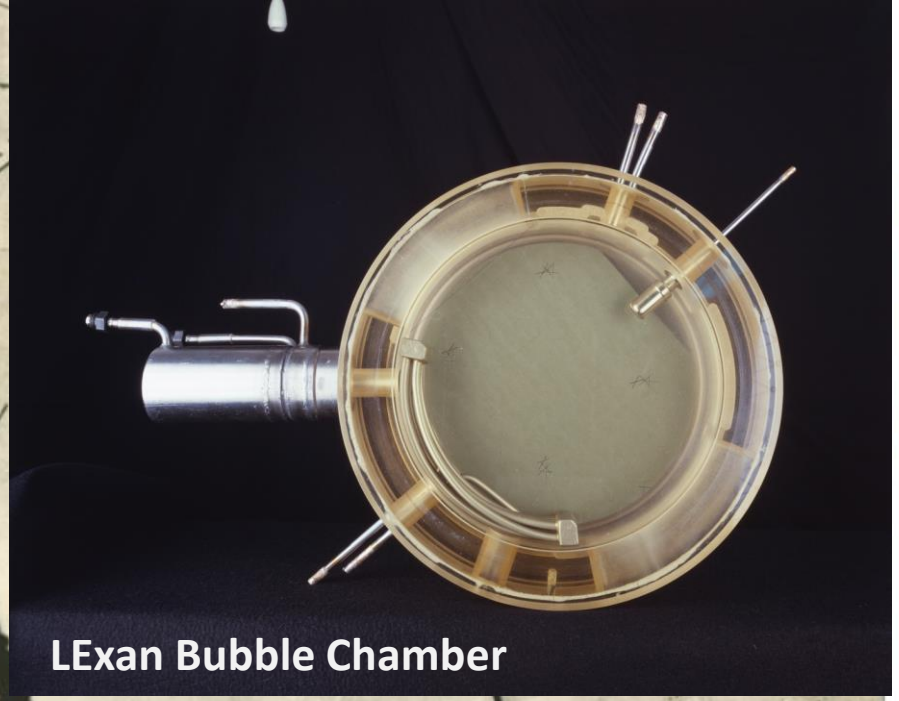
Efficient Particle Accelerators

What is on the Horizon

EPA core team V. Kain, A. Calia, L. Felsberger, J.C. Garnier, R. Gorbonosov, M. Hostettler, A. Huschauer, F. Irannejad, D. Jacquet, K. Papastergiou, C. Petrone, M. Schenk, M. Sobieszek, G. Trad, F. Velotti

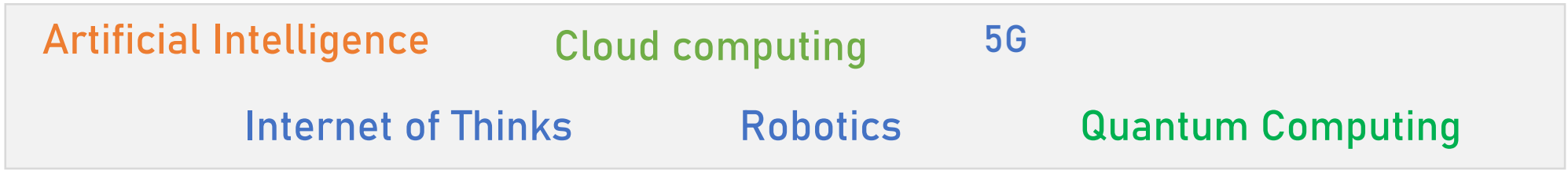
Joint Accelerator Performance Workshop 2023 , Montreux, 7 December 2023


LExan Bubble Chamber

From manual to automatic data analysis

2023 Efficiency Think Tank

Technology evolves with a fast pace

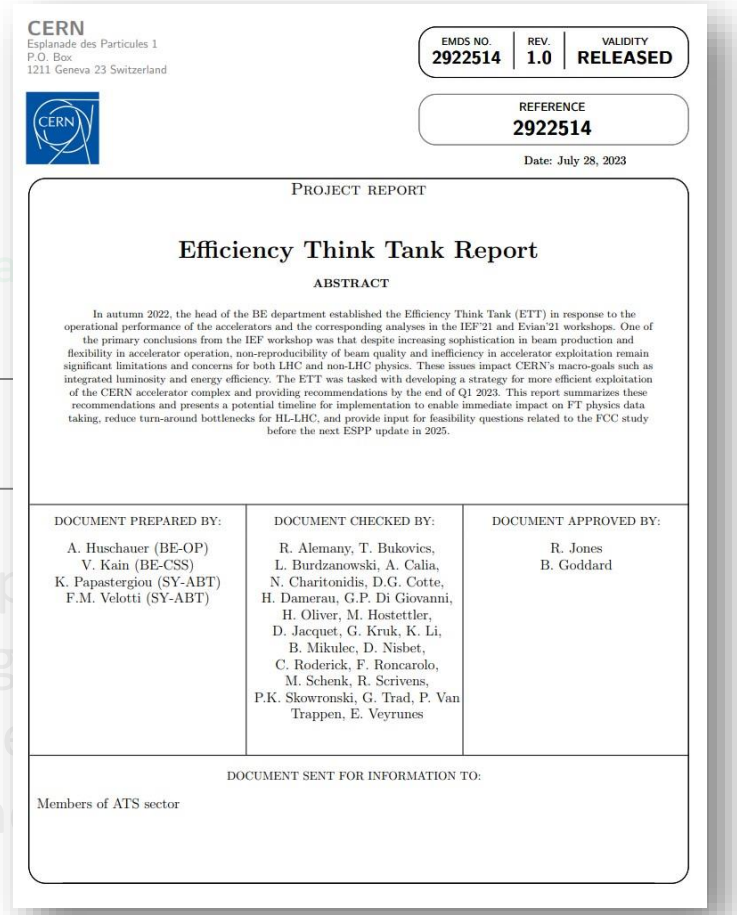


What is in the horizon for our CERN Exploitation model?
How can we address some known limitations?

- Beam Quality and beam stability of the non LHC physics beams
- Turn-around time, availability and commissioning versus physics time
- Need for definition and tracking of new metrics (ex. energy efficiency)
- Efficient interventions and preventive maintenance of system

2023 Efficiency Think Tank

ETT Report and EPA Indico



CERN
Esplanade des Particules 1
P.O. Box
1211 Geneva 23 Switzerland

EMDS NO. 2922514 | REV. 1.0 | VALIDITY RELEASED

REFERENCE 2922514

Date: July 28, 2023

PROJECT REPORT

Efficiency Think Tank Report

ABSTRACT

In autumn 2022, the head of the BE department established the Efficiency Think Tank (ETT) in response to the operational performance of the accelerators and the corresponding analyses in the IEF'21 and Evian'21 workshops. One of the primary conclusions from the IEF workshop was that despite increasing sophistication in beam production and flexibility in accelerator operation, non-reproducibility of beam quality and inefficiency in accelerator exploitation remain significant limitations and concerns for both LHC and non-LHC physics. These issues impact CERN's macro-goals such as integrated luminosity and energy efficiency. The ETT was tasked with developing a strategy for more efficient exploitation of the CERN accelerator complex and providing recommendations by the end of Q1 2023. This report summarizes these recommendations and presents a potential timeline for implementation to enable immediate impact on FT physics data taking, reduce turn-around bottlenecks for HL-LHC, and provide input for feasibility questions related to the FCC study before the next ESPP update in 2025.

DOCUMENT PREPARED BY:	DOCUMENT CHECKED BY:	DOCUMENT APPROVED BY:
A. Huschauer (BE-OP) V. Kain (BE-CSS) K. Papastergiou (SY-ABT) F.M. Velotti (SY-ABT)	R. Alemany, T. Bukovics, L. Burdzanowski, A. Calia, N. Charitonidis, D.G. Cotte, H. Damerau, G.P. Di Giovanni, H. Oliver, M. Hostettler, D. Jacquet, G. Kruk, K. Li, B. Mikulec, D. Nisbet, C. Roderick, F. Roncarolo, M. Schenk, R. Scrivens, P.K. Skowronski, G. Trad, P. Van Trappen, E. Veyrunes	R. Jones B. Goddard

DOCUMENT SENT FOR INFORMATION TO:

Members of ATS sector

Efficient Particle Accelerators project

7 ETT recommendations = 9 EPA work packages

During project preparation identified necessity of controls infrastructure evolution.

Each WP is high-level deliverable.

Project Lead and Coordination: V. Kain
Deputy: A. Huschauer

WP1 Dynamic Beam Scheduling Lead: F. Irannejad	WP2 Automatic LHC Filling Lead: A. Huschauer, G. Trad	WP3 Automatic Parameter Control & Optimisation Lead: M. Schenk
WP4 Hysteresis Compensation Lead: C. Petrone	WP5 Next Generation Sequencer Lead: R. Gorbonosov	WP6 Efficient Settings Management Lead: M. Hostettler
WP7 Automated Equipment Testing Lead: A. Calia, J.C. Garnier	WP8 Automate Equipment Lead: F. Velotti, K. Papastergiou	WP9 Data Processing Framework Lead: M. Sobieszek

Farhad Irannejad

WP1 Dynamic Beam Scheduling

Receive and schedule user beam requests automatically in a continues train of beam, departing from the Supercycle model towards something new.

To LS3: Automate the manual work needed to create BCDs with new Scheduler application and Pilot of Scheduler as the unique planner for beams

During LS3: Implementation and clean-up and homogenisation with other machines

Read more on https://indico.cern.ch/event/1334157/contributions/5615970/attachments/2730989/4747484/dynamic_beam_scheduling.pdf

Alexander Huschauer & George Trad

WP2 Automatic LHC Filling

Develop a framework to automatically prepare and execute dedicated LHC filling & fixed target physics sequences, reducing LHC turnaround & increasing stability & performance for other users.

To LS3: majority of functionalities shall be developed

- Announcer upgrade, PS2SPS transfer Vistar, Sequences, PS splitting optimisation, PS2SPS trajectory correction
- Develop and deploy filling orchestrator
- Streamline longitudinal observation across the complex

Read more on https://indico.cern.ch/event/1332225/contributions/5607896/attachments/2729044/4743720/WP2_automated_filling.pdf

Michael Schenk

WP3 Automated Parameter Control & Optimisation

Implement algorithms & software infrastructure to improve operational efficiency, reliability, reproducibility & user experience.

To LS3: Further develop Acc-geoff4ucap to cover additional use cases and incorporate new functions. Add support for BO algorithms to GeOff. Add optimiser package & event builders, new algorithms. Identify and implement/deploy specific parameter optimisation and drift compensation problems

During LS3: Evaluation and improvements, expand to AD/ELENA/ISOLDE

Read more on: https://indico.cern.ch/event/1330235/contributions/5599762/attachments/2725086/4735717/wp3_initial_planning_021023.pdf

Carlo Petrone

WP4 Hysteresis Compensation

Establish measurement method, perform data acquisition, train hysteresis prediction AI models. Come up with appropriate feed-forward implementations for faster cycling machines

To LS3: pilot on SPS main dipoles, quadrupoles, octupoles, sextupoles and bumbers

During LS3: measurement, modeliing and deployment to other machines

Roman Gorbonosov

WP5 Next Generation Sequencer

Consolidate Sequencers with single editor and execution engine and incorporate new use cases. Expand use in all machines. Sequencer is a key tool for several other work-packages

- Reduce technical debt (different editors and execution engines)
- Collect new user requirements from Automatic LHC filling, Equipment testing workpackages etc.

Read more on: https://docs.google.com/presentation/d/18UQv_NKF9140IM2-jPUtSXJ0Vk-FgZnG1NbLznpmoa0/edit#slide=id.g285d368fa9e_0_30

Michi Hostettler

WP6 Efficient Settings Management

Inputs from SMWG

Implement a number of actions for uniform machine-wide settings management

Grouped in four categories:

Model-based controls - LSA in Experimental areas, PS RF re-modelling, etc

Settings consistency - reliable settings propagation LSA-to-HW, reliable mapping & drive, other

Integration with Automation – python APIs, UCAP trims, external LSA make rules

Efficient Generation and Operation – GUIs, multi-context generation, clone with tags, etc.

Read more on: https://indico.cern.ch/event/1332225/contributions/5607898/attachments/2729037/4743636/202310_EPA_WP6_Start-1.pdf

Andrea Calia & Jean-Christophe Garnier

WP7 Automated Equipment Testing

Coordination with **RAWG**

Start next Run with a fully automated IST & HW Commissioning campaign in Injectors and the LHC

To LS3: Collect user requirements from Next Generation sequencer (EPA-5), Equipment automation (EPA-8) and the data processing framework (EPA-9). Prepare roadmap for Acc-Testing tool and develop solutions

During LS3: Staged deployment in different machines (CPS, SPS, LHC)

Start of Run 4: First automated HWC and ISTs for LHC and Injectors.

Read more on: https://indico.cern.ch/event/1334157/contributions/5615969/attachments/2731356/4748349/2023-10-10%20EPA%20WP7%20Project%20Definition.pdf

Francesco Velotti & Kostas Papastergiou

WP8 Equipment Automation

Coordination with CCTB RAWG

Introduce a framework for the implementation of expert diagnostic and prognostic functionalities for accelerator equipment, including automatic fault recovery

Define the scope and requirements with equipment groups. Define Key Performance Indicators (KPIs) to measure efficiency improvements. Produce guidelines for the standardisation of state reporting across accelerator equipment

Pilot projects to demonstrate

- Pilot 1 (small-scale/large impact): Automating expert diagnostics and speed up recovery (example kicker vacuum spike analysis)
- Pilot 2 (large-scale/cumulative impact): Benefits/economies of scale (example BLMs or converters)
- Pilot 3 (medium-scale/medium impact): Benefits of device self-configuration
- Pilot 4: Internet of Things (IoT) devices and data acquisition for prognostic purposes

Read more on: https://docs.google.com/presentation/d/130UolLf9o8UhCt4jOGE1xjmaZxSLKH2Tx90BCM7fwwc/edit#slide=id.g289e2de1abc_0_5

Marcin Sobieszek

WP9 Data Processing Framework

Coordination with **CCTB**

Development of a data processing and analysis framework for use by all partners

A unified platform for online and offline data processing with serverless architecture and proof of concept with vertical slice implementation.

Staged approach:

- Address offline processing first (during Run3)
- Address online processing use cases (end of LS3)

EPA Project Vision

A Roof for existing and new automation developments

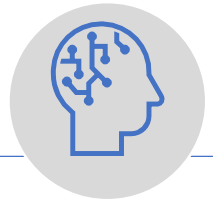
- A place for synergies and discussion
- A coordination of needs and solutions

Tools for the Operation Teams

- Less repetitive work and process automation
- More time for meaningful/intellectual work
- Efficiency culture with Key Performance Indicators, etc

Informed interventions

- Fault analysis and recovery
- generate assisted workflows/recommendations to equipment experts/piquet teams



A roadmap for future accelerator exploitation

Relevant Talks

Michael Schenk - Automating accelerators – evolution since last year

Alex Huschauer - Automated equipment monitoring: status and evolution

Georges Trad – Who wants a dedicated LHC Filling

we would like to hear from you!