Quantum sensors: status and plans

Ongoing projects (since mid-2021 / late 2021 / early 2022)

- graphene for GEMs: Giorgio Orlandini / Florian Brunbauer
- quantum dots for scintillators: Isabel Frank / Etiennette Auffrey Hillemans
- atomic physics control system ➔ CERN experiment / Marco Volponi / M.D.

Michael Doser / EP

CERN quantum initiative

https://quantum.web.cern.ch/

CERN | IQ QUANTUM TECHNOLOGY INITIATIVE

Scientific Objectives

- Assess the **areas of potential quantum advantage** in HEP applications (QML, classification, anomaly detection, tracking)
- Develop **common libraries of algorithms, methods, tools**; benchmark as technology evolves
- Collaborate to the development of shared, **hybrid classic-quantum infrastructures**
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Computing & Algorithms

- Identify and develop techniques for **quantum simulation** in collider physics, QCD, cosmology within and beyond the SM
- Co-develop quantum computing and sensing approaches by providing **theoretical foundations** to the identifications of the areas of interest
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Simulation & Theory

- Develop and promote **expertise in quantum sensing** in low- and high-energy physics applications
- Develop quantum sensing approaches with emphasis on **low-energy particle physics measurements**
- Assess **novel technologies and materials** for HEP applications
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Sensing, Metrology & Materials

currently: 2.5 PhD's

- **Co-develop CERN technologies relevant to quantum infrastructures** (time synch, frequency distribution, lasers)
- Contribute to the **deployment and validation of quantum infrastructures**
- Assess requirements and **impact of quantum communication on computing applications** (security, privacy)

Communications & Networks

https://quantum.web.cern.ch/

What's next? Short term (under Quantum Technology initiative):

Potential new projects (cost sharing between CERN and outside institute, no funding appropriated for these topics yet)

- quantum dots for chromatic calorimetry (w/ Shizuoka / INFN?)
- high Tc RF cavity coatings (w/ Munich / DESY?)
- atomic traps / fountains / detector development (w/ TRIUMF)
- cryogenic electronics (w/ UK)
- IR scintillators / detectors (?)

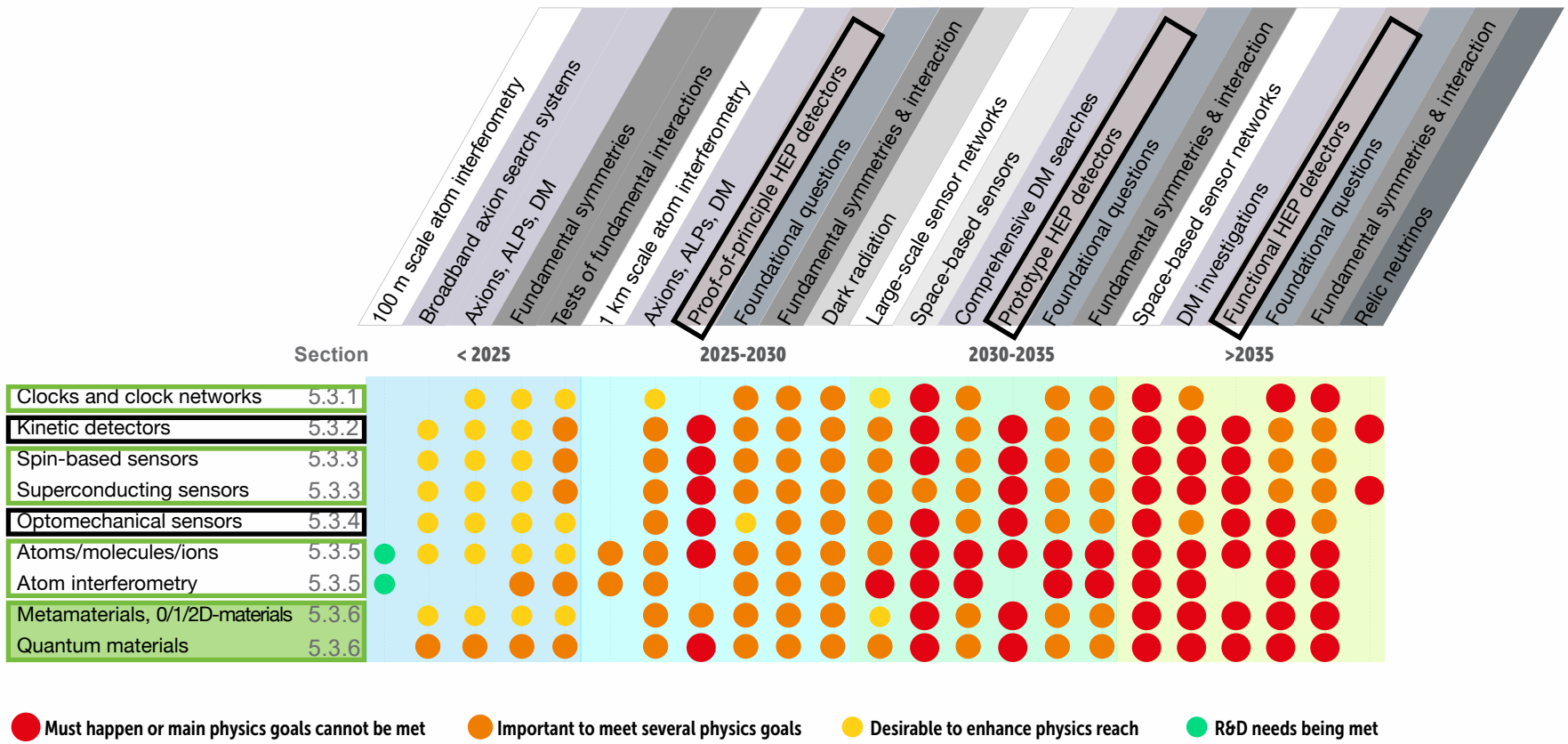
Projects should be relevant to experiments or detector R&D at CERN... your input needed

Michael Doser / EP

RECFA Detector R&D roadmap 2021

https://cds.cern.ch/record/2784893

Chapter 5: Quantum and Emerging Technologies Detectors



Chapter 4: Particle Identification and Photon Detectors

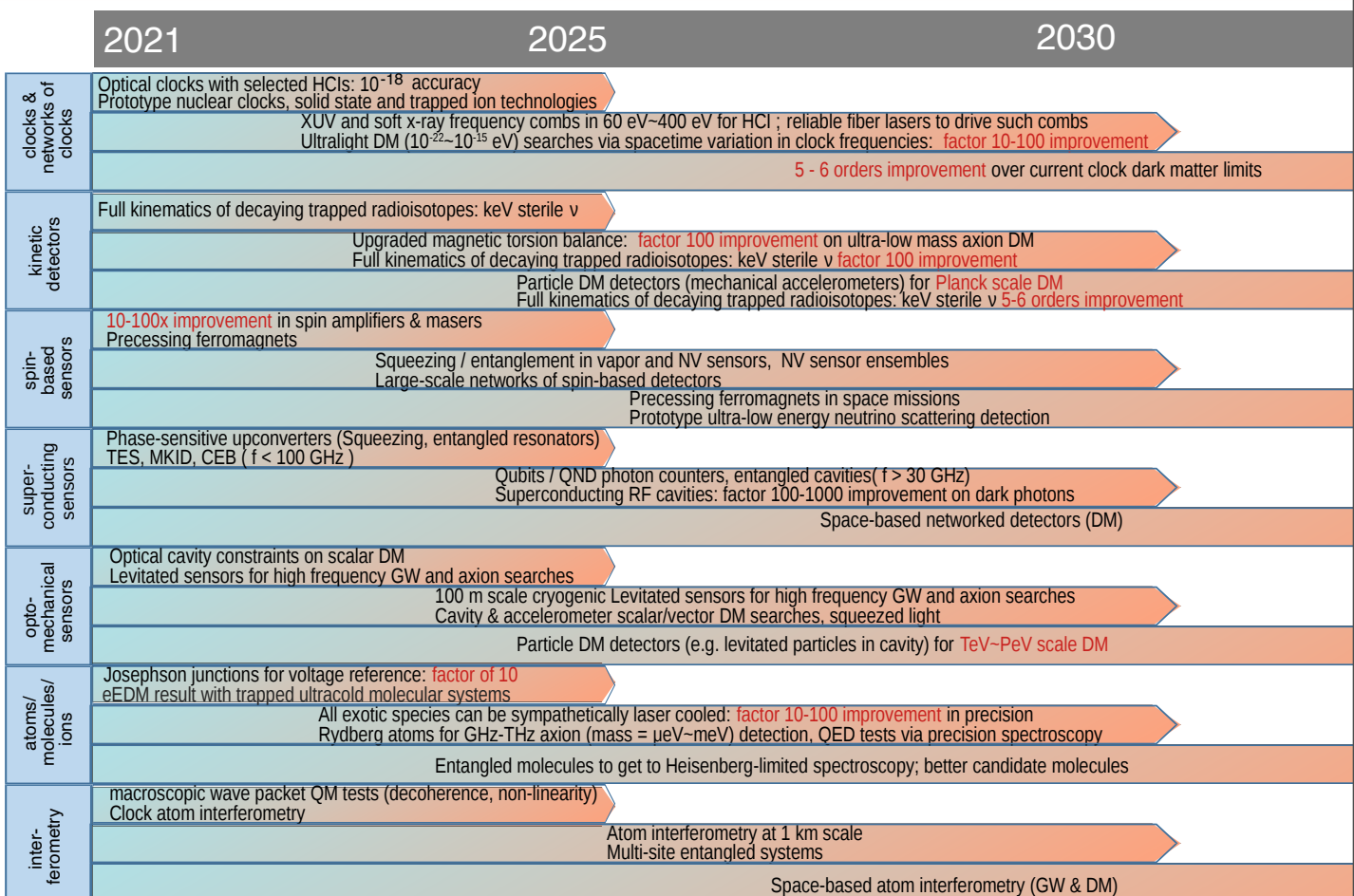
It is recommended that several "blue-sky" R&D activities be pursued. The development of solid state photon detectors from novel materials is an important future line of research, as is the development of cryogenic superconducting photosensors for accelerator- based experiments. Regarding advances in PID techniques, gaseous photon detectors for visible light should be advanced. Meta-materials such as photonic crystals should be developed, giving tune-able refractive indices for PID at high momentum. Finally, for TRD imaging detectors, the detection of transition radiation with silicon sensors is an important line of future research.

What's next?

The potential applications of quantum sensors also in HEP require dedicated R&D to evaluate their potential and feasibility.

In line with the RECFA R&D roadmap, it makes sense to consider a quantum-sensing R&D program that brings together the following strands:

- Clocks and clock networks 5.3.1
- Kinetic detectors 5.3.2
- Spin-based sensors 5.3.3
- Superconducting sensors 5.3.3
- Optomechanical sensors 5.3.4
- Atoms/molecules/ions 5.3.5
- Atom interferometry 5.3.5
- Metamaterials, 0/1/2D-materials
- Quantum materials 5.3.6



also for HEP!

What's next? Medium term:

Need to define a semi-grassroots, semi-top down implementation of RECFA roadmap

- identify ongoing activities in ECFA states, US, Canada, Japan (and their scale)

- target specific developments that can be relevant both nationally and at CERN, for both low energy and high energy particle physics communities, bearing in mind the different communities working at CERN (HEP and FT, but also ISOLDE and AD)

- establish an RDnn-like structure to form an umbrella and an exchange point for R&D on a number of sub-areas of quantum sensing

- identify needed common infrastructures (e.g. connection to European atomic clock networks) and budgets (national level, CERN)

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