ECFA Detector R&D for Quantum Sensing: implementation of the roadmap

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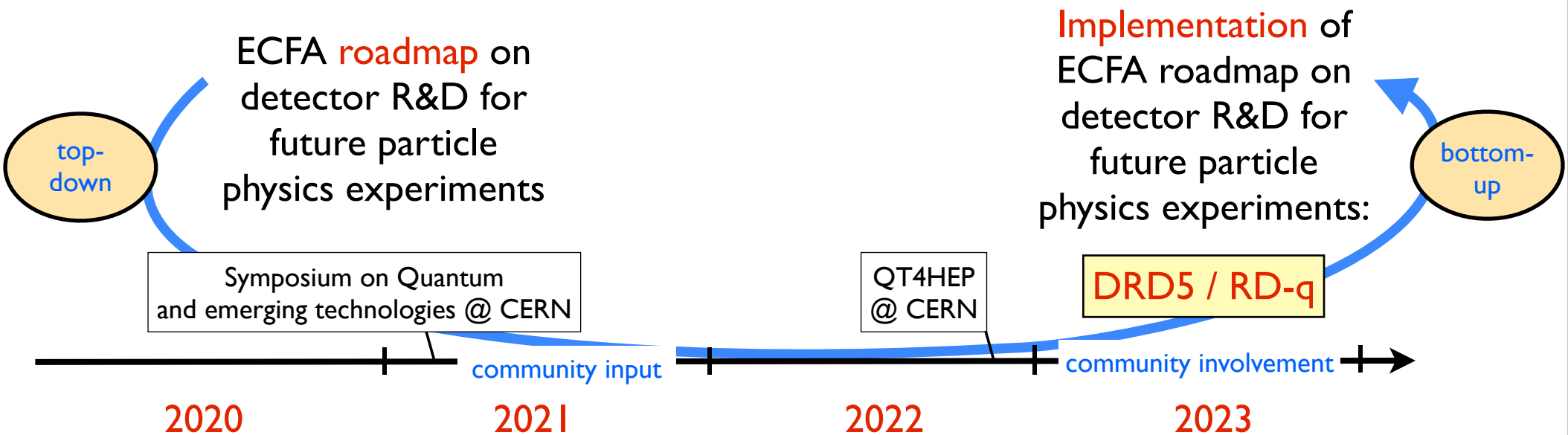
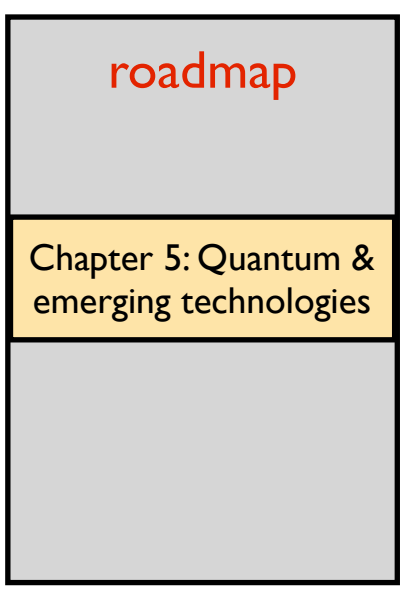
CPAD, Nov. 2023

Overview



ECFA Task Forces's :

1: Gaseous detectors
2: Liquid detectors
3: Solid state detectors
4: Photon detectors & PID
5: Quantum & emerging technologies
6: Calorimetry
7: Electronics & on-detector processing
8: Integration
9: Training



Six families:

1. superconducting devices (TES, SNSPD, …) / cryo-electronics
2. spin-based, NV-diamonds
3. optical clocks
4. ionic / atomic / molecular
5. optomechanical sensors
6. metamaterials, 0/1/2-D materials

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Boundary conditions:

- diverse levels of activities and pre-existing expertise and collaboration (some very active, some emergent, some mature, others starting up); eclectic fields, dynamic approaches and wide geographic spread

  focus on those areas that are beyond the abilities of individual groups and that the different communities identify as being potentially crucial for advances

- no pre-existing community

  gradual reaching out to the different communities, organic, open to growth

- financial limitations

  no annual membership fees, minimal access requirements, no resources

- goal: sensor R&D!

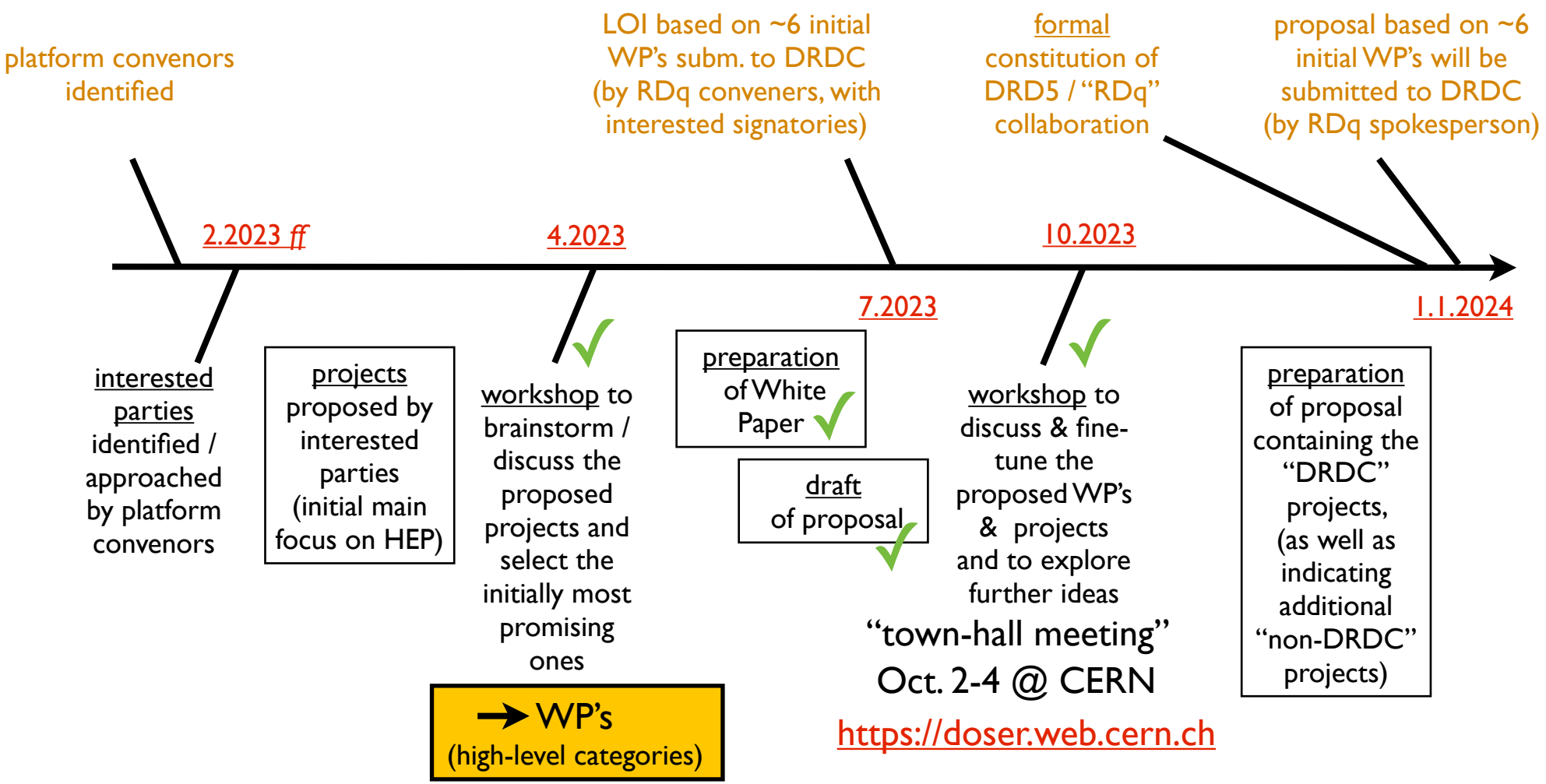
  not targeted towards specific experiments

DRD5 / RD-q not your usual R&D collaboration, more like a network

Two goals for end of 2023 for the future DRD5 / RDq collaboration:

- preparation of a proposal for detector R&D → CERN DRDC
- formation of a global collaboration (Europe, Americas, Asia) → MOU

focus on technical developments that go beyond what a single group can do



WP's over time

WP's after April workshop

WP1 Network, signal & clock distribution (clock network; std. 'portable' clocks)

WP2 Exotic systems in traps & beams (HCI's, Rydberg systems & molecules; beam-beaker-beam)

WP3 Cryogenic systems (4K electronics; TES/KID's/...; integration challenges)

WP4 Theory (bound state calculations; Heisenberg limit; parameter space comparators)

WP5 Scaling up to macroscopic ensembles (0, 1, 2-D nano-structured materials; spins; ...)

WP6 Capability driven design (cross-disciplinary exchanges; test infrastructure; education)

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WP's after v 0.5 of proposal
(same content, different coordinate basis)

aim for version 1.0 by end of year, submission at beginning of 2024 after final community input (open to participation by all)

- **WP1** Atomic, Nuclear and Molecular systems in traps & beams
- **WP2** Quantum components (0,1,2-D, cryogenic components)
- **WP3** Large ensembles of quantum systems (scaling up numbers of elements)
- **WP4** Scaling up to macroscopic bulk systems
- **WP5** Quantum techniques for sensing
- **WP6** Capability building (education; cross-disciplinary exchanges; test infrastructure;)

detailed work in form of sub-WP, specific projects; document designed to be extendable & fluid

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WP's as of v 0.7

BOTH EXPERIMENTAL AND THEORETICAL PHYSICS GROUPS INVOLVED IN WP's

WP1 ATOMIC, NUCLEAR AND MOLECULAR SYSTEMS IN TRAPS & BEAMS

- WP-1a: Exotic systems in traps and beams
  - WP-1aa: Extension & improved manipulation of exotic systems
  - WP-1ab: Bound state calculations
  - WP-1ac: Global analysis in the presence of new physics
- WP-1b: Interferometry
- WP-1c: Networks, signal and clock distribution
  - WP-1ca: Large-scale clock networks
  - WP-1cb: Portable references and sources

WP2 QUANTUM COMPONENTS

- WP-2a: 0-, 1- and 2-D materials
  - WP-2aa: Application-specific tailoring
  - WP-2ab: Extended functionalities
- WP-2b: Cryogenic systems
  - WP-2ba: The 4K stage
  - WP-2bb: Cryogenic quantum sensors for particle and photon detection
  - WP-2bc: Resilient integration of superconducting systems

WP3 DEVELOPMENT OF LARGE ENSEMBLES OF QUANTUM SYSTEMS

- WP-3a: Multi-modal devices (e.g. Opto-mechanical systems, transduction)
- WP-3b: Quantum-system-inspired parallel readout (for 'classical' detectors)

WP4 SCALING UP "QUANTUM" (FOR MIP's)

- WP-4a: Massive spin polarized ensembles
- WP-4b: Hybrid devices
  - WP-4ba: Scintillators
  - WP-4bb: Ensembles of heterostructures
  - WP-4bc: Heterodox devices

WP5 QUANTUM TECHNIQUES FOR SENSING

- WP-5a: Squeezing
- WP-5b: Entanglement
- WP-5c: Back action evasion
- WP-5d: Optimization of physics reach

WP6 CAPACITY BUILDING

- WP-6a: Education platforms
- WP-6b: Exchange platforms
- WP-6c: Shared infrastructures

BOTH EXPERIMENTAL AND THEORETICAL
PHYSICS GROUPS INVOLVED IN WP's

WP's as of v 0.6

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WP-1c: Networks, signal and clock distribution
- WP-1ca: Large-scale clock networks
- WP-1cb: Portable references and sources

WP

WP

WP

WP

This set of Quantum Sensor R&D topics is incomplete,

partly by choice (where we could not identify a clear experimental approach-transcending R&D goal),

but also partly by absence of groups proposing and willing to collaborate broadly on specific technologies

→ ease-in mechanism for further topics:
Project Evaluation Board

rticle and photon detection
ucting systems

stems, transduction)

r 'classical' detectors)

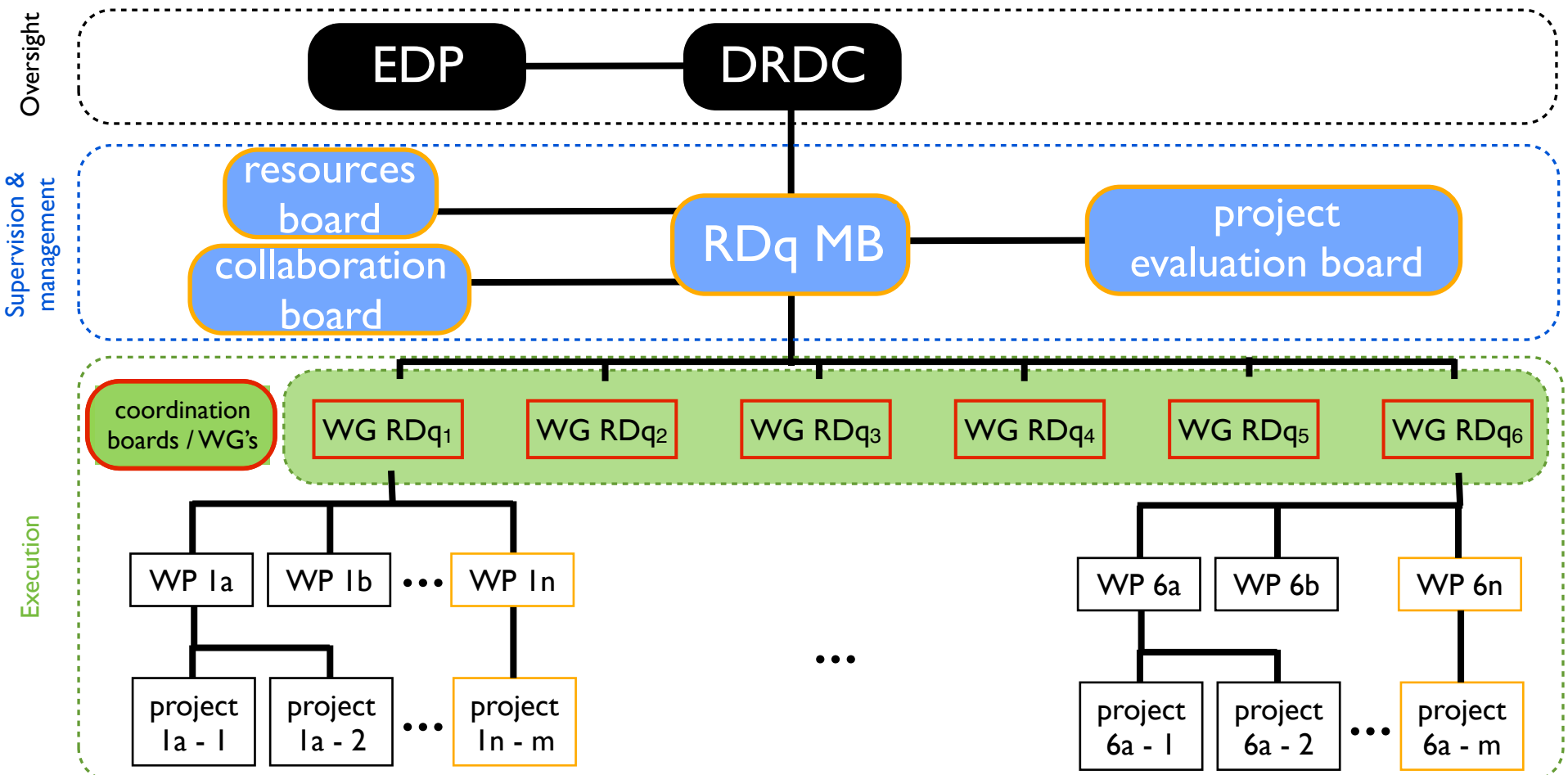
WP-5d: Optimization of physics reach

WP6 CAPACITY BUILDING

WP-6a: Education platforms
WP-6b: Exchange platforms
WP-6c: Shared infrastructures

collaboration structure

- Lightweight structure!
- No collaboration resources except those that the collaborators bring in
- global by design (aim for equitable representation @ WG coordination level and above)
- some boundary conditions defined by ECFA / CERN / DRDn template
- try to anticipate future growth / industrial involvement / IP issues



(WG's may be mono-site or multi-site but carry the responsibility to shepherd the spread-out activities related to their specific WP)

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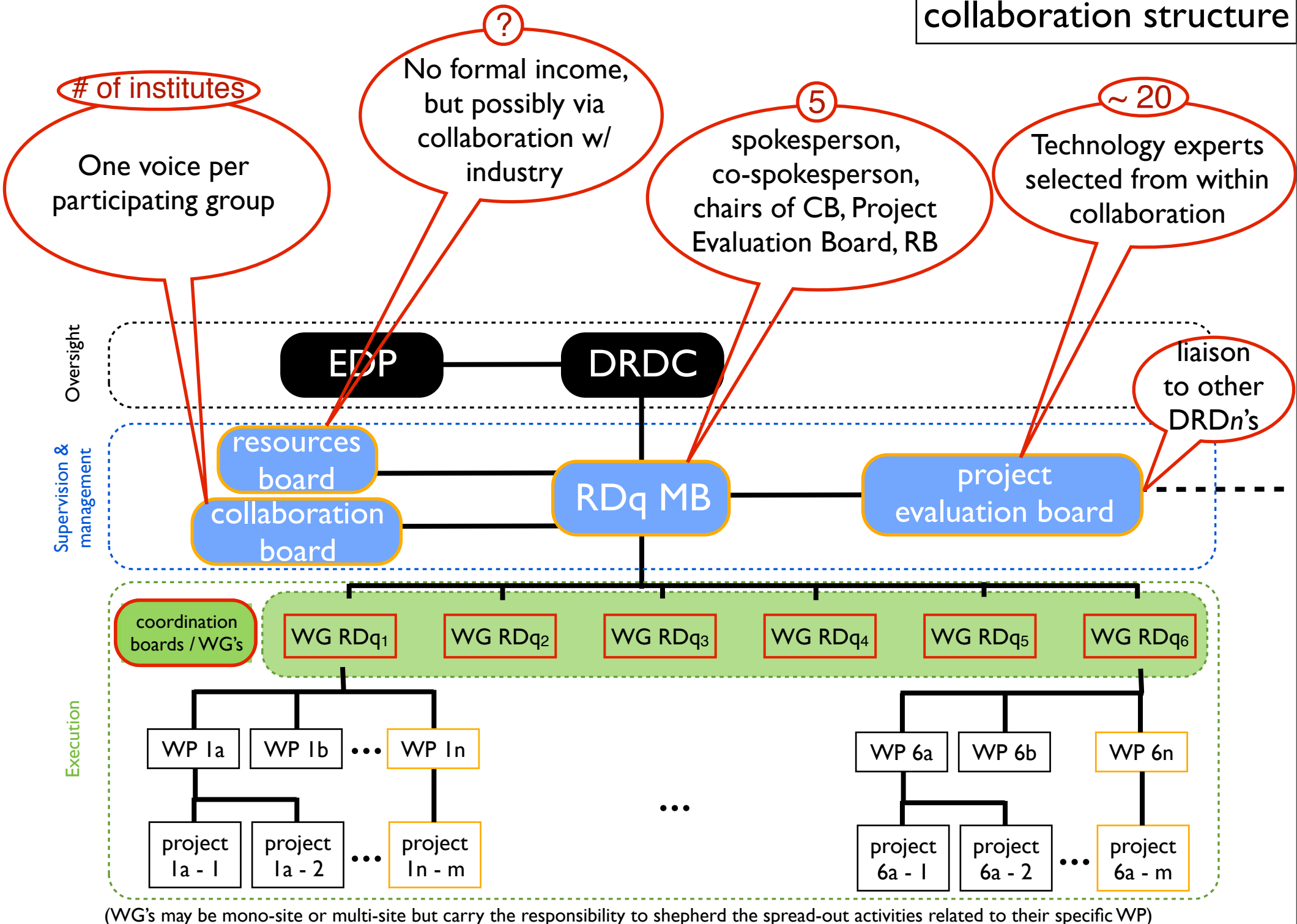

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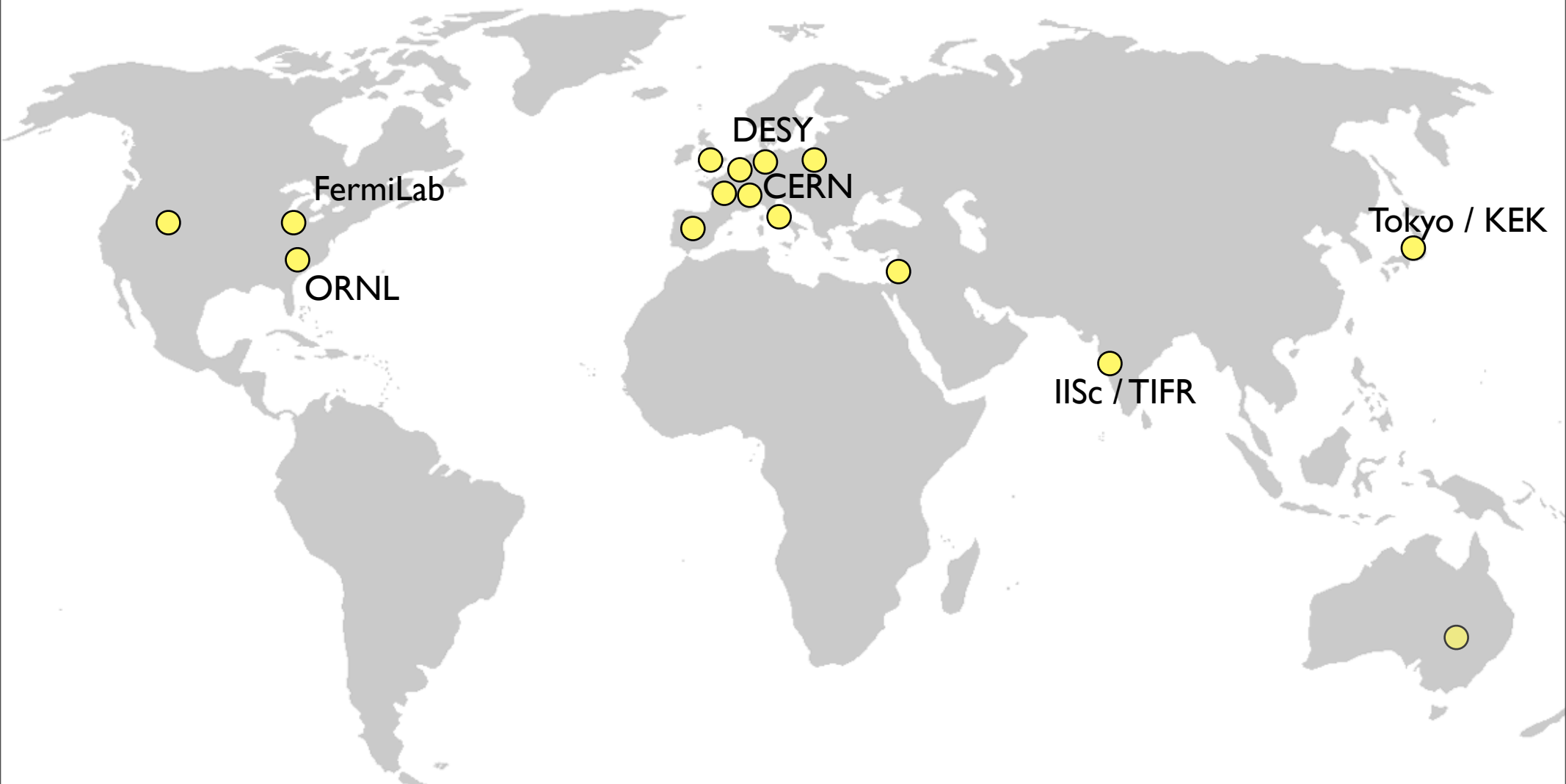
Sharing of responsibilities for coordinating the technical work of the WP's



groups currently involved in RD-q process / HEP-related Quantum initiatives

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please join!

Sharing of responsibilities for coordinating the technical work of the WP's

DRD5 / RD-q is a global distributed effort with the goal of advancing the incredibly promising and rapidly growing field of Quantum Sensors via targeted general-interest R&D with no entry cost to any group.

For it to be successful, it needs motivated, active and interested participants...

groups involved in RD-q process / HEP-related Quantum initiatives