HOW DOES BIG SCIENCE FACILITIES WORK AND WHAT ARE THE POSSIBILITIES





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Big Science Sweden

Vetenskapsrådet Swedish Research Council

VINNOVA Sweden's Innovation Agency

Big Science för Västerbotten

tillväxtverket

region västerbotten

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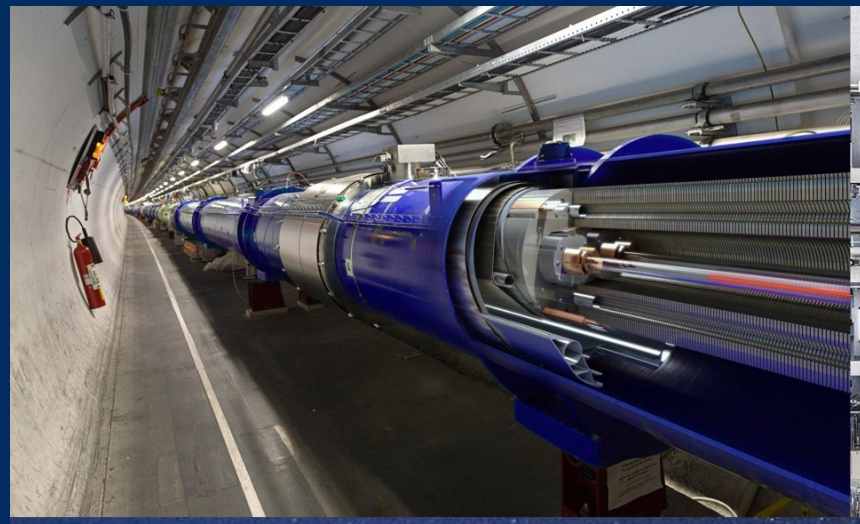
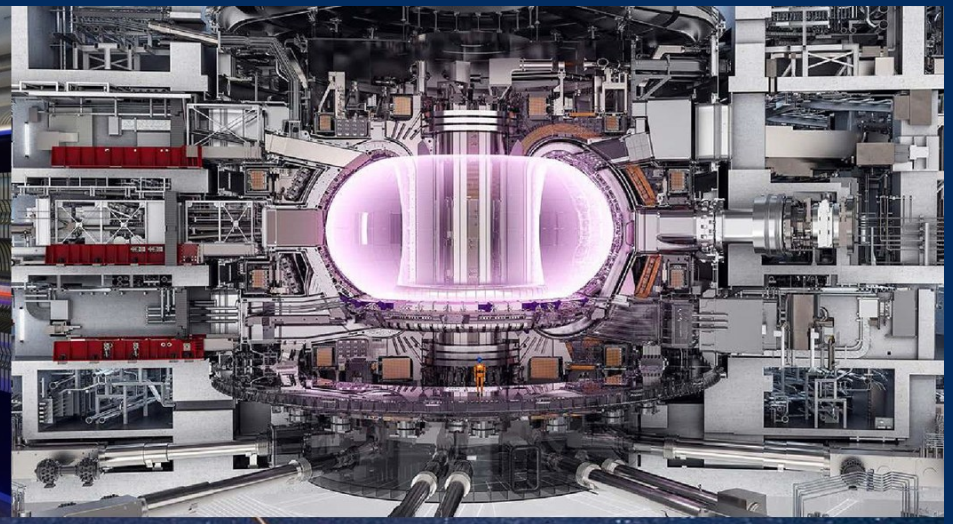
THREE MAIN TYPES OF FACILITIES

- **Accelerator based** (x-ray facilities, neutron facilities and for fundamental research)
- **Fusion reactors**
- Telescopes (optical, radar and radio)







ACCELERATOR BASED: Filming with X-rays instead of light

Accelerates and shakes electrons to create x-rays

MAX IV – IN LUND

The MAX IV Laboratory is a synchrotron light facility, whose beamlines provide modern X-ray spectroscopy, scattering/diffraction, and imaging techniques.



Used to develop/investigate

Medicines

Materials

Electronics

…….

Also at XFEL, ESRF, DESY

ACCELERATOR BASED:
Filming with Neutrons instead of light

Accelerates protons, smash into neutron rich material -> Neutrons

ESS IN LUND

European Spallation Source, ESS, currently under construction in Lund, Sweden, will be a multi-disciplinary research facility using the world's most powerful neutron source, based on particle accelerators and spallation technology.

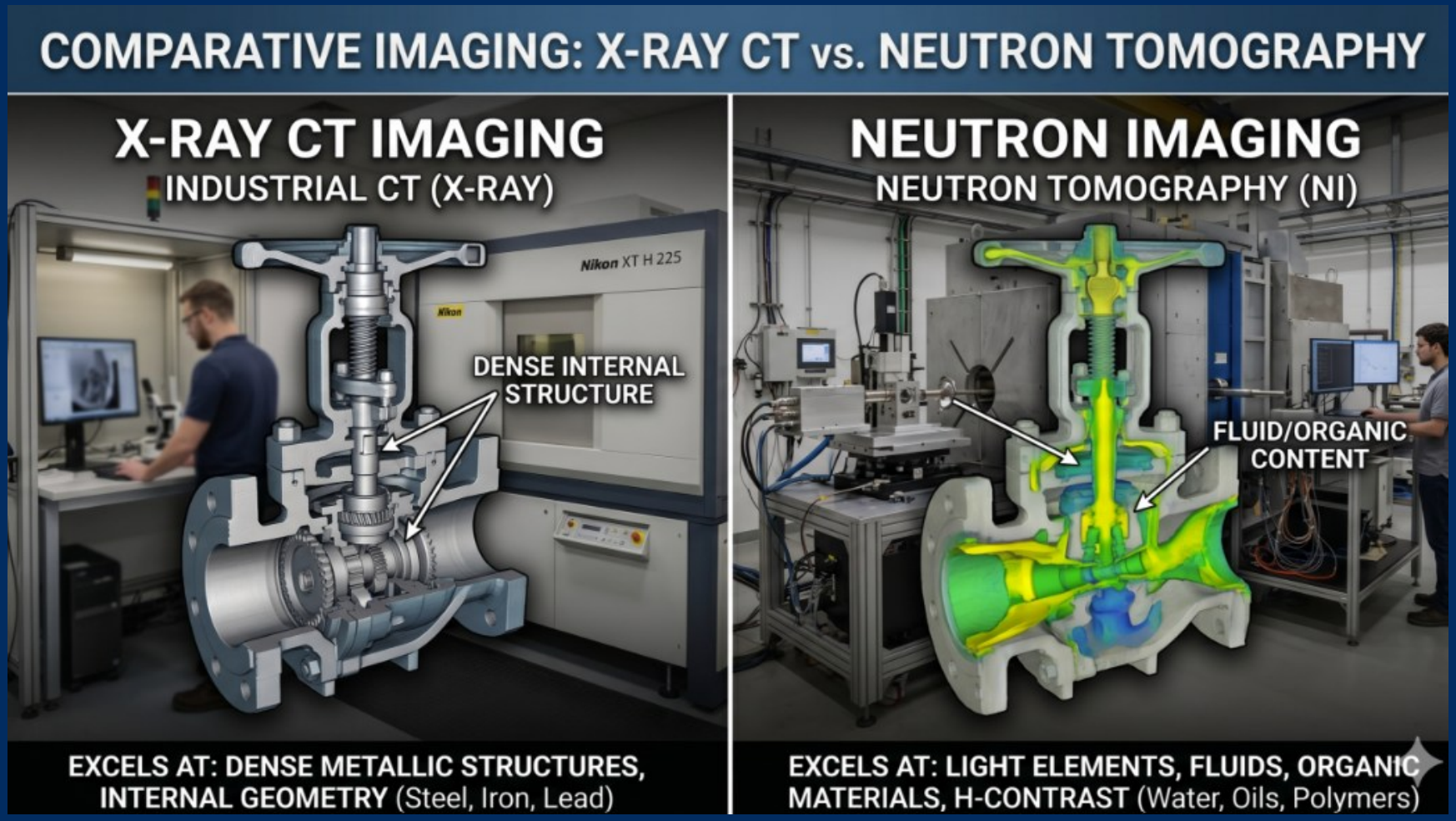


Used to develop/investigate

Medicines
Materials
Electronics
.....

Also at **ISIS** and **ILL***

What you miss with X-rays is visible with Neutrons



ACCELERATOR BASED:
Particle colliders – fundamental research

CERN in Geneva
FAIR in Darmstadt

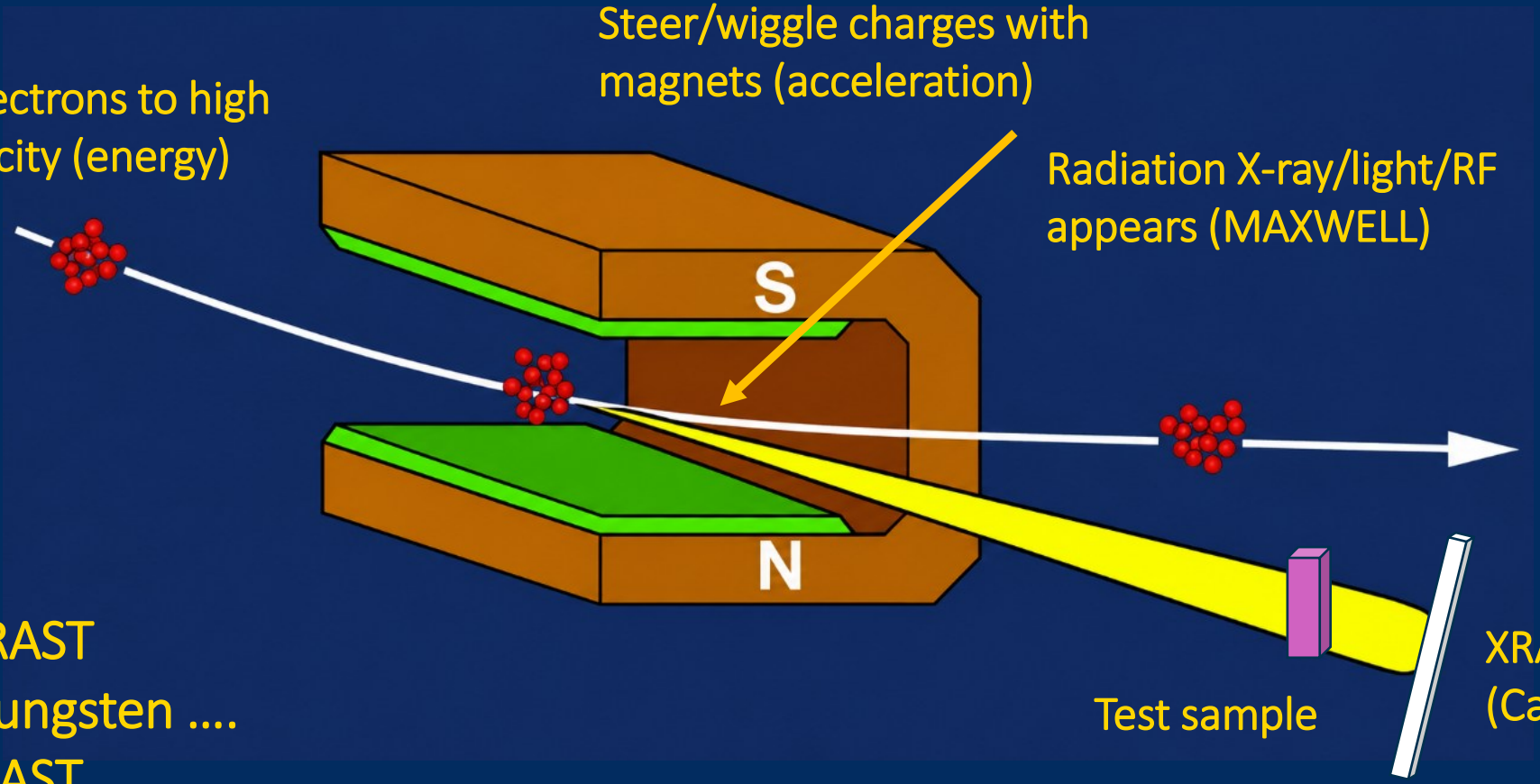
Accelerates protons and heavy ions and smash them





WHY PARTICLE ACCELERATORS IN X-RAY FACILITIES?

Filming with X-rays in Light/X-ray sources (synchrotrons), MAXIV, ESRF, XFEL



HIGH CONTRAST
Lead, Iron, Tungsten ....
LOW CONTRAST
Hydrogen, water, plastic…

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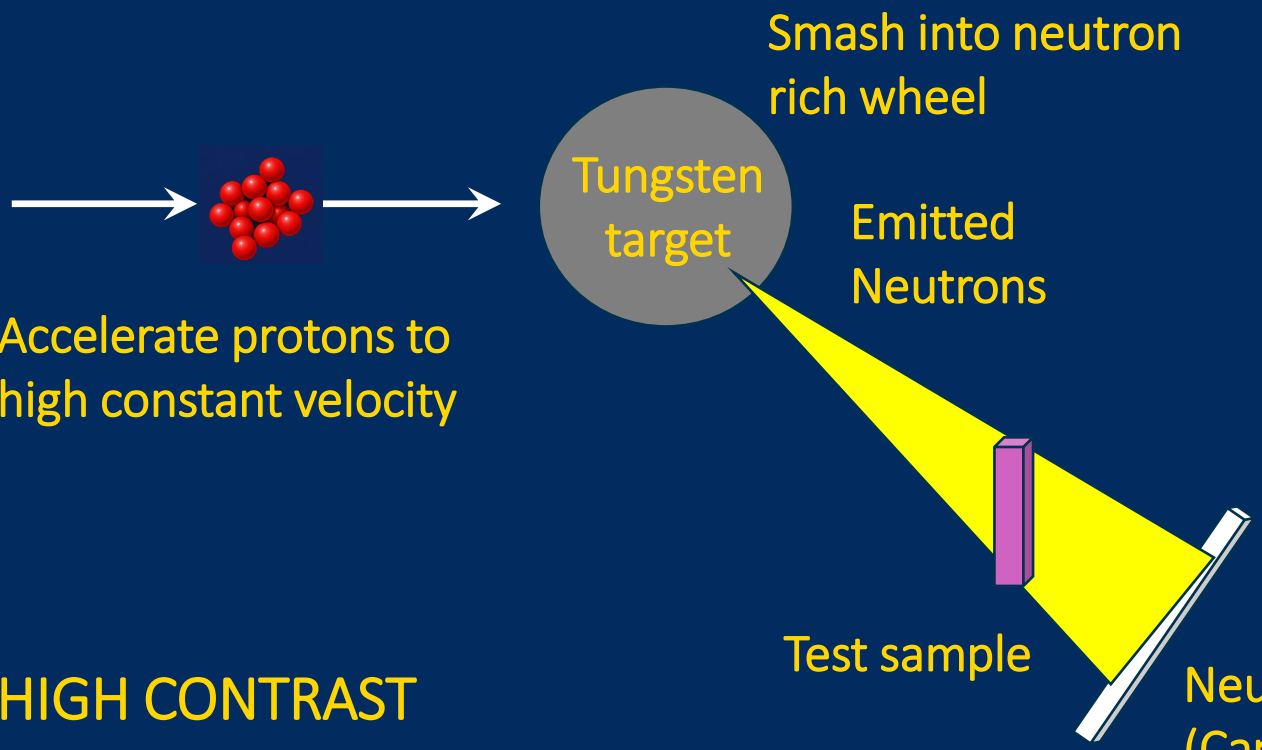
WHY PARTICLE ACCELERATORS IN NEUTRON FACILITIES?

Filming with Neutrons in spallation sources, ESS, ISIS, DONES





HIGH CONTRAST
Hydrogen, water, plastic..
LOW CONTRAST
Lead, Aluminum ..

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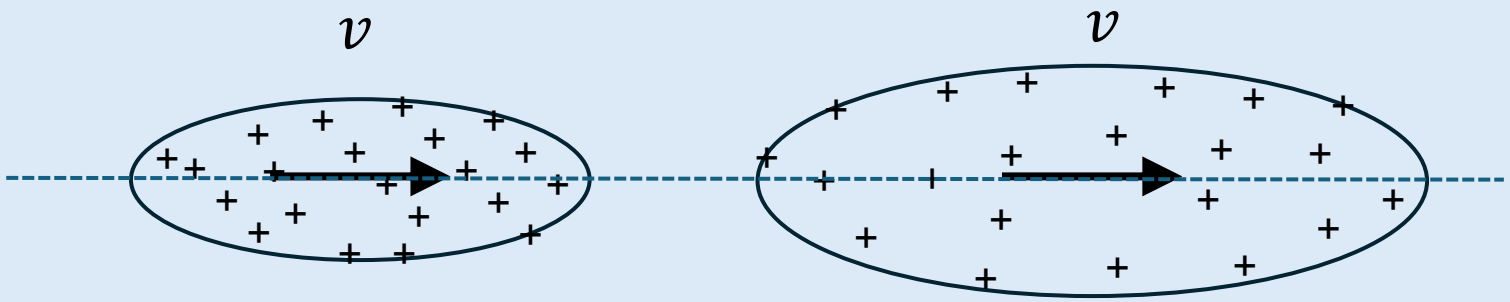
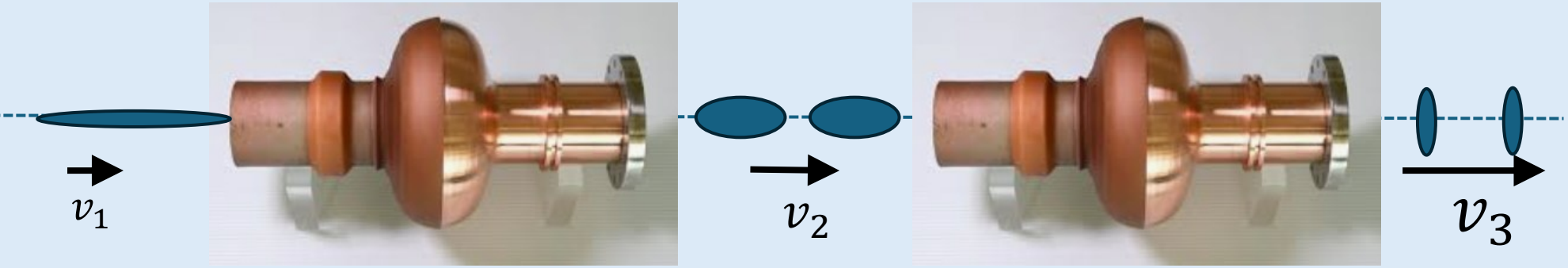
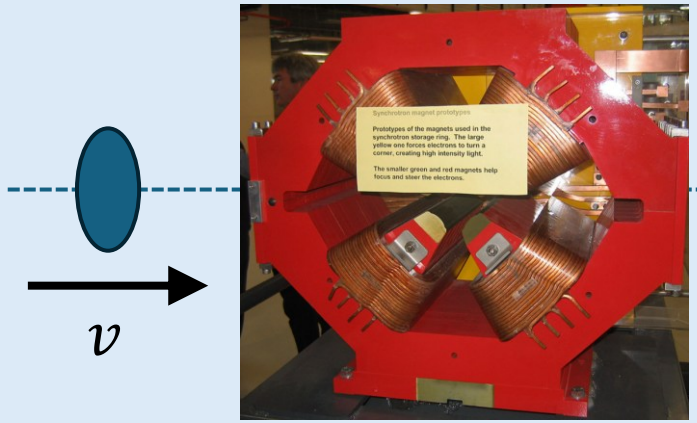
A particle beam is a stream of particle bunches (Lorentz force)



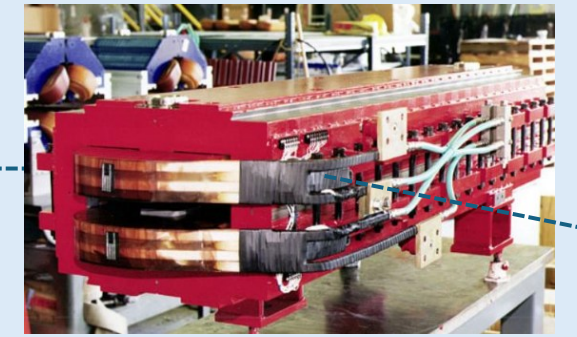
A particle bunch is a growing cloud of about ca 100 billion particles with the same charge (repelling)



Cavities increase speed, clusters and compresses the cloud in the direction of speed



4-pole magnets compress the cloud ⊥ to speed in one plane (-> pairwise use)



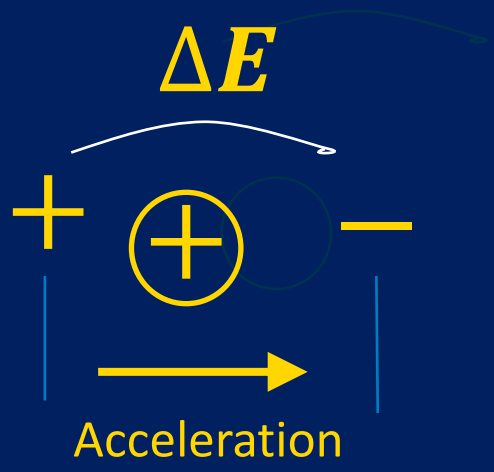
Dipole **magnets steer** particle cloud

Magnets steer at Constant speed

HOW ARE PARTICLES ACCELERATED?



Lorentz force (first term)



RESONANCE CAVITY -> EXTREMELY LARGE ELECTRIC FIELDS

$\Delta E \approx 5 \frac{kV}{m}$ from 400 kV powerline

$\Delta E \approx 50\,000 \frac{kV}{m}$ in resonance cavity

100MHz-10GHz,

3000-30 mm free wavelength $\lambda = \frac{c}{f}$



Example: Push the swing at the ”right” moment -> high speed with soft push at resonance frequency

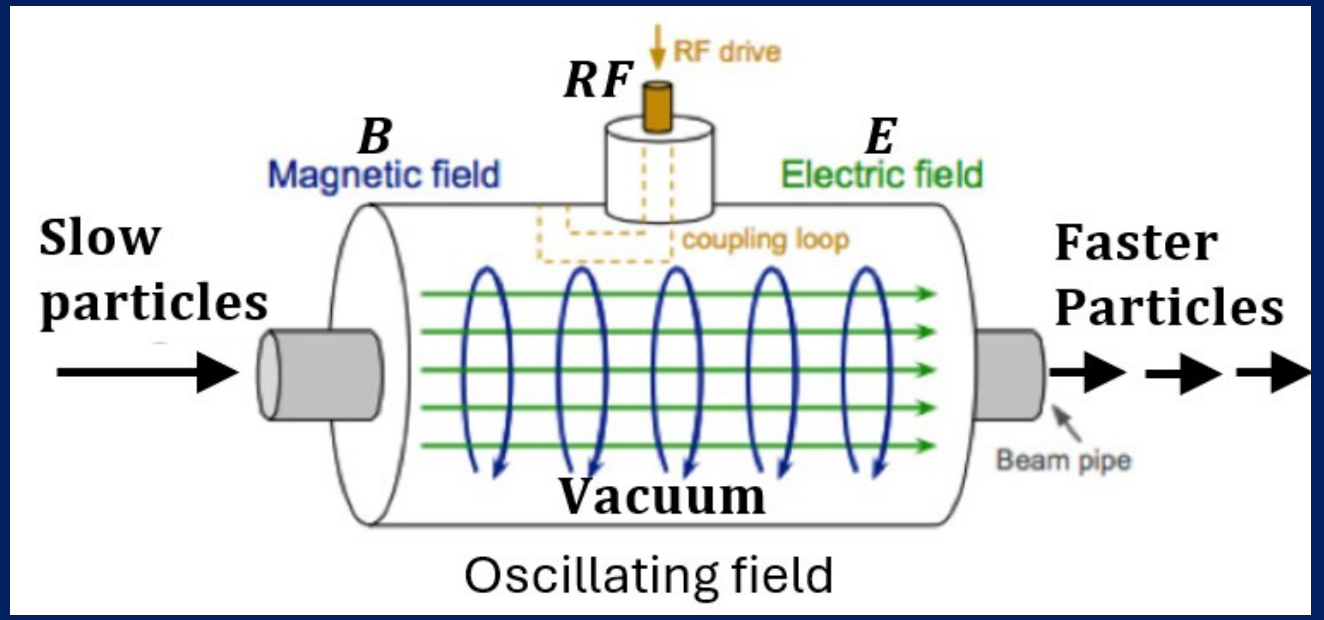
Shorter rope give shorter time period (higher frequency)

Analogy for accelerator cavity: Blowing air into bottles

Resonance tone when blowing air into bottles. Large volume give lower tone (frequency Hz)



Electromagnetic resonance in a vacuum cavity (tin can) when radiofrequency waves (RF) are inserted



Electromagnetic **resonance** in a cavity gives an axially oscillating electric field $\boldsymbol{E}$ and an oscillating rotating magnetic field $\boldsymbol{B}$ => Particles exit the cavity in bunches with roughly the same speed. **Described by Maxwells equations for $\boldsymbol{E}$ and $\boldsymbol{B}$.**

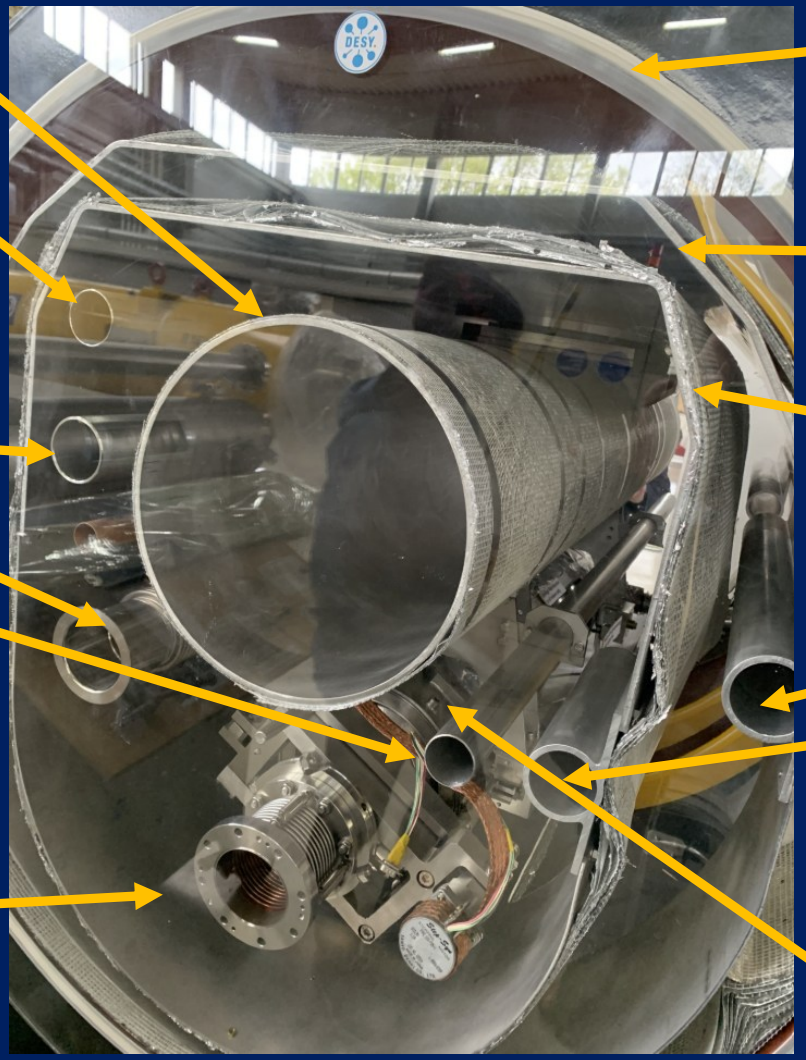
WHAT IS CONTAINED WITHIN A BEAM LINE

2-PHASE COOLING
- Helium gas return pipe $\sim 2K$
- Liquid Helium pipe $\sim 2K$

(for superconductive cavities and magnets etc.)

Additional helium gas
Transfer lines 5-8K
and start-up line

Particle beam pipe
UHV $\sim 10^{-10}$ mbar to
avoid collisions with air



Outer vacuum vessel
$\sim 10^{-6}$ mbar for insulation

Outer thermal shield
Temperature 40-80 K

Inner thermal shield
Temperature 5-8 K

THERMAL SHIELD COOLING
- Helium gas 40-80 K
- Helium gas 5-8 K

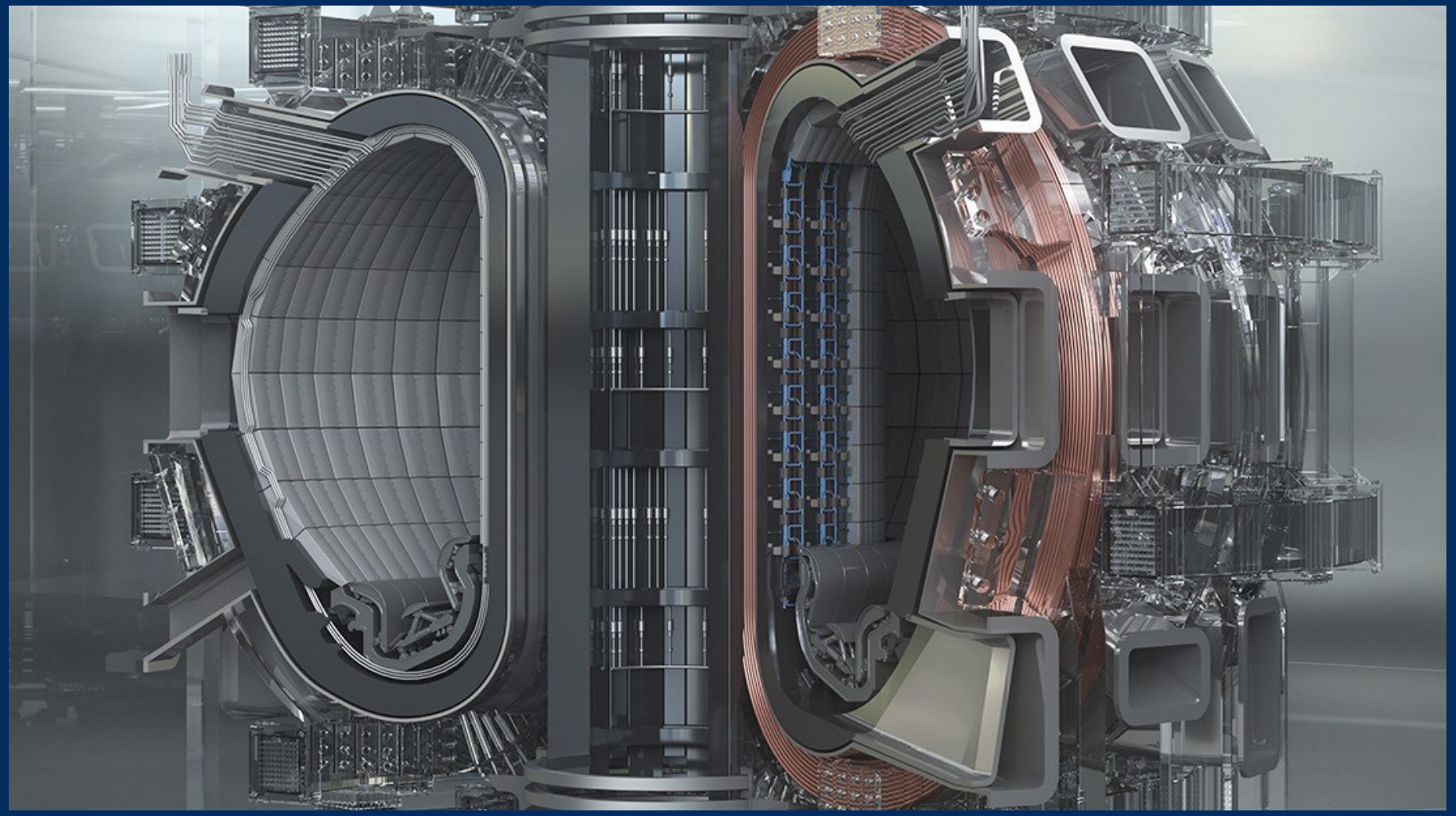
HIDDEN ACCELERATOR CAVITY

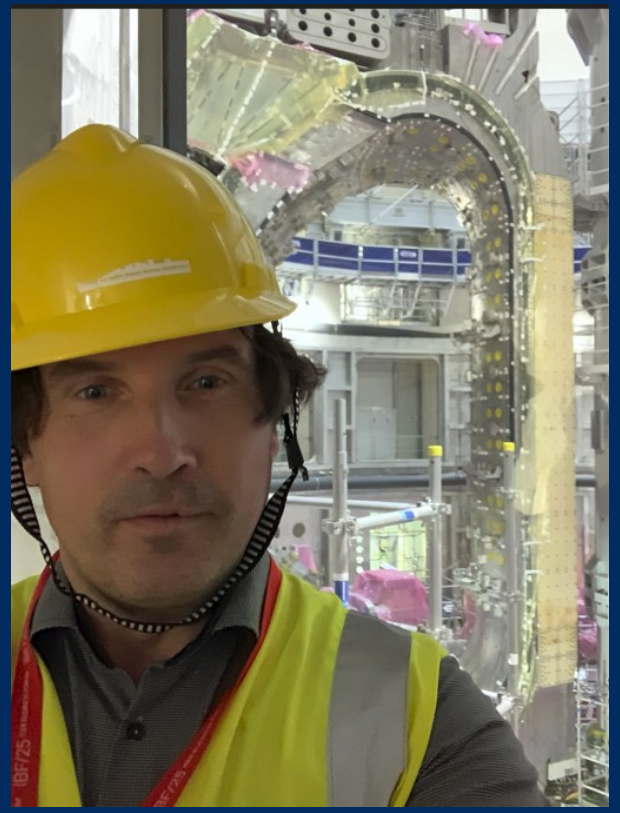
2-PHASE COOLING
- Helium gas return pipe $\sim 2K$
- Liquid Helium pipe $\sim 2K$

(for superconductive cavities and magnets etc.)

FUSION – AN ENERGY SOURCE FOR THE FUTURE

ITER in Cadarache
F4E in Barcelona
JT-60 in Japan





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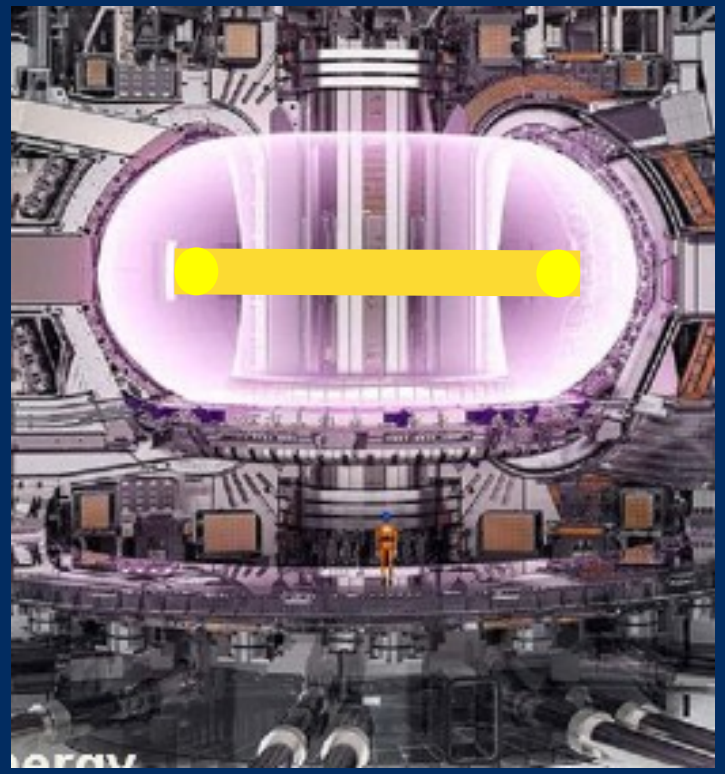
FUSION FACTS AND CHALLENGES

ITER is an experimental Fusion reactor in Cadarache



Note the person at the bottom
Cost > 200 miljarder SEK (600)

Fusion – The energy source of the future

- Sun on earth *(”a nuclear gas furnace”)*
- Energy of 1 gram fusion fuel correspond to 11 tons of coal
- Fuel is partly in water (hydrogen as deuterium and tritium)
- Very little long term radioactivity created from a fusion reactor
- Fuel for about 10 sec in the reactor due to continuous fuel supply gives safe worst case scenario as compared to conventional fission power

Fusion – material challenges

- Plasma is about 150 million degrees and contained in a donut shaped combustion chamber
- Plasma is kept away from the walls with strong superconducting magnets kept at -268C about 2m from the plasma
- Massive doses of neutron radiation gives extensive material damage
- First wall materials are Tungsten-CuCrZr-stainless steel-B4C

IMPORTANT TECHNOLOGY AREAS

- Accelerator technology
- Vacuum technology
- Detector technology
- Cryogenics
- AI and machine learning
- Advanced materials, coatings, joining and casting
- Data management and visualisation
- Data transmission and signal processing
- Magnets
- Software and control systems
- Optics
- Robotics
- Sensors and detectors
- Radiation protection and monitoring
- Remote control
- Electronics, RF and microwave technology

CERN have 2700 staff and 12 000 external researchers. Most staff work with the areas above

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POSSIBILITIES FOR RESEARCHERS

- **AIMday**

Main purpose:	Start cooperations between Swedish researchers, companies and Big Science facilities to obtain state of the art research infrastructures
Topics:	Current technical needs identified by Big Science facilities (CERN, F4E, …)
Aimed at:	Swedish companies and researchers together with Big Science facilities
IP rights:	Normally reasonable
Typical projects:	Small prestudies in areas where Big Science facilities need help
Funding:	Seed funding about 80 000 SEK
Link:	www.bigsciencesweden.se/business/business/aimday-big-science-technology/

POSSIBILITIES FOR RESEARCHERS

- **F4E Technology Development Programme (TDP)**

Main purpose:	Develop technology critical to fusion
Aimed at:	European industry and universities/applied researchers
IP rights:	Normally reasonable
Typical projects:	New materials, Tritium technology, 3D-printing of special materials, Magnets…. Preferably industry/academia cooperations, industry lead for higher TRL, academia lead on low TRL
Funding:	100% funding, Often 3-year projects ~100 000 EUR/year, 3-4 winners/proj
Link:	https://industryportal.f4e.europa.eu/categories/tdp-news/

POSSIBILITIES FOR RESEARCHERS

- **Fusion Technology Transfer Demonstrator Projects by F4E and Eurofusion**

Main purpose:	To transfer and commercialize fusion technology to other fields
Aimed at:	Companies, researchers and technology owners
IP rights:	Varies but often owned by technology developers
Typical projects:	Adaptation of materials, sensors and manufacturing methods to new markets Applications due June and November yearly
Funding:	50 000 EUR/project+three months work from the technology developers
Link to technologies:	https://fusion-technology-transfer.europa.eu/fusion-technology-portfolio/
Link to call (2026):	https://fusion-technology-transfer.europa.eu/open-call-for-fusion-technology-transfer-demonstrator-proposals/

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Swedish Research Council

VINNOVA
Sweden's Innovation Agency

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