 staff members
- Access to advanced design tools
- Rapid prototyping and testing lab

Scientific Expertise

- Particle physics detection and tracking
- Radiation detection
- Readout electronics for Particle Physics detectors

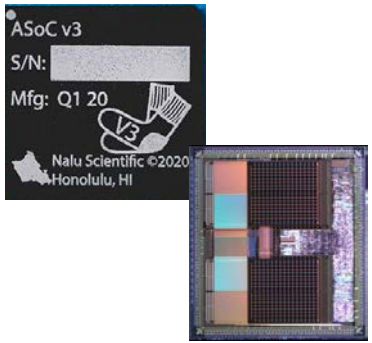
Technical Expertise

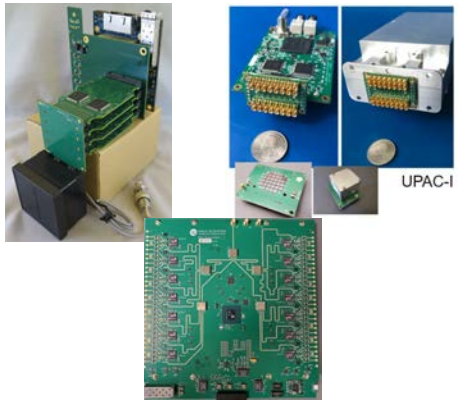
- Analog + digital System-on-Chip (SoC)
- Field Programmable Gate Arrays (FPGA)
- Complex multi-layer Printed Circuit Boards (PCBs)

Nalu = 'wave' in Hawaiian language

NALU SCIENTIFIC
ENABLING INNOVATION

Analog to Digital converter Microchips
FOR PRECISE TIME OF FLIGHT ESTIMATION





1. Front-end Chips:

- Event based digitizer+DSP
- 4-32 channel scope on chip
- 1-15 Gsa/s, 12 bit res.
- Low SWaP-C
- User friendly: FW/SW tools

2. Integration:

- SiPM
- M/A PMTs
- LAPPD
- Detector arrays

3a. Main application:

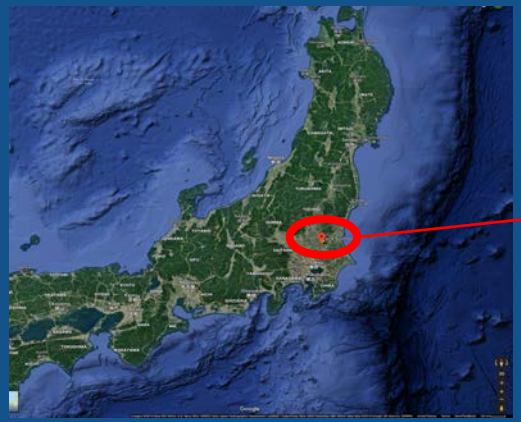
- NP/HEP experiments
- Astro particle physics

3b. Other applications:

- Beam Diagnostics
- Plasma/fusion diagnostics
- Lidar
- PET imaging

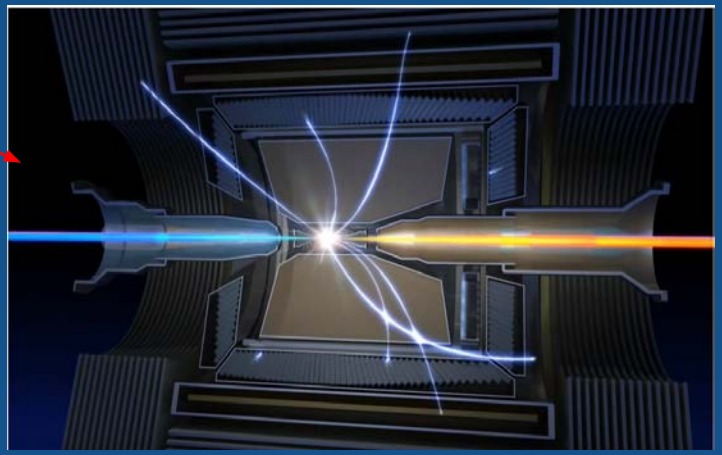
WHERE WE STARTED

A Search for New Physics – The Belle II Experiment



Tsubuka City
Located 60 mi north of Tokyo

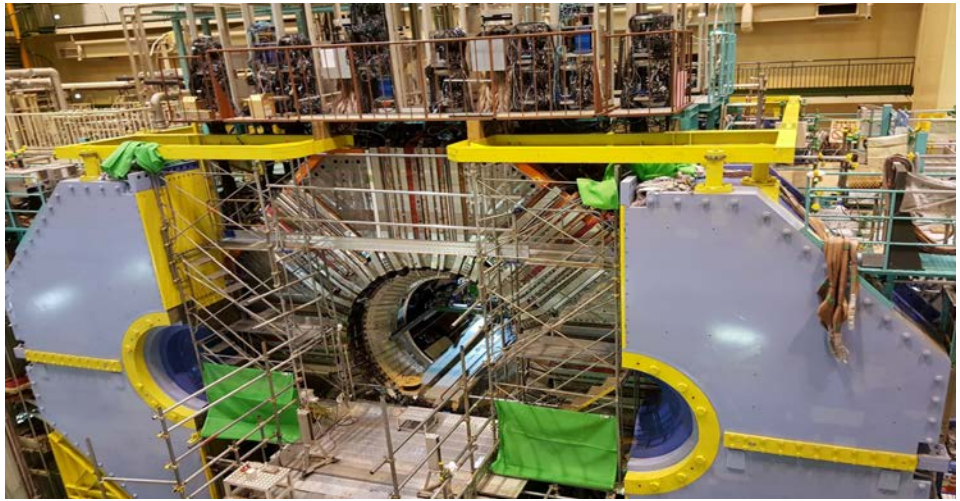
High Energy Accelerator Research Facility (KEK)
in Tsukuba



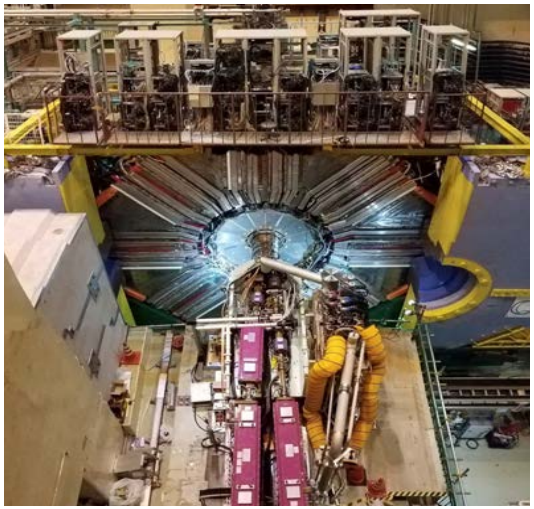
Interaction point inside the electron/positron collider
Belle II Youtube page

HISTORY - BELLE II

Belle II Upgrade is a 26+ Country, 900 Member Collaboration



2015



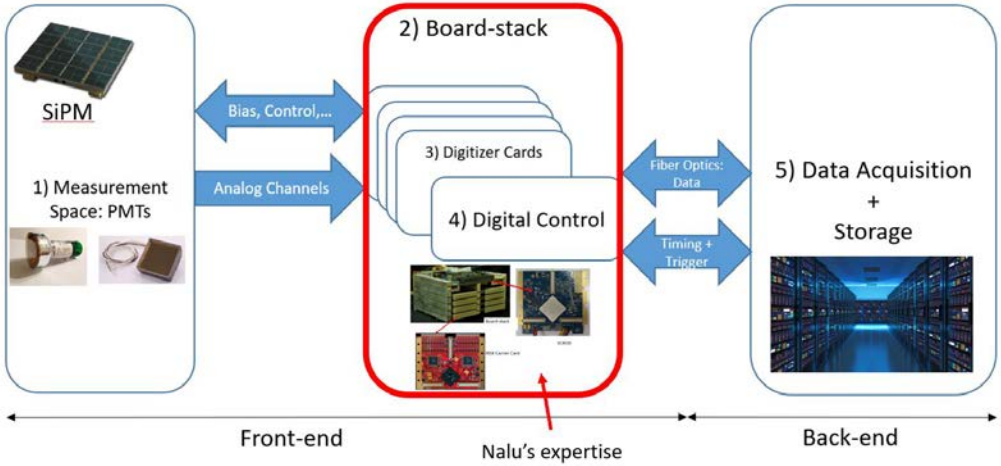
2018

Nalu Staff designed and implemented front-end electronics and FW for KLM (muon system) and iTOP (Cerenkov-based PID) sub-detectors.

Belle II: e+ e- experiment at 40x luminosity of Belle -> Detector needs to operate at severe beam background.
L1 trigger at 30 kHz

HOW DO PARTICLE PHYSICS EXPERIMENT WORK?

LESSON ONE



LESSON TWO

Needs:
- Survive harsh environments
- High performance
- Accommodate long trigger delay
- Low cost, low power
- User friendly

Solution: New System-on-Chip Integrated Circuit

Opportunity: Not many commercial options available

Funding: US Department of Energy

Proposed Solution:
Chip level integration of switched capacitor array (analog) with digital processing.

Funding, Collaboration and Workforce Development

FY16-21

✔ **$11 M Secured by Nalu**
- ✔ 9x SBIR Phase I
- ✔ 6x SBIR Phase II
- ✔ Various matching grants
- ✔ Misc. contracts

FY16-20

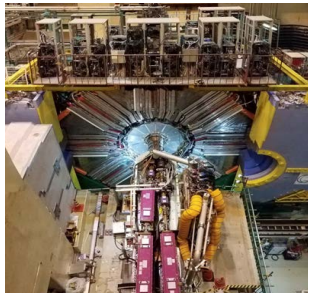
✔ **$1.2M Sponsored Research**
- ✔ University of Hawaii
- ✔ National Labs
- ✔ 4x post docs
- ✔ 4x graduate students
- ✔ Misc. materials and supplies

2x MS and 2x PhDs had their first jobs at Nalu Scientific.

FY21-23

✔ **New possibilities:**
- ✔ New tech-dev based on capabilities
- ✔ Sensor integration
- ✔ Custom design
- ✔ New partnerships

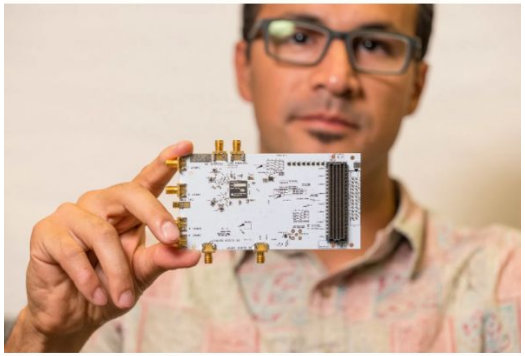
Why Hawaii?
- Strategic location - Asia <> US
- University of Hawaii
- Greater impact on State
- “Hawaii Brand”
- Retain local expertise



Getting the Word Out

- Awards (40U40, most innovative, …)
- Attending conferences, trade shows, pitch competitions
- Media attention on restarting/diversifying economy in Hawaii esp post COVID
- **New website, Social Media handles: FB, LinkedIn, Twitter**

HawaiiBusiness magazine



LEADERSHIP – APRIL 6, 2020

Virtual Interview on COVID-19: Isar Mostafanezhad, Founder and CEO, Nalu Scientific

Booth and AARDVARC Live demo at US-Japan Particle Physics Symposium in Honolulu (April 2019)

Pacific Biz News 40 under 40

IEEE Young Professionals Panel IMS2019 - Boston

IPAC 2019 booth- Melbourne

Hawaii Biz Magazine
Most Innovative Small Biz of the year

Hawaii Congressman Ed Case visit

Factors attributing to funding success

- Business is main focus and career:
  - Full time founder/CEO willing to go the extra mile and do what it takes - persistence
- Started small (DOE Phase 0 - check it out)
- Leveraged ‘Hawaii brand’ and relationship with University
- Revise and resend based on feedback
- Always going back asking for more money:
  - It’s never enough money! Need to keep workforce busy.
  - Propose new tech to create coverage in tech offering (faster, cheaper, better, smaller, etc)
  - Talk to PMs to see what else is on their minds
  - Leverage the team
  - Leverage new relationships - Universities, National Labs, consultants
- Failure is an opportunity to do better next time

Summary

- Our journey:
  - SBIR Funding
  - Team Growth
  - Tech Development
  - Collaboration
- Workforce development
  - Hiring
  - Retaining Institutional Knowledge
- Industry Relations
  - Distributors
  - System integrators
  - Commercialization Pathway
- Get help from wherever and whomever you can!
  - HTDC
  - UH
  - SBDC

ACKNOWLEDGEMENTS

US Department of Energy Office of Science

Hawaii Technology Development Corporation (HTDC)

University of Hawai'i at Manoa Department of Physics