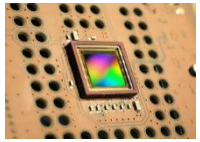
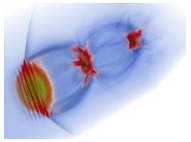
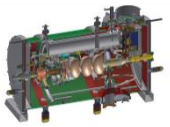
HELMHOLTZ

MATTER AND TECHNOLOGIES

RESEARCH FOR GRAND CHALLENGES

ARD-ST3

Erik Bründermann, KIT (Spokesperson ST3)
Holger Schlarb, DESY (Spokesperson ST3)
Thorsten Kamps, HZB
Pavel Evtushenko, HZDR
Peter Forck, GSI

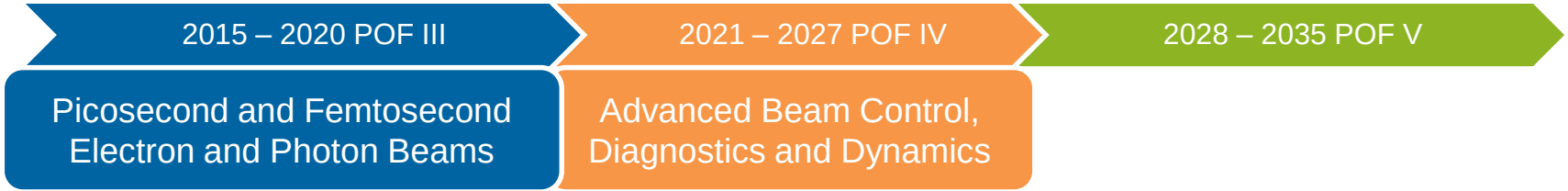
July, 7th, 2023
Annual MT ARD ST3 Meeting
12:15-13:15

Y(OUR) VISION

Where do you see yourself in …

- 5 years ???
- 12 years ???

program-oriented funding



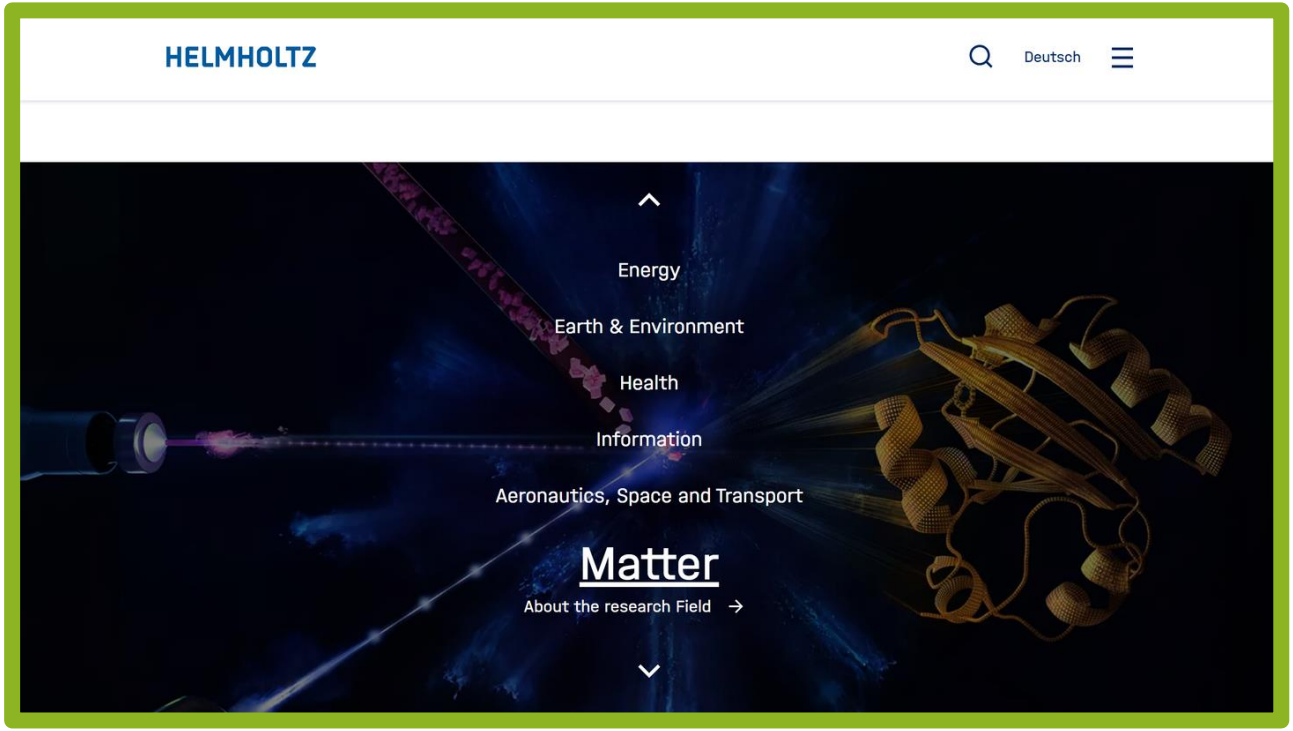
INFORMATION IN INDICO

INCLUDING TUTORIALS IN PREVIOUS ANNUAL MEETINGS

- The **vision** for MT ARD ST3 (PoF 4, 2021-2027): https://indico.desy.de/event/36133/page/4250-vision
- Description of ST3 for PoF 4: https://www.helmholtz-ard.de/e42986/e43194/index_eng.html

OUR RESEARCH

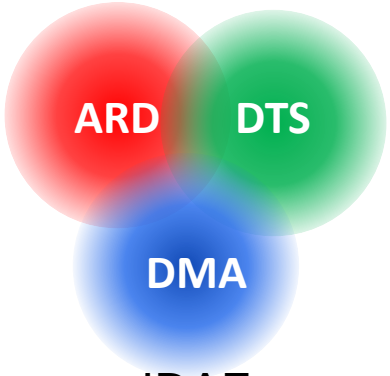
IN OUR 6 RESEARCH FIELDS, WE WORK ON THE PRESSING ISSUES FACING OUR SOCIETY.



MATTER AND TECHNOLOGIES

WHAT WE ARE

From MT Annual Meeting 2022
T. Behnke, A.-S. Müller

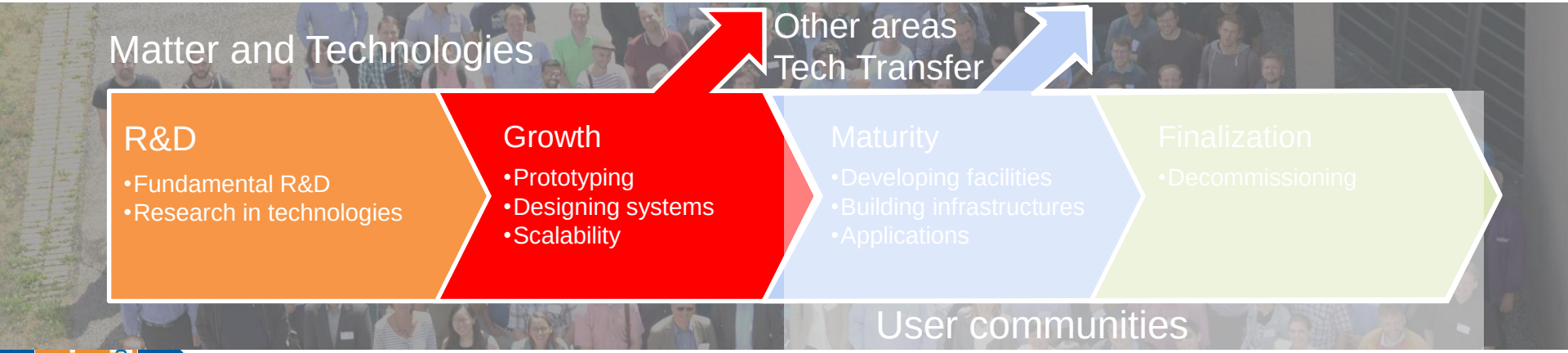


IDAF

Accelerator science
Detector science
Data analytics

- Research in *Matter* is bold and broad
- It relies on people and on advanced technologies

MT is a program for the future of *Matter*
closely intertwined with MML and MU



THE CHALLENGES

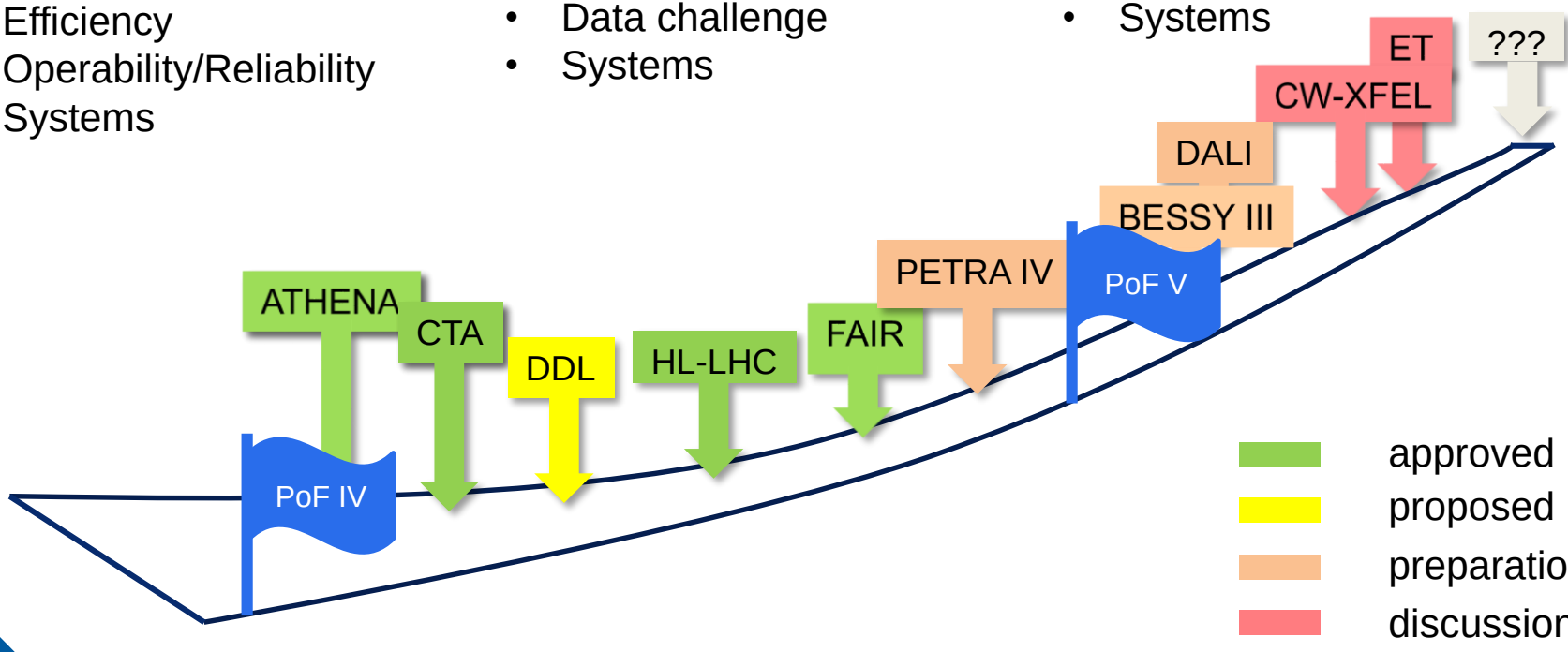
CHANGING THE WAY WE DO SCIENCE

From MT Annual Meeting 2022
T. Behnke, A.-S. Müller

Accelerators
- Performance
- Compactness
- Efficiency
- Operability/Reliability
- Systems

Detectors
- Resolution
- Speed
- Data challenge
- Systems

Data analytics
- Data challenge
- Algorithms
- Systems



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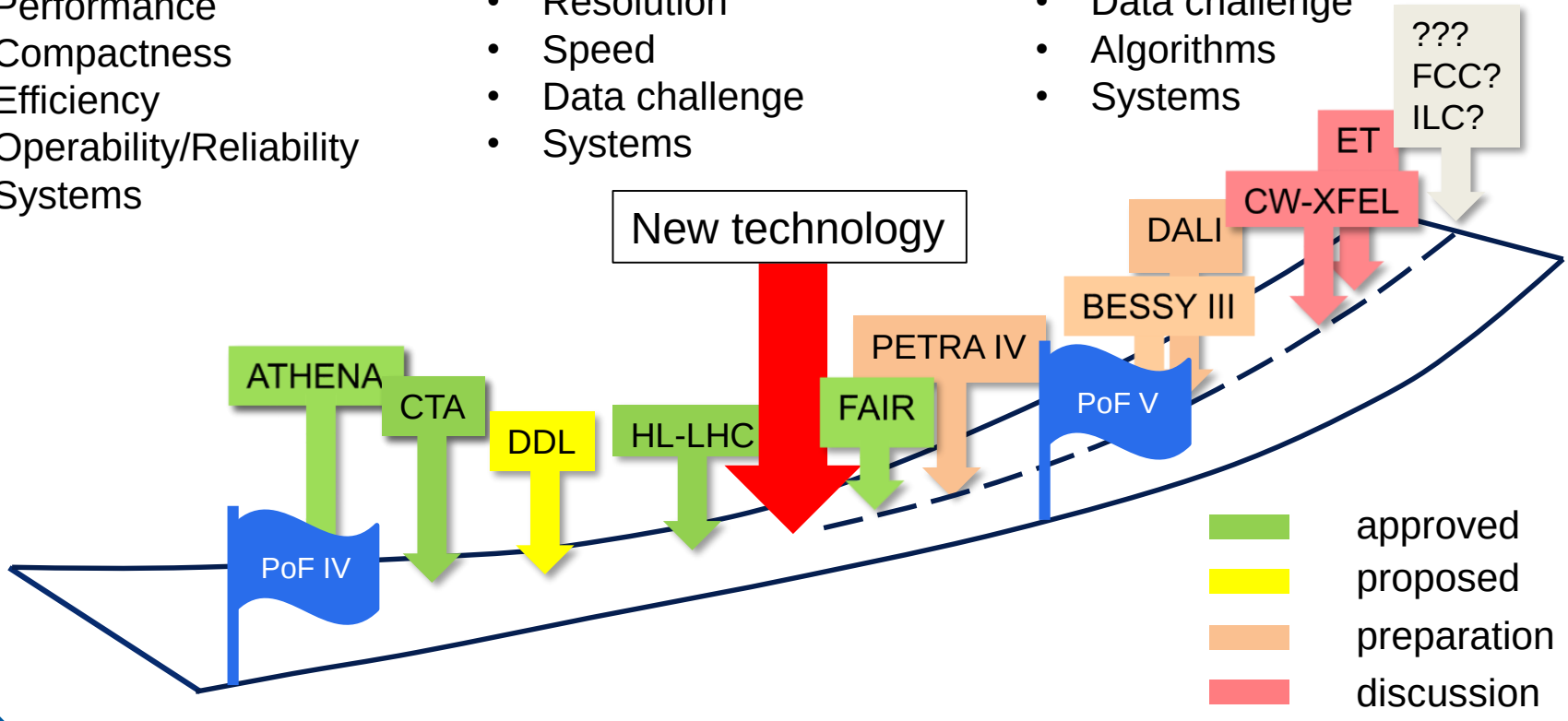

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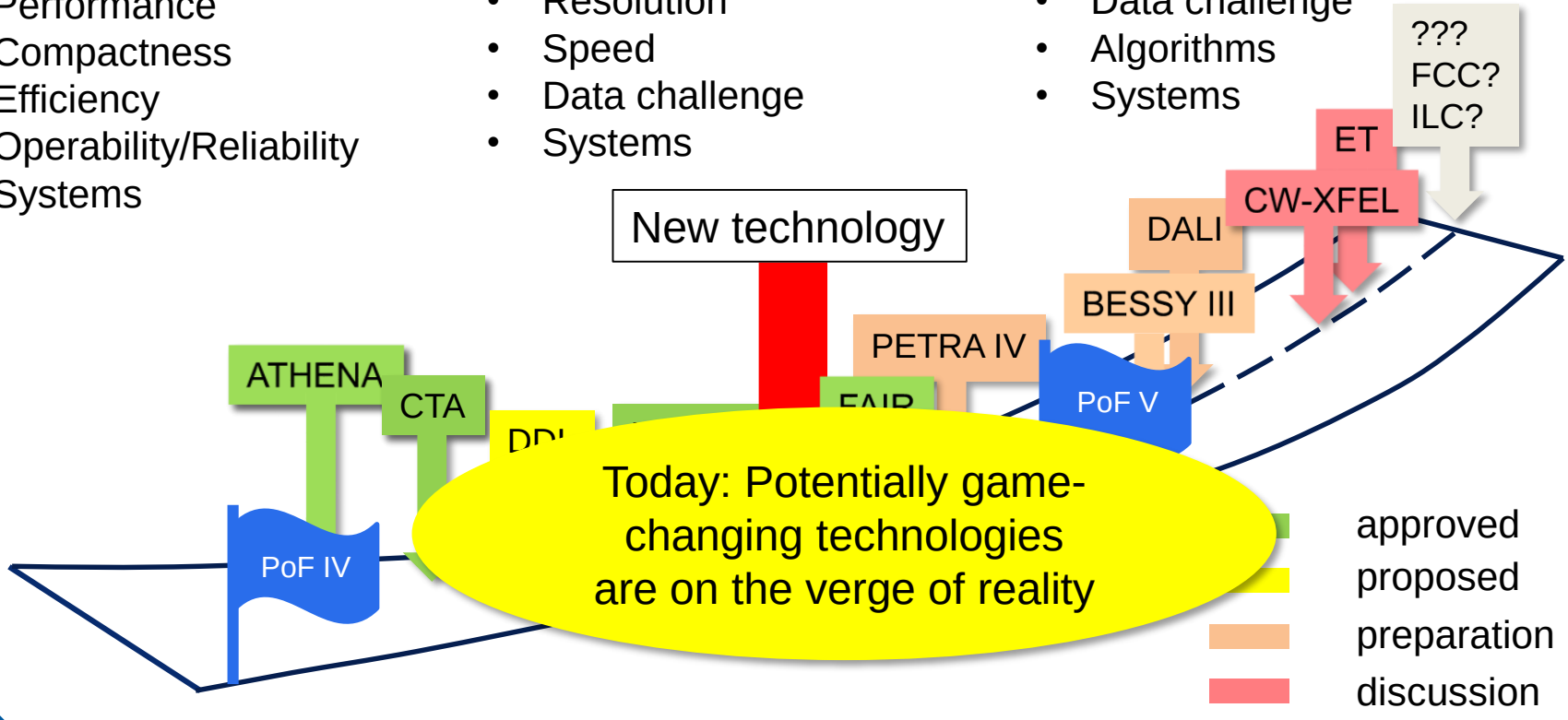


ST3 – THE BASE & THE PILLARS

ARD-01	2023	Review usage and impact of ML
ARD-02	2024	Update evaluation of the user needs for guidance

Mst	Year	Milestone (centers)
ARD-10	2024	First stage demonstration of experimental and theoretical methods for **tailored longitudinal phase space generation** (all)
ARD-11	2025	Establish **routine femtosecond precision operation** at short-pulse accelerator facilities (DESY, HZDR, KIT)
ARD-12	2027	Demonstration of experimental and theoretical methods for **tailored 6D phase space generation** (all)

2021 – 2027 PoF IV

- **ST1** Advanced CW SRF-Systems
- **ST2** New Concepts and Prototypes for Maximizing the Performance of Hadron & Electron Accelerators
- **ST3** Advanced Beam Control, Diagnostics and Dynamics
- **ST4** Ultra Compact, Novel Accelerators and their Applications

Advanced Beam Control, Diagnostics and Dynamics

Dynamics of extreme beams	Extreme range beam diagnostics	Stability, Controls & Synchronization
fs & as pulses	Time domain	Advanced Feedback controls
Coherent radiation & high fields	Frequency domain	RF controls
Custom beam: bunch shape manipulation	Particle beams	Laser controls of particle beams
Transient phenomena & large dynamic range	Photon beams	Controlling Synchronization

Technology Transfer & Networking* & Test Facilities

* & Education (Tutorials, …)

A LOOK BACK - KEYWORDS

A start

- Attosecond metrology
- Extreme dynamic range
- Compact technology & technology for compact accelerators
- Ultra-high throughput
- Massive standardisation to maximise synergies
- Low-cost / low-maintenance systems (-> max. societal impact)
- …
- Exploit ST3 strong points: networking, technology transfer, …
- ST3 as “hub” within MT-ARD but also linking MT topics (DTS, DMA)
- …

A.-S. Müller, 28.09.2018

https://indico.desy.de/event/20689/contributions/40054/attachments/25682/32513/MT_ST3_POF4.pdf

A LOOK BACK - KEYWORDS CONTINUED

- Photon pulse diagnostics; photon synthesis
- Undulators
- Beam dynamics & beam control; coherence;
- Emittance control
- Advanced feedback controls
- Modelling (control modelling)
- Phase space synthesis
- Machine learning / AI
- Advanced injection schemes
- Laser system transport & stability
- Bunch profile control; close the loop from diagnostics to control
- High-resolution parasitic diagnostics
- System integration! (modelling, alignment, diagnostics, control, to photons…. “the whole chain”)
- Stabilisation of components (e.g. RF sources)

A.-S. Müller, 28.09.2018

https://indico.desy.de/event/20689/contributions/40054/attachments/25682/32513/MT_ST3_POF4.pdf

HELMHOLTZ MT ARD

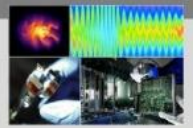
RESEARCH FOR GRAND CHALLENGES

ST3 – ADVANCED BEAM CONTROL, DIAGNOSTICS & DYNAMICS

Heart beat of Matter – Faster, more throughput, at highest precision

ARD subtopic 3, MT programme, POF-4: 2021-2027

Control of extreme beams at the forefront of technology



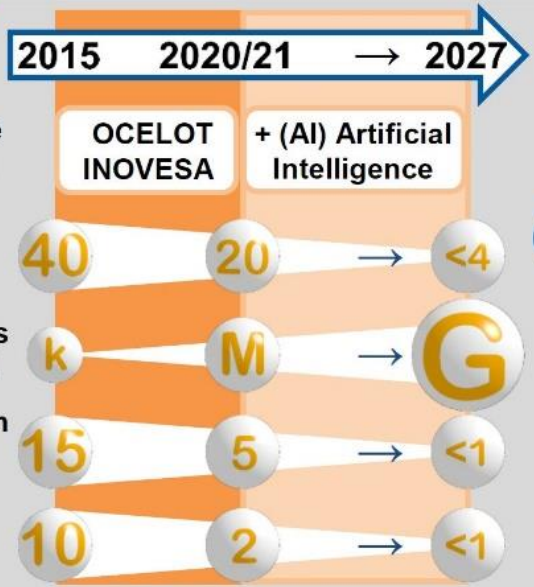
Dynamics code
micro-bunching instabilities

XUV seeding
nm

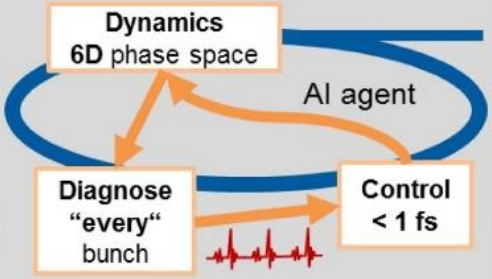
Diagnostic rates
Frames/second

Synchronization
in accelerators
fs

Time-resolved
fs



Custom & Extreme Beams
Extreme dynamic range



Advanced beam control
Attosecond metrology

Connecting Sub-Topics and being a hub to DTS and DMA

VISION

ARD-ST3 KEYWORDS 2023++

Picked up from discussions during the MT-ARD-ST3 meeting

- Diagnostics
  - fC (UED, …)
  - ST4 (optical, lasers…)
  - …
- Dynamics
  - Non-equilibrium (cSTART, …)
  - SSMB = Steady State Microbunch (MLS, …)
  - …
- Control
  - Faster (ST3)
  - Slow (ST2)
  - AI
  - …

ARD-ST3 KEYWORDS - POST-DISCUSSION

- General
  - Structured beams, microstructured beams, for FEL and storage rings/synchrotrons
    - Could be an important cross-center topic (MBI, seeding, SSMB, ...)
  - Non-equilibrium physics (cSTART, …)
  - UED (fC bunches at high repetition rates, extension of the limits on dynamic range, source development, challenges for non-invasive diagnostics in general).
  - FEL source development and high brightness beams (e.g. RF/SRF guns)
- Beam Diagnostics
  - Non-invasive diagnostics (e.g. photon detection: transition radiation, dynamic range, ST4 topics, etc.)
- Beam Dynamics
  - Non-equilibrium beam dynamics
  - Models in general, also for ion beams (spilling).
- Beam Control
  - AI at the most difficult level with reinforcement learning and on hardware for real-time.
    - Define interface, boundaries with ST2.