HELMHOLTZ

RESEARCH FOR
GRAND CHALLENGES

Research Field Matter
Matter and Technologies

Topic 2 – Detector Technologies and Systems

FACILITIES

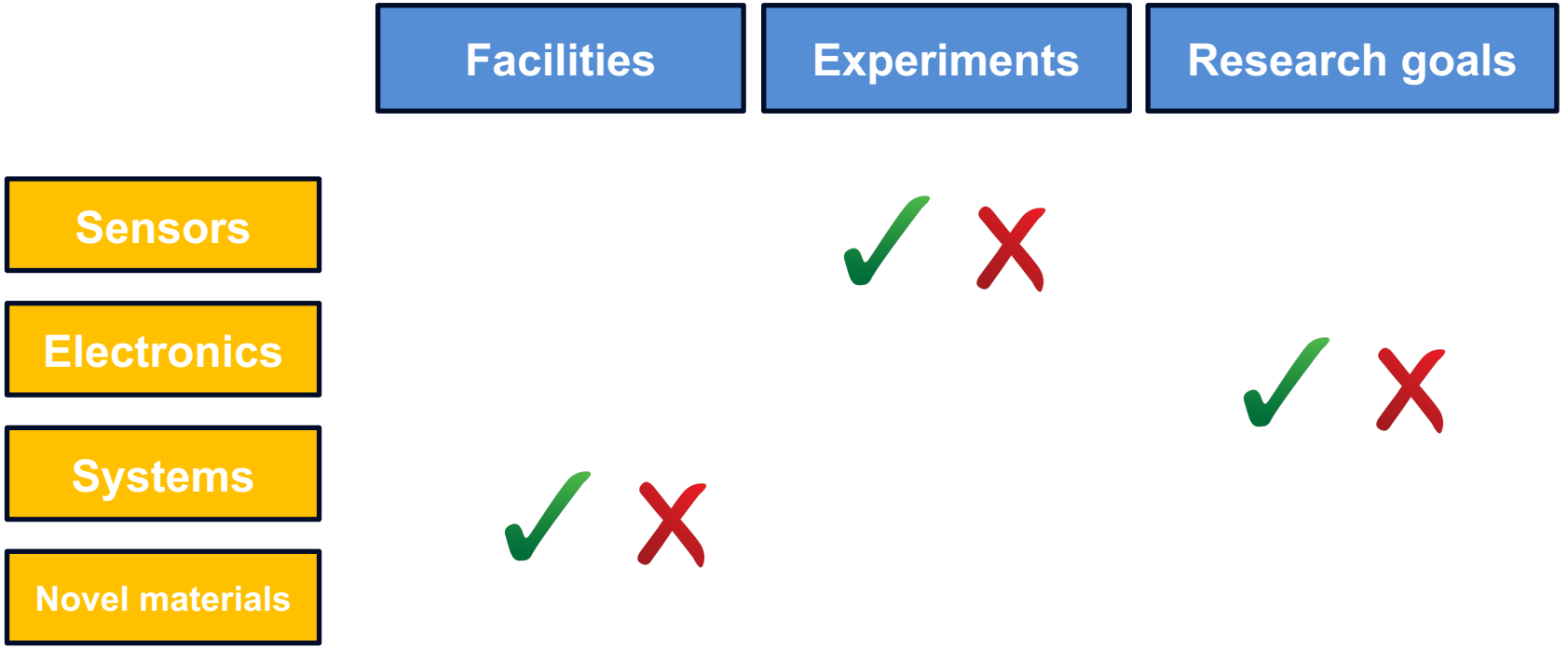
Silvia Masciocchi and Marc Weber

DTS meeting, Kassel
January 11, 2024

DTS in POF V

Map of DTS activities and facilities and research plans in Matter

Disclaimer: here
just a cartoon



DTS in POF V

Map of DTS activities and facilities and research plans in Matter

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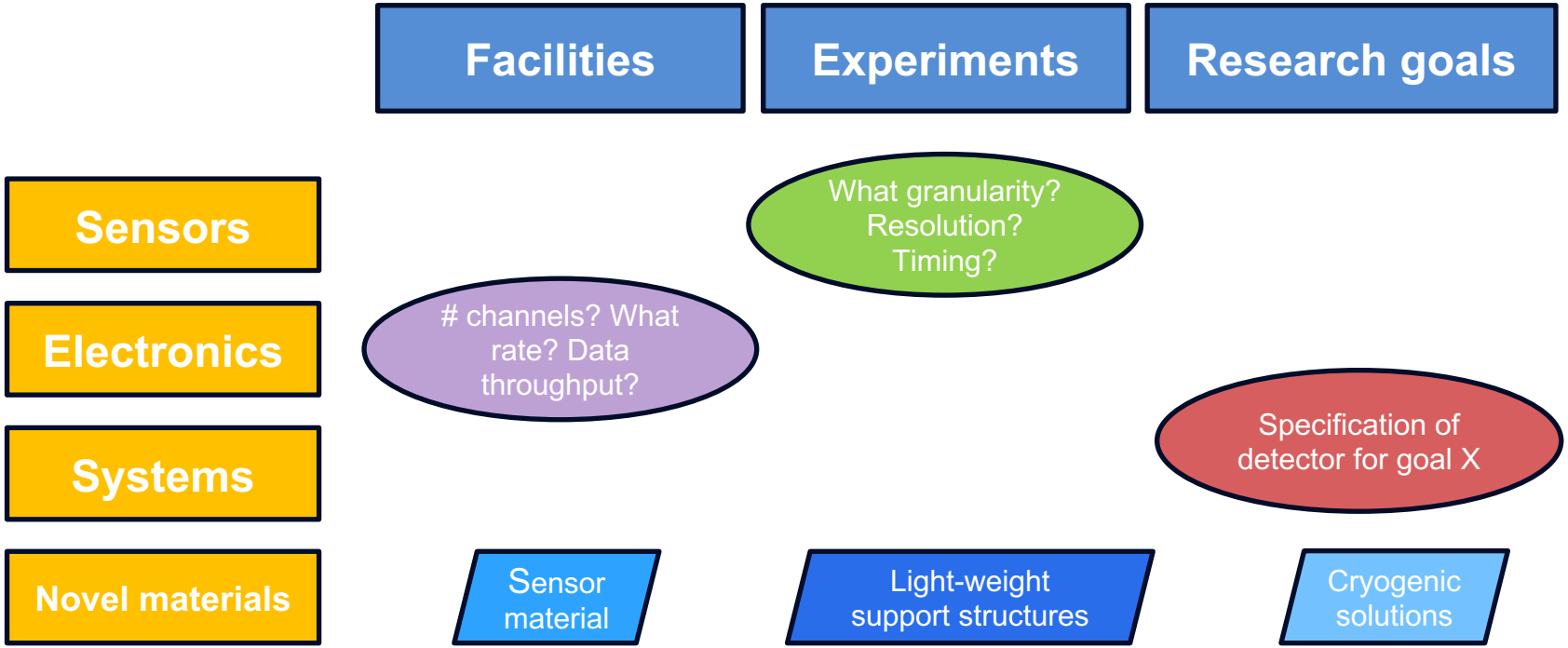
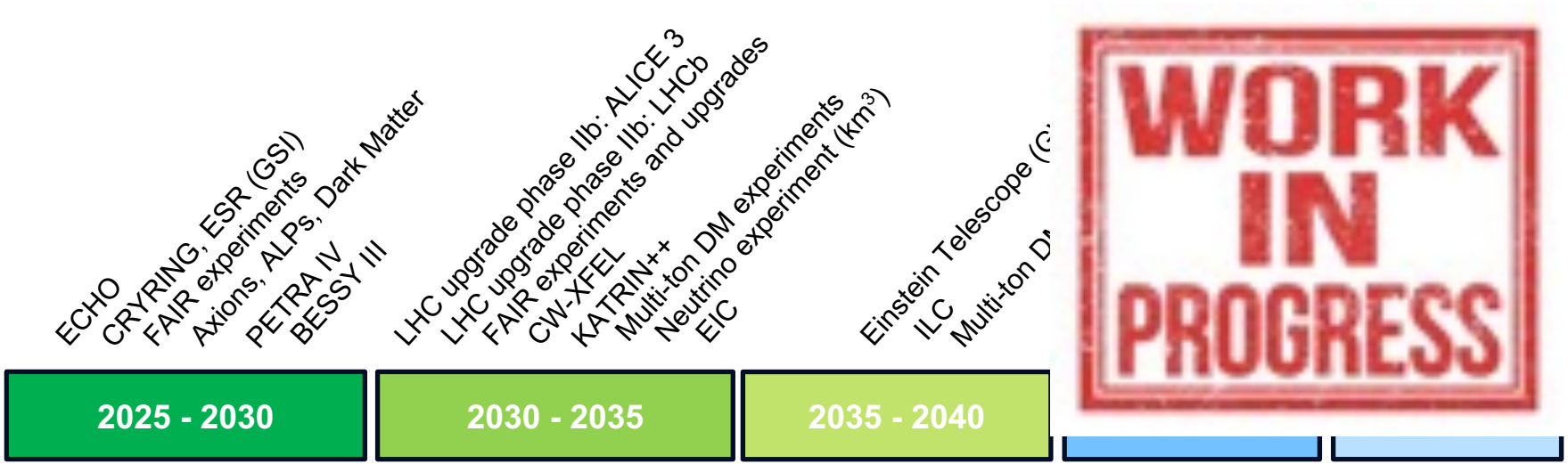


RF Matter: Facilities, experiments and applications

(MT meeting at KIT Oct 2023: to be completed)



Plus: beam physics applications
medical applications
etc.

Inspired by the ECFA detector R&D roadmap

RF Matter: Facilities, experiments and applications

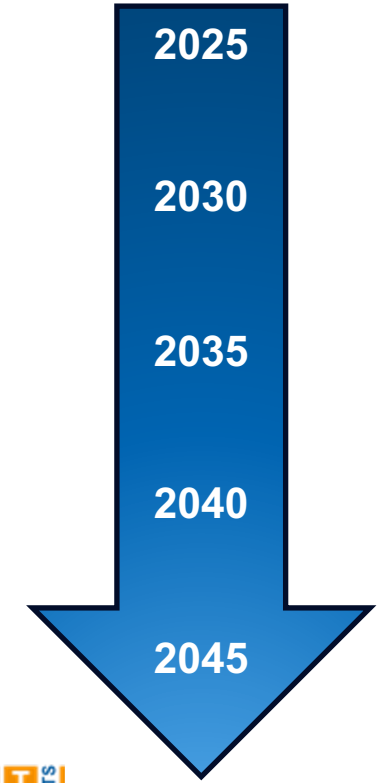
Now with a more structured approach

Input regarding:

- Photon science
- High-energy particle and heavy-ion physics, part of the FAIR program
- Quantum sensors

Photon science

Input from Heinz



FLASH – 2020

PETRA IV
BESSY III

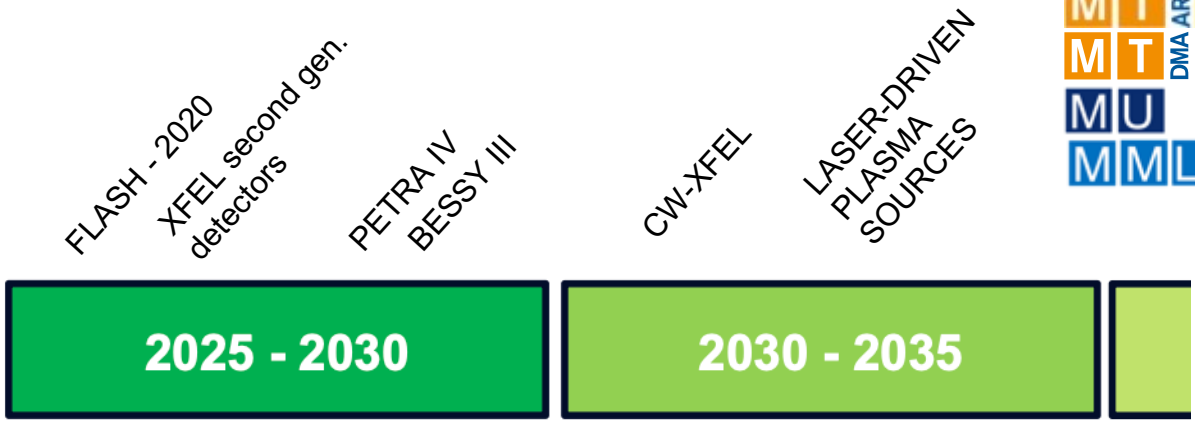
CW-XFEL

LASER-DRIVEN PLASMA SOURCES → soft X-rays (to start with)

Photon science

Input from Heinz

(trying to improve …
Still in progress)



Megapixel systems, smaller pixels
MHz frame rate
On-chip frame storage

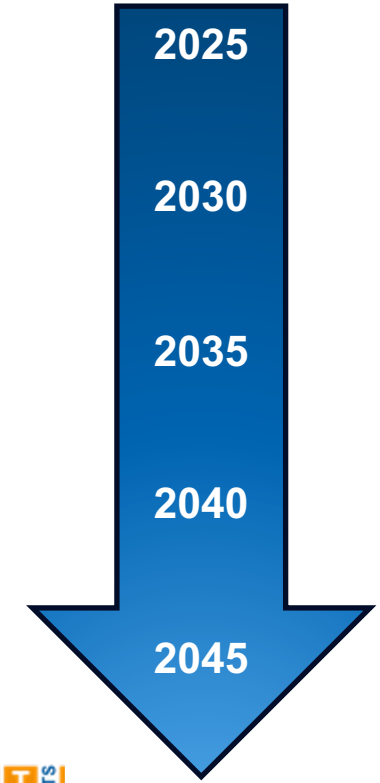
CMOS MAPS
Cryogenic det. for high-resolution spectroscopy

Soft X-rays: (i-)LGADs

Hard X-rays: High-Z sensors, perovskite

High-energy particle and heavy-ion physics (LHC, EIC and later) plus part of the FAIR experiments

Input from Frank, S.



ALICE, LHCb Phase IIb upgrades operation
Electron-ion collider (EIC)
Upgrades of FAIR experiments (CBM, R3B, PANDA, …)

Future e^+e^- machine: ILC, FCC-ee, CLIC

FCC-eh, FCC-hh

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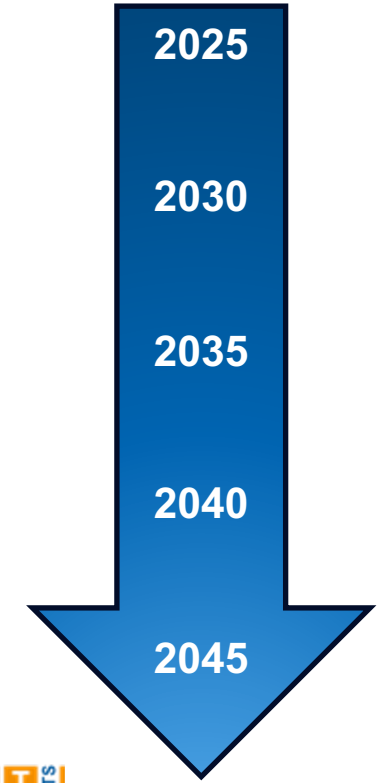
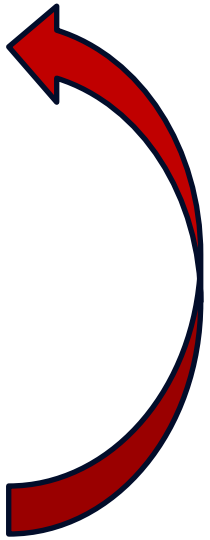


O(10 years): R&D → technology choice (Technical Design Reports) → pre-production → production and construction



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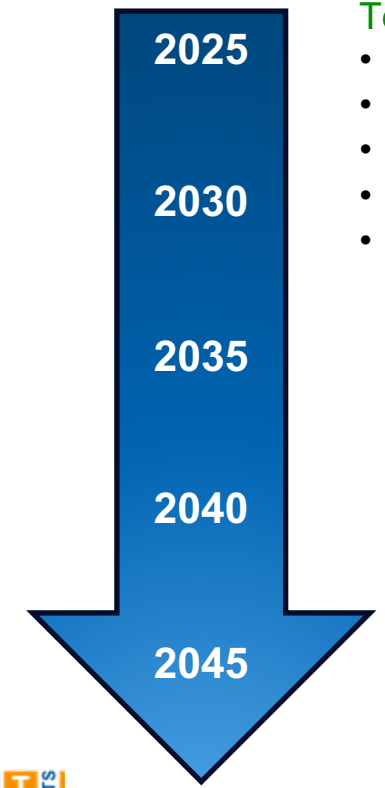

Technology choice for (mostly during POF IV):

- Large area CMOS MAPS for ALICE 3 (O(60 m^2))
- Pixel sensors for LHCb Mighty Tracker
- (5D calorimetry for EIC)
- CMOS MAPS for CBM, PANDA, R3B
- Gas detectors at FAIR

ALICE, LHCb Phase IIb
Electron-ion collider (EIC)
FAIR Upgrades

ILC, FCC-ee, CLIC

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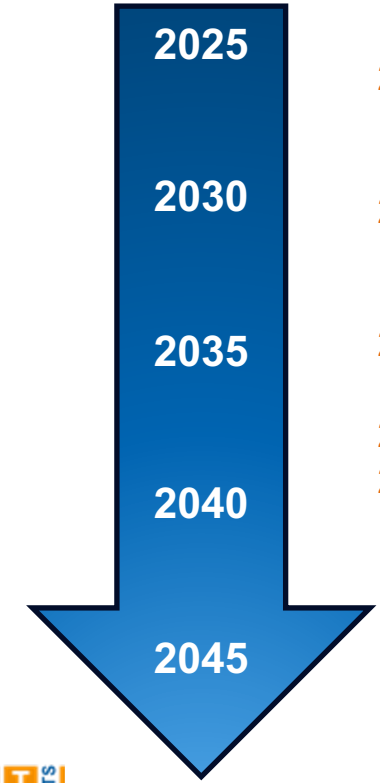
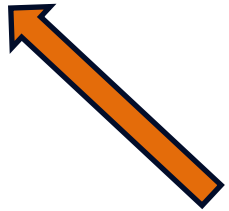


2025: Detector Expression Of Interests

2031: Detector Conceptual Design Reports

2035: Detector Technical Design Reports
= technology choice
2036: Production Start
2041: Installation Start



ALICE, LHCb Phase IIb
Electron-ion collider (EIC)
FAIR Upgrades

Higgs factory:
ILC, FCC-ee, CLIC

FCC-eh, FCC-hh

High-energy particle and heavy-ion physics (LHC, EIC and later) plus part of the FAIR experiments

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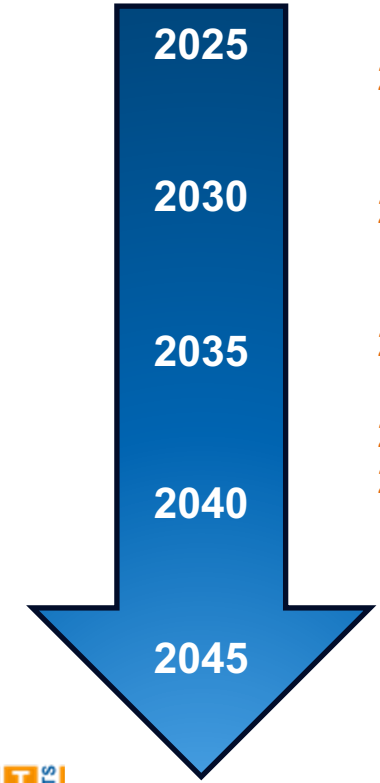

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- Tracking: pixel sensors (hybrid, monolithic) (rad hardness)
- Calorimetry

ALICE, LHCb Phase IIb
Electron-ion collider (EIC)
FAIR Upgrades

Higgs factory:
ILC, FCC-ee, CLIC

FCC-eh, FCC-hh

Inspired by the ECFA detector R&D roadmap

Beam physics applications
Medical applications
ECHO
CRYRING, ESR (GSI)
FAIR experiments
Axions, ALPs, Dark Matter
PETRA IV
BESSY III
LHC upgrade phase IIb: ALICE 3
LHC upgrade phase IIb: LHCb
FAIR experiments and upgrades
CW-XFEL
KATRIN++
Multi-ton DM experiments
Neutrino experiment (km^3)
EIC
Einstein Telescope (GW)
ILC
Multi-ton DM experiments
FCC-ee
CLIC
FCC-hh
FCC-ee
Mu

2025 - 2030 | 2030 - 2035 | 2035 - 2040 | 2040 - 2045 | > 20

Quantum sensors

Tracking:
- CMOS MAPS
- Rad-hard new materials (SiC)

Photon science:
- Mega-pixel systems
- High-Z materials (perovskite)

High-throughput DAQ

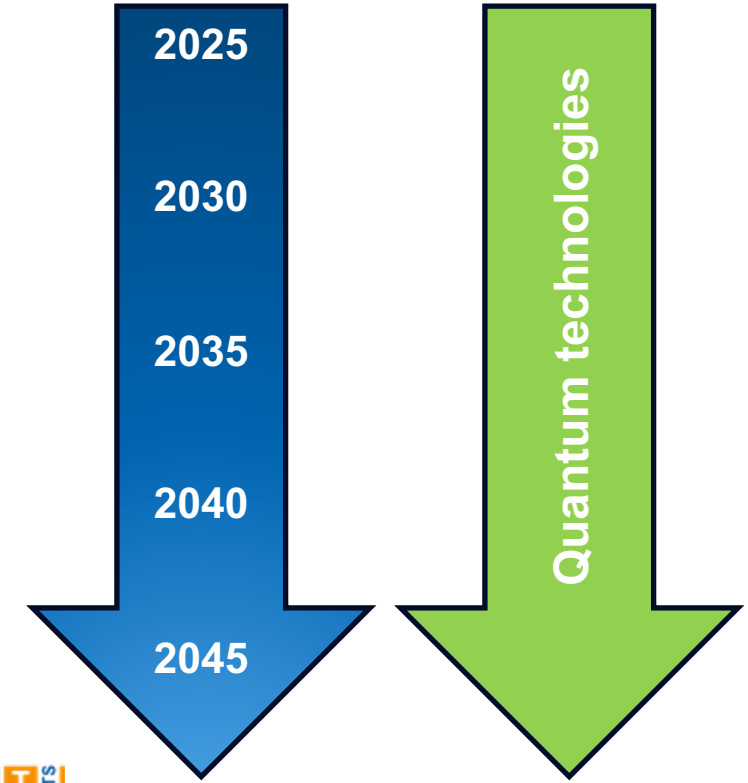
Calorimetry:
5D=space+energy+timing

Packaging

Input from D.Eckstein, M. Deveaux, A. Kopmann, F.Simon, M. Fiederle, T. Blank, M. Caselle, D. Pennicard, D. Emschermann, A. Dierlamm, etc.

Quantum sensors, experiments and facilities/infrastructures

Input from Thomas, Steve, Sebastian



Very different dynamics:

- Emerging technology, **continuous developments**
- "**Disruptive**": not dominated by incremental improvements but it opens fully new possibilities not reachable with traditional det. (beyond the limits of what is possible today)
- As the technology gets established more and more, new and **additional applications** coming up all the time

Quantum sensors, experiments and facilities/infrastructures

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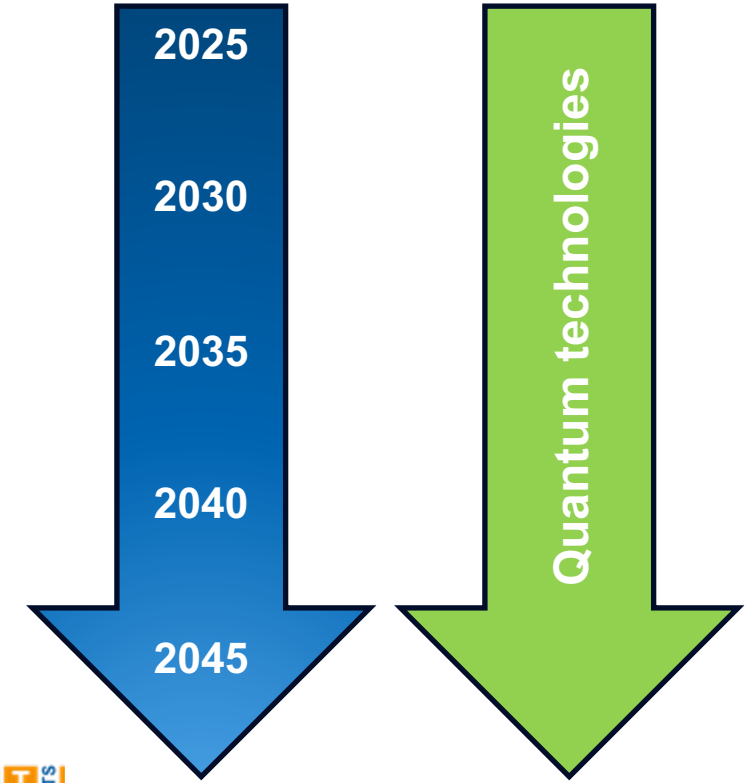


High-precision measurements:

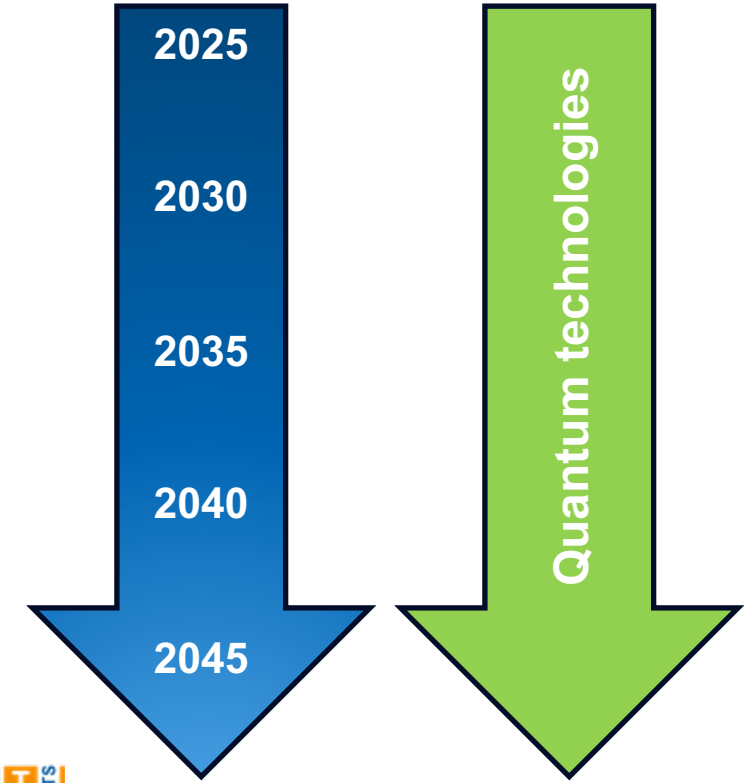
- Single-photon sensitivity
- Extremely low noise
- Low energy measurements

Applications pursued at the moment:

- High-resolution spectroscopy (nuclear structure, photon science, etc)
- Beam diagnostic (e.g. Cryogenic Current Comparator)
- Searches for dark matter candidates: axions-like (e.g. ALPSII, transition edge sensors)
- Very small energy/mass measurements (e.g. ECHo, microcalorimeters)
- Table-top experiments (e.g. optical atomic clocks, measurement of $\Delta\alpha/\alpha$ → ultra-light DM)

Quantum sensors, experiments and facilities/infrastructures

Input from Thomas, Steve, Sebastian



Experiments/facilities for which quantum techologies are foreseen:

GSI/FAIR: Cryring, ESR, HITRAP (micro-calorimeters: high-res energy measurements)

Small (O(kg)) DElight
(Baby-)IAXO (qubits)
KATRIN++

Sensors for synchrotron and FEL sources

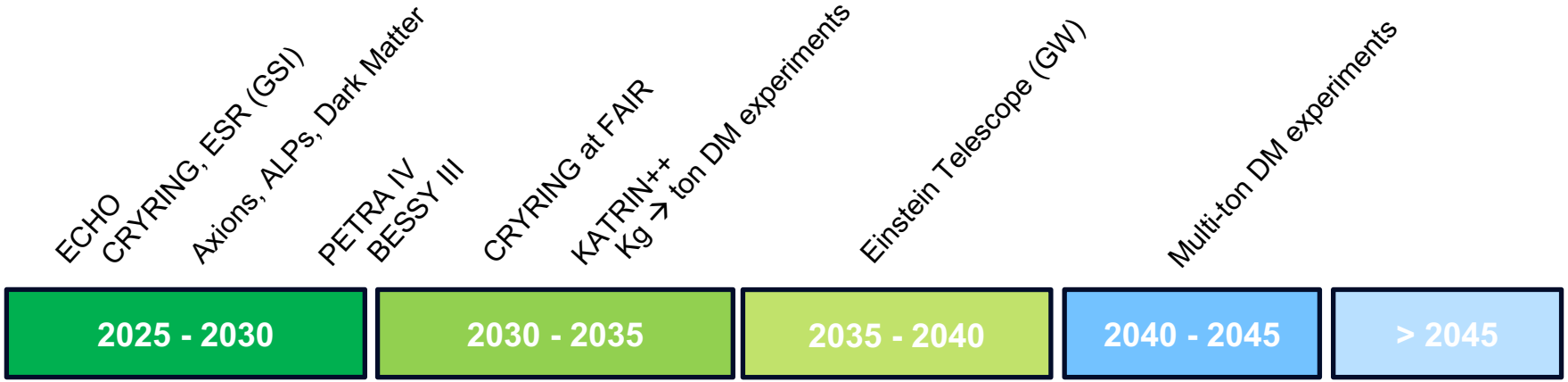
Einstein Telescope

DElight: light mass DM searches (superfluid helium + quantum sensors, mK cryostat. From kg to (multi-)tons)

… and millicharged particles, etc.
PLUS fabs and testing **facilities** (KIT, DESY, Jena)

Quantum sensors, experiments and facilities/infrastructures

Input from Thomas, Steve, Sebastian



Growing system size:

- Some pixels → kilopixels → megapixels
- Cryostats, readout, shielding, data analysis

PLUS table-top experiments

DTS in POF V: facilities

Base for our future structure in DTS

Many thanks for the input already received: Heinz, Frank, Thomas, Steve, Sebastian !!!

Great base to brainstorm on the future plans and structure of DTS

E.g. : very different time scales, granularity of developments in different fields

To be continued, improved and completed!