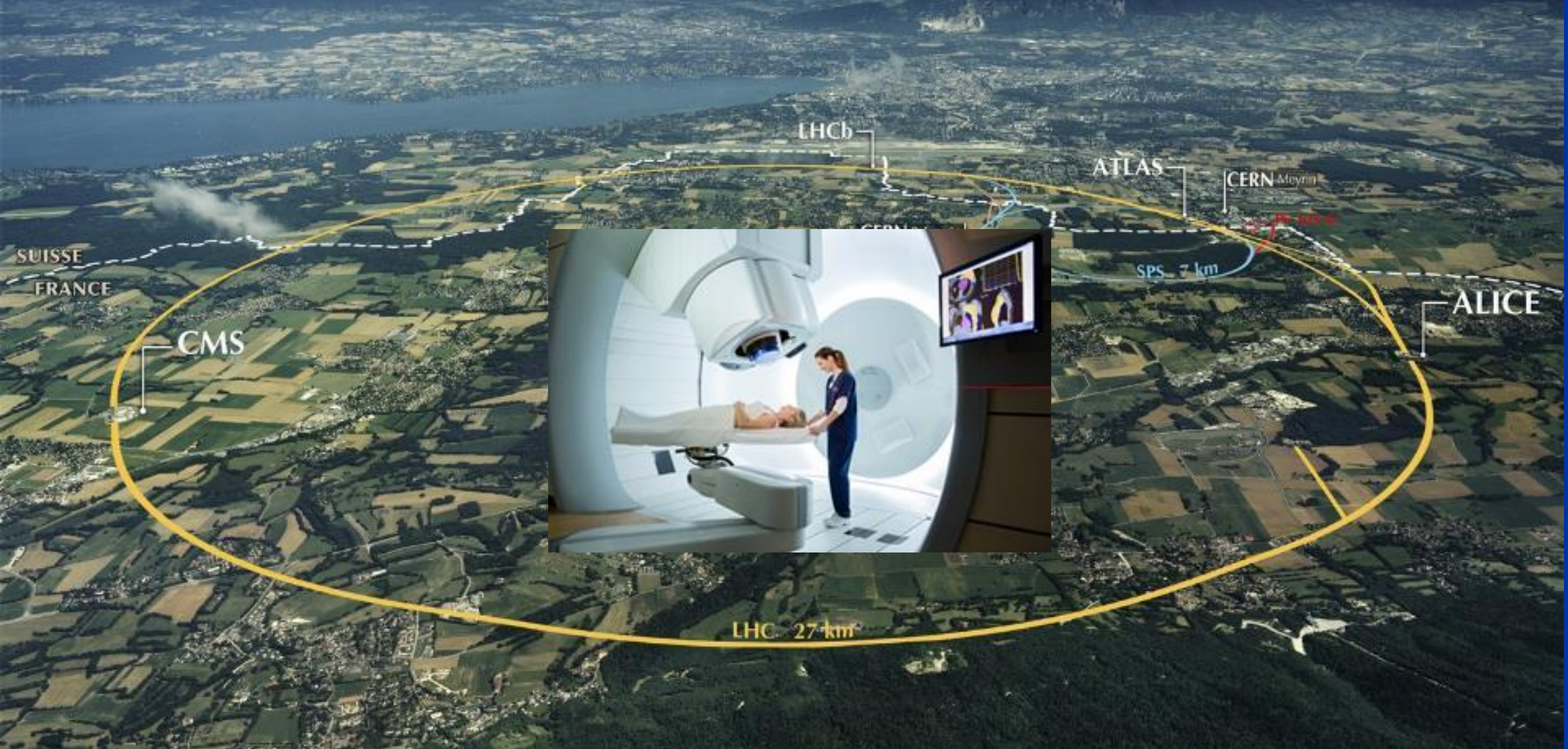
Accelerator technology and advanced particle therapy options for Baltics



Baltic Assembly and CERN Baltic Group Meeting

Maurizio Vretenar

CERN ATS Project Office, Leader of the Next Ion Medical Machine Study

CERN

nimms

7 February 2022

Particle accelerators for medicine and industry

The Large Hadron Collider is the largest and most powerful particle accelerator

But the majority of particle accelerators are small machines operating for medicine or industry

Less than 1% of accelerators operate for research

>35000 accelerators in use world-wide:

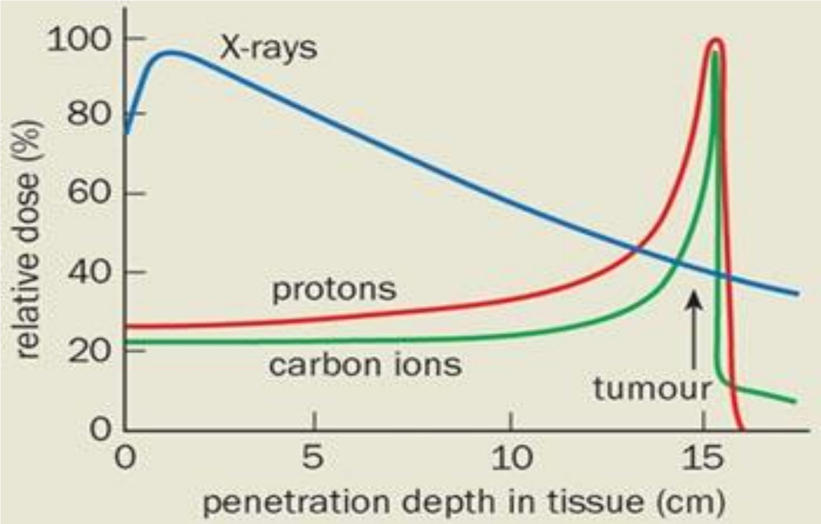
- **44% for radiotherapy**
- **41% for ion implantation**
- **9% for industrial applications**
- **4% low energy research**
- **1% medical isotope production**

Treatment of cancer with X-rays: 15,000 X-ray linacs (linear accelerators) in hospitals worldwide

Radiotherapy linear accelerator (linac)
I(from radiologyinfo.org)

Curing cancer with particle beams

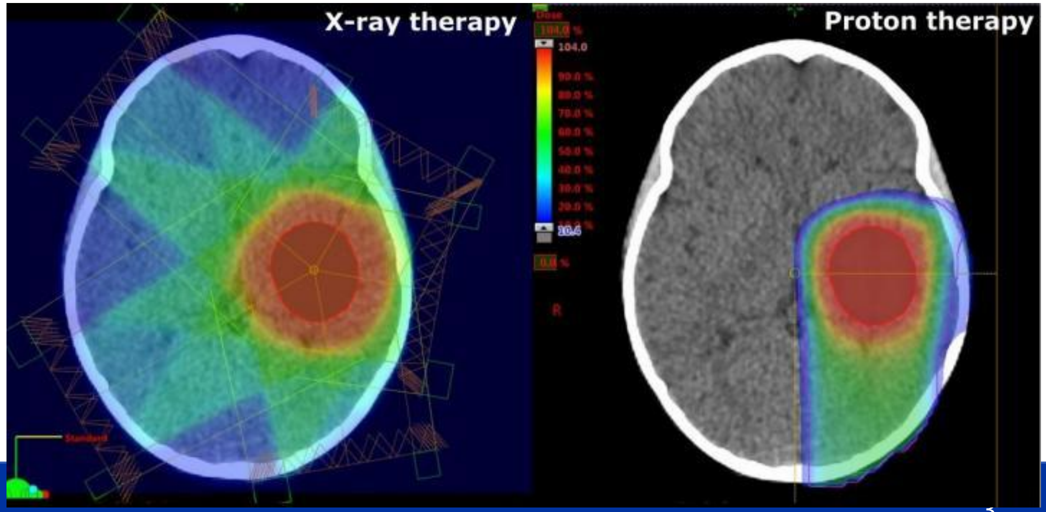
Goal: curing deep solid tumours with particle beams, with minimum damage to surrounding organs



Treating cancer with **particle beams** is a modern developing alternative to the traditional use of **X-rays** (and cobalt before X-rays).

Particles (protons or **ions)** produced by an accelerator deposit their energy at a well-defined position **inside the body**, precisely on the tumour with minimum irradiation of the healthy tissues around.

X-rays instead leave a significant radiation dose outside the tumour.



A comparison of x-ray (left) and proton therapy outcomes in children.

Credit: University of South Australia

Particle therapy of cancer – where are we now

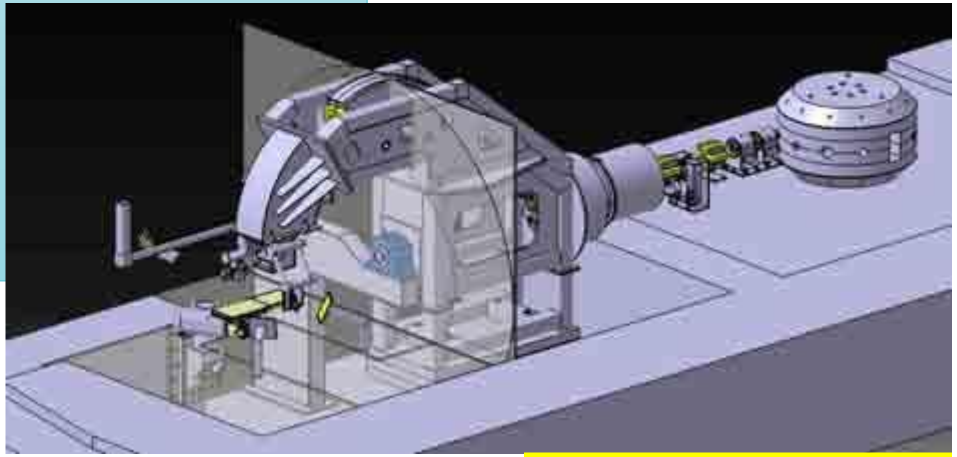
Particle therapy of cancer is a modern treatment that:

- allows treating deep cancers with lower damage and risk for other organs
- is particularly recommended for children (lower risk of recurrent cancers)
- allows for better quality of life after treatment

but:

- the accelerator is larger and more expensive.
- techniques are still developing, more research is needed.

Protons are clinically used since 1990, carbon ions since 1994

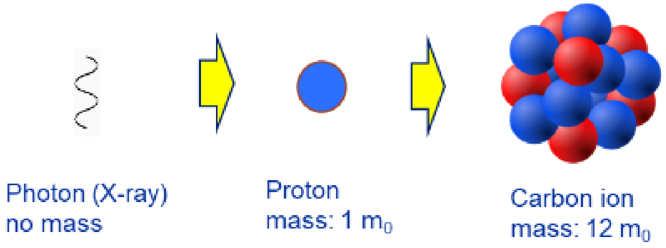


A proton therapy unit

Courtesy of Ion Beam Applications

2022:
5 vendors on the market selling proton therapy facilities.
In operation worldwide more than **120** proton facilities, and **12** carbon ion facilities

Cancer therapy with protons is now commercial, while therapy with ions that is more precise and can treat more types of cancers is developing slowly because of larger dimensions and cost of the accelerator



The CERN Next Ion Medical Machine Study (NIMMS)

Application of CERN accelerator technologies to medicine is coherent with the wider CERN mission.

CERN has launched a new collaborative initiative to develop a **new generation of compact accelerator for cancer therapy with ions**.

Profiting of the CERN experience in particle accelerator technologies, CERN can contribute to a next generation cancer therapy accelerator that will have:

- Operation with multiple ions: protons, helium, carbon, oxygen, etc. for therapy and research.
- Lower cost and dimensions, compared to present;
- Faster dose delivery with higher beam intensity and new delivery schemes (FLASH)
- A rotating device to precisely deliver the dose to the tumour.

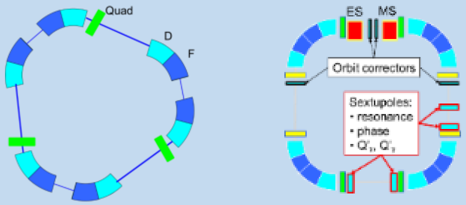
Establishment of NIMMS, the
Next Ion Medical Machine Study at CERN (2018):

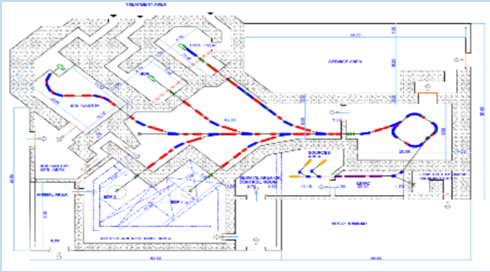
- Building on the experience of the PIMMS (proton-ion medical machine study) of 1996/2000;
- Federating a large number of partners to develop designs and technologies for next-generation ion therapy;
- **Partners** can use the NIMMS technologies to assemble their own optimized facility.

nimms

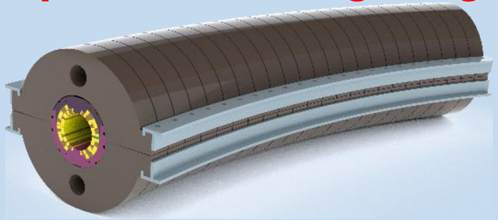
CERN research lines for particle therapy

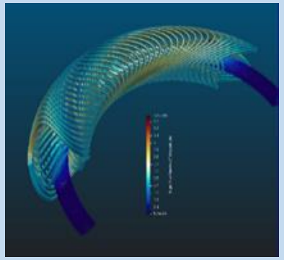
1. Small synchrotron accelerators (rings)



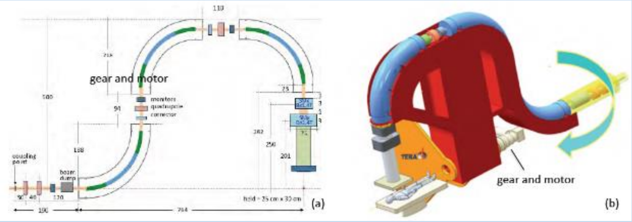


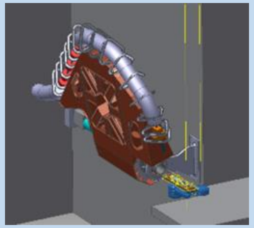
2. Superconducting magnets for small accelerators

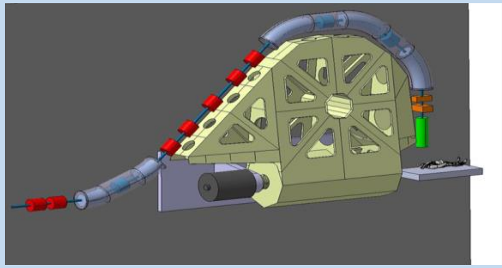




3. Superconducting rotating gantries for ions







4. Compact linear accelerators for ions

International collaborations:

- SEEIIST Association (CH)
- TERA Foundation (Italy)
- GSI (Germany)
- INFN (Italy)
- CIEMAT (Spain)
- Cockcroft Institute (UK)
- University of Manchester (UK)
- CNAO (Italy)
- Imperial College (UK)
- MedAustron (Austria)
- Riga Technical University (Latvia)
- U. Melbourne (Australia)
- ESS-Bilbao (Spain)
- Thessaloniki University (Greece)
- Sarajevo University (Bosnia &H.)

Geography of particle therapy in Europe

Particle therapy centres in Europe. Courtesy of ENLIGHT, 2020

Only 2 areas in Europe without particle therapy facilities:

- **South East Europe**
- **Baltics**

To cover South East Europe, CERN is collaborating with the SEEIIST institute planning to build a large multiple-ion research and therapy facility in the Balkans.

Options for the Baltics

Discussions with the RTU team at CERN on possible options to bring particle therapy to the Baltics. The basic choice is between:

- A commercial proton therapy system, or
- **A new and more advanced facility operating with different ions and new treatment techniques,** established as Baltic cooperation, which on top of treating patients would:
  - Involve local industry in the construction;
  - Start a research programme on new cancer therapy techniques;
  - Attract researchers and patients from all Europe.

5 options identified and discussed in the CERN Baltic Group:

1. **cyclinac**
2. **Carbon linac**
3. **Helium synchrotron**
4. **Carbon synchrotron**
5. **superconducting Carbon synchrotron**

Conclusions from the CERN Baltic Group – 10/2021

A **compact synchrotron to accelerate protons and helium ions to treat deep tumours** is an appropriate choice for the Baltics:

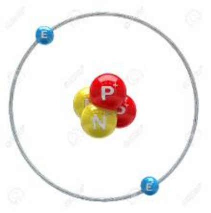
- Limited additional cost from commercial unit;
- Can treat patients with protons from start;
- Has a broader treatment range (flash therapy);
- Allows a wide cancer research programme;
- When helium is approved for therapy, offers wider and more precise treatment than protons;
- Engages the Baltic medical and industrial community in a promising cancer therapy direction;
- Connects with ongoing cancer research and accelerator developments in Europe;
- Present moderate technical risk, and high medical and scientific gain.

increasing cost →

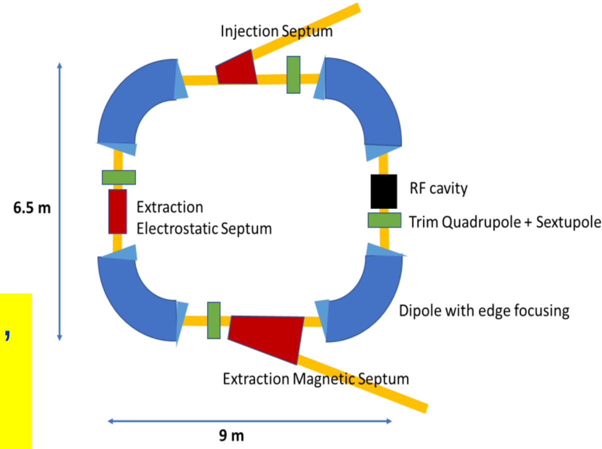
	Cyclinac	C-linac	He-synchrotron	C-synchrotron (RT)	C-synchrotron (SC)
Particles	p	p, He, C	p, He	p, He, O, C	p, He, C
Dimensions (1)	~400 m² (?)	~600 m²	~600 m²	~1,200 m²	~600 m²
Approx. cost (2)	20	30	20	40	30
R&D needed	medium	high	low	low	high
Risk for R&D	low	medium	low	low	medium
Time to TDR (3)	~1y	~4y	~1.5y	~1.5y	~5y
Radioisotopes	Yes, wide range	no	if needed	yes	if needed
Gantry (4)	no	no	yes (>5y)	yes (>5y)	yes (>5y)
Comm. interest	low	medium	medium	low	high

Note that all these options will need medical licensing before treating patients (cost and time)

(1) Accelerator only – no rooms, without shielding
(2) Accelerator only. Rough estimate in arbitrary units for cost of acc. components
(3) Assuming an expert team working full time; TDR=Technical Design Report
(4) Use of SIGRUM superconducting gantry



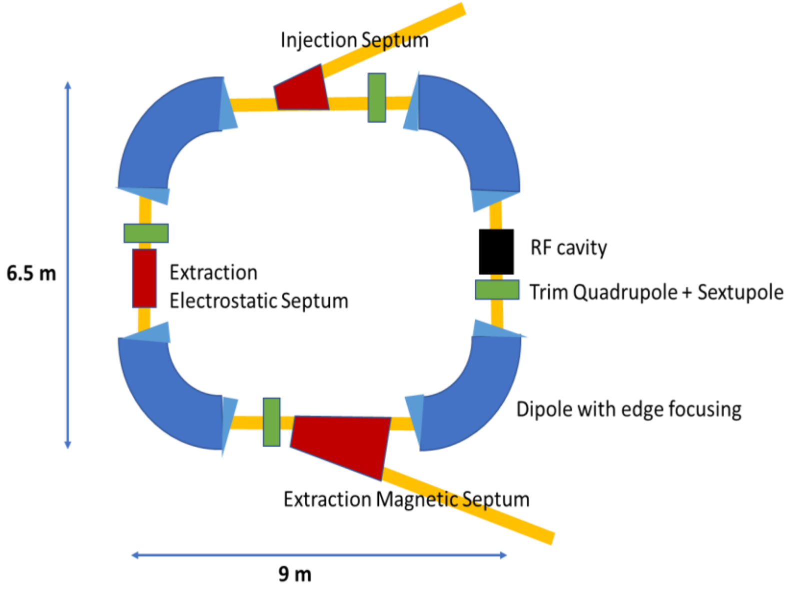
Helium atoms:
2 protons,
2 neutrons,
2 electrons



The helium therapy synchrotron, dimensions 9 m x 6.5 m

Elena Benedetto, SEEIIST/CERN

Compact proton and helium synchrotron



Advantages:

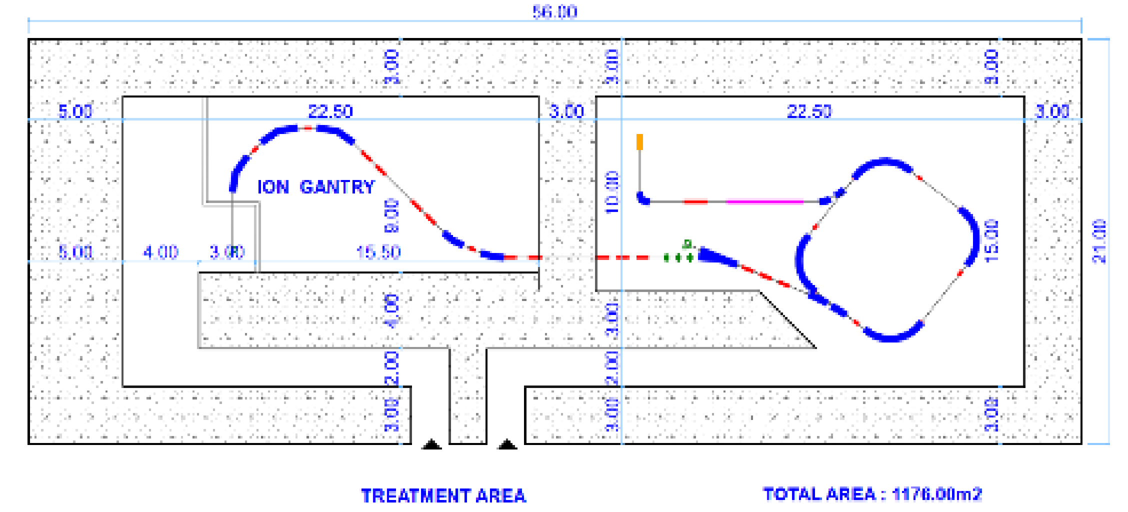
- Simple and compact, known technologies
- Synchrotron based on standard components
- Can use new gantry design

NIMMS has started the design of a Compact Helium Synchrotron

Helium gives better precision than protons and could treat some radioresistant tumours at lower cost than carbon – wide interest in medical physics community. Tests starting at HIT centre.

Can use the ongoing gantry design

Option of radioisotope production and short range (11 cm) carbon therapy



Size of the facility: 1,200 m^2 for treatment + about 500 m^2 for research

- Conceptual design ready in June 2022.
- Could be followed by a Technical Design in 2022/23 with the contribution of the Baltic scientific institutions.

Thank you for your attention

maurizio.vretenar@cern.ch

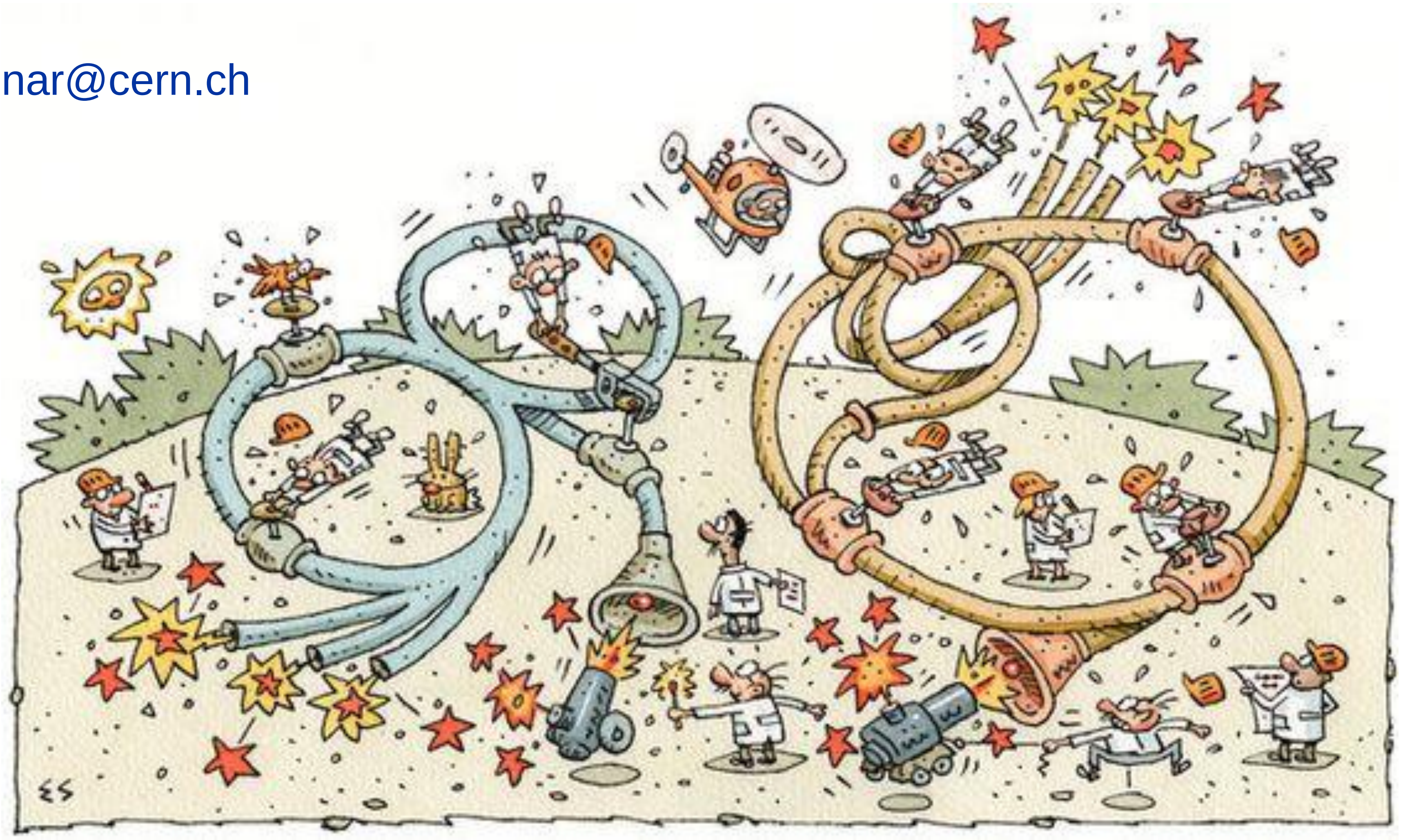


Image credit: Elwood H. Smith, The New York Times