

# Fundamental Research in an international Perspective

CERN – European Organization for Nuclear Research  
The Organization, current research, and education.

Dr. Sascha Marc Schmeling

L'insegnamento della fisica e delle scienze in una prospettiva sistematica, storica e critica.  
Settimo convegno nazionale LS-OSA  
Bologna, 27.01.2022



# Science for peace

## CERN was founded in 1954 with 12 European Member States



### 23 Member States

Austria – Belgium – Bulgaria – Czech Republic  
Denmark – Finland – France – Germany – Greece  
Hungary – Israel – Italy – Netherlands – Norway  
Poland – Portugal – Romania – Serbia – Slovakia  
Spain – Sweden – Switzerland – United Kingdom

### 3 Associates Member States in the pre-stage to membership

Cyprus – Estonia – Slovenia

### 7 Associate Member States

Croatia – India – Latvia – Lithuania – Pakistan – Turkey – Ukraine

### 6 Observers

Japan – Russia – USA  
European Union – JINR – UNESCO

CERN's annual budget  
is 1200 MCHF (equivalent  
to a medium-sized European  
university)

As of 31 December 2020  
Employees:  
**2635** staff, **756** fellows

Associates:  
**11 399** users, **1687** others

### More than 50 Cooperation Agreements with non-Member States and Territories

Albania – Algeria – Argentina – Armenia – Australia – Azerbaijan – Bangladesh – Belarus – Bolivia  
Bosnia and Herzegovina – Brazil – Canada – Chile – Colombia – Costa Rica – Ecuador – Egypt – Georgia – Iceland  
Iran – Jordan – Kazakhstan – Latvia – Lebanon – Malta – Mexico – Mongolia – Montenegro – Morocco – Nepal  
New Zealand – North Macedonia – Palestine – Paraguay – People's Republic of China – Peru – Philippines – Qatar  
Republic of Korea – Saudi Arabia – Sri Lanka – South Africa – Thailand – Tunisia – United Arab Emirates – Vietnam

# A laboratory for people around the world

Distribution of all CERN Users by the country of their home institutes as of 31 December 2020



Geographical & cultural diversity  
Users of **110 nationalities**  
~ **23% women**

## Member States **6632**

Austria 82 – Belgium 122 – Bulgaria 37 – Czech Republic 221  
Denmark 35 – Finland 79 – France 794 – Germany 1185  
Greece 138 – Hungary 67 – Israel 63 – Italy 1388  
Netherlands 166 – Norway 78 – Poland 272 – Portugal 80  
Romania 99 – Serbia 35 – Slovakia 66 – Spain 325  
Sweden 96 – Switzerland 329 – United Kingdom 875

## Associate Member States **27** in the pre-stage to membership

Cyprus 11 – Slovenia 16

## Associate Member States **390**

Croatia 38 – India 151 – Lithuania 13 – Pakistan 35  
Turkey 124 – Ukraine 29

## Observers **3071**

Japan 211 – Russia 1021 – United States of America 1839



## Other countries **1279**

Algeria 2 – Argentina 15 – Armenia 10 – Australia 23 – Azerbaijan 2 – Bahrain 2 – Belarus 26 – Brazil 108  
Canada 196 – Chile 22 – Colombia 15 – Cuba 3 – Ecuador 4 – Egypt 14 – Estonia 26 – Georgia 35  
Hong Kong 20 – Iceland 3 – Indonesia 7 – Iran 13 – Ireland 6 – Kuwait 2 – Latvia 6 – Lebanon 17  
Malaysia 4 – Malta 3 – Mexico 49 – Montenegro 5 – Morocco 18 – New Zealand 11 – Oman 1  
People's Republic of China 334 – Peru 2 – Puerto Rico 2 – Republic of Korea 132 – Singapore 3  
South Africa 57 – Sri Lanka 8 – Taiwan 50 – Thailand 16 – United Arab Emirates 2

## CERN Council

President: E. Rabinovici  
Secretary: CERN DG



- (Associate) Member States: 2 delegates each
- ex-officio members
  - FC Chairperson
  - SPC Chairperson
- different observers on invitation, incl. ECFA Chairperson

## Finance Committee

Chairperson: U. Doselli



- (Associate) Member States: 1-3 delegates each
- ex-officio members
  - Council President
  - SPC Chairperson

## Scientific Policy Committee

Chairperson: L. Rivkin



- 14 individual members
- ex-officio members
  - ECFA Chairperson
  - Chairpersons of CERN Committees (LHCC, MAC, SPSC, INTC)
- standing invitations
  - CERN DG, Council President, FC Chairperson

## Audit Committee

Chairperson: FC Chair

## Tripartite Employment Forum

Chairperson: B. Åsman



## Pension Fund Governing Board

Chairperson: O. Malmberg



# CERN – The Organization





Council Secretariat  
Legal Service

Director General  
**Fabiola Gianotti** 

Internal Audit  
Health, Safety, and Environment Unit

Finance and Human  
Resources  
**Rafael Bello** 


Research and Computing  
**Joachim Mnich** 

Accelerators and  
Technology  
**Mike Lamont** 

International Relations  
**Charlotte Warakaulle** 

Finance and  
Administrative Procedures  
Florian Sonnemann 

Experimental Physics  
Manfred Krammer 

Beams  
Rhodri Jones 

Education, Communication,  
and Outreach

Human Resources  
James Purvis 


Theoretical Physics  
Gian Giudice 

Engineering  
Katy Foraz 


Diplomatic and Stakeholder  
Relations

Industry, Procurement, and  
Technology Transfer  
Christopher Hartley 

Information Technologies  
Enrica Porcari 

Systems  
Brennan Goddard 

Site and Civil Engineering  
Mar Capeans 

Technology  
Jose Miguel Jimenez 



**CERN Organisation 2021-2025** (after 30.06.2021)

# „The Mission“

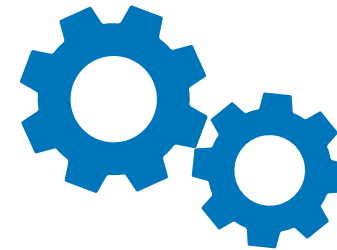
## Fundamental Research

at the frontier of human knowledge

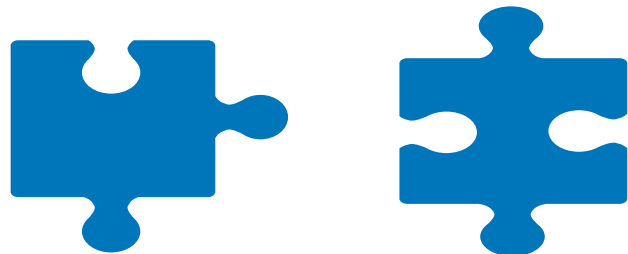


## Innovative Technologies

for research

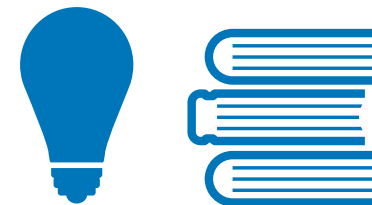


## Collaboration



## Education & Inspiration

e.g. training of scientist and engineers, but  
also educating everyone, from kindergarten to old age



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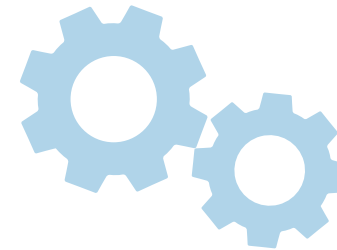
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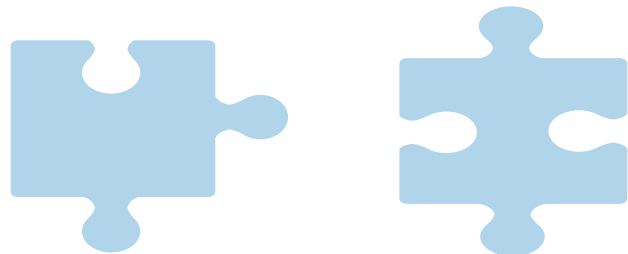


## Innovative Technologies

for research

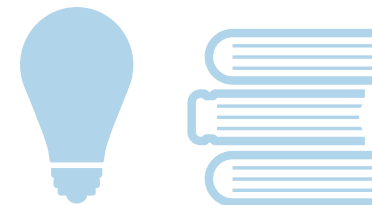


## Collaboration



## Education & Inspiration

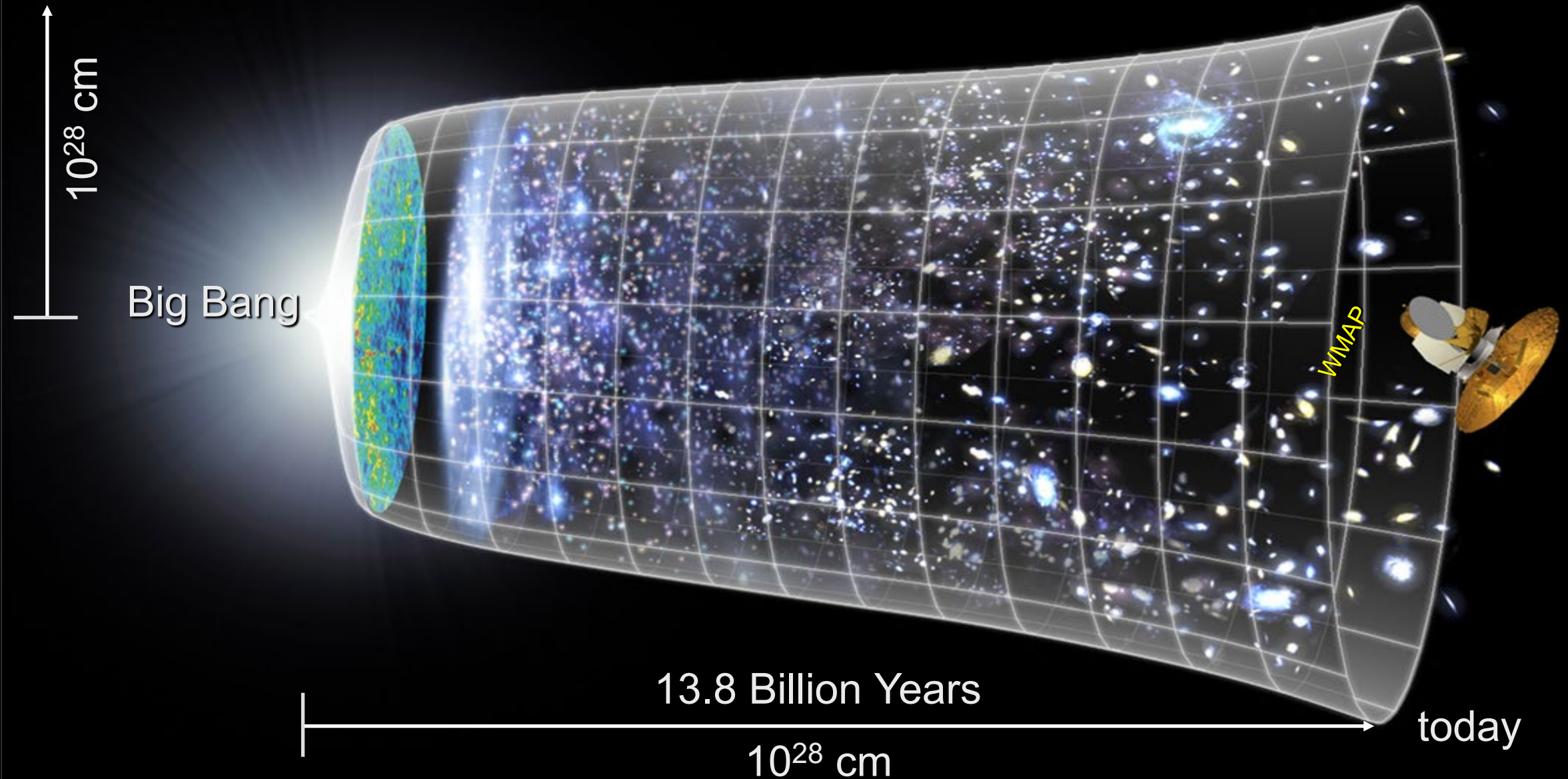
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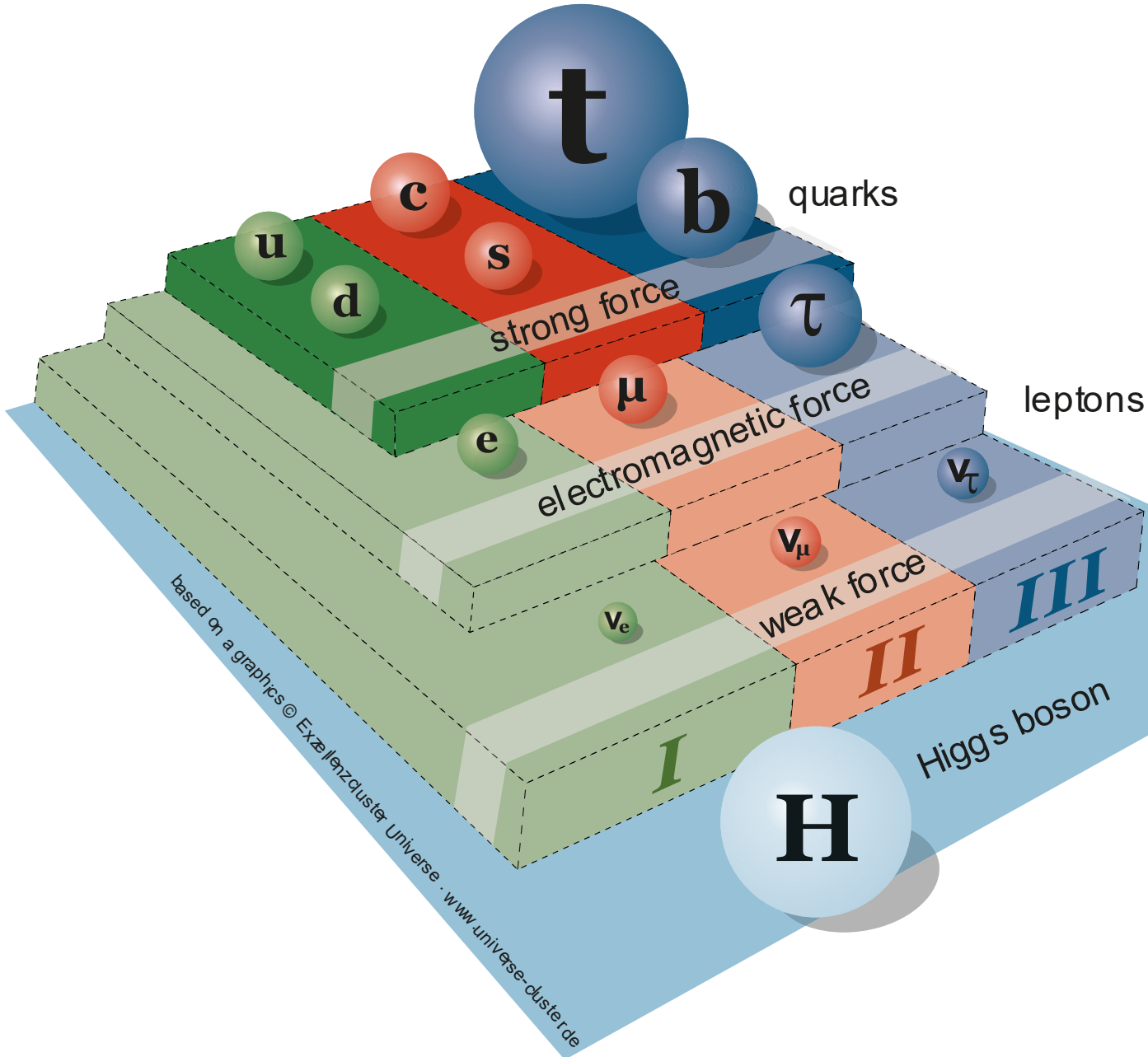


# The Scientific Challenge

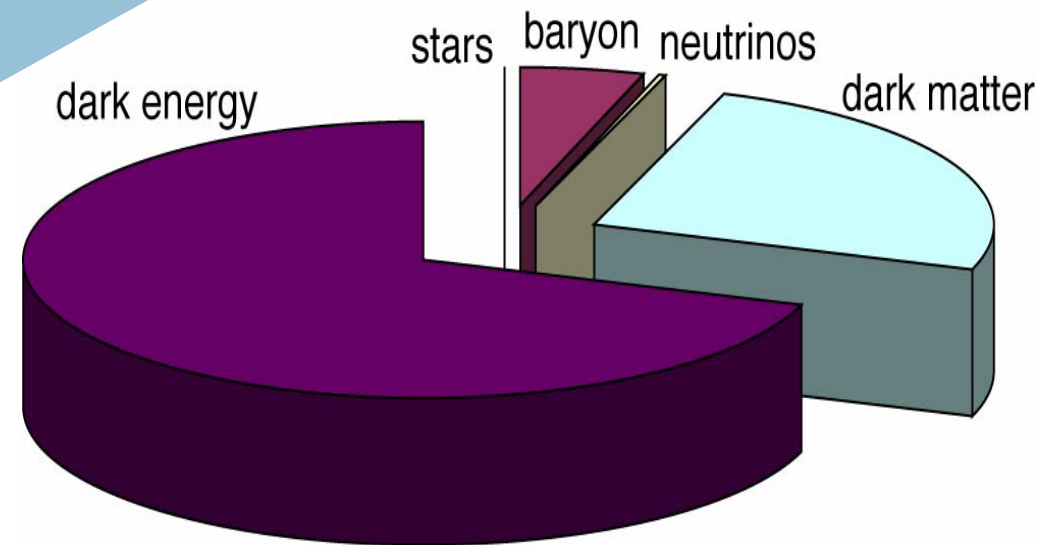
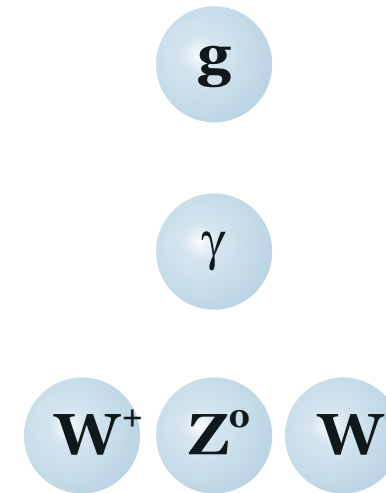
## Research on the Development of the Universe







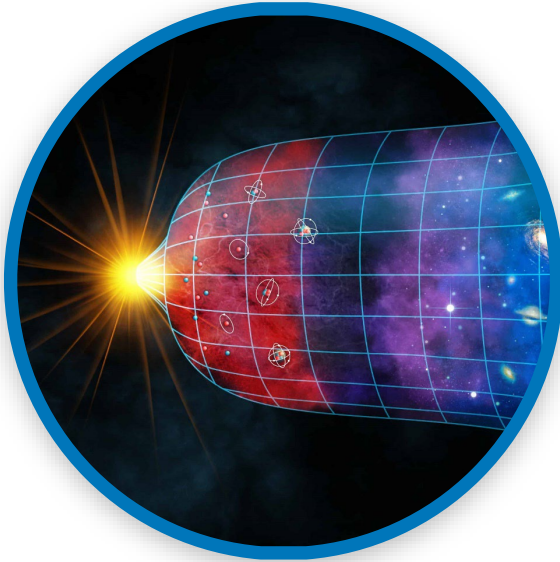
force carriers



# Standard Model

# Further Research Questions

Early Universe



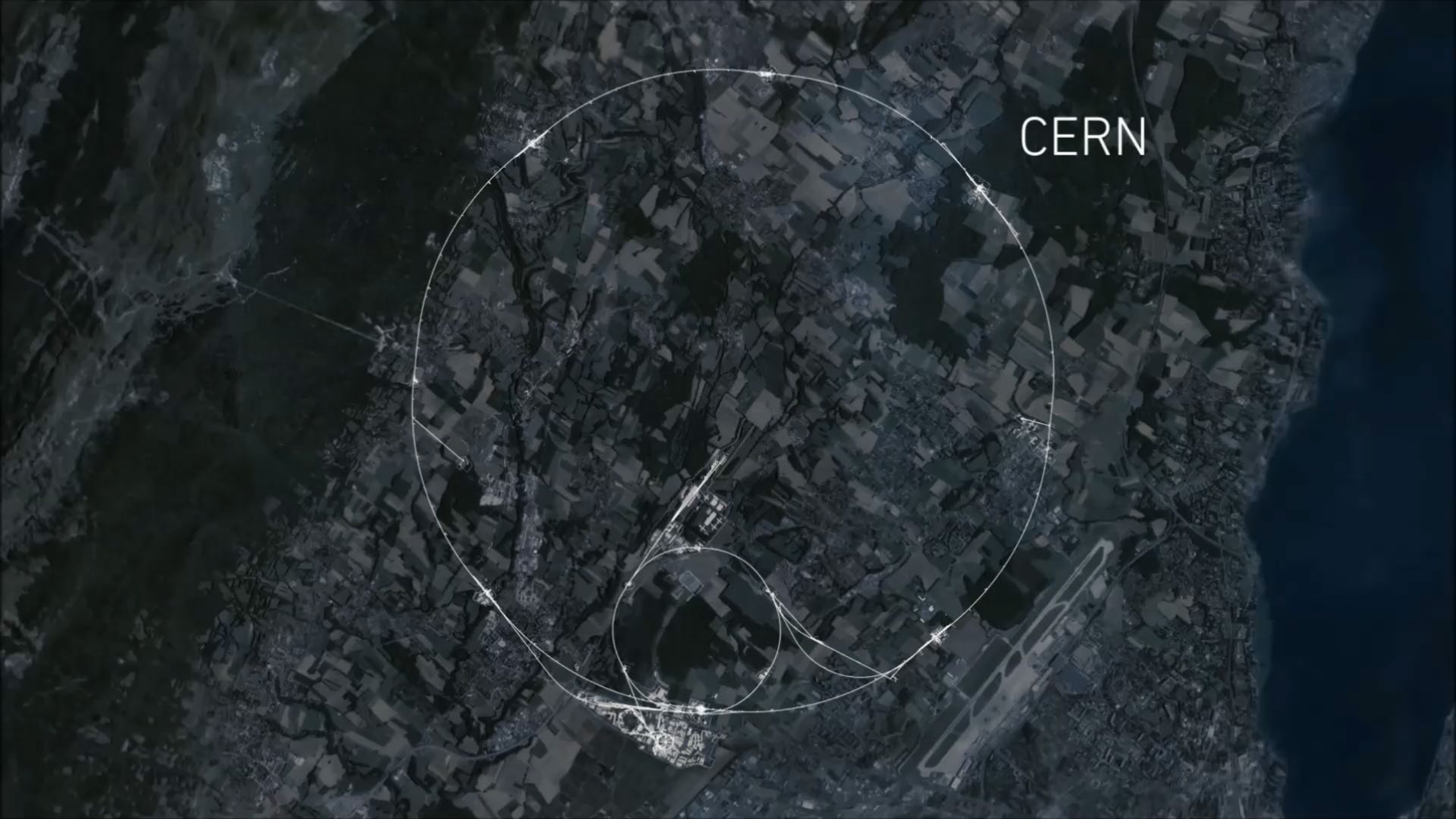
Anti-Matter



Dark Matter



CERN





# „The Mission“

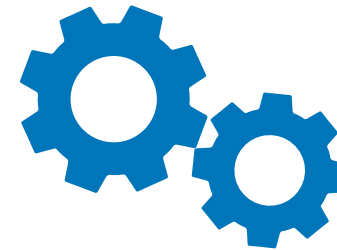
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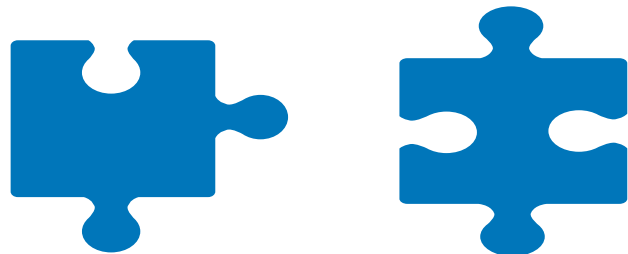


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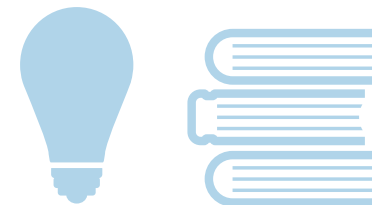


## Collaboration



## Education & Inspiration

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also educating everyone, from kindergarten to old age





Particle Detection

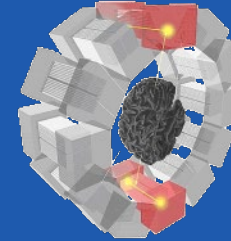


## Imaging

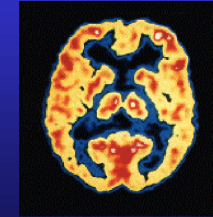
ClearPEM



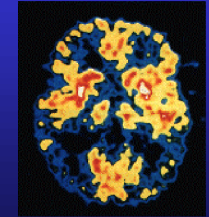
## PET Scanner



Brain Metabolism in Alzheimer's Disease: PET Scan



Normal Brain



Alzheimer's Disease

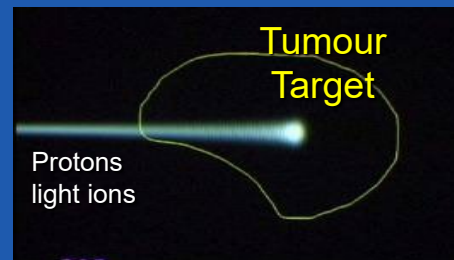


## Accelerated Particle Beams

~30'000 accelerators world-wide  
~17'000 for medical applications



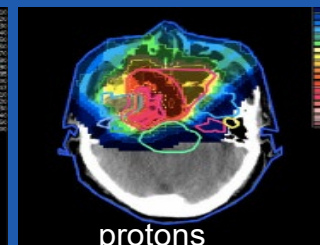
## Hadron Therapy



>70'000 patients/a world-wide (30 institutes)  
>21'000 patients/a in Europe (9 institutes)



X-ray

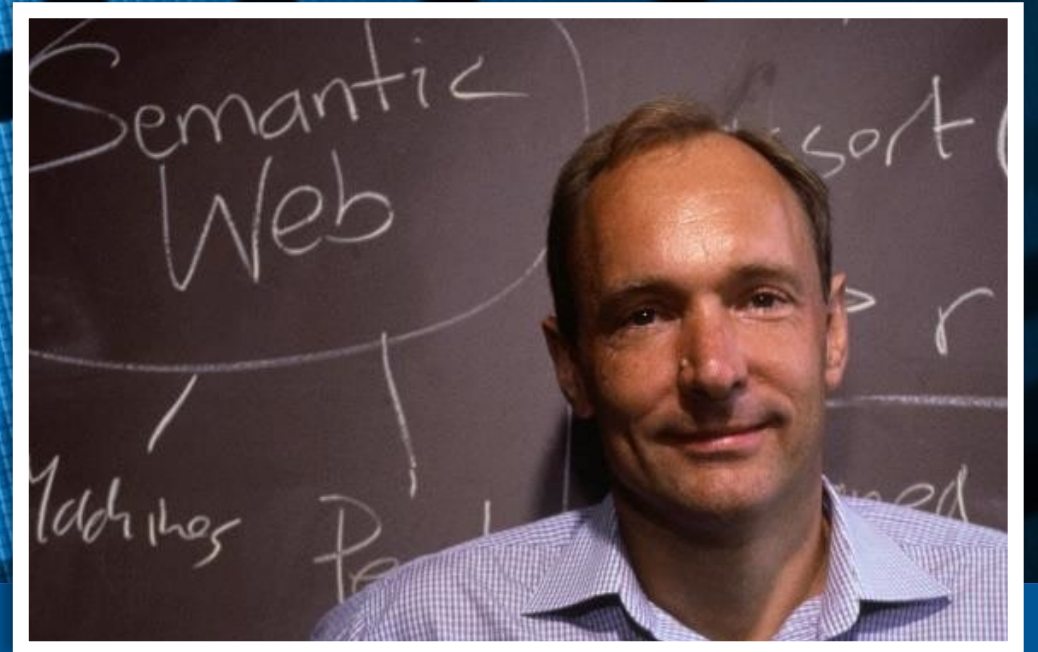


protons



# World Wide Web

# WWW



European Organization for Particle Physics  
*Organisation européenne pour la physique des particules*

# What happens just now?

# LHCb: Flavour Anomalies

Intriguing results from LHCb in bottom and charm decays, for example in  $b \rightarrow s \ell \ell$  decays

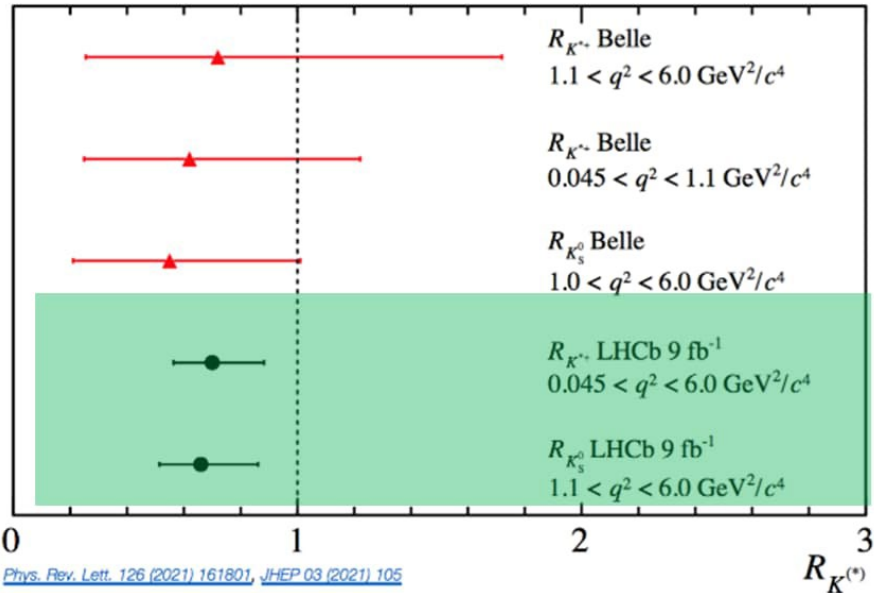
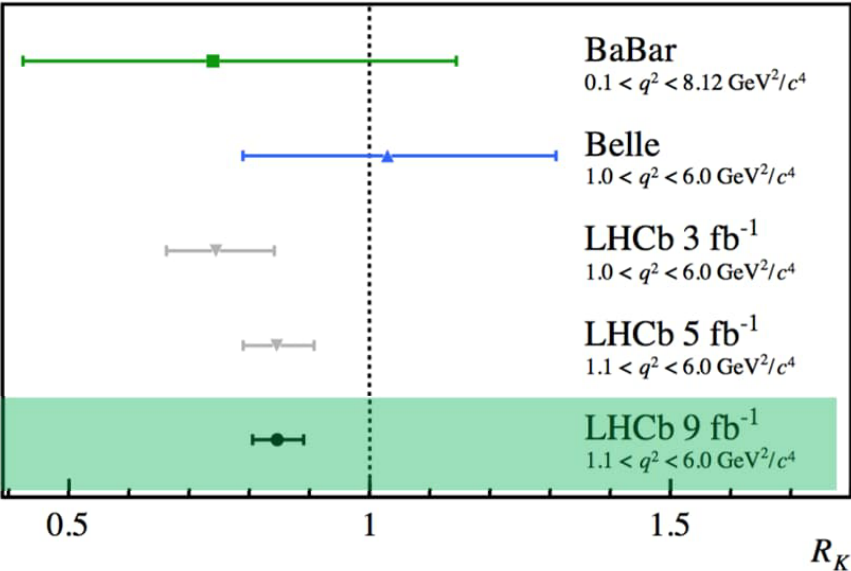
Recall: SM predicts equal couplings of electrons and muons

- March 2021: 3.1 sigma muon deficit in  $B \rightarrow K \ell^+ \ell^-$
- October 2021:  $\approx 1$  sigma muon deficits in  $B \rightarrow K^{*+} \ell^+ \ell^-$  and  $B \rightarrow K_s^0 \ell^+ \ell^-$

Flavour anomalies workshop October 20<sup>th</sup>: combined LHC experiments event incl. theory

Eagerly waiting for more results from the LHC experiments to clarify the origin of these anomalies

$$R_K = N(B \rightarrow K \mu^+ \mu^-) / N(B \rightarrow K e^+ e^-)$$



Phys. Rev. Lett. 126 (2021) 161801, JHEP 03 (2021) 105



# CMS: Measurement of Higgs Total Width

Evidence for off-shell Higgs production in

$$H \rightarrow ZZ \rightarrow 2l2\nu \text{ and } 4l$$

Recall:  $m_H = 125 \text{ GeV}$ ,  $m_Z = 91 \text{ GeV}$

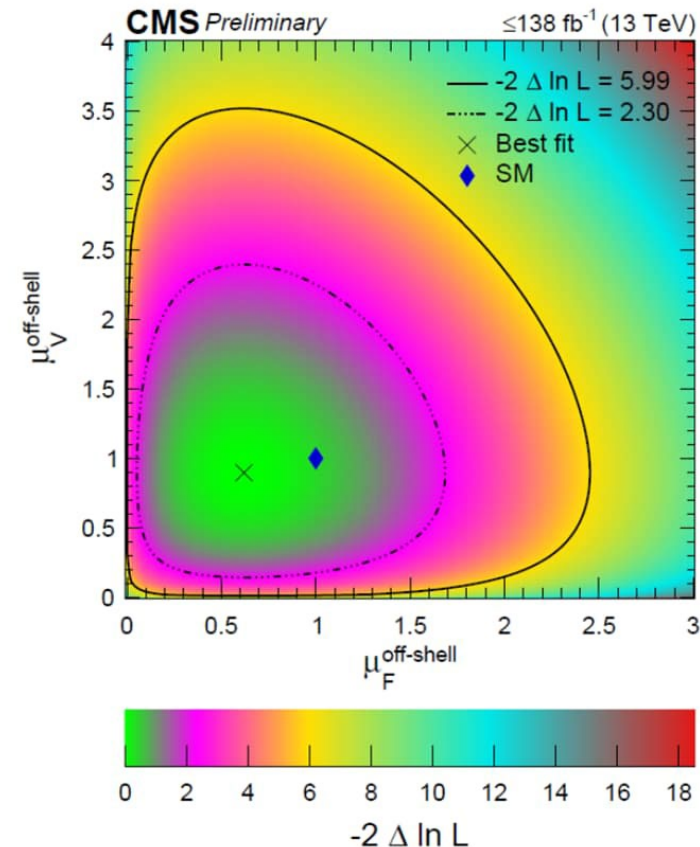
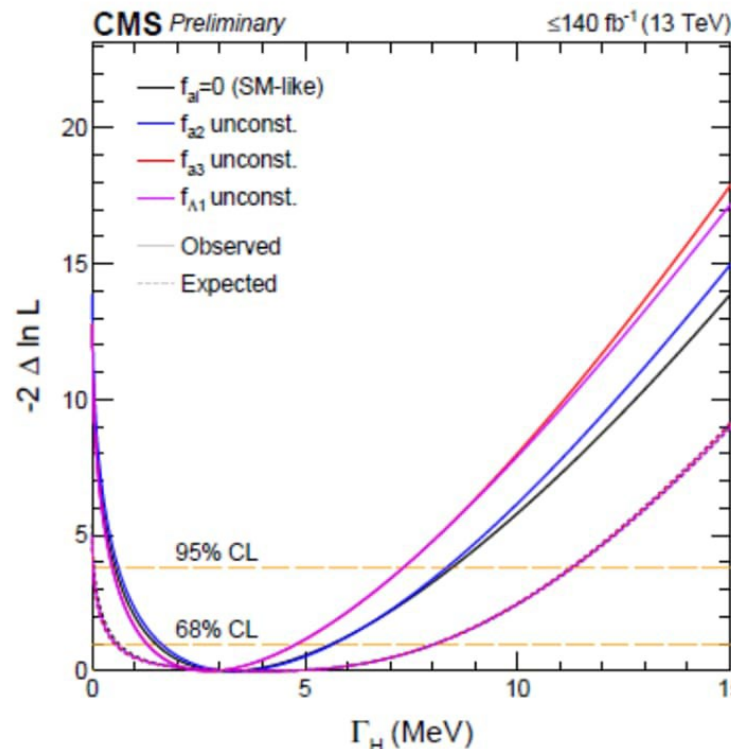
on-shell  $H \rightarrow ZZ^*$

off-shell  $H^* \rightarrow ZZ$  (approx. 10%)

- Allows measurement of the Higgs total width:

$$\Gamma_H = 3.2^{+2.4}_{-1.7} \text{ MeV}$$

- Compatible with SM expectation 4.1 MeV
- Width zero excluded with 3.6 sigma
- Provides also test of anomalous couplings



This is also a measurement of the lifetime of the Higgs boson:  $\tau = 2 \cdot 10^{-22} \text{ s}$

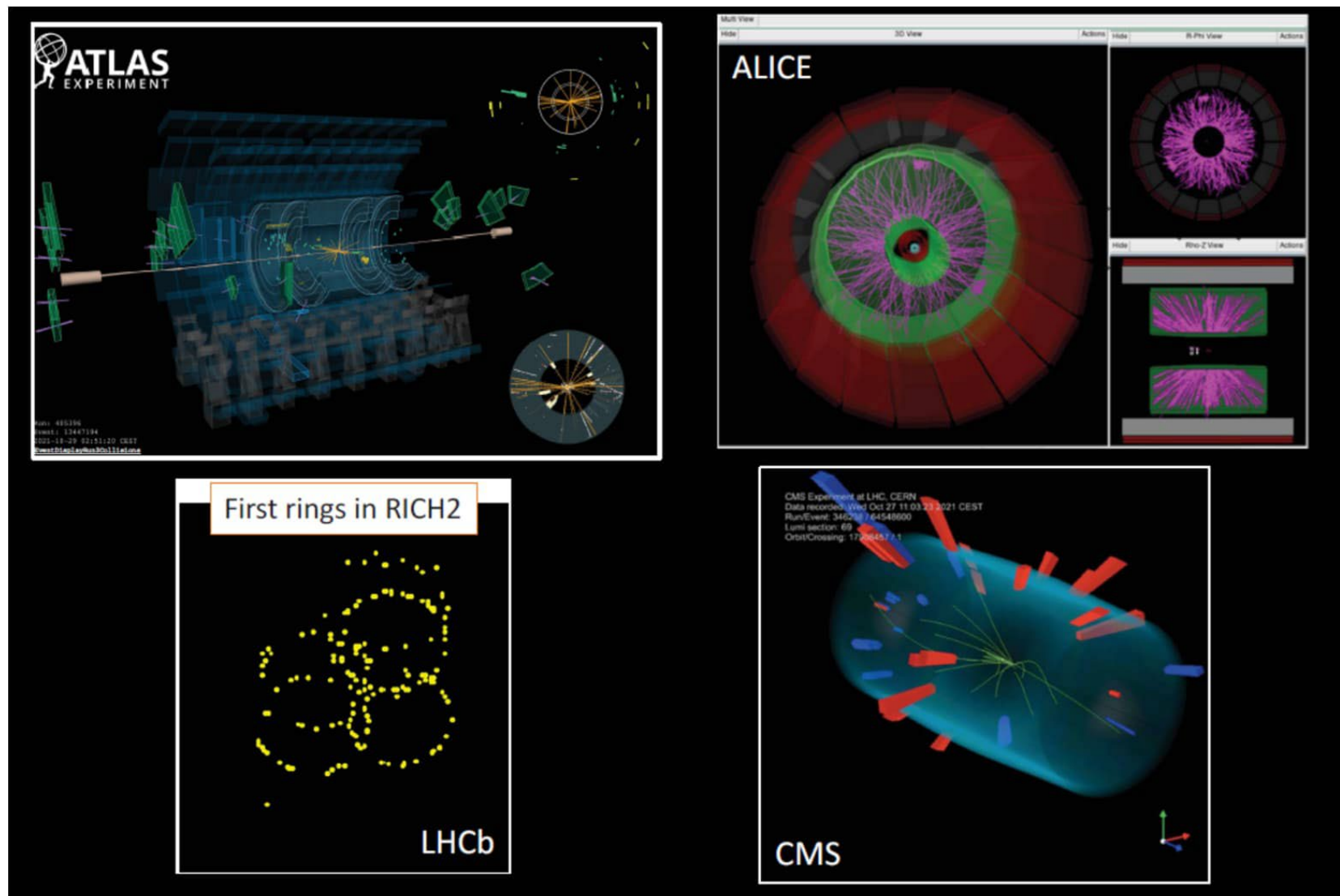
# Pilot Run October 2021

All 4 experiments  
successfully participated  
and took collision data

**Exceptional achievement  
under very difficult  
circumstances!**

Good prospects to start  
Run 3 with upgraded  
detectors in spring 2022

**However: Impact of Covid  
remains a big challenge!**







# ANTIMATTER FACTORY

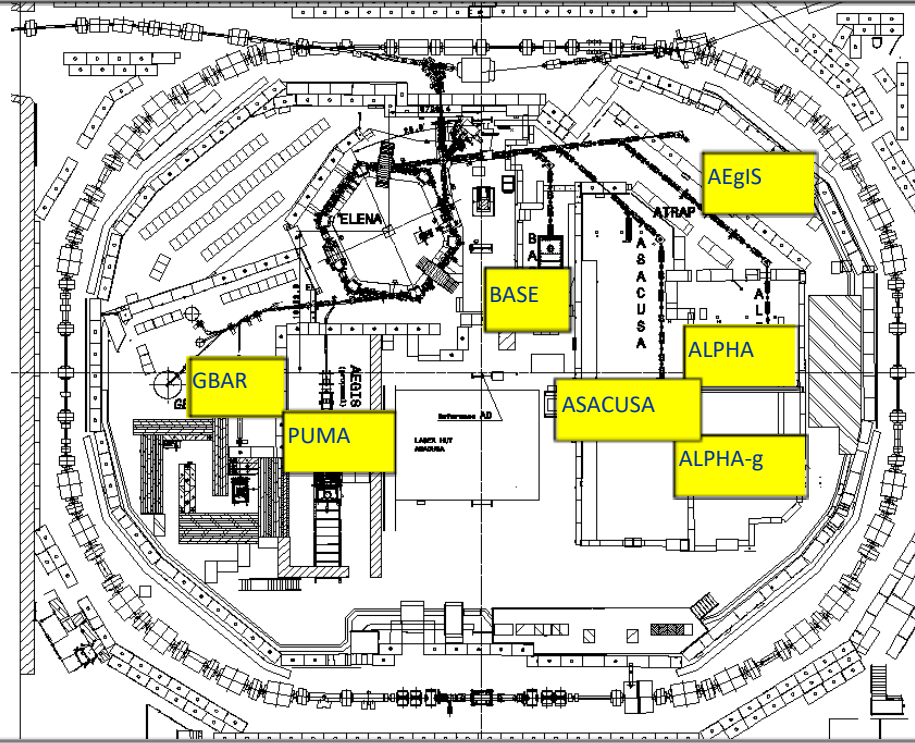


2021 highlights

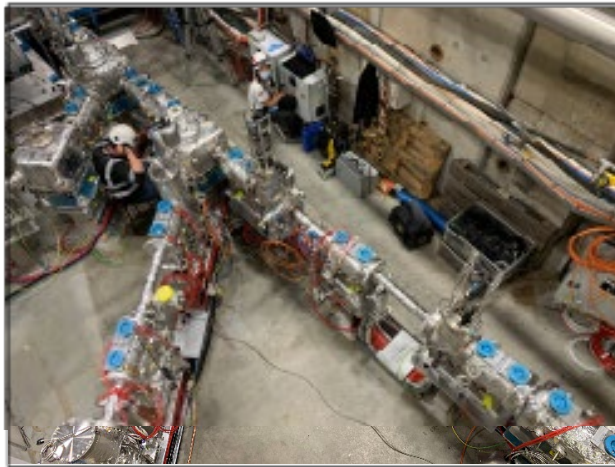
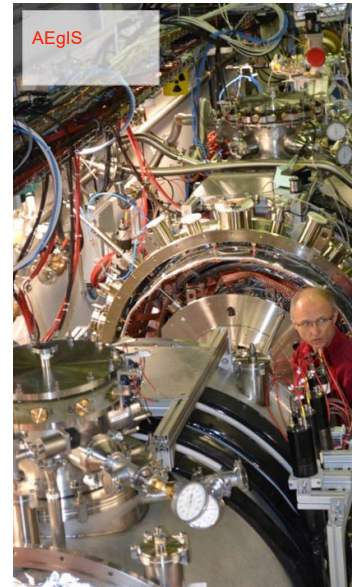
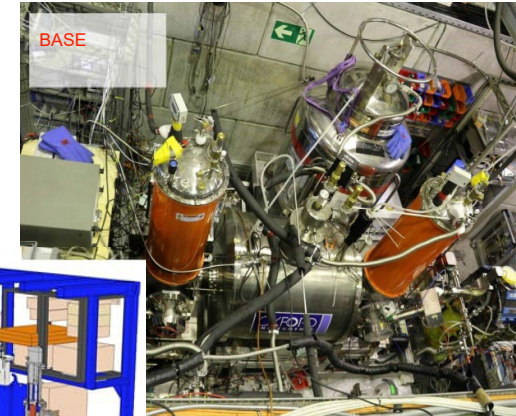
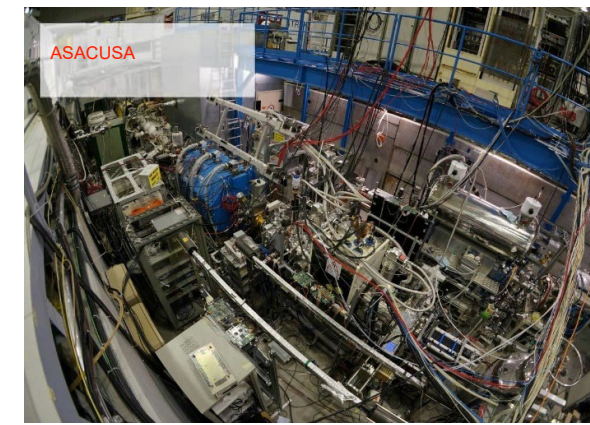
Smooth AD  
restart after LS2

ELENA: new  
100 keV TL's  
1st operation

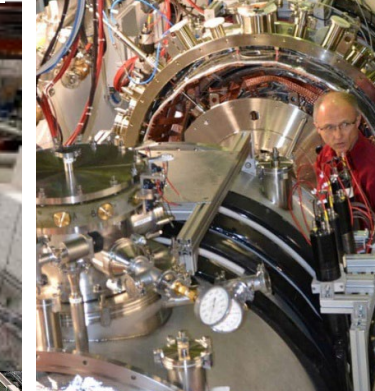
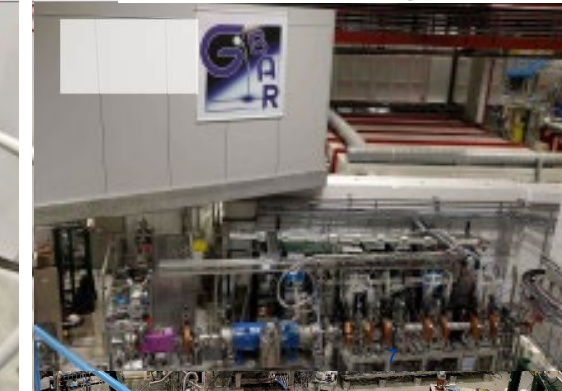
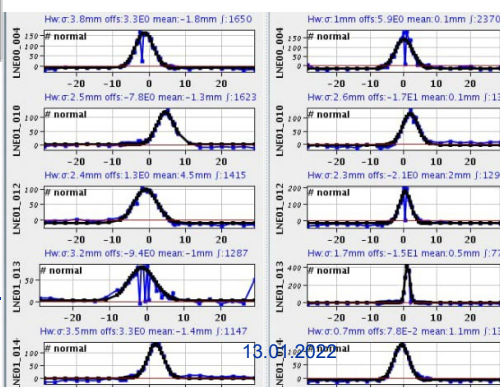
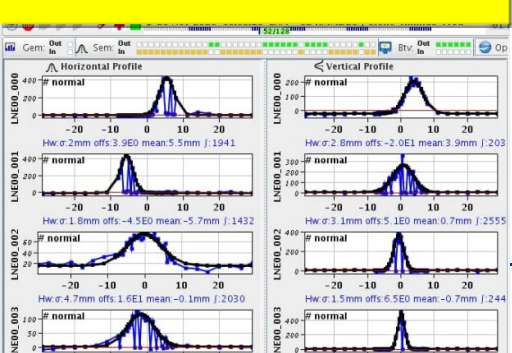
60 Research Institutes/Universities – 350 Scientists – 6 Active Collaborations



Excellent performance: stable beams, stable intensity, reliable!



## Beam profiles in transfer lines (TL's)



13.01.2022

J. Misch | Experiments and Computing

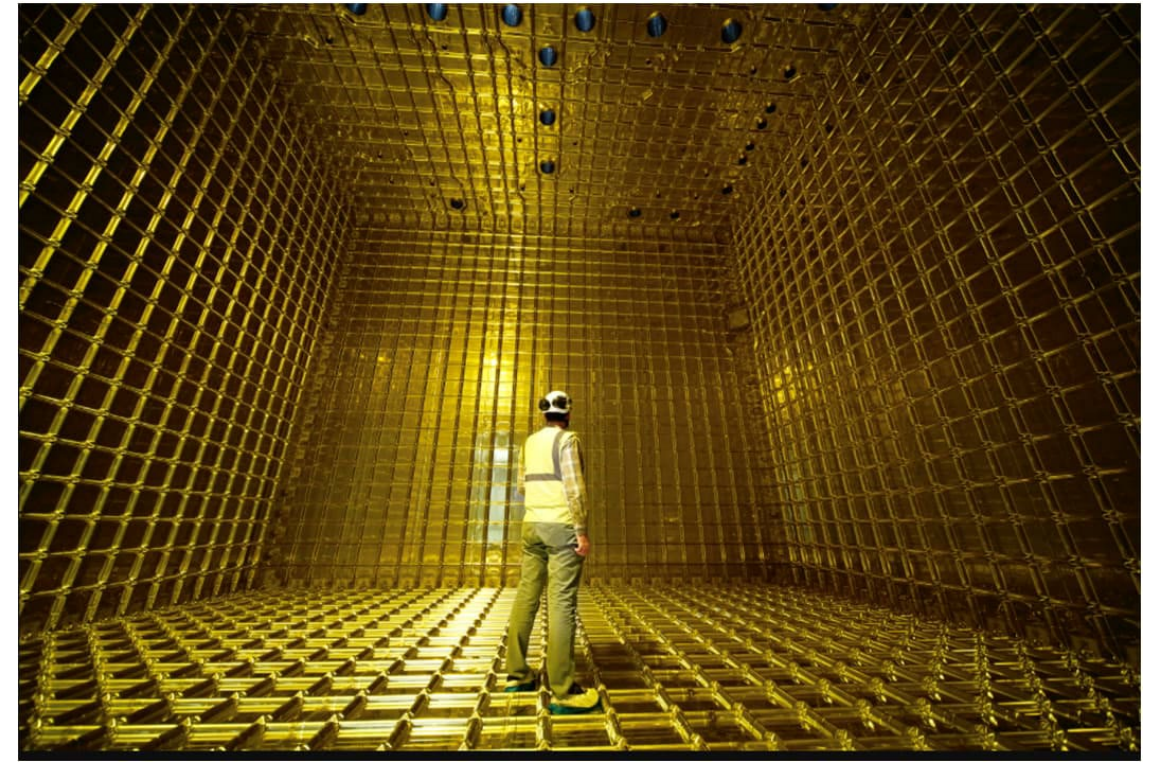
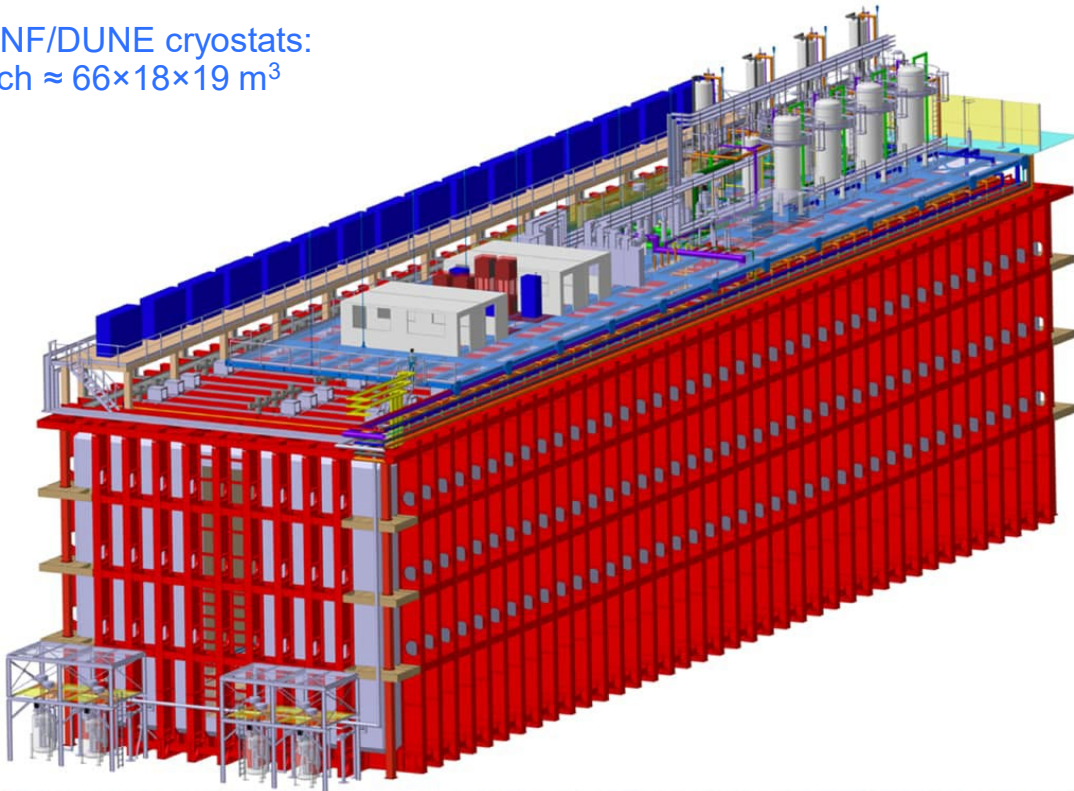


# CERN Neutrino Platform

Main activity:

- Procurement and construction of the large 2 cryostats for LBNF/DUNE will commence in 2022

LBNF/DUNE cryostats:  
each  $\approx 66 \times 18 \times 19 \text{ m}^3$



1:20 scale cryostat at the Neutrino Platform  $\approx 12 \times 12 \times 12 \text{ m}^3$

In addition:

- Development of LAr TPC for DUNE (ProtoDUNE) in two 1:20 scale cryostats
- Several R&D projects also for T2K and HyperK

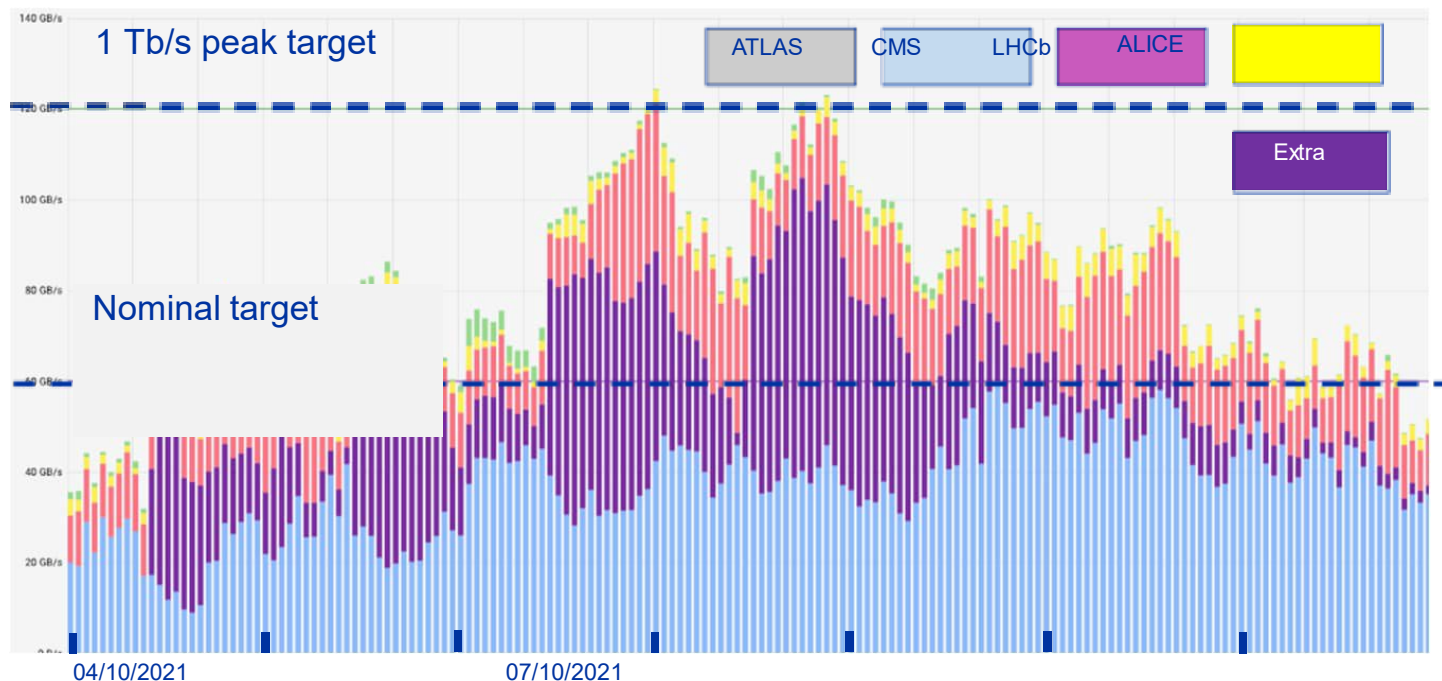
# Status Computing: Commissioning for Run3

Planned data challenges executed

- Testing the network and archive storages

Targets were met

- Nominal rate sustained
- Peak transfer rate were reached



Data challenges are part of a longer-term process to prepare for the HL-LHC needs

More commissioning tests are planned before the start of Run 3

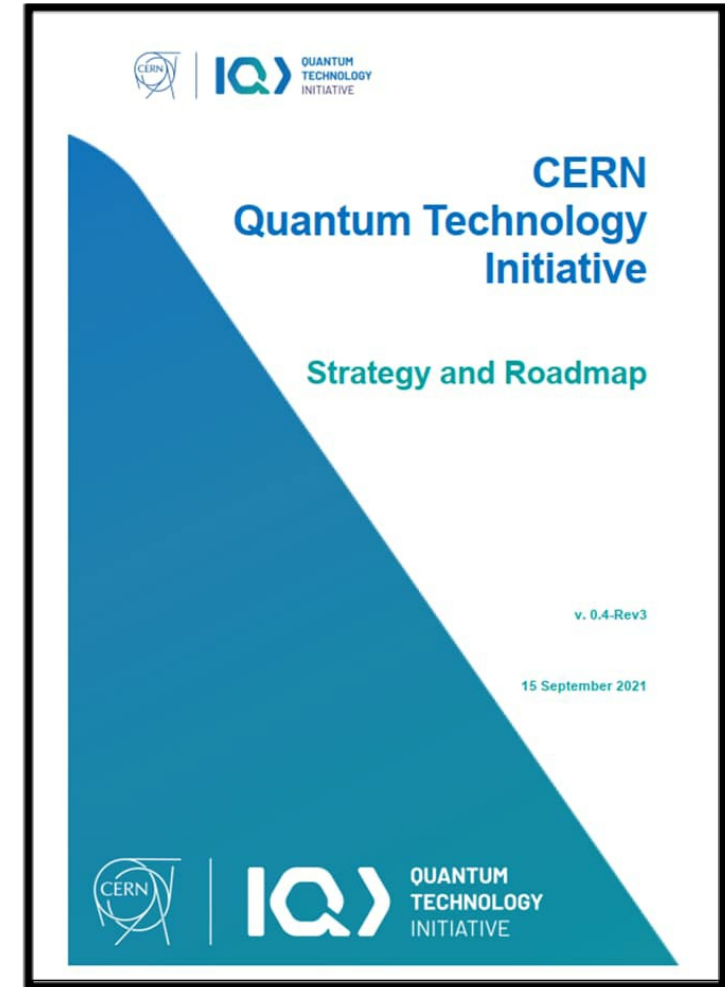


# CERN Quantum Technology Initiative

Established in September 2020

Achievements in 2021:

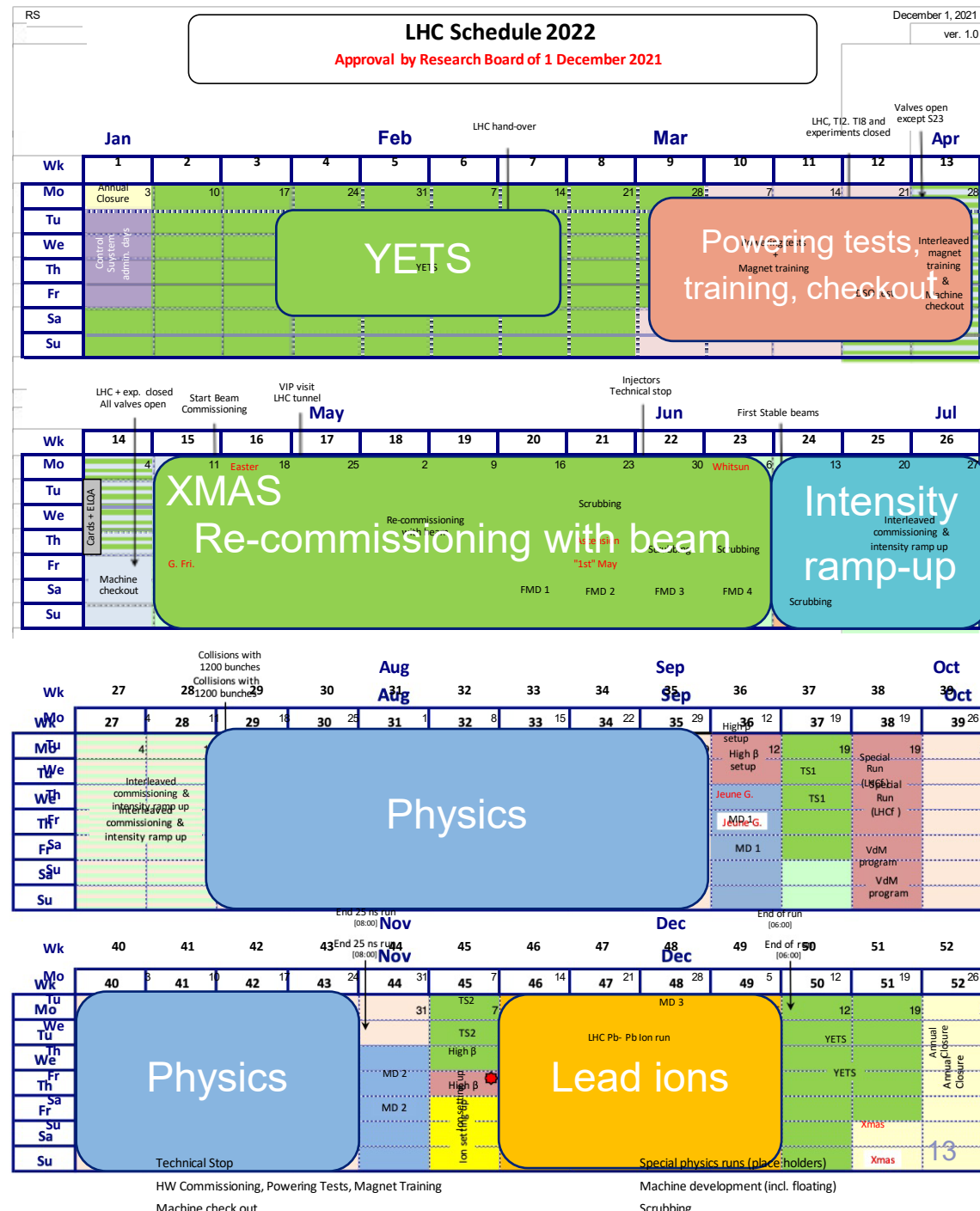
- Setting up the initiative and its governance
  - Coordination Task Force, Advisory Board, Web site, comms channels, branding, awareness
- Projects and PhD programme
  - Research programme as part of CERN DOCT programme
  - Research collaborations with institutes in the Member States and beyond (17 ongoing projects)
- Infrastructure
  - Local classic cluster for quantum computing simulations, a dedicated simulator, and access to quantum hardware from different providers
- Strategy and Roadmap
  - Developed in discussions with the CERN community, the Advisory Board and experts from the HEP/quantum communities, published in September 2021



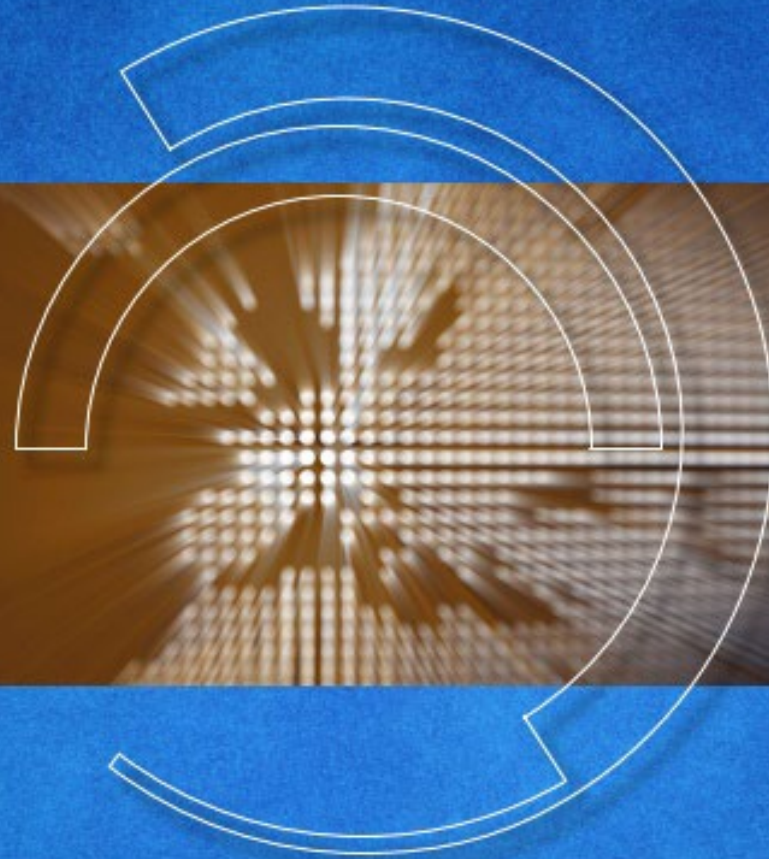
<https://doi.org/10.5281/zenodo.5553774>

# LHC 2022

- Warm-up and repair of sector 23 complete, cool-down ongoing
- Thereafter:
  - Powering tests
  - Finish training S23 to 6.8 TeV
  - Close machine second half March
  - Start beam commissioning in April
  - First Stable Beams in June
- 81 days of 25 ns running with > 1200 bunches
- 10 days of special physics runs
- 27 days of Pb-Pb ions physics, inc. p-p reference run



# And then?



2020 UPDATE OF THE EUROPEAN STRATEGY  
FOR PARTICLE PHYSICS

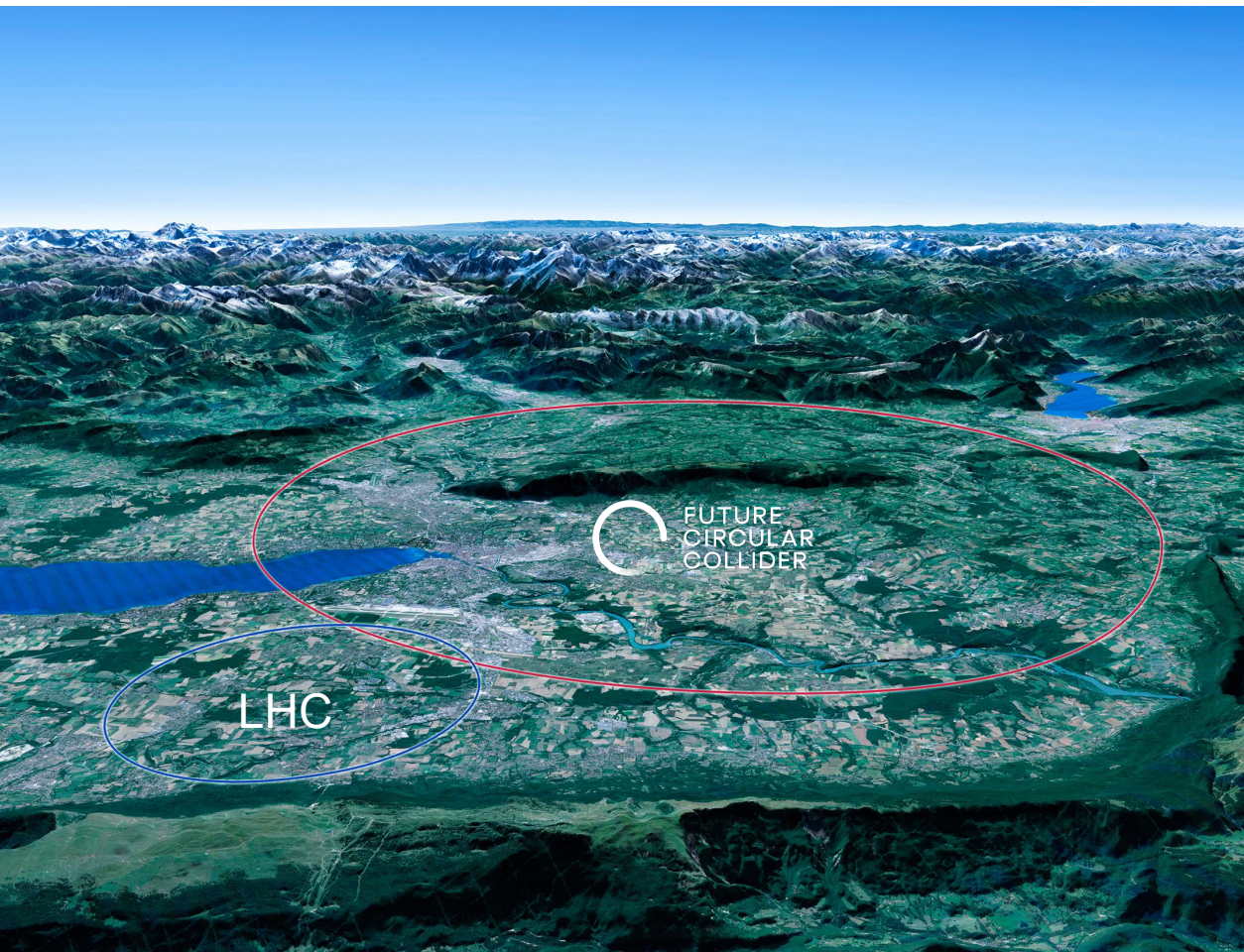
by the European Strategy Group



# CERN Scientific Priorities for the Future

Implementation of the recommendations of the **2020 Update of the European Strategy for Particle Physics**:

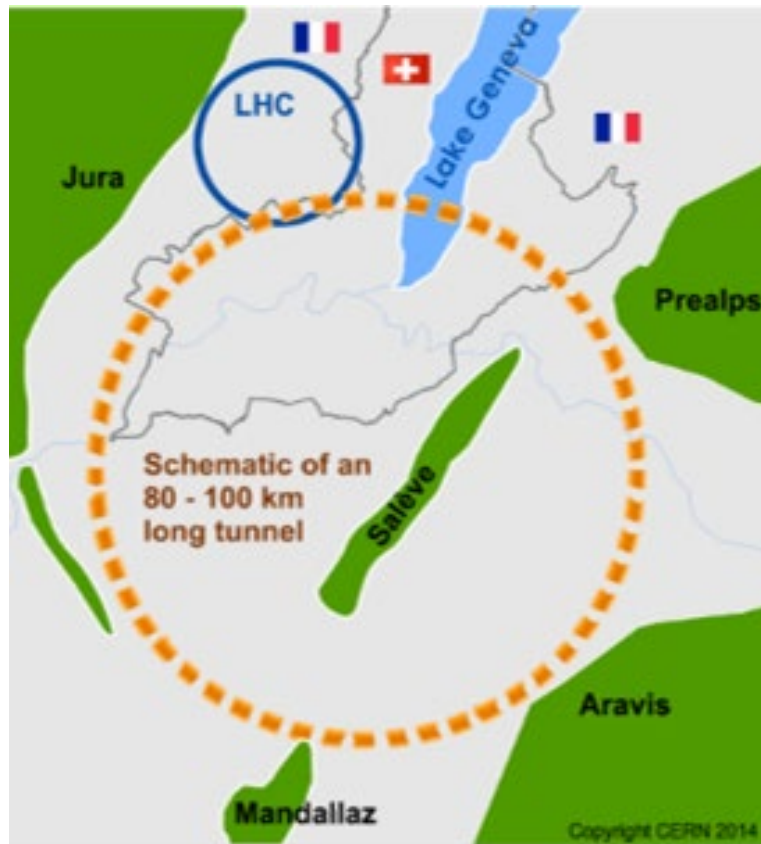
- Fully exploit the LHC & HL-LHC.
- Build a Higgs factory to further understand this unique particle.
- Investigate the technical and financial feasibility of a future energy-frontier 100 km collider at CERN.
- Ramp up relevant R&D.
- Continue supporting other projects around the world.



# The FCC Integrated Programme

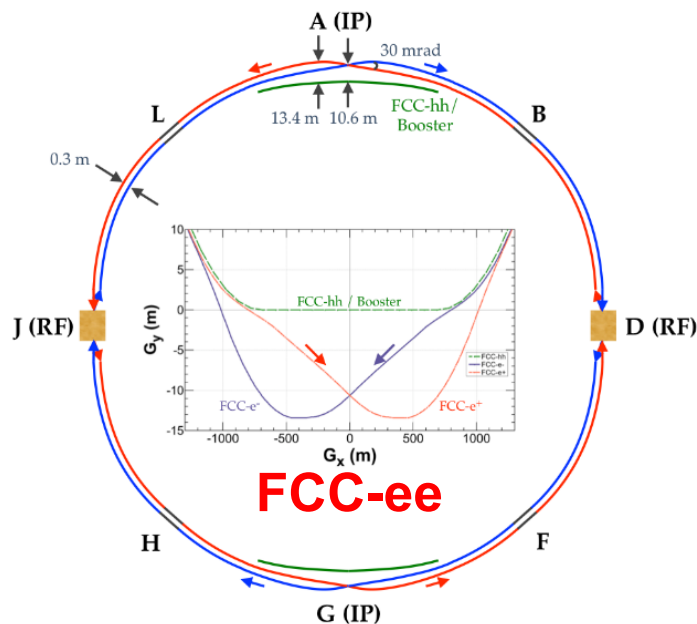
## Inspired by successful LEP – LHC Programmes at CERN

Complementary physics, common civil engineering and technical infrastructures, building on and reusing CERN's existing infrastructure, FCC integrated project allows seamless continuation of HEP after HL-LHC



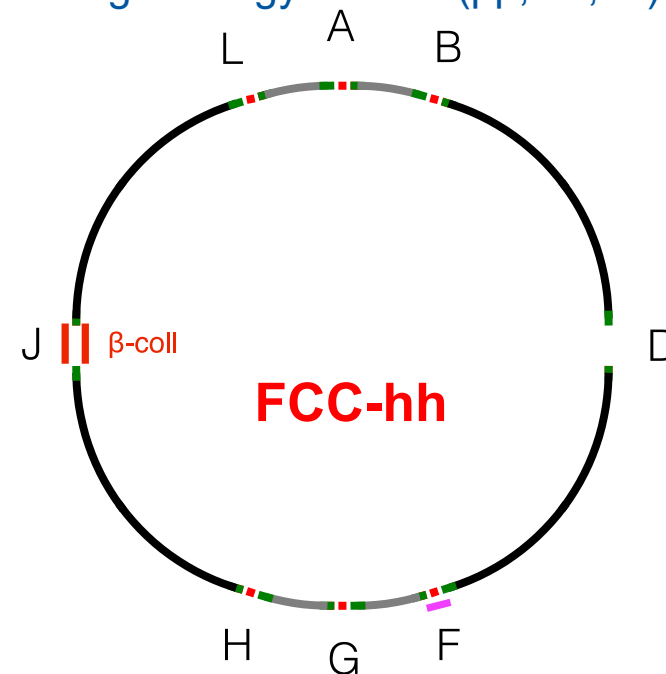
2020 - 2040

**Phase 1 : FCC-ee**  
**electron – positron Collider**  
Higgs, Z, W, ttbar Factory at highest lumi



2040 - 2055

**Phase 2 : FCC-hh**  
**proton – proton Collider**  
High-energy frontier (pp, ion, eh)



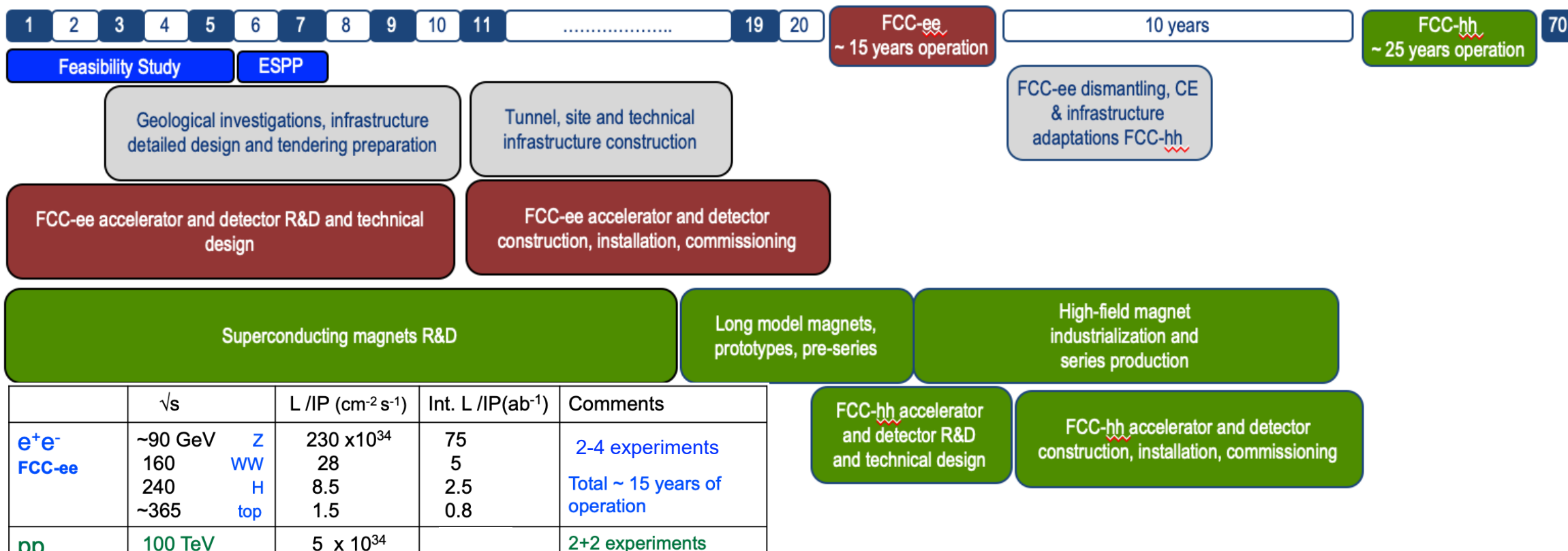
2060 - 2090





# Timeline of the FCC Integrated Programme

Technical  
schedule



	$\sqrt{s}$	L /IP (cm <sup>-2</sup> s <sup>-1</sup> )	Int. L /IP(ab <sup>-1</sup> )	Comments
<b>e<sup>+</sup>e<sup>-</sup></b> <b>FCC-ee</b>	~90 GeV <b>Z</b> 160 <b>WW</b> 240 <b>H</b> ~365 <b>top</b>	230 x 10 <sup>34</sup> 28 8.5 1.5	75 5 2.5 0.8	2-4 experiments Total ~ 15 years of operation
<b>pp</b> <b>FCC-hh</b>	100 TeV	5 x 10 <sup>34</sup> 30	20-30	2+2 experiments Total ~ 25 years of operation
<b>PbPb</b> <b>FCC-hh</b>	$\sqrt{s_{NN}} = 39\text{TeV}$	3 x 10 <sup>29</sup>	100 nb <sup>-1</sup> /run	1 run = 1 month operation
<b>ep</b> <b>Fcc-eh</b>	3.5 TeV	1.5 10 <sup>34</sup>	2 ab <sup>-1</sup>	60 GeV e- from ERL Concurrent operation with pp for ~ 20 years
<b>e-Pb</b> <b>Fcc-eh</b>	$\sqrt{s_{eN}} = 2.2\text{ TeV}$	0.5 10 <sup>34</sup>	1 fb <sup>-1</sup>	60 GeV e- from ERL Concurrent operation with PbPb

- ☐ Feasibility Study: 2021-2025
- ☐ If project approved before end of decade → construction can start beginning 2030s
- ☐ FCC-ee operation ~2045-2060
- ☐ FCC-hh operation 2070-2090++

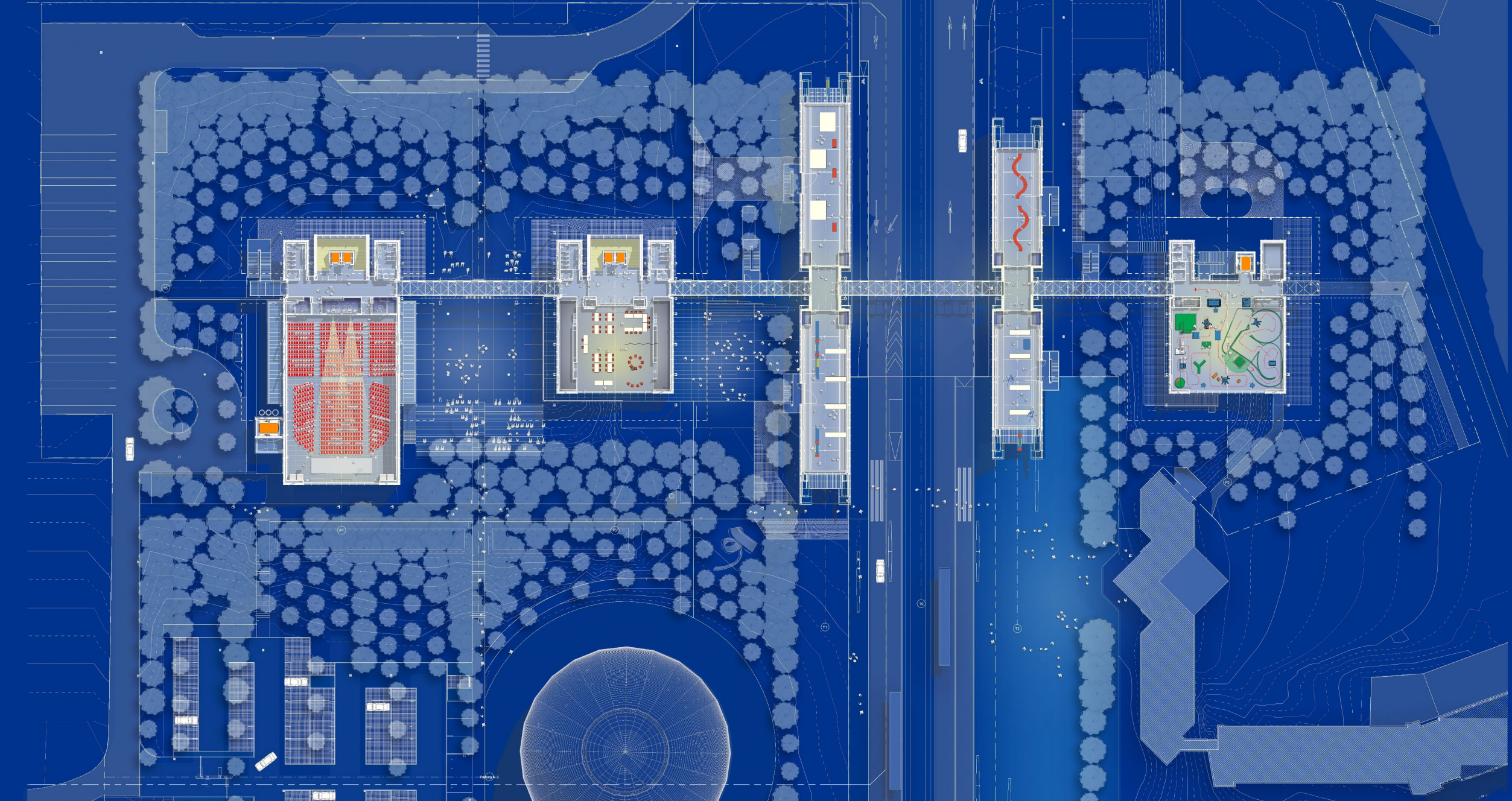




# CERN Science Gateway

















# „The Mission“

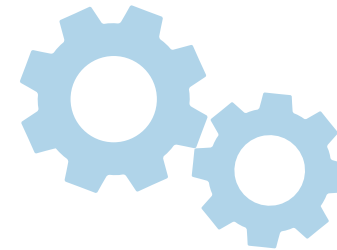
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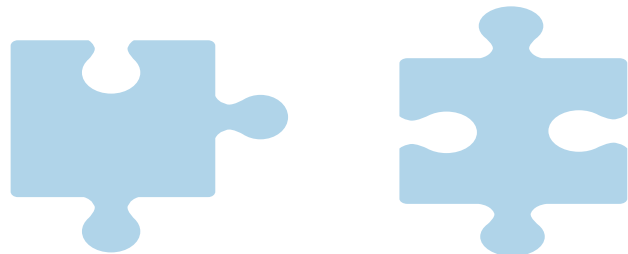


## Innovative Technologies

for research

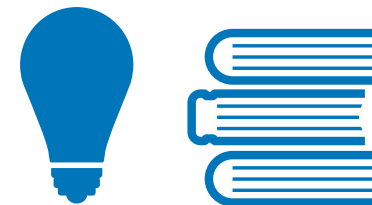


## Collaboration



## Education & Inspiration

e.g. training of scientist and engineers, but  
also educating everyone, from kindergarten to old age





# CERN Education Programme for Teachers and Students

Teacher Programmes

1 staff 

S'Cool LAB

1 fellow   
2 doct   
  
1 technician 

Competitions

1 fellow   
  
1 user 

Internships







½ fellow 

Publications

1 staff   
1 admin   
1 tech 

Collaboration 1 user 

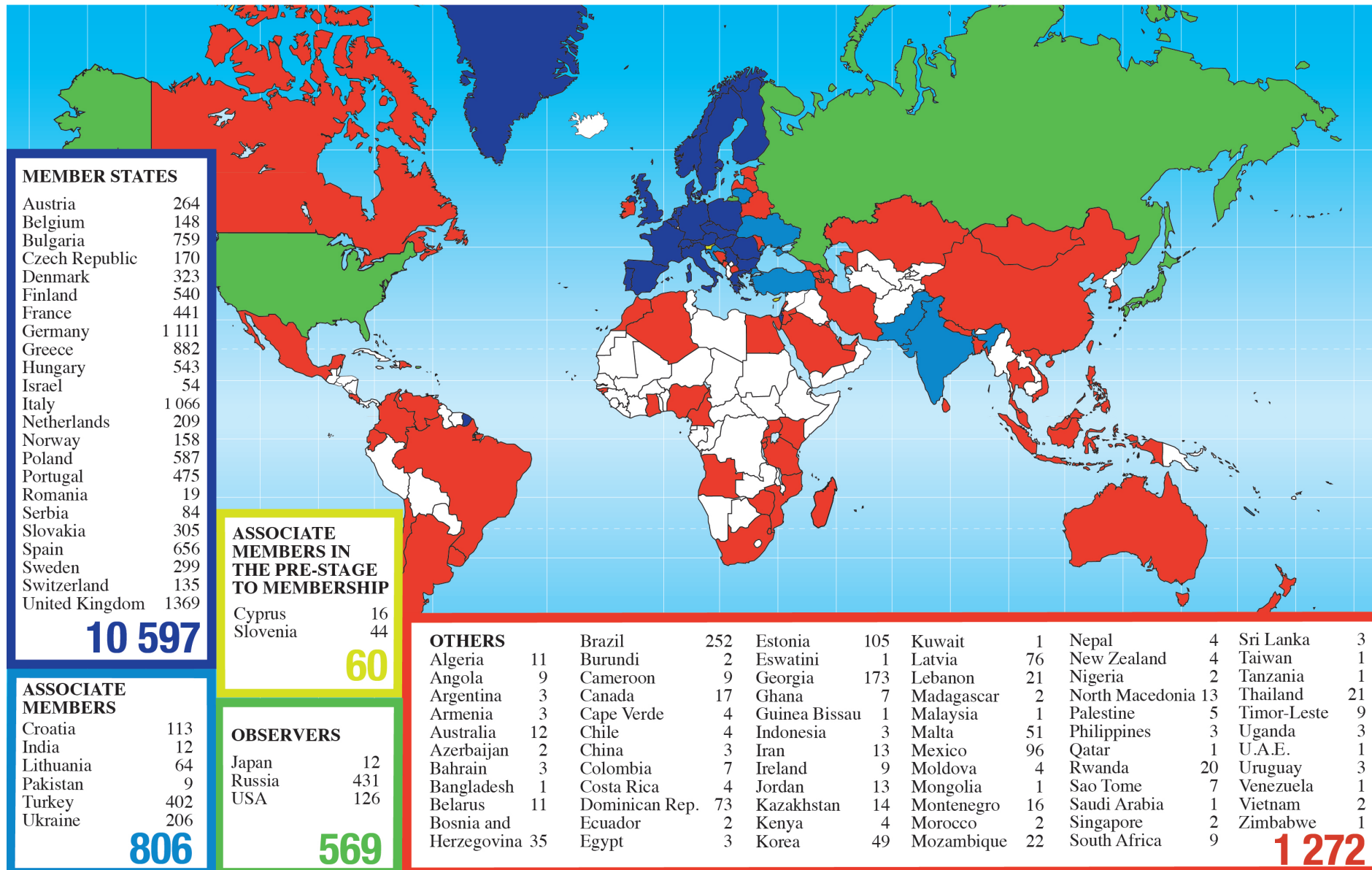
Physics Education Research 3 doct 

  
1 staff   
3 fellows   
**Science Gateway**  
1 doct 



## Education Team 2022

# Teacher Programme Participants 1998 - 2020 (Total: 13 304)





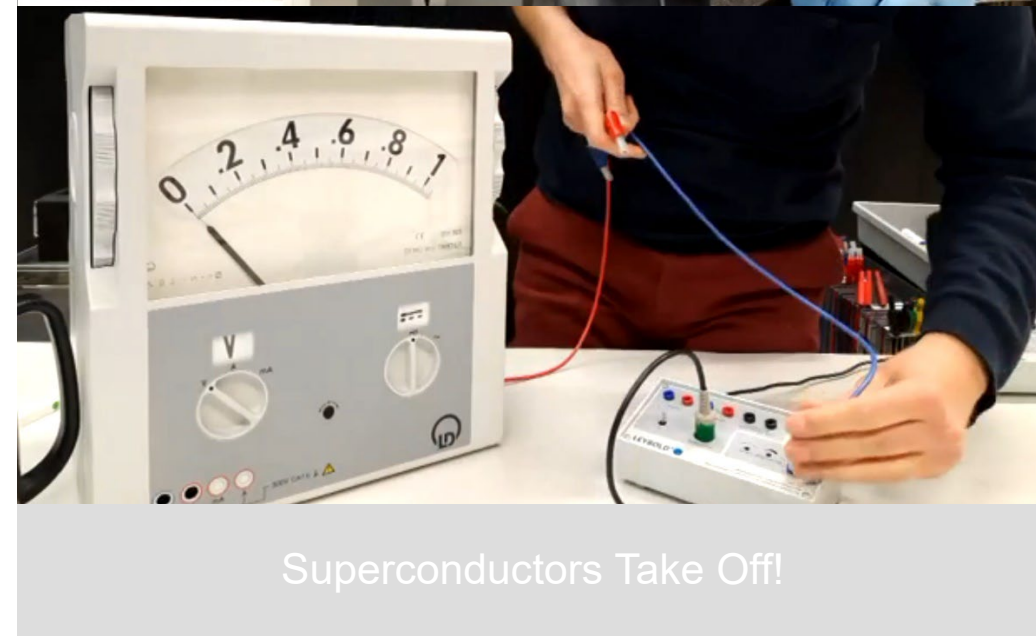
S'Cool  
LAB

Welcome





- Live interactive demonstrations of scientific phenomena
- Links to CERN research
- Questions and answers
- Various languages



Superconductors Take Off!



# Virtual Science Shows – the pandemic as great opportunity



2017



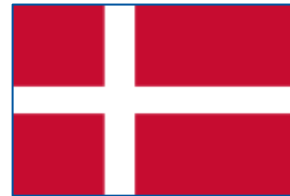
2018



2019



2021

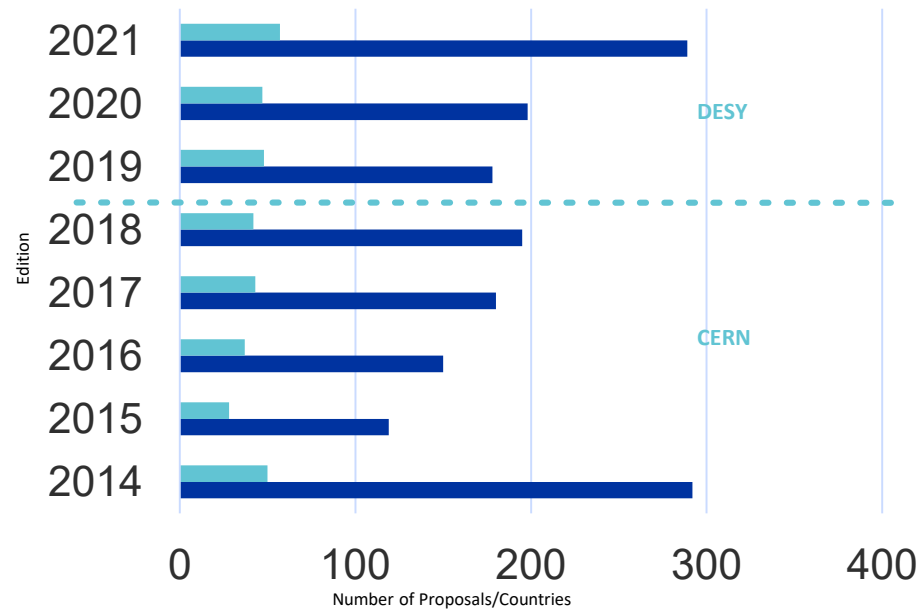
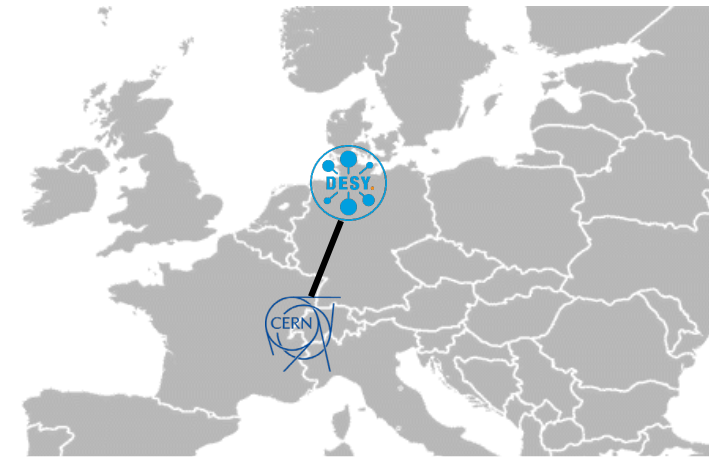


2022



# High-School Students Internship Programme

- Competition for High-School Student Teams
- Normally at CERN's PS, 2019-21 at DESY
- Participation 2021
  - 298 proposals
- 2022
  - back at CERN for the finals of the competition
- Italian Participation
  - winning teams in 2015, 2017, and 2021



# Beamline for Schools Competition



# Evaluation of CER

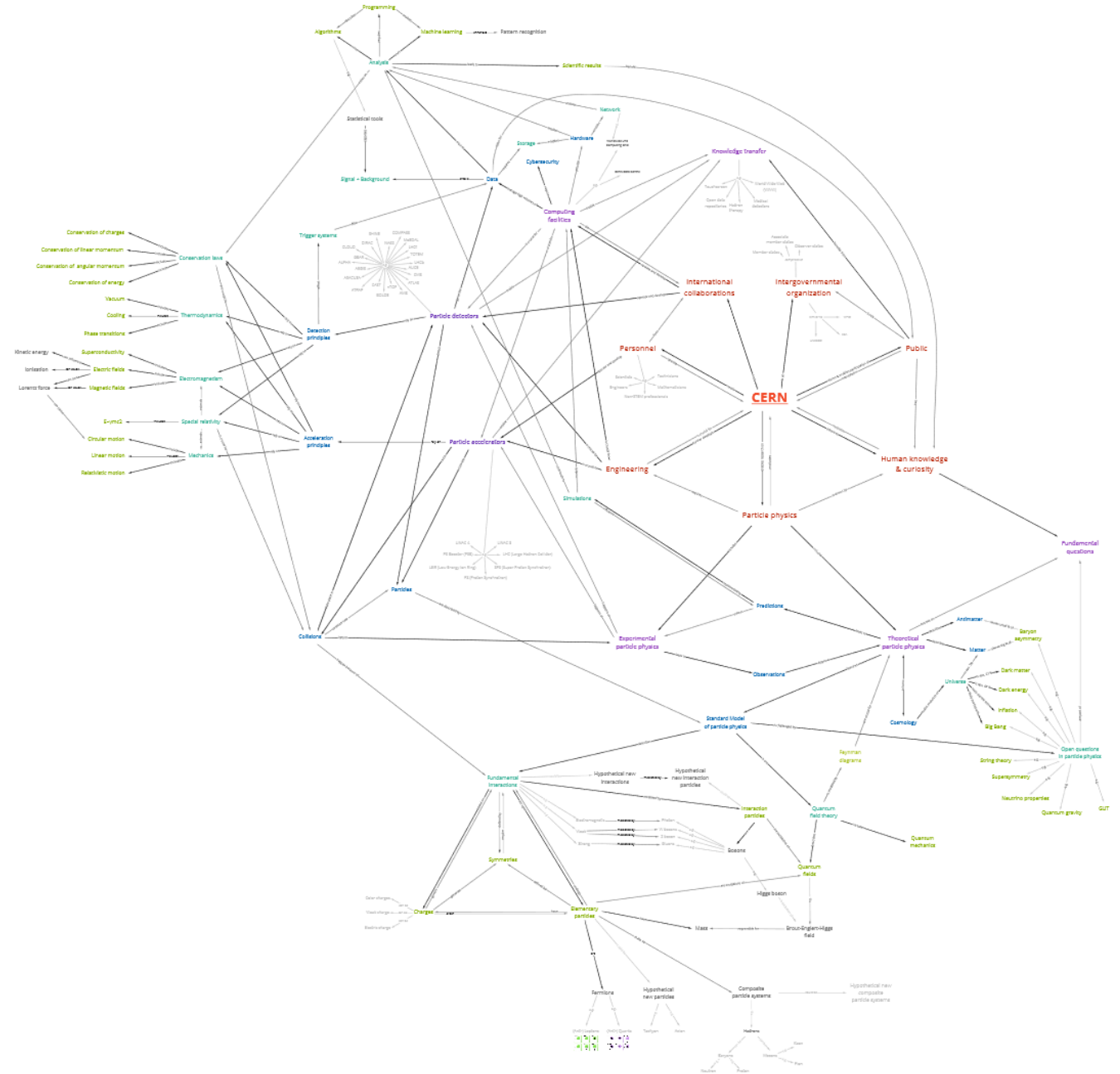
Anja Kranjc Horvat

[Link to CERN](#)

Evaluation of CERN's Tea  
overview of concepts in th  
physics" to ...

- inform and improve C
- create a valuable tea

Paper: Kranjc Horvat, A., Wiener, J., S  
Learning goals of professional devel  
institutions: A Delphi study with differ  
Teacher Education.



# Fostering i

*Sarah Zöchling*

[Link to CERN](#)

Development of  
interest in partic  
students' interes  
contexts to ...

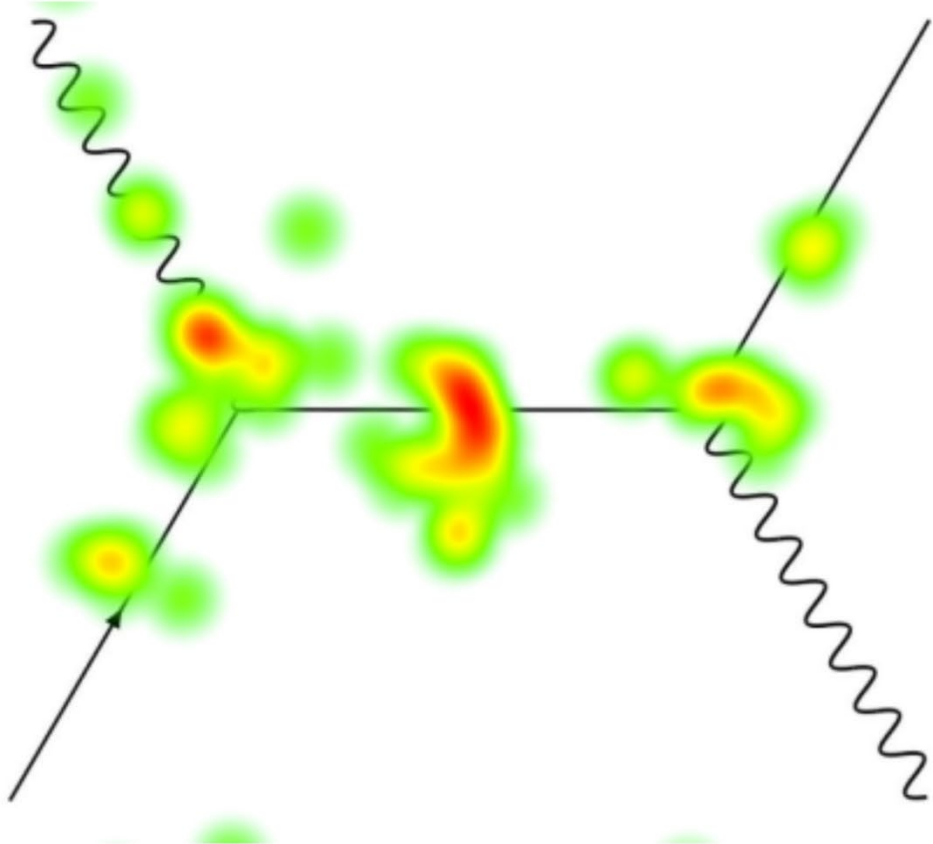
- define interest
- give recommen  
material



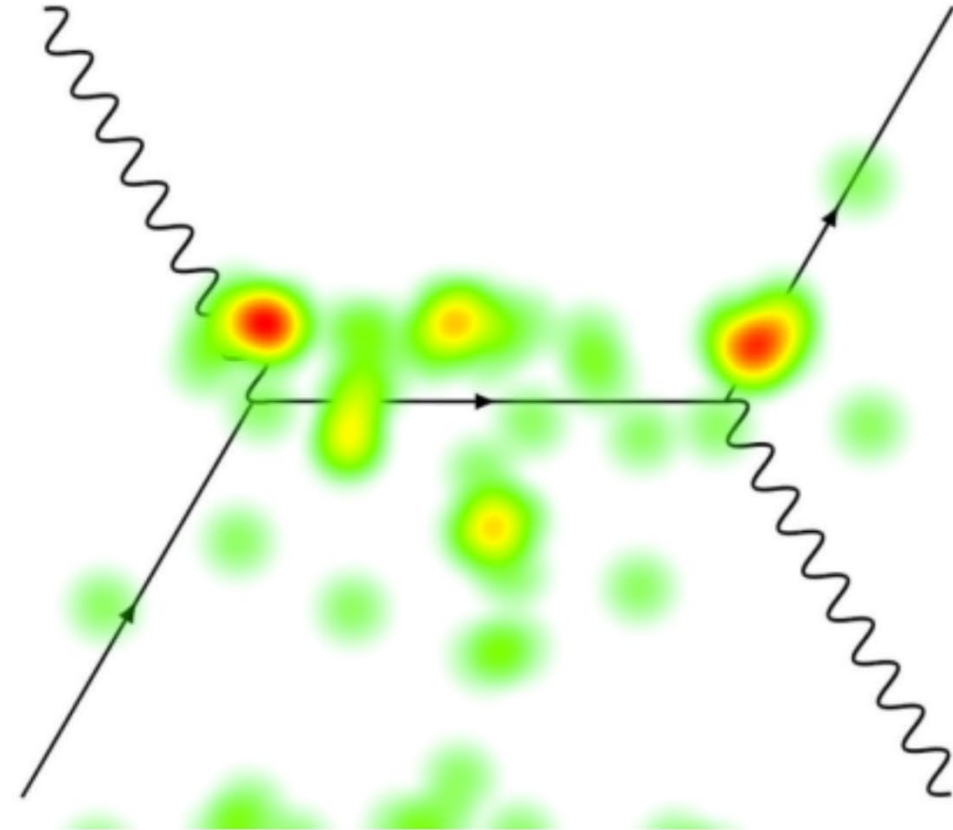


# Eye Tracking in PER

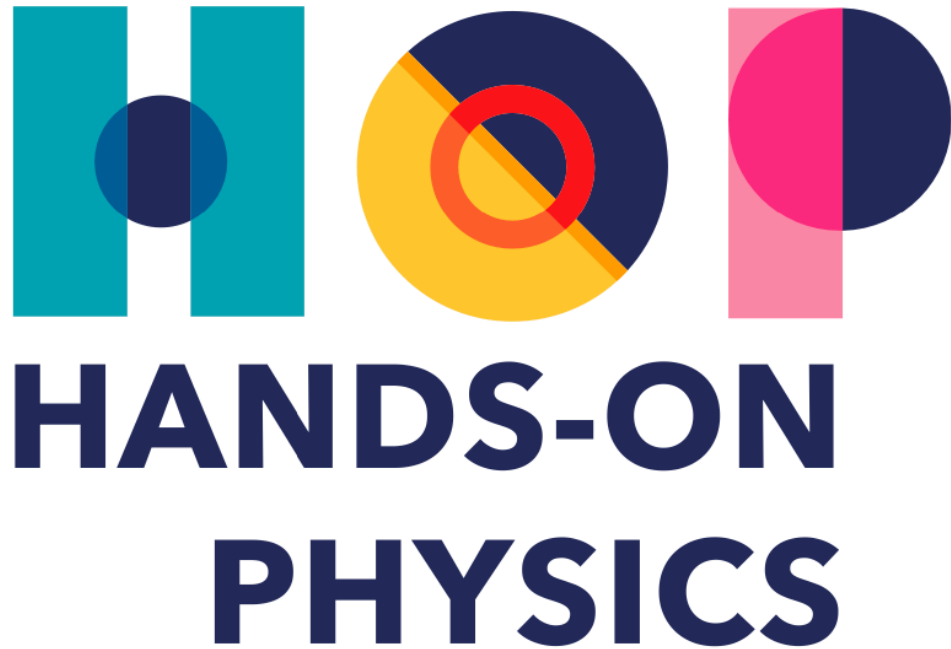
## Novices



## Experts



How many Vertices is the diagram composed of?



- ⦿ HOP is a project of CERN in collaboration with INFN and Fondazione Agnelli.
- ⦿ It aims to empower Italian Middle school teachers to integrate physics hands-on activities in their lessons.

### **Why?**

The science curriculum in middle school includes several topics, and Physics often receive less attention than other subjects.

### **How?**

More than 1500 teachers from all over Italy will have the possibility to:

- ⦿ Receive a kit for experimental activities in their classroom.
- ⦿ Take part in a teacher training class.





The **kit** will consists in a unique box containing all the items to perform experiments on four different topics:

- ⊙ Scientific Method
- ⊙ Pressure
- ⊙ Light
- ⊙ Electricity

All the activities will be conducted using an inquiry based approach, based on the current research on physics education.



The teachers who will receive the kit will take part in a **teacher training session**.

Over a period of three years more than 40 sessions will be organised and they will cover the entire country.

Goals:

- ⊙ Getting familiar with the inquiry-based approach.
- ⊙ Exploring the kit and the activities included.

# Your Questions

