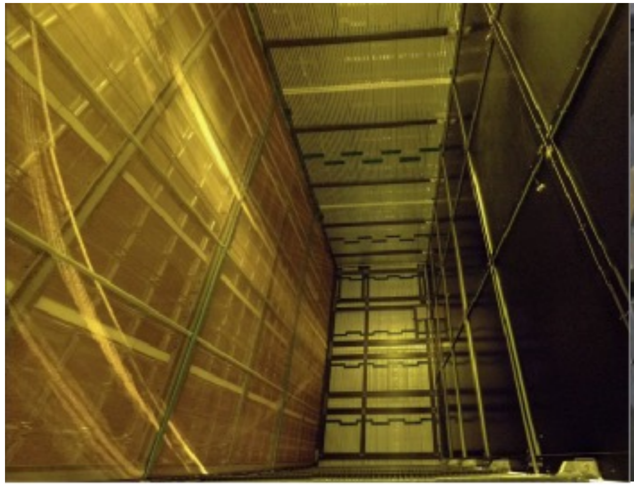
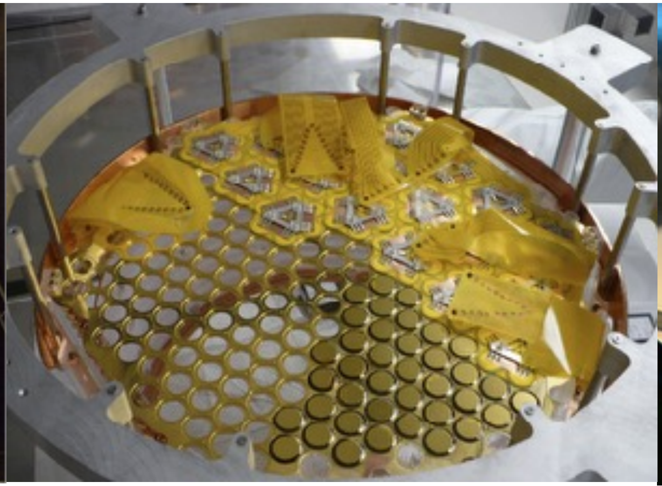
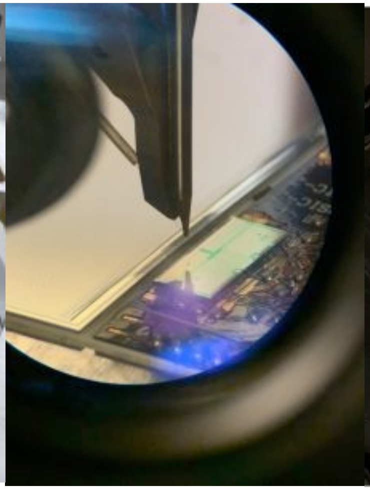
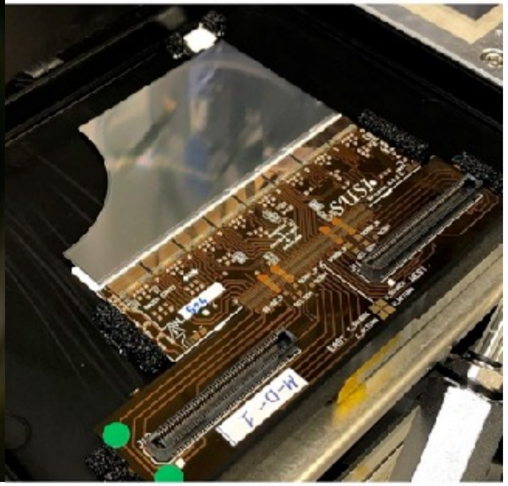
CPAD's View of Detector R&D Strengths in the US

Petra Merkel (Fermilab) – CPAD Chair

US FCC Workshop, BNL, April 24-26, 2023

Overview

- Brief introduction to CPAD
- BRN for Detectors and ECFA Roadmap
- Snowmass Recommendations: US Generic R&D Collaborations
- Synergies between specific collider detector needs and alignment with US instrumentation expertise

CPAD: Coordinating Panel for Advanced Detectors of the APS/DPF

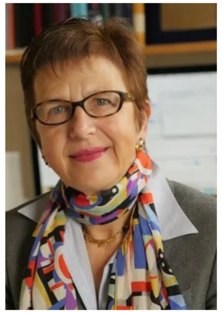
- Chairs and members of Executive Board on 2-year, renewable terms
- New members rotated in every year (community and self nominations)
- Seeking balance between technical expertise, lab/university, gender, etc.

Co-Chairs

PETRA MERKEL
FNAL
CHAIR

JONATHAN ASAADI
UNIVERSITY OF TEXAS
VICE CHAIR

Executive Board



MARINA ARTUSO
SYRACUSE UNIVERSITY
RARE/PRECISION, SILICON

DAVID ASNER
BROOKHAVEN NATIONAL LABORATORY
INSTRUMENTATION

CARMEN CARMONA
PENN STATE UNIVERSITY
DM, LXE DETECTORS

NOAH KURINSKY
SLAC
QUANTUM SENSORS FOR RARE EVENT SEARCHES

KIM PALLADINO
OXFORD UNIVERSITY
DM, LXE

SALLY SEIDEL
UNIVERSITY OF NEW MEXICO
SILICON DETECTORS, RADIATION DAMAGE

MICHELLE STANCARI
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SILICON, COLLIDER AND ASTROPARTICLE INSTRUMENTATION, QIS

JINLONG ZHANG
ARGONNE NATIONAL LABORATORY
ENERGY, TDAQ

CPAD Webpage: https://cpad-dpf.org/

CPAD's Primary Activities

- Started by DPF as taskforce in 2011
- Primary role: promote, coordinate and assist in generic detector R&D nationally, on behalf of 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: supporting DOE in SBIR, STTR
  - Interfacing with other disciplines, e.g. QIS, Material Science, Chemistry, etc.
  - Recognition and nurturing for careers in detector instrumentation: annual DPF Instrumentation Awards and GIRA Awards (Graduates in Instrumentation Research Award)

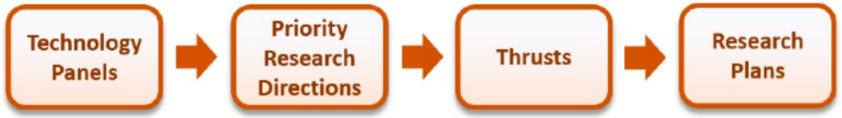
BRN for Detectors in 2019

Basic research Needs for High Energy Physics Detector Research and Development

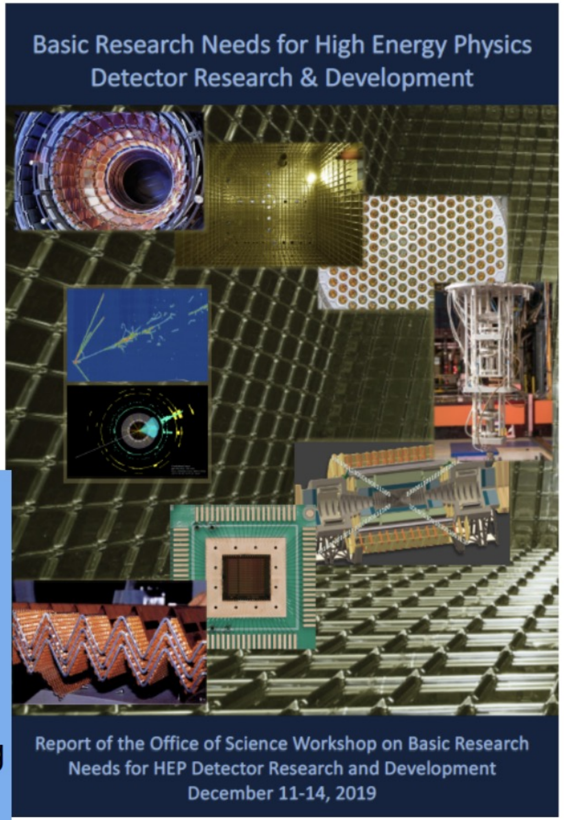
- Methodology:
  - examine connections between physics drivers and detector requirements, considering ALL the physics drivers

} 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 Report: link

BRN: identifies Priority Research Directions

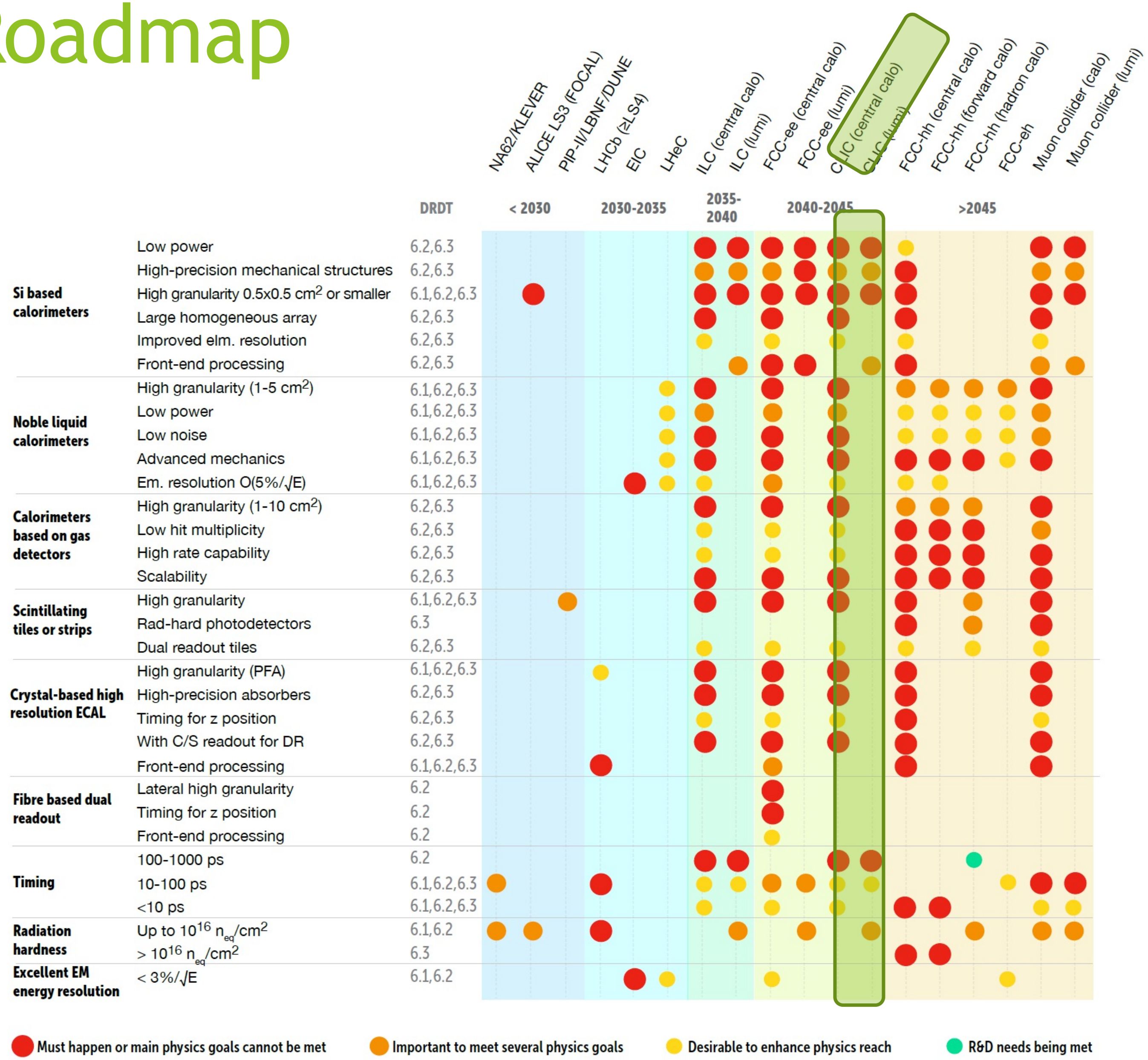
- For example: solid state tracking:

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)	RLepton and hadron collider, heavy flavor experiments at hadron machine, dark matter, charged lepton flavor violation

M.Artuso, P5 Townhall at BNL

Synergies with ECFA Roadmap

- Similar process as US BRN and Snowmass
- Tables with R&D directions, maturity and synergies
- For example: Calorimetry
  - Requirements in granularity, power consumption, readout, …
  - Covering various technologies: Si-based, noble liquids, gaseous, plastic scintillators, crystals, fibers



ECFA Roadmap: document

Snowmass 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.

Snowmass IF: report

CPAD R&D 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

RDC1	Noble Element Detectors
RDC2	Photodetectors
RDC3	Solid State Tracking
RDC4	Readout and ASICs
RDC5	Trigger and DAQ
RDC6	Gaseous Detectors
RDC7	Low-background Detectors
RDC8	Quantum and Superconducting Sensors
RDC9	Calorimetry
RDC10	Detector Mechanics
RDC11	Fast Timing

CPAD RDCs: webpage

Intra-Collider Synergies

- 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

Summary

- Many synergies exist in detector R&D needs for future colliders
  - HL LHC, linear and circular e+e-, hadron, muon colliders and EIC (NP)

Harvard Business Review illustration on Global Collaborations

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Harvard Business Review illustration on Global Collaborations

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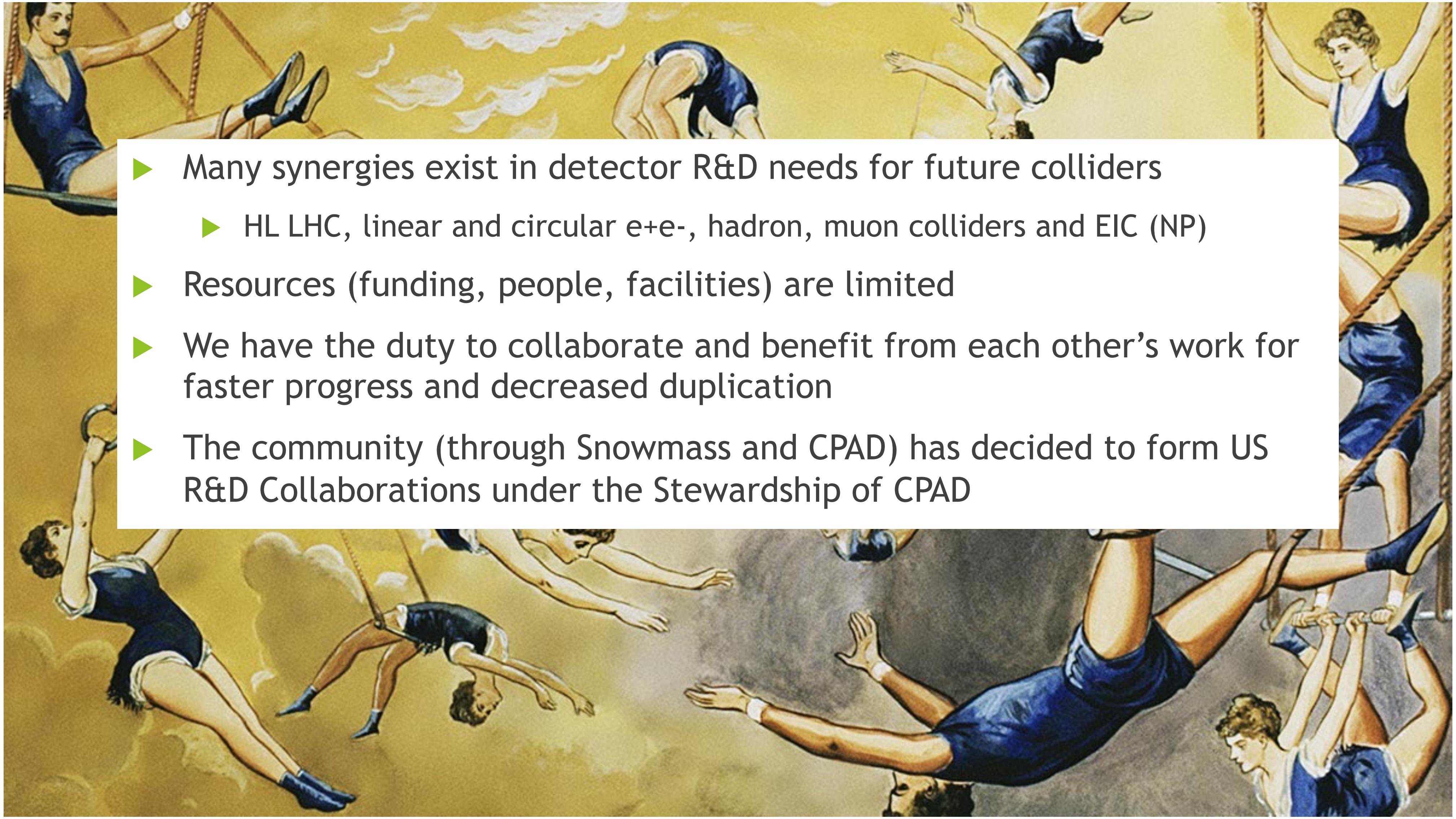

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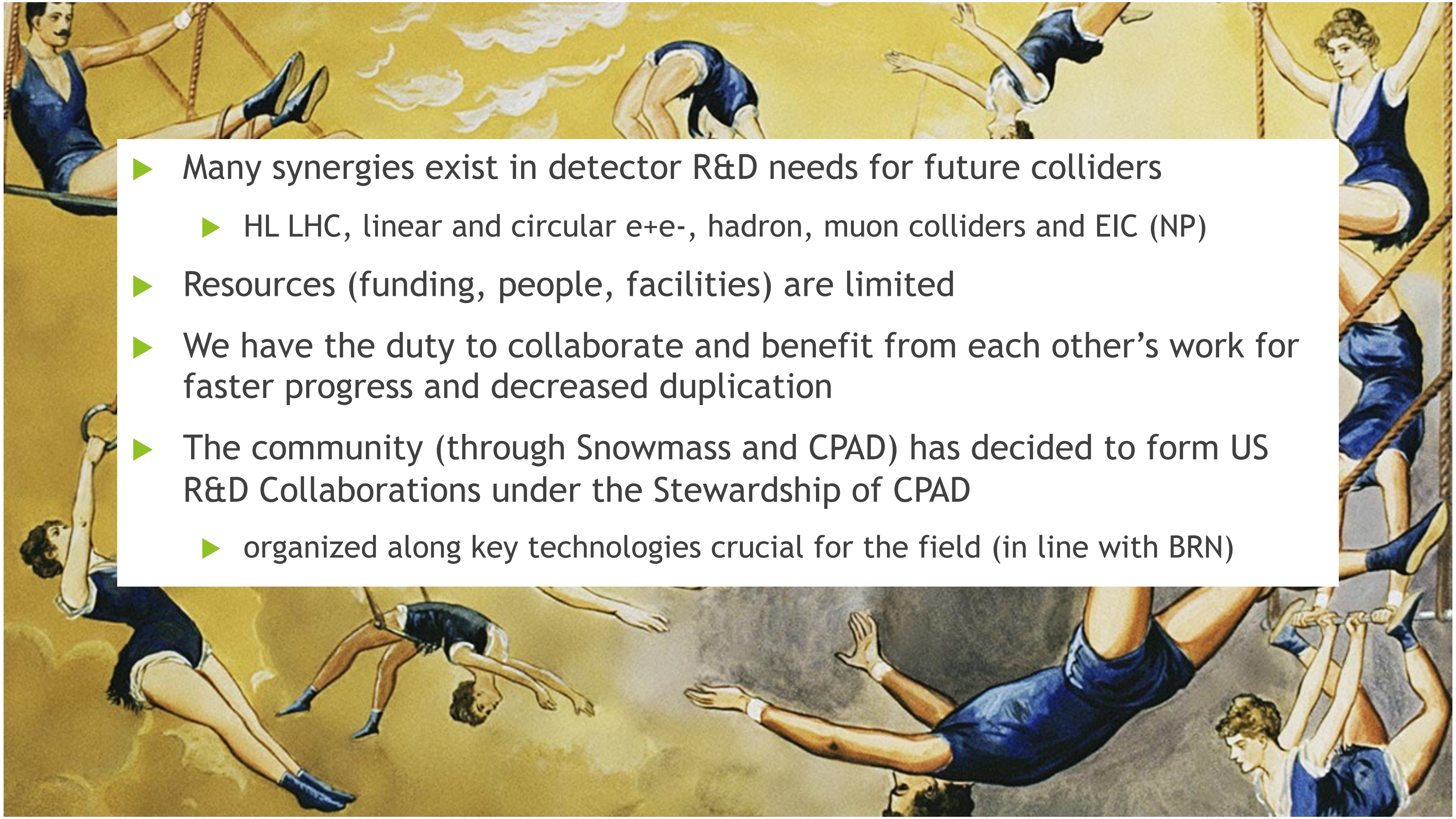

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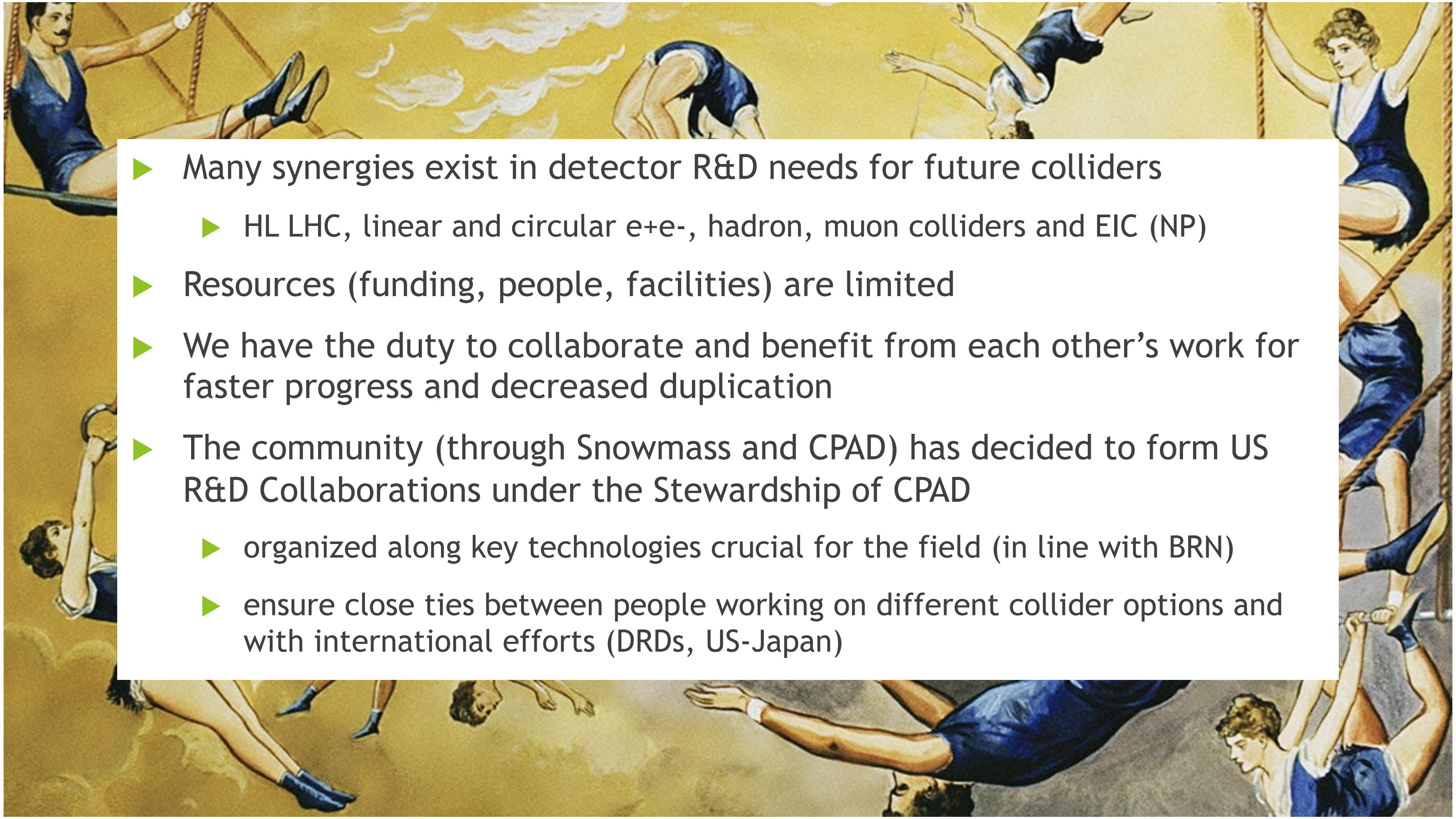

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- The community (through Snowmass and CPAD) has decided to form US R&D Collaborations under the Stewardship of CPAD
  - organized along key technologies crucial for the field (in line with BRN)
  - ensure close ties between people working on different collider options and with international efforts (DRDs, US-Japan)

Harvard Business Review illustration on Global Collaborations