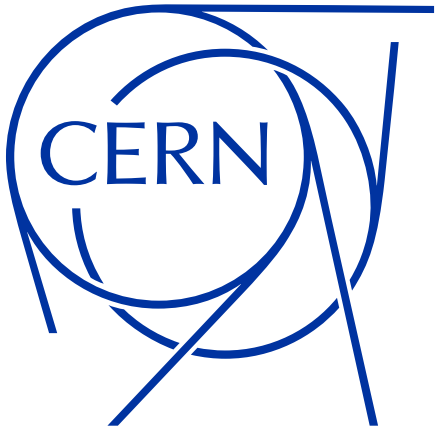


Automation during the equipment design process

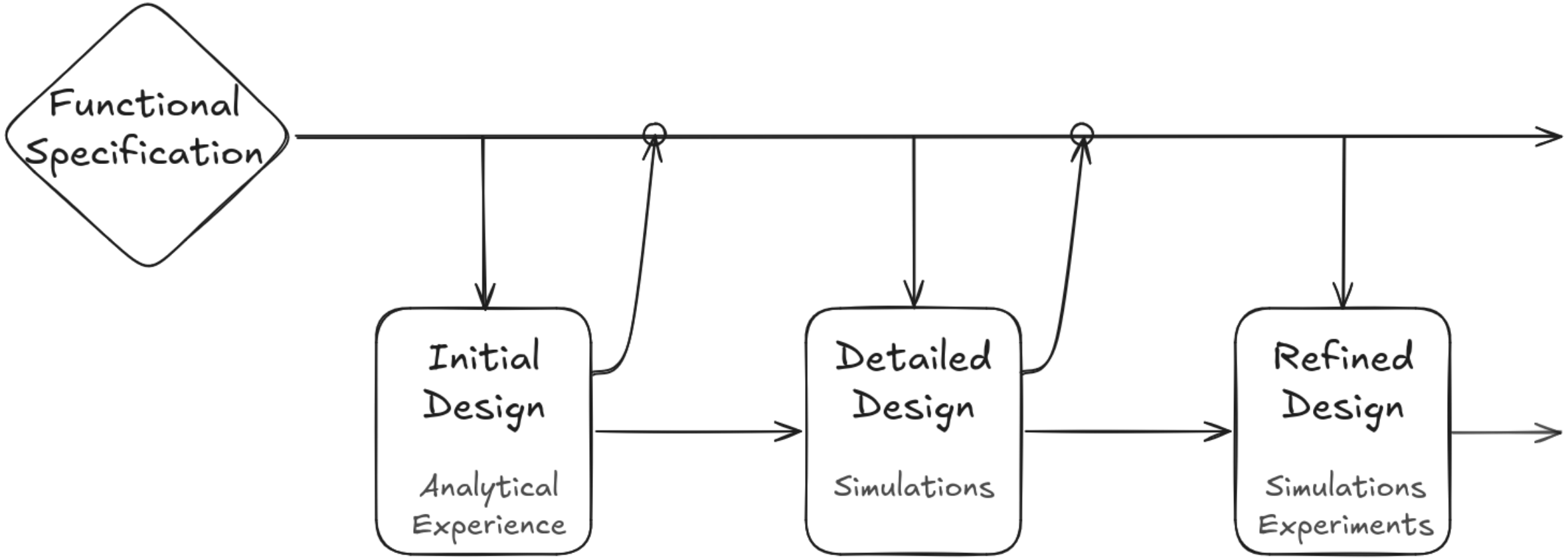
F. Huhn, F. M. Velotti

Joint Accelerator Performance Workshop 2024

2024/12/12

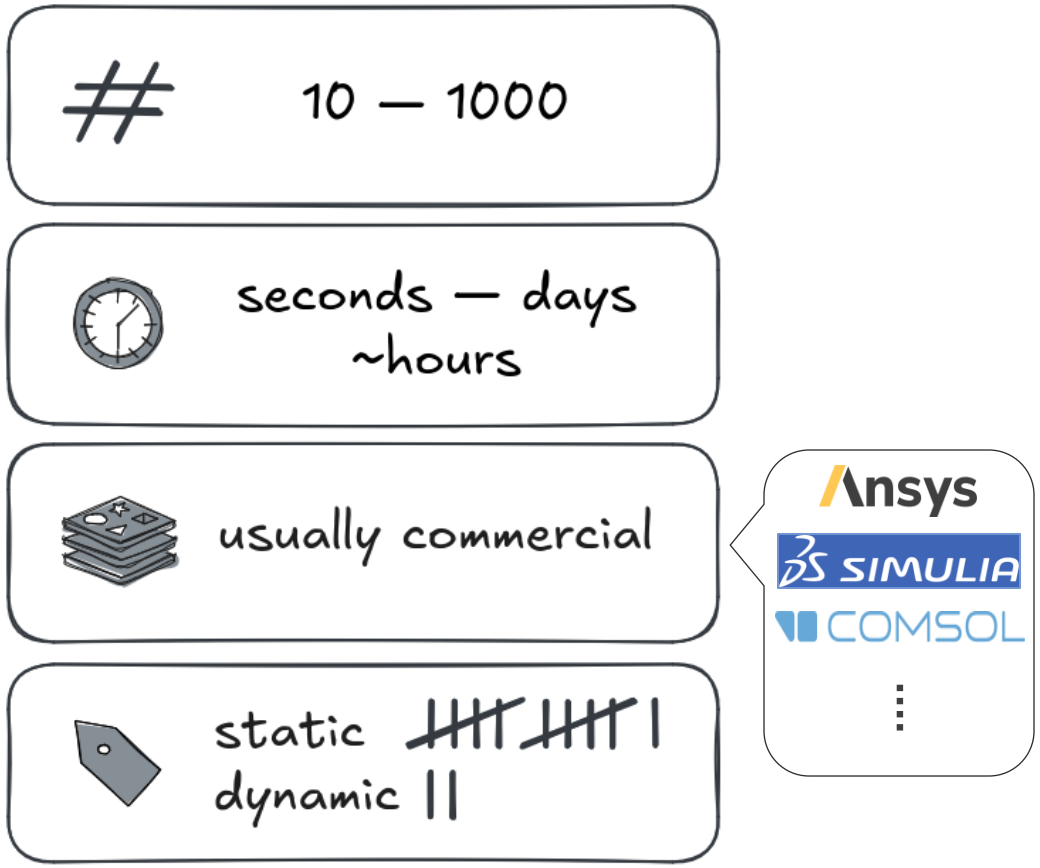
Montreux

General overview of design process

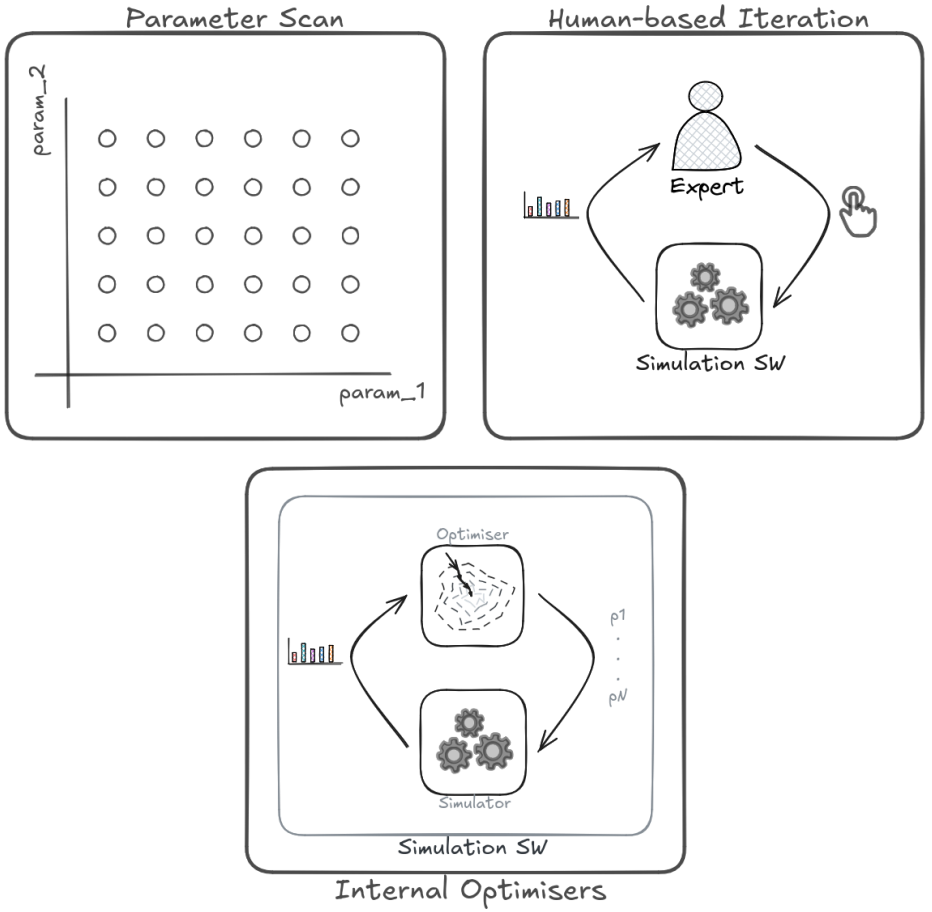


Simulations and design process

Simulations



Design Process



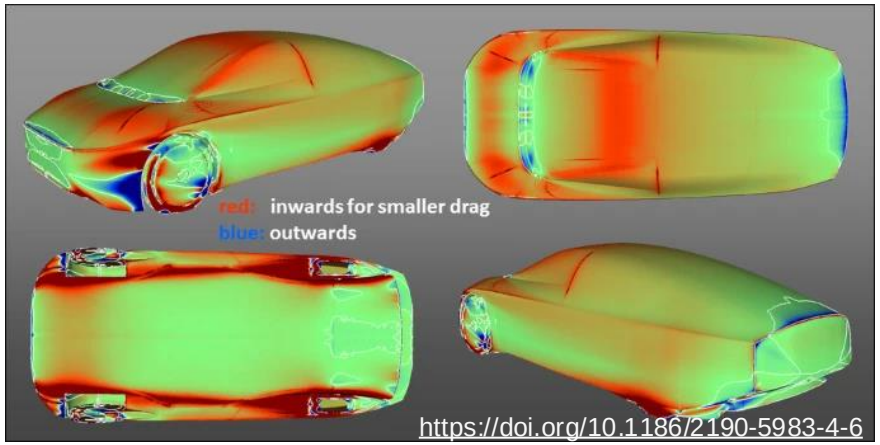
Optimisation, an alternative

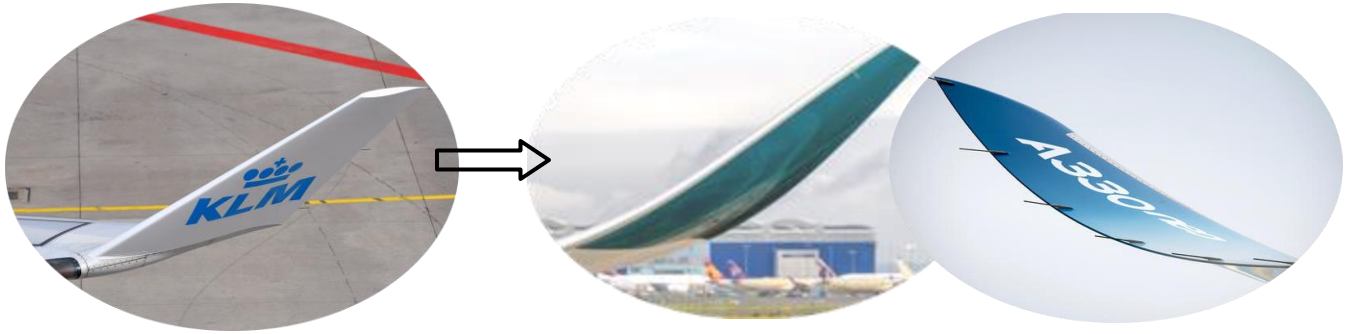
Gradient-free (∇_p ❌)

- Sometimes provided by simulation software suite
- Low development cost: write interfacing with simulation software
- Useful when #parameters is low

Gradient-based (∇_p needed)

- Scales well (gradient cost ≠ *f*(#parameters))
- Design robustness (higher-order derivatives)
- Mesh refinement (tangent gradient)
- Seldom provided by simulation software
- High development cost (impl. differentiable sim.)

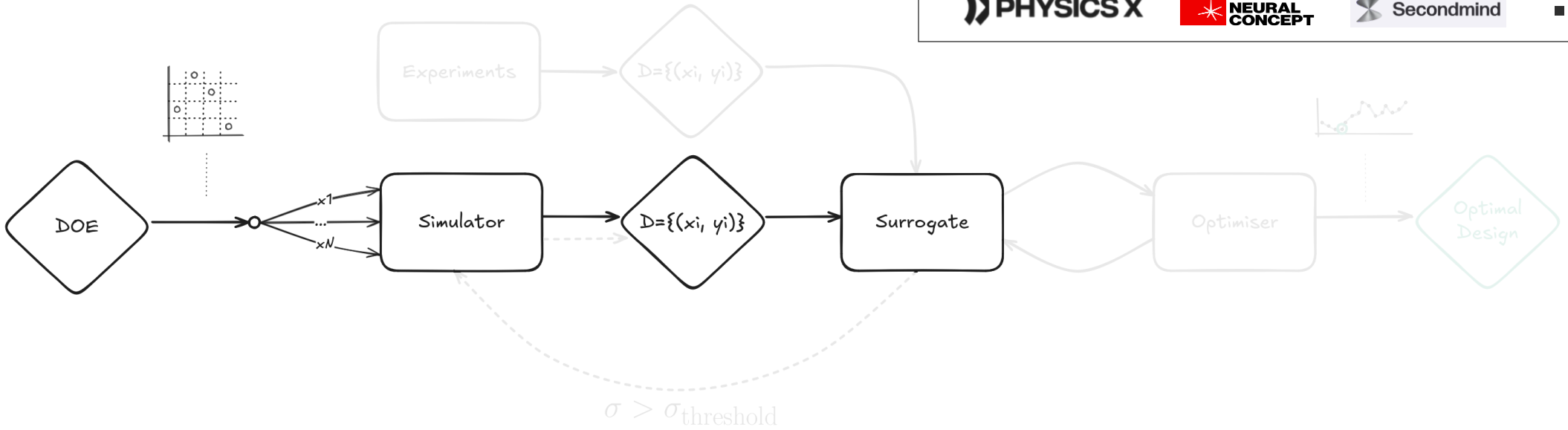




Surrogate-based design

Check out F. M. Velotti's talk on surrogates!
https://indico.cern.ch/event/1439972/contributions/6159176

PHYSICS X | NEURAL CONCEPT | Secondmind | ■ ■ ■



robust exploration

low computational cost
fast iterations
large exploration

multi-fidelity integration

low-fidelity simulations
high-fidelity simulations
experimental data

prediction

objective (target)
constraints
spatiotemporal quantities

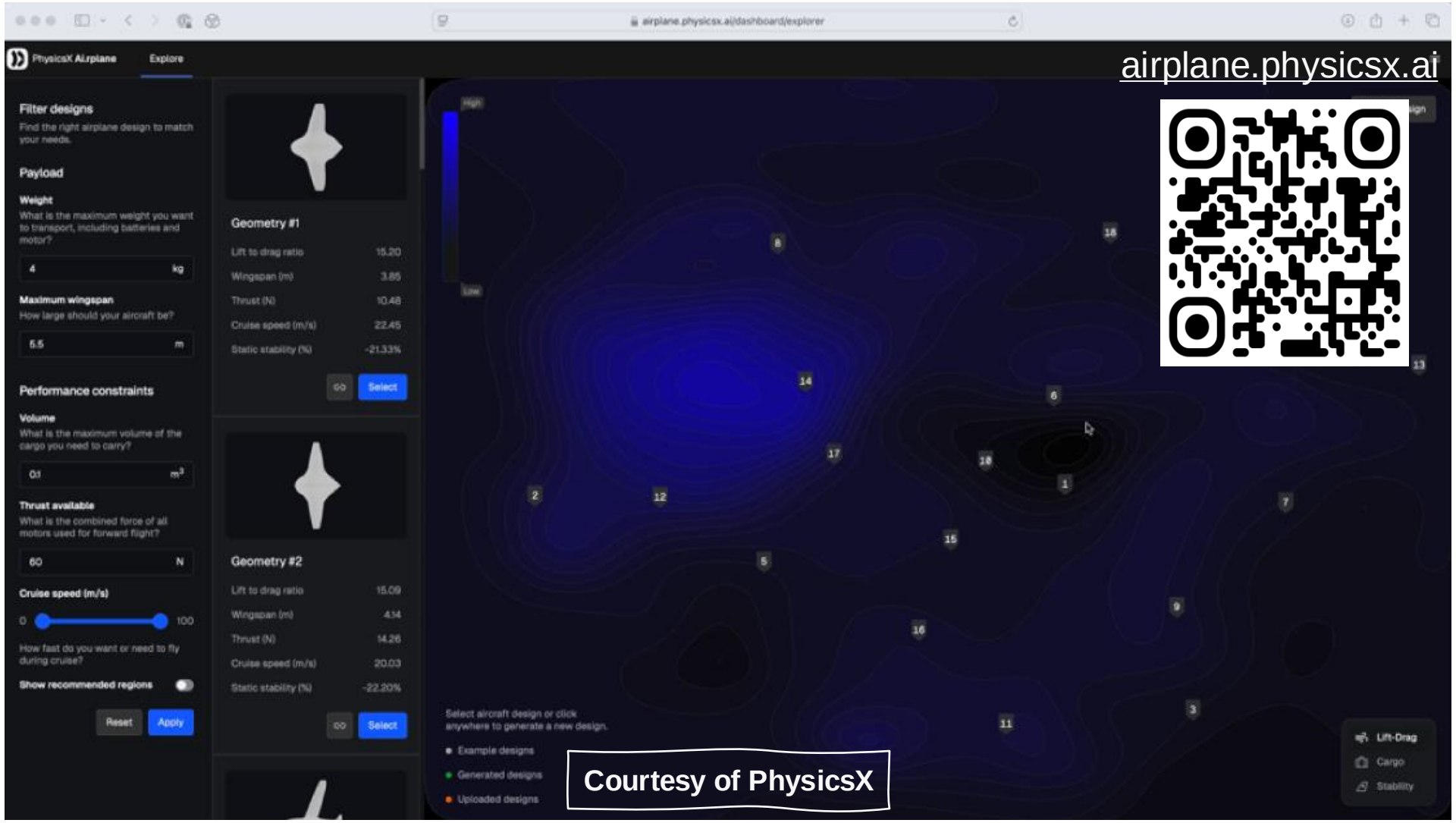
Surrogate-based design: example

Surrogate-based design: example

Surrogate-based design: generative design

Surrogate-based design: example

Surrogate-based design: Ai.rplane

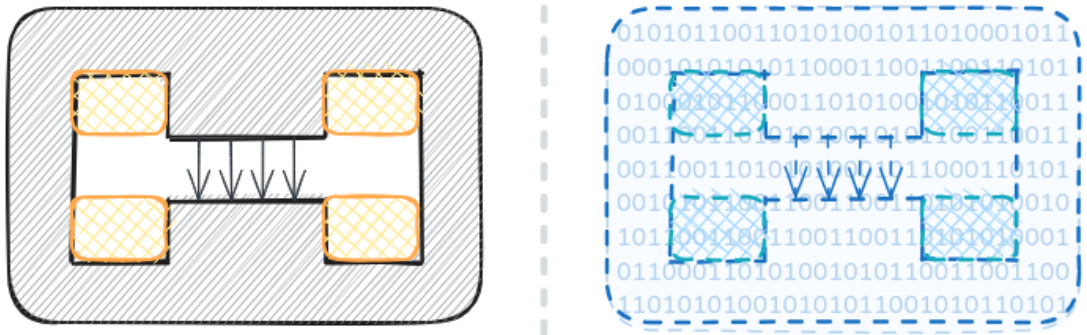


Digital twins

Check out Workshop for Digital Twins @ CERN!
https://indico.cern.ch/event/1304817/

real-world physical system

digital model of physical system



Only as useful as far as it can be executed.

⇩

Surrogate models are prime candidates!

- Virtual Sensors
- Forecasting
- Optimisation & Control
- Quality Control
- ⋮

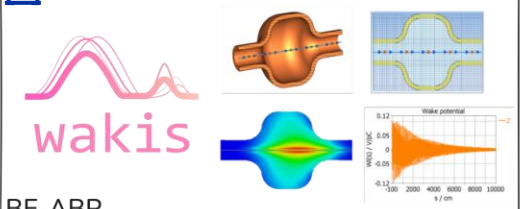
What’s needed

Challenges	Potential Solutions
People set in traditional ways	Pilot projects and dedicated resources
Little know-how of new techniques	Collaboration with expert partners
Rigid simulation software (config-, interface-, script-abillity, …)	Explore SW capabilities; develop alternatives; harmonise processes

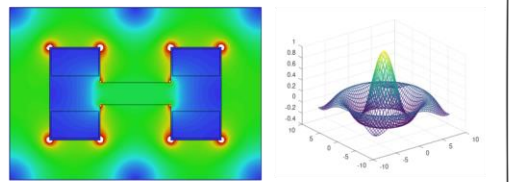
What's happening

Tools

[1]

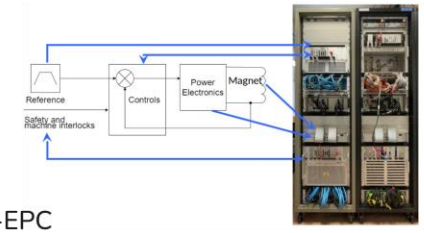


BE-ABP



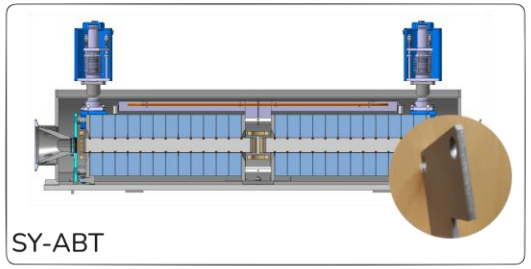
TE-MSC

[2]

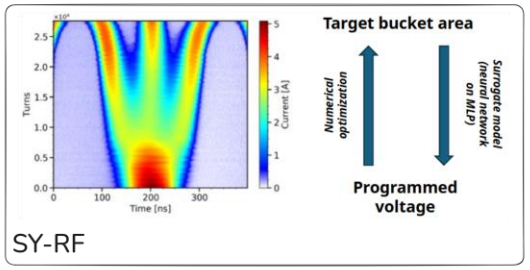


SY-EPC

Digital Twins

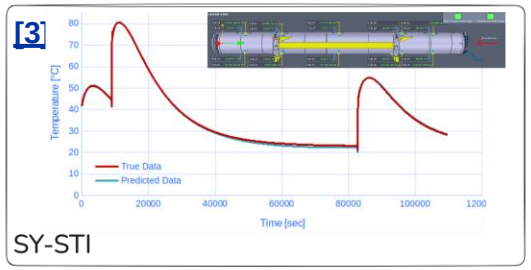


SY-ABT



SY-RF

[3]

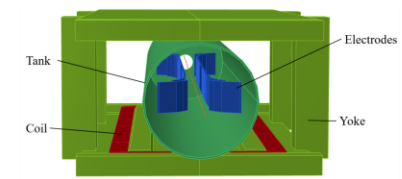


SY-STI

⋮

Automated Design

[4]



SY-ABT PHYSICS X

Hopefully more!

Conclusion and Acknowledgments

Conclusion

- There is momentum in automation, digital twins, tool development, but still limited (especially in automated design)
- Industry is moving towards this approach – various startups in the field, partnerships with large tech & engineering companies
- We should explore and exploit surrogate models and automated design to improve efficiency and performance

Acknowledgments

Francesco M. Velotti

A. Huschauer

Jérémie Bauche

Giorgia Favia

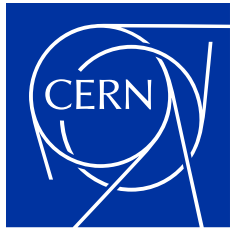
Raul Murillo Garcia

Alexandre Lasheen

Rui Ximenes

Carlo Zannini

PhysicsX


CERN