Accelerators for Society

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PAUL SCHERRER INSTITUT

Plenary ECFA, CERN, November 15, 2018

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

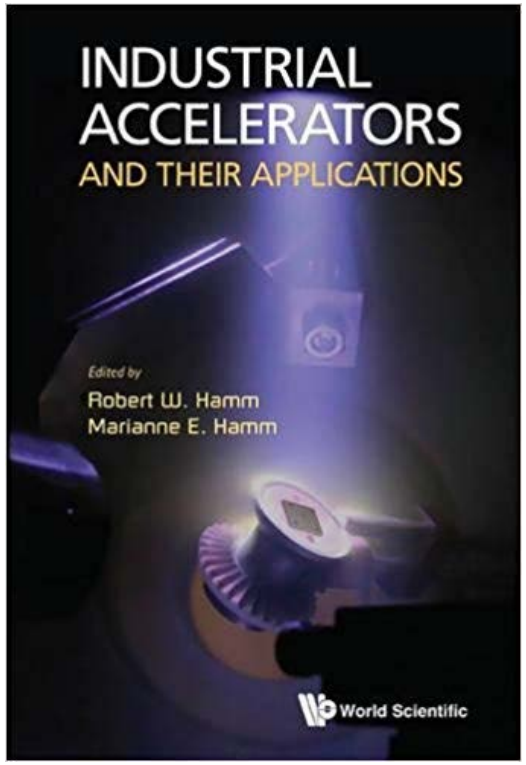
Accelerator driven applications to meet the needs of society

- Advanced instruments for basic and applied science
- Analysis of physical, chemical and biological materials
- Modification of physical, chemical and biological properties of matter
- Medical: diagnostics, treatment and targeted drug design
- Security: cargo scanning, IT hardware
- Environment
- Energy

Applications of Accelerators: some sources of information

http://apae.ific.uv.es/apae/

http://www.accelerators-for-society.org/

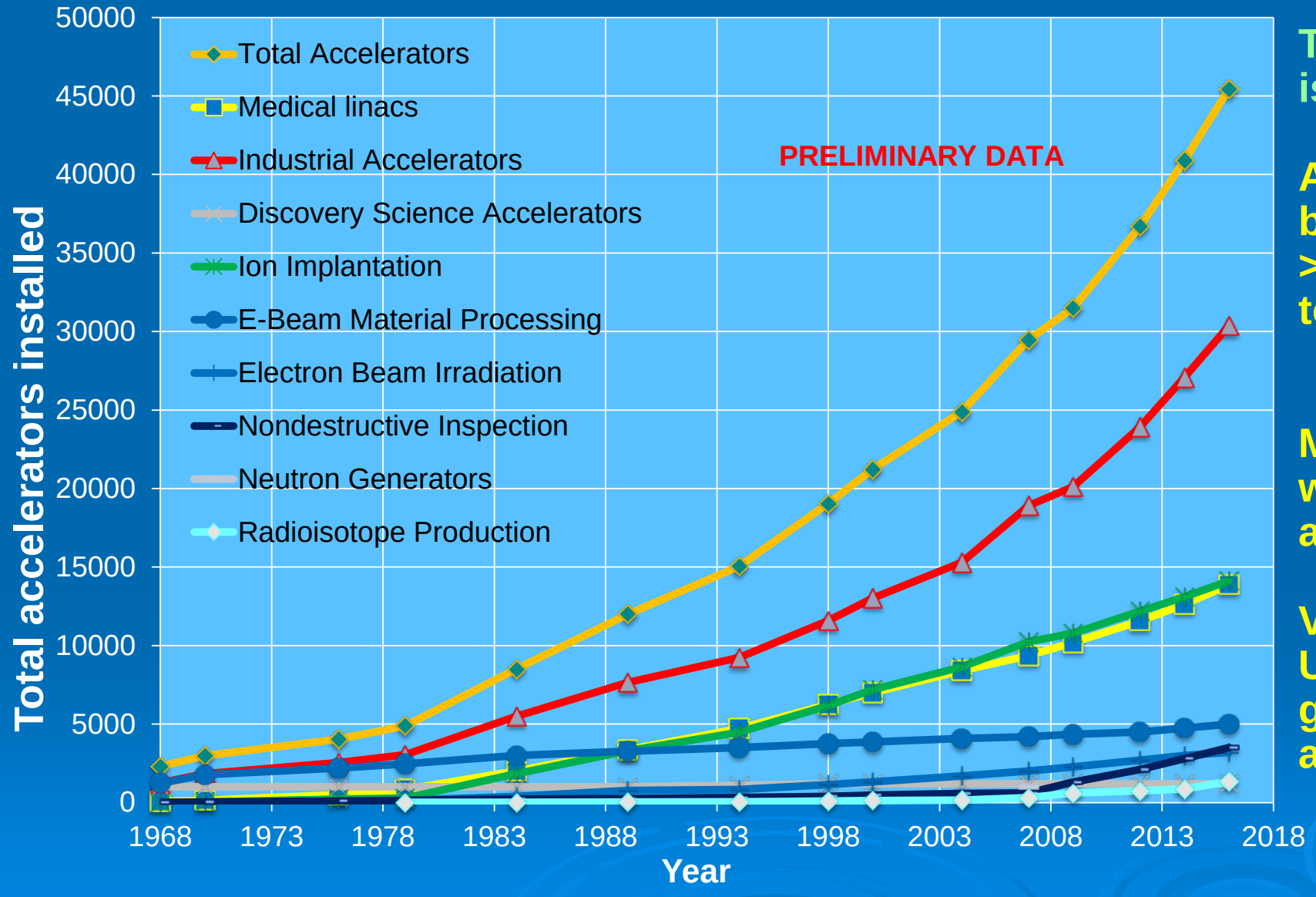


http://www.acceleratorsamerica.org/index.html

A beam of particles is a very useful tool.
A beam of the right particles with the right energy at the right intensity can shrink a tumor, produce cleaner energy, spot suspicious cargo, make a better radial tire, clean up dirty drinking water, map a protein, study a nuclear explosion, design a new drug, make a heat-resistant automotive cable, diagnose a disease, reduce nuclear waste, detect an art forgery, implant ions in a semiconductor, prospect for oil, date an archaeological find, package a Thanksgiving turkey
or
discover the secrets of the universe

From the Report "Accelerators for America's Future", US Department of Energy, 2010

Accelerators Installed Worldwide



Total sales of accelerators is ~US$5B annually

About 47,000 systems have been sold,
> 40,000 still in operation today

More than 100 vendors worldwide are in the accelerator business.

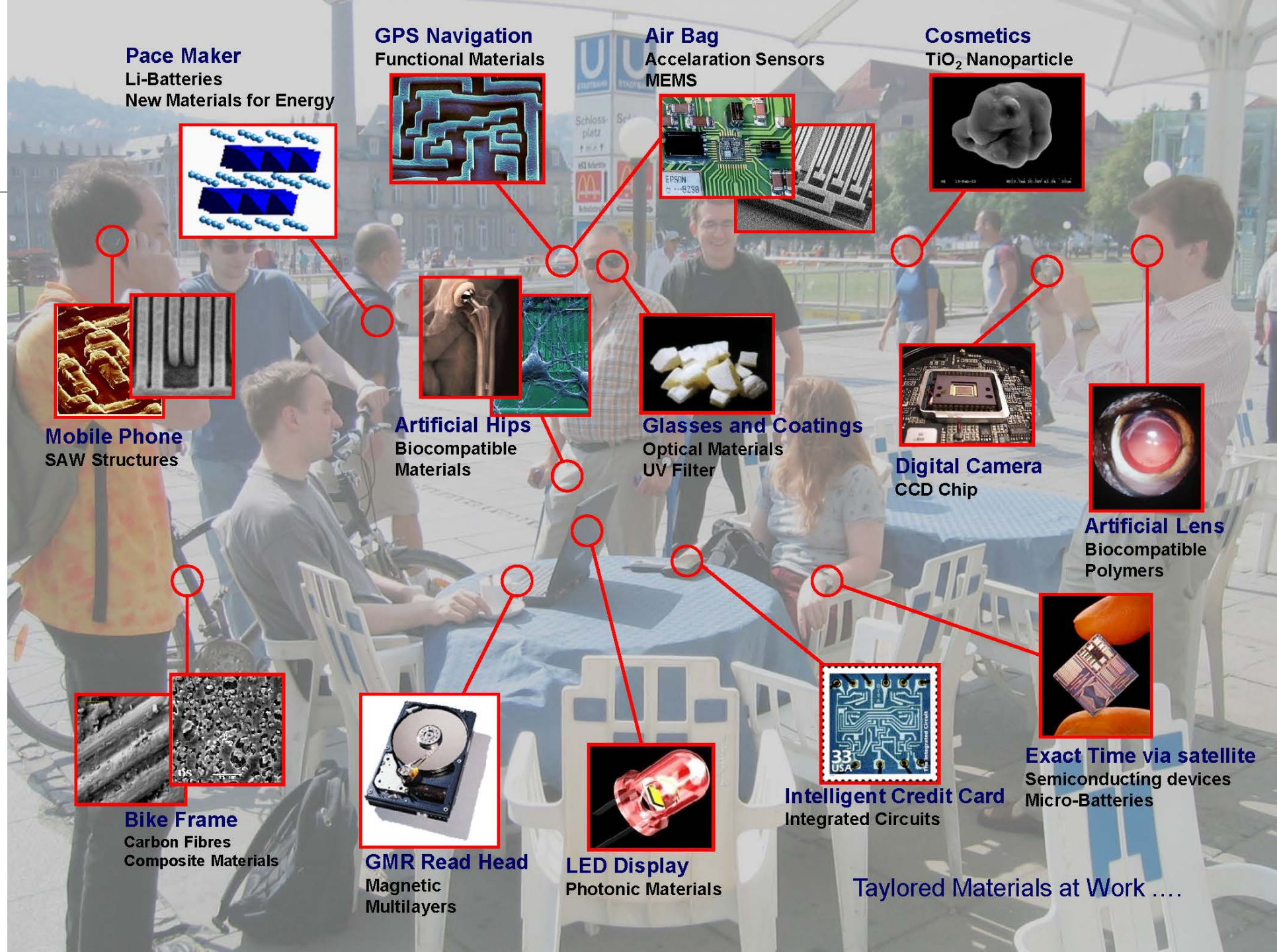
Vendors are primarily in US, Europe and Japan, but growing in China, Russia and India

Materials

Modern day materials

Accelerators had an impact on a wide range of materials

Modern day materials



Accelerators: Essential Tools in Industry

Ion Implantation

- Accelerators can precisely deposit ions modifying materials and electrical properties (boron, phosphorus)

Semi Conductors

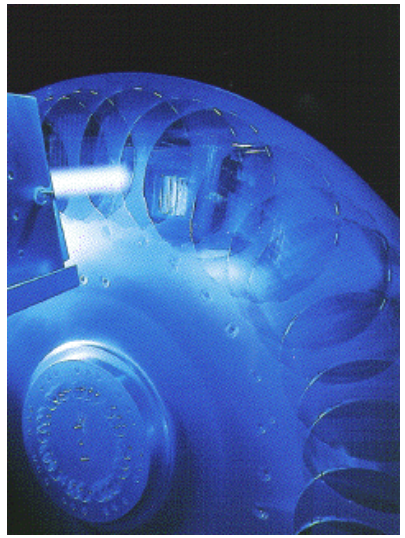
- CMOS transistor fabrication of essentially all IC's
- CCD & CMOS imagers for digital cameras
- Cleaving silicon for photovoltaic solar cells
- Typical IC may have 25 implant steps

Metals

- Harden cutting tools
- Reducing friction
- Biomaterials for implants

Ceramics and Glasses

- Harden surfaces
- Modify optics
- Color in Gem stones!



N2 ions reduce wear and corrosion in this artificial femur

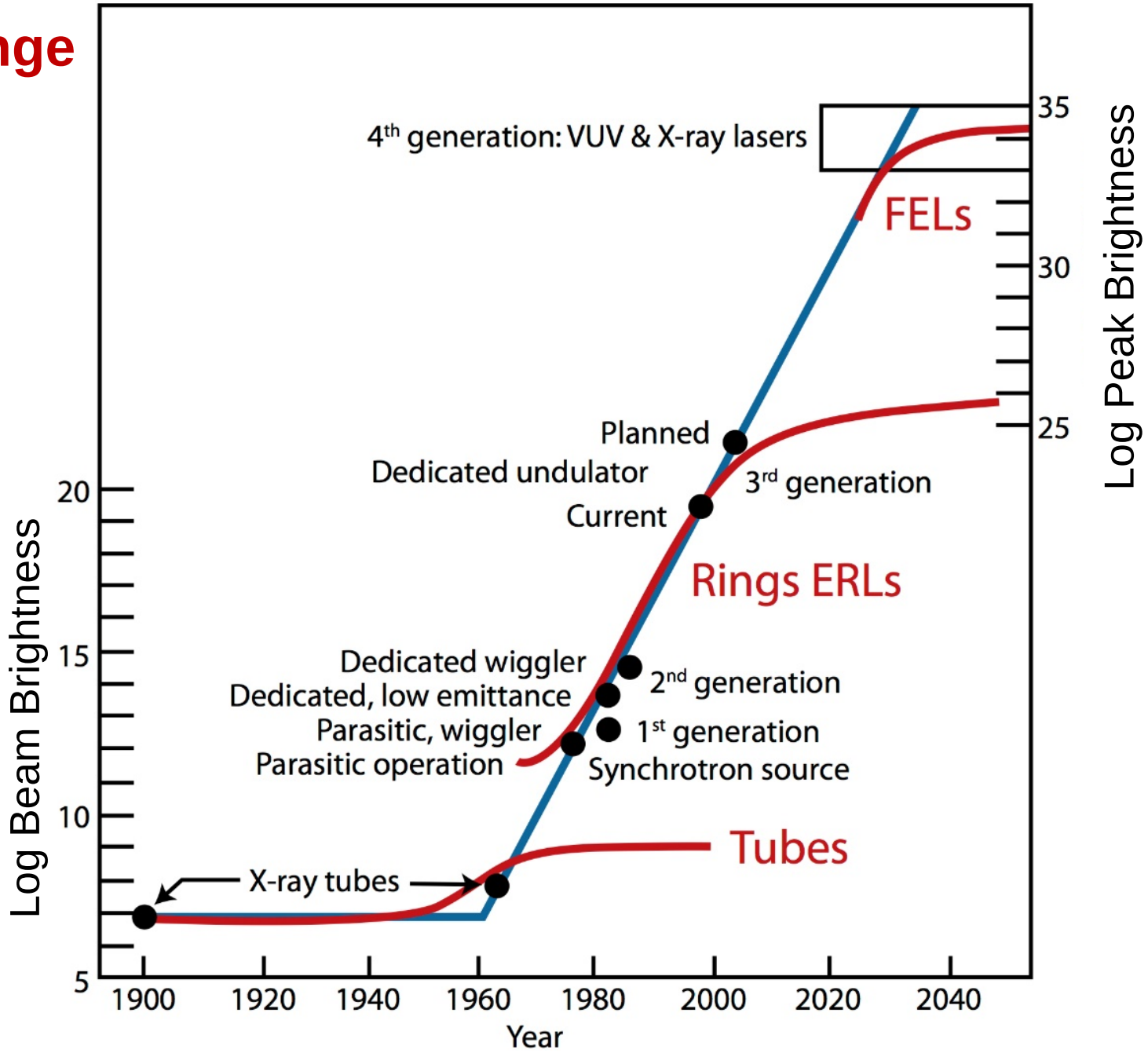
Easter morning 1900: 5th A
the automobile.

Easter morning 1913: 5th Ave, New York City.
Spot the horse.

Light sources

Brightness: disruptive change

- X-ray Tubes
- Storage Rings
- FELs
- ? Compact sources ?



Synchrotron Light Sources: about 50 storage ring based

60‘000 users world-wide

Established, mature technology

Australian Synchrotron

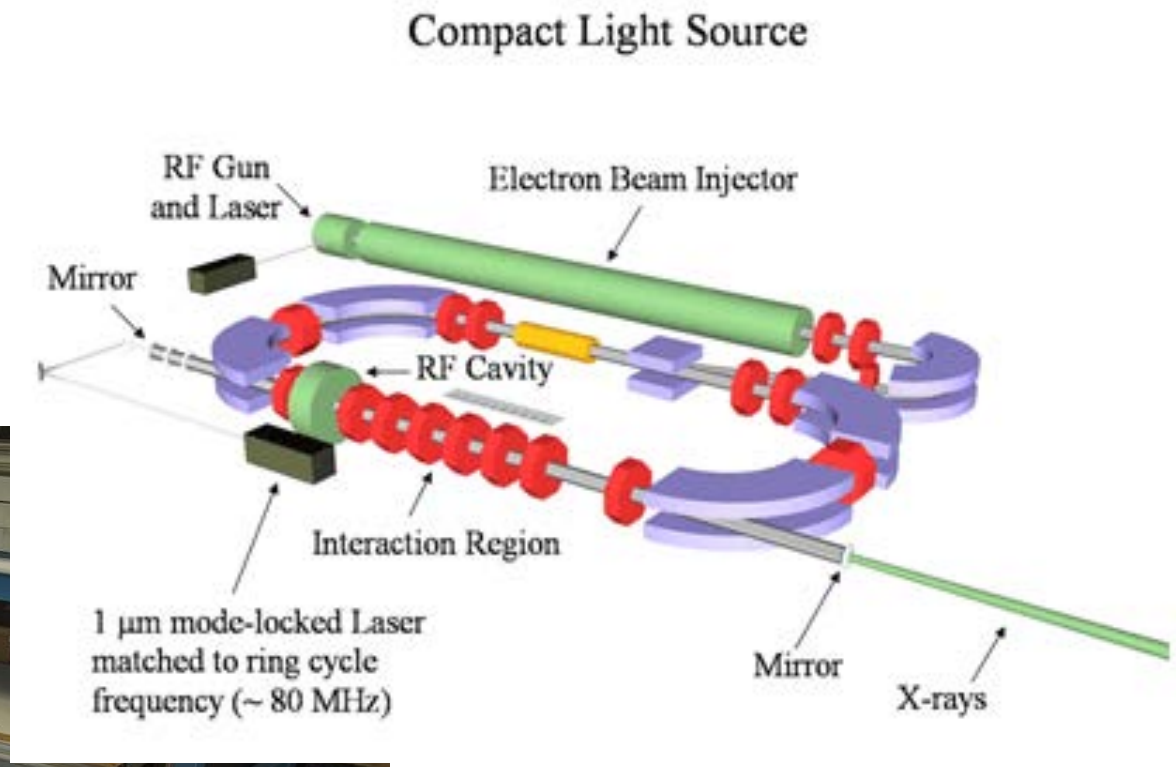
- The Australian Synchrotron produces powerful beams of light that are used at individual experimental facilities to examine the molecular and atomic details of a wide range of materials.

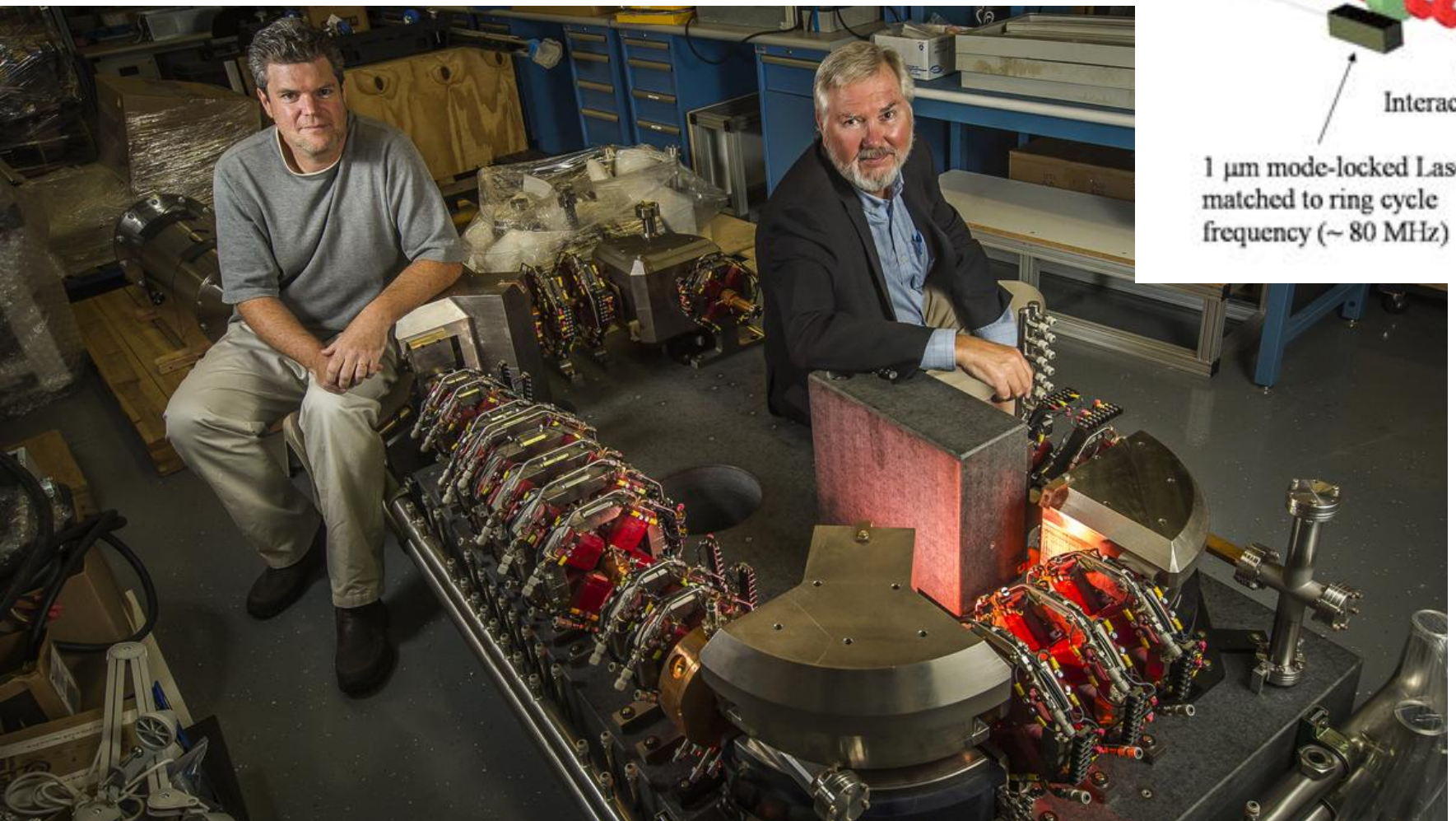
- Assessment of: (a) Gold in eucalypt leaves, saving cost and time involved in drilling and unnecessary exploration; (b) Understanding the nano structure of casein micelles, significant potential benefits for dairy farming, manufacturing and export; (c) Faster and more detailed analysis of proteins and other molecules, important role in new pharmaceuticals

The estimated net present value of the Synchrotron is $799.3 million (2016-17 dollars), with a benefit cost of 68.3. Note these are based on 3 projects.

Compact accelerators:
sources of photons, neutrons, electrons etc.

Compact
Compton backscattering sources of hard X-Rays

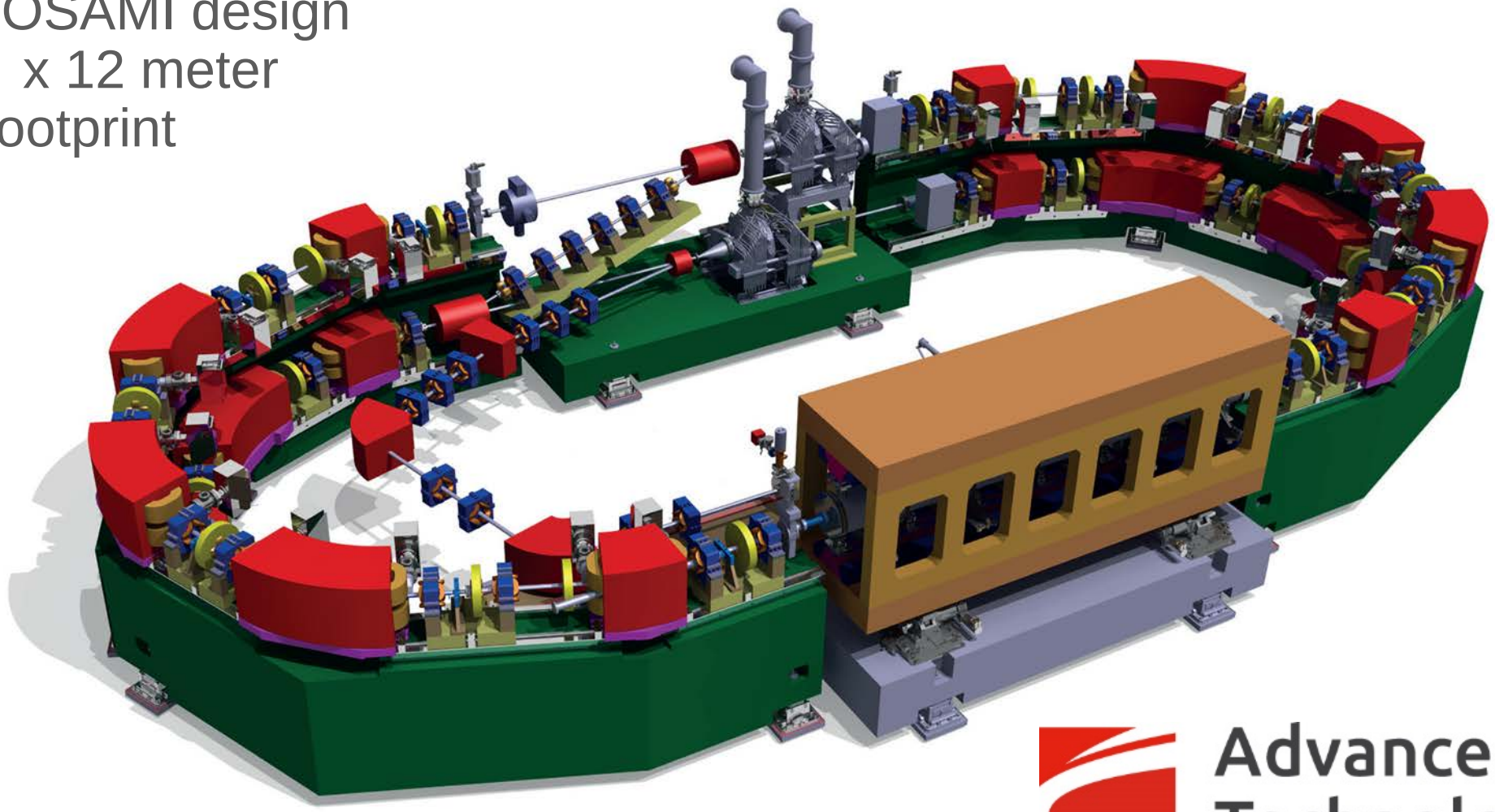




lyncean TECHNOLOGIES, INC.

Disruptive storage rings technology change: a much brighter compact sources e.g. for shorter wavelength lithography

COSAMI design
5 x 12 meter
Footprint

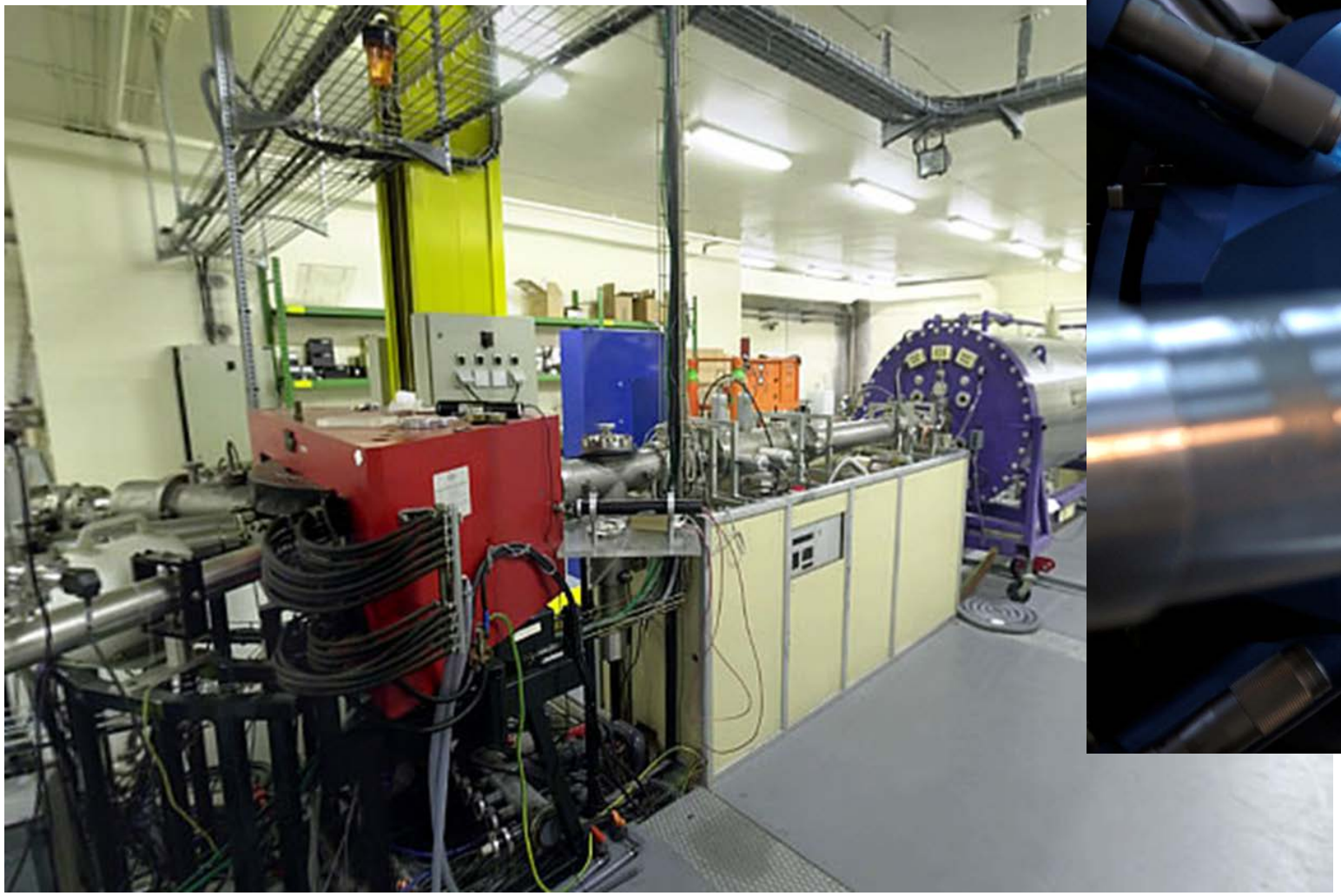


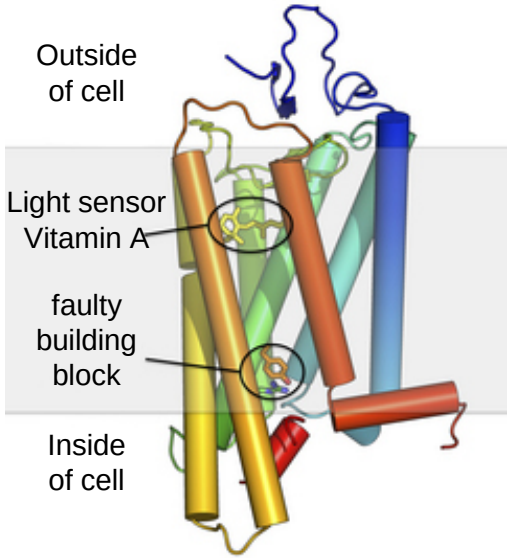
Advanced Accelerator Technologies

Cultural heritage

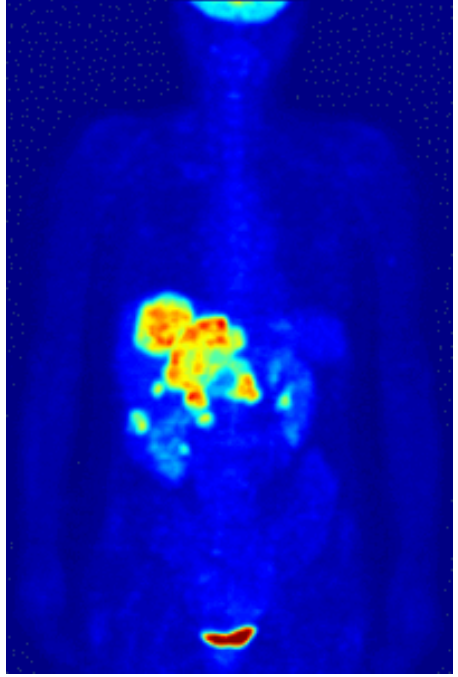
Paris, Louvre, 15 m underground

AGLAE: Accélérateur Grand Louvre d’analyse élémentaire



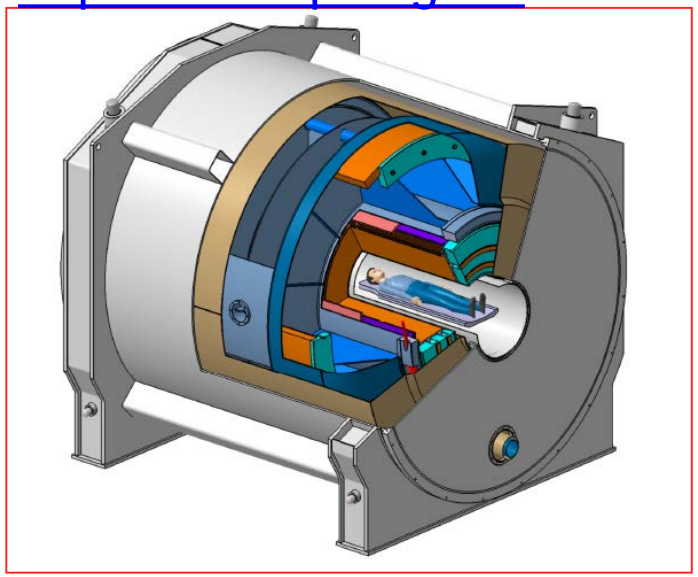


Structure of proteins:
targeted drug design



Radio pharmaceuticals:
diagnostics and therapy

Particle therapy:
https://www.ptcog.ch/



ISEULT
Whole body MRI 11.75 T

Accelerators for medicine

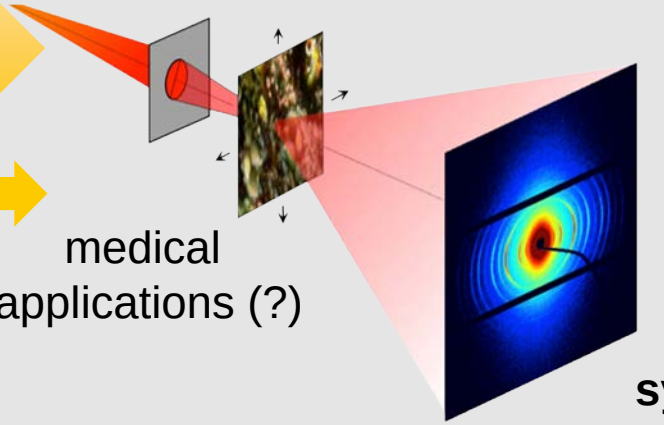
Spin-off product from basic research

15 years

pixel detector for particle physics

CMS detector at CERN, Geneva

spin-off



medical applications (?)

synchrotron sources worldwide

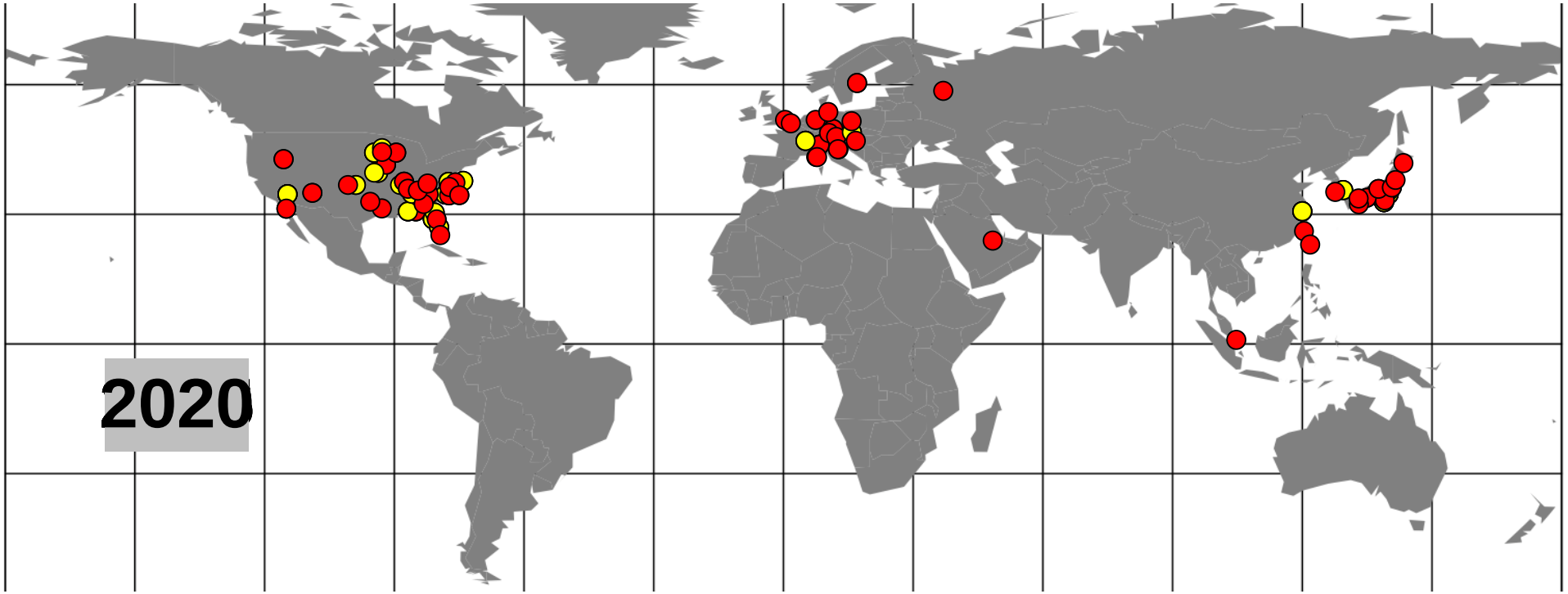
applications in materials research

PILATUS 6M Pixel-Detector (Dectris Ltd., Switzerland)

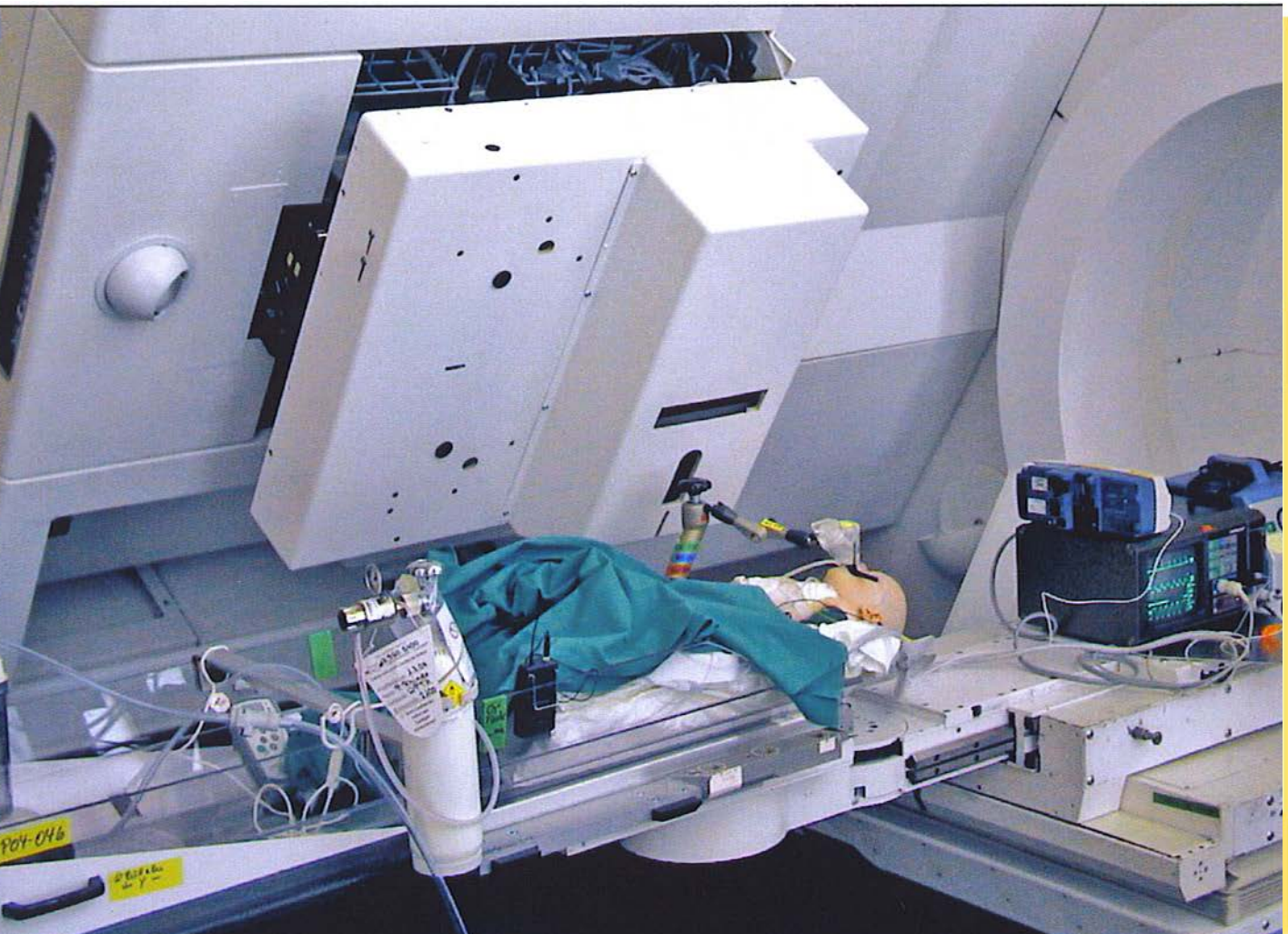
Spread of proton therapy technologies (Gantries)

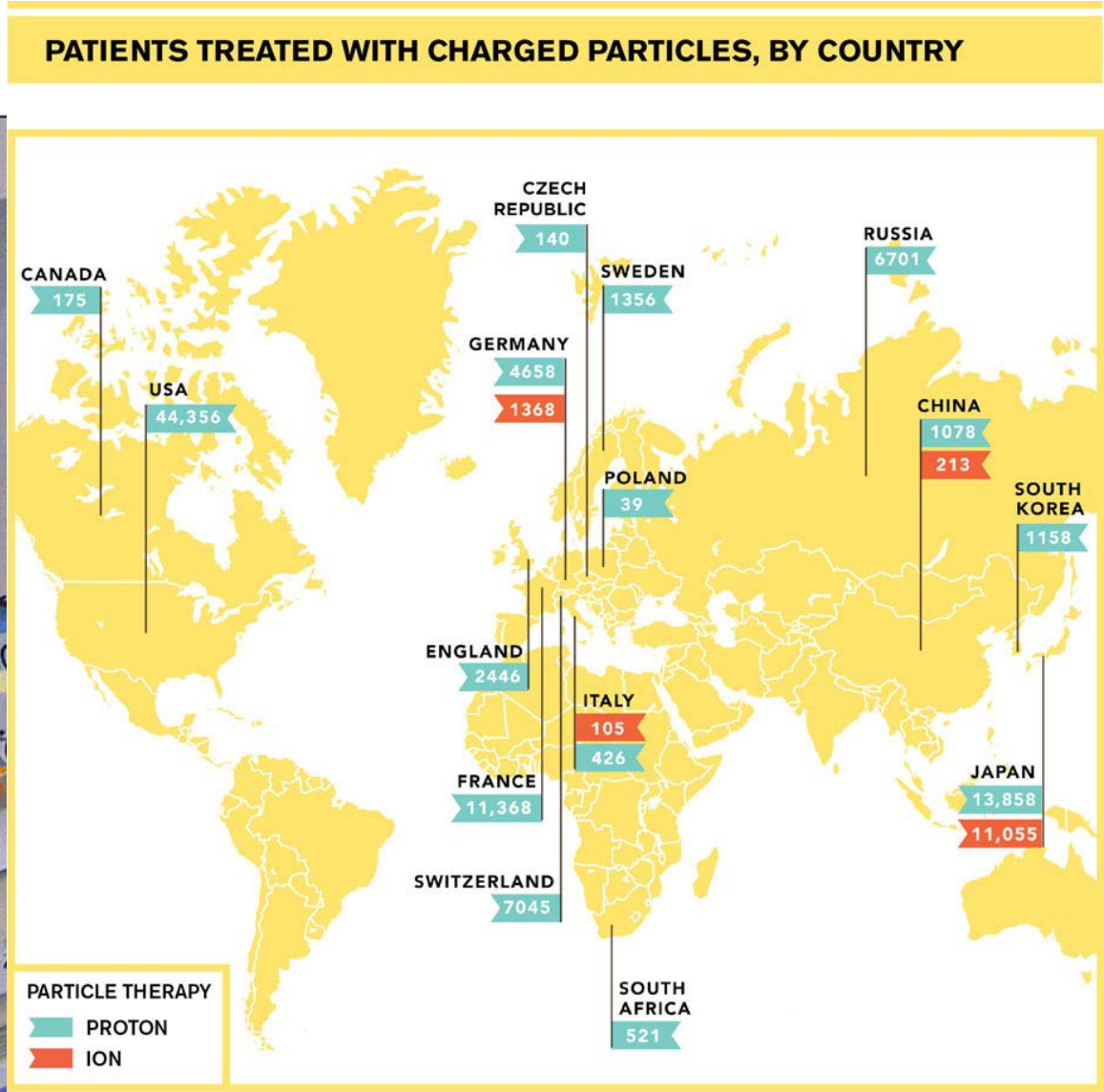
“Passive Scattering”
(developed at Harvard/Loma Linda/FermiLab

“Pencil Beam Scanning”
(developed at PSI)

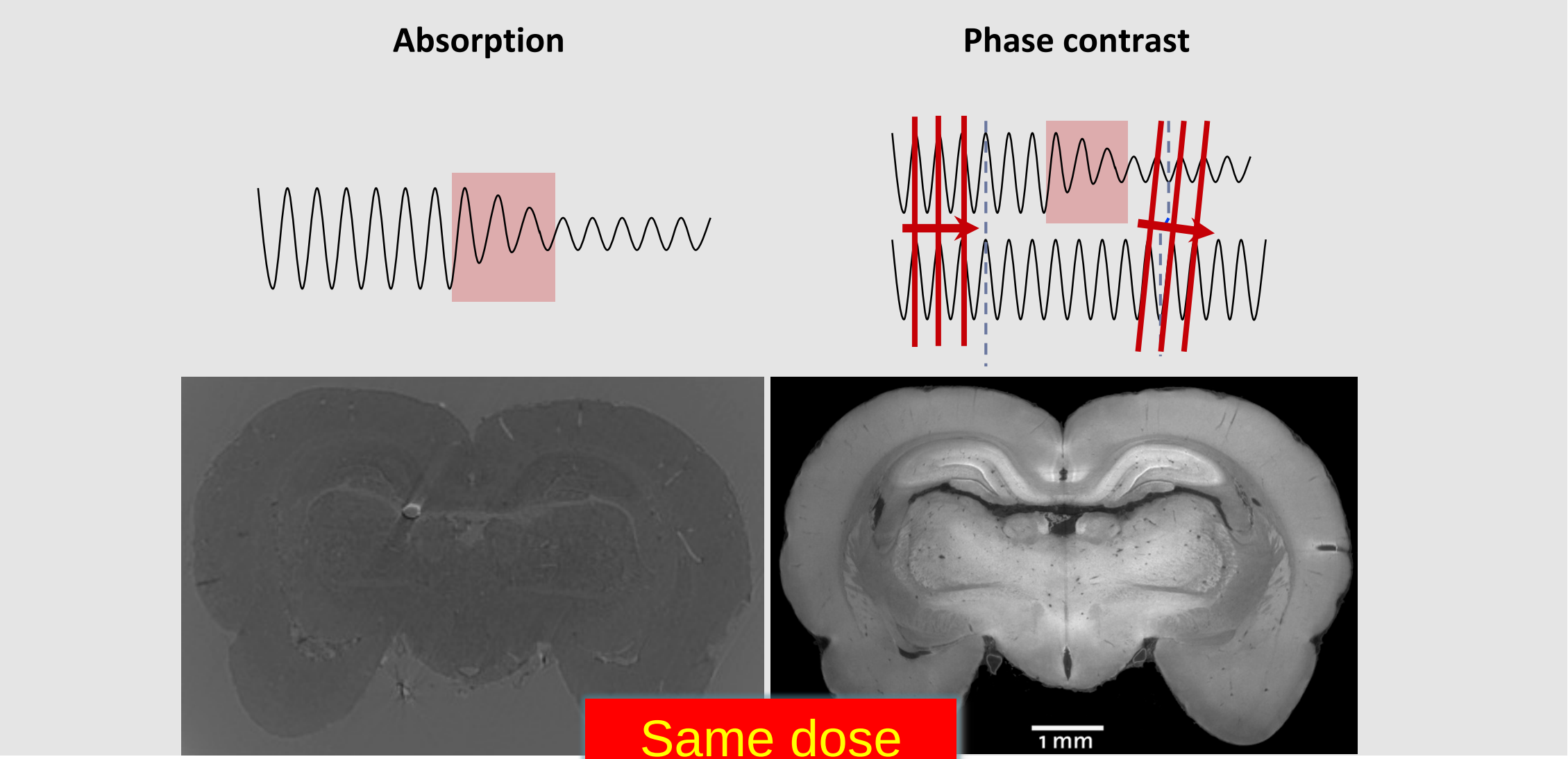


Hadron therapy: method of choice for pediatric cancers

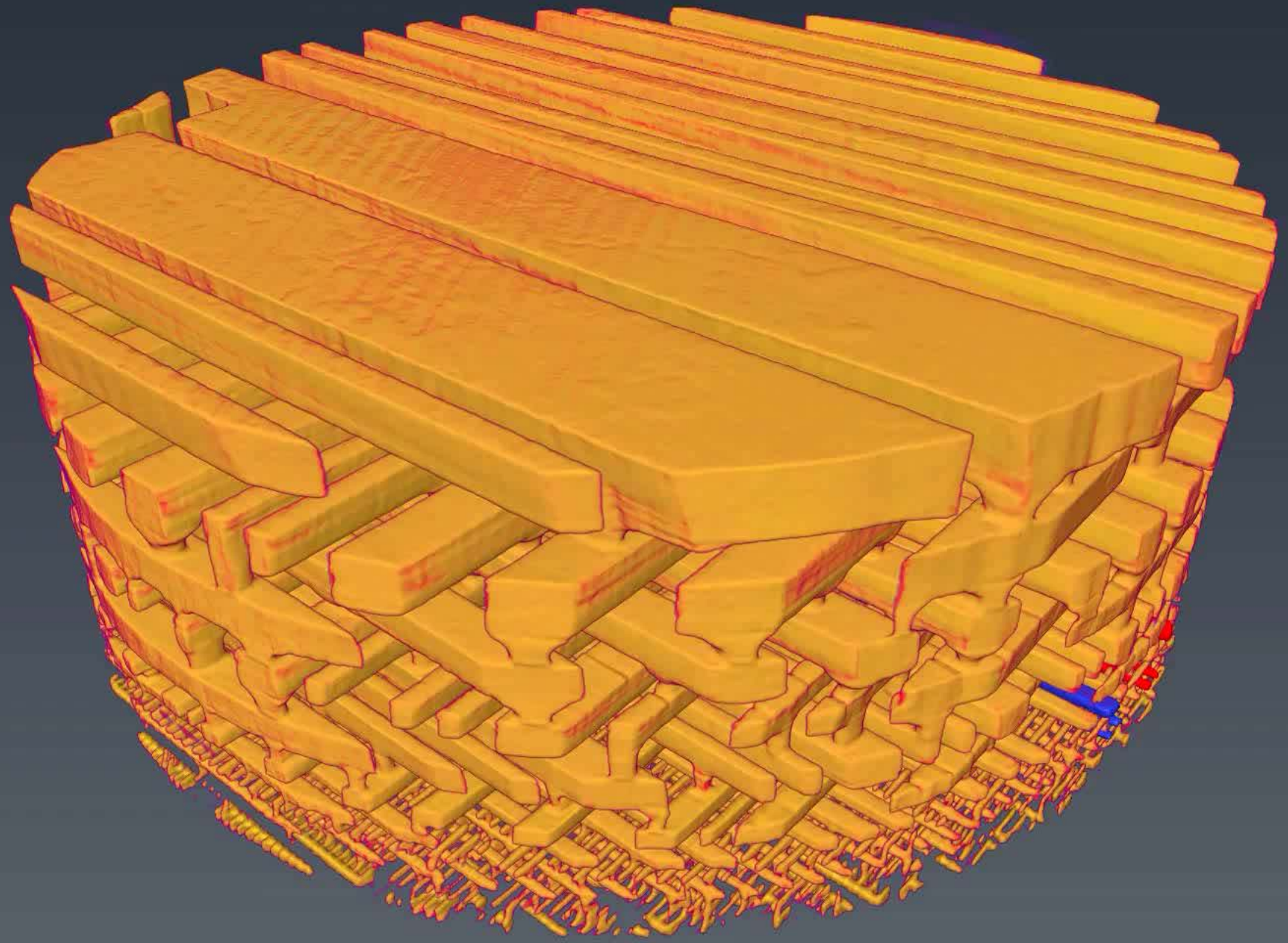




Phase contrast X-Ray imaging: improved soft tissue contrast



Security



Holler *et al.,* Nature 543, 402–406 (16 March 2017)

Summary

In the past 90 years accelerators have become an essential tool for research and numerous applications (proton therapy, synchrotron light sources, neutron sources etc.), able to address society's essential needs

Accelerator development ushers in new, powerful applications in many fields

Future poses formidable challenges for the accelerator R&D, not the least of them is educating the new generation of specialists
(cf. the preceding presentation by E. Metral)