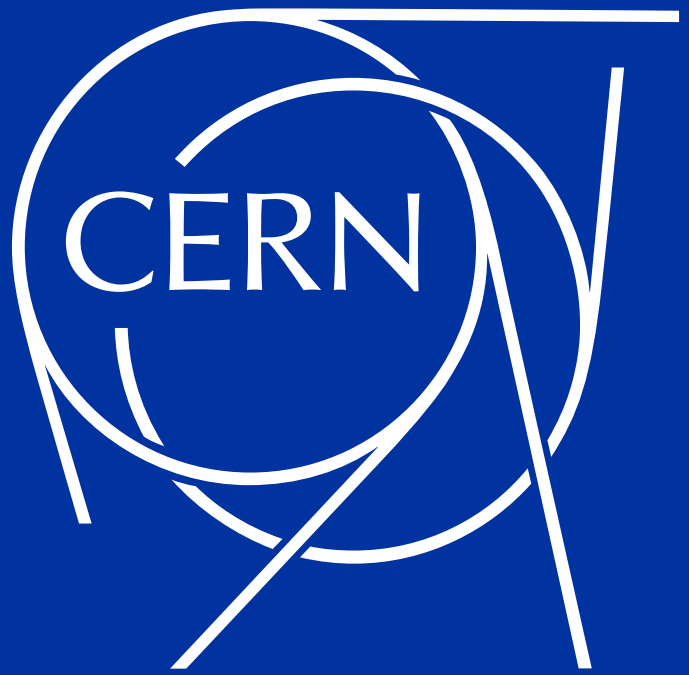
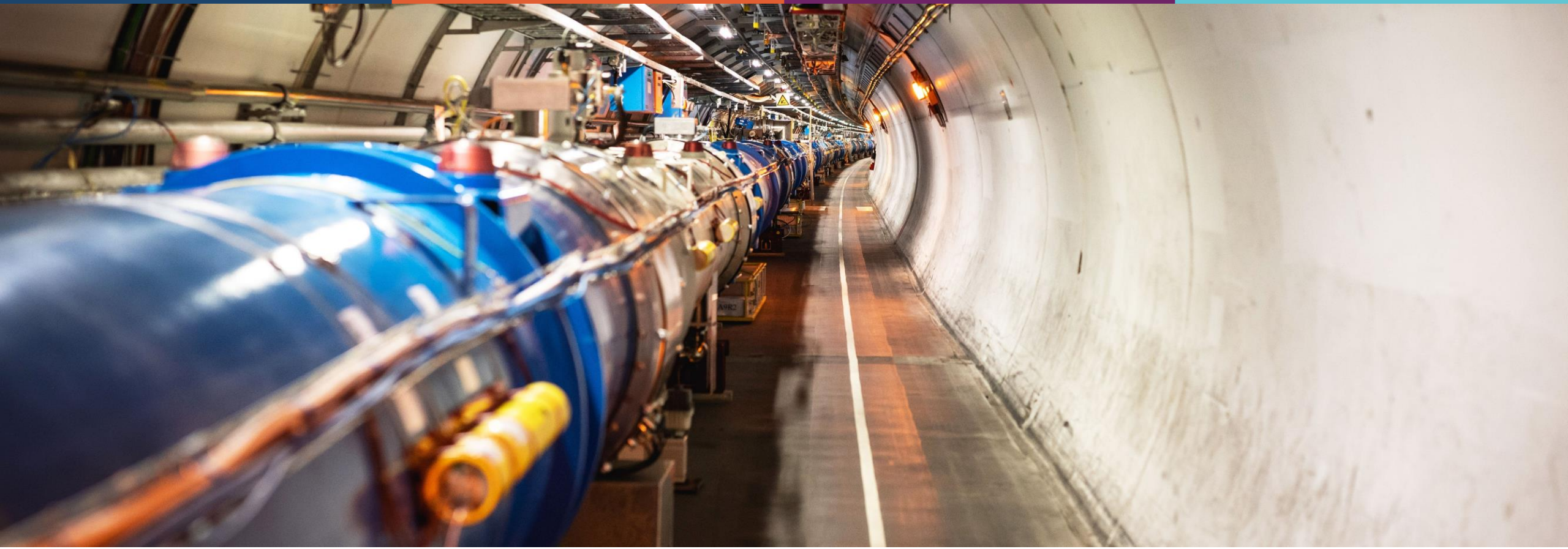
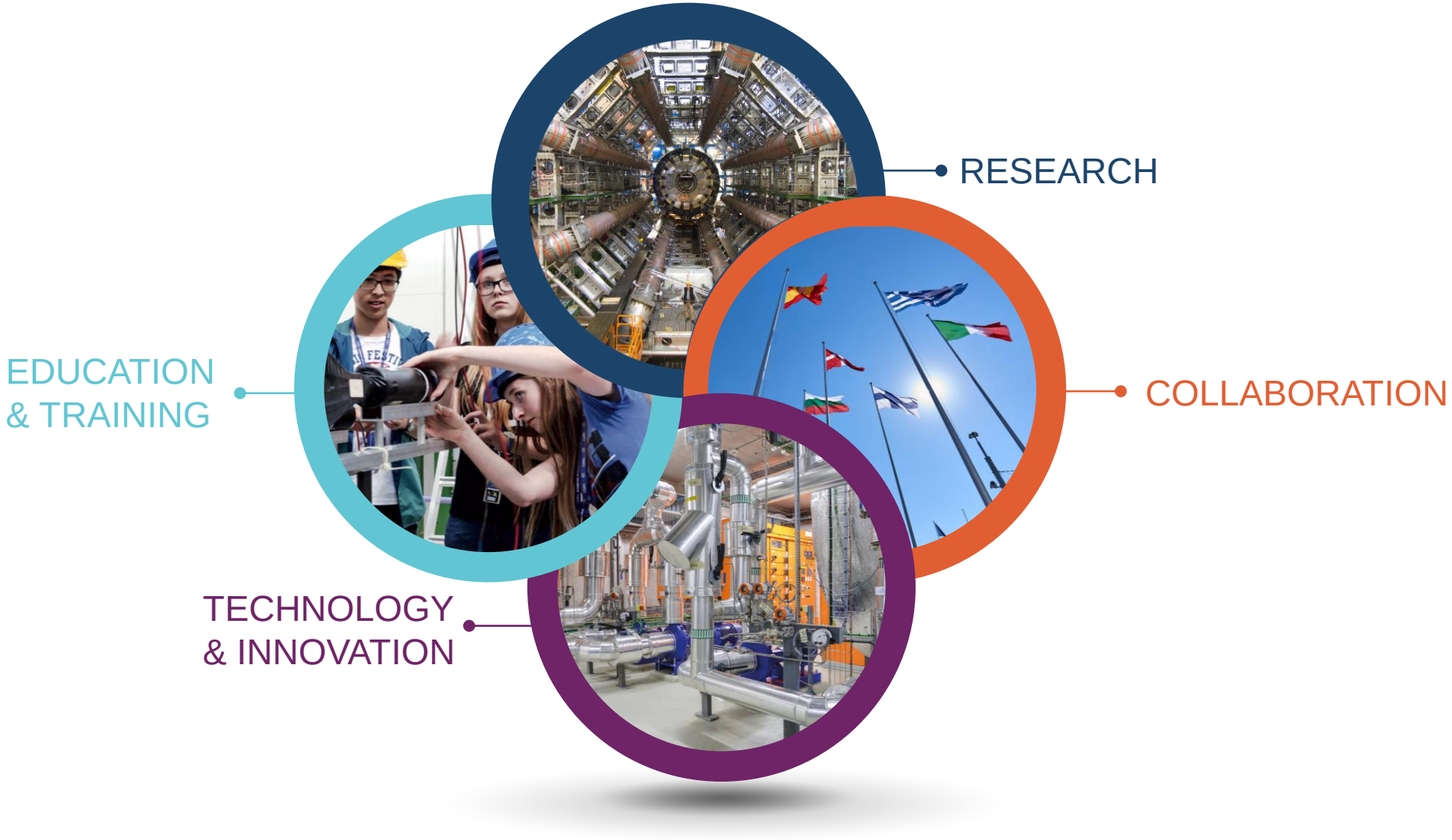

CERN



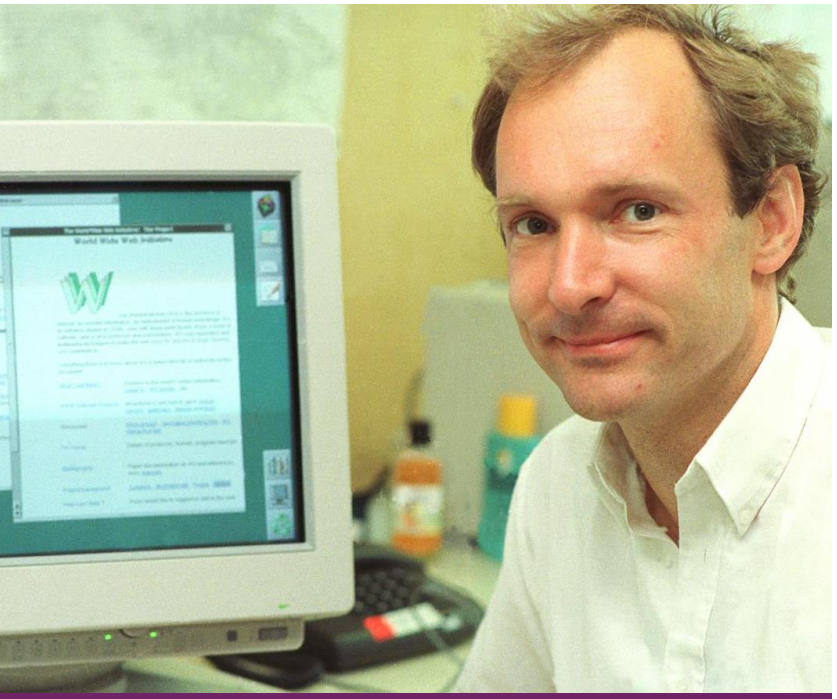
Accelerating Innovation: How CERN Technology Makes its Way into Society

Giovanni Anelli, Head of Knowledge Transfer Group, CERN

Four pillars underpin CERN's mission

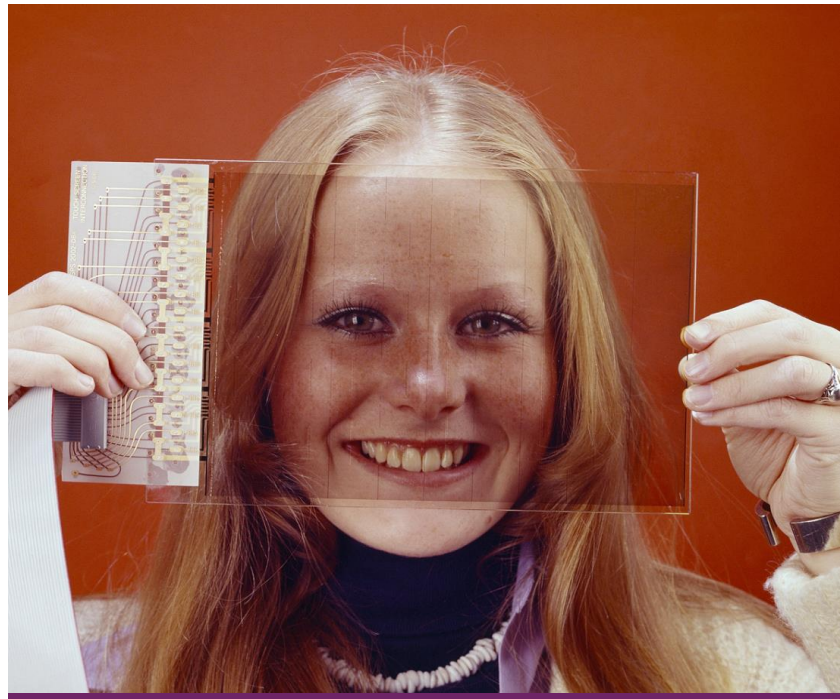


Some historic examples



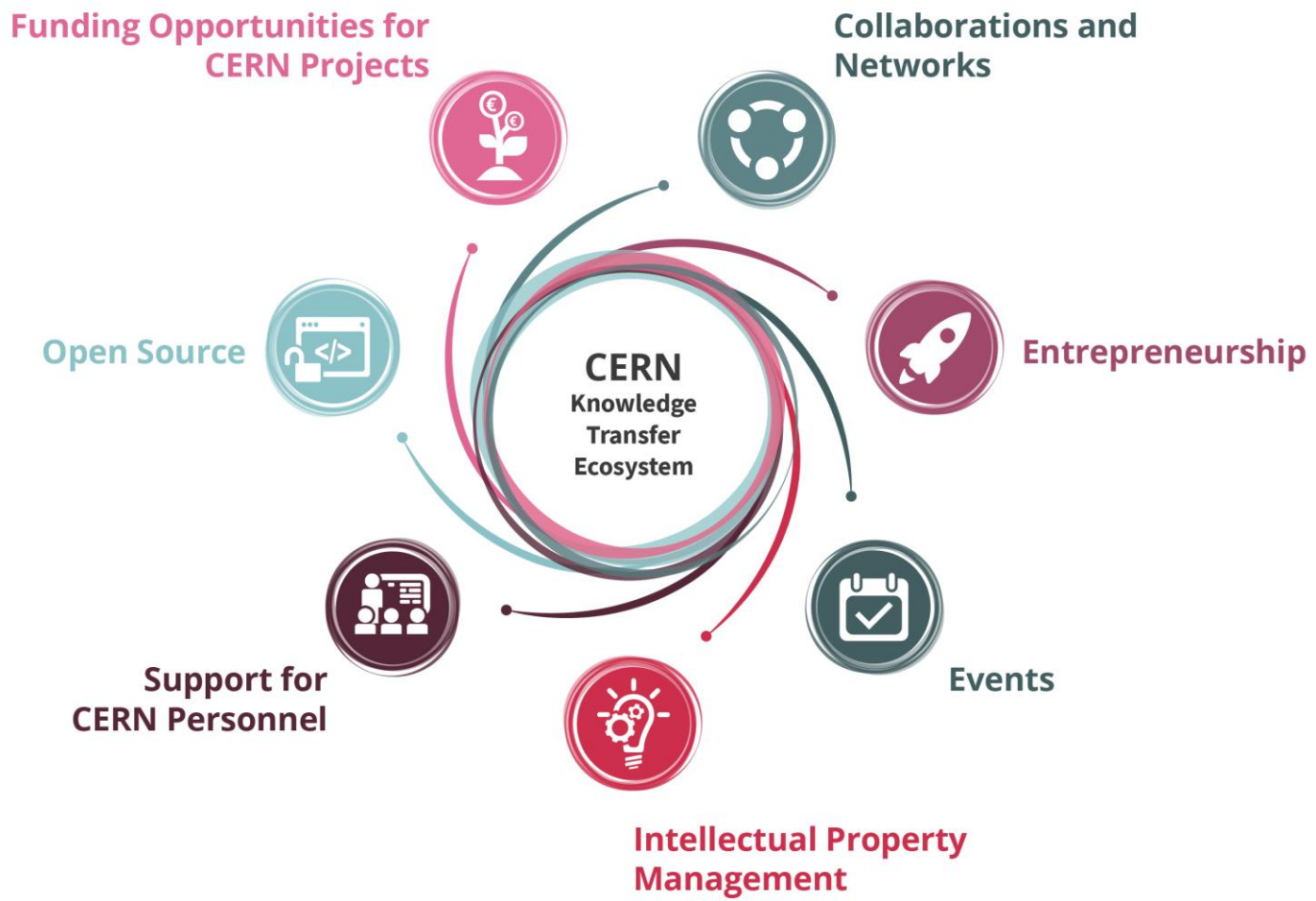
WWW

TRACKERBALL



TOUCHSCREEN

Our toolbox to accelerate innovation



Knowledge Transfer Channels

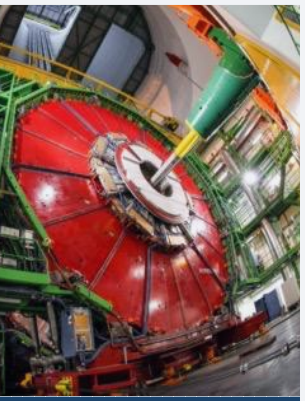
Dedicated actions to **foster the transfer of technologies and know-how** to other fields than particle physics
(very often with the involvement of industry)

Technology-intensive **procurement contracts**

People
(very hard to quantify but extremely impactful for particle physics)

Hybrid strategy: tech push & market pull


ACCELERATORS


DETECTORS


COMPUTING

- Mobilize tech experts
- Create tech and IP dossiers
- Scout for technologies

- Mobilize innovation partners
- Create value propositions
- Search unmet needs


HEALTHCARE

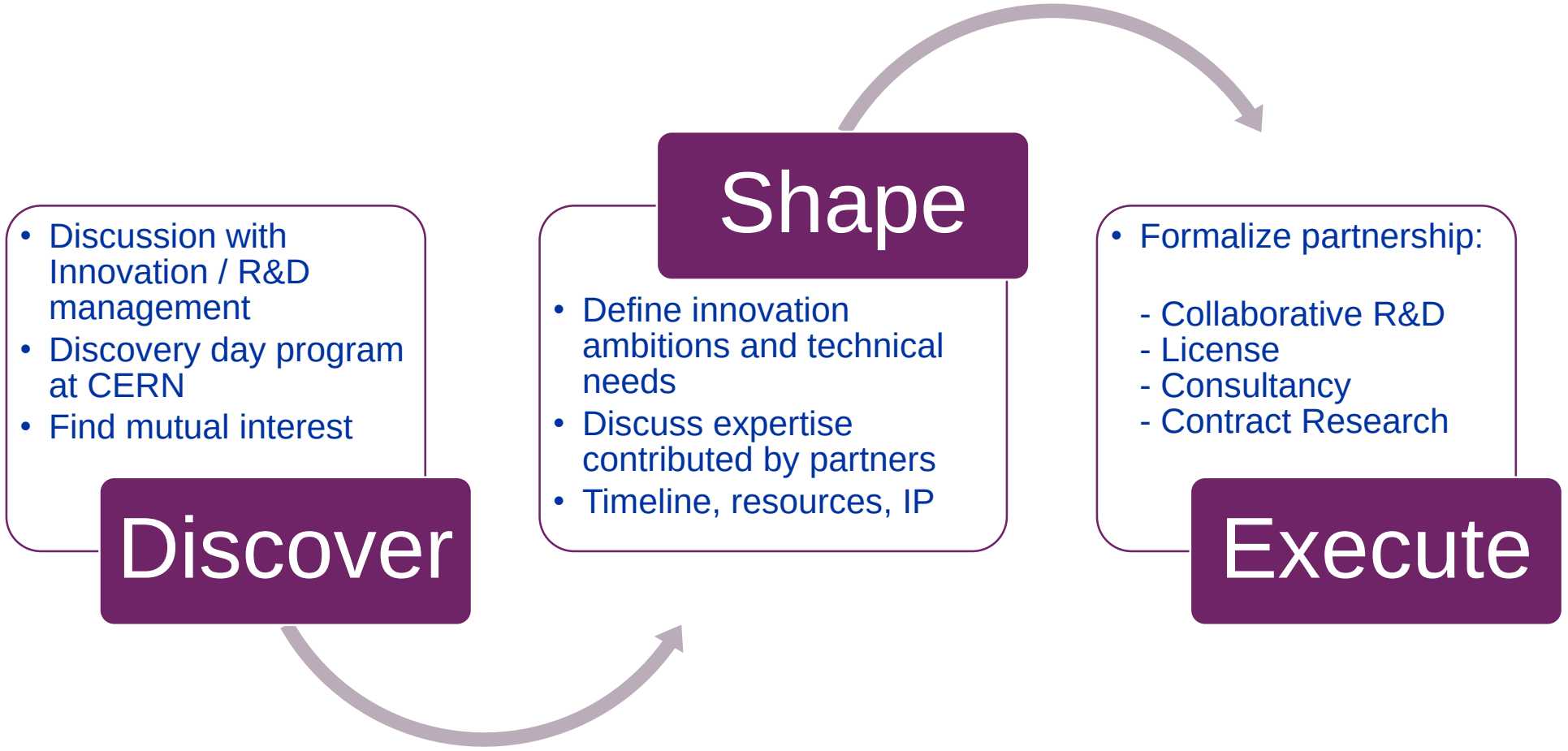

ENVIRONMENT


DIGITAL


AEROSPACE


QUANTUM

Shaping innovation partnerships



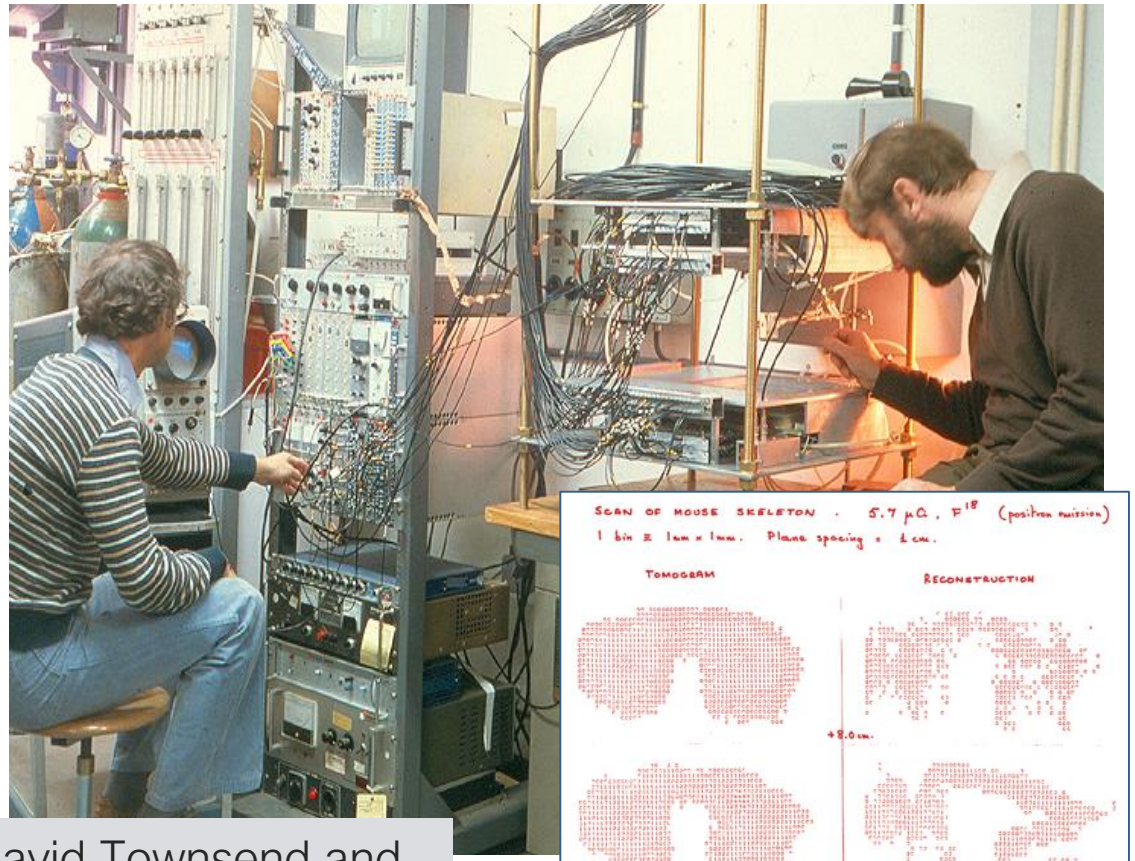
Radioprotection 2005 DOI: 10.1051/radiopro:2005010
Vol. 40, n° 2, pages 245 à 255

Produit nouveau

Une nouvelle imagerie ostéo-articulaire basse dose en position debout : le système EOS

J. DUBOUSSET[1], G. CHARPAK[2], I. DORION[2], W. SKALLI[3], F. LAVASTE[3], J. DEGUISE[4], G. KALIFA[5], S. FEREY[5]

Georges Charpak, Fabio Sauli and Jean-Claude Santiard working on a multiwire chamber in 1970

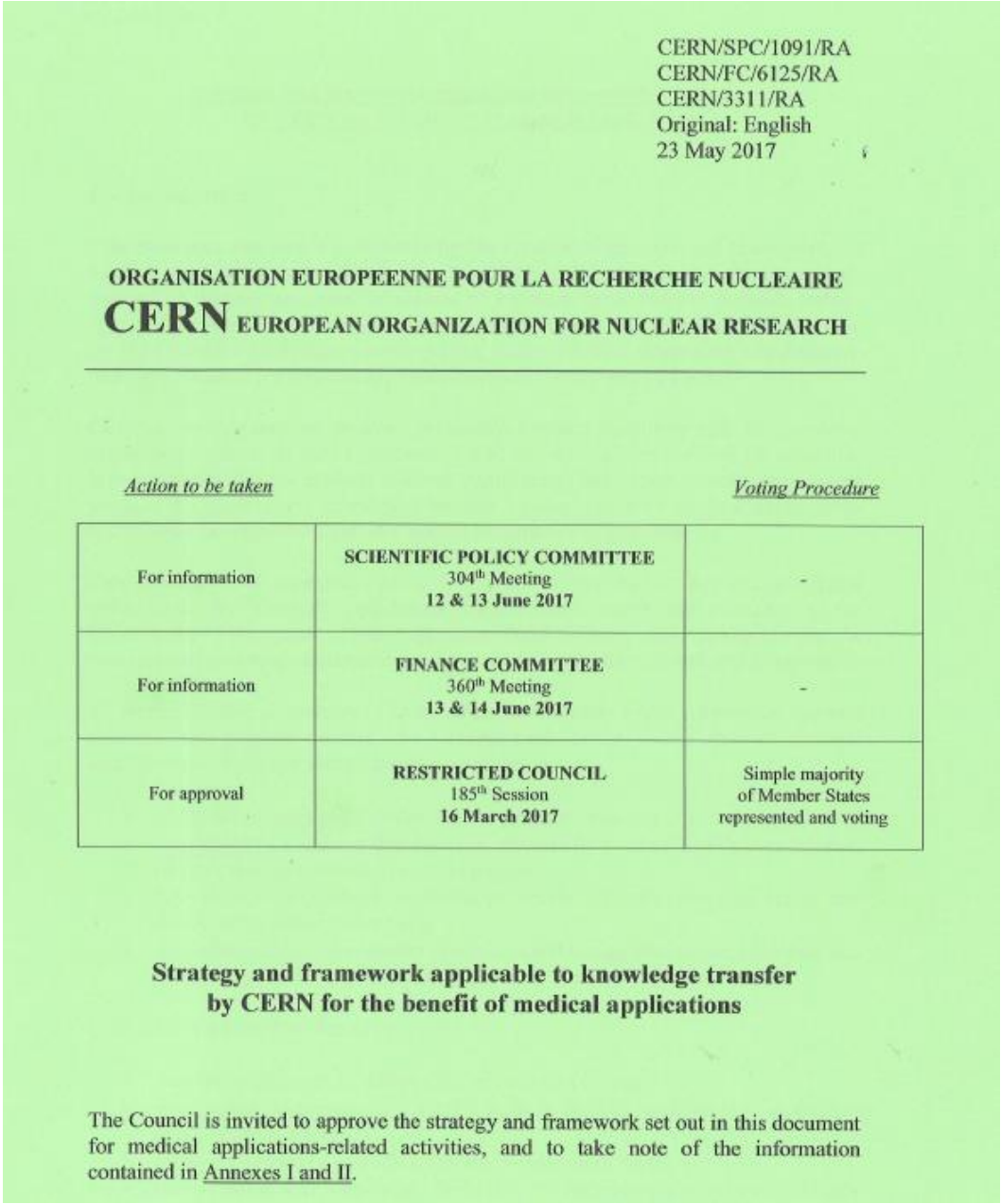


David Townsend and Alan Jeavons, 1978

From CERN technologies to medical and biomedical applications

Updated June 2023

https://cds.cern.ch/record/2864317/files/English.pdf



CERN/SPC/1091/RA
CERN/FC/6125/RA
CERN/3311/RA
Original: English
23 May 2017

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Action to be taken		*Voting Procedure*
For information	**SCIENTIFIC POLICY COMMITTEE** 304th Meeting **12 & 13 June 2017**	-
For information	**FINANCE COMMITTEE** 360th Meeting **13 & 14 June 2017**	-
For approval	**RESTRICTED COUNCIL** 185th Session **16 March 2017**	Simple majority of Member States represented and voting

Strategy and framework applicable to knowledge transfer by CERN for the benefit of medical applications

The Council is invited to approve the strategy and framework set out in this document for medical applications-related activities, and to take note of the information contained in Annexes I and II.

ICT for medical applications

Nuclear Medicine

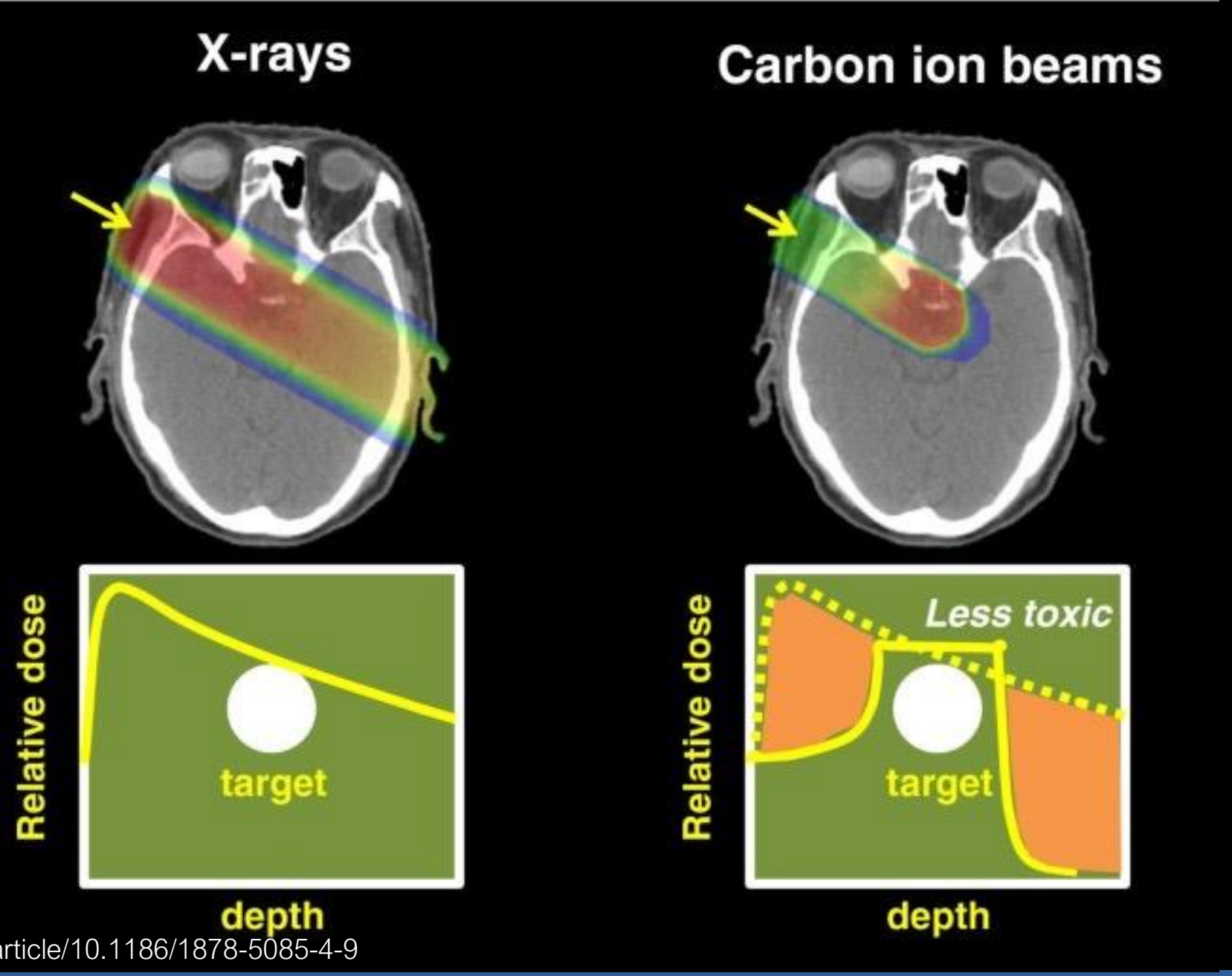
Medical Imaging

Radiotherapy

Radiation Monitoring and Dosimetry

Robotics

Medical devices



https://link.springer.com/article/10.1186/1878-5085-4-9

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
CERN - PS DIVISION

CERN/PS 2000-007 (DR)

PROTON-ION MEDICAL MACHINE STUDY (PIMMS) PART II

Accelerator Complex Study Group*
supported by the Med-AUSTRON, Onkologie-2000 and the TERA Foundation
and hosted by CERN

ABSTRACT

The Proton-Ion Medical Machine Study (PIMMS) group was formed following an agreement between the Med-AUSTRON (Austria) and the TERA Foundation (Italy) to combine their efforts in the design of a cancer therapy synchrotron capable of accelerating either light ions or protons. CERN agreed to support and host this study in its PS Division. A close collaboration was also set up with GSI (Germany). The study group was later joined by Onkologie-2000 (Czech Republic). Effort was first focused on the theoretical understanding of slow extraction and the techniques required to produce a smooth beam spill for the conformal treatment of complex-shaped tumours with a sub-millimetre accuracy by active scanning with proton and carbon ion beams. Considerations for passive beam spreading were also included for protons. The study has been written in two parts. The more general and theoretical aspects are recorded in Part I and the specific technical design considerations are presented in the present volume, Part II. An accompanying CD-ROM contains supporting publications made by the team and data files for calculations. The PIMMS team started its work in January 1996 in the PS Division and continued for a period of four years.

*Full-time members: L. Badano[1], M. Benedikt[2], P.J. Bryant[2] (Study Leader), M. Crescenti[1], P. Holy[3], A. Maier[2+4], M. Pullia[1], S. Reimoser[2+4], S. Rossi[1],
Part-time members: G. Borri[1], P. Knaus[1+2]
Contributors: F. Gramatica[1], M. Pavlovic[4], L. Weisser[5]
1) TERA Foundation, via Puccini. 11, I-28100 Novara.
2) CERN, CH 1211 Geneva-23.
3) Oncology-2000 Foundation, Na Morani 4, CZ-12808 Prague 2.
4) Med-AUSTRON, c/o RIZ, Prof. Dr. Stephan Korenstr.10, A-2700 Wr. Neustadt.
5) Sommer & Partner Architects Berlin (SPB), Hardenbergplatz 2, D-10623 Berlin.

Geneva, Switzerland
May 2000

From the PIMMS Study @

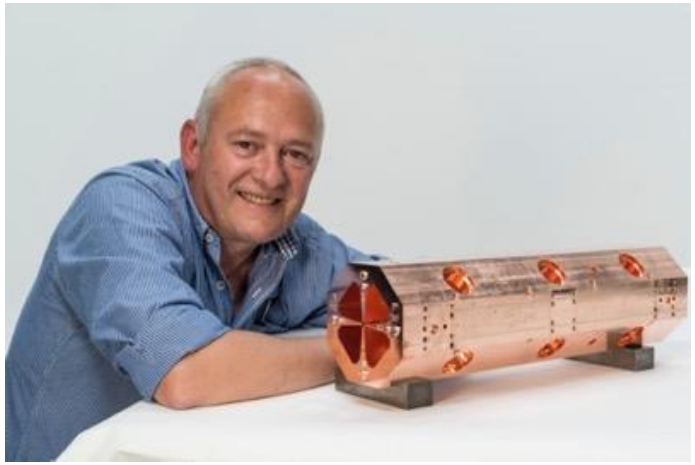
INFN

fondazioneCNAO

MedAustron

Hadron therapy

Active since the 1990s:
- synchrotrons for C-ion therapy
- linear accelerators for innovative proton therapy systems



Licensed to AVO (Advanced Oncotherapy) – ADAM

fondazioneCNAO

4400 patients treated 2011-2022

MedAustron

1680 patients treated 2017-2022

Since 2019:
focus on innovative technologies for multi-ion therapy

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
CERN - PS DIVISION

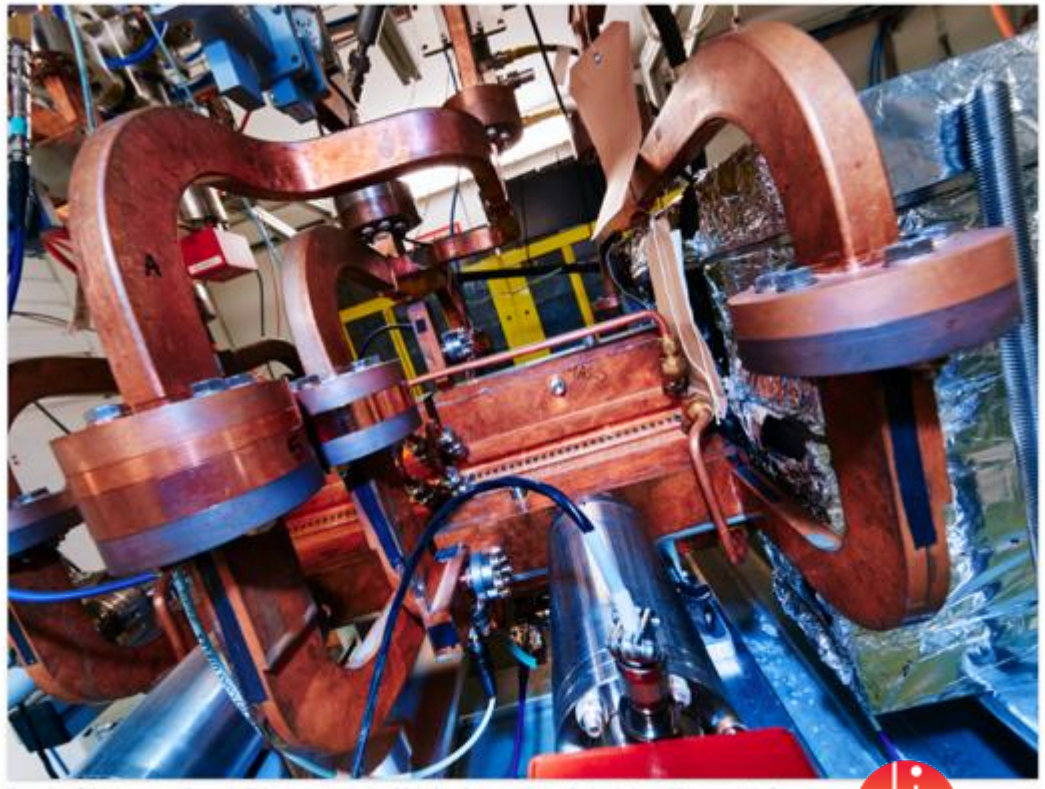
CERN/PS 2000-007 (DR)

PROTON-ION MEDICAL MACHINE STUDY (PIMMS)
PART II

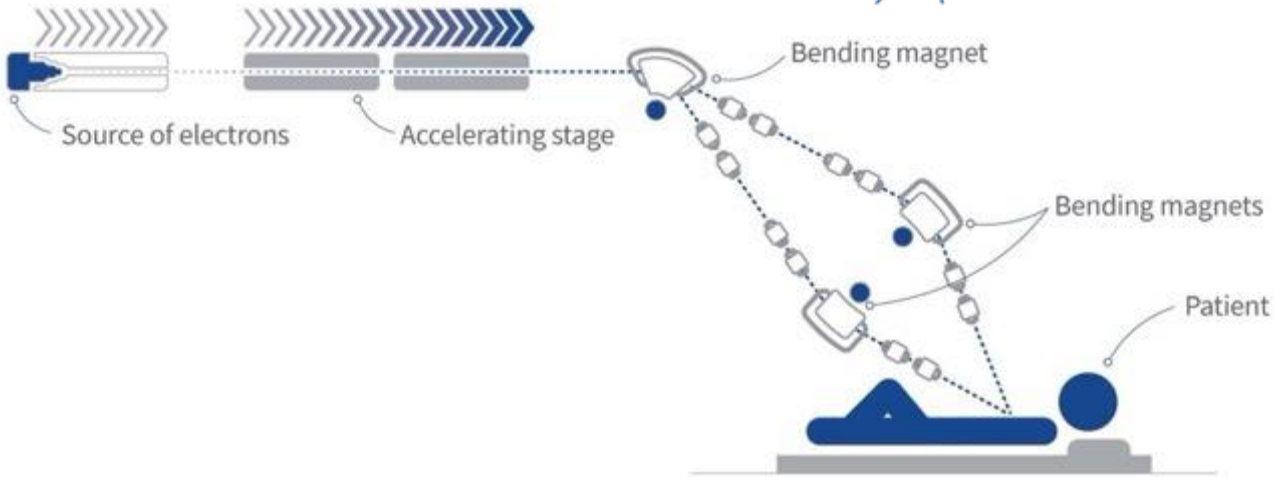
Accelerator Complex Study Group*
supported by the Med-AUSTRON, Onkologie-2000 and the TERA Foundation
and hosted by CERN

FLASH VHEE therapy

CLIC technology for a FLASH VHEE facility being developed in collaboration with CHUV (Lausanne University Hospital) and THERYQ (ALCEN Group)



Close-up of the Compact Linear Collider prototype, on which the electron FLASH design is based (Image: CERN)



An intense beam of electrons is produced in a photoinjector, accelerated to around 100 MeV and then is expanded, shaped and guided to the patient.

The design of this facility is the result of an intense dialogue between groups at CHUV and CERN.

Jean Bourhis from CHUV:
"The clinical need that we have really converges with the technological answer that CERN has."

The remarkable connection between CLIC technology and FLASH electron therapy

Very intense electron beams

- CLIC – to provide brightness needed for delicate physics experiments
- FLASH – to provide dose fast for biological FLASH effect

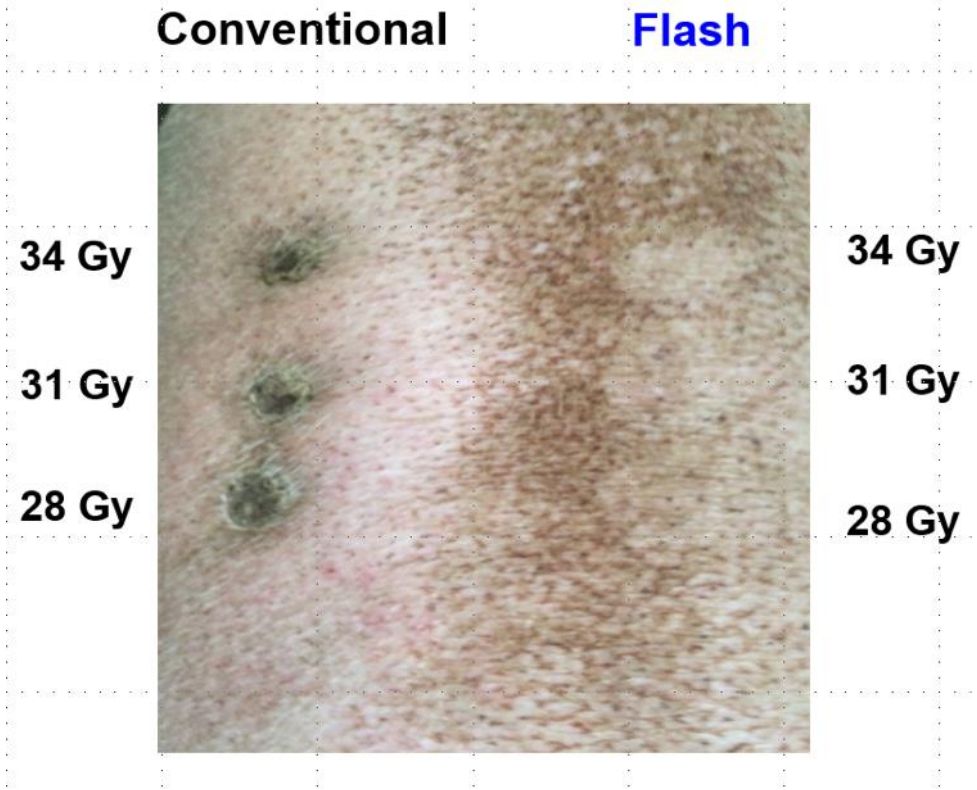
Very precisely controlled electron beams

- CLIC – to reduce the power consumption of the facility
- FLASH – to provide reliable treatment in a clinical setting

High accelerating gradient (that is high beam energy gain per length)

- CLIC – fit facility in Lac Leman region and limit cost
- FLASH – fit facility on typical hospital campuses and limit cost of treatment

FLASH therapy – a growing clinical interest



Vozenin et al
Clin Cancer Res
2018

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Original Article

Treatment of a first patient with FLASH-radiotherapy

Jean Bourhis [a,b,*], Wendy Jeanneret Sozzi [a], Patrik Gonçalves Jorge [a,b,c], Olivier Gaide [d], Claude Bailat [c], Fréderic Duclos [a], David Patin [a], Mahmut Ozsahin [a], François Bochud [c], Jean-François Germond [c], Raphaël Moeckli [c,1], Marie-Catherine Vozenin [a,b,1]

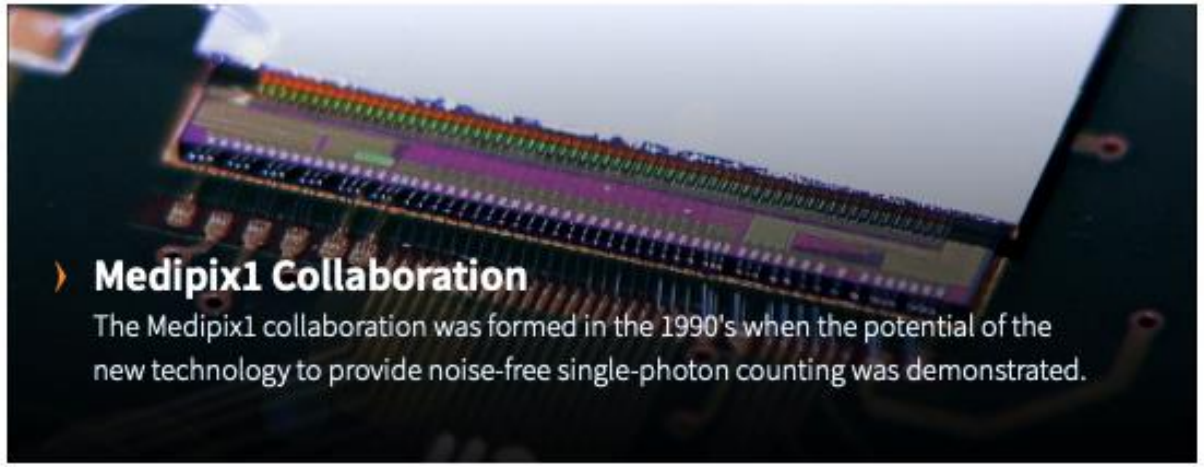
[a] Department of Radiation Oncology, Lausanne University Hospital and University of Lausanne; [b] Radiation Oncology Laboratory, Department of Radiation Oncology, Lausanne University Hospital and University of Lausanne; [c] Institute of Radiation Physics, Lausanne University Hospital and University of Lausanne; and [d] Department of Dermatology, Lausanne University Hospital and University of Lausanne, Switzerland

Fig. 1. Temporal evolution of the treated lesion: (a) before treatment; the limits of th PTV are delineated in black; (b) at 3 weeks, at the peak of skin reactions (grade 1 epithelitis NCI-CTCAE v 5.0); (c) at 5 months.

First human patient – skin cancer treated with 10 MeV-range electrons

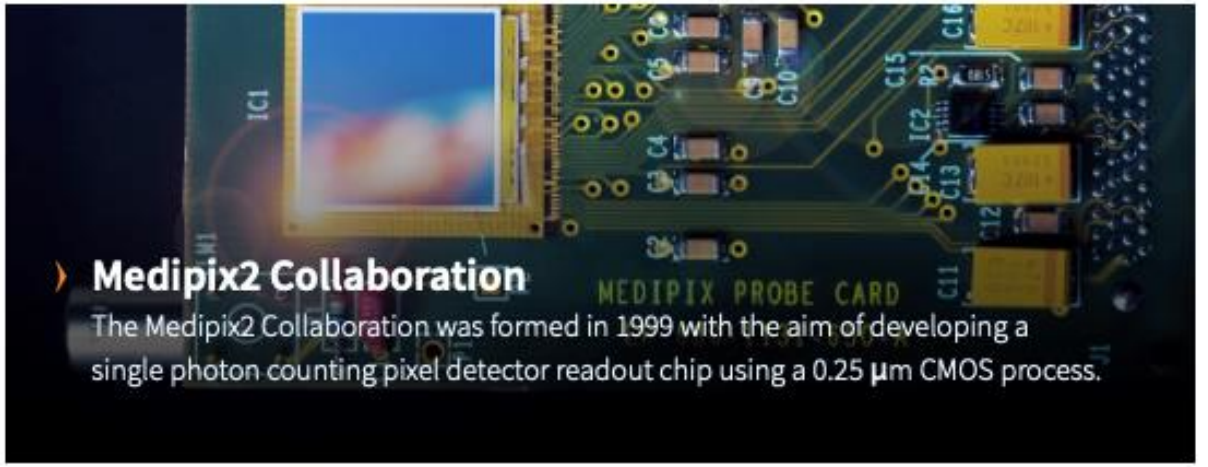
Medipix

A family of pixel detector read-out chips for particle imaging and detection developed by the Medipix Collaborations



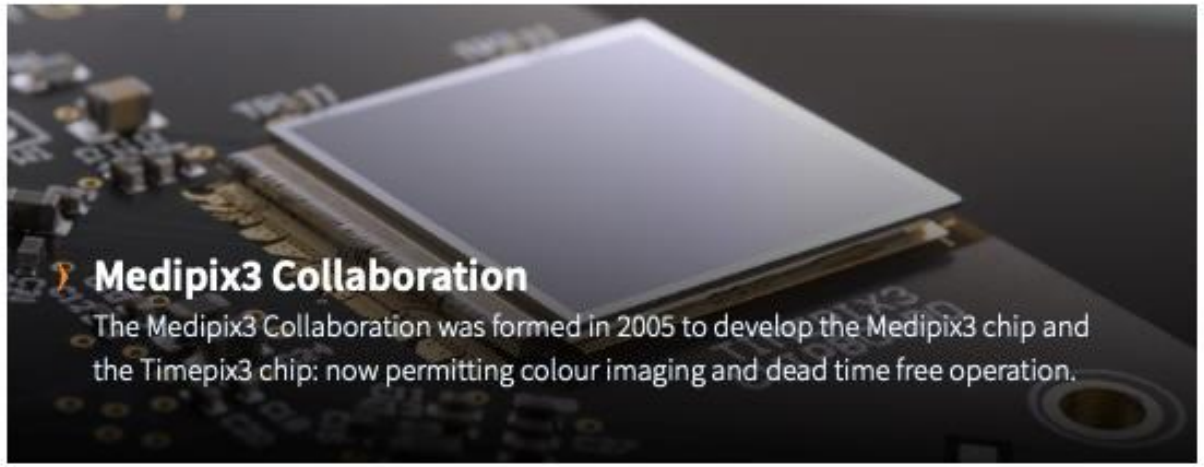
Medipix1 Collaboration

The Medipix1 collaboration was formed in the 1990's when the potential of the new technology to provide noise-free single-photon counting was demonstrated.



Medipix2 Collaboration

The Medipix2 Collaboration was formed in 1999 with the aim of developing a single photon counting pixel detector readout chip using a 0.25 µm CMOS process.



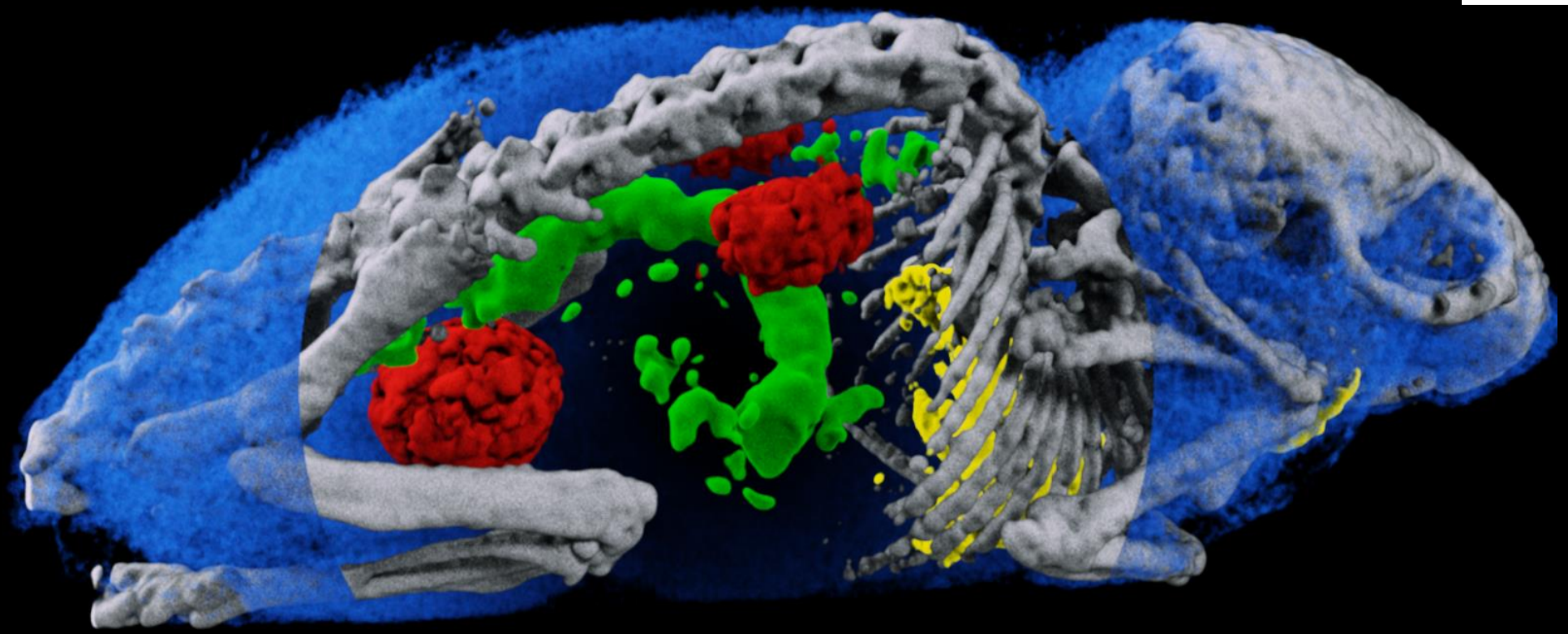
Medipix3 Collaboration

The Medipix3 Collaboration was formed in 2005 to develop the Medipix3 chip and the Timepix3 chip: now permitting colour imaging and dead time free operation.

Medipix4 Collaboration

The Medipix4 Collaboration was launched in 2017. The aim is designing pixel read-out chips fully prepared for TSV processing that may be tiled on all four sides.

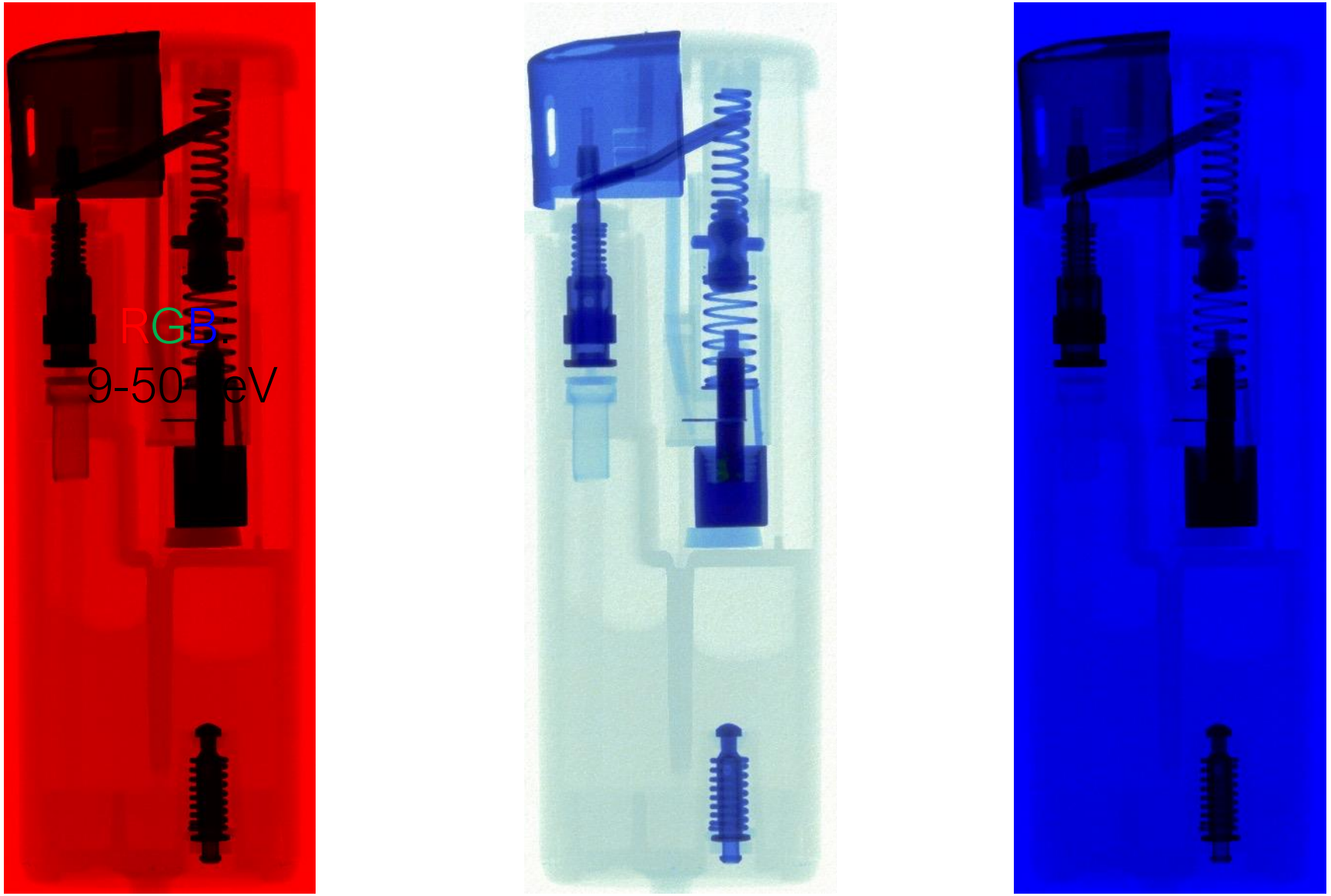
Spectroscopic information permits material separation



The water has been partly cut away to reveal the bone, gold, gadolinium and iodine

Images presented and the European Congress of Radiology, Vienna, March 2017.

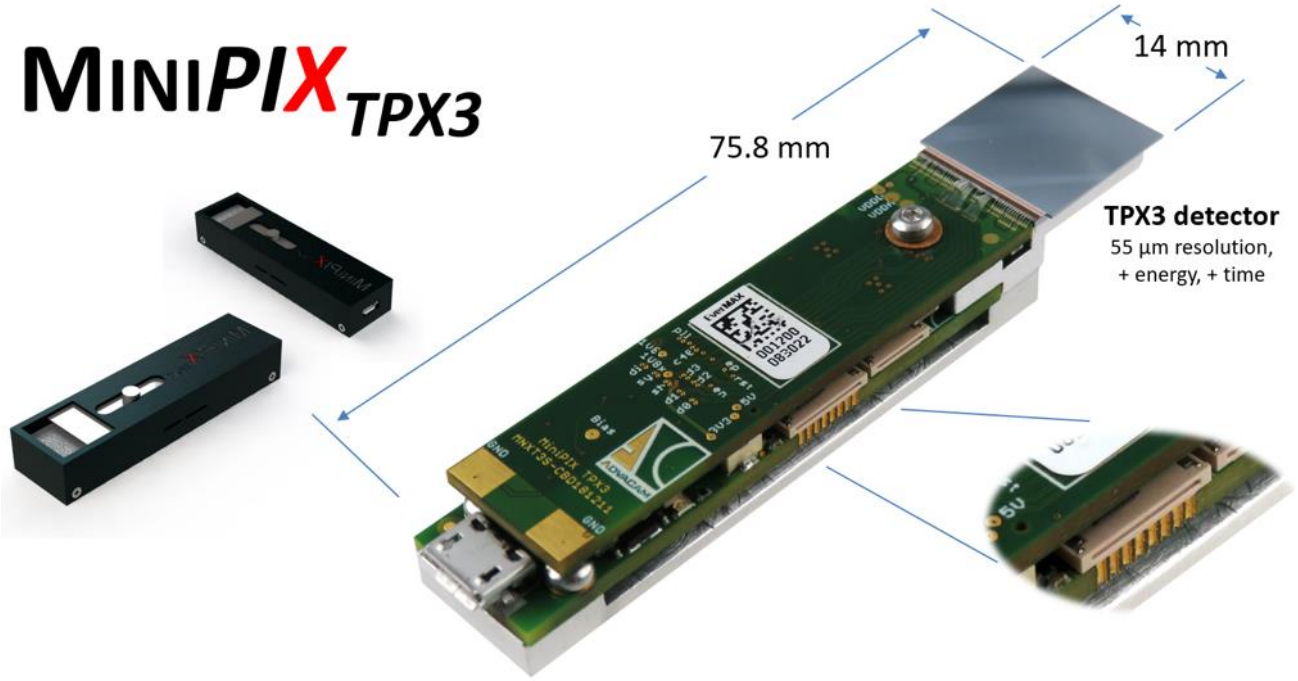
Colour x-ray of a lighter



S. Procz et al.

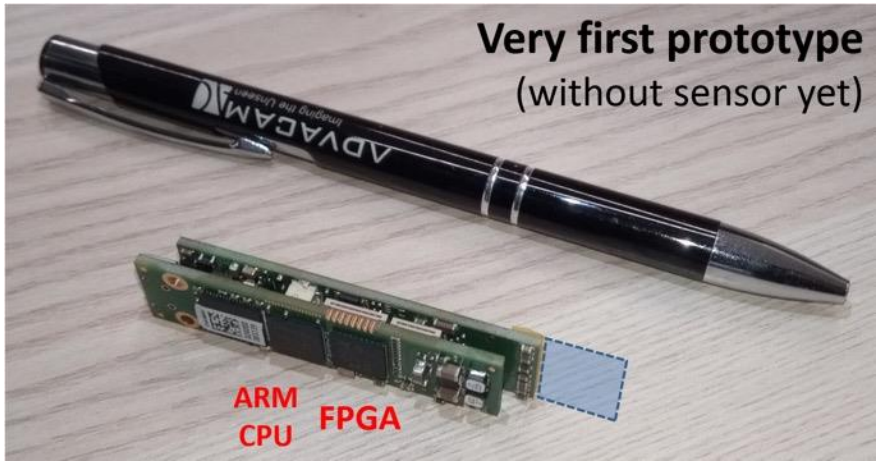
MiniPIX TPX3

Miniaturized spectral camera supporting Si and CdTe sensors

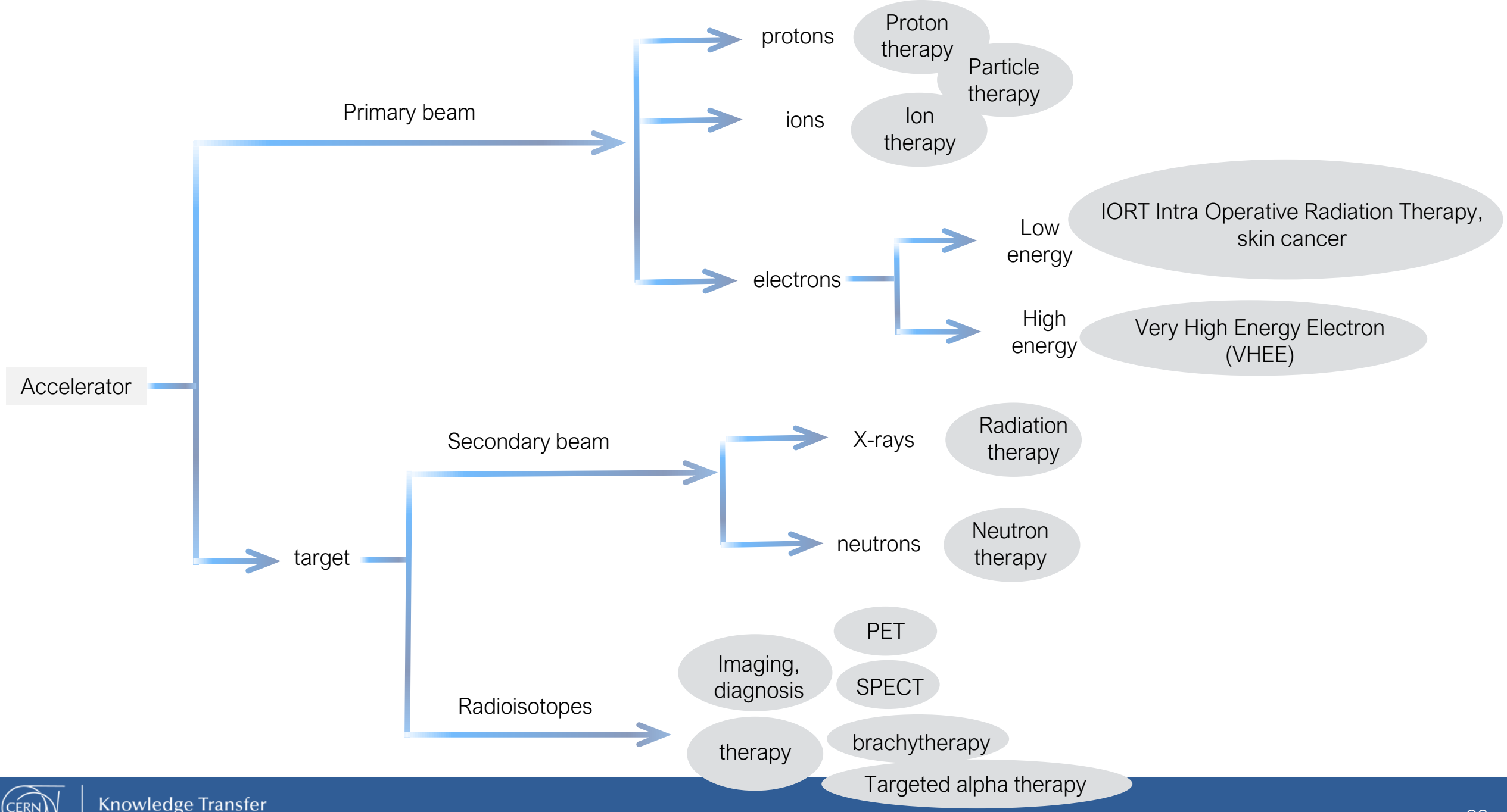


ADVACAM
Imaging the Unseen

It's really small...

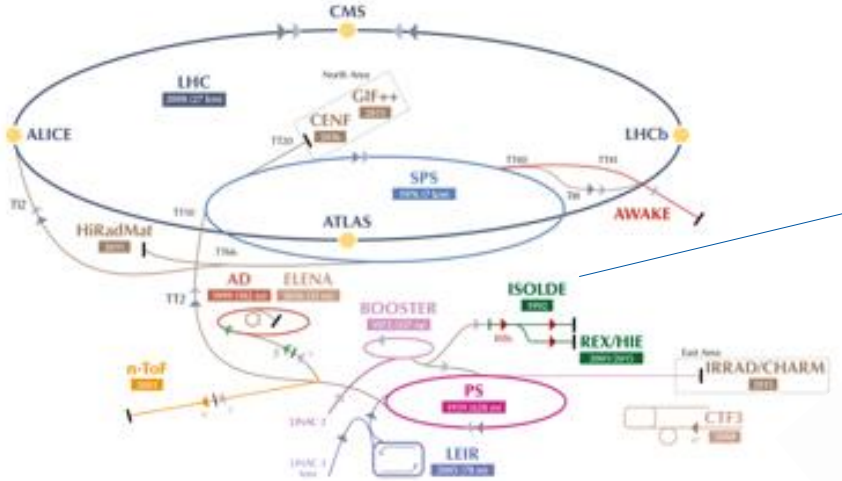


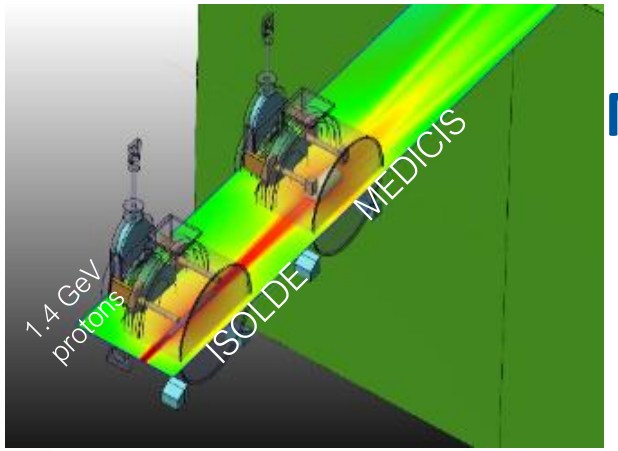
mars


Accelerator
Primary beam
protons
Proton therapy
Particle therapy
ions
Ion therapy
electrons
Low energy
IORT Intra Operative Radiation Therapy, skin cancer
High energy
Very High Energy Electron (VHEE)
target
Secondary beam
X-rays
Radiation therapy
neutrons
Neutron therapy
Radioisotopes
Imaging, diagnosis
PET
SPECT
therapy
brachytherapy
Targeted alpha therapy

CERN-MEDICIS

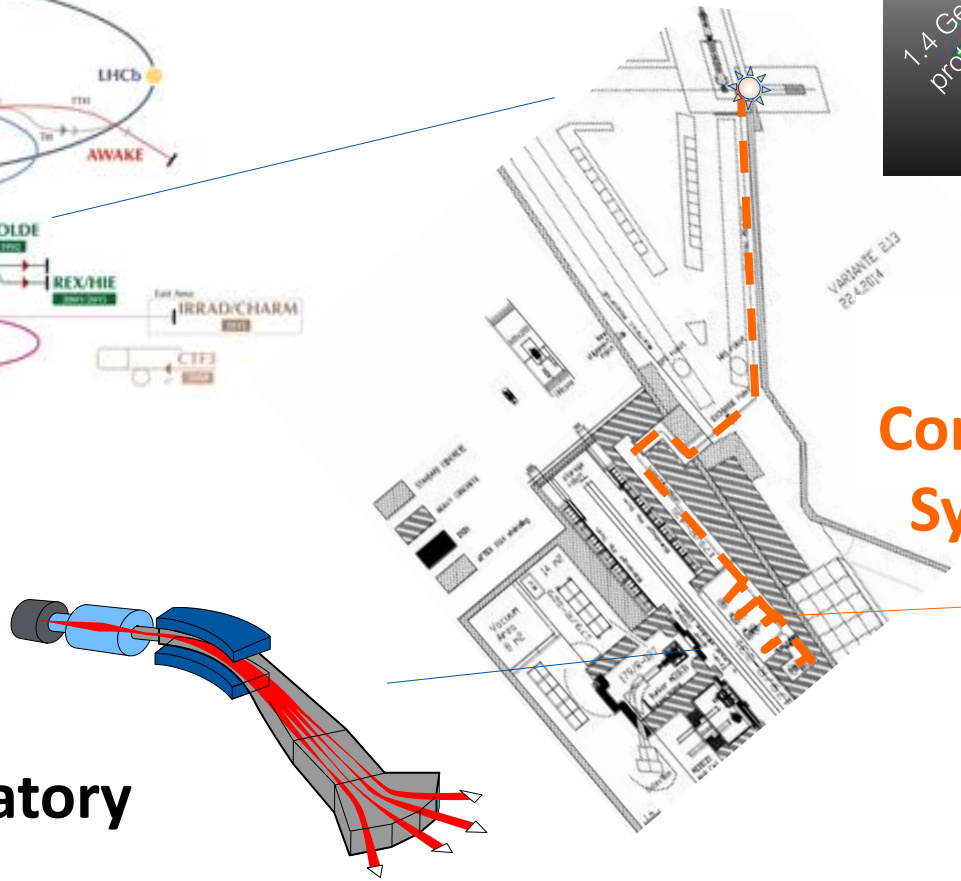
Non-conventional isotopes collected by mass separation for new medical applications





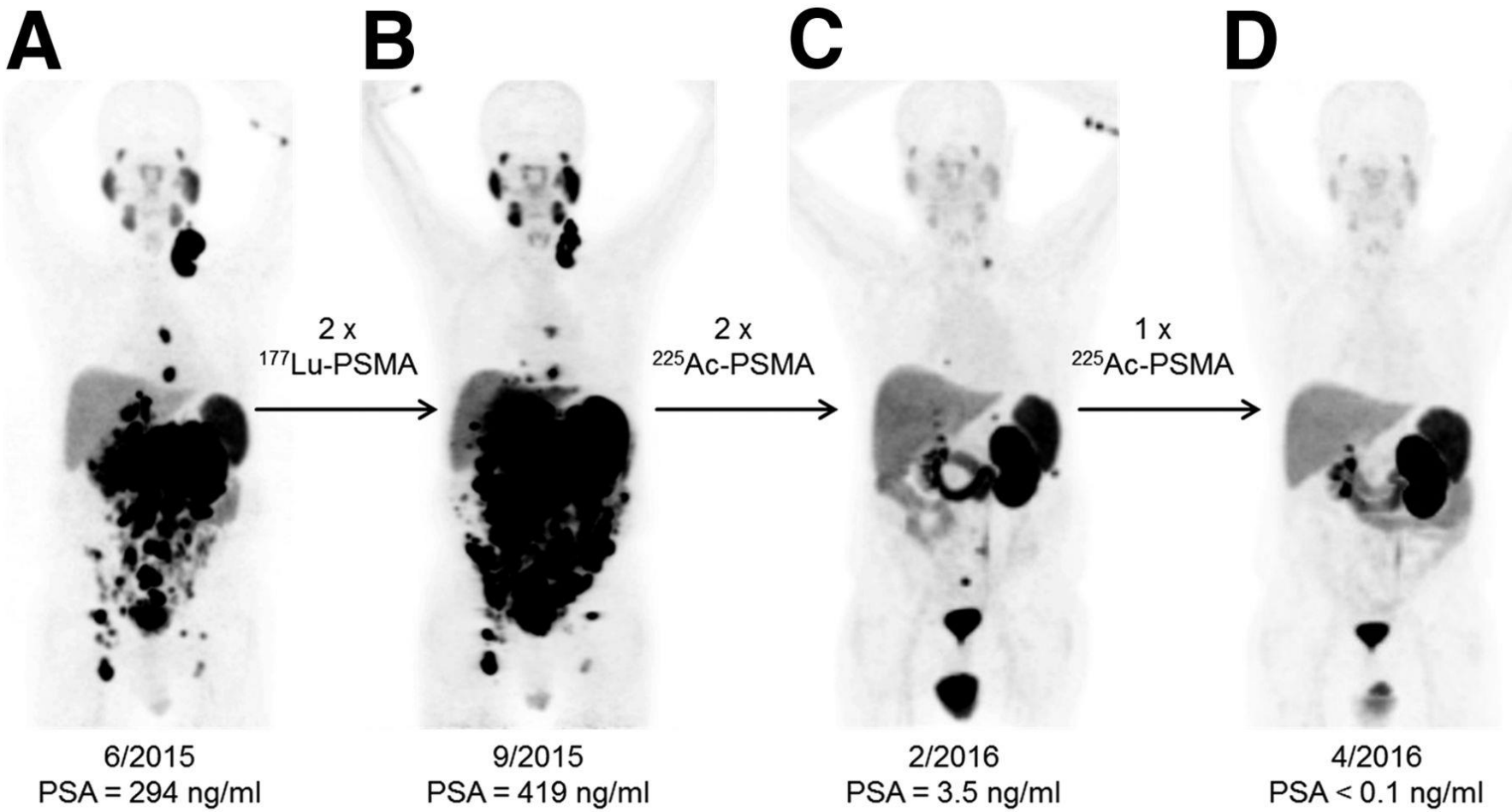
MEDICIS Target Irradiation

"Free" proton beam (otherwise lost in the dump)



Rail Conveyor System

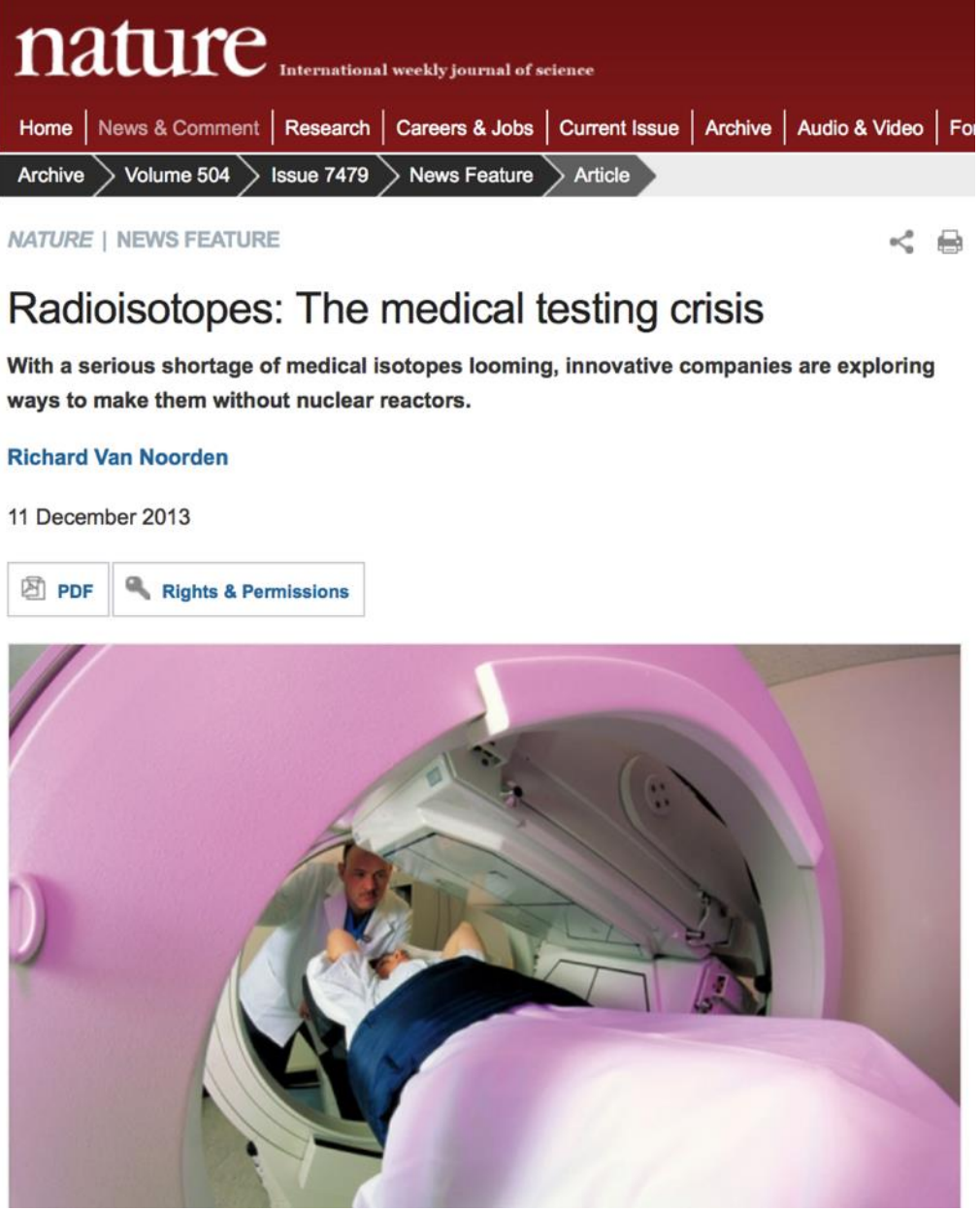
MEDICIS Laboratory



68Ga-PSMA-11 PET/CT scans of patient B. In comparison to initial tumor spread (A), restaging after 2 cycles of β-emitting 177Lu-PSMA-617 presented progression (B).
Clemens Kratochwil et al. J Nucl Med 2016;57:1941-1944

JNM The Journal of NUCLEAR MEDICINE

Radioisotopes & Nuclear Medicine



Classification of isotopes for Medicine:

1. Established isotopes → Industrial suppliers
^{99m}Tc, ^{18}F, ^{123,125,131}I, ^{111}In, ^{90}Y

2. Emerging isotopes → Small innovative suppliers
^{68}Ga, ^{82}Rb, ^{89}Zr, ^{177}Lu, ^{188}Re

3. R&D isotopes → Research labs
^{44,47}Sc, ^{64,67}Cu, ^{134}Ce, ^{140}Nd, $^{149, 152, 155, 161}$Tb, ^{166}Ho, ^{195m}Pt, ^{211}At, $^{212, 213}$Bi, ^{223}Ra, ^{225}Ac,…

Courtesy U. Koester

Theranostics

Tb 149	
4.2 m	4.1 h
ϵ β+ α 3.99 γ 796; 165...	ϵ α 3.97 β+ 1.8 γ 352; 165...

Tb 152	
4.2 m	17.5 h
Iγ 283; 160... ϵ; β+... γ 344; 411...	ϵ β+ 2.8... γ 344; 586; 271...

Tb 155
5.32 d
ϵ γ 87; 105;... 180, 262

Tb 161
6.90 d
β- 0.5; 0.6... γ 26; 49; 75... e-

A Unique Matched Quadruplet of Terbium Radioisotopes for PET and SPECT and for α- and β⁻-Radionuclide Therapy: An In Vivo Proof-of-Concept Study with a New Receptor-Targeted Folate Derivative
Cristina Müller, Konstantin Zhernosekov, Ulli Köster, Karl Johnston, Holger Dorrer, Alexander Hohn, Nico T. van der Walt, Andreas Türler and Roger Schibli
Journal of Nuclear Medicine December 2012, 53 (12) 1951-1959; DOI: https://doi.org/10.2967/jnumed.112.107540

CAFEIN

A modular **federated learning** platform to support medical analysis, diagnosis and predictions.
Being applied to brain imaging, cancer screening, stroke management.
EC-funded project Trustroke.

MARCHESE

Remote contactless human recognition and **health monitoring system**. Neonatal monitoring, rehab, elderly patients, search and rescue.
Collaboration with CHU Lille.

CAiMIRA

a risk assessment tool developed to model the **concentration of viruses in enclosed spaces**
Collaboration with WHO.
Open-source, used worldwide

BioDynaMo

An **agent-based simulation environment for multidisciplinary use**
Open source, collaboration for specific use cases

MACHINA

Movable Accelerator for Cultural Heritage In-situ Non-destructive Analysis

Photo: INFN

Construction of a compact, transportable accelerator

based on the HF-RFQ developed at CERN

In collaboration with INFN-CHNet (Cultural Heritage Network)

InsightArt
Start-up using Medipix
X-ray eyes for cultural heritage

Consultancy

Bundesdruckerei (Berlin) works with CERN on next generation ideas for identity management and cryptography and data handling.

ZENSEACT (Volvo Cars Company) teams up with CERN on extremely fast machine learning using FPGAs.

Collaborative R&D

Collaborative R&D

CERN and ABB team up on reducing electricity in cooling and ventilation.

Collaborative R&D

Collaboration with CORMEC and WUR to support national banks and regulators to detect trading anomalies in stock market.

License

MARS Bio Imaging: next generation X ray finally in color using CERN chips

Timepix on the ISS

Courtesy of NASA, photo ref. no. iss036e006175

Digital Preservation

Photo: Renee Jones Schneider, Star Tribune

TIND:
a **CERN spin-off** providing solutions for library management and data preservation based on the CERN open source software Invenio

Key lessons learned

- CERN is strong in the ‘extremes’ of the technology scale
- You need passionate experts on both sides to succeed
- Start with a concrete project and clear business need
- Mind the gap – in language, ‘clockspeed’ and culture
- Driving deep tech innovation requires courage

Key challenges

- CERN experts are busy
- Our technologies have low TRL
- What is our Unique Value Proposition?

Molte grazie
per
l’attenzione