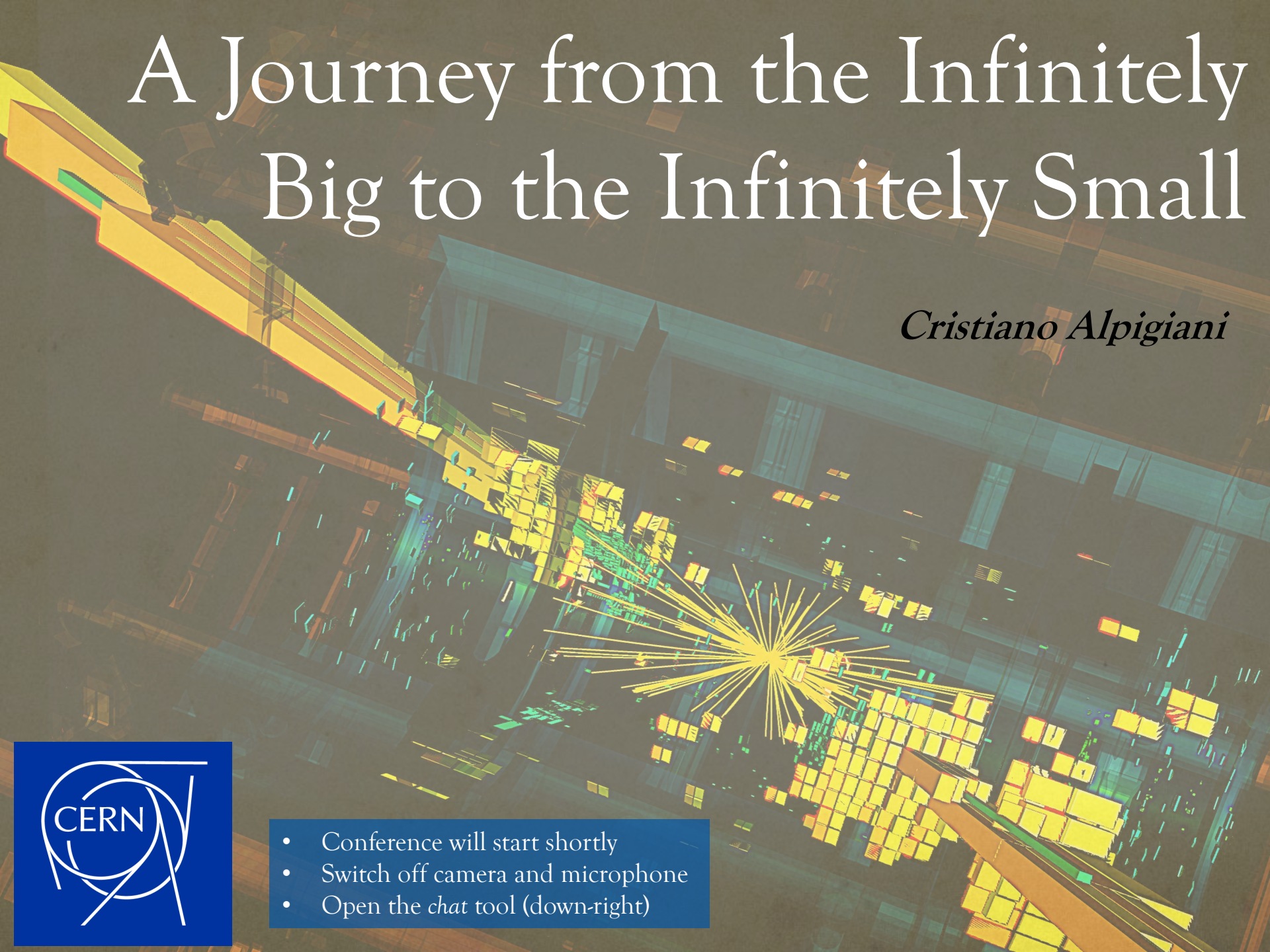
A Journey from the Infinitely Big to the Infinitely Small

Cristiano Alpigiani

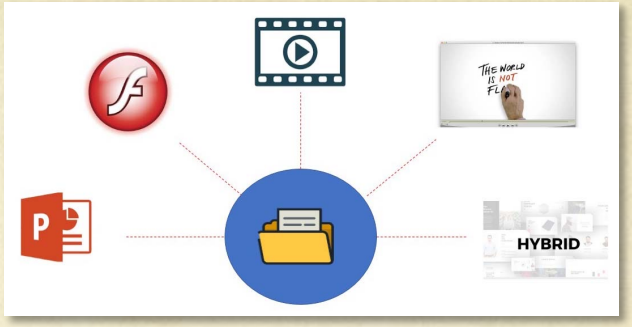


- Conference will start shortly
- Switch off camera and microphone
- Open the *chat* tool (down-right)

Your Virtual Conference

Format

- Presentation (~45 minutes in total)
- Questions and answers (20 minutes in total)
- But please **ask questions also during it!**

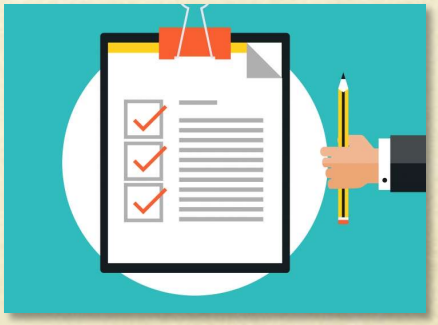


During presentation

- Ask questions using the chat
- Use microphone or camera only if needed

After presentation

- Please fill out survey on Indico page
- Material and links available on Indico page

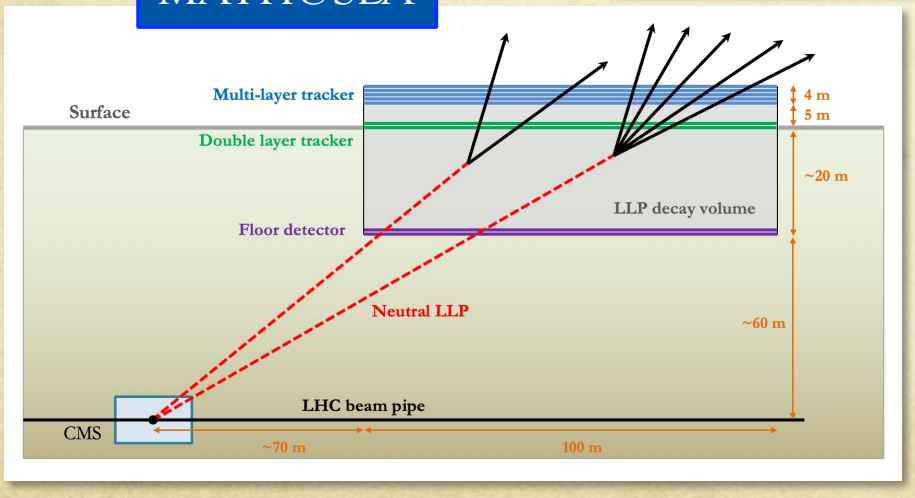


The conference is a general presentation about CERN, its organization, the research, people behind the scenes, etc. All scheduled conferences will have the same format

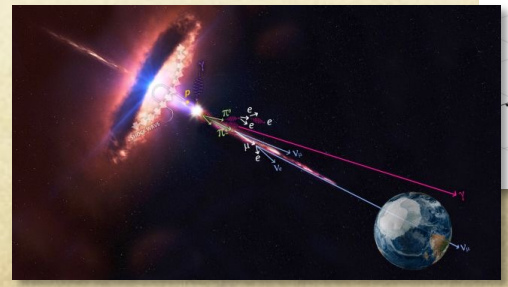
I am...

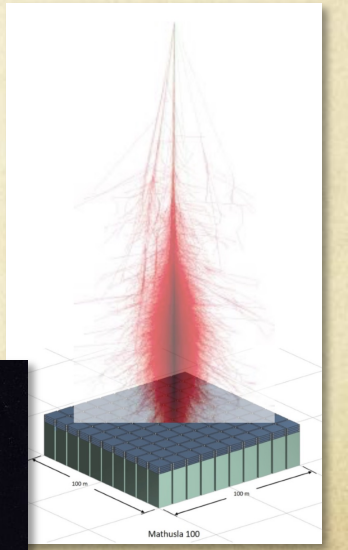
- A **particle physicist** working in the ATLAS experiment
- I am looking for Physics Beyond the Standard Model (mainly **long-lived particles**)
- I am searching for particles from the **Dark/Hidden Sector**

MATHUSLA



- I am also working on a proposal for a future (big) experiment searching for **very long-lived particles** and **cosmic rays**





CERN

Conseil
Européen pour la
Recherche
Nucléaire
1953

Organisation
Européenne pour la
Recherche
Nucléaire
1954

24 Member States

Budget (2024)

- ~1.2 billion CHF
- ~*1.2 miliardi EUR*
- ~*1.1 billion GBP*
- ~*1.3 billion USD*

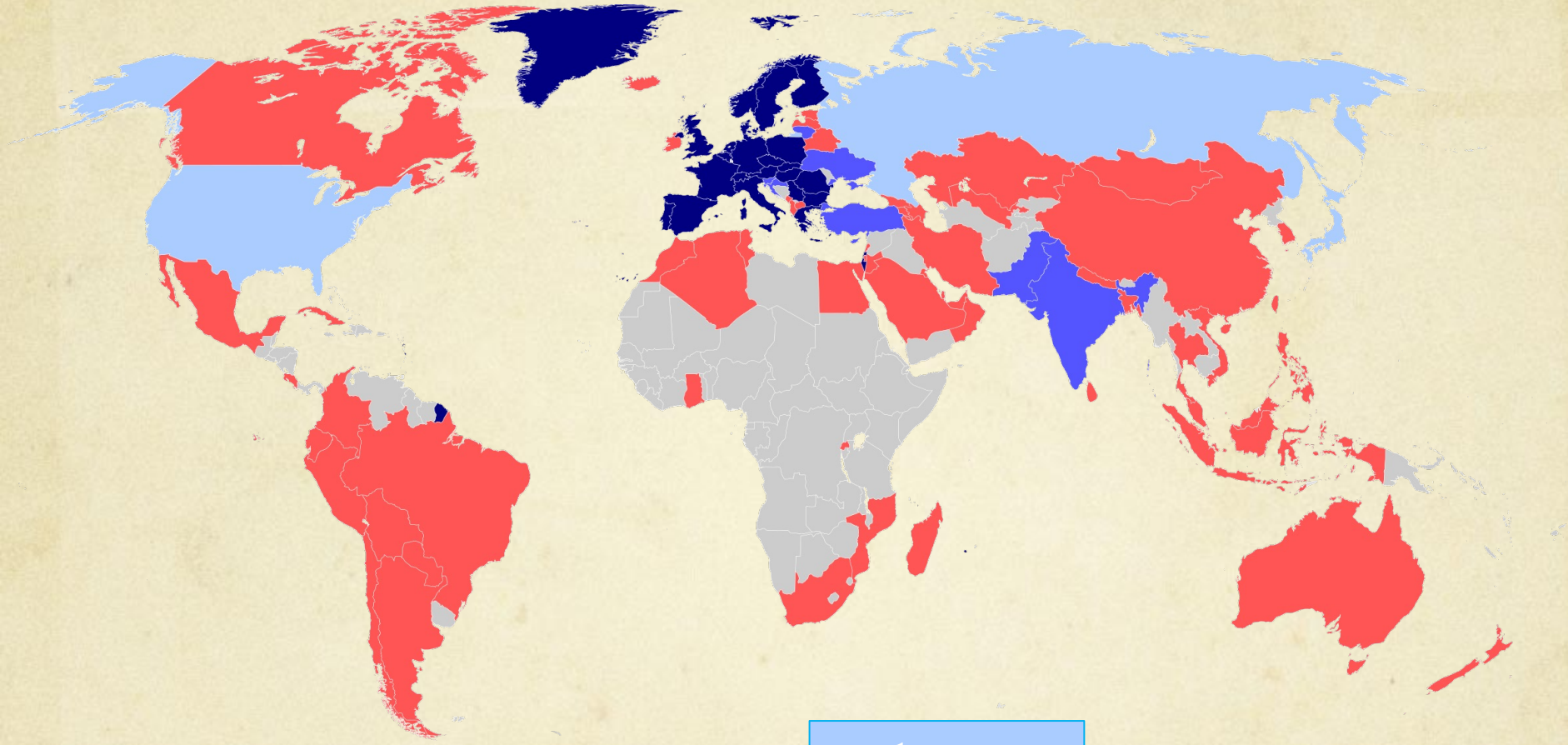
Austria (1959)
Belgium (1953)
Bulgaria (1999)
Czech Republic (1993)
Denmark (1953)
Finland (1991)
France (1953)
Germany (1953)
Greece (1953)
Hungary (1992)
Israel (2014)
Italy (1953)
Netherlands (1953)
Norway (1953)
Poland (1991)
Portugal (1986)
Romania (2016)
Serbia (2019)
Slovakia (1993)
Spain (1961-1968, 1983-)

Sweden (1953)
Switzerland (1953)
United Kingdom (1953)

States in accession to Membership and Associate Members

Croatia (2019)
Cyprus (2016)
India (2017)
Lithuania (2018)
Pakistan (2015)
Slovenia (2017)
Turkey (2015)
Ukraine (2016)

A World Collaboration!



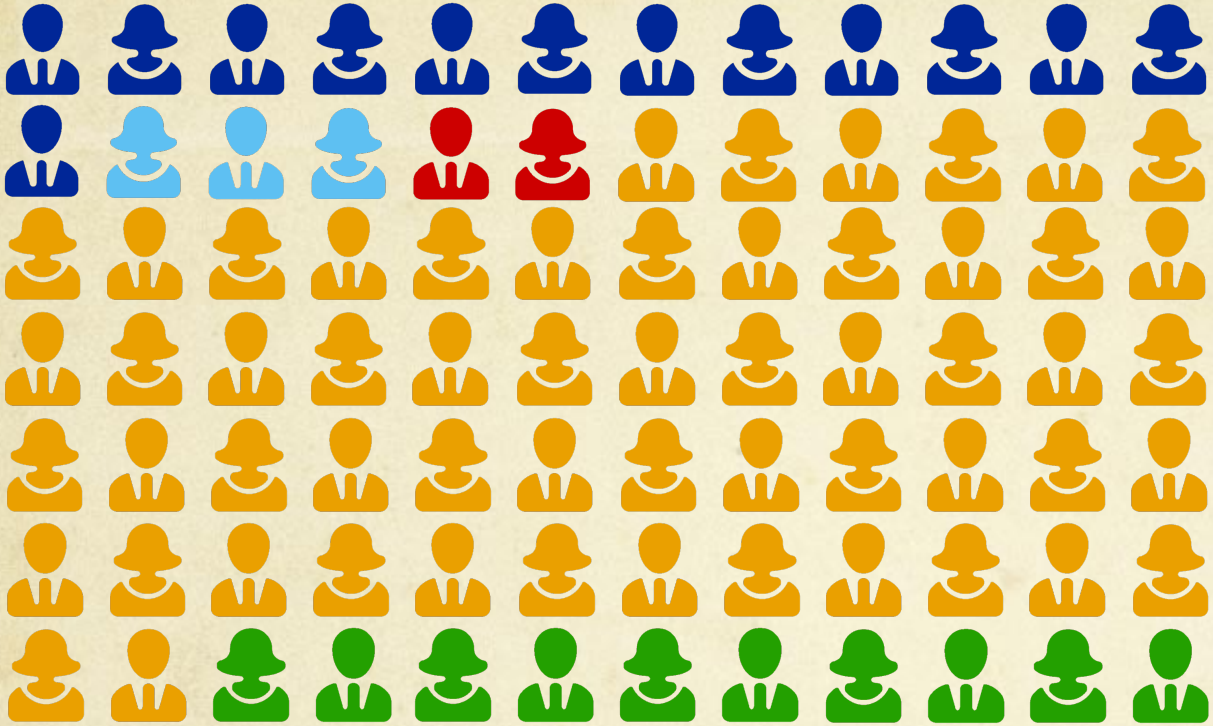
23 members

3 observers

8 associated

61 with agreements

How Many Persons Are Working at CERN?



2 600 staff

800 fellows

apprentices

550 students

15 000 users

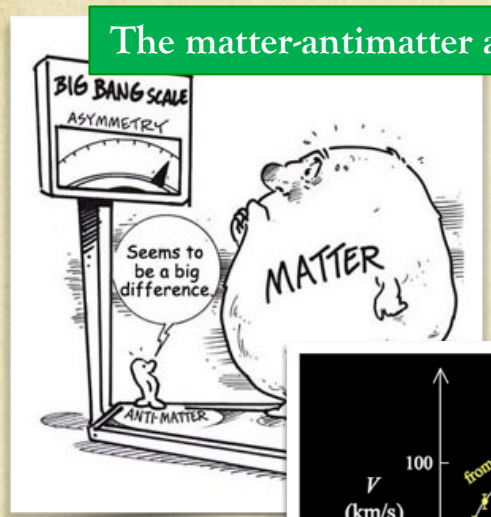
2 000 external companies

Total ~20 000!

A small town...

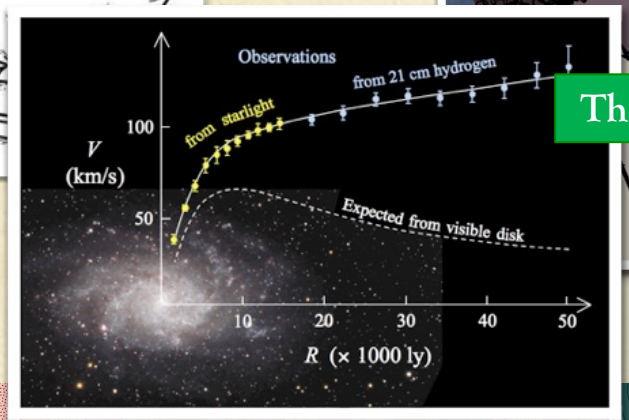
Many Open Questions...Still Waiting for an Answer

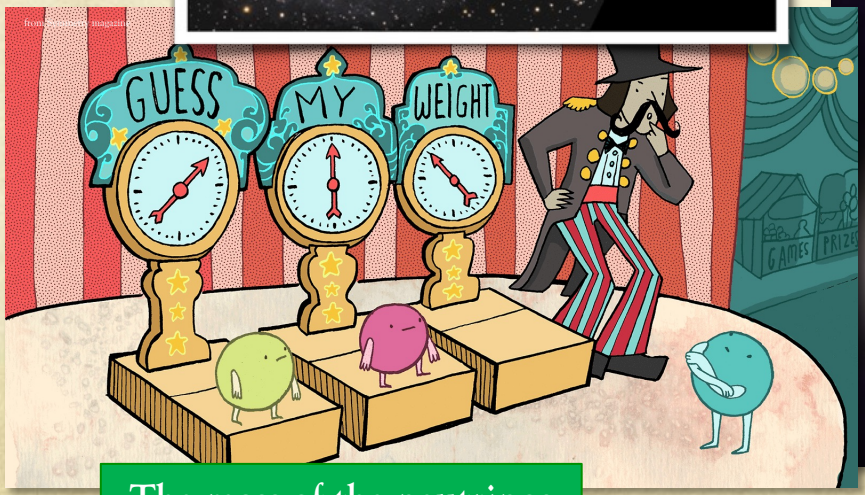
The matter-antimatter asymmetry



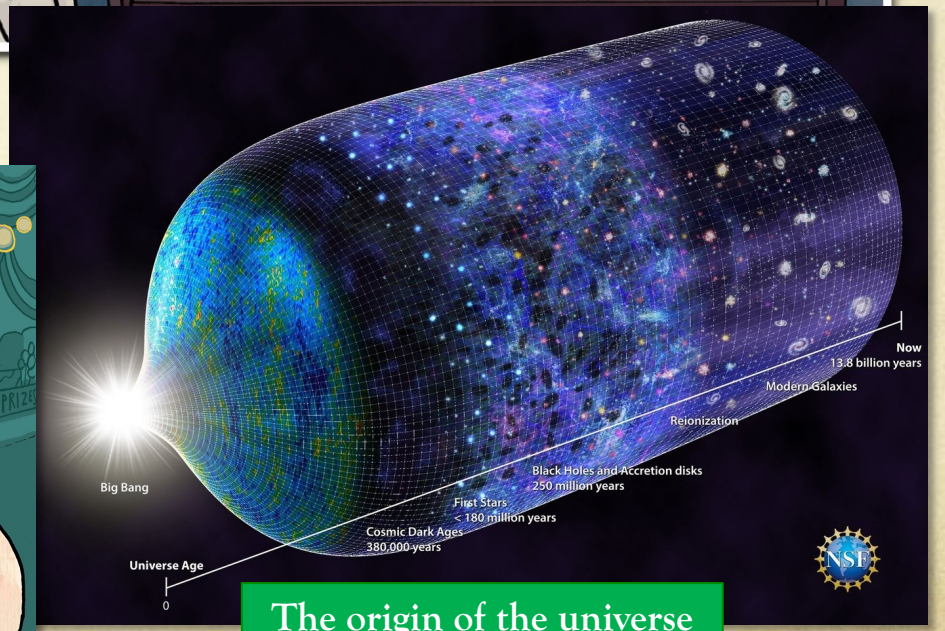
The dark matter

https://home.cern/science/physics/dark-matter





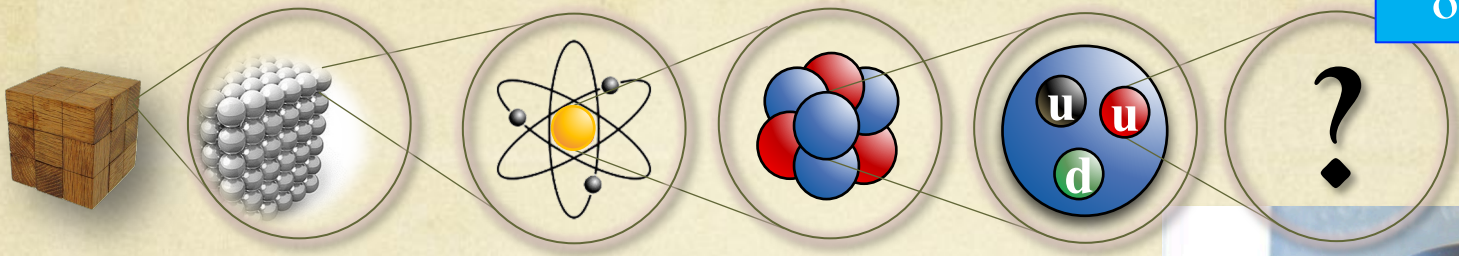
The mass of the neutrinos



The origin of the universe

What is Matter Made of?

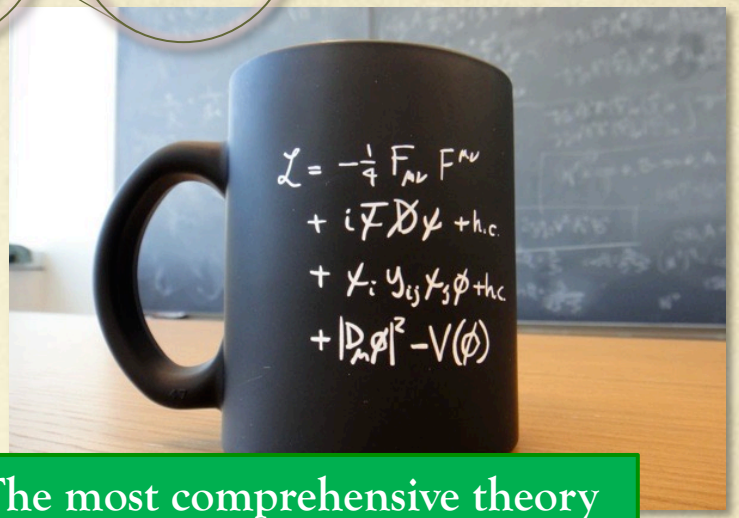
The Standard Model of particle physics



	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
mass	≃2.2 MeV/c²	≃1.28 GeV/c²	≃173.1 GeV/c²	0	≃124.97 GeV/c²
charge	⅔	⅔	⅔	0	0
spin	½	½	½	1	0
QUARKS	u up	c charm	t top	g gluon	H higgs
	≃4.7 MeV/c²	≃96 MeV/c²	≃4.18 GeV/c²	0	
	−⅓	−⅓	−⅓	0	
	½	½	½	1	
	d down	s strange	b bottom	γ photon	
LEPTONS	≃0.511 MeV/c²	≃105.66 MeV/c²	≃1.7768 GeV/c²	≃91.19 GeV/c²	
	−1	−1	−1	0	
	½	½	½	1	
	e electron	μ muon	τ tau	Z Z boson	
	<1.0 eV/c²	<0.17 MeV/c²	<18.2 MeV/c²	≃80.39 GeV/c²	
	0	0	0	±1	
	½	½	½	1	
	νe electron neutrino	νμ muon neutrino	ντ tau neutrino	W W boson	

SCALAR BOSONS

GAUGE BOSONS
VECTOR BOSONS



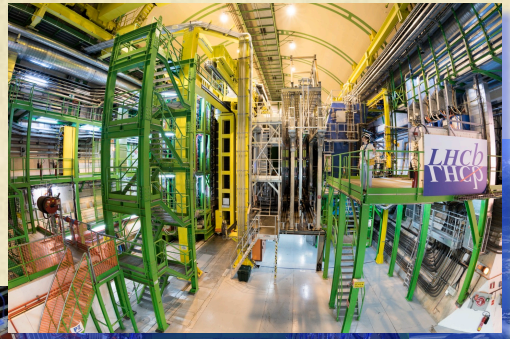
The most comprehensive theory of nature...up to now...

Gravity currently not fitting this "scheme"

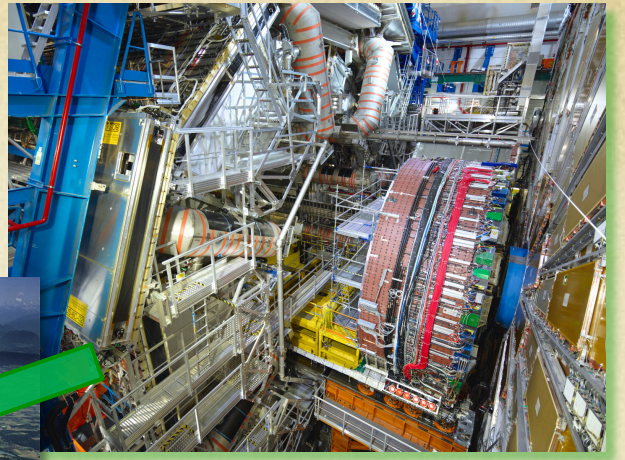
[Video on CERN YouTube channel]

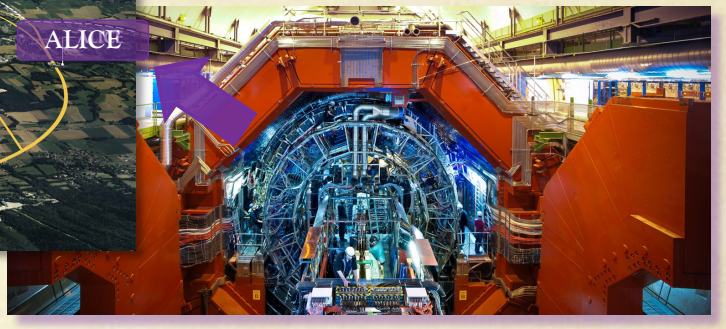
[More on the Standard Model]

Many Many Experiments...

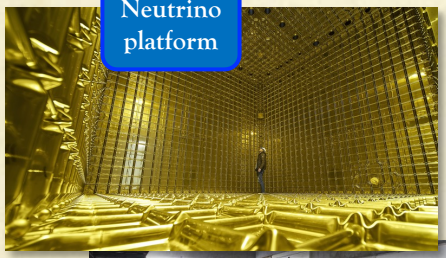


The 4 LHC giants





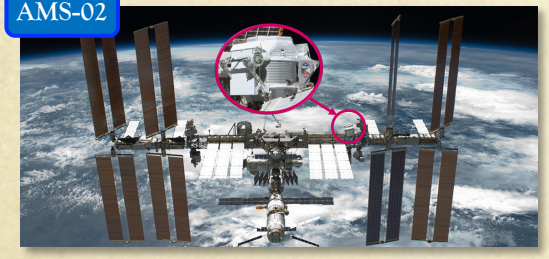
Neutrino platform



CAST

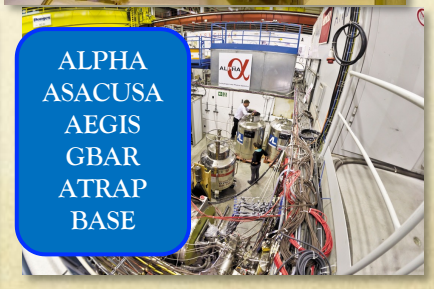
CLOUD

AMS-02

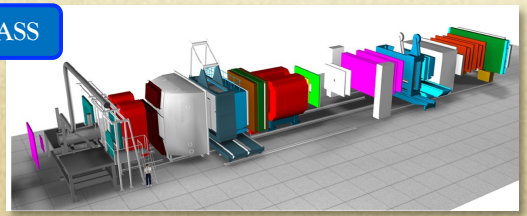


AD

ALPHA
ASACUSA
AEGIS
GBAR
ATRAP
BASE

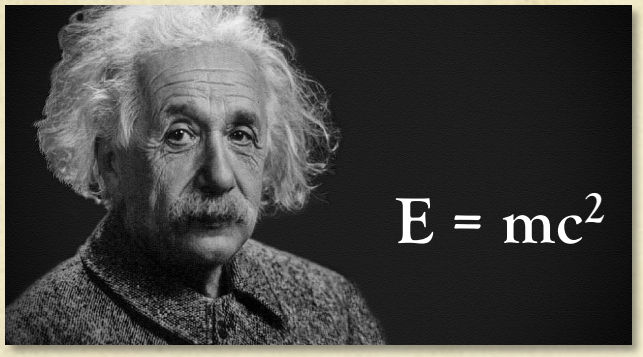


COMPASS

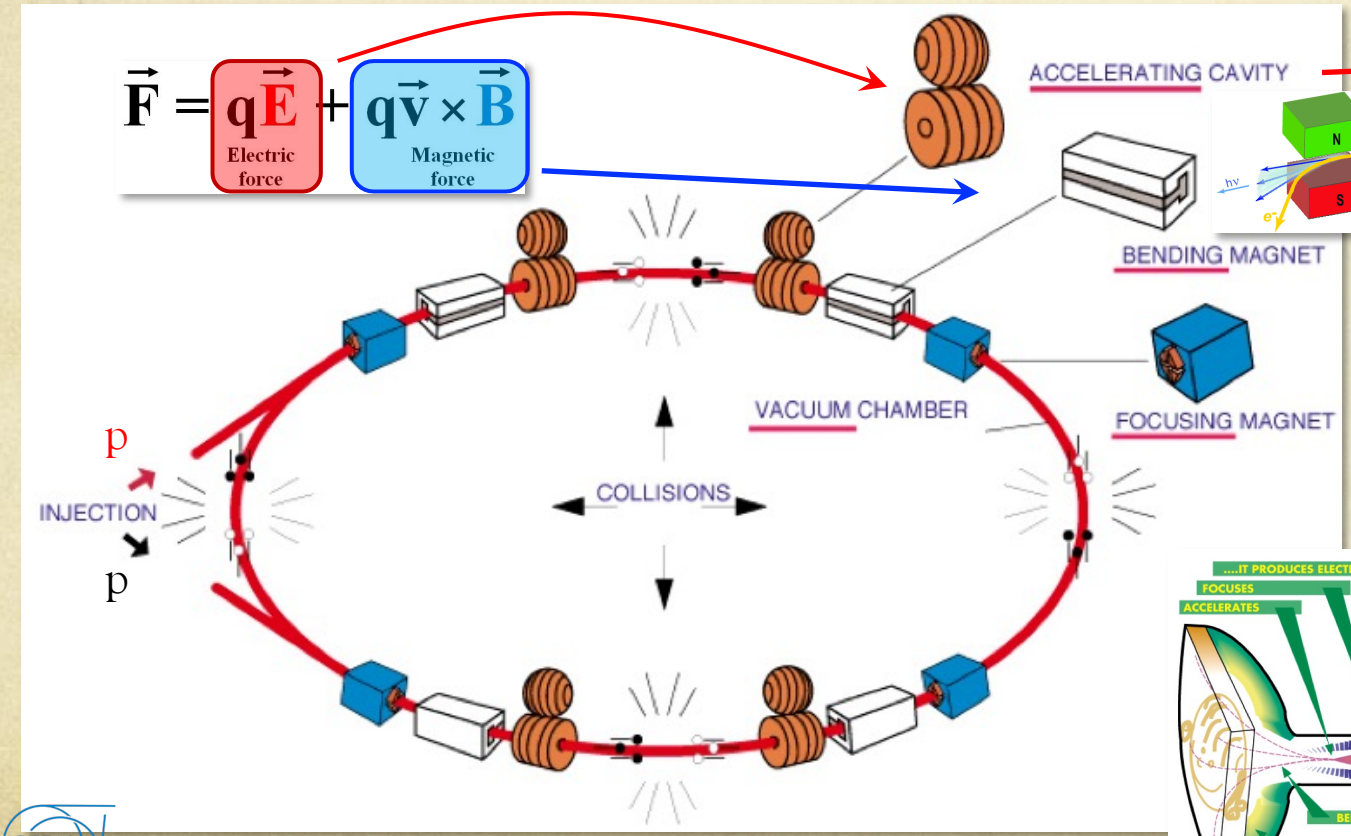


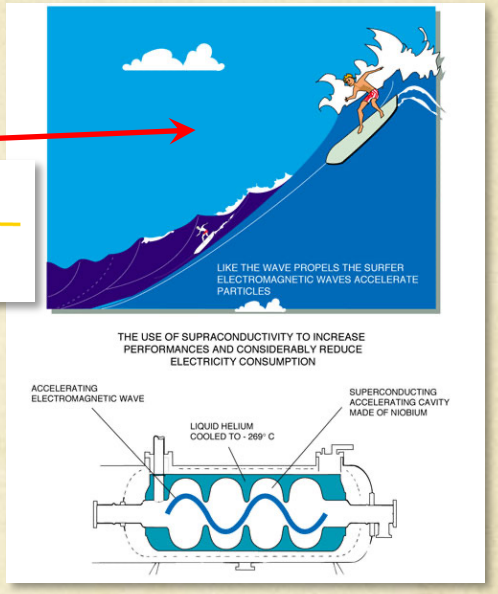
And many more...

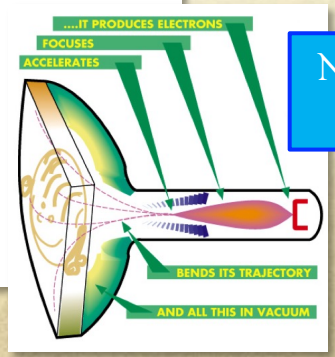
But We Have to Accelerate Particles…



- A particle accelerator is a **super-microscope** to "see" tiny particles (quarks, lepton, etc)
- **Accelerators can be used to transform energy into mass (and vice-versa)**

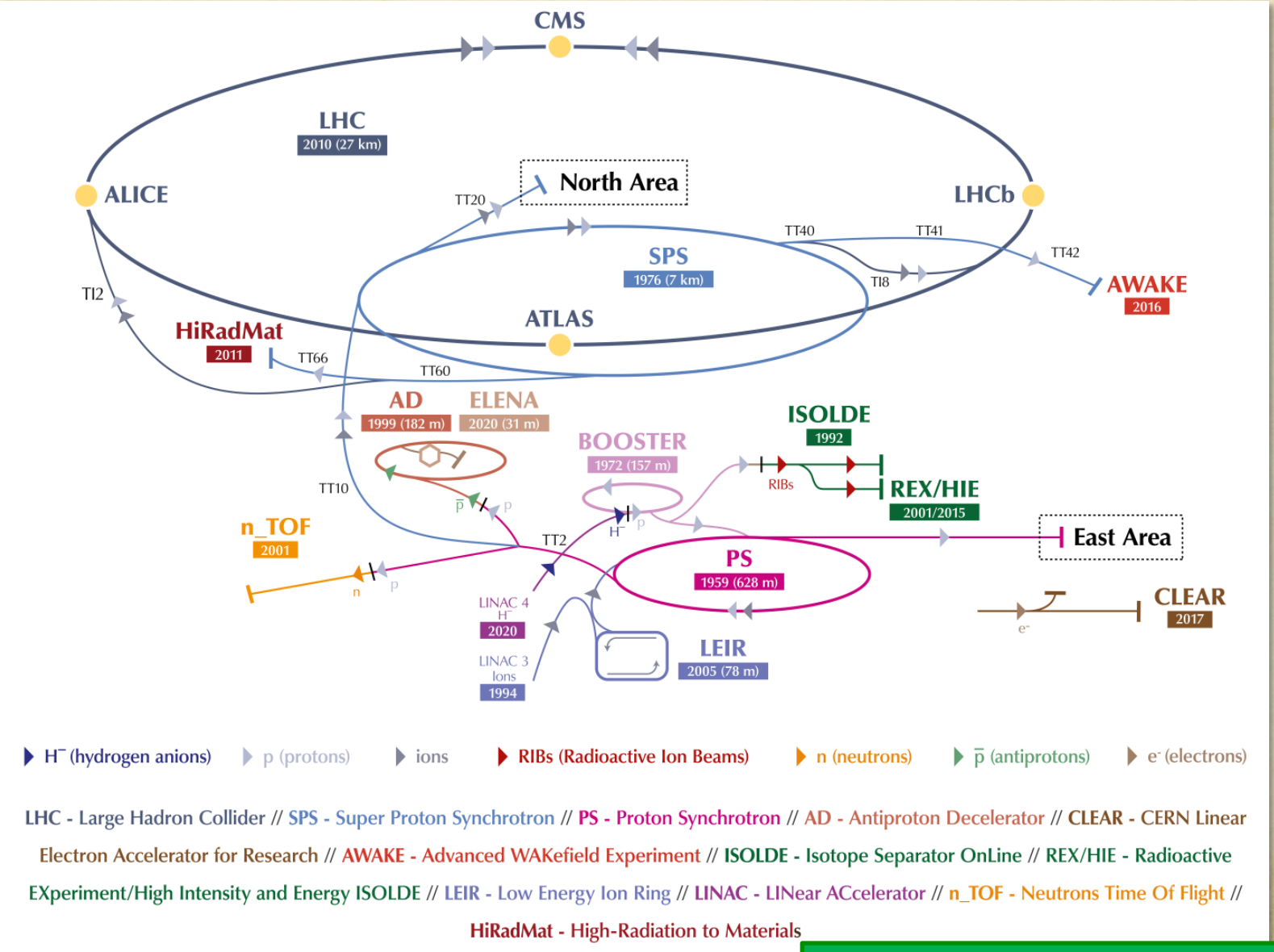




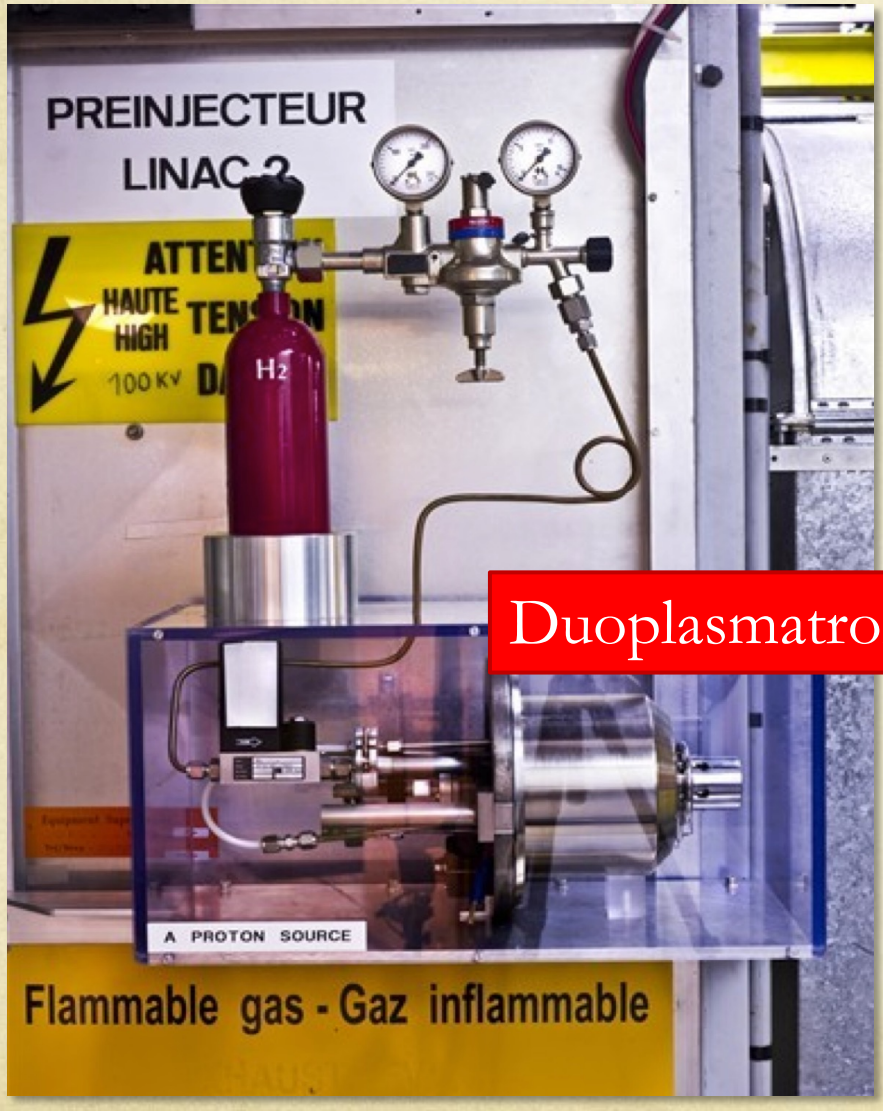


Not so different from an (OLD) TV set…

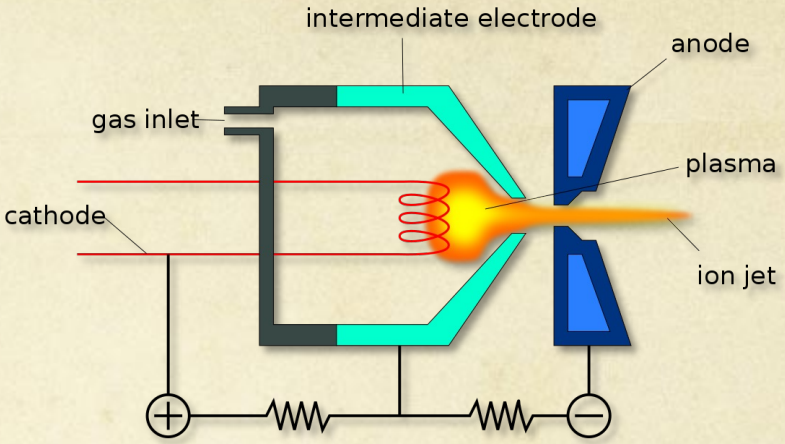
The CERN Accelerator Complex



Where Do we Take the Protons?



Duoplasmatron



1. Cathode filament emits electrons into a vacuum chamber
2. H_2 gas is introduced in very small
3. Gas become charged or ionised through interactions with the free electrons
4. Plasma is accelerated through a series of charged grids

The Bending Magnets

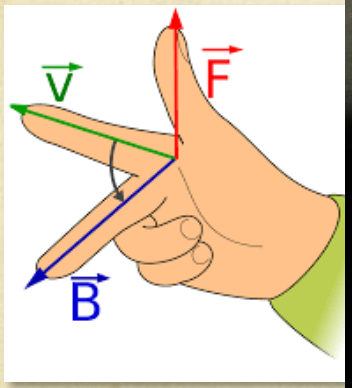
-271 °C (1.9 K)

Niobium-Titanium (Nb-Ti)

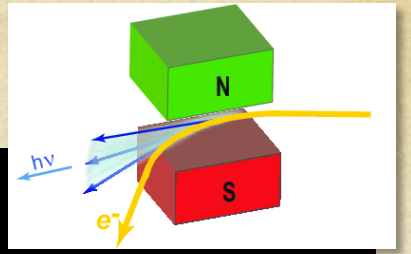
$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

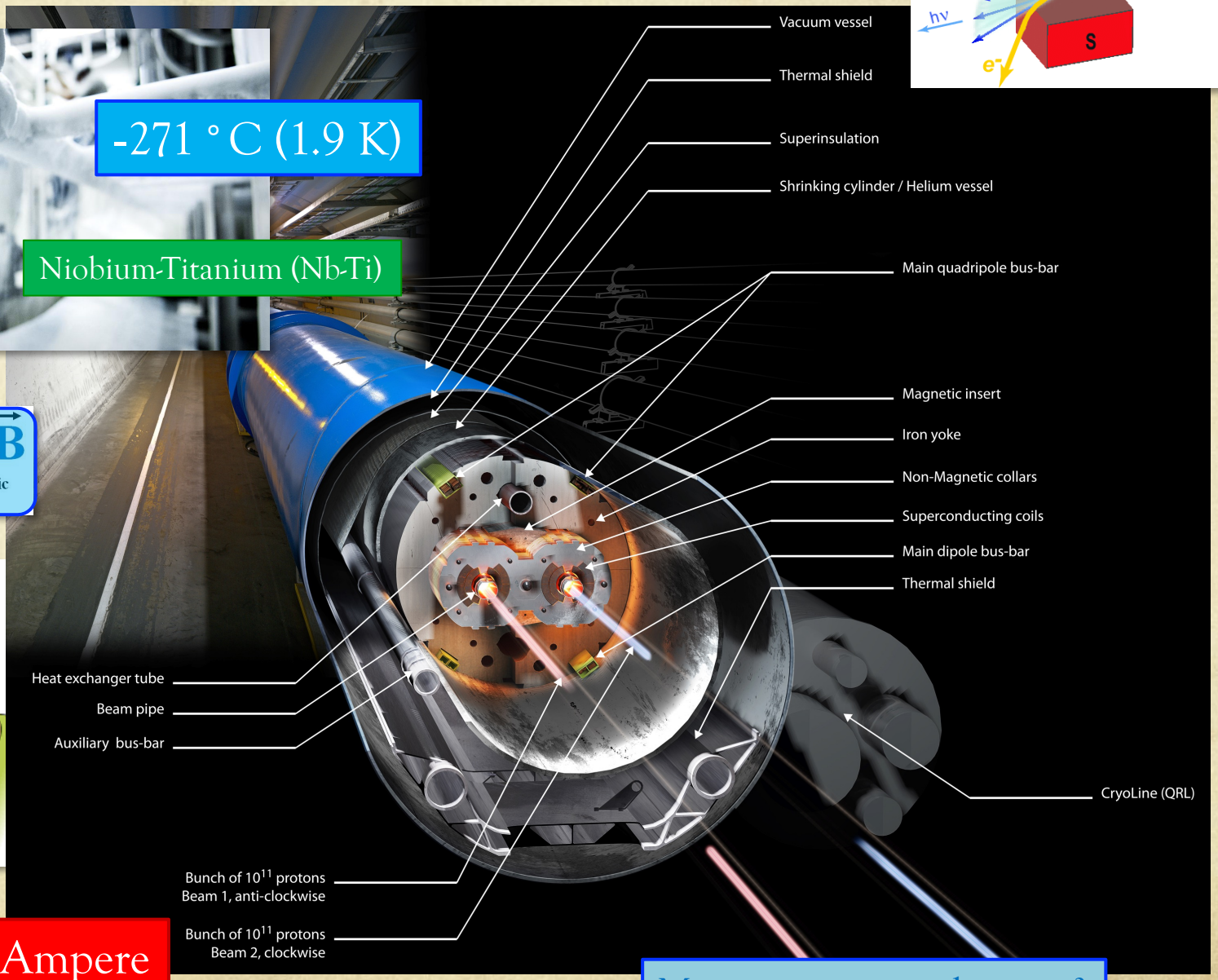
Electric force

Magnetic force



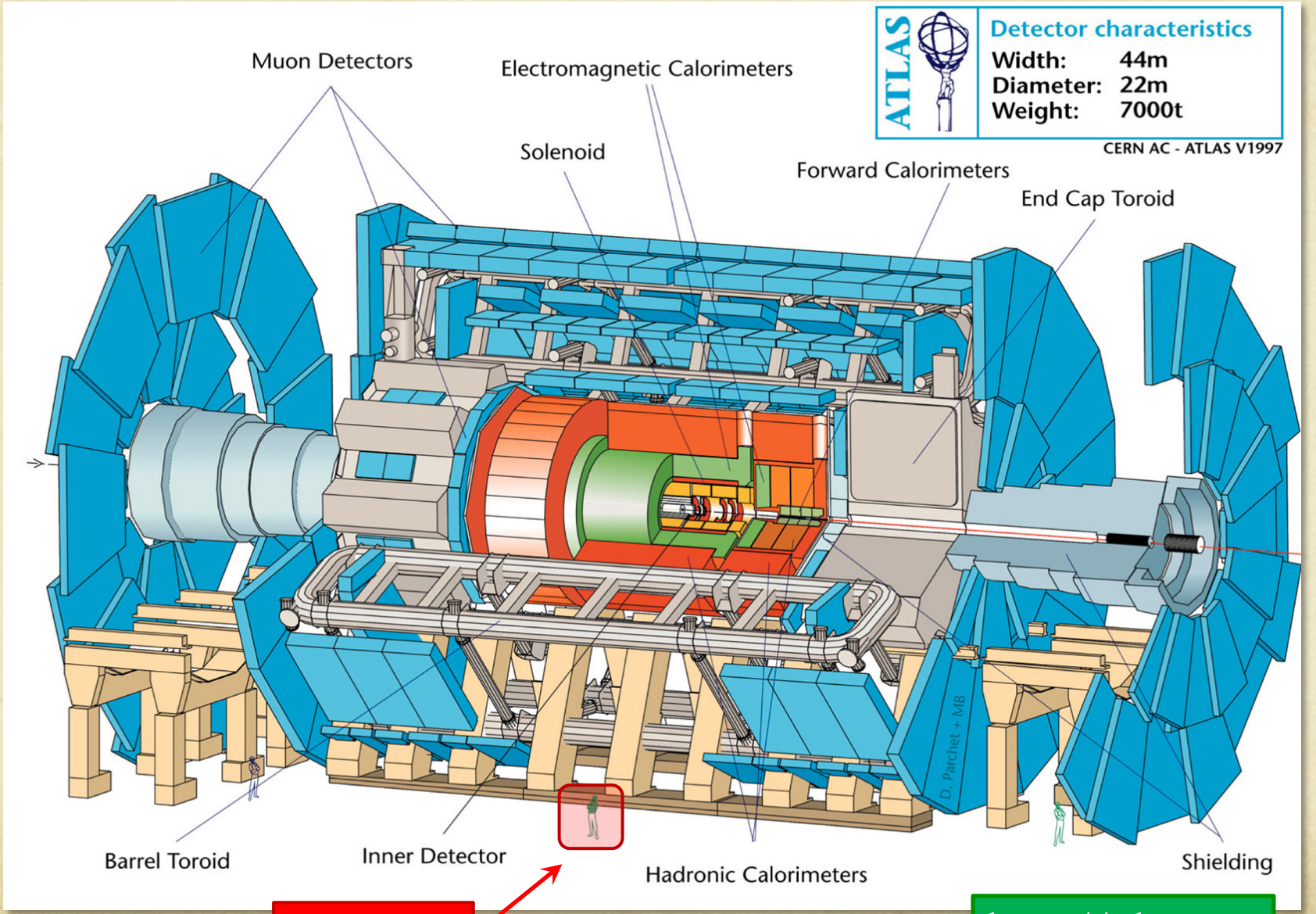
13,000 Ampere





More on superconductivity?

A Very Powerful Camera

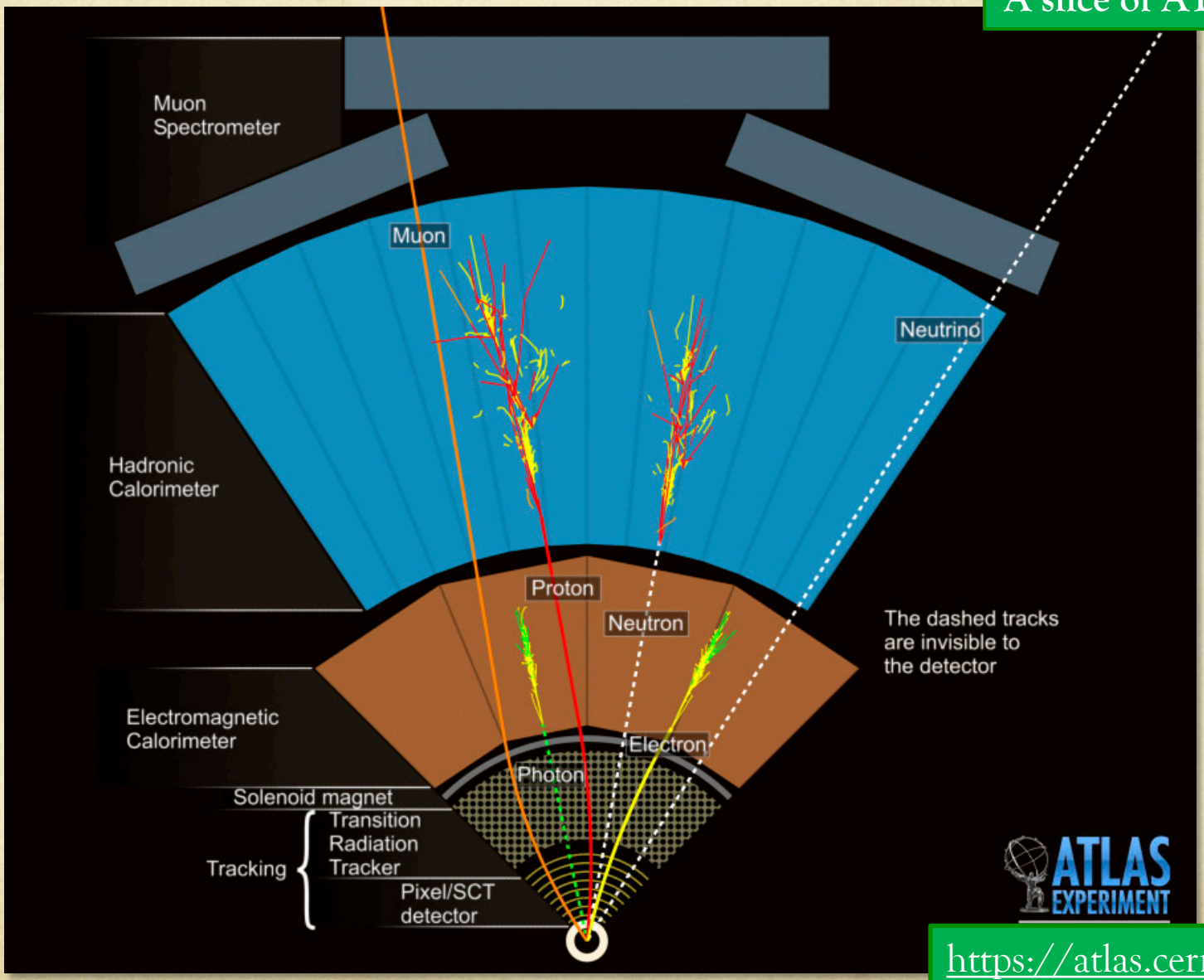


A person...

https://atlas.cern

A Very Powerful Camera

A slice of ATLAS



https://atlas.cern

The LHC Computing Grid

The largest computing grid

- 42 countries
- 170 data centres
- Over 2 millions tasks executed every days
- 1 million computer cores
- 1 storage exabyte

Live talk: from data to discovery (J. Catmore)

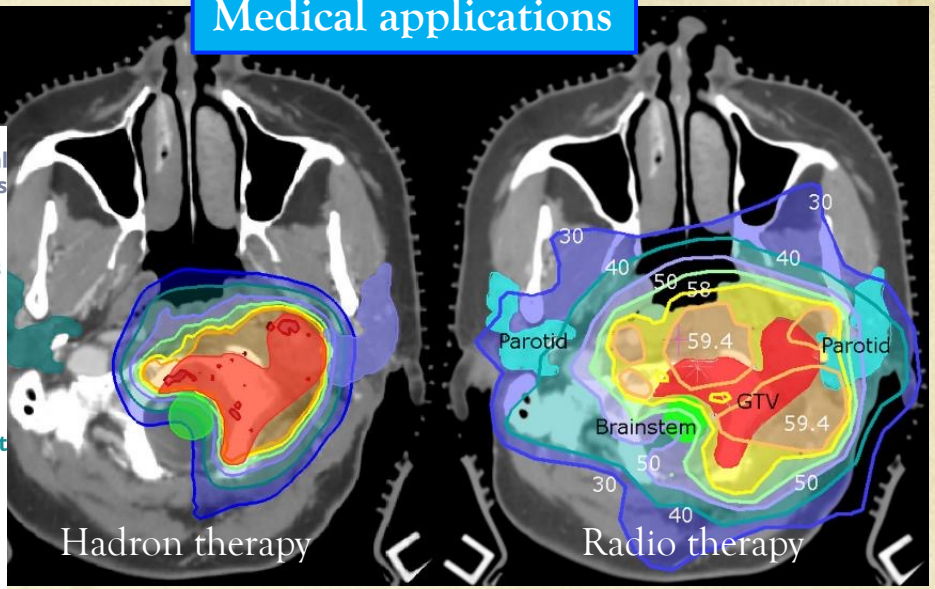
https://wlcg-public.web.cern.ch

CERN is Not Only Fundamental Research

Technology transfer in benefit of society

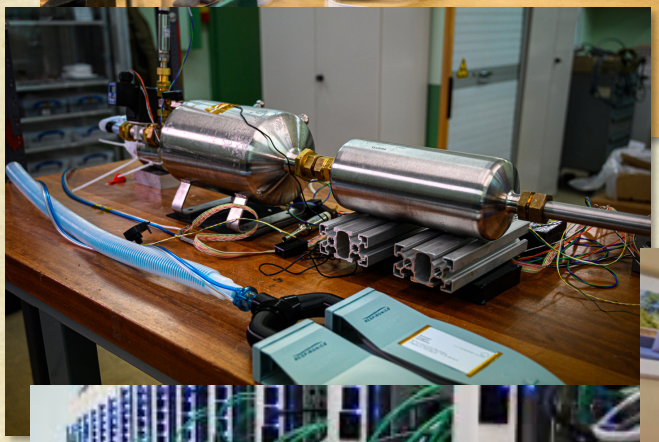
https://kt.cern/

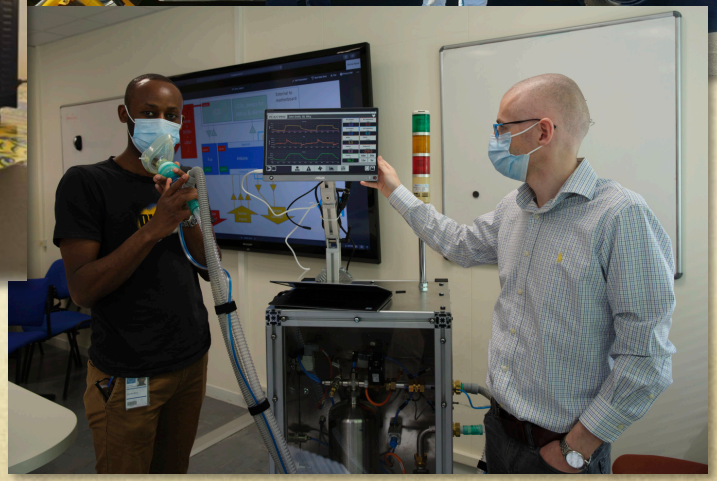
Medical applications



Humanitarian missions

CERN Against COVID





https://againstcovid19.cern

CERN Opportunities for Students

- **Many opportunities for a student** (visit https://careers.cern/students)
  - Summer Student Programme
  - CERN Openlab Summer Student Programme
  - Short-term Internship Programme
  - Doctoral Student Programme
  - Marie-Curies PhD positions
  - Technical Student Programme
  - Administrative Student Programme
  - Opportunities reserved for students with disabilities
  - Beamline for Schools → https://beamlineforschools.cern

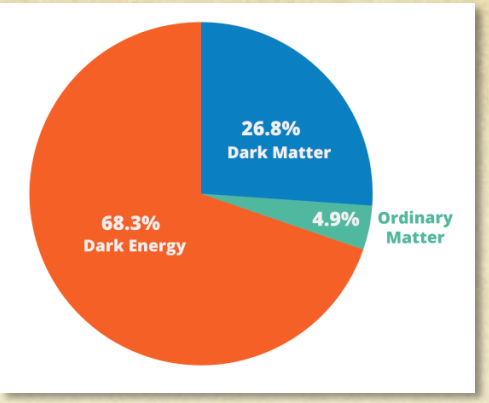
Further Research Material

- Want to play with some LHC data? CERN Open Data
- Want more photos or outreach material? CERN Document Server (Multimedia and Outreach)
- Want to know more? Upcoming events @CERN (for general public, but can select a different audience)
- More about CERN history? See here !
- Art @CERN? See here!
- Want to "see" particle collisions? ATLAS event displays, Other event displays
- And much more on https://home.cern

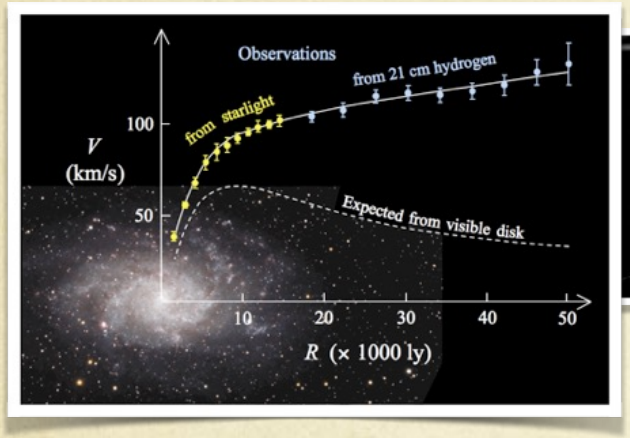
Thank you!

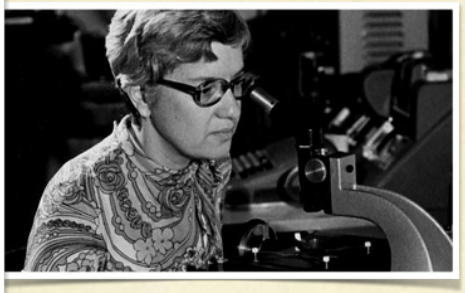
BACKUP

Dark Matter / Dark Energy



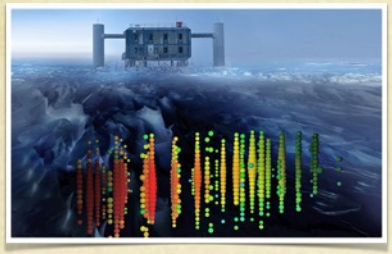
- First observed by Fritz Zwicky → velocity dispersions of galaxies in the Coma cluster (idea neglected for 40 years!)

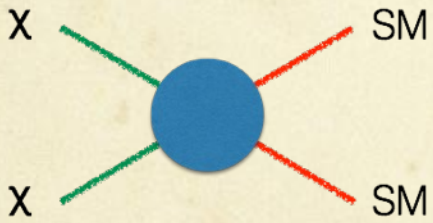




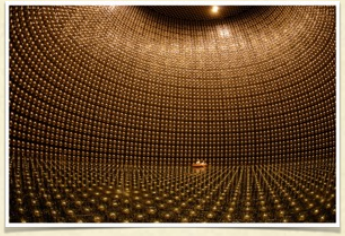
- Precisely measured by Vera Rubin → velocity of gas near Andromeda
  - **Estimated factor of 10 more dark mass than visible mass**

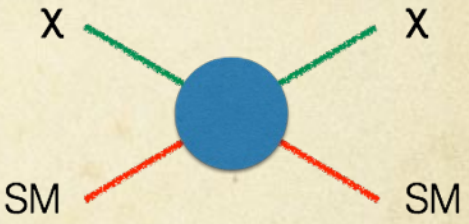
Indirect detection: DM-DM **annihilation** process





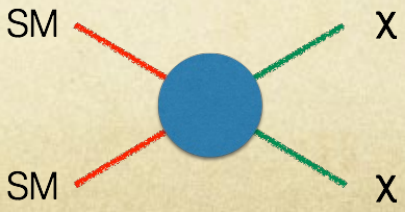
Direct detection: **recoil** from DM-nucleus scattering



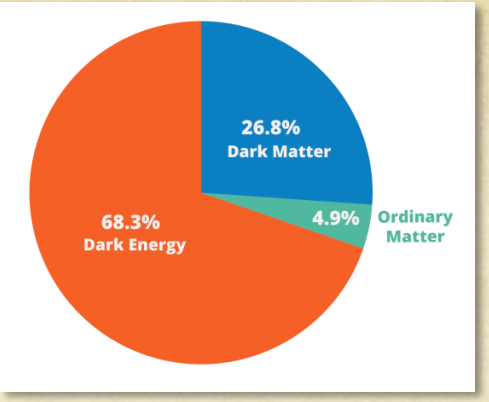


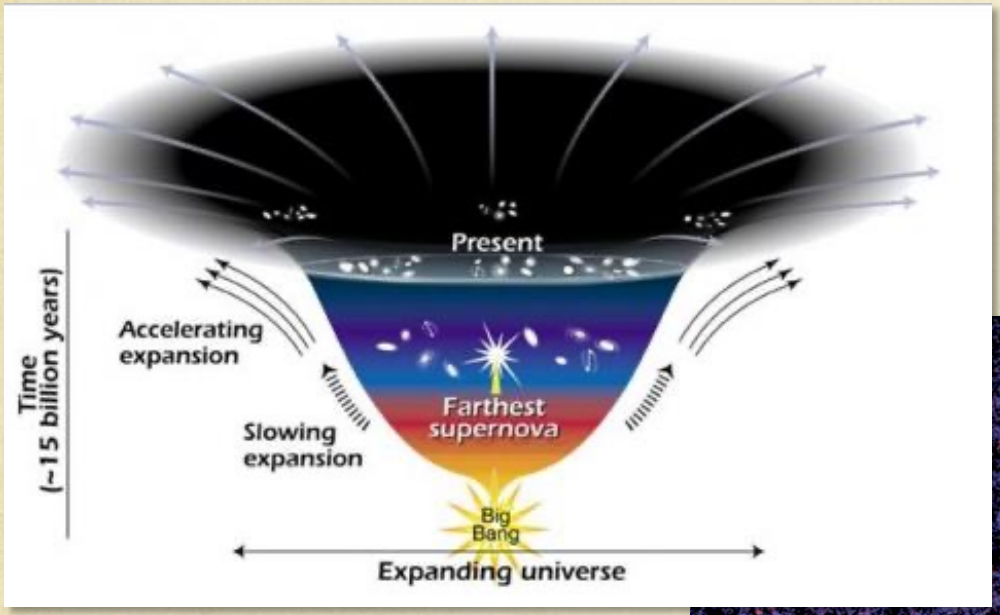
At LHC

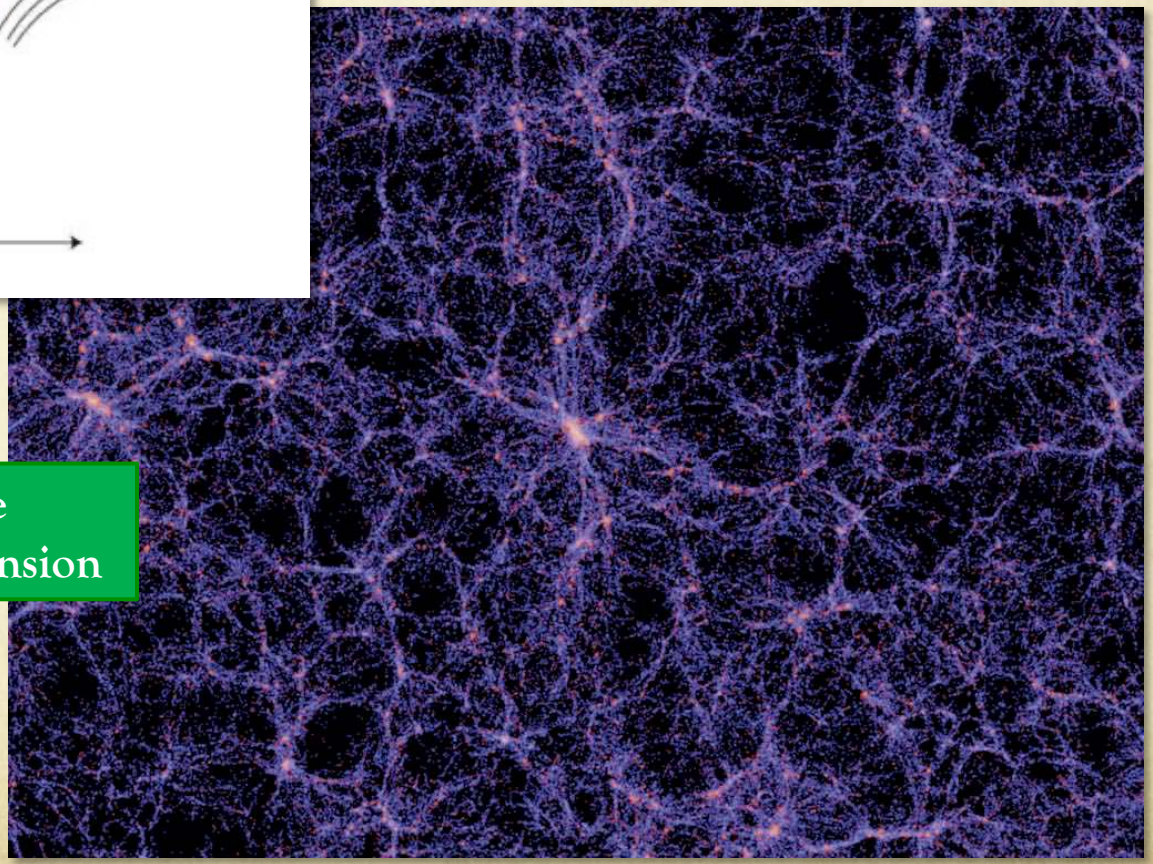
- ✓ No DM interaction with the detector → missing E_T
- ✓ Initial state radiation to detect it (jets, photons, W, ...)
- ✓ Searches for high-mass di-jet resonances



Dark Matter / Dark Energy

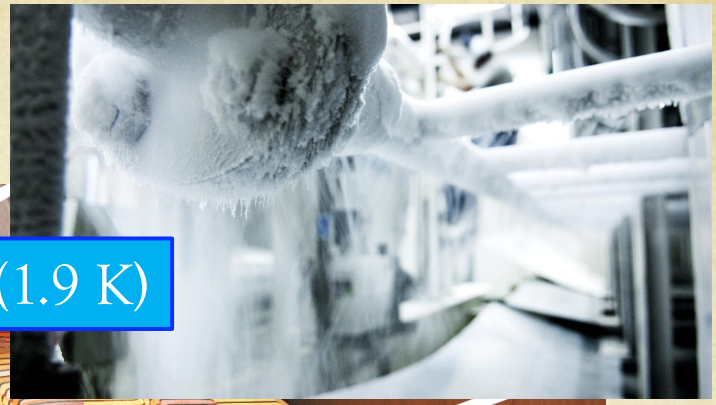


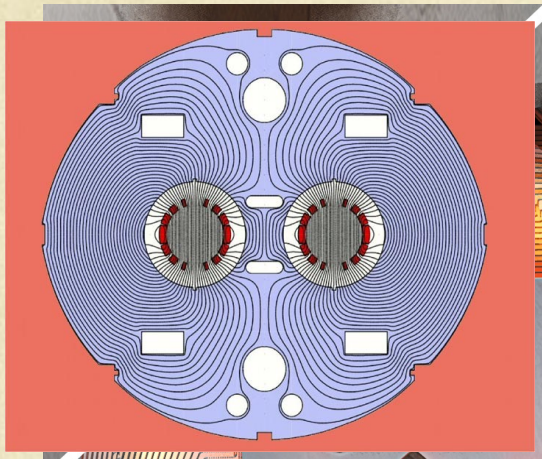




Dark energy is responsible for the acceleration of the Universe expansion

The Bending Magnets





-271 °C (1.9 K)

B

175 Tons/m

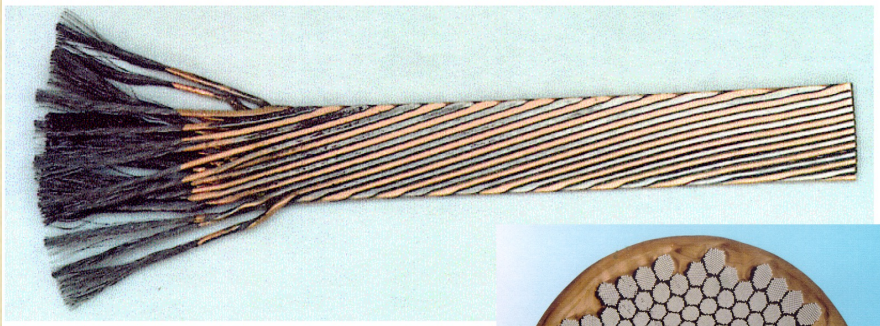
F

B

85 Tons/m

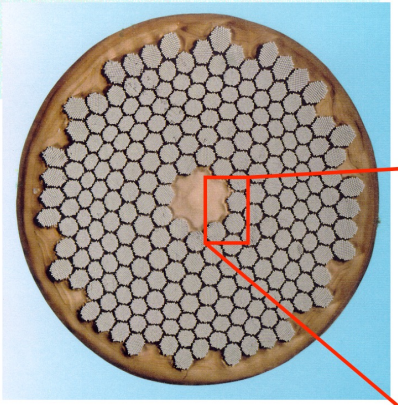
13,000 Ampere

The Superconductors

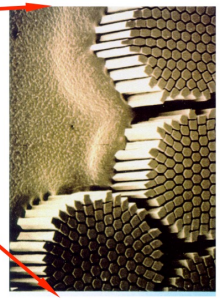


superconducting cable

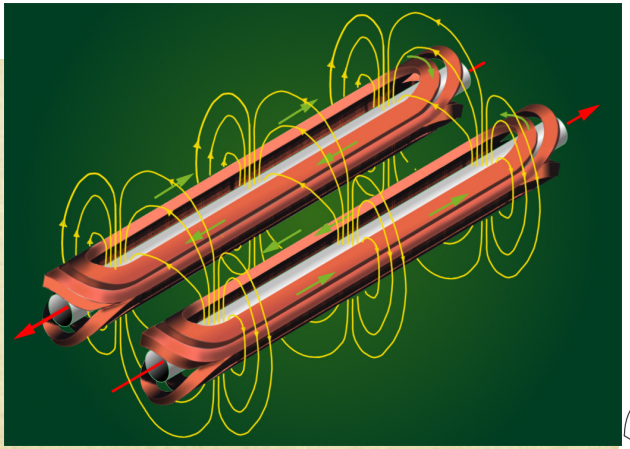
SC strand

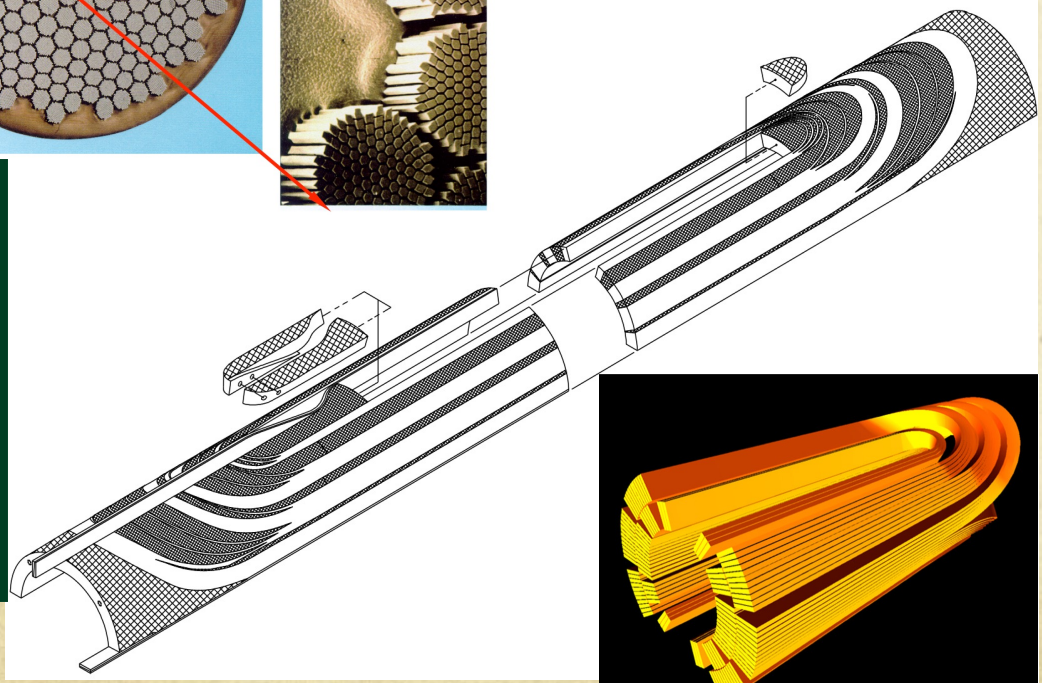


SC filament



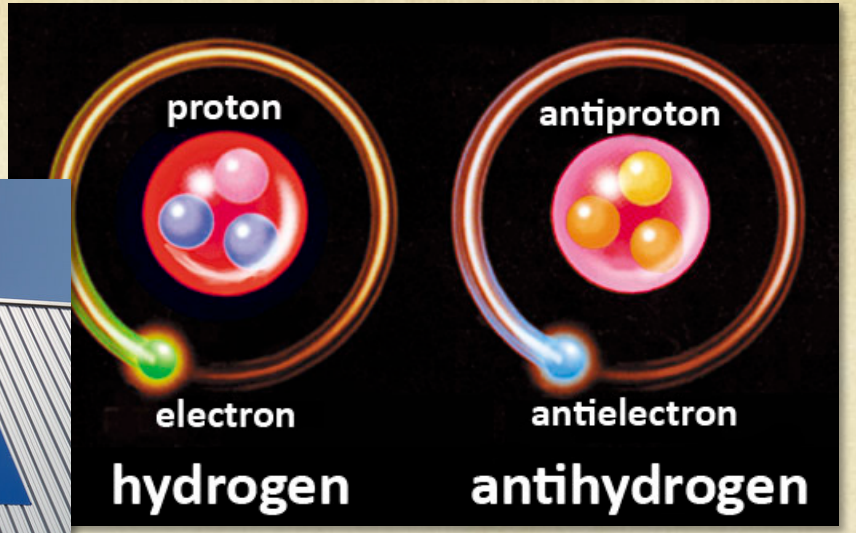
13,000 Ampere

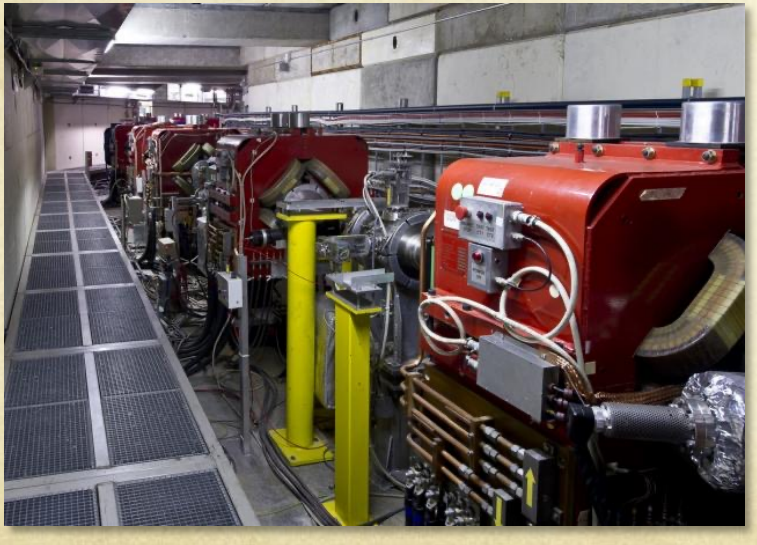


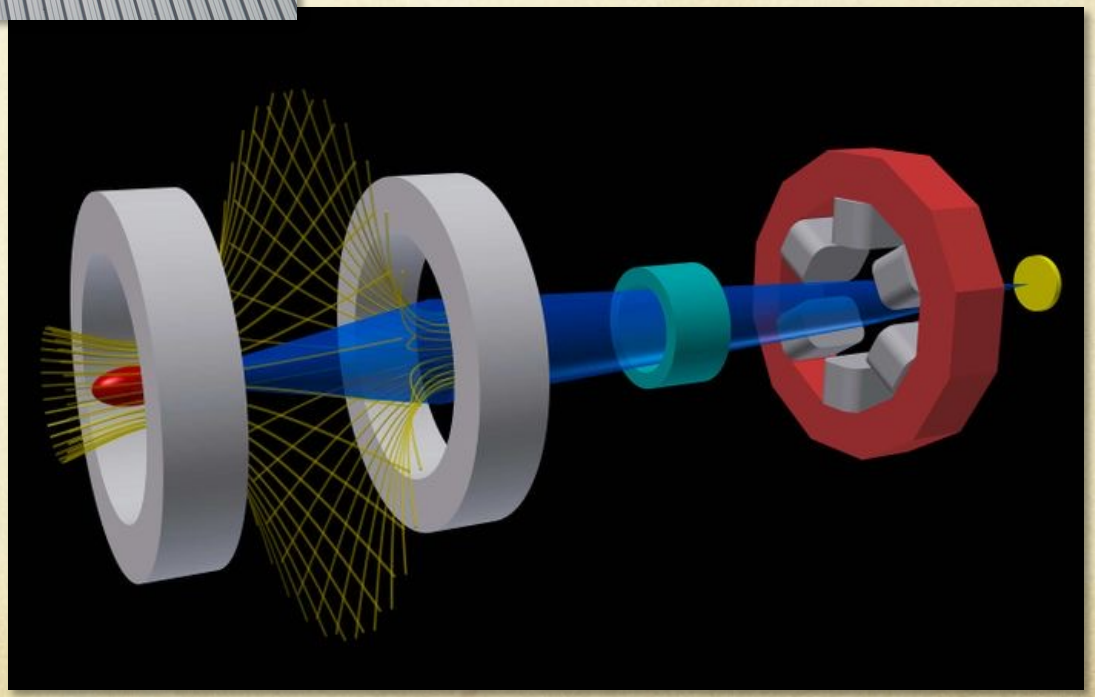


Antimatter

393
ANTIMATTER
FACTORY
ELENA


proton
antiproton
electron
antielectron
hydrogen
antihydrogen





CERN is…

…a scientific laboratory, that devises its own solutions

SCIENCE	TECHNOLOGY	ENGINEERING	ARTS	MATH
• Observing	• Being inventive	• Problem solving	• Creativity	• Patterning
• Experimenting	• Using tools	• Using materials	• Aesthetics	• Sequencing
• Making predictions	• Making things work	• Designing & creating	• Imagination	• Exploring shapes, numbers, volumes and size
• Asking questions	• Identify issues,	• Building	• Expressing individuality	
	• Using computers			