Using CERN Technologies for Medical Applications

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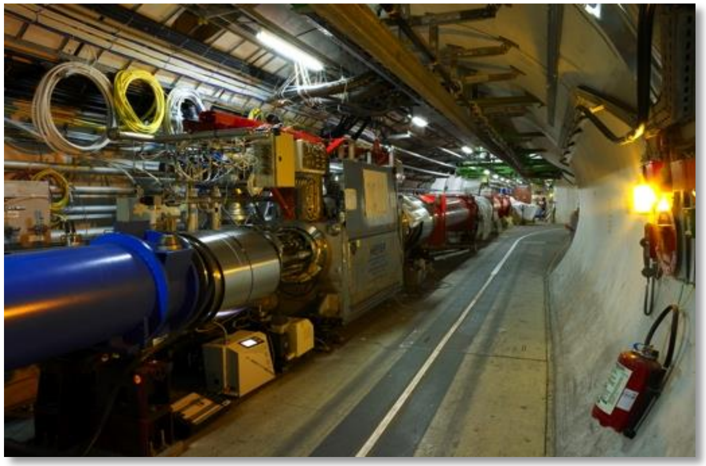
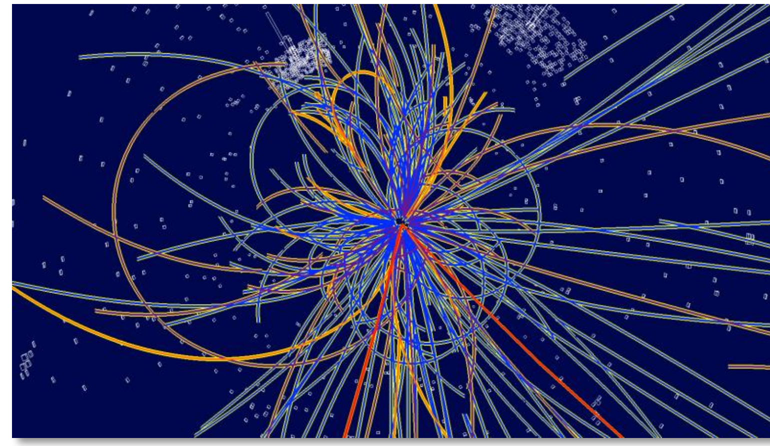
Geneva, Switzerland

12th June 2013,

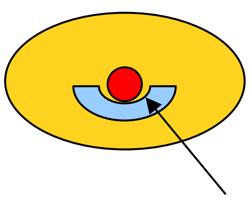
CERN’s Technologies



Accelerating particle beams



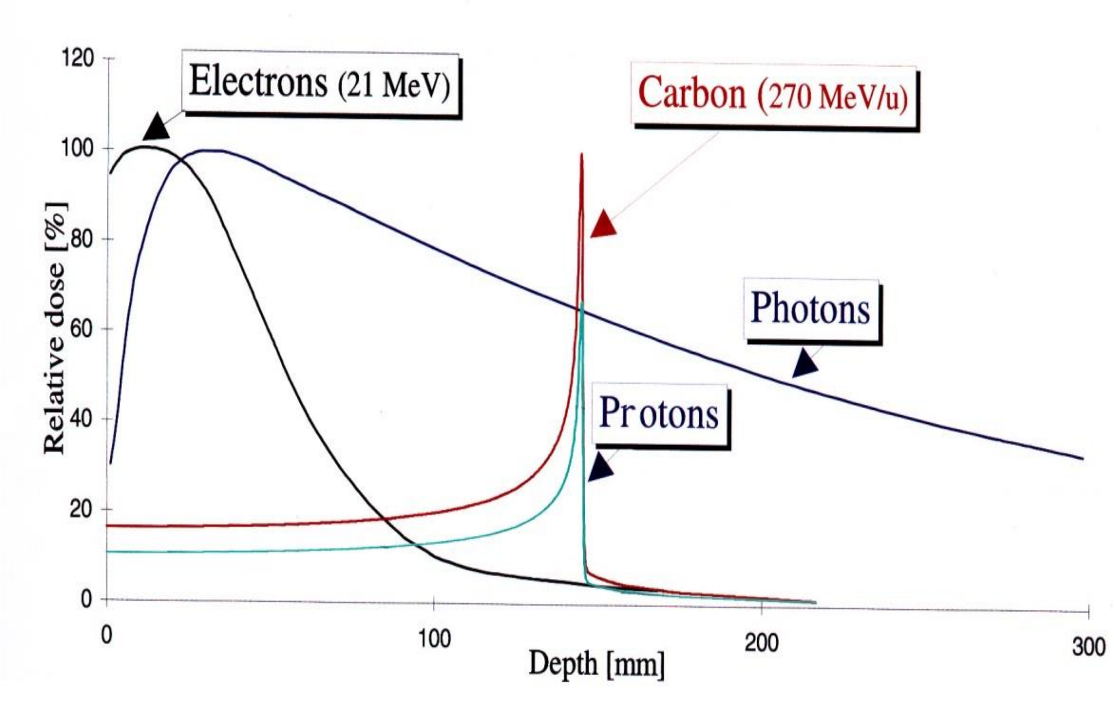
Detecting particles



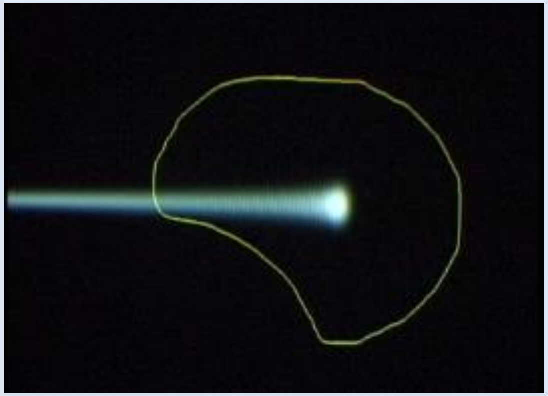
Cancer and Medical Applications

Large-scale computing (Grid)

The Bragg Peak



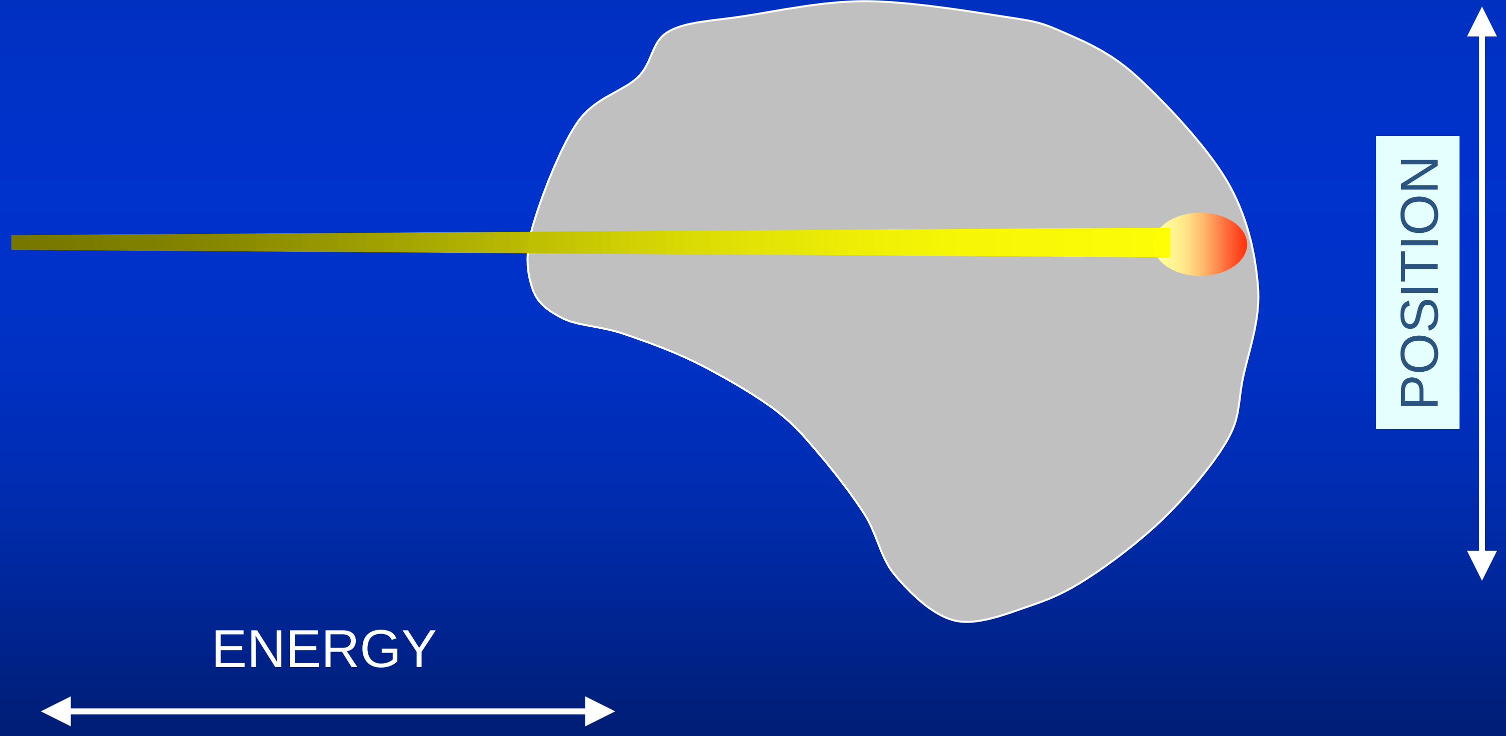
Energy deposition



- Precision
- Reduction of collateral damage to healthy tissue

- Tumours close to critical organs
- Tumours in children
- Radio-resistant tumours

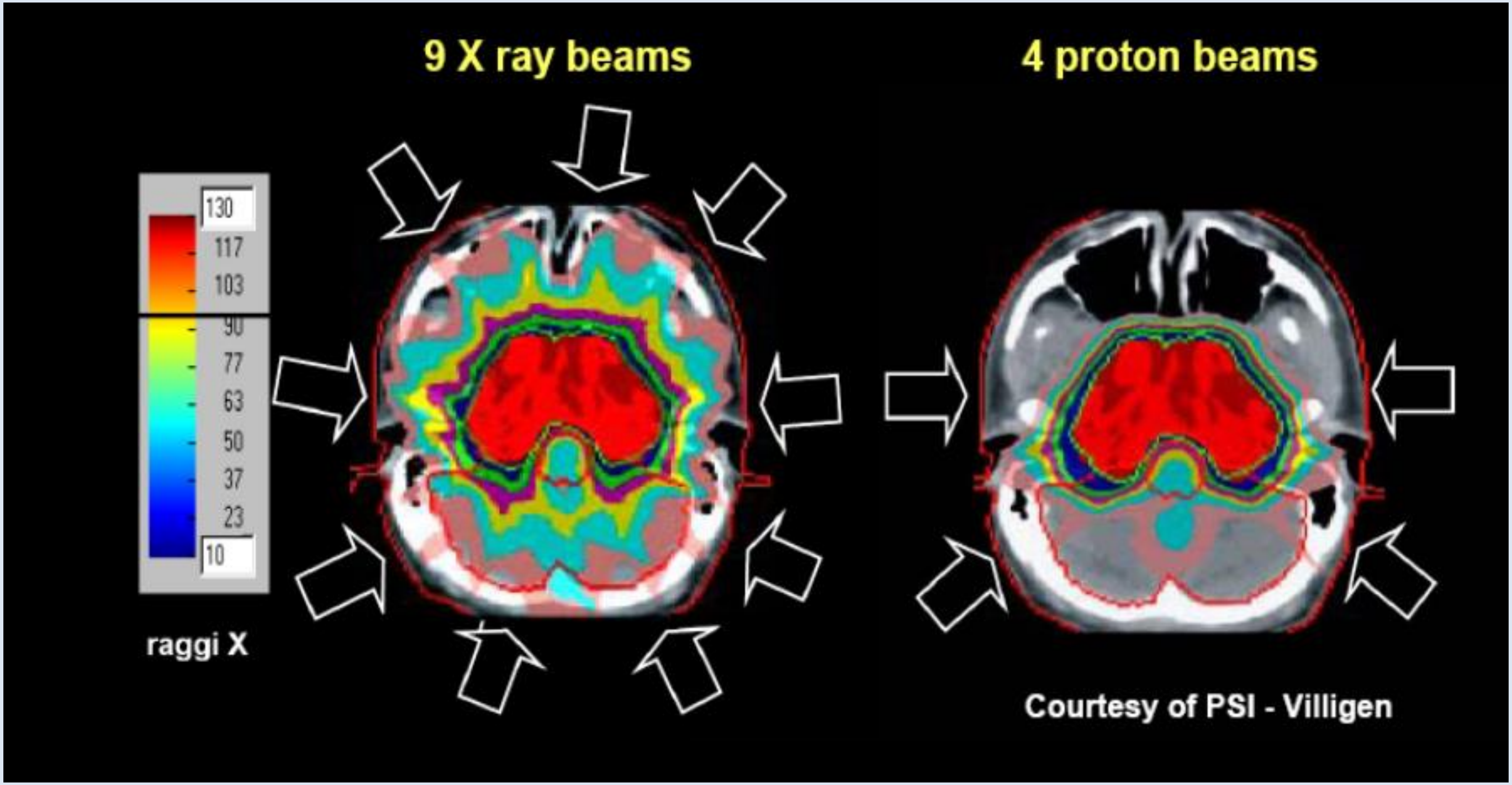
SPOT SCANNING



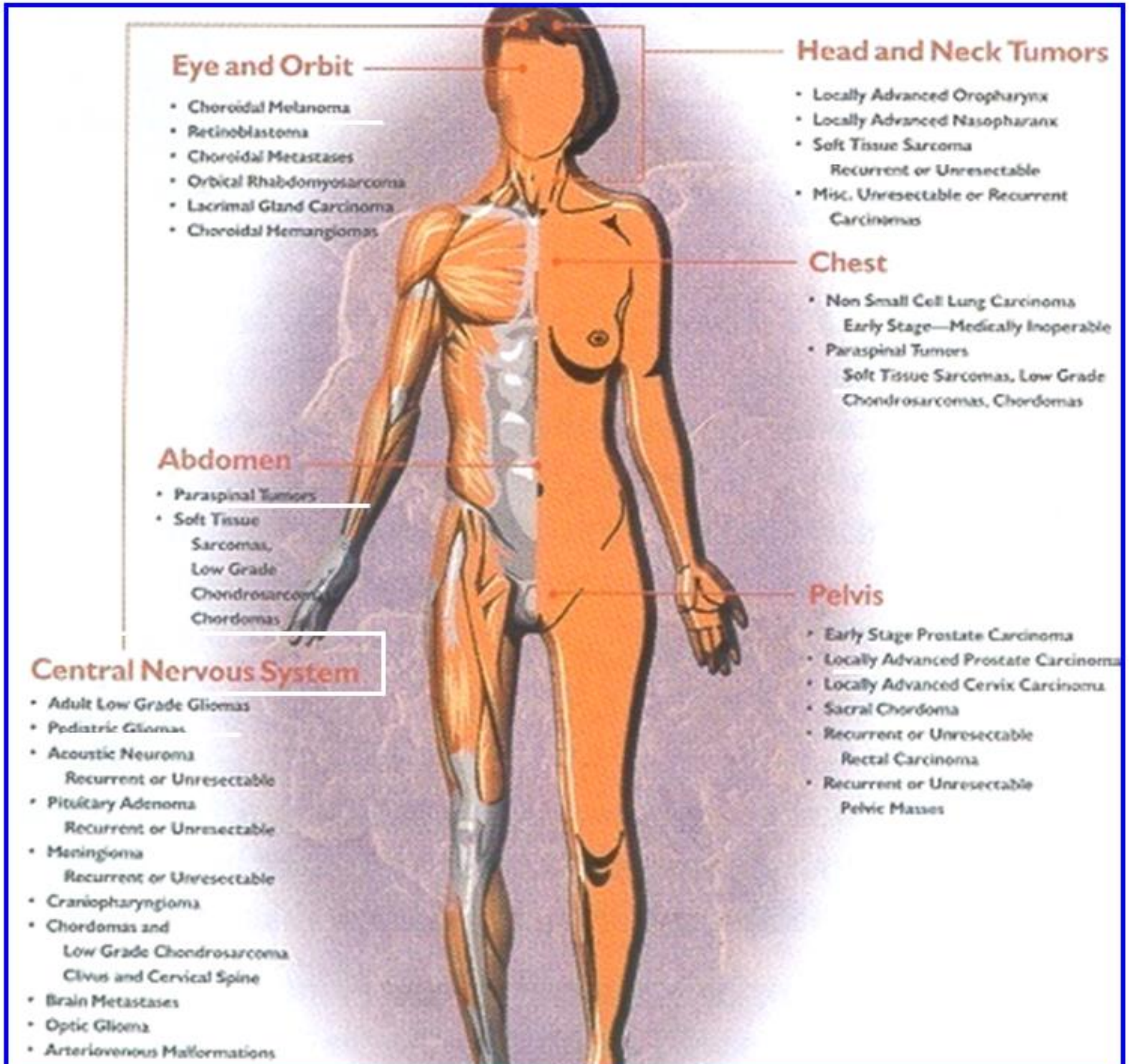
The Bragg Peak

- Allows more precise allocation of the dose to the tumour
- BUT makes dosimetry and diagnostics more difficult because the energy is deposited preferentially inside the patient
- To take full advantage, we need improved diagnostics
    - To steer the beam spot by measurement of the location of the energy deposition
    - To control the dose (dosimetry)

Comparison of Collateral Damage



The sites treated



In the world

protons:

100'000 patients

(+10% per year)

carbon ions

9'000 patients

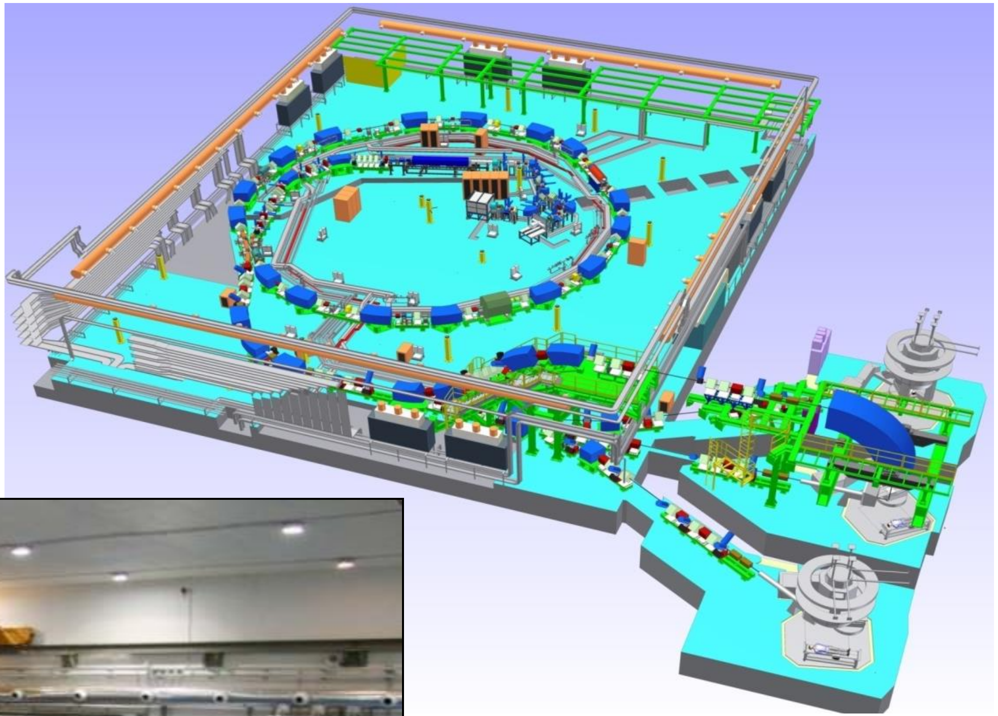
MAINLY IN JAPAN

History and Reminders

Initiative: Accelerator reminder PIMMS

“In 1996, CERN initiated the Proton Ion Medical Machine Study (PIMMS), which aimed at designing a synchrotron optimized for the treatment of moving organs with carbon ions (and protons). Together with CERN part-time staff, the study participants were the TERA Foundation (Italy), the MedAustron project (Austria) and Oncology 2000 (Czech Republic). The design was summarized in two reports issued in 2000. The project was adapted by TERA and used as a basis for the CNAO centre, which has just been completed in Pavia by the CNAO Foundation and INFN. The MedAustron facility utilises the same synchrotron design, and is currently being built in Wiener Neustadt (Austria).”

CNAO (Pavia) is treating patients




CNAO in Pavia

MedAustron is building a centre in Wiener Neustadt

The technical drawings for MedAustron were acquired from CNAO Foundation, modified and updated

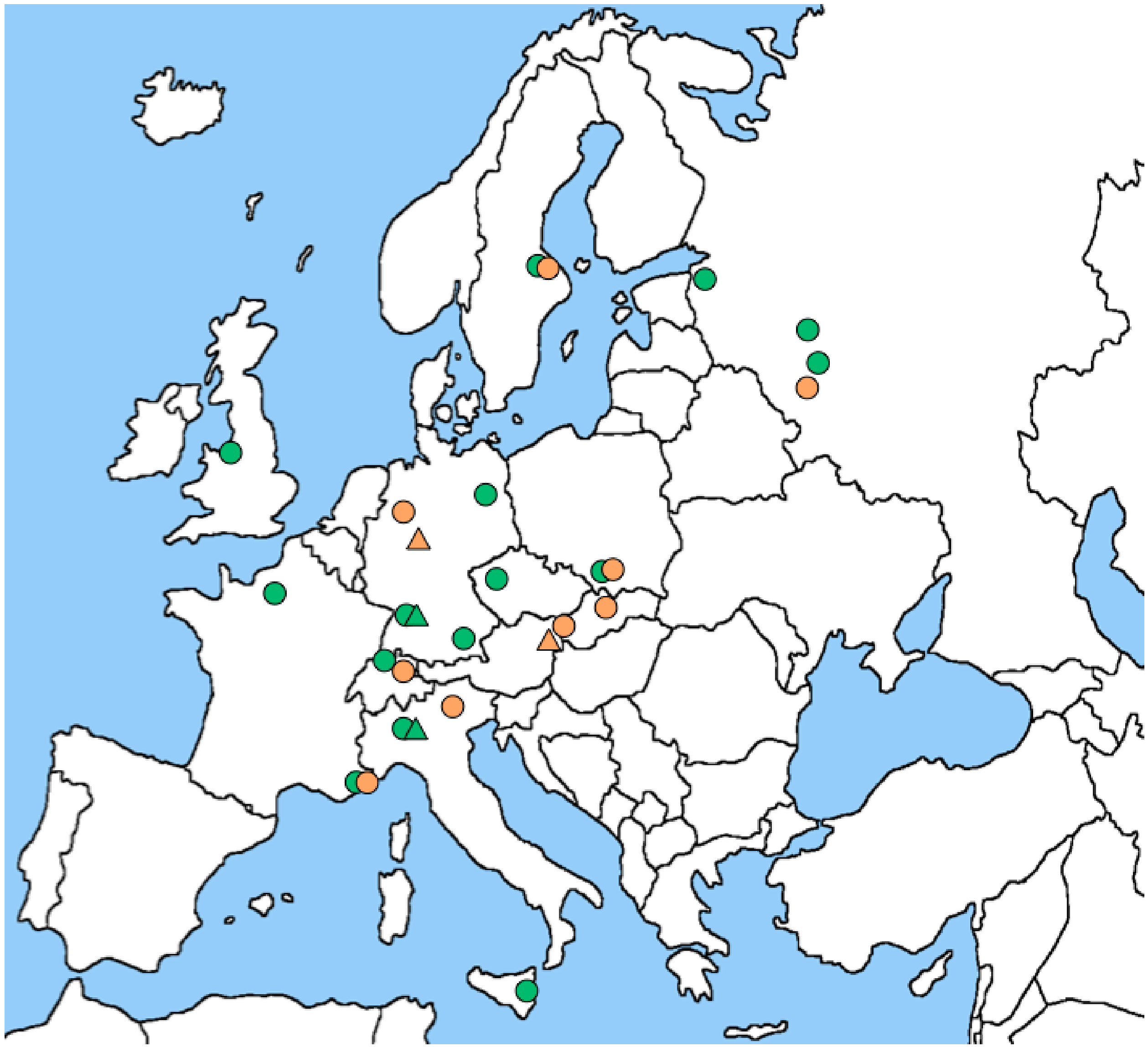
MedAustron Status – Wiener Neustadt

PIMMS1 design has been a big service to the community

- **2 source branches installed**
- **Beam commissioning**

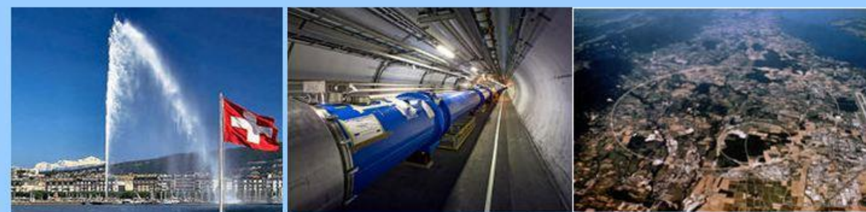
- **Synchrotron hall installation**

More and more hadron therapy centres



- Proton centres in operation
- C-ION centres in operation
- Proton centres under construction
- C-ION centres under construction

PHE Workshop



PHYSICS FOR HEALTH IN EUROPE WORKSHOP

(Towards a European roadmap for using physics tools in the development of diagnostics techniques and new cancer therapies)

2-4 February 2010

The workshop aimed at reviewing the progress in the domain of physics applications in life sciences, stimulating the exchange between different teams and indicating the subjects most suitable for further studies in diagnosis and therapy.
Following the Physics for Health workshop, a Strategy Document has been published and advertised in a Press Release by CERN.
To view the detailed website and get the workshop material please click here

... aim was stressed in the opening address by CERN Director General, who stated that the Workshop was organized .... not *for CERN and not by CERN - but at CERN to help the* medical and physics communities to discuss and, by strengthening their already existing links, to improve the quality of the health care ...

The CERN Initiatives

1. Medical Accelerator Design
   - coordinate an international collaboration to design a new compact, cost-effective accelerator facility, which would use the most advanced technologies
2. Biomedical Facility
   - creation of a facility at CERN that provides particle beams of different types and energies to external users interested in radiobiology and detector development
3. Detectors for beam control and medical imaging
4. Dosimetry for control of radiation
5. Radio-Isotopes
   - Set up a European user facility to supply innovative radioisotopes (produced at ISOLDE-CERN, ILL, PSI, Arronax,...) for R&D in life sciences (preclinical and clinical studies)
6. Large Scale Computing for medical applications

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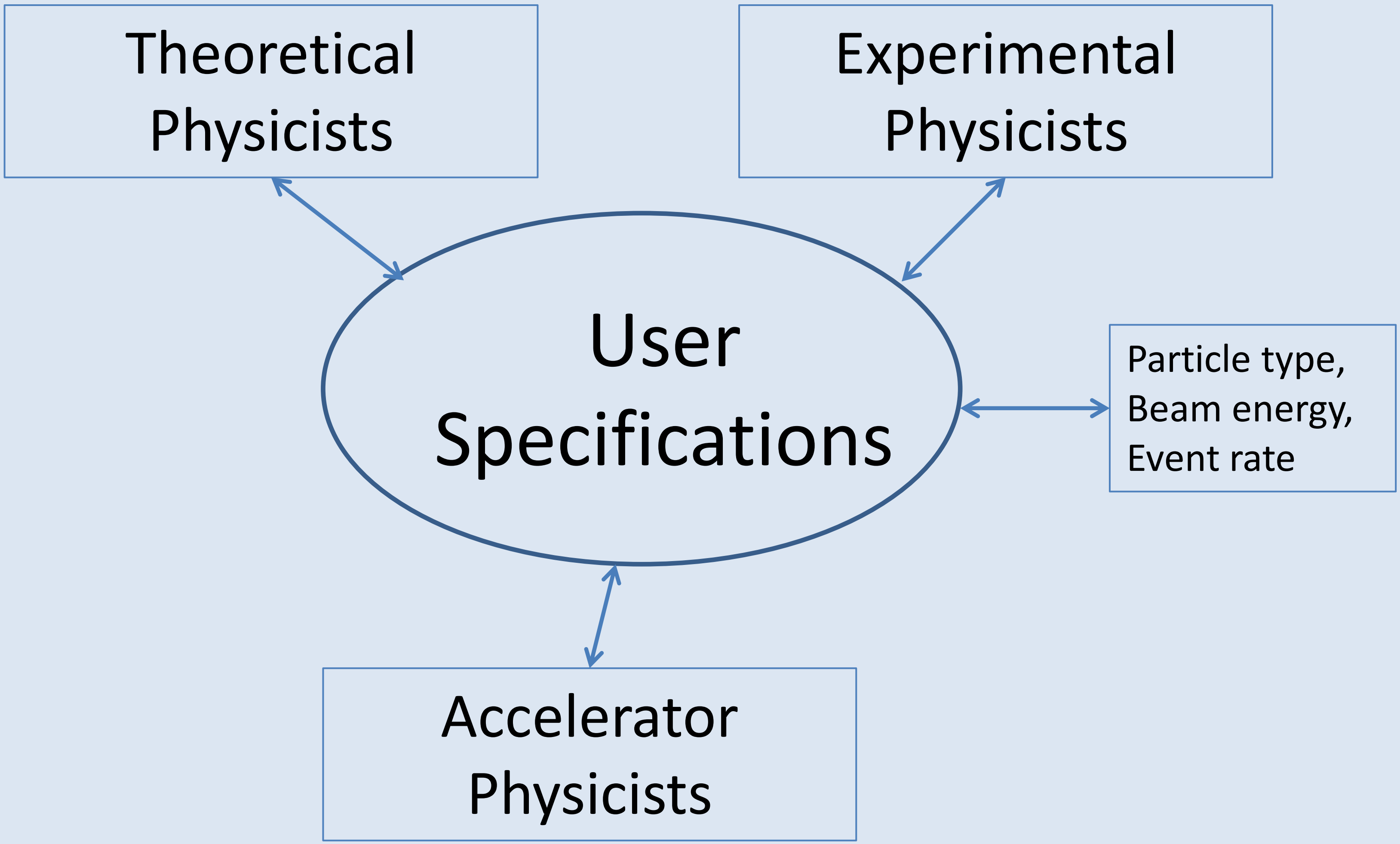
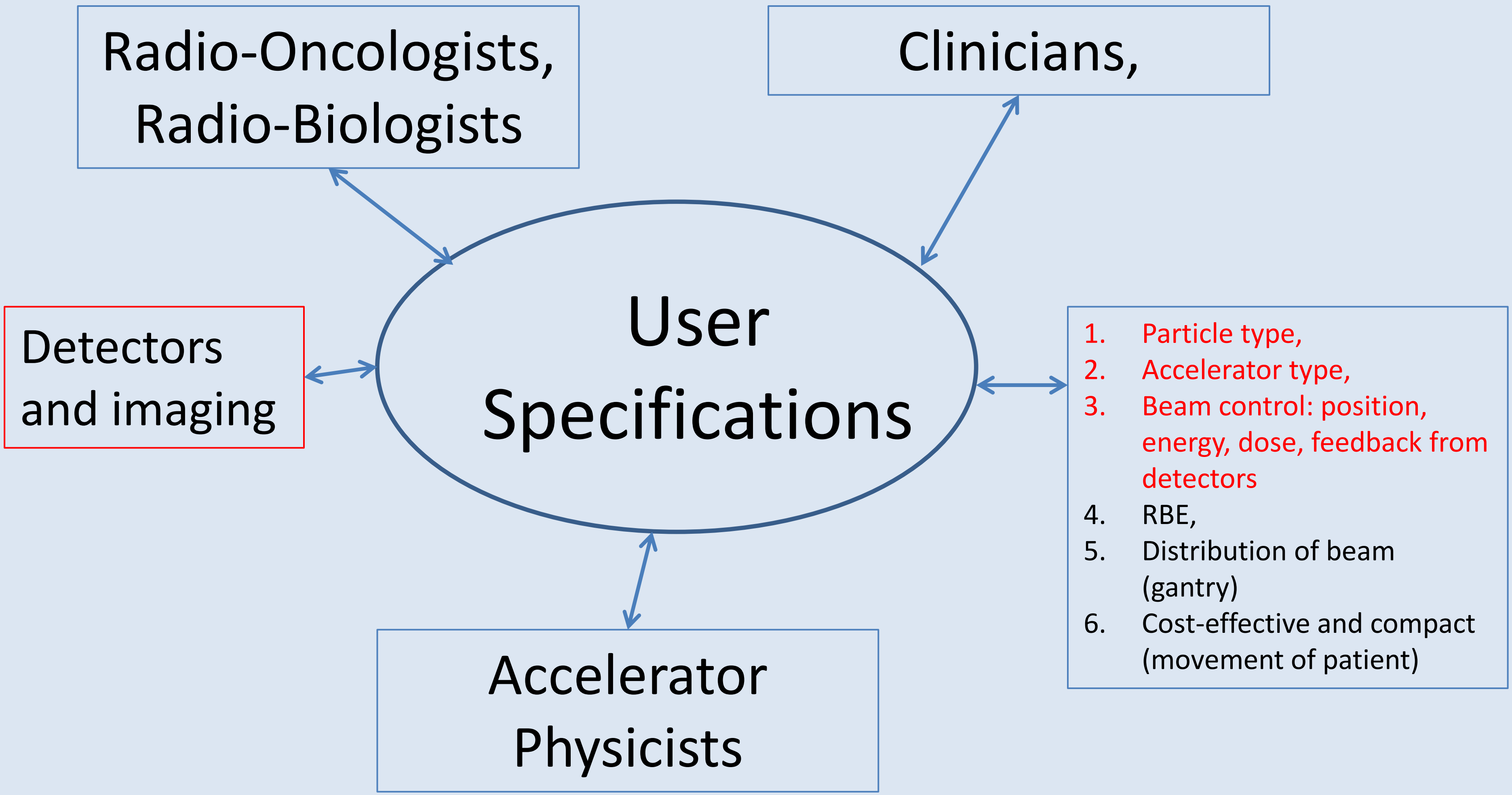
1) New Accelerator Design

- Seed funding now proposed by CERN management in Medium Term Plan (5 year)
- Extremely important to get the “user” specifications correct
  - Will requires specialists from many disciplines to give their input
- Presently organising a brainstorming retreat (Chamonix type)

User Specs for HEP Accelerators/Detectors



User Specs for Hadron Therapy



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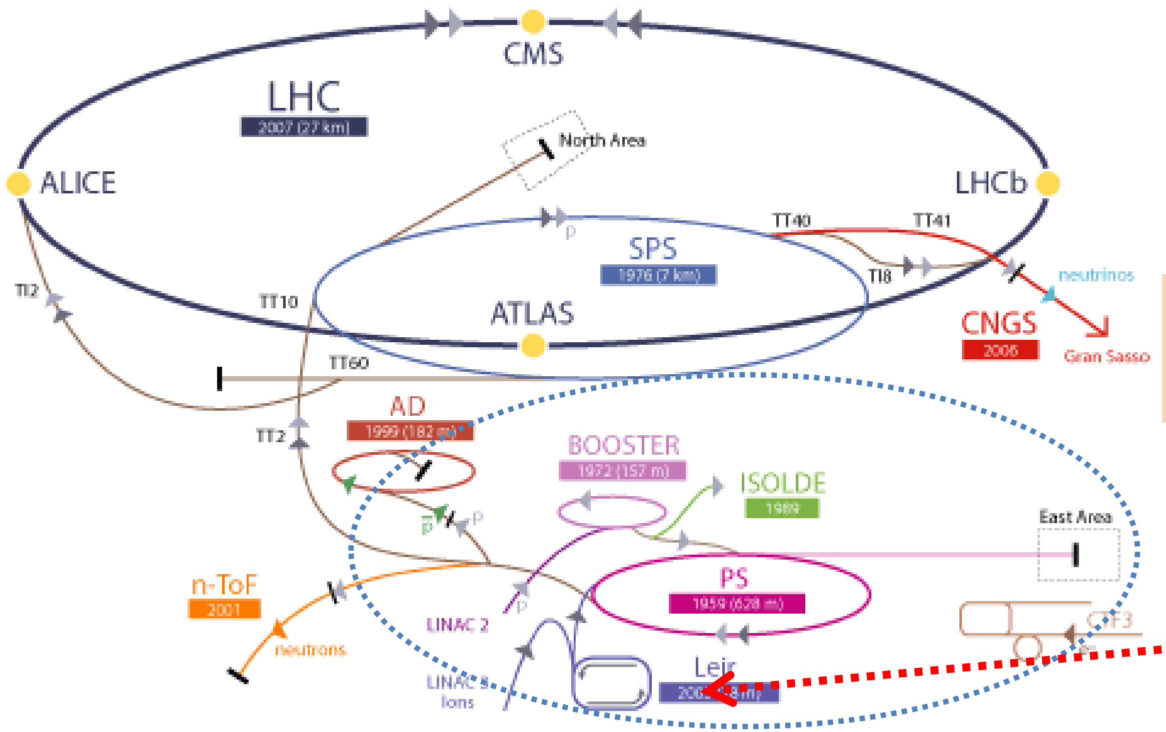
2) The Proposed Biomedical Facility



NOT TO SCALE!
LHC diameter = 8.5 km
LEIR diameter = 25 m

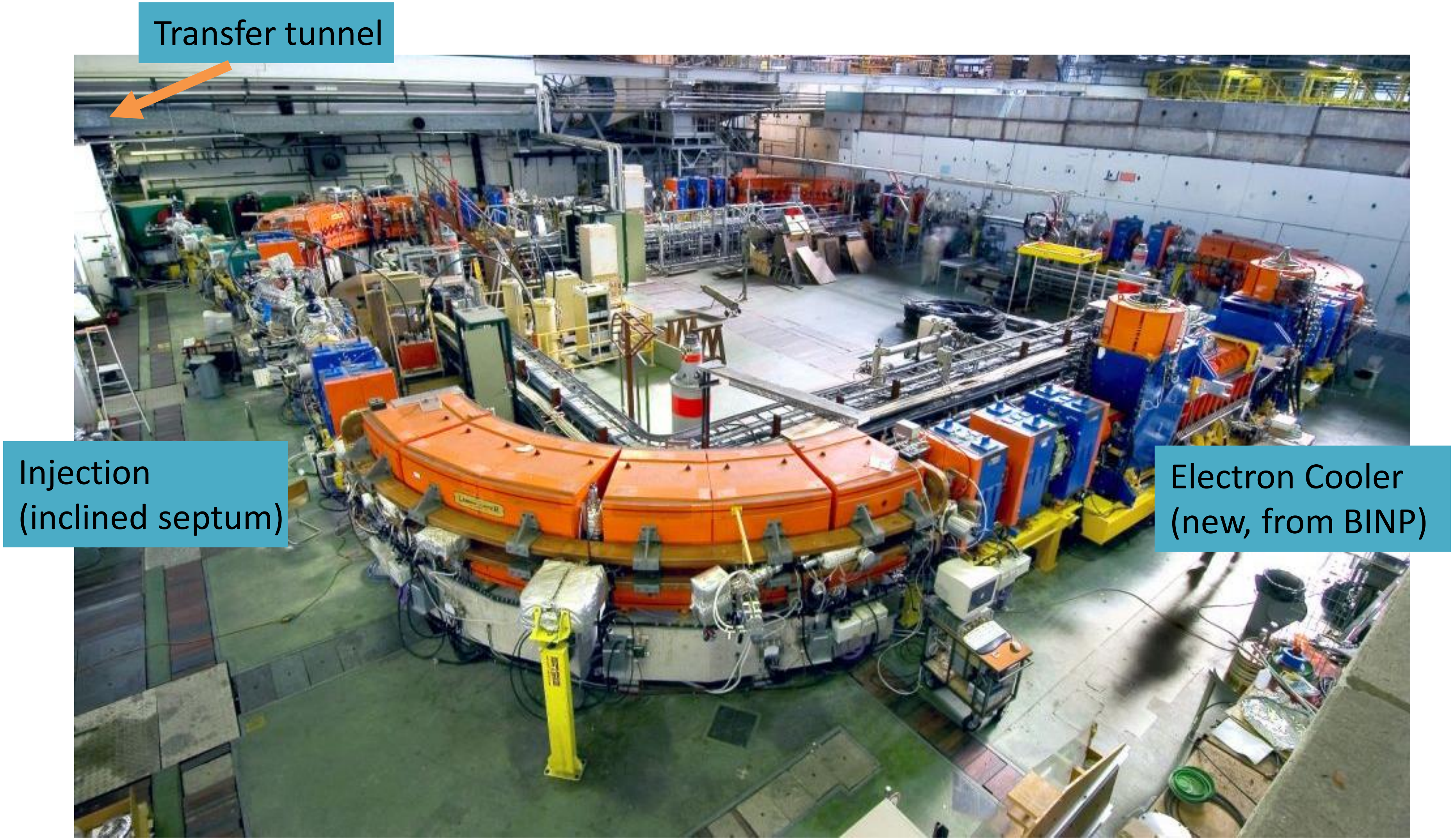
The CERN accelerator complex

LEIR:
- Provides ion beams for LHC
- Accumulation of several pulses from Linac3 with electron cooling

Why LEIR?

- Existing accelerator maintained for LHC (and SPS fixed target)
- Energy range similar to treatment ion facilities
- Small upgrades required to provide beams for bio-medical experiments

Biomedical Facility at LEIR

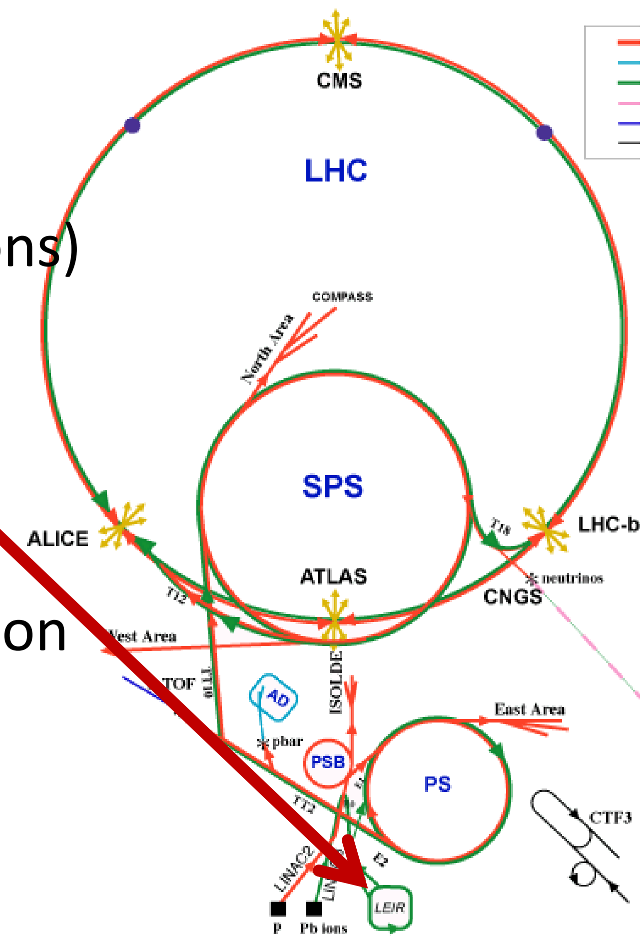


Radiobiological Facility @ CERN

@ **LEIR** (Low Energy Ion Ring)

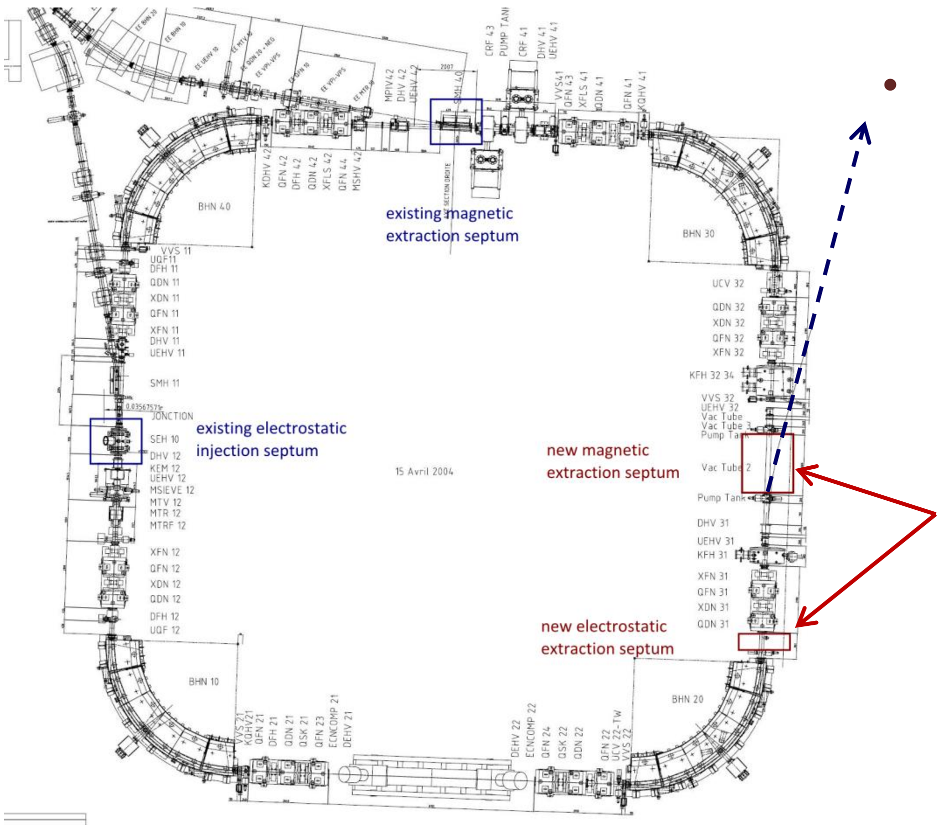
- part of LHC injection chain
- accumulator for LHC ion programme (lead ions)
  - only used for several weeks / year

- Planned to **establish facility** for
  - **radiobiology**
  - basic physics studies such as fragmentation of ion beams
  - dosimetry
  - tests of instrumentation



Radiobiological Facility @ CERN

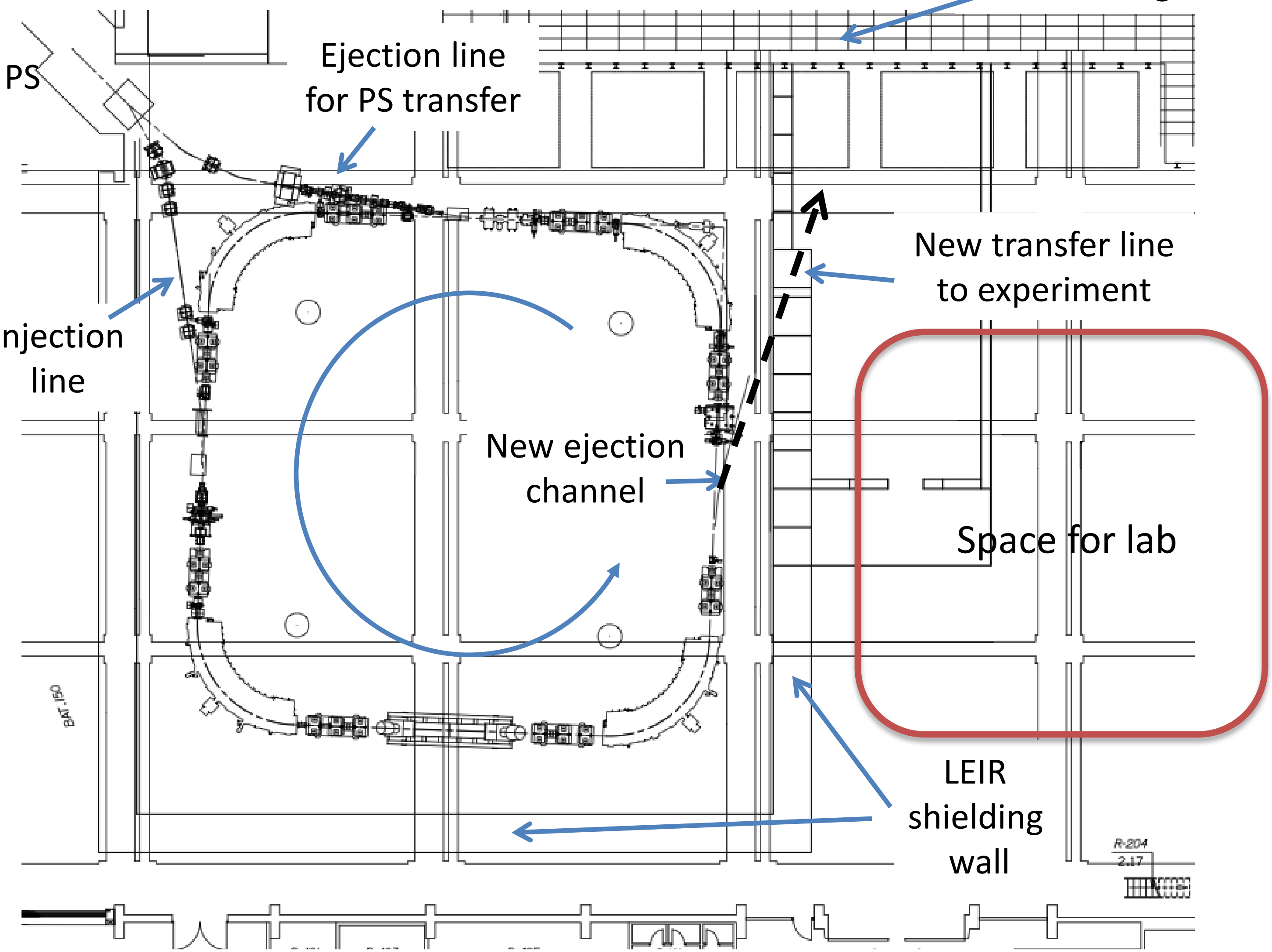
Feasibility Study for using LEIR as accelerator for radiobiological facility



- **Beam transport lines**
  - for low energy irradiation (medical applications, **vertical** beamline)
  - high energy irradiation (space radiobiology, **horizontal** beamline)

- LEIR **lattice** requires **modifications**: septa for new ‘**slow extraction**’ channel

Facility for Radiobiology Studies
Sketch of LEIR



Radiobiological Facility @ CERN

Ions	Priority Rating /5	Why
Protons	5	Clinical
(molecular ion) H_2	2	Correlated particle experiments Experiments -Spatial distribution Variation in response
Helium $_2^3$	5	Possibly clinical
Helium $_2^4$	4	Stable and possibly clinically relevant
D	4 (if clean), 0 (if not)	Radiobiologically interesting, not clinically useful
Li $^6_3$	4	RBE greater than P Fragmentation tail shorter, less dose deposited past the distal edge
B $_5^{10}$	2	Potentially clinical Fragmentations more than Li, better than C
C $_6^{12}$	5	Clinical
N $_7^{14}$	3	Radiobiological Studies
O $_8^{16}$	4	Possibly clinically relevant Radiobiological Studies
Ne $_{10}^{20}$	3-4	Comparison to present radiobiological studies
Ne-Fe	1	To analyse radiobiological trends across the ions
Ca $_{20}^{40}$	1	Intermediate Biologically important trace element
Fe $_{26}^{56}$	3	Radiobiological interpolation

Dosanjh

Collection of requirements for Radiobiology Facility

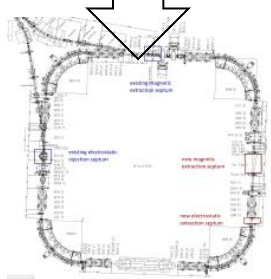
What radiobiological experiments are of interest?

What are the desired beam properties?

- ion species & energies
- beam intensities & duration
- beam size
  (micro vs. broad beam)
- beam homogeneity

How could an end-station for radiobiological experiments be designed

- Precision of beam-cell positioning
- Setup and Tooling



LEIR Biomedical Facility Status

- With a new Front End (Source)
  - LEIR can provide ions of interest for biomedical studies up to <430 MeV for fully stripped ^{12}C or ^{16}O ions
  - Facility can also be used to test detectors, diagnostics and simulation results
  - Study well under way:
    - (Re-)implemention of slow ejection with longitudinal and/or transverse excitation
    - New extraction channel (septa) and transfer line to experiment
    - Radio protection issues (ceiling above LEIR probably required)
- Funding Expected soon

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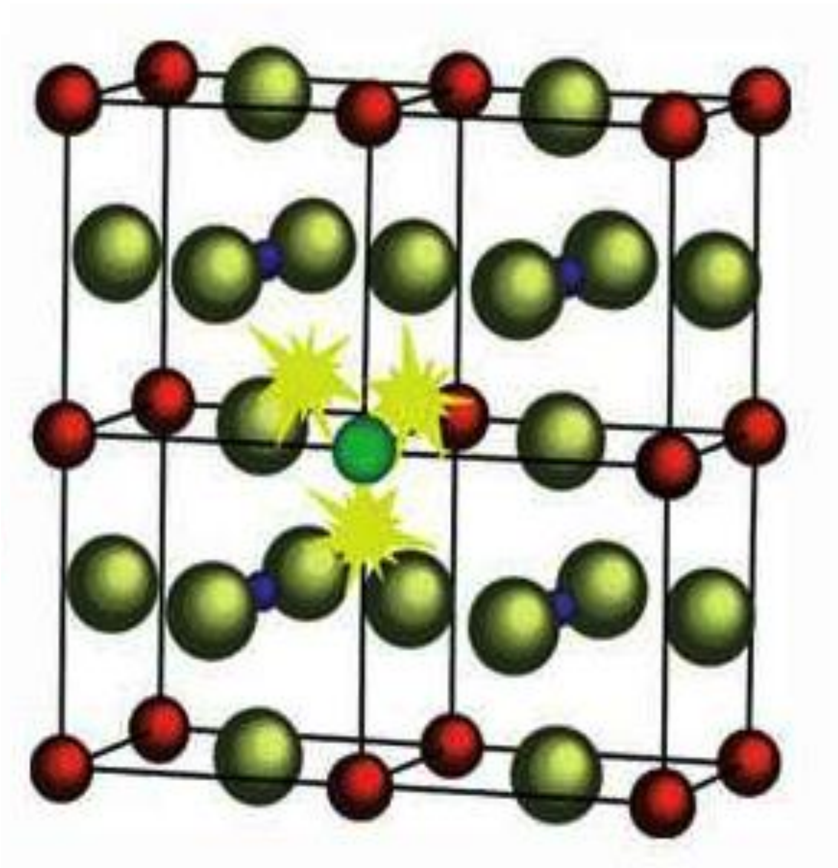
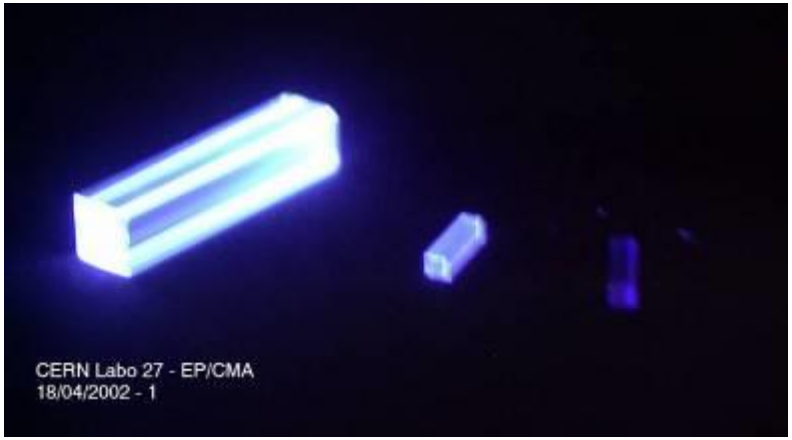
3) Detectors

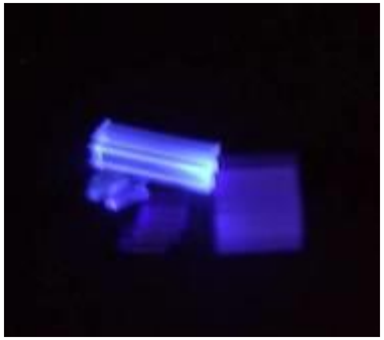
- Continuous development on particle physics detectors at CERN

What is a scintillating crystal ?

A **scintillator** is a substance that emits light when it absorbs energy from incident photons or charged particles



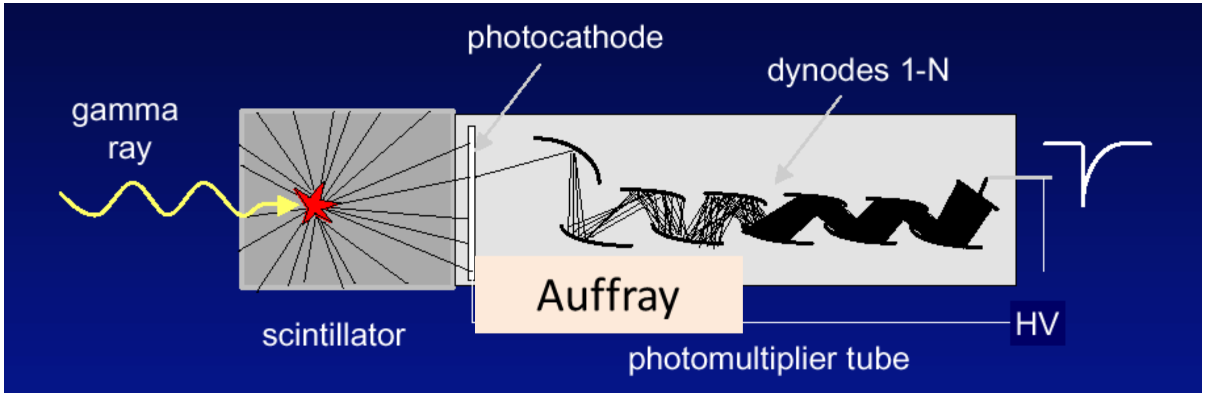




Auffray

Scintillating crystals in Physics?

Scintillators are used in High Energy Physics to detect electromagnetic particles and measure their energy.



Scintillators convert incident energy to light, which is then detected by photo detectors, e.g. photomultiplier tubes (PMTs)

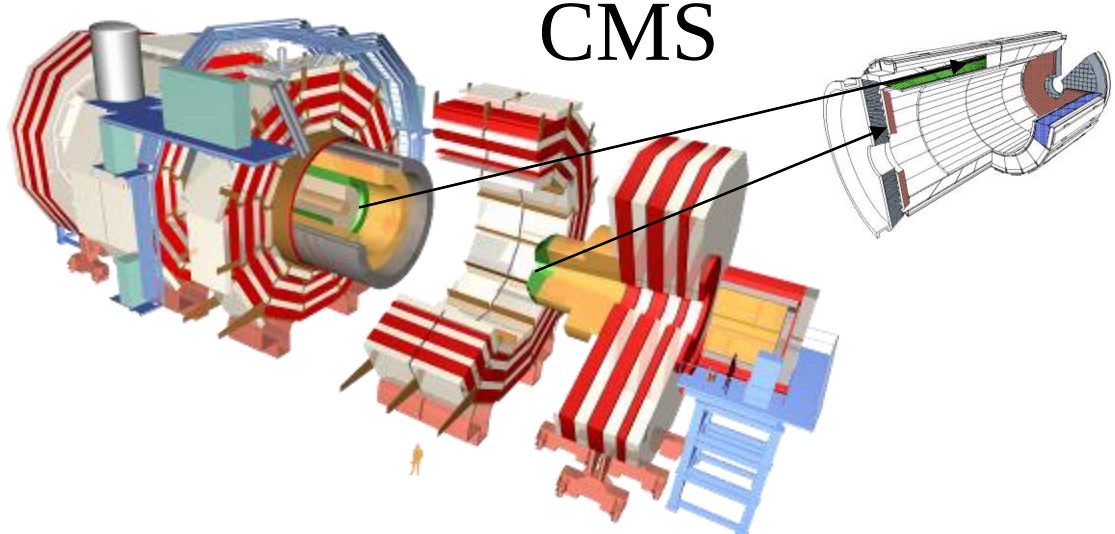
The intensity of the measured light is proportional to the energy of the incident particle

The detectors are used in the Electromagnetic calorimeters

In the CERN Large Hadron Collider (LHC) 2 experiments will use scintillating crystals : Lead tungstate crystals : $PbWO_4$

Alice :18000 crystals

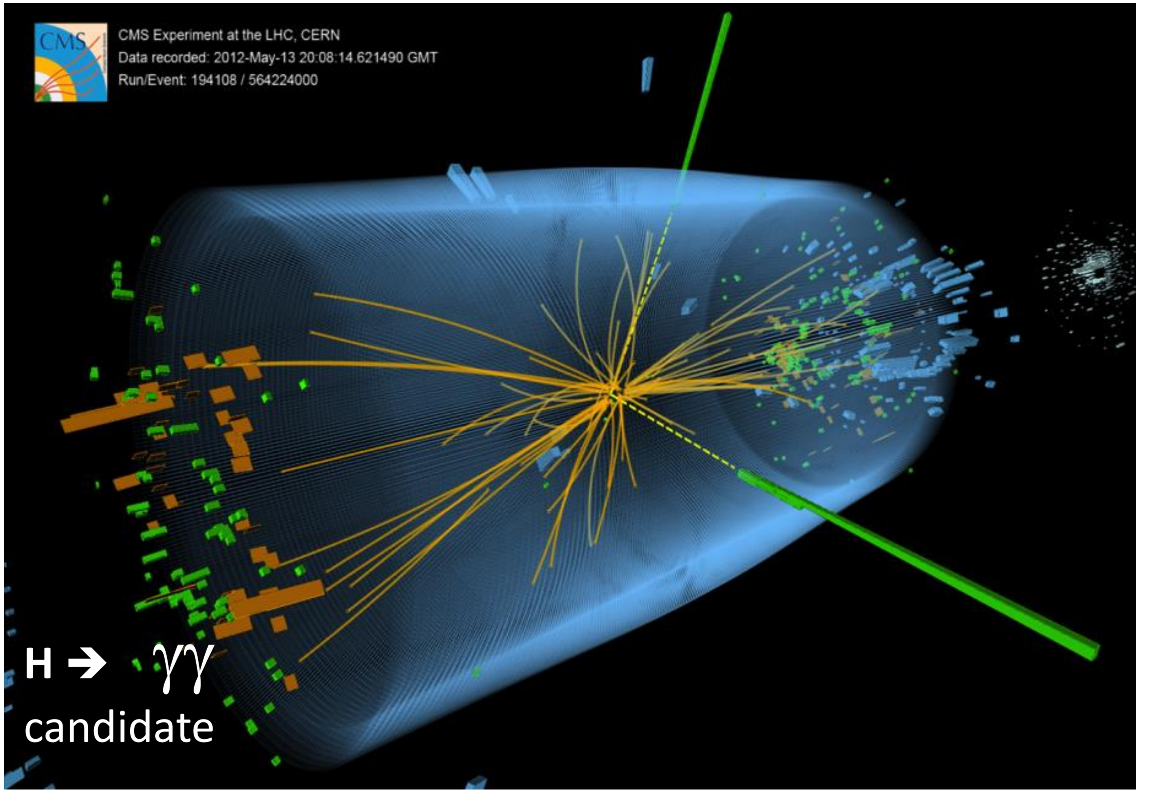
CMS

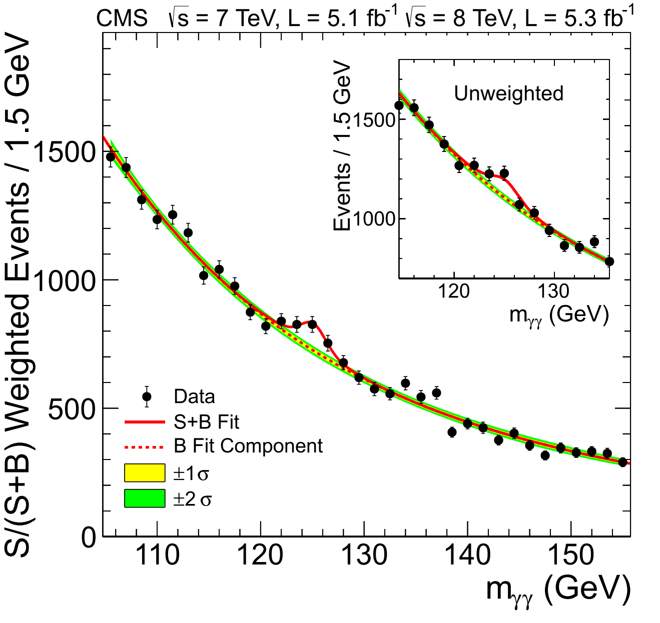


75000 crystals = 100 tons

Auffray

Higgs Bosons in 2 gamma





CMS Collab., Phys. Lett. B716 (2012) 30-61

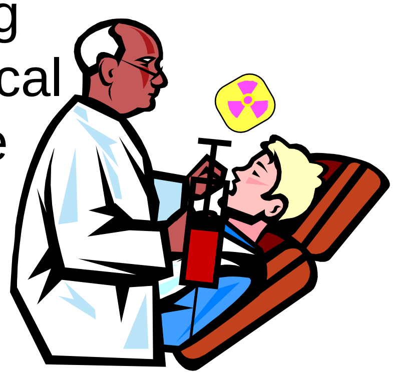
Auffray

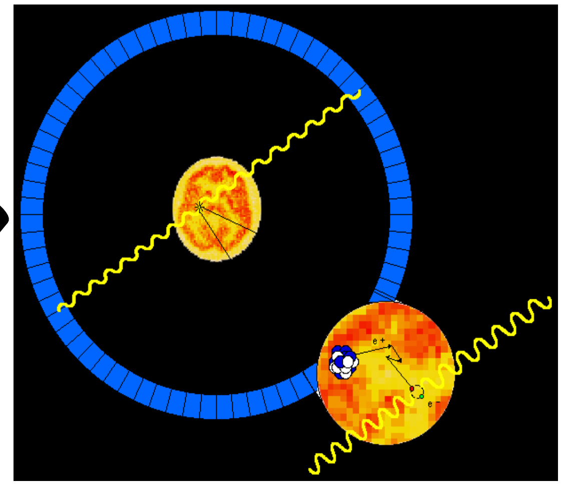
Scintillating crystals are also used for medical Imaging

In particular for positron emission tomography (PET)

PET Principle

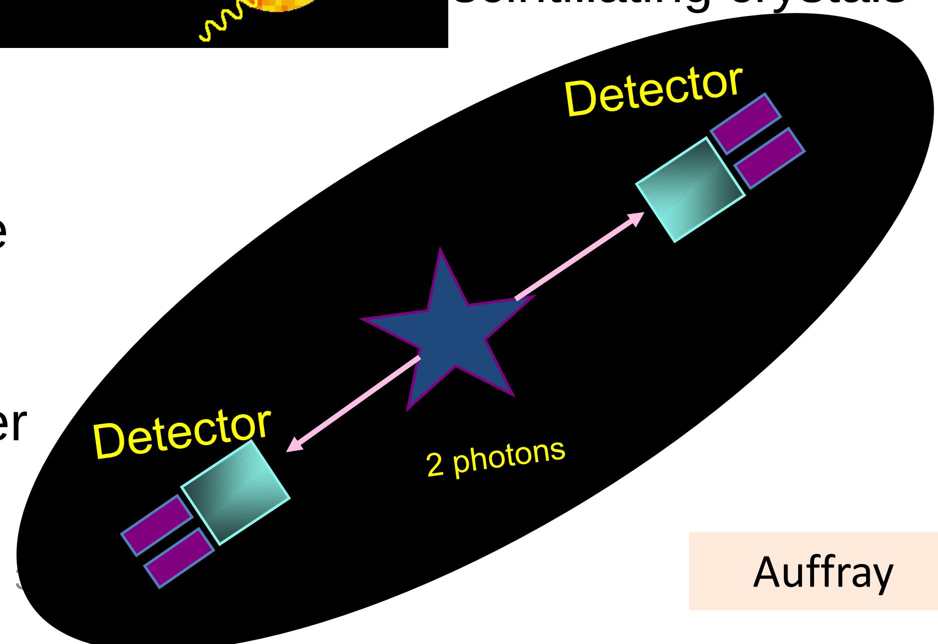
A positron emitting radiopharmaceutical is injected into the patient: the distribution





The emitted positrons annihilate with electrons in the tissue producing back-to-back photons detected by scintillating crystals

After some time the patient is placed in the imaging scanner



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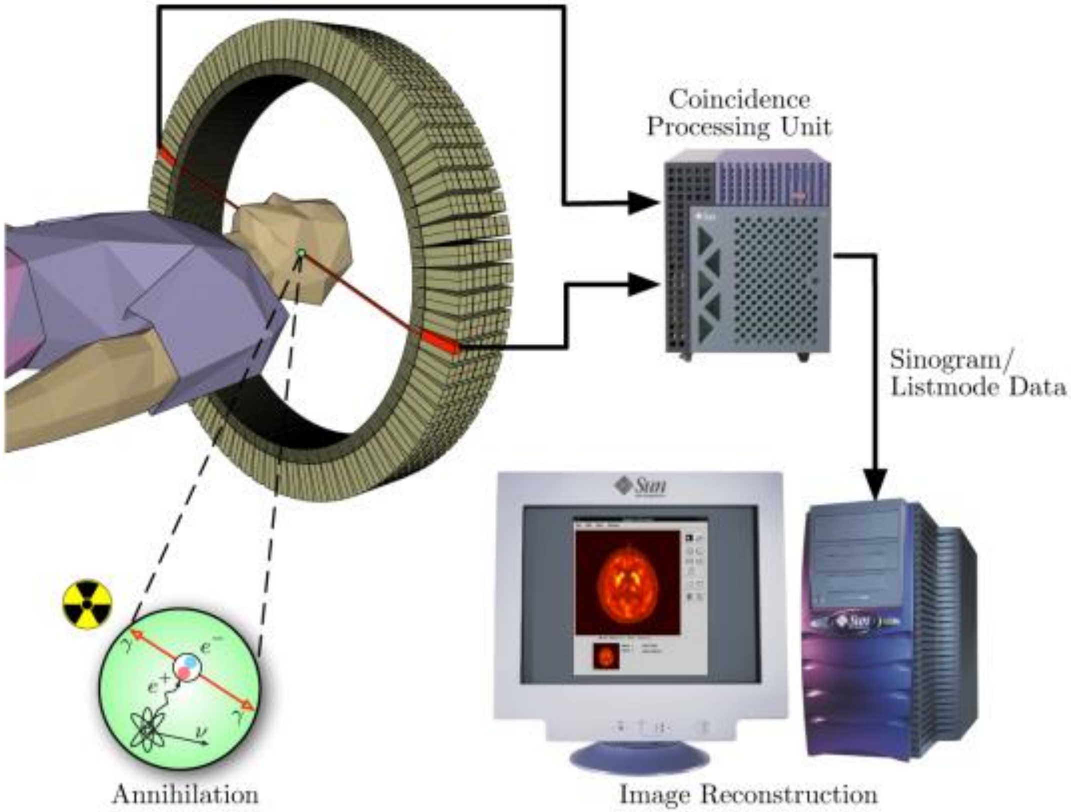
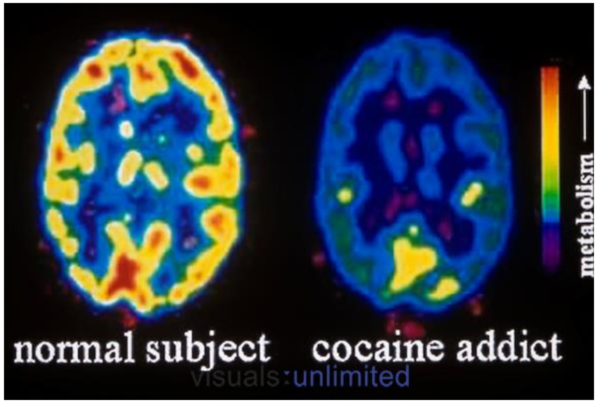
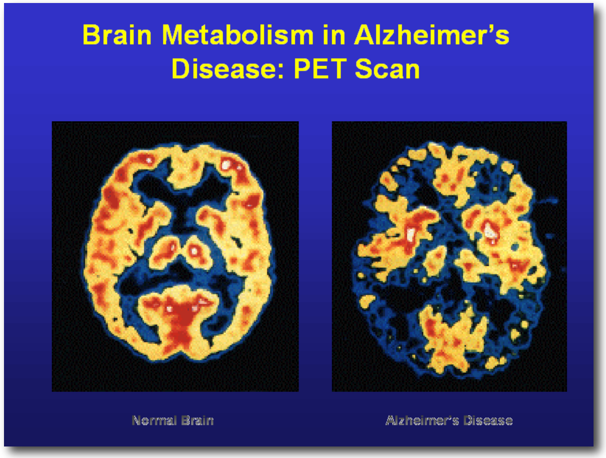
PET (Positron Emission Tomography) Imaging

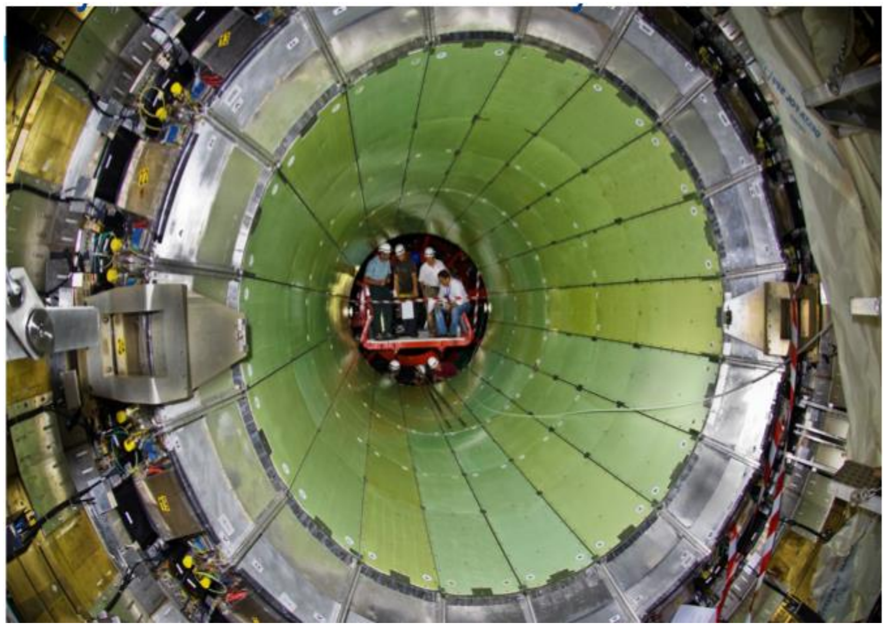




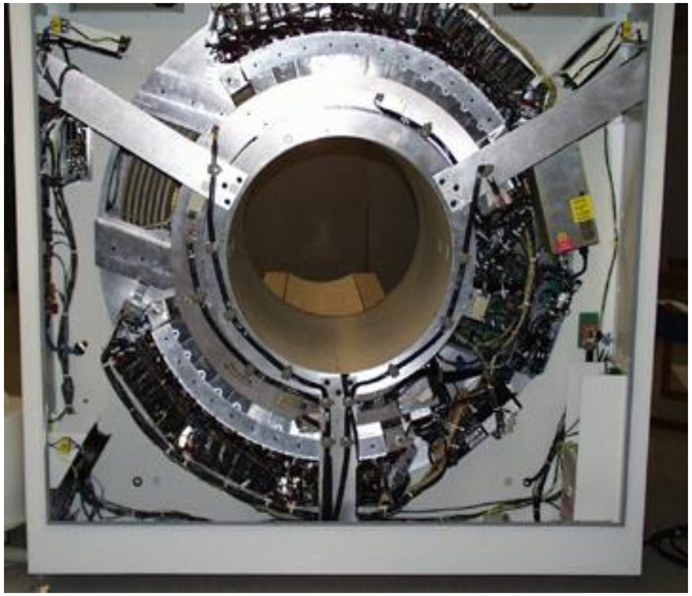


Similar Challenges in HEP and medical imaging

CMS Electromagnetic calorimeter



Positron Emission Tomograph (PET)



@ CERN

The Crystal Clear Collaboration was created in 1990 initially as part of an R&D (RD18) program for the LHC to study new scintillators for electromagnetic calorimeters.

LeCocq

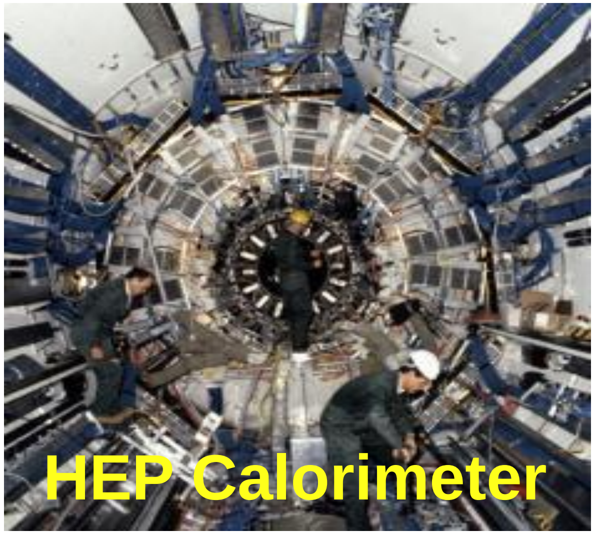
Today :

- Generic R&D on scintillating materials and photodetectors
- High energy physics related projects on scintillating detectors and related readout electronics
- Applied Research Projects mainly in medical imaging:
  Small animal PET scanner (ClearPET)
  Dedicated PET
  for mammography: ClearPEM/ClearPEM-Sonic
  BrainPET
  EndoTOFPET
  PET/MRI

http://crystalclear.web.cern.ch/crystalclear/

HEP and PET detectors

- New scintillating crystals and detection
- Compact photo-detectors
- Highly integrated low noise electronics
- High performance DAQ
- Advanced simulation & reconstruction



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6. Large Scale Computing for medical applications

5) Radio-Isotopes

Key Points : Radio-Isotopes

- Securing an adequate supply of radioisotopes is a big challenge, not only for $^{99}Mo/^{99m}Tc$ but even more for promising "new" radioisotopes such as alpha emitters for radio-immunotherapy.
- A European user facility to be created to supply innovative radioisotopes (produced at ISOLDE-CERN, ILL, PSI, Arronax,...) for R&D in life sciences (preclinical and clinical studies).

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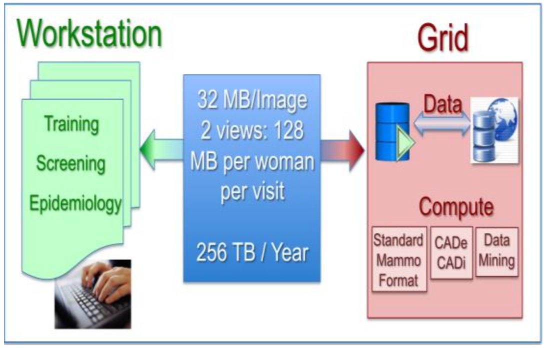
Sciences using the CERN Grid (EGEE)

- Archeology
- Astronomy & Astrophysics
- Civil Protection
- Computational Chemistry
- Computational Fluid Dynamics
- Computer Science/Tools
- Condensed Matter Physics
- Earth Sciences
- Finance (through the Industry Task Force)
- Fusion
- Geophysics
- High-Energy Physics
- Life Sciences
- Multimedia
- Material Sciences
- ... Further applications under evaluation



Grid computing for medical data management and analysis

Computing Technologies: the Grid

Computing (Health-e-grid, HISP, Mammogrid) – distributed safe and secure computing

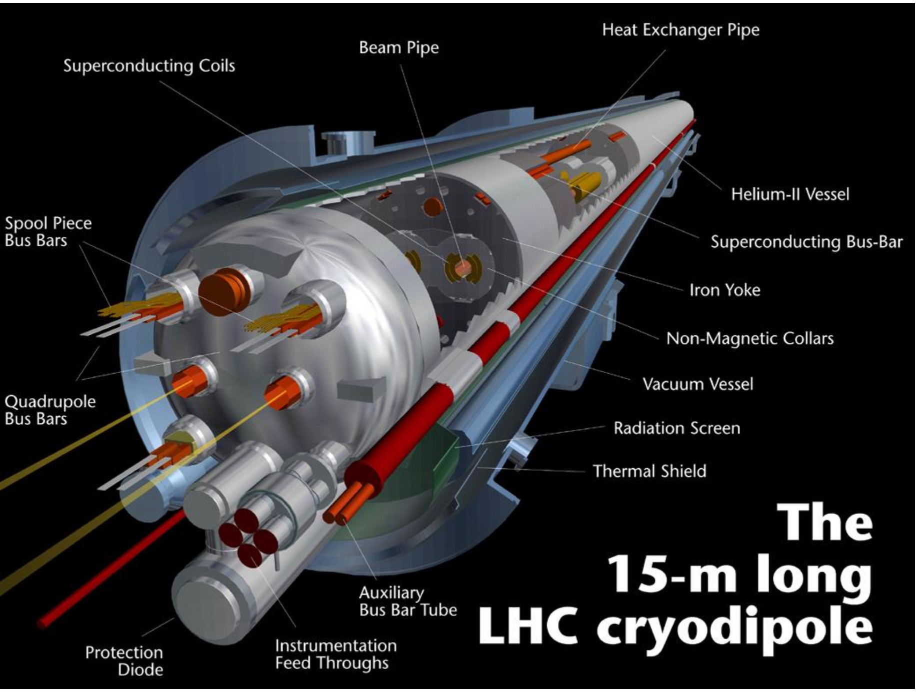
Health-e-Child (http://www.health-e-child.org/)

The consortium is in its final year of work towards giving clinicians a comprehensive view of a child's health by vertically integrating biomedical data, information and knowledge that spans the entire spectrum from imaging to genetic to clinical and epidemiological data. Utilising the power of the GRID the consortium has developed a biomedical information platform which supports sophisticated and robust search, optimisation and matching techniques for heterogeneous information.

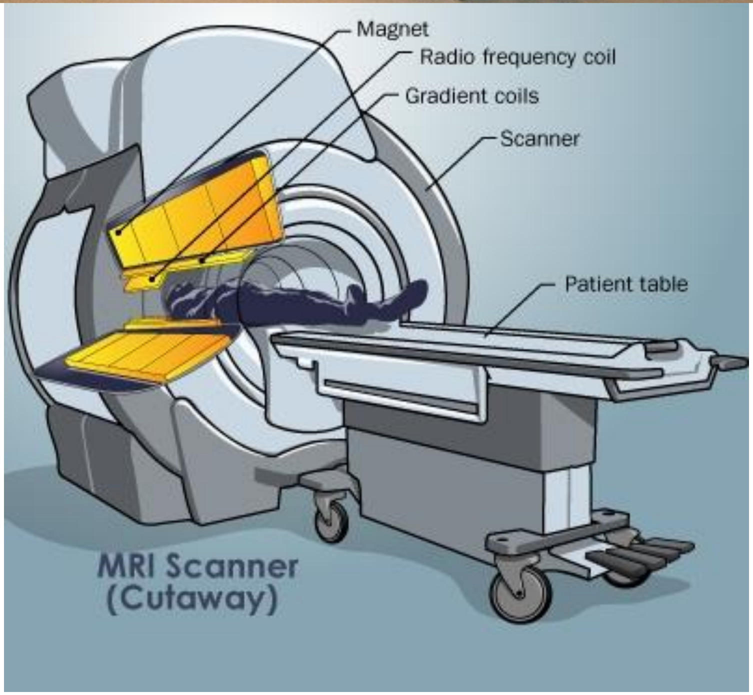
MammoGrid: develop an European-wide database of mammograms and to support effective co-working between EU healthcare professionals.

HISP: Hadron therapy grid

Example of other CERN technologies



Superconducting magnet technology applied to MRI scanners



EU funded projects

- Wide range of hadron therapy projects: training, R&D, infrastructures
- A total funding of **~24 M Euros**
- Coordinated by CERN and CNAO (ULICE)
- Under the umbrella of ENLIGHT

PARTNER

- Marie Curie ITN
- 12 institutions

ULICE

- Infrastructures for hadron therapy
- 20 institutions

ENVISION

- R&D on medical imaging for hadron therapy
- 16 institutions

ENTERVISION

- Marie Curie ITN
- 12 institutions

Dosanjh

The Plan

- Set up an international collaboration group to improve the coherency of the work going on in medical applications related to hadron therapy and imaging
- Use this group to bring consensus to the user requirements for a hadron therapy beam provider
- Investigate non cancer applications of hadron beams

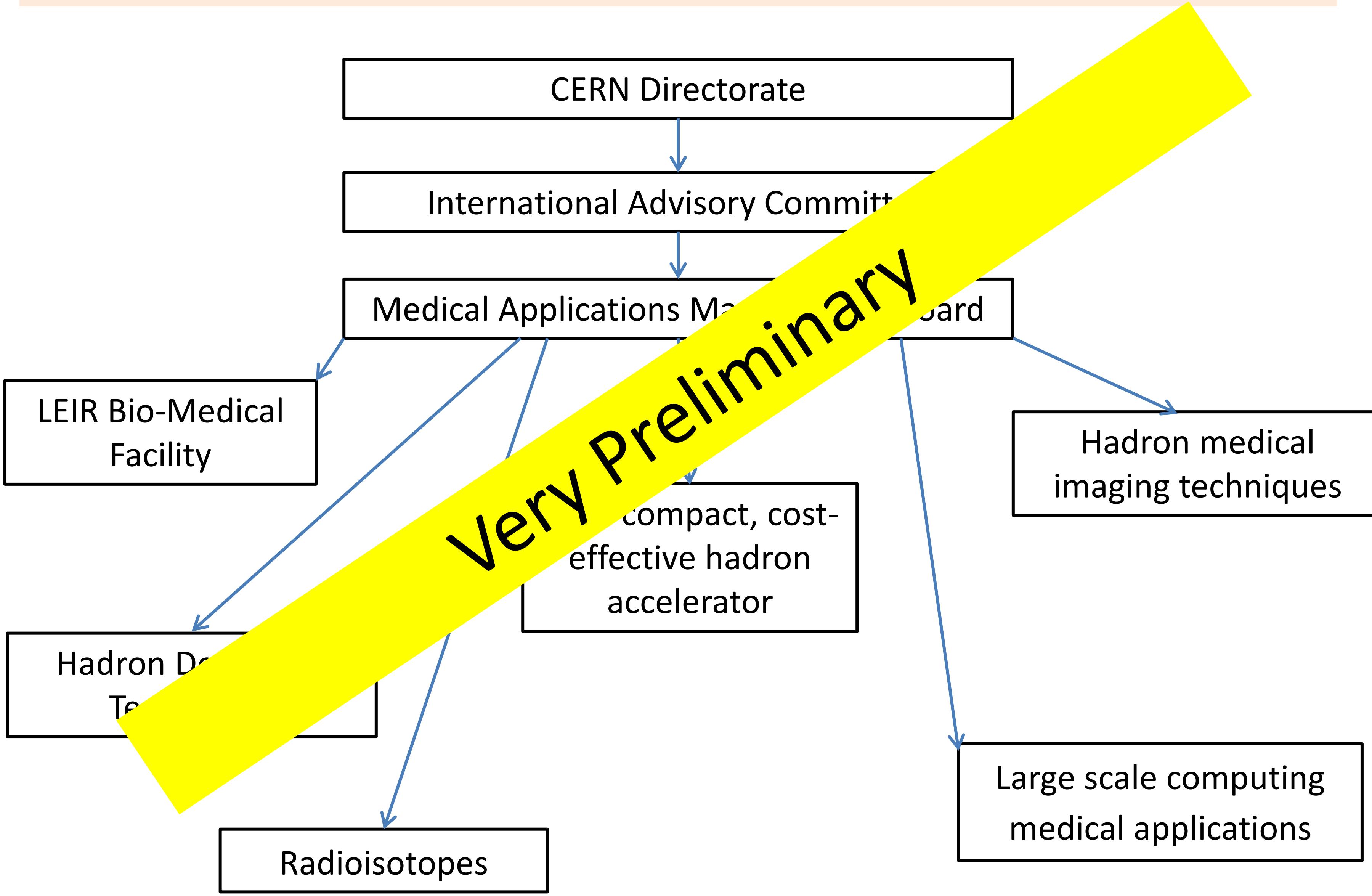
Concretely

- First retreat to discuss the user requirements and way forward.
- International group of accelerator specialists to design the new compact cost effective accelerator as specified by the user requirements
    - CERN will be the FACILITATOR
- Seed funding to come from CERN
- Obtain additional funding from the EC, philantrophers, trusts funds, etc

Priorities

- Hadron Therapy accelerator AND biomedical facility
- Detector and dosimetry

Possible Structure



Thank you for your attention