TRAINABLE workshop- Anomaly Detection WG

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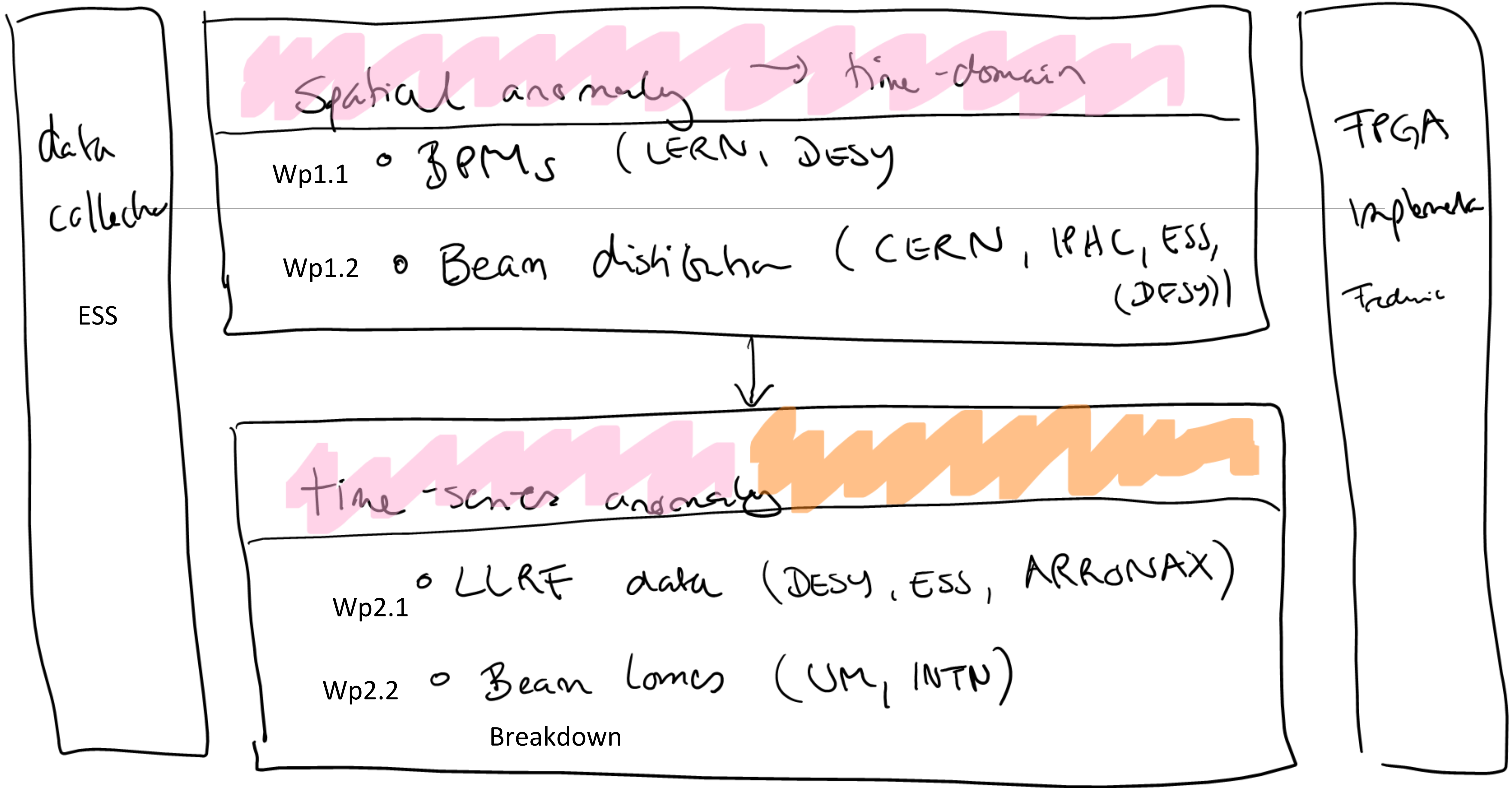
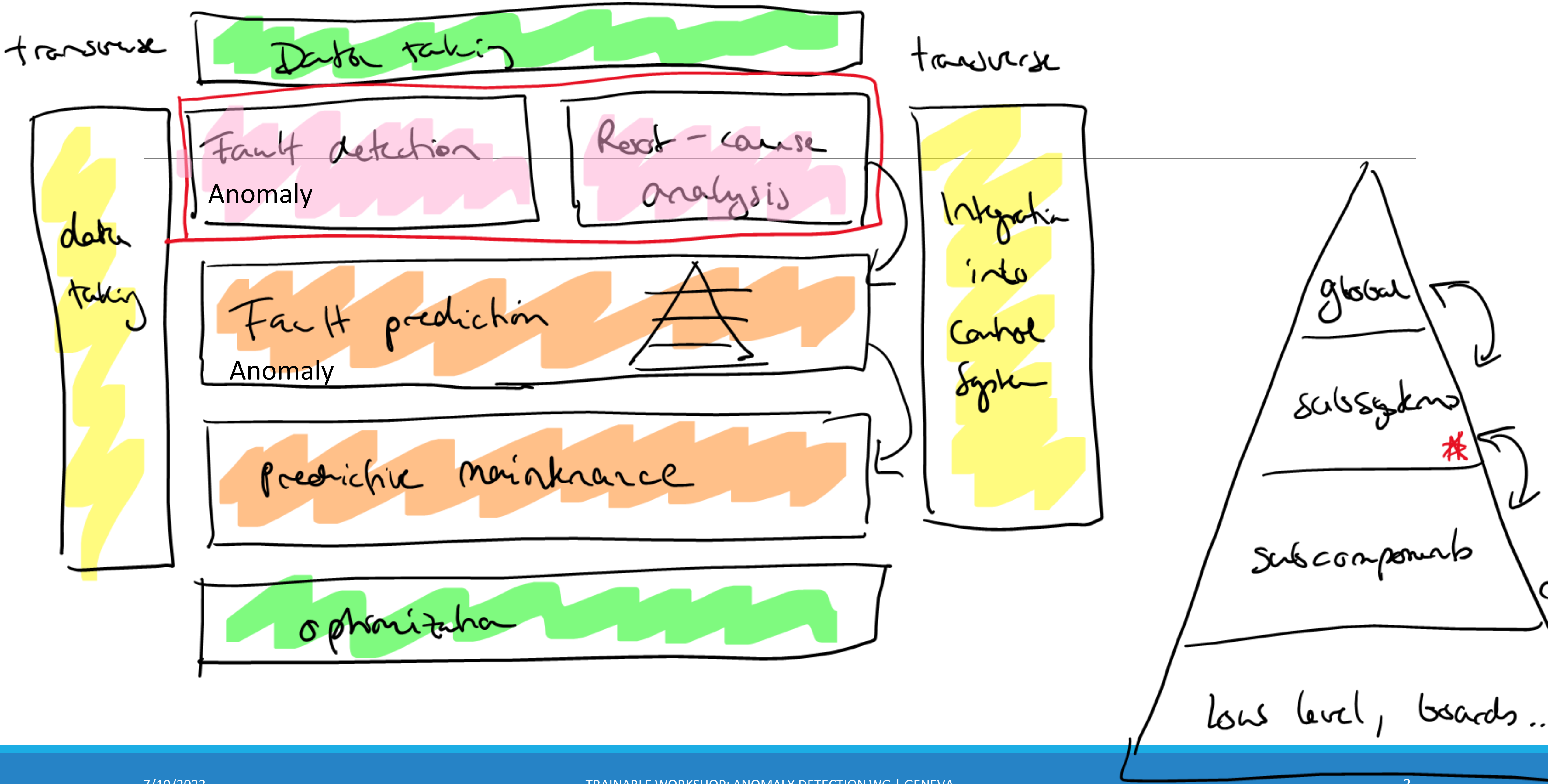

data
ESS
Spatial anomaly → time-domain
Wp1.1 ∘ BPMs (CERN, DESY
Wp1.2 ∘ Beam distribution (CERN, IPHC, ESS, (DESY))
time-series anomaly
Wp2.1 ∘ LLRF data (DESY, ESS, ARRONAX)
Wp2.2 ∘ Beam losses (UM, INTN)
Breakdown
FPGA
Frederic

> **14:00 - 14:45**


transverse
Data taking
transverse
Fault detection
Anomaly
Root-cause analysis
data taking
Integration into Control System
Fault prediction
Anomaly
global
subsystems
Predictive maintenance
subcomponents
optimization
low level, boards...

Work-packages

	Work Packages	WP's objectives	WP's leader	Expected deliverables/results	Demonstrator	What do groups offer
WP1.1	BPM	Manual effort reduction, robustness, reproducibility	DESY	bring algorithms from LHC to PETRA III	PETRA III	DESY: Application and FPGA specialists CERN: Algorithm experience
WP1.2	Beam distribution	accuracy resolution improvement, not sufficient solution yet, improve stability of optimization, loss minimization	IPHC	Apply experience from CERN to other kind of particles and get feedback from real experiments, virtual diagnostics (robust)	Industry benchmark	CERN: Algorithm development IPHC: Hardware development + industrial partners ESS: teststand + interest to integrate into th control system DESY: interest to transfer algorithm to electrons
WP2.1	LLRF	availability, money & energy, more science	ESS	Algorithm develpment and implementation (on FPGA, server solution as intermediate), classification and forecasting	Data and teststands (DESY and ESS, Spiral2)	ESS: Implementation specialist (data taking FPGA) DESY: Algorithm experience (offline, detection and classification) ARRONAX
WP2.2	Breakdowns	reducing beam losses, availability	INFN	Do algorithm development and cross check	TEX, LHC, XBand, ARES?	UM: Algorithm experience INFN:

Transverse Groups – to other WG

Optimization

- Optimizers should not guide towards unhealthy states (fault prediction)
- Optimizers should not use corrupted data (data checking)

Data generation

- Unbalanced data (a lot healthy data)
- For root-cause-analysis, data for different faults needs to be there (or needs to be generated, realistic faults)
- use results to insert realistic faults
- guided parameter scans (to save time, decision boundary)

Transverse groups

Data

- Quality standards (eg. raw, bronze, silver and gold)
- Curation at each stage
- Data owners, provenance
- Formats, structures (as above)

Integration of data sources – ex. kafka to broker diverse sources, uniform API to data pool, etc

Performance of archivers and other continuous logging systems:

- Ingestion
- Query

Data acquisition – triggered, buffered acquisition; trigger management; backpressure management

- Data analysis environment – offline and streaming; algorithm portability from data center to edge devices.

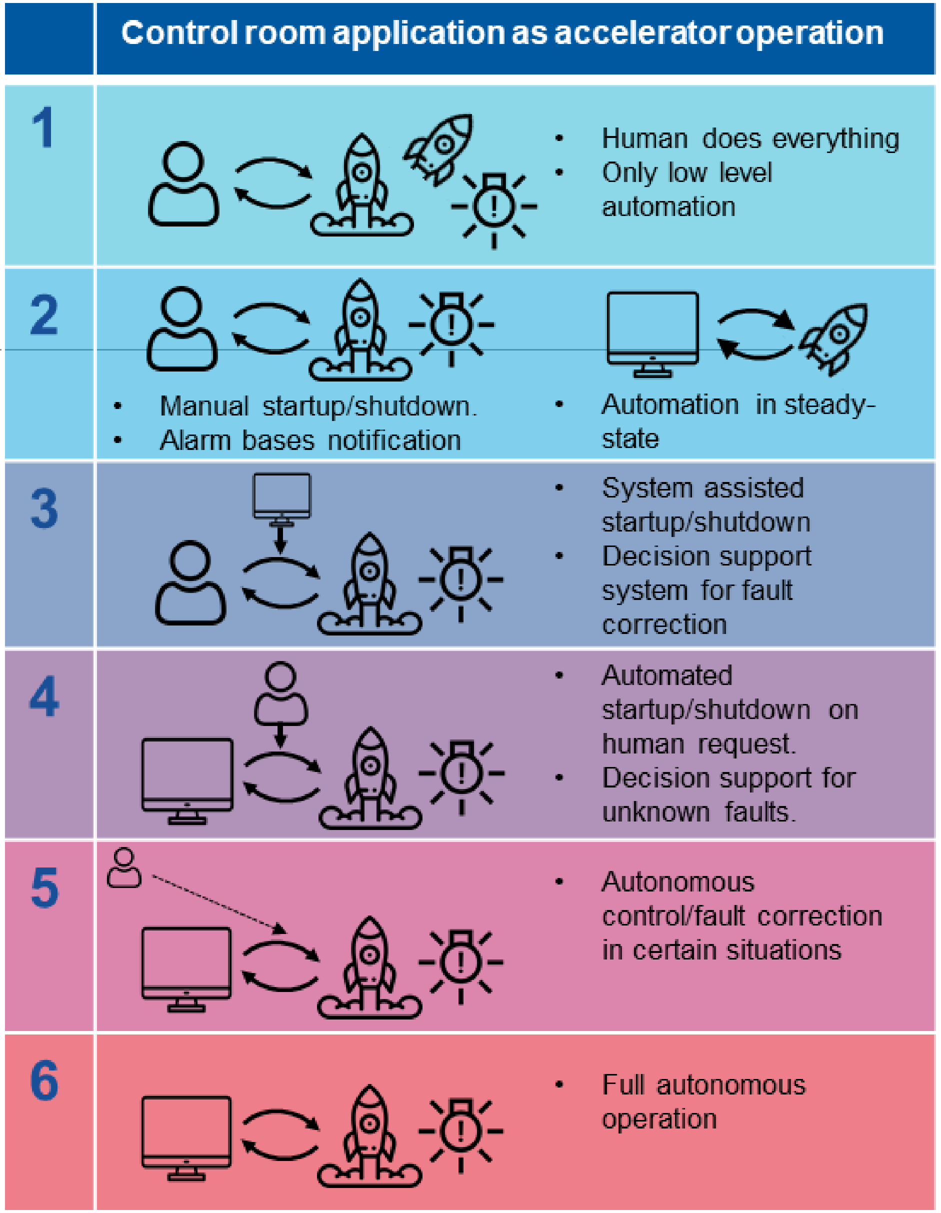
Implementation

- Embedded implementations
- GPU solutions
- Bandwidth limitations
- Solution is dependent on the hierrachy

	Specific needs *What are the specific needs that triggered this project ?*	Expected results *What do you expect to generate by the end of the project ?*	Dissemination, exploitation and communication measures *What dissemination, exploitation and communication measures will you apply to the results ?*	Target groups *Who will use or further up-take the results of the project?* *Who will benefit from the results of the project?*	*Outcomes* *What change do you expect to see after successful dissemination and exploitation of project results to the target group(s)?*	Impacts *What are the expected wider scientific, economic and societal effects of the project contributing to the expected impacts outlined in the respective destination in the work programme?*
1.1	Beam optics corrections and control of beam trajectory are crucial to enable stable and safe beam operation. In synchrotrons, as LHC and PETRA III/IV the beam optics and orbit measurements rely on turn-by-turn data acquired from Beam Position Monitors. The failures of BPMs degrade the quality of data used for beam optics and orbit analysis, and hence it is required to detect these faults before computing these properties. The traditional methods for turn-by-turn data cleaning (e.g SVD) are not reliable and efficient enough as has been seen on the example of the LHC, requiring additional manual cleaning and increasing the time needed for analysis. For orbit feedback specifically, fast (MHz time-scale) methods which can be deployed on FPGAs are needed.	Reusable (model-free) ML algorithms to be implemented at different facilities : PETRA III/IV LHC Implementation at the edge on FPGA is required for PETRA III/IV, the main goal is to detect the faulty measurements before the next turn. (ESS does it) Interpretable ML algorithms to be used (as already done for the LHC) to link the signal artifacts to causes of instrumentation failures Analyze multi-variate data to achieve robustness and limit false alarms and false intermediate input to other processes.	Communicating the Exploitation: knowledge transfer to other research infrastructures. dissemination : data, solutions, results and applications sharing through publications, conferences, tutorial, repositories ... Communication towards community: Exchange the knowledge between different groups of experts within accelerators domain (beam physics and beam instrumentation/ hardware experts)	LHC, PETRA III/IV, potentially other storage rings If extending to other instrumentation and data types (beyond tbt-data): other types of accelerators can profit too. other groups maybe?	- Reduction of manual effort in performing beam measurements -Faster, more robust feedback systems -joint effort, and a solution to be exploited by at least two RIs (LHC, PETRA III/IV)	- Improved tbt-data quality will lead to more precise optics measurements and better corrections, improving the luminosity (LHC), beam time (PETRA III/IV), increase of discovery potential Improved beam diagnostics - narrowing the search for the faults (e.g. closer look at only 100 BPMs predicted by ML out of 1000 BPMs) more numbers maybe ?
1.2	Current methods rely on background elimination, and the assumption of a Gaussian beam; and due to small signal to noise ratio, background elimination eliminates true beam information	Benchmark presentation with industrial partner Algorithm development common based on simulation and real data (adapt algorithm for developed for different particles; image recognition)	Scientific/ publications and demonstrators dissemination of the ML method to other particles (electrons); addressing also other communities	Labs in Europe/ CERN, GSI ESS, GANIL, possibly also electrons accelerators (algorithm part)	All labs successfully implement new measurement device plus algorithm (at least) better virtual diagnostics	Higher reliability; better knowledge and trust better performance of infrastructure better results of experiments economic/ higher competitiveness of industrial partner; business gain, European advance
2.1		Curated set of data: • standardised,.... a toolkit to • identify unwanted stops leading to incapacity to deliver the beam • Capture the data • characterise and classify RF anomalies, quenches, ... • predict			Measure of saved downtime improve/increase scientific output (users community) improve economic performance, increase yield	development of new scientific instrumentation, tools and methods for research infrastructures taking into due account resource efficiency toolkit/methods Facilities to benefit first: ESS, XFEL, Spiral2, ... training of RI staff for the operation and use of these new solutions toolkit maturity usable for operation (documentation, portable, usable by operators)

Issues

- Definition: Identification of anomaly (compared to a drift)
  - Wanted (forced) drifts
  - Unwanted drifts
- Time-varying nature of the application: for supervised methods —> retraining is necessary, automatically identify when retraining is necessary (not to train on anomalies, faulty data)
- Operators/Experts in the loop —> Decision support system
- Action to take as a response to a fault
  - Some need to be automatic due to timescale
  - Operators choice: here retraining would be an option as others
- For getting trust: start step by step, first implement the detection visualization in control room before actually action is taken
  - Work on visualization
- Technical readiness level



T. Gamer et. al., "The autonomous industrial plant -future ofprocess engineering, operations and mainte
Symposium DYCOPS, vol. 52, no. 1, pp. 454–460, 2019.