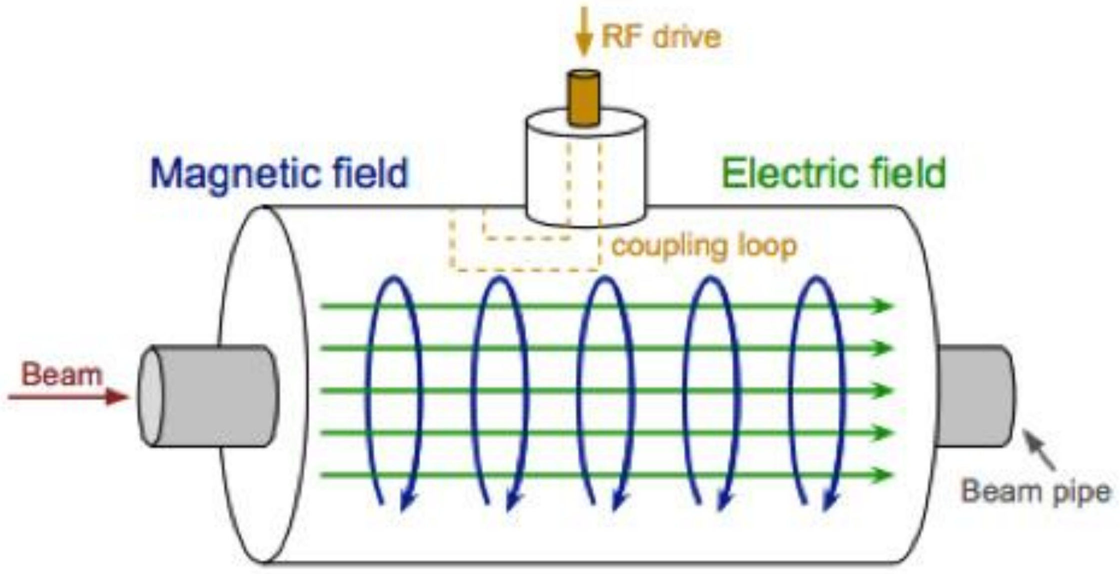
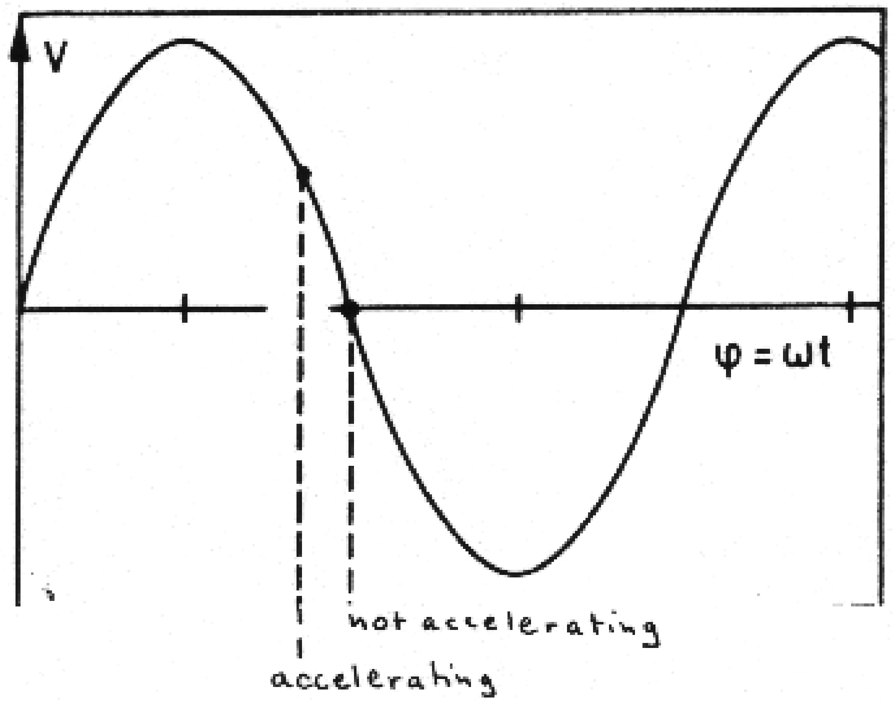
Zanimivi tipi pospeševalnikov
ali
Jedrskih pospeševalnikov ne uporabljajo samo jedrski fiziki

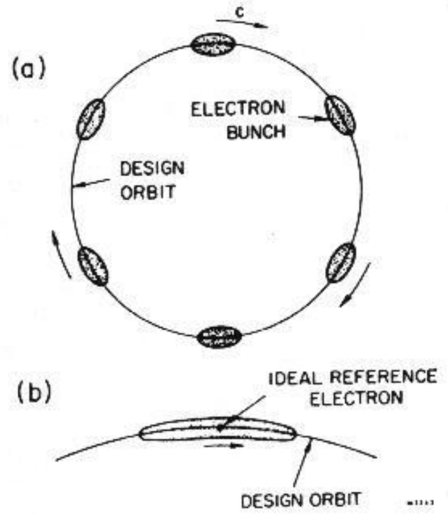
Mark Pleško
Institut Jožef Stefan
Inženirska Akademija Slovenije
Cosylab d.d.

How are particles acclerated and steered

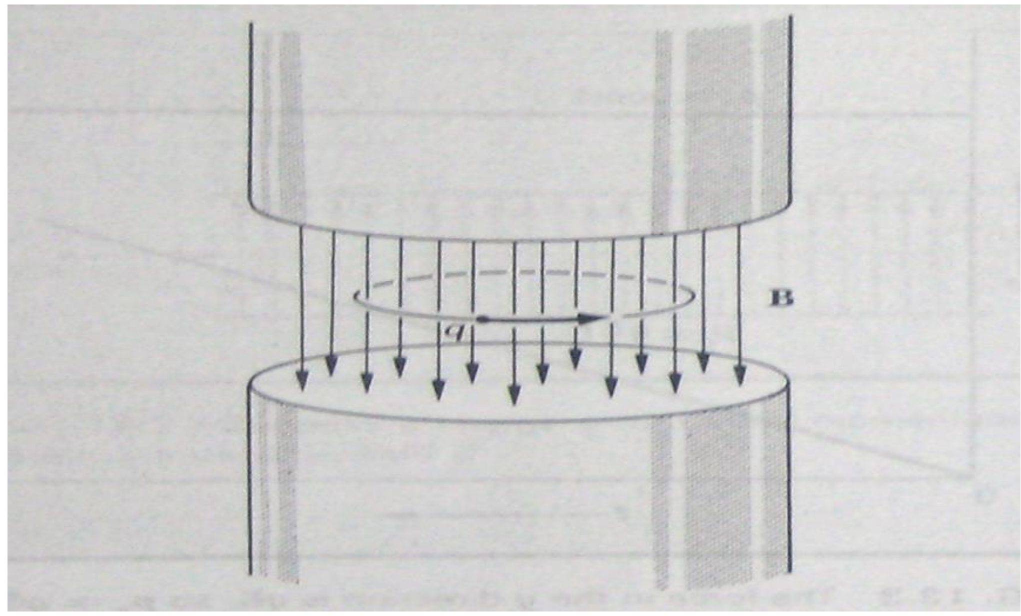
- Electro-magnetic (EM) field
  - **Electrical component accelerates/decellerates particles**
    - Because the EM field is oscillating as a sine wave, particles are bunched together (one bunch on each sine period)

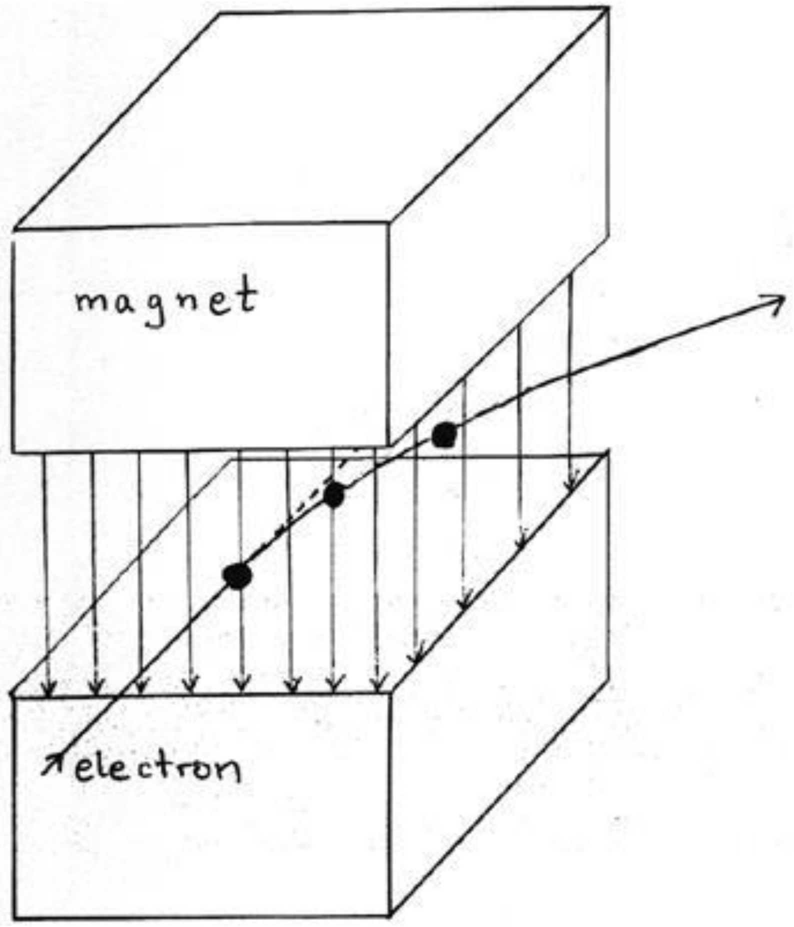


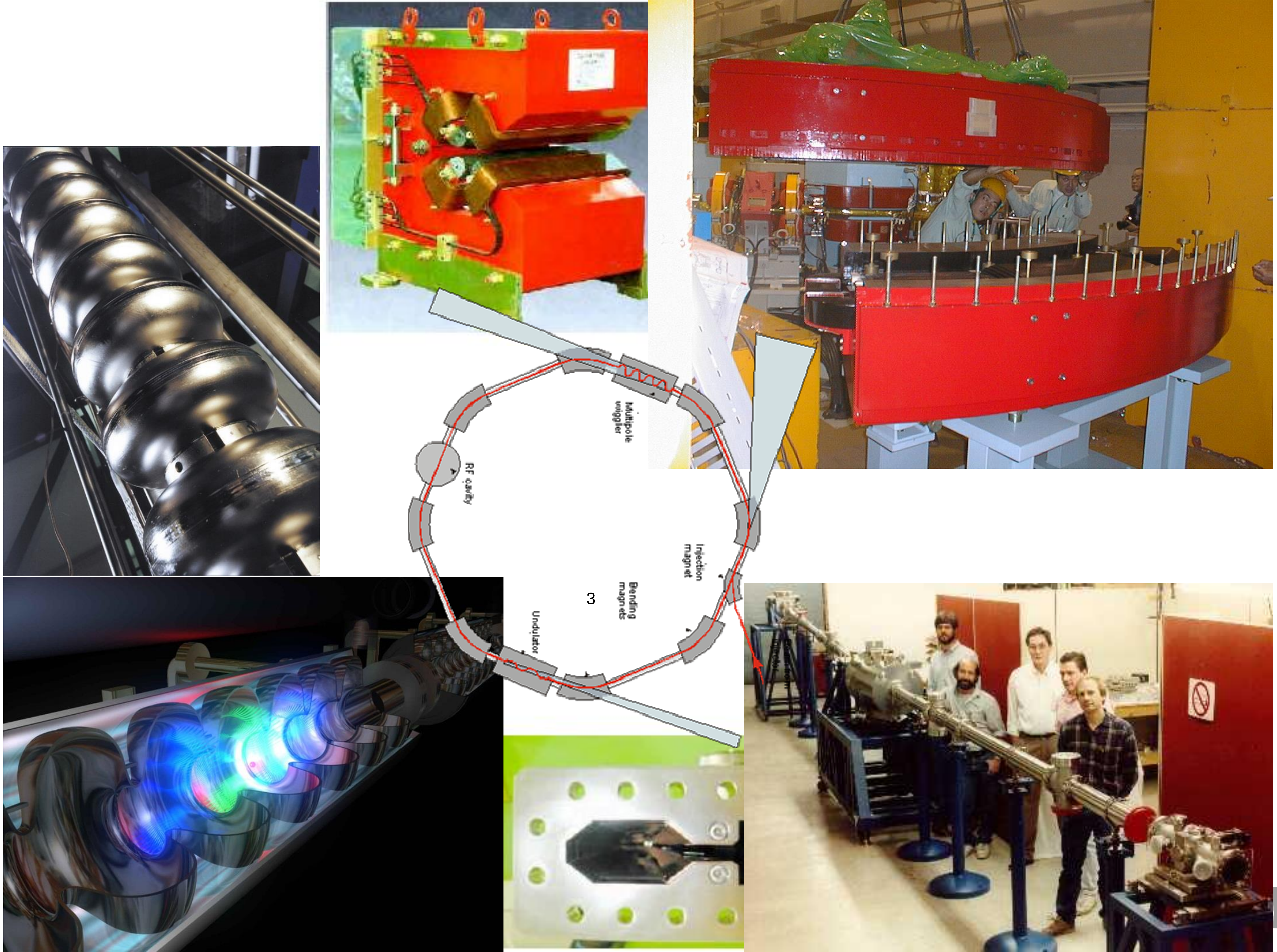




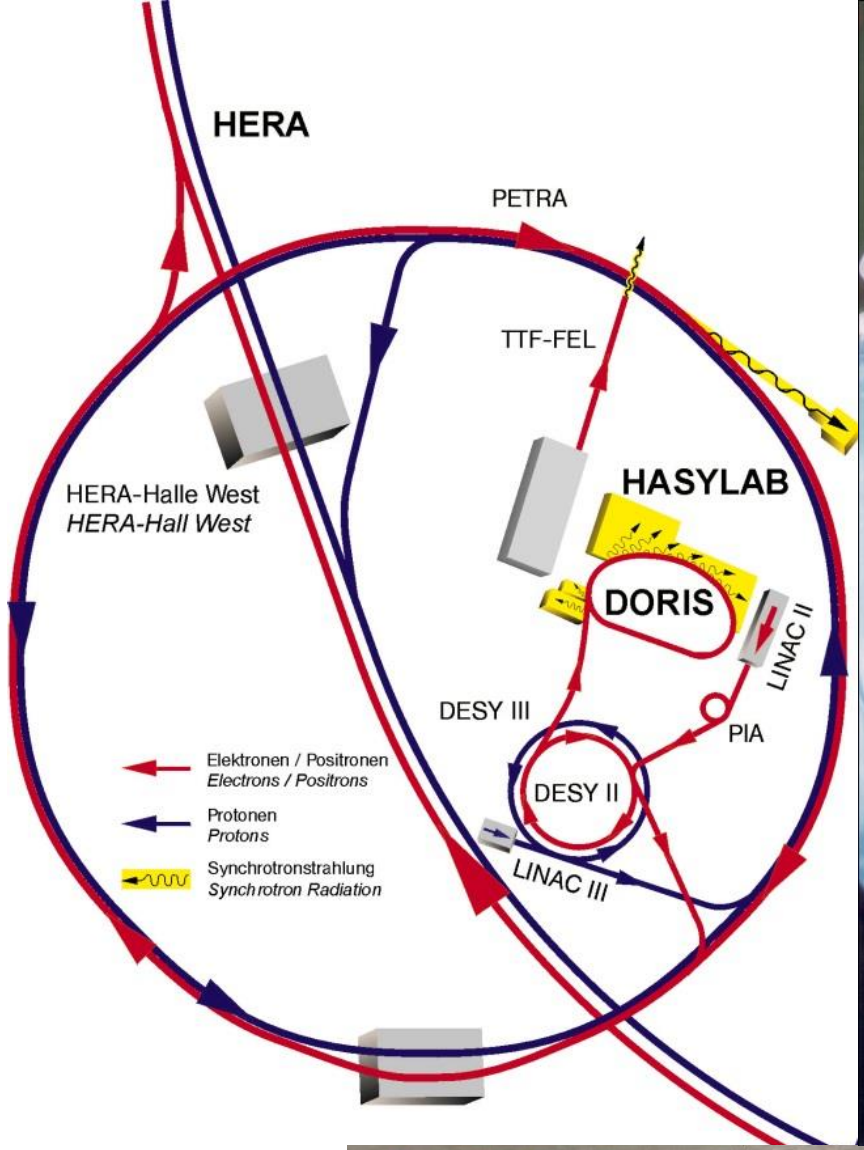
  - **Magnetic component changes particle direction**

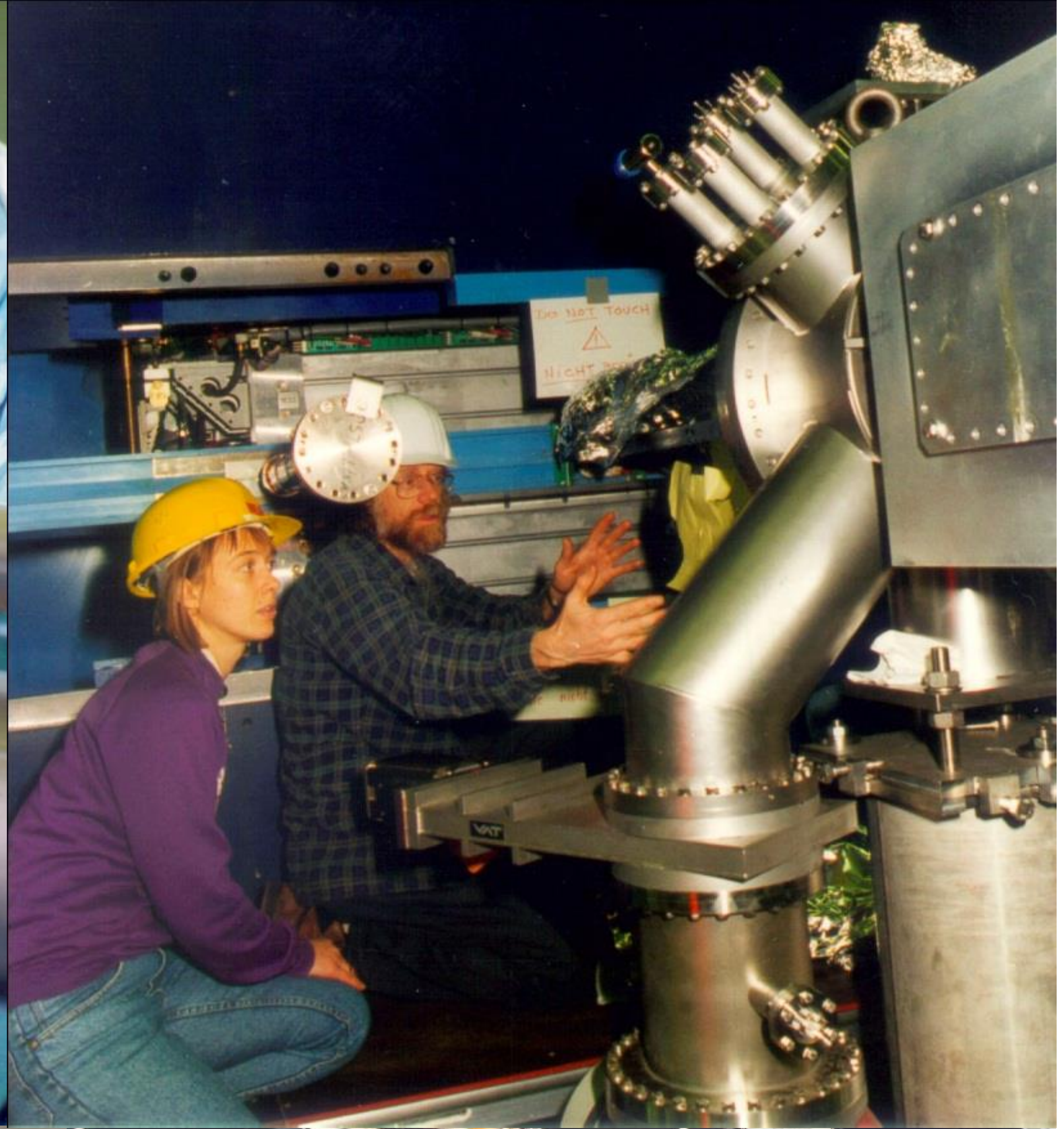




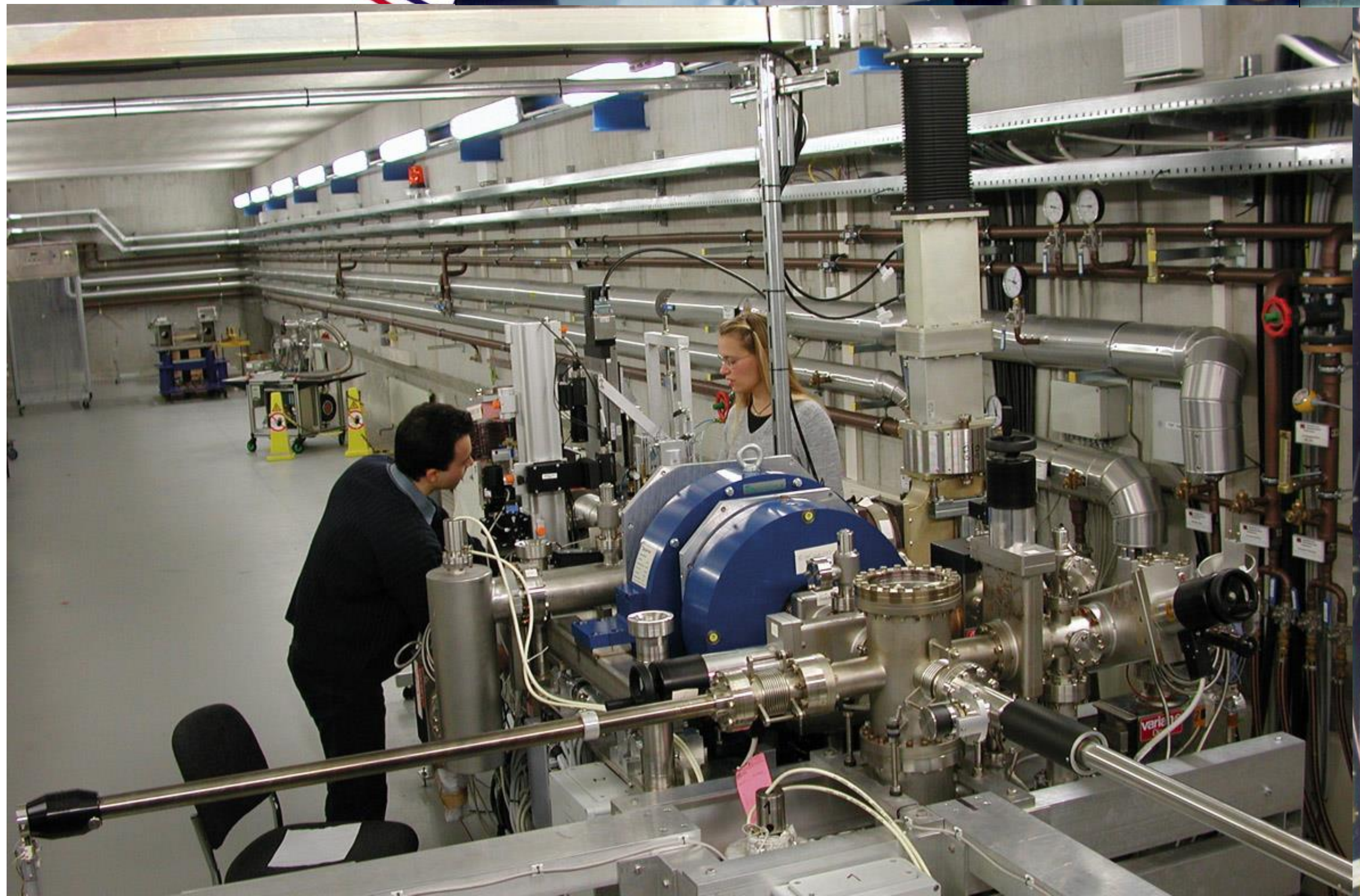


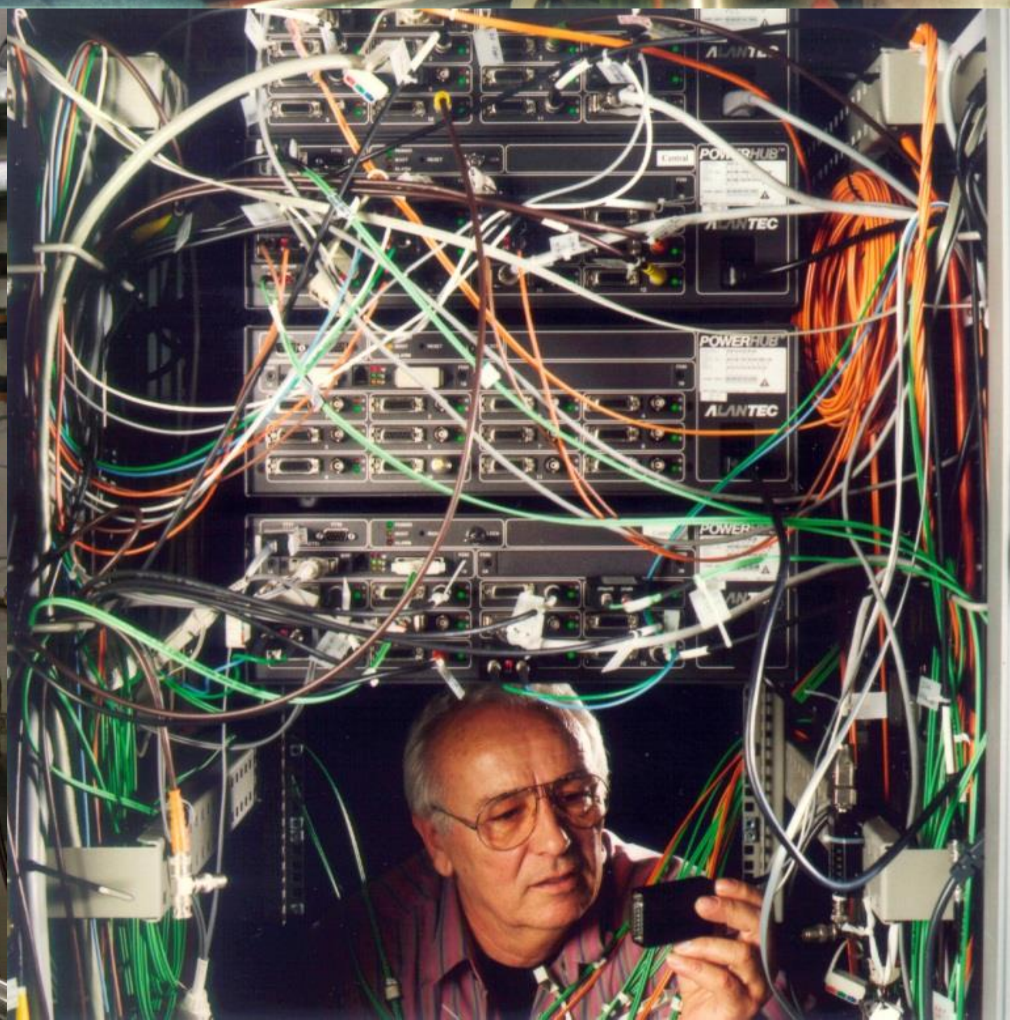
Multipole wiggler
RF cavity
Injection magnet
Bending magnets
Undulator



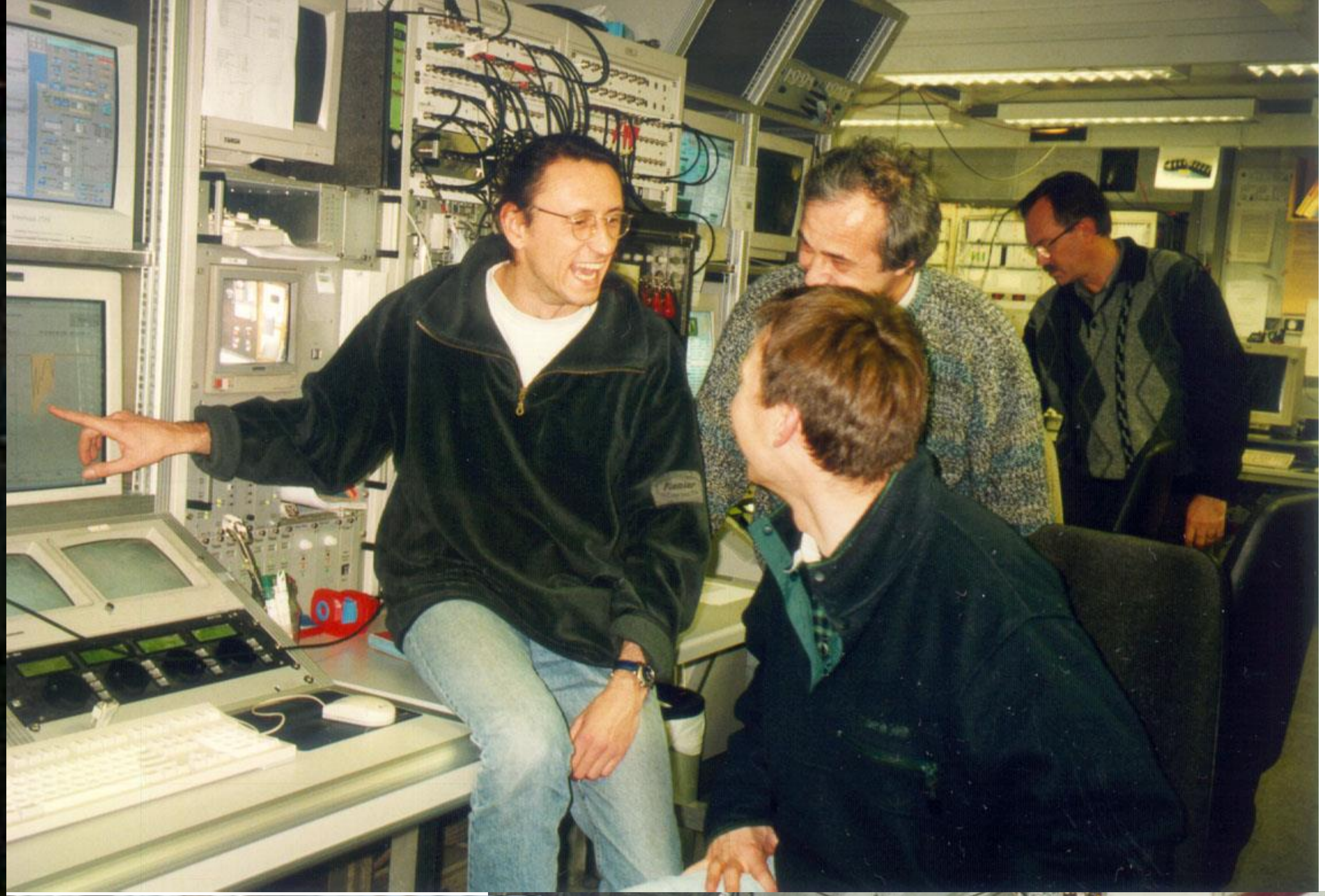


SSS 2004

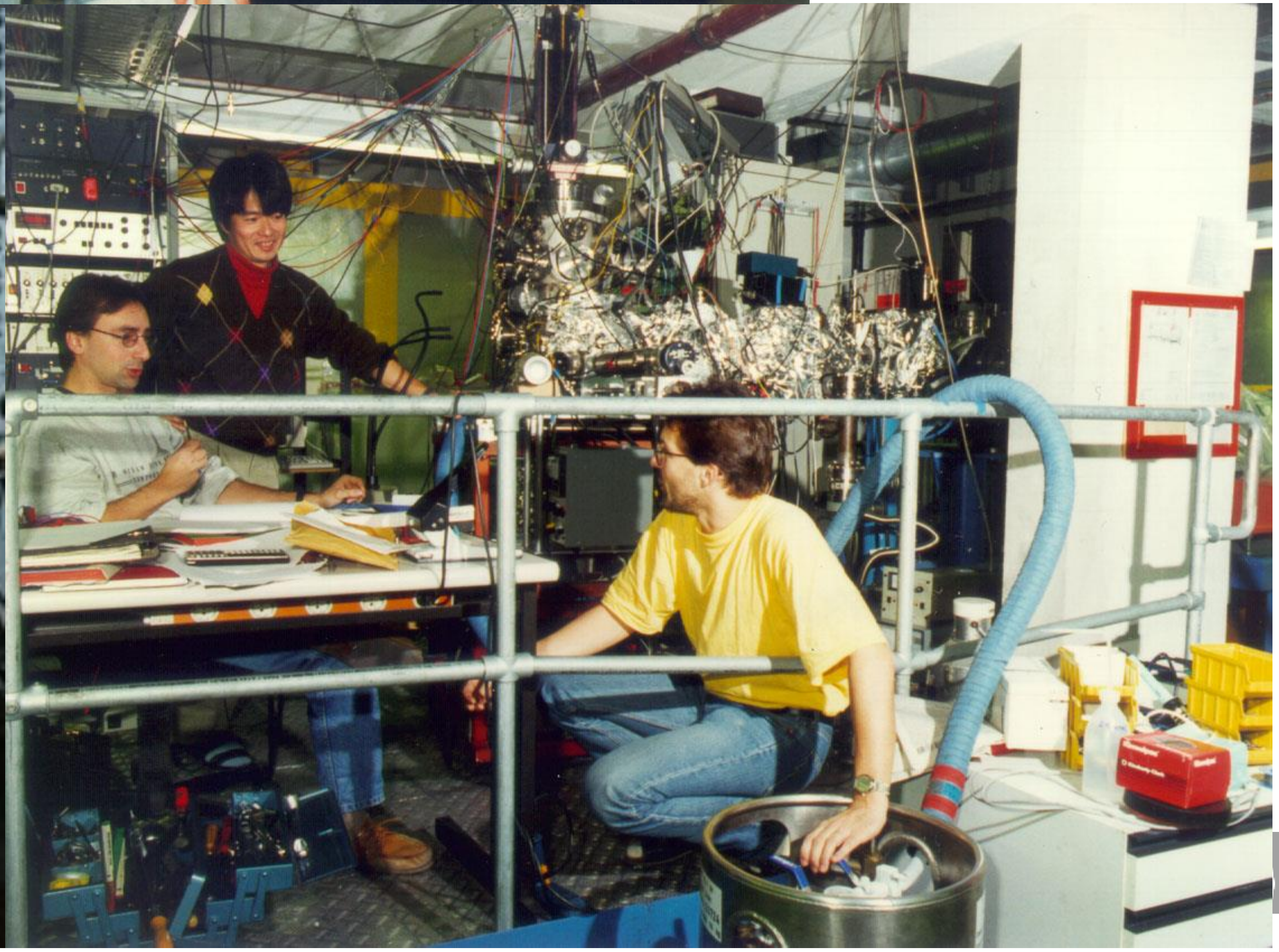




YLAB

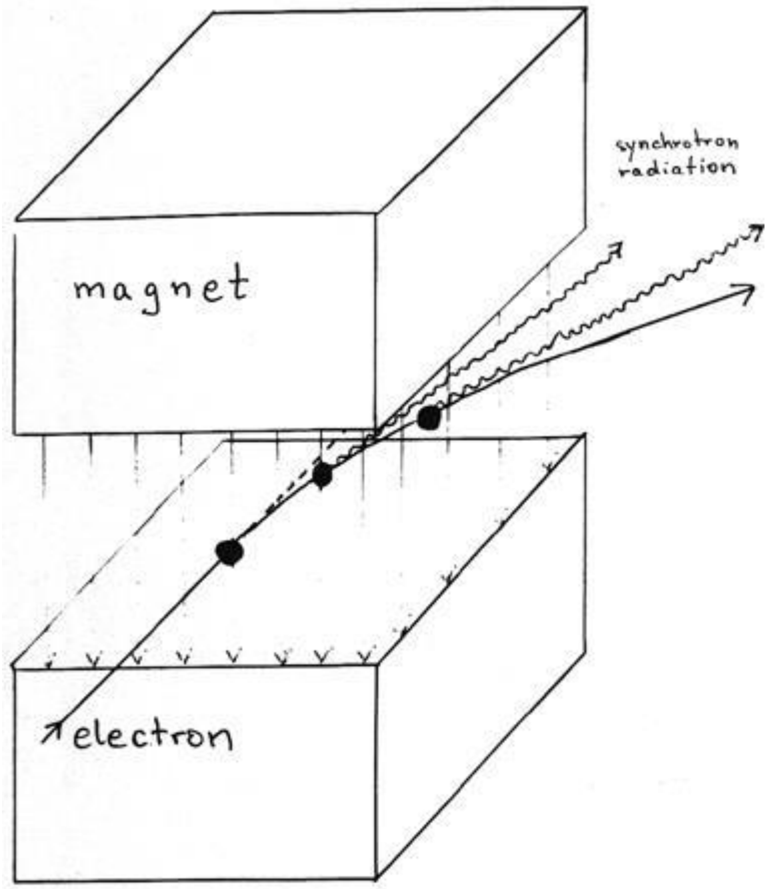


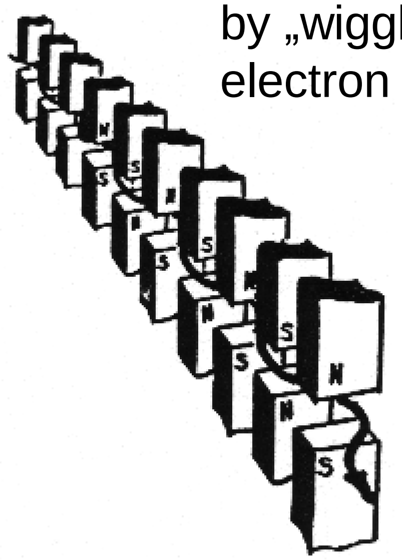
SSS 2004



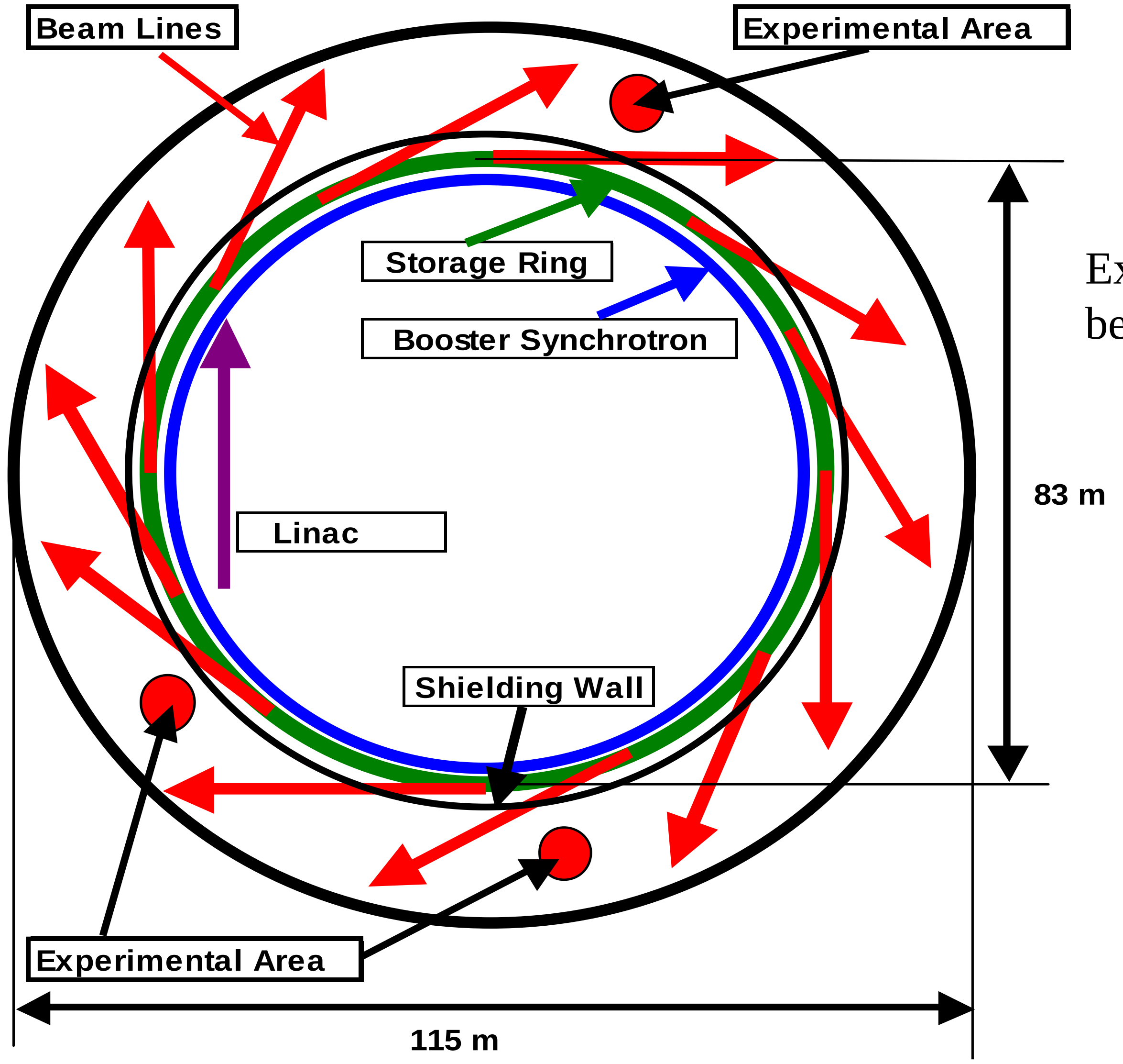
Accelerator types – light sources

- Light sources: electron beam -> X-ray light
  - Synchrotron lightsources (circular, e.g. Solaris, SKIF)
  - Free-electron lasers - FEL (linear, e.g. SwissFEL, PAL XFEL)
  - Classical cancer radiotherapy (linear, e.g. RosAtom)
  - Industrial (e.g. linear Lighthouse)

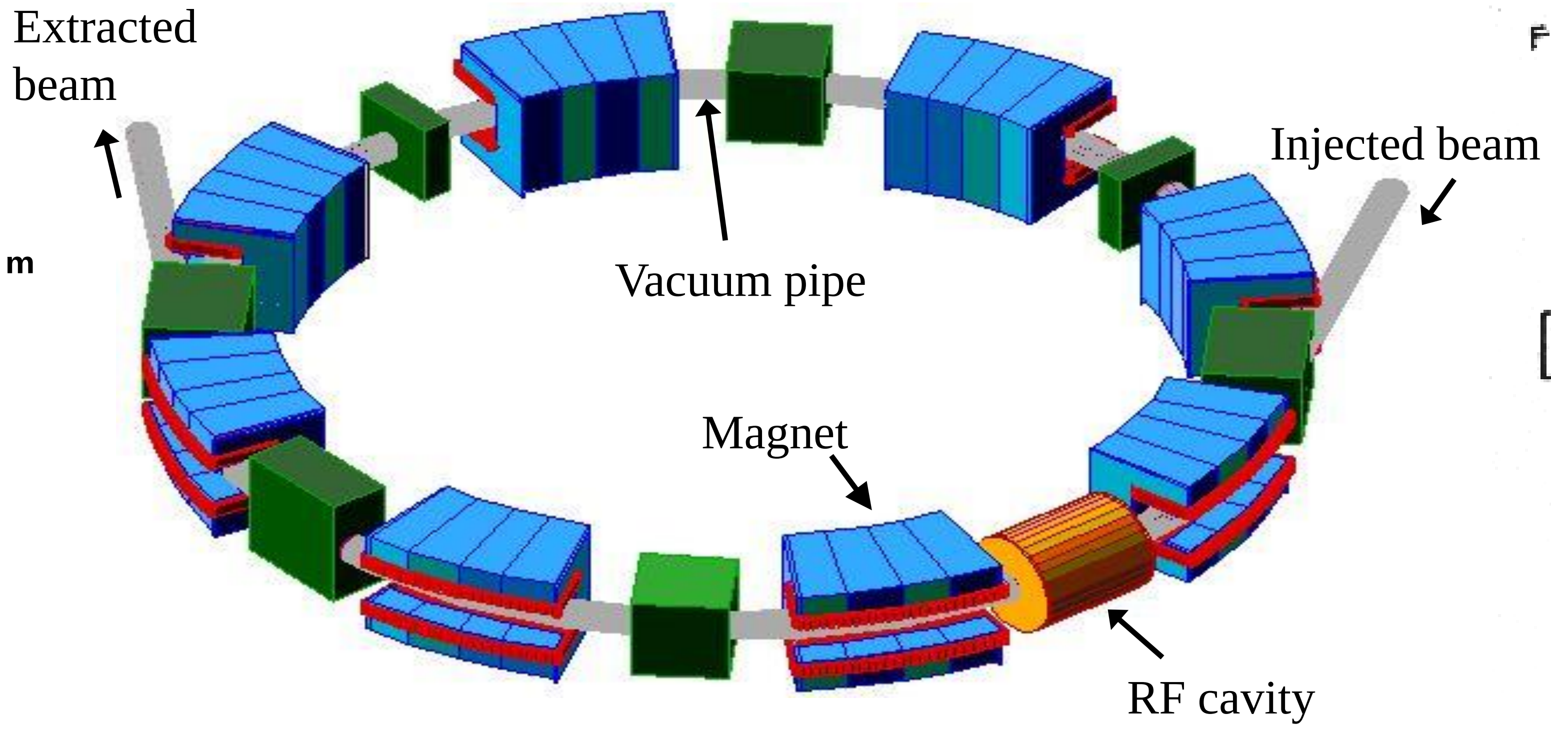


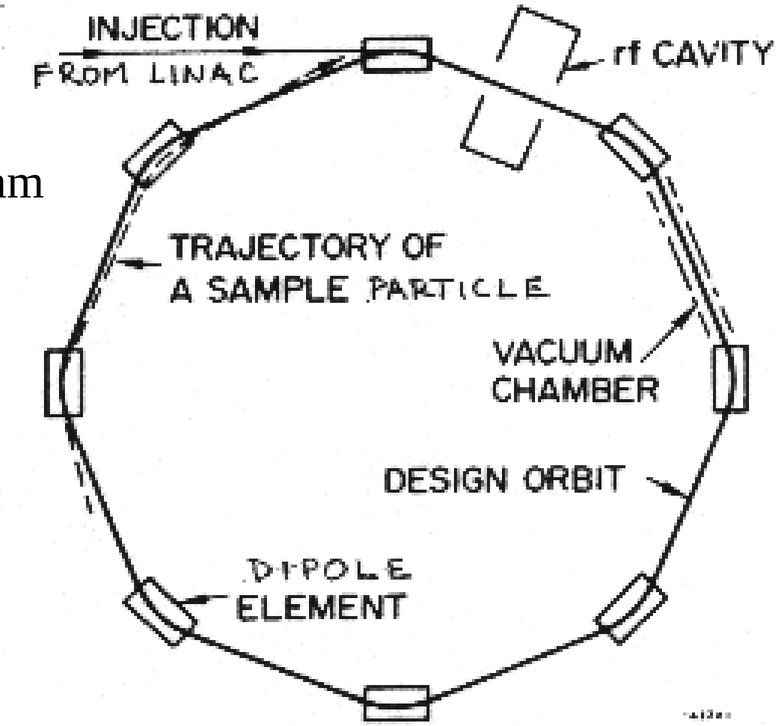


Undulators produce synchrotron light by „wiggling“ the electron beam



Synchrotron





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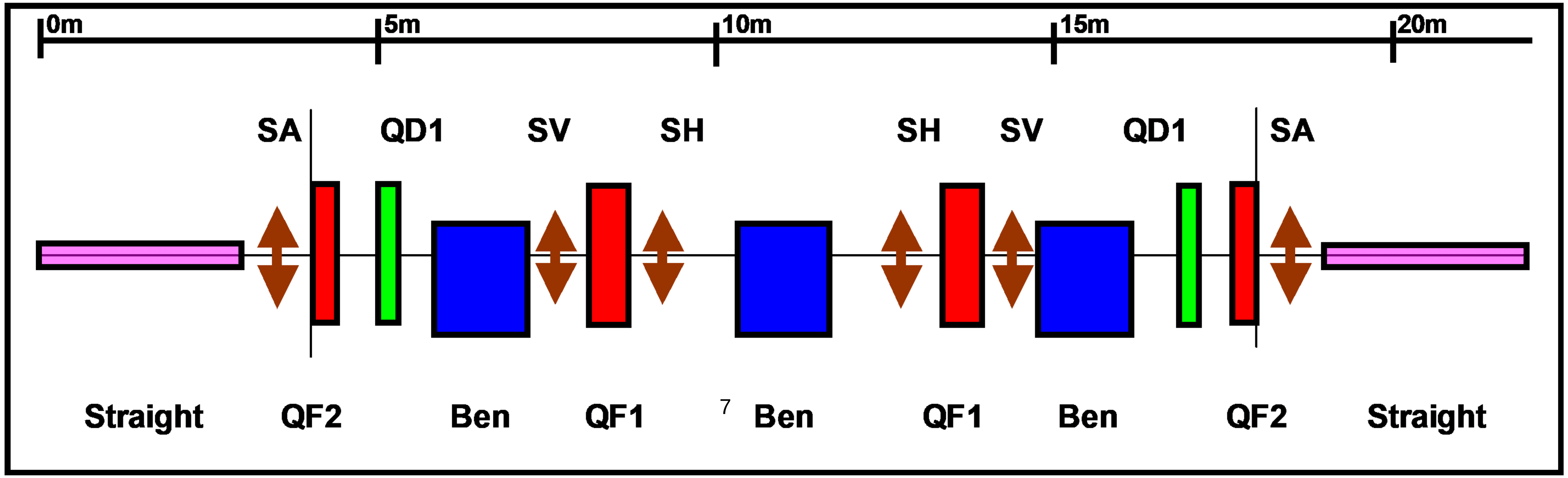
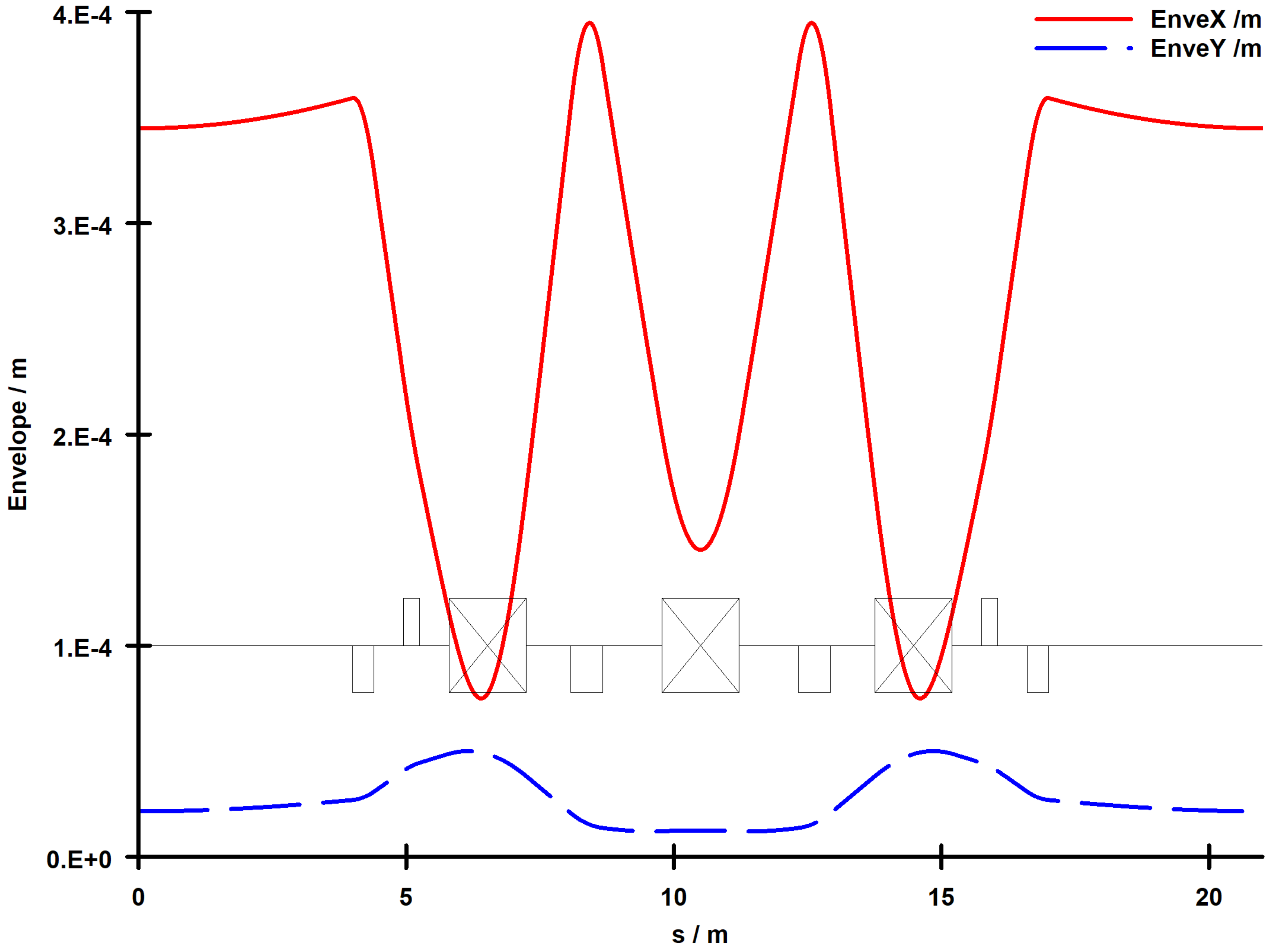
Magnet Elements within the Unit Cell of LLS (1997)



Ben = Bending magnet, QF = Focussing quadrupole, QD = Defocussing quadrupole, SH = Focussing sextupole, SV = Defocussing sextupole

Beam cross section at LLS (1997): TBA-Lattice



Parameters:

E =2.5 GeV

ε_x= 8.6 nmrad

β_x= 13.7

β_y= 5.33

σ_x= 344 µm

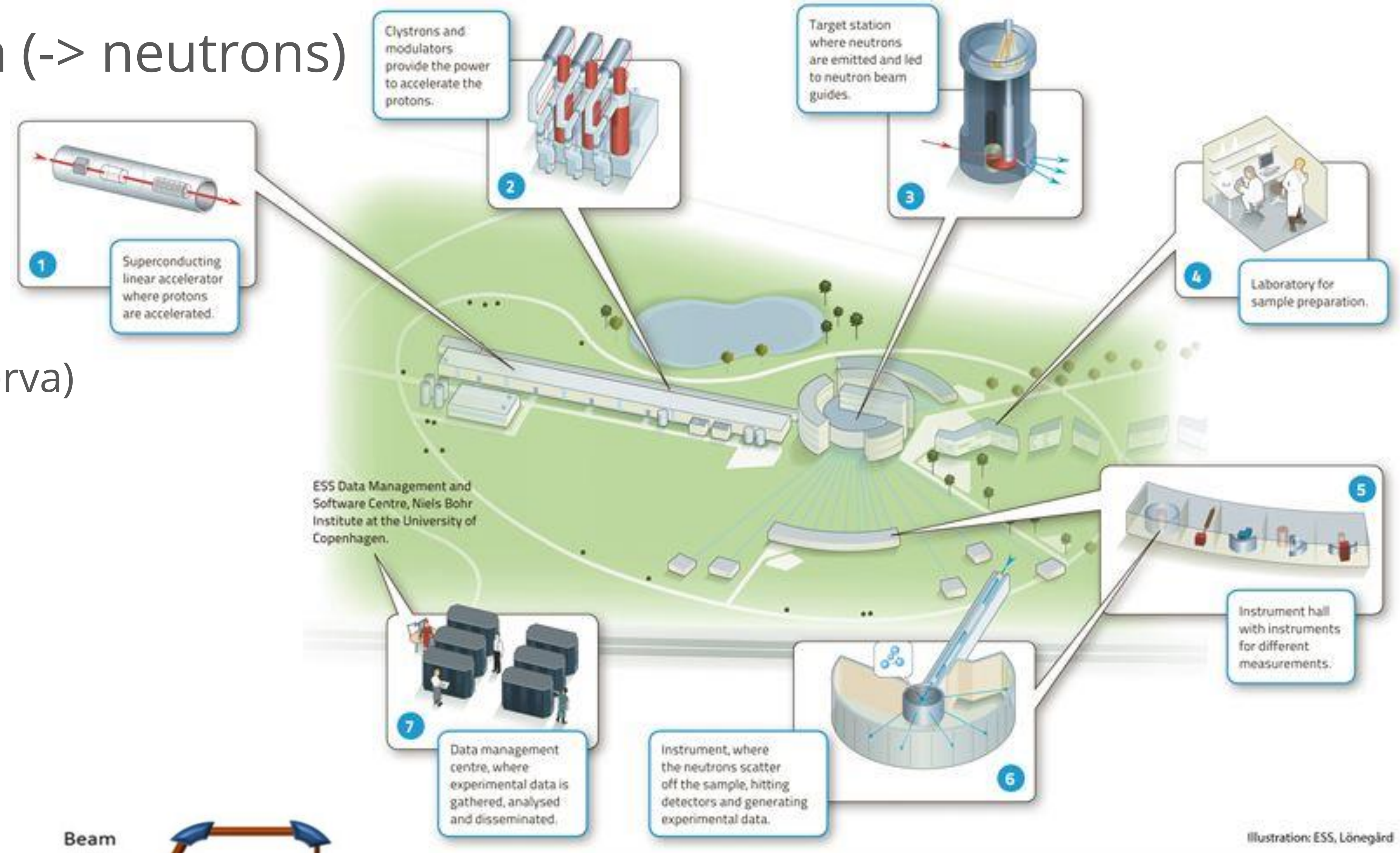
σ_y= 21.5 µm

$\delta E/E = 8.8 \cdot 10^{-4}$

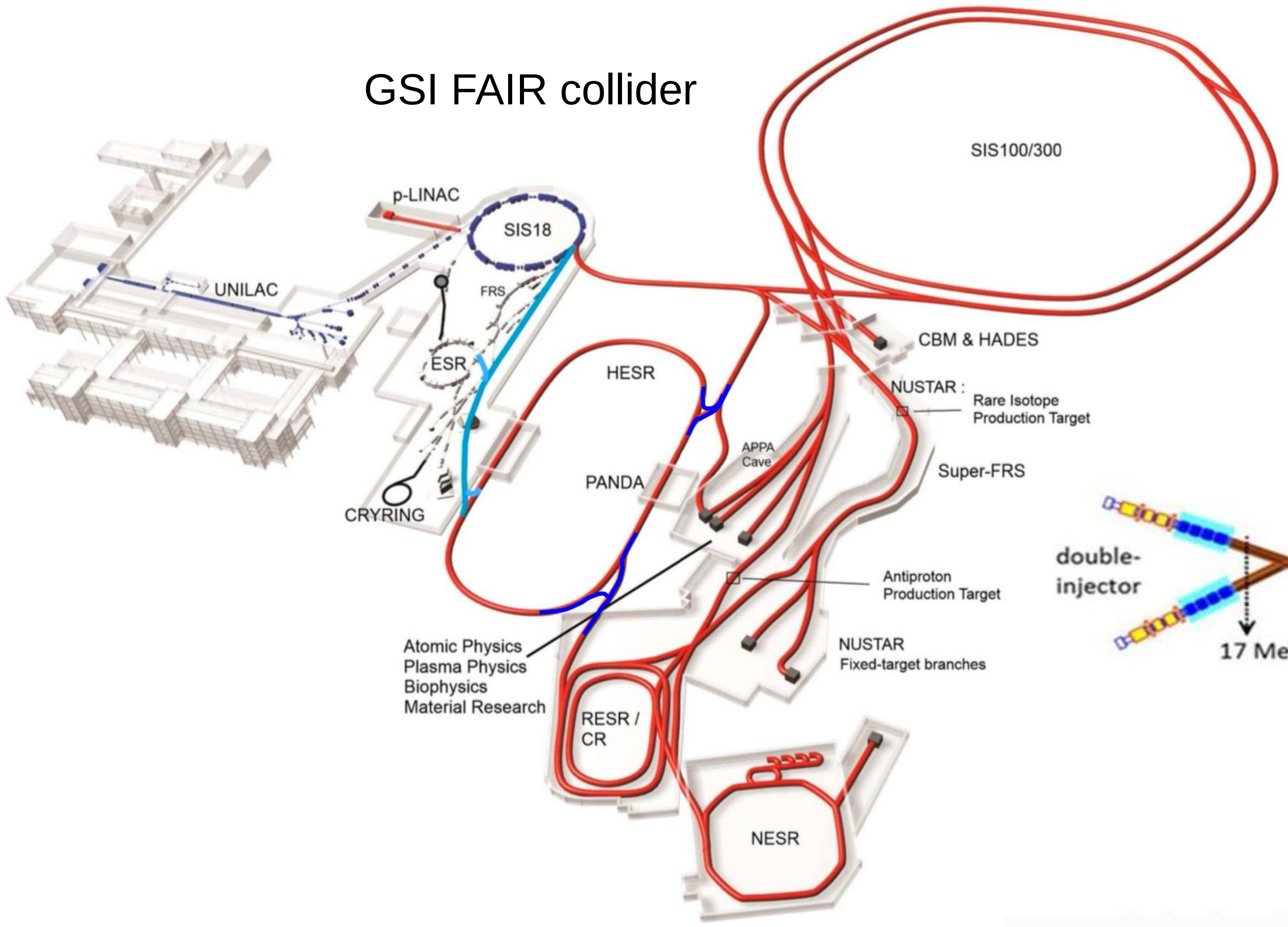
Accelerator types – heavy particle accelerators

- Heavy particle accelerators: proton or ion beam (-> neutrons)
  - Colliders (e.g. circular LHC, FAIR, linear ILC)
    - two opposing particle beams -> particles collide
  - Neutron sources
    - Neutron imaging (e.g. linear ESS)
    - Accelerator driven systems – ADS (linear, e.g. Myrrha/Minerva)

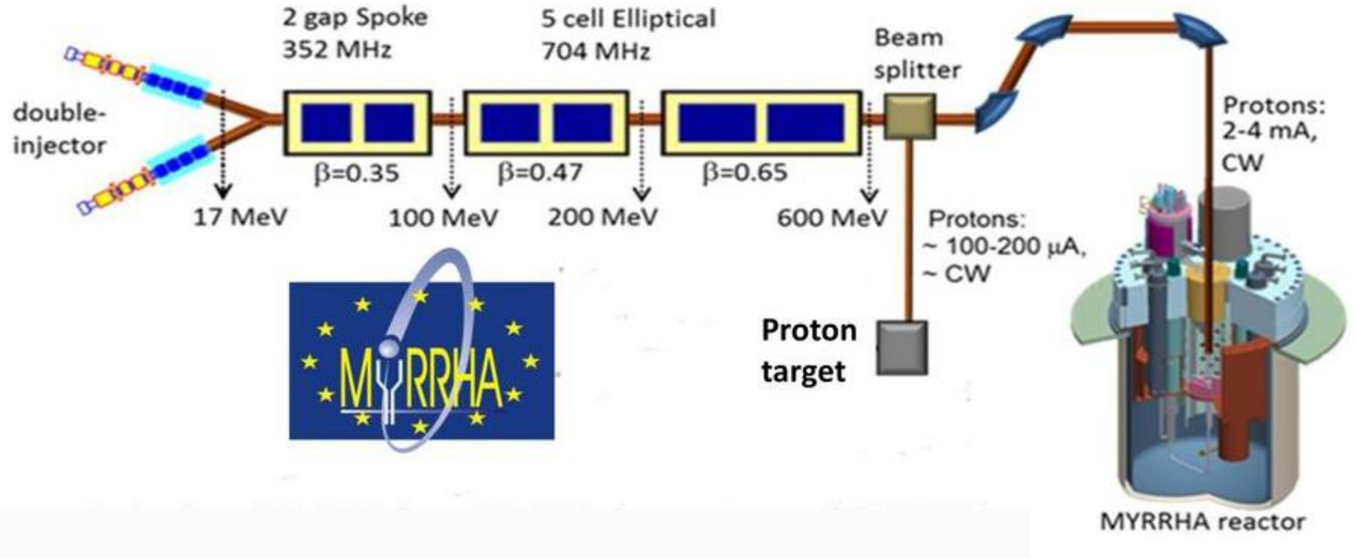
European Spallation Source



GSI FAIR collider



Myrrha ADS



Accelerator types – heavy particle accelerators, cont.

- Proton cancer treatment
  - Cyclotrons (e.g. Varian)
  - Synchrotrons (circular, e.g. ProTom, MedAustron)

Varian cyclotron

ProTom synchrotron

MedAustron synchrotron

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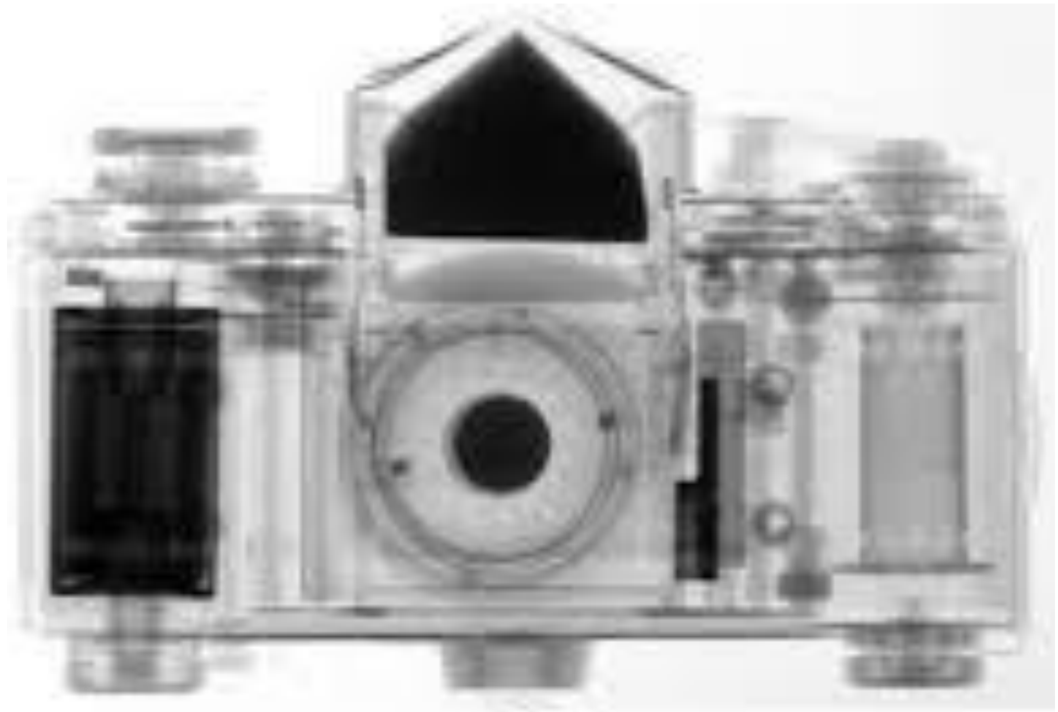
Why neutron sources? – neutron imaging

- Neutron imaging is a complementary imaging technology to X-rays

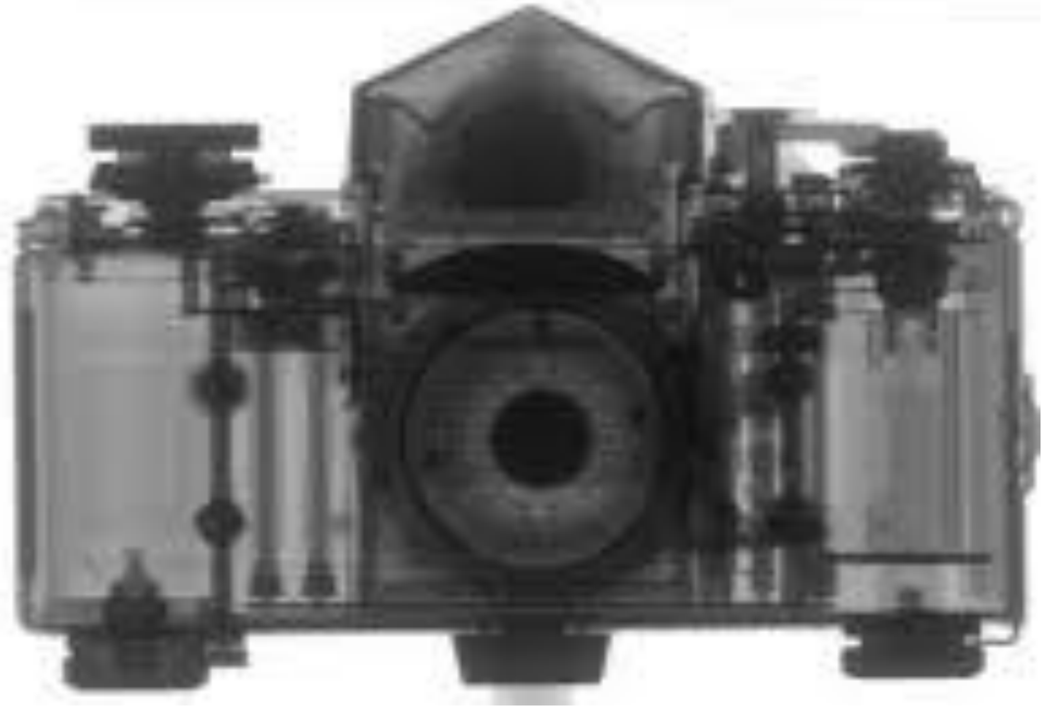
- Neutron imaging typically used for research of „soft“ materials (like soft organic tisue etc.)

- X-ray imaging for hard materials (like metal, bones etc.)

Neutron image

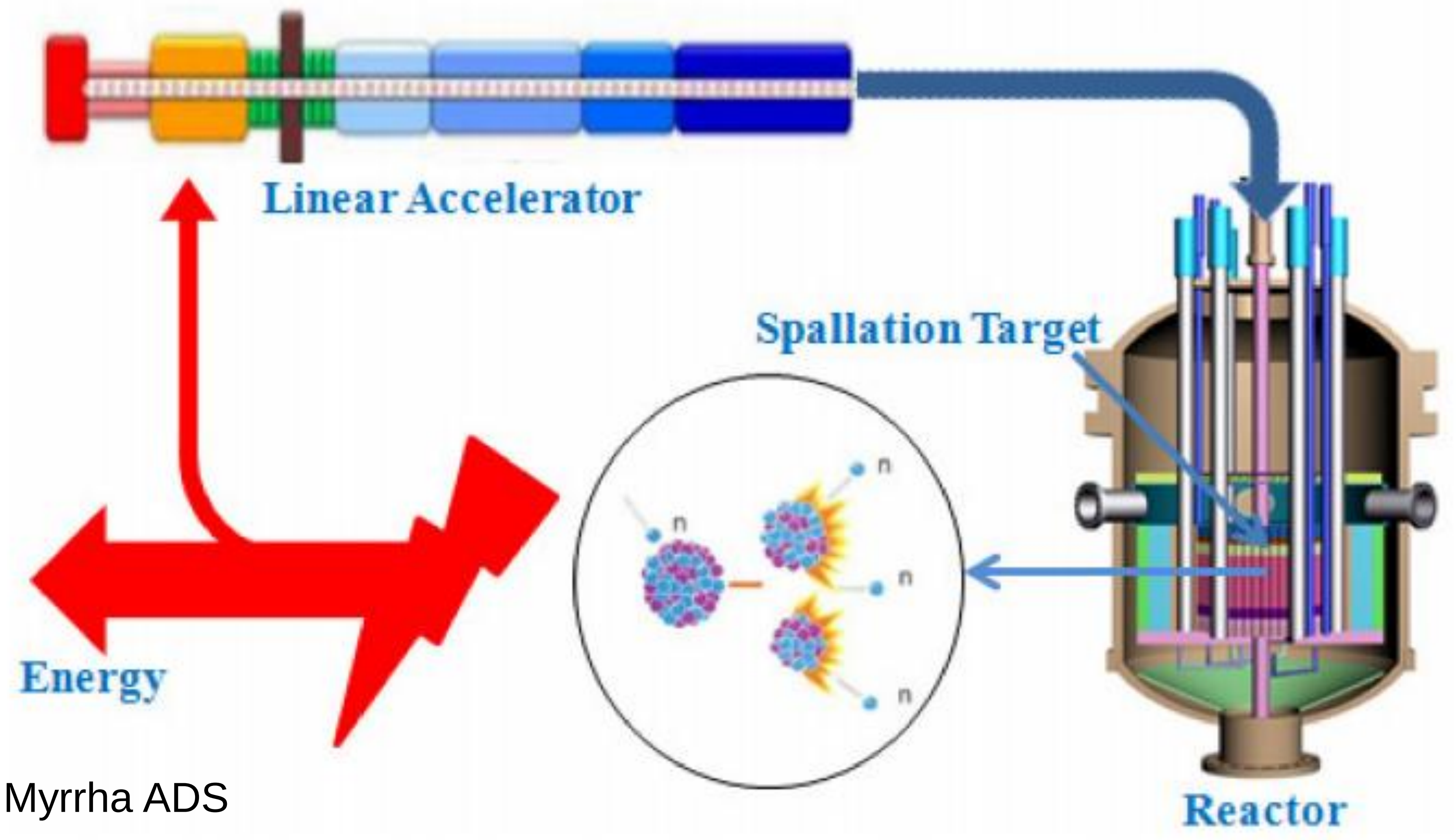


X-ray image



Why neutron sources? - ADS

- ADS: Accelerator Driven System
- Proton beam –> neutrons -> sub-critical nuclear reactor
- Benefits
  - Reaction is sub-critical, meaning if accelerator is stopper, neutron flux stops and reaction dies
    - Much lower risk than classical fission reactors, where it's very hard to stop the chain reaction
  - Can use depleted nuclear fuel from fission reactors for further energy production
- **Combination of energy production and nuclear waste management**



Myrrha ADS

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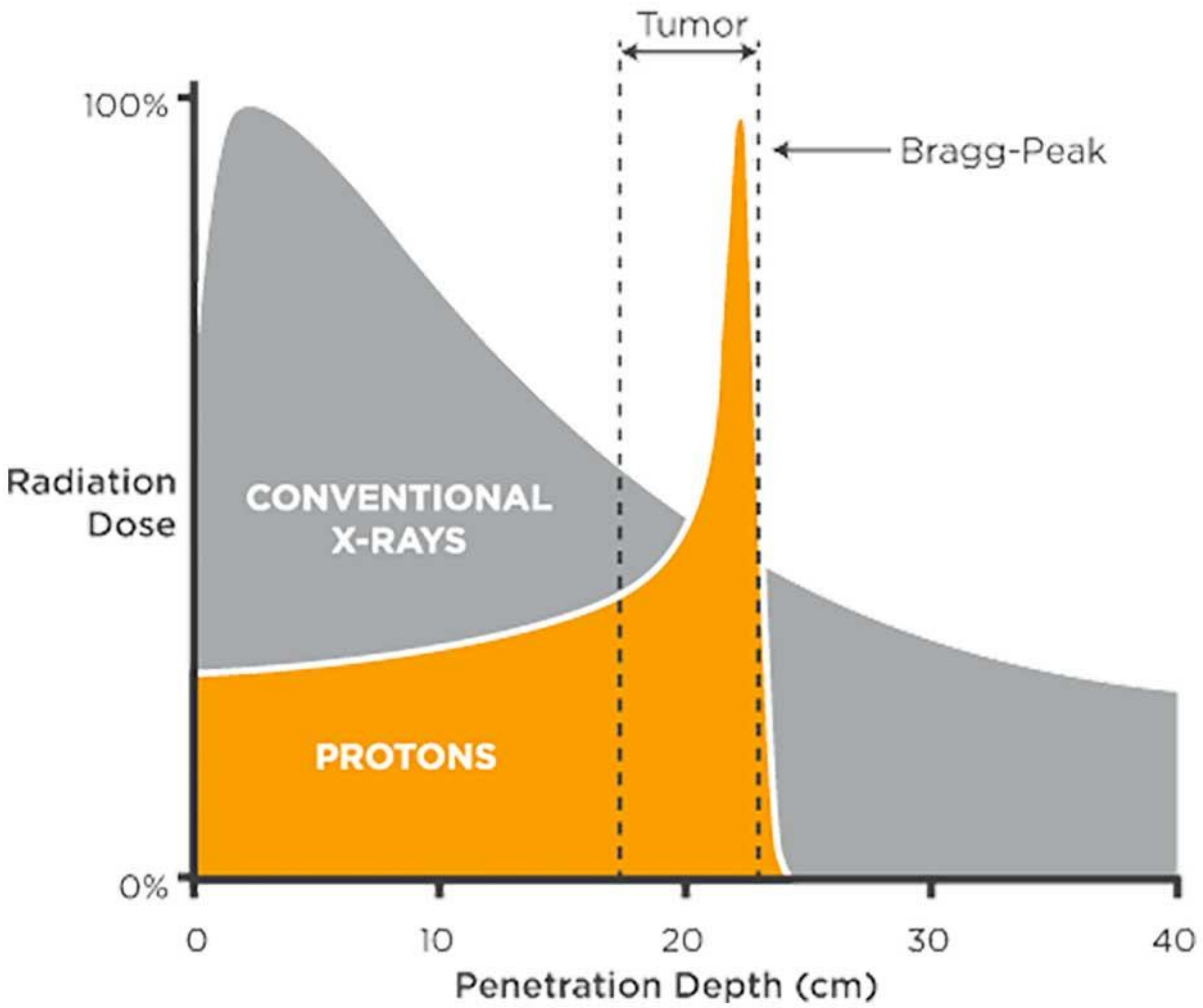
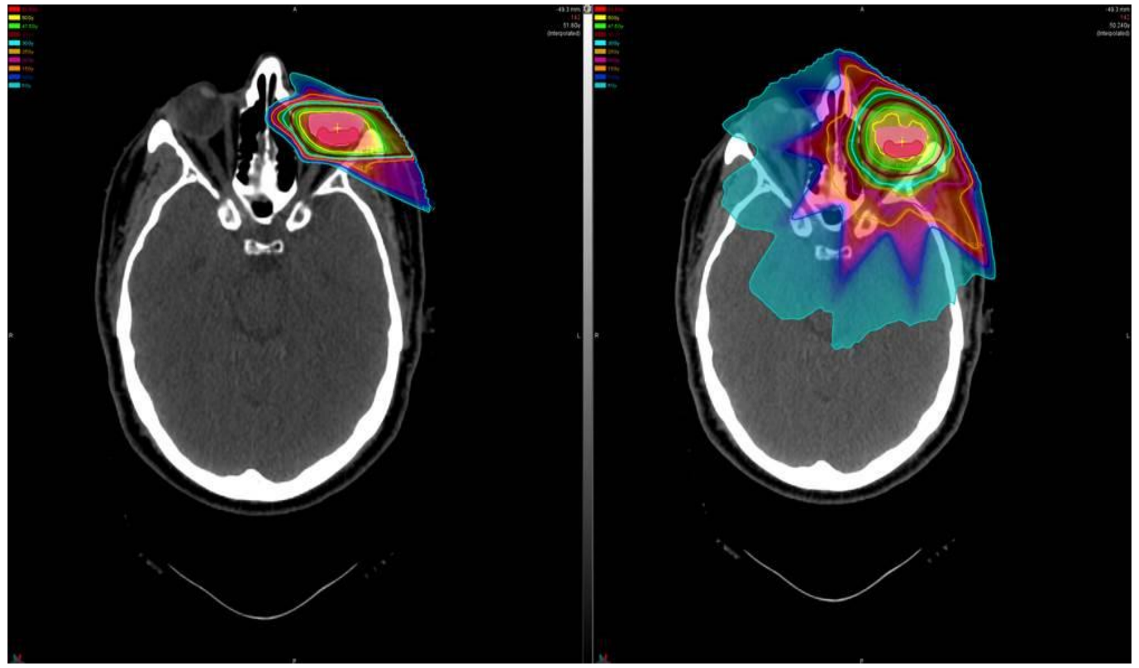
Why proton therapy? (vs radiotherapy)

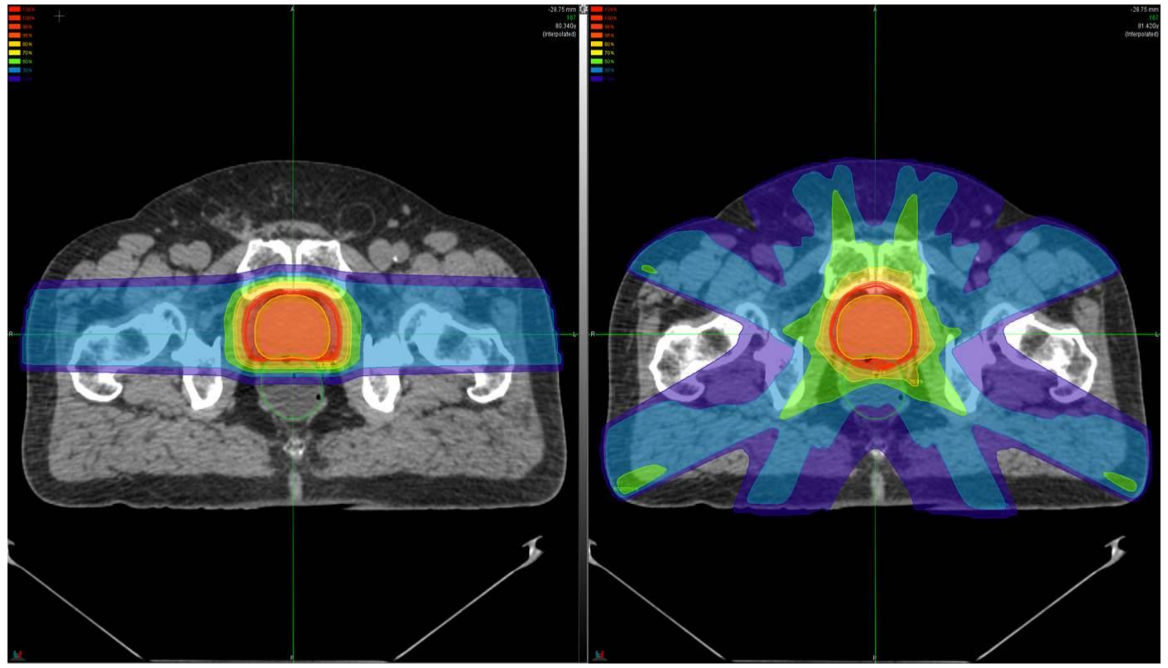


Ocular melanoma



PT (protons) RT (photons)

Prostate cancer



PT (protons) RT (photons)

- Protom introduction video: https://www.youtube.com/watch?v=gZK57SK24fU

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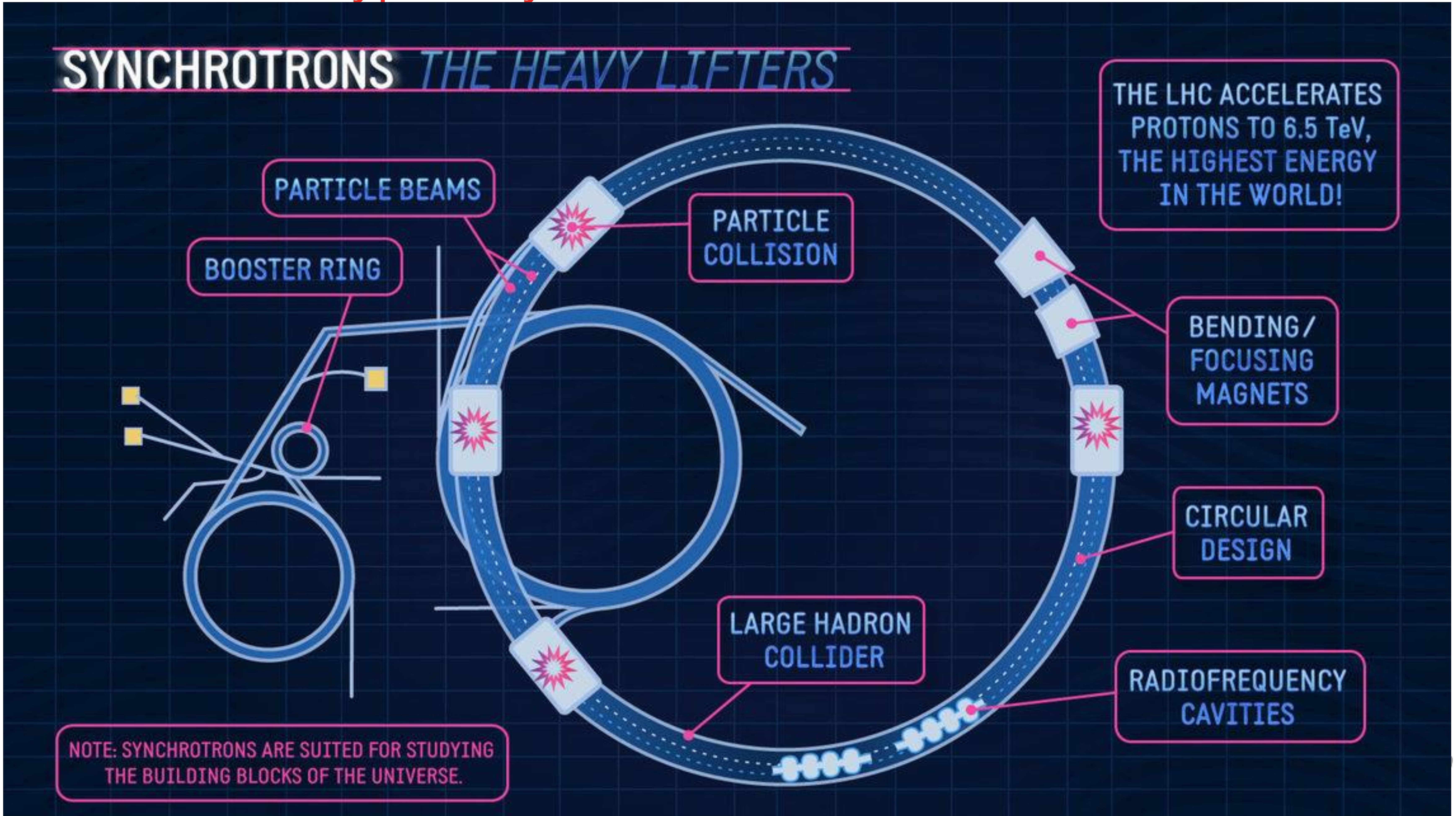
Circular vs. linear accelerators – challenges

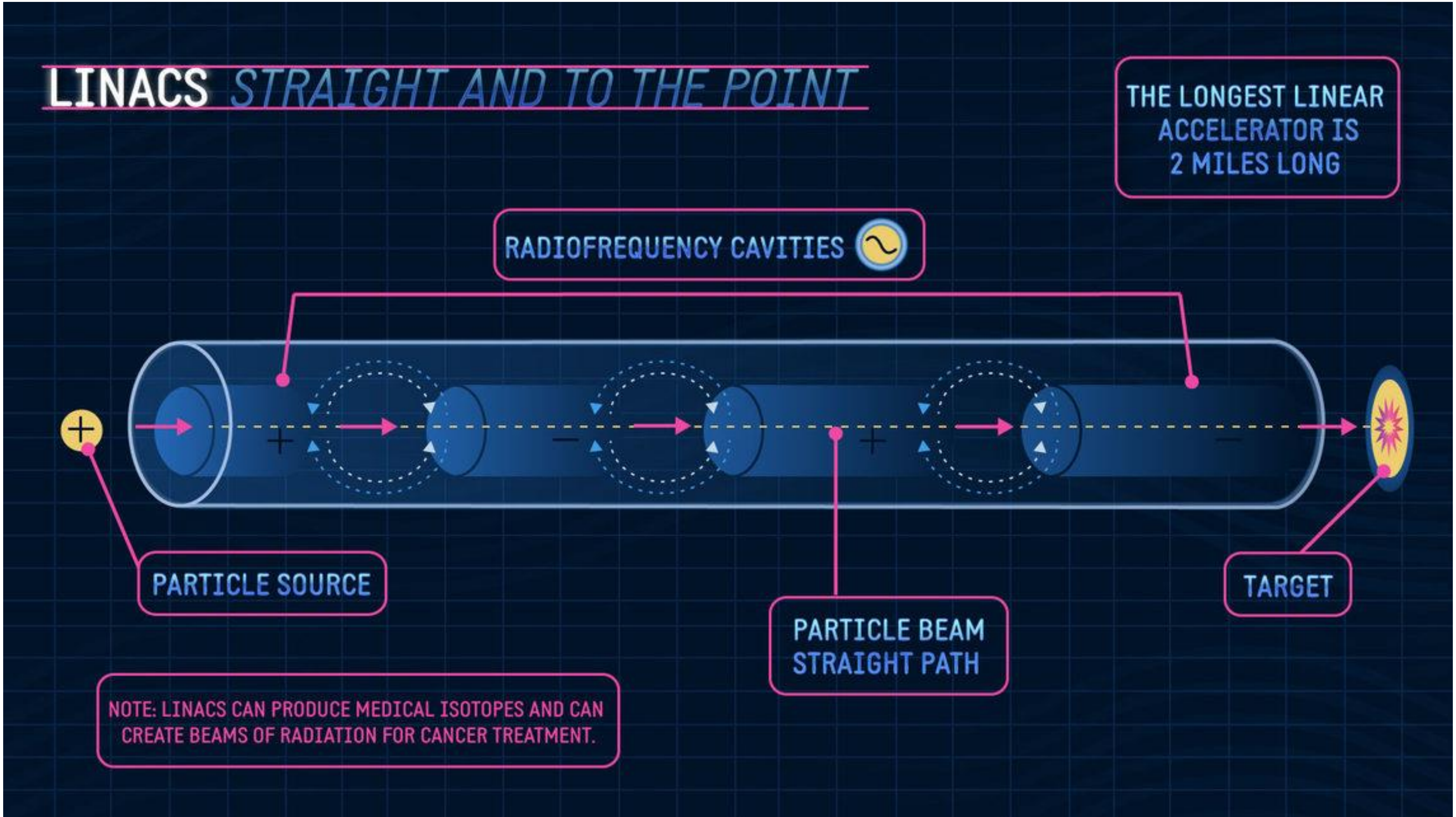
- Cicular
  - Each particle passes one accelerating element (RF cavity) multiple times
    - Only one RF cavity needed, energy gradient not critical
  - Particles travelling at almost the speed of light need to stay tightly in a circular orbit
    - ➢ Magnetic field of bending magnets (dipols) needs to synchronously ramp up with energy/velocity increase of the particles
      - This is where the name „synchrotron" comes from
      - **Time-synchronization of devices (RF and magnets) has to be very precise** (ps or even fs synchronization) -> timing system!
    - **For heavy particles at high-energies/speeds a very strong magnetic field is needed to keep the particles in a reasonably small orbit. For this reason, bending magnets often need to be super-conducting**
      - For super-conductivity, the temperature of the magnet coils need to be close to absoulute zero, typically below 2 Kelvins. This means a cryo system is needed to produce liquid helium to cool the coils. Coils are encapsulated in a so-called cryo module that isolates the coil from surrounding systems at „room temperature".
      - Even with super-conductive bending magnets, LHC circumference is 27 km, for example ☺

- Linear
  - Each particle passes one accelerating element (RF cavity) only once
    - Multiple cavities needed, high energy gradient is crucial (high gradient vs. length of linac)
    - **To reach high gradients super-conductive cavities are needed**
      - Cryo system needed again, this time fo cool down the entire RF cavity, which is encapsulated in a cryo-module.
  - Particles are traveling on a linear path, so only small corrections are needed by bending magnets (no extremely high magnetic fields required)

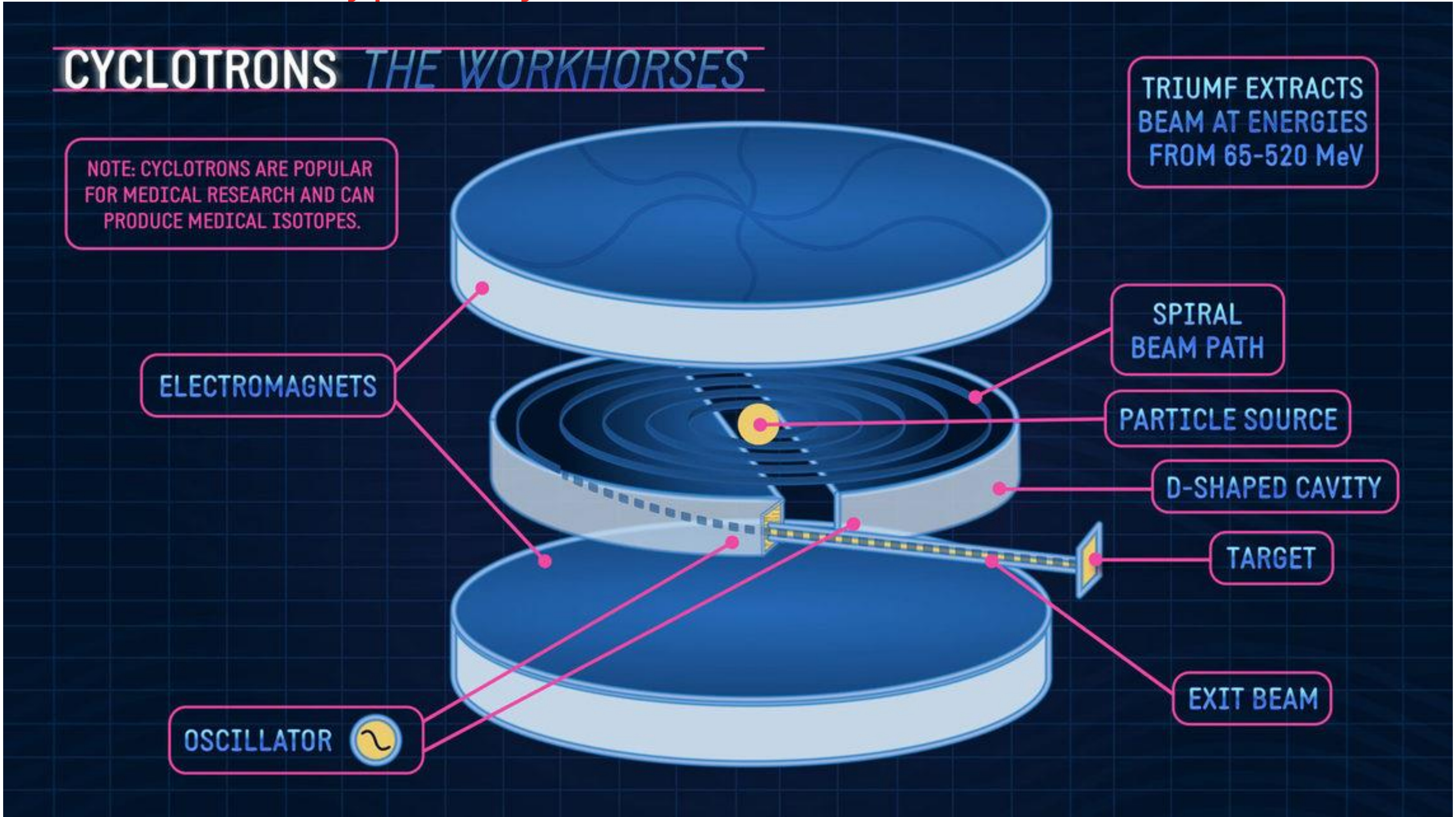
Accelerator types - synchrotron



Accelerator types - linac



Accelerator types - cyclotron



Accelerator devices/systems

- Particle source (electron gun, proton/ion source)
- Vacuum – removing particle obstacles
  - Vacuum pipe, a lot of vacuum pumps.
- Magnets – steering and focusing of particle beam
  - Dipoles: bending
  - Quadrupols, sextupols: focusing (magnetic lense)
    - Focuses in one dimension, defocuses in the other, that is why quadrupoles always come in pairs rotated by 90 degrees.

Dipole

Quadrupole

Ion source

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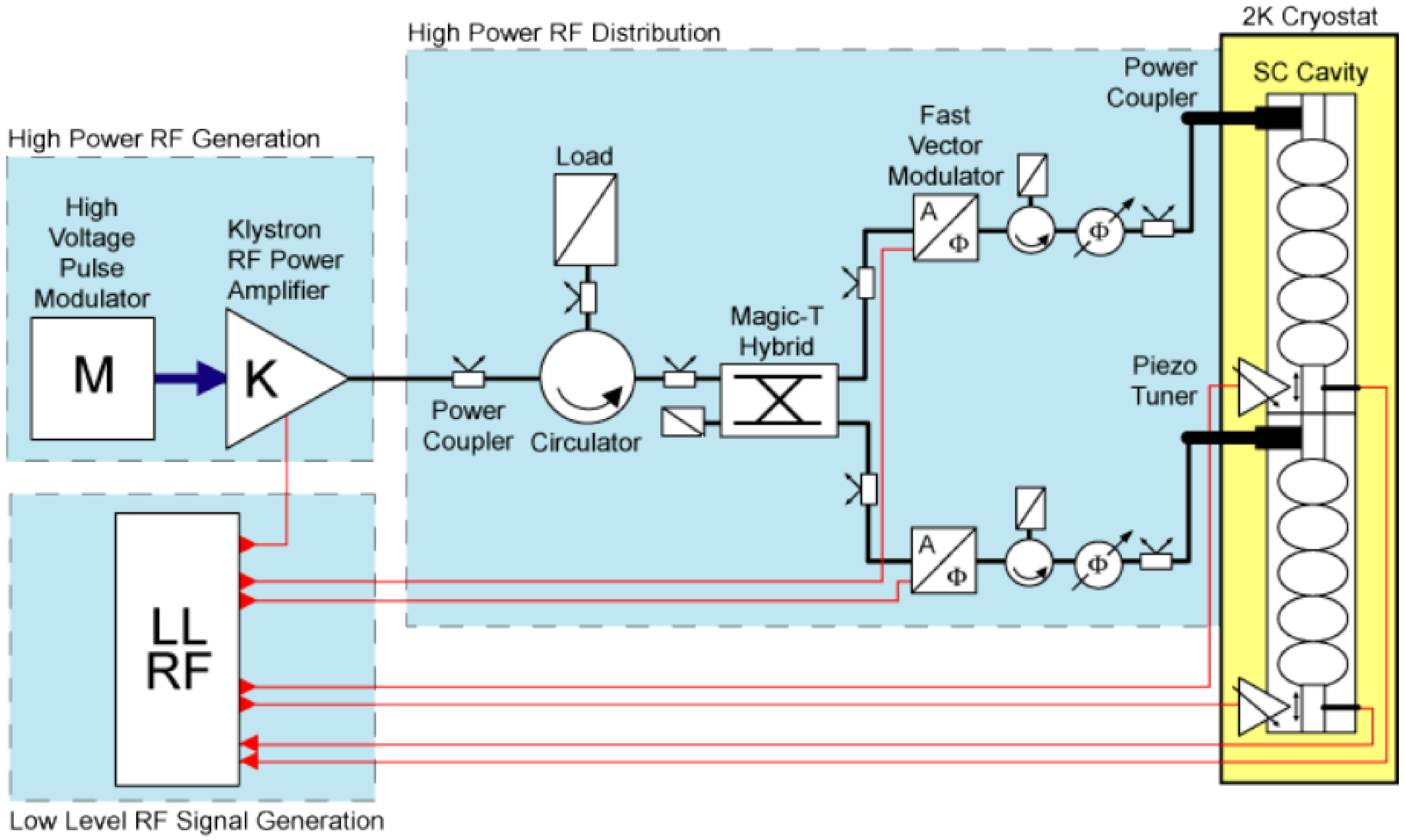
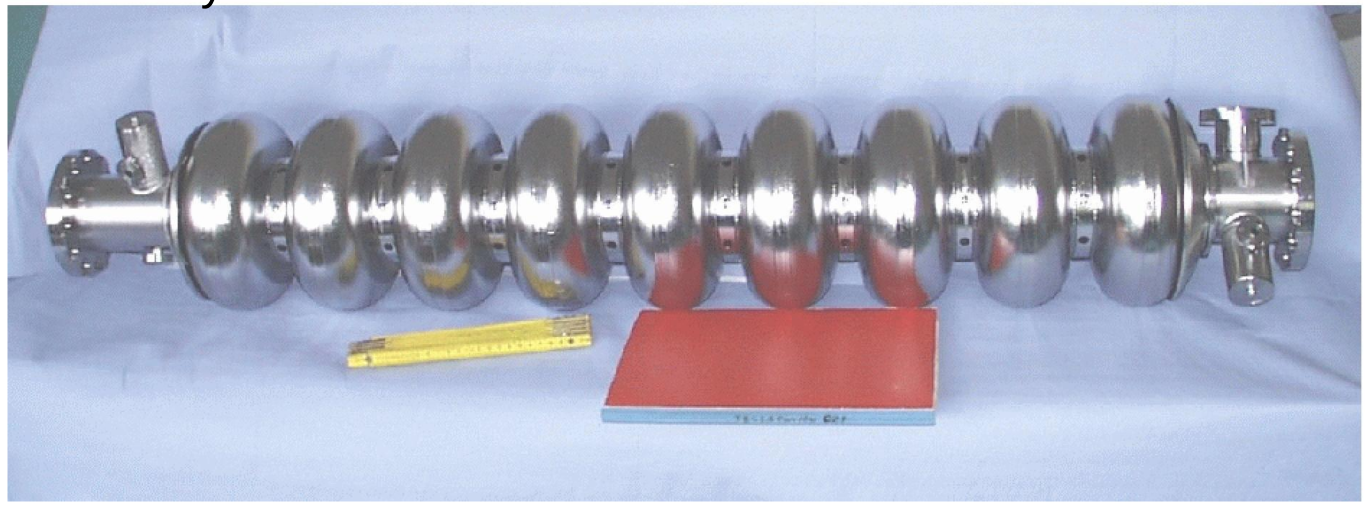
Accelerator devices/systems, cont.

- RF – acceleration of particles
  - RF cavities (accelerating particles)
  - LLRF (regulation of EM field in cavities)
  - Klystrons (EM field amplifiers)
    - In recent years solid-state amplifiers are becoming more and more popular as a modern alternative to klystrons



RF cavity

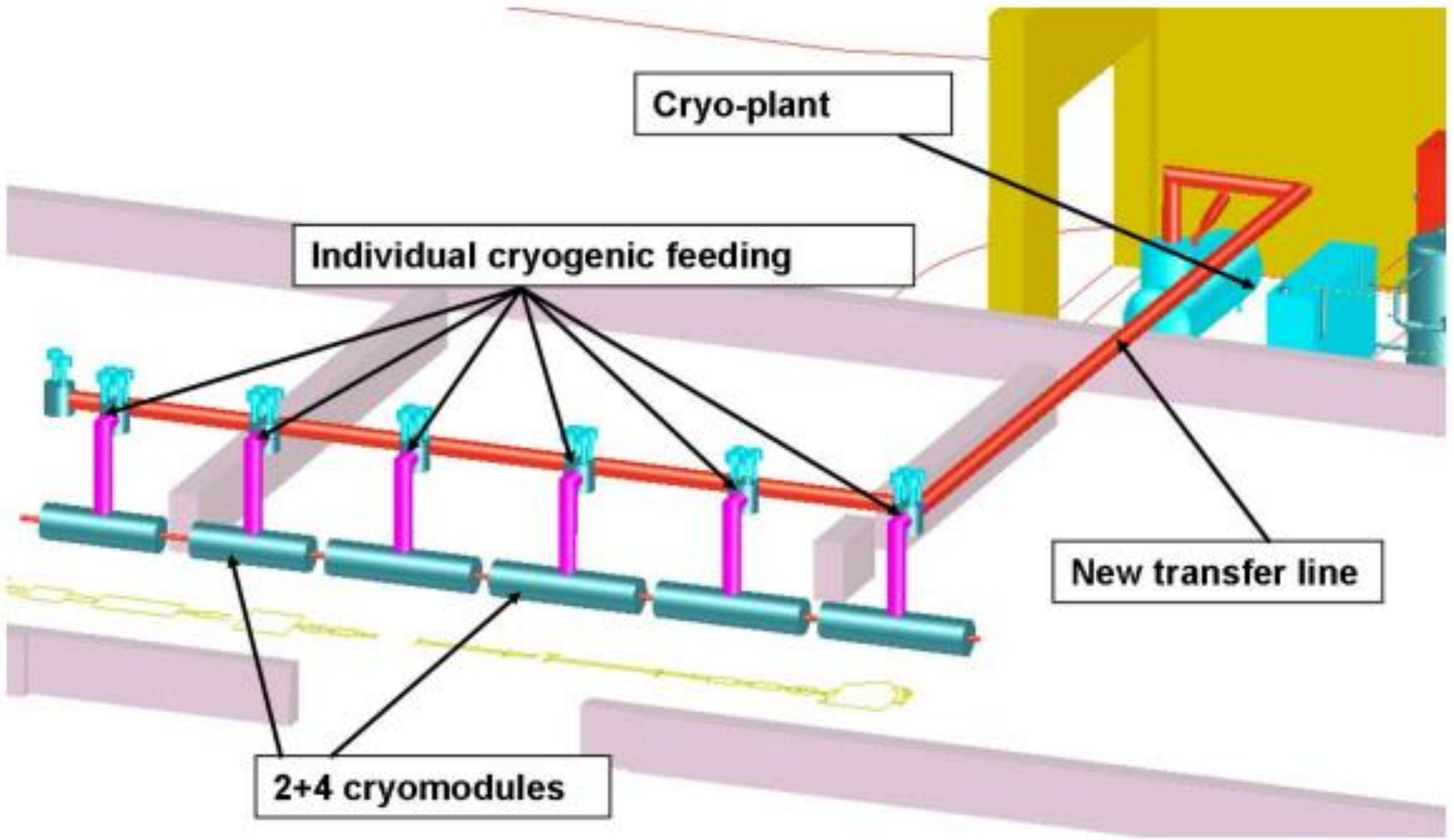


Klystron

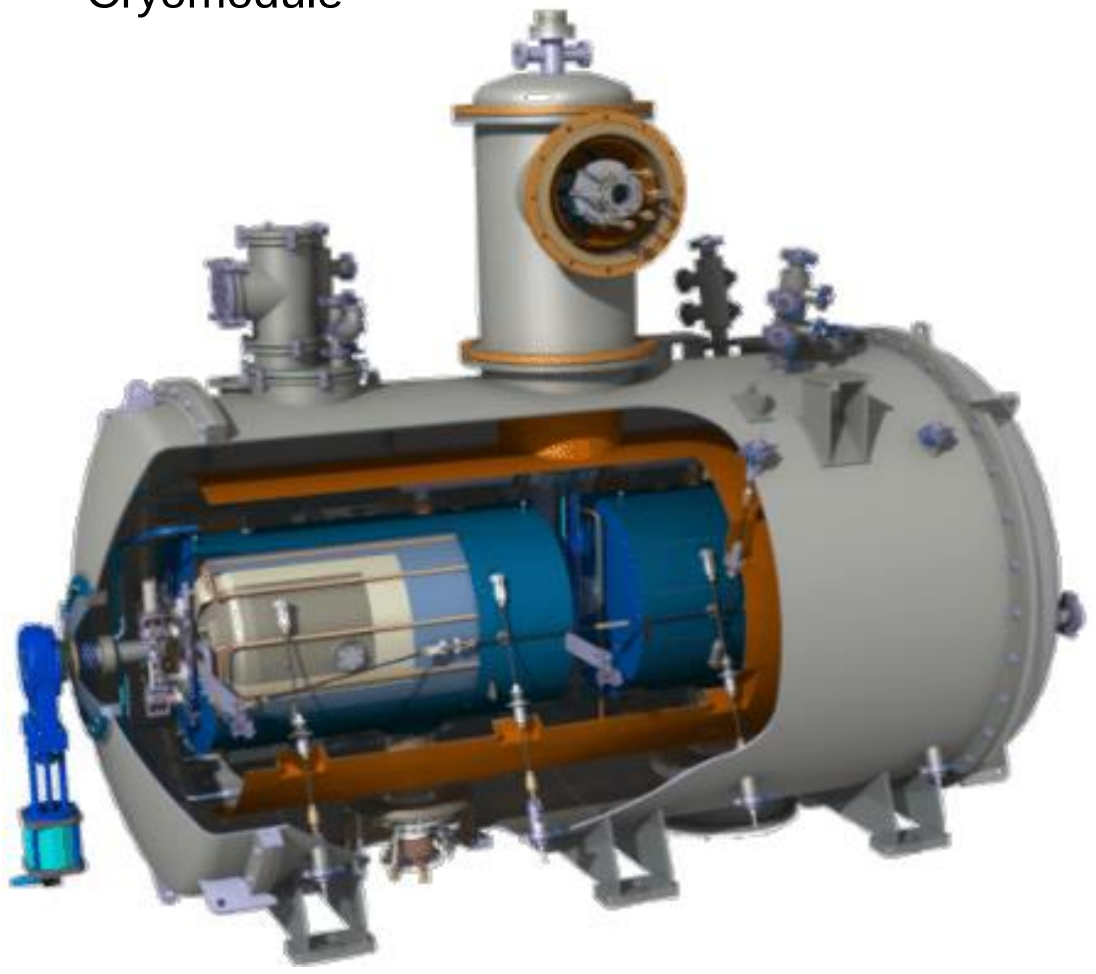
Modulator   Klystron

Accelerator devices/systems, cont.

- Cryo(genics) – cooling down cavities or bending magnets for superconductivity
  - Cryoplant: basically a huge refrigerator for helium ☺
  - Helium transfer lines
  - Cryomodules: encapsulate RF cavities in a cold environment



Cryomodule



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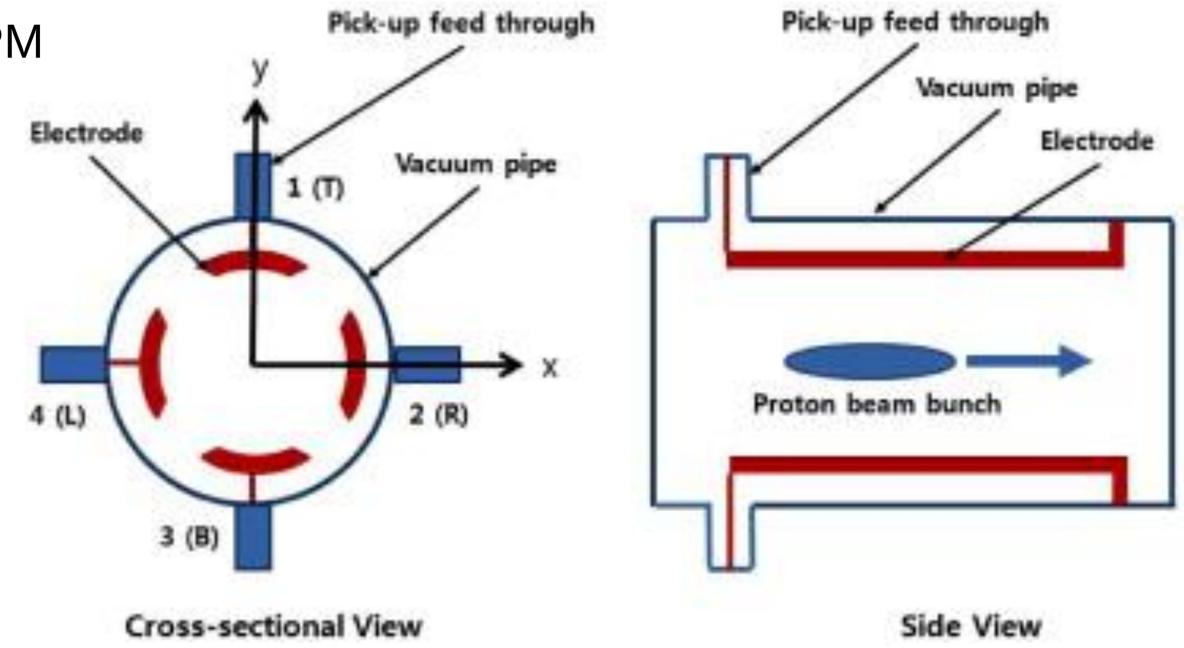
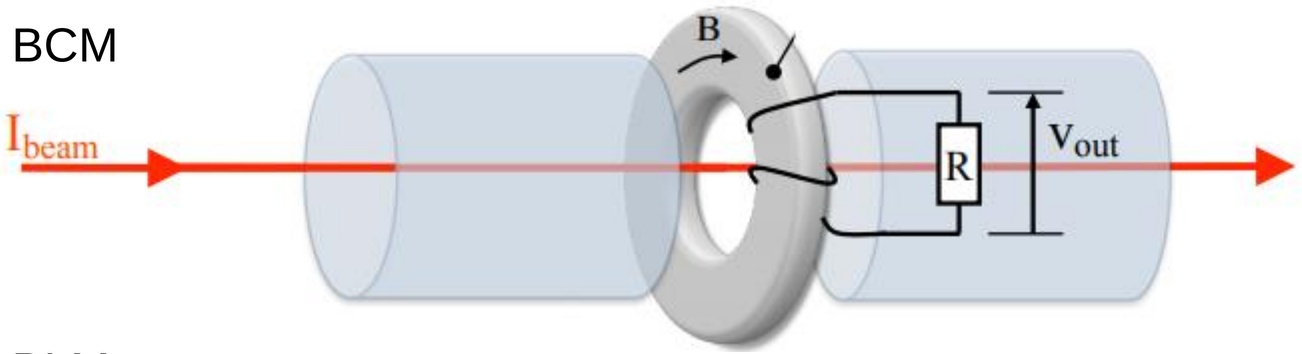
Accelerator devices/systems, cont.

- Diagnostics – look at the particle beam
  - Beam position monitor (BPM), beam loss monitor (BLM), beam current monitor (BCM), wire-scanner, …
  - … a lot of specialized sensors with more or less complicated read-out (from „slow“ scalar values to „fast“ giga-samples-per-second waveforms)

BPM

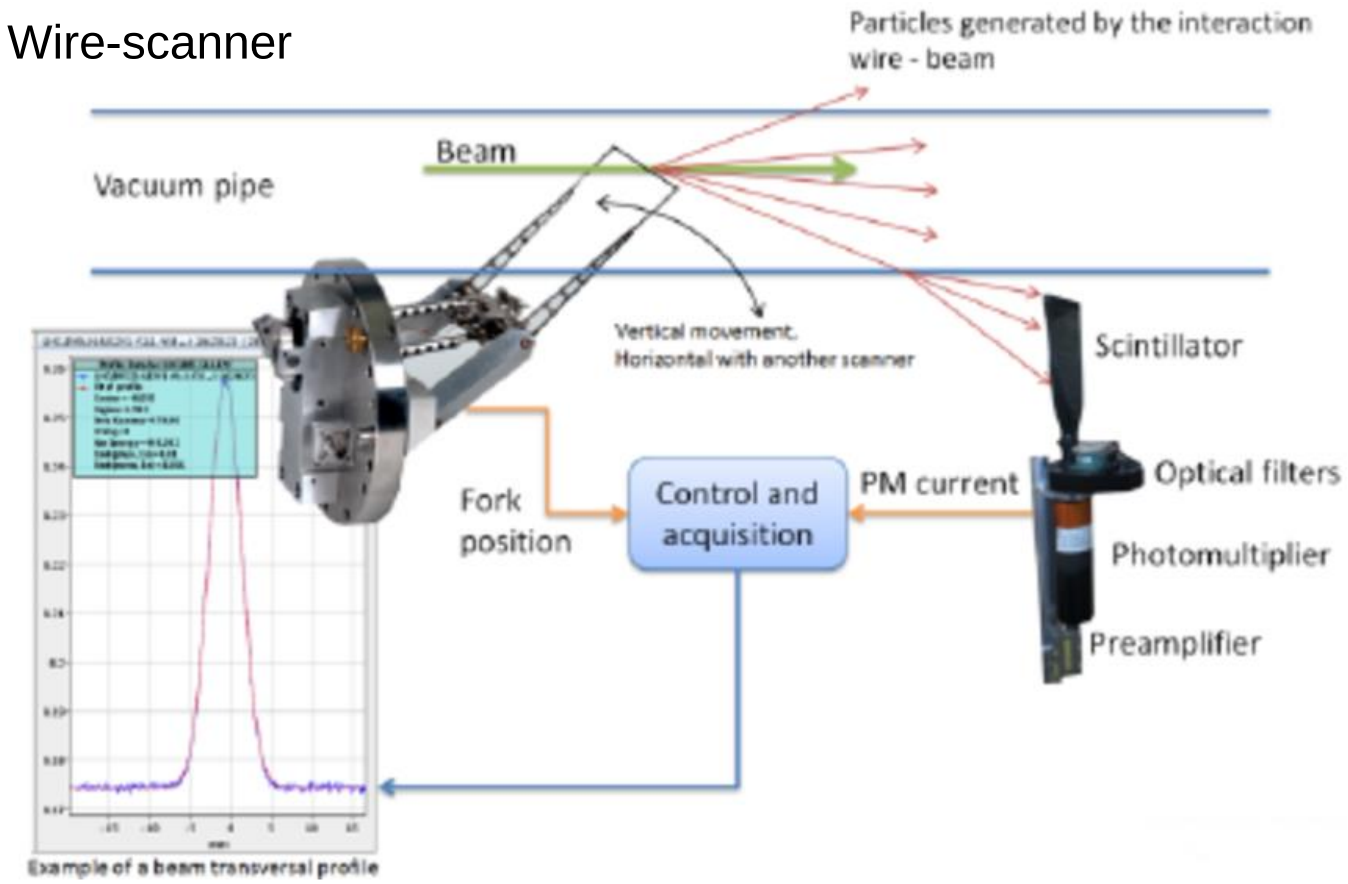


BCM



BLM

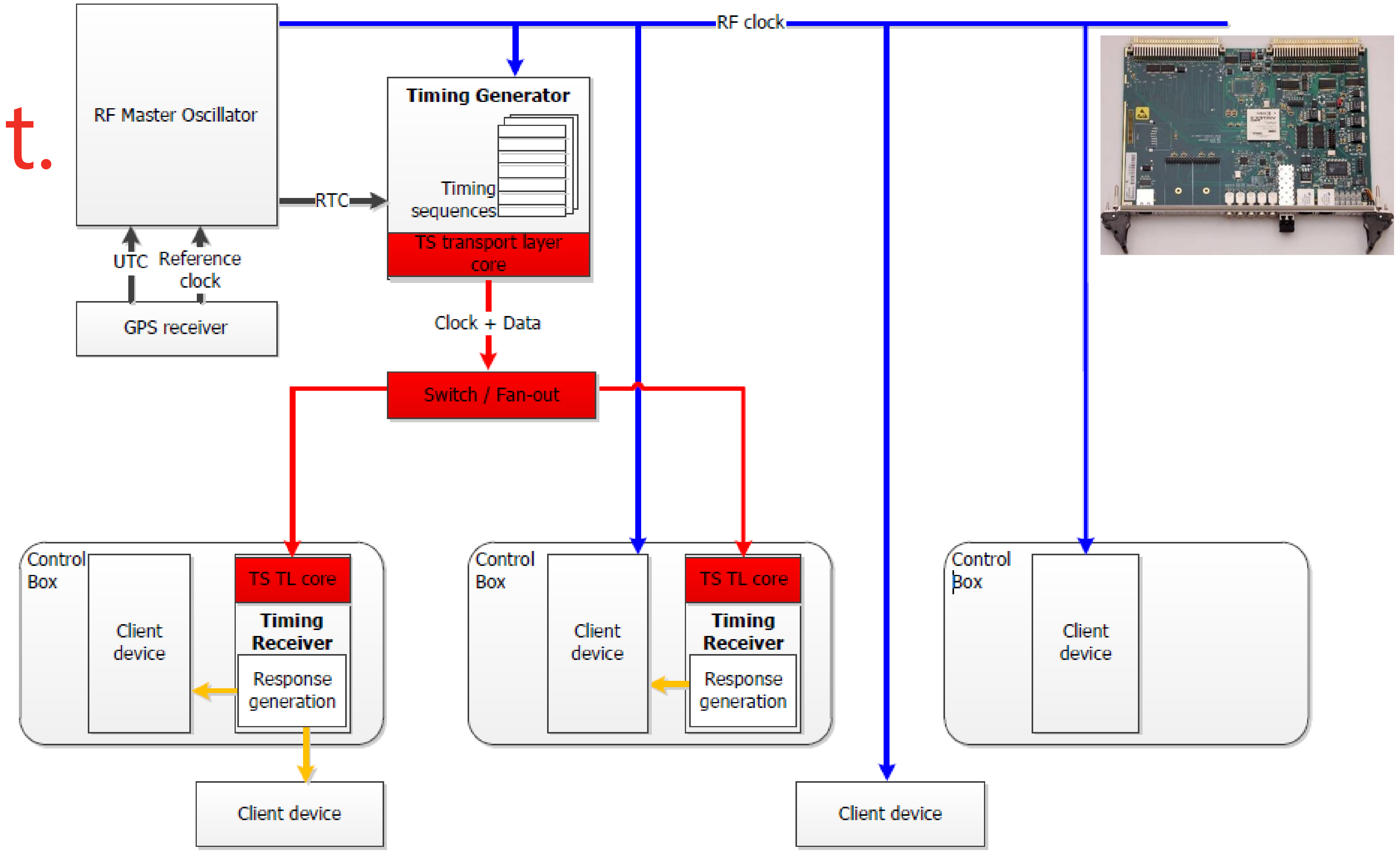
Wire-scanner



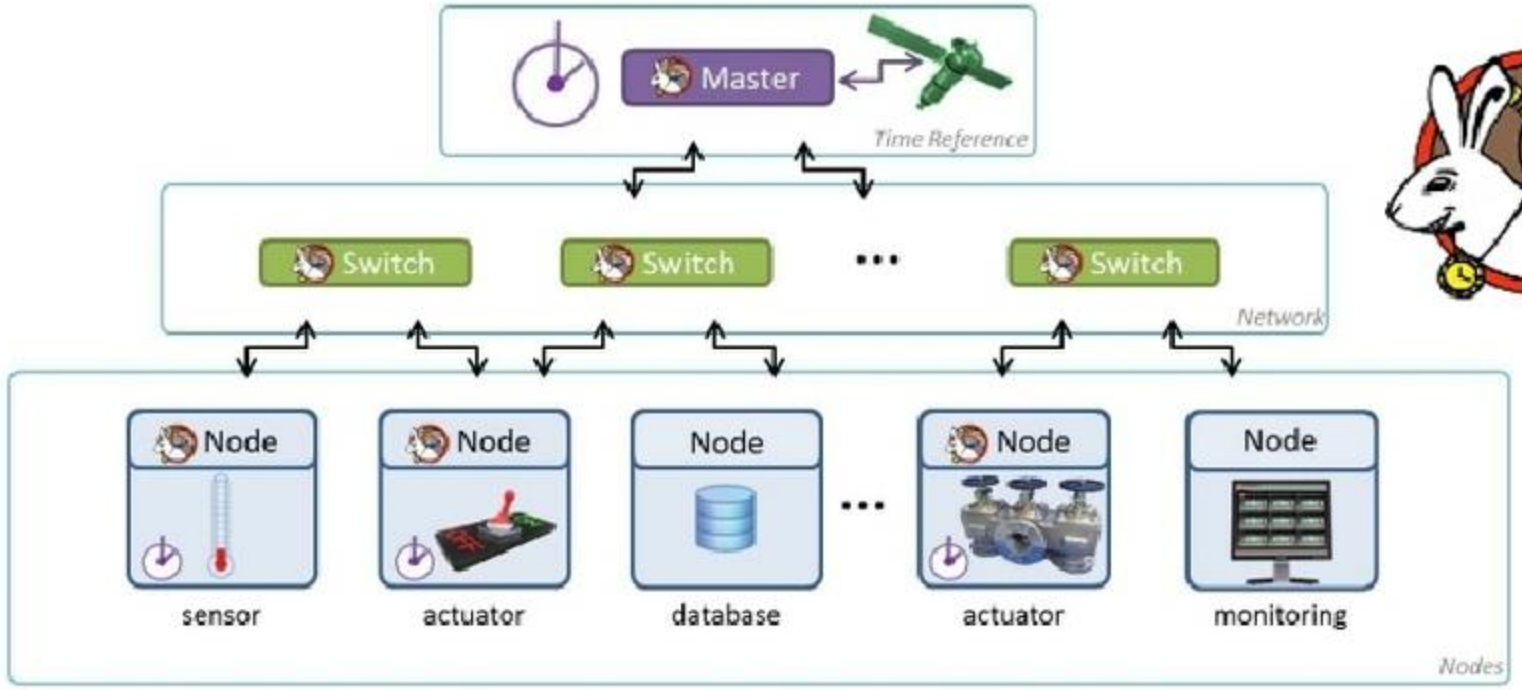
Accelerator devices/systems, cont.

- Timing and synchronization
  - RF reference - all RF devices have a stable reference to which they regulate their output
    - Input to LLRF, ensuring femto-second phase stability of EM field in cavities
  - Event timing system - precise synchronization of devices with hardware triggers
    - Pico-second synchronization for light particles (electrons), nano-second synchronization for heavy particles (protons, ions)
    - Solutions: Micro-research Finland, White Rabbit, homebrew
    - Challenge: cable length delay compensation

MRF-based ESS timing system



White Rabbit timing system



Event timing systems work like player pianos – playing out predefined sequences with extreme time accuracy

Accelerator devices/systems, cont.

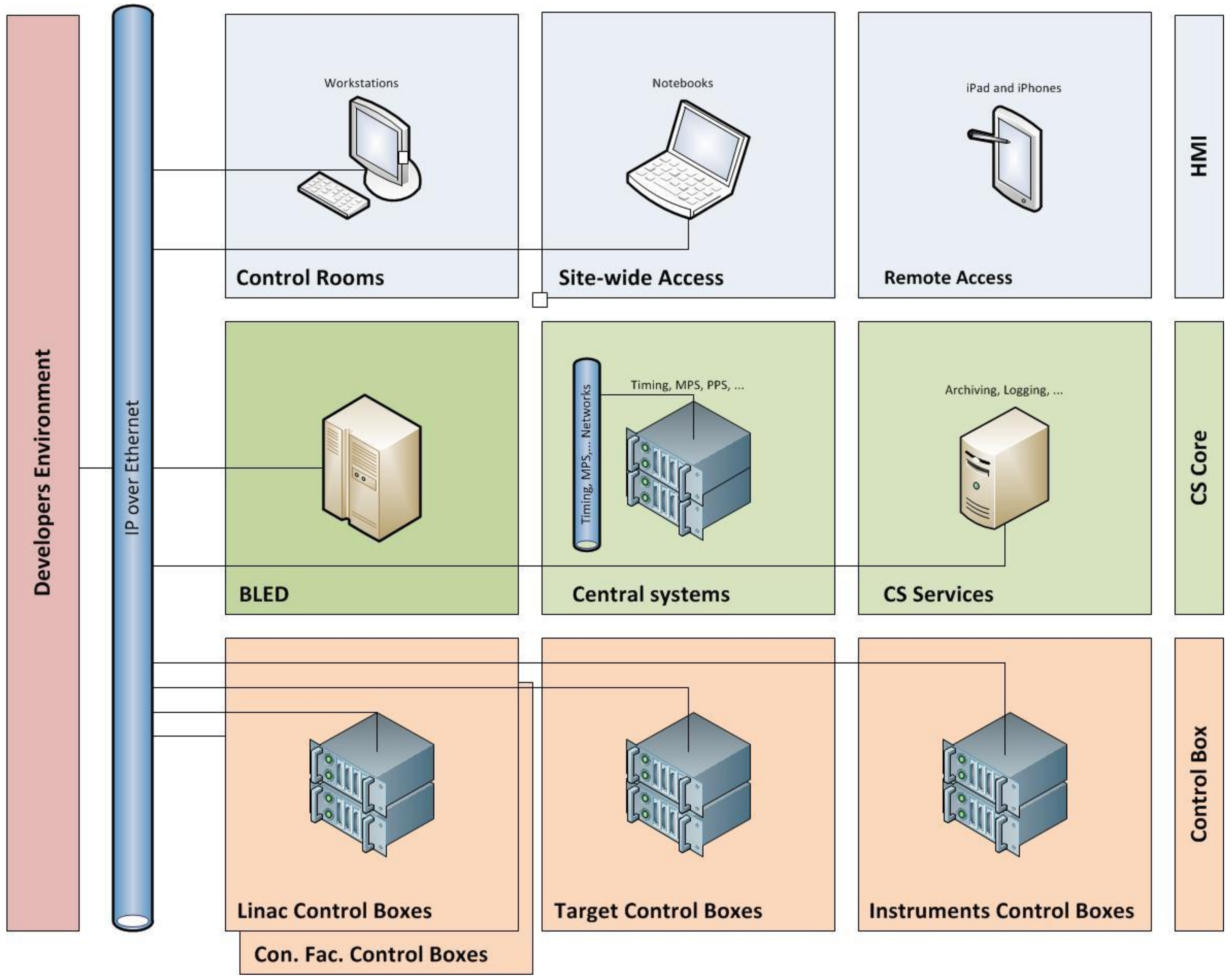
- Machine protection system (MPS)
  - Protection of accelerator devices (big cost if hardware destroyed by beam)
  - High-energy heavy-particle accelerators can do a lot of damage if operated incorrectly. That is why fast MPS solution is very important. Typical required response times is couple of microseconds.
    - Challenge: cable length (1km of cable = 5us delay!)
- Personnel safety system (PSS or. PPS)
  - Safety of human personnel (prevention of injury/death)

- Also experimental stations (sensors, motion control), target control (in case of neutron sources), undulators (in case of lightsources) …

Cosylab's role: control systems

- Control System tiers:
  - Device/sub-system control
    - IOCs with local device logic, controlling accelerator devices
  - Central CS systems
    - Timing and synchronization
    - Machine protection
  - Central CS services
    - Archiving
    - Logging
    - Alarms
    - Authentication and authorisation
    - Remote access
    - Configuration management
    - Scripting environment / commissioning support
  - Presentation
    - Central UIs
    - Expert device UIs
  - Development environment
    - Common frameworks, e.g. EPICS, Tango, …
    - Continuous integration
    - Deployment

ESS control system tiers

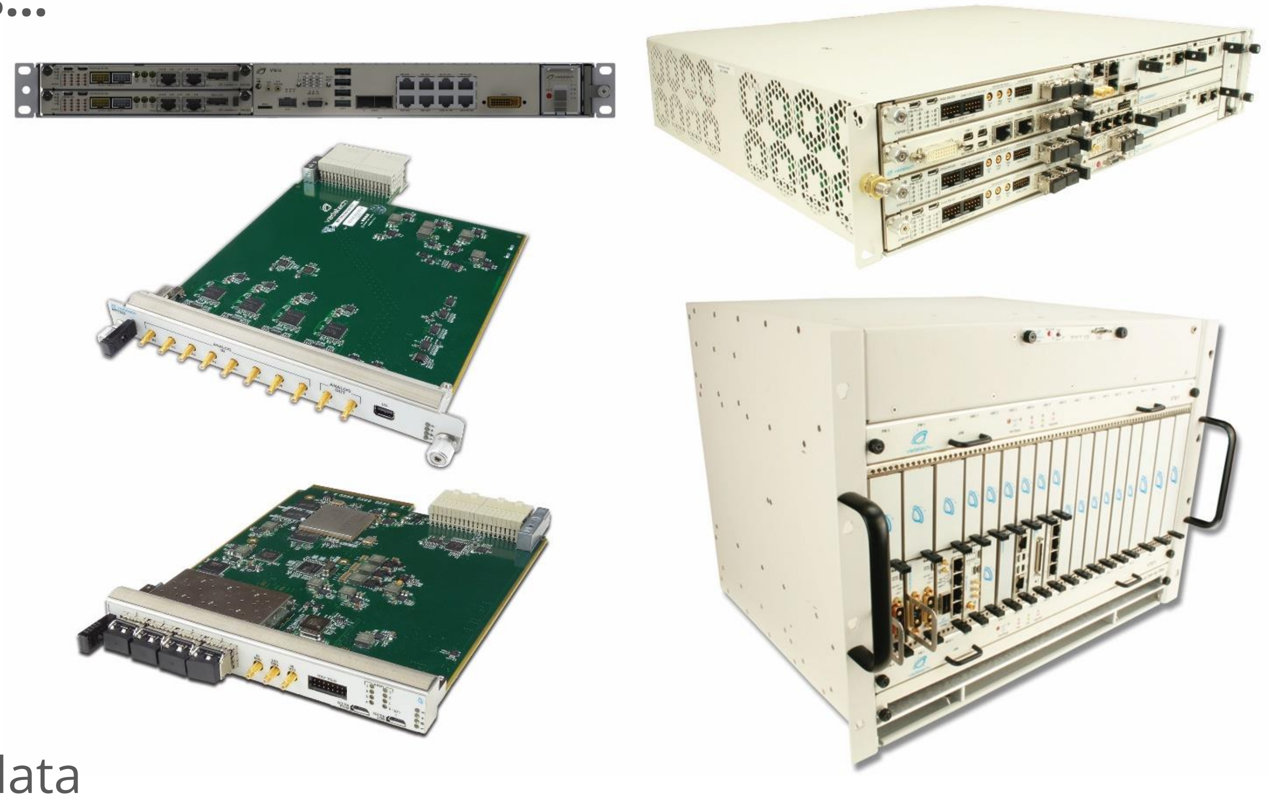


Device/sub-system control

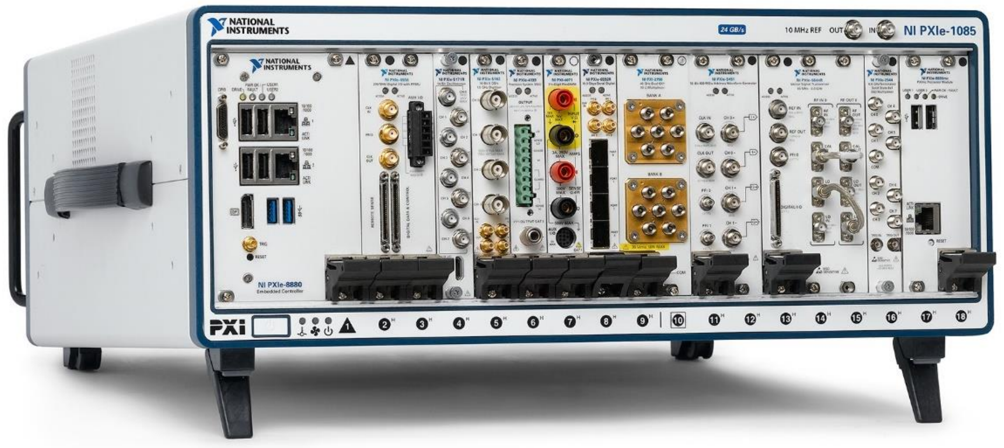
- **Slow systems** typically controlled with **PLCs**
  - PLC = Programmable Logic Controller, „robust/safe“ computer
  - Because of redundancy and other measures to increase safety and robustness, PLCs are only useful for slow devices with simple interfaces
  - Local response times in millisecond range
  - Example systems: **Vacuum, personnel safety, cryo, klystron/modulators, undulators…**
- **Fast systems** typically controlled **with industrial-grade controllers with expendable IO options**
  - Computer with IO cards connected over standardized backplane (from slow IOs to fast digitizers)
    - Often called IOCs (Input/Output Controllers) or Device Controllers
  - Different „form-factors“: VME, PXI/PXIe, microTCA, …
  - Typically used together with one of the CS frameworks like EPICS, Tango, …
    - These frameworks handle things:
      - Able to implement local CS functionalities with pre-developed generic building blocks.
        - Option to do complex control with hand-written code directly and optimize for performance and/or complex functionality
      - All devices have a common interface to upper tiers, i.e. all devices present themself on the internal network in a standardised way so that all computers know how to interact with each-other.
  - Local response times below 1 millisecond, digitizers with mega- or giga-bits-per-second data
  - Examples: **beam diagnostics, magnet power supplies, RF …**
- **Deterministic and/or fast safety applications** require **specialized solutions or platforms**
  - E.g. Timing Systems, fast Machine Protection Systems

PLC

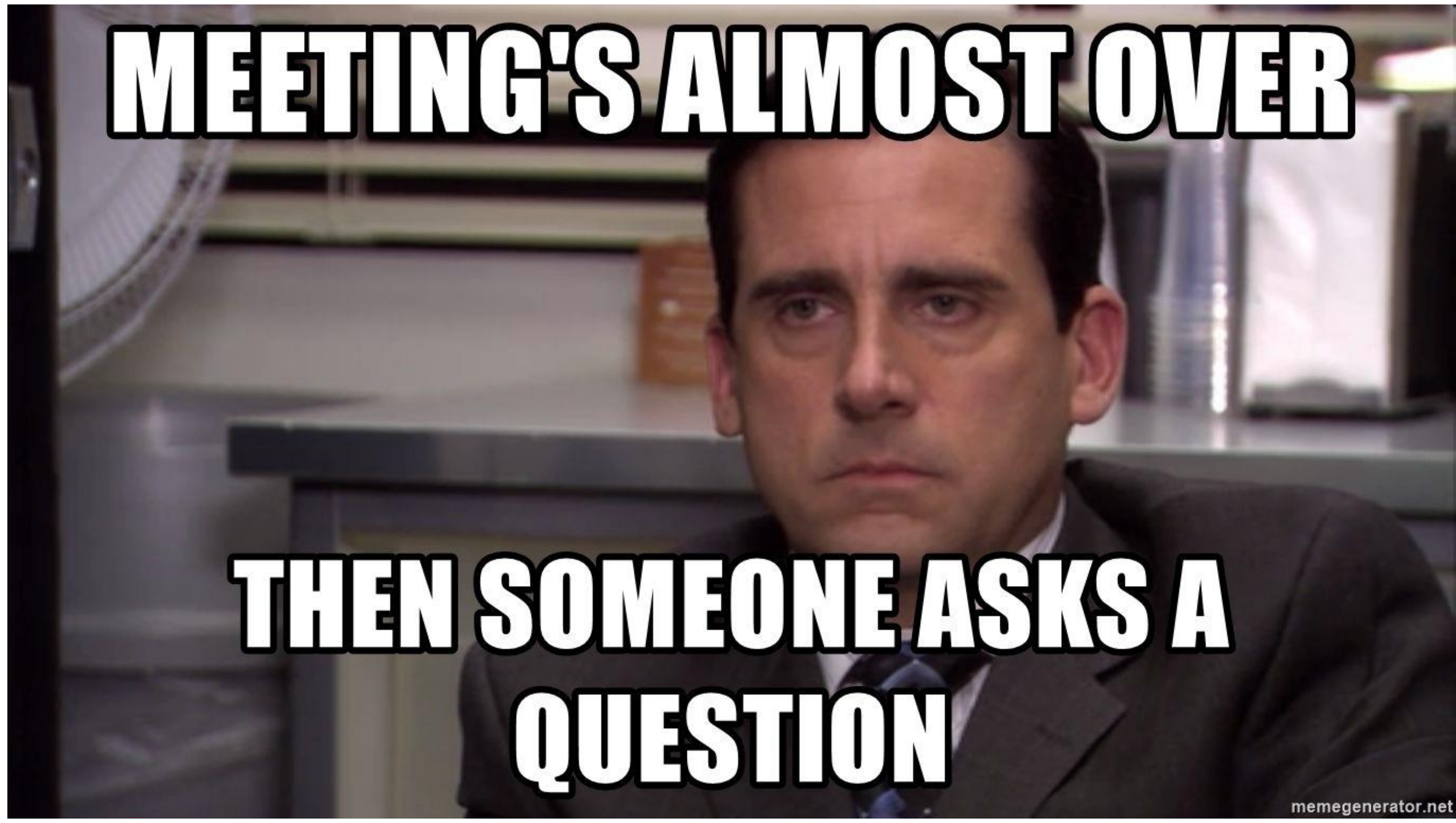
microTCA



PXIe



Questions?



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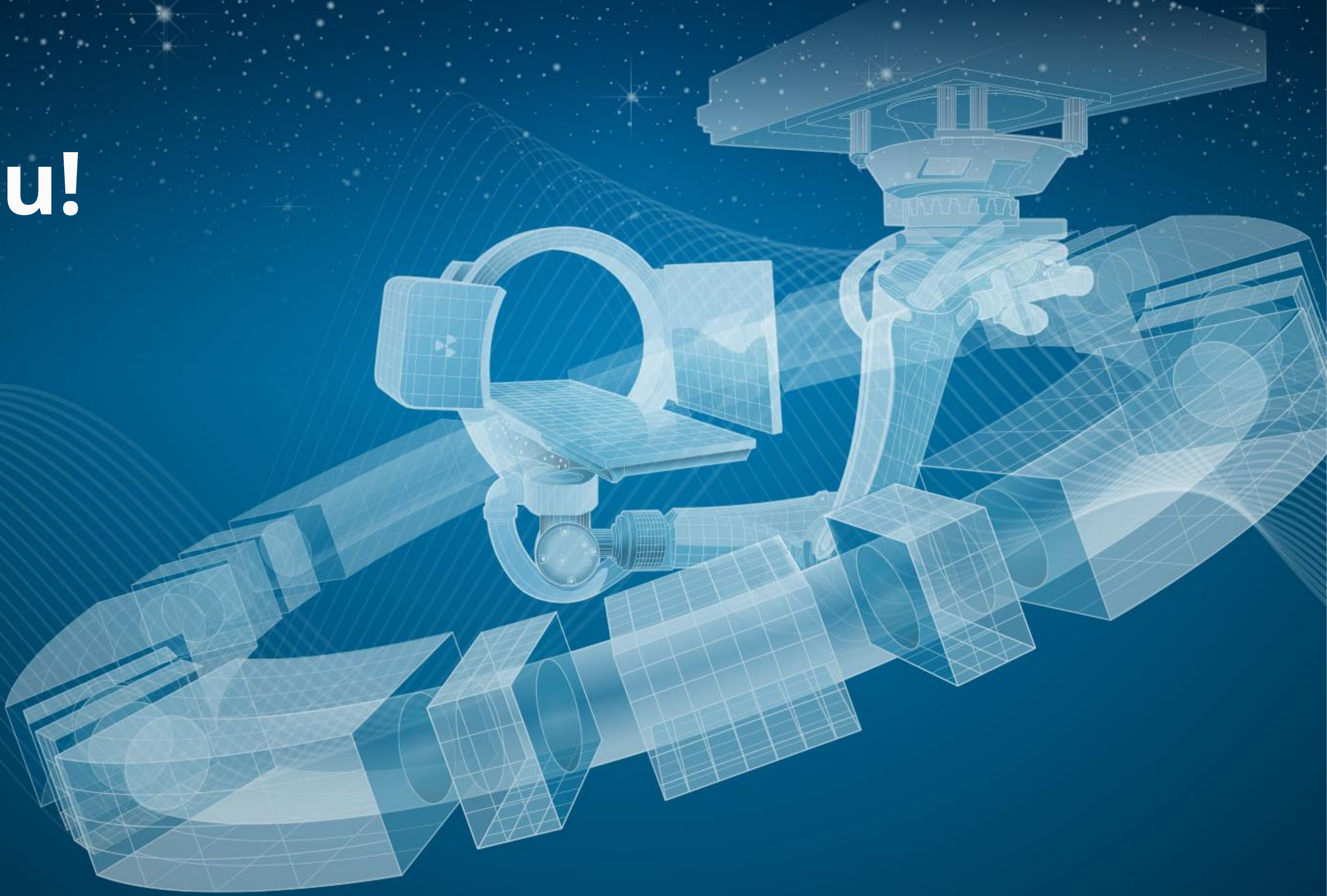
Thank you!

Žiga Kroflič



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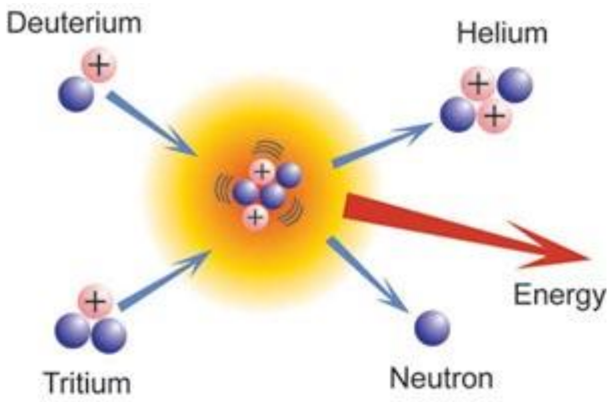
Project examples

SCIENTIFIC market

ITER

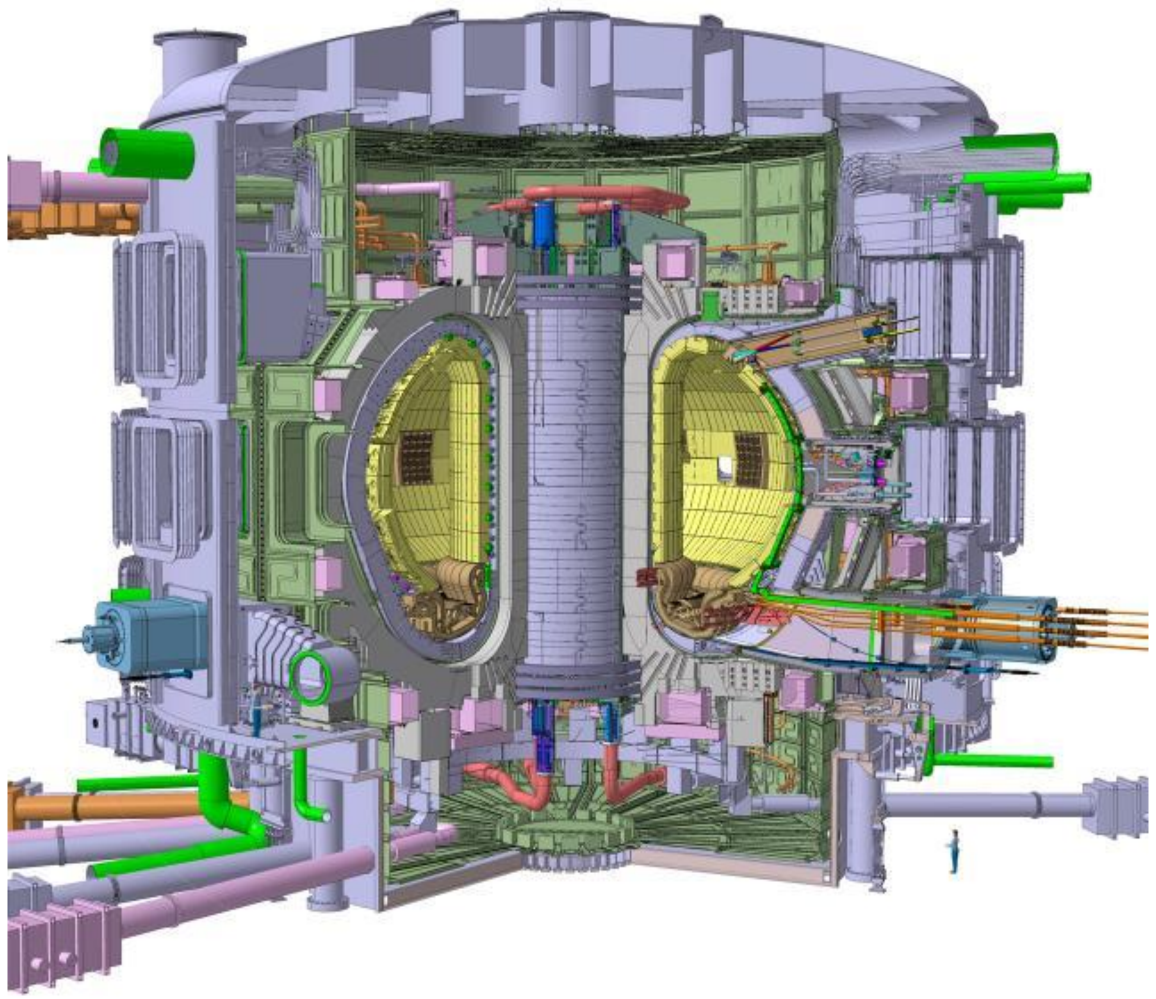
- **I**nternational **T**hermonuclear **E**xperimental **R**eactor
- Official objective: “to demonstrate the scientific and technological feasibility of fusion energy for peaceful purposes"
- Deuterium and tritium fusion

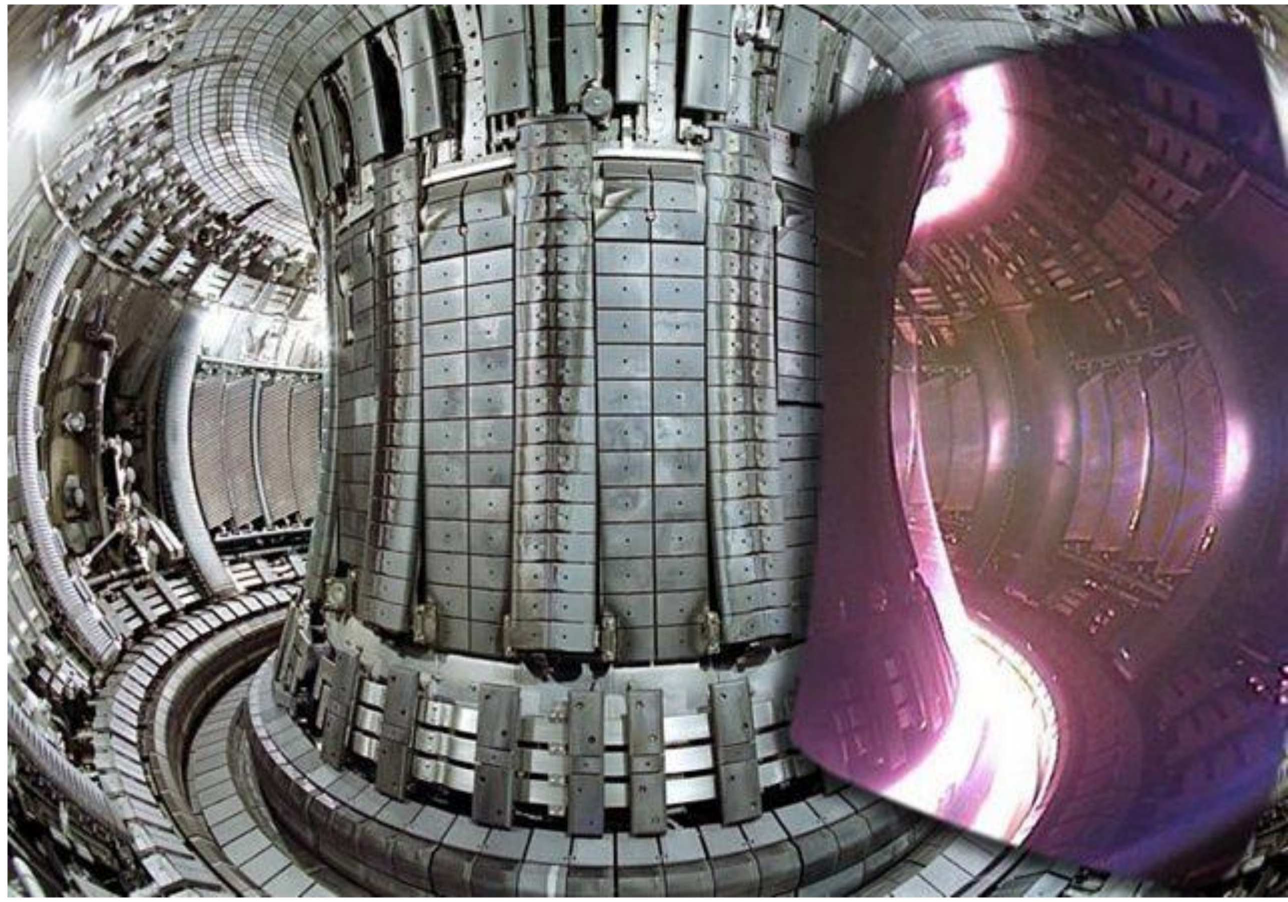
$$^2_1\mathrm{H} + ^3_1\mathrm{H} \rightarrow ^4_2\mathrm{He} + ^1_0\mathrm{n} + 17.6\ \mathrm{MeV}$$



  - releases roughly three times as much energy as uranium 235 fission
- Conditions for fusion:
  - very high temperature (to provoke high-energy collisions)
  - sufficient plasma particle density (to increase the likelihood that collisions do occur)
  - sufficient confinement time (to hold the plasma, which has a propensity to expand, within a defined volume).
- Challenge: extremely strong magnetic field needed to confine plasma in the center of the tokamak -> super-conducting magnets at almost absolute zero temperature vs. 150.000.000 degrees Celsius inside the tokamak!

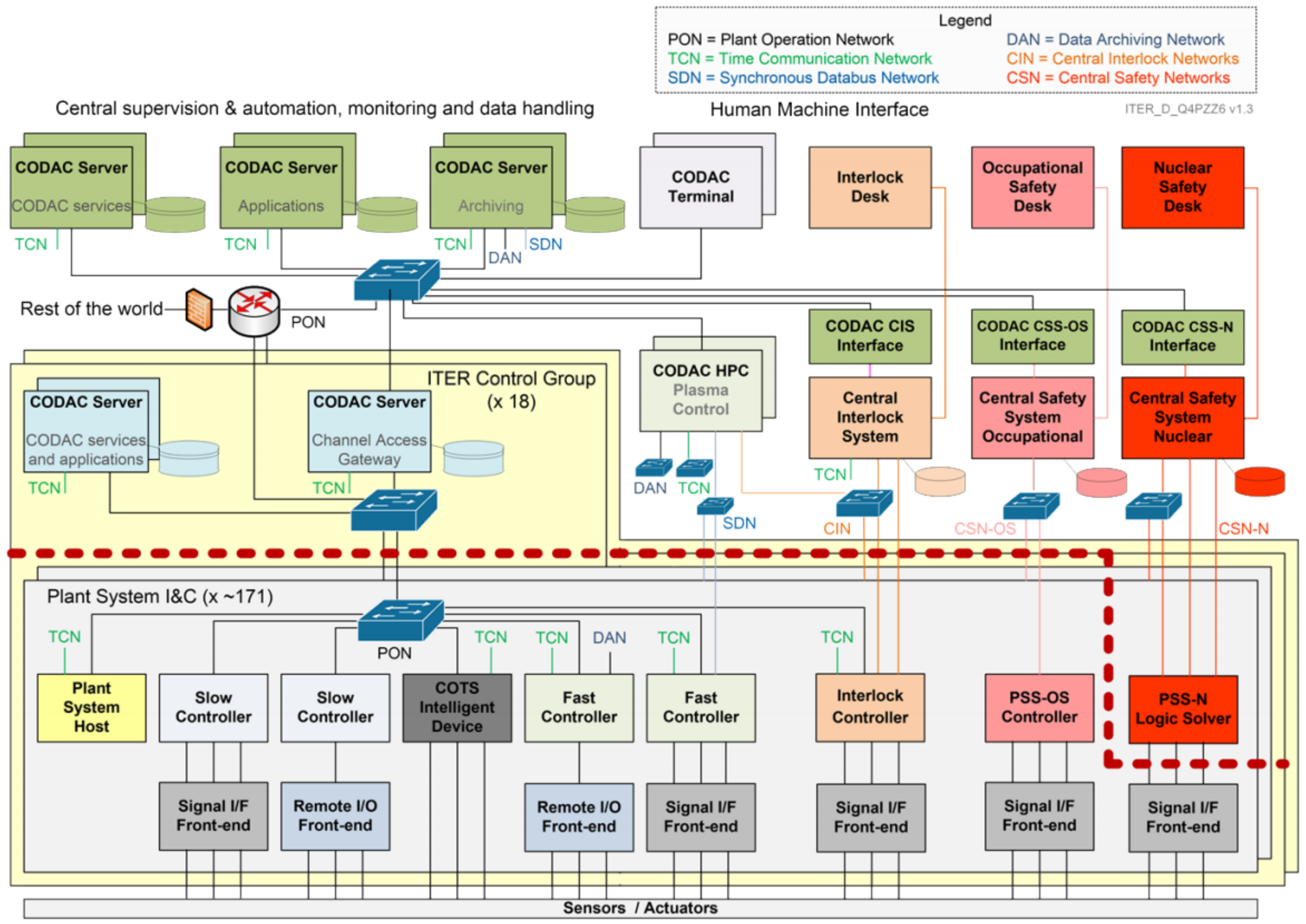
ITER tokamak





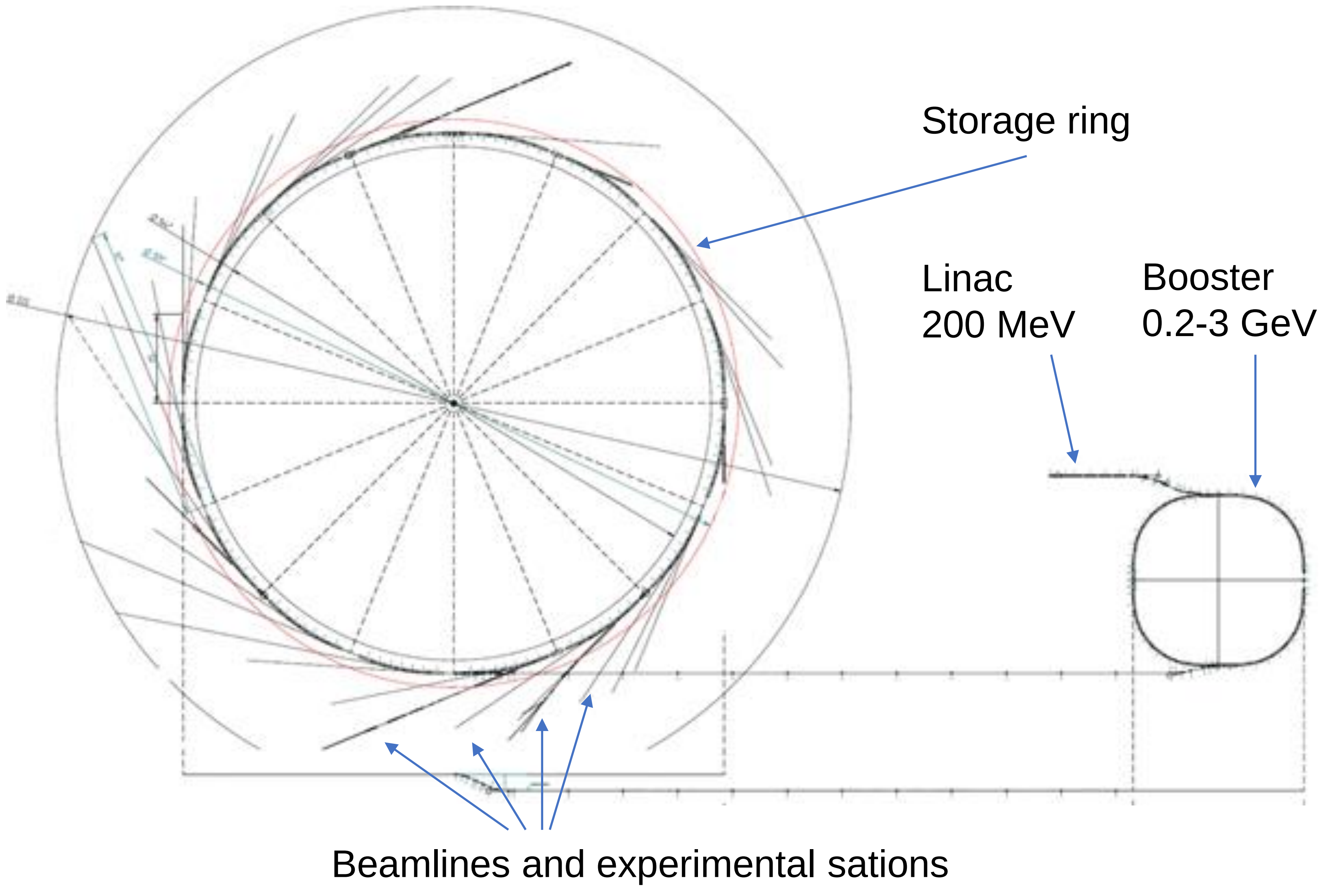
ITER, cont.

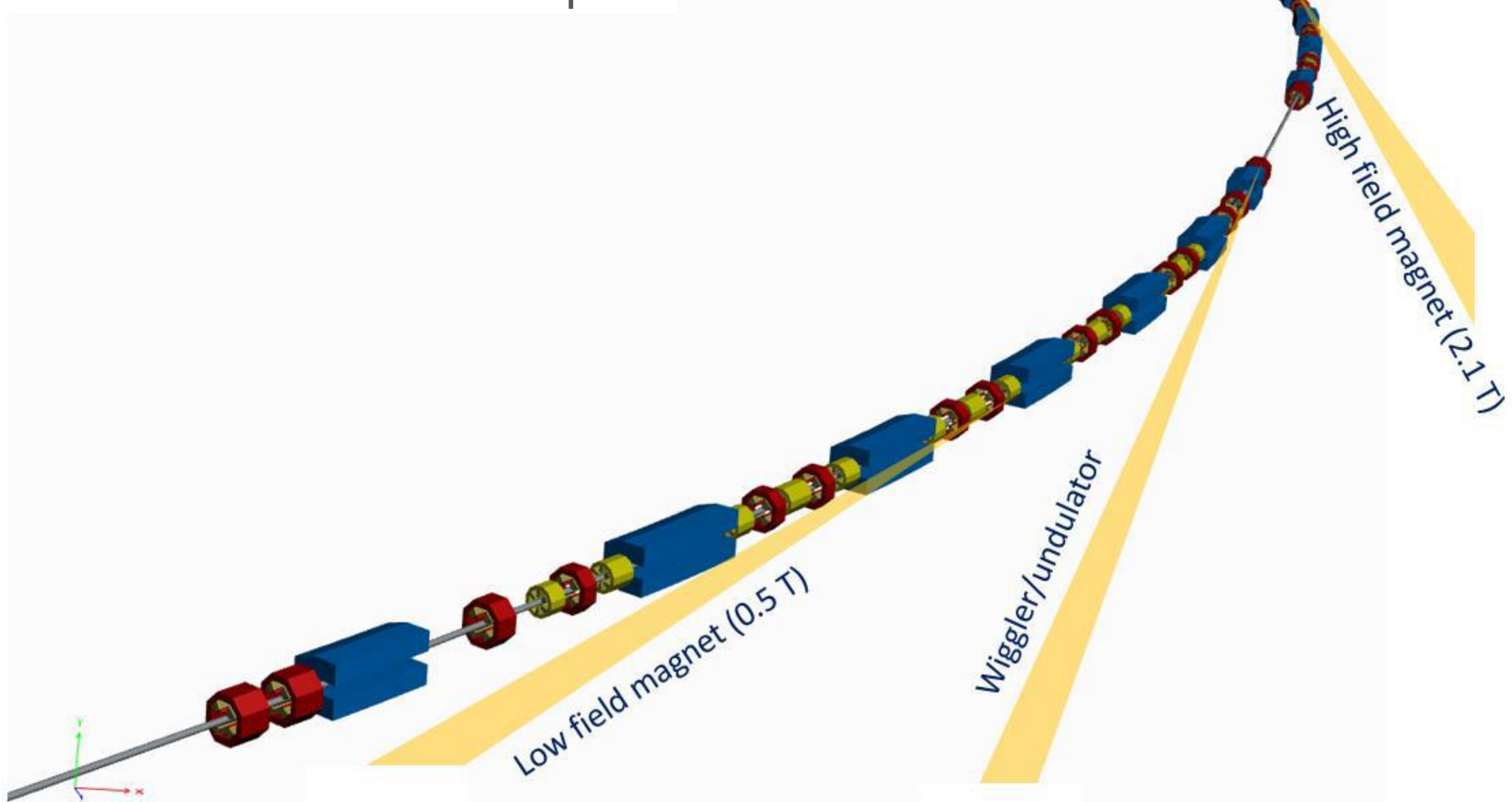
- ITER project is mostly funded with in-kind contributions
- Cosylab is working on ITER for over 10 years
- Projects we did so far include:
  - CODAC Core system – an elaborate control system framework based on EPICS enabling fast device/system integration without deep programming knowledge
    - Including long-term support to users
  - Remote handling control system
  - RTF – realtime framework for plasma control
  - Diagnostics – integration of diagnostic systems
- So far most of our work was done directly for central ITER organization (IO).
- Latest projects and opportunities focus also on harvesting projects from DA (domestic agencies, responsible for local in-kind contributions), like F4E (EU DA), USITER (US DA) etc.



SKIF

- 4th generation lightsource being built in Akademgorodok* (near Novosibirsk), Siberia, Russia, by Budker Institute for Nuclear Physics (BINP)
  - *Home of the scientists :D
- Beam energy 3GeV, multiple beamlines (hard X-ray, soft X-ray, VUV)
- Variety of applications: pharmacy, chemistry, biology, archeology, material science, lithography...
- CSL collaborating with BINP internal team on control system development via CSL Siberia
- Timeline very agressive, but already promissed to the president ;)
- No big contract yet, still in sales phase, but aiming at around 10MEur for CS development!





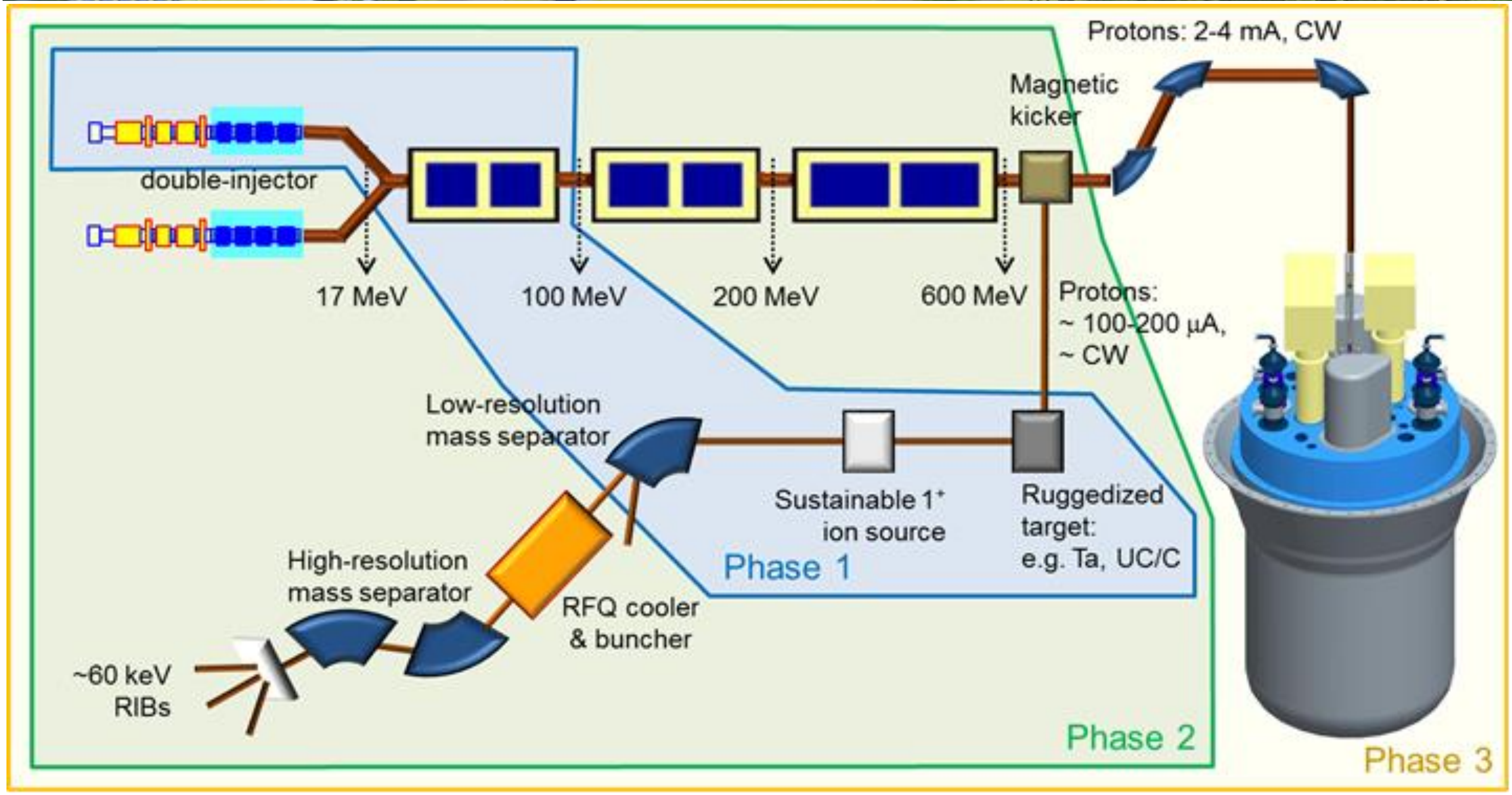
Myrrha

- MYRRHA ADS - Accelerator Driven System:

  Hi-power p-LINAC
  → neutron spallation inside subcritical Nuclear reactor
  → reduce half-life of used nuclear fuel.

- It is a large scale demonstrator and a few such (~20) facilities promise to **solve nuclear waste challenge**, **enable irradiation of medical isotopes**, drive **fundamental research**...
- to be completed by 2036 with the budget of 1,7 BEUR
  - stage 1 – MINERVA – is 500 MEur **accelerator test-stand**
  - objective: showcase that the necessary availability can be met
  - 10x better availability than today's state of the art accelerators is sought.
- MYRRHA project in CSL – it's already 8 years, almost 1mio so far
  - CS study, some small project, TDR

- Start of work on control system is planned Q2 2021
- Our estimates so far are up to 20 FTEs in the next four years (CSL only!)

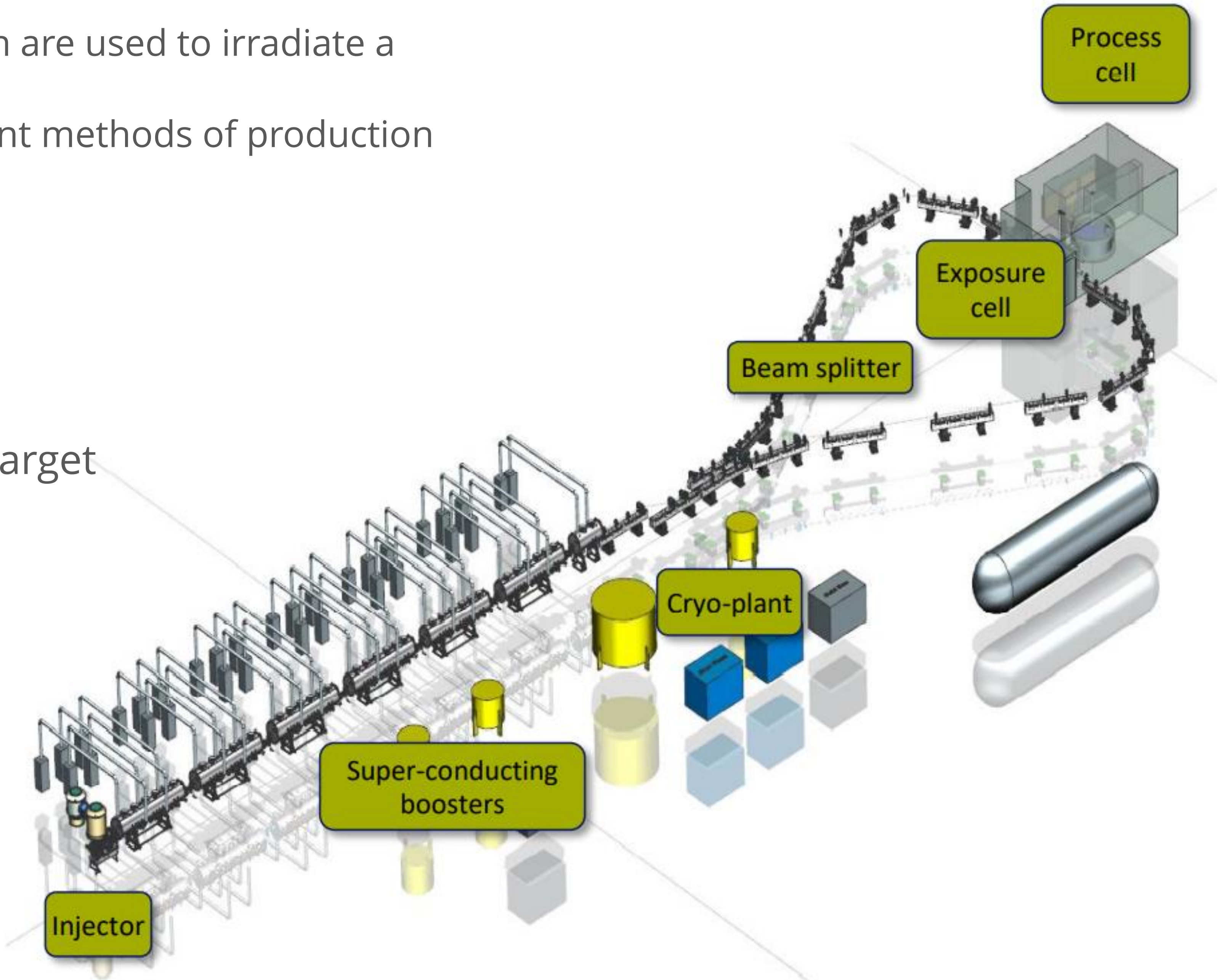


Lighthouse

- Despite scientific progress, cancer remains a major cause of death in ages 40 or older. The number of people diagnosed with cancer each year is expected to grow to 23.6 million worldwide by 2030. New and cheaper ways of diagnosing and fighting cancer are needed in order to combat this increase in people suffering from cancer.
- Isotopes can be used for both diagnostic and treatment/therapy purposes
- At the moment, most of the isotopes used in therapy are produced in a handful of nuclear reactors around the world, which are all starting to approach the end of their life cycle. This means that supply is limited and isotopes generally have to be transported over long distances.
- LH accelerator uses an electron accelerator to create high-energetic photons which are used to irradiate a certain target and create a medical isotope. (Mo-99)
- Primary benefit: results in little nuclear waste and is more cost-efficient than current methods of production

Let's follow an electron

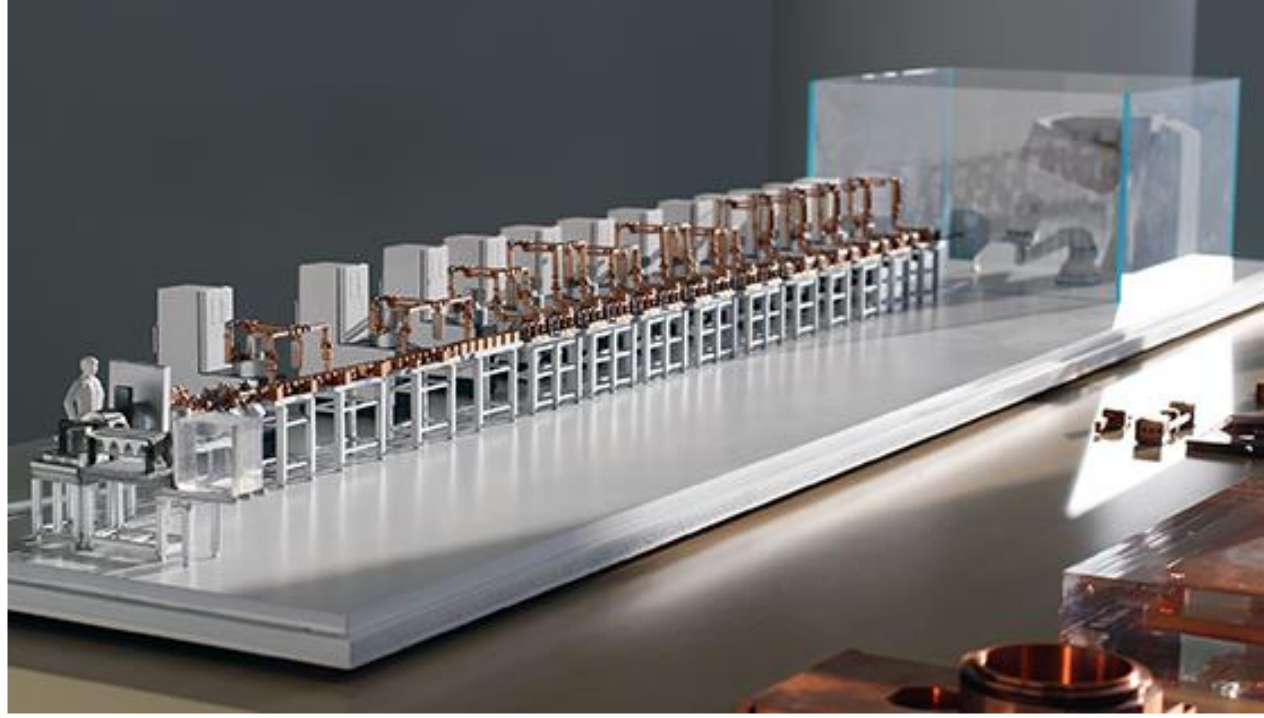
- Electrons are released in the injector
- They are accelerated to 75 MeV in the super-conducting boosters
- The beam is split to approach the target from two sides
- In the exposure cell the high energy electrons are stopped in the Mo-100 target and produce Bremsstrahlung (gamma-rays or γ-rays) which transmute Mo-100 into Mo-99
- The target is cooled as the electrons create also a high thermal load on the target
- After exposure of the target during a week, part of the target is harvested and processed to create the Active Pharmaceutical Ingredient (API) Mo-99

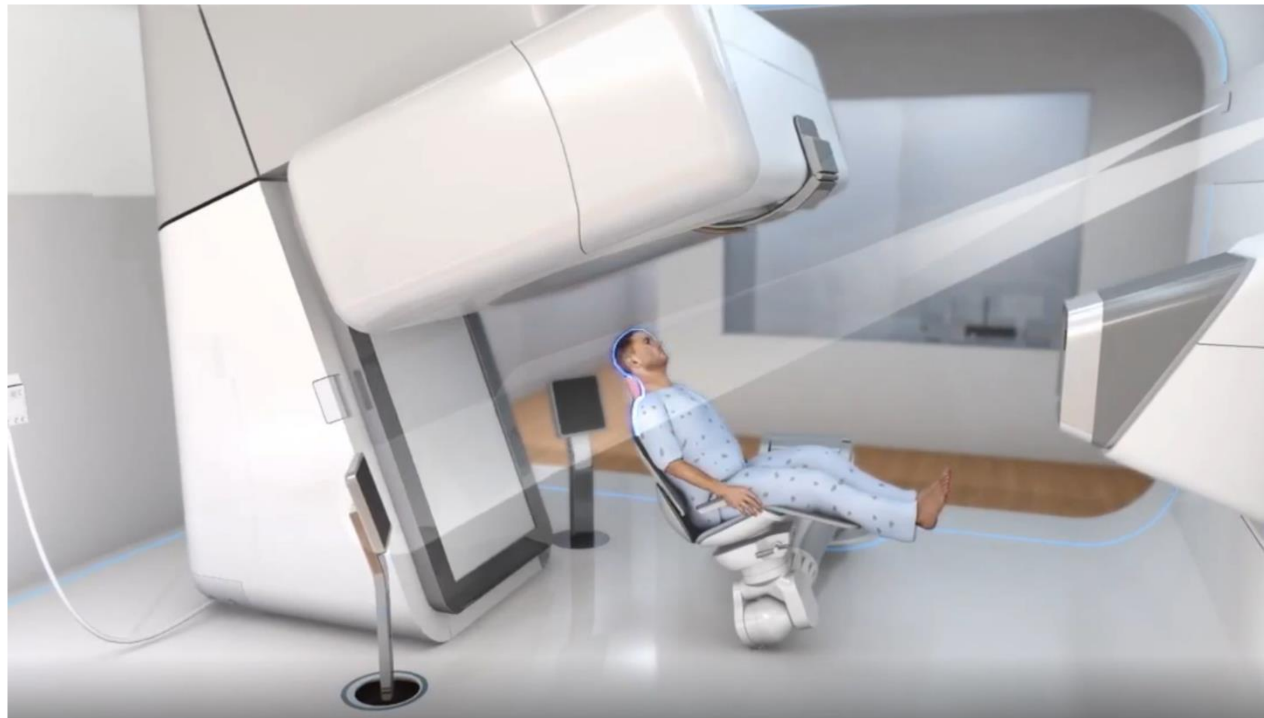


ADAM

- AVO (Advanced Oncotherapy) is developing the advanced LIGHT system:
  - LIGHT is a linear proton accelerator
  - requires neither the massive infrastructure nor the extensive shielding of older and current forms of proton accelerators.
  - It’s modular and brings the flexibility to customize cancer treatment plans
  - The dynamic transversal modulation allows a precise 3D treatment of the tumors via the 'spot scanning’ technique.
  - The specifications of this system allows hospitals to have their facilities among residential areas.
  - is the 1st LINAC for PT facilities
  - is 25 m long, generates 230MeV energy
  - is very fast, 200 Hz (this means the control system has 1 ms to do its job)

- Cosylab team size cca 14 FTE (the peak is now!)
  - 4 on-site:
    - Geneva (SWITZERLAN)
    - Daresbury (UK)
  - CSL scope mosly revolves around Labview-based accelerator control system („industrial“)





CTA – Cherenkov Telescope Array

- Over 100 telescopes on 2 locations (North: La Palma, South: Atacama)
- High energy gama-ray observatory (biggest and most sensitive in the world)
- International project – mostly In Kind Contributions
- Weight of 400MEur

- Among other packages Germany plans to contribute ACADA (The Array Control and Data Acquisition) Using ACS
  - developed by CSL in „the old days“ for ALMA
- After several small contracts since 2017 Cosylab is bidding on a bigger tender – assessed at 11.000 man-hours over next 4 years.

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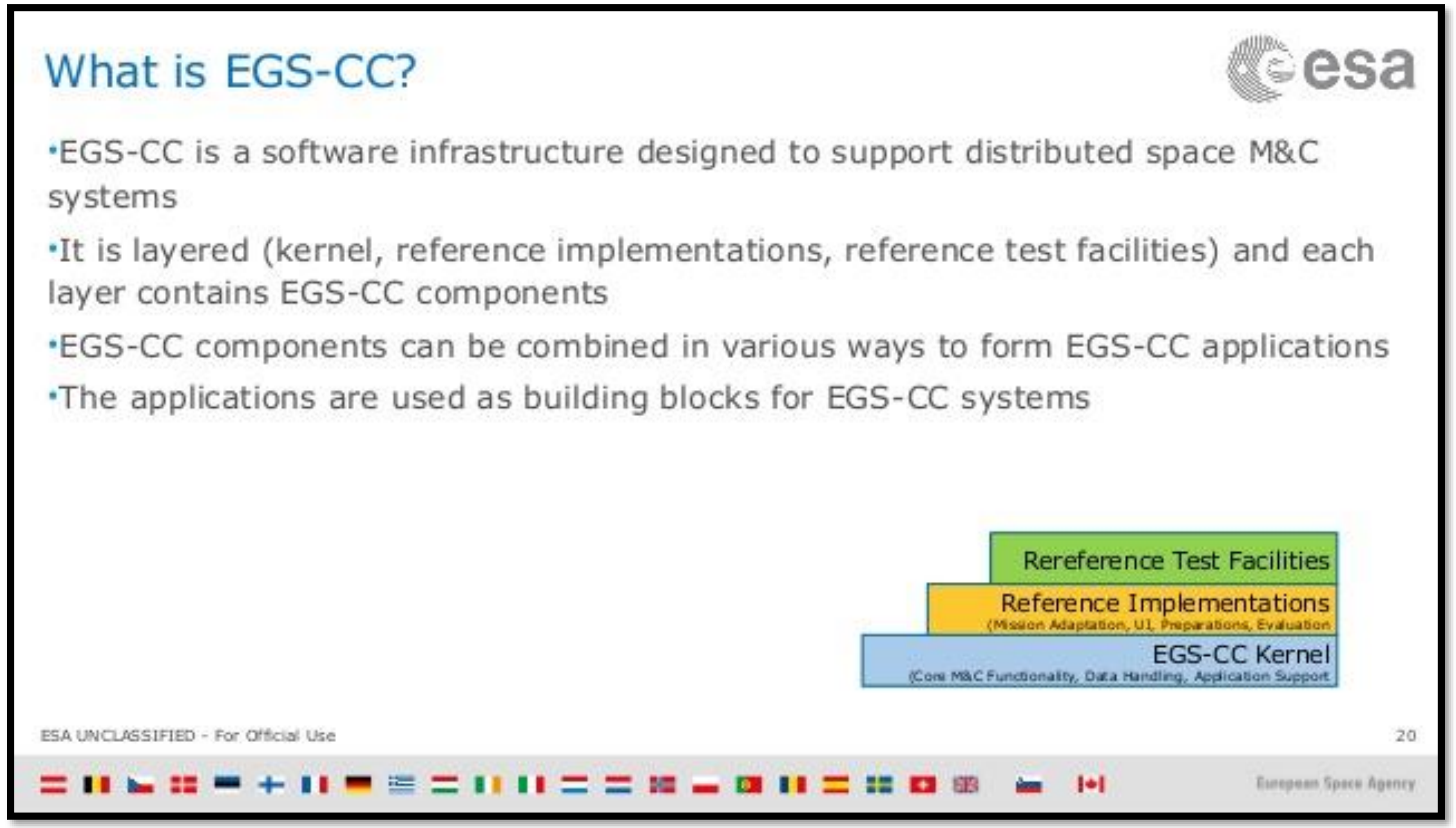
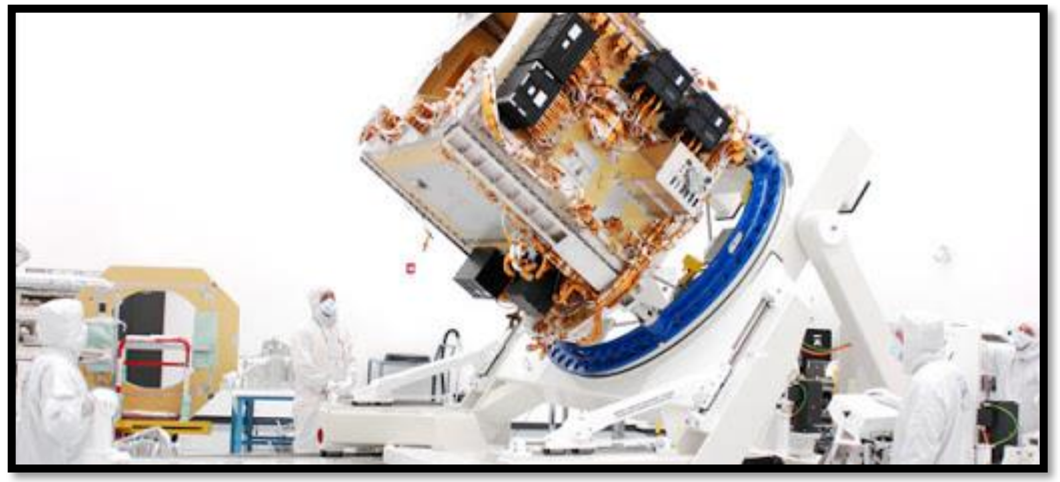
Space

- Ground Segment
- EGS-CC (European Ground System – Common Core)
  - Common infrastructure to support space systems monitoring and control in pre- and post-launch phases for all mission types.
  - AIT (Assembly, Integration and Testing) – pre-launch
  - Operations (Mission Control) – post-launch
  - It's a Java based Control System (OSGi FTW)
- Collaboration between ESA, European National Agencies and European Large System Integrators
  - CNES, DLR, UK Space Agency
  - AIRBUS Defence and Space, Thales Alenia Space (France and Italy), OHB System



Space Projects

- ESTEC (European Space Research and Technology Centre)
  - Supporting AIT
  - EGS-CC
  - First project
    - HW Bus Integration into EGS-CC
- ESOC (European Space Operations Centre)
  - Mission Control
  - EGS-CC
  - EUD (Common ESOC GUI framework)
  - Eclipse RCP based
  - Second Project
    - GUI product integrating EUD and EGS-CC
- Future – fixing EGS-CC



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Project examples

MEDICAL market

ProTom

PROTOM
proton therapy technologies

- **Manufacturer of Radiance 330 - proton therapy system**
- Collaborating with them since 2015
  - 10+ year contract
  - Project size: 40+ person-years
  - >50 CSL people contributed so far

- CSL developed complete treatment delivery and motion control software and more

- **First system treating patients at Massachusetts General Hospital** in Boston
  - Currently in Maintenance & Support phase of the project
  - To say it simply: fixing bugs and implementing new features

- **Future**
  - Convincing them to use our products: C-TCS, C-DDS, C-OIS, proton imaging...
  - Their next installation in Adelaide, Australia
    - Multi-room site, first patient planned for 2025
  - Setting up a partnership for the Chinese market
    - Goal: Cosylab to take over more responsibility such as: installation, integration, commissioning

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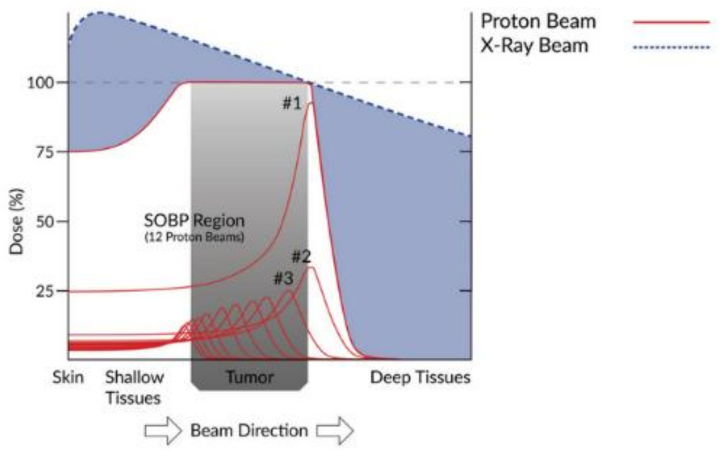
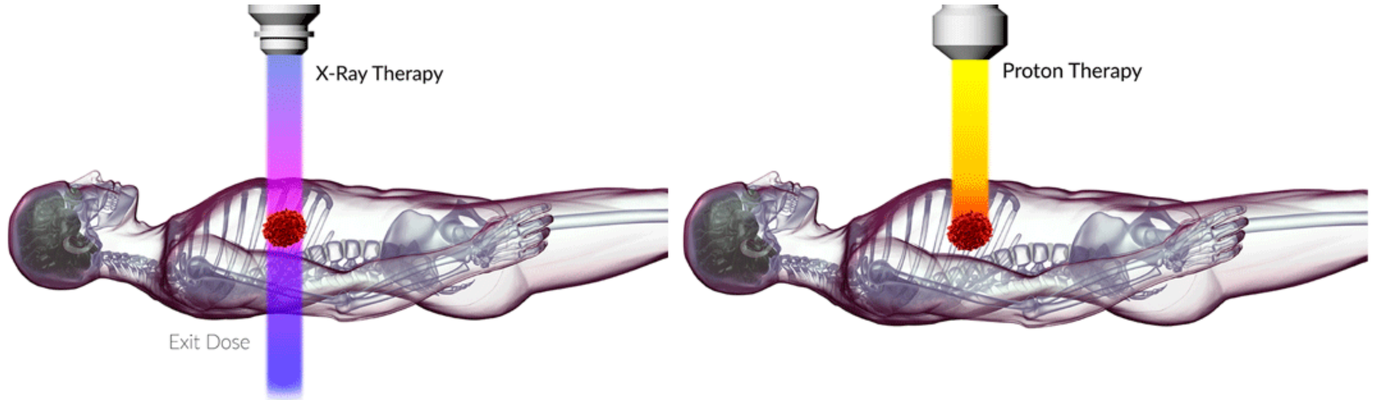
ProTom Project – Proton Therapy

- Utilizing the unique property of protons for cancer treatment
  - Bragg peak

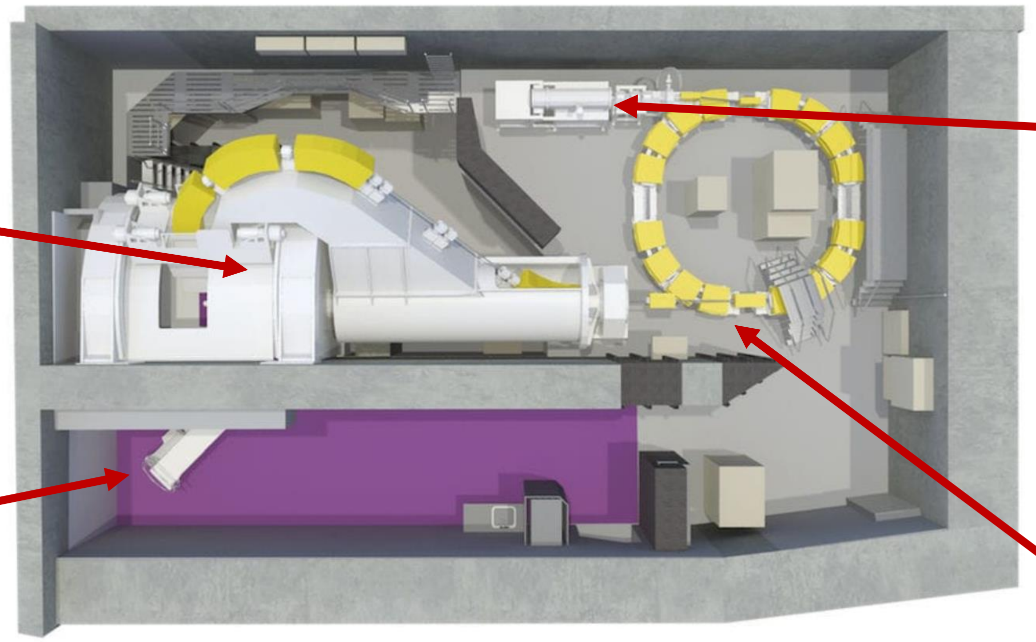




- Facility layout

Gantry

Robotic couch

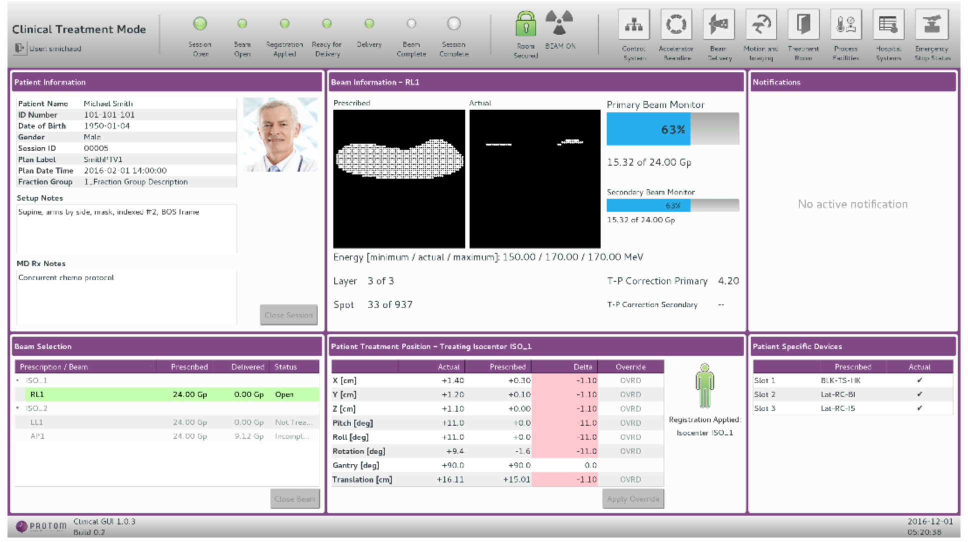


Ion source, injector

Synchrotron

ProTom Project - Our Contribution

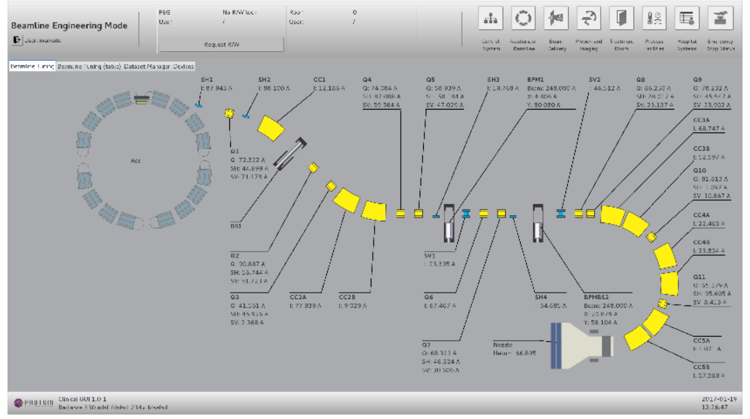
- Treatment Control System

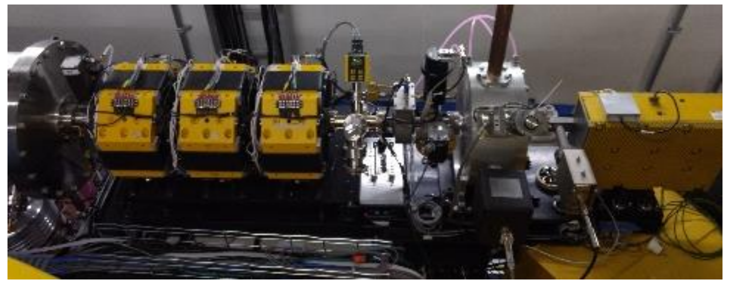


- Motion Control System

- Systems of Safety

- Beam Tuning and Commissioning





ProTom Project - Medical Device – Safety!

- Safety is extremely important
  - Patient and personnel safety
- Medical software development
  - Regulations and standards
  - Systems engineering
  - Risk management
  - Testing

Title: TDCS Requirement-level Test Plan Report, Radiance 330 TDCS	
Date: 2019-04-18	**Page** 1 of 1012

- ~60 documents per system





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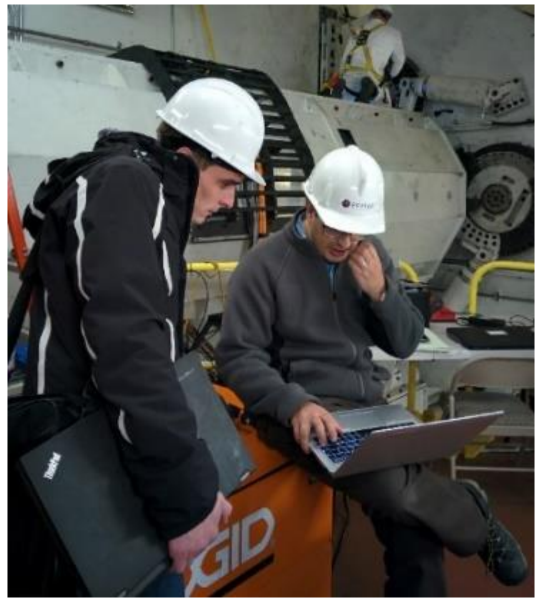
ProTom Project - How Our Work Looks Like 1/2

- A lot of on-site visits
  - Short-term and long-term visits
- In-person discussions
  - Defining requirements, what they need
- On-site development, integration, testing
- On-site demos to the board of directors and investors

ProTom Project - How Our Work Looks Like 2/2

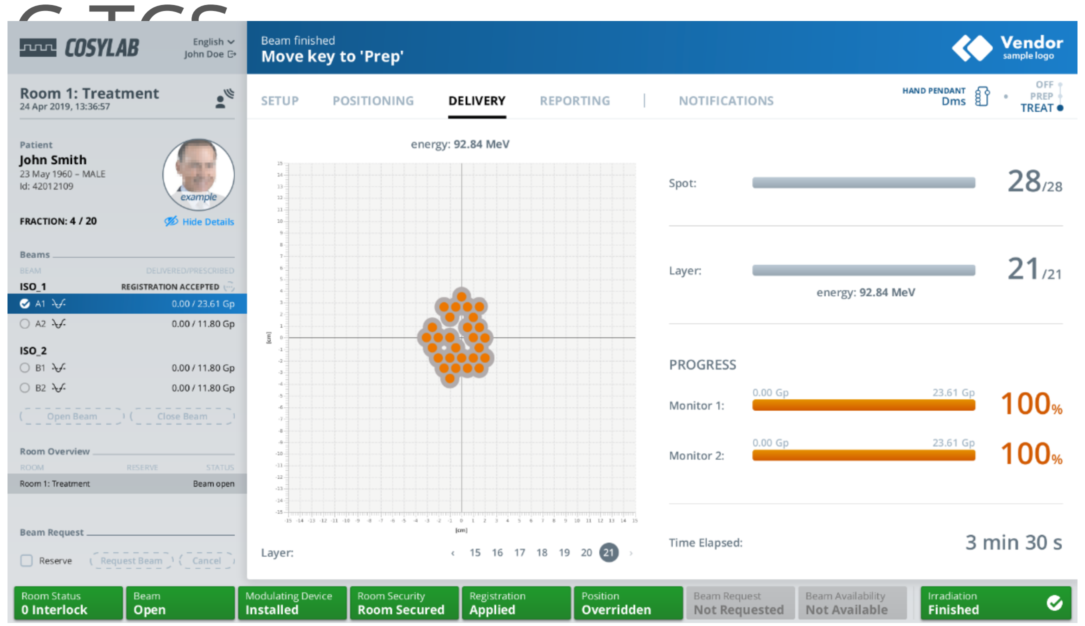
- Integration and testing at the hospital
- ProTom is finalizing their first installation at MGH
  - Our software accepted in 2018
  - First patient treated in beginning of 2020
- We‘re developing a new generation of software for future installations



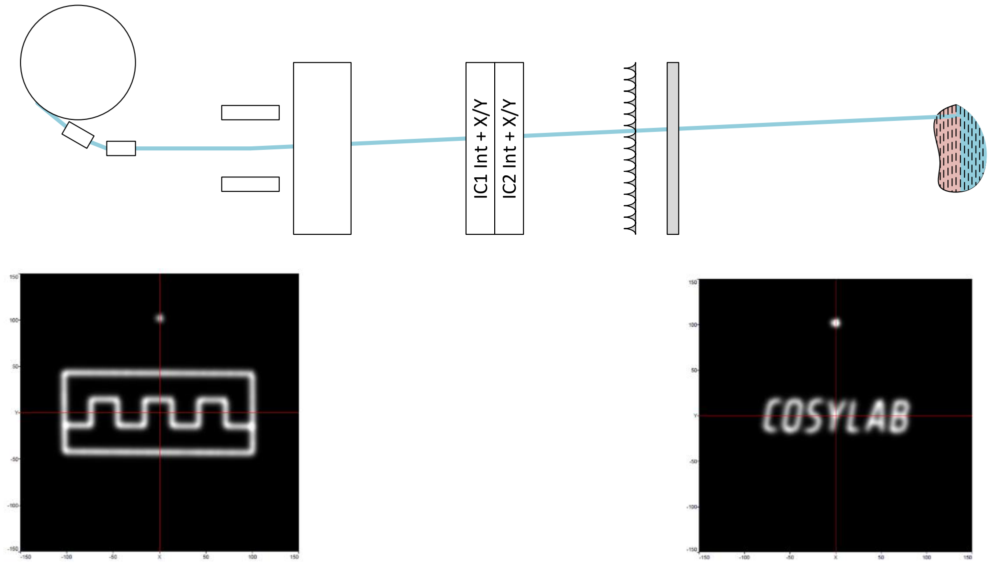
ProTom Project - Future Of The Project

- Adelaide - Australia, Hainan - China

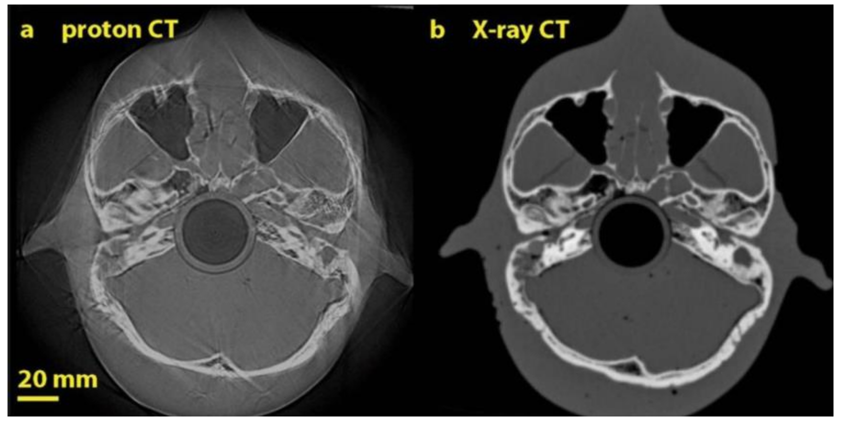
- C-TCS



- Cosylab Dose Delivery System (C-DDS)



- Proton Imaging



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Relationship With ProTom

- We have an outstanding partnership
  - *“Exceptional competence and the best extension-of-workforce I've worked with thus far in my career.„*
  - *„ProTom CEO got feedback on Cosylab demo from MGH, their report was excellent.“*
  - *„I’m very, very happy with the work product.“*
  - *„Cosylab is simply the best SW company in the (PT) market by far.“*

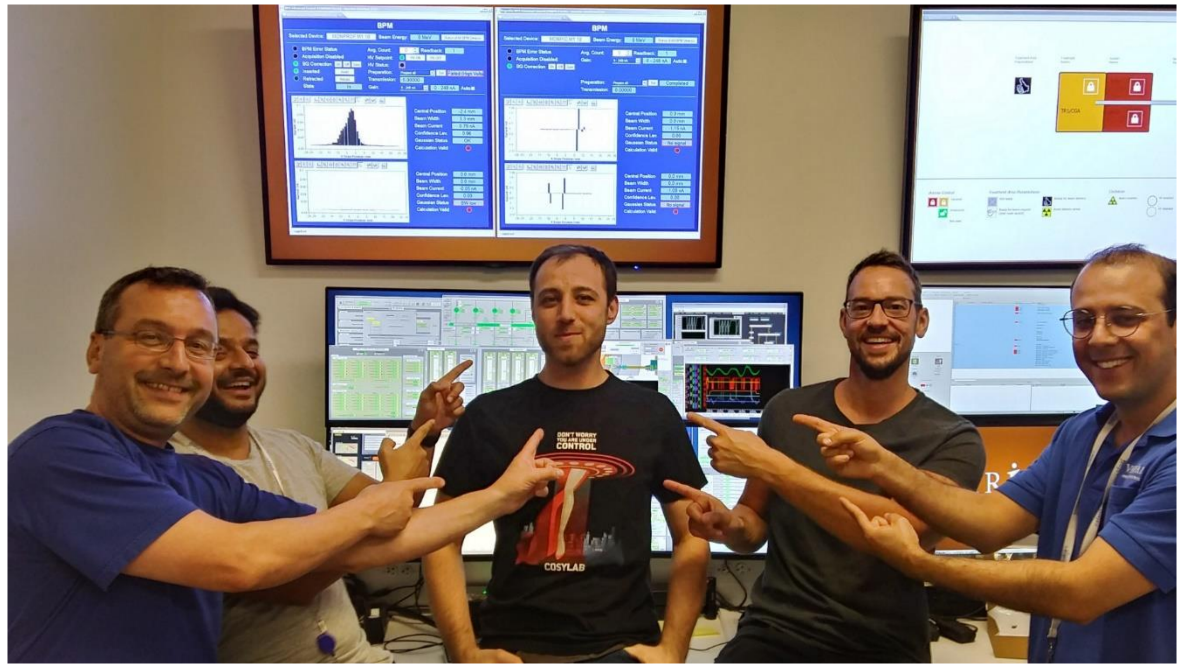
ProTom Project - Enjoying Work and Having Fun

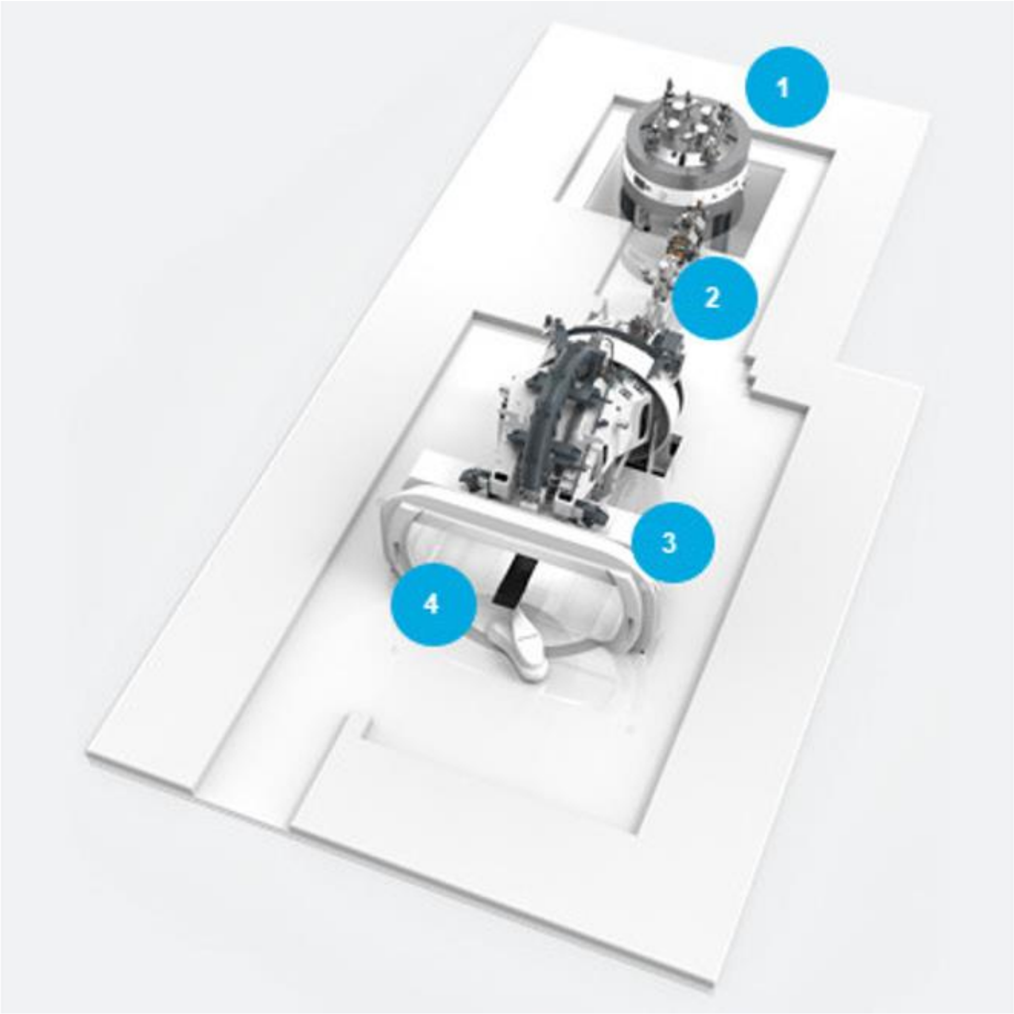
COSYLAB

VARIAN Medical Systems

- **Biggest vendor of PT systems**
  - Product: ProBeam platform (15+ installations)
  - Includes OIS (Aria) and TPS (Eclipse) in portfolio

- **Current Projects:**
  - **Embedded SW development:** beamline control system (EPICS).
  - **Application SW development:** C# software for remote service feature.
  - **System Quality Engineering:** ProBeam V&V activities.
  - **On-Site installation and commissioning:** on-site installations.
- **Plans:**
  - New framework agreement to be defined for fiscal year 2021
  - Propose a redesign of their existing beamline control system
  - Continue I&C support
- **Misc:**
  - 1 month ago, they were bought by Siemens Healthineers for 16b $.
  - New generation of PT machine - ProBeam360, first installation in Q2 2021.

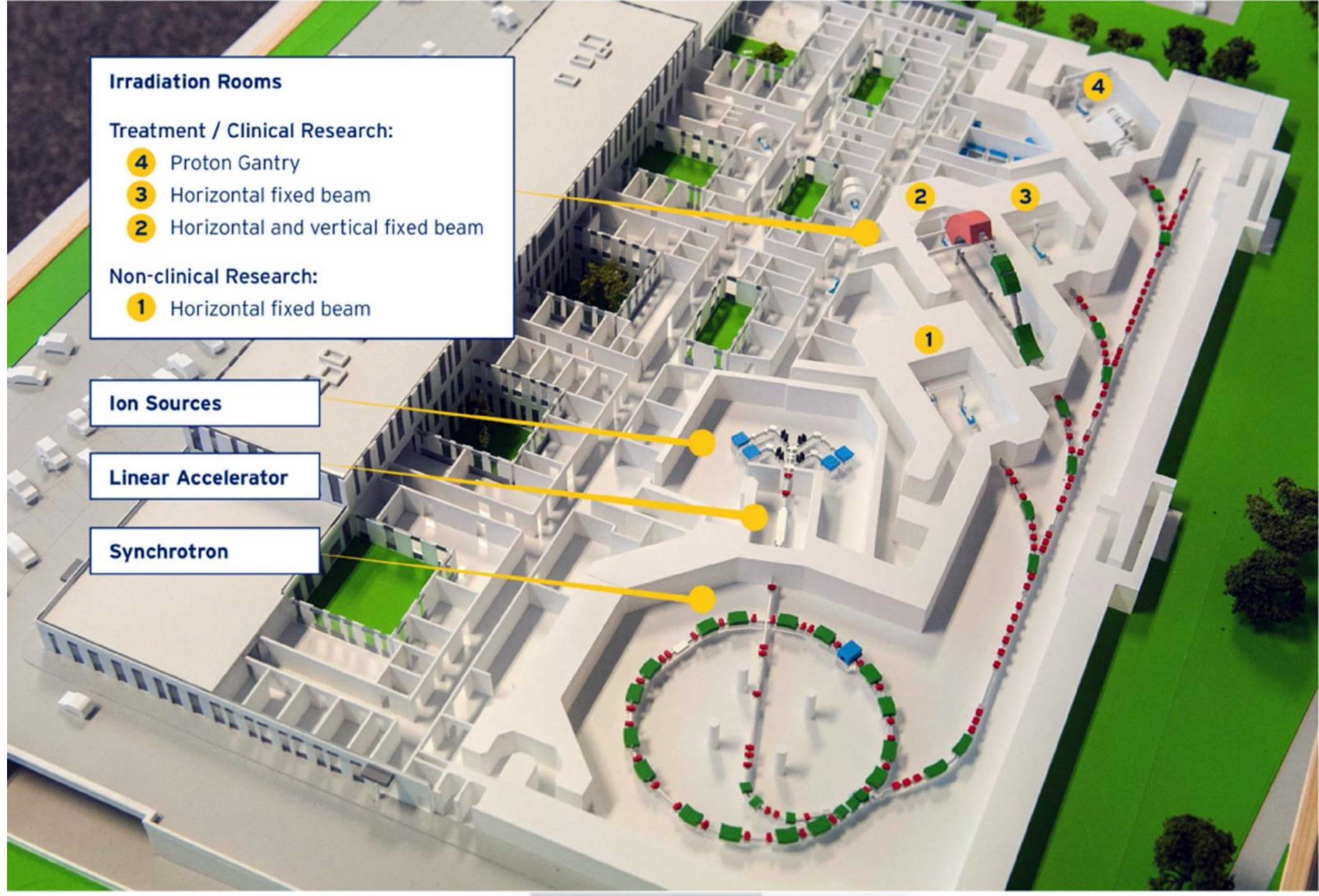


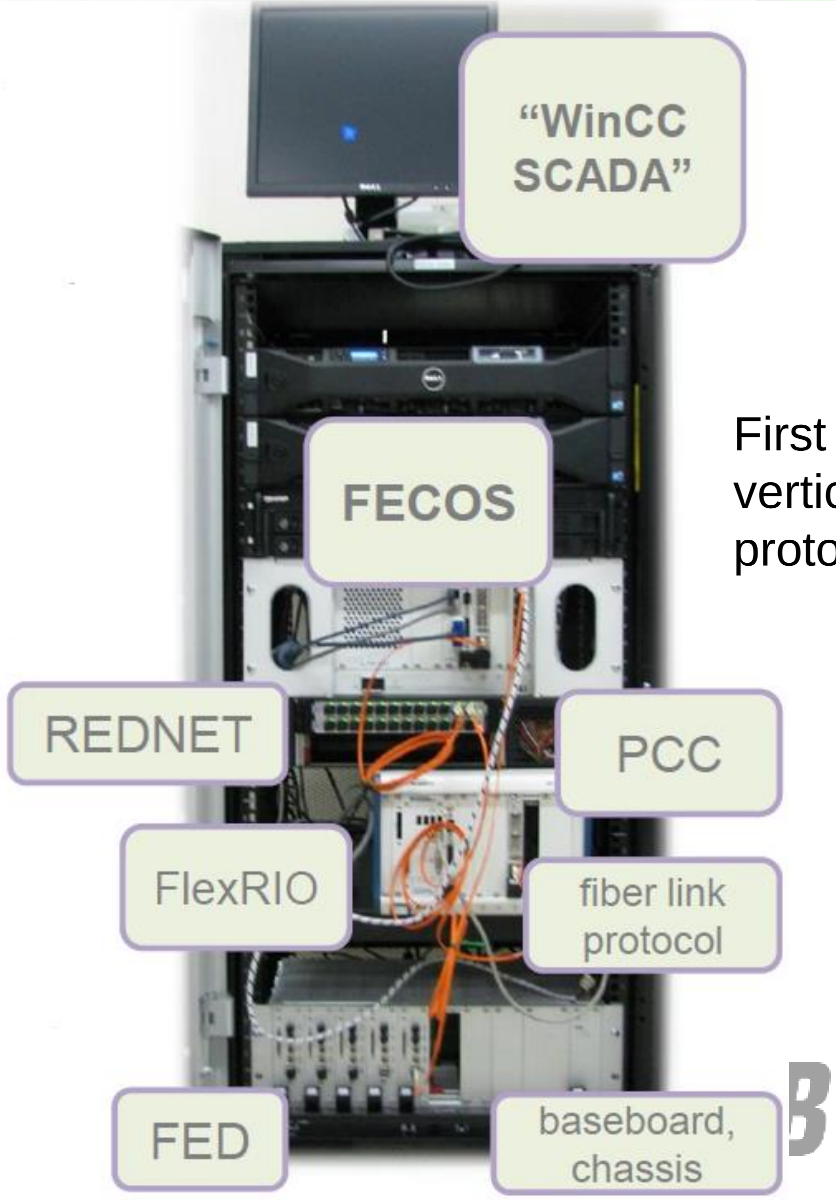


MedAustron

- Synchrotron accelerator in Wiener-Neustadt
  - 4 irradiation rooms, 1 gantry
  - Proton and carbon ion therapy, clinical and non-clinical research

- CSL working for MA for 10+ years. In chronological order we worked on:
  - **Accelerator control system** projects
    - Front End Control Systems FECOS; LabVIEW framework; unify & simplify device integration
    - Main timing system REDNET (MTS); MRF-based highly customized timing system, PXI / PXIe
    - Power Converter Controller (PCC); complete solution for power supply control, synchronous control of 300 different power supplies; static and waveform
    - Ion Source
    - Injector LLRF integration
    - Signal Acquisition and Distribution System; 150 channel, Tektronix based, CS integrated commissioning tool
  - **Medical front-end device** projects
    - EVS, ITS, DIG/DMUX, ORBox, ITU (ITS upgrade) – many HW devices bridging the connection between „industrial“ control system and CNAO DDS (scanning system)
    - **First set of serious medical device development for CSL**, we gained tremendous experience here that enabled us to go deeper into PT and other medical projets!
  - Current projects: **upgrades and redesigns**
    - MADAM upgrade due to HW changes and partner company change (MedPhoton –> Cosylab)
    - MAI SCADA UI; redesign of upper tiers of acc CS for Iran site





First acc CS vertical prototype

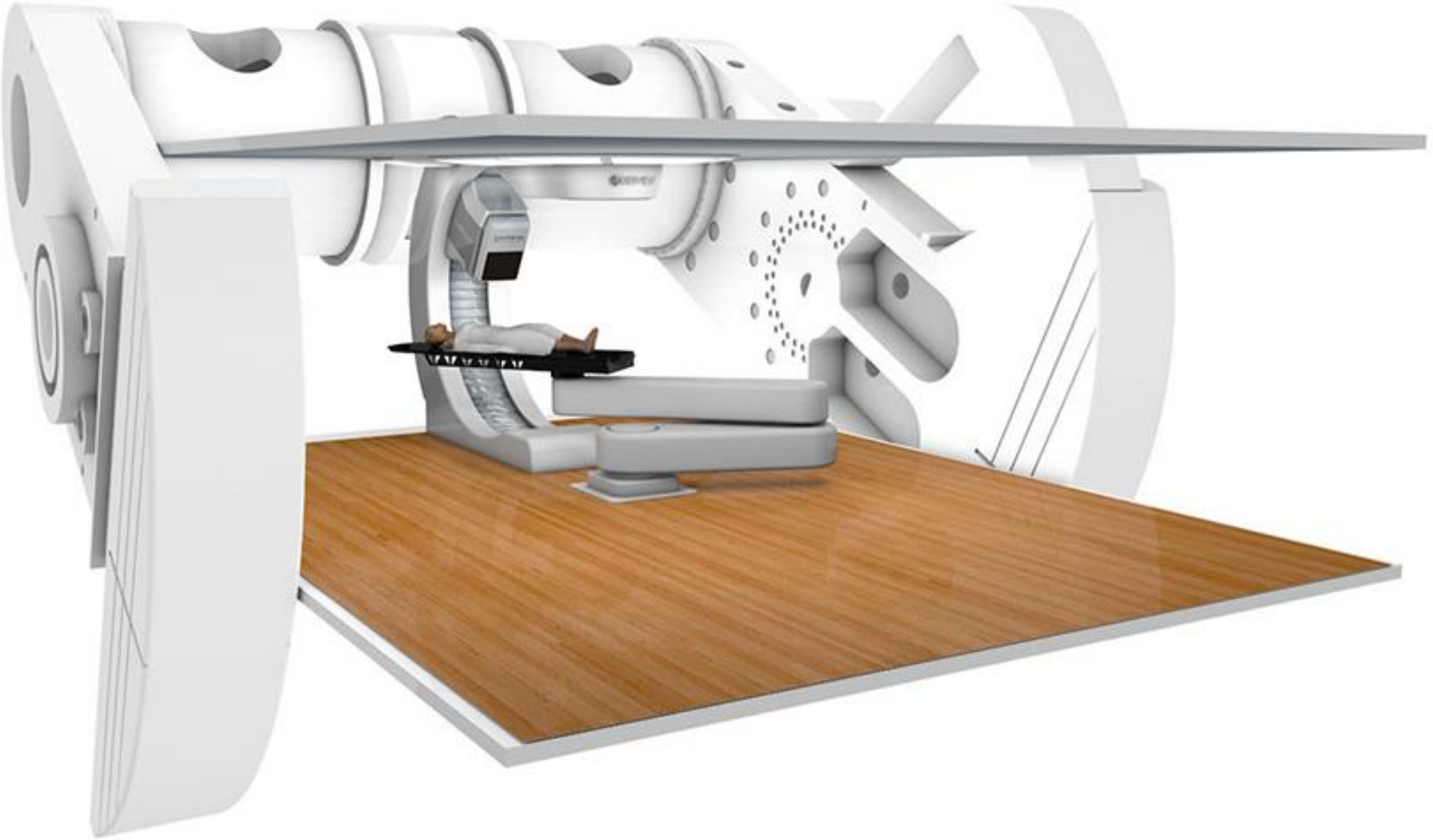
MEVION Medical Systems

- Proton therapy vendor from in Massachusetts, USA
  - MEVION S250 Series™ product has the smallest footprint and advertised low cost of operation

- Involvement of Cosylab:
  - C++ development service,
  - Our team works in close collaboration with Mevion SW development team,
  - 4 developers, partially from HQ and partially from Cosylab Ukraine.

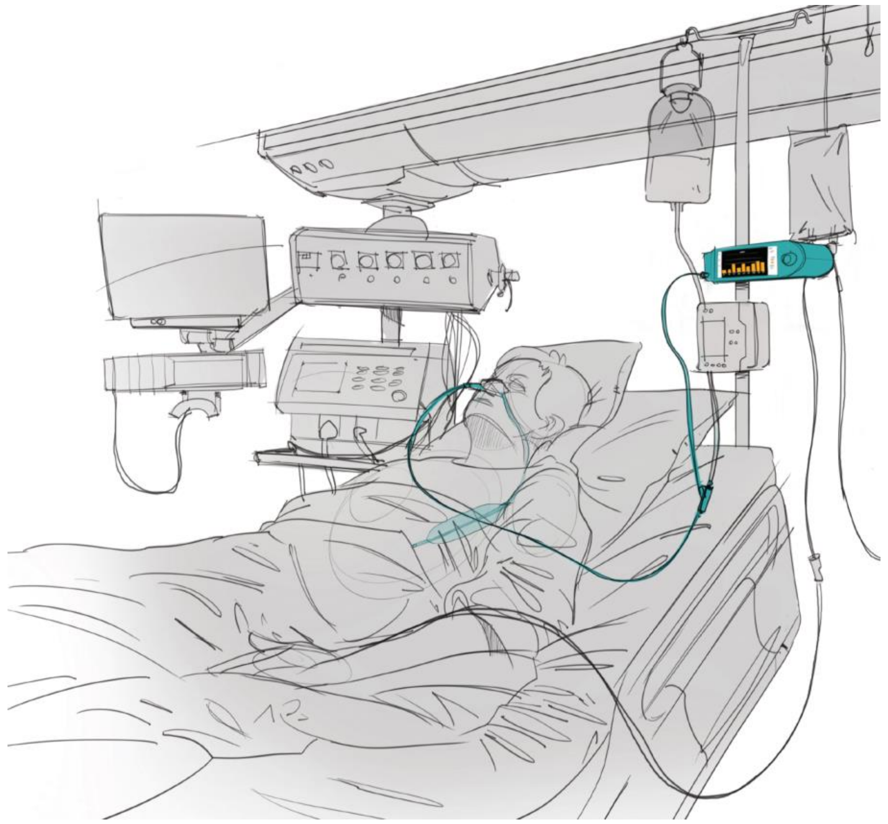
- Technical Tasks:
  - Upgrade of Motion control system,
  - Adaptive aperture (beam collimator) upgrade,
  - Unification of two Mevion products Scattering and Scanning,
  - Implementation of X-ray generator communication protocol,
  - C++ development tasks in general on a various components of the system,
  - Remote & Onsite support ...

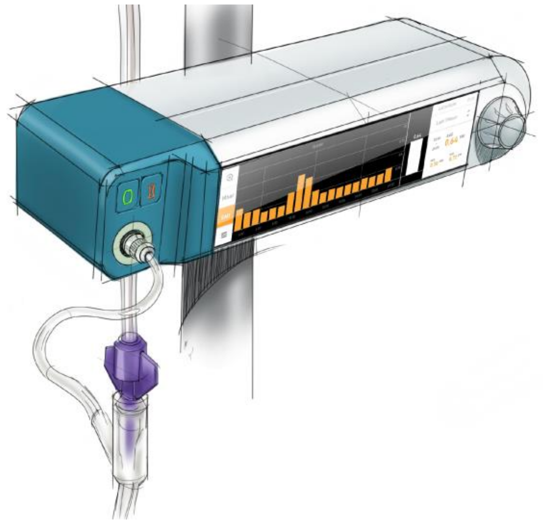
MEVION medical systems



VIPUN

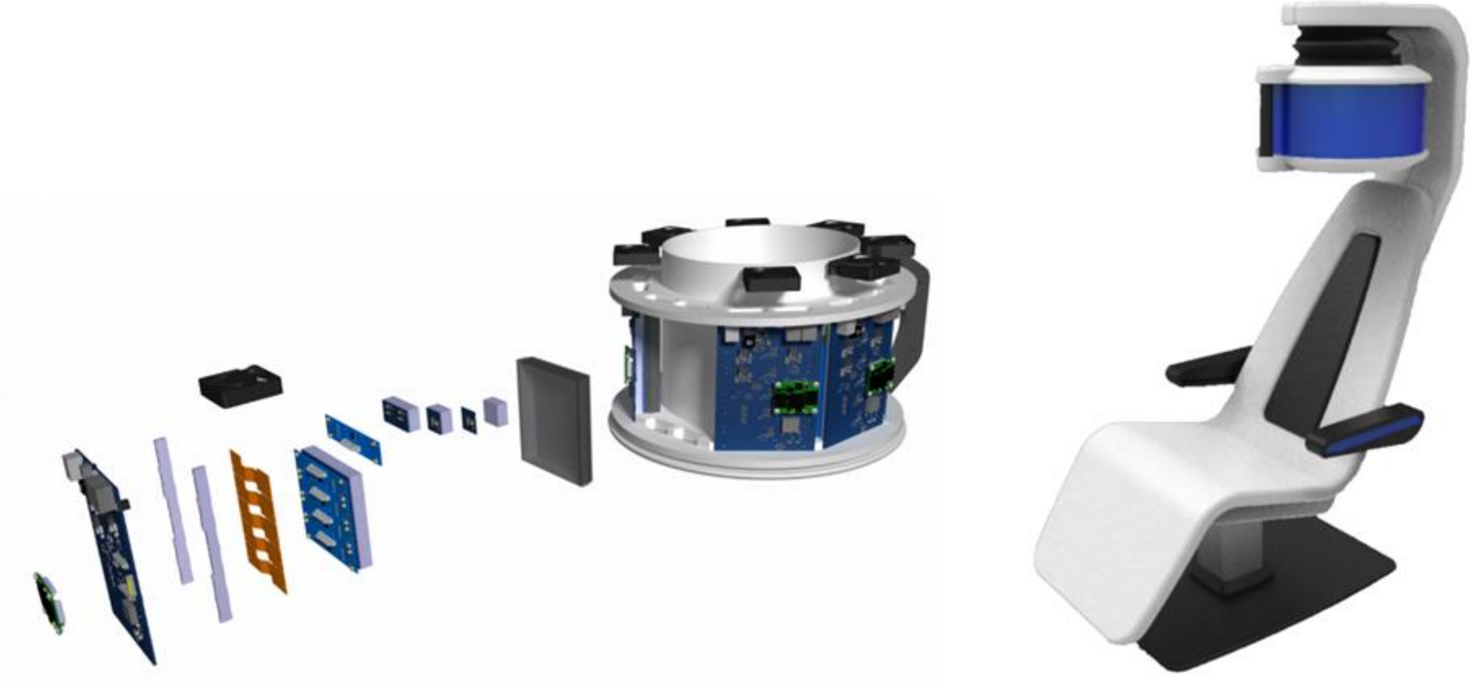
- **VIPUN Gastric Monitoring System**
  - A novel method for monitoring gastric activity (aimed at ICU patients)
  - Measures gastric motility i.e. stomach contractions
  - Indicates when it is appropriate to start/stop feeding the patient
- First contact with VIPUN in Oct 2019
  - Convince them we‘re better than local competition
  - Signed the contract in May 2020 (165 person-weeks in 2 years)
- Cosylab to develop the device from scratch
  - Full-stack device engineering
  - Design, software, hardware, documentation, ready for certification
- Finishing requirements phase
  - Starting the architecture and design
  - Choosing hardware components, preparing the first prototype

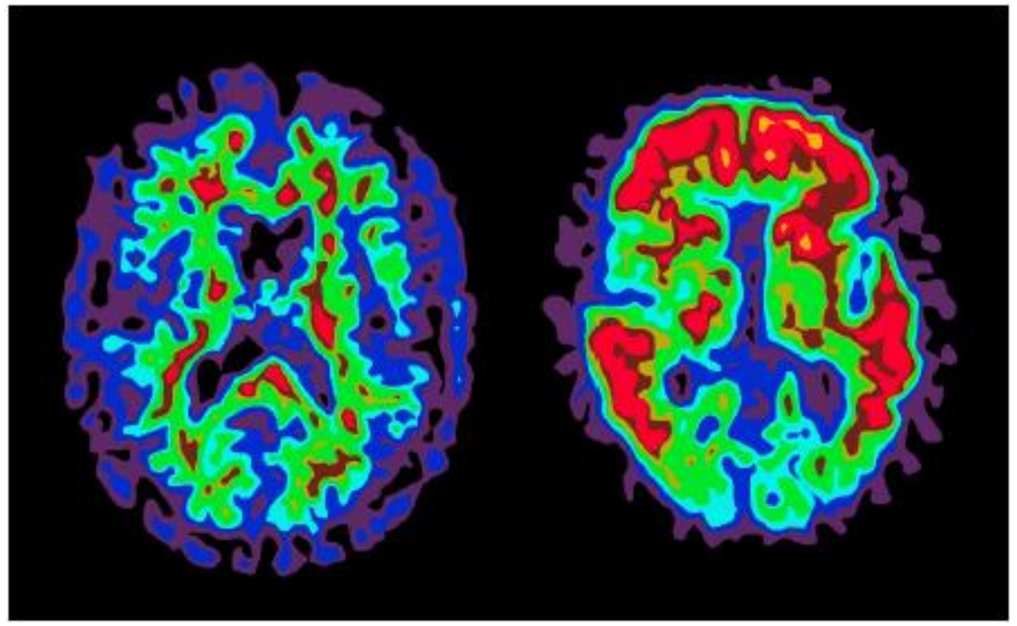




Positrigo

- **Brain PET* Scanner Development**
  - Main purpose: **early diagnosis of dementia**
- Challenges:
  - Fast **raw data acquisition**
  - Efficient **data processing** and **image reconstruction**
- Ongoing **Phase 1**:
  - gathering requirements,
  - planning software development,
  - analyzing the current status
- The Plan: **Phase 2** (SW development) and sucessfully deliver
  - Potential: PT integration (dose delivery verification)





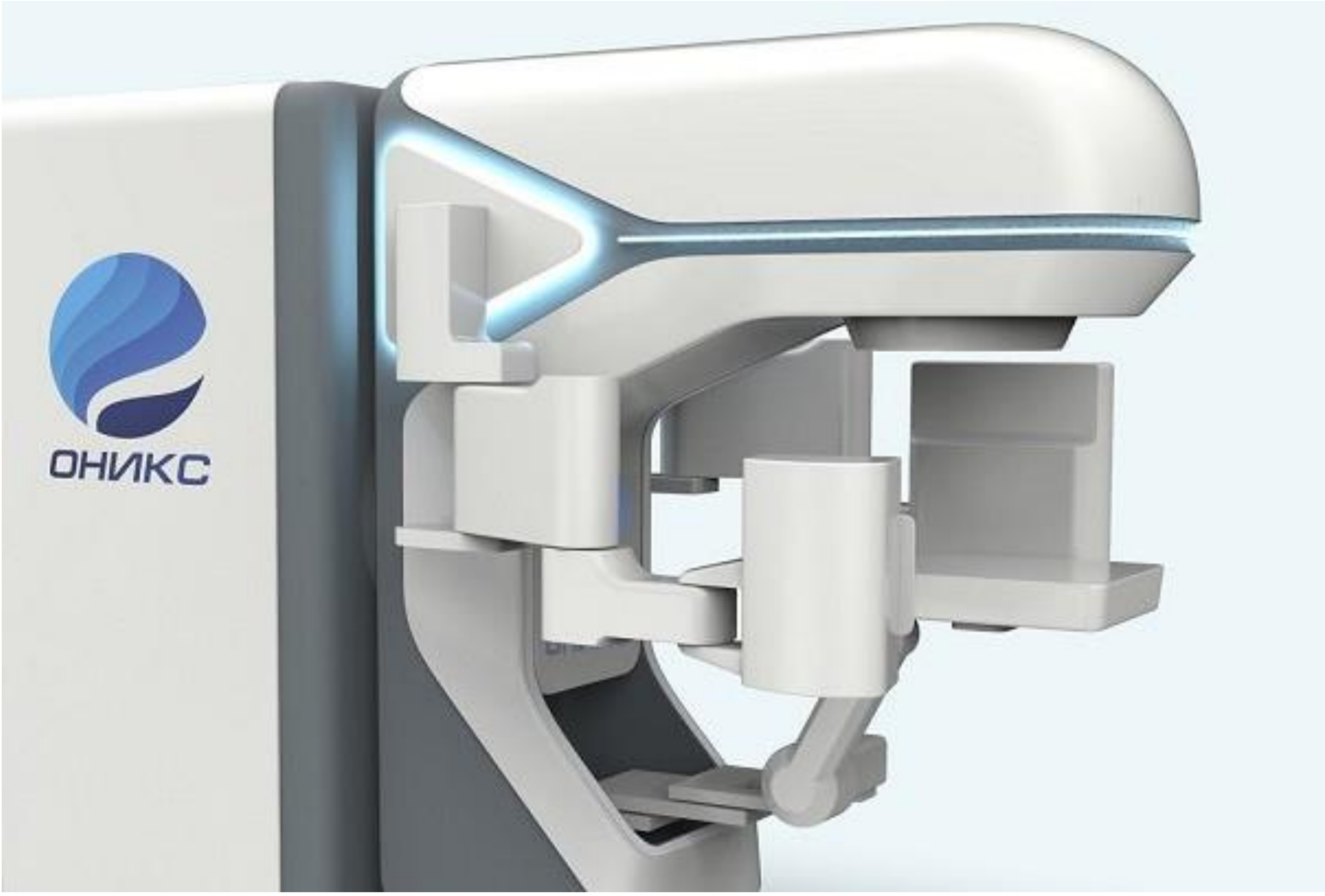
* **Positron emission tomography** (**PET**) is a functional imaging technique that uses radioactive substances known as radiotracers to visualize and measure changes in metabolic processes, and in other physiological activities including blood flow, regional chemical composition, and absorption. Different tracers are used for various imaging purposes, depending on the target process within the body.

Project examples

CSL Products

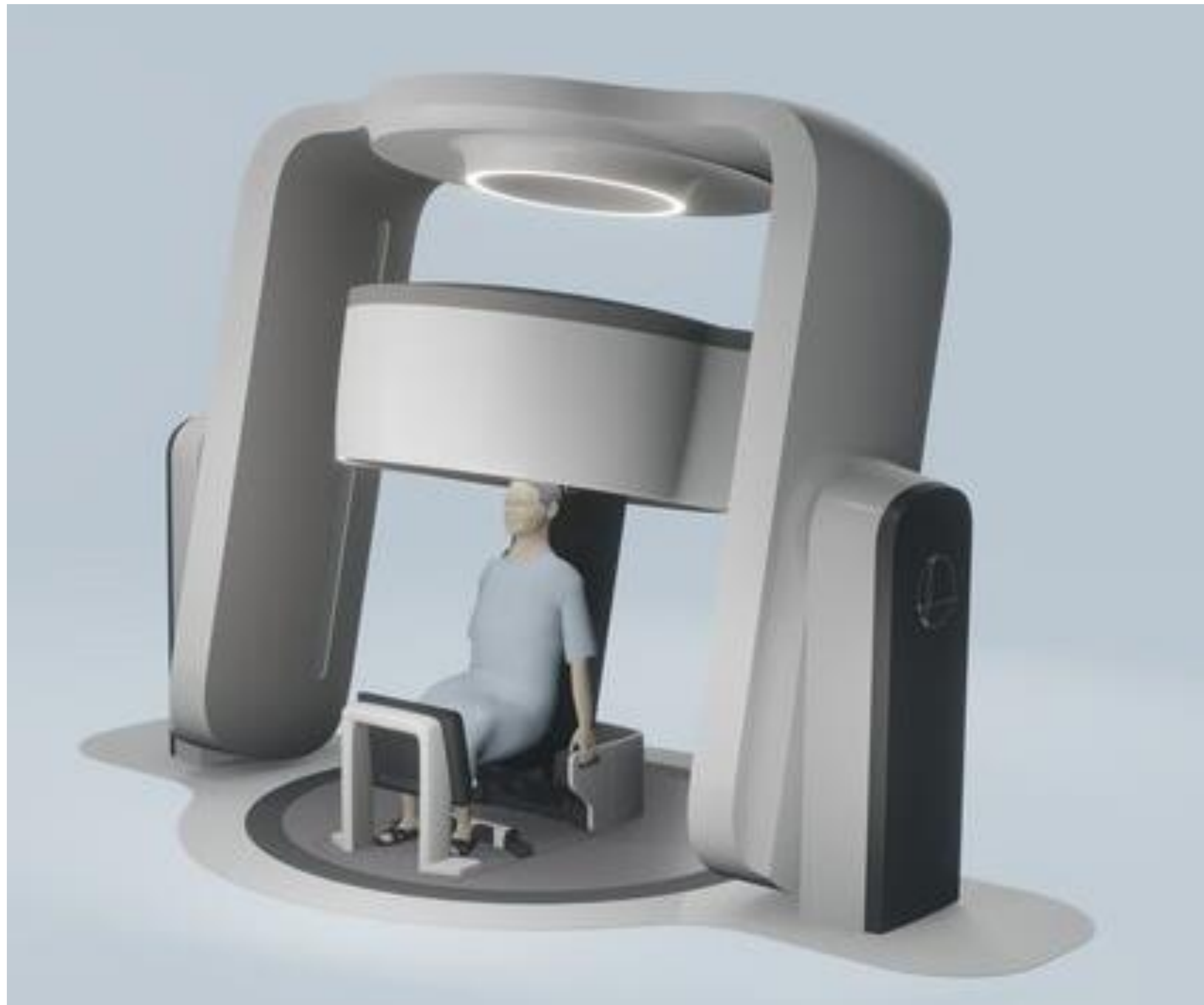
RosAtom Healthcare

- Joint venture with RosAtom healthcare for development of clinical software
- RosAtom is developing its own medical linac for radiotherapy
- Cosylab is developing clinical software: OIS and TPS
  - In time could also expend and do the controls for the linac machine
- Very big project, effort estimates for v1.0 at 50+ MY
- Expected delivery of software in mid 2022
- In order to reach a milestone, we have started development of TPS in spring. OIS was started last year.



LCC

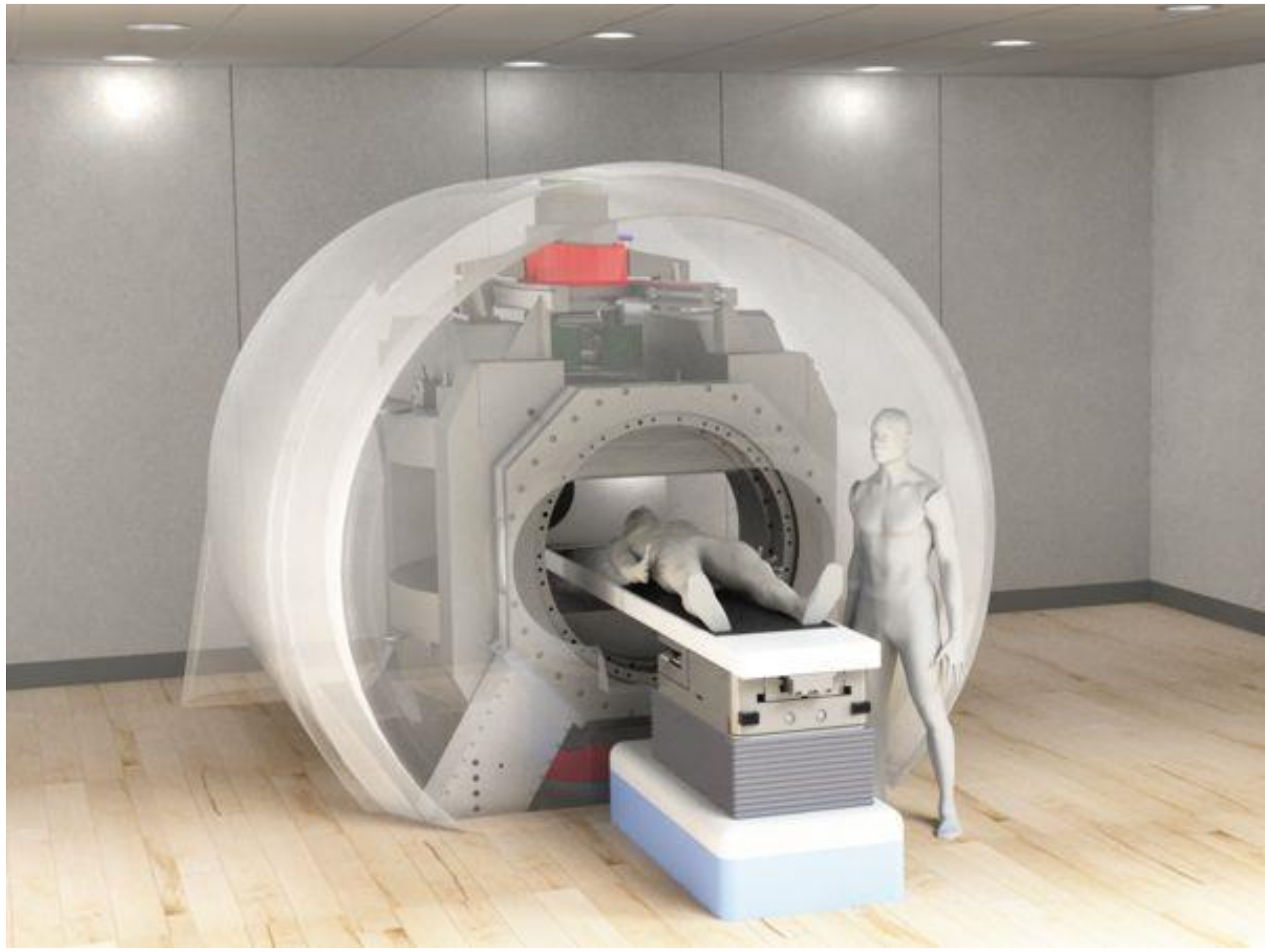
- Startup from US developing an upright patient positioning system (chair ☺) to be used with RT Linac and PT
- Cosylab is a partner taking over software
- Started collaboration in early 2020 with 1st project: CS for chair (Beckhoff PLCs)
- then 2nd on C-TCS for chair (clinical workflow manager)
- Just couple of weeks ago signed the 1st phase of development of a control system for the CT* that will be mounted on the chair,
- And signed a contract for 5 licenses for the position calibration software (called also the Imaging system)



* A **CT scan** or **computed tomography scan** is a medical imaging technique that uses computer-processed combinations of multiple X-ray measurements taken from different angles to produce tomographic (cross-sectional) images (virtual "slices") of a body, allowing the user to see inside the body without cutting.

MagnetTx

- Canada-based company is developing an MR*-linac for radiotherapy
- Cosylab is developing a so-called master controller: the brains of the machine that takes care of irradiation and control of the machine (analogous to C-DDS in PT)
  - Beckhoff PLCs turned out performant enough for more relaxed requirements of medical linacs as oppose to PT
- Started project Dec 2019 and are now already testing on-site (shorter dev lifecycle compared to PT)
- Team of approx. 7 working since March



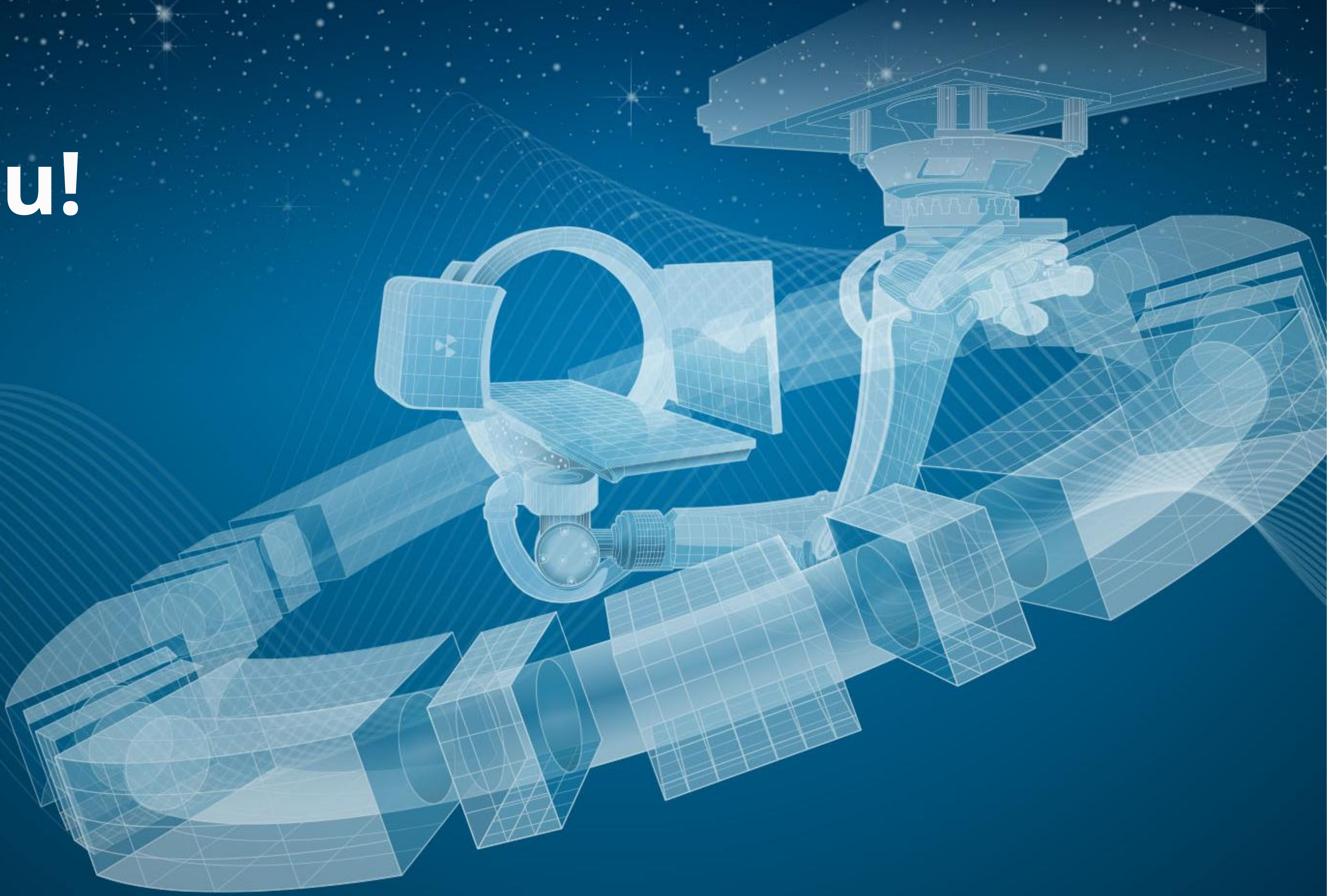
*** Magnetic resonance imaging** (**MRI**) is a medical imaging technique used in radiology to form pictures of the anatomy. MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves to generate images of the organs in the body. MRI does not involve X-rays or the use of ionizing radiation, which distinguishes it from CT and PET scans. MRI is a medical application of nuclear magnetic resonance (NMR)

HIMM – TAIJI and IMP

- Institute of modern physics (IMP) and spin out company of that institute TAIJI are developing a synchrotron based proton therapy machine
- In 2016, CSL started collaboration with a 1M EUR project on the accelerator, but clinical software they wanted to do themselves.
- In 2019 they called us to help on the clinical side as well due to problems with their own developments for the first machine (HIMM1)
- Now, we are working on the HIMM2 machine on C-TCS integration
- And we have an MoU for HIMM3-8 machines on the complete machine software: ACS, TCS, Safety and DDS, plus the OIS from the clinical SW side.

Thank you!

Žiga Kroflič



COSYLAB