COSYLAB
# Basics of Accelerator Control Systems

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Who are we?

- **2001 Cosylab** is founded after succesfully developed a control system for a German accelerator ANKA

- **10** locations **worldwide**
  - USA, China, Korea, Japan, Ukraine, Slovenia, Switzerland, Sweden, France, Russia (Siberia)

- **200+ people**
  - 150 + highlly skilled developers and engineers
 - 22 PhD holders from STEM fields
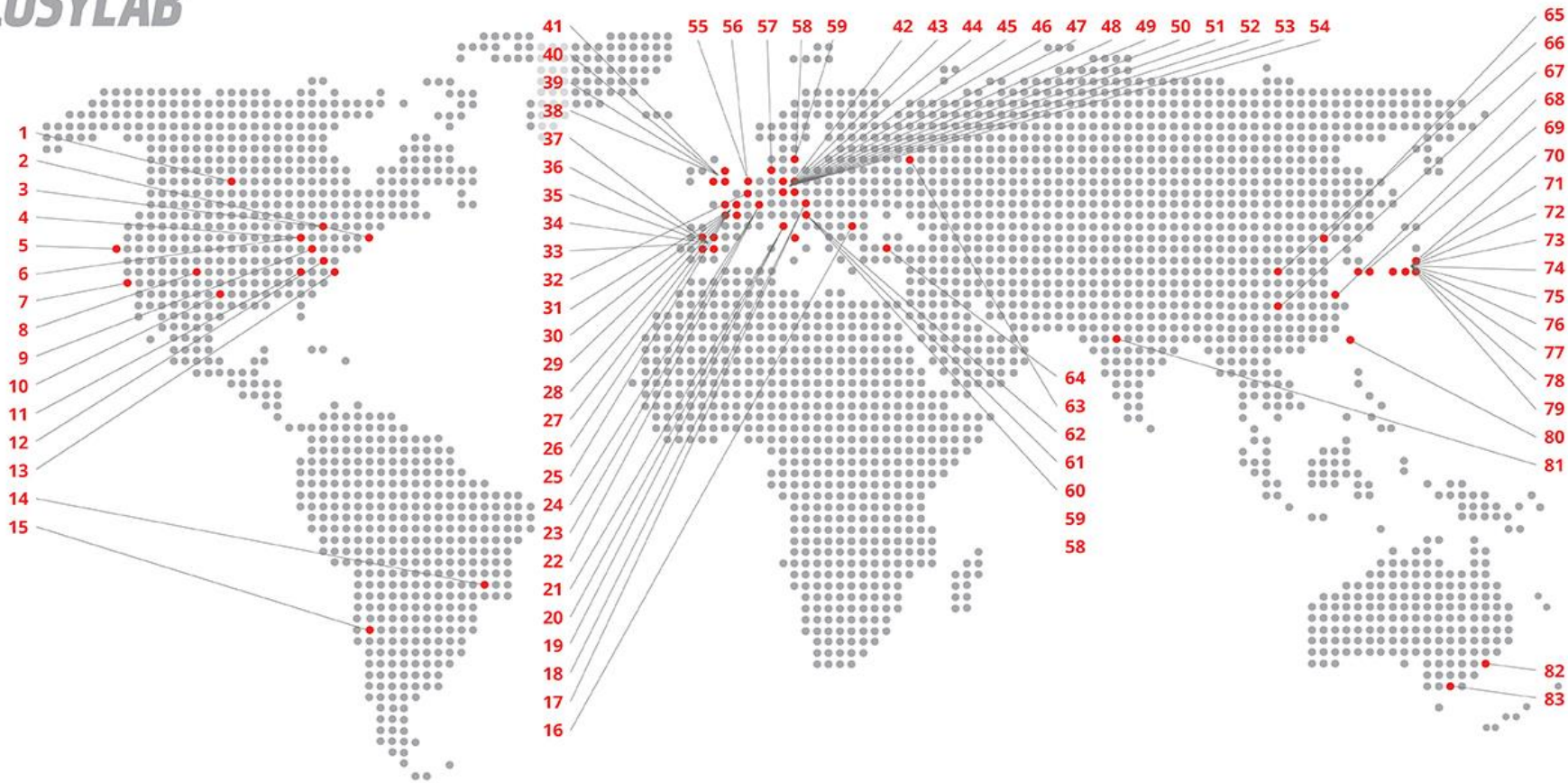
Customes From All Major Labs Worldwide

1. Canadian Light Source - CSL (CA)
2. Brookhaven National Laboratory - BNL (US)
3. Facility for Rare Isotope Beams - FRIB (US)
4. Advanced Photon Source - APS at Argonne National Laboratory (US)
5. Stanford Linear Accelerator Center - SLAC (US)
6. Ferni National Accelerator Laboratory - FNAL (US)
7. Varian medical systems (US)
8. Los Alamos National Laboratory - LANL (US)
9. Indiana University (US)
10. National Instruments - NI (US)
11. Spallation Neutron Source - SNS (US)
12. National Radio Astronomy Observatory - NRAO (US)
13. Thomas Jefferson National Accelerator Facility - JLAB (US)
14. Brazilian Synchrotron Light Laboratory (LNLS)
15. Atacama Large Milimeter Array - ALMA (RCH)
16. IFIN-HH (RO)
17. Cividec Instrumentation GmbH (AT)
18. EBG MedAustron (AT)
19. Sinchrotrone Trieste - ELETTRA (IT)
20. Kyma (IT)
21. Instituto Nazionale di Fisica Nucleare - INFN-LNL (IT)
21b. Instituto Nazionale di Fisica Nucleare - INFN-LNF (IT)

22. CERN - European Organization for Nuclear Research (CH)
23. Paul Scherer Institut - PSI (CH)
24. Linde Kryotachnik (CH)
25. Maatel Scientific Instrumentation (FR)
26. Xenocs (FR)
27. French Atomic Energy Commision (FR)
28. International Thermonuclear Experimental Reactor - ITER (FR)
29. European Synchrotron Radiation Facility - ESRF (FR)
30. bioMérieux (FR)
31. Synchrotron Soleil (FR)
32. Ion Beam Applications - IBA (B)
33. Procon Systems (ES)
34. CELLS - ALBA (ES)
35. Ciemat (ES)
36. Observatorio Astronómico Nacional - OAN (ES)
37. ESS Bilbao (ES)
38. Rutheford Appelton Laboratory (UK)
39. Daresbury Laboratory (UK)
40. Diamond (UK)
41. FMBO Oxford (UK)
42. Siemens (DE)
43. ACCEL (DE)

44. Electron accelerator - ELSA (DE)
45. Helmholtz Zentrum Berlin fur Materialien und Energie (DE)
46. European Molecular Biology Laboratory - EMBL (DE)
47. Physikalisch-Technische Bundesanstalt Berlin - PTB (DE)
48. Jenoptik AG Jena (DE)
49. Forschungzentrum Karlsruhe (DE)
50. Dortmunder Elektronen Speicherring Anlage (DE)
51. Deutsches Elektronen-Synchrotron DESY (DE)
52. European Southern Observatory ESO (DE)
53. Gesellschaft fur Schwerionenforschung (DE)
54. Feinwerk-und-Messetechnik GmbH (DE)
55. Imtech Vonk (NL)
56. Kernfysisch Versneller Instituut - KVI (NL)
57. Danfysik (DK)
58. European Spallation Source (SE)
59. MAX-lab, Lund University (SE)
60. J. Stefan Institute (SI)
61. ISKRATEL (SI)
62. BioSistemika (SI)
63. National Research Centre "Kurchatov Institute" (RU)
64. Turkish Accelerator and Radiation Laboratory at Ankara (TUR)
65. Tsinghua University (CN)

66. Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou (CN)
67. Southwestern Institute of Physics - SWIP, Chengdu (CN)
68. Shanghai Institute of Applied Physics, Chinese Academy of Sciences (CN)
69. Pohang Accelerator Laboratory (KR)
70. Hiroshima University (JP)
71. Institute for Molecular Science (JP)
72. Riken (JP)
73. Repic Corporation (JP)
74. Nichizou Denshi Seigyo Kabushikigaisha (JP)
75. Japan Atomic Energy Research Institute - JAERI (JP)
76. High Energy Accelerator Research Organisation - KEK (JP)
77. The University of Tokyo (JP)
78. Hitachi Zosen (JP)
79. Japan Synchrotron Radiation Research Institute - JASRI (JP)
80. NSRRC - National Synchrotron Radiation Research Center (TW)
81. Raja Ramanna Centre of Advanced Technology - RRCAT (IN)
82. Australian national nuclear research and development organisation - ANSTO (AU)
83. Australian Synchrotron - AS (AU)
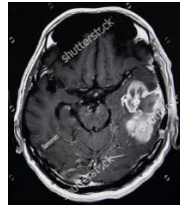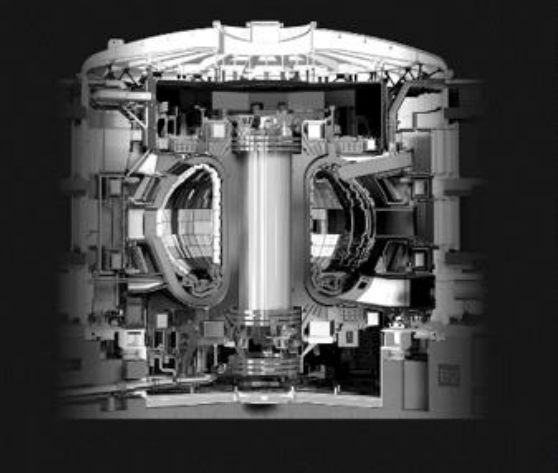
Areas Of Expertise

- A lot of our work revolves around **particle accelerator technologies**
  - But also:
    - Fusion reactors (e.g. ITER)
    - Radiotelesopes (e.g. CTA, ALMA)
    - Space (e.g. ESA, NASA)
    - Industrial (e.g. Qualysense)

- We offer **services** and **products** which require **expert knowledge**

- We develop **state-of-the-art hardware** and **software**

- We **integrate** them into **mankind's most complex machines**

- **Turnkey control system adapted for each accelerator** – with open source components

- **Integration of subsystems and equipment** into control system
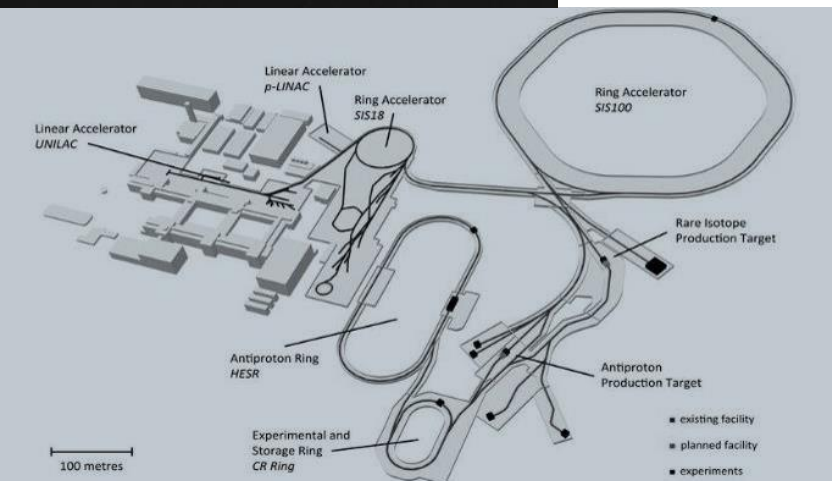
How are particles acclerated and steered

- 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**
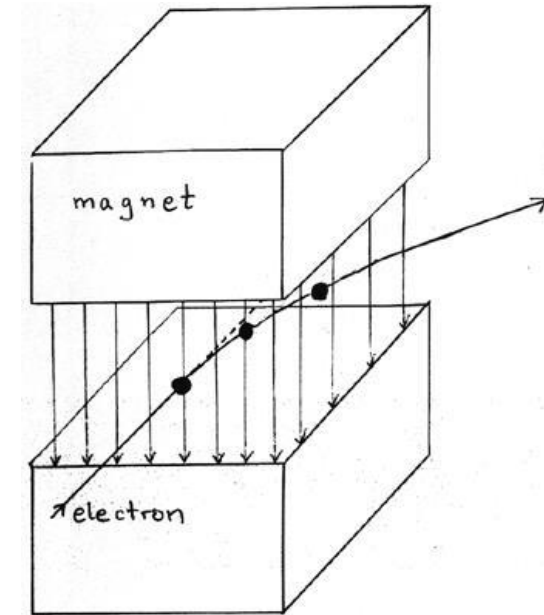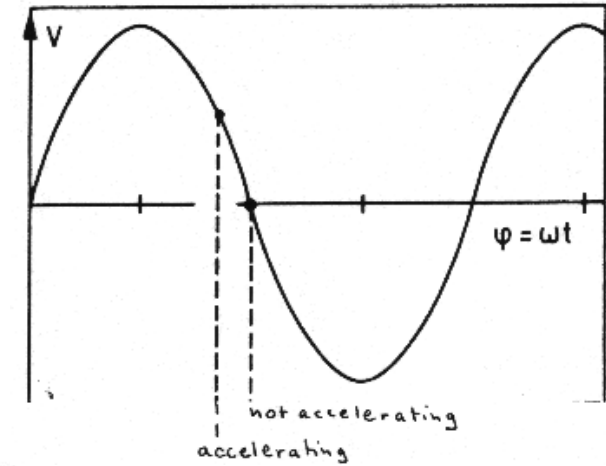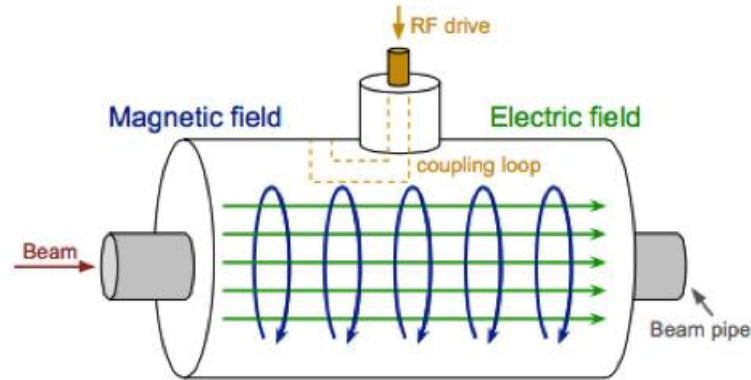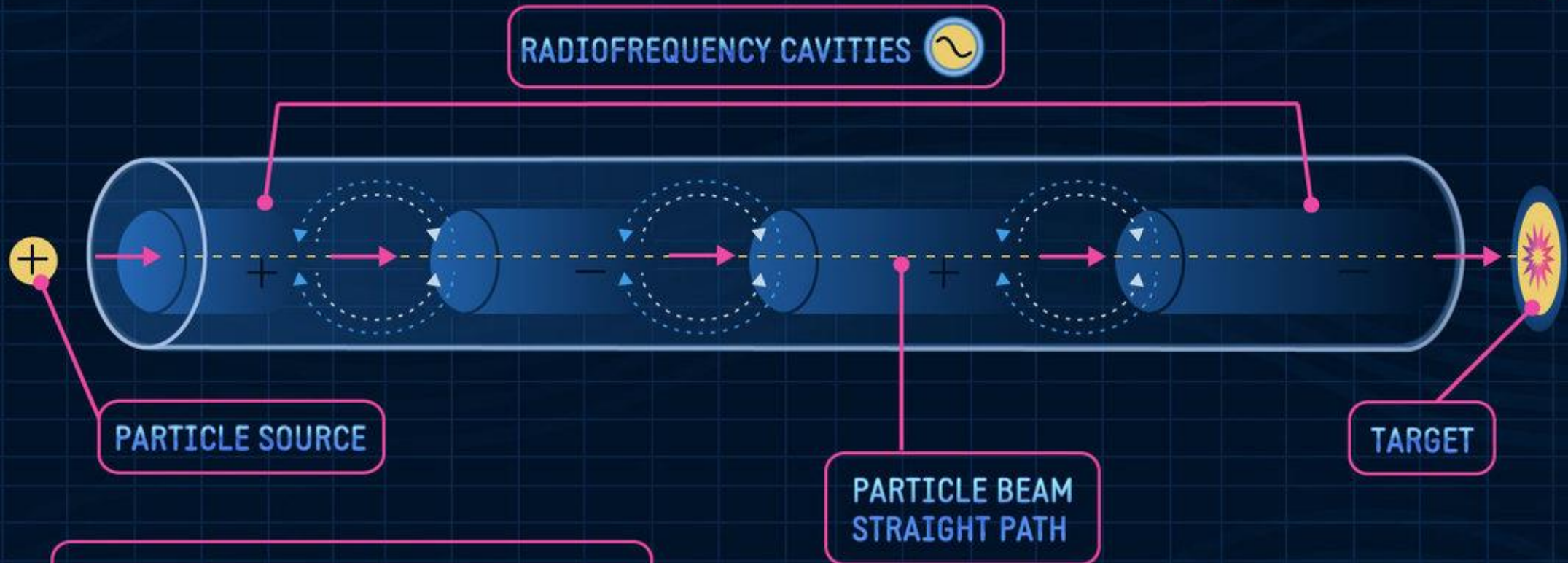
Accelerator types - synchrotron
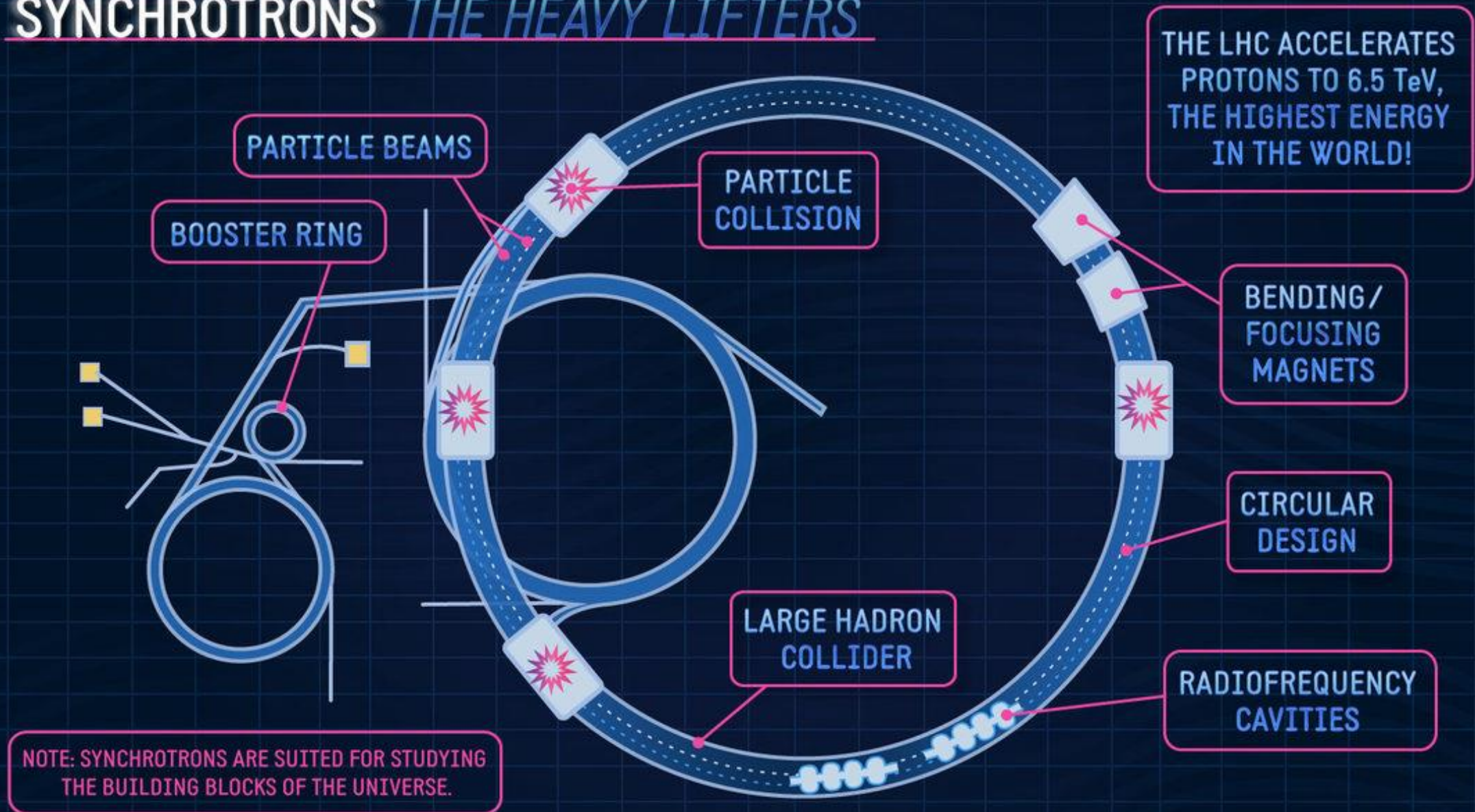
Accelerator types - linac

LINACS *STRAIGHT AND TO THE POINT*

THE LONGEST LINEAR ACCELERATOR IS 2 MILES LONG

RADIOFREQUENCY CAVITIES

PARTICLE SOURCE

PARTICLE BEAM STRAIGHT PATH

TARGET

NOTE: LINACS CAN PRODUCE MEDICAL ISOTOPES AND CAN CREATE BEAMS OF RADIATION FOR CANCER TREATMENT.

Accelerator types - cyclotron
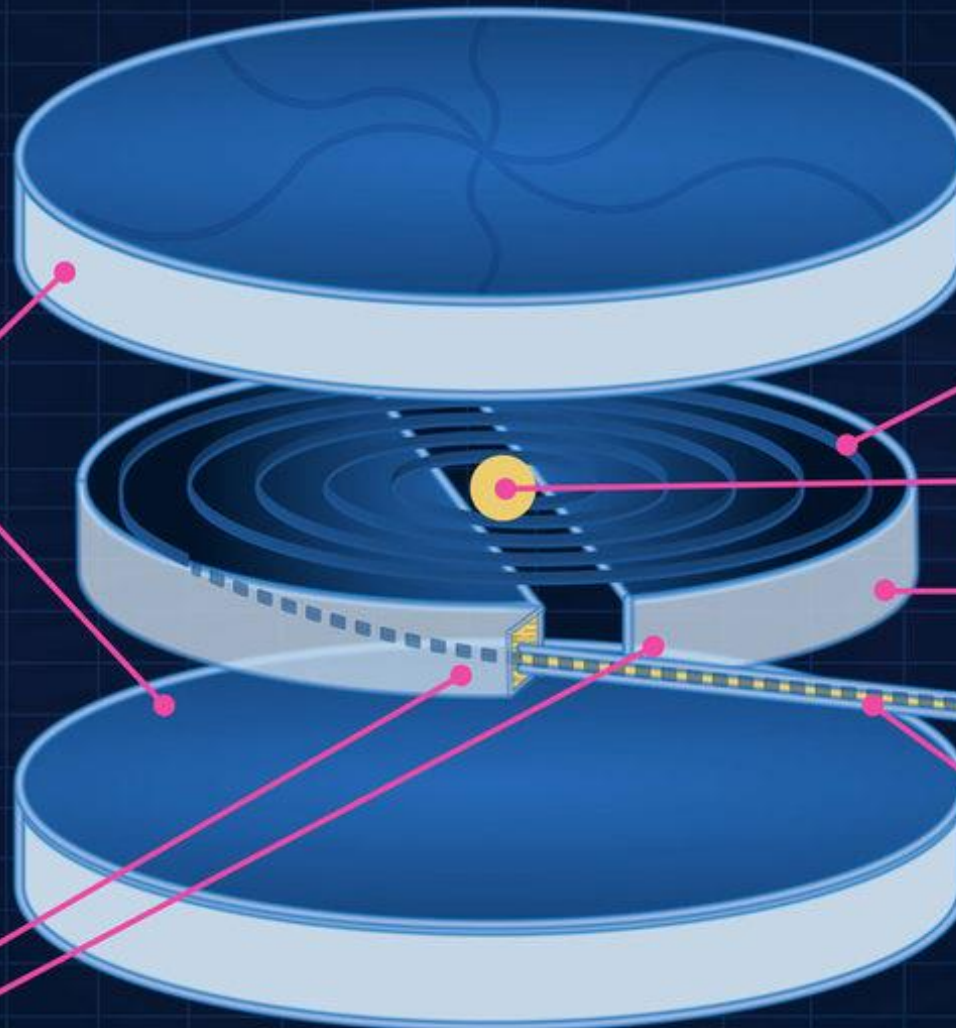
Accelerator devices/systems

Ion source

- 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.

Power Converters
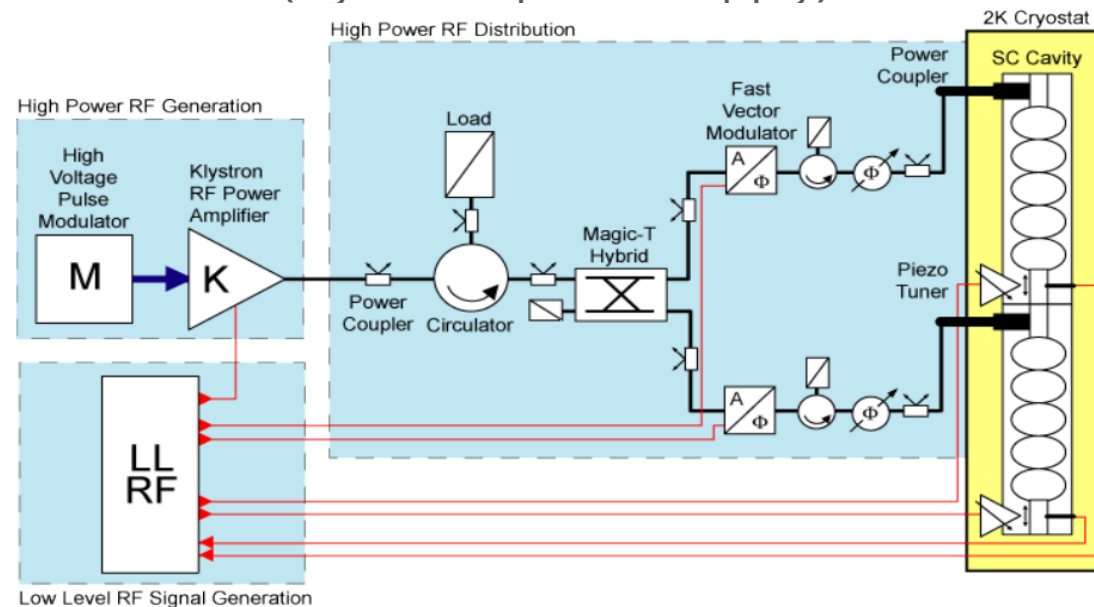

Quadrupole

Dipole

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
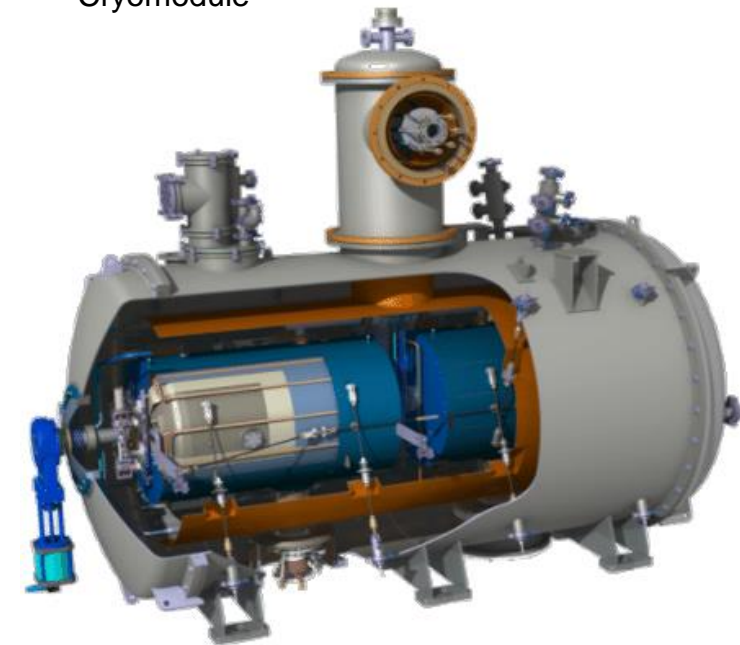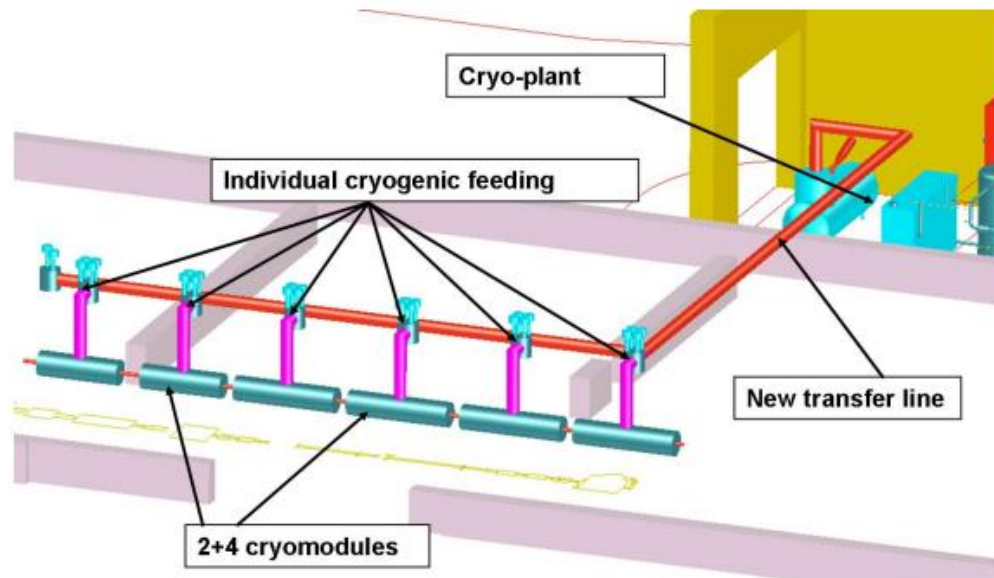 - Modulators (klystron's power supply)

RF cavity
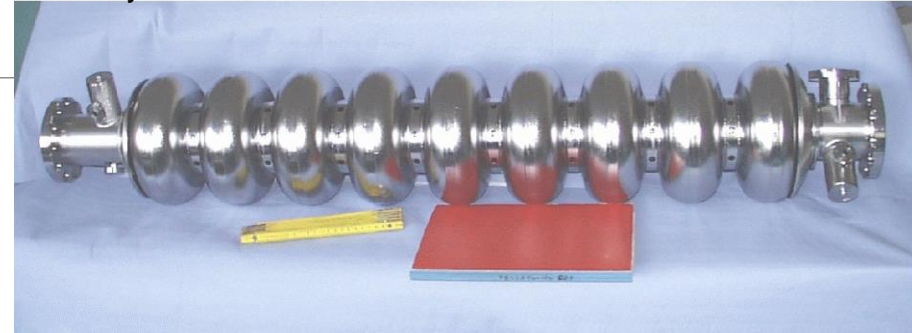
Klystron

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

Accelerator devices/systems, cont.

- Diagnostics – look at the particle beam
  - Beam position monitor (BPM), beam loss monitor (BLM), beam current monitor (BCM), wire-scanner, ...
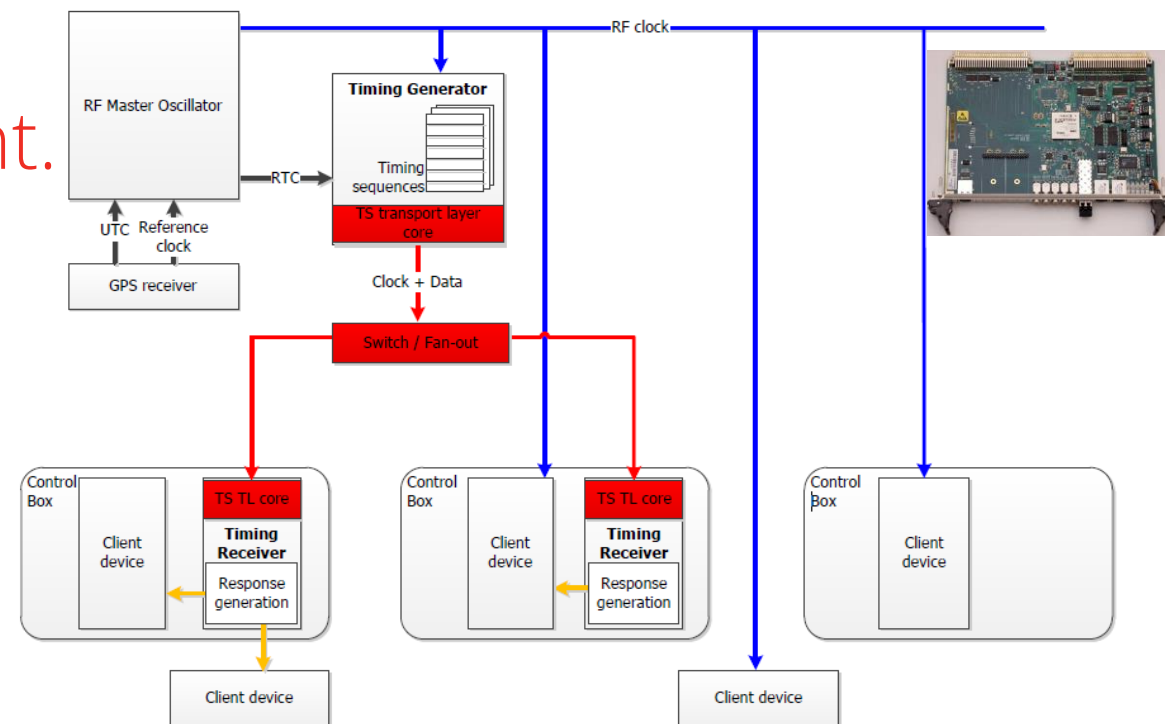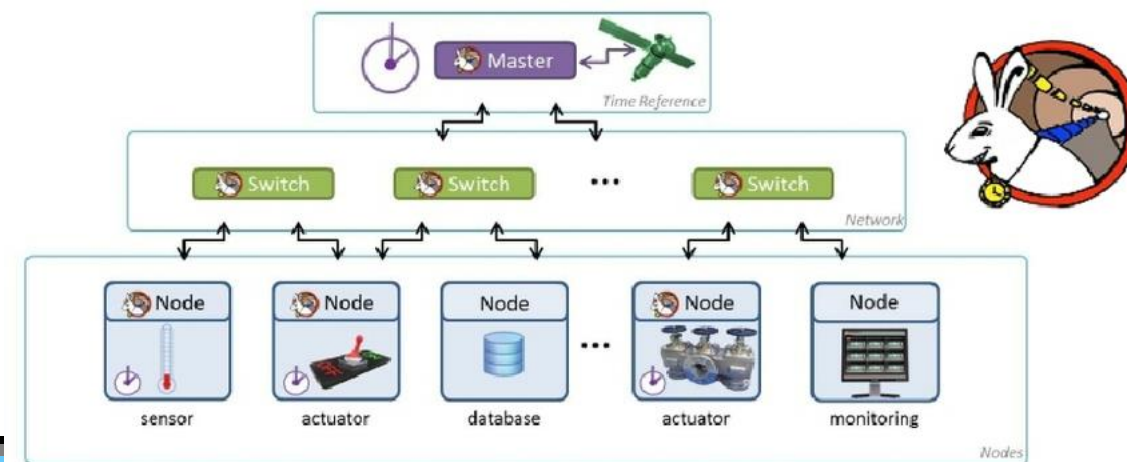
BPM

BCM

BLM

Wire-scanner
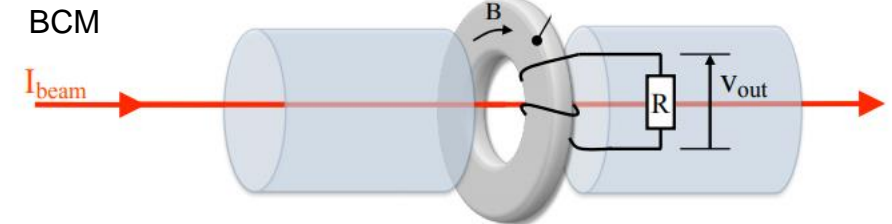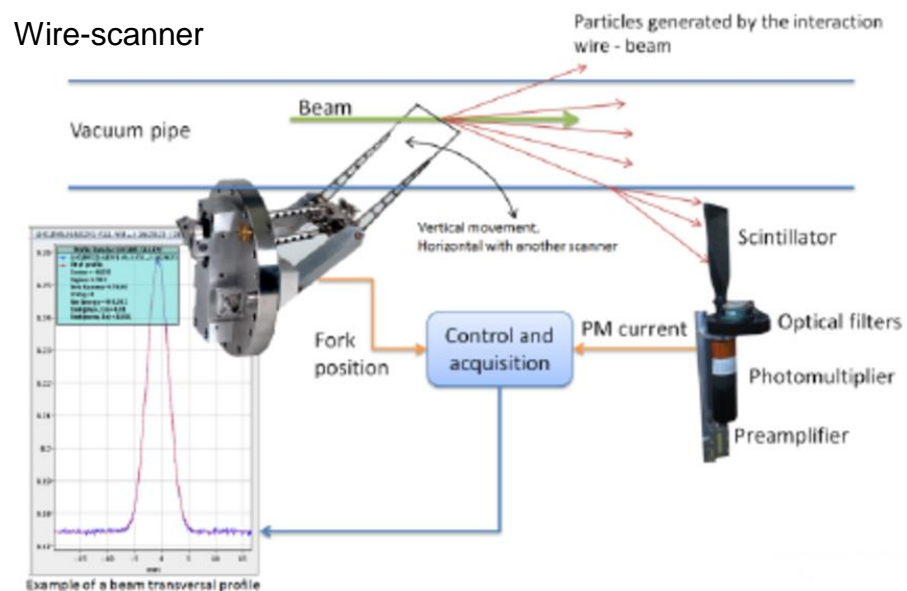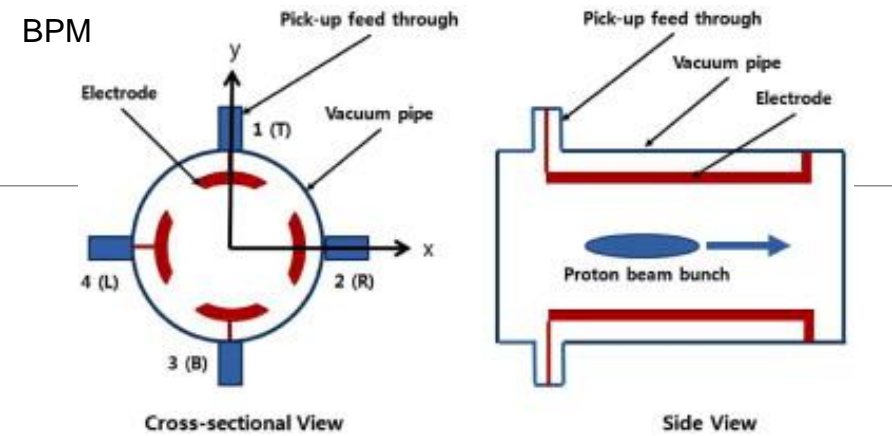
Accelerator devices/systems, cont.

- Timing and synchronization
  - RF reference - all RF devices have a stable reference to which they regulate their output
  - 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

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

White Rabbit timing system

Accelerator devices/systems, cont.

- Machine protection system (MPS)
  - Protection of accelerator devices (big cost if hardware destroyed by beam)
- 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
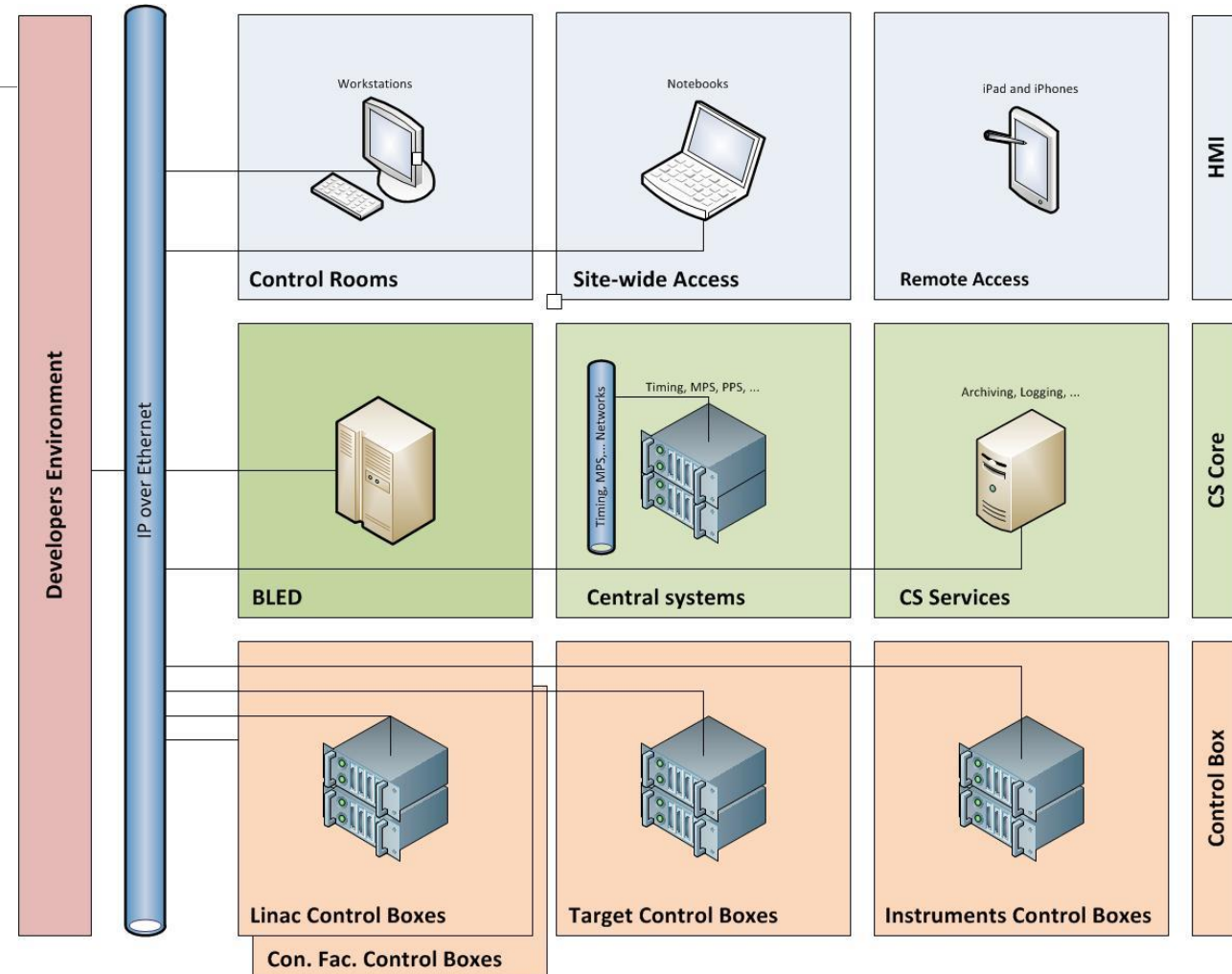
What does it take to build control system

- Be aware: control system is only **10%** of enitre project
  - Others: cooling, vacuum, power, RF...
- Skills needed
  - Technological and scientific knowledge
  - Good project management (coordination between teams)
  - Good system design and architecture (timing systems, MPS,..)
    - Hundreds of devices need to be controlled and monitores
    - Synchronization
  - Experience (which devices to chose for certain type of accelerators)

What does it take to build control system

- **Services** and **products** which require **expert knowledge**

- **State-of-the-art hardware** and **software**

- **Integration** of software and hardware into **mankind's most complex machines**

- **Knowledge** of **Integration of subsystems and equipment** into control system

Our contribution

MedAustron, Austria
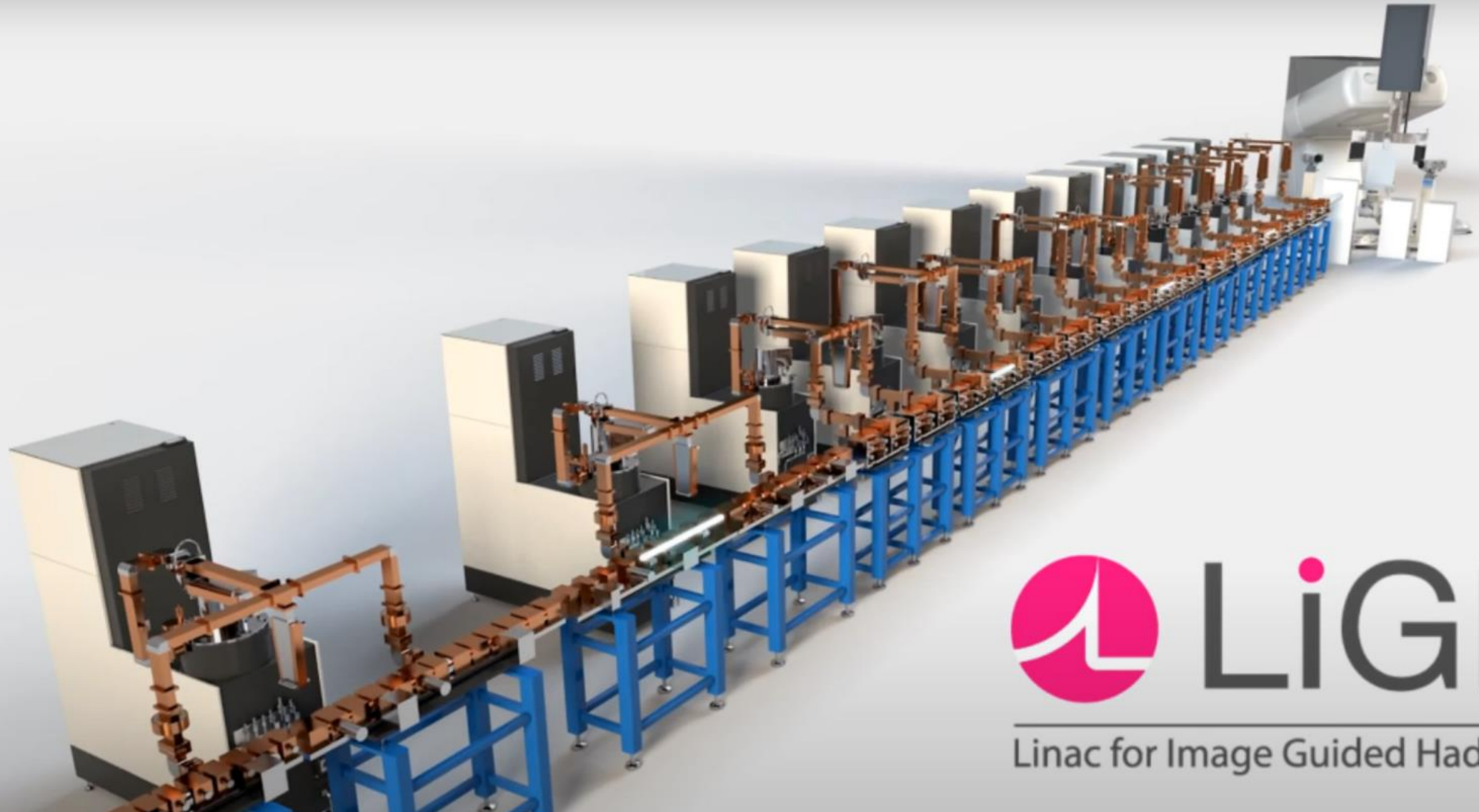– The most cutting-edge centers for cancer treatment and research

ADAM, Switzerland/UK
– LIGHT system

THANK YOU!

HITRI

Heavy Ion Therapy Research Integration

This material was prepared and presented within the HITRIplus Heavy Ion Therapy MasterClass school, and it is intended for educational purposes to facilitate students;
people interested to use any of the material for any other purposes
(such as other lectures, courses etc) are kindly requested to please contact the authors Matej Polzelnik,
matej.polzelnik@cosylab.com

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Heavy Ion Therapy Research Integration