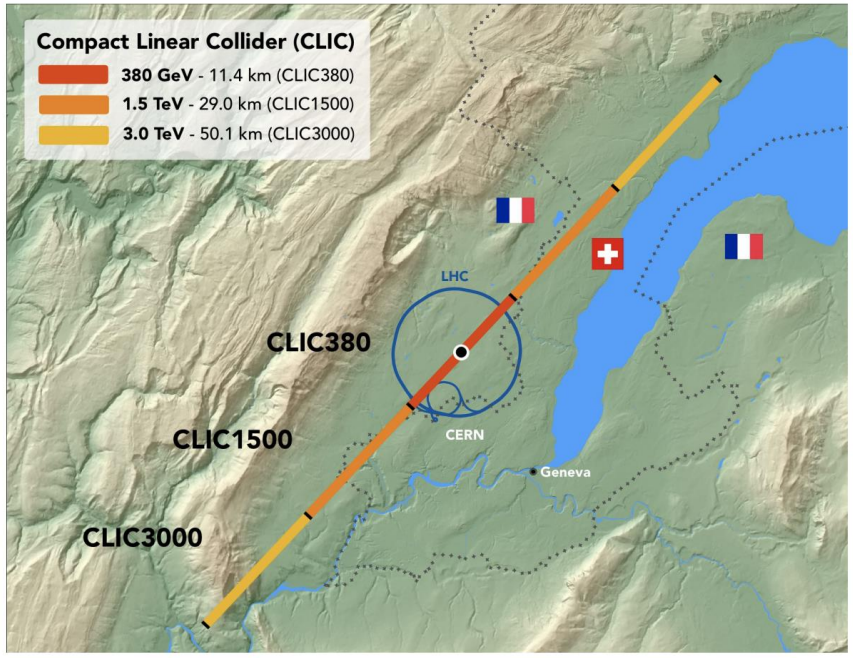
ML Applications in Compact Electron Linacs

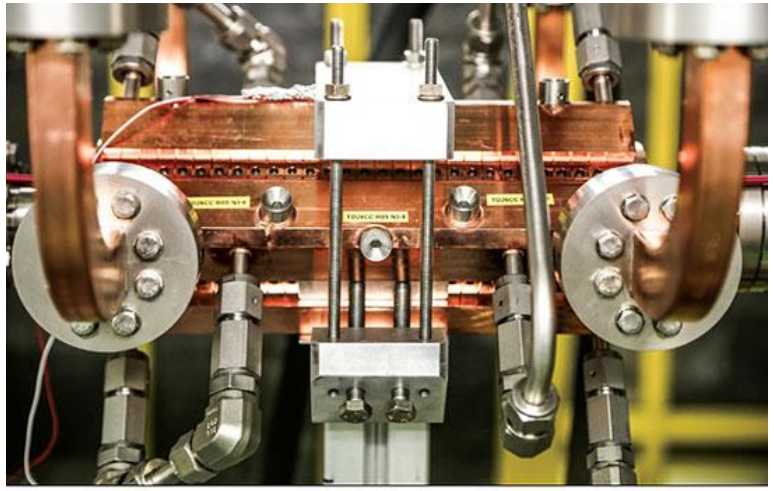
Laurence Wroe (CERN, ATS-DO)
laurence.wroe@cern.ch

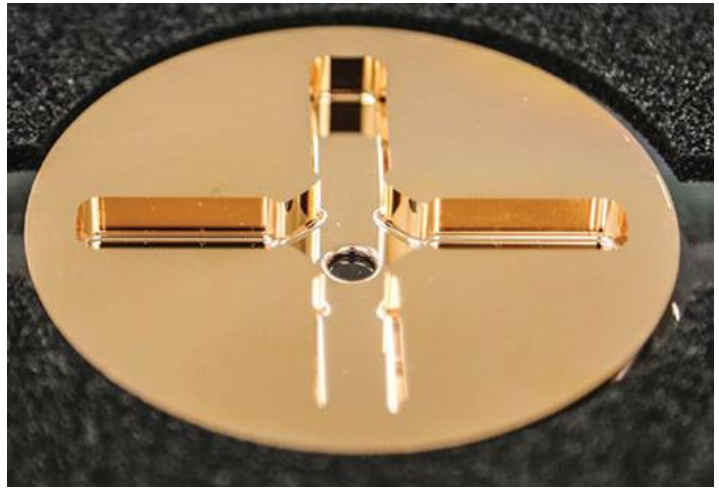
Lightning Talk
tCSC Machine Learning 2025, Malmö, Thursday 12th June

Compact electron linear accelerators

- Particle accelerators have many applications outside of colliders
  - > 50,000 accelerators worldwide for medical, industrial, research
- CERN high-level motivation: industrialise high-gradient accelerating structures – this will benefit CLIC







ML / AI and Compact Electron Accelerators

What can AI do for accelerators? The vision..

Autonomous accelerators

Key words: optimal control and optimisation, anomaly detection and prescriptive maintenance, surrogate modelling, differentiable simulations, virtual diagnostics,…

Optimised accelerator design

Key words: fast-executing simulations for optimisation algorithms, differentiable simulations,…

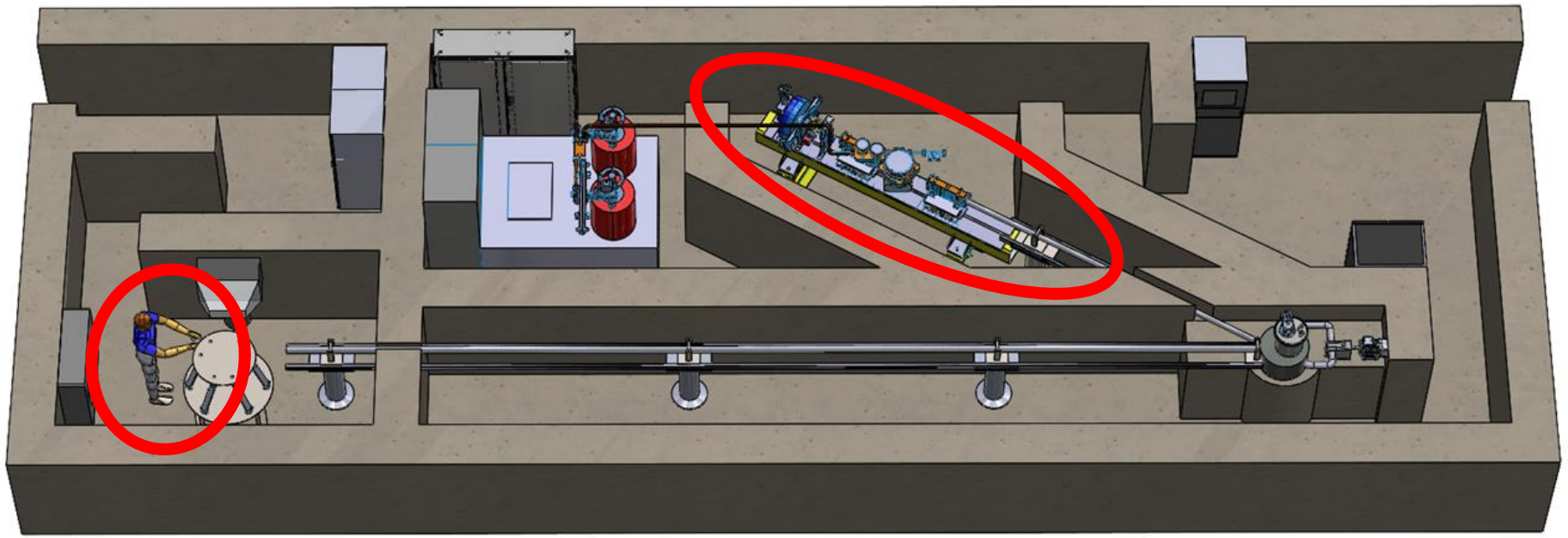
Generic AI for efficient research and development

Key words: AI assistants for code development, knowledge retrievable,…

tCSC on ML 2025, Malmö, V. Kain, 8-14 June 2025

VULCAN

- Compact Accelerator-based Neutron Sources (CANS) are an alternative method for generating neutrons compared to nuclear reactors and spallation sources
- VULCAN: optimised for producing neutrons (via e^-) for stress analysis



VULCAN – ML / AI Benefits?

Optimised accelerator design:

- Client provide beam specification
- Design accelerator to meet specification and maximise figures of merits
  - Cost, beam power, compactness, R&D vs ready-made components

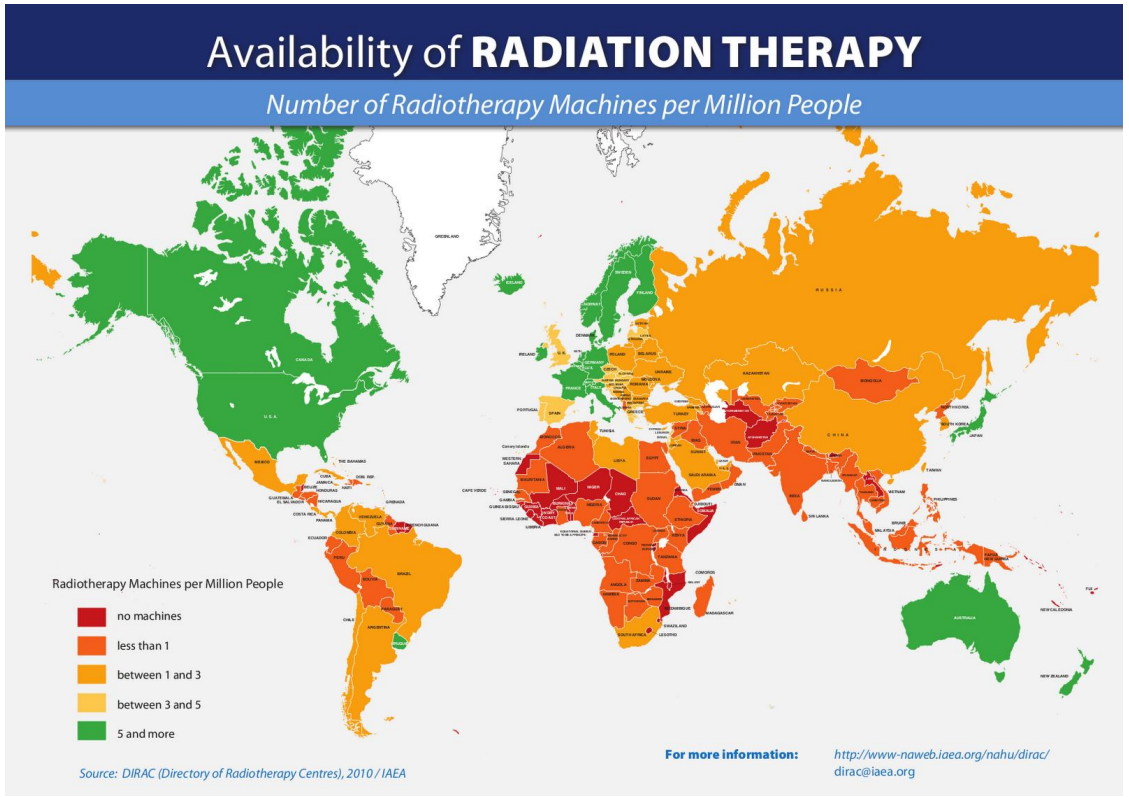
Autonomous accelerators:

- Maximise uptime
- Minimise operational costs

	Parameter	Value	Unit
Requirements	Accelerator Length	< 10	m
	Average Beam Power	> 1	kW
	Accelerator Cost	< 5	M$
Beam Specification	Energy	35	MeV
	Energy Spread	< 5	MeV
	Transverse Size	< 5	mm
	Transverse Jitter	< 2	mm
	Train Length	< 1	µs
	Train Frequency	~ 100	Hz

STELLA

- Cancer can be treated with photon radiotherapy
- STELLA: optimised photon radiotherapy machine (using e^-) for deployment in LMICs



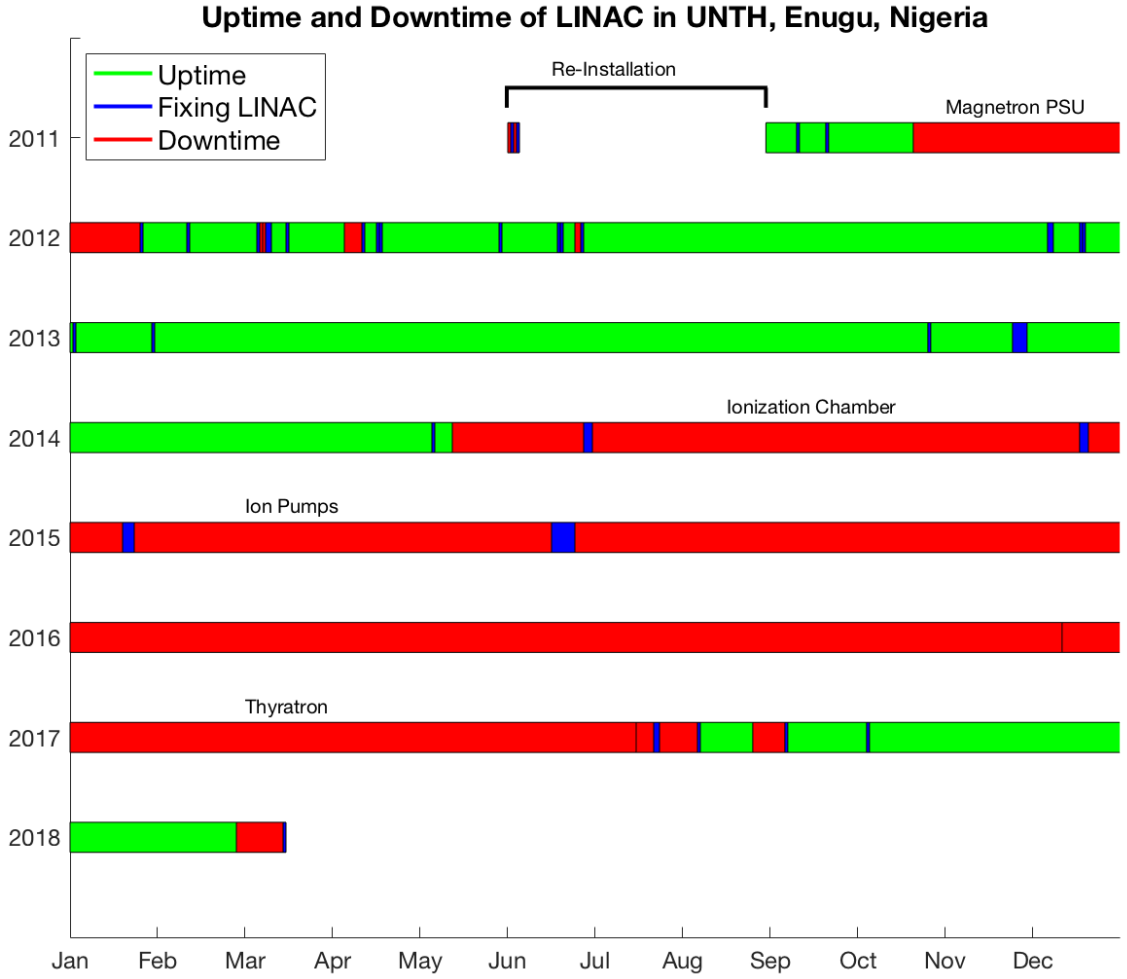
STELLA – ML / AI Benefits

Autonomous accelerators:

- Maximise uptime
  - Predictive maintenance
  - Prescriptive maintenance
  - Virtual diagnostics
  - Digital twin
- Maximise lifetime
  - Wear-state adaption

Many other AI benefits in the imaging, treatment planning aspects

STELLA – Maximise uptime



Food Security

- 30 % of harvested food is lost to waste
- Irradiate food to extend shelf life

- New project coalescing to design an optimised accelerator for this application space

- AI : maximise the performance, cost, complexity trade-offs

Finishing points

- V happy to discuss these projects further! Come and talk to me

- My background is accelerator physics
- But ML is clearly essential for optimising cost / performance / complexity (+ more) of these machines
- V happy to discuss how to utilise ML - advice / collaboration is v welcome!