EUROPEAN
SPALLATION
SOURCE

Last update: Dec 2021

Fast Machine Learning for Accelerator Controls

FastML for Science workshop
Imperial College London, 25-28 September 2023

KARIN RATHSMAN

2023-09-26

European Spallation Source

2003
Concept design of ESS presented

2009
Decision to site ESS in Lund

2012
ESS design update phase complete

2014
Start of construction

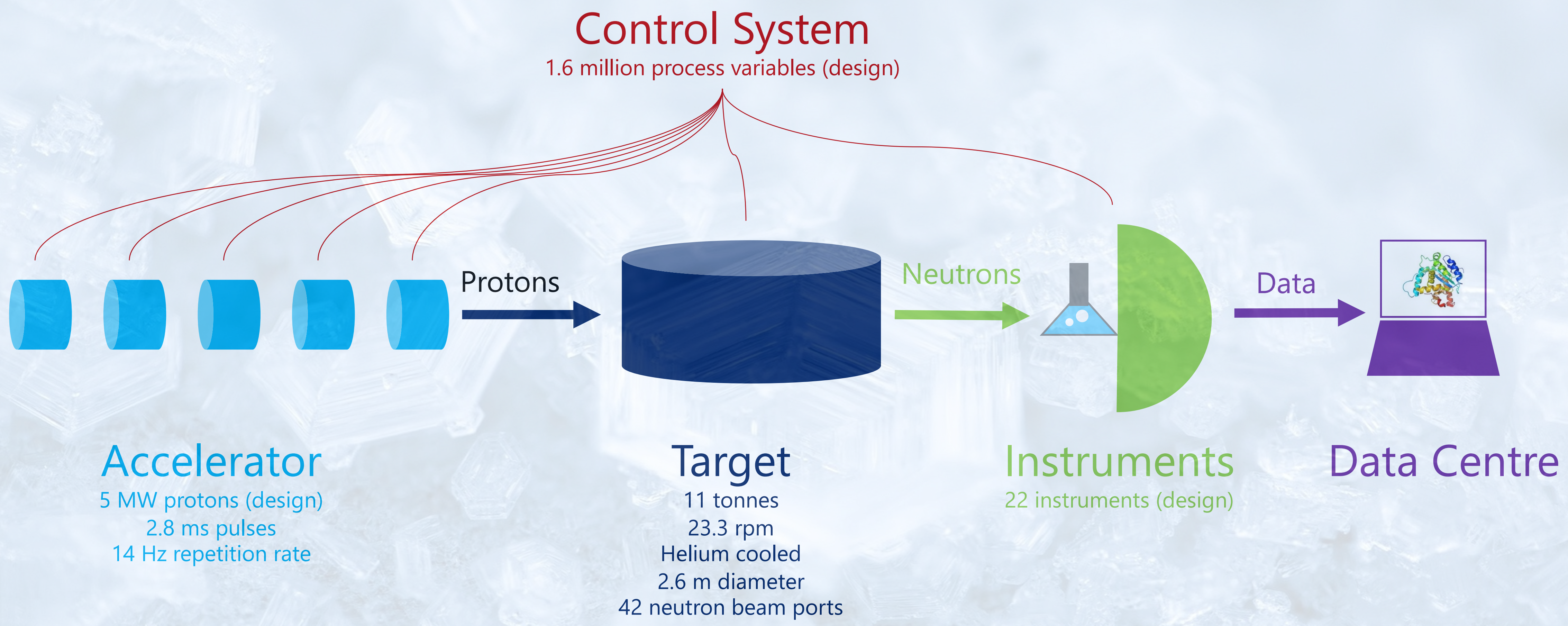
2019
Start of initial operations phase

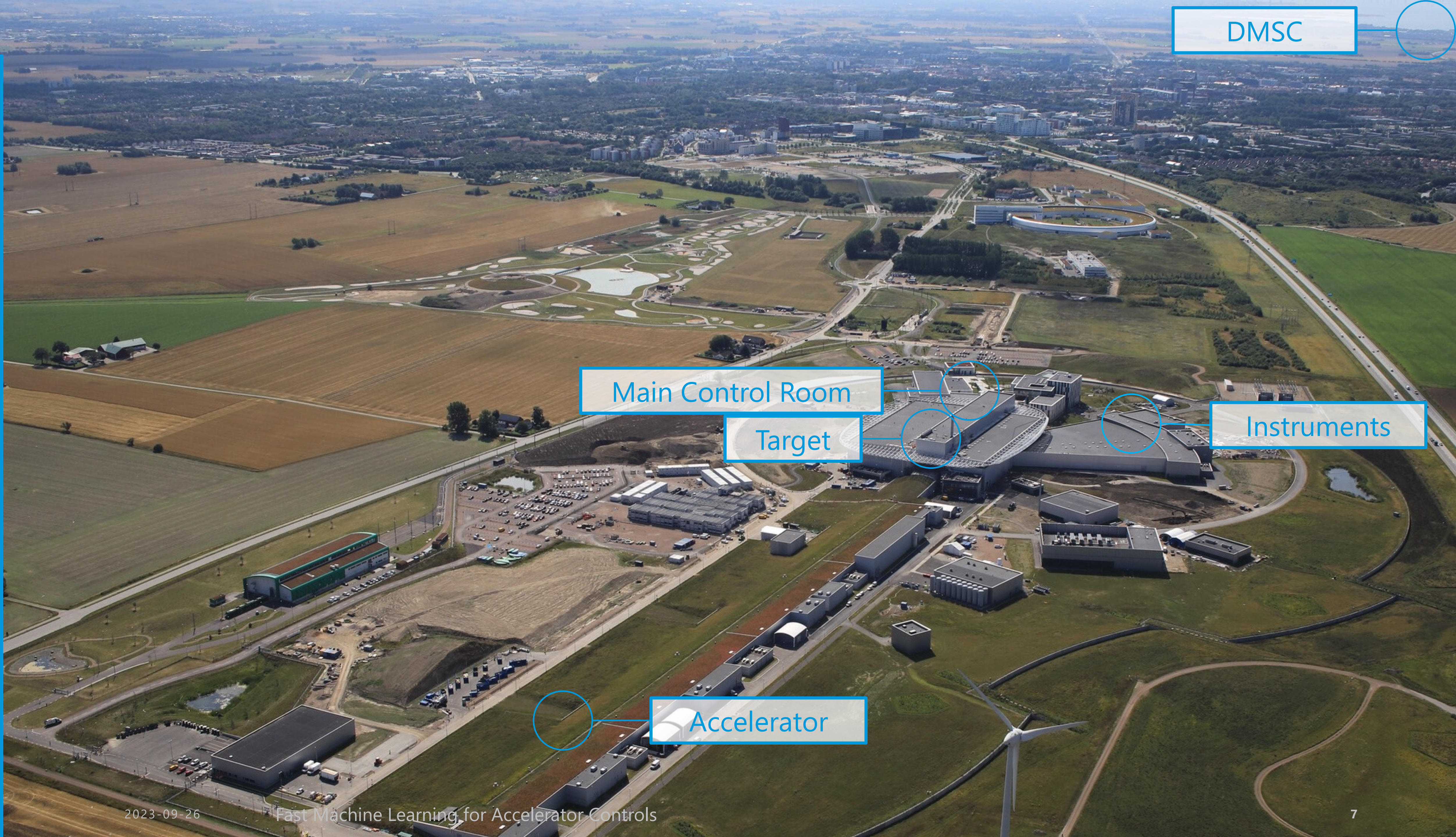
2027
First science


PAUL SCHERRER INSTITUT
PSI
neutron imaging & activation group


MEDICINE & HEALTH
ENERGY
ENGINEERING
WORLD AROUND US
ess
Drug development
Better batteries
Lighter, stronger materials
Advanced data storage
New generation MRI
Green fuel
Superconductivity
Disease resistant crops
Cellular biology
Improved solar cells
Better catalytic systems
Examining artefacts

The ESS Machine



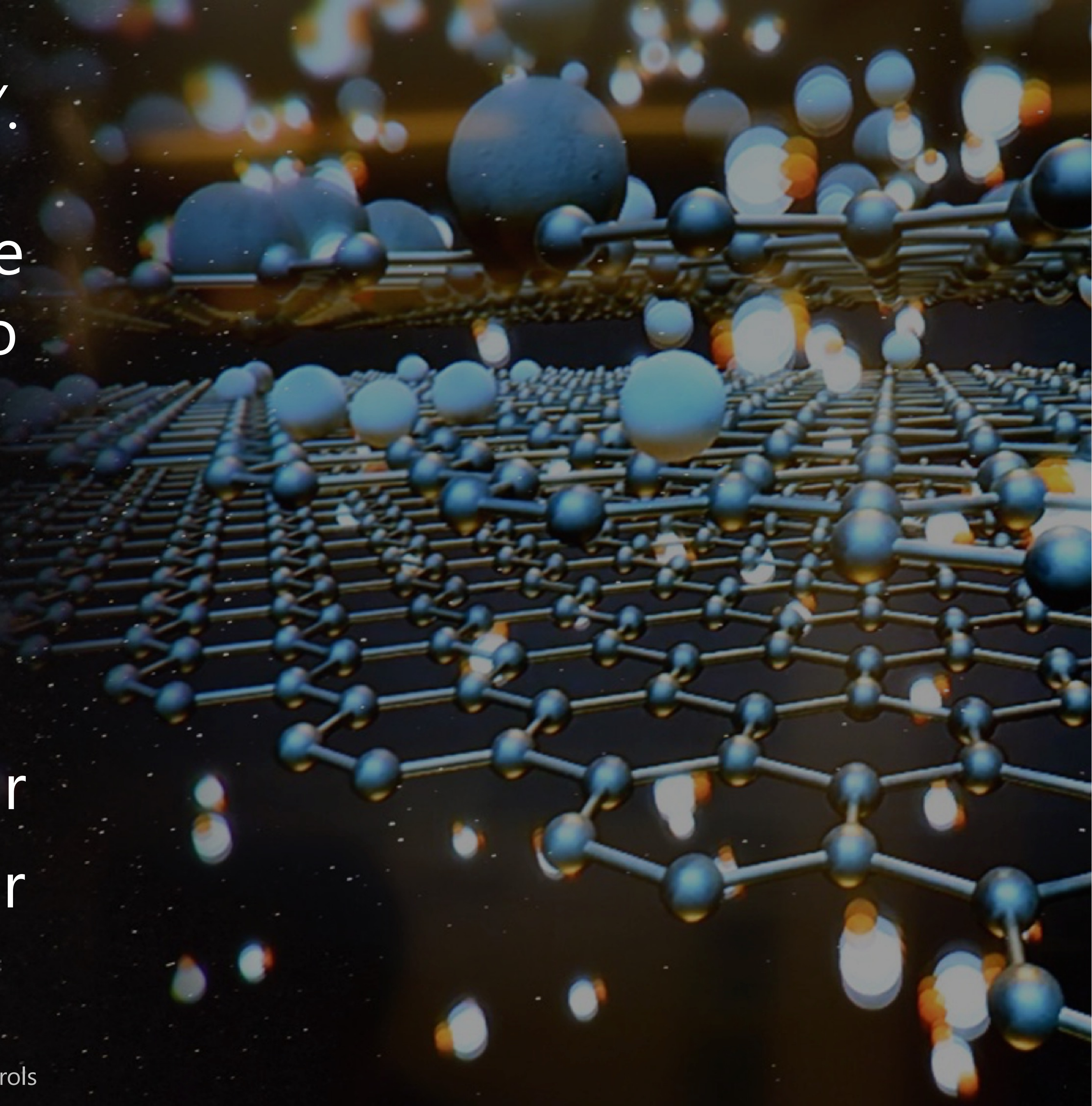

DMSC
Main Control Room
Target
Instruments
Accelerator

ESS is a *user facility*.

Scientists from all over the world will be welcomed to ESS with their specimens to do experiments.

Expectations:

- 800 experiments per year
- 3 000 guest scientists per year



Challenges

- Accelerator – based facilities are some of the worlds most complex systems
- ESS is a user facility with a 95% availability goal
  - High availability requirements on equipment
  - The control system plays a key role for the availability of the facility

Control System Machine Learning Project

2019 - 2023

- Explore if machine learning can be used to:
- Increase facility availability.
- Increase efficiency of operation
- Enhance process understanding
- Lower operational and maintenance costs
- Decrease commissioning time

Resources

- 100 % me
- Overwhelming interest from
  - Colleagues
  - Students
  - Academia
  - Companies

ESS Control System Data Lab

https://wasp-sweden.org/a-big-machine-with-lots-of-data-wasp-researchers-in-a-pilot-study-with-ess/

WASP | WALLENBERG AI AUTONOMOUS SYSTEMS AND SOFTWARE PROGRAM

← NEWS

A big machine with lots of data – WASP researchers in a pilot study with ESS

April 28th, 2021

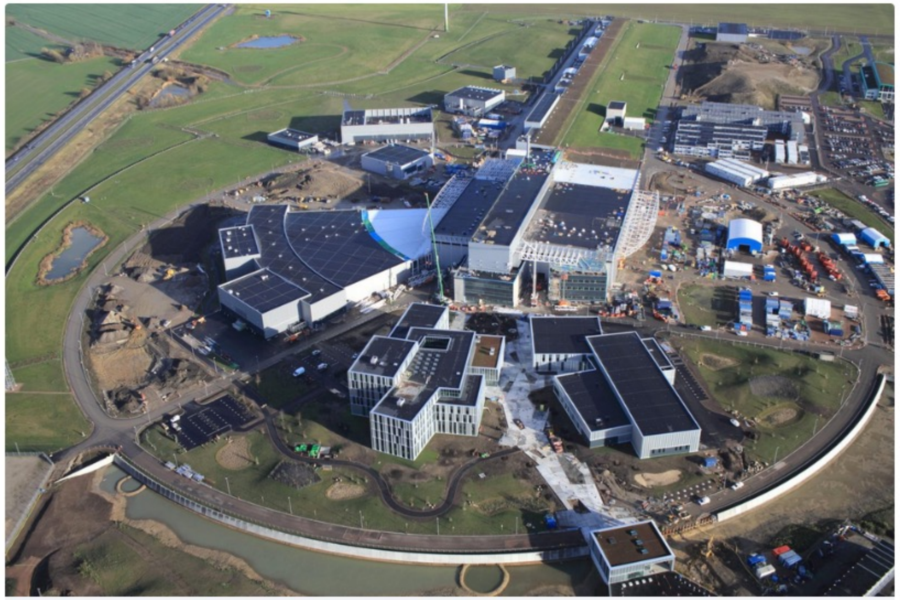


Image: Perry Nordeng/ESS

When finished, the European Spallation Source (ESS) in Lund will have the most complex control system in Sweden, and AI, especially machine learning, is crucial for optimizing its operation. WASP associated researchers Per Runeson and Emma Söderberg, both from Lund University, recently contributed to a pilot study on data sharing for machine learning research from ESS.

In their contribution, they have investigated several issues regarding data sharing. How can data be shared between organizations in order to achieve more and better training data for machine learning models? One useful solution is sharing through data ecosystems with various degrees of openness, where one company shares data, and another annotates it. This could be beneficial in terms of increased knowledge and better prediction models.

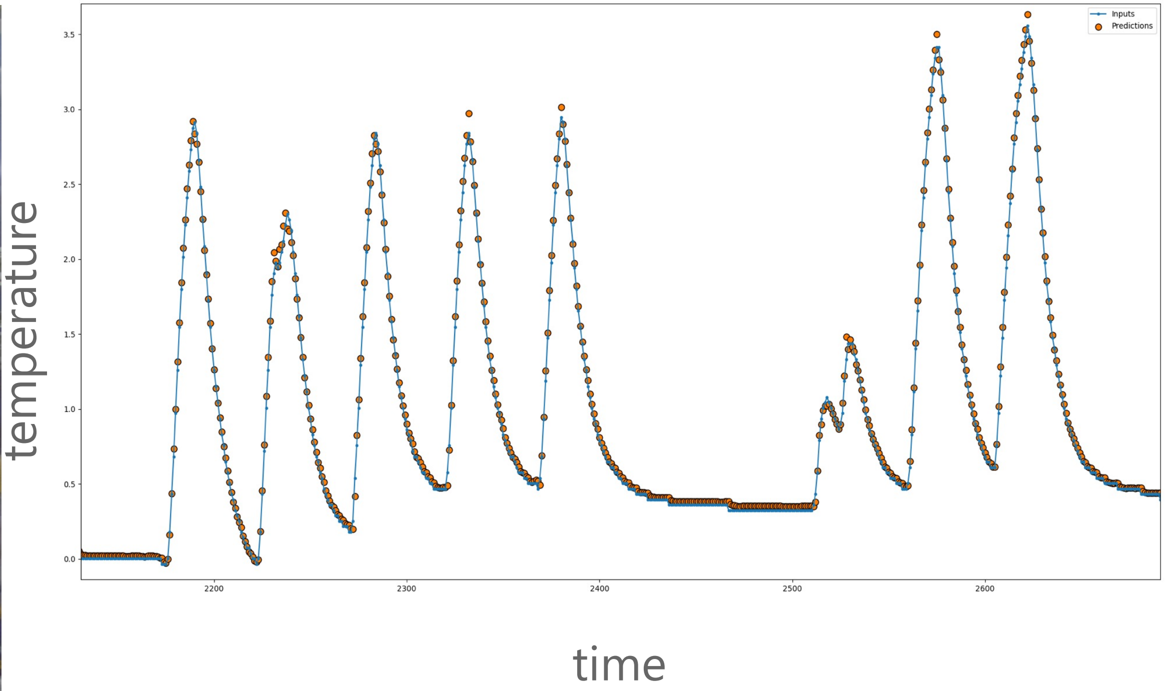
"We conclude in our report that by sharing data, ESS can function as a catalyst for Industry 4.0 digitalisation, both in industry and other research facilities," explains Per Runeson, Professor in Software Engineering. "Data sharing fulfills the function of sharing knowledge, and our project shows that it is possible for ESS to be a role model and share relevant data with industry," he adds.

Another topic addressed was how to build long-term reliable data pipelines. They found that agile tools and approaches are needed in order to collect, process and maintain data. Also, data traceability and handling of meta data are important quality factors that needs attention when working with machine learning.

"We found that a lot of the literature cover challenges with Big Data, but in practice for companies in this space the data sets may many times be smaller and there are challenges in how to trace data versions and how to share understanding of the data between developers. We see a potential in further exploring how agile methods and tools from software development can be utilized in management of data," says Emma Söderberg.

Klystron oil temperature

https://www.dvel.se/news/new-collaboration-with-ess-within-vinova-project-regarding-machine-learning-and-ai/



Use case:

- Warn before temperatures gets too high.
- Warn about fault sensors or calibration issues.
- Apply feedback loop to keep the temperature within limit.

Student Project: Tuning the DTL

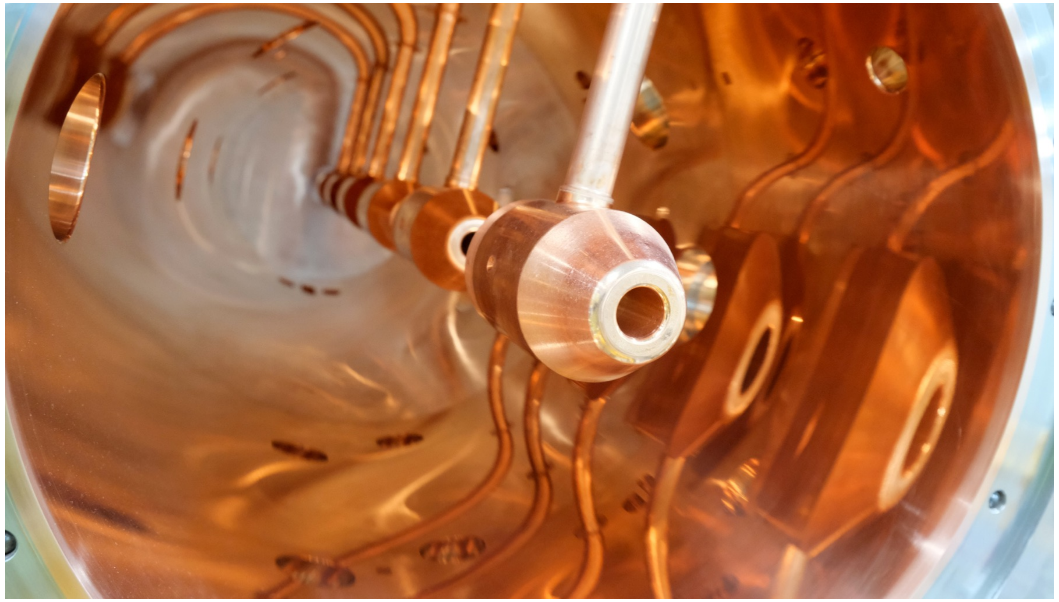
Developing an ML-based model for RF tuning of DTL machine at ESS

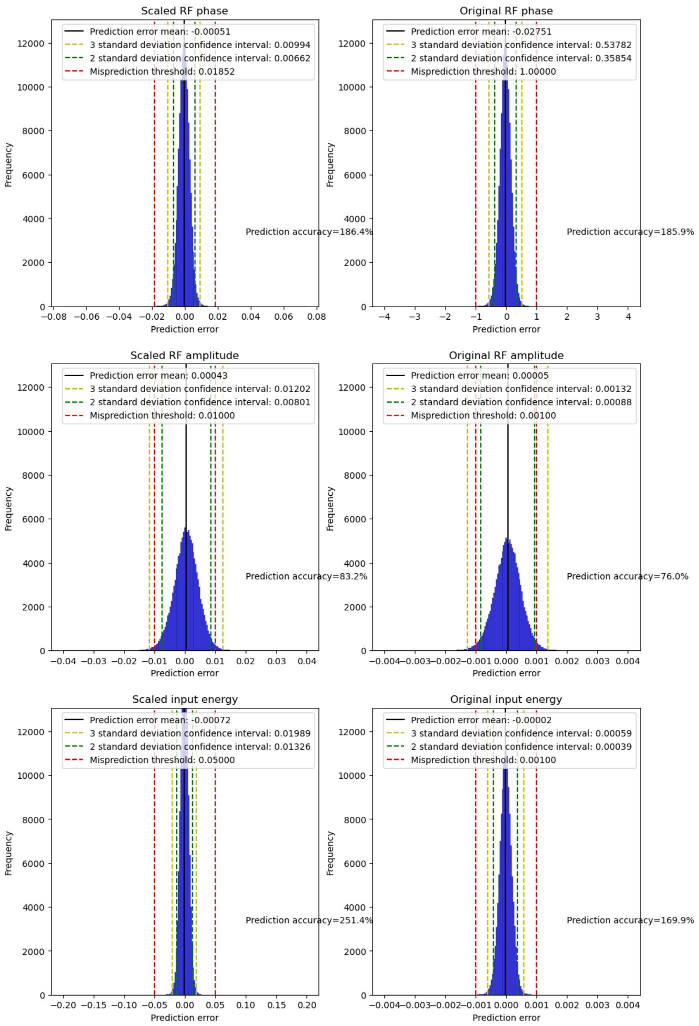
Student: Amin Hosseini Nejad.

Institute: Automatic Controls LU

Course: Master's Program in Machine Learning, Systems and Control

ESS Supervisor: Natalia Milas (accelerator)





Student Project: Alarm Cascades

https://drops.dagstuhl.de/opus/volltexte/2023/19098/

Common Alarm Problems

- Many alarms are unnecessary
- Some alarms are missing
- Many alarms have badly tuned parameters
- Some alarms has a higher priority than others.
- Many alarms are only relevant in certain operational states
- A fault often leads to several consequences

Analyzing Complex Systems with Cascades Using Continuous-Time Bayesian Networks

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European Spallation Source ERIC, Lund, Sweden
Marco Scutari
Istituto Dalle Molle di Studi sull'Intelligenza Artificiale (IDSIA), Lugano, Switzerland
Fabio Stella
Department of Informatics, Systems and Communication, University of Milano-Bicocca, Italy
Søren Wengel Mogensen
Department of Automatic Control, Lund University, Sweden

Abstract
Interacting systems of events may exhibit *cascading* behavior where events tend to be temporally clustered. While the cascades themselves may be obvious from the data, it is important to understand which states of the system trigger them. For this purpose, we propose a modeling framework based on *continuous-time Bayesian networks* (CTBNs) to analyze cascading behavior in complex systems. This framework allows us to describe how events propagate through the system and to identify likely *sentry states*, that is, system states that may lead to imminent cascading behavior. Moreover, CTBNs have a simple graphical representation and provide interpretable outputs, both of which are important when communicating with domain experts. We also develop new methods for knowledge extraction from CTBNs and we apply the proposed methodology to a data set of alarms in a large industrial system.

2012 ACM Subject Classification Mathematics of computing → Markov processes; Mathematics of computing → Bayesian networks

Keywords and phrases event model, continuous-time Bayesian network, alarm network, graphical models, event cascade

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1 Introduction

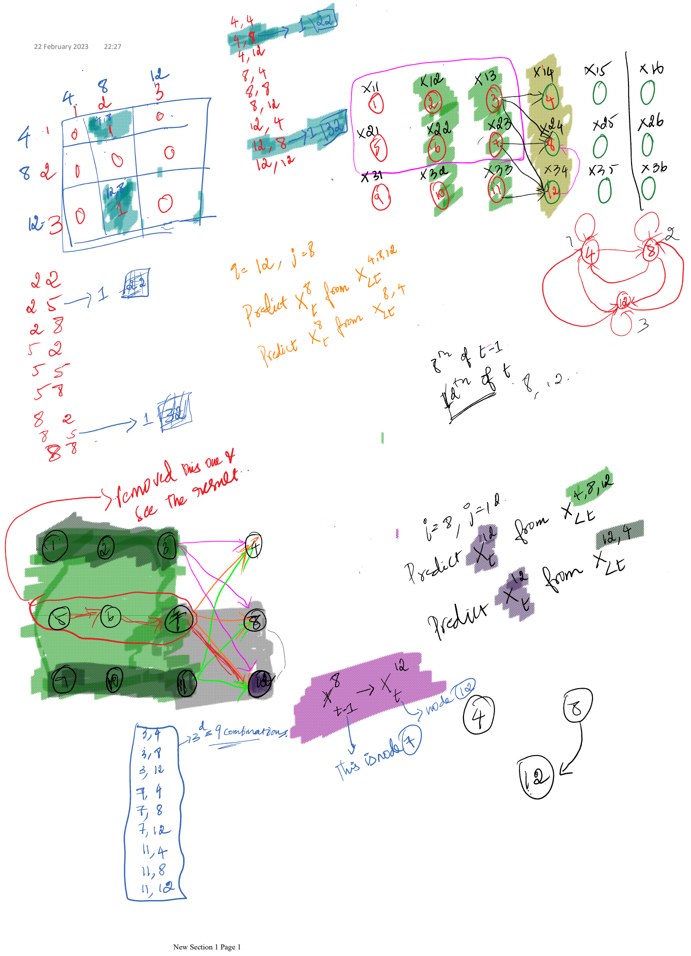
Many real-world phenomena can be modeled as interacting sequences of events of different types. This includes social networks where user activity influences the activity of other users [11]. In healthcare, patient history may be modeled as a sequence of events [46]. In this paper, we focus on an industrial application in which the events are alarm signals of a complex engineered system. As an illustration, consider Figure 1. Three different alarms (A, B, and C) monitor a process each within an industrial system. These processes may, for instance, represent measured temperatures or pressures. An alarm transitions to *on* when its the process it monitors leaves a prespecified range of values and transitions to *off* when the

30th International Symposium on Temporal Representation and Reasoning (TIME 2023).
Editors: Alexander Artikis, Florian Bruse, and Luke Hunsberger; Article No. 8; pp. 8:1–8:21
LIPICS Leibniz International Proceedings in Informatics
Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Dagstuhl Publishing, Germany

Student project: Alarms

Causal event processes and alarm analysis at ESS

- Student: Vishnu Pradheep Raveendran
- Department: Automatic controls, Lund University.
- Degree: MsC in Machine Learning, Systems and Control



Student project: Anomaly detection

https://gupea.ub.gu.se/handle/2077/78206

Student: Vernita Gouws

Title: A Software Process Workflow for Smart Anomaly Detection Systems

Degree: BSc Software Engineering and Management

ESS Supervisor: Target division

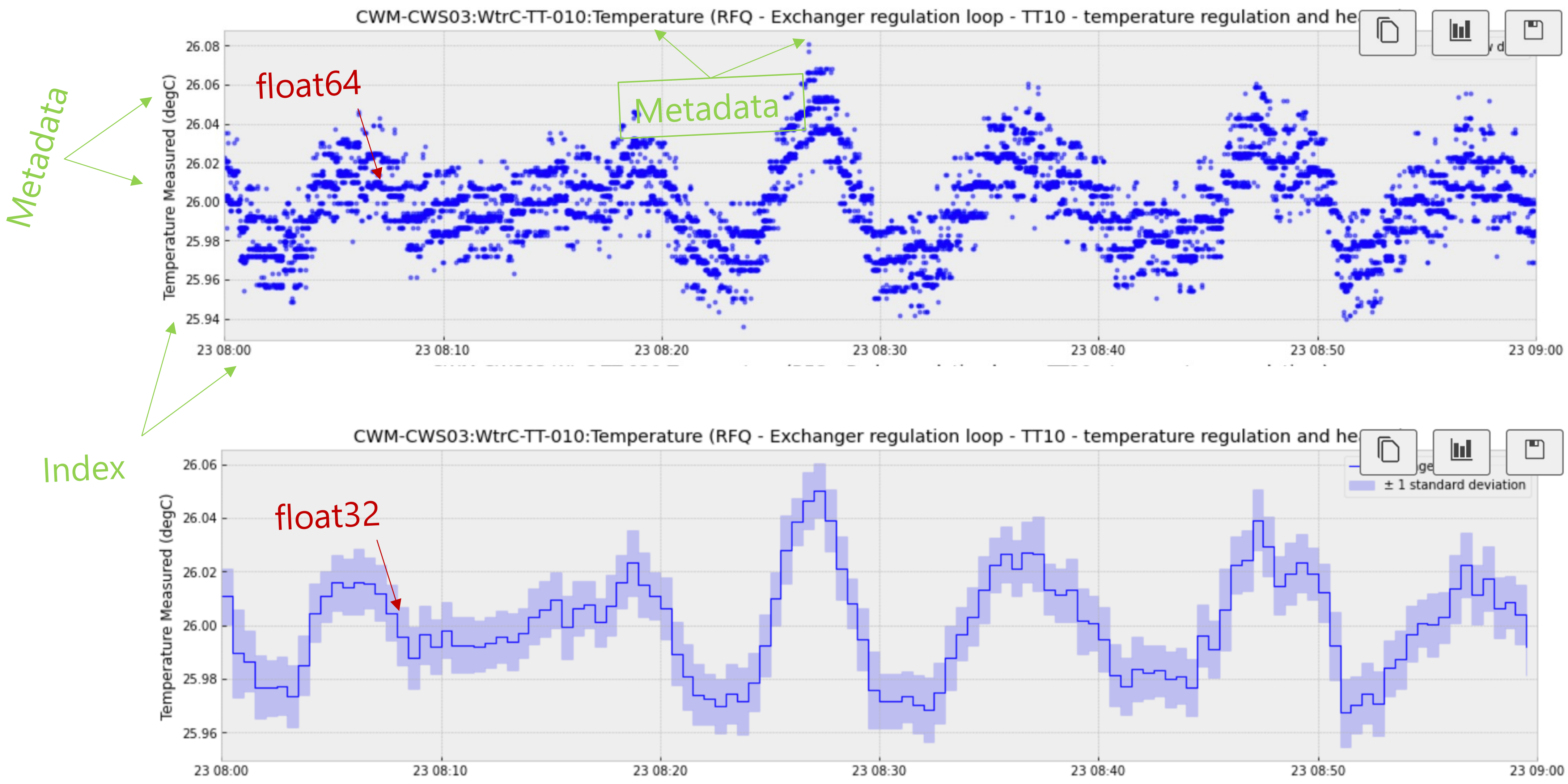
University: Chalmers and Göteborg University

Data

Machine learning models can never perform better than the data they were trained on.

- Reduce volume of data to mitigate network problems, reduce time to retrieve data, reduce costs to store data and reduce costs to pre-process data.
- Enhance information in control system data: Set alarm limits, description, units, operational limits, dead bands, calibration parameters…
- Develop data model and control system data protocol to minimize need of complicated interfaces.
- Make control system data easier to understand for non-experts in control systems (compare with data model in e.g. Numpy, Pandas, Tensorflow, Pytorch, Spark)

More metadata and less data



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