Global Longitudinal Beam-based Feedbacks with Distributed Detectors

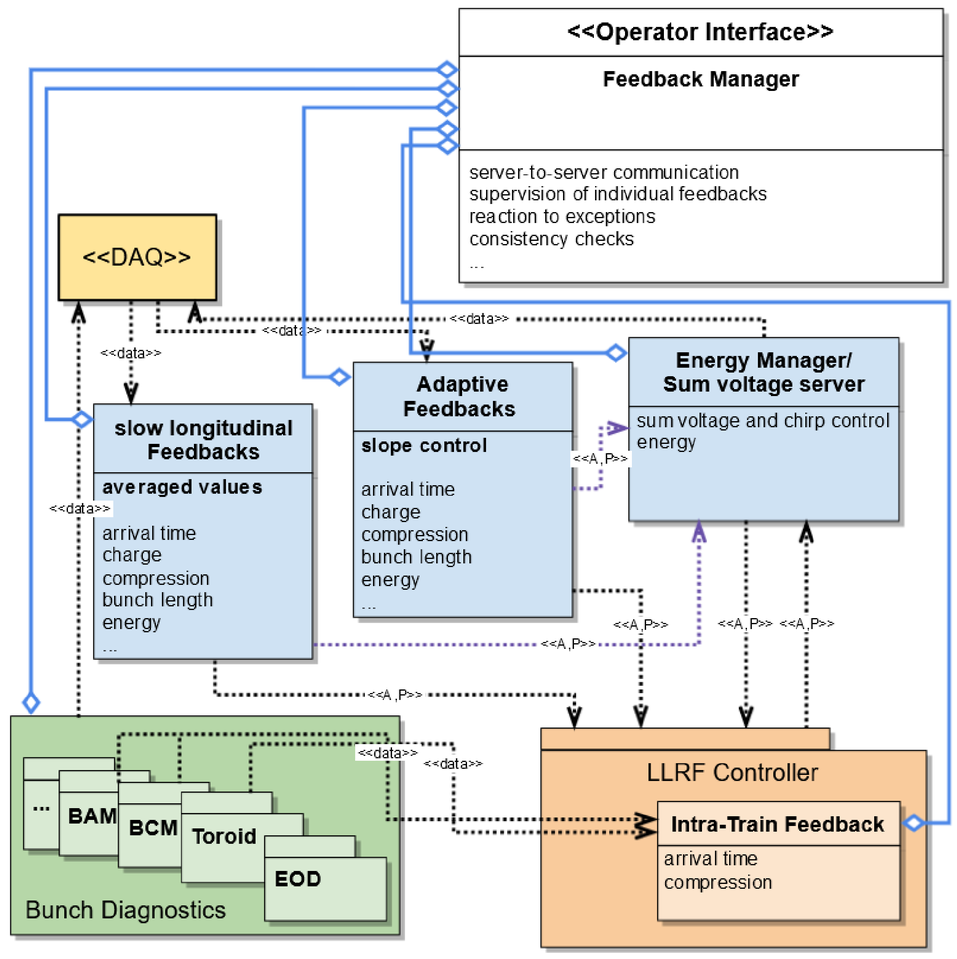
Activities at FLASH - The Free-Electron Laser at DESY, Hamburg, Germany

M.K. Czwalinna, J. Rönsch-Schulenburg, Holger Schlarb, on behalf of the FLASH team and MSK

A global feedback approach is needed for improved & reproducible machine setup and to accommodate special user requirements.

There is a large potential for applying machine-learning supported tuning approaches :

1. **Global longitudinal feedback:**
   - Restoring and optimization of the longitudinal e-bunch and FEL properties,
   - Stabilisation against drifts and short-term jitter.
2. **Smart automation:**
   - improving and stabilising the FEL operation,
   - optimising beam pointing, SASE intensity, SASE spectral properties, …
3. **AI supported tuning :**
   - use a combination of FEL simulations and beam-diagnostics (actual or virtual),
   - tailoring the e-beam to accommodate for special user requests



Smart Automation & Global Feedback

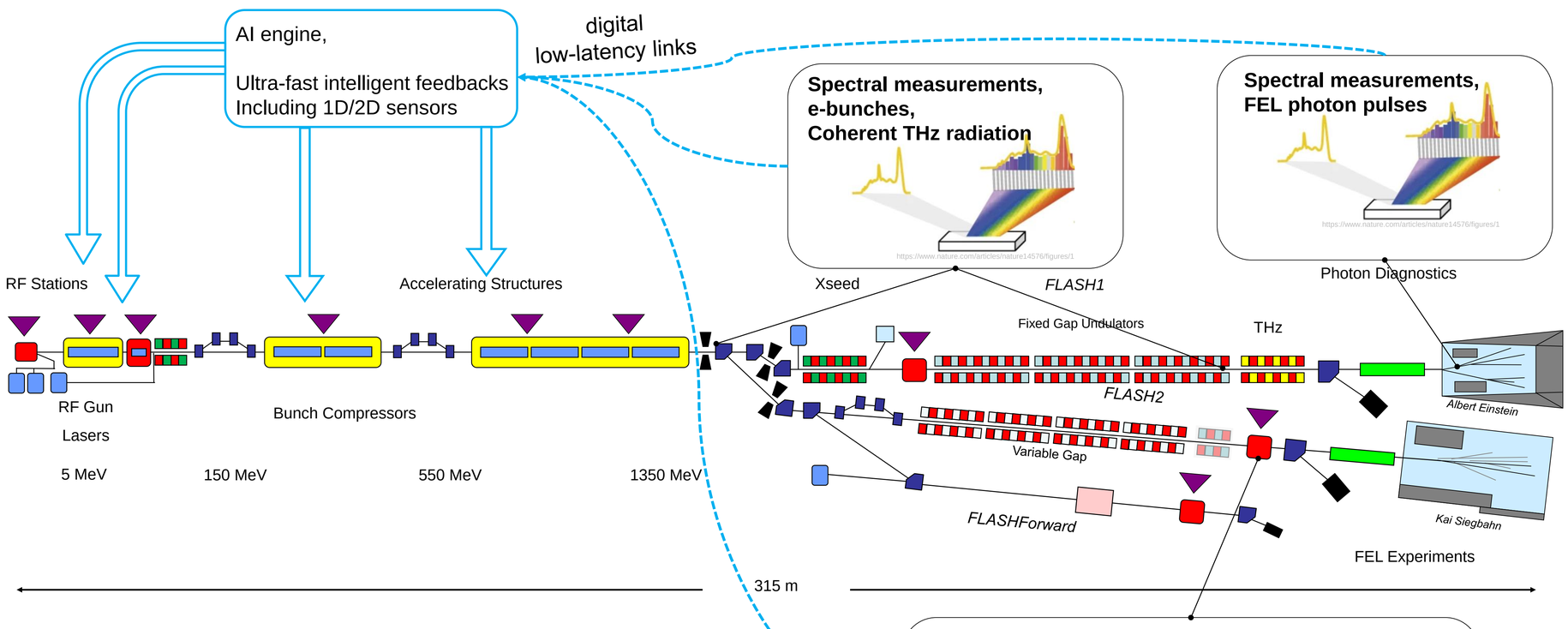
> Server-based solution: "**Feedback manager**"

- New middle-layer server communicating with all implemented, separated beam-based feedback tools
- Minimal user interface : machine operators selects on/off option and possible new target values,
- Detailed feedback configuration and exception handling solely done by the feedback manager

> Project status

- Tests of individual modules on-going at FLASH and European XFEL
- Expected deployment of first light-weight version by end of 2022

AI Engines & Ultra-Fast Diagnostics



> Established near real-time 0-d diagnostics :

- arrival time measurement,
- compression signal,
- e-bunch position (orbit)
- ..

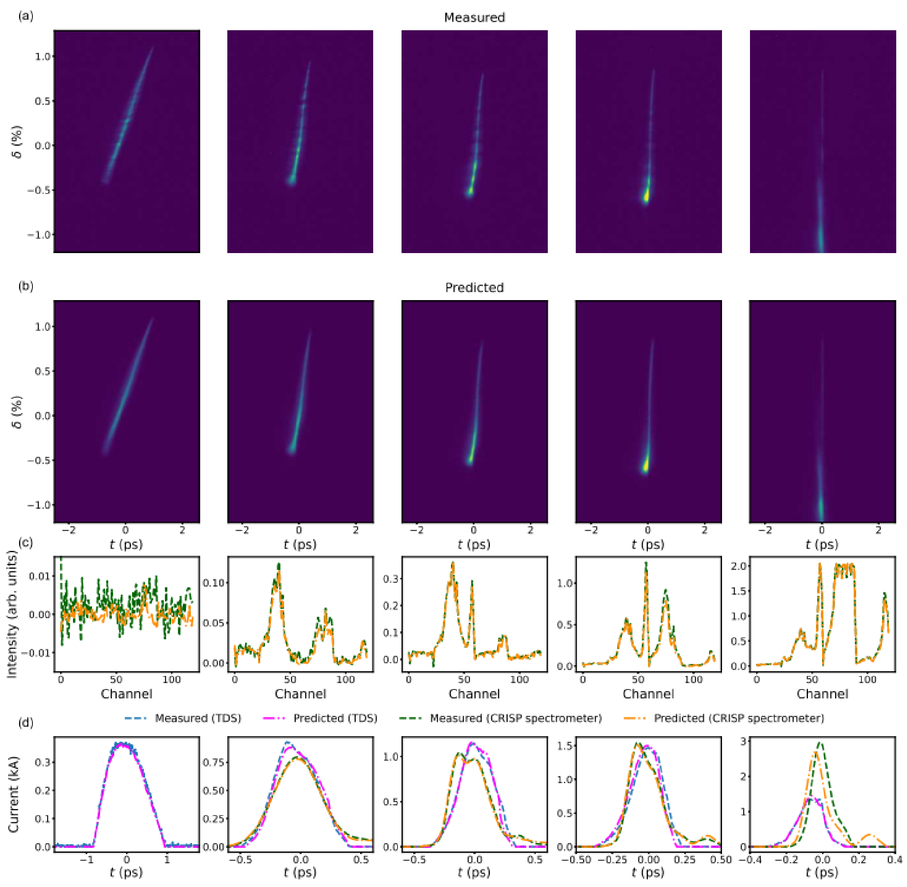
> Additional information :

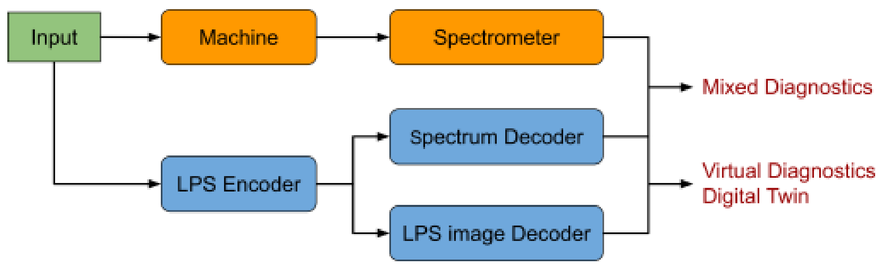
- 1d spectral measurements
- 2d images/screens (invasive)
- …

> Availability of suited, non-invasive, fast read-out diagnostics can be an issue.

> Need for substituting by virtual diagnostics.

Longitudinal Phase Space (LPS) Prediction





based on worked done by Jun Zhu:

> Apply an encoder-decoder neural network model with more than one decoder for heterogeneous predictions of electron bunch longitudinal properties.

> Follow-up on this approach at FLASH & EuXFEL

> Five typical results from the test data of a dataset of one working point.

> The compression strength increases monotonically from left to right.

> (a) Measured LPS images. δ denotes the fractional energy deviation. (b) Predicted LPS images. (c) Comparisons between the measured and predicted spectra from the low-frequency grating set of the CRISP spectrometer. (d) Comparisons of the current profiles calculated from the measured and predicted LPS images as well as reconstructed from the measured and predicted spectra.

11th Workshop on Longitudinal Electron Bunch Diagnostics | 29.06. - 01.07.2022