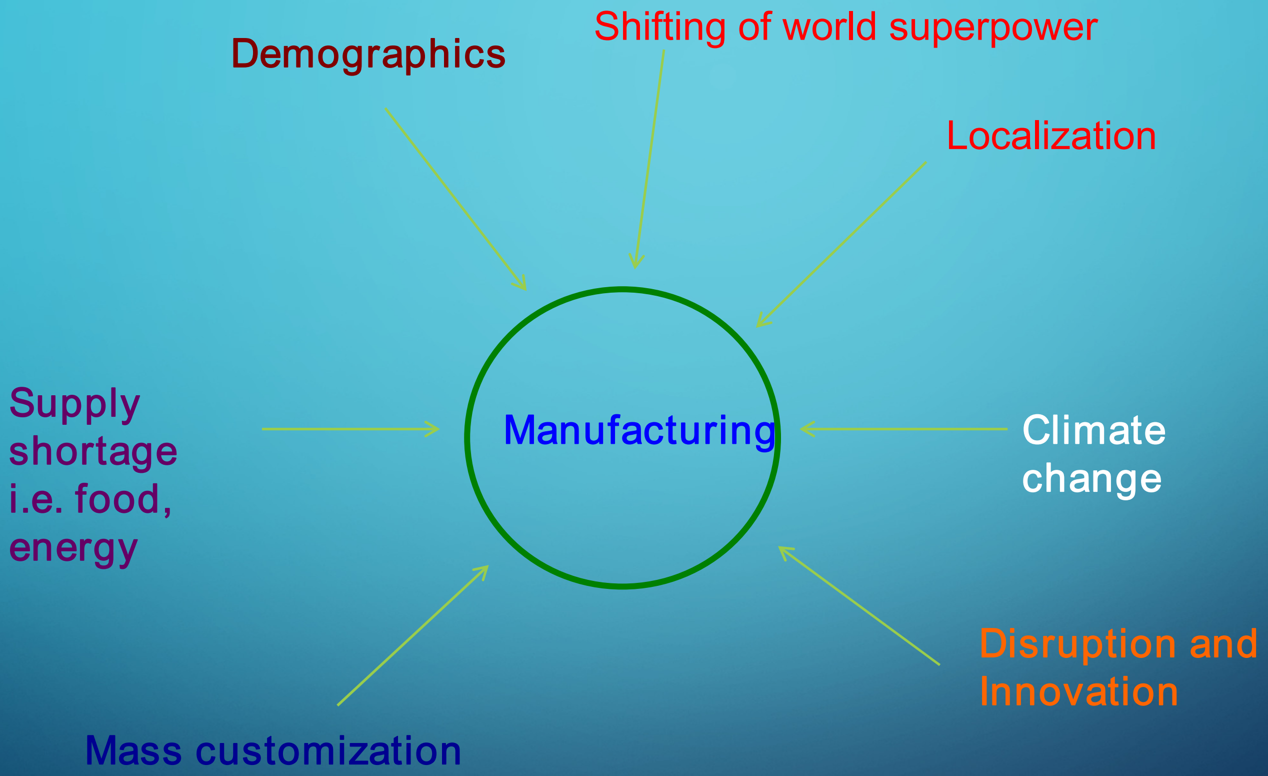
SYNCHROTRON TECH – THE WAY FORWARD FOR THAI INDUSTRY FROM THE SMALLEST VISION

JACK CLANCY RUGSANCHAROENPHOL

DEPUTY SECRETARY GENERAL – FEDERATION OF THAI INDUSTRIES

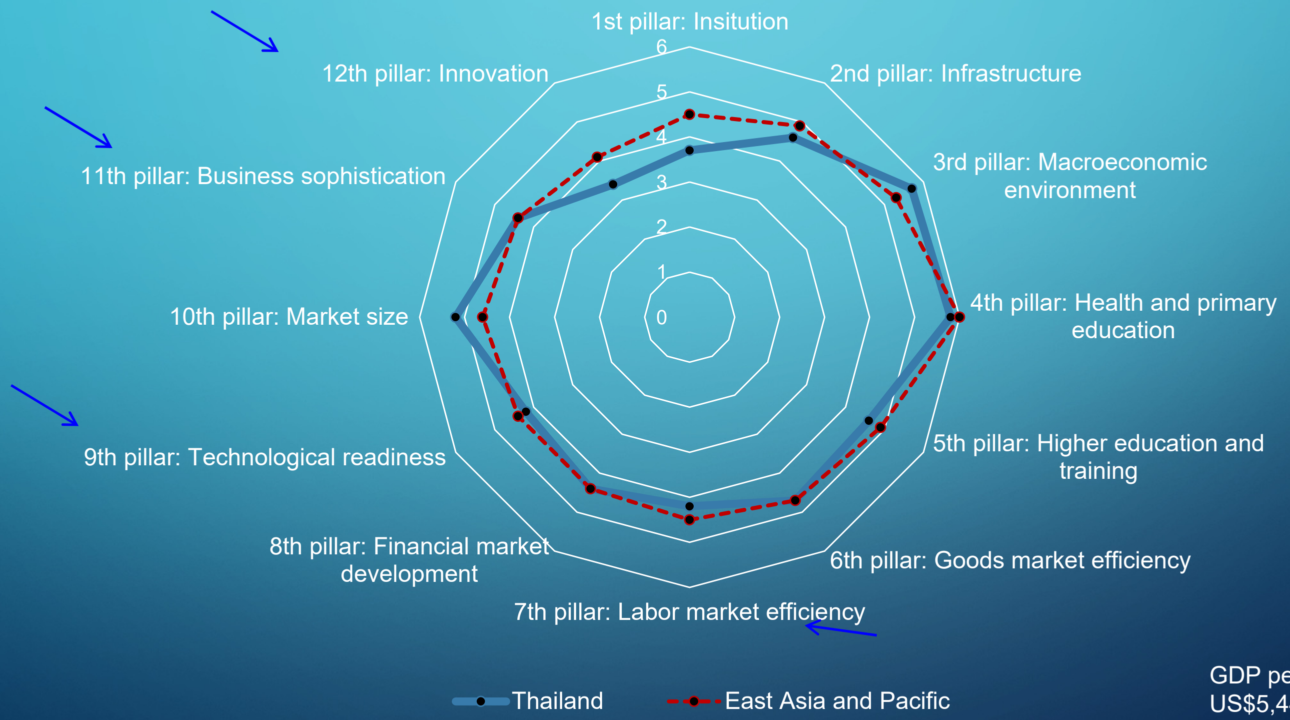
Volatile, Uncertainty, Complexity and Ambiguity

GLOBAL TRENDS



THAILAND COMPETENCY CHART

Global Competitiveness Index (2016)



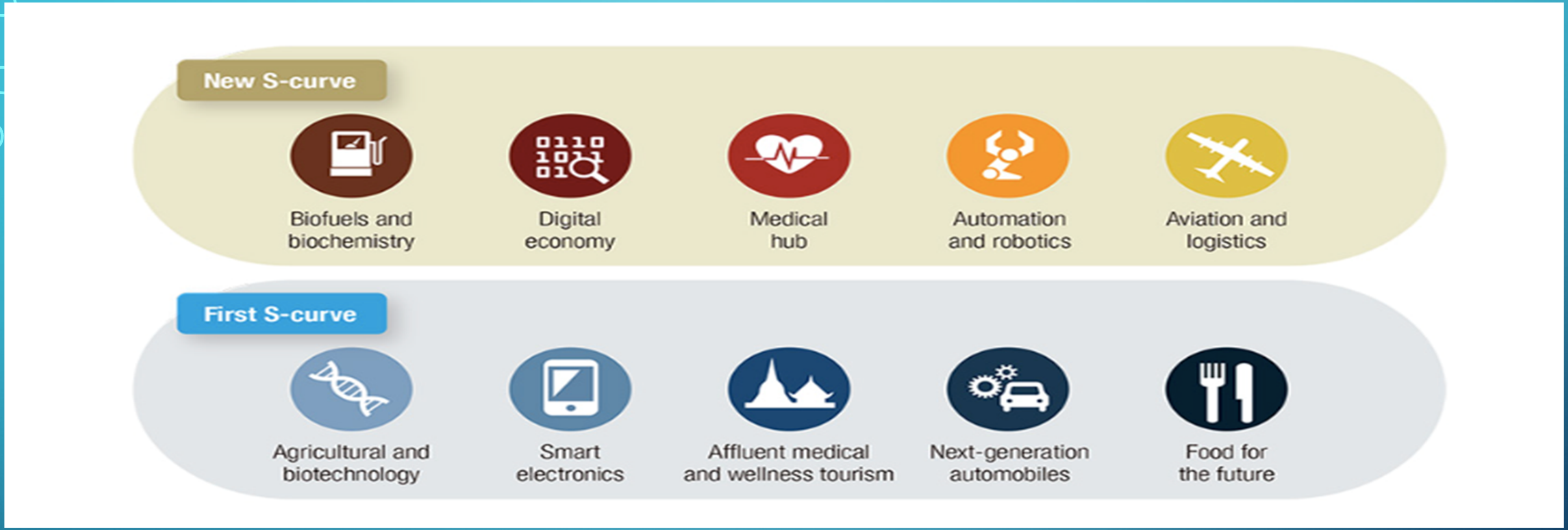
GDP per Capita 2014
US$5,445.-

THAI INDUSTRY BIGGEST CHALLENGE

OEM model → Innovation driven model

THAI INDUSTRY BIGGEST CHALLENGE (CONT)

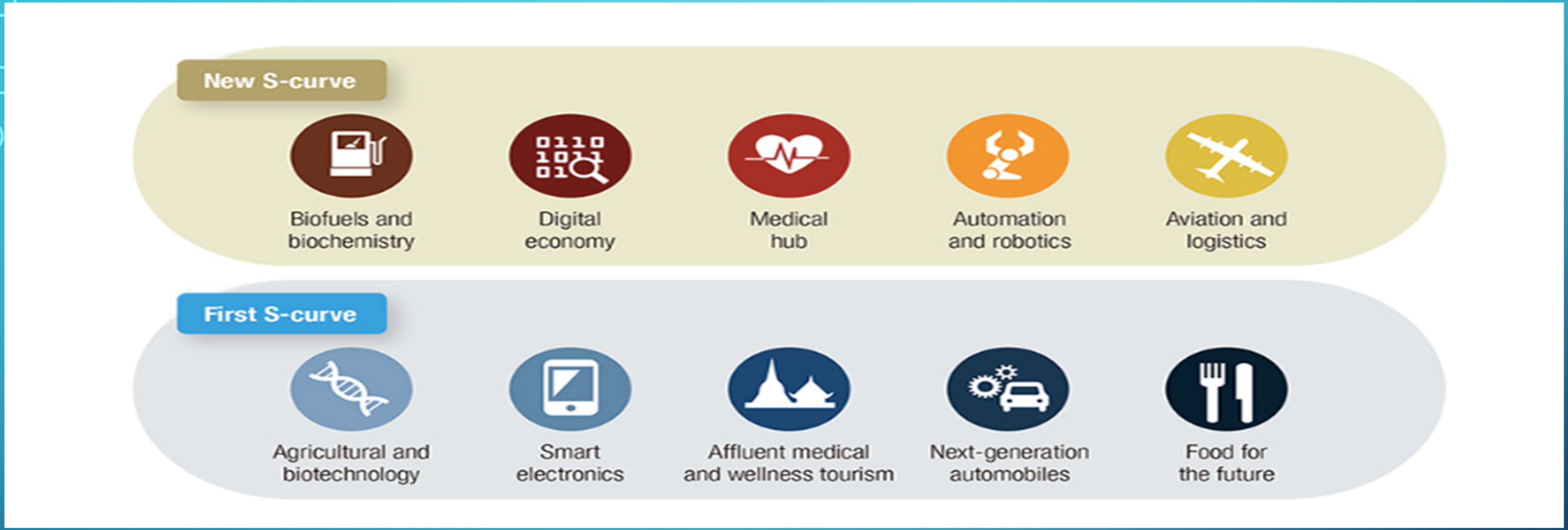
S CURVE EMPOWERMENT ENGINE



The key is "Research & development and Tech Transition to Industry"

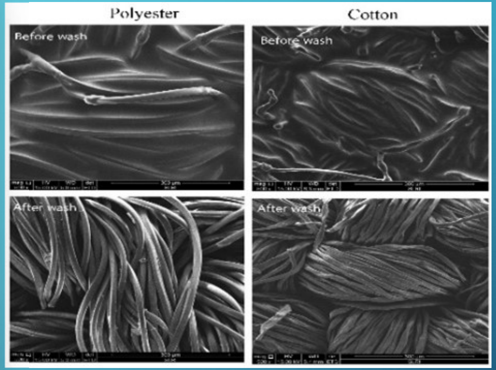
“If you cannot understand it, you cannot improve it”

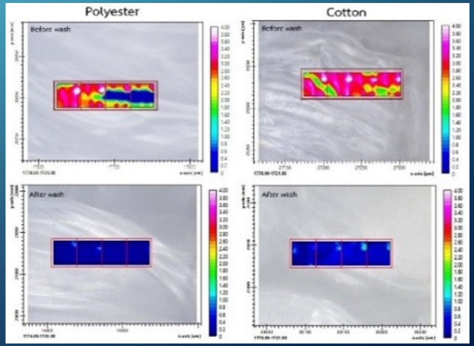
S CURVE EMPOWERMENT ENGINE



The key is “Research & development and Tech Transition to Industry”

”Synchrotron Technology”





Certified R&D results for detergent enhancement feature
And Nano scale

Synchrotron-FTIR to analyse chemical compound as part of food life span extending

Technique: Synchrotron-FTIR

Product: Yogurt from Coconut

GAP ANALYSIS AND WHERE DO WE GO FROM HERE

Develop awareness of how important Particle accelerator technology is to Thai industry

Enabling platform to all S – curve industries policy

Step up from being enabling platform to be stimulator of Hi precision/deep tech industry in Thailand

INDUSTRIAL PERSPECTIVE ON ACCELERATOR TECHNOLOGY

Hans Priem
VDL Enabling Technologies Group
June 15, 2022

Outline

- Introducing VDL ETG
- Challenges in our main markets served
- Relevance of (accelerator) science
- Industrial spin-offs

VDL ETG: high-end contract manufacturing

facts and figures

10 COMPANIES

SPREAD ACROSS
3 CONTINENTS

REVENUE
>€1,5BILLION

4,000 EMPLOYEES

> 50% EXPORT

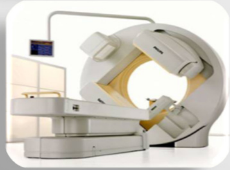
SERVING **>4 MARKETS**

STRONG BALANCE SHEET POSITION
SOLVENCY **54%**

VDL ETG - core markets

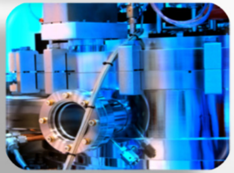
Semiconductor Capital Equipment
Wafer Handling, positioning and processing

Analytical Equipment
High-end microscopes, mass-spectrometry



Medical Equipment
CT / MRI assembly & testing

Science & Industry
Accelerators, astronomy instruments, satellites

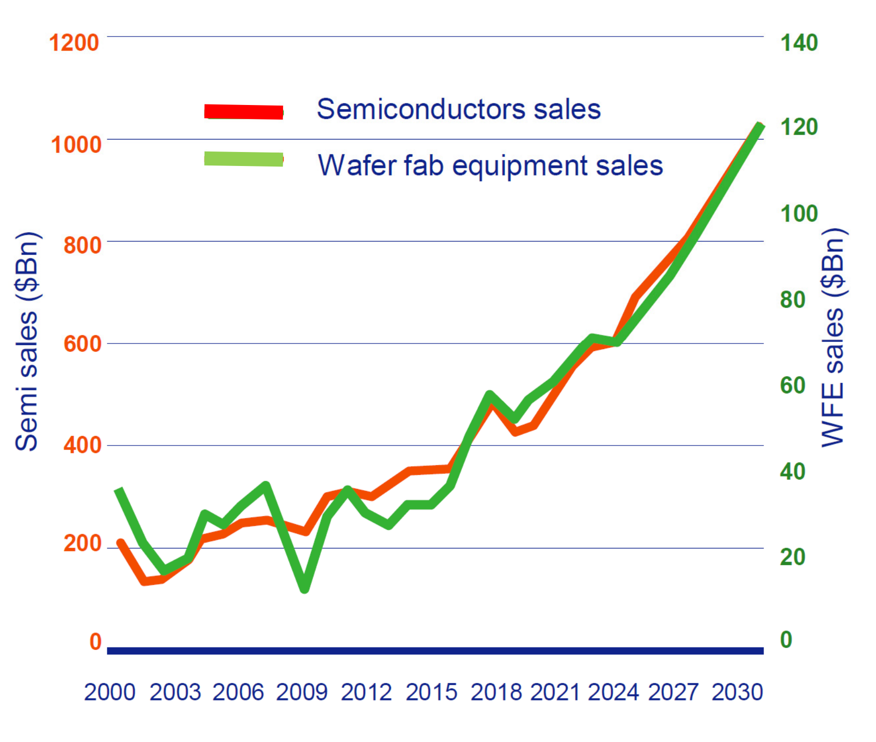


Led Manufacturing Equipment
Full process automation

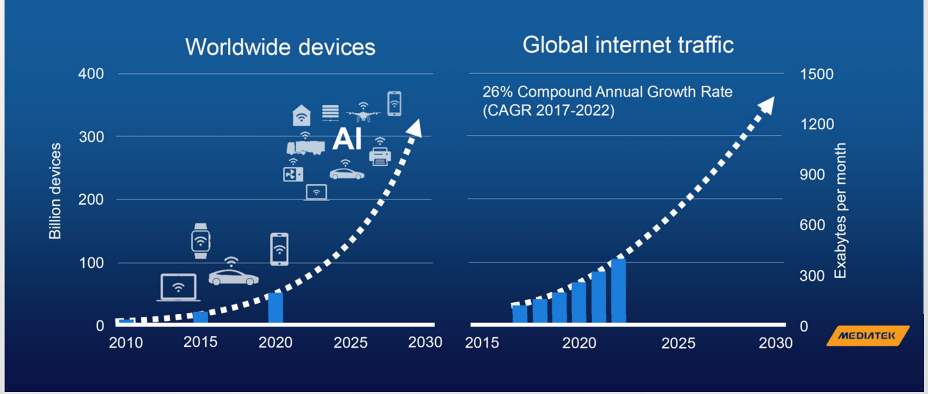
Solar Production Equipment
Substrate handling and surface treatment processing

Semiconductors: demand keeps increasing, while..

Semiconductors vs. Wafer Fab Equipment

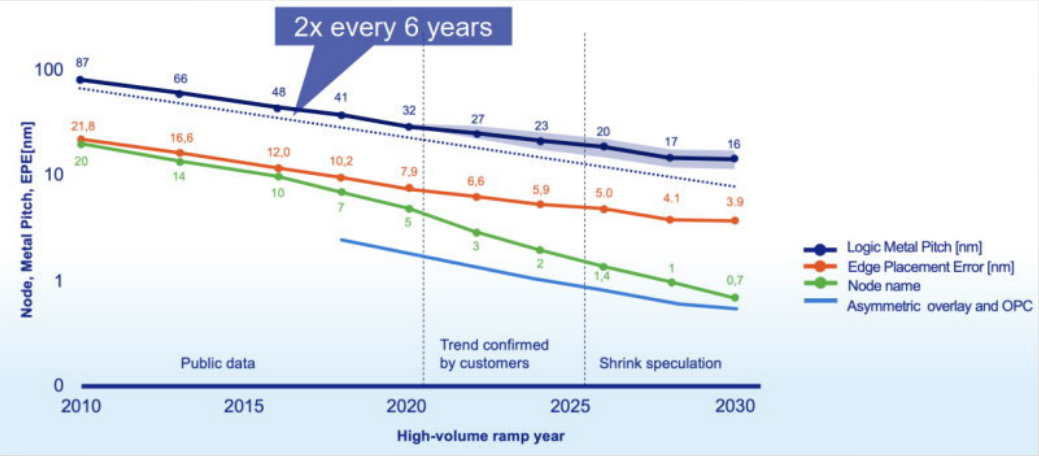


Semi content per unit	2015	2020	2025F
HIGH END SMARTPHONE	$100	$170	$275
AUTO (GLOBAL AVERAGE)	$310	$460	$690
DATACENTER SERVER (CPU + ACCELERATOR)	$1,620	$2,810	$5,600
SMARTHOME (GLOBAL AVERAGE)	$2	$4	$9



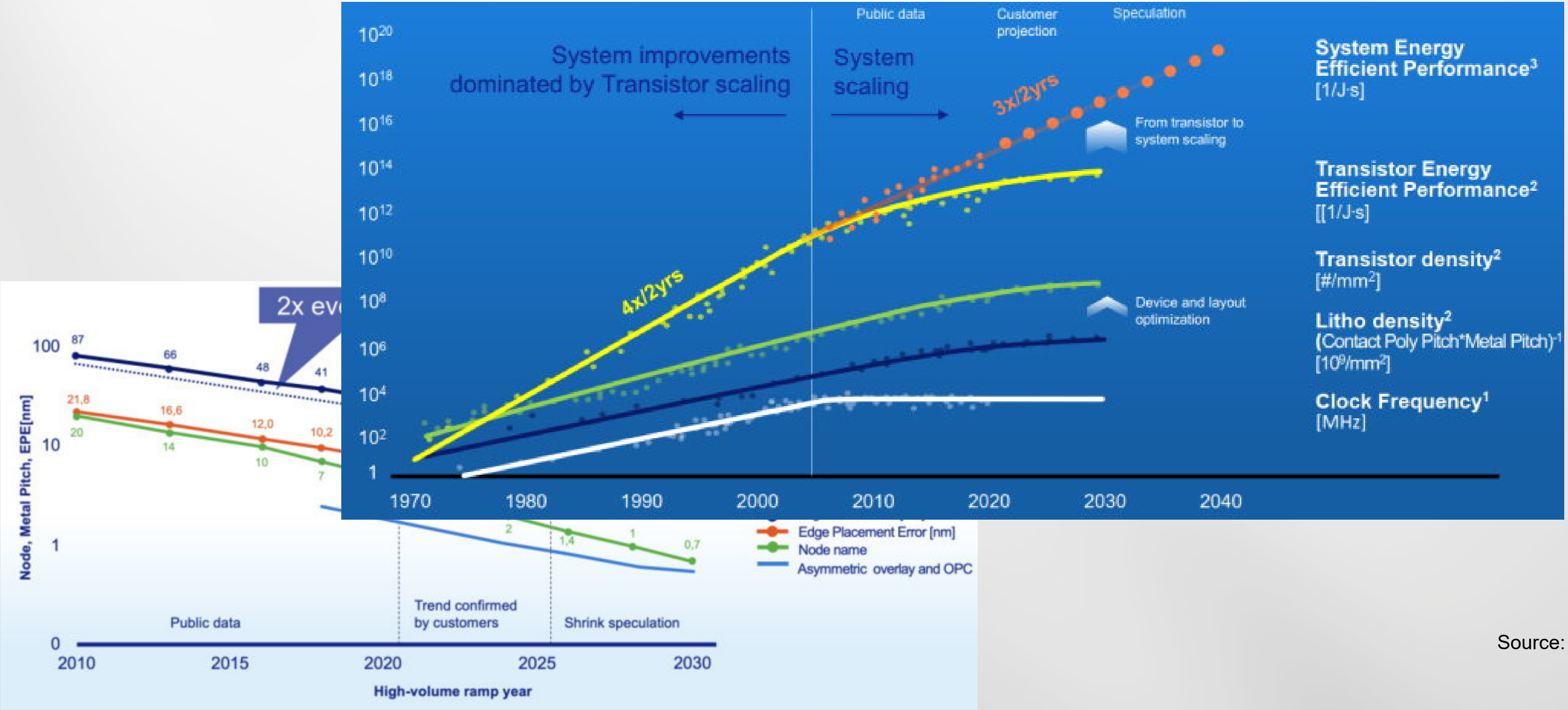
Semicon content grows as everything gets smarter => cyclicality of semi market vanished

…innovation further accelerates



Source: ASML

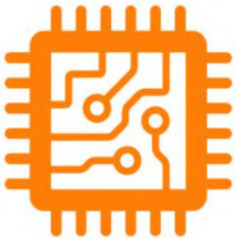
...innovation further accelerates



Source: ASML

The challenges of our market segments

Semiconductor equipment



Modules for lithography tools
Modules for metrology tools

EUV, E-beam and X-ray productivity and yield

Vacuum
Cleanliness
Superconductors, cryo
Precision mechanics

Medical equipment

Modules and parts for medical treatment/diagnostics equipment

Better diagnostics – X-ray
treatment – proton therapy

Vacuum
X-ray, proton sources
Accelerators and RF
Precision mechanics

Analytical equipment

Modules and parts for analytical equipment

New diagnostic techniques
More reliable analytics

Vacuum and cryo
X-ray and E-beam sources
Cleanliness
Precision mechanics

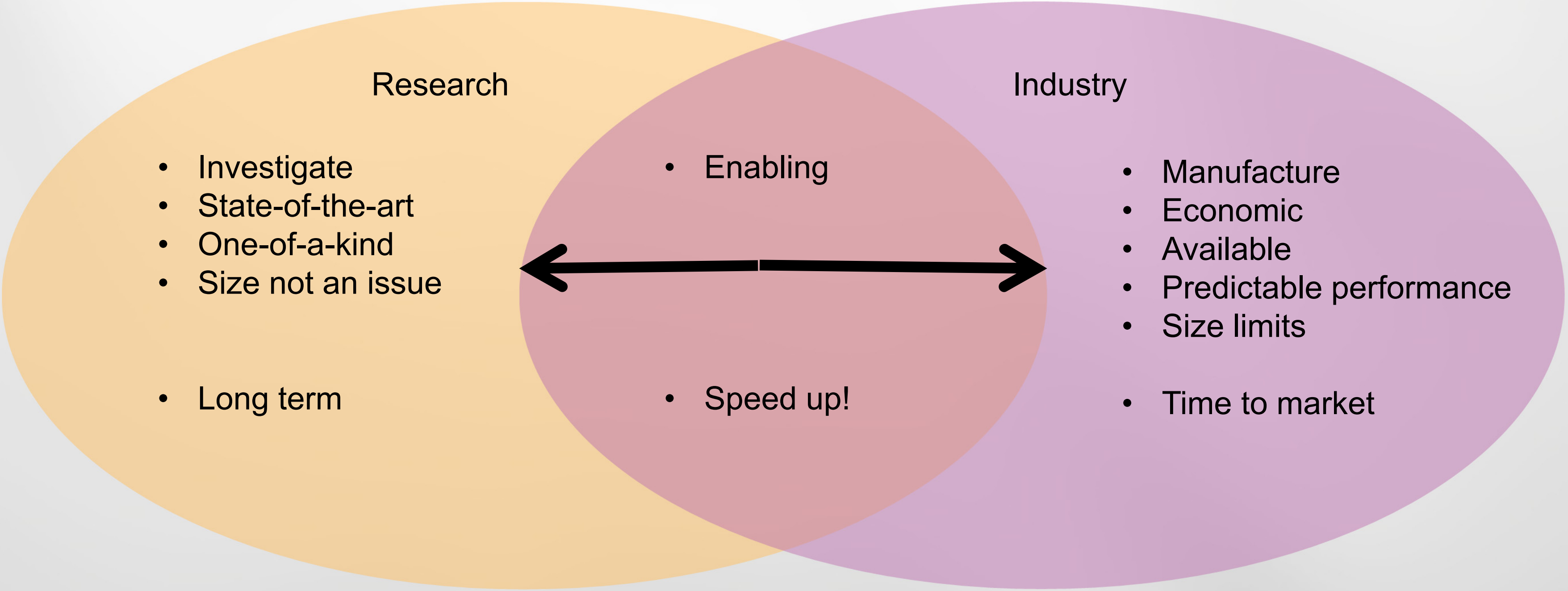
So…why is accelerator science very relevant to us?

PUSHING LIMITS, NEW (DISRUPTIVE) TECHNOLOGIES

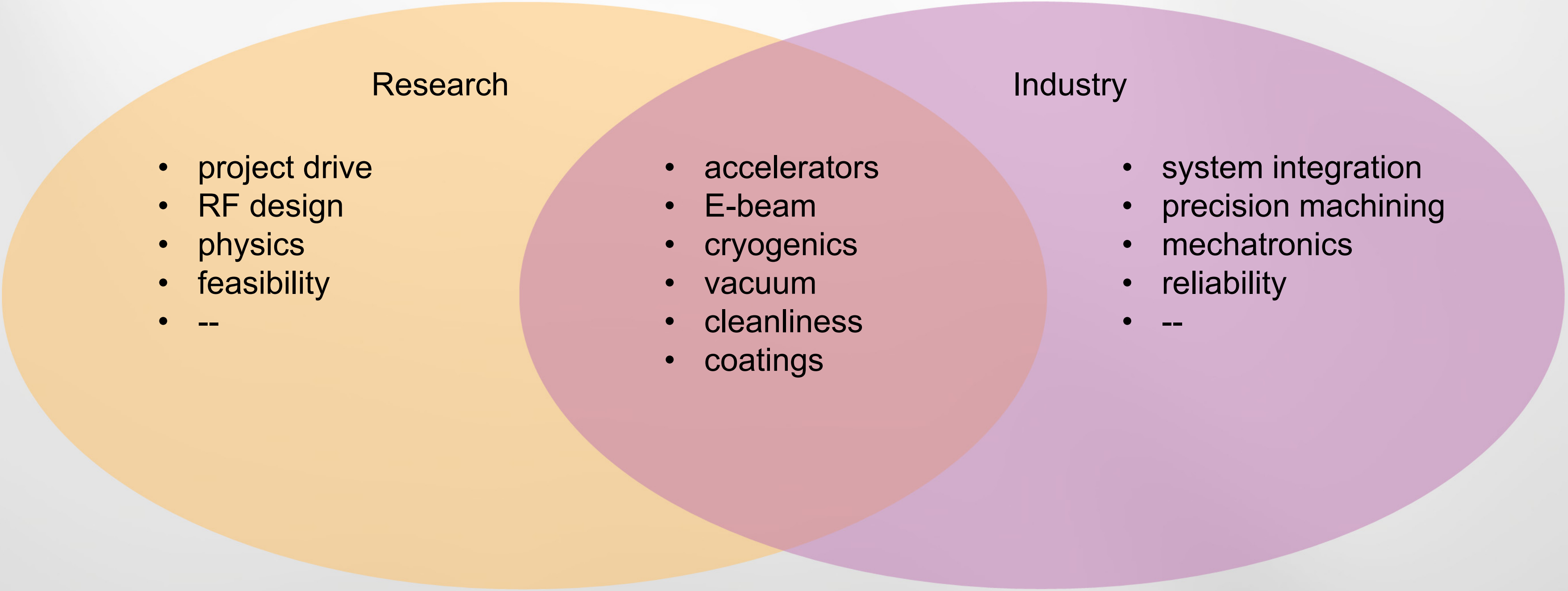
- The technology is relevant for our customers, and we act on behalf of our customers
- We need to learn to apply new technologies, and embed these in our roadmaps
- Relevant mindset – pushing the limits
  - Volume production → stay within the control limits, process control…whereas
  - Innovation → push the limits
  - System approach is very similar

- Enabling our customers to provide a differentiated proposition

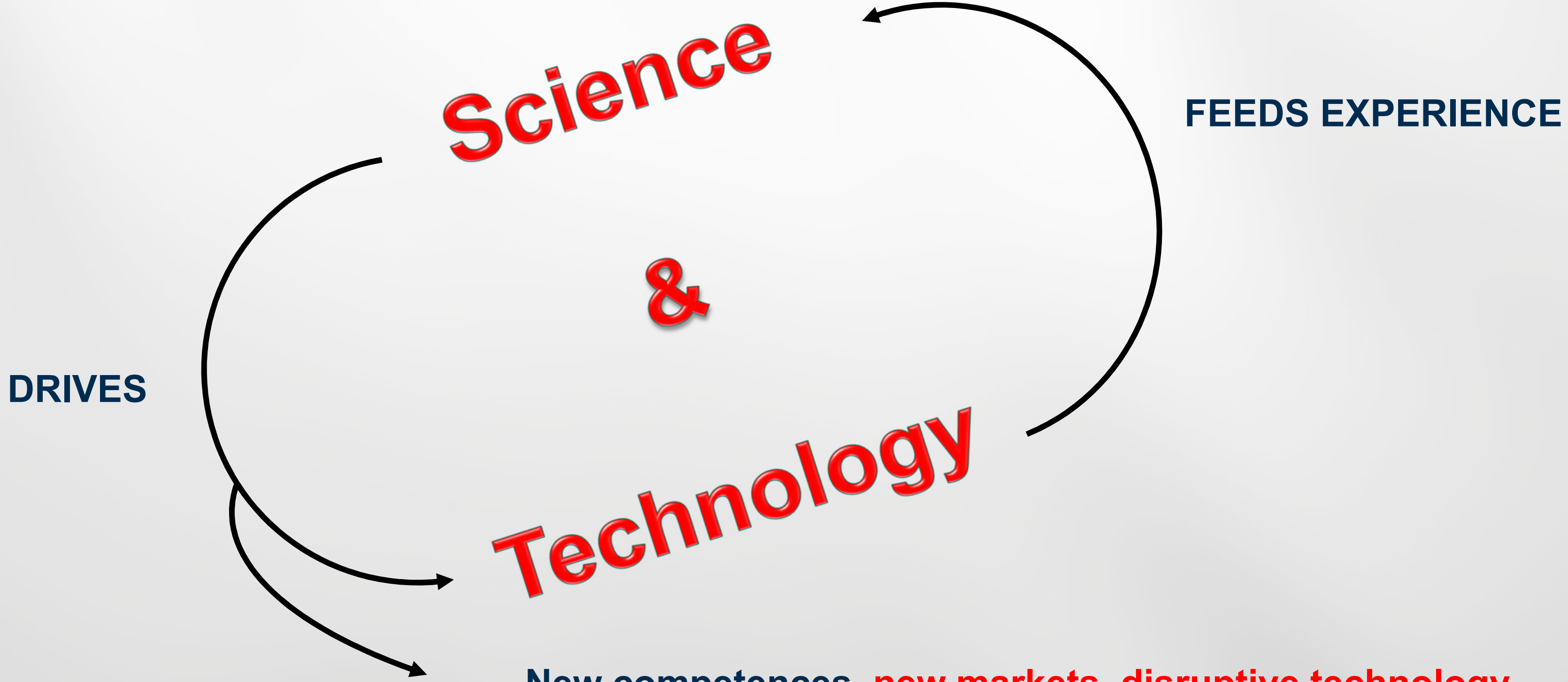
Where science and industry meet – synergy



Large overlap in technology strenghts and challenges



It drives new applications & disruption as well



New competences, new markets, disruptive technology

Accelerator spin-offs - applications

Accelerators

Electron

Low energy application
(large market)

Material treatment
(existing / growing market)

E-beam Welding
(growing market)

SEM/ TEM
(existing market)

Fundamental research
(niche market)

Generating radiation

Collision with target to generate X-Ray
(existing and large market)

X-ray imaging
(large market)

Tumor treatment
(large market)

Sterilization
(existing / growing market)

Security
(proof of concept)

Free Electron Laser
wide range of wavelengths
(growing market)

Materials and biological research
(growing market)

Light source lithography
(ideas)

Defense (USA)
(ideas)

Fundamental research
(niche market)

Proton

Tumor treatment
(small but growing market)

Materials Research
(small market)

Proton beam lithography
(ideas)

Fundamental research
(niche market)

Other elements

Tumor treatment
(proof-of-concept)

Material treatment
(growing market)

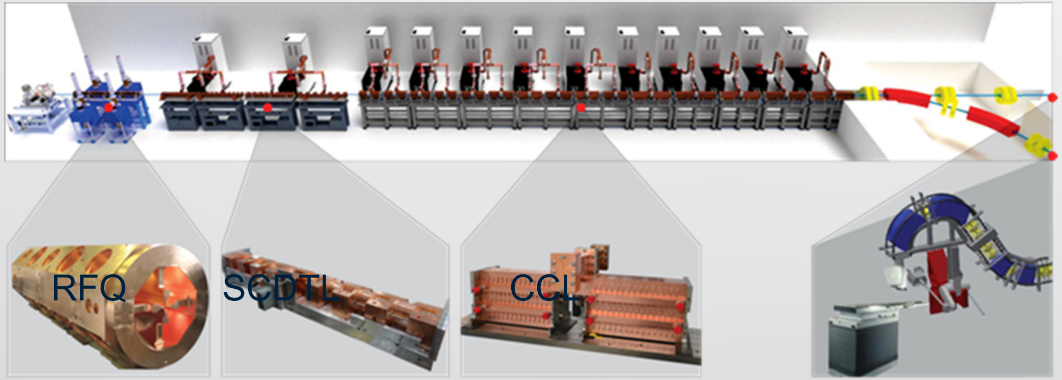
Fundamental research
(niche market)

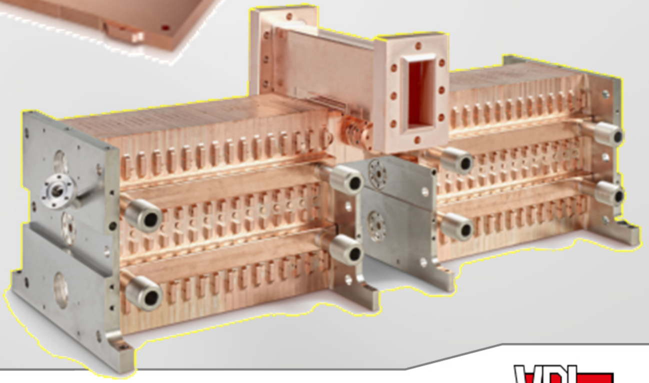
Normal Conducting X-band

ADVANCED ONCOTHERAPY

Disruption: proton therapy

- LIGHT (Linac for Image Guided Hadron Therapy) developed by ADAM
- VDL ETG is partnering to manufacture, build and test the CCL accelerating modules

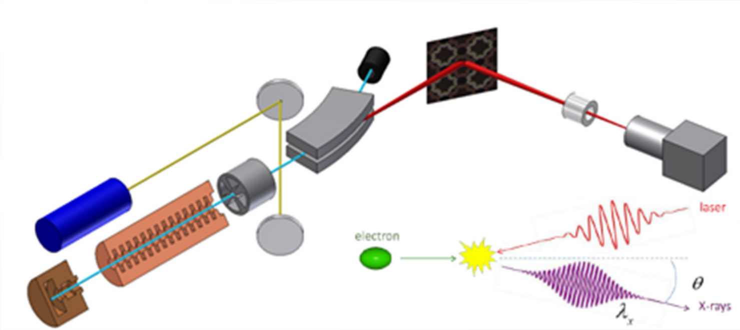


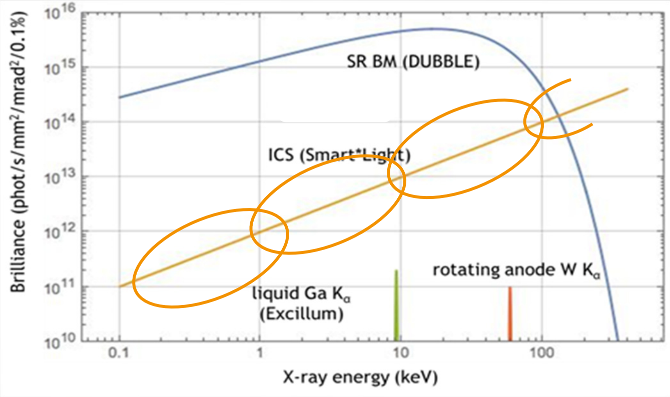


New application: ICS light source

- A compact, high brilliance, monochromatic X-ray source
  - “the PC version of the mainframe synchrotron”

- Compared to machines currently under development, ICS source is
  - Compact
  - Configurable and tunable (machine modular)
  - Energy switching securing high throughput / fast imaging
  - Field upgradeable
  - Ready for volume production





Building bridges between science and industry

SOME IMPORTANT ELEMENTS TO BE ADDRESSED

- To enable future innovation (trends), bridges are crucial
- To enable future science programs, bridges are crucial

- Overcome the cultural gaps by valueing each others strengths
- Build science-industry teams to address the challenges we have
- Close the gap between (proof of) technology concept and commercial product development

IPAC22

Industry Session

HOW A SMALL SIZE MARKET COMPANY CAN CROSS THE CHASM BETWEEN A NICHE MARKET TOWARDS WIDER INDUSTRIAL MARKETS

Enrico Braidotti

CAEN ELS s.r.l.

IPAC22 – Bangkok – June 15th, 2022

SUMMARY

- Introduction
- Approaching industry
- Personal case history
- Unsuccessful (or successful?) example
- Wrap-up
- Lesson Learned

INTRODUCTION

- electronic designer at accelerator facility
- interaction with technology transfer office
- moved to a scientific instrumentation company
- founded another scientific instrumentation company
- Design ⇨ Sales ⇨ Marketing ⇨ Management
- growth in the scientific market

“Why not moving to industrial applications?”

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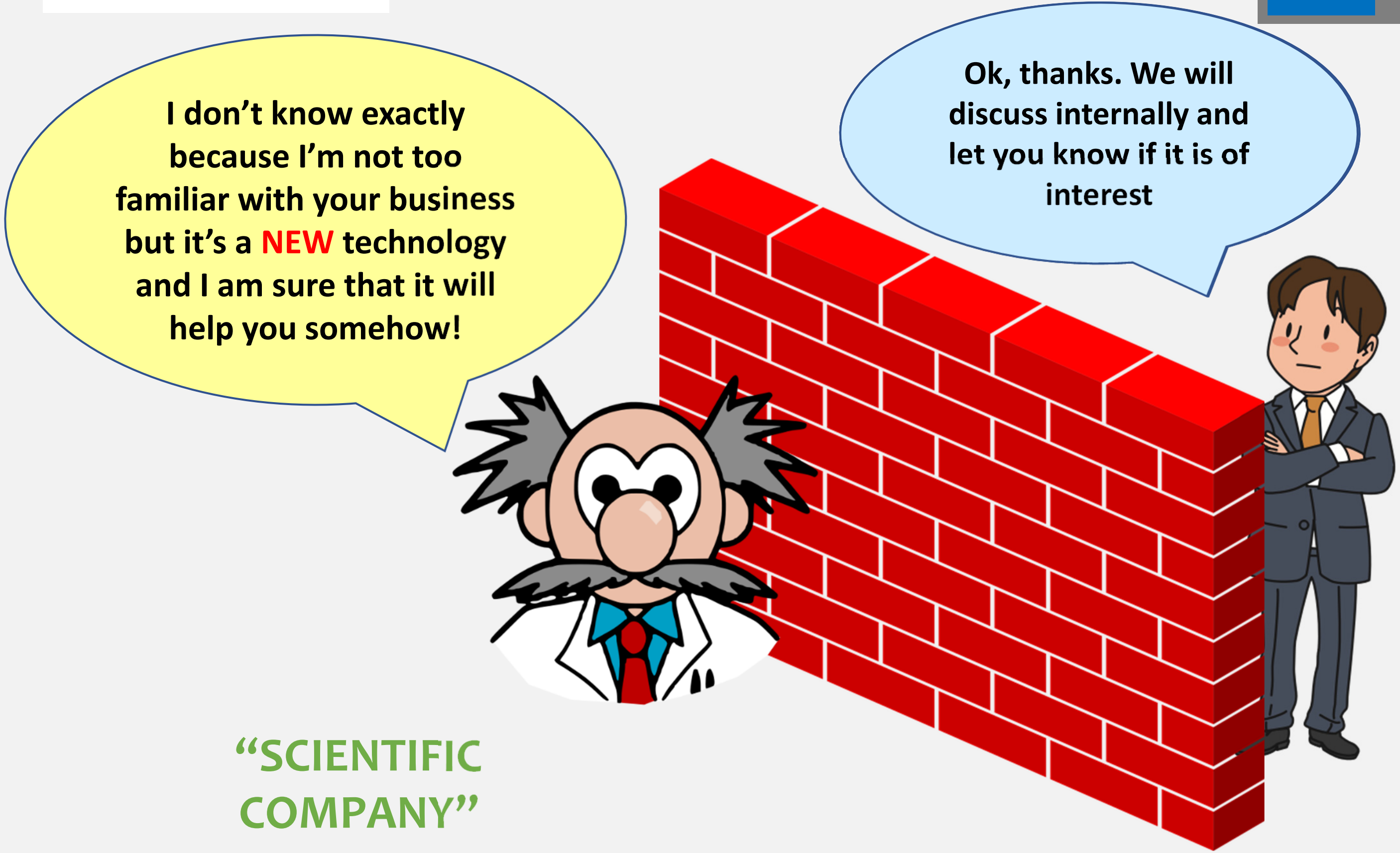
APPROACHING INDUSTRY



"SCIENTIFIC COMPANY"

"INDUSTRY"

What is the reason for this connection failure?

Is this technology really NOT technically interesting for the industry?

- speaking different languages
    - not having the same focus (technical aspects vs advantages)
    - missing link - translation

What turns out to be REALLY of interest

What SCIENTIFIC technology looks like

What the INDUSTRY uses

Sometimes (or most of the times) only an aspect/section of technology may be of interest for the industry, not the whole package

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CASE HISTORY

First approach to industry:

- hire and train young physicists/engineers for scientific applications
- send them to explore if any industry field of application needs a specific product or technology

⇨ UNSUCCESSFUL (or limited success)

We tried a different path:

- visit or approach industries on their fields (industrial fairs, exhibitions)
- establish connections and invest in bringing "industrial" people on-board (at the conditions of their field, unfortunately) to act as translators

What is happening now?

⇨ RAILWAYS, GYROSCOPE CALIBRATION, PV CELL TESTING SYSTEMS, HARD DRIVE TESTING, FOOD STERILIZATION, BATTERY TESTING, MEDICAL and others

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EXAMPLE

DC Current Transformer technology (DCCT)

- used in accelerators (CERN) since the 60s on beam current
- later extremely popular on magnet power supplies
- great technical advantages

Good ROI for industry <u>now</u>!!!

So, why NOT much in the industry?

Too expensive, other technical limitations

Now **EVs**, **battery testing**, **electrical smart grids** and others

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WRAP-UP

My PERSONAL “two cents”:

- technology and products from accelerators are cutting-edge (but sometimes way too ahead!) and have industrial applications
- industrial and scientific markets are separate planets
  - different people as interlocutors, need to speak the same language
  - different needs, volumes, schedules, targets
- migration from technology to advantages for the industry
- attract people from industry, they will be translators

“other side” ⇨ “MY SIDE”

“their” ⇨ “OUR”

Vice-versa industrial-oriented not very effective with scientific community

LESSON LEARNED

“Law of the instrument”

"IF THE ONLY TOOL YOU HAVE IS A HAMMER, IT IS TEMPTING TO TREAT EVERYTHING AS IF IT WERE A NAIL"

Abraham MASLOW, *Psychologist*

THANK YOU
for your attention!

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

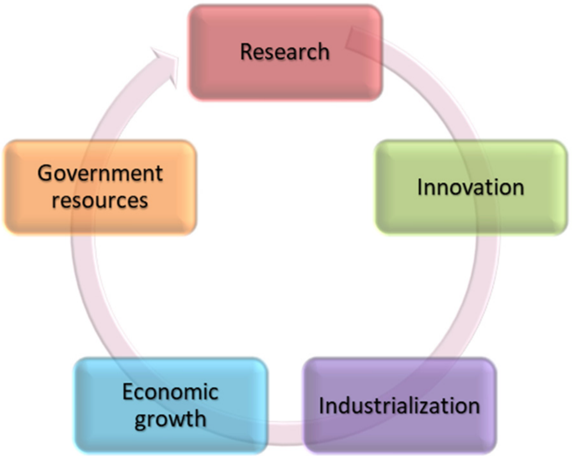
Times have changed

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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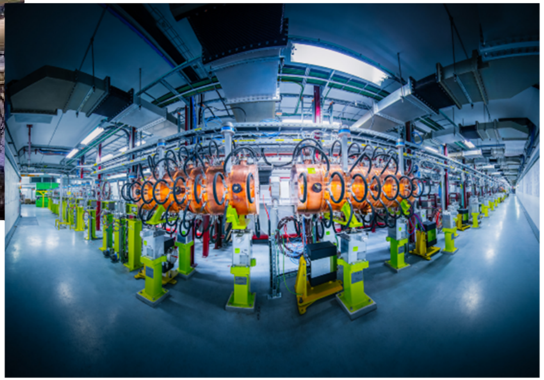
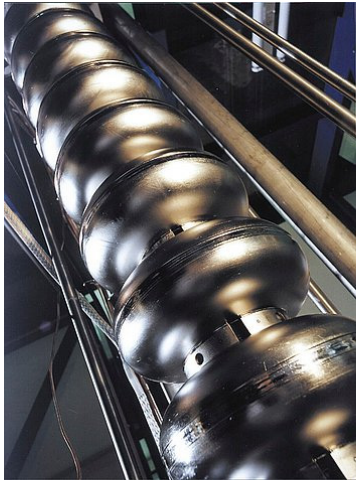
This project has received funding from the European Union's Horizon 2020 Research and In

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

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**.





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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Technology

CERN inside a Shoebox? Small Particle Accelerators Are Coming

January 19, 2022 / Science Journalist / 8 min read

Table of Contents:

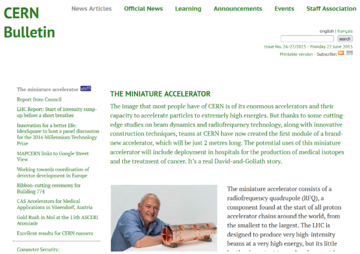
CERN. The most notable discovery so far has been the fundamental particle, the Higgs boson. What lies ahead?


NEWS

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

Effort could revolutionize scientific and medical research

By Martyn Williams


CERN Bulletin

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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.


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

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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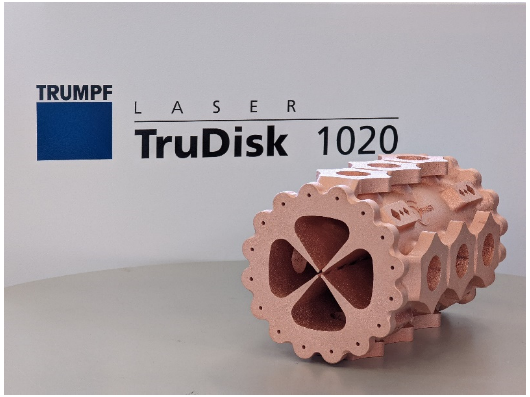
Opportunities…

- 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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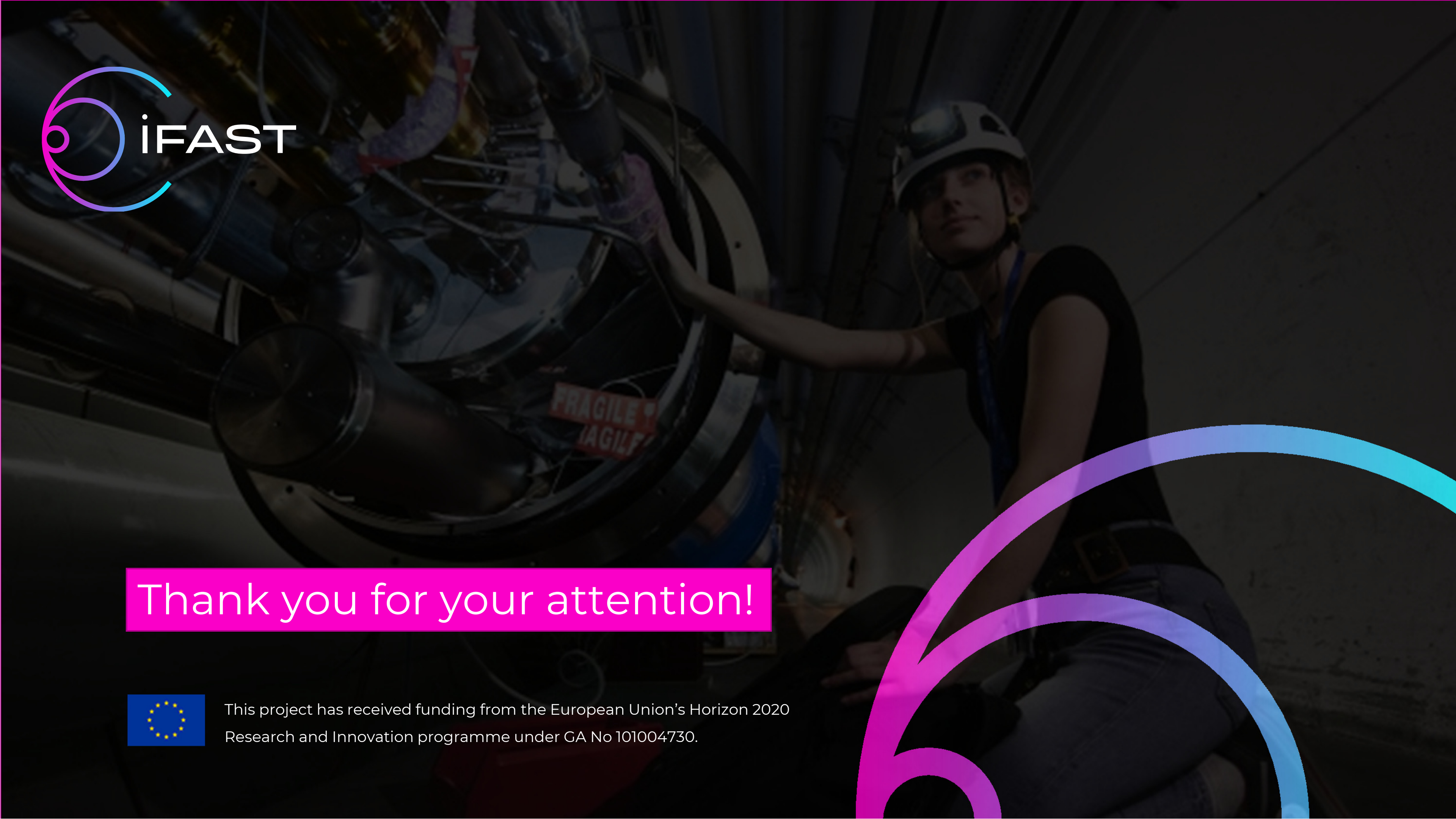
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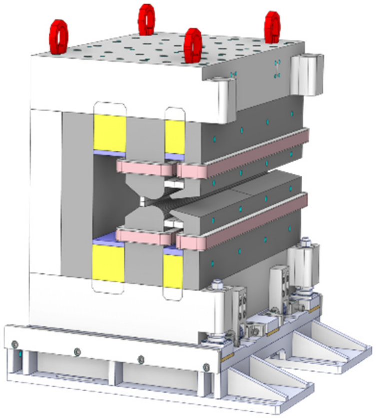
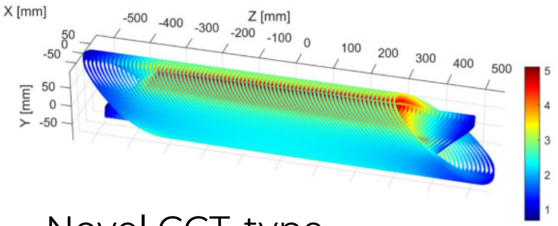
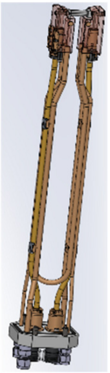
Some examples of I.FAST technologies



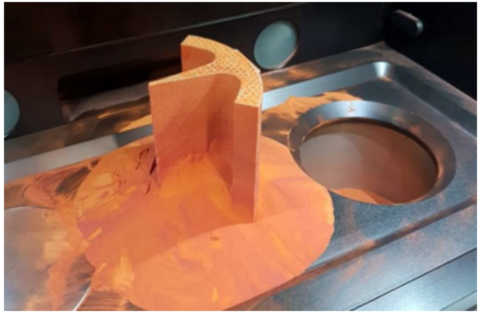
Permanent Magnet Quadrupoles and Combined Function Magnets for Ultra-Low Emittance Storage Rings



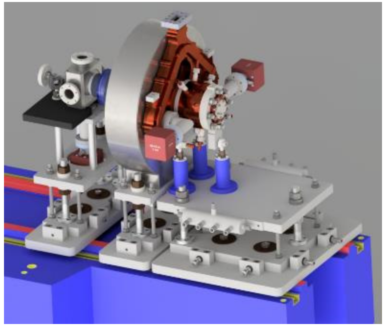
Novel CCT-type superconducting magnets for small synchrotrons and medical applications



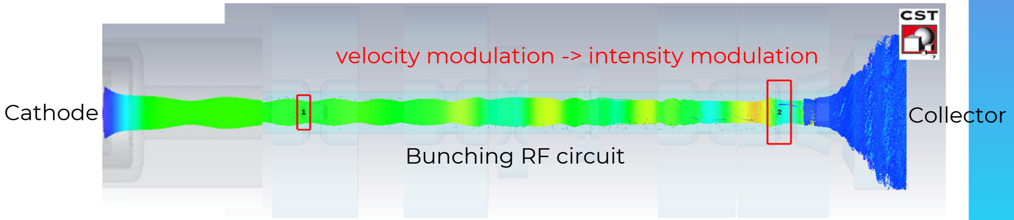
Internal source for small cyclotrons



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

iFAST

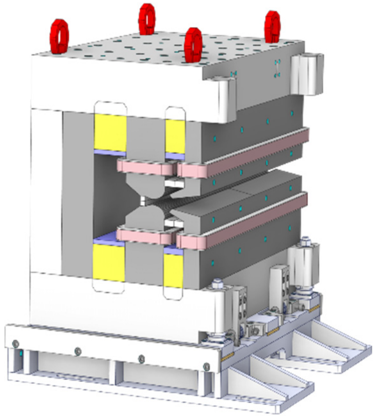
Particle accelerator R&D: challenges and opportunities

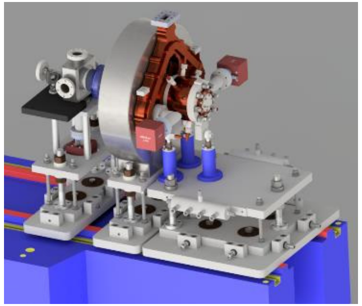
Opportunities:

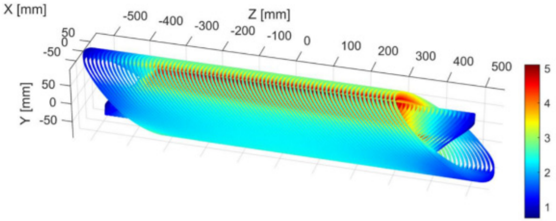
- Strong demand for R&D: accelerators are crucial tools in the progress of modern science and technology (physics, biology, medicine, material science, etc.).
- Mature technology, with large industry involvement.
- Supported by a wide, motivated, and rapidly expanding scientific and technological community,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



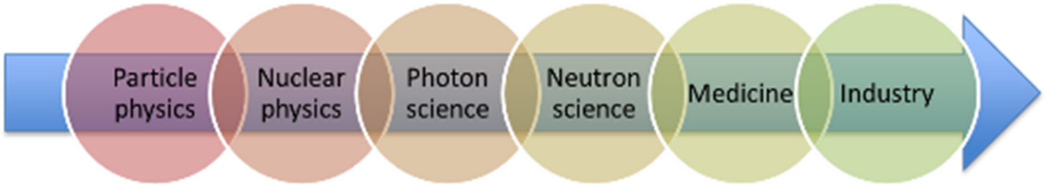




iFAST

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.



iFAST

ELEMENT AERO

PRESENT STATUS AND OPPORTUNITIES FOR IMPLEMENTING DISRUPTIVE TECHNOLOGIES ARISING IN PARTICLE ACCELERATOR R&D INDUSTRIAL MARKET

SANDRA G. BIEDRON

ELEMENT AERO AND THE CENTER FOR BRIGHT BEAMS (CBB)

15 JUNE 2022

IPAC 2022

BANGKOK, THAILAND

The Center for BRIGHTBEAMS
A National Science Foundation Science & Technology Center

THANK YOU FOR THE INVITATION

- Thanks especially to Raffaella Geometrante for organizing this session

WHAT I DID IN MY PAST
AND SOME ALSO NOW IN PRESENT TIMES

- Nearly 20 years at Argonne National Laboratory - building accelerators, lasers and RF/mm-wave systems and running a Department of Defense Project Office
- Started a small business in 2002
- Served as Deputy for Test and Integration for a major weapons program for Boeing
- Since 2004, experience educating and graduating 8 Ph.D. students
- Support/advisory roles to government agencies
- Roles in policy and advocacy – IEEE USA R&D and AI Policy committees; Served as voice for particle physics leading messages to legislators after the last P5 report derived from Snowmass.

WHAT I DO TODAY

- Since 2002 - Managing Member and Chief Scientist, Element Aero (consulting and research and development - mostly in defense and security, including systems engineering)
- Knowledge Transfer Director, Center for Bright Beams (CBB) based at Cornell University sponsored by the National Science Foundation
- Guest Scientist Positions at Brookhaven National Laboratory (Office of Science) and Los Alamos National Laboratory (NNSA)
- Research Professor Electrical and Computer Engineering and Mechanical Engineering, the University of New Mexico (mentor students, do research)

THIS VANTAGE POINT PROVIDES SEVERAL PERSPECTIVES

- Industry
- National and federal labs
- International bodies, e.g. NATO S&T Panels
- Academia
- Government
- Not-for-Profits (e.g. user organizations, professional societies, etc.)
- ***And most important – the people – a variety of disciplines is what really makes a difference***

MY STANCE IS THAT

- All of these entities play a role in how industry is involved in particle accelerators and peripheral technologies.
- Because of that we must bridge all of these genres of entities.

TODAY

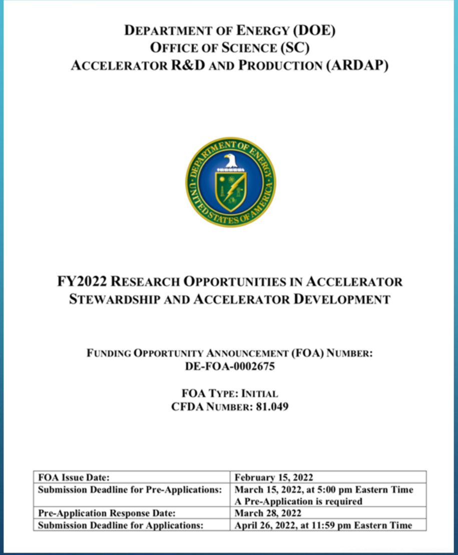
- I can express only a few examples of successes of overlaps and also some thoughts on cooperation of the future to really launch industry endeavors.

UNIQUE POINT IN TIME FOR GOVERNMENT SEEDING PRIVATE PUBLIC PARTNERSHIPS

- Many activities budding that seek to seed industry in particle accelerators and peripherals.
- Other countries and regions can take inspiration.

UNITED STATES

- Studies have expanded the legislative interest in accelerators
- DOE Office of Science just reorganized in part because of the need for US Accelerator activities. The new office: Accelerator R&D And Production (ARDAP) - was recently established.
- Calls for proposals for funding are expected to be released annually.


DEPARTMENT OF ENERGY (DOE)
OFFICE OF SCIENCE (SC)
ACCELERATOR R&D AND PRODUCTION (ARDAP)

FY2022 RESEARCH OPPORTUNITIES IN ACCELERATOR STEWARDSHIP AND ACCELERATOR DEVELOPMENT

FUNDING OPPORTUNITY ANNOUNCEMENT (FOA) NUMBER:
DE-FOA-0002675

FOA TYPE: INITIAL
CFDA NUMBER: 81.049

FOA Issue Date:	February 15, 2022
Submission Deadline for Pre-Applications:	March 15, 2022, at 5:00 pm Eastern Time A Pre-Application is required
Pre-Application Response Date:	March 28, 2022
Submission Deadline for Applications:	April 26, 2022, at 11:59 pm Eastern Time

EUROPE AND THE UK

iFAST

HOME ABOUT WORK PACKAGES RESULTS INDUSTRY NEWS ARIES CONTACT

Innovation Fostering in Accelerator Science and Technology (I.FAST)

Particle accelerators currently face critical challenges related to the size and performance of future facilities for fundamental research, to the increasing demands coming from accelerators for applied science, and to the growing applications in medicine and industry.

I.FAST aims to enhance innovation in the particle accelerator community, mapping out and facilitating the development of breakthrough technologies common to multiple accelerator platforms. The project involves 49 partners, including 17 companies as co-innovation partners, to explore new alternative accelerator concepts and advanced prototyping of key technologies. These include, among others, new accelerator designs and concepts, advanced superconducting technologies for magnets and cavities, techniques to increase brightness of synchrotron light sources, strategies and technology to improve energy efficiency, and new societal applications of accelerators.

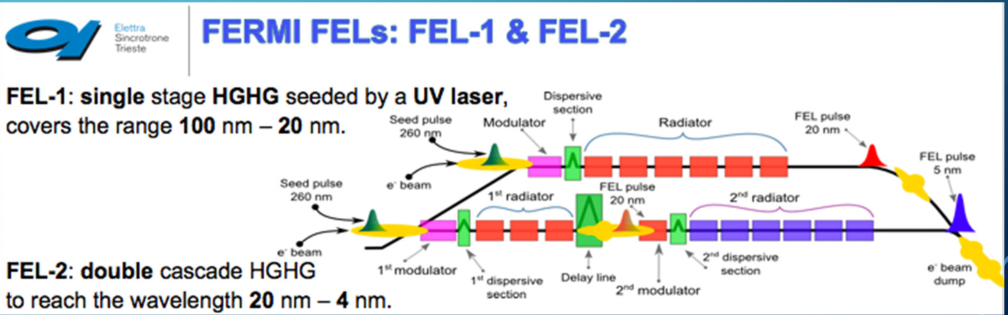
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 101004730.

LABS AS CENTERS OF PARTNERSHIP TO HELP SEED INDUSTRY
A FEW EXAMPLES

Accelerator Test Facility at Brookhaven National Laboratory

Argonne Leadership Computing Facility

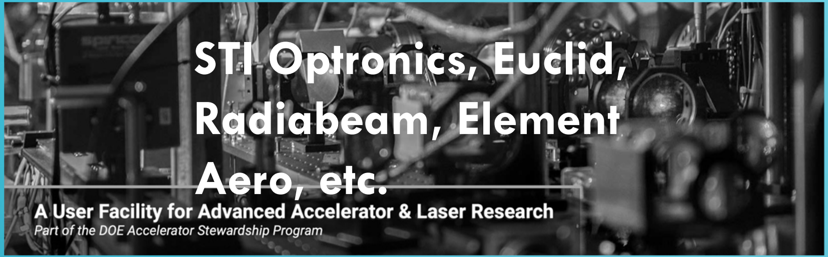
LANSCE at Los Alamos National Laboratory



FERMI@Elettra

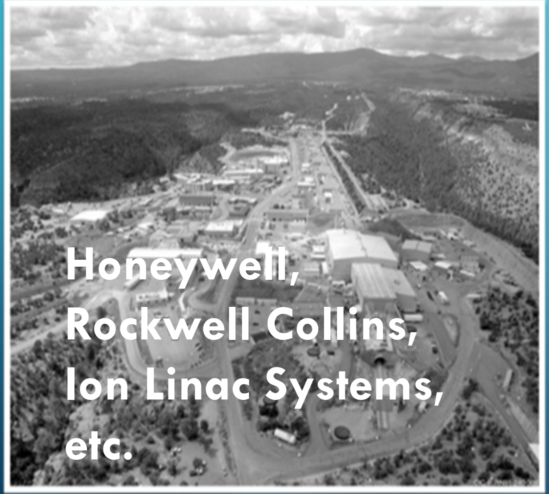
JLAB, SLAC, etc

LABS AS CENTERS OF PARTNERSHIP TO HELP SEED INDUSTRY
A FEW EXAMPLES

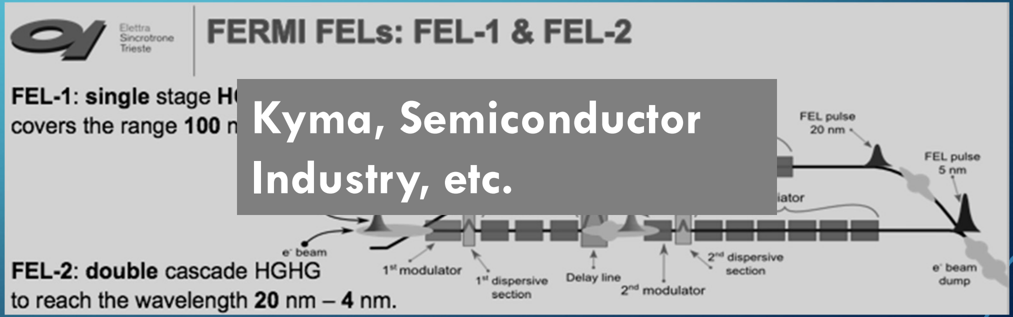


Accelerator Test Facility at Brookhaven National Laboratory

Argonne Leadership Computing Facility



LANSCE at Los Alamos National Laboratory



FERMI@Elettra

JLAB, SLAC, etc

RADIATION TESTS OF ELECTRONICS

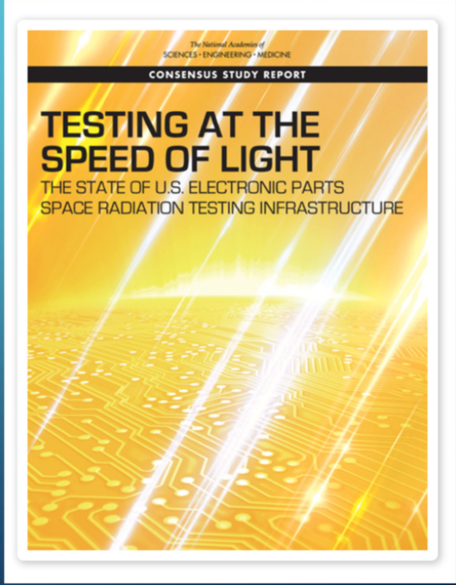
- Lots of interest and the take-home message from multiple recent meetings absolutely in no uncertain terms does not have the radiation test capabilities and access demanded by the government and industry.

NASA Electronic Parts and Packaging (NEPP) Program
2021 Domestic High-Energy Single-Event Effects (SEE) Testing Users Meeting

https://nepp.nasa.gov/workshops/dhesee2021/presentations.cfm

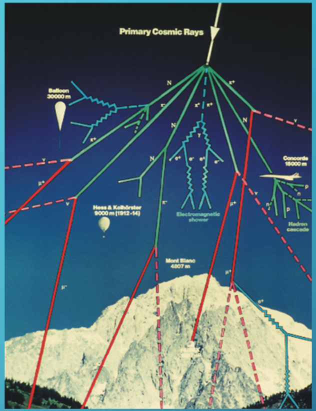
Spacecraft depend on electronic components that must perform reliably over missions measured in years and decades. Space radiation is a primary source of degradation, reliability issues, and potentially failure for these electronic components. Although simulation and modeling are valuable for understanding the radiation risk to microelectronics, there is no substitute for testing, and an increased use of commercial-off-the- shelf parts in spacecraft may actually increase requirements for testing, as opposed to simulation and modeling.

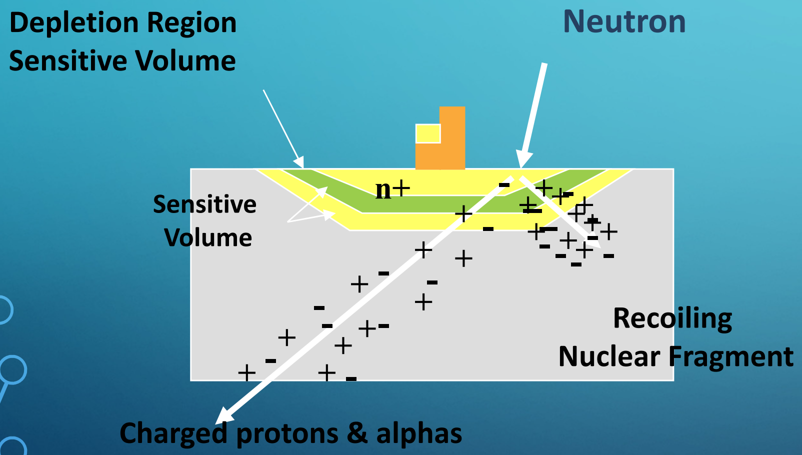
National Academies of Sciences, Engineering, and Medicine. 2018. Testing at the Speed of Light: The State of U.S. Electronic Parts Space Radiation Testing Infrastructure. Washington, DC: The National Academies Press.https://doi.org/10.17226/24993.



NEUTRONS FOR INDUSTRIAL USERS: ENSURING ROBUSTNESS OF ELECTRONICS AGAINST COSMIC-RAY BOMBARDMENT

- **Neutrons produced by cosmic rays penetrate the atmosphere**
- **Can interact with electronics and can cause single event upsets or latch ups**
- **At LANSCE the neutron flux is 1 million times that experienced at 35,000 ft**
- **We operate 2 flight paths dedicated to industrial users paying full cost recovery**

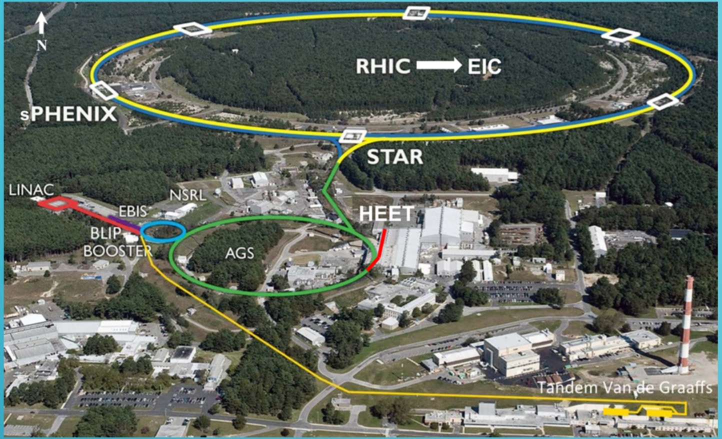




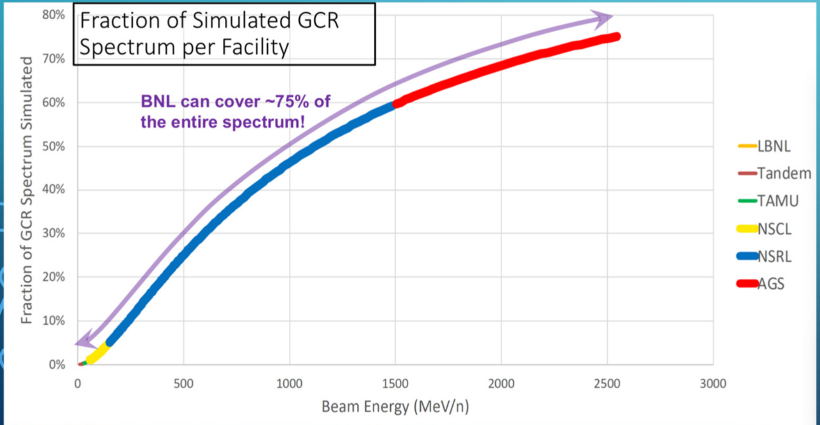
- Advanced Micro Devices
- Marvell Semiconductor, Inc.
- Arista Networks
- Prairie View A&M University
- Honeywell
- Infineon Technologies, AG
- Rockwell Collins, Inc.
- Sandia National Laboratories
- KVA Engineering, Inc.
- Texas Instruments
- University of South Dakota

Courtesy LANL

BNL COMPLEX: NSRL AND THE NEW PROPOSED HEET



NSRL Target room



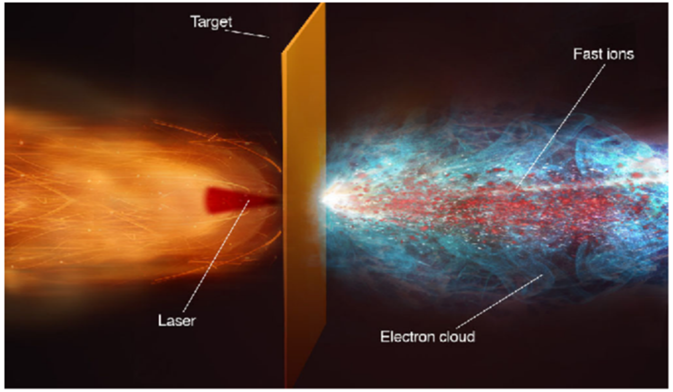
- The proposed High Energy Events Test facility would have
  - Beam energies from **40 MeV/n** to **2000 MeV/n** and possibly higher will be available
  - **Ions from H to U [Z = 1 to 92]**
  - Beam quality tailored for single event effects testing requirements
- Facility can be available **6000 hours/yr**
- Target Room & User Facility - plenty of space for all needs
- Highly professional and experienced team for building, operating, and supporting experimenter needs
- Once construction begins, **could be operational within 3 to 4 years**

Courtesy Kevin Brown, BNL

ONE APPROACH - LASER-DRIVEN IONS IS ONE APPROACH THAT REALLY LOOKS TO THE FUTURE INFRASTRUCTURE DRIVER (LASERS)

Element Aero

- Physics is proven. (Lasers can drive ion accelerators.)
- Laser needs to be architected to be optimized for this application.
- Can meet many needs in radiation testing gap.
- Can provide multiple species simultaneously over a spectrum of energies.
- Complementary to standard accelerators.
- Seeks to reduce the footprint and buy-in cost to increase access.
- Using industry and DOD systems engineering approaches as a disruptive tool.



Artists view of a typical experiment on proton emission from laser-irradiated solid targets. From Macchi, A., M. Borghesi and M. Passoni. "Ion acceleration by superintense laser-plasma interaction." Reviews of Modern Physics 85 (2013): 751-793.

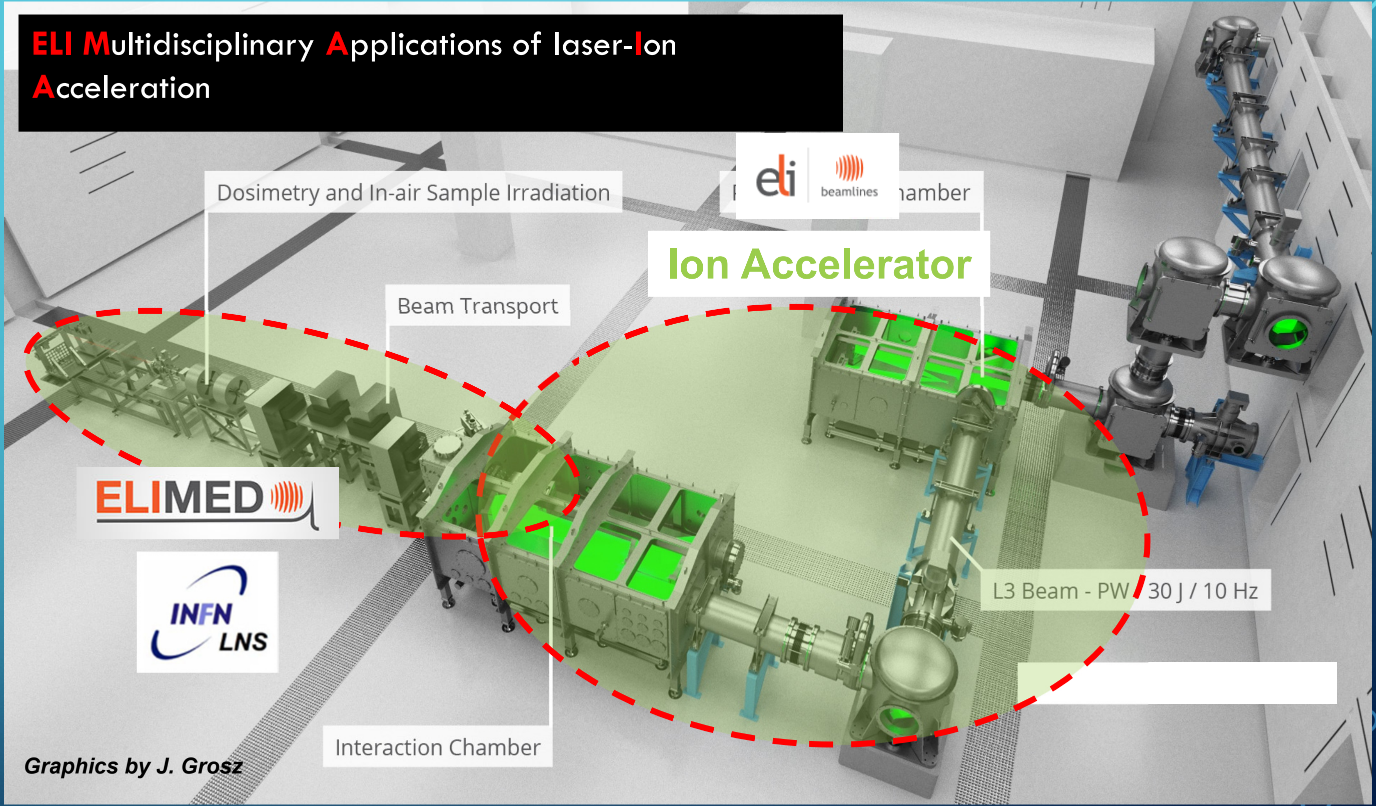
ELEMENT AERO AND BROOKHAVEN NATIONAL LABORATORY, ONGOING

Brookhaven National Laboratory

MEDICAL ACCELERATOR DEVELOPMENTS
ALSO USE OF LASER DRIVERS

ELIMAIA: a <u>User</u> Beamline

- ELI-Beamlines Host
- INFN-LNS
- Lawrence Livermore built the laser
- Sigma Phi built the magnets
- NTG laser beam transport
- Fantini Sud (vacuum chambers)
- Etc.

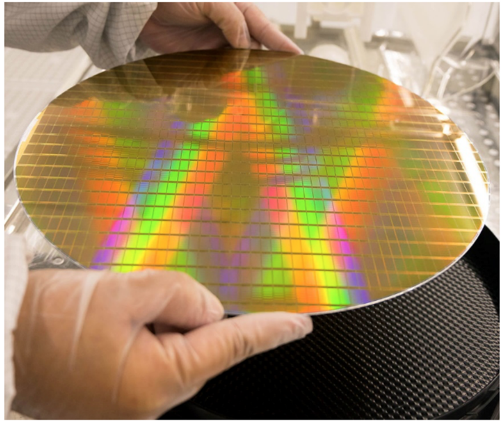


Specific niche, not replacing proton or ion therapy

ELECTRONICS/SEMICONDUCTOR INDUSTRY CAN BENEFIT

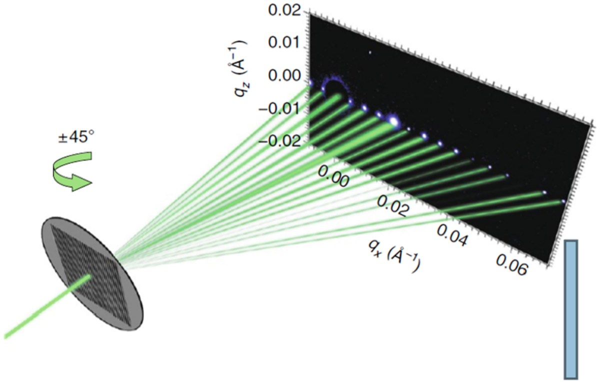
METROLOGY

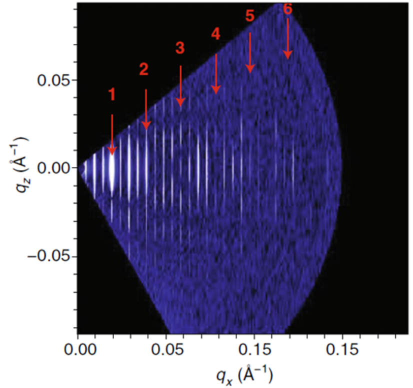
Extreme-UV Lithography

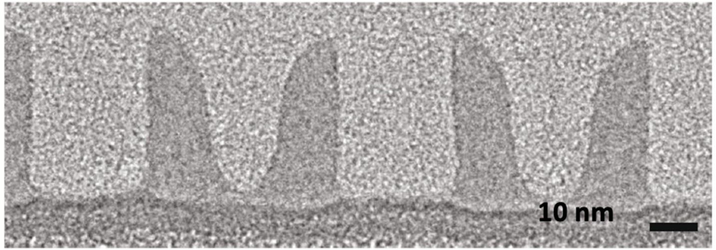


Single-digit Nanoscale structures: unique metrology challenges

Critical Dimension Small-Angle Scattering (CD-SAXS)







Orji et al.
Nature El. 2018

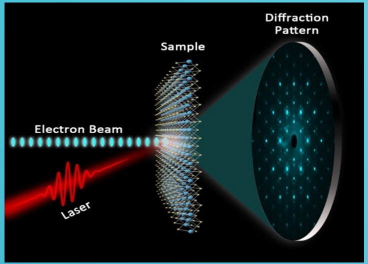
Biodesign Institute
Arizona State University

CXFEL Labs

Slide Courtesy of Dr. Robert A. Kaindl, Arizona State University

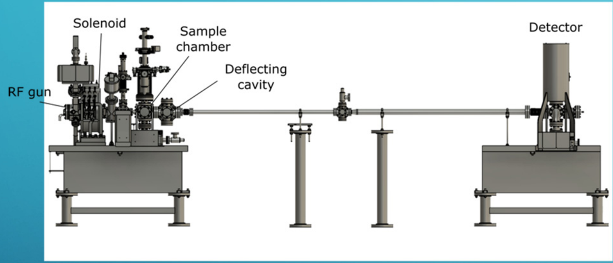
MEV ULTRAFAST ELECTRON DIFFRACTION (MUED)

Courtesy Jin Tao



It is a powerful structural measurement technique for exploring time-resolved, ultrafast processes in different material systems.

Accelerator Test Facility (ATF @ BNL)



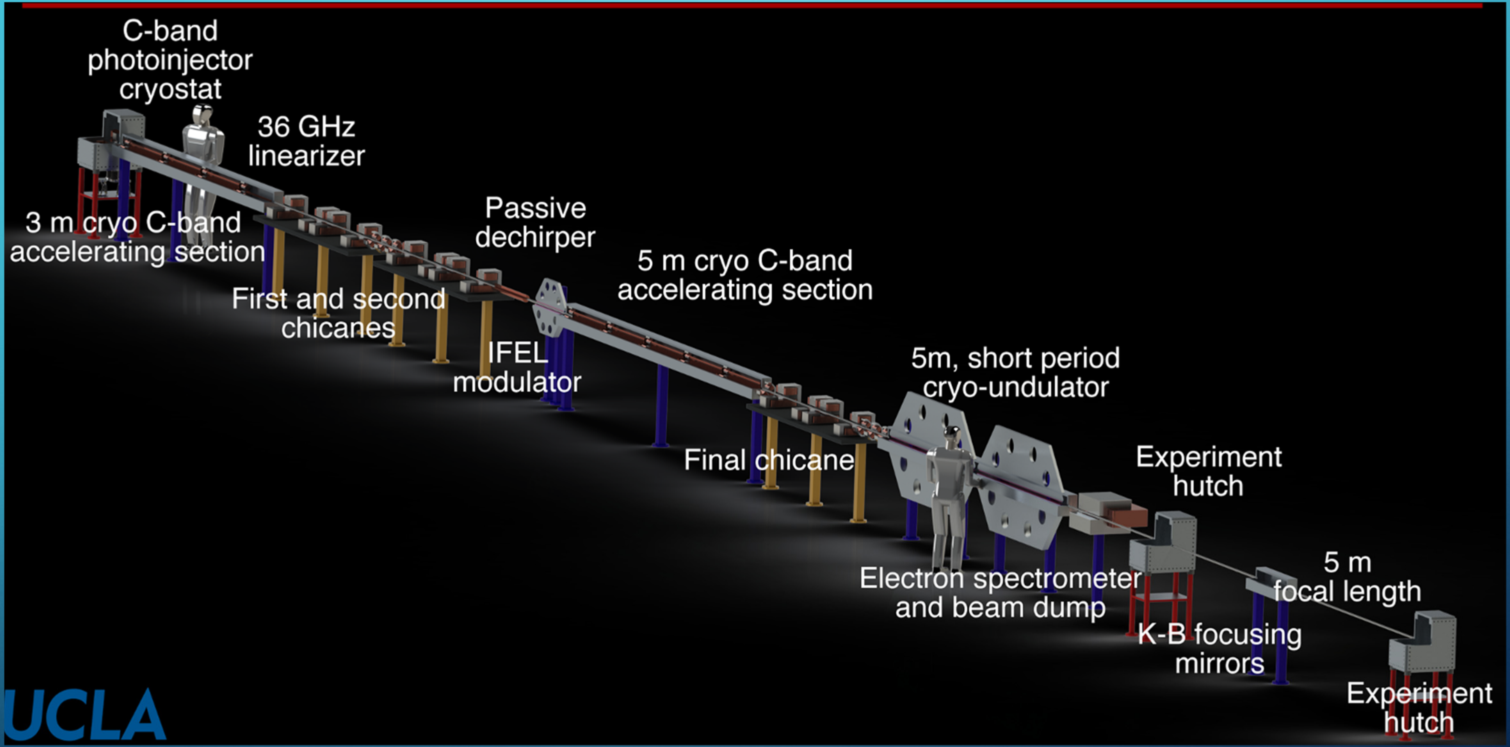
Argonne Leadership Computing Facility (ALCF)

- We have allocation at Theta and ThetaGPU for this experiment.
- We establish connection from a computer in the control room at BNL to ALCF.
- We allow users to train / do inference with the model using ALCF resources for near-real time results (training on single GPU ~ 12 sec/epoch).
- This is as simple as running a Jupyter notebook (for inference) and we already have custom built code for analysis and instrumental diagnostics.

UNM, Element Aero, BNL, LANL, Argonne

DOE Funded

COMPACT XFELS
UC-XFEL

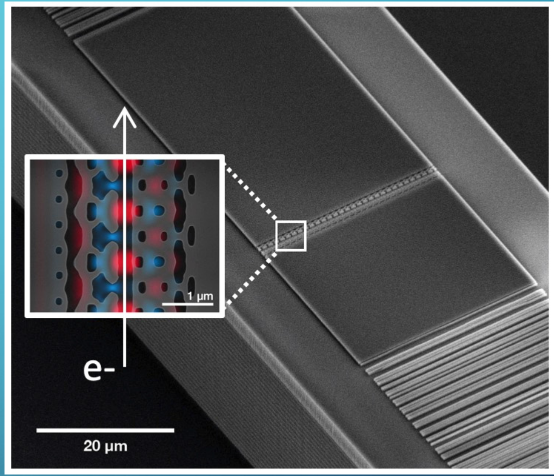


Smaller, cheaper, to meet the gap of access

Courtesy UCLA

COMPACT ACCELERATORS

- Joel England's talk discussed the large team that was funded by DOE (lab) and the Gordon and Betty Moore Foundation (NFP) and has participants from
- Universities (Stanford University, Purdue, Erlangen, TU Darmstadt, UCLA, Tel-Aviv University, Techion;
- Industry: Tech-X
- Labs: SLAC, DESY, PSI, LLNL



N. Sapra, et al., Science **367**, 6473 (2020)

Accelerator on a Chip: Various Applications for Dielectric Laser Accelerators are Now Being Explored

SLAC

Application	Field	Time-Scale	Kinetic Energy	Species	Beam Power
Radiobiology, Endoscopic RT	Medical	5 yrs	100 keV to 10 MeV	e-	1-5 mW
UED/UEM and Attosecond Science	Science	5 yrs	1-5 MeV	e-	10 to 50 μW
Radiation Sources (EUV, IR, THz)	Industry	5-10 yrs	10 to 100 MeV	e-	0.5 W
Compton X-ray Source	Medical	5-10 yrs	10 to 60 MeV	e-	20 to 60 mW
Proton/Hadron Therapy	Medical	10-20 yrs	70 to 250 MeV	p+	3-400 mW
Compact XFEL	Science	10-20 yrs	1 GeV	e-	1.5 kW
Multi-Axis Tomography	Science	10-20 yrs	1 GeV	e-	1.5 kW
Colliding Beam Fusion	Industry	20+ yrs	15 keV to 1 MeV	p+	1 MW
Linear Collider	HEP	20+ yrs	1 to 10 TeV	e-/e+	10 to 200 MW

Near term applications in attosecond and quantum information science are well matched to DLA performance (ultrafast, low charge, high rep).

1

Courtesy Joel England, SLAC

PARTICLE ACCELERATORS FOR QUANTUM

IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received December 2, 2021, accepted January 2, 2022, date of publication February 2, 2022, date of current version February 8, 2022.
Digital Object Identifier 10.1109/ACCESS.2022.3147727

Artificial Intelligence-Assisted Design and Virtual Diagnostic for the Initial Condition of a Storage-Ring-Based Quantum Information System

BOHONG HUANG[1], CLIO GONZÁLEZ-ZACARÍAS[2], SALVADOR SOSA GÜITRÓN[3], (Member, IEEE), AASMA ASLAM[3], (Graduate Student Member, IEEE), SANDRA G. BIEDRON[3,4,5], (Senior Member, IEEE), KEVIN BROWN[6,7], (Senior Member, IEEE), AND TRUDY BOLIN[3,5]
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[2]Department of Electrical and Computer Engineering, University of Southern California, Los Angeles, CA 90007, USA
[3]Electrical and Computer Engineering Department, The University of New Mexico, Albuquerque, NM 87106, USA
[4]Mechanical Engineering Department, The University of New Mexico, Albuquerque, NM 87106, USA
[5]Element Aero, Chicago, IL 60643, USA
[6]Department of Electrical and Computer Engineering, Stony Brook University, Stony Brook, NY 11794, USA
[7]Collider Accelerator Department, Brookhaven National Laboratory, Upton, NY 11973, USA
Corresponding author: Bohong Huang (bohong.huang@stonybrook.edu)

This work was supported in part by the U.S. Department of Energy for the management and operation of the Brookhaven National Laboratory (BNL) under Contract DE-SC0012704, and in part by the Argonne Leadership Computing Facility, a DOE Office of Science User Facility, under Contract DE-AC02-06CH11357.

One example:

Sometimes it is not about hardware or a method, but need computing to be the disruptive technology.

Mostly about (classical) computing being the enabler.

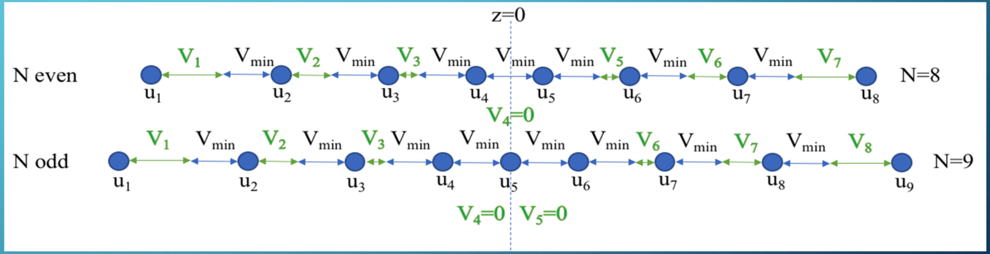
MOTIVATION FOR ML ALGORITHMS

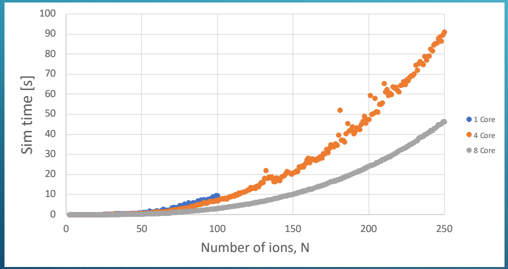
- We are interested on a chain with a large number of ions.
- The numerical calculation quickly becomes impractical for large *N*.
- This problem can be formulated in terms of the minimum separation between ion.
  - This reduces the numbers of variables

Table 1. Scaled equilibrium positions of the trapped ions for different total numbers of ions [a]

N	Scaled equilibrium positions									
2	−0.62996	0.62996								
3	−1.0772	0	1.0772							
4	−1.4368	−0.45438	0.45438	1.4368						
5	−1.7429	−0.8221	0	0.8221	1.7429					
6	−2.0123	−1.1361	−0.36992	0.36992	1.1361	2.0123				
7	−2.2545	−1.4129	−0.68694	0	0.68694	1.4129	2.2545			
8	−2.4758	−1.6621	−0.96701	−0.31802	0.31802	0.96701	1.6621	2.4758		
9	−2.6803	−1.8897	−1.2195	−0.59958	0	0.59958	1.2195	1.8897	2.6803	
10	−2.8708	−2.10003	−1.4504	−0.85378	−0.2821	0.2821	0.85378	1.4504	2.10003	2.8708

D.F.V. James, Appl. Phys. B 66, 181-190 (1998)

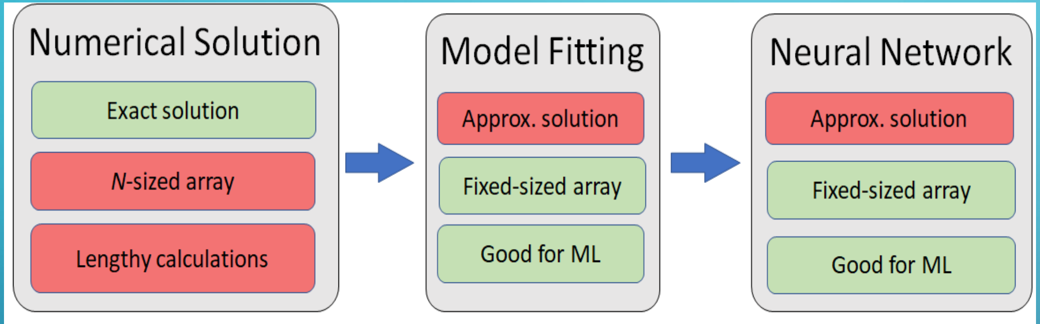




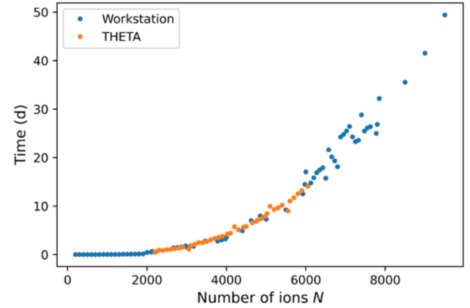
We implement **ML algorithms for rapid calculation** *in lieu* of numerical calculation for design, operation and control.

RAPID CALCULATION OF THE EQUILIBRIUM STATE WITH NN

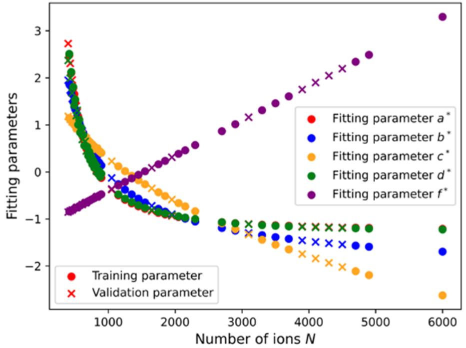
- The numerical solution of the equilibrium position of an ion chain is computationally expensive with increasing *N*.
- A NN approach:



- Approximate the solution given a discrete number of numerical solutions.
- Train a NN to predict the fitting parameters for solutions that have not been determined numerically.
- Reduced computation time at the cost of an approximation error.



Numerical computation quickly becomes prohibitive with increasing *N*.



Use an approximated model with a few fitting parameters. Train on the fitting parameters.

B. Huang *et al.*, in *IEEE Access*, vol. 10, 2022, doi: 10.1109/ACCESS.2022.3147727.

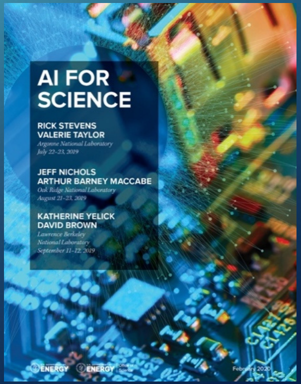
DISRUPTIONS

"Digital twins" reference transformational approaches for expanding optimization to include an entire manufacturing lifespan, from raw materials to shape/topology to manufacturing process to end use

- Can perform information fusion from disparate sources
- Coupling real-time data with models (e.g., a "digital twin")
- AI-driven, real-time intelligence
- Surrogate models could form the basis for digital twins that guide design and operation.

Report on the Department of Energy (DOE) Town Halls on Artificial Intelligence (AI) for Science, February 2020

The combination of machine hardware, advanced computing for simulation, and data science for surrogate modelling, training of neural networks and data analysis is inspired by our past work and our participation on DOE meetings, workshops and reports such as AI for Science (*https://www.anl.gov/ai-for-science-report*).



Center for
BRIGHT BEAMS
A National Science Foundation Science & Technology Center

Center Vision:

Gain the fundamental understanding needed to transform the brightness of beams available to science, medicine and industry.

Science, technology, workforce, and knowledge transfer deliverables.

Courtesy of Ritchie Patterson, Cornell

Gaining the fundamental understanding needed to increase the brightness of electron beams

COLLABORATORS

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[U New Mexico](#)
Sandra Biedron

[Arizona State](#)
Siddharth Karkare

[U Florida](#)
Richard Hennig

Courtesy of Ritchie Patterson, Cornell

Knowledge Transfer

A few of our industry partners:

Thermo Scientific; CEOS Corrected Electron Optical Systems GmbH	High brightness guns and tuning algorithms for TEM and SEM.
Ultramet Advanced Materials Solutions	High gradient SRF cavities
RadiaBeam Technologies	RF gun load-lock. Compton sources.
Star Cryoelectronics	MgB_2-coated SRF cavities for nuclear physics
IDES Integrated Dynamic Electron Solutions; JEOL Solutions for Innovation	Ultrafast electron microscopes and diffraction systems
Niowave	High Q superconducting linacs
KLA Keep Looking Ahead	Bright sources for faster wafer inspection.
Tech-X	Photocathode simulation

Courtesy of Ritchie Patterson, Cornell

Sampler of Lab Collaborations

Lab(s)	Collaboration	Lab(s)	Collaboration
SLAC National Accelerator Laboratory	X-ray FEL source optimization (LCLS-II HE)	Fermilab; Jefferson Lab; SLAC National Accelerator Laboratory	SRF for X-ray FEL (LCLS-II HE)
Fermilab; Jefferson Lab	SRF for International Linear Collider cost reduction	Berkeley Lab	Electron sources and emittance diagnostics
SLAC National Accelerator Laboratory; Argonne National Laboratory	Advanced techniques for accelerator tuning	Argonne National Laboratory	SRF coatings
Brookhaven National Laboratory	CBB-improved SRF for NSLS-II X-ray source	Fermilab	Advanced optics

Courtesy of Ritchie Patterson, Cornell

SUSTAINABILITY

CHECK FOR SAFETY, FIX ONLY WHAT IS NEEDED TO BE FIXED

First Bridge Inspection by 3.95MeV X-ray Source in Japan on October 26, 27, 2018

NHK World News - Science View – on November 21, 2018

Courtesy Mitsuru Uesaka, worked performed at the University of Tokyo

SUSTAINABILITY

Energy & Environmental Accelerator Applications

POSSIBLE WITH CURRENT TECHNOLOGY

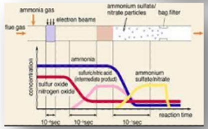
1. **Treating the sludge for a city of 100,000:** — 1.2 kW
   - 7 tons/day @ 10 kGy (per 40 CFR 503); *Cost $70/dry ton (CC: $100-300/dt)*
   - Class-A sludge can then be used as fertilizer in many states; methane yield increases with irradiation
2. **Treating the regulated medical waste for 10 cities of 100,000 ea:** — 5 kW
   - 5 tons/day @ 50 kGy; *Cost: 4¢/pound (CC: 18¢/pound)*
3. **Sterilize water & medical waste at a WHO emergency site of 500 people:** — 33 kW (P)
   - 100 gal/person/day → 0.05 MGD = 2.1 kg/s @ 10 kGy
   - 200-bed hospital ⇔ 1000 lbs of RMW/day ⇔ .01 kg/s @ 50 kGy; *Cost: $1,500/day*
4. **Sterilizing U. S. Government Mail** — 130 kW
   - New Jersey facility 5 MeV x-rays/10 MeV electrons
5. **Treating the power plant SOX/NOX emissions for a city of 100,000:** — 150 kW
   - 3300 MW-hr/day from coal ⇔ @ 9 kGy [SOX↓95%, NOX↓70%];
   - Process byproduct is 17 tons/day of high-grade fertilizer; *Cost: 0.12 ¢/kW-hr (CC: 0.27 ¢/kW-hr)*

NOT POSSIBLE WITH CURRENT TECHNOLOGY

6. **Upgrading heavy crude oil at a single wellhead** — 550 kW
   - 500 BBL/day @ 500 kGy (cf. thermal refining requires ~2 MGy); *Cost: $11/barrel (CC: $5/barrel)*
7. **Treat entire industrial effluent stream of DuPont Circleville, OH Plant** — 1.3 MW
   - 0.9 MGD @ 25 kGy; *Cost: $3/m³ (CC: $0.30-0.70/m³)*
8. **Hardening 3 lane-miles per day of interstate highway:** — 1.4 MW (P)
   - 2 cm depth @ 100 kGy dose; *Cost: $14k/lane-mile (resurface CC: $310k/l-m)*
9. **Emergency water treatment for Elk River, WV MCHM spill (2014)** — 2.4 MW (P)
   - 5 gal/person/day, 300,000 people, @ 25 kGy; *Cost: $5/m³ (trucked-in: $13/m³)*
10. **Cleaning up an oil drilling site in two weeks:** — 3.5 MW (P)
    - Treating soil within 50m radius to depth of 0.5 m
    - 6,300 tons/2 weeks @ 500 kGy; *Cost: $0.6M/cleanup site (haul-away cost: $1.1M)*
11. **Treating entire domestic water supply for a city of 100,000:** — 6.3 MW
    - 100 gal/person/day → 10 MGD @ 10 kGy; *Cost: $0.65/m³ (CC: Chlorine: 9¢/m³ Desalination: $1.25/m³)*

1.


4.


5.


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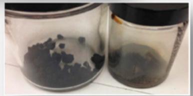

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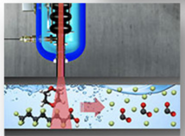


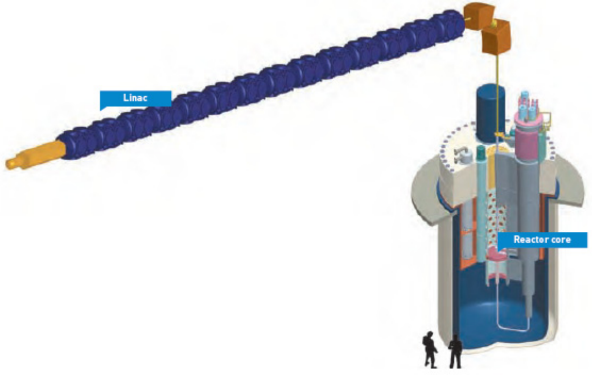
U.S. DEPARTMENT OF ENERGY | Office of Science

N.B. Cost estimates are approximate.
CC= current cost of existing process

(P) – portable system required

Slide courtesy of Eric Colby, DOE
Note:
Community input

SUSTAINABILITY



The MYRRHA research reactor in Belgium will test accelerator-driven systems for nuclear power generation.

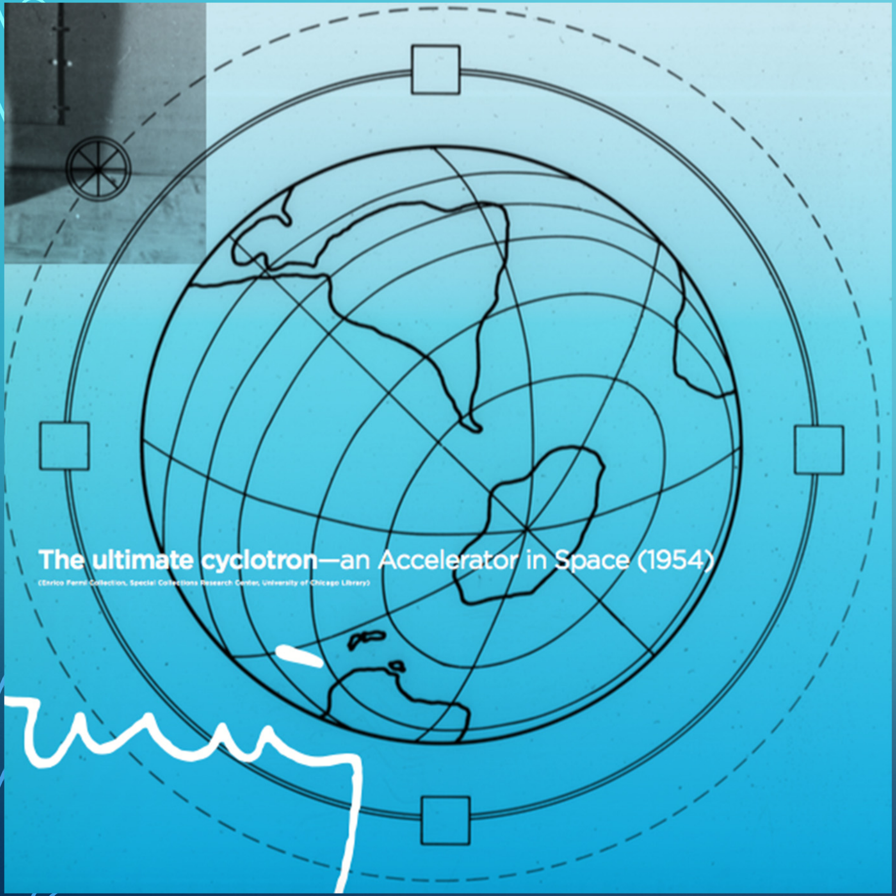
Proton accelerators to drive nuclear power plants or transmute nuclear waste into shorter lived, more manageable by-products.

Accelerator-driven Nuclear Energy

(Updated August 2018)

- Powerful accelerators can produce neutrons by spallation.
- This process may be linked to conventional nuclear reactor technology in an accelerator-driven system (ADS) to transmute long-lived radioisotopes in used nuclear fuel into shorter-lived fission products.
- There is also increasing interest in the application of ADSs to running subcritical nuclear reactors powered by thorium.

DISRUPTIVE TECHNOLOGIES START WITH COLLABORATION



Accelerator encompassing Earth

Maybe Enrico Fermi actually meant by his accelerator encompassing the Earth idea that accelerators (and other analytical research tools) would in a figurative way encompass the Earth.

We need the people and collaborations and combining of resources to be disruptive to drive us to disruptive technologies.

Figure courtesy University of Chicago

THE UNIVERSITY OF MELBOURNE

Impact of disruptive accelerator technologies on human health

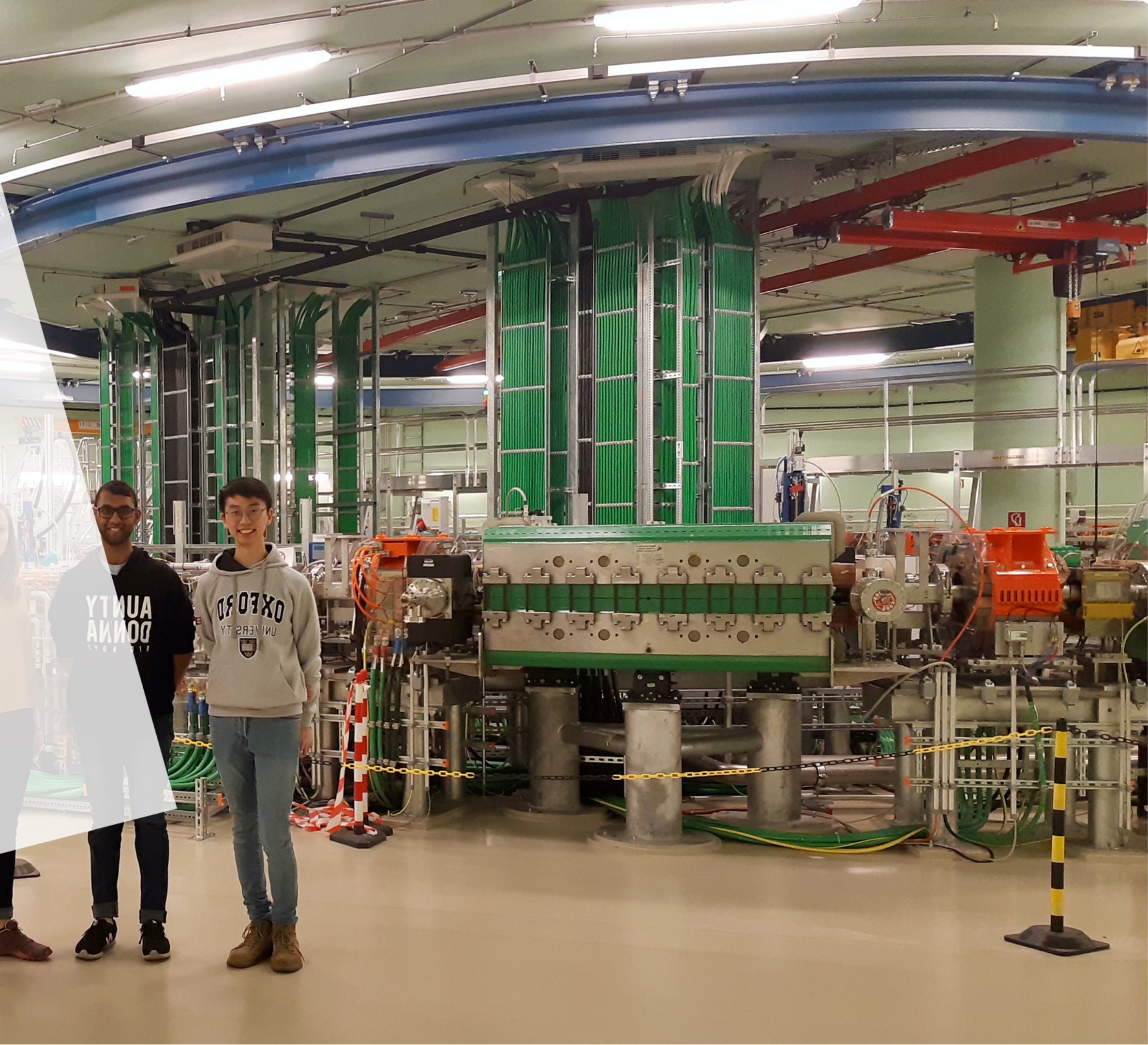
– Industry Session, IPAC22

Dr. Suzie Sheehy

Senior Lecturer, University of Melbourne

Baker/ANSTO Fellow in Medical Accelerator Physics

@suziesheehy



What is a disruptive technology?

Clayton Christensen introduced the idea of disruptive technologies in a 1995 Harvard Business Review article*.

*“**sustaining** technologies tend to* **maintain a rate of improvement**; that is, they give customers something more or better in the attributes they already value”

“Disruptive technologies introduce a different attributes from the mainstream … and **often perform far worse along one or two dimensions** that are particularly important to those customers.

As a rule, mainstream customers are **unwilling to use a disruptive product in applications they know and understand.**

At first, disruptive technologies tend to be used and valued only in new markets or new applications; in fact, they generally make possible the emergence of new markets.

*https://hbr.org/1995/01/disruptive-technologies-catching-the-wave

Disruptive technologies

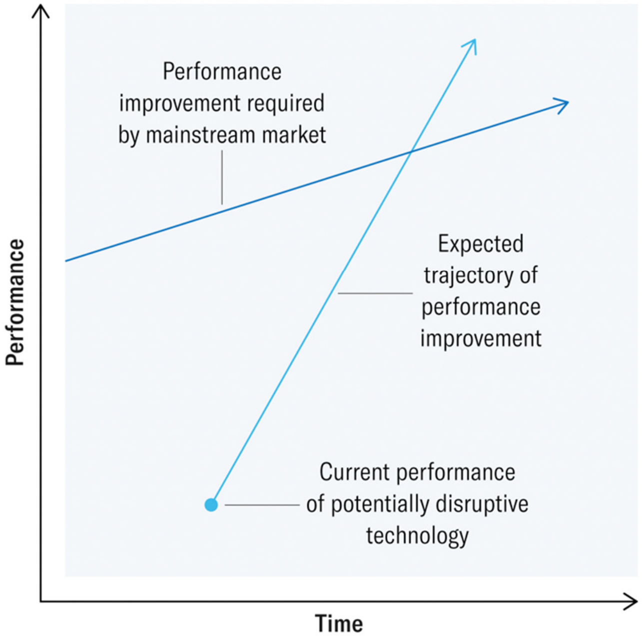
Innovation/technology that:

"displaces an established technology and shakes up the industry"

or

"a ground-breaking product that creates a completely new industry"

How to Assess Disruptive Technologies

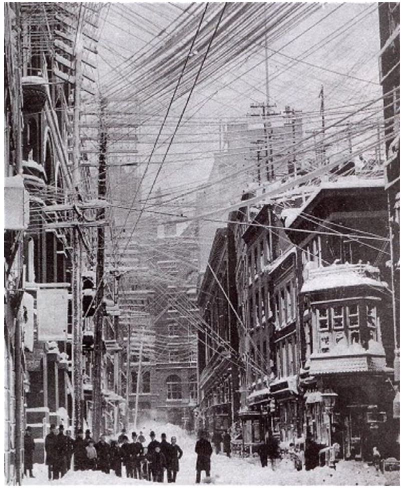


HBR

Some examples in other industries

Automobile, electricity service, and television were all disruptive.

More recent examples include: personal computers, online news sites, ride-sharing apps, and GPS systems.

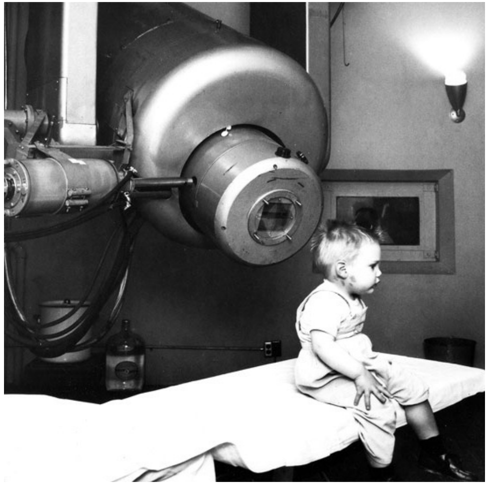


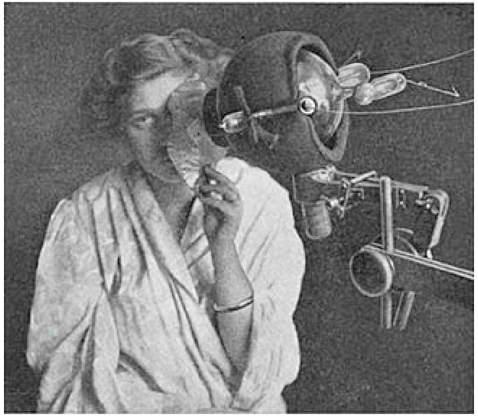
Sweeps away the systems or habits it replaces because it has attributes that are recognizably superior.

Examples from accelerator technology: Radiotherapy

S-band linear accelerator technology:

- Recognisably superior technology: *displaced existing*
- ~40% of successfully cured patients use radiotherapy

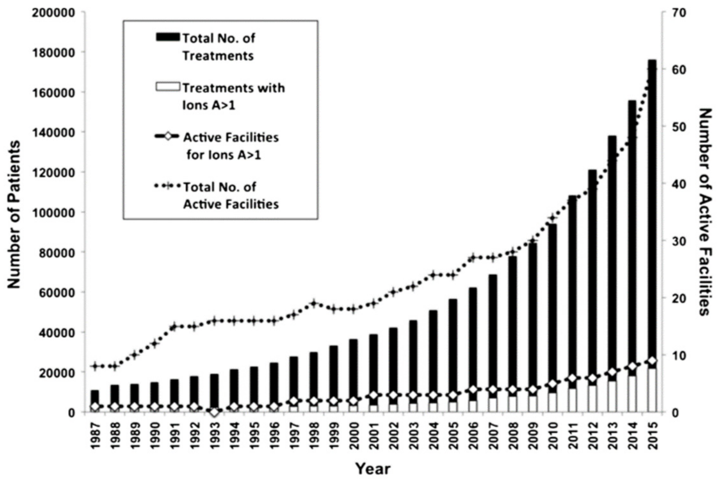




Examples from accelerator technology: Hadron therapy

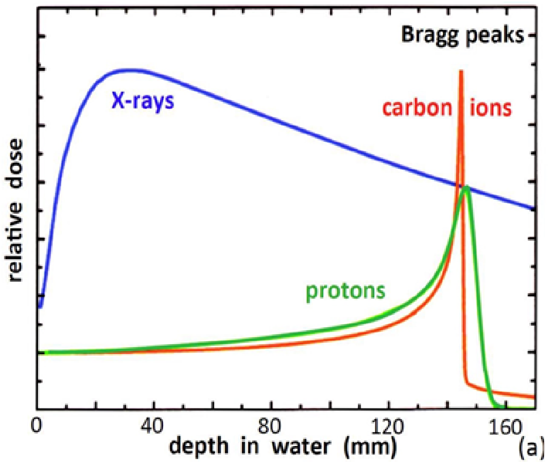
- Recognisably superior outcomes, created a *new market*

    Despite costing more than RT!



BUT remains a niche in cancer therapy:

- 22,000 patients/year (2018) treated with particles
- vs 25,000,000 patients/year with conventional RT



Disruptive accelerator technologies

Could have the following features:

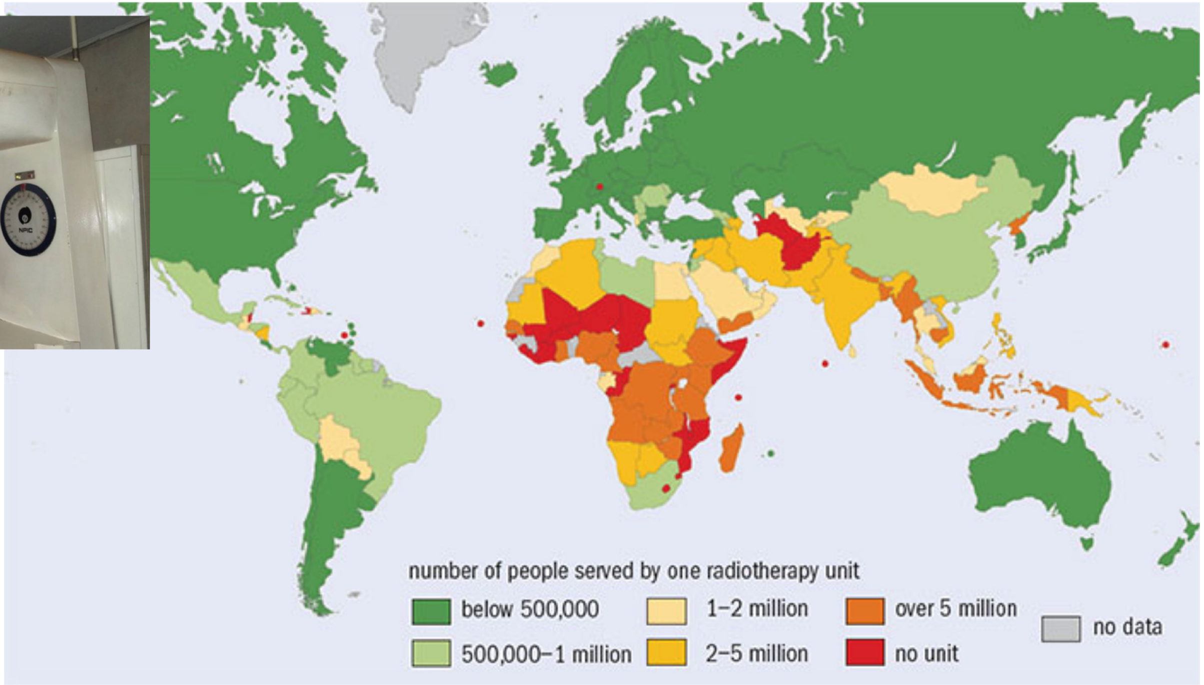
1. Displace existing due to obviously superior capabilities
2. New treatments or capabilities: a new ‘must-have’
3. Reach new markets that are ‘under-served’

I will focus mostly on beam therapies, not covered: radioisotopes, medical sterilization, medical imaging or major facilities medical applications

Radiotherapy: the *robust* frontier

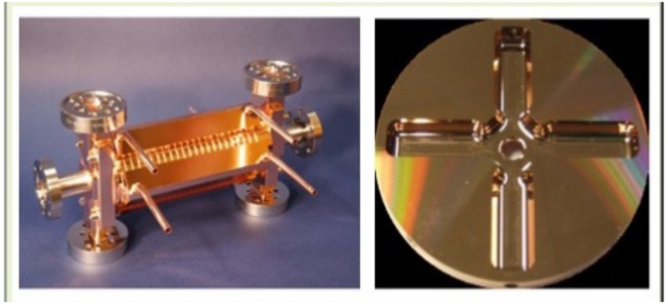
See Manjit Dosanjh's talk FRIDAY (this conference)

Potential *new* markets by creating products where existing solutions are not working

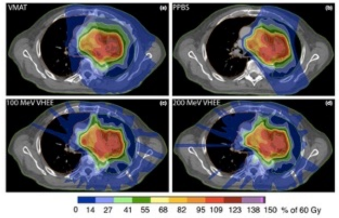


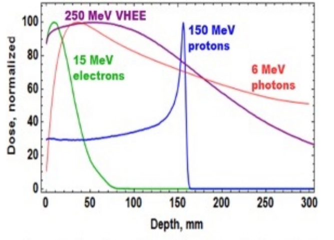
FLASH: electrons or protons/ions

- Higher dose rate/beam current
- Superior biological effect (?)
- Could ‘speed up’ radiotherapy from 25 fractions to (potentially) 1-2



Very High Energy Electron (VHEE) therapy to complement existing X-ray, proton, and ion therapy. Use 250 MeV electron beam to treat tumors.





Dose profiles for various particle beams in water (beam widths $r = 0.5$ cm)

E.g. X-band compact electron accelerators, and cooled copper structures

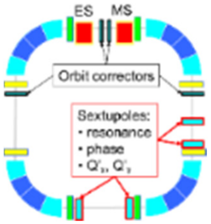
In hadron therapy:

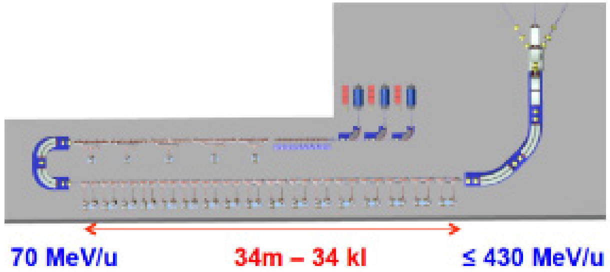
Smaller/cheaper/faster
Accelerators + beam delivery

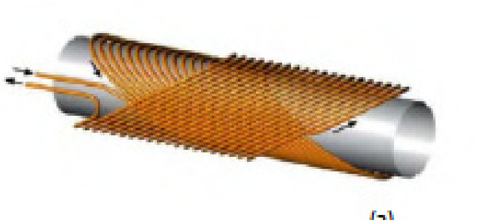
Superconducting technology:
- lower energy consumption,
- smaller footprint

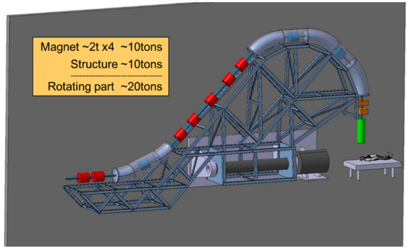
- Multi-ion optimisation
- Spatially structured beams

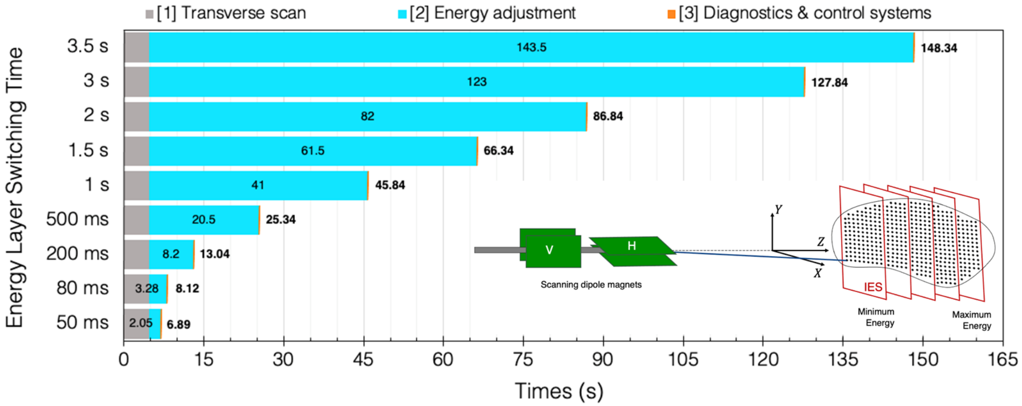
MRI-guided proton/ion therapy











Yap J, De Franco A and Sheehy S (2021) Front. Oncol. 11:780025.

Advanced ‘novel’: Laser-Plasma Accelerators

High dose rate

Electrons AND ions

“the use of LWFA can be meaningful only if the parameters of the electron beams are advantageous compared to what is achieved using conventional accelerator technology.”
– Albert et al. 2021

“When it comes to medical applications, LWFA electron beams do have unique properties over conventional sources: they not only provide very short bunches, but also dose rates as high as 10^9 Gy s^{-1}. Therefore, LWFA could be particularly relevant for the field of radio-biology.
– Albert et al. 2021

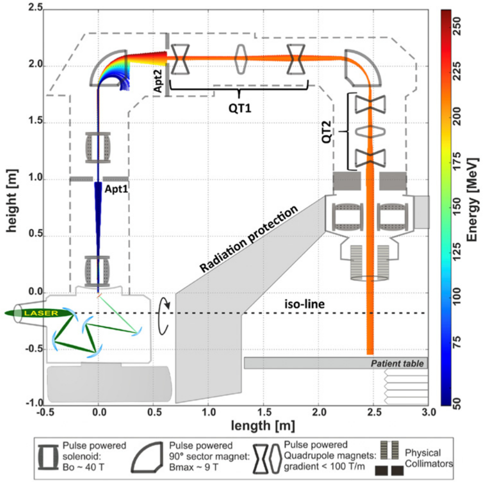


Figure 6. The figure shows the schematic design of the 360° rotatable gantry with laser target chamber and patient treatment site. For a compact arrangement, the idea

Félicie Albert *et al* 2021 *New J. Phys.* **23 031101

U Masood et al 2017 Phys. Med. Biol. **62** 5531

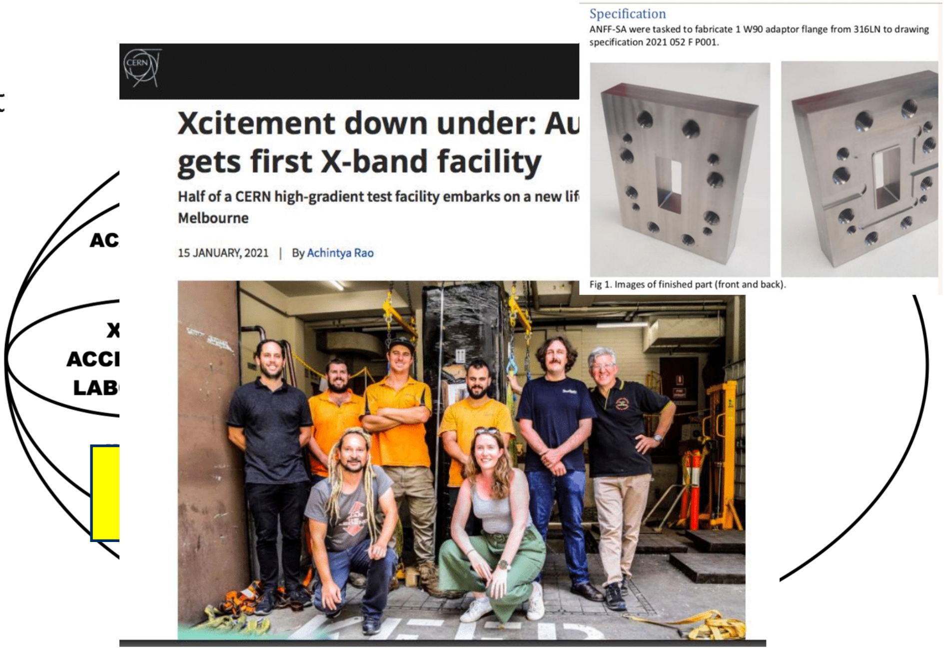
To create disruption, needs an ‘eco-system’

Example: Australia

Now entering a new era for accelerator development and applications, including **new activity in medical accelerators**, space technologies, and advanced materials development.

We are re-launching an existing national-scale collaboration in accelerator science ACAS: Australian Collaboration for Accelerator Science **with industry members as a core players**. (Best advice for us?)

New laboratory (X-LAB), developing industrial partnerships to enable translation of technologies.



Thoughts for industry session

Accelerators have had a dramatic impact on human health. They could do so further in future:

- Are we over-focused on trying to ‘disrupt’ existing markets in medical technologies (e.g. hadron therapy), rather than creating NEW markets?

- How can countries (like Australia, but others too) learn from those who have well established academic/lab/industry connections?

- Disruptive innovation requires dedicated effort/expertise, how to balance this against more ‘traditional’ publication demands especially in academic setting?

THE UNIVERSITY OF MELBOURNE

Thankyou

Dr. Suzie Sheehy
suzie.sheehy@unimelb.edu.au
@suziesheehy

Pictured: X-LAB pre-renovation at University of Melbourne (Photo: M. Volpi)

Conclusion

- Develop awareness of how important particle accelerator technology is to industry
- Building bridges between science and industry to enable future innovation and future science programs.
- New applications are appearing that might considerably expand the particle accelerator market and provide interesting opportunities for companies in the accelerator technology market.
- Have an annual IPAC technology transfer and partnership award open to nominations for industry as well as teams (e.g. industry, labs, academia, government). Each person on the team would receive a plaque presented in the awards session.
- The committee would be led by an industry person with a mixture of industry, labs, academics, NFPs, and government persons.
- Have a small workshop as part of the conference with subject areas of discussion for sparking collaboration.
- Foster the submission of scientific papers from Industry - there are lots of scientists working in the companies!
- A message to Industry: foster Industry aggregations/cooperation/consortia etc. which include start-up and SME.
- Promote diversity not only in terms of gender and minorities but including different educational backgrounds, essential for the development of new models of collaboration, innovation and business.

IPAC as a booster of a new style of the Industry Session, to foster the integration between labs and companies with concrete actions?

A wishful thinking or a valuable reality?