US Perspective

- The planned R&D structure in the US (slides 2-7 from the CPAD Meeting, May 3, 2024)
- RDC9 (Calorimetry) information (slides 8-17) from the calorimetry co-coordinators Marina Artuso and Minfang Yeh

The American Physics Society (APS) and Division of Particles and Fields (DPF) Coordinating Panel for Advanced Detectors (CPAD)

CPAD Mission and Goals:

- The Coordinating Panel for Advanced Detectors (CPAD), seeks to promote, coordinate and assist in the research and development of instrumentation and detectors for high energy physics experiments.
- By helping to coordinate the development of both evolutionary and transformative detector instrumentation across the national laboratories and with the university community, CPAD works to ensure the future of high-energy physics experiments.

It is out of these aspects of CPAD's mission and goals and the work of the Snowmass process which the concept of the formation of Research and Development Collaborations (RDC's) within CPAD was born

CPAD and RDCs

- **CPAD R&D Collaborations** (**RDCs**) cover major technology areas in line with the 2019 BRN with the goal to bring together the community in a more persistent way than the annual CPAD workshops alone, to coordinate R&D efforts, and to forge collaboration.
    - Therefore RDCs focus on generic, blue-sky (high-risk high-reward), long-term topics
        - Note that the main goal of RDCs is to identify priorities and define work packages, to coordinate efforts and forge collaboration
        - Facilitating FY2025 proposal preparation is just a near-term action and not a primary function

Some critical aspects from the P5 report

The particle physics community has identified the need for stronger coordination between the different groups carrying out detector R&D in the US. We strongly support the R&D Collaborations (RDCs) that are being established and will be stewarded by CPAD, the Coordinating Panel for Advanced Detectors, overseen by the APS/DPF. The RDCs are organized along specific technology directions or common challenges, and aim to define and follow roadmaps to achieve specific R&D goals. This coordination will help to achieve a more coherent detector instrumentation program in the US, and will help to avoid duplication while addressing common challenges. International collaboration is also crucial, especially in cases where we want to have technological leadership roles. Involvement in the newly established Detector R&D Groups at CERN is encouraged, as are contributions to the design and planning for the next generation of international or global projects. Targeted future collider detector R&D in particular, such as for Higgs factories or a muon collider, is covered in Section 6.5.

The RDC's are in the P5 report as is participation in the DRD's

Area Recommendation 6: Increase the budget for generic Detector R&D by at least $20 million per year in 2023 dollars. This should be supplemented by additional funds for the collider R&D program.

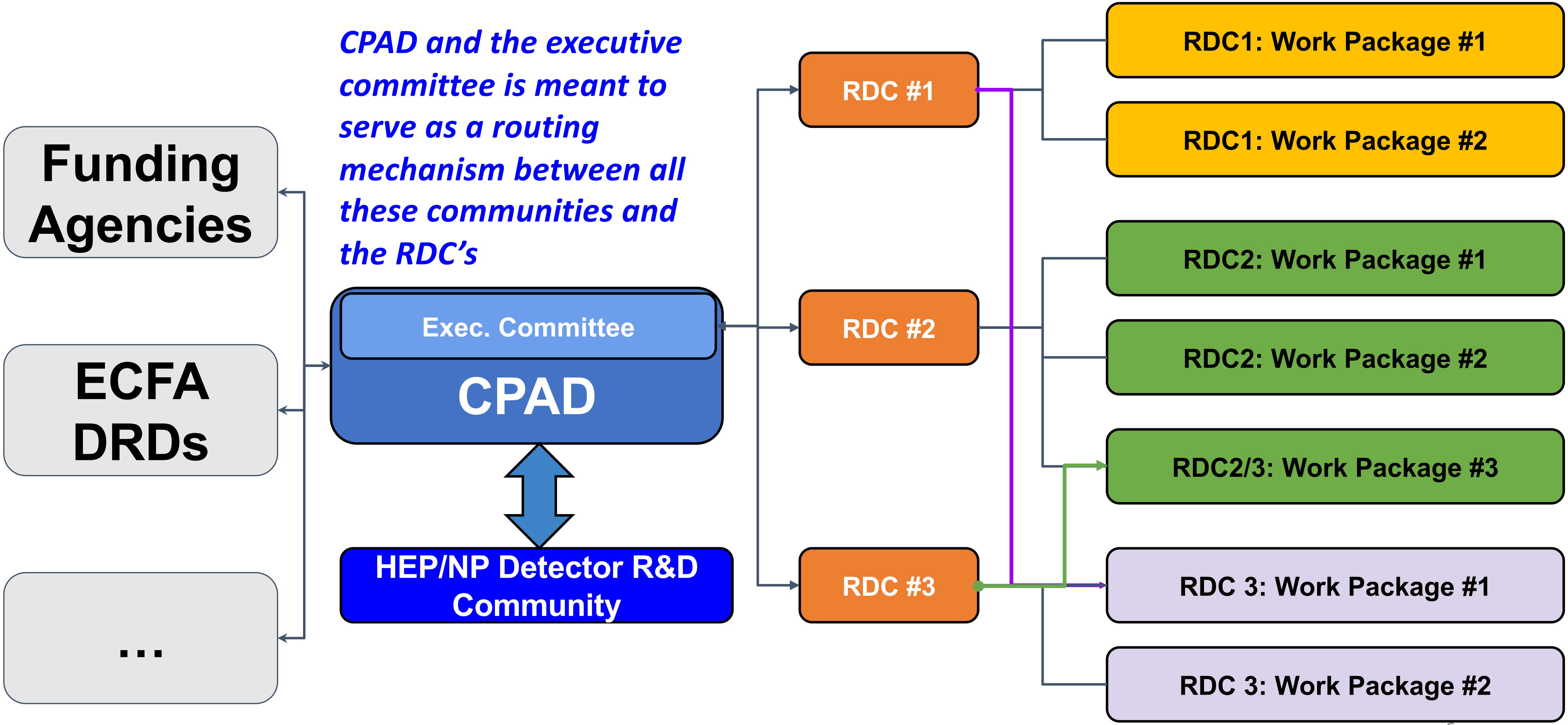
Area Recommendation 7: The detector R&D program should continue to leverage national initiatives such as QIS, microelectronics, and AI/ML.

CPAD and RDCs

- Future projects highlighted in 2023 P5 report will likely have separated R&D organizations, so called **targeted R&D**s, which are anticipated to have coordination by their relevant project
  - For example, FCC-ee, DUNE Phase-2, etc
  - RDCs will work closely with these areas of targeted R&D to optimize the resources and promote the work being done
    - There are ongoing R&D projects/activities that comprise both generic and targeted aspects, and RDCs will work with those for smooth evolvement and transition as appropriate
- Broadly speaking, for a given technology area, the scope of the **ECFA DRD** is a superset of the CPAD RDC one and all relevant project specific R&Ds
  - Please engage the relevant DRD activities and communicate with the RDCs
  - CPAD will establish regular communication with DRD organization, develop the coherency in due time
- We are all eagerly waiting new guidance from the office of science and DOE following the P5 report

What is the envisioned structure (so far)

CPAD and the executive committee is meant to serve as a routing mechanism between all these communities and the RDC's



R&D Collaborations - Status

RDC	Topic	Coordinators
1	Noble Element Detectors	Jonathan Asaadi, Carmen Carmona
2	Photodetectors	Shiva Abbaszadeh, Flavio Cavanna
3	Solid State Tracking	Sally Seidel, Tony Affolder
4	Readout and ASICs	Angelo Dragone, Mitch Newcomer
5	Trigger and DAQ	Jinlong Zhang, Zeynep Demiragli
6	Gaseous Detectors	Prakhar Garg, Sven Vahsen
7	Low-Background Detectors (incl. CCDs)	Noah Kurinsky, Guillermo Fernandez-Moroni, Daniel Baxter
8	Quantum and superconducting Detectors	Aritoki Suzuki, Rakshya Khatiwada
9	Calorimetry	Marina Artuso, Minfang Yeh
10	Detector Mechanics	Andy Jung, Eric Anderssen
11	Fast Timing	Gabriele Giacomini, Matt Wetstein

US Perspectives on calorimetry R&D

- Overall goals
- Overview of ongoing detector-specific efforts:
  - Energy frontier - connections with CERN DRDs
  - Neutrino frontier
  - Rare processes and precision measurements frontier (quark flavor, precision experiments)

illustrative

- Generic interdisciplinary R&D efforts being developed: intersections of research fields and technologies

The big picture

We seek technologies with transformative power on:

- ❑ The energy resolution of calorimeters
- ❑ Ultra-fast light collection
- ❑ High spatial and time resolution in harsh environments
- ❑ Front-end electronics to optimize energy/time resolution
- ❑ Overall system optimization [lightweight support structures, cooling, power distribution, data concentration and transmission]

Areas of interest

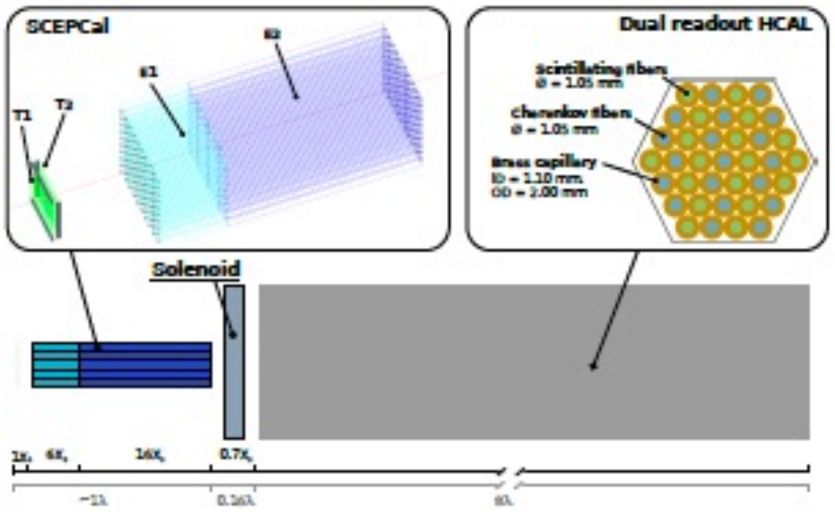
1. New materials for calorimetry, and how they can be tailored to a specific application (including prospects from nanotechnology)
2. Front-end electronics needs for high energy resolution
3. Front-end electronics needs for picosecond timing calorimetry
4. System aspects (mechanical): low mass support & cooling
5. System aspects (electronics): powering scheme & interconnections
6. System aspects (data processing): "intelligent calorimeter"
7. Concepts from the above lines of investigation that can be adapted to hadron identification (time-of-flight, RICH…)

Challenges and needs for calorimetry R&D:

1. Novel materials for specific needs: light yields, fast timing, scalability
2. Front-end electronics needs for high energy resolution: high-dynamic range
3. Front-end electronics for fast timing: waveform-sampling & time stamp extraction
4. System aspects (mechanical): low mass support & cooling
5. System aspects (electronics): powering scheme & interconnections
6. System aspects (data processing): “intelligent calorimeter”
7. Concepts from the above lines of investigation that can be adapted to hadron identification (time-of-flight, RICH…)

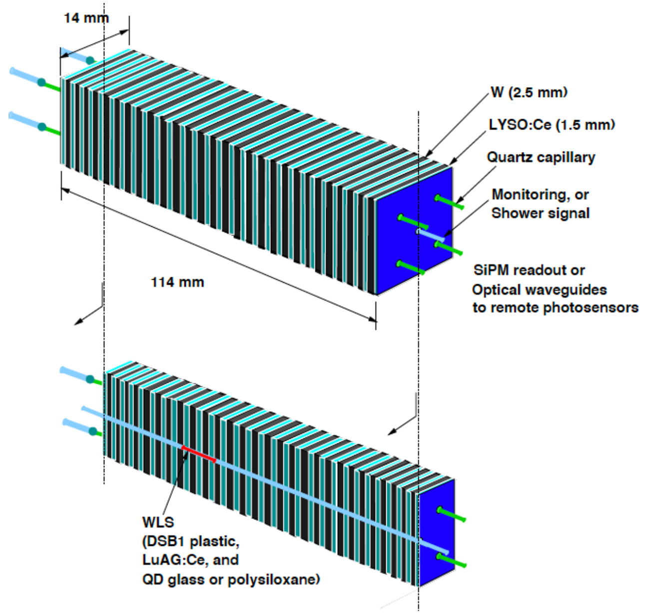
Two examples of ongoing efforts (EF)

- CALVISION



Develop components for dual readout calorimeters (Cherenkov light detection/scintillation detection)

- RADiCAL



Ultracompact, RAD hard EM calorimeter aiming as an energy resolution of 10%/sqrt(E), 10 ps time resolution and position resolution of a few mm, can be used to test different technologies

New Initiatives: Imaging Si calorimeter

- Maps:
  - CMOS wafers affordable
  - Integration of calorimetry and tracking (particle flow)
  - Requires development of embedded electronics
- Ultrafast Si (or other materials):
  - Can break the 10 ps time-stamp barrier
  - Applicable to TOF hadron PID detectors
  - Requires VLSI electronics and electronics infrastructure to preserve time resolution
- Both approaches involve interface issues: large scale devices with a high number of channels, requires close attention to services (mechanics and electronics integration) [synergy with R&D in VLSI, picosecond timing and system design]

New initiatives – affordable scale-up system

- From neutrino experiments to rare decays (e.g. Pioneer ~ 25 radiation length with 1~2% energy resolution).
- How do we build a large-scale calorimeter at >10tons?
- A cost effective, scalable calorimeter using liquid scintillators ($3.5K per ton; ~orders of magnitude cheaper than LXe or inorganic crystal) that performance and compatibility have been largely improved over the past decades through multiple neutrino experiments.
- A new Water-based Liquid Scintillator allowing Cherenkov and scintillation detections with additional safety enhancement and the capability of loading heavy metal at 10s of percent.
  - Adjustable to highly scattered (mm) liquid (self-imaging) incorporating with pixelated technology using SiPM for particle tracking and discriminations.

All these initiatives involve common threads

1. Development of new materials with targeted specifications
   - Bright fast radiation hard inorganic scintillators:
   - Ultrafast inorganic scintillators
   - Dense-UV transparent, cost-effective inorganic scintillator [metal-doped water-based liquid scintillator] (HHCAL)
   - Silicon or Wide band gap detectors
2. **Optical coupling and light extraction:** Wavelength shifters to match scintillator (quantum dots on organic plastic, fluors/WLS mixture: pTP, flavenols, PPO, …, etc.)
3. **Development of new photon detectors:** SiPM adaptation to different environments, low dark current alternatives etc.

The newly formed RDC9 intends to provide a forum between different communities working on these developments to identify synergies and develop new collaborative efforts.

Conclusions

- The US community is engaged in world-wide collaborative efforts in calorimetry for the energy frontier and the intensity frontier (neutrino-quarks)
- In parallel an effort to put in place interdisciplinary "blue sky" R&D initiatives are being discussed; this effort, motivated by the Snowmass community study and P5 has just started
- We promote dialog between different frontiers to identify common threads
- Interface between targeted R&D (e.g. DRDs) and new initiatives are being examined to avoid duplication of effort and foster collaborative exchanges

The end