ARD-ST3 Discussion session

R&D at DESY for PoFIV

Topics

- Advanced beam diagnostics
- Precision synchronization for accelerator facilities

- Next generation RF field controls towards sub-femtosecond precision
- High brilliance electrons injector developments

- Laser seeding / FEL Schemes / Laser Beam manipulation
- X-ray FEL Oscillators (XFELO)

- Dissemination & development of advanced MicroTCA electronics for accelerator controls
- Implementation and integration of AI methods for accelerators

- Facilities… and associated ARD-ST3 programs…

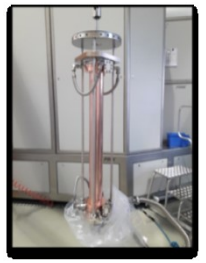
Advanced beam diagnostics

Also here rather wide field of topics to be addressed,

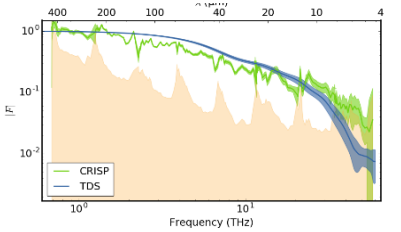
- Precision longitudinal diagnostics (e.g. PolariX/advanced BAM/ THz spectrometer)
- Transverse profiling (screens/wire scanner)
- Advanced beam position monitors (high rep rates / high precision)
- Parasitic operation for high current / CW accelerators
- Large dynamic range …. very low / very high bunch charge
- High data throughput … 1D detector arrays
- Suited for low latency fast beam feedbacks

Pickup BAM

PolariX

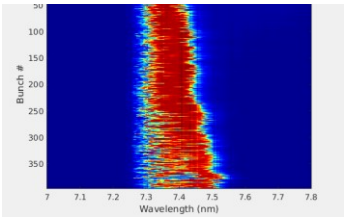


THz spectrometer



…

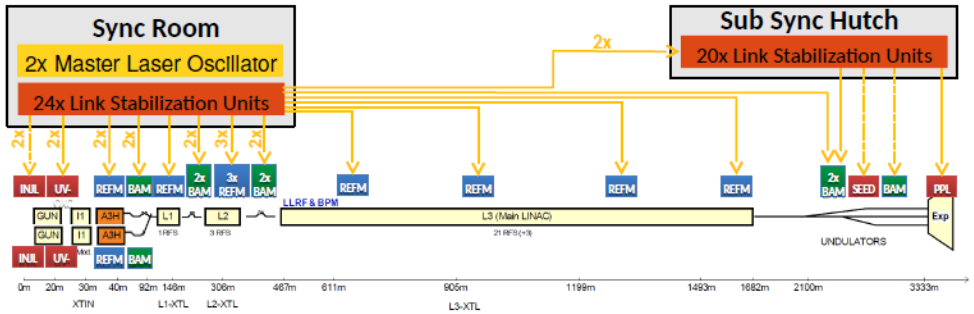
1D detector for spectral measurements (Kalypso)



Precision synchronization of acc. facilities

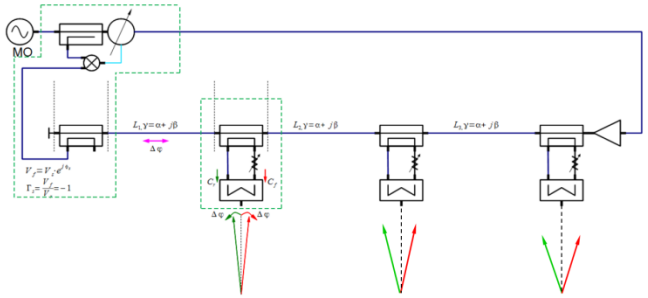
Exploration of different synchronization technologies (cost reduction / performance / reliability)

Ultra-high precision …. ~ 1 fs goal (laser pulses)



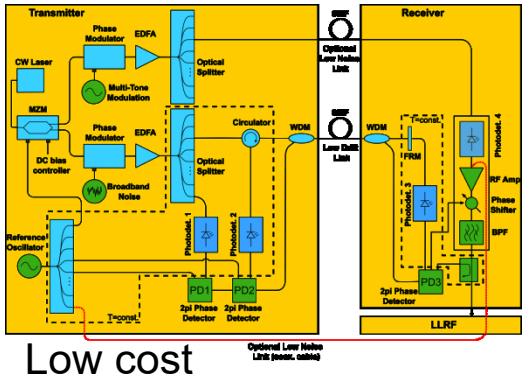
High cost

For RF sub-distributions ~ 10 fs (RF)



Low cost

Large distances ~ 20 fs (laser CW)



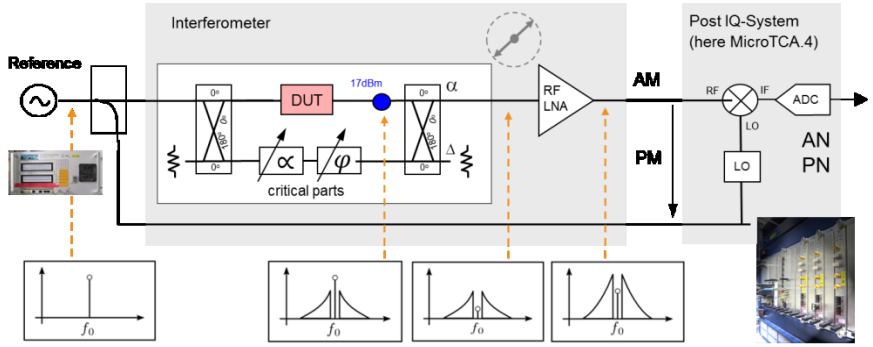
Low cost

Next generation RF field controls

Wide area with different topics to be addressed, e.g.

- RF field detection techniques and methods towards attosecond resolution / femtosecond drift stability
- RF feedback controller designs and perturbation suppression (predictive controllers / microphonic's etc.)
- Automation algorithm and failure diagnostics
- Component stabilizations (passive/active, RF structure/RF source/ RF cables)
- RF field simulations and interconnect to RF controls

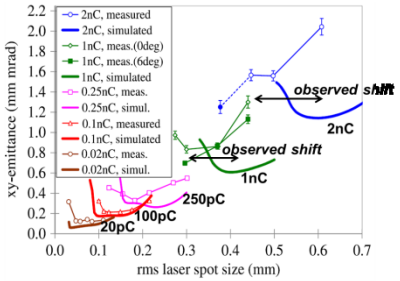
Carrier Suppression Tech. < 100as resolution



High brilliance electrons injector developments

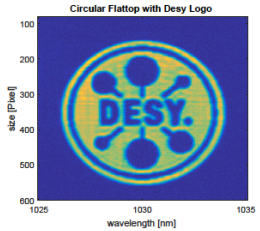
Toward lower emittances (~0.1um) … and CW operation

Cathode development / emission models / laser pulse shaping…



M. Krasilnikov, et al., Phys. Rev. ST Accel. Beams 15, 100701 (2012)

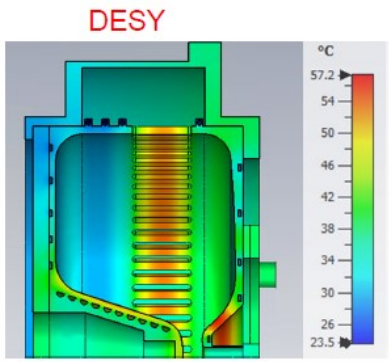
Courtesy: Y.L. Chen/ M. Krasilnikov

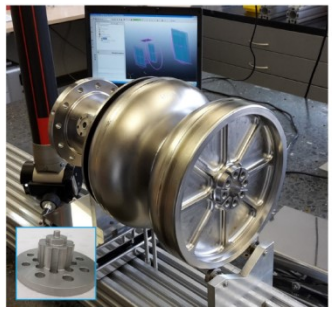


$$\varepsilon_n \propto \sqrt{\varepsilon_{th}^2 + \varepsilon_{spch}^2 + \varepsilon_{rf}^2 + \varepsilon_{Bz}^2 + \cdots}$$

intrinsic emittance (ε_{th})
space charge emittance (ε_{spch})
rf emittance (ε_{rf})
cathode magnetic field caused emittance (ε_{Bz})

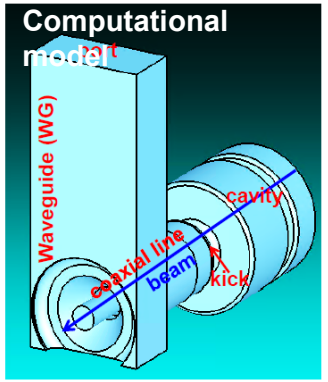
CW guns (NRF/SRF)





Courtesy: H. Qian, Summery guns CW FEL2019

Opportunistic effects + suppression

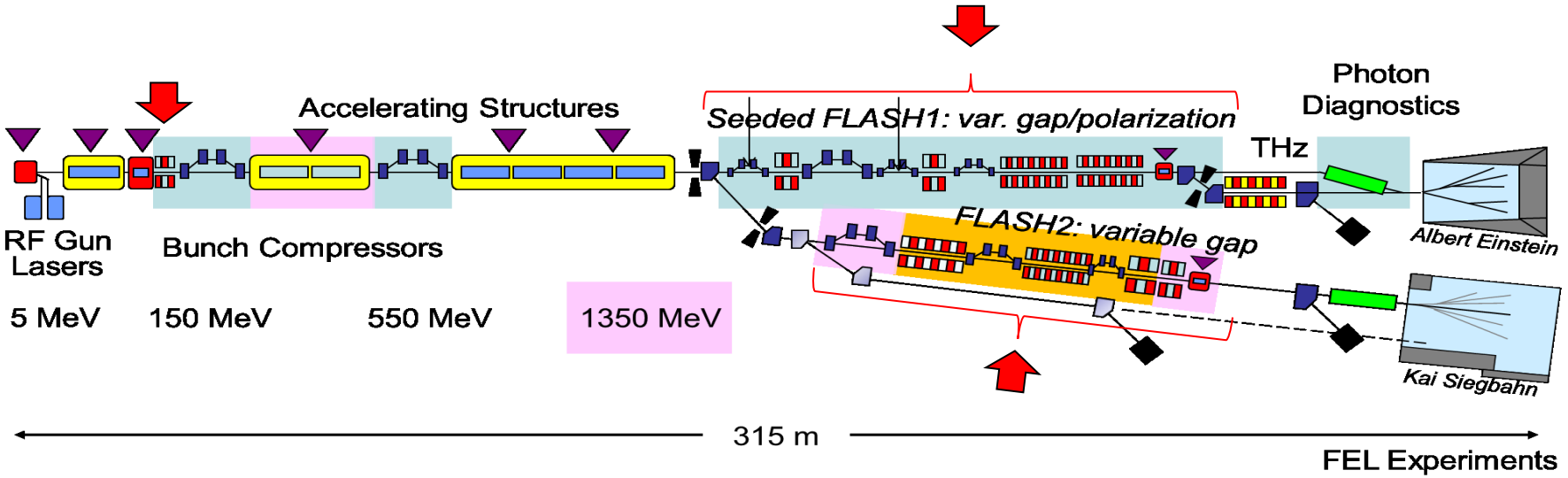


e.g. time dependent coupler kicks & focusing variations due to thermal pulsing

Laser seeding / FEL Schemes / Laser Beam manipulation

Exploring laser seeding and novel FEL lasing concepts (attosecond) at FLASH2020+

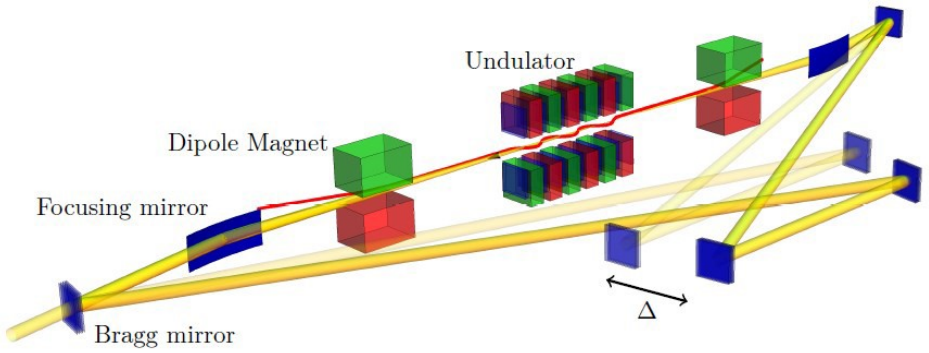
- HGHG/EEHG seeding @FLASH1
- Various FEL Schemes @FLASH2
- Targeted manipulation of beam at laser heater
- Major upgrade for FLASH2020+ planned
- High rep. rate … up to MHz

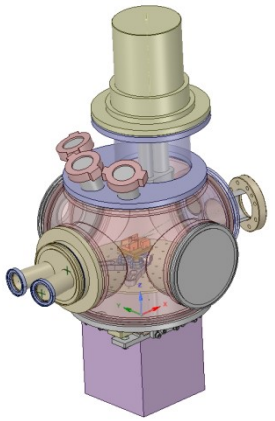


X-ray FEL Oscillators (XFELO)

Seeding at Angstrom wavelength for high rep. rate machines…

- Extreme narrow bandwidth FELs dw/w < 1e-6
- CW / Quasi-CW machines (applicable at EuXFEL)
- Bragg crystal / mirror stability (angular / timing)
- + desired wavelength tuneability ~ 1e-3
- Thermal deformation and transient effects





Courtesy: H. Thiessen, DESY

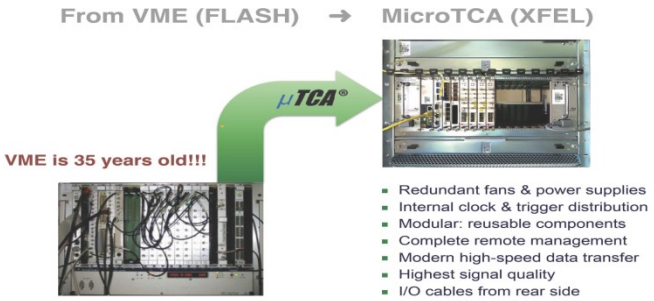
Dissemination & development of MicroTCA electronics for accelerator controls

Make use of standardization to ease high-tech electronics / systems at various accelerator facilities

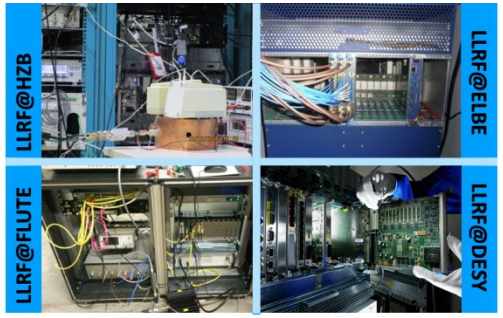
Applications

- Beam diagnostics
- Low Level RF controls
- Timing and MPS systems
- Fast feedback controls
- High speed data processing
- …

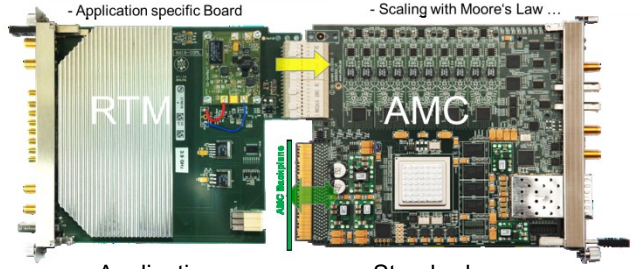
Legacy systems…



Reusability (HW/SW/FW)



Adaptable



Application Specific (may differ for facilities)

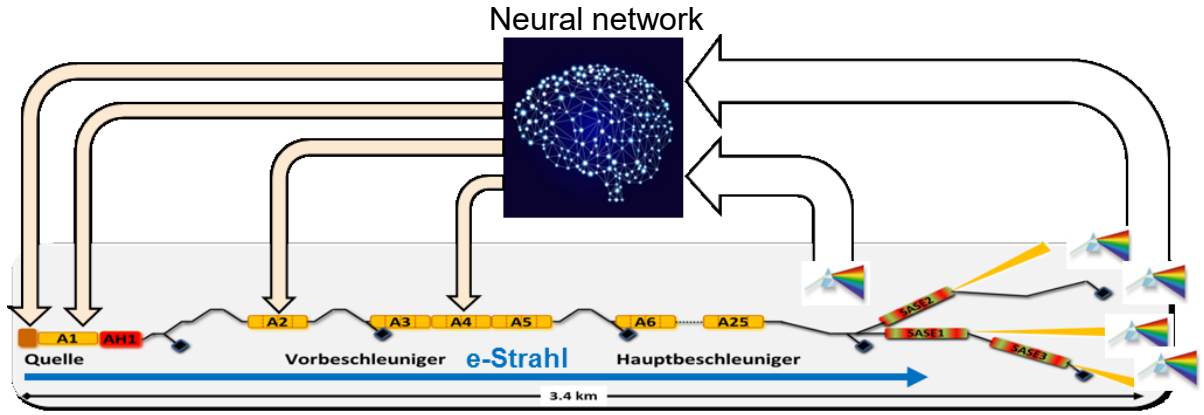
Standard component

Implementation and integration of AI methods for accelerators

Implementation of AI methods in accelerator controls

Used for

- Accelerator tuning and optimization
- Fault diagnosis, anomaly detection, supervision
- Stabilization and ultra-fast feedbacks
- Improved facility understanding / classification and identify hidden parameters
- …

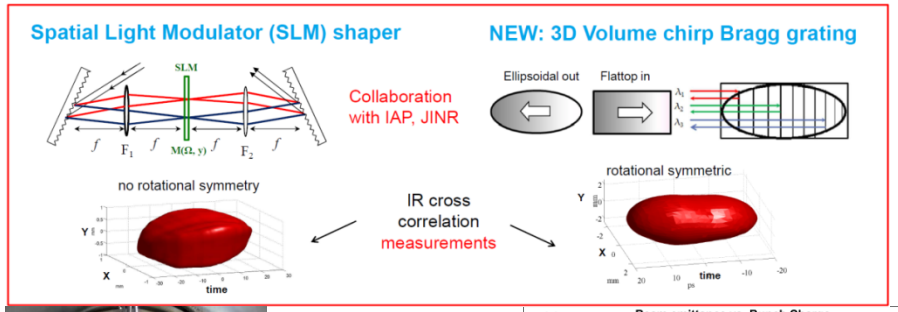


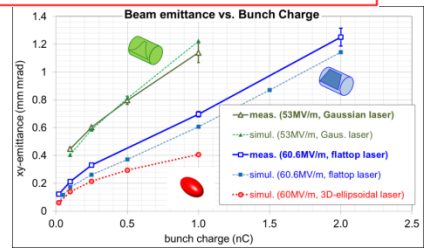
Facilities…

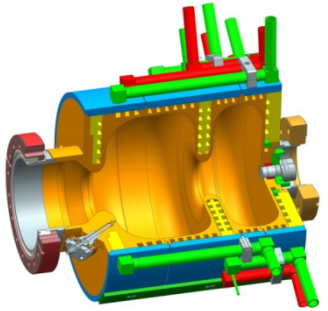
A&D Programs at PITZ (Test Facility)

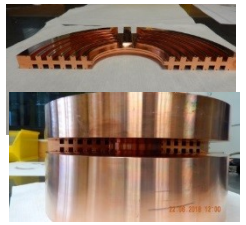
Various topics from high brightness …. to THz generation

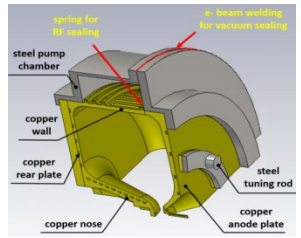
- Towards ultimately low emittance beams
  - 3D ellipsoidal laser pulse shape
  - Cathode development
  - Residual field errors
  - …
- Next generation of pulsed & CW RF gun
- THz generation

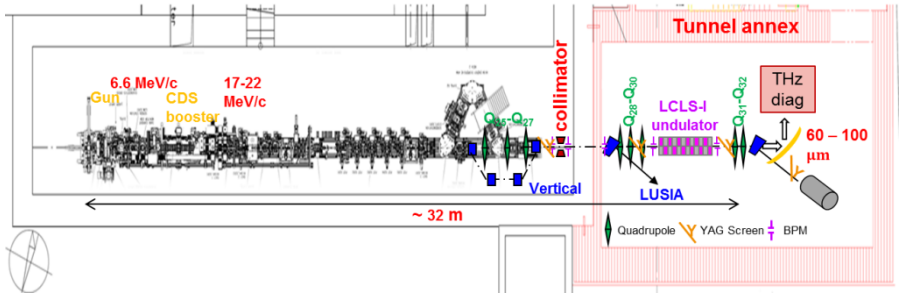






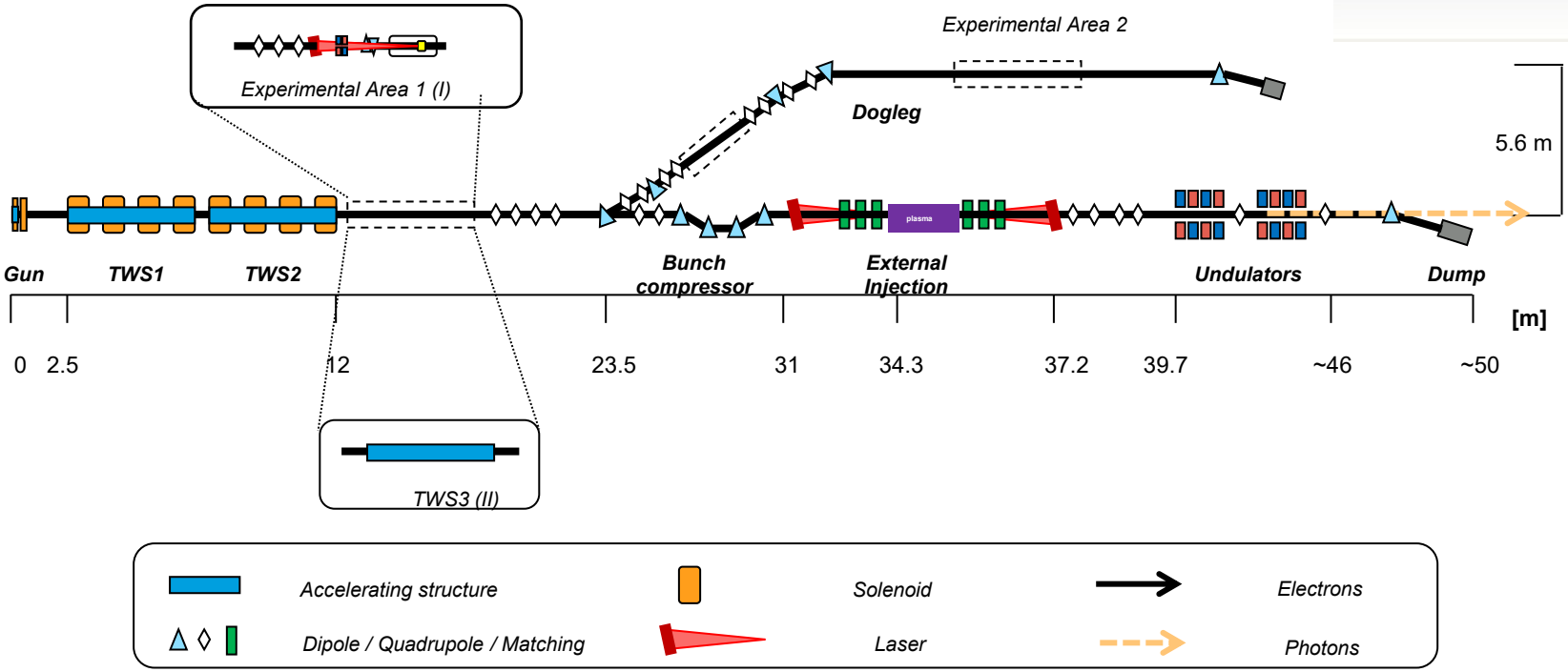






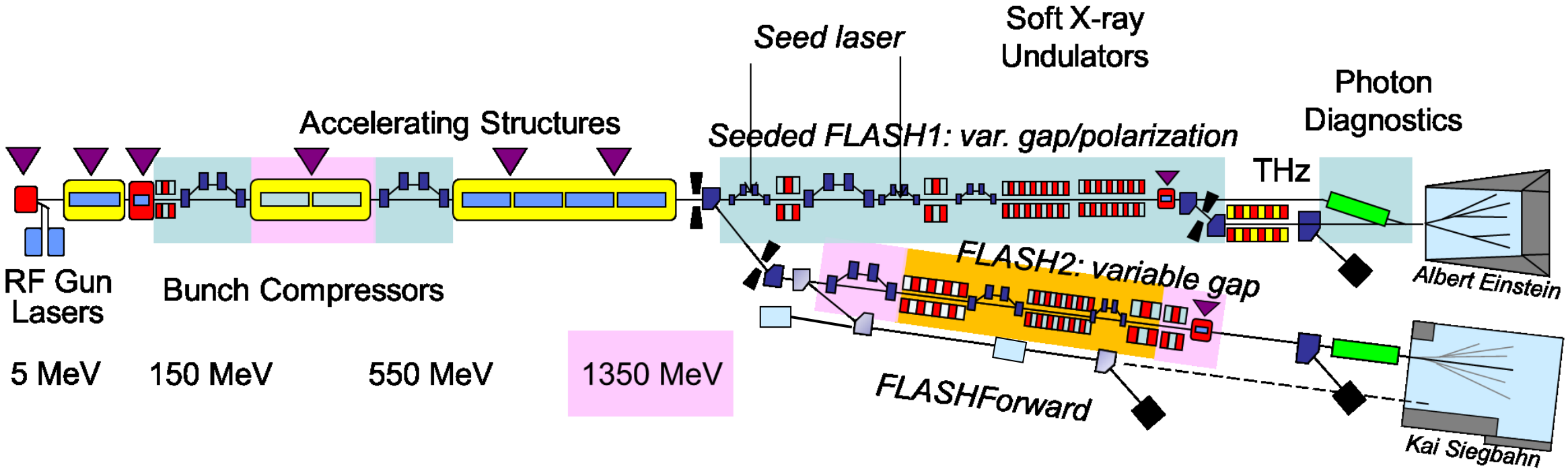
A&D Programs ATHENAe / ARES (Test Facility)

PWA & other novel accelerators (ACHIP e.g.) & test bench…



A&D Programs at FLASH … FLASH2020+

Towards a seeded high repetition rate XUV and soft X-ray FEL



Step 1
Energy upgrade
3rd BC (FLASH2)
TDS (FLASH2)
Injector Laser
Afterburner FLASH2

Step 2
Variable gap undulators (FLASH1)
Pump-Probe laser (FLASH1)

Laser heater in 1st BC
New 2nd bunch compressor (BC)

Step 3
High rep.rate seeding (FLASH1)
Photon diagnostics (FLASH1)

Step 4
New variable gap undulators + chicanes
for new lasing concepts (FLASH2)

POF-IV
OUTLOOK

POF-IV OUTLOOK

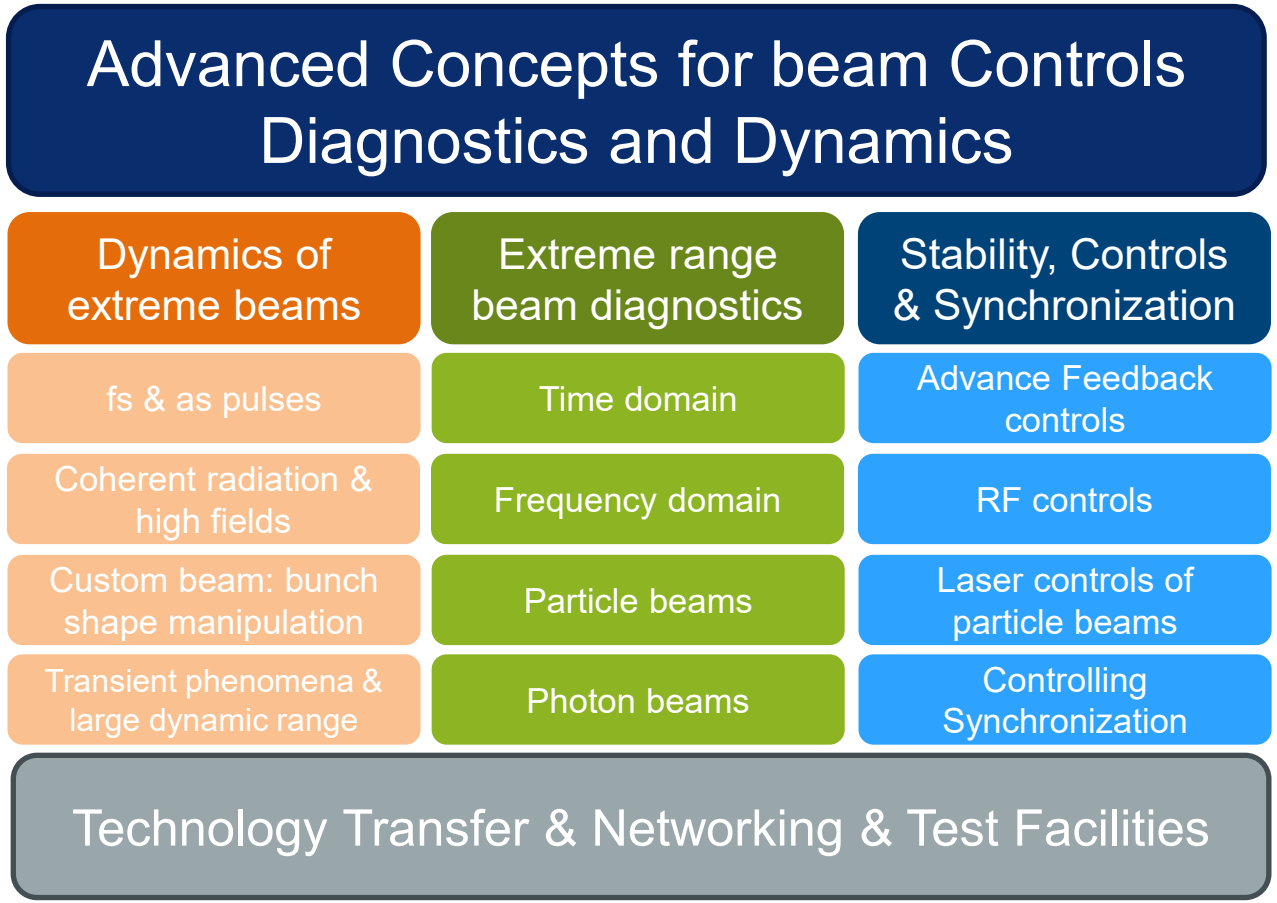
- Change Sub-topic name from „ps-fs electron and photon beams“ to
  „**Advanced Concept for beam Controls, Diagnostics and Dynamics**”

- Overarching theme:

➔ **Controlling extreme beams**!
(…at the for front of technology)

- Tight connection to
  - Sensor developments
  - High throughput electronics
  - …
- Tight connection to
  - Control systems
  - Data analytics (ML)
  - Feedbacks …
- Technology Transfer & *Networking* & Test facilities strong focus of ARD-ST3

+ Education!!



POF-IV OUTLOOK

- Extension of test facilities:
  - FLUTE
  - PITZ
  - SINBAD/ARES
  - KARA
  - cSTART
  - BerLINPro

➔ Access & Complementary & exploit Synergies

- **Key words** for ARD Program in ST3:
  - Extreme dynamic range
  - Feedbacks, control, stabilization
  - Attosecond metrology
  - Technology for compact accelerators
  - Standardization & maximize synergies …

➔ST3 as “hub” within MT-ARD but also linking MT topics DTS/DMA

Topics from center‘s for ARD-ST3:

- Photon pulse diagnostics; photon synthesis
- Beam dynamics & beam control;
- Coherence control
- Emittance improvement & control
- Advanced feedback systems
- 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”)
- Stabilization of components (e.g. RF sources)

…