Workforce for Next Generation Detector Systems Development, Training, Maintenance & Support Emergent Needs for Next Gen Systems..

MITCH NEWCOMER   RDC4

Topics Training, Maintence, Support

- Who …Needs for Training
- DOE sponsored Traineeship experience/status comments from leadership
- Cherry picks from the HEPAP Benchmarking Panel Presentation Nov 2
- Looking on the Horizon

Training Experts Who… Us

- **Experimental Physicists /PHD students**
  - As Instrumentation designers and system managers
  - As reviewers
  - As Mentors for large scale projects
  - As Liaison among systems
- **Electrical Engineers**
  - In ASIC & FPGA design/development, HS Communications System Reliability Performance
  - For Extreme Environments eg. Temperature, Radiation Radio-purity
- **Mechanical Engineers**
  - Detector construction
  - Structural Design

DOE sponsored Instrumentation Traineeship

Principal Investigator	Title	Institution	City	State
Mahn, Kendall	TRAIN-MI Program: High Energy Physics Instrumentation Traineeship in Michigan	Michigan State University	East Lansing	MI
Horowitz, Mark A.	HEP IC Design Apprenticeship Program	Stanford University	Stanford	CA
Tripathi, Sudhindra M.	HEP Consortium for Advanced Training	University of California, Davis	Davis	CA

TRAIN-MI (HEP Instrumentation focus) status and comment on their experience..

Currently 8 trainees (the planned number) & students in a graduate instrumentation certificate program established by MSU with DOE support. They have given two courses: Detectors Lab and DAQ lab that full with 5 on the waiting list. - So the course work part of their program is well subscribed.

Two impediments: Citizenship Requirement & 2yr support for 4yr PHD candidates.
Faculty are happy with the program. Note that these are introductory courses…

HEPIC ASIC Traineeship Led by Stanford University combined comment from Stanford, SLAC & LBL

- @ SLAC 3 interns so far:
  - 2 express high interest in HEP , 1 in early stages of ASIC training
- Program could be expanded based on subscription to 2 years of the HEPIC summer study at SLAC (especially true with MSEE's)
- Struggled to get University faculty to join in.
  - Stanford, UCSC & UC Davis joined Initially then UT Arlington with student at FNAL
- Creating opportunities for internships is Key..
  - Hands on projects capture interest.
  - Creates experience in multi-disciplinary environment.
  - Detector systems have grown in complexity and require a mix of skillsets
    - ASIC designs require expertise in EE skillsets (not restricted to EE's)

HEPIC comment continued

- Students work on small unique interesting projects fit the needs of labs.
- Students are trained in skills they will need for the next generation collider projects.
- Number of students that can be accommodated is constrained by the ability of an available trained engineers to mentor.
- Inspirational Thought.. **Joint student driven R&D ASIC program *for* HEPIC**

…. Following initial training or a more formal candidacy process

  - Immersion research project with mentorship researchers in the field but self driven with reporting and archiving requirements so that allow rotation of membership…
  - 1 FTE per institution with 2 or 3 students / Institution and several institutions involved in a consortium of members.
  - Design process would mirror the distributed design model developed for ATLAS…
  - Produces new R&D results and students trained in HEP IC design techniques..

…Developing this idea could be part of a training work package….

DOE sponsored Traineeship FOA

- Path to improve subscribership*
  - Relax Requirement for US Citizenship
  - Duration of support should be compatible with the degree program.   2 yrs Masters, 2 additional for PHD
- University Faculty perspective
  - Physics Majors the program requirement to be at a lab or away from the home institution several months at a time after academic requirements are complete delays their contributions to faculty research objectivers.   Shorter periods away from the home institution, remote learning or participation at a University affiliated project lab would be useful.
  - EE departments - Faculty incentives publishing or particpatoin as co-PI's in HEP projects might be helpful..

* Useful comments here from Stanford, SLAC, LBL program leaders

Nuclear Science & Security Consortium and HEP Consortium for Advanced Training

HEPCAT and NAT Summer School

June 20-30, UC Davis

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
	19-Jun	20-Jun	21-Jun	22-Jun	23-Jun	24-Jun	25-Jun	26-Jun	27-Jun	28-Jun	29-Jun	30-Jun
	Arrival	Arrival					Off Day				Annual meeting See Tab	Departure
8:30		Check-in at the dorms	Coffee	Coffee	Coffee	Coffee		Coffee	Coffee	Coffee		Coffee
9:00			Lecture - Goldblum	Lecture - Mulhearn	Lecture - Tyson	Lecture - Aminaei		Lecture - Nachman	Lecture - Sweany	Lecture - Grace		Complete Hands-on tasks
10:00			Hands-on activities	Hands-on activities	Hands-on activities	Hands-on activities		Hands-on activities	Hands-on activities	Hands-on activities		
11:00		See "Day 1" Tab										Exit Activities
12:30			Lunch	Lunch	Lunch	Lunch		Lunch	Lunch	Lunch		Check-out
13:30			Hands-on activities	Hands-on activities	Hands-on activities	Hands-on activities		Hands-on activities	Hands-on activities	Hands-on activities		
16:00	Check-in at the dorms											
16:30			Tea	Tea	Tea	Tea		Tea	Tea	Tea		
17:00			Lecture - Shutt	Lecture - Golwala	Lecture - Irwin	Lecture - Schumm		Lecture - Svoboda	Lecture - Xu	Lecture - Prebys		

DAY 1	6/20/2022 - Room 185
11:00	Welcome - Mani Tripathi
11:10	Safety & Forms - Mike Mulhearn
11:30	Scintillators - Billy Boxer
11:50	FPGAs - Ryan Hensley
12:10	Neutron Activation - Leon Pickard
12:30	Lunch
13:30	CCDs - Dan Polin
13:50	Muons - Julie He
14:10	Dark Radio - Ben Godfrey
14:30	Liquid Argon - Jimmy Kingston
14:50	Cross section - Lena Korkeila
15:10	Tea
15:30	Crocker tour

Lecture Schedule

Date	Speaker	Topic
21-Jun	Bethany Goldblum	Scintillation Detectors
21-Jun	Tom Shutt	Liquid Noble Detectors
22-Jun	Mike Mulhearn	Radiation Damage Studies
22-Jun	Sunil Golwala	Crystalline Cryogenic Detectors
23-Jun	Tony Tyson	Modern Astronomy Instruments
23-Jun	Kent Irwin	Quantum Devices in HEP
24-Jun	Amin Aminaei	RF Electronics & Applications
24-Jun	Bruce Schumm	Si Detectors in HEP
26-Jun	Ben Nachman	AI/ML in Instrumentation
26-Jun	Bob Svoboda	Water & Liquid scintillator Detectors
27-Jun	Melinda Sweany	Instrumentation for Non-proliferation
27-Jun	Jingke Xu	Photosensors
28-Jun	Carl Grace	Custom ICs in HEP
28-Jun	Eric Prebys	Low Energy Accelerators

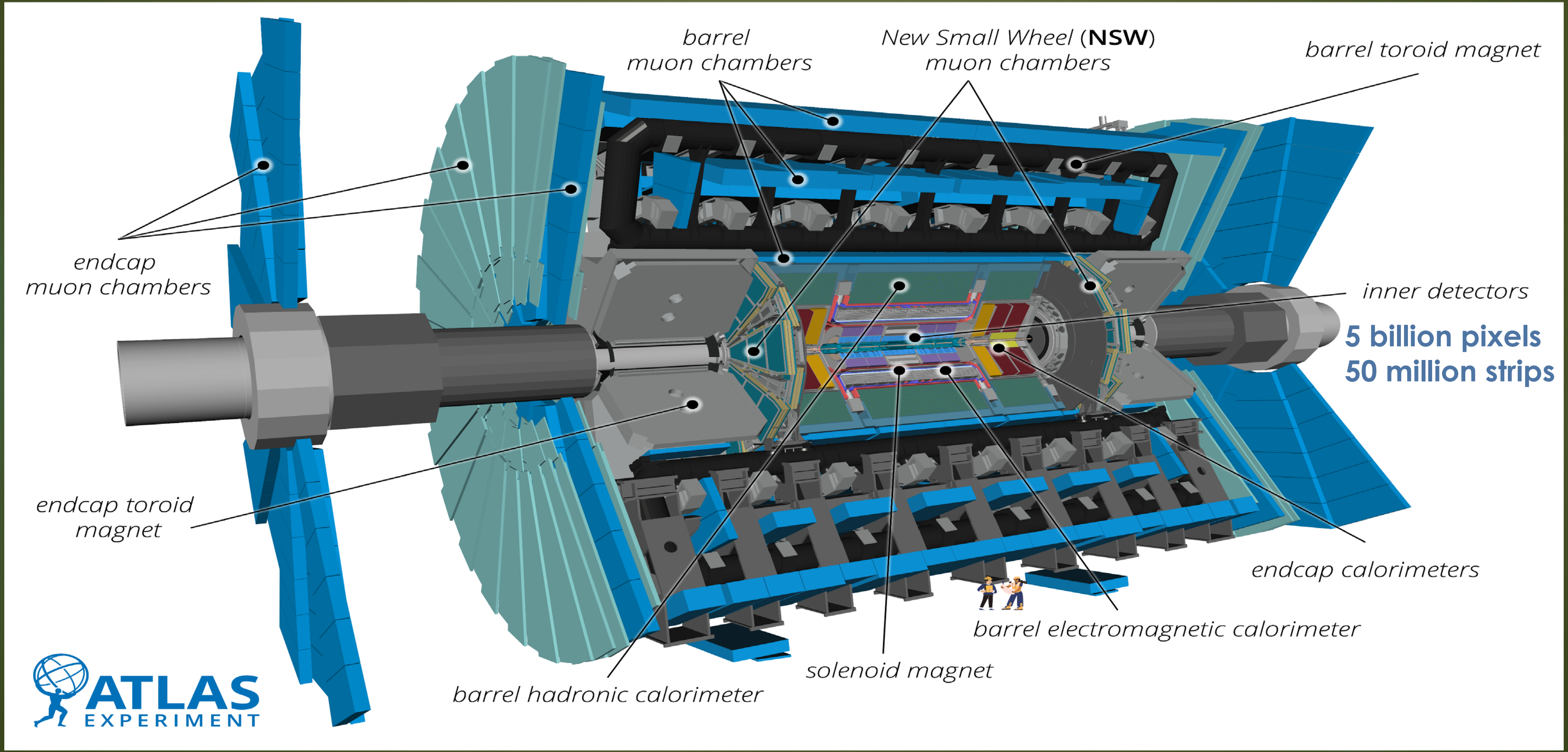
	29-June: Annual Meeting
8:30	Coffee
9:00	Welcome - Tripathi
9:10	Eric Prebys - Electronics
9:25	Bethany Goldblum - Scintillators
9:40	Jingke Xu - Liquid Nobel Detectors
10:05	Tony Tyson - Dark Radio
10:20	Leon Pickard - Neutron Activation Analysis
10:35	Break
10:50	Javier Duarte - AI/ML in Instrumentation
11:05	Billy Boxer - SiPMs
11:20	Lena Korkeila - Cross section measurements
11:35	EAB Meeting with Faculty and Scientists
12:30	Lunch + Poster session
14:00	EAB Meeting with Students || HEPCAT Faculty & Scientists Meeting
15:00	EAB closed session || Faculty & Scientists Meeting with students
16:00	EAB Debrief over Tea
16:30	Colloquium - John Womersley
18:00	Collaboration Dinner

Identified areas of Importance for advanced detector design / training

- ASIC's Training/Access/collaboratoin
- FPGA design Training, advanced implementation communication
- Computing
- AI/ML
- QIS
- Modeling & Verification ASICs, modules, Sub-systems, Detector Levels
- ……

- … not too often mentioned **System Aware Design**
  - Modeling / Verification that enables a vision of system performance

Integration of the Detector System …Excellent in the past, but becoming strained as “off” and “on” detector readout & triggering sub-systems specialize in different silos… Unlikely to spontaneously evolve without specific investigation and community investment in modeling, verification & training.



Emergent Skills and Disciplines Required for System Level Design

Co–Design/Development tool to Model & Verify the Full Detector Readout system

Potentially a "Work Package" to develop the process…

- Initially an Abstracted description of a future Detector as the Model.
- Expand to keep pace with evolving sub-system
- Integrate elements as they are conceived as models that can be verified as designs are completed. Sample data may be all that is needed for detector level simulation.
- Optimize Data FLOW
  - Constructing Managing transmitting Receiving Decoding Big Data

Support

Common observations

- The research tools we need have a cost that puts many but the most basic tools beyond the reach of our Labs and Universities.
- The US needs to find a model similar to Europractice and the support that CERN's ESE groups have provided for ASICs that levels the playing field among users and allows for collaboration among institutions.
- **Shared IP** and **broad institutional technology access** is essential to integrating community wide participation that optimizes creativity and allows the scrutiny necessary to find and correct flaws in designs.
- This essentially defines the process by which Science takes leaps and bounds forward.

Some Crucial Points about Training and Support from the HEPAP Benchmarking presentation on Instrumentation

These ideas have percolated up through BRN and SNOWMASS and been embellished with new perspectives.

Natural Training & Discovery

Small Projects are essential

The U.S. HEP community of national laboratory and university groups working on small projects is vibrant and continues to innovate and push the bounds of what is possible to measure by harnessing cutting-edge technology including quantum sensing and AI/ML.

- Experiments of all scales — large, medium, and small — accomplish impactful science.
- Experiments at different scales frequently complement one another, particularly at the cosmic and intensity frontiers.
- Demonstrator-scale and small projects lay the foundation for future larger experiments. Leadership entails leading on small experiments as well as leading on large experiments.
- Small projects are also outstanding training grounds for students and postdocs, allowing them to experience the whole life cycle of an experiment.
- The 2014 P5 report recommended the support for experiments at all scales.
- Groups from other nations are nimbler in moving from concept to data-taking experiments than in the U.S. This affects US scientists with respect to both their ability to partner with non-US groups and their ability to compete with non-US groups. Hence, it affects US leadership.

Crucial Recommendations **underway** to Encourage & Sustain membership in a world class R&D Workforce

Invest in **Instrumentation research and development** to enable the discovery science of the future

Europe is renewing an ambitious, collaborative, coordinated program of detector R&D.

…the U.S. particle physics community has played a prominent role in several of the very successful CERN RDs. The U.S. should build on this by participating in the ECFA DRDs and engage with the broader instrumentation R&D community within and beyond particle physics…

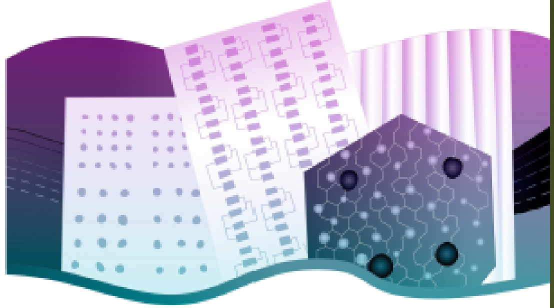
Snowmass 2021 Instrumentation frontier recommendations:

1) *Advance performance limits of existing technologies and develop new techniques and materials, nurture enabling technologies for new physics, and scale new sensors and readout electronics to large, integrated systems using co-design methods.*
2) *Develop and maintain the critical and diverse technical workforce, and enable careers for technicians, engineers and scientists across disciplines working in HEP instrumentation at laboratories and universities.*
3) *Double the U.S. Detector R&D budget over the next five years, and modify existing funding models to enable R&D consortia along critical key technologies for the planned long-term science projects, sustaining the support for such collaborations for the needed duration and scale.*
4) *Expand and sustain support for blue sky R&D, small-scale R&D, and seed funding. Establish a separate agency review process for such pathfinder R&D, independently from other research reviews.*
5) *Develop and maintain critical facilities, centers, and capabilities for the sharing of common knowledge and tools, as well as develop and maintain close connections with international technology roadmaps, other disciplines, and industry.*

HEPAP sub panel report…

Advancing National Initiatives

Microelectronics – an essential technology



Finding: **Application Specific Integrated Circuits (ASICs) are ubiquitous in particle physics, in other scientific disciplines, and in society. ASICs are an essential part of almost every detector technology in particle physics.**

Recommendations:

DOE HEP and NSF Physics should regenerate and maintain at a leadership level expertise in microelectronics for particle physics instrumentation. Efforts should include support of both targeted and generic R&D in microelectronics to advance microelectronics applications as well as to maintain expertise and to attract talent. DOE HEP and NSF Physics should exploit synergies with the needs of other parts of the DOE Office of Science and NSF programs.

The agencies and the community should work together to establish a program providing cost-effective access to design licenses and tools and to foundries for national laboratories and universities. Consider a program that extends across the DOE Office of Science and the NSF Mathematical and Physical Sciences Directorate.

The majority of detector instrumentation R&D in particle physics requires ASIC development.

The challenges include the ability to develop ASICs that can operate in the extreme environments of high radiation, high data rates, low temperatures, and/or outer space.

Common Observations…

Invest and innovate in **Microelectronics**

ASICs are ubiquitous both in society and in our field; ASICs are a key part of almost every detector technology.

In recent years, US leadership in custom IC design has slipped or lapsed, with experiments more frequently looking to CERN or other European groups for IC designs.

ASIC R&D, both targeted and generic is **needed to maintain the relevance of U.S. High Energy** Physics contributions in the international arena.

Foundry access is crucial, the cost is high, and few foundries will engage with particle physics. The work is exceptionally specialized and depends on a stable long term HEP workforce.

The advent of Europractice, funded by the European Union, has given HEP ASIC developers at CERN and across European institutions an advantage by providing a brokerage service to lower costs across industry and academia.

Establishing in the U.S. **cost-effective access to licenses and tools and high-priority, cost-effective access to foundries** would benefit ASIC development beyond DOE HEP and NSF Physics, e.g. broadly across the DOE Office of Science and NSF programs.

Building a robust workforce

Workforce development in key technologies:
Instrumentation, accelerator science and technology, and large-scale computing

Recommendations: **Attract, nurture, recognize and sustain the careers of physicists, engineers and technicians dedicated to the development of instrumentation, accelerator science and technology, and large-scale computing.**

Recommended actions include:

- Conduct a comprehensive study to identify areas of inadequate expertise in the U.S. particle physics workforce, such as instrumentation, accelerators, and large-scale computing.
- Shore up deficiencies by encouraging more students to pursue those areas of study.
- Establish more university programs offering degrees in accelerator science and technologies.

Encourage Workshops & Topical training among Peers:
Encourage sharing state of the art Ideas / Techniques.

Foster Training of Instrumentation Specialists at Universities to acknowledge the value of their Contribution to Discovery in Basic Science

Building a robust workforce

Workforce needs in microelectronics

Finding: **Microelectronics, and ASICs (Application Specific Integrated Circuits) in particular, are ubiquitous in particle physics. In the U.S. particle physics community, there is a shortage of both specialist ASIC design engineers and particle physicists sufficiently knowledgeable in ASIC design to work effectively with ASIC designers and to review systems designed with ASICs. These factors limit U.S. leadership in this crucial area of the field.**

Recommendation: **DOE should fund and work with universities to create an enhanced integrated program to train university Ph.D. and Master's students in system design of the experiment and subsystem design of the detector and readout and appropriate implementation and design of ASICs for the detector readout.**

Concluding Thoughts

The commercial technologies exploited in our sub-systems designs off and on the detector are highly complex and many require specialized training. We need to arrange ways of sharing the knowledge and updating the skills of our workforce.
Shared access to technology and IP will encourage the highest levels of innovation and scrutiny. Both of which are requirements for breakthrough designs.

Instrumentation Workshops and Conferences share the knowledge of what can / is being done.

Immersion projects like small scale experiments are likely the most natural way for young PHD's to gain experience and learn about HEP instrumentation

(Including the limitations and capabilities of ASICs).

Broad topic Traineeships seem to be very effective.
We need to explore synergistic ways to scale up subscribership…

Recommendation…

- We might want to follow in the footsteps of our European colleagues who have a specialized Training Panel like DRD9 to preserve and enhance the capabilities and support for the US Advanced Detector workforce.