Implementation of the HEP Instrumentation R&D Roadmap in the US

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HSTD13– VANCOUVER

DECEMBER 3-8, 2023

Outline

Strategic Planning Process in the US

Recommendations for Detector Instrumentation

Coordinating Panel for Advanced Detectors

R&D Collaborations

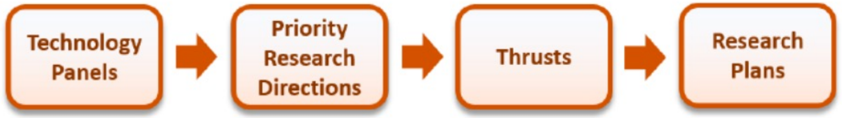
BRN for Detectors in 2019:

Basic Research Needs for HEP Detector R&D (DOE-driven exercise)

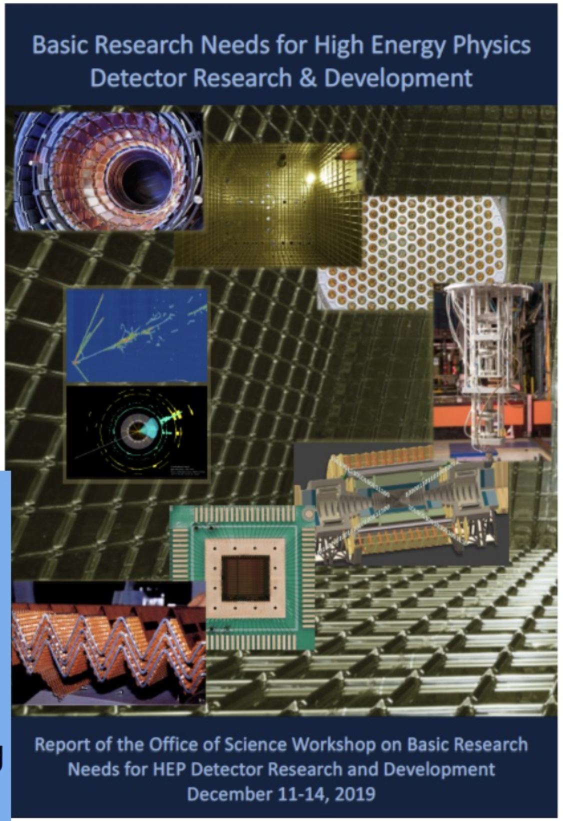
- Methodology:
  - examine connections between physics drivers and detector requirements, considering ALL the physics drivers

} Work organized around 2014 P5 Physics Drivers

  - Connect with current cutting-edge technologies and identify big ideas to support physics reach



1. Calorimetry
2. Noble elements
3. Photodetectors
4. Quantum sensors
5. Readout and ASICs
6. Solid State and Tracking
7. Trigger and DAQ
8. Cross-Cutting Research



BRN: identifies Priority Research Directions

e.g. for silicon tracking:

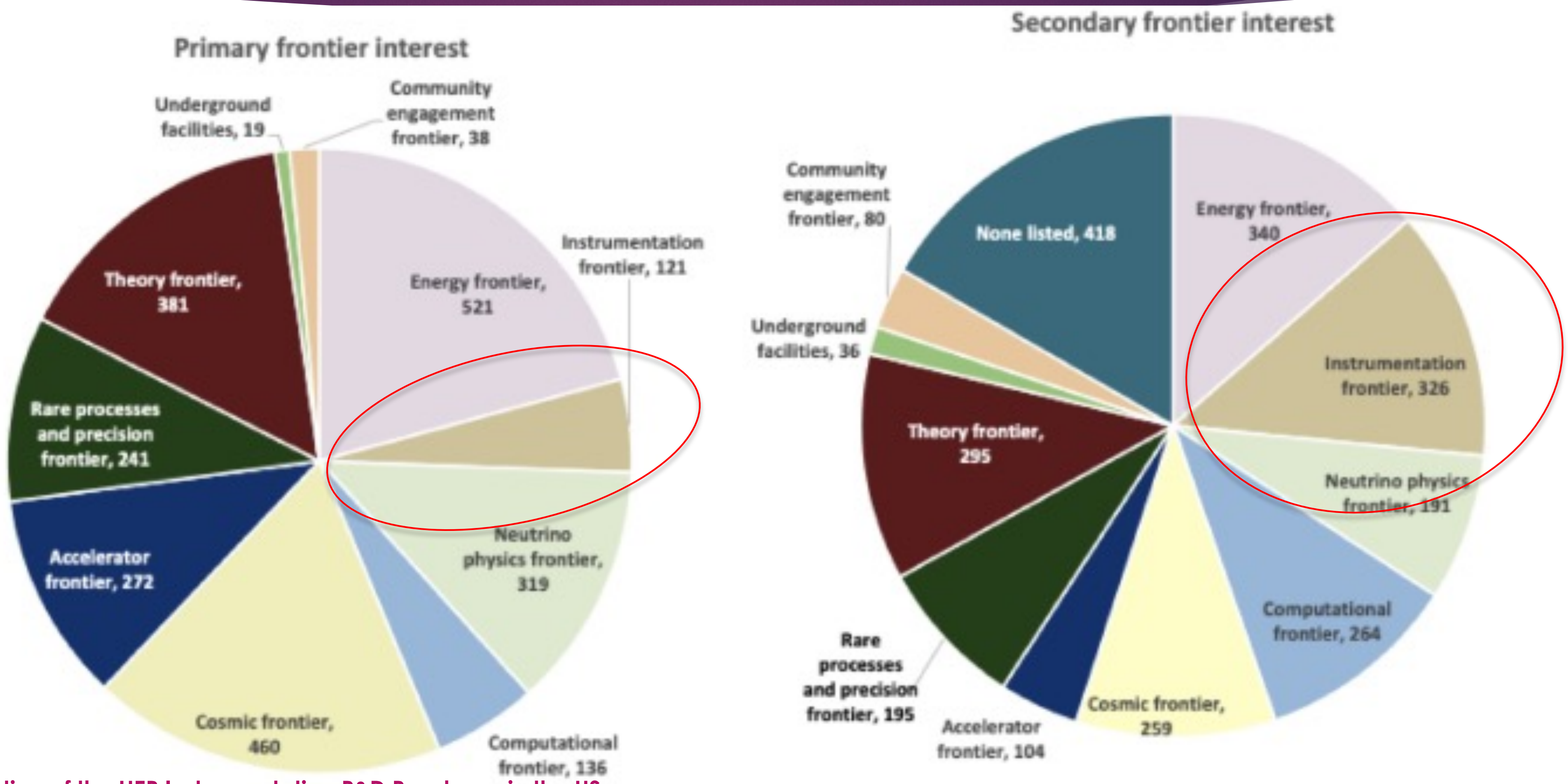
PRD	Thrust	Synergies
Develop high spatial resolution pixel detectors with precise per-pixel time resolution to resolve individual interactions in high-collision-density environments	1. small pixel size ≈10μm 2. timing O(1-10ps) 3. Extreme radiation ($10^{18} n_{eq}/cm^2$)	Lepton colliders, LHCb Upgrade 2 Hadron colliders
Adapt new materials and fabrication/integration techniques for particle tracking	1. Adapting new materials and novel configuration sensors with new industrial partnerships 2. Develop readout electronics matched to new sensor characteristics, including new processing such as 3D integration	Lepton and hadron colliders Charged lepton flavor violation
Realize scalable, irreducible mass trackers	1. Highly integrated monolithic active sensors 2. Scaling of low mass detector systems 3. System for special applications (space/dark matter/rare processes)	Lepton and hadron collider, heavy flavor experiments at hadron machines, dark matter, charged lepton flavor violation

Snowmass 2021-2022:
HEP community-driven planning

- Organized in 10 Frontiers (physics, technology, community)
- Instrumentation Frontier is geared to discuss detector technologies and R&D needs for future experiments in collider physics, neutrino physics, intensity physics and at the cosmic frontier, paying close attention to synergies between the different Topical Groups, and with other Frontiers and research areas outside HEP

1.5-year long process culminated in a 2-week meeting in July 2022 in Seattle

From the 2021 Snowmass community workshop survey



Snowmass IF webpage: IF wiki

Organization

IF conveners:
Phil Barbeau (Duke), Petra Merkel (FNAL), Jinlong Zhang (ANL)

Topical Group	Co-Conveners			
Quantum Sensors	Thomas Cecil (ANL)	Kent Irwin (SLAC)	Reina Maruyama (Yale)	Matt Pyle (Berkeley)
Photon Detectors	Chris Rogan (KU)	Juan Estrada (FNAL)	Carlos Escobar (FNAL)	
Solid State Detectors and Tracking	Tony Affolder (UCSC)	Artur Apresyan (FNAL)	Steve Worm (DESY/Humboldt)	
Trigger and DAQ	Darin Acosta (Rice)	Wes Ketchum (FNAL)	Stephanie Majewski (Oregon)	
Micro Pattern Gas Detectors	Bern Surrow (Temple)	Maxim Titov (Saclay)	Sven Vahsen (Hawaii)	
Calorimetry	Andy White (UTA)	Minfang Yeh (BNL)	Rachel Yohay (FSU)	
Electronics/ASICs	Gabriella Carini (BNL)	Mitch Newcomer (Penn)	John Parsons (Columbia)	
Noble Elements	Eric Dahl (Northwestern/FNAL)	Roxanne Guenette (Harvard)	Jen Raaf (FNAL)	
Cross Cutting and System Integration	Jim Fast (JLab)	Maurice Garcia-Sciveres (LBNL)	Ian Shipsey (Oxford)	
Radio Detection	Amy Connolly (OSU)		Albrecht Karle (Wisconsin)	

Frontier	Liaison		
Energy	Caterina Vernieri (SLAC)	Maxim Titov (CEA Saclay)	
Neutrino	Mayly Sanchez (ISU)		
Rare	Marina Artuso (Syracuse)		
Cosmic	Hugh Lippincott (UCSB)		
Acceler.	Andy White (UTA)		
Comput.	Darin Acosta (Rice)		
Undergr.	Eric Dahl (Northwestern)	Maurice Garcia -Sciveres (LBNL)	
Commun.	Farah Fahim (FNAL)		
Early Career	S.Butalla (FIT)	K.Dunne (Stockholm)	J.Zettlemoyer (FNAL)

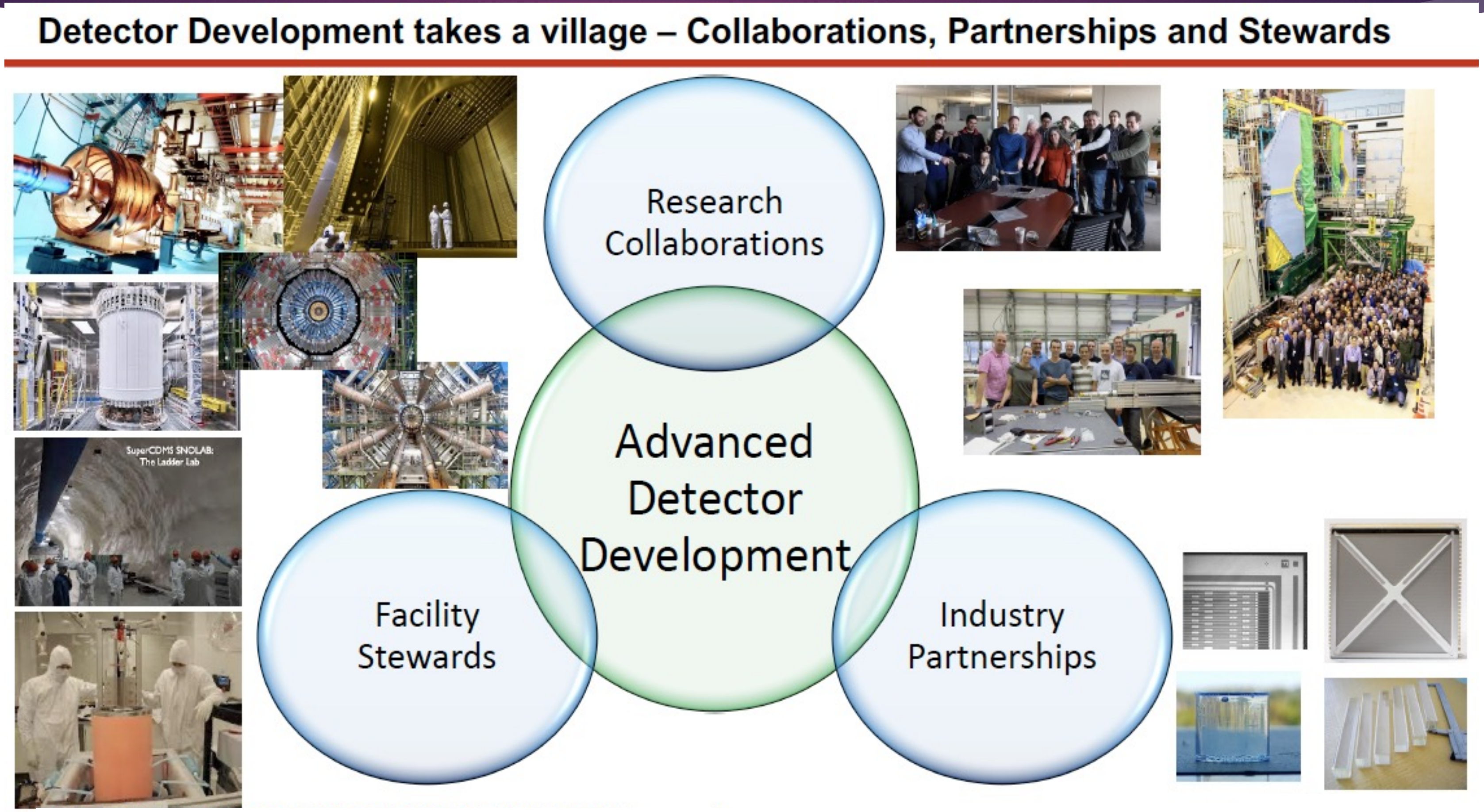
Intra-Collider Synergies

take advantage of these synergies until Higgs Factory decision is taken globally

- **Current/near-future:**
  - Si-based Calorimetry: Calice & CMS HGCal
  - Scintillator-tile-based calorimetry: CMS HGCal & EIC
  - LGADs: HL LHC ATLAS & HL LHC CMS & EIC
- **Future:**
  - MAPS: will be ubiquitous; low mass, high granularity, can include fast timing: HL LHC & EIC, FCC-ee, ILC, MuC
  - Standard silicon tracking
  - Calorimetry: PF and Dual Readout, different materials and technologies: many commonalities among different colliders
  - Gaseous detectors: applications in tracking, calorimetry, muon detection
  - Radiation hardness: FCC-hh & MuC
  - Many other synergies: ASICs, readout electronics, TDAQ, on-detector AI/ML

(Moved technology and R&D details into backup, here focus on:) Cross Cutting Topics

Collaborations, Partnerships, Facilities



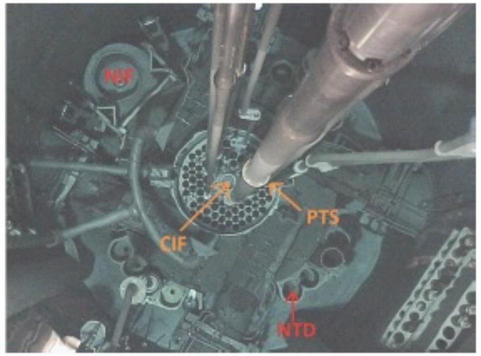
Technology Access

- **Ensure institutional retention of >3 decades of collider detector instrumentation design and development experience:**
  - System design → moving towards co-design/co-simulation
  - Hierarchical approach to design and simulation of high-channel detector sub-systems
  - Integrated sensors and readout on single/multiple parallel substrates (e.g. MAPS)
  - Engage designers in building radiation tolerant ASIC blocks for future Systems-on-a-Chip (SoC) → to maintain state of art readiness (front-end readout, local memory, on-chip supply conversion DC-DC and LDOs)
- Maintain HEP-specific ASIC web resources for tutorials, examples, references (rad-tolerant/cryo)
- **Future designs will require broad, multi-institutional access to:**
  - Advanced technology nodes for ASIC fabrication
  - CAD design and design management tools and training
  - Hierarchical system simulation tools

Need to maintain & enhance our facilities

Facilities/Capabilities are a vital element of detector technology development

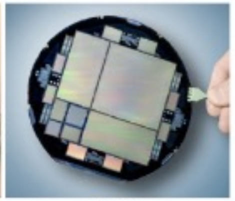
- Test Beams
  - Hadrons at FNAL, LANL, CERN, KEK
  - Electrons at SLAC, Mainz, JLab
- Calibration Facilities
  - Low energy beams, especially neutrons
- Irradiation Facilities
  - BNL, FNAL, PNNL, Sandia
- Dedicated detector development labs
  - SiDet and NLTF at FNAL
  - MSL at LBNL
- Ultra-low background materials and radioassay
  - PNNL, SURF, LBNL
- Ultra-low-background radiochemical analysis and mass-spectrometry
  - PNNL (ICPMS), ANL (AMS)
- Microelectronics, sensor and imager design
  - BNL, FNAL, LBNL, SLAC, Sandia
  - Penn, Northwestern, SMU, Stony Brook University, Washington University, UIC, UIUC, Purdue, UW, Columbia, Stanford etc.




Lithography

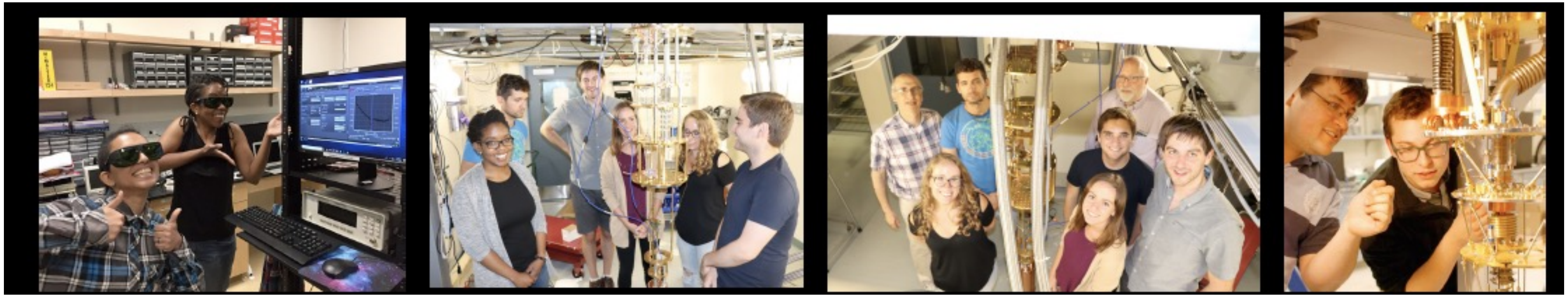

Etching


Film Deposition


CCD Wafer

Training the Instrumentation Workforce

- Fundamental to the success of HEP
  - Exciting physics + instrumentation = opportunity to attract and train students from diverse backgrounds
- Build on current success:
  - Dissertation awards, fellowships, traineeship awards
  - Student and postdoc placement and retention
  - Investment for University, National Lab and Industry workforce

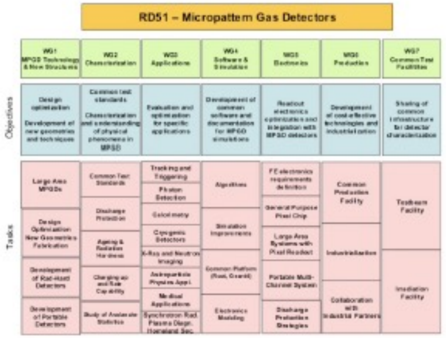


Detector R&D Consortia

New R&D frameworks could enhance U.S. leadership in detector technology

- CERN RD Collaboration Model
  - Topical collaborations around specific technology developments
  - Originated in 1990 with RD-1, now at RD-53
  - ECFA Detector Roadmap (2021)recommended creation of new ones in Calorimetry, Photo Sensors & PID, Liquid Detectors and Quantum Sensing. These RD Collaborations are proposed to be global in extent. **The US HEP community should engage broadly and early to help shape these new RD collaborations**

- NNSA Office of Defense Nuclear Nonproliferation (NA-20) Consortia
  - Topical collaborations around specific thrust areas in nonproliferation
  - Based out of Universities
  - Laboratories participate via existing funding streams from NA-22 and benefit from students and pipeline for career scientists in the field
  - **Strong focus on workforce development**



Snowmass IF: report

Snowmass IF Recommendations

- From the 2021 Snowmass Report: key recommendations from the Instrumentation Frontier:

IF-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.

IF-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.

IF-3 **Double the US 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.

IF-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.

IF-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.

CPAD: webpage

What is CPAD?

Coordinating Panel for Advanced Detectors

a panel of the APS/DPF (American Physical Society / Division of Particles and Fields)

- CPAD seeks to promote, coordinate and assist in the research and development of instrumentation and detectors for high energy physics experiments
- Originated from 2012 Snowmass process (Instrumentation Frontier)
- Over last few years developed bylaws that regulate CPAD leadership: 2-year rotating terms for Chairs and Executive Committee members, nominations from the community

Main activities:

- **Annual workshops** hosting vibrant exchange for people working on detector R&D, brainstorming on new technologies and applications; essential networking opportunities for early career colleagues
  e.g. organized **Quantum Sensing for HEP** workshop in 2017, kicking off a whole new field in US
- Interfacing with **industry partners**
- Interfacing with **other disciplines**, e.g. Nuclear Physics, QIS, Material Science, Chemistry, etc.
- **Recognition and nurturing of careers** in detector instrumentation: annual DPF Instrumentation Awards and GIRA Awards (Graduates in Instrumentation Research Award)
- **NEW: RDCs = R&D Collaborations**

What are the RDCs?

- Newly formed groups under the stewardship of CPAD
- Born out of Snowmass recommendation
- Create a **network** of US Detector R&D Collaborations
  - coordination between different RDCs and exchange with ECFA DRDs
- These Collaborations were created covering major technology areas in line with the 2019 BRN. The goal is to bring together the community in a more persistent way than the annual CPAD workshops alone, to coordinate R&D efforts and to forge collaborations

- Goals:
  - Create a robust R&D program towards the technologies needed to enable discoveries in future HEP detectors and foster innovation in instrumentation
  - Allow for more streamlined and synergistic collaboration between university teams and laboratories to share expertise, tools and facilities, and avoid duplication in light of limited funds
  - Potential to uncover new materials and methods for HEP/collider dets.
  - Facilitate easy communication and connections between participants in US R&D Collaborations and CERN DRDs and other relevant partners
- First step: organize R&D Collaborations (RDCs) along specific key technologies in line with BRN
  - identify initial lead people and liaisons with European DRDs
  - organize workshops to define key R&D directions that connect different communities

Principal Ideas behind the RDCs

Detector R&D in many different technology areas is essential to realize many of the future planned experimental efforts spanning all of the frontiers in High Energy / Nuclear Physics

Much of the efforts needed require **collaboration** and **coordination** in order to realize the technologies required

- **Collaboration**: The required expertise/resources/new ideas often live within multiple people, institutions, labs and only by bringing these pieces together can we hope to realize the technological challenges
- **Coordination**: We live in a resource limited funding environment and so we need efforts to be coherent, minimize duplication, and to build off of progress happening elsewhere (both in other technologies and in other places)

Principal Ideas b

Collaboration

RDCs can work to identify needed R&D, put together work-packages, and aid in the execution of the work

Detector R&D in many different ... future planned experimental efforts sp... ysics

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Principal Ideas b

Coordination

This is what CPAD is meant to help provide and why these collaborations are being formed within our structure/charge

Detector R&D in many differen t uture planned experimental efforts spa ysics

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What will the RDCs do?

Long term goal:

- **Provide a collaboration** which can link together facilities, expertise, people, and experience to tackle technology challenges across HEP/NP
- **Facilitate new funding mechanisms** for R&D related to a specific technology area which will take place as part of the collaborations' activities
- Work with the CPAD executive committee, **ECFA DRDs**, and the broader R&D community to foster a collaborative, supportive, and coordinated environment for new ideas, blue sky efforts, and **non-project specific R&D**

What will the RDCs NOT do?

The RDCs will NOT:

- **Discourage single/small team efforts in R&D**
  - We still need for individual PIs to be able to work in their labs on their favorite ideas and leave room for innovation and unexpected solutions
- **Break up existing collaborations / structures**
  - We already have communities within HEP/NP which coordinate on specific technological challenges (e.g. HEP-IC) and we want to utilize/leverage these efforts and communities to help make the CPAD-RDCs successful
- **Discourage project specific R&D**
  - There is some R&D which will/has reach(ed) a level of maturity that it is time to realize it for a specific implementation and the RDCs should encourage this transition from generic to specific R&D

What is the envisioned structure

- **Each RDC has 2-3 coordinators who work with CPAD executive committee and the community to define the R&D goals**
  - These need to align with the BRN and Snowmass efforts
  - These should be sufficiently generic to allow for new or unforeseen ideas
- **The RDC coordinators will work with the community to put together "work packages" which bring together a collaboration to tackle some idea / technology**
  - These can be university- or lab-led
  - Should have associated timelines and milestones
- **These work packages can then be turned into proposals for funding**
  - In the short-term future, these may be responses to the comparative review funding announcements or reallocation of lab-based (KA25) funds
  - In the long term, this hopefully becomes a new funding mechanism with dedicated FOA and a new funding stream

➔ planning to submit a few coordinated funding proposals for next round of DOE funding opportunity in ~September 2024

R&D Collaborations

RDC#	TOPIC	COORDINATORS	MAILING LIST
1	Noble Element Detectors	Jonathan Asaadi, Carmen Carmona	cpad_rdc1@fnal.gov
2	Photodetectors	Shiva Abbaszadeh, Flavio Cavanna	cpad_rdc2@fnal.gov
3	Solid State Tracking	Anthony Affolder, Sally Seidel	cpad_rdc3@fnal.gov
4	Readout and ASICs	Angelo Dragone, Mitch Newcomer	cpad_rdc4@fnal.gov
5	Trigger and DAQ	Zeynep Demiragli, Jinlong Zhang	cpad_rdc5@fnal.gov
6	Gaseous Detectors	Prakhar Garg, Sven Vahsen	cpad_rdc6@fnal.gov
7	Low-Background Detectors	Daniel Baxter, Guillermo Fernandez-Moroni, Noah Kurinsky	cpad_rdc7@fnal.gov
8	Quantum and Superconducting Sensors	Rakshya Khatiwada, Aritoki Suzuki	cpad_rdc8@fnal.gov
9	Calorimetry	Marina Artuso, Minfang Yeh	cpad_rdc9@fnal.gov
10	Detector Mechanics	Eric Anderssen, Andreas Jung	cpad_rdc10@fnal.gov
11	Fast Timing	Gabriele Giacomini, Matt Wetstein	cpad_rdc11@fnal.gov

Many thanks to these people for taking on the tasks to form these groups, identify R&D topics, goals and roadmaps!

2023 CPAD Workshop at SLAC - November 7-10

RDC Kick-off

279 participants (record due to RDCs?!) - including 33 remote and 54 students

33 parallel sessions with 191 presentation

20 plenary presentations

29 posters

What's Next?

- RDCs can be organized as grassroots effort, but everything else needs enhanced budgets for detector instrumentation
- The vision of the HEP community now needs support from the funding agencies
- 2023: Particle Physics Project Prioritization Panel (P5) took Snowmass report and many other inputs and formulated a 10-year strategic plan with a 20-year vision for HEP. The report will be released this Thursday!
  - Last P5 report from 2013 received broad community support and was crucial to growing HEP budget in the US

2023 P5 Report

Summary

- Decadal strategic planning for HEP in the US concludes this week
  - BRN for Detectors, Snowmass, P5
- CPAD is in the process of enabling enhanced collaboration in detector instrumentation → RDCs
  - planning on strong ties with other regions

BACKUP

SNOWMASS Findings: Detectors for Collider Experiments

Tracking

Push 4D resolution, low mass and radiation hardness:

- Development of sensor technologies
  - Achieve 4D-capability from timing sensors with fine segmentation and able to cope with high occupancies and radiation tolerance
  - Large area sensors with improved uniformity, e.g. traditional sensors, LGADs, and wafer-scale MAPS
  - Sensors that deliver tracklet 4-vectors instead of hit data
  - Major advances in ASIC development and approaches: bandwidth optimization, low noise, small area and low power dissipation
  - New materials for sensor and electronics: unified design of full systems
- Advanced packaging and edge-computing paradigms
  - Vertical integration of multi-tier processing electronics and sensors, optimization of detector thickness
  - Industry partnerships and adoption of new technologies
- Radiation hard technologies and more effective cooling
- Cohesive set of simulation tools

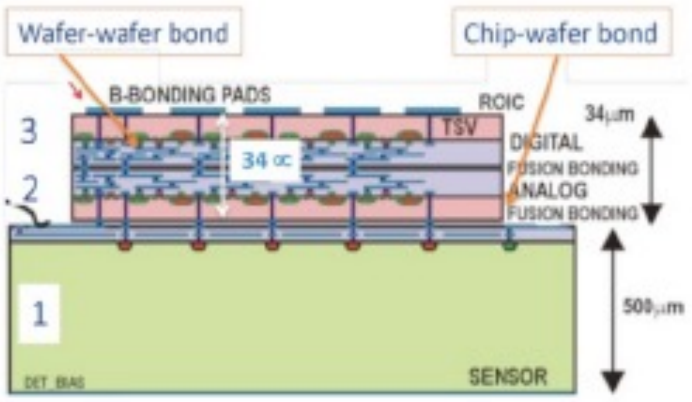
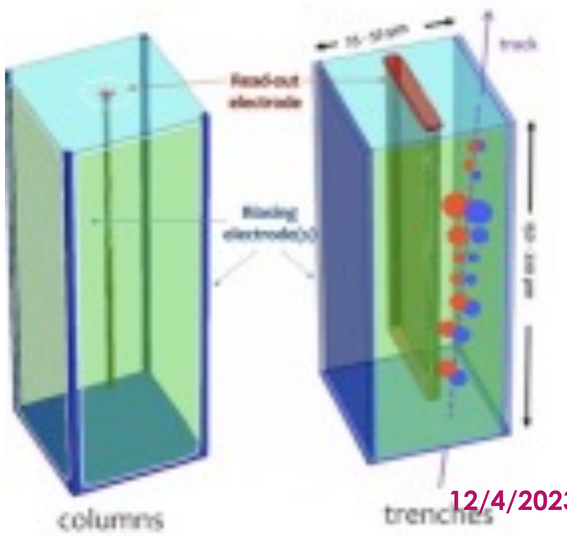
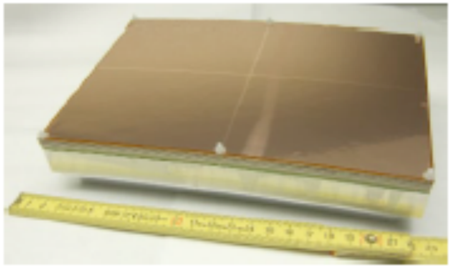


Figure 1: Example of 3D integration of sensor and readout chip.

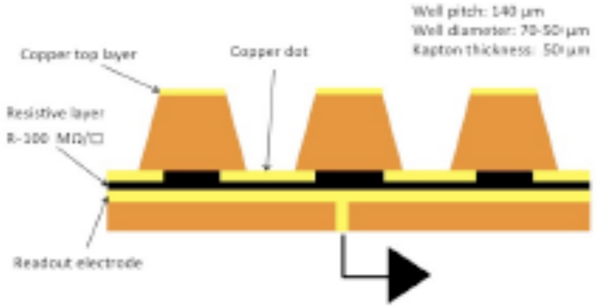


Tracking with Micro Pattern Gas Detectors

- MPGDs have major roles in TPCs and large area muon detection systems. Essential features – large area, low material budget
- TPCs – ILD/ILC, potential Belle II wire chamber replacement, for a detector at CEPC
  - MPGD readout: GEM, GridPix, ...
  - Synergy with Si ASIC development – wafer post-processing, gas amplification on top of pixelized r/o chip
- Muon detection systems
  - Precise muon tracking, trigger and tagger for collider detectors
  - Instrument large areas, high efficiency, in high-background, high-radiation environment
- Challenges:
  - Discharge protection (e.g. micro R-well), miniaturization of readout elements
  - FCC-hh very forward endcap regions
  - Multi-TeV Muon Collider: Fast Timing MPGD, use timing to mitigate beam-induced background



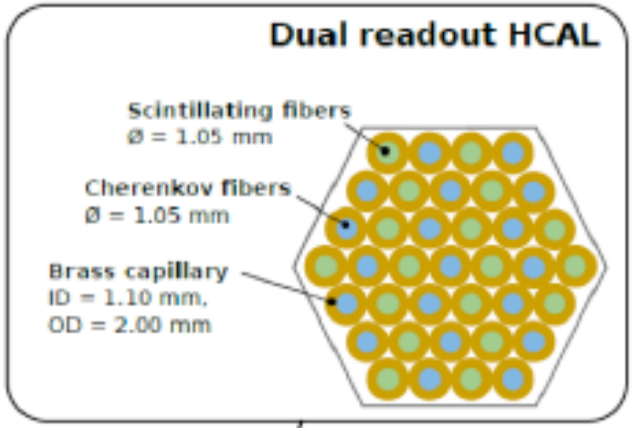
Triple-GEM r/o module for LCTPC

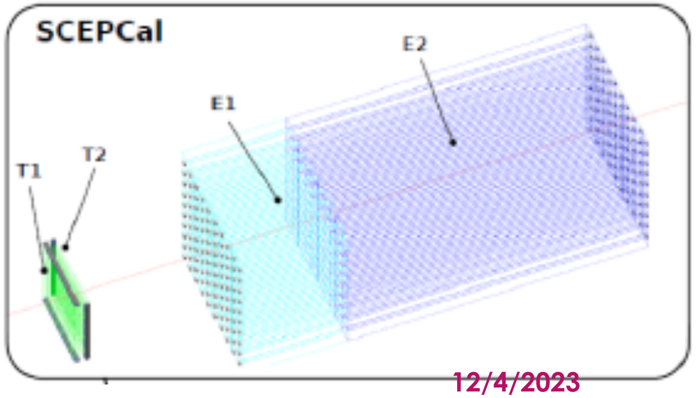


Micro R-well

Calorimetry

- **Two major approaches: particle flow (PF) and dual readout (DR)**
- Recent addition of fast timing information
- Development of new, radiation-hard active materials
- Challenges remain:
  - Mechanics, integration, costing of a realistic spaghetti calorimeter
  - Red-sensitive SiPMs and novel optical materials to boost the Cherenkov signal/noise in homogeneous crystal setups
  - Scaling to 10-100M channels at reasonable cost
  - Thermal and power management of front-end ASICs
  - Compact design (minimizing gaps between sampling layers)

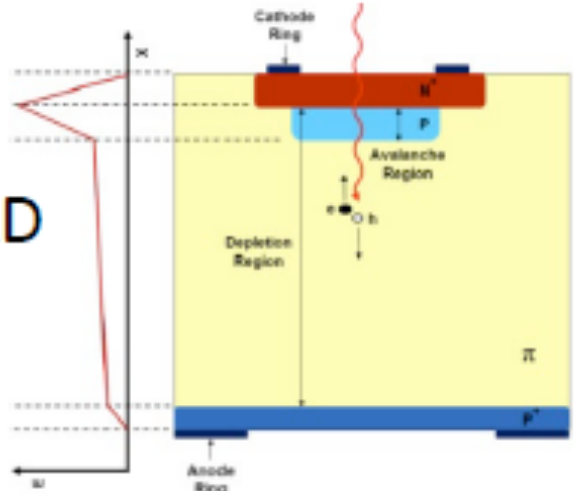


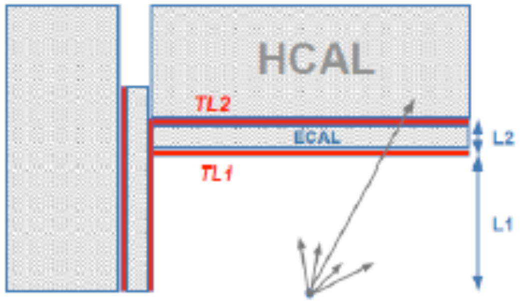


Picosecond Timing

- Timing layers
  - Low-gain Avalanche Detectors (LGADs): ~30ps time and 1mm spatial resolution
  - Ultra-fast silicon monolithic sensors with integrated readout (CMOS): 10-20ps
  - Micro-channel plate (MCP) detectors for single ionizing particles: ~few ps
  - 2-stage Micromegas + Cherenkov radiator equipped with photocathode: <100ps
  - LYSO crystals + SiPM: few 10s ps
  - Deep-diffused avalanche photodiodes: ~40ps
  - Coherent microwave Cherenkov detectors: ~0.3 – 3ps
- Volume timing:
  - Silicon tiles, e.g. LGADs: few 10s ps
  - Plastic scintillator tiles or strips with SiPM readout: sub-ns - few 10s ps
  - Multi-gap RPCs: sub-100ps
  - Highly-granular crystal-based detectors, using a highly-segmented readout
- **R&D needed on electronics to support timing resolution satisfying the constraints on power consumption associated with highly-integrated systems with extreme channel counts**

LGAD





Current CPAD Leadership

Petra Merkel
FNAL
Chair

Jonathan Asaadi
Texas, Arlington
Vice-Chair

Marina Artuso
Syracuse

David Asner
BNL

Carmen Carmona
Penn State

Noah Kurinsky
SLAC

Kim Palladino
Oxford

Sally Seidel
New Mexico

Michelle Stancari
FNAL

Aritoki Suzuki
LBNL

Steve Worm
Humboldt/DESY

Jinlong Zhang
ANL

RDC Kick-Off @ 2023 CPAD Workshop: Status and Plans for the RDCs

RDC1: Noble Element Detectors

Jonathan Asaadi
Carmen Carmona

- 5 sessions (3 RDC1, 1 joint RDC1/RDC2/RDC7, 1 joint RDC1/RDC4), 24 presentations + 5 posters
- List of work packages already identified. Based on DRD2, but more packages added to adapt to US groups:
  - Heat Readout: Phonon Sensors
  - Charge Readout: Pixels; Charge+Light; Charge-to-light (EL and Amp.); Ion Detection (EL and Amp.)
  - Light Readout: Increased sensor Q.E./P.D.E; Wavelength Shifters/Expanded Wavelength; Increase Collection
  - Target Properties: Properties and Isotope and chemical; Chemical Purity; Target Response and Modeling; Low Energy / Spurious Signals
  - Scaling-Up Challenges: Radiopurity & Background Mitigation; Detector and Target Procurement/production; Large Area Readouts; Material Properties; In-situ Calibrations; High Voltage; Infrastructure
  - New Initiatives/Novel Architectures: Solid Nobles; Phase Changing Detectors
  - Cross RDC: Data Volume
  - Facility Coordination
- We will plan regular meetings

RDC2: Photodetectors

Shiva Abbaszadeh
Flavio Cavanna

- 3 sessions (2 RDC2, 1 joint RDC1/RDC2/RDC7) 20 oral and 9 poster
- List of work packages already identified:
  - **Innovative photosensor breakthrough:**
    - Blue skies research aiming to advance single photon detection, VUV sensitive,tunable spectral sensitivity, high granularity and fast timing, radiation tolerance and large area capability.
  - **Large Area Photodetector Systems and Scalability:**
    - Project-specific Research and Development (R&D) for Large Area Photodetector Systems, integrating photo-sensors with advanced readout technologies. Photodetector integration and deployment (overlap with RDC1, 4, 5, 10, 11)
- Planned quarterly meetings
  - Started a shared google drive to coordinate different universities lab capabilities, facilities to identify existing and potential areas for collaboration: https://docs.google.com/presentation/d/1_5JCRbVtqJJkyK7p3A7z6Z8cLZ3TKLIokTJd_7cvs-M/edit?usp=sharing
  - Will send out survey to identify potential topics for virtual workshop

RDC3: Solid State Tracking

Anthony Affolder
Sally Seidel

- 3 sessions (1 RDC3, 1 joint RDC3/RDC4, 1 joint RDC3/RDC11), 17 presentations+ 1 poster
- List of work packages already identified
  - First suggested work packages based on BRN/Snowmass will need refinement based on community inputs in the near future:
    - Topic Area #1: Adapting non-silicon and novel-configuration sensors
    - Topic Area #2: Scalable, low-mass detector systems
    - Topic Area #3: Trackers for Lepton Colliders
    - Topic Area #4: Trackers for Hadronic Colliders
    - Topic Area #5: Advanced modeling
- Planned regular meetings or workshops
  - Plan general quarterly meetings across the whole workpackage
  - Additional ad-hoc meetings will be necessary to define and follow cross RDC work packages
- Next steps to get towards September 2024 FOA
  - At least 2 "Blue Skies" joint university-national lab partnerships presented
  - Larger cross RDC work package possible based on MAPs and LGAD technologies based on the critical mass of presentation (see next slide)

RDC3/RDC4/RDC10/RDC11 Tracking Work Packages

Common Projects:

- In the short term, we need special meeting in order to define tracking work package across RDCs
  - Do we have central proposals and a set of proposals?
  - Need roadmap technical milestones which are iterative and allow parallel development paths
- Understand the interaction with ECFA DRD3/DRD7 based on the understanding of what the US want to do
  - Do we work collaboratively, in competitions, or divide up needed developments?

MAPs-based trackers

- Do we target general e+e- where most of current activity is OR by even more inclusive (muons/hh/blue sky ideas)?
  - What are the sensor sizes, scale of tracker?
  - What are generic specifications? Are there particular options we need to consider (like power-pulsing for LCs)?
- Do we want to include all system aspects or pick specific elements: some potential items brought up in presentations include pixel matrix, data/command systems, power management, services, mechanics

LGAD-based trackers

- Is there a common general target we can work towards?
- How to we coordinate the ASIC, sensor and system elements?
- Is there common system aspects we want to address as a community?

RDC4: Readout and ASICs

Angelo Dragone
Mitch Newcomer

- **57 abstracts, 27 cross RDC abstracts** 4 Sessions, 4 combined sessions
- WP structure will consist of a portfolio of thrusts under an overarching theme. Members will share knowledge and build on shared results to define blue sky goals. Each work package will have a workforce training component.
- WP's yet to be finalized the ones below indicate thrust.(we will need to interface with DRD7 and understand which projects are collaborations and which are independent thrusts)
  - **Front End Control/ Readout techniques TBD & likely merged with other RD's Calo Tracking Photon systems**
  - **Tracking Readouts Feature Extraction for AC strip interpolation 4D Maps**
  - **Calorimetry readout… 5D detectors SiPM on tile eFPGA or SMART processing on detector**
  - **Fast Timing readout… Clock/Calib distribution on detector through to ASIC front end**
  - **HEP relevant Extreme environment models and digital librarys for ASICs**
  - **Sub 65nm and smaller SOC universal building blocks design/develop/submit/test/document for future chips**
  - **High Rate Data Management** (Big Data)
    - Aggregation of on Detector Data
    - Data Driven routing
    - Rate/Power optimized Drivers / Receivers
  - **Workforce Training & Support -> Contribute input to a more horizontal service under a different umbrella.**
    - Mentored ASIC Project led by trainees
    - Instrumentation Specific Certificates/degree programs at Universities
  - **Intelligent Data processing (ASICs and Electronics)**
    - eFPGA
    - AI/ML
    - Edge Computing
  - **System Interfaces**
    - Interconnect technologies
  - **Powering / Management < may distributed into Front End Readout specific Topics**
  - Future … System / Sub-system Aware Design/verification/project organization
- We will keep collecting input from the community until November 30th
- Planned regular meetings or workshops follow up with RDC 1, 9, 3, 11
  - Intention agreed Schedule TBD
- Next steps to get towards September 2024 FOA - Organize projects under Work Package Topics

RDC5: Trigger and DAQ

Zeynep Demiragli
Jinlong Zhang

- 11 abstracts, 2 sessions
- Work packages being discussed
    - Intelligent data reduction and processing (with RDC4)
        - Real-time / low-latency data reduction and feature extraction
        - Fast artificial intelligence and neuromorphic computing on real-time hardware
    - Link technology (with RDC4)
        - High-bandwidth, rad-hard, low-power optical link (>50Gbps)
        - Wireless readout
    - Integrating modern computing architecture and emerging technologies
    - Self-running DAQ system
    - Timing distribution with picosecond synchronization (1ps over 1 km) (with RDC4)
- Regular meetings being planned to further develop the work packages
- Aim consortium proposal(s) to respond September 2024 FOA

RDC6: Gaseous Detectors

Prakhar Garg
Sven Vahsen

- 13 abstracts, 2 parallel sessions, 1 awards talk
- We plan to not replicated the large DRD1 structure in the US.
- Rather, we want to prepare work packages where US groups have specific expertise and strong interest, and then integrate these packages into the DRD1 plans.
- There are some obvious synergies between RDC6 groups working in different fields. For example, highly segmented MPGD-based charge readout schemes are foreseen at DUNE near detector, rare event searches, and at future collider detectors in HEP and NP.
- While specific work packages need proper discussion by the whole RDC6, preliminary ideas floated include:

  1. "Advancing gaseous TPC readout to the fundamental sensitivity limit"
  2. "Improved MPGD structures for nuclear physics and challenging environments"
     (for gases w/o quencher, negative ion drift, high charge density)
  3. "Achieving cost-effective scaling of gaseous TPCs"

- We will organize meetings to converge on 2-3 highest-priority work packages.
- Meetings will (only) be announced to the RDC6 mailing list. Sign up now! https://cpad-dpf.org/?page_id=1549

RDC7: Low-Background Detectors

Daniel Baxter
Guillermo Fernandez-Moroni Noah Kurinsky

- 26 abstracts w/ 23 presentations and 2 posters across 2 (+2 joint) sessions
- Infrequently-held meetings on Tuesdays at noon EST
  - Get on RDC7 mailing list to know when one is happening
- Work with RDCs 1/2/8 to distill suggestions into a viable number of WPs and collaborations to move forward
  - Clearly need to break up WP7 into smaller pieces, some of which may get absorbed into RDC8
  - Some identified WP's are under-represented at CPAD2023

WP	Topic	Overlap	Talks	Poll
1	Ultra-Pure Material Production		0	6
2	GEANT4/G4CMP Development		1	4
3	Radioassay Facilities and Techniques		1.5	5
4	Noble Element Purification	RDC1	1.5	4
5	Phenomenology of Materials		3.5	2
6	Low-Threshold Calibration Techniques		4	4
7	Low-Background Device Fabrication	RDC8	9.5	9
8	Supporting Technologies		1	10
9	Radon-Mitigation Strategies		1	5

RDC8: Quantum and Superconducting Sensors

Rakshya Khatiwada
Aritoki Suzuki

- Wide range of interests
  - 30 abstracts, 6 sessions, 1 joint sessions with RDC 7
  - 5 subgroup talks w/ discussions, 2 round table discussions, 24 contributed talks
- Planned meetings: ~(bi)monthly meetings to discuss work packages
  - Mailing list + Slack (?) communication
  - Second survey (collaborate with RDC7?) to gather more information
- Workshops (to be confirmed through second survey)
  - Best practices for cryostat setup → handbook → summer school?
  - Amplifiers: How to meet demand by the community. Spec, supply, test facility
  - Simulation packages: Share how packages such as G4CMP, COMSOL, HFSS are used
- Work packages
  - Review BRN. Update with the latest developments and inputs
  - Set milestones → map work package ideas on to it
  - Collect ideas through discussions and surveys

RDC9: Calorimetry

Marina Artuso
Minfang Yeh

- 24 abstracts, 2 sessions, and 1 round table discussion
- List of work packages already identified
  - New materials for calorimetry: Scale-up material (liquid scintillators and water-based liquid scintillators) and Inorganic crystals/glass that are bright, fast, rad hard, dense-UV transparent, and cost-effective
  - Optical coupling and light extraction (WLS)
  - Photon detectors
  - Front-end electronics needs for high energy resolution and picosec timing calorimetry
  - System aspects (mechanical for low mass support & cooling; (electronics) for powering scheme & interconnections; (data processing) for intelligent calorimeter
  - Concepts from the above lines of investigation adapted to hadron identification (TOF, RICH…)
- Infrastructure needs to support our work: improvement of simulation packages with respect to GEANT; Test beam for near-future; and early career support.
- Planned regular meetings or workshops: continue monthly community meeting and cross-RDCs conversations
- Next steps to get towards September 2024 FOA
  - Identify R&D drivers; open for community inputs/comments; final report posted in August

RDC10: Detector Mechanics

Eric Anderssen
Andreas Jung

- 11 abstracts, 6 Presentations, 3 Joint, +3 Posters, 2 sessions
- List of work packages already identified
  - Will solicit work packages in community survey.
  - Likely to include 'Ultra-low mass support', Cooling, Services--intend to grow
- Planned regular meetings or workshops
  - Kick-off meeting in January with initial monthly/bi-monthly meetings to establish and build a community
  - Occasional joint meetings with other RDC or RDC WP with similar cross-cutting needs.
  - DRD Kickoff in December (shared interests at CERN), and FTDM in May 2024 at Purdue
- Next steps to get towards September 2024 FOA
  - Circulate community survey in coming days
  - Identify cross-cut work-packages identified in other RDC's
  - Grow and diversify mechanics community to reach beyond typical Tracking detector mechanics subjects relevant to other RDC's e.g. cryo, materials

RDC11: Fast Timing

Gabriele Giacomini
Matt Wetstein

- One session pure RDC11 (4 talks), two 3/4/11 sessions: one with 7 talks about LGADs, one with 5 talks on MAPS. Other talks could fit.
- Work packages:
  - Clock distribution and sync
  - LGADs
  - LAPPD
  - TOF/PID techniques
  - Non-silicon/new materials fast sensors
  - MAPS (3D, monolithic LGADs)
  - ASICs (fast ditigizer, …)
- Online meetings every second month + one in person - next meeting in early December (TBA next week)
- Next steps to get towards September 2024 FOA:
  - Coordination with other RDCs
  - Collect inputs from parties

Transversal Forum on Training and Workforce

- Discussions throughout the week of the workshop indicated it might be useful to create a transversal forum dedicated to training and workforce development
- Mandate could include:
  - Assisting the RDCs with including training aspects in their work packages and in funding proposals
  - Organization of instrumentation schools, perhaps adjacent to CPAD workshop? Or enhancement of existing school
  - Increased training collaborations funded through DOE Traineeship funds
  - Assist with networking between institutes participating in RDCs to match students and supervisors at labs
  - Etc.
- Need to find volunteers who want to take this on