



**CERN**

European Organization for Nuclear Research

Organisation Européenne pour la Recherche Nucléaire


# **The industrial & societal impact of particle physics**

## **Particle physics, a key driver for innovation**

*Wednesday June 12<sup>th</sup>*

**International Linear Colliders, a world event, Geneva**

*Jean-Marie Le Goff, PhD, Dphil*  
**CERN**



Today: Designing, constructing and developing physics instruments and understanding the observations is central to the endeavours of most contemporary physics.

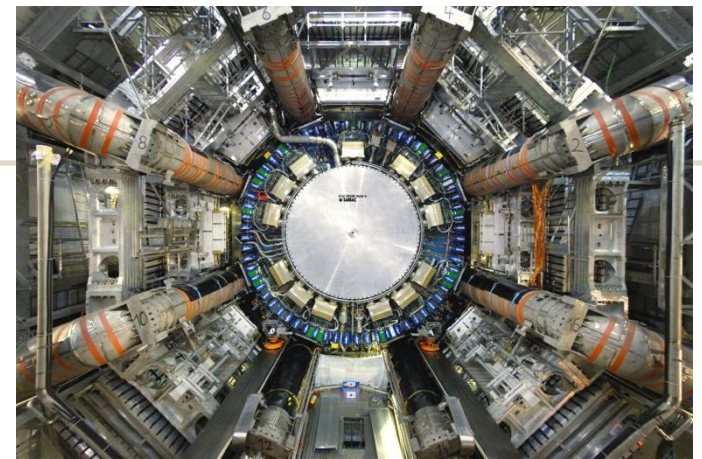
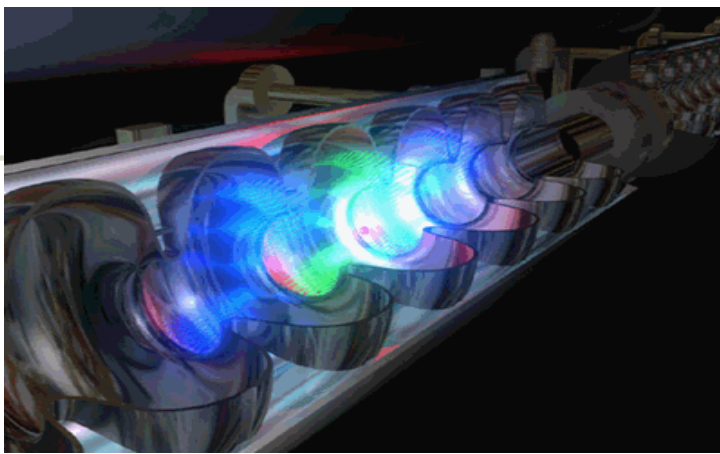
Basic research has often been considered as a construction of mind requiring experiments for its validation

## From basic research to innovation and technology

Quantum physics has dramatically changed this view by considering the instrument themselves as essential constituents of the theory since these measurements actually interact with the phenomena being observed.

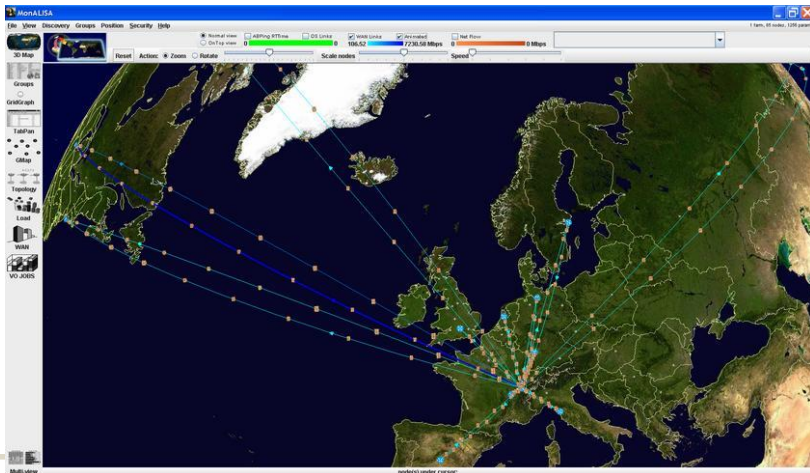
Large PP infrastructures demand developments in applied sciences & high-tech engineering

- Highly qualified experts
- Groundbreaking technology and innovation are key to the success of large projects
- Innovation occurs especially where basic research meets applied sciences and high-tech industry



***The complex and sophisticated tools of particle physics are rich sources of new concepts, innovation and groundbreaking technologies, which benefit various applied research disciplines and eventually find their way into many applications that have a significant impact on the knowledge economy and society.***

## Main impact of particle physics



ILC, a world event  
Geneva, June 12<sup>th</sup>, 2013

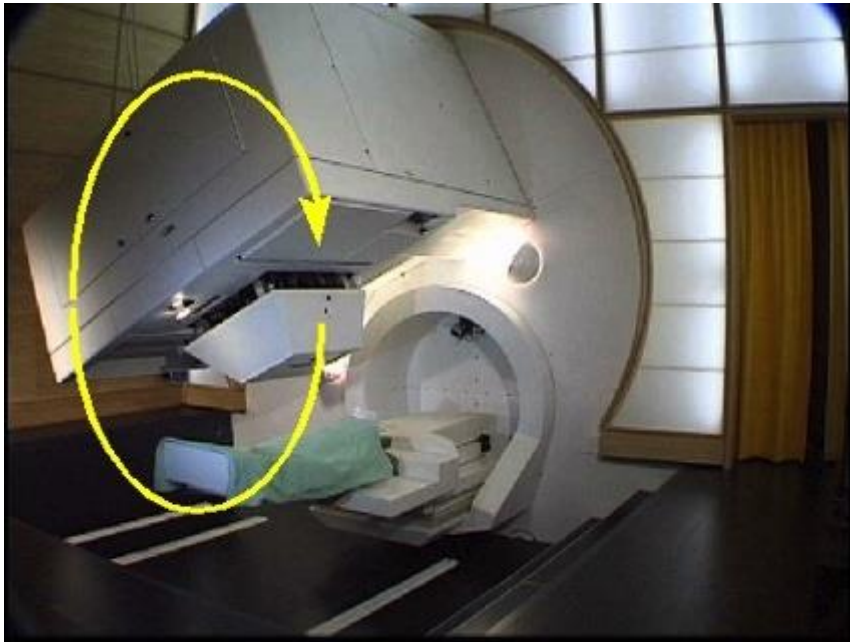


Particle Physics, a key driver for innovation

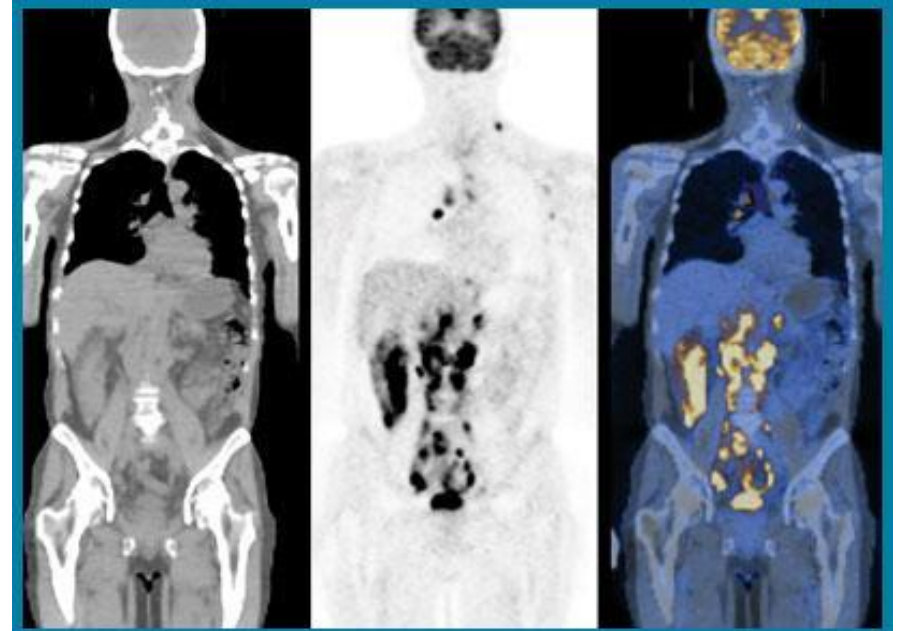


# Impact: Health

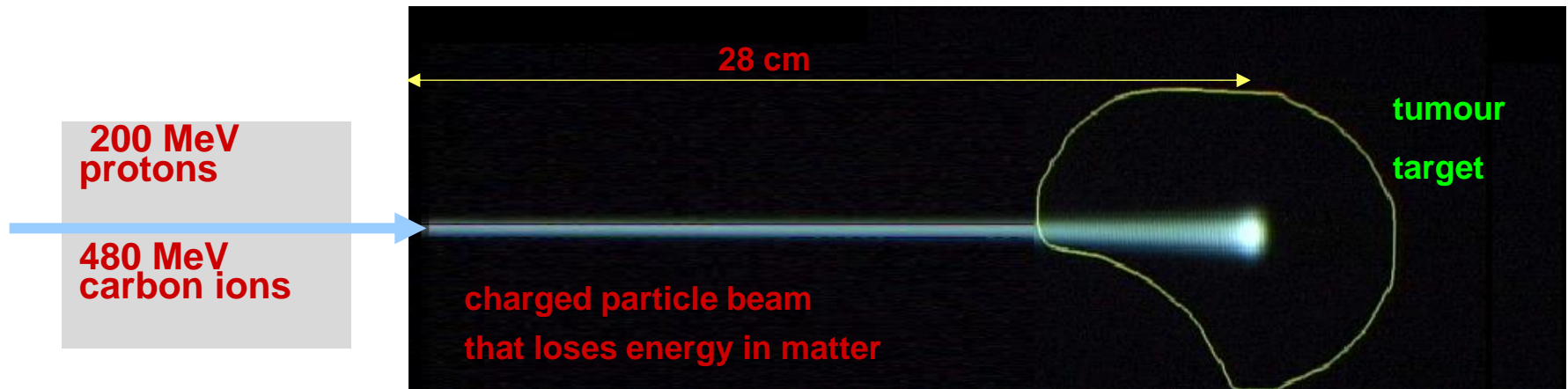
## Treating cancer



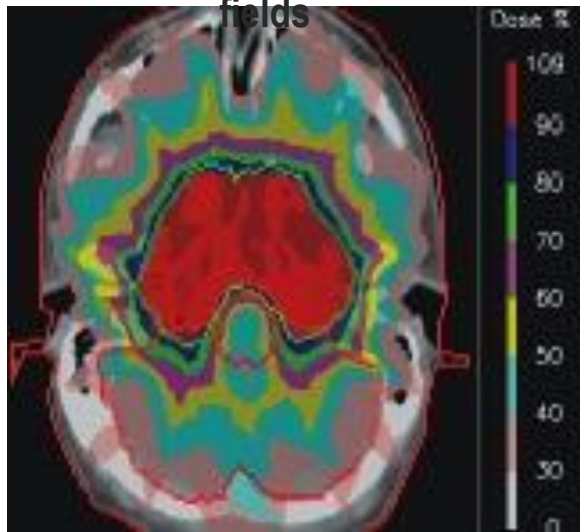
## Imaging diseases



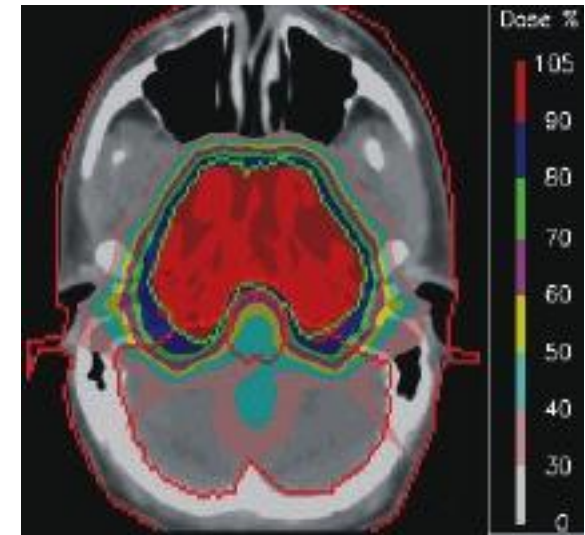
# Particles are more effective to treat deep-seated tumours than photons (radiotherapy)



9 X-ray fields



4 proton fields



Ex: For Cordrosarcomas, the survival rate at 5 years is

- 98% for protons
- <35% for conventional RT

# Imaging modalities originating from particle physics

Modalities serve different purposes and are complementary



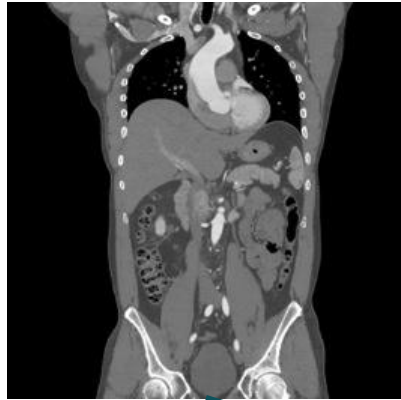
Computed Tomography



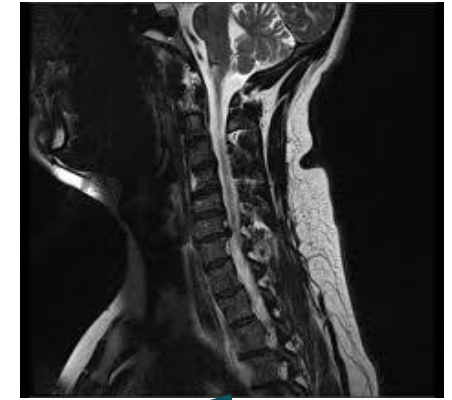
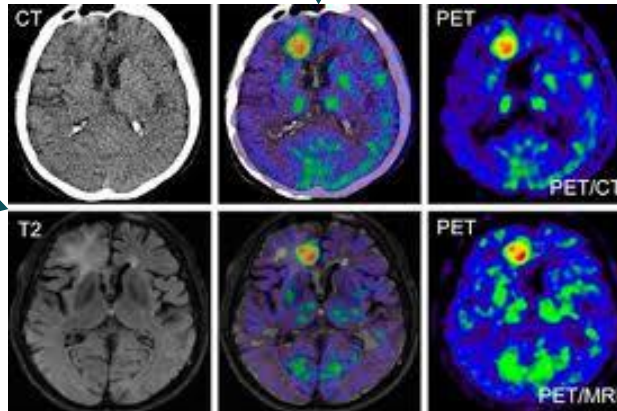
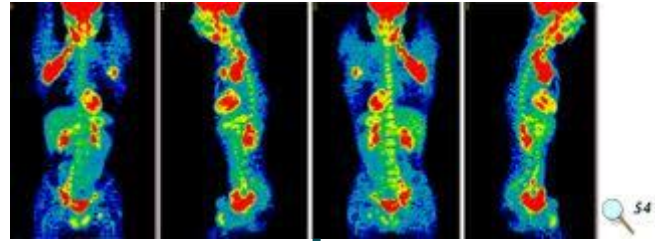
Positron Emission Tomography



Magnetic Resonance Imaging



3-D X-rays  
Morphological imaging



SC Magnet  
Morphological imaging

Image fusion

Cancer treatment planning and follow-up  
Image guided surgery

$\beta^+$  for functional imaging

Particle Physics, a key driver for innovation

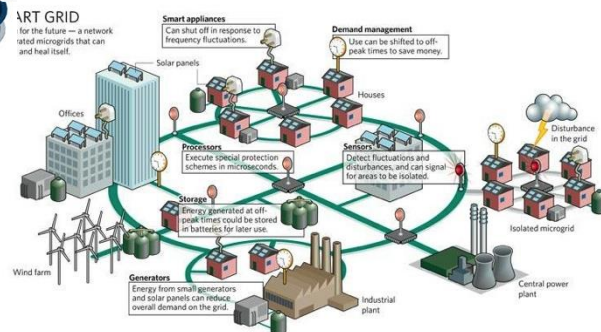
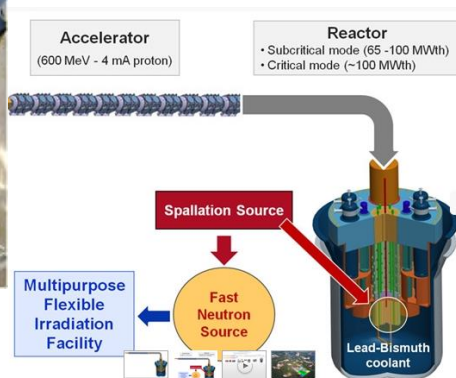


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# Impact on Energy and the environment

## Energy

- Solar thermal energy
- Nuclear energy
- Smart



## Environment

- Flue gas
- Waste water treatment
- Sterilisation



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Particle Physics, a key driver for innovation

# Accelerator ultra vacuum technology is the answer!

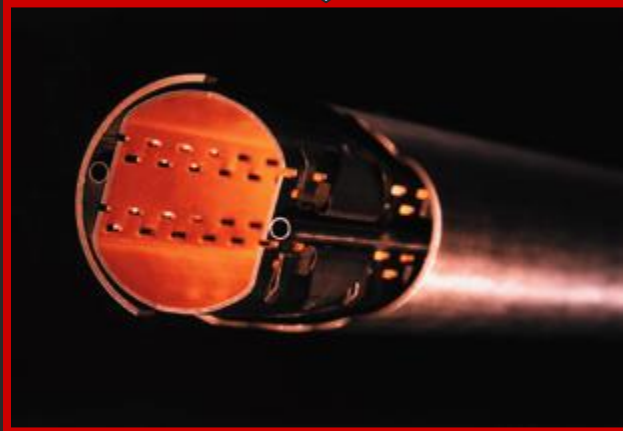


High vacuum  
for flat solar  
collectors



Achieve XUHV  
( $10^{-13}$  Torr) in  
vacuum tubes

Heating & Cooling, industrial  
processes, Electricity,  
Agriculture, Desalination

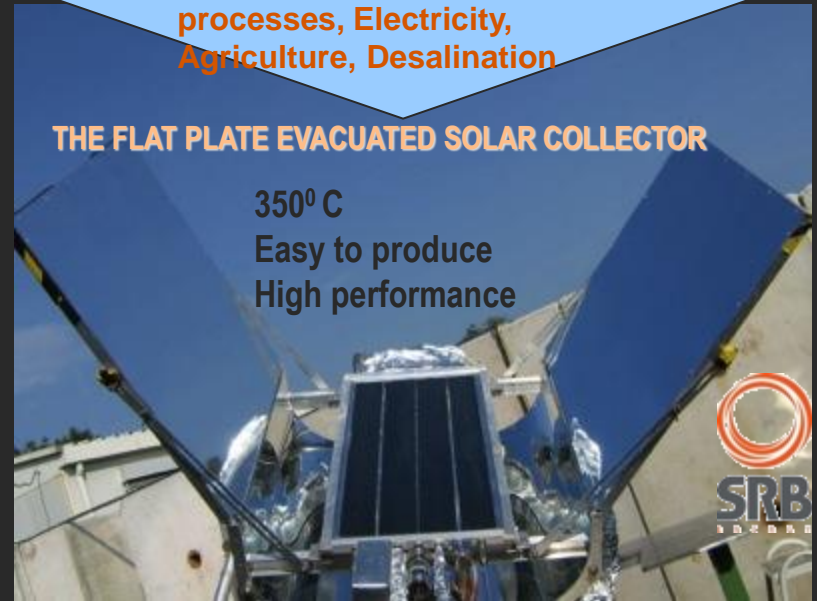


THE FLAT PLATE EVACUATED SOLAR COLLECTOR

350° C

Easy to produce

High performance





# Accelerators for sub-critical nuclear reactors ?

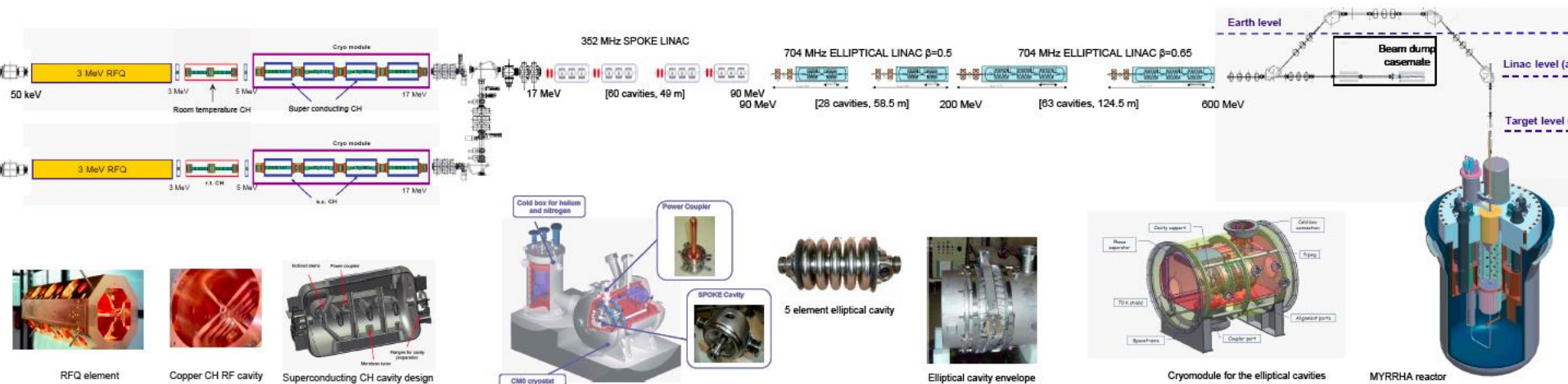
## Characteristics

- Thorium is a naturally occurring element 4 times more abundant than Uranium
- There is enough thorium available to sustain ADSR systems for more than ten centuries (today's consumption)
- **20 MW** are required for the operation of an ADSR producing **600 MW** of electrical power
- Best prospect for dramatically reducing radiotoxicity and lifetime of radioisotopes in spent fuel

### General layout of the superconducting linac

The design of the accelerator is a European collaboration, started in FP5 (PDS-XADS) and pursued in FP6 (EUROTRANS).

- The main partners are CNRS (France), CEA (France), INFN (Italy), U. Frankfurt (Germany).
- Smaller contributors are Empresarios Agrupados (Spain), ITN (Portugal) and SCK-CEN (Belgium).



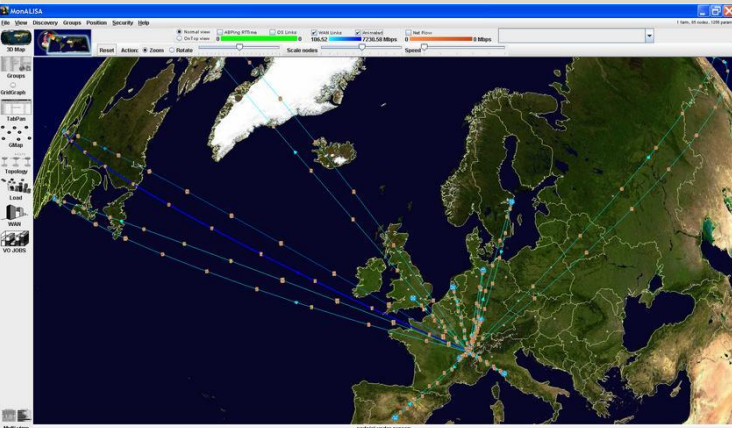
## An Accelerator Driven Subcritical Reactor (ADSR) MYRRHA (Prototype at SCK-CEN)



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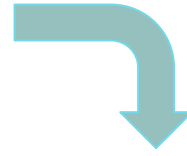
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# No smart electrical grid without Grid computing



PP computing needs

Closing the loop



Industry developed Connectivity



Optimize energy flow  
Renewable energy in the grid

**Mellanox TECHNOLOGIES**  
Connect. Accelerate. Outperform.  
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Choose an InfiniBand Based Cloud Provider Today!  
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**HPC**  
In the Cloud

Weekly Update  
May 24, 2013

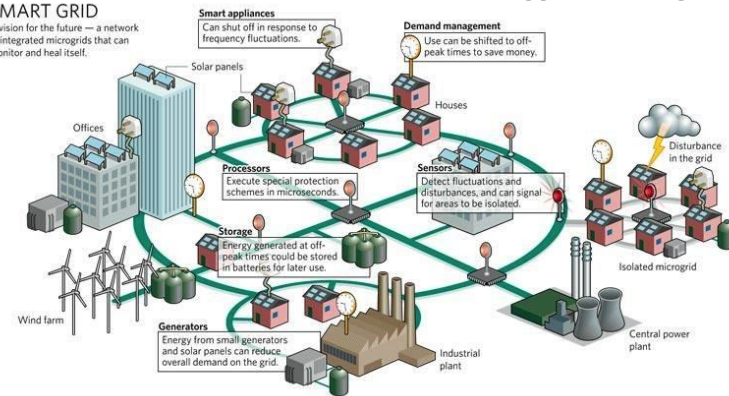
Dedicated to covering high-end cloud computing in science, industry and the datacenter

## CERN, Google, and the Future of Global Science Initiatives

Large-scale, worldwide scientific initiatives rely on some cloud-based system to both coordinate efforts and manage computational efforts at peak times that cannot be contained within the combined in-house HPC resources. Last week at Google I/O, Brookhaven National Lab's Sergey Panitkin discussed the role of the Google Compute Engine in providing computational support to ATLAS, a detector of high-energy particles at the Large Hadron Collider (LHC). [Read more...](#)

### SMART GRID

A vision for the future — a network of integrated microgrids that can monitor and heal itself.



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# Impact on the environment



## ***Flue gases for power plans***

- Remove up to 95% of  $\text{SO}_x$  and 90% of  $\text{NO}_x$ .
- System needs 1% of the electrical power produced by the plant
- Produce fertilizers from the synthesis of  $\text{NH}_3$  with the pollutants



## ***Waste water***

- convert non-degradable pollutants into degradable species
- large variety of reactive species are generated in situ without the addition of any chemicals

## ***Removing human pathogens in sludge for land applications***

- Action:
  - DNA and protein damage  $\rightarrow$  Cell death
  - Indirect: Water radiolysis generate high active intermediates that react with biomolecules  $\rightarrow$  Cell death
- Importance: 13800 Mt of dried sewage sludge production (US and EU)



# Impact: industrial applications of accelerators

## *Ion-beam accelerators for digital electronics*

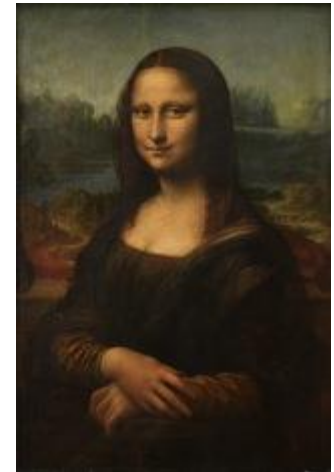
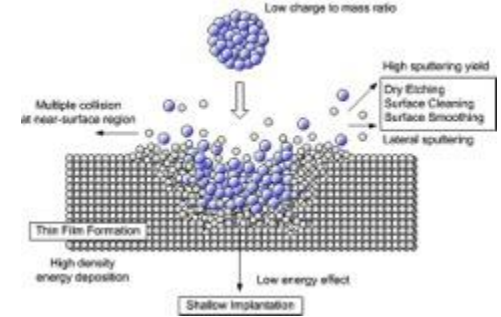
- Dope sub-microscopic regions of Si or Ge substrates and create junctions to build fast transistors in chips

## *E-Beam for greener industrial processes*

- Curing inks (Energy consumption 10% of thermal techniques)
- Strengthening of polyethylene water pipes.
- Using X-ray-cured carbon composites in cars
  - reduce vehicle weight by 80% and
  - energy consumption by 50%
- Hardening tyres

## *Cultural heritage (Accelerator Mass Spectroscopy)*

- Date paintings and detect fraudulent copies
- Age estimate of organic remains in archaeological findings
- Authenticate wine vintages



# Scientific collaborations to bring large projects to completion

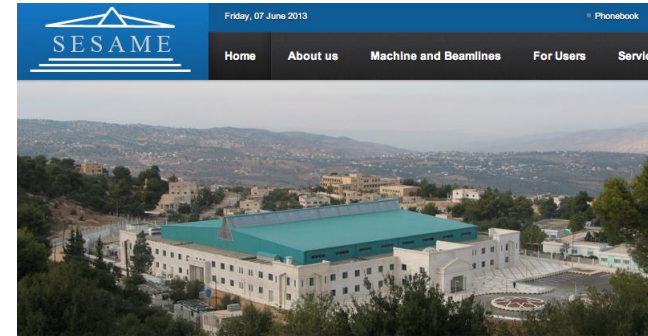


**1955:** CERN, first formal international scientific collaboration

**2008:** A world wide collaboration completed the construction of the largest physics instrument



**2013:** Uniting people around science in the middle east

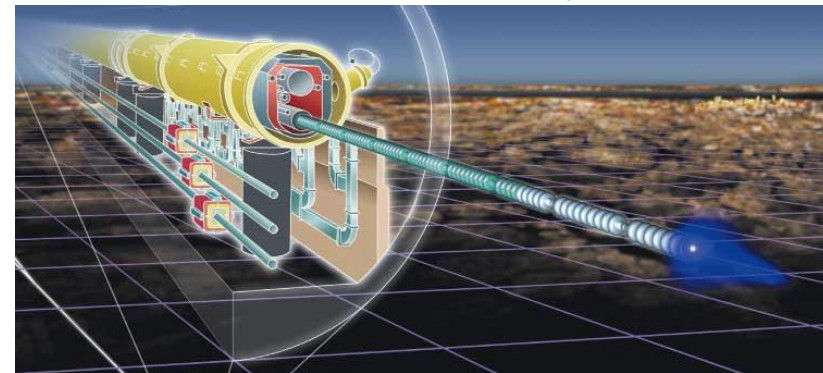


**SESAME | SYNCHROTRON-LIGHT FOR EXPERIMENTAL SCIENCE AND APPLICATIONS IN THE MIDDLE EAST**

## → Benefits for society

Experience in large scientific collaborations is central in establishing genuine, creative and sustainable **research areas** needed to face the unprecedented challenges of energy, environment and health with success

International collaborations: a key asset for ILC



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# Economic benefits

*More than 30,000 accelerators are active worldwide; Less than 200 are for research purposes.*

*All the final products that are processed, treated or inspected by the particle beams of industrial accelerators worldwide, have a collective annual value of about \$500 billion.*

Application	Total systems	Systems sold/year	Sales/year (€M)	System price (€M)
Cancer therapy	9,100	500	1,800	2.0 – 5.0
Ion implantation	9,500	500	1,400	1.5 – 2.5
e <sup>-</sup> welding & cutting	4,500	100	150	0.5 – 2.5
e- and X-ray irradiators	2,000	75	130	0.2 – 8.0
Radioisotopes	550	50	70	1.0 – 30
Non-destructive testing	650	100	70	0.3 – 2.0
Ion analysis	200	25	30	0.4 – 1.5
Neutron generators	1,000	50	30	0.1 – 3.0
<b>Total</b>	<b>27,500</b>	<b>1,400</b>	<b>3,680</b>	

2007 data  
Market growth >= 10%/year

ESGARD: European Steering Group for Accelerator Research and Development



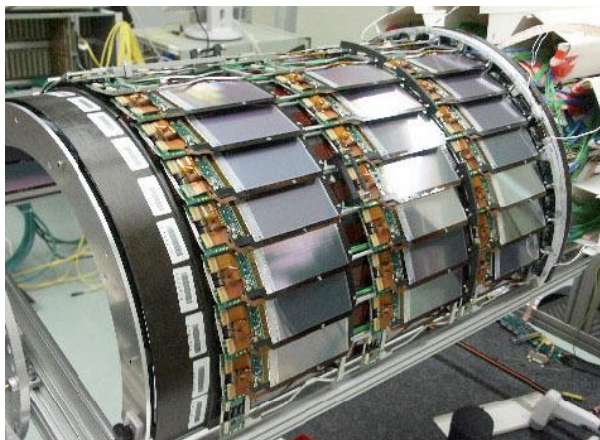


***Basic and applied sciences go hand in hand, relying on and challenging one another. Public support is instrumental to fostering this delicate alchemy. World future prosperity depends on it.***

## **Fostering innovation**

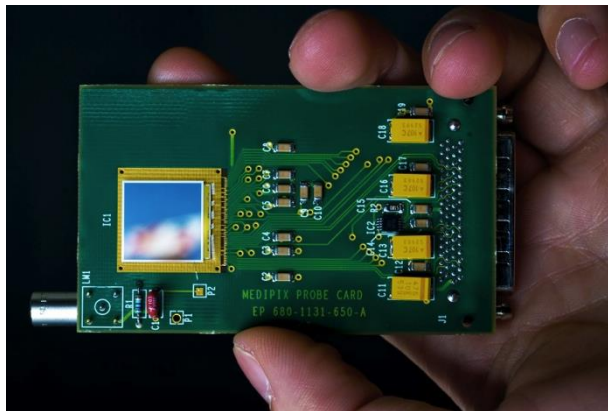
- Research requirements
- Application of physics discoveries to research

# PP Research requirements' driven innovation



**Particle tracking** calls for counting electronics

**Medipix** for PP counting applications and medical imaging



**Color Computed Tomography**  
- Higher resolution & better quality  
- Lower dose







Heike Kamerlingh Onnes

1911: discovery of superconductivity

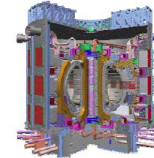
# Applying new discovery to boost innovation

# Superconductivity as a key technology from small electronics to large magnet applications



← Medicine

Science →



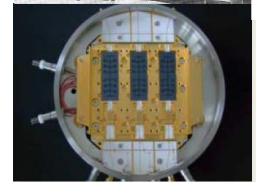
← Energy

Engineering →



← Transport

Electronics →

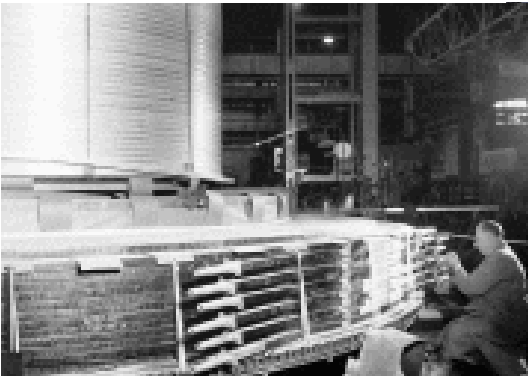


M. Noe Academia – Industry matching event – Fostering collaborations in Superconductivity  
May 27<sup>th</sup>- 28<sup>th</sup> 2013, Madrid, Spain

## Status

## Status in 2013

### Large Scale Energy Applications



1955: SC magnet manufacturing for research

2008: LHC

	Technology Demonstration	Prototypes in field operation	First commercial products	Full market entry
LTS Fusion magnets		13		
HTS Fusion magnets	13			
AC Cable			13	
DC Cable		13		
Power generator	13			
Ship propulsion		13		
Hydro generator	13			
Wind generator	13			
Transformer		13		
MV FCL			13	
HV FCL		13		
HTS SMES			13	
LTS SMES		13		
Magnetic separation				13
Magnetic levitation		13		



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# Conclusions

Large research instruments are instrumental to future high-tech developments

Research in curiosity-driven science is a key driver for technological innovation and economic success

## From basic research to innovation and technology

Scientific collaborations are key to the completion of large projects with proper control of cost and schedule

Huge impact of particle physics on industry and society  
→ There is more to come with the future research programme!