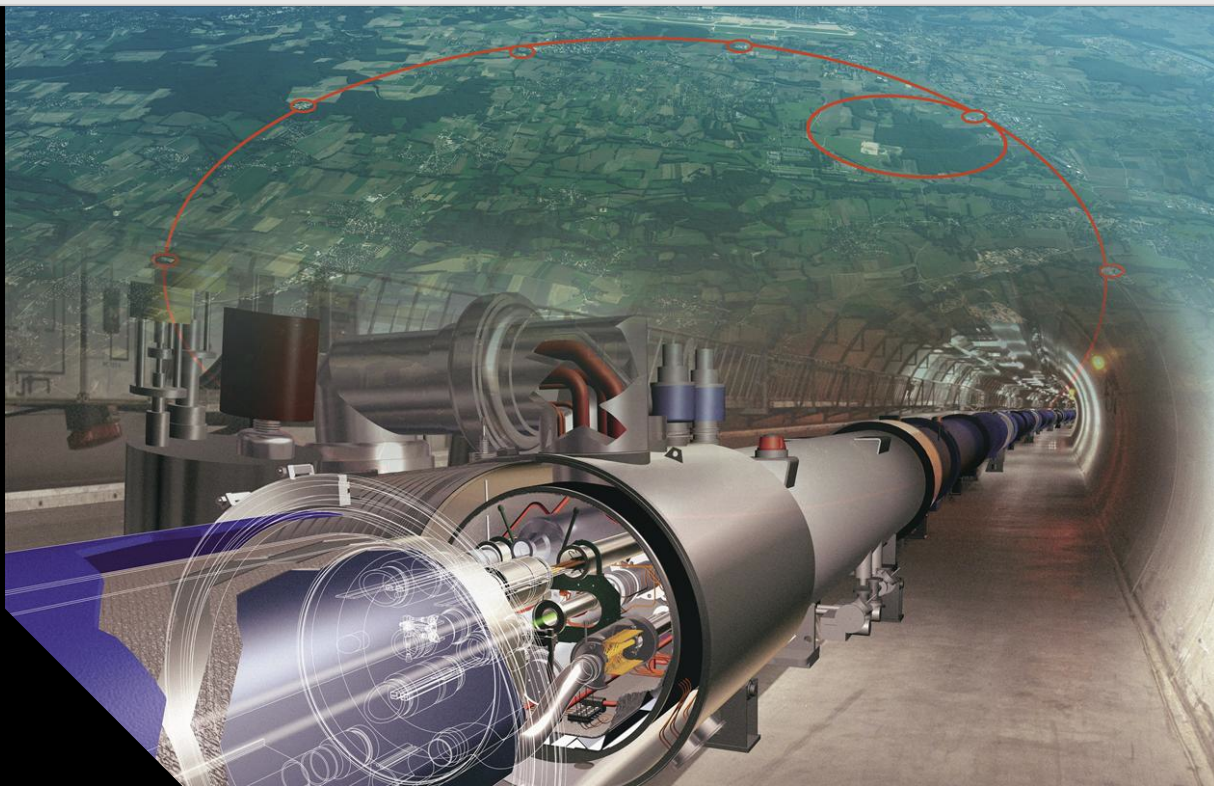


Belgium and Particle Physics @ CERN

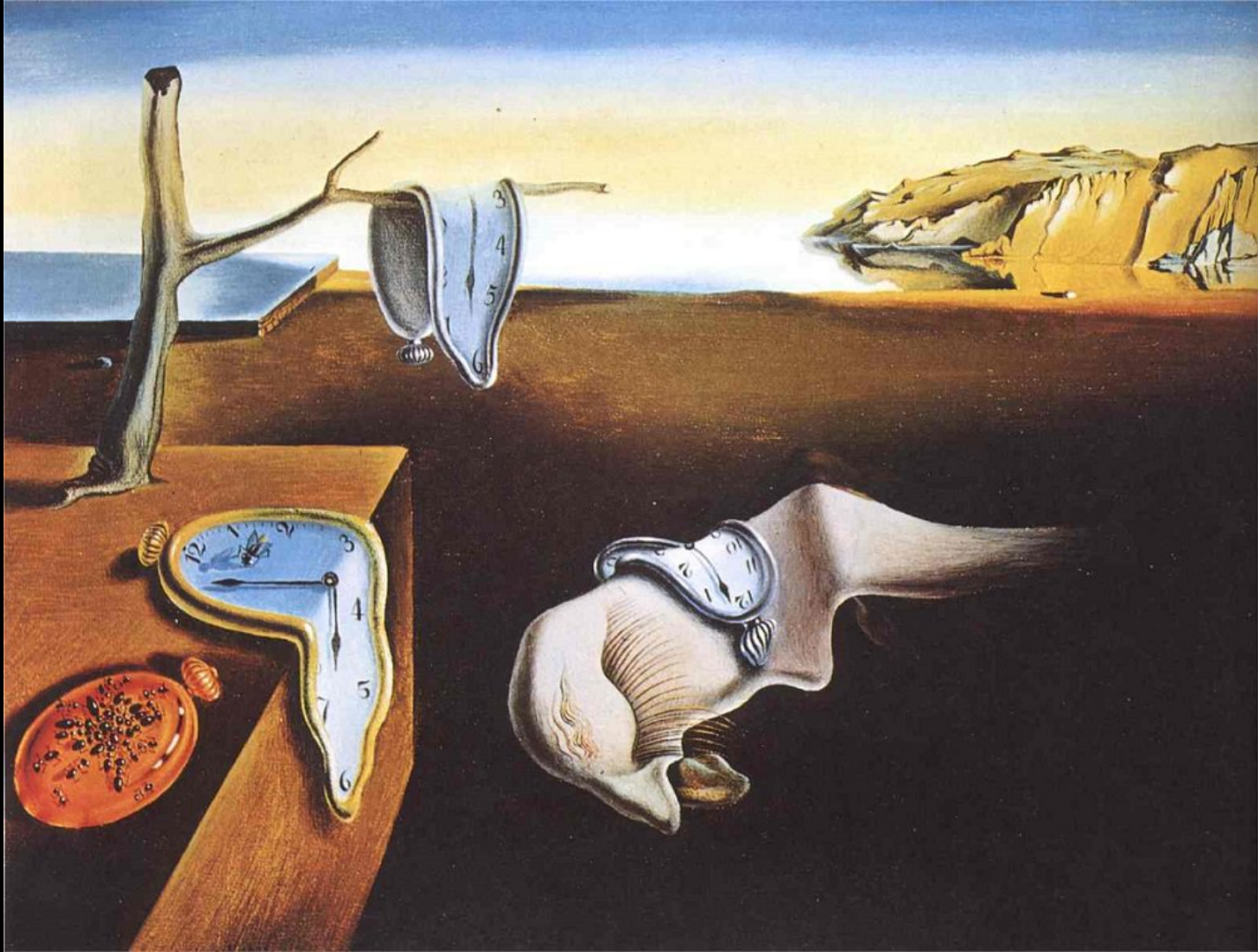
Jorgen D'Hondt
Vrije Universiteit Brussel
ECFA chairperson
(<https://ecfa.web.cern.ch>)

KVAB
30 November 2018
Brussels



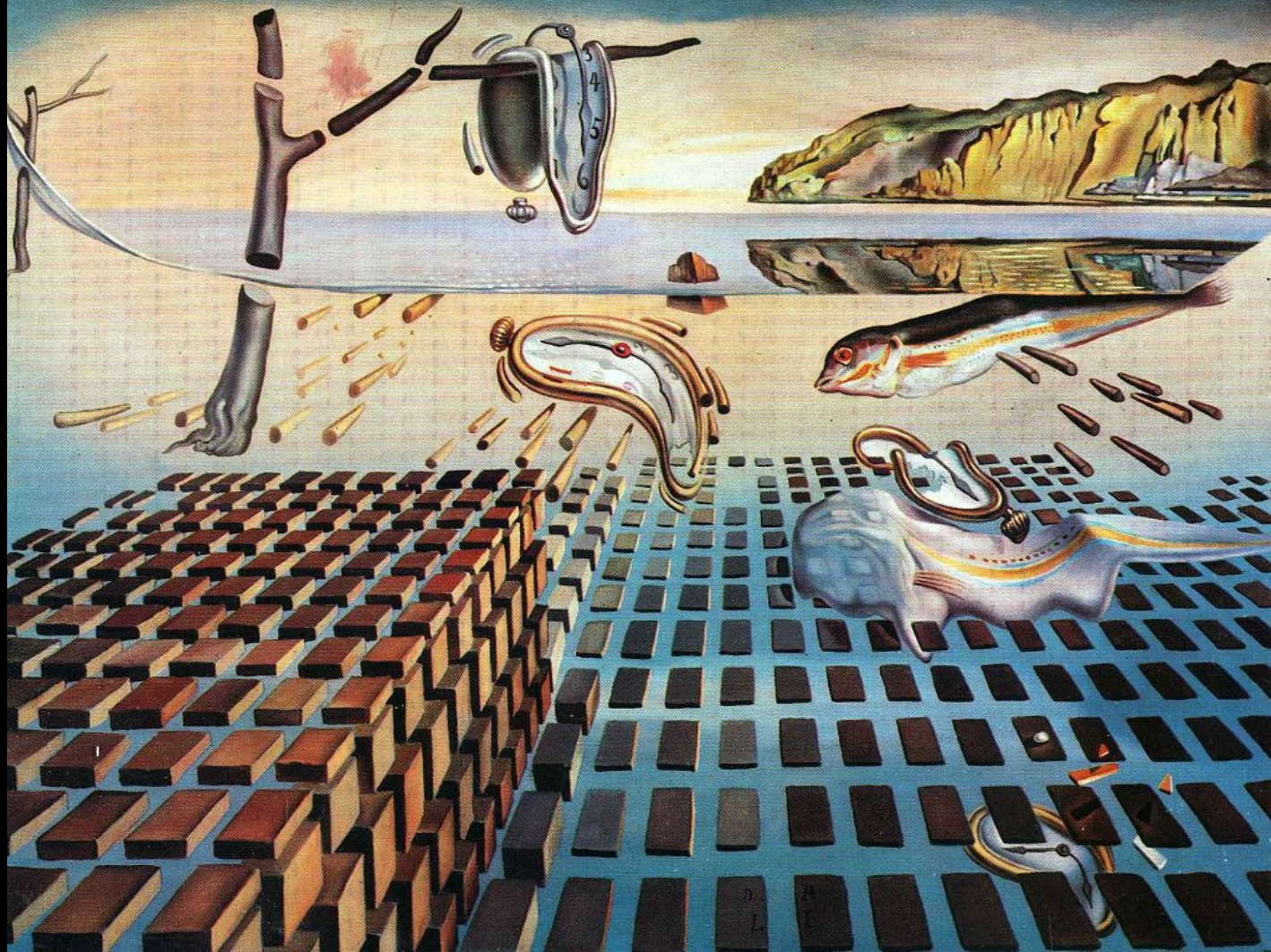
HEP@VUB
BRUSSELS

VUB
iihe
BRUXELLES BRUSSEL

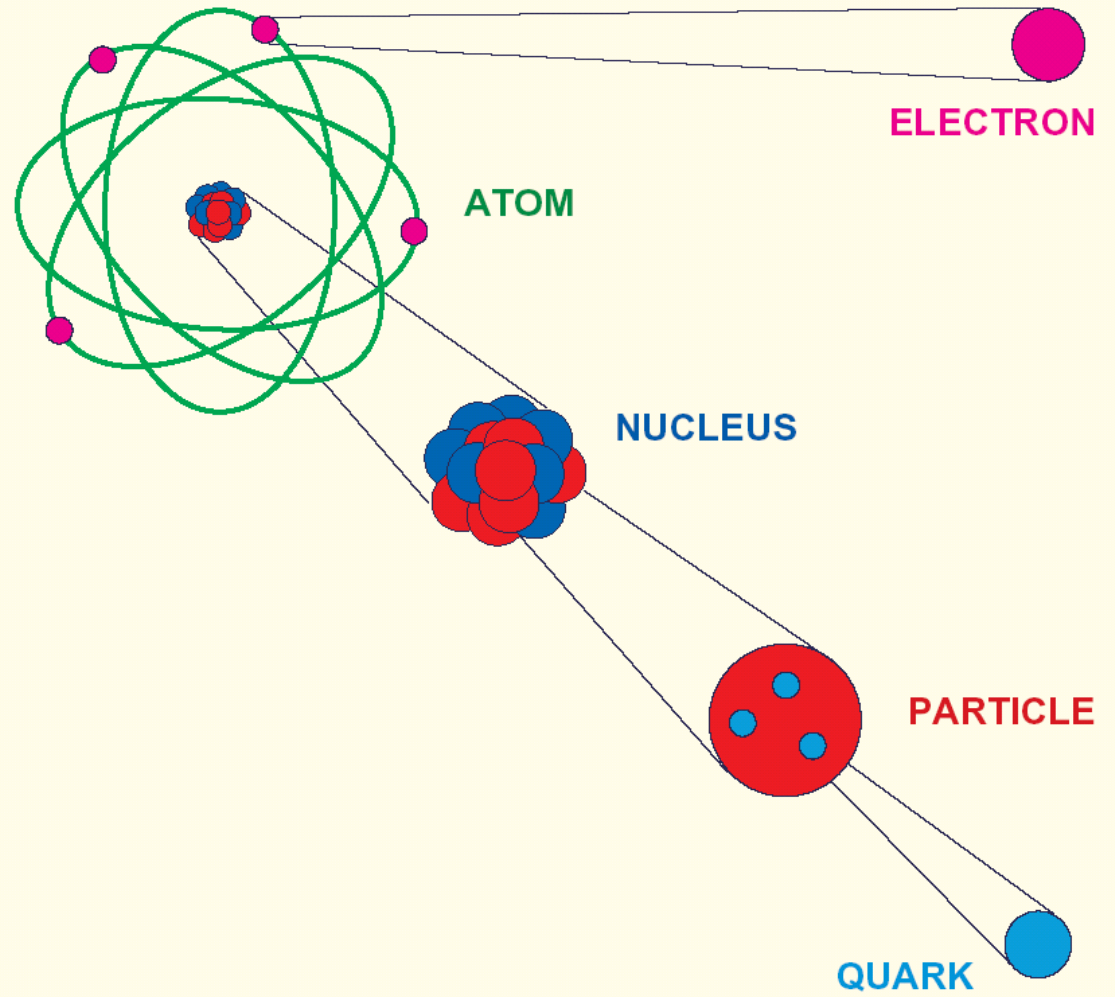


1931

1952



The largest and the smallest



High-energy physics in Belgium
we are 277 FTE

(nuclear + particle)

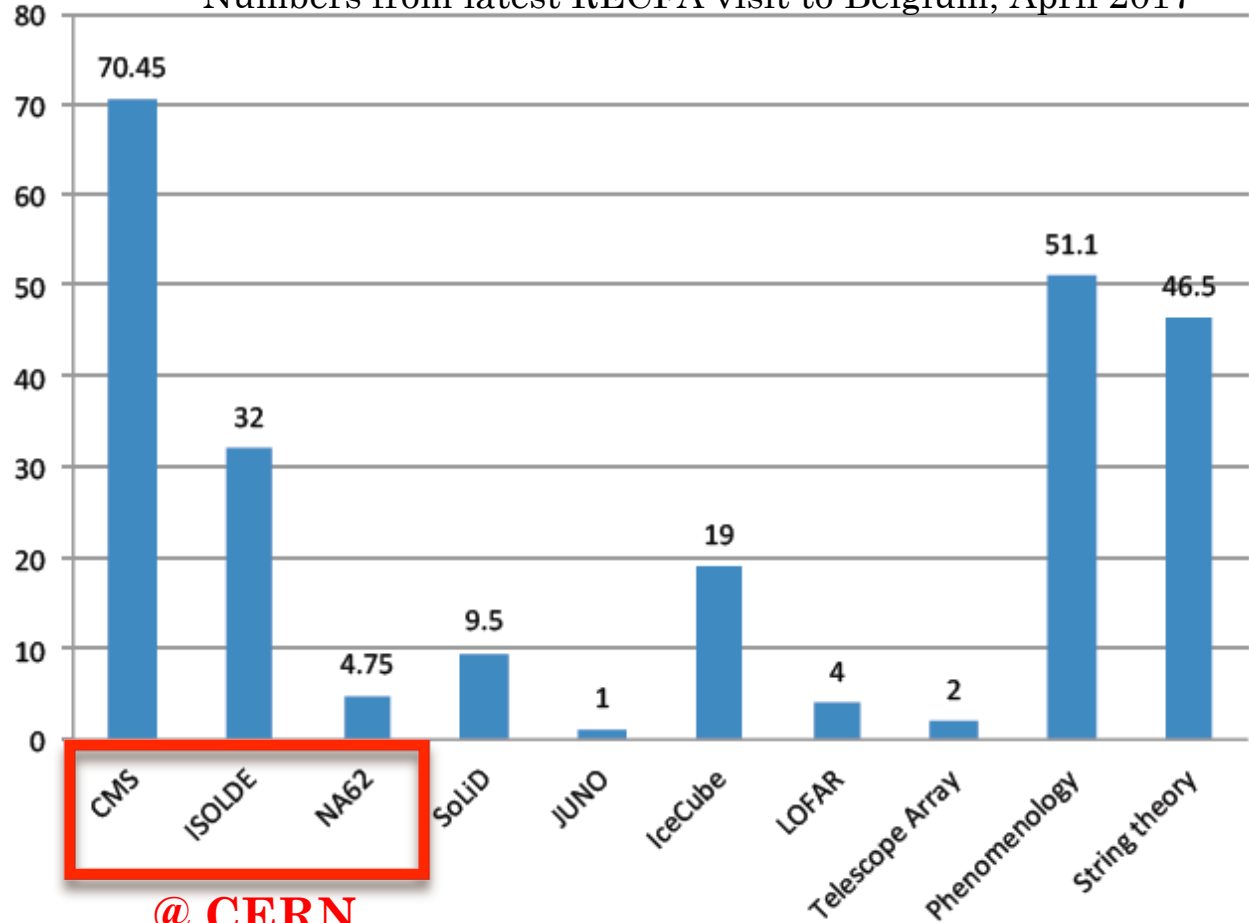
Permanents
Postdocs
PhD students

1/3 theory
2/3 experiment

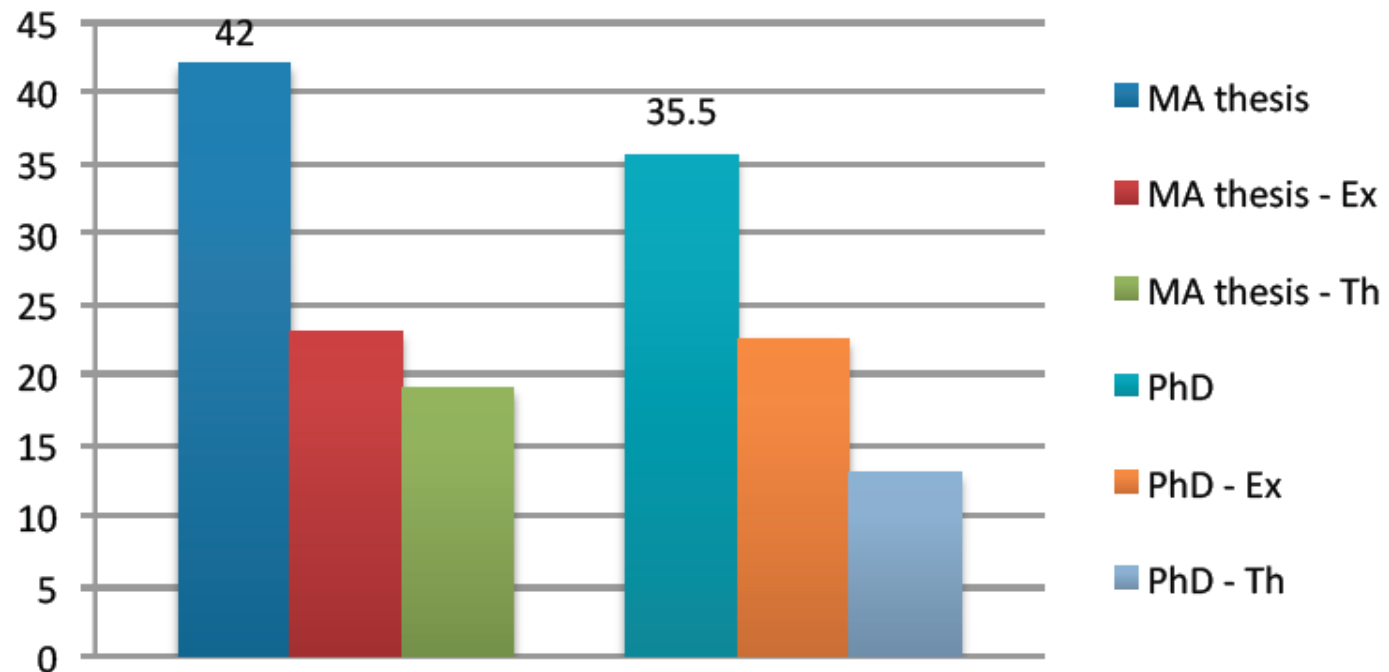
88% male (permanents)
84% male (postdocs)
78% male (PhD students)

BE manpower - 277 FTE in total

Numbers from latest RECFA visit to Belgium, April 2017



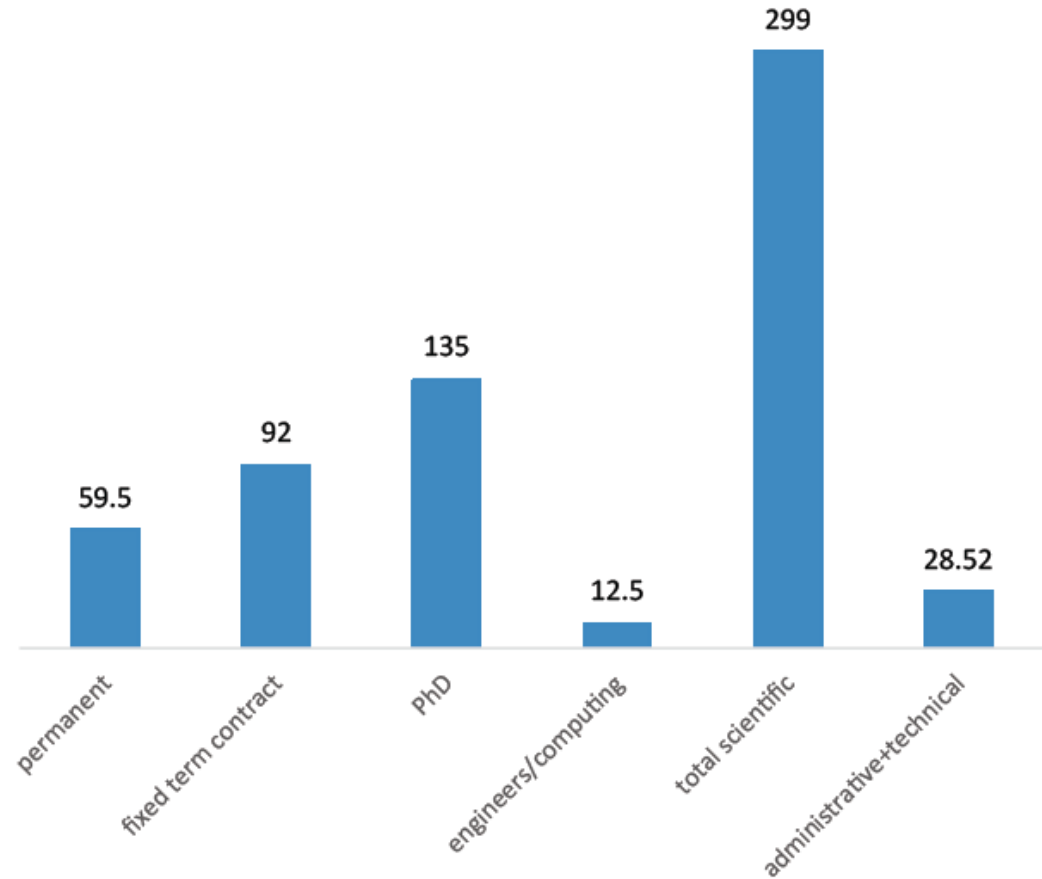
Number of thesis per year



→ 3.2 PhD/y/Mhab

Permanents: 60% below 50 year

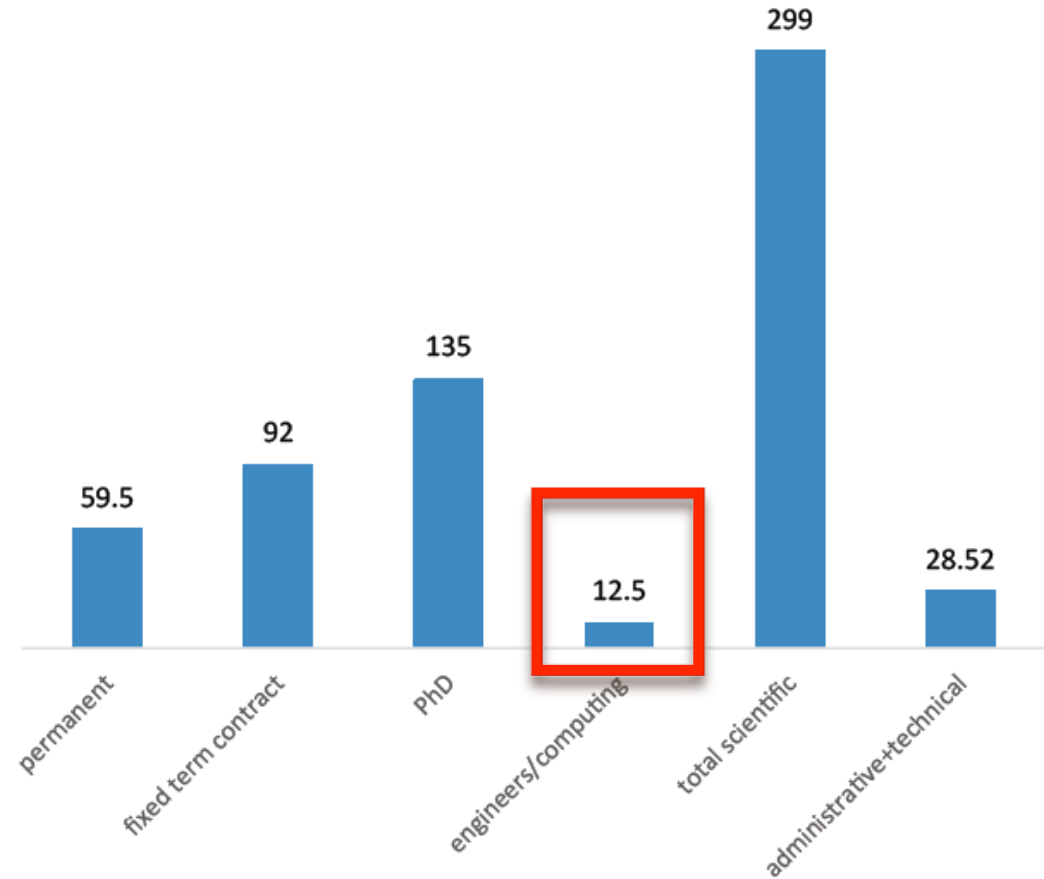
BE manpower per category



Permanents: 60% below 50 year

Engineers/computing:
8 high-level IT/computing
2 nuclear research engineers (!!)
2.5 particle research engineers (!!)

BE manpower per category



Permanents: 60% below 50 year

Engineers/computing:

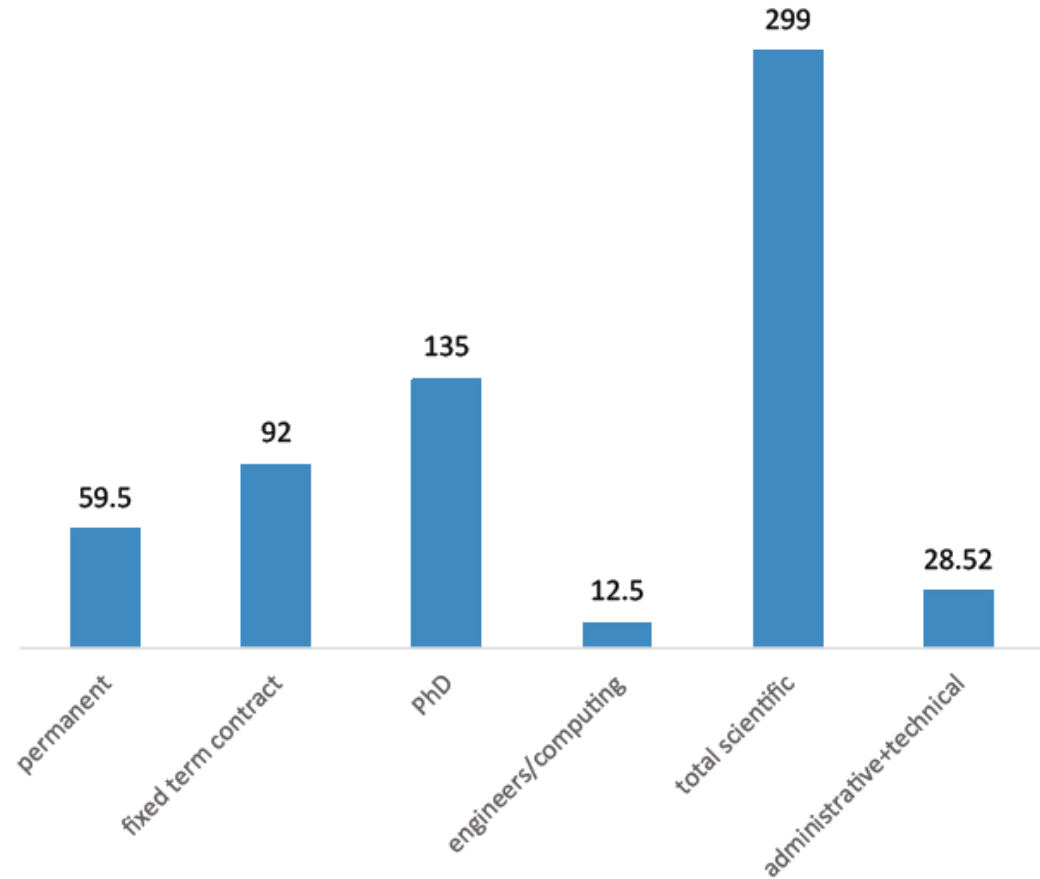
8 high-level IT/computing

2 nuclear research engineers (!!)

2.5 HEP research engineers (!!)

	theory	exp	adm +tech
1995	53	74	41
2003	71	76	33
2010	108	105	26
2017	98	137	24

BE manpower per category



Permanents: 60% below 50 year

Engineers/computing:

8 high-level IT/computing

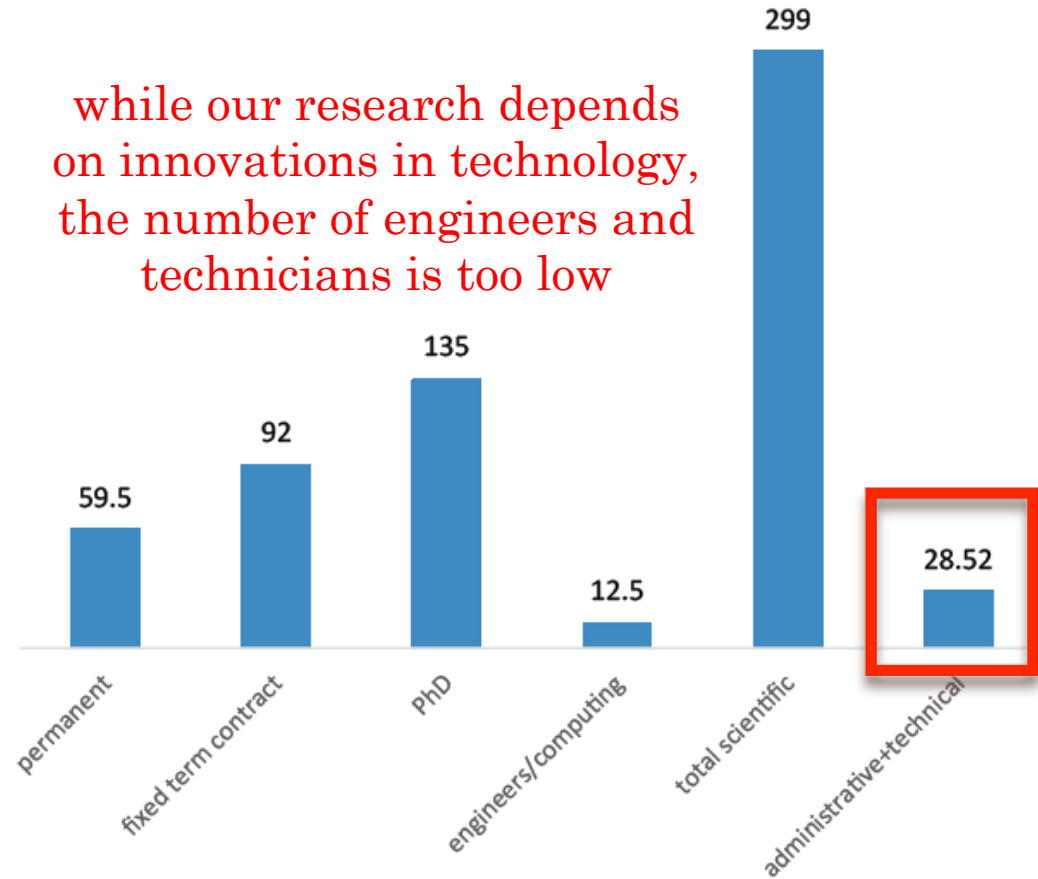
2 nuclear research engineers (!!)

2.5 HEP research engineers (!!)

	theory	exp	adm +tech
1995	53	74	41
2003	71	76	33
2010	108	105	26
2017	98	137	24

BE manpower per category

while our research depends on innovations in technology, the number of engineers and technicians is too low



Permanents: 60% below 50 year

Engineers/computing:
8 high-level IT/computing
2 nuclear research engineers (!!)
2.5 HEP research engineers (!!)

	theory	exp	adm +tech
1995	53	74	41
2003	71	76	33
2010	108	105	26
2017	98	137	24

Numbers NIKHEF:
(RECFA visit Oct 2018)

Permanent Staff	77
PhD students	97
Postdocs	31
Technical/engineer	71
Support	33

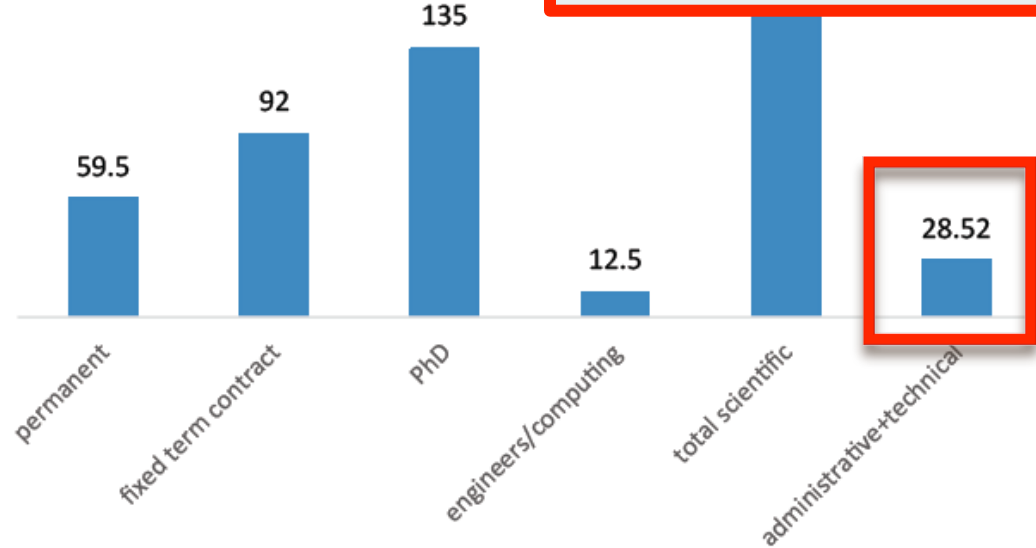
BE: 227 postdoc + PhD students

NL: 128 postdoc + PhD students

BE: ~25 techn/eng

NL: 71 techn/eng

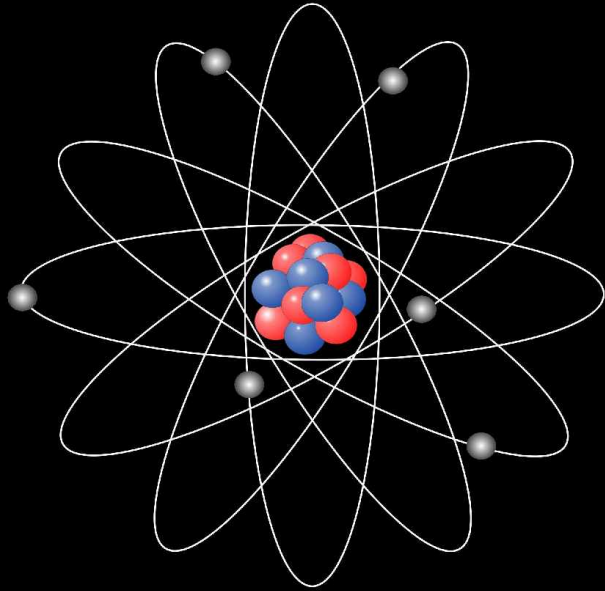
Factor of x5
too few for techn/eng



Technology challenge
make the invisible visible

Imagine an atom has the size of the Earth ...

... a quark would be smaller than a rice grain in the volume of the Earth



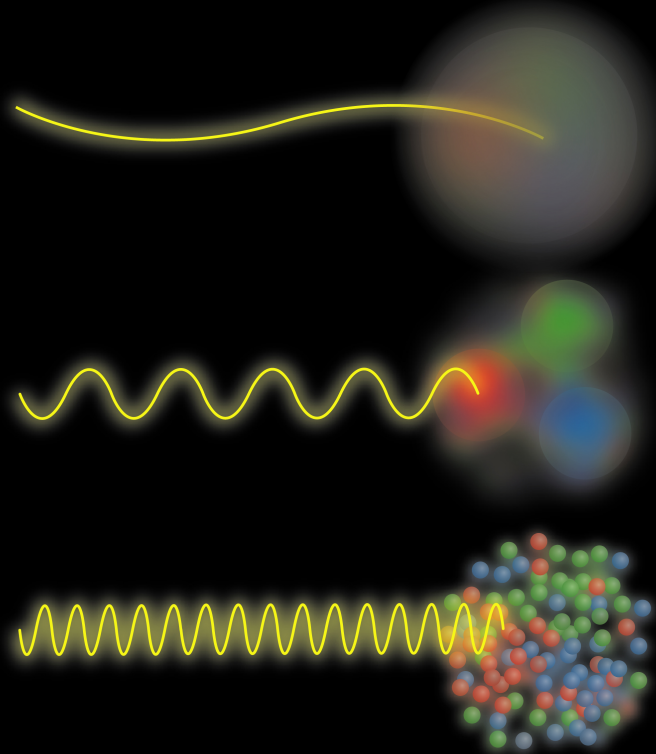
$\sim 0,0000000001$ meter



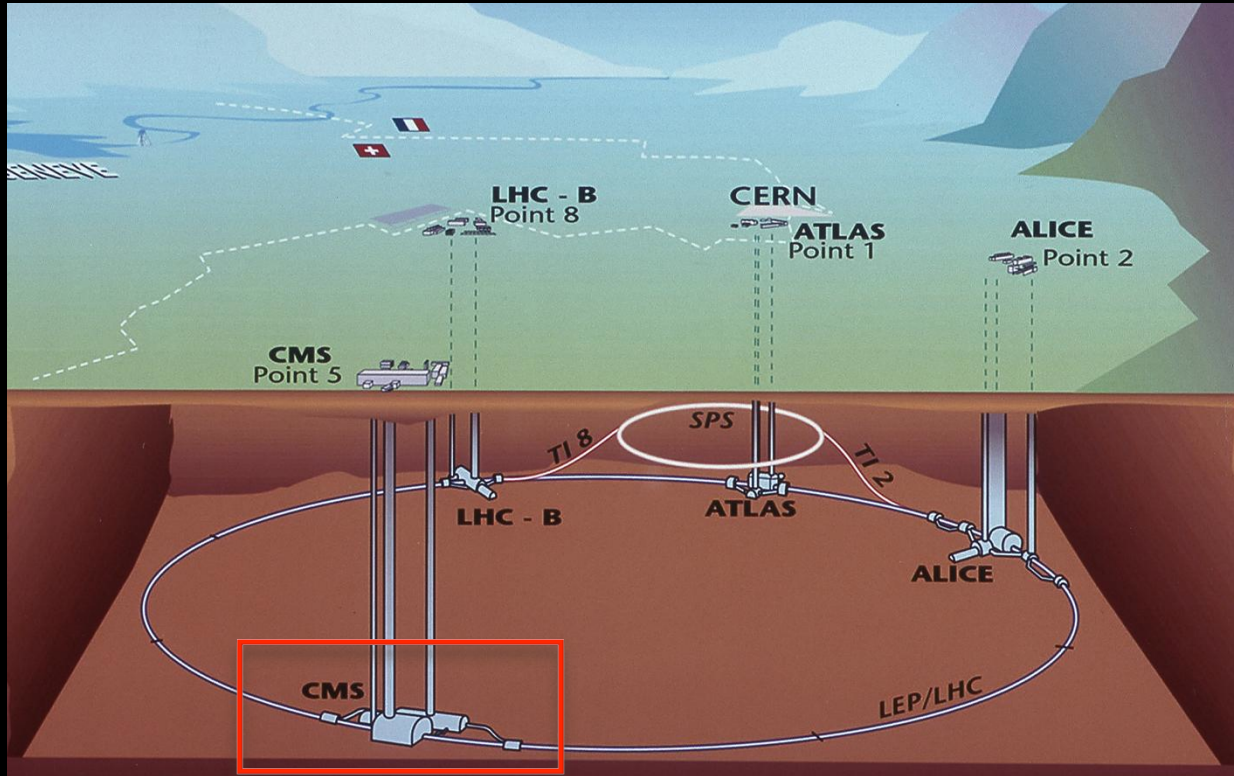
$\sim 10.000.000$ meter

Accelerators

higher energy, higher frequency, higher resolution



The Large Hadron Collider @ CERN



1990-2000
designs and R&D

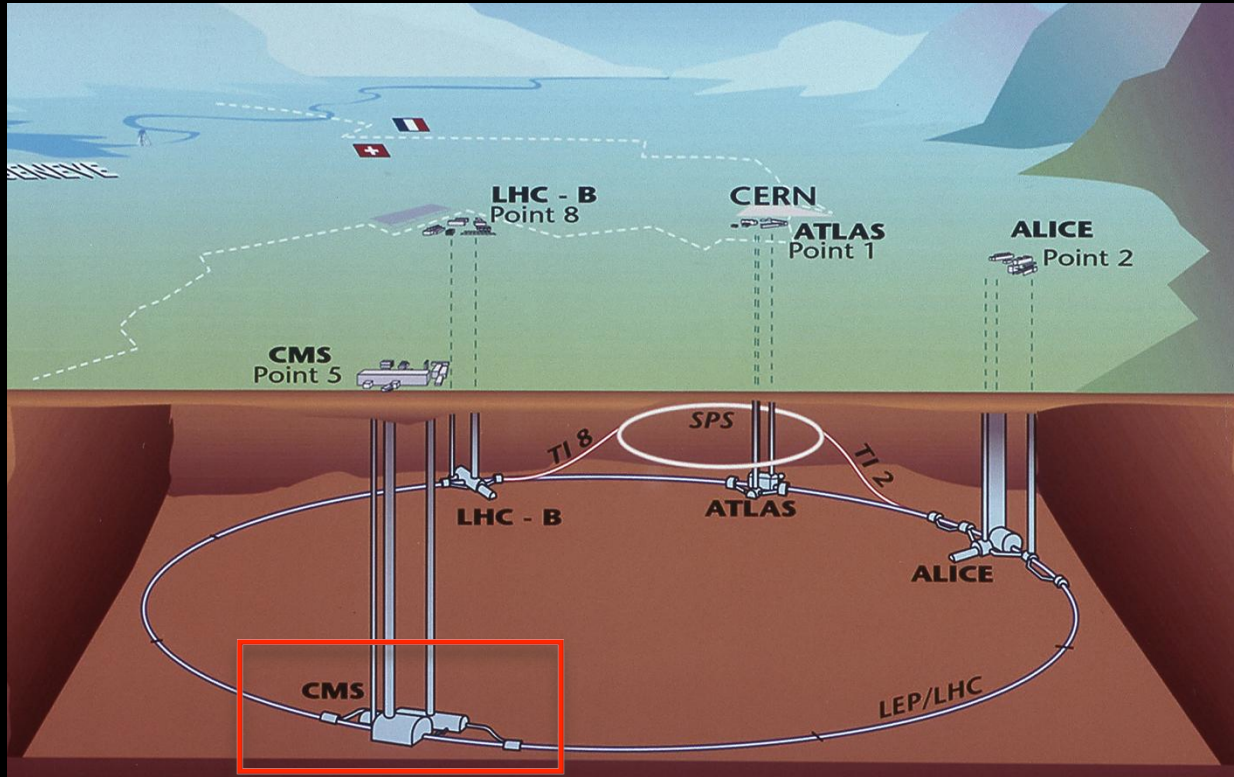
2000-2008
construction LHC
construction CMS

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



1990-2000
designs and R&D

2000-2008
construction LHC
construction CMS

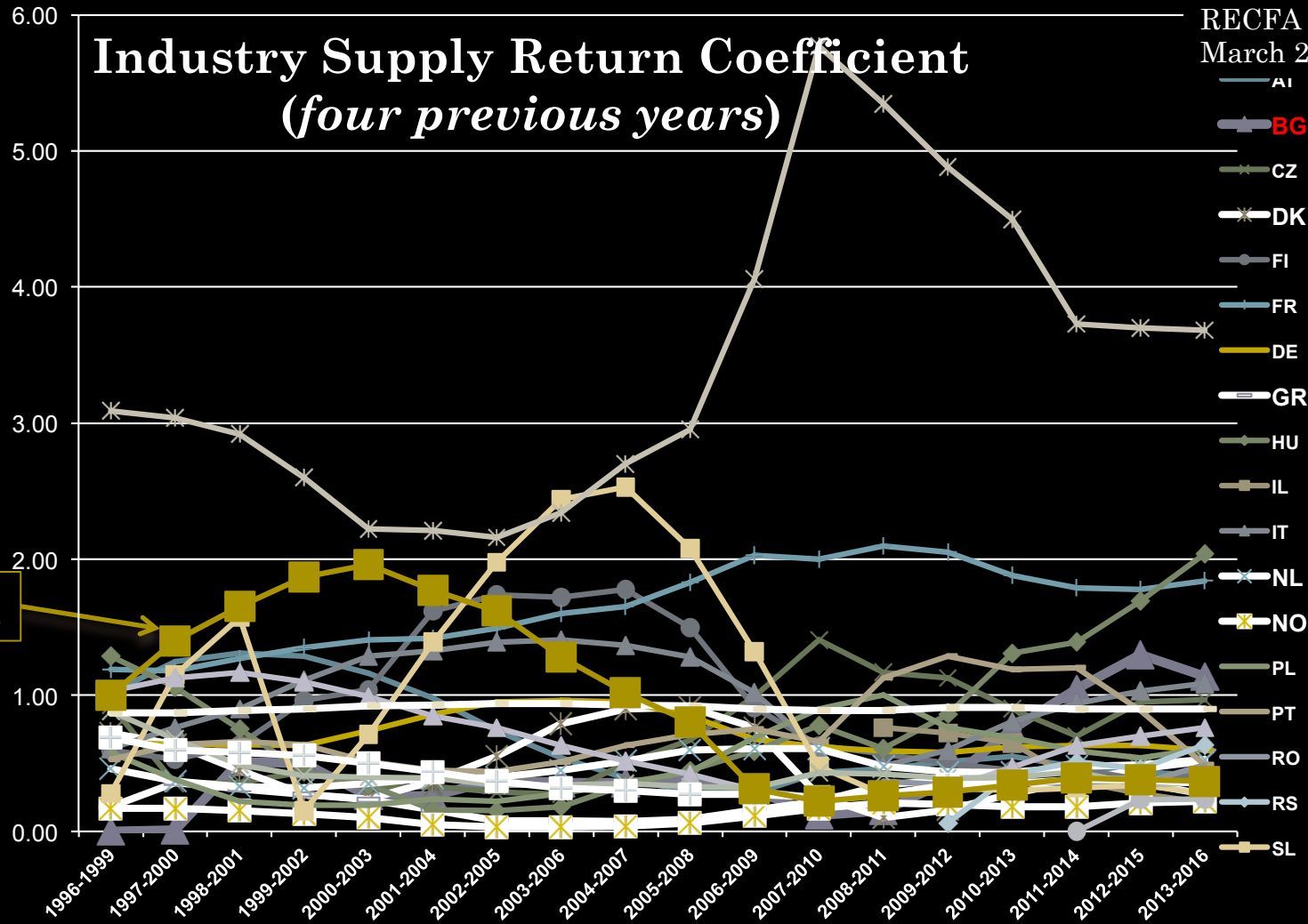
2009-2023 (LHC)
operational Phase-1

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

The accelerator is co-financed using the Belgian contribution to CERN (~28 M EUR/year) from the Federal government. Total budget CERN is ~1 B EUR/year.

Industry Supply Return Coefficient (four previous years)

RECFA visit Bulgaria
March 2017



Belgium

The CMS Collaboration and experiment

A worldwide collaboration
established 25 years ago, and
still growing

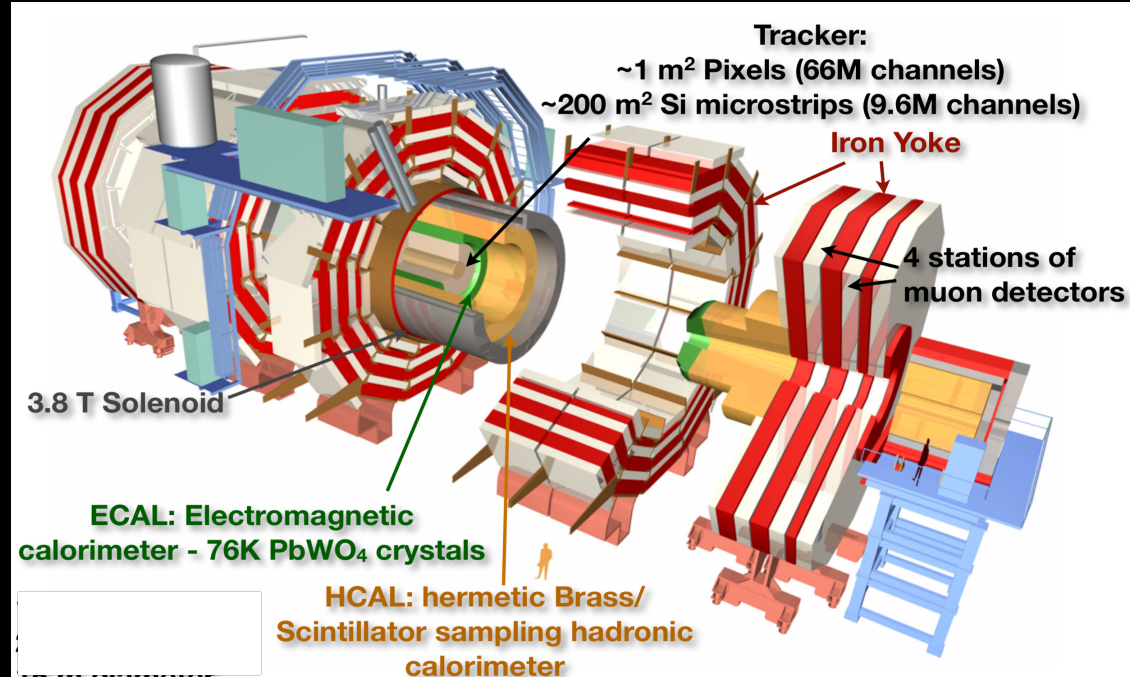
50 countries

~230 institutions

2885 scientists (incl. 922 PhD students)

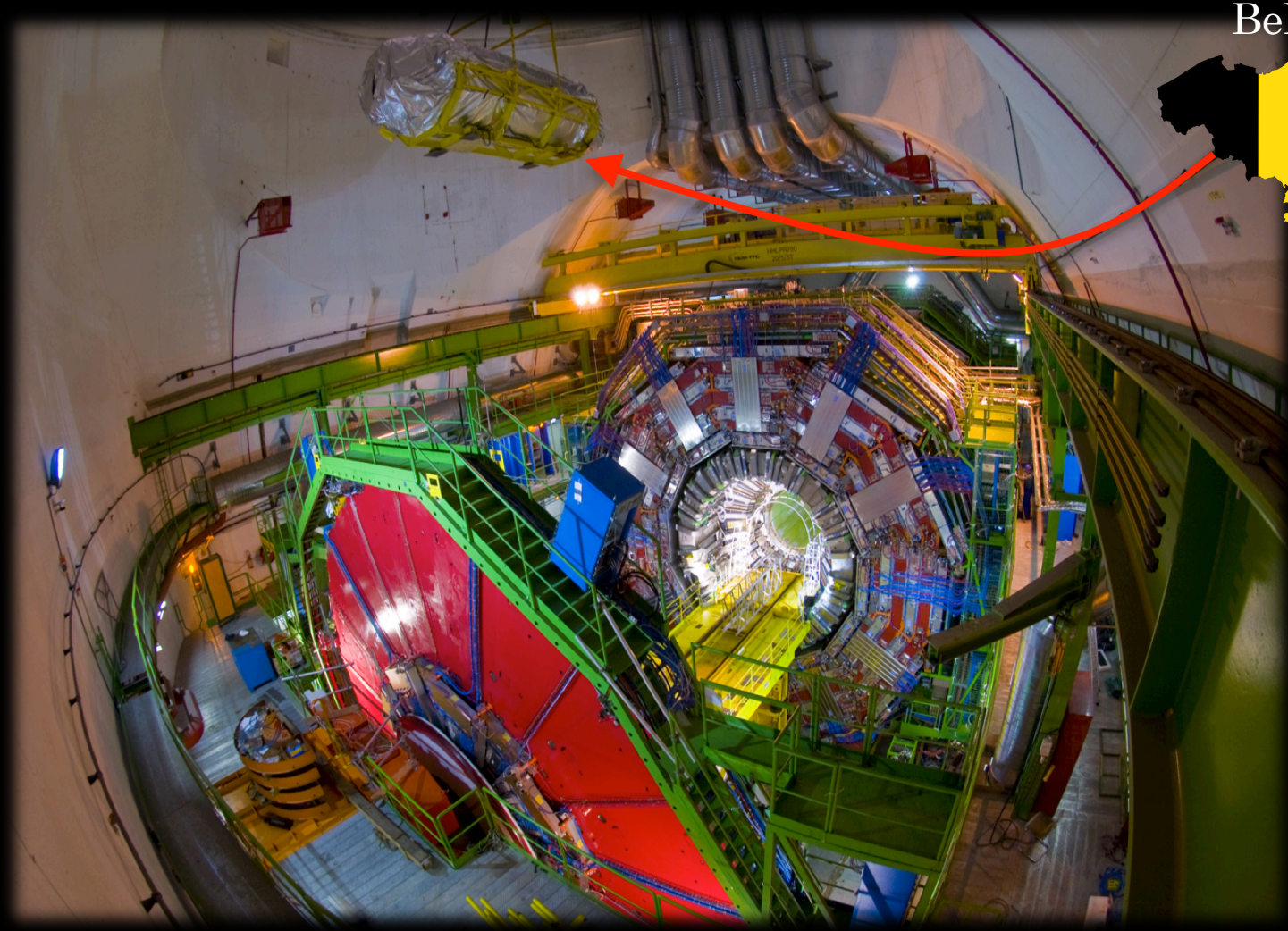
1274 engineers & technicians

100 journal publications per year



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.

Belgium



The CMS Collaboration and Belgium

Belgium is involved from the start of the experiment 25 years ago.

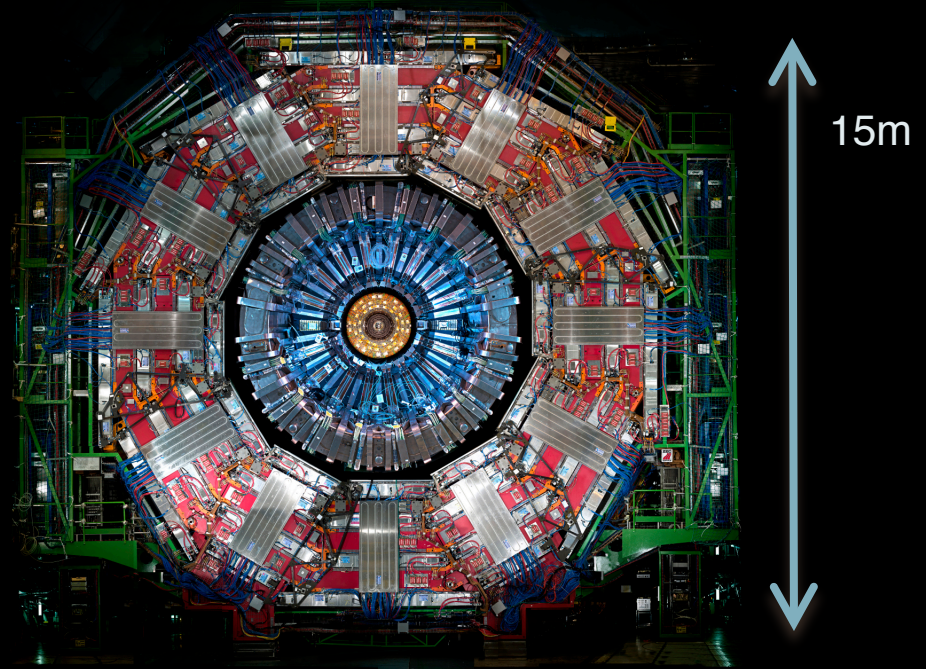
Belgium

17 faculty members

4.4% of the authors

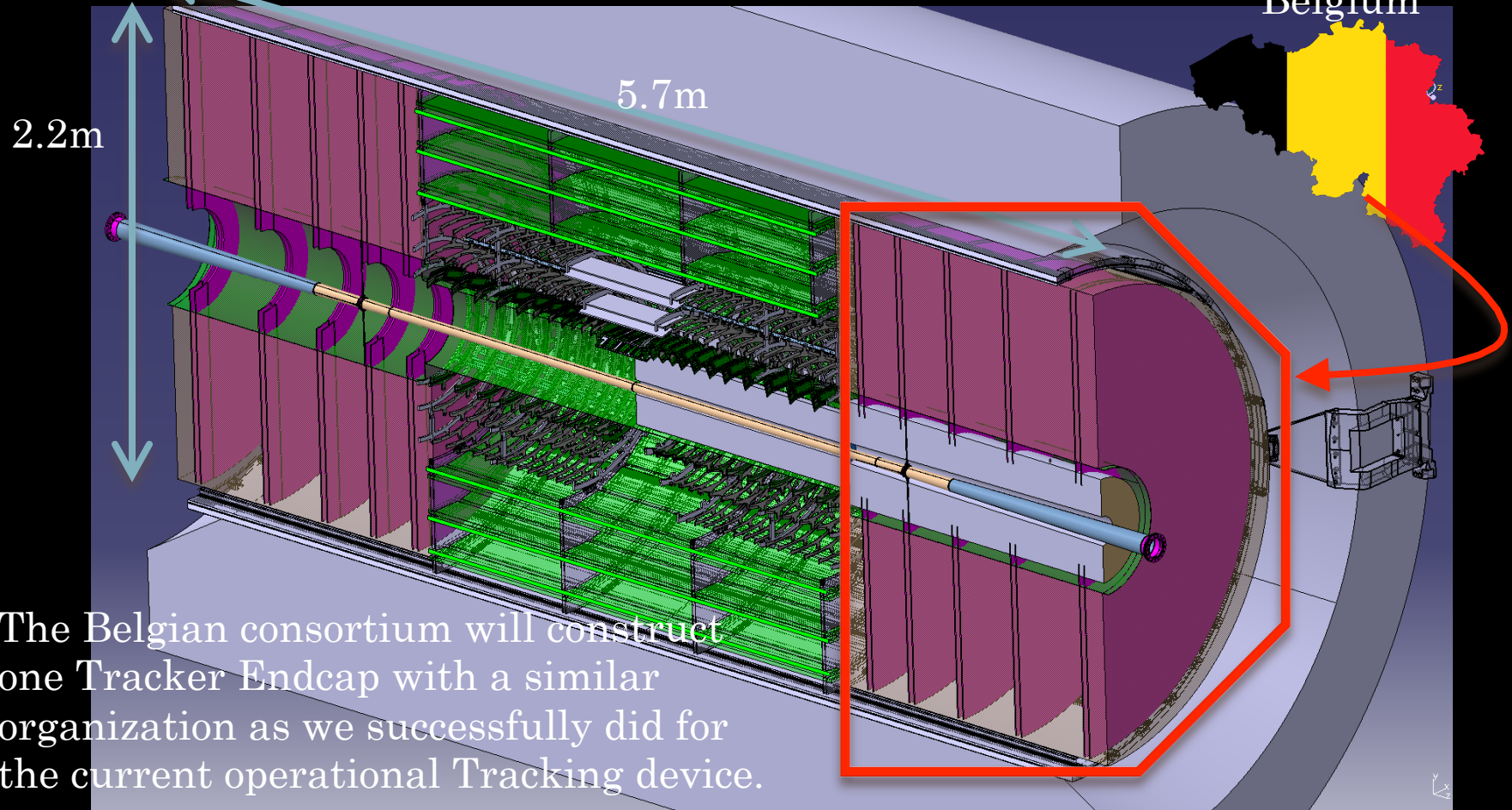
89 PhDs graduated in our teams

~40 PhD students ongoing



The foreseen upgrade of the CMS detector by 2026 is co-financed through a Belgian contribution (~10 MEUR). Total upgrade cost is ~250 MEUR.

The CMS Collaboration and Belgium



Belgium in the CMS Collaboration

- For a relative small Belgian financial investment, we have access to one of the worlds most unique and powerful scientific instruments.
- Operational funding relates to the number of PhD-titled authors
 - ✧ 3.7% of the PhD-titled authors are at Belgian institutions
 - ✧ 4.4% of the authors on CMS publications
 - ✧ 5.3% of the number of PhD students
 - ✧ 6.6% of physics area conveners
 - ✧ 8.3% of the major conference talks
 - ✧ 14% (1/7) of the Collaboration Board chairs
 - ✧ 33% (6/18) of the Best PhD Thesis Awards (x9 above our “fair-share”)

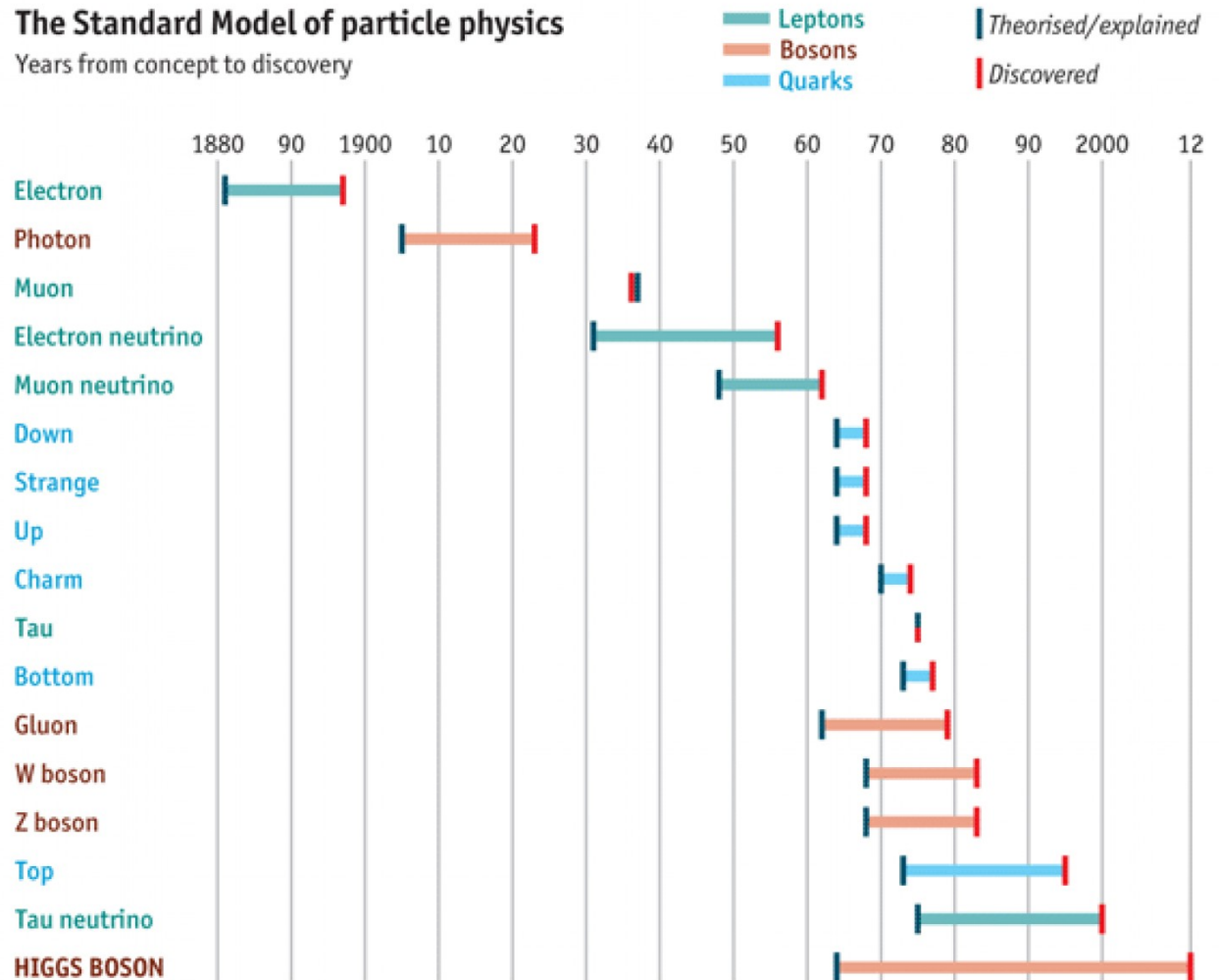
a “small” country performing well in a “large” collaboration

July 4, 2012

Source:
The Economist
July 4th, 2012

The Standard Model of particle physics

Years from concept to discovery

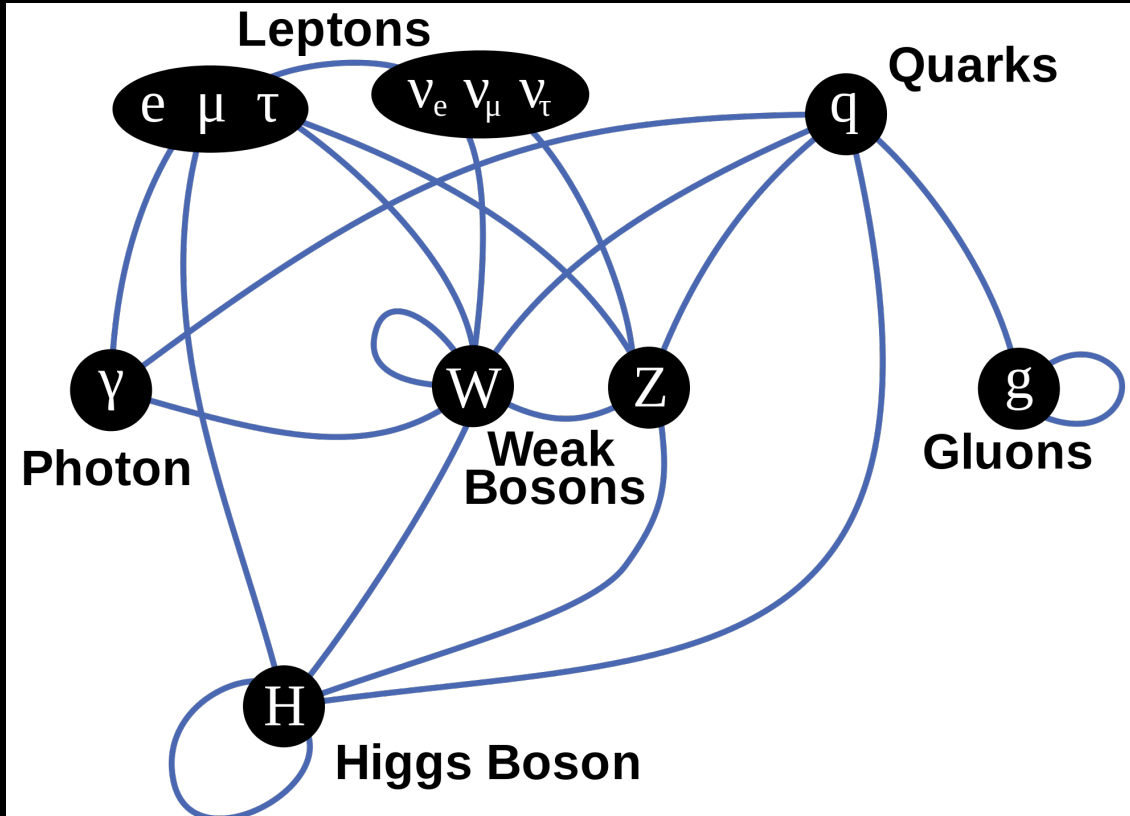


Source: *The Economist*



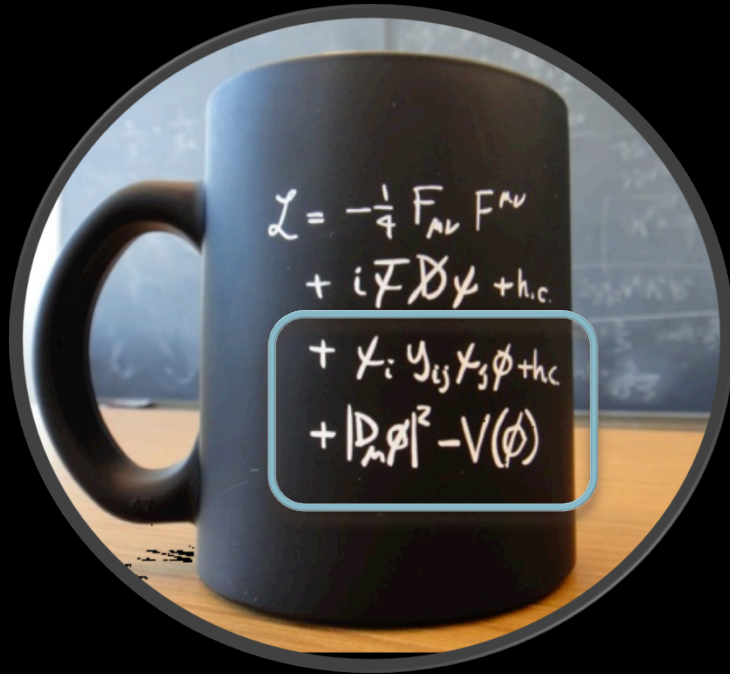
Nobel Prize 2013, F. Englert

Particle Physics today

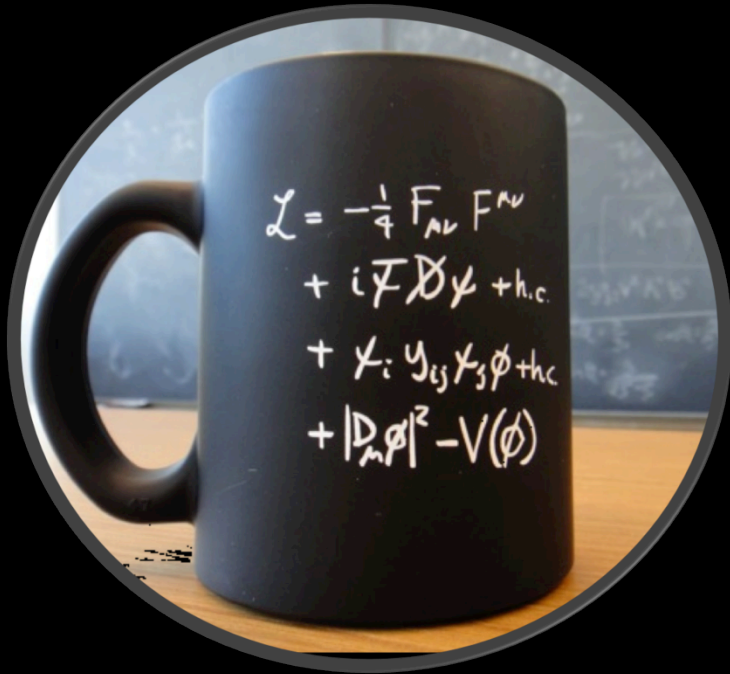


- the Higgs particle is confirmed in 2012 and its interactions with other particles are step by step being discovered
- Higgs – Z boson (2012)
- Higgs – W boson (2014)
- Higgs – tau lepton (2016)
- Higgs – top quark (2018)
- Higgs – bottom quark (2018)
- Higgs – muons, electrons, charm quark, self-coupling,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

Particle Physics today



Particle Physics today



description \neq understanding

The scaffolding of Dark Matter in our universe



125 Mpc/h

Simulations of the formation, evolution and clustering of galaxies and quasars, *Nature* **435**, 629-636 (2 June 2005)

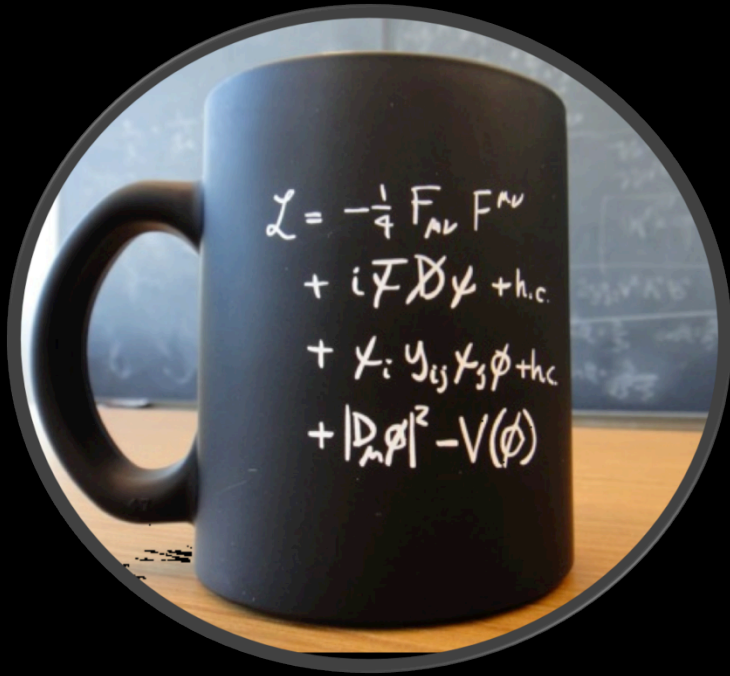
The scaffolding of Dark Matter in our universe



125 Mpc/h

80% of the matter in the universe is dark

Particle Physics today

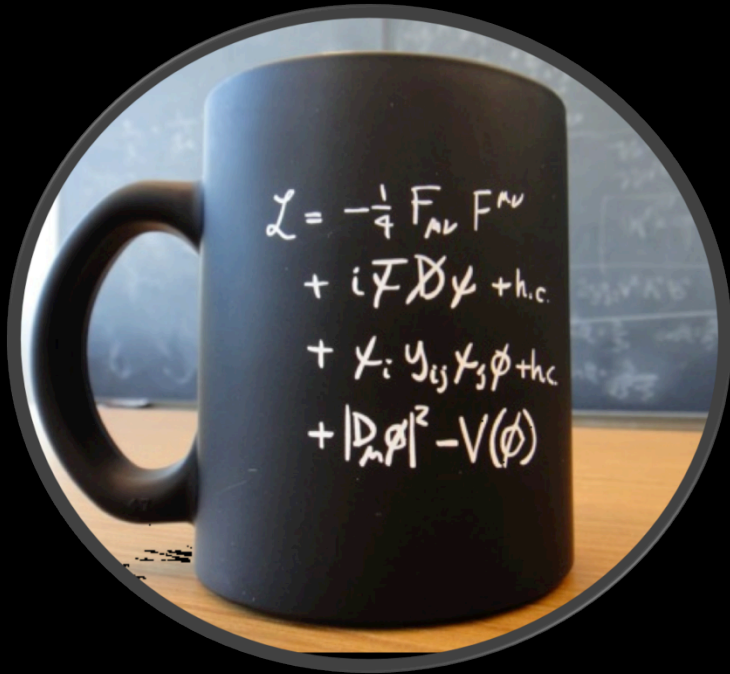


description \neq understanding



new physics

Particle Physics today

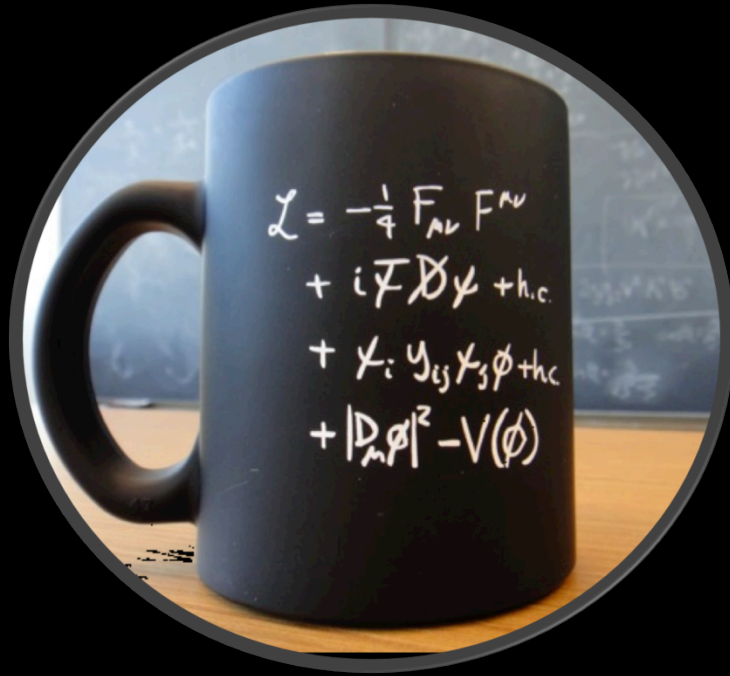


description \neq understanding



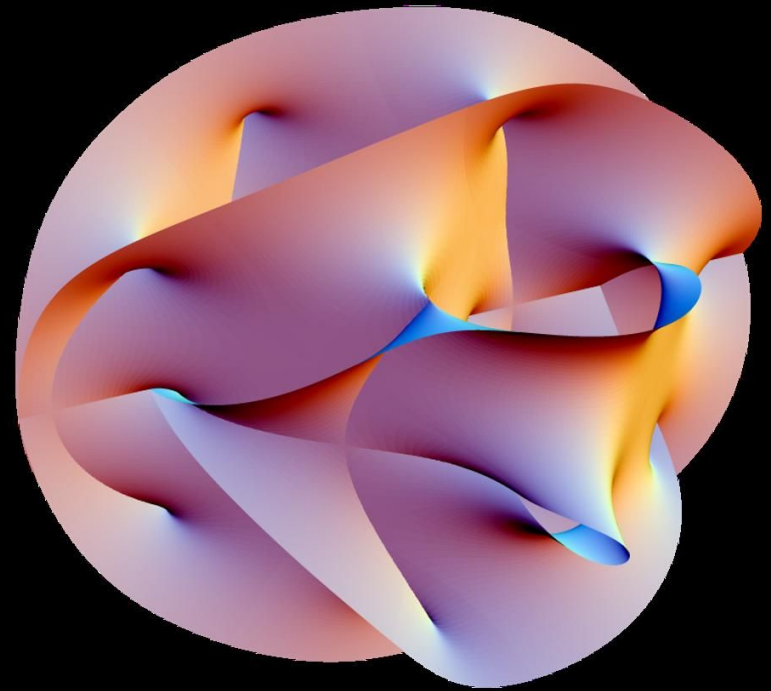
new physics

Particle Physics today



description \neq understanding

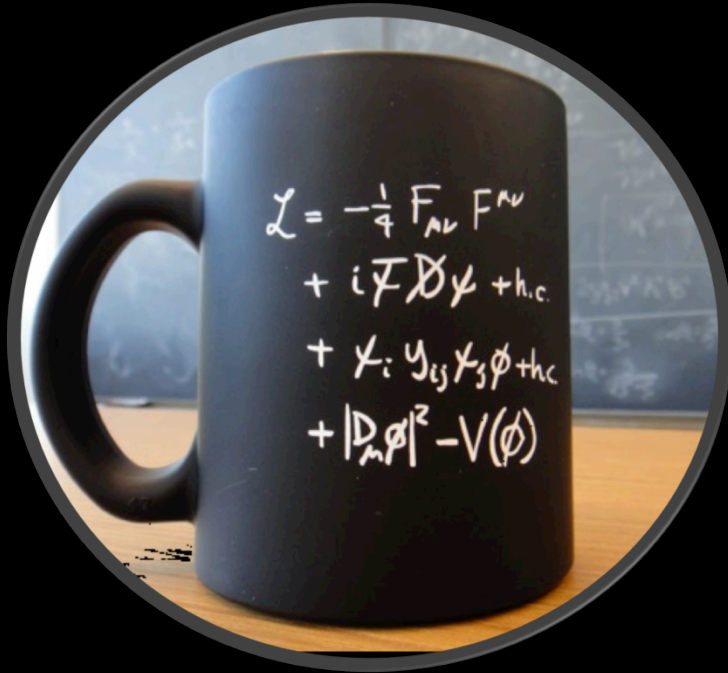
or more elegant ?



new physics

Particle Physics today

or more surreal?

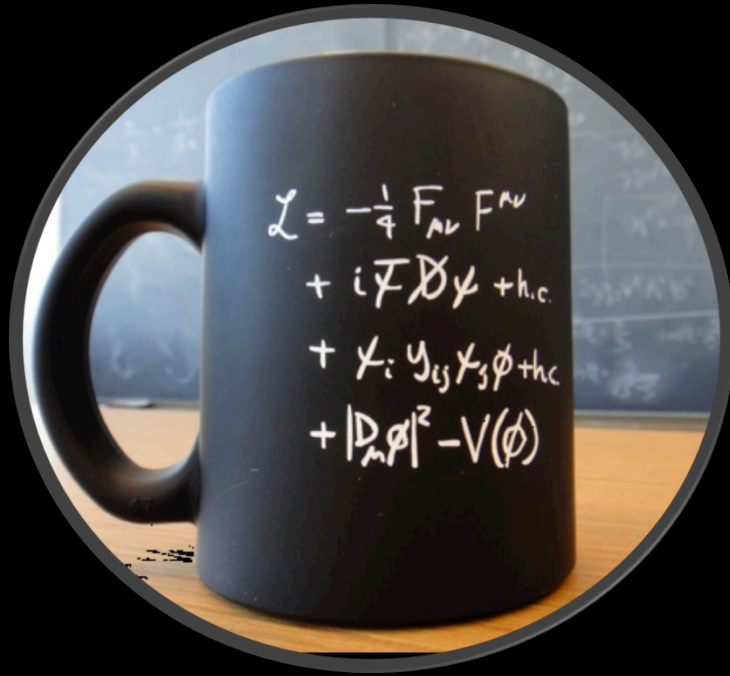


description \neq understanding

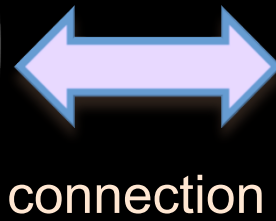


new physics

Particle Physics today

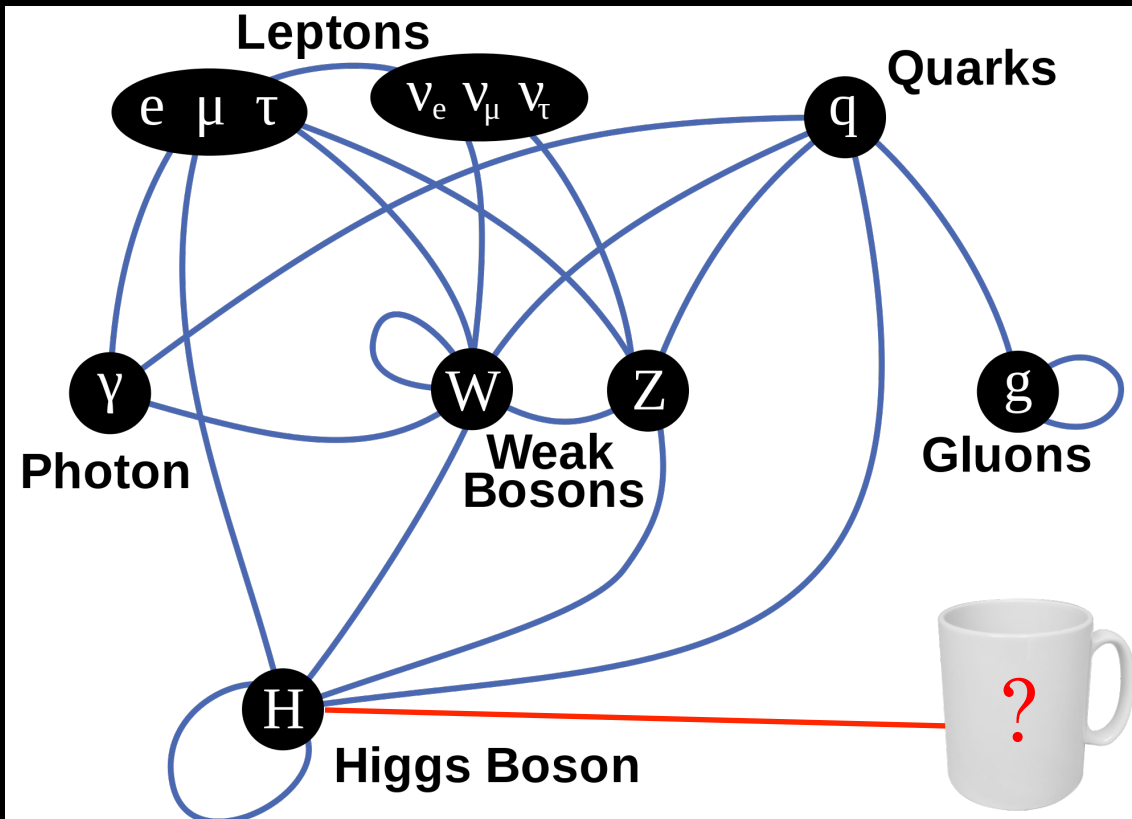


description \neq understanding



new physics

Exploration of the scalar sector - <https://be-h.be/>

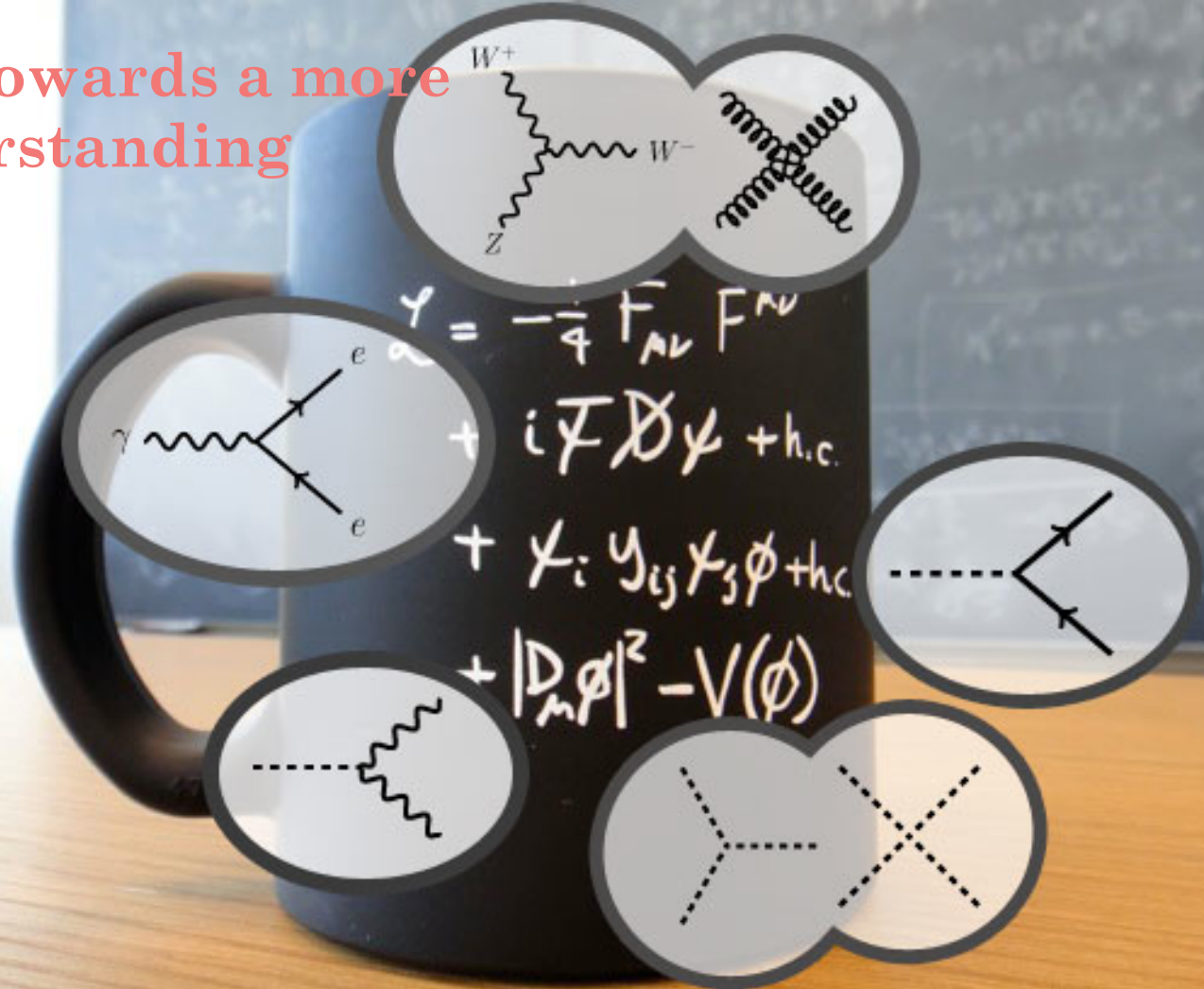


EOS
THE EXCELLENCE
OF SCIENCE



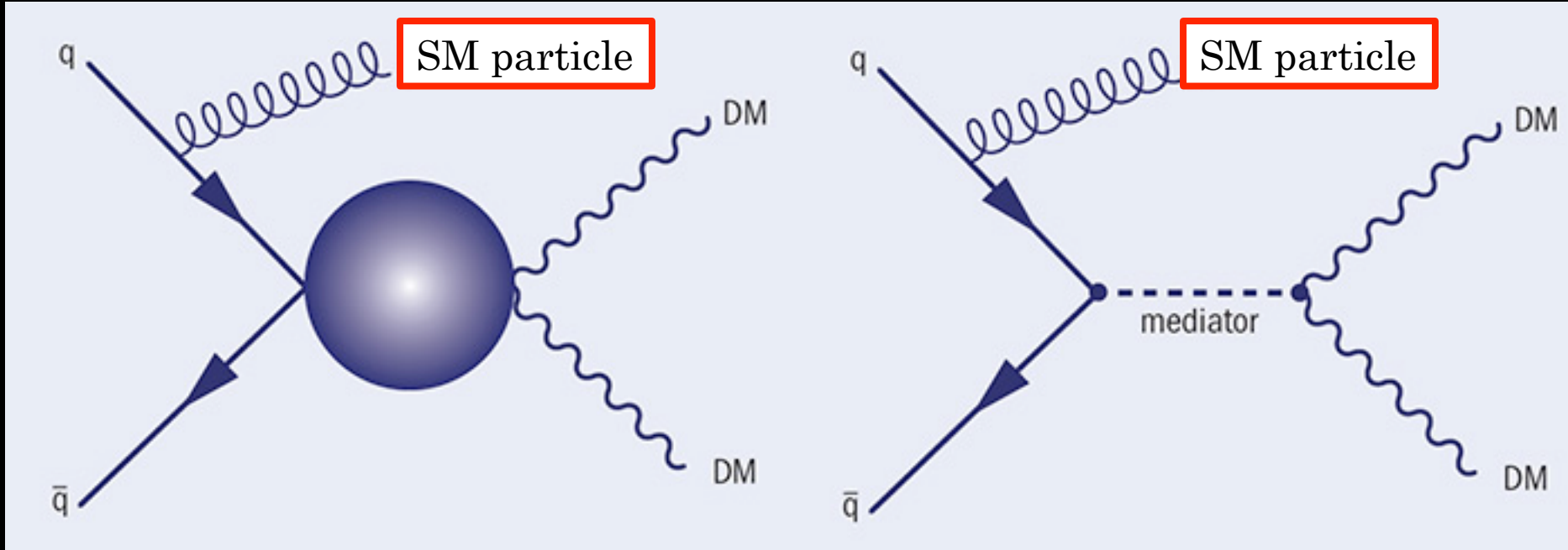
Belgian consortium of EXP
and TH researchers

With the LHC towards a more profound understanding



New physics must be somewhere, but not yet found

Example of dark matter



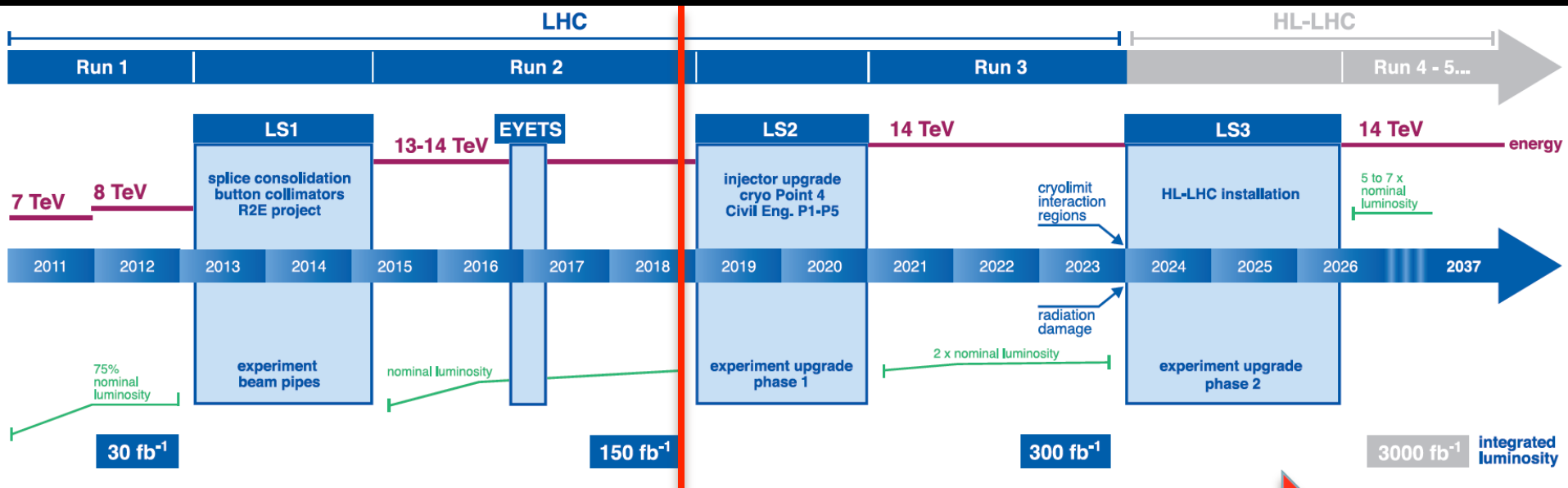
Dark matter particles can have different properties, but in general we exclude many theoretical models where it has a mass between 1 and 1000 proton masses.

No clear indication where new
physics is hiding,
hence experimental observations
will have to guide us in our
exploration

No clear indication where new
physics is hiding,
hence experimental observations
will have to guide us in our
exploration

Need more data !

Timeline of the LHC and HL-LHC (2026-2037)



construct a new detector

~100 publications per year
on this data by the CMS Collaboration
(incl. Higgs discovery with >8800 citations)

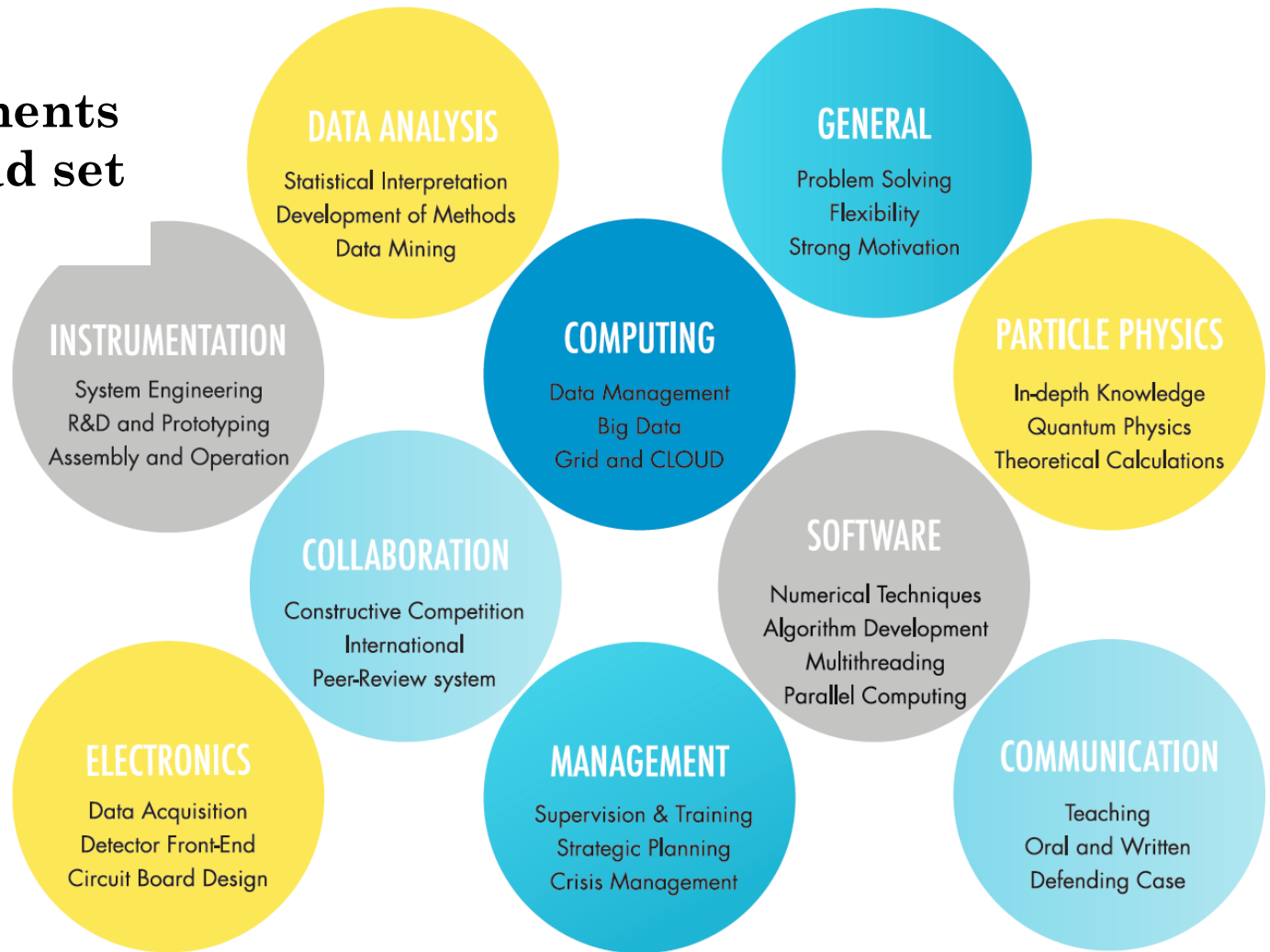
Collect an equal amount of
collisions per year as during
the whole LHC period

Bring CERN technology and science to society

People with talents



These experiments require a broad set of skills



Simple calculation

In Belgium we have 2000 defended PhDs per year with their talents going towards the industry, typically with a 17% higher salary compared to the Master degree, they also bring 17% more tax-income to the state.

In total, simply from the additional tax money, this provides

>400 M EUR extra tax-income per year

(after subtracting the initial investment of a 4-year PhD contract)

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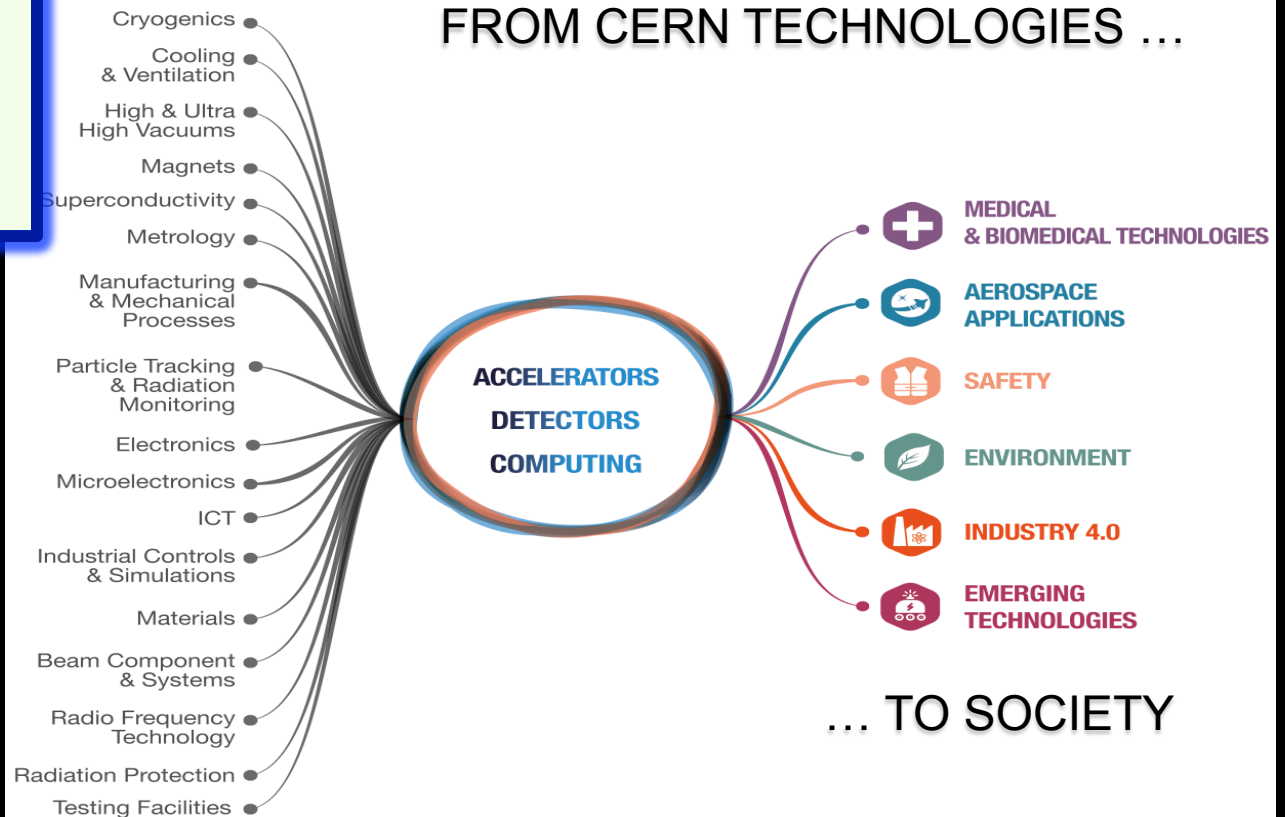
Additional value after working at CERN: 17% → 26%

>400 M EUR becomes >800 M EUR extra tax-income per year

Bring CERN technology to society - <https://kt.cern/>

Applications in society are as well important to motivate large scale experiments.

- Since 2011 CERN signed more than 300 licenses and other kind of agreements with industry and other partners
- Every year several tens of new technology disclosures (73 in 2017)
- 23 new start-ups are using CERN technologies since 2012

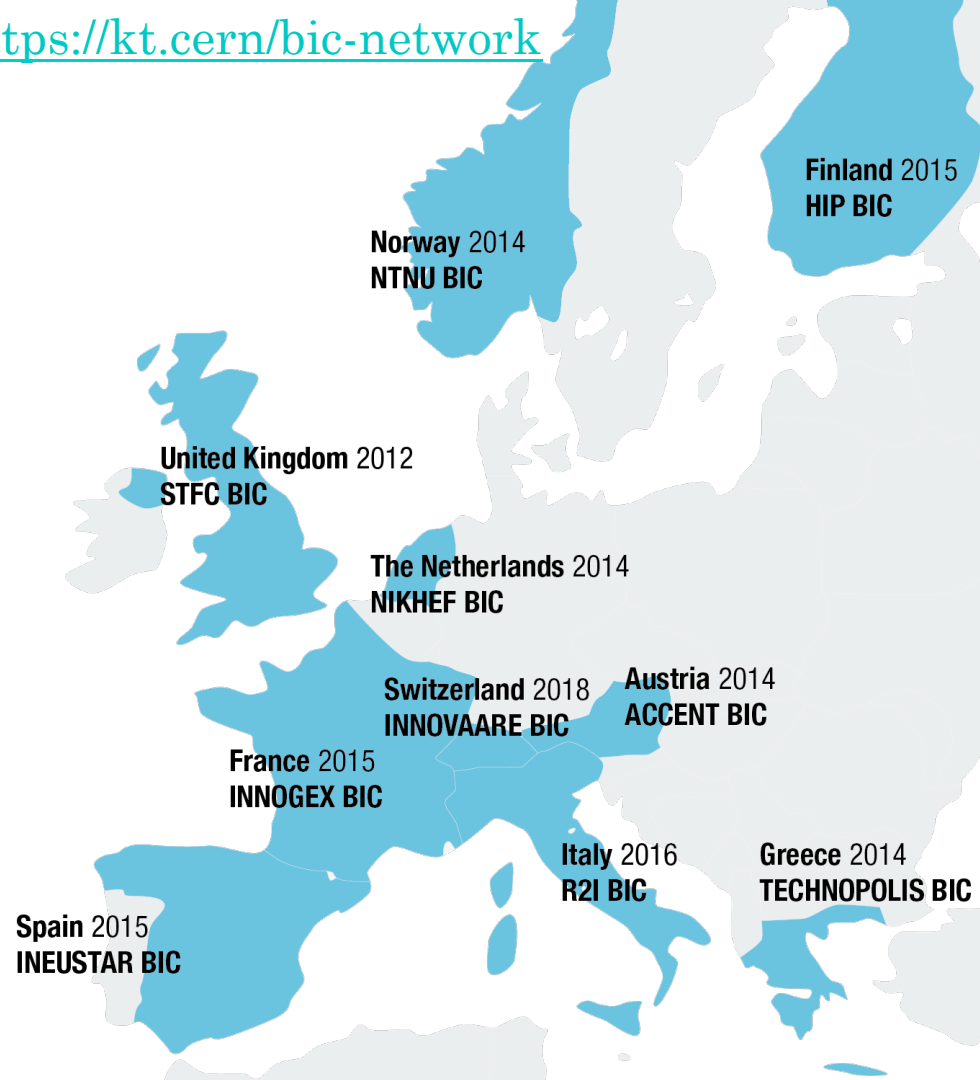


Business Incubation Centers

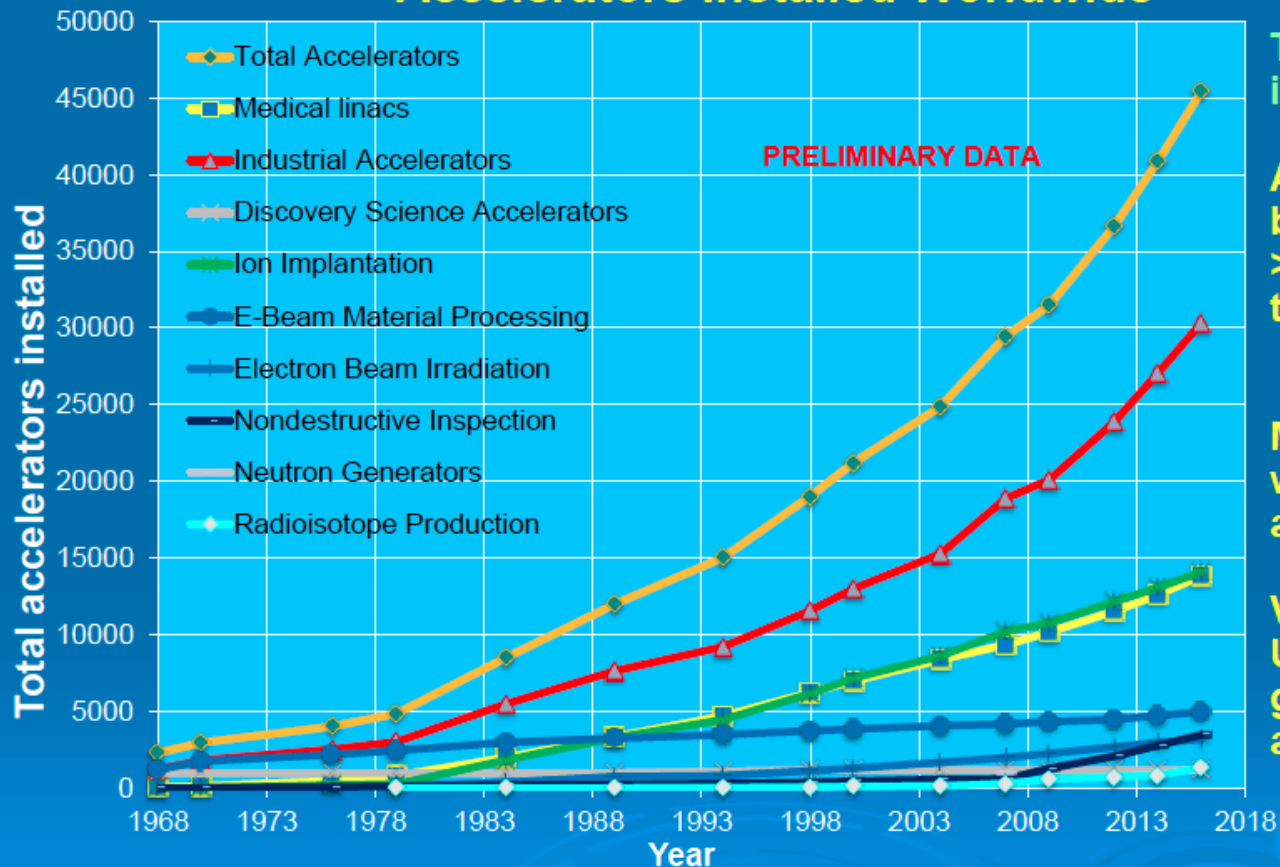
<https://kt.cern/bic-network>

“CERN has established a network of ten BICs throughout its Member States, to assist entrepreneurs and small businesses in taking CERN technologies and expertise to the market.”

In practice, CERN supports the selected companies through technical visits to CERN, technical consultancy and services, and preferential rate licensing of CERN intellectual property. The BIC managers provide office-space, expertise, business support, access to local and national networks, and support in accessing finance.”



Accelerators Installed Worldwide



Total sales of accelerators is ~US\$5B annually

About 47,000 systems have been sold, > 40,000 still in operation today

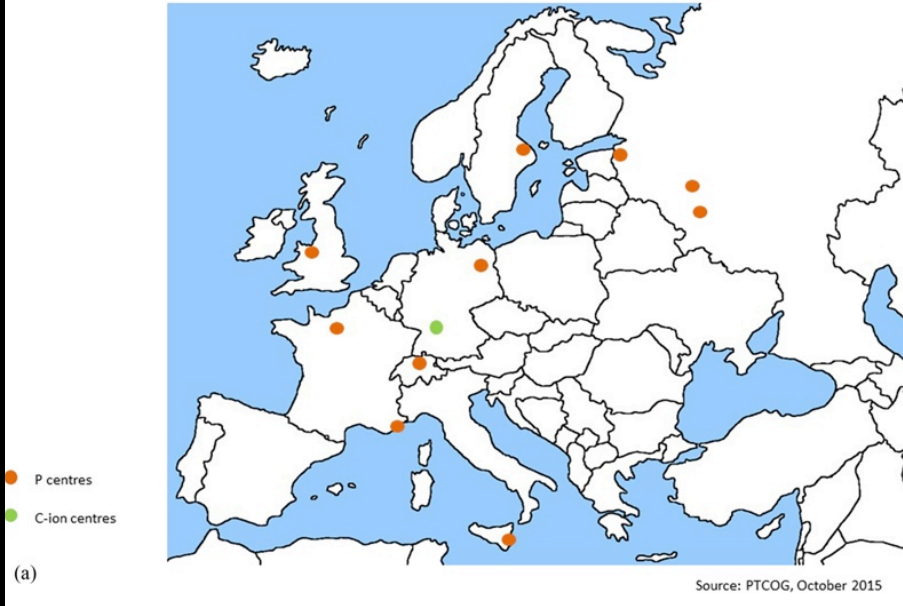
More than 100 vendors worldwide are in the accelerator business.

Vendors are primarily in US, Europe and Japan, but growing in China, Russia and India

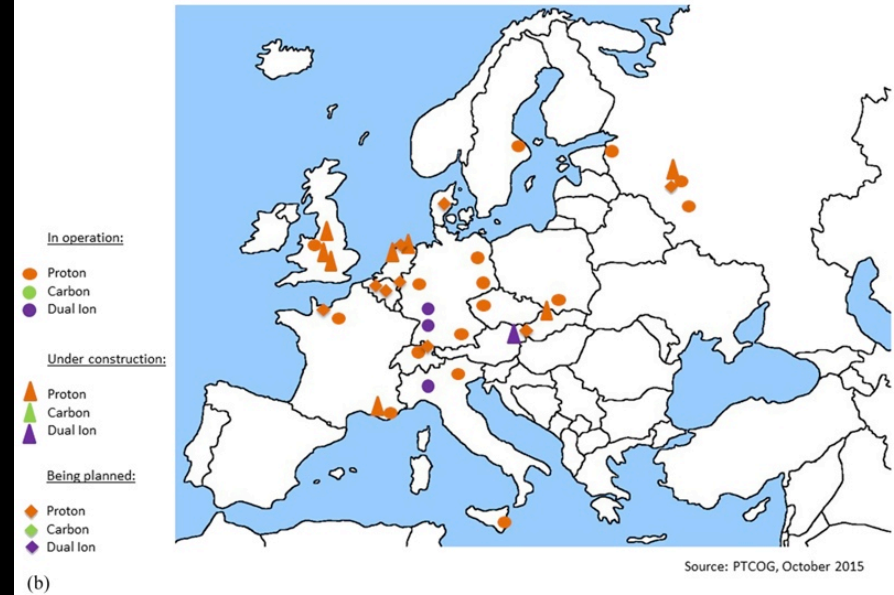
Particle Therapy

European Network for Light Ion Therapy (ENLIGHT) since 2002

Particle therapy centres in Europe - 2002



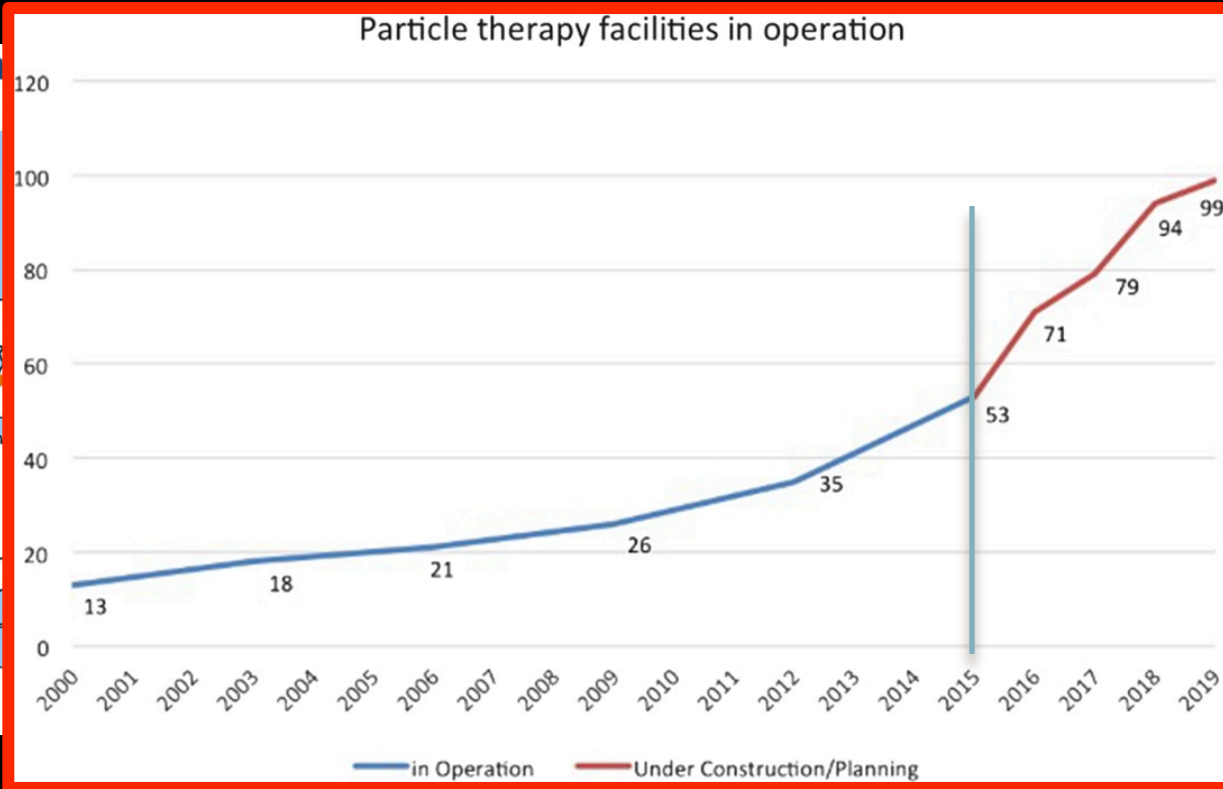
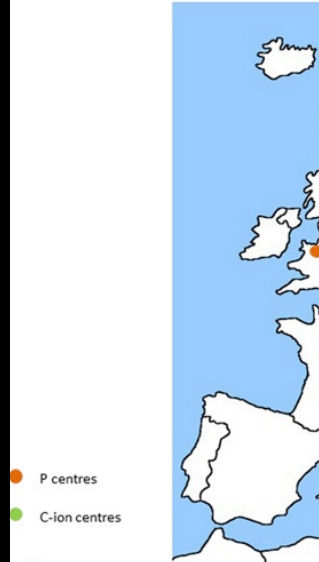
Particle therapy centres in Europe - 2015



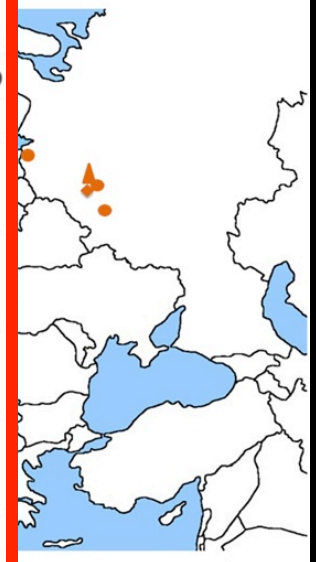
Particle Therapy

European Network for Light Ion Therapy (ENLIGHT) since 2002

Particle therapy



Europe - 2015



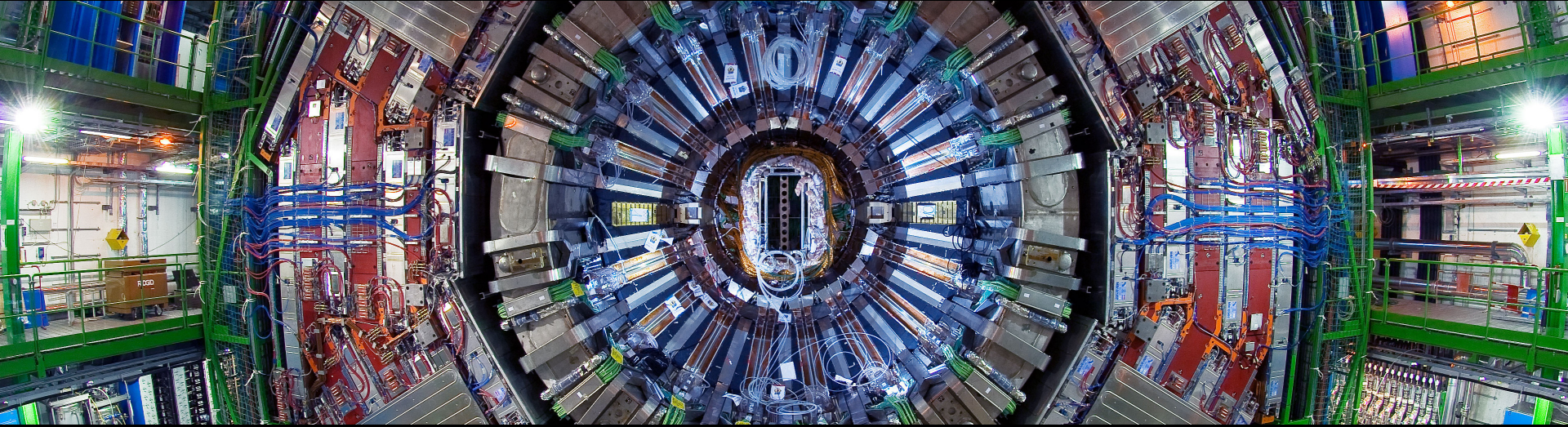
When an accelerator meets a nuclear reactor: the MYRRHA project in Belgium



The only project in Belgium on the ESFRI list

“Scientific curiosity which ends up in your pocket”

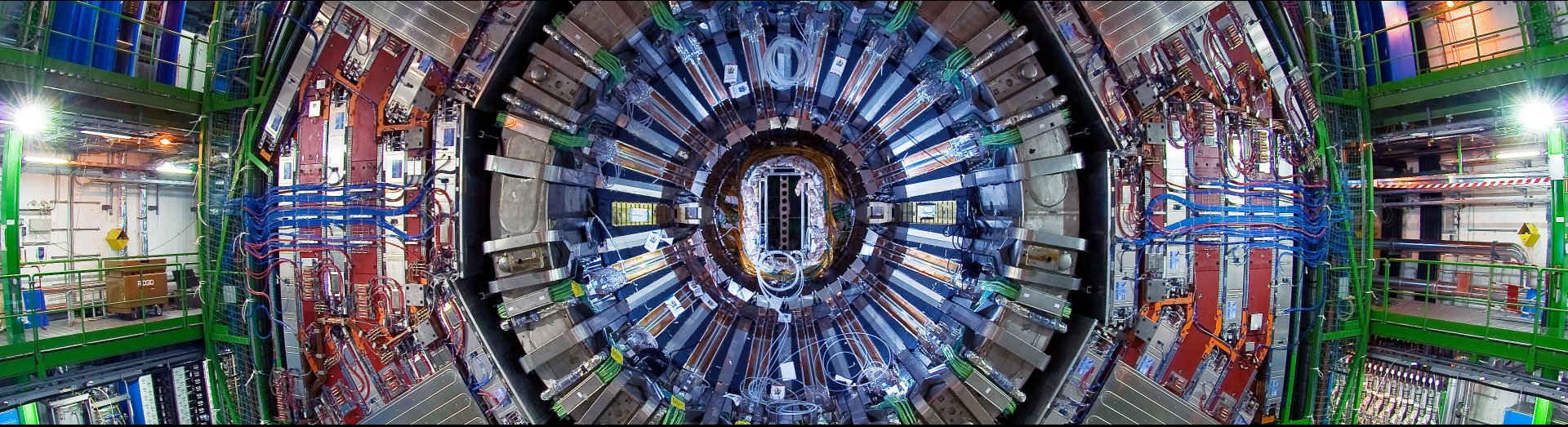
Rolf Heuer (previous Director General of CERN)



With appropriate investments in technical and physics talents

“Scientific curiosity which ends up in your pocket”

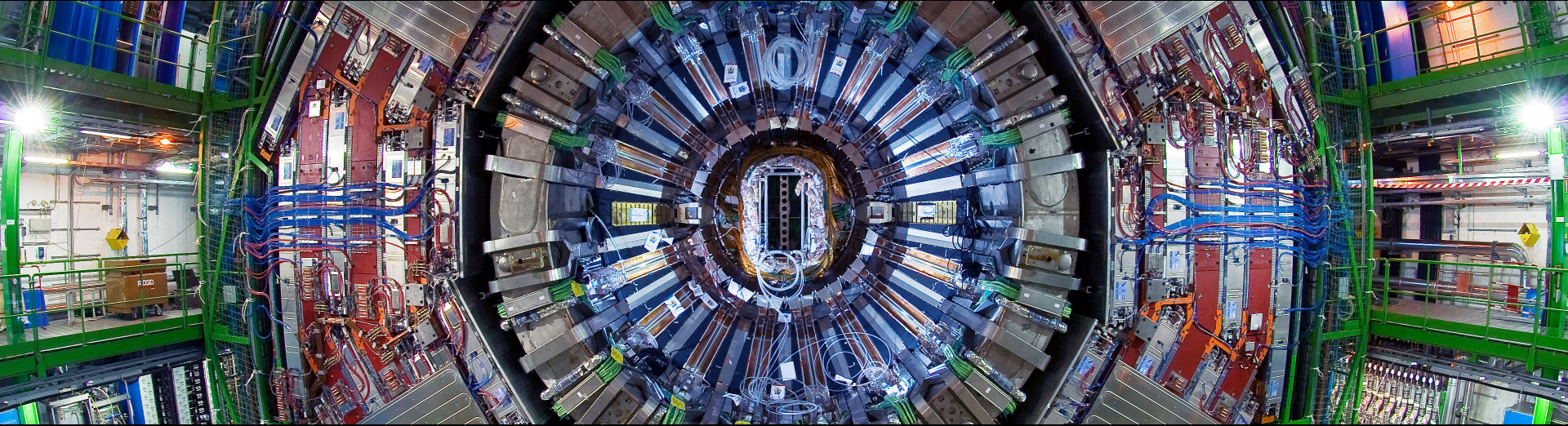
Rolf Heuer (previous Director General of CERN)



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Thank you for your attention

