This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

1. A new role of industry in the accelerator innovation ecosystem

M. Vretenar, CERN, I.FAST Coordinator

IPAC'22, 15 June 2022

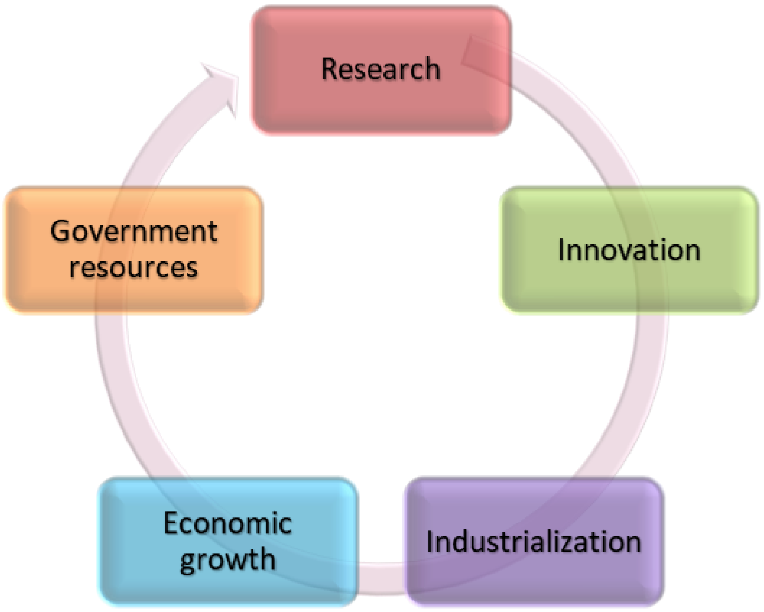
Times have changed

We observe that around accelerators has grown a network of companies, most of them SME's, often run by scientists or by people with a scientific background, that are creative, flexible, innovative, continuously looking for new markets and new applications.

Accelerator laboratories must help these companies to grow and to compete in the global market, to:

a) sustain the virtuous circle of scientific innovation, and

b) b) demonstrate the social and economical impact of accelerator-based research.



The virtuous circle of scientific innovation

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A EC-supported tool: the I.FAST project

Innovation Fostering in Accelerator Science and Technology

Innovation Pilot, A new pilot instrument to demonstrating the role of Research Infrastructures in the translation of Open Science into Open Innovation.

An evolution of our R&D programmes towards more industry participation that is supported by the European Commission.

- Wider goal: **48 beneficiaries of EC funding** – 8 large RI operators, 12 national research centres, 12 universities, 16 industrial partners (**1/3**, including 11 SMEs) - from 15 European Countries, supported by 12 partner organisations and >20 collaborating institutions, jointly developing technologies for the next generation of particle accelerators.
- Timeline: **4 years**, starting 1 May 2021.
- Resources: **10 M€** EC contribution, out of a total project cost of about **19 M€.**

With 16 industrial partners, industry makes up 1/3 of the consortium. Other 12 companies participate in the Industry Advisory Board.

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From suppliers to co-innovators

I.FAST is fostering a new role of industry in Big Science.

Most of the activities within the project (Tasks) have one or more industrial partners that are fully “**co-innovators**”, participating from the early stage in the R&D, giving their contribution to the development of prototypes at different Technology Readiness Level.

Early participation of industry guarantees a faster feedback on the technological requirements, and an easier adoption of industrial standards and technologies, resulting in simpler and less expensive final products – and a consistent sharing of ideas!

Challenges:

- administration (on both sides!),
- corporate culture in large companies,
- Sharing of responsibilities and risks,
- IP management,
- Keeping competition for series production.

From Open Science to Open Innovation

Particle accelerator community entering the age of open innovation:
Sharing of ideas between scientific institutions and companies, to improve high technology products and to identify new products and markets.

Creation of an innovation ecosystem *(Keywords: community, trust, openness, creativity, connection to industry)*

The long-term goal is to create a common language and a common working ground between academia and industry, and to favour exchanges – in both directions!

A career in industry, in particular in small dynamic SME's, should no longer be a second choice for physicists!

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New challenges ahead

We have to work together to expand the particle accelerator market. I see three main directions:

1. Production by industry of increasingly standardized **components for accelerators**, possibly develop in co-innovation with academia.
2. Access with components made for accelerators to **other industrial or "Big Science" markets**.
3. Production by industry of complete accelerator set-ups for **applications in industry, medicine, environment, etc.**

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2. The quest for the miniature accelerator: wishful thinking, or a key to expanding the particle accelerator market?

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The potential

- Particle accelerators have a wide potential to expand beyond their present boundaries: they are our **unique tool to access the atomic and subatomic world**.
- Our technological processes are slowly moving from the **chemical and molecular dimension** to the **atomic and subatomic dimension.** Accelerators provide a (controlled) way to access to and interact with this dimension.
- Already now, out of the more than 30'000 accelerators in the world only 1% operate for fundamental research - 95% are used as everyday instruments for **medicine and industry**.

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The challenge if the miniature accelerator: just a dream?

- The LHC in a shoebox…
- Every technological progress starts from a dream, and accelerator builders are good at dreaming… but is the dream coming true? And if yes, when and how?

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Scientific discoveries from around the world

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Technology

CERN inside a Shoebox? Small Particle Accelerators Are Coming

January 19, 2022 / Science Journalist / 8 min read

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CERN. The most notable discovery so far has been the fundamental particle, the Higgs boson. What lies ahead?

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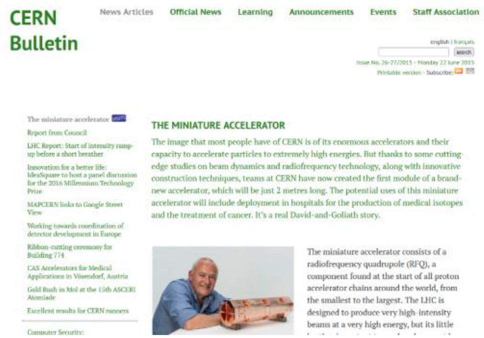
Project eyes particle accelerator in a shoe box with Gordon Moore grant

Effort could revolutionize scientific and medical research

By Martyn Williams



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THE MINIATURE ACCELERATOR

The image that most people have of CERN is of its enormous accelerators and their capacity to accelerate particles to extremely high energies. But thanks to some cutting-edge studies on beam dynamics and radiofrequency technology, along with innovative construction techniques, teams at CERN have now created the first module of a brand-new accelerator, which will be just 2 metres long. The potential uses of this miniature accelerator will include deployment in hospitals for the production of medical isotopes and the treatment of cancer. It's a real David-and-Goliath story.

The miniature accelerator consists of a radiofrequency quadrupole (RFQ), a component found at the start of all proton accelerator chains around the world, from the smallest to the largest. The LHC is designed to produce very high-intensity beams at a very high energy, but its little

sciencealert

Trending

(Shanghai Institute of Optics and Fine Mechanics)

PHYSICS

This Miniature Particle Accelerator Powers a Tiny Laser With Huge Promise

DAVID NIELD 30 JULY 2021

Particle accelerators are hugely important in the study of the matter of the Universe, but the ones we think of tend to be gigantic instruments – surrounding cities in some cases. Now scientists have made a much smaller version to power an advanced laser, a setup that could be just as useful as its larger counterparts.

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What is the offer: “miniature” technologies today

Category	Particle	Configuration	Energy/Footprint (achieved, acc. only)	Ancillaries	Main limitations
Incremental technologies (RF)	protons	mini-RFQ	~ 2 MeV/m^2	RF system	RF power density, beam acceptance
	protons	mini-cyclotron	~ 5 MeV/m^2	RF, power supply	Shielding, magnet weight
	electrons	X-band RF	~ 20 MeV/m^2	RF system	Breakdown rate
Disruptive technologies (laser)	p, ions	laser accelerator	~ 10 MeV/m^2	Laser	Energy dispersion, beam emittance, efficiency
	electrons	dielectric laser (DLA)	~ GeV/m^2	Laser	Beam optics, thermal loading, radiation damage, efficiency

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Today's opportunities

		Minimum energy	Market	Challenges	Opportunities
Medicine	Radioisotope production	7 MeV (PET)	Mature (several competing vendors)	Reduce cost/dose, production in hospitals	New isotopes under study or clinical trials
	Cancer treatment	250 MeV (p), 100 MeV (e) 430 MeV/u (carbon)	Expanding (6 vendors for protons)	Reduce cost, size. Integrate diagnostics.	FLASH treatment for electrons and protons
Industry	Ion Beam Analysis	2 MeV (protons)	Limited by cost	Reduce cost, size	Artwork analysis, film analysis in industry, etc.
	Neutron radiography	4 MeV (deuterons, protons)	Presently small	Activation, portability	Industrial imaging
	X-ray analysis	> 4 MeV electrons	Mature, expanding	Portability	Security
	Beam treatment	< 1 MeV electrons	Slowly expanding	Beam power, public perception	Environment (sludge, microplastics, flue gas)

plus many more ideas on alternative and original usages of particle beams…

- while many companies sell accelerator components, **only few company in the market sell a «beam»**, i.e. are fully responsible for the beam quality.
- Small ("miniature") accelerators can be excellent entry points for new companies entering the field.

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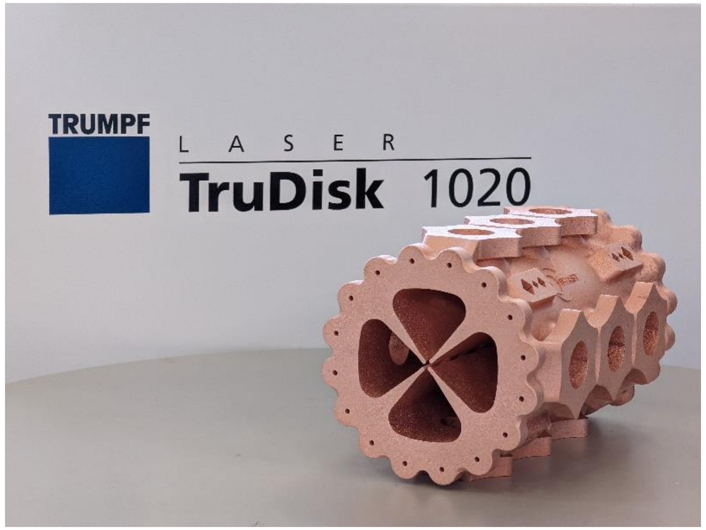
Opportunities…

- Laser-based acceleration can be the next enabling technology for the miniature accelerator, but usable beam power and stability are still a long way to go for medical or industrial applications. Developments target the medical field – but this is where requirements in terms of stability and reproducibility are the most stringent.
- Conventional RF acceleration (linacs and cyclotrons) has still some margin for improvements towards "miniaturisation": higher RF frequencies, solid-state RF (possibly integrated with the accelerating structure), small PMQ's, some superconductivity, compact ion sources, …
- Additive Manufacturing can be an enabling technology for reducing the size of accelerators: perfectly suited for small dimensions, high precision, small series – and copper is now becoming a standard material for AM.



The additive manufactured 750 MHz RFQ prototype recently completed by the I.FAST project team in collaboration with industry, 25 cm length.

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Some conclusions - Innovation in particle accelerator technologies

Making accelerator-based research sustainable over the long-term, increasing at the same time the benefits of particle accelerators for society are the main challenges to the accelerator community in this XXIst century.

To address these critical issues we need **innovation** developed in a collaborative environment where **industry** is one of the key actors.

Our network of innovative SME's is a crucial **asset** of the particle accelerator community, and I see two directions for expansion:

- More **co-innovation programmes** between industry and academia, with rules defined by our funding agencies or by specific agreements;
- An expansion of the market to make **new applications of accelerators** accessible with compact ("miniature")accelerators made by industry, either by "integrating" companies responsible for beam performance or by consortia of SME's.

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Thank you for your attention!

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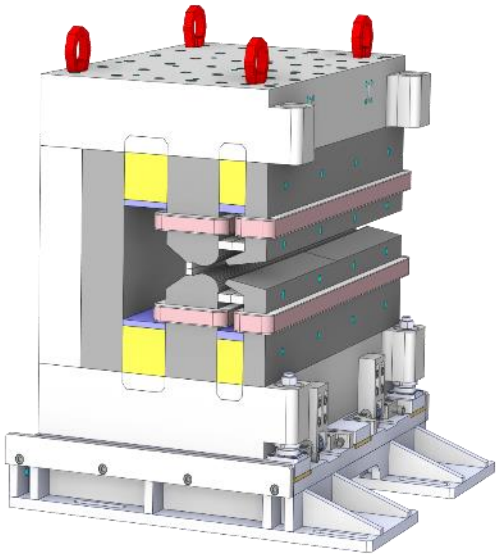
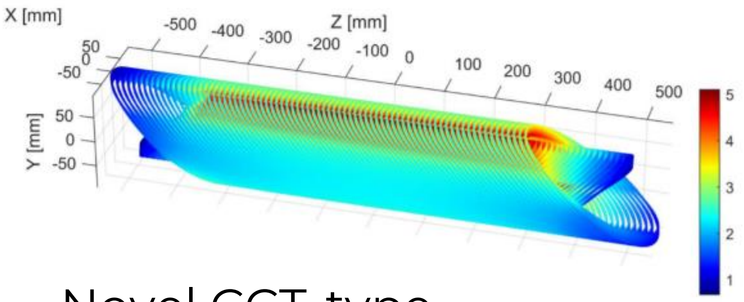
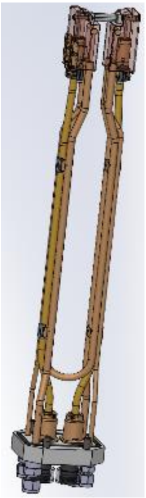
Some examples of I.FAST technologies



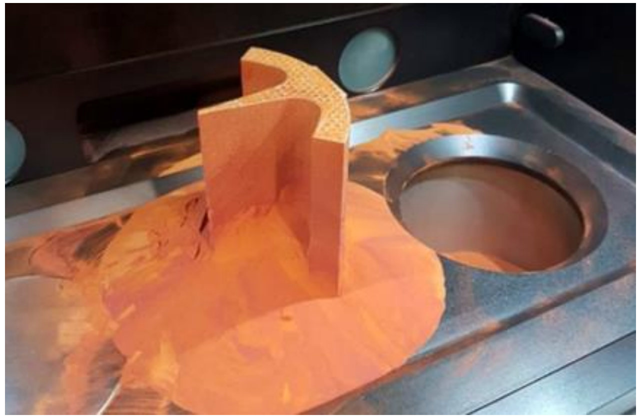
Permanent Magnet Quadrupoles and Combined Function Magnets for Ultra-Low Emittance Storage Rings



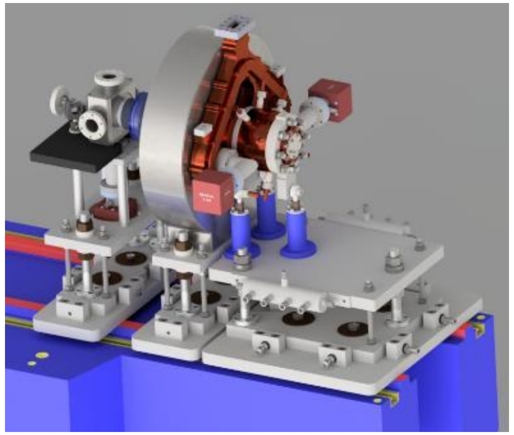
Novel CCT-type superconducting magnets for small synchrotrons and medical applications



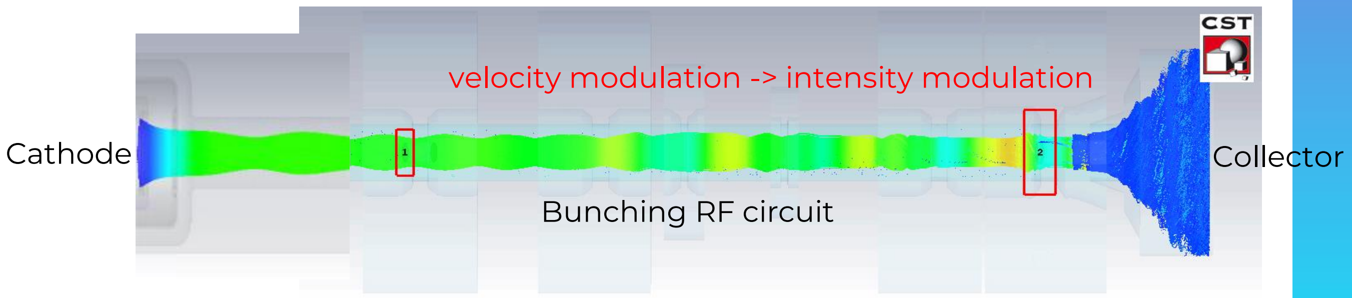
Internal source for small cyclotrons



Additive-manufactured samples of critical accelerator components



Very high gradient electron guns operating at high frequency



High efficiency klystron prototype

Two initiatives to promote innovation

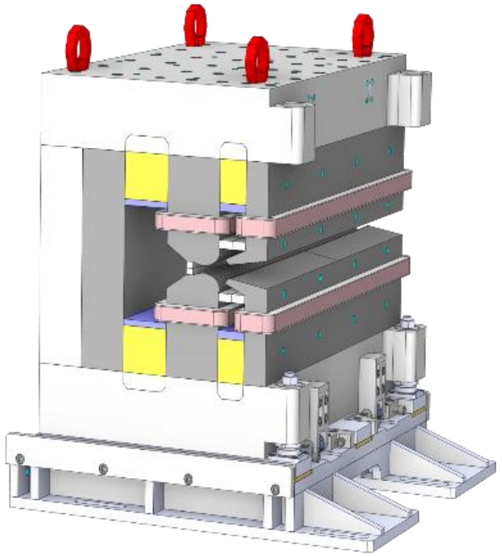
Challenge Based Innovation on Accelerators for the environment for teams of master-level students from different disciplines (physics, engineering, environment, law, and economics). At the ESI campus at Archamps near Geneva between 26 July and 4 August 2022.

4 teams of 6 students from all Europe selected among 187 applicants, will compete for a prize to the best innovative idea.

The call for the **I.FAST Innovation Fund** is now out. A fast-track, competitive process will finance emerging technologies, processes, research, business models and other innovative solutions, at both development and prototype stages. The fund will finance projects, involving industry, each receiving a contribution between 100 and 200 k€.

Information: https://ifast-project.eu/iif

Particle accelerator R&D: challenges and opportunities

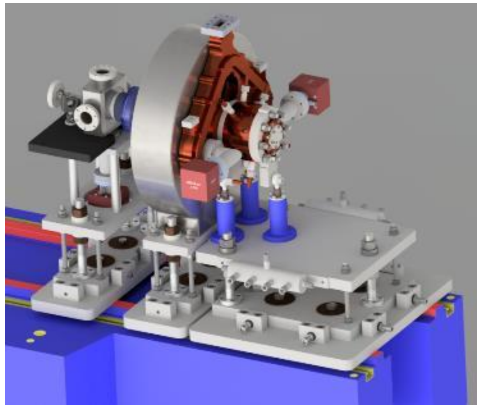


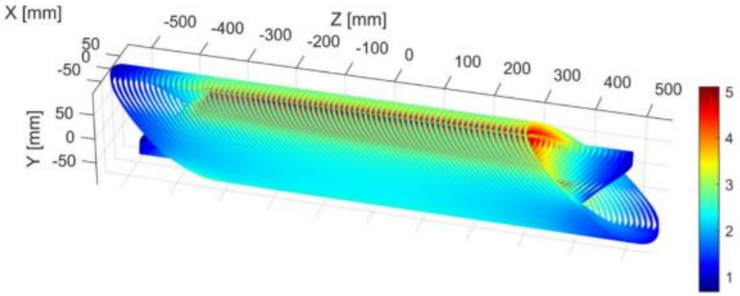
Opportunities:

- Strong demand for R&D: accelerators are crucial tools in the progress of modern science and technology (physics, biology, medicine, material science, etc.).
- Mature technology, with large industry involvement.
- Supported by a wide, motivated, and rapidly expanding scientific and technological community, spanning across continents.

Challenges:

- Presence of many actors, many projects, many technologies, with different priorities and time-scales.
- Long time scale and high cost of accelerator R&D, well beyond the capabilities of single EU projects.
- Strong dependence on post-ww2 technologies increasingly faraway from modern industry's focus.
- Needs coordination and sharing of resources.





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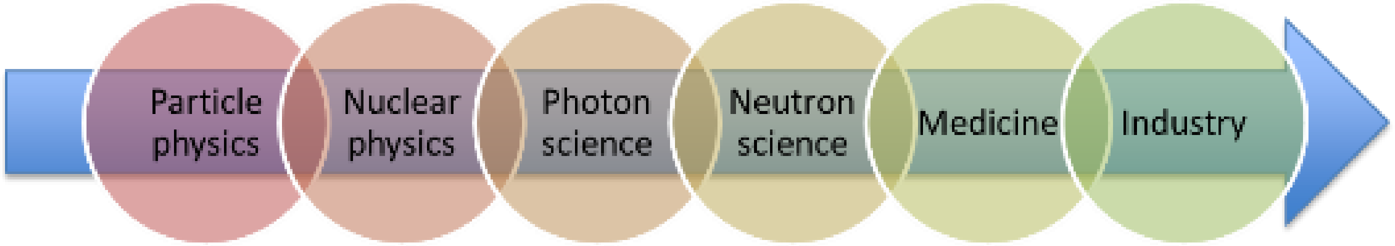
Creating an Innovation Ecosystem

- Main strategic goals for EU accelerator projects:
  1. **Transverse approach** based on synergies between accelerators for different users: particle and nuclear physics, photon and neutron science, medicine and industry.
  2. **Collaborative schemes** involving laboratories, university and industry.
  3. Priority to **long-term R&D** topics, beyond the specific needs of approved projects and developments, starting from low TRL activities.



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