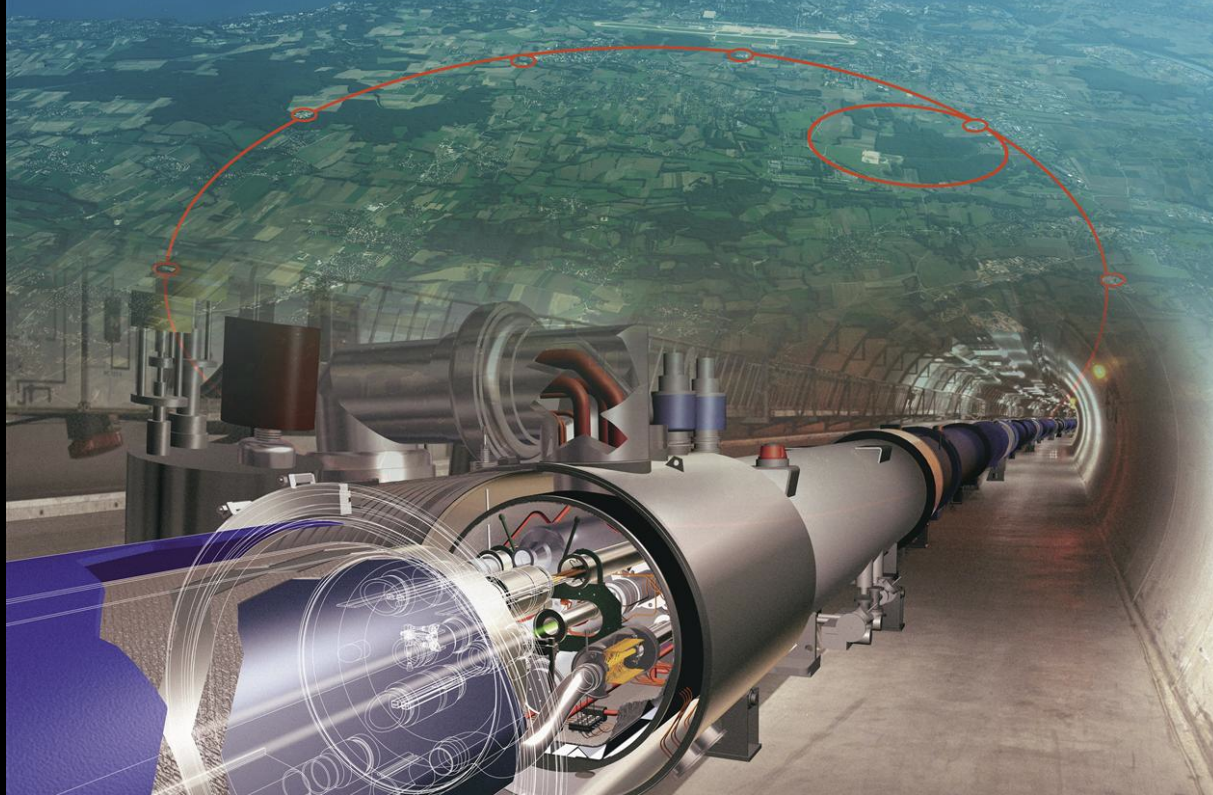


*THE CMS EXPERIMENT AT THE  
LARGE HADRON COLLIDER AT CERN*



# International collaboration including Flanders/Belgium

Three Flemish universities are involved in CMS, with directors/teamleaders:

Prof. Jorgen D'Hondt

Prof. Pierre Van Mechelen

Dr. Michael Tytgat

Vrije Universiteit Brussel – promoter

Universiteit Antwerpen

Universiteit Gent

Taking into account newly granted projects at our universities and on the Belgian level (e.g. EoS) we expect a team size of 56 researchers in Flanders.

Including in total 7 faculty members (professor or equivalent).

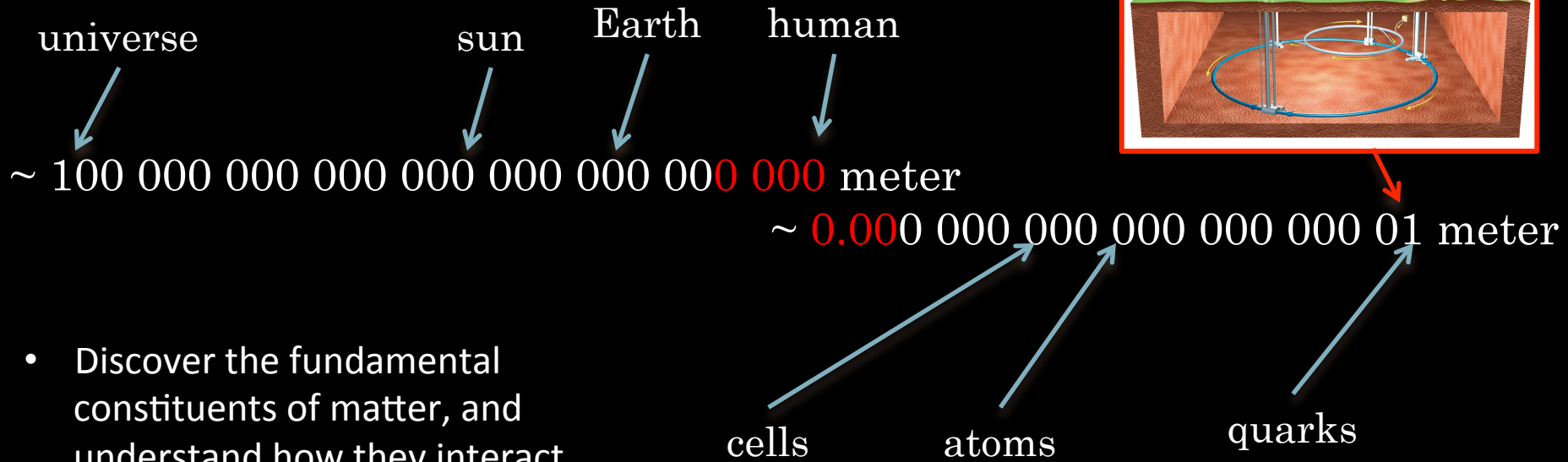


VRIJE  
UNIVERSITEIT  
BRUSSEL



Universiteit  
Antwerpen

# Particle Physics



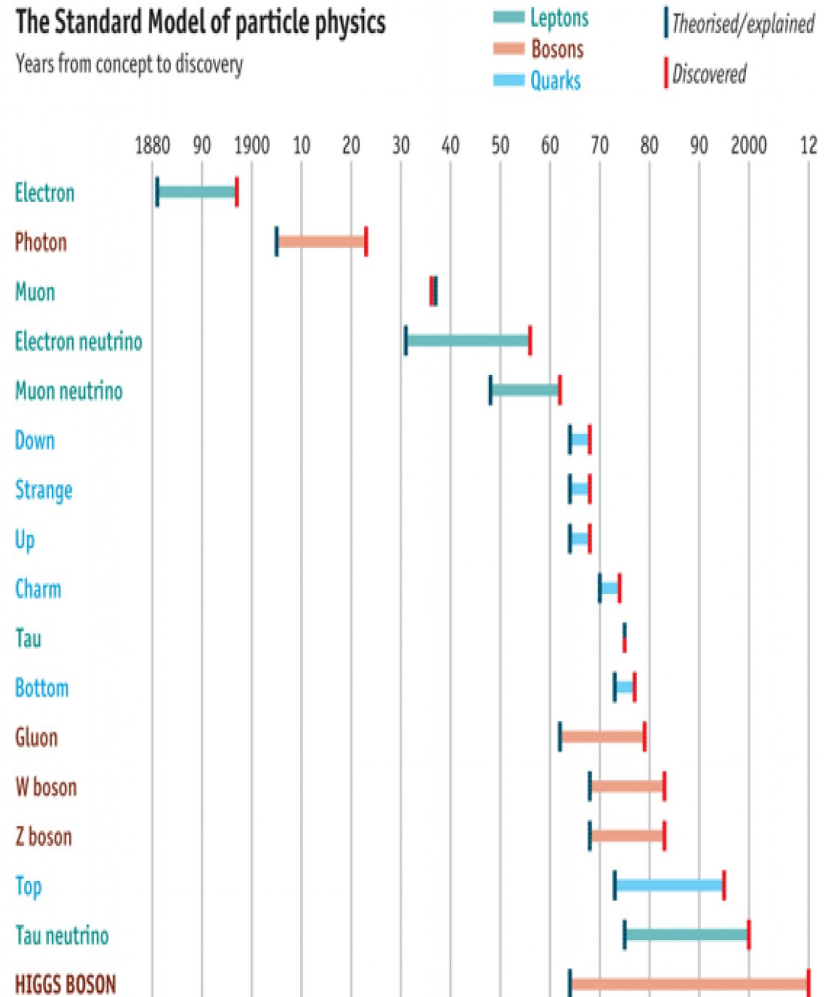
- Discover the fundamental constituents of matter, and understand how they interact among each other.
- Develop dedicated instruments to measure the phenomena at the largest possible energies.

# Particle Physics

- The Standard Model of Particle Physics is a theory describing the structure of matter at its most fundamental level
- The theory was established and precisely tested throughout the last century
- The discovery of the Higgs particle (2012) opened several new questions and leaves many fundamental questions to be answered
  - *the theory predicts that we might be living in only a semi-stable universe*
  - *the theory does not explain the vast amount of dark matter in the universe*
  - *the theory does not explain why we observe more matter compared to anti-matter*
- There must be a more profound structure yet to be discovered...

## The Standard Model of particle physics

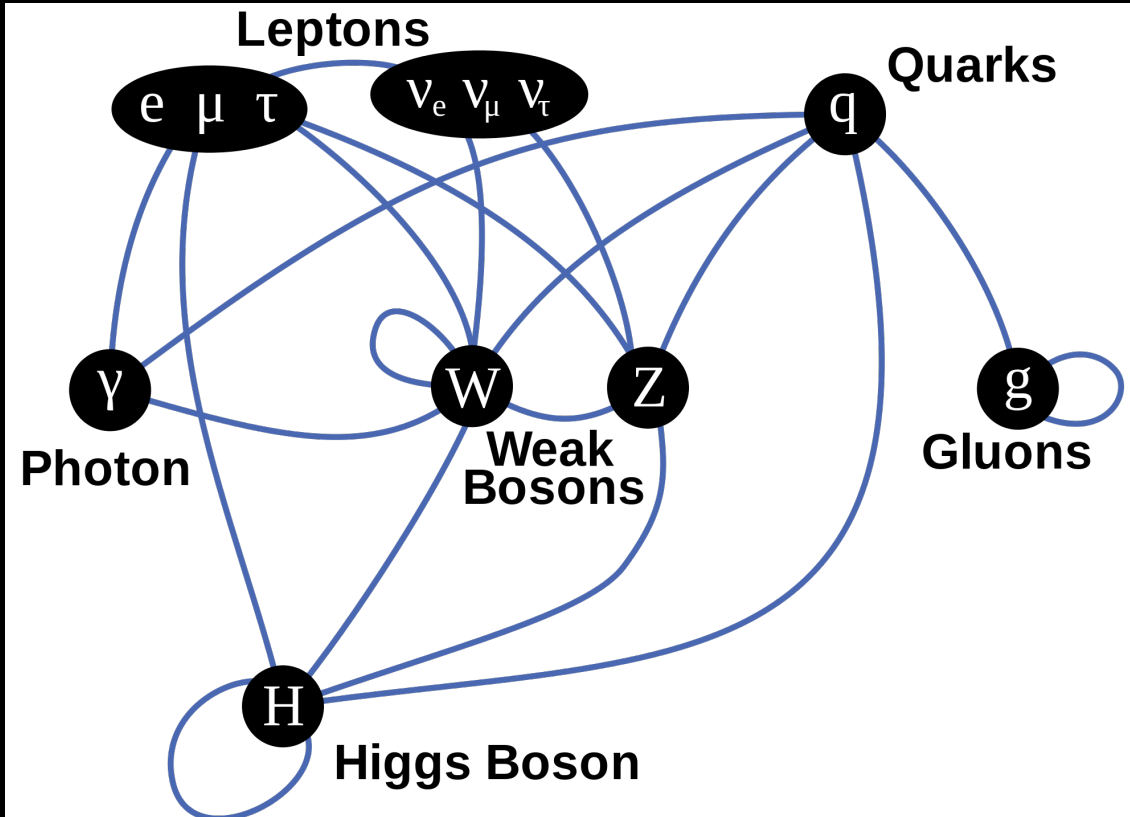
Years from concept to discovery



Source: *The Economist*

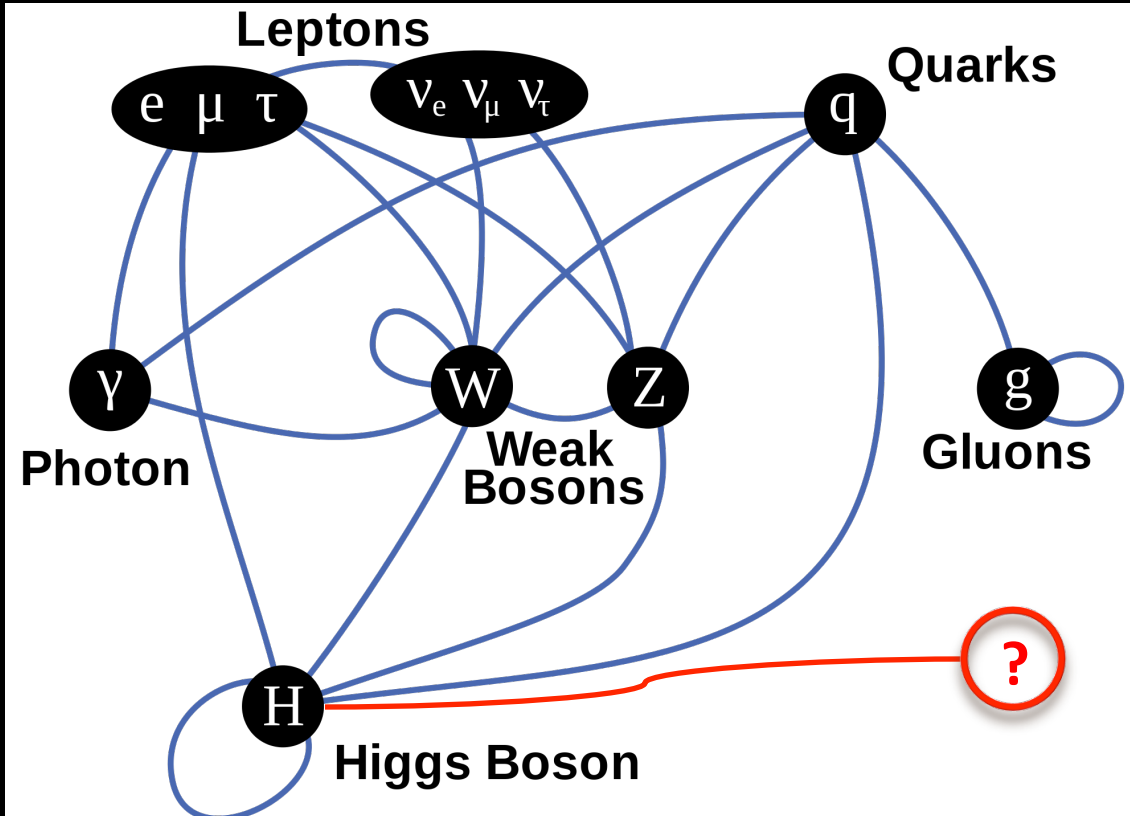
Source: *The Economist*, July 4<sup>th</sup>, 2012

# Particle Physics



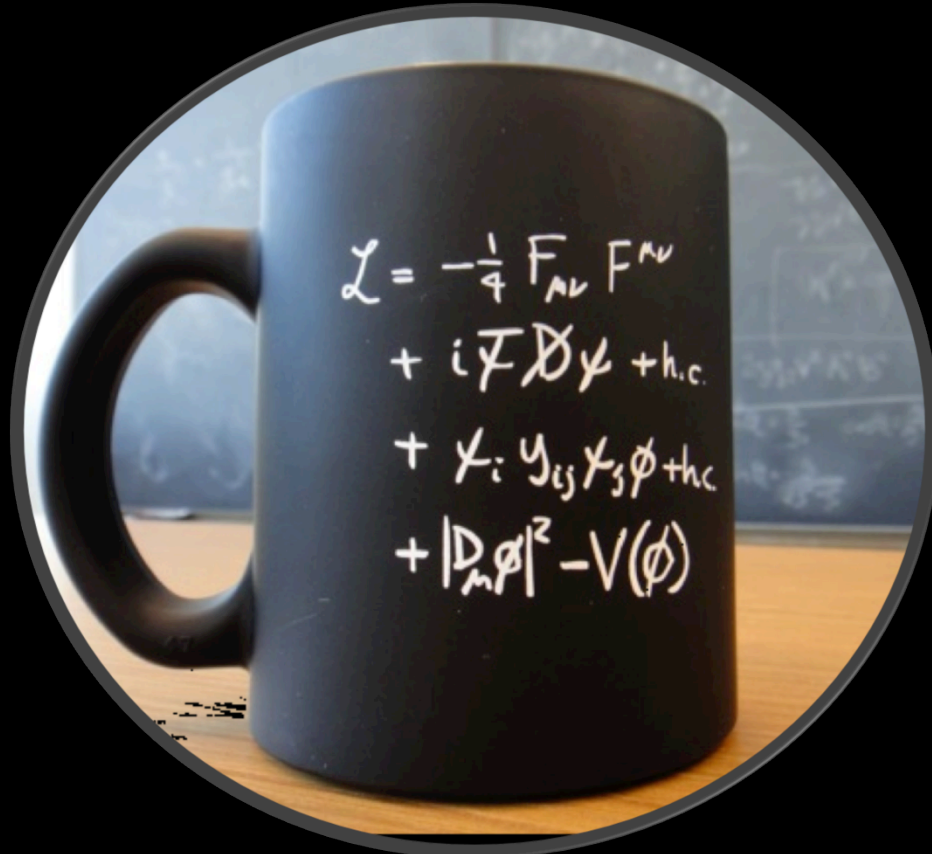
- the Higgs particle is confirmed in 2012 and its interactions with other particles are step by step being discovered
- Higgs – Z boson (2012)
- Higgs – W boson (2014)
- Higgs – tau lepton (2016)
- Higgs – top quark (2018)
- Higgs – bottom quark (2018)
- Higgs – muons, electrons, charm quark, self-coupling, etc. yet to come

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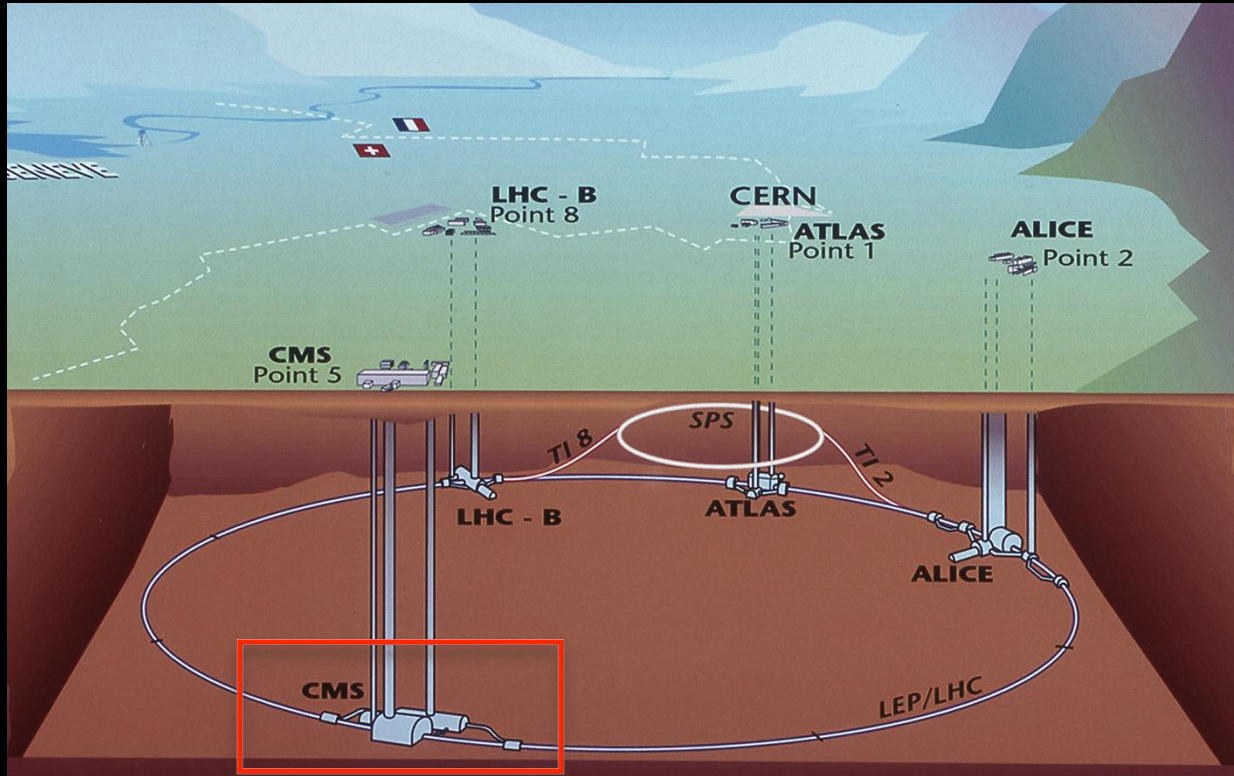
# Particle Physics



*compact version*

- free parameters of the theory are to be measured precisely
- needed to calculate precise prediction that can be verified
- need to zoom-in into matter to confront the predictions with experimental observations
- the Large Hadron Collider at CERN is the unique laboratory for this exploration at the highest energies

# The Large Hadron Collider @ CERN



1990-2000  
designs and R&D

2000-2008  
construction LHC  
construction CMS

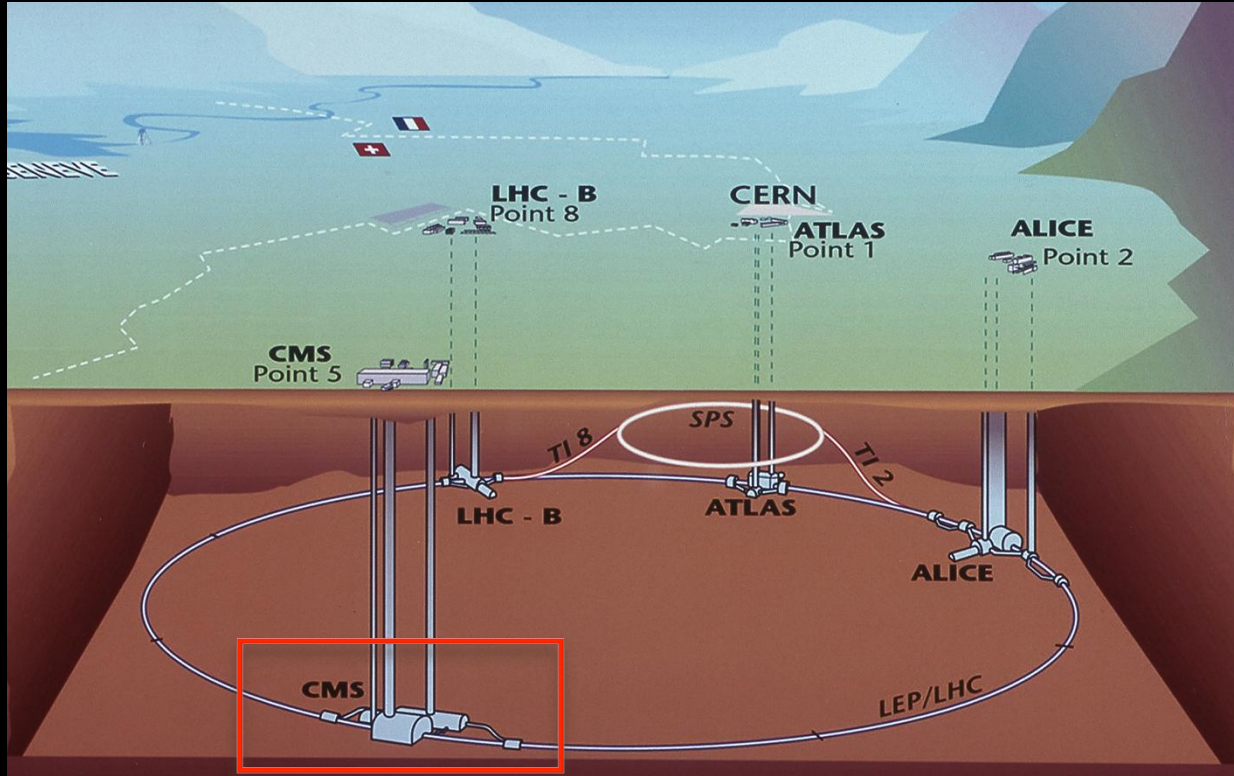
2009-2023 (LHC)  
operational Phase-1

2026-2037 (HL-LHC)  
Phase-2 of the program

A unique collider worldwide at the highest energies ever, and with a step-by-step increasing proton-proton collision rate from the LHC to the HL-LHC Phase.



# The Large Hadron Collider @ CERN



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designs and R&D

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2009-2023 (LHC)  
operational Phase-1

2026-2037 (HL-LHC)  
Phase-2 of the program

The LHC/HL-LHC accelerator is co-financed through a sustained annual Belgian contribution (~28 MEUR/year) from the Federal government.

# The CMS Collaboration and experiment

A worldwide collaboration established 25 years ago, and still growing

50 countries

~230 institutions

2885 scientists (incl. 922 PhD students)

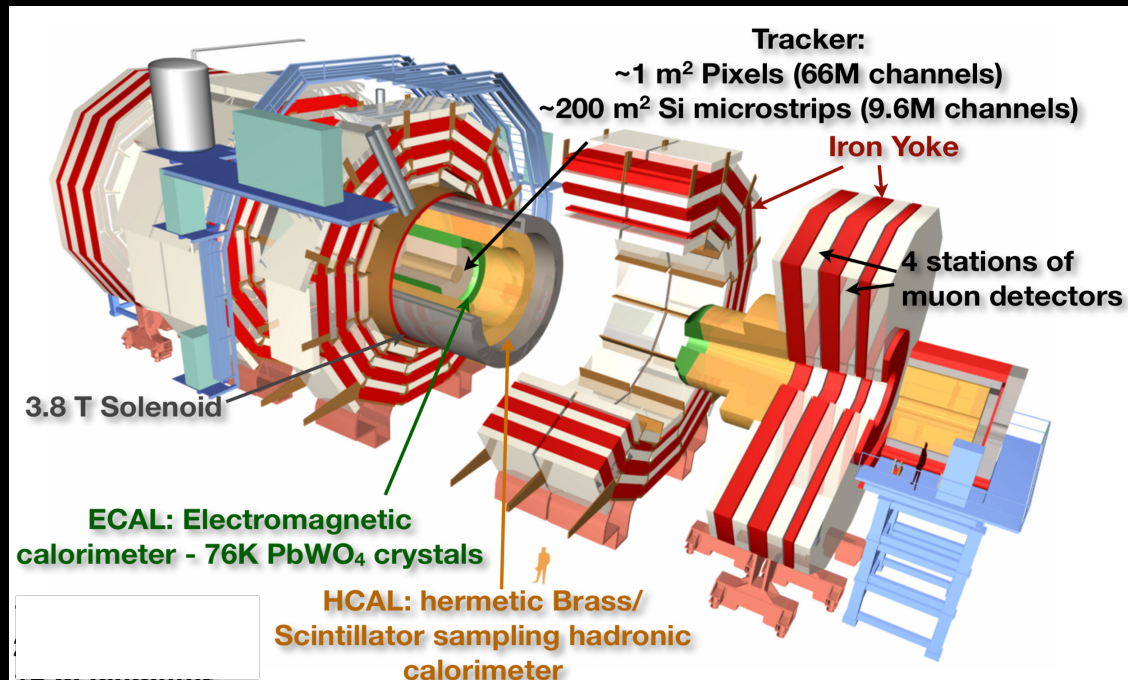
1274 engineers & technicians

100 journal publications per year

Flanders = ~2% of the authors

51 PhDs graduated in our teams

27 PhD students ongoing



Several instruments have to be integrated and synchronized together to make the experiment a success. The responsibility to construct, commission, operate, maintain each instrument is typically connected to a consortium of institutions and formulated in Memoranda of Understanding (MoU) with funding agencies.

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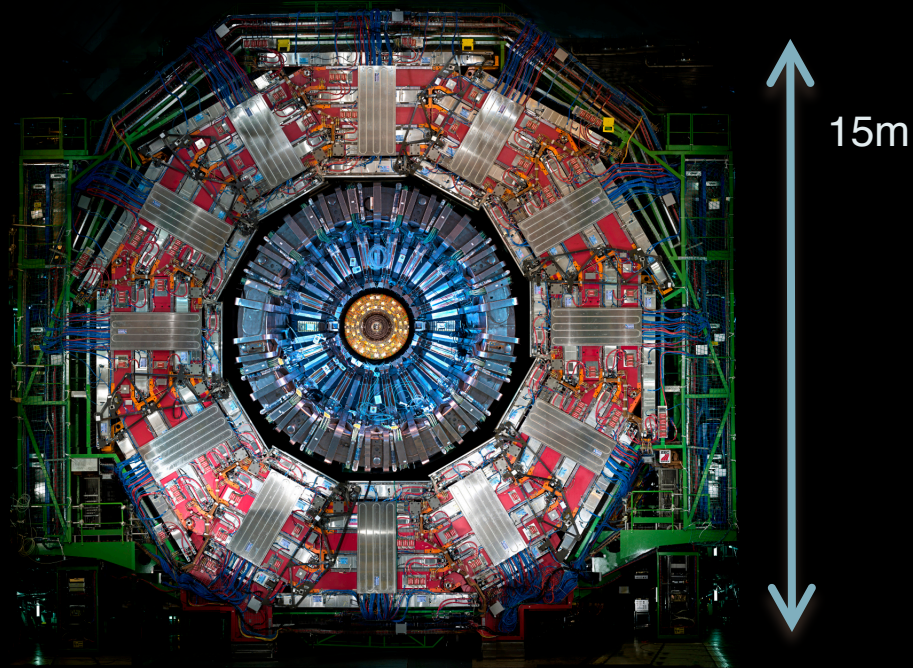
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**The foreseen upgrade of the CMS detector by 2026 is co-financed through a Belgian contribution (~10 MEUR) obtained in the “Hercules programme”.  
Therefore no equipment investment is requested in this application.**

# IRI application: recurrent costs fixed in agreements

For the participation in the CMS experiment a funding agency signed a Memorandum of Understanding (MoU) to contribute:

- in the annual Maintenance and Operation costs (M&O)
- in the required computing resources (TIER-2)
- in the operation of the experiment (collecting good data)
- in the common cost to upgrade the experiment (Common Fund)

The CMS experiment operates within a flat budget year-after-year. For Flanders and for 2018 the required budget (and granted by the FWO) was calculated to be 1.15 MEUR.

For the years 2019-2022 we maintain this annual budget, modulo a small additional budget to cover the cost of technical personnel to construct the upgraded CMS detector, and the participation of the PI/co-PIs in the CMS Collaboration meetings.

The **resulting budget is 1.32 MEUR per year** (23.6 kEUR / year / researcher). Additional direct matching funds of around 0.55 MEUR per year, and the indirect leverage factor with similar contributions from institutions worldwide in the CMS Collaboration is around 50.

# IRI application: annual costs

- Maintenance and Operation costs (M&O): in agreement with the funding agencies involved (incl. FWO) this is fixed by the experiment to be 13 kEUR per year and PhD-titled researcher
- Computing resources (TIER-2): in agreement with the funding agencies involved (incl. FWO) this is fixed in units of disk space and CPU power, and it reflects a total of 200 kEUR per year to plug in our local computing center into the worldwide LHC GRID network
- Operation of the experiment (collecting good data): as researchers we need to deliver “services” to collect good data of 4 months per year per researchers (6 months for new researchers) typically at the detector for which we foresee a 60 kEUR travel budget per year and a cost of 60 kEUR to rent adequate apartments
- Common cost to upgrade the experiment (Common Fund): in agreement with the funding agencies involved (incl. FWO) this is fixed by the experiment to cover the technical installation of the new CMS detector, spread over the years this results in 100 kEUR per year
- Cost for the participation of PI/co-PIs in collaboration meetings (5x per year) of 24.5 kEUR per year, and cost of basic technical tools to support the construction of 22.5 kEUR per year

# IRI application: annual costs and personnel

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- Computing resources (TIER-2): in agreement with the funding agencies involved (incl. FWO) this is fixed in units of disk space and CPU power, and it reflects a total of 200 kEUR per year to plug in our local computing center into the worldwide LHC GRID network + 1.5 FTE techn
- Operation of the experiment (collecting good data): as researchers we need to deliver “services” to collect good data of 4 months per year per researchers (6 months for new researchers) typically at the detector for which we foresee a 60 kEUR travel budget per year and a cost of 60 kEUR to rent adequate apartments + 3 FTE researchers (post-doc level)
- Common cost to upgrade the experiment (Common Fund): in agreement with the funding agencies involved (incl. FWO) this is fixed by the experiment to cover the technical installation of the new CMS detector, spread over the years this results in 100 kEUR per year
- Cost for the participation of PI/co-PIs in collaboration meetings (5x per year) of 24.5 kEUR per year, and cost of basic technical tools to support the construction of 22.5 kEUR per year
- **Technical personnel to support the construction of the new detector: 4.5 FTE techn**

# The unique national & international context of the project

- The LHC/HL-LHC project is the top priority in the international vision for particle physics (conclusion from US and European strategy panels)
- Since the start of the FWO Big Science funding programme the CMS experiment is by far the major project for particle physics in Flanders, and in Belgium
- Although we are growing in size, the requested budget of 1.32 MEUR per year is a continuation of previously obtained budgets since about 10 years; and valorise the Belgian investment in CERN (~28 MEUR/year) and the Flemish/Belgian investment in the upgrade of the CMS detector (~10 MEUR)
- The requested budget is the required cost to participate in the CMS experiment, it is the basis for several research projects funded through other programmes (e.g. FWO, EoS, university grants of excellence, etc.), e.g. 27 on-going PhD students
- Our participation and this request is based on our strong international reputation and successes confirmed by the reviewers

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Thank you for your attention.