



Unleashing the power of digital transformation in accelerator physics

a new collaborative approach

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Outline

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*When **FAIR** and **OPEN** become a catalyser*

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Phyiscs, science, industry and society



Introduction

What are accelerators ? Why are they important ?



What are accelerators ?

- Magnificent machines built to explore the boundaries of the human knowledge ;
 - From the Rutherford¹ experiment, the Cockroft² and the Van Der Graaf³ machines to Lawrence's Cyclotron⁴ ;
 - Accelerators have now penetrated every aspect of our lives and given us the chance to expand our knowledge.

1. Rutherford (1909)

2. Cockcroft and Walton (1932)

3. Graaff (1931)

4. Lawrence et al. (1932)



Why are they important (1/2) ?

- Their applications span accross different disciplines :
 - Particle physics
 - Nuclear physics
 - Light sources
 - Medicine
 - ...



Why are they important (2/2) ?

More than **30 000** accelerators operational world wide¹

More than **99%** used in industry and medicine :

- Industrial applications > **20 000** ;
- Medical applications > **10 000**.

Less than **1%** used in research and discovery science :

- Cyclotrons ;
- FFAG ;
- Synchrotrons ;
- Synchrotron light sources ;
- Linear and circular accelerators/colliders.



Challenges

- Accelerators pose **quasi-industrial** challenges in terms of operation and reliability ;
 - **Detecting**, preventing anomalies ;
 - **Optimising** beam time ;
- **Frugal** complex physics simulation is another important aspect for future accelerators :
 - New digital twins ;
- Several groups/labs and RI and are trying to meet these challenges.

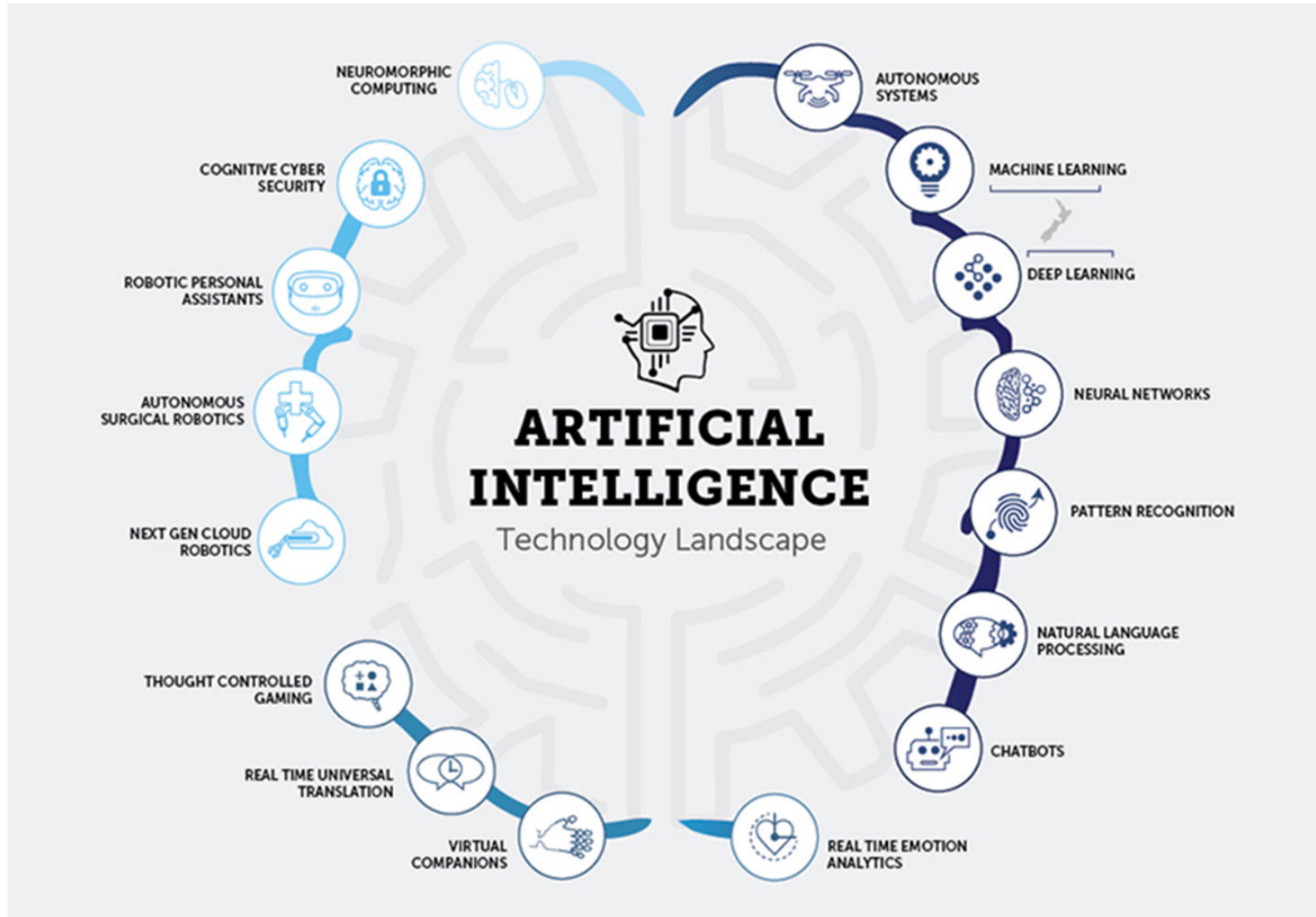


The AI Context

- Artificial Intelligence applications for physics and society is **revolutionizing** the way we do and think our roles ;
- The acclerator community is catching up fast ;
- However, **synergy** is much needed for data as well as for methods and applications.



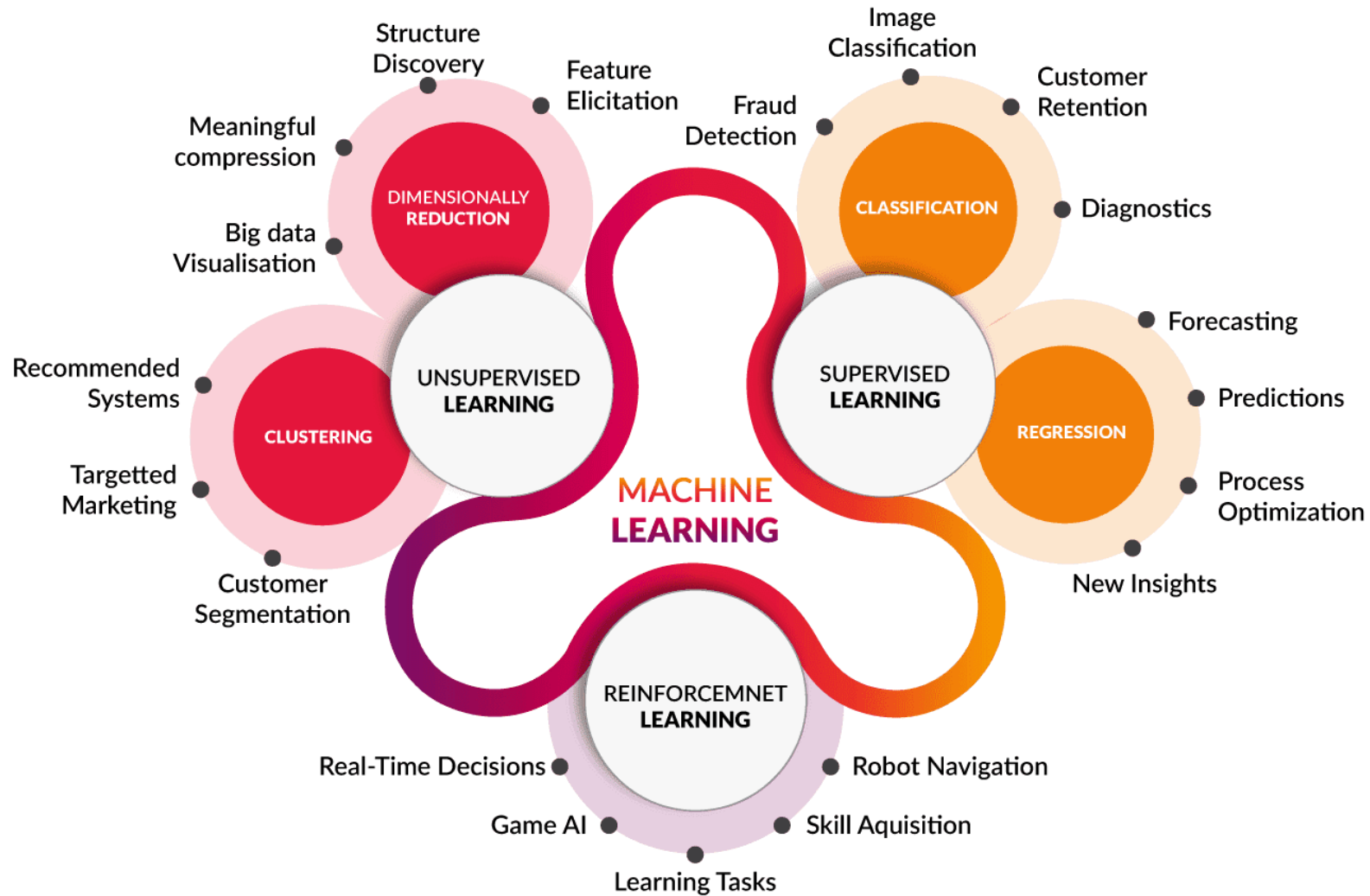
The AI big picture



#Disrupt 4.0



and the ML picture



Pugliese, Regondi, and Marini (2021)

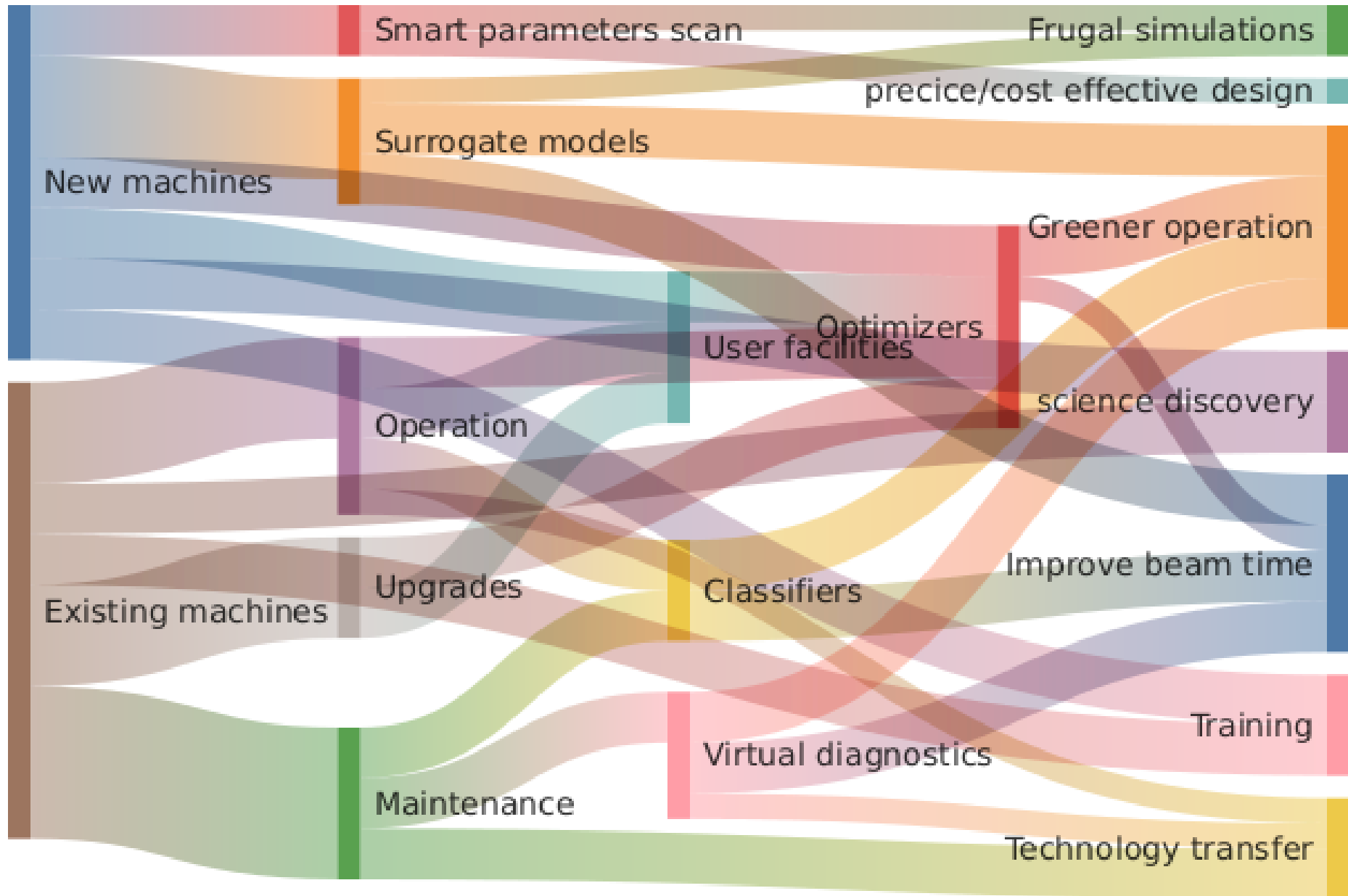


Scattered developments

Separate ways of dealing with the same picture

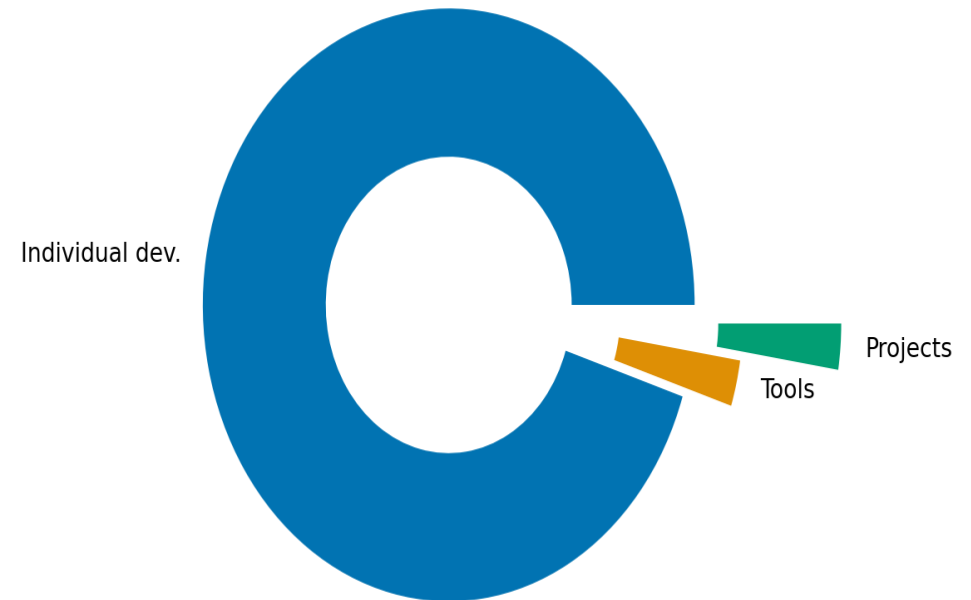


A complex picture



A mostly scattered developments landscape

- Mostly individual and scattered efforts
- Collaborations
 - Large RI infrastructures or accelerator projects
 - Specific tools for optimization and operation



Few examples

Tools




- Badger/Xopt¹
- Radasoft²
- GeOFF³

Badger


The Missing Optimizer in ACR

[Get Started](#)




Easy to Use

Badger was specifically designed for operators. You could re-run an optimization routine with just one command/click.



Fast to Extend

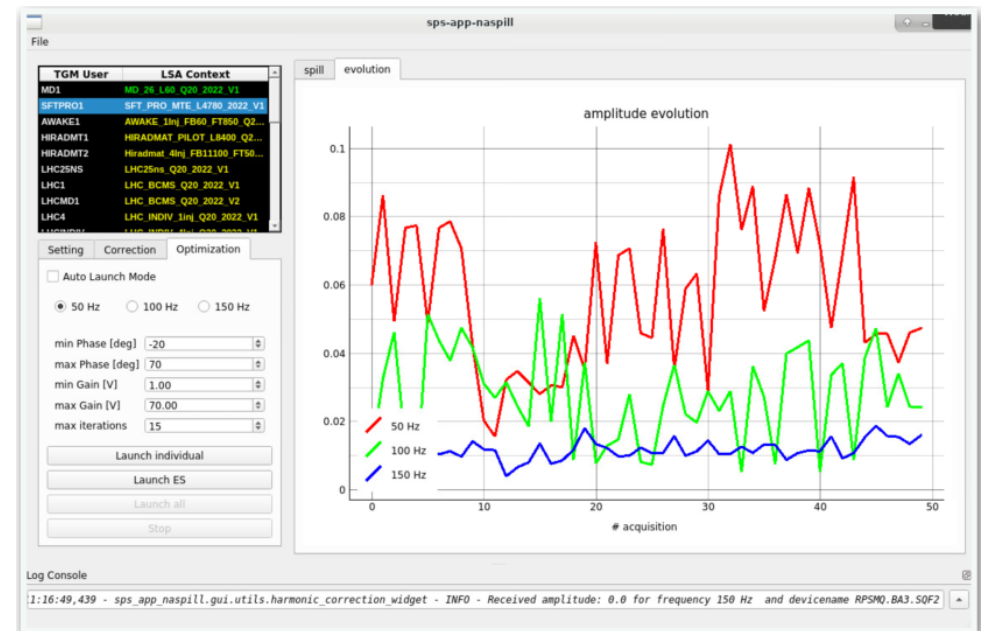
Badger can be extended through its plugin system. Shape your algorithm/problem into a plugin in 5 minutes.



Multiple Mode

Badger can be used as a library, a command line tool, or a GUI application. Use Badger the way you want.

<https://slac-ml.github.io/Badger>



Few examples

Projects

- Real-Time Edge AI for Distributed Systems (**READS**)¹
- Artificial Intelligence for the Electron Ion Collider (**AI4EIC**)²
- EUROpean Laboratories for Accelerator Based Science (**EURO-LABS**)³
- CERN accelerator Machine Learning platform⁴

1. Hazelwood et al. (2021)

2. Allaire et al. (2023)

3. <https://web.infn.it/EURO-LABS/>

4. Martel, Gorbonosov, and Madysa (2022)



But there are limitations ...

There are many limitations to scattered developments :

- Numerous tools doing almost the same thing :
 - Risk of non sustainable development ;
- Large projects focused developments :
 - Limited impact on smaller RI ;
- Lots of redudancies :
 - Ressources intensive calculation, storage, machine studies ;



A new synergetic approach

When **FAIR** and **OPEN** become a catalyser



General Purpose

- We want to unlock the use of **artificial intelligence** in particle and nuclear accelerators as well as in light/neutron sources ;
- We want to tackle **all challenges** of particle accelerators.



The network

Two key workshops that led to the creation of two networks :

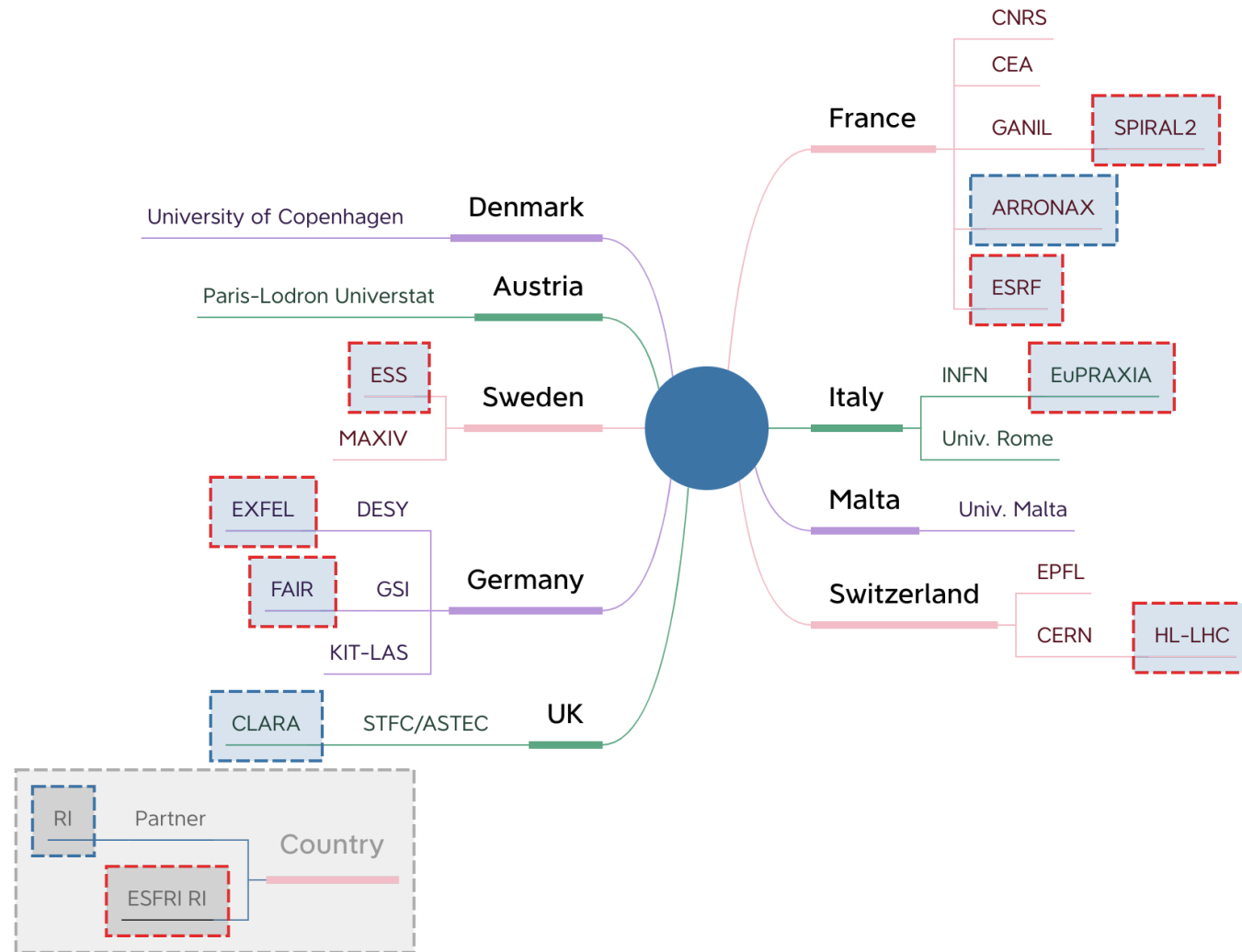
1. A French network - **M4CAST**¹
2. A European Network - **TRAINABLE**²

and target Horizon Europe project - **ARTIFACT**³

1. Multiphysics Modelling, Machine learning and Model-based Control in Accelerator Sciences and Technologies
2. TowARds An INternational network for multiphysics modelling, machine learning And model-Based control in accelerator sciences and technoLogiEs
3rd African Conference on Fundamental and Applied Physics | 25-29 Sep. 2023
3. ARTifical Intelligence For Accelerators. user Communities and associated Technologies



The network



9 countries, 18 partners and even more direct and indirect beneficiaries.

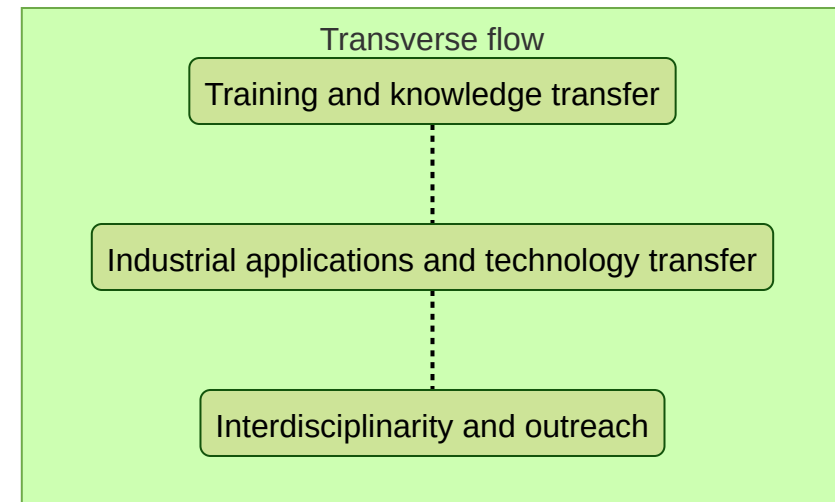
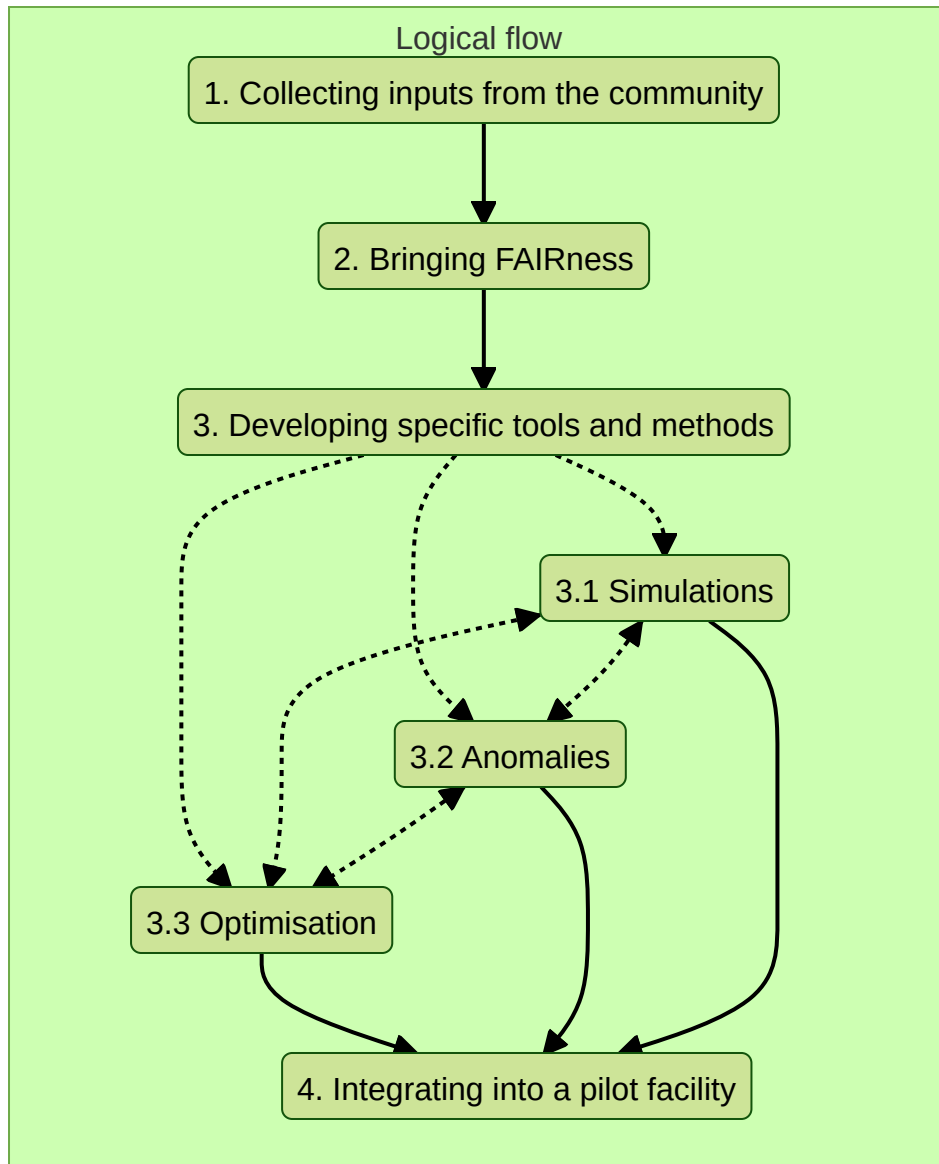


What came out of it ...

1. We need **guidelines** to unlock the use of AI in accelerators ;
2. We need to **standardize and open** our data and approaches ;
3. We need to **structure** ourselves to work in a fertile collaborative space ;
4. We need to keep an **open mind** (astrop, HEP, medicine, ...) ;
5. We need to **train people** : students as well as professionals ;
6. We need a common goal : **one to rule them all !**



In other words



And in numbers

- 4 years
- 10 M€
- 86e+11 neurons¹
 - To kick-off a European roadmap on the matter ;



Crossing boundaries

Physics, science, industry and society



The obvious boundaries

- We are taking a way **others** have taken before us ;
- But we learned along the way that our way is somehow **different** ... yet **complimentary** ;
- We see that some of our weaknesses in research can be compensated by strong **industrial partnership** ;

\rightarrow **Boundaries are meant to be crossed.**



The hidden boundaries

Cultures, countries, languages, religions, genders are also boundaries that are not meant to limit us, but to enrich us so that we can go further.

\(\rightarrow\) The **TRAINABLE** network should work hand in hand with its **US**, **African** and **Asian** counterparts ;

- If not, help pave the road for their creation through common scientific programs.



Conclusion

- Exciting times ahead for the field ;
- But we need everyone to make progress ;
- And hope that **AFRICA** will play a significant role in the challenges ahead.



Thank



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