The European Frontier of Particle Physics

Update of the European Strategy for Particle Physics

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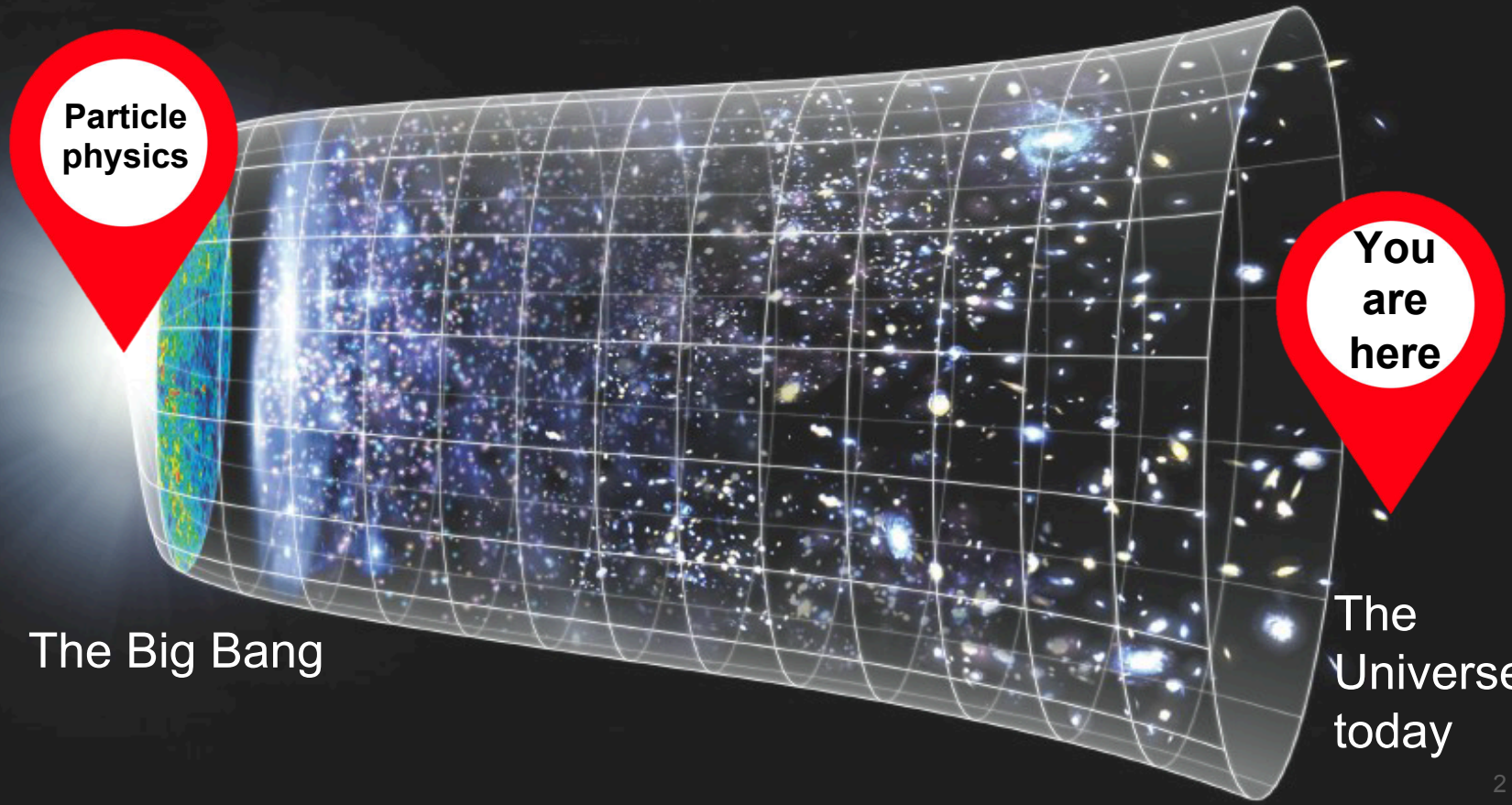
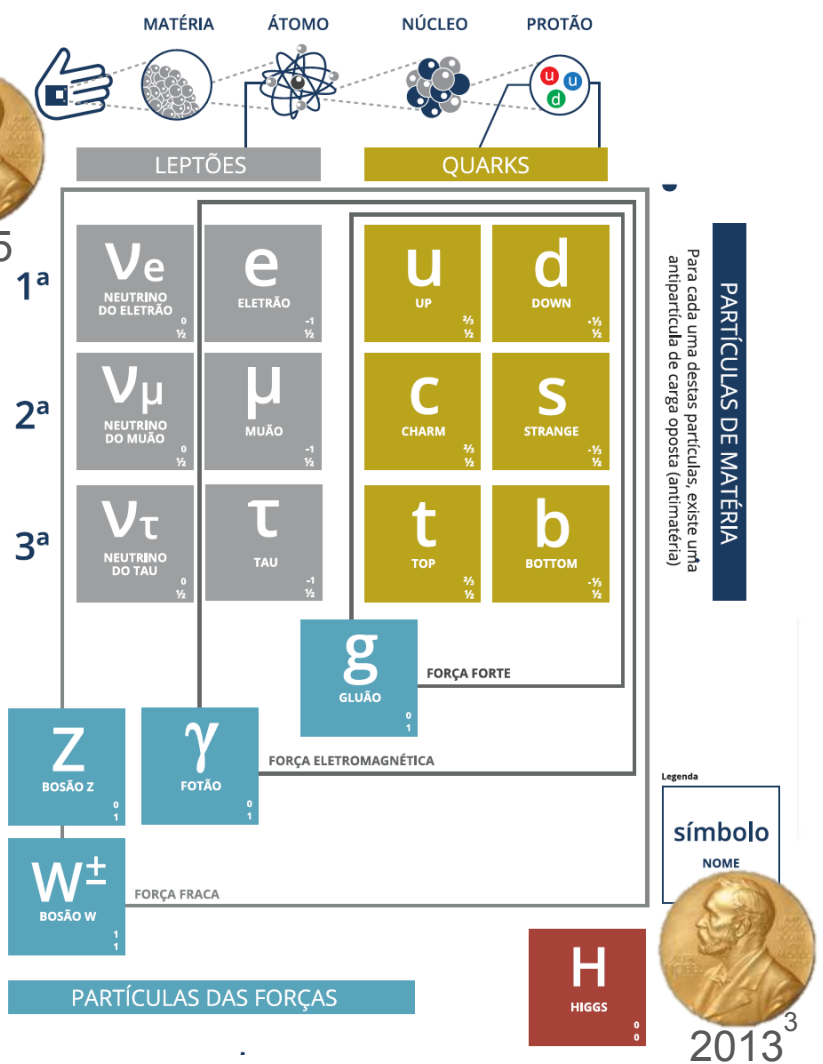
What is particle physics?

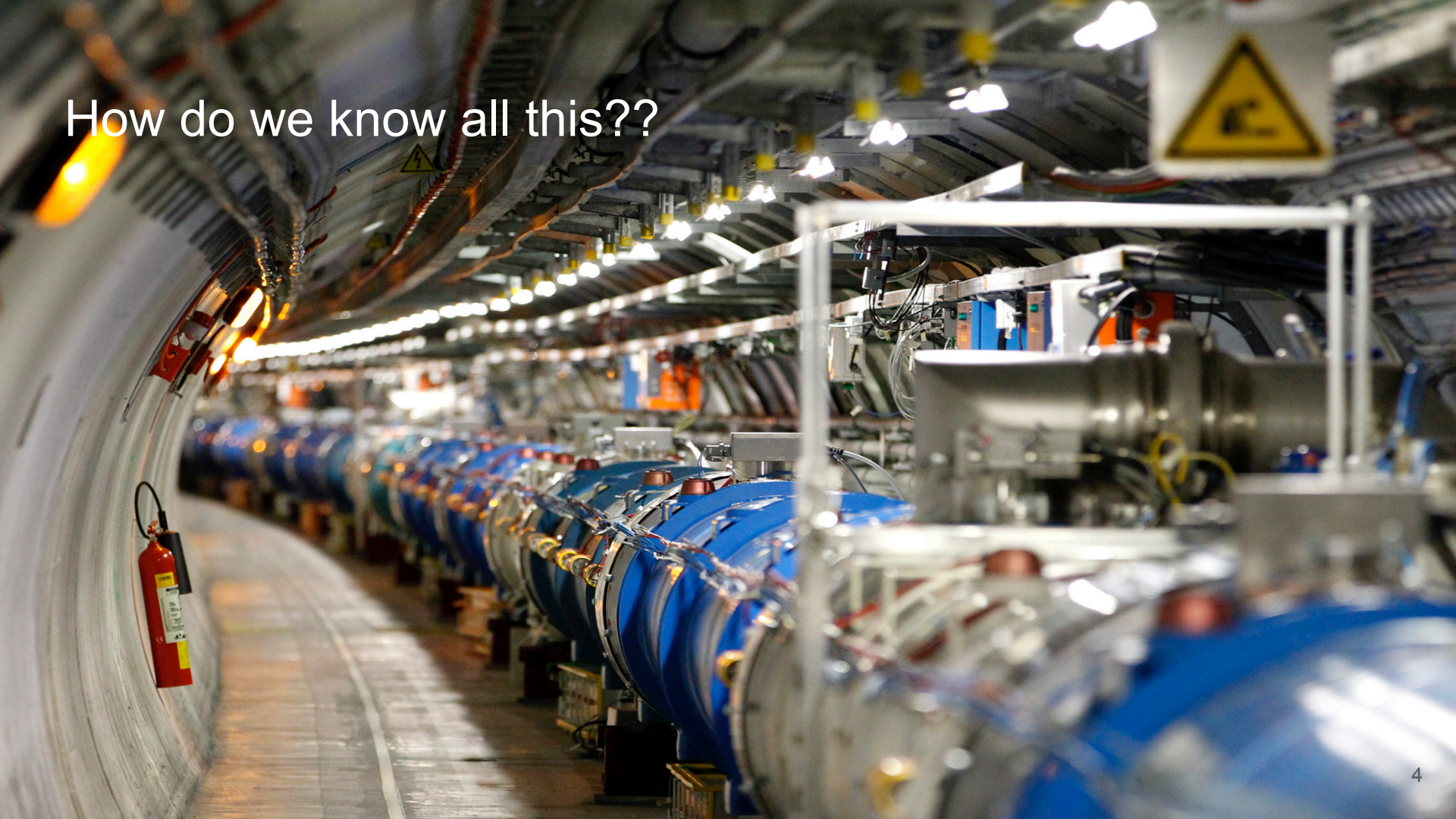


What do we know (so far)?

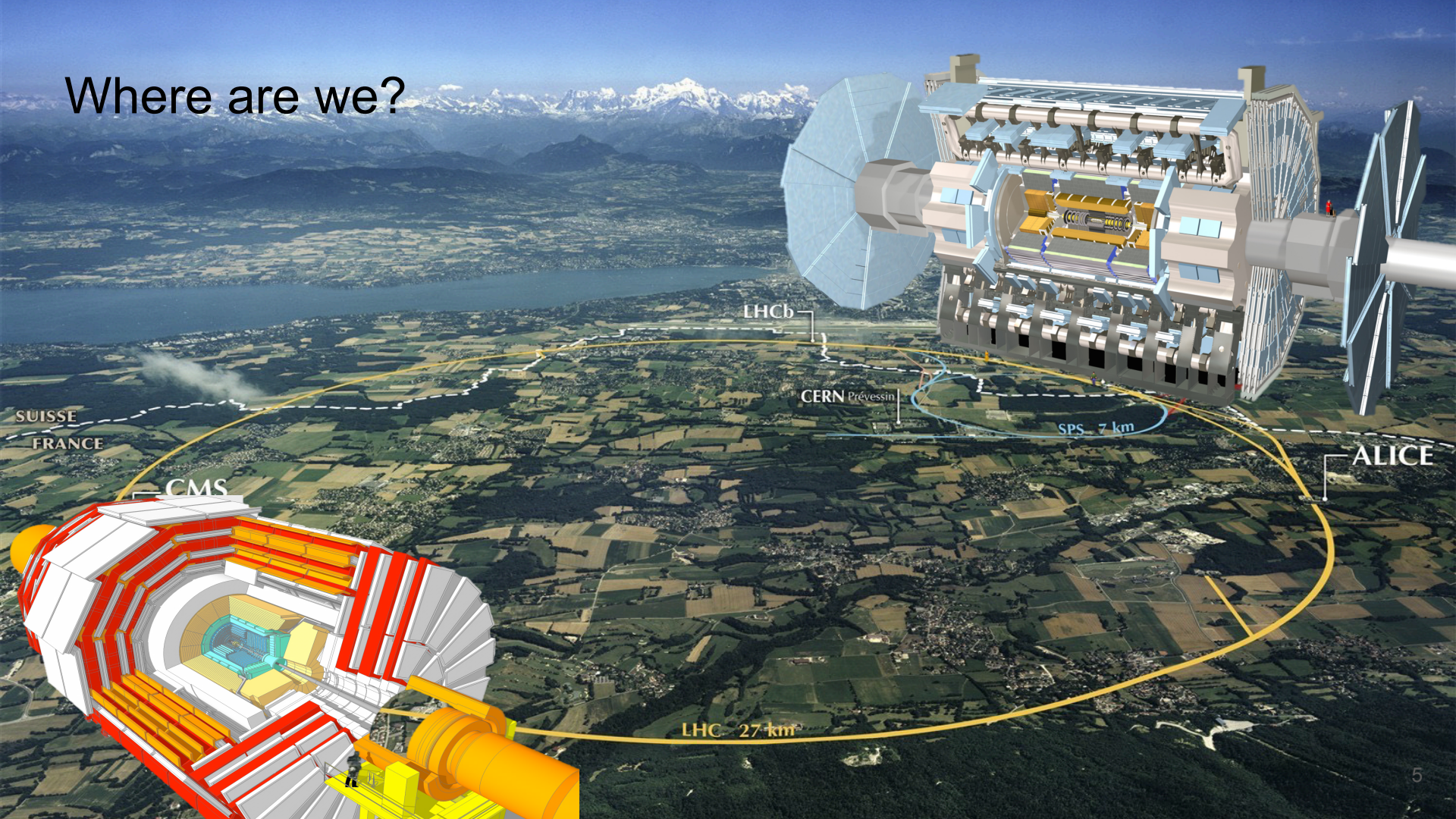
2015



2013


How do we know all this??

Where are we?

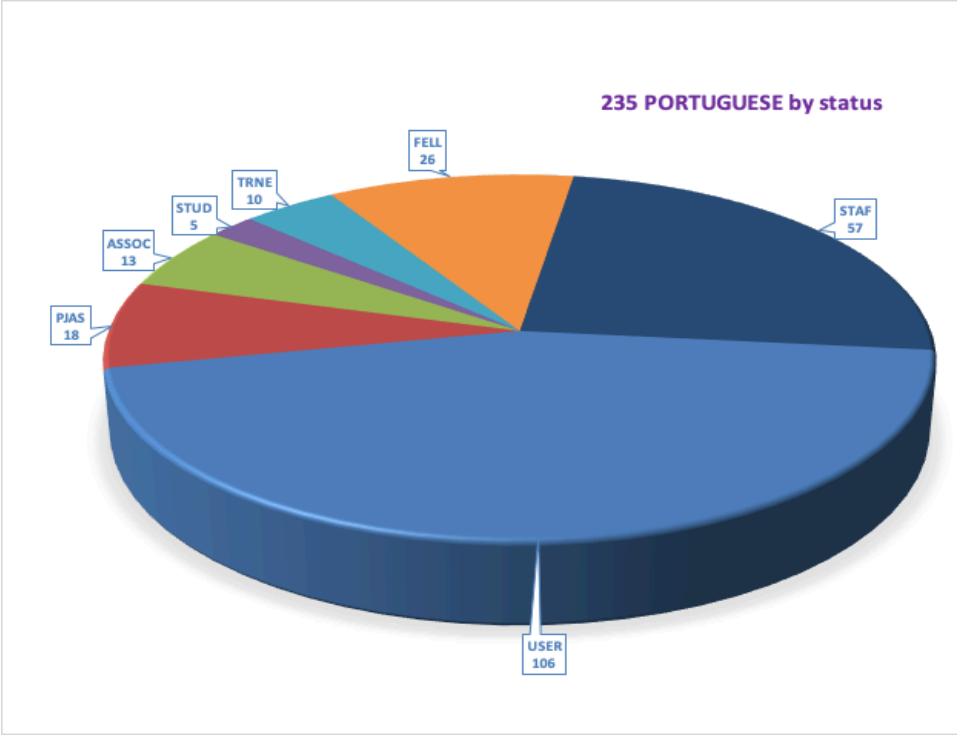

LHCb
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km

CERN and Portugal

- Global laboratory
- ~2500 staff, 800 fellows
- ~12000 users of 110 nationalities
- ~1200 MCHF annual budget
  - 23 member states + 3 pre-membership
  - 3 observer states
  - 34 states have collaboration agreements

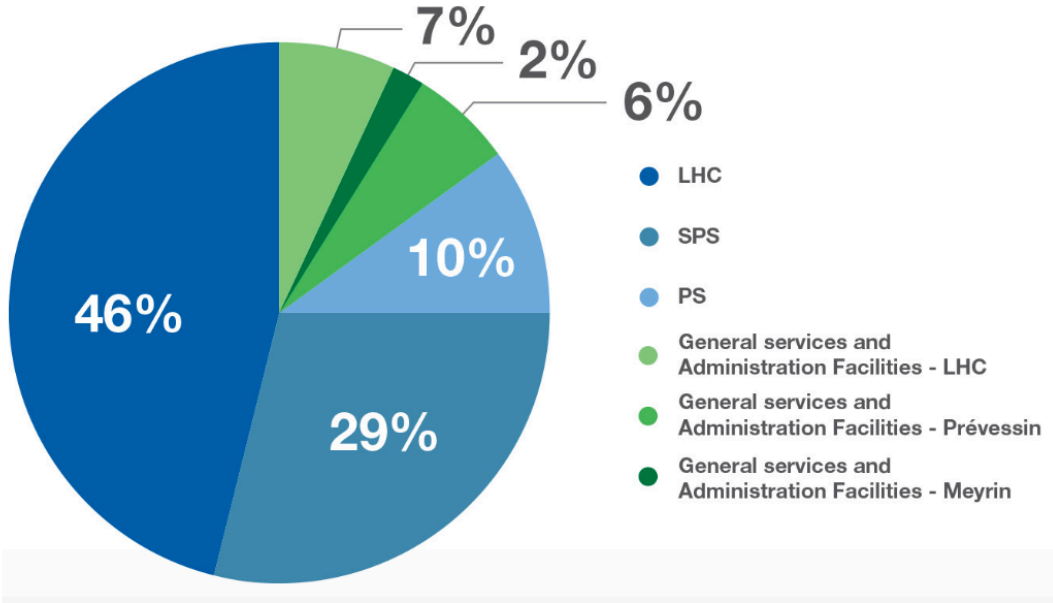
- 235 Portuguese at CERN
  - 57 members of CERN staff
  - 106 Users (academics, students etc)
  - ~1/2 in LHC experiments; 1/3 in Isolde
  - Programmes in education, engineer training, technology transfer, etc

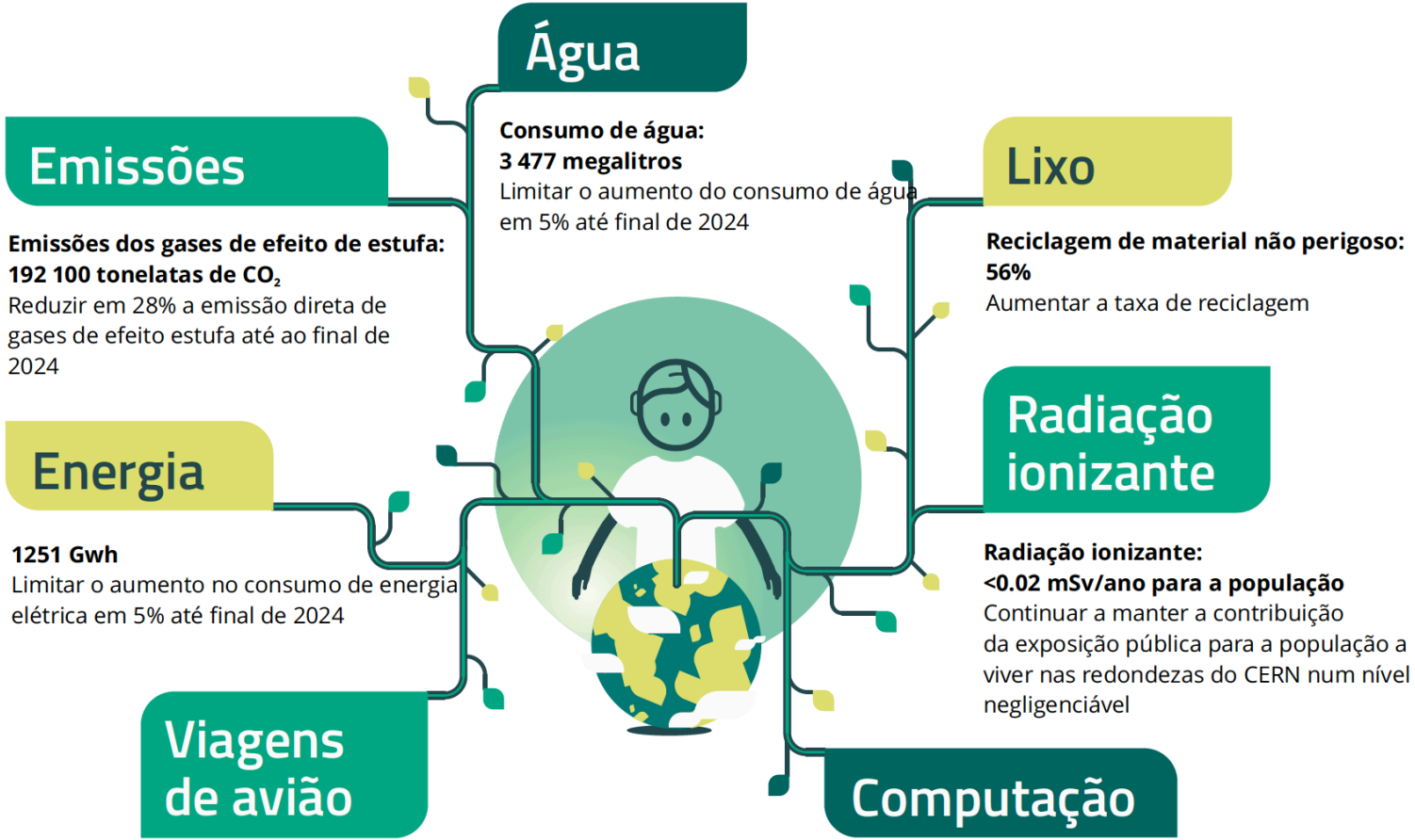
- Significant industrial return
  - Total CERN spending ~500 MCHF/year
  - >50 technology-based Portuguese companies work with CERN



What about the environment?

- CERN's electrical consumption around 1.2 TWh / year
  - Similar to domestic consumption of Geneva
  - 87.9% from carbon-free sources
- A lot? Yes.
- Other sources of impact? Yes.
- Anything being done about it? Yes!
  - First public Environment Report published in 2020
  - CERN's new strategy for reducing its ecological footprint



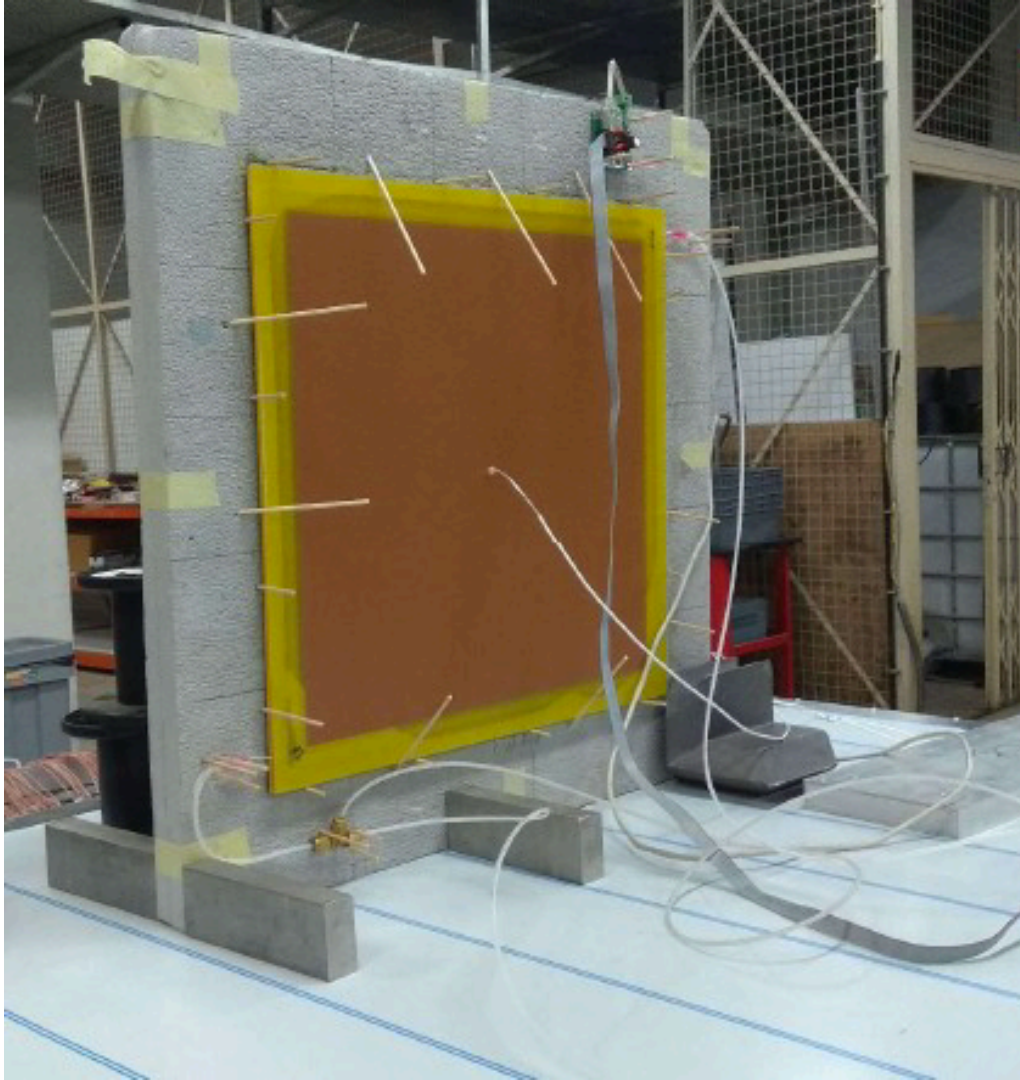

Água
Consumo de água:
3 477 megalitros
Limitar o aumento do consumo de água em 5% até final de 2024
Emissões
Emissões dos gases de efeito de estufa:
192 100 tonelatas de CO_2
Reduzir em 28% a emissão direta de gases de efeito estufa até ao final de 2024
Lixo
Reciclagem de material não perigoso:
56%
Aumentar a taxa de reciclagem
Energia
1251 Gwh
Limitar o aumento no consumo de energia elétrica em 5% até final de 2024
Radiação ionizante
Radiação ionizante:
<0.02 mSv/ano para a população
Continuar a manter a contribuição da exposição pública para a população a viver nas redondezas do CERN num nível negligenciável
Viagens de avião
Reduzir ao máximo as viagens de avião
Limitar ao estritamente necessário.
Recorrer a participação remota em reuniões e conferências. Optar por distância menores.
Computação
Diminuir o impacto da computação
Usar eletricidade mais verde,
recuperar o calor dissipado,
partilhar amostras de dados,
ensinar programação eficiente

Can we do even better?

- Sure we can!
- Science is a precious resource for shaping the future of the planet
- It must become more aware of its own impact on environment, and do the best to improve it

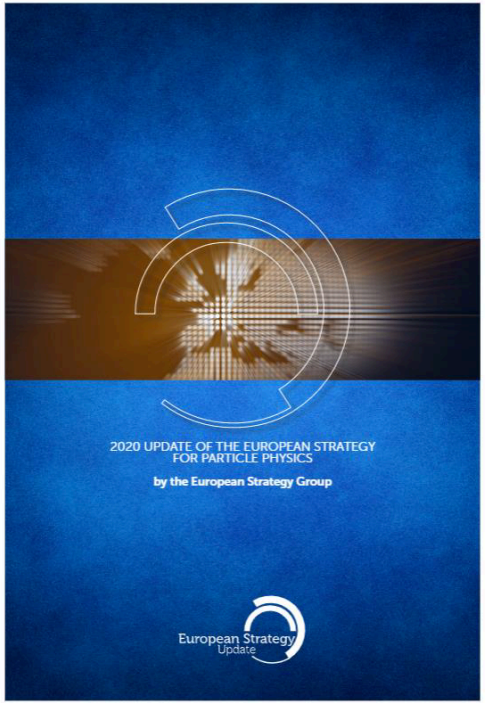
Example:

- At LIP we are developing new particle detectors with no (zero!) greenhouse gas emmission



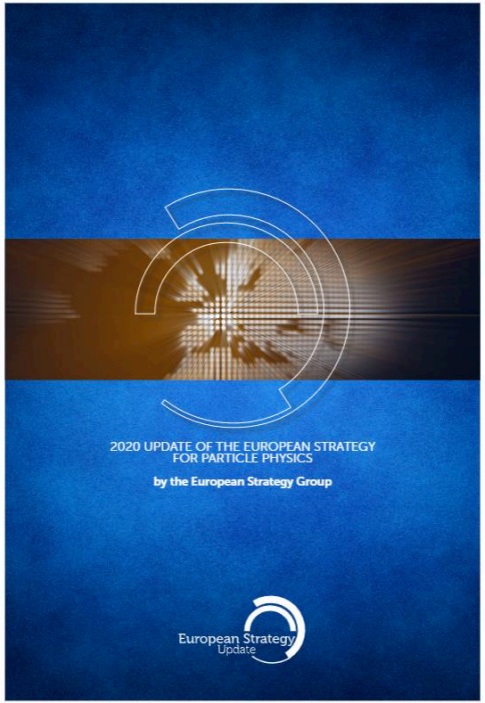
European Strategy for Particle Physics

- Long development cycles and very large facilities
  - LHC: construction started 1998 – physics run until 2040
- European Strategy for Particle Physics
  - Cornerstone of Europe's decision-making process for **the long-term future** of the field
  - Mandated by CERN Council
  - **Community-driven** process: **world-wide** grass-roots consultation
  - Close coordination with similar processes in US and Japan
- First strategy document approved at a special Restricted Session of CERN Council in **Lisbon, 14 July 2006**
  - Reviewed every ~7 years
  - Updated in 2013 and recently in **2020**



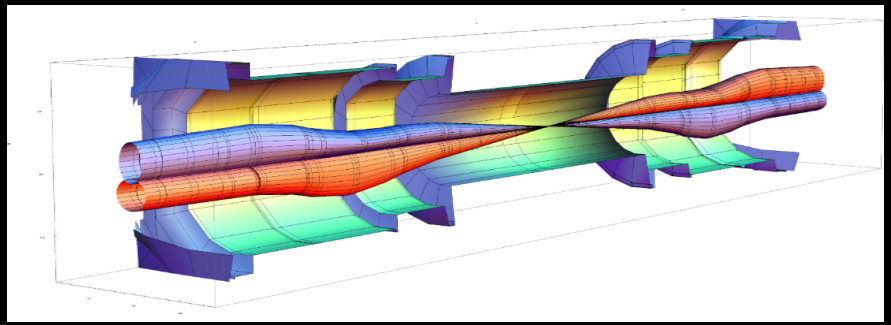
European Strategy for Particle Physics: 2020 update

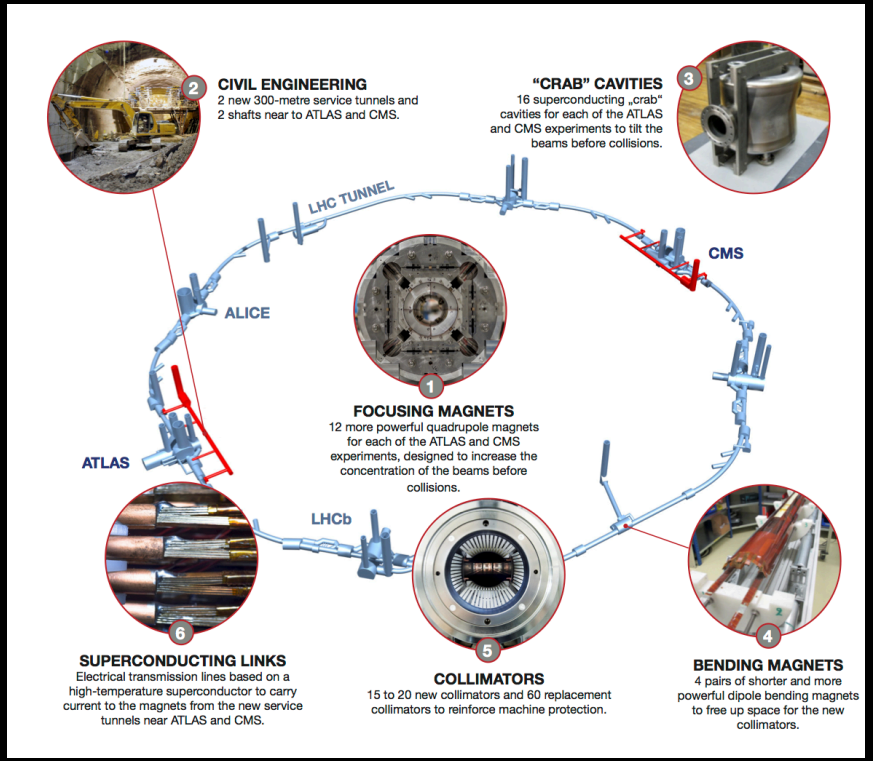
1. Full physics exploitation of the LHC and HL-LHC
2. Next priority is **a e^+e^- "Higgs factory"**
   - Major contender: the **FCC-ee** (also CLIC or CEPC elsewhere)
3. Increased R&D on enabling accelerator technologies:
   - High-field superconducting magnets, high-gradient accelerating structures, plasma wakefield, muon colliders, etc
   - Support long-term goal of a **100 TeV hadron collider: FCC-hh**
4. Support neutrino projects in US and Japan
5. Support high-impact scientific diversity programme complementary to high-energy colliders



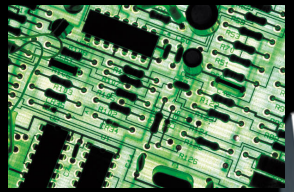
High-Luminosity LHC Upgrades

- Development of a new generation of superconducting magnets (Nb_3Sn)
  - Reach 13.5 T instead of 8 T (LHC, NbTi)
- Novel accelerator features
  - E.g. “crab cavities” to tilt beams and increase collision efficiency
- Colimators, superconducting connectors, civil engineering, etc

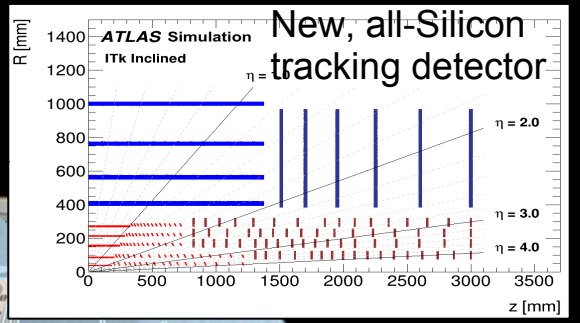




HL-LHC Upgrade

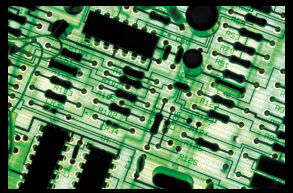


New electronics and High Voltage power supplies and distribution



New, all-Silicon tracking detector

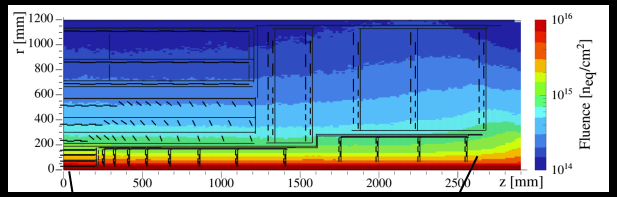
New muon detector "Small Wheel"



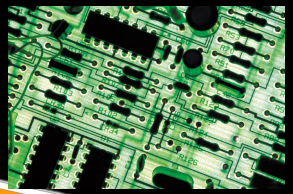
Hardware to reconstruct charged tracks

High Granularity Timing Detector (30ps/track)

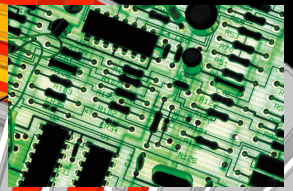
New MIP Timing Detector
(Barrel & Endcap)



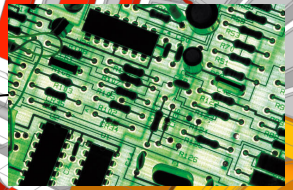
Replacement of tracking detector



New electronics for muon chamber operation

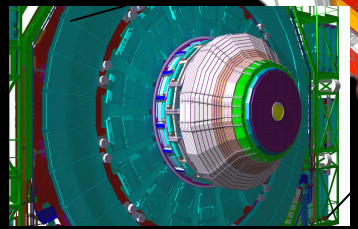


Hardware to reconstruct charged tracks (trigger)



New electronics for calorimeter readout

New High Granularity Calorimeter

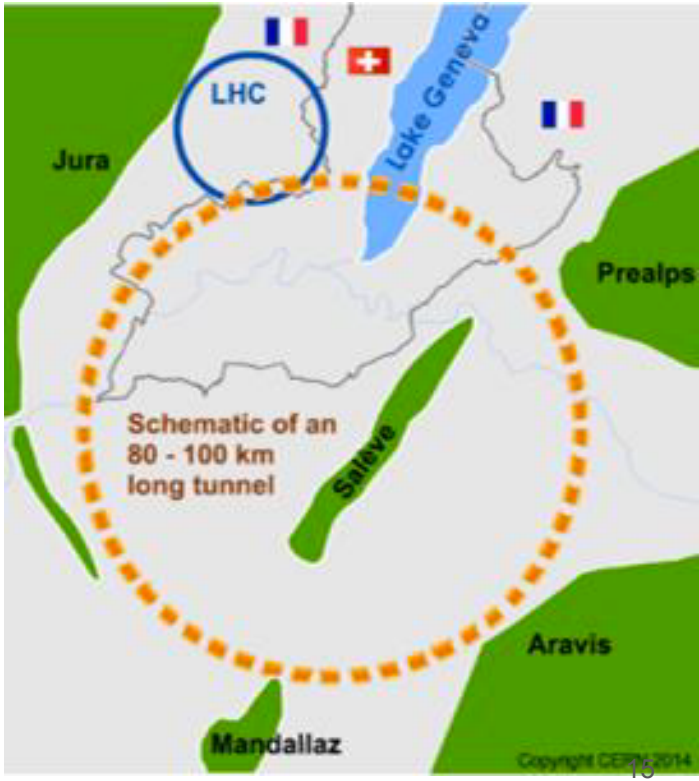


The Future Circular Collider Feasibility Study

- International study for FCC “Conceptual Design” as part of European Strategy discussion
  - Very comprehensive study of physics potential and detector technologies
  - 1350 contributors from 370 institutes, including LIP

- Two main scenarios - using the same tunnel:
  - **FCC-ee**: 90 to 350 GeV e+e- collider
  - **FCC-hh**: 100 TeV p-p and ion collider
  - 100 km perimeter tunnel!

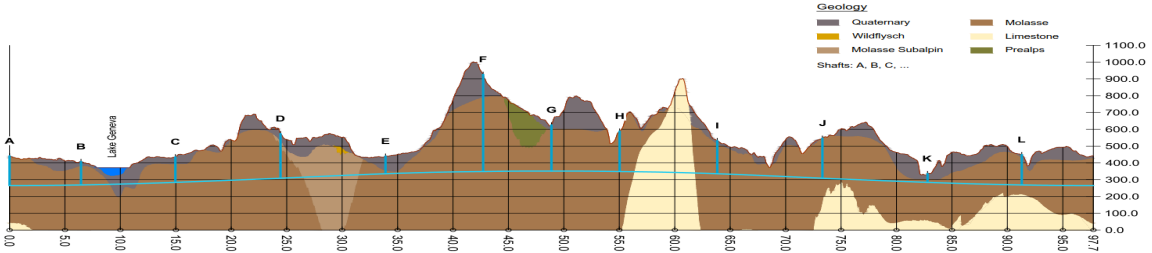
- Evolved to “**FCC Feasibility Study**” after European Strategy approval

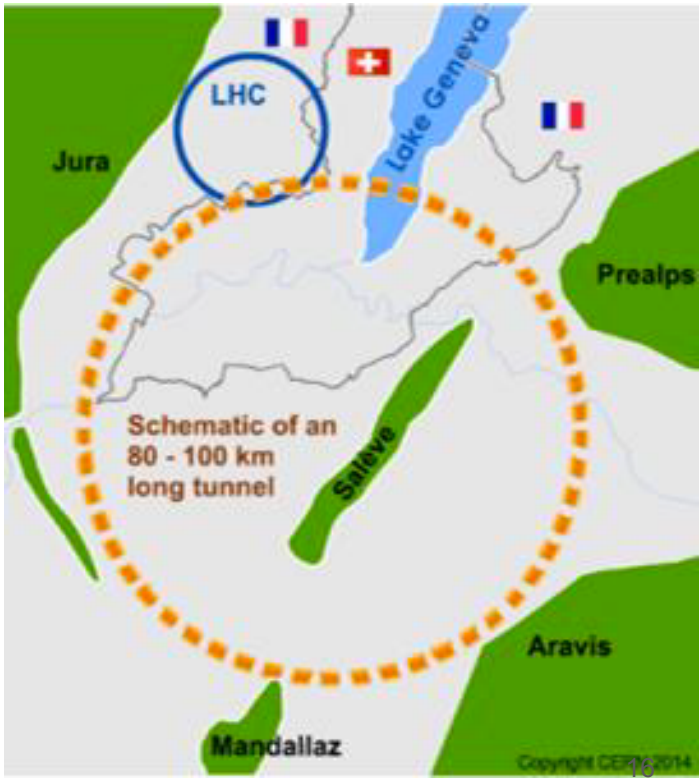


The Future Circular Collider Feasibility Study

FUTURE CIRCULAR COLLIDER

- Comprehensive long-term program, maximizing physics opportunities – timescale 2025:
  - Stage 1: FCC-ee as Higgs factory, electroweak and top-quark factory
  - Stage 2: FCC-hh to reach energy frontier - ion & e-h options
- Complementary physics
- Common civil engineering and technical infrastructures
- Building on and reusing CERN's existing infrastructure
- FCC integrated project allows seamless continuation of Particle Physics programme after HL-LHC





FUTURE CIRCULAR COLLIDER
Innovation Study

Status of Global FCC Collaboration

“The next accelerator and the next focus for particle physics must be in Europe. That is the only way to ensure that the best people will continue to come to Europe.”

José Mariano Gago, Special Restricted Session of the CERN Council, 1st European Strategy for Particle Physics, Lisbon, 14 July 2006

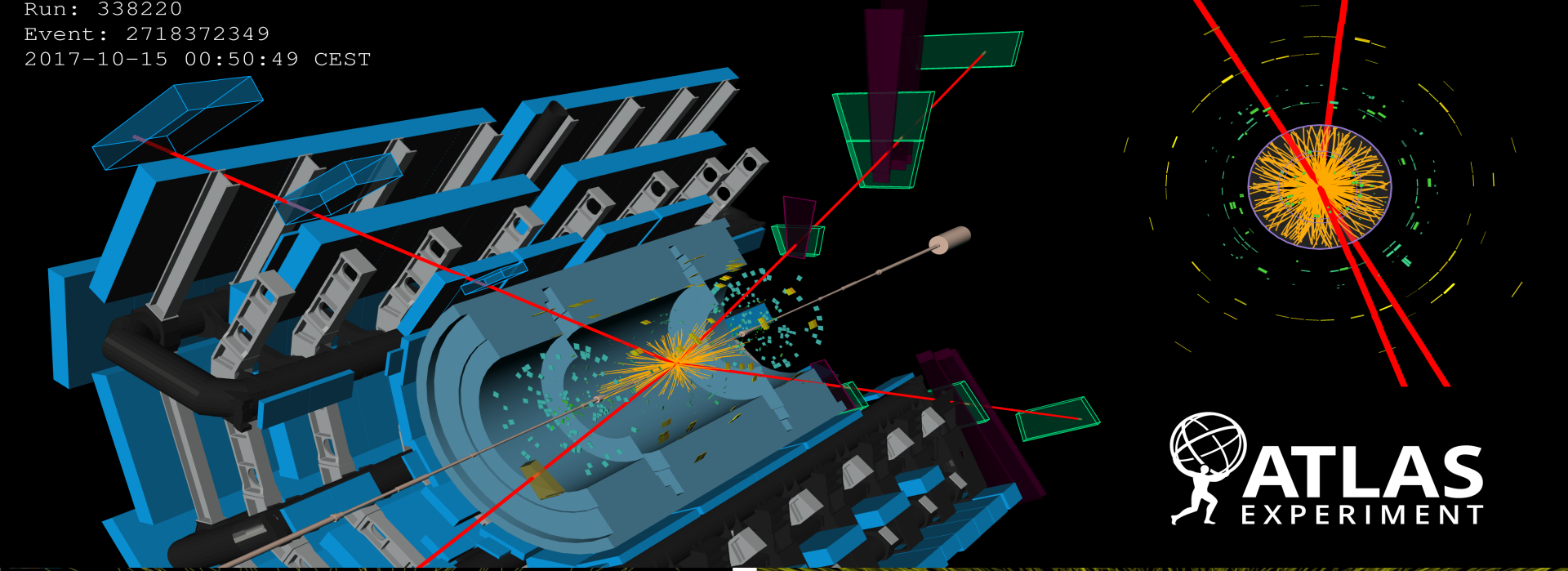
Conclusions

- Particle physics is a **vibrant field** with huge scientific activity and potential for discovery
  - **Exploration** at the deepest level: the elementary particles and fundamental forces in the Universe
- Science (and big science) is an amazing achievement of mankind
  - The capacity to explore, together in peaceful collaboration, the secrets of Nature is **priceless**
- But we must be aware of our own impact on nature – ignorance is no longer an option!

Thank you!

LIP

LET'S INSPIRE PEOPLE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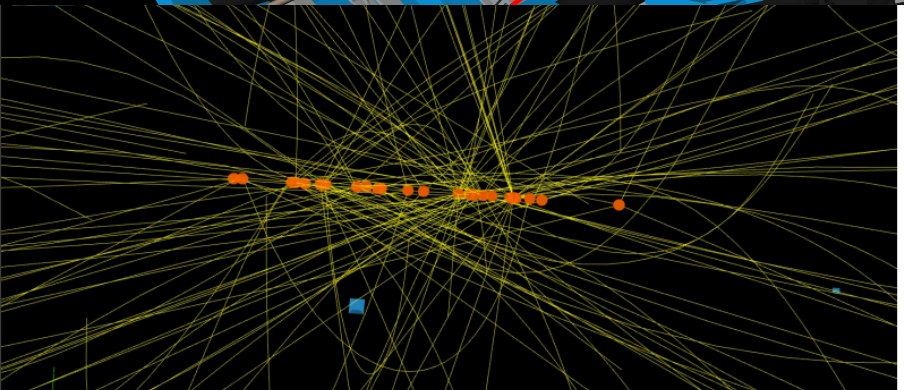
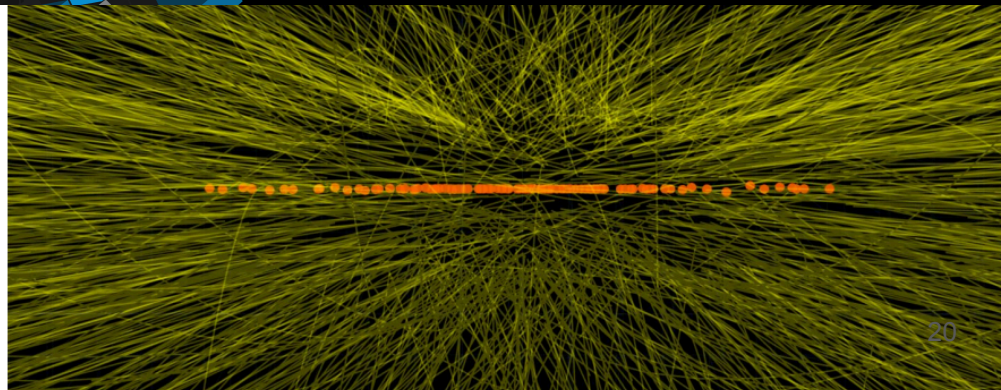
ATLAS
EXPERIMENT





4th July 2012

Discovery of the Higgs Boson

The Higgs mechanism

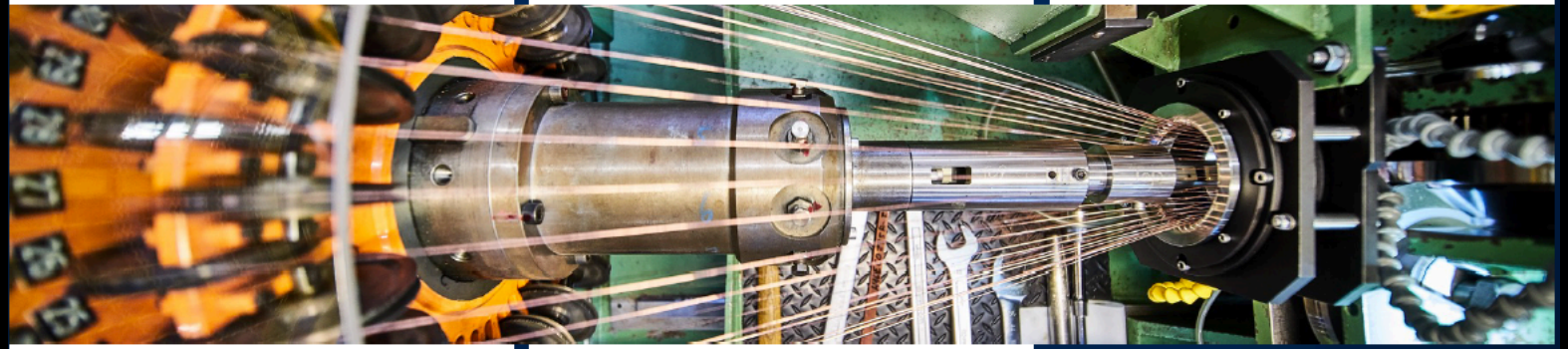
Doing business with CERN

- 2017 survey of 669 suppliers in 37 countries

48%
improved products and services

42%
developed new products

55%
improved technical knowledge in their field



18%
found or opened a new market to address

62%
used CERN as a marketing reference

Doing business with CERN: what do we buy ?

Civil engineering

- Construction
- Renovation of buildings
- Metallic structures
- Earthworks
- Roads

Electrical engineering and magnets

- Transformers
- Switchboards and switchgear
- Cables
- Automation
- Power supplies
- Magnets

Information Technology

- Computing systems
- Servers
- Software
- Network equipment
- Personal computer equipment

Mechanical engineering and raw materials

- Machining
- Sheet metal work and arc welding
- Special fabrication techniques
- Raw materials, finished and semi-finished products (plates, pipes, etc.)
- Offsite engineering and testing

Electronics and radiofrequency

- Electronic components
- PCBs and assembled boards
- LV and HV power supplies
- Radiofrequency plants
- Amplifiers

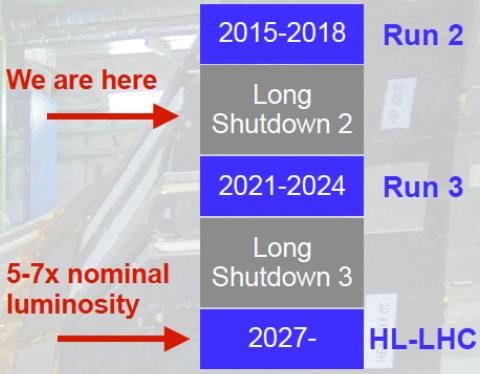
As well as

- Cryogenic and vacuum equipment
- Optics and photonics
- Particle and photon detectors
- Health and safety equipment,
- Transport and handling equipment
- Office supply, furniture
- Industrial services on the CERN site

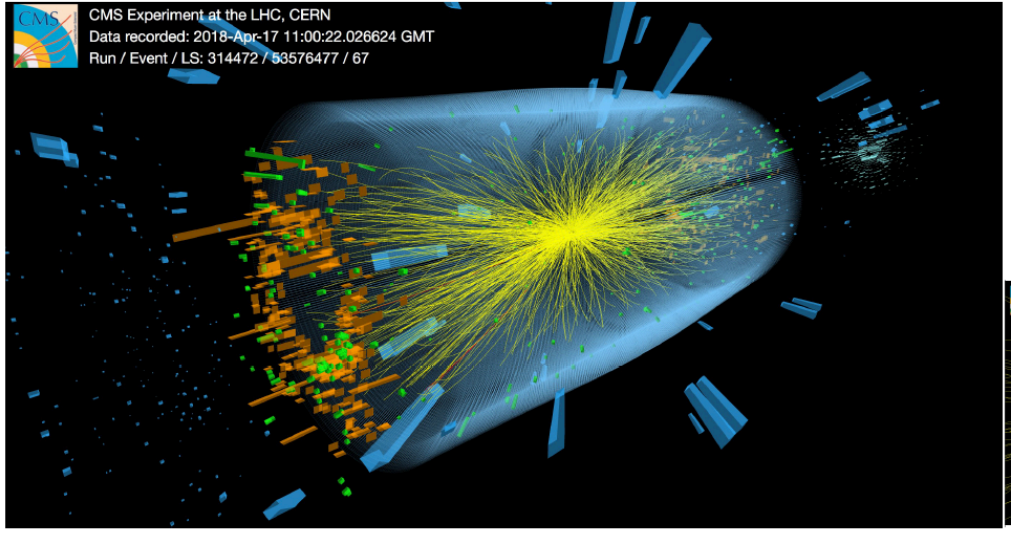
The technological frontiers

Detector electronics

40 million collisions per second, but we can only store 10 000 every second. Need to decide which ones on-the-fly!

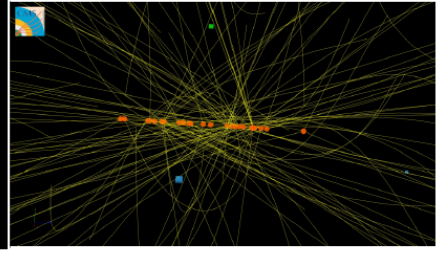


CMS tracker alone has 75 million electronic read-out channels

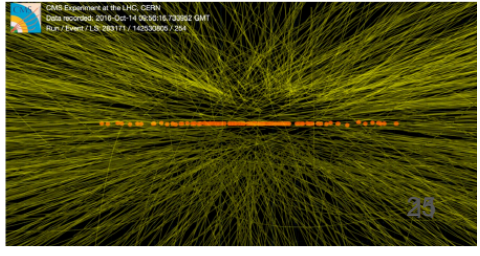


We need fast, high-rate and radiation tolerant electronics to meet the challenges of higher collision rates.

Now



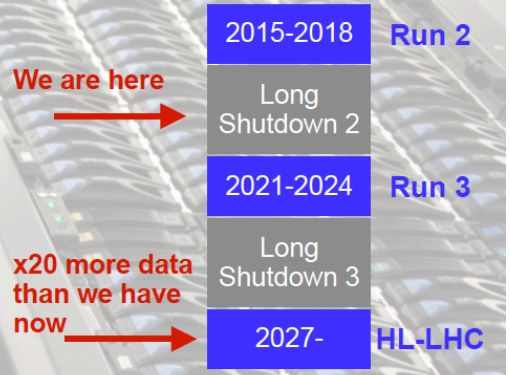
HL-LHC



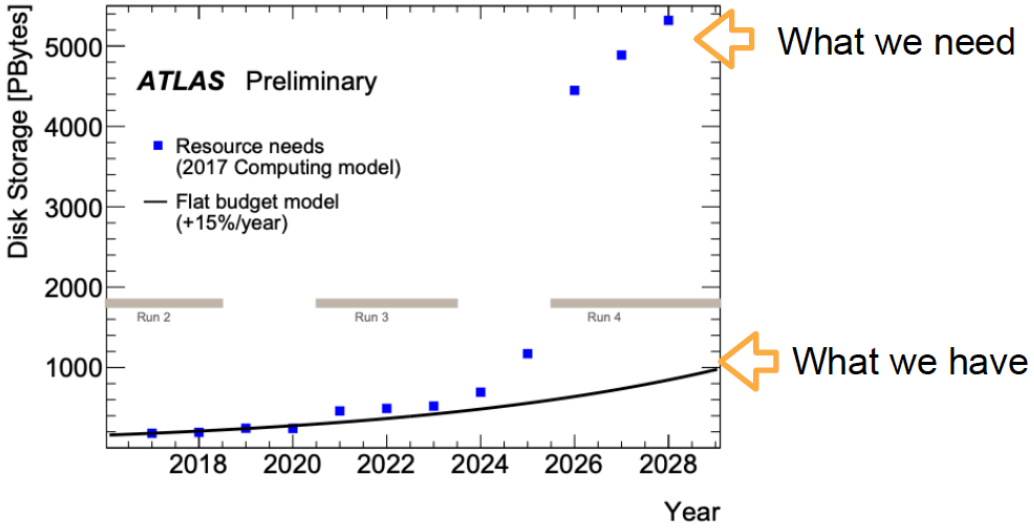
The technological frontiers

Computing

Examining every corner of the Standard Model requires unprecedented data rates and volumes.



Disk storage projection for one experiment



Current solutions don't scale to the CPU and storage demands of the HL-LHC.

Urgent need to tackle the massive data challenges of the LHC experiments.

Need sustainable and effective software solutions for the next decades of computing advances.

LHC resources in 2017:
1 exabyte storage, 500k CPU cores

The technological frontiers

Accelerators

For decades, larger and more powerful accelerators have driven us to the frontiers of particle physics.

Smaller scales

↓

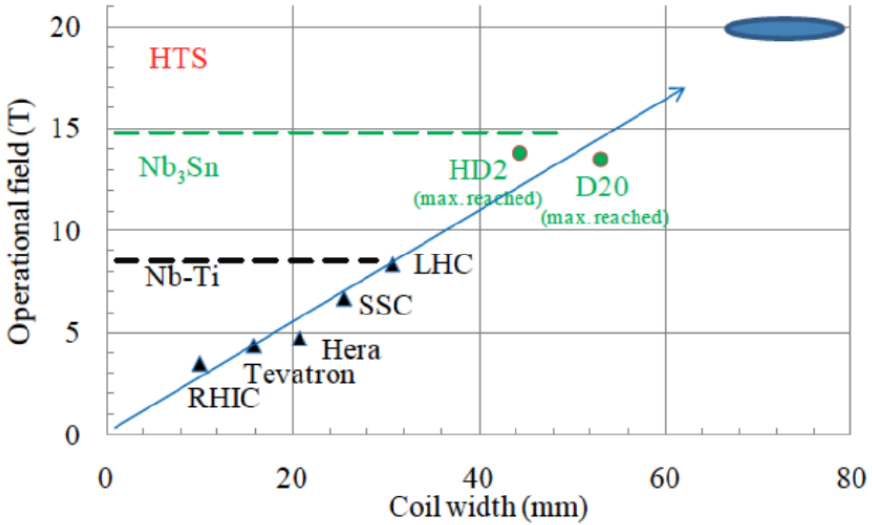
Higher energies

↓

More powerful accelerators

↓

Stronger magnets



The LHC magnets are the current state-of-the-art.

Higher collision rates and energies require pushing the limits of superconducting materials and high-field magnet technologies.

Evolution of superconducting Nb-Ti magnets for particle accelerator use.