Accelerating Science and Innovation

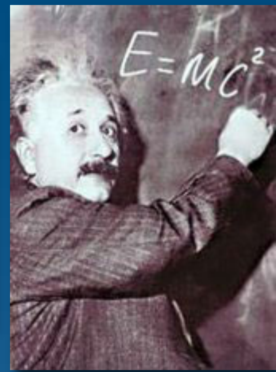
Accelerators as Tools of Discovery, Innovation and Global Collaboration

Bridgelab Symposium

R.-D. Heuer

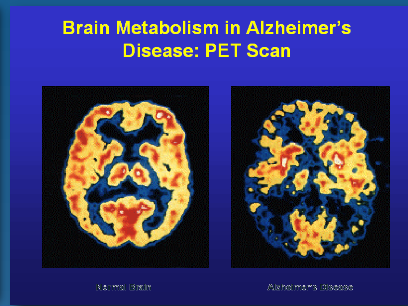
Innovation
Education
CERN
uniting people
Research

The Mission of CERN



- **Push back** the frontiers of knowledge

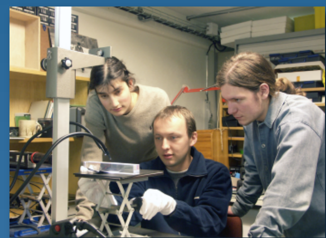
  E.g. the secrets of the Big Bang …what was the matter like within the first moments of the Universe’s existence?



- **Develop** new technologies for accelerators and detectors

  Information technology - the Web and the GRID

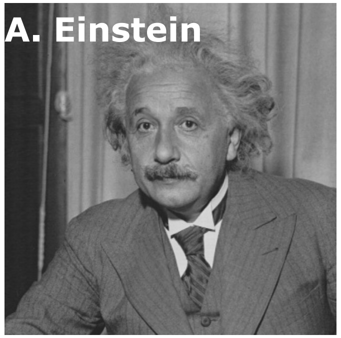
  Medicine - diagnosis and therapy



- **Train** scientists and engineers of tomorrow

- **Unite** people from different countries and cultures

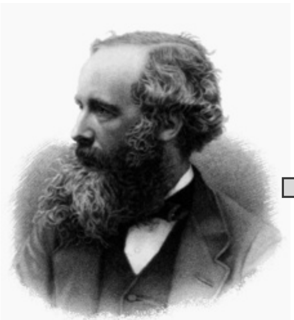
Fundamental research has always been a driver for Innovation



Relativity

100% SCIENCE

GPS



J.C. Maxwell

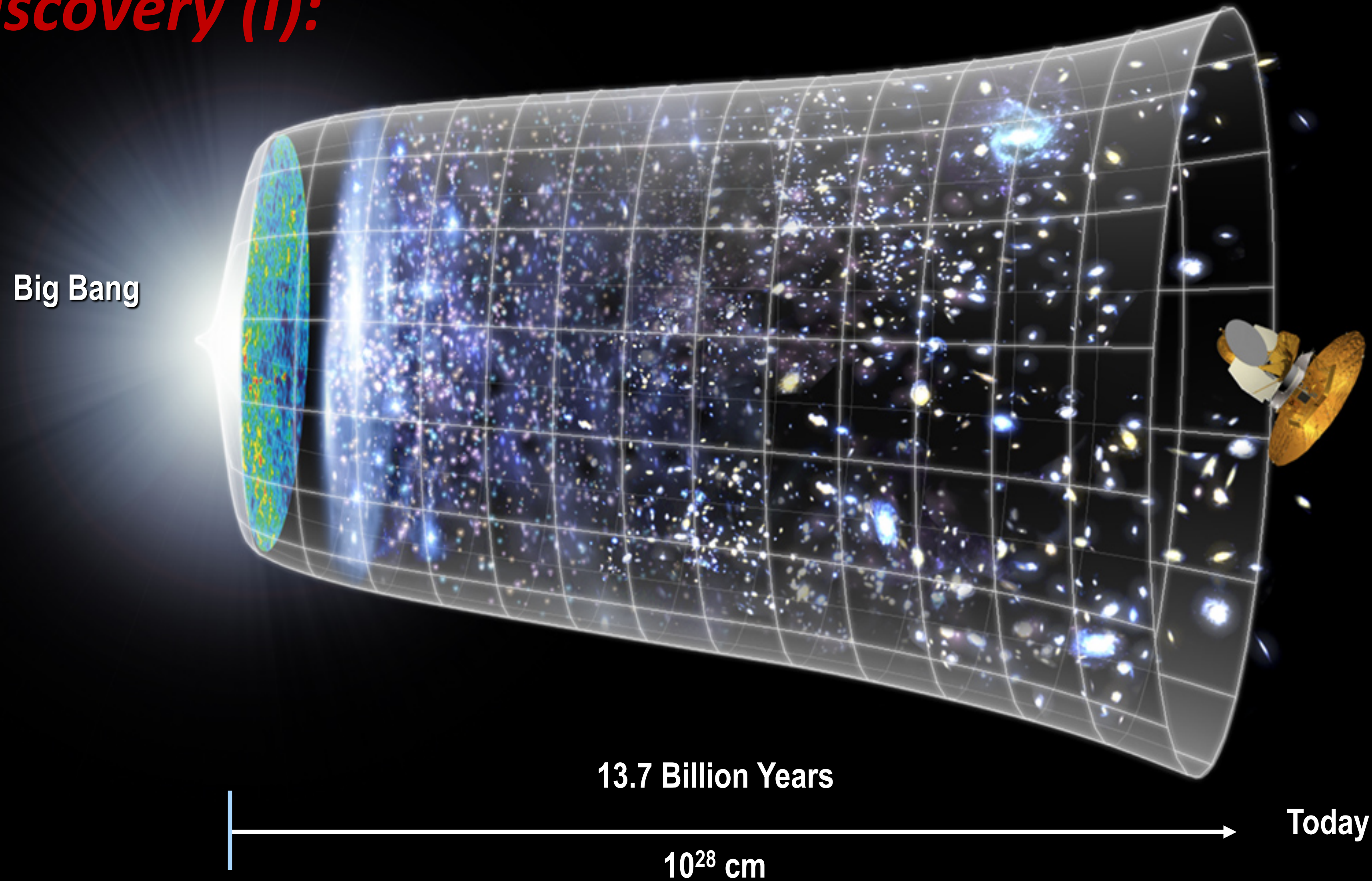
Electromagnetism

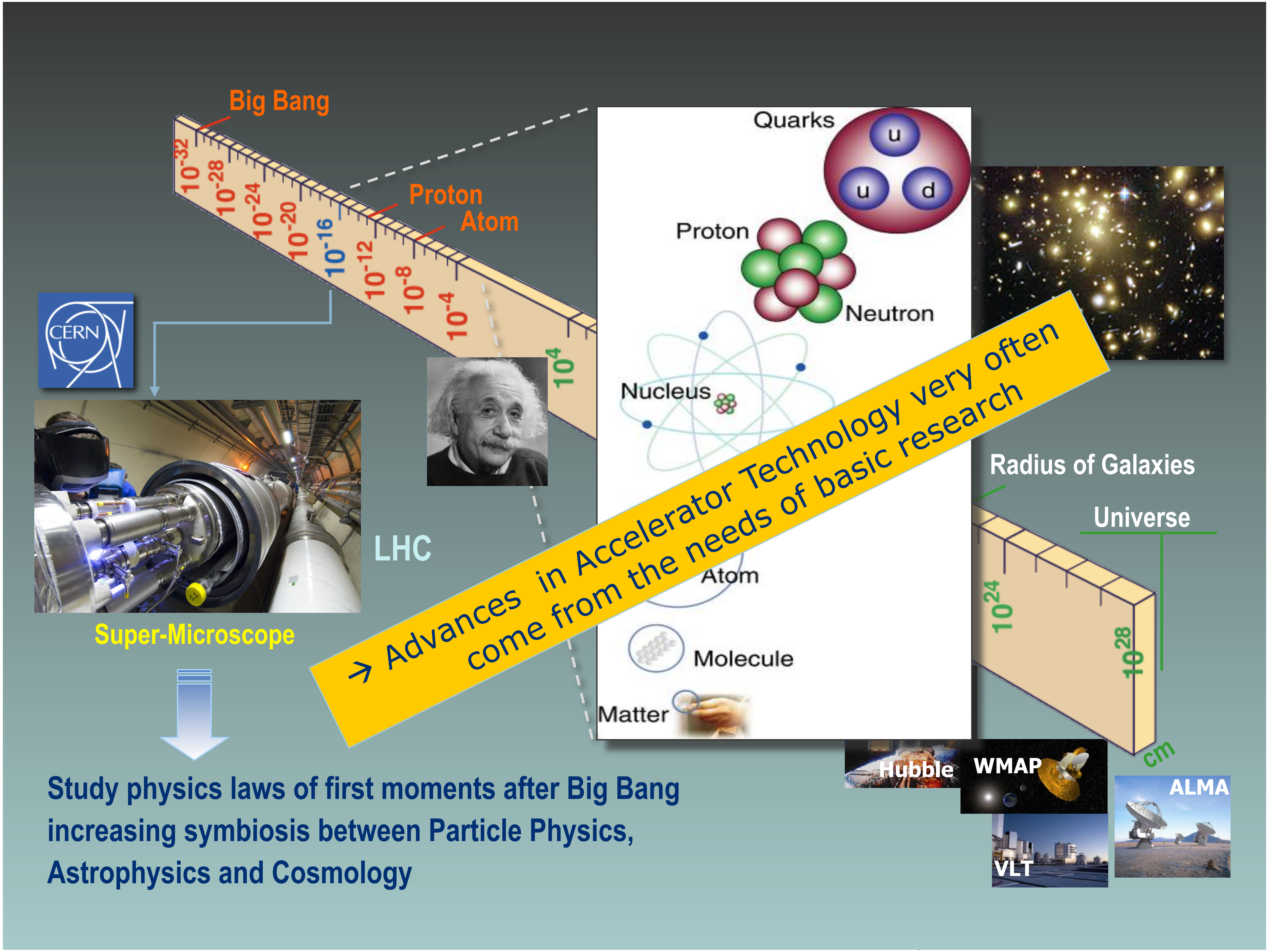
100% SCIENCE

Use of electromagnetic waves for telephony

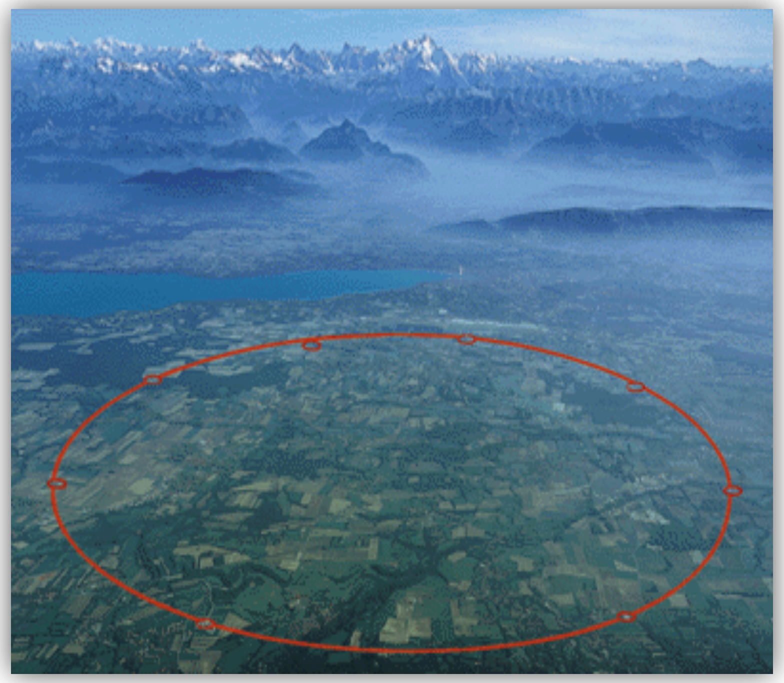
Evolution of the Universe

Discovery (I):



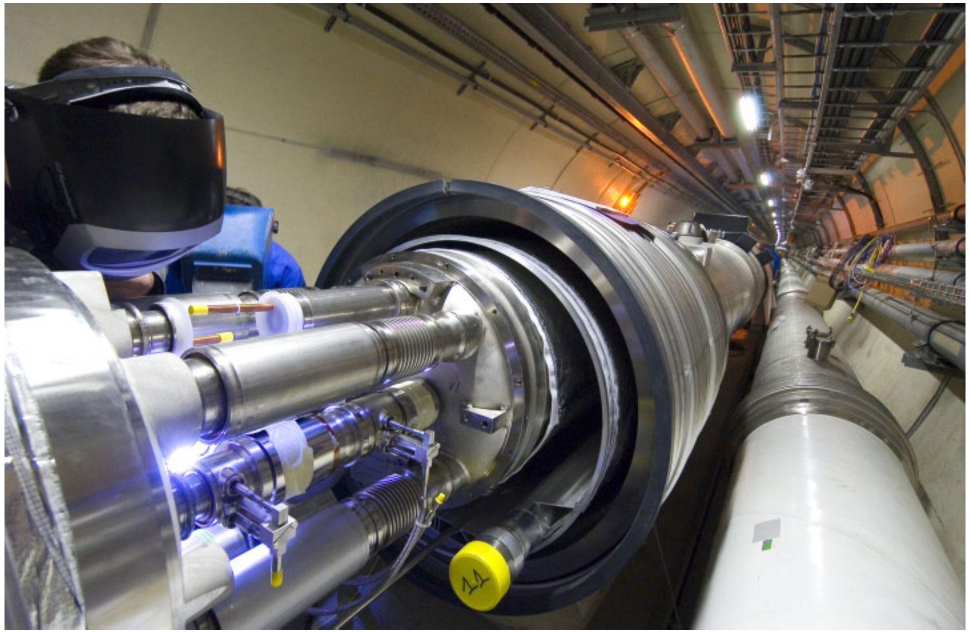

Big Bang
Proton
Atom
10-32
10-28
10-24
10-20
10-16
10-12
10-8
10-4
104
CERN
LHC
Super-Microscope
Quarks
u
u
d
Proton
Neutron
Nucleus
Atom
Molecule
Matter
→ Advances in Accelerator Technology very often
come from the needs of basic research
Radius of Galaxies
Universe
1024
1028
cm
Hubble
WMAP
VLT
ALMA
Study physics laws of first moments after Big Bang
increasing symbiosis between Particle Physics,
Astrophysics and Cosmology

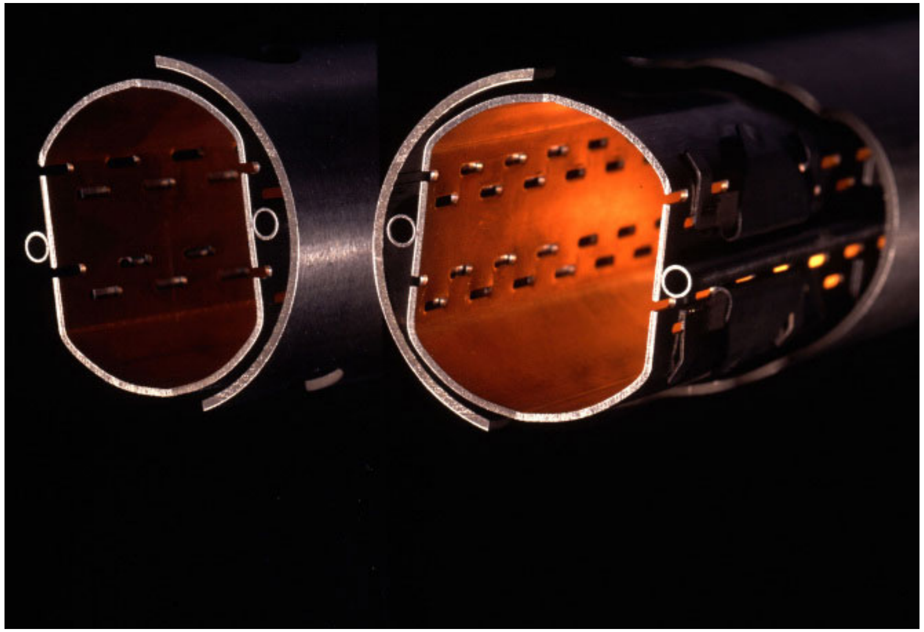
LHC – A Unique Machine



Circumference: 27 km (100 m underground)
Projected lifetime: 20+ years
4 large experiments (ALICE, ATLAS, CMS, LHCb)

The most **empty** place in the solar system……



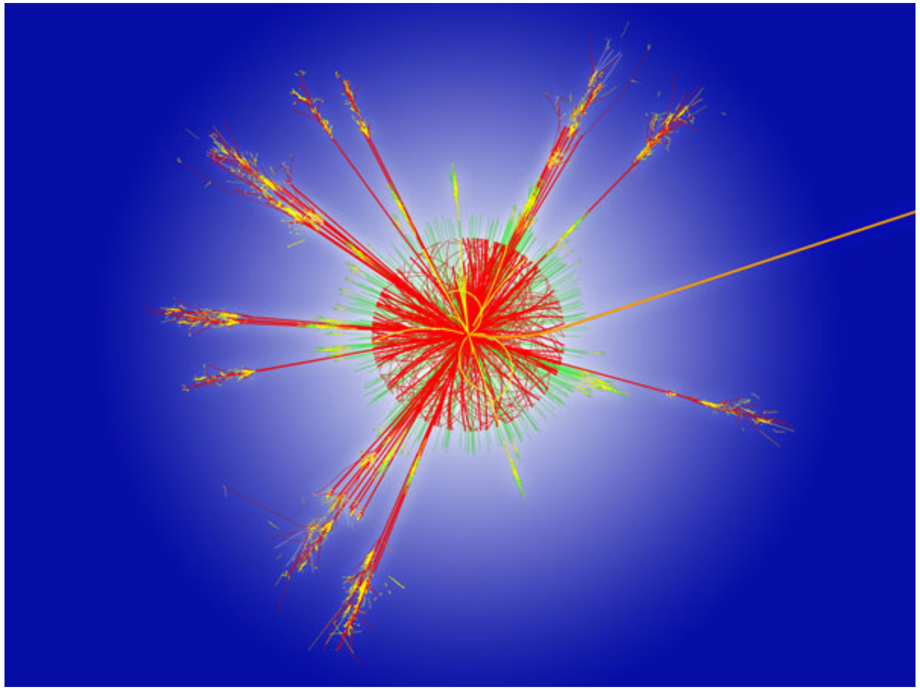


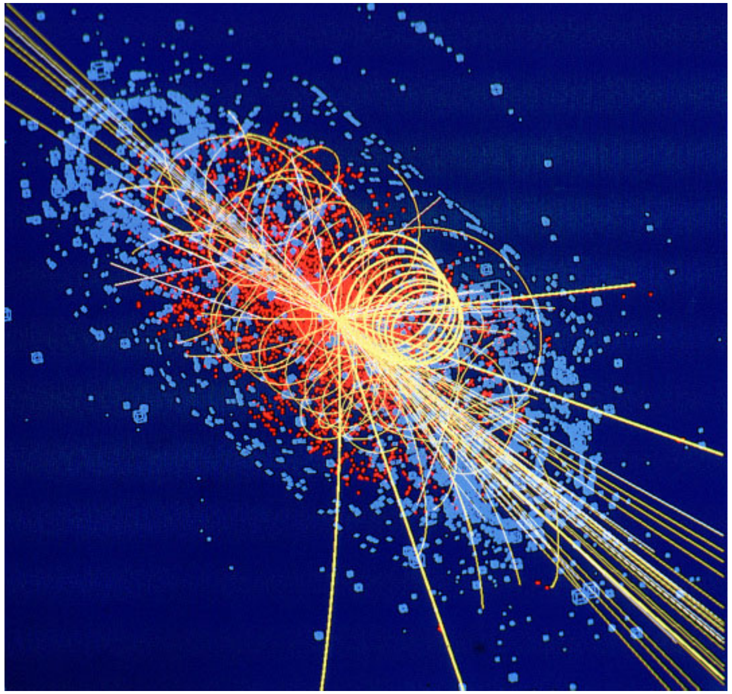
In order for particles to circulate in the LHC, a vacuum similar to that in interstellar space is needed.
The pressures in the vacuum tubes of the LHC are similar to those on the surface of the moon.

One of the coldest places in the Universe...

With a temperature of -271 C, or 1.9 K above absolute zero, the LHC is colder than outer space.

One of the hottest places in the galaxy…

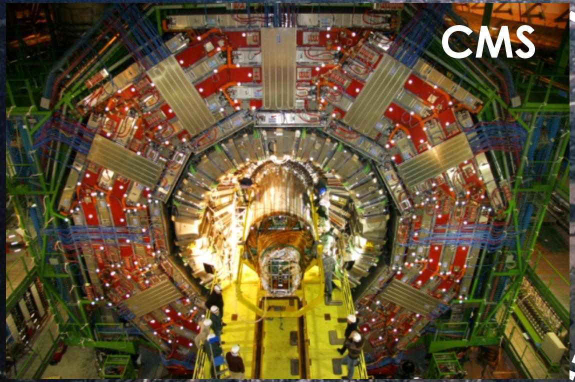




The collision of two proton beams generates temperatures 1000 million times larger the those at the centre of the Sun, but in a much more confined space.

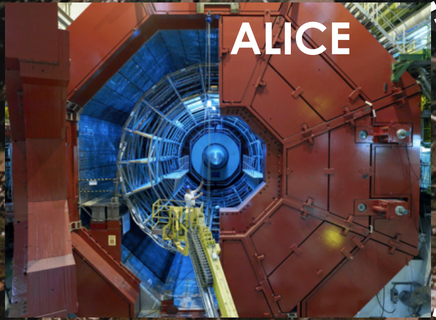
Enter a New Era in Fundamental Science

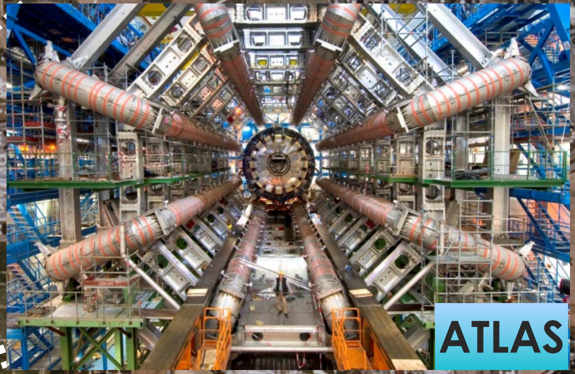
Start-up of the Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is the most exciting turning point in particle physics.



Exploration of a new energy frontier

Proton-proton collisions at up to E_{CM} = 14 TeV





Large scientific projects stimulate innovation

- Space : Apollo missions, Space Station, Pioneer/Voyager Missions
- Particle Physics : accelerators in general
  - At CERN : LEP, LHC

Pushing back the frontiers of technology. CERN Examples:

- Superconductivity, magnets, cryogenics, vacuum, survey/metrology.
- Transport and installation of heavy equipment.
- Solid-state detectors resistant to high-intensity radiation.
- Large-scale industrial control systems.
- Electronic and information systems.
- Project management and co-ordination.

all topics addressed in accelerator systems

Innovation in Fundamental Research

Research and Training in Accelerator Science provide a variety of science opportunities and possibilities for interdisciplinary work

Development of innovative acceleration techniques, such as those based on lasers, will enhance connection between diverse scientific and engineering domains and strengthen relations to industry

Beyond discoveries

Besides

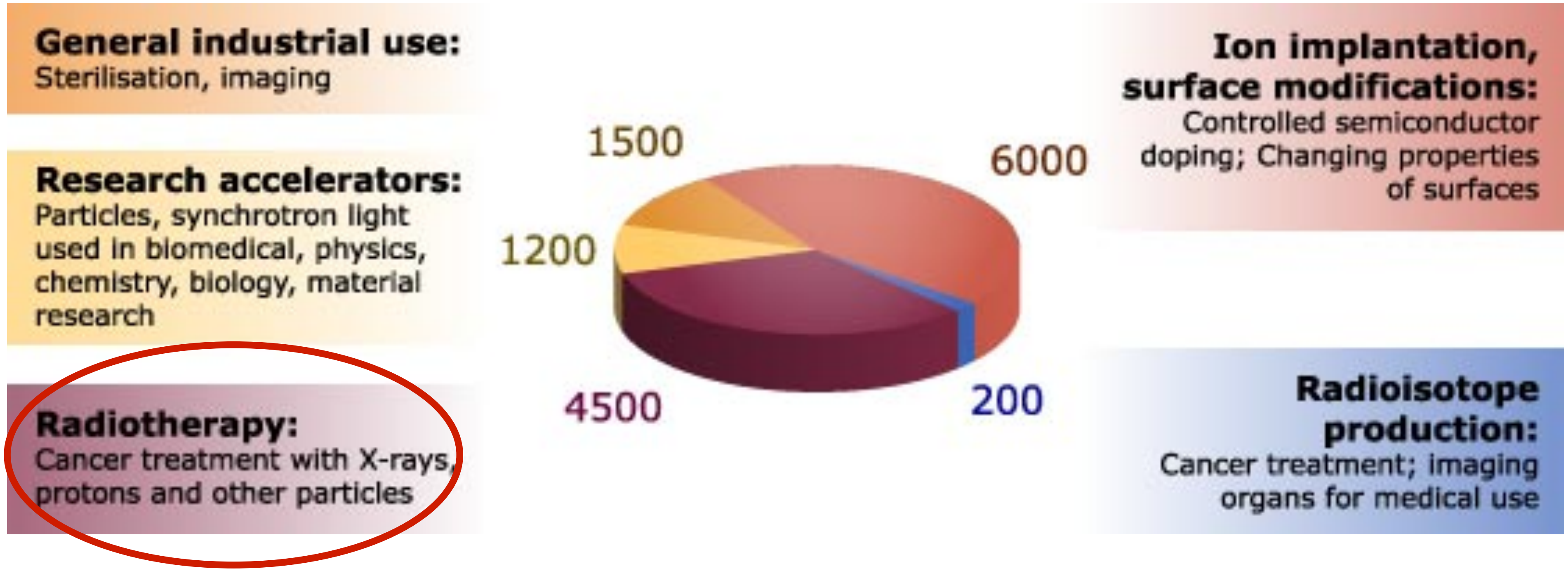
discovering the secrets of the Universe

a beam of the right particles with the right energy at the right intensity can shrink a tumour, produce cleaner energy, spot suspicious cargo, make a better radial tire, clean up dirty drinking water, map a protein, studya nuclear explosion, design new drug, make a heat resistant automotive cable, diagnose a decease, reduce nuclear waste, detect an art forgery, implant ions in a semi-conductor, prospect oil, date an archeological find, or package a christmas turkey.*)

*) (Accelerators for America's Future, DOE)

Transfer of Technology of Accelerators

Most of the world's accelerators are used outside fundamental research

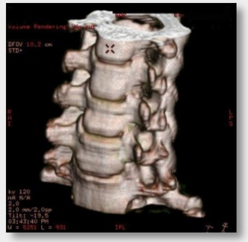


As Accelerator Science and Technology continue to advance, so will there benefits to society

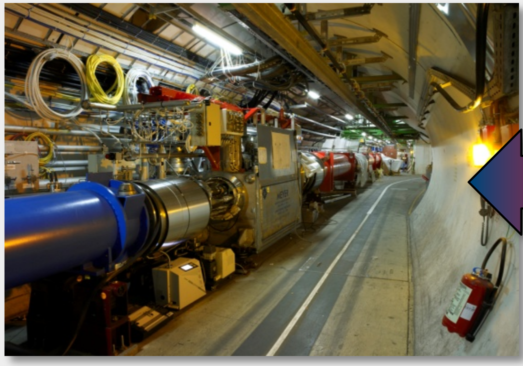
CERN Technologies - Innovation

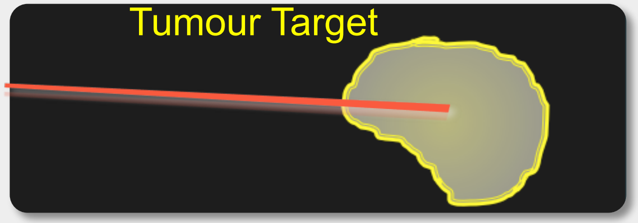
Examples: medical applications

Medical imaging



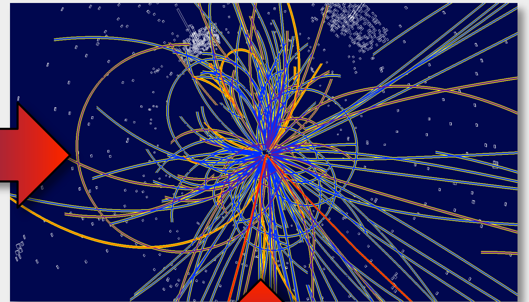
Accelerating particle beams

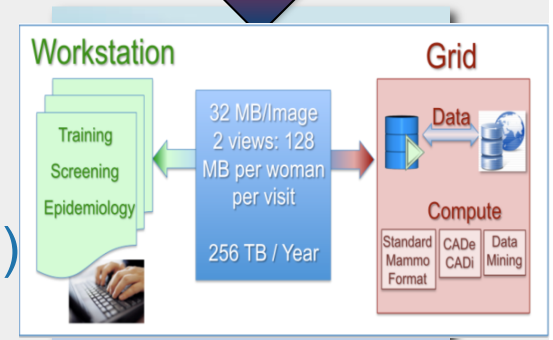




Charged hadron beam that loses energy in matter

Detecting particles

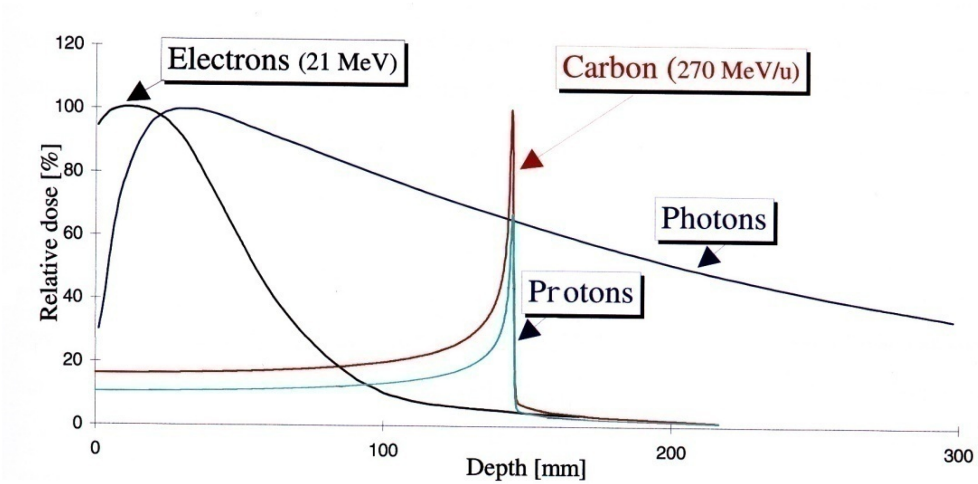


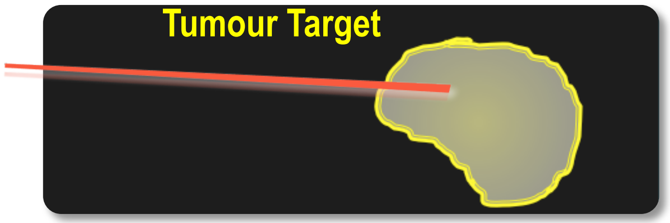


Large-scale **computing** (Grid)

Grid computing for medical data management and analysis

Accelerators for Radiotherapy

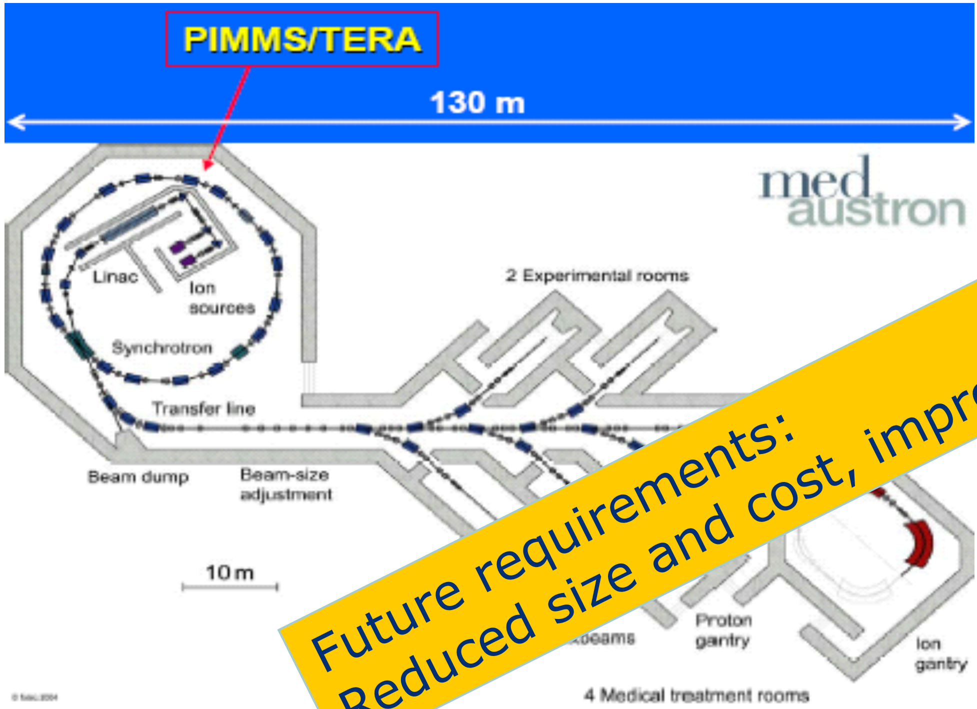




Charged hadron beam that loses energy in matter

Transfer of Technology – Medical Sciences

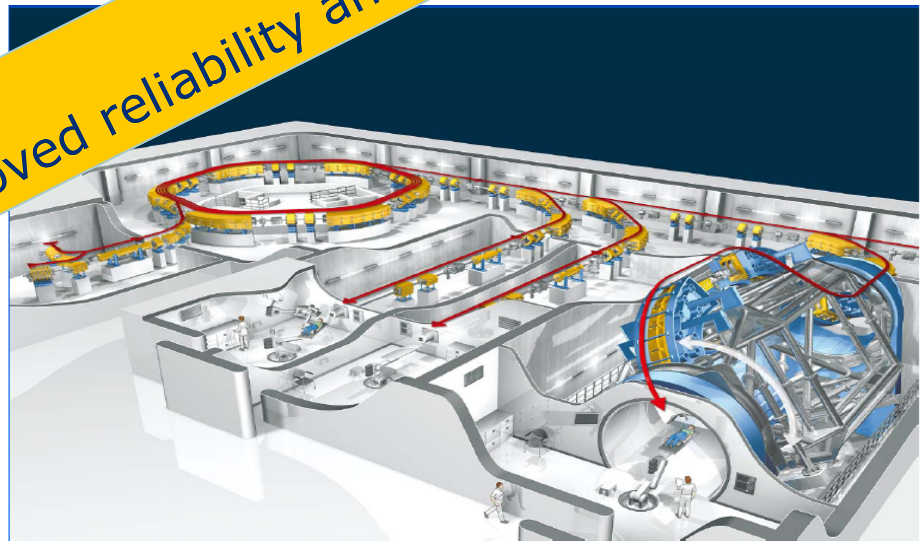
MedAustron is constructing a centre
based on the concept of CNAO
(CERN-CNAO-INFN Agreement)



Approved in 2007 by the Government
of Lower Austria

Future requirements:
Reduced size and cost, improved reliability and efficiency

The therapy cent ions at
He
(in collab SIEMENS)



Inauguration 2010

Synchrotron Radiation Science

Synchrotron Radiation Sources

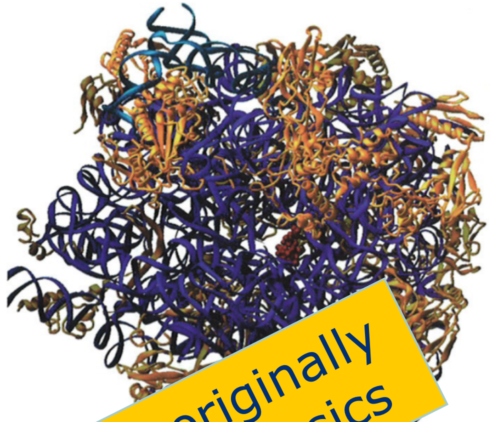
Class of electron accelerators to study a variety of problems in the world around us by unraveling the structure of materials, crystals and molecules.

Beams of ultraviolet light and X-rays used for example in:

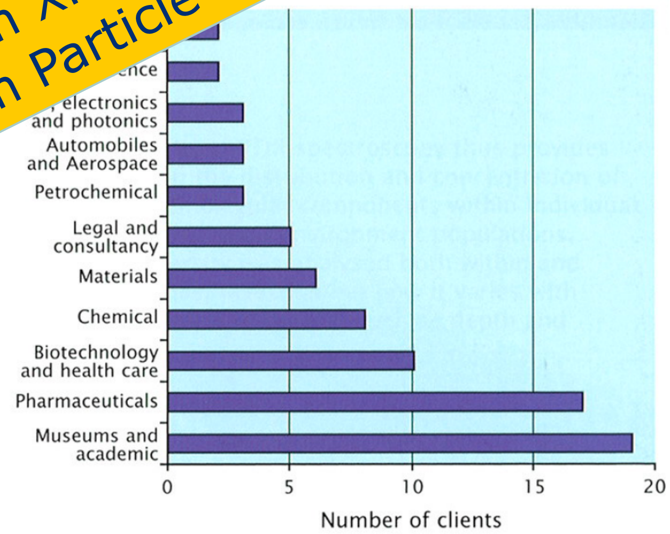
- Crystallography
- Enzyme biology
- Magnetic properties of material for hard discs
- Origins of high-T superconductivity
- Surface phenomena (wear of aircraft turbines)
- Structure of DNA and proteins
- Study of osteopororis
- Design of pharmaceuticals
- …

SRS at Daresbury Laborator
- World's first dedicated … radiation source.
- Operated for close to 30 … completion in August 2008.
- Baton now passed to Diamond Light Source as the UK's national SR facility.

Development of the European XFEL originally driven by requirements from Particle Physics



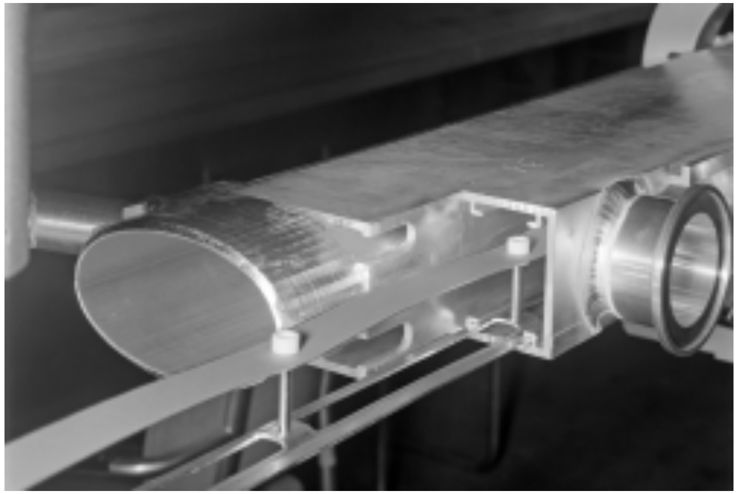
Structure of complex protein molecule



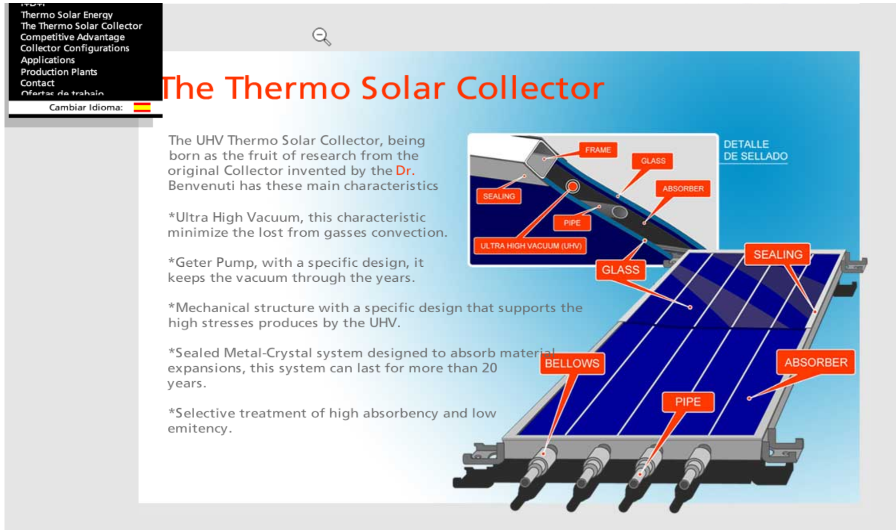
Commercial clients using the SRS from 1997 to 2007 according to industry type.

Transfer of Technology – From extreme vacuum systems of accelerators to performant solar panels

SRB Energy – a Spanish company, founded at the beginning of the decade, developed the Ultra-High Vacuum (UHV) systems of LEP for commercial use. Today, the company produces solar panels that are amongst the most performant in the world.



LEP vacuum chamber with Non Evaporable Getter (NEG) – 1983; Pressure < 10⁻⁸ Pa



Solar panels capable of working at temperatures between 150 ºC and 350 ºC thanks to the technology developed at CERN

Discovery (II):

Beyond LHC: LHC will tell the way Nature wants us to go

Possible ways beyond initial LHC:

Luminosity upgrade (sLHC)

Doubling the energy (DLHC)

New machine, R&D on high-field magnets ongoing

Electron-Positron Collider

ILC

CLIC

Electron-Proton Collider

LHeC

High Energy Colliders: CLIC (E_{cm} up to ~ 3TeV)

- **High acceleration gradient: ~ 100 MV/m**

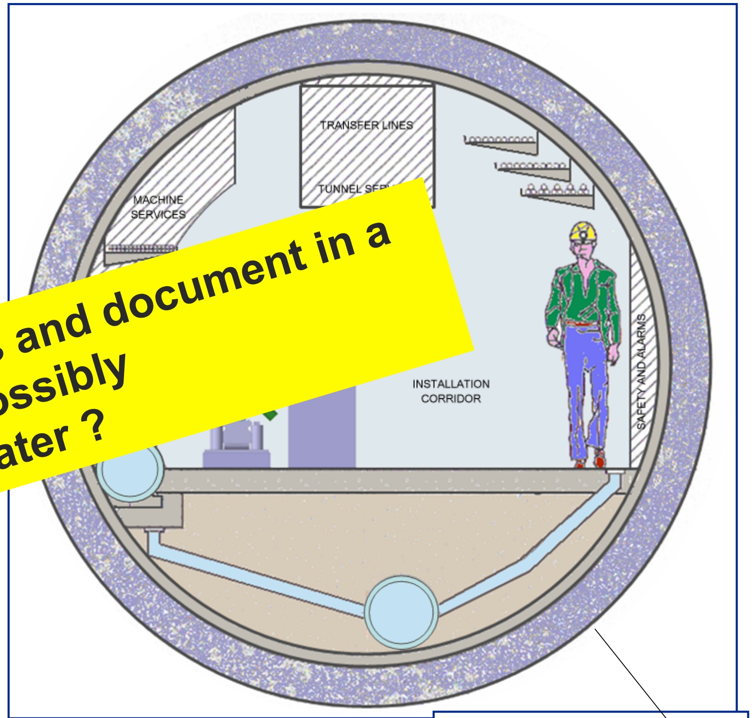
- "Compact" collider – total length < 50 km at 3 TeV
- Normal conducting acceleration structures at high frequency

Novel Two-Beam Acceleration Scheme

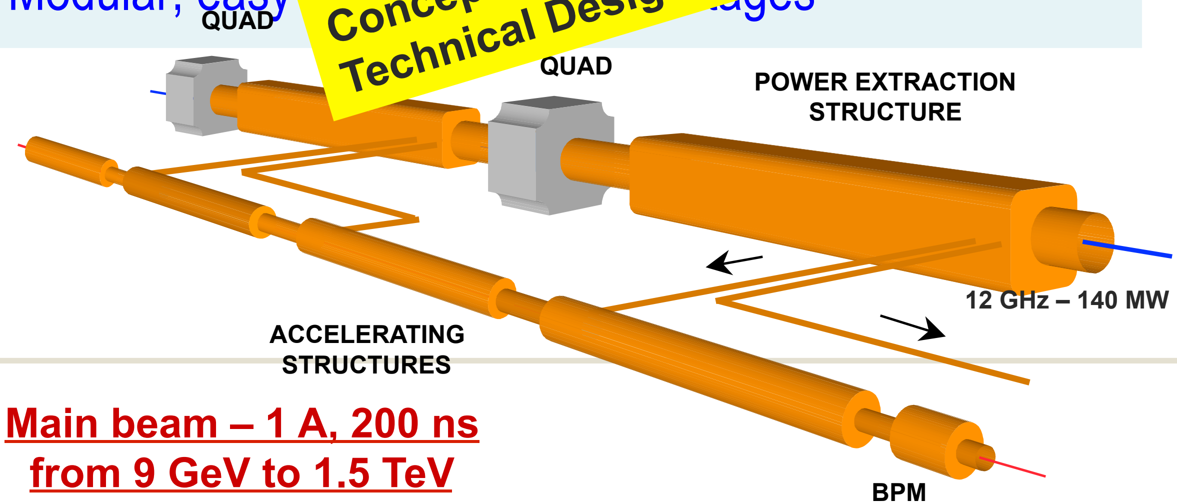
- Cost effective, reliable, efficient
- Simple tunnel, no acti
- Modular, easy ages

Aim: Demonstrate all key feasibility issues and document in a Conceptual Design Report by 2011 and possibly Technical Design Report minimum 5 yrs later ?

CLIC TUNNEL CROSS-SECTION



4.5 m diameter



Drive beam - 95 A, 300 ns from 2.4 GeV to 240 MeV

Main beam – 1 A, 200 ns from 9 GeV to 1.5 TeV

High Energy Colliders: ILC (E_{cm} up to ~ 1TeV)

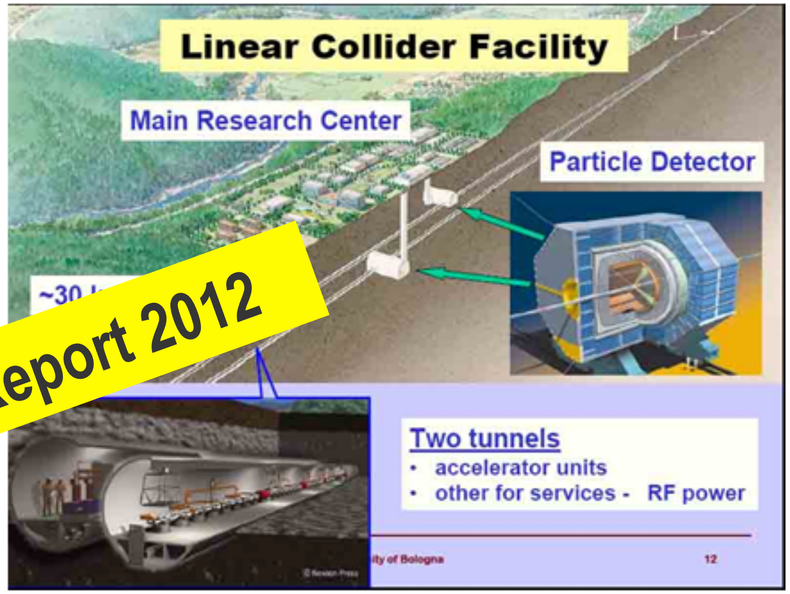
ILC @ 500 GeV

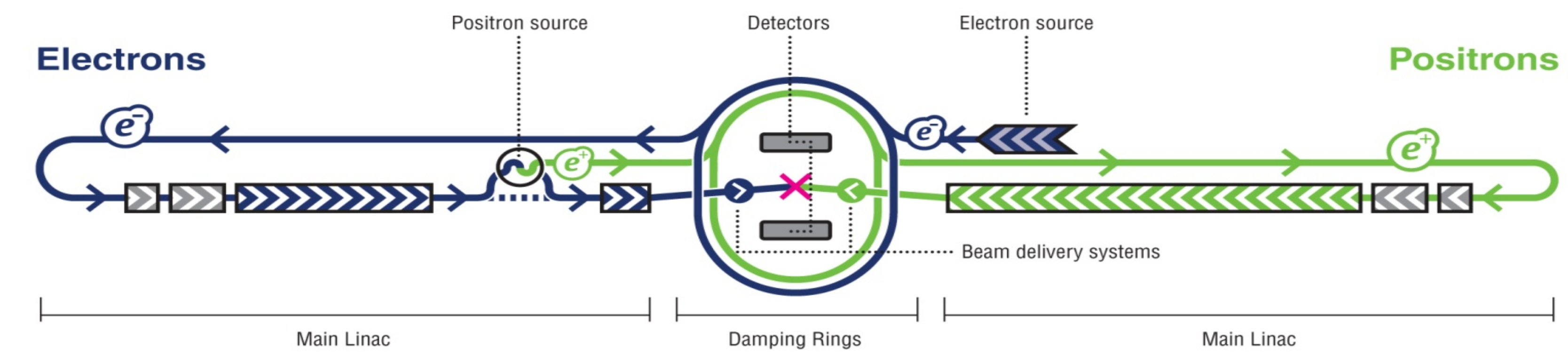
ILC web site: http://www.linearcollider.org/cms/

Max. Center-of-mass energy	500	GeV
Peak Luminosity	$\sim 2 \times 10^{34}$	$cm^{-2}s^{-1}$
Beam Current	9.0	mA
Repetition rate	5	Hz
Average accelerating gradient	31.5	MV/m
Beam pulse length	0.95	[illegible]
Total Site Length	[illegible]	[illegible]
Total AC Power Consumption	230	MW

~31 Km

Technical Design Report 2012





CERN and Global Collaboration (I)

TODAY:
CLIC Collaboration
Prime example of collaboration in accelerator development
modeled after experiment's collaboration

1954 European Reconstructio
1st Session of CERN C

1980 The East Meets the West
Visit of delegation from Beijing

2009 Global Collaboration
The LHC brings together > 7000 scientists from > 100 countries

Global Collaboration (II)

To advance accelerators at the energy frontier we need

- to maintain expertise in all regions;

- ensure long term stability and support in all three regions;

- engage all countries with particle physics communities;

- to integrate particle physics from developing countries (regions);

- global view from funding agencies;

- a closer linkage of partners for development of technologies;

But that's not enough. . .

We need to define the most appropriate organisational form NOW and need to be open and inventive (scientists, funding agencies, politicians. . .)

Mandatory to have accelerator laboratories in all regions as partners in accelerator development / construction / commissiong / exploitation

Planning and execution of HEP projects today need global partnership for *global, regional and national* projects
in other words: for the whole program

Use the exciting times ahead to establish such a partnership

Conclusions

- Accelerators have become an indispensible component of particle physics research and discovery.
- Fundamental research in particle physics stimulates people to search for novel solutions as well as putting together new global collaborations.
- Each new accelerator and each new detector is a prototype, always unique in its type, and which requires the application of new technologies and methodologies.
- Innovative solutions for various problems are developed in collaboration with industry, solutions which result often in products with much added value.

As in the past, the accelerators of particle physics can and should play their role as spearheads in discovery, innovation and global collaboration now and in future.